Comparisons of hadronic shower models

G.Mavromanolakis, University of Cambridge

Outline

- General
- Brief description
- Results
- Conclusions

General

- ▶ .
  simulation studies focused on CALICE ECAL-HCAL prototypes, to support and guide the testbeam program

- ▶ . survey of hadronic models in **GEANT3** and **GEANT4**

▷ **GEANT3.21**	: GHEISHA	: GHEISHA SLAC
	: FLUKA + GHEISHA	: GCALOR
	: FLUKA + MICAP	
▷ **GEANT4.6.1*** **	: LHEP	: QGSP
	: LHEP-BERT	: QGSP-BERT
	: LHEP-BIC	: QGSP-BIC
	: LHEP-GN	: QGSC
	: LHEP-HP	: FTFP

+ FLUKA under **GEANT4** (FLUGG) thanks to N.K.Watson

*** with hadronic physics list PACK 2.5

model tag		brief description
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 format, preliminary, thanks to N.K.Watson

FLUKA under GEANT4 – N.K.Watson

(update since LCWS04, Paris)

- ► .

  : higher activity in odd/even layers in prototype genuine effect also seen in GEANT4, not an artefact of FLUKA

- ► .

  : individual energy deposits from FLUKA are material type and (x,y,z)

- ► .

  : use detailed knowledge of geometry of active regions to:

  - sum energy deposits per event in each cell
  - allow direct comparison with G3/G4 models
  - "reverse look-up" CGA routine (x,y,z)$\rightarrow$cell/layer index would help especially when numbering schemes change

- ► .

  : differences seen in GEANT3-4 vs G3-FLUKA vs G4+FLUKA(FLUGG), not understood for electrons in particular, under investigation

FLUKA under GEANT4 – N.K.Watson

(update since LCWS04, Paris)

- ► .

  : know that FLUKA models energy loss as either

  - ▷ at a point: elastic or inelastic recoils, low energy neutron kerma, etc.
  - ▷ or distibuted along a step: ionisation by charged particles

- ► .

  : for comparison with G3/G4, "old" FLUKA energy deposition algorithm used which assigns ionisation energy at middle of step

  - ▷ inaccurate when steps are $\sim$ region size
  - ▷ FLUKA authors strongly recommend energy deposition distributed along steps

- ► .

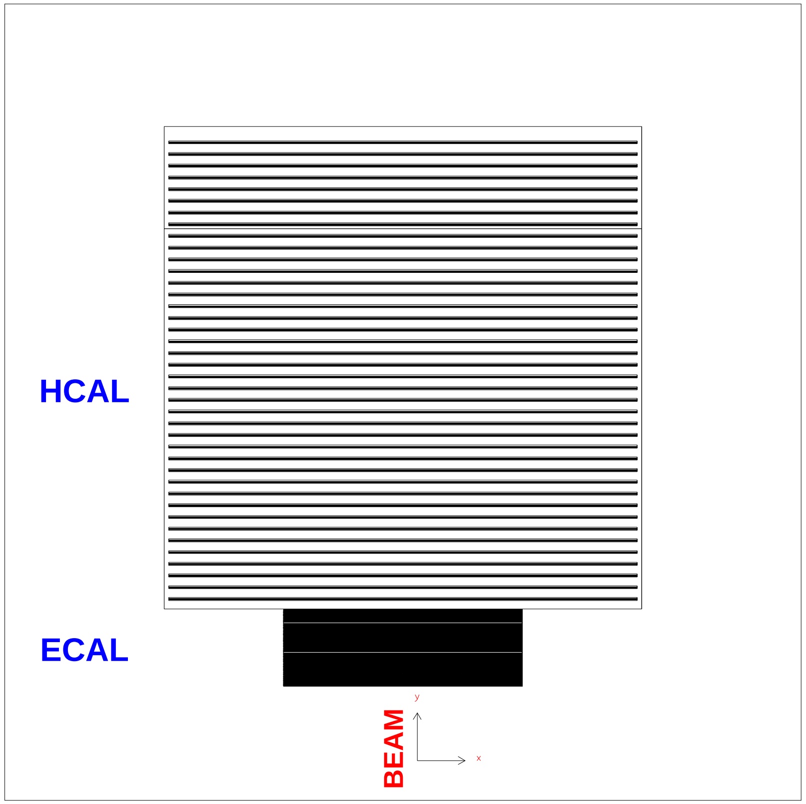
  : N.K.Watson will follow up and ensure we can use FLUKA predictions for test beam studies

Brief description

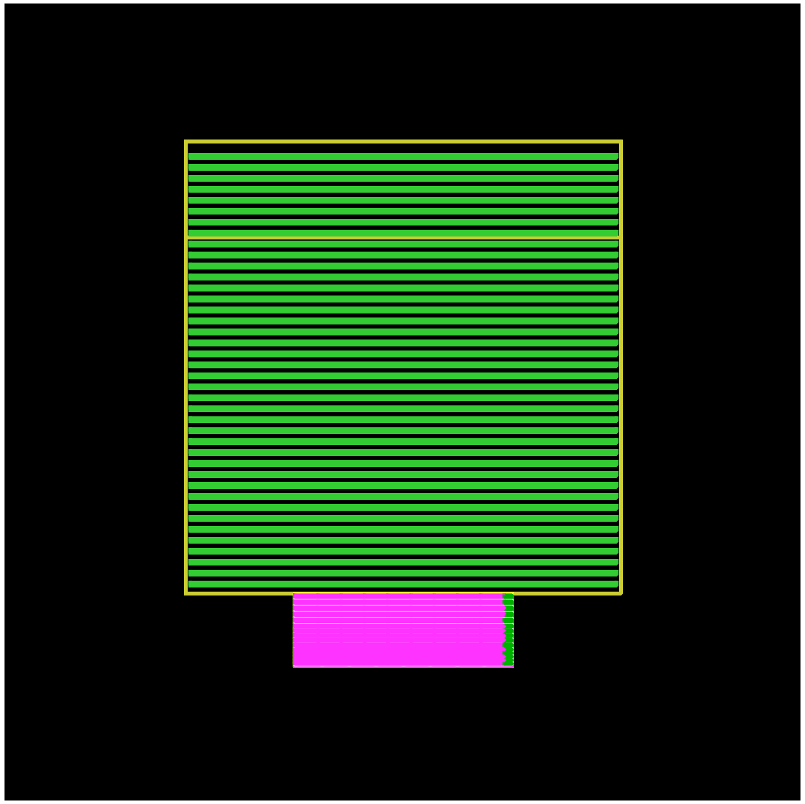
- .
  run under Mokka(v2.2) and Brahms(v3.01) frameworks
  (GEANT4.6.1 and GEANT3.21 based, respectively)
- .
  study with W/Si ECAL+Fe/Scint or RPC HCAL CALICE prototypes
  porting detector geometry from GEANT4 to GEANT3
- .
  cutoffs : GEANT3 energy cutoffs EM = 10 keV, HAD = 0.1 MeV
  : GEANT4 range cutoff = 5 μm

  : ECAL, HCAL cellsize 1$\times$1 cm^2, threshold = 0.5 mip
- .
  samples of 10000 events,
  results normalised to G4-LHEP case,
  shown $\pm$10% and $\pm$20% bands wrt 1 to guide the eye

GEANT3



GEANT4



ECAL 30 layers × 50 cm × 38 cm interleaved with 0.5 mm Si pads

- ▹ W absorber, 10+10+10 layers, 1.4 mm:2.8 mm:4.2 mm thick per respective layer
- ▹ readout by 1 cm^2 cells

HCAL 40 layers × 100 cm × 100 cm interleaved with 6.5 mm scintillator or 1.2 mm RPCgas (digital HCAL)

- ▹ Fe absorber, 18 mm thick per layer
- ▹ readout by 1 cm^2 cells

Difficulties

- .
  - : define identical geometries in GEANT3-4. OK can be done ✓
  - : define identical materials in GEANT3-4. OK can be done ✓
- .
  - : physics control parameters,
    - ▷ energy cutoff for GEANT3. Can be different for different media
    - ▷ range cutoff for GEANT4. Same for all media

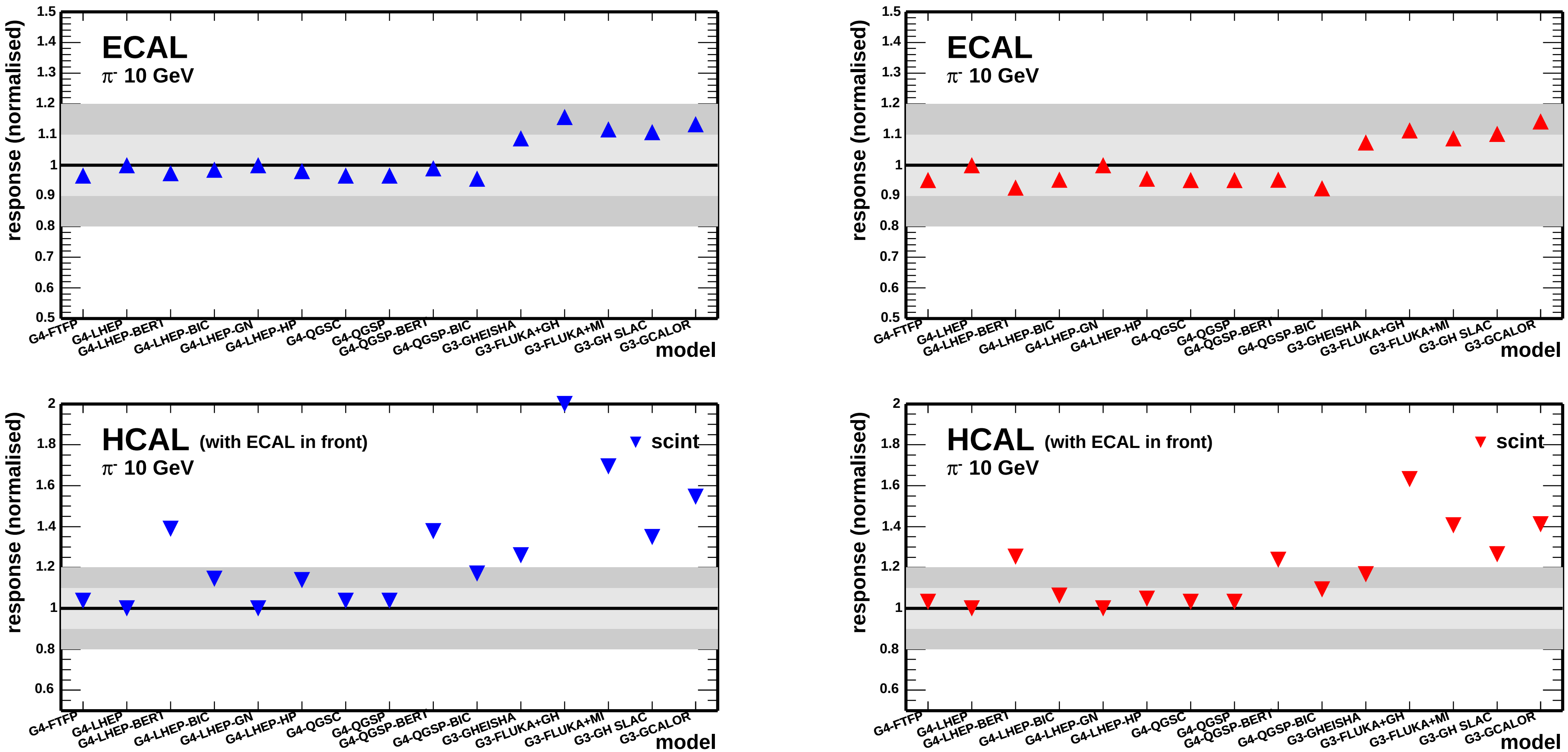
energy cutoffs (in keV) for different range cutoff

material	5 μm	50 μm	0.5 mm	5 mm
tungsten	53	220	1219	12952
iron	39	150	727	6112
silicium	7	80	335	2044
polystyrene	3	58	226	1189
RPC gas	1	1	1	31

- .
  - : Tune control parameters between GEANT3 and 4 to have what ?
    - ▷ identical energy cutoffs per material ?
    - ▷ or identical mip peak ?
    - ▷ or identical response to electrons ?
  - : Fix mip peak seems the natural choice

ECAL+HCAL scint "response" vs model, π^- 10 GeV

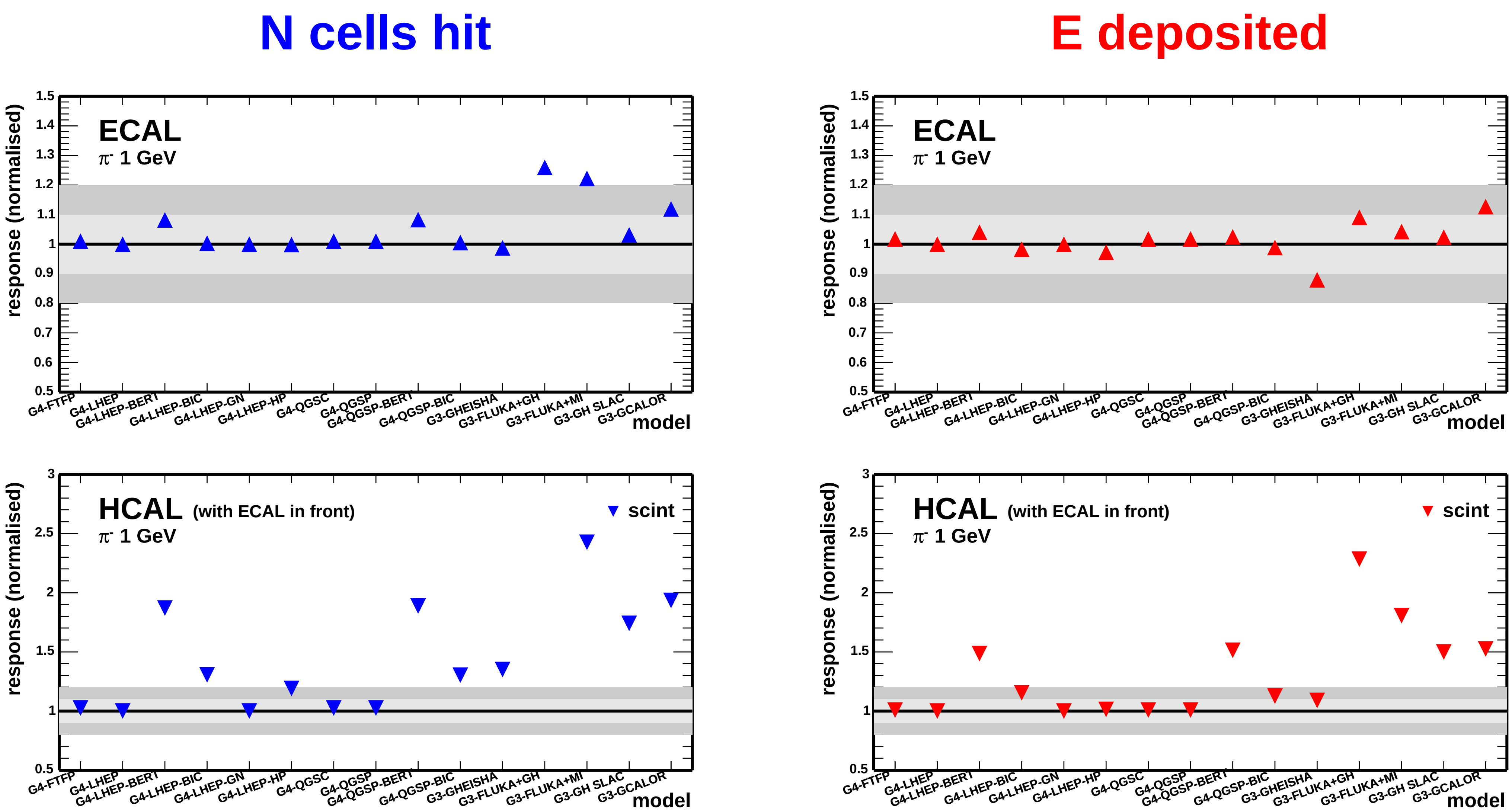
N cells hit | **E deposited**



- ▷ **different models predict different calorimeter response**
- ▷ **HCAL more sensitive than ECAL**
- ▷ **EM discrepancies between frameworks seen by ECAL**

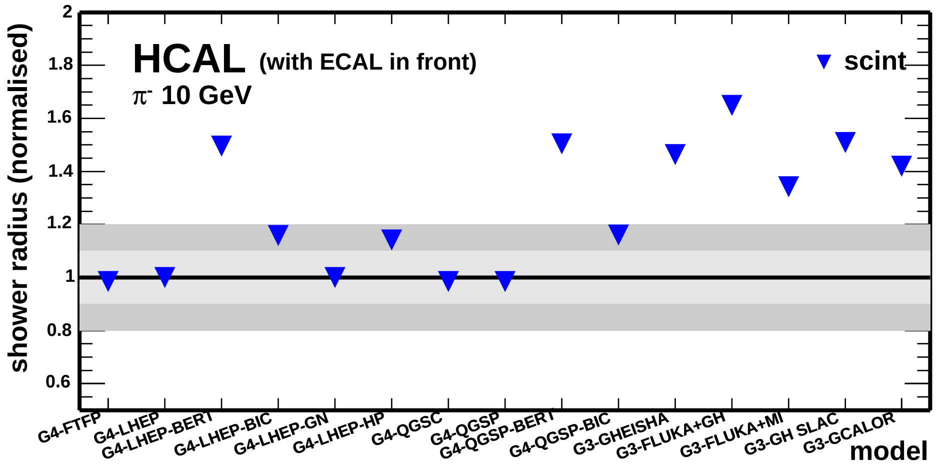
ECAL+HCAL scint "response" vs model, π^- 1 GeV

N cells hit | E deposited

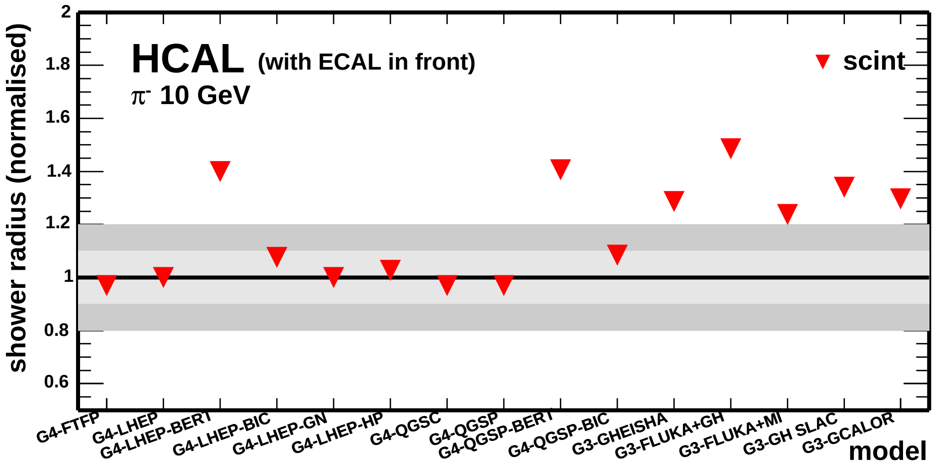


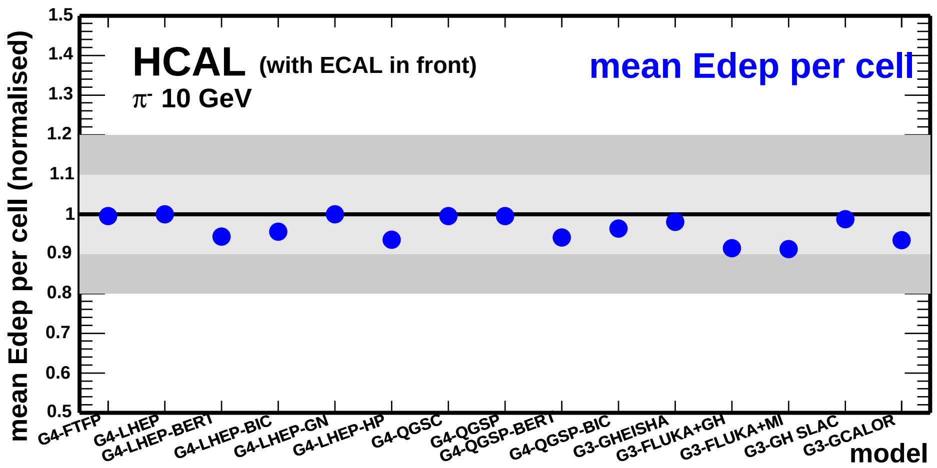
- ▷ same pattern as at 10 GeV case, even more pronounced
- ▷ ECAL standalone may have some discriminating power

shower transverse width vs model



weighted by Edep per cell

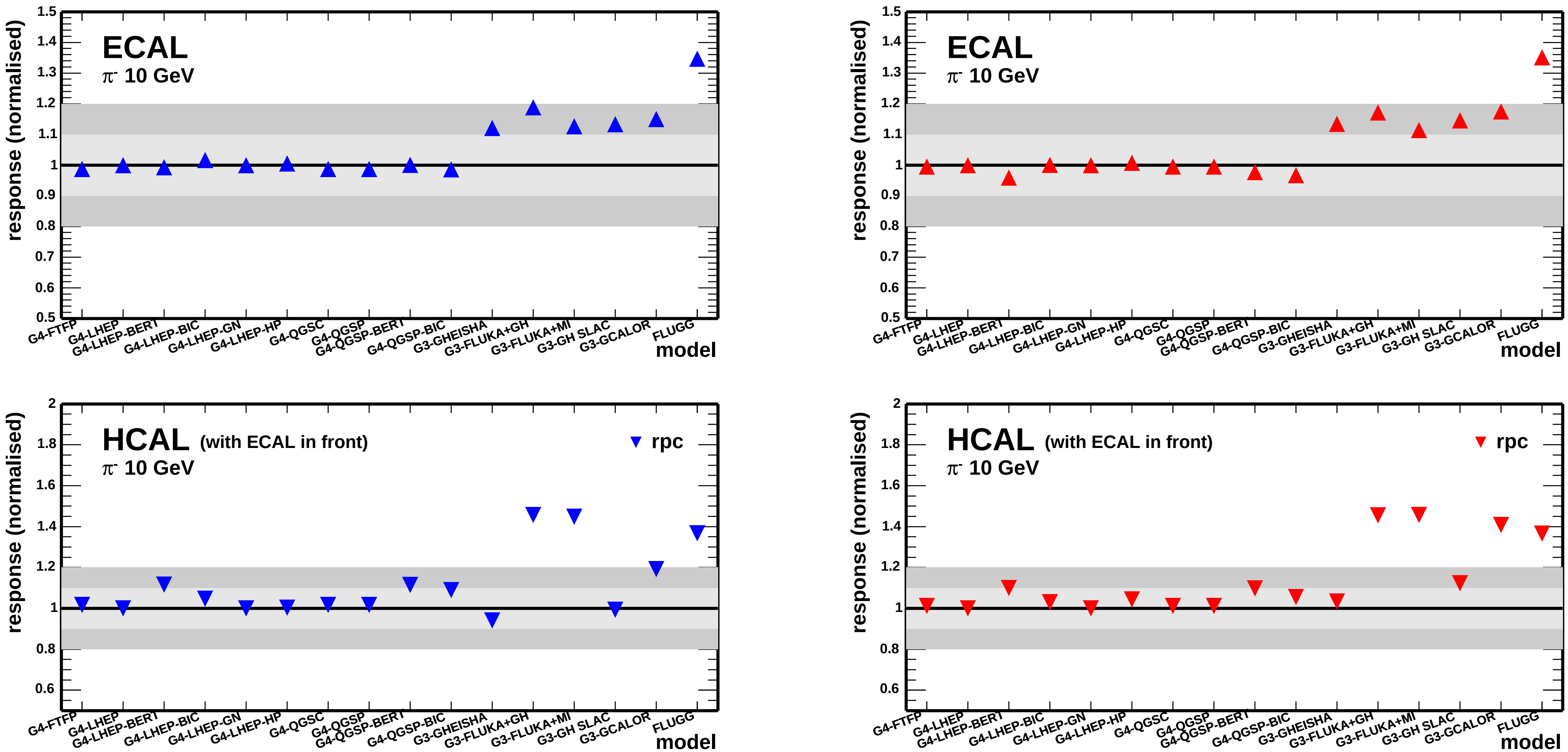




- **models agree within $\pm$5% for mean energy deposited/cell**
- **different calorimeter response per model is largely because of predicting different shower size**

ECAL+HCAL rpc "response" vs model, π^- 10 GeV

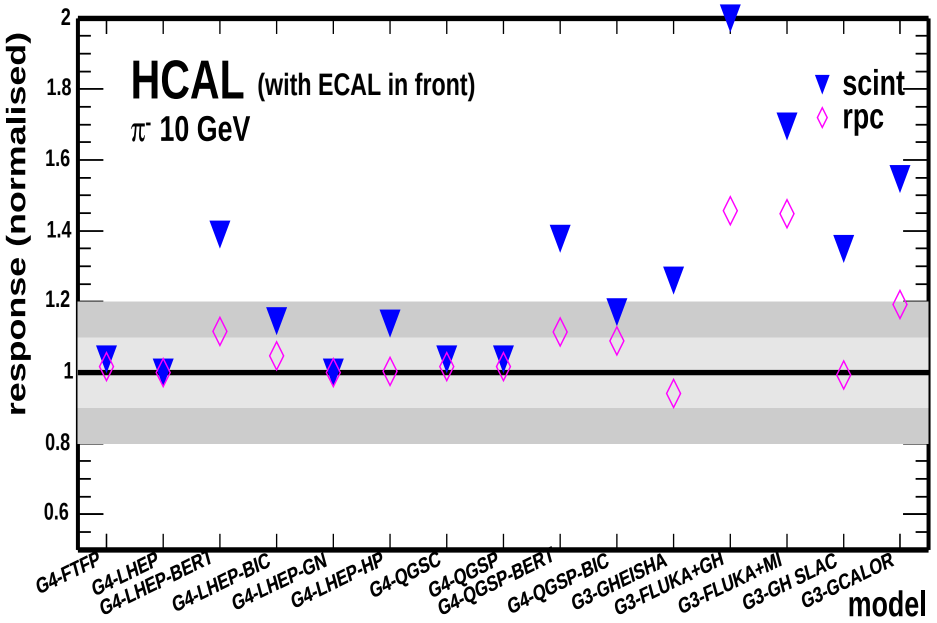
N cells hit | **E deposited**



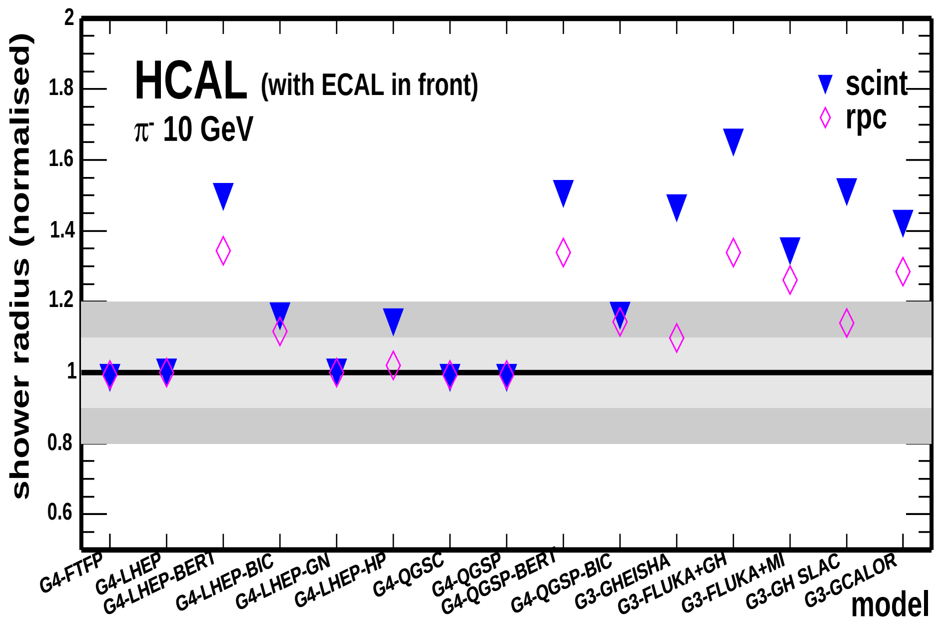
- ▷ **HCAL rpc less sensitive to neutrons than HCAL scint**
- ▷ **FLUGG included in the list**
- ▷ **EM discrepancies between frameworks seen by ECAL**

HCAL rpc – HCAL scint

N cells hit



shower width

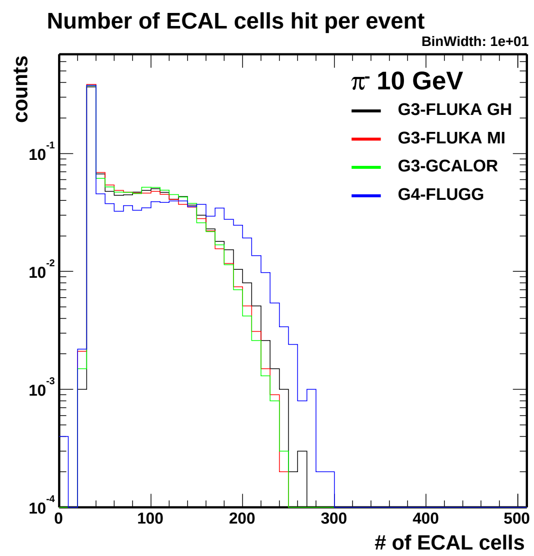


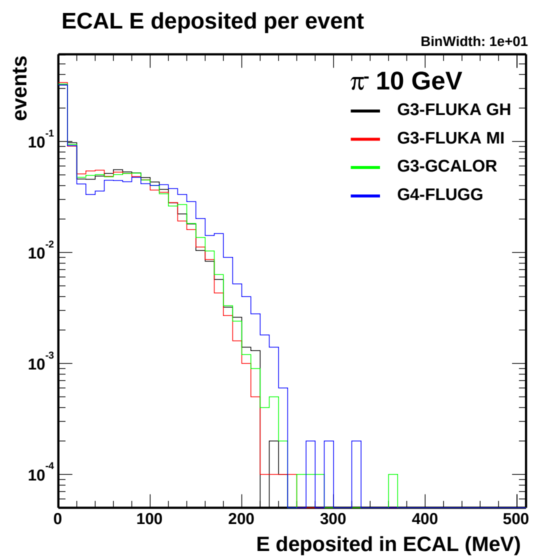
▷ **HCAL rpc less sensitive to low energy neutrons than HCAL scint**

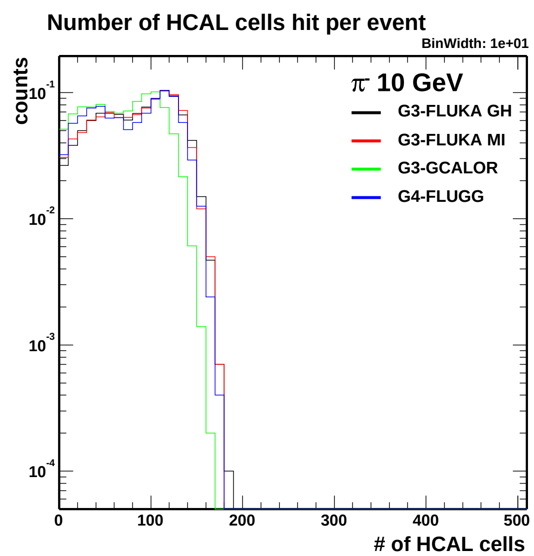
fluka based models in more detail

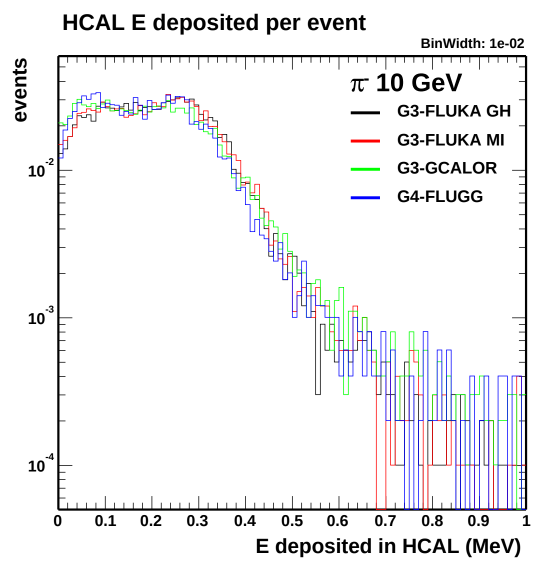
N cells hit

E deposited



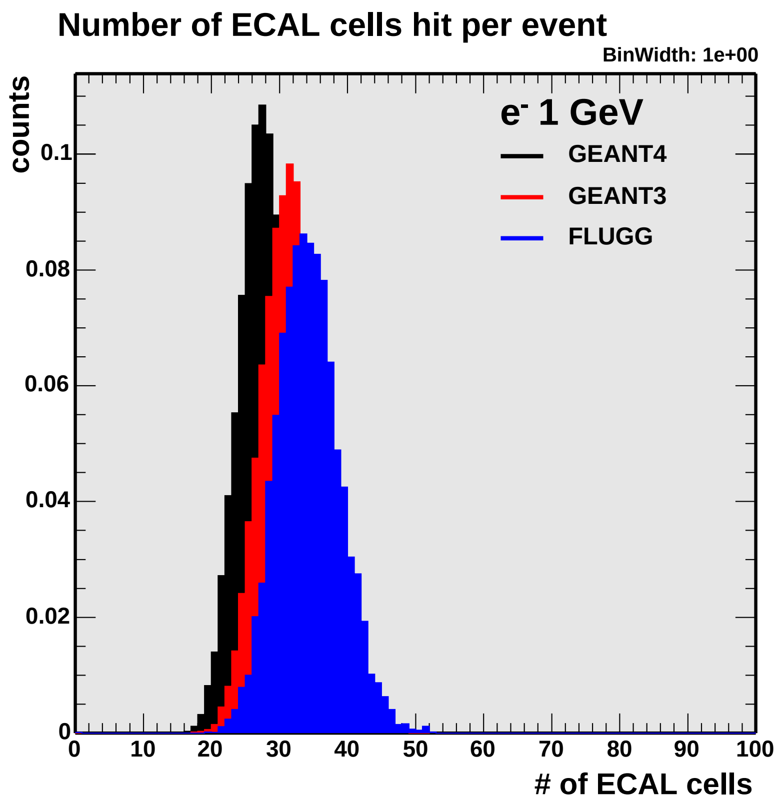




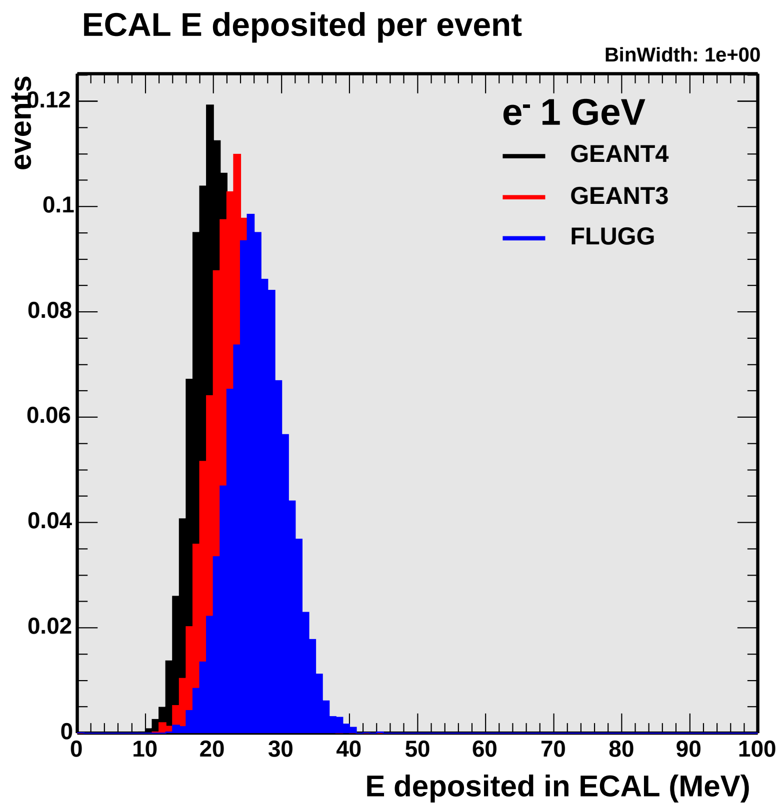


discrepancies between frameworks

N cells hit



E deposited



GEANT3 14% higher than GEANT4

FLUGG 24% higher than GEANT4

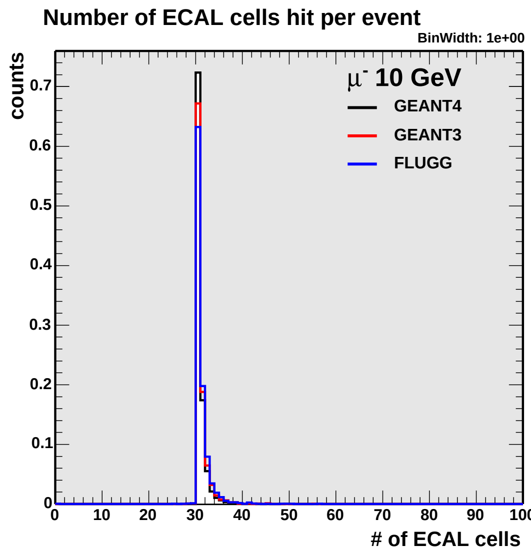
GEANT3 14% higher than GEANT4

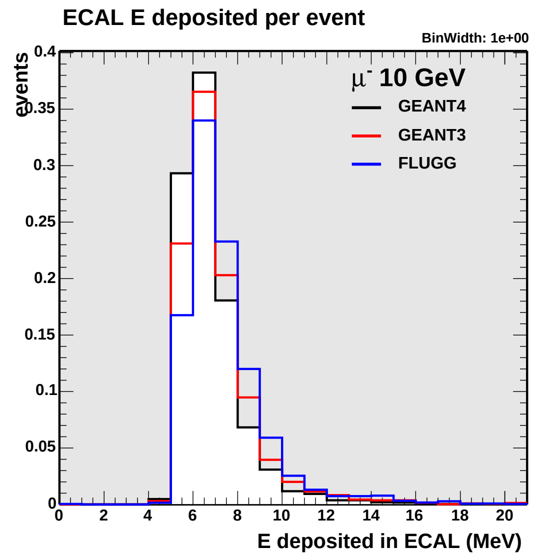
FLUGG 30% higher than GEANT4

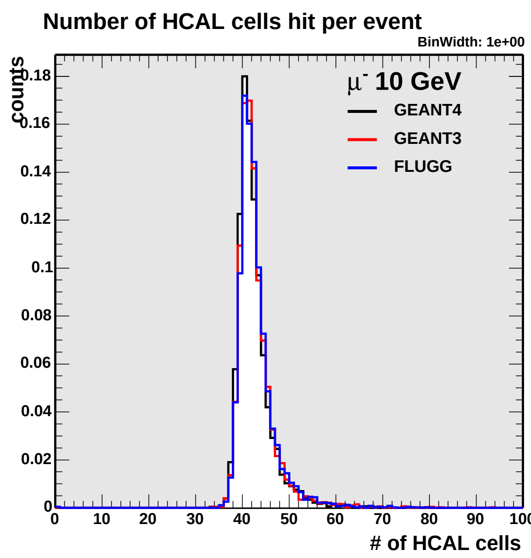
agreement between frameworks

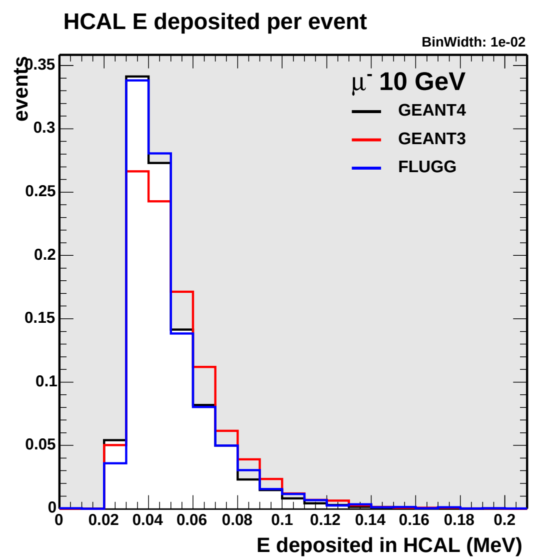
N cells hit

E deposited









Conclusions

- .
  - : GHEISHA based models are in relative "agreement"
  - : FLUKA based models are definitely different
  - : low energy neutrons are important especially for the HCAL scint
    (e.g. compare G3-FLUKA+GH, G3-FLUKA+MI, G3-GCALOR or G4-LHEP with G4-LHEP-HP)
  - : intranuclear cascade models are also important
    (e.g. compare Bertini or Binary cascade models with the rest)
- .
  - : HCAL scint more sensitive than HCAL rpc
  - : ECAL standalone may have some discriminating power at low energies
- .
  - : different models predict different calorimeter response
    - ▹ mainly as a consequence of predicting different shower size

  thus, different models predict different optimum calorimeter granularity