



# Testing suite for validation of Geant4 hadronic generators

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# Validation suite for thin target data on hadron inelastic interaction

- Exist since 2002
- Neutron production by p, d,  $\alpha$ ,  $^{12}\text{C}$  with  $E \leq 3 \text{ GeV}$ 
  - $p + A \rightarrow n + X$
  - $d + A \rightarrow n + X$
  - $\alpha + A \rightarrow n + X$
  - $^{12}\text{C} + A \rightarrow n + X$
- Pion production by protons and pions  $P < 13 \text{ GeV}/c$ 
  - $P + A \rightarrow \pi^\pm + X$
- More 100 thin target setups
- Data versus Geant4 models
- Control on differential spectra
- Model level test
- Models under testing:
  - PreCompound
  - Binary Cascade
  - Binary Ion cascade
  - Bertini Cascade
  - Wilson-Abrasion model
  - LHEP
  - QGSP
  - QGSC
  - FTFP
- A new model can be easily included

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# Updated validation infrastructure at CERN

- Software and results stored at AFS public
  - AFS volume with backup
  - Started from g4 8.1
  - Test data and scripts in CVS
- Driving by scripts
- ROOT based analysis
- From g4 8.1 running at LXBATCH
  - Complete run needs from few days to one week
- Directories are structured by tag name

\$VFHAD/test30/data/pn\_al\_256

    /pn\_al\_1500

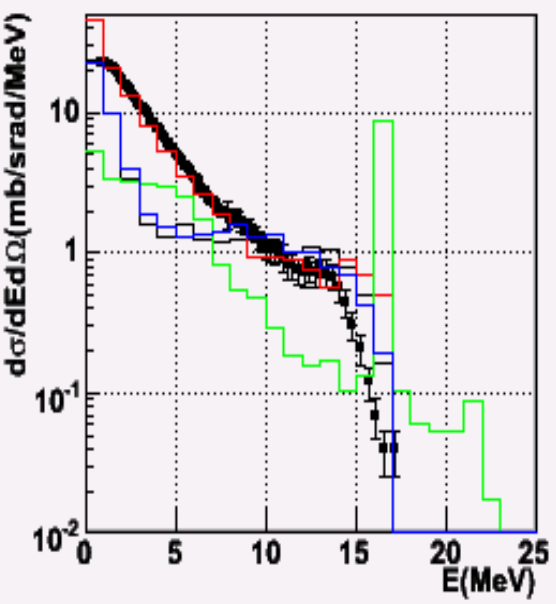
\$VFHAD/test30/geant4-08-01-ref-00/pn\_al\_256/r.out

    /pn\_al\_256/bic.paw

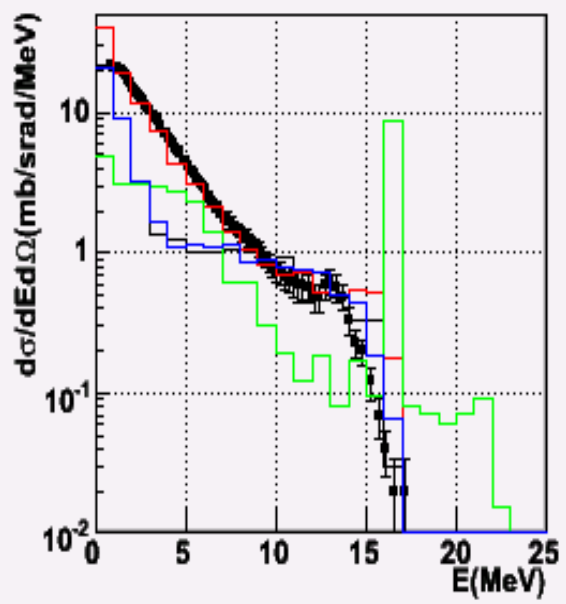
    /pn\_al\_256/bert.paw

- Results for g4 9.0 will be shown below
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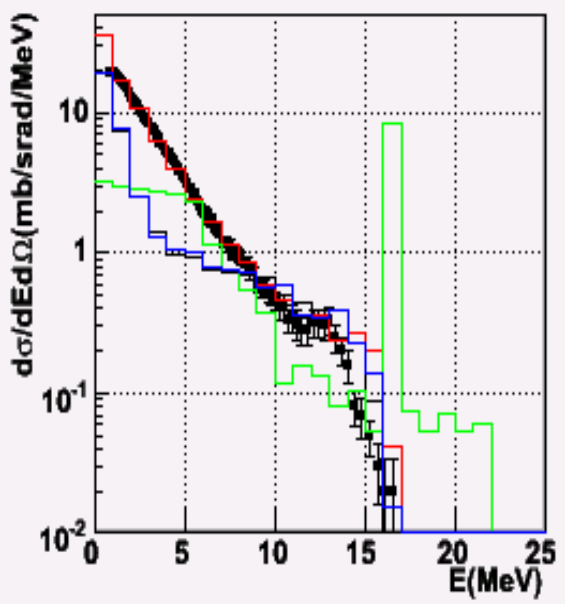
$p + \text{Fe} \rightarrow n + X, E = 22 \text{ MeV}, \theta = 30^\circ$



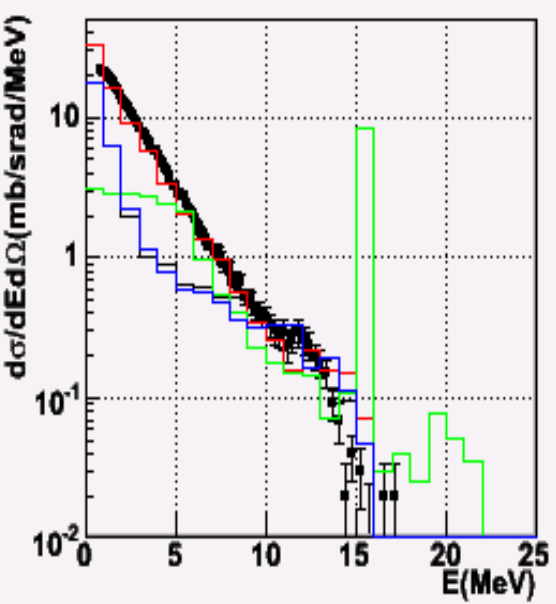
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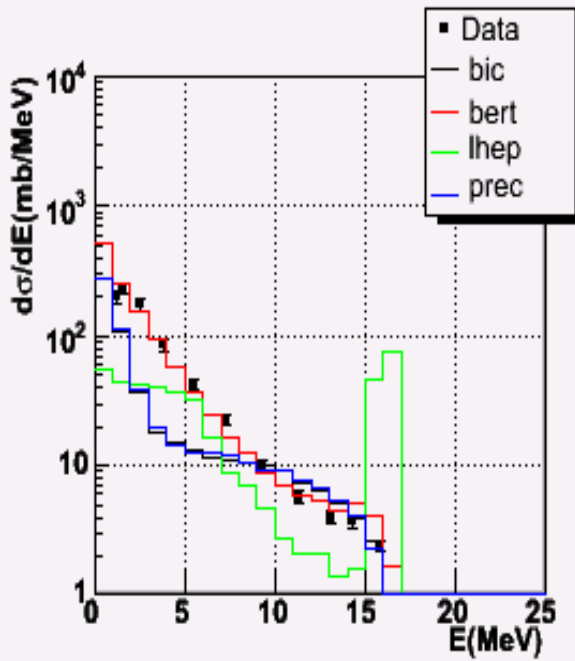
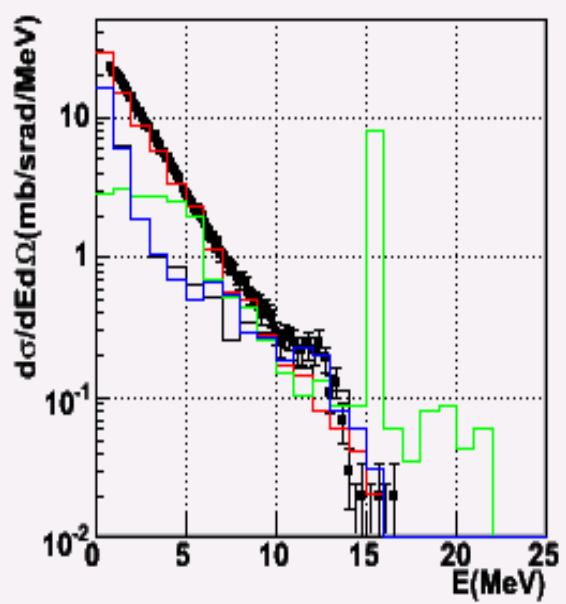
$\theta = 90^\circ$



$\theta = 120^\circ$

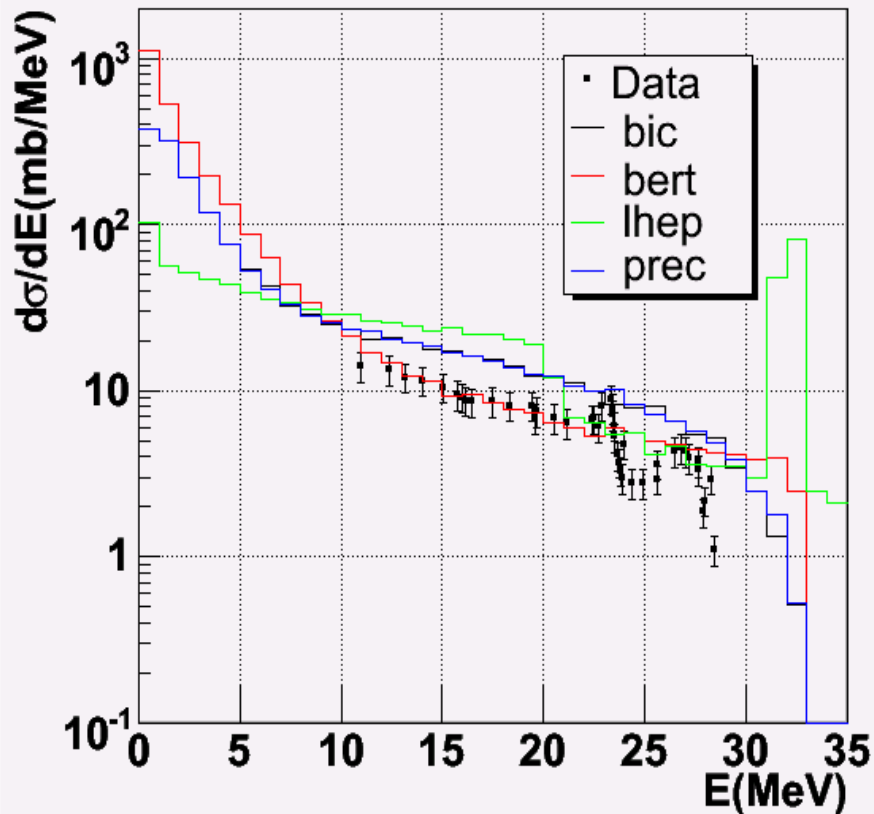


$\theta = 150^\circ$

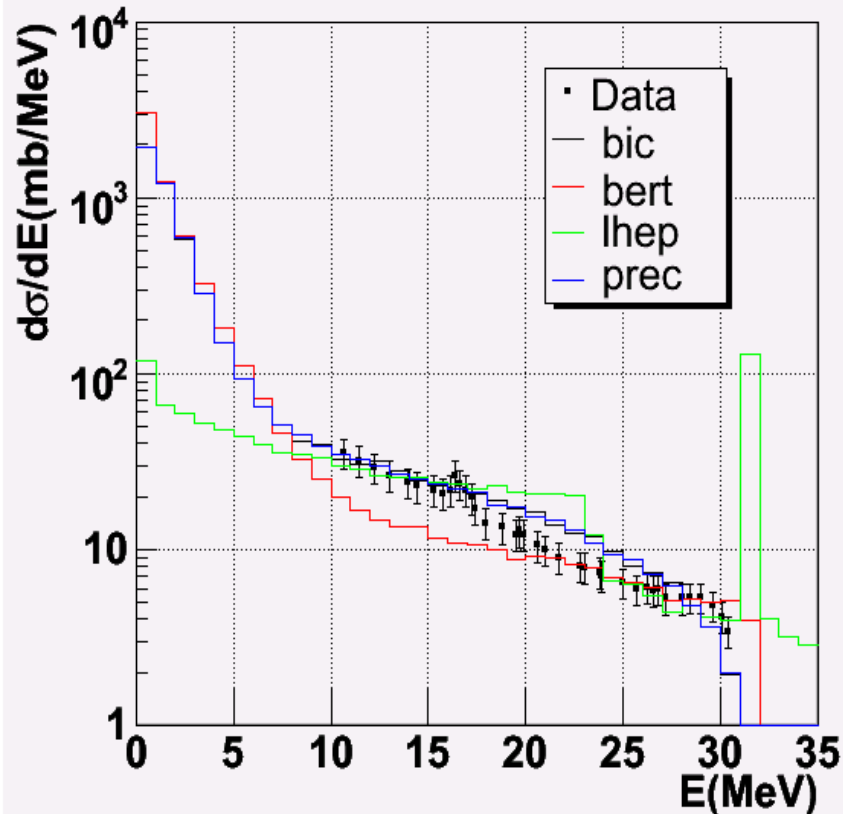


# Neutron production by 35 MeV proton beam in heavy targets

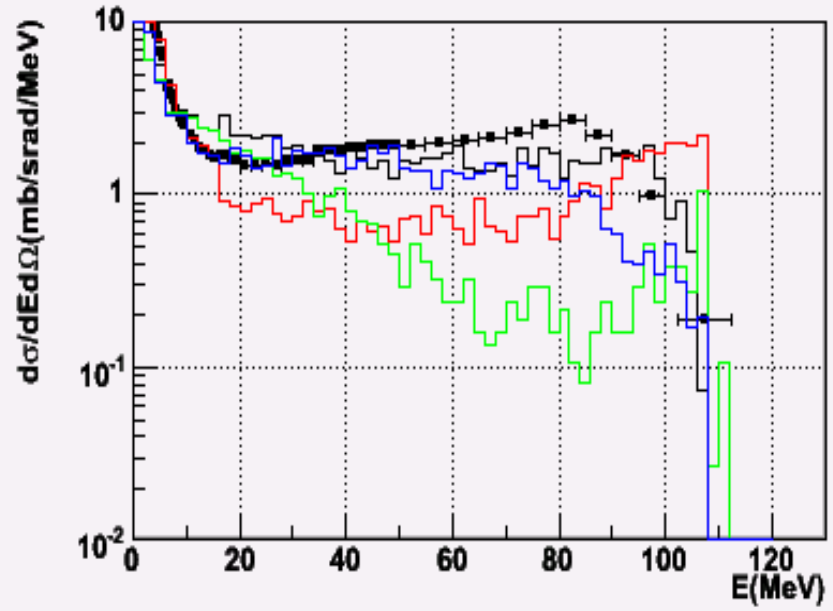
$p + \text{Zr} \rightarrow n + X, E = 35 \text{ MeV}$



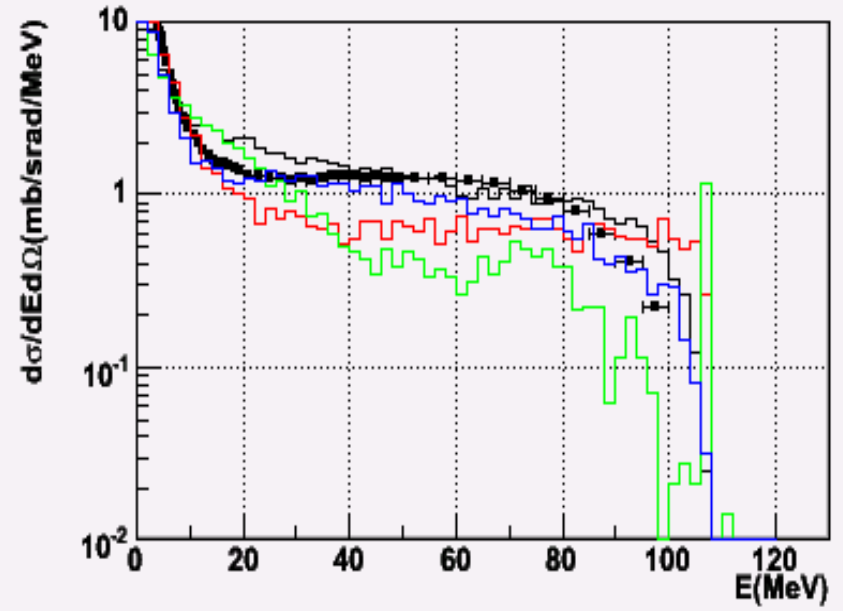
$p + \text{Pb} \rightarrow n + X, E = 35 \text{ MeV}$



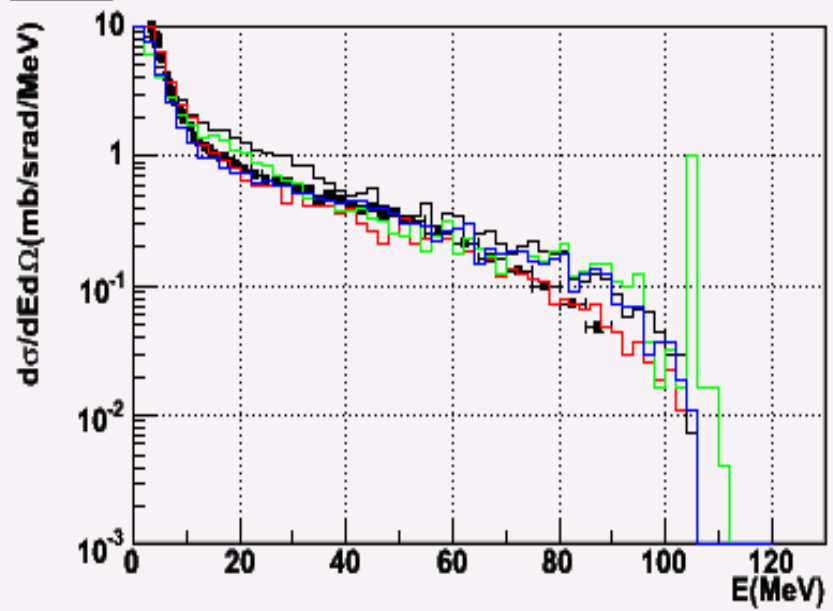
$p + \text{Fe} \rightarrow n + X, E = 113 \text{ MeV}, \theta = 7.5^\circ$



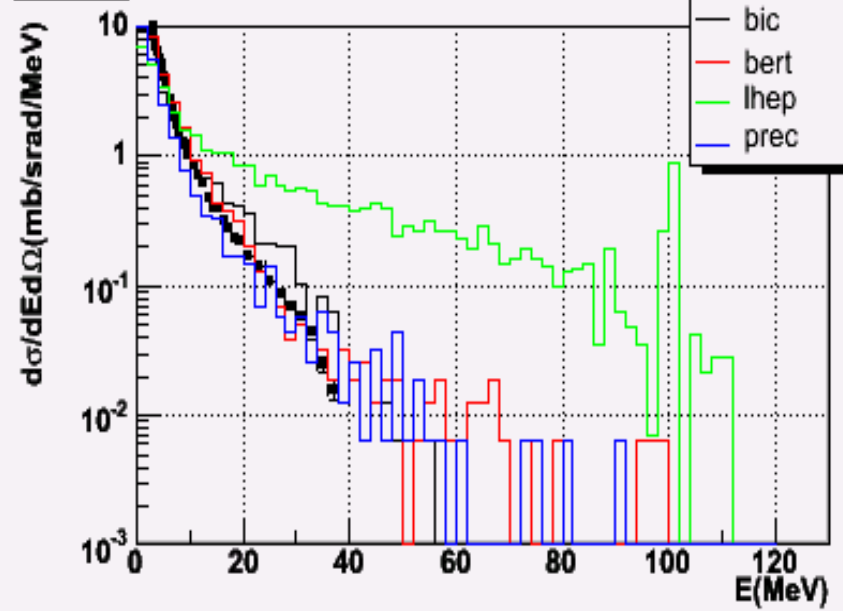
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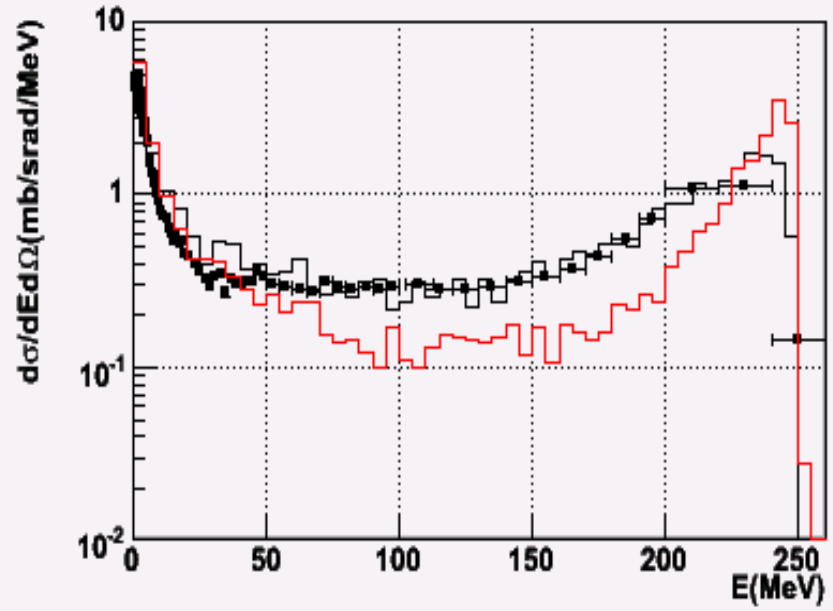
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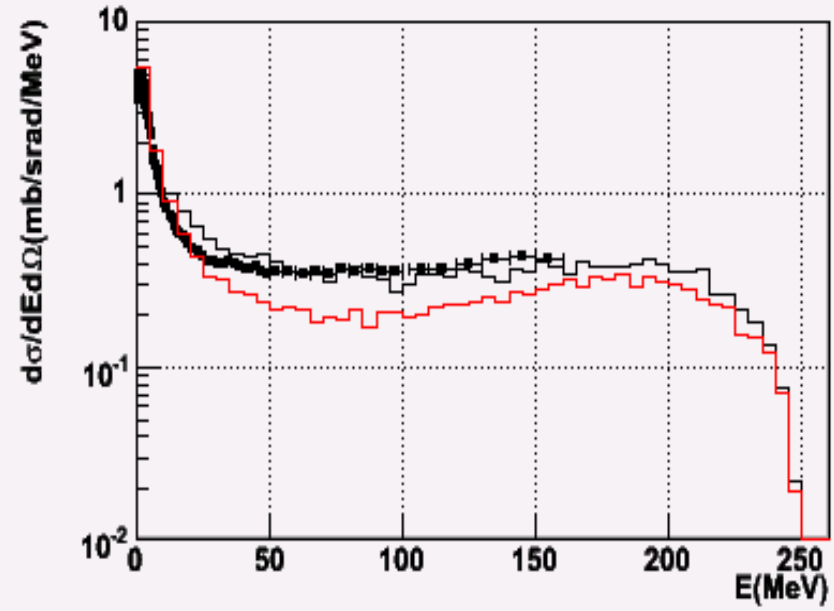
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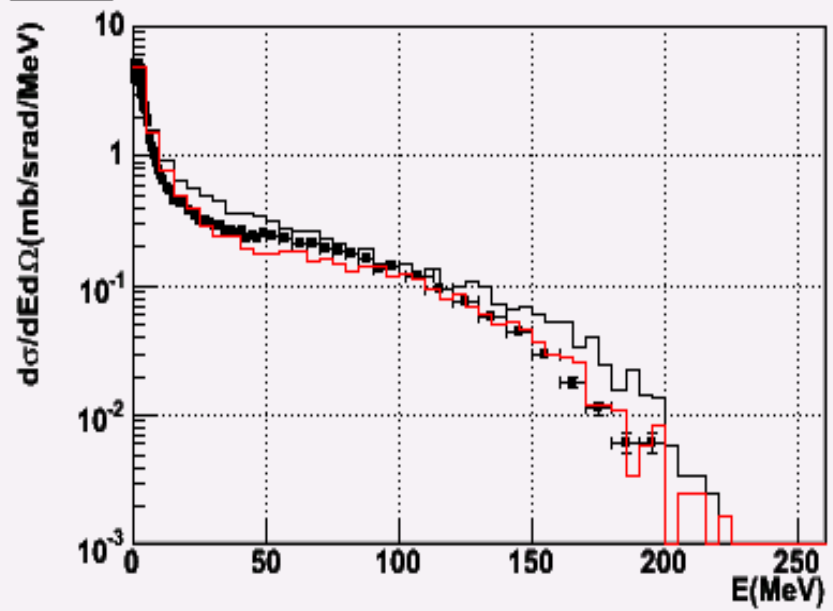
$p + Al \rightarrow n + X, E = 256 \text{ MeV}, \theta = 7.5^\circ$



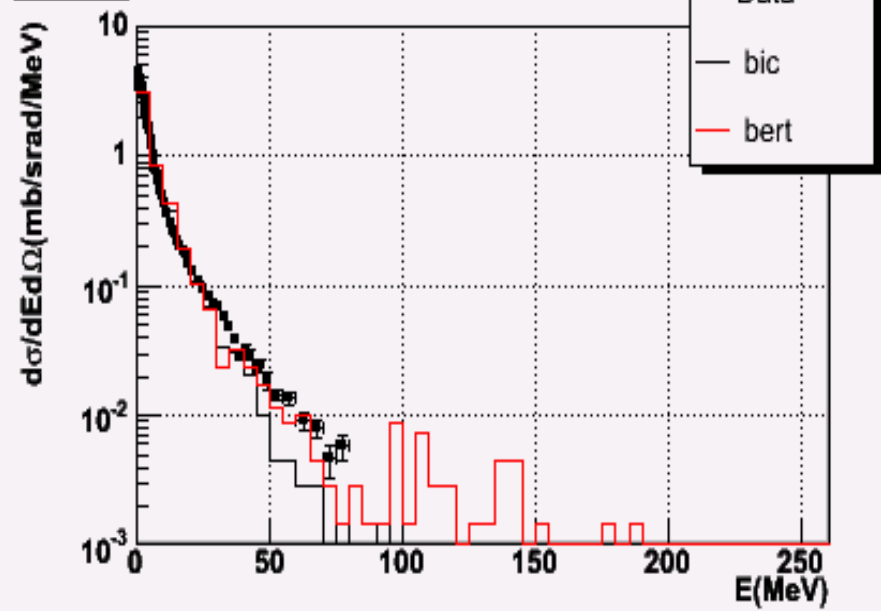
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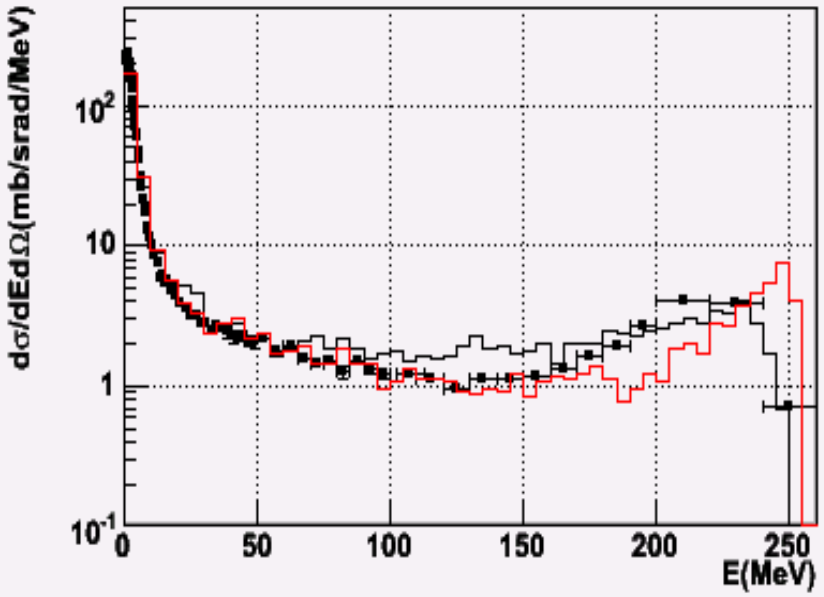
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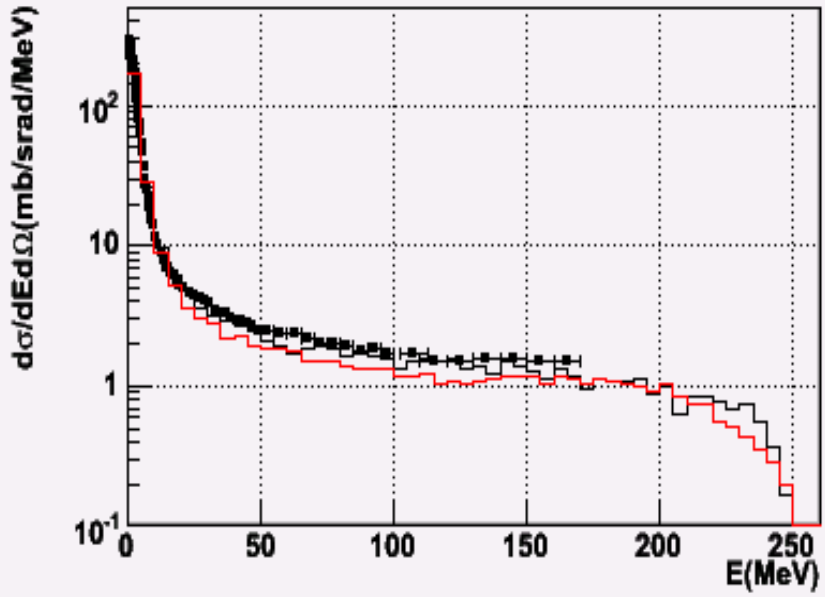
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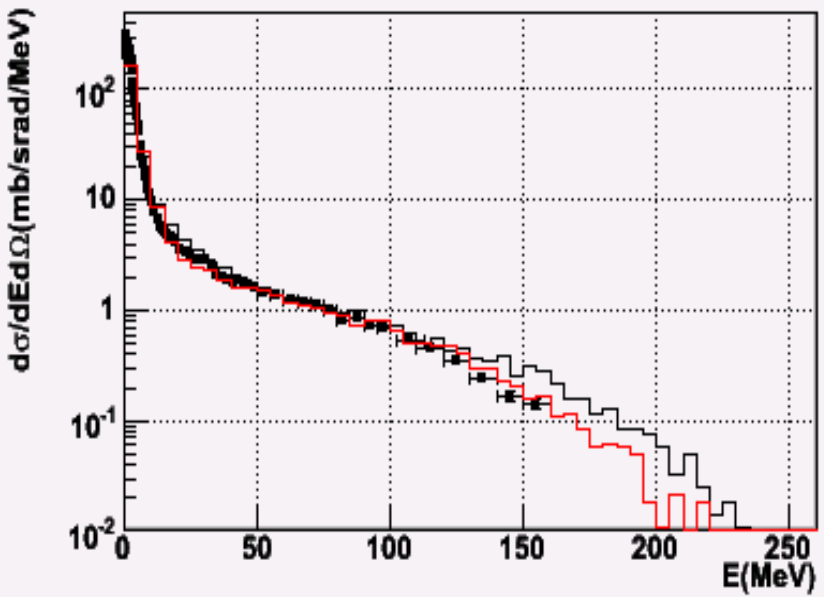
$p + \text{Pb} \rightarrow n + X, E = 256 \text{ MeV}, \theta = 7.5^\circ$



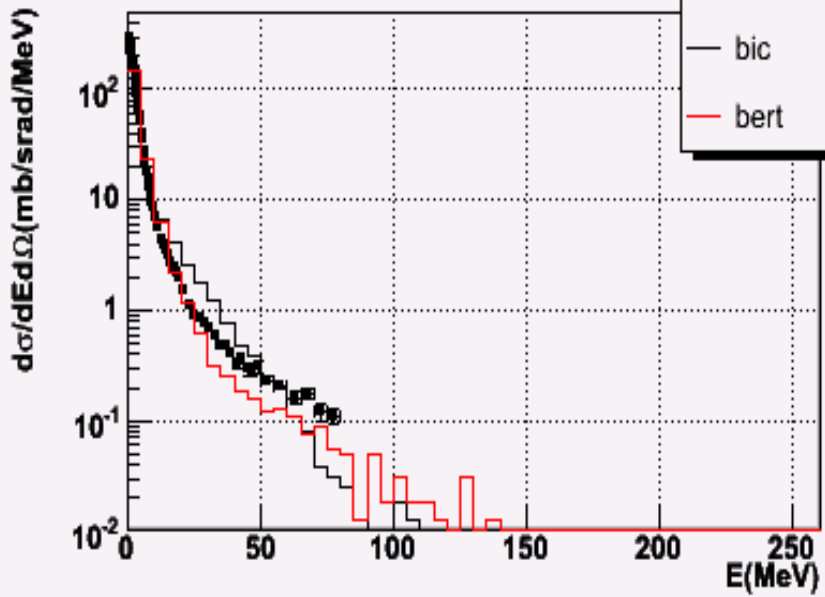
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$\theta = 60^\circ$

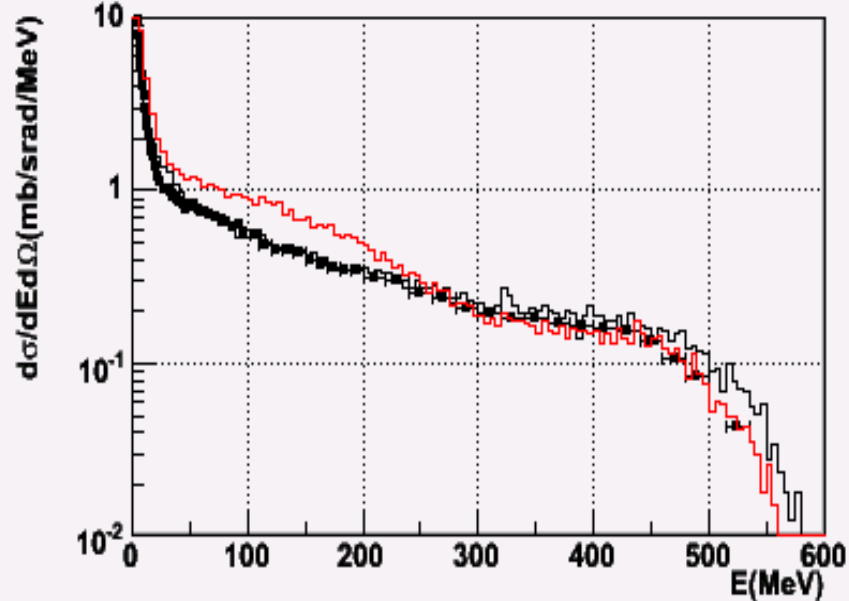


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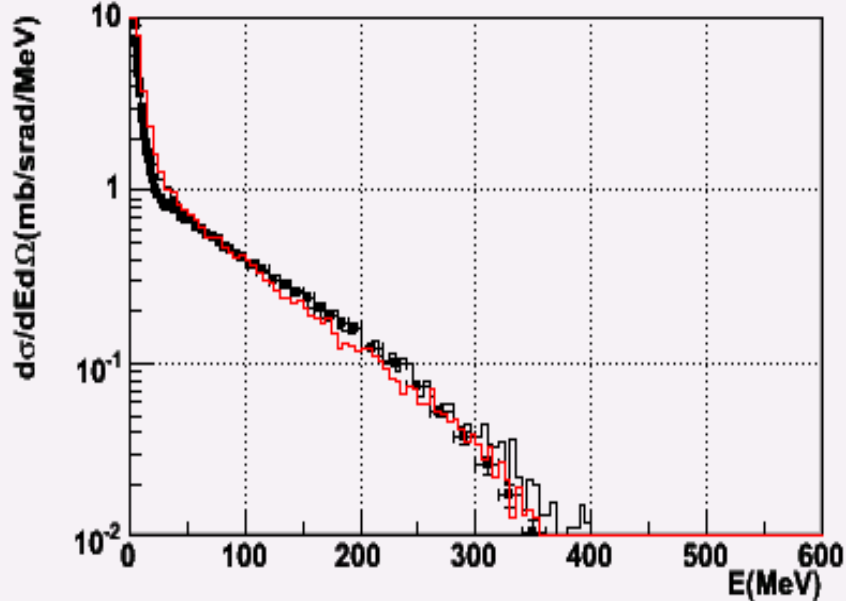




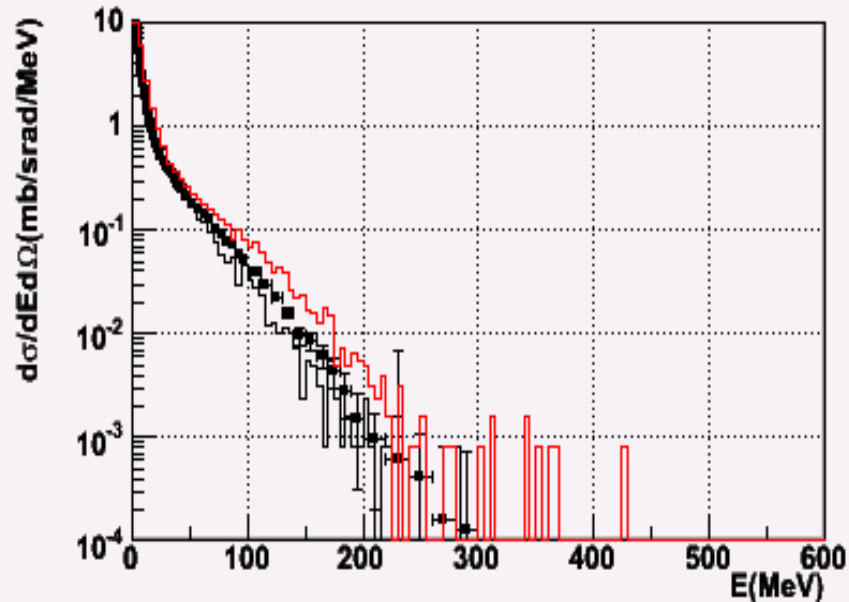
$p + \text{Fe} \rightarrow n + X, E = 597 \text{ MeV}, \theta = 30^\circ$



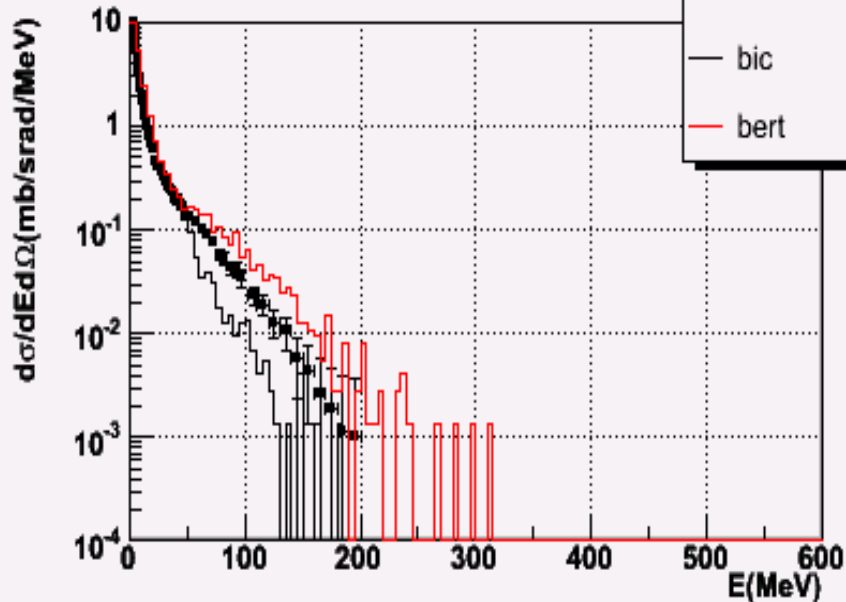
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$\theta = 120^\circ$

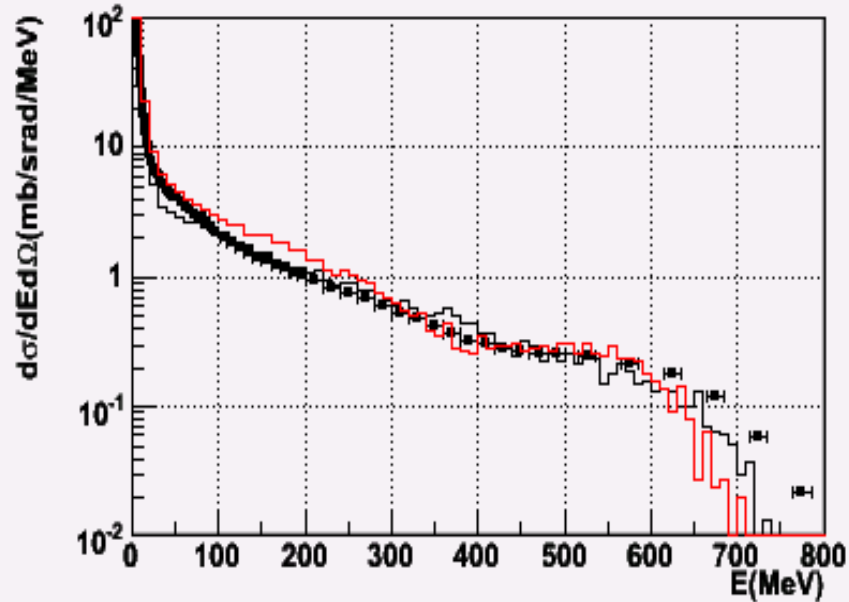


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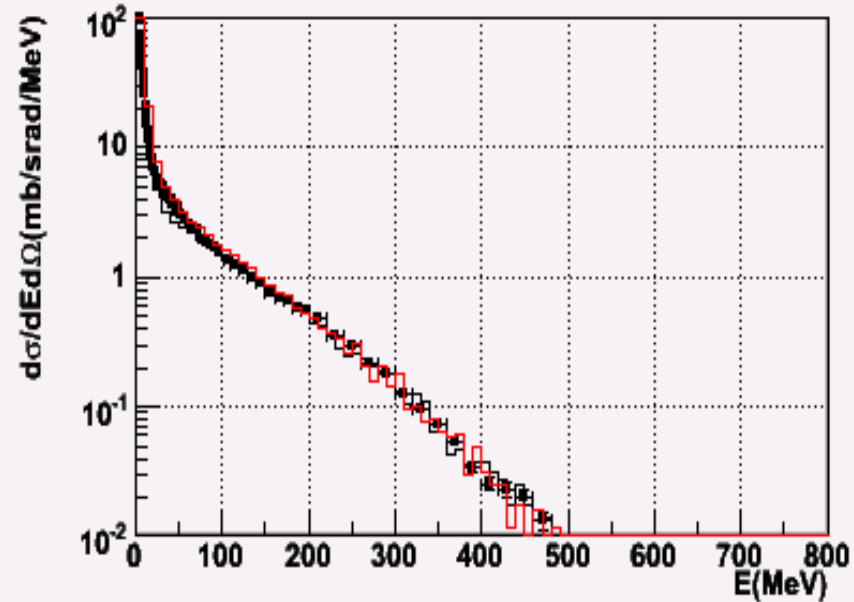


■ Data  
— bic  
— bert

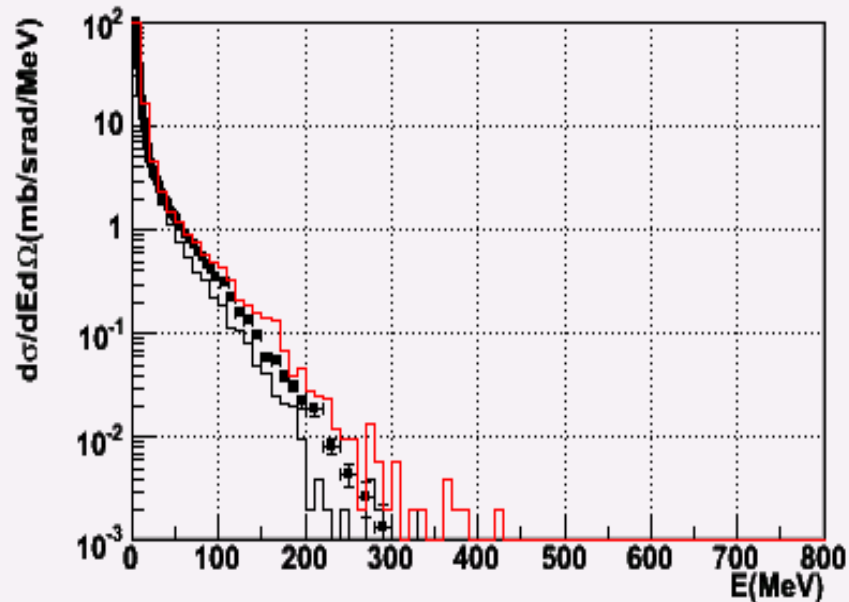
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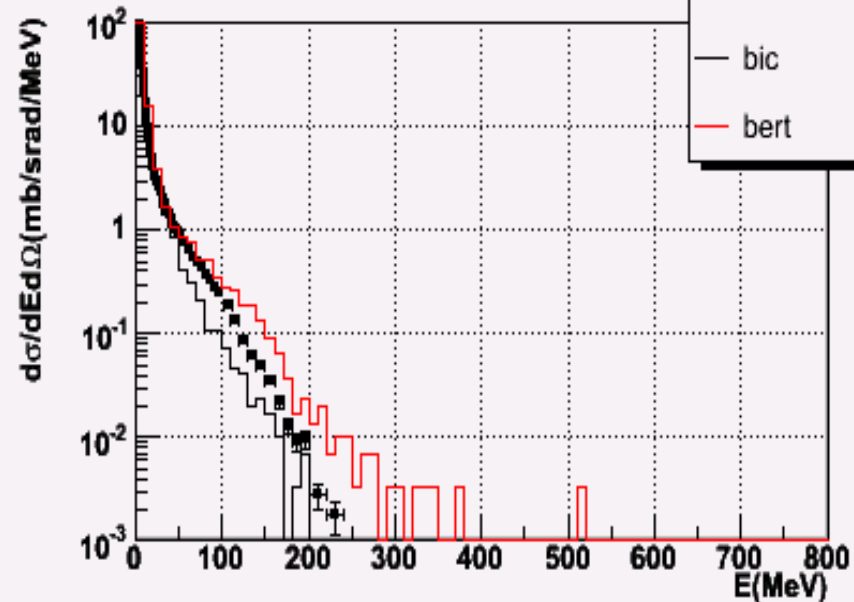
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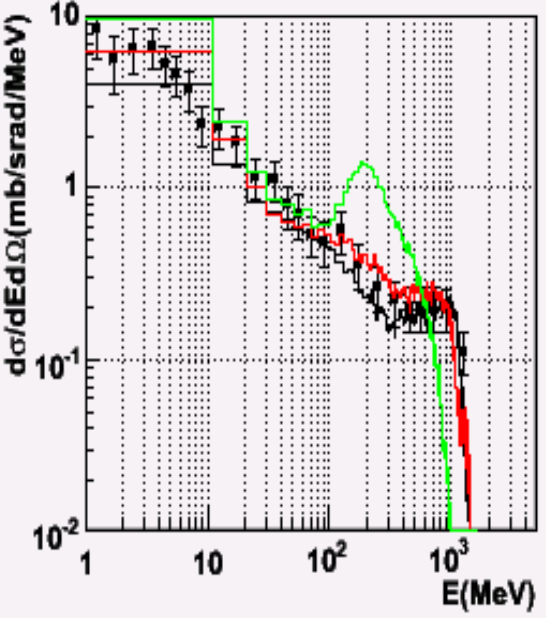
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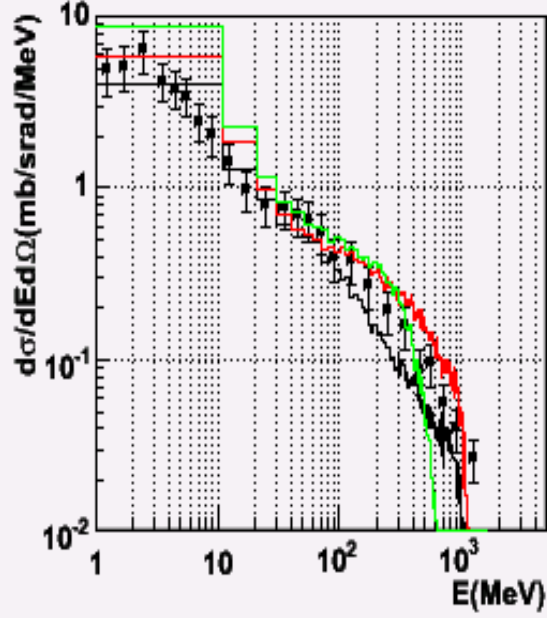
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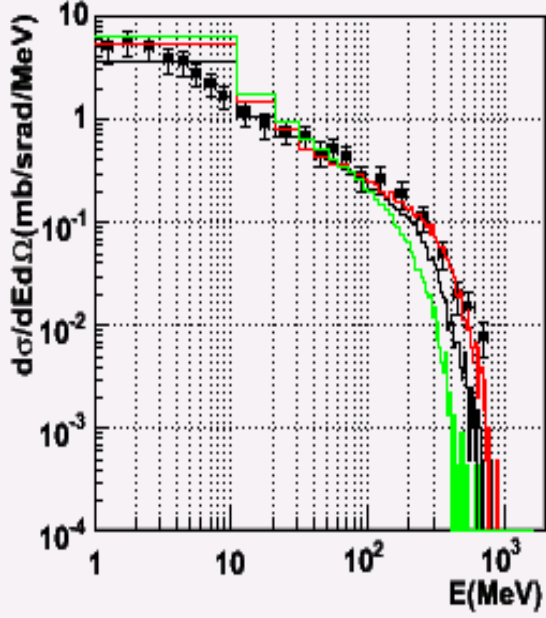
$p + Al \rightarrow n + X, E = 1.5 \text{ GeV}, \theta = 15^\circ$



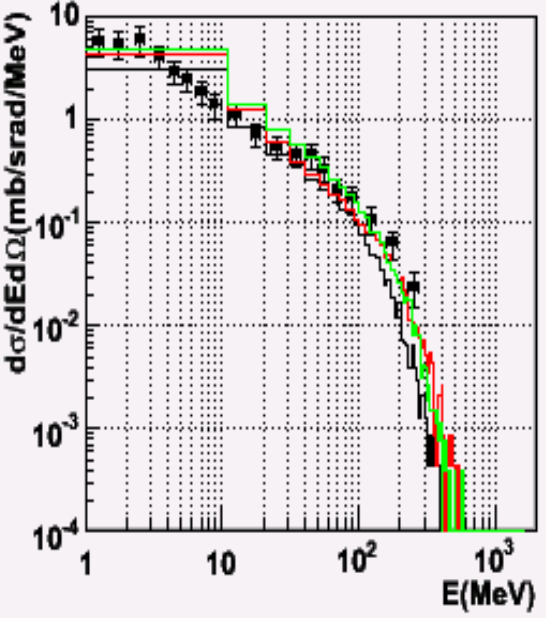
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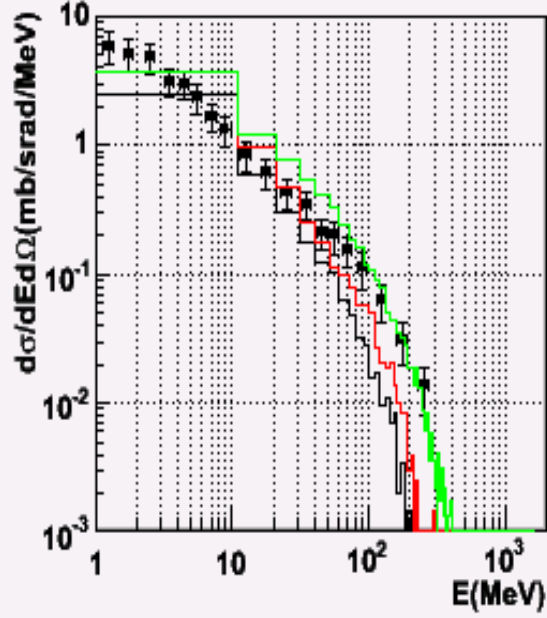
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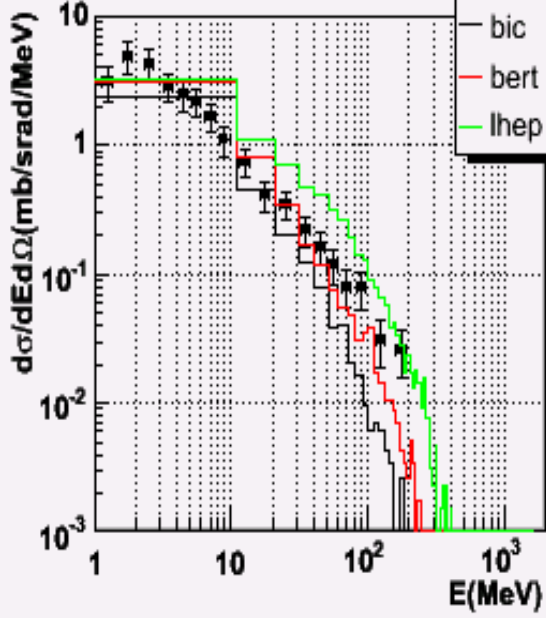
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$\theta = 120^\circ$

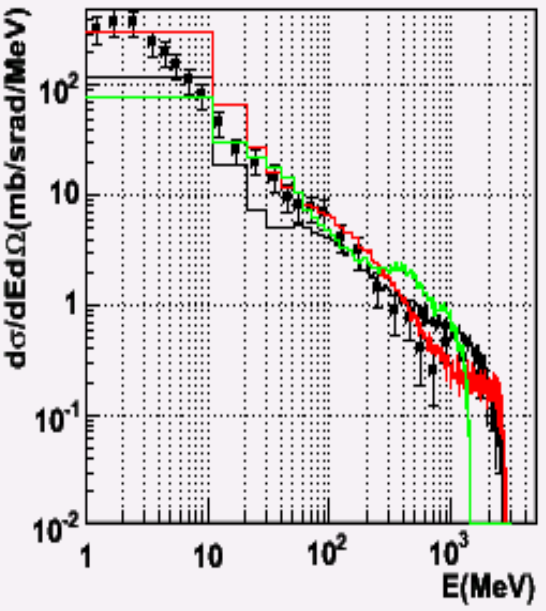


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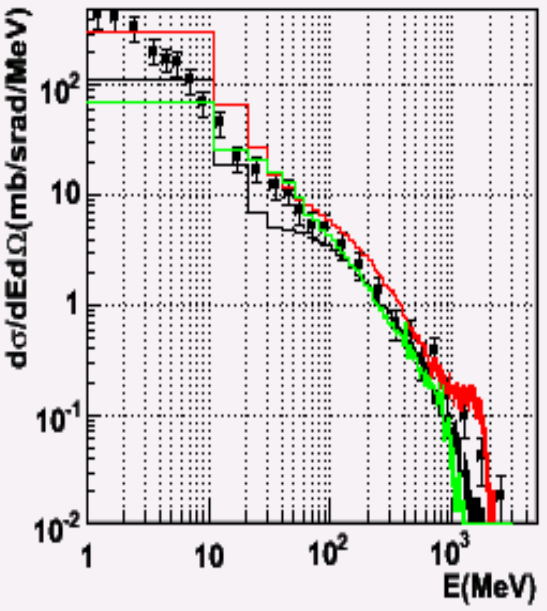


■ Data  
— bic  
— bert  
— lhep

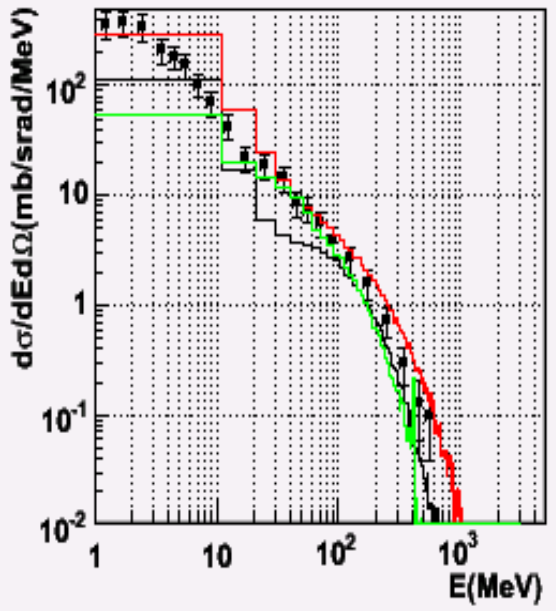
$p + Pb \rightarrow n + X, E = 3 \text{ GeV}, \theta = 15^\circ$



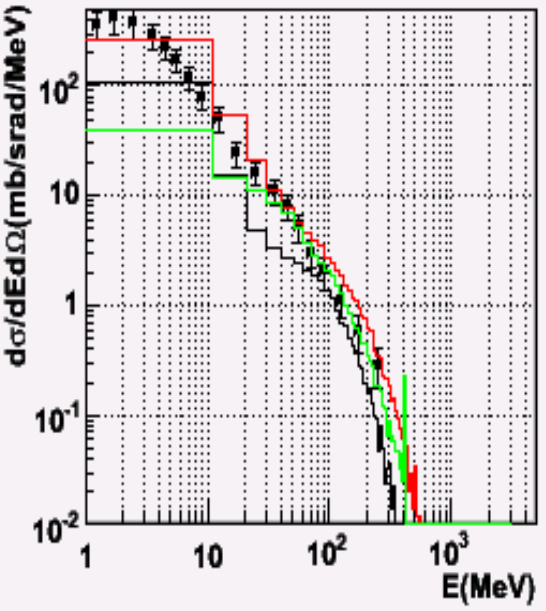
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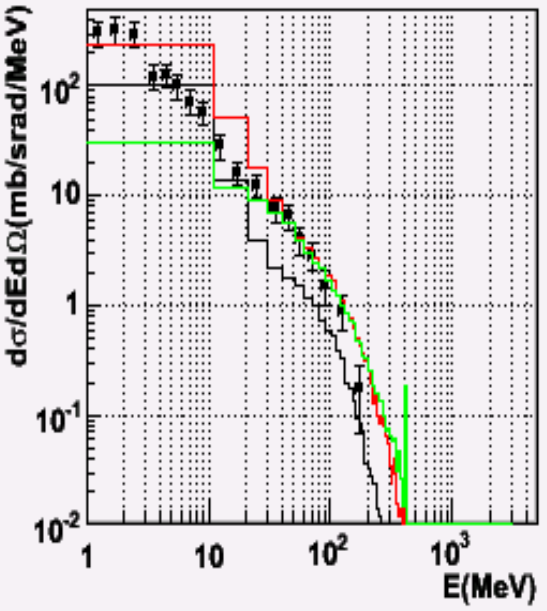
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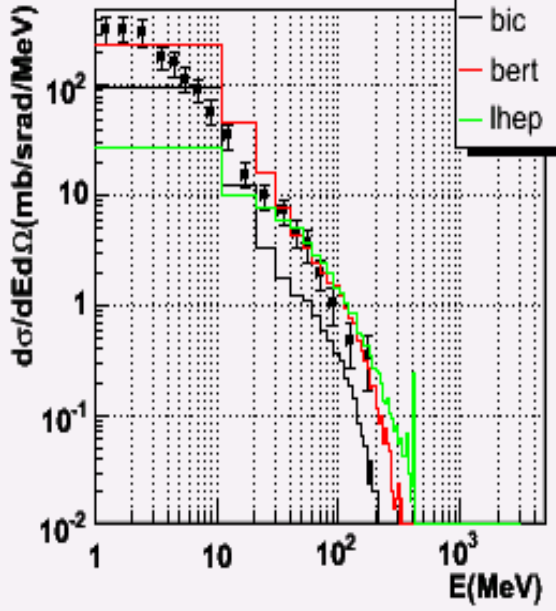
$\theta = 90^\circ$



$\theta = 120^\circ$



$\theta = 150^\circ$

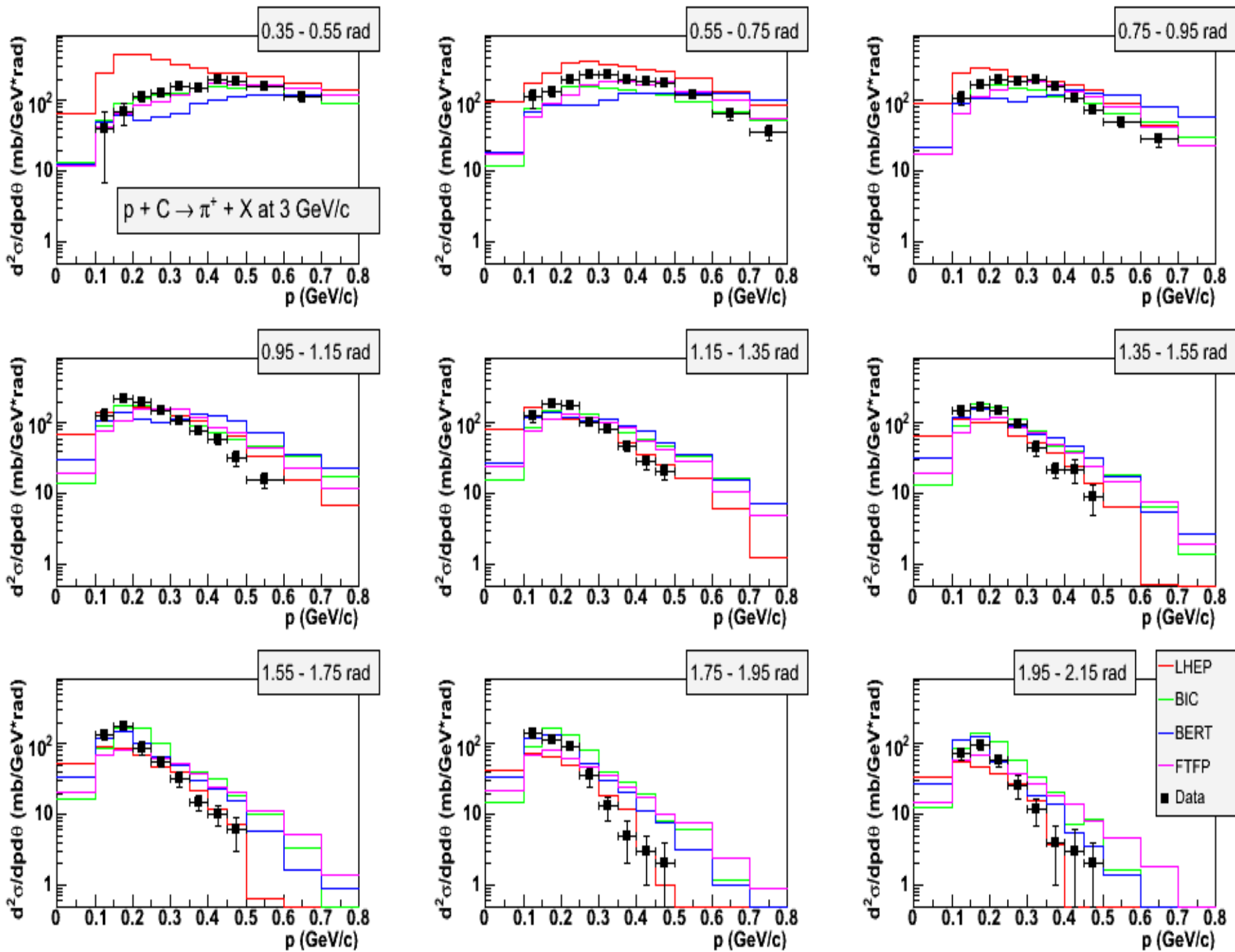


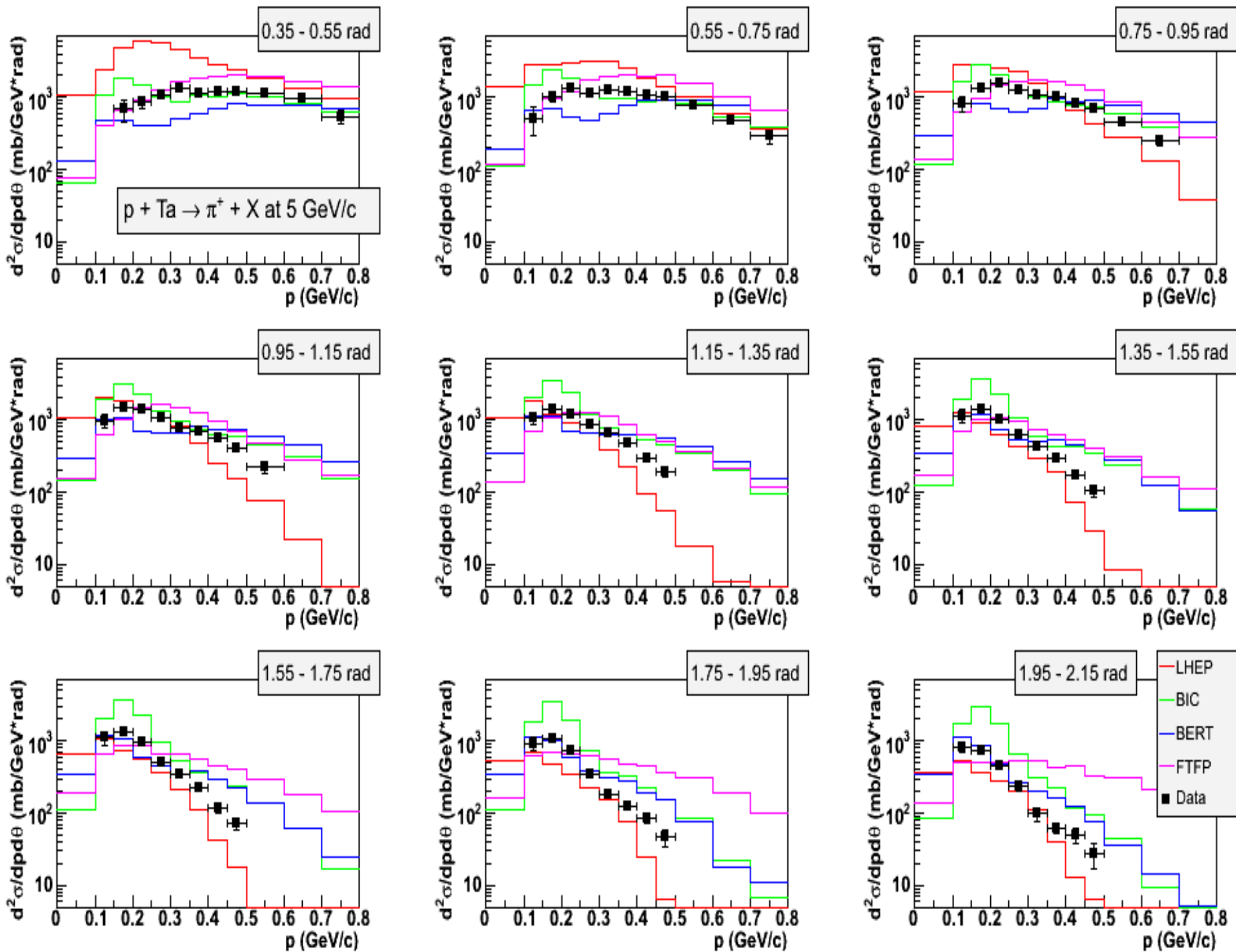
■ Data  
 — bic  
 — bert  
 — lhcp

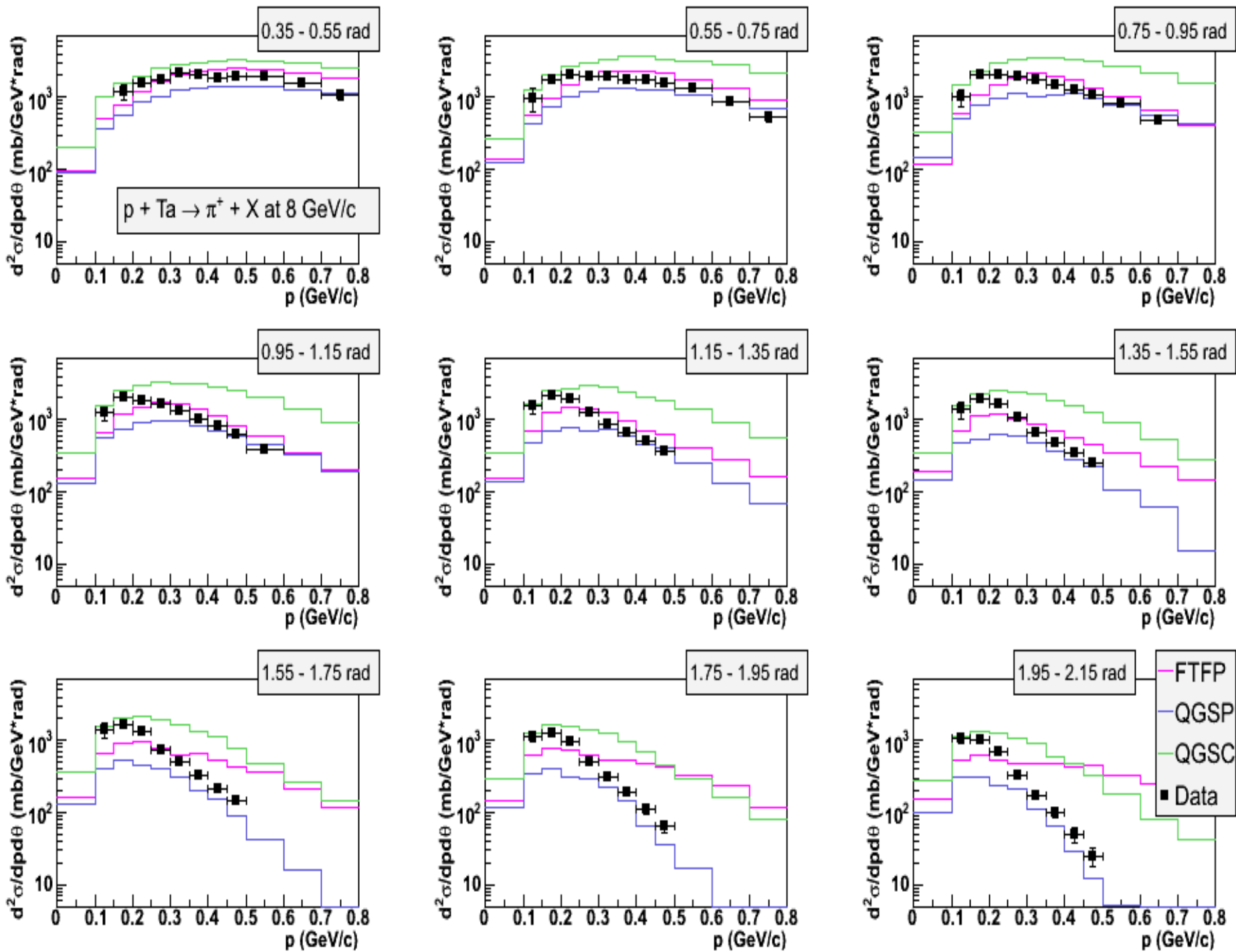
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# Neutron production summary

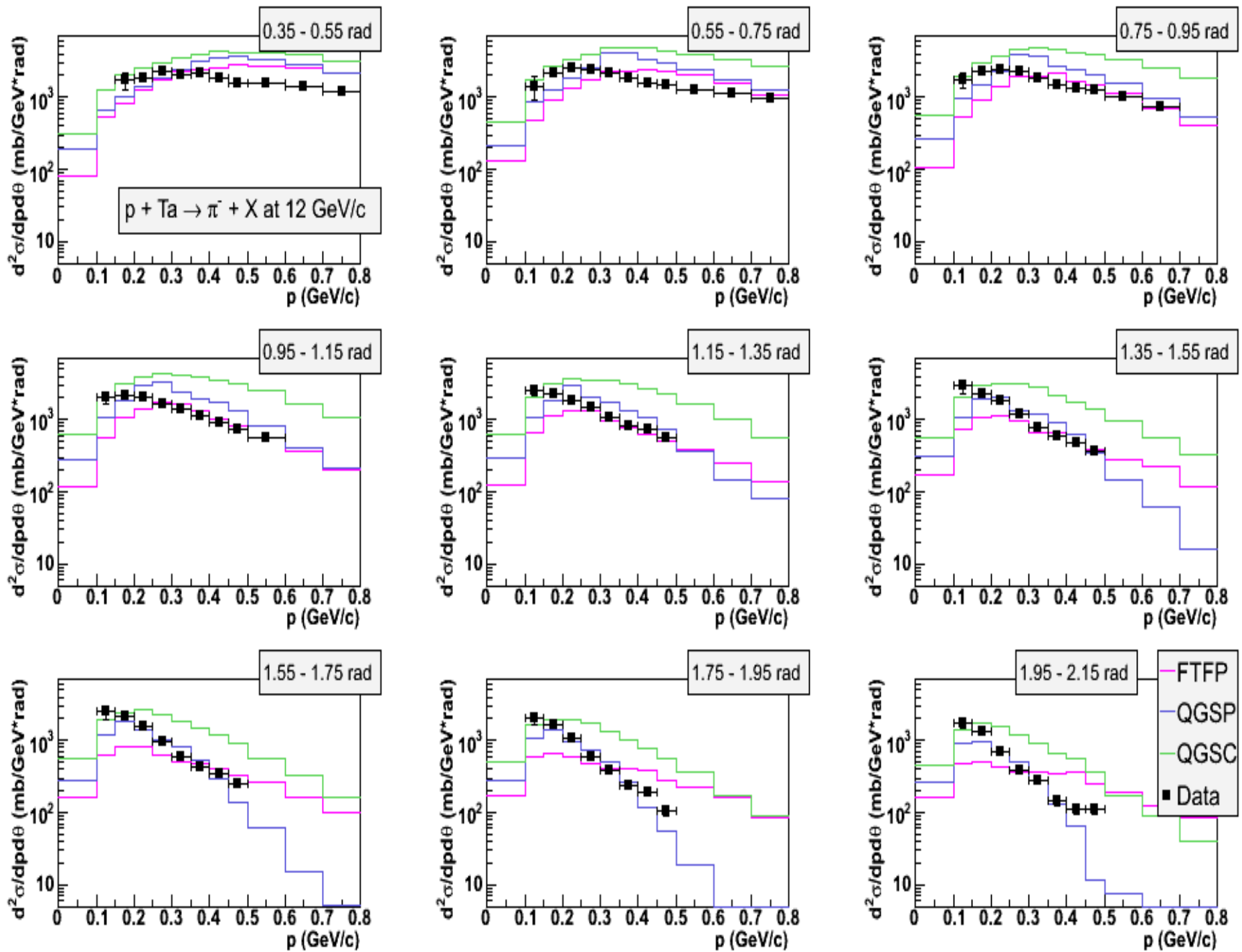
- Pre-Compound and Binary Cascade have problem for light nuclei and low energy
  - Quasi- elastic part of models at 113 MeV and below requires improvements for all models
  - For Bertini Cascade at 600 MeV there is a problem in neutron spectra
  - Binary Cascade underestimate neutron production above 1 GeV
  - Bertini Cascade overestimate neutron flux
  - LHEP can be improved at all energies
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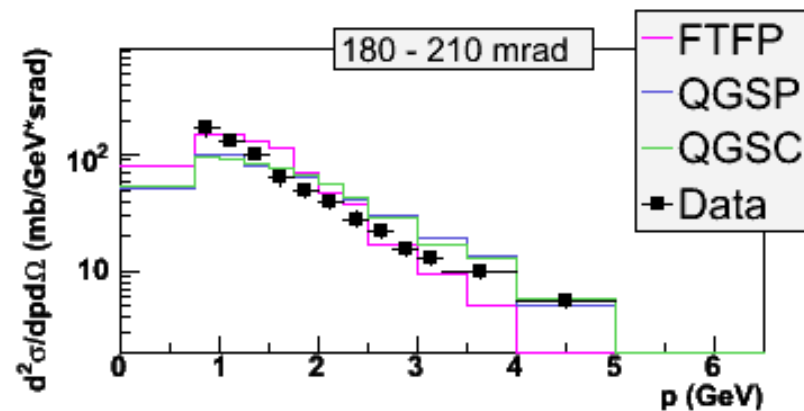
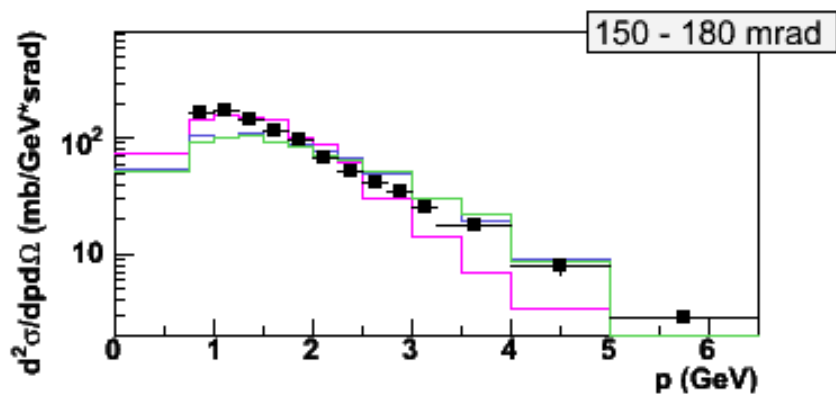
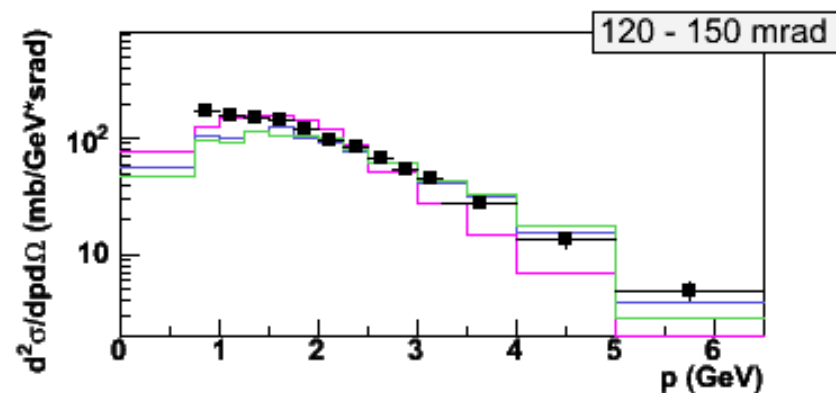
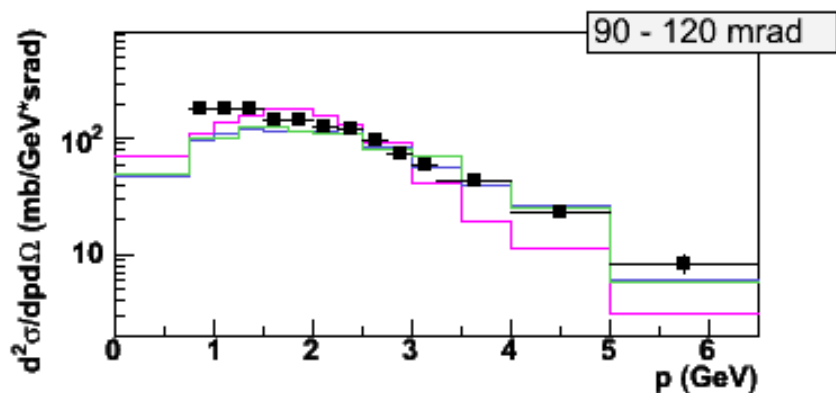
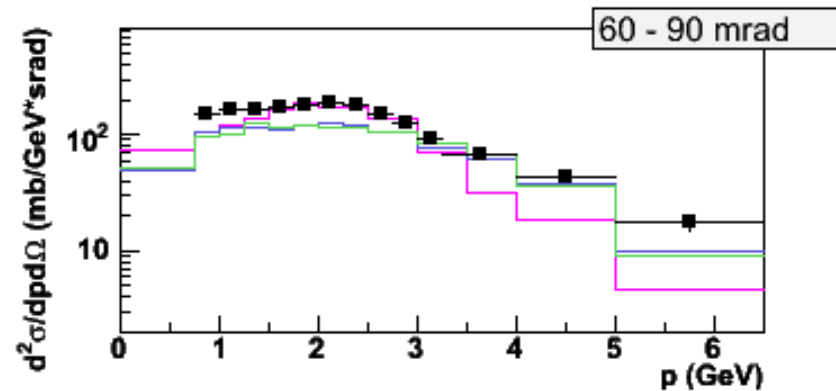
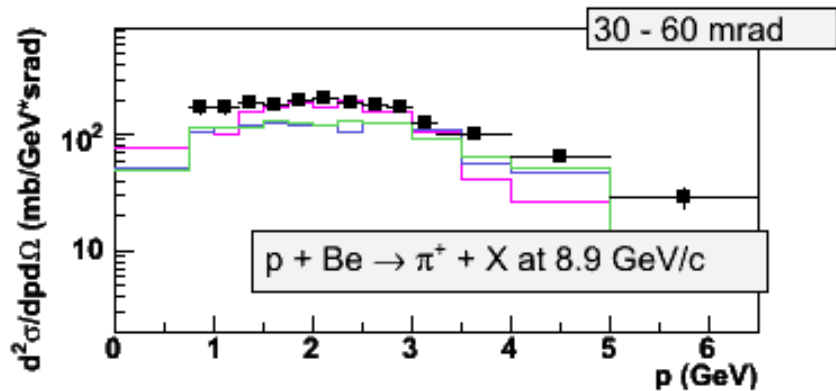


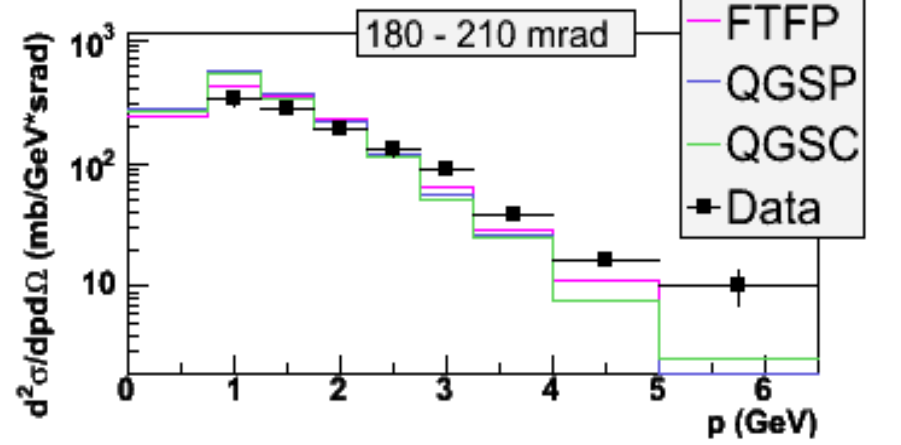
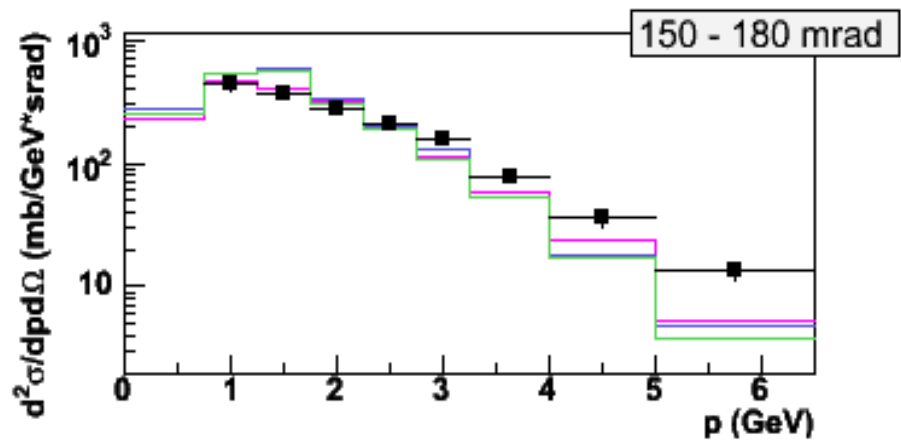
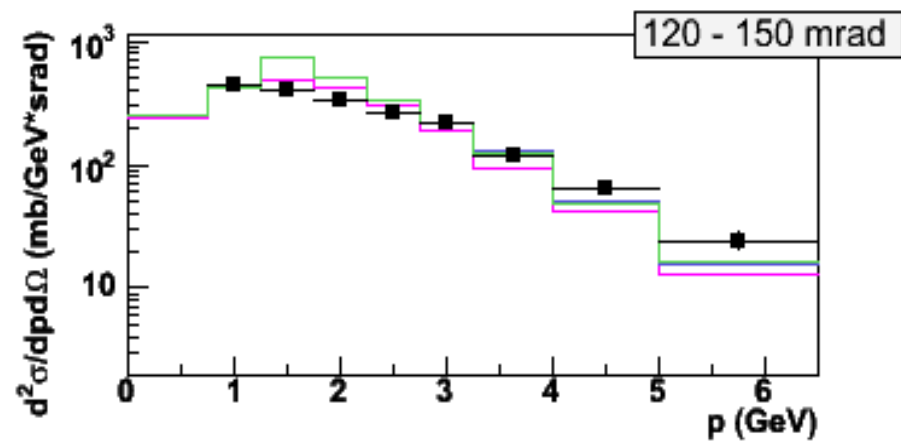
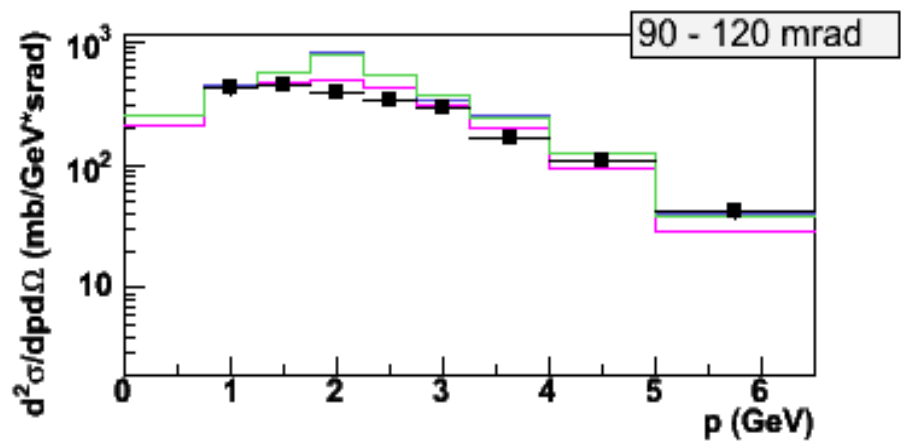
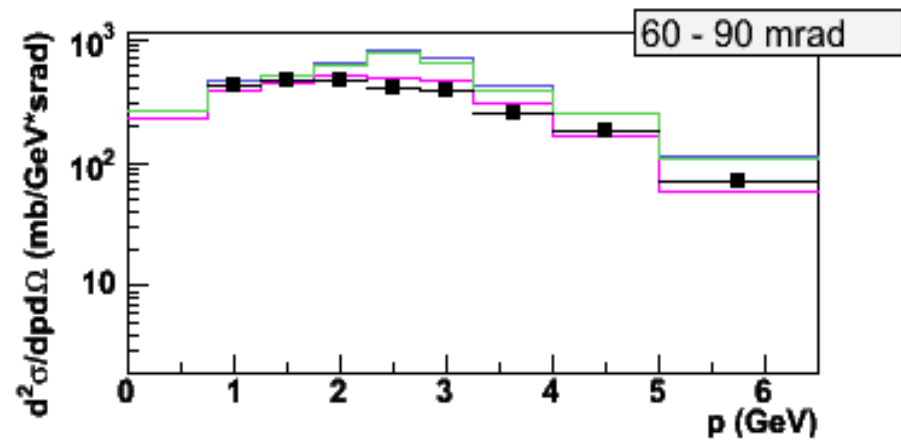
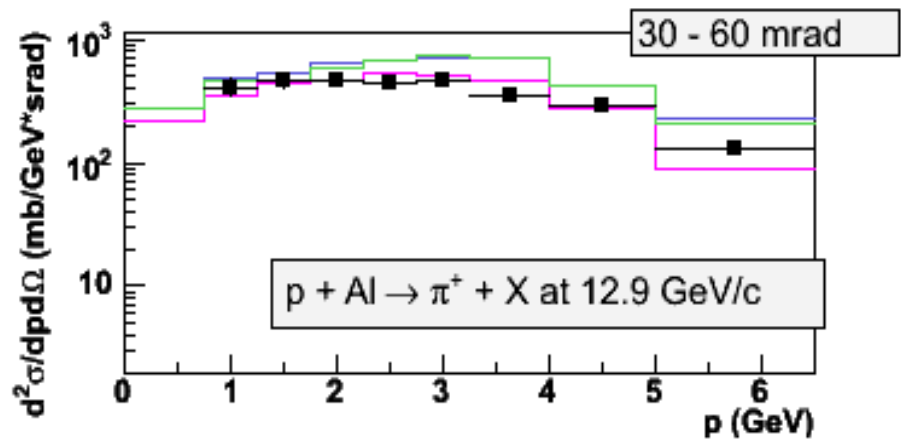












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# Summary for pion production

- Most of the models overestimate backward production of pions with higher momentum
    - Shower shape effected
  - LHEP overestimate forward production of pions and well reproduce spectra at large angles
  - Revised FTFP model is the best for forward production but does not reproduce spectra in backward hemisphere
  - Revised QGSP reproduce data better than QGSC
  - QGSC significantly overestimate pion flux at large angles
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# Conclusion remarks

- Testing infrastructure at CERN have been updated recently
  - More than 100 thin target setups are available
    - data are selected
    - set of Geant4 models per data set are selected
    - scripts are prepared to provide “production” style of work
  - New/old problems of hadronic generators are identified
  - Only small part of plots is shown and only for g4 9.0
    - access to results via web
  - Software allows extensions
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