Discussion on the energy loss simulation in MPD TPC

I.Rufanov, A.Zinchenko

(L.Malinina, G.Nigmatkulov, V.Vasendina)

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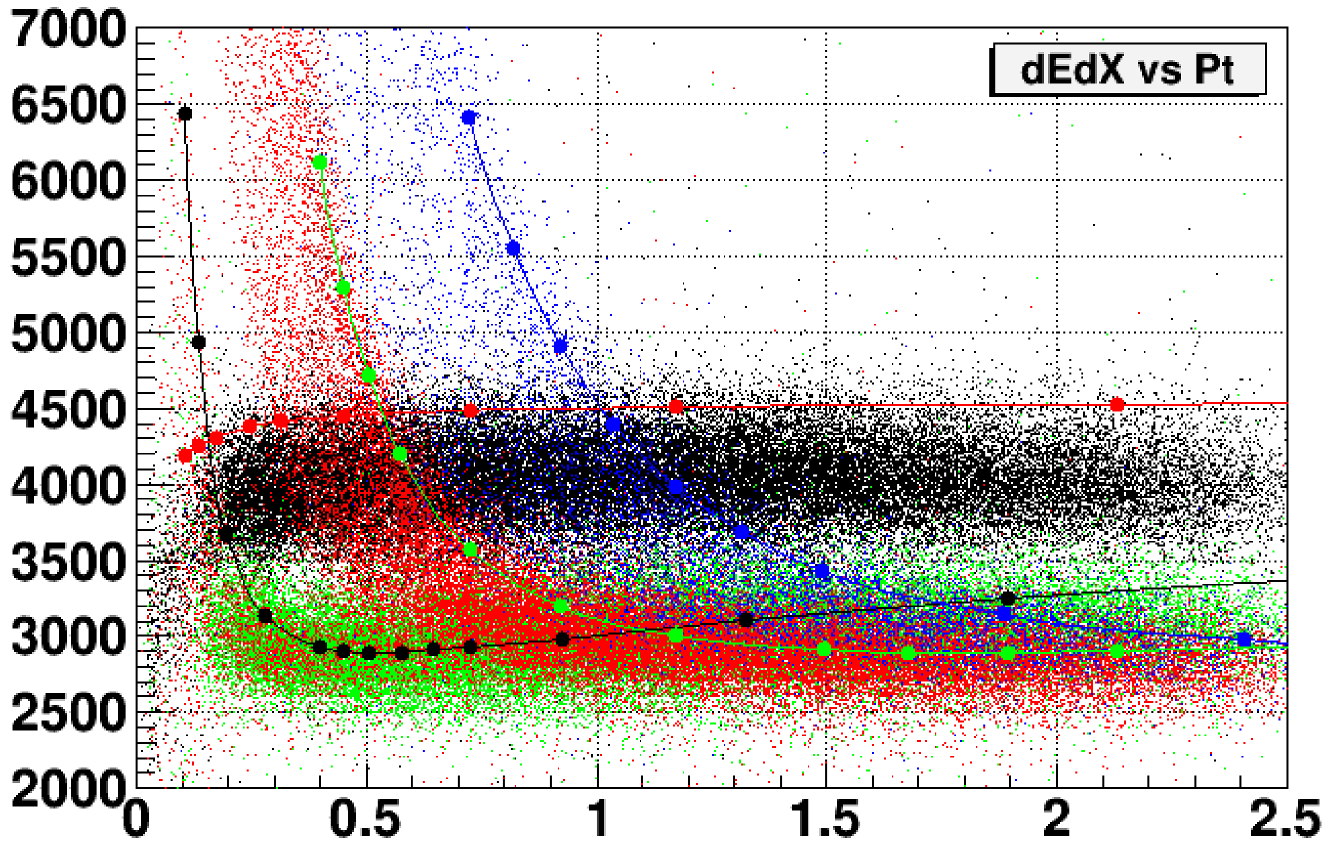
TPC PID at the moment.



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

TPC configurations.

	ALICE	STAR	MPD
Gas	85% Ne mixtures	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.

Bichsel’s model.

NIM A562 (2006), 154-197

Review

A method to improve tracking and particle identification in TPCs and silicon detectors

Hans Bichsel

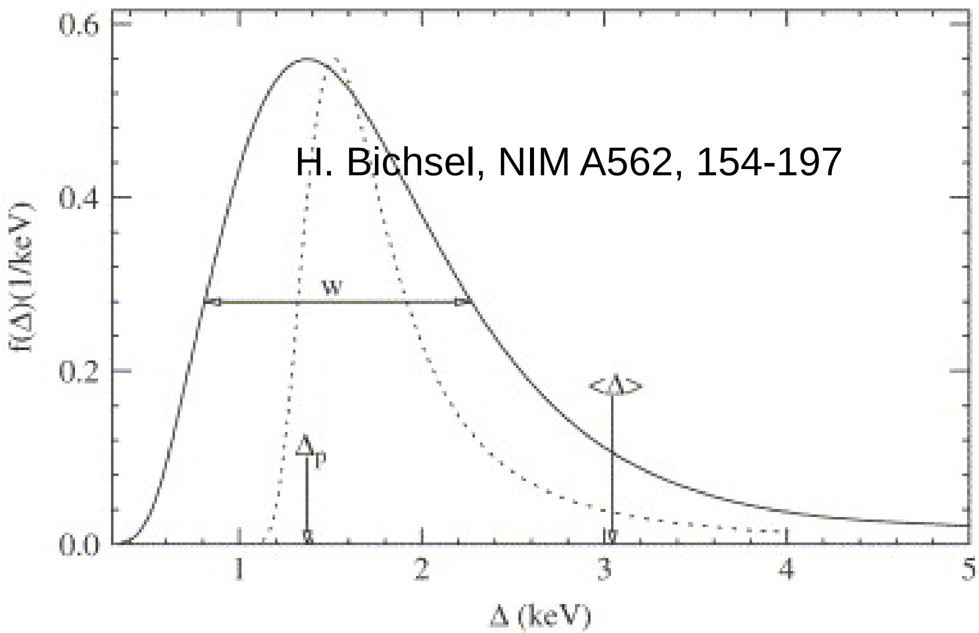
Detailed description of energy loss, energy deposition, ionization and pulse height measurement processes in Time Projection Chambers. Analysis of dE/dx reconstruction and PID algorithm.

Use of photo absorption ionization model (PAI) for differential collision cross-section calculation and variety of optical measurements for parametrizations.

Basic model of STAR TPC data analysis.

Straggling function

— probability density function (pdf) $f(\Delta)$ for Δ energy losses of particles with given $\beta\gamma$ traversing distance *x*.



SF for particles with $\beta\gamma = 3.6$ traversing 1.2 cm of Ar gas (solid line).
Δ_P — most probable value, $\langle \Delta \rangle$ — mean value. Landau function (dotted).

- No good analytic function.
- Complex dependence on distance *x*.
- Mean value of ~70% truncated samples used in data analysis is far from $\langle \Delta \rangle$.

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 *σ(E)*.

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

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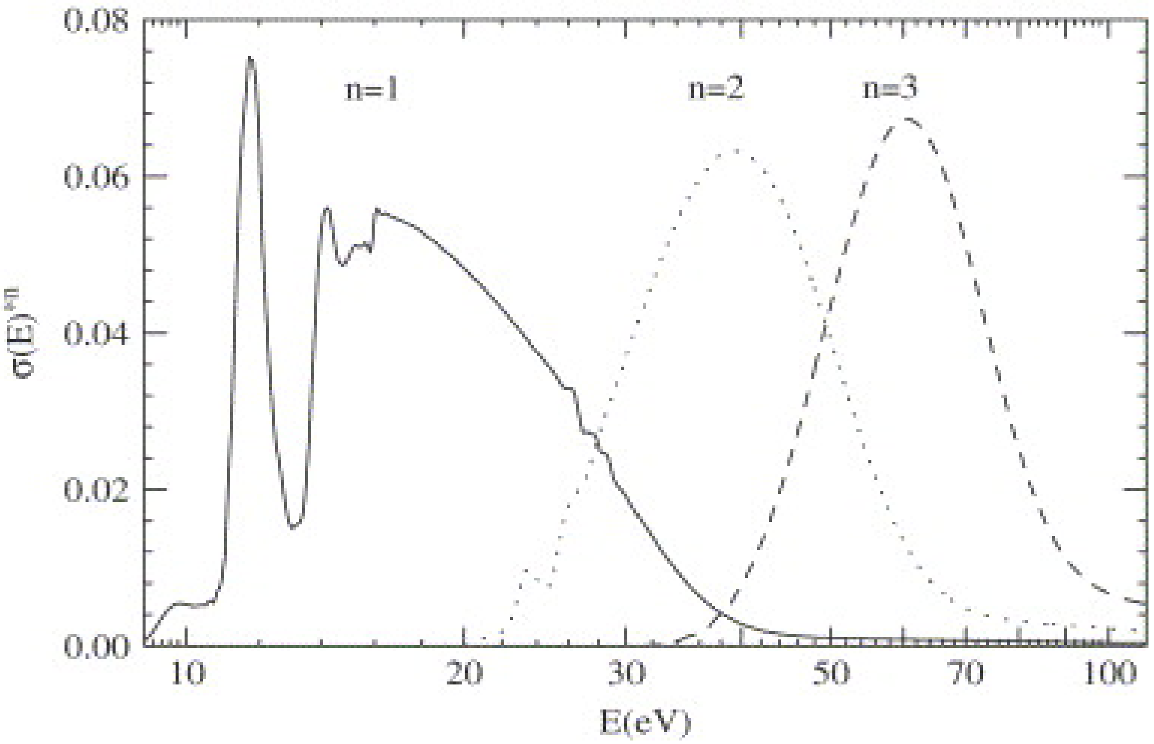

n= 1 — single collision cross-section for P10-gas,
n= 2, 3 — convolutions.
Large reduction of the 12 *ev* spike for n = 2, and
its complete disappearance for n = 3.

Models of collision cross-sections.

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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). Interaction with ***bounded*** elecron is considered as emission of virtual photons by the fast particle, which then are absorbed by the material. 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.”

Comparison of CCS models.

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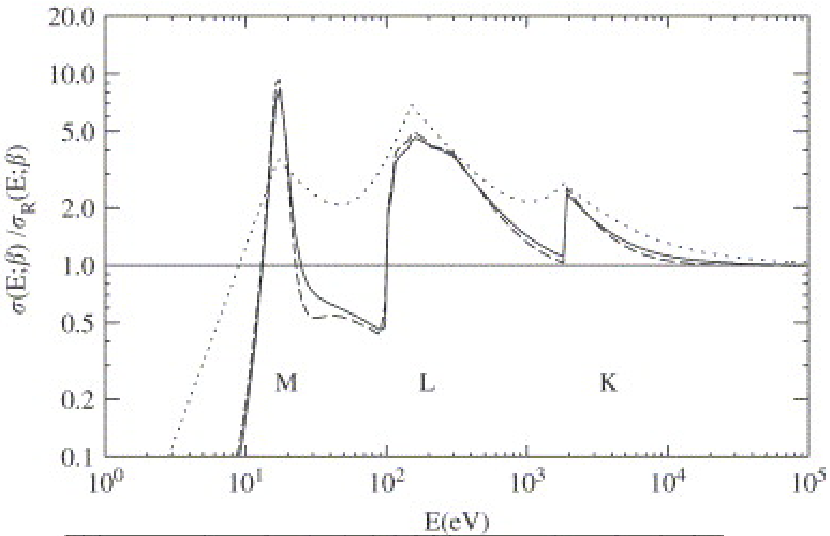
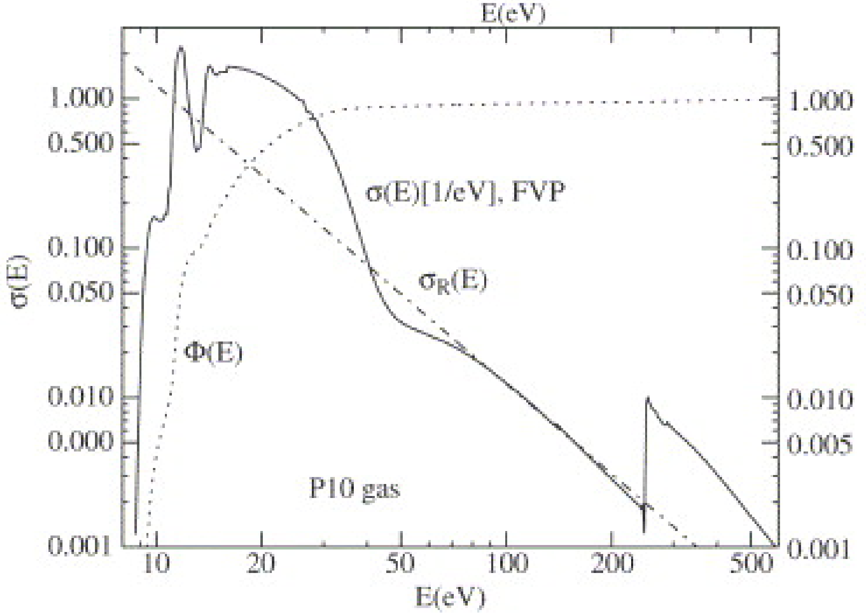


CSS ratio in Si by particles with $\beta\gamma=4$.
σ_{BF}/σ_R — solid line.
σ_{FVP}/σ_R — dashed line.

Good agreement of FVP and BF.
No BF calculations for P10-gas.



CSS in P10-gas by particles with $\beta\gamma=3.6$
σ_{FVP} — solid line.
σ_R — dash-dotted line.

Cumulative Φ(E) for CCS in P10.

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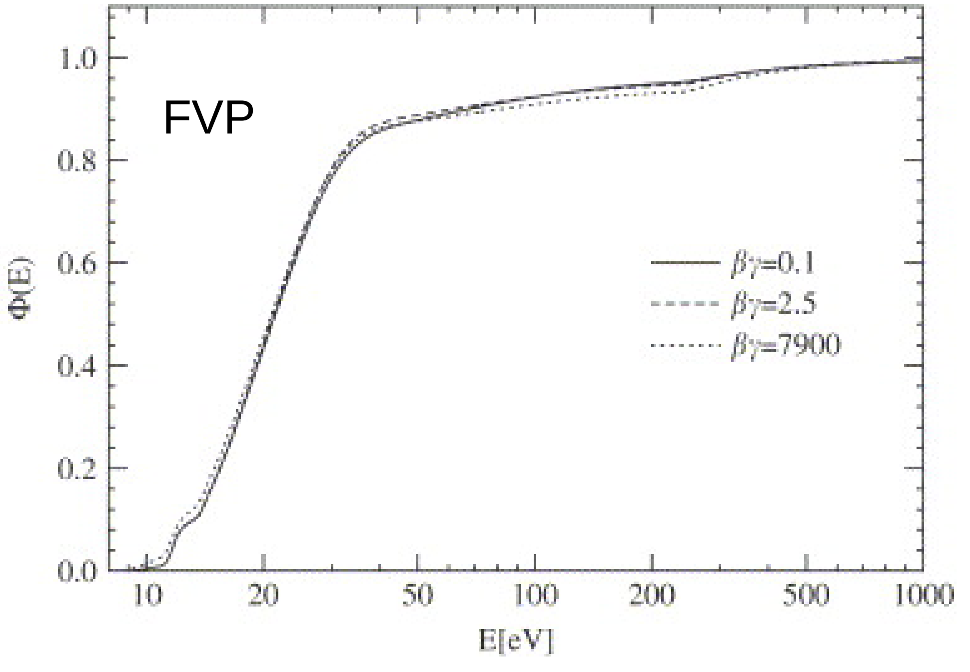
$$\Phi(E;\beta\gamma)=\int^{E}\sigma(E';\beta\gamma)\,dE'/\int^{\infty}\sigma(E';\beta\gamma)\,dE'$$

(in Monte Carlo the stochastic energy loss for single collisions is selected from cumulative p. d. f.)



"The dependence of these functions on βγ is not large.
… a single function Φ(E) can be used for all speeds."

Stages from interaction to signal.

- energy loss
- energy deposition
- ionization
- transport of electrons
- proportional counter output
- pulse-height or ADC output

“differences between p.d.f.’s of energy loss, deposition and ionization for the STAR TPC are not large. In most reports so far they have been disregarded.”

ALICE Monte Carlo

ALICE Technical Design Report of the Time Projection Chamber,
CER/LHCC 2000-001, ALICE TDR 7 (7 January 2000)

$$P(s)=\frac{1}{D}\exp\frac{-s}{D}$$

— free path between collisions

$$D=\frac{1}{N_{prim}\cdot f(\beta\gamma)}$$

— mean free path

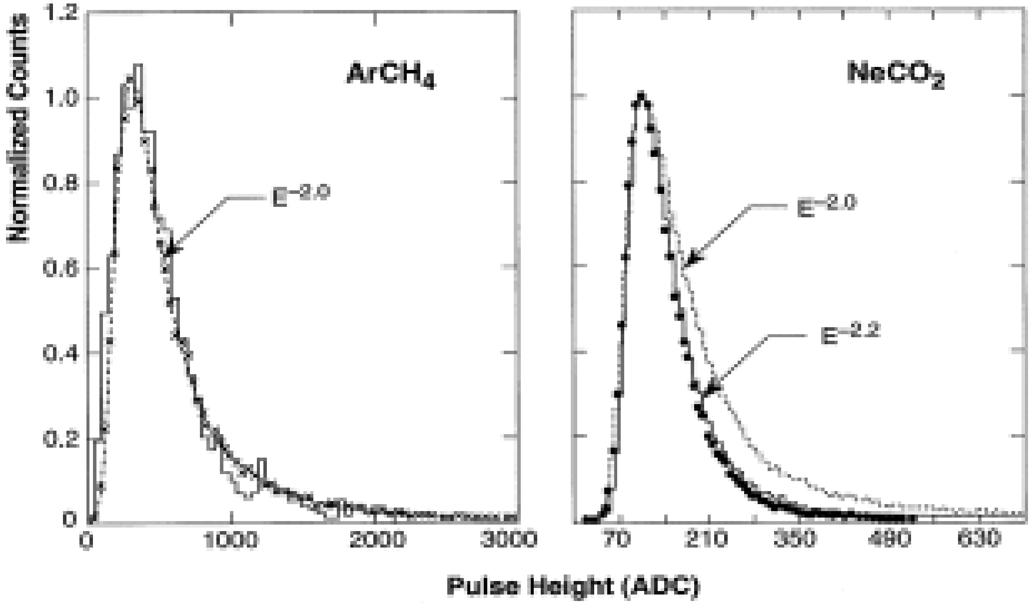
N_{prim} — number of primary electrons per 1 cm measured for MIP

$f(\beta\gamma)$ — measured Bethe-Bloch curve

$1/E^{2.2}$ rule of the energy transfer to atomic electrons for 90% Ne, 10% CO_2 gas mixture

Energy transfer in Ne and Ar based mixtures

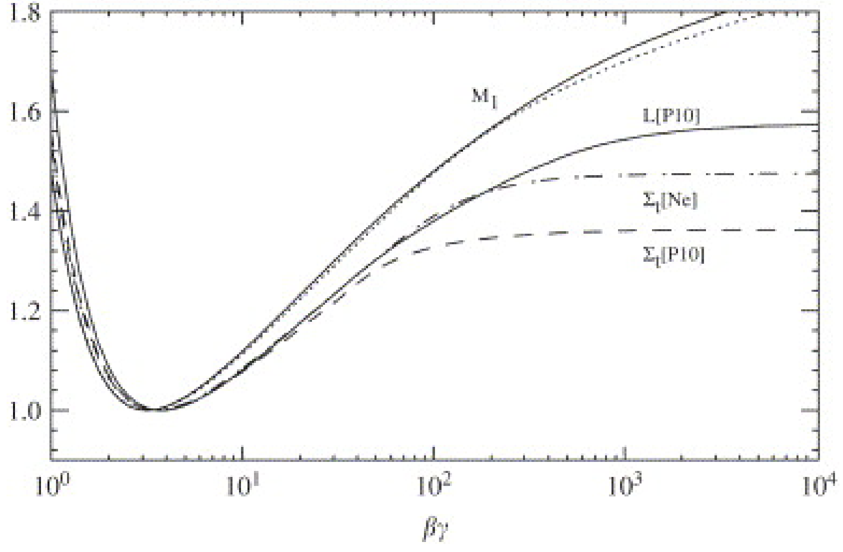
B. Lasiuk, NIM A409, 402-406



“while an $E^{-2.0}$ distribution describes a typical Ar mixture quite well, it overestimates the width of the distribution from the Ne mixture by a significant amount. Because counting statistics predict that Ne will have a reduced resolution compared to Ar, there must be some sort of medium dependence in the functional form of the energy transfer. In fact in the case of Ne, the distribution is much better described if an energy dependence of $E^{-2.2}$ is assumed.”

Bichsel's conclusion about AliRoot Monte Carlo

No major changes are needed for the simulations with AliRoot Monte Carlo with the proposed model:

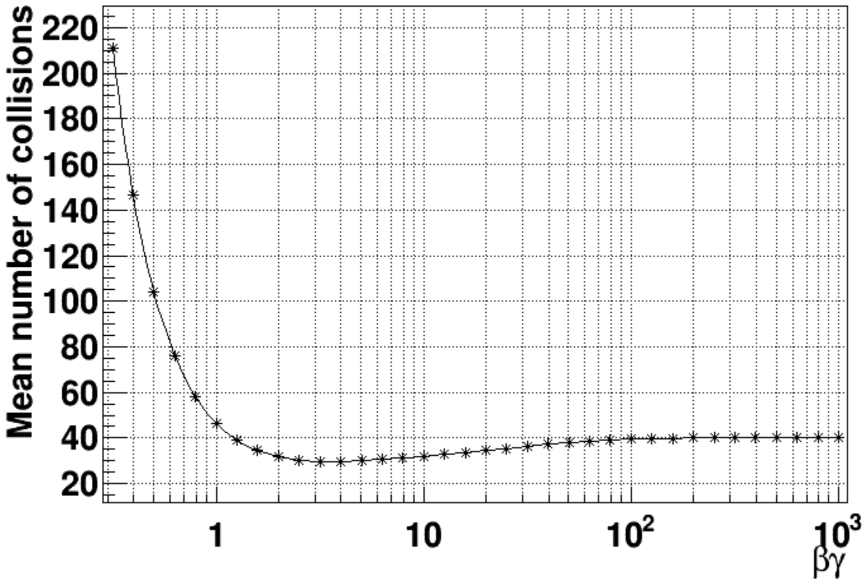


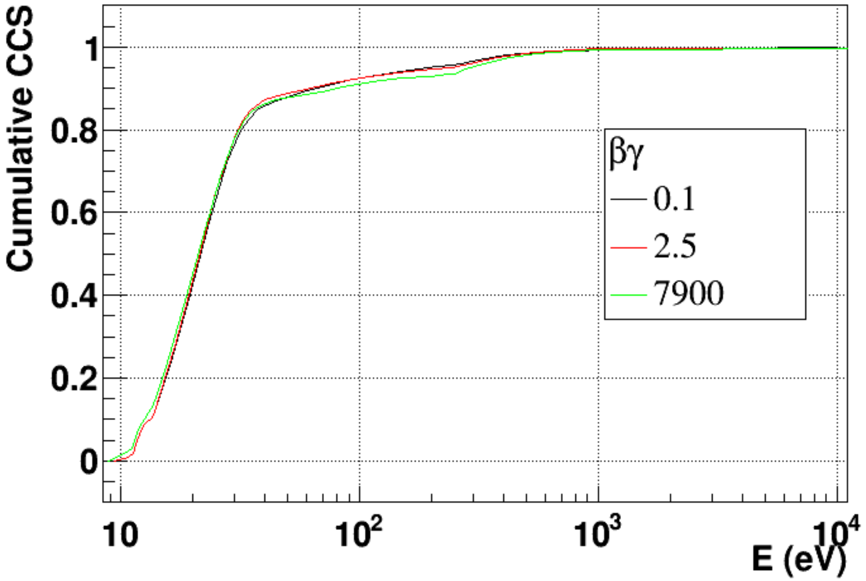
The function *f(βγ)* should be replaced by Σ_t. Σ_t normalized to 1.0 at minimum ionization is shown in figure.

For the energy losses in single collisions use the tabulated inverted energy loss spectrum from FVP calculation. (for 10 values of *βγ* is given in http://www.star.bnl.gov/~bichsel/)

(Both corrections concerns parametrizations only.)

Parametrizations from paper.





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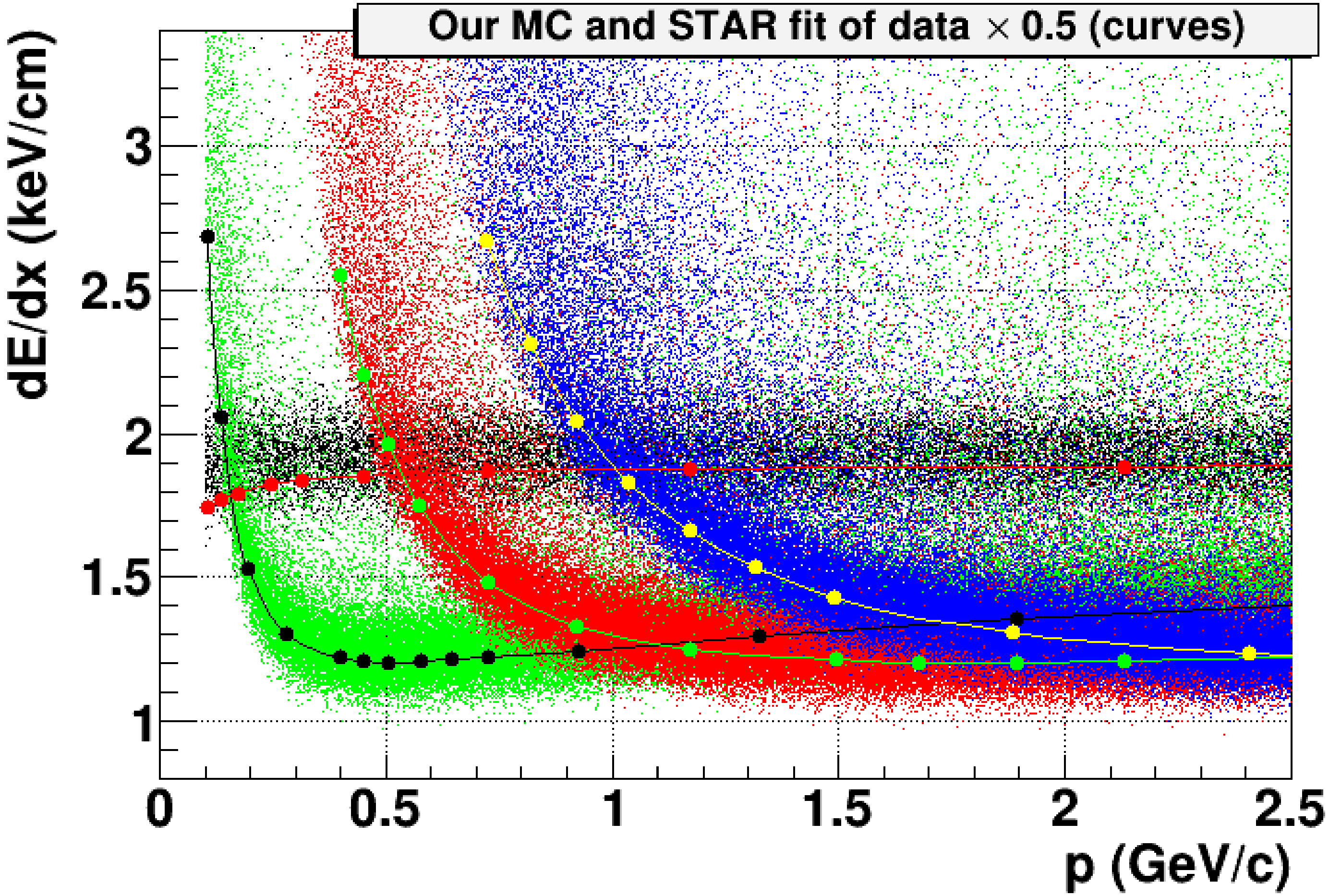
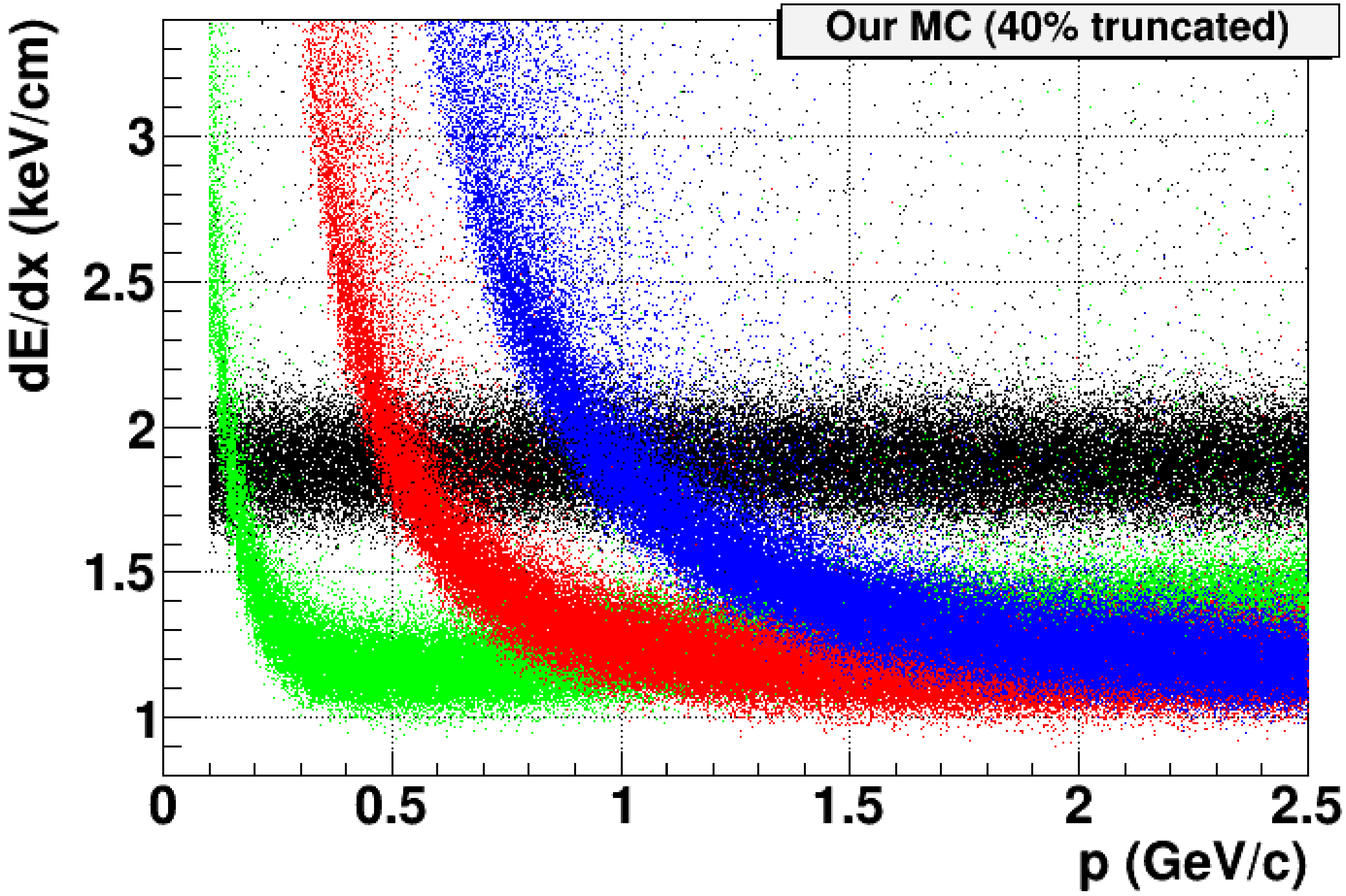
Refference 26 on “data and function” is unavalable at the moment.

Results of simple Monte Carlo.



Mean value after 30% truncation in 45 samples with x=2 см (like in STAR).
Collision cross-section with βγ=2.5 are used for π, K and p. βγ=7900 for electrons.

40% truncated.



Summary

- MPD TPC energy loss simulation can be done following the ALICE TPC procedure;
- Basic gas parameters (number of clusters / cm) and energy loss cross-sections should be taken as in STAR);
- Some information is not fully available;
- Extraction of dE/dx values still needs some attention.

Scale 0.51 for 30% truncated.