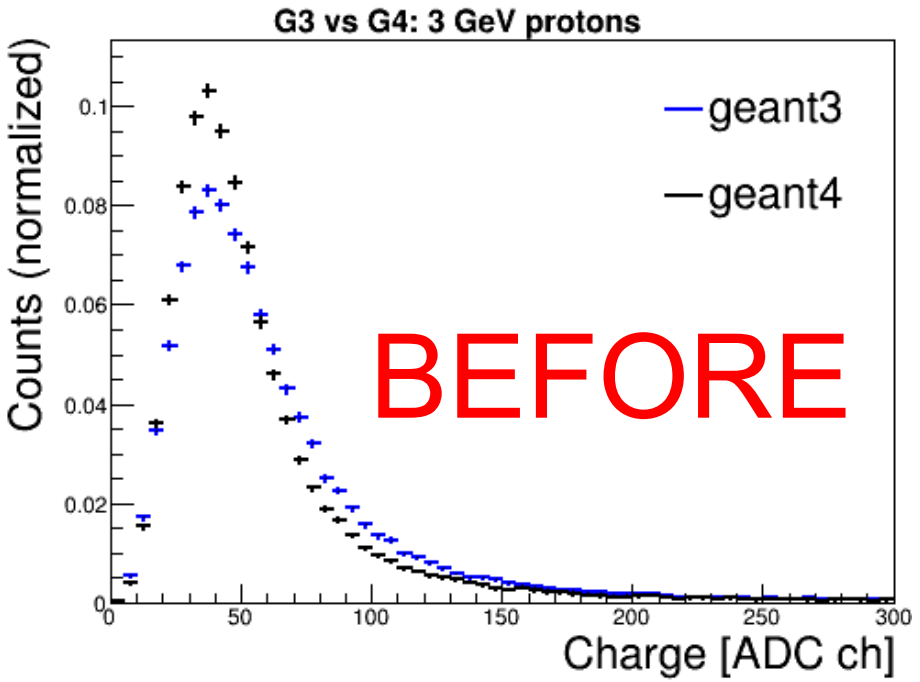
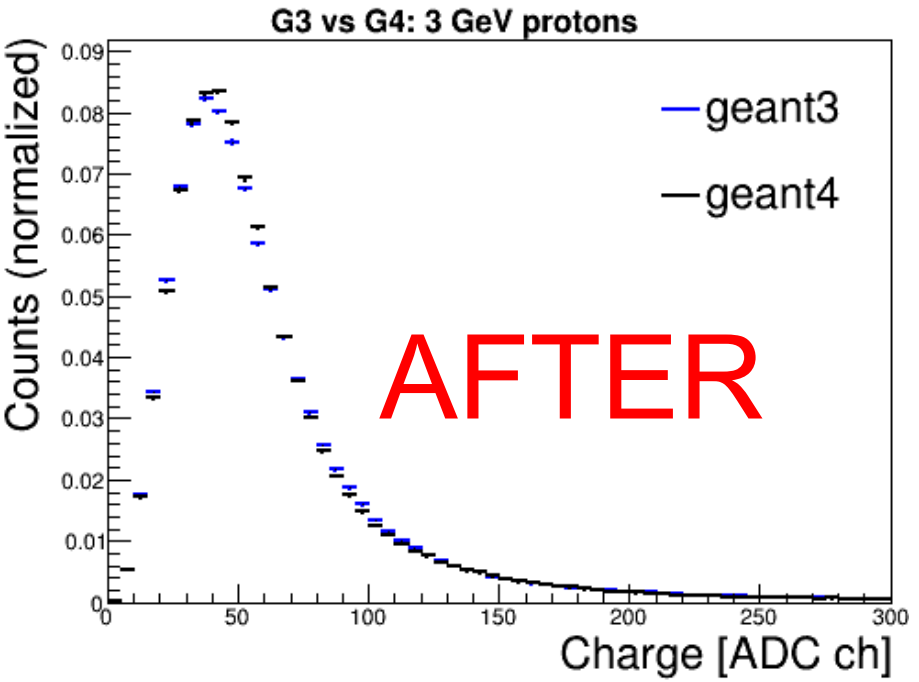
Tuning the Geant4 implementation in the Alice TPC simulation





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ALICE

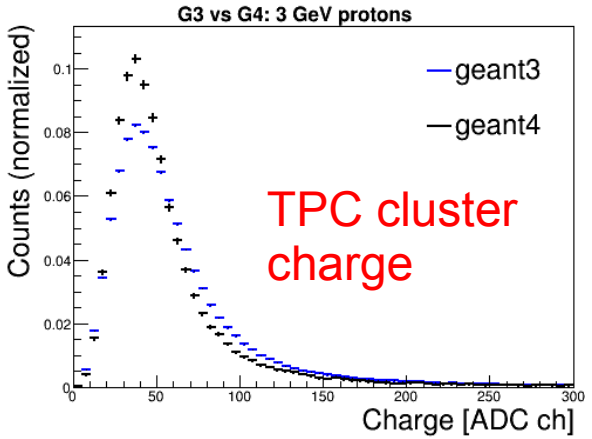
Introduction

- Geant 3 known to describe 2004 TPC test beam with IROC
- Tune Geant 4 implementation to match results using Geant 3
- Simulate 1 and 3 GeV protons under test beam like conditions:
  - Short drift (about 90 cm)
  - No magnetic field
  - Only use IROC part of track
  - Gain scaled by a factor of 3 to avoid missing (sub threshold) clusters
  - Simulate 10000 tracks

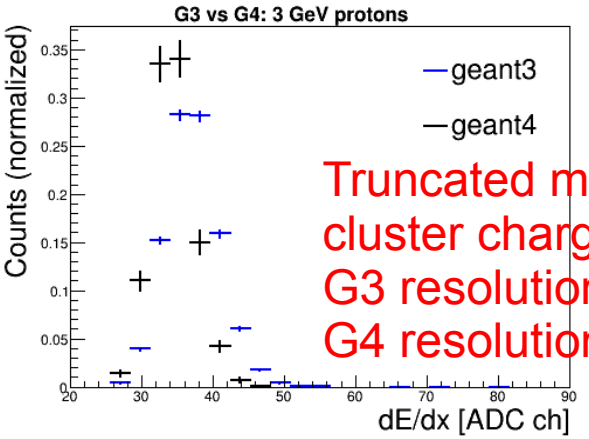
Introduction

- Geant 4 implementation in the TPC simulation is not able to reproduce the dE/dx-response that is obtained using the Geant 3 implementation (which matches test beam data).
- The straggling function and spatial resolution seen in Geant 3 is not matched by Geant 4 results. E.g. the truncated mean distribution is too narrow.

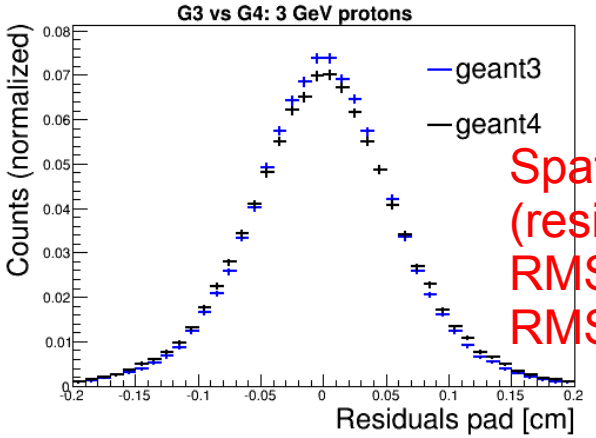
Comparison G3 and G4: 3GeV protons



TPC cluster charge

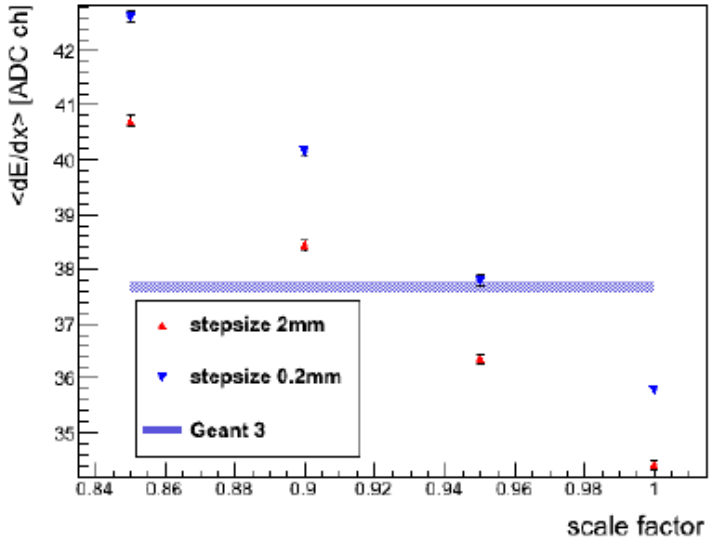


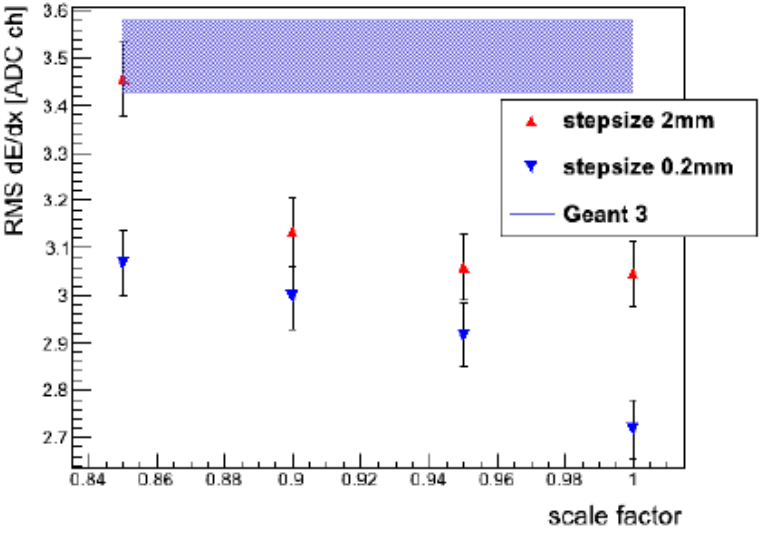
Truncated mean of cluster charge (0-60%)
G3 resolution: 10.006%
G4 resolution: 8.58%

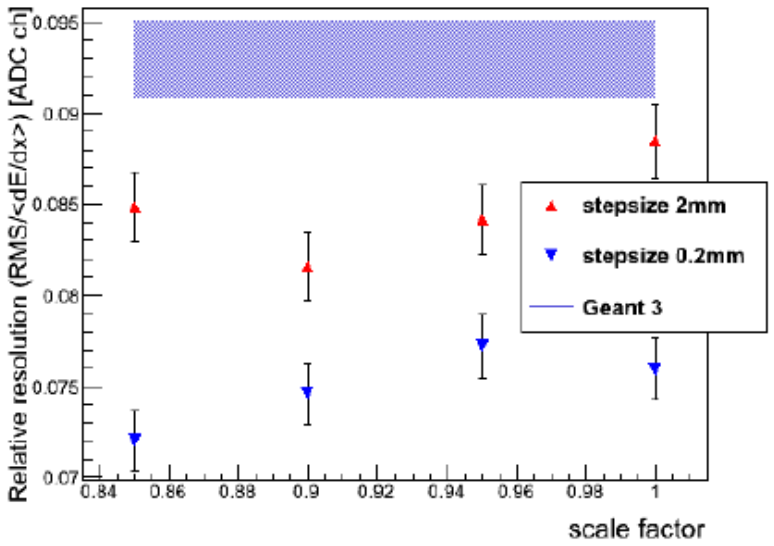


Spatial resolution (residuals)
RMS G3: 0.0588cm
RMS G4: 0.0644cm

Attempt to rescale W







- Try to tune the energy W needed to create an ion-electron pair (simply multiplying W with a scaling factor).
- Matching of dE/dx resolution was not improved by this.

New approach

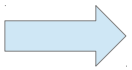
- What is the problem?
  - The Geant 3 implementation works on a collision by collision basis.
  - In the Geant 4 implementation, the particle's energy loss over a certain step length is converted to ion-electron pairs. We do not have information about every single interaction and fluctuations will be averaged out.
    - There is even some step size dependence
  - Try to introduce fluctuations in the number of ion-electron pairs created at a fixed step size of ~2mm

New approach

- The calculated number of electron-ion pairs is smeared using a gamma distribution.
- mean_ion = E_deposited/W
- $$f\left(x|\alpha,\beta\right)=\frac{\beta^{\alpha}x^{\alpha-1}e^{-\beta x}}{\Gamma\left(\alpha\right)}$$

(W = required energy for electron-ion pair)

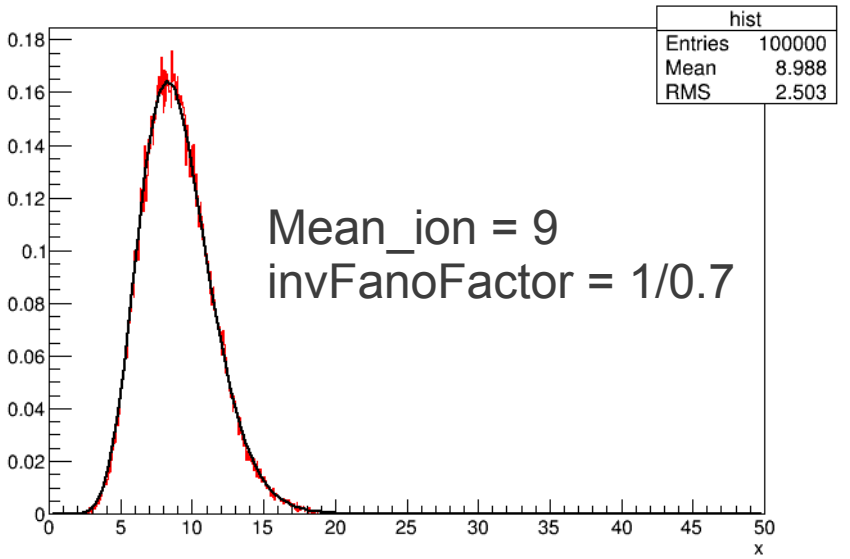
- α = mean_ion*invFanoFactor
- β = invFanoFactor



- mean = mean_ion
- variance = mean_ion/invFanoFactor

New approach

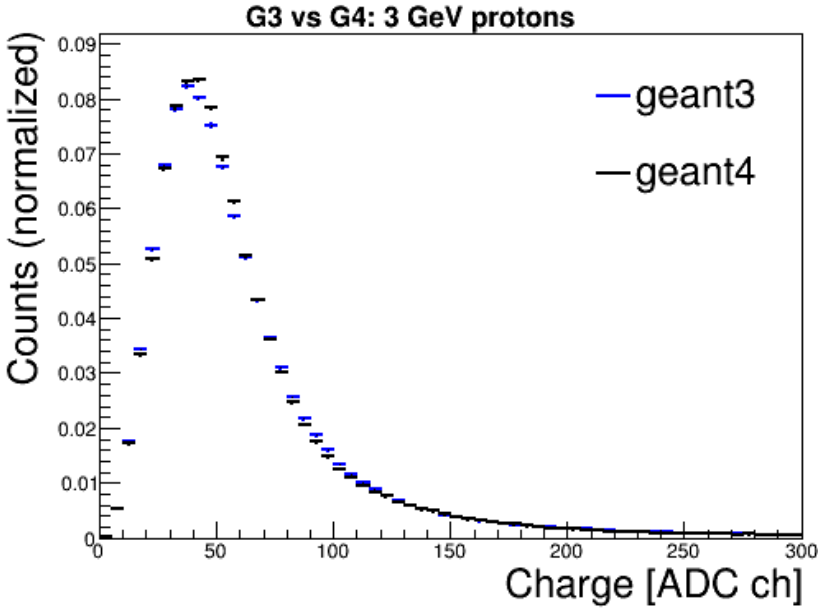
- For every step (stepsize 2mm +- rndm*0.5), calculate mean_ion (floating point) and draw number of electrons from distribution (rounded to nearest integer).

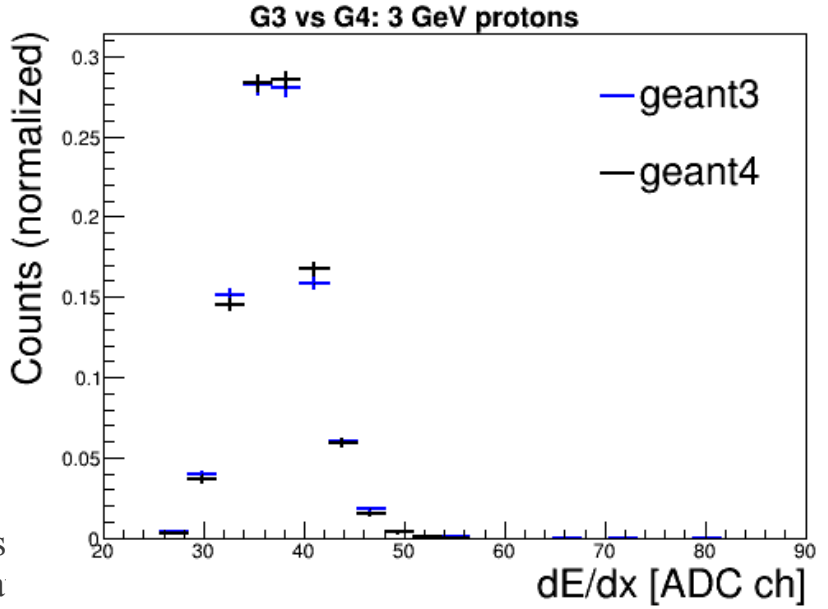


Example: Entries generated from gamma distribution (normalized to 1) + pdf drawn on top

3 GeV protons

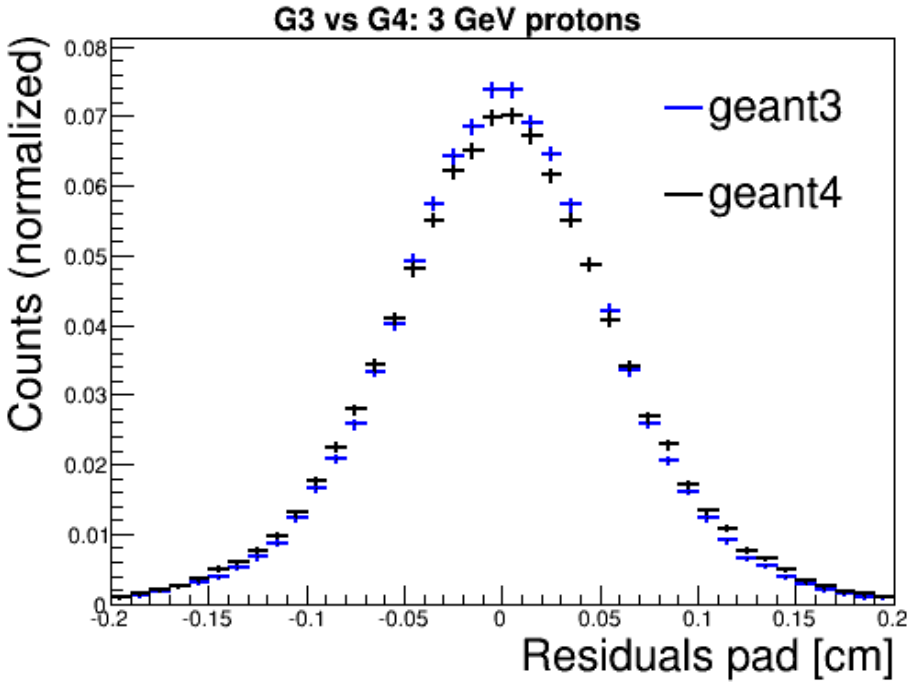
- β = 1/0.7 and W' = W*0.85 reproduces the Geant 3 result





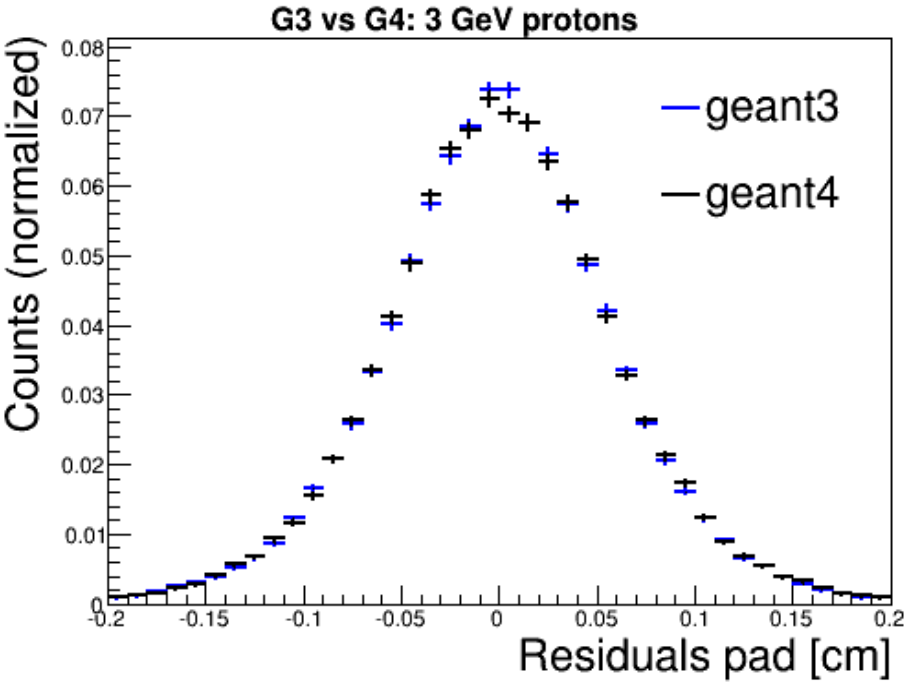
3 GeV protons

Before tuning:



G3 RMS = 0.0588cm
G4 RMS = 0.0644cm

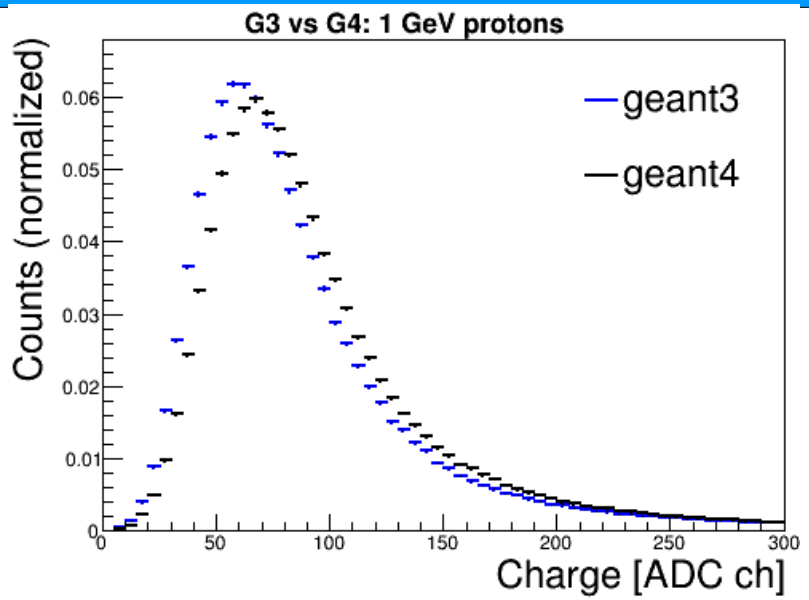
After tuning:

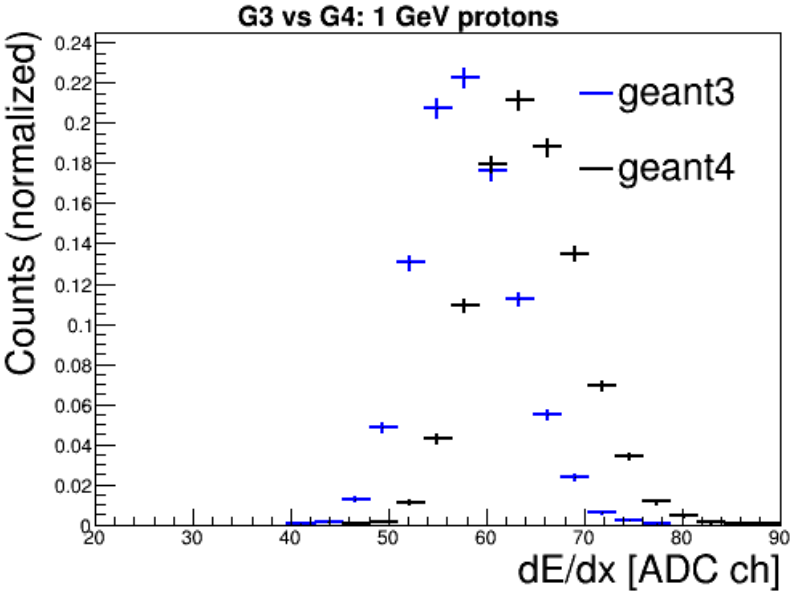


G3 RMS = 0.0588cm
G4 RMS = 0.0593cm

Apply to 1 gev

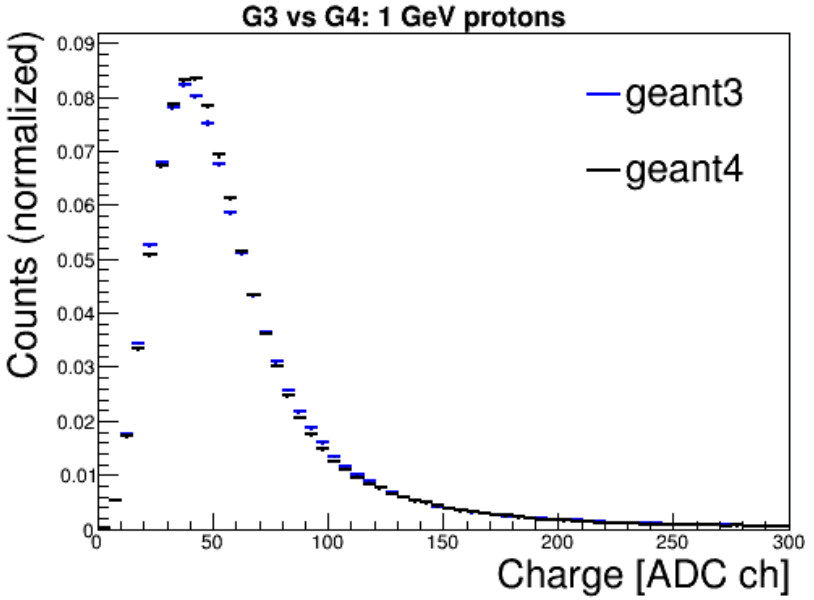
- Same parameters applied to simulation of 1 gev protons.
- Distributions do not overlap but the shapes are reproduced.

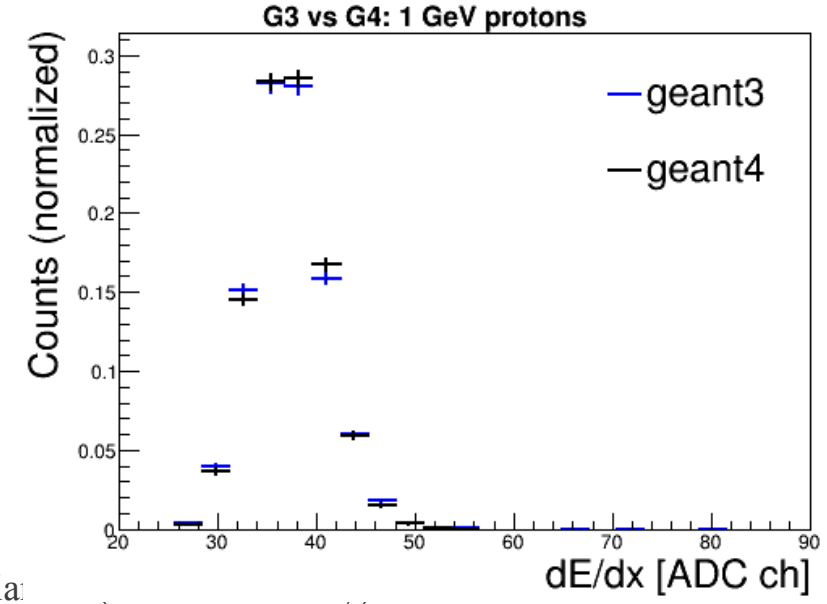




Scaling of 1 Gev result

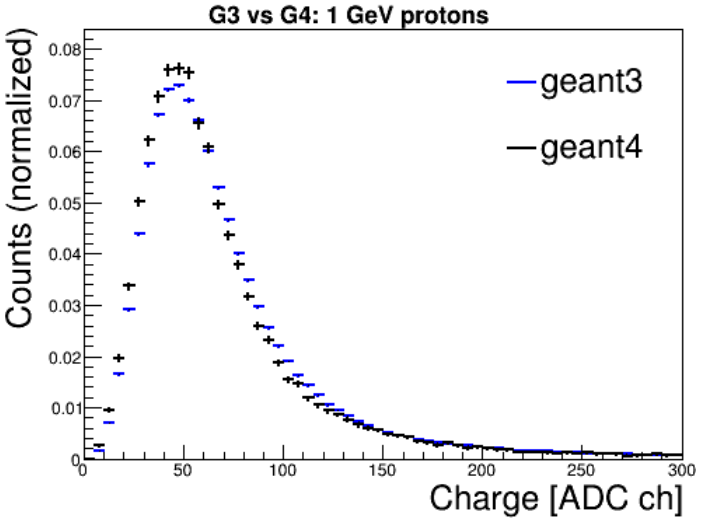
- Scaling the G4 result by multiplying each entry with a factor 0.9



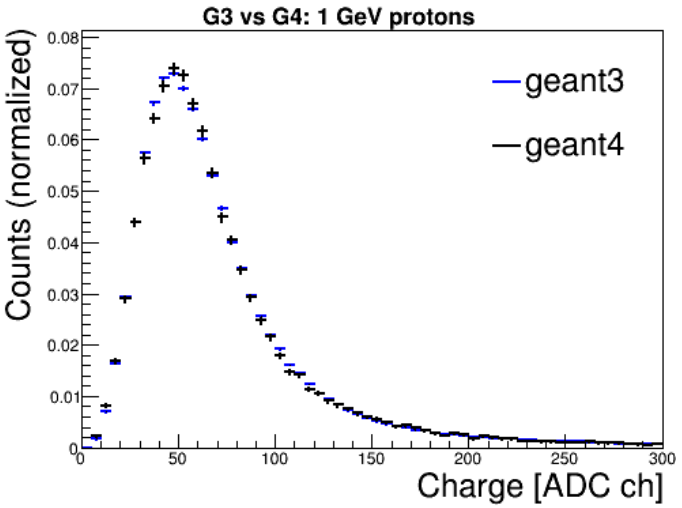


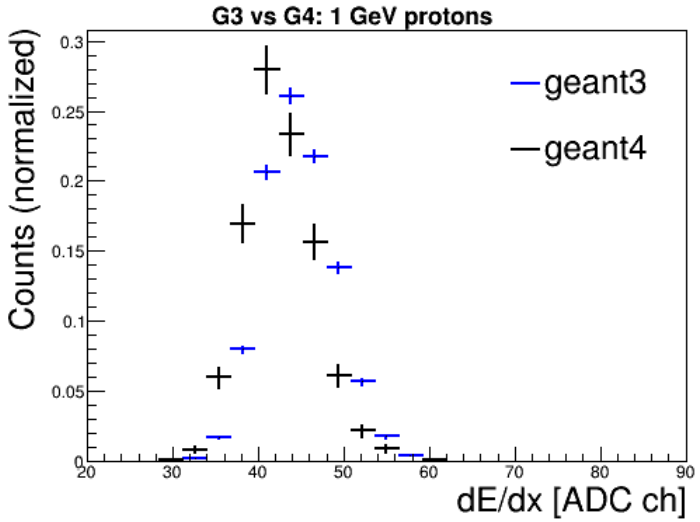
Scaling 15 Gev Result

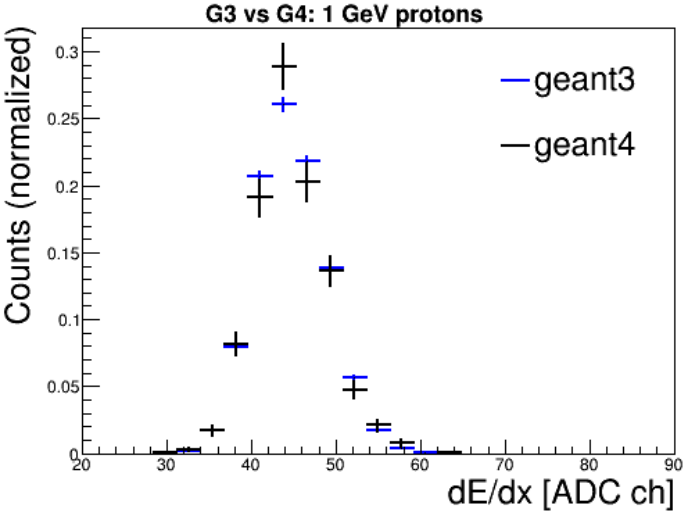
W/o scaling



Scale factor 1.05

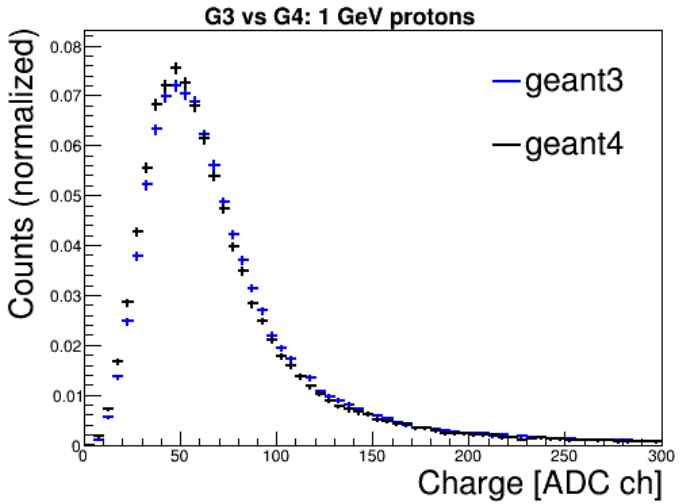


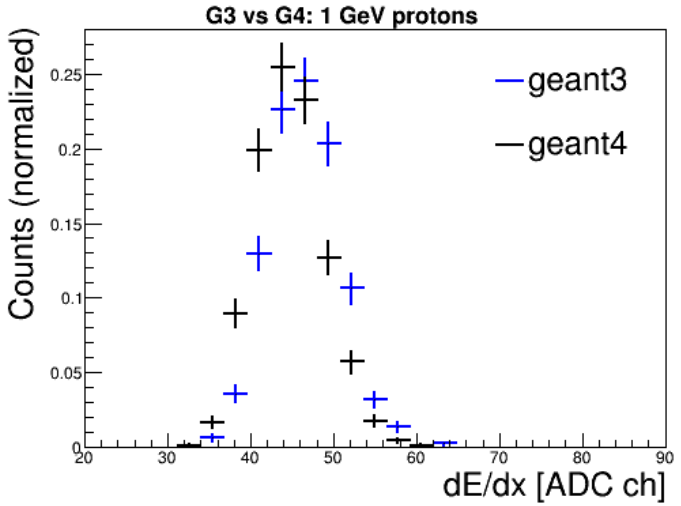




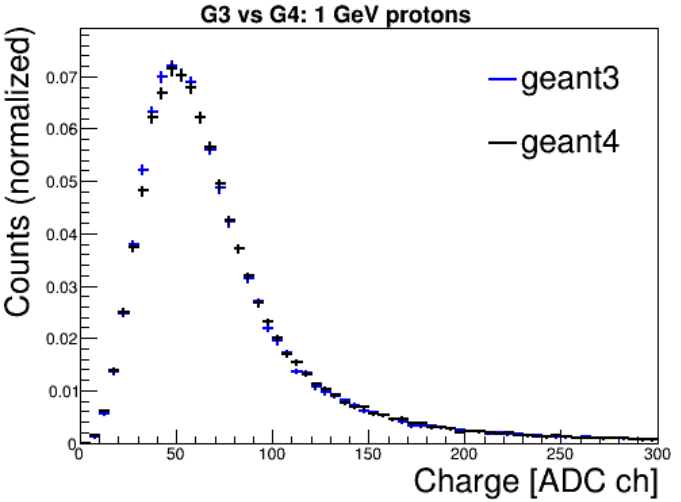
Scaling 20 Gev results

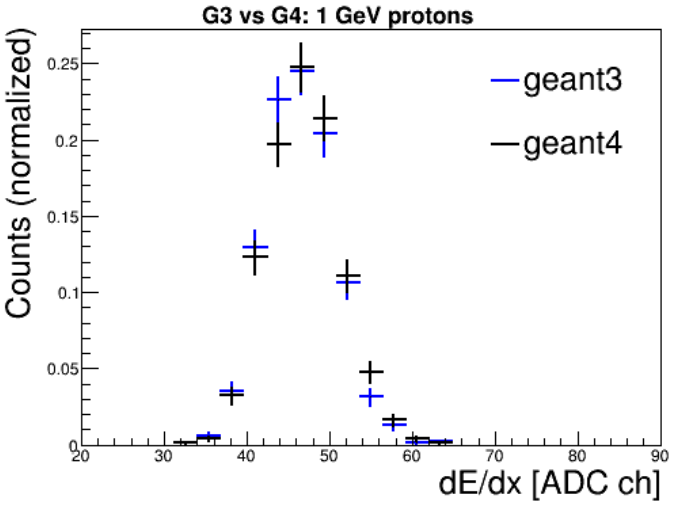
W/o scaling





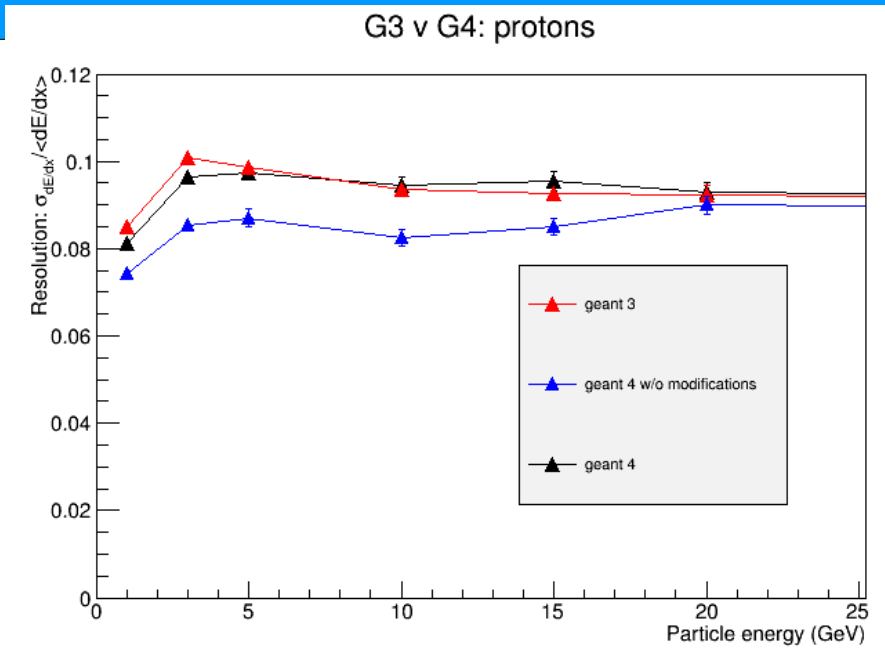
Scale factor 1.05

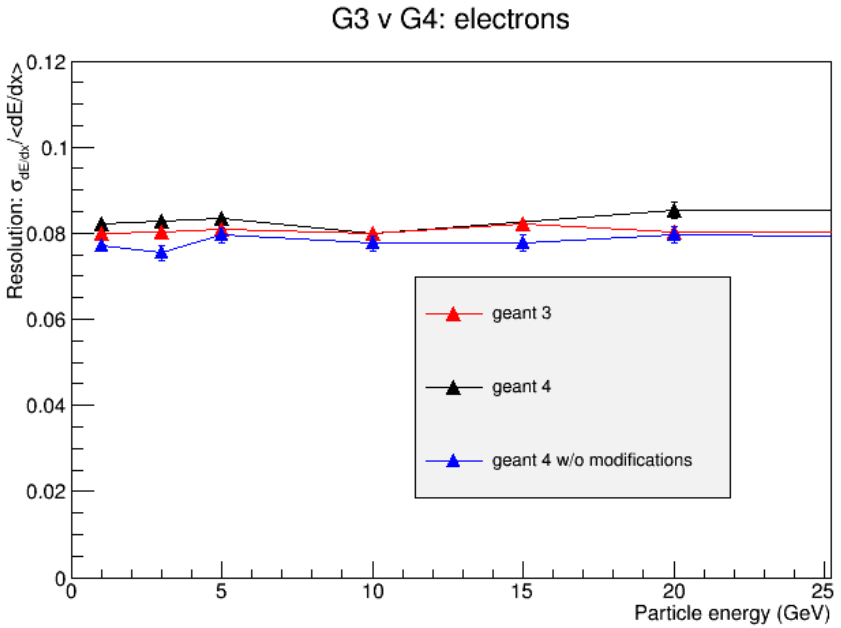




dE/dx resolution

- The resolution is now reproduced much more accurately.
- Previously, the Geant 4 results showed a resolution that was about 1 percentage point better (for protons) than the Geant 3 implementation.





Status

- Modified code not yet committed:
  - Current implementation depends on Roofit package. Gamma function should perhaps be generated directly in TPC code.
  - Energy loss parametrization in Geant 3 is being tuned to data. Once this is done, this can be used to tune Geant 4.
- This tuning was done using the Urban (default) energy loss model which is less precise but faster than PAI. This shows that this faster method might be sufficient.

Conclusion

- The Geant 4 Alice TPC simulation was tuned to match simulations in the Geant 3 implementation (starting with 3 GeV protons).
- Introduce fluctuations by smearing the number of produced ion pairs using a gamma distribution
- It seems possible to tune the simulation in this way.
- Once energy loss parametrization in Geant 3 is tuned to data, the same can be done for Geant 4. Code not yet in Aliroot since we decided to wait for this.
- This was done using the standard Geant 4 eloss model (Urban) and not PAI, suggesting that one can obtain good results using a less precise (but faster) model.