Fluka, comparison of hadronic models

Using Fluka for CALICE

- Motivation
- Updates since Paris
- Summary

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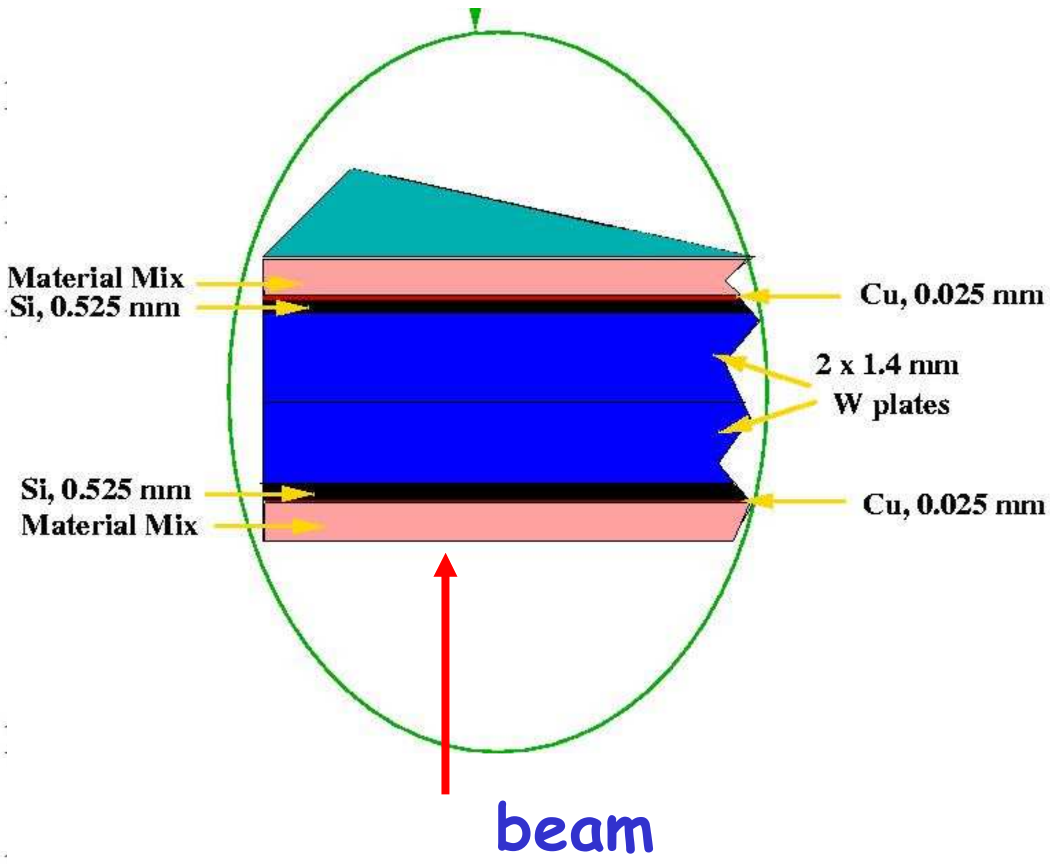
Motivation

- Detector design choices require reliable hadronic interaction modelling
- Fluka offers very serious alternative physics models to those in GEANT
- Well designed test beam study should discriminate between models
- Systematic comparison of GEANT and FLUKA physics
  - Identify key areas for CALICE test beam(s)
  - Availability of FLUKA via G4 coming, but CALICE test beam earlier!
- Wish to…
  - Test new Mokka detector models
  - Avoid coding each geometry directly in FLUKA
    - ⇒ difficult, error prone, may introduce non-physics differences
  - Also investigate full TDR type geometry
- Issues
  - Fluka geometry defined by data cards
  - Only limited geometrical structures supported
  - Repeated structures at 1 level only
- Closely related to G3/G4 studies (G.Mavromanolakis, D.Ward)

Models compared

model tag		brief description [NB:15/16 models from G.Mavromanolakis!]
G3-GHEISHA	:	GHEISHA
G3-FLUKA+GH	:	FLUKA, for neutrons with $E < 20$ MeV GHEISHA
G3-FLUKA+MI	:	FLUKA, for neutrons with $E < 20$ MeV MICAP
G3-GH SLAC	:	GHEISHA with some bug fixes from SLAC
G3-GCALOR	:	$E < 3$ GeV Bertini cascade, $3 < E < 10$ GeV hybrid Bertini, FLUKA, $E > 10$ GeV FLUKA for neutrons with $E < 20$ MeV MICAP
G4-LHEP	:	GHEISHA ported from GEANT3
G4-LHEP-BERT	:	$E < 3$ GeV Bertini cascade, $E > 3$ GeV GHEISHA
G4-LHEP-BIC	:	$E < 3$ GeV Binary cascade, $E > 3$ GeV GHEISHA
G4-LHEP-GN	:	GHEISHA + gamma nuclear processes
G4-LHEP-HP	:	as G4-LHEP, for neutrons with $E < 20$ MeV use evaluated cross-section data
G4-QGSP	:	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-QGSP-BERT	:	$E < 3$ GeV Bertini cascade, $3 < E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-QGSP-BIC	:	$E < 3$ GeV Binary cascade, $3 < E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-FTFP	:	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model with fragmentation ala FRITJOF
G4-QGSC	:	$E < 25$ GeV GHEISHA, $E > 25$ GeV quark-gluon string model
G4-FLUGG	:	a FLUKA interface to GEANT4 geometry

Longitudinal Response, 1 GeV μ^-



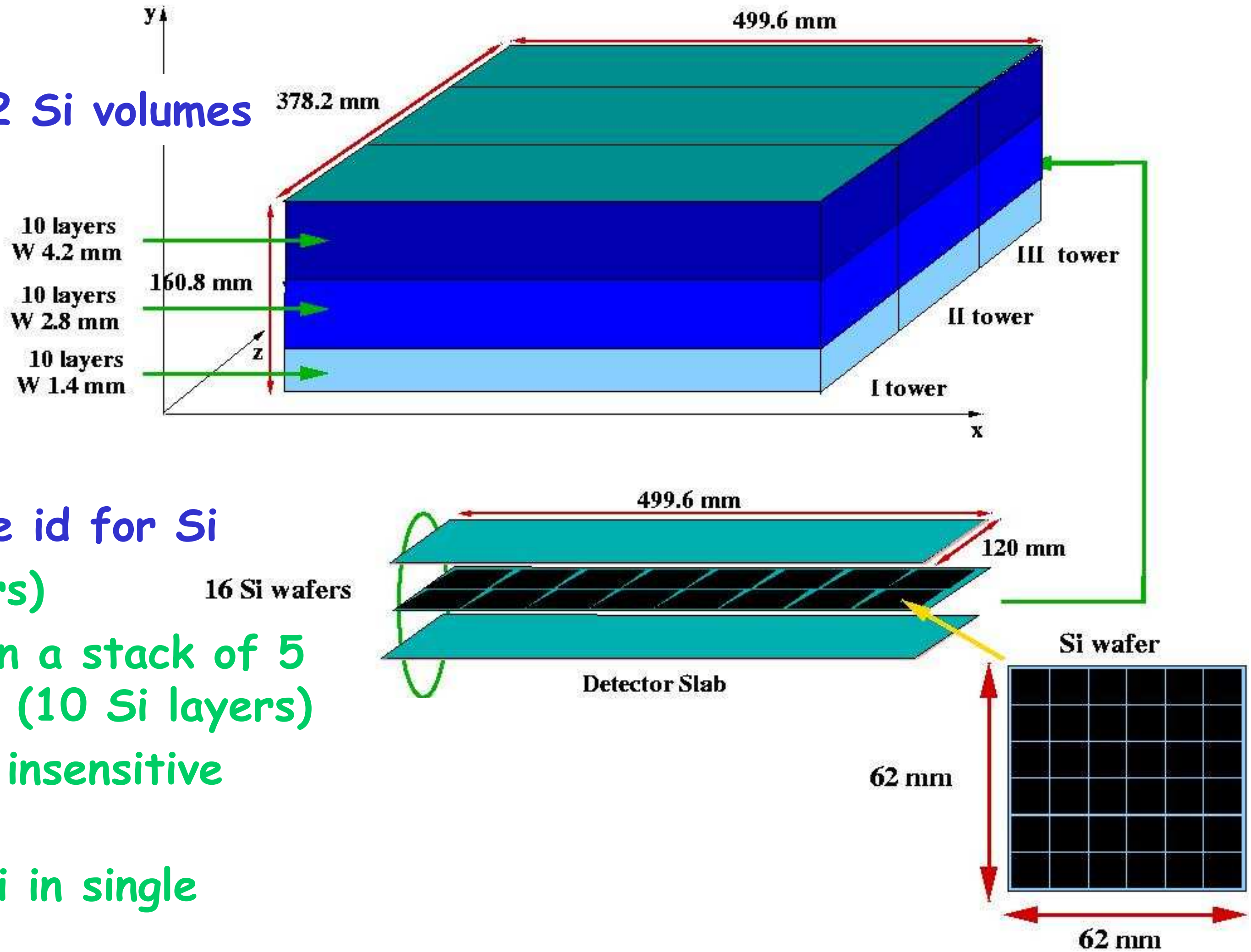
- Structure is from prototype "mix"
- Produces higher energy tail in odd Si layers
- Originally thought to be Fluka artefact, but also seen in G4 studies

Energy deposition

- Fluka attributes energy loss, either:
  - At a point: elastic/inelastic recoils, low energy neutron kerma, etc.
  - Distributed along a step: ionisation by charged particles
- For comparison with G3/G4, "old" fluka energy deposition algorithm (assigns ionisation energy at middle of step) is used.
  - Inaccurate when steps ~ volume size
  - Fluka authors strongly recommend track length apportioning algorithm

Fluka view of CALICE prototype

- FLUKA 'sees' 3x32 Si volumes



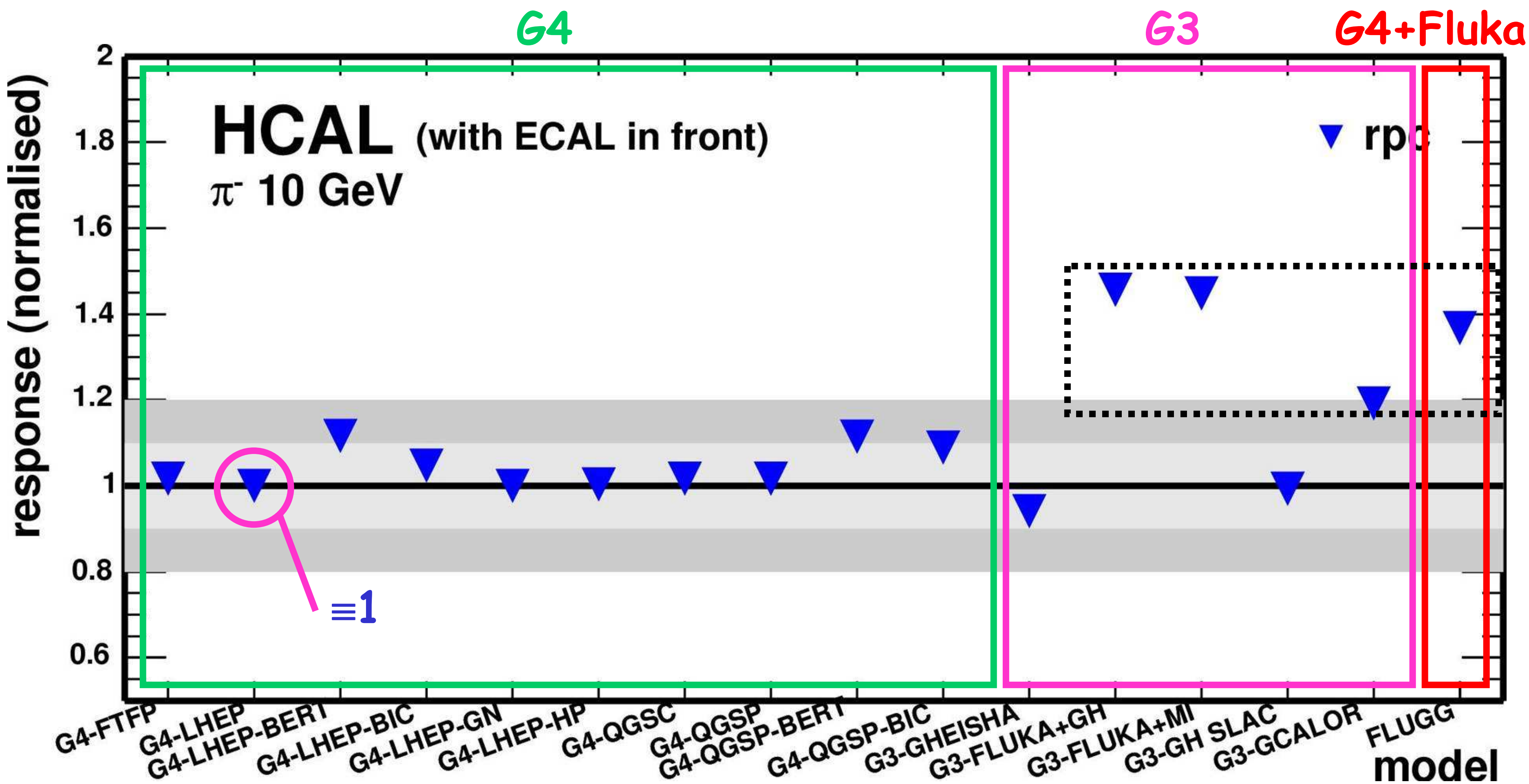
- Degenerate volume id for Si
  - In z (x3 towers)
  - In depth within a stack of 5 detector slabs (10 Si layers)
  - Correspond to insensitive regions
  - All sensitive Si in single volume id

[Fig. C. Lo Bianco]

Direct comparisons with G3/G4

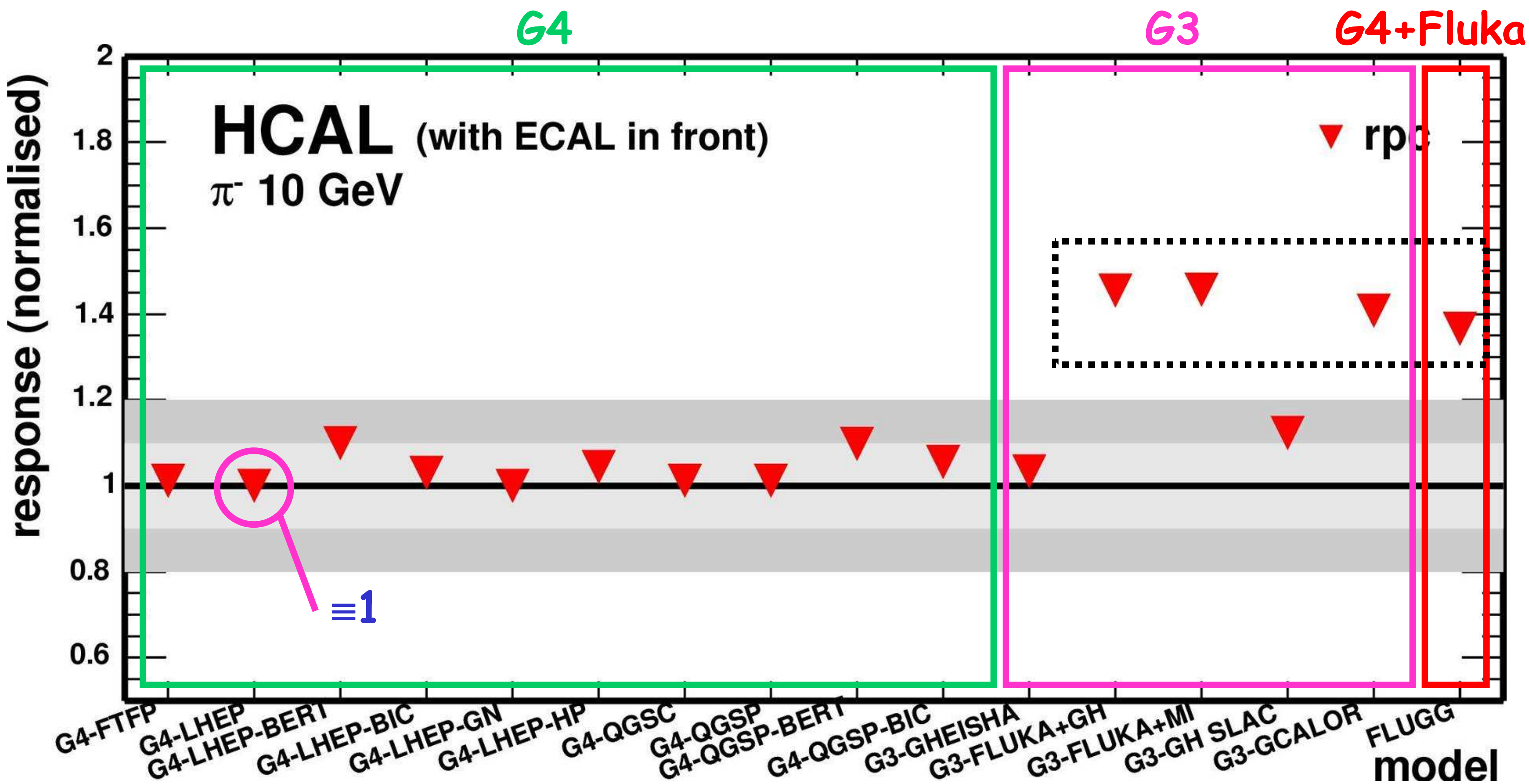
- Individual energy deposits from FLUKA are material type + (x,y,z)
- CGA method to provide {(x,y,z)→cell index} would be ideal
- Currently, use detailed knowledge of ECAL/HCAL geometry and active regions to
  - Sum energy deposits per cell per event
  - Write out hits files a la Mokka
    - ⇒ Allows direct comparison with G3/G4 model studies of GM/DRW
  - Labour intensive for changes to geometry/numbering…
- Some differences found between G3-4 vs. G3-FLUKA vs. G4+FLUKA (Flugg)
  - To be understood

<No. HCAL cells hit/event>, 10 GeV π^-



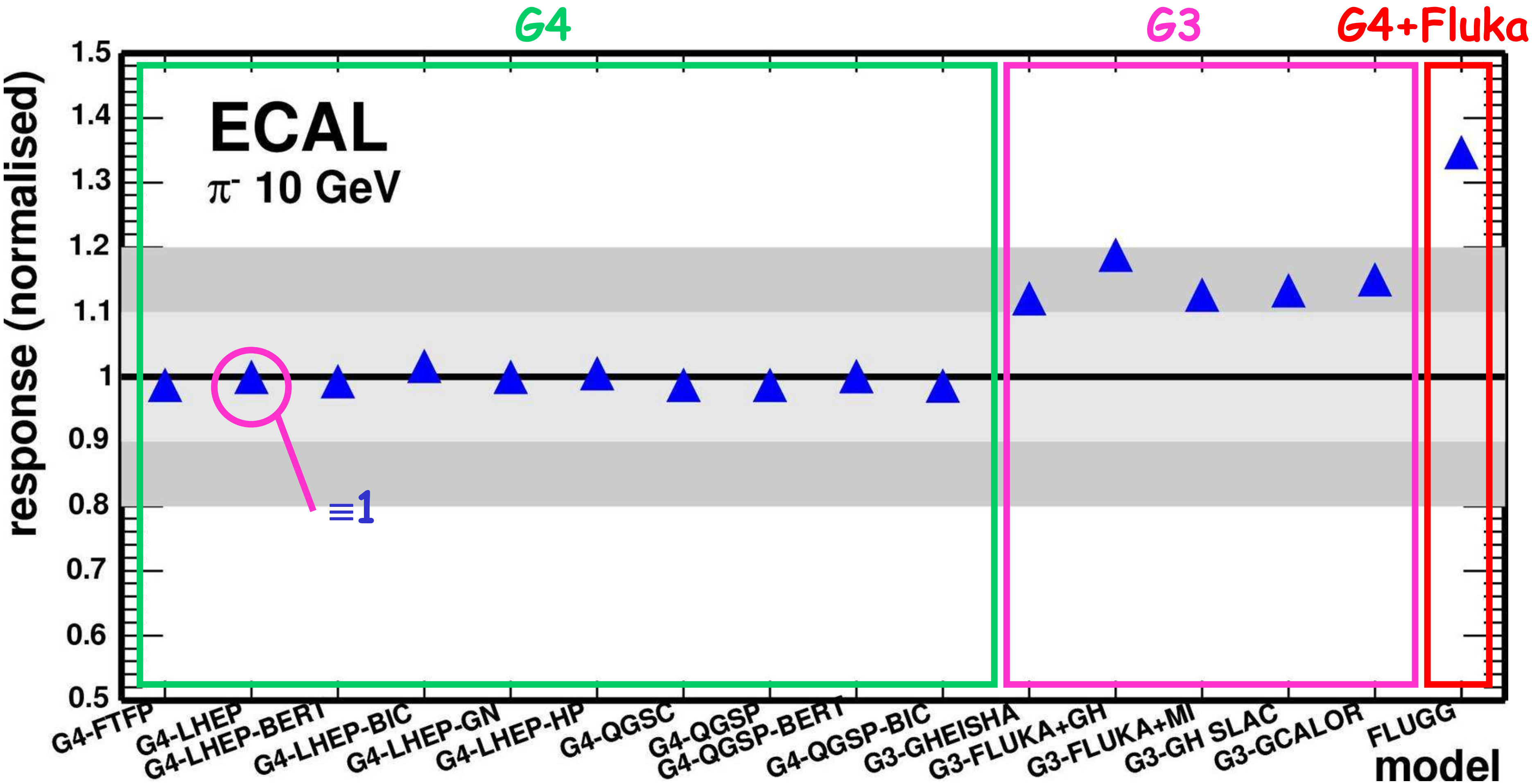
- RPC HCAL more stable vs. model than scint.
- Models incorporating FLUKA >20% above G4-LHEP

<HCAL energy observed/event>, 10 GeV π^-



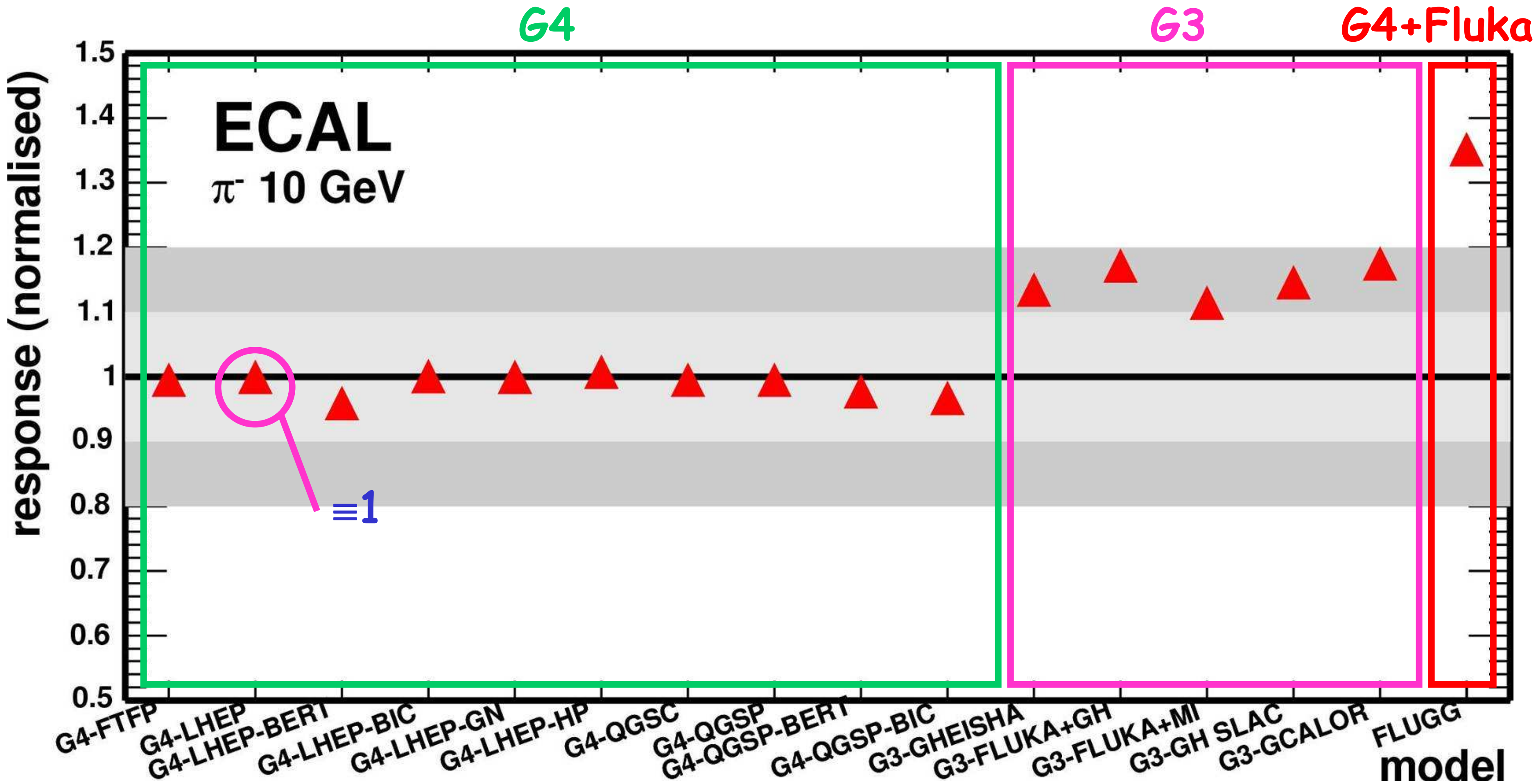
- FLUKA based models ~ similar in different frameworks

<No. ECAL cells hit/event>, 10 GeV π^-



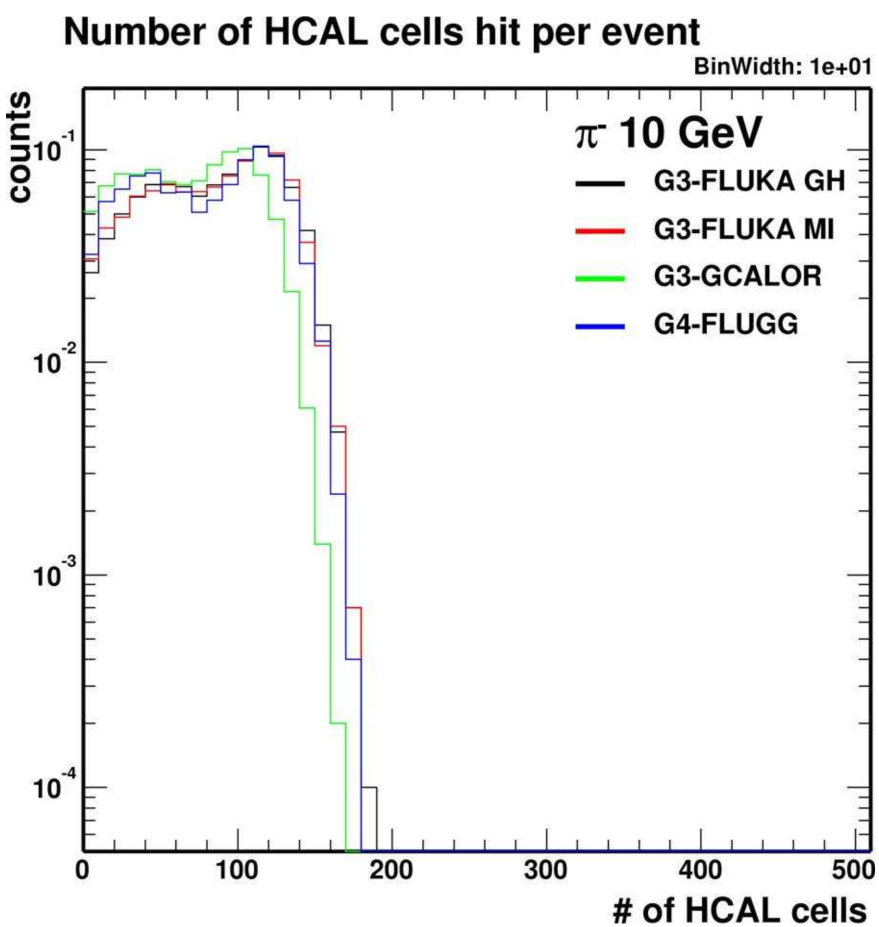
- Differences in EM response between G3/G4/Flugg frameworks

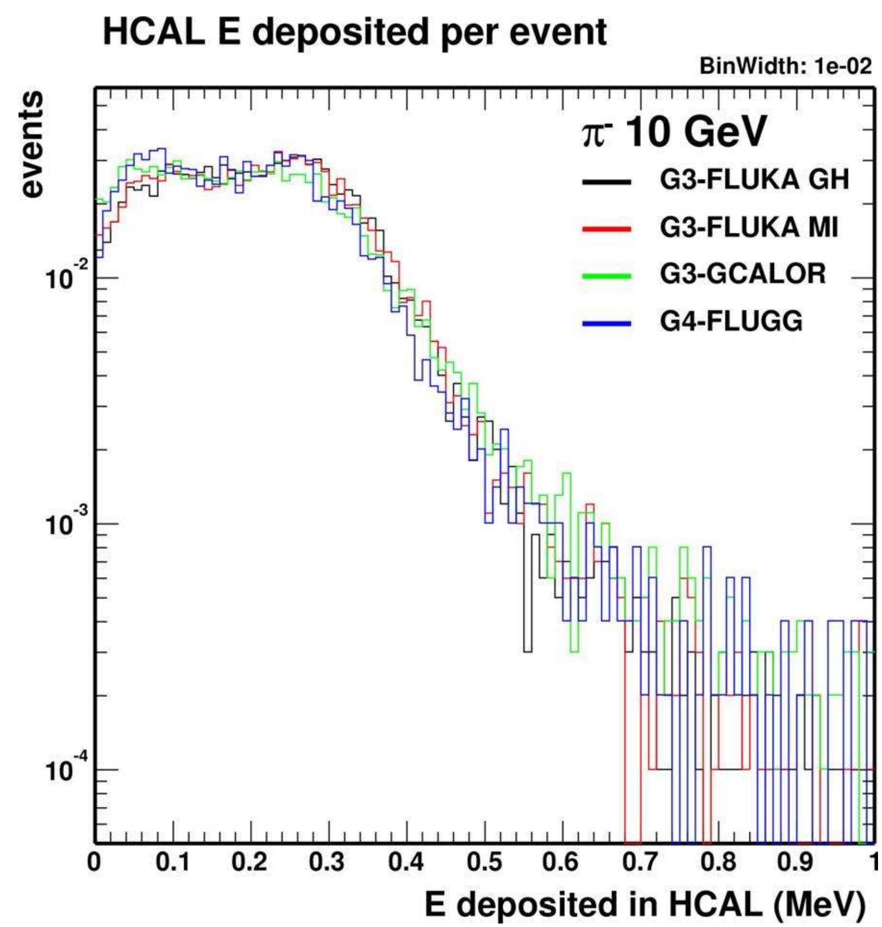
<ECAL energy observed/event>, 10 GeV π^-



- Energy/cell ~ agree OK

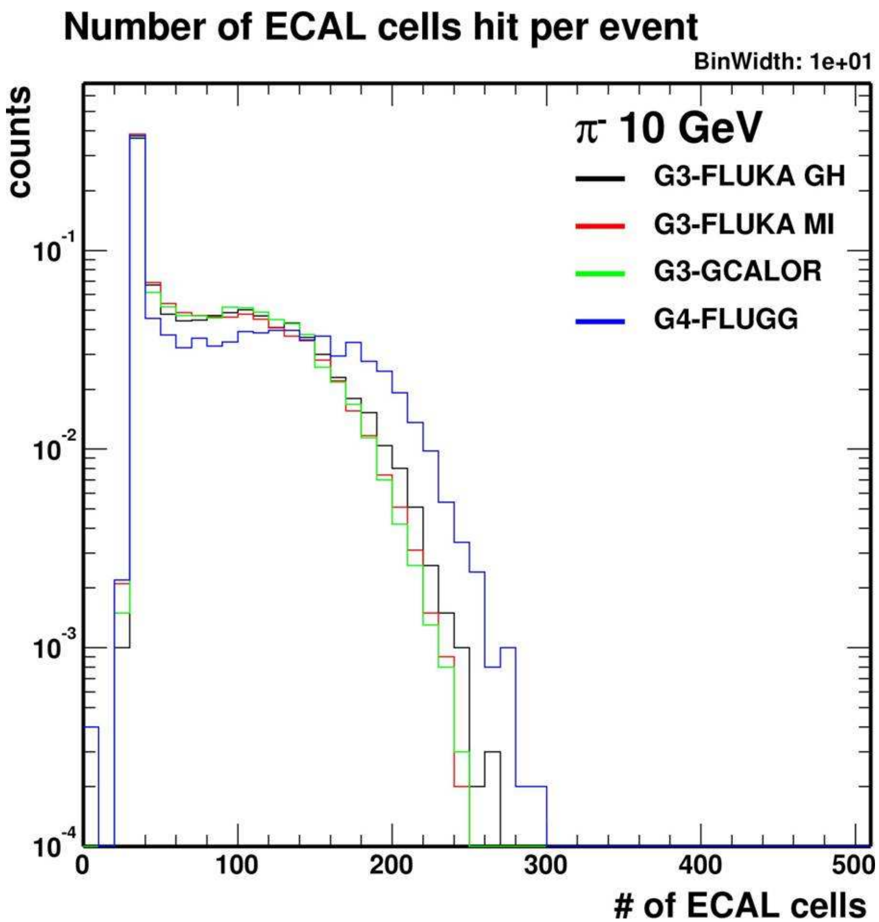
HCAL in FLUKA based models

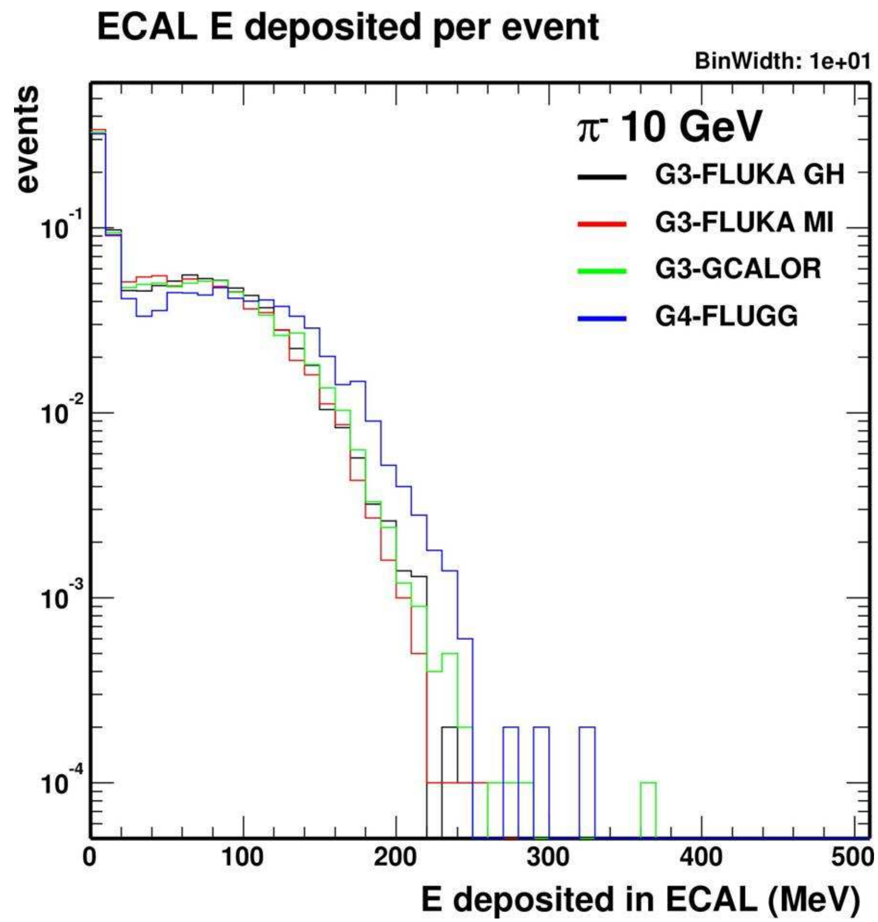




- Hcal cells hit lower for mixed G3-Fluka+Bertini, as earlier

ECAL in FLUKA based models

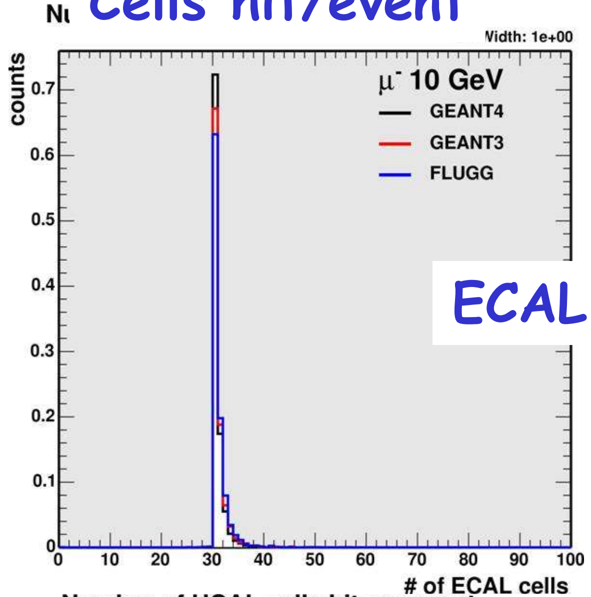


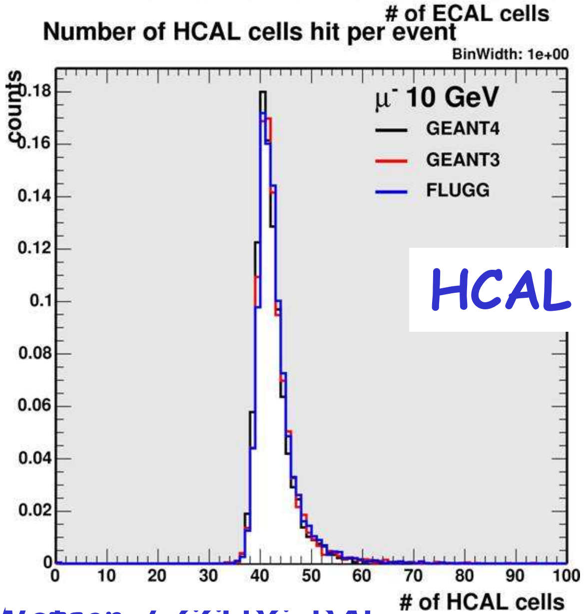


- Flugg higher both in hits and energy
- Consider muons and electrons separately

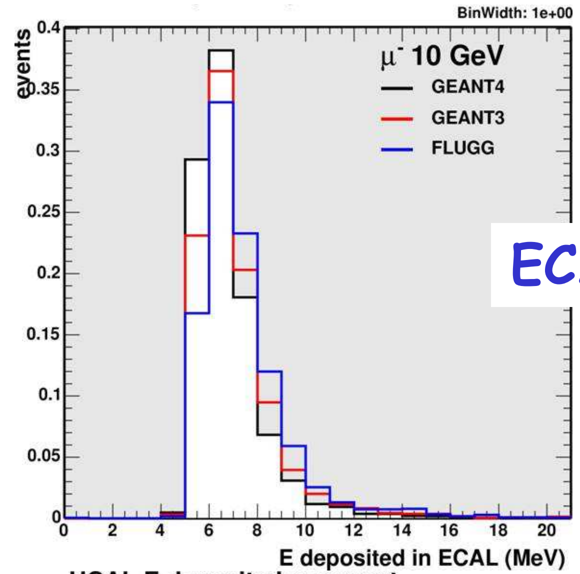
Agreements

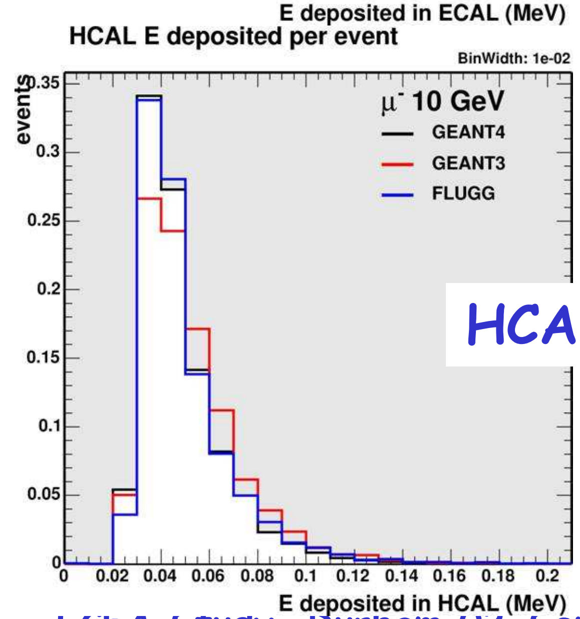
Cells hit/event



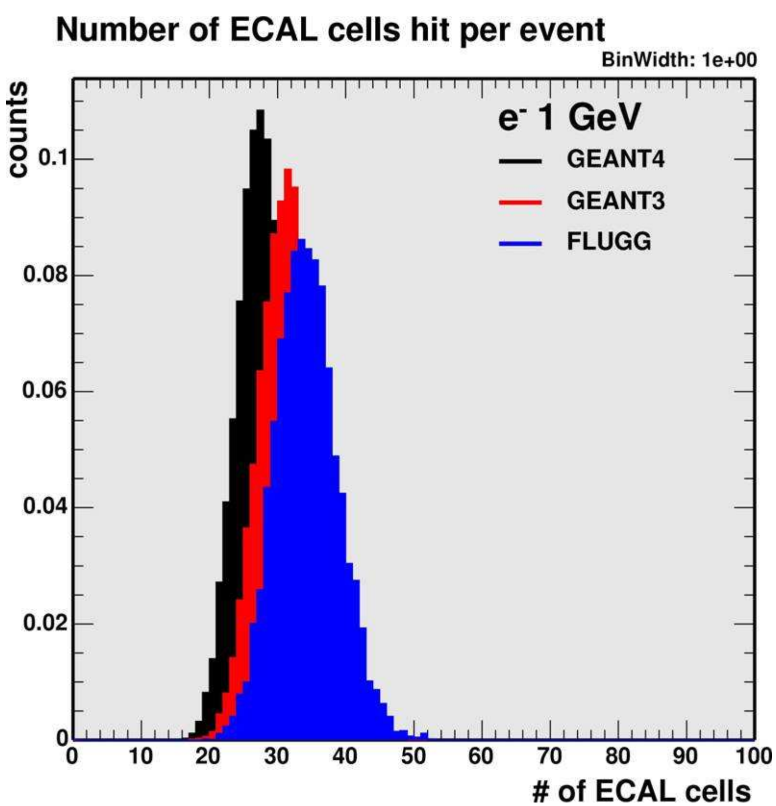


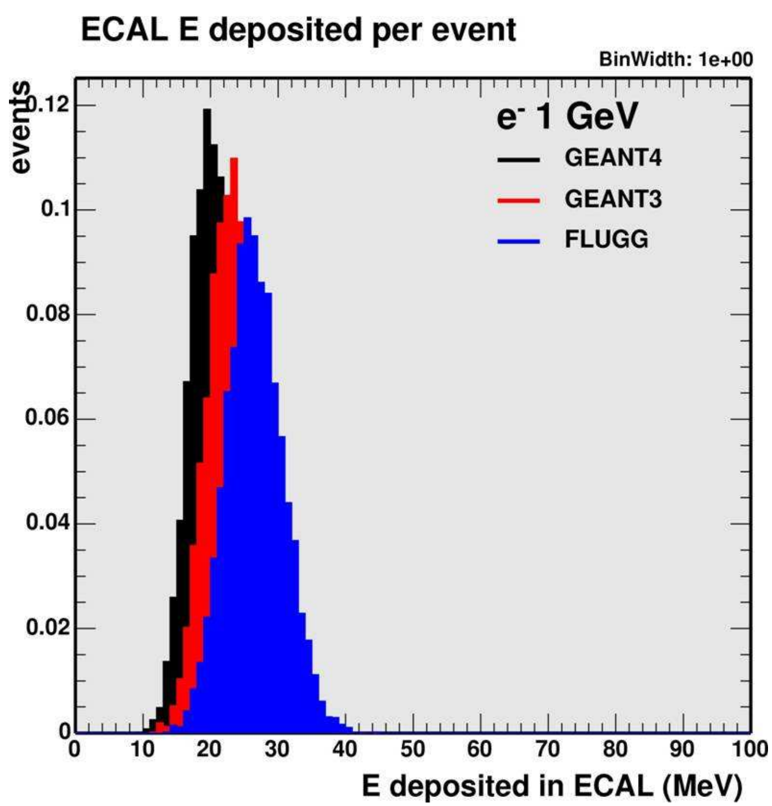
Energy deposited/event





Disagreements





- G3 ~ 14% higher than G4 in hits and energy
- Flugg ~ 24% (~ 30%) higher hits (energy) than G4
- Do need to understand e.m. behaviour of ECAL

Summary

Comparison of G4/Fluka
- Alternative to deprecated G-Fluka
- Preferable to "standalone" Fluka as more efficient for variations in geometry

Emulation of old mokka output format allows direct comparison with GM/DRW studies

Integration with Mokka geometry classes
- Need to feed changes back to Mokka developers

Impact on test beam design (interpretation!) soon

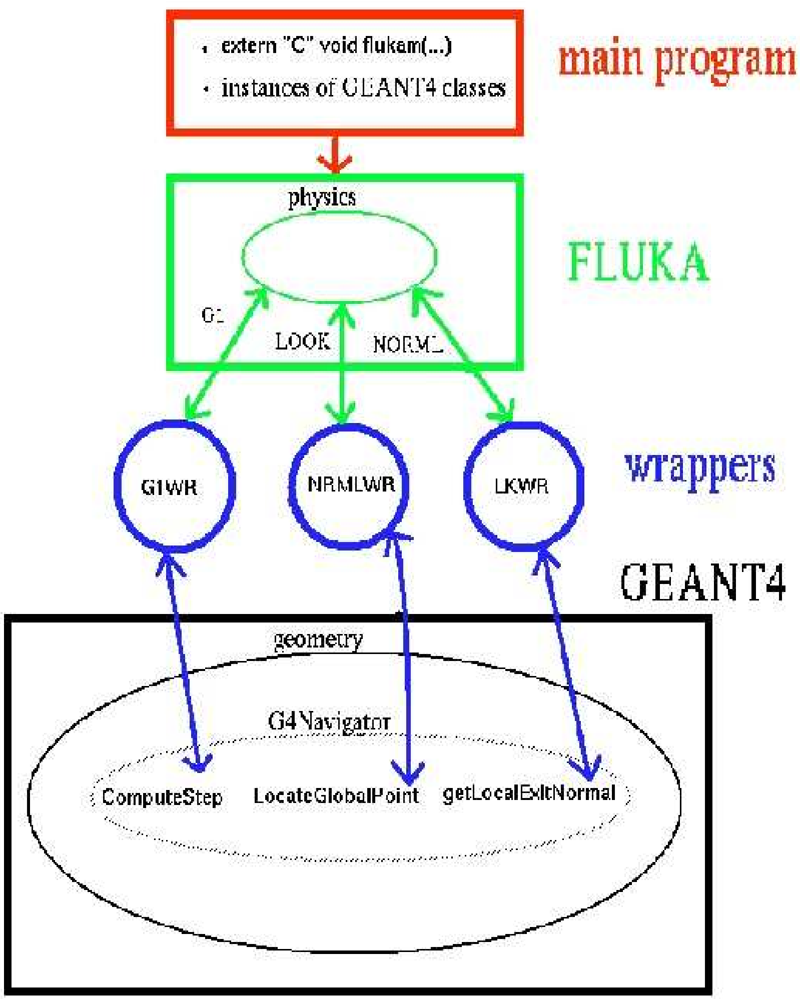
Ongoing Work

- Improve reliability for larger samples
  - ~understood technical issue
- Review thresholds/step sizes to improve speed
  - Discuss material mixtures with FLUKA authors
- Alternative HCAL technology options
- Compare systematically with G3/G4 results,
  - Same initial conditions
  - Thresholds, mip normalisation, etc.
  - Adopt same output format as DRW/GM, integrate with GM studies.

Step Size & Cut-offs

- Two principal options
  - Step such that fixed % of kinetic energy is lost in a given material
    - $\Rightarrow$ For $e^+/e^-/\gamma$ and μ/hadrons separately
  - Step length (range) in cm, in given detector region
    - $\Rightarrow$ For all charged particles
- If both present, smaller of the two
- Default: 20% of energy loss
  - Poor for very thin regions
- Mainly interested in Si, where use:
  - 3% energy loss for μ/hadrons
  - 6% energy loss for $e^+/e^-/\gamma$
  - 5—50 μm steps
- Fluka, have to specify min. e^+/e^- and γ energies (for each material)
- e^+ only annihilate at end of step, all steps end on boundary crossing, accumulation near boundary
  - Choose 10 keV initially

“Flugg” Package (P.Sala et al)



[From ATL-SOFT-98-039]

- Geomety & physics decoupled in G4 and Fluka
- Wrappers for f77/C++
- Fluka authors’ comparisons of G4 with Flugg (FLUka+G4 Geometry)
  - Simple detectors, identical results
  - Complex T36 calorimeter: 81 layers Pb (10mm)-scint.(2.5mm) Consistent results
- Initial test benchmarks
  - Use T36 calorimeter as above

Current Status

- Mokka running within flugg/Fluka framework
  - Using Mokka-01-05 + Geant4.5.0.p01 + clhep1.8.0 + gcc3.2
  - Flugg05 (Jan. 2003)
  - Fluka 2002.4 (May 2003)
- Procedure: start from Mokka release and delete:
  - All classes except for detector construction, detector parametrisation, magnetic field construction
  - Corresponding #include, variable, class definitions in .cc/.hh
  - Anything related to G4RunManager, DetectorMessenger
  - Code where SensitiveDetector is set
  - Interactive code, visualisation, etc.
- Validation
  - Minimal debugging tools in flugg, e.g. P55 prototype geometry
  - Library/compiler consistency (fluka object-only code)
- Using ProtEcalHcalRPC model
  - P66WNominal (driver proto01)
  - SinglehcalFeRPC1 (driver hcal03)

Flugg Operation

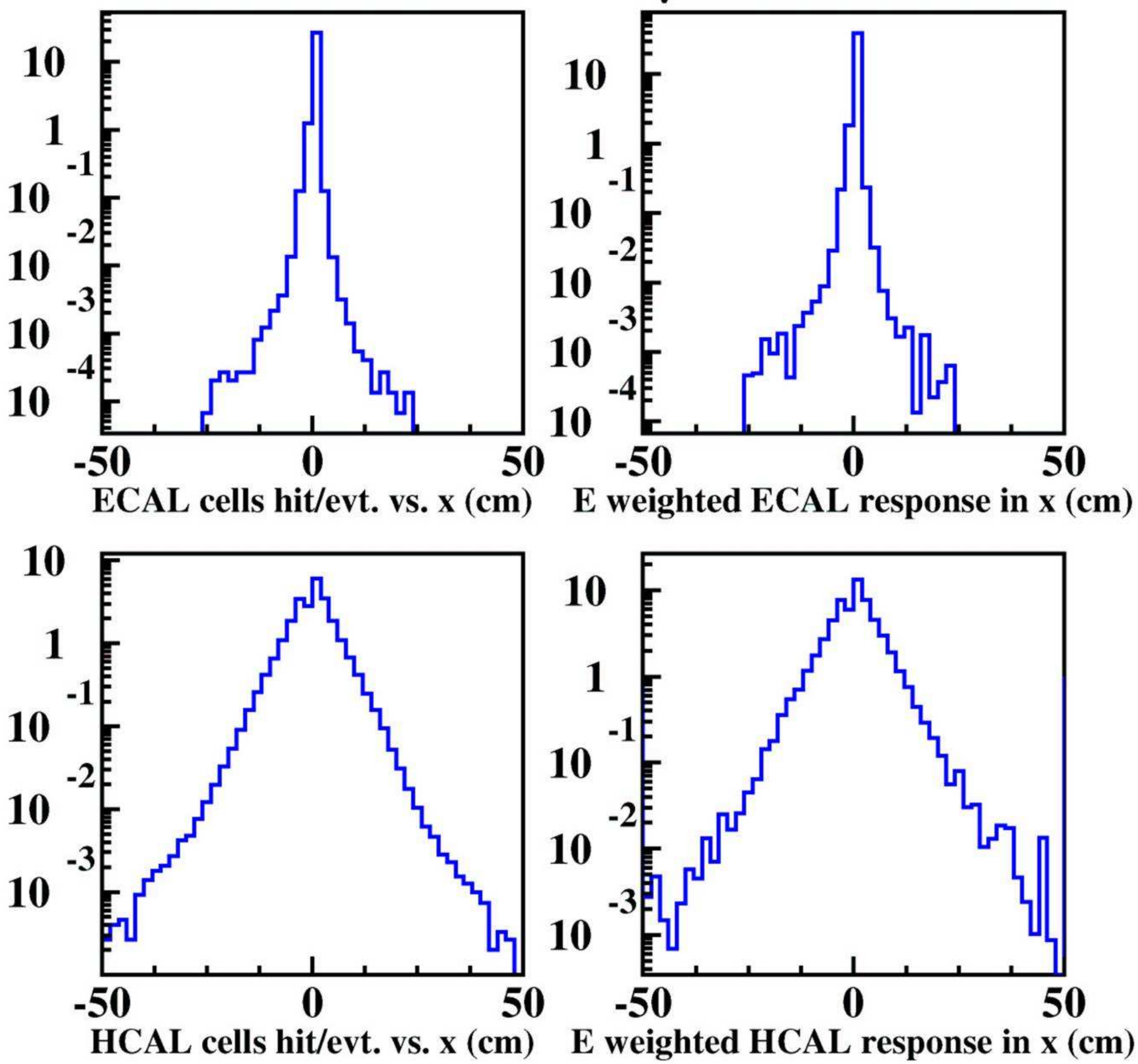
Two pass operation

- One-time initialisation
  - Read G4 geometry/material definitions
  - Generate fluka input cards
    - ⇒ Material/compound definitions
    - ⇒ Material to volume assignments
- Subsequent runs with a given geometry model
  - Use generated Fluka cards
  - Tracking within G4 geometry
  - Physics processes from Fluka
- Electromagnetic properties of materials not provided, have to create yourself using PEMF processor using Sternheimer tables, etc.
- Well described, but not so clear for exotic materials

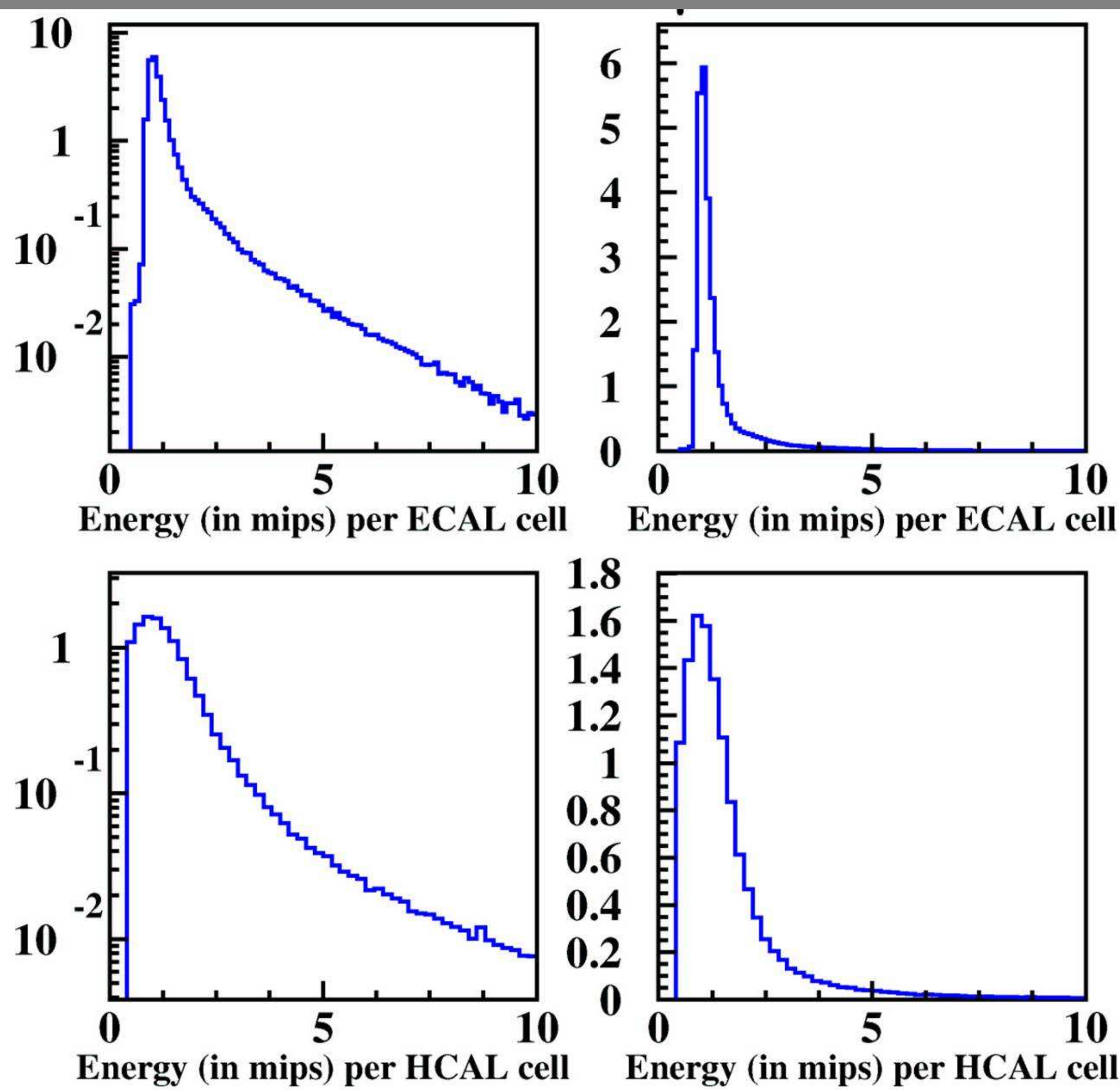
Modelling Response

- Consider variety of
  - Particle species (e, μ, π, p)
  - Energies
  - Experimentally accessible distributions
- Look for combinations with significant difference compared to Geant models
  - Will exchange results with George M.!
  - Initially, pencil beam incident at 90^o on ECAL front face at (x,z)=(0.5,0.5) [cm]
  - 1 GeV: 15k μ^-, 6k e^-, 11k π^-, 8k p,
  - 10 GeV: 15k μ^-, 14k π^-, 8k p,

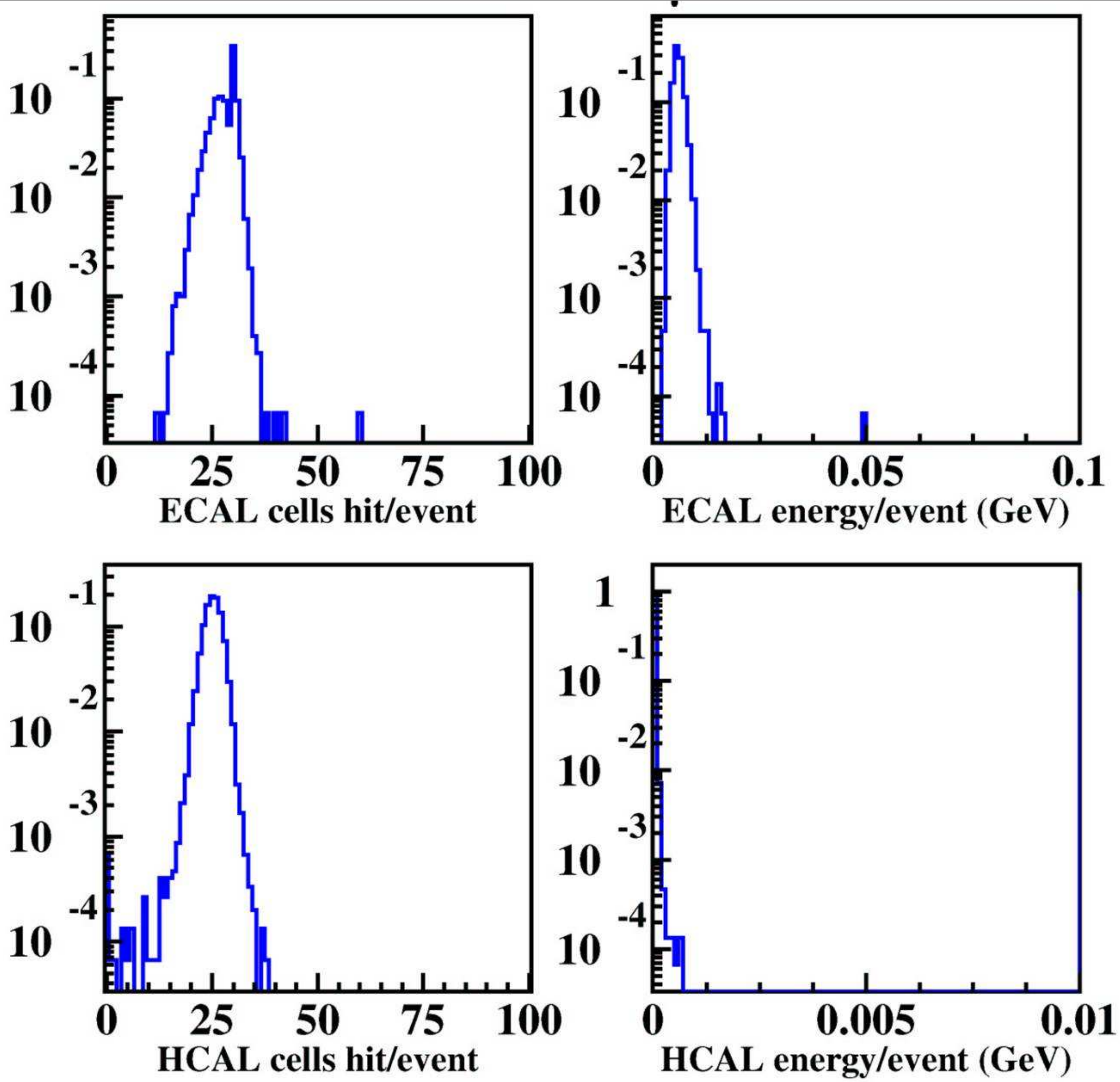
Transverse Response, 1 GeV μ^-



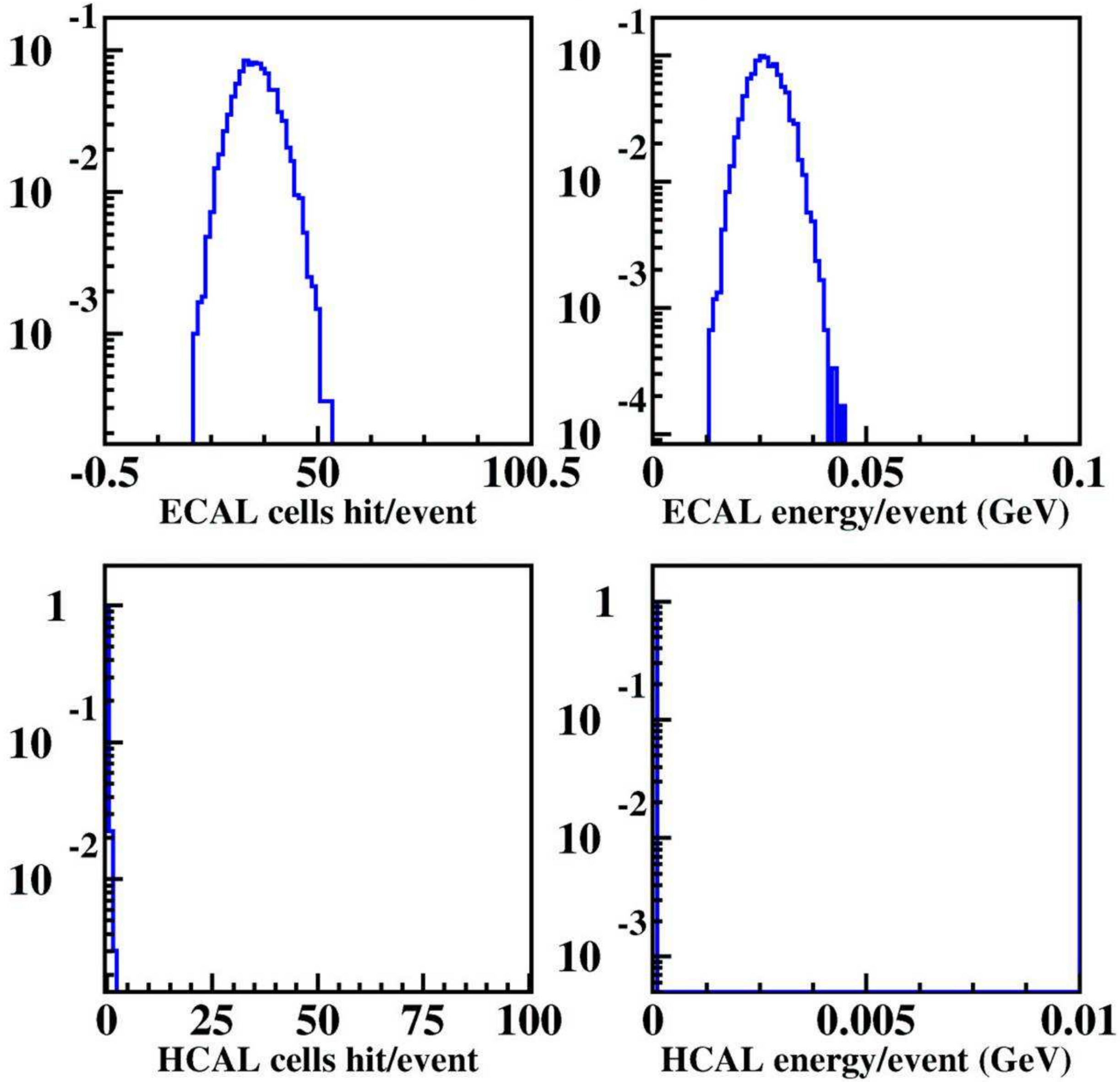
Response per cell, 1 GeV μ^-



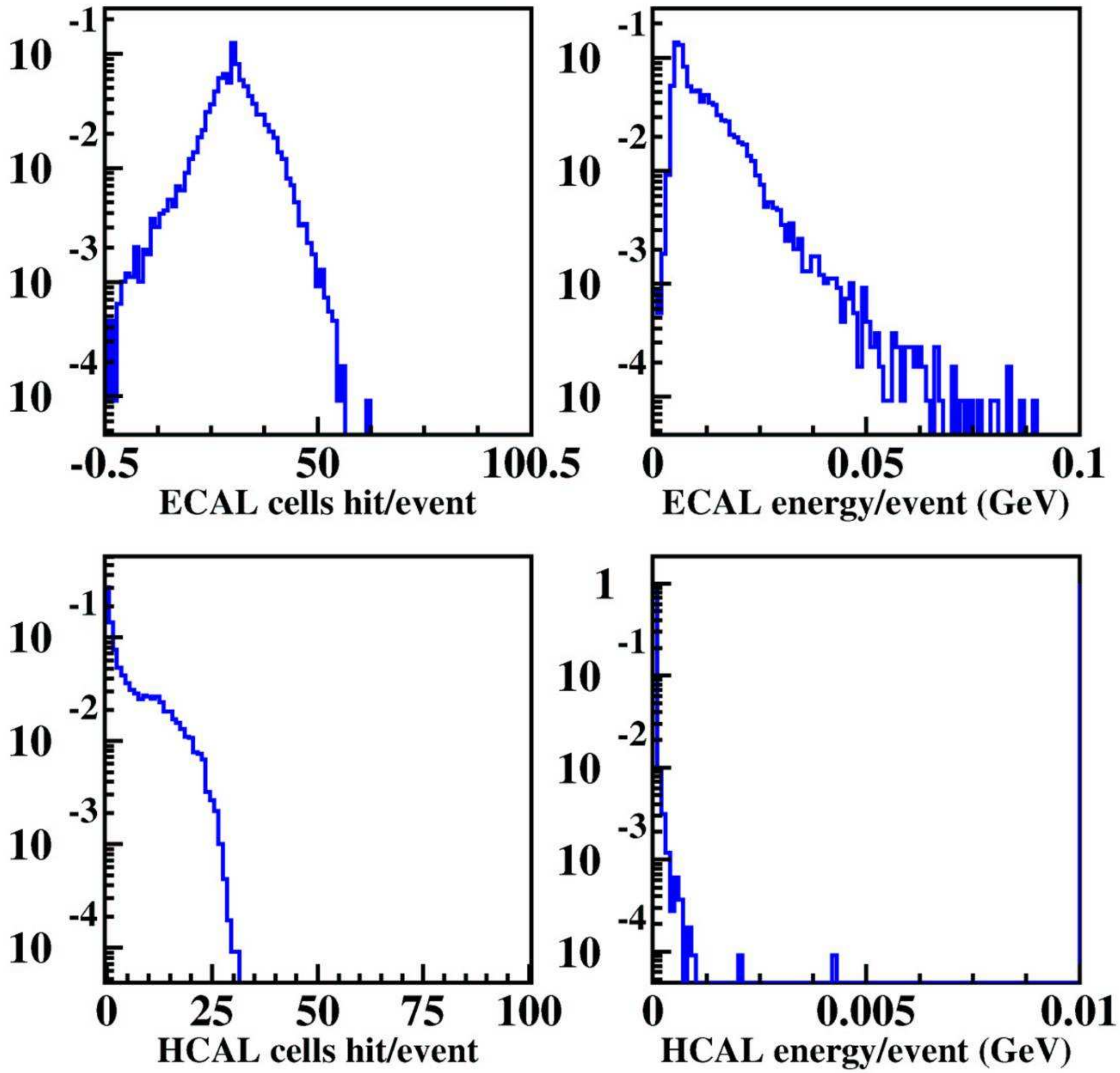
Total Response, 1 GeV μ^-



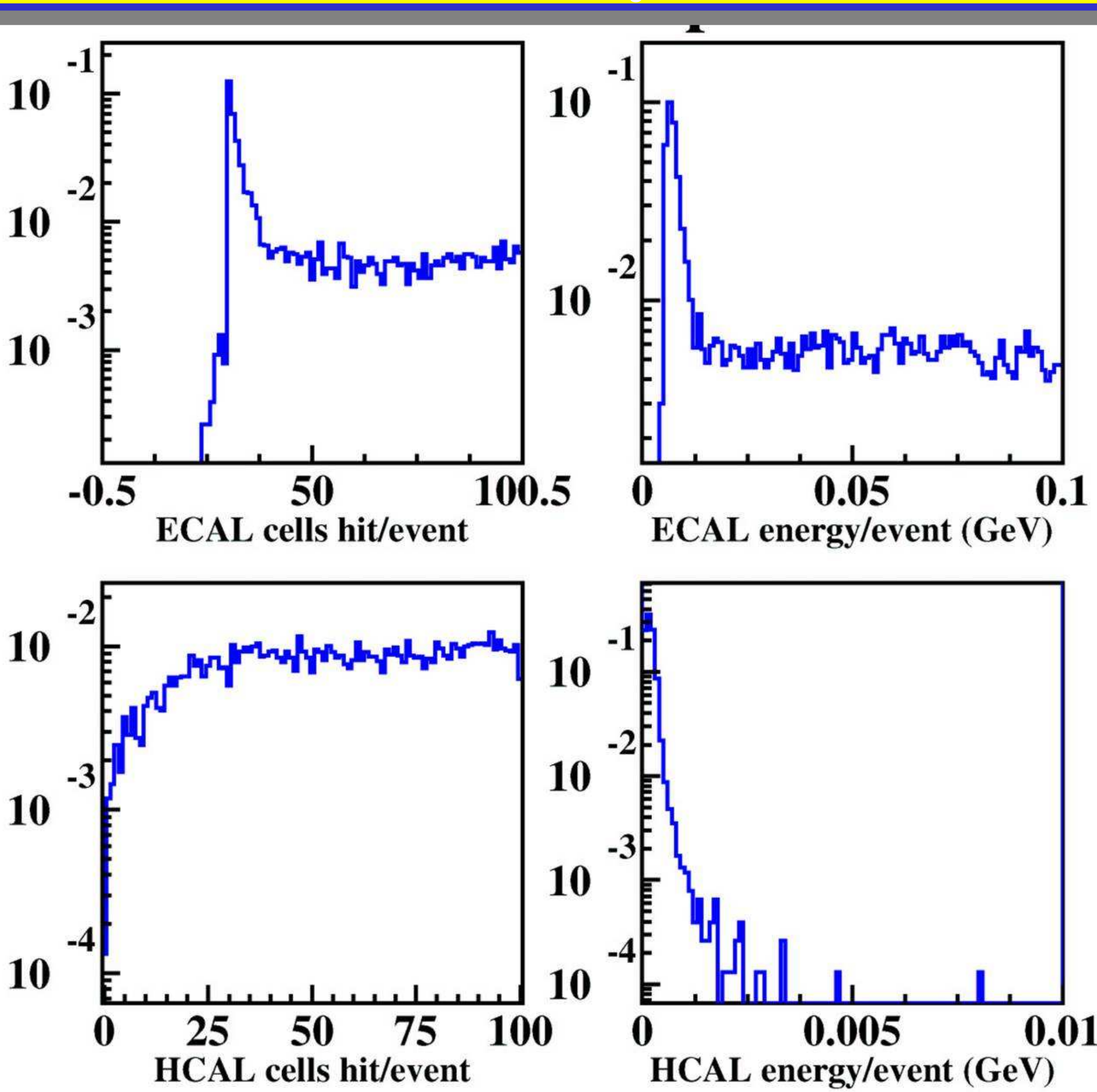
Total Response, 1 GeV e^-



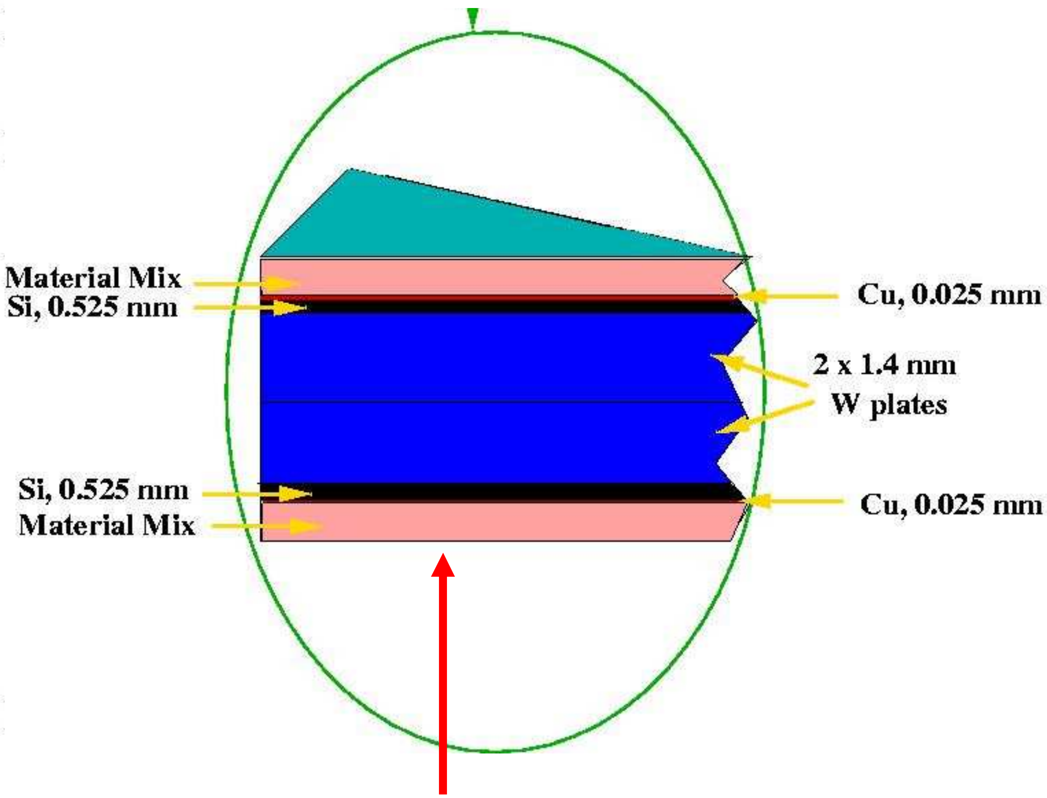
Total Response, 1 GeV π^-



Total Response, 10 GeV p



Longitudinal Response, 1 GeV μ^-



- Structure is from prototype "mix"
- Produces higher energy tail in odd Si layers

Possibly related to e.m definition (NKW)

To follow up with Fluka authors