Development in Bertini Cascade

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Geant4 Collaboration Meeting

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Outline

- Phase space problem
- Revisiting internal nucleon-nucleon cross sections
- Adding delta-resonance
- LENDorBertini model validation
- Electro-nuclear validation

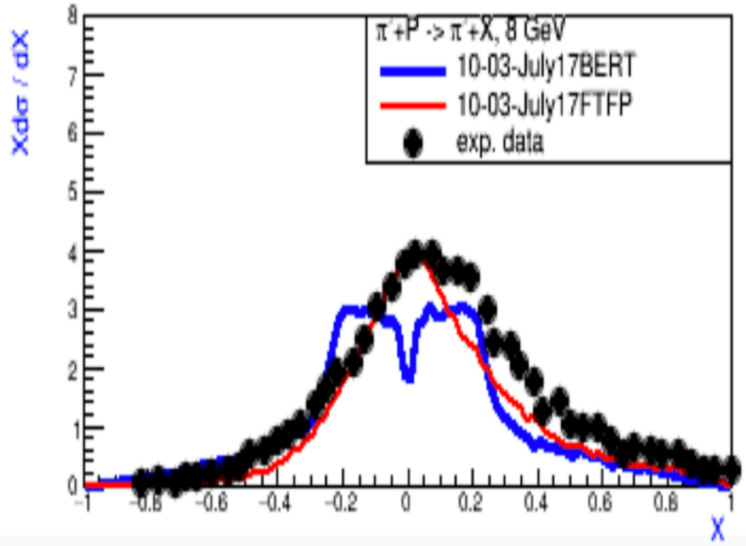
Phase Space Final State Generation

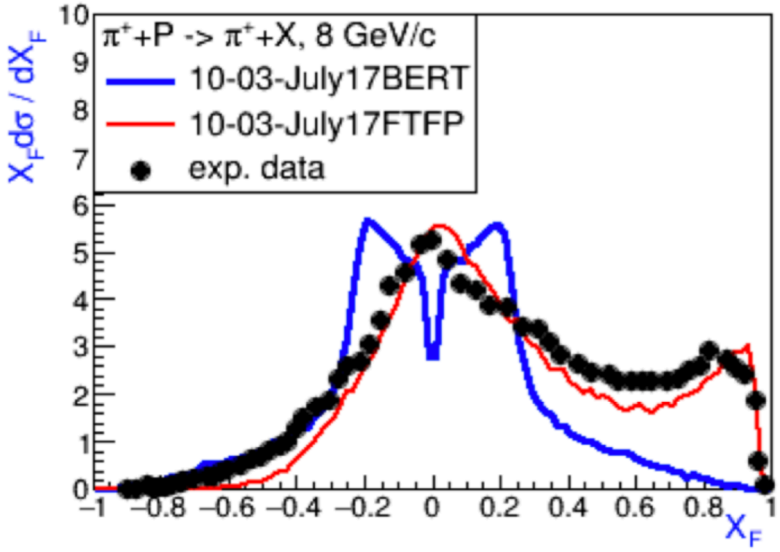
- For hadronic final states with more than two bodies, need phase space generation
- Original generator in Bertini is physically incorrect
  - too simple, symmetric in theta

- Try new ones
  - Kopylov (already an option in Bertini)
    - validated against large data set
    - improvement in some cases, deterioration in others --> no preference over original generator
  - biased Raubold-Lynch
    - exploits unused degree of freedom to tune final state rotation according to data

Original Bertini Phase Space Generator: samples sin(θ) and reflects

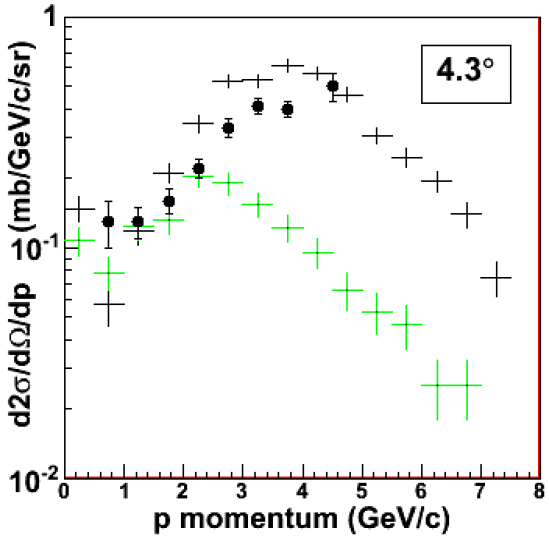
$\pi^- p \rightarrow \pi^- X$ @ 8 GeV/c

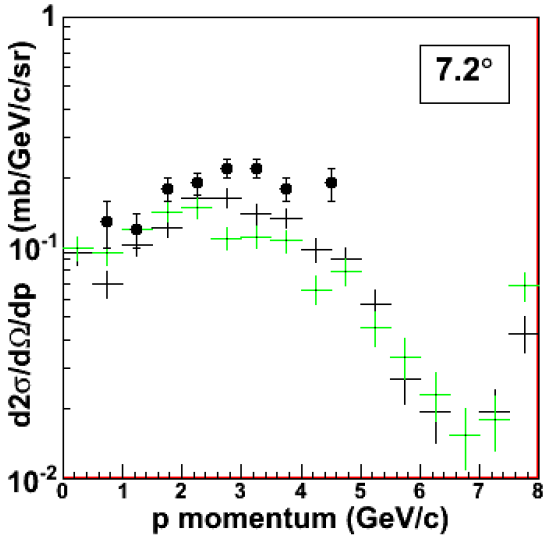


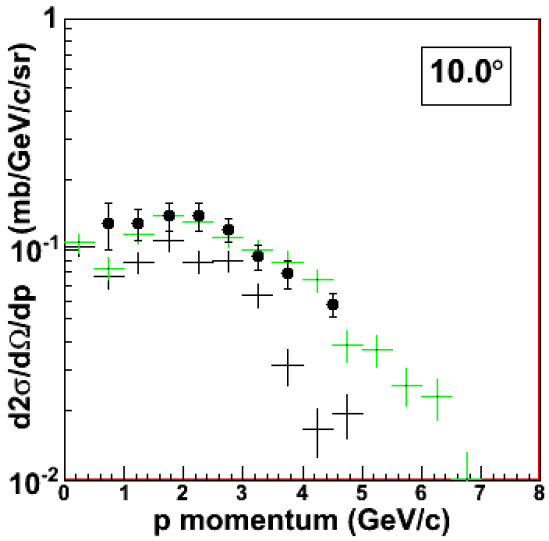


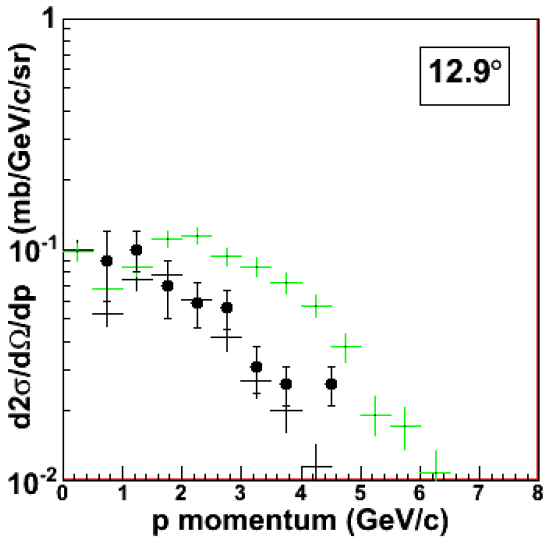
$\pi^+ p \rightarrow \pi^+ X$ @ 8 GeV/c

Biased Phase Space p + C -> p + X @ 8 GeV/c







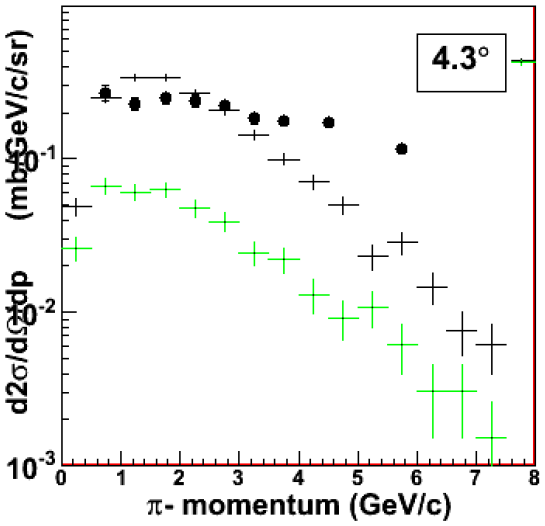


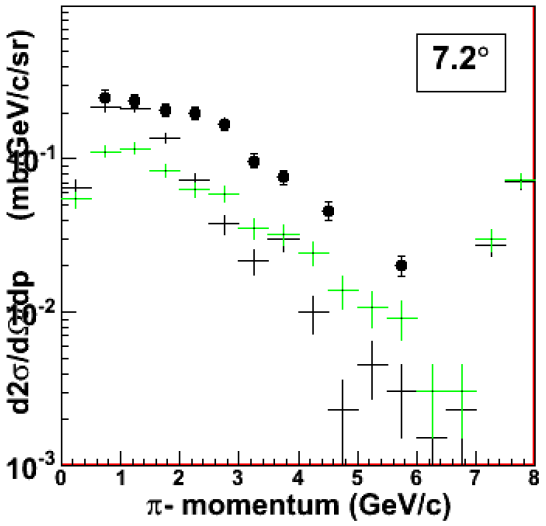
HARP data:
black dots

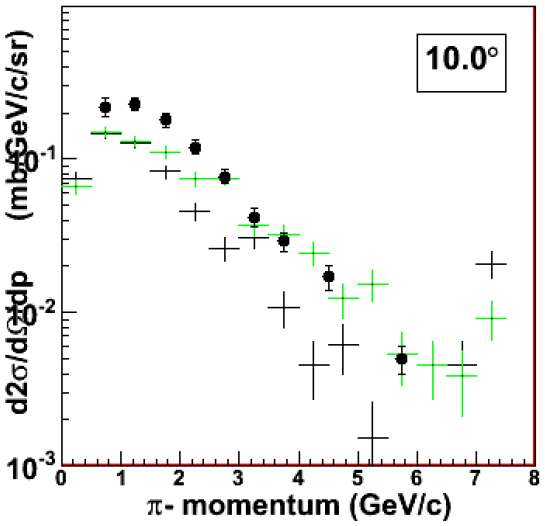
Original Bertini generator :
green crosses

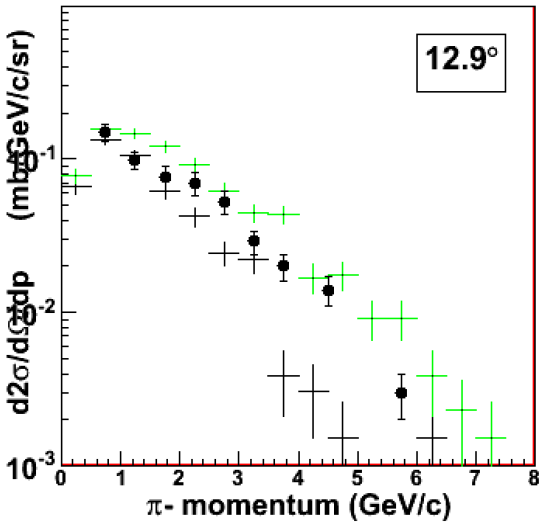
Biased phase space:
black crosses

Biased Phase Space π^- + C -> π^- + X @ 8 GeV/c









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green crosses

Biased phase space:
black crosses

Phase Space Final State Generation

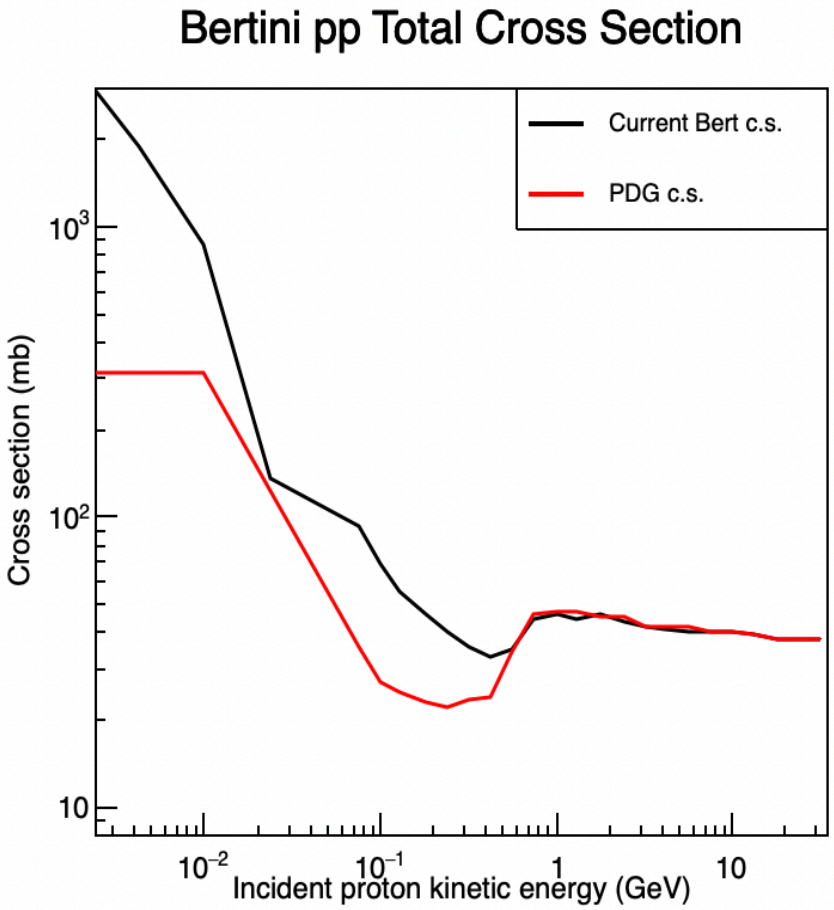
- Biased Raubold-Lynch tried for C, Ta and compared against HARP data
  - substantial improvement at forward angles for cases like p A -> p X
    - but really need large angle data (> 13 degrees)
  - inconclusive for cases like π^- A -> π^- X

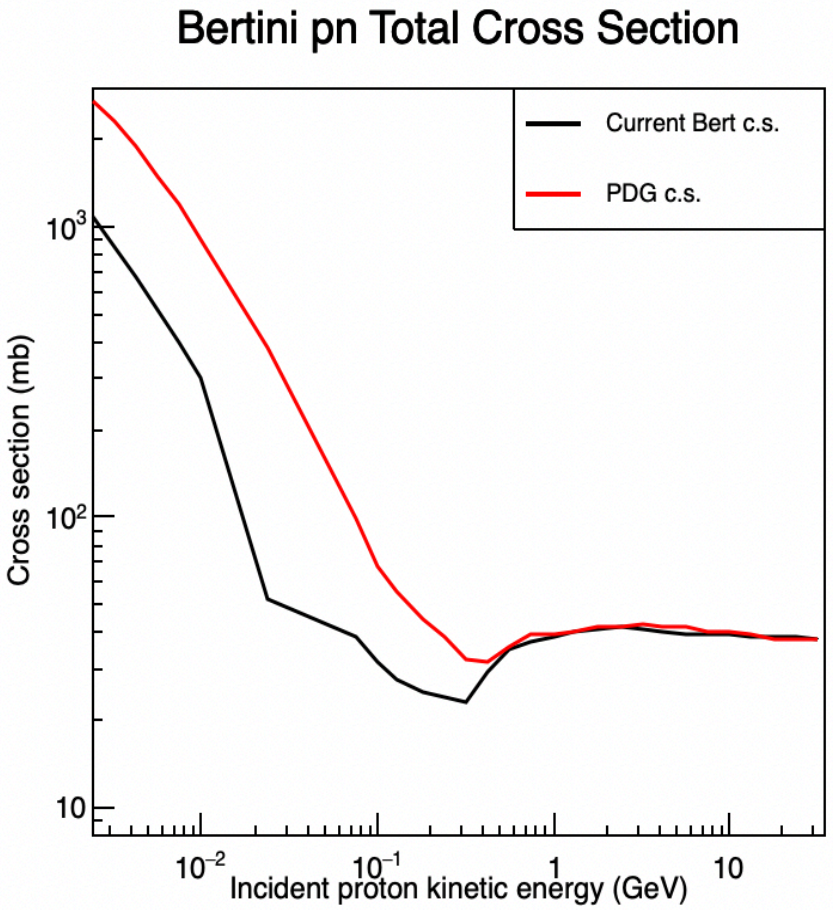
- Possible to use biased Raubold-lynch only for nucleon-induced reactions, Kopylov for others
  - much more validation required

Elementary Cross Sections

- Gradually removing parameterizations from Bertini
  - especially cross sections
- Original Stepanov code had many parameterized cross sections which did not agree with PDG, but produced good hadron-nucleus reactions
- Many years ago, tried to replace Stepanov pp, pn and nn cross sections with PDG values
  - seemed to improve agreement with thin target validations
  - made thick target agreement worse
- Try this substitution again, now that
  - parameter fitting has been done on a large data set
  - low energy behavior of pp, pn, nn cross sections are better understood
  - repeat parameter fitting after this change

Nucleon-nucleon Cross Sections

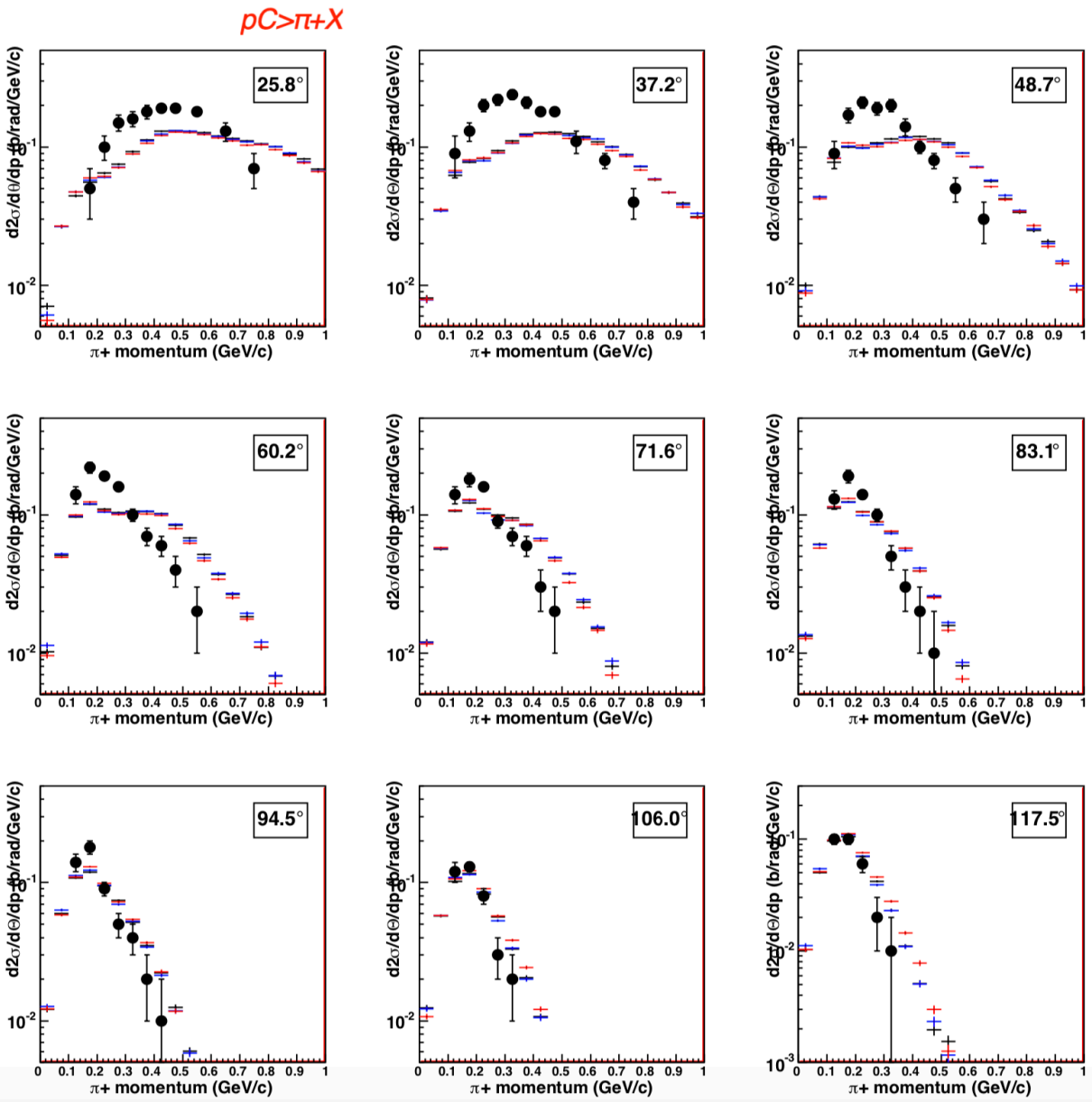




HARP Validation and the Delta (3 GeV/c)

- Generally poor agreement for C(p, π^+)X at large angles
  - mostly above pion momentum of 0.5 GeV/c
  - also poor for other targets
- Why?
  - delta resonance important in this region (p p -> p n π^+)
  - unlike Binary Cascade, Bertini does not generate or decay Δ
  - cross section includes delta production, but not correct three-body angular distribution
- Fix?
  - instead of phase space for angular distribution, use Δ quantum numbers to generate correct distribution → sum of two-body decays
  - embed in Bertini internal angular distributions
- Very little effect (too low in energy)

HARP data 3 GeV/c protons on C



Geant4 Gamma- and Electro-nuclear Physics

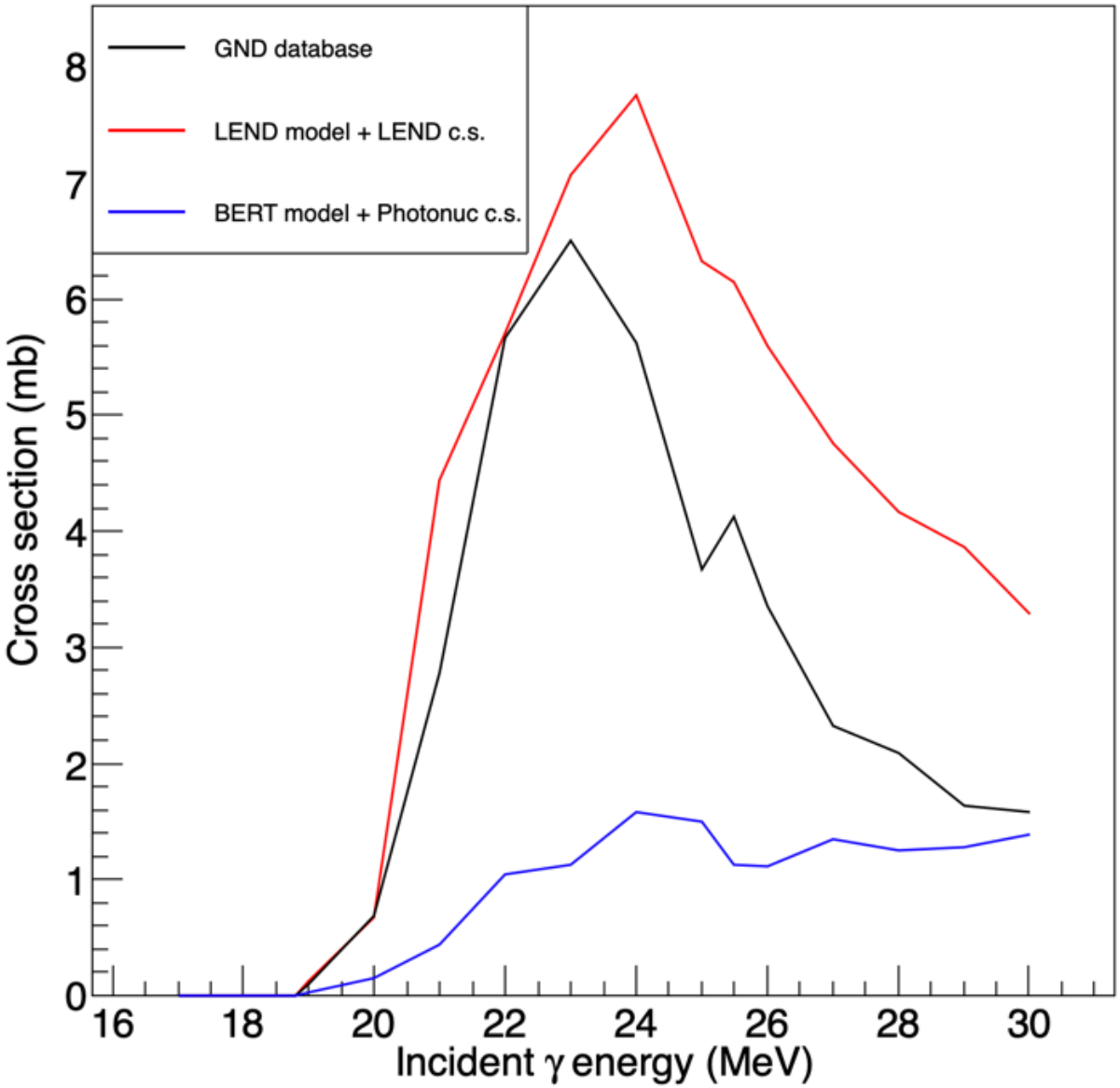
LENDorBert Model

- Design
  - use LEND (GND-based hadronic model) at low energy (< 20 MeV)
  - Bertini above 20 MeV
  - also Bertini when no appropriate data in GND

- Verification begun for gamma-nuclear reactions
  - is combination model correctly designed?
  - can the GND data be reproduced with Geant4 process-level tests?
  - test by using pure Bertini and pure LEND, then comparing

- Validation to follow
  - GND data cover many isotopes from 1 MeV to 150 MeV
  - also covers several reactions
  - lots of data for (γ, n)

^{12}C (γ, n) X


GND database
LEND model + LEND c.s.
BERT model + Photonuc c.s.
Cross section (mb)
Incident γ energy (MeV)
0
1
2
3
4
5
6
7
8
16
18
20
22
24
26
28
30

LENDorBert Model

- Early conclusions (for ^{12}C)
  - LEND much better than Bertini in Giant Dipole region
  - LEND overestimates data
    - protons being produced below threshold is part of the reason
    - but precompound/deexcitstion models apparently not called

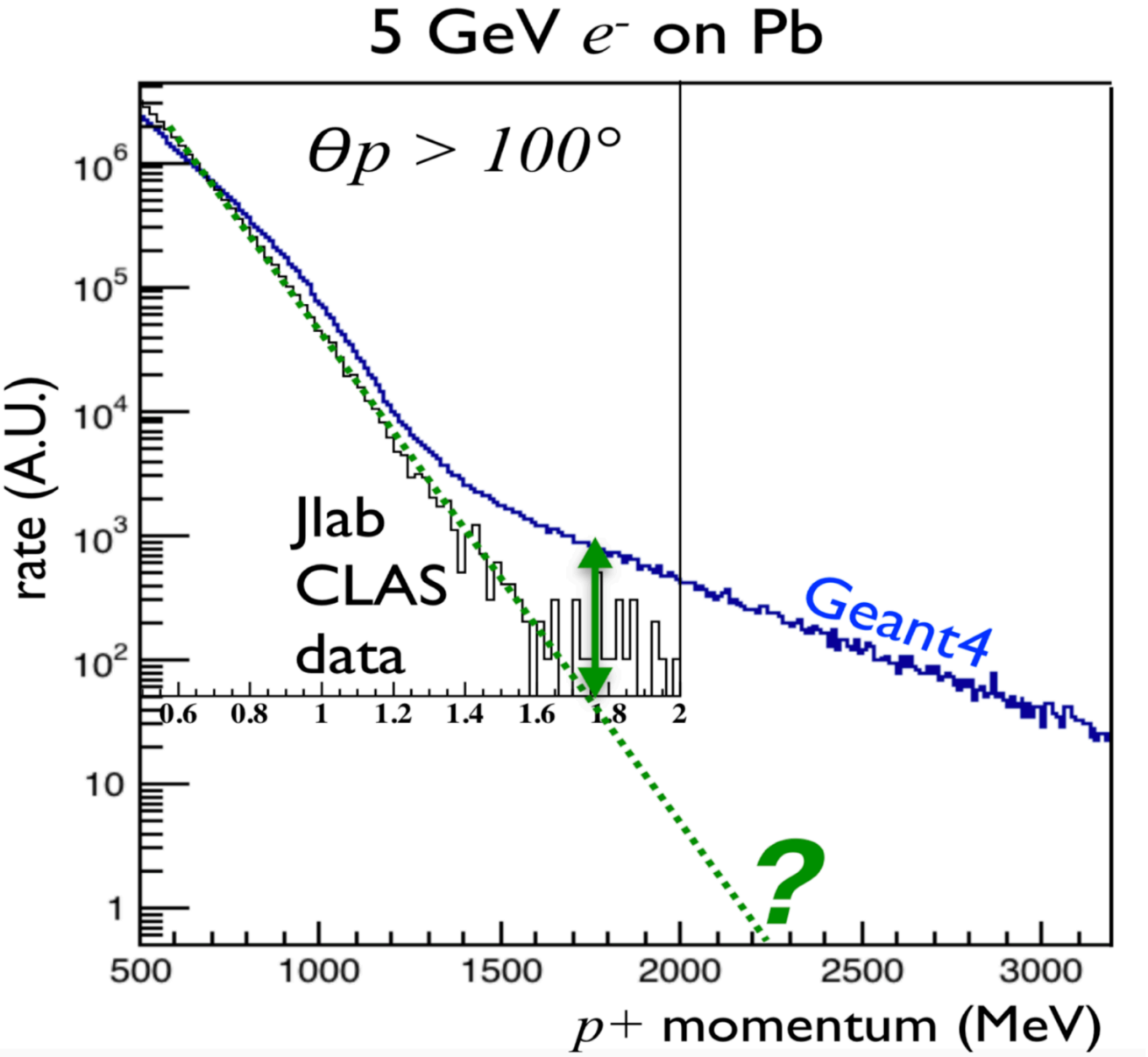
- General findings for LENDorBERT gamma-nuclear
  - bug in code causes Bertini to always be selected
  - 20 MeV cross-over from LEND to Bertini too low
    - 30 MeV or more looks better
  - large number of energy non-conservation warnings

- Plans
  - find reason that pure LEND does not exactly reproduce GND data
  - look at many other target nuclei to see where to set LEND-Bertini cross-over

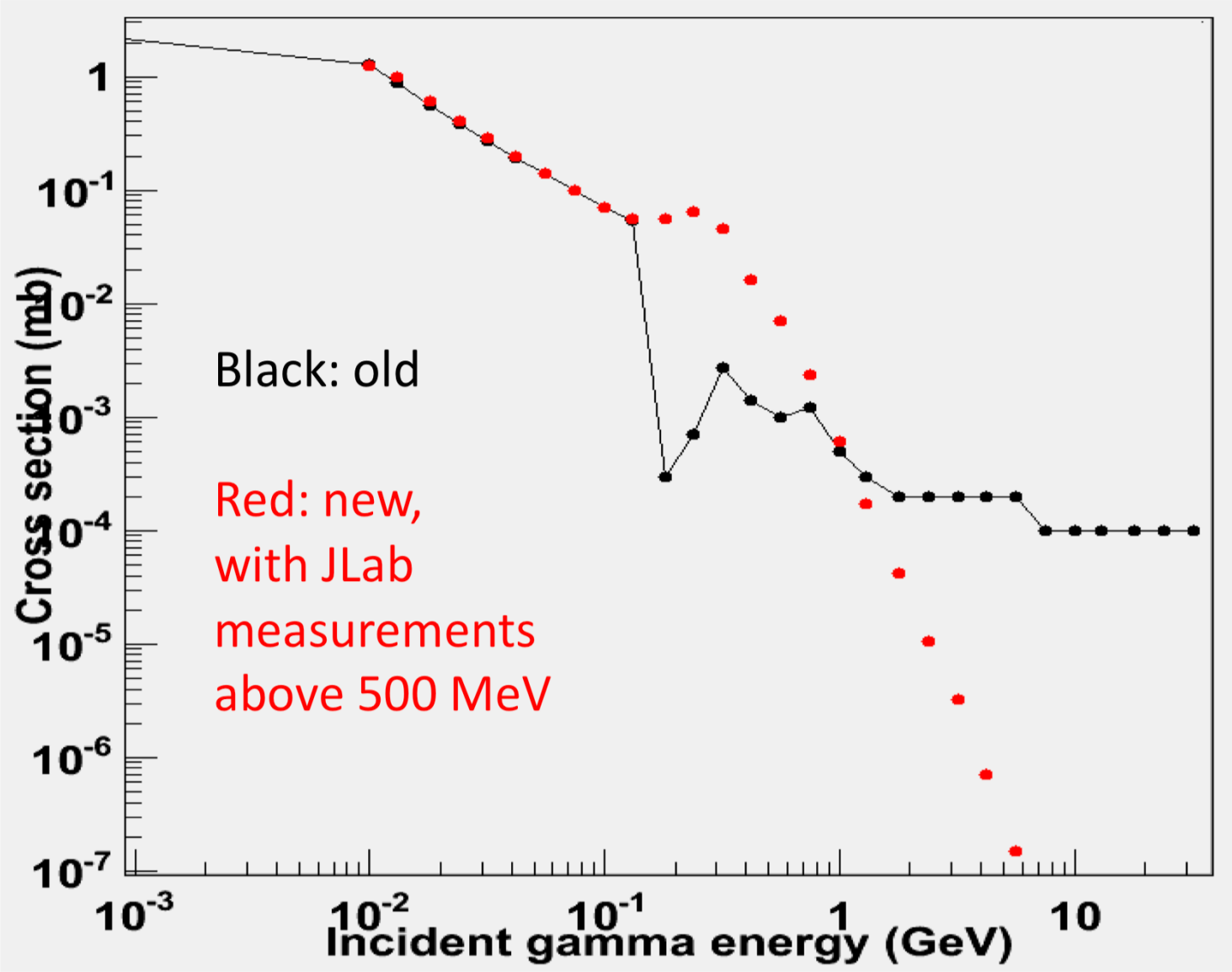
Electro-nuclear Validation

- Initial validation against JLAB data mentioned last year
- For 5 GeV e^- on Pb, Geant4 over-produces protons
- High energy quasi-deuteron cross section may be the cause
  - recently fixed in Bertini
- Validation plot with new QD cross section not yet produced

Electro-nuclear Problem in Geant4



Improved Quasi-deuteron Photo-disintegration Cross Section



Summary

- Phase space problem is still a problem
- Better internal nucleon-nucleon cross sections should be tried now that they are available
- Implicit addition of delta-resonance did not improve agreement with HARP data at 3 GeV/c
- LENDorBertini model validation has just begun
- Improved quasi-deuteron cross section has resulted from electro-nuclear validation – need to test