CERN
PH/SFT in Geant4

Gabriele Cosmo, PH/SFT

CERN PH/SFT in Geant4

- The focus of the team is on the LHC experiments: the customers
- Our actions in the last 3 years have focused on:
  - Improving responsiveness and support to the LHC experiments
  - Assuring that the physics performance required by LHC experiments is attained
  - Ensuring that the code of the physics models can be maintained
  - Becoming more efficient in undertaking these goals
- These were recommendations of PH/SFT review (2009)

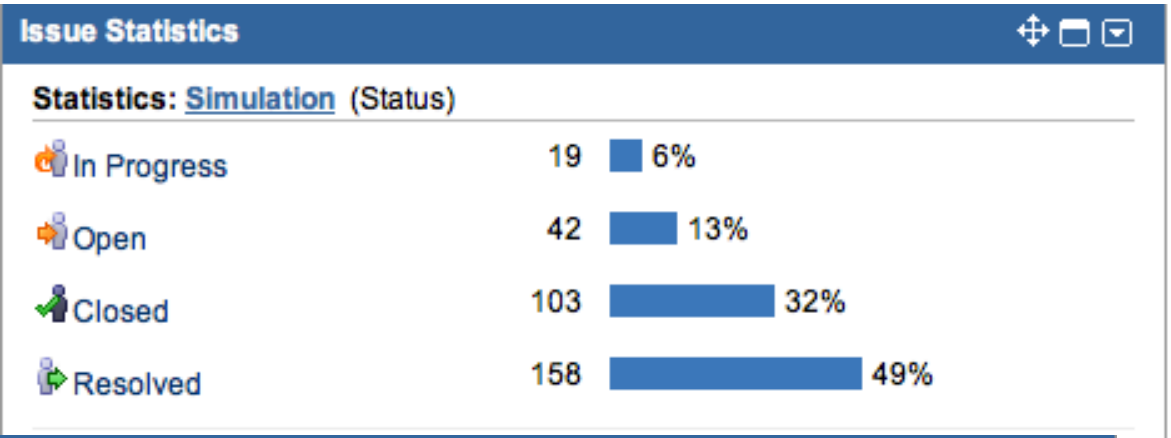
Constant contact with experiments

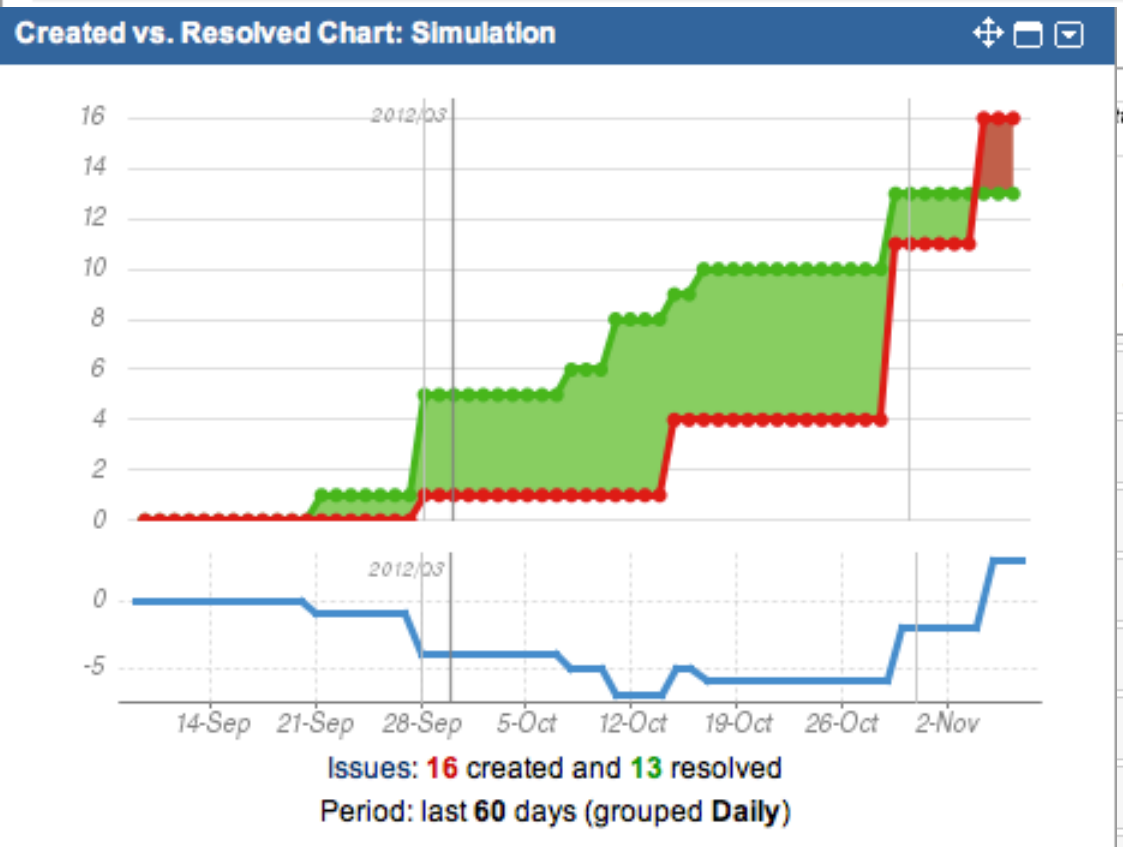
- Contact persons appointed for all LHC experiments
  - Contacts attend the *weekly simulation meetings* of ATLAS and CMS
  - Feedback is quickly circulated, and reviewed each week in our *SFT Simulation meeting*
- The contact persons are
  - V.Ivantchenko, CMS Simulation co-convener; G.Cosmo contact person
  - J.Apostolakis, A.Dotti, contacts for ATLAS
  - W.Pokorski, A.Dotti, contacts for LHCb
  - A.Ribon, contact for ALICE and CALICE

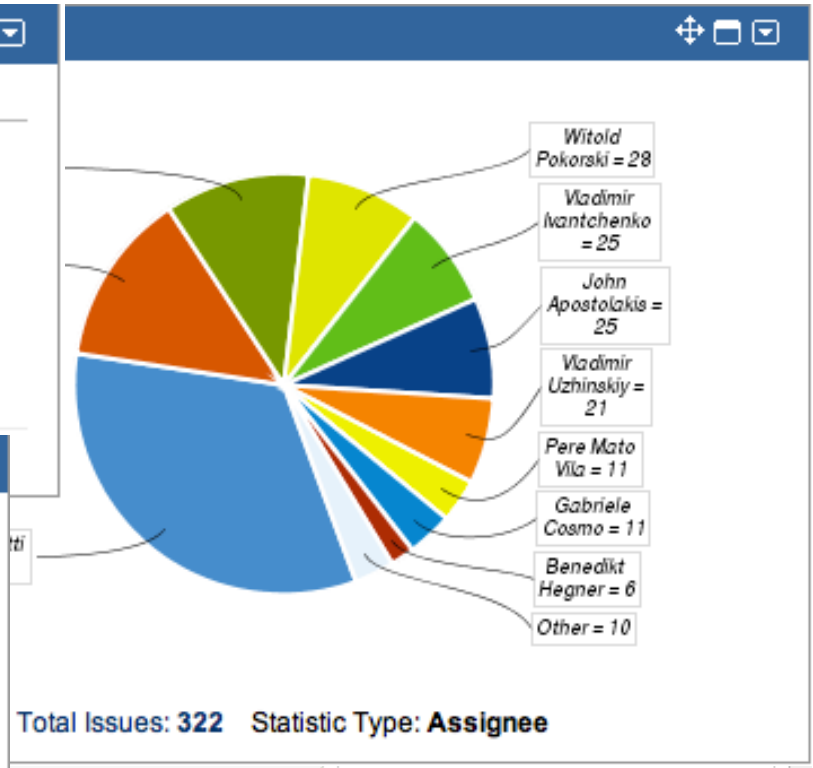
Prioritizing our work

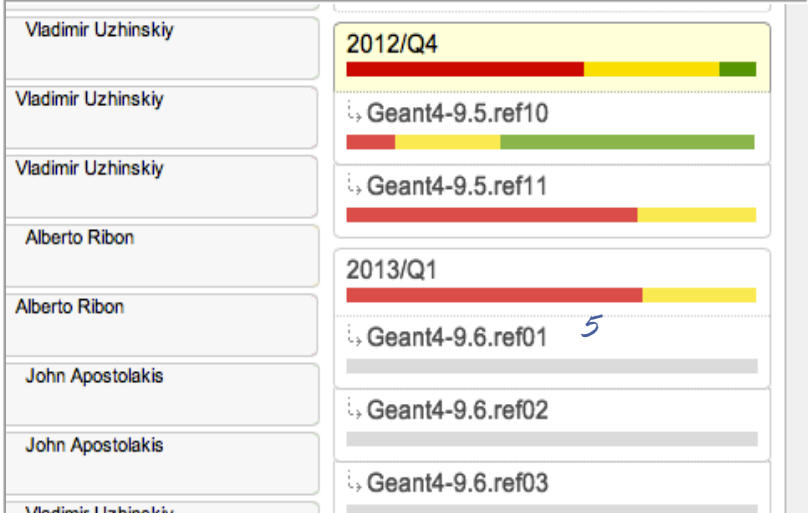
- Rethought how we organize our work
- Adopted new approach for managing our daily tasks
  - Define short-term goals and tasks
  - Review each item's status weekly in *SFT Simulation Meeting*
  - All tasks and major issues/bugs are recorded in the JIRA tool
- Are transparent: what we work on is visible to everybody
- Reports on news from each LHC experiment and progress on follow up of action items
  - Resulting in quick response to requests
- We synchronize our program of work with the overall work plan of the Geant4 Collaboration

The JIRA system









Assuring long term maintenance for physics

- Put in place a team of experts in physics
  - group members started campaign to review physics code
    - 2 FTEs dedicated to this
  - cleanup of physics code
    - removing unnecessary duplication (cross-sections, physics-lists ….)
  - isolated parts of the CHIPS model needed in standard physics-lists
    - separated and re-engineered in provision to phase out problematic code
  - focus on improving models relevant for LHC experiments
    - several bugs (some critical) found and fixed
- Resulting is visible improvement in code maintainability, physics performance (improved models) and CPU speedup
- Campaign to improve event reproducibility
  - lead also to discovery and fix of several bugs
  - important for work on parallelisation of code

Revisited Physics Validation

- Project running since early 2002 and providing a forum for discussion with experiments on validation of simulation against real data
- Organised LPCC workshop at CERN in fall 2011 with LHC experiments and experimental groups
  - strong participation of experiments and Geant4 developers
  - review of comparisons of simulation results against first collider data of LHC (see plots in backup slides)
  - agreement to hold another workshop during LS1 to review latest comparisons with new collider data

Physics Validation: identified new objectives

- Identified requirements and priorities to guide the physics validation activity for the next years
  - Improvements of hadronic shower shapes (both lateral and longitudinal)
  - continue to guarantee stability of simulation in terms of both physics and software performance
  - concentrate improvements on physics models in use by the experiments (Precompound, Bertini, Fritiof)
  - collect public results from collision data in a website to serve as a repository for validation of detector simulations
    - Started active collaboration with FNAL colleagues
- New format for the project: topical meetings with detector experts on agreed aspects

Improving efficiency - Synergy

- Sought Synergies with other SFT projects
  - Development of a common software component
  - Adoption of common tools for software development
- Participation in the EU/AIDA project for detector description
  - joint work with ROOT to create common library for geometrical primitives, with goal to improve the existing implementations
  - new tessellated solid providing factor 1000 speedup, prepared to address the LHCb Velo use-case
  - new multiple-union solid, optimised for unions of 5 or more volumes (target use-cases of ATLAS)
- Adoption of tools for configuration/testing and Q/A
  - CMake/CDash/Ctest suite, Electric Commander, Coverity, …
- JIRA tool for project management
- Synchronisation of yearly release with SFT software
- Integration of Geant4 releases to CVMFS
  - Adopted in GRID release validation and training suite
- Adaptation of validation tests suite to use ROOT for analysis

Software performance

- Direct participation to the SFT concurrency project
  - Concurrency Project provides a unique forum for reviewing progress in all initiatives and proposals addressing how to prepare for new CPU architectures
  - Strong participation of the whole community (developers, experiment collaborators, …)
    - including all LHC experiments, High Intensity programme (FNAL), Super-B, etc….
  - Geant4-MT and thread-safety among the demonstrators
- Participation in R&D studies on vector and GPU prototypes

Areas of contribution in Geant4

- Electromagnetic physics development & maintenance
  - *V.Ivantchenko* (coordinator)
- Hadronic physics development & maintenance
  - A.Ribon (coordinator), G.Folger, W.Pokorski, *A.Dotti*, V.Uzhinskiy, V.Grichine*
- Geometry and Field transport
  - G.Cosmo (coordinator), J.Apostolakis, *M.Gayer, T.Nikitina*
- Release, Testing & Q/A
  - G.Folger (coordinator), G.Cosmo (release manager), P.Mato

in summary…

- Activities in PH/SFT Geant4 team focused on addressing LHC experiments needs
- Considerably improved the way we manage the team work plan and interaction with experiments
- Core group of Geant4 developers for geometry, hadronic and EM physics and physics validation is part of the PH/SFT team at CERN
- Made team activities more effective by increasing the synergy within the PH/SFT projects and software development tools adopted

Backup slides

Computing resources & infrastructure services

- SVN services from CERN/IT Department
- Web service & maintenance
- Core testing infrastructure & mailing lists
- Software tools
  - Cdash/Ctest
  - Electric Commander (site license)
  - Coverity (site license)

Recommendations from 2009 PH/SFT review

- *Increase efforts on support of experiments; demonstrate visible improvement in reaction time to experiments' feedback & requests*
- *Identify CERN-based person for managing physics performance issues*
  - *contact with developers*
  - *gain familiarity with the physics code to tackle problems and improve features& performance*
  - *run Physics Validation and provide a forum for developers and experimentalists*
- *Investigate opportunities for increasing synergy with the other SFT projects (SPI, Root, CVM,…)*

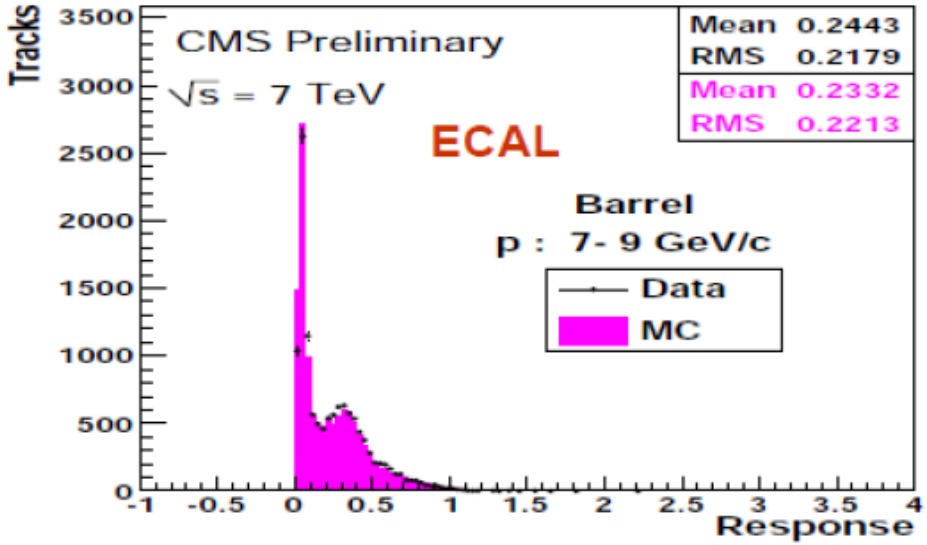
Training

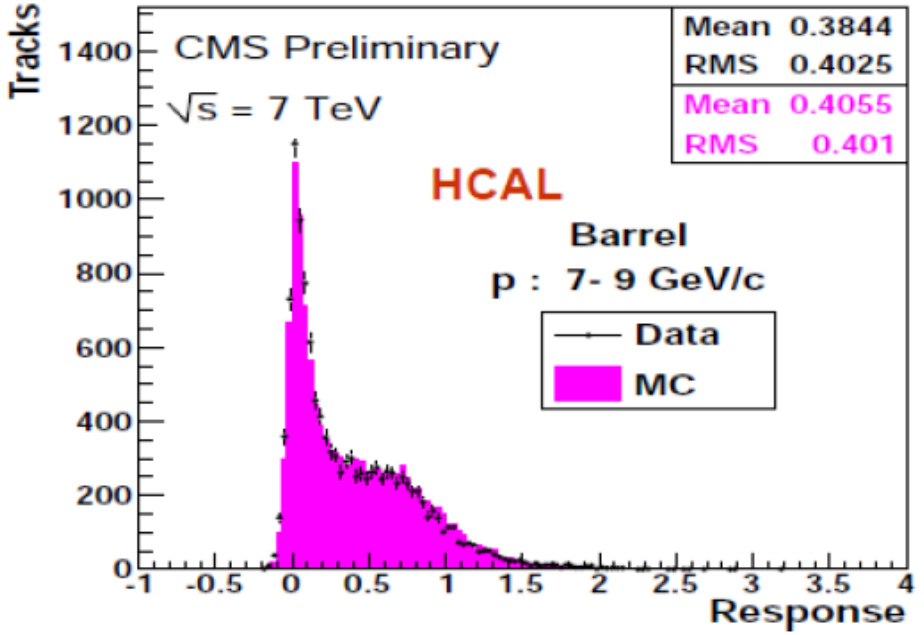
- Participation in Geant4 training courses
  - Last training school held at CERN in 2010, focused on HEP. Of 45 participants, 26 were from LHC/ILC/CERN experiments, and 7 from nuclear physics experiment.
  - Integration with CERNVM for training exercises
- Participation in the last two editions of African School of Physics in South-Africa and Ghana
- *Simulation/Geant4 is a great opportunity and very suitable for science dissemination and contribution to the CERN Technology Transfer program!*

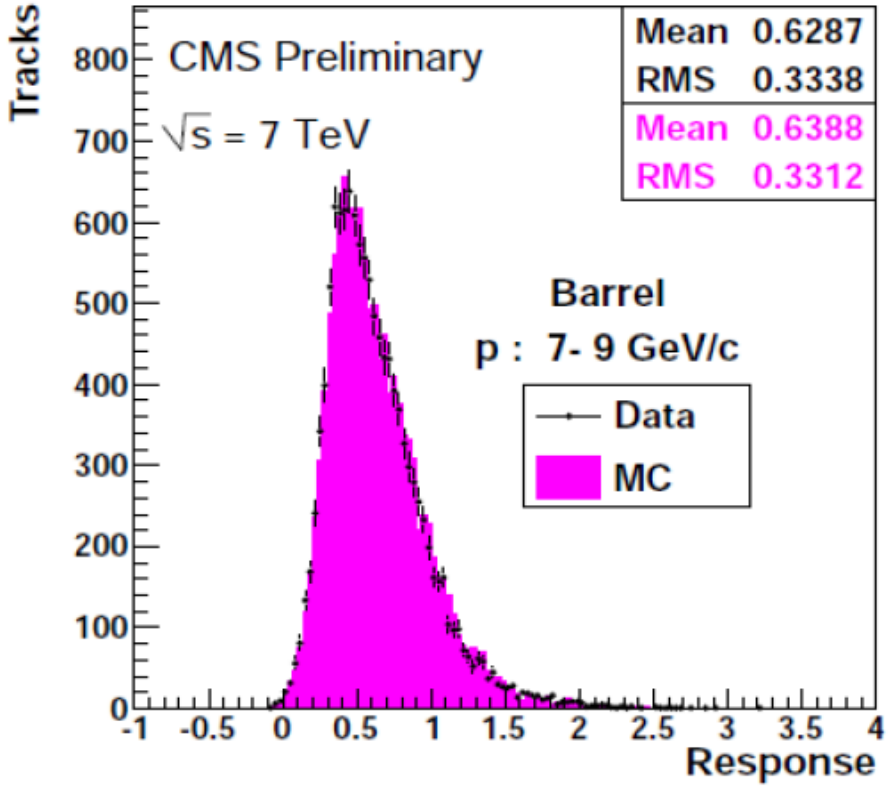
LHC Collision Data

(in-situ validation)

Barrel Region (I)







- Overall agreement is quite reasonable: small difference in individual contributions

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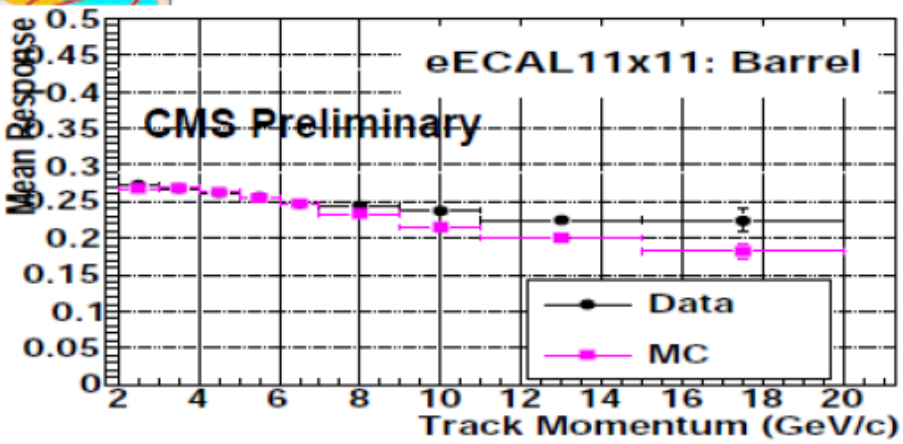
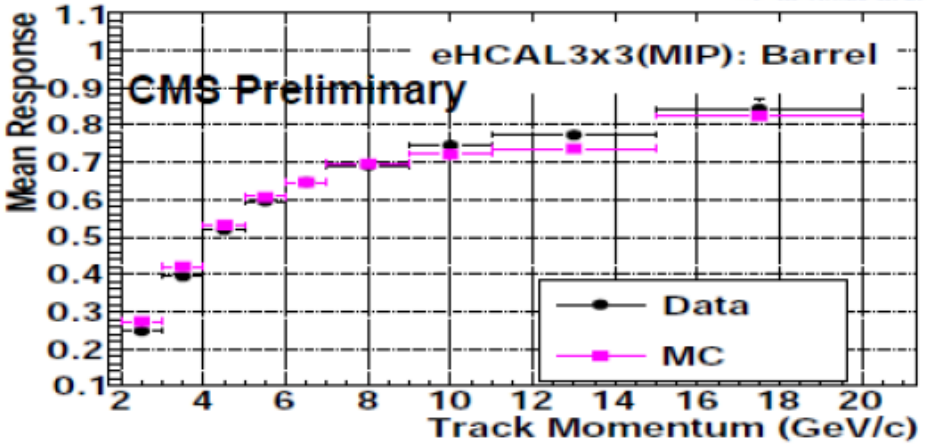
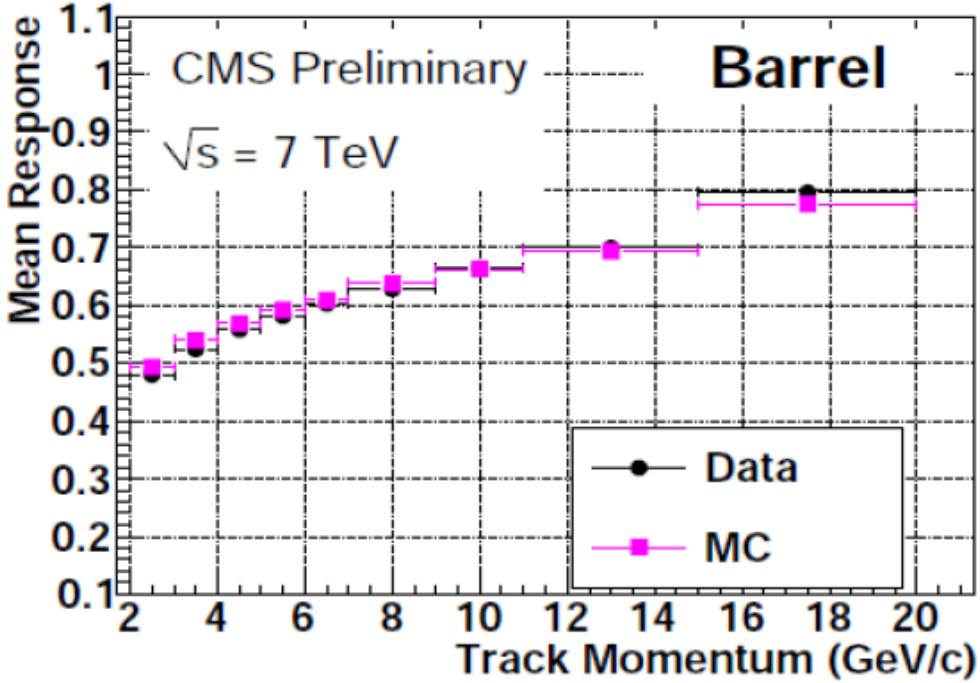
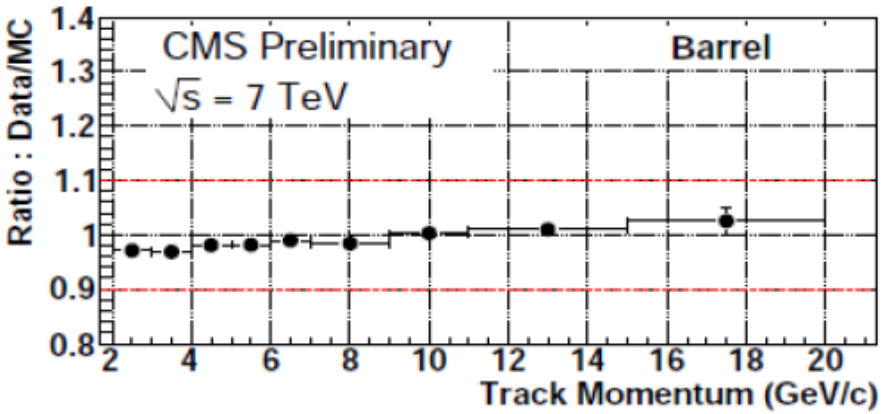
Barrel Region (II)









- Data/MC agreement is better than ±3% between 2-20 GeV/c

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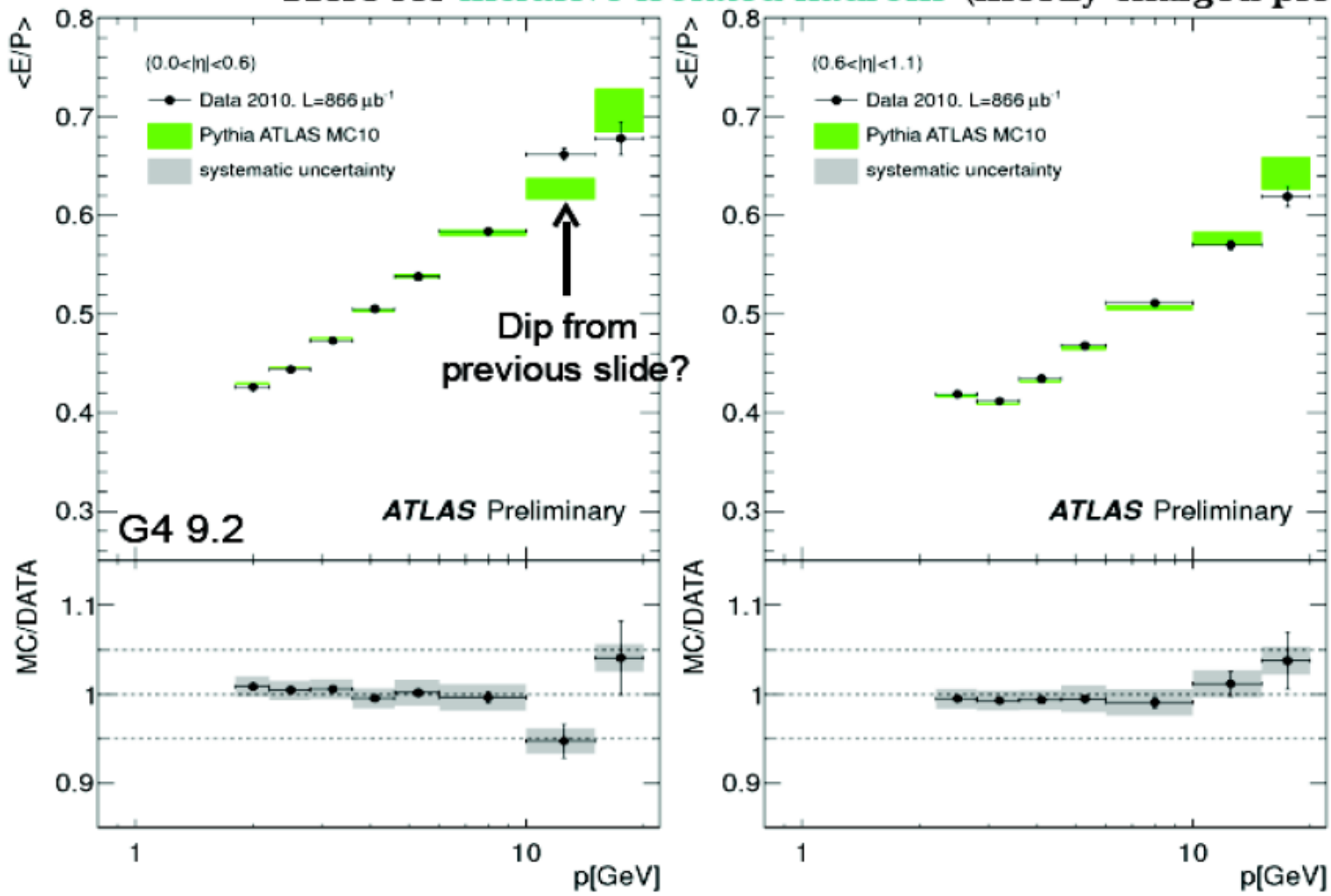
Energy Response (II)

- Next, move to *in situ* measurements
  - Here for *inclusive isolated hadrons* (mostly charged pions)



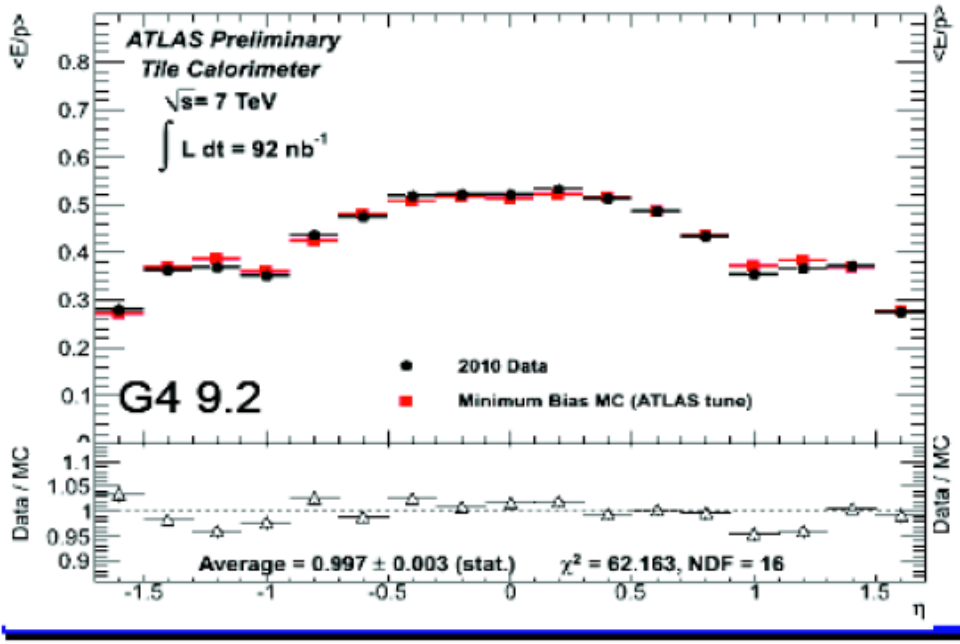
High p:
not isolated, so low statistics

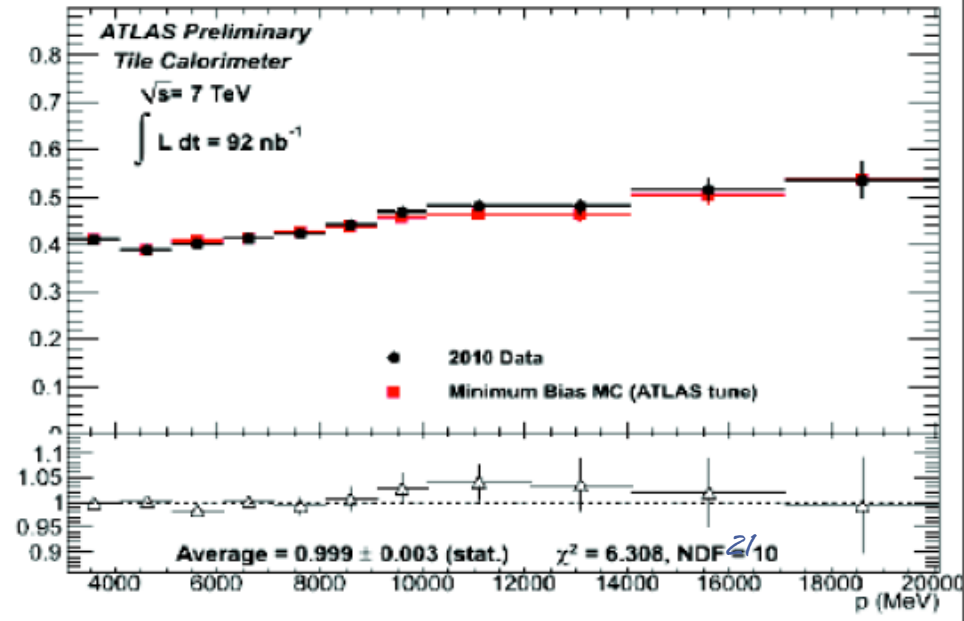
However:
Low p dominate jet kinematics!

Big p bins:
hard to resolve features, but excellent agreement!

Energy Response (III)

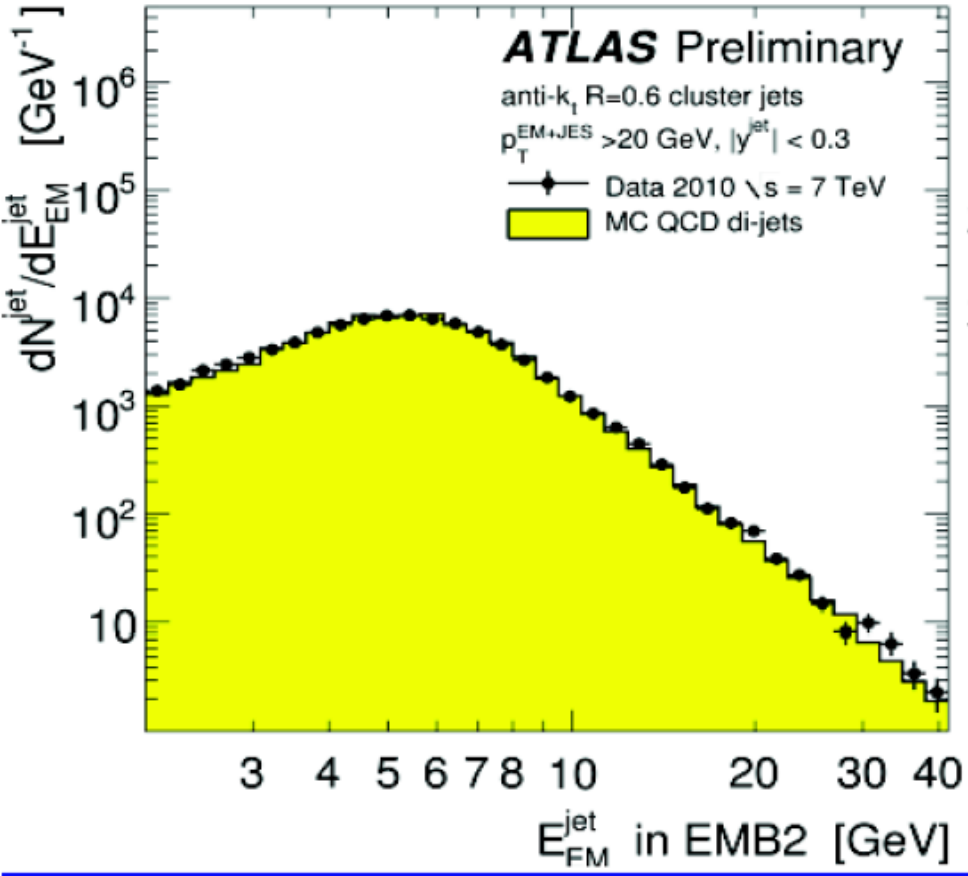
- Also measured in the tile calorimeter in situ using particles that deposit only minimal energy in the EM calorimeter
  - Background is largely caught by the EM calorimeter, so this should really be measuring isolated hadron response in the tile calorimeter
- Excellent agreement with the MC simulation
  - Note: no statement about the fraction of hadrons not interacting in

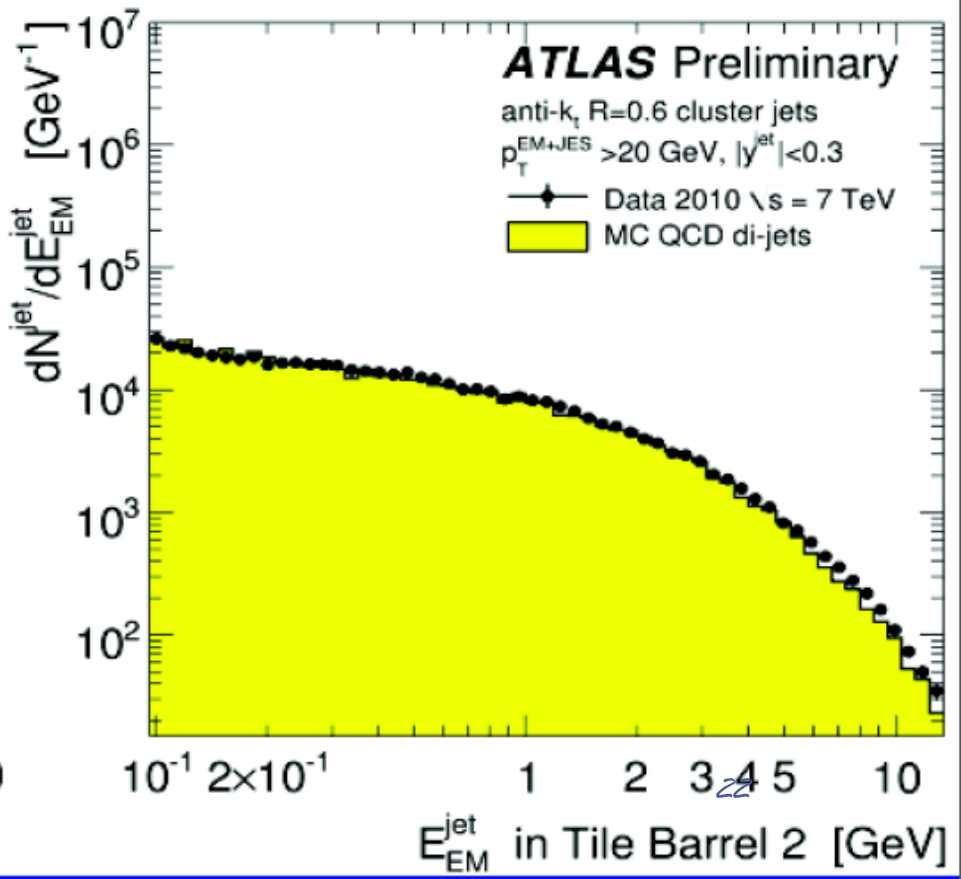




Longitudinal Shower Shapes (III)

- Jet layer fraction is the in situ longitudinal shower shape
  - Tough to measure – depends on jet kinematics, generator spectra...
  - Still, quite good data/MC agreement, even very early on!





η spectrum

Calo jets **JPT jets** **PF jets**

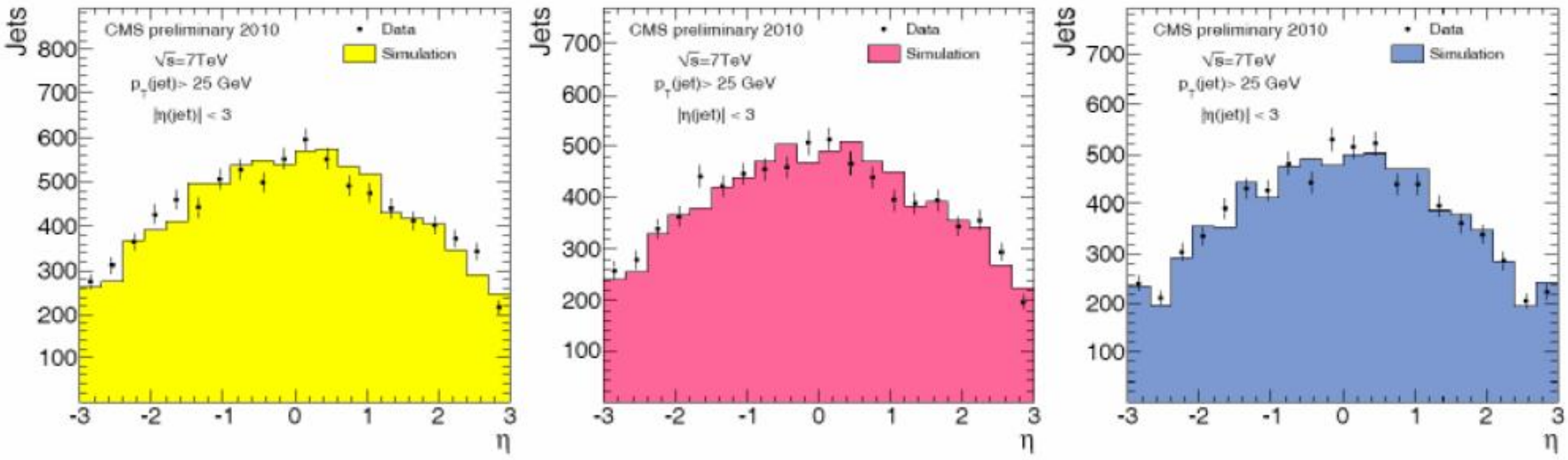


Figure: Data vs MC: Jet η for dijet events: Calorimeter Jets, JPT jets, PFjets.

Dijet Mass

Calo jets **JPT jets** **PF jets**

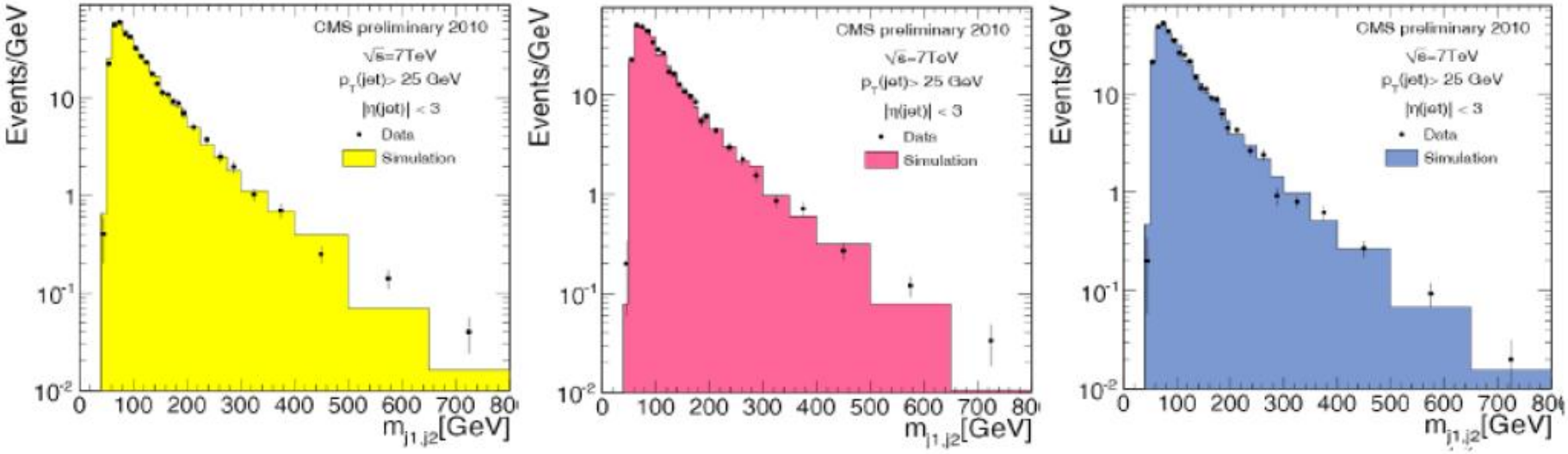
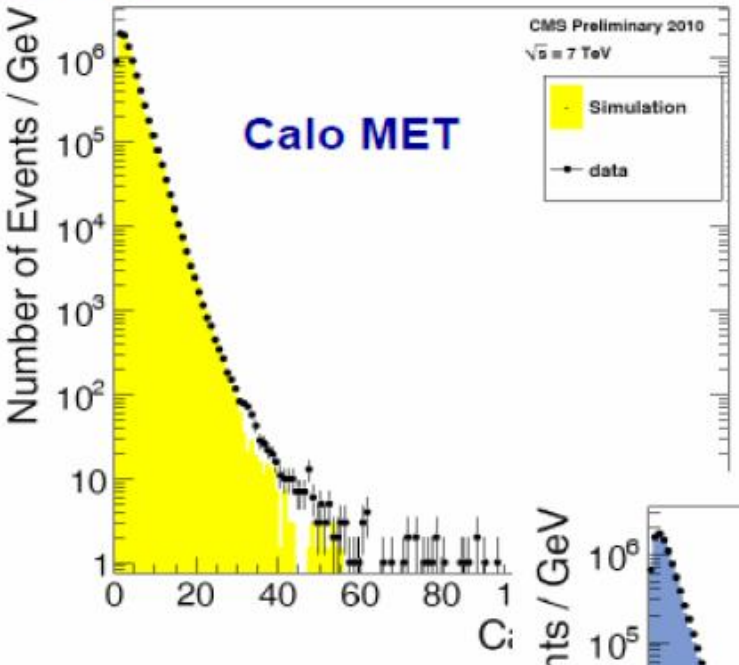
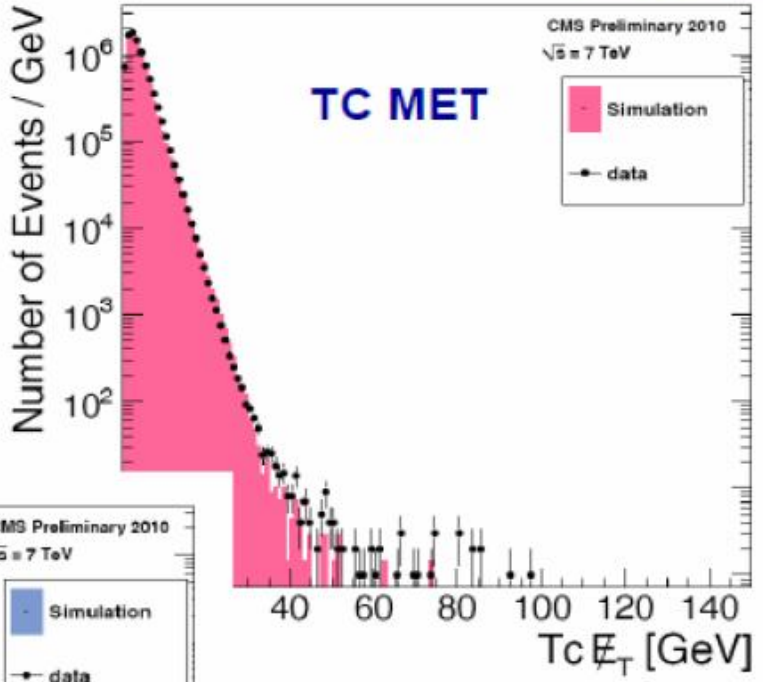
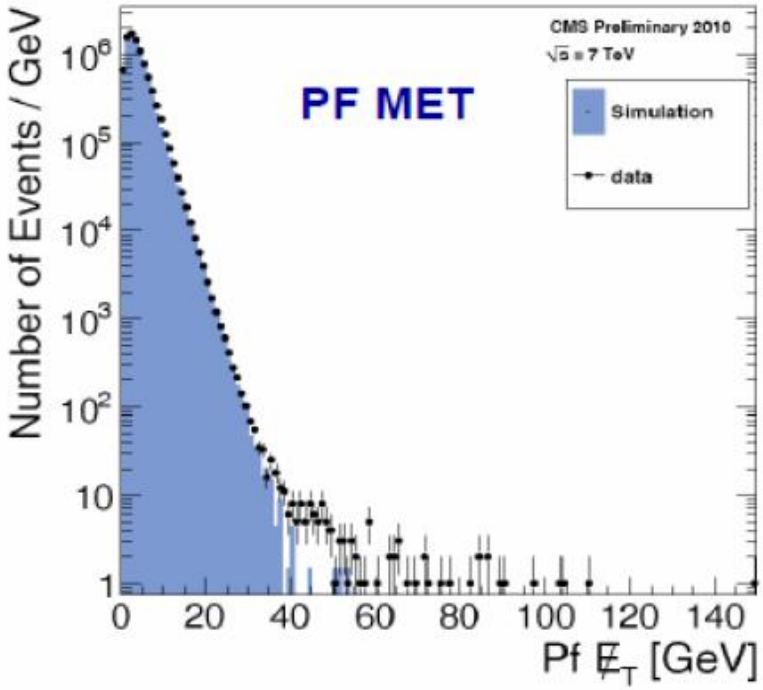


Figure: Data vs MC: Di jet mass $m_{j1,j2}$ for Calorimeter Jets, JPT jets, PFjets.

Inclusive MET

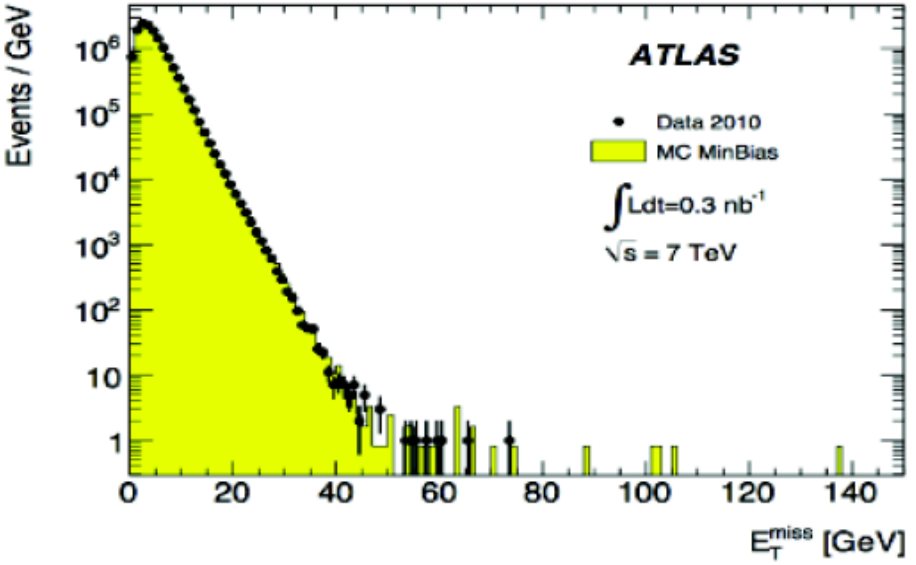


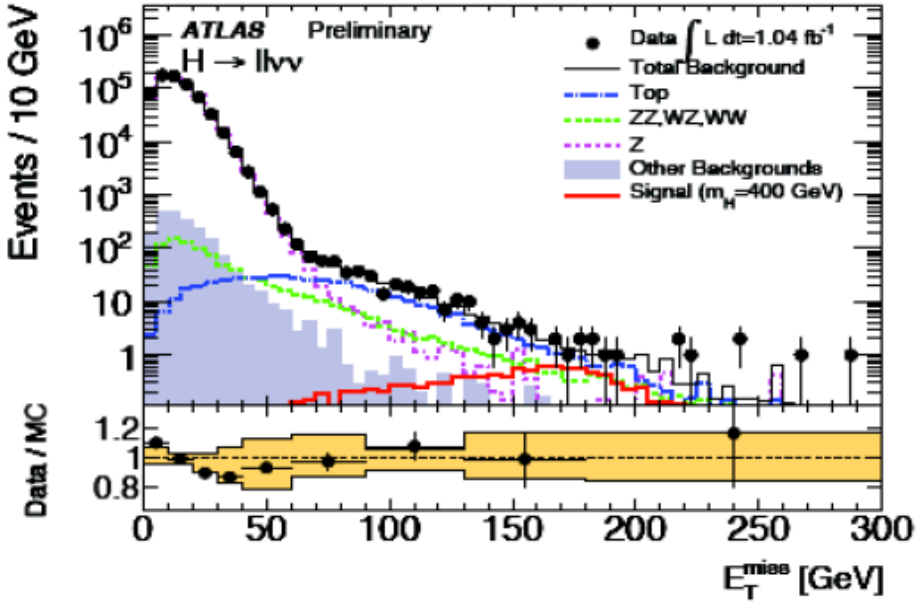


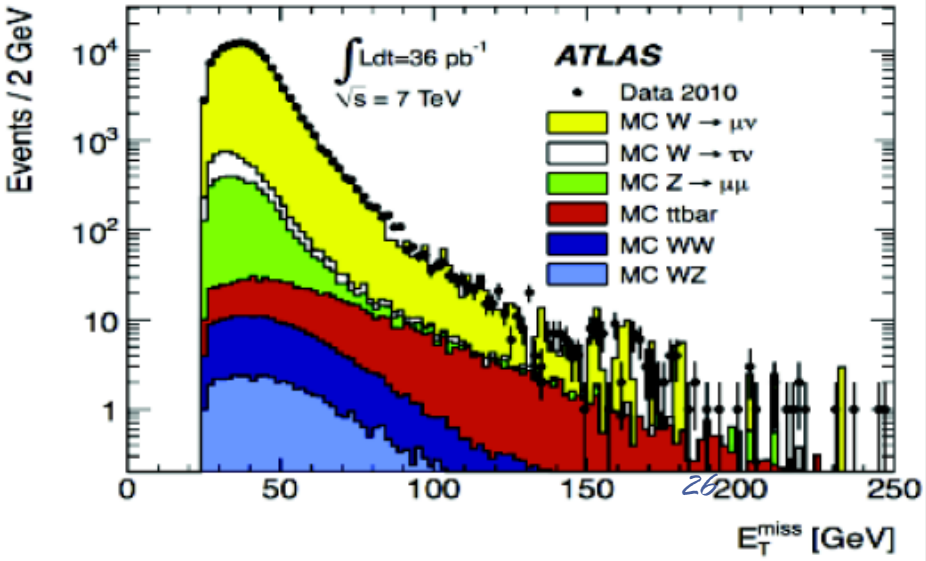


Missing Energy

- Missing energy and ΣE_T are, of course, *very* complicated variables, with many effects entering
- Still, excellent agreement with data, in both the core and tails, in events with and without true MET
- Builds more confidence in our modeling of all aspects of the data



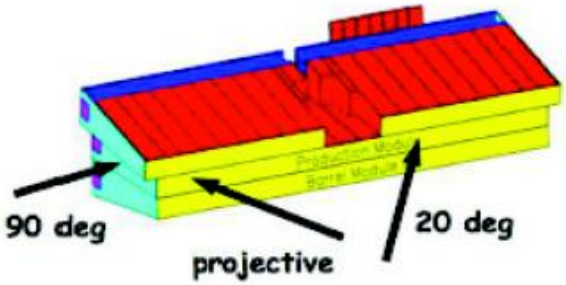


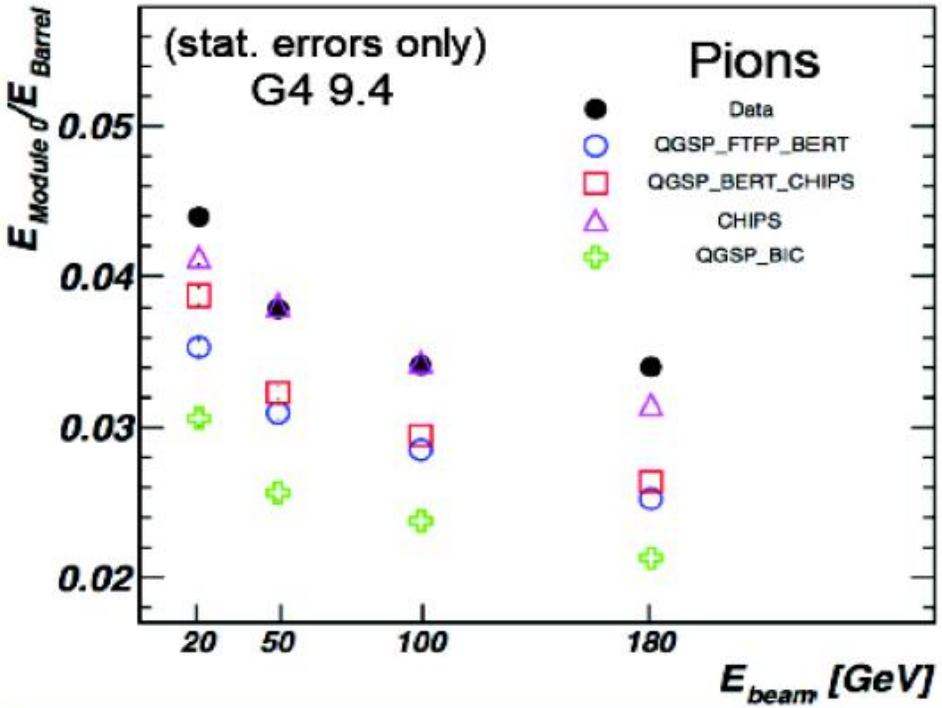


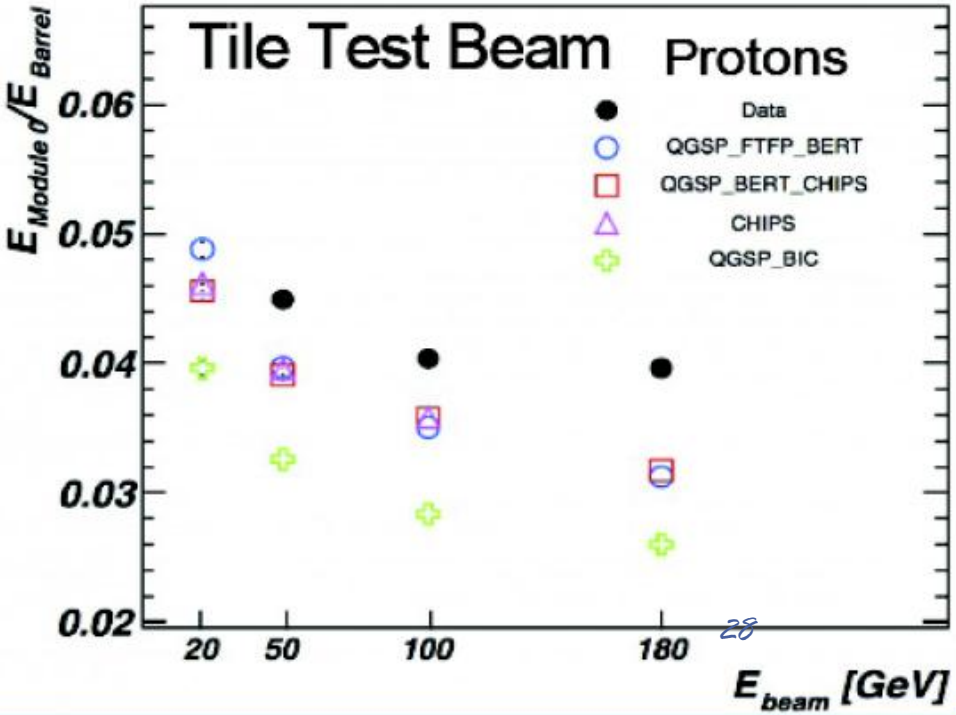
LHC test-beam Data

Lateral Shower Shapes

- In most models, showers are laterally too narrow
  - By about 30%, depending on the metric
- Long-standing problem for G4
  - Low-energy brem or low-energy n physics problem?
  - See Olivier Arnaez's talk for some part of the story in the EM calorimeter







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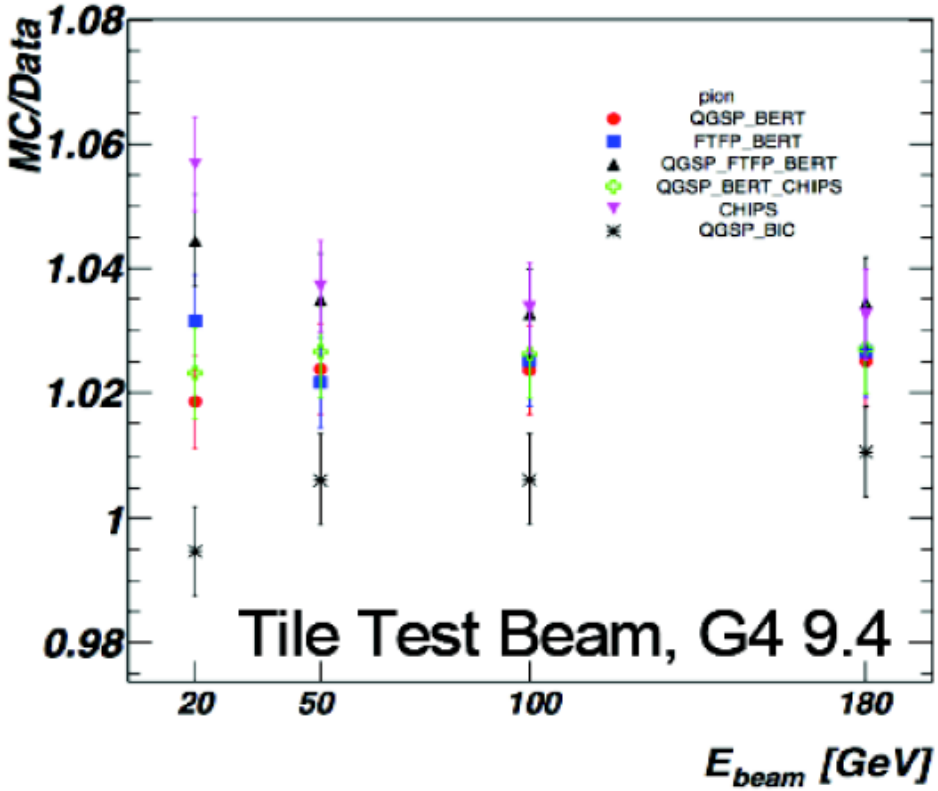
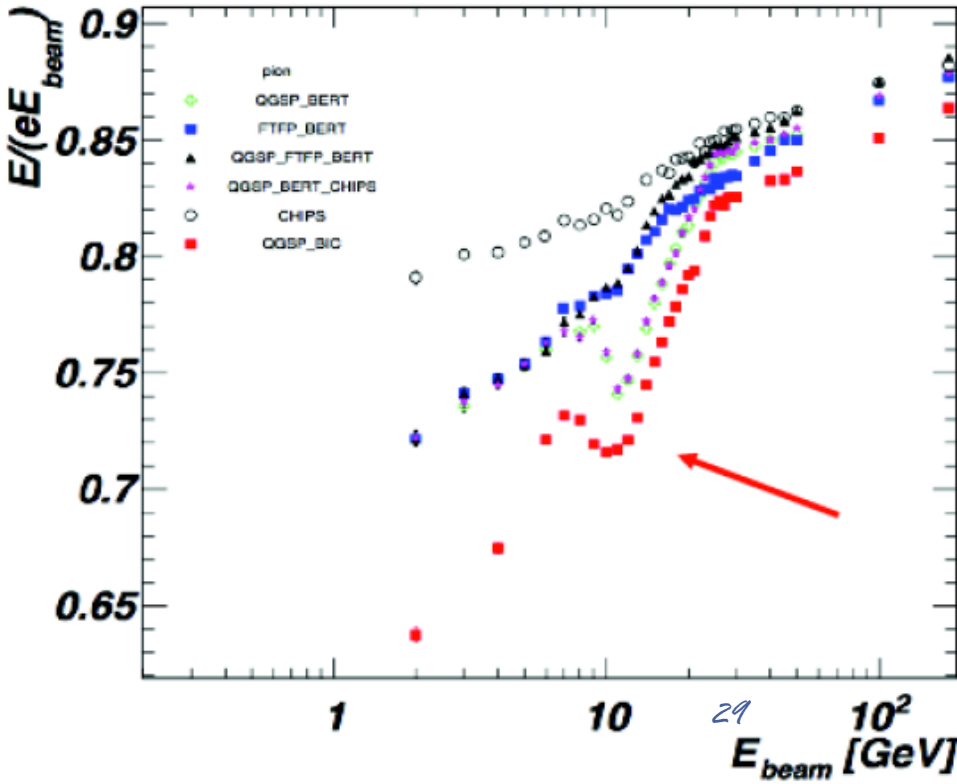
Energy Response

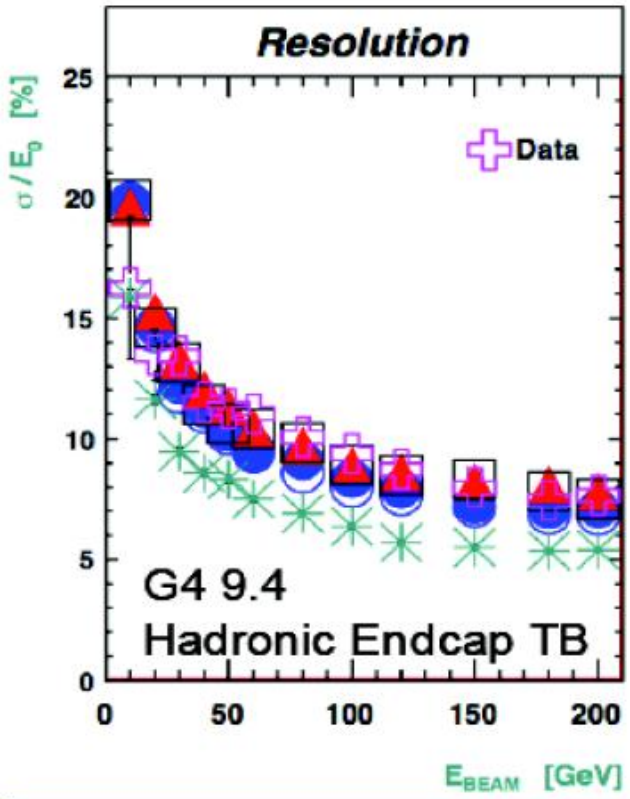
- Obvious first choice: single pion response vs physics list
  - Energy measured in the calorimeter / track p (or beam energy) = E/p
    - Only measured within the tracker coverage, $|\eta| < 2.5$
  - Agreement is within a few percent for most lists
- Fine binning reveals some nasty features – very hard to spot in-situ!

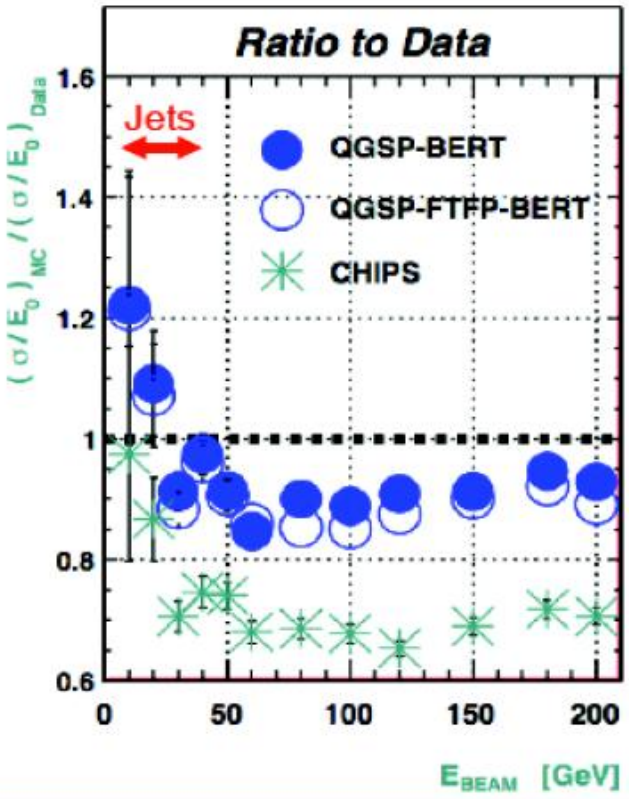


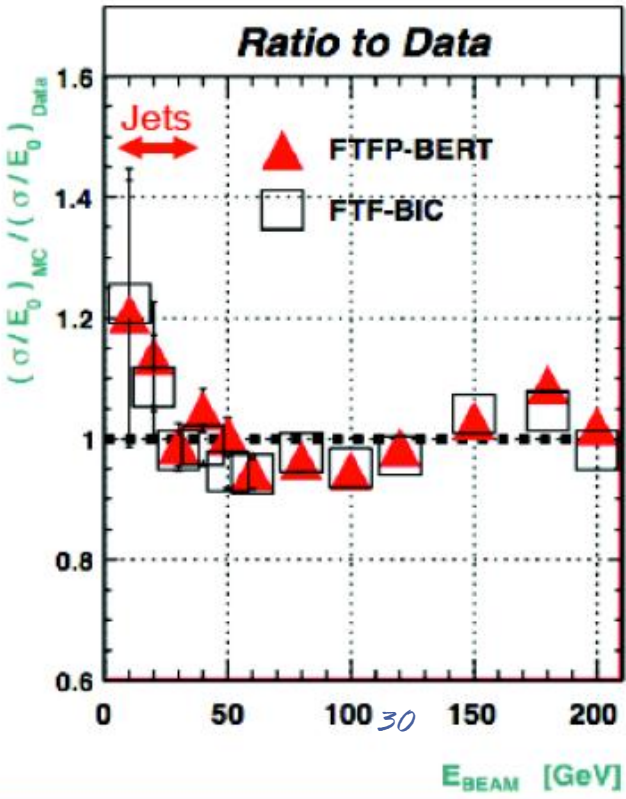


Resolution

- Considerably more variation in resolution
  - In situ, we have to also deal with background variations, which make resolution measurements *very* tricky - go to test beam!
  - Also varies against G4 release considerably more than response

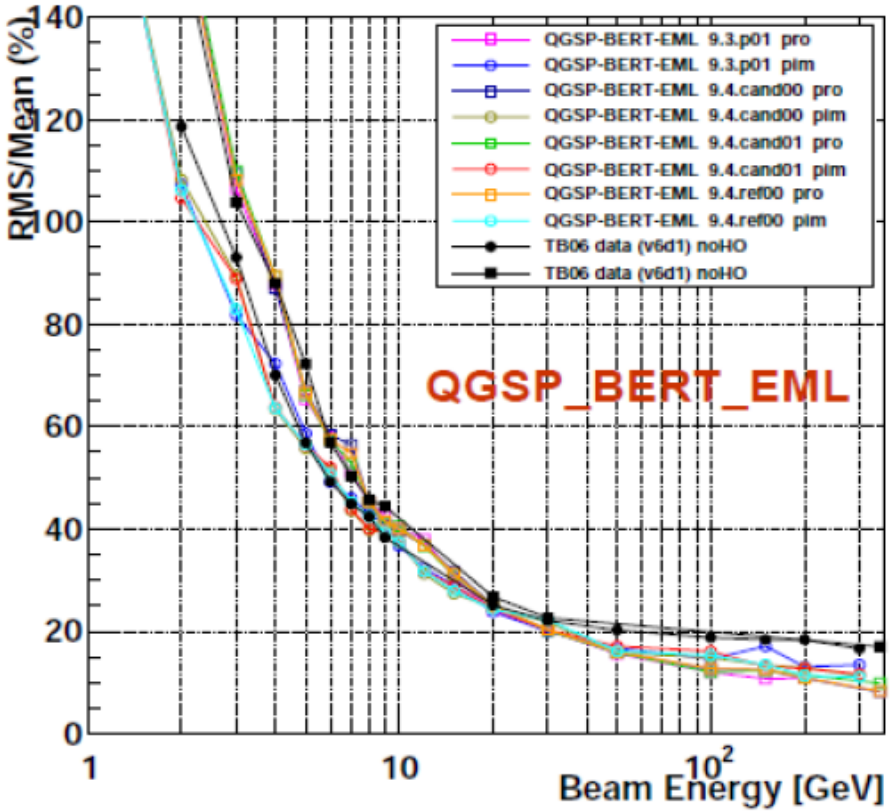




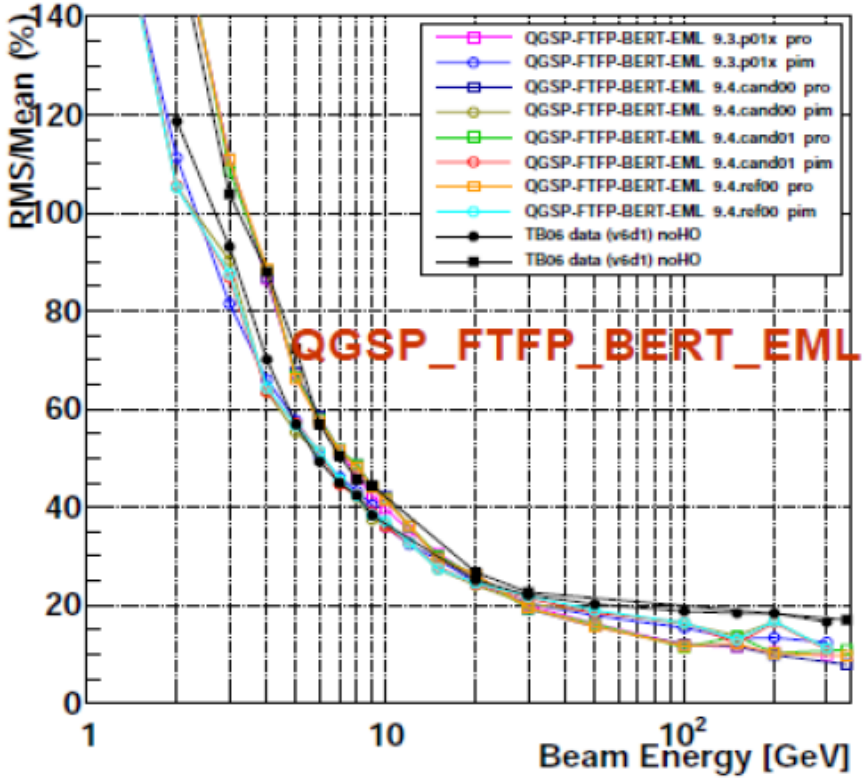


HCAL Energy Resolution

Calo Resolution (MCidealMIP)



Calo Resolution (MCidealMIP)



- Two lists give similar predictions and change from 9.3 to 9.4 does not change predictions significantly
- Geant4 gives too good resolution at high energies

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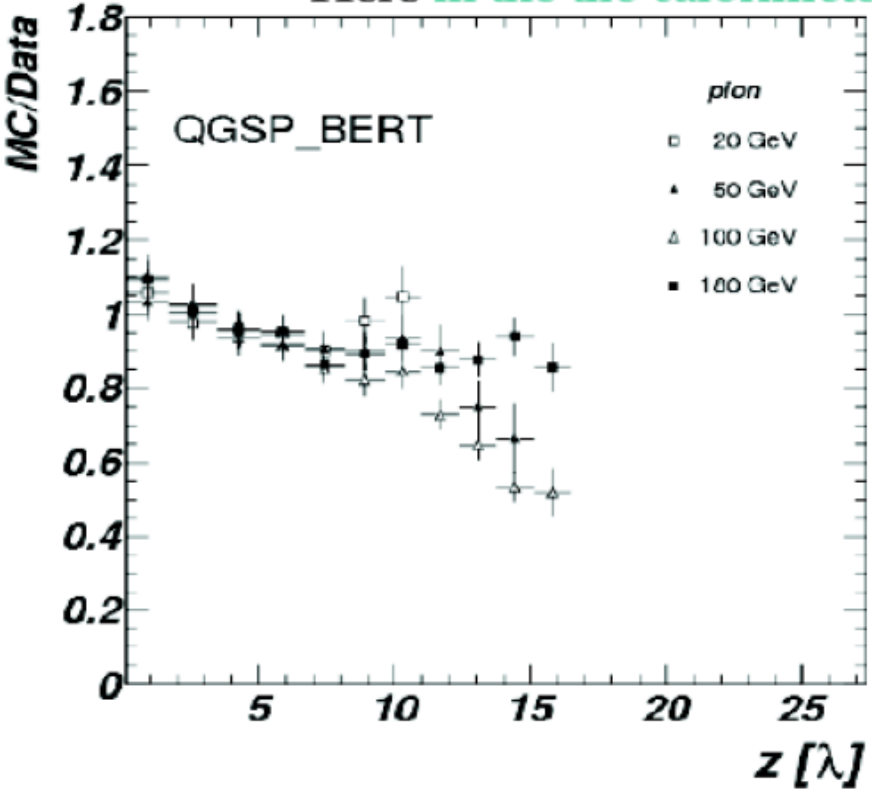
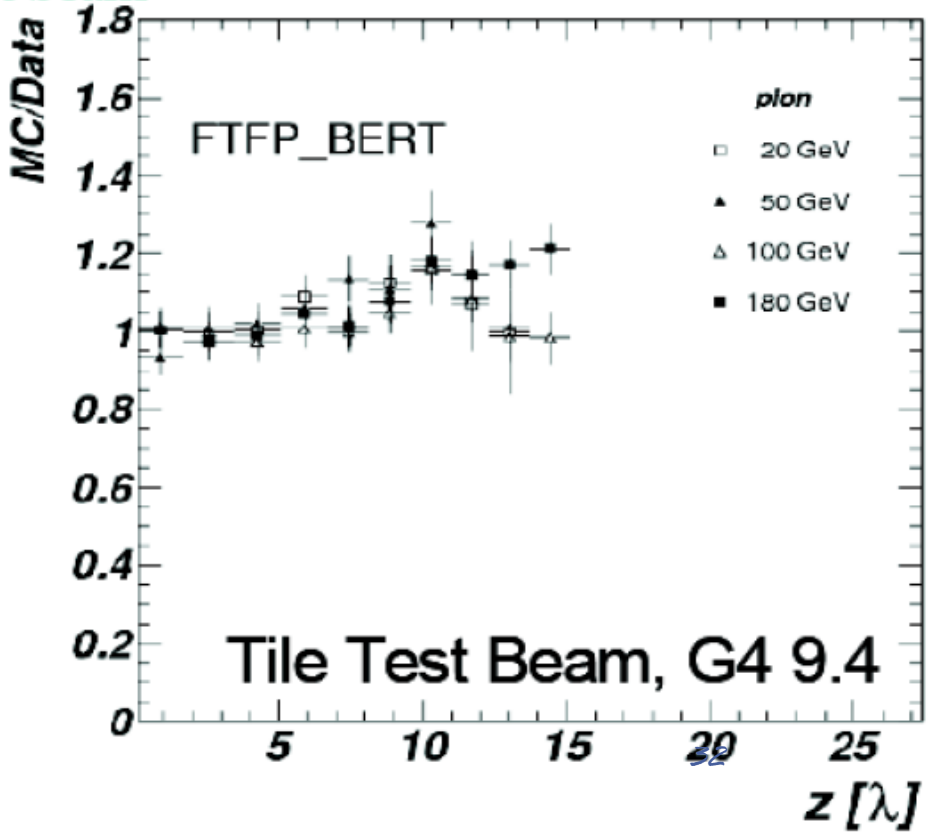
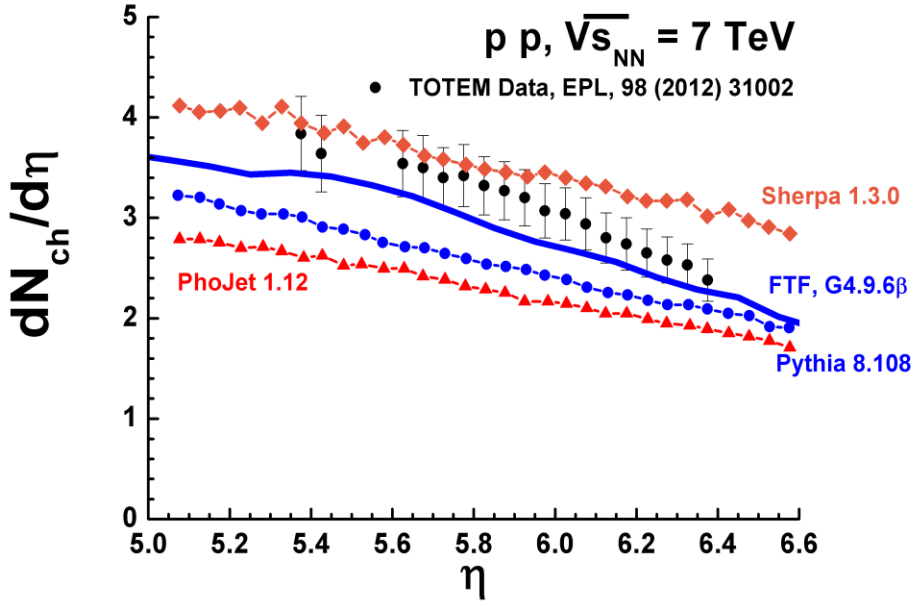
Longitudinal Shower Shapes

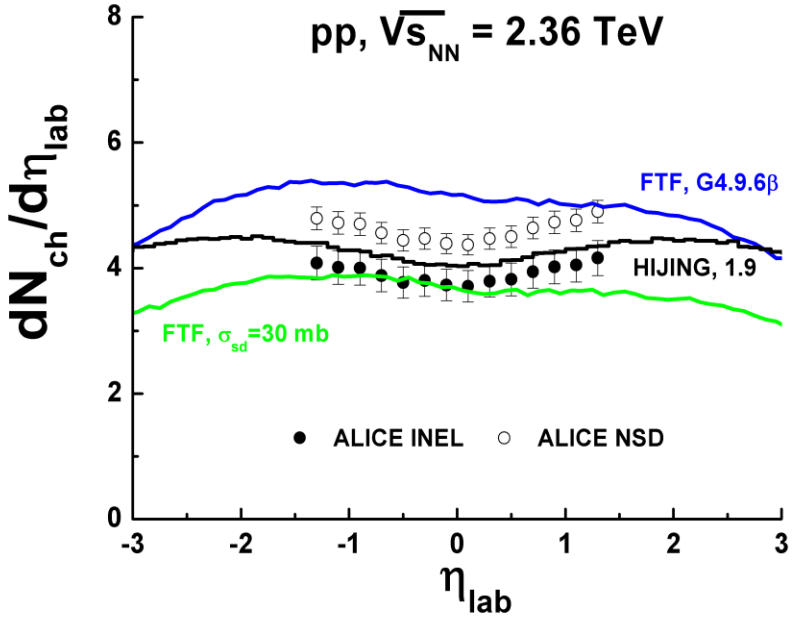
- Shower depth was measured in test beam(s)
  - Without background this is an easier measurement to make!
  - QGSP_BERT too short, FTFP_BERT too long
  - Here in the *tile calorimeter test beam*





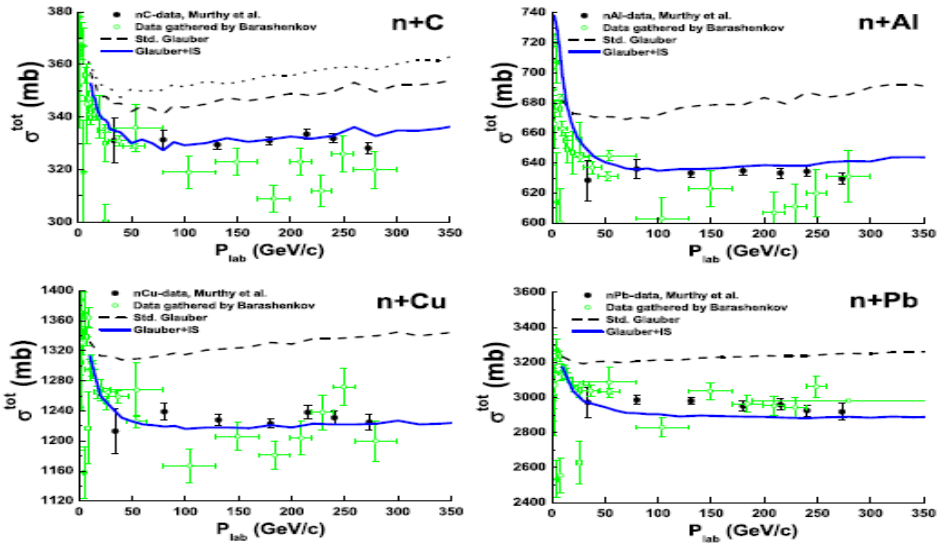
GEANT 4 LHC

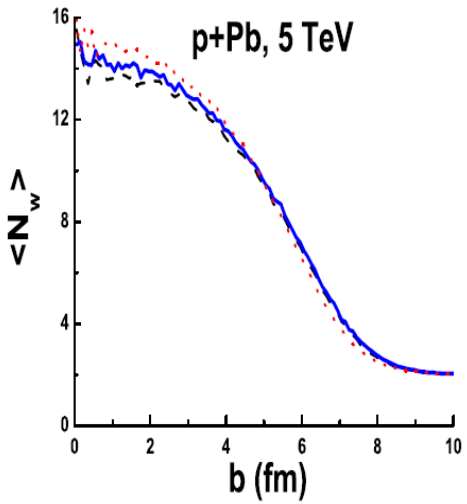


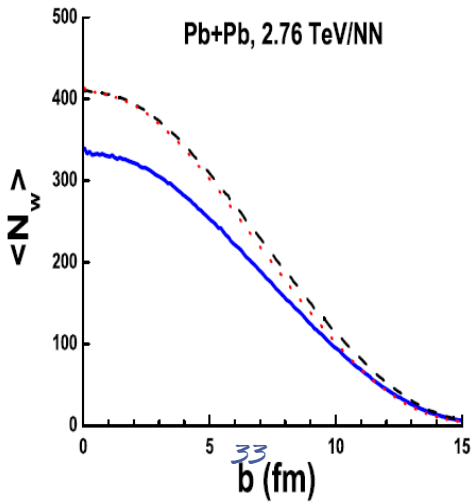


V. Uzhinsky, 29 Oct. 2012

Simulation of Interactions at LHC Energies in Geant4

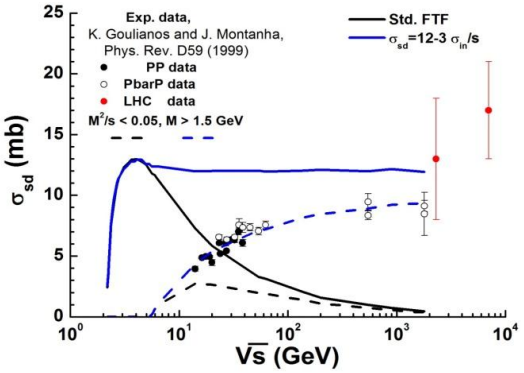




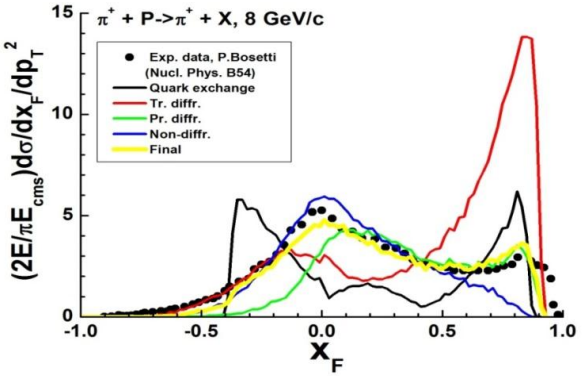


Role of Gribov's inelastic screening in nuclear collisions, up to 20 % in central nucleus-nucleus

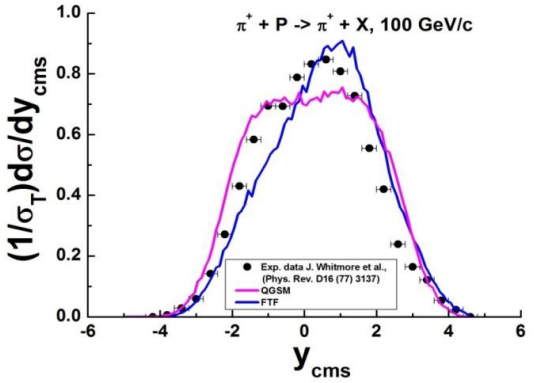
Diffraction dissociation implemented in Geant4



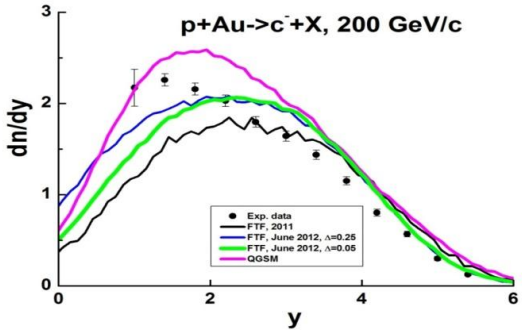
Fitting of PP



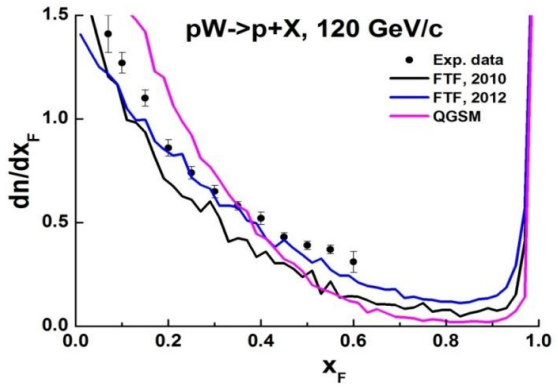
Attempts for Pi+P



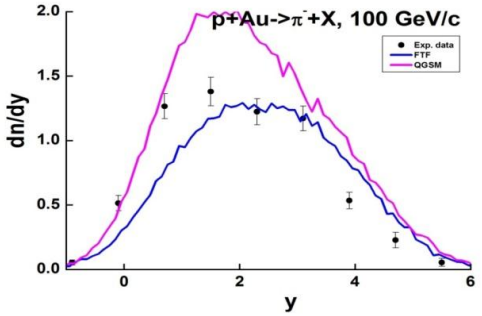
Results for Pi+A



NA35 Collab. (T. Alber et al.)
Eur. Phys. J. C2 (1998) 643



Description of CERN-SPS data on
pA->pX, 120 GeV/c



pA interactions at 100 GeV/c,
J.J. Whitmore et al.,
Z. Phys. C 62, 199-227 (1994)

Prediction for the LHC