Neutrons and lateral shower shape

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Overview

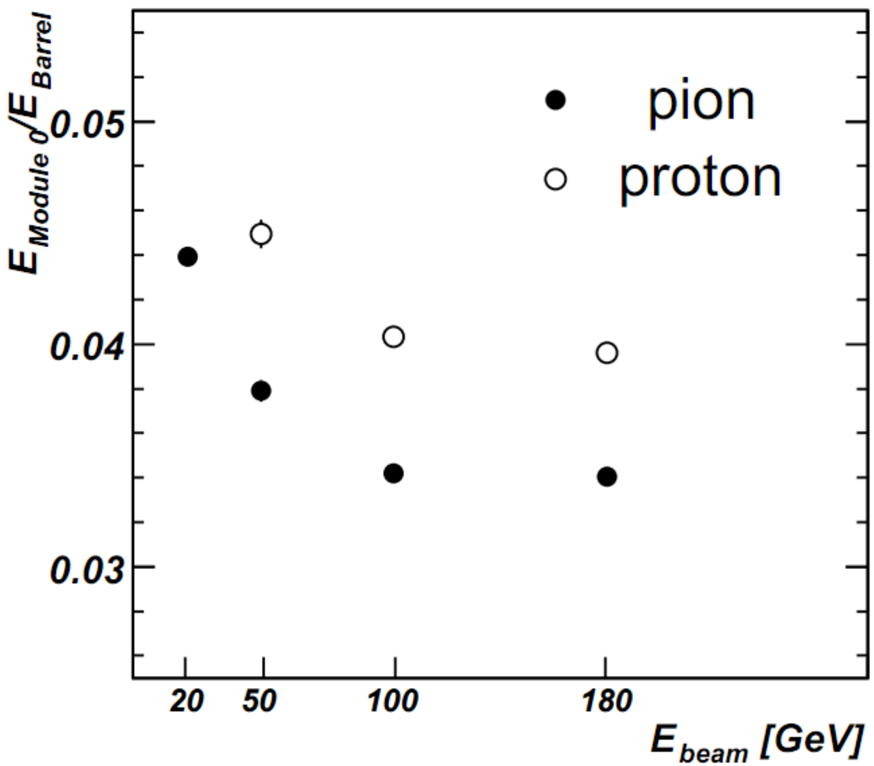
- The issue
  - Lateral shower shape deficit
- Analysis
  - Contributing factors
  - Deficiencies in cross sections, modeling
- Investigation plan

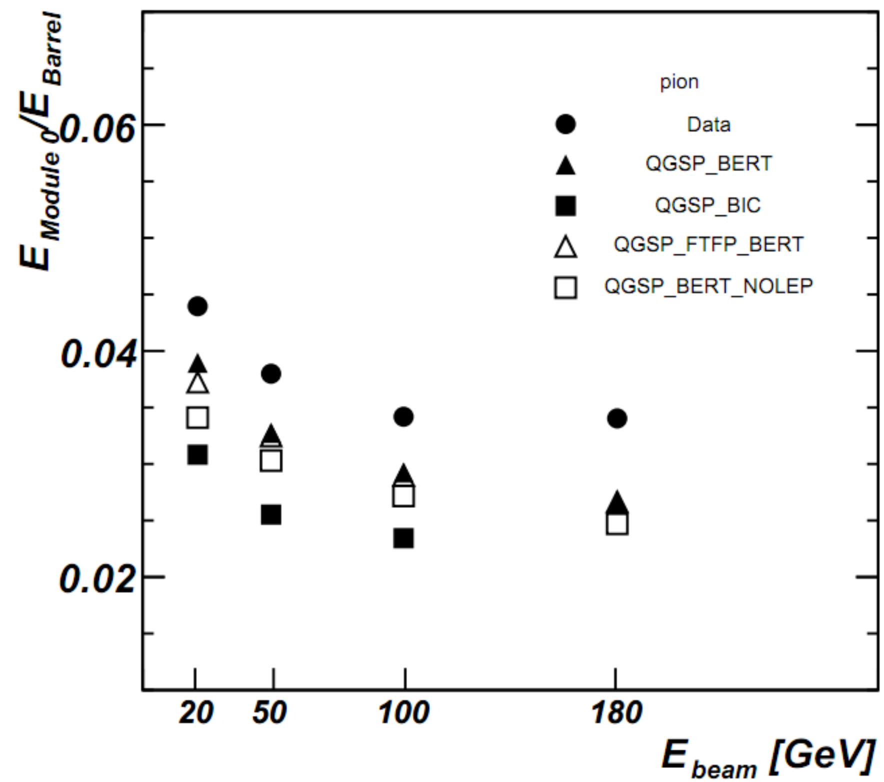
The issue / challenge

- The lateral shower shape is narrow
  - See e.g. report from ATLAS TileCal (Mar 2010)

Lateral Spread

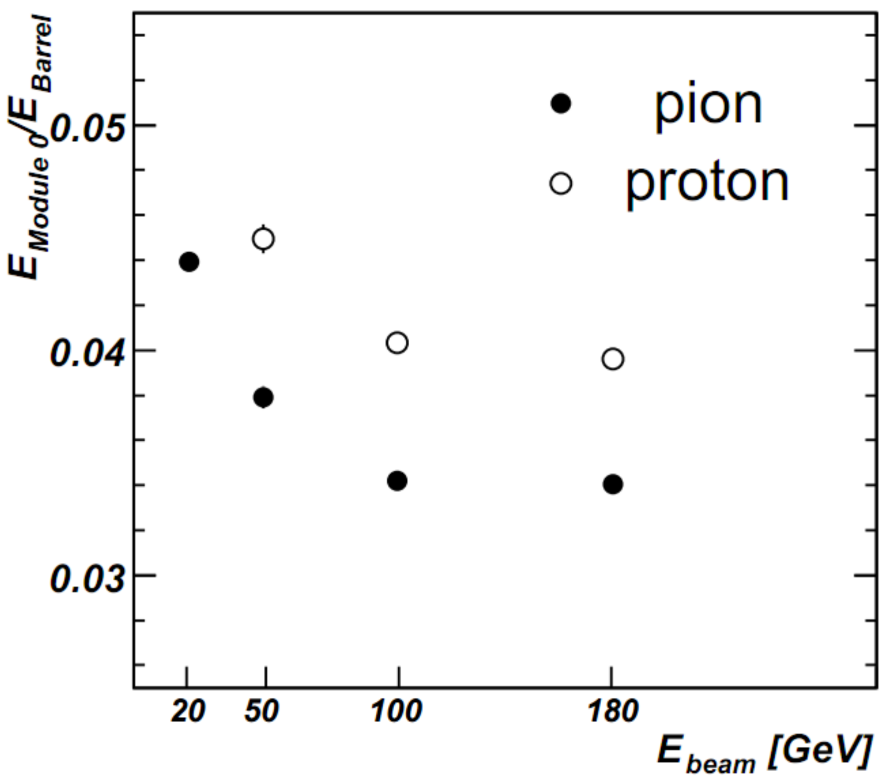
The ratio of energy measured in the bottom and central modules is an estimate of lateral spread.

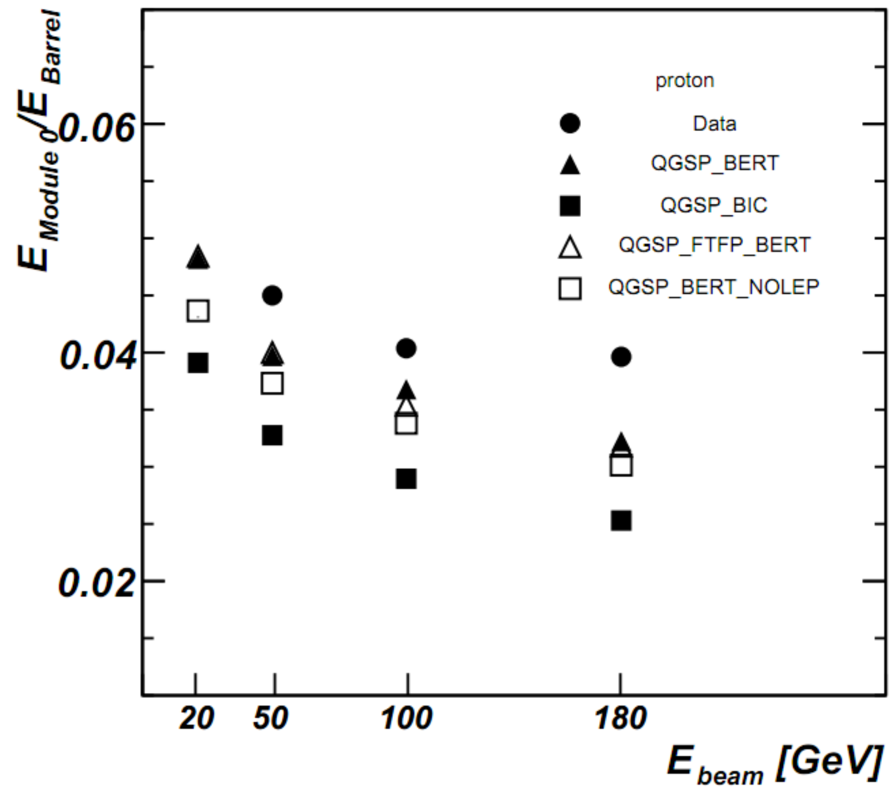




- Proton induced showers are wider than pion induced ones.
- All models predict narrow showers.
- QGSP_BERT is closer to data.

Lateral shower shape: protons





- Proton induced showers are wider than pion induced ones.
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Analysis

- The lateral size / shape are determined by neutrons
  - Neutrons travel the furthest laterally
- To identify the source(s) of the discrepancies, we must examine
  - Neutron transport
    - At all energies
  - Neutron production
    - Primarily in reactions at E>20 MeV, but also below

Neutron Transport

- All interactions are relevant
  - Inelastic: (n, 2n), (n, 3n), ..
  - Capture: (n, γ)
  - Elastic
- The basic options Geant4 for n-transport are:
  - LHEP (baseline)
  - HP data-driven models with G4NDL cross-sections

Particular concerns

- Known deficiencies in
  - Capture used in production e.g. QGSP_BERT
    - Cross sections
    - Model (LHEP)
- Alternative approaches
  - HP ‘high precision’: data driven E < 20 MeV
  - XS simple model with cross sections interpolated from G4NDL library used by HP (V. & A. Ivantenko)
  - New LLNL module (models and cross section libraries)
- Note: all physics lists without HP use LHEP process, except
  - QBBC uses XS
  - CHIPS has its own elastic, (capture/inelastic unfinished)

HP neutron processes

- HP utilises G4NDL data libraries
  - for cross-sections and (some) final state sampling
- G4NDL was created from 1997-2011
  - HP Wellisch: 1997-2004, selected data from many sources
  - T Koi: 2005-present: added data requested by LHC, other users.
- Cross sections for some elements are derived from old neutron data libraries (e.g. ENDF/B VI)
  - Mikhail pointed out a number of elements/isotopes which have old data

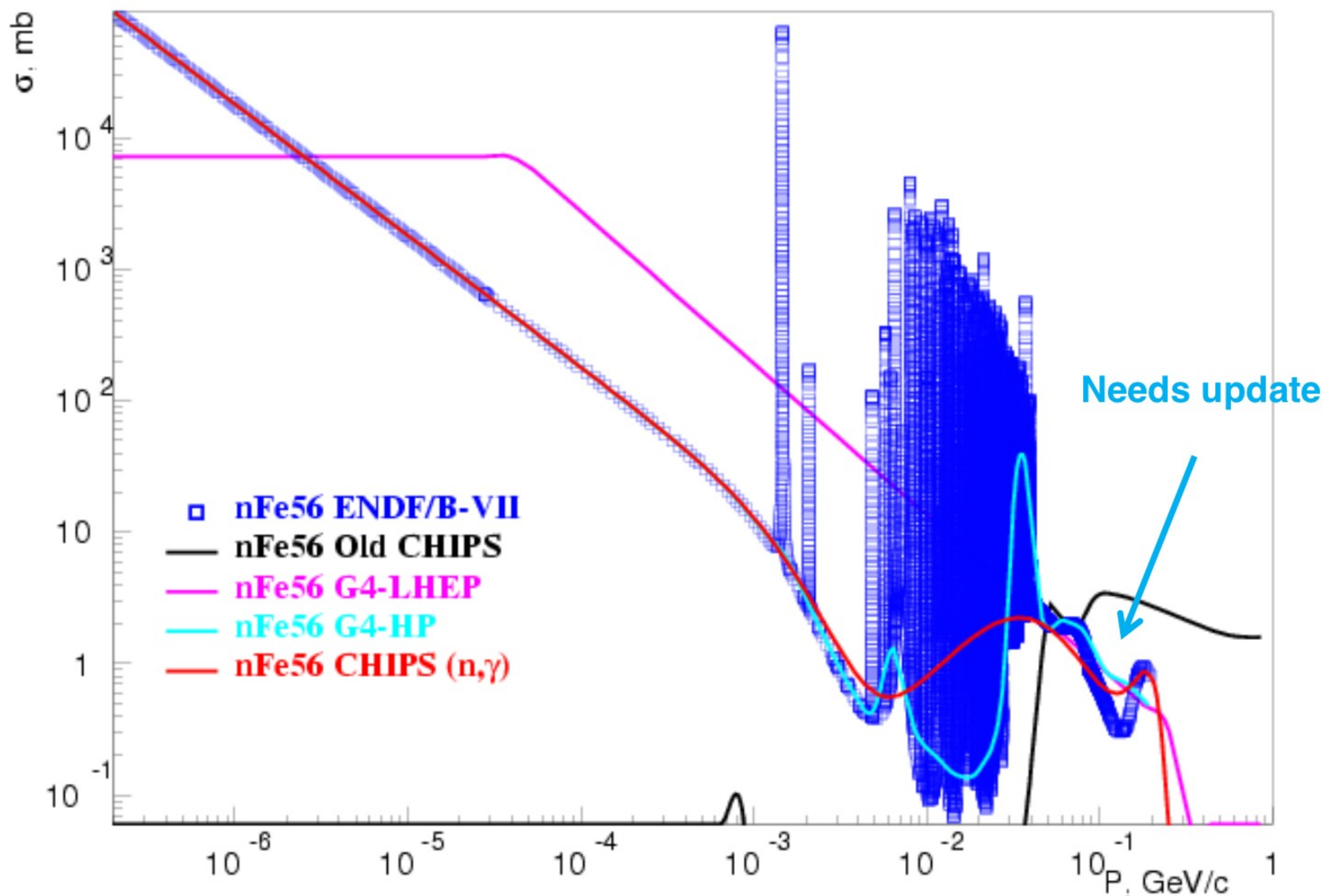
Elastic: elements to improve

- Mikhail's summary: 78/157 need updates
- Our list of the important ones:
  - **Ar**^{40}, Sn, Ag, **W**, Fe(?), for LHC detectors
  - Ti, Nb: in superconducting wires:
  - Kr, Xe, I, U: for other HEP detectors
  - Potential needs: Cd, Ni, Ge, S, Ca

Inelastic: elements to improve

- Mikhail's summary: ?/? need updates
- Additional important ones:
  - Be^7, Be^9, C, Fe^{56}
- Also the same as inelastic
  - **Ar^{40}**, Sn, Ag, **W**, Fe(?), for LHC detectors
    - **W** does not exist in G4NDL ? (tbc)
  - Ti, Nb: in superconducting wires:
  - Kr, Xe, I, U: for other HEP detectors
  - Potential needs: Cd, Ni, Ge, S, Ca.

CHIPS improvement of nFe56 (n,γ) cross-section



Goals for next two months

- Check Low-energy neutron transport (E < 20 MeV)
  - Either **eliminate** imprecision **as** the **leading cause** of lateral shower shape discrepancy, **or**
  - **Identify the 'proportion'** it contributes for typical HEP use case, e.g. Fe-Sci, Cu-lAr, Pb-Si.
  - Leading suspect today:
    - Absorption cross section & treatment
- In JIRA this is SIM-78 – target is 30 April 2011.

Next items (alternative causes)

- Neutron production
  - Missing re-scattering: less neutrons
    - Corrections to Binary (BIC) connection to FTF
      - (BIC is only existing rescattering option)
    - Encourage SLAC effort to enable rescattering in BERTini
- Improve γ production from neutrons
  - Substitute pre-compound for (n,γ)
    - It is alternative final state model for n-absorption
    - This is now being reviewed / improved
      - After feedback of issues from hadrontherapy users