Status of the

Geant4 Simulation

CALICE Analysis Meeting

8 November 2010

Geant4 Team

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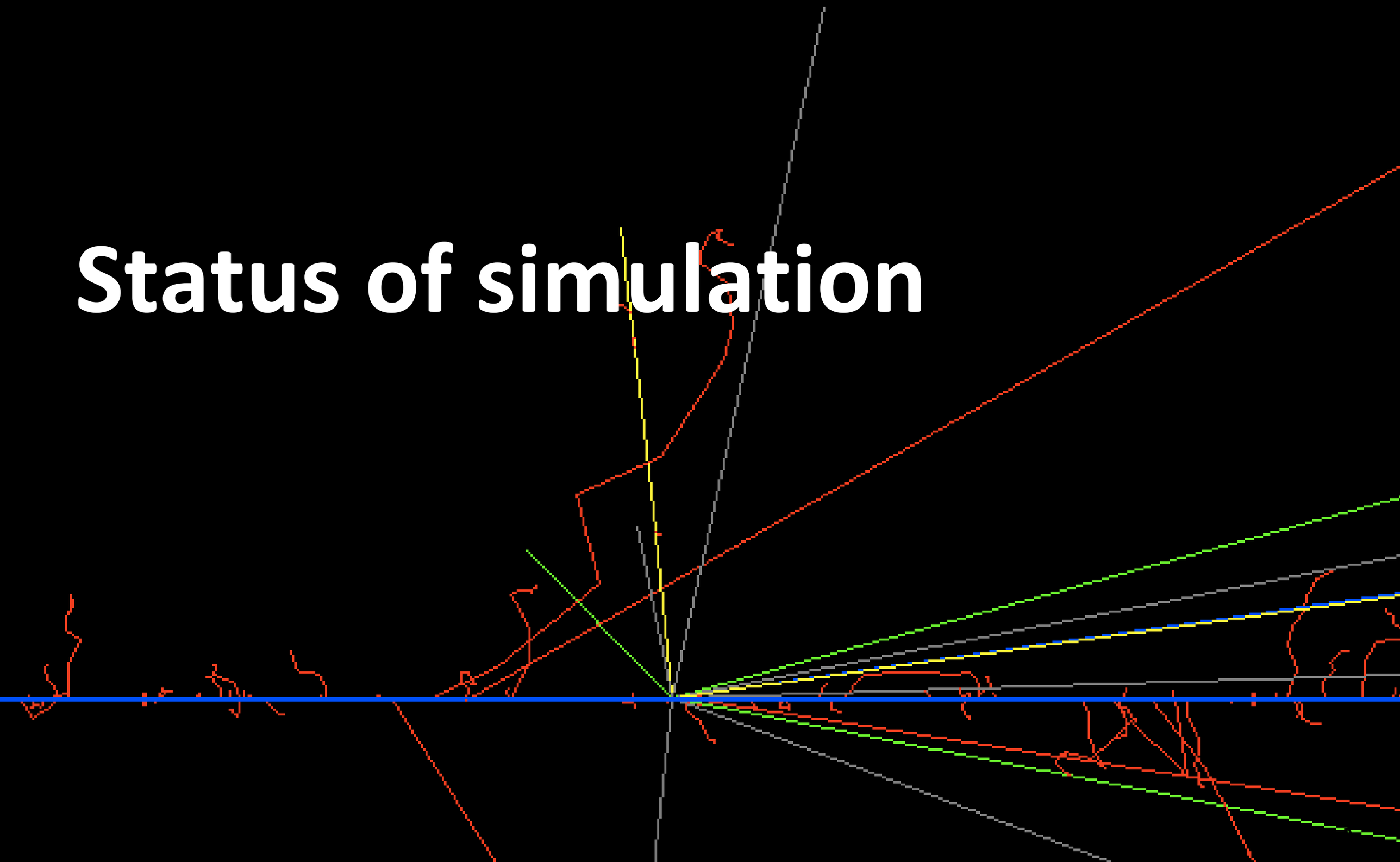
Outlook

- Status of the simulation and recent developments
- Geant4 9.4 release (Dec. 2010)
- Shower shapes. What's next?
- Conclusions

Status of simulation



Feedback from LHC (test-beams)

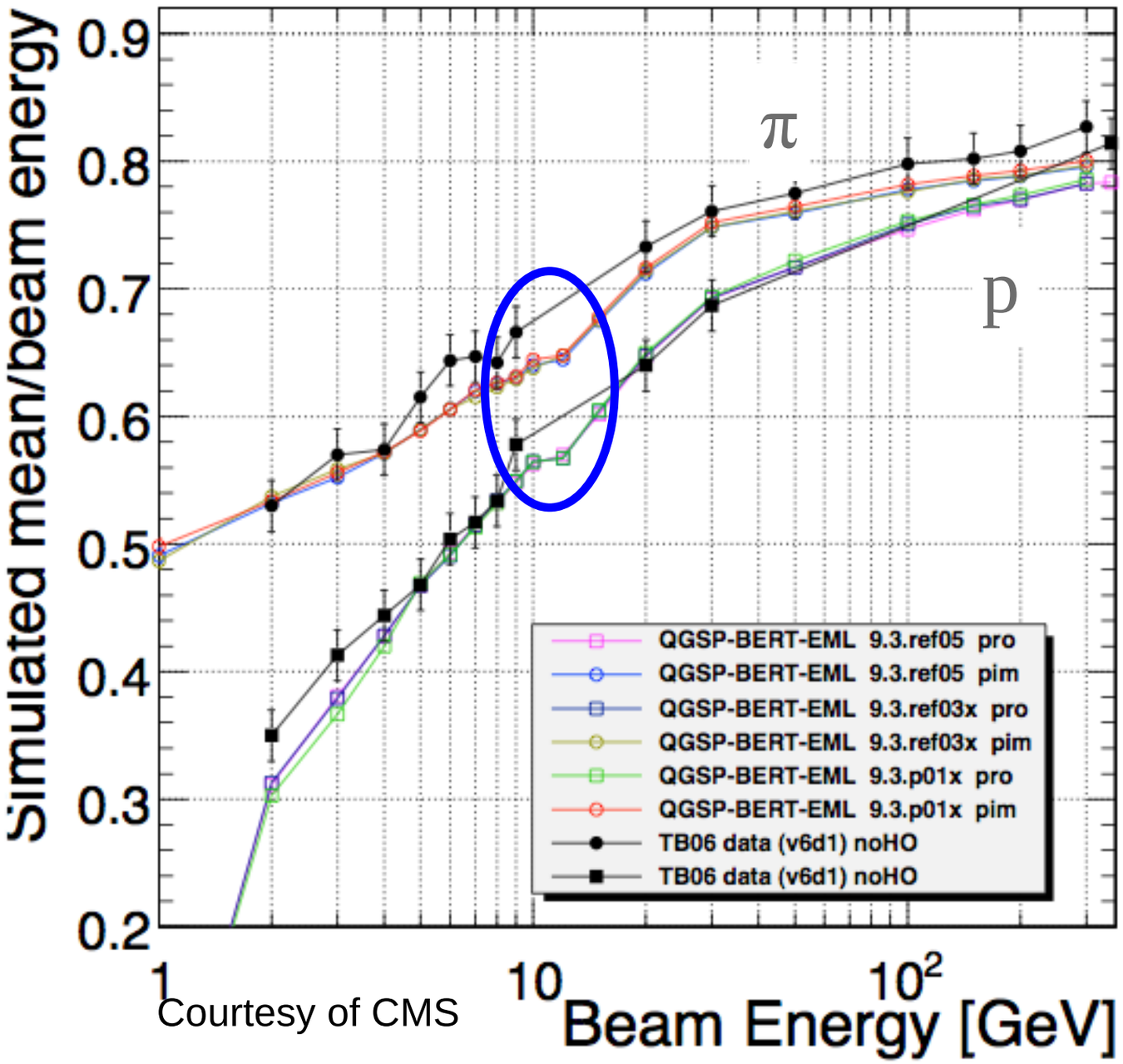
- Need for precise simulation of observables for LHC (CERN-LCGAPP-2004-02):
  - Response (e/pi), resolution, shower shapes
- Results from ATLAS & CMS test beam (from 2009 reports):
  - best description obtained with QGSP_BERT physics list
  - Response: good agreement, within 3%
  - Resolution: simulation is too narrow, within 10%
  - Showers shorter and narrower than data:
    - pions 10% up to 10λ
    - protons 30% up to 10λ

CERN-LCGAPP-2010-02

- Results from CMS 06 test-beam (EM+HAD)
- FTFP_BERT smooth, CHIPS smooth but too high response

S. Piperov

geant4 (ref05: May 2010)



Courtesy of CMS

Transition region: discontinuities. Use of LHEP

- Results from CMS 06 test-beam (EM+HAD)
- FTFP_BERT smooth, CHIPS smooth but too high response

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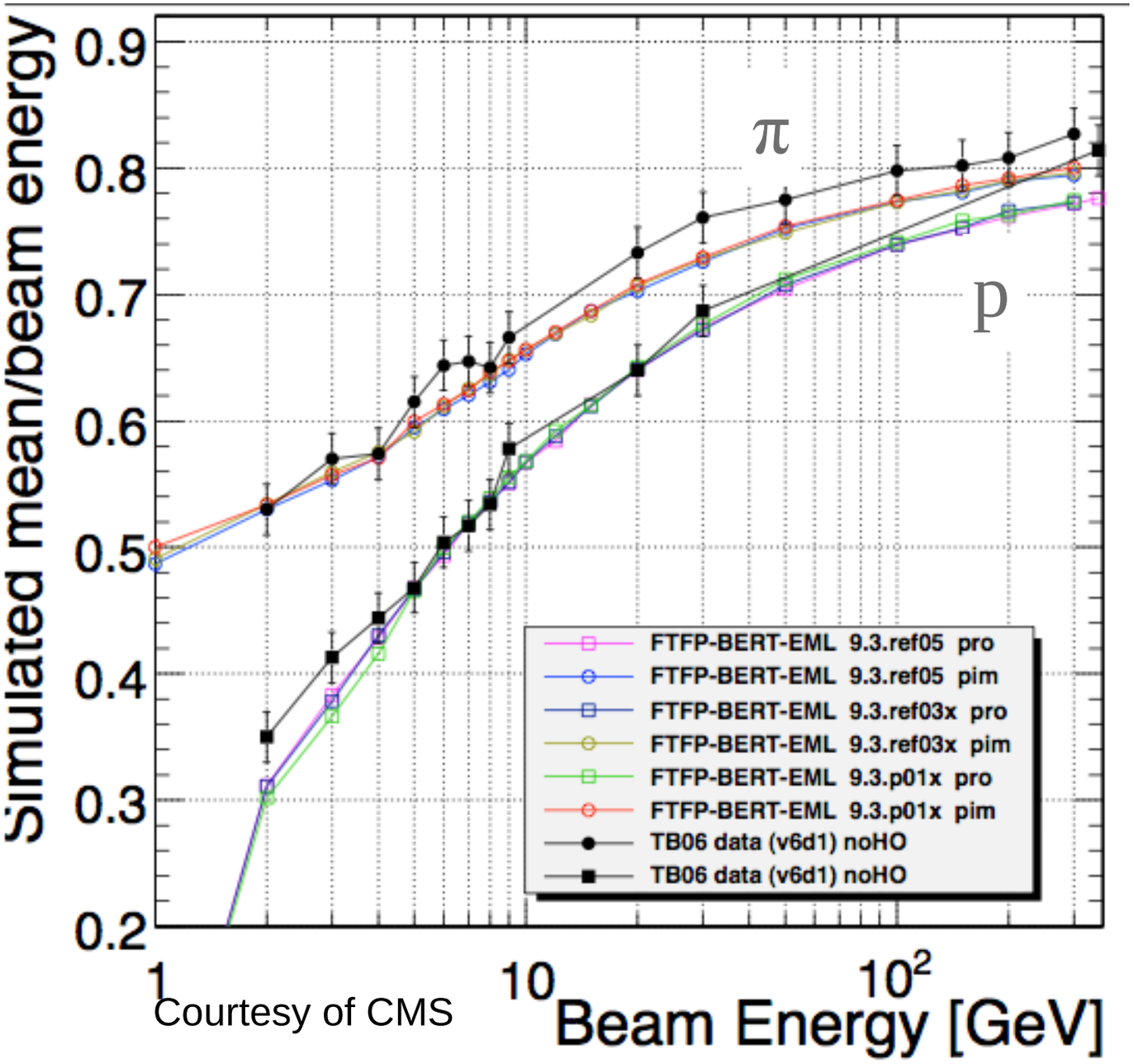

Courtesy of CMS

FTFP_BERT smooth response very similar to QGSP_BERT

- Results from CMS 06 test-beam (EM+HAD)
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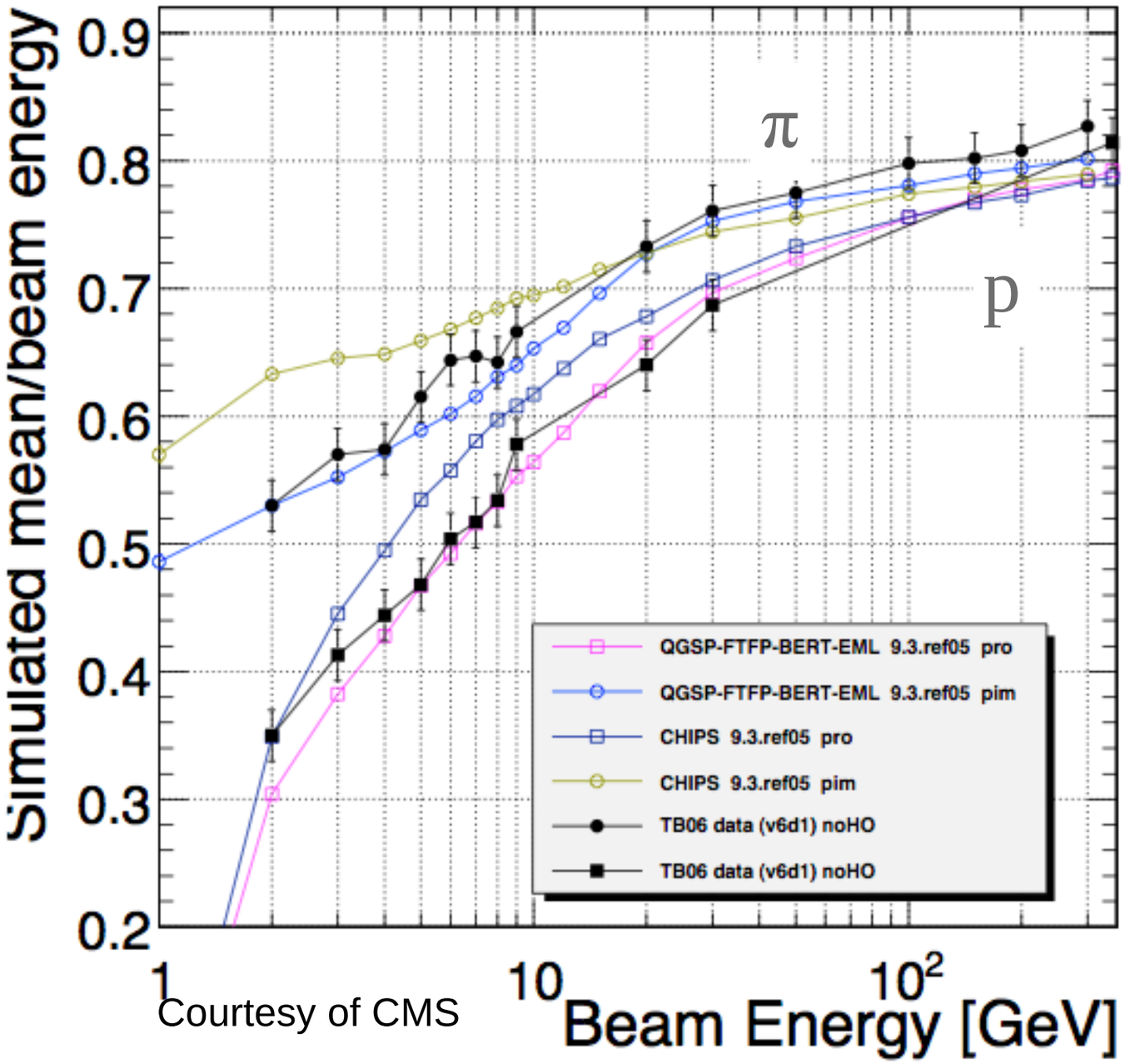


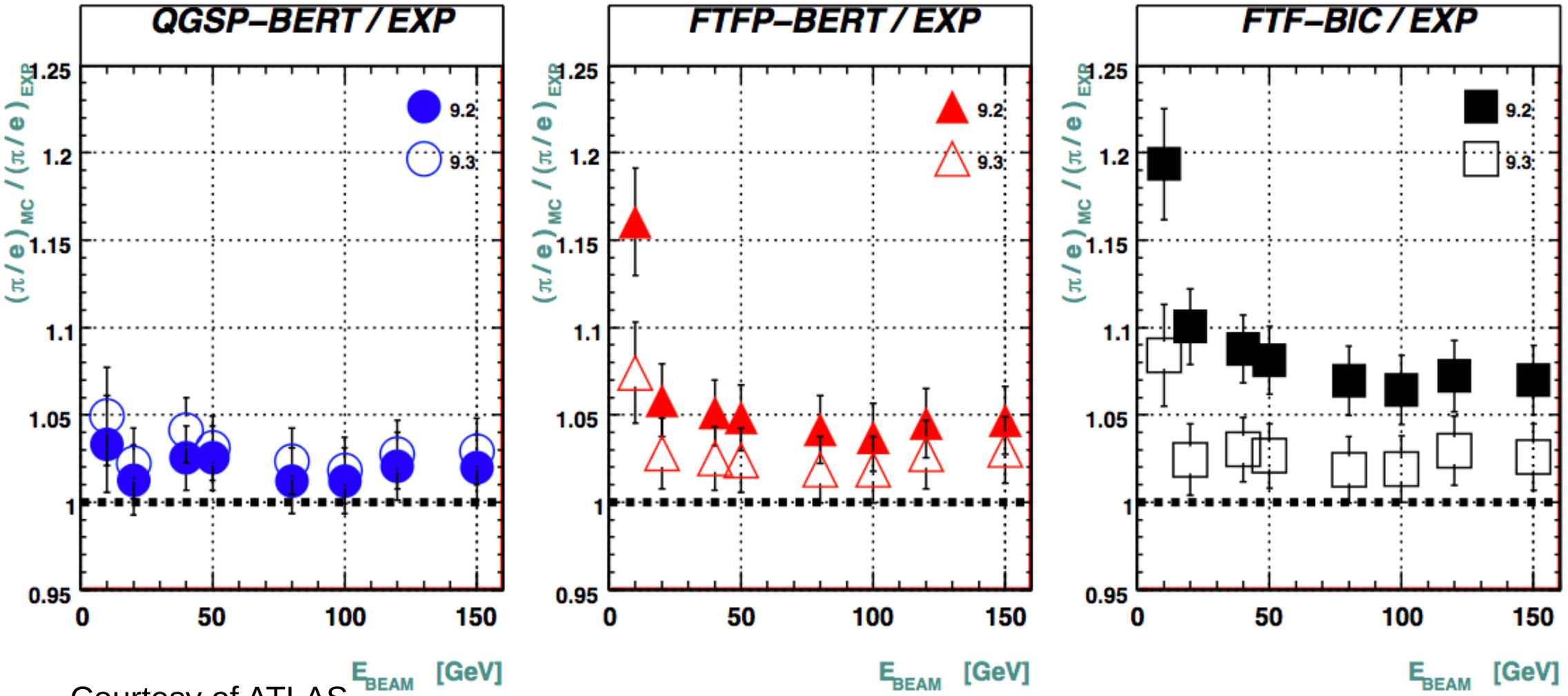
Courtesy of CMS

Too high response

CHIPS

Evolution of Simulation

P. Strizenec

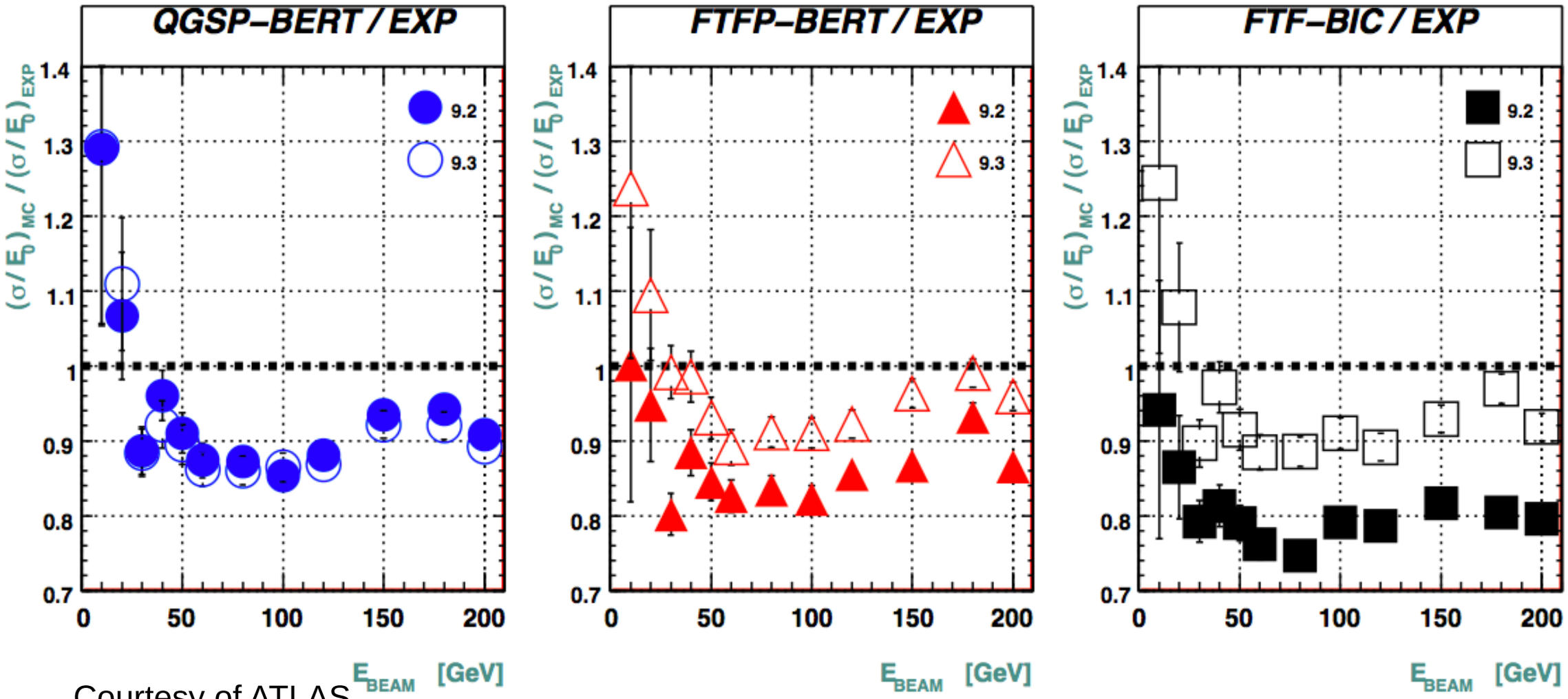


Courtesy of ATLAS

Response: 9.3 better than 9.2

Evolution of Simulation

P. Strizenec

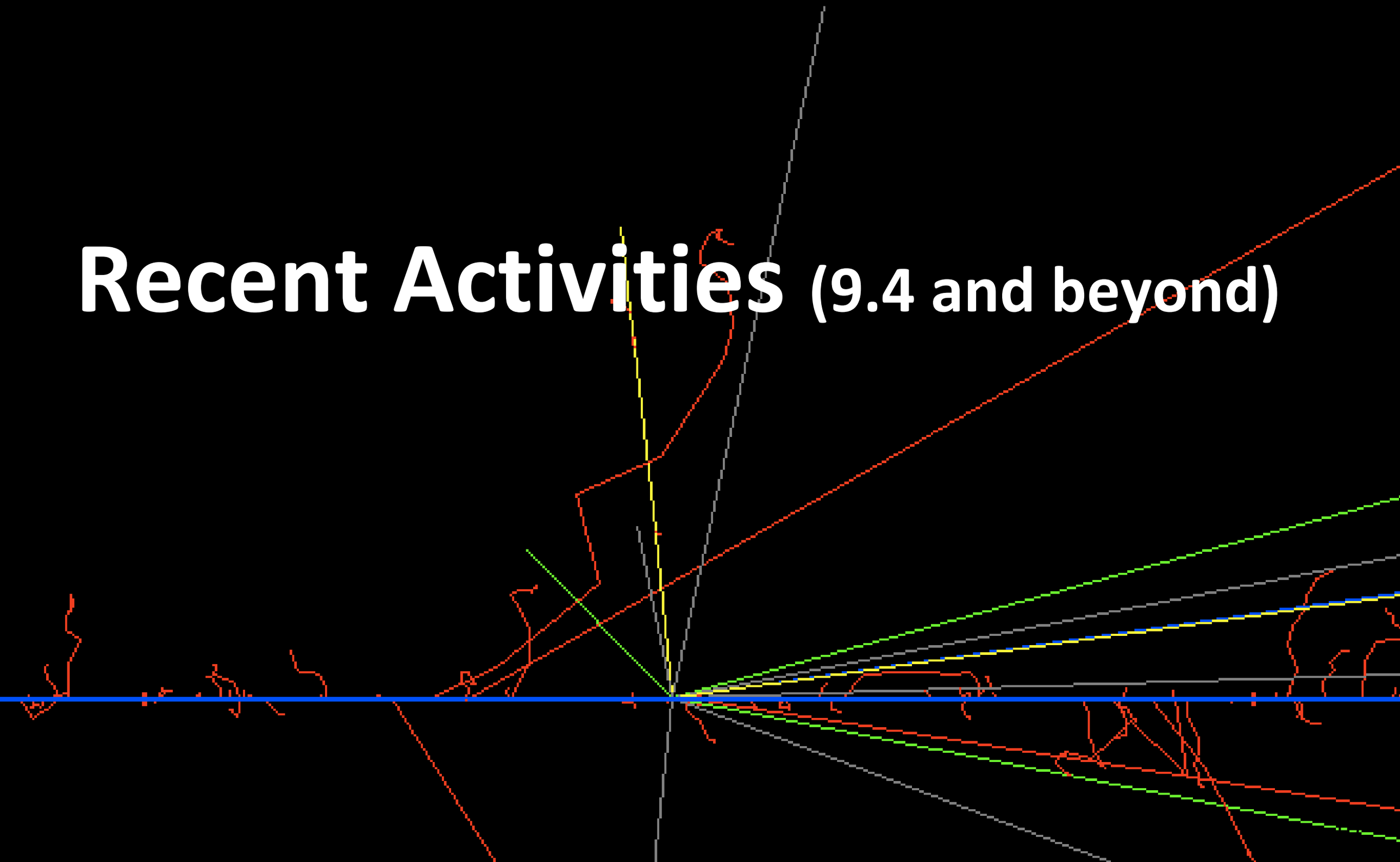


Courtesy of ATLAS

Careful validation of reference tags to maintain trends for 9.4

Resolution: 9.3 better than 9.2

Recent Activities (9.4 and beyond)

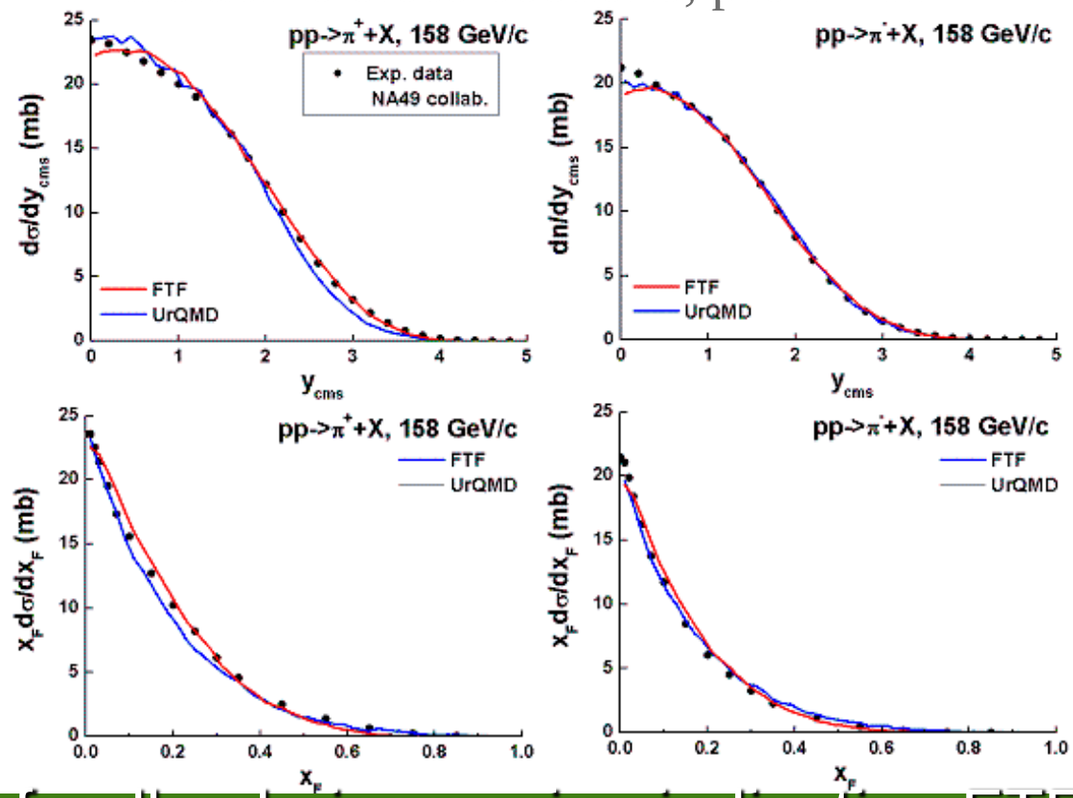


Bertini improvements

- partial cross sections
- final state angular distributions
- Prototype coupling to ‘native’ G4 precompound and evaporation
- Ensured E conservation
  - handling nuclear binding energy
- several bug-fixing
- reduced memory churn

Fritiof model (FTF)

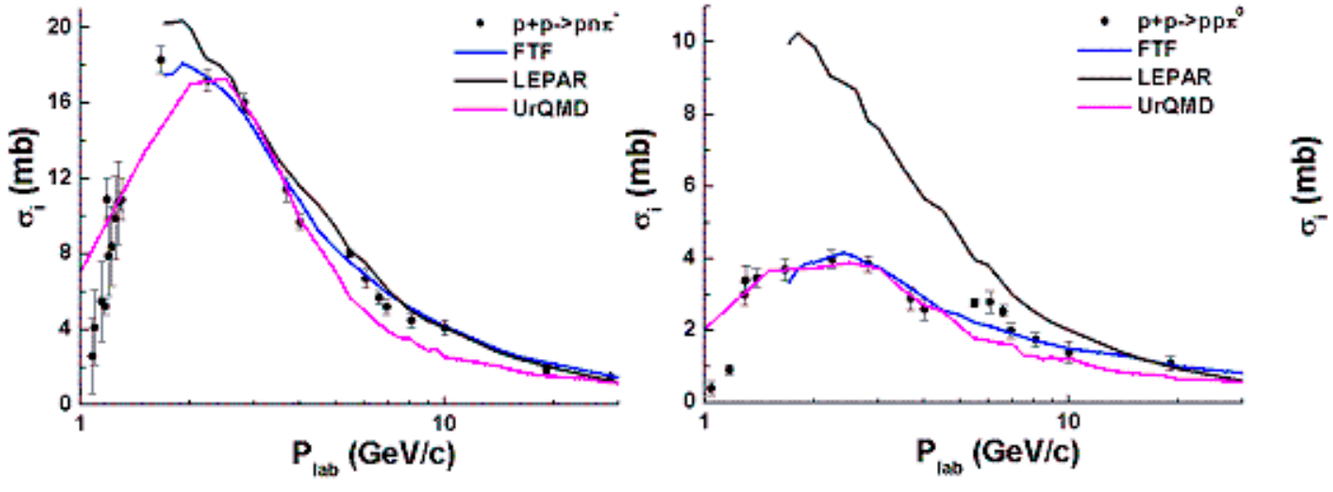
inclusive cross-sections, pion + X

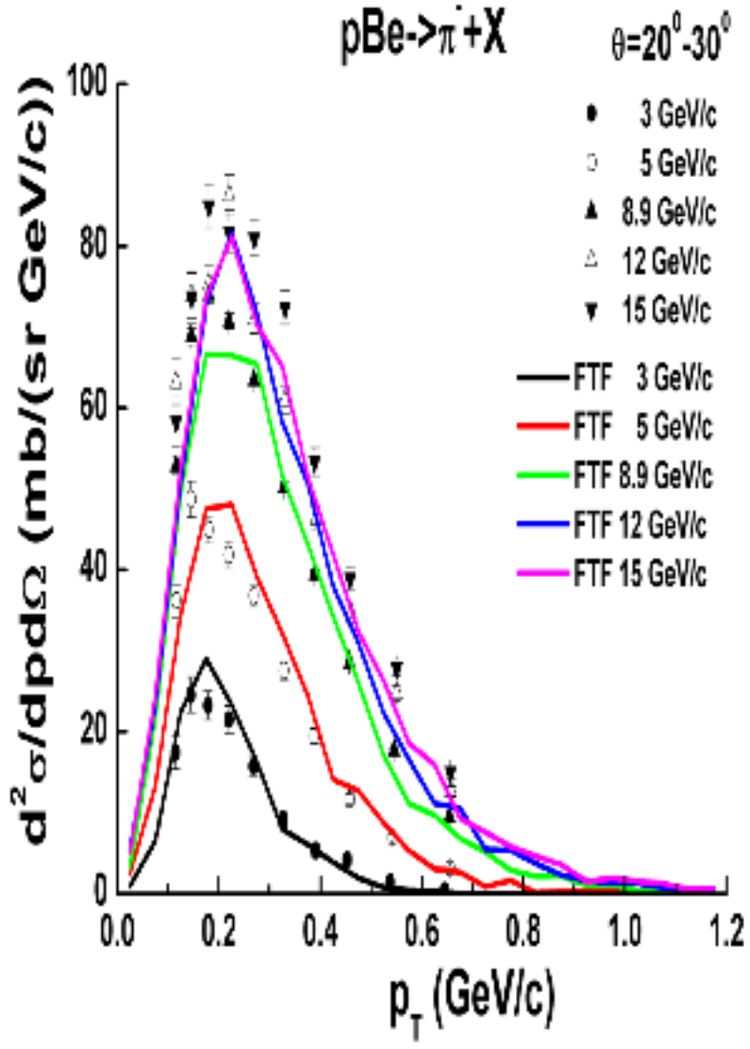


- Tuning with HARD-CDP data during 2010
- To monitor: CPU speed

LHC feedback: increasing indication FTFP_BERT best

PP interaction cross section, exclusive channels

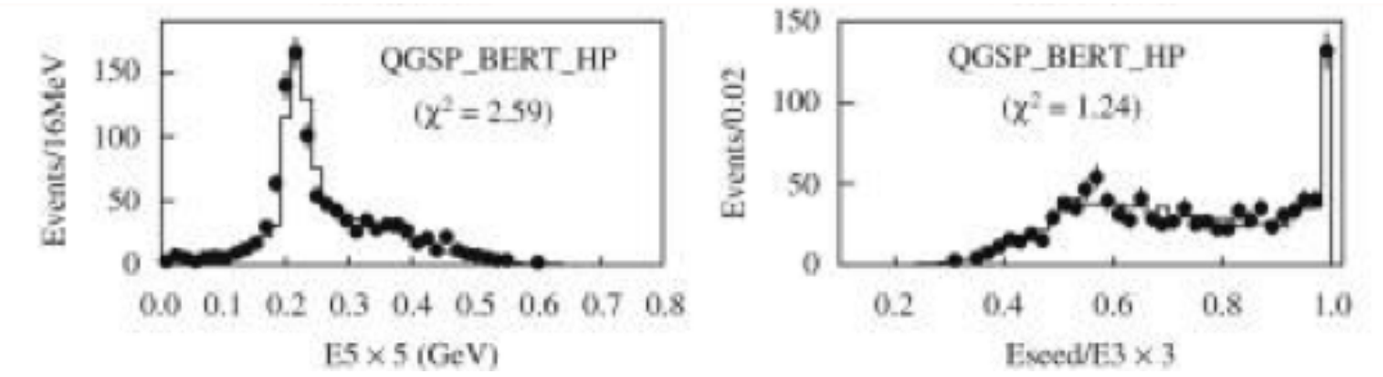




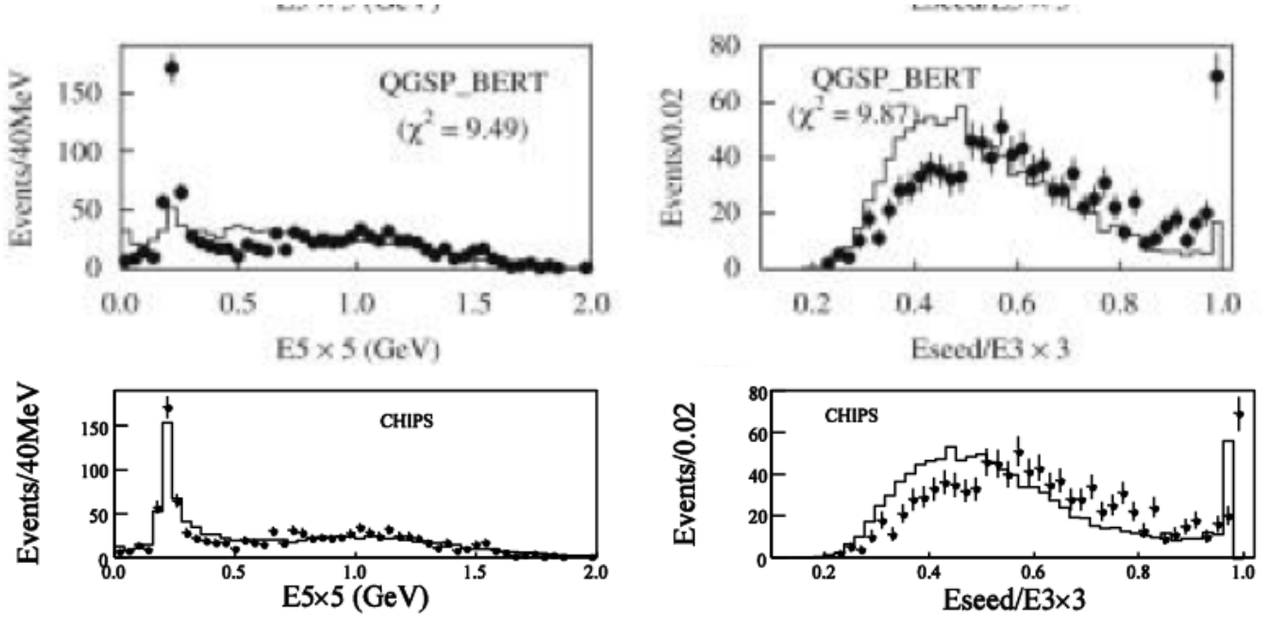
Anti-protons Simulation

Protons

G.F. Cao, H.M. Liu



Anti-protons



Courtesy of BESIII

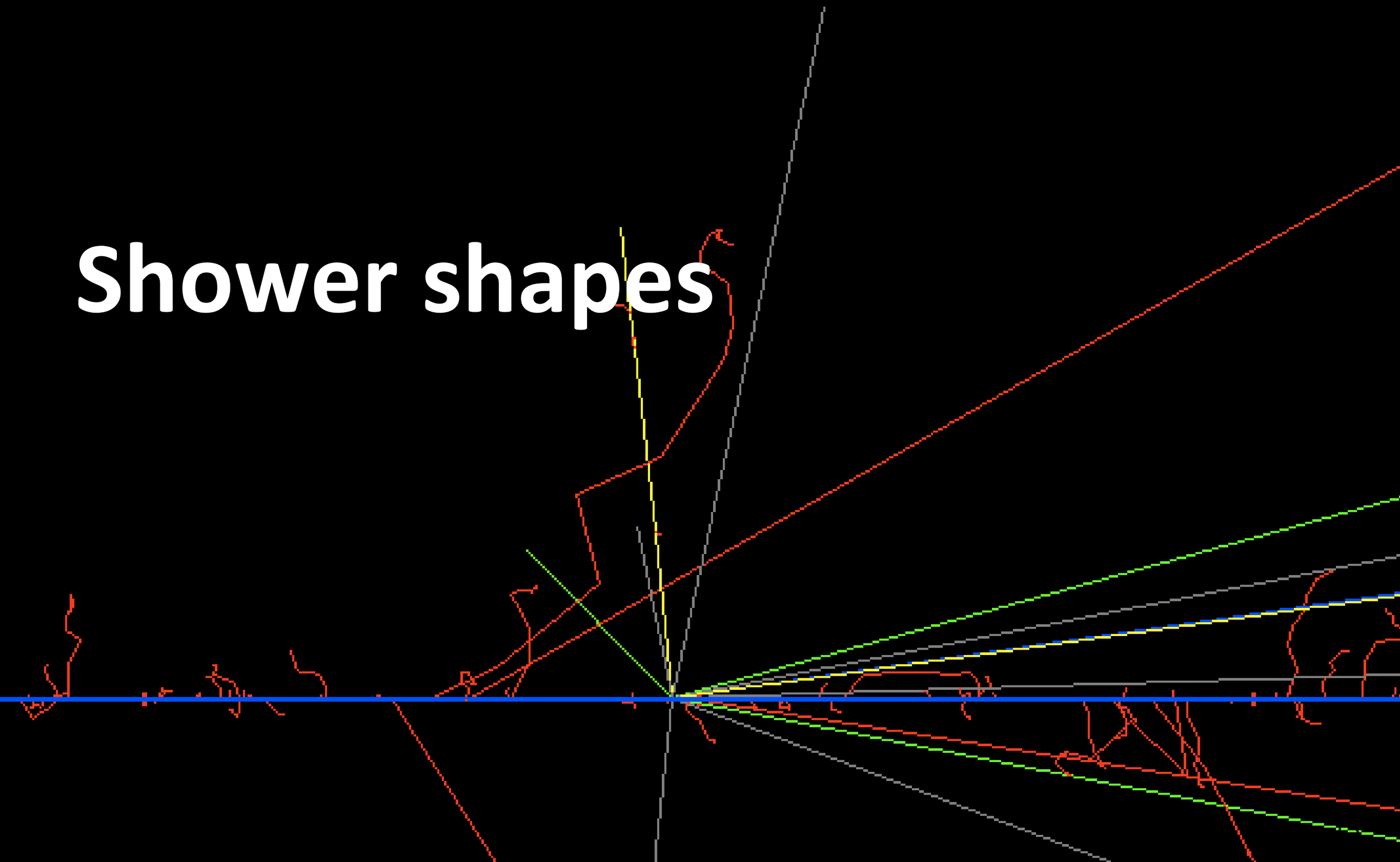
- Poor agreement for anti-p (and kaons)
- Parametrized models
- Alternative: CHIPS
- BESIII sees clear improvement
- Not so good in CMS

New from 9.4.beta: FTFP_BERT , QGSP_FTFP_BERT and QGSP_BERT_CHIPS use CHIPS for all “misc” particles and for K cross-sections

Anti-D, anti-t, anti-He

- Following request of ALICE
- First priority: cross-sections
  - In the framework of Glauber-Gibrov models
  - To be included in 9.4
- e.m. , elastic and quasi-elastic interactions with matter will follow

Shower shapes



LHC experience

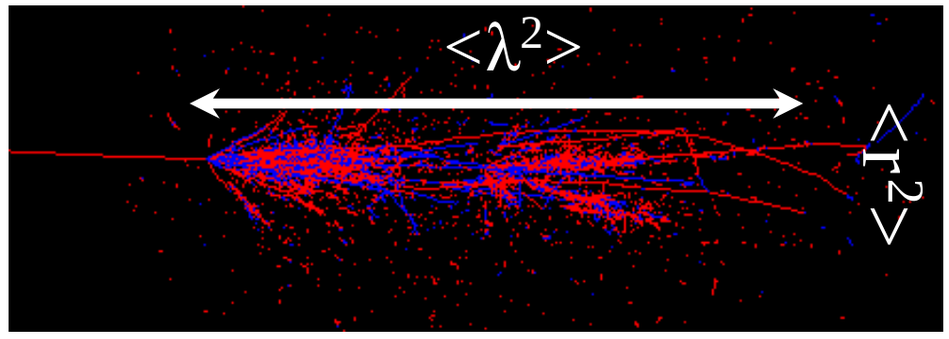
- From ATLAS comparison with test-beam
  - Showers are too short (10-30%) and too compact (10%)
- Rough granularity of LHC calorimeters limit possibilities
- CALICE is the perfect “tool”

What we routinely do

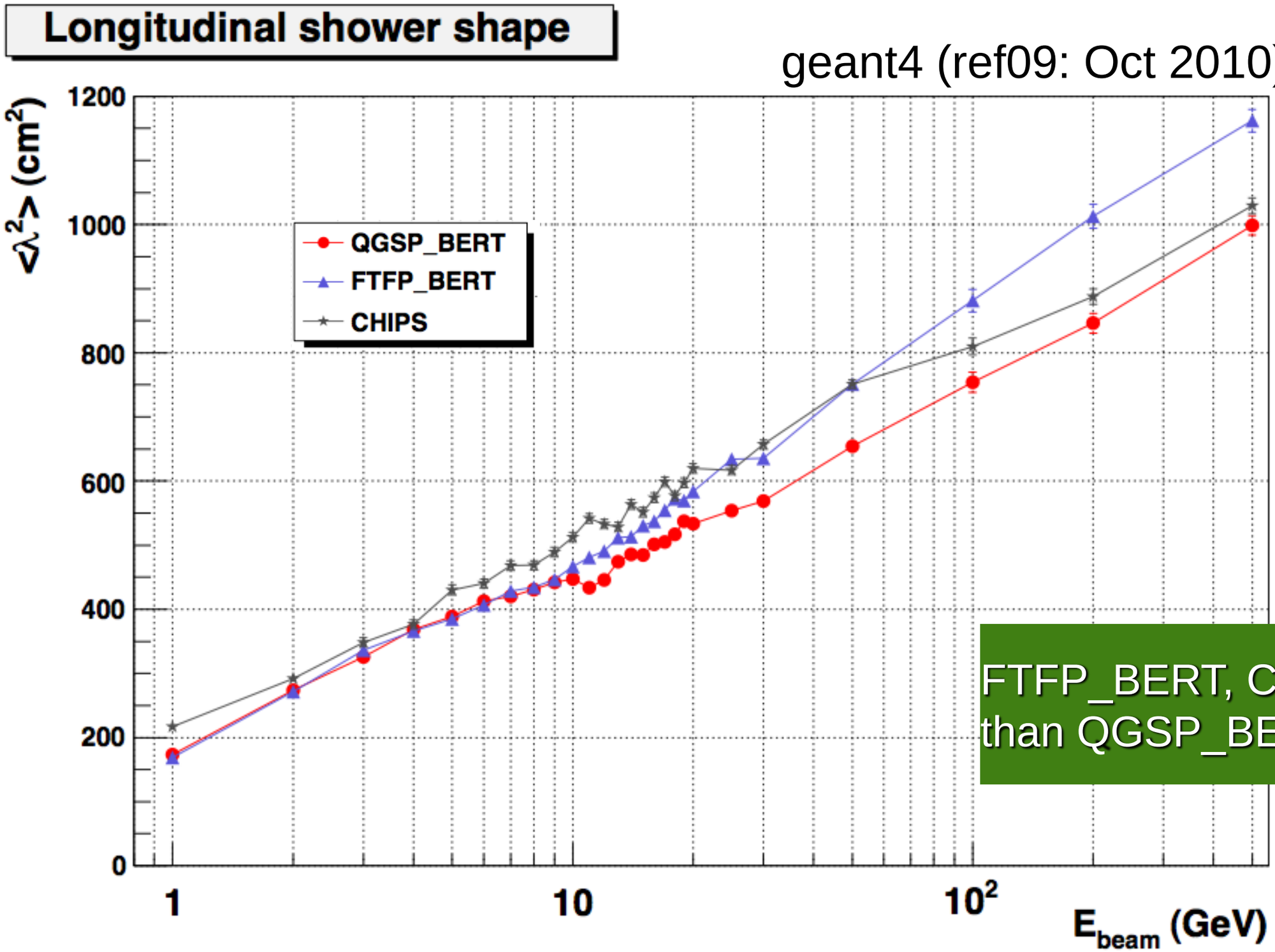
- Compare: physics lists, releases
- Simplified calorimeters (LHC materials, no read-our, simplified geometries)
- Very small pseudo-cells (5x5x5cm^3)

$$< \lambda^2 >= \frac{\sum_{cell} E_{cell} \lambda_{cell}^2}{\sum_{cell} E_{cell}}$$

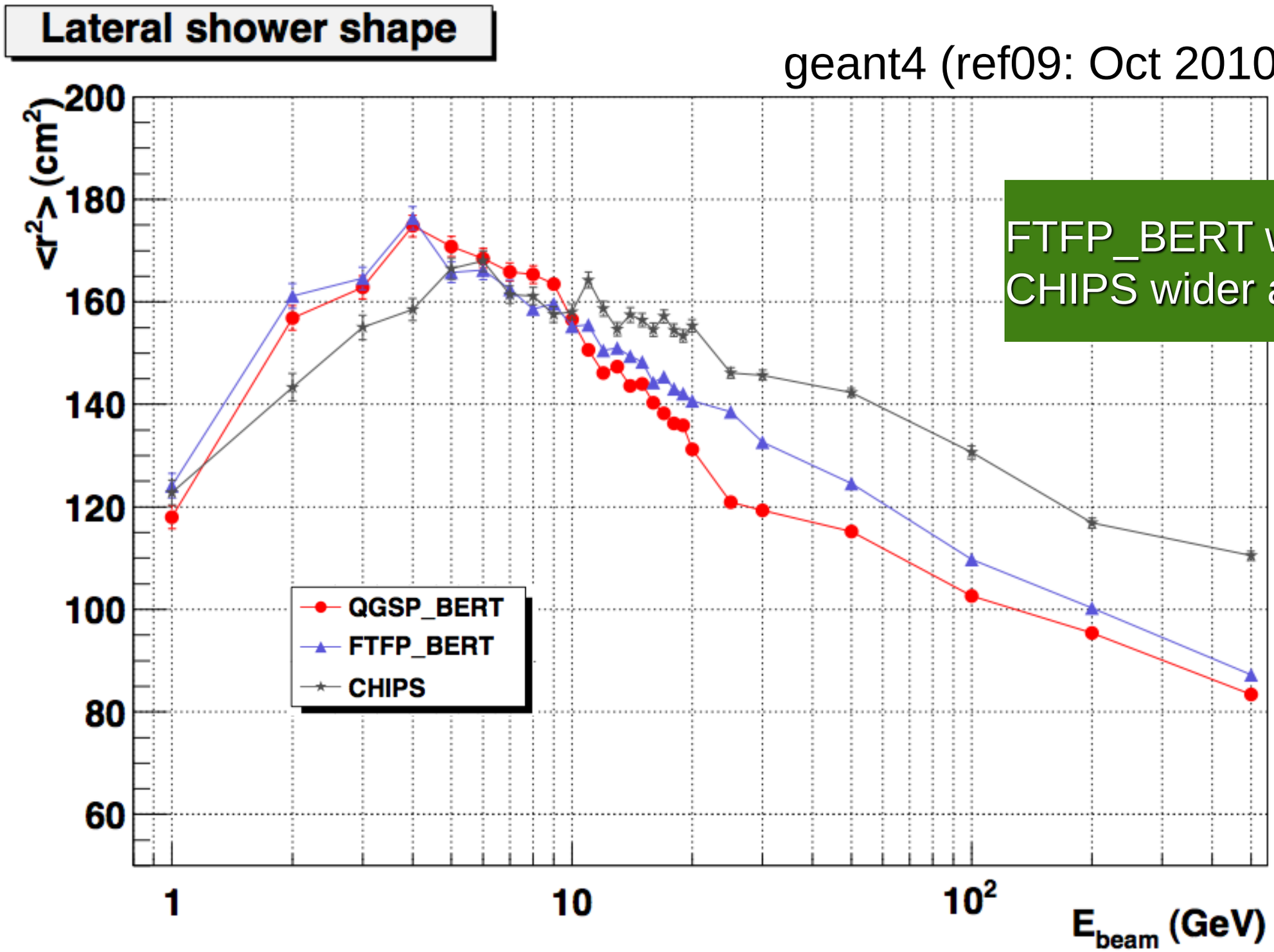
$$< r^2 >= \frac{\sum_{cell} E_{cell} r_{cell}^2}{\sum_{cell} E_{cell}}$$



Longitudinal shower shape



Lateral shower shape



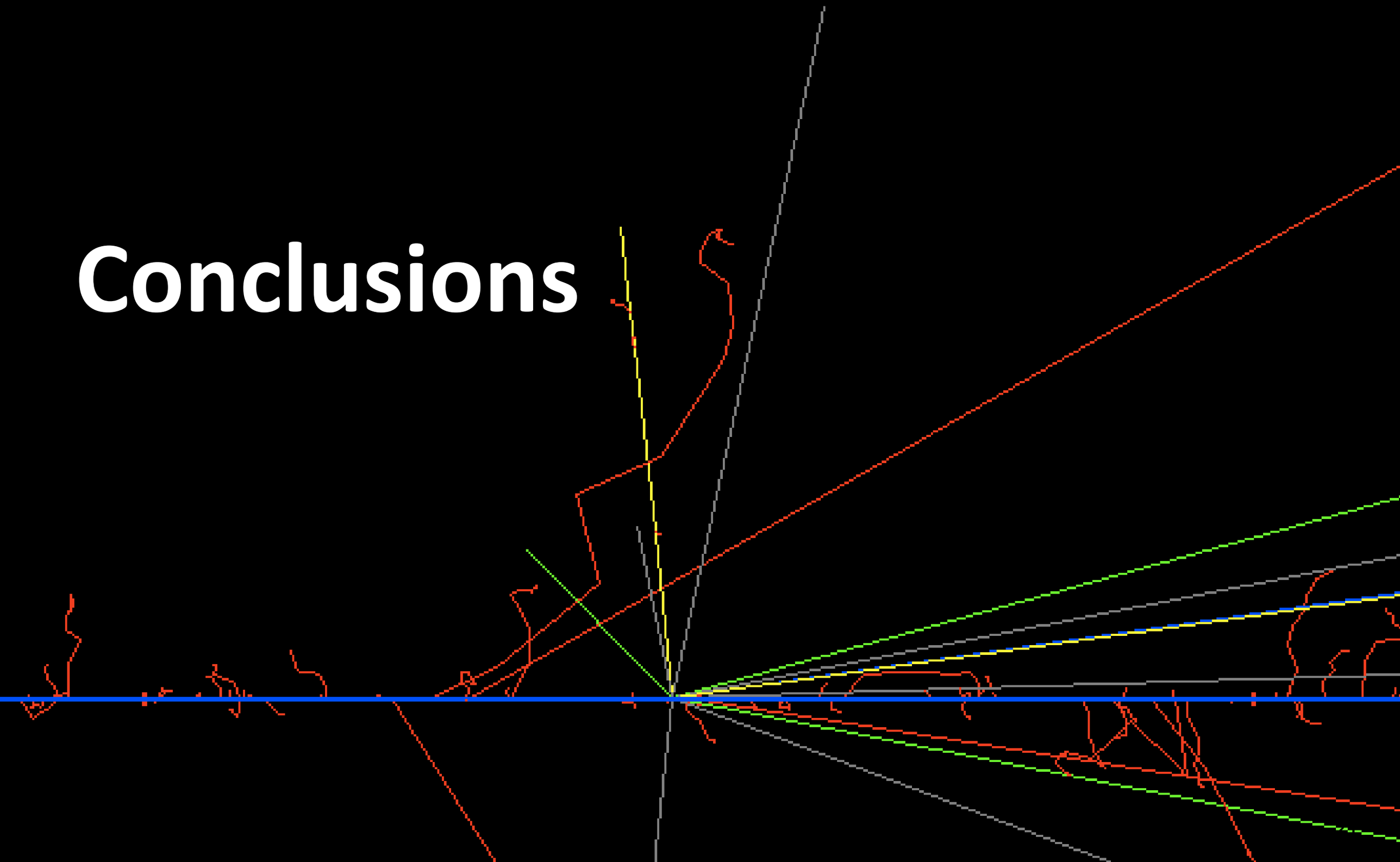
Shower Shape: what's next?

- We could add CALICE materials to SimplifiedCalorimeters
- Routinely check trend of shower shapes
- Our calculations: cells dimensions similar to CALICE one
- Could CALICE provide for direct comparison

$$< \lambda^2 >= \frac{\sum_{cell} E_{cell} \lambda^2_{cell}}{\sum_{cell} E_{cell}}$$

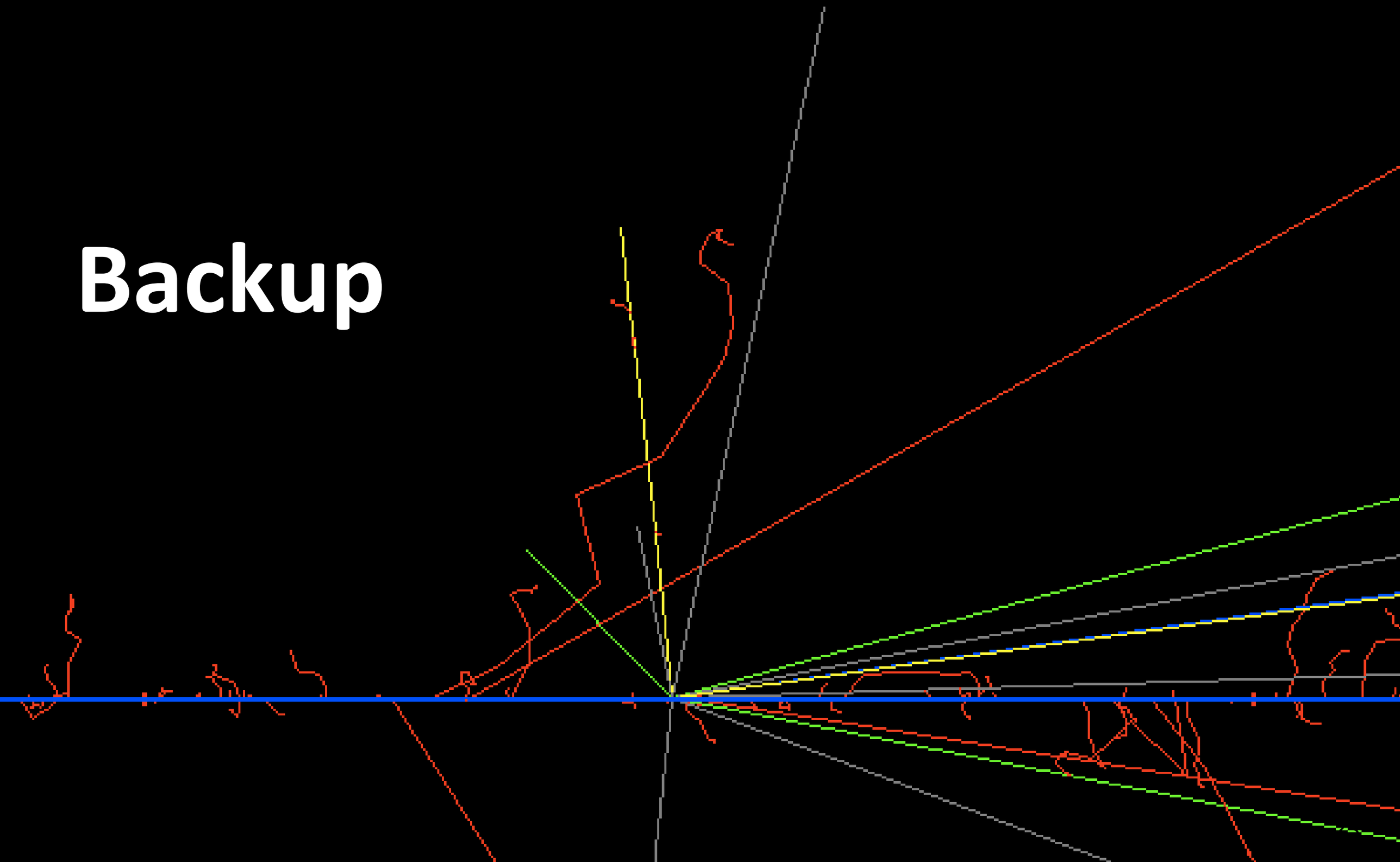
$$< r^2 >= \frac{\sum_{cell} E_{cell} r^2_{cell}}{\sum_{cell} E_{cell}}$$

Conclusions



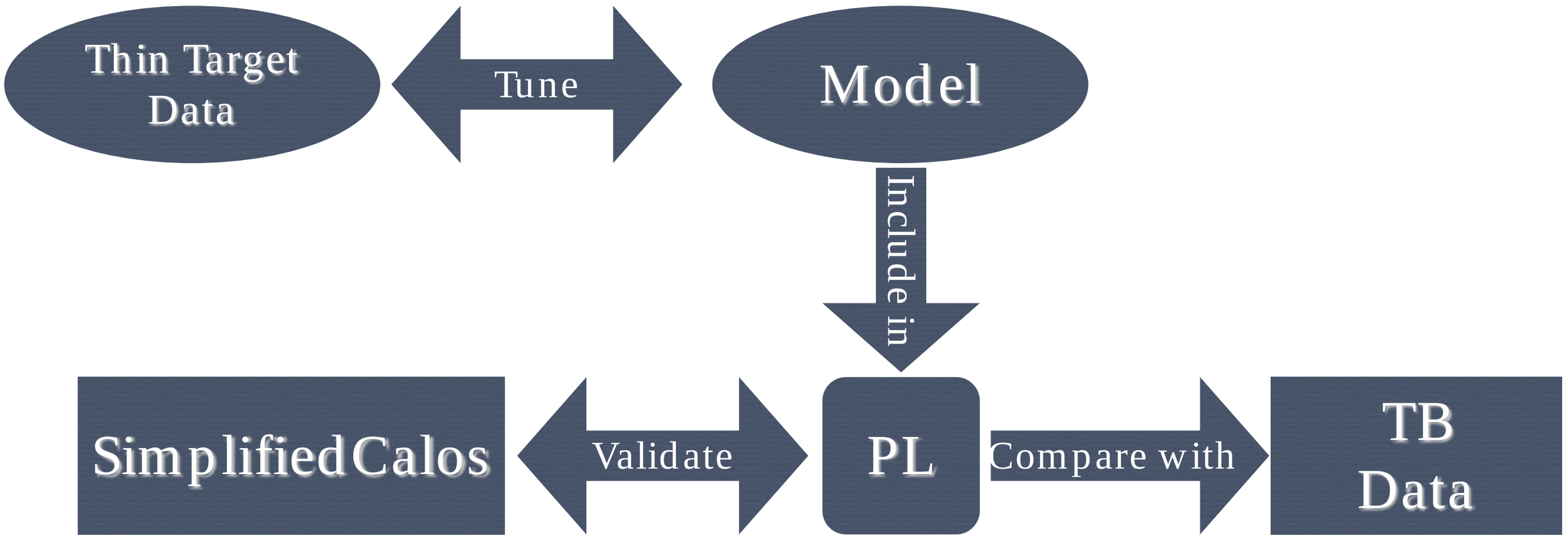
- Good agreement for response with LHC data
- Sufficient agreement for resolution with LHC data
- More work to do on shower shapes
- FTFP_BERT is at the moment the most promising alternative to QGSP_BERT
- New developments (expected in 9.4):
  - Improvements of existing models (FTF, BERT)
  - Add simulation of anti-N and anti-nuclei (light)

Backup

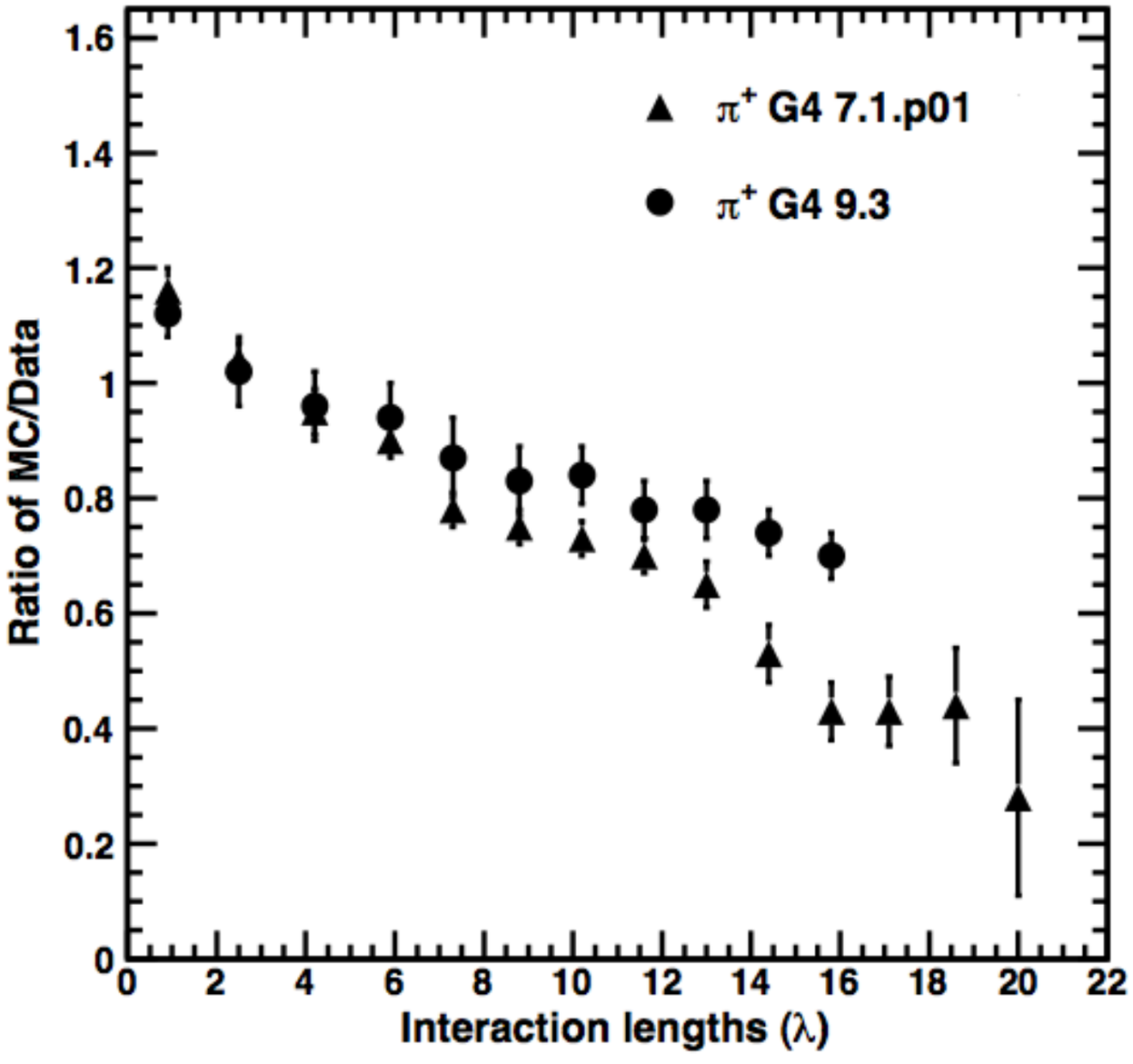


Working model

- Models are tuned with thin target data (not calorimeters test-beam)
- Models are assembled in physics lists: stable configurations (few billions of events simulated)
  - Example: QGSP_BERT (used at LHC since 3-4 years)
- Experiments compare physics lists with test-beam data
- We use simplified calorimeters to study the impact of hadronic models on calorimeter observables



QGS improvements (2009)

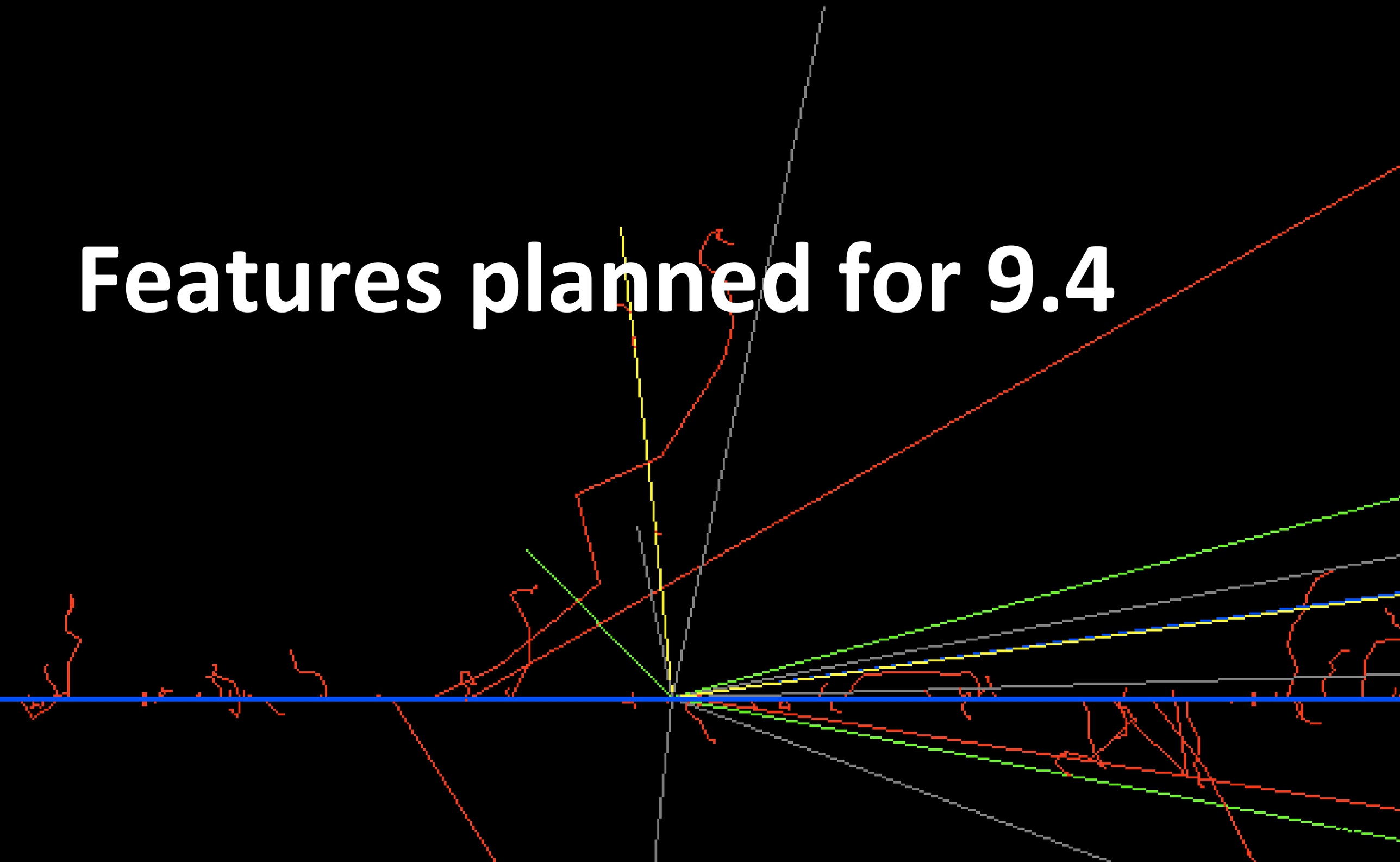


- Inclusion of quasi-elastic
- Shower become longer

Pre-compound and de-excitation models

- For g4 9.3p01 (December 2009) improving:
  - Light ion production
  - Fission of excited residual fragments
  - Isotope production
-
  - FermiBreakUp model for light ion fragments (A < 17)
  - G.E.M. evaporation samples 68 decay channels
  - Photon Evaporation module
  - Multi-Fragmentation Model (off by default)

Features planned for 9.4



Geometry

- Review of navigation verbosity & control at step number – Implementation of precise ComputeSafety() in navigation
- Extension of divisions to allow for gaps in replicated daughters
- Q/A review to code and addressing open issues

Materials and Particles

- Addition of extra data for ion stopping powers
- Review of atomic shell energies
- Introduction of variable density

- Update properties of particles to PDG 2010
- Review implementation of static tables and
- treatment of ions for thread-safety

Em Physics: standard

- Extend capability of helper classes
- Establish more effective sampling of displacement in Urban multiple-scattering
- Updated Bremsstrahlung model for e+- for energies E < 1 GeV
- Development of Doppler broadening parameterisation

Em Physics: Low Energy

- Penelope 2008 e+/- processes
- Pair production in the electron electric field (*)
- Radiative correction for pair production in the nuclear field (*)
- Reimplementation of anti-proton model of ionisation

(*) Not confirmed

Hadronic Physics

- Implementation of fast neutron capture model
- ENDL neutron database alternative models (*)
- Improved break-up method in de-excitation
- Complete migration to integer Z and A interface
- Complete interface from Bertini cascade to pre-compound and optimised fixes for energy/momentum conservation
- Interface of INCL to pre-compound & carbon ions in INCL/ABLA
- Integral elastic cross sections for coherent elastic model
- Extension of FTF model to nucleus-nucleus collisions
- Development of ion-ion model for elastic scattering
- Development of integral nucleus-nucleus cross-sections

(*) Not confirmed

More features

- Scoring
  - Full revision of scorers to accept user-defined unit
  - Cylindrical and spherical meshes for command-based scoring
- UI & Environments
  - Support for Python 3.0 in G4Py
- Visualization
  - Support of dynamic loading for visualization drivers
  - Improved visualization tools for regular voxel geometries
  - Support filtering of geometry according to attributes
  - Integrated visualization of field lines
- Advanced Examples
  - Introduction of DICOM images for Medical-Linac and Hadrontherapy examples
  - New examples: GammaKnife (simulation of a real 'radio-surgery' apparatus); IORT (*)(simulation of a real apparatus for Intra Operative Radio Therapy); Cexmc (Charge exchange Monte Carlo)

(*) Not confirmed

More features

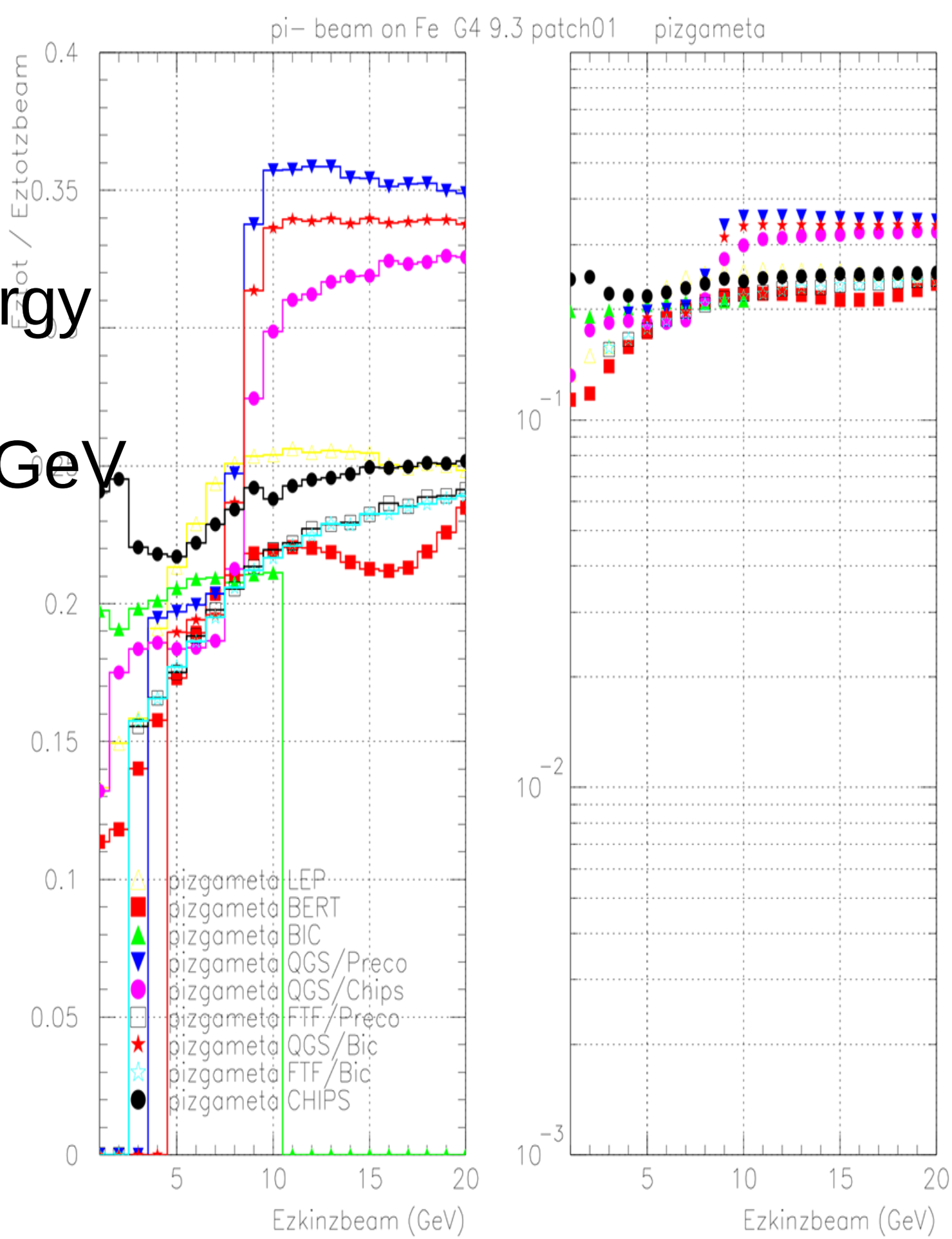
- Configuration
  - New optional configuration & installation system based on CMake
- First prototype thread-safe/multi-core kernel
  - Alternative code tree based on 9.4 series
- Complete list of planned developments for 2010 at:
- http://geant4.cern.ch/support/planned_features.shtml

Yaxis:Outgoing energy /Beam energy

Xaxis: Beam Energy/GeV

$\pi^0 + \gamma + \eta s$

Geant4 9.3 patch 1



Outgoing energy /Beam energy

$\pi^0 + \gamma + \eta s$

Geant4 9.3 ref 09 (29 Oct 2010)