Comparisons of hadronic shower packages

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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

  - **GEANT4.6.0***** : LHEP : QGSP : LHEP-BERT : QGSP-BERT : LHEP-BIC : QGSP-BIC : LHEP-GN : QGSC : LHEP-HP : FTFP

*** with hadronic physics list PACK 2.3

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

Brief description

- run under Mokka(v2.2) and Brahms(v3.01) frameworks
  (GEANT4.6.0 and GEANT3.21 based, respectively)

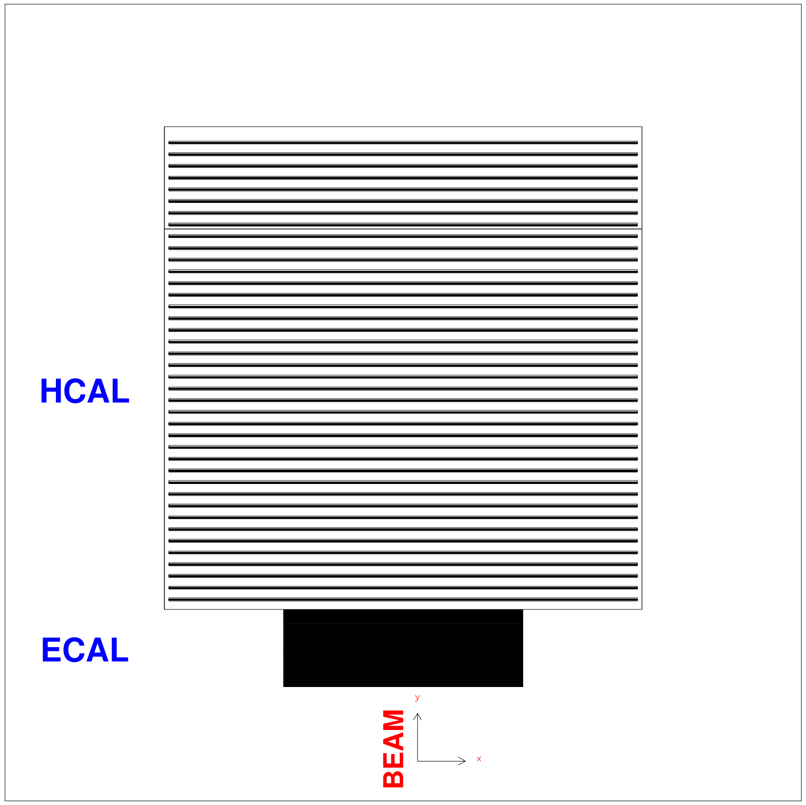
- study with W/Si ECAL+Fe/Scint or RPC HCAL CALICE prototypes
  porting detector geometry from GEANT4 to GEANT3

- cutoffs : GEANT3 energy cutoffs EM = 10 keV, HAD = 0.1 MeV
  : GEANT4 range cutoff = 5 μm

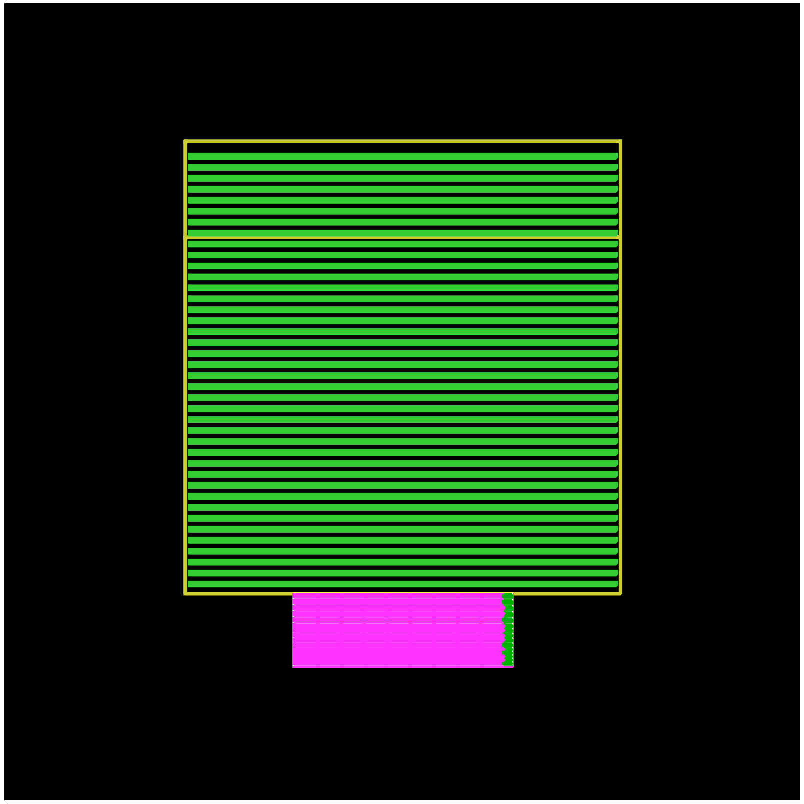
  : ECAL, HCAL cellsize 1×1 cm^2, threshold = 0.5 mip

- samples of 10000 events,
  results normalised to G4-LHEP case (Mokka default),
  shown $\pm$10% and $\pm$20% bands wrt 1 to guide the eye

GEANT3



GEANT4



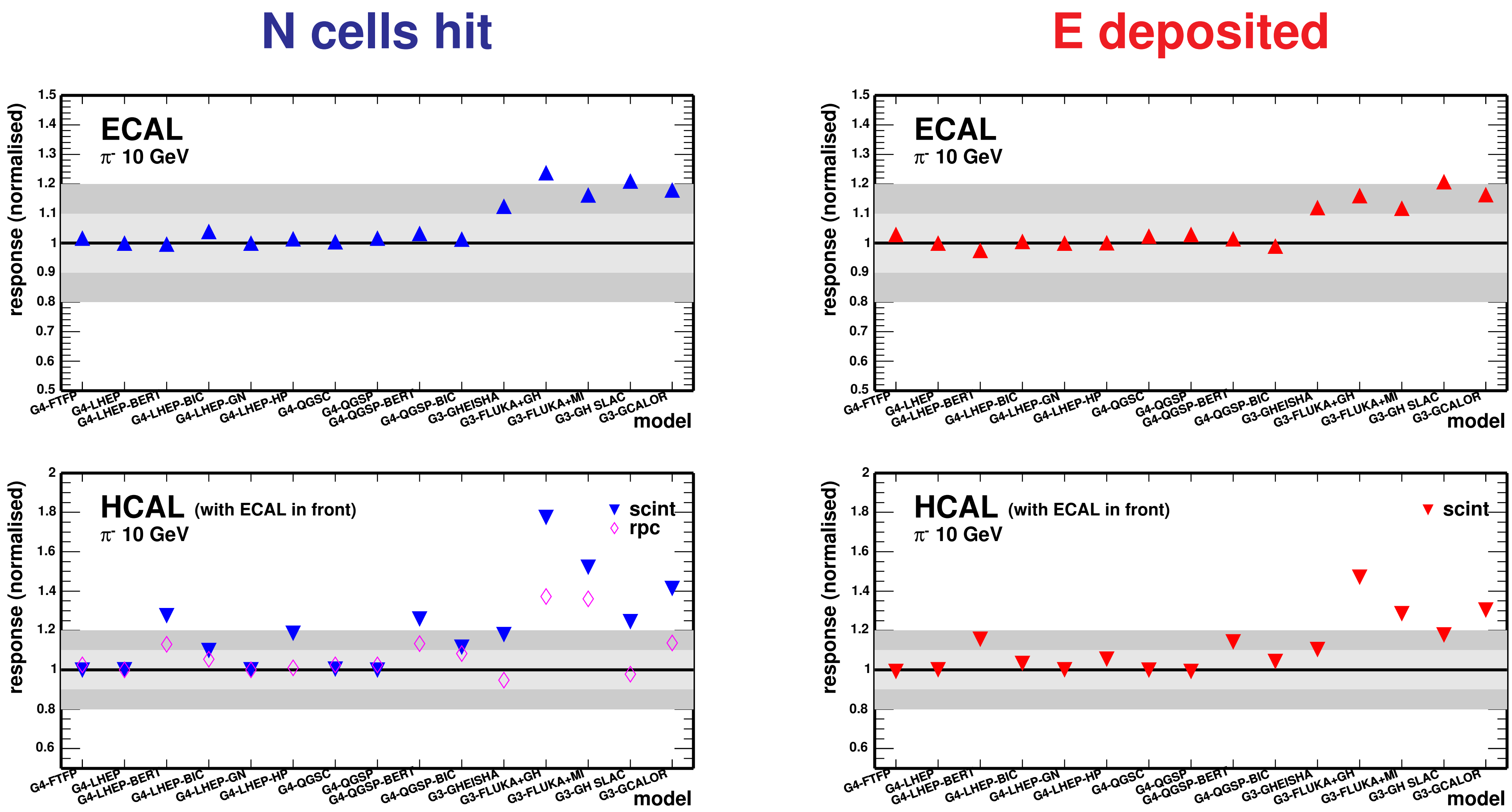
ECAL 30 layers × 50 cm × 38 cm interleaved with 0.5 mm Si pads

- ▷ 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

"response" vs model, π^- 10 GeV/c

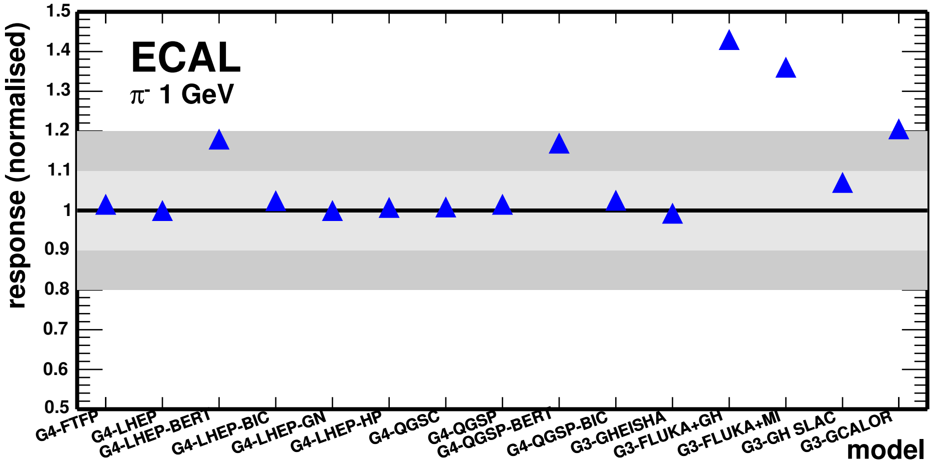


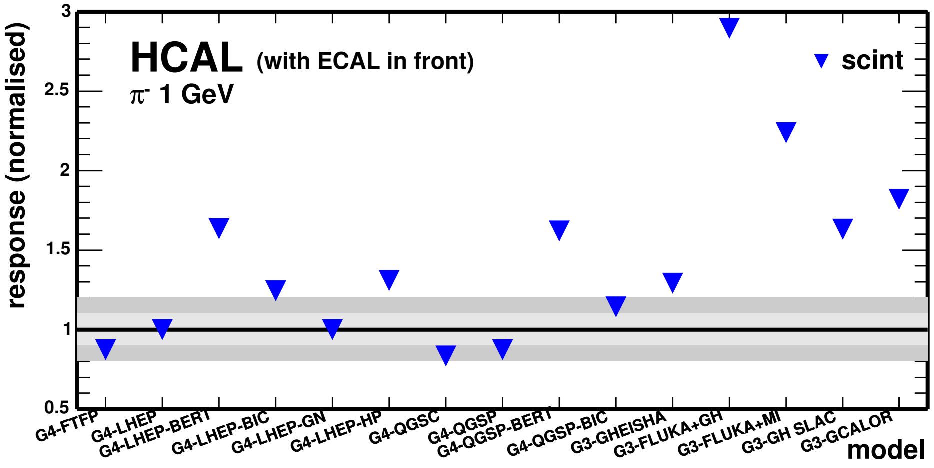
▷ different models predict different calorimeter response

▷ HCAL more sensitive than ECAL

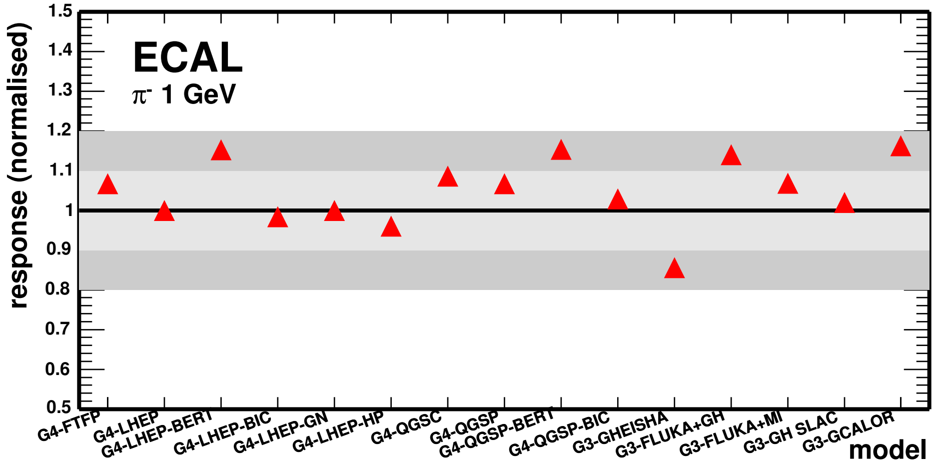
"response" vs model, π^- 1 GeV/c

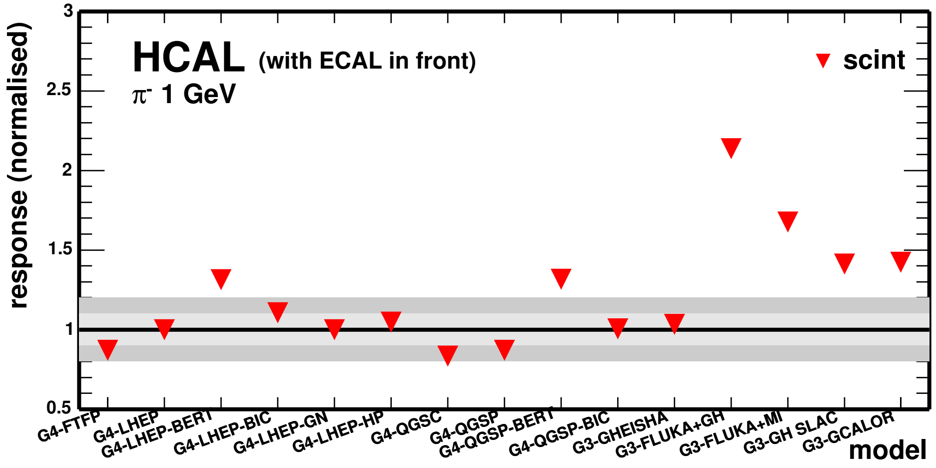
N cells hit





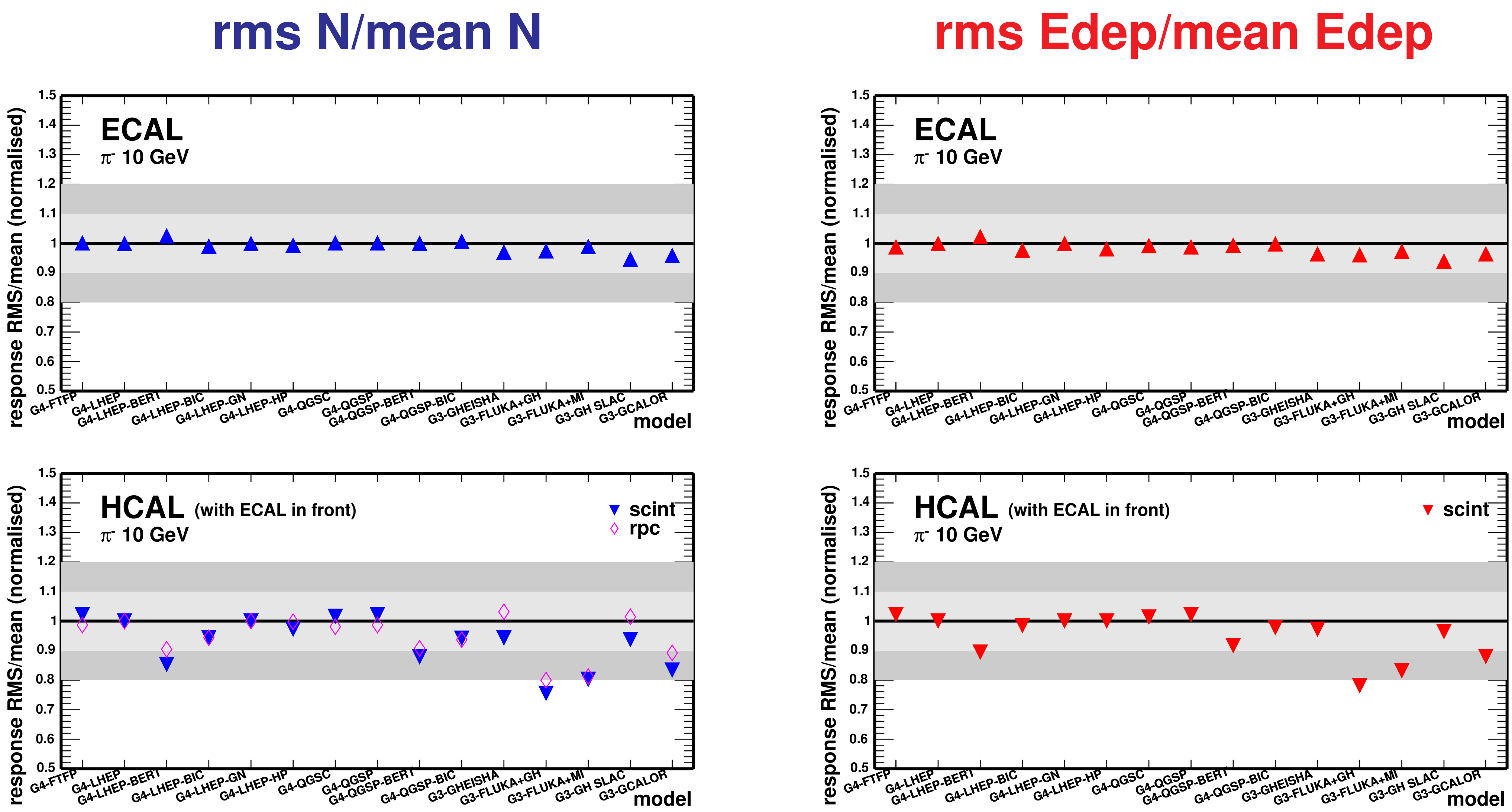
E deposited





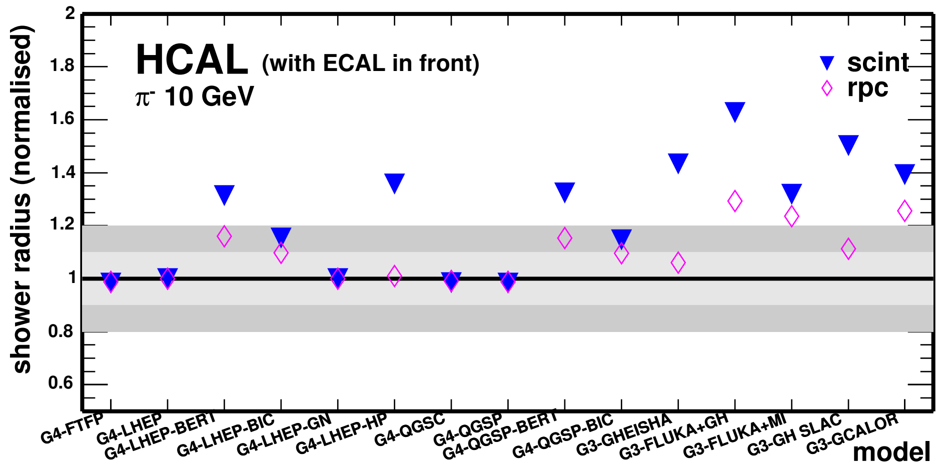
- ▷ same pattern as at 10 GeV case, even more pronounced
- ▷ ECAL standalone may have some discriminating power

"response" rms/mean vs model, π^- 10 GeV/c

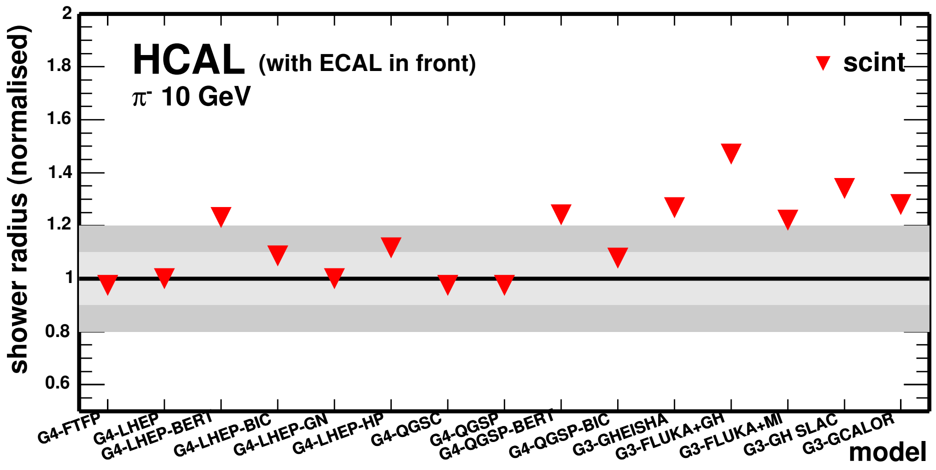


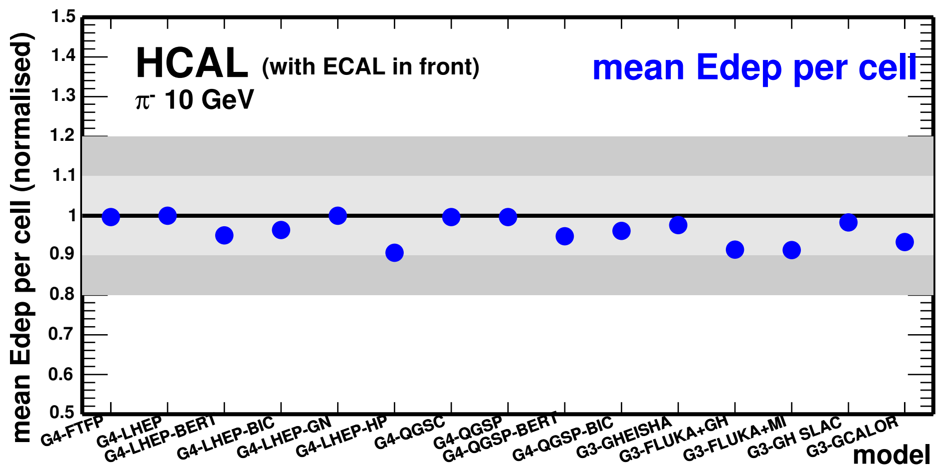
▷ **differences are still present but they are smaller**

shower transverse width vs model, π^- 10 GeV/c



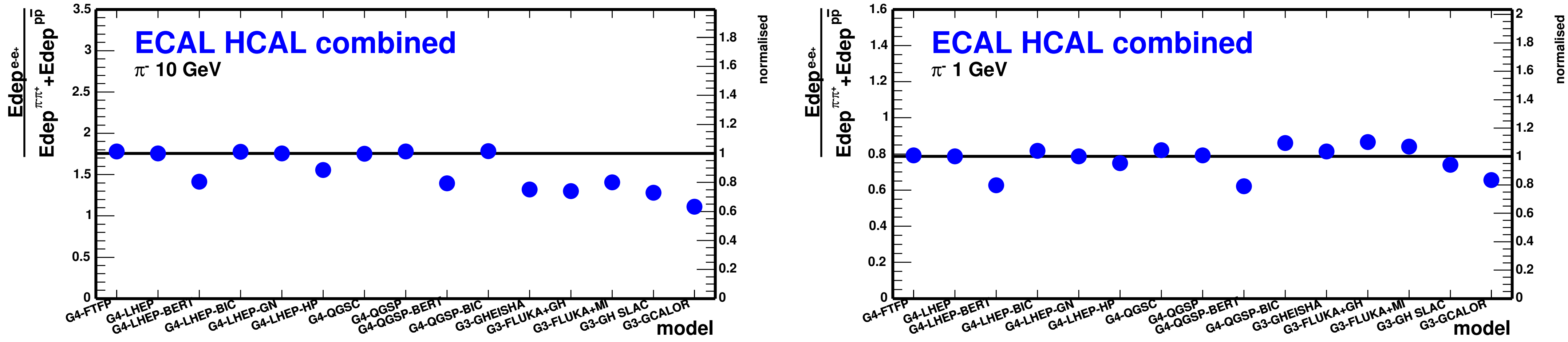
weighted by Edep per cell





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

Edep by e^+, e^-/Edep by $\pi^+, \pi^-, p, \bar{p}$



- ▷ **better agreement at 1 GeV**
- ▷ **Bertini cascade based models consistent with each other**

Conclusions

- .
  : all GHEISHA based models agree within $\pm 20\%$ at 10 GeV,
  $\pm 30\%$ at 1 GeV

  : G3-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)

  : intranuclear cascade models are also important
  (e.g. compare Bertini or Binary cascade models with the rest)

- .
  : 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

Reminder

- .
  - : LHC experiments conducted a wide program of testbeams to validate hadronic shower simulation
  - : in general, ... the level of agreement between simulation and data is close to requirements in some cases (e.g. e/π ratio) whereas more work is needed for other cases (e.g. shower profiles)
- . **please note**
  - : LHC testbeams at $E_{hadron} > 20$ GeV
  - : LC's region of interest is mainly in $E_{hadron} < 20$ GeV
- . **so**
  - : suitable data desperately needed
  - : for the time being predictions are expected to have low reliability and low persistency