Geant4 Physics Update

presentation at AWLC17

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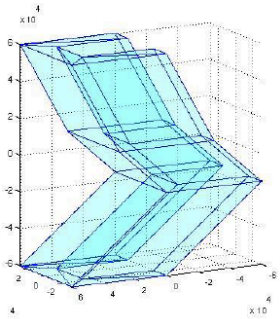
Outline

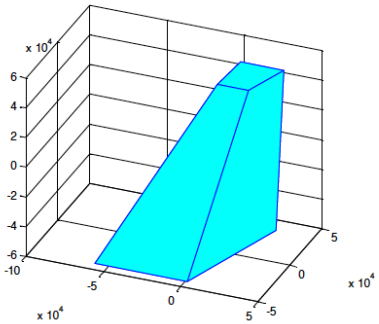
- Geant4 kernel notes
- Electromagnetic physics updates
- Hadronic physics updates
- Results from calorimeter simulations

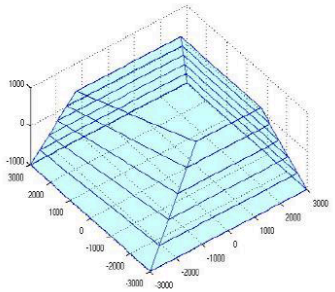
Geant4 Kernel

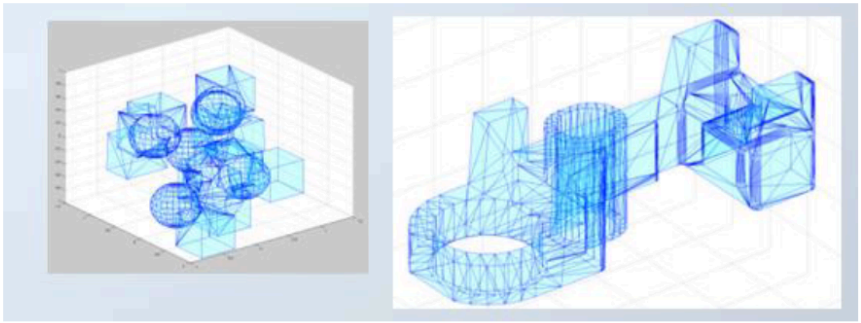
Geometry

Geometrical primitives - USolids









- AIDA Unified Solids library update
  - As optional component, for replacing the original solids (G4GEOM_USE_USOLIDS flag)
  - Was embedded in 10.0 inside geometry module; can be adopted as external separate library in 10.1
  - Going to evolve with new and even more optimised implementations from VecGeom
- Optimised implementation and bug fixes for several shapes
  - UPolycone in particular
- Included new shapes
  - UExtrudedSolid, UGenericTrap, Utrap
- New UMultiUnion structure
  - Replaces multiple use of 'binary' Boolean unions for volumes with same material
  - Benefits above 3-4 components
  - Supported in GDML, version 3.1.1

Please, try it out and give us your feedback!

USolids Geometry

- Now fully incorporated into Geant4 geometry
  - G4Box → G4UBox
  - G4Tubs → G4UTubs
  - G4Cons → G4UCons
  - G4Sphere → G4USphere
  - G4Trap → G4UTrap
  - and more
- Can make straight substitution in your geometry
  - expect to see speed-up
- Will eventually be replaced with VecGeom solids
  - external library for this now available

Other Geometry Items

- G4ScaledSolid
  - can scale any solid in x, y, z or any combination of these

- New minor release of GDML schema: GDML-3.1.4
  - fully compatible with old schema versions
  - supports scaled solids

C++11

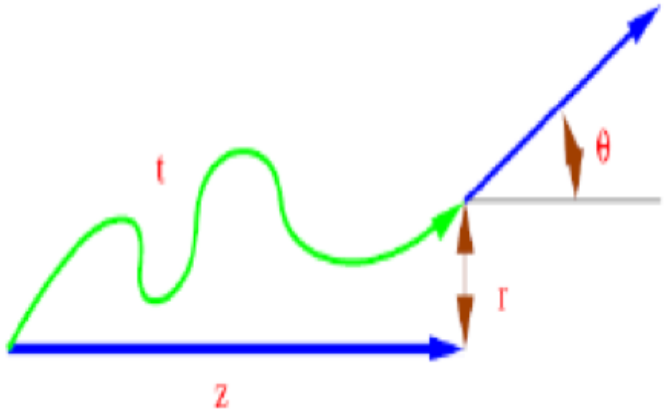
- Compilation using C++ 11 standard is now the default. Compilers must support:
  - null pointers
  - range-based for loops
  - uniform initialization
  - automatic type definition
  - and more

- Gradual migration of Geant4 code underway
  - C++11 features make multi-thread coding easier

Electromagnetic Physics

Multiple Coulomb Algorithm

- Legend
  - True path length : t
  - Longitudinal or geometrical displacement : z
  - Lateral displacement : r
  - Angular deflection : (θ, Φ)

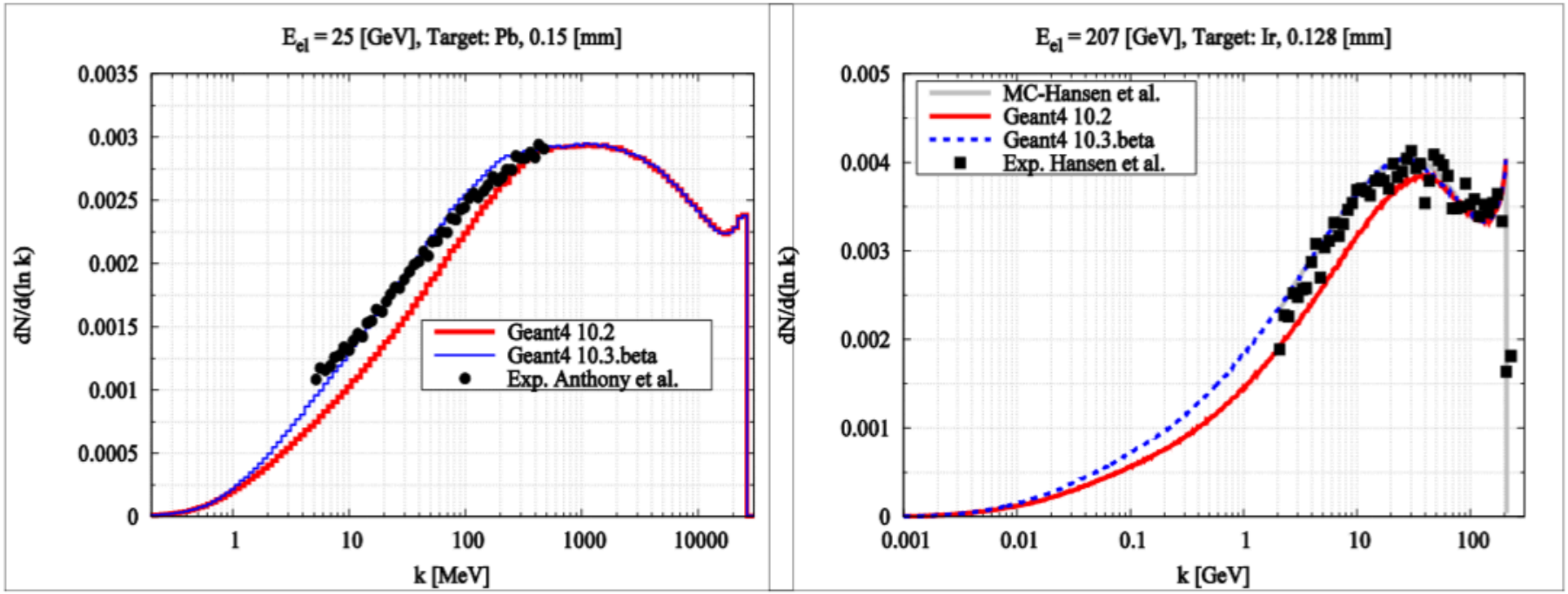


Improvements in lateral displacement sampling

recent addition of Goudsmit-Saunderson model showed significant improvement in this area

improved sampling in Urban model followed
→ EM shower shapes improved

Bremsstrahlung and Improved LPM effect



- Effect on shower shapes seems to be small (parts per thousand)

Hadronic Physics

Nuclear De-excitation

- Close to completing photon evaporation with correlated gamma emission
  - keep track of nuclear polarization from transition to transition
  - use transition angular momentum to provide correlation and angular distribution of gammas
  - could affect low energy part of EM shower shapes, as previous model had only isotropic gamma distributions

- New photon evaporation database required
  - PhotonEvaporation5.0
  - contains J^{π} information for each gamma level

Bertini Cascade

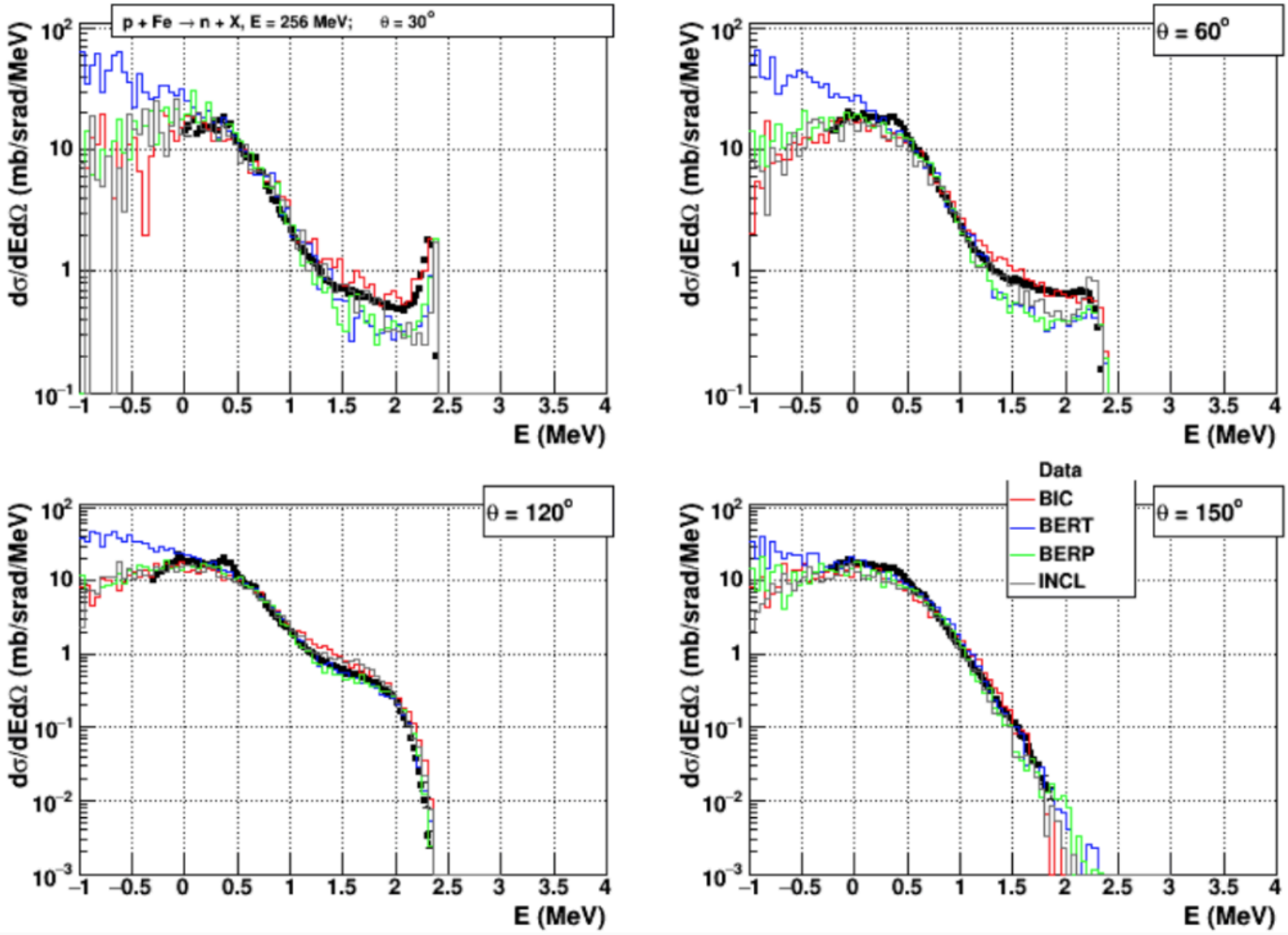
- Kaon extension to 30 GeV
  - added 8- and 9-body final state channels to get to higher energy
  - practical limit to approach of embedding elementary interaction in nucleus
- Coalescence model
  - now that Bertini is used up to 9 GeV, much more memory used -> coalescence mode is culprit
  - remove storage of intermediate nucleon combinations -> memory use back to normal
  - shower shapes narrower, though

Bertini Cascade

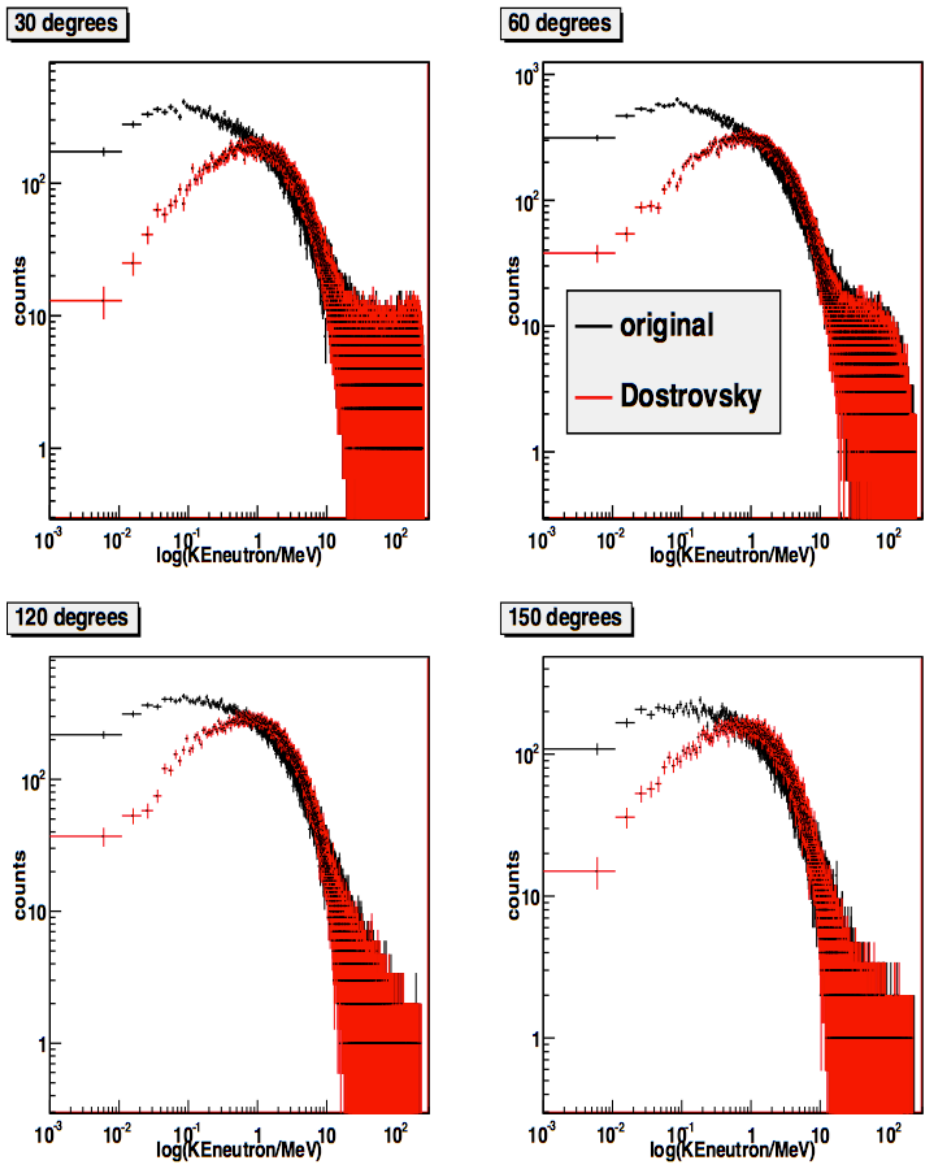
- Equilibrium evaporator model
  - handles low energy emission of nucleons from de-exciting nucleus
  - nominally based on Dostrovsky model

- A more faithful implementation of Dostrovsky results in fewer neutrons evaporated
  - partially solves long-standing problem of too many low energy neutrons in Bertini

Low Energy Neutron Production in Bertini (old)



Low Energy Neutron Production in Bertini (new)



INCL++ Cascade

- More detailed alternative to Bertini
  - includes delta resonances in cascade
  - takes more time, though

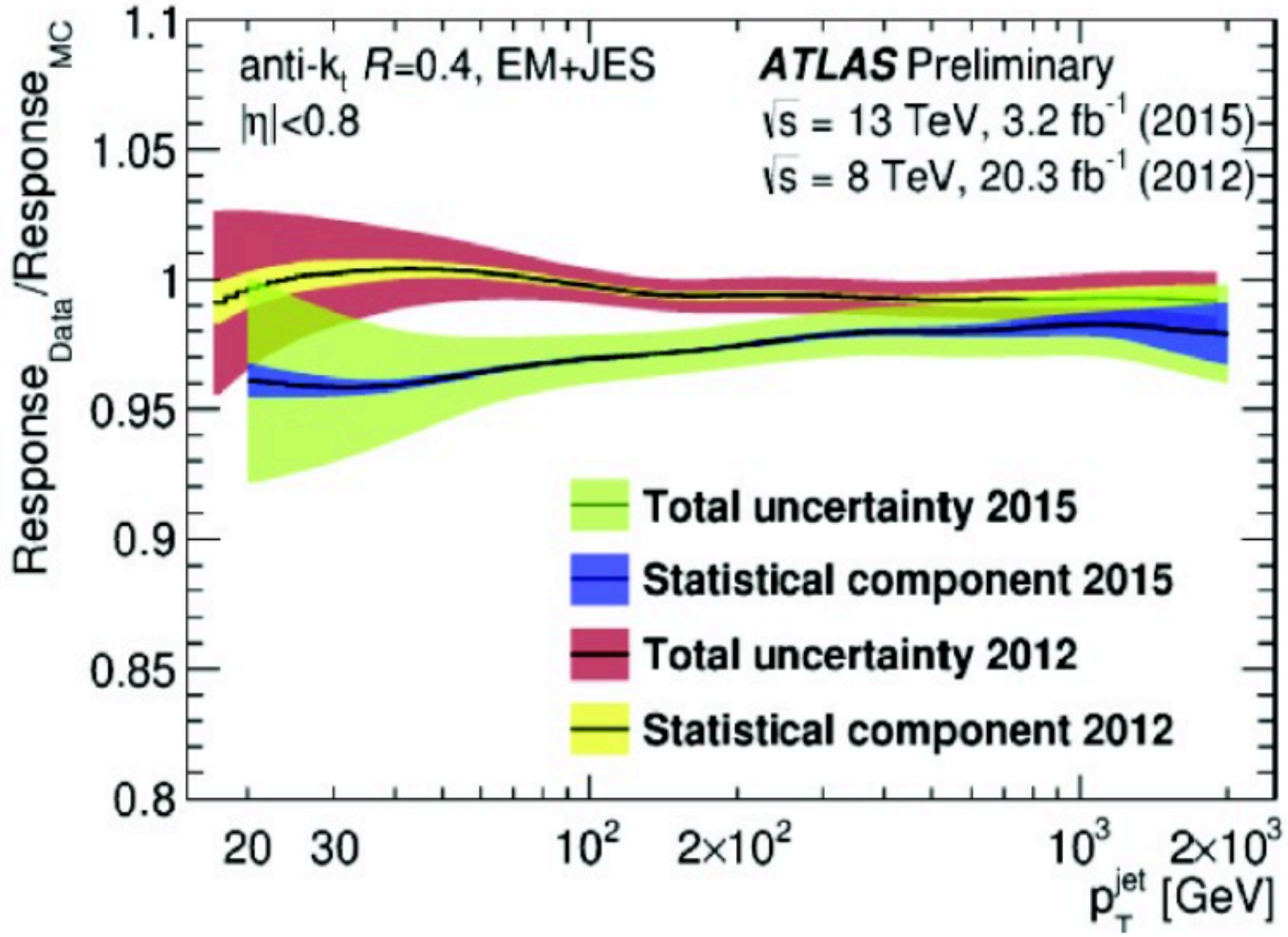
- Extended to include eta and omega meson production
- In process of extending to kaons

- Physics lists using this model are available for use
  - FTFP_INCLXX_HP - similar to FTFP_BERT_HP (or Shielding)

High Energy Models

- Recent analysis by ATLAS and CMS has shown a shift in ratio of simulated to measured response at jet energy scale
  - between Run 1 (8 TeV) with G4 9.4 and Run 2 (13 TeV) with G4 9.6
- FTF and Bertini used by both ATLAS and CMS physics lists
  - despite many changes to Bertini, little effect on showers
  - FTF is now the suspect
- Created new physics list for ATLAS
  - transition from BERT to FTF moved from [4–5] GeV to [4-9] GeV
  - restores some lost shower width
  - wait to see results of new ATLAS analysis

Problem at the Jet Energy Scale



FTF Model

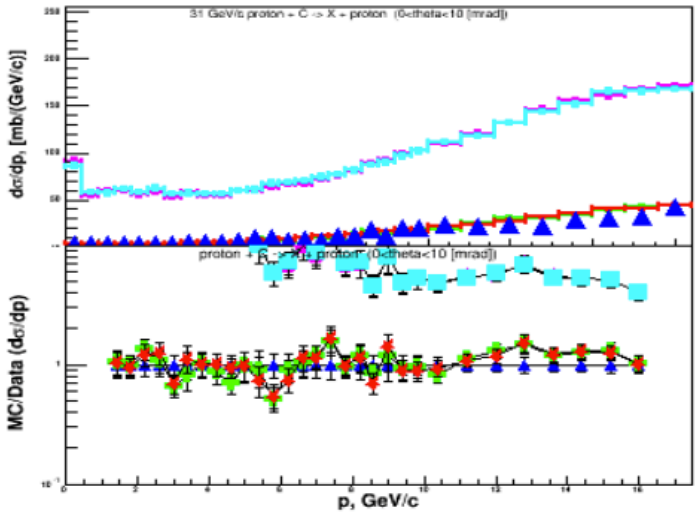
- Has been the "go-to" model for high energies
- Work continues by Vladimir Uzhinsky and Alberto Ribon
  - new hadron fragmentation functions, other physics improvement
  - parameter tuning, such as mean P_t

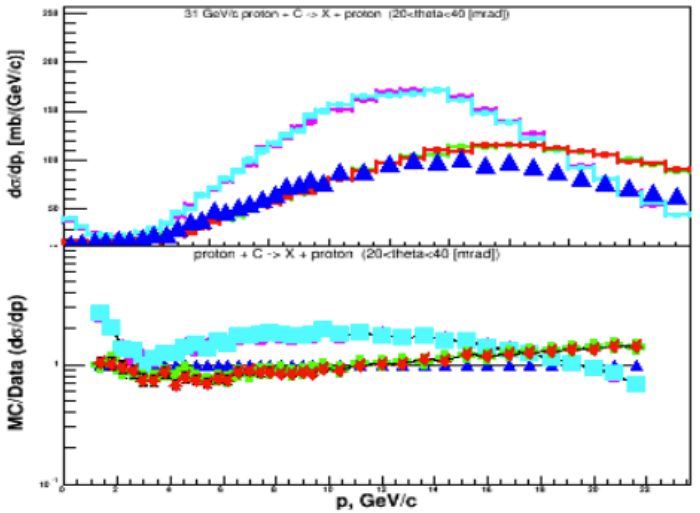
- However, may have reached point of diminishing returns
  - still small improvements in agreement with thin target data
  - but departures from calorimeter data
  - now using Bertini at higher energies (up to 9 GeV) to get better agreement with hadronic showers
  - time to go to a more theory-driven model?

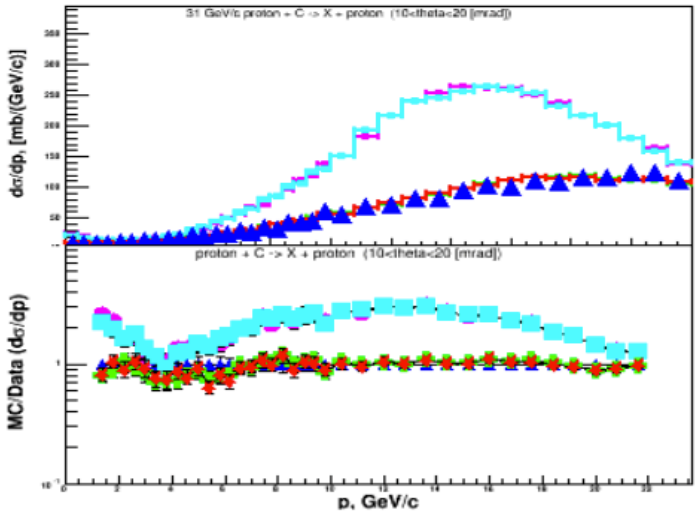
QGS Improvements

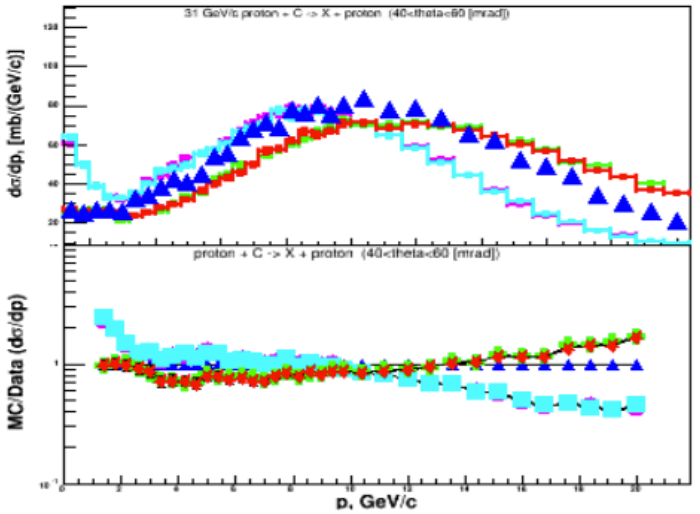
- QGS has lain dormant for many years
- Work resumed (by Vladimir Uzhinsky) because
  - model is more theoretically based
  - can be extended to much higher energies (multi-Tev)
  - FTF model may be reaching its limits
- Changes
  - use constituent quark masses (instead of massless)
  - Pomeron and Reggeon parameters set up according to Kaidalov and Poghosyan
  - quark exchange improved
  - some parameter tuning

QGSPP: 31GeV/c p+C -> p



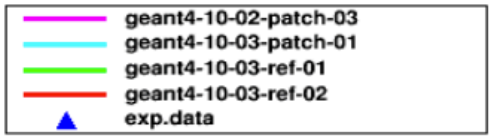






qgsp vs NA61 Data; χ^2/NDF calculated over ALL theta bins

χ^2/NDF = 155.851 for geant4-10-02-patch-03
χ^2/NDF = 156.461 for geant4-10-03-patch-01
χ^2/NDF = 13.1912 for geant4-10-03-ref-01
χ^2/NDF = 13.0215 for geant4-10-03-ref-02



ParticleHP

- NeutronHP has been merged with its analogue for high precision charged particle interactions, ParticleHP
  - now handles n, p, d, t, α
  - new code is ParticleHP, but NeutronHP kept for backward compatibility
  - mostly for E < 20 MeV, but some data up to 200 MeV

- Database
  - G4NDL4.5 now required
  - to reduce size data files stored in zlib format
  - code automatically unpacks this, but to get human readable data, you need to run zlib (http://www.zlib.net)

ParticleHP – Problems Solved

- Reproducibility now restored in multithreaded running
  - Release 10.2

- Large memory consumption problem solved
  - Release 10.3

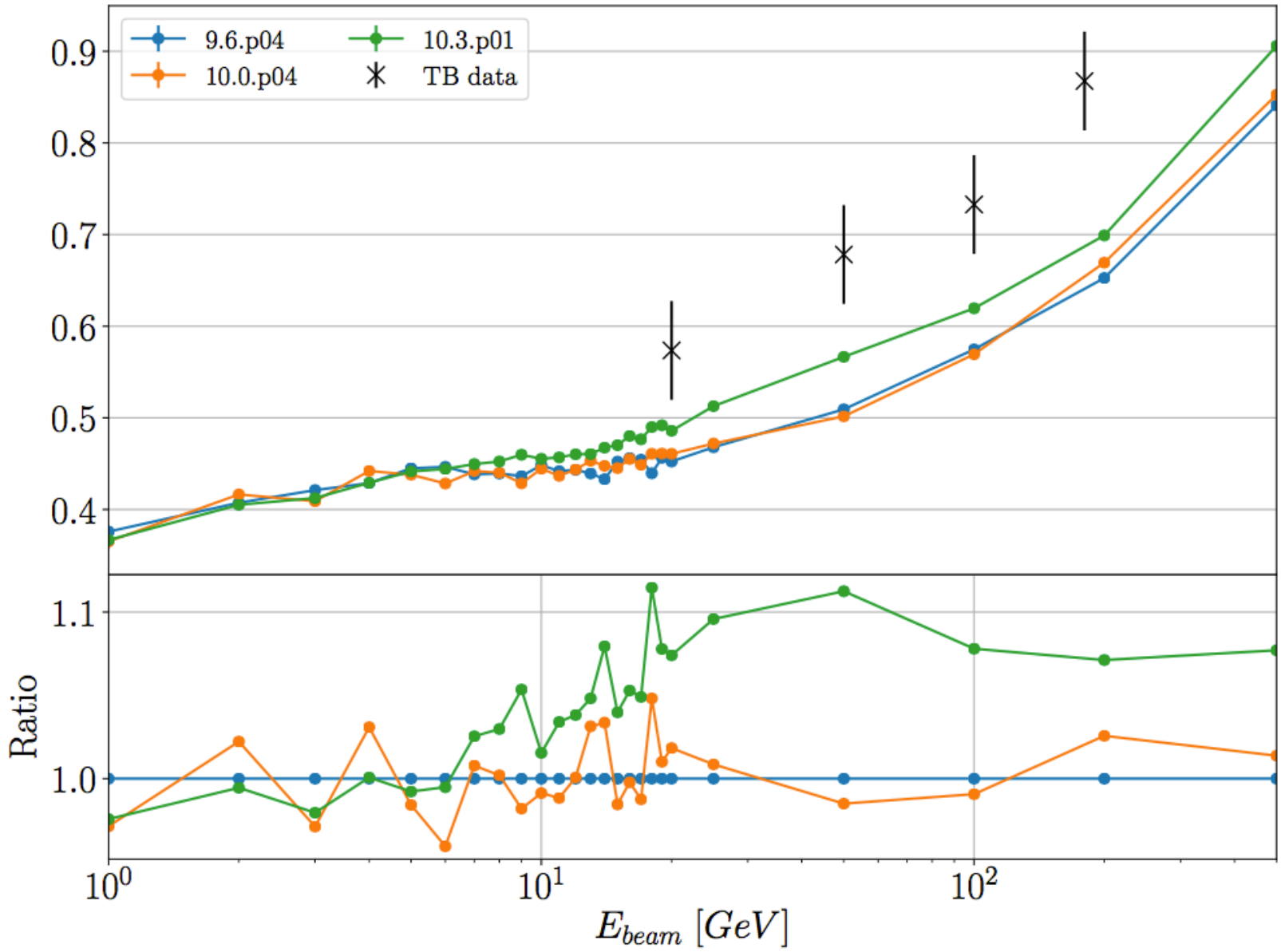
GND/GIDI/LEND

- Generalized Nuclear Data (GND)
  - new low energy particle database with more modern, rationalized format
  - includes all ENDF/B-VII data
  - upgrade of Generalized Interaction Data Interface (GIDI) used to access new GND format

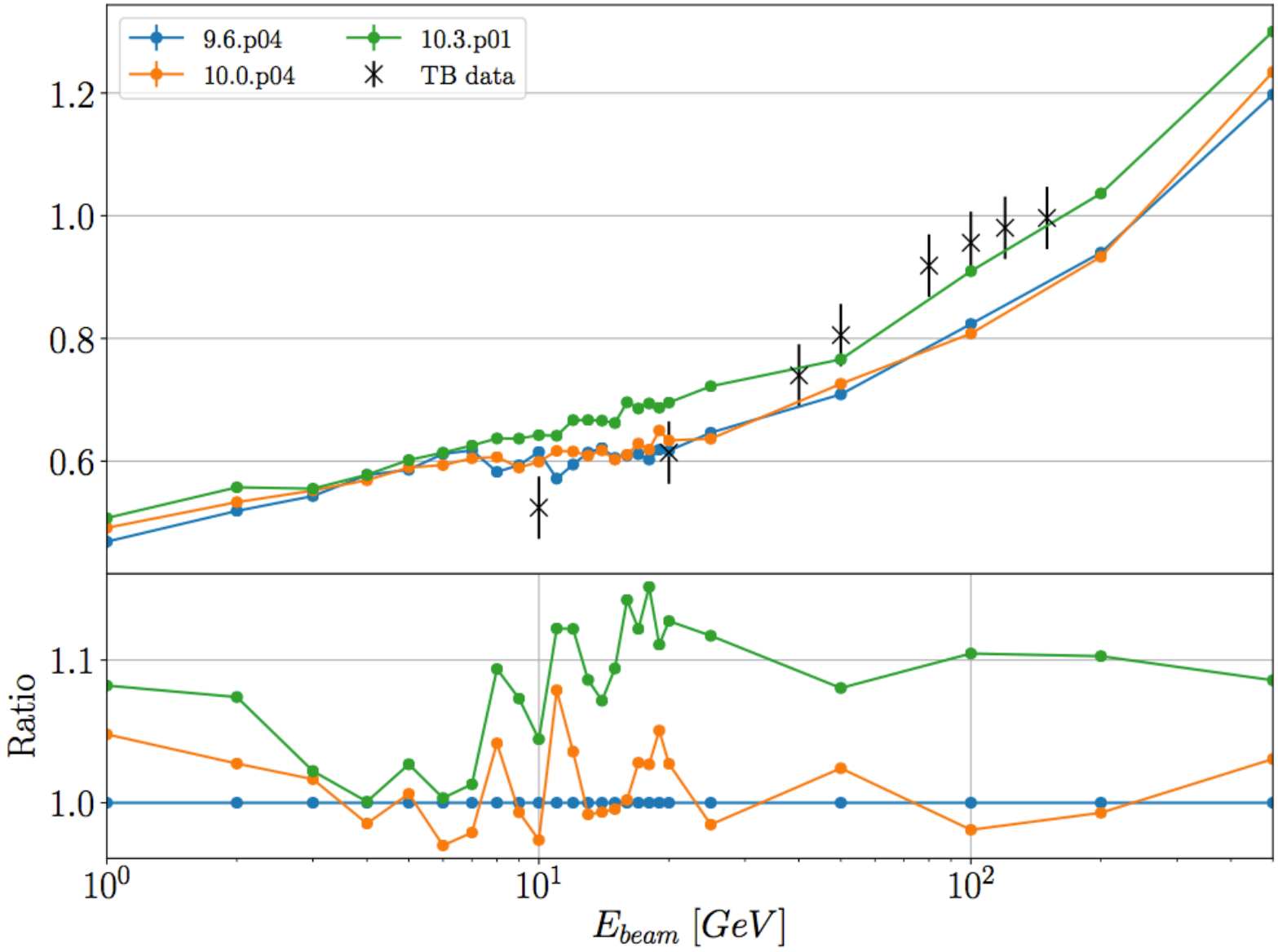
- Can already try the new data
  - use G4LEND neutron models
  - or G4HadronElasticPhysicsLEND physics constructor
  - need to download data from ftp: //gdo-nuclear.uclln l.org/pub

Simplified Calorimeter Results (π^- beams)

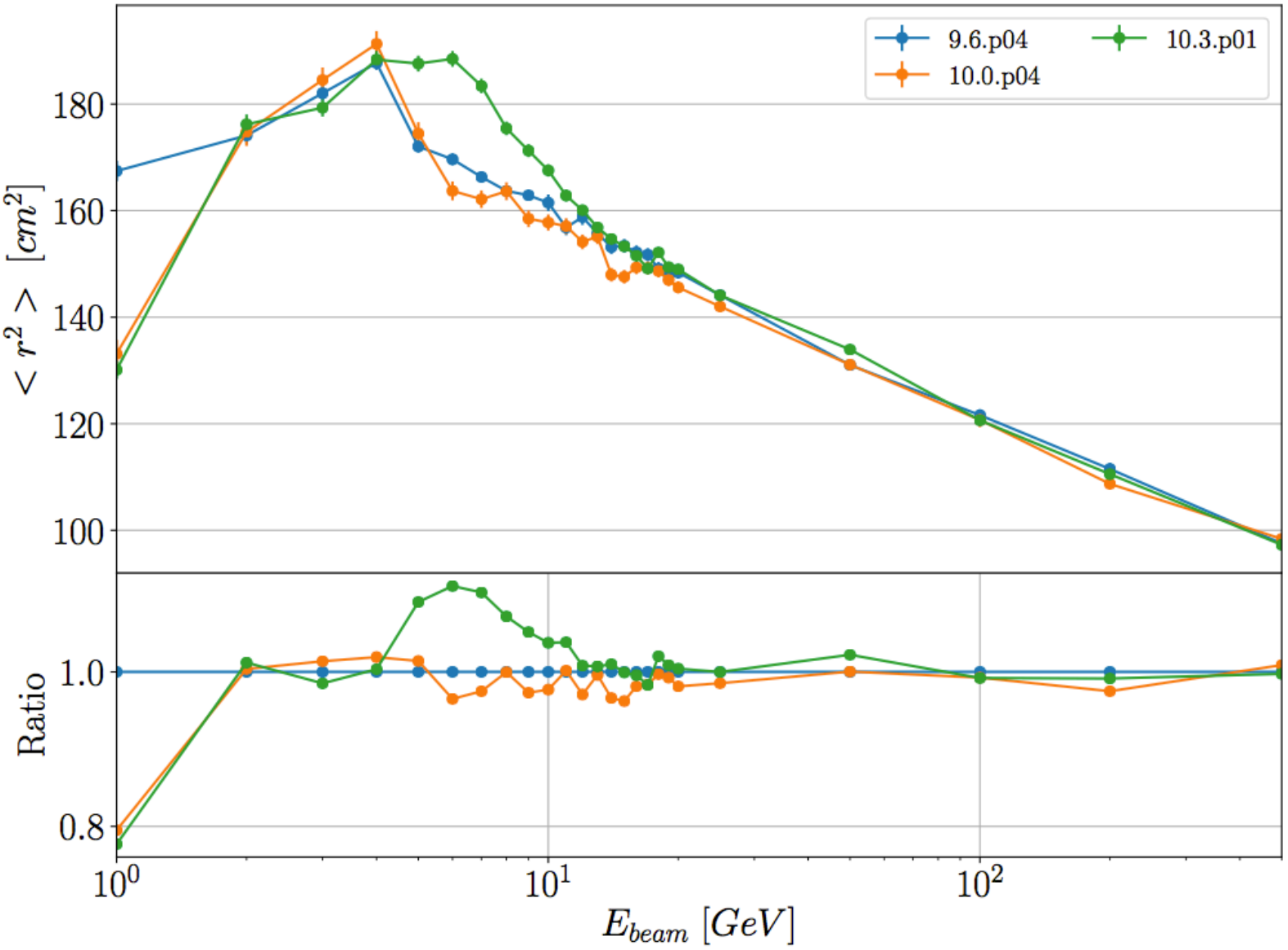
Scint/Fe Cal. Results: resolution



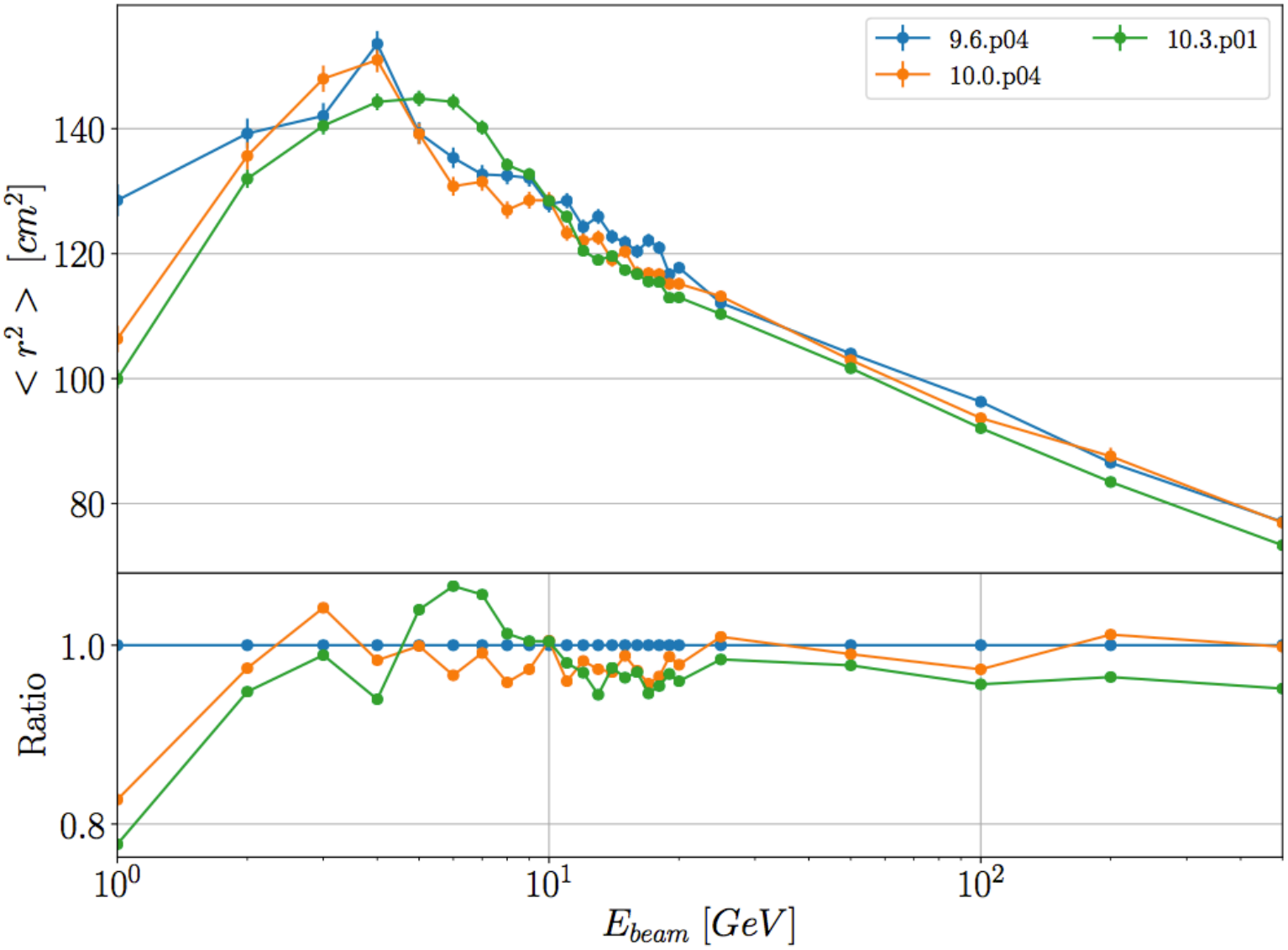
LAr/Pb Cal. Results: resolution



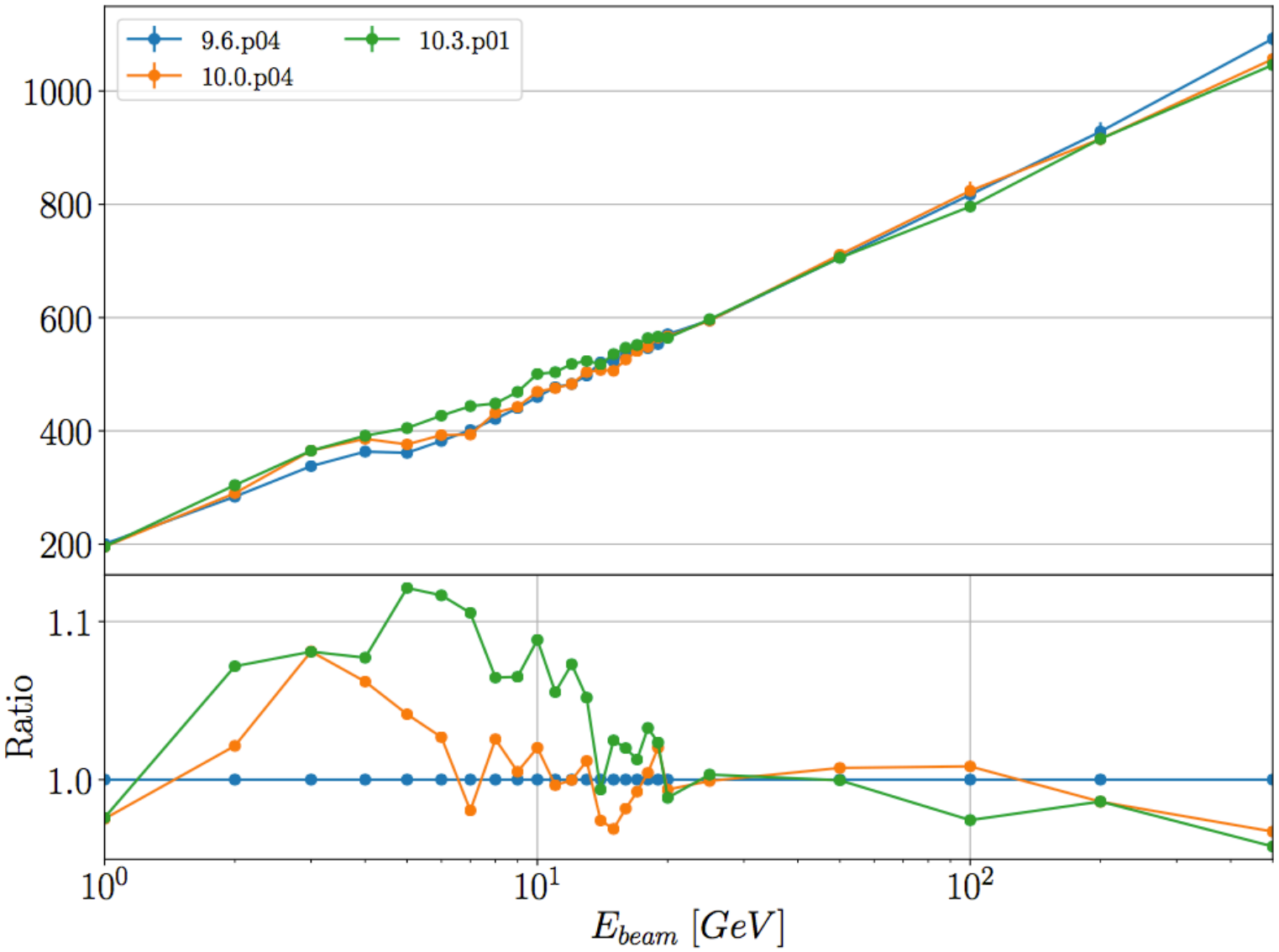
Scint/Fe Cal. Results: lateral shape



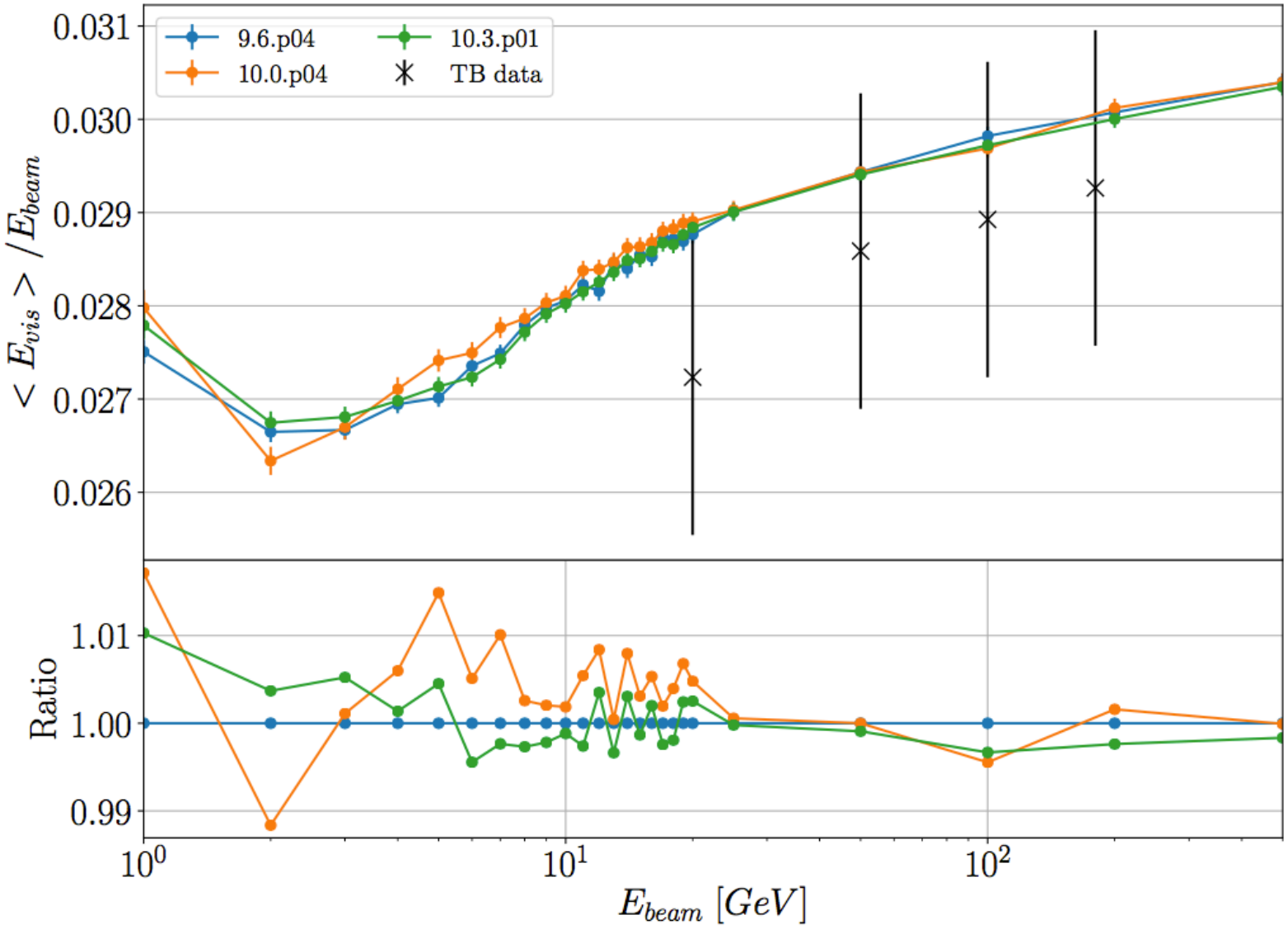
LAr/Pb Cal Results: lateral shape



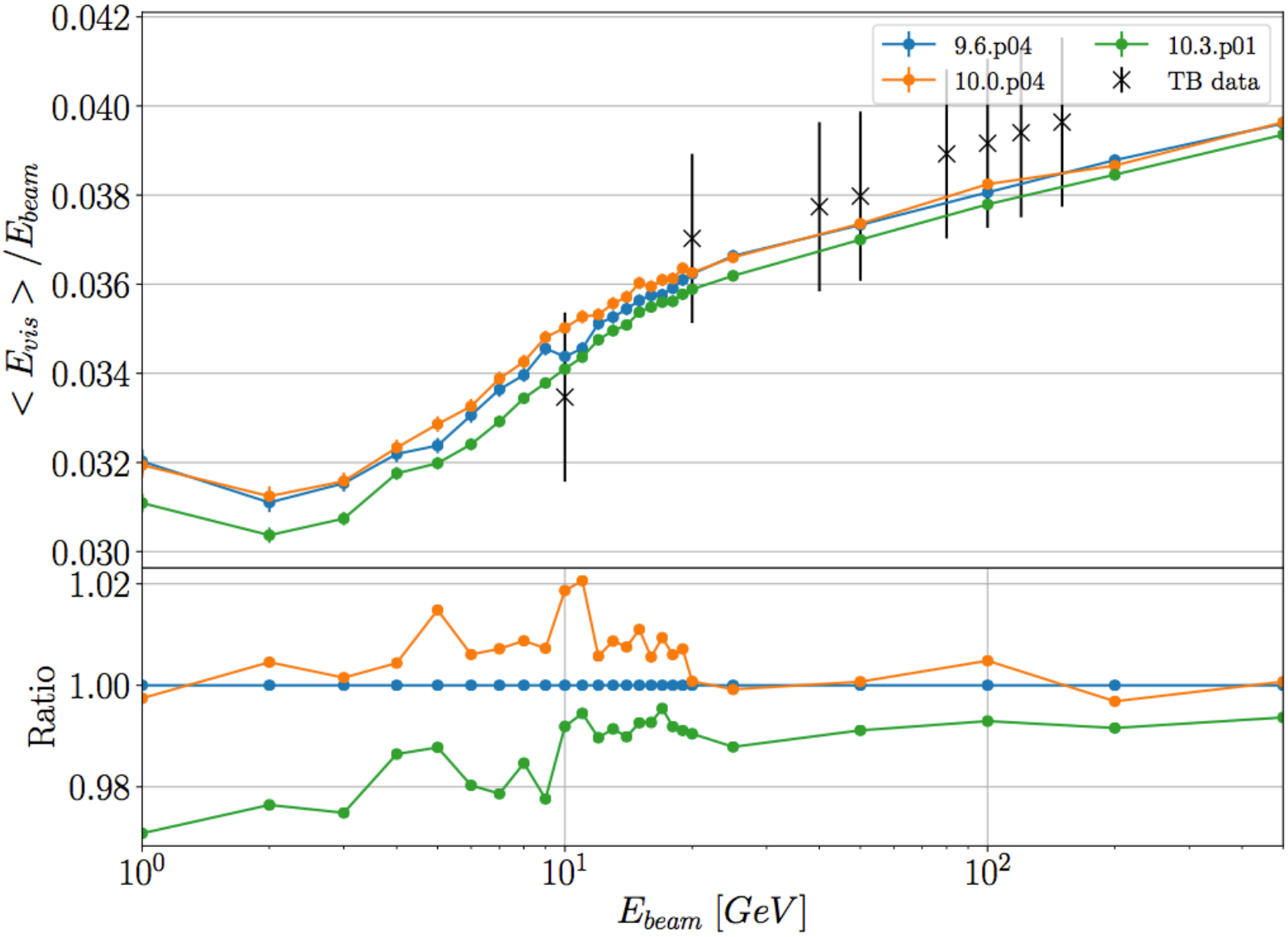
Scint/Fe Cal. Results: longitudinal shape



Scint/Fe Cal. Results: visible energy



LAr/Pb Cal. Results: visible energy



Conclusion from Calorimeter Simulations

- From Geant4 9.6 to 10.3 we see small but steady improvements
  - better resolution in 10.3
  - with new transition region between Bertini and FTF models, showers are smoother and a little wider below 10 GeV

- WRT Calice
  - not expecting large changes relative to Calice Fe/Scint paper (arXiv: 1412.2653)
  - some changes expected for Si/W detector in 10.3: wider showers between 4 and 10 GeV → closer to arXiv:1411.7215

- Some problems in 10.2 with W