GEANT4 energy loss of protons, electrons and magnetic monopole

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About speaker

M. Vladymyrov has finished school #145 in Kiev (Ukraine) and entered Moscow Institute of Physics and Technology, Department of General and Applicated Physics. This year he has finished his bachelor and now is master-course student and does his diploma in Lebedev Physical Institute (Moscow).

This work is carried out within Summer Student program at CERN, working in SFT-group, GEANT4 team.

PART I

Proton's energy loss

Proton’s energy loss

- The simulation performance and accuracy depends on the values of used simulation parameters.
- We used G4 9.0 examples/extended/hadronic/Hadr01 to study dependence on parameters.
- The target was water cylinder, long enough for the track to stop in it. It was divided to thin slices perpendicular to the beam, and energy loss was averaged within each slice.
- Beam energy was 70MeV, 110MeV, 160MeV and 400MeV

Proton's energy deposition:
dependence on cut

Production threshold (Cut) is measure of
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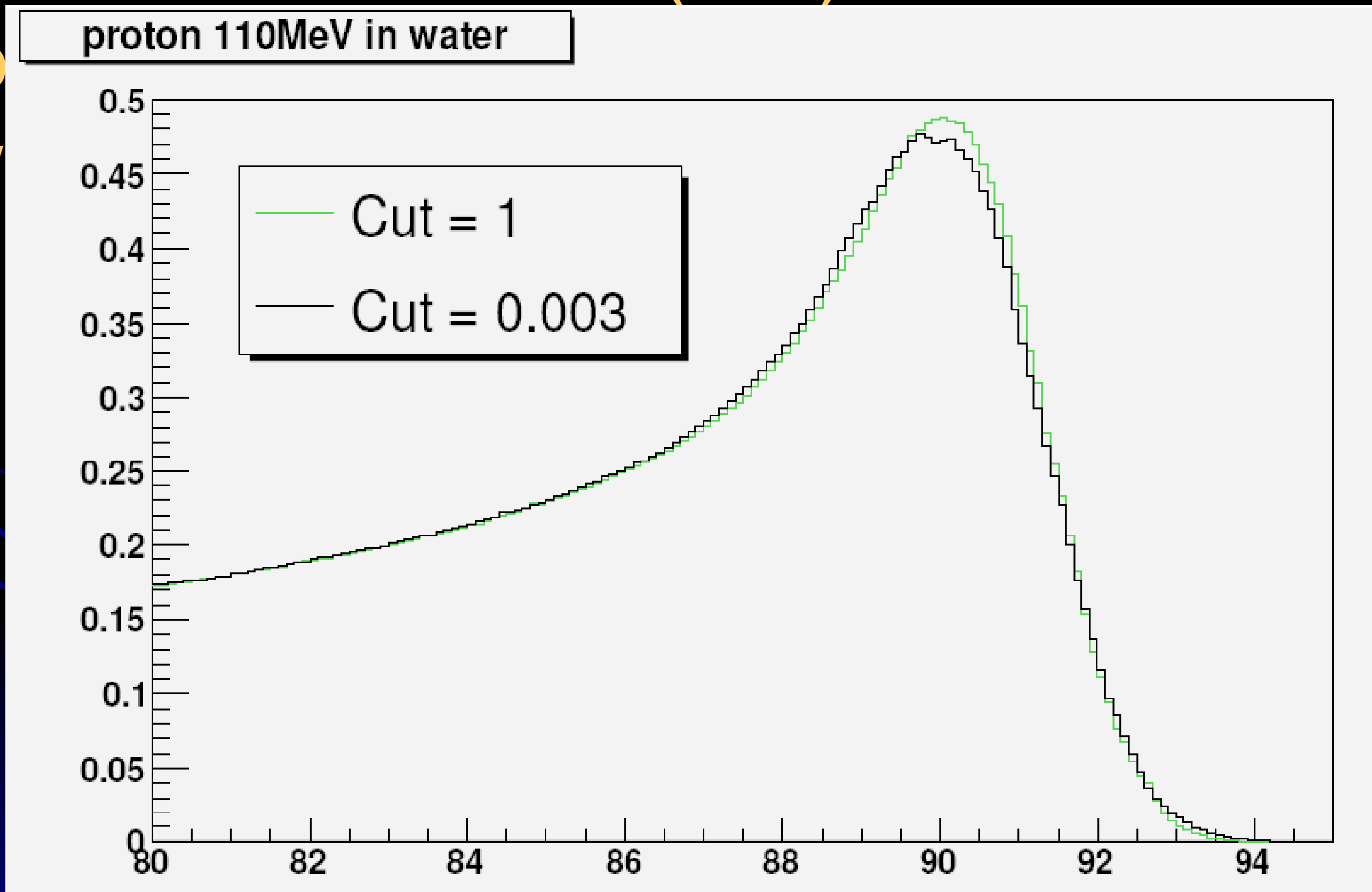


For lower energy the effect is even bigger, since for higher – negligible (see Appendix)

Proton's energy deposition:
dependence linLossLimit (LLL)

linLossLimit parameter is used to choose algorithm to calculate energy losses:

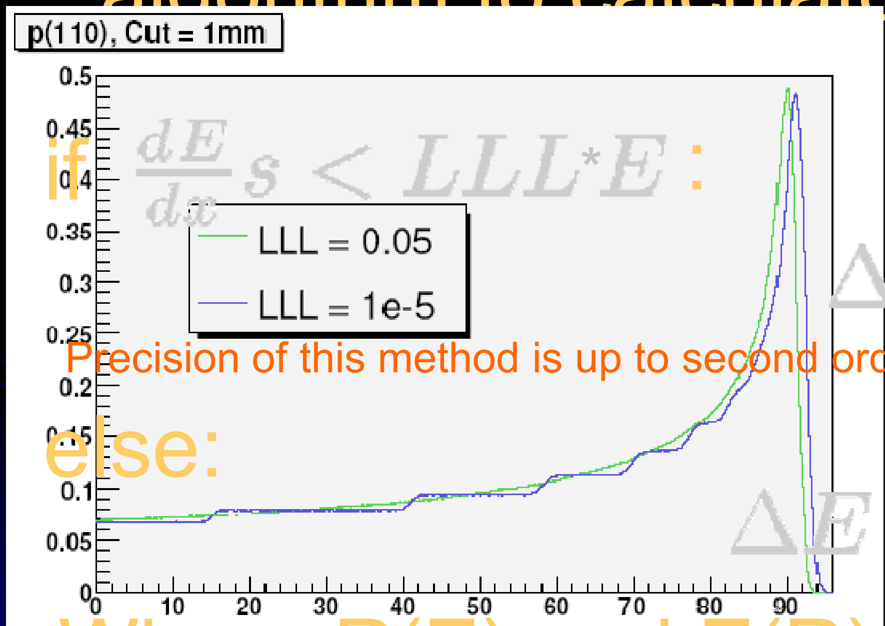
if $\frac{dE}{dx}s < LLL^{*}E$:

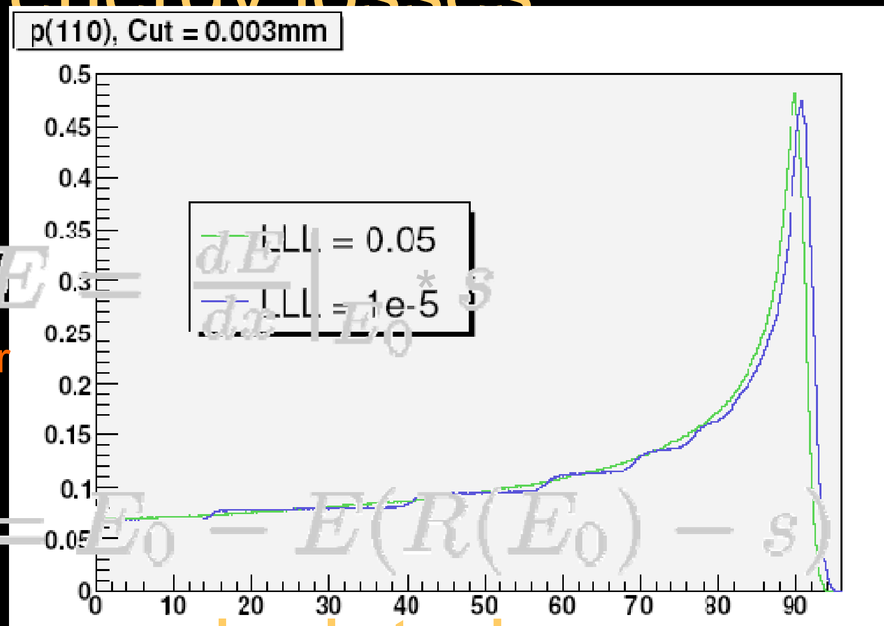
$$\Delta E = \left.\frac{dE}{dx}\right|_{E_0}{}^{*} s$$

Precision of this method is up to second order

else:

$$\Delta E = E_0 - E(R(E_0) - s)$$





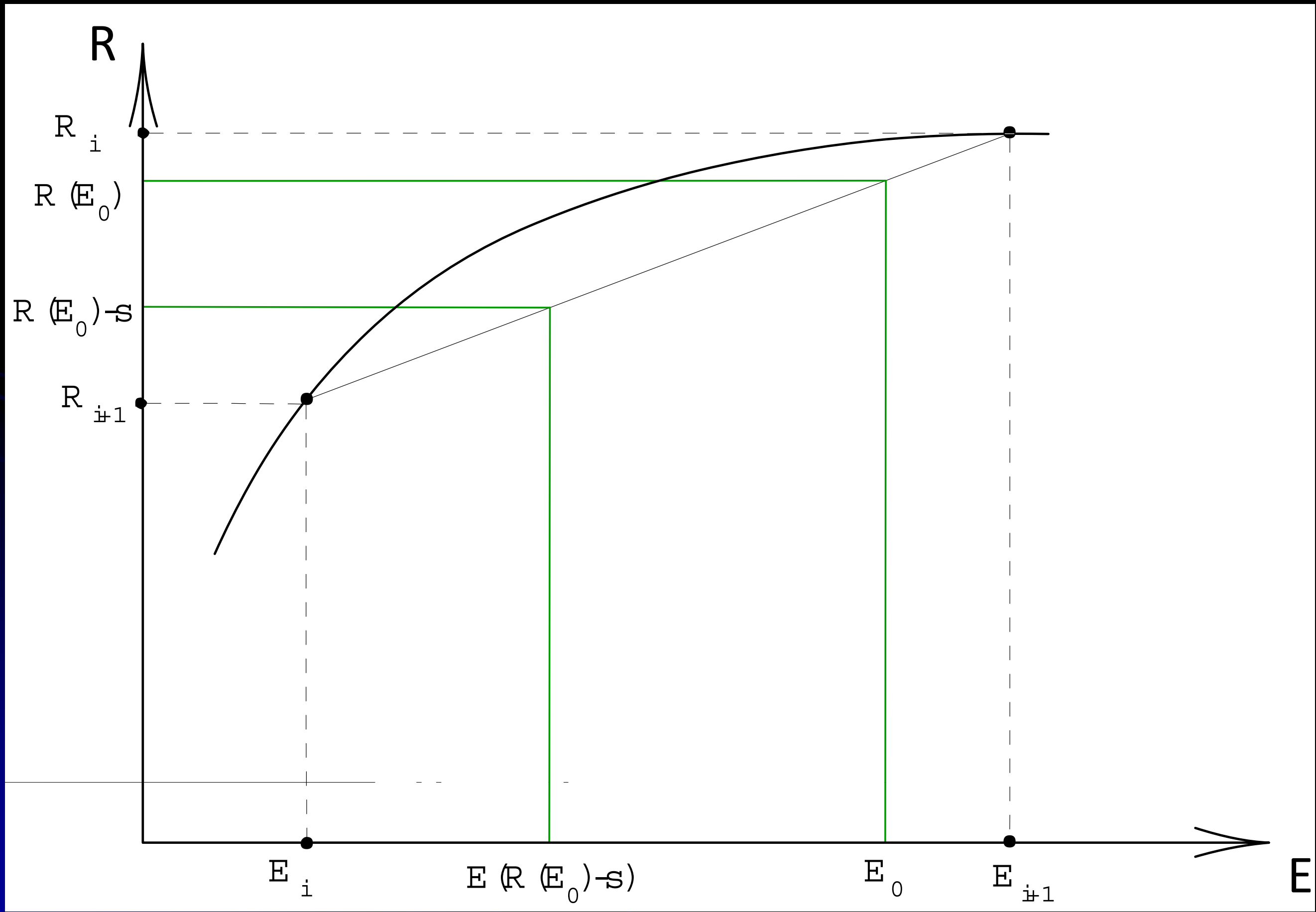
Where R(E) and E(R) are calculated from corresponding tables

Step size is 0.1 mm. We see, that for low LLL appear waves.

Precision of this method we study

Proton's energy deposition: waves

To understand, the origin of the waves, let's see, how second algorithm works.



When

$s < R_{i+1} - R_i$

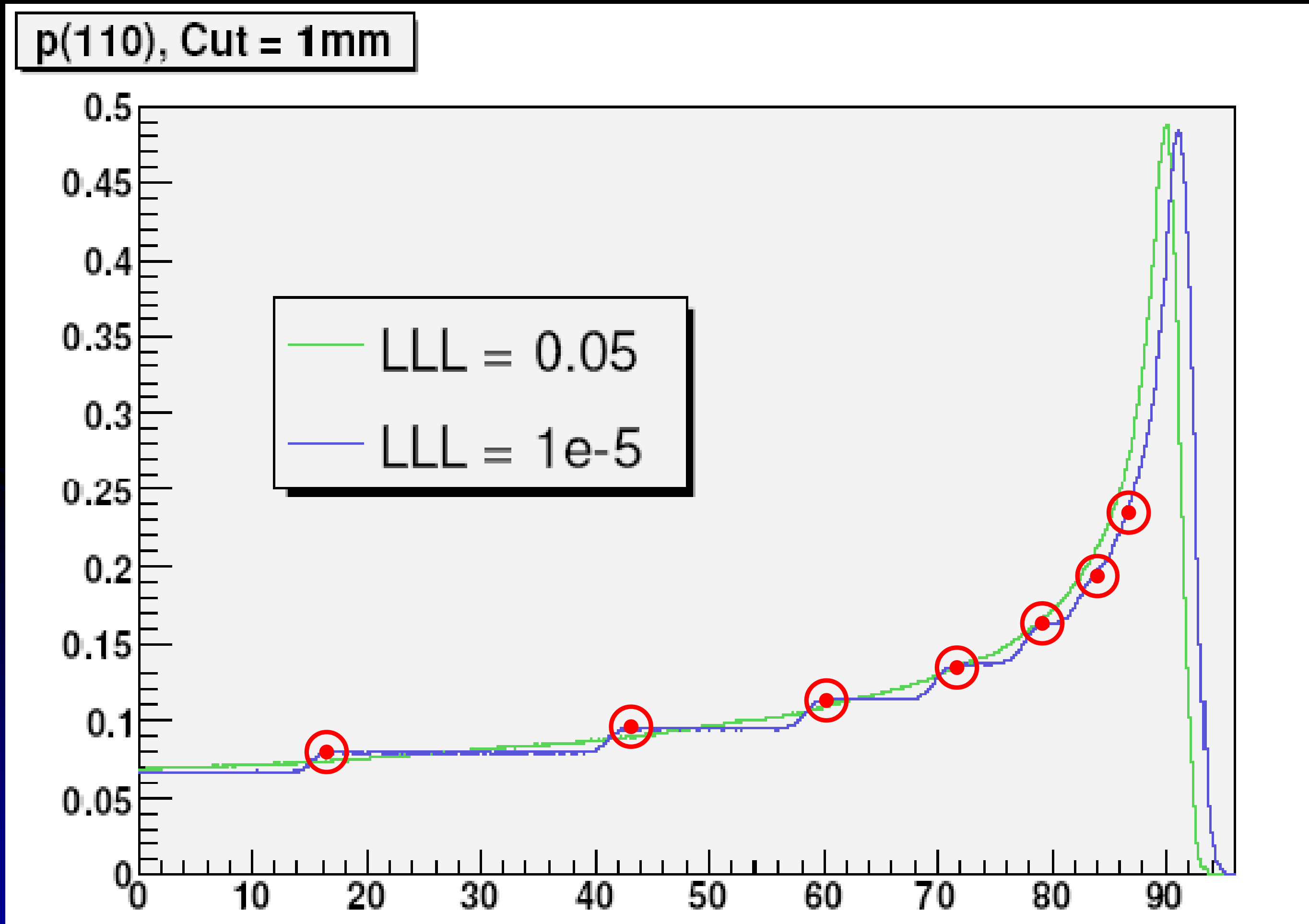
ΔE does not

depend on E_0

within 2

neighbor nodes

Proton's energy deposition: dependence linLossLimit (LLL)

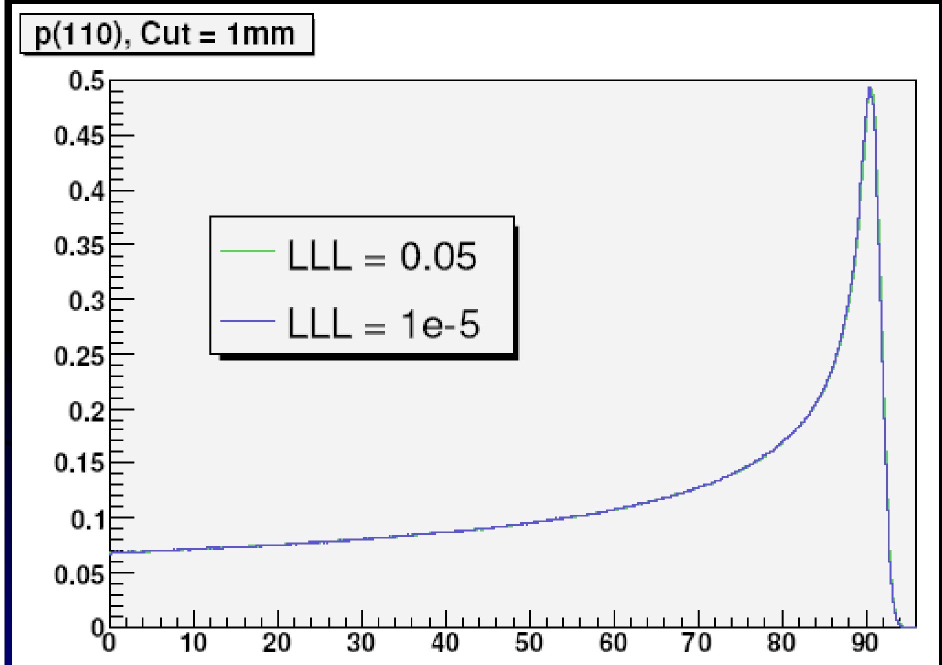


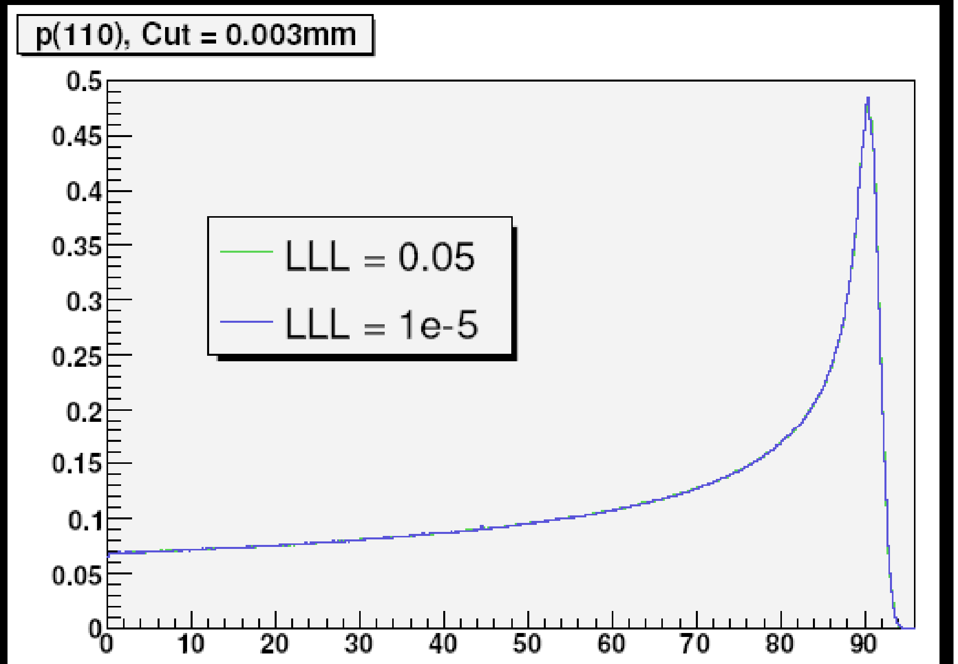
Each step corresponds to same 2 nodes in the table.

⊙ table node

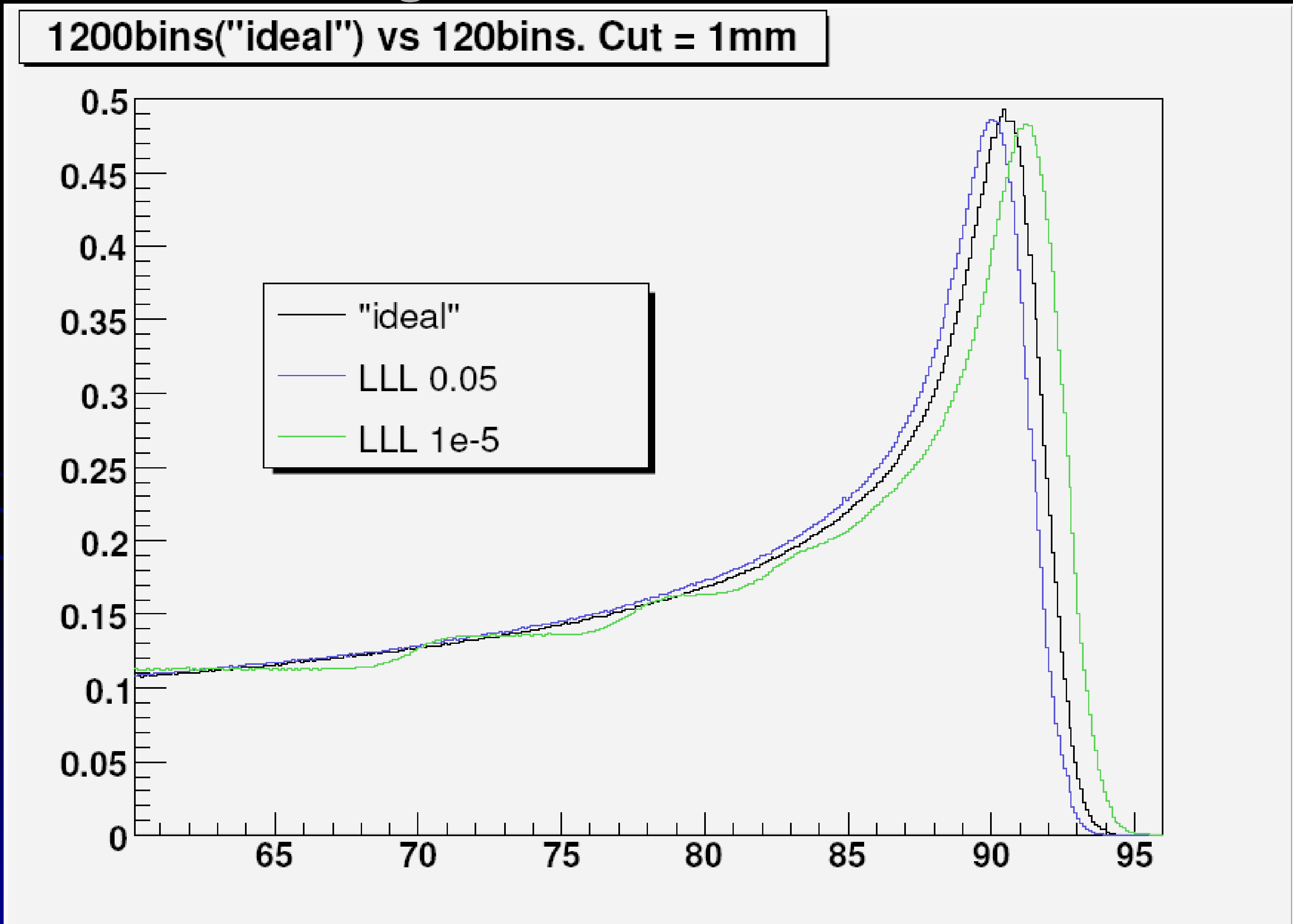
Proton's energy deposition:
large number of bins (1200)

As we could expect, increasing number of bins (default value is 120 bins) in the table solves the problem :





Proton's energy deposition:
large number of bins



Proton’s energy deposition: conclusion

- Default parameters are stable (don’t provide waves)
- Systematic accuracy of peak position for 100MeV proton is about 0.5 mm.
- For better accuracy one has to use lower LLL, and simultaneously increase number of bins in tables for dedx and ranges.
- The same behavior was obtained also in aluminium and lead.

PART II

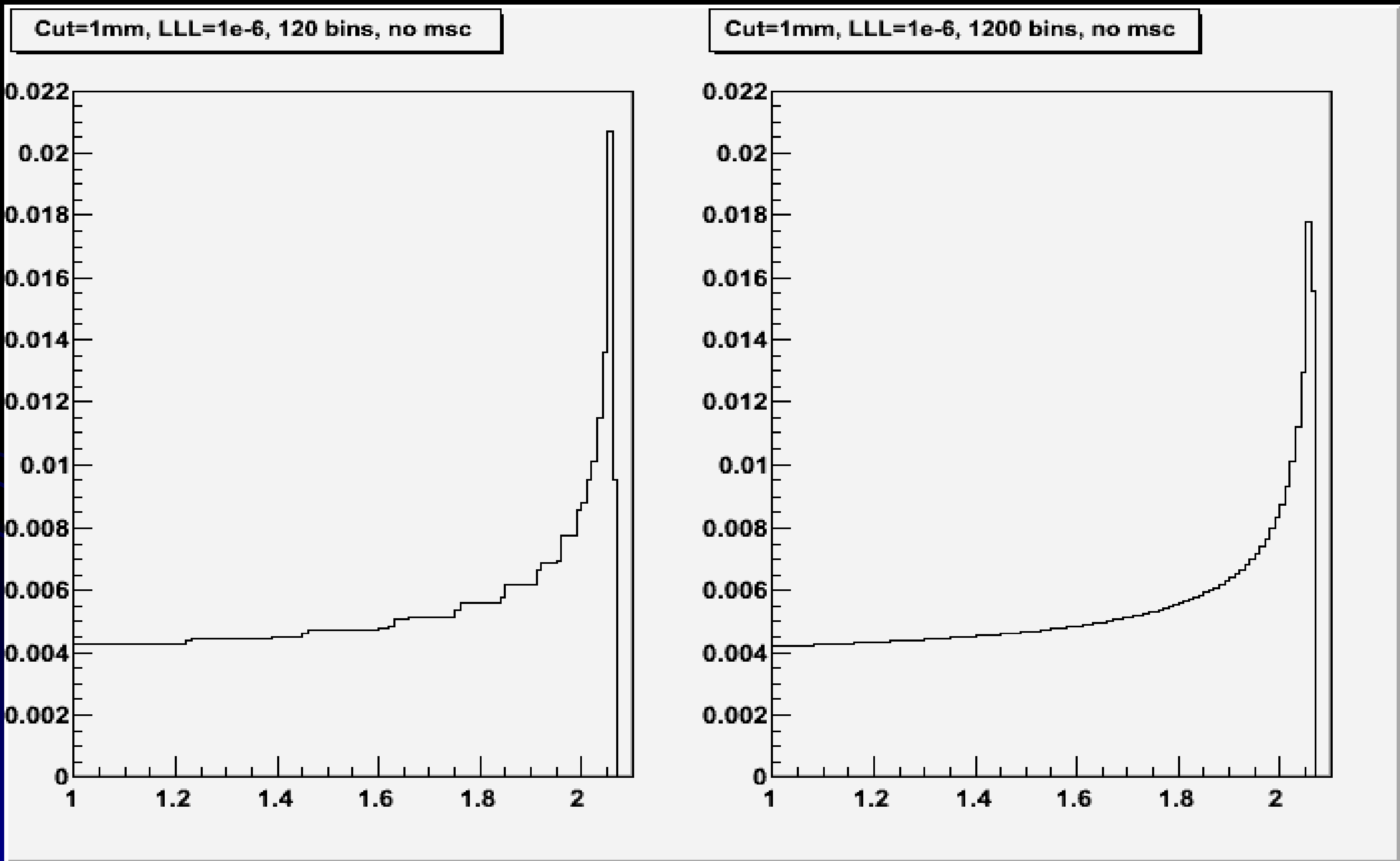
Electron’s energy deposition

Electron's energy deposition

The studies for electron were almost the same, as for proton, but with lower energy: 1MeV.

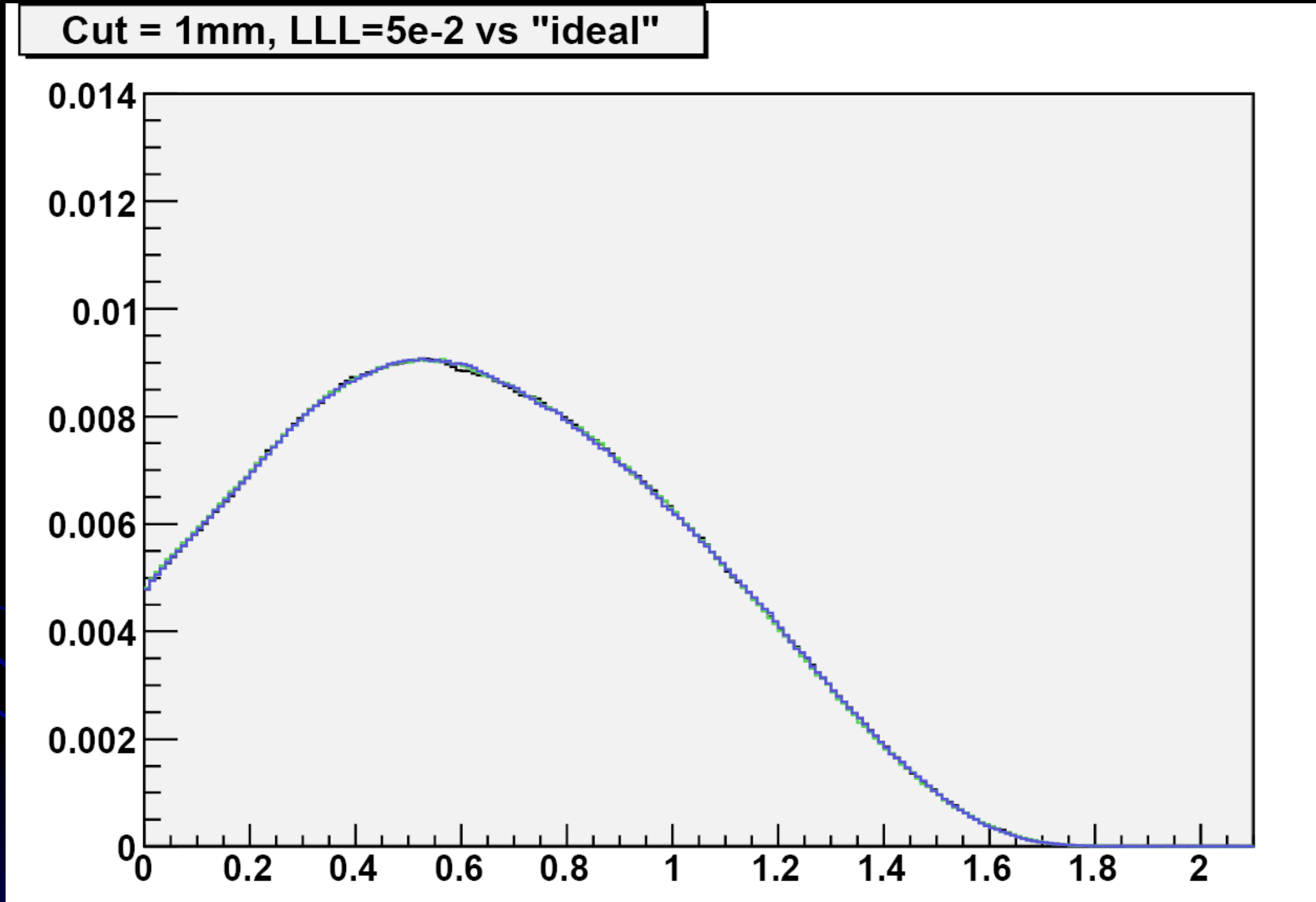
- Bremsstrahlung low
- Significant part of EM shower

Electron's energy deposition



No fluctuations and multiple scattering

Electron's energy deposition



Despite the parameters doesn't effect the ELoss shape explicitly (because of fluctuations and msc), we should take it into account for simulation in tiny absorbers.

Electron's energy deposition : conclusion

- Results are similar to that for protons
- Stepped structure is even with default values (see Appendix for more plots)
- For precise results one has to increase binning

PART III

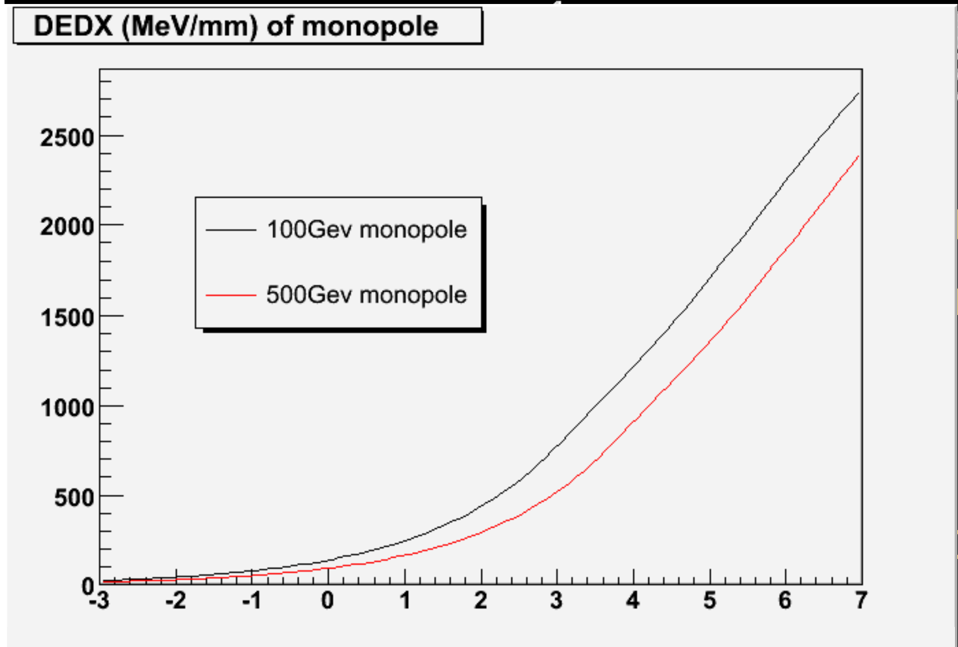
Magnetic monopole

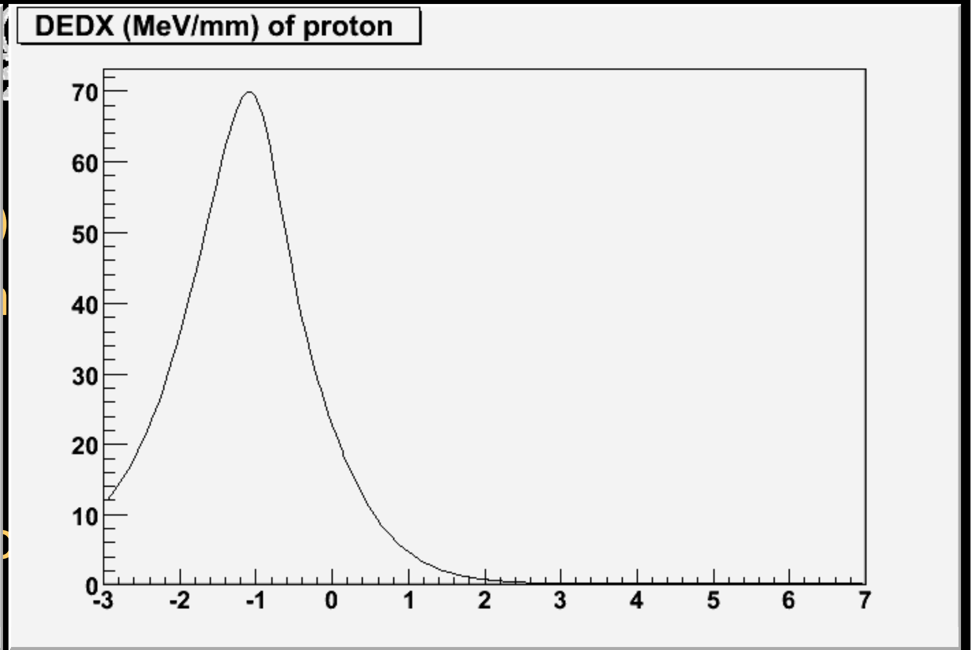
Magnetic monopole

- GEANT4 monopole energy losses were checked and fixed
- New GEANT4 example was created and added to reference tag geant4.9.0.ref01 (examples/extended/exoticphysics/monopole)
- QGSP physics list
- Extra builder was created
  - G4Monopole added
  - standard transportation and G4mplIonisation

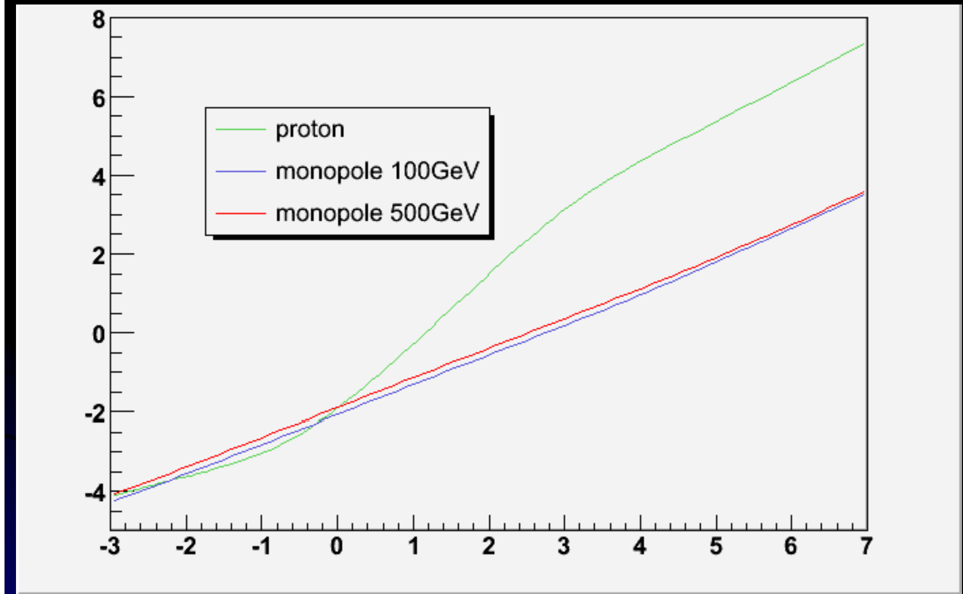
Magnetic monopole: Energy losses

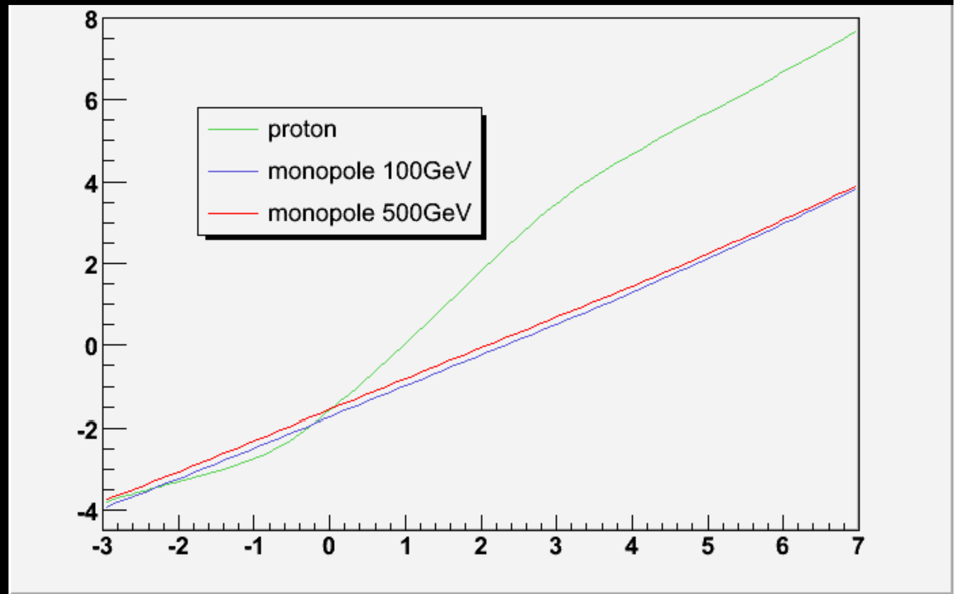
Ahlen's formula for monopole stopping power (Rev.Mod.Phys 52.(1980), 121)



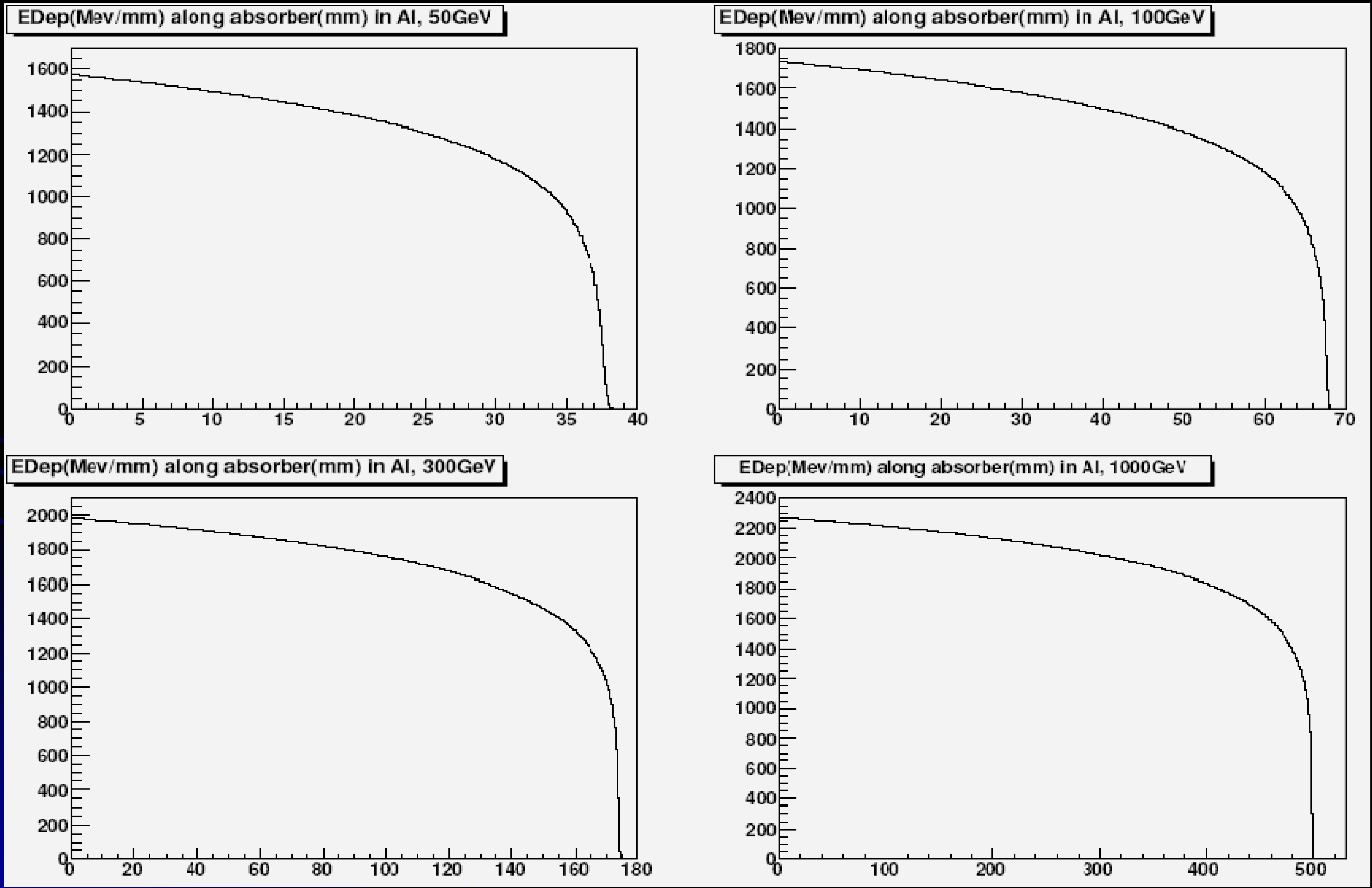


Magnetic monopole: Ranges in aluminium and liquid argon





100GeV Magnetic monopole: Energy deposition in Al

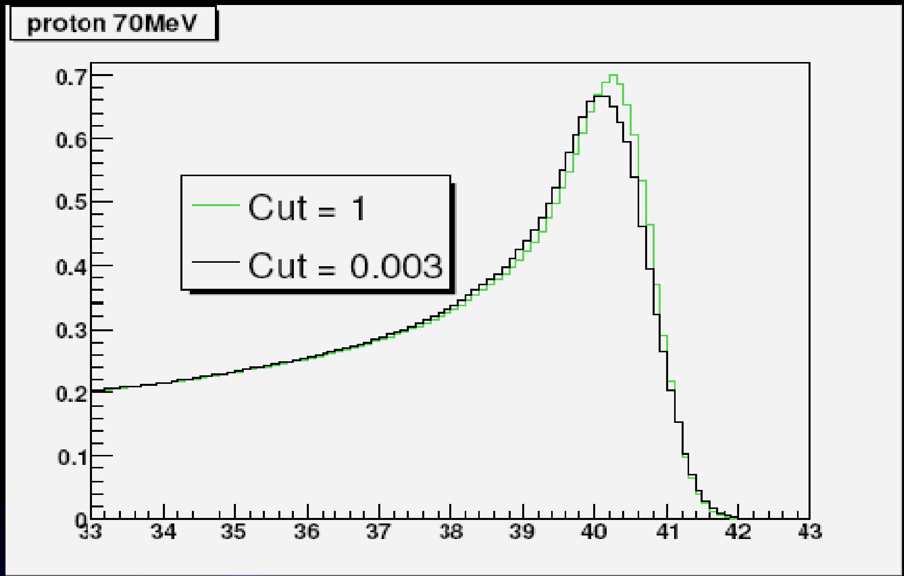


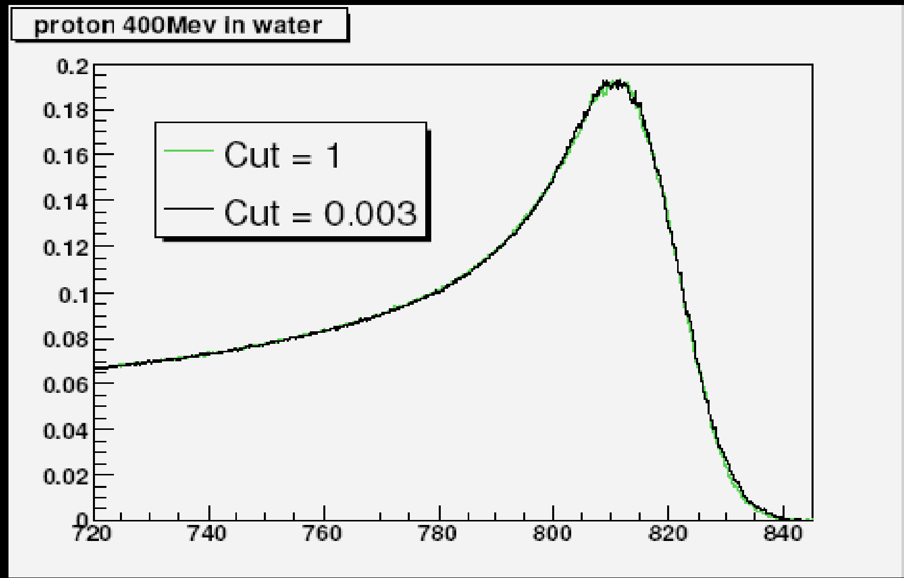
Magnetic monopole: conclusion

- It was shown how to add an exotic particle to the QGSP physics list
- Example with monopole physics was created and included in G4 distribution
- We are ready to make R-hadron example, but better understanding of R-hadron interactions with media is required

Questions?...

Appendix

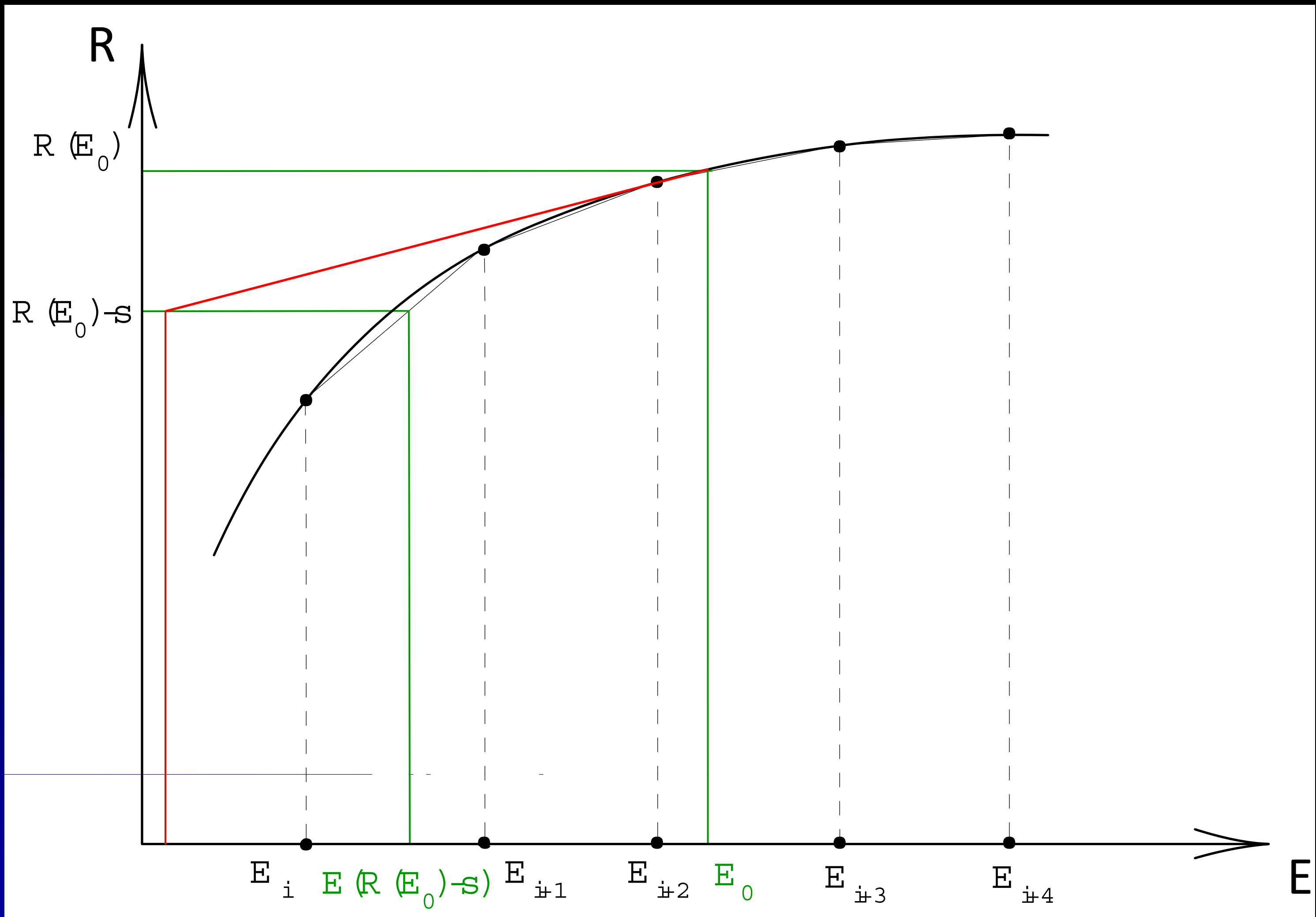




For low energies the result strongly depend on cut

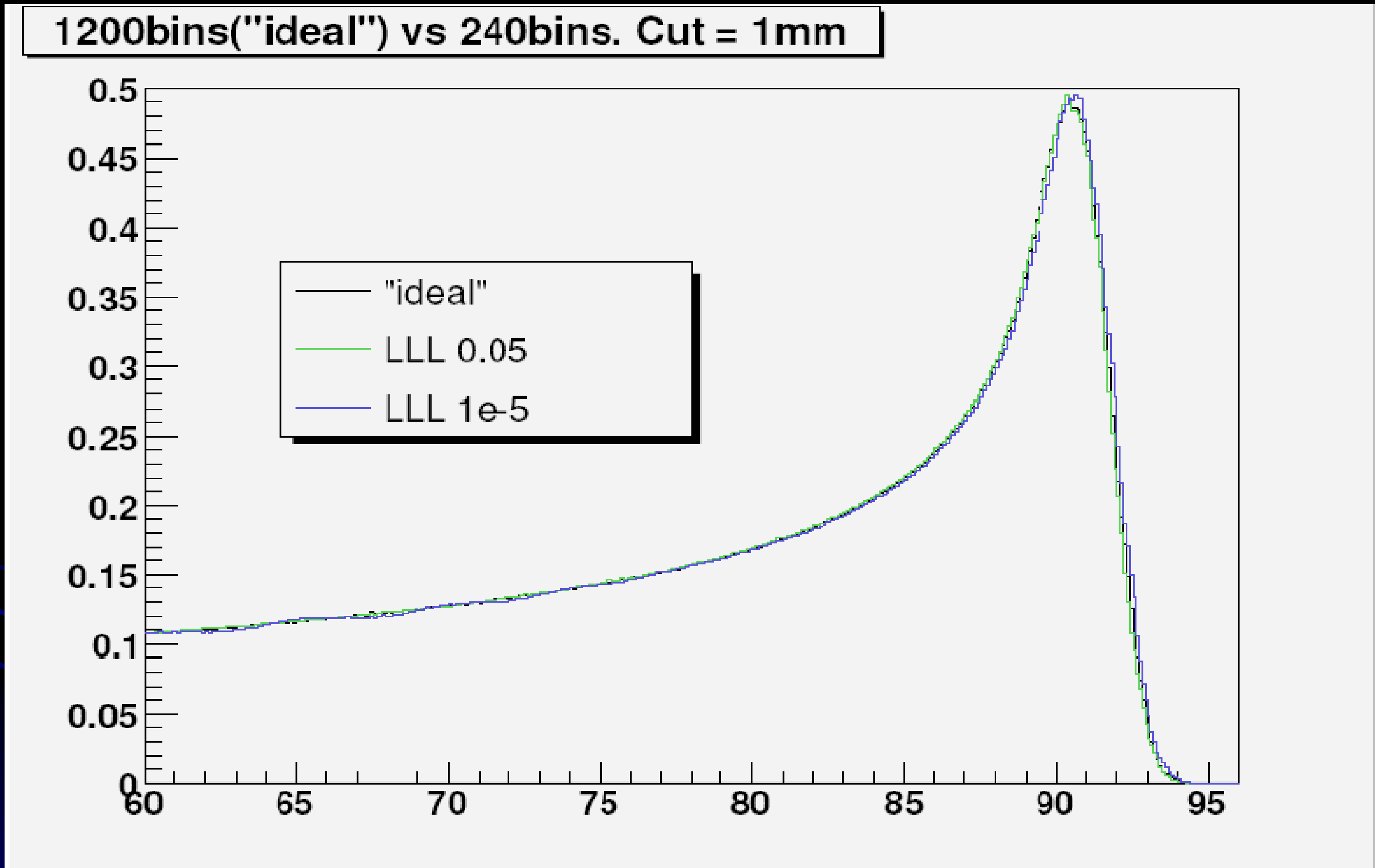
Proton's energy deposition: waves

This method is good when s >> r



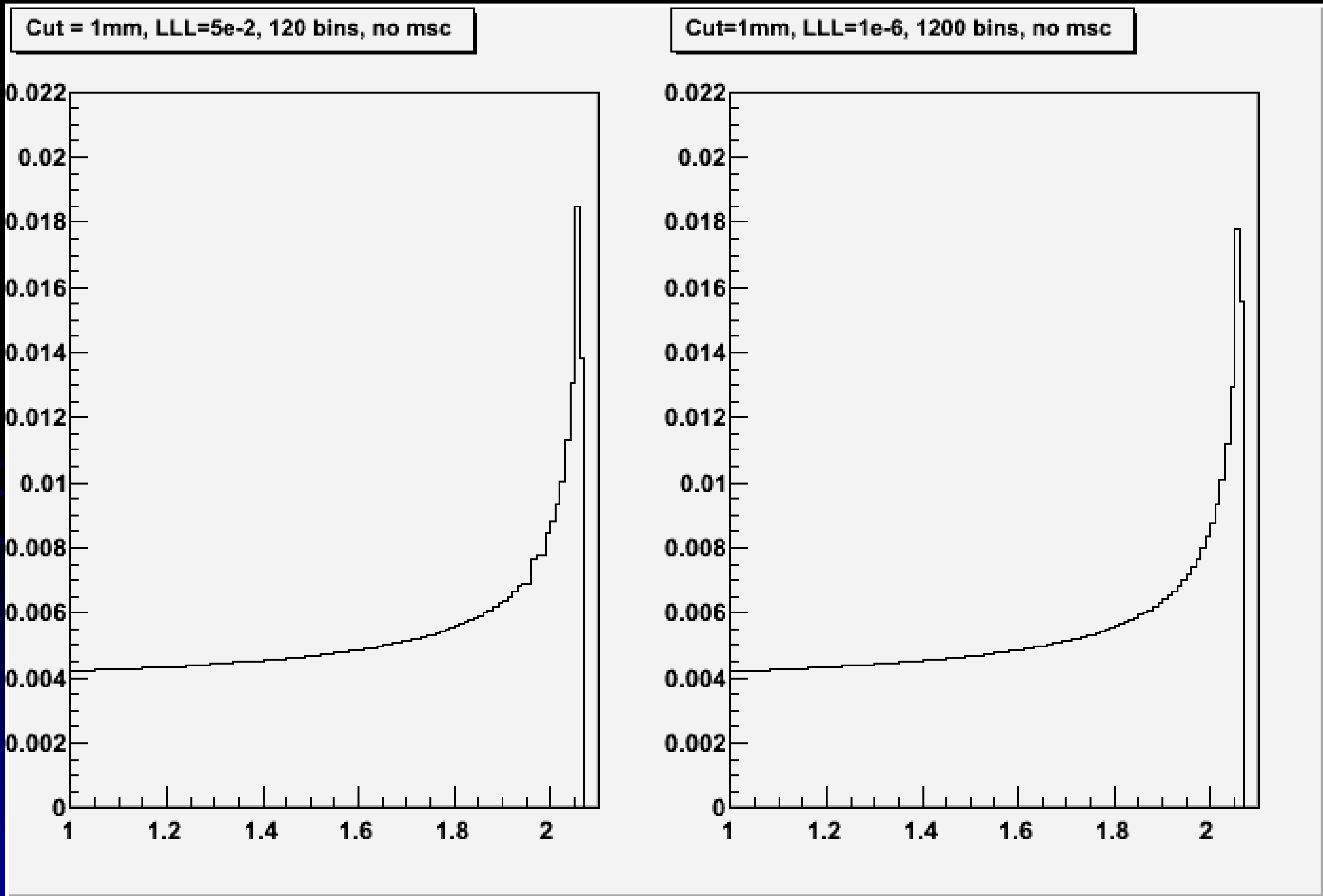
Red line – calculation using first method

Appendix

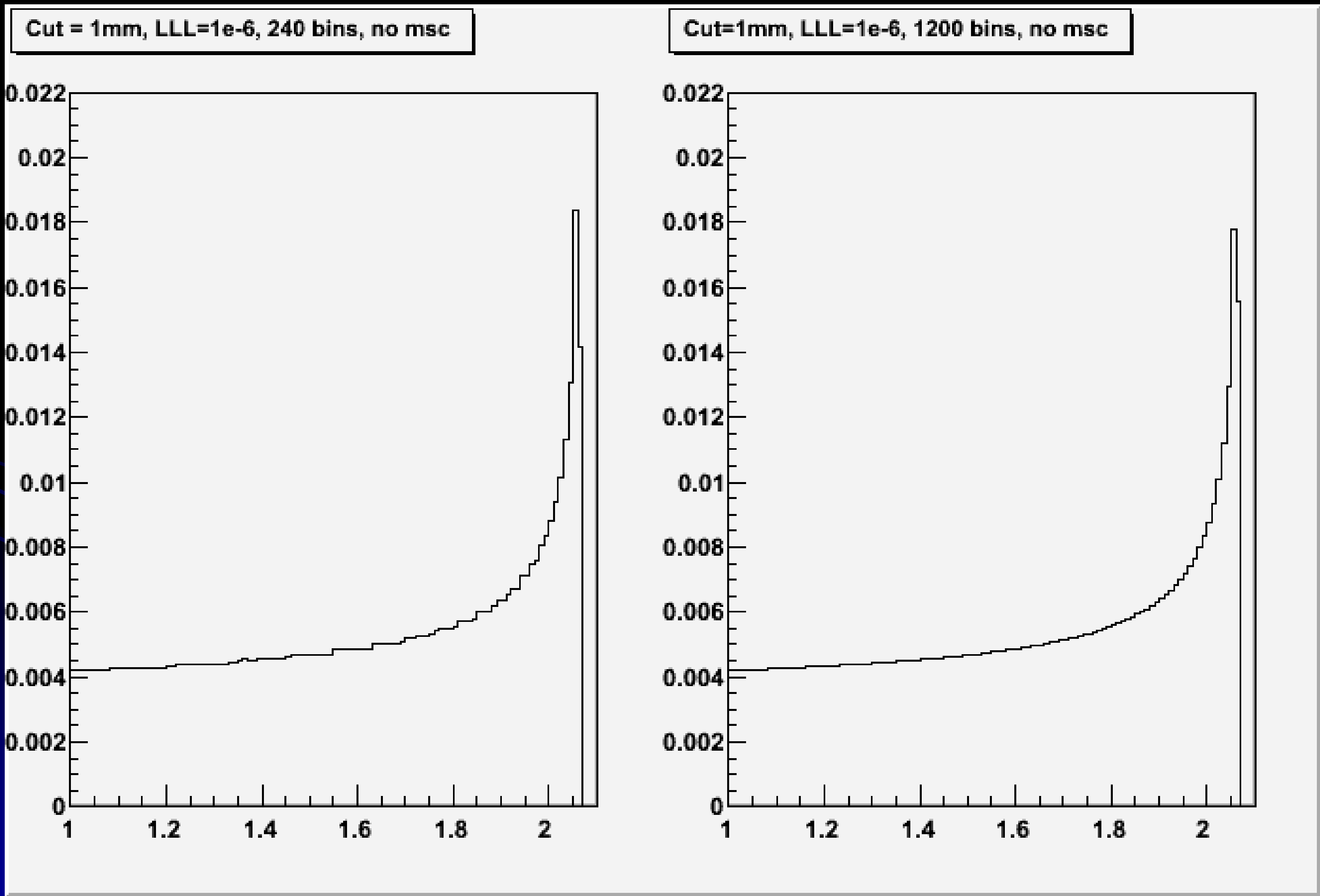


Comparison 1200 with 240 bins table results

Electron's energy deposition



Electron's energy deposition



100GeV Magnetic monopole: Energy deposition in lAr