Fluka+Geant4 Simulation of CALICE

Using Fluka for CALICE

- Motivation
- Method
- Initial results
- Future

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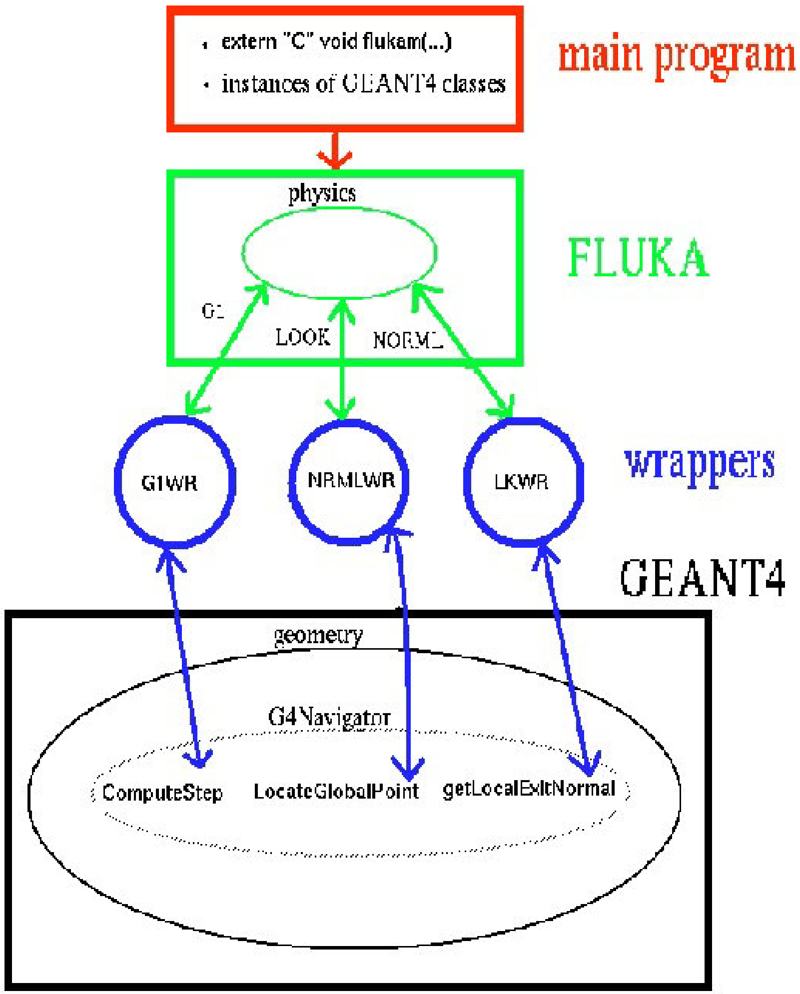
Motivation

- 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)

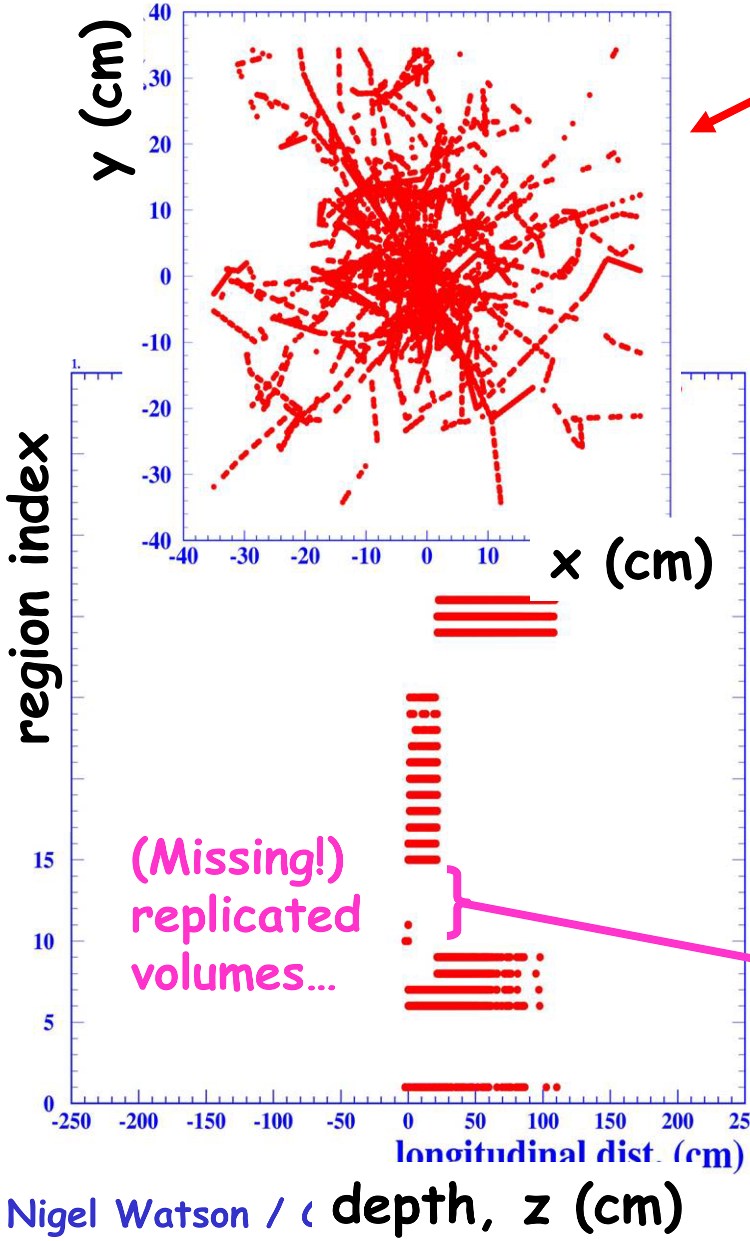
"Flugg" Package (P.Sala et al)



[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

Flugg Issues



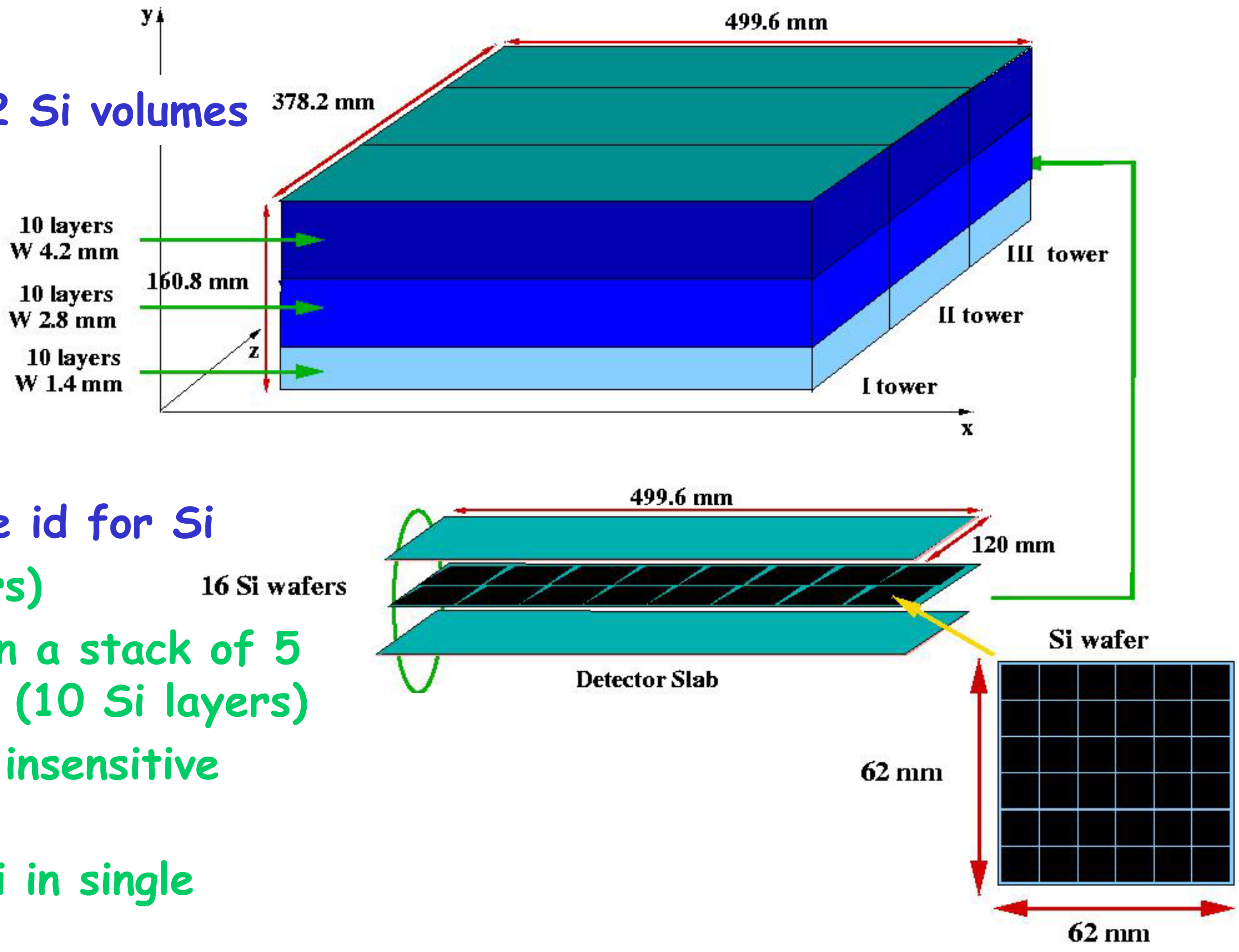
- Transverse response of T36 calo. to 10 GeV π^- in flugg
- User control available at:
  - every tracking step, via simple drawing routine (slow)
  - every energy deposition event

<u>Note</u>

- For G4 replicated or parametrised volumes (correspond to Fluka "lattice volumes")
  - Region index is degenerate
  - Boundary crossing not detected

CALICE Prototype Volume Ambiguity

- 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]

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

First pass, G4 → FLUKA conversion

```
Connecting to the database models00

Building sub_detector P66WNominal, geometry db P66WNominal, driver proto01:
Ecal prototype driver  with W  ideal thickness (reference)
Connecting to the database P66WNominal
proto01: proto size is (499.600000,160.800000,378.
proto01: placing prototype at (0.000000,236.000000
Sub_detector P66WNominal DONE!


Building sub_detector SinglehcalFeRPC1, geometry d
Single module Hcal Fe & RPC as prototype
Connecting to the database SinglehcalFeRPC1
The sensitive model in Hcal chambers is RPC1
Iron is the radiator material being placed.
Sub_detector SinglehcalFeRPC1 DONE!

tRadlen() = 89867.3 mm
Styropor->GetRadlen() = 17518.3 mm
C->GetRadlen() = 188.496 mm
CGAGeometryManager starting the detector construct
Asking for the model ProtoEcalHcalRPC:

Building Proto release 01
total_W_layers = 30
MixDensite = 2.15747 g/cm3
Mix->GetRadlen()= 75.0202 mm
Proto done.
```

```
Building Hcal...
Detector construction done.
            * G4PhysicalVolumeStore (0x401b5288) has 2424 volumes.
            * Storing information...
                        + Tungsten: dens. = 19.3g/cm3, nElem = 1
                          Stored as TUNGSTEN
                        + TungstenModified: dens. = 11g/cm3, nElem
                          Stored as TUNGST02
                        + Copper: dens. = 8.96g/cm3, nElem = 1
                          Stored as COPPER
                        + Silicium: dens. = 2.33g/cm3, nElem = 1
                          Stored as SILICIUM
                        + SiVXD: dens. = 8.72g/cm3, nElem = 1
                          Stored as SIVXD
                        + Iron: dens. = 7.87g/cm3, nElem = 1
                          Stored as IRON
                        + Aluminum: dens. = 2.7g/cm3, nElem = 1
                        + TetraFluoroEthane: dens. = 0.00455g/cm3,
                          Stored as TETRAFLU
                          Stored as RPCGAS1
                          Stored as GRAPHITE
                        + Mix: dens. = 2.15747g/cm3, nElem = 9
                          Stored as MIX
         --------------- … ---------------
            * Printing FLUKA materials...
            * Printing FLUKA compounds...
            * G4PhysicalVolumeStore (0x401b5288) has 2424 volumes.
            * Printing ASSIGNMAT...
            * Printing Magnetic Field...
              No field found...
 *** Entering UsrIni.f!! ***
 *** Entering HistIn.f!! ***
```

generates fluka input deck →

Operation

G4 volume index

```
*
1         WorldPhysical
8         DeadWBlock
2         SensWafferPhys
3         DeadWBlock
4         DeadWBlock
5         DeadWBlock
6         DeadWBlock
7         DeadWBlock
9         DeadWBlock
10        SlabWBlock
11        SlabWBlock
```

& etc

```
2417      EndCapChamberPhys
2418      EndCapChamberPhys
2419      EndCapChamberPhys
2420      EndCapChamberPhys
2421      EndCapChamberPhys
2422      EndCapChamberPhys
2423      EndCapChamberPhys
2424      EndCapChamberPhys
```

material definitions

```
******************
....+....4....+....5..
*
MATERIAL      74.0   183.840 1.930e+01      3.0
TUNGSTEN
MATERIAL      74.0   183.840 1.100e+01      4.0
TUNGST02
LOW-MAT        4.0
TUNGSTEN
MATERIAL      29.0    63.546 8.960e+00      5.0
MATERIAL      14.0    28.090 2.330e+00      6.0
SILICIUM
MATERIAL      14.0    28.090 8.720e+00      7.0                 SIVXD
MATERIAL      26.0    55.850 7.870e+00      8.0                 IRON
MATERIAL      13.0    26.980 2.700e+00      9.0
ALUMINUM
MATERIAL       4.0     9.012 1.848e+00     10.0
BERYLLIU
MATERIAL      18.0    39.950 1.780e-03     11.0                 ARGON
MATERIAL                     1.290e-03     12.0                 AIR
MATERIAL       7.0    14.010 9.990e-01     13.0
NITROGEN
MATERIAL       8.0    16.000 9.990e-01     14.0                 OXIGEN
MATERIAL                     1.000e-05     15.0                 BEAM_
MATERIAL                     2.200e+00     16.0                 QUARTZ
MATERIAL      14.0    28.090 9.990e-01     17.0                 SILICON
MATERIAL                     1.300e+00     18.0                 EPOXY
MATERIAL       1.0     1.010 9.990e-01     19.0
HYDROGEN
MATERIAL       6.0    12.010 9.990e-01     20.0                 CARBON
MATERIAL                     1.700e+00     21.0                 G10
```

material to region assignments

```
ASSIGNMAT       12.0        1.0
ASSIGNMAT        6.0        2.0
ASSIGNMAT        3.0        3.0
ASSIGNMAT        3.0        4.0
```

& etc

```
ASSIGNMAT       21.0     2423.0
ASSIGNMAT       21.0     2424.0
ASSIGNMAT        1.0     2425.0
```

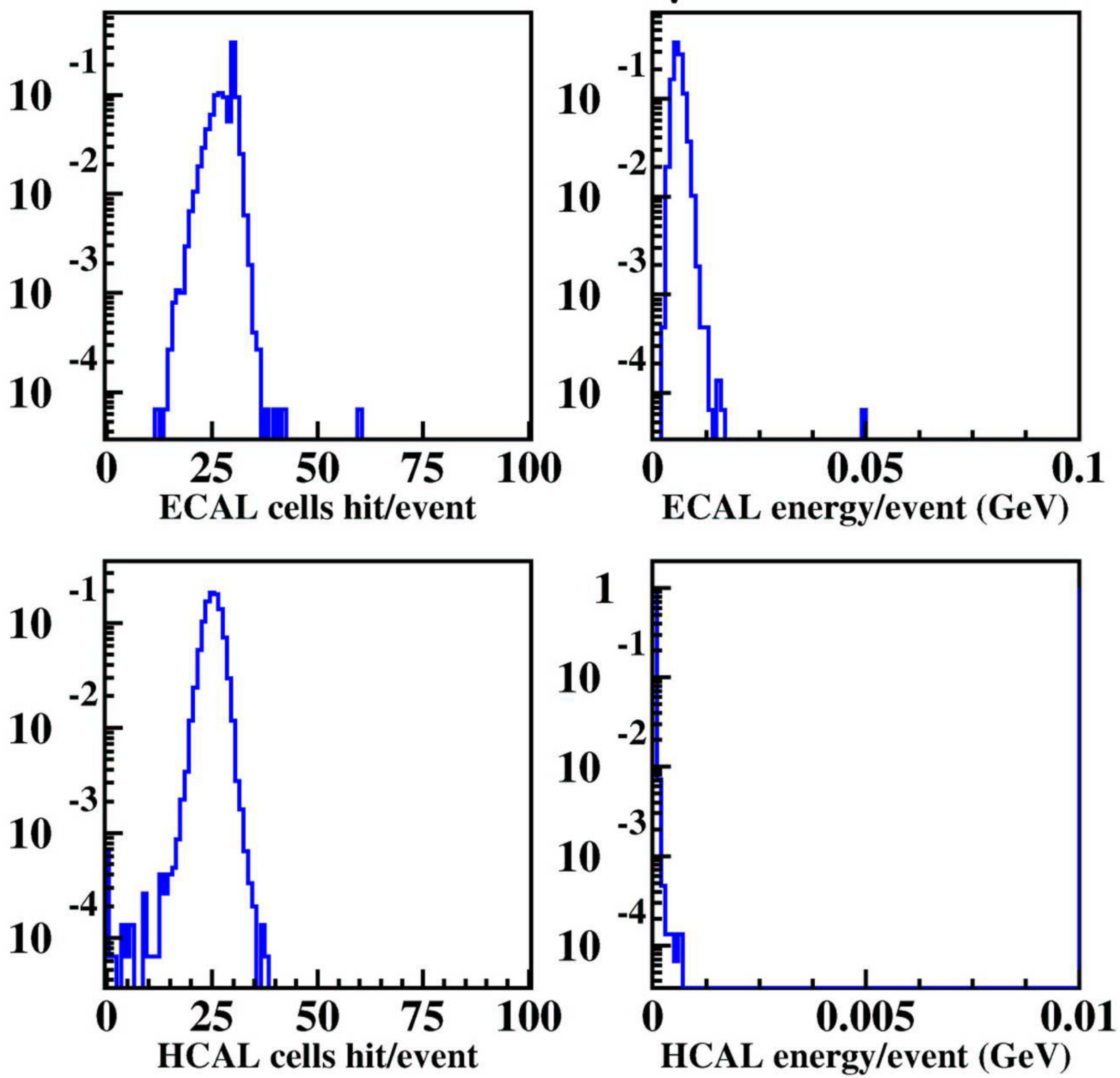
Step Size & Cut-offs

- Two principal options
  - Step such that fixed % of kinetic energy is lost in a **given material**
    - ⇒ For $e^+/e^-/\gamma$ and μ/hadrons separately
  - Step length (range) in cm, in given **detector region**
    - ⇒ 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

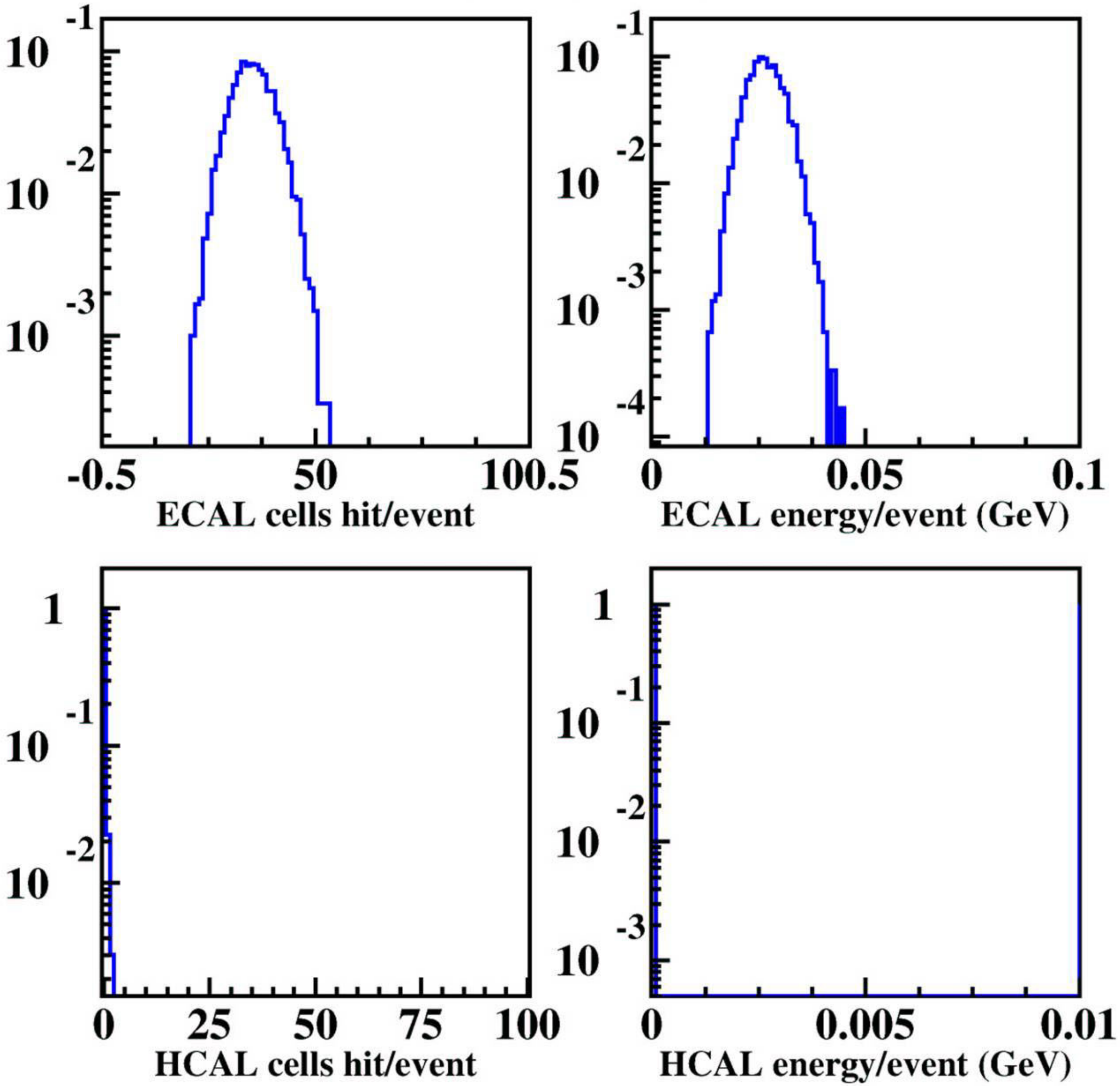
Modelling Response

- 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° 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,

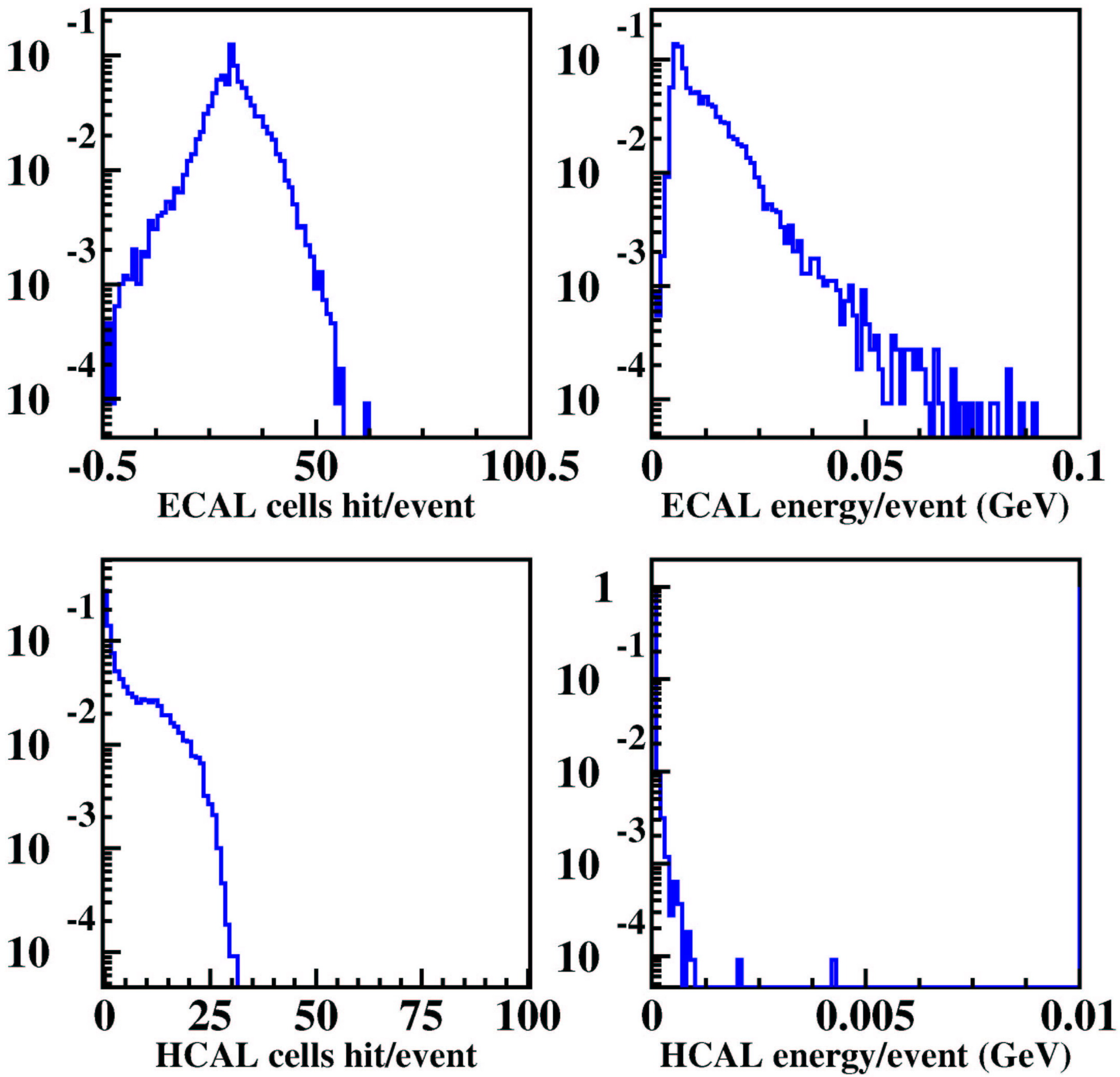
Total Response, 1 GeV μ^-



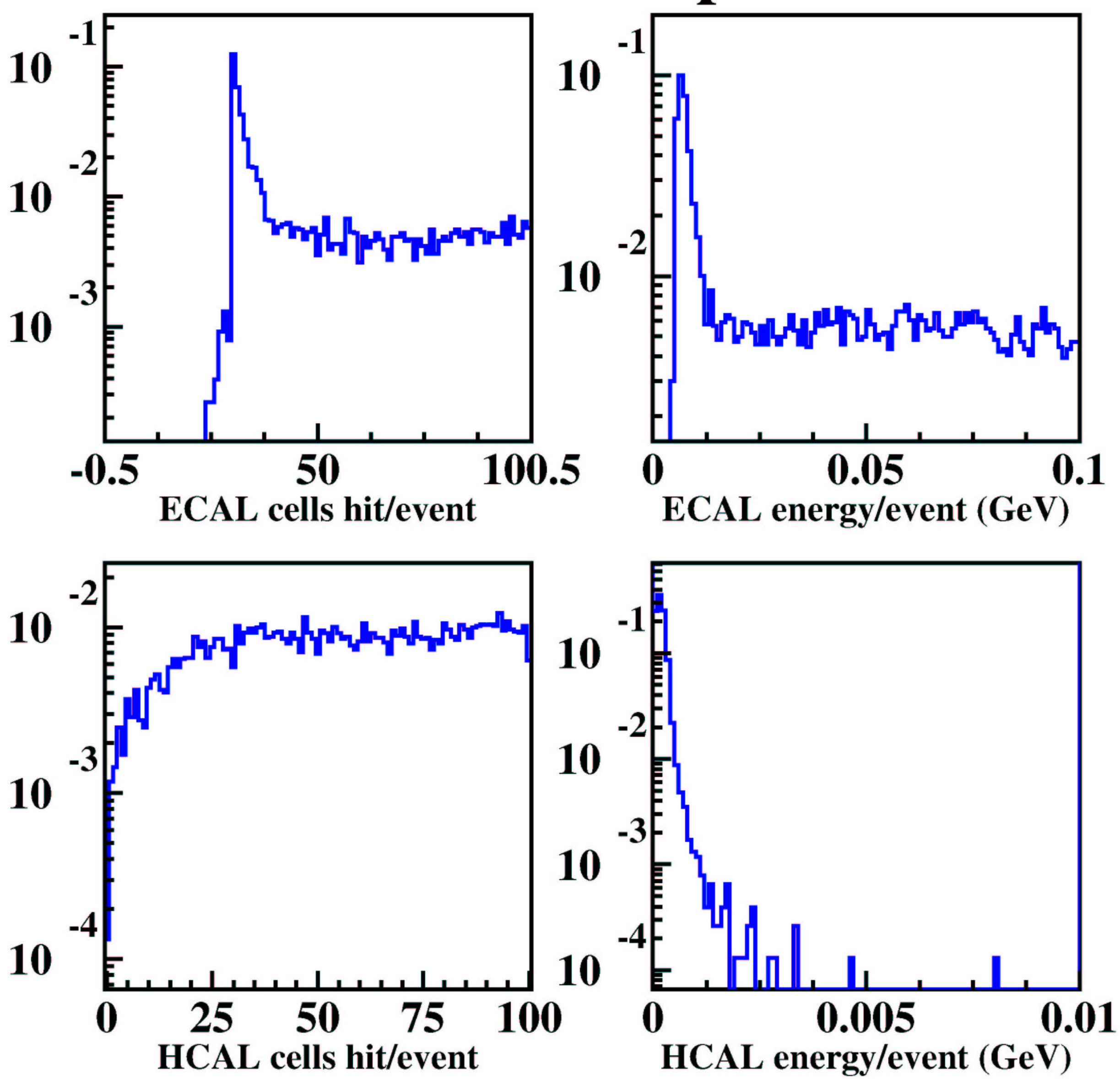
Total Response, 1 GeV e^-



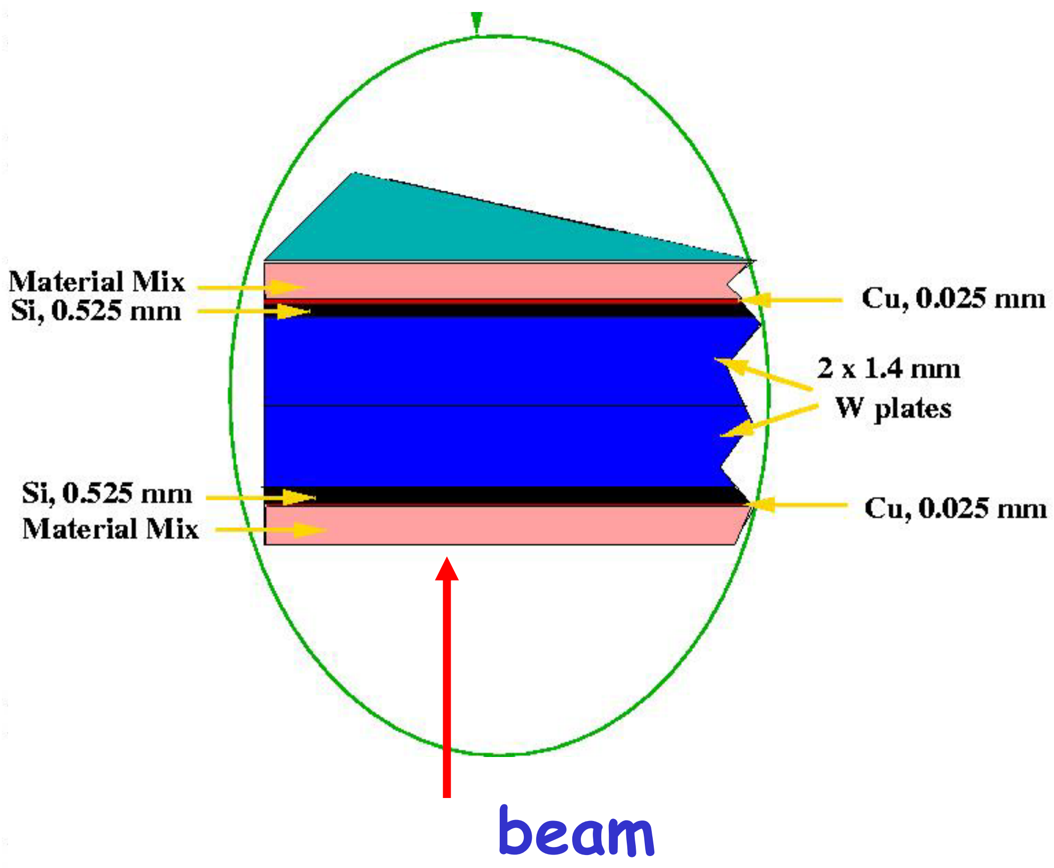
Total Response, 1 GeV π^-



Total Response, 10 GeV p



Longitudinal Response, 1 GeV μ^-

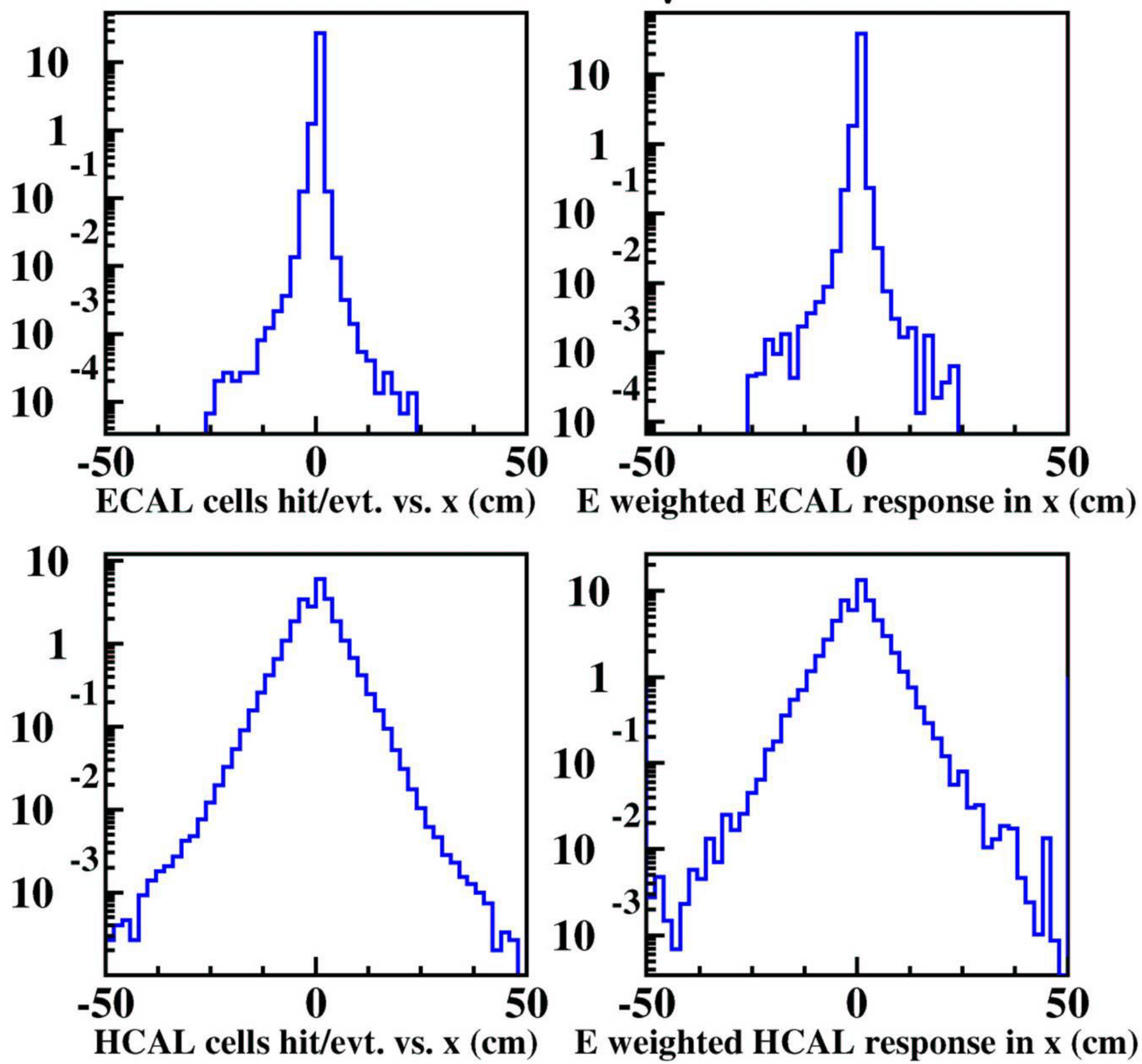


- Structure is from prototype "mix"
- Produces higher energy tail in odd Si layers

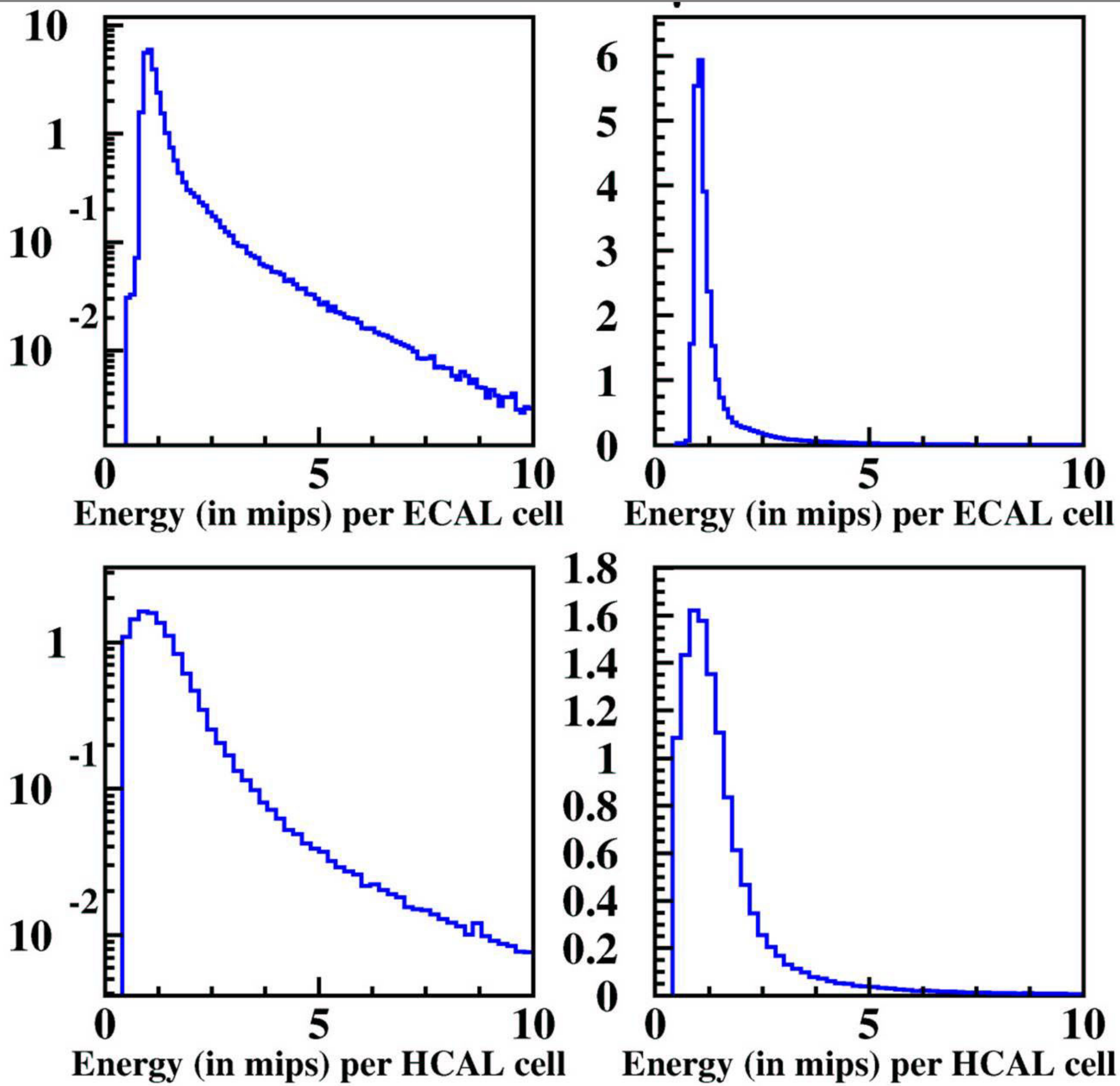
Possibly related to e.m definition (NKW)

To follow up with Fluka authors

Transverse Response, 1 GeV μ^-



Response per cell, 1 GeV μ^-



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.

Summary

Identified pragmatic way of comparing G4/Fluka

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

Integration with Mokka geometry classes

- Need to feed changes back to Mokka developers

Impact on test beam design (interpretation!) soon