FastSim dE/dx Resolution

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BaBar

- BaBar NIM Paper: 7.5% dE/dx resolution
- Sasha Telnov's BAD 1500: It's complicated, but around 7.5%
- Resolution defined as follows with measured and expected truncated means:

$$\frac{\left\langle \frac{dE}{dx} \right\rangle_{meas} - \left\langle \frac{dE}{dx} \right\rangle_{exp}}{\left\langle \frac{dE}{dx} \right\rangle_{exp}}$$

SuperB

- We expect slightly worse dE/dx performance due to different geometry (~8%)
- We are still working toward a cluster-counting technique

SuperB DCH in FastSim

dE/dx measurements for each cell hit by a track are drawn from a Gaussian distribution with mean given by the Bethe formula and standard deviation given by:

$$\mu_0 = \left[\frac{dE}{dx}\right]$$

Bethe formula result normalized to material density, per unit length

$$\sigma_0 = p_1 \left(\frac{\mu_0}{C}\right)^{p_2} L^{p_3}$$

C: Bethe formula result for minimum ionizing particles in appropriate units (1.622e-3)

L: Track segment length in cm (cell_thickness/sin(theta) at large momentum

A fraction of the individual measurements are used to form a truncated mean, which is then fed to the normal reconstruction code.

trunc_frac="0.7"
p1="0.00154"
p2="1" ← This being identically 1 is important
p3="-0.34"

dE/dx Resolution in FastSim

For a track crossing M layers, with a T truncated mean fraction, you get k = MT samples. Model a straight uniform track, then the truncated mean will also be a Gaussian variable with the same mean, and reduced standard deviation

$$\mu = \mu_0$$

$$\sigma = \frac{\sigma_0}{\sqrt{k}}$$

The resolution we use is the RMS/mean of the truncated mean measurements:

$$\Gamma = p_1 \frac{\mu_0^{p_2 - 1}}{\sqrt{k} C^{p_2}} L^{p_3}$$

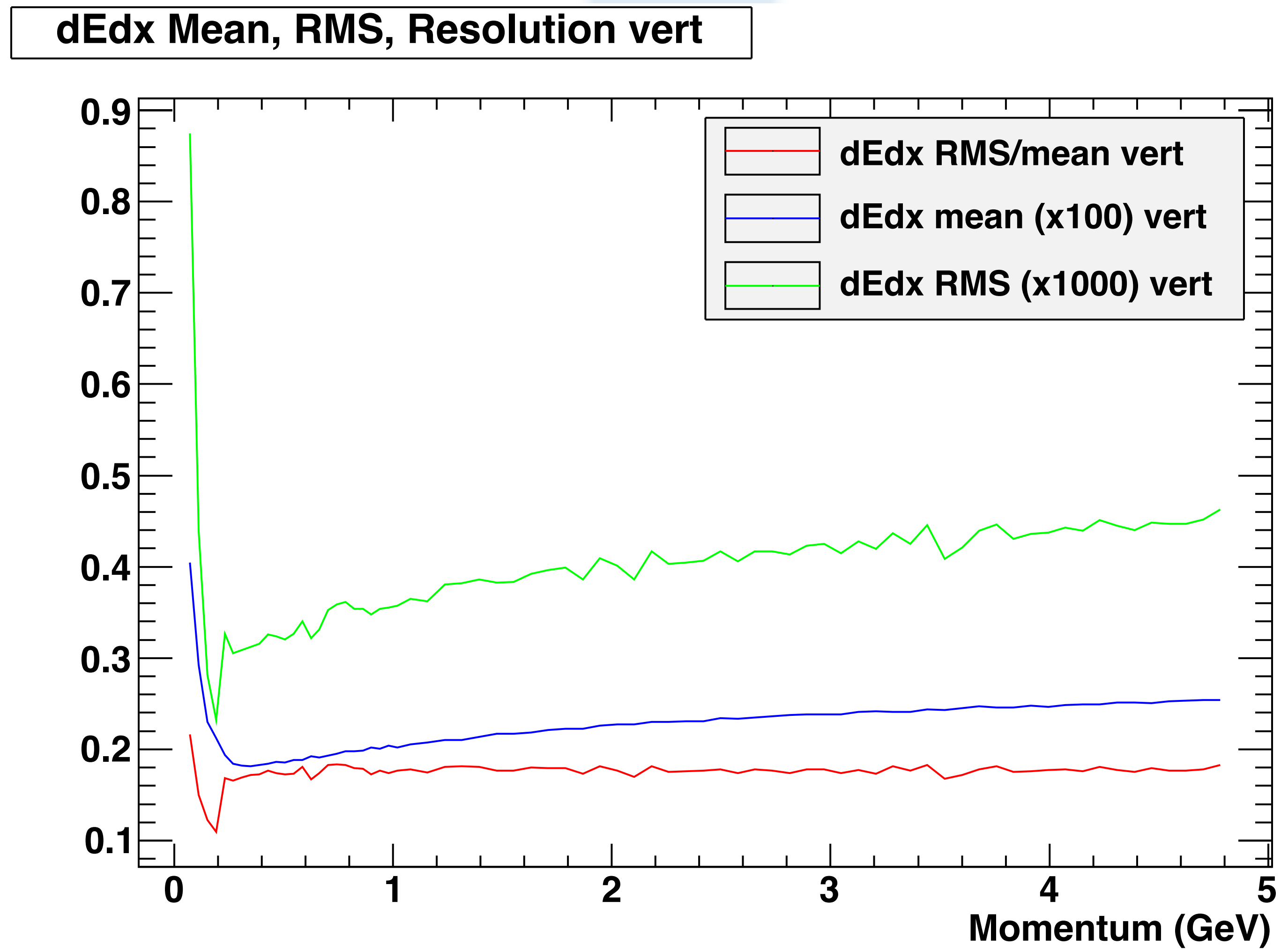
Given that the second parameter is identically 1, this reduces to a constant function of the track segment length:

$$\Gamma = \frac{p_1 L^{p_3}}{\sqrt{k} C}$$

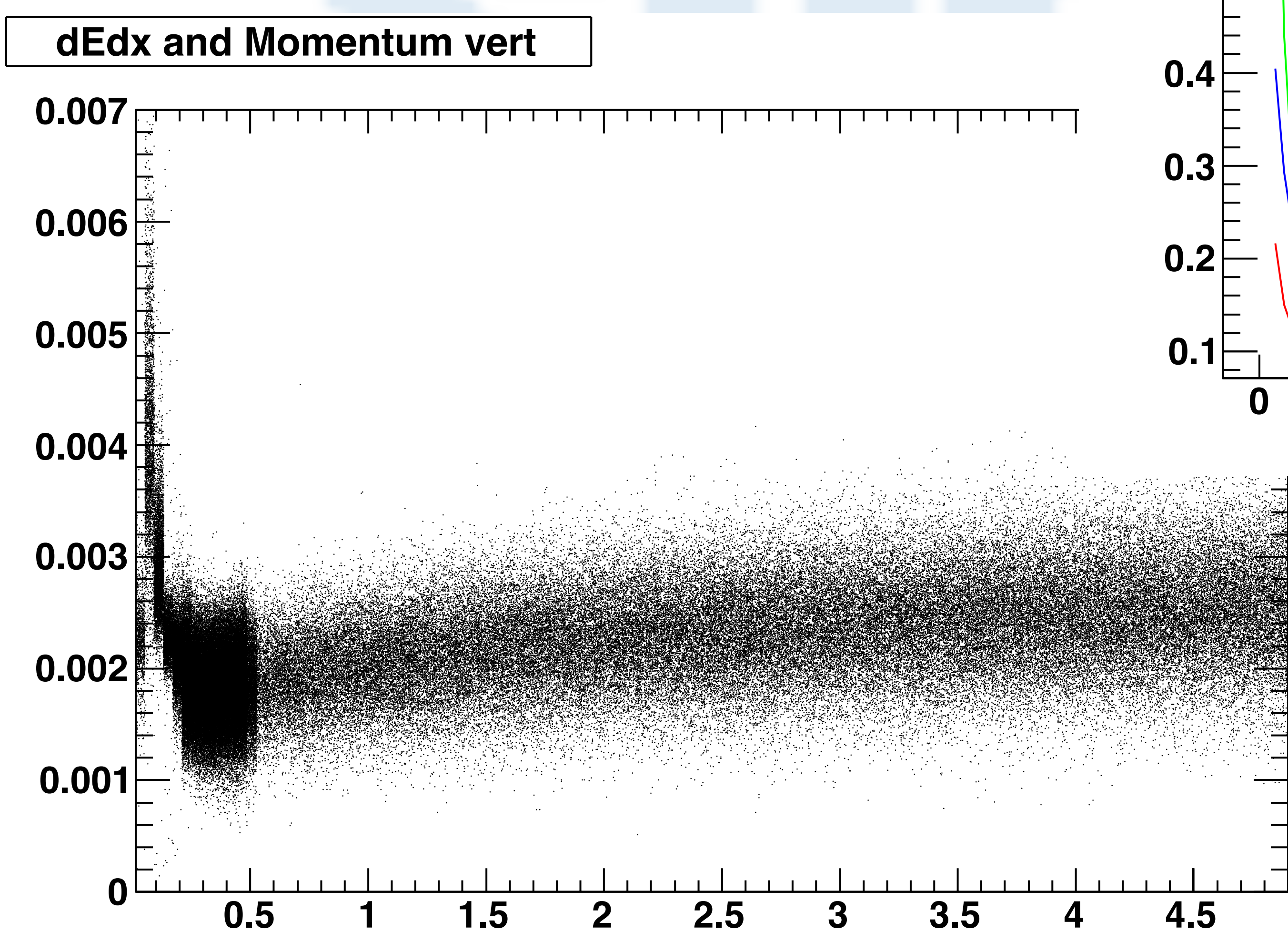
Putting in the numerical factors (13.75mm cells):

$$\Gamma = 0.161$$

Confirmation in Simulation



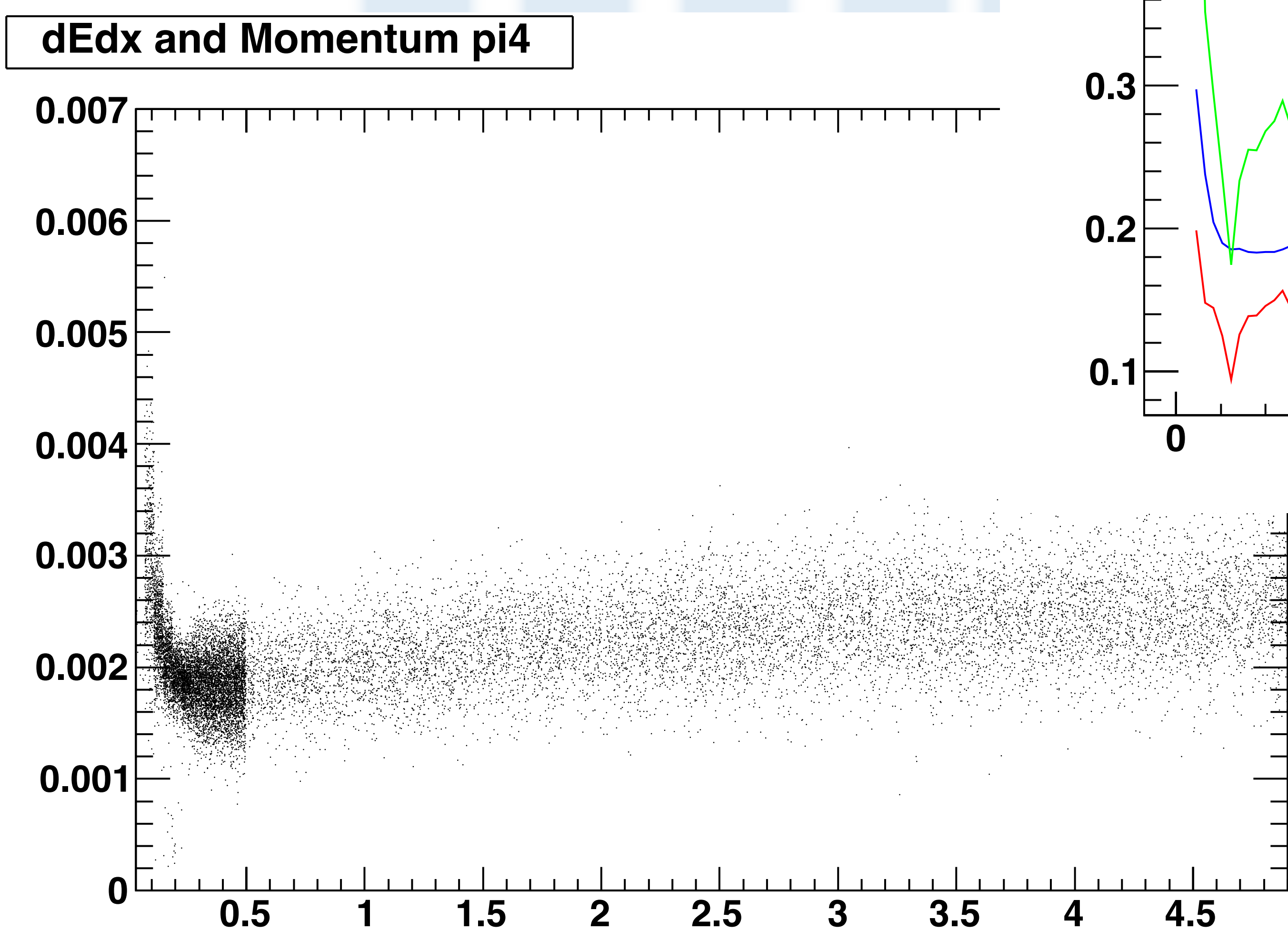
From FastSim V0.3.1, single muons at theta = pi/2

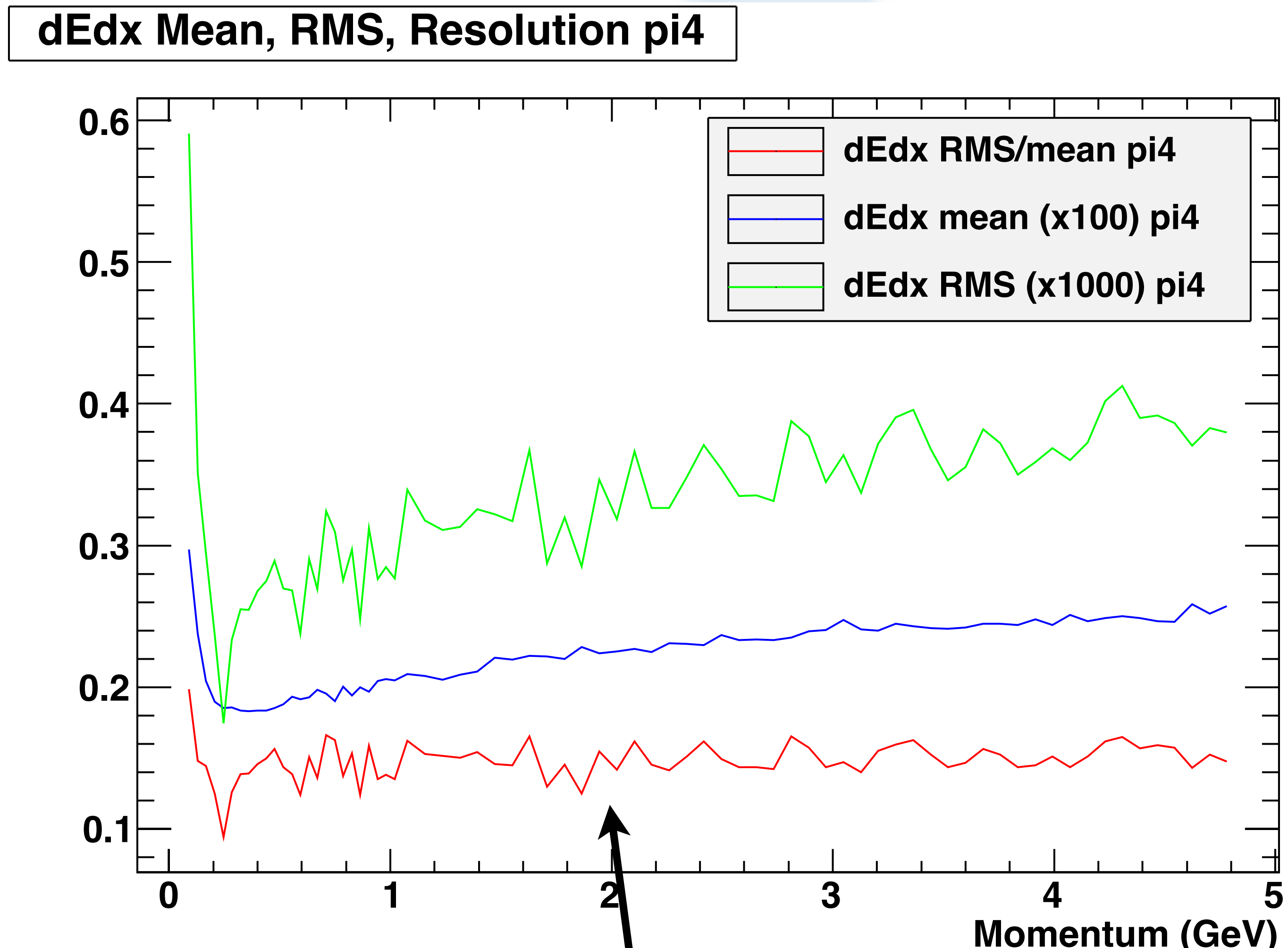


Constant at ~15-20%

Confirmation in Simulation

From FastSim V0.3.1, single muons at theta = pi/4 (smaller statistics)





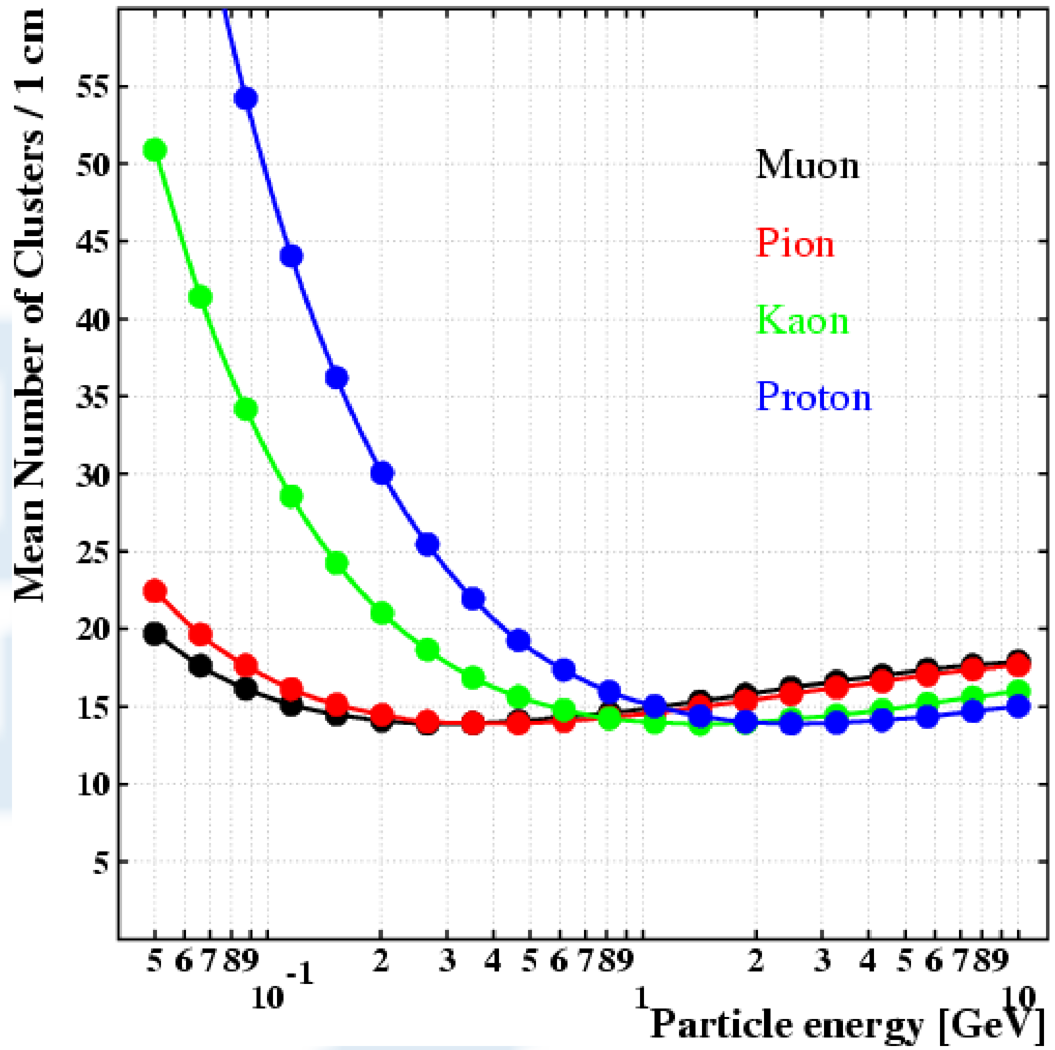
Constant at ~15%

Cluster Counting

It would be difficult to implement microscopic simulation of cluster counting in FastSim, so instead we would use "parametrized" cluster counting. A certain amount of dE/dx could correspond to a cluster

The uncertainty in counting follows simple Poisson statistics, reflected in a choice of p2 = 1/2

Cluster-counting efficiency is reflected in the choice of p1. Expected efficiency is around 60%



From Garfield in He:Isobutane 90:10

Deriving Parameters for Cluster Counting

$$\mu_c = \left[\frac{dE}{dx}\right]$$

(1) the mean ionization per unit length normalized by gas density, given by the Bethe formula.

$$\mu_{c_{cell}} = \mu_c L$$

(2) mean ionization in a cell of size L

$$\sigma_c = p_1 \left(\frac{\mu_c}{C}\right)^{p_2} L^{p_3}$$

(3) standard deviation of the ionization per unit length

$$\sigma_{c_{cell}} = \sigma_c L$$

(4) standard deviation of the total ionization in a cell of size L.

$$\mu_{N_{cell}} = \alpha\epsilon\mu_{c_{cell}}$$

(5) mean number of clusters counted in a cell, proportional to the total ionization in that cell.

$$\sigma_{N_{cell}} = \sqrt{\mu_{N_{cell}}}$$

(6) standard deviation of the number of clusters counted in a cell from Poisson statistics.

$$\sigma_{N_{cell}} = \alpha\epsilon\sigma_{c_{cell}}$$

(7) also the standard deviation of the number of clusters counted in a cell, following from equation 5

C ionization per unit length of a minimally-ionizing particle

p_1 parameter with dimension of ionization density$*cm^{-p_3}$

p_2

p_3 dimensionless parameters

α average ionization corresponding to one cluster

ϵ cluster-counting efficiency

N_{min} number of clusters created per cm by a minimally-ionizing particle

Equate (6) and (7), substitute (2),(3), and (5)...

Deriving Parameters for Cluster Counting (2)

$$\sqrt{\alpha\epsilon\mu_c L} = \alpha\epsilon L p_1 \left(\frac{\mu_c}{C}\right)^{p_2} L^{p_3}$$

This holds for all cell sizes L and mean ionization densities, so we immediately get:

$$p_2 = \frac{1}{2}$$

$$p_3 = -\frac{1}{2}$$

The rest of the parameters are globbed up into p1:

$$p_1 = \frac{C^{p_2}}{\sqrt{\alpha\epsilon}} = \sqrt{\frac{C}{\alpha\epsilon}}$$

N_{min} is the minimum number of clusters created, so

$$N_{min}\epsilon L = \alpha\epsilon C L$$

$$\alpha = \frac{N_{min}}{C}$$

$$p_1 = \frac{C}{\sqrt{N_{min}\epsilon}}$$

Deriving Parameters for Cluster Counting (3)

Numerical values for some constants (in appropriate units):

$$C = 1.622 \times 10^{-3}$$

$$\epsilon \approx 0.6$$

$$N_{min} \approx 13$$

$$p_1 = 5.808 \times 10^{-4}$$

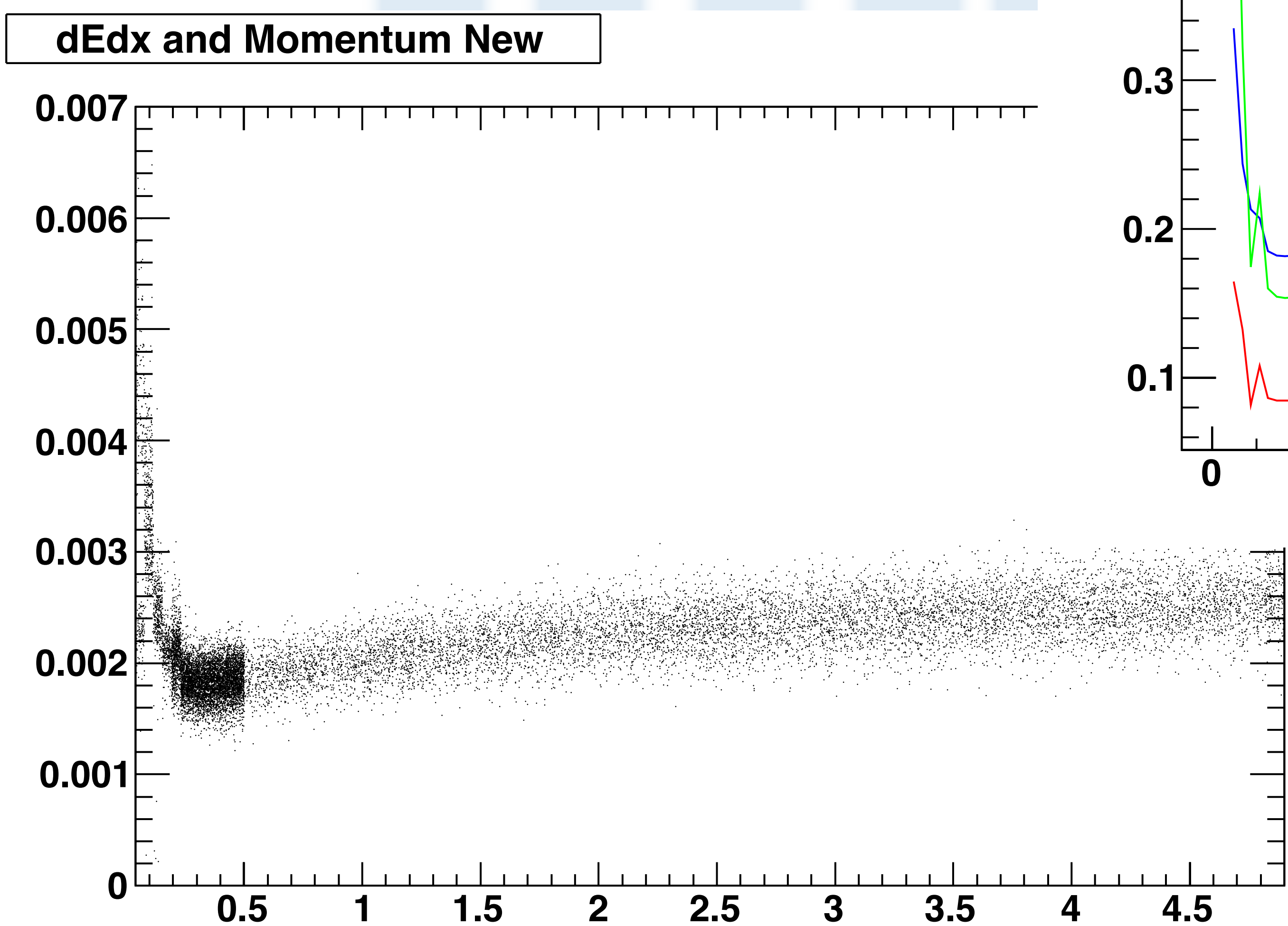
Proposal

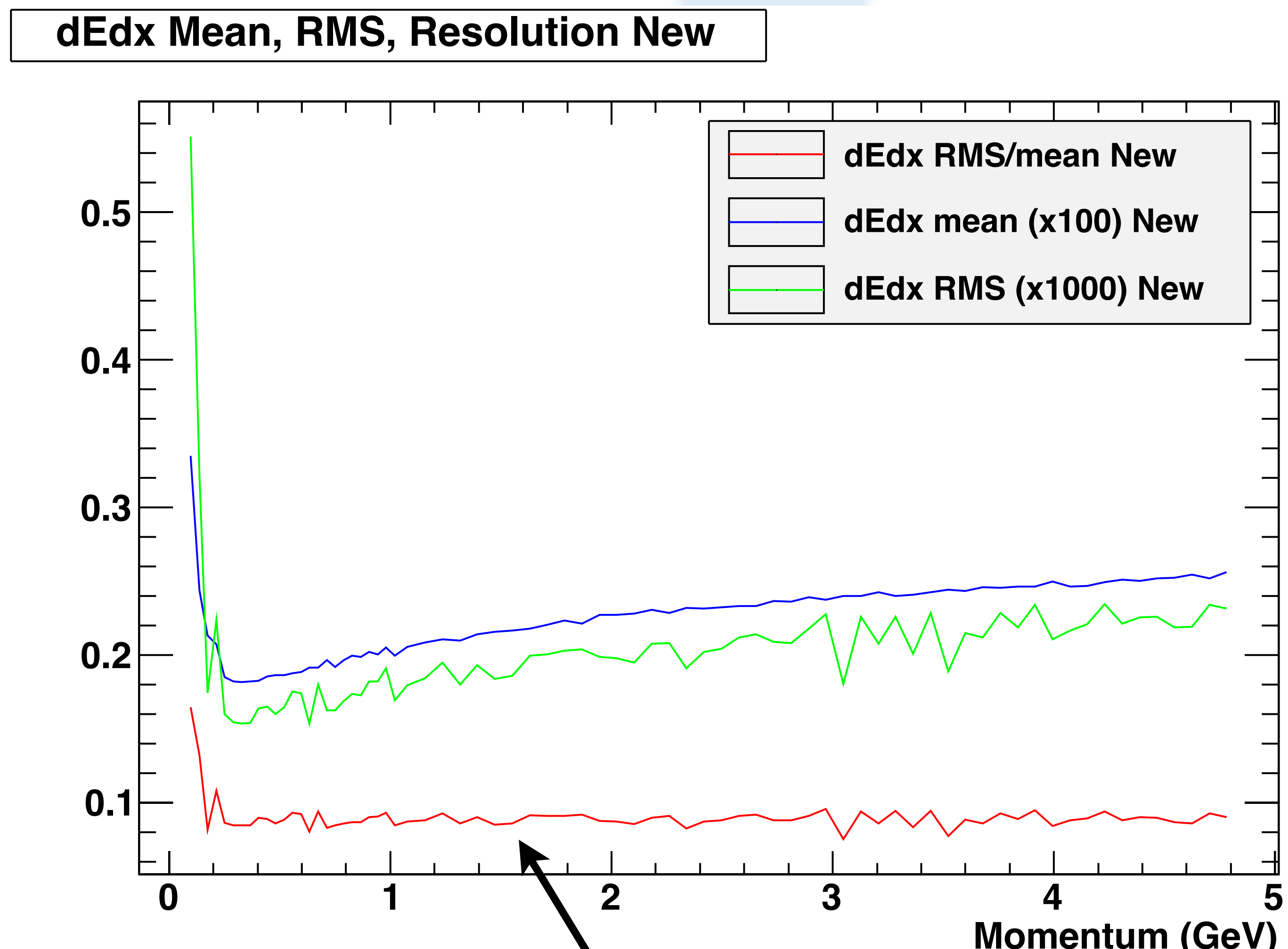
- For regular productions, change the first dE/dx parameter to 0.000765 (from 0.00154) to get ~8% dE/dx resolution (direct scaling of result to 8%)

- For cluster-counting simulation, change the first parameter to 0.0005808 (from 0.00154), change second parameter to 1/2 (from 1) and the third parameter to -1/2 (from -0.34) to reflect the cluster counting parametrization presented above

Preliminary Results

FastSim V0.3.1, single muons at pi/2, new dE/dx configuration





As claimed by BaBar

Preliminary Results

FastSim V0.3.1, single muons at pi/2, proposed cluster-counting configuration