Energy losses simulation for the MPD TPC

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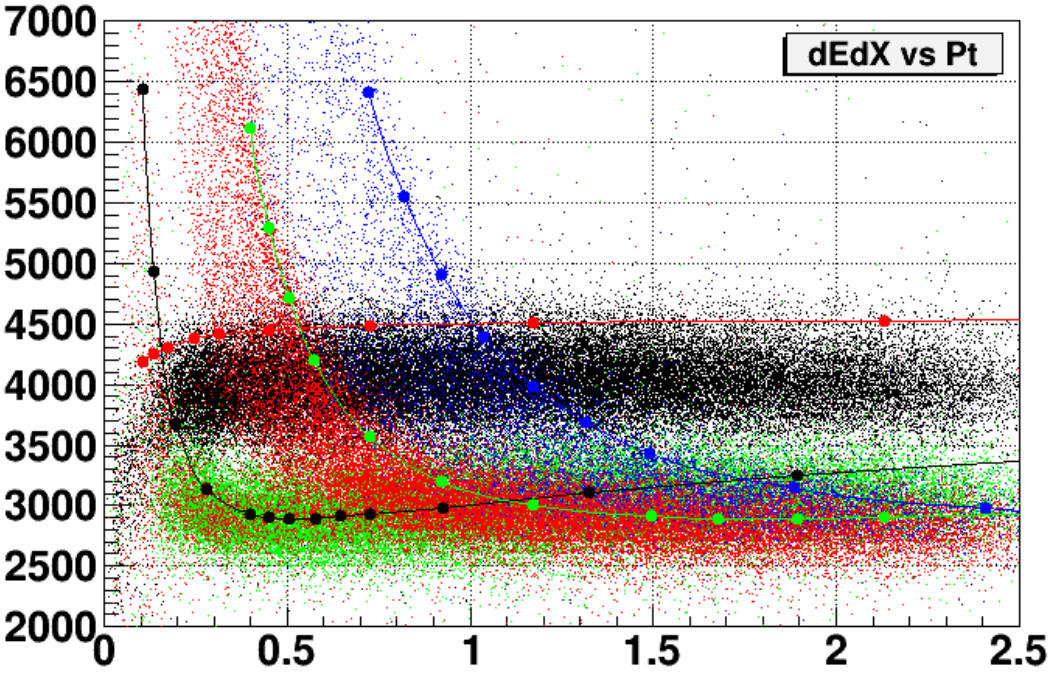
PWG2 meeting 29-JUL-2020

reminder

MPD Physics Seminar 19-Sep-2019: https://indico.jinr.ru/event/983/

TPC PID at the moment.



dE/dx vs momentum from MPD BOX MC for *e*, *pi*, *K* and *p*.
Curves – STAR parametrisation for expimental data.
(NIM A558 (2006) 419-429)

TPC configurations.

	ALICE	STAR	MPD
Gas	85% Ne mixetures	P10	P10
N rows × pitch(mm):			
inner pads	64 × 7.5 mm	13 × 12 mm	26 × 12 mm
outer pads	64 × 10 mm	32 × 20 mm	27 × 18 mm
outer-2 pads	32 × 32 mm	-	-

P10 mixture – 90% Ar, 10% methane.

Straggling function calculation.

H. Bichsel, NIM A562, 154-197

$$f(\Delta; x, \beta\gamma) = \sum_{n=0}^{\infty} P(n) \cdot \sigma(\Delta, \beta\gamma)^{*n}$$

$$P(n) = \frac{m_c^n}{n!} e^{-m_c}$$

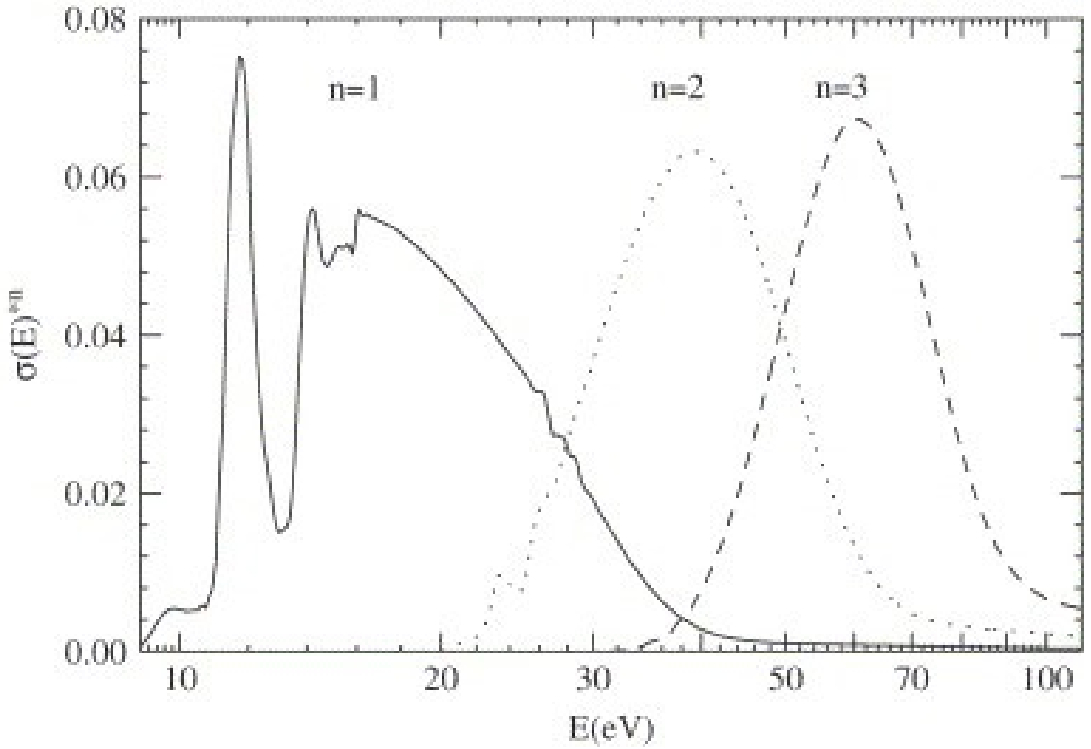
— Poisson distributin giving the number of collisions in segment x. $m_c = x/\lambda$.

$$\sigma(\Delta)^{*n} = \int_0^{\Delta} \sigma(E) \cdot \sigma^{*(n-1)}(\Delta - E)\, dE \qquad \sigma(\Delta)^{*1} = \sigma(E)$$

— energy loss spectra for n collisions, calculated as n-fold convolution of the single spectrum $\sigma(E)$.

Convolution spectra $\sigma(E)^{*n}$ for P10.

H. Bichsel, NIM A562, 154-197



n= 1 — single collision cross-section for P10-gas,
n= 2, 3 — convolutions.
Large reduction of the 12 *ev* spike for $n = 2$, and
its complete disappearance for $n = 3$.

Comparision of CCS models.

H. Bichsel, NIM A562, 154-197

Rutherford. Collision of two ***free*** charged particles.

$$\sigma_R(E;\beta)=\frac{k_R}{\beta^2}\frac{\left(1-\beta^2 E/E_{max}\right)}{E^2}$$

Fermi virtual photon (FVP). Interation with ***bounded*** elecron is considered as emission of virtual photons by the fast particle, which then are absorbed by the materail. The differential CCS then is closely related to the photo absorption cross-section of the molecules. Optical data are used for parametrizations.

Bethe-Fano. “Bethe derived an expression for a cross-section doubly differential in energy loss E and momentum transfer K using the first Born approximation for inelastic scattering on free atoms. Fano extended the method for solids.”

Garfield++

https://garfieldpp.web.cern.ch/garfieldpp/examples/heed/ -

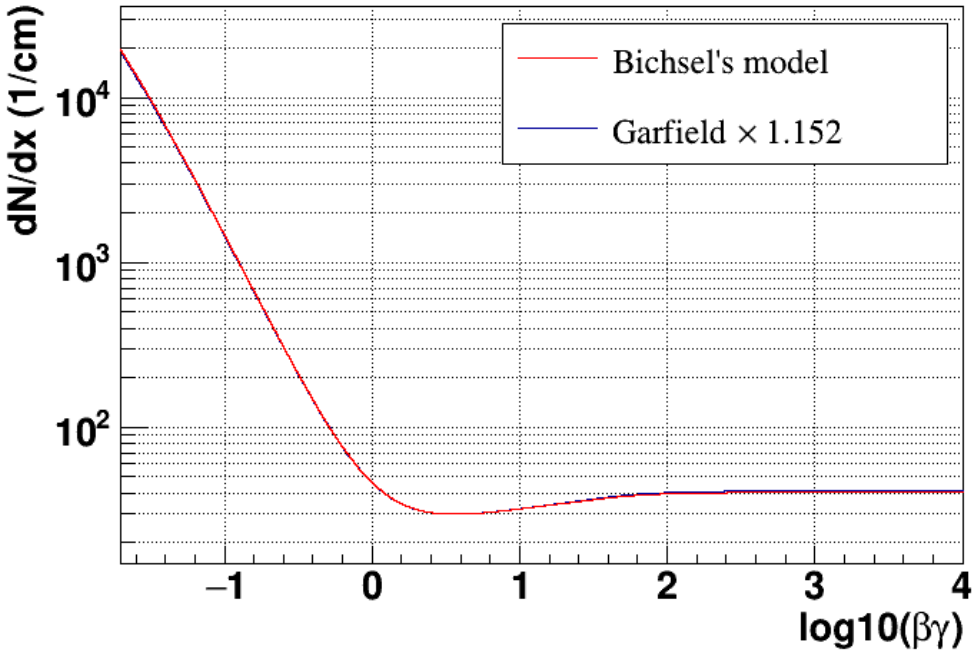
HEED example applications

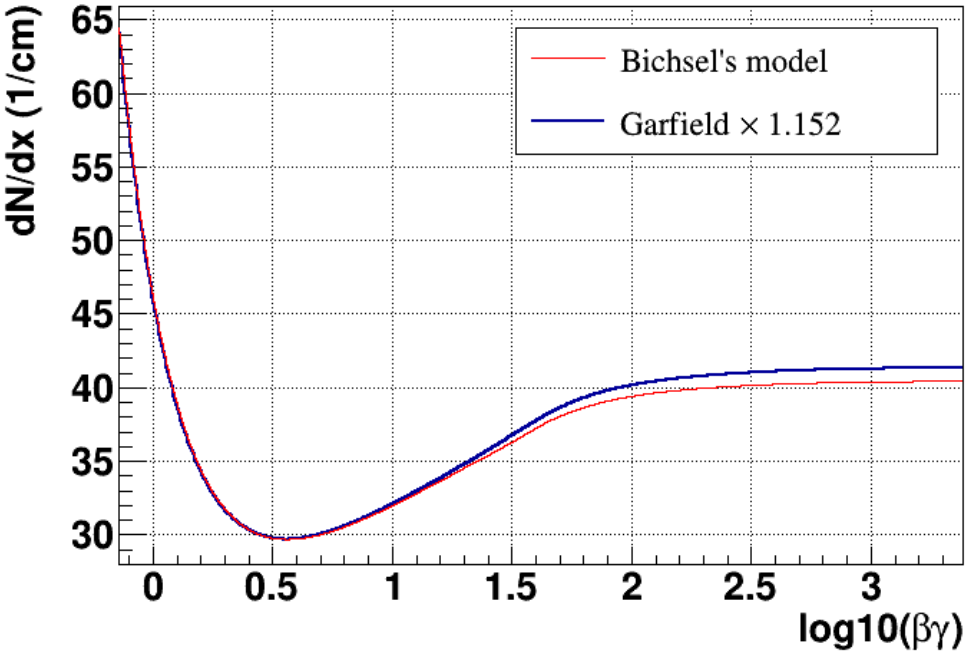
edep.C - energy loss and ionization spectra in Ar/CO_2

HEED - “High Energy Electro-Dynamics”, calculation (simulation) of interaction of fast charged particles with matter and its ionization.
The program Heed is an implementation of the photo-absorption ionization (PAI) model. It was written by I. Smirnov.

Number of collisions dN/dX

TrackHeed::GetClusterDensity();

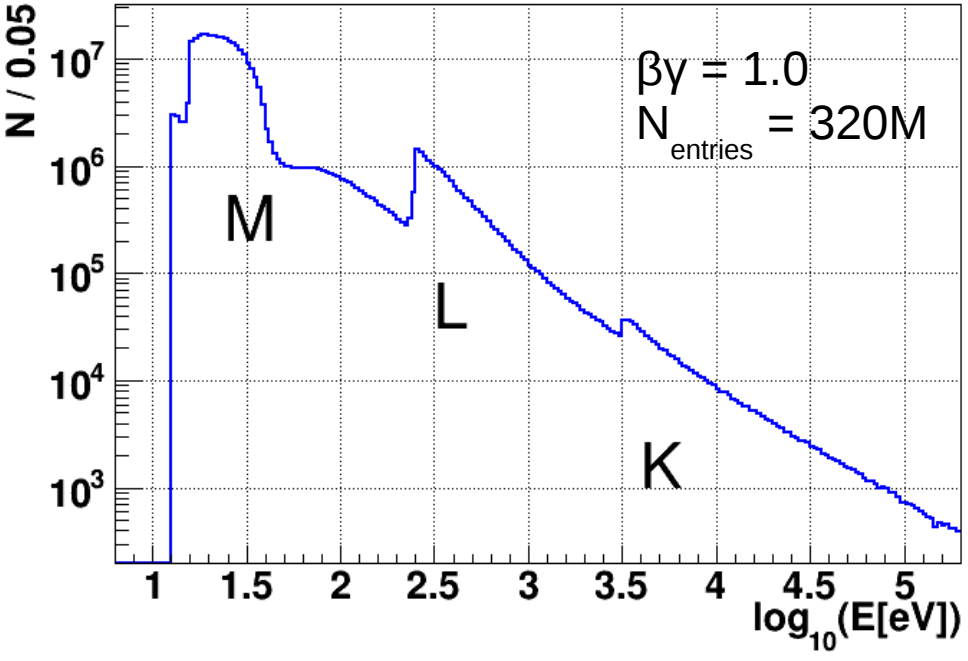


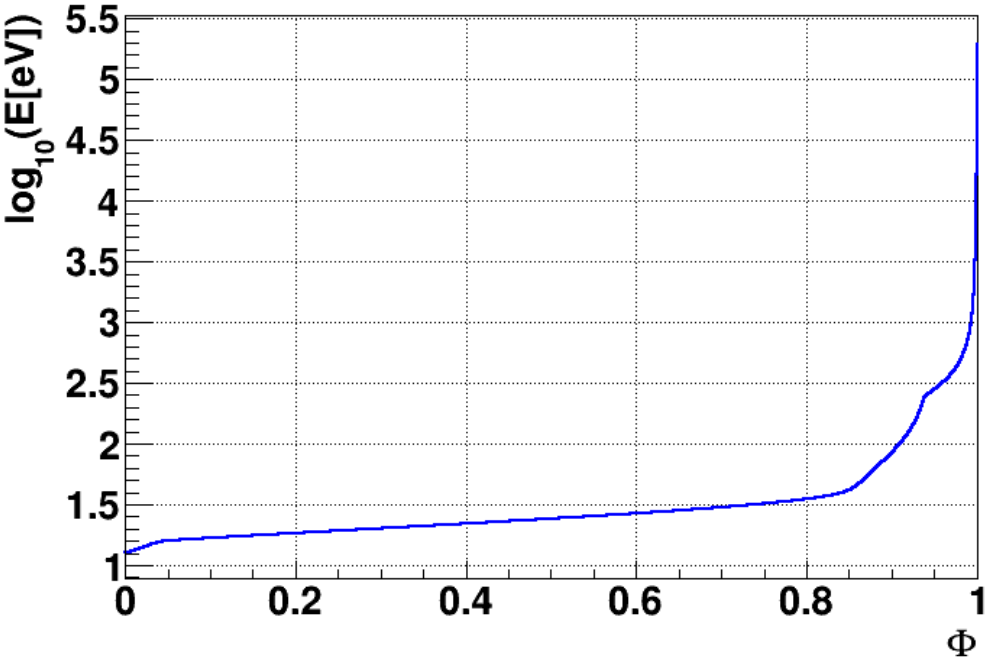


Cumulative probability density Φ(E)

$$\Phi(E;\beta\gamma) = \int^{E} \sigma(E';\beta\gamma)\,\mathrm{d}E' \Big/ \int^{\infty} \sigma(E';\beta\gamma)\,\mathrm{d}E'.$$

Φ(E) is calculated for 115 values of $\log_{10}(\beta\gamma)$ = -1.725 ÷ 4.025





700k bins of $\log_{10}$(E) histo from 0 to 7.0 → 10k bins of Φ function

Code in MPDROOT

tpc/MpdTpcEDepParams.cxx, .h

Double_t GetEloss (Double_t log10bg, Double_t step) -
random energy loss for given $\log_{10}(\beta\gamma)$ and step (cm)

input/TpcEDepParamsHeed.root - parametrization data

TH1D NcollTab – <N> of collisions per cm as a function of $\log_{10}(\beta\gamma)$

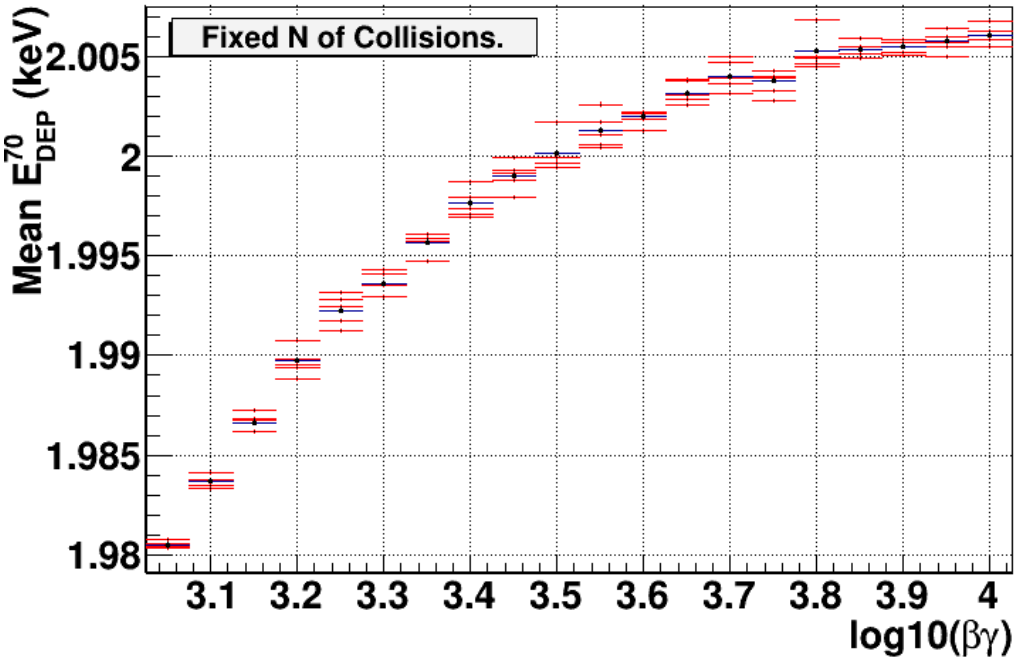
TH2D InvertedProbFuncEDep2 – $\log_{10}(E)$ of single collision
as a function of $\log_{10}(\beta\gamma)$ and umulative probability Φ

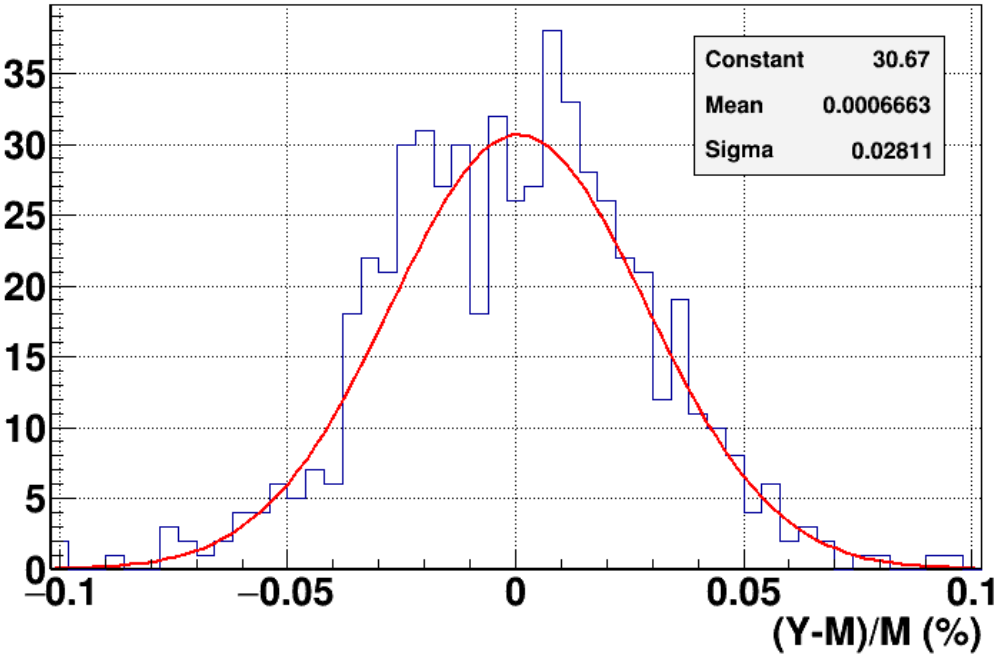
Test of precision.

Is N=320M of simulated for Φ collisions enough?

Toy model C70 calculations of mean value of 2M samples with identical <Ncoll>=36.

320M collisions used for parametrization
4 subsets of 320M statistics

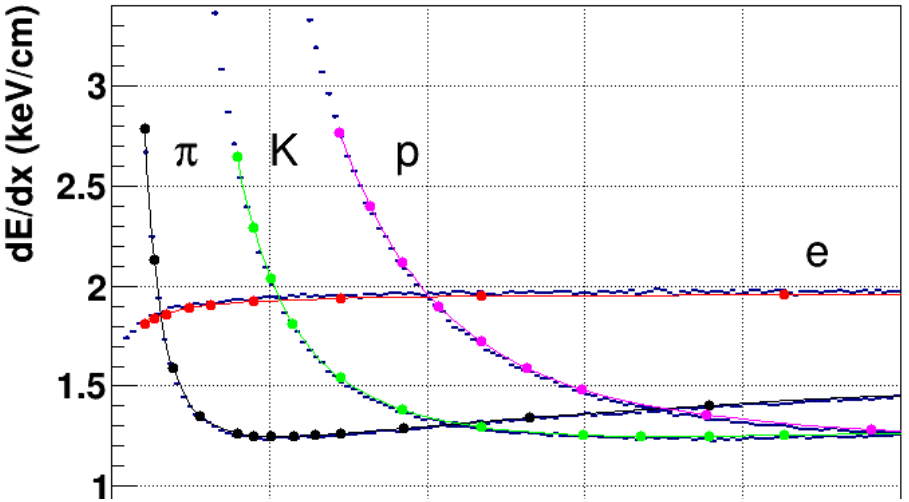


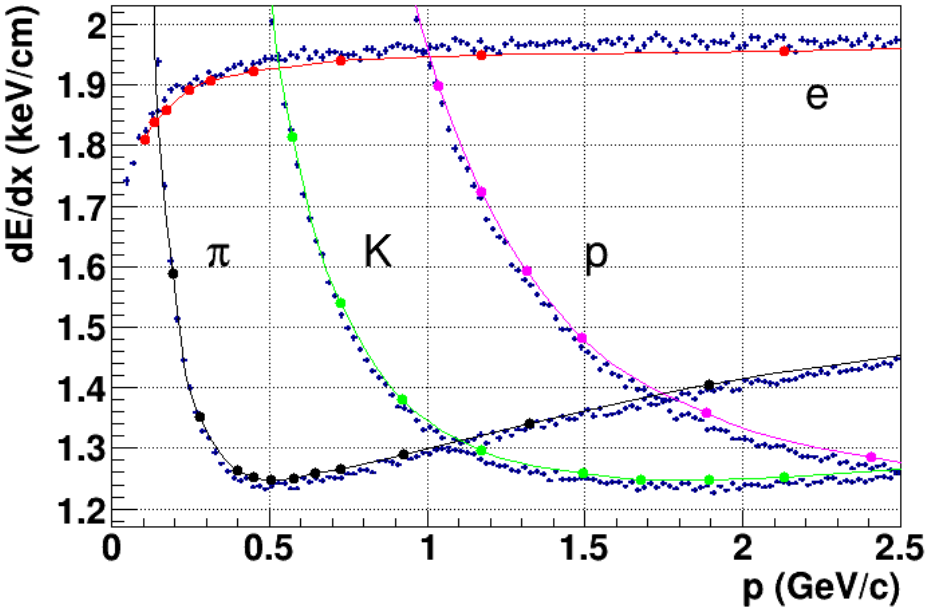


Error of parametrization (and jumps between βγ bins) is better than σ= 0.028%.

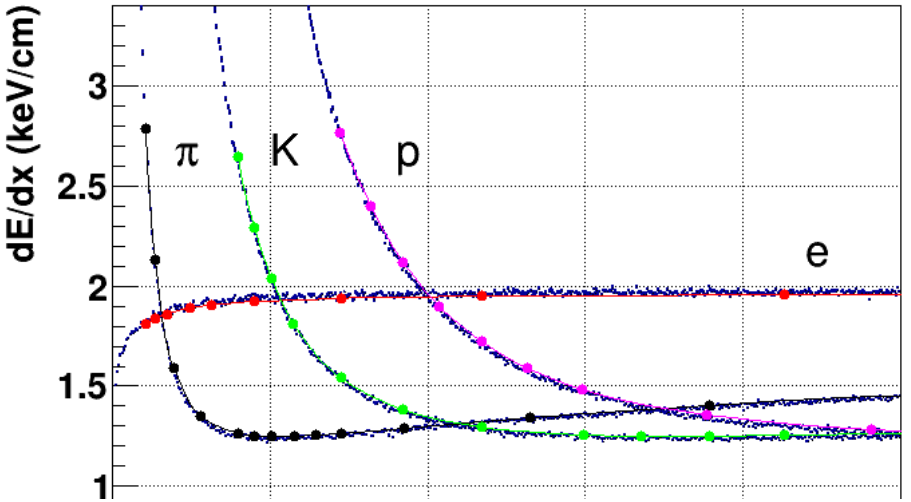
Comparison of models results.

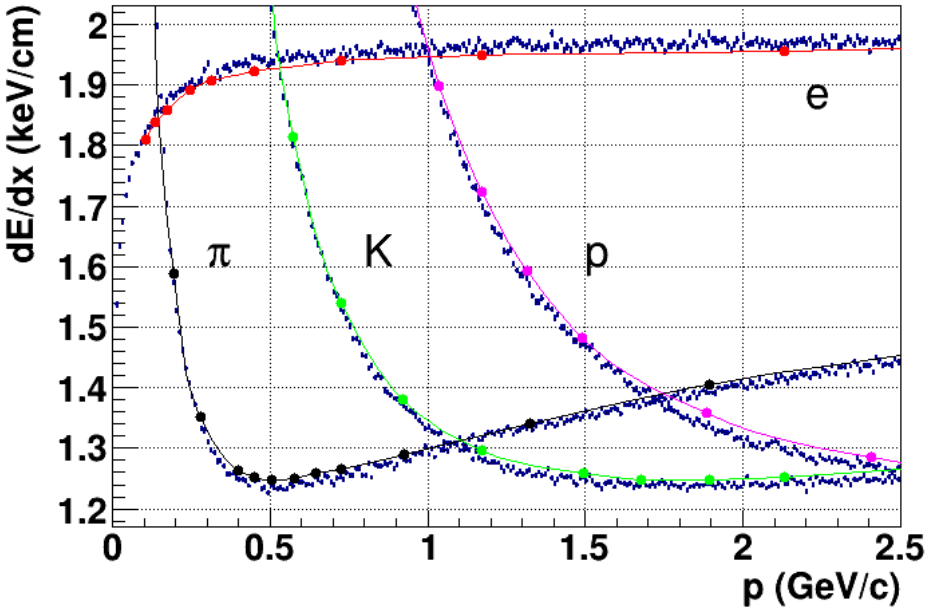
Garfield++ and Bichsel's model x1.037





Toy with param. and Bichsel's model x1.037

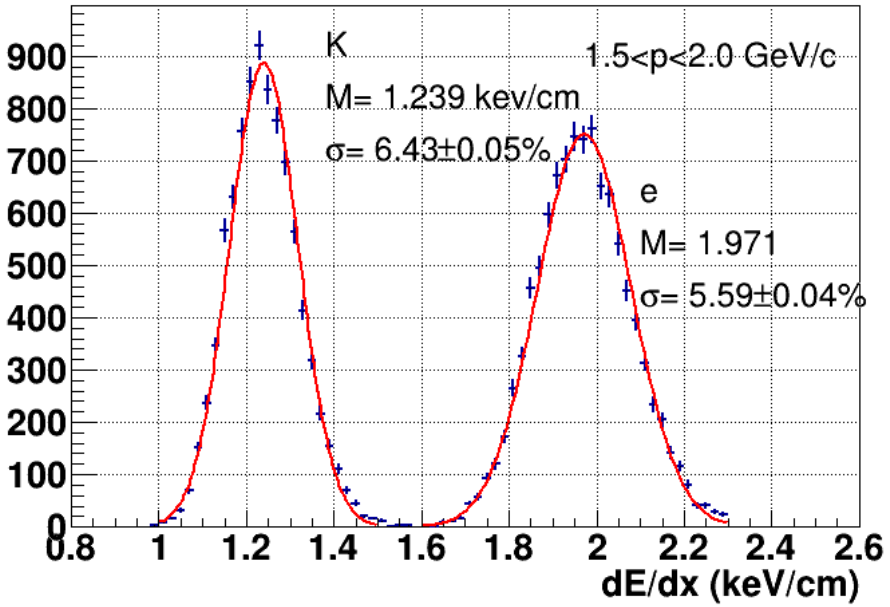




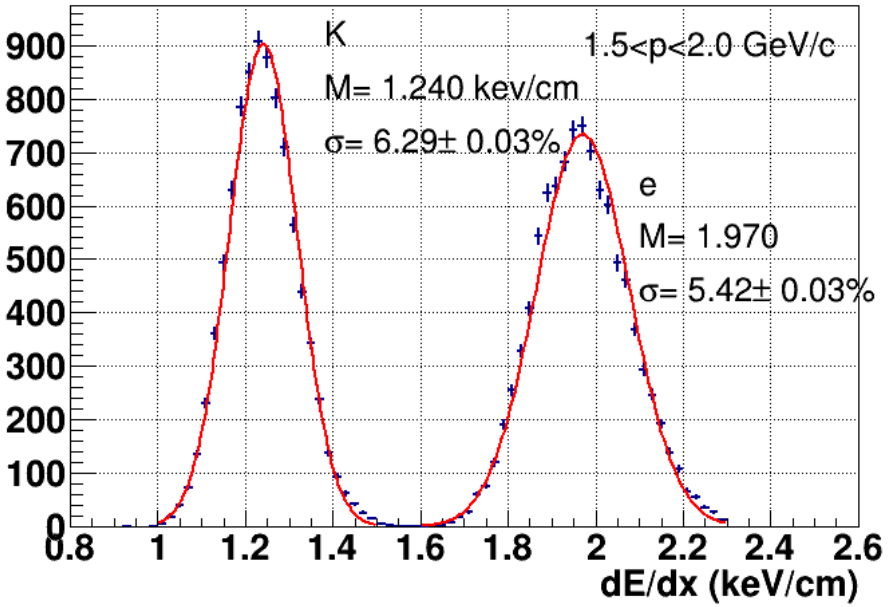
Rise to MIP ratio: Bichsel - 1,563; Garfield – 1.590.

Comparison 2.

Garfield++.



“Toy” model.

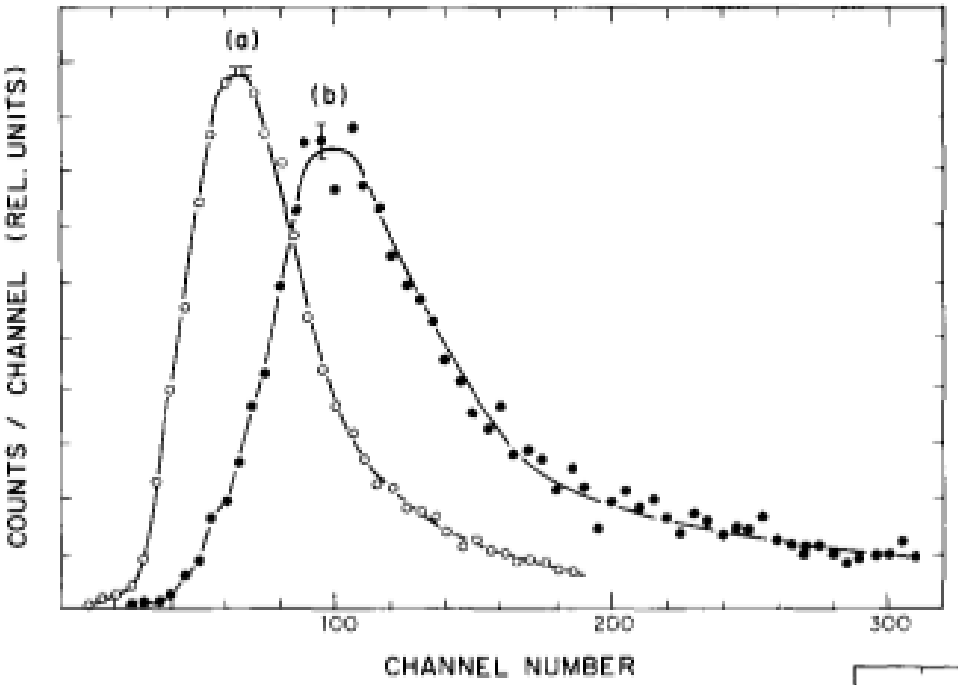


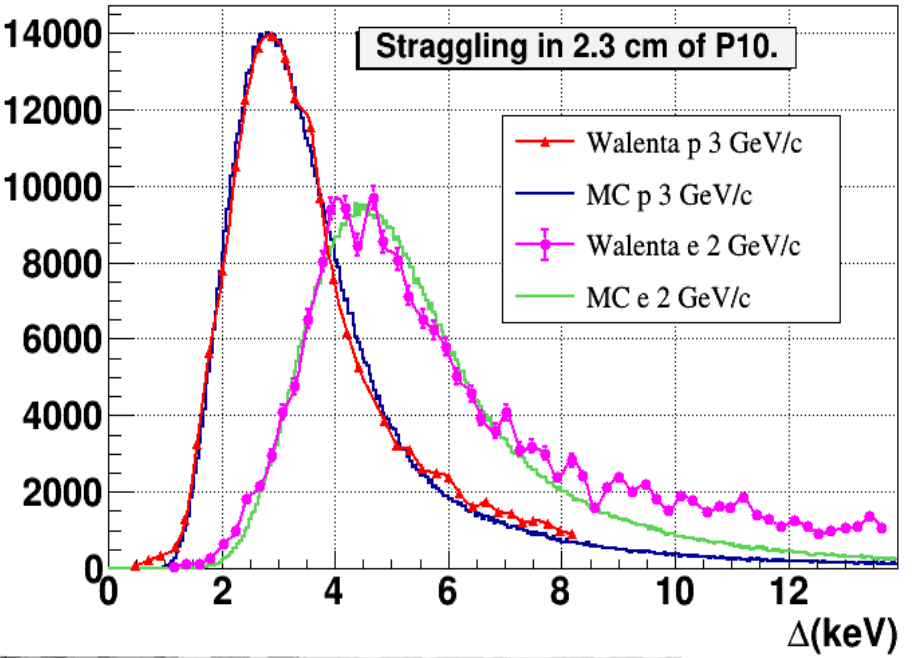
Almost the same resolutions of C70.

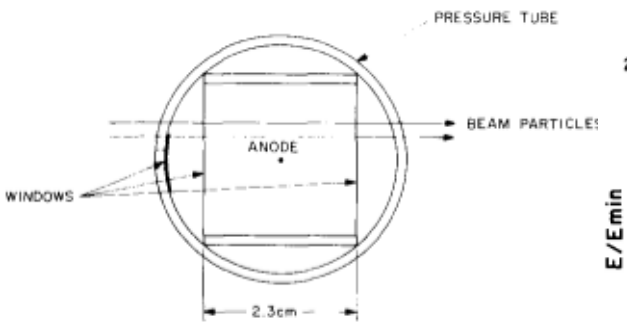
Straggling function.

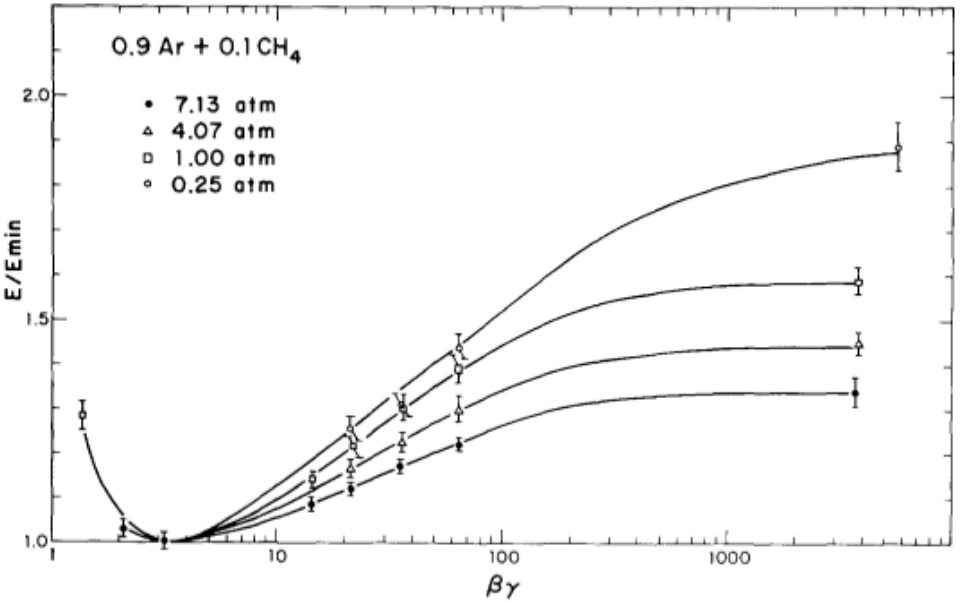
Min. ionizing proton and high energy electron.

A.H.Walenta et al., NIM 161 (1979) 45-58.



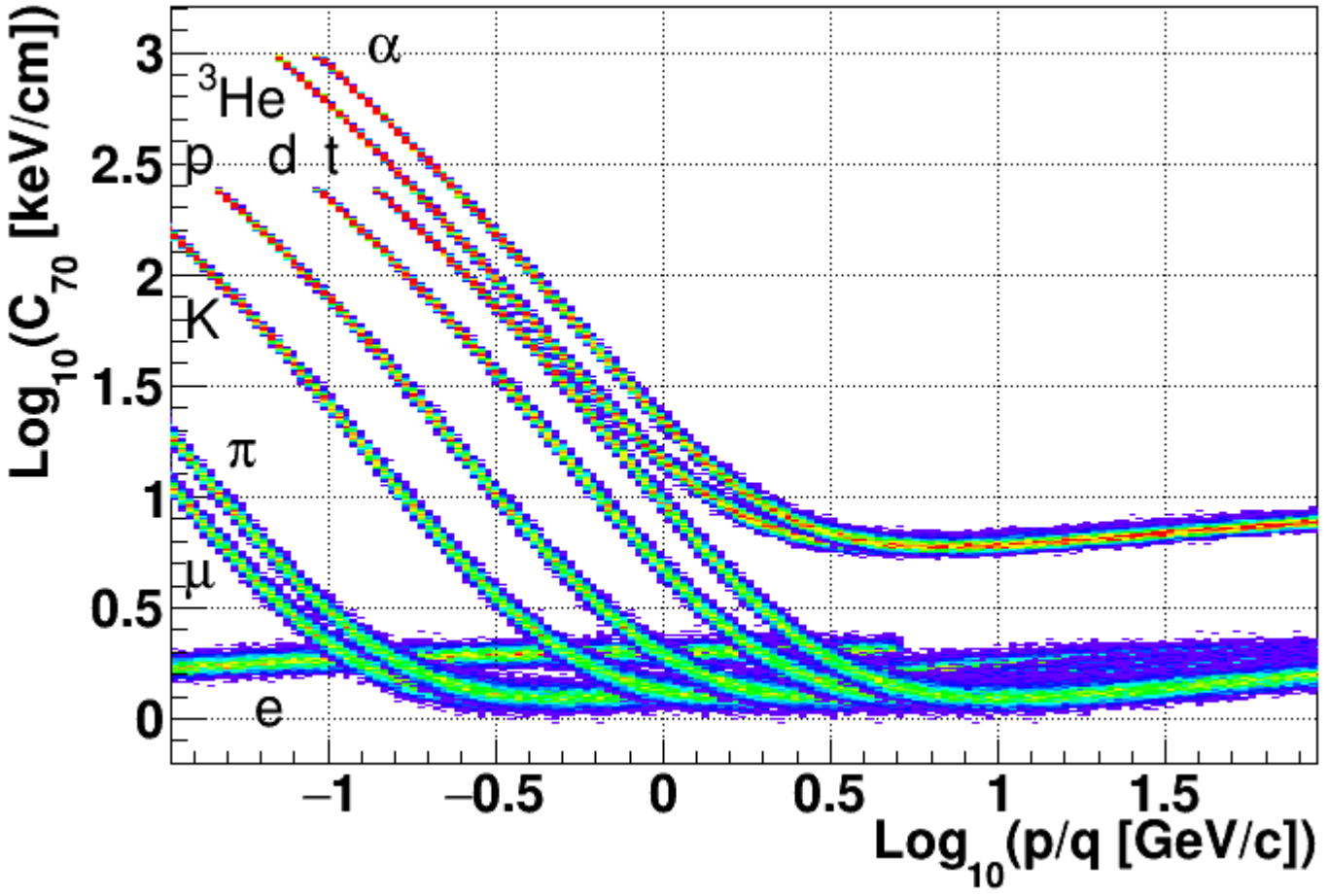






“Toy” model for MPD configuration.

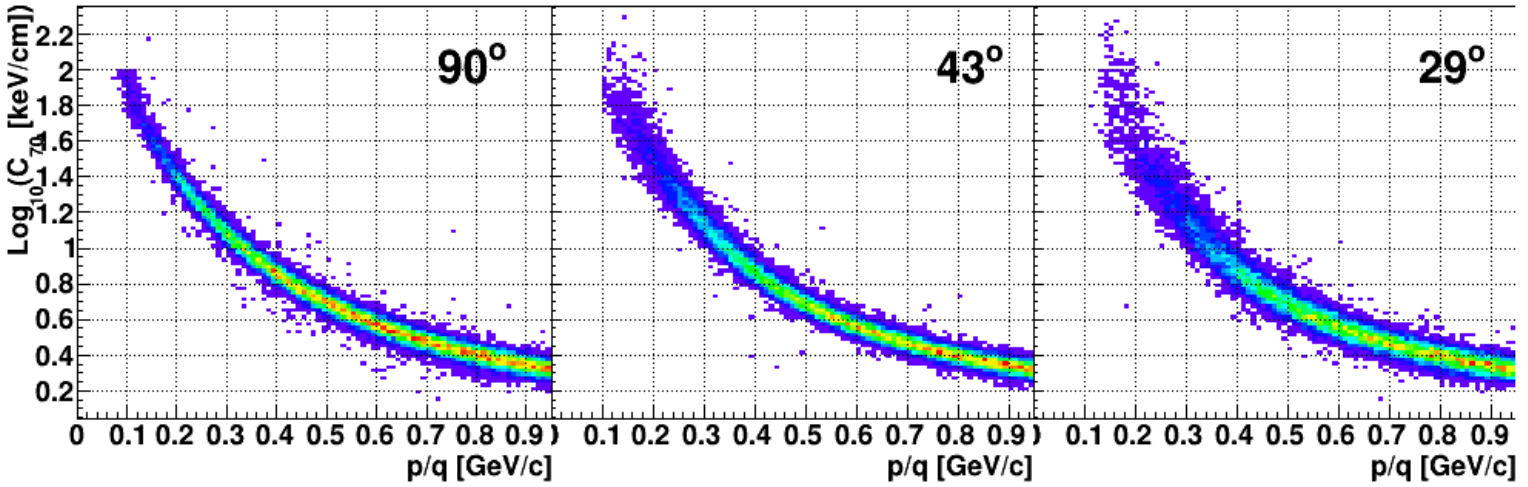
θ=90º, no field, no stopping.



MPD reco

MC BOX version with unlimited ADC range

protons



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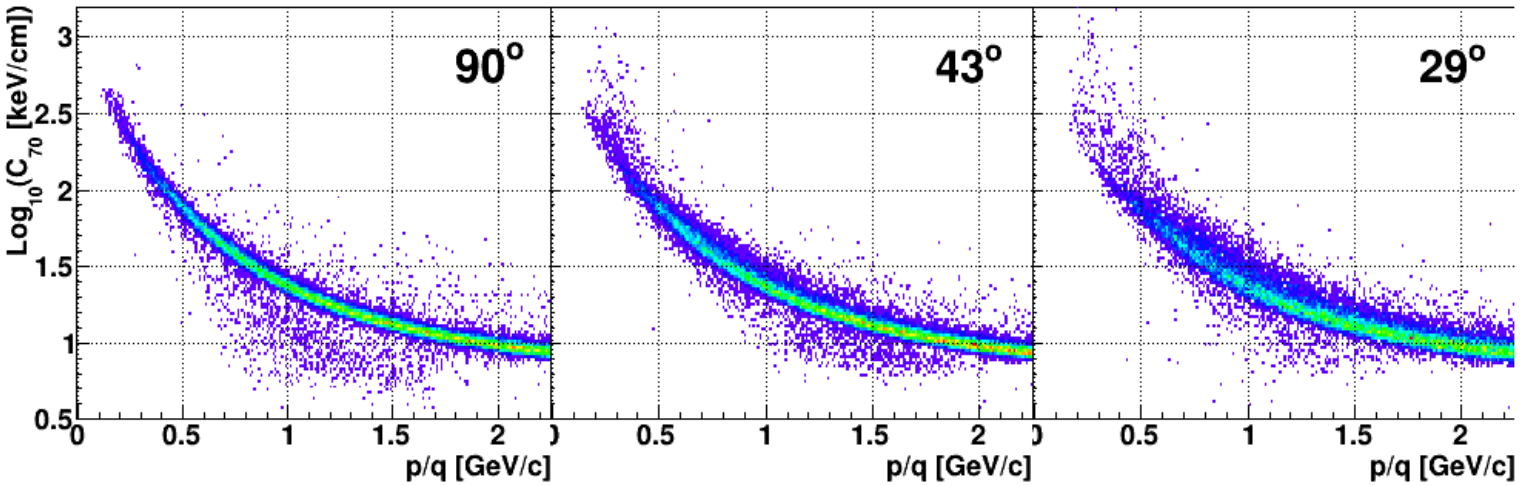

Conclusions

- New dE/dx model for TPC has been implement in MPDROOT
- The model uses parametrizations obtained from Garfield++ HEED calculations
- Results of new calculations are in a good agreement with predictions of Bichsel’s model, which was successfully used by STAR experiment
- Due to the parametrizatio the model operates much faster than Garfield++ HEED code

Thank you.