VALSIM progress report

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A. Ribon, V. Uzinskiy

Aug 27, 2007

Outline

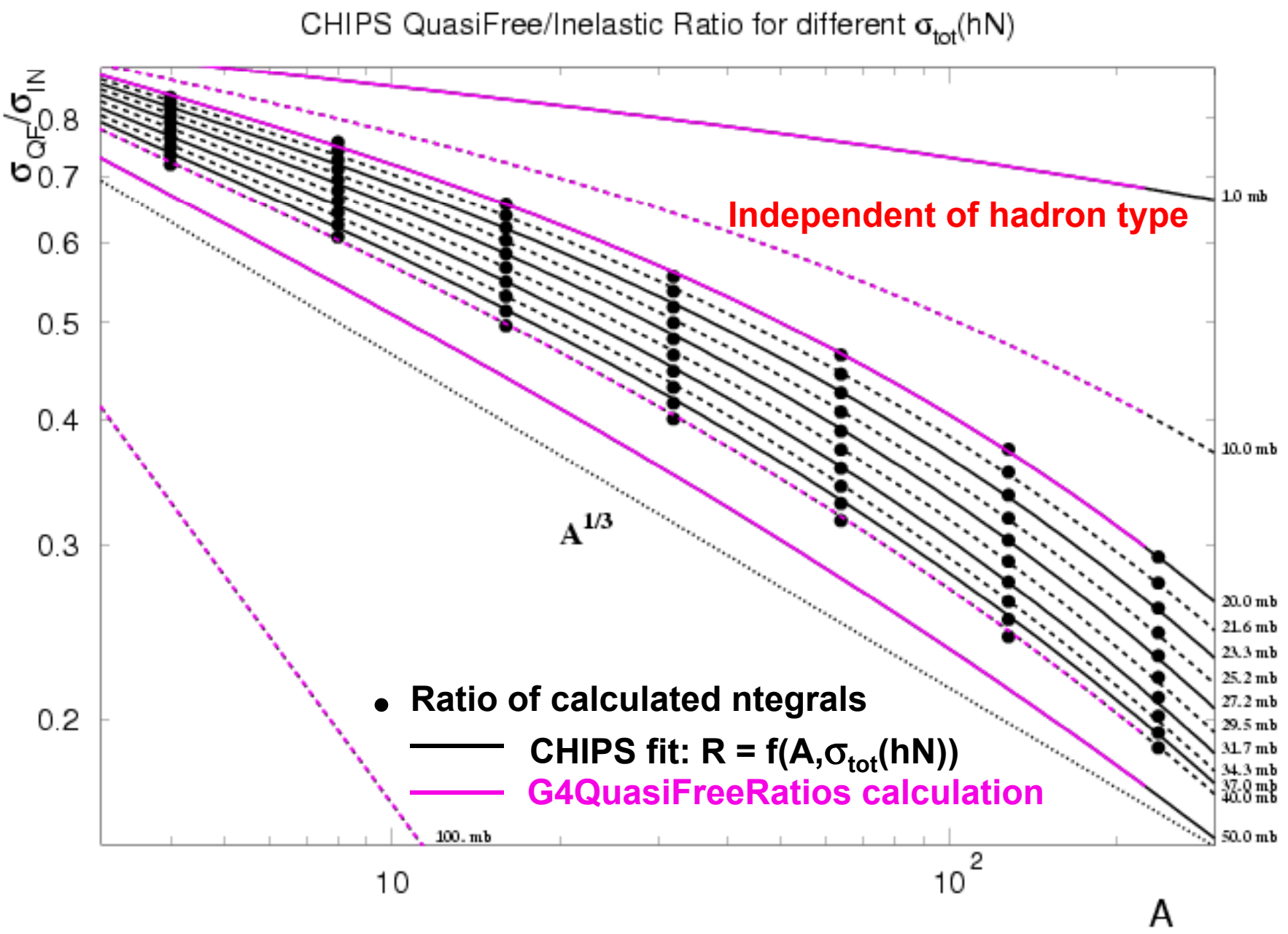
- Introduction
- Model improvements
- Geant4 Releases
  - Quasi-elastic channel
  - Revised FTF model
- Validation
  - Cross sections
  - Comparisons with TARC experiment data
- Open Issues

Model improvements

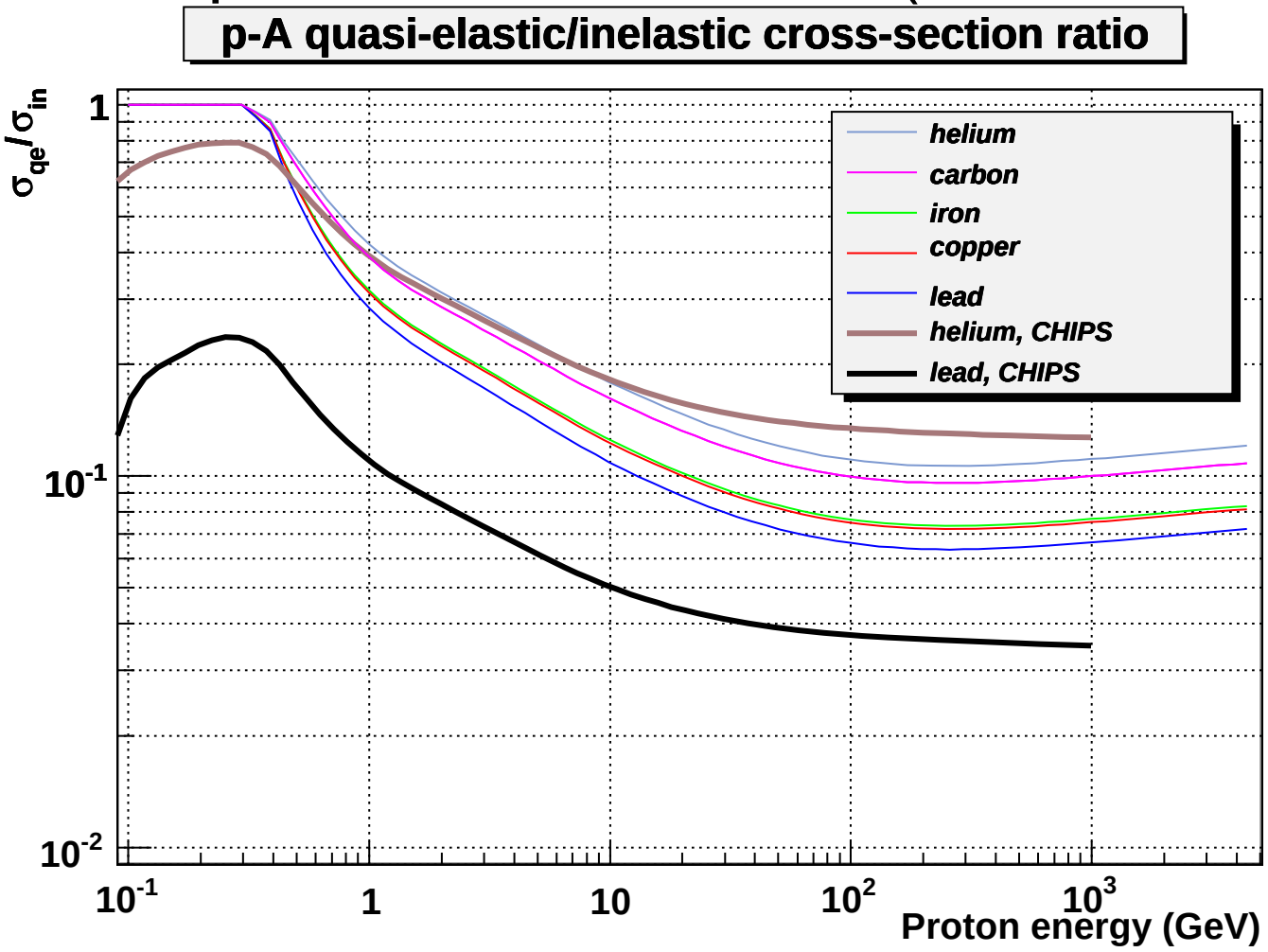
- Identified diffraction and quasi-elastic channels as key channels
  - Influence shower shape significantly
  - Need for validation
  - String models deficient in modeling these
- Improvements undertaken
  - FTF model revised (V. Uzinskiy)
  - Separate Quasi-elastic channel created for our QGS model (G. Folger, M. Kossov)
  - Improved elastic scattering: cross-sections, t-distribution from fits to data (M. Kossov)

Quasi-elastic and inelastic

- To model Quasi-elastic interactions
  - Calculated ratio of cross-sections
    - Quasi-elastic / Inelastic
  - Split inelastic cross-section of QGS
    - deep inelastic for our QGS model
    - Quasi-elastic for new model (M.K.)


CHIPS QuasiFree/Inelastic Ratio for different σtot(hN)
σQF/σIN
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Independent of hadron type
A1/3
1.0 mb
10.0 mb
20.0 mb
21.6 mb
23.3 mb
25.2 mb
27.2 mb
29.5 mb
31.7 mb
34.3 mb
37.0 mb
40.0 mb
50.0 mb
100. mb
• Ratio of calculated ntegrals
CHIPS fit: R = f(A,σtot(hN))
G4QuasiFreeRatios calculation
10
10 2
A

Simplified Glauber model (V. Grichine)

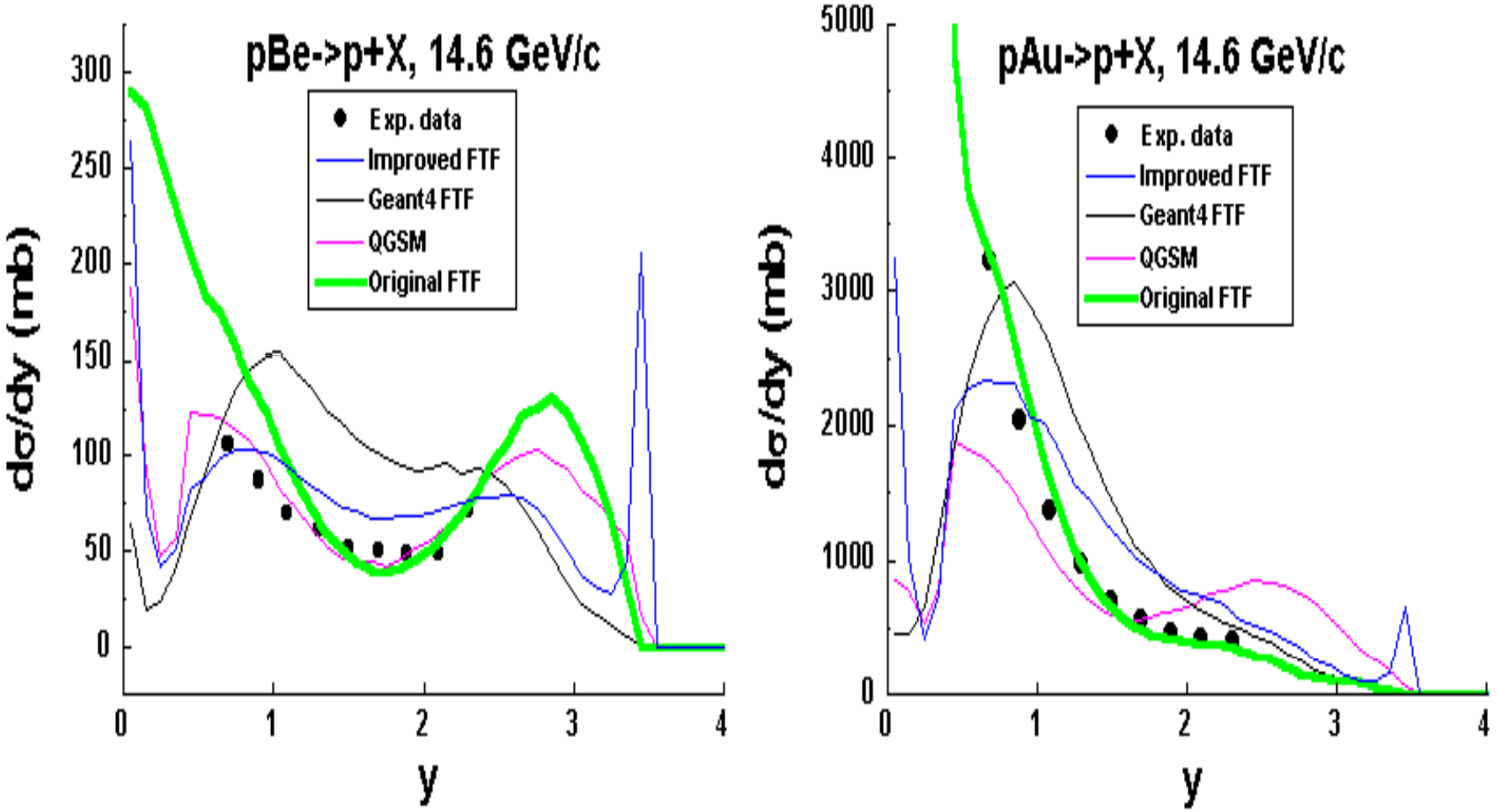


Revision of Fritiof model

V. Uzhinskiy

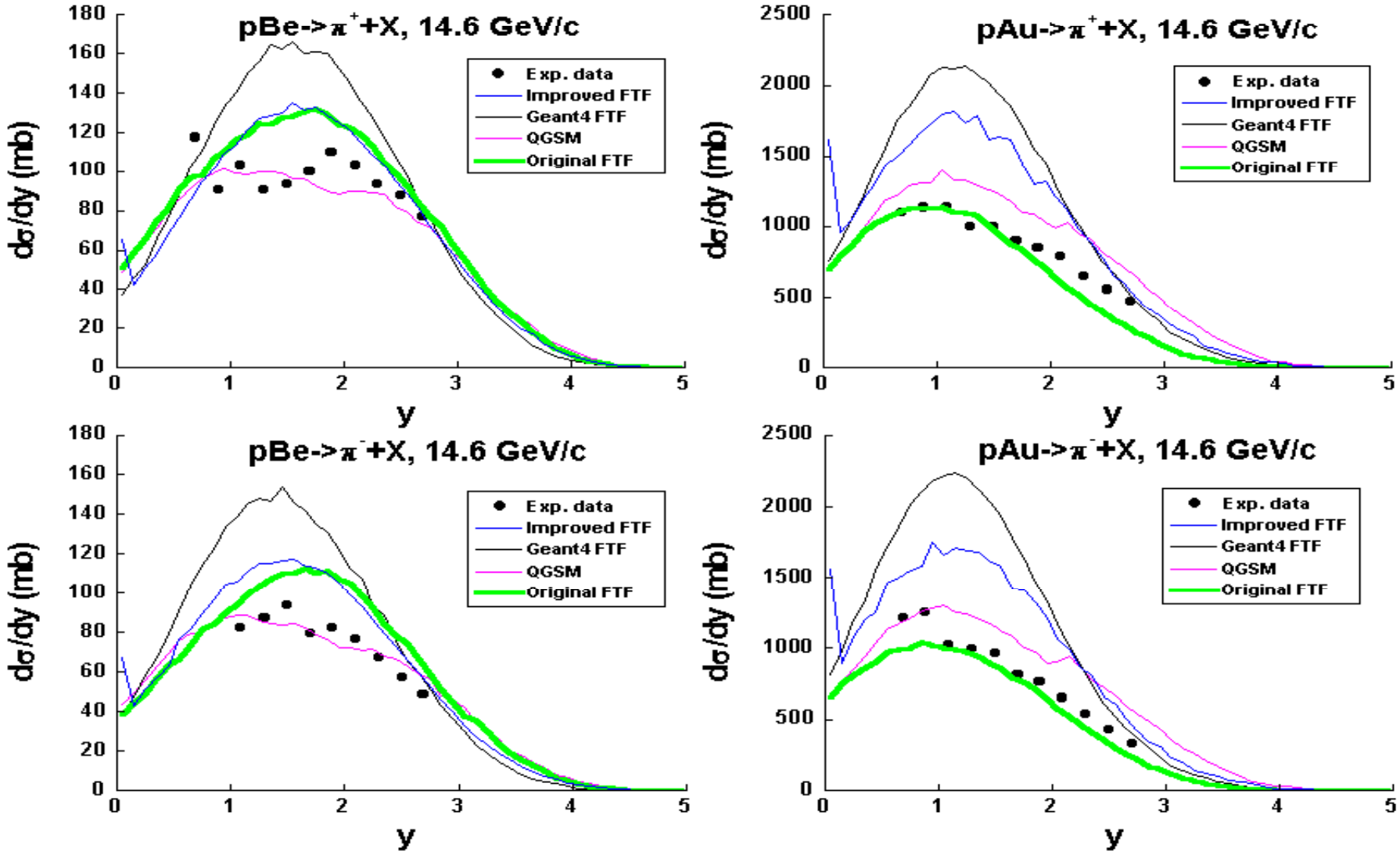
p+Be, p+Au interactions at 14.6 GeV/c
T. Abbott et al. (E-802 Callab.), Phys. Rev. D45 (1992) 3906

Comparison with exp. data



In FTF model probabilities of intra-nuclear collisions were taken from QGSM.
In the original FRITIOF model - from Glauber approximation

Comparison with exp. data

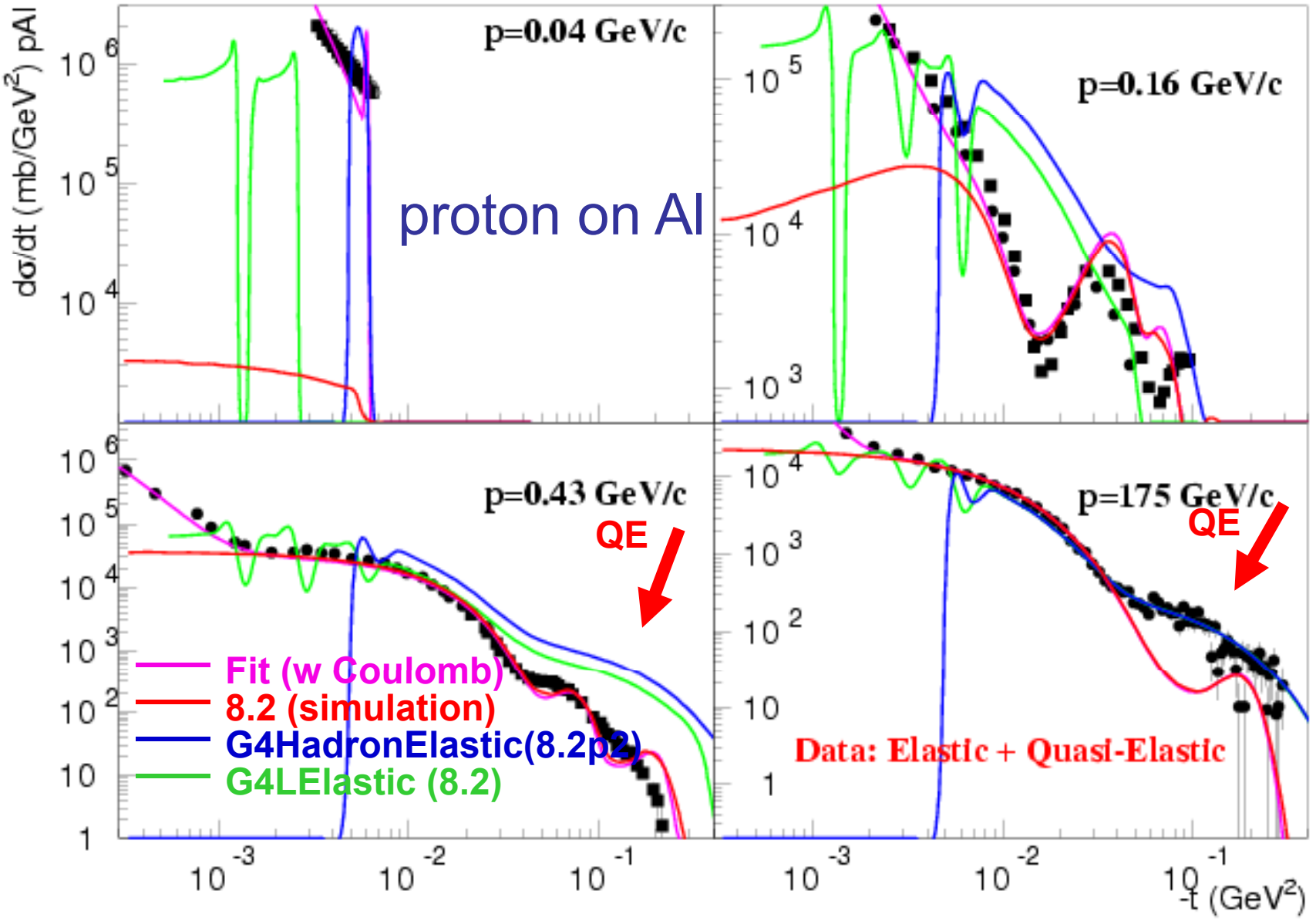


There is a problem with description of rapidity distributions

Improvement of Elastic Scattering

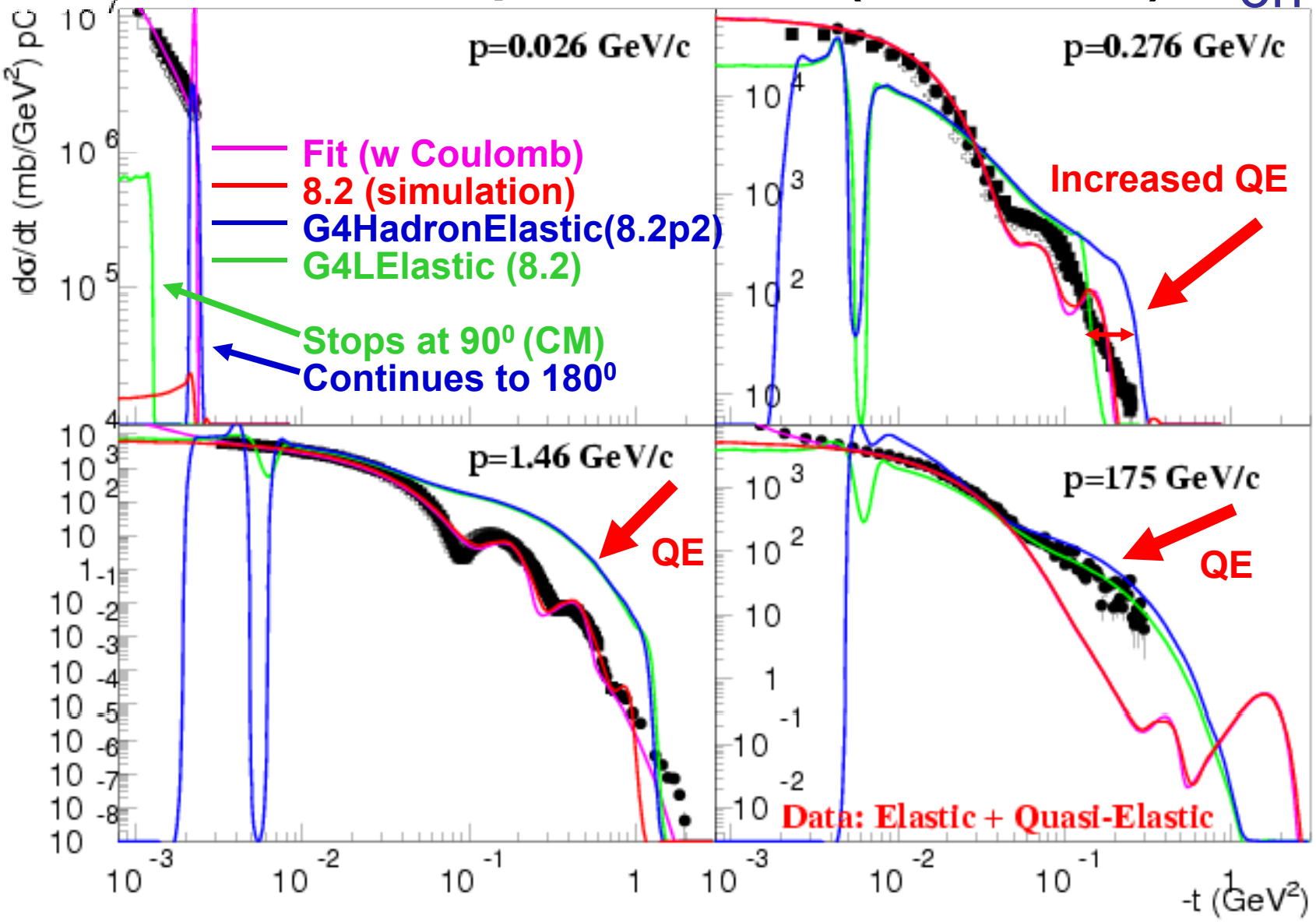
M. Kossov

Improvement of Elastic Scattering



New Elastic process (CHIPS)

proton on C



Process is called 'QElastic'

M. Kosov

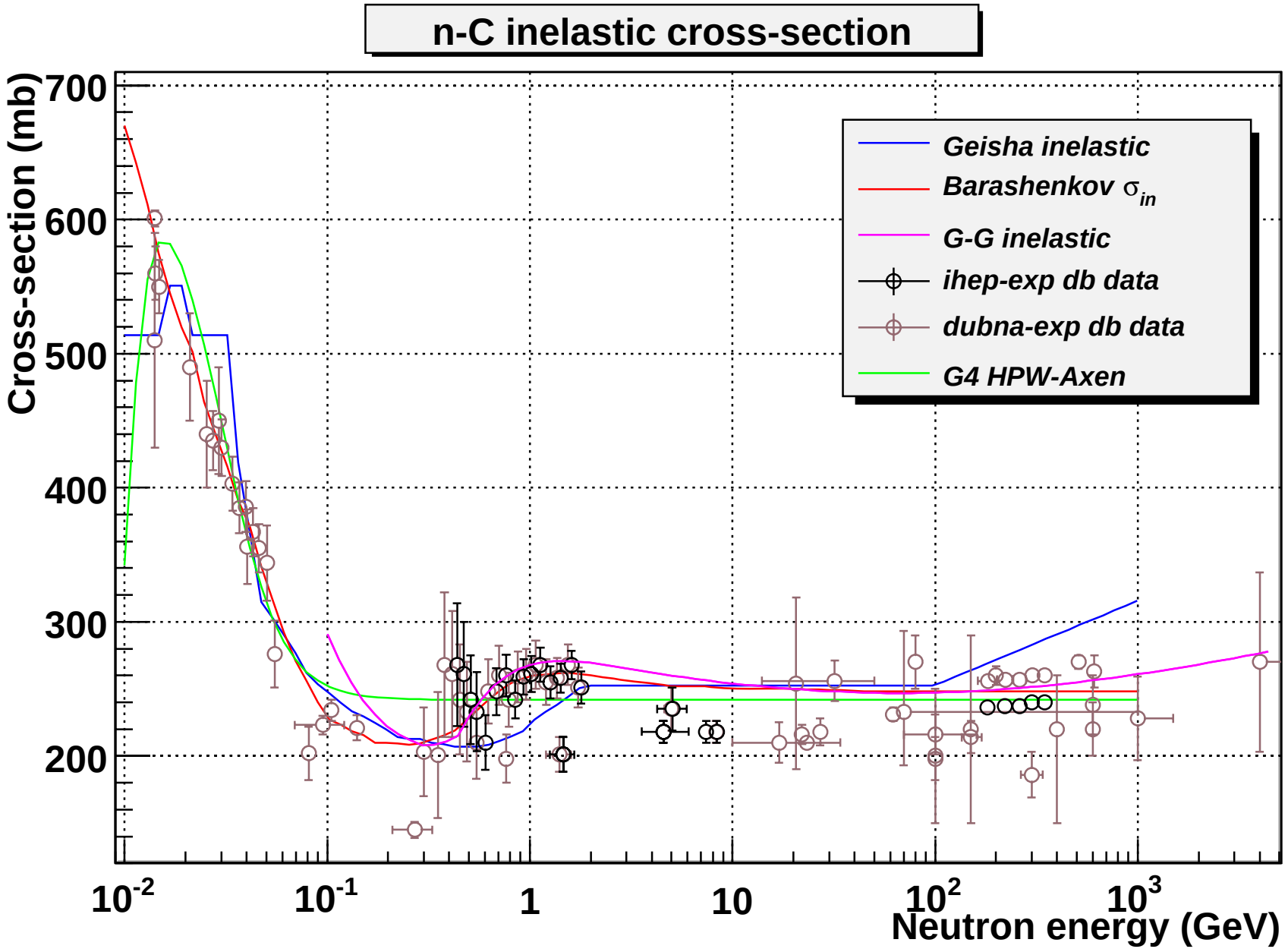
Physics lists and the Quasi-elastic channel

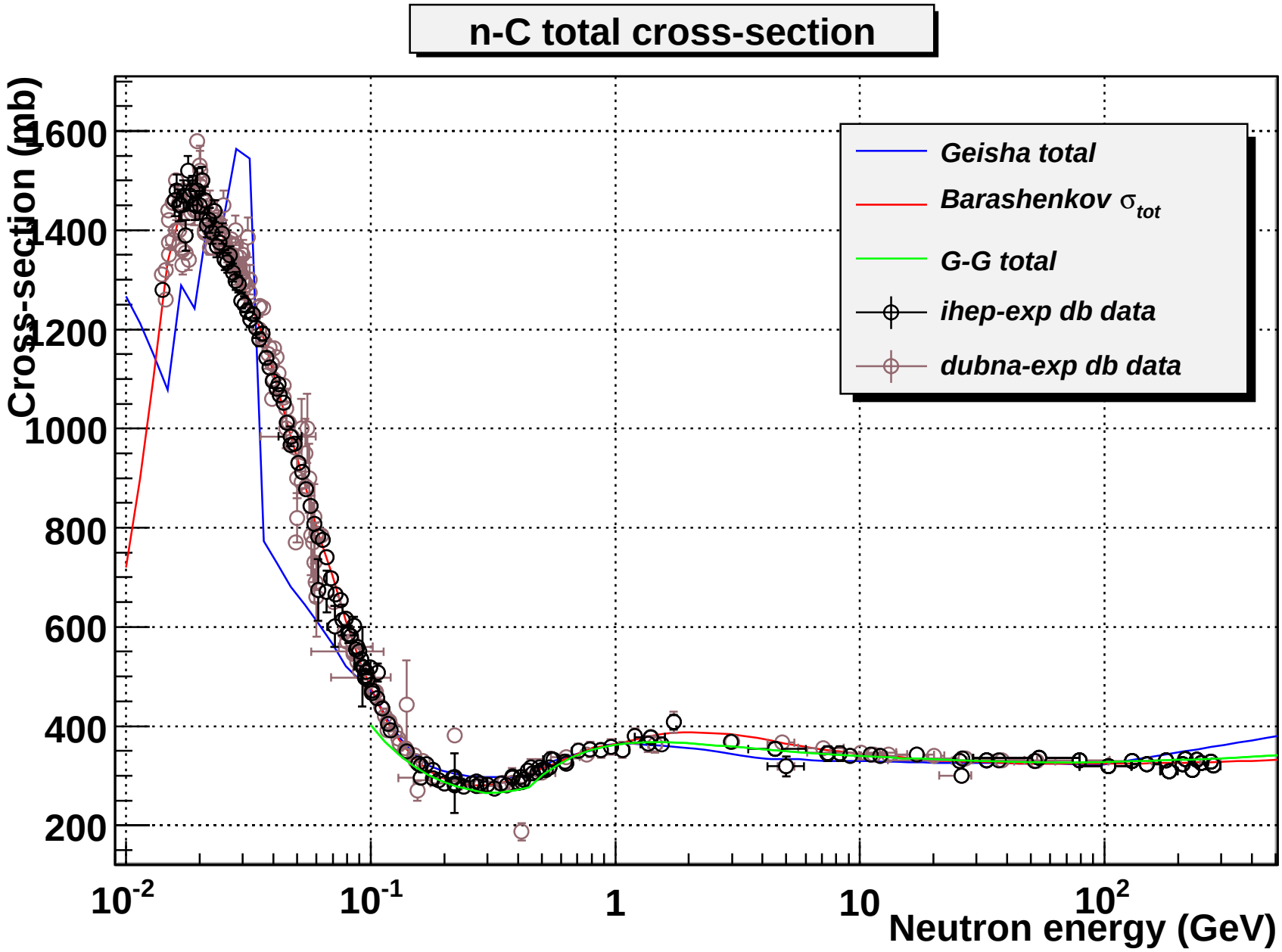
- The new option splits the inelastic cross-section
  - between the Quark Gluon String (QGS) model and a quasi-elastic interaction
- It is activated in QGS physics lists:
  - QGSP, QGSC, QGSP_BERT, QGSP_BIC
  - QGSP_EMV, QGSP_BERT_EMV
  - QGSP_BERT_HP, QGSP_BIC_HP **(to be verified)**
- Except in QGSP_NQE, QGSP_BERT_NQE where it is inactive
  - New temporary list, created to offer this possibility.
- Not relevant to FTFx, LHEP physics lists
  - They do not use QGS model.

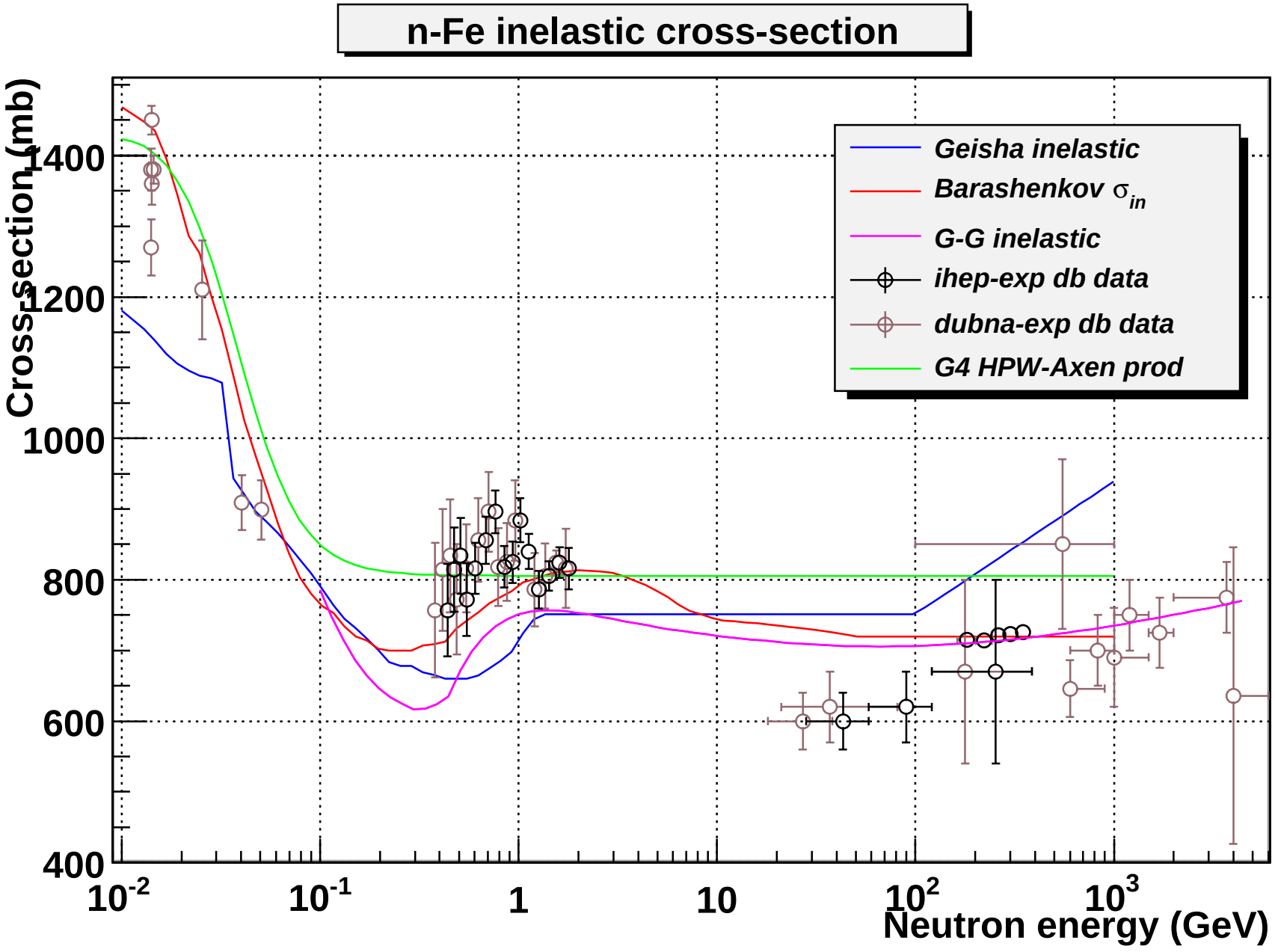
Cross sections

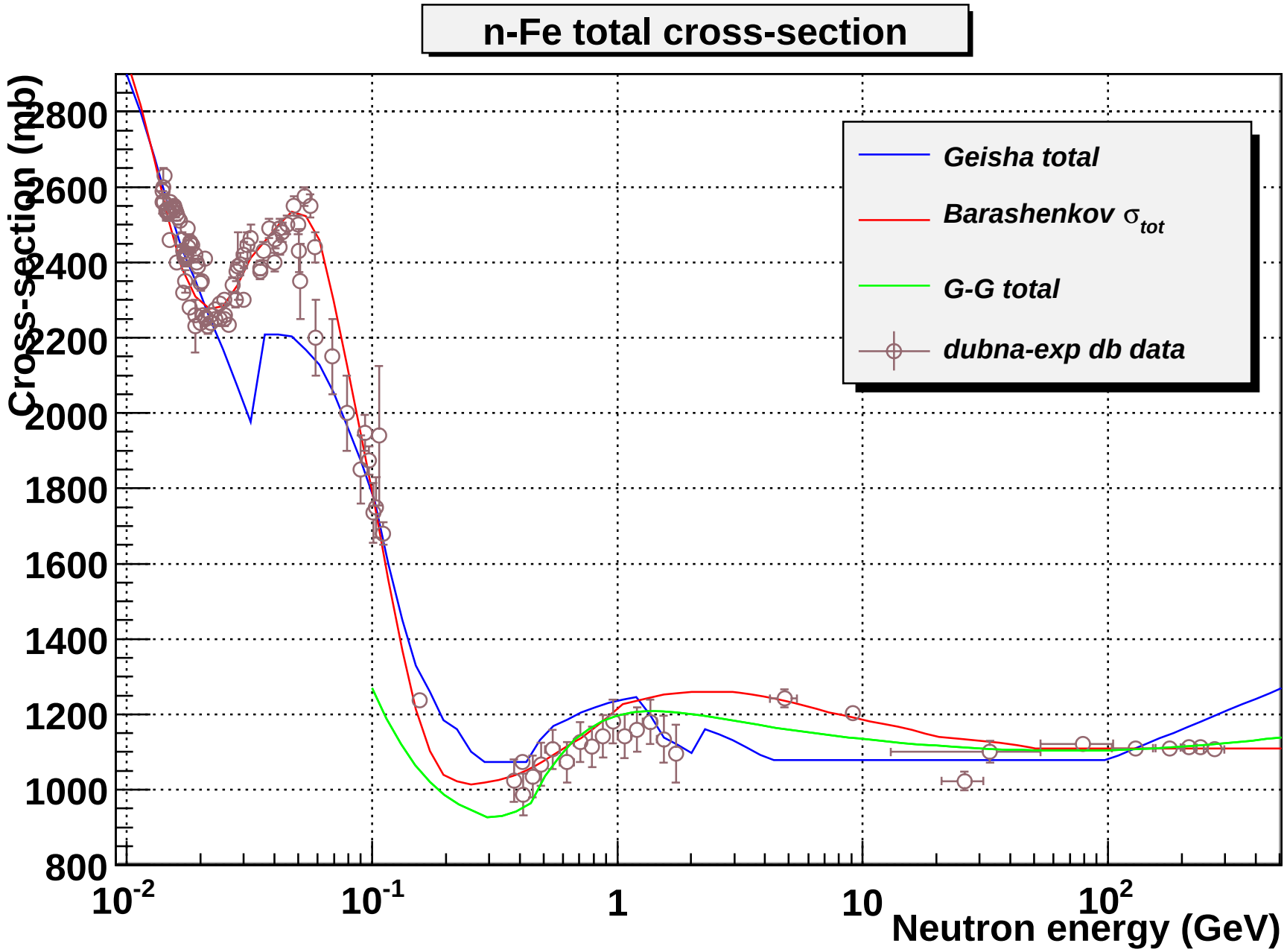
V. Grichine

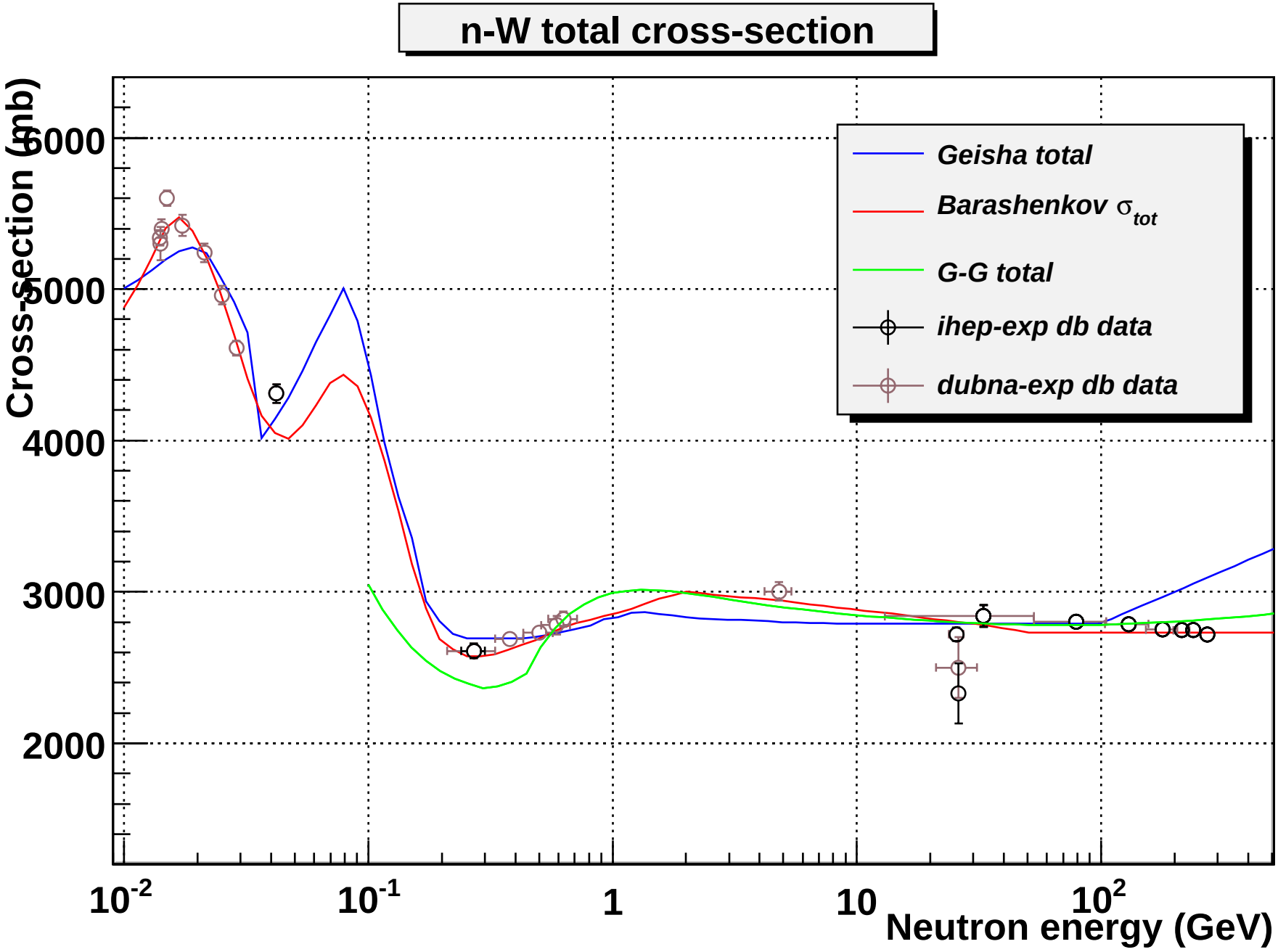
- Review and validation of G4 cross-sections
  - Inelastic hadron-nuclear
  - Total hadron-nuclear
    - Note: In Geant4 the elastic and inelastic are separate
      - The totals are the sums elastic & inelastic, as used in different physics lists
- As a result, created two new cross section classes:
  - Barashenkov cross-sections for nucleons
  - Simplified ‘Glauber-Gribov’ model for scaling E>10 GeV


n-C inelastic cross-section
Cross-section (mb)
700
600
500
400
300
200
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
Neutron energy (GeV)
Geisha inelastic
Barashenkov σ_{in}
G-G inelastic
ihep-exp db data
dubna-exp db data
G4 HPW-Axen


n-C total cross-section
Cross-section (mb)
1600
1400
1200
1000
800
600
400
200
10^{-2}
10^{-1}
1
10
10^{2}
Neutron energy (GeV)
Geisha total
Barashenkov σ_{tot}
G-G total
ihep-exp db data
dubna-exp db data

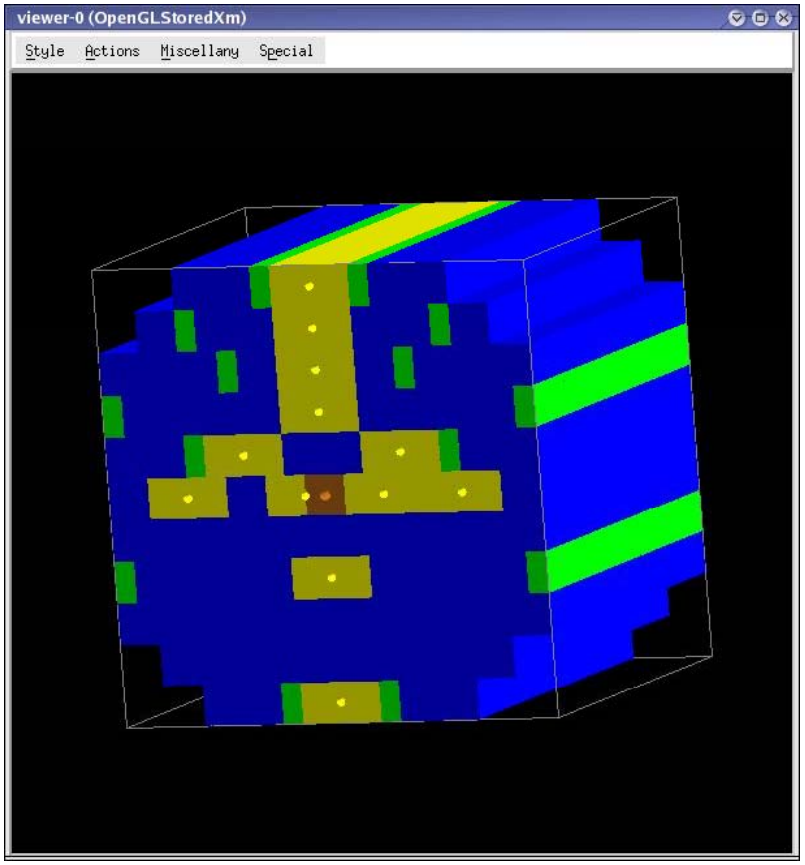

n-Fe inelastic cross-section
Cross-section (mb)
1400
1200
1000
800
600
400
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
Neutron energy (GeV)
Geisha inelastic
Barashenkov σ_{in}
G-G inelastic
ihep-exp db data
dubna-exp db data
G4 HPW-Axen prod


n-Fe total cross-section
Cross-section (mb)
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
10^{-2}
10^{-1}
1
10
10^{2}
Neutron energy (GeV)
Geisha total
Barashenkov σ_{tot}
G-G total
dubna-exp db data


n-W total cross-section
Cross-section (mb)
6000
5000
4000
3000
2000
10^{-2}
10^{-1}
1
10
10^{2}
Neutron energy (GeV)
Geisha total
Barashenkov σ_{tot}
G-G total
ihep-exp db data
dubna-exp db data

The TARC Experiment

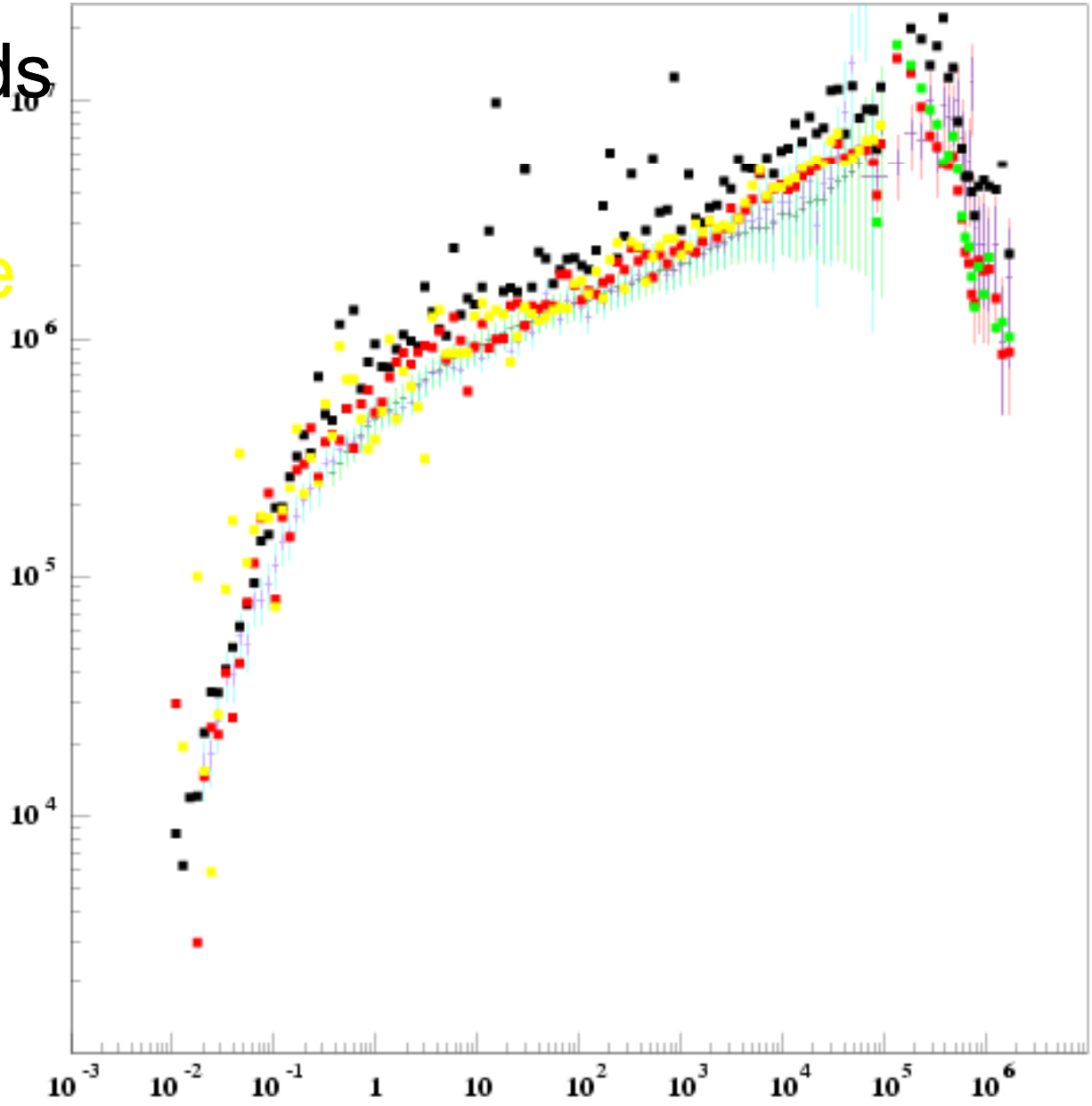
- Neutron Driven Nuclear Transmutation by Adiabatic Resonance Crossing (Cern 96-97)
- 2.5 or 3.5 GeV/c proton beam.
- 334 tons of Pb in cylindrical 3.3m x 3.3m x 3m block.
- The lead is 99.99% pure.
- Beam enters through a 77.2mm diameter blind hole, 1.2m long.
- 12 sample holes are located inside the volume to measure capture cross-sections on some isotopes.



Fluence Bertini cascade

Different methods to measure:

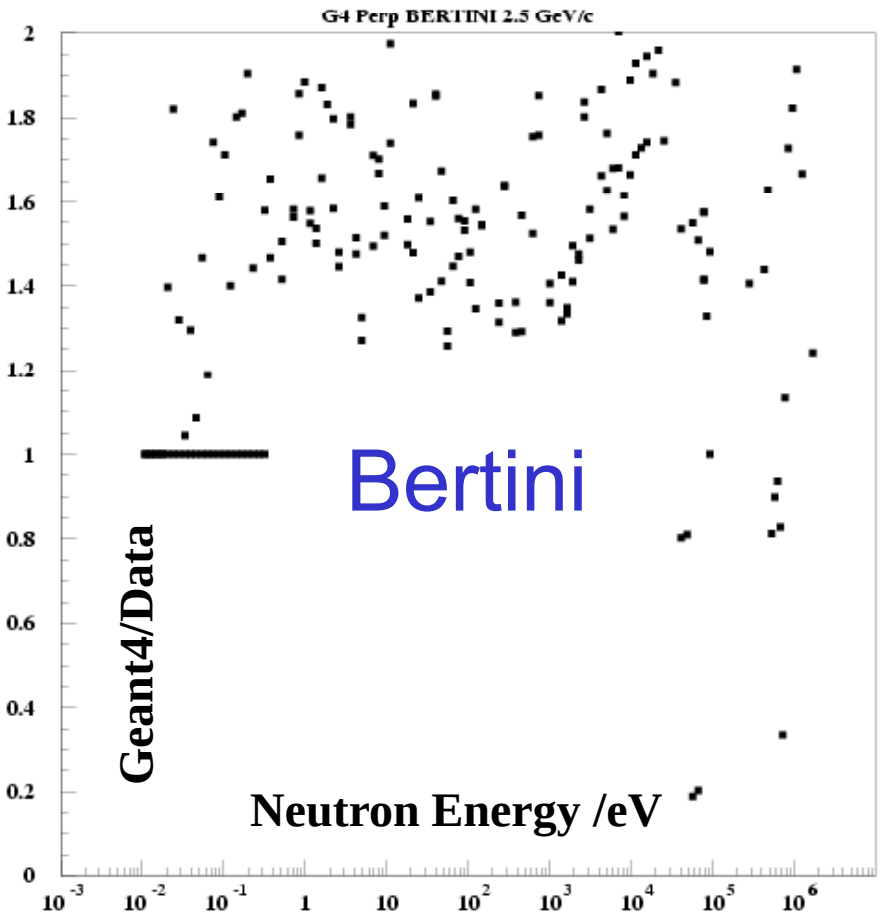
- Yellow: sphere
- Red: cylinder
- Black: Full $4\pi/\cos\theta$

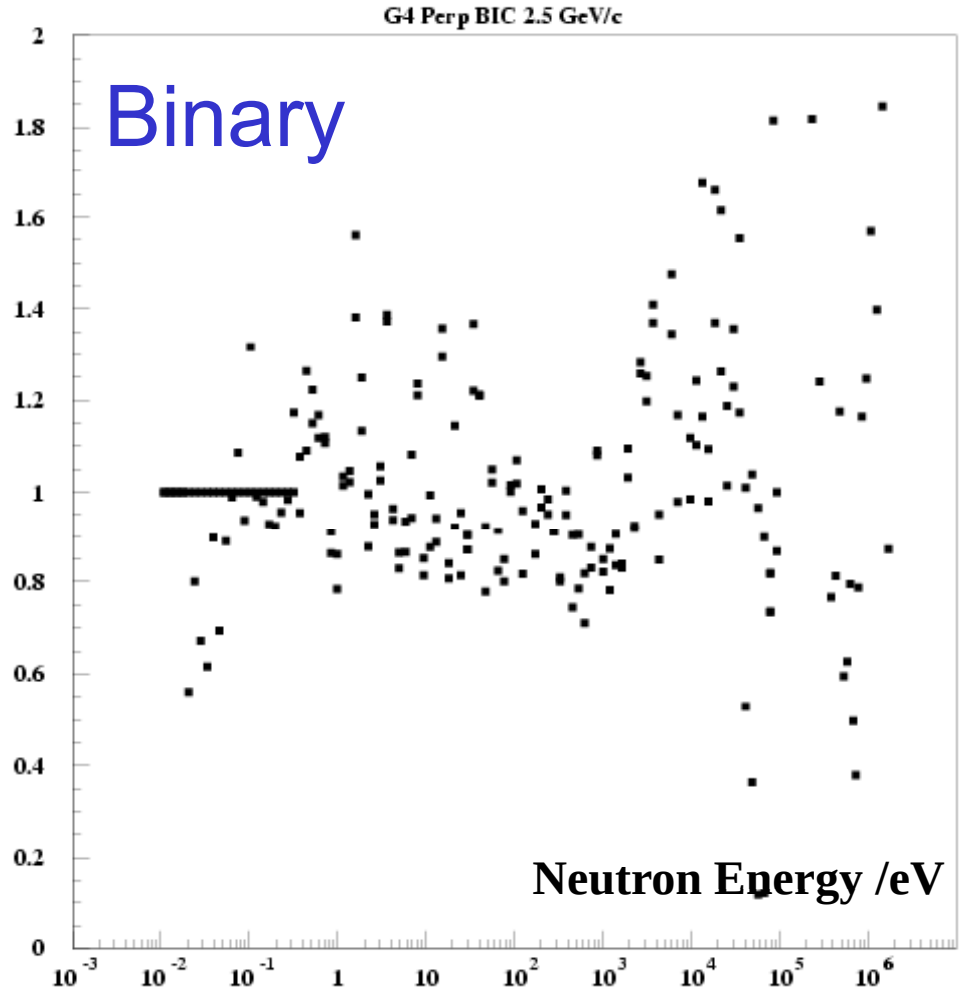


5000 Events
BERTINI 2.5 GeV/c

Ratios of fluence

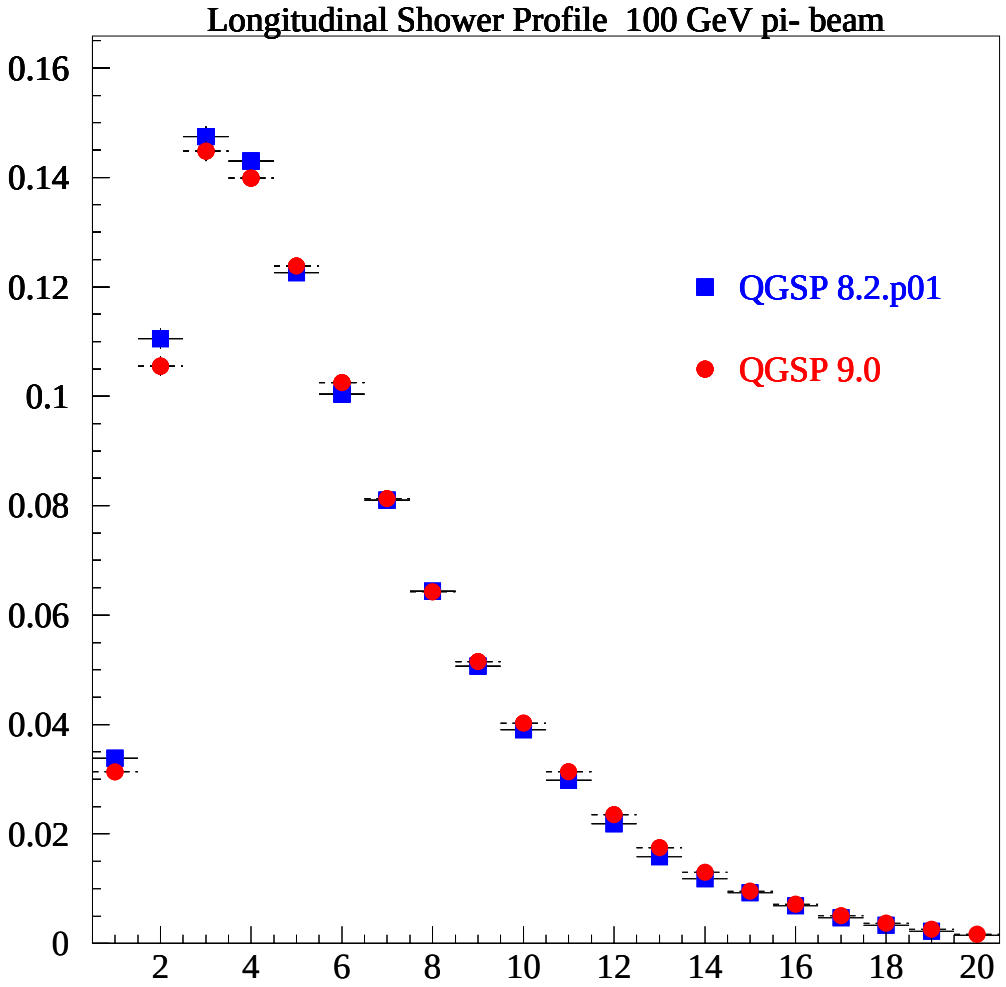
- Ratio of simulated $4\pi/\cos\theta$ versus Data
- Two-sets of data
- Dominated by systematic errors of experiment





- **Binary**
  - Approximately agrees
    - ~10% under-estimated
- **Bertini:**
  - Overestimated ~ 50-60%

Longitudinal Shower Shape Profiles of Iron-Scintillator Calorimeter (simplified ATLAS TileCal)A. Ribon



The shower (10 λ) becomes a bit longer due to quasi-elastic processes

Lateral Shower Profiles (A. Ribon)

For the lateral shower profile

	8.2.p01	9.0
f_L1	55.7 +/- 0.3%	54.5%
f_L2	33.6 +/- 0.2%	34.0%
f_L3	8.9 +/- 0.1%	9.5%
f_L4	1.8 +/- 0.05%	2.0%

(the errors in parenthesis are statistical, for samples of 5000 events):

- **f_L1 : fraction of the visible energy in the first quarter of the calorimeter (corresponding to 2.5 lambdas of Fe);**
- **f_L2 : fraction of the visible energy in the second quarter;**
- **f_L3 : fraction of the visible energy in the third quarter;**
- **f_L4 : fraction of the visible energy in the fourth quarter.**

The calorimeter is a cylinder, 10 (Fe) λ long, and 10 λ in diameter.)

Summary

- Improvements being release in Geant4 8.3 (May 2007):
  - Revised FTF model
  - Quasi-elastic channel coupled with QGS model
- Already released
  - New elastic scattering process (8.1, 8.2)
- Cross-section review
- Validation of neutron transport in TARC

Backup slides

Deliverable

- VALSIM month 18 milestone (June 2007)
  - "First release of improved version of the hadronic processes and physics lists in GEANT4“
- Improvements identified and undertaken:
  - Issues identifies as a result of validation
  - Revised FTF model, improving diffraction
  - New modeling of quasi-elastic channel

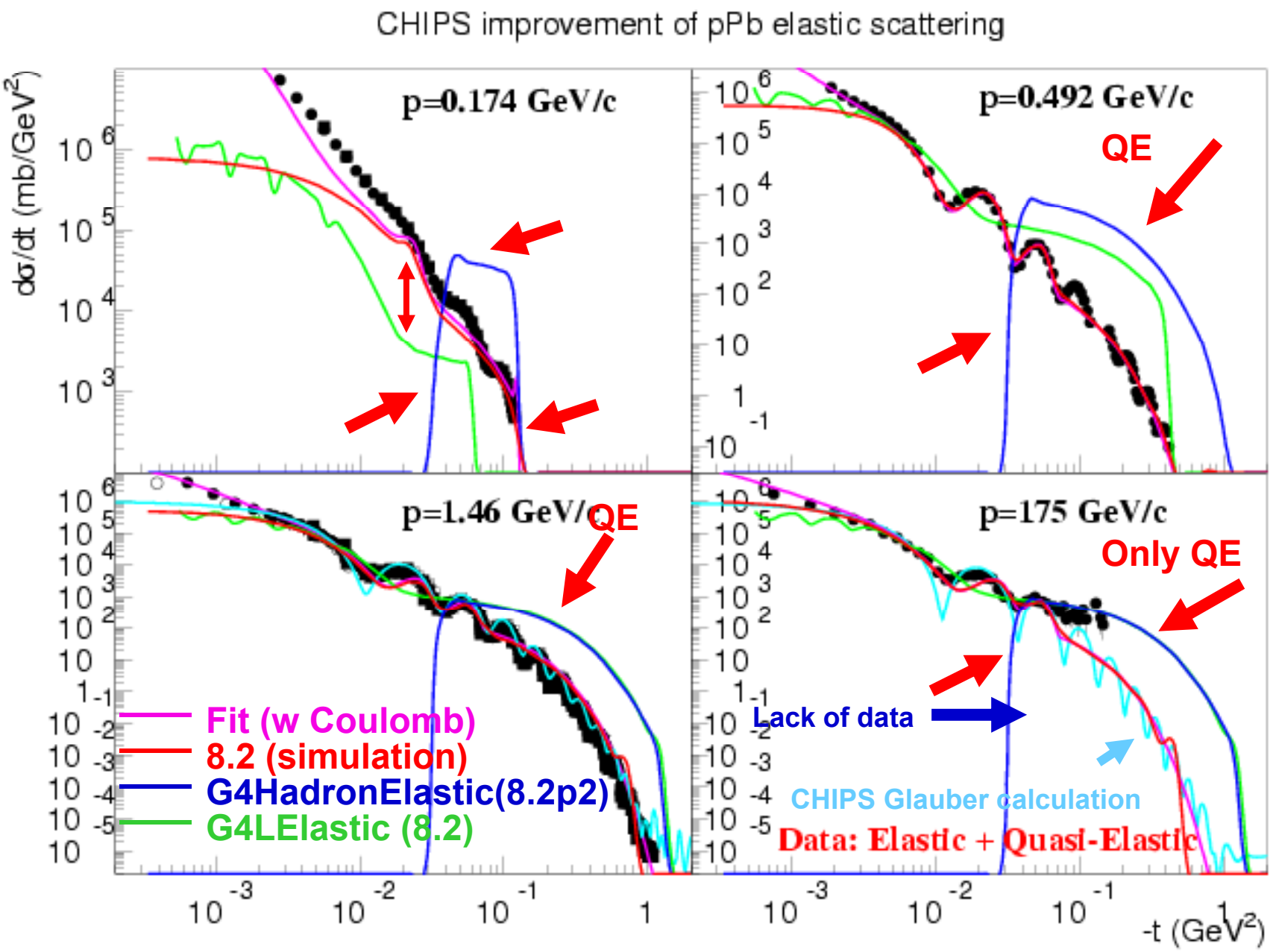
Geant4 Releases

- The upcoming minor release Geant4 8.3 includes
  - the revised FTF model (in place of the original)
  - Option to split the inelastic cross-section between the QGS model and a quasi-elastic interaction
    - Activated in QGSx family of Physics lists (see next page)
  - Fix to Copper cross-section
    - which was reduced in 7.0 (tbv) by 4% compared to data
- It is planned for public release on 9th May 2007
- Geant4 9.0 is the scheduled release of June.

Releases and Elastic improvement

- Improved Elastic scattering
  - Most important for Hydrogen
  - Most relevant for light targets, but all improved
- The new ‘QElastic’ (M. Kossov)
  - As a process available for all elements in 8.2
    - Used in QGSC and QGSP_QEL
- Intermediate solution (since Geant4 8.1)
  - HadronElastic (V. Ivantchenko) used QElastic for Hydrogen
    - Used in QGSx , FTFx physics lists in 8.1-8.3

CHIPS: new Elastic


CHIPS improvement of pPb elastic scattering
dσ/dt (mb/GeV²)
p=0.174 GeV/c
p=0.492 GeV/c
QE
p=1.46 GeV/c
QE
p=175 GeV/c
Only QE
Fit (w Coulomb)
8.2 (simulation)
G4HadronElastic(8.2p2)
G4LElastic (8.2)
Lack of data
CHIPS Glauber calculation
Data: Elastic + Quasi-Elastic
-t (GeV²)

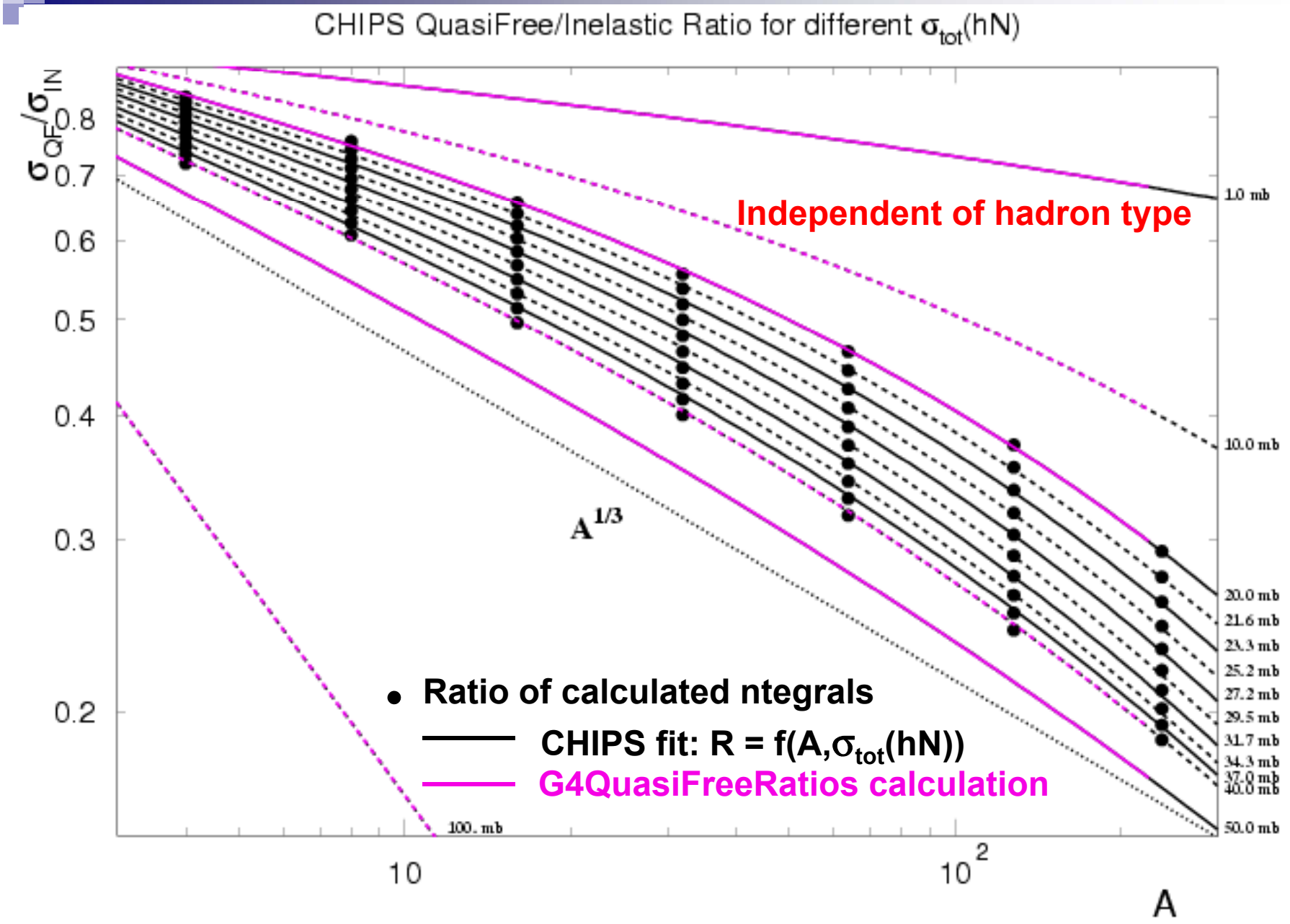
CHIPS: new Quasi-Elastic

CHIPS method for quasi-elastic scattering

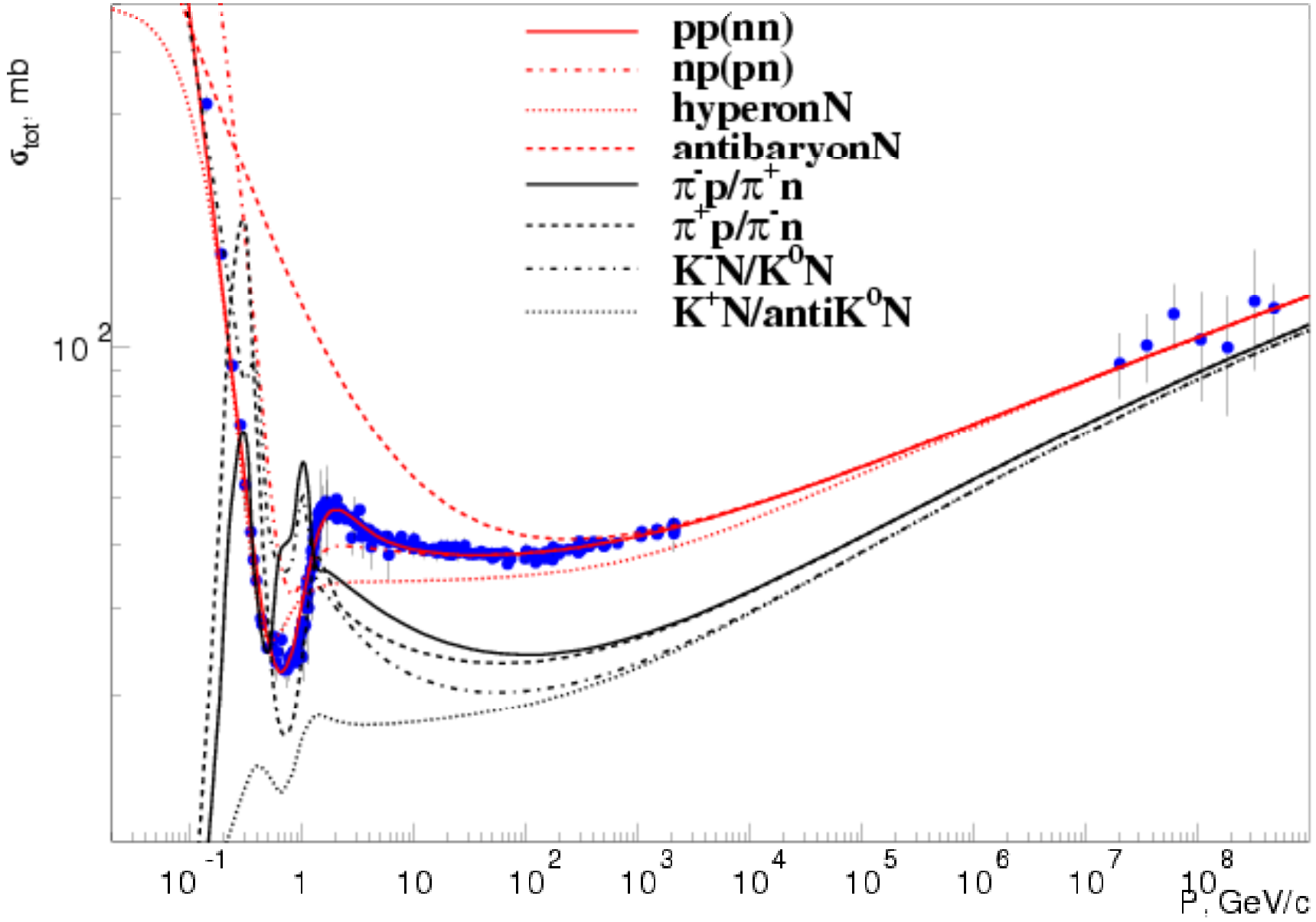
- Calculate and approximate R=QE/Inelastic
  - Probability of interaction: $\sigma_{in}=\int 1-e^{-\sigma\cdot T(b)}d^2\mathbf{b}$, $\sigma=\sigma^{tot}(hN)$
  - Probability to interact once: $\sigma_{QF}=\int \sigma\cdot T(b)\cdot e^{-\sigma\cdot T(b)}d^2\mathbf{b}$
- Precize approximation of $\sigma^{el}(hN)$ & $\sigma^{tot}(hN)$
  - $n\bar{n}/pp$ and np/pn interactions
  - N-N and Hyperon-N interactions
  - π^-p/π^+n and π^+p/π^-n interactions
  - K^-N/K^0N and $K^+N/\bar{K}^0N$ interactions

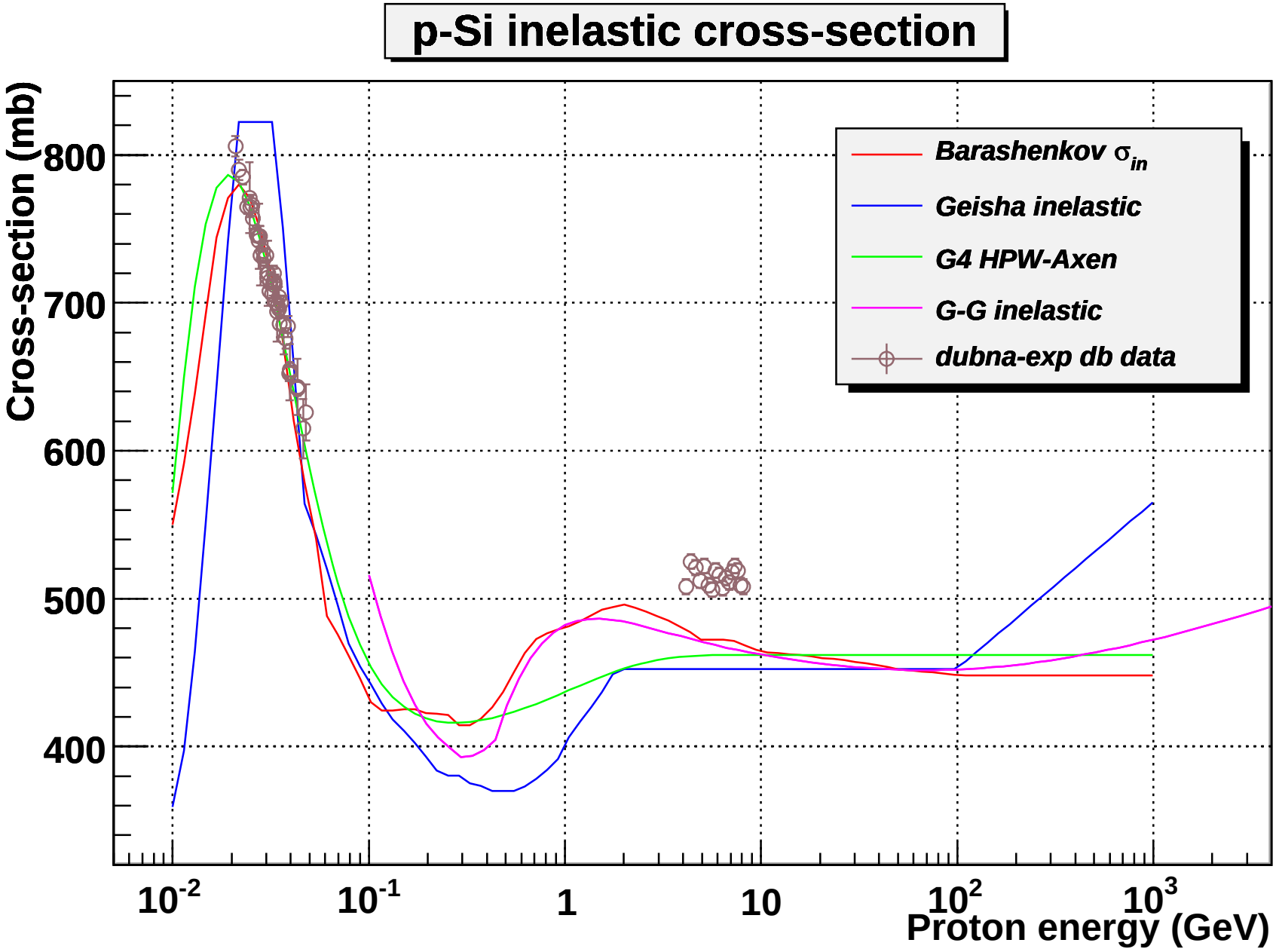
  } **8 isotopic groups**

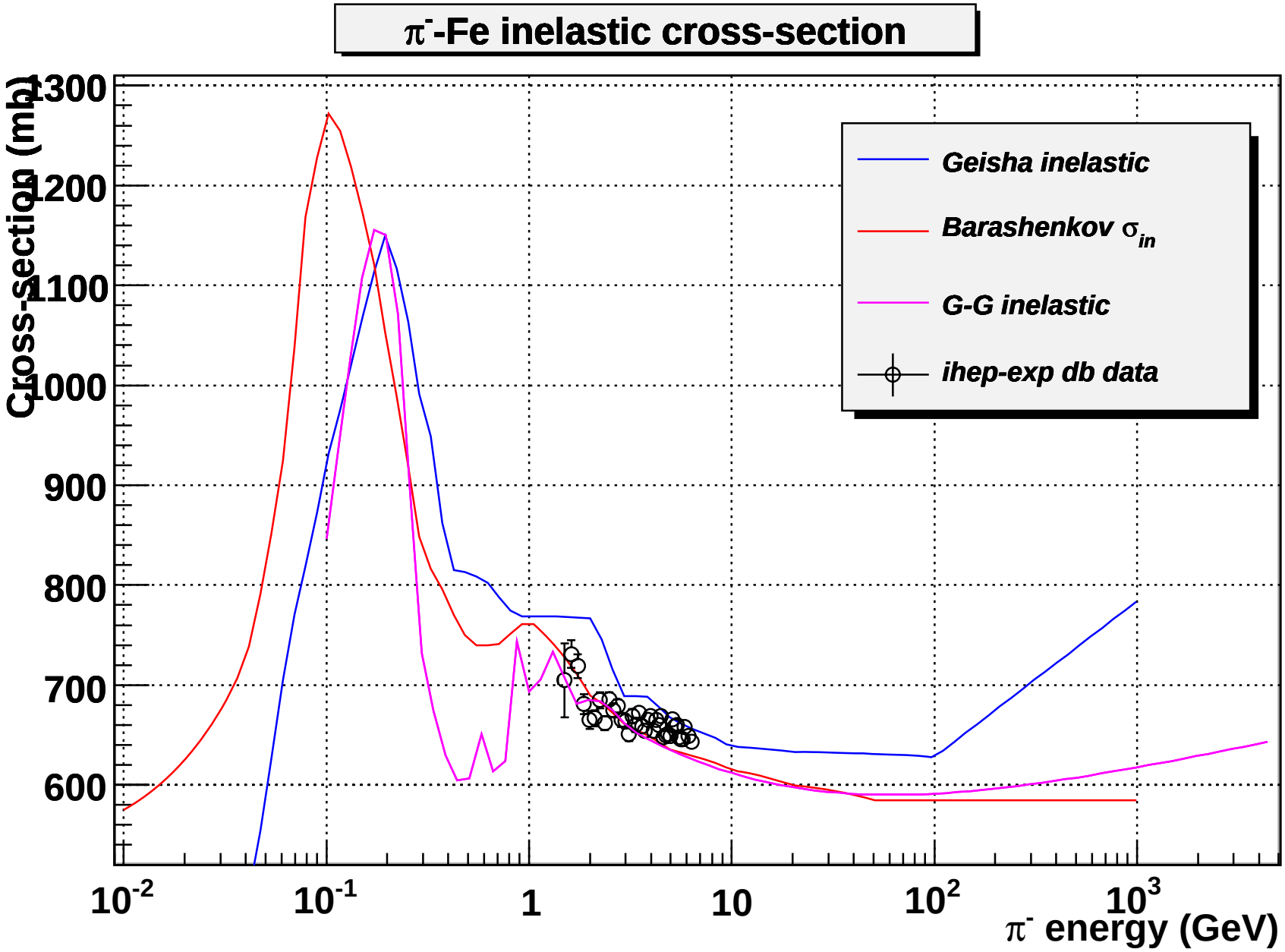
- Calculation of QElastic/In & QFree/In ratios


CHIPS QuasiFree/Inelastic Ratio for different σtot(hN)
σQF/σIN
0.8
0.7
0.6
0.5
0.4
0.3
0.2
Independent of hadron type
1.0 mb
10.0 mb
A1/3
20.0 mb
21.6 mb
23.3 mb
25.2 mb
27.2 mb
29.5 mb
31.7 mb
34.3 mb
37.0 mb
40.0 mb
50.0 mb
100. mb
• Ratio of calculated ntegrals
CHIPS fit: R = f(A,σtot(hN))
G4QuasiFreeRatios calculation
10
10 2
A

CHIPS improvement of hadron-nucleon total cross-section



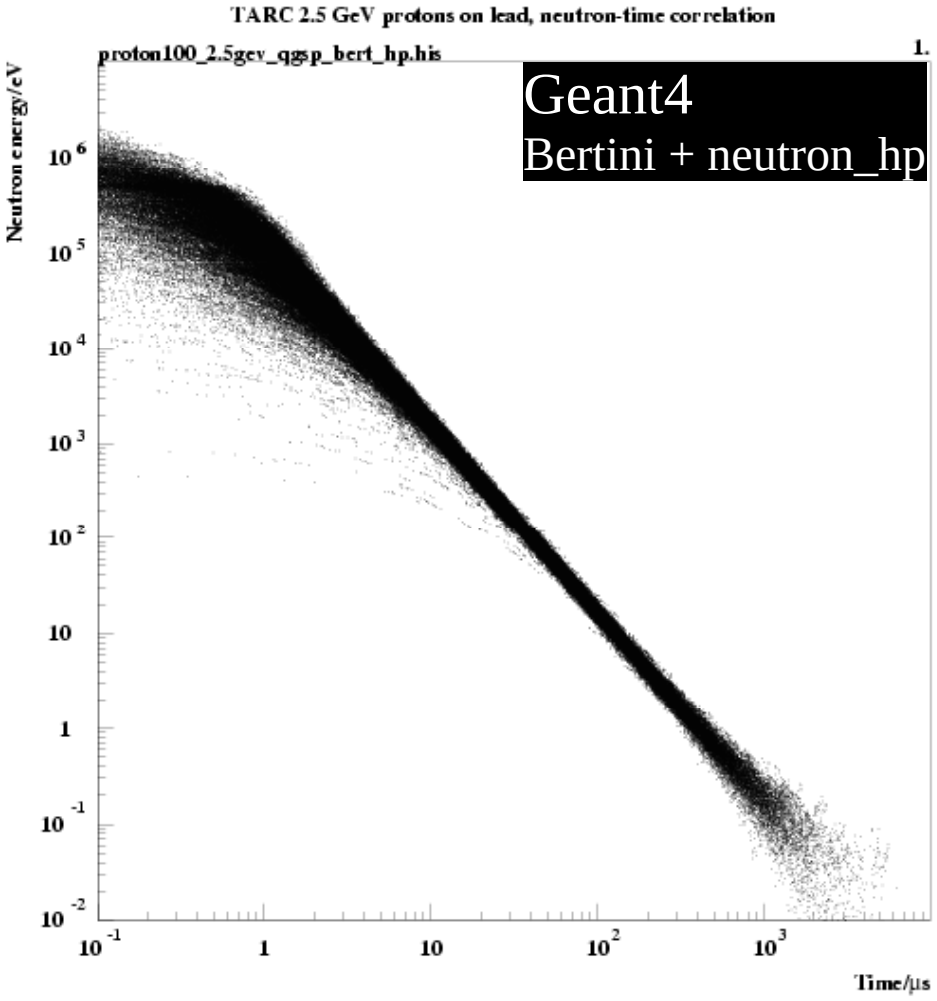

p-Si inelastic cross-section
Cross-section (mb)
800
700
600
500
400
10^{-2}
10^{-1}
1
10
10^{2}
10^{3}
Proton energy (GeV)
Barashenkov σ_{in}
Geisha inelastic
G4 HPW-Axen
G-G inelastic
dubna-exp db data


π⁻-Fe inelastic cross-section
Cross-section (mb)
1300
1200
1100
1000
900
800
700
600
10⁻²
10⁻¹
1
10
10²
10³
π⁻ energy (GeV)
Geisha inelastic
Barashenkov σin
G-G inelastic
ihep-exp db data

TARC simulation

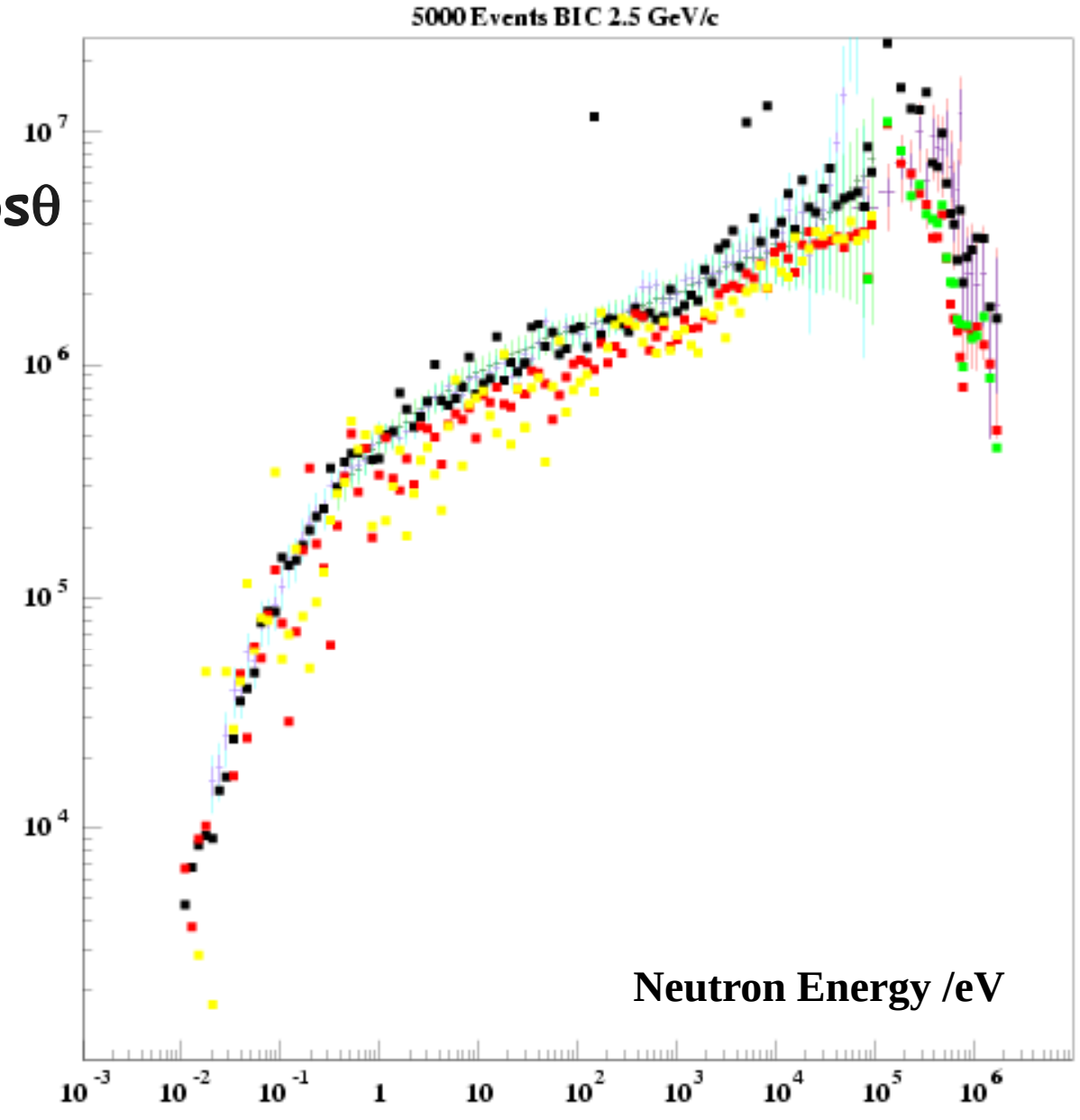
Neutron Energy-Time Correlation

- A first test of neutron transportation in Geant4 is to look at energy-time correlation
- This relies heavily on the high precision neutron_hp model for neutrons < 20 MeV
- Neutron energy and time are stored for the flux through a given radial shell
- Reasonable agreement with expectation, although the low energy population is quite different between physics list (as expected)



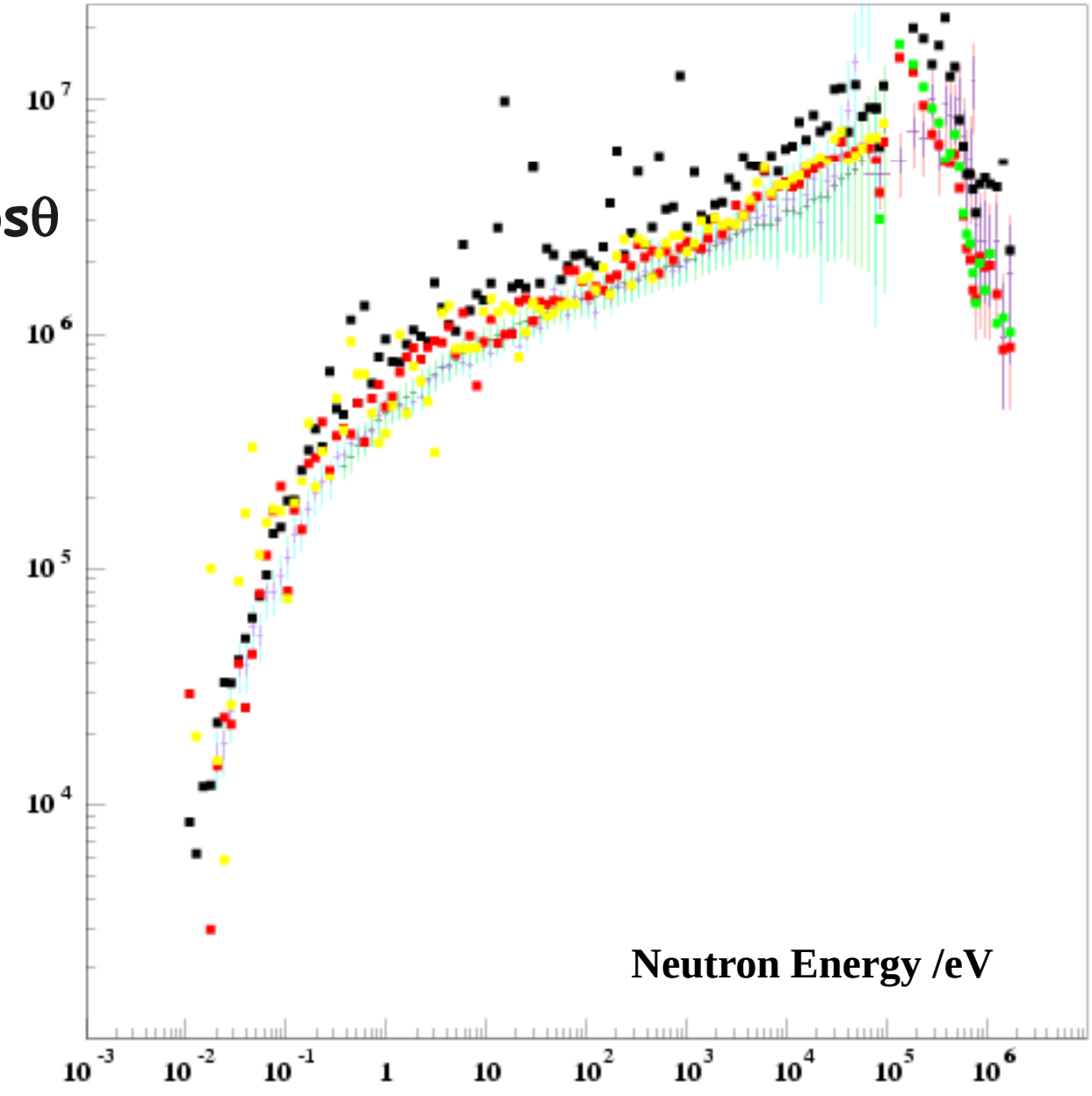
Fluence Binary cascade

- Yellow: sphere
- Red: cylinder
- Black: Full 4π/cosθ



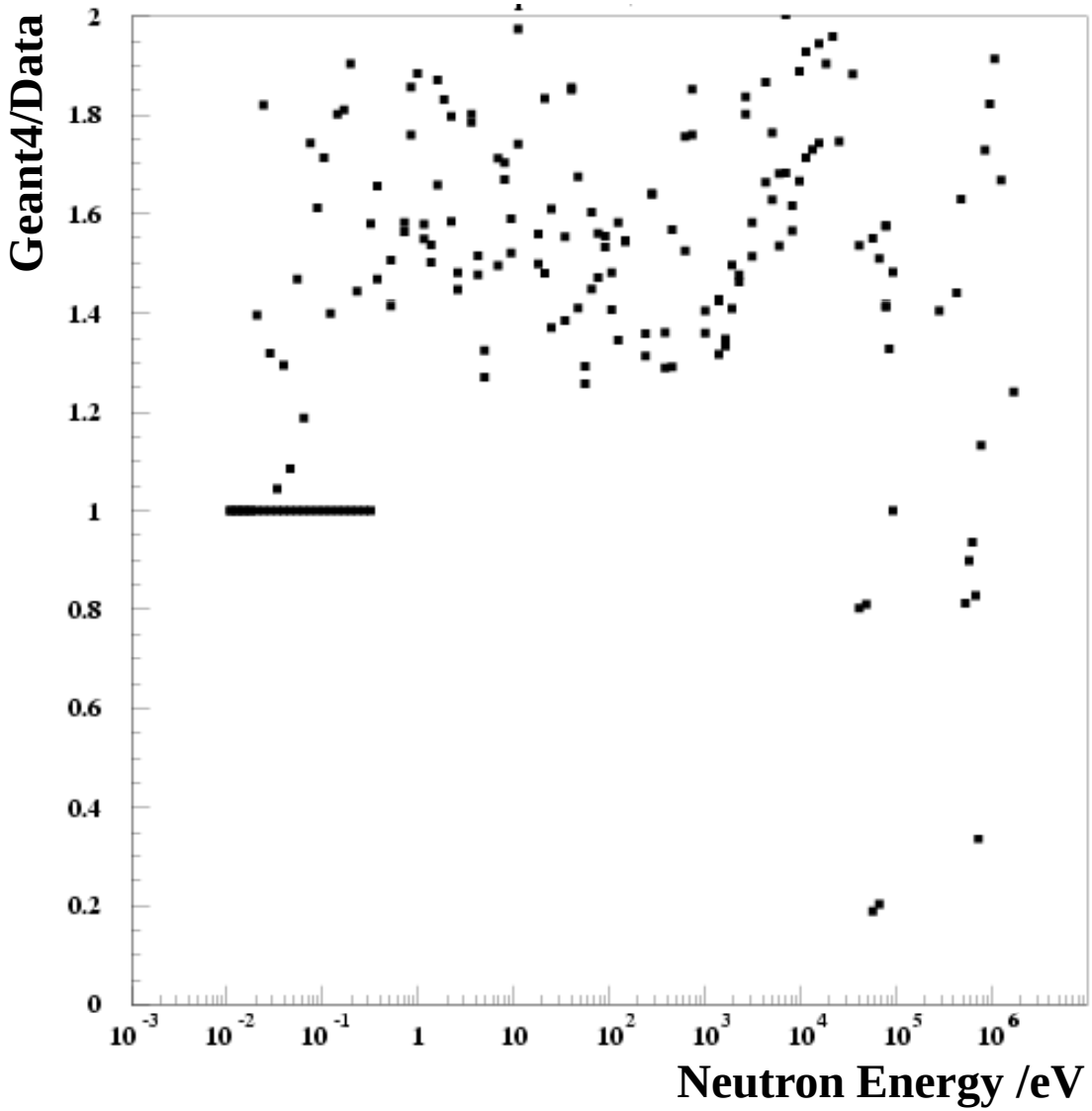
Fluence Bertini cascade

- Yellow: sphere
- Red: cylinder
- Black: Full $4\pi/\cos\theta$



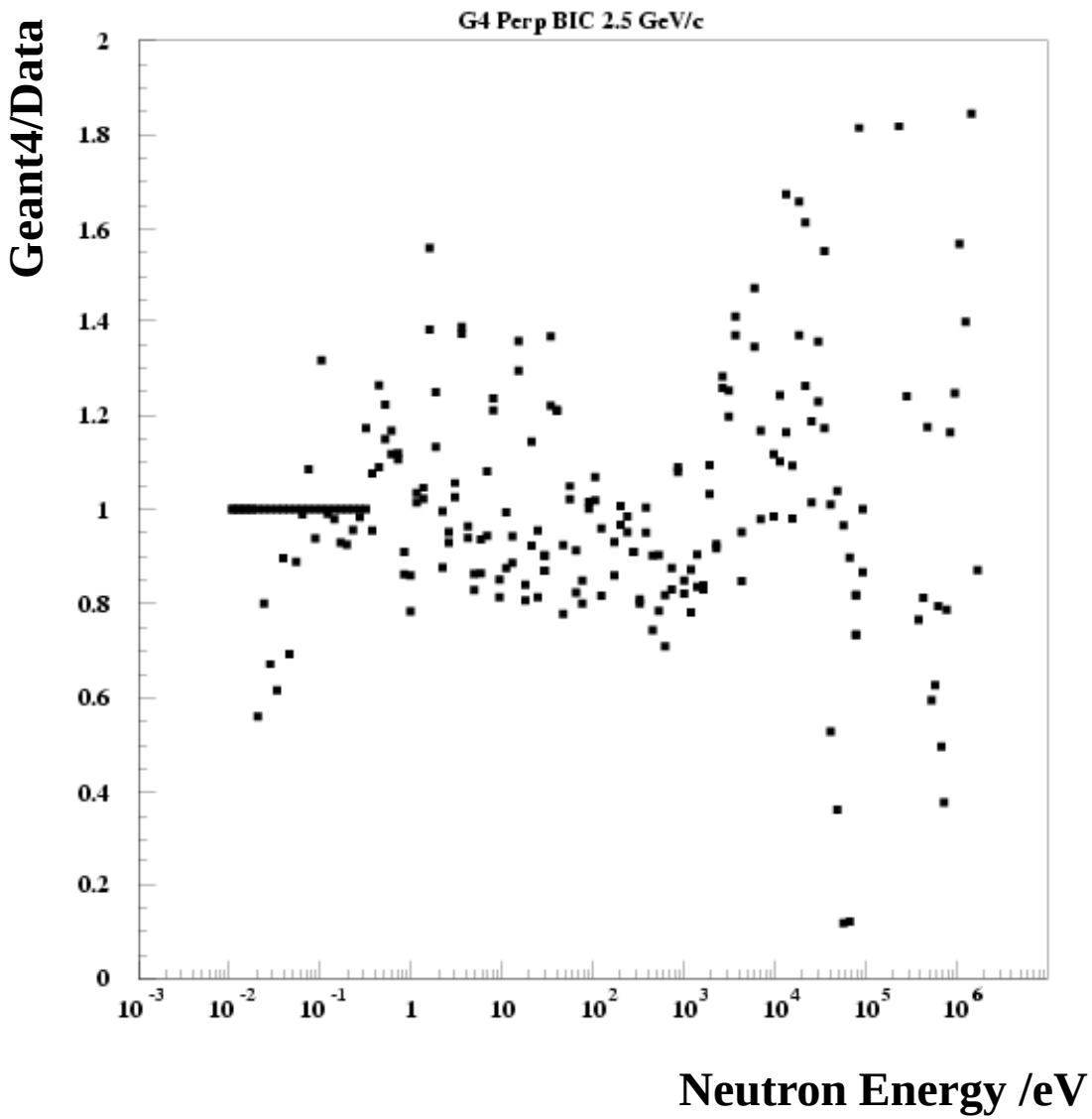
Ratio of fluence G4/Data – Bertini

- Ratio of $4\pi/\cos\theta$: Data
- Two-sets of data
- Approximately 50-60% overestimated
- Dominated by systematic errors of experiment



Ratio of fluence G4/Data – Binary

- Ratio of $4\pi/\cos\theta$: Data
- Two-sets of data
- Approximately agrees (~10% under-estimated)
- Dominated by systematic errors of experiment



Other cross sections

- **In addition created and validated**
  - cross sections for elastic scattering of p, n
    - Released H, D, He in G4 8.1 (June 2006) and other elements in G4 8.2 (December 2006)
    - Final state t-distribution also fitted to data.

M. Kossov