Geant3/Geant4 comparisons

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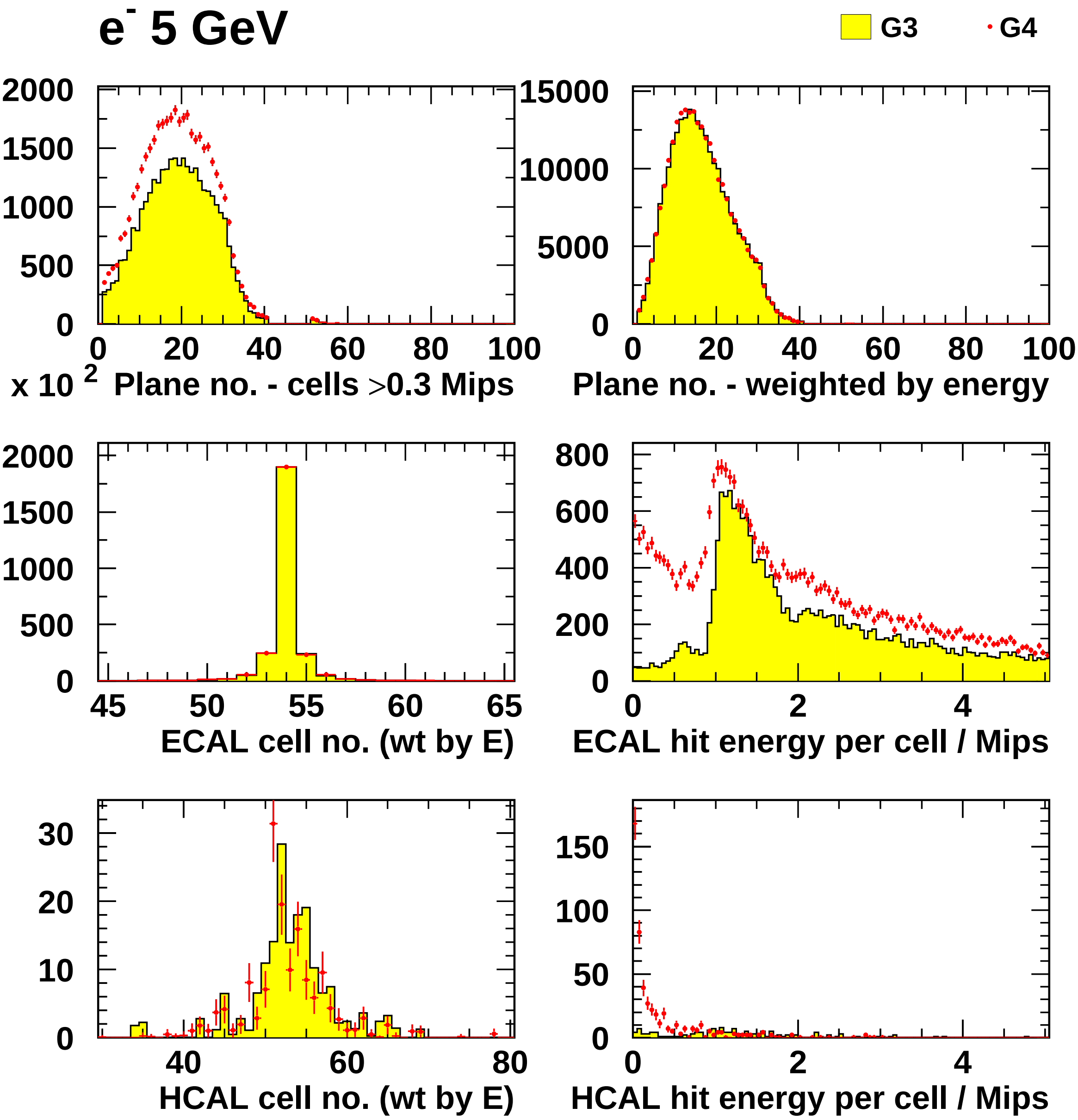
- Motivation for highly segmented calorimeter - Energy Flow.
- Simulation (Mokka/Geant4) $\Rightarrow$ 30%/$\sqrt{E}$ resolution achievable. But can we trust the Monte Carlo for hadronic shower simulation?
- Preliminary comparison of GEANT3 with GEANT4.
- + brief study of different models in Geant4.
- + brief comparison RPC vs scintillator HCAL.
- Part of our program of simulation work as proposed to the PPRP.

Geant4/Geant3 comparison – procedure

- Broad idea is to compare physics content of Mokka (GEANT4) against other available MC's. Identify aspects of physics which differ and could affect jet or particle energy measurement. Hence find key areas where CALICE test beam data are needed to reinforce MC results.
- Start with TDR geometry. Compare Mokka/Geant3/Fluka etc. response for single particles. Identify differences / dependence on cutoffs.
- Run 5 GeV e^-, $\pi^\pm$, μ^- etc. (1000 of each) through Mokka-01-00. "Out of the box". Using GEANT 4.4.1 Patch01. Also samples at 2 GeV and 15 GeV.
- Using Tesla TDR geometry (later move on to test beam prototype); particles generated at normal incidence on front of barrel ECAL.
- Mokka allows the same geometry to be written as GEANT3 Fortran code (for this geometry). Implement this in BRAHMS (using bruser.car) for convenience.
- Run 2, 5, 15 GeV particles through BRAHMS. Default parameters (initially).
- Write out flat files of "hits" (energy deposits in detector cells) in same format as Mokka. Compare.

Electrons

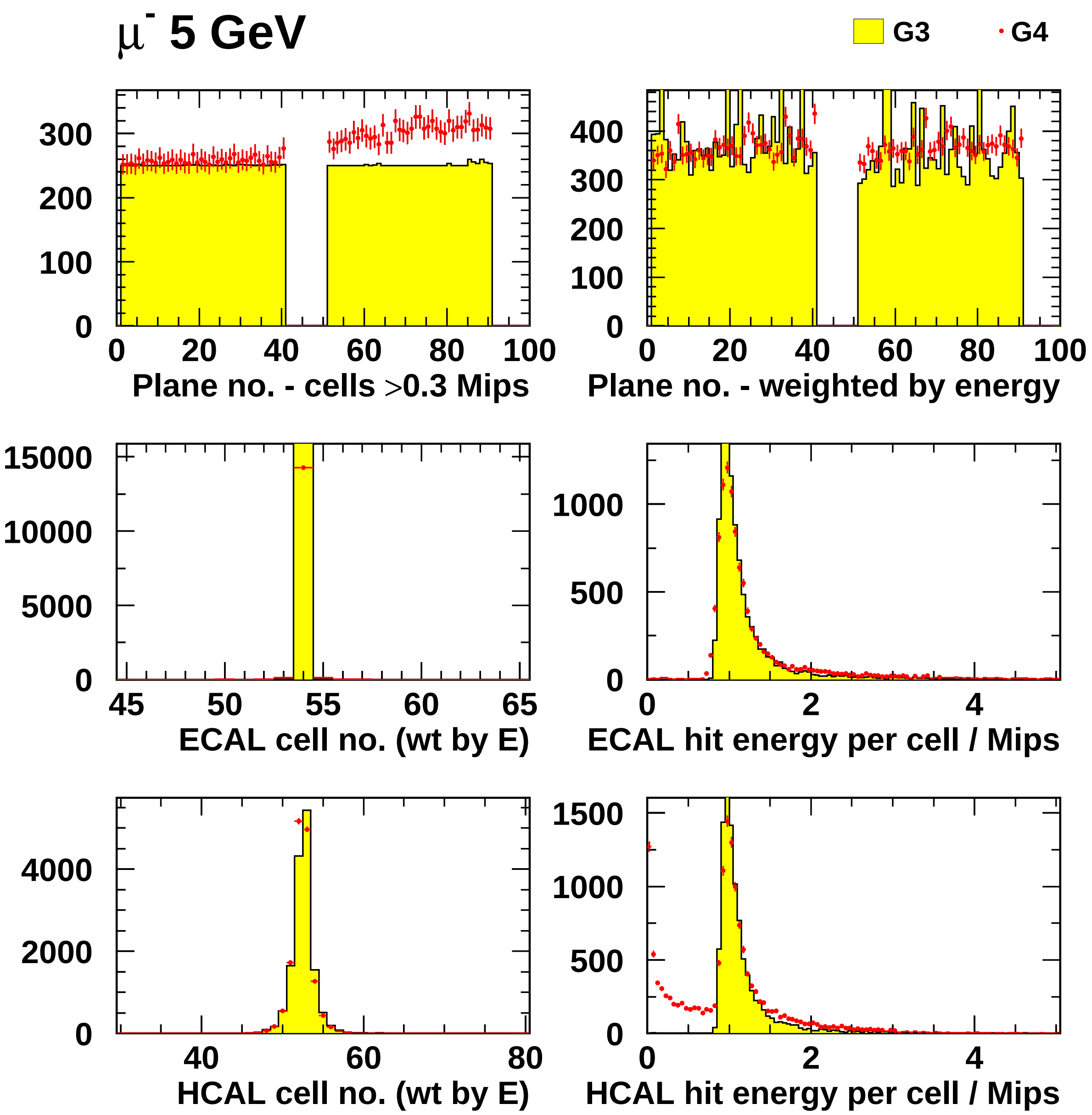
Compare samples of 250 5 GeV electrons.



Longitudinal profiles - energy looks OK; many more hit pads in G4 than G3. Additional hits of very low energy. n.b. transverse profiles shown in z-direction; orthogonal to magnetic field.

Muons

Compare samples of 250 5 GeV muons.

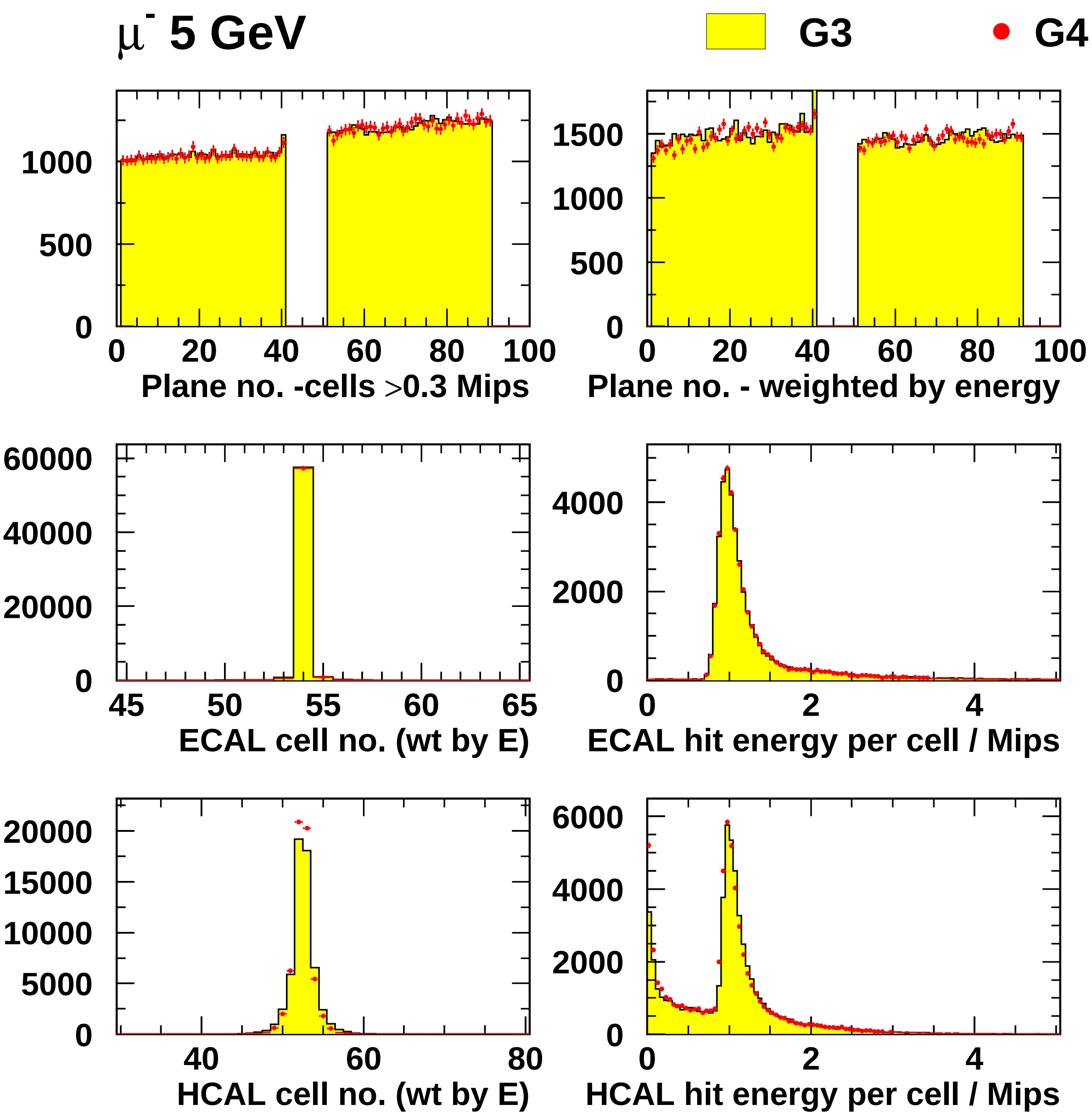


Additional hits in G4 turn out to be generated by electrons. By default Geant3/Brahms does not generate δ-rays; tracking cutoffs 1 MeV for e$^{\pm}/\gamma$, c.f. range cut of 5 μm in Mokka.

Muons

Turn on $\delta-$rays in BRAHMS; set tracking cutoffs to 10 keV for $e^{\pm}/\gamma$. Geant3 becomes slow.

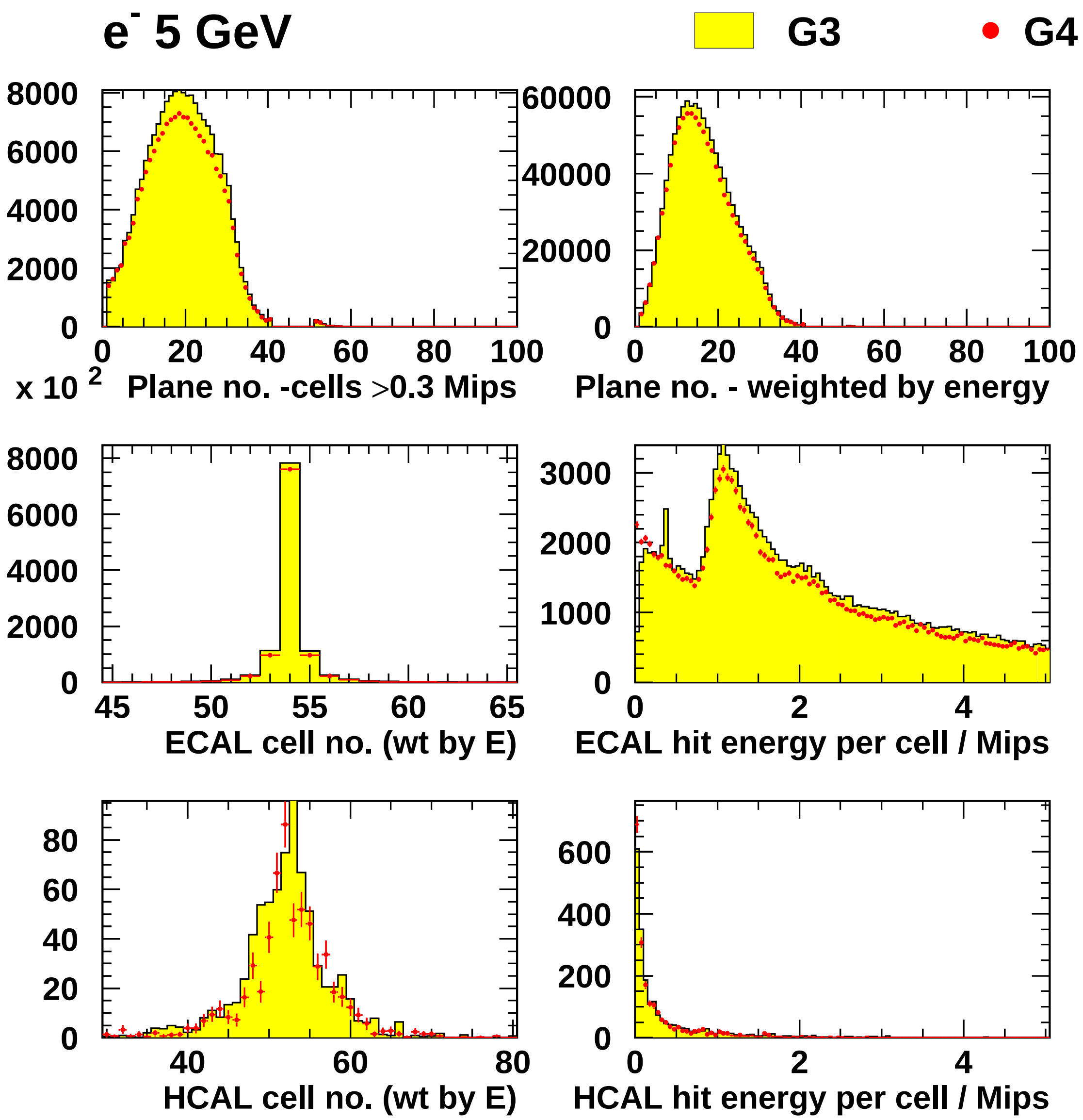
Compare samples of 1000 5 GeV muons.



Now comparison looks very good.

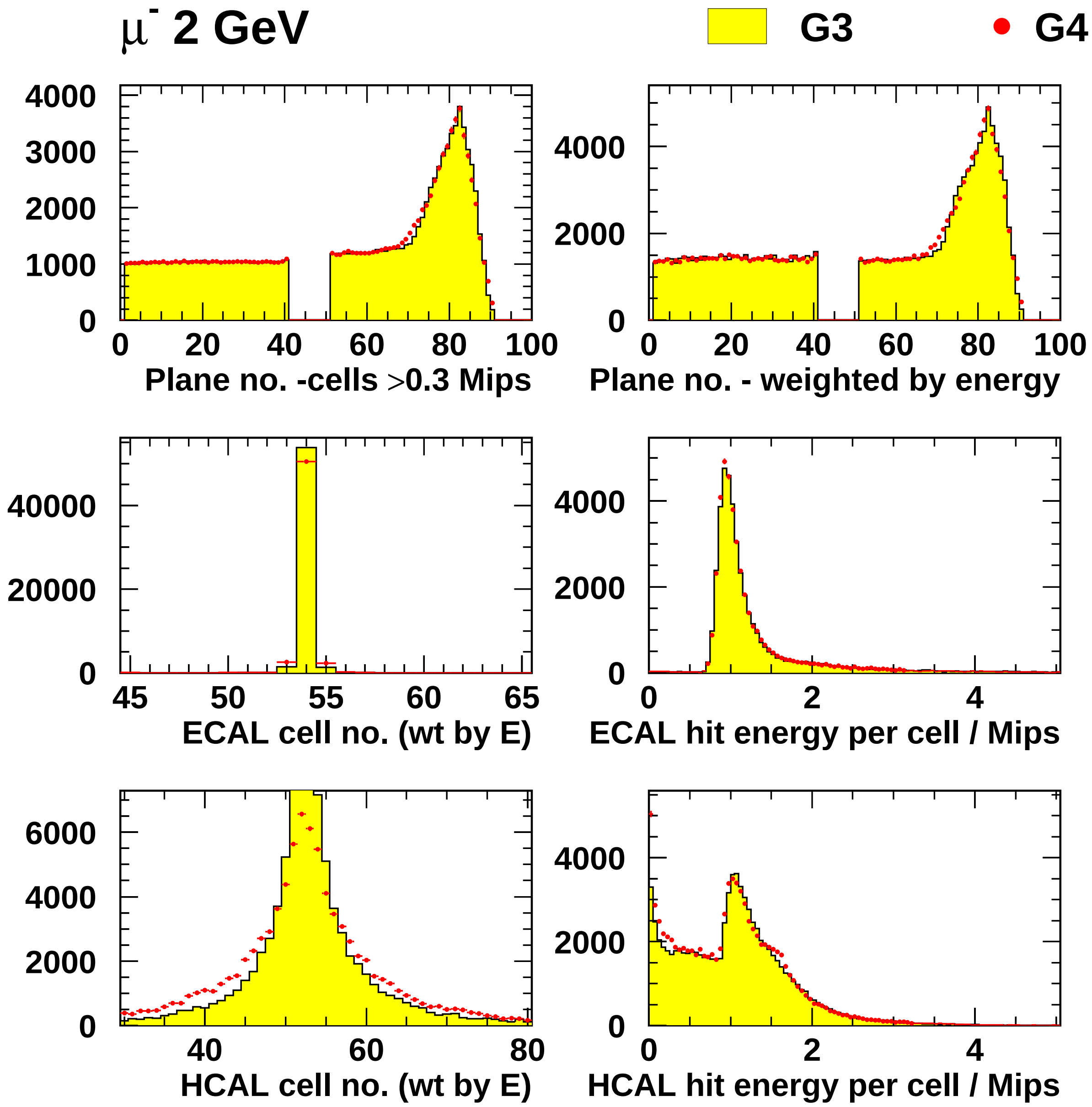
Electrons

Turn on $\delta-$rays in BRAHMS; set tracking cutoffs to 10 keV for e$^{\pm}/\gamma$. (Very slow).Compare samples of 1000 5 GeV electrons.



Again, much improved. Small discrepancies - possibly caused by different implementation of cutoffs? $\sim 6\%$ discrepancy in energy normalization.

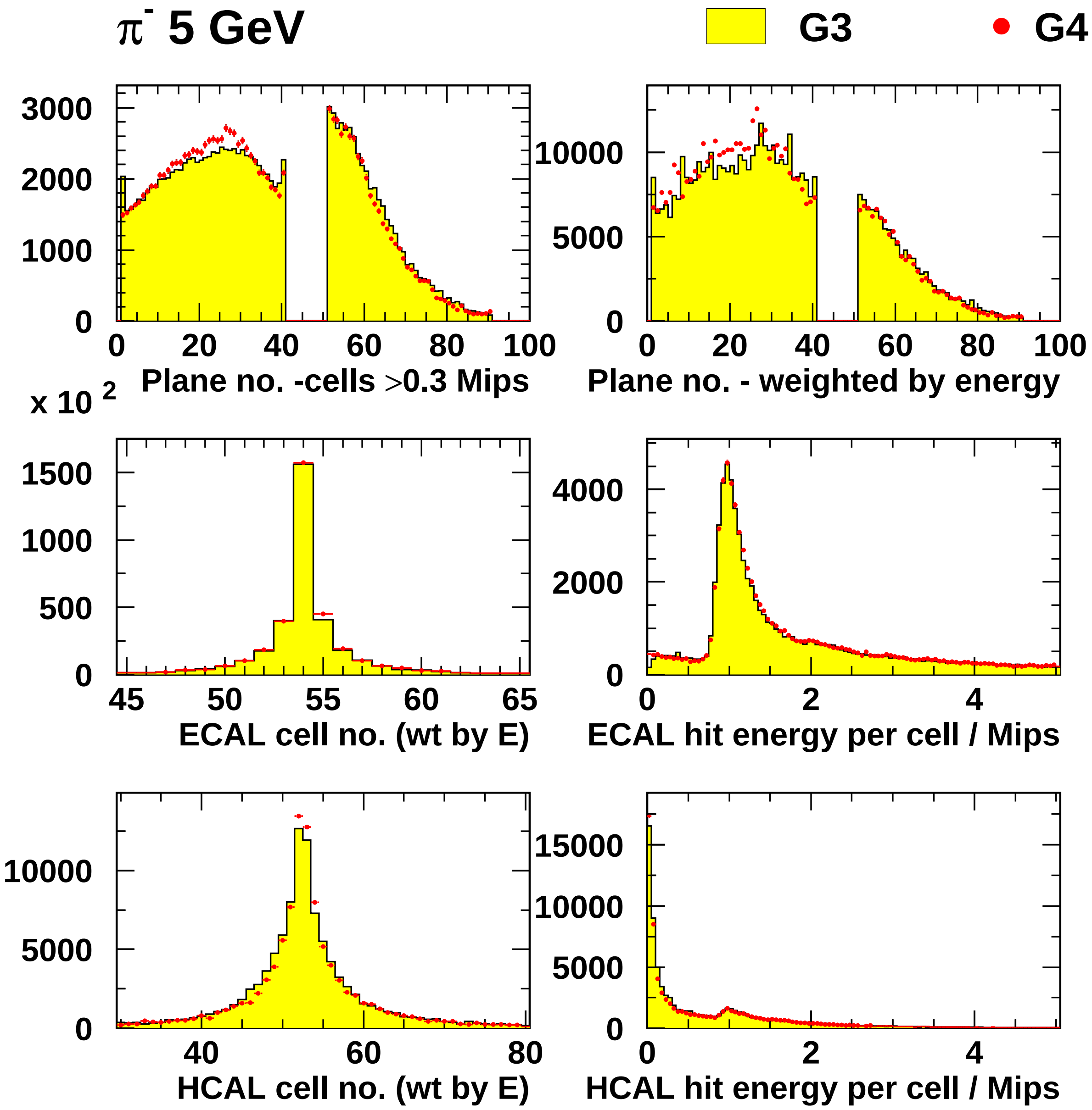
Stopping muons



OK in the ECAL; small differences in the HCAL where the muon spirals before stopping. Differences in multiple scattering? Needs investigation, but probably not too important for us.

Pions

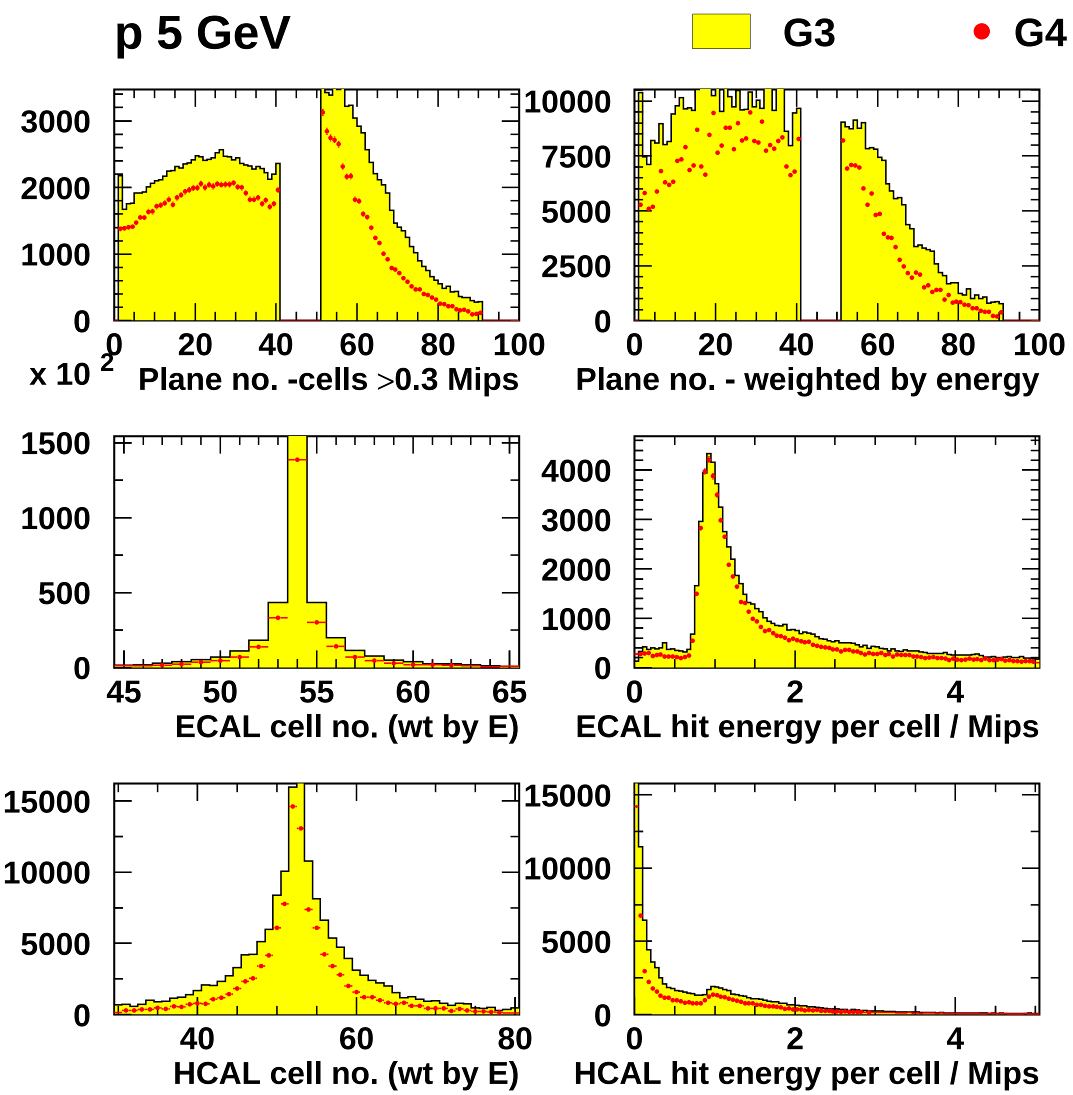
1000 event samples



Pretty good, though some small discrepancies seen. Statistics probably somewhat insufficient. Similar results at 2, 15 GeV.

Protons

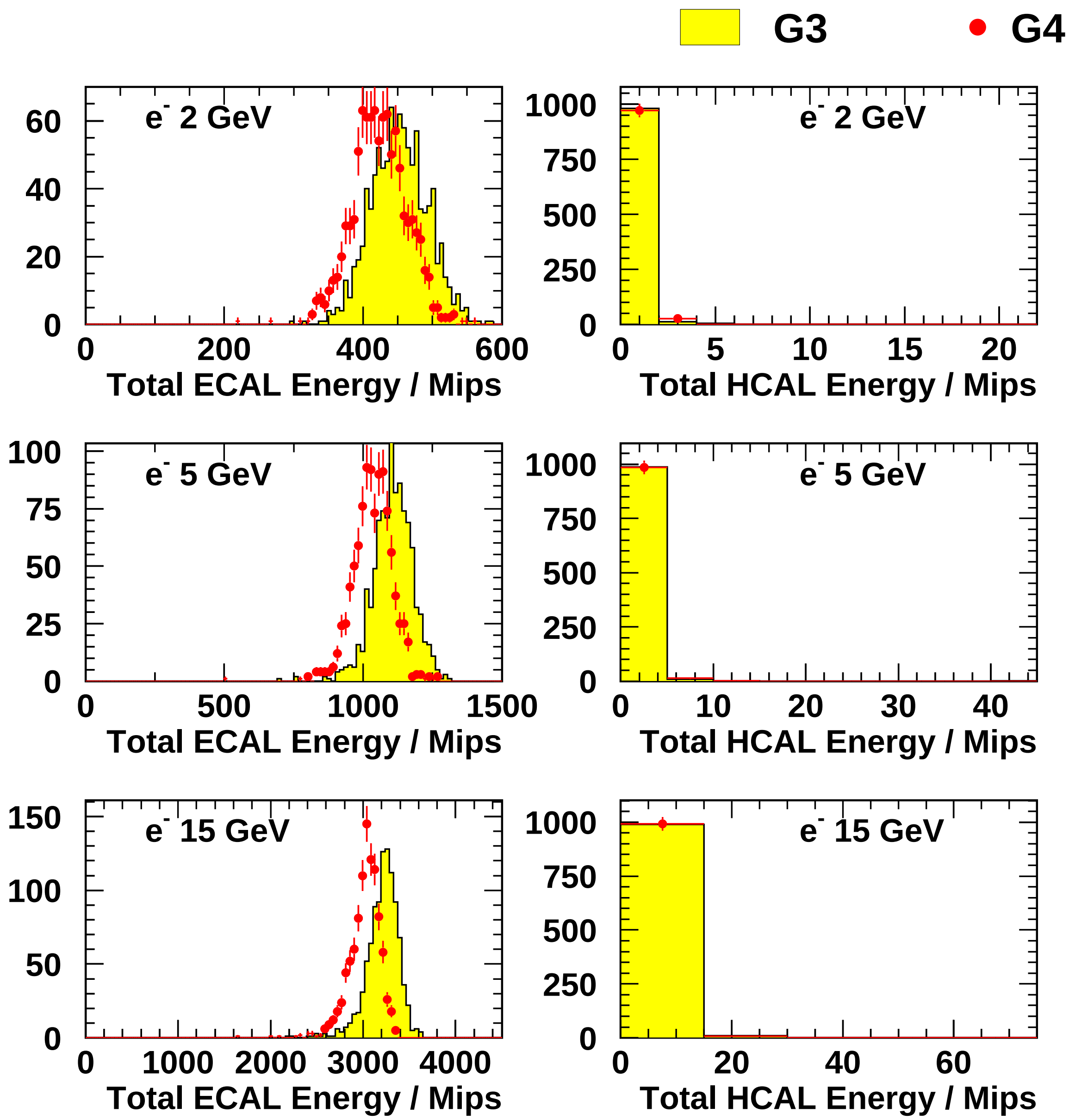
1000 event samples



Big discrepancies. Similar but larger differences at 2 GeV; similar but smaller at 15 GeV.

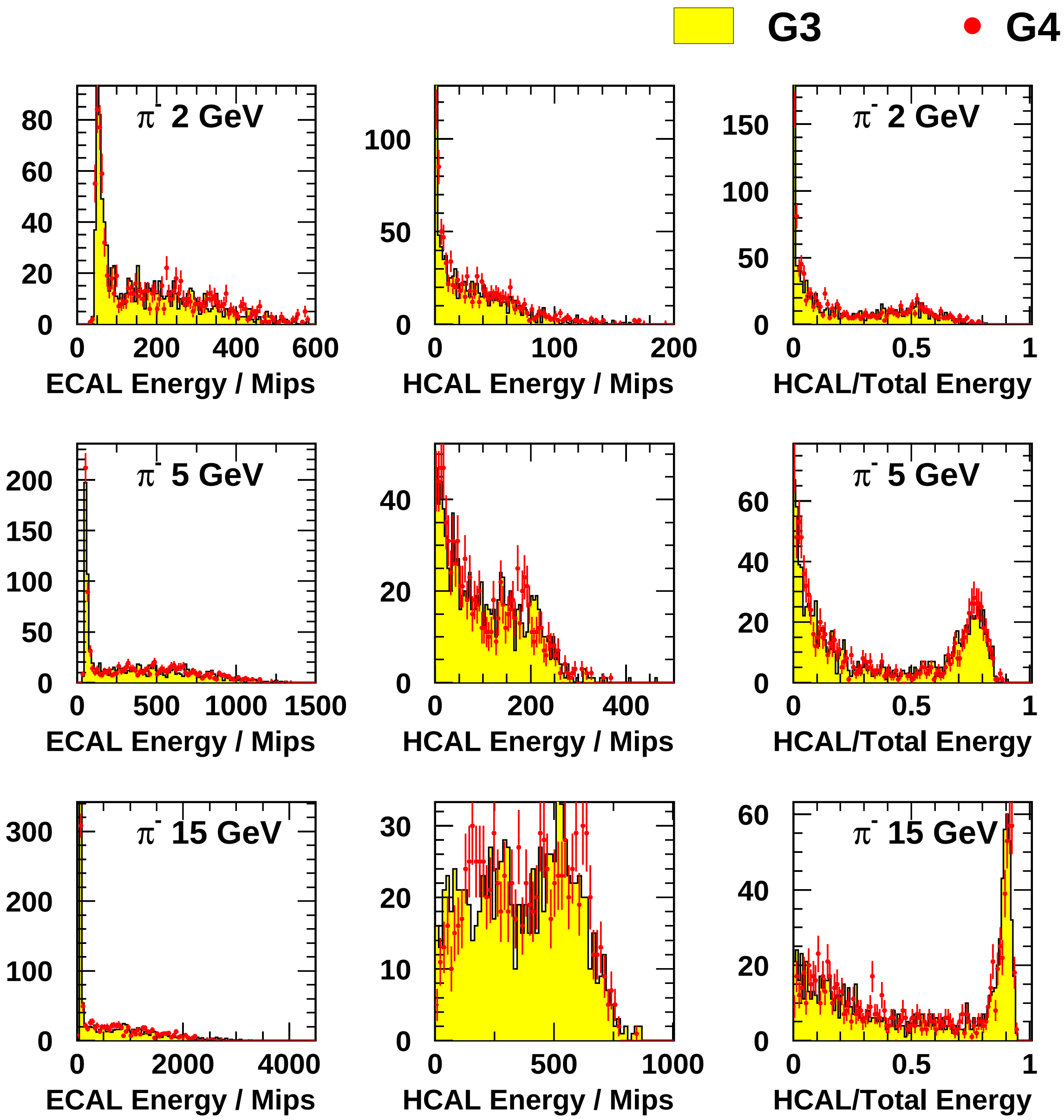
Study other hadrons – $\pi^{\pm}$, $K^{\pm}$ and K^0_L show similar levels of G3/G4 agreement. Neutrons look just as bad as protons.

Electron summary



Resolution in reasonable agreement, but response a little higher ($\sim 6\%$) in Geant3 than Geant4. (Actually energy scale was better before reduced thresholds in Geant3, but resolution worse!) Needs more work to understood this better.

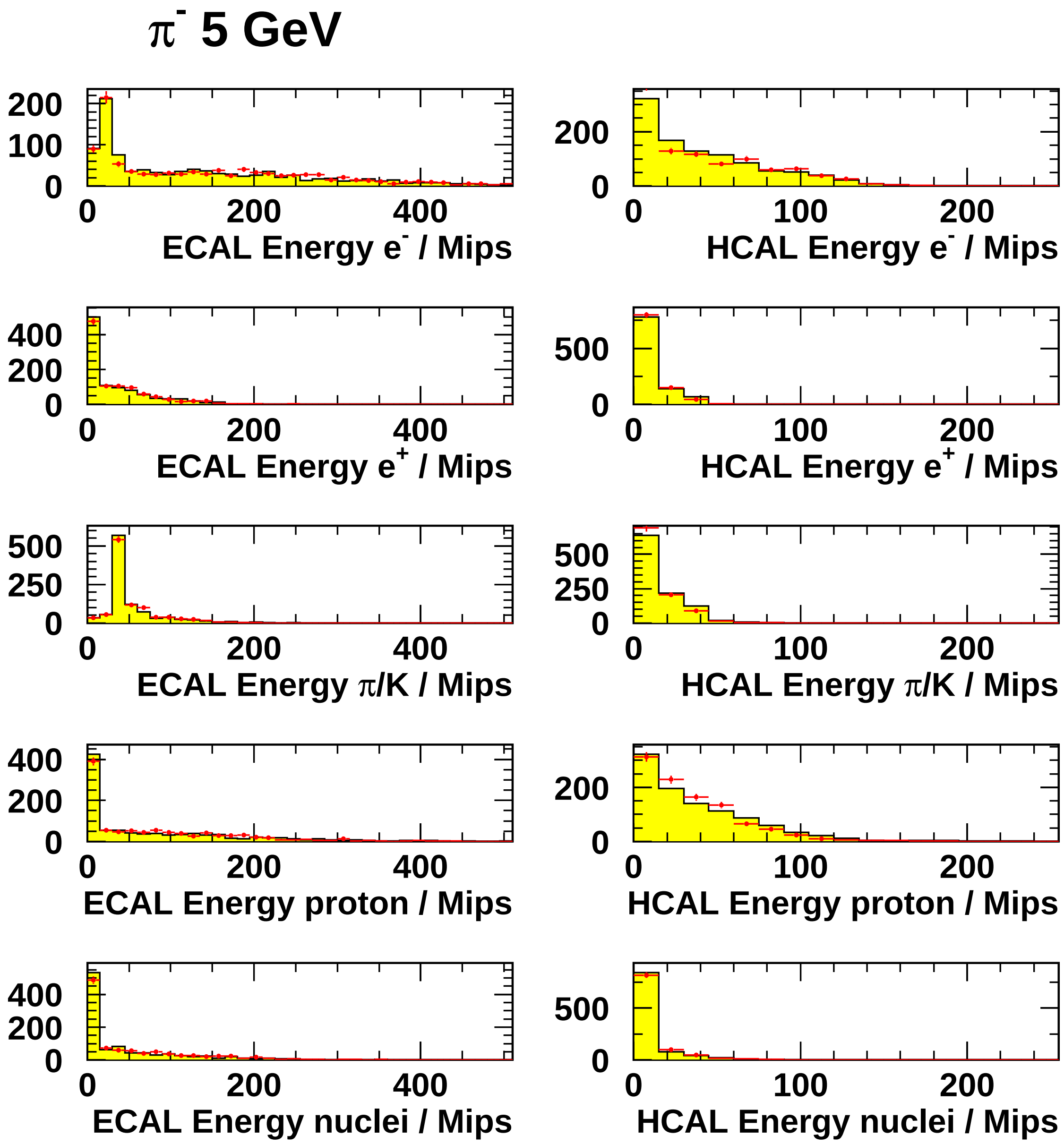
Pion summary



ECAL looks pretty good. Some discrepancies in HCAL. Follow these up...

Pion shower composition

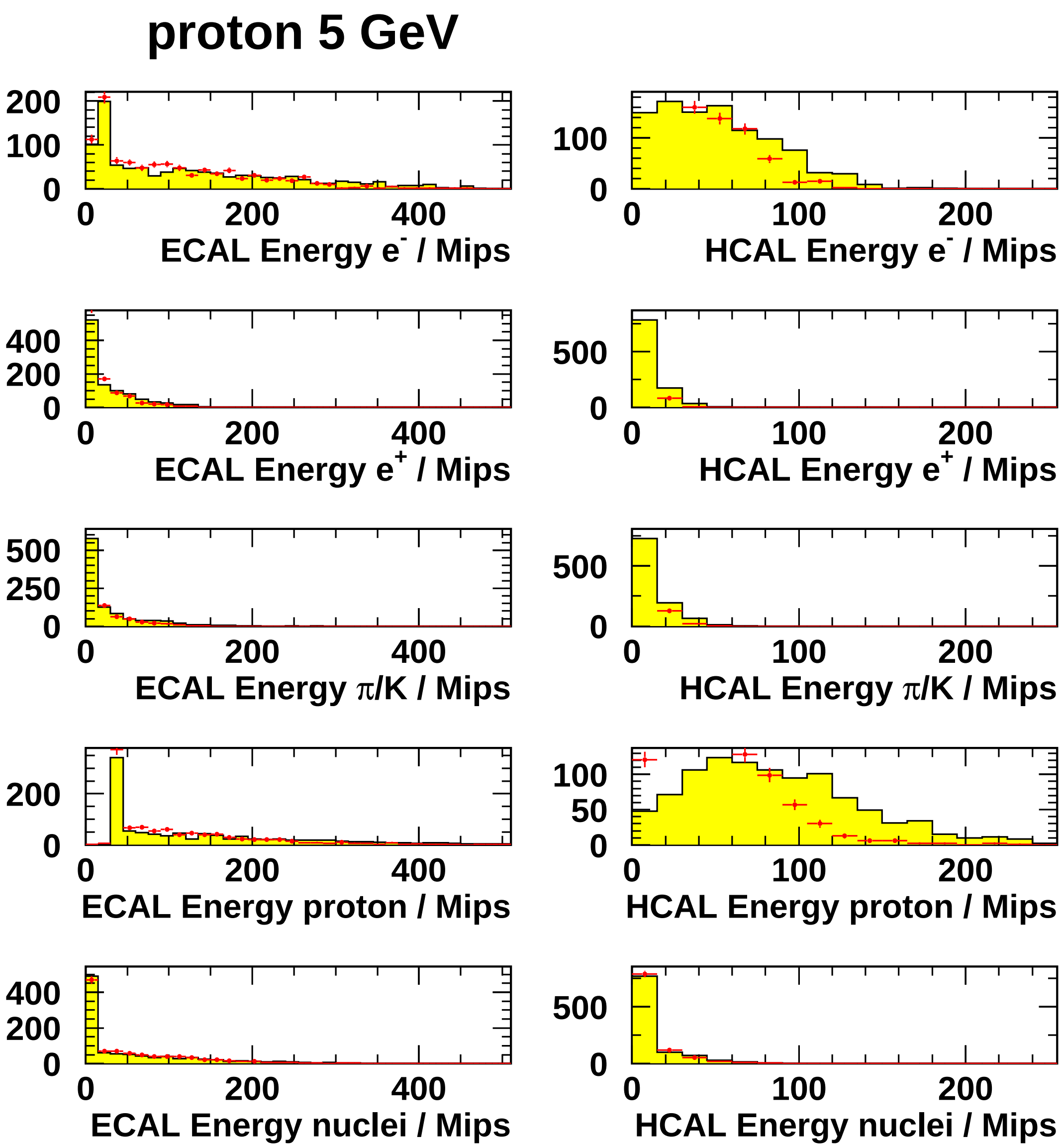
Can look at energy deposited by various particle types.



ECAL looks pretty good. Discrepancies in HCAL mostly associated with proton component.

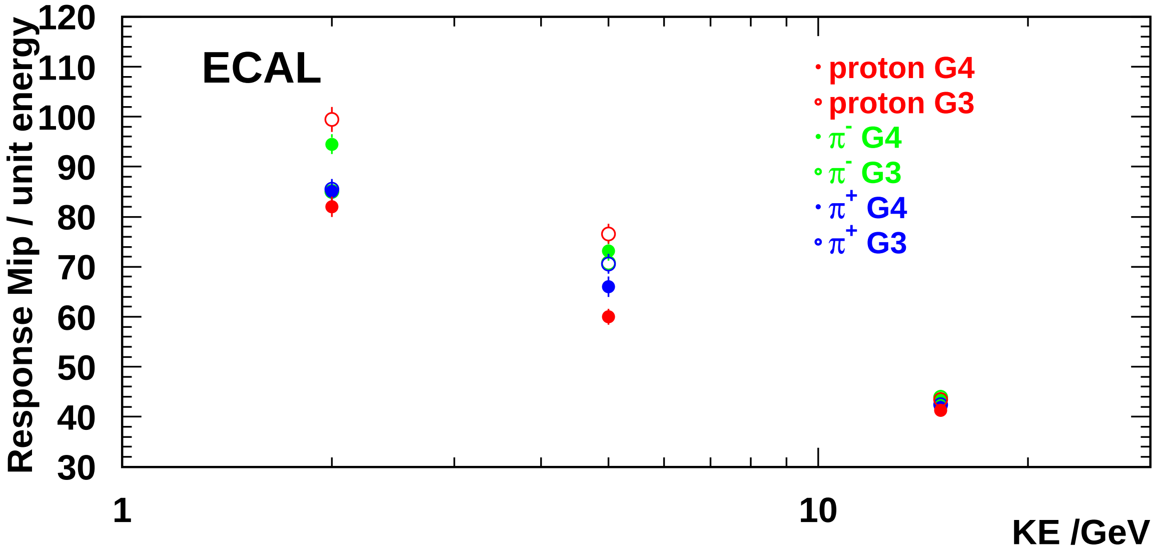
Proton shower composition

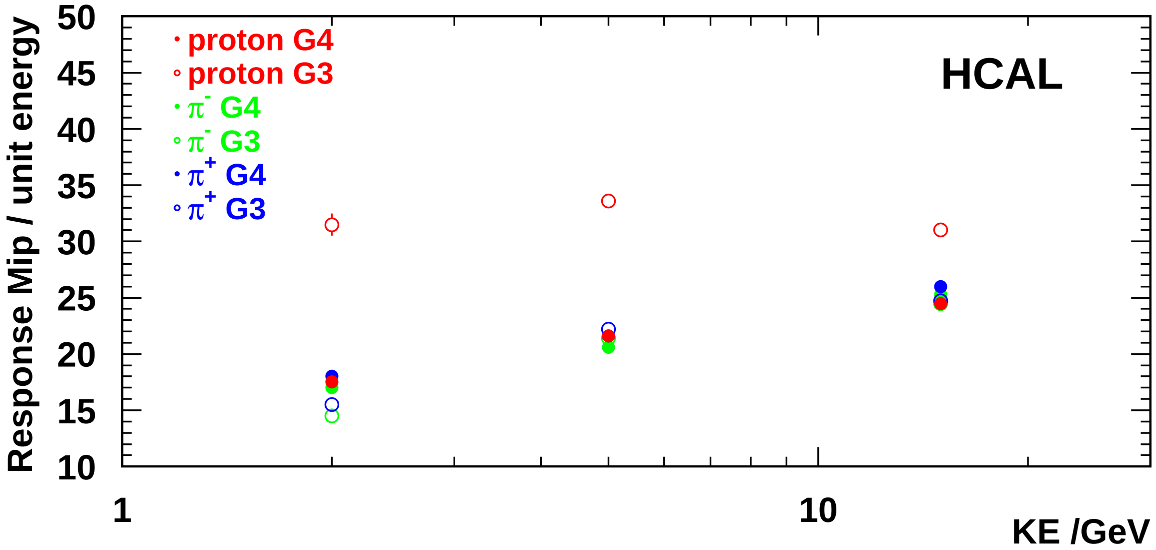
Can look at energy deposited by various particle types.



The much larger discrepancies in HCAL again mostly associated with proton component. Maybe differences in creation/transport of low energy neutrons?

Hadron response

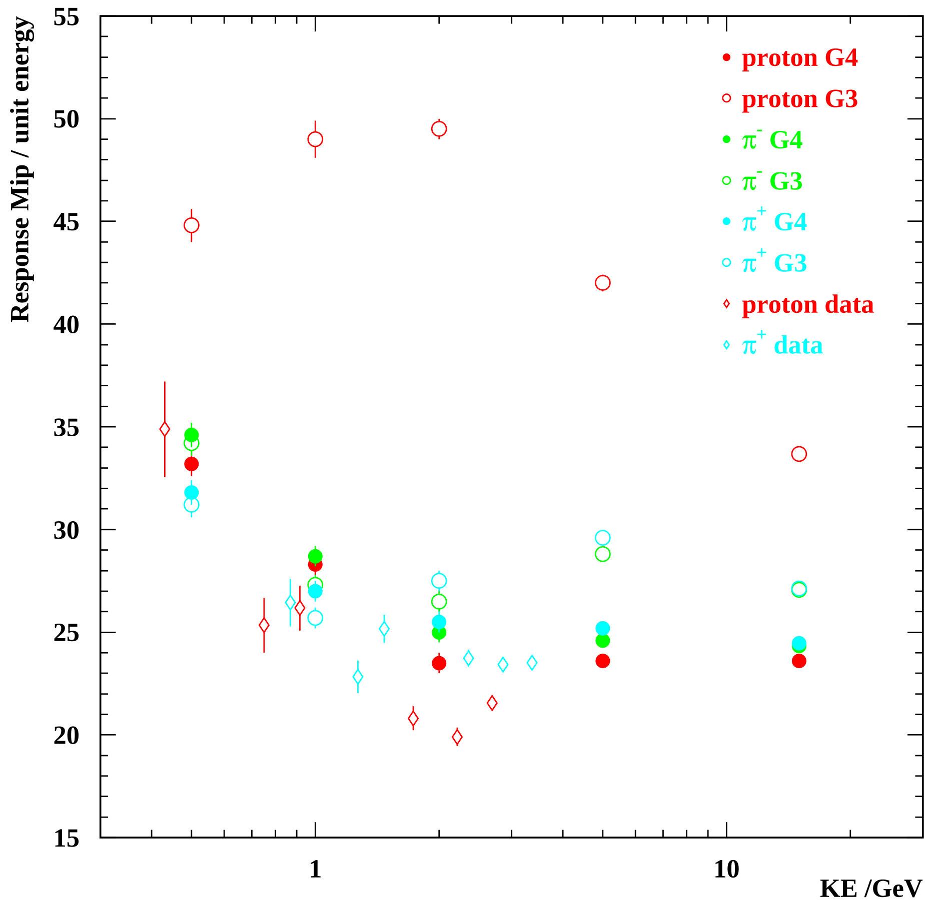




Summarises discrepancy between Geant3/Geant4 for protons again.

Comparison with MINOS

Performing similar comparisons between Geant3 and Geant4 for MINOS. And MINOS has a fine-grained Fe-Scintillator calibration module in the test beams at CERN.

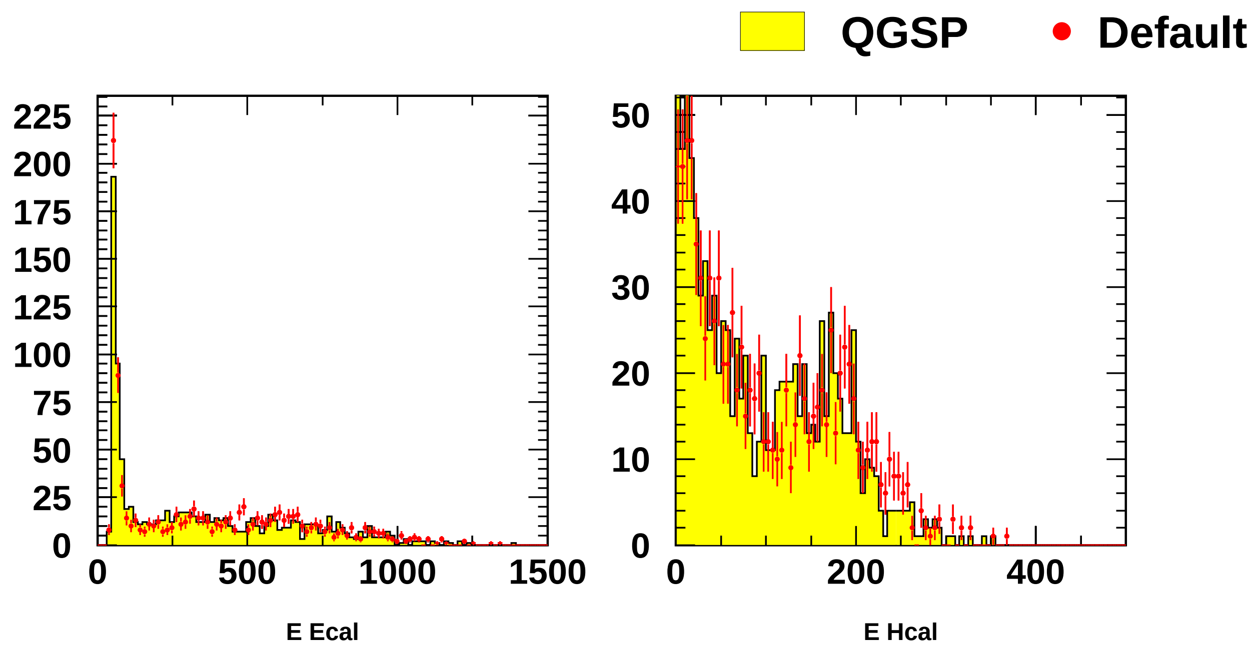


Similar discrepancy between protons and pions seen in MINOS as in Calice simulation. Data seem to favour Geant4. Better data on the way.

Physics lists for calorimetry.

Geant4 is a toolkit; provides various alternative physics models, and it's not obvious which to use.

In Geant 4.4.1 standard packaged sets of physics processes have been provided. Have started to look at these, taking 5 GeV π^- for comparison (very preliminary).



Seems that the (more detailed) QGSC and QGSP models differ from LHEP (basically what Mokka uses) by a few %. Maybe a bit more for the baryon content of showers.

From Geant4 web page...

For calorimetry, we provide four alternative physics lists.

- The first physics list, LHEP, is the fastest, when it comes to CPU. It uses the LEP and HEP parametrized models for inelastic scattering. The modeling parametrizes the final states individual inelastic reactions, so you will not see resonances, and the detailed secondary angular distributions for O(100MeV) reactions may not be described perfectly. The average quantities will be well described.

- The second physics list, QGSP, uses theory driven modeling for the reactions of energetic pions, kaons, and nucleons. It employs quark gluon string model for the 'punch-through' interactions of the projectile with a nucleus, the string excitation cross-sections being calculated in quasi-eikonal approximation. A pre-equilibrium decay model with an extensive evaporation phase to model the behavior of the nucleus 'after the punch'.

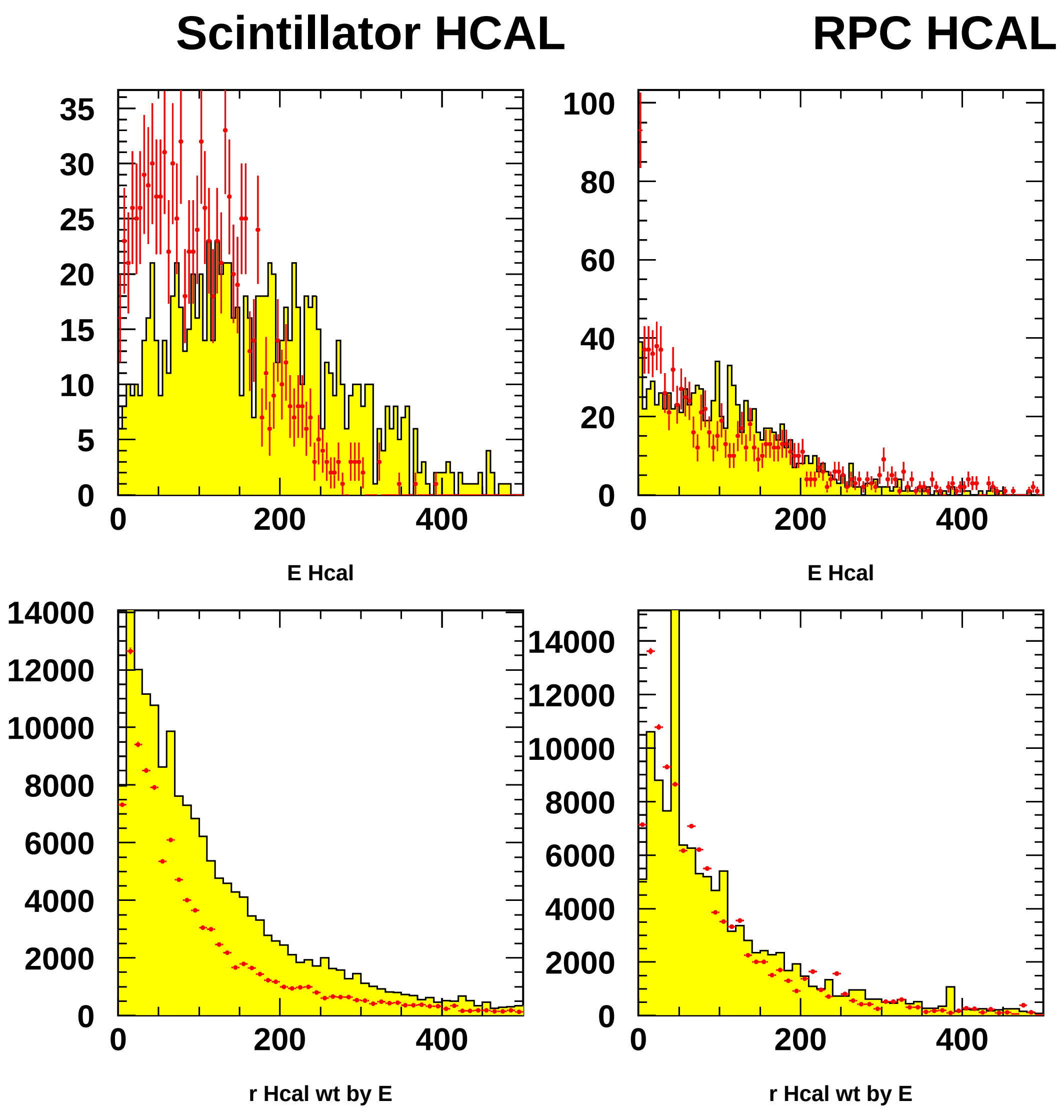
- The third list, QGSC, is as QGSP for the initial reaction, but uses chiral invariant phase-space decay (multi-quasmon fragmentation) to model the behavior of the system's fragmentation.

- The fourth list, FTFP, is similar to QGSP for the treatment of the fragmentation, but the string excitation/fragmentation is changed from quark-gluon string model to a diffractive string excitation similar to that in FRITJOF, and the Lund fragmentation functions.

Note that the models used in lists 2,3,4 in general give somewhat better descriptions of microscopic cross-section data than list 1, and will produce the resonances. Once the electromagnetic part of the shower is parametrized, you will see a marked difference in CPU performance, though. The moment we can convince ourselves that LHEP can describe the test-beam data, it will therefor be the preferred solution for calorimeter simulation.

Choice of HCAL technology?

At Jeju, Henri Videau reported differences in shower width in the HCAL between scintillator and RPC. Both are implemented in Mokka, and have now also looked in Geant3. Very preliminary. Samples of 5 GeV neutrons.



Curious. Geant3/Geant4 agreement MUCH better for RPC than scintillator. In both cases, showers narrower in RPC than scintillator. Need to understand what's going on here.

Summary

- Aiming to evaluate physics content of various Monte Carlos and understand key requirements for Linear Collider physics.
- Starting at the bottom – single particles – then move on to jets and physics studies.
- First comparisons of Geant3/Geant4 look very encouraging. Most things agree to few% level.
- Several topics clearly need to be investigated further.
- Interesting to look at Fluka, which has a more different hadronic model.