Status of Hadronic Shower Simulation for LHC

17th Collaboration Meeting
Chartres, 10-14 September 2012

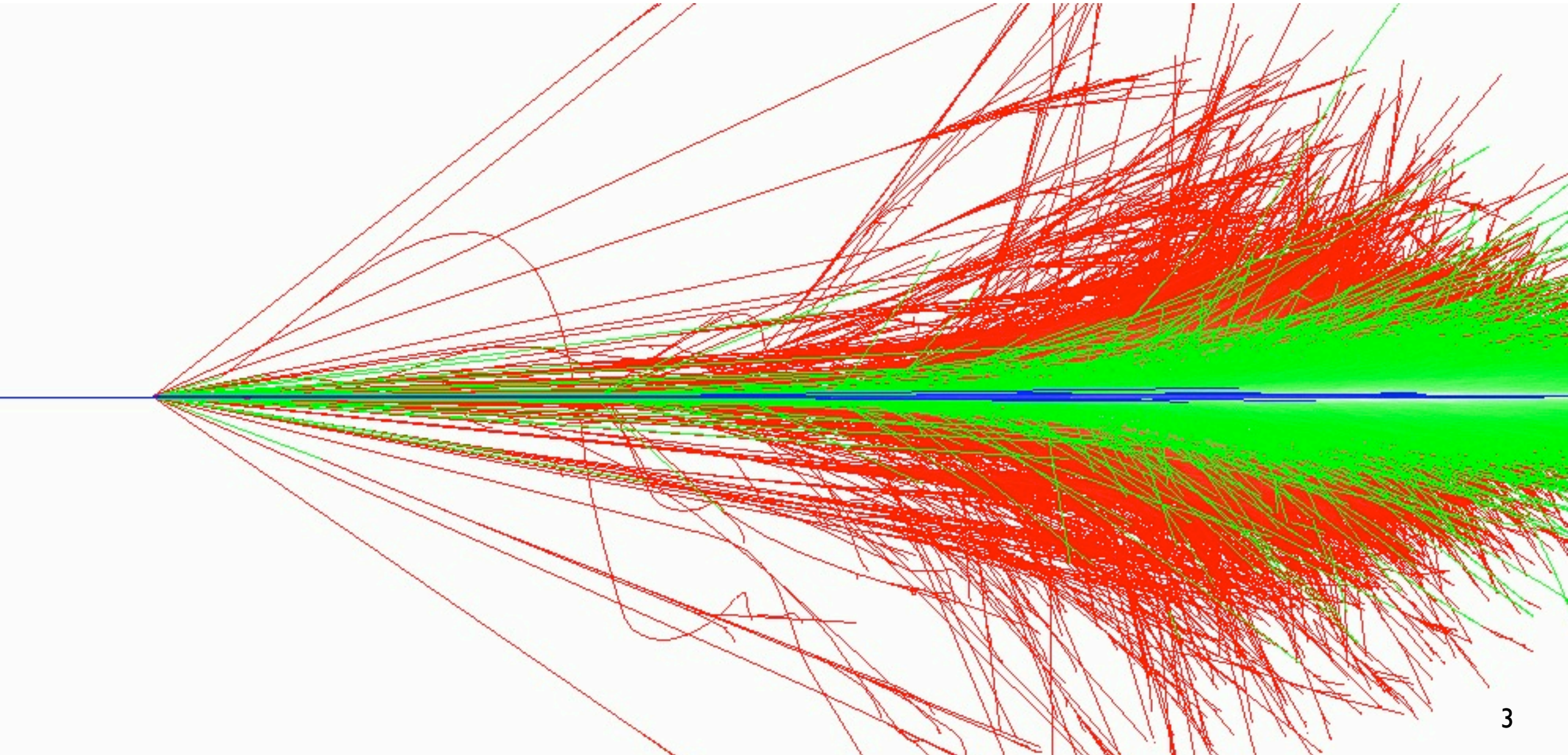
Andrea Dotti (andrea.dotti@cern.ch)

Outlook

- Status of calorimetric observables
  - Response
  - **Resolution**
  - **Lateral shower shape**
  - **Longitudinal shower shape**
  - Additional issues
- Comments and conclusions
  - A possible list of working items

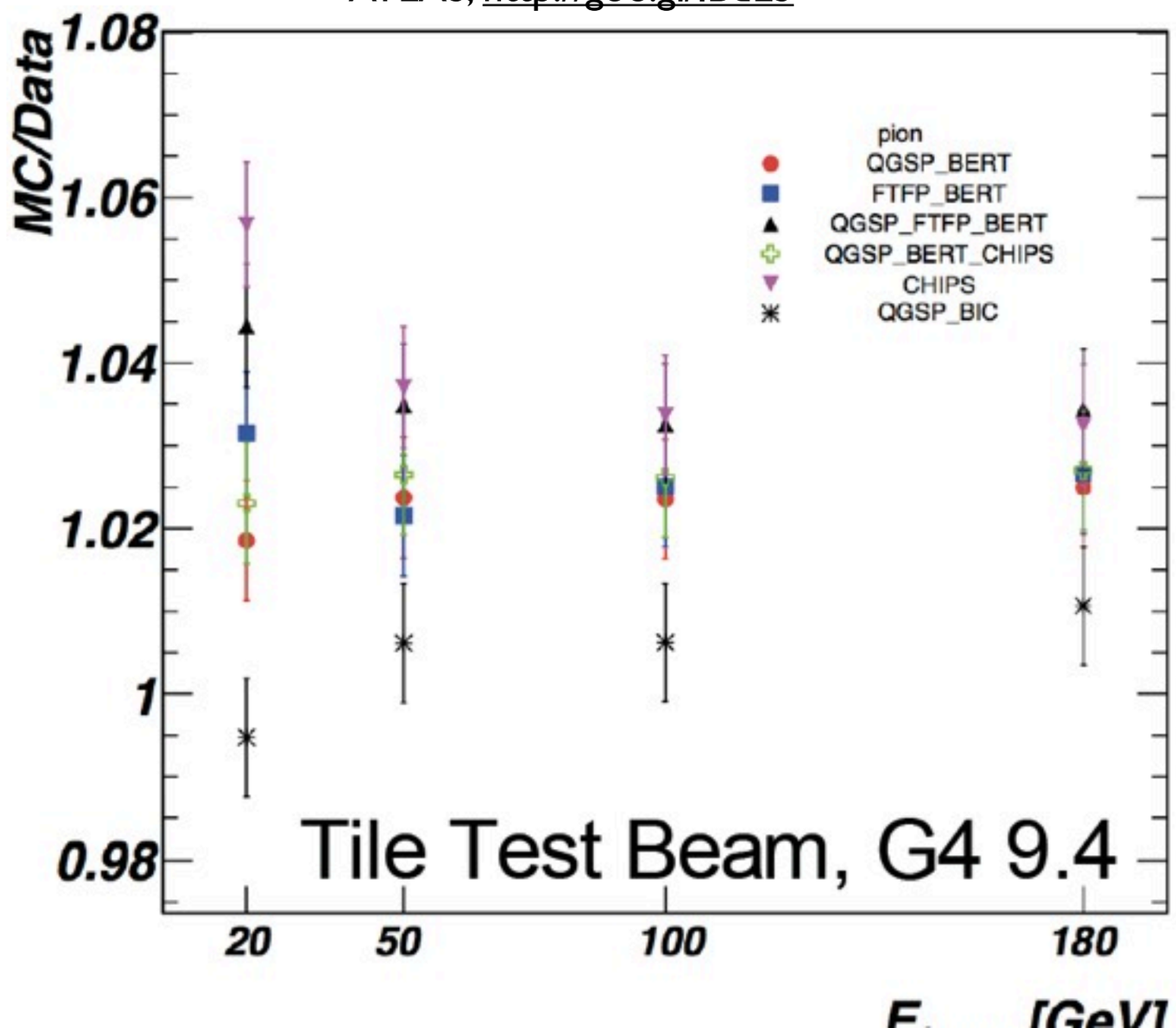
Based on input from LHC and CALICE calorimeters

Response



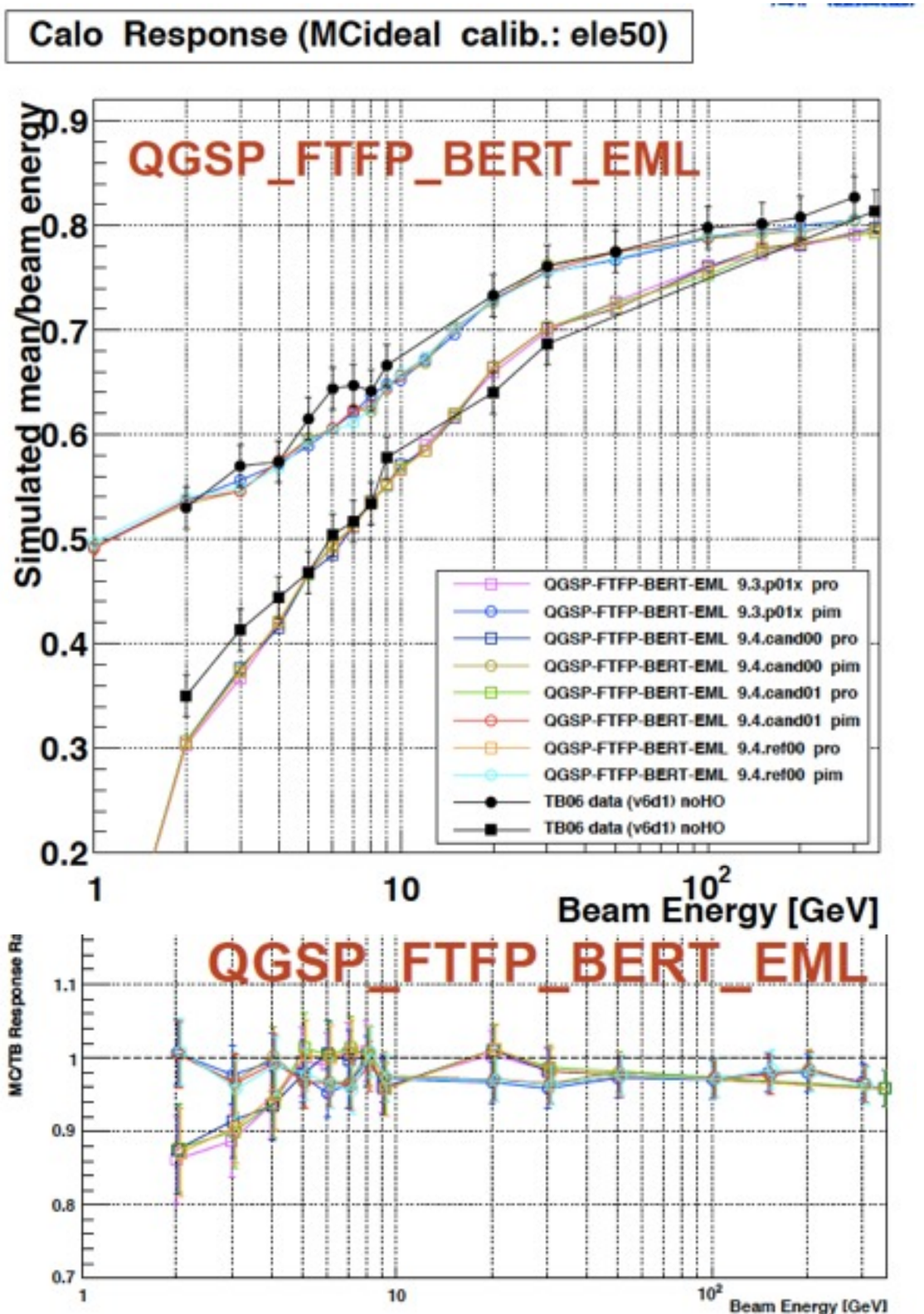
Response: ATLAS Tile

ATLAS, http://goo.gl/IBdL3



- ATLAS Tile-Calorimeter
- FTF models predict higher energy ~2-3%

Response CMS combined



CMS, http://goo.gl/VN0jb

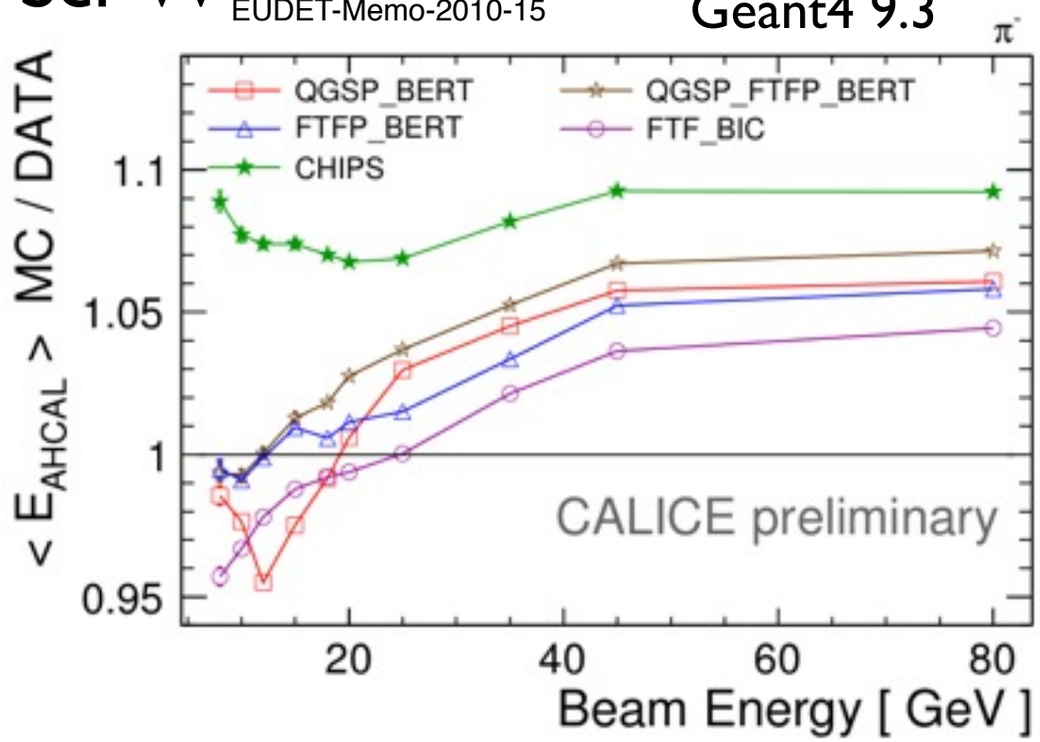
- Similar conclusion with CMS hadronic stand alone test-beam data

CALICE

Sci-W

EUDET-Memo-2010-15

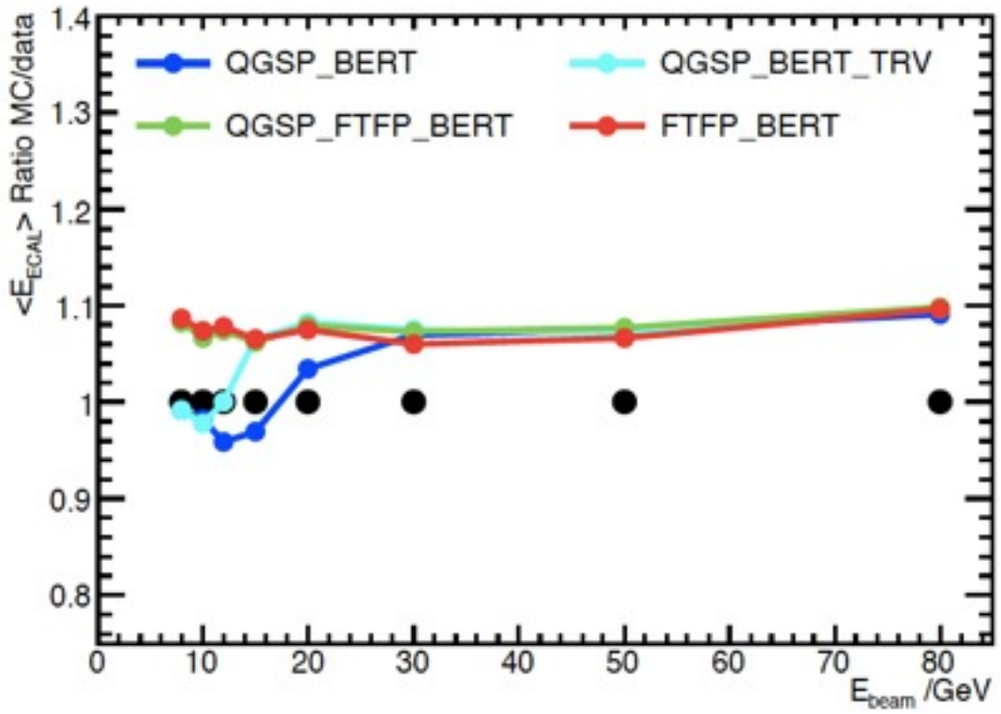
Geant4 9.3



Si-W

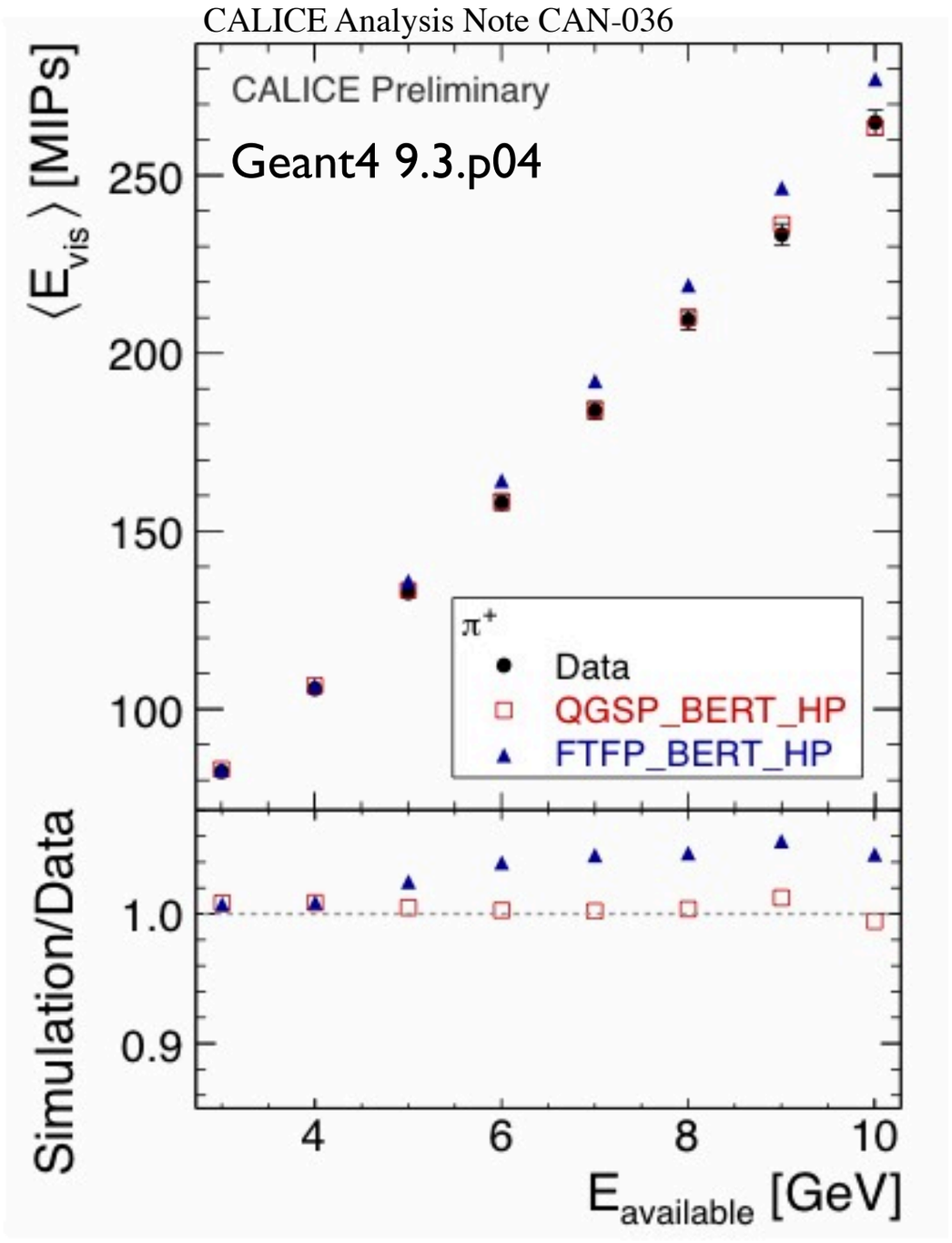
JINST **5** P05007

Geant4 9.3



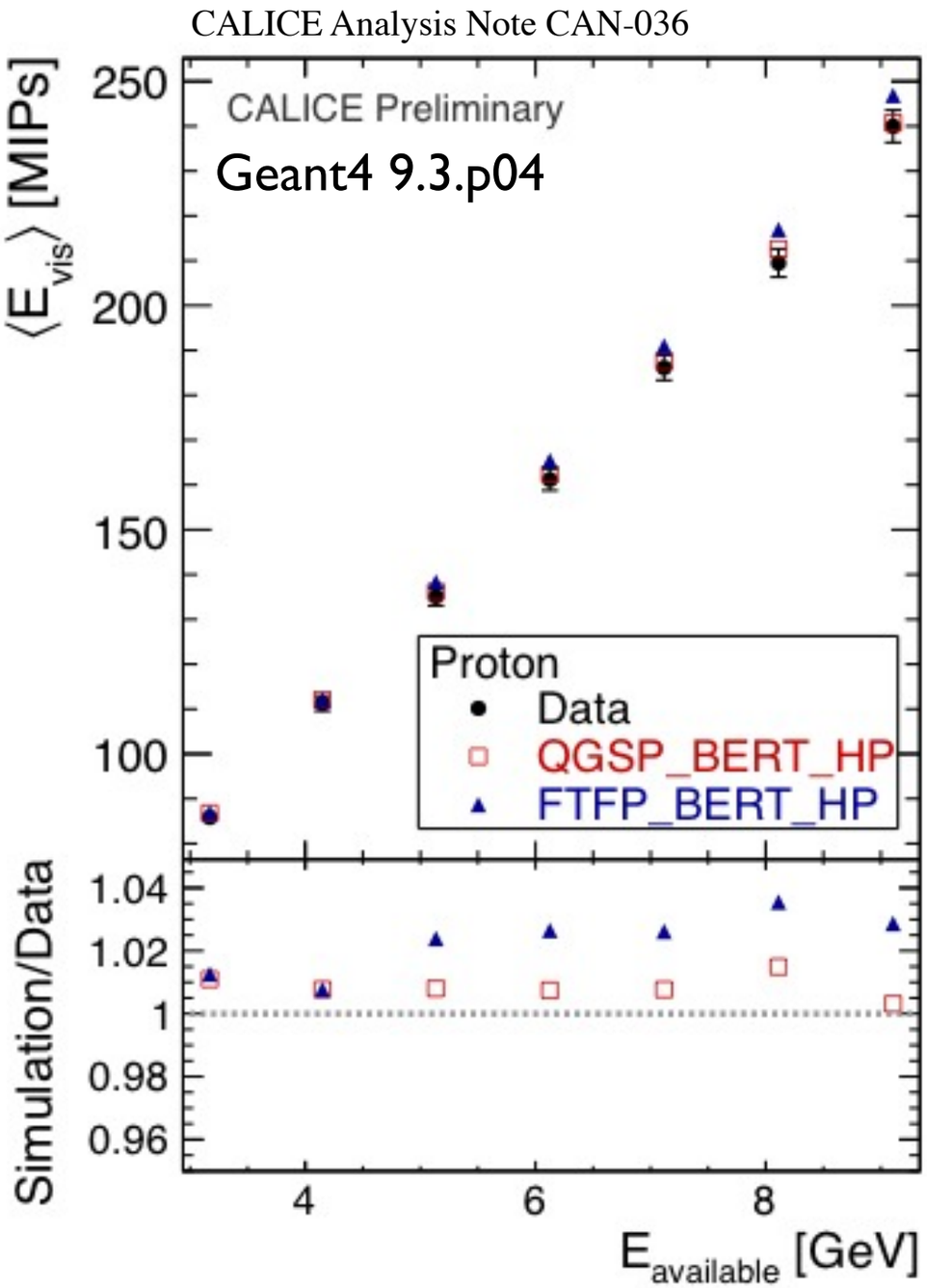
- Similar results obtained by CALICE collaboration
- Sci-W calorimeter and Si-W calorimeter (EM)
- Shorter ($5\lambda_I$) w.r.t. LHC ones

CALICE: Si-W low-E



- CALICE data seems to prefer QGSP_BERT in range 4-10GeV
  - BERT gives good agreement with data (+1%)
- Suggests we can use BERT up to higher energies in FTFP_BERT

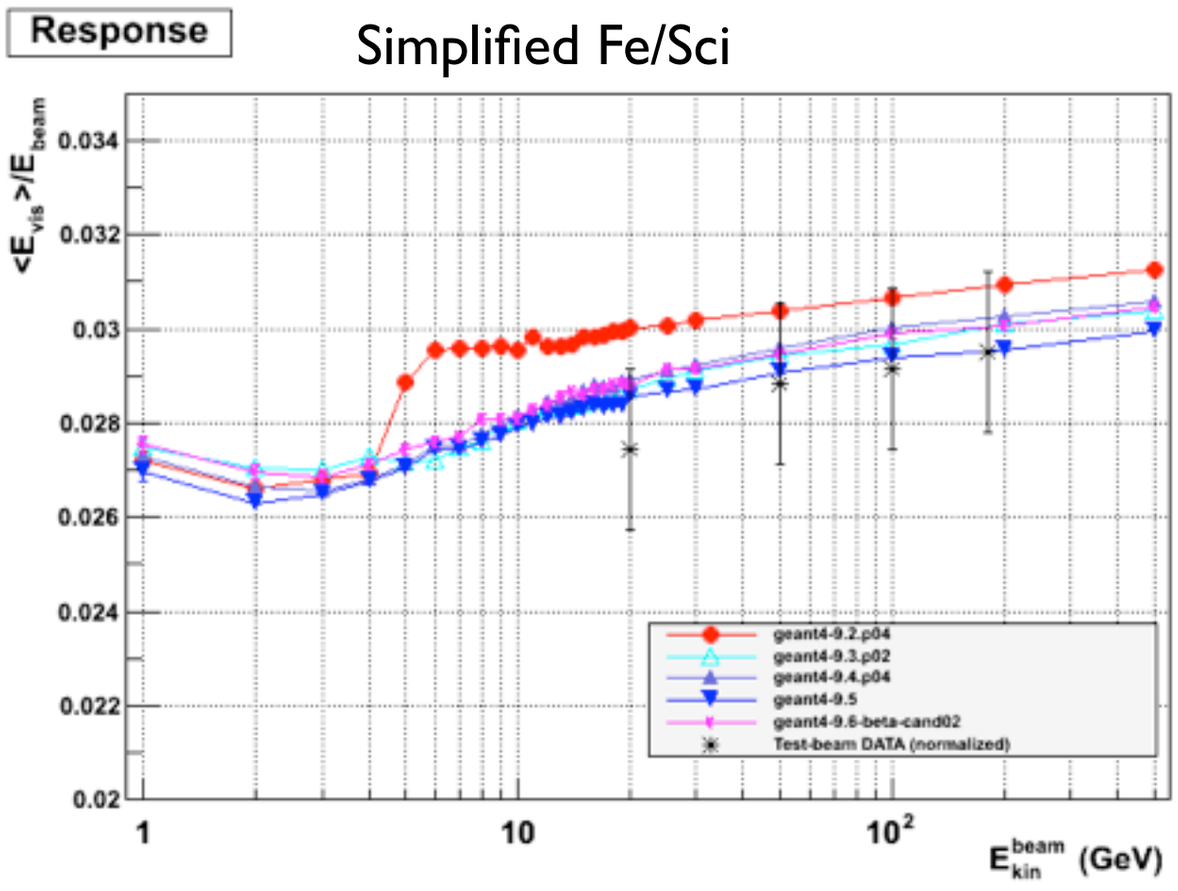
CALICE: Si-W low-E

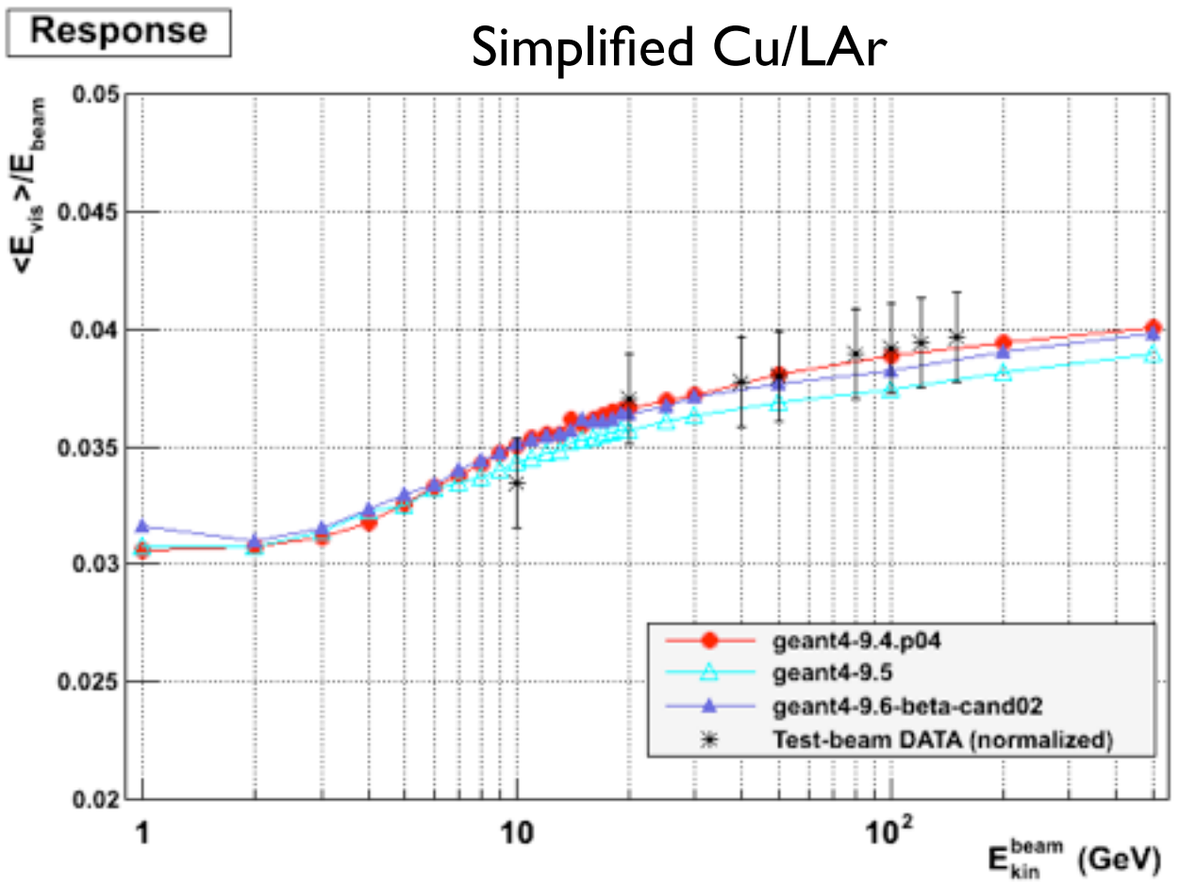


- Similar conclusions for proton beams

Response: Conclusions

- Positive reports from experiments
  - Visible energy is however too high from FTF
  - BERT gives very good agreement with low-E data
- In recent versions of Geant4 constant improvement
  - **Geant4 9.6.beta FTF goes back at higher energy**

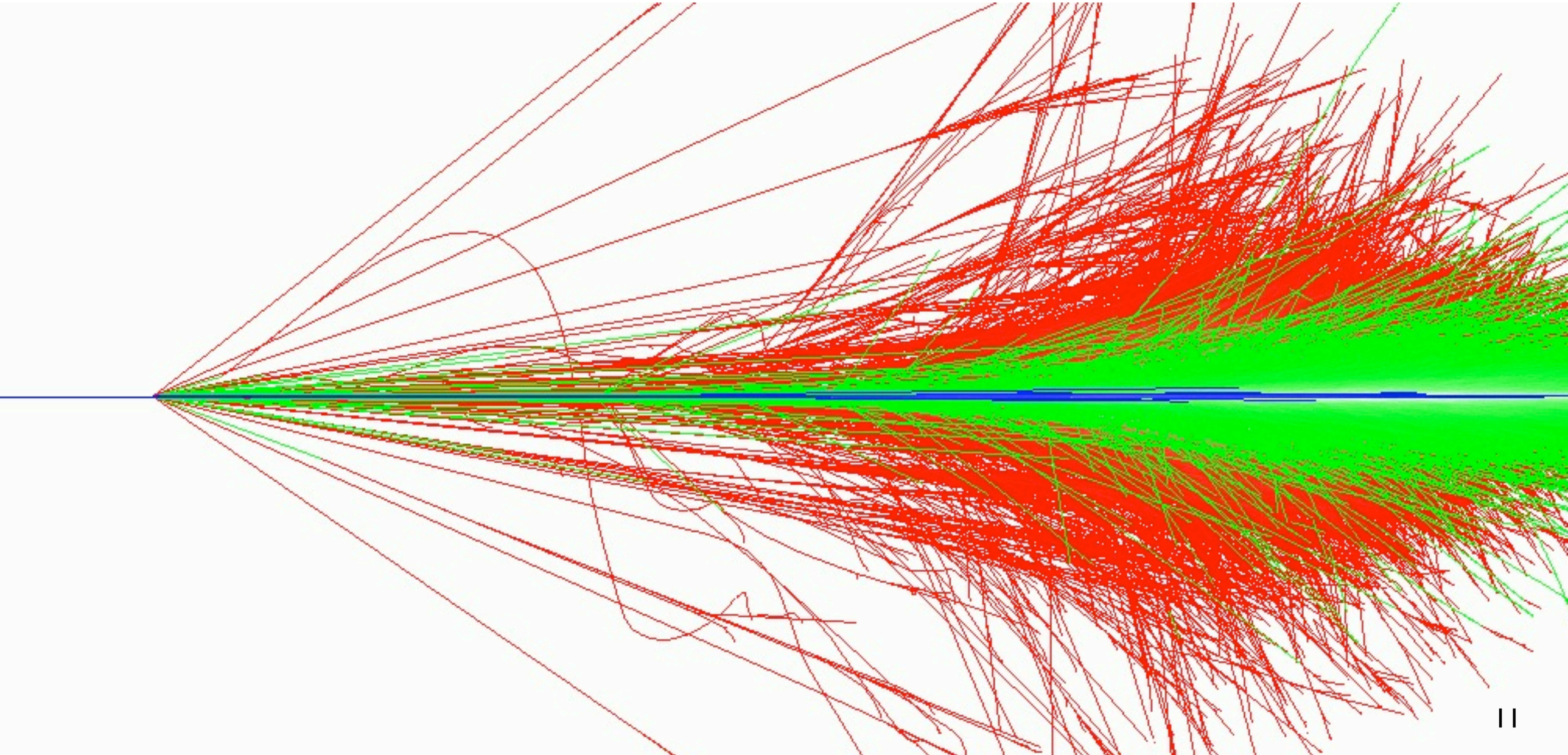




Possible Actions

- From a preliminary study by Witek: http://goo.gl/cId2b
  - Comparison with NA22 data: π^0 production at high energy (250 GeV)
  - **Geant4 produces too many π^0**
- Suggest to validate/tune π^0 production
  - Could have also impact on resolution (see next slides)
- FTF in 9.5 is going correct direction, 9.6.beta seems to revert back to too high energy deposit

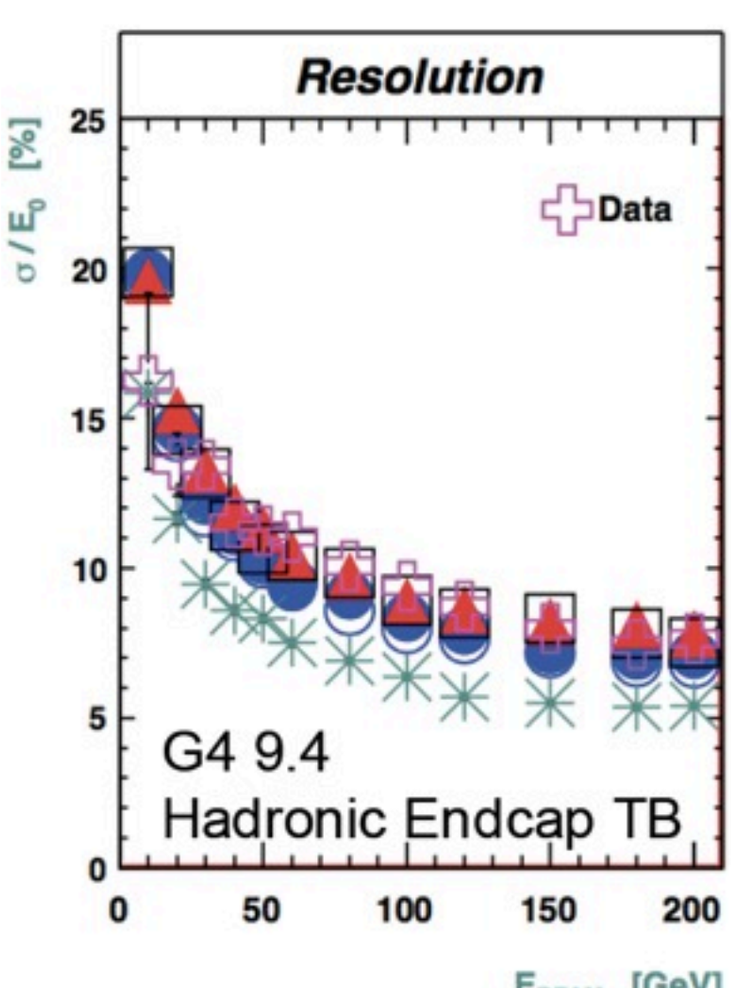
Resolution

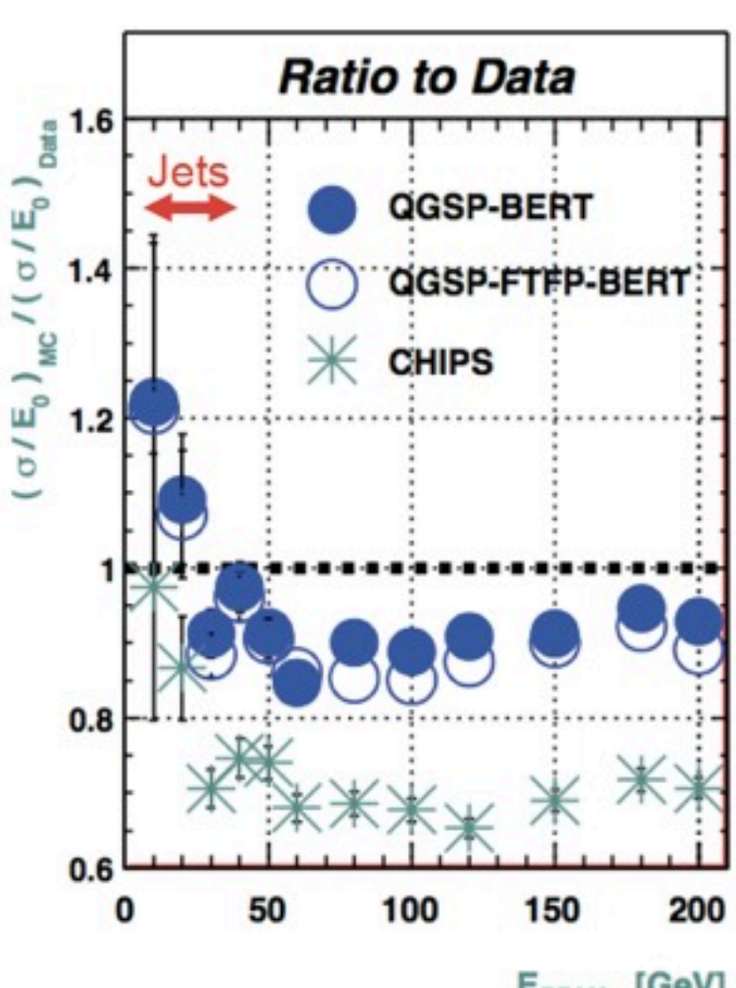


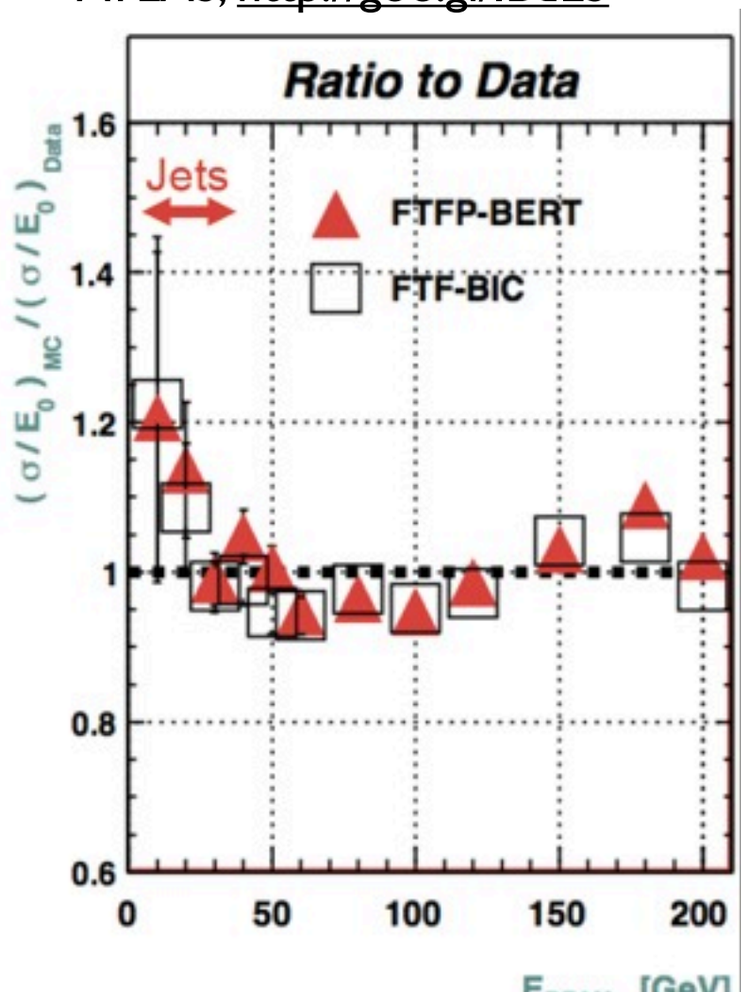
ATLAS HEC: Cu/LAr

- FTF seems adequate at high energy
- QGS too good
- Low-E has large error bars: difficult to judge, but goes in the opposite direction
- Similar conclusions for CMS

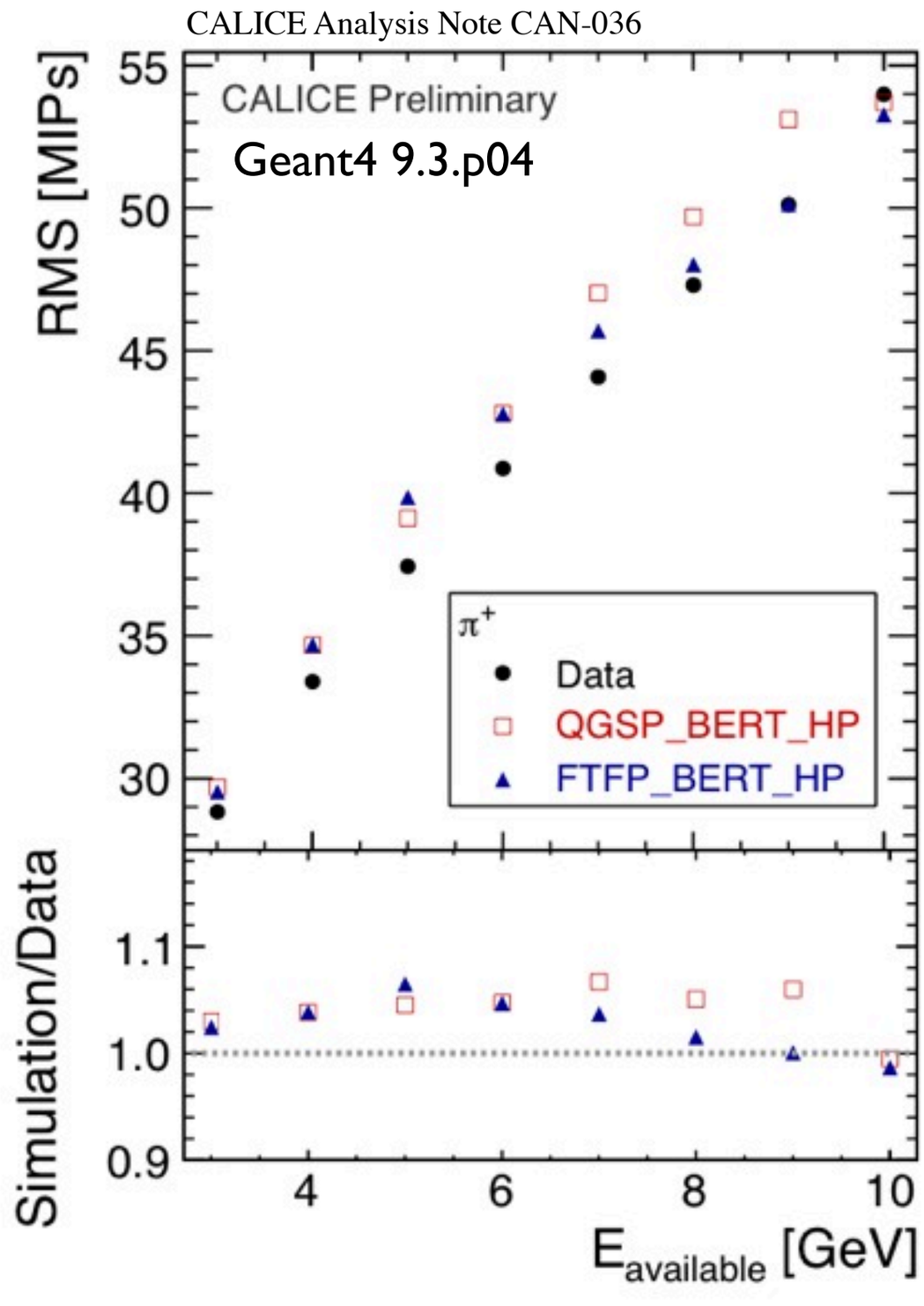
ATLAS, http://goo.gl/IBdL3





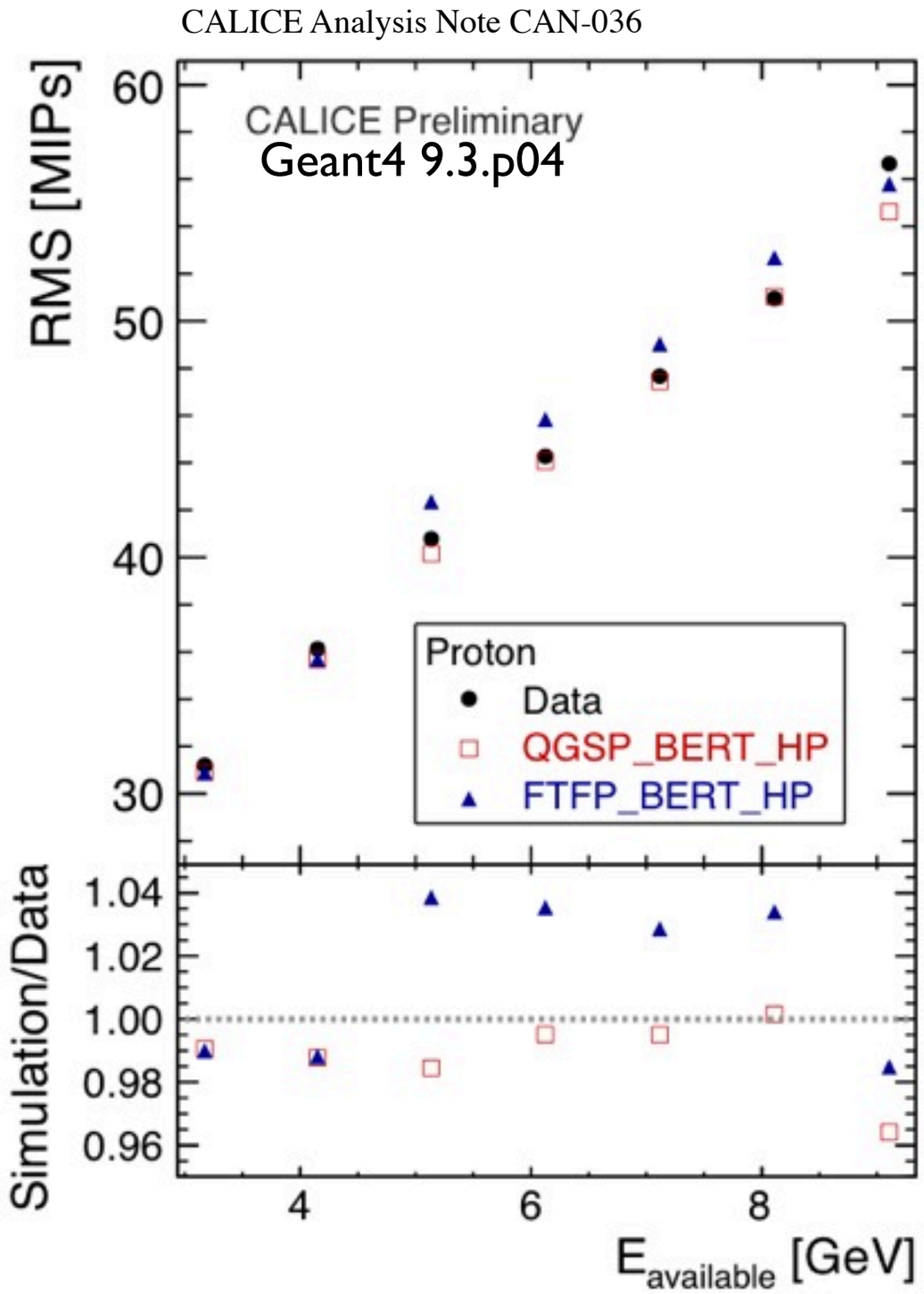


CALICE: Si-W at low-E



- CALICE data at low-E (<10 GeV): **opposite conclusions** w.r.t. high energy
  - FTF seems a bit better for pion beams
- Note: CALICE uses slightly different definition of resolution

CALICE: Si-W at low-E

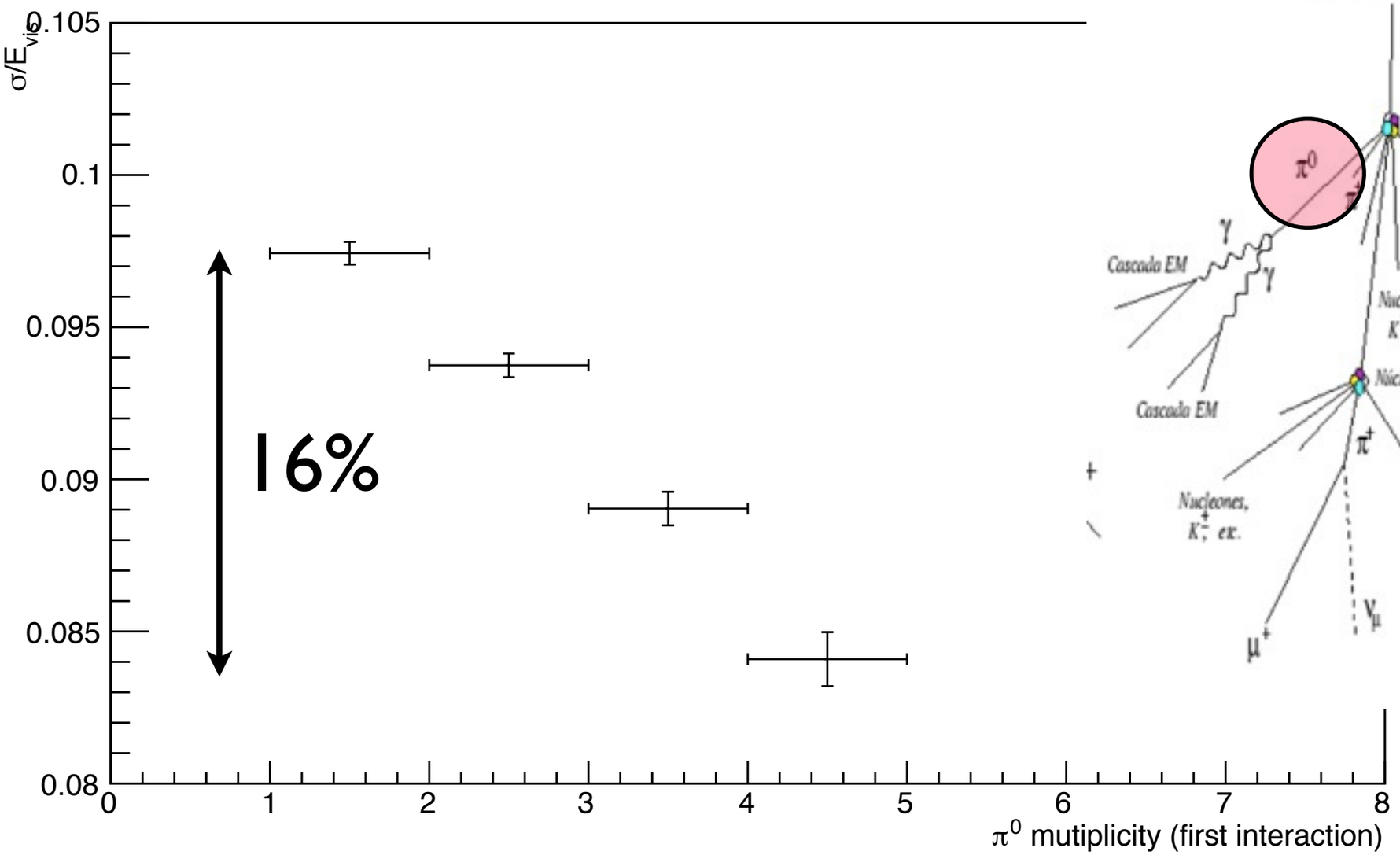


- Proton beams: similar conclusions
  - Larger difference FTF / BERT: transition effect at 4 GeV
- BERT could be extended up to 10 GeV

π0 Multiplicity

Resolution-piz

π⁻@20 GeV Pb/LAr

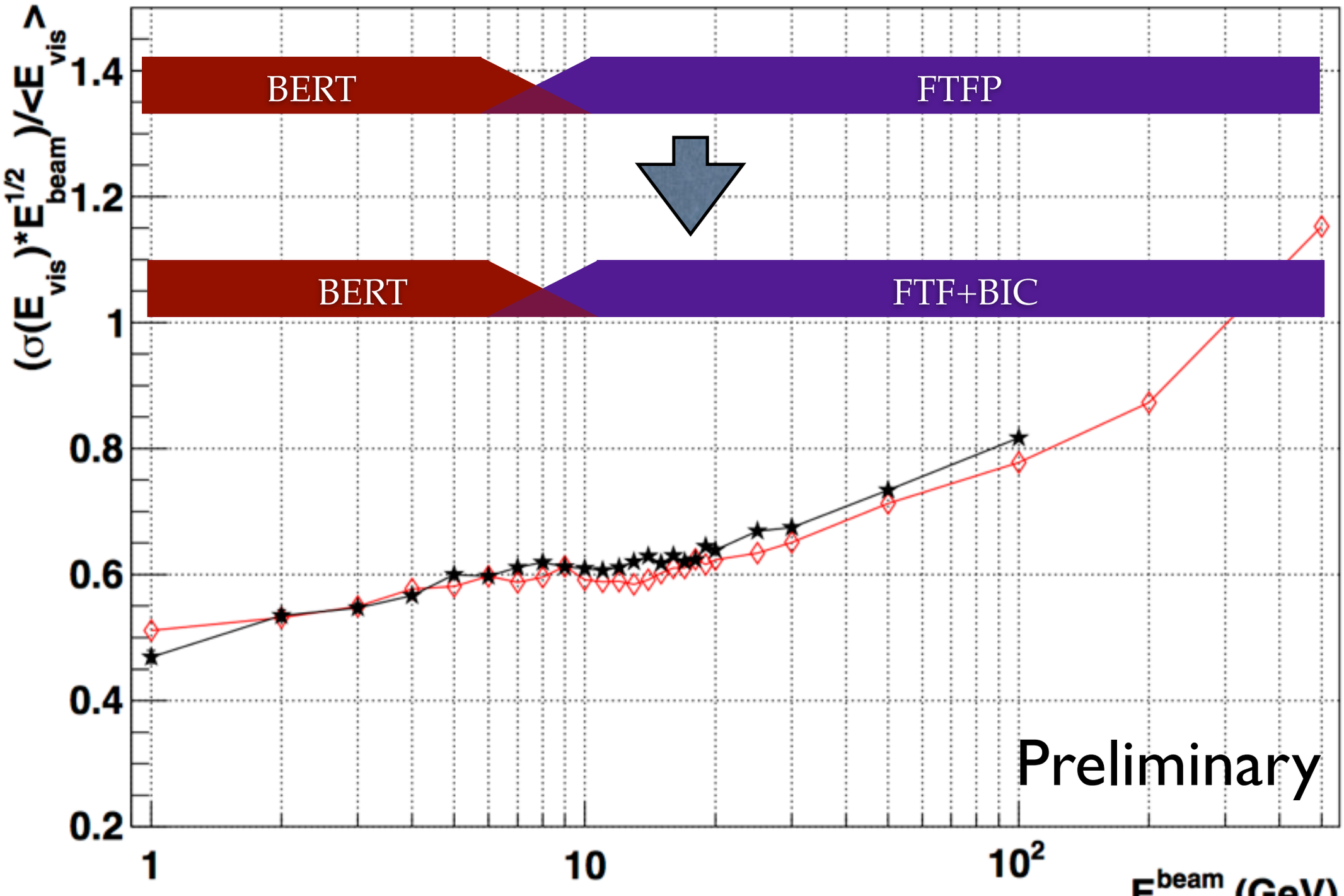


Study of resolution as a function **of multiplicity** of particles species at **first interaction**

Adding cascade to FTF

Resolution

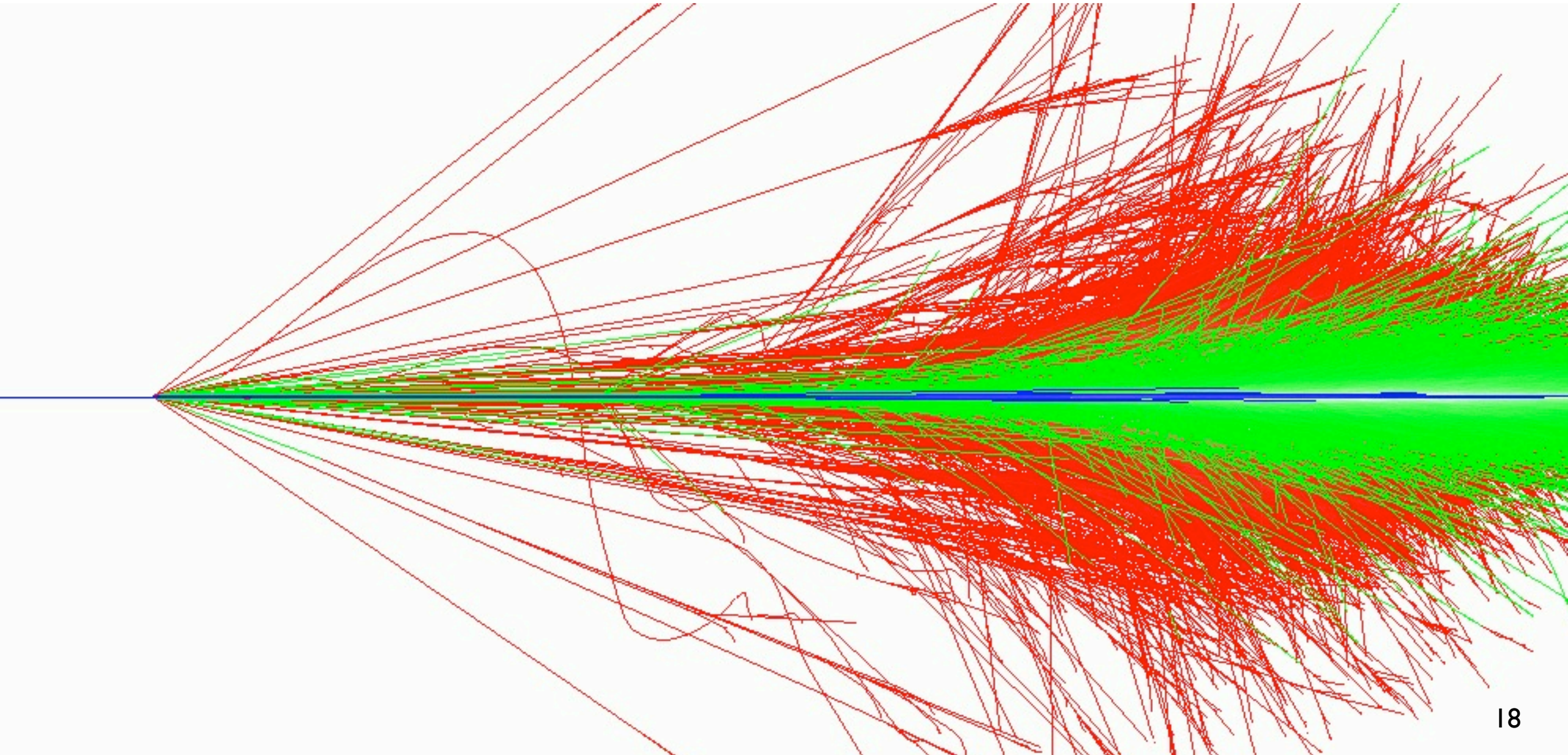
π^- Cu/LAr ; geant4 9.5



Possible Actions

- Resolution is a very difficult observable
  - Important instrumental effect
- No particular trend observed comparing Geant4 versions
- Validation and tuning of FTF π^0 production: could improve agreement with data
- "Re-scattering" could also improve agreement with data
  - **FTF already includes Reggeon cascading, need to re-evaluate how to avoid "double counting" effect**

Lateral shower shape



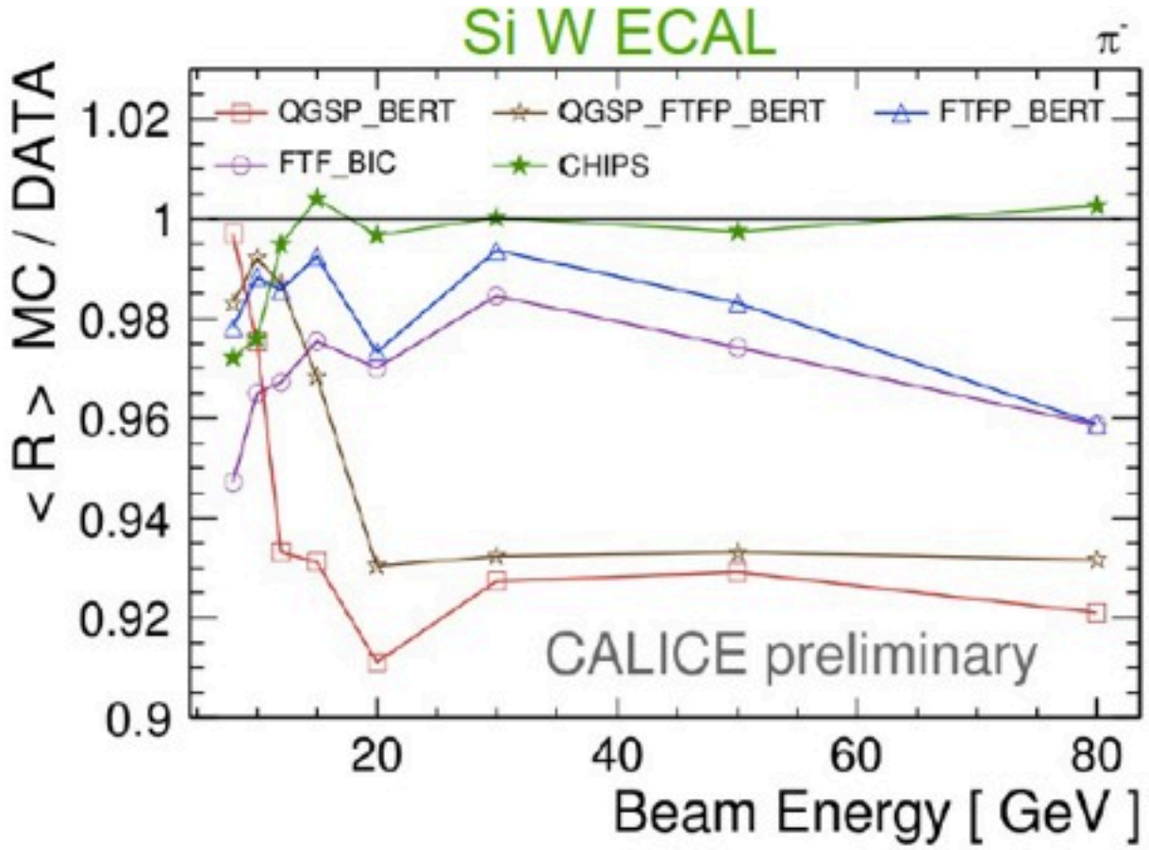
LHC

- Single data set from TileCal test-beam
  - Very rough granularity
- Showers, with all physics lists, are **too compact**
  - expressed as ratio of energy in "lateral" module w.r.t. "central" module

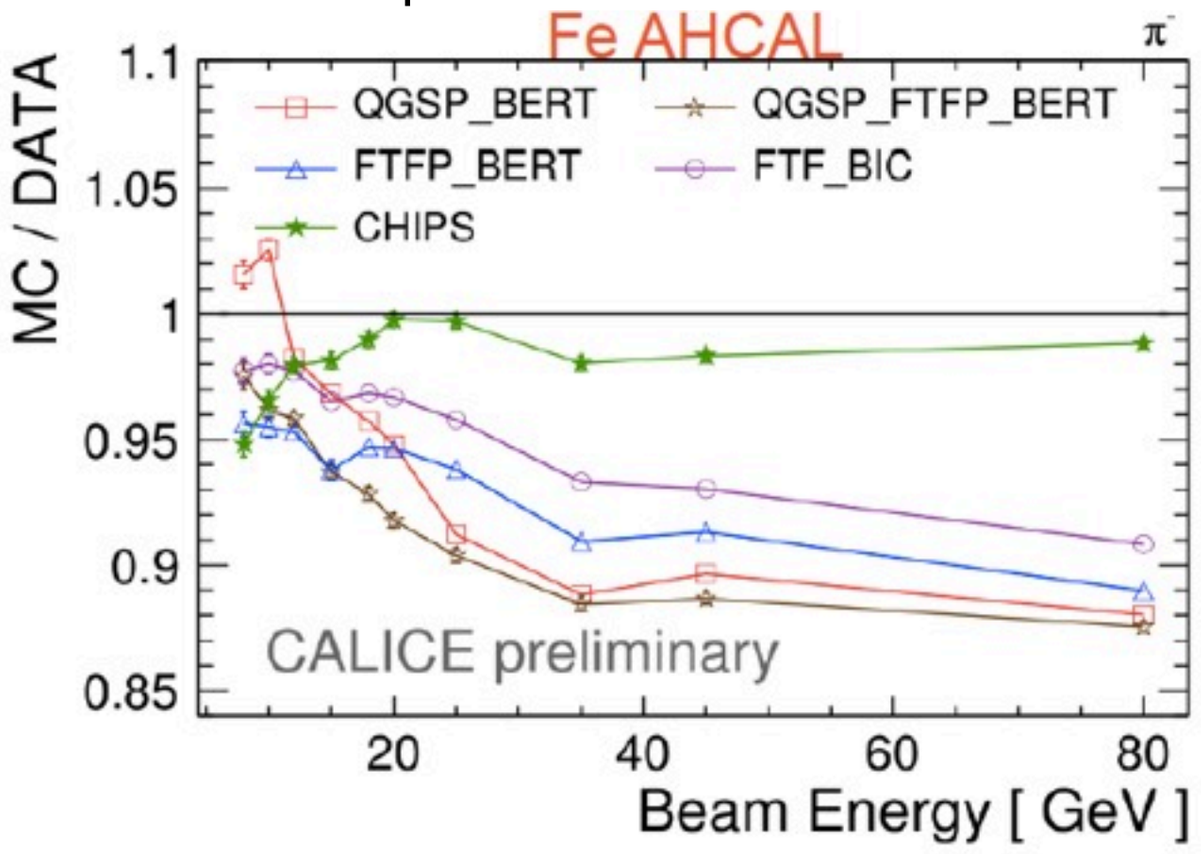
- Due to detector design only limited information can be obtained from LHC calorimeters
  - Concentrate on CALICE data

CALICE data

CALOR2012 http://goo.gl/jG9xR

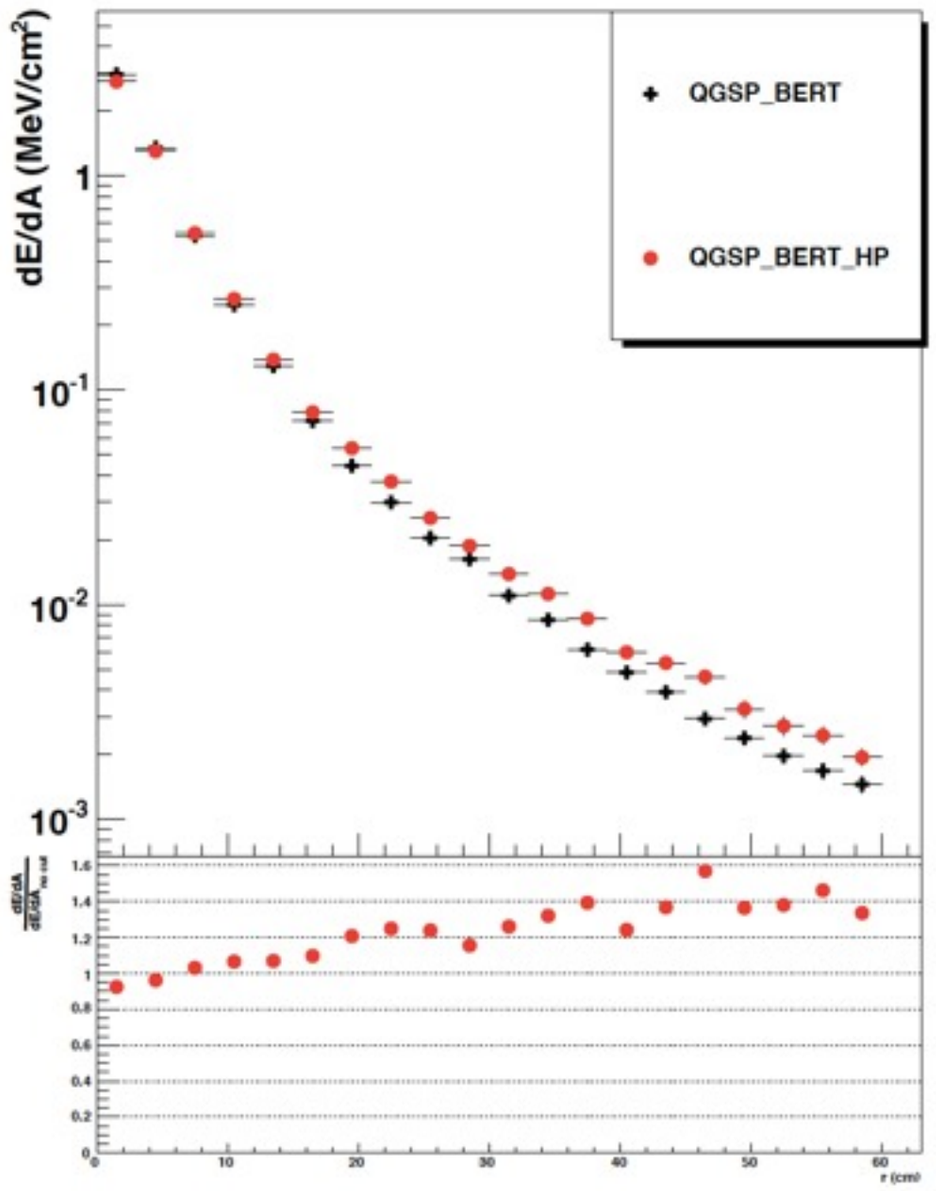


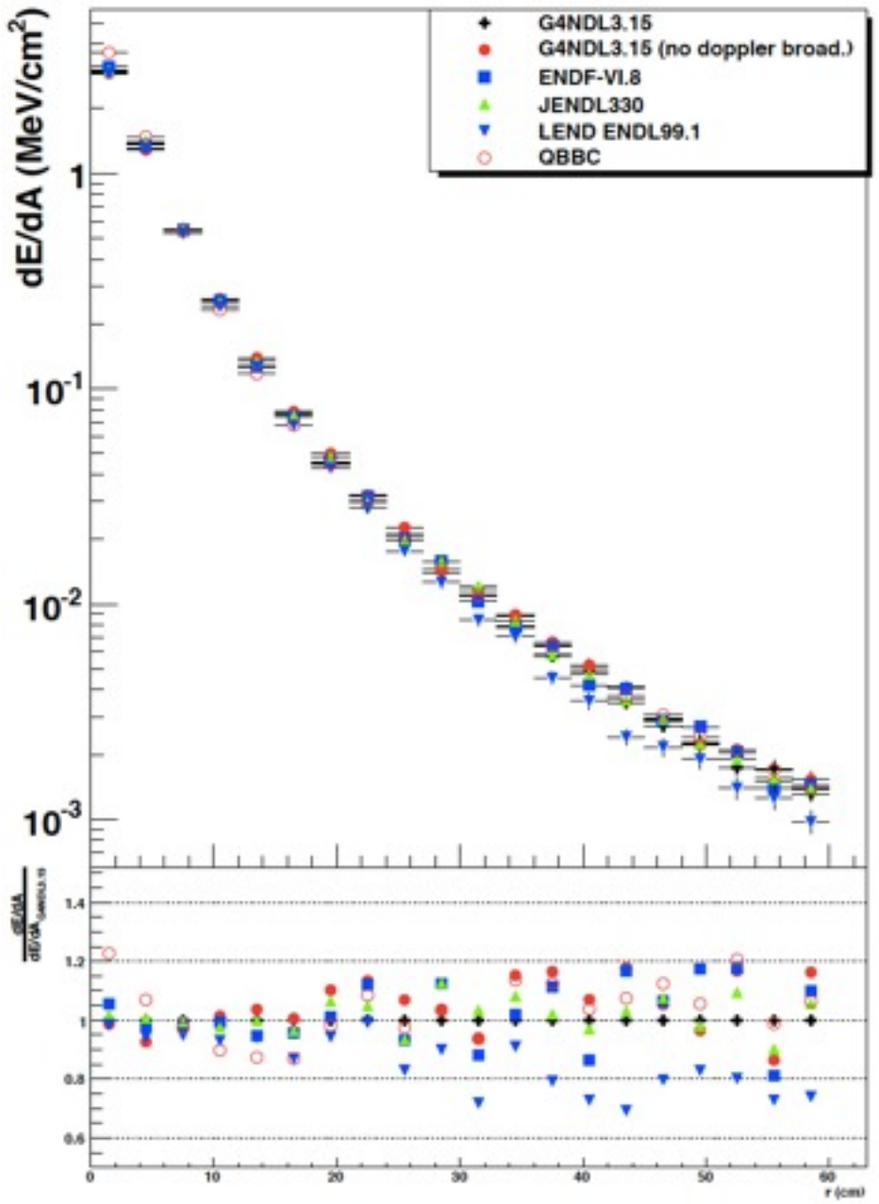
Geant4 9.3.p04



- FTFP_BERT better describes lateral shower shape
- Showers too compact of 2% for Si-W; **10% for Sci-Fe**

Role of neutrons

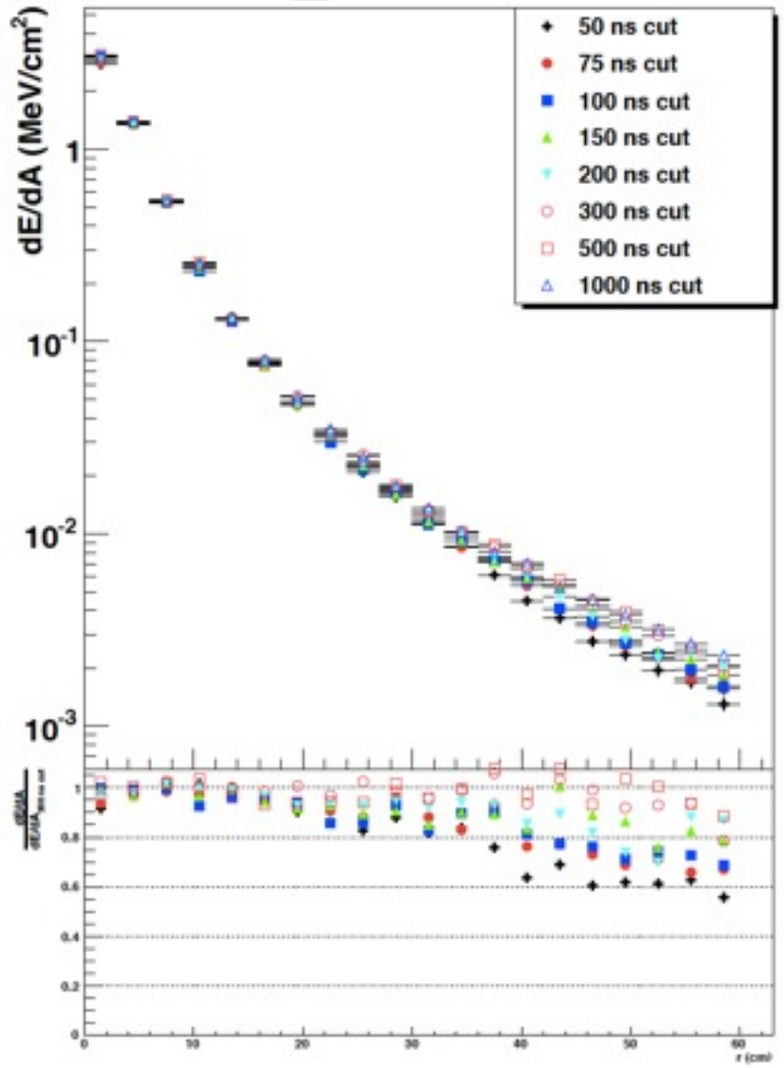




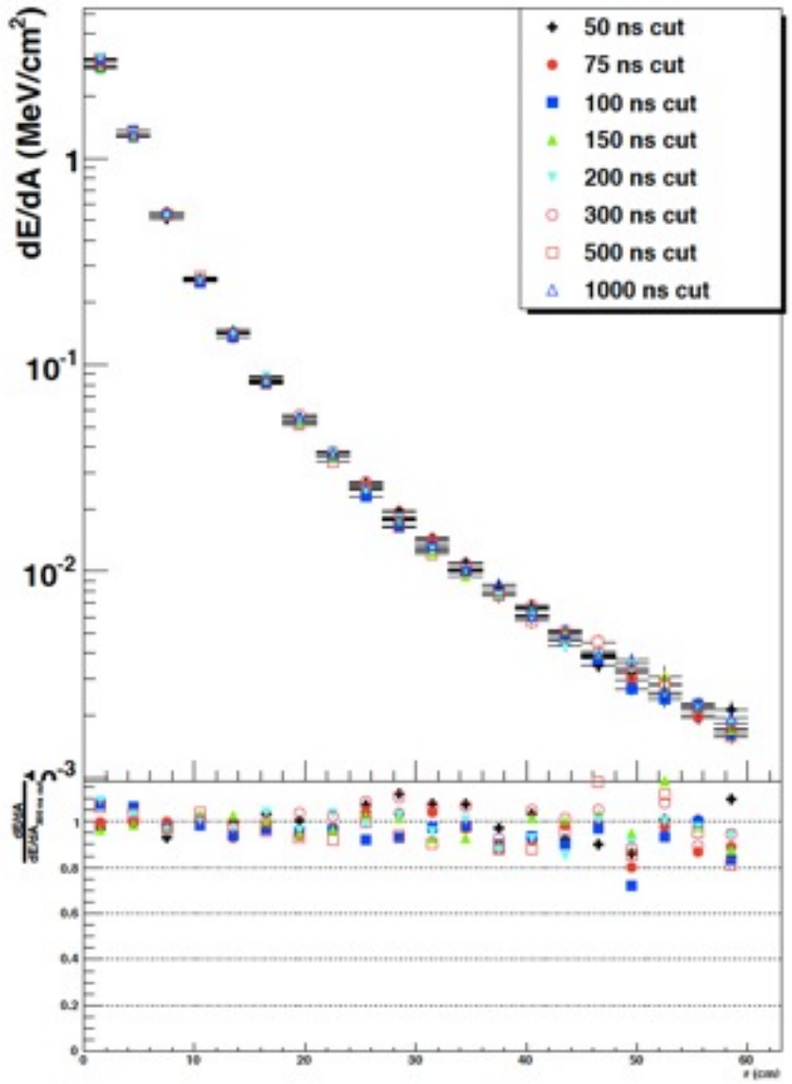
- HP models give larger showers
- **Doppler broadening can be switched off** w/o degrading physics results
- See: CERN-LCGAPP-2012-02 for additional details

Time structure

QGSP_BERT



QGSP_BERT_HP



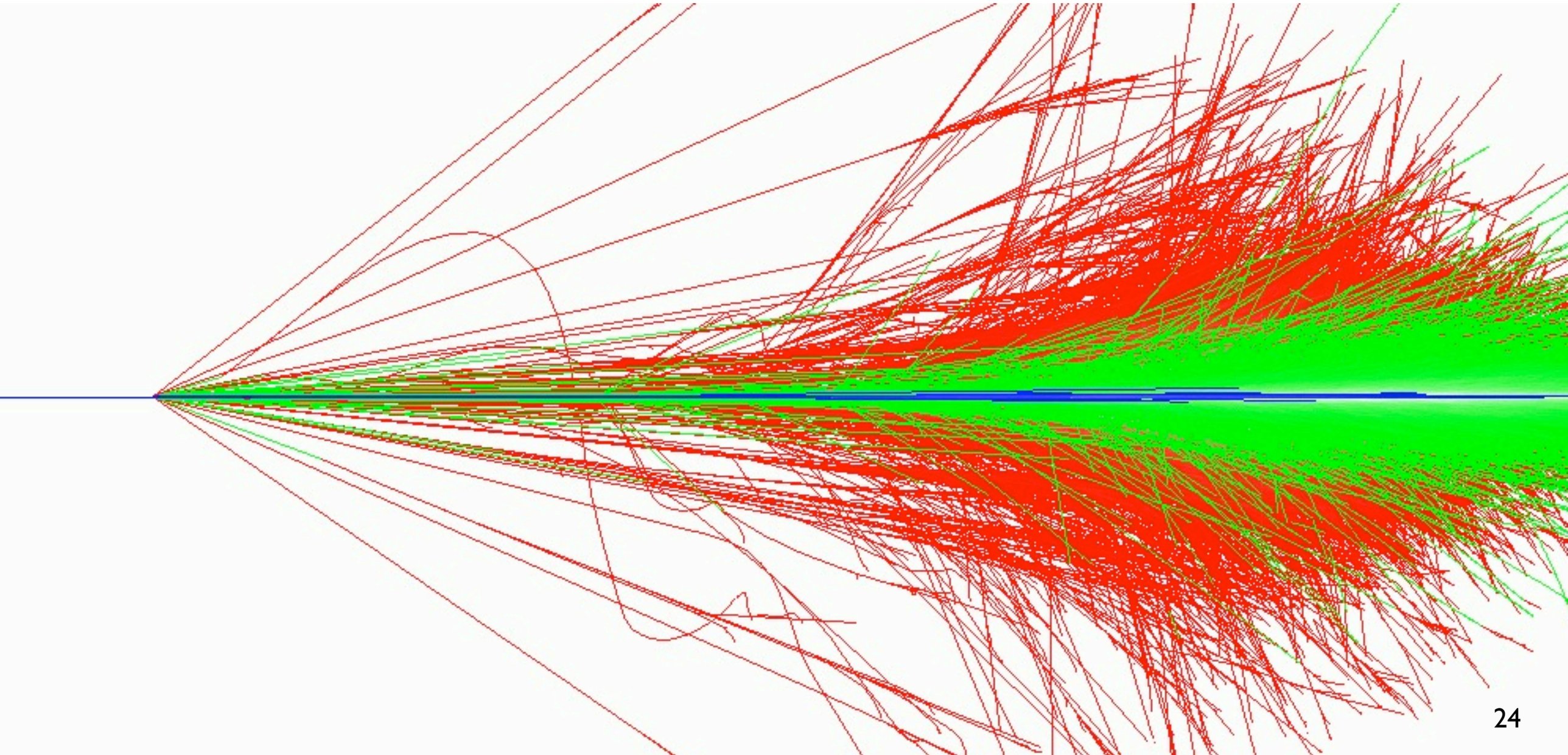
- QGSP_BERT shows stronger dependence on time-cut w.r.t. HP models
- Hint to further study time structure (see later slides)

Possible Actions

- We know since few years that cascading is needed to substantially improve lateral shower shape (TileCal test-beams)
- CALICE data show FTFP_BERT is substantially better than QGSP_BERT (and also QGSP_FTFP_BERT)

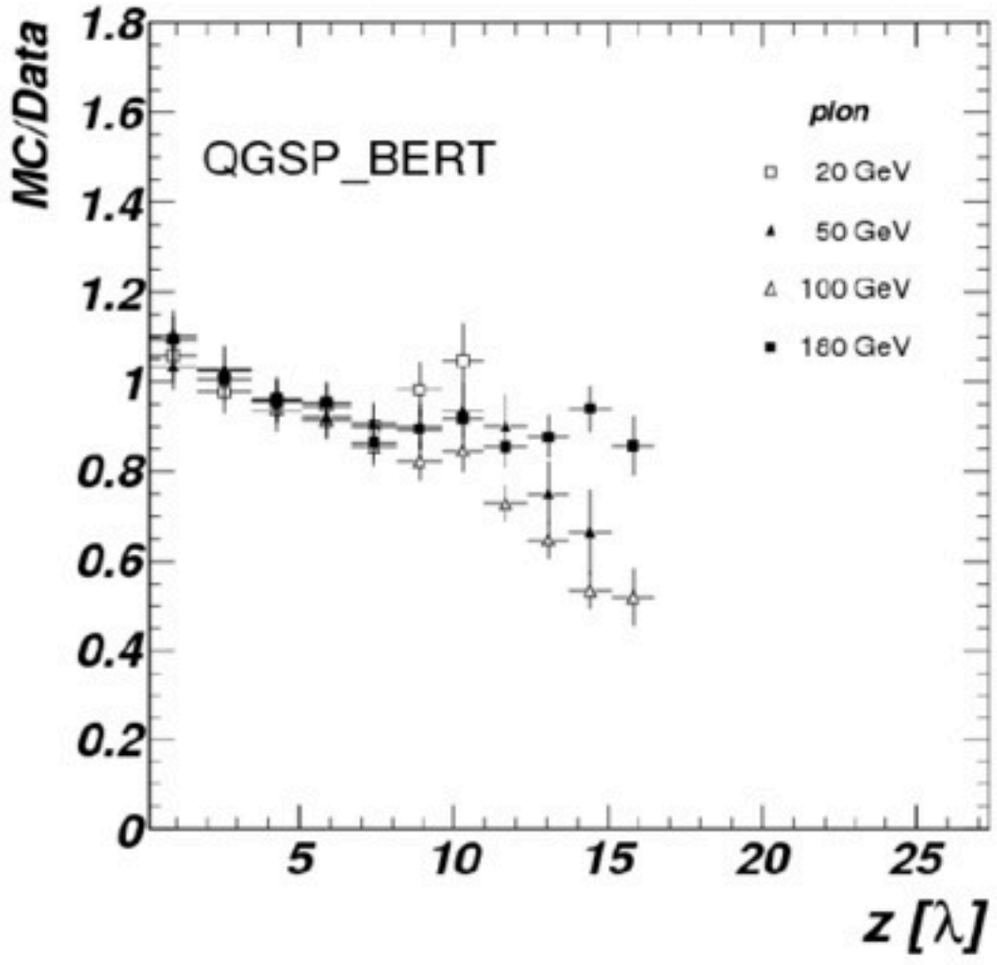
- Low-E neutrons show important effect
  - HP increases lateral shower shape
  - HP Vs LEND: similar physics results, but LEND is much faster. Worth trying as alternative to HP for calorimeters
- To study: neutron production models (Precompound/deexcitation)

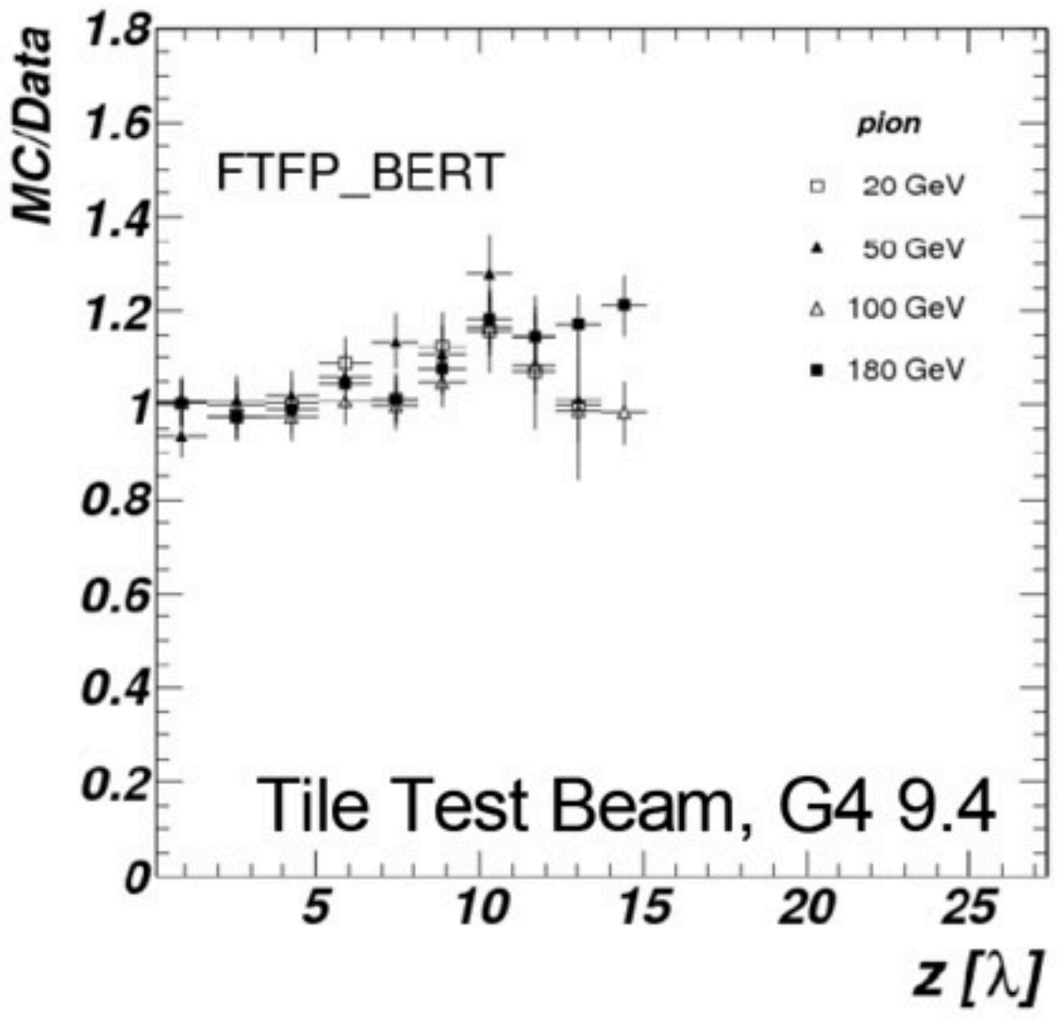
Longitudinal Shower Shape



LHC: TileCalorimeter

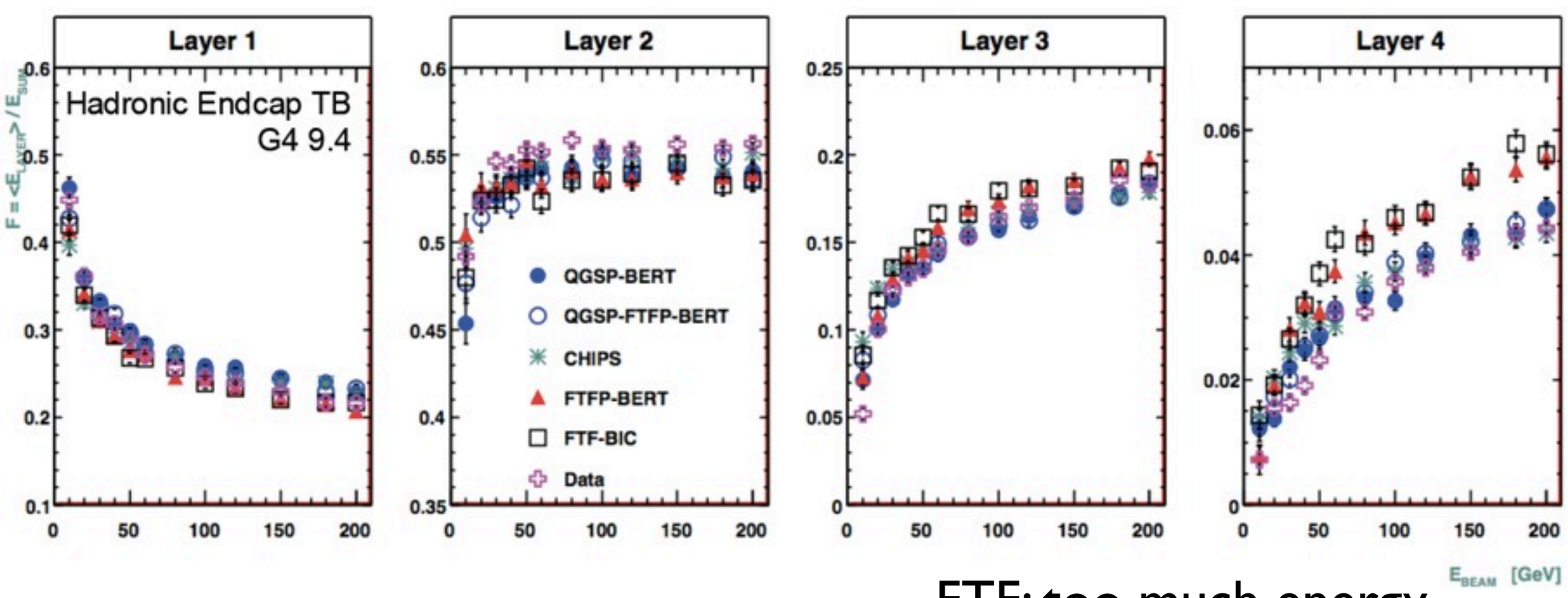
- Coarse granularity
- Special runs measure longitudinal profile up to 20 λ_I
- Large systematics: FTF too long, QGS too short





LHC: ATLAS HEC (Cu/LAr)

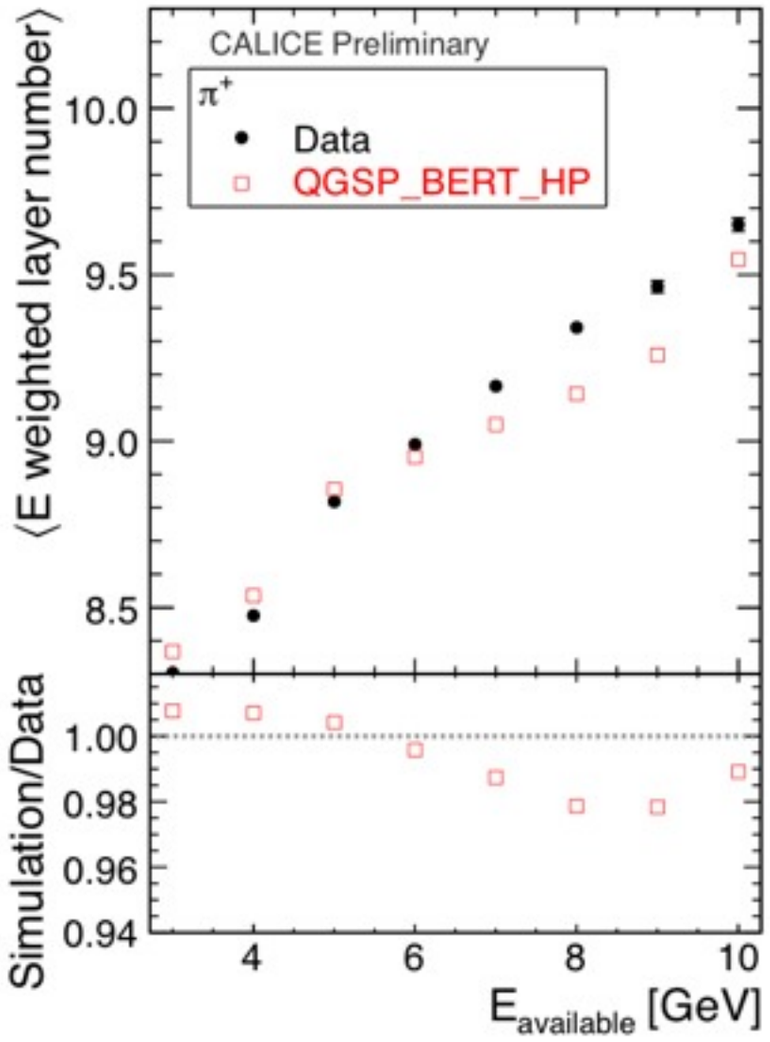
- Good agreement for this calorimeter (only 4 longitudinal segmentation)



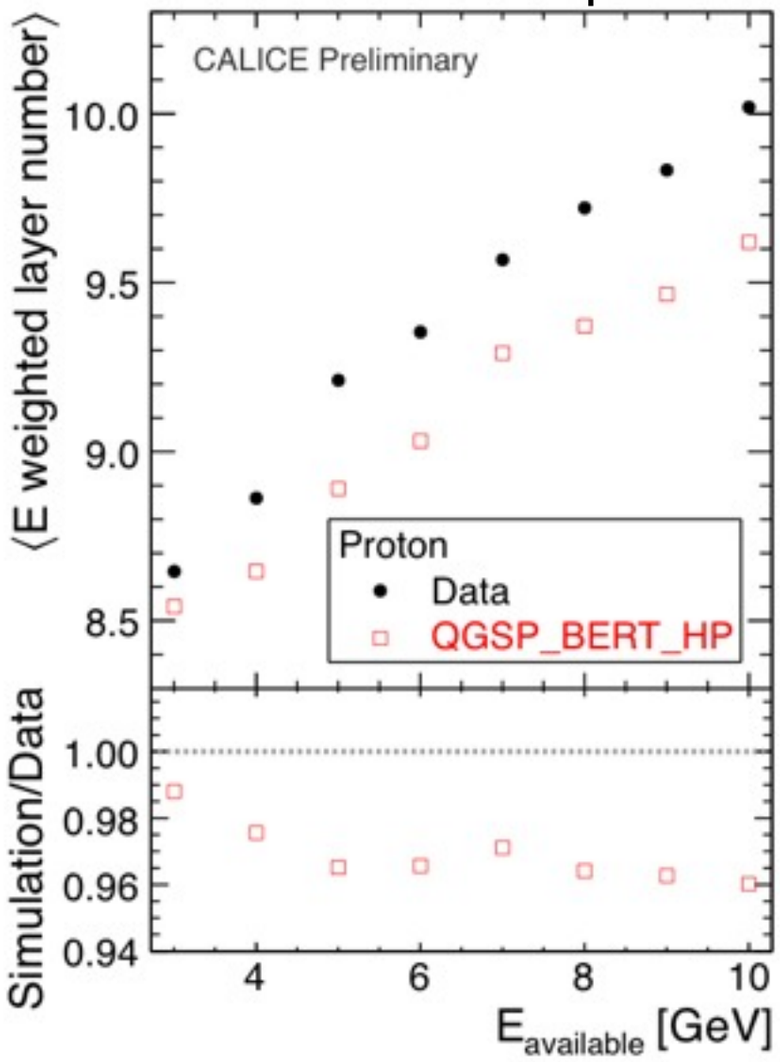
FTF: too much energy in tails

CALICE low-E: Si-W

CALICE Analysis Note CAN-036



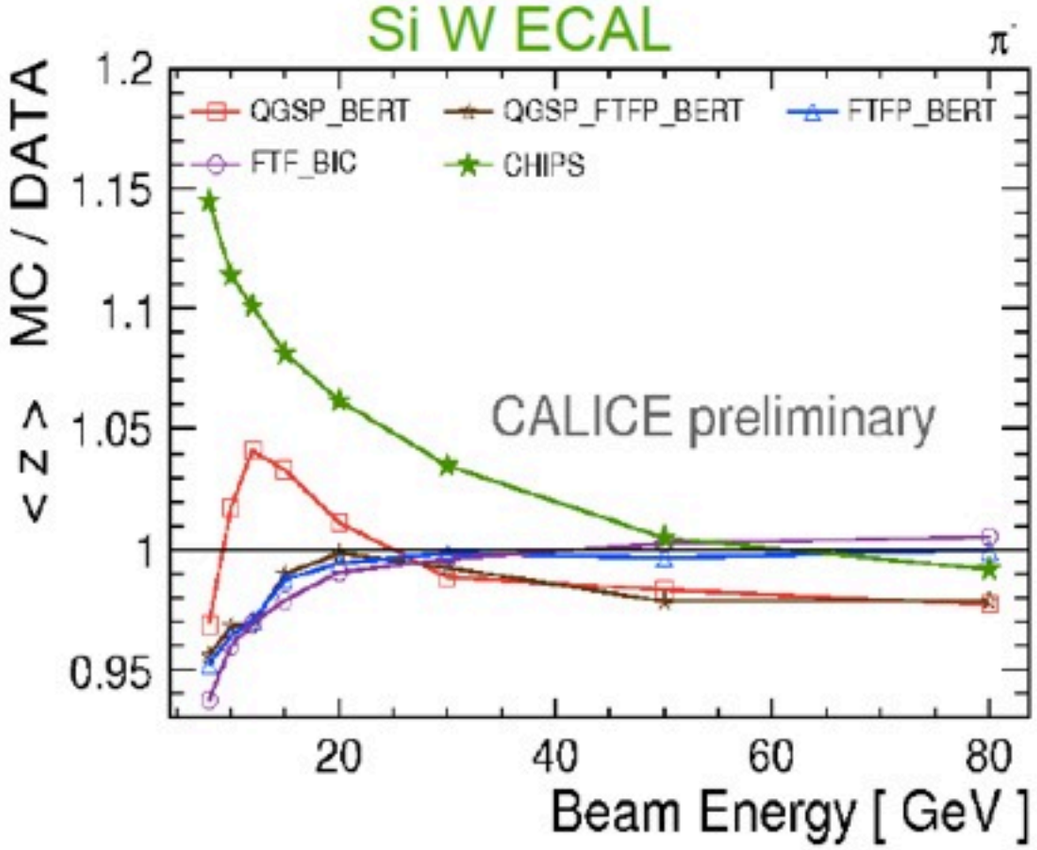
Geant4 9.3.p04

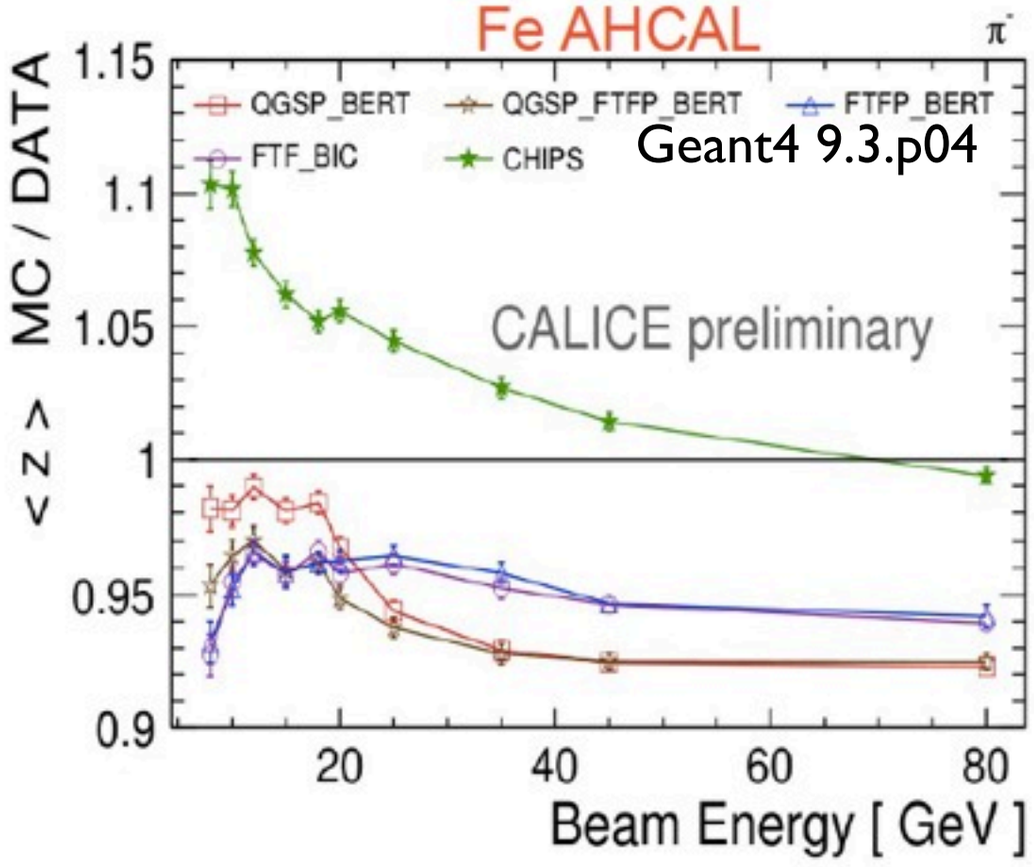


- Good agreement with BERT for pions
- Less precise description for proton beams

CALICE data

CALOR2012 http://goo.gl/jG9xR



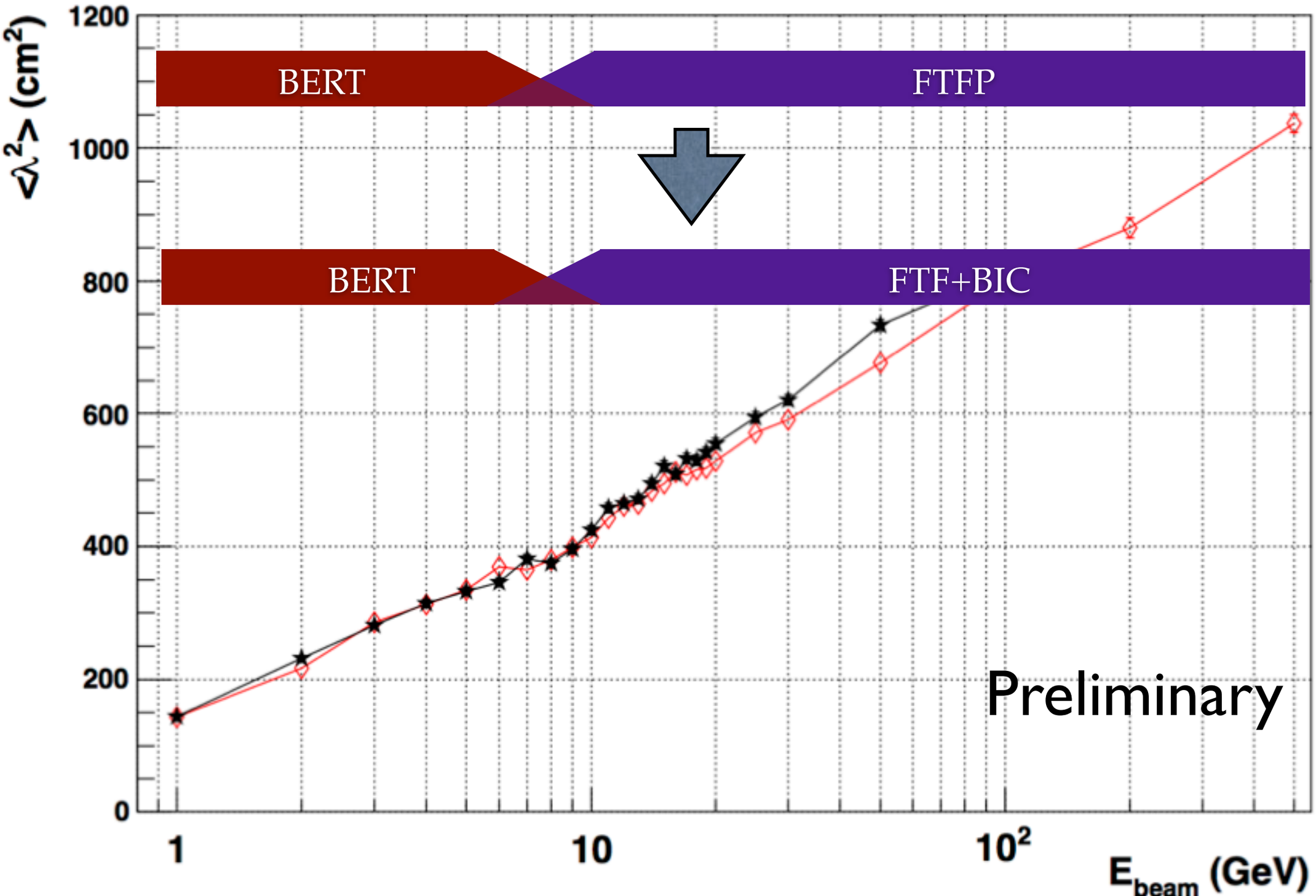


- FTF models better describe data on both technologies
- Better shower shape description for non-sci calorimeter
- Discrepancy with LHC: CALICE has smaller error bars but calorimeters are shorter

Adding cascade to FTF

Longitudinal shower shape

π^- Cu/LAr ; geant4 9.5

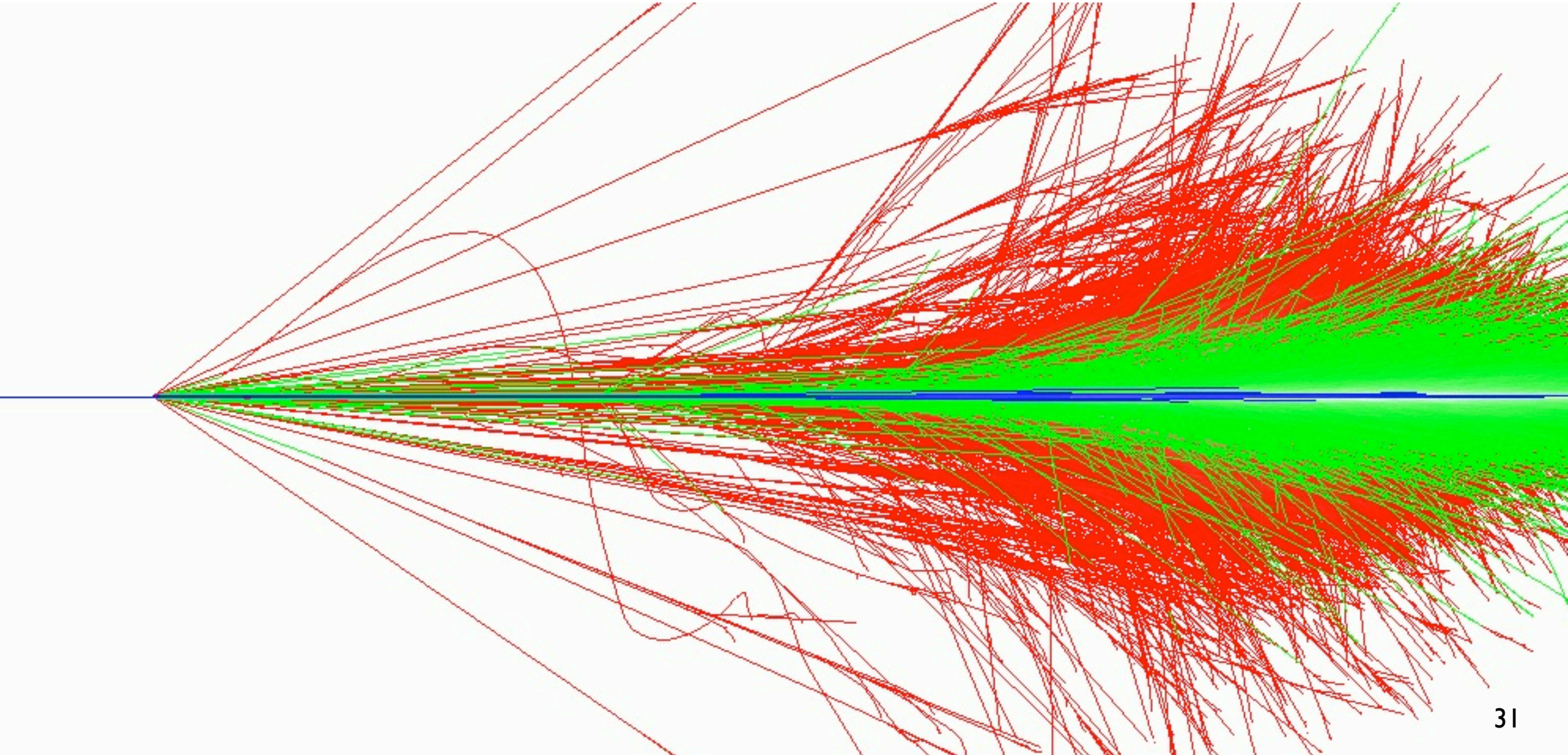


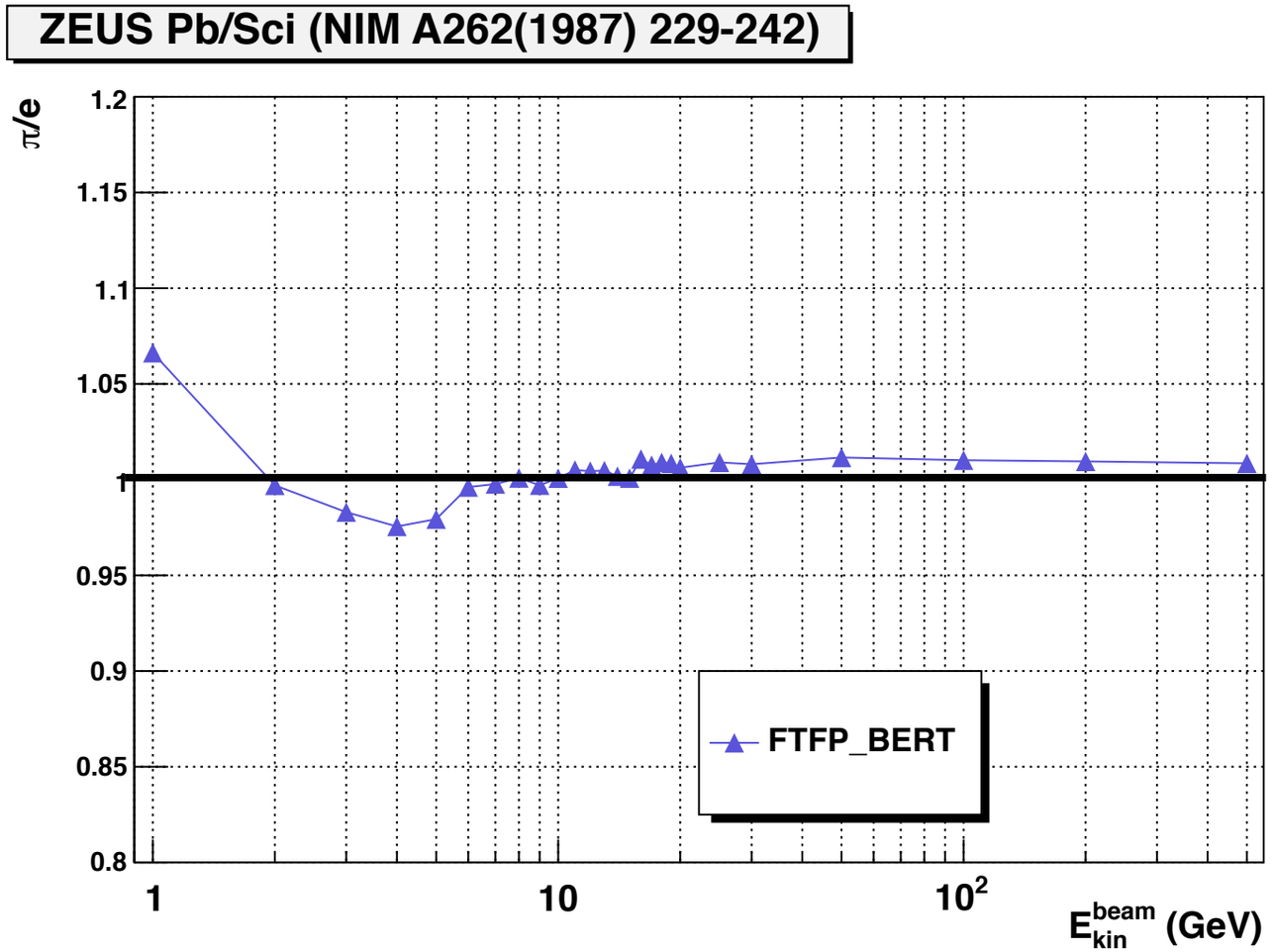
Possible Actions

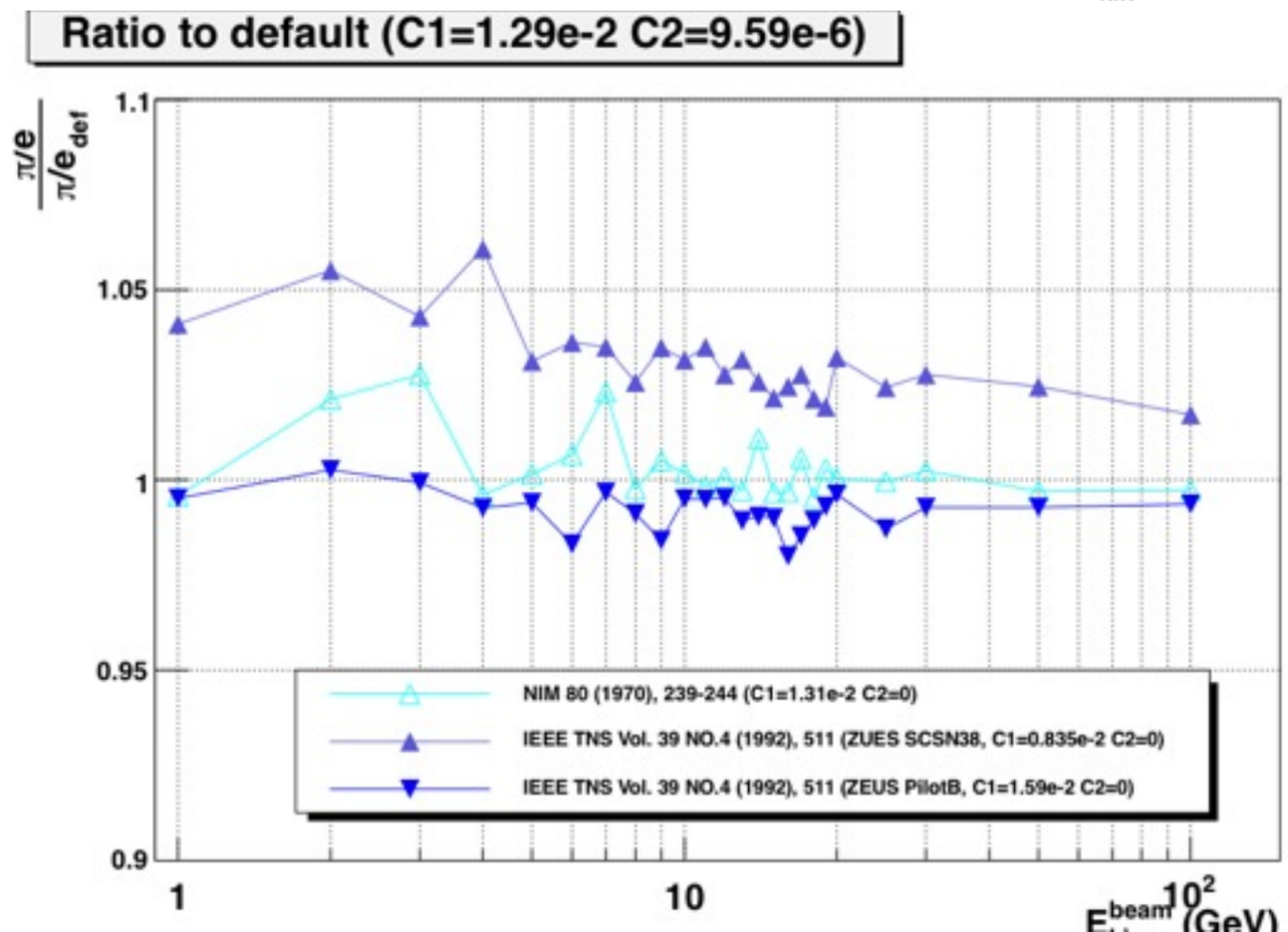
- FTF model describes CALICE data
- For longer calorimeter (>10λ_I) FTF is too long but large uncertainty in data
- CALICE precise data situation for shower shape is not so bad...

- **We need to continue validation of forward physics**
  - Last year we have shown validation of target diffraction with HELIOS data: FTF too high cross section; confirmed by NA22 data
  - Review quasi-elastic (?): very difficult to find data
- Addition of cascading as de-excitation to FTF makes shower longer

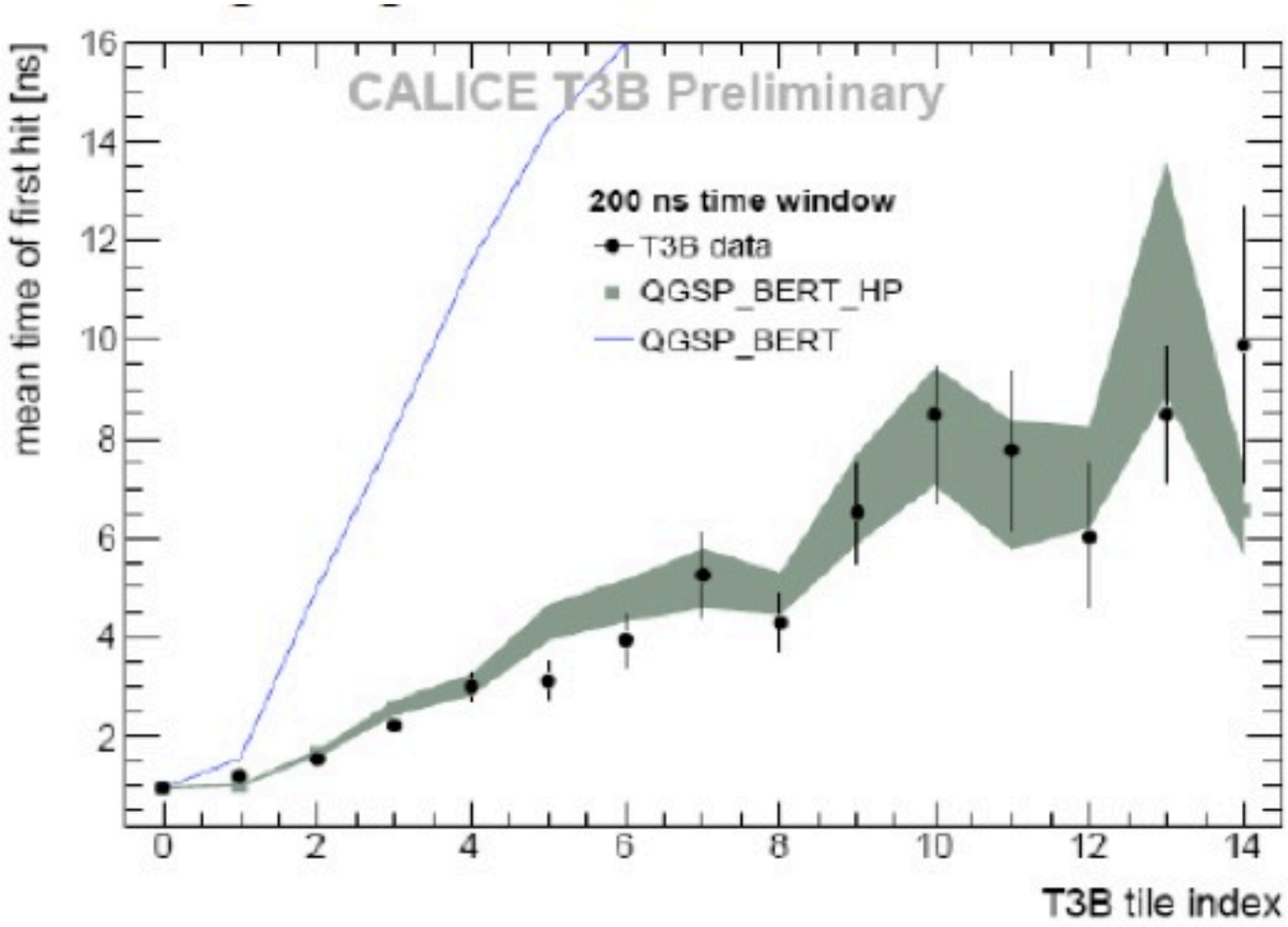
Other notes



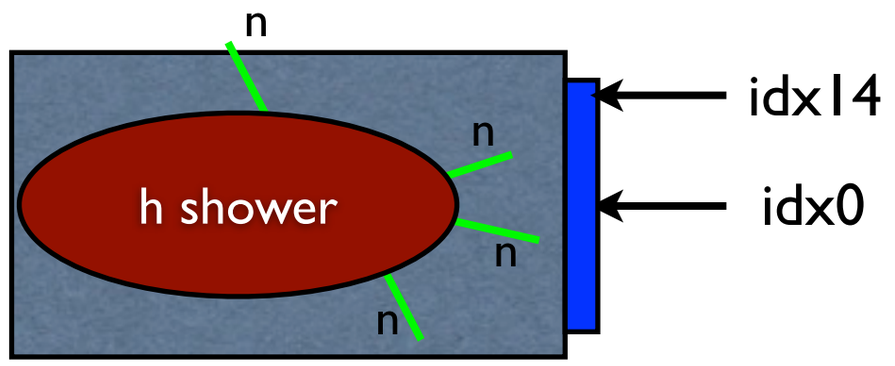




- FTFP_BERT not only for LHC and CALICE
  - **Good results also on ZEUS calorimeters**
- Scintillator based calorimeters
  - Important variations due to correct Birks' attenuation
  - **For LHC calorimeters coefficients are not measured**
    - Measured only for CALICE
  - We should take this into account when comparing with scintillators results

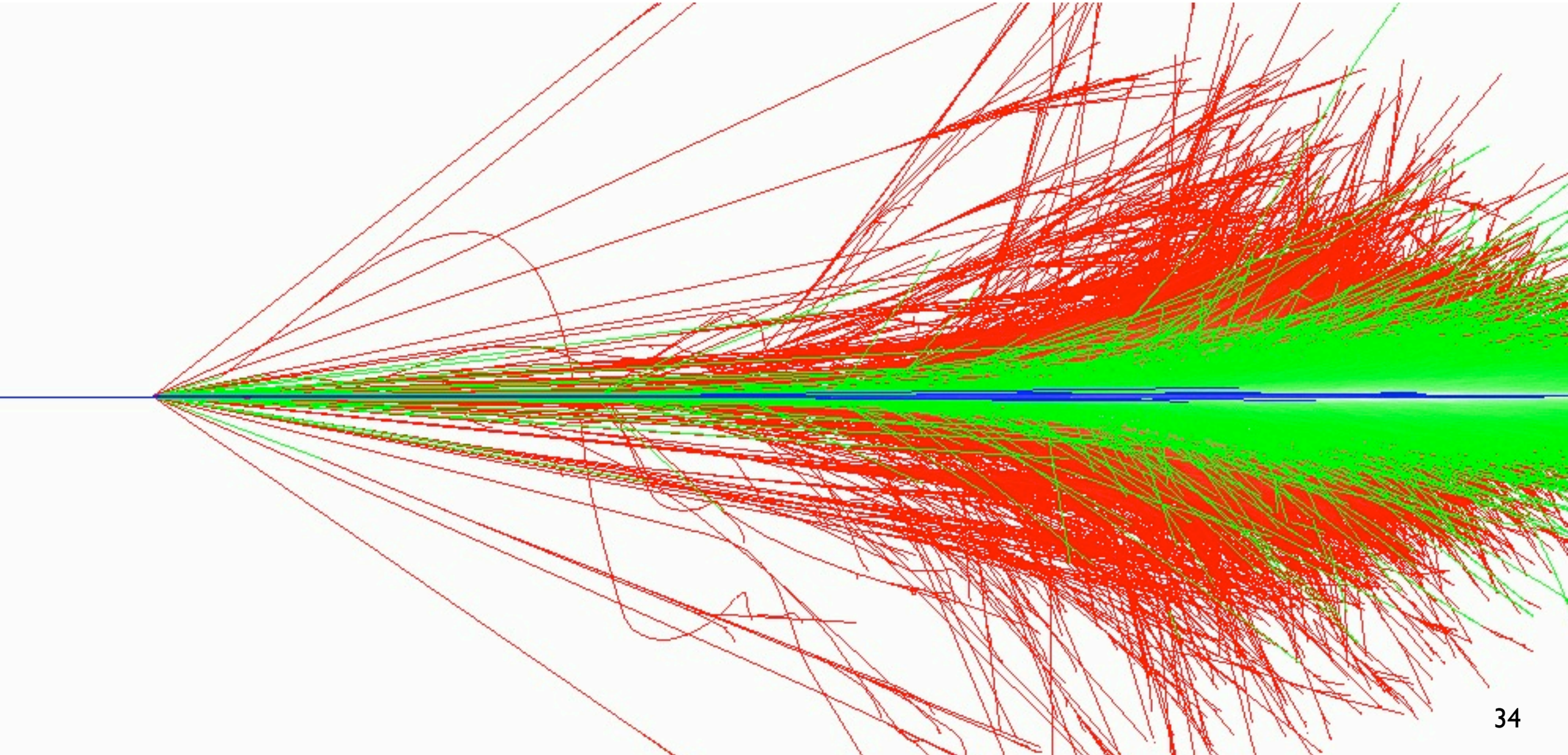


Time of first hit as a function of radius



- CALICE results show HP model can predicts time-structure of showers
- Non-HP model is giving wrong results
- Unexpected results: HP models give earlier hits

Conclusions



- CALICE data are now available
  - Not always the most up-to-date version of Geant4
  - They could become the preferred way to test Geant4
    - Additional benefit for LHC: complete independent validation data-set!
  - **They agree with LHC data**
    - Note: they do not agree where LHC data show large uncertainties
- **Scintillator based calorimeters show largest differences**
  - Clear need to treat correctly Birks' effect, precise coefficients are not available for LHC
  - Challenging aspect: neutron elastic scattering on H
- **General good agreement on all observables**
  - Longitudinal shower shapes are in better agreement for CALICE than LHC
  - **Worst cases: +10% Evis for CALICE SiW; -10% too compact shower for CALICE SciW**
- No doubt the combination **FTF + BERT + Preco** is the best physics list for calorimetry
  - Evidence that low-E n models are needed to further increase precision

A possible todo list

- **Neutron interactions** (even at low-E) are very important to study details of showers
  - Effect on lateral shower shape
  - In some cases (time structure) are needed to correctly describe data
  - Doppler broadening not needed (important CPU reduction)
  - **Need dedicated validation of neutrons on scintillators (recoil of H nuclei)**: all PLs use CHIPS σ
- **Adding of a cascade backend** (re-scattering) to string model
  - Hints that can make shower longer (**discrepancy between TileCal and CALICE**)
  - Improved agreement for resolution
  - **Important:** latest FTF tuning includes Reggeon cascading, possible "double counting" issue
- **A review/tune of π^0 production** from FTF could:
  - Reduce visible energy (that is too high)
  - Increase agreement for resolution
- Need to **define a list of models parameters and study their effect** on all observables

A possible todo list

- **Neutron interactions** (even at low-E) are very important to stu
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- **A review/tune of π^0 production** from FTF could:
  - Reduce visible energy (that is too high)
  - Increase agreement for resolution
- Need to **define a list of models parameters and study their effect** on all observables

Important: conclusions
based on my **personal experience**
as LCG Physics Coordinator
(validation for LHC experiments)
these are not conclusions of the HadWG
Additional input is needed!

A naive proposal...

- We have not yet studied in detail the role of Precompound/deexitation model for HEP experiments
  - But we know it is very important!
- CALICE data show FTF_BIC is not so bad...
  - And we have thin-target data showing BIC is even the best model in some cases
- A possible future **“universal physics list for calorimetry”**