

シビアアクシデント時原子力発電所内線量評価システムの改良 - IE法によるビルドアップ係数の整備とQAD, G33両コードの深層透過問題への対応 -

Improvement of Dose Evaluation System for Employees at Severe Accident of Nuclear Power Plant - Development of Gamma-Ray Buildup Factors by Invariant Embedding Method and Application to Deep Penetration Problem by QAD Code and G33 Code -

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要約 著者らは原子力発電所のシビアアクシデント時における現場従業員の被ばく線量を評価するため、QADコードとG33コードを用いて直接線、スカイシャイン線の評価システムを開発した。現状のコードで使用されているガンマ線のビルドアップ係数は深い層に対する値が不足し、精度に問題があったため、ビルドアップ係数の改良を行った。計算にはIE (invariant embedding) 法を利用し、制動放射線の現実的なモデルを導入して深さ300mfpまで拡張した。その結果、300mfpまで十分な精度で、従来のビルドアップ係数を大幅に改良することができた。加えて、改良されたビルドアップ係数を利用してGP (geometric progression) 式のフィッティングパラメータを算出した。実際に深層透過問題に適用するため、改良ビルドアップ係数およびGP式のフィッティングパラメータをQADコードとG33コードに導入した。

キーワード シビアアクシデント, 被ばく線量評価, QAD, G33, ビルドアップ係数, IE法, GP式, 深層透過

Abstract The authors developed the system that estimates direct line and skyshine using the QAD code and the G33 code in order to evaluate the radiation dose of employees at severe accident in a nuclear power plant. Since the gamma-ray buildup factors used presently is lacking in data of very deep region and there is a problem in accuracy, the buildup factors were improved. The data set of buildup factor was extended up to depths of 300mfp with the invariant embedding (IE) method and the realistic model for the effect of bremsstrahlung on the buildup factors. Consequently, it was shown that the buildup factors had sufficient accuracy to 300 mfp and the conventional data set of buildup factor had been improved considerably. Moreover, the parameters of geometric progression (GP) formula to the improved buildup factors were computed. In order to apply to a very deep penetration problem, the improved buildup factors and GP fitting parameters were introduced into the QAD code and the G33 code.

Keywords severe accident, dose evaluation, QAD, G33, buildup factor, invariant embedding method, geometric progression formula, very deep penetration

1. まえがき

原子力発電所におけるシビアアクシデントに対し、事業者は、1) アクシデントマネジメントの実施、2) 被災者の救助活動、3) 故障機器の復旧作業、4) 従業員避難誘導等を適切に行う必要がある。アクシデントマネジメントの実施により事故の拡大防止措置を講じるが、こうした活動を実施する場所の線量率は、事故状況により、大きく変化するので現場活動に先

立ち発電所構内の線量率を予測しておく必要がある。

そこで著者らは、これまでにシビアアクシデント時における従業員の被ばく線量を評価するための線量評価システムを開発した⁽¹⁾⁻⁽³⁾。本線量評価システムでは、事故状況を踏まえた放射性物質の拡散状況を解析し、推定した放射線源と従業員が滞在する場所の間に存在する遮蔽壁等の設置状況から直接線およびスカイシャイン線線量率を求め、各滞在所における滞在時間との積から被ばく線量を評価する。

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ここで、直接線線量率計算にはQAD-CGGP2Rコード⁽⁴⁾(以下QADコードという)、スカイシャイン線線量率計算にはG33-GP2Rコード⁽⁴⁾(以下G33コードという)を用いた。両コードは一般に公開されている。

QADコードは点減衰核法を用いている。この点減衰核法は、線源から放出された光子群が一度も衝突せずに評価点に到達する線束による線量率に、遮蔽体内での散乱による増倍効果を表すビルドアップ係数を掛け合わせるにより線量率を算出する計算法である。一方G33コードは一回散乱法と呼ばれる簡易計算手法を用いている。この計算法は、線源から散乱点までを点減衰核法で計算し、散乱点から評価点までを散乱の物理公式で評価する。QADコードとG33コードは、モンテカルロ法やSn法などの計算手法と比較して計算速度が高速であり、同じく点減衰核法を用いている原子力発電所の設置許可申請計算に用いられるSPANコード⁽⁵⁾やSCATTERINGコード⁽⁶⁾と比較して同等の性能を有している。両コードに内蔵されているビルドアップ係数は、米国原子力学会(American Nuclear Society, ANS)の標準化委員会によって26種類の物質、0.015から15MeVの線源エネルギーについて深さ40mfp(平均自由行程, mean free path)まで求められたデータであり、今日の標準データとして広く利用されている(以下ANS標準データという)⁽⁷⁾。

しかしながら原子力発電所のような大きな体系の場合、40mfpを超える深さの遮蔽計算も必要とされるが、従来は便宜的に40mfpでのビルドアップ係数で代用される⁽⁴⁾。これまでに、40mfpを超える深さでのビルドアップ係数を求めた例を見ると、Chibaniがモンテカルロ法を使っていくつかの代表的な物質について60mfpまで計算している⁽⁸⁾。清水はIE(invariant embedding)法を使って100mfpまで水、鉄、鉛について計算を行っている⁽⁹⁾⁽¹⁰⁾。QADコードおよびG33コードに採用されているGP(geometric progression)式⁽²⁰⁾と呼ばれるフィッティング式によってビルドアップ係数を補間する場合、40mfpから60mfpまで外挿⁽⁴⁾することが可能となっている。しかしながら、透過距離や物質種類の面でまだ十分とは言えない。

一方、このANSデータは、銅以下の低Z核種では、断面積データNBS29⁽¹²⁾を使ったモーメント法で計算されており、制動放射線の効果は考慮されていない⁽⁷⁾。また、モリブデン以上の高Z核種では、断面積データPHOTX⁽⁷⁾を使ったPALLASコード⁽¹⁴⁾で計算され、制動放射線を簡易モデルで考慮しているために誤差

を指摘されている⁽¹⁵⁾。

そこで、本研究では、深い層におけるガンマ線遮蔽計算、シビアアクシデント時における従業員の被ばく線量評価の精度向上に資するため、上記の標準データの深さ、精度の問題を解決する新たなビルドアップ係数データセットの整備を行った。十分深い層までのデータを整備するには、モンテカルロ法による計算は十分なヒストリーを得るまでに時間がかかりすぎることから現実的に不可能であり、他の計算方法でも比較検証ができないため精度の確認ができない。そのため、100mfpまでの実績があり、独自に精度の評価が可能であるIE法に基づく輸送計算コード⁽¹⁶⁾⁻⁽²⁰⁾を使用した。得られたビルドアップ係数データを実際に活用するため、QADコードとG33コードに反映させた。

2. 改良ビルドアップ係数の整備

2.1 対象とした物質と深さ

mfp単位での透過距離が実際にどの程度の距離に相当するかは、線源エネルギーと遮蔽物質の種類によって異なるが、例えば、線源エネルギー0.5MeVのガンマ線に対するコンクリートの場合、40mfpとは約2mに相当する。原子力発電所での被ばく線量評価では、この何倍もの深さでの計算が求められる。そこでビルドアップ係数データセットの整備は300mfpまで行うこととした。

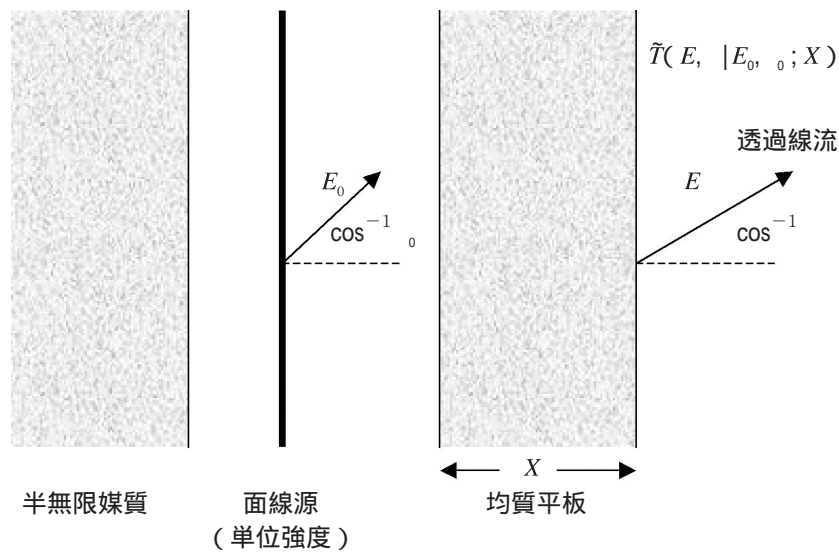
ANS標準データの問題点を改善するため、最新の断面積データであるPHOTXを統一的に使用し、現実的な制動放射線のモデル⁽¹⁰⁾を導入して計算した。ビルドアップ係数は、無限均質媒質中の点等方線源に対するガンマ線照射線量ビルドアップ係数を計算した。計算対象は26物質(Be, B, C, N, O, Na, Mg, Al, Si, P, S, Ar, K, Fe, Cu, Rb, Mo, Sn, La, Gd, W, Pb, U, 水, コンクリート, 空気)を選択した。エネルギーはANS標準データと同じものを選択した(0.015から15.0MeV, 但しU, Pbについては0.03から15.0MeV)。高Z核種では、K端付近のエネルギーについても計算した。深さは48点(0.5, 1, 2, 3, 4, 5, 6, 7, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 90, 95, 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220, 230, 240, 250, 260, 270, 280, 290,

表1 ビルドアップ係数データセットの比較

| | ANSI/ANS データセット | | 改良ビルドアップ係数データセット | |
|----------------|-----------------|------------|------------------|---------|
| 深さ (mfp) | 0.5 ~ 40mfp | | 0.5 ~ 300mfp | |
| | 低Z核種 * | 高Z核種 ** | 低Z核種 * | 高Z核種 ** |
| ガンマ線 断面積データ | NBS29 | PHOTX | PHOTX | |
| 制動放射線の効果 | なし | 簡易モデル | 現実的モデル | |
| 計算法 | モーメント法 | PALLAS コード | IE 法 | |

* 低Z核種: Be ~ Cu, 水, 空気およびコンクリート

** 高Z核種: Mo ~ U

図1 修正透過関数 \tilde{T} の定義

300mfp) を選択した。角度分点数は15, エネルギー群数は95とした。表1にビルドアップ係数データセットの比較を示す。なお, 制動放射線の効果は, 1.5MeV未達の領域では, 0.5%未達とほぼ無視できることから, 1.5MeV以上の領域で考慮した。

2.2 IE法による計算方法の概要⁽¹⁶⁾⁻⁽²⁰⁾

IE法は, 遮蔽体における放射線の入出力関係だけに着目して計算する計算法で, IE法独自の反射関数 $R(E, |E_0, \theta_0; X)$ と, 修正透過関数 $\tilde{T}(E, |E_0, \theta_0; X)$ を計算し, 光子の輸送計算を行う。修正透過関数は, 図1に示すように, 面線源, 一定厚さ X の均質平板, および均質平板と同じ組成の半無限媒質が配置された体系で面線源からの放射線流が単一エネルギー E_0 , 単一方向 θ_0 を持ち単位強度であるとき, 平板外面に生じるエネルギー E , 方向 θ の透過線流強度を表す。反射関数および修正透過関数から得られる厚さ X に

関する微分方程式を初期の微小厚さ(例えば 2^{-9} mfp)だけ Runge-Kutta 法で数値的に解けば, 後は修正透過関数の汎関数関係から, その2倍の厚さ (2^{-9} mfpの2倍, 2^{-8} mfp) について計算することが可能である。以後同様に厚さを2倍にしていくことで高速に深い距離まで計算することができる。面線源は点線源の集合であることから, 無限均質媒質中の面等方線源によるビルドアップ係数が求められる。

IE法は, モンテカルロ法と比較して, 非常に高速に計算できるため, 非常に深い透過距離まで輸送計算が可能である。また, 計算結果の精度も独自の手法により評価可能となっている。これまでにビルドアップ係数の精度を評価したところ, 100mfpまでは約10%の誤差が含まれると評価されている⁽⁹⁾。

IE法では, 角度分点数に起因する影響を評価する角度分点誤差係数と, エネルギー群数に起因するエネルギー群誤差係数を近似計算し, ビルドアップ係

数の精度を評価する．角度分点誤差係数を $Ea(G, X)$, エネルギー群誤差係数を $Ee(N, X)$ とし, これらは次のように定義される .

$$Ea(G, X) = B(G, N; X) / B(\infty, N; X) \quad (1)$$

$$Ee(N, X) = B(G, N; X) / B(G, \infty; X) \quad (2)$$

ここで G は角度分点数, N はエネルギー群数, X は透過距離, B はビルドアップ係数である .

G および N を無限大にとったときの値 $B(\infty, \infty; X)$ がビルドアップ係数の理論値であり, 次の関係がある .

$$B(G, \infty; X) < B(\infty, \infty; X) < B(\infty, N; X) \quad (3)$$

$Ea(G, X)$ および $Ee(N, X)$ は近似的に求めることが可能で, 計算結果を $Ea(G, X)$ および $Ee(N, X)$ と表すと,

$$Ea(G, X) < Ea(G, X) \quad (4)$$

$$Ee(N, X) > Ee(N, X) \quad (5)$$

の関係がある . これらより, 次の関係があることが分かる .

$$\frac{B(G, N; X)}{Ee(N, X)} < B(\infty, \infty; X) < \frac{B(G, N; X)}{Ea(G, X)} \quad (6)$$

エネルギー群数 N および角度分点数 G によらない十分な数の分点数でビルドアップ係数の計算を行い, $Ea(G, X)$ および $Ee(N, X)$ を計算することで, 精度を評価することができる .

2.3 IE法によるビルドアップ係数計算結果

IE法による照射線量ビルドアップ係数(以下改良ビルドアップ係数という)の計算結果のうち, 鉄, 鉛, 水, 空気およびコンクリートの計算結果を表2から表6に示す. 鉄, 鉛, 水, 空気およびコンクリートについて, 10MeV および 0.5MeV におけるANS標準データとの比較結果を図2に示す. 10MeV における鉄, 水, 空気およびコンクリートのビルドアップ係数比が1を超えるのは, 制動放射線の効果を新たに含めたためである. また, 10MeV における鉛のビルドアップ係数比が1を下回るのは, ANS標準データが制動放射線の効果を簡易モデルで考慮したことによる過大評価⁽¹⁵⁾が原因であると考えられる.

高Z核種について, ビルドアップ係数比1からの差違が大きい15MeV におけるANS標準データとの比較結果を図3に示す. ANS標準データと比較して, ランタンは, 制動放射線の過大評価によって最大約3倍のビルドアップ係数の過大評価をしていることが分かった. 鉛について1 MeV 以下におけるANS標準データとの比較結果を図4に示す. 鉛のK端付近の線源エネルギー0.089~0.15MeVの範囲で, ANS標準データは最大約30%の過大評価をしていることが分かった.

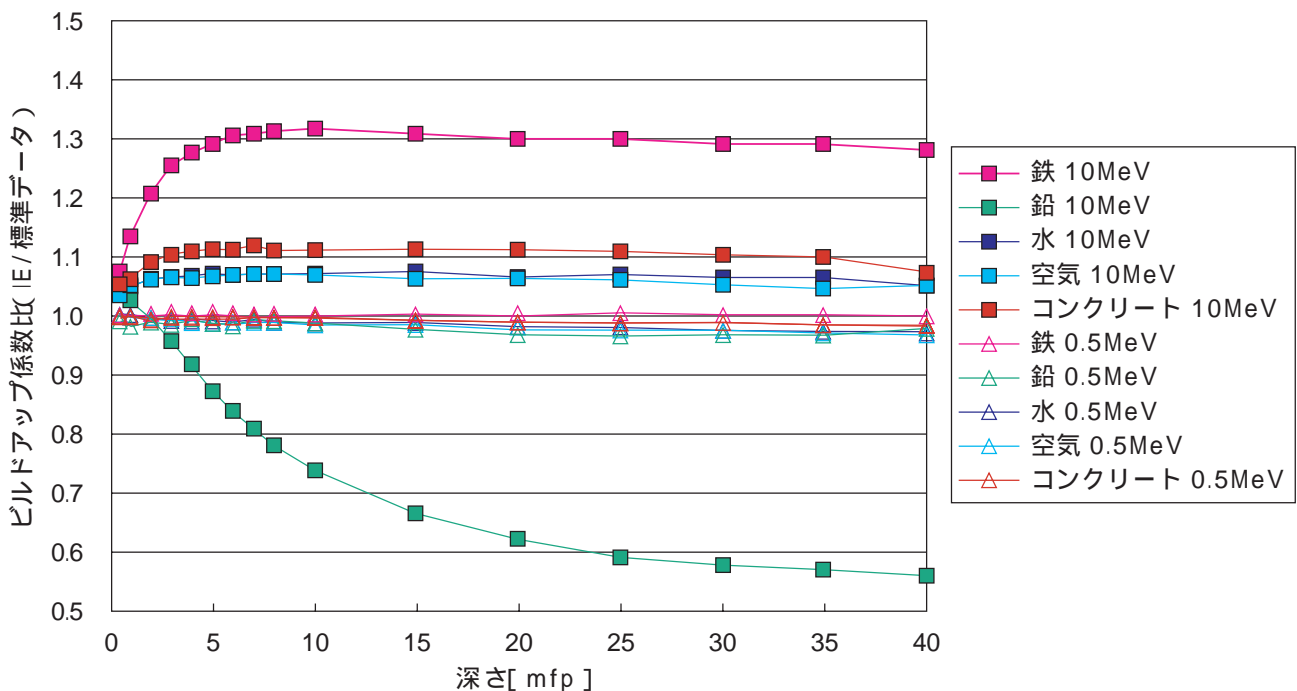


図2 IE法による改良ビルドアップ係数とANS標準データとの比
鉄 鉛 水 空気 コンクリート 線源エネルギー10MeV 0.5MeV

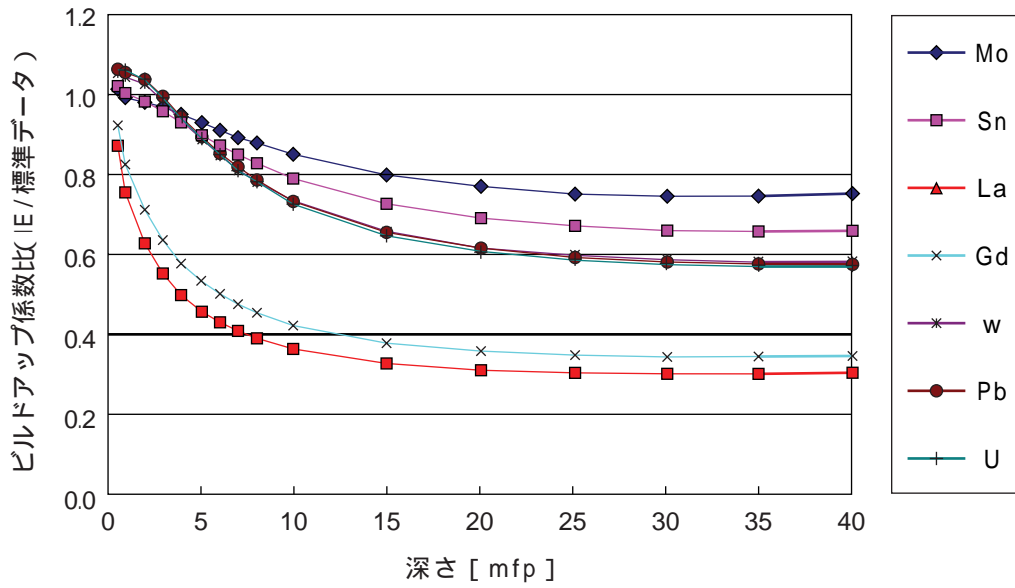


図3 IE法による改良ビルドアップ係数とANS標準データとの比
高Z核種 線源エネルギー15MeV

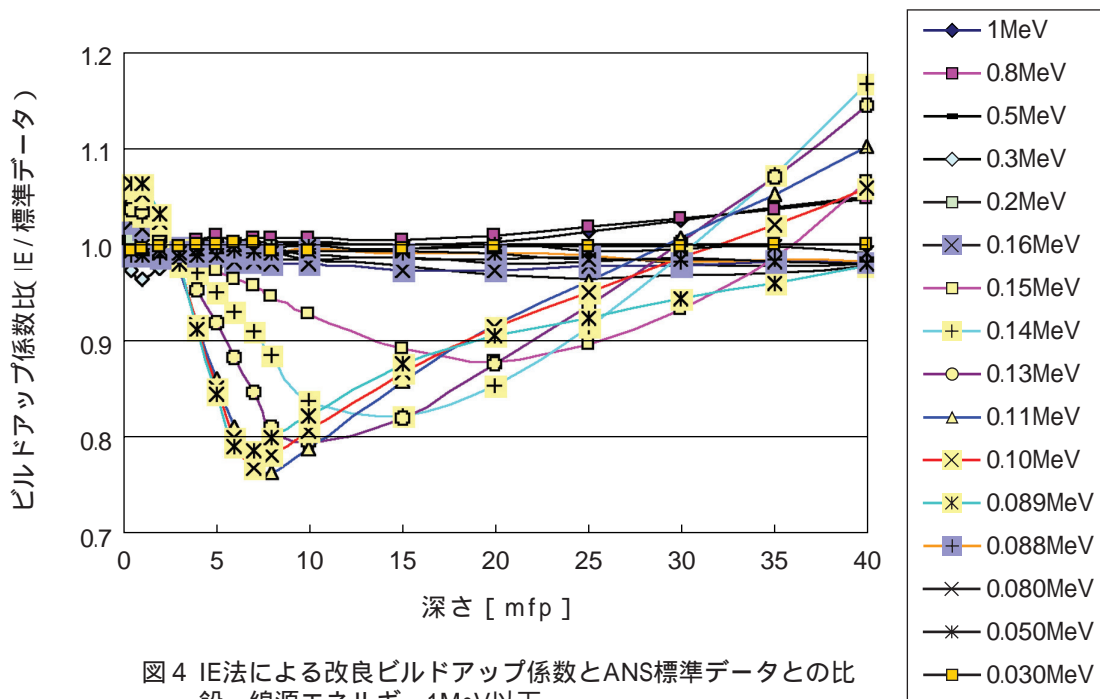


図4 IE法による改良ビルドアップ係数とANS標準データとの比
鉛 線源エネルギー1MeV以下

表2 (1/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
鉄 (15-0.5MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 15.0 | 10.0 | 8.0 | 6.0 | 5.0 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 | 0.8 | 0.6 | 0.5 |
| 0.5 | 1.28E+00 | 1.28E+00 | 1.29E+00 | 1.30E+00 | 1.31E+00 | 1.32E+00 | 1.34E+00 | 1.36E+00 | 1.38E+00 | 1.43E+00 | 1.43E+00 | 1.46E+00 | 1.48E+00 |
| 1.0 | 1.52E+00 | 1.51E+00 | 1.53E+00 | 1.56E+00 | 1.58E+00 | 1.62E+00 | 1.67E+00 | 1.73E+00 | 1.78E+00 | 1.88E+00 | 1.90E+00 | 1.96E+00 | 1.99E+00 |
| 2.0 | 1.97E+00 | 1.92E+00 | 1.95E+00 | 2.03E+00 | 2.10E+00 | 2.20E+00 | 2.33E+00 | 2.53E+00 | 2.65E+00 | 2.89E+00 | 2.97E+00 | 3.09E+00 | 3.13E+00 |
| 3.0 | 2.42E+00 | 2.33E+00 | 2.38E+00 | 2.52E+00 | 2.63E+00 | 2.79E+00 | 3.03E+00 | 3.39E+00 | 3.63E+00 | 4.05E+00 | 4.22E+00 | 4.41E+00 | 4.46E+00 |
| 4.0 | 2.90E+00 | 2.76E+00 | 2.84E+00 | 3.03E+00 | 3.18E+00 | 3.42E+00 | 3.77E+00 | 4.31E+00 | 4.71E+00 | 5.35E+00 | 5.64E+00 | 5.94E+00 | 5.99E+00 |
| 5.0 | 3.44E+00 | 3.23E+00 | 3.32E+00 | 3.57E+00 | 3.77E+00 | 4.08E+00 | 4.55E+00 | 5.29E+00 | 5.86E+00 | 6.80E+00 | 7.24E+00 | 7.66E+00 | 7.71E+00 |
| 6.0 | 4.03E+00 | 3.74E+00 | 3.84E+00 | 4.14E+00 | 4.39E+00 | 4.78E+00 | 5.37E+00 | 6.33E+00 | 7.09E+00 | 8.38E+00 | 9.01E+00 | 9.58E+00 | 9.63E+00 |
| 7.0 | 4.68E+00 | 4.28E+00 | 4.40E+00 | 4.75E+00 | 5.05E+00 | 5.50E+00 | 6.22E+00 | 7.41E+00 | 8.38E+00 | 1.01E+01 | 1.09E+01 | 1.17E+01 | 1.17E+01 |
| 8.0 | 5.40E+00 | 4.87E+00 | 4.98E+00 | 5.38E+00 | 5.72E+00 | 6.25E+00 | 7.10E+00 | 8.54E+00 | 9.74E+00 | 1.19E+01 | 1.30E+01 | 1.40E+01 | 1.40E+01 |
| 10.0 | 7.09E+00 | 6.17E+00 | 6.27E+00 | 6.74E+00 | 7.16E+00 | 7.84E+00 | 8.95E+00 | 1.09E+01 | 1.26E+01 | 1.59E+01 | 1.76E+01 | 1.91E+01 | 1.92E+01 |
| 15.0 | 1.31E+01 | 1.03E+01 | 1.02E+01 | 1.07E+01 | 1.12E+01 | 1.22E+01 | 1.40E+01 | 1.74E+01 | 2.07E+01 | 2.75E+01 | 3.15E+01 | 3.50E+01 | 3.53E+01 |
| 20.0 | 2.28E+01 | 1.60E+01 | 1.51E+01 | 1.53E+01 | 1.58E+01 | 1.71E+01 | 1.95E+01 | 2.46E+01 | 2.97E+01 | 4.11E+01 | 4.85E+01 | 5.51E+01 | 5.57E+01 |
| 25.0 | 3.82E+01 | 2.35E+01 | 2.12E+01 | 2.06E+01 | 2.10E+01 | 2.23E+01 | 2.53E+01 | 3.24E+01 | 3.95E+01 | 5.66E+01 | 6.82E+01 | 7.91E+01 | 8.02E+01 |
| 30.0 | 6.22E+01 | 3.32E+01 | 2.85E+01 | 2.65E+01 | 2.66E+01 | 2.80E+01 | 3.15E+01 | 4.05E+01 | 5.00E+01 | 7.36E+01 | 9.05E+01 | 1.07E+02 | 1.09E+02 |
| 35.0 | 9.88E+01 | 4.56E+01 | 3.72E+01 | 3.31E+01 | 3.27E+01 | 3.39E+01 | 3.79E+01 | 4.91E+01 | 6.10E+01 | 9.21E+01 | 1.15E+02 | 1.38E+02 | 1.41E+02 |
| 40.0 | 1.54E+02 | 6.10E+01 | 4.72E+01 | 4.04E+01 | 3.92E+01 | 4.01E+01 | 4.46E+01 | 5.80E+01 | 7.26E+01 | 1.12E+02 | 1.42E+02 | 1.73E+02 | 1.77E+02 |
| 45.0 | 2.36E+02 | 8.01E+01 | 5.88E+01 | 4.82E+01 | 4.61E+01 | 4.66E+01 | 5.15E+01 | 6.72E+01 | 8.46E+01 | 1.33E+02 | 1.71E+02 | 2.11E+02 | 2.17E+02 |
| 50.0 | 3.56E+02 | 1.03E+02 | 7.19E+01 | 5.66E+01 | 5.33E+01 | 5.33E+01 | 5.85E+01 | 7.66E+01 | 9.70E+01 | 1.55E+02 | 2.02E+02 | 2.52E+02 | 2.61E+02 |
| 55.0 | 5.31E+02 | 1.31E+02 | 8.68E+01 | 6.57E+01 | 6.09E+01 | 6.03E+01 | 6.57E+01 | 8.63E+01 | 1.10E+02 | 1.78E+02 | 2.35E+02 | 2.96E+02 | 3.08E+02 |
| 60.0 | 7.84E+02 | 1.65E+02 | 1.03E+02 | 7.53E+01 | 6.89E+01 | 6.74E+01 | 7.31E+01 | 9.63E+01 | 1.23E+02 | 2.02E+02 | 2.69E+02 | 3.43E+02 | 3.58E+02 |
| 65.0 | 1.15E+03 | 2.05E+02 | 1.22E+02 | 8.54E+01 | 7.71E+01 | 7.47E+01 | 8.06E+01 | 1.06E+02 | 1.36E+02 | 2.27E+02 | 3.06E+02 | 3.94E+02 | 4.12E+02 |
| 70.0 | 1.66E+03 | 2.52E+02 | 1.43E+02 | 9.62E+01 | 8.57E+01 | 8.23E+01 | 8.82E+01 | 1.17E+02 | 1.50E+02 | 2.54E+02 | 3.44E+02 | 4.47E+02 | 4.69E+02 |
| 75.0 | 2.38E+03 | 3.07E+02 | 1.65E+02 | 1.07E+02 | 9.45E+01 | 9.00E+01 | 9.60E+01 | 1.27E+02 | 1.64E+02 | 2.81E+02 | 3.84E+02 | 5.03E+02 | 5.30E+02 |
| 80.0 | 3.40E+03 | 3.72E+02 | 1.90E+02 | 1.19E+02 | 1.04E+02 | 9.78E+01 | 1.04E+02 | 1.38E+02 | 1.79E+02 | 3.08E+02 | 4.25E+02 | 5.62E+02 | 5.94E+02 |
| 85.0 | 4.82E+03 | 4.47E+02 | 2.17E+02 | 1.32E+02 | 1.13E+02 | 1.06E+02 | 1.12E+02 | 1.49E+02 | 1.93E+02 | 3.37E+02 | 4.69E+02 | 6.24E+02 | 6.61E+02 |
| 90.0 | 6.79E+03 | 5.33E+02 | 2.47E+02 | 1.45E+02 | 1.23E+02 | 1.14E+02 | 1.20E+02 | 1.60E+02 | 2.08E+02 | 3.66E+02 | 5.13E+02 | 6.89E+02 | 7.32E+02 |
| 95.0 | 9.51E+03 | 6.33E+02 | 2.79E+02 | 1.58E+02 | 1.33E+02 | 1.22E+02 | 1.29E+02 | 1.72E+02 | 2.23E+02 | 3.97E+02 | 5.59E+02 | 7.57E+02 | 8.06E+02 |
| 100.0 | 1.33E+04 | 7.46E+02 | 3.13E+02 | 1.72E+02 | 1.43E+02 | 1.31E+02 | 1.37E+02 | 1.83E+02 | 2.39E+02 | 4.28E+02 | 6.07E+02 | 8.27E+02 | 8.83E+02 |
| 110.0 | 2.54E+04 | 1.02E+03 | 3.91E+02 | 2.02E+02 | 1.64E+02 | 1.49E+02 | 1.54E+02 | 2.07E+02 | 2.70E+02 | 4.92E+02 | 7.07E+02 | 9.75E+02 | 1.05E+03 |
| 120.0 | 4.77E+04 | 1.38E+03 | 4.80E+02 | 2.33E+02 | 1.87E+02 | 1.67E+02 | 1.72E+02 | 2.31E+02 | 3.02E+02 | 5.59E+02 | 8.13E+02 | 1.14E+03 | 1.22E+03 |
| 130.0 | 8.86E+04 | 1.84E+03 | 5.82E+02 | 2.67E+02 | 2.10E+02 | 1.86E+02 | 1.91E+02 | 2.56E+02 | 3.35E+02 | 6.29E+02 | 9.24E+02 | 1.31E+03 | 1.41E+03 |
| 140.0 | 1.62E+05 | 2.41E+03 | 6.98E+02 | 3.03E+02 | 2.35E+02 | 2.05E+02 | 2.10E+02 | 2.82E+02 | 3.69E+02 | 7.02E+02 | 1.04E+03 | 1.49E+03 | 1.62E+03 |
| 150.0 | 2.93E+05 | 3.12E+03 | 8.28E+02 | 3.41E+02 | 2.60E+02 | 2.26E+02 | 2.30E+02 | 3.09E+02 | 4.04E+02 | 7.77E+02 | 1.16E+03 | 1.68E+03 | 1.83E+03 |
| 160.0 | 5.25E+05 | 4.01E+03 | 9.74E+02 | 3.81E+02 | 2.87E+02 | 2.47E+02 | 2.51E+02 | 3.36E+02 | 4.39E+02 | 8.55E+02 | 1.29E+03 | 1.88E+03 | 2.06E+03 |
| 170.0 | 9.31E+05 | 5.10E+03 | 1.14E+03 | 4.23E+02 | 3.14E+02 | 2.68E+02 | 2.72E+02 | 3.64E+02 | 4.75E+02 | 9.36E+02 | 1.42E+03 | 2.09E+03 | 2.31E+03 |
| 180.0 | 1.64E+06 | 6.43E+03 | 1.32E+03 | 4.67E+02 | 3.42E+02 | 2.90E+02 | 2.93E+02 | 3.93E+02 | 5.11E+02 | 1.02E+03 | 1.56E+03 | 2.32E+03 | 2.56E+03 |
| 190.0 | 2.85E+06 | 8.04E+03 | 1.51E+03 | 5.13E+02 | 3.71E+02 | 3.13E+02 | 3.15E+02 | 4.22E+02 | 5.48E+02 | 1.10E+03 | 1.70E+03 | 2.55E+03 | 2.83E+03 |
| 200.0 | 4.94E+06 | 9.98E+03 | 1.73E+03 | 5.60E+02 | 4.01E+02 | 3.36E+02 | 3.38E+02 | 4.52E+02 | 5.86E+02 | 1.19E+03 | 1.85E+03 | 2.79E+03 | 3.11E+03 |
| 210.0 | 8.49E+06 | 1.23E+04 | 1.97E+03 | 6.09E+02 | 4.31E+02 | 3.59E+02 | 3.61E+02 | 4.82E+02 | 6.23E+02 | 1.28E+03 | 2.00E+03 | 3.05E+03 | 3.41E+03 |
| 220.0 | 1.45E+07 | 1.51E+04 | 2.23E+03 | 6.60E+02 | 4.62E+02 | 3.83E+02 | 3.84E+02 | 5.13E+02 | 6.61E+02 | 1.37E+03 | 2.16E+03 | 3.31E+03 | 3.71E+03 |
| 230.0 | 2.46E+07 | 1.84E+04 | 2.50E+03 | 7.11E+02 | 4.93E+02 | 4.07E+02 | 4.08E+02 | 5.44E+02 | 6.98E+02 | 1.46E+03 | 2.32E+03 | 3.58E+03 | 4.03E+03 |
| 240.0 | 4.16E+07 | 2.23E+04 | 2.80E+03 | 7.64E+02 | 5.25E+02 | 4.32E+02 | 4.32E+02 | 5.76E+02 | 7.36E+02 | 1.55E+03 | 2.48E+03 | 3.86E+03 | 4.37E+03 |
| 250.0 | 7.00E+07 | 2.70E+04 | 3.13E+03 | 8.18E+02 | 5.57E+02 | 4.56E+02 | 4.56E+02 | 6.08E+02 | 7.73E+02 | 1.65E+03 | 2.65E+03 | 4.15E+03 | 4.71E+03 |
| 260.0 | 1.17E+08 | 3.24E+04 | 3.47E+03 | 8.73E+02 | 5.89E+02 | 4.81E+02 | 4.81E+02 | 6.40E+02 | 8.11E+02 | 1.75E+03 | 2.82E+03 | 4.45E+03 | 5.07E+03 |
| 270.0 | 1.95E+08 | 3.87E+04 | 3.84E+03 | 9.29E+02 | 6.22E+02 | 5.06E+02 | 5.06E+02 | 6.72E+02 | 8.48E+02 | 1.84E+03 | 3.00E+03 | 4.76E+03 | 5.44E+03 |
| 280.0 | 3.23E+08 | 4.62E+04 | 4.24E+03 | 9.85E+02 | 6.54E+02 | 5.31E+02 | 5.31E+02 | 7.04E+02 | 8.84E+02 | 1.94E+03 | 3.17E+03 | 5.08E+03 | 5.83E+03 |
| 290.0 | 5.33E+08 | 5.48E+04 | 4.66E+03 | 1.04E+03 | 6.87E+02 | 5.56E+02 | 5.56E+02 | 7.37E+02 | 9.21E+02 | 2.04E+03 | 3.35E+03 | 5.40E+03 | 6.22E+03 |
| 300.0 | 8.78E+08 | 6.47E+04 | 5.10E+03 | 1.10E+03 | 7.19E+02 | 5.81E+02 | 5.82E+02 | 7.69E+02 | 9.56E+02 | 2.14E+03 | 3.54E+03 | 5.74E+03 | 6.63E+03 |

表2 (2/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
鉄 (0.4-0.015MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.4 | 0.3 | 0.2 | 0.15 | 0.10 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.015 |
| 0.5 | 1.50E+00 | 1.50E+00 | 1.46E+00 | 1.39E+00 | 1.24E+00 | 1.17E+00 | 1.10E+00 | 1.06E+00 | 1.04E+00 | 1.02E+00 | 1.01E+00 | 1.00E+00 |
| 1.0 | 2.01E+00 | 1.99E+00 | 1.85E+00 | 1.67E+00 | 1.39E+00 | 1.26E+00 | 1.14E+00 | 1.09E+00 | 1.05E+00 | 1.02E+00 | 1.01E+00 | 1.00E+00 |
| 2.0 | 3.13E+00 | 3.02E+00 | 2.60E+00 | 2.16E+00 | 1.60E+00 | 1.39E+00 | 1.20E+00 | 1.13E+00 | 1.07E+00 | 1.03E+00 | 1.01E+00 | 1.01E+00 |
| 3.0 | 4.42E+00 | 4.14E+00 | 3.34E+00 | 2.59E+00 | 1.78E+00 | 1.48E+00 | 1.25E+00 | 1.16E+00 | 1.09E+00 | 1.04E+00 | 1.01E+00 | 1.01E+00 |
| 4.0 | 5.88E+00 | 5.38E+00 | 4.10E+00 | 3.00E+00 | 1.93E+00 | 1.56E+00 | 1.28E+00 | 1.18E+00 | 1.10E+00 | 1.05E+00 | 1.02E+00 | 1.01E+00 |
| 5.0 | 7.52E+00 | 6.72E+00 | 4.88E+00 | 3.38E+00 | 2.06E+00 | 1.63E+00 | 1.31E+00 | 1.20E+00 | 1.11E+00 | 1.05E+00 | 1.02E+00 | 1.01E+00 |
| 6.0 | 9.32E+00 | 8.16E+00 | 5.67E+00 | 3.76E+00 | 2.19E+00 | 1.69E+00 | 1.34E+00 | 1.21E+00 | 1.12E+00 | 1.05E+00 | 1.02E+00 | 1.01E+00 |
| 7.0 | 1.13E+01 | 9.69E+00 | 6.47E+00 | 4.12E+00 | 2.30E+00 | 1.75E+00 | 1.36E+00 | 1.22E+00 | 1.12E+00 | 1.06E+00 | 1.02E+00 | 1.01E+00 |
| 8.0 | 1.34E+01 | 1.13E+01 | 7.28E+00 | 4.46E+00 | 2.41E+00 | 1.80E+00 | 1.38E+00 | 1.23E+00 | 1.13E+00 | 1.06E+00 | 1.02E+00 | 1.01E+00 |
| 10.0 | 1.82E+01 | 1.48E+01 | 8.94E+00 | 5.13E+00 | 2.60E+00 | 1.89E+00 | 1.41E+00 | 1.25E+00 | 1.14E+00 | 1.06E+00 | 1.02E+00 | 1.01E+00 |
| 15.0 | 3.28E+01 | 2.50E+01 | 1.32E+01 | 6.68E+00 | 2.99E+00 | 2.06E+00 | 1.48E+00 | 1.29E+00 | 1.16E+00 | 1.07E+00 | 1.02E+00 | 1.01E+00 |
| 20.0 | 5.12E+01 | 3.68E+01 | 1.77E+01 | 8.10E+00 | 3.32E+00 | 2.20E+00 | 1.53E+00 | 1.32E+00 | 1.17E+00 | 1.08E+00 | 1.03E+00 | 1.01E+00 |
| 25.0 | 7.30E+01 | 5.02E+01 | 2.22E+01 | 9.43E+00 | 3.60E+00 | 2.32E+00 | 1.57E+00 | 1.34E+00 | 1.18E+00 | 1.08E+00 | 1.03E+00 | 1.01E+00 |
| 30.0 | 9.84E+01 | 6.50E+01 | 2.69E+01 | 1.07E+01 | 3.85E+00 | 2.42E+00 | 1.61E+00 | 1.36E+00 | 1.19E+00 | 1.09E+00 | 1.03E+00 | 1.01E+00 |
| 35.0 | 1.27E+02 | 8.11E+01 | 3.16E+01 | 1.19E+01 | 4.08E+00 | 2.51E+00 | 1.64E+00 | 1.38E+00 | 1.20E+00 | 1.09E+00 | 1.03E+00 | 1.01E+00 |
| 40.0 | 1.59E+02 | 9.85E+01 | 3.64E+01 | 1.31E+01 | 4.30E+00 | 2.59E+00 | 1.66E+00 | 1.39E+00 | 1.21E+00 | 1.09E+00 | 1.03E+00 | 1.01E+00 |
| 45.0 | 1.94E+02 | 1.17E+02 | 4.13E+01 | 1.42E+01 | 4.50E+00 | 2.66E+00 | 1.69E+00 | 1.40E+00 | 1.21E+00 | 1.09E+00 | 1.03E+00 | 1.01E+00 |
| 50.0 | 2.32E+02 | 1.37E+02 | 4.63E+01 | 1.54E+01 | 4.69E+00 | 2.73E+00 | 1.71E+00 | 1.41E+00 | 1.22E+00 | 1.10E+00 | 1.03E+00 | 1.02E+00 |
| 55.0 | 2.73E+02 | 1.57E+02 | 5.14E+01 | 1.65E+01 | 4.87E+00 | 2.80E+00 | 1.73E+00 | 1.43E+00 | 1.22E+00 | 1.10E+00 | 1.03E+00 | 1.02E+00 |
| 60.0 | 3.17E+02 | 1.79E+02 | 5.66E+01 | 1.76E+01 | 5.05E+00 | 2.87E+00 | 1.75E+00 | 1.44E+00 | 1.23E+00 | 1.10E+00 | 1.03E+00 | 1.02E+00 |
| 65.0 | 3.64E+02 | 2.02E+02 | 6.18E+01 | 1.87E+01 | 5.22E+00 | 2.93E+00 | 1.77E+00 | 1.45E+00 | 1.23E+00 | 1.10E+00 | 1.03E+00 | 1.02E+00 |
| 70.0 | 4.14E+02 | 2.25E+02 | 6.72E+01 | 1.98E+01 | 5.39E+00 | 2.99E+00 | 1.79E+00 | 1.46E+00 | 1.24E+00 | 1.11E+00 | 1.03E+00 | 1.02E+00 |
| 75.0 | 4.66E+02 | 2.50E+02 | 7.26E+01 | 2.09E+01 | 5.56E+00 | 3.05E+00 | 1.81E+00 | 1.47E+00 | 1.24E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 80.0 | 5.22E+02 | 2.76E+02 | 7.81E+01 | 2.20E+01 | 5.73E+00 | 3.11E+00 | 1.83E+00 | 1.48E+00 | 1.25E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 85.0 | 5.80E+02 | 3.02E+02 | 8.37E+01 | 2.31E+01 | 5.89E+00 | 3.17E+00 | 1.85E+00 | 1.48E+00 | 1.25E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 90.0 | 6.42E+02 | 3.30E+02 | 8.94E+01 | 2.42E+01 | 6.06E+00 | 3.23E+00 | 1.86E+00 | 1.49E+00 | 1.25E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 95.0 | 7.06E+02 | 3.58E+02 | 9.53E+01 | 2.53E+01 | 6.22E+00 | 3.28E+00 | 1.88E+00 | 1.50E+00 | 1.26E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 100.0 | 7.73E+02 | 3.88E+02 | 1.01E+02 | 2.65E+01 | 6.39E+00 | 3.34E+00 | 1.90E+00 | 1.51E+00 | 1.26E+00 | 1.11E+00 | 1.04E+00 | 1.02E+00 |
| 110.0 | 9.15E+02 | 4.50E+02 | 1.13E+02 | 2.88E+01 | 6.71E+00 | 3.45E+00 | 1.93E+00 | 1.52E+00 | 1.27E+00 | 1.12E+00 | 1.04E+00 | 1.02E+00 |
| 120.0 | 1.07E+03 | 5.16E+02 | 1.26E+02 | 3.11E+01 | 7.04E+00 | 3.56E+00 | 1.96E+00 | 1.54E+00 | 1.27E+00 | 1.12E+00 | 1.04E+00 | 1.02E+00 |
| 130.0 | 1.23E+03 | 5.85E+02 | 1.39E+02 | 3.36E+01 | 7.37E+00 | 3.67E+00 | 1.99E+00 | 1.55E+00 | 1.28E+00 | 1.12E+00 | 1.03E+00 | 1.01E+00 |
| 140.0 | 1.41E+03 | 6.59E+02 | 1.53E+02 | 3.61E+01 | 7.70E+00 | 3.77E+00 | 2.01E+00 | 1.56E+00 | 1.28E+00 | 1.12E+00 | 1.03E+00 | 1.01E+00 |
| 150.0 | 1.60E+03 | 7.37E+02 | 1.67E+02 | 3.87E+01 | 8.03E+00 | 3.87E+00 | 2.04E+00 | 1.57E+00 | 1.28E+00 | 1.11E+00 | 1.03E+00 | 1.01E+00 |
| 160.0 | 1.80E+03 | 8.19E+02 | 1.82E+02 | 4.15E+01 | 8.37E+00 | 3.97E+00 | 2.06E+00 | 1.58E+00 | 1.28E+00 | 1.11E+00 | 1.02E+00 | 1.00E+00 |
| 170.0 | 2.01E+03 | 9.05E+02 | 1.98E+02 | 4.43E+01 | 8.70E+00 | 4.06E+00 | 2.07E+00 | 1.58E+00 | 1.28E+00 | 1.10E+00 | 1.01E+00 | 9.92E-01 |
| 180.0 | 2.23E+03 | 9.95E+02 | 2.14E+02 | 4.72E+01 | 9.02E+00 | 4.15E+00 | 2.09E+00 | 1.58E+00 | 1.27E+00 | 1.10E+00 | 1.01E+00 | 9.83E-01 |
| 190.0 | 2.47E+03 | 1.09E+03 | 2.31E+02 | 5.01E+01 | 9.35E+00 | 4.24E+00 | 2.10E+00 | 1.58E+00 | 1.26E+00 | 1.09E+00 | 9.95E-01 | 9.73E-01 |
| 200.0 | 2.72E+03 | 1.19E+03 | 2.48E+02 | 5.32E+01 | 9.67E+00 | 4.31E+00 | 2.10E+00 | 1.57E+00 | 1.26E+00 | 1.07E+00 | 9.84E-01 | 9.60E-01 |
| 210.0 | 2.98E+03 | 1.29E+03 | 2.67E+02 | 5.64E+01 | 9.99E+00 | 4.39E+00 | 2.11E+00 | 1.57E+00 | 1.24E+00 | 1.06E+00 | 9.70E-01 | 9.47E-01 |
| 220.0 | 3.25E+03 | 1.40E+03 | 2.86E+02 | 5.97E+01 | 1.03E+01 | 4.45E+00 | 2.11E+00 | 1.56E+00 | 1.23E+00 | 1.05E+00 | 9.55E-01 | 9.32E-01 |
| 230.0 | 3.54E+03 | 1.51E+03 | 3.05E+02 | 6.31E+01 | 1.06E+01 | 4.51E+00 | 2.10E+00 | 1.54E+00 | 1.22E+00 | 1.03E+00 | 9.39E-01 | 9.16E-01 |
| 240.0 | 3.83E+03 | 1.63E+03 | 3.26E+02 | 6.65E+01 | 1.09E+01 | 4.57E+00 | 2.10E+00 | 1.53E+00 | 1.20E+00 | 1.01E+00 | 9.22E-01 | 8.99E-01 |
| 250.0 | 4.14E+03 | 1.75E+03 | 3.47E+02 | 7.01E+01 | 1.12E+01 | 4.62E+00 | 2.09E+00 | 1.51E+00 | 1.18E+00 | 9.96E-01 | 9.04E-01 | 8.81E-01 |
| 260.0 | 4.47E+03 | 1.88E+03 | 3.69E+02 | 7.38E+01 | 1.15E+01 | 4.66E+00 | 2.07E+00 | 1.50E+00 | 1.16E+00 | 9.77E-01 | 8.85E-01 | 8.62E-01 |
| 270.0 | 4.80E+03 | 2.01E+03 | 3.92E+02 | 7.76E+01 | 1.18E+01 | 4.70E+00 | 2.06E+00 | 1.48E+00 | 1.14E+00 | 9.57E-01 | 8.65E-01 | 8.42E-01 |
| 280.0 | 5.15E+03 | 2.15E+03 | 4.15E+02 | 8.14E+01 | 1.20E+01 | 4.73E+00 | 2.04E+00 | 1.45E+00 | 1.12E+00 | 9.36E-01 | 8.45E-01 | 8.22E-01 |
| 290.0 | 5.51E+03 | 2.29E+03 | 4.40E+02 | 8.54E+01 | 1.23E+01 | 4.76E+00 | 2.02E+00 | 1.43E+00 | 1.10E+00 | 9.14E-01 | 8.24E-01 | 8.02E-01 |
| 300.0 | 5.88E+03 | 2.44E+03 | 4.65E+02 | 8.95E+01 | 1.26E+01 | 4.78E+00 | 2.00E+00 | 1.41E+00 | 1.07E+00 | 8.92E-01 | 8.03E-01 | 7.81E-01 |

表3 (1/3) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
鉛 (15-1.0MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 15.0 | 10.0 | 8.0 | 6.0 | 5.0 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 |
| 0.5 | 1.39E+00 | 1.32E+00 | 1.29E+00 | 1.27E+00 | 1.25E+00 | 1.25E+00 | 1.25E+00 | 1.25E+00 | 1.23E+00 | 1.20E+00 |
| 1.0 | 1.71E+00 | 1.55E+00 | 1.49E+00 | 1.44E+00 | 1.42E+00 | 1.42E+00 | 1.43E+00 | 1.45E+00 | 1.43E+00 | 1.37E+00 |
| 2.0 | 2.42E+00 | 2.00E+00 | 1.86E+00 | 1.77E+00 | 1.75E+00 | 1.76E+00 | 1.80E+00 | 1.83E+00 | 1.79E+00 | 1.67E+00 |
| 3.0 | 3.31E+00 | 2.51E+00 | 2.27E+00 | 2.13E+00 | 2.10E+00 | 2.12E+00 | 2.19E+00 | 2.22E+00 | 2.15E+00 | 1.95E+00 |
| 4.0 | 4.50E+00 | 3.13E+00 | 2.75E+00 | 2.54E+00 | 2.50E+00 | 2.52E+00 | 2.60E+00 | 2.61E+00 | 2.49E+00 | 2.20E+00 |
| 5.0 | 6.09E+00 | 3.89E+00 | 3.31E+00 | 3.00E+00 | 2.93E+00 | 2.96E+00 | 3.03E+00 | 3.02E+00 | 2.83E+00 | 2.44E+00 |
| 6.0 | 8.25E+00 | 4.82E+00 | 3.98E+00 | 3.53E+00 | 3.42E+00 | 3.43E+00 | 3.49E+00 | 3.42E+00 | 3.17E+00 | 2.67E+00 |
| 7.0 | 1.12E+01 | 5.97E+00 | 4.76E+00 | 4.12E+00 | 3.97E+00 | 3.95E+00 | 3.98E+00 | 3.84E+00 | 3.50E+00 | 2.90E+00 |
| 8.0 | 1.52E+01 | 7.40E+00 | 5.70E+00 | 4.80E+00 | 4.58E+00 | 4.51E+00 | 4.49E+00 | 4.27E+00 | 3.83E+00 | 3.11E+00 |
| 10.0 | 2.83E+01 | 1.14E+01 | 8.12E+00 | 6.45E+00 | 5.99E+00 | 5.76E+00 | 5.59E+00 | 5.13E+00 | 4.48E+00 | 3.52E+00 |
| 15.0 | 1.36E+02 | 3.37E+01 | 1.95E+01 | 1.28E+01 | 1.10E+01 | 9.78E+00 | 8.77E+00 | 7.40E+00 | 6.09E+00 | 4.45E+00 |
| 20.0 | 6.58E+02 | 9.99E+01 | 4.58E+01 | 2.43E+01 | 1.89E+01 | 1.53E+01 | 1.26E+01 | 9.78E+00 | 7.67E+00 | 5.29E+00 |
| 25.0 | 3.15E+03 | 2.94E+02 | 1.06E+02 | 4.43E+01 | 3.07E+01 | 2.25E+01 | 1.69E+01 | 1.23E+01 | 9.22E+00 | 6.07E+00 |
| 30.0 | 1.49E+04 | 8.52E+02 | 2.40E+02 | 7.82E+01 | 4.82E+01 | 3.17E+01 | 2.18E+01 | 1.48E+01 | 1.07E+01 | 6.81E+00 |
| 35.0 | 6.96E+04 | 2.43E+03 | 5.35E+02 | 1.34E+02 | 7.32E+01 | 4.32E+01 | 2.72E+01 | 1.74E+01 | 1.22E+01 | 7.51E+00 |
| 40.0 | 3.21E+05 | 6.87E+03 | 1.17E+03 | 2.26E+02 | 1.09E+02 | 5.74E+01 | 3.31E+01 | 2.00E+01 | 1.37E+01 | 8.19E+00 |
| 45.0 | 1.46E+06 | 1.91E+04 | 2.54E+03 | 3.73E+02 | 1.58E+02 | 7.46E+01 | 3.95E+01 | 2.27E+01 | 1.52E+01 | 8.85E+00 |
| 50.0 | 6.61E+06 | 5.26E+04 | 5.42E+03 | 6.06E+02 | 2.25E+02 | 9.52E+01 | 4.64E+01 | 2.54E+01 | 1.66E+01 | 9.50E+00 |
| 55.0 | 2.96E+07 | 1.43E+05 | 1.14E+04 | 9.70E+02 | 3.16E+02 | 1.20E+02 | 5.37E+01 | 2.81E+01 | 1.80E+01 | 1.01E+01 |
| 60.0 | 1.31E+08 | 3.87E+05 | 2.39E+04 | 1.53E+03 | 4.38E+02 | 1.49E+02 | 6.15E+01 | 3.08E+01 | 1.94E+01 | 1.08E+01 |
| 65.0 | 5.78E+08 | 1.04E+06 | 4.94E+04 | 2.40E+03 | 5.99E+02 | 1.82E+02 | 6.97E+01 | 3.36E+01 | 2.08E+01 | 1.14E+01 |
| 70.0 | 2.53E+09 | 2.76E+06 | 1.01E+05 | 3.72E+03 | 8.13E+02 | 2.21E+02 | 7.83E+01 | 3.64E+01 | 2.22E+01 | 1.20E+01 |
| 75.0 | 1.10E+10 | 7.28E+06 | 2.06E+05 | 5.71E+03 | 1.09E+03 | 2.66E+02 | 8.72E+01 | 3.92E+01 | 2.36E+01 | 1.26E+01 |
| 80.0 | 4.76E+10 | 1.91E+07 | 4.16E+05 | 8.69E+03 | 1.45E+03 | 3.18E+02 | 9.66E+01 | 4.20E+01 | 2.49E+01 | 1.32E+01 |
| 85.0 | 2.05E+11 | 4.98E+07 | 8.36E+05 | 1.31E+04 | 1.92E+03 | 3.76E+02 | 1.06E+02 | 4.48E+01 | 2.63E+01 | 1.39E+01 |
| 90.0 | 8.77E+11 | 1.29E+08 | 1.67E+06 | 1.98E+04 | 2.53E+03 | 4.43E+02 | 1.16E+02 | 4.76E+01 | 2.76E+01 | 1.45E+01 |
| 95.0 | 3.74E+12 | 3.33E+08 | 3.32E+06 | 2.95E+04 | 3.30E+03 | 5.19E+02 | 1.27E+02 | 5.05E+01 | 2.89E+01 | 1.51E+01 |
| 100.0 | 1.59E+13 | 8.56E+08 | 6.55E+06 | 4.38E+04 | 4.28E+03 | 6.03E+02 | 1.38E+02 | 5.33E+01 | 3.02E+01 | 1.58E+01 |
| 110.0 | 2.83E+14 | 5.58E+09 | 2.52E+07 | 9.52E+04 | 7.09E+03 | 8.05E+02 | 1.60E+02 | 5.91E+01 | 3.29E+01 | 1.71E+01 |
| 120.0 | 4.99E+15 | 3.59E+10 | 9.56E+07 | 2.03E+05 | 1.15E+04 | 1.06E+03 | 1.84E+02 | 6.48E+01 | 3.54E+01 | 1.85E+01 |
| 130.0 | 8.68E+16 | 2.27E+11 | 3.57E+08 | 4.27E+05 | 1.85E+04 | 1.36E+03 | 2.09E+02 | 7.06E+01 | 3.80E+01 | 1.99E+01 |
| 140.0 | 1.49E+18 | 1.42E+12 | 1.32E+09 | 8.84E+05 | 2.91E+04 | 1.74E+03 | 2.35E+02 | 7.65E+01 | 4.05E+01 | 2.13E+01 |
| 150.0 | 2.55E+19 | 8.83E+12 | 4.80E+09 | 1.81E+06 | 4.54E+04 | 2.19E+03 | 2.62E+02 | 8.23E+01 | 4.30E+01 | 2.28E+01 |
| 160.0 | 4.31E+20 | 5.42E+13 | 1.73E+10 | 3.66E+06 | 7.00E+04 | 2.72E+03 | 2.90E+02 | 8.81E+01 | 4.55E+01 | 2.44E+01 |
| 170.0 | 7.24E+21 | 3.30E+14 | 6.20E+10 | 7.33E+06 | 1.07E+05 | 3.36E+03 | 3.19E+02 | 9.39E+01 | 4.79E+01 | 2.60E+01 |
| 180.0 | 1.21E+23 | 2.00E+15 | 2.20E+11 | 1.46E+07 | 1.61E+05 | 4.11E+03 | 3.48E+02 | 9.97E+01 | 5.03E+01 | 2.76E+01 |
| 190.0 | 2.00E+24 | 1.20E+16 | 7.73E+11 | 2.87E+07 | 2.42E+05 | 4.99E+03 | 3.79E+02 | 1.05E+02 | 5.26E+01 | 2.93E+01 |
| 200.0 | 3.29E+25 | 7.13E+16 | 2.70E+12 | 5.60E+07 | 3.59E+05 | 6.01E+03 | 4.10E+02 | 1.11E+02 | 5.48E+01 | 3.11E+01 |
| 210.0 | 5.39E+26 | 4.22E+17 | 9.38E+12 | 1.09E+08 | 5.31E+05 | 7.19E+03 | 4.42E+02 | 1.17E+02 | 5.70E+01 | 3.29E+01 |
| 220.0 | 8.79E+27 | 2.49E+18 | 3.24E+13 | 2.10E+08 | 7.78E+05 | 8.55E+03 | 4.74E+02 | 1.22E+02 | 5.91E+01 | 3.48E+01 |
| 230.0 | 1.43E+29 | 1.46E+19 | 1.11E+14 | 4.01E+08 | 1.13E+06 | 1.01E+04 | 5.06E+02 | 1.27E+02 | 6.11E+01 | 3.67E+01 |
| 240.0 | 2.30E+30 | 8.49E+19 | 3.79E+14 | 7.65E+08 | 1.64E+06 | 1.19E+04 | 5.39E+02 | 1.33E+02 | 6.30E+01 | 3.86E+01 |
| 250.0 | 3.70E+31 | 4.93E+20 | 1.29E+15 | 1.45E+09 | 2.37E+06 | 1.39E+04 | 5.72E+02 | 1.38E+02 | 6.48E+01 | 4.06E+01 |
| 260.0 | 5.93E+32 | 2.85E+21 | 4.34E+15 | 2.73E+09 | 3.39E+06 | 1.62E+04 | 6.05E+02 | 1.42E+02 | 6.66E+01 | 4.27E+01 |
| 270.0 | 9.46E+33 | 1.64E+22 | 1.46E+16 | 5.13E+09 | 4.84E+06 | 1.88E+04 | 6.38E+02 | 1.47E+02 | 6.82E+01 | 4.48E+01 |
| 280.0 | 1.50E+35 | 9.38E+22 | 4.90E+16 | 9.58E+09 | 6.87E+06 | 2.16E+04 | 6.71E+02 | 1.52E+02 | 6.98E+01 | 4.69E+01 |
| 290.0 | 2.38E+36 | 5.36E+23 | 1.63E+17 | 1.78E+10 | 9.71E+06 | 2.49E+04 | 7.04E+02 | 1.56E+02 | 7.12E+01 | 4.91E+01 |
| 300.0 | 3.77E+37 | 3.05E+24 | 5.43E+17 | 3.30E+10 | 1.37E+07 | 2.85E+04 | 7.36E+02 | 1.60E+02 | 7.26E+01 | 5.14E+01 |

表3(2/3) 改良ビルドアップ係数(照射線量ビルドアップ係数)
鉛(0.8-0.13MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.8 | 0.6 | 0.5 | 0.4 | 0.3 | 0.2 | 0.16 | 0.15 | 0.14 | 0.13 |
| 0.5 | 1.18E+00 | 1.15E+00 | 1.13E+00 | 1.10E+00 | 1.07E+00 | 1.16E+00 | 1.25E+00 | 1.29E+00 | 1.33E+00 | 1.38E+00 |
| 1.0 | 1.33E+00 | 1.27E+00 | 1.22E+00 | 1.17E+00 | 1.11E+00 | 1.20E+00 | 1.36E+00 | 1.44E+00 | 1.52E+00 | 1.64E+00 |
| 2.0 | 1.59E+00 | 1.46E+00 | 1.38E+00 | 1.28E+00 | 1.18E+00 | 1.23E+00 | 1.46E+00 | 1.60E+00 | 1.78E+00 | 2.04E+00 |
| 3.0 | 1.81E+00 | 1.62E+00 | 1.50E+00 | 1.36E+00 | 1.23E+00 | 1.25E+00 | 1.51E+00 | 1.69E+00 | 1.97E+00 | 2.41E+00 |
| 4.0 | 2.02E+00 | 1.77E+00 | 1.61E+00 | 1.43E+00 | 1.27E+00 | 1.27E+00 | 1.53E+00 | 1.75E+00 | 2.13E+00 | 2.80E+00 |
| 5.0 | 2.21E+00 | 1.90E+00 | 1.70E+00 | 1.50E+00 | 1.30E+00 | 1.28E+00 | 1.54E+00 | 1.79E+00 | 2.28E+00 | 3.24E+00 |
| 6.0 | 2.38E+00 | 2.01E+00 | 1.78E+00 | 1.55E+00 | 1.33E+00 | 1.30E+00 | 1.55E+00 | 1.83E+00 | 2.44E+00 | 3.77E+00 |
| 7.0 | 2.55E+00 | 2.12E+00 | 1.86E+00 | 1.60E+00 | 1.36E+00 | 1.31E+00 | 1.56E+00 | 1.87E+00 | 2.61E+00 | 4.46E+00 |
| 8.0 | 2.71E+00 | 2.23E+00 | 1.94E+00 | 1.64E+00 | 1.38E+00 | 1.32E+00 | 1.57E+00 | 1.90E+00 | 2.81E+00 | 5.35E+00 |
| 10.0 | 3.01E+00 | 2.42E+00 | 2.07E+00 | 1.72E+00 | 1.42E+00 | 1.34E+00 | 1.58E+00 | 1.98E+00 | 3.34E+00 | 8.19E+00 |
| 15.0 | 3.67E+00 | 2.83E+00 | 2.34E+00 | 1.88E+00 | 1.50E+00 | 1.37E+00 | 1.60E+00 | 2.20E+00 | 6.15E+00 | 3.29E+01 |
| 20.0 | 4.24E+00 | 3.17E+00 | 2.56E+00 | 2.00E+00 | 1.56E+00 | 1.40E+00 | 1.61E+00 | 2.52E+00 | 1.46E+01 | 1.74E+02 |
| 25.0 | 4.76E+00 | 3.48E+00 | 2.75E+00 | 2.11E+00 | 1.61E+00 | 1.42E+00 | 1.62E+00 | 3.00E+00 | 4.12E+01 | 1.01E+03 |
| 30.0 | 5.24E+00 | 3.77E+00 | 2.93E+00 | 2.20E+00 | 1.66E+00 | 1.44E+00 | 1.62E+00 | 3.75E+00 | 1.27E+02 | 6.13E+03 |
| 35.0 | 5.69E+00 | 4.04E+00 | 3.09E+00 | 2.27E+00 | 1.69E+00 | 1.46E+00 | 1.63E+00 | 5.00E+00 | 4.08E+02 | 3.79E+04 |
| 40.0 | 6.12E+00 | 4.30E+00 | 3.24E+00 | 2.34E+00 | 1.72E+00 | 1.47E+00 | 1.64E+00 | 7.09E+00 | 1.35E+03 | 2.38E+05 |
| 45.0 | 6.53E+00 | 4.56E+00 | 3.39E+00 | 2.41E+00 | 1.75E+00 | 1.49E+00 | 1.64E+00 | 1.07E+01 | 4.58E+03 | 1.52E+06 |
| 50.0 | 6.93E+00 | 4.81E+00 | 3.53E+00 | 2.47E+00 | 1.78E+00 | 1.50E+00 | 1.65E+00 | 1.69E+01 | 1.58E+04 | 9.82E+06 |
| 55.0 | 7.32E+00 | 5.06E+00 | 3.67E+00 | 2.52E+00 | 1.80E+00 | 1.51E+00 | 1.66E+00 | 2.76E+01 | 5.47E+04 | 6.40E+07 |
| 60.0 | 7.71E+00 | 5.31E+00 | 3.81E+00 | 2.57E+00 | 1.83E+00 | 1.52E+00 | 1.66E+00 | 4.65E+01 | 1.92E+05 | 4.21E+08 |
| 65.0 | 8.09E+00 | 5.56E+00 | 3.95E+00 | 2.62E+00 | 1.85E+00 | 1.53E+00 | 1.67E+00 | 7.97E+01 | 6.78E+05 | 2.79E+09 |
| 70.0 | 8.47E+00 | 5.82E+00 | 4.08E+00 | 2.67E+00 | 1.87E+00 | 1.54E+00 | 1.67E+00 | 1.38E+02 | 2.41E+06 | 1.86E+10 |
| 75.0 | 8.85E+00 | 6.08E+00 | 4.22E+00 | 2.71E+00 | 1.89E+00 | 1.55E+00 | 1.68E+00 | 2.41E+02 | 8.57E+06 | 1.25E+11 |
| 80.0 | 9.22E+00 | 6.35E+00 | 4.36E+00 | 2.76E+00 | 1.91E+00 | 1.57E+00 | 1.68E+00 | 4.23E+02 | 3.06E+07 | 8.39E+11 |
| 85.0 | 9.60E+00 | 6.62E+00 | 4.50E+00 | 2.80E+00 | 1.92E+00 | 1.58E+00 | 1.69E+00 | 7.44E+02 | 1.10E+08 | 5.66E+12 |
| 90.0 | 9.98E+00 | 6.90E+00 | 4.64E+00 | 2.84E+00 | 1.94E+00 | 1.59E+00 | 1.69E+00 | 1.31E+03 | 3.93E+08 | 3.82E+13 |
| 95.0 | 1.04E+01 | 7.19E+00 | 4.78E+00 | 2.88E+00 | 1.96E+00 | 1.59E+00 | 1.70E+00 | 2.32E+03 | 1.41E+09 | 2.59E+14 |
| 100.0 | 1.08E+01 | 7.48E+00 | 4.92E+00 | 2.91E+00 | 1.97E+00 | 1.60E+00 | 1.71E+00 | 4.09E+03 | 5.06E+09 | 1.76E+15 |
| 110.0 | 1.15E+01 | 8.09E+00 | 5.22E+00 | 2.99E+00 | 2.00E+00 | 1.62E+00 | 1.72E+00 | 1.28E+04 | 6.54E+10 | 8.10E+16 |
| 120.0 | 1.23E+01 | 8.73E+00 | 5.52E+00 | 3.05E+00 | 2.03E+00 | 1.64E+00 | 1.72E+00 | 4.00E+04 | 8.46E+11 | 3.75E+18 |
| 130.0 | 1.32E+01 | 9.40E+00 | 5.83E+00 | 3.12E+00 | 2.05E+00 | 1.65E+00 | 1.73E+00 | 1.25E+05 | 1.10E+13 | 1.74E+20 |
| 140.0 | 1.40E+01 | 1.01E+01 | 6.15E+00 | 3.17E+00 | 2.07E+00 | 1.67E+00 | 1.74E+00 | 3.92E+05 | 1.42E+14 | 8.05E+21 |
| 150.0 | 1.49E+01 | 1.08E+01 | 6.47E+00 | 3.23E+00 | 2.09E+00 | 1.68E+00 | 1.74E+00 | 1.22E+06 | 1.83E+15 | 3.73E+23 |
| 160.0 | 1.58E+01 | 1.16E+01 | 6.80E+00 | 3.28E+00 | 2.11E+00 | 1.69E+00 | 1.74E+00 | 3.83E+06 | 2.37E+16 | 1.73E+25 |
| 170.0 | 1.67E+01 | 1.24E+01 | 7.13E+00 | 3.32E+00 | 2.12E+00 | 1.69E+00 | 1.74E+00 | 1.19E+07 | 3.07E+17 | 8.04E+26 |
| 180.0 | 1.77E+01 | 1.32E+01 | 7.47E+00 | 3.36E+00 | 2.13E+00 | 1.70E+00 | 1.74E+00 | 3.72E+07 | 3.96E+18 | 3.73E+28 |
| 190.0 | 1.87E+01 | 1.41E+01 | 7.80E+00 | 3.39E+00 | 2.13E+00 | 1.70E+00 | 1.73E+00 | 1.16E+08 | 5.12E+19 | 1.73E+30 |
| 200.0 | 1.97E+01 | 1.50E+01 | 8.14E+00 | 3.42E+00 | 2.13E+00 | 1.69E+00 | 1.72E+00 | 3.61E+08 | 6.60E+20 | 8.05E+31 |
| 210.0 | 2.07E+01 | 1.59E+01 | 8.48E+00 | 3.44E+00 | 2.13E+00 | 1.69E+00 | 1.70E+00 | 1.12E+09 | 8.51E+21 | 3.74E+33 |
| 220.0 | 2.17E+01 | 1.69E+01 | 8.82E+00 | 3.45E+00 | 2.12E+00 | 1.68E+00 | 1.69E+00 | 3.48E+09 | 1.10E+23 | 1.73E+35 |
| 230.0 | 2.27E+01 | 1.78E+01 | 9.15E+00 | 3.46E+00 | 2.11E+00 | 1.67E+00 | 1.67E+00 | 1.08E+10 | 1.41E+24 | 8.05E+36 |
| 240.0 | 2.38E+01 | 1.88E+01 | 9.48E+00 | 3.47E+00 | 2.10E+00 | 1.66E+00 | 1.65E+00 | 3.34E+10 | 1.82E+25 | Inf |
| 250.0 | 2.49E+01 | 1.98E+01 | 9.82E+00 | 3.47E+00 | 2.08E+00 | 1.64E+00 | 1.63E+00 | 1.03E+11 | 2.33E+26 | Inf |
| 260.0 | 2.60E+01 | 2.09E+01 | 1.01E+01 | 3.46E+00 | 2.06E+00 | 1.62E+00 | 1.60E+00 | 3.19E+11 | 3.00E+27 | Inf |
| 270.0 | 2.71E+01 | 2.20E+01 | 1.05E+01 | 3.45E+00 | 2.04E+00 | 1.60E+00 | 1.58E+00 | 9.86E+11 | 3.85E+28 | Inf |
| 280.0 | 2.82E+01 | 2.31E+01 | 1.08E+01 | 3.44E+00 | 2.02E+00 | 1.58E+00 | 1.55E+00 | 3.04E+12 | 4.93E+29 | Inf |
| 290.0 | 2.93E+01 | 2.42E+01 | 1.11E+01 | 3.42E+00 | 1.99E+00 | 1.56E+00 | 1.52E+00 | 9.38E+12 | 6.32E+30 | Inf |
| 300.0 | 3.05E+01 | 2.53E+01 | 1.14E+01 | 3.40E+00 | 1.96E+00 | 1.54E+00 | 1.49E+00 | 2.89E+13 | 8.09E+31 | Inf |

Inf : 1.0E38以上

表3 (3/3) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
鉛 (0.12-0.03MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.12 | 0.11 | 0.10 | 0.09 | 0.089 | 0.088 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 |
| 0.5 | 1.44E+00 | 1.51E+00 | 1.60E+00 | 1.68E+00 | 1.69E+00 | 1.04E+00 | 1.03E+00 | 1.02E+00 | 1.01E+00 | 1.01E+00 | 1.00E+00 |
| 1.0 | 1.77E+00 | 1.94E+00 | 2.15E+00 | 2.36E+00 | 2.38E+00 | 1.06E+00 | 1.05E+00 | 1.03E+00 | 1.02E+00 | 1.01E+00 | 1.01E+00 |
| 2.0 | 2.39E+00 | 2.85E+00 | 3.47E+00 | 4.16E+00 | 4.25E+00 | 1.08E+00 | 1.07E+00 | 1.04E+00 | 1.03E+00 | 1.02E+00 | 1.01E+00 |
| 3.0 | 3.08E+00 | 4.06E+00 | 5.48E+00 | 7.27E+00 | 7.51E+00 | 1.10E+00 | 1.09E+00 | 1.05E+00 | 1.03E+00 | 1.02E+00 | 1.01E+00 |
| 4.0 | 3.93E+00 | 5.80E+00 | 8.79E+00 | 1.30E+01 | 1.36E+01 | 1.12E+00 | 1.10E+00 | 1.05E+00 | 1.04E+00 | 1.02E+00 | 1.01E+00 |
| 5.0 | 5.08E+00 | 8.46E+00 | 1.45E+01 | 2.40E+01 | 2.54E+01 | 1.13E+00 | 1.11E+00 | 1.06E+00 | 1.04E+00 | 1.02E+00 | 1.01E+00 |
| 6.0 | 6.67E+00 | 1.26E+01 | 2.44E+01 | 4.52E+01 | 4.83E+01 | 1.14E+00 | 1.12E+00 | 1.06E+00 | 1.04E+00 | 1.02E+00 | 1.01E+00 |
| 7.0 | 8.96E+00 | 1.94E+01 | 4.22E+01 | 8.65E+01 | 9.35E+01 | 1.15E+00 | 1.12E+00 | 1.07E+00 | 1.04E+00 | 1.03E+00 | 1.01E+00 |
| 8.0 | 1.23E+01 | 3.03E+01 | 7.40E+01 | 1.68E+02 | 1.83E+02 | 1.16E+00 | 1.13E+00 | 1.07E+00 | 1.05E+00 | 1.03E+00 | 1.01E+00 |
| 10.0 | 2.49E+01 | 7.87E+01 | 2.37E+02 | 6.47E+02 | 7.20E+02 | 1.17E+00 | 1.14E+00 | 1.07E+00 | 1.05E+00 | 1.03E+00 | 1.01E+00 |
| 15.0 | 1.95E+02 | 1.07E+03 | 5.03E+03 | 2.07E+04 | 2.39E+04 | 1.20E+00 | 1.16E+00 | 1.09E+00 | 1.06E+00 | 1.03E+00 | 1.02E+00 |
| 20.0 | 1.88E+03 | 1.70E+04 | 1.22E+05 | 7.24E+05 | 8.62E+05 | 1.22E+00 | 1.18E+00 | 1.09E+00 | 1.06E+00 | 1.04E+00 | 1.02E+00 |
| 25.0 | 1.95E+04 | 2.93E+05 | 3.18E+06 | 2.70E+07 | 3.30E+07 | 1.24E+00 | 1.19E+00 | 1.10E+00 | 1.06E+00 | 1.04E+00 | 1.02E+00 |
| 30.0 | 2.09E+05 | 5.21E+06 | 8.65E+07 | 1.05E+09 | 1.32E+09 | 1.25E+00 | 1.20E+00 | 1.10E+00 | 1.07E+00 | 1.04E+00 | 1.02E+00 |
| 35.0 | 2.28E+06 | 9.42E+07 | 2.41E+09 | 4.24E+10 | 5.47E+10 | 1.26E+00 | 1.21E+00 | 1.11E+00 | 1.07E+00 | 1.04E+00 | 1.02E+00 |
| 40.0 | 2.51E+07 | 1.72E+09 | 6.81E+10 | 1.74E+12 | 2.31E+12 | 1.27E+00 | 1.22E+00 | 1.11E+00 | 1.07E+00 | 1.04E+00 | 1.02E+00 |
| 45.0 | 2.80E+08 | 3.16E+10 | 1.94E+12 | 7.20E+13 | 9.86E+13 | 1.28E+00 | 1.22E+00 | 1.11E+00 | 1.07E+00 | 1.04E+00 | 1.02E+00 |
| 50.0 | 3.16E+09 | 5.84E+11 | 5.54E+13 | 3.01E+15 | 4.25E+15 | 1.28E+00 | 1.23E+00 | 1.12E+00 | 1.07E+00 | 1.04E+00 | 1.02E+00 |
| 55.0 | 3.59E+10 | 1.09E+13 | 1.59E+15 | 1.26E+17 | 1.84E+17 | 1.29E+00 | 1.23E+00 | 1.12E+00 | 1.08E+00 | 1.04E+00 | 1.02E+00 |
| 60.0 | 4.11E+11 | 2.03E+14 | 4.59E+16 | 5.33E+18 | 8.03E+18 | 1.30E+00 | 1.24E+00 | 1.12E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 65.0 | 4.75E+12 | 3.82E+15 | 1.33E+18 | 2.25E+20 | 3.51E+20 | 1.30E+00 | 1.24E+00 | 1.12E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 70.0 | 5.52E+13 | 7.22E+16 | 3.86E+19 | 9.55E+21 | 1.54E+22 | 1.31E+00 | 1.25E+00 | 1.12E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 75.0 | 6.44E+14 | 1.37E+18 | 1.13E+21 | 4.06E+23 | 6.75E+23 | 1.31E+00 | 1.25E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 80.0 | 7.55E+15 | 2.61E+19 | 3.29E+22 | 1.73E+25 | 2.97E+25 | 1.32E+00 | 1.25E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 85.0 | 8.89E+16 | 4.99E+20 | 9.65E+23 | 7.36E+26 | 1.31E+27 | 1.32E+00 | 1.26E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 90.0 | 1.05E+18 | 9.57E+21 | 2.84E+25 | 3.15E+28 | 5.79E+28 | 1.32E+00 | 1.26E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 95.0 | 1.24E+19 | 1.84E+23 | 8.36E+26 | 1.35E+30 | 2.56E+30 | 1.33E+00 | 1.26E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 100.0 | 1.48E+20 | 3.56E+24 | 2.47E+28 | 5.78E+31 | 1.14E+32 | 1.33E+00 | 1.26E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 110.0 | 2.09E+22 | 1.34E+27 | 2.18E+31 | 1.07E+35 | 2.25E+35 | 1.34E+00 | 1.27E+00 | 1.13E+00 | 1.09E+00 | 1.05E+00 | 1.02E+00 |
| 120.0 | 2.97E+24 | 5.06E+29 | 1.93E+34 | Inf | Inf | 1.34E+00 | 1.27E+00 | 1.13E+00 | 1.09E+00 | 1.05E+00 | 1.02E+00 |
| 130.0 | 4.24E+26 | 1.93E+32 | 1.73E+37 | Inf | Inf | 1.34E+00 | 1.27E+00 | 1.13E+00 | 1.08E+00 | 1.05E+00 | 1.02E+00 |
| 140.0 | 6.06E+28 | 7.37E+34 | Inf | Inf | Inf | 1.34E+00 | 1.27E+00 | 1.13E+00 | 1.08E+00 | 1.04E+00 | 1.02E+00 |
| 150.0 | 8.68E+30 | 2.83E+37 | Inf | Inf | Inf | 1.34E+00 | 1.27E+00 | 1.13E+00 | 1.08E+00 | 1.04E+00 | 1.01E+00 |
| 160.0 | 1.24E+33 | Inf | Inf | Inf | Inf | 1.34E+00 | 1.27E+00 | 1.12E+00 | 1.07E+00 | 1.03E+00 | 1.01E+00 |
| 170.0 | 1.78E+35 | Inf | Inf | Inf | Inf | 1.33E+00 | 1.26E+00 | 1.12E+00 | 1.07E+00 | 1.03E+00 | 1.00E+00 |
| 180.0 | 2.56E+37 | Inf | Inf | Inf | Inf | 1.33E+00 | 1.26E+00 | 1.11E+00 | 1.06E+00 | 1.02E+00 | 9.92E-01 |
| 190.0 | Inf | Inf | Inf | Inf | Inf | 1.32E+00 | 1.25E+00 | 1.10E+00 | 1.05E+00 | 1.01E+00 | 9.81E-01 |
| 200.0 | Inf | Inf | Inf | Inf | Inf | 1.30E+00 | 1.24E+00 | 1.09E+00 | 1.03E+00 | 9.96E-01 | 9.69E-01 |
| 210.0 | Inf | Inf | Inf | Inf | Inf | 1.29E+00 | 1.22E+00 | 1.07E+00 | 1.02E+00 | 9.82E-01 | 9.55E-01 |
| 220.0 | Inf | Inf | Inf | Inf | Inf | 1.27E+00 | 1.21E+00 | 1.06E+00 | 1.01E+00 | 9.67E-01 | 9.40E-01 |
| 230.0 | Inf | Inf | Inf | Inf | Inf | 1.25E+00 | 1.19E+00 | 1.04E+00 | 9.89E-01 | 9.51E-01 | 9.24E-01 |
| 240.0 | Inf | Inf | Inf | Inf | Inf | 1.23E+00 | 1.17E+00 | 1.02E+00 | 9.71E-01 | 9.34E-01 | 9.07E-01 |
| 250.0 | Inf | Inf | Inf | Inf | Inf | 1.21E+00 | 1.15E+00 | 1.00E+00 | 9.52E-01 | 9.15E-01 | 8.89E-01 |
| 260.0 | Inf | Inf | Inf | Inf | Inf | 1.19E+00 | 1.13E+00 | 9.84E-01 | 9.33E-01 | 8.96E-01 | 8.70E-01 |
| 270.0 | Inf | Inf | Inf | Inf | Inf | 1.17E+00 | 1.11E+00 | 9.63E-01 | 9.12E-01 | 8.76E-01 | 8.51E-01 |
| 280.0 | Inf | Inf | Inf | Inf | Inf | 1.14E+00 | 1.08E+00 | 9.42E-01 | 8.91E-01 | 8.56E-01 | 8.30E-01 |
| 290.0 | Inf | Inf | Inf | Inf | Inf | 1.12E+00 | 1.06E+00 | 9.20E-01 | 8.70E-01 | 8.35E-01 | 8.10E-01 |
| 300.0 | Inf | Inf | Inf | Inf | Inf | 1.09E+00 | 1.04E+00 | 8.97E-01 | 8.48E-01 | 8.13E-01 | 7.89E-01 |

Inf : 1.0E38以上

表4 (1/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
水 (15-0.5MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 15.0 | 10.0 | 8.0 | 6.0 | 5.0 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 | 0.8 | 0.6 | 0.5 |
| 0.5 | 1.21E+00 | 1.24E+00 | 1.26E+00 | 1.29E+00 | 1.30E+00 | 1.32E+00 | 1.35E+00 | 1.39E+00 | 1.42E+00 | 1.47E+00 | 1.51E+00 | 1.57E+00 | 1.61E+00 |
| 1.0 | 1.37E+00 | 1.44E+00 | 1.49E+00 | 1.56E+00 | 1.60E+00 | 1.65E+00 | 1.73E+00 | 1.84E+00 | 1.93E+00 | 2.08E+00 | 2.19E+00 | 2.34E+00 | 2.45E+00 |
| 2.0 | 1.64E+00 | 1.78E+00 | 1.88E+00 | 2.04E+00 | 2.14E+00 | 2.29E+00 | 2.50E+00 | 2.84E+00 | 3.13E+00 | 3.63E+00 | 3.98E+00 | 4.50E+00 | 4.88E+00 |
| 3.0 | 1.89E+00 | 2.10E+00 | 2.26E+00 | 2.50E+00 | 2.67E+00 | 2.90E+00 | 3.27E+00 | 3.90E+00 | 4.48E+00 | 5.53E+00 | 6.28E+00 | 7.45E+00 | 8.33E+00 |
| 4.0 | 2.13E+00 | 2.41E+00 | 2.62E+00 | 2.95E+00 | 3.18E+00 | 3.52E+00 | 4.06E+00 | 5.02E+00 | 5.96E+00 | 7.72E+00 | 9.03E+00 | 1.12E+01 | 1.28E+01 |
| 5.0 | 2.36E+00 | 2.71E+00 | 2.98E+00 | 3.39E+00 | 3.70E+00 | 4.14E+00 | 4.86E+00 | 6.20E+00 | 7.54E+00 | 1.02E+01 | 1.22E+01 | 1.56E+01 | 1.83E+01 |
| 6.0 | 2.59E+00 | 3.01E+00 | 3.33E+00 | 3.83E+00 | 4.21E+00 | 4.76E+00 | 5.68E+00 | 7.43E+00 | 9.22E+00 | 1.29E+01 | 1.58E+01 | 2.08E+01 | 2.48E+01 |
| 7.0 | 2.81E+00 | 3.30E+00 | 3.67E+00 | 4.27E+00 | 4.71E+00 | 5.38E+00 | 6.51E+00 | 8.70E+00 | 1.10E+01 | 1.59E+01 | 1.98E+01 | 2.67E+01 | 3.25E+01 |
| 8.0 | 3.03E+00 | 3.59E+00 | 4.01E+00 | 4.70E+00 | 5.22E+00 | 6.01E+00 | 7.34E+00 | 1.00E+01 | 1.29E+01 | 1.91E+01 | 2.42E+01 | 3.34E+01 | 4.12E+01 |
| 10.0 | 3.47E+00 | 4.15E+00 | 4.68E+00 | 5.56E+00 | 6.22E+00 | 7.25E+00 | 9.04E+00 | 1.27E+01 | 1.68E+01 | 2.62E+01 | 3.43E+01 | 4.92E+01 | 6.23E+01 |
| 15.0 | 4.52E+00 | 5.51E+00 | 6.31E+00 | 7.65E+00 | 8.69E+00 | 1.04E+01 | 1.34E+01 | 2.00E+01 | 2.79E+01 | 4.76E+01 | 6.62E+01 | 1.03E+02 | 1.38E+02 |
| 20.0 | 5.55E+00 | 6.83E+00 | 7.88E+00 | 9.68E+00 | 1.11E+01 | 1.35E+01 | 1.78E+01 | 2.78E+01 | 4.02E+01 | 7.36E+01 | 1.07E+02 | 1.78E+02 | 2.48E+02 |
| 25.0 | 6.56E+00 | 8.12E+00 | 9.42E+00 | 1.17E+01 | 1.35E+01 | 1.66E+01 | 2.23E+01 | 3.60E+01 | 5.35E+01 | 1.03E+02 | 1.56E+02 | 2.73E+02 | 3.96E+02 |
| 30.0 | 7.55E+00 | 9.37E+00 | 1.09E+01 | 1.36E+01 | 1.59E+01 | 1.96E+01 | 2.69E+01 | 4.45E+01 | 6.77E+01 | 1.37E+02 | 2.13E+02 | 3.89E+02 | 5.82E+02 |
| 35.0 | 8.53E+00 | 1.06E+01 | 1.24E+01 | 1.56E+01 | 1.82E+01 | 2.27E+01 | 3.15E+01 | 5.32E+01 | 8.27E+01 | 1.74E+02 | 2.78E+02 | 5.26E+02 | 8.08E+02 |
| 40.0 | 9.50E+00 | 1.18E+01 | 1.39E+01 | 1.75E+01 | 2.05E+01 | 2.58E+01 | 3.62E+01 | 6.22E+01 | 9.83E+01 | 2.13E+02 | 3.49E+02 | 6.83E+02 | 1.08E+03 |
| 45.0 | 1.05E+01 | 1.30E+01 | 1.53E+01 | 1.94E+01 | 2.29E+01 | 2.88E+01 | 4.09E+01 | 7.14E+01 | 1.15E+02 | 2.56E+02 | 4.28E+02 | 8.60E+02 | 1.38E+03 |
| 50.0 | 1.14E+01 | 1.42E+01 | 1.68E+01 | 2.13E+01 | 2.52E+01 | 3.19E+01 | 4.56E+01 | 8.08E+01 | 1.31E+02 | 3.01E+02 | 5.13E+02 | 1.06E+03 | 1.74E+03 |
| 55.0 | 1.24E+01 | 1.54E+01 | 1.82E+01 | 2.32E+01 | 2.75E+01 | 3.50E+01 | 5.04E+01 | 9.04E+01 | 1.49E+02 | 3.49E+02 | 6.05E+02 | 1.28E+03 | 2.13E+03 |
| 60.0 | 1.33E+01 | 1.66E+01 | 1.96E+01 | 2.51E+01 | 2.98E+01 | 3.81E+01 | 5.52E+01 | 1.00E+02 | 1.67E+02 | 4.00E+02 | 7.03E+02 | 1.51E+03 | 2.57E+03 |
| 65.0 | 1.43E+01 | 1.78E+01 | 2.11E+01 | 2.70E+01 | 3.21E+01 | 4.12E+01 | 6.01E+01 | 1.10E+02 | 1.86E+02 | 4.53E+02 | 8.08E+02 | 1.77E+03 | 3.05E+03 |
| 70.0 | 1.53E+01 | 1.90E+01 | 2.25E+01 | 2.89E+01 | 3.45E+01 | 4.44E+01 | 6.50E+01 | 1.20E+02 | 2.05E+02 | 5.09E+02 | 9.20E+02 | 2.06E+03 | 3.59E+03 |
| 75.0 | 1.62E+01 | 2.03E+01 | 2.40E+01 | 3.09E+01 | 3.69E+01 | 4.75E+01 | 7.00E+01 | 1.30E+02 | 2.24E+02 | 5.68E+02 | 1.04E+03 | 2.36E+03 | 4.16E+03 |
| 80.0 | 1.72E+01 | 2.15E+01 | 2.54E+01 | 3.28E+01 | 3.93E+01 | 5.08E+01 | 7.51E+01 | 1.41E+02 | 2.45E+02 | 6.29E+02 | 1.16E+03 | 2.68E+03 | 4.79E+03 |
| 85.0 | 1.82E+01 | 2.27E+01 | 2.69E+01 | 3.48E+01 | 4.17E+01 | 5.40E+01 | 8.02E+01 | 1.51E+02 | 2.66E+02 | 6.93E+02 | 1.29E+03 | 3.03E+03 | 5.47E+03 |
| 90.0 | 1.92E+01 | 2.39E+01 | 2.84E+01 | 3.68E+01 | 4.42E+01 | 5.74E+01 | 8.55E+01 | 1.62E+02 | 2.87E+02 | 7.59E+02 | 1.43E+03 | 3.39E+03 | 6.20E+03 |
| 95.0 | 2.02E+01 | 2.52E+01 | 2.99E+01 | 3.88E+01 | 4.67E+01 | 6.08E+01 | 9.08E+01 | 1.73E+02 | 3.09E+02 | 8.28E+02 | 1.58E+03 | 3.79E+03 | 6.98E+03 |
| 100.0 | 2.12E+01 | 2.64E+01 | 3.15E+01 | 4.09E+01 | 4.93E+01 | 6.42E+01 | 9.62E+01 | 1.84E+02 | 3.32E+02 | 8.99E+02 | 1.73E+03 | 4.20E+03 | 7.82E+03 |
| 110.0 | 2.32E+01 | 2.90E+01 | 3.46E+01 | 4.52E+01 | 5.45E+01 | 7.13E+01 | 1.07E+02 | 2.07E+02 | 3.79E+02 | 1.05E+03 | 2.05E+03 | 5.10E+03 | 9.66E+03 |
| 120.0 | 2.53E+01 | 3.16E+01 | 3.78E+01 | 4.96E+01 | 6.00E+01 | 7.87E+01 | 1.19E+02 | 2.30E+02 | 4.28E+02 | 1.21E+03 | 2.41E+03 | 6.10E+03 | 1.17E+04 |
| 130.0 | 2.74E+01 | 3.43E+01 | 4.12E+01 | 5.41E+01 | 6.57E+01 | 8.65E+01 | 1.31E+02 | 2.55E+02 | 4.81E+02 | 1.39E+03 | 2.79E+03 | 7.21E+03 | 1.41E+04 |
| 140.0 | 2.95E+01 | 3.71E+01 | 4.46E+01 | 5.89E+01 | 7.16E+01 | 9.46E+01 | 1.44E+02 | 2.80E+02 | 5.36E+02 | 1.58E+03 | 3.21E+03 | 8.42E+03 | 1.66E+04 |
| 150.0 | 3.16E+01 | 3.99E+01 | 4.81E+01 | 6.38E+01 | 7.78E+01 | 1.03E+02 | 1.57E+02 | 3.06E+02 | 5.95E+02 | 1.78E+03 | 3.66E+03 | 9.76E+03 | 1.95E+04 |
| 160.0 | 3.37E+01 | 4.28E+01 | 5.18E+01 | 6.89E+01 | 8.43E+01 | 1.12E+02 | 1.71E+02 | 3.33E+02 | 6.57E+02 | 1.99E+03 | 4.15E+03 | 1.12E+04 | 2.27E+04 |
| 170.0 | 3.58E+01 | 4.57E+01 | 5.54E+01 | 7.42E+01 | 9.10E+01 | 1.21E+02 | 1.85E+02 | 3.60E+02 | 7.22E+02 | 2.22E+03 | 4.67E+03 | 1.28E+04 | 2.62E+04 |
| 180.0 | 3.79E+01 | 4.86E+01 | 5.92E+01 | 7.96E+01 | 9.79E+01 | 1.31E+02 | 2.00E+02 | 3.89E+02 | 7.91E+02 | 2.46E+03 | 5.23E+03 | 1.45E+04 | 3.00E+04 |
| 190.0 | 4.00E+01 | 5.15E+01 | 6.31E+01 | 8.52E+01 | 1.05E+02 | 1.41E+02 | 2.16E+02 | 4.18E+02 | 8.63E+02 | 2.72E+03 | 5.84E+03 | 1.64E+04 | 3.42E+04 |
| 200.0 | 4.21E+01 | 5.45E+01 | 6.70E+01 | 9.09E+01 | 1.12E+02 | 1.51E+02 | 2.32E+02 | 4.49E+02 | 9.40E+02 | 3.00E+03 | 6.49E+03 | 1.85E+04 | 3.88E+04 |
| 210.0 | 4.41E+01 | 5.75E+01 | 7.09E+01 | 9.68E+01 | 1.20E+02 | 1.62E+02 | 2.49E+02 | 4.80E+02 | 1.02E+03 | 3.29E+03 | 7.18E+03 | 2.07E+04 | 4.38E+04 |
| 220.0 | 4.61E+01 | 6.04E+01 | 7.49E+01 | 1.03E+02 | 1.28E+02 | 1.73E+02 | 2.66E+02 | 5.11E+02 | 1.10E+03 | 3.60E+03 | 7.92E+03 | 2.31E+04 | 4.93E+04 |
| 230.0 | 4.80E+01 | 6.34E+01 | 7.90E+01 | 1.09E+02 | 1.36E+02 | 1.84E+02 | 2.84E+02 | 5.44E+02 | 1.19E+03 | 3.93E+03 | 8.72E+03 | 2.56E+04 | 5.52E+04 |
| 240.0 | 4.99E+01 | 6.64E+01 | 8.31E+01 | 1.15E+02 | 1.45E+02 | 1.96E+02 | 3.02E+02 | 5.77E+02 | 1.29E+03 | 4.28E+03 | 9.56E+03 | 2.84E+04 | 6.16E+04 |
| 250.0 | 5.17E+01 | 6.93E+01 | 8.72E+01 | 1.22E+02 | 1.53E+02 | 2.08E+02 | 3.21E+02 | 6.11E+02 | 1.38E+03 | 4.65E+03 | 1.05E+04 | 3.14E+04 | 6.86E+04 |
| 260.0 | 5.35E+01 | 7.23E+01 | 9.14E+01 | 1.28E+02 | 1.62E+02 | 2.21E+02 | 3.41E+02 | 6.46E+02 | 1.49E+03 | 5.05E+03 | 1.14E+04 | 3.46E+04 | 7.61E+04 |
| 270.0 | 5.52E+01 | 7.52E+01 | 9.56E+01 | 1.35E+02 | 1.71E+02 | 2.34E+02 | 3.61E+02 | 6.81E+02 | 1.59E+03 | 5.46E+03 | 1.24E+04 | 3.80E+04 | 8.43E+04 |
| 280.0 | 5.68E+01 | 7.81E+01 | 9.98E+01 | 1.42E+02 | 1.80E+02 | 2.47E+02 | 3.82E+02 | 7.17E+02 | 1.70E+03 | 5.90E+03 | 1.35E+04 | 4.17E+04 | 9.30E+04 |
| 290.0 | 5.84E+01 | 8.10E+01 | 1.04E+02 | 1.49E+02 | 1.90E+02 | 2.61E+02 | 4.04E+02 | 7.53E+02 | 1.82E+03 | 6.36E+03 | 1.47E+04 | 4.57E+04 | 1.03E+05 |
| 300.0 | 6.00E+01 | 8.39E+01 | 1.08E+02 | 1.56E+02 | 2.00E+02 | 2.75E+02 | 4.26E+02 | 7.90E+02 | 1.94E+03 | 6.85E+03 | 1.59E+04 | 4.99E+04 | 1.13E+05 |

表4 (2/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
水 (0.4-0.015MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.015 |
| 0.5 | 1.66E+00 | 1.75E+00 | 1.91E+00 | 2.07E+00 | 2.38E+00 | 2.57E+00 | 2.65E+00 | 2.51E+00 | 2.18E+00 | 1.69E+00 | 1.25E+00 | 1.11E+00 |
| 1.0 | 2.61E+00 | 2.85E+00 | 3.31E+00 | 3.76E+00 | 4.57E+00 | 4.98E+00 | 4.93E+00 | 4.40E+00 | 3.41E+00 | 2.25E+00 | 1.41E+00 | 1.17E+00 |
| 2.0 | 5.43E+00 | 6.29E+00 | 7.89E+00 | 9.41E+00 | 1.18E+01 | 1.26E+01 | 1.14E+01 | 9.12E+00 | 6.02E+00 | 3.20E+00 | 1.64E+00 | 1.26E+00 |
| 3.0 | 9.61E+00 | 1.16E+01 | 1.54E+01 | 1.89E+01 | 2.36E+01 | 2.44E+01 | 2.02E+01 | 1.50E+01 | 8.81E+00 | 4.04E+00 | 1.81E+00 | 1.32E+00 |
| 4.0 | 1.52E+01 | 1.92E+01 | 2.66E+01 | 3.30E+01 | 4.08E+01 | 4.08E+01 | 3.15E+01 | 2.19E+01 | 1.17E+01 | 4.80E+00 | 1.95E+00 | 1.36E+00 |
| 5.0 | 2.24E+01 | 2.92E+01 | 4.19E+01 | 5.28E+01 | 6.43E+01 | 6.25E+01 | 4.53E+01 | 2.98E+01 | 1.48E+01 | 5.52E+00 | 2.07E+00 | 1.40E+00 |
| 6.0 | 3.11E+01 | 4.18E+01 | 6.20E+01 | 7.91E+01 | 9.51E+01 | 9.00E+01 | 6.17E+01 | 3.87E+01 | 1.80E+01 | 6.21E+00 | 2.18E+00 | 1.44E+00 |
| 7.0 | 4.16E+01 | 5.74E+01 | 8.77E+01 | 1.13E+02 | 1.34E+02 | 1.24E+02 | 8.09E+01 | 4.86E+01 | 2.13E+01 | 6.88E+00 | 2.27E+00 | 1.47E+00 |
| 8.0 | 5.38E+01 | 7.61E+01 | 1.20E+02 | 1.56E+02 | 1.83E+02 | 1.65E+02 | 1.03E+02 | 5.95E+01 | 2.48E+01 | 7.53E+00 | 2.36E+00 | 1.49E+00 |
| 10.0 | 8.42E+01 | 1.24E+02 | 2.06E+02 | 2.72E+02 | 3.14E+02 | 2.73E+02 | 1.57E+02 | 8.48E+01 | 3.21E+01 | 8.79E+00 | 2.52E+00 | 1.54E+00 |
| 15.0 | 1.99E+02 | 3.23E+02 | 5.92E+02 | 8.18E+02 | 9.13E+02 | 7.35E+02 | 3.61E+02 | 1.69E+02 | 5.30E+01 | 1.19E+01 | 2.86E+00 | 1.63E+00 |
| 20.0 | 3.81E+02 | 6.65E+02 | 1.34E+03 | 1.92E+03 | 2.10E+03 | 1.59E+03 | 6.91E+02 | 2.89E+02 | 7.78E+01 | 1.48E+01 | 3.13E+00 | 1.70E+00 |
| 25.0 | 6.37E+02 | 1.19E+03 | 2.61E+03 | 3.90E+03 | 4.22E+03 | 3.04E+03 | 1.19E+03 | 4.50E+02 | 1.06E+02 | 1.78E+01 | 3.36E+00 | 1.76E+00 |
| 30.0 | 9.78E+02 | 1.95E+03 | 4.60E+03 | 7.16E+03 | 7.71E+03 | 5.32E+03 | 1.90E+03 | 6.57E+02 | 1.39E+02 | 2.07E+01 | 3.57E+00 | 1.81E+00 |
| 35.0 | 1.41E+03 | 2.97E+03 | 7.55E+03 | 1.22E+04 | 1.32E+04 | 8.74E+03 | 2.87E+03 | 9.17E+02 | 1.75E+02 | 2.36E+01 | 3.76E+00 | 1.85E+00 |
| 40.0 | 1.94E+03 | 4.30E+03 | 1.17E+04 | 1.97E+04 | 2.13E+04 | 1.37E+04 | 4.16E+03 | 1.24E+03 | 2.15E+02 | 2.66E+01 | 3.93E+00 | 1.88E+00 |
| 45.0 | 2.57E+03 | 5.98E+03 | 1.73E+04 | 3.02E+04 | 3.30E+04 | 2.05E+04 | 5.83E+03 | 1.62E+03 | 2.58E+02 | 2.95E+01 | 4.09E+00 | 1.92E+00 |
| 50.0 | 3.31E+03 | 8.04E+03 | 2.47E+04 | 4.48E+04 | 4.93E+04 | 2.98E+04 | 7.95E+03 | 2.07E+03 | 3.05E+02 | 3.24E+01 | 4.24E+00 | 1.95E+00 |
| 55.0 | 4.17E+03 | 1.05E+04 | 3.42E+04 | 6.42E+04 | 7.16E+04 | 4.21E+04 | 1.06E+04 | 2.60E+03 | 3.56E+02 | 3.54E+01 | 4.38E+00 | 1.97E+00 |
| 60.0 | 5.15E+03 | 1.35E+04 | 4.62E+04 | 8.97E+04 | 1.01E+05 | 5.81E+04 | 1.38E+04 | 3.20E+03 | 4.11E+02 | 3.84E+01 | 4.52E+00 | 2.00E+00 |
| 65.0 | 6.25E+03 | 1.69E+04 | 6.09E+04 | 1.22E+05 | 1.40E+05 | 7.86E+04 | 1.77E+04 | 3.90E+03 | 4.70E+02 | 4.14E+01 | 4.65E+00 | 2.02E+00 |
| 70.0 | 7.48E+03 | 2.09E+04 | 7.89E+04 | 1.64E+05 | 1.90E+05 | 1.04E+05 | 2.24E+04 | 4.69E+03 | 5.33E+02 | 4.45E+01 | 4.78E+00 | 2.04E+00 |
| 75.0 | 8.84E+03 | 2.54E+04 | 1.00E+05 | 2.15E+05 | 2.53E+05 | 1.37E+05 | 2.80E+04 | 5.58E+03 | 5.99E+02 | 4.76E+01 | 4.90E+00 | 2.06E+00 |
| 80.0 | 1.03E+04 | 3.06E+04 | 1.26E+05 | 2.78E+05 | 3.32E+05 | 1.76E+05 | 3.46E+04 | 6.58E+03 | 6.71E+02 | 5.08E+01 | 5.02E+00 | 2.08E+00 |
| 85.0 | 1.20E+04 | 3.64E+04 | 1.56E+05 | 3.55E+05 | 4.30E+05 | 2.24E+05 | 4.22E+04 | 7.69E+03 | 7.46E+02 | 5.41E+01 | 5.13E+00 | 2.10E+00 |
| 90.0 | 1.38E+04 | 4.30E+04 | 1.91E+05 | 4.46E+05 | 5.51E+05 | 2.82E+05 | 5.10E+04 | 8.93E+03 | 8.26E+02 | 5.74E+01 | 5.25E+00 | 2.12E+00 |
| 95.0 | 1.58E+04 | 5.02E+04 | 2.32E+05 | 5.56E+05 | 6.97E+05 | 3.51E+05 | 6.12E+04 | 1.03E+04 | 9.11E+02 | 6.08E+01 | 5.36E+00 | 2.14E+00 |
| 100.0 | 1.79E+04 | 5.83E+04 | 2.78E+05 | 6.85E+05 | 8.72E+05 | 4.33E+05 | 7.29E+04 | 1.18E+04 | 1.00E+03 | 6.43E+01 | 5.47E+00 | 2.16E+00 |
| 110.0 | 2.27E+04 | 7.69E+04 | 3.91E+05 | 1.01E+06 | 1.33E+06 | 6.43E+05 | 1.01E+05 | 1.53E+04 | 1.20E+03 | 7.15E+01 | 5.69E+00 | 2.19E+00 |
| 120.0 | 2.81E+04 | 9.92E+04 | 5.35E+05 | 1.45E+06 | 1.97E+06 | 9.27E+05 | 1.37E+05 | 1.94E+04 | 1.41E+03 | 7.91E+01 | 5.90E+00 | 2.22E+00 |
| 130.0 | 3.44E+04 | 1.26E+05 | 7.14E+05 | 2.02E+06 | 2.84E+06 | 1.31E+06 | 1.82E+05 | 2.42E+04 | 1.65E+03 | 8.71E+01 | 6.10E+00 | 2.24E+00 |
| 140.0 | 4.15E+04 | 1.56E+05 | 9.34E+05 | 2.75E+06 | 3.99E+06 | 1.80E+06 | 2.38E+05 | 2.99E+04 | 1.92E+03 | 9.55E+01 | 6.30E+00 | 2.27E+00 |
| 150.0 | 4.95E+04 | 1.92E+05 | 1.20E+06 | 3.67E+06 | 5.51E+06 | 2.43E+06 | 3.07E+05 | 3.66E+04 | 2.22E+03 | 1.04E+02 | 6.49E+00 | 2.29E+00 |
| 160.0 | 5.85E+04 | 2.33E+05 | 1.52E+06 | 4.82E+06 | 7.46E+06 | 3.23E+06 | 3.90E+05 | 4.42E+04 | 2.54E+03 | 1.14E+02 | 6.68E+00 | 2.30E+00 |
| 170.0 | 6.86E+04 | 2.80E+05 | 1.90E+06 | 6.23E+06 | 9.95E+06 | 4.24E+06 | 4.90E+05 | 5.30E+04 | 2.90E+03 | 1.24E+02 | 6.86E+00 | 2.32E+00 |
| 180.0 | 7.97E+04 | 3.33E+05 | 2.35E+06 | 7.94E+06 | 1.31E+07 | 5.49E+06 | 6.09E+05 | 6.32E+04 | 3.30E+03 | 1.34E+02 | 7.03E+00 | 2.33E+00 |
| 190.0 | 9.21E+04 | 3.93E+05 | 2.87E+06 | 9.99E+06 | 1.70E+07 | 7.02E+06 | 7.51E+05 | 7.47E+04 | 3.74E+03 | 1.45E+02 | 7.20E+00 | 2.33E+00 |
| 200.0 | 1.06E+05 | 4.61E+05 | 3.47E+06 | 1.24E+07 | 2.18E+07 | 8.89E+06 | 9.18E+05 | 8.78E+04 | 4.22E+03 | 1.57E+02 | 7.36E+00 | 2.33E+00 |
| 210.0 | 1.21E+05 | 5.37E+05 | 4.16E+06 | 1.53E+07 | 2.77E+07 | 1.11E+07 | 1.11E+06 | 1.03E+05 | 4.75E+03 | 1.69E+02 | 7.51E+00 | 2.33E+00 |
| 220.0 | 1.37E+05 | 6.22E+05 | 4.96E+06 | 1.87E+07 | 3.48E+07 | 1.39E+07 | 1.34E+06 | 1.20E+05 | 5.33E+03 | 1.82E+02 | 7.65E+00 | 2.33E+00 |
| 230.0 | 1.55E+05 | 7.16E+05 | 5.87E+06 | 2.26E+07 | 4.34E+07 | 1.71E+07 | 1.61E+06 | 1.39E+05 | 5.97E+03 | 1.96E+02 | 7.78E+00 | 2.32E+00 |
| 240.0 | 1.75E+05 | 8.21E+05 | 6.89E+06 | 2.72E+07 | 5.38E+07 | 2.09E+07 | 1.91E+06 | 1.60E+05 | 6.66E+03 | 2.10E+02 | 7.91E+00 | 2.31E+00 |
| 250.0 | 1.97E+05 | 9.38E+05 | 8.06E+06 | 3.25E+07 | 6.60E+07 | 2.55E+07 | 2.27E+06 | 1.84E+05 | 7.43E+03 | 2.25E+02 | 8.02E+00 | 2.29E+00 |
| 260.0 | 2.21E+05 | 1.07E+06 | 9.36E+06 | 3.85E+07 | 8.06E+07 | 3.08E+07 | 2.68E+06 | 2.11E+05 | 8.27E+03 | 2.41E+02 | 8.13E+00 | 2.27E+00 |
| 270.0 | 2.46E+05 | 1.21E+06 | 1.08E+07 | 4.53E+07 | 9.78E+07 | 3.70E+07 | 3.14E+06 | 2.41E+05 | 9.18E+03 | 2.58E+02 | 8.23E+00 | 2.25E+00 |
| 280.0 | 2.74E+05 | 1.36E+06 | 1.25E+07 | 5.31E+07 | 1.18E+08 | 4.43E+07 | 3.68E+06 | 2.75E+05 | 1.02E+04 | 2.75E+02 | 8.32E+00 | 2.23E+00 |
| 290.0 | 3.05E+05 | 1.53E+06 | 1.43E+07 | 6.19E+07 | 1.41E+08 | 5.28E+07 | 4.29E+06 | 3.13E+05 | 1.13E+04 | 2.94E+02 | 8.41E+00 | 2.21E+00 |
| 300.0 | 3.38E+05 | 1.72E+06 | 1.63E+07 | 7.19E+07 | 1.69E+08 | 6.25E+07 | 4.98E+06 | 3.56E+05 | 1.25E+04 | 3.13E+02 | 8.48E+00 | 2.18E+00 |

表5 (1/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
空気 (15-0.5MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 15.0 | 10.0 | 8.0 | 6.0 | 5.0 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 | 0.8 | 0.6 | 0.5 |
| 0.5 | 1.21E+00 | 1.24E+00 | 1.26E+00 | 1.29E+00 | 1.30E+00 | 1.32E+00 | 1.35E+00 | 1.39E+00 | 1.42E+00 | 1.47E+00 | 1.51E+00 | 1.57E+00 | 1.60E+00 |
| 1.0 | 1.36E+00 | 1.44E+00 | 1.49E+00 | 1.56E+00 | 1.60E+00 | 1.65E+00 | 1.73E+00 | 1.84E+00 | 1.93E+00 | 2.08E+00 | 2.18E+00 | 2.33E+00 | 2.44E+00 |
| 2.0 | 1.63E+00 | 1.78E+00 | 1.88E+00 | 2.04E+00 | 2.14E+00 | 2.28E+00 | 2.49E+00 | 2.83E+00 | 3.10E+00 | 3.60E+00 | 3.94E+00 | 4.45E+00 | 4.82E+00 |
| 3.0 | 1.89E+00 | 2.10E+00 | 2.26E+00 | 2.50E+00 | 2.67E+00 | 2.90E+00 | 3.26E+00 | 3.88E+00 | 4.43E+00 | 5.47E+00 | 6.19E+00 | 7.32E+00 | 8.16E+00 |
| 4.0 | 2.13E+00 | 2.41E+00 | 2.63E+00 | 2.95E+00 | 3.18E+00 | 3.52E+00 | 4.05E+00 | 5.00E+00 | 5.87E+00 | 7.61E+00 | 8.88E+00 | 1.09E+01 | 1.25E+01 |
| 5.0 | 2.37E+00 | 2.72E+00 | 2.99E+00 | 3.40E+00 | 3.70E+00 | 4.14E+00 | 4.85E+00 | 6.17E+00 | 7.42E+00 | 1.00E+01 | 1.20E+01 | 1.52E+01 | 1.77E+01 |
| 6.0 | 2.60E+00 | 3.02E+00 | 3.34E+00 | 3.85E+00 | 4.22E+00 | 4.77E+00 | 5.67E+00 | 7.39E+00 | 9.07E+00 | 1.27E+01 | 1.55E+01 | 2.02E+01 | 2.40E+01 |
| 7.0 | 2.83E+00 | 3.31E+00 | 3.69E+00 | 4.29E+00 | 4.73E+00 | 5.39E+00 | 6.50E+00 | 8.65E+00 | 1.08E+01 | 1.56E+01 | 1.94E+01 | 2.59E+01 | 3.13E+01 |
| 8.0 | 3.06E+00 | 3.61E+00 | 4.04E+00 | 4.73E+00 | 5.24E+00 | 6.02E+00 | 7.34E+00 | 9.95E+00 | 1.26E+01 | 1.87E+01 | 2.37E+01 | 3.24E+01 | 3.97E+01 |
| 10.0 | 3.51E+00 | 4.19E+00 | 4.72E+00 | 5.60E+00 | 6.26E+00 | 7.28E+00 | 9.04E+00 | 1.27E+01 | 1.65E+01 | 2.57E+01 | 3.35E+01 | 4.75E+01 | 5.99E+01 |
| 15.0 | 4.62E+00 | 5.60E+00 | 6.40E+00 | 7.73E+00 | 8.78E+00 | 1.04E+01 | 1.34E+01 | 1.99E+01 | 2.73E+01 | 4.67E+01 | 6.46E+01 | 9.90E+01 | 1.32E+02 |
| 20.0 | 5.71E+00 | 6.97E+00 | 8.04E+00 | 9.82E+00 | 1.13E+01 | 1.36E+01 | 1.79E+01 | 2.77E+01 | 3.93E+01 | 7.22E+01 | 1.05E+02 | 1.70E+02 | 2.37E+02 |
| 25.0 | 6.79E+00 | 8.32E+00 | 9.64E+00 | 1.19E+01 | 1.37E+01 | 1.67E+01 | 2.24E+01 | 3.59E+01 | 5.23E+01 | 1.01E+02 | 1.53E+02 | 2.61E+02 | 3.77E+02 |
| 30.0 | 7.87E+00 | 9.64E+00 | 1.12E+01 | 1.39E+01 | 1.62E+01 | 1.99E+01 | 2.70E+01 | 4.44E+01 | 6.60E+01 | 1.34E+02 | 2.08E+02 | 3.71E+02 | 5.54E+02 |
| 35.0 | 8.95E+00 | 1.09E+01 | 1.28E+01 | 1.59E+01 | 1.86E+01 | 2.30E+01 | 3.17E+01 | 5.31E+01 | 8.04E+01 | 1.70E+02 | 2.71E+02 | 5.00E+02 | 7.68E+02 |
| 40.0 | 1.00E+01 | 1.22E+01 | 1.43E+01 | 1.79E+01 | 2.10E+01 | 2.62E+01 | 3.64E+01 | 6.21E+01 | 9.55E+01 | 2.09E+02 | 3.41E+02 | 6.48E+02 | 1.02E+03 |
| 45.0 | 1.11E+01 | 1.35E+01 | 1.58E+01 | 1.99E+01 | 2.34E+01 | 2.93E+01 | 4.11E+01 | 7.13E+01 | 1.11E+02 | 2.51E+02 | 4.18E+02 | 8.16E+02 | 1.31E+03 |
| 50.0 | 1.22E+01 | 1.48E+01 | 1.74E+01 | 2.19E+01 | 2.58E+01 | 3.25E+01 | 4.59E+01 | 8.07E+01 | 1.27E+02 | 2.95E+02 | 5.02E+02 | 1.00E+03 | 1.64E+03 |
| 55.0 | 1.32E+01 | 1.61E+01 | 1.89E+01 | 2.39E+01 | 2.82E+01 | 3.56E+01 | 5.07E+01 | 9.03E+01 | 1.43E+02 | 3.42E+02 | 5.92E+02 | 1.21E+03 | 2.02E+03 |
| 60.0 | 1.43E+01 | 1.73E+01 | 2.04E+01 | 2.58E+01 | 3.06E+01 | 3.88E+01 | 5.56E+01 | 1.00E+02 | 1.60E+02 | 3.92E+02 | 6.88E+02 | 1.43E+03 | 2.43E+03 |
| 65.0 | 1.54E+01 | 1.86E+01 | 2.20E+01 | 2.78E+01 | 3.31E+01 | 4.20E+01 | 6.05E+01 | 1.10E+02 | 1.78E+02 | 4.44E+02 | 7.91E+02 | 1.68E+03 | 2.89E+03 |
| 70.0 | 1.65E+01 | 1.99E+01 | 2.35E+01 | 2.98E+01 | 3.55E+01 | 4.53E+01 | 6.55E+01 | 1.20E+02 | 1.95E+02 | 4.99E+02 | 9.01E+02 | 1.94E+03 | 3.39E+03 |
| 75.0 | 1.76E+01 | 2.11E+01 | 2.50E+01 | 3.19E+01 | 3.80E+01 | 4.86E+01 | 7.05E+01 | 1.30E+02 | 2.13E+02 | 5.56E+02 | 1.02E+03 | 2.22E+03 | 3.94E+03 |
| 80.0 | 1.87E+01 | 2.24E+01 | 2.66E+01 | 3.39E+01 | 4.05E+01 | 5.19E+01 | 7.57E+01 | 1.41E+02 | 2.31E+02 | 6.16E+02 | 1.14E+03 | 2.53E+03 | 4.53E+03 |
| 85.0 | 1.98E+01 | 2.37E+01 | 2.82E+01 | 3.60E+01 | 4.30E+01 | 5.52E+01 | 8.09E+01 | 1.51E+02 | 2.50E+02 | 6.78E+02 | 1.27E+03 | 2.85E+03 | 5.17E+03 |
| 90.0 | 2.09E+01 | 2.50E+01 | 2.98E+01 | 3.81E+01 | 4.56E+01 | 5.87E+01 | 8.62E+01 | 1.62E+02 | 2.69E+02 | 7.43E+02 | 1.40E+03 | 3.19E+03 | 5.86E+03 |
| 95.0 | 2.21E+01 | 2.63E+01 | 3.14E+01 | 4.02E+01 | 4.82E+01 | 6.22E+01 | 9.15E+01 | 1.73E+02 | 2.88E+02 | 8.10E+02 | 1.55E+03 | 3.56E+03 | 6.59E+03 |
| 100.0 | 2.32E+01 | 2.76E+01 | 3.30E+01 | 4.23E+01 | 5.09E+01 | 6.57E+01 | 9.70E+01 | 1.84E+02 | 3.08E+02 | 8.80E+02 | 1.70E+03 | 3.95E+03 | 7.38E+03 |
| 110.0 | 2.55E+01 | 3.02E+01 | 3.64E+01 | 4.68E+01 | 5.64E+01 | 7.30E+01 | 1.08E+02 | 2.07E+02 | 3.48E+02 | 1.03E+03 | 2.01E+03 | 4.79E+03 | 9.12E+03 |
| 120.0 | 2.79E+01 | 3.29E+01 | 3.98E+01 | 5.13E+01 | 6.21E+01 | 8.06E+01 | 1.20E+02 | 2.31E+02 | 3.89E+02 | 1.19E+03 | 2.36E+03 | 5.72E+03 | 1.11E+04 |
| 130.0 | 3.02E+01 | 3.56E+01 | 4.34E+01 | 5.61E+01 | 6.80E+01 | 8.86E+01 | 1.32E+02 | 2.55E+02 | 4.31E+02 | 1.36E+03 | 2.74E+03 | 6.76E+03 | 1.33E+04 |
| 140.0 | 3.26E+01 | 3.84E+01 | 4.70E+01 | 6.10E+01 | 7.41E+01 | 9.69E+01 | 1.45E+02 | 2.80E+02 | 4.74E+02 | 1.54E+03 | 3.15E+03 | 7.89E+03 | 1.57E+04 |
| 150.0 | 3.50E+01 | 4.11E+01 | 5.07E+01 | 6.61E+01 | 8.06E+01 | 1.06E+02 | 1.58E+02 | 3.06E+02 | 5.19E+02 | 1.74E+03 | 3.60E+03 | 9.14E+03 | 1.84E+04 |
| 160.0 | 3.74E+01 | 4.39E+01 | 5.46E+01 | 7.14E+01 | 8.72E+01 | 1.15E+02 | 1.72E+02 | 3.34E+02 | 5.64E+02 | 1.95E+03 | 4.07E+03 | 1.05E+04 | 2.14E+04 |
| 170.0 | 3.98E+01 | 4.67E+01 | 5.85E+01 | 7.69E+01 | 9.42E+01 | 1.24E+02 | 1.87E+02 | 3.61E+02 | 6.10E+02 | 2.17E+03 | 4.59E+03 | 1.20E+04 | 2.47E+04 |
| 180.0 | 4.21E+01 | 4.95E+01 | 6.25E+01 | 8.25E+01 | 1.01E+02 | 1.34E+02 | 2.02E+02 | 3.90E+02 | 6.57E+02 | 2.41E+03 | 5.14E+03 | 1.36E+04 | 2.83E+04 |
| 190.0 | 4.44E+01 | 5.23E+01 | 6.65E+01 | 8.82E+01 | 1.09E+02 | 1.44E+02 | 2.18E+02 | 4.20E+02 | 7.05E+02 | 2.66E+03 | 5.74E+03 | 1.54E+04 | 3.23E+04 |
| 200.0 | 4.67E+01 | 5.50E+01 | 7.06E+01 | 9.42E+01 | 1.16E+02 | 1.55E+02 | 2.34E+02 | 4.50E+02 | 7.54E+02 | 2.93E+03 | 6.38E+03 | 1.73E+04 | 3.66E+04 |
| 210.0 | 4.89E+01 | 5.78E+01 | 7.48E+01 | 1.00E+02 | 1.24E+02 | 1.65E+02 | 2.51E+02 | 4.81E+02 | 8.03E+02 | 3.22E+03 | 7.06E+03 | 1.93E+04 | 4.13E+04 |
| 220.0 | 5.10E+01 | 6.04E+01 | 7.90E+01 | 1.06E+02 | 1.32E+02 | 1.77E+02 | 2.68E+02 | 5.13E+02 | 8.53E+02 | 3.52E+03 | 7.79E+03 | 2.15E+04 | 4.64E+04 |
| 230.0 | 5.31E+01 | 6.31E+01 | 8.33E+01 | 1.13E+02 | 1.41E+02 | 1.88E+02 | 2.86E+02 | 5.46E+02 | 9.02E+02 | 3.85E+03 | 8.57E+03 | 2.39E+04 | 5.20E+04 |
| 240.0 | 5.50E+01 | 6.56E+01 | 8.75E+01 | 1.19E+02 | 1.49E+02 | 2.01E+02 | 3.05E+02 | 5.79E+02 | 9.53E+02 | 4.19E+03 | 9.41E+03 | 2.65E+04 | 5.80E+04 |
| 250.0 | 5.69E+01 | 6.82E+01 | 9.19E+01 | 1.26E+02 | 1.58E+02 | 2.13E+02 | 3.24E+02 | 6.13E+02 | 1.00E+03 | 4.55E+03 | 1.03E+04 | 2.93E+04 | 6.46E+04 |
| 260.0 | 5.87E+01 | 7.06E+01 | 9.62E+01 | 1.33E+02 | 1.67E+02 | 2.26E+02 | 3.44E+02 | 6.48E+02 | 1.05E+03 | 4.93E+03 | 1.12E+04 | 3.23E+04 | 7.17E+04 |
| 270.0 | 6.05E+01 | 7.30E+01 | 1.01E+02 | 1.40E+02 | 1.77E+02 | 2.39E+02 | 3.64E+02 | 6.83E+02 | 1.10E+03 | 5.34E+03 | 1.22E+04 | 3.55E+04 | 7.93E+04 |
| 280.0 | 6.21E+01 | 7.53E+01 | 1.05E+02 | 1.47E+02 | 1.86E+02 | 2.53E+02 | 3.85E+02 | 7.19E+02 | 1.15E+03 | 5.77E+03 | 1.33E+04 | 3.89E+04 | 8.76E+04 |
| 290.0 | 6.36E+01 | 7.76E+01 | 1.09E+02 | 1.54E+02 | 1.96E+02 | 2.67E+02 | 4.07E+02 | 7.56E+02 | 1.21E+03 | 6.22E+03 | 1.45E+04 | 4.26E+04 | 9.65E+04 |
| 300.0 | 6.51E+01 | 7.98E+01 | 1.14E+02 | 1.61E+02 | 2.06E+02 | 2.81E+02 | 4.29E+02 | 7.93E+02 | 1.26E+03 | 6.70E+03 | 1.57E+04 | 4.65E+04 | 1.06E+05 |

表5 (2/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
 空気 (0.4-0.015MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.015 |
| 0.5 | 1.66E+00 | 1.75E+00 | 1.91E+00 | 2.06E+00 | 2.36E+00 | 2.53E+00 | 2.59E+00 | 2.45E+00 | 2.12E+00 | 1.65E+00 | 1.23E+00 | 1.10E+00 |
| 1.0 | 2.59E+00 | 2.83E+00 | 3.28E+00 | 3.70E+00 | 4.46E+00 | 4.83E+00 | 4.73E+00 | 4.19E+00 | 3.23E+00 | 2.15E+00 | 1.38E+00 | 1.16E+00 |
| 2.0 | 5.35E+00 | 6.18E+00 | 7.70E+00 | 9.11E+00 | 1.13E+01 | 1.19E+01 | 1.06E+01 | 8.42E+00 | 5.55E+00 | 2.99E+00 | 1.58E+00 | 1.24E+00 |
| 3.0 | 9.39E+00 | 1.13E+01 | 1.48E+01 | 1.80E+01 | 2.21E+01 | 2.25E+01 | 1.84E+01 | 1.35E+01 | 7.95E+00 | 3.72E+00 | 1.73E+00 | 1.29E+00 |
| 4.0 | 1.48E+01 | 1.85E+01 | 2.52E+01 | 3.10E+01 | 3.75E+01 | 3.70E+01 | 2.81E+01 | 1.94E+01 | 1.04E+01 | 4.38E+00 | 1.86E+00 | 1.33E+00 |
| 5.0 | 2.16E+01 | 2.79E+01 | 3.94E+01 | 4.90E+01 | 5.83E+01 | 5.58E+01 | 3.98E+01 | 2.60E+01 | 1.30E+01 | 4.99E+00 | 1.96E+00 | 1.37E+00 |
| 6.0 | 2.99E+01 | 3.97E+01 | 5.79E+01 | 7.26E+01 | 8.52E+01 | 7.94E+01 | 5.35E+01 | 3.33E+01 | 1.56E+01 | 5.57E+00 | 2.06E+00 | 1.40E+00 |
| 7.0 | 3.98E+01 | 5.42E+01 | 8.12E+01 | 1.03E+02 | 1.19E+02 | 1.08E+02 | 6.93E+01 | 4.14E+01 | 1.83E+01 | 6.13E+00 | 2.14E+00 | 1.43E+00 |
| 8.0 | 5.14E+01 | 7.16E+01 | 1.10E+02 | 1.41E+02 | 1.61E+02 | 1.43E+02 | 8.74E+01 | 5.02E+01 | 2.11E+01 | 6.67E+00 | 2.22E+00 | 1.45E+00 |
| 10.0 | 8.01E+01 | 1.16E+02 | 1.87E+02 | 2.43E+02 | 2.72E+02 | 2.31E+02 | 1.31E+02 | 7.02E+01 | 2.69E+01 | 7.71E+00 | 2.36E+00 | 1.49E+00 |
| 15.0 | 1.89E+02 | 2.99E+02 | 5.30E+02 | 7.13E+02 | 7.66E+02 | 6.01E+02 | 2.90E+02 | 1.35E+02 | 4.31E+01 | 1.02E+01 | 2.65E+00 | 1.58E+00 |
| 20.0 | 3.59E+02 | 6.12E+02 | 1.18E+03 | 1.65E+03 | 1.72E+03 | 1.27E+03 | 5.39E+02 | 2.24E+02 | 6.17E+01 | 1.26E+01 | 2.88E+00 | 1.64E+00 |
| 25.0 | 6.00E+02 | 1.09E+03 | 2.29E+03 | 3.30E+03 | 3.40E+03 | 2.36E+03 | 9.03E+02 | 3.41E+02 | 8.28E+01 | 1.49E+01 | 3.08E+00 | 1.69E+00 |
| 30.0 | 9.20E+02 | 1.78E+03 | 4.00E+03 | 6.00E+03 | 6.11E+03 | 4.06E+03 | 1.41E+03 | 4.88E+02 | 1.06E+02 | 1.72E+01 | 3.26E+00 | 1.73E+00 |
| 35.0 | 1.33E+03 | 2.70E+03 | 6.52E+03 | 1.01E+04 | 1.03E+04 | 6.54E+03 | 2.09E+03 | 6.68E+02 | 1.32E+02 | 1.94E+01 | 3.41E+00 | 1.77E+00 |
| 40.0 | 1.82E+03 | 3.90E+03 | 1.01E+04 | 1.62E+04 | 1.64E+04 | 1.00E+04 | 2.97E+03 | 8.83E+02 | 1.60E+02 | 2.16E+01 | 3.56E+00 | 1.80E+00 |
| 45.0 | 2.41E+03 | 5.41E+03 | 1.48E+04 | 2.47E+04 | 2.51E+04 | 1.48E+04 | 4.09E+03 | 1.14E+03 | 1.89E+02 | 2.38E+01 | 3.69E+00 | 1.83E+00 |
| 50.0 | 3.11E+03 | 7.25E+03 | 2.10E+04 | 3.63E+04 | 3.71E+04 | 2.12E+04 | 5.49E+03 | 1.43E+03 | 2.22E+02 | 2.60E+01 | 3.81E+00 | 1.85E+00 |
| 55.0 | 3.91E+03 | 9.48E+03 | 2.90E+04 | 5.17E+04 | 5.33E+04 | 2.96E+04 | 7.20E+03 | 1.77E+03 | 2.56E+02 | 2.83E+01 | 3.93E+00 | 1.88E+00 |
| 60.0 | 4.83E+03 | 1.21E+04 | 3.90E+04 | 7.18E+04 | 7.46E+04 | 4.03E+04 | 9.26E+03 | 2.16E+03 | 2.92E+02 | 3.05E+01 | 4.04E+00 | 1.90E+00 |
| 65.0 | 5.86E+03 | 1.52E+04 | 5.13E+04 | 9.74E+04 | 1.02E+05 | 5.38E+04 | 1.17E+04 | 2.59E+03 | 3.31E+02 | 3.27E+01 | 4.15E+00 | 1.92E+00 |
| 70.0 | 7.01E+03 | 1.88E+04 | 6.62E+04 | 1.30E+05 | 1.37E+05 | 7.05E+04 | 1.46E+04 | 3.08E+03 | 3.72E+02 | 3.50E+01 | 4.25E+00 | 1.94E+00 |
| 75.0 | 8.29E+03 | 2.28E+04 | 8.41E+04 | 1.69E+05 | 1.82E+05 | 9.11E+04 | 1.80E+04 | 3.63E+03 | 4.16E+02 | 3.72E+01 | 4.35E+00 | 1.96E+00 |
| 80.0 | 9.71E+03 | 2.74E+04 | 1.05E+05 | 2.18E+05 | 2.36E+05 | 1.16E+05 | 2.20E+04 | 4.23E+03 | 4.61E+02 | 3.96E+01 | 4.45E+00 | 1.97E+00 |
| 85.0 | 1.13E+04 | 3.26E+04 | 1.30E+05 | 2.77E+05 | 3.04E+05 | 1.46E+05 | 2.65E+04 | 4.89E+03 | 5.10E+02 | 4.19E+01 | 4.54E+00 | 1.99E+00 |
| 90.0 | 1.29E+04 | 3.85E+04 | 1.59E+05 | 3.47E+05 | 3.86E+05 | 1.82E+05 | 3.17E+04 | 5.62E+03 | 5.61E+02 | 4.43E+01 | 4.64E+00 | 2.01E+00 |
| 95.0 | 1.48E+04 | 4.49E+04 | 1.92E+05 | 4.30E+05 | 4.85E+05 | 2.24E+05 | 3.76E+04 | 6.42E+03 | 6.14E+02 | 4.67E+01 | 4.73E+00 | 2.02E+00 |
| 100.0 | 1.68E+04 | 5.21E+04 | 2.30E+05 | 5.28E+05 | 6.03E+05 | 2.74E+05 | 4.44E+04 | 7.30E+03 | 6.71E+02 | 4.92E+01 | 4.82E+00 | 2.04E+00 |
| 110.0 | 2.13E+04 | 6.87E+04 | 3.23E+05 | 7.75E+05 | 9.09E+05 | 4.00E+05 | 6.04E+04 | 9.28E+03 | 7.92E+02 | 5.44E+01 | 4.99E+00 | 2.07E+00 |
| 120.0 | 2.64E+04 | 8.85E+04 | 4.40E+05 | 1.10E+06 | 1.33E+06 | 5.67E+05 | 8.04E+04 | 1.16E+04 | 9.26E+02 | 5.97E+01 | 5.16E+00 | 2.09E+00 |
| 130.0 | 3.23E+04 | 1.12E+05 | 5.86E+05 | 1.53E+06 | 1.89E+06 | 7.85E+05 | 1.05E+05 | 1.43E+04 | 1.07E+03 | 6.53E+01 | 5.32E+00 | 2.11E+00 |
| 140.0 | 3.90E+04 | 1.39E+05 | 7.64E+05 | 2.07E+06 | 2.64E+06 | 1.07E+06 | 1.35E+05 | 1.74E+04 | 1.24E+03 | 7.12E+01 | 5.48E+00 | 2.13E+00 |
| 150.0 | 4.65E+04 | 1.71E+05 | 9.81E+05 | 2.75E+06 | 3.60E+06 | 1.42E+06 | 1.72E+05 | 2.10E+04 | 1.41E+03 | 7.74E+01 | 5.63E+00 | 2.15E+00 |
| 160.0 | 5.50E+04 | 2.07E+05 | 1.24E+06 | 3.59E+06 | 4.83E+06 | 1.86E+06 | 2.15E+05 | 2.51E+04 | 1.61E+03 | 8.39E+01 | 5.78E+00 | 2.16E+00 |
| 170.0 | 6.44E+04 | 2.49E+05 | 1.55E+06 | 4.62E+06 | 6.38E+06 | 2.41E+06 | 2.66E+05 | 2.98E+04 | 1.82E+03 | 9.07E+01 | 5.92E+00 | 2.17E+00 |
| 180.0 | 7.49E+04 | 2.96E+05 | 1.90E+06 | 5.86E+06 | 8.33E+06 | 3.09E+06 | 3.27E+05 | 3.51E+04 | 2.06E+03 | 9.78E+01 | 6.05E+00 | 2.18E+00 |
| 190.0 | 8.65E+04 | 3.50E+05 | 2.32E+06 | 7.35E+06 | 1.07E+07 | 3.90E+06 | 3.98E+05 | 4.11E+04 | 2.31E+03 | 1.05E+02 | 6.18E+00 | 2.18E+00 |
| 200.0 | 9.93E+04 | 4.10E+05 | 2.81E+06 | 9.11E+06 | 1.37E+07 | 4.89E+06 | 4.81E+05 | 4.79E+04 | 2.59E+03 | 1.13E+02 | 6.30E+00 | 2.18E+00 |
| 210.0 | 1.13E+05 | 4.77E+05 | 3.37E+06 | 1.12E+07 | 1.72E+07 | 6.07E+06 | 5.77E+05 | 5.56E+04 | 2.90E+03 | 1.21E+02 | 6.41E+00 | 2.18E+00 |
| 220.0 | 1.29E+05 | 5.52E+05 | 4.00E+06 | 1.36E+07 | 2.15E+07 | 7.47E+06 | 6.89E+05 | 6.41E+04 | 3.24E+03 | 1.30E+02 | 6.51E+00 | 2.17E+00 |
| 230.0 | 1.46E+05 | 6.36E+05 | 4.73E+06 | 1.64E+07 | 2.67E+07 | 9.12E+06 | 8.17E+05 | 7.37E+04 | 3.60E+03 | 1.39E+02 | 6.61E+00 | 2.16E+00 |
| 240.0 | 1.65E+05 | 7.29E+05 | 5.55E+06 | 1.97E+07 | 3.28E+07 | 1.11E+07 | 9.64E+05 | 8.45E+04 | 4.00E+03 | 1.48E+02 | 6.69E+00 | 2.15E+00 |
| 250.0 | 1.85E+05 | 8.32E+05 | 6.48E+06 | 2.34E+07 | 4.01E+07 | 1.34E+07 | 1.13E+06 | 9.65E+04 | 4.43E+03 | 1.58E+02 | 6.77E+00 | 2.13E+00 |
| 260.0 | 2.07E+05 | 9.46E+05 | 7.52E+06 | 2.77E+07 | 4.87E+07 | 1.60E+07 | 1.32E+06 | 1.10E+05 | 4.91E+03 | 1.68E+02 | 6.85E+00 | 2.11E+00 |
| 270.0 | 2.32E+05 | 1.07E+06 | 8.69E+06 | 3.25E+07 | 5.87E+07 | 1.91E+07 | 1.54E+06 | 1.25E+05 | 5.42E+03 | 1.79E+02 | 6.91E+00 | 2.09E+00 |
| 280.0 | 2.58E+05 | 1.21E+06 | 1.00E+07 | 3.80E+07 | 7.04E+07 | 2.27E+07 | 1.79E+06 | 1.41E+05 | 5.98E+03 | 1.90E+02 | 6.97E+00 | 2.07E+00 |
| 290.0 | 2.87E+05 | 1.36E+06 | 1.15E+07 | 4.42E+07 | 8.40E+07 | 2.68E+07 | 2.07E+06 | 1.60E+05 | 6.59E+03 | 2.02E+02 | 7.02E+00 | 2.04E+00 |
| 300.0 | 3.18E+05 | 1.53E+06 | 1.31E+07 | 5.12E+07 | 9.98E+07 | 3.15E+07 | 2.38E+06 | 1.80E+05 | 7.25E+03 | 2.14E+02 | 7.07E+00 | 2.01E+00 |

表6 (1/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
コンクリート (15-0.5MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 15.0 | 10.0 | 8.0 | 6.0 | 5.0 | 4.0 | 3.0 | 2.0 | 1.5 | 1.0 | 0.8 | 0.6 | 0.5 |
| 0.5 | 1.22E+00 | 1.25E+00 | 1.26E+00 | 1.29E+00 | 1.30E+00 | 1.32E+00 | 1.34E+00 | 1.38E+00 | 1.40E+00 | 1.45E+00 | 1.48E+00 | 1.53E+00 | 1.57E+00 |
| 1.0 | 1.39E+00 | 1.44E+00 | 1.49E+00 | 1.55E+00 | 1.58E+00 | 1.63E+00 | 1.70E+00 | 1.79E+00 | 1.86E+00 | 1.99E+00 | 2.07E+00 | 2.19E+00 | 2.27E+00 |
| 2.0 | 1.69E+00 | 1.79E+00 | 1.88E+00 | 2.02E+00 | 2.11E+00 | 2.23E+00 | 2.41E+00 | 2.68E+00 | 2.89E+00 | 3.25E+00 | 3.48E+00 | 3.81E+00 | 4.02E+00 |
| 3.0 | 1.97E+00 | 2.13E+00 | 2.26E+00 | 2.48E+00 | 2.63E+00 | 2.83E+00 | 3.14E+00 | 3.64E+00 | 4.04E+00 | 4.74E+00 | 5.19E+00 | 5.84E+00 | 6.25E+00 |
| 4.0 | 2.24E+00 | 2.46E+00 | 2.65E+00 | 2.94E+00 | 3.15E+00 | 3.44E+00 | 3.90E+00 | 4.66E+00 | 5.31E+00 | 6.44E+00 | 7.20E+00 | 8.27E+00 | 8.96E+00 |
| 5.0 | 2.52E+00 | 2.79E+00 | 3.03E+00 | 3.40E+00 | 3.67E+00 | 4.06E+00 | 4.68E+00 | 5.74E+00 | 6.67E+00 | 8.36E+00 | 9.49E+00 | 1.11E+01 | 1.22E+01 |
| 6.0 | 2.80E+00 | 3.12E+00 | 3.41E+00 | 3.87E+00 | 4.20E+00 | 4.69E+00 | 5.47E+00 | 6.86E+00 | 8.12E+00 | 1.05E+01 | 1.21E+01 | 1.44E+01 | 1.59E+01 |
| 7.0 | 3.07E+00 | 3.46E+00 | 3.79E+00 | 4.34E+00 | 4.74E+00 | 5.33E+00 | 6.29E+00 | 8.03E+00 | 9.65E+00 | 1.28E+01 | 1.49E+01 | 1.81E+01 | 2.02E+01 |
| 8.0 | 3.36E+00 | 3.79E+00 | 4.18E+00 | 4.81E+00 | 5.27E+00 | 5.97E+00 | 7.12E+00 | 9.24E+00 | 1.13E+01 | 1.52E+01 | 1.81E+01 | 2.22E+01 | 2.50E+01 |
| 10.0 | 3.93E+00 | 4.47E+00 | 4.96E+00 | 5.76E+00 | 6.35E+00 | 7.27E+00 | 8.81E+00 | 1.18E+01 | 1.47E+01 | 2.07E+01 | 2.52E+01 | 3.18E+01 | 3.64E+01 |
| 15.0 | 5.43E+00 | 6.21E+00 | 6.93E+00 | 8.15E+00 | 9.09E+00 | 1.06E+01 | 1.32E+01 | 1.85E+01 | 2.42E+01 | 3.71E+01 | 4.73E+01 | 6.36E+01 | 7.53E+01 |
| 20.0 | 7.04E+00 | 8.00E+00 | 8.95E+00 | 1.06E+01 | 1.19E+01 | 1.40E+01 | 1.78E+01 | 2.58E+01 | 3.48E+01 | 5.68E+01 | 7.53E+01 | 1.07E+02 | 1.30E+02 |
| 25.0 | 8.74E+00 | 9.83E+00 | 1.10E+01 | 1.30E+01 | 1.47E+01 | 1.74E+01 | 2.24E+01 | 3.35E+01 | 4.63E+01 | 7.93E+01 | 1.09E+02 | 1.60E+02 | 2.01E+02 |
| 30.0 | 1.05E+01 | 1.17E+01 | 1.31E+01 | 1.55E+01 | 1.75E+01 | 2.08E+01 | 2.72E+01 | 4.15E+01 | 5.85E+01 | 1.05E+02 | 1.47E+02 | 2.25E+02 | 2.89E+02 |
| 35.0 | 1.24E+01 | 1.36E+01 | 1.52E+01 | 1.80E+01 | 2.03E+01 | 2.43E+01 | 3.20E+01 | 4.98E+01 | 7.13E+01 | 1.32E+02 | 1.90E+02 | 3.00E+02 | 3.94E+02 |
| 40.0 | 1.44E+01 | 1.56E+01 | 1.73E+01 | 2.04E+01 | 2.31E+01 | 2.78E+01 | 3.69E+01 | 5.84E+01 | 8.47E+01 | 1.62E+02 | 2.38E+02 | 3.87E+02 | 5.17E+02 |
| 45.0 | 1.64E+01 | 1.75E+01 | 1.94E+01 | 2.29E+01 | 2.60E+01 | 3.13E+01 | 4.19E+01 | 6.71E+01 | 9.85E+01 | 1.94E+02 | 2.90E+02 | 4.83E+02 | 6.58E+02 |
| 50.0 | 1.86E+01 | 1.95E+01 | 2.15E+01 | 2.54E+01 | 2.88E+01 | 3.48E+01 | 4.69E+01 | 7.60E+01 | 1.13E+02 | 2.28E+02 | 3.47E+02 | 5.90E+02 | 8.16E+02 |
| 55.0 | 2.08E+01 | 2.16E+01 | 2.37E+01 | 2.80E+01 | 3.17E+01 | 3.84E+01 | 5.20E+01 | 8.51E+01 | 1.27E+02 | 2.64E+02 | 4.08E+02 | 7.08E+02 | 9.93E+02 |
| 60.0 | 2.31E+01 | 2.36E+01 | 2.59E+01 | 3.05E+01 | 3.45E+01 | 4.19E+01 | 5.71E+01 | 9.44E+01 | 1.43E+02 | 3.01E+02 | 4.72E+02 | 8.36E+02 | 1.19E+03 |
| 65.0 | 2.54E+01 | 2.57E+01 | 2.81E+01 | 3.30E+01 | 3.74E+01 | 4.55E+01 | 6.22E+01 | 1.04E+02 | 1.58E+02 | 3.41E+02 | 5.41E+02 | 9.75E+02 | 1.40E+03 |
| 70.0 | 2.79E+01 | 2.78E+01 | 3.03E+01 | 3.56E+01 | 4.03E+01 | 4.91E+01 | 6.74E+01 | 1.13E+02 | 1.74E+02 | 3.83E+02 | 6.15E+02 | 1.12E+03 | 1.64E+03 |
| 75.0 | 3.04E+01 | 3.00E+01 | 3.26E+01 | 3.82E+01 | 4.33E+01 | 5.28E+01 | 7.27E+01 | 1.23E+02 | 1.90E+02 | 4.26E+02 | 6.92E+02 | 1.29E+03 | 1.89E+03 |
| 80.0 | 3.29E+01 | 3.21E+01 | 3.49E+01 | 4.08E+01 | 4.62E+01 | 5.65E+01 | 7.80E+01 | 1.33E+02 | 2.06E+02 | 4.71E+02 | 7.73E+02 | 1.46E+03 | 2.17E+03 |
| 85.0 | 3.56E+01 | 3.43E+01 | 3.71E+01 | 4.34E+01 | 4.92E+01 | 6.02E+01 | 8.34E+01 | 1.43E+02 | 2.23E+02 | 5.18E+02 | 8.58E+02 | 1.64E+03 | 2.46E+03 |
| 90.0 | 3.83E+01 | 3.66E+01 | 3.95E+01 | 4.61E+01 | 5.22E+01 | 6.39E+01 | 8.89E+01 | 1.53E+02 | 2.40E+02 | 5.66E+02 | 9.47E+02 | 1.83E+03 | 2.78E+03 |
| 95.0 | 4.12E+01 | 3.88E+01 | 4.18E+01 | 4.88E+01 | 5.53E+01 | 6.78E+01 | 9.44E+01 | 1.63E+02 | 2.57E+02 | 6.17E+02 | 1.04E+03 | 2.04E+03 | 3.11E+03 |
| 100.0 | 4.41E+01 | 4.11E+01 | 4.42E+01 | 5.15E+01 | 5.84E+01 | 7.16E+01 | 1.00E+02 | 1.74E+02 | 2.74E+02 | 6.69E+02 | 1.14E+03 | 2.25E+03 | 3.47E+03 |
| 110.0 | 5.01E+01 | 4.58E+01 | 4.91E+01 | 5.71E+01 | 6.47E+01 | 7.95E+01 | 1.12E+02 | 1.95E+02 | 3.10E+02 | 7.79E+02 | 1.35E+03 | 2.72E+03 | 4.25E+03 |
| 120.0 | 5.63E+01 | 5.06E+01 | 5.40E+01 | 6.27E+01 | 7.11E+01 | 8.76E+01 | 1.23E+02 | 2.17E+02 | 3.46E+02 | 8.97E+02 | 1.57E+03 | 3.23E+03 | 5.13E+03 |
| 130.0 | 6.29E+01 | 5.55E+01 | 5.91E+01 | 6.86E+01 | 7.78E+01 | 9.60E+01 | 1.36E+02 | 2.40E+02 | 3.83E+02 | 1.02E+03 | 1.81E+03 | 3.80E+03 | 6.11E+03 |
| 140.0 | 6.98E+01 | 6.06E+01 | 6.43E+01 | 7.46E+01 | 8.46E+01 | 1.05E+02 | 1.48E+02 | 2.63E+02 | 4.22E+02 | 1.16E+03 | 2.08E+03 | 4.42E+03 | 7.19E+03 |
| 150.0 | 7.68E+01 | 6.57E+01 | 6.96E+01 | 8.07E+01 | 9.16E+01 | 1.14E+02 | 1.61E+02 | 2.87E+02 | 4.61E+02 | 1.30E+03 | 2.36E+03 | 5.09E+03 | 8.37E+03 |
| 160.0 | 8.41E+01 | 7.09E+01 | 7.49E+01 | 8.69E+01 | 9.88E+01 | 1.23E+02 | 1.75E+02 | 3.11E+02 | 5.00E+02 | 1.45E+03 | 2.66E+03 | 5.82E+03 | 9.67E+03 |
| 170.0 | 9.16E+01 | 7.61E+01 | 8.04E+01 | 9.32E+01 | 1.06E+02 | 1.32E+02 | 1.88E+02 | 3.36E+02 | 5.41E+02 | 1.61E+03 | 2.98E+03 | 6.61E+03 | 1.11E+04 |
| 180.0 | 9.92E+01 | 8.13E+01 | 8.58E+01 | 9.97E+01 | 1.14E+02 | 1.42E+02 | 2.02E+02 | 3.62E+02 | 5.82E+02 | 1.78E+03 | 3.32E+03 | 7.46E+03 | 1.26E+04 |
| 190.0 | 1.07E+02 | 8.66E+01 | 9.13E+01 | 1.06E+02 | 1.21E+02 | 1.51E+02 | 2.17E+02 | 3.88E+02 | 6.23E+02 | 1.96E+03 | 3.68E+03 | 8.38E+03 | 1.43E+04 |
| 200.0 | 1.15E+02 | 9.18E+01 | 9.68E+01 | 1.13E+02 | 1.29E+02 | 1.61E+02 | 2.32E+02 | 4.14E+02 | 6.65E+02 | 2.14E+03 | 4.07E+03 | 9.37E+03 | 1.61E+04 |
| 210.0 | 1.23E+02 | 9.70E+01 | 1.02E+02 | 1.19E+02 | 1.37E+02 | 1.72E+02 | 2.47E+02 | 4.41E+02 | 7.07E+02 | 2.34E+03 | 4.48E+03 | 1.04E+04 | 1.81E+04 |
| 220.0 | 1.31E+02 | 1.02E+02 | 1.08E+02 | 1.26E+02 | 1.44E+02 | 1.82E+02 | 2.62E+02 | 4.68E+02 | 7.49E+02 | 2.55E+03 | 4.92E+03 | 1.16E+04 | 2.02E+04 |
| 230.0 | 1.38E+02 | 1.07E+02 | 1.13E+02 | 1.32E+02 | 1.52E+02 | 1.92E+02 | 2.78E+02 | 4.96E+02 | 7.91E+02 | 2.77E+03 | 5.38E+03 | 1.28E+04 | 2.25E+04 |
| 240.0 | 1.46E+02 | 1.12E+02 | 1.18E+02 | 1.39E+02 | 1.60E+02 | 2.03E+02 | 2.94E+02 | 5.24E+02 | 8.33E+02 | 3.00E+03 | 5.87E+03 | 1.41E+04 | 2.50E+04 |
| 250.0 | 1.54E+02 | 1.17E+02 | 1.24E+02 | 1.46E+02 | 1.68E+02 | 2.14E+02 | 3.10E+02 | 5.52E+02 | 8.75E+02 | 3.24E+03 | 6.39E+03 | 1.55E+04 | 2.76E+04 |
| 260.0 | 1.61E+02 | 1.22E+02 | 1.29E+02 | 1.52E+02 | 1.76E+02 | 2.25E+02 | 3.26E+02 | 5.81E+02 | 9.17E+02 | 3.50E+03 | 6.93E+03 | 1.69E+04 | 3.05E+04 |
| 270.0 | 1.69E+02 | 1.26E+02 | 1.34E+02 | 1.59E+02 | 1.84E+02 | 2.35E+02 | 3.43E+02 | 6.09E+02 | 9.58E+02 | 3.76E+03 | 7.50E+03 | 1.85E+04 | 3.35E+04 |
| 280.0 | 1.76E+02 | 1.31E+02 | 1.39E+02 | 1.65E+02 | 1.92E+02 | 2.46E+02 | 3.60E+02 | 6.38E+02 | 9.99E+02 | 4.04E+03 | 8.11E+03 | 2.02E+04 | 3.68E+04 |
| 290.0 | 1.83E+02 | 1.35E+02 | 1.44E+02 | 1.72E+02 | 2.00E+02 | 2.58E+02 | 3.77E+02 | 6.67E+02 | 1.04E+03 | 4.34E+03 | 8.75E+03 | 2.19E+04 | 4.02E+04 |
| 300.0 | 1.90E+02 | 1.40E+02 | 1.48E+02 | 1.78E+02 | 2.09E+02 | 2.69E+02 | 3.94E+02 | 6.95E+02 | 1.08E+03 | 4.64E+03 | 9.42E+03 | 2.38E+04 | 4.39E+04 |

表6 (2/2) 改良ビルドアップ係数 (照射線量ビルドアップ係数)
コンクリート (0.4-0.015MeV)

| R (mfp) | Energy (MeV) | | | | | | | | | | | |
|------------|--------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| | 0.4 | 0.3 | 0.2 | 0.2 | 0.1 | 0.08 | 0.06 | 0.05 | 0.04 | 0.03 | 0.02 | 0.015 |
| 0.5 | 1.61E+00 | 1.68E+00 | 1.77E+00 | 1.84E+00 | 1.87E+00 | 1.81E+00 | 1.62E+00 | 1.46E+00 | 1.28E+00 | 1.13E+00 | 1.04E+00 | 1.02E+00 |
| 1.0 | 2.37E+00 | 2.52E+00 | 2.71E+00 | 2.81E+00 | 2.75E+00 | 2.55E+00 | 2.09E+00 | 1.77E+00 | 1.45E+00 | 1.21E+00 | 1.06E+00 | 1.03E+00 |
| 2.0 | 4.30E+00 | 4.66E+00 | 5.04E+00 | 5.11E+00 | 4.60E+00 | 3.94E+00 | 2.86E+00 | 2.23E+00 | 1.68E+00 | 1.30E+00 | 1.09E+00 | 1.04E+00 |
| 3.0 | 6.78E+00 | 7.42E+00 | 7.99E+00 | 7.89E+00 | 6.59E+00 | 5.28E+00 | 3.51E+00 | 2.59E+00 | 1.85E+00 | 1.36E+00 | 1.11E+00 | 1.05E+00 |
| 4.0 | 9.83E+00 | 1.08E+01 | 1.16E+01 | 1.11E+01 | 8.73E+00 | 6.63E+00 | 4.11E+00 | 2.91E+00 | 1.99E+00 | 1.41E+00 | 1.13E+00 | 1.05E+00 |
| 5.0 | 1.35E+01 | 1.50E+01 | 1.59E+01 | 1.49E+01 | 1.10E+01 | 7.99E+00 | 4.68E+00 | 3.19E+00 | 2.11E+00 | 1.46E+00 | 1.14E+00 | 1.06E+00 |
| 6.0 | 1.78E+01 | 1.99E+01 | 2.09E+01 | 1.92E+01 | 1.35E+01 | 9.38E+00 | 5.22E+00 | 3.45E+00 | 2.21E+00 | 1.49E+00 | 1.15E+00 | 1.06E+00 |
| 7.0 | 2.27E+01 | 2.56E+01 | 2.67E+01 | 2.41E+01 | 1.62E+01 | 1.08E+01 | 5.76E+00 | 3.70E+00 | 2.31E+00 | 1.53E+00 | 1.16E+00 | 1.07E+00 |
| 8.0 | 2.84E+01 | 3.21E+01 | 3.34E+01 | 2.96E+01 | 1.91E+01 | 1.23E+01 | 6.27E+00 | 3.93E+00 | 2.40E+00 | 1.56E+00 | 1.16E+00 | 1.07E+00 |
| 10.0 | 4.20E+01 | 4.81E+01 | 4.96E+01 | 4.24E+01 | 2.54E+01 | 1.53E+01 | 7.29E+00 | 4.37E+00 | 2.56E+00 | 1.61E+00 | 1.18E+00 | 1.08E+00 |
| 15.0 | 9.04E+01 | 1.07E+02 | 1.09E+02 | 8.67E+01 | 4.45E+01 | 2.34E+01 | 9.71E+00 | 5.35E+00 | 2.90E+00 | 1.71E+00 | 1.20E+00 | 1.09E+00 |
| 20.0 | 1.62E+02 | 1.98E+02 | 2.01E+02 | 1.51E+02 | 6.83E+01 | 3.23E+01 | 1.20E+01 | 6.21E+00 | 3.18E+00 | 1.79E+00 | 1.22E+00 | 1.09E+00 |
| 25.0 | 2.58E+02 | 3.25E+02 | 3.32E+02 | 2.37E+02 | 9.68E+01 | 4.17E+01 | 1.42E+01 | 6.98E+00 | 3.42E+00 | 1.85E+00 | 1.23E+00 | 1.10E+00 |
| 30.0 | 3.81E+02 | 4.95E+02 | 5.09E+02 | 3.48E+02 | 1.30E+02 | 5.18E+01 | 1.64E+01 | 7.70E+00 | 3.63E+00 | 1.91E+00 | 1.25E+00 | 1.10E+00 |
| 35.0 | 5.32E+02 | 7.11E+02 | 7.37E+02 | 4.85E+02 | 1.68E+02 | 6.23E+01 | 1.85E+01 | 8.38E+00 | 3.82E+00 | 1.96E+00 | 1.26E+00 | 1.11E+00 |
| 40.0 | 7.14E+02 | 9.79E+02 | 1.02E+03 | 6.51E+02 | 2.10E+02 | 7.33E+01 | 2.06E+01 | 9.02E+00 | 3.99E+00 | 2.00E+00 | 1.27E+00 | 1.11E+00 |
| 45.0 | 9.28E+02 | 1.30E+03 | 1.38E+03 | 8.47E+02 | 2.57E+02 | 8.48E+01 | 2.26E+01 | 9.63E+00 | 4.15E+00 | 2.04E+00 | 1.27E+00 | 1.12E+00 |
| 50.0 | 1.17E+03 | 1.69E+03 | 1.80E+03 | 1.08E+03 | 3.08E+02 | 9.67E+01 | 2.46E+01 | 1.02E+01 | 4.31E+00 | 2.07E+00 | 1.28E+00 | 1.12E+00 |
| 55.0 | 1.45E+03 | 2.13E+03 | 2.30E+03 | 1.34E+03 | 3.64E+02 | 1.09E+02 | 2.67E+01 | 1.08E+01 | 4.46E+00 | 2.11E+00 | 1.29E+00 | 1.12E+00 |
| 60.0 | 1.77E+03 | 2.65E+03 | 2.88E+03 | 1.64E+03 | 4.24E+02 | 1.22E+02 | 2.87E+01 | 1.14E+01 | 4.60E+00 | 2.14E+00 | 1.29E+00 | 1.12E+00 |
| 65.0 | 2.12E+03 | 3.23E+03 | 3.55E+03 | 1.98E+03 | 4.89E+02 | 1.35E+02 | 3.07E+01 | 1.20E+01 | 4.74E+00 | 2.17E+00 | 1.30E+00 | 1.13E+00 |
| 70.0 | 2.51E+03 | 3.90E+03 | 4.32E+03 | 2.36E+03 | 5.59E+02 | 1.49E+02 | 3.28E+01 | 1.25E+01 | 4.88E+00 | 2.20E+00 | 1.30E+00 | 1.13E+00 |
| 75.0 | 2.94E+03 | 4.64E+03 | 5.19E+03 | 2.78E+03 | 6.34E+02 | 1.63E+02 | 3.48E+01 | 1.31E+01 | 5.01E+00 | 2.23E+00 | 1.31E+00 | 1.13E+00 |
| 80.0 | 3.41E+03 | 5.46E+03 | 6.17E+03 | 3.24E+03 | 7.14E+02 | 1.78E+02 | 3.69E+01 | 1.36E+01 | 5.14E+00 | 2.26E+00 | 1.31E+00 | 1.13E+00 |
| 85.0 | 3.92E+03 | 6.38E+03 | 7.26E+03 | 3.75E+03 | 7.99E+02 | 1.94E+02 | 3.90E+01 | 1.42E+01 | 5.27E+00 | 2.28E+00 | 1.32E+00 | 1.13E+00 |
| 90.0 | 4.47E+03 | 7.38E+03 | 8.47E+03 | 4.31E+03 | 8.89E+02 | 2.09E+02 | 4.12E+01 | 1.47E+01 | 5.40E+00 | 2.31E+00 | 1.32E+00 | 1.13E+00 |
| 95.0 | 5.07E+03 | 8.48E+03 | 9.82E+03 | 4.91E+03 | 9.84E+02 | 2.26E+02 | 4.34E+01 | 1.53E+01 | 5.52E+00 | 2.34E+00 | 1.33E+00 | 1.13E+00 |
| 100.0 | 5.72E+03 | 9.69E+03 | 1.13E+04 | 5.57E+03 | 1.08E+03 | 2.43E+02 | 4.56E+01 | 1.59E+01 | 5.65E+00 | 2.36E+00 | 1.33E+00 | 1.14E+00 |
| 110.0 | 7.14E+03 | 1.24E+04 | 1.47E+04 | 7.05E+03 | 1.30E+03 | 2.78E+02 | 5.01E+01 | 1.70E+01 | 5.90E+00 | 2.41E+00 | 1.34E+00 | 1.14E+00 |
| 120.0 | 8.77E+03 | 1.56E+04 | 1.87E+04 | 8.76E+03 | 1.54E+03 | 3.17E+02 | 5.48E+01 | 1.82E+01 | 6.15E+00 | 2.46E+00 | 1.35E+00 | 1.14E+00 |
| 130.0 | 1.06E+04 | 1.92E+04 | 2.34E+04 | 1.07E+04 | 1.81E+03 | 3.57E+02 | 5.97E+01 | 1.94E+01 | 6.40E+00 | 2.50E+00 | 1.35E+00 | 1.14E+00 |
| 140.0 | 1.27E+04 | 2.34E+04 | 2.88E+04 | 1.29E+04 | 2.10E+03 | 4.01E+02 | 6.49E+01 | 2.06E+01 | 6.64E+00 | 2.54E+00 | 1.35E+00 | 1.14E+00 |
| 150.0 | 1.50E+04 | 2.82E+04 | 3.50E+04 | 1.54E+04 | 2.42E+03 | 4.48E+02 | 7.02E+01 | 2.18E+01 | 6.88E+00 | 2.58E+00 | 1.35E+00 | 1.13E+00 |
| 160.0 | 1.75E+04 | 3.36E+04 | 4.21E+04 | 1.83E+04 | 2.77E+03 | 4.98E+02 | 7.58E+01 | 2.31E+01 | 7.12E+00 | 2.61E+00 | 1.35E+00 | 1.13E+00 |
| 170.0 | 2.04E+04 | 3.96E+04 | 5.01E+04 | 2.14E+04 | 3.15E+03 | 5.52E+02 | 8.16E+01 | 2.44E+01 | 7.35E+00 | 2.64E+00 | 1.35E+00 | 1.12E+00 |
| 180.0 | 2.35E+04 | 4.63E+04 | 5.91E+04 | 2.49E+04 | 3.57E+03 | 6.10E+02 | 8.77E+01 | 2.57E+01 | 7.58E+00 | 2.67E+00 | 1.35E+00 | 1.12E+00 |
| 190.0 | 2.69E+04 | 5.38E+04 | 6.92E+04 | 2.88E+04 | 4.02E+03 | 6.71E+02 | 9.41E+01 | 2.70E+01 | 7.80E+00 | 2.69E+00 | 1.34E+00 | 1.11E+00 |
| 200.0 | 3.06E+04 | 6.21E+04 | 8.04E+04 | 3.31E+04 | 4.51E+03 | 7.37E+02 | 1.01E+02 | 2.84E+01 | 8.01E+00 | 2.70E+00 | 1.33E+00 | 1.09E+00 |
| 210.0 | 3.47E+04 | 7.12E+04 | 9.29E+04 | 3.78E+04 | 5.04E+03 | 8.08E+02 | 1.08E+02 | 2.98E+01 | 8.22E+00 | 2.72E+00 | 1.32E+00 | 1.08E+00 |
| 220.0 | 3.92E+04 | 8.13E+04 | 1.07E+05 | 4.29E+04 | 5.62E+03 | 8.83E+02 | 1.15E+02 | 3.12E+01 | 8.42E+00 | 2.72E+00 | 1.30E+00 | 1.07E+00 |
| 230.0 | 4.40E+04 | 9.23E+04 | 1.22E+05 | 4.86E+04 | 6.24E+03 | 9.64E+02 | 1.22E+02 | 3.26E+01 | 8.61E+00 | 2.73E+00 | 1.29E+00 | 1.05E+00 |
| 240.0 | 4.92E+04 | 1.04E+05 | 1.38E+05 | 5.48E+04 | 6.91E+03 | 1.05E+03 | 1.30E+02 | 3.41E+01 | 8.79E+00 | 2.73E+00 | 1.27E+00 | 1.03E+00 |
| 250.0 | 5.49E+04 | 1.18E+05 | 1.57E+05 | 6.15E+04 | 7.64E+03 | 1.14E+03 | 1.38E+02 | 3.56E+01 | 8.96E+00 | 2.72E+00 | 1.25E+00 | 1.01E+00 |
| 260.0 | 6.10E+04 | 1.32E+05 | 1.77E+05 | 6.88E+04 | 8.42E+03 | 1.24E+03 | 1.47E+02 | 3.70E+01 | 9.13E+00 | 2.72E+00 | 1.23E+00 | 9.93E-01 |
| 270.0 | 6.76E+04 | 1.48E+05 | 1.98E+05 | 7.68E+04 | 9.27E+03 | 1.34E+03 | 1.56E+02 | 3.85E+01 | 9.28E+00 | 2.71E+00 | 1.21E+00 | 9.73E-01 |
| 280.0 | 7.47E+04 | 1.65E+05 | 2.22E+05 | 8.54E+04 | 1.02E+04 | 1.46E+03 | 1.65E+02 | 4.00E+01 | 9.43E+00 | 2.69E+00 | 1.19E+00 | 9.52E-01 |
| 290.0 | 8.24E+04 | 1.83E+05 | 2.48E+05 | 9.48E+04 | 1.12E+04 | 1.58E+03 | 1.74E+02 | 4.16E+01 | 9.57E+00 | 2.68E+00 | 1.17E+00 | 9.30E-01 |
| 300.0 | 9.06E+04 | 2.03E+05 | 2.76E+05 | 1.05E+05 | 1.22E+04 | 1.70E+03 | 1.84E+02 | 4.31E+01 | 9.70E+00 | 2.66E+00 | 1.14E+00 | 9.07E-01 |

2.4 GP式フィッティングパラメータの算出

播磨らによって提案されたGP式⁽¹¹⁾は、線源エネルギーに依存するフィッティングパラメータを持つビルドアップ係数近似式であり、ビルドアップ係数の補間計算が高速で行える。フィッティング式は、以下のように線源エネルギーと透過距離からなる。

$$B(E,x)=1+(b-1)(K^x-1)/(K-1) \quad \text{for } K \neq 1$$

$$B(E,x)=1+(b-1)x \quad \text{for } K=1$$

$$K(E,x)=cx^a+d[\tanh(x/X_k-2)-\tanh(-2)]$$

$$/ [1-\tanh(-2)]$$

E : 線源エネルギー (MeV)
 x : 透過距離 (mfp)
 b : 1 mfpでのビルドアップ係数
 a, c, d, X_k : フィッティングパラメータ

従来、フィッティングパラメータは、ANS標準データを利用して得られていた。また、40mfp以上の深さでは35mfpと40mfpでのフィッティングパラメータと外挿式⁽²¹⁾からビルドアップ係数を算出していたが、60mfpまでの上限が設定されていた⁽⁴⁾。

本研究でIE法による改良ビルドアップ係数が得られたことから、0～100mfpを対象としてGP式のフィッティングパラメータを算出し直した（以下新フィッティングパラメータという）。鉄、鉛、水、空気およびコンクリートに対する新フィッティングパラメータを表7から表11に示す。100～300mfpのビルドアップ係数については、95mfpと100mfpでのフィッティングパラメータと外挿式から算出するようにし、60mfpの上限を300mfpまでに修正した。

新フィッティングパラメータを用いたGP式で算出したビルドアップ係数と、IE法による改良ビルドアップ係数との比較を、26物質全てに対して実施した。その内、鉄、鉛、水、空気およびコンクリートについて、透過距離10、50、100、150、200、250、300mfpの比較結果を図5から図9に示す。水、空気およびコンクリートでは100mfp以上で大きな差が認められた。鉄では100mfpまでは良い一致が認められたが、150mfp以上では0.3MeV以上で大きな差が認められた。鉛ではK端付近で大きな差が認められた。全体的に、低Z核種でも比較的軽い核種において、フィッティング範囲の0～100mfpの間でも少し差が認められた。また100mfpまでの間は、比較的良く一致していたが、100mfpを超えると透過距離が大きくなるにつれて差が大きくなる傾向が認

められた。線源エネルギーが0.05～1MeVの範囲において大きな差が見られた。今後、100mfp以上の深い距離に対応できるフィッティングパラメータの算出および外挿式についての検討が必要であると考えられる。

表7 GP式新フィッティングパラメータ
媒質：鉄，レスポンス：空気

| $E(\text{MeV})$ | b | c | a | Xk | d | $Max.Dev.$ | $xmax$ | $St.Dev.$ |
|-----------------|-------|-------|--------|-------|---------|------------|--------|-----------|
| 0.015 | 1.003 | 0.621 | 0.048 | 8.00 | 0.0495 | 0.06% | 0.5 | 0.022% |
| 0.020 | 1.007 | 0.566 | 0.062 | 6.76 | 0.0598 | 0.12% | 0.5 | 0.039% |
| 0.030 | 1.023 | 0.498 | 0.081 | 5.53 | 0.0779 | 0.26% | 0.5 | 0.097% |
| 0.040 | 1.050 | 0.495 | 0.085 | 5.53 | 0.0783 | 0.60% | 0.5 | 0.207% |
| 0.050 | 1.088 | 0.506 | 0.085 | 5.31 | 0.0802 | 1.04% | 0.5 | 0.358% |
| 0.060 | 1.133 | 0.538 | 0.080 | 5.53 | 0.0756 | 1.59% | 0.5 | 0.539% |
| 0.080 | 1.240 | 0.610 | 0.068 | 6.16 | 0.0644 | 2.74% | 0.5 | 0.927% |
| 0.100 | 1.354 | 0.691 | 0.053 | 6.64 | 0.0534 | 3.65% | 0.5 | 1.263% |
| 0.150 | 1.611 | 0.833 | 0.039 | 32.47 | -0.0198 | 4.70% | 0.5 | 1.517% |
| 0.200 | 1.795 | 0.992 | 0.004 | 29.05 | -0.0061 | 4.36% | 0.5 | 1.318% |
| 0.300 | 1.938 | 1.152 | -0.027 | 38.59 | 0.0090 | 3.61% | 0.5 | 0.956% |
| 0.400 | 1.982 | 1.220 | -0.038 | 39.40 | 0.0128 | 2.26% | 0.5 | 0.777% |
| 0.500 | 1.995 | 1.238 | -0.041 | 39.54 | 0.0140 | 2.42% | 3.0 | 0.983% |
| 0.600 | 1.958 | 1.256 | -0.045 | 36.75 | 0.0171 | 2.14% | 100.0 | 0.874% |
| 0.800 | 1.926 | 1.235 | -0.042 | 37.49 | 0.0167 | 2.27% | 2.0 | 0.983% |
| 1.000 | 1.875 | 1.217 | -0.040 | 36.22 | 0.0175 | 1.62% | 10.0 | 0.883% |
| 1.500 | 1.790 | 1.158 | -0.030 | 36.54 | 0.0132 | 1.36% | 2.0 | 0.686% |
| 2.000 | 1.726 | 1.126 | -0.024 | 37.21 | 0.0103 | 0.96% | 70.0 | 0.471% |
| 3.000 | 1.654 | 1.067 | -0.010 | 16.30 | -0.0055 | 1.55% | 4.0 | 0.749% |
| 4.000 | 1.572 | 1.062 | -0.009 | 22.73 | -0.0040 | 2.96% | 1.0 | 1.039% |
| 5.000 | 1.517 | 1.054 | -0.006 | 27.78 | -0.0074 | 4.21% | 0.5 | 1.433% |
| 6.000 | 1.472 | 1.063 | -0.007 | 29.01 | -0.0072 | 5.64% | 1.0 | 1.777% |
| 8.000 | 1.488 | 1.013 | -0.010 | 6.50 | 0.0637 | 4.60% | 25.0 | 2.568% |
| 10.000 | 1.423 | 1.065 | -0.013 | 7.89 | 0.0420 | 5.76% | 1.0 | 2.396% |
| 15.000 | 1.409 | 1.119 | -0.013 | 9.73 | 0.0284 | 7.30% | 1.0 | 2.643% |

Max.Dev. : 改良ビルドアップ係数からの最大偏差

xmax : 最大偏差となる透過距離(mfp)

St.Dev. : 標準偏差

表8 GP式新フィッティングパラメータ
媒質：鉛，レスポンス：空気

| $E(\text{MeV})$ | b | c | a | Xk | d | $Max.Dev.$ | $xmax$ | $St.Dev.$ |
|-----------------|-------|-------|--------|-------|---------|------------|--------|-----------|
| 0.015 | 0.000 | 0.000 | 0.000 | 0.00 | 0.0000 | 0.00% | 0.0 | 0.000% |
| 0.020 | 0.000 | 0.000 | 0.000 | 0.00 | 0.0000 | 0.00% | 0.0 | 0.000% |
| 0.030 | 1.005 | 0.553 | 0.061 | 6.83 | 0.0676 | 0.08% | 0.5 | 0.029% |
| 0.040 | 1.011 | 0.488 | 0.075 | 5.67 | 0.0920 | 0.11% | 0.5 | 0.055% |
| 0.050 | 1.018 | 0.504 | 0.072 | 5.71 | 0.0893 | 0.22% | 0.5 | 0.092% |
| 0.060 | 1.026 | 0.526 | 0.069 | 5.78 | 0.0831 | 0.36% | 0.5 | 0.137% |
| 0.080 | 1.045 | 0.575 | 0.061 | 6.40 | 0.0708 | 0.69% | 0.5 | 0.245% |
| 0.088 | 1.053 | 0.591 | 0.058 | 6.41 | 0.0697 | 0.83% | 0.5 | 0.297% |
| 0.089 | 2.181 | 1.689 | 0.035 | 6.80 | 0.1091 | 16.16% | 100.0 | 7.837% |
| 0.090 | 2.217 | 1.648 | 0.036 | 7.33 | 0.1322 | 13.44% | 25.0 | 8.497% |
| 0.100 | 1.801 | 1.579 | 0.032 | 9.98 | 0.0974 | 16.11% | 1.0 | 6.855% |
| 0.110 | 1.622 | 1.383 | 0.037 | 9.00 | 0.1252 | 16.38% | 1.0 | 7.572% |
| 0.120 | 1.457 | 1.214 | 0.042 | 9.23 | 0.1239 | 17.83% | 1.0 | 8.246% |
| 0.130 | 1.559 | 0.890 | 0.063 | 8.70 | 0.2294 | 24.33% | 15.0 | 12.227% |
| 0.140 | 1.257 | 0.890 | 0.053 | 11.53 | 0.1154 | 17.54% | 1.0 | 8.781% |
| 0.150 | 1.329 | 0.576 | 0.089 | 15.83 | 0.2033 | 8.37% | 100.0 | 5.366% |
| 0.160 | 1.364 | 0.276 | 0.120 | 5.00 | 0.0005 | 0.61% | 0.5 | 0.263% |
| 0.200 | 1.192 | 0.224 | 0.200 | 5.00 | 0.1215 | 1.92% | 0.5 | 0.548% |
| 0.300 | 1.105 | 0.673 | 0.050 | 7.80 | 0.0460 | 1.11% | 0.5 | 0.449% |
| 0.400 | 1.156 | 0.726 | 0.043 | 8.11 | 0.0343 | 1.38% | 0.5 | 0.575% |
| 0.500 | 1.209 | 0.749 | 0.046 | 8.35 | 0.0217 | 1.52% | 0.5 | 0.587% |
| 0.600 | 1.245 | 0.783 | 0.047 | 34.31 | -0.0104 | 1.97% | 1.0 | 0.609% |
| 0.800 | 1.315 | 0.820 | 0.039 | 32.79 | -0.0133 | 1.16% | 0.5 | 0.571% |
| 1.000 | 1.351 | 0.868 | 0.028 | 33.88 | -0.0095 | 1.45% | 0.5 | 0.600% |
| 1.500 | 1.398 | 0.943 | 0.013 | 32.69 | -0.0084 | 2.50% | 0.5 | 0.835% |
| 2.000 | 1.407 | 0.998 | 0.003 | 30.30 | -0.0074 | 3.60% | 0.5 | 1.115% |
| 3.000 | 1.370 | 1.069 | -0.008 | 28.67 | -0.0080 | 5.49% | 0.5 | 1.624% |
| 4.000 | 1.409 | 1.032 | -0.014 | 6.30 | 0.0752 | 6.00% | 4.0 | 3.133% |
| 5.000 | 1.348 | 1.107 | -0.018 | 7.28 | 0.0513 | 6.72% | 0.5 | 2.624% |
| 6.000 | 1.329 | 1.144 | -0.017 | 8.14 | 0.0420 | 8.65% | 0.5 | 2.982% |
| 8.000 | 1.348 | 1.180 | -0.012 | 8.89 | 0.0448 | 9.76% | 0.5 | 3.640% |
| 10.000 | 1.400 | 1.219 | -0.009 | 8.66 | 0.0521 | 9.91% | 0.5 | 3.937% |
| 15.000 | 1.709 | 1.224 | -0.002 | 6.36 | 0.1339 | 11.50% | 25.0 | 6.275% |

表9 GP式新フィッティングパラメータ
媒質：水，レスポンス：空気

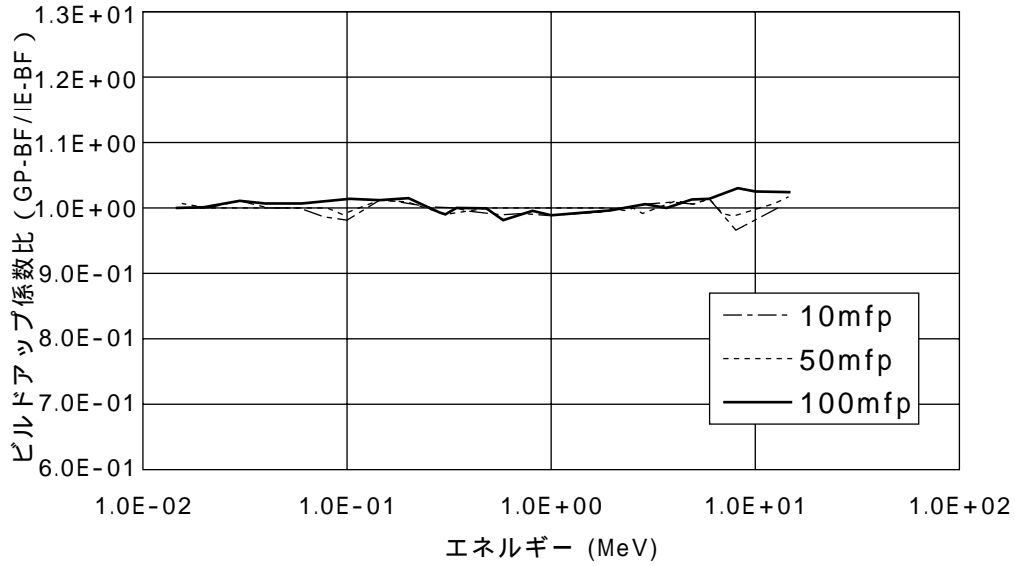
| $E(\text{MeV})$ | b | c | a | Xk | d | $Max.Dev.$ | $xmax$ | $St.Dev.$ |
|-----------------|-------|-------|--------|-------|---------|------------|--------|-----------|
| 0.015 | 1.160 | 0.595 | 0.063 | 6.97 | 0.0678 | 1.70% | 0.5 | 0.634% |
| 0.020 | 1.384 | 0.645 | 0.061 | 6.96 | 0.0614 | 2.80% | 0.5 | 1.160% |
| 0.030 | 2.172 | 0.847 | 0.024 | 8.29 | 0.0407 | 4.57% | 0.5 | 1.893% |
| 0.040 | 3.417 | 1.085 | -0.012 | 20.73 | -0.0023 | 0.55% | 25.0 | 0.258% |
| 0.050 | 4.584 | 1.333 | -0.055 | 35.00 | 0.0214 | 5.44% | 0.5 | 2.423% |
| 0.060 | 5.421 | 1.435 | -0.050 | 8.14 | -0.0676 | 12.93% | 0.5 | 5.738% |
| 0.080 | 5.675 | 1.604 | -0.063 | 8.04 | -0.1066 | 18.20% | 0.5 | 8.352% |
| 0.100 | 5.304 | 1.679 | -0.069 | 8.20 | -0.1190 | 19.73% | 0.5 | 9.328% |
| 0.150 | 4.313 | 1.727 | -0.074 | 8.28 | -0.1255 | 16.63% | 100.0 | 9.609% |
| 0.200 | 3.799 | 1.683 | -0.072 | 8.68 | -0.1142 | 15.63% | 100.0 | 9.243% |
| 0.300 | 3.298 | 1.568 | -0.064 | 9.32 | -0.0906 | 15.72% | 1.0 | 8.219% |
| 0.400 | 2.994 | 1.476 | -0.056 | 9.81 | -0.0761 | 14.71% | 1.0 | 7.308% |
| 0.500 | 2.787 | 1.407 | -0.049 | 9.99 | -0.0673 | 13.76% | 1.0 | 6.458% |
| 0.600 | 2.638 | 1.356 | -0.044 | 10.14 | -0.0587 | 12.74% | 1.0 | 5.724% |
| 0.800 | 2.407 | 1.284 | -0.036 | 10.04 | -0.0489 | 9.91% | 1.0 | 4.566% |
| 1.000 | 2.202 | 1.315 | -0.058 | 35.00 | 0.0307 | 5.87% | 1.0 | 2.696% |
| 1.500 | 2.009 | 1.190 | -0.037 | 34.43 | 0.0197 | 4.18% | 0.5 | 1.684% |
| 2.000 | 1.876 | 1.124 | -0.025 | 34.66 | 0.0135 | 2.40% | 0.5 | 0.987% |
| 3.000 | 1.727 | 1.043 | -0.009 | 35.75 | 0.0055 | 0.78% | 2.0 | 0.397% |
| 4.000 | 1.636 | 0.992 | 0.002 | 19.17 | -0.0013 | 0.97% | 2.0 | 0.297% |
| 5.000 | 1.572 | 0.960 | 0.009 | 30.18 | -0.0044 | 1.75% | 1.0 | 0.558% |
| 6.000 | 1.528 | 0.935 | 0.015 | 31.43 | -0.0084 | 2.05% | 1.0 | 0.807% |
| 8.000 | 1.447 | 0.914 | 0.020 | 32.78 | -0.0115 | 2.89% | 1.0 | 0.999% |
| 10.000 | 1.392 | 0.908 | 0.021 | 33.55 | -0.0108 | 3.33% | 1.0 | 1.124% |
| 15.000 | 1.323 | 0.886 | 0.027 | 33.94 | -0.0156 | 3.54% | 0.5 | 1.329% |

表10 GP式新フィッティングパラメータ
媒質：空気，レスポンス：空気

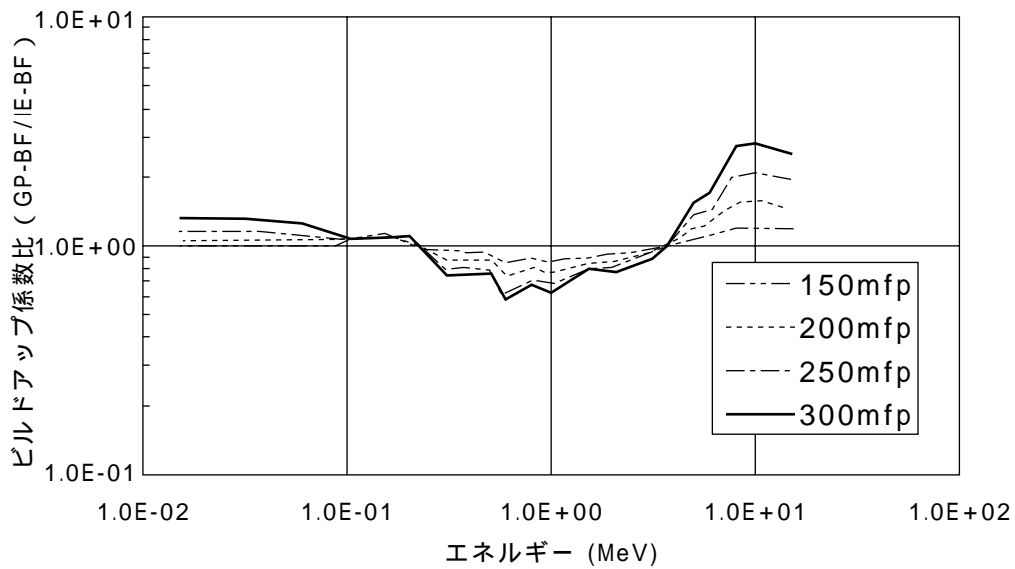
| $E(\text{MeV})$ | b | c | a | Xk | d | $Max.Dev.$ | $xmax$ | $St.Dev.$ |
|-----------------|-------|-------|--------|-------|---------|------------|--------|-----------|
| 0.015 | 1.148 | 0.587 | 0.065 | 6.47 | 0.0675 | 1.56% | 0.5 | 0.604% |
| 0.020 | 1.348 | 0.643 | 0.061 | 7.19 | 0.0588 | 3.12% | 0.5 | 1.133% |
| 0.030 | 2.070 | 0.825 | 0.028 | 8.18 | 0.0433 | 4.98% | 0.5 | 1.910% |
| 0.040 | 3.205 | 1.048 | -0.005 | 29.08 | -0.0048 | 1.28% | 0.5 | 0.496% |
| 0.050 | 4.369 | 1.278 | -0.046 | 35.36 | 0.0159 | 4.90% | 0.5 | 1.797% |
| 0.060 | 5.170 | 1.387 | -0.046 | 8.48 | -0.0551 | 12.01% | 0.5 | 4.958% |
| 0.080 | 5.475 | 1.559 | -0.060 | 8.22 | -0.0941 | 17.18% | 0.5 | 7.649% |
| 0.100 | 5.122 | 1.646 | -0.067 | 8.16 | -0.1101 | 17.98% | 0.5 | 8.660% |
| 0.150 | 4.259 | 1.691 | -0.072 | 8.42 | -0.1138 | 16.35% | 0.5 | 9.029% |
| 0.200 | 3.809 | 1.643 | -0.070 | 9.09 | -0.0985 | 16.13% | 1.0 | 8.694% |
| 0.300 | 3.235 | 1.555 | -0.063 | 9.35 | -0.0872 | 14.31% | 1.0 | 7.835% |
| 0.400 | 2.959 | 1.464 | -0.055 | 9.94 | -0.0725 | 14.25% | 1.0 | 6.981% |
| 0.500 | 2.744 | 1.404 | -0.049 | 9.98 | -0.0654 | 12.46% | 1.0 | 6.175% |
| 0.600 | 2.581 | 1.358 | -0.044 | 9.91 | -0.0607 | 10.77% | 1.0 | 5.514% |
| 0.800 | 2.413 | 1.272 | -0.035 | 10.60 | -0.0439 | 10.69% | 1.0 | 4.403% |
| 1.000 | 2.193 | 1.305 | -0.056 | 35.00 | 0.0285 | 5.52% | 0.5 | 2.524% |
| 1.500 | 1.997 | 1.189 | -0.037 | 34.36 | 0.0194 | 3.79% | 0.5 | 1.531% |
| 2.000 | 1.874 | 1.120 | -0.024 | 35.00 | 0.0124 | 2.36% | 0.5 | 0.963% |
| 3.000 | 1.738 | 1.035 | -0.007 | 38.59 | 0.0038 | 1.14% | 0.5 | 0.300% |
| 4.000 | 1.644 | 0.985 | 0.004 | 26.67 | -0.0033 | 0.87% | 20.0 | 0.408% |
| 5.000 | 1.570 | 0.965 | 0.008 | 29.98 | -0.0042 | 1.87% | 1.0 | 0.592% |
| 6.000 | 1.521 | 0.947 | 0.012 | 31.56 | -0.0061 | 2.50% | 1.0 | 0.811% |
| 8.000 | 1.448 | 0.922 | 0.018 | 33.10 | -0.0099 | 2.82% | 1.0 | 1.018% |
| 10.000 | 1.393 | 0.913 | 0.020 | 34.78 | -0.0112 | 3.26% | 1.0 | 1.170% |
| 15.000 | 1.313 | 0.904 | 0.023 | 33.70 | -0.0138 | 4.04% | 0.5 | 1.282% |

表11 GP式新フィッティングパラメータ
 媒質：コンクリート，レスポンス：空気

| $E(\text{MeV})$ | b | c | a | Xk | d | $Max.Dev.$ | $xmax$ | $St.Dev.$ |
|-----------------|-------|-------|--------|-------|---------|------------|--------|-----------|
| 0.015 | 1.026 | 0.530 | 0.071 | 5.00 | 0.0768 | 0.59% | 20.0 | 0.332% |
| 0.020 | 1.057 | 0.581 | 0.062 | 7.90 | 0.0556 | 0.71% | 0.5 | 0.285% |
| 0.030 | 1.194 | 0.544 | 0.079 | 5.90 | 0.0766 | 1.51% | 0.5 | 0.746% |
| 0.040 | 1.418 | 0.612 | 0.069 | 6.52 | 0.0707 | 3.36% | 0.5 | 1.234% |
| 0.050 | 1.711 | 0.707 | 0.050 | 6.97 | 0.0637 | 4.84% | 0.5 | 1.868% |
| 0.060 | 2.011 | 0.815 | 0.028 | 7.23 | 0.0541 | 5.32% | 0.5 | 2.135% |
| 0.080 | 2.445 | 0.977 | 0.010 | 30.49 | -0.0141 | 4.53% | 0.5 | 1.721% |
| 0.100 | 2.688 | 1.126 | -0.018 | 21.09 | -0.0057 | 2.87% | 0.5 | 0.981% |
| 0.150 | 2.833 | 1.316 | -0.051 | 39.34 | 0.0153 | 1.06% | 15.0 | 0.607% |
| 0.200 | 2.833 | 1.328 | -0.044 | 12.86 | -0.0239 | 4.73% | 100.0 | 2.419% |
| 0.300 | 2.674 | 1.348 | -0.046 | 12.13 | -0.0311 | 6.11% | 1.0 | 3.078% |
| 0.400 | 2.515 | 1.333 | -0.044 | 11.78 | -0.0345 | 6.12% | 1.0 | 3.284% |
| 0.500 | 2.421 | 1.300 | -0.040 | 12.18 | -0.0328 | 6.65% | 1.0 | 3.250% |
| 0.600 | 2.338 | 1.335 | -0.057 | 37.95 | 0.0221 | 6.76% | 1.0 | 2.556% |
| 0.800 | 2.123 | 1.319 | -0.057 | 35.00 | 0.0267 | 3.10% | 85.0 | 1.730% |
| 1.000 | 2.038 | 1.267 | -0.049 | 35.43 | 0.0233 | 2.41% | 1.0 | 1.445% |
| 1.500 | 1.895 | 1.180 | -0.035 | 34.52 | 0.0176 | 1.88% | 1.0 | 1.091% |
| 2.000 | 1.818 | 1.112 | -0.022 | 35.00 | 0.0102 | 1.56% | 1.0 | 0.731% |
| 3.000 | 1.684 | 1.055 | -0.011 | 37.31 | 0.0053 | 0.94% | 1.0 | 0.358% |
| 4.000 | 1.610 | 1.012 | -0.002 | 20.00 | 0.0000 | 1.23% | 1.0 | 0.615% |
| 5.000 | 1.542 | 0.991 | 0.003 | 27.23 | -0.0037 | 2.41% | 1.0 | 0.763% |
| 6.000 | 1.501 | 0.974 | 0.007 | 30.75 | -0.0060 | 3.16% | 1.0 | 1.015% |
| 8.000 | 1.439 | 0.951 | 0.013 | 32.20 | -0.0109 | 3.42% | 1.0 | 1.255% |
| 10.000 | 1.391 | 0.941 | 0.016 | 32.36 | -0.0135 | 4.08% | 0.5 | 1.397% |
| 15.000 | 1.335 | 0.931 | 0.020 | 33.48 | -0.0179 | 4.01% | 0.5 | 1.534% |

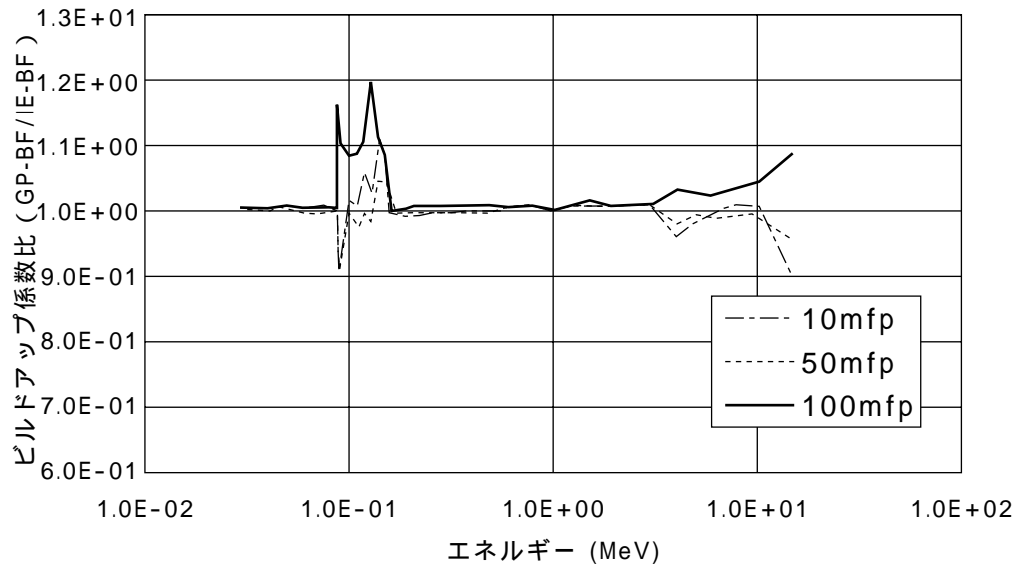


(a)

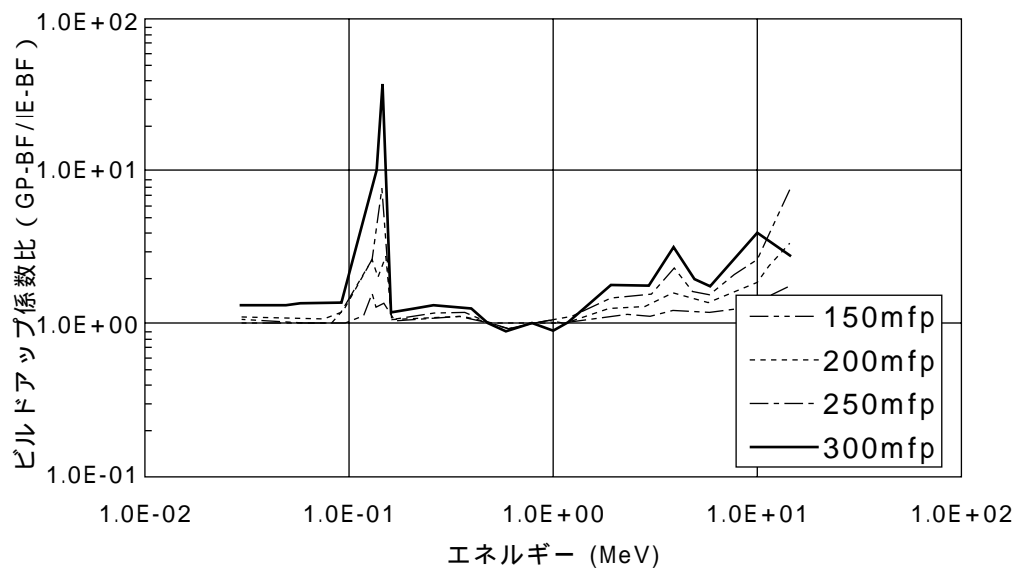


(b)

図5 新フィッティングパラメータを用いたGP式で算出したビルドアップ係数 (GP-BF)とIE法による改良ビルドアップ係数(IE-BF)との比 (鉄)
(a) : 10~100mfp , (b) : 150~300mfp

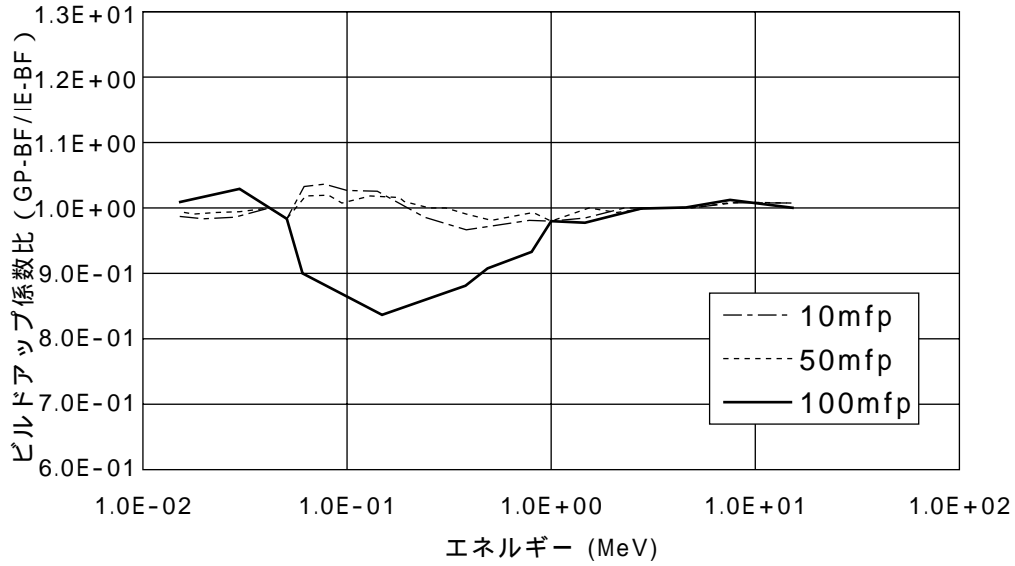


(a)

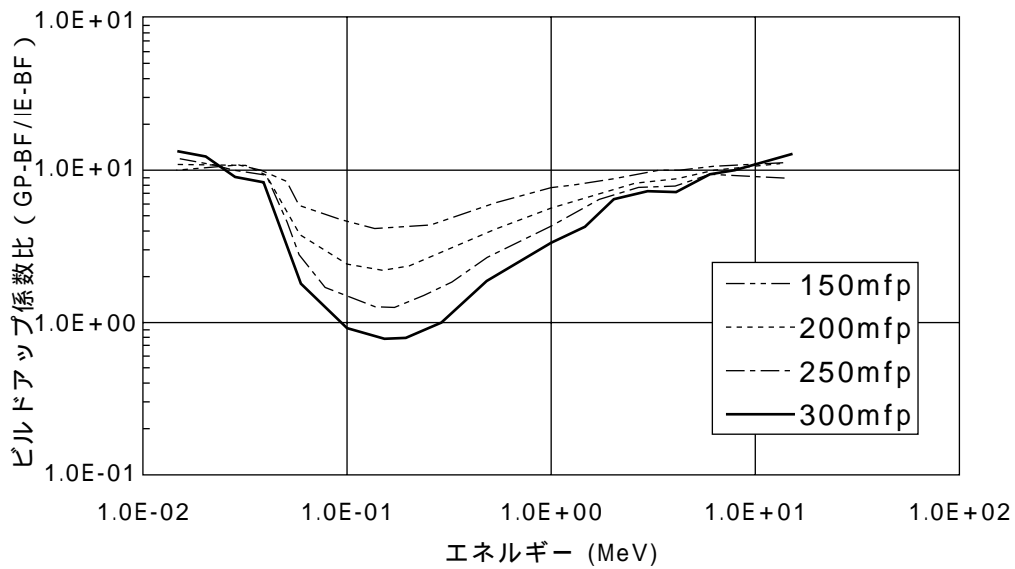


(b)

図6 新フィッティングパラメータを用いたGP式で算出したビルドアップ係数 (GP-BF)とIE法による改良ビルドアップ係数(IE-BF)との比 (鉛)
 (a) : 10~100mfp , (b) : 150~300mfp

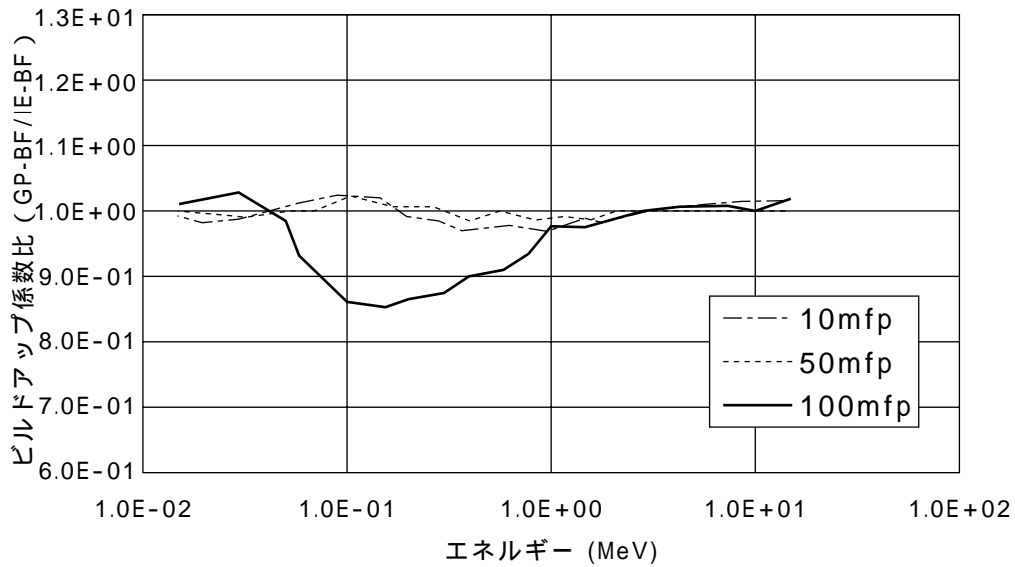


(a)

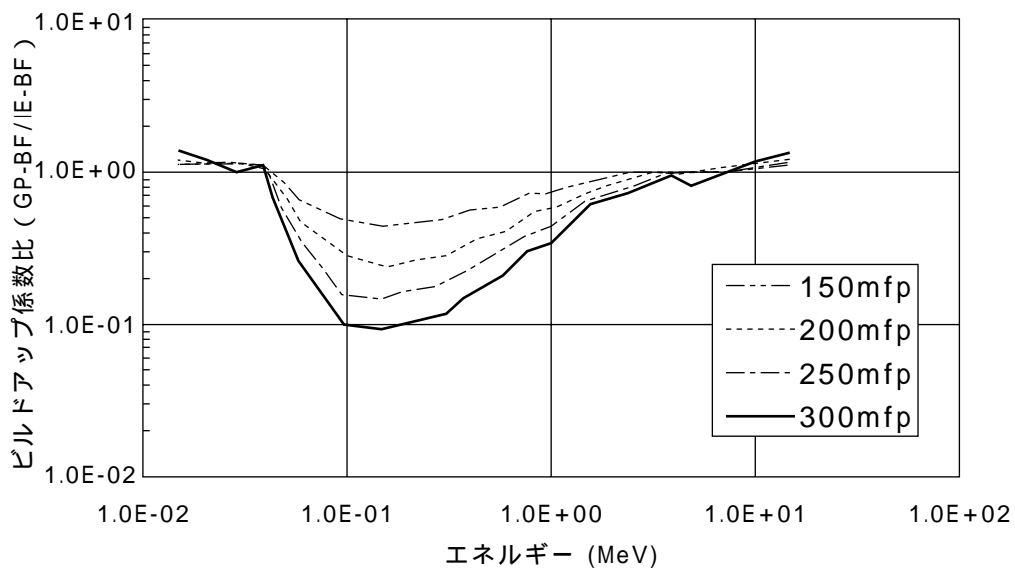


(b)

図7 新フィッティングパラメータを用いたGP式で算出したビルドアップ係数 (GP-BF)とIE法による改良ビルドアップ係数(IE-BF)との比(水)
 (a) : 10~100mfp , (b) : 150~300mfp

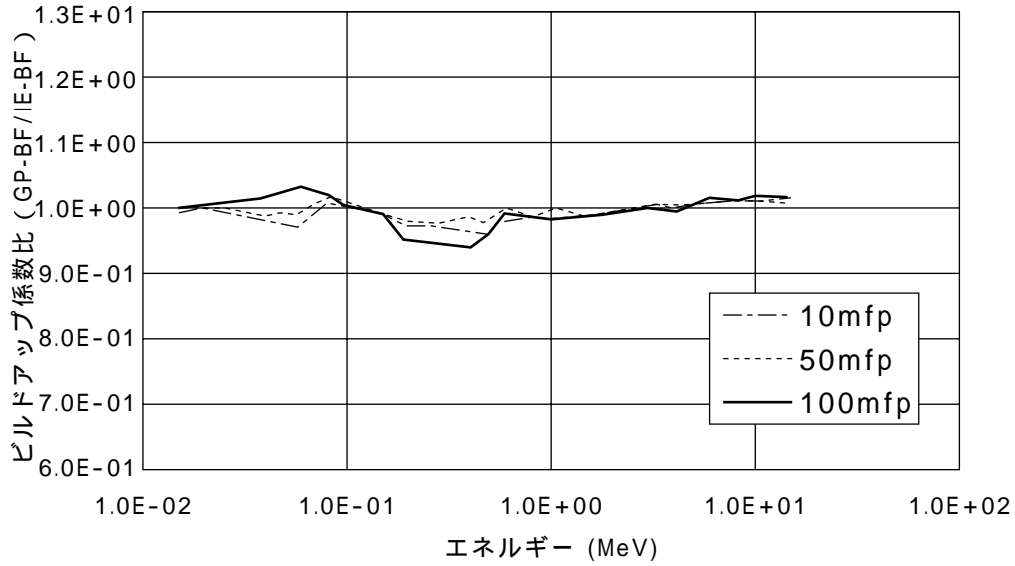


(a)

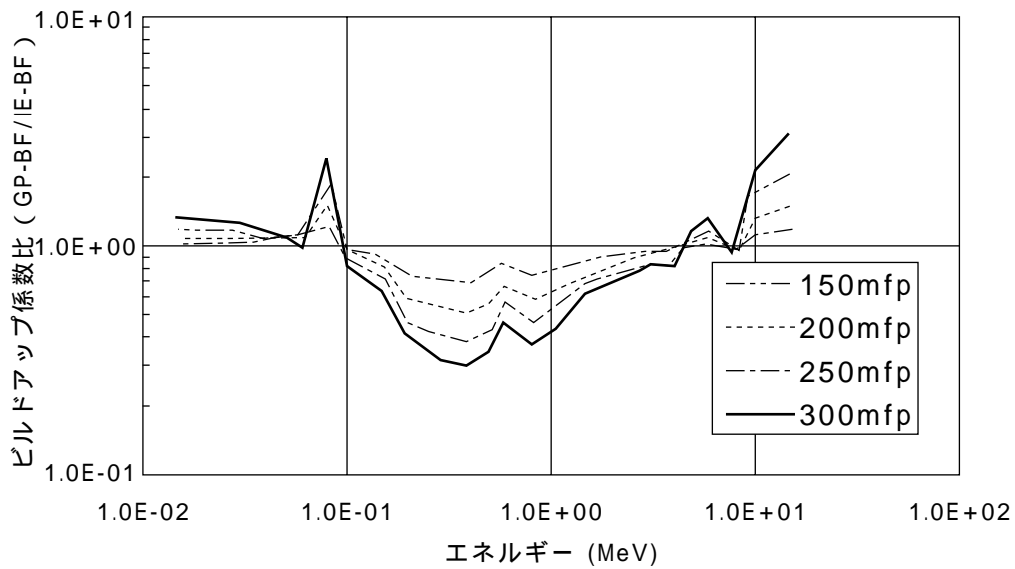


(b)

図8 新フィッティングパラメータを用いたGP式で算出したビルドアップ係数 (GP-BF)とIE法による改良ビルドアップ係数(IE-BF)との比 (空気)
 (a) : 10~100mfp , (b) : 150~300mfp



(a)



(b)

図9 新フィッティングパラメータを用いたGP式で算出したビルドアップ係数 (GP-BF)とIE法による改良ビルドアップ係数(IE-BF)との比 (コンクリート)
 (a) : 10~100mfp , (b) : 150~300mfp

2.5 コードへの組み込み

改良ビルドアップ係数の QAD コードおよび G33 コードへの組み込みは、1) 物質毎に線源エネルギーと mfp の 2 次元テーブルでビルドアップ係数を格納するファイルを組み込み、Lagrange の 3 点補間で内挿してビルドアップ係数を取り出す方法、2) これまでのように、GP 式のフィッティングパラメータを格納するファイルを組み込み、GP 式でビルドアップ係数を算出する方法、の 2 通りで行った。入力ファイルによって 2 通りを使い分けることができるようにした。これは、2.4 節で示したように、GP 式によるビルドアップ係数と改良ビルドアップ係数との差違が大きい場合があるためである。

3. まとめ

まず、深い透過距離での遮蔽計算に対応するため、最新断面積データ、制動輻射線の現実的なモデルを用いて実用上十分と考えられる 300mfp までの照射線量ビルドアップ係数の整備を IE 法で行った。ANS 標準データとの比較の結果、ANS 標準データの過大評価を最大約 1/3 (ランタン 10MeV の場合) にまで修正し、K 端付近でのビルドアップ係数が約 30% (鉛の場合) 修正されたことが分かった。300mfp では誤差 1 桁となるが、300mfp になると非散乱成分は $e^{-300} \approx 10^{-131}$ となるため、十分な精度を有していると考えられる。

次に、得られた改良ビルドアップ係数から 300mfp までの新 GP フィッティングパラメータを算出した。GP 式でビルドアップ係数を計算した結果、改良ビルドアップ係数と GP 式で計算したビルドアップ係数との間に大きな差違が発生し、特に 100mfp 以上で差違が大きかった。

改良ビルドアップ係数を活用するため、改良ビルドアップ係数および新 GP フィッティングパラメータを QAD コード、G33 コードに導入し、これまでにない深い透過距離での遮蔽計算を可能とした。

今後は、実効線量ビルドアップ係数および吸収線量ビルドアップ係数を整備し、改良版 QAD コードおよび G33 コードとして一般に公開するとともに、線量評価システムに導入する予定である。また、今後 100mfp を超える領域での GP 式のフィッティングパラメータ導出および外挿式について検討を行う予定である。

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