Geant4 Hadronic Physics Working group: Verification and validation strategy and results

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GHAD Validation&Verification (3.1)

- Our validation strategy is deployed since spring 1999. It was also submitted as paper to CHEP2001 at the time of the last review. My apologies for not having presented it last time.
- It was subsequently presented again in CMS and ATLAS, at the LHC-geant4 validation meeting, and the recent ACAT conference in Moscow.
- I would have been pleased to also present it in invited talks at the SATIF workshop, and the IDM2002 workshop, but I had to turn these down due to lack of travel-money at CERN.

Model validation

- Four tier strategy
  - Author validation plots for the individual models
    - Precondition for model to be a candidate for inclusion.
  - Independent validation on thin target data with regression suites by the working groups
    - Verified before every release
  - Independent validation on benchmarks, where these are available
    - Verified before every release, where possible
  - Validation on full simulation programs
- geant4 takes model validation much more seriously than it was in the times of geant3.

Author validation

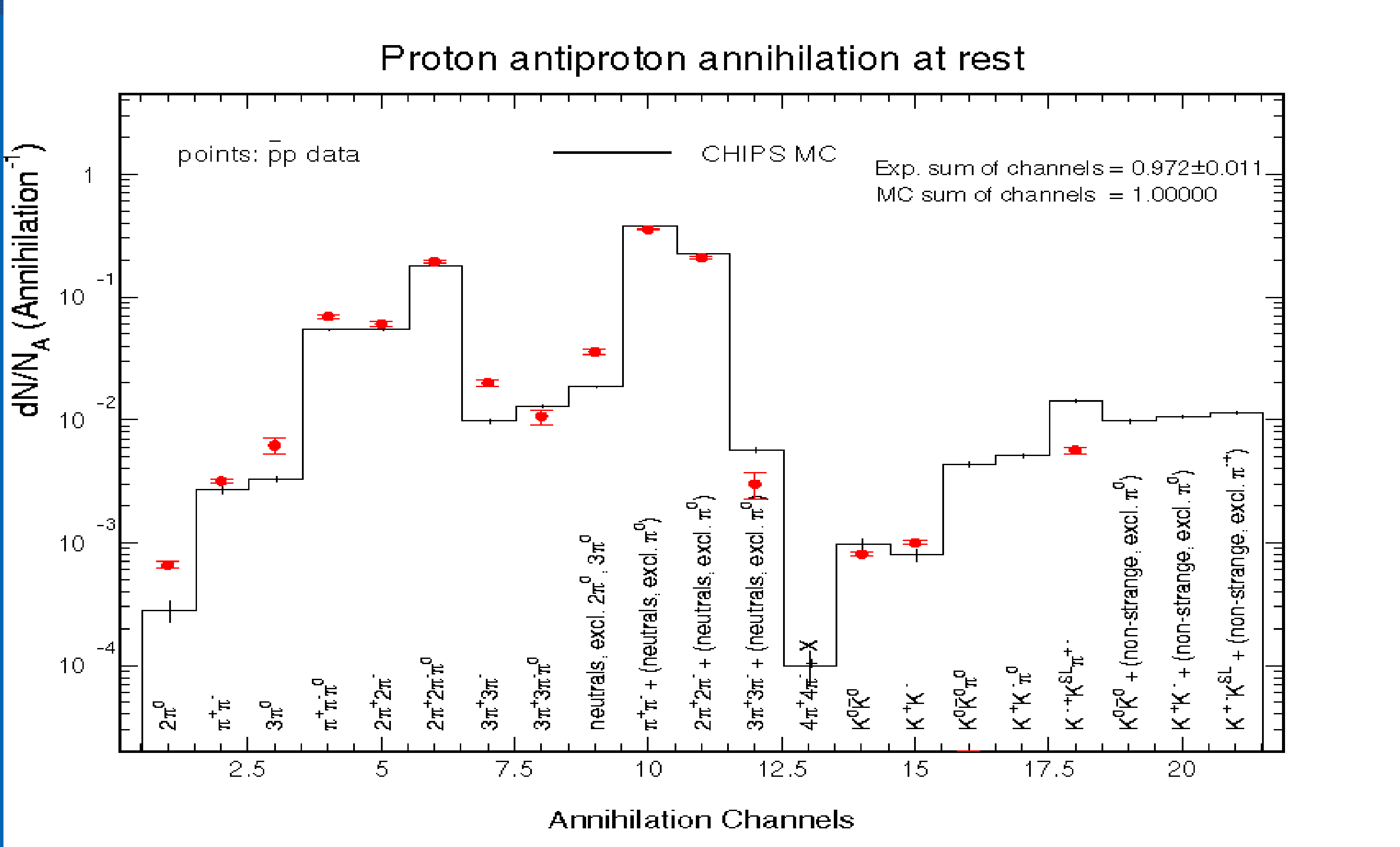
- Author validation
  - Comparisons, typically with measurements from thin target data; I.e. event generator like application.
  - Looking at cross-sections, particle yields and distribution, ta and pt distributions, invariant cross-sections, xf distributions, particle rations, etc..
  - Requested by the working group when mayor changes to a model occur.

  - Owned by the author, like the test-beam result of an experimental group

Working group validation

- Working group validation suites
  - For eta, pt, xf, mult, d3σ/d3p, dσ/dT, n_prong, charge ratios, dσ/dΩdE, etc. in place for the various energy regimes. Is already quite satisfactory.
  - Trivial quantities now also are checked.
  - Note that this can be done only with the consent of the author.
  - This level of validation was never performed in any depth for geant3.

Anti proton annihilation



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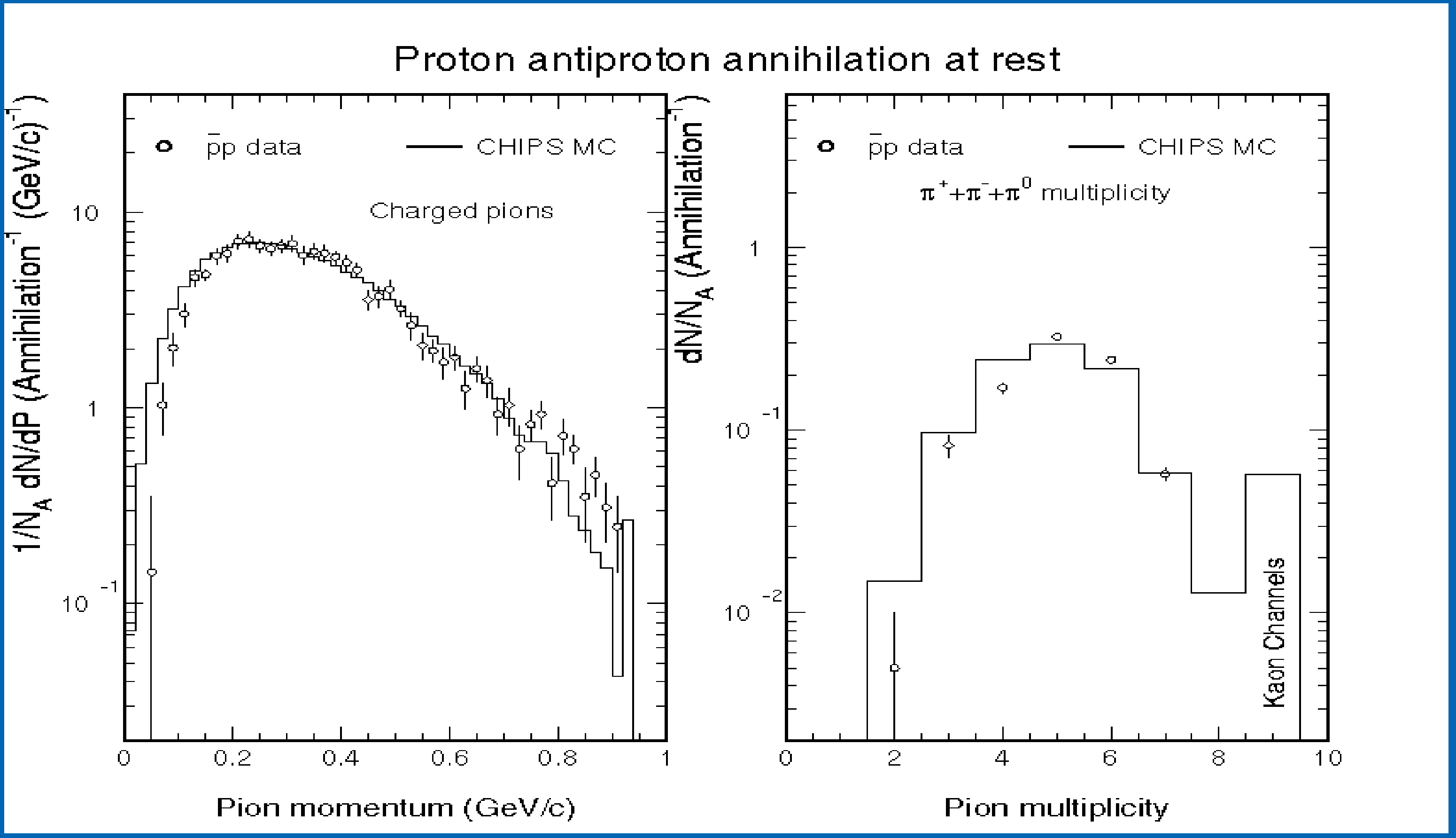
Anti proton annihilation



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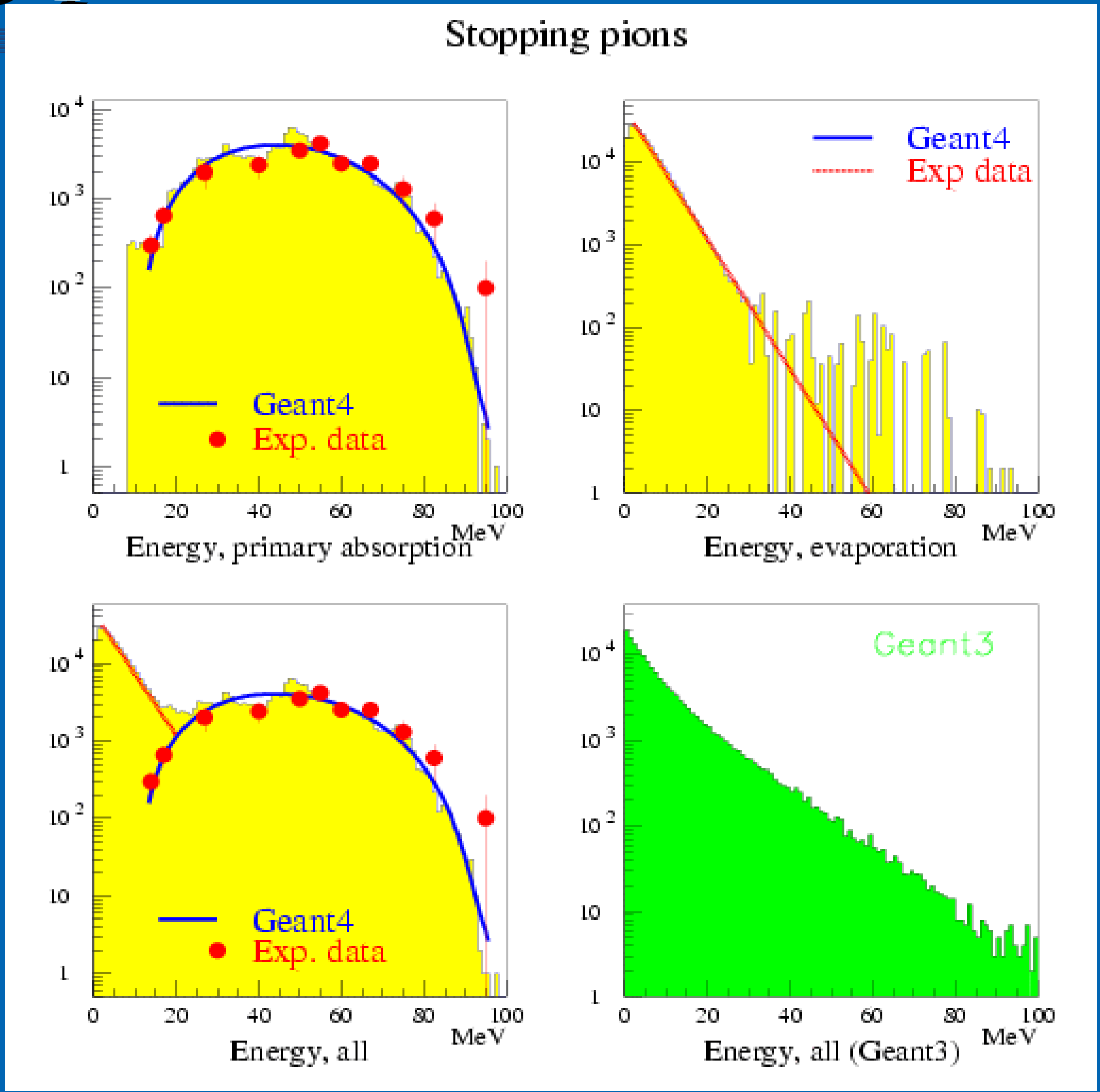
Stopping pion minus



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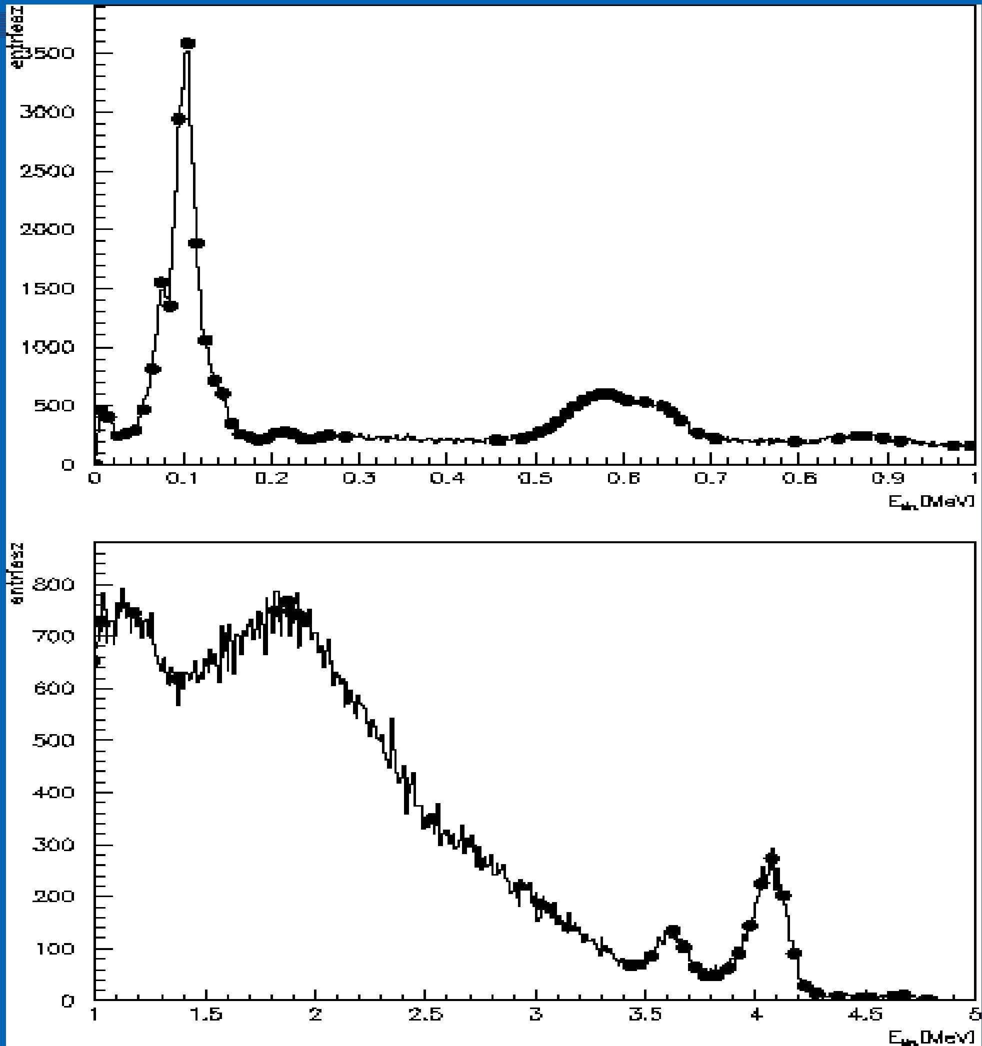
Low energy neutron capture



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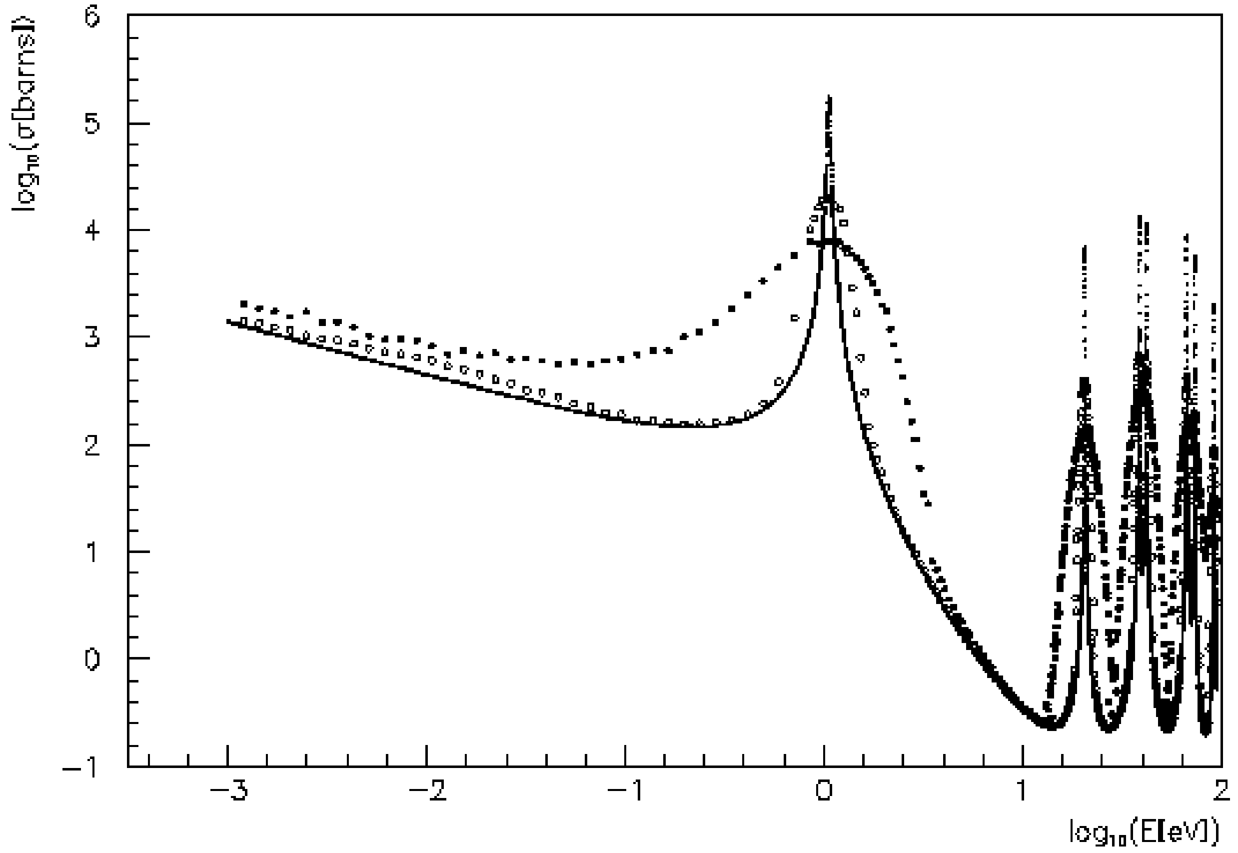
Doppler broadening



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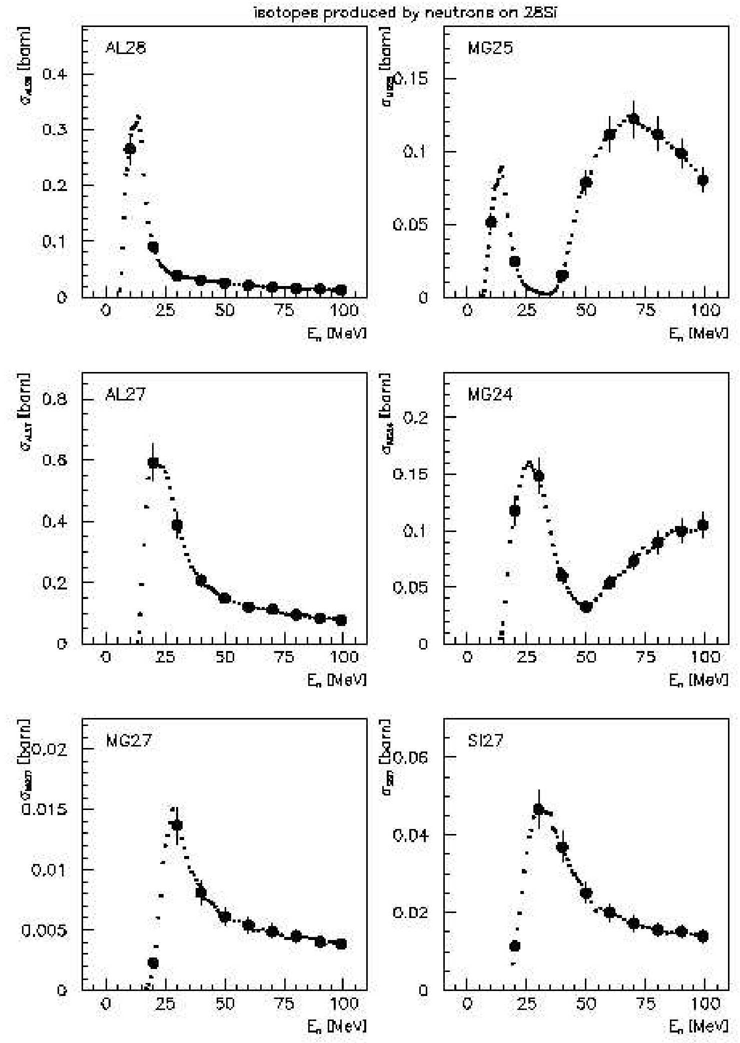
Neutron induced isotope production



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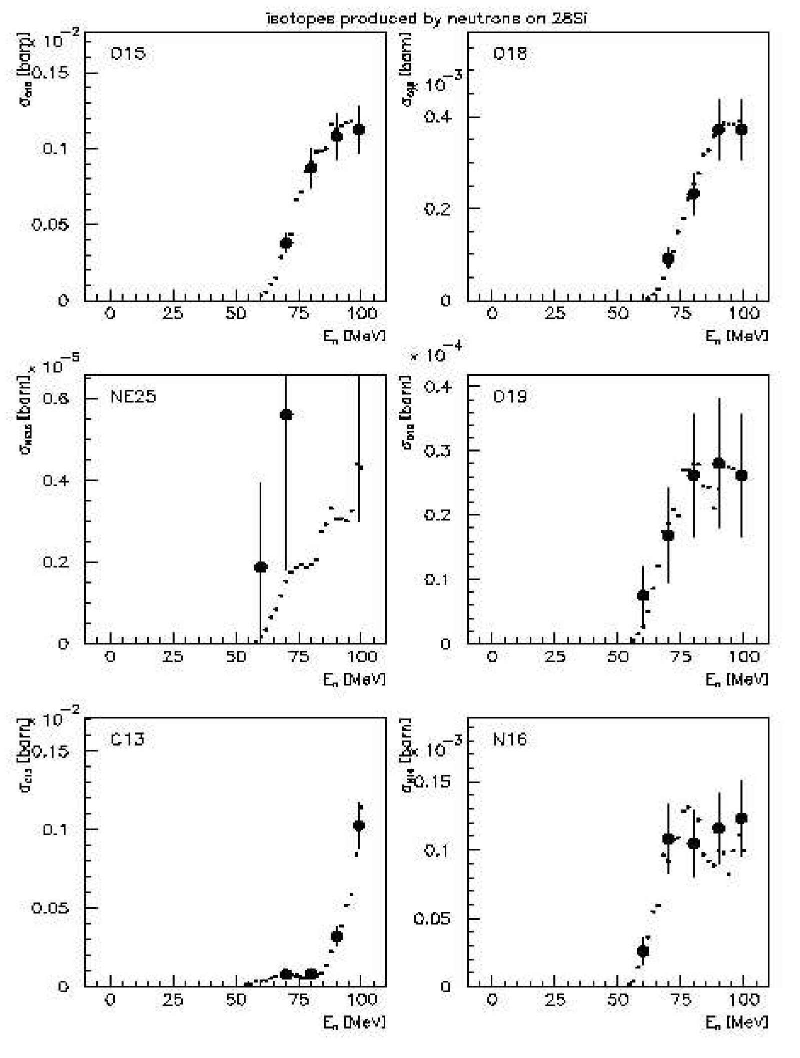
Isotope production



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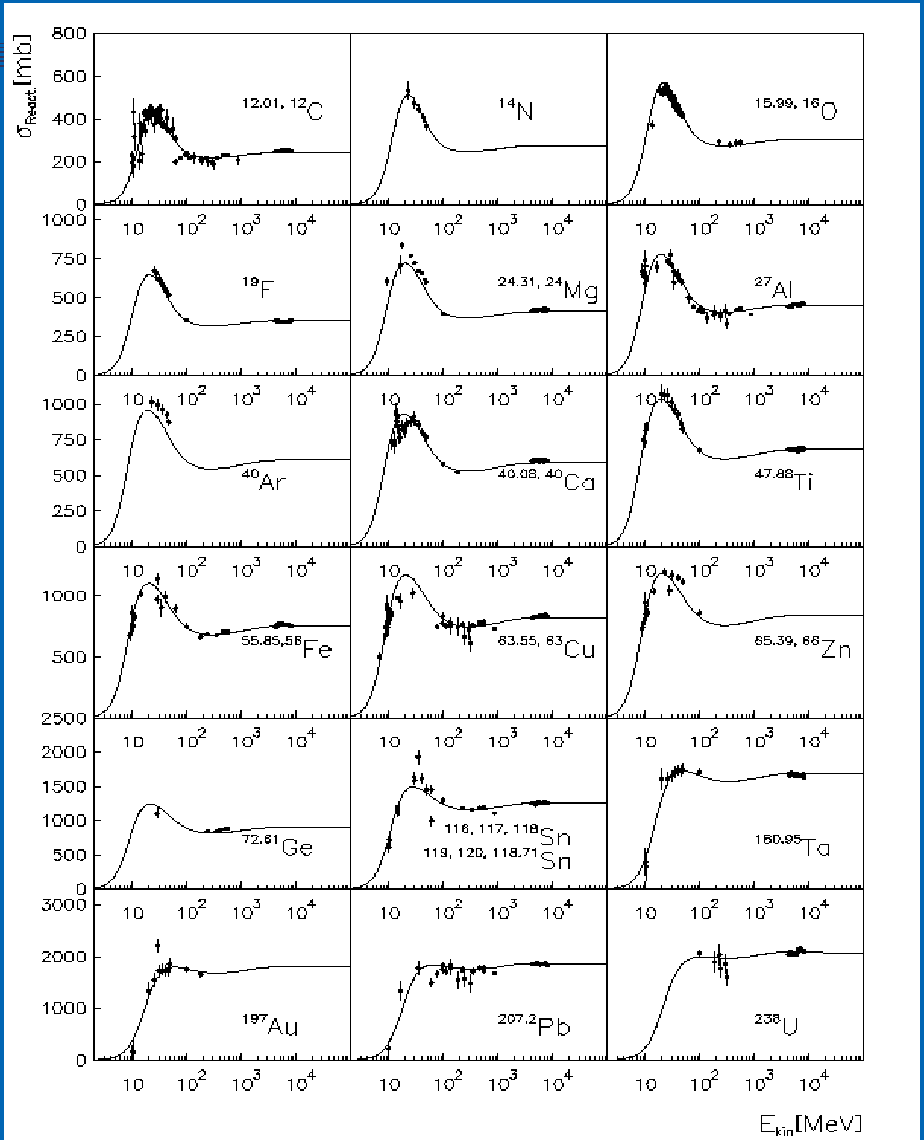
Proton induced reactions



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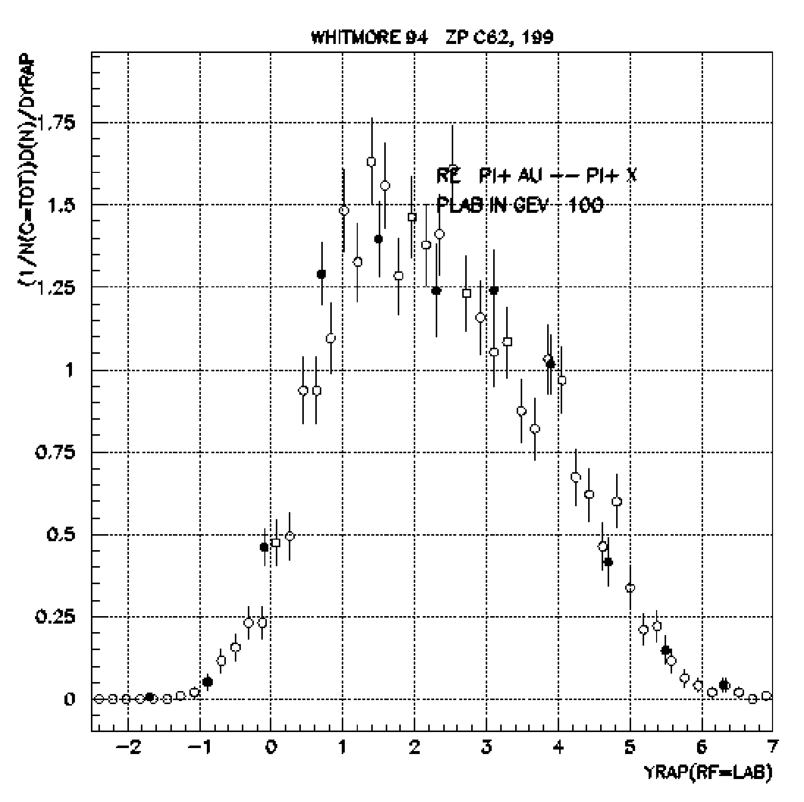
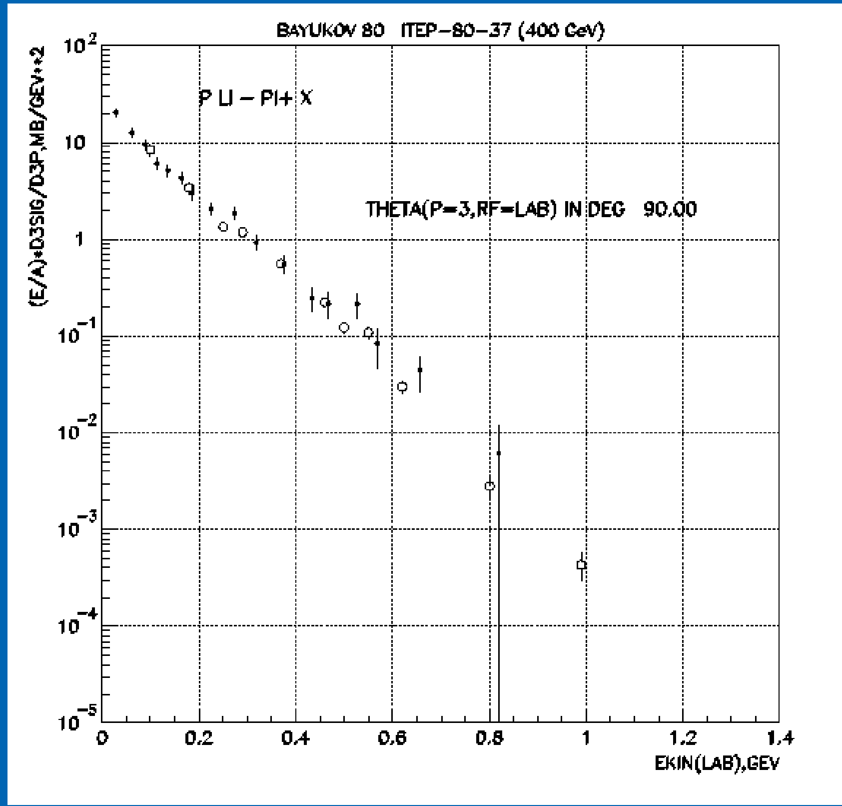
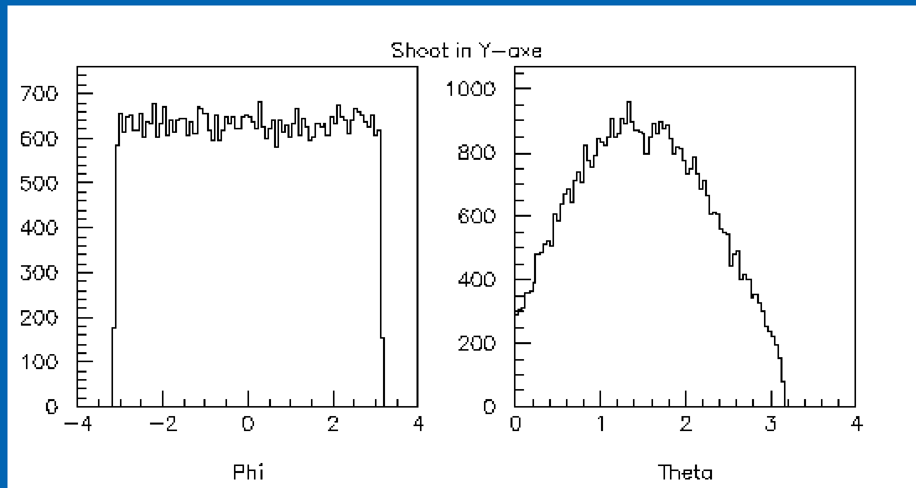
Example WG test results







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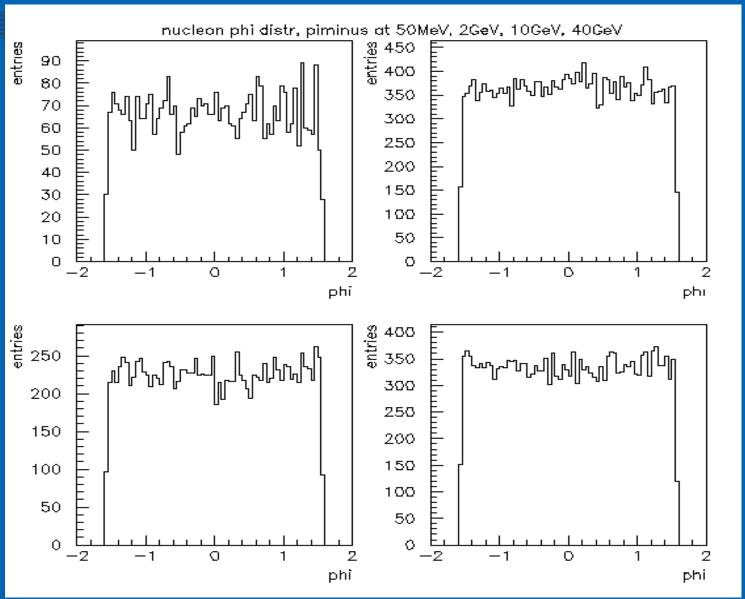
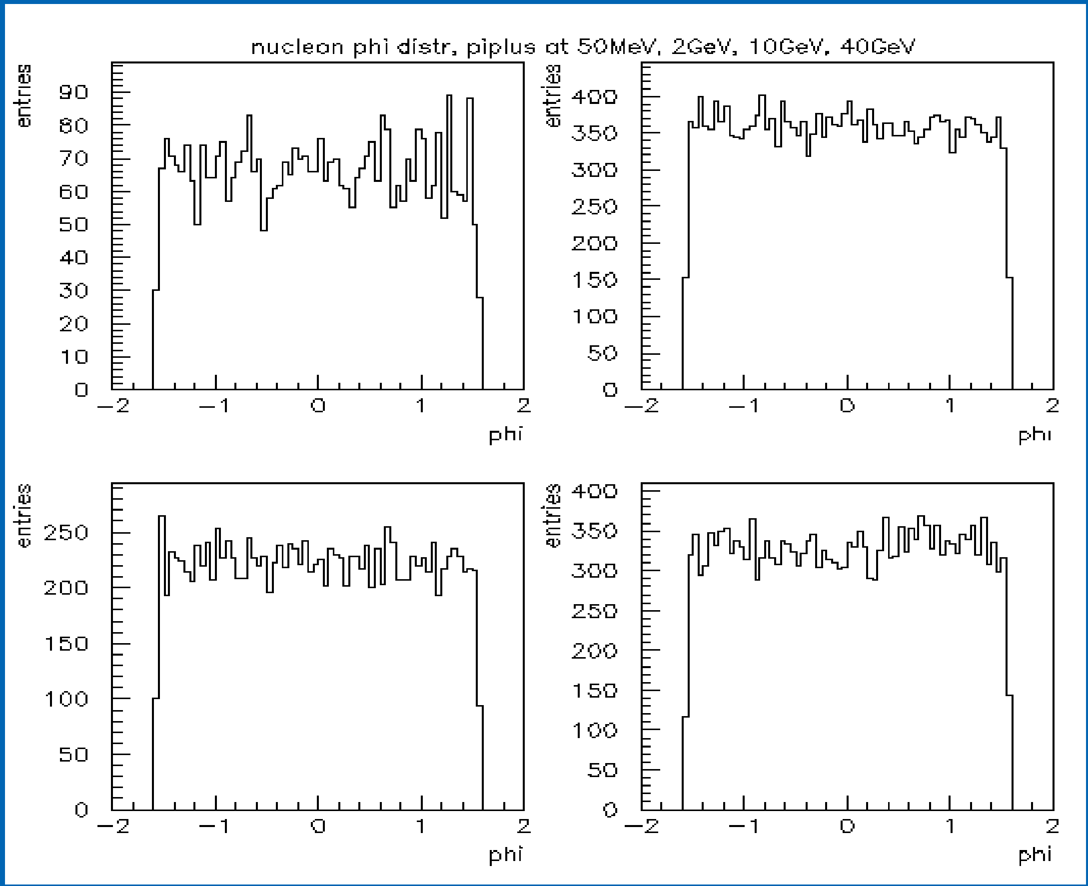
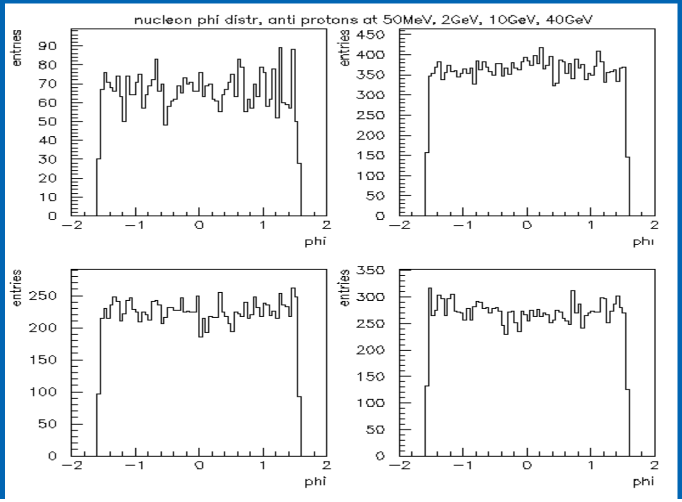
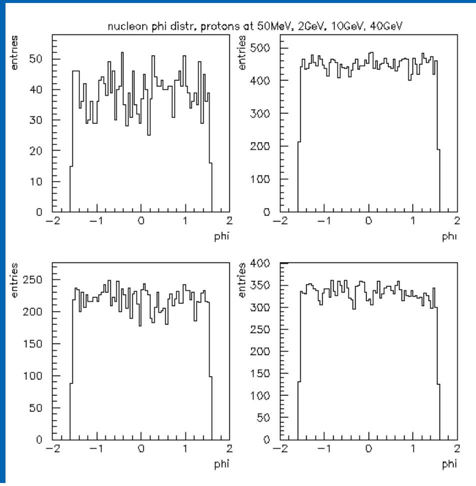
'phi' plots (in Pb)









Nucleon phi distributions
For incident π+, π-,p-bar,p
At energies 50MeV-40GeV

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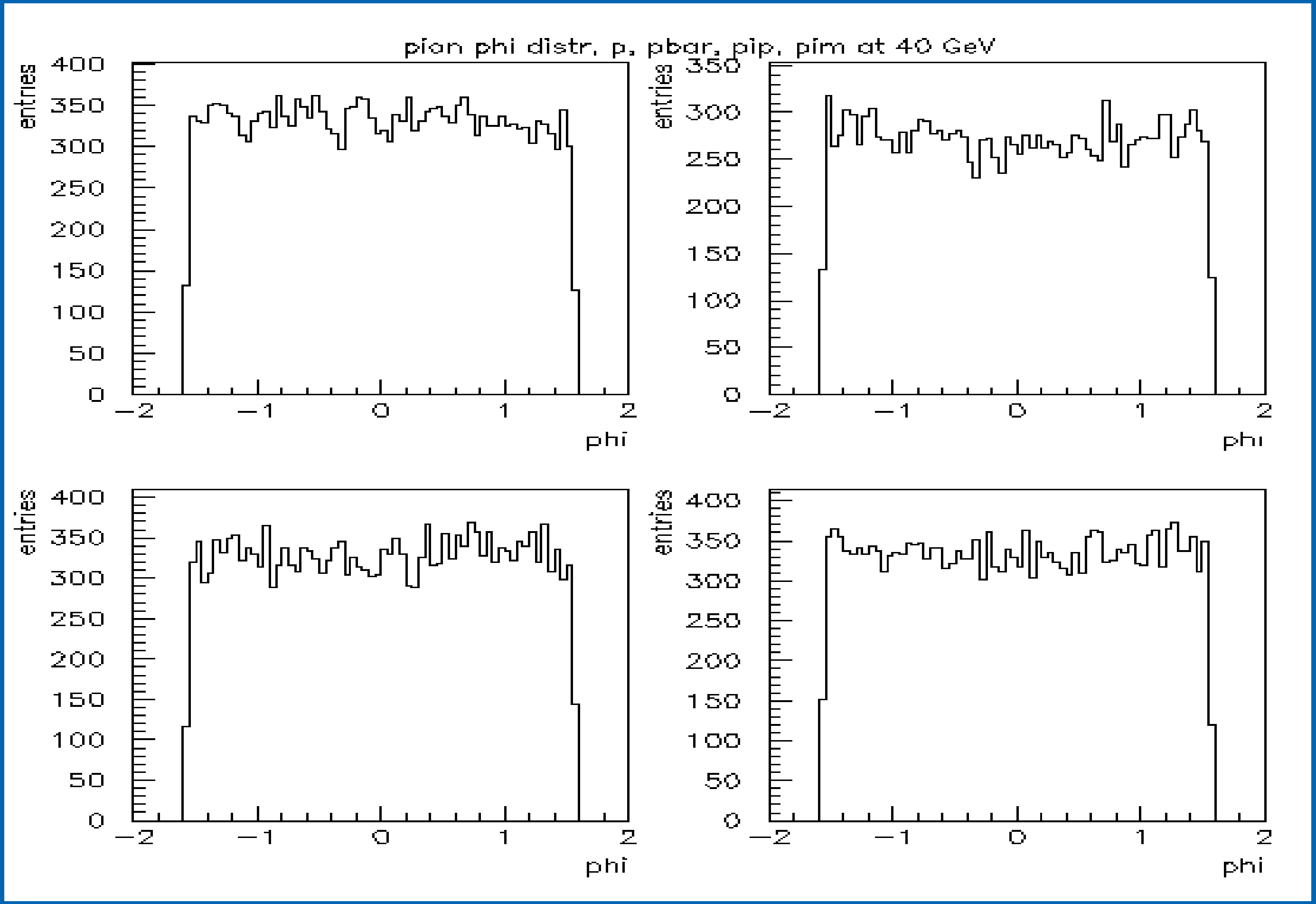
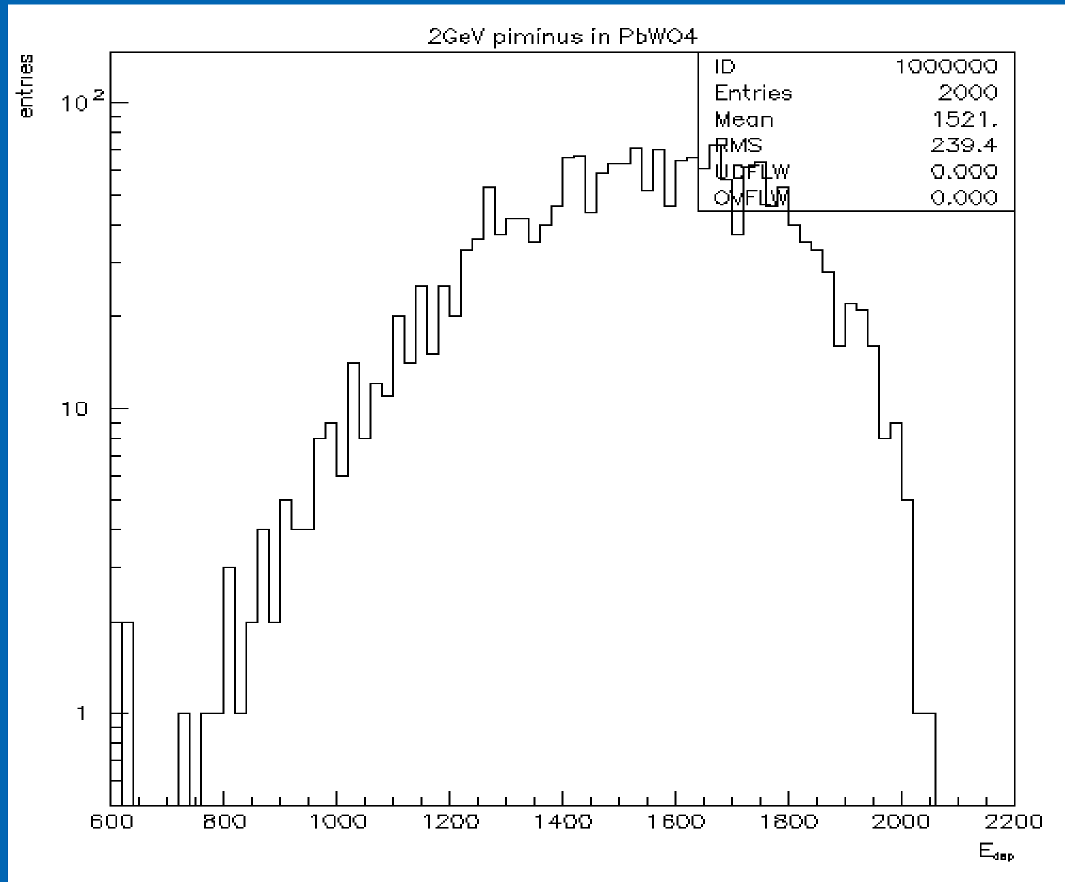
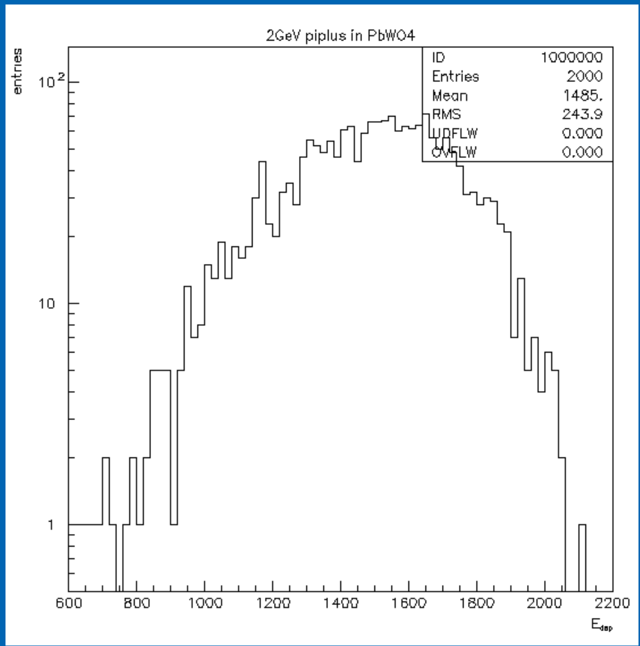
More 'phi' distributions (in lead)

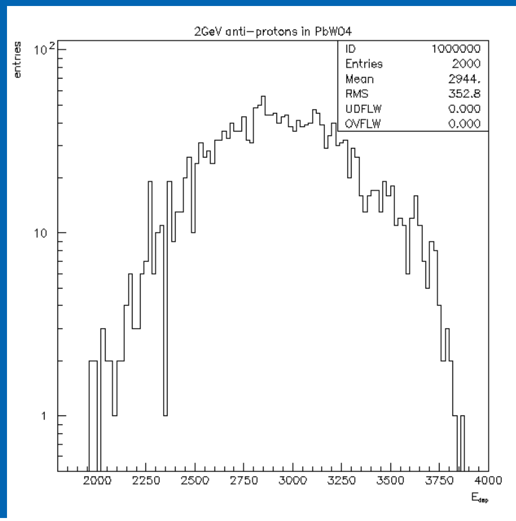


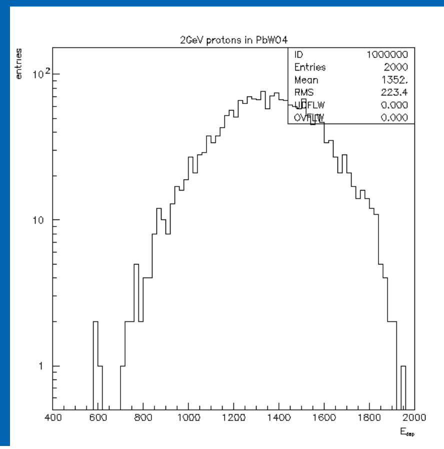
'Trivial' plots energy deposition





BTEV: All distributions are in the expected energy range





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Validation in complete applications

- Independent validation on benchmarks, where these are available
  - Verified before every release.
- Validation on full simulation programs
  - The validation projects

Benchmark comparisons

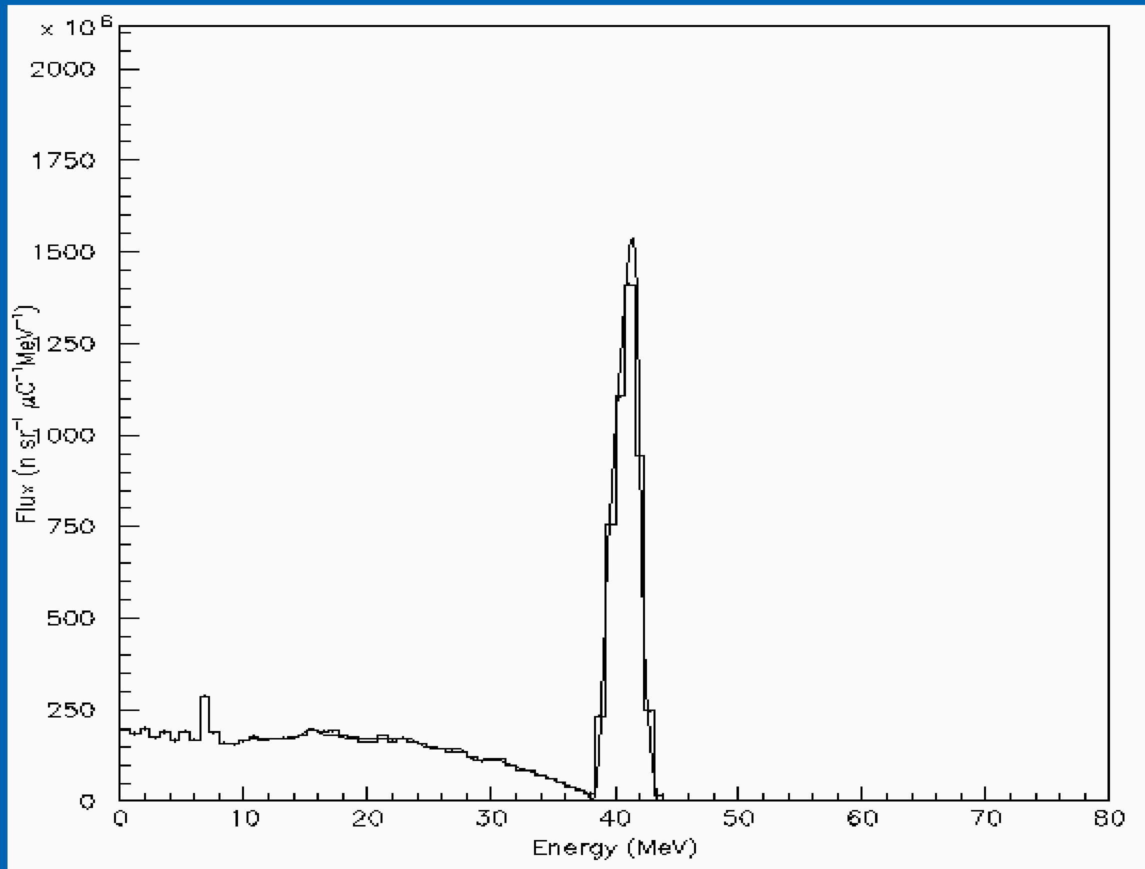
- Validation on benchmarks
  - Test-beam simulations
    - Two test-beam simulations in regression
    - Both run prior to each release, to verify model performance.
  - Radiation benchmarks
    - Currently considering two radiation benchmarks
      - Tiara,
      - SATIF-6 and NEA 'standard' benchmark comparisons
  - Experiencing a continued influx of manpower to extend and standardize this further.

Radiation benchmarks – example

- Tiara - low energy neutron penetration schielding.
  - 43 or 68 MeV (peak) neutron source
  - Use 25cm or 50cm of concrete schielding, or 20 cm or 40 cm of iron schielding
  - Measure neutron flux at beam-axis, and 20cm or 40 cm off beam axis.

- For a few sample plots, please see the next slides.

A sample source spectra



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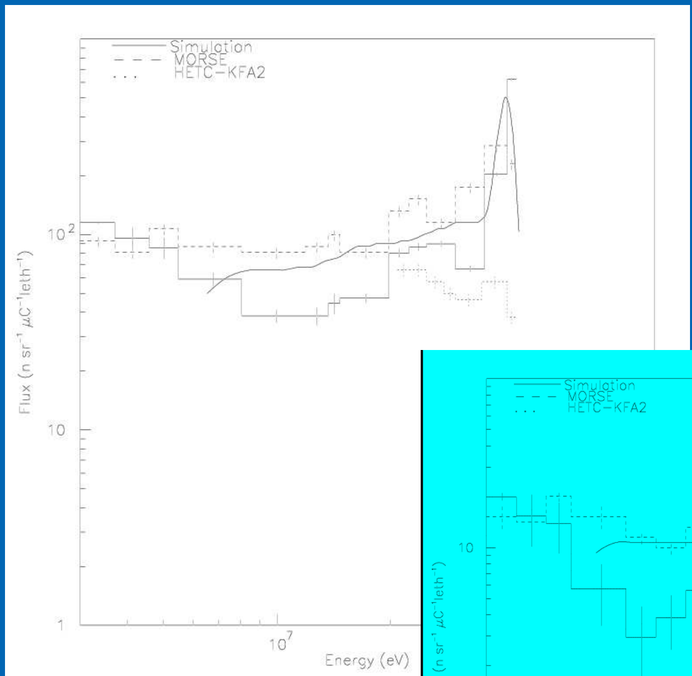
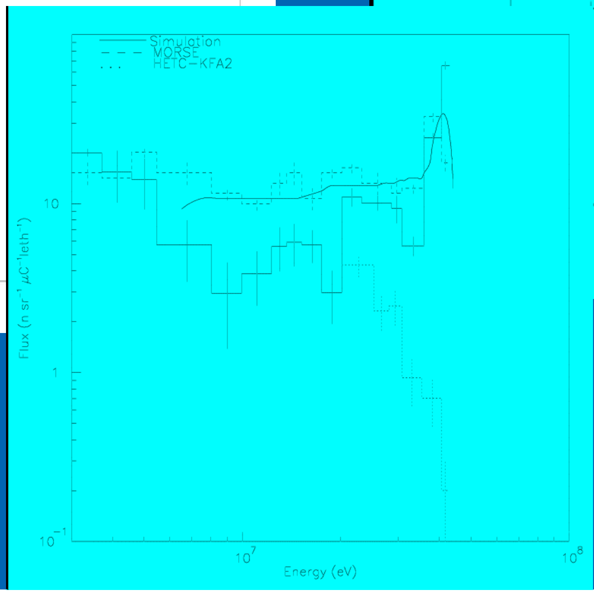
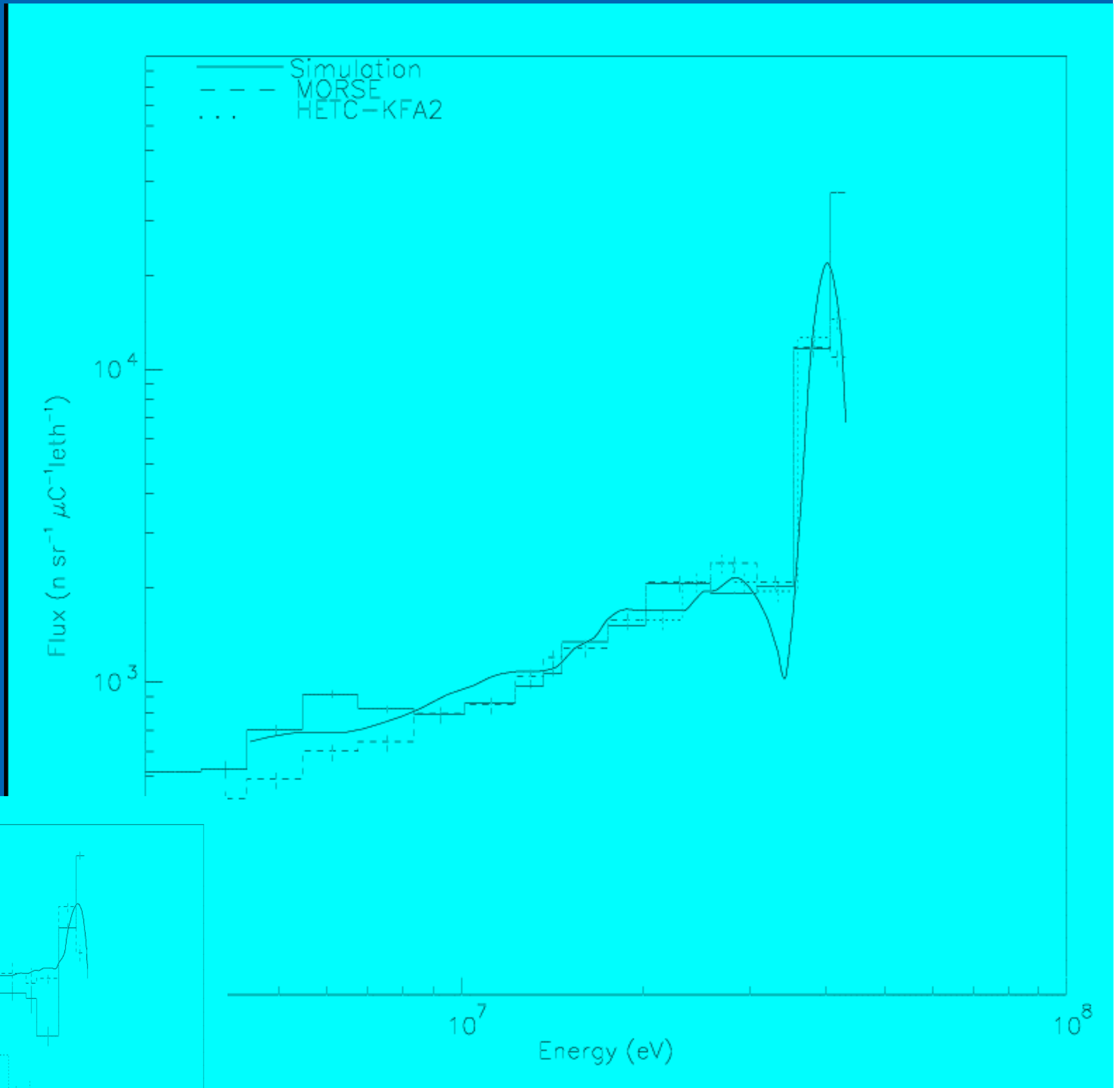
25 cm schielding 43MeV







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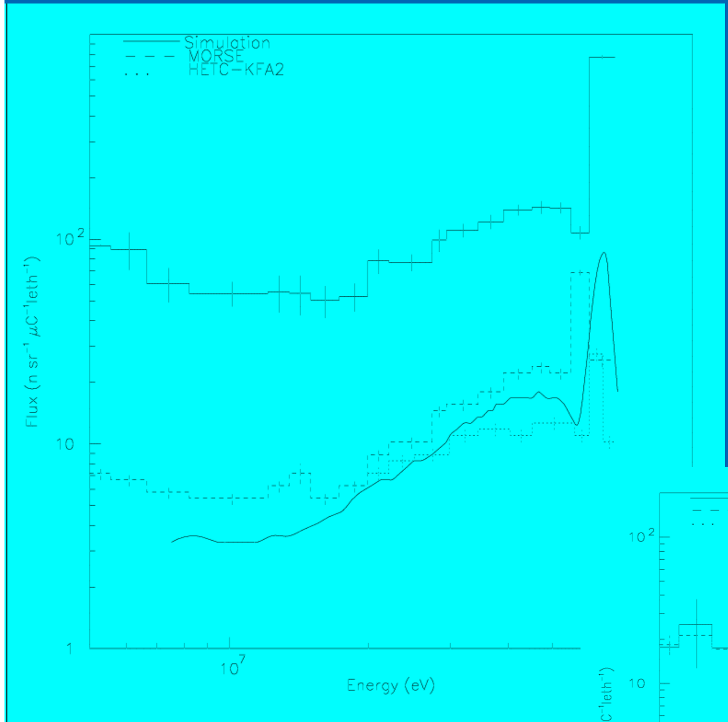
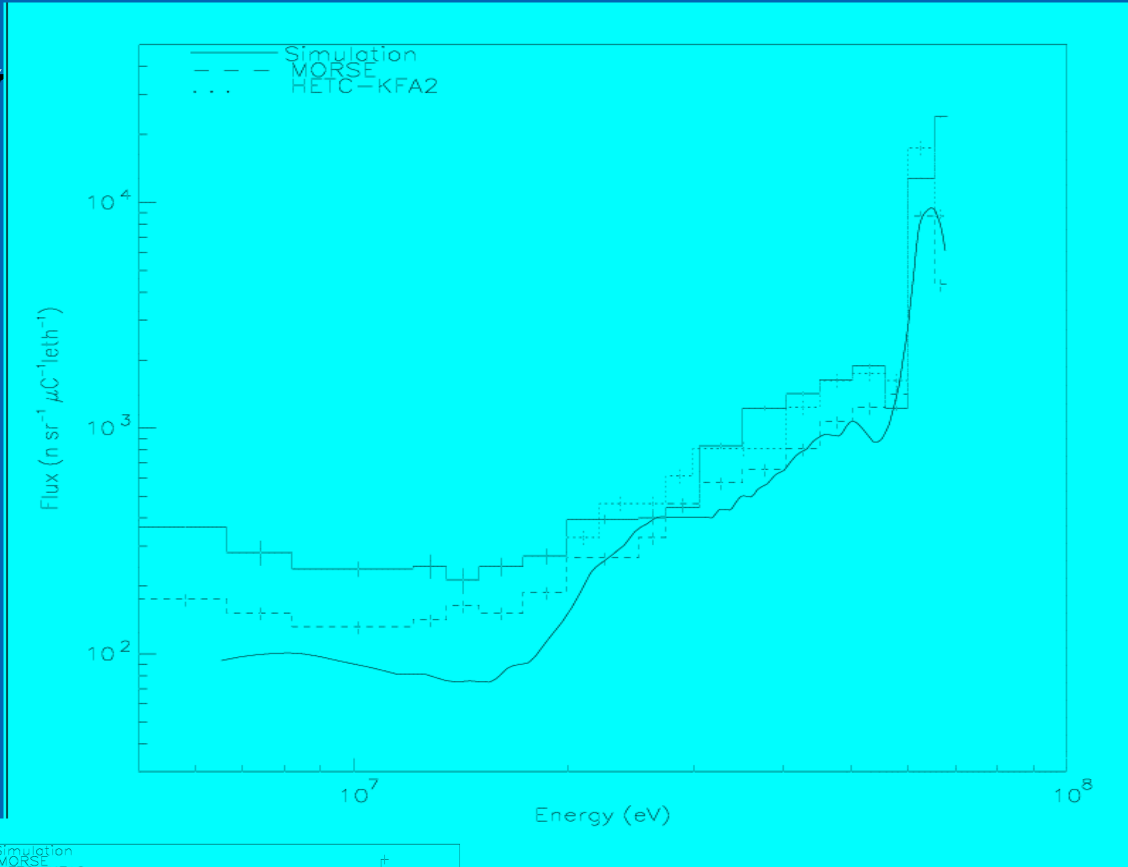
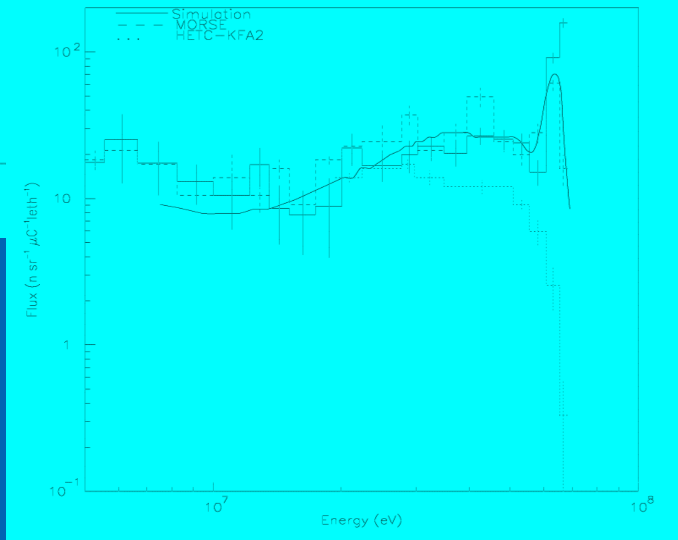
50 cm schielding 68MeV







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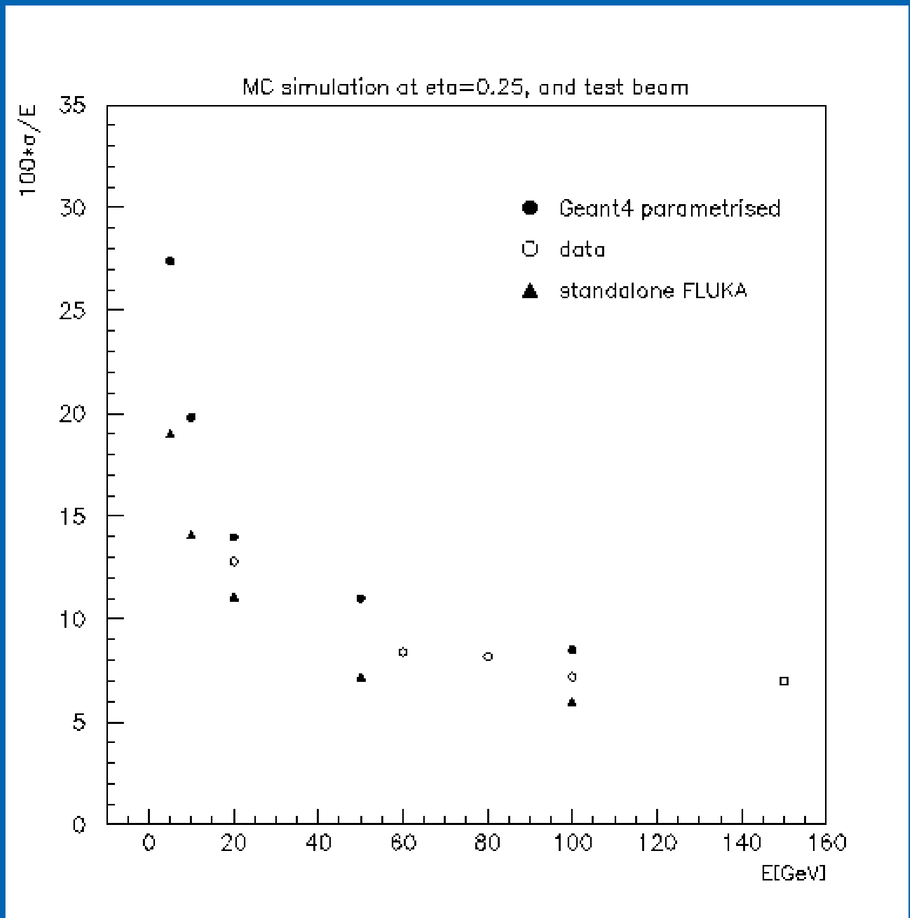
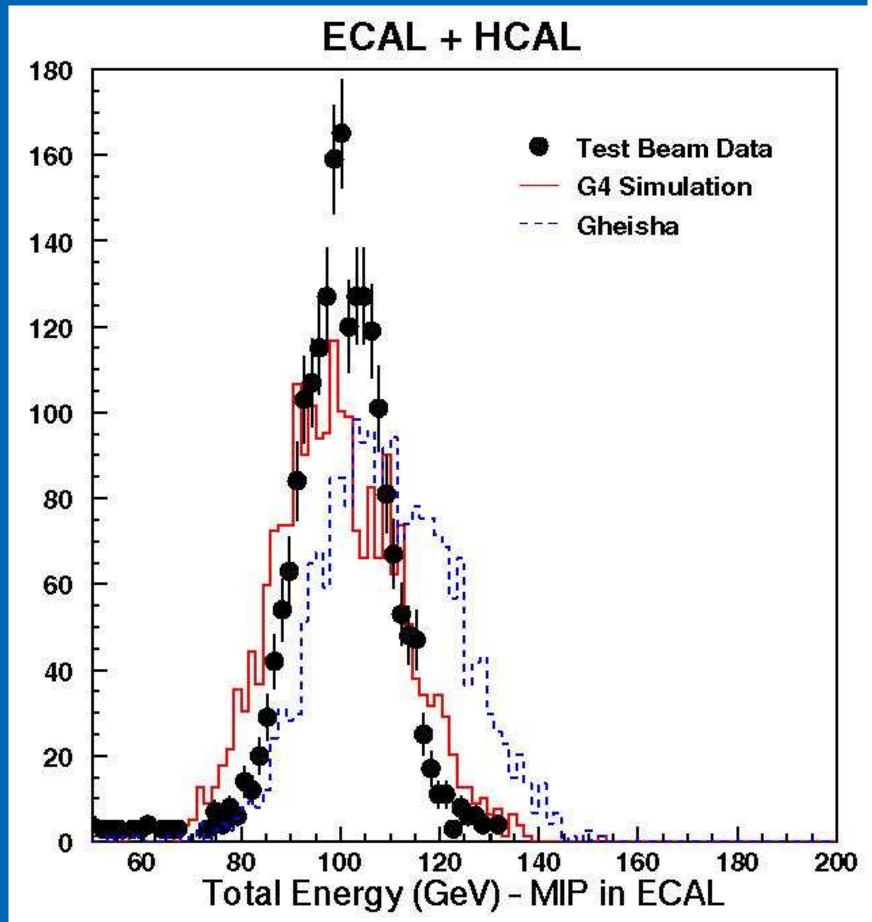
Test-beams

- Hadronic test-beam comparisons come from collaboration of experiments' detector groups with 'core' geant4 personnel.
  - ATLAS Tile test-beam
  - CMS Tile test-beam
  - ATLAS HEC test-beam
  - ATLAS FCAL test-beam
  - BTEV crystal test-beam
  - CMS combined test-beam
  - CsI test-beam benchmark
  - GLAST (starting) test-beam

  - Plots being solicited as courtesy of the experimental groups.

Test-beam sample result





Courtesy of ATLAS TILE prelim.

Courtesy of CMS prelim.

A test beams study in regression

- ATLAS HEC as a calorimeter benchmark set-up
- Detailed description of the detector
  - Very constructive help from the ATLAS calorimeter community
- Analysis: E=E_front + 2E_back
- Results from the ATLAS test-beam analysis are overlaid , and labeled as 'org.'.
- Data are taken from CALOR 2002 paper

The physics lists studied in test-beam

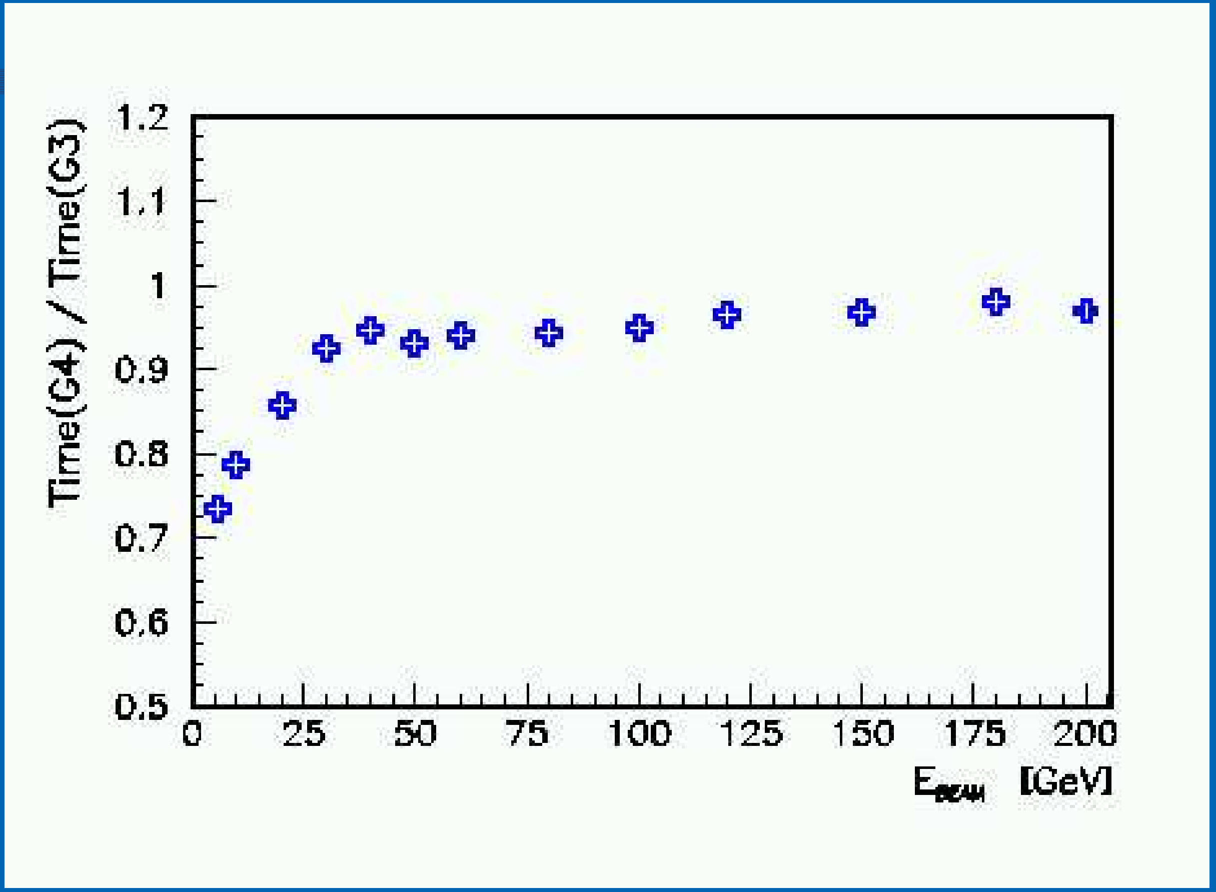
- The physics lists used:
  1. Low energy and high energy parameterized models (LHEP) – check against ATLAS test-beam analysis
  2. Pion inelastic scattering final states simulate with quark gluon string model (first interactions)+chiral invariant phase-space decay (fragmentation) (QGSC)
  3. Pion inelastic scattering final states simulate with quark gluon string model+precompound model (QGSP)
  4. Pion inelastic scattering final states simulate with diffractive string model+precompound model (FTFP)

The overall parameters

- Geant4 version:
  - geant4 4.0 patch 1+2; no tuning
- Energies:
  - 10, 20, 30, 40, 50, 60, 80, 100, 120, 150, 180, 200 GeV pions and electrons
- 700 microns range cut
- 2000 events per ‘point’

- Looking at performance, linearity, shower shape, energy resolution, and e/pi

Relative timing of geant3 and geant4 for pion test-beam



ATLAS HEC, CALOR 2002

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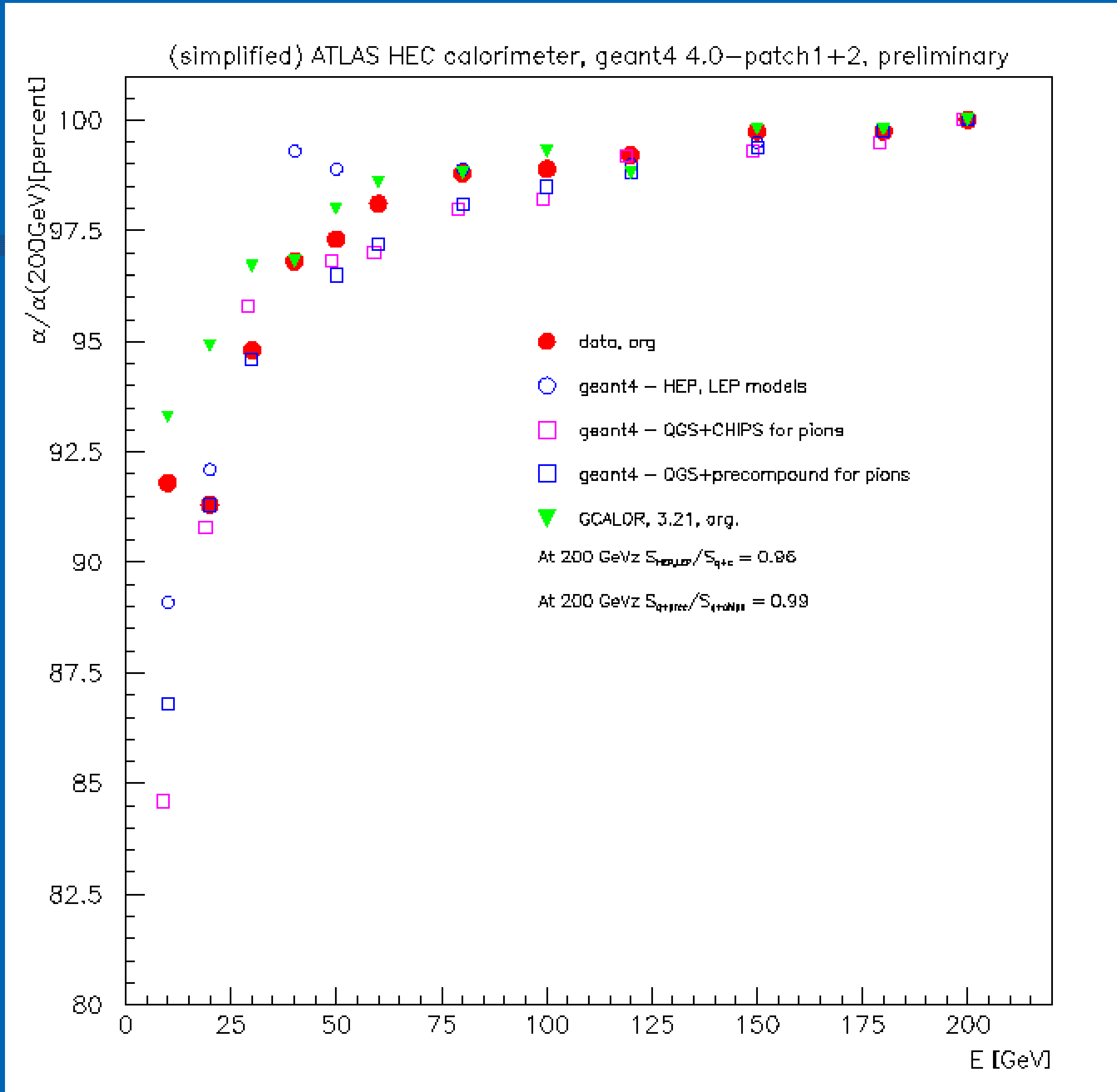

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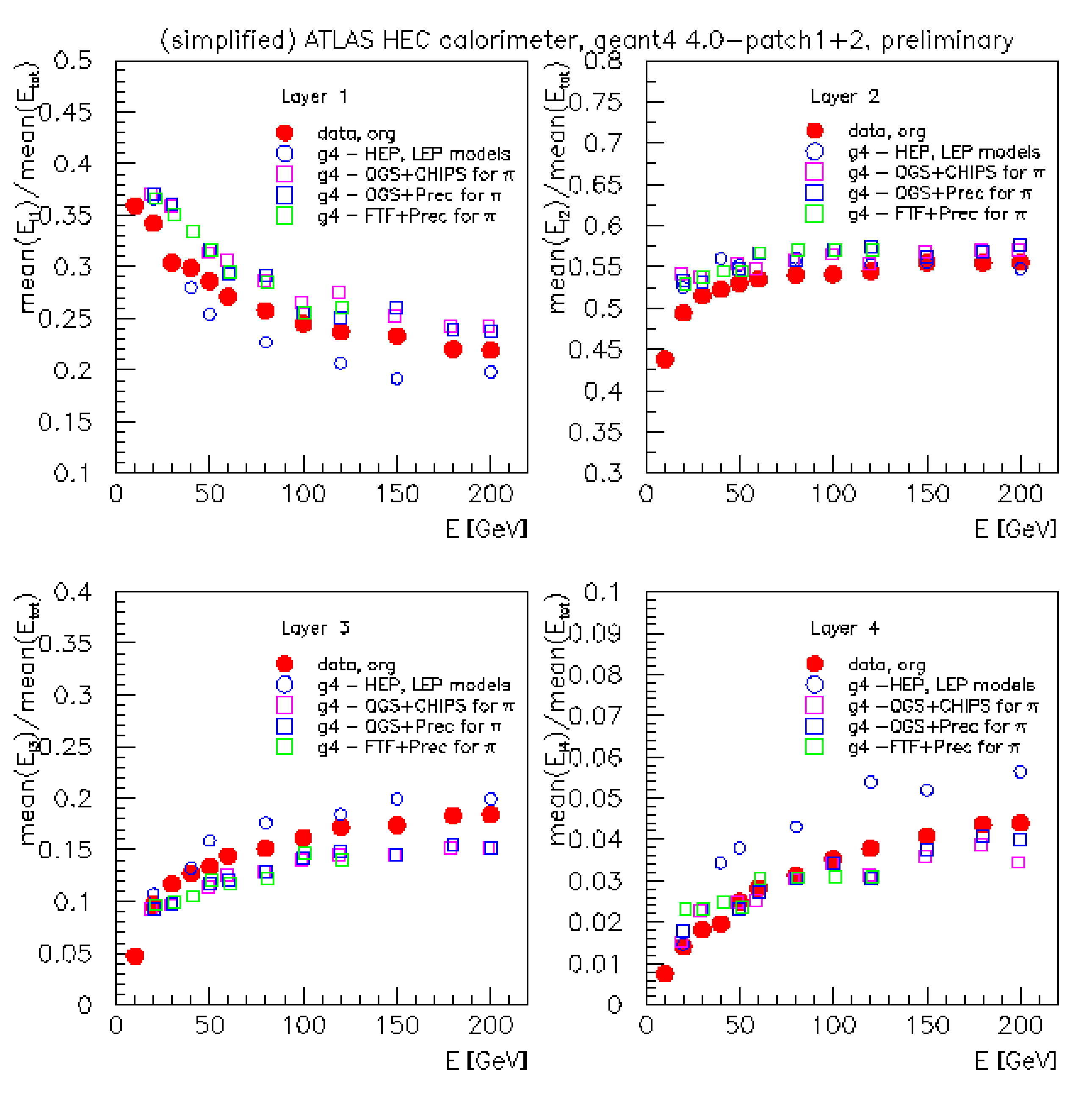

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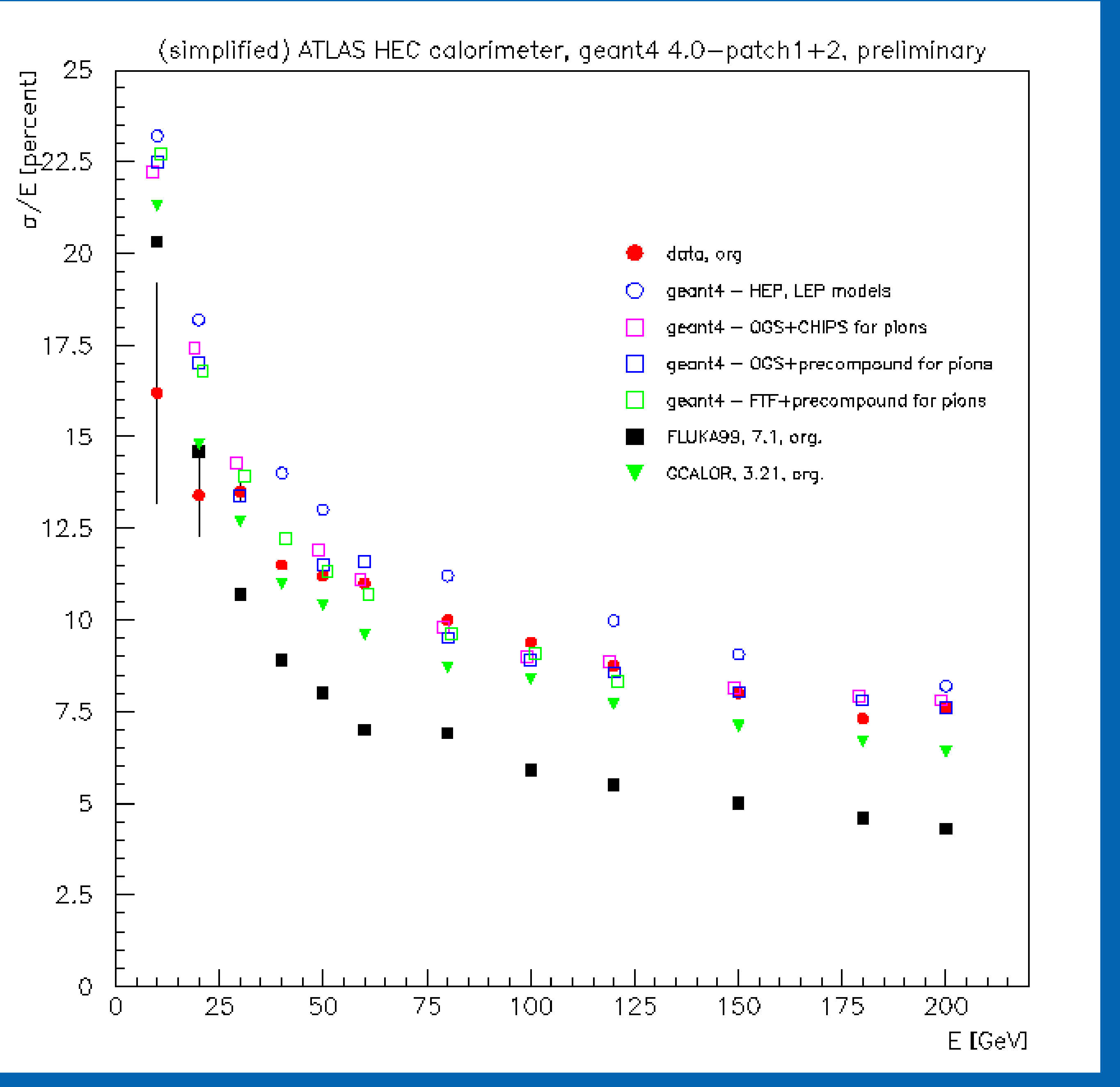

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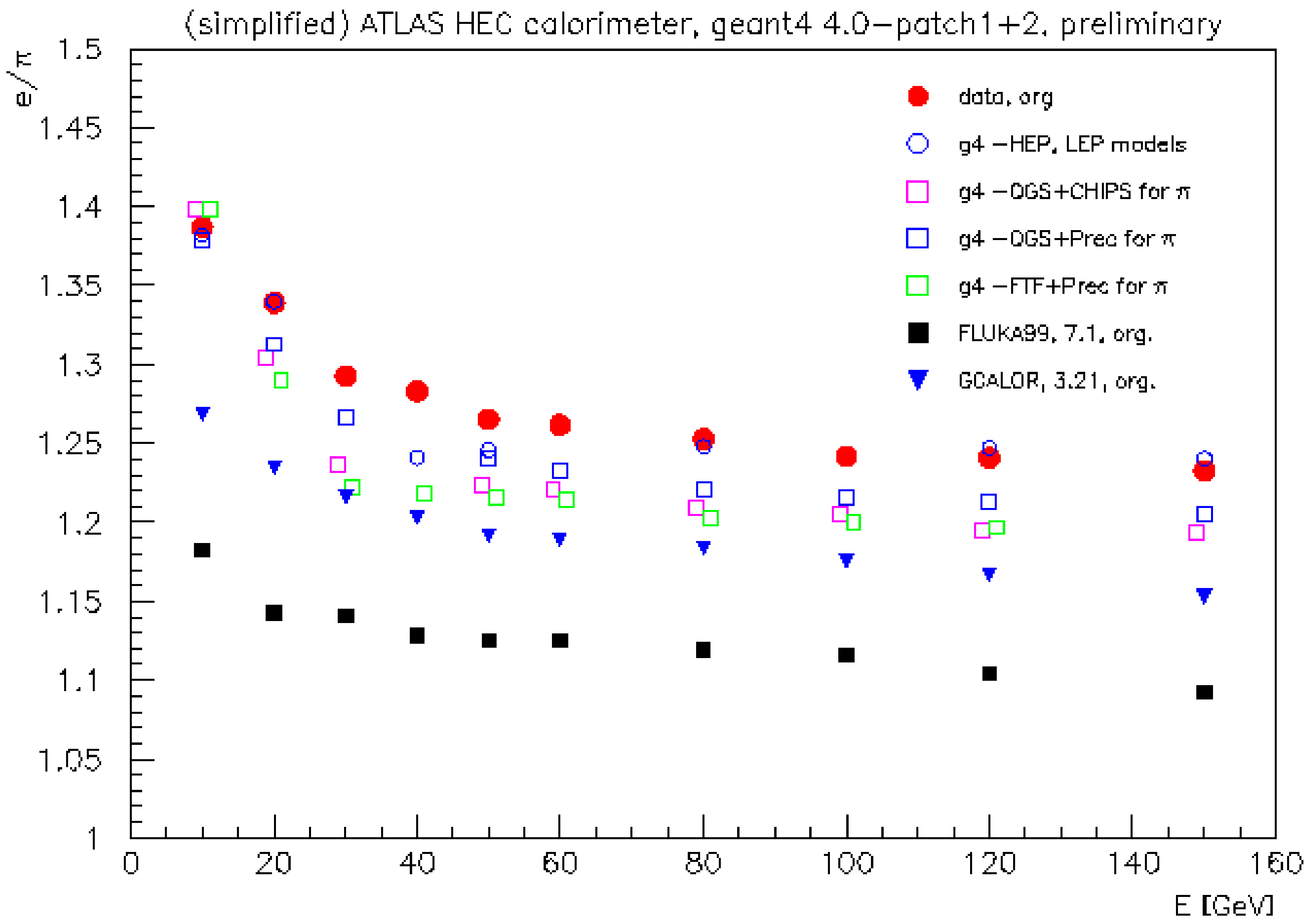

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Conclusions

- The theory driven models available in geant4 resolve the problem of simulation of energy resolution
- The quantities studies are at the level (shower shape) or better (all other) than the geant3.
- ➔Verification of results for theoretical models in true test-beam analysis was done within the ATLAS calorimeter community; results confirmed.
- Now focusing on shower shapes.

Other areas of known usage (likely incomplete)

- Tracker performance
  - ATLAS, CMS, BaBar
- Medical
  - Uppsala, TERA
- Neutron dosimetry, measurement, beam-lines
  - SNO, Los Alamos, CERN/PS, DoD/Can, etc..
- Radiation schielding, activation, thermalization
  - DYNAMIX, MECO, ALICE?, CMS, ESA, etc..
- Oil search and similar
  - Mitsubishi, General electrics, EXXON, ALCATEL…

Collaboration with 3rd parties
Some of the reasoning:

- Geant3 had used two strategies. There were shower packages released with geant3, and there were interfaces released with geant3; the latter were interfacing to external packages. The first was a working model, for the latter, geant3 always was claimed to be obsolete.
- GISMO: the no physics situation, but only interfacing to external packages. They never really got support for the use of these codes with GISMO.
- MCNPX: Gets it right. They encourage and help 3rd parties to release MCNP interfaces with their 3rd party code. It solves the support question.

Collaboration with 3rd parties

- Basis: We provide a set of well defined, published, and highly stable interfaces that allows interested 3rd parties to release adapters to use their code, or to use geant4 physics implementations within their infrastructure.
- EGS: geant4 chips code for γ-nuclear reactions also in EGS
- HETC: Being re-written to become natively available in G4
- INUCL: Being integrated to become natively available in G4
- UrQMD: In the process of being re-engineered to become natively available in geant4
- MCNP: Discussion on using the geant4 interfaces in MCNP
- G-FLUKA: Interfaced by 'air shower' users for their own use.
- Liege Cascade code: Discussion in progress. We hope that they will release a G4 interface soon, and are of course happy to help.

Conclusions

- It is very important that individual contributors are enfranchised to join the collaboration, in particular in the area of physics modeling.
- They must feel assured that they are well protected from any attempt to deprive them off (or copy/steal/subltiliser) the work that built their careers, I.e. their code and/or publication potential.
- They otherwise would be asked to contribute at their own peril.
- We should explicitly state a policy ensuring this in the MoU revision.