NA2 Status VALSIM Task

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Annual EUDET meeting, Munich, 20th Oct 2006

VALSIM

- Motivation
  - Issues from hadronic shower simulation
    - Good e/pi, linearity
    - Not as good shower shape
      - ATLAS / CMS test beam comparisons
  - Validate relevant aspects of the hadronic models
- Challenges
  - Which are the most important aspects for shower evolution ?
  - How well are neutrons simulated ?

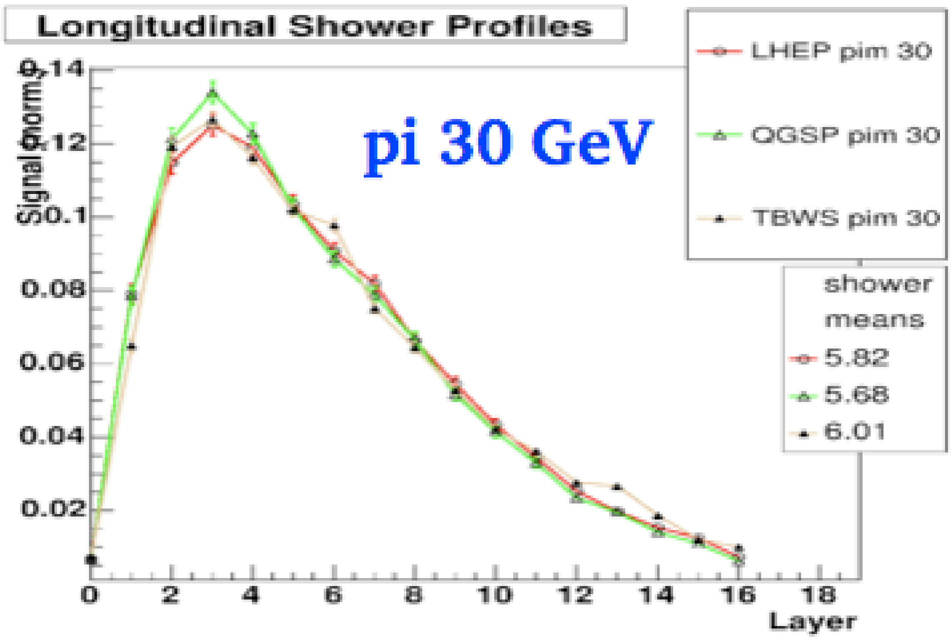
Work items and meetings

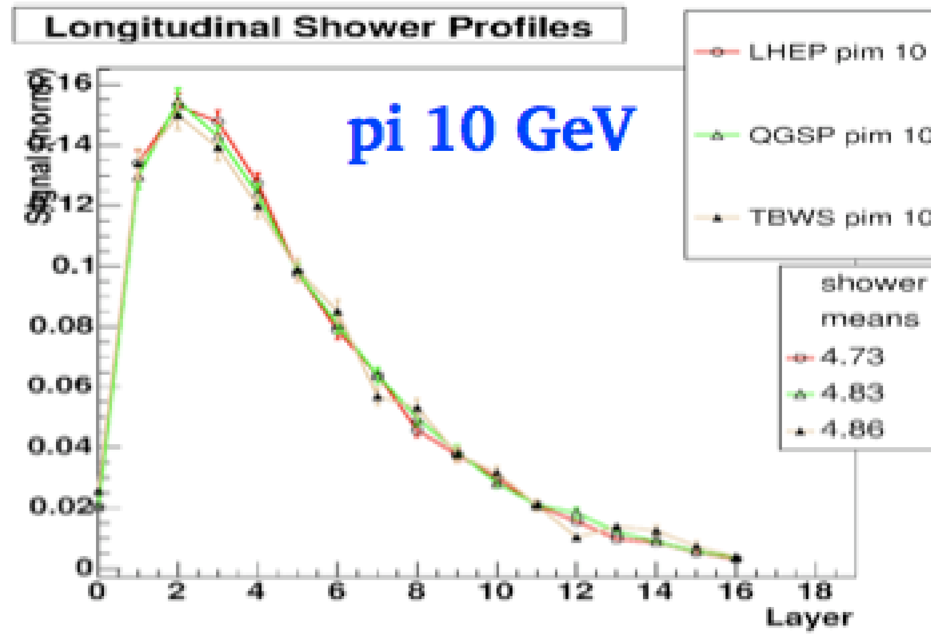
- Current work
  - Study the shower evolution (in simulation)
    - Comparing also between approaches
  - Identify key aspects for additional comparisons with data ('thin-target')
  - Extend benchmarking comparisons of neutrons (TARC)
- 3 day workshop July 2006 at CERN
  - 'Geant4 Physics Verification and Validation'
  - Concentrated on the status of hadronic V&V
  - Main discussion in Geant4 Workshop, 8-15 Oct
  - Visitors from KEK, SLAC, INFN, …

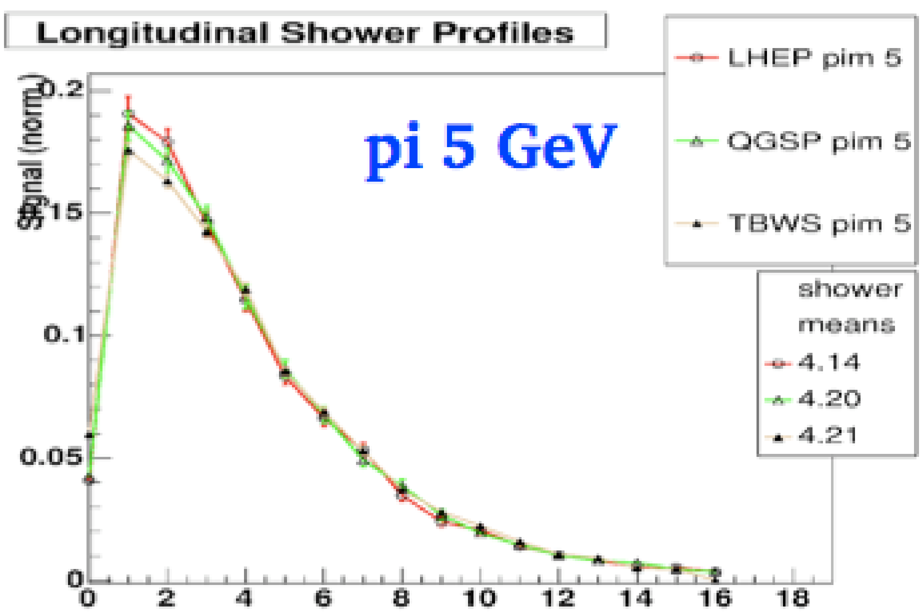
Shower shape

- Summary of issues
- Ongoing verification

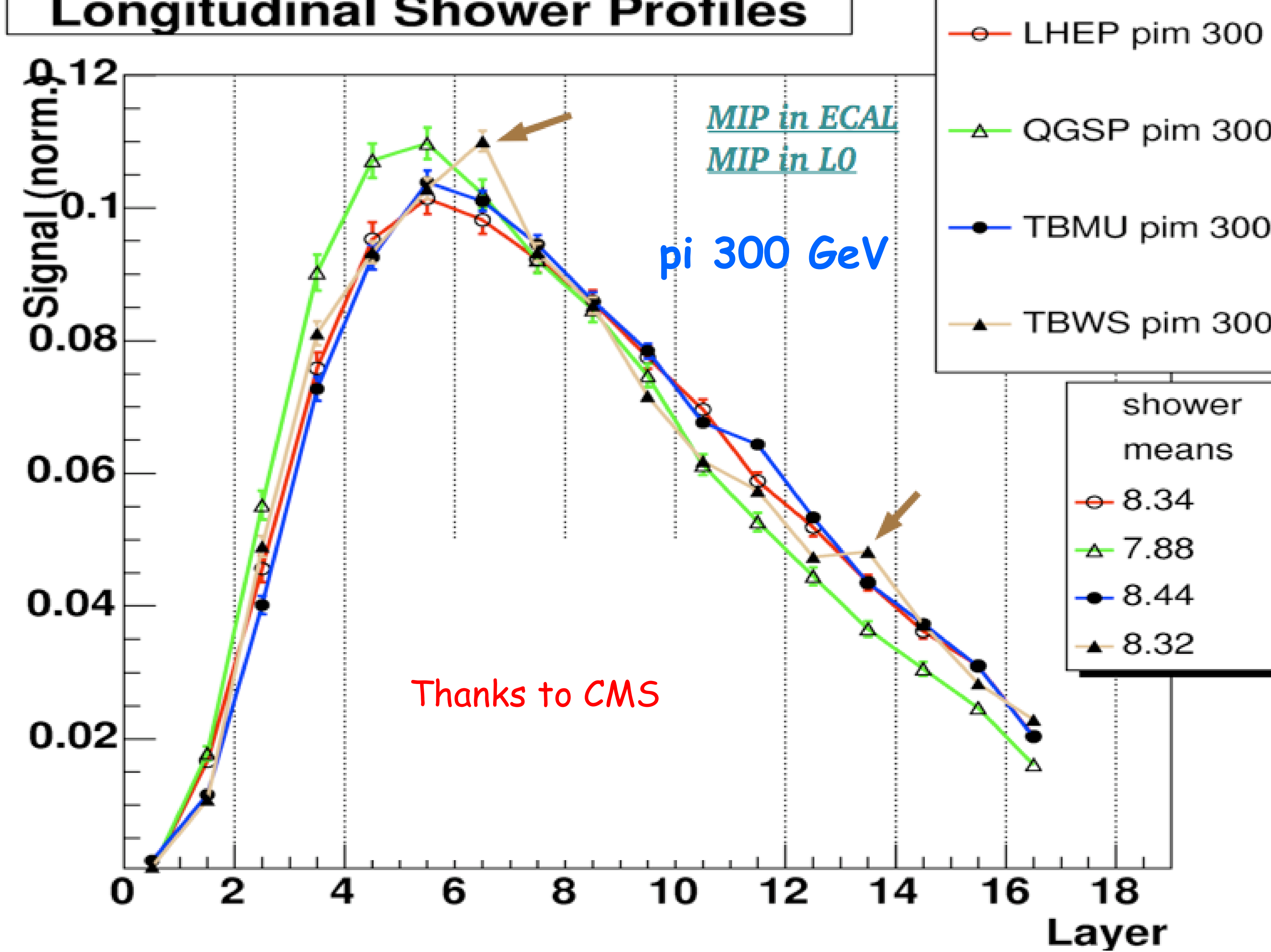
Longitudinal shower profiles







LHEP and QGSP show good agreement with test beam data at low and intermediate energies



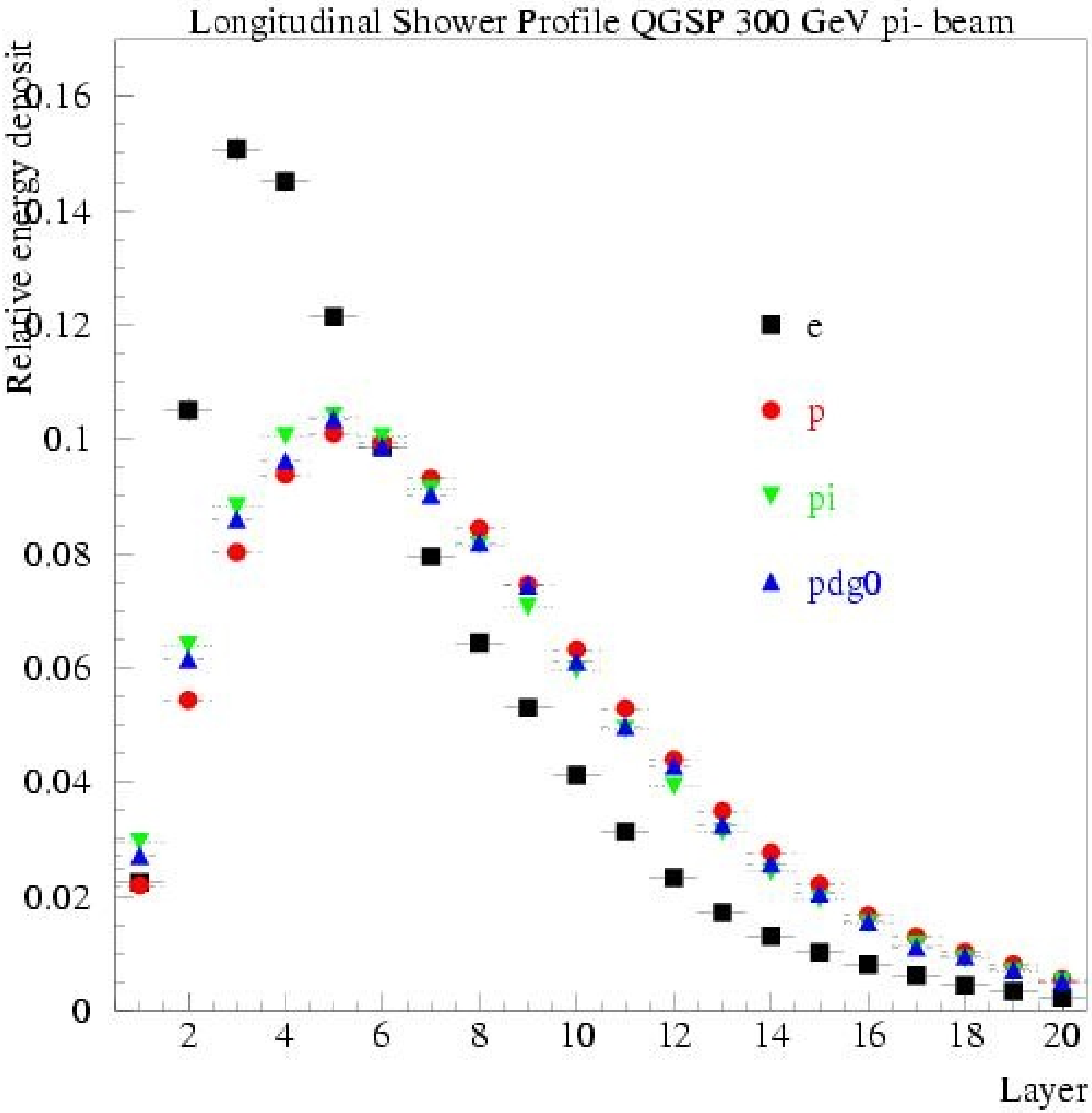
Longitudinal Shower Profiles
Signal (norm.)
0.12
0.1
0.08
0.06
0.04
0.02
0
2
4
6
8
10
12
14
16
18
Layer
LHEP pim 300
QGSP pim 300
TBMU pim 300
TBWS pim 300
shower
means
8.34
7.88
8.44
8.32
MIP in ECAL
MIP in L0
pi 300 GeV
Thanks to CMS

Shower shape studies in Geant4

The goal is to understand the impact of the various physics processes on the development of hadronic showers, in order to improve the longitudinal (and lateral) shower profiles.

To tackle this complex problem we use two complementary approaches:

1. "microscopic" : study for instance:
   - elastic scattering
   - neutron production and transportation
   - pion inelastic cross-sections
   - multiplicity and spectra.
2. "macroscopic" : monitor the observables of a simplified sampling calorimeter setup to compare different physics simulations.



Contribution
to energy deposit
per particle type
along shower

(pdg0 – all ions
(mainly: d,α))

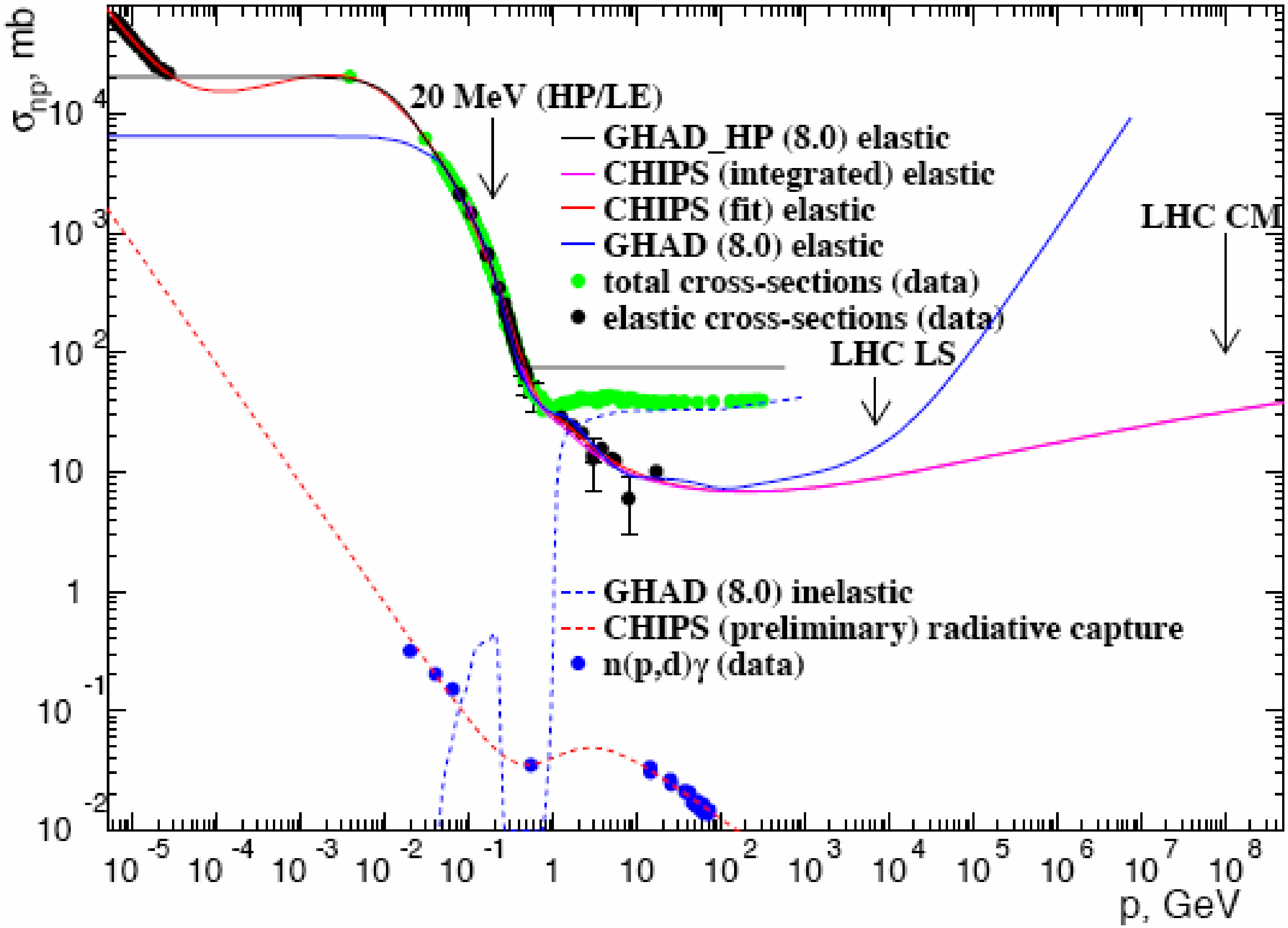
Key aspects identified

- Elastic (total) hadronic process
  - Energy deposit in scintilators
- Inelastic (integral) cross sections
  - Pions ($\pi^0/\pi^\pm$ - ratio)
- Neutron production and interaction
  - Significant for lateral shower shape, leakage
  - probed in TARC comparisons (next)
- Leading particle carries momentum
- Contribution of protons ~ 1-10 GeV

Hadronic cross-sections

- Elastic on hydrogen
- Integral total/inelastic

n-H elastic scattering (M. Kosov). Blue is old GHAD (data driven – only for < 20MeV), magenta is new CHIPS parametrisation



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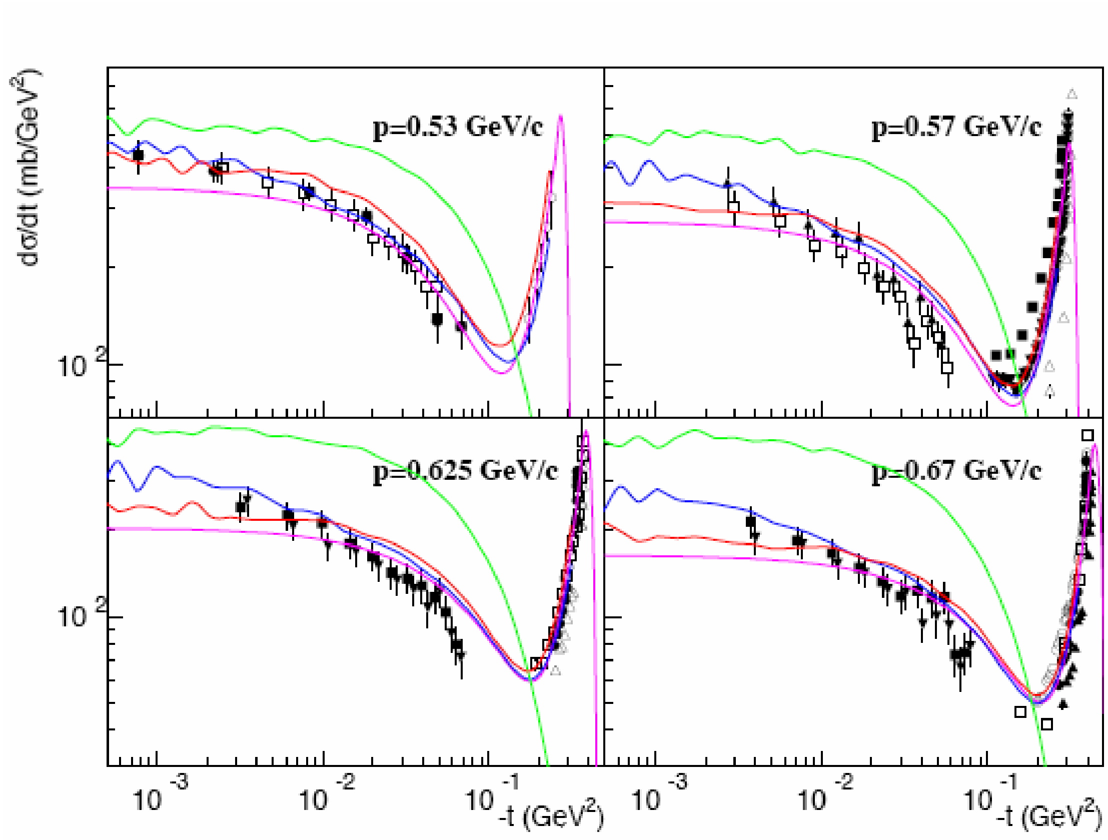
n-H elastic : dσ/dt (M. Kosov)



Other elastic scattering cases already parametrized:

p-H , p-d , p-He4 , p-Be ...

Simplified Glauber-Gribov model for integral total and inelastic hadron-nucleus (h-A) cross-sections:

$$\sigma_{tot} = 2\pi R^2 \ln\left(1 + \frac{A\sigma_{tot}^{hN}}{2\pi R^2}\right)$$

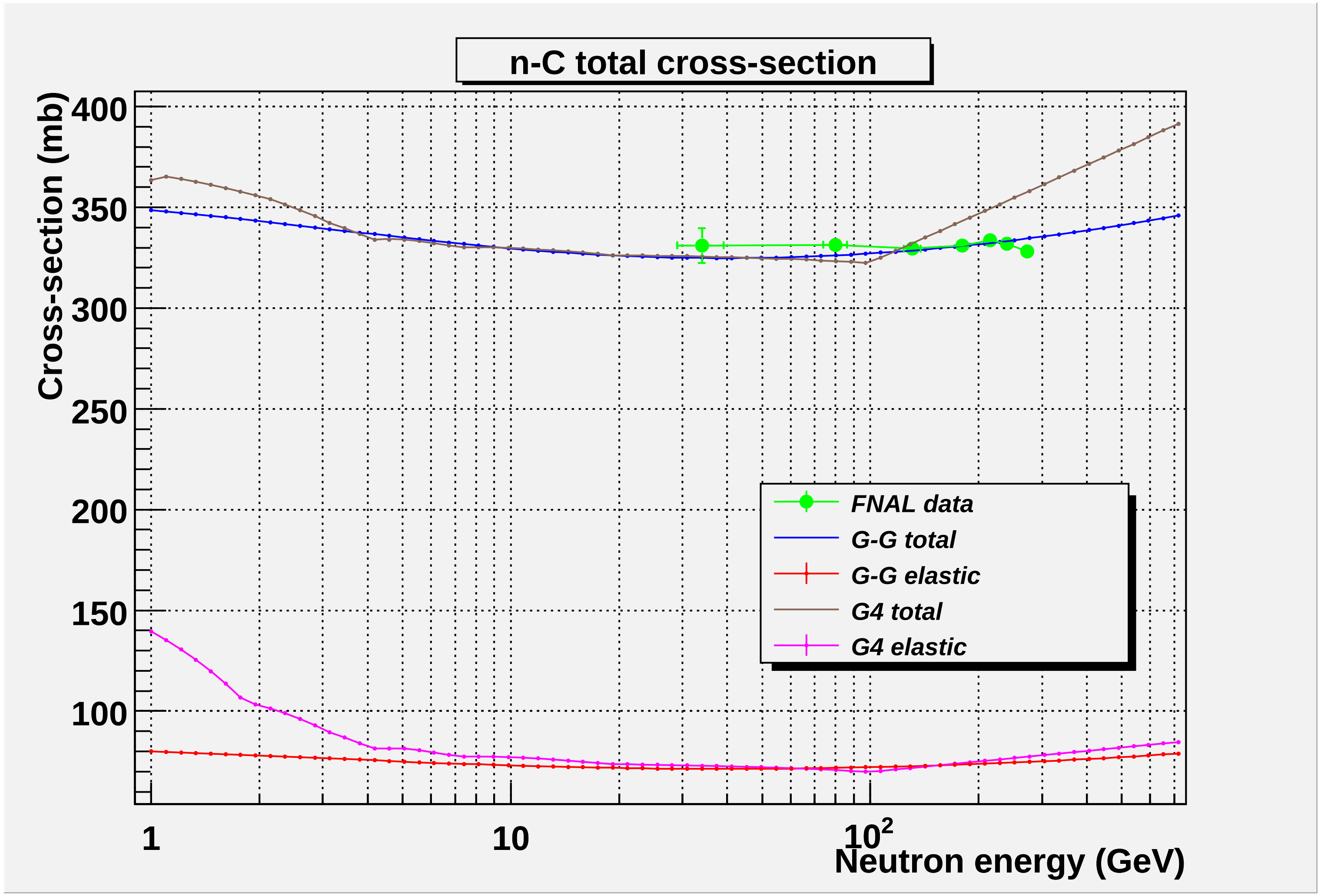
, inelastic: 2->1

A is the nucleus weight,

σ_{tot}^{hN} is the total hadron-nucleon cross-section (PDG),

R = K(A)$r_o A^{1/3}$ (K(A) ~ 0.8-1.2) is the RMS radius of gaussian single nucleon density.

N-C total/elastic cross sections
Geant4(Geisha (LHEP), Glauber-Gribov models) and FNAL data



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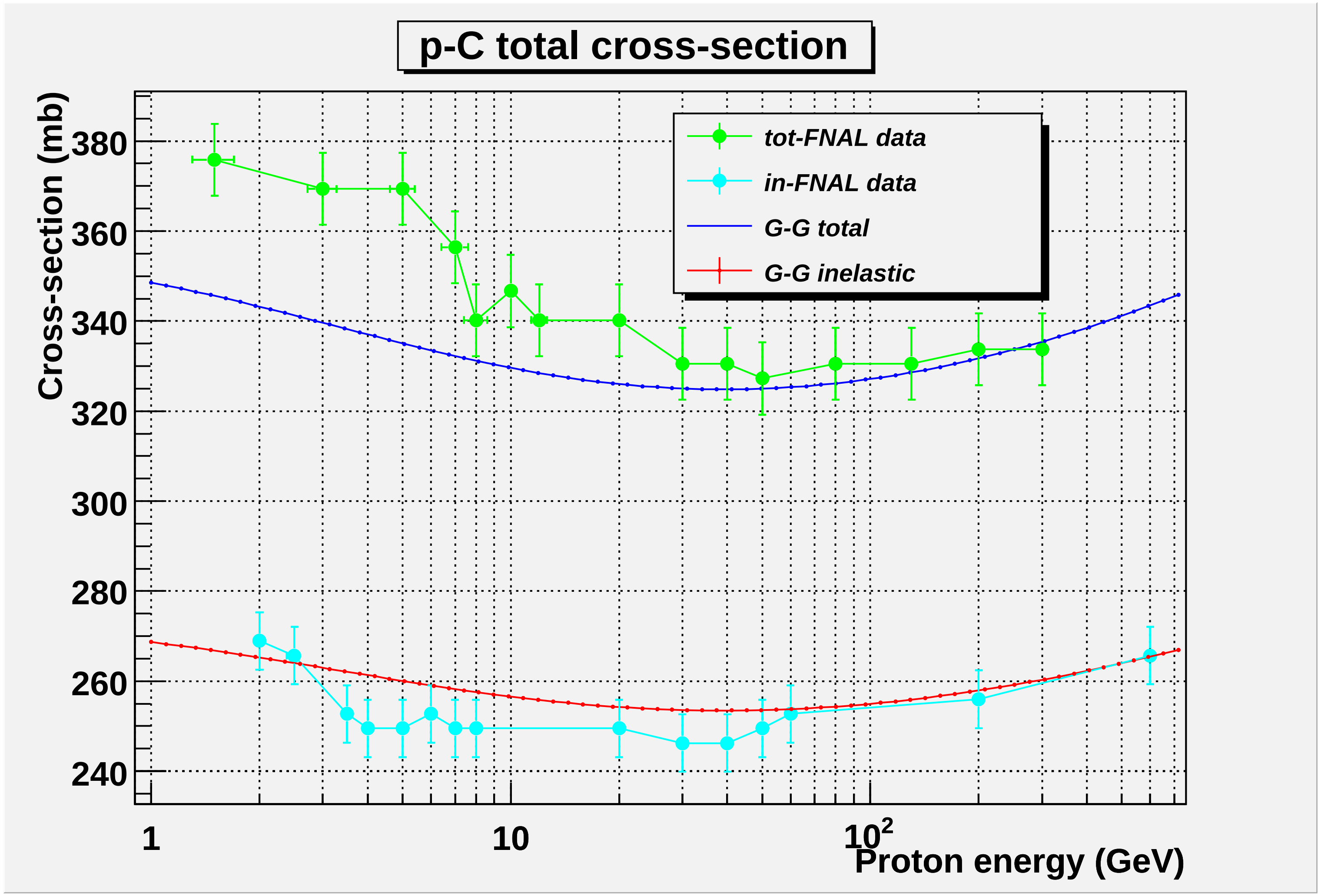
p-C total/inelastic cross sections
Geant4(Glauber-Gribov) vs experimental data



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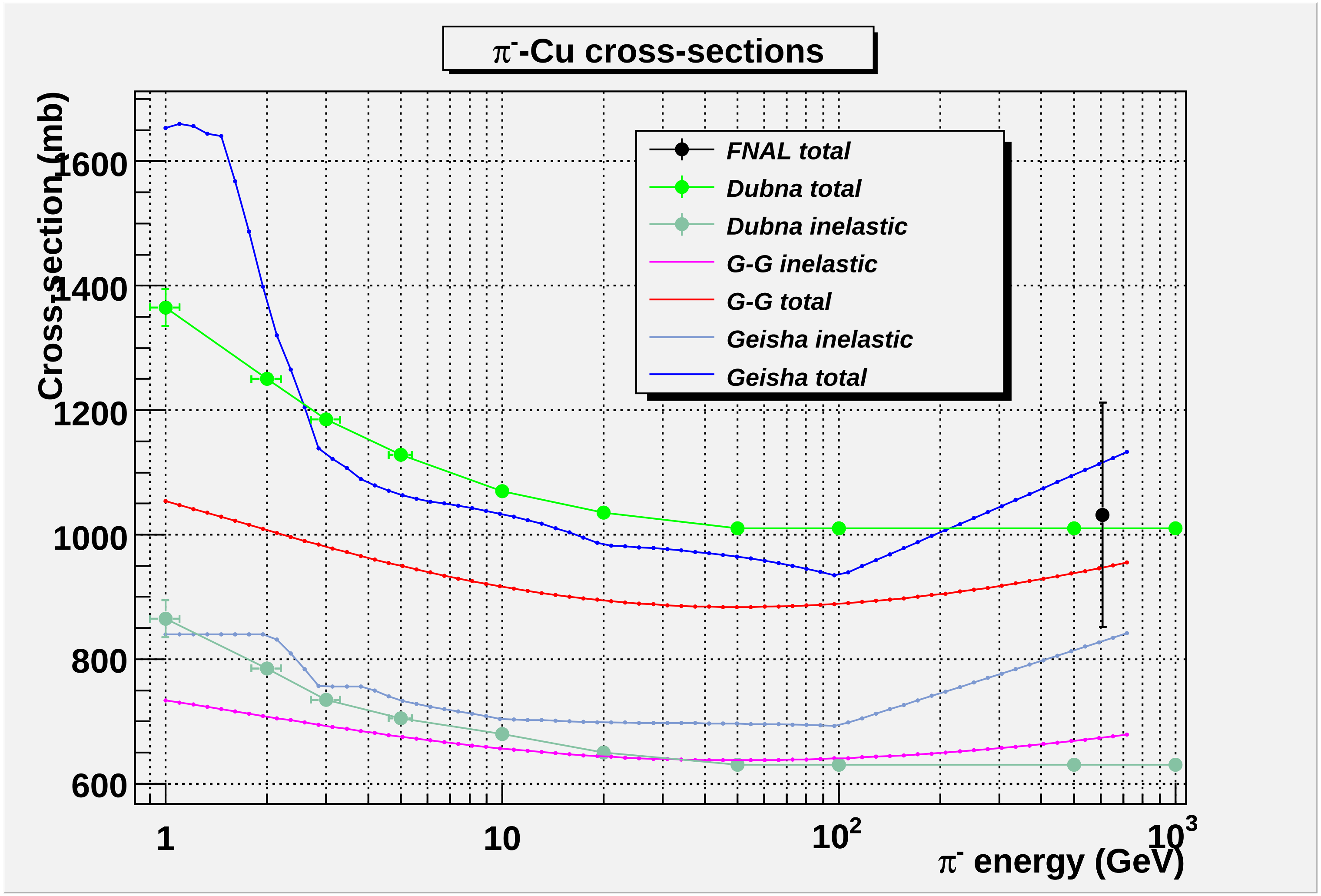
π-Cu total/inelastic cross sections
Geant4(Dubna, Geisha, Glauber-Gribov models) and FNAL data



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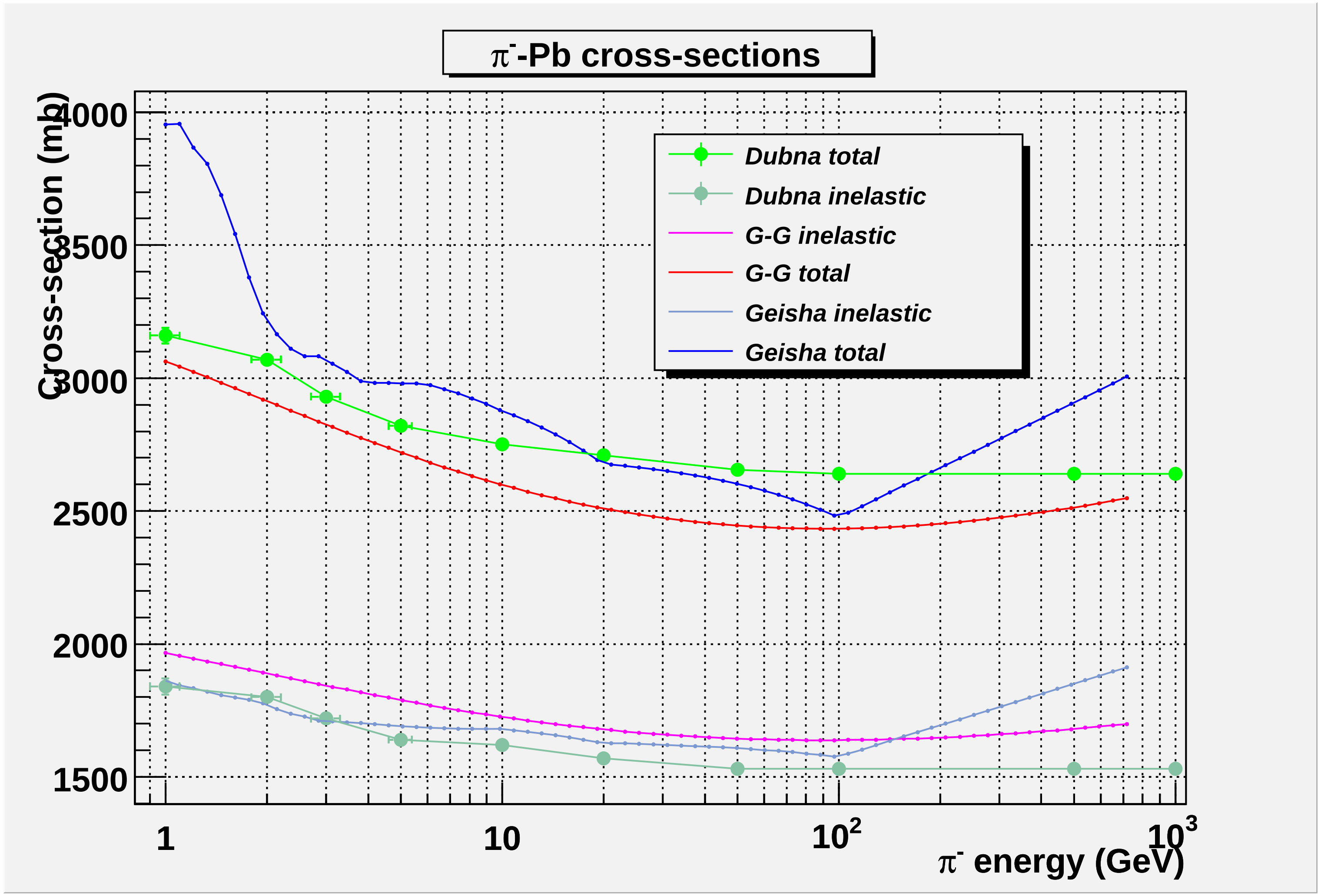
π-Pb total/inelastic cross sections Geant4(Dubna, Geisha, and Glauber-Gribov models)



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Neutrons:

Comparing withTARC measurements

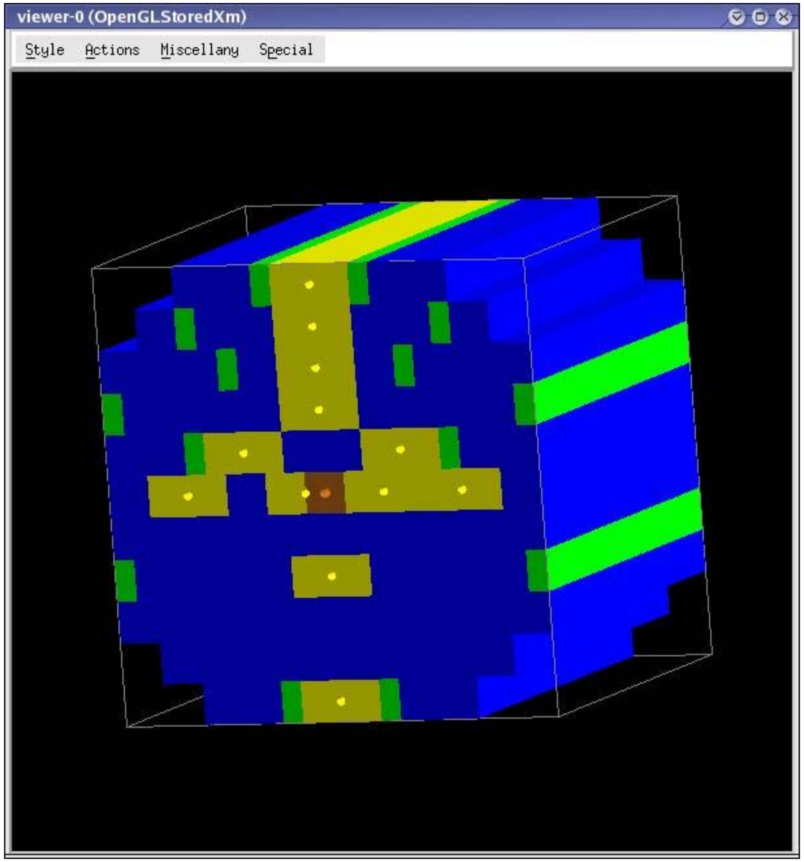
TARC – neutron validation

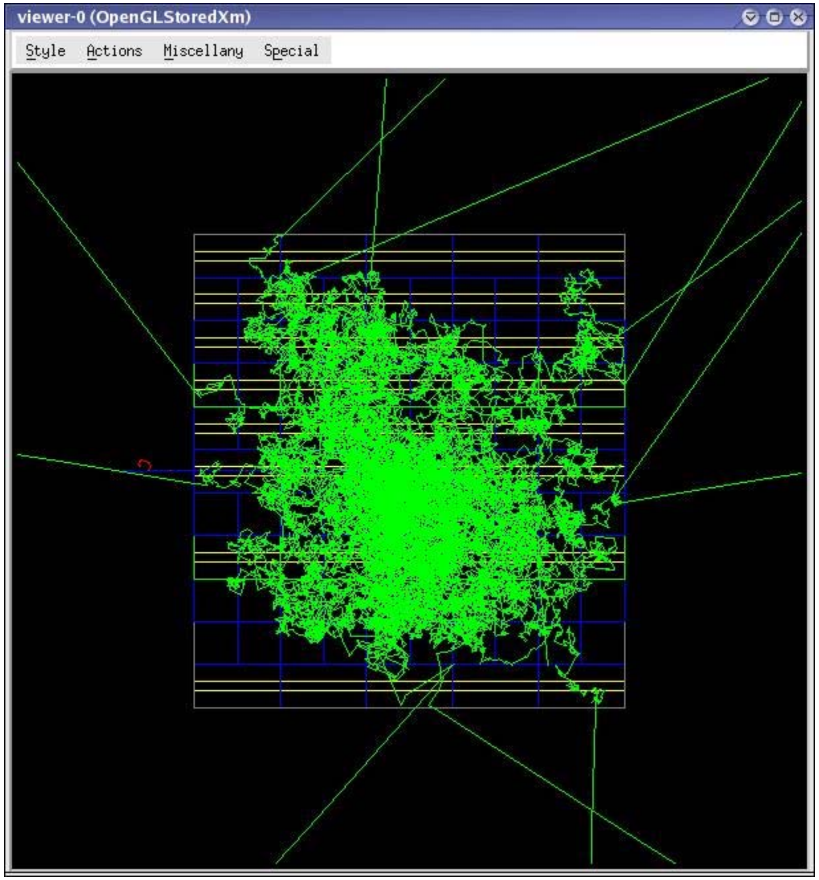
- TARC – Neutron-Driven Nuclear Transmutation by Adiabatic Resonance Crossing
  - Validates spallation neutron production from 2.5 and 3.5 GeV/c protons on pure lead
  - Validates energy-time relationship and thermalisation of neutrons
  - Absolute Neutron fluence spectrum from spallation production
  - Measures capture cross-sections on a number of specific isotopes -

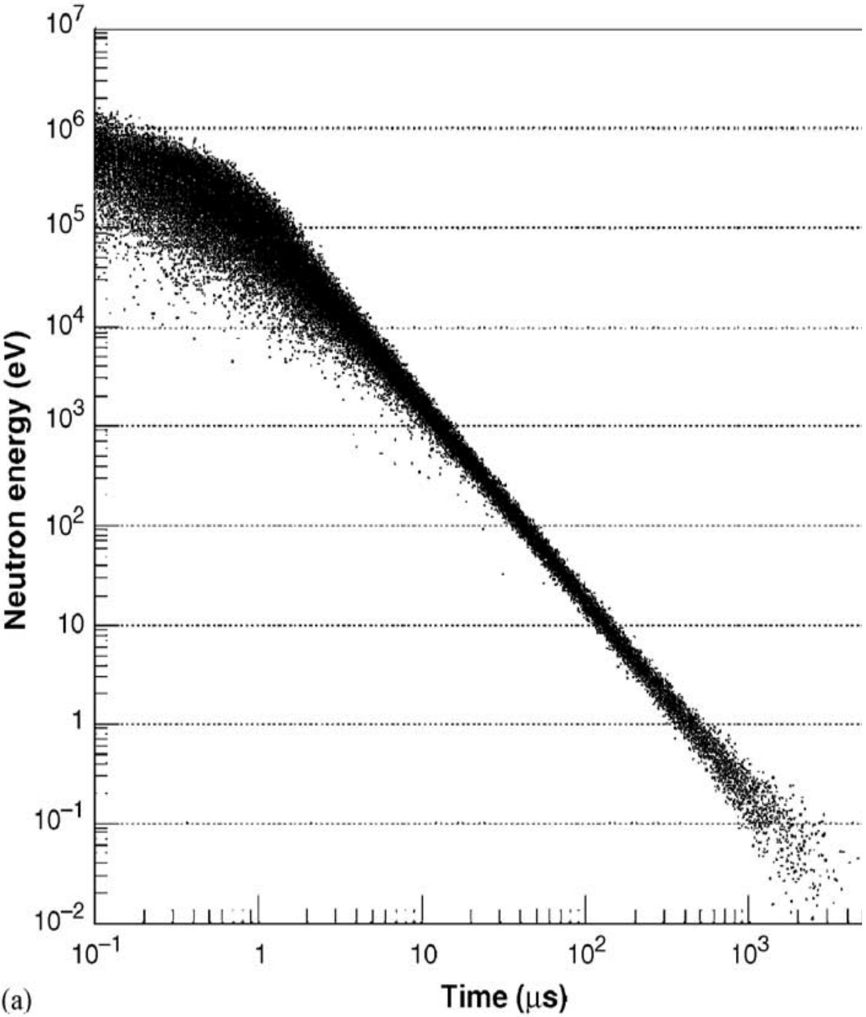
Isotopes used for CeF^3 activation calibration:-
^{nat}Ta, ^{nat}Au, ^{nat}Ag, ^{nat}In, ^{nat}Mn, ^{99}Tc. An unverified data-set for ^{99}Tc is available in G4NDL. Tantalum and silver are missing, the rest are present.
The energy is thus verified by picking up the resonance of each isotope and taking that as the neutron energy. The resonant energies are: ^{181}Ta(4.28eV), ^{197}Au(4.906eV), ^{109}Ag(5.19eV), ^{99}Tc(5.584eV), ^{115}In(9.07eV), ^{107}Ag(16.30eV), ^{xx}Tc(20.30eV) and ^{55}Mn(337eV).

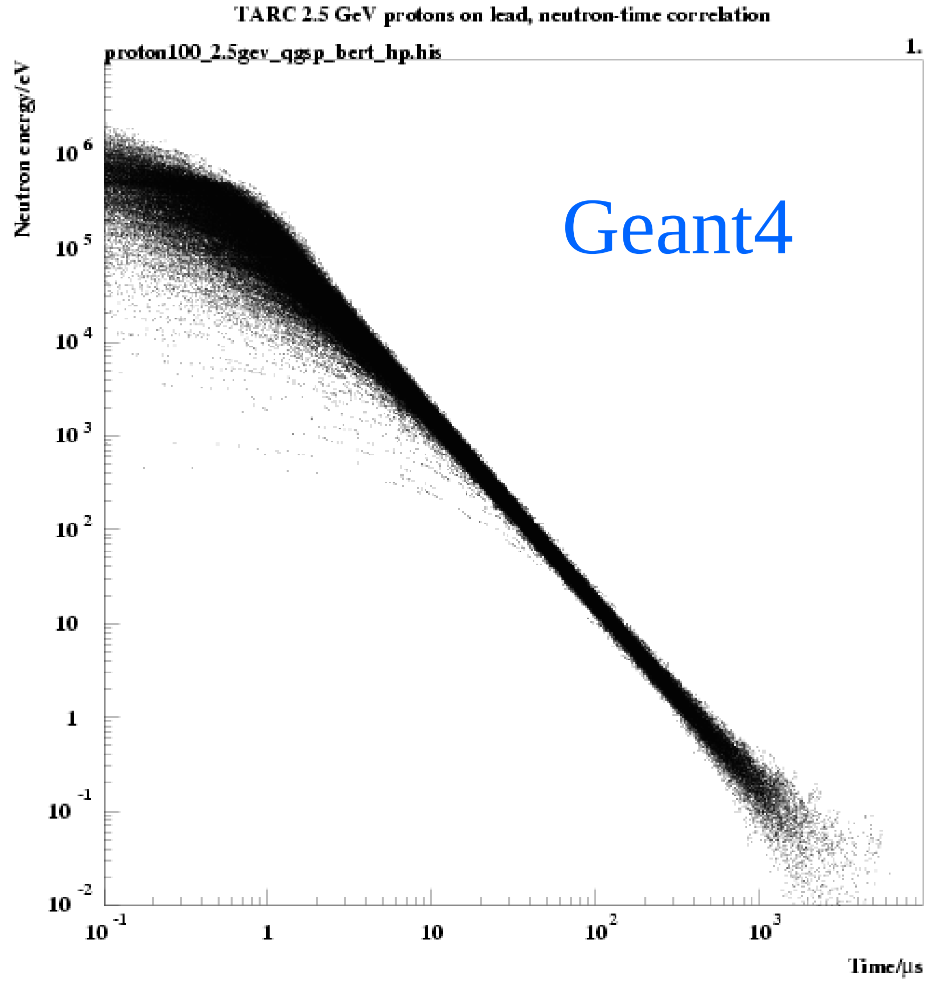
Experimental Set-up

- TARC comprises 334 tonnes of lead in a 3.3m x 3.3m x 3m cylindrical block
- 12 sample holes are located inside the volume
- Primary particle beam is either 2.5 or 3.5 GeV/c protons





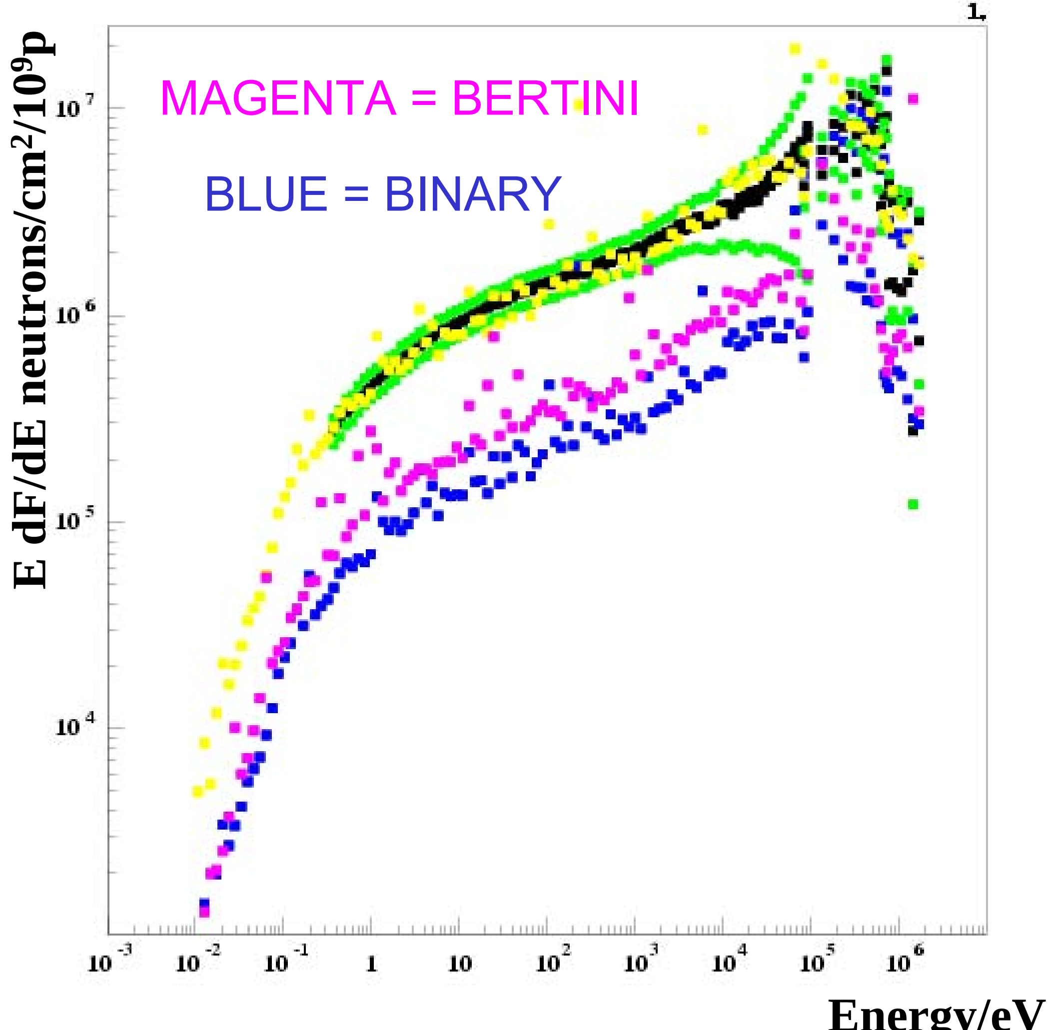




- Energy-Time correlation (right – Geant 4)
- (left-TARC/Fluka/Color), although the low energy population is quite different between physics list (as expected)

TARC Fluence

- Spectral fluence is determined from the energy-time correlation with cross-checks (lithium activation and He3 ionisation detectors)
- The simulated fluence is still below measurement
- The Bertini cascade gets closest to the data
- The spectral shape looks reasonable
- Yellow curve is ~ 4xBERTINI

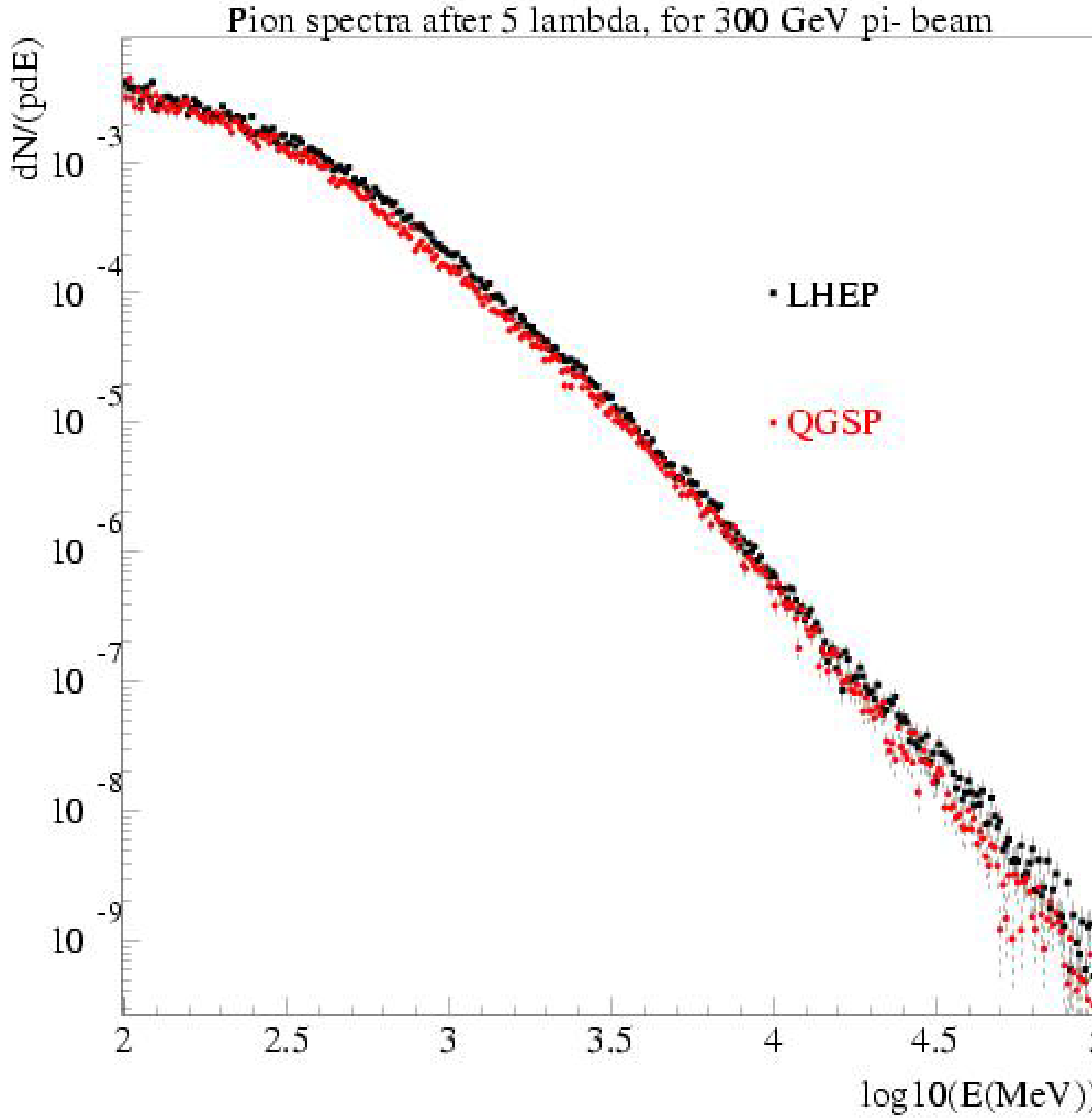


Shower shape – summary of general issues

- Investigated
  - Leading particle
  - Shower composition
  - π^0 production (ratio)
- Key open issues
  - π^0 production (rate)
  - Cross-sections
  - Verification for projectiles 3 GeV/c < p < 50 GeV/c
  - Neutron production (TARC comparisons)
    - Relevant for lateral shower shape
- Need for better coverage in region 3 GeV < E < 20 GeV
  - Extending current models (QGS) ?
  - Slow ~ 1-10 GeV proton production
  - New models ?

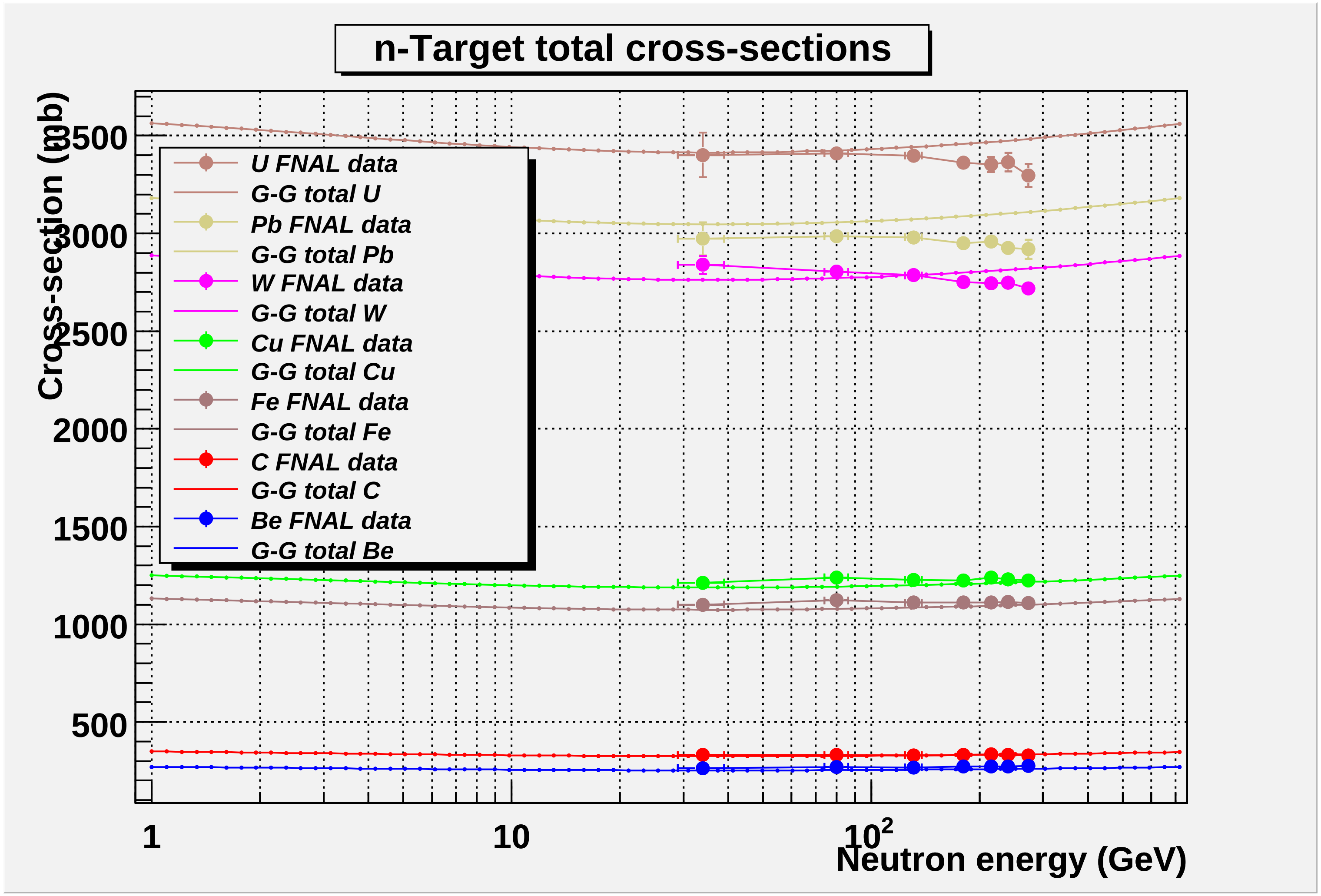
Additional slides

Spectrum at a surface



n-A total cross sections

Simplified Glauber-Gribov model vs. FNAL data



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TARC – aims and setup

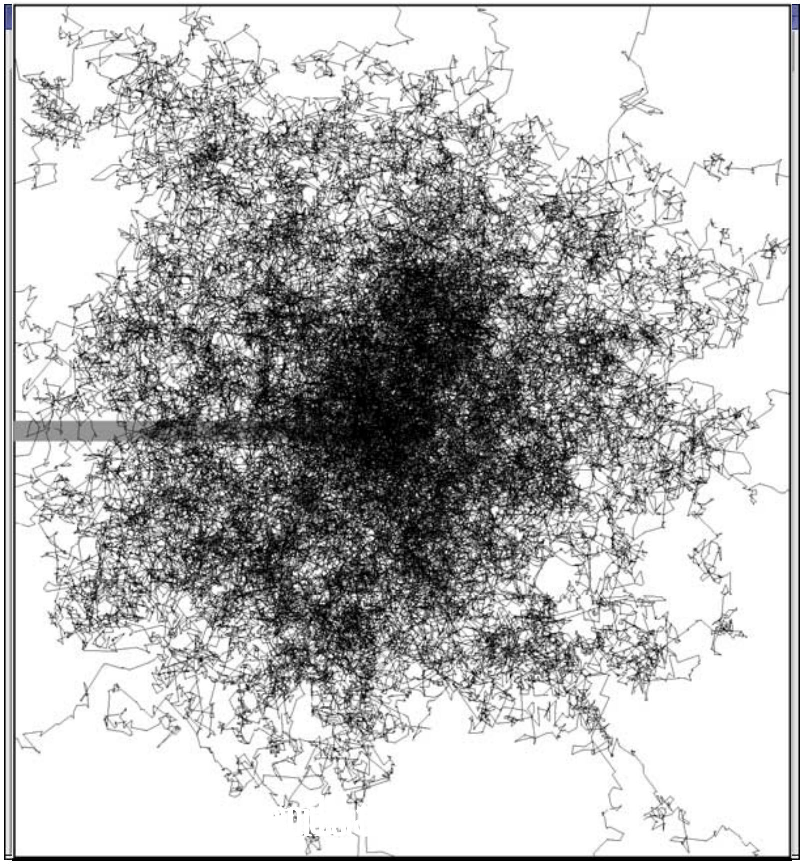
- Aims of experiment:
  - neutron production by GeV protons hitting a large lead volume;
  - neutron transport properties, on the distance scale relevant to industrial applications (reactor size);
  - efficiency of transmutation of ^{99}Tc and ^{129}I.

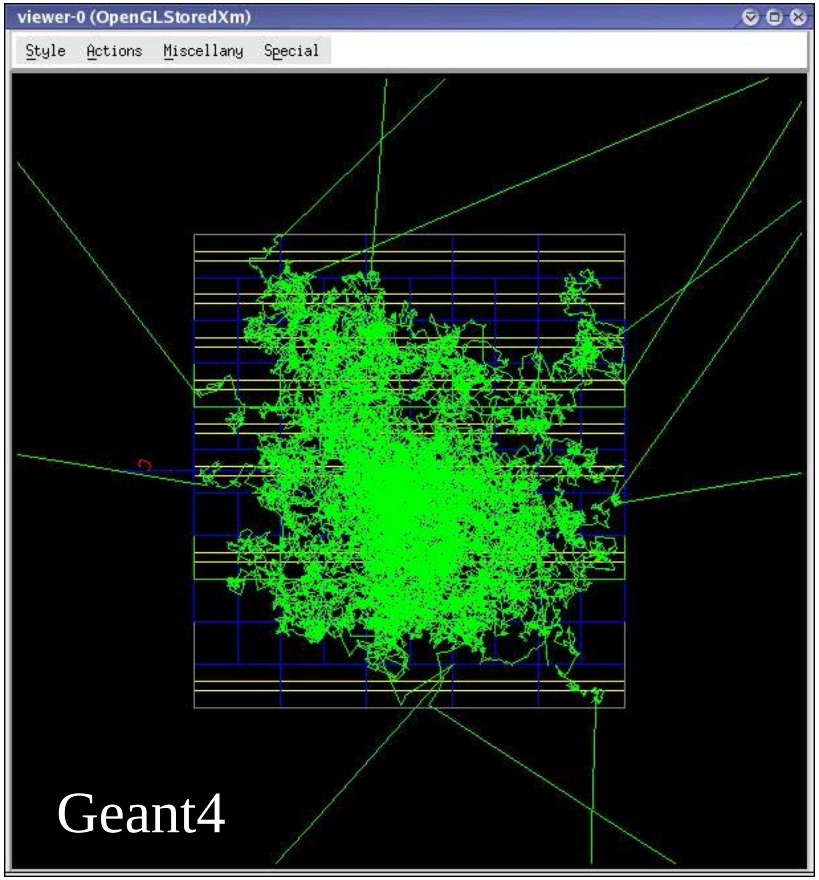
- Two types of measurements performed:
  - neutron fluence measurements with several complementary techniques over a broad neutron energy range from thermal up to a few MeV;
  - neutron capture rate measurements on ^{99}Tc (both differential and integral measurements) and on ^{129}I and ^{127}I (integral measurements). For ^{99}Tc a high statistics measurement of the apparent capture cross-section was obtained up to ~1 keV. Below this energy 85% of all captures occur in a typical TARC neutron spectrum.

- The set-up is 334 tonnes of pure lead with approximate cylindrical symmetry about the beam axis. Diameter is 3.3m and length 3m. Lead volume is 29.3 m^3. The beam is introduced through a 77.2mm diameter blind hole, 1.2m long. This leads to the neutron shower being approximately centred in the middle of the 3m lead length. The lead is 99.99% pure.

Experimental Set-up

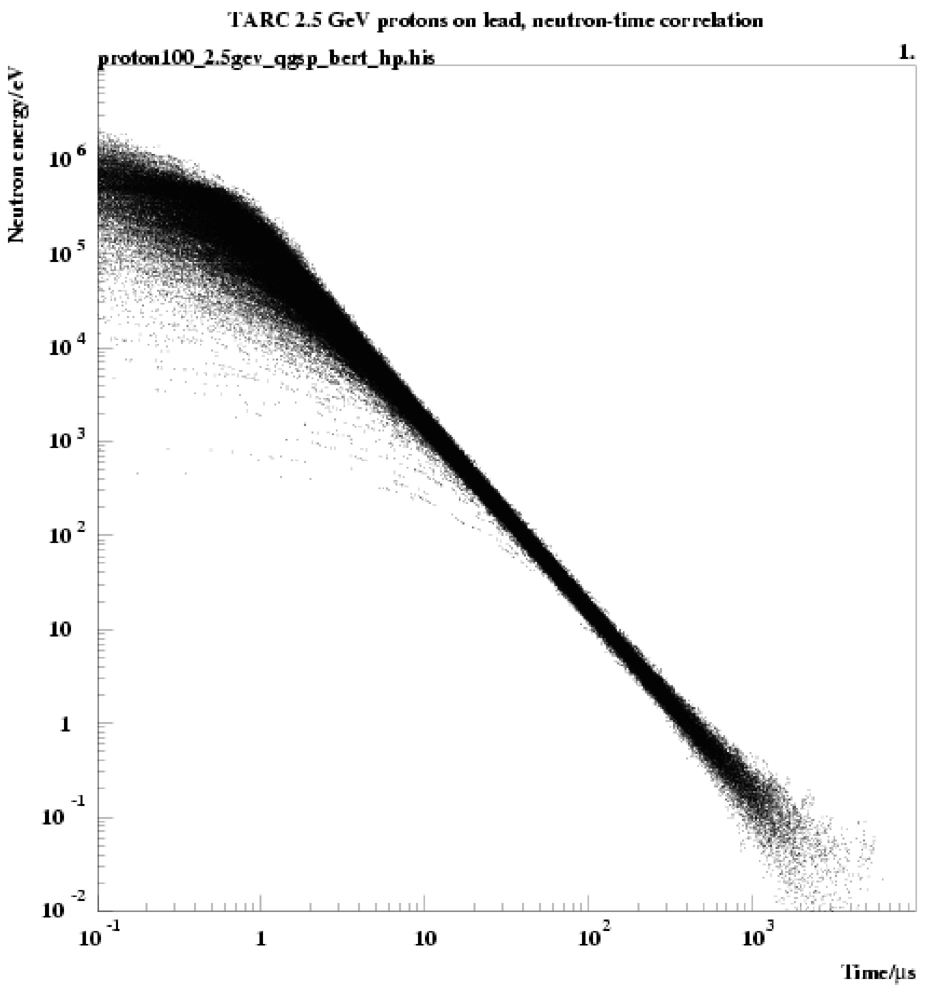
- TARC comprises 334 tonnes of lead in a 3.3m x 3.3m x 3m cylindrical block
- 12 sample holes are located inside the volume
- Primary particle beam is either 2.5 or 3.5 GeV/c protons





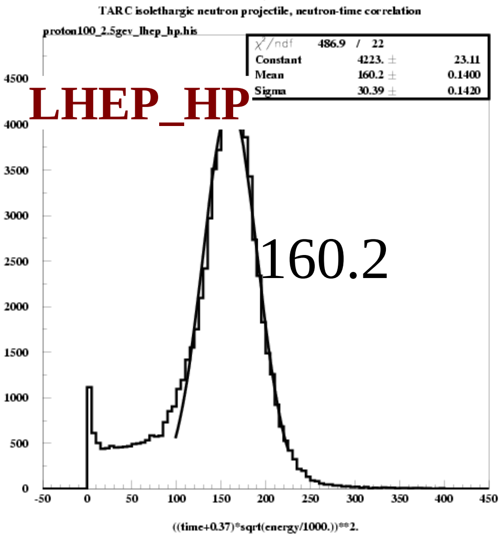
Neutron Energy-Time Correlation

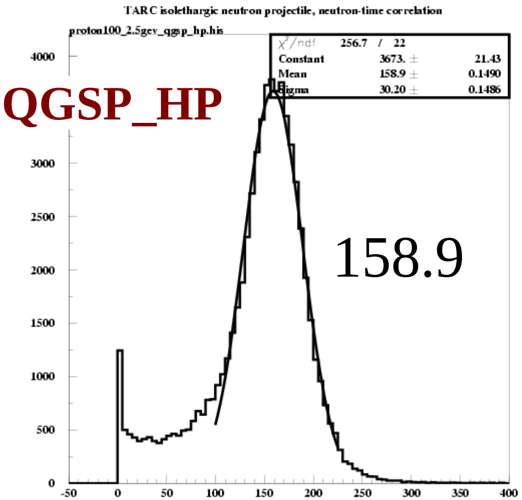
- Neutron energy and time are stored for the flux through a given radial shell



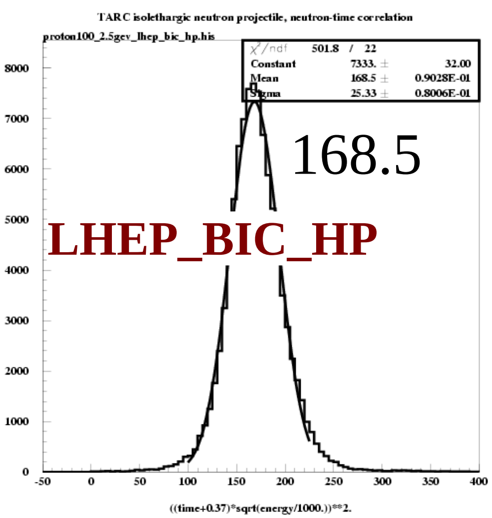
Neutron Energy-Time Correlation

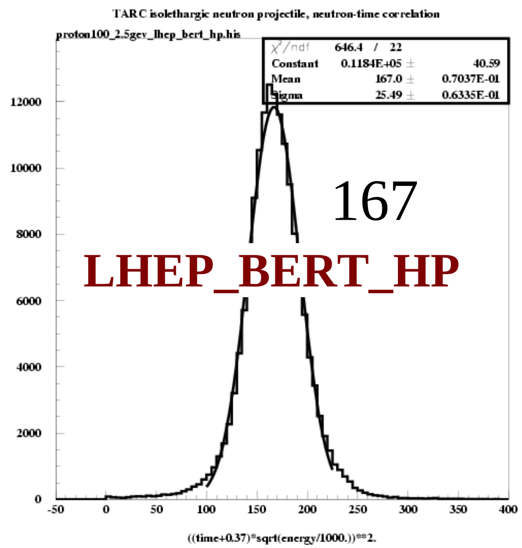
- The slope of the correlation can approximate a Gaussian distribution





experiment and TARC simulation give 173±2



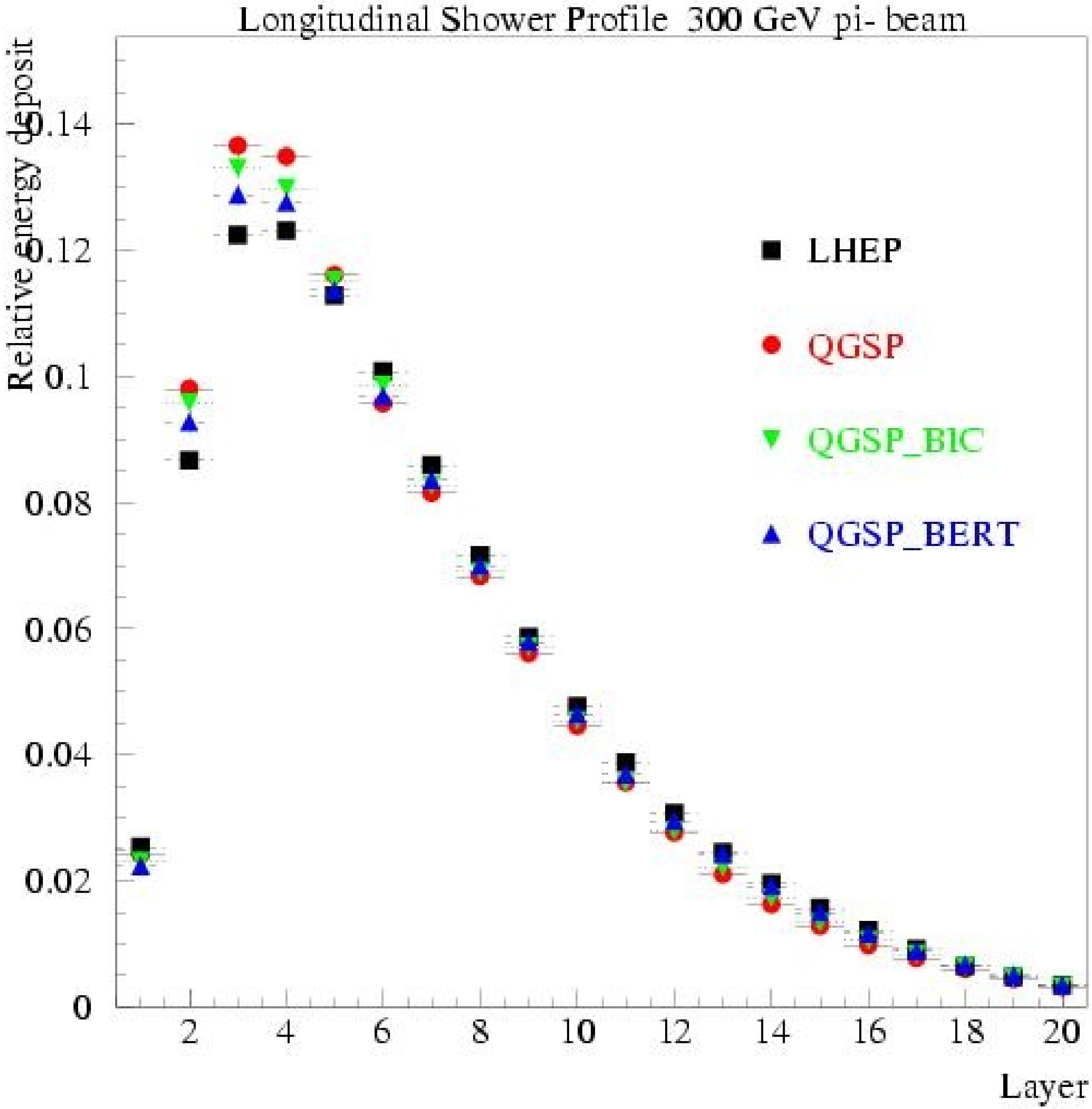


- Bertini and Binary cascades are close to agreement with experiment

Minuit errors on the mean are between 0.03 and 0.08

Fluence Calculation

- In the TARC analysis they use a definition of fluence as follows:
  - For monoenergetic neutrons of velocity *V* and density *n*, the neutron flux is defined as ϕ = *Vn and is a quantity that upon multiplying by the macroscopic cross-section (Σ), one obtains the neutron reaction rate per unit volume*
  - *Should not be confused with the rate of particles crossing a surface element, which is a 'current' and depends on the orientation of the direction of the particles*
- Three procedures were used to determine the fluence:
  1) dN/dS_{perp} is the number of neutrons crossing a surface element dS, with dS_{perp} = dScos❑ where ❑ is the neutron angle to the normal
  2) the average fluence in a volume element dV as dl/dV, where dl is the total track length of neutrons in dV
  3) Number of interactions in a detector and computing fluence as
     ($1/\Sigma$)dN/dV, where dN is the number of interactions in dV
- The first two were used in simulation



Longitudinal Shower Profile 300 GeV pi- beam
Relative energy deposit
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2
4
6
8
10
12
14
16
18
20
Layer
LHEP
QGSP
QGSP_BIC
QGSP_BERT

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