Mean free path of X-ray transition radiation generation

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Abstract

GEANT4 simulation of X-ray transition radiation (XTR) at small angles (less than 1 mrad) is discussed. New development concerning the definition of the XTR mean free path (MFP) is described. The model calculations are compared with recent experimental data from the ATLAS TRT test beam as well as with the FNAL $\bar{N}_{XTR}(\gamma)$ data. Irregular XTR radiators are considered to optimize the XTR yield.

1 Motivation

1. The ATLAS TRT team based on the test beam results required to improve the X-ray transition radiation (XTR) angle distribution for the angles less than milliradian.

2. It is assumed usually that the points of the XTR generation inside a radiator are exponentially distributed with constant mean free path ($\sim L_{rad}/\bar{N}_{XTR}$).

3. The description XTR angular distribution requires definition of the XTR generation mean free path (MFP). The latter is limited in accuracy by the coherence length of the XTR quantum formation (basically $\sim t_1 + t_2$).

Mean free path of X-ray transition radiation generation

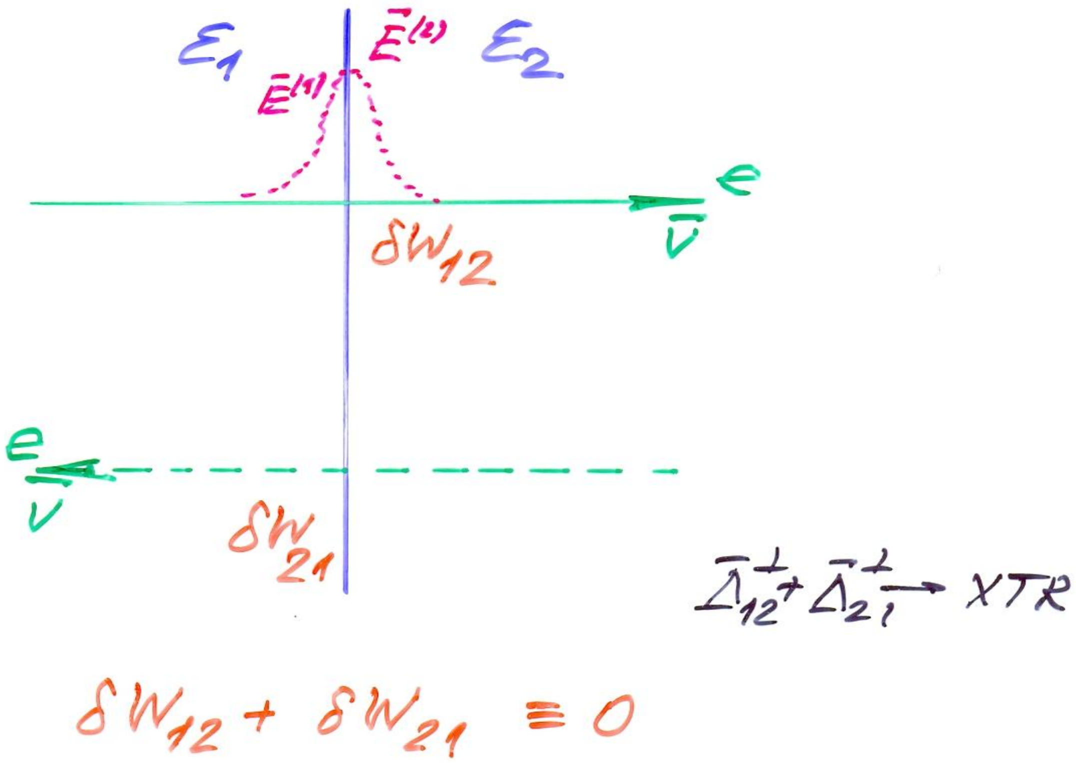
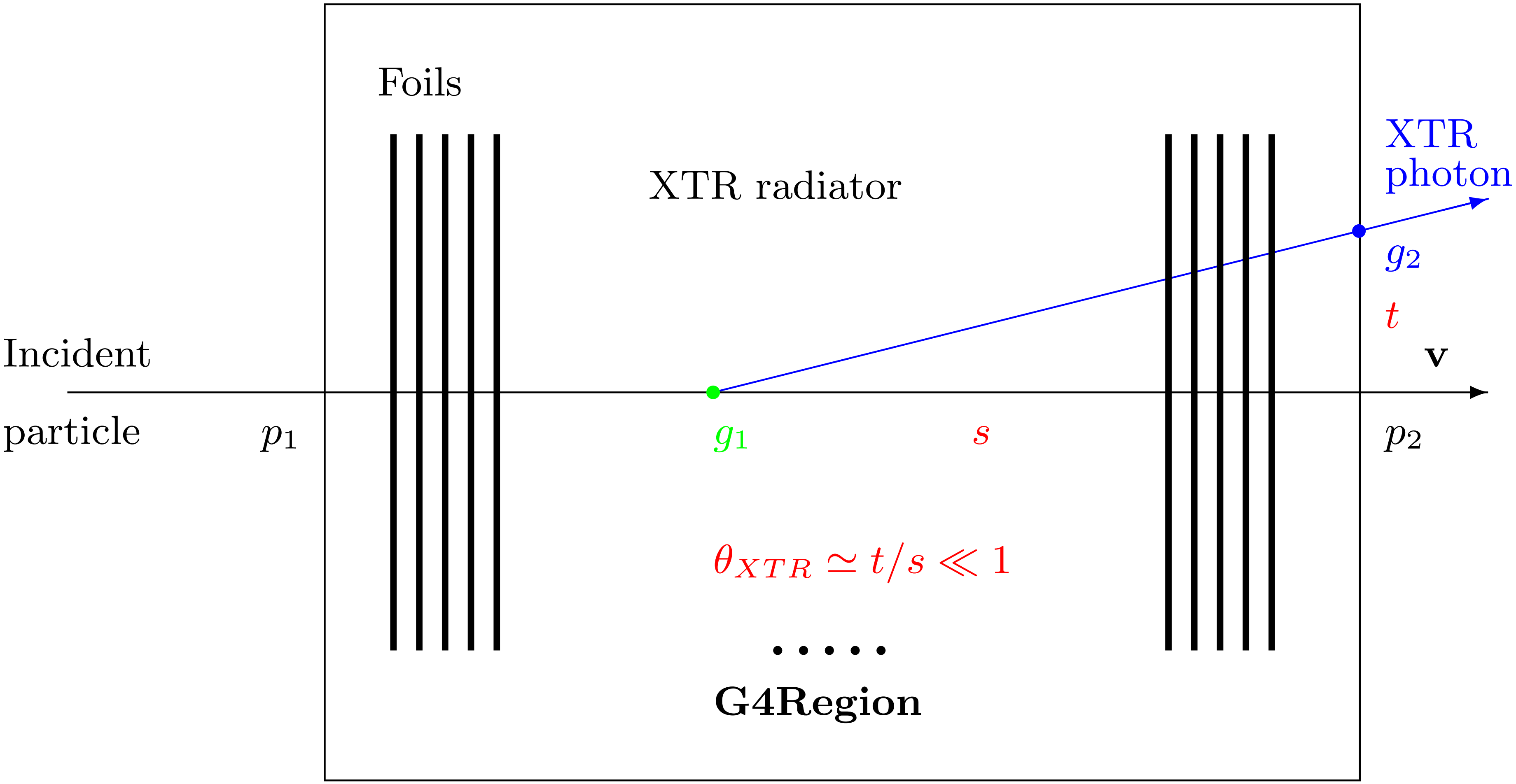


Diagram of a charged particle crossing the single interface between two absorbing media. XTR yield ($\sim \alpha$) requires many interface radiator.



The diagram of the XTR generation according to external flux models

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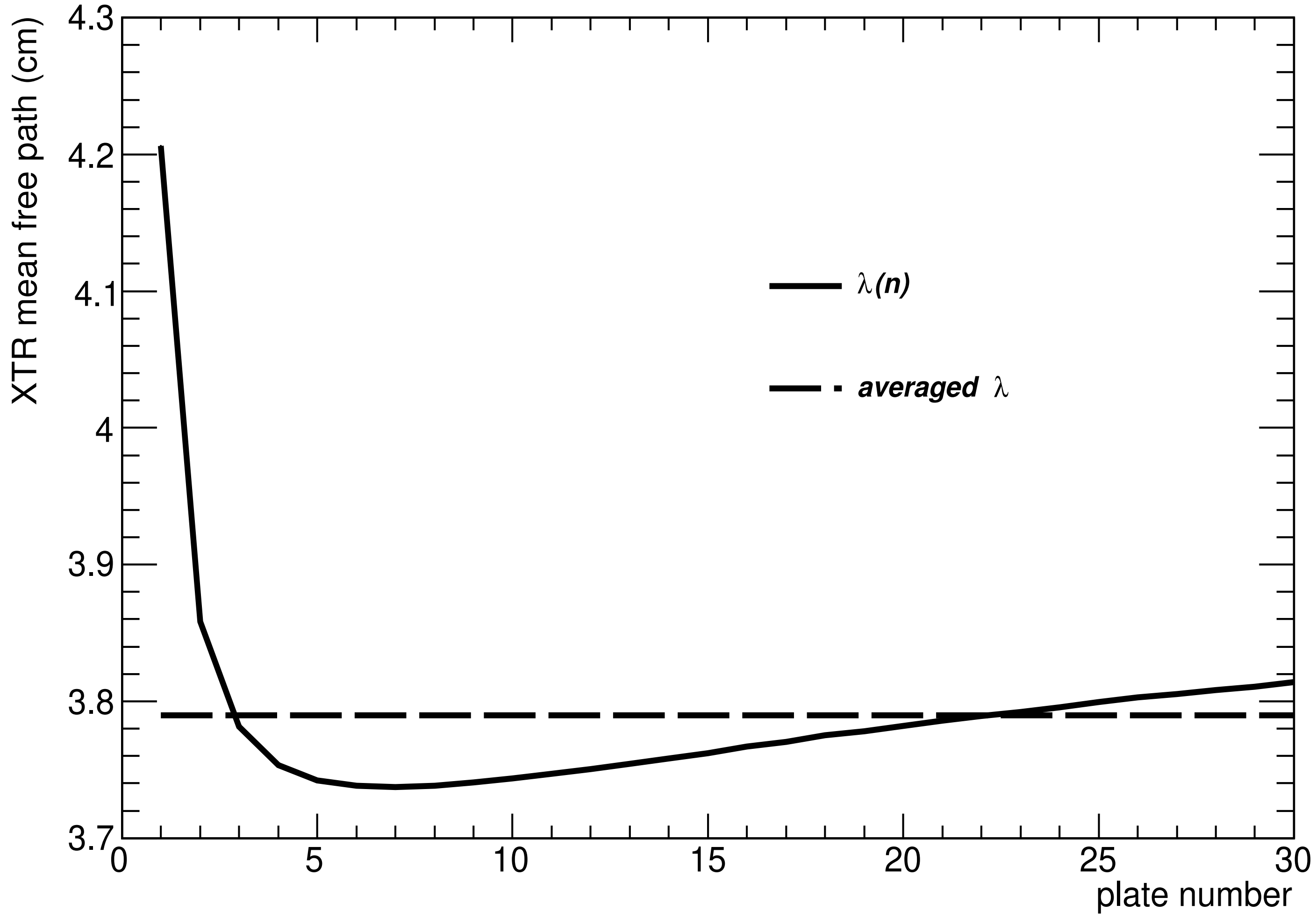
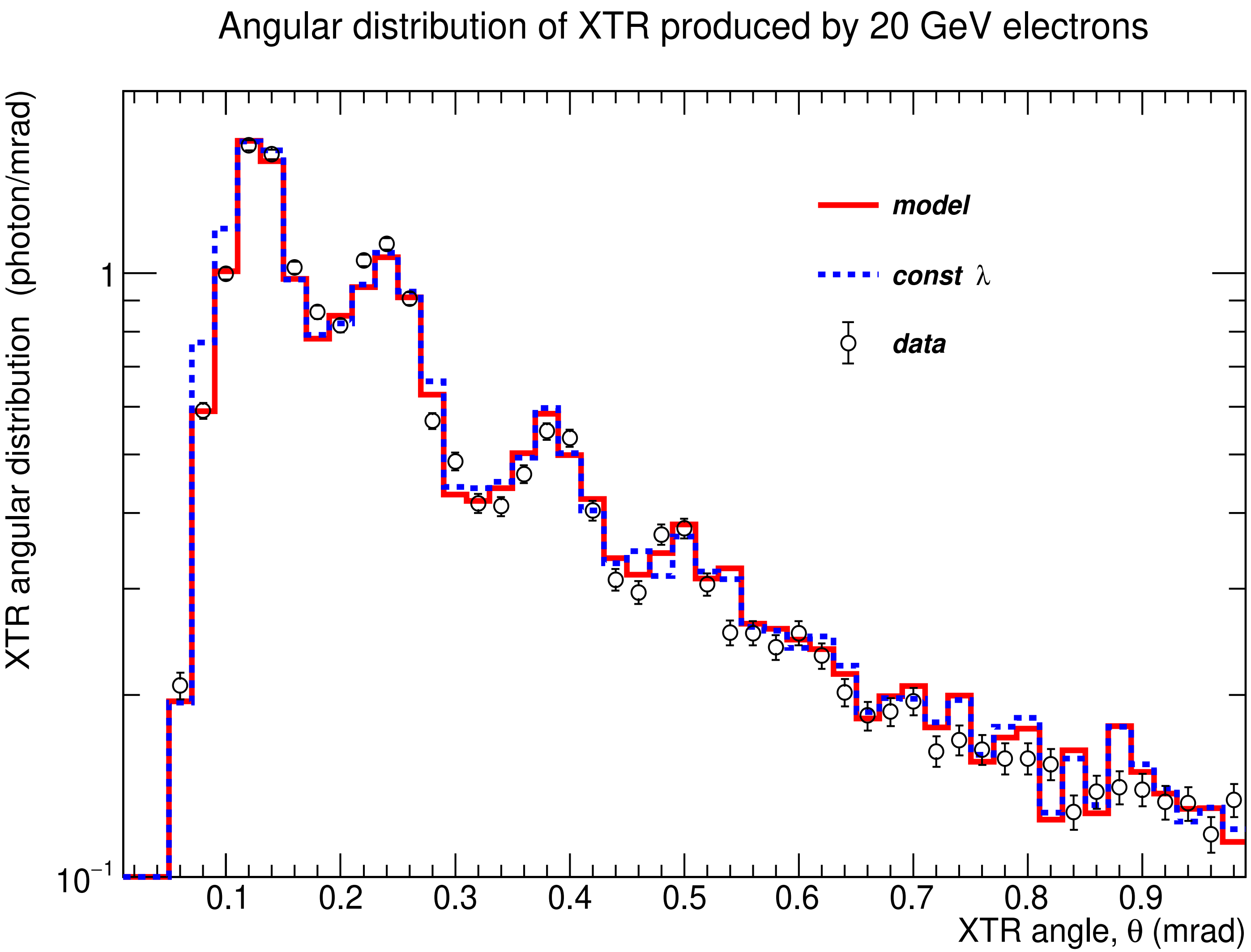
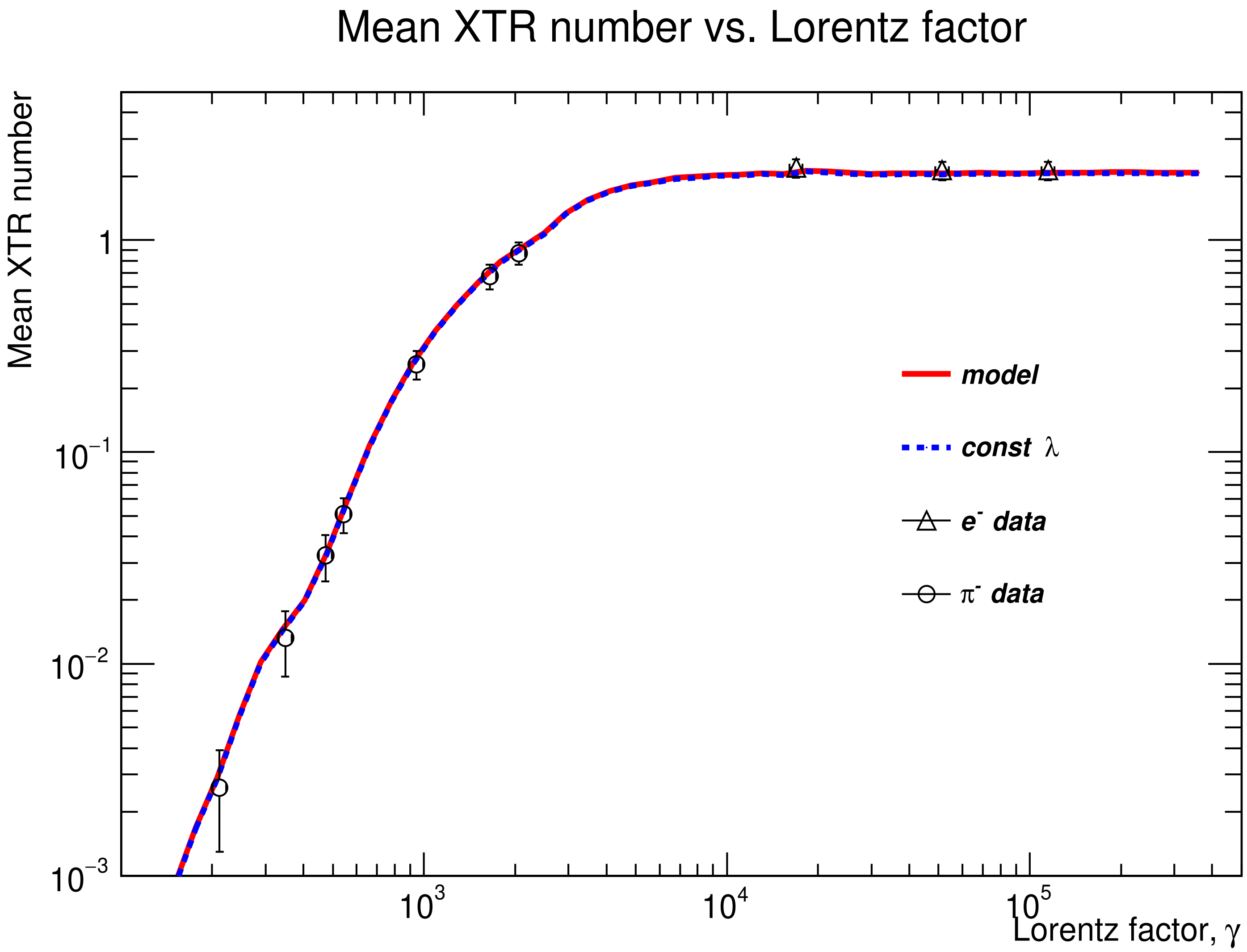


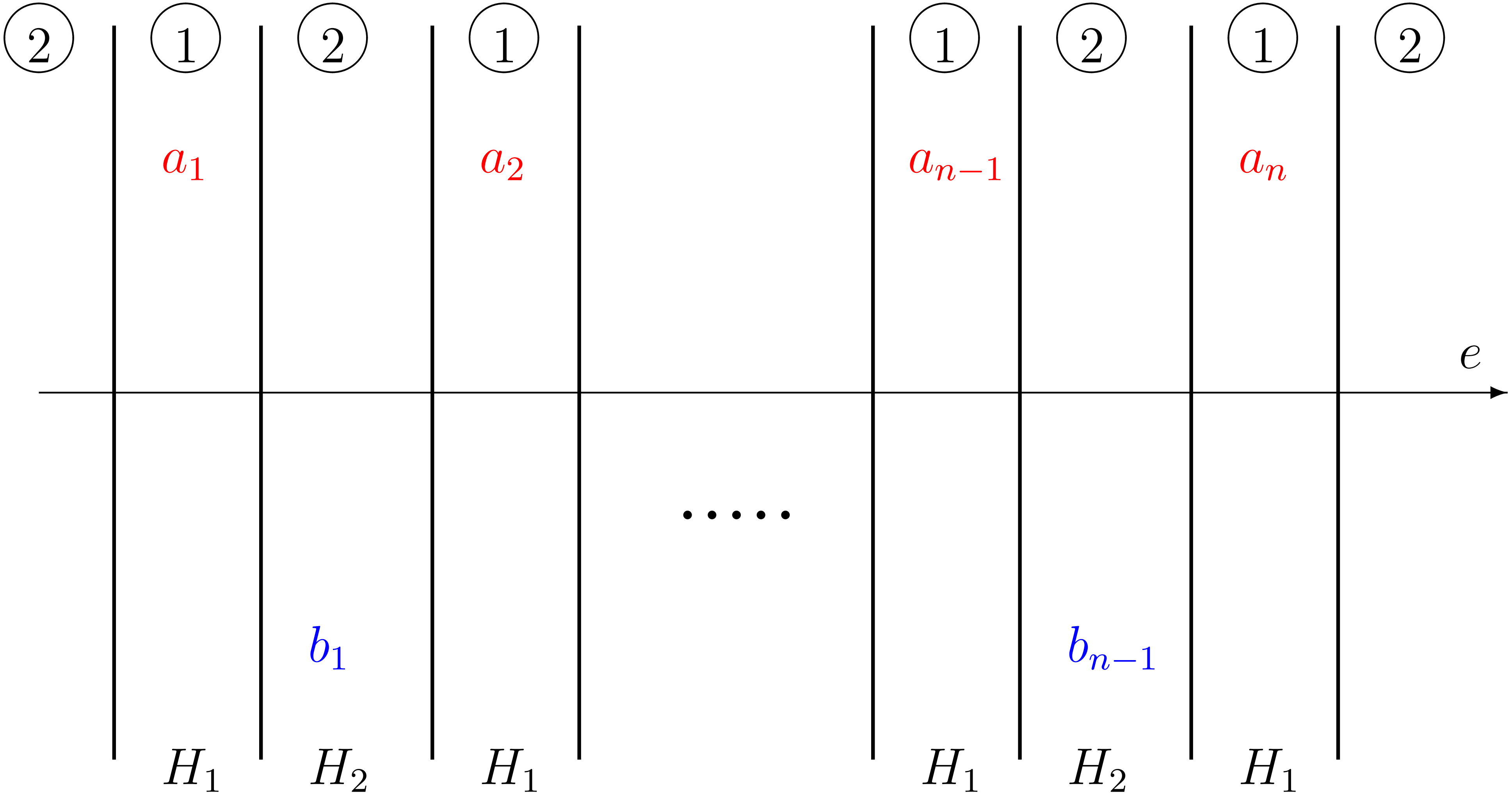
Mean free path of the X-ray transition radiation produced by 20 GeV electrons (formalism in *NIM A1062 (May 2024) 169180*).



Angular distribution of the X-ray transition radiation produced by 20 GeV electrons (thirty 50 μm thick mylar foils separated by ∼2.96 mm air gaps).



X-ray transition radiation yield vs. the radiating particle Lorentz factor detected in MWPC with threshold 6 eV.



Irregular n-foil XTR radiator

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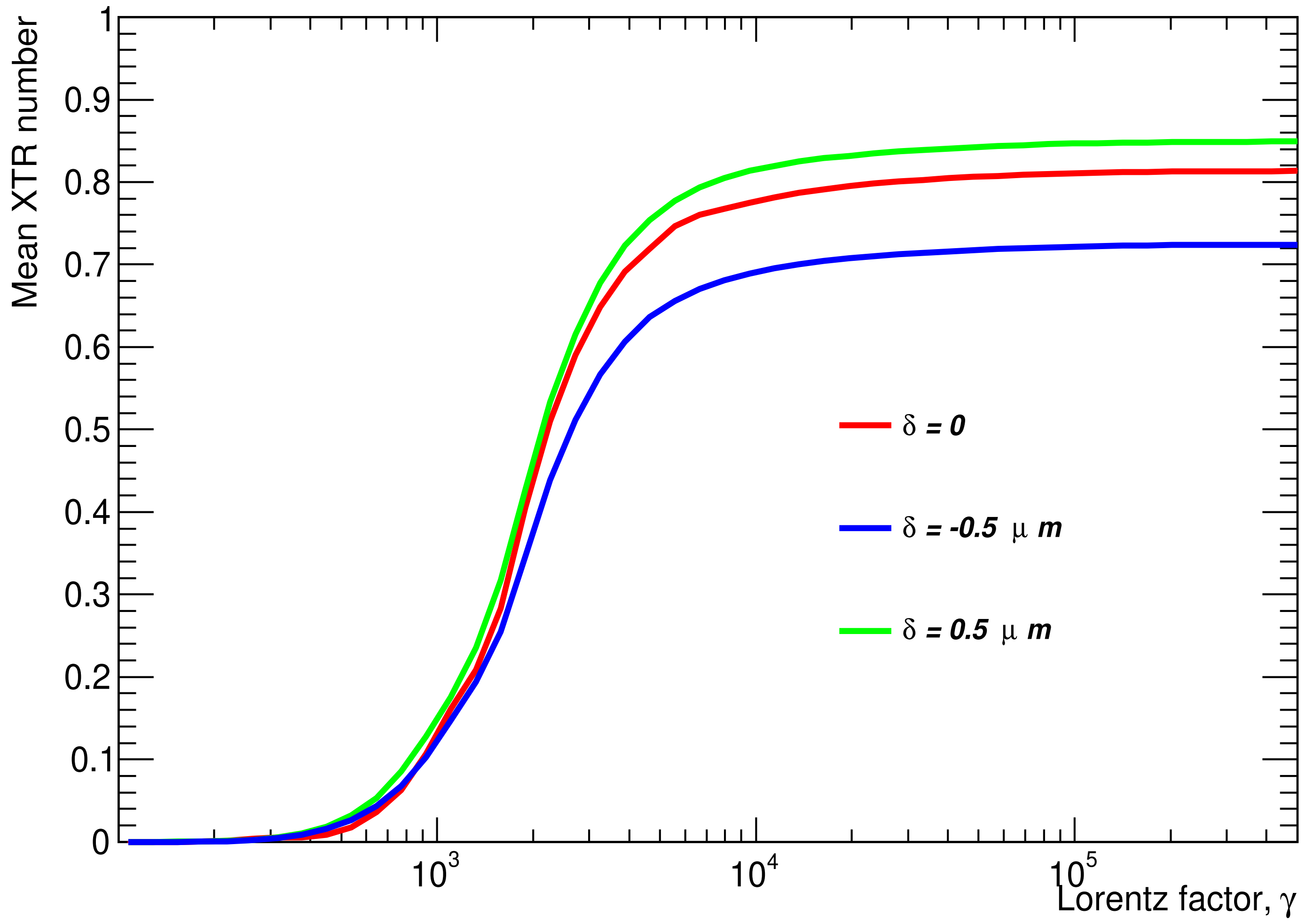
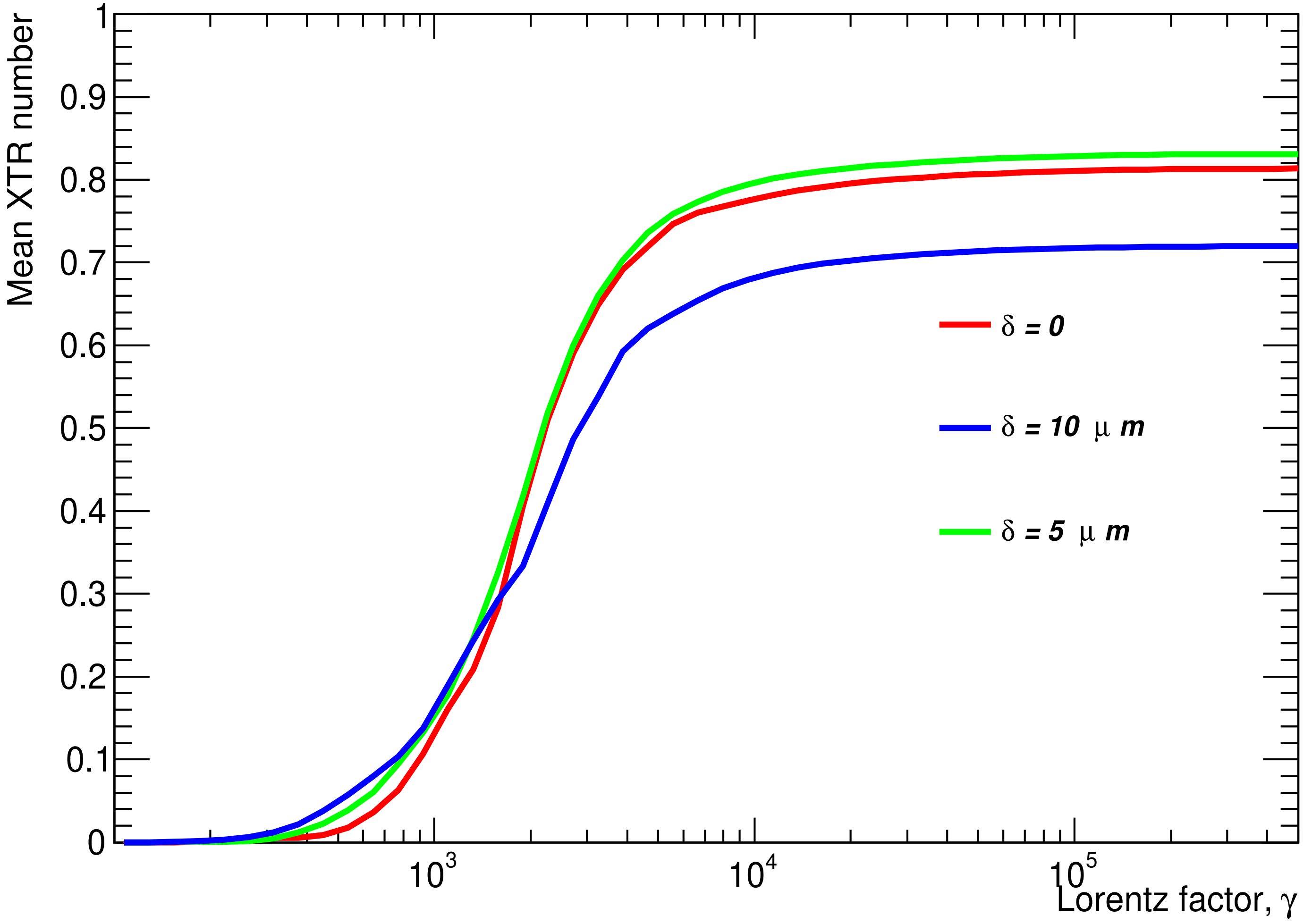
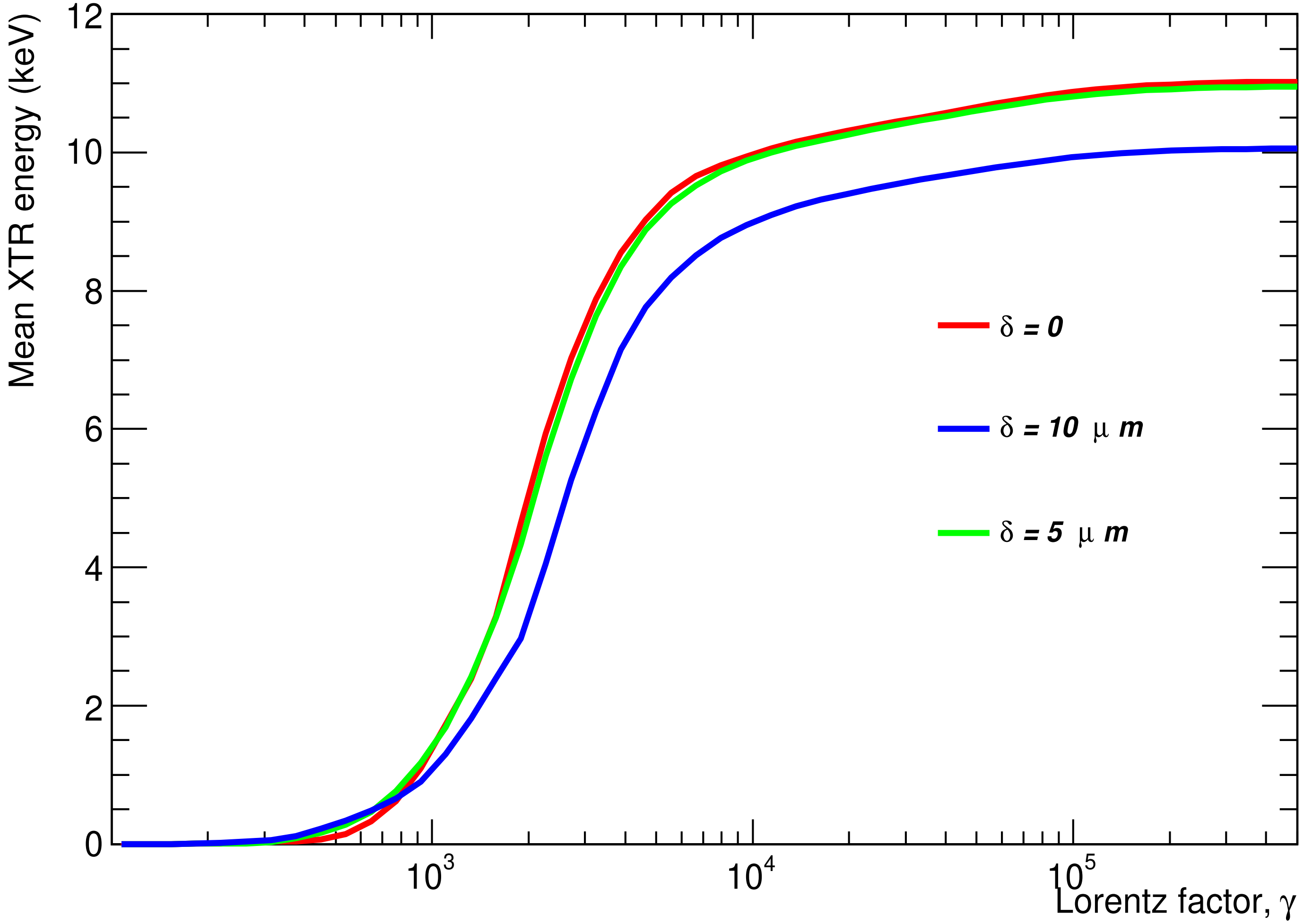


$\bar{N}_{XTR}(\gamma)$: a[i]=22.5μm - i*δ, b[i]=480μm - 20*i*δ,

(δ=0, ATLAS TRT end-cup, 30 15μm/330μm).



$\bar{N}_{XTR}(\gamma)$: a[i]=(15μm+δ), b[i]=(330μm+δ) for i$\leq$15, a[i]=(15μm-δ), b[i]=(330μm-δ) for i>15 (δ=0, ATLAS TRT end-cup).



$\bar{\Delta}_{XTR}(\gamma)$: a[i]=(15$\mu$m+$\delta$), b[i]=(330$\mu$m+$\delta$) for i$\leq$15, a[i]=(15$\mu$m-$\delta$), b[i]=(330$\mu$m-$\delta$) for i>15 ($\delta$=0, ATLAS TRT end-cup).

2 Conclusions

1. The accuracy for the X-ray transition radiation angle distribution in the sub-milliradian range was slightly improved by more accurate estimation of XTR MFP. Though this accuracy is much smaller compared with technological spread of the XTR radiator parameters (foil and gas-gap thicknesses).
2. The flexibility of the GEANT4 XTR library allows a user to tune (changing models and parameters) the accuracy requirements in different ranges of angles and energies.
3. Irregular XTR radiators can be optimized by tuning of the sequence of the foil and gas-gap thicknesses. However the current implementation is relatively slow for the model initialization while being at the same sampling performance.
4. Irregular XTR radiators can be used for more realistic estimation of influence of the technological spread on the energy and angular XTR distributions. In progress ...