HiRes and TA Composition Measurements

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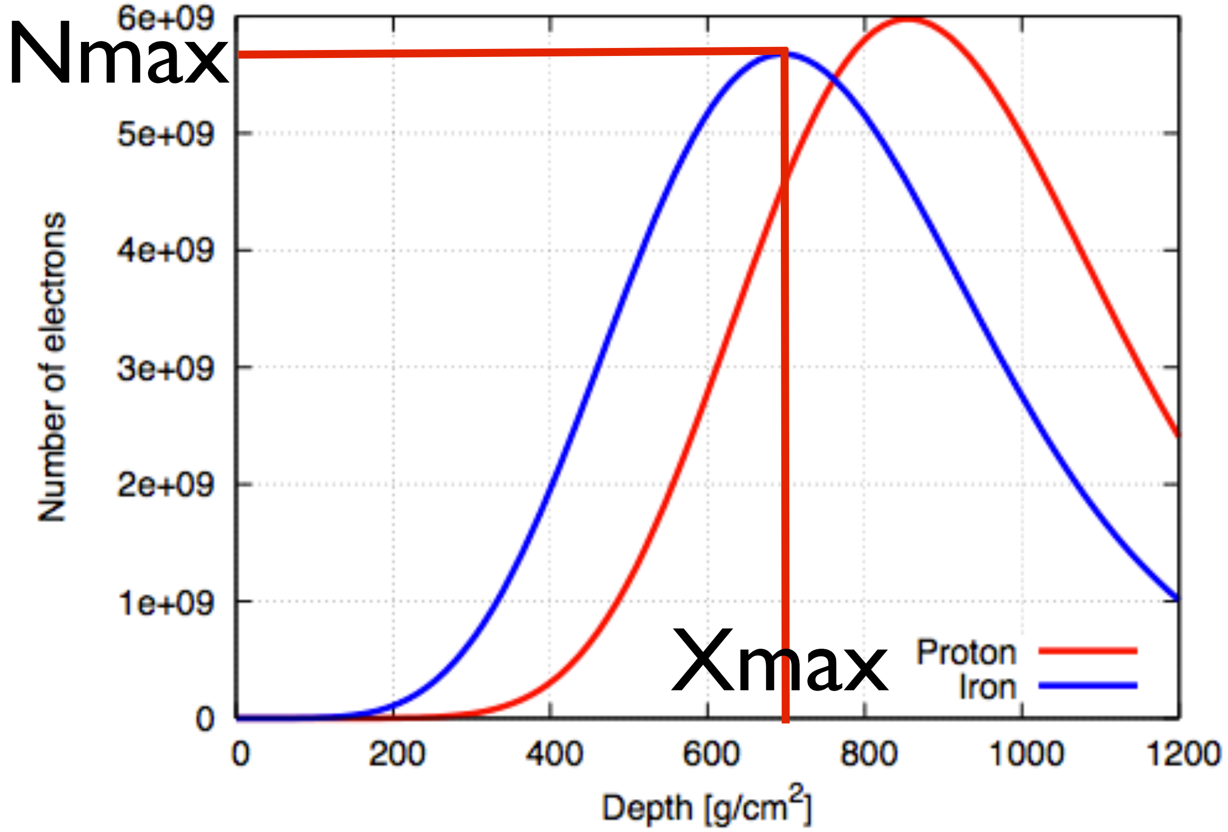
for the Telescope Array and HiRes Collaboration

Outline

- Introduction
- Detectors
  - HiRes, Telescope Array
- Event Reconstruction
  - geometry, shower profile
- Xmax analysis
  - Averaged Xmax, distribution of Xmas

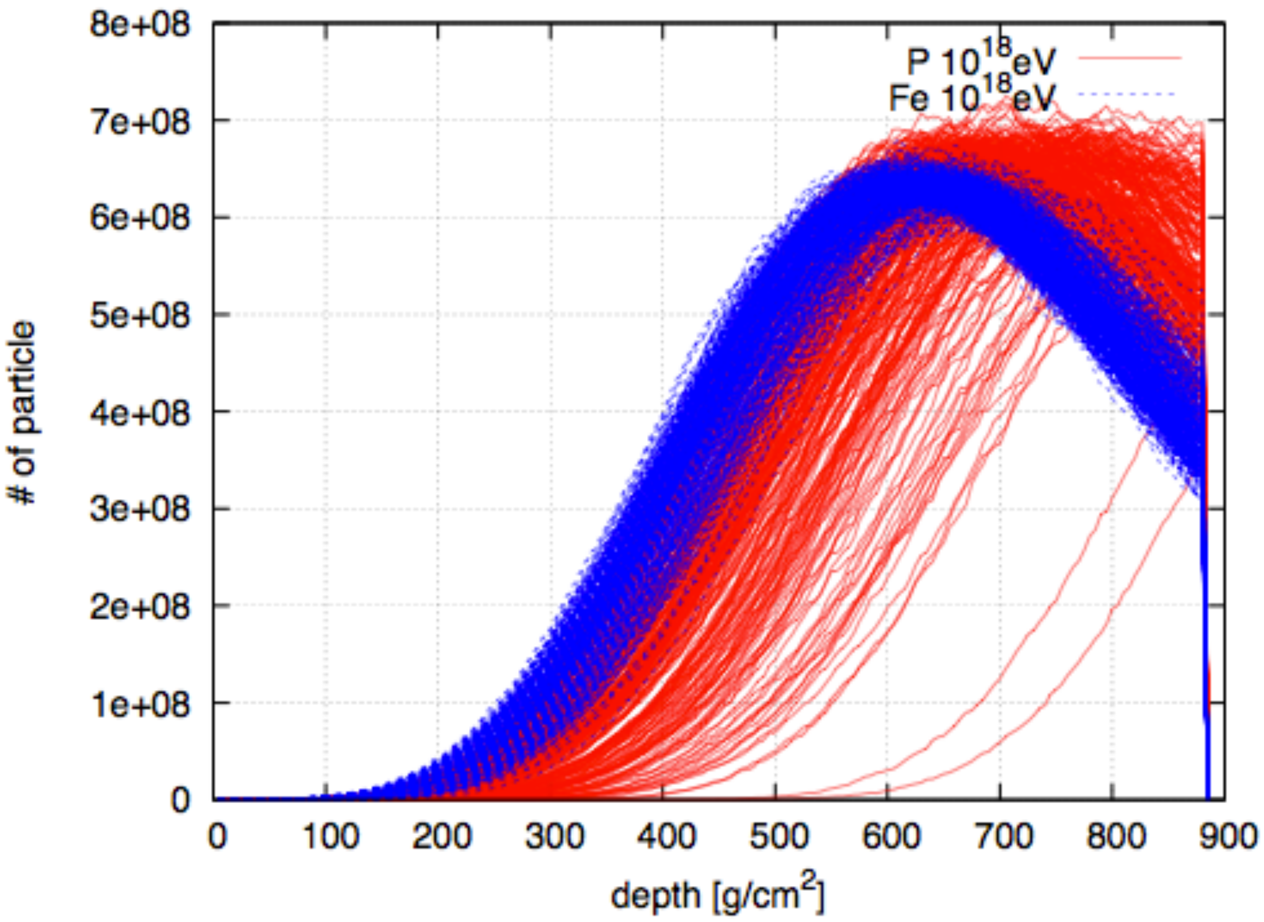
Xmax technique



e.g. airshower profile

- Shower longitudinal development depends on primary particle type.
- FDs observe shower development directly.
- Xmax is the most efficient parameter for determining primary particle type.

Xmax technique



- Shower longitudinal development depends on primary particle type.
- FDs observe shower development directly.
- Xmax is the most efficient parameter for determining primary particle type.
- Large fluctuation of Xmax
  ---> Average, width, distribution

HiRes

HiRes-I:

- 21 mirrors, 1 ring, 3°<elev.<17°
- Sample and hold

HiRes-II:

- 12.6 km SW of HiRes-I
- 42 mirrors, 2 rings, 3°<elev<31°
- FADC 100 ns sampling

Mirrors & Phototubes:

- 4.2 m^2 spherical mirror
- 16 x 16 array of phototubes

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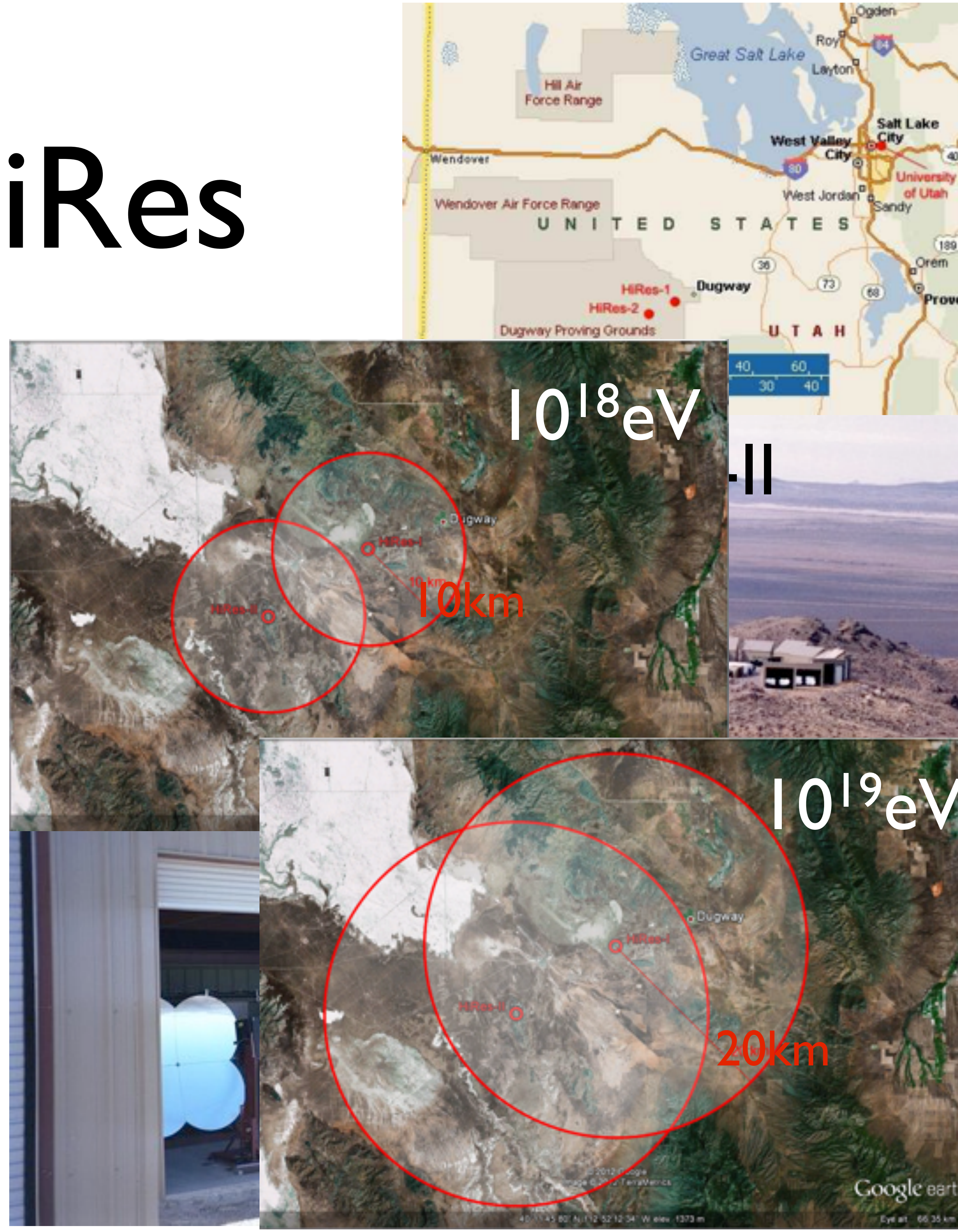


Telescope Array

FD

Black rock, Long ridge:

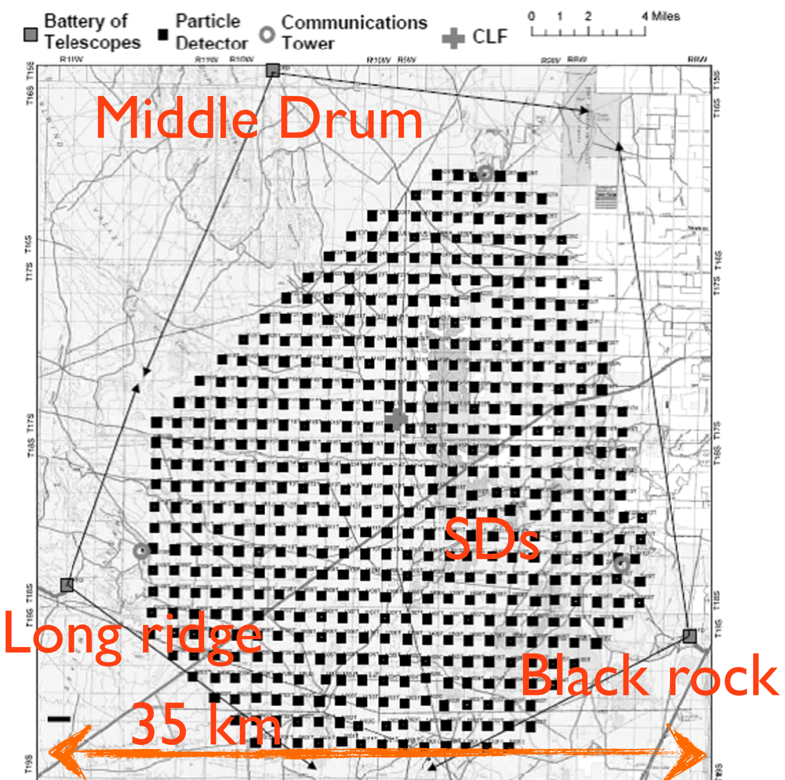
- 2 stations, 24 mirrors
  3°<elev.<33°
- 100ns sampling FADC
- 6.8 m^2 spherical mirror
- 16 x 16 PMT cluster

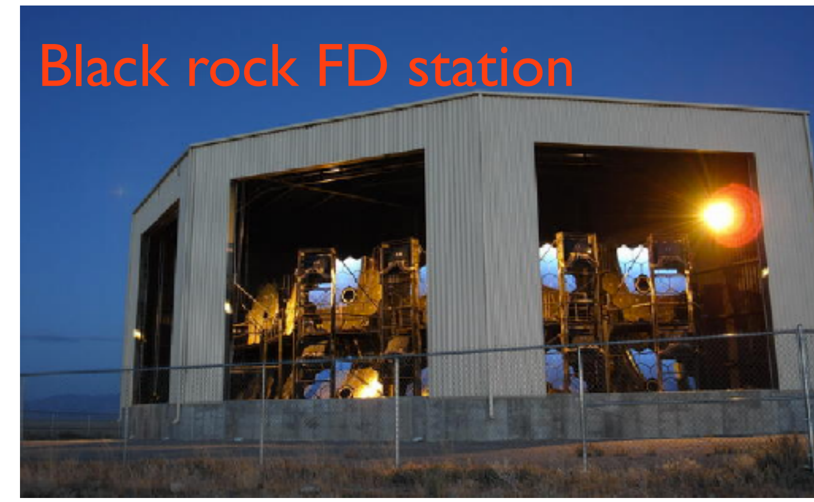
Middle Drum:

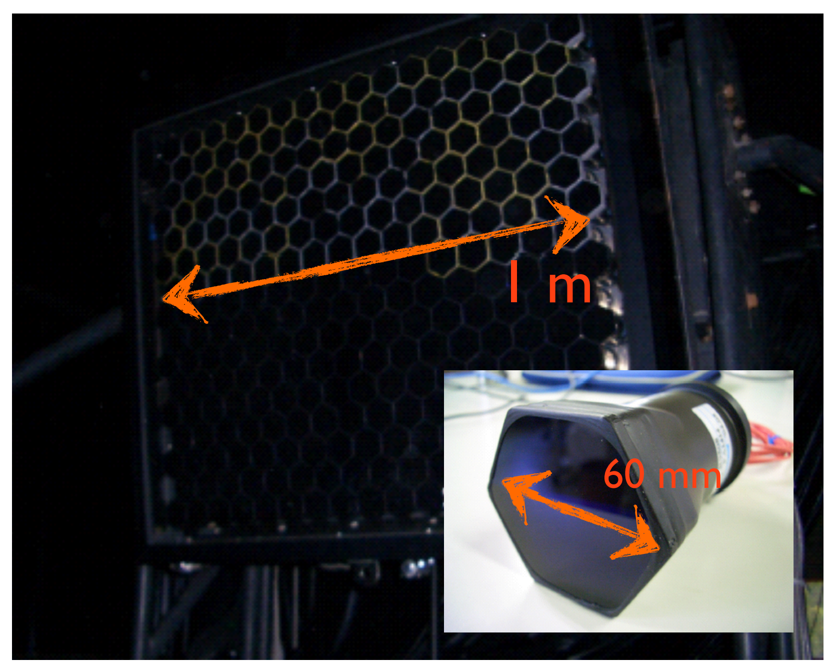
- Transferred from HiRes-I
- 14 mirrors, 2rings

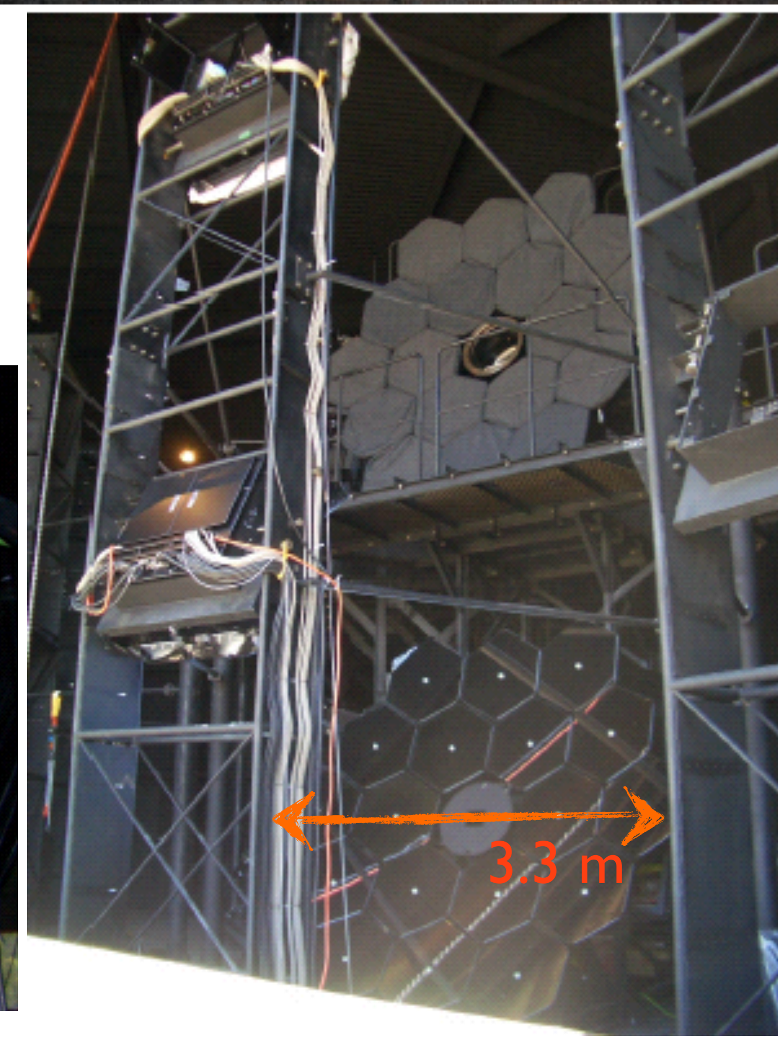
SD

- 507 surface detectors
- Covering 680km^2









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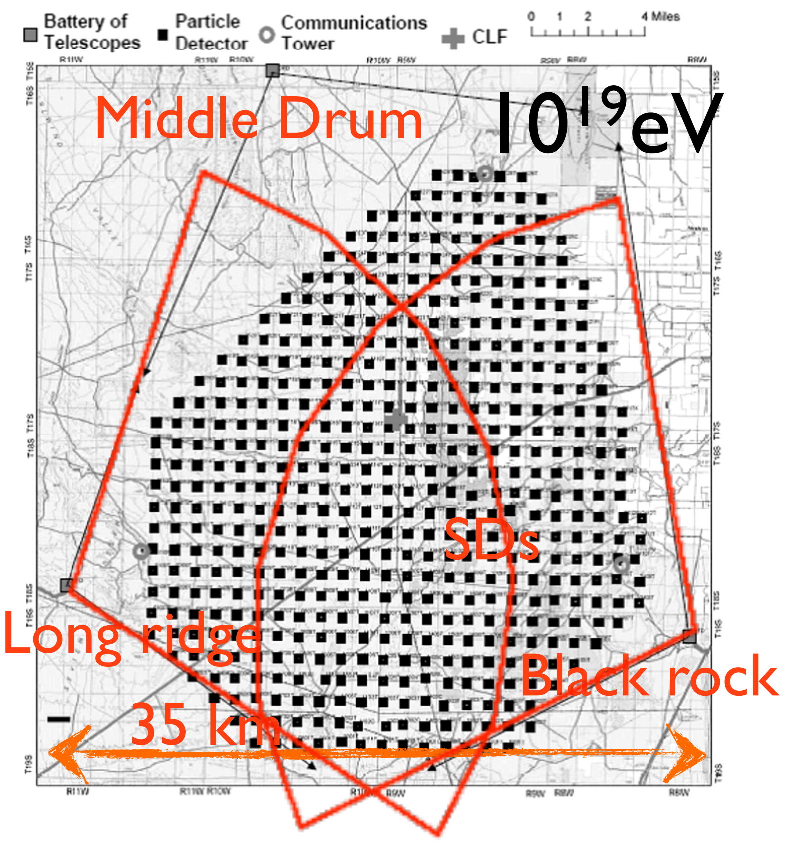
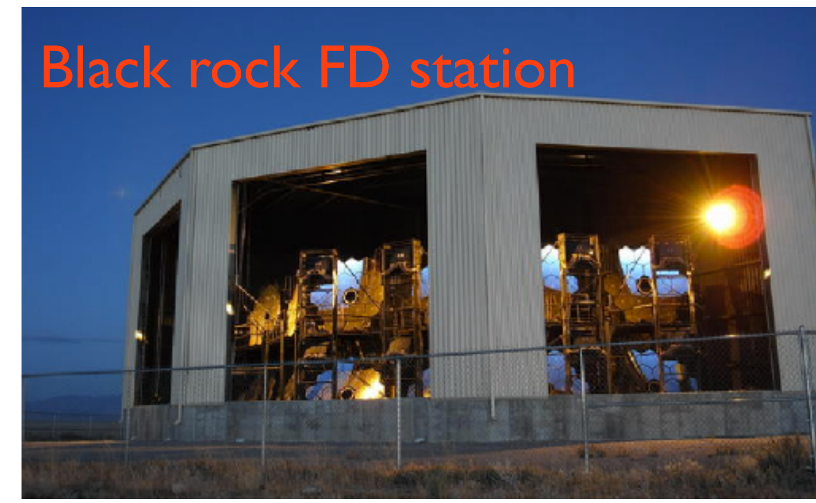
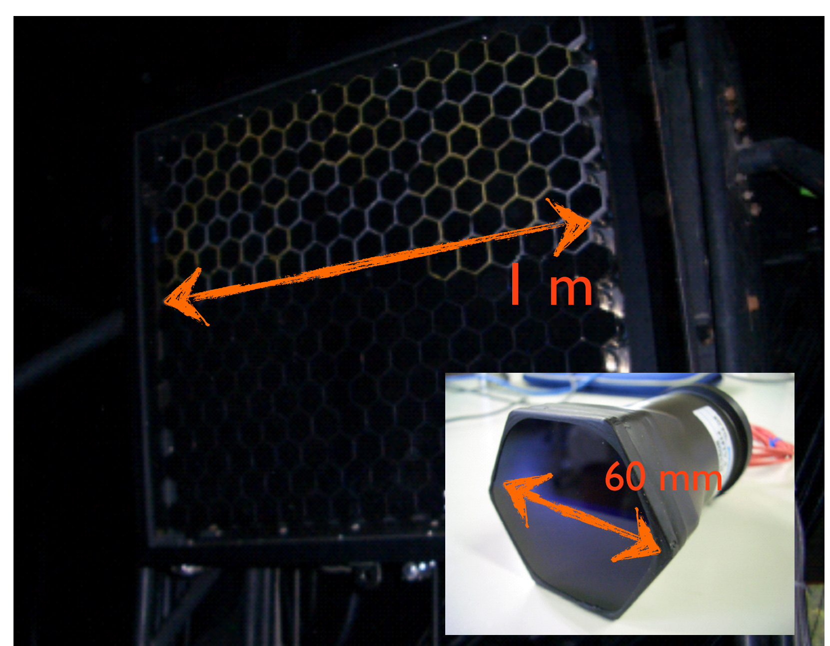
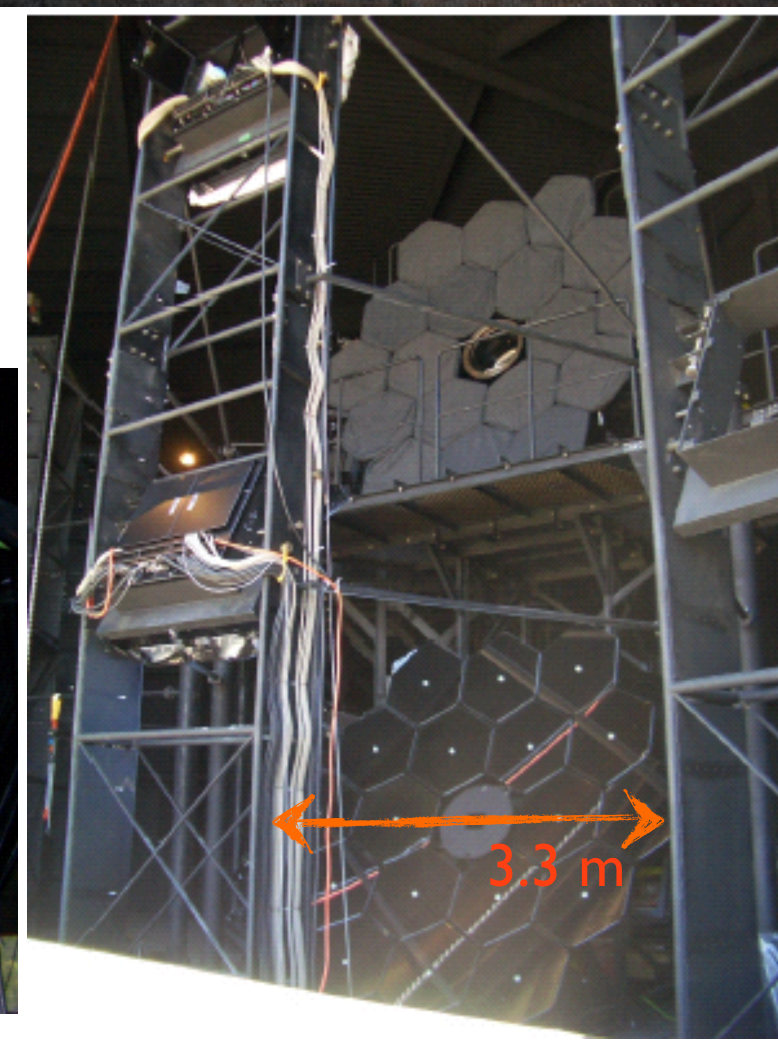
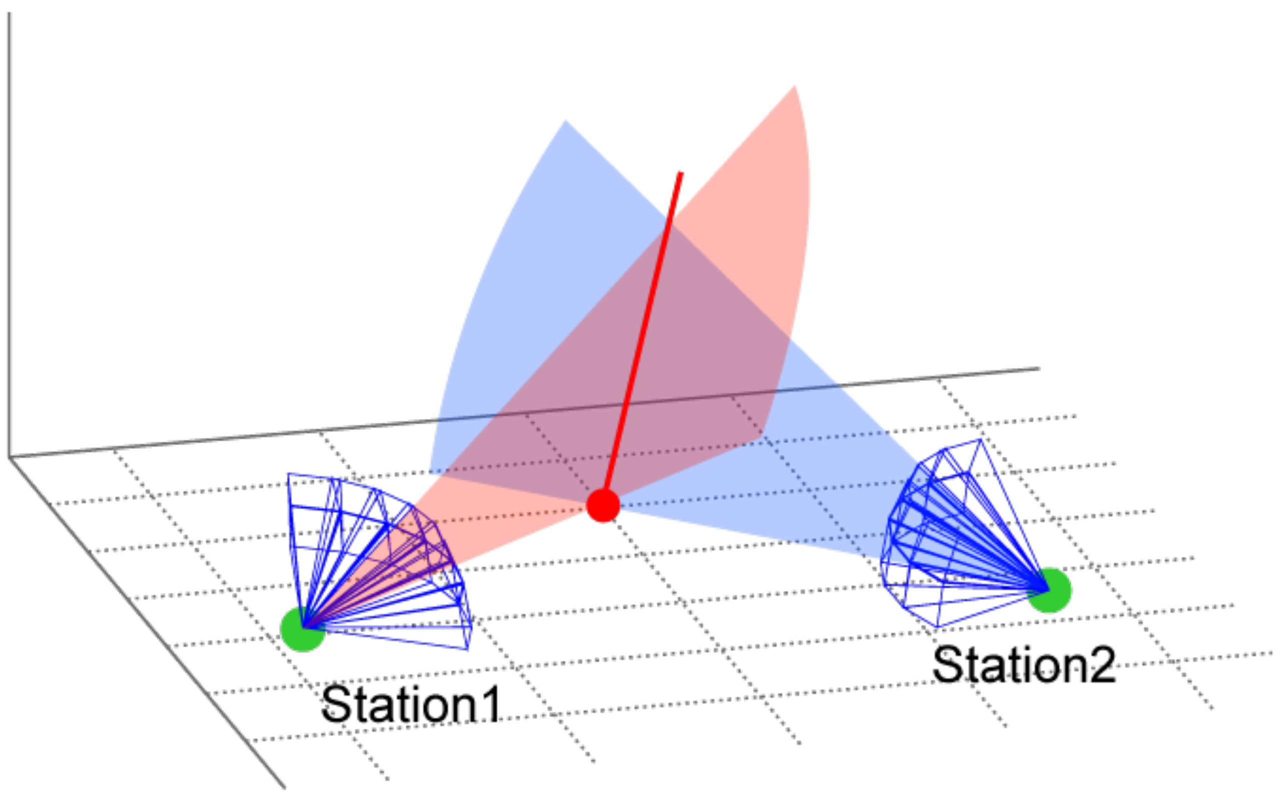




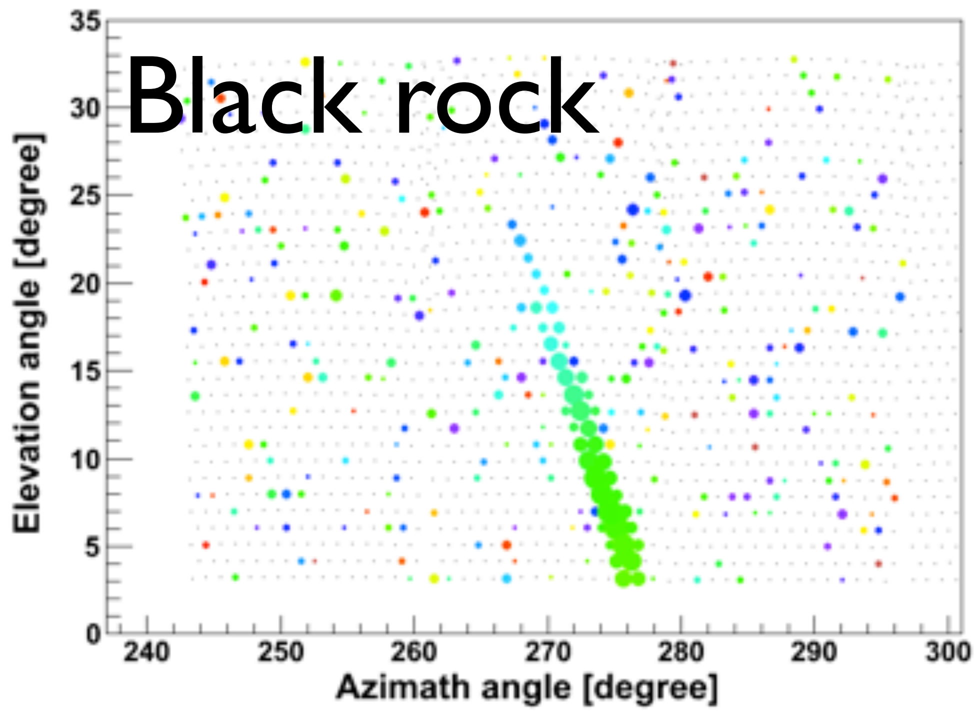


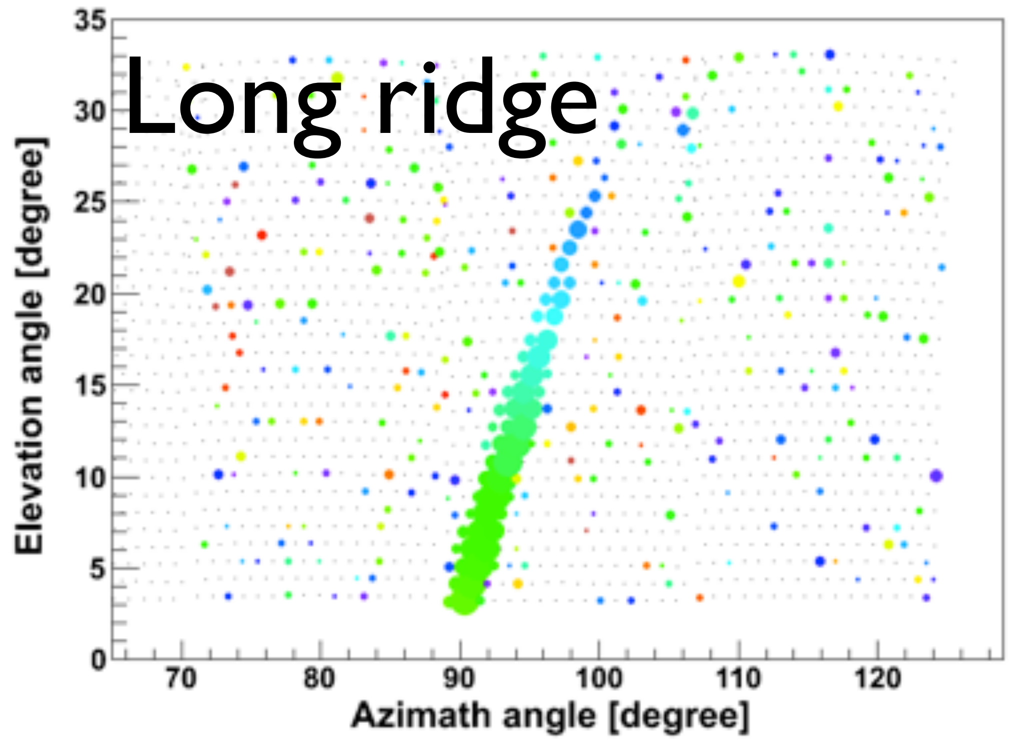


Event Reconstruction: Geometry

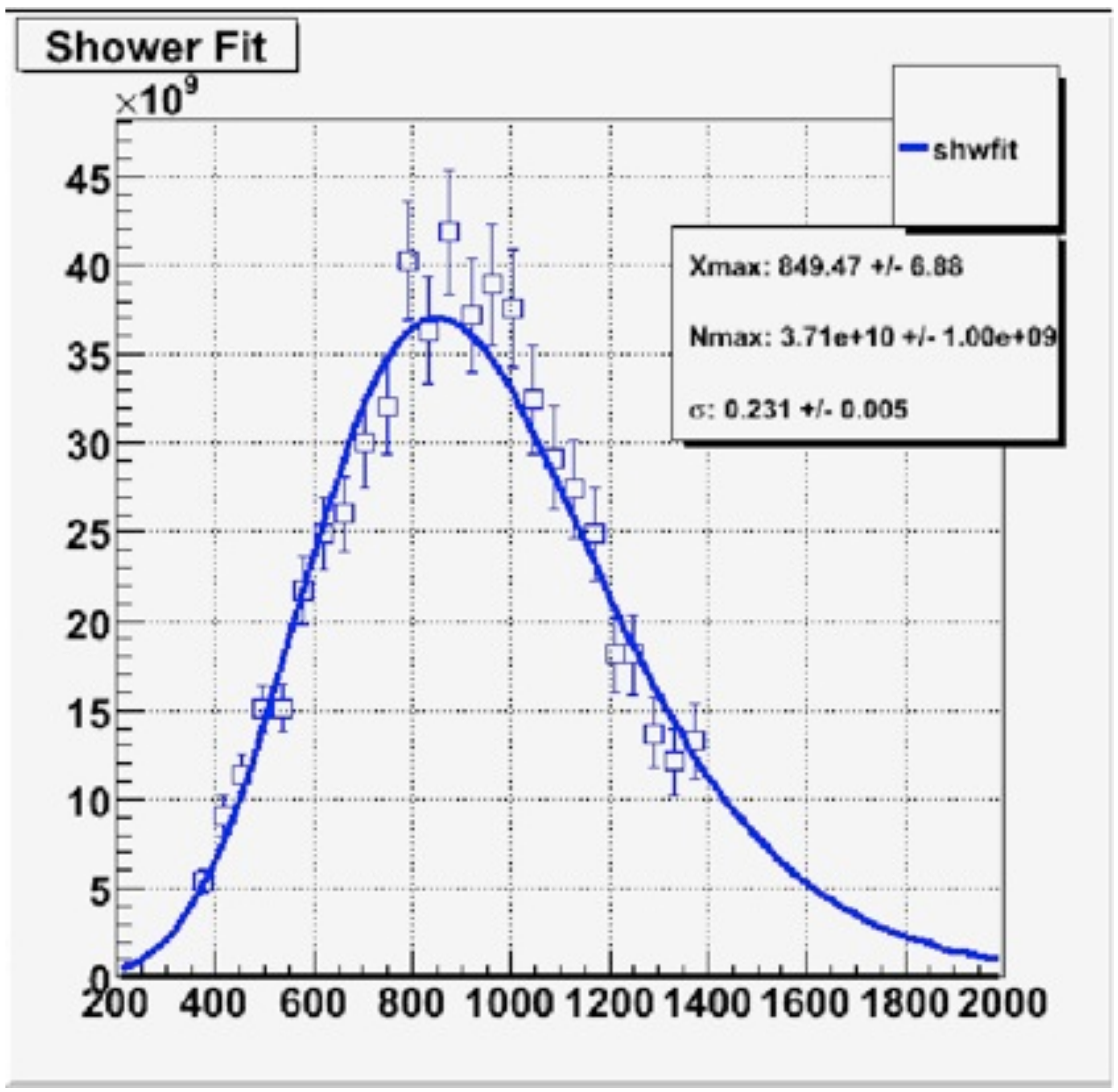


Shower axis:
intersection of SDPs





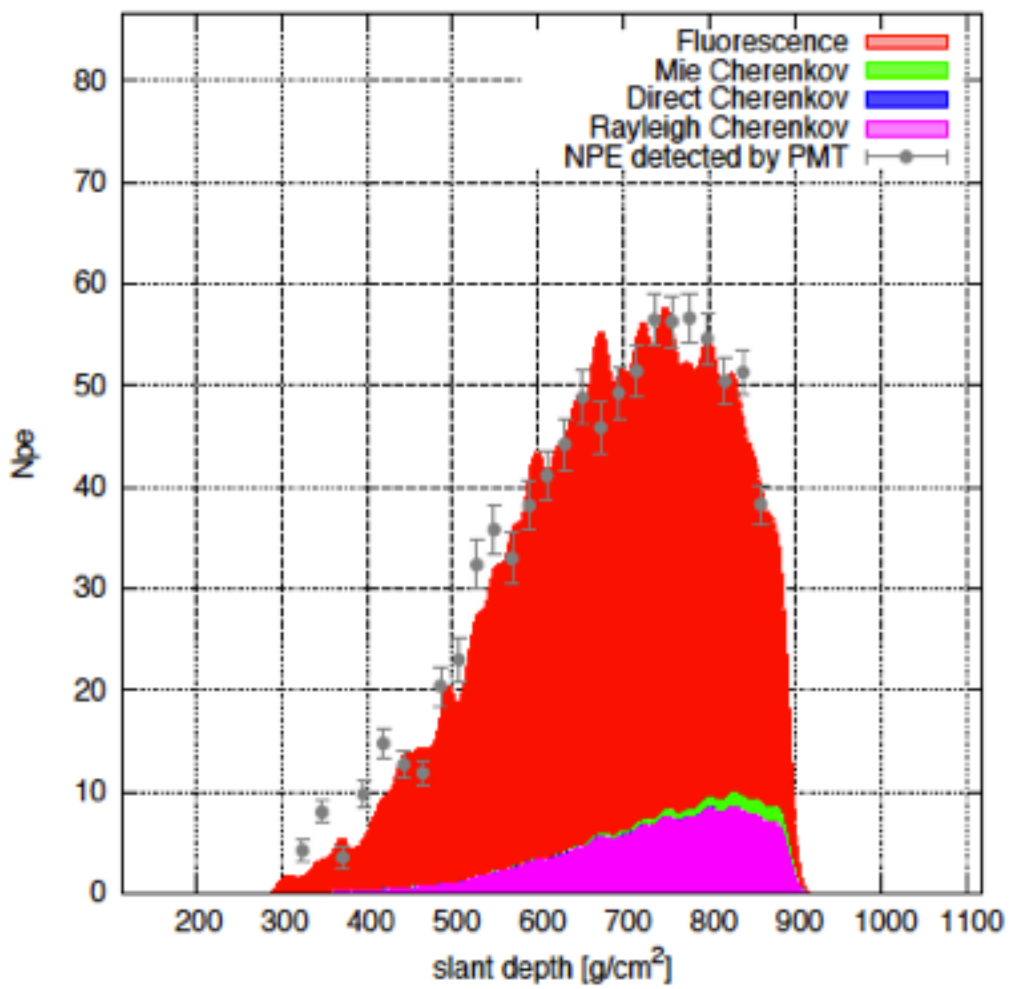
Event Reconstruction: Shower development(HiRes)



HiRes:

- Longitudinal development of Charged particle
- Fit w/ Gaussian dist. in age
- Xmax: fitting parameter
- Energy: Integration of fitted function

Event Reconstruction: Shower development(TA)

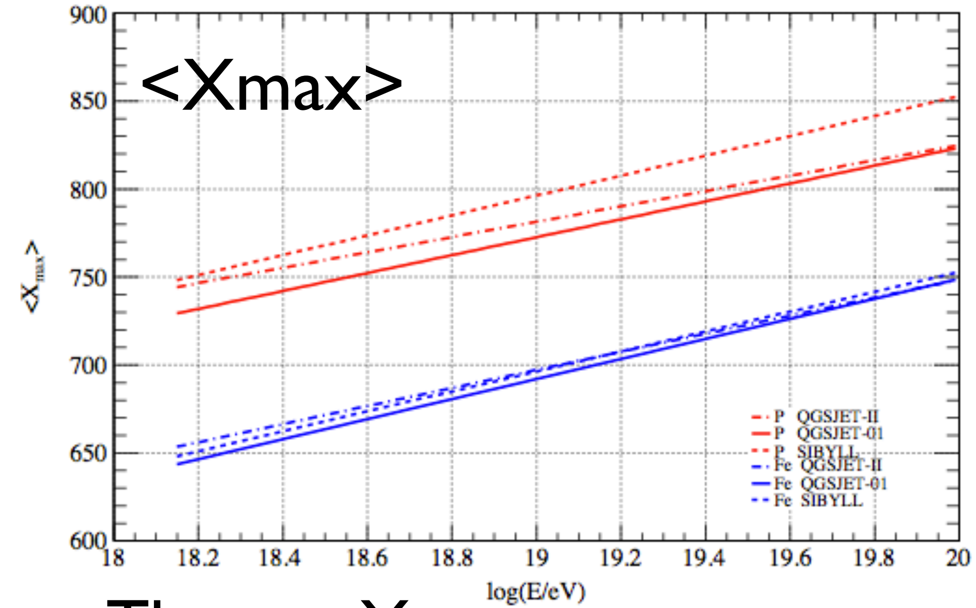


Telescope Array:

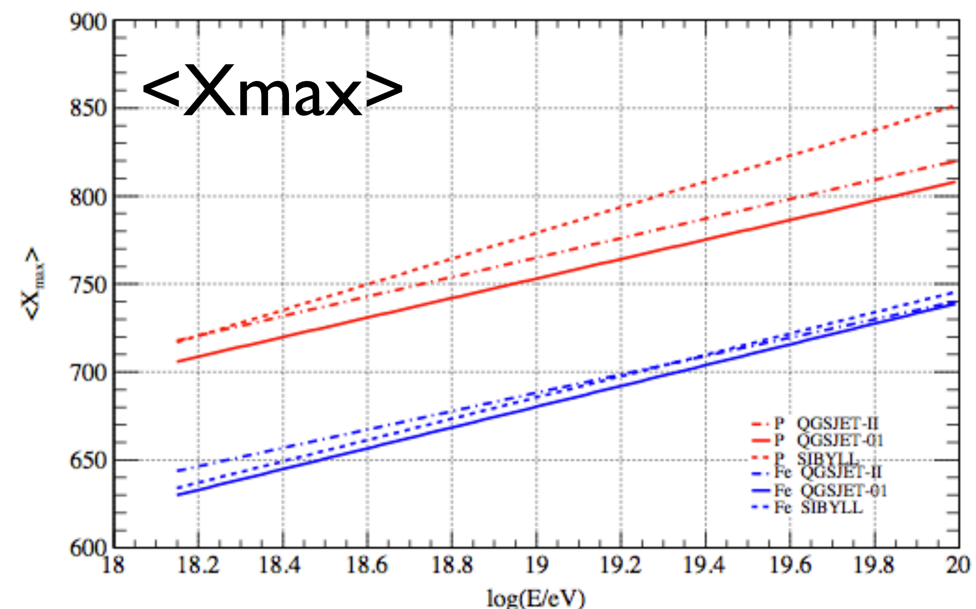
- Inverse Monte Carlo method
  - Compared with MC
  - Supposing G-H function as a longitudinal development of energy deposit
- Energy: Integral of fitted G-H
- Xmax: fitting parameter

Averaged Xmax

- Comparison with <xmax> prediction
- Airshower simulation (CORSIKA)
- Full detector simulation
  - Actual detector response
  - Atmosphere
  - Analysis procedure same as data
- Biases
  - Reconstruction bias:
    - Event reconstruction
  - Acceptance bias:
    - Triggering effects
    - Events failing reconstruction
    - Quality cuts



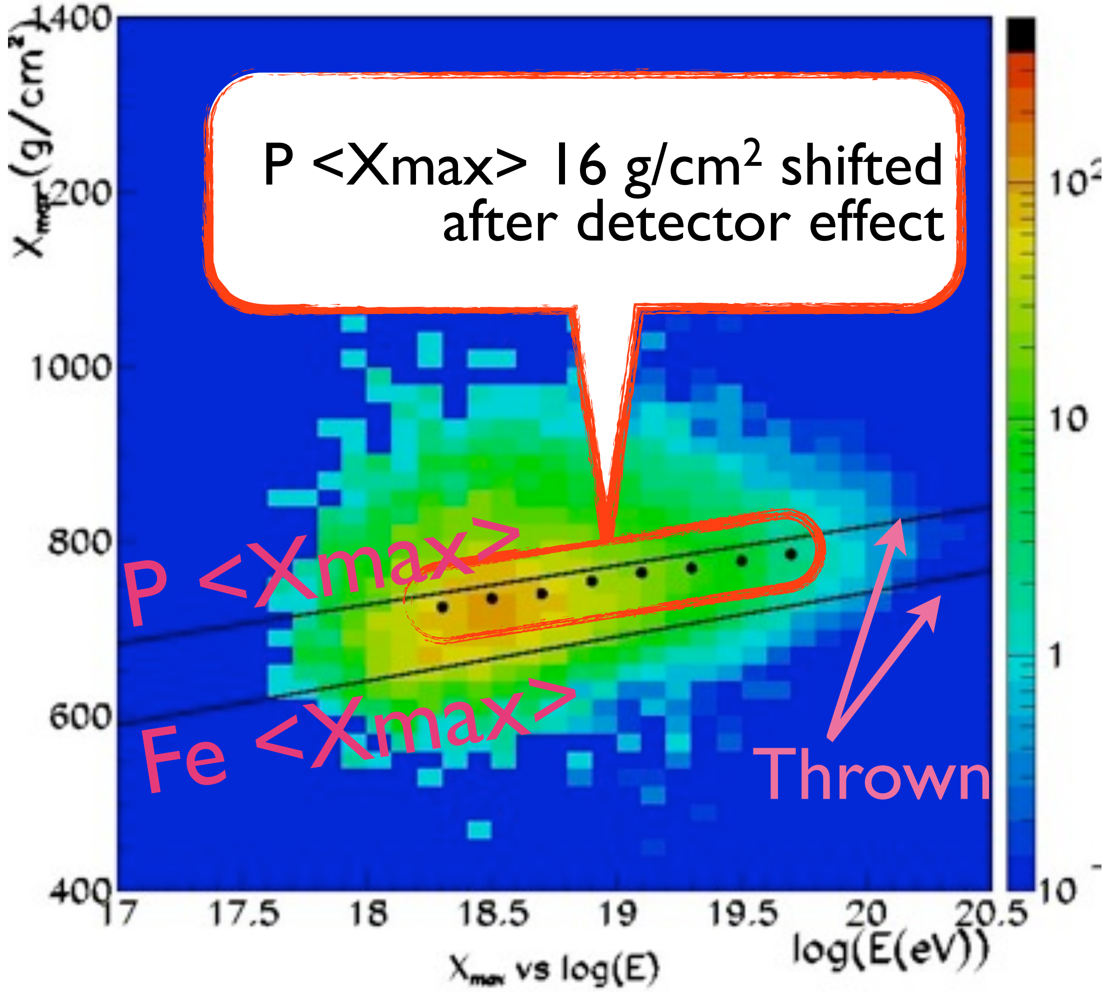
Thrown Xmax



w/ TA rec. & acceptance biases

Averaged Xmax

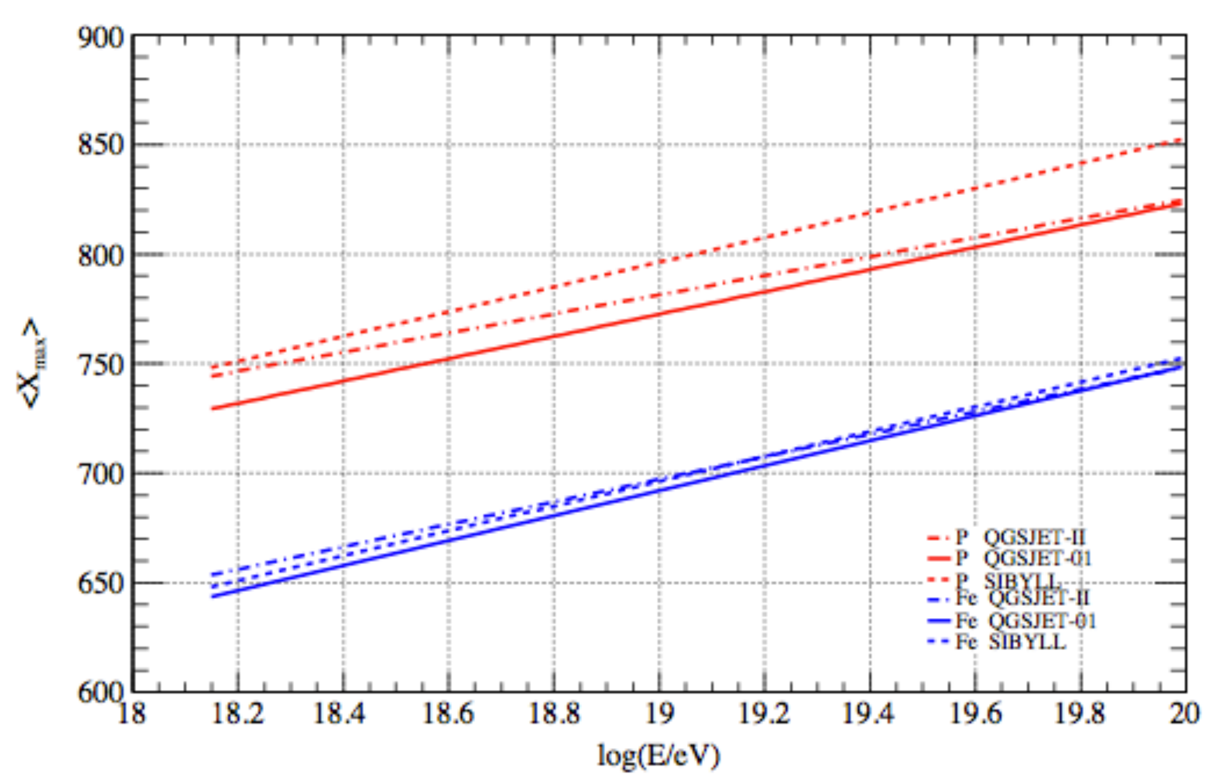
HiRes



Reconstruction bias:
negligible w/ quality cut

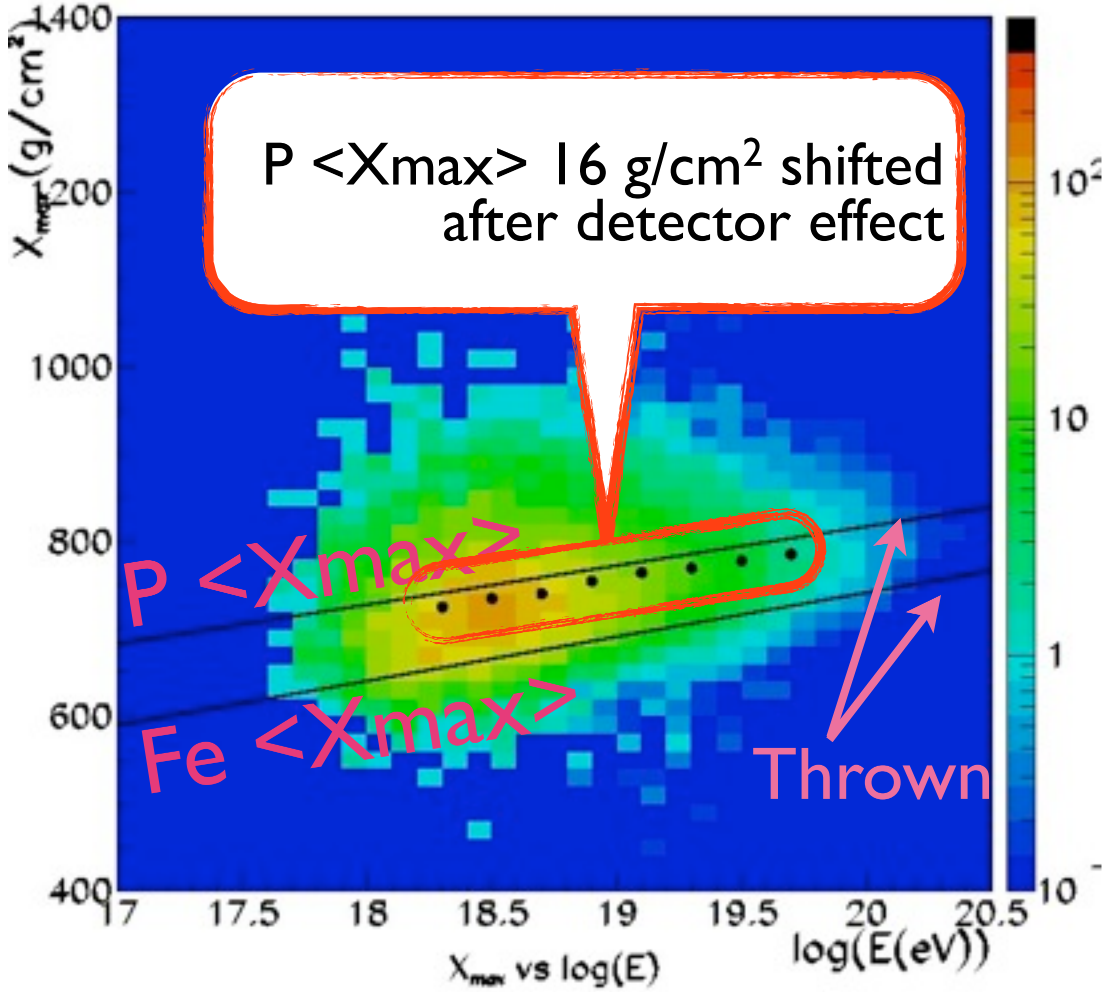
Telescope Array

<Xmax>; Shower simulation



Averaged Xmax

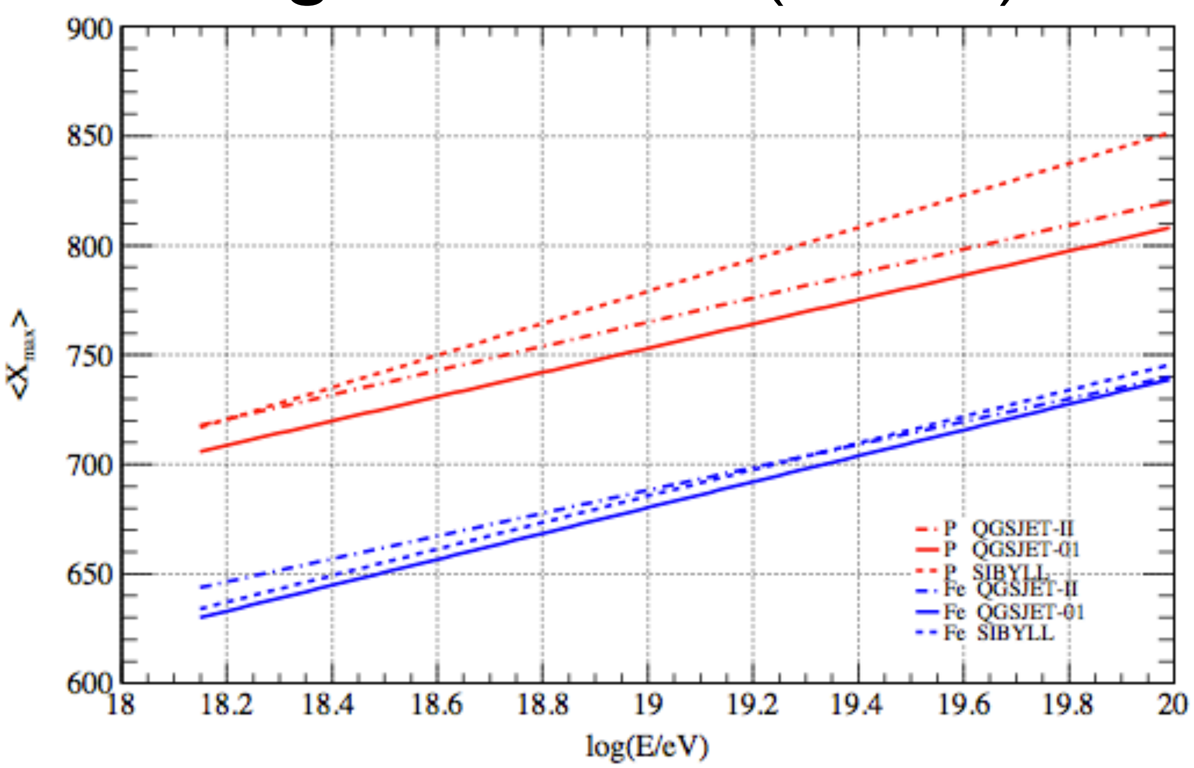
HiRes



Reconstruction bias: negligible w/ quality cut

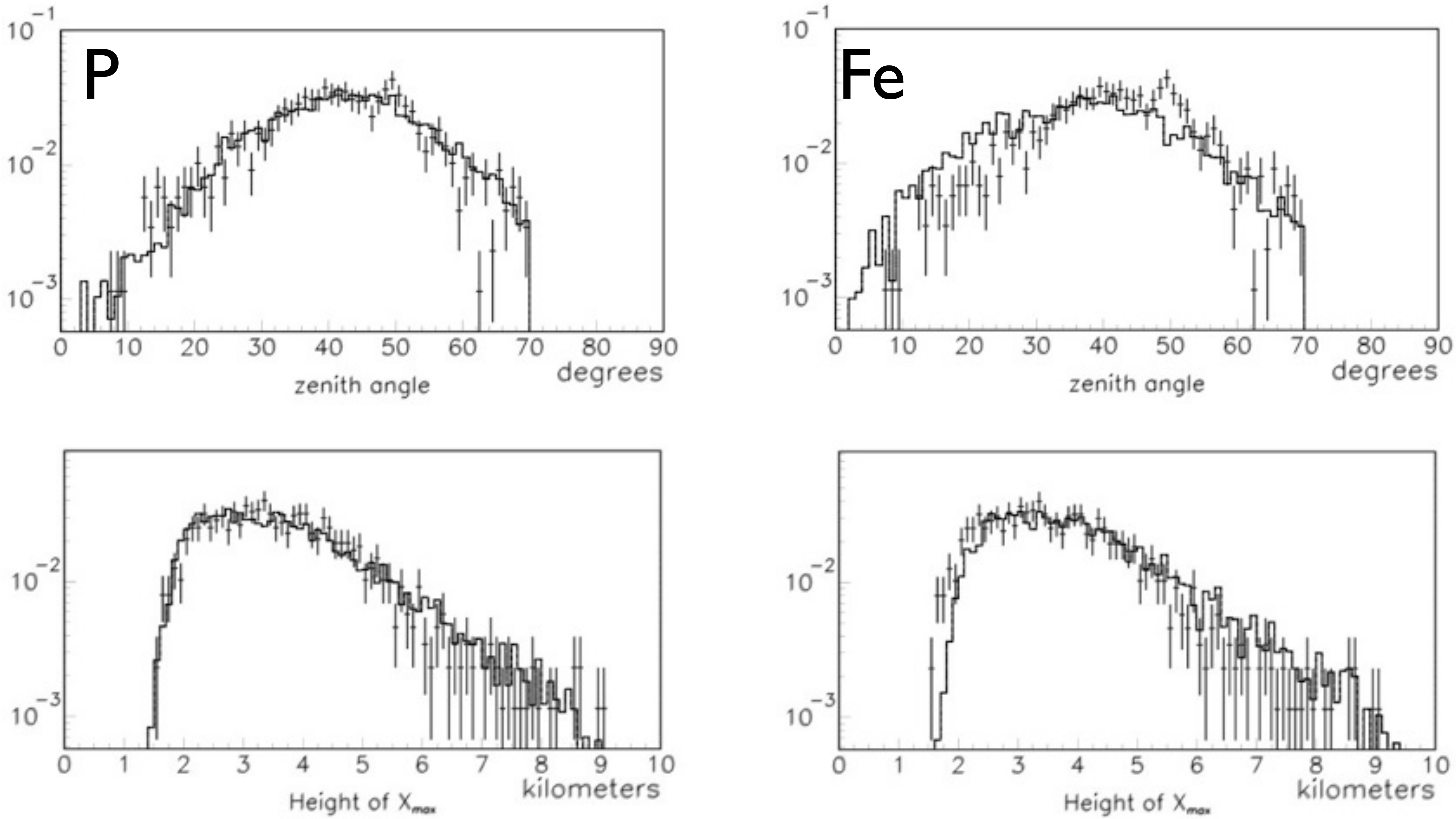
Telescope Array

<Xmax>; after detector effect 5~10g/cm^2 shifted (P case)

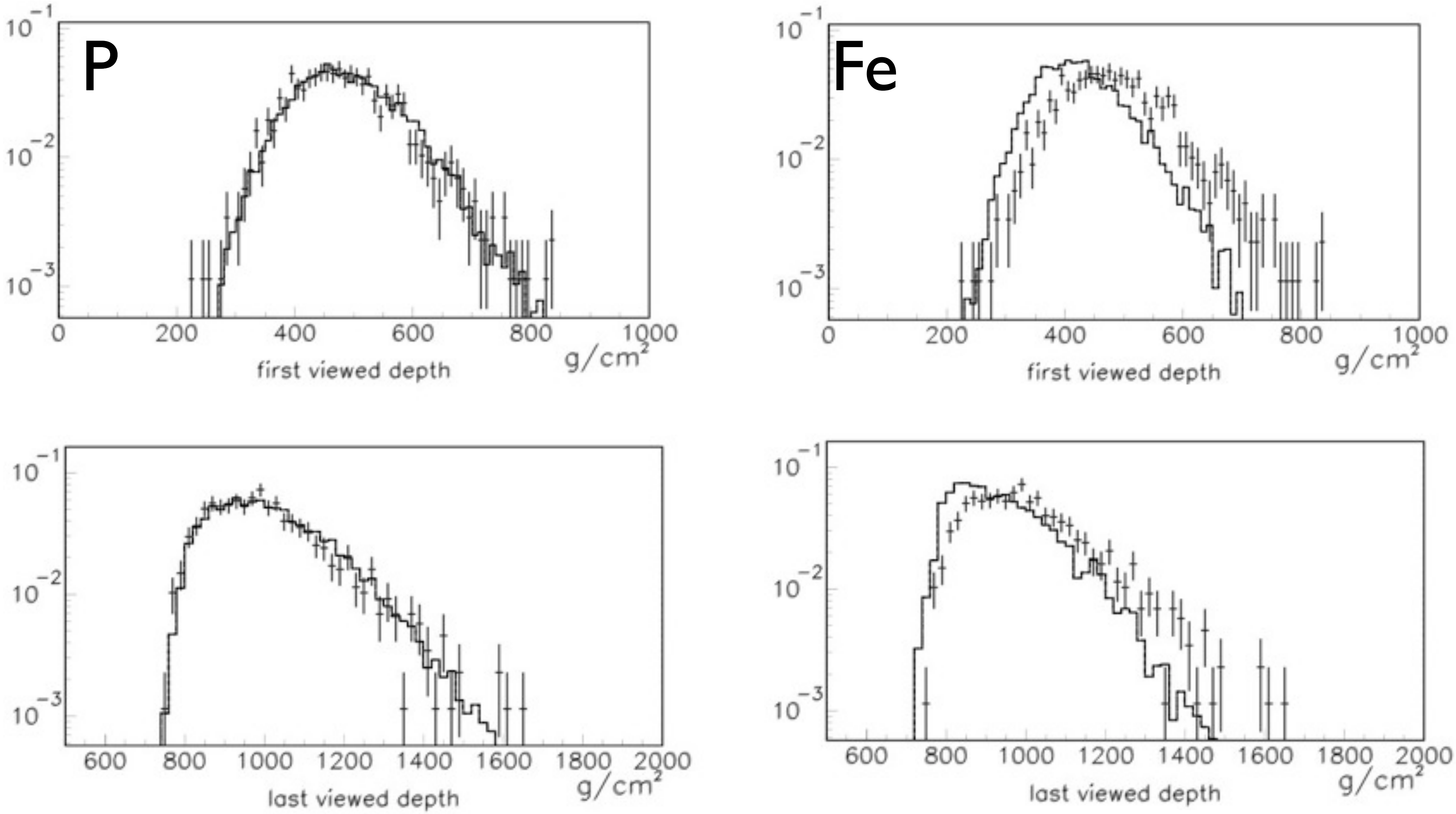


Still including reconstruction bias: 5~10g/cm^2

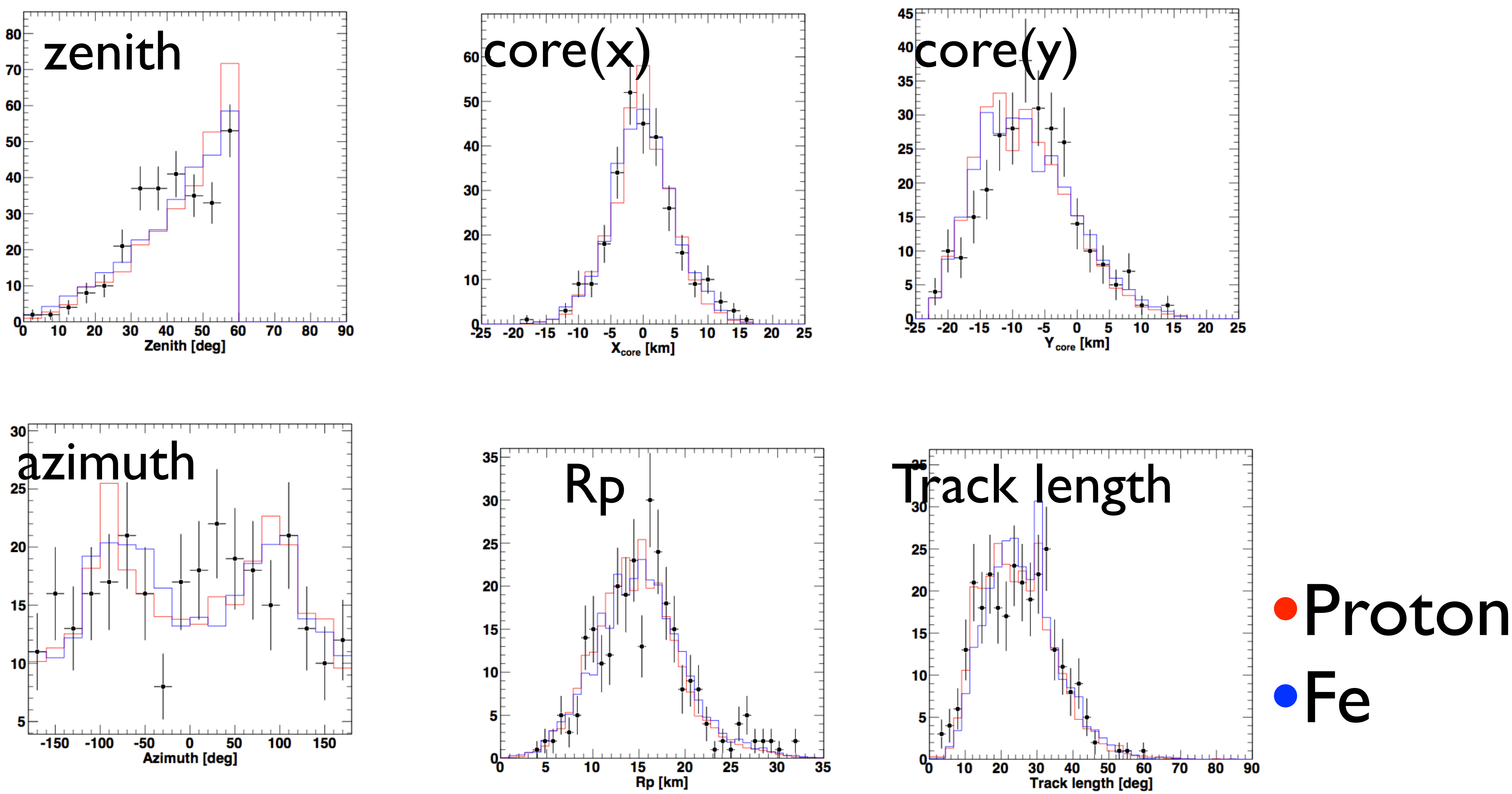
Data/MC Comp. (HiRes, QGSJET-II)



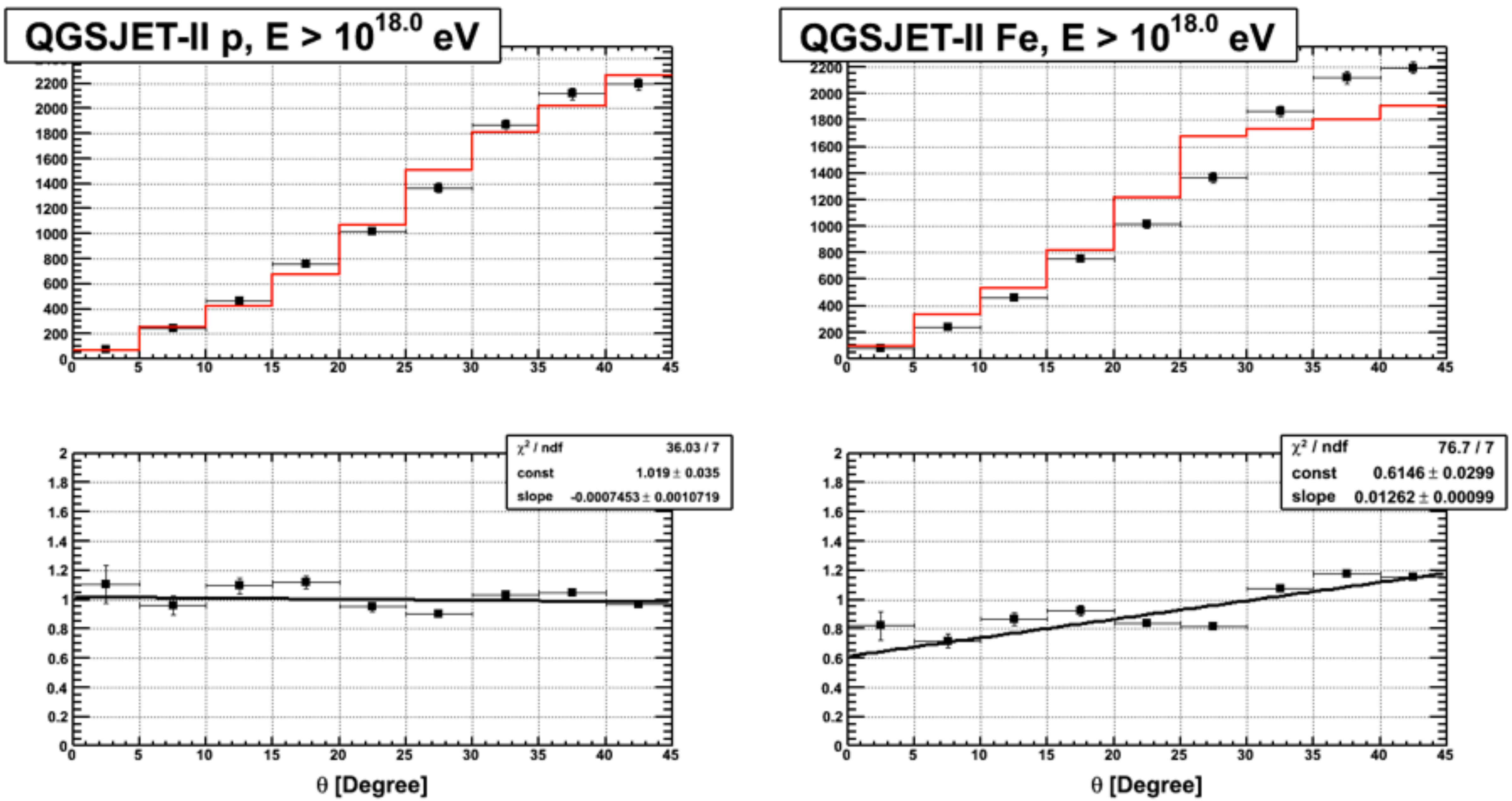
Data/MC Comp. (HiRes, QGSJET-II)



Data/MC Comp.
(TA, QGSJET-II)



Data/MC Comp. (TA-SD, Zenith angle)



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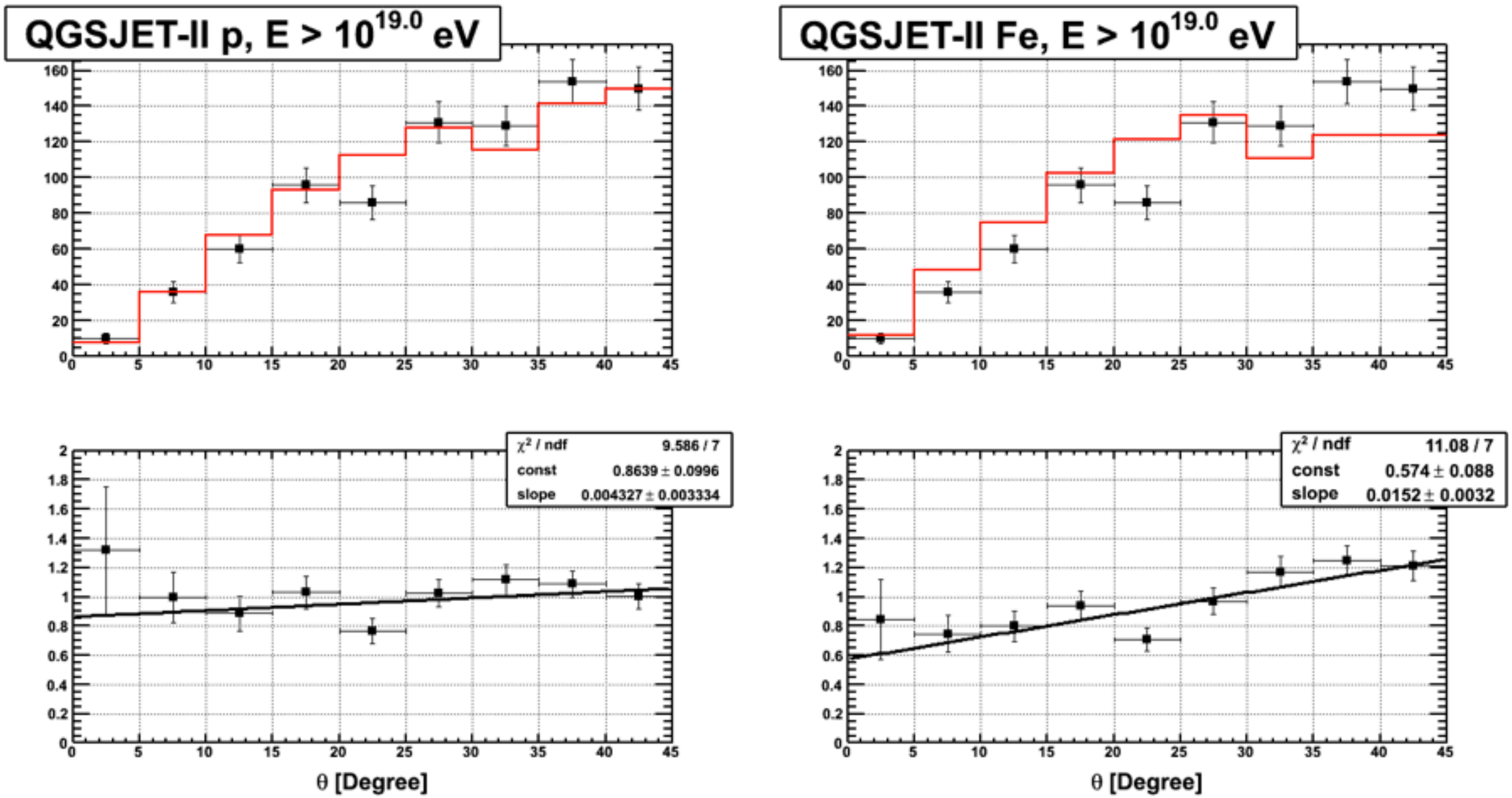
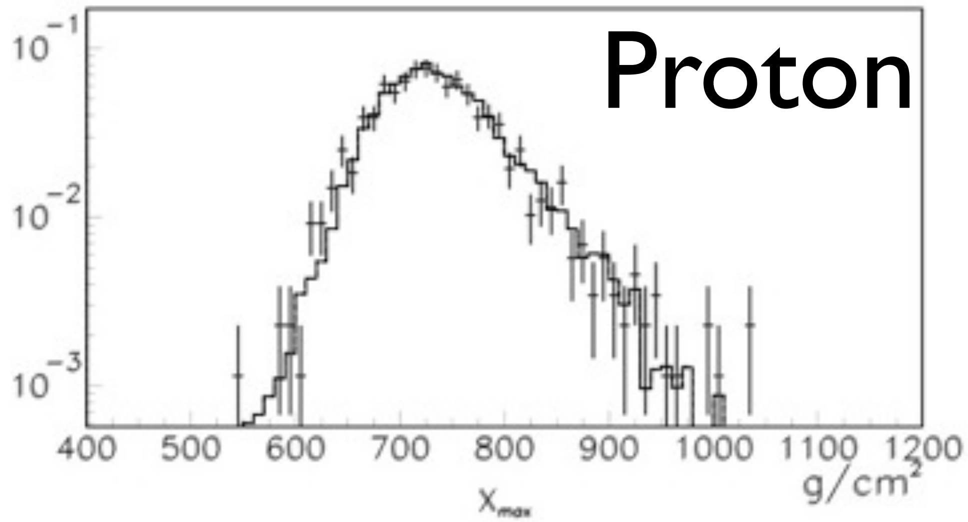
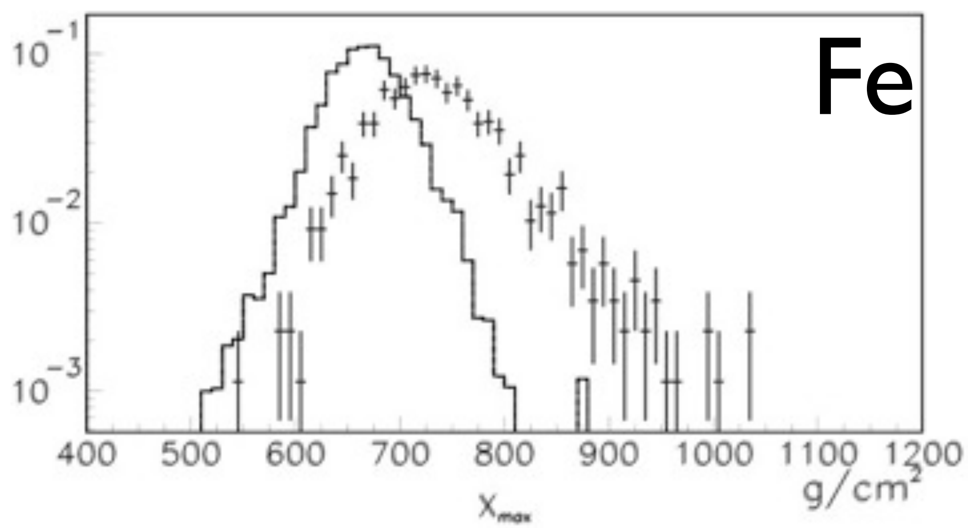


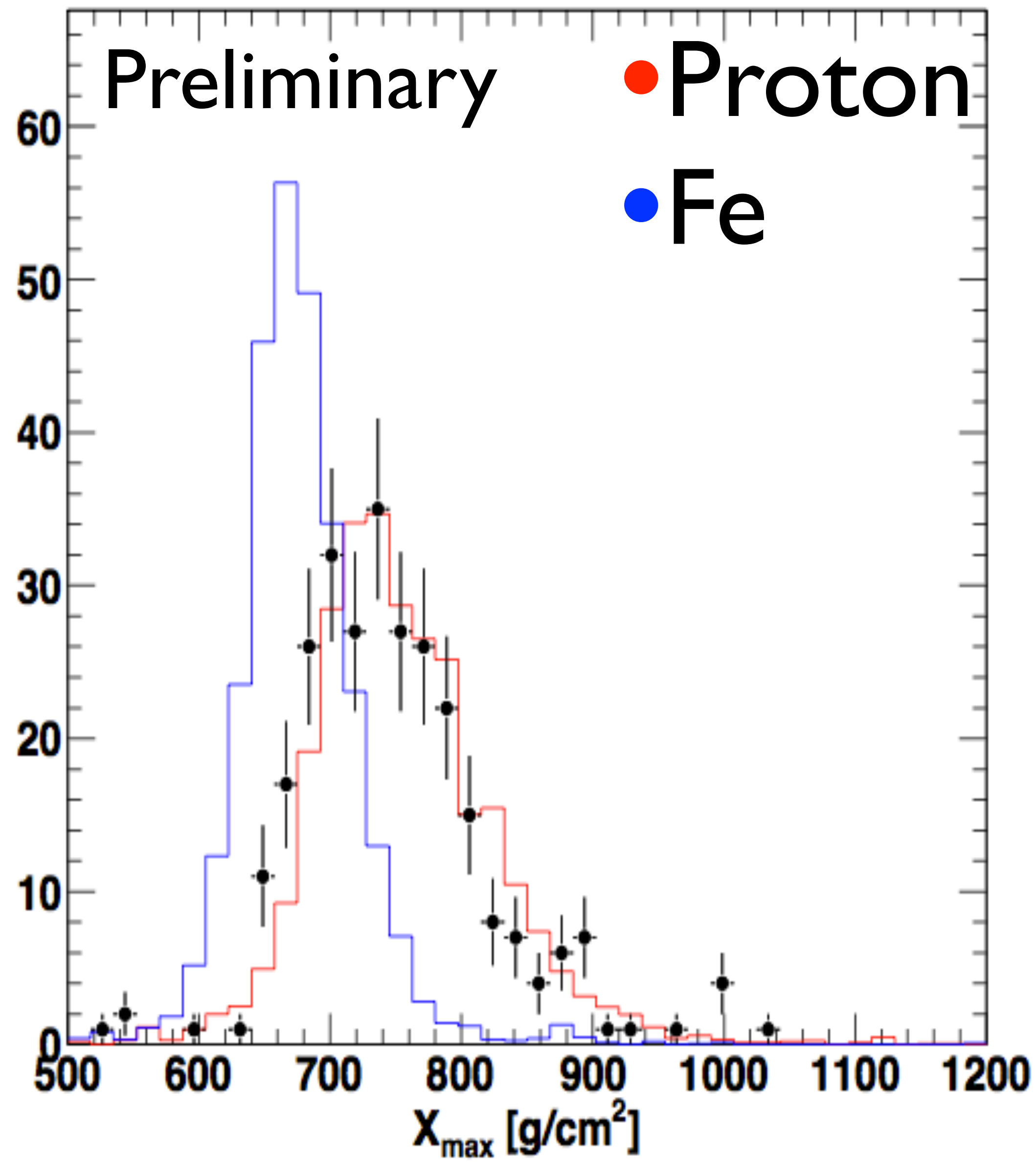
Xmax Distribution MC/Data (QGSJET-II)

HiRes



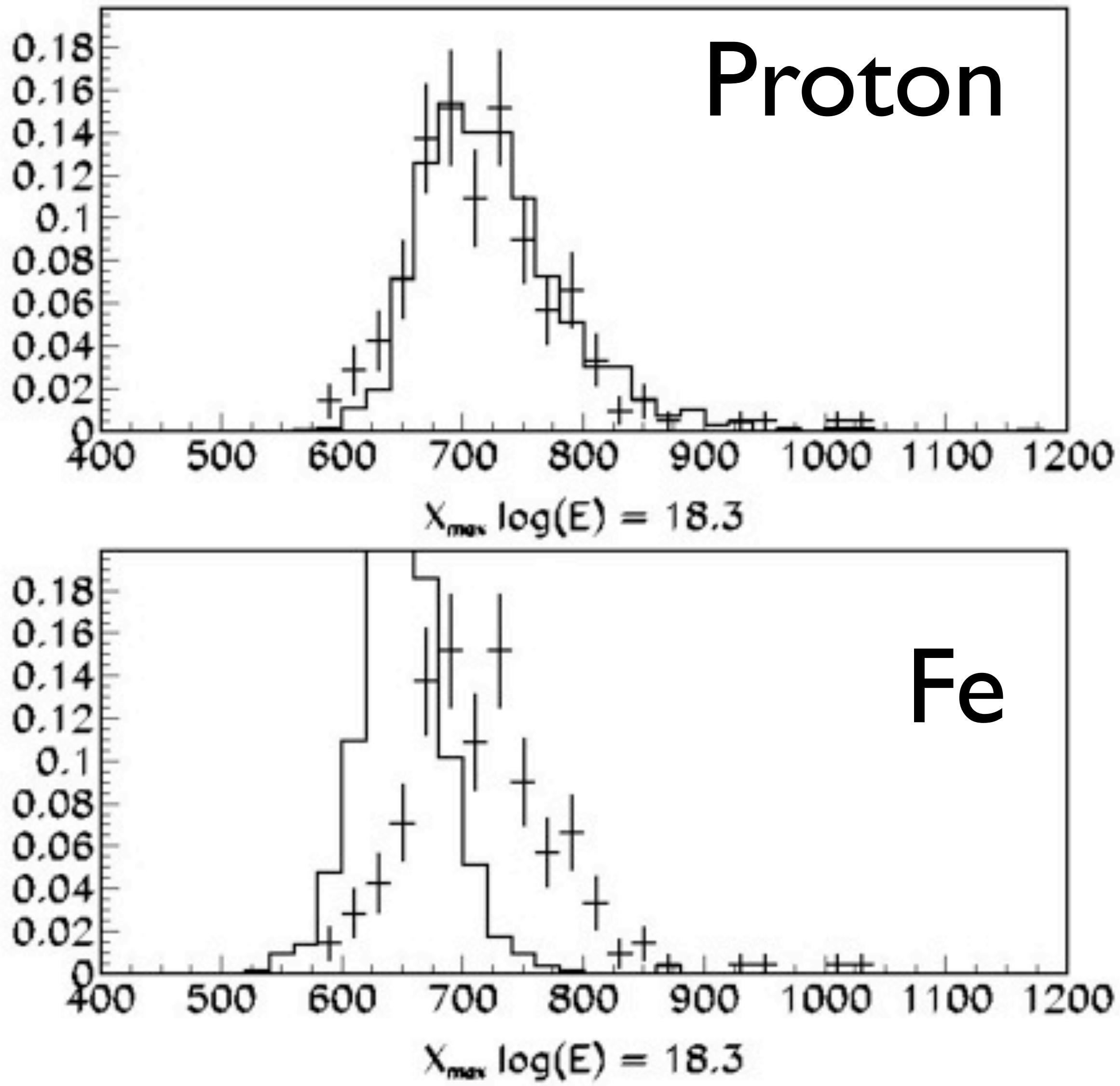


TA

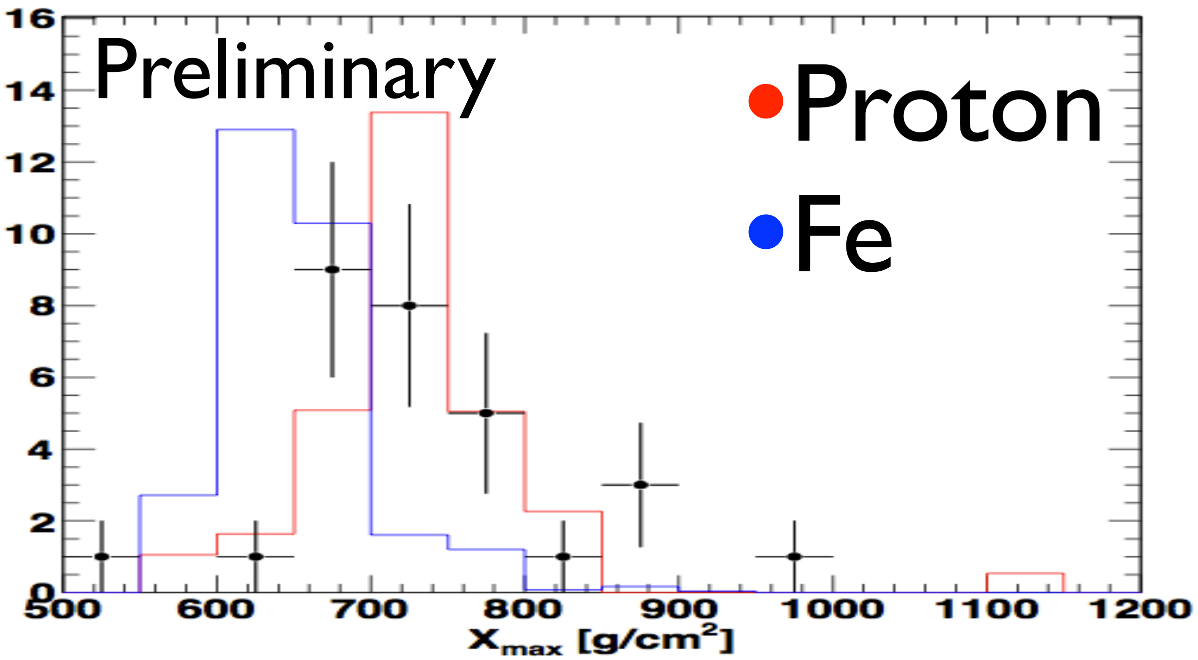


Xmax Distribution in energy bin (QGSJET-II)

HiRes



TA



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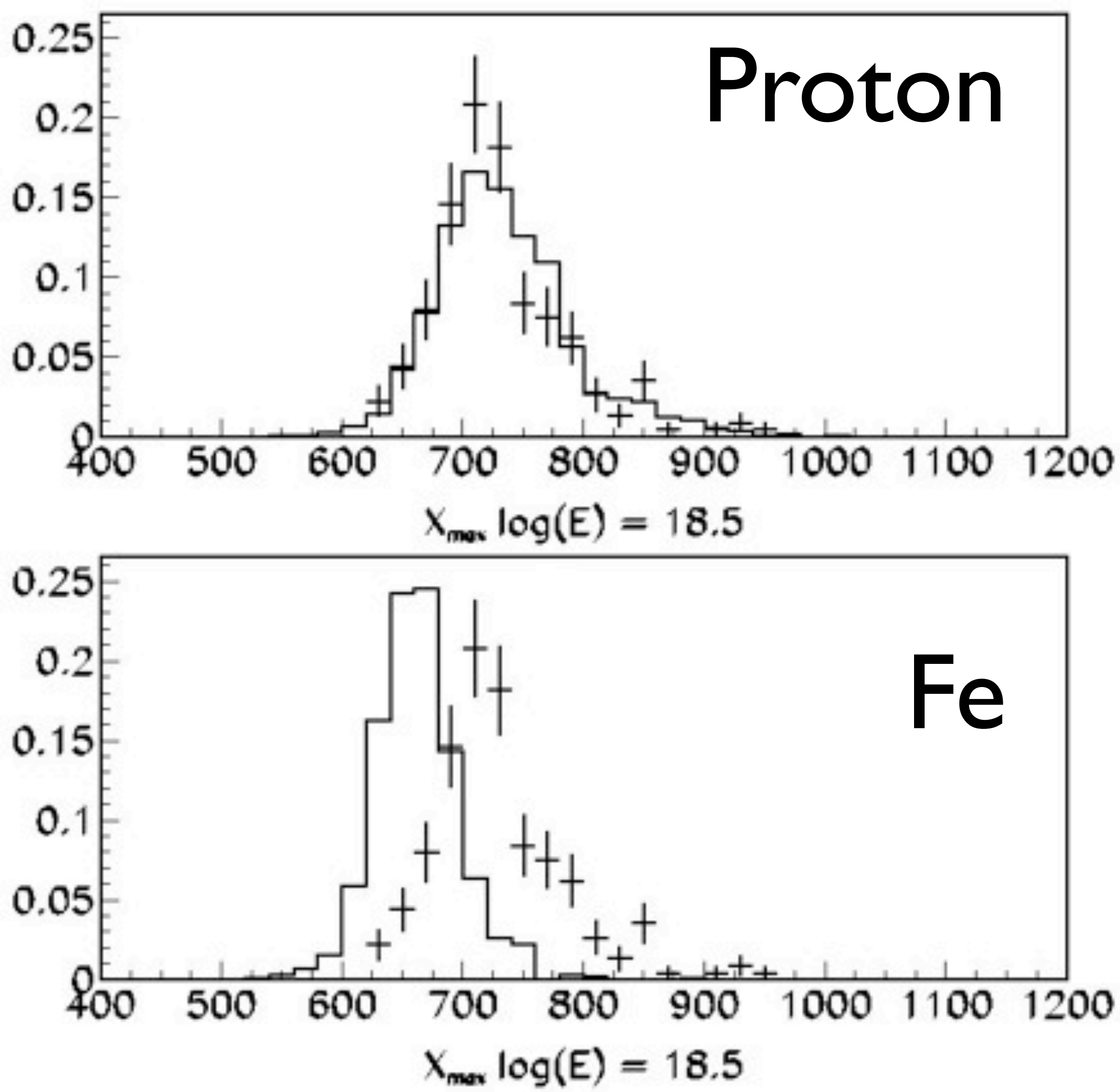

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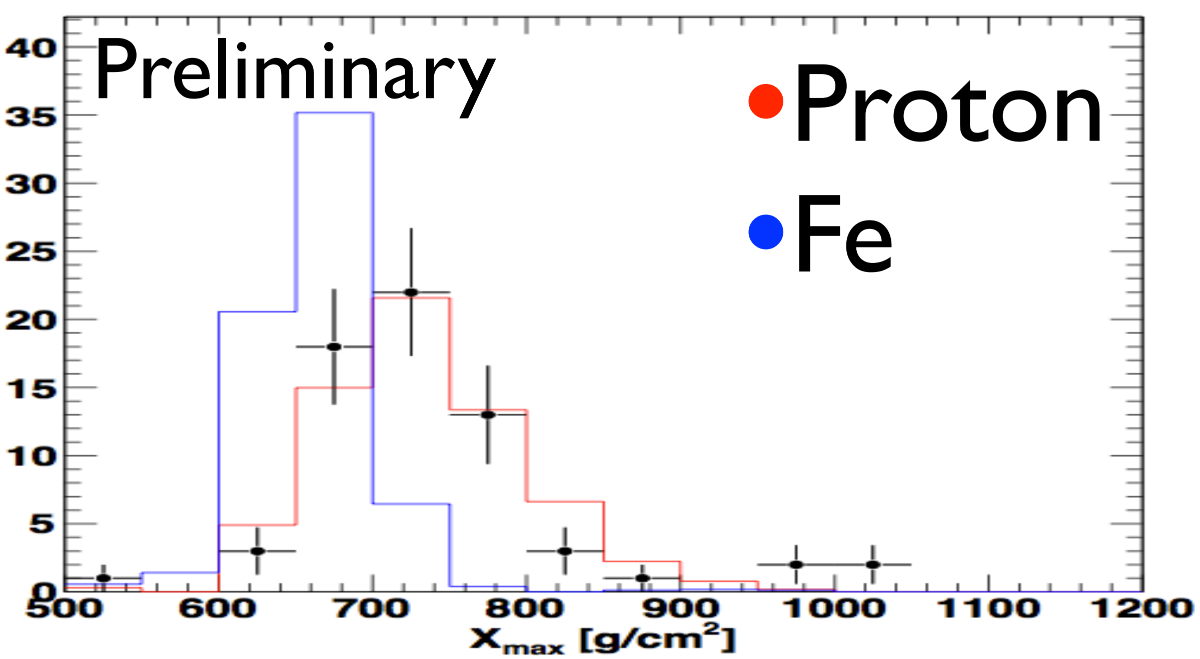

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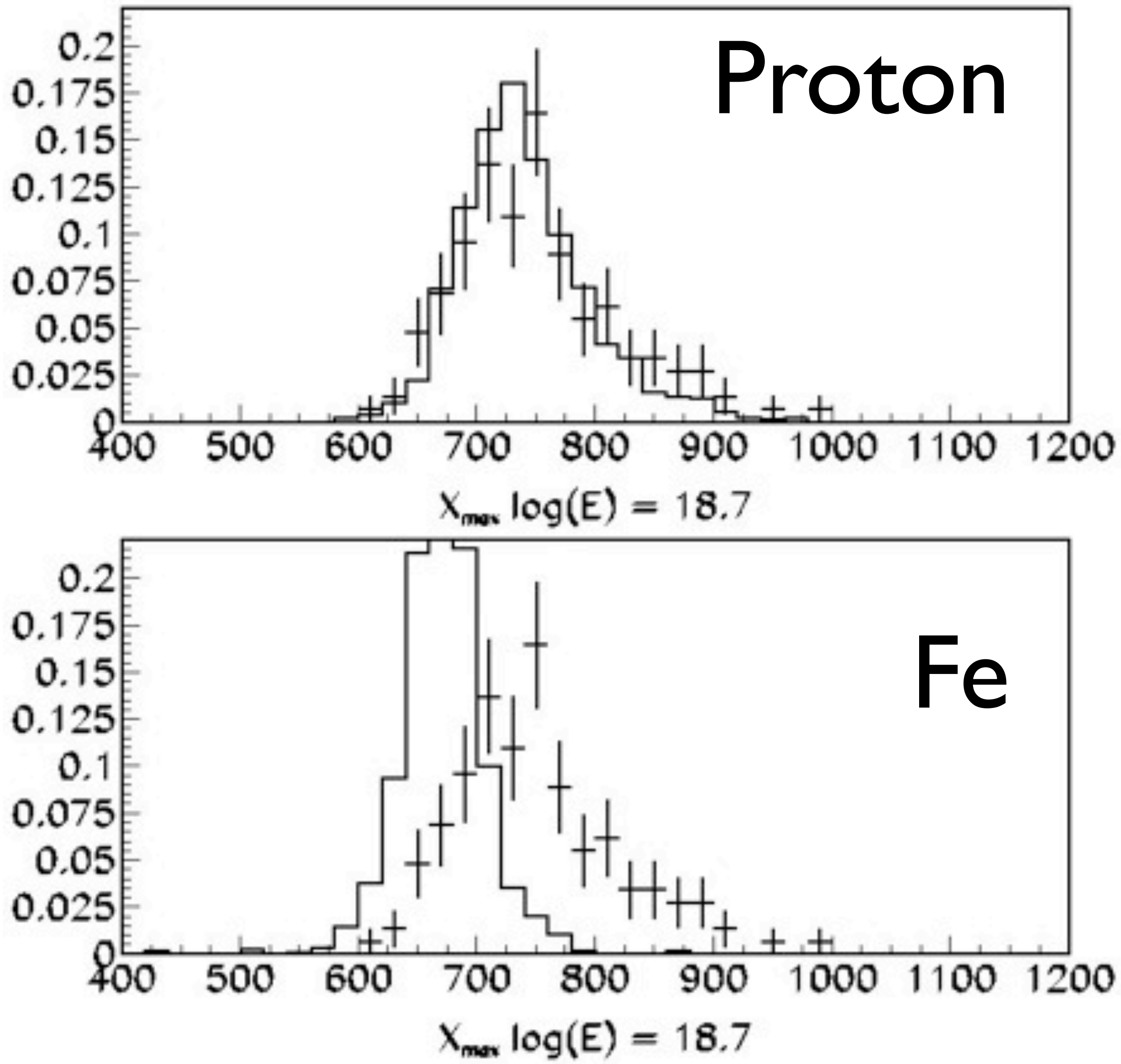

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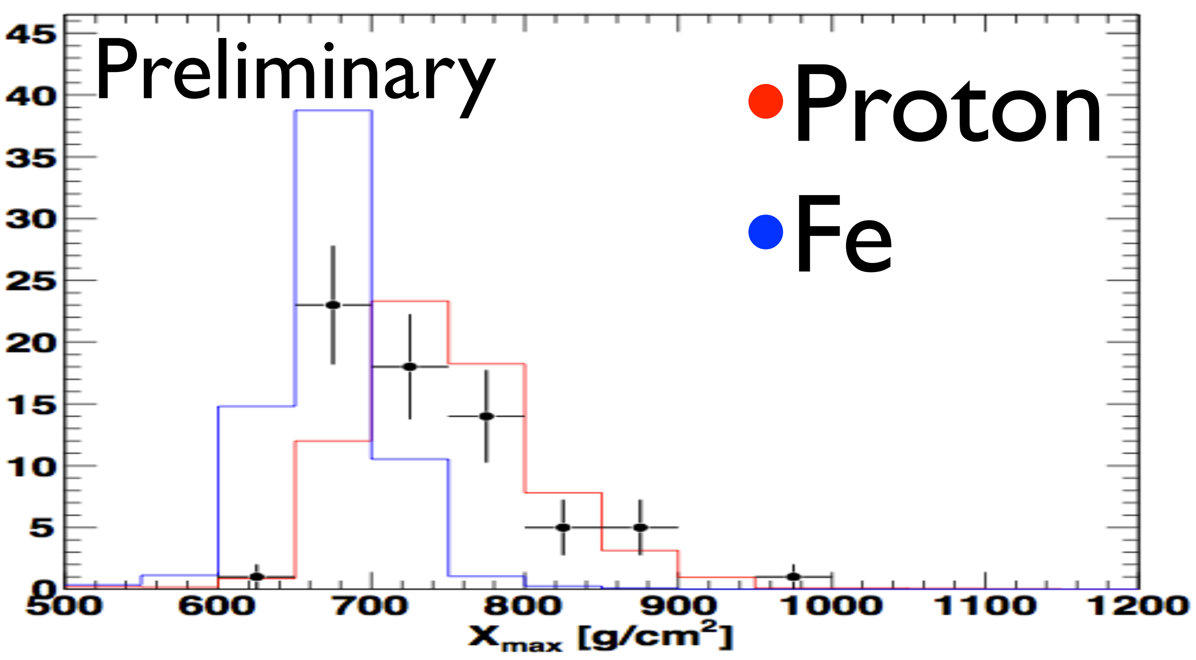

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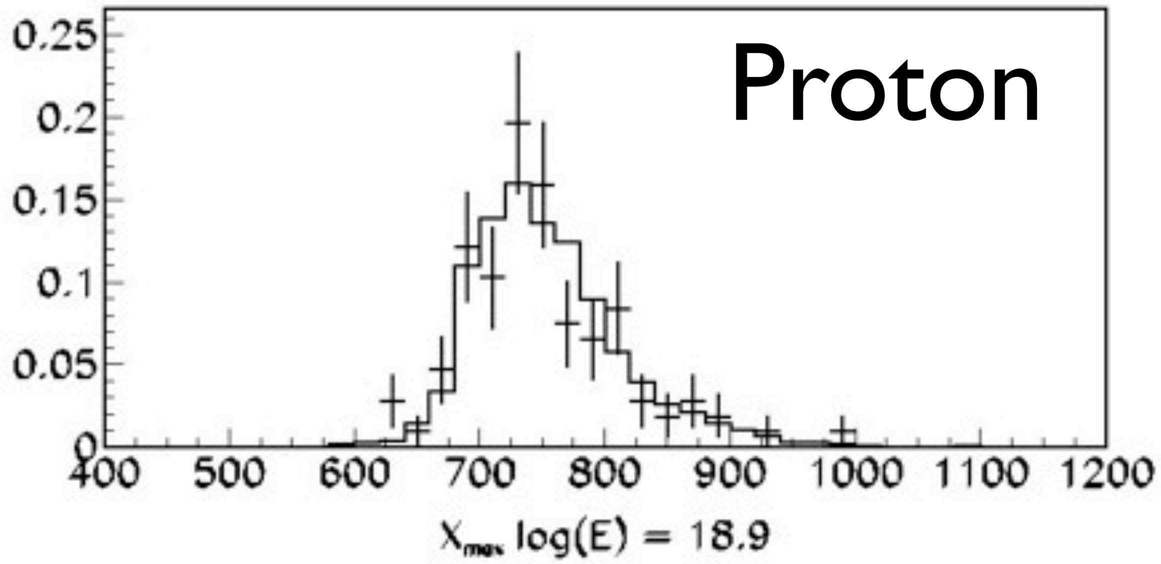

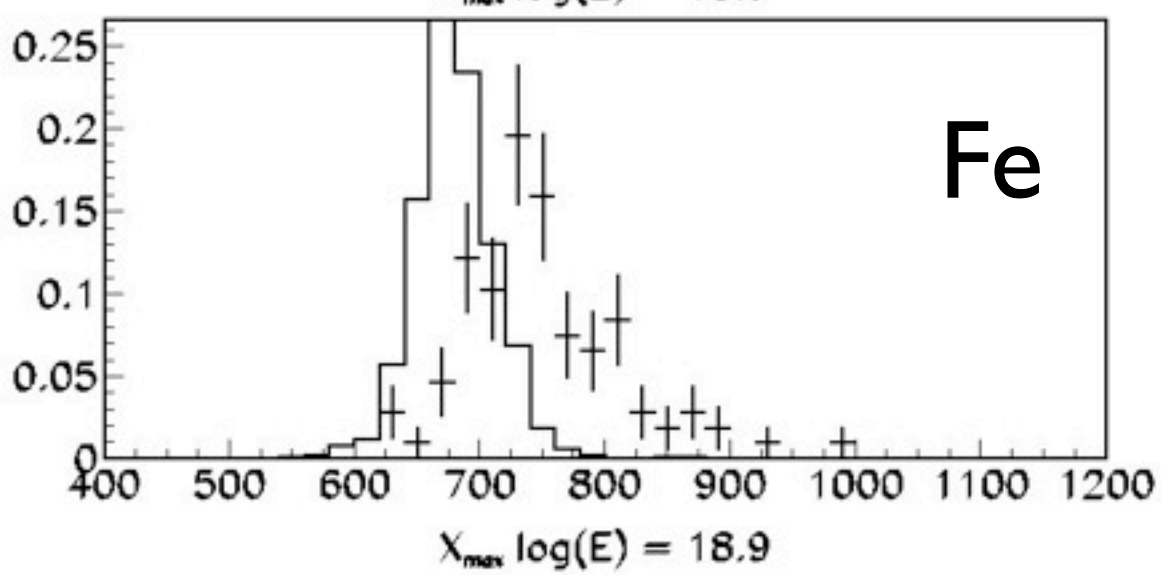

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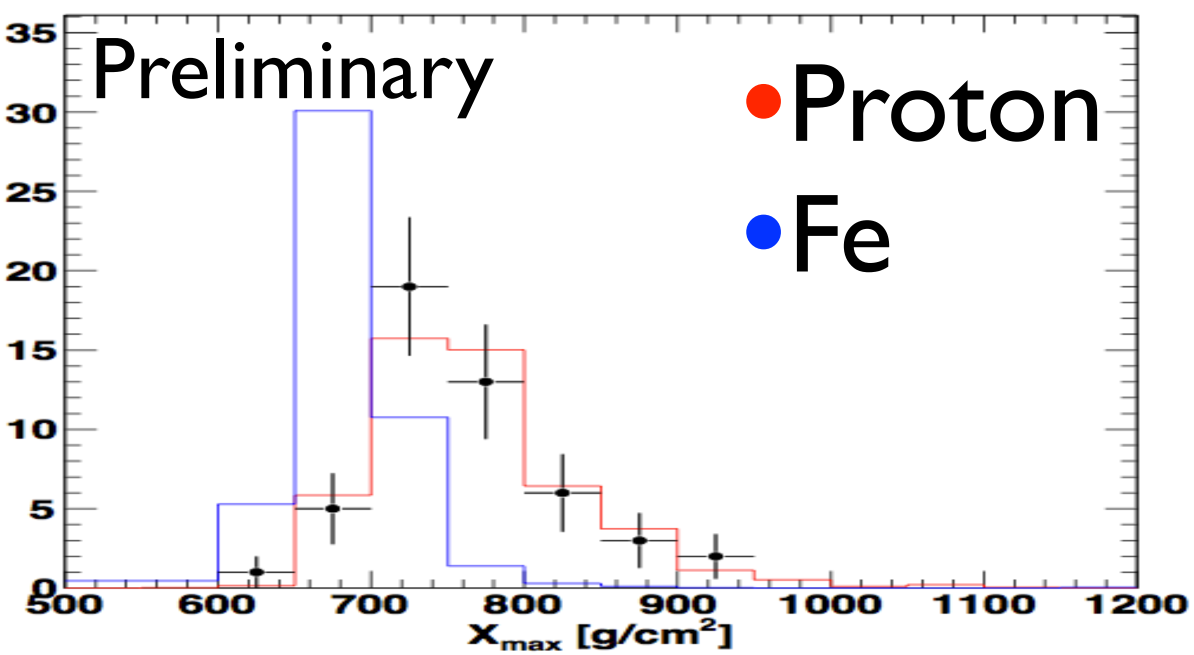

Xmax Distribution in energy bin (QGSJET-II)

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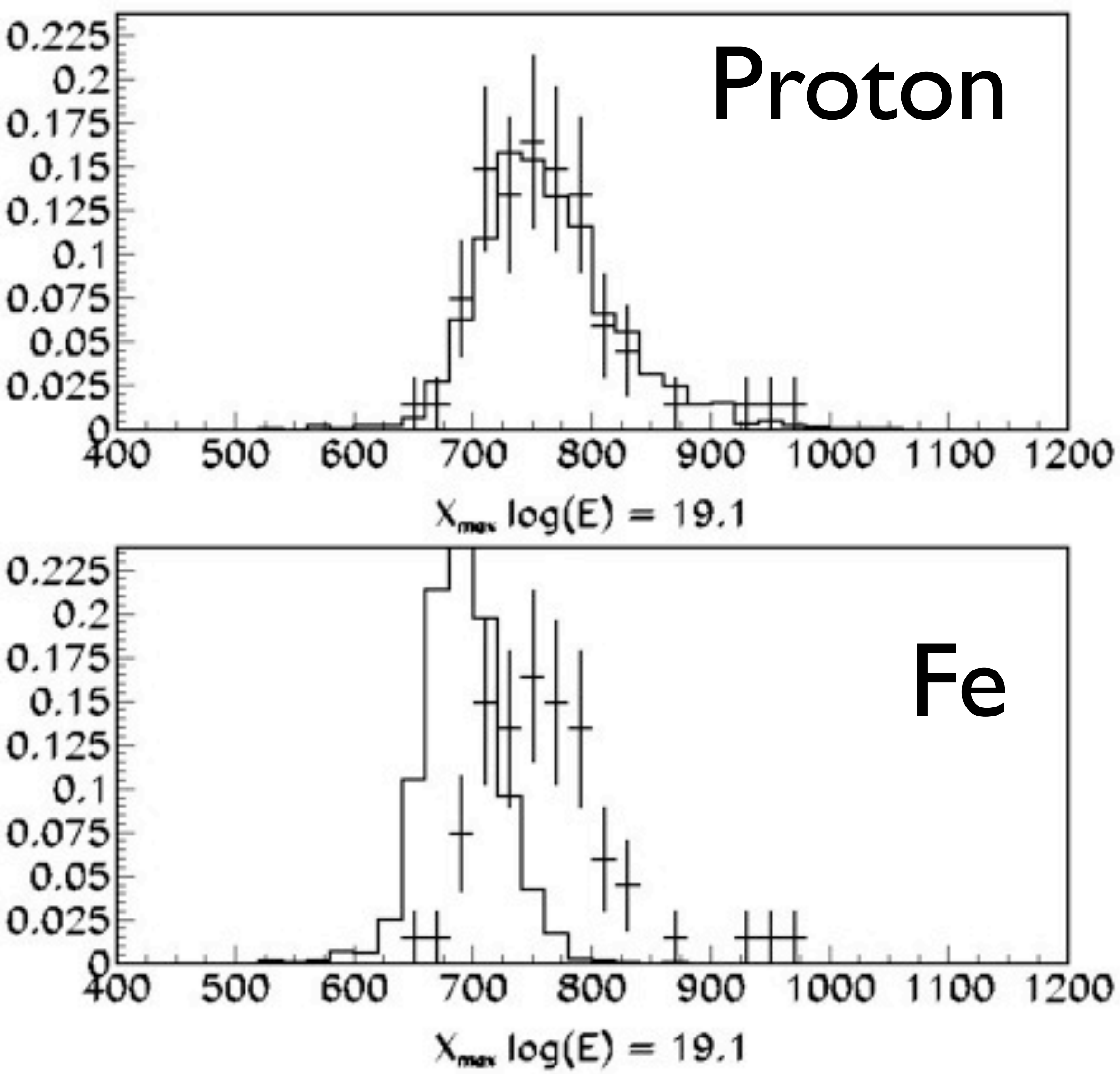

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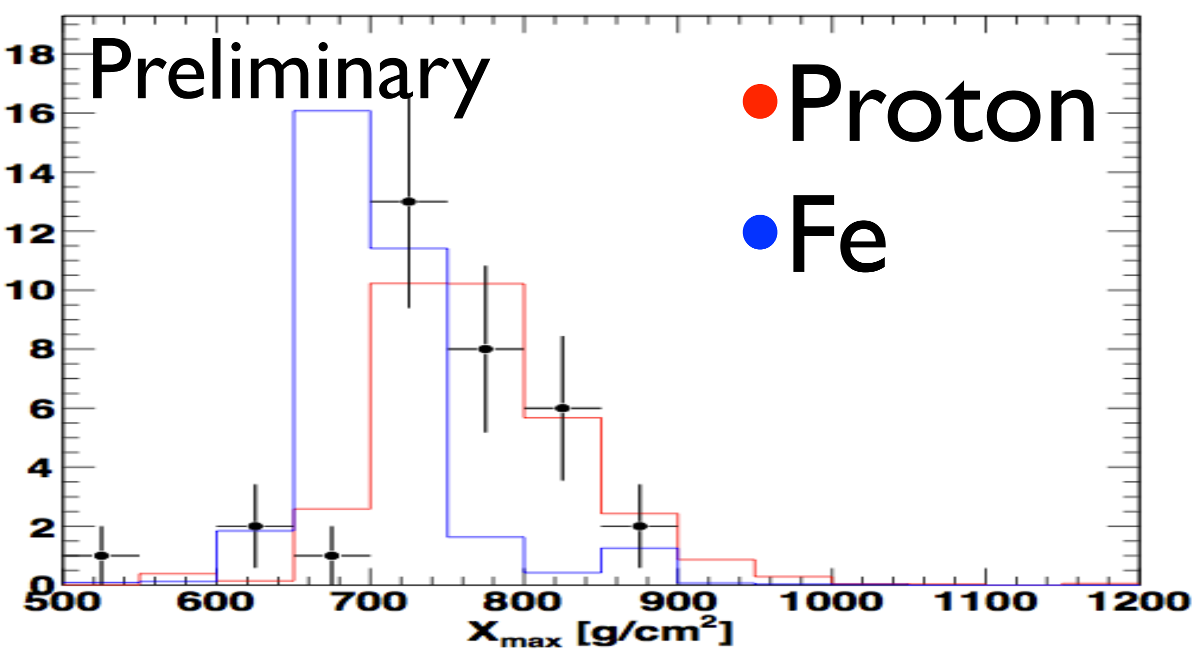
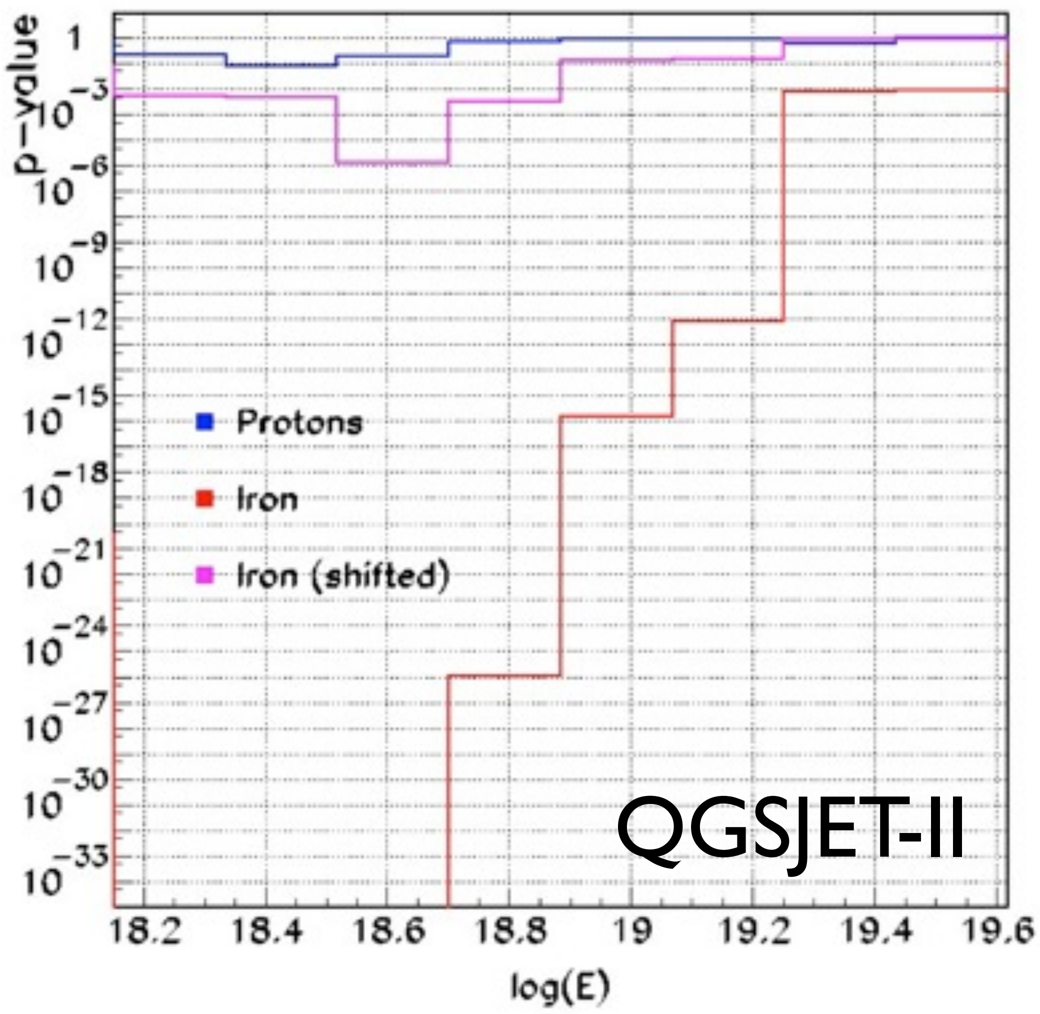


Xmax distribution vs Energy

KS test

HiRes



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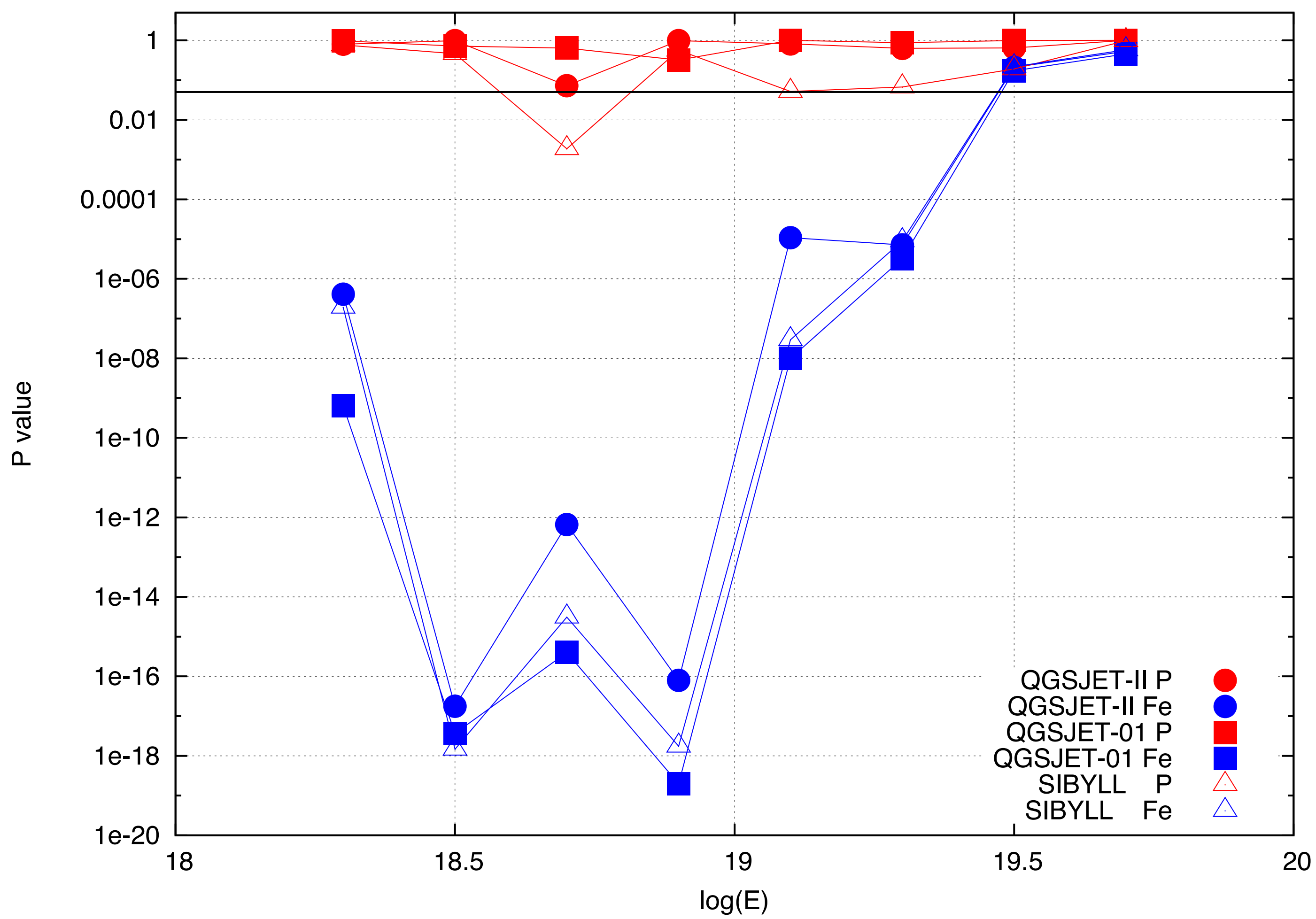
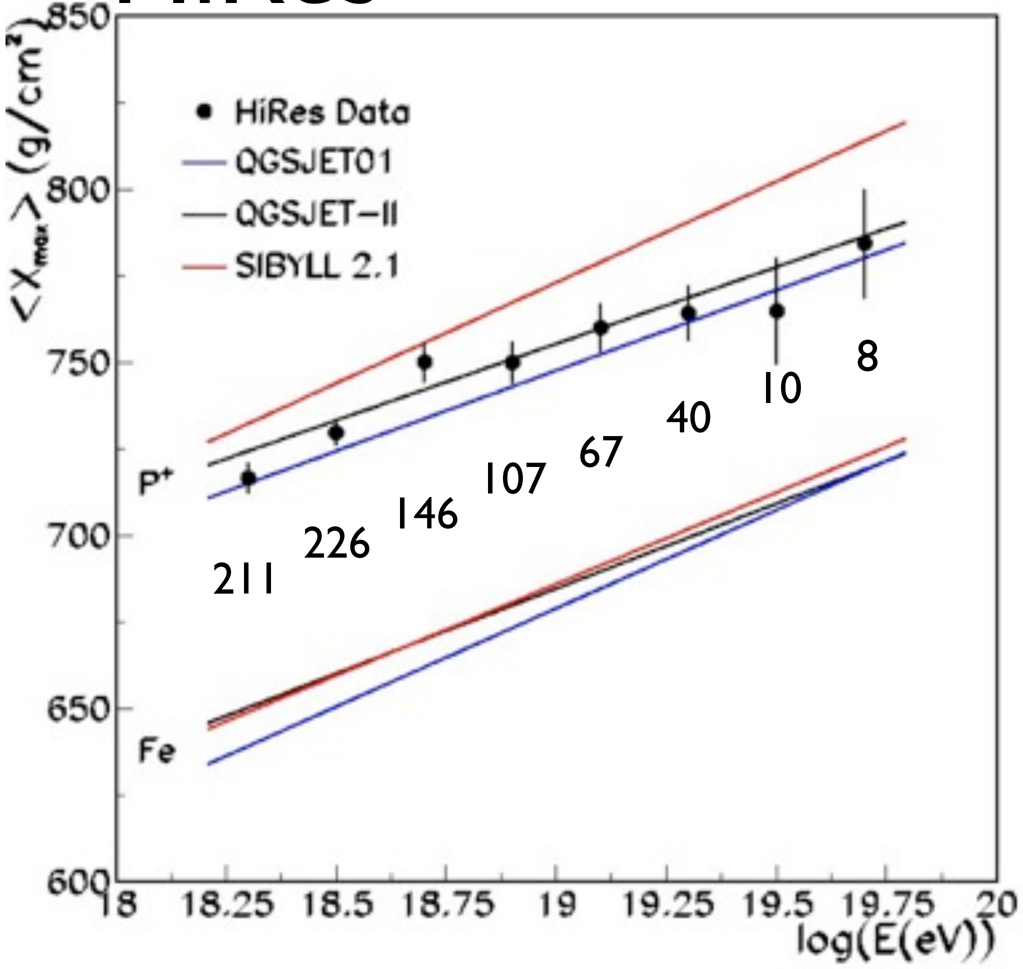


Evolution of <Xmax> w/ Energy

HiRes



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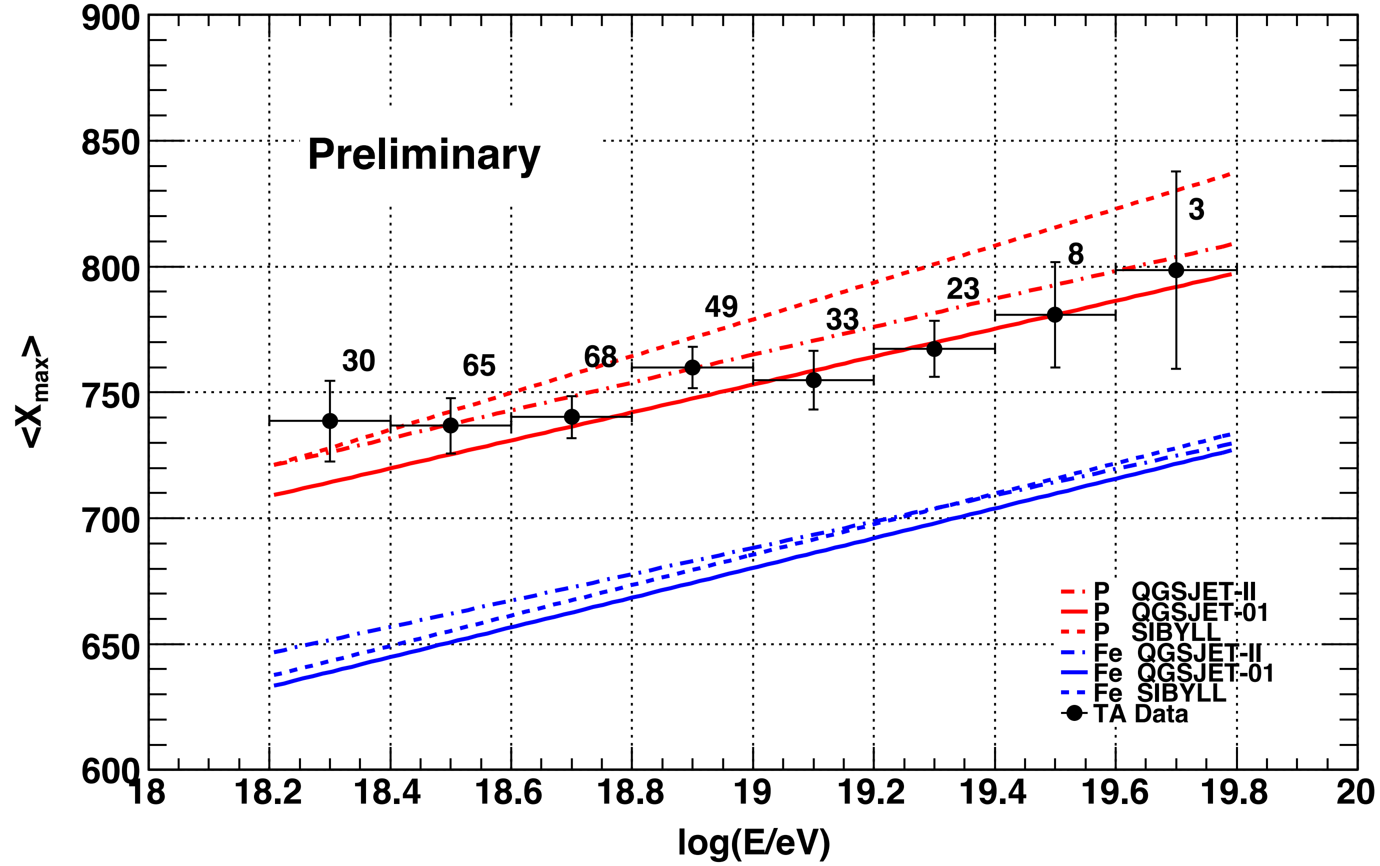


Summary

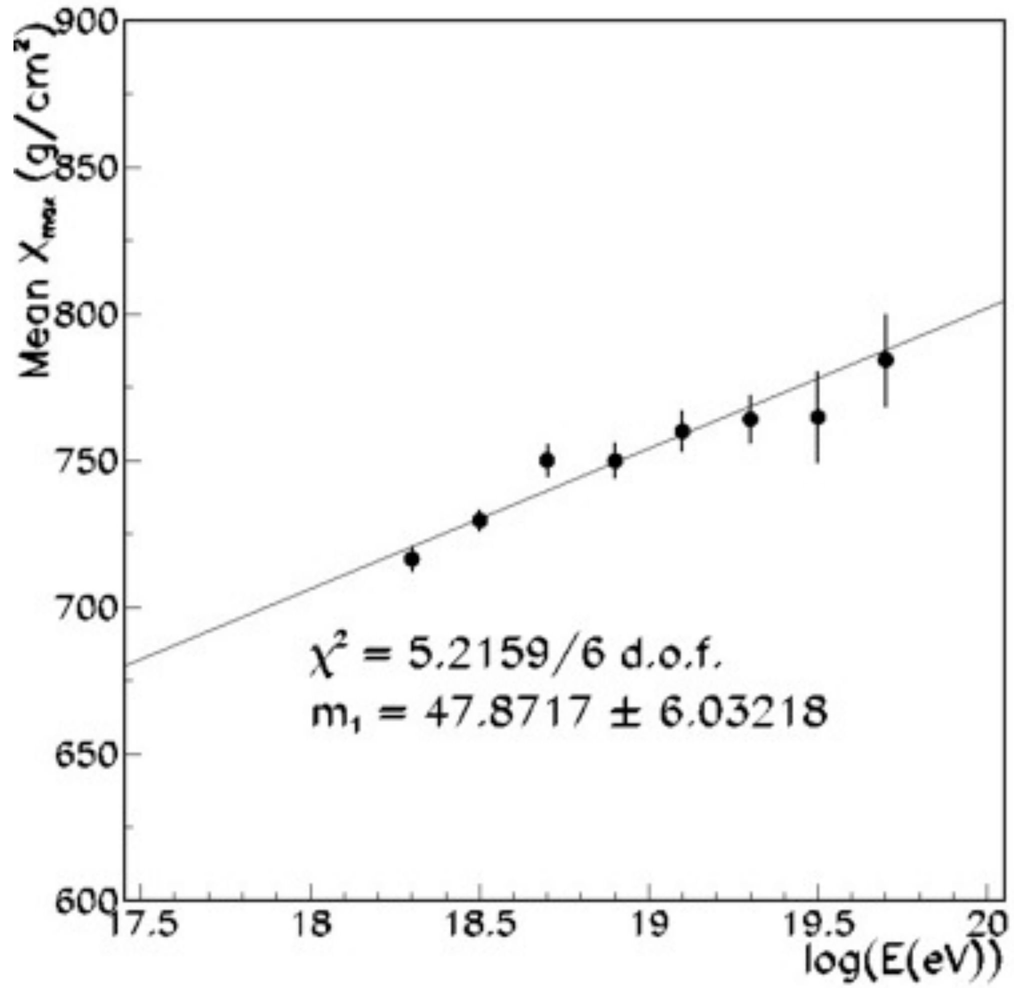
- Data/MC comparison
  - Checking carefully to evaluate MC.
  - QGSJET-II Proton model is preferable.
  - Zenith angle distributions of HiRes and TA-SD are consistent with QGSJET-II Proton model with higher statistics.
- Xmax distribution
  - QGSJET-II, Proton model shows good agreement with HiRes and TA data for whole energy region.
- Averaged Xmax
  - Consistent with QGSJET, Proton model

Memo

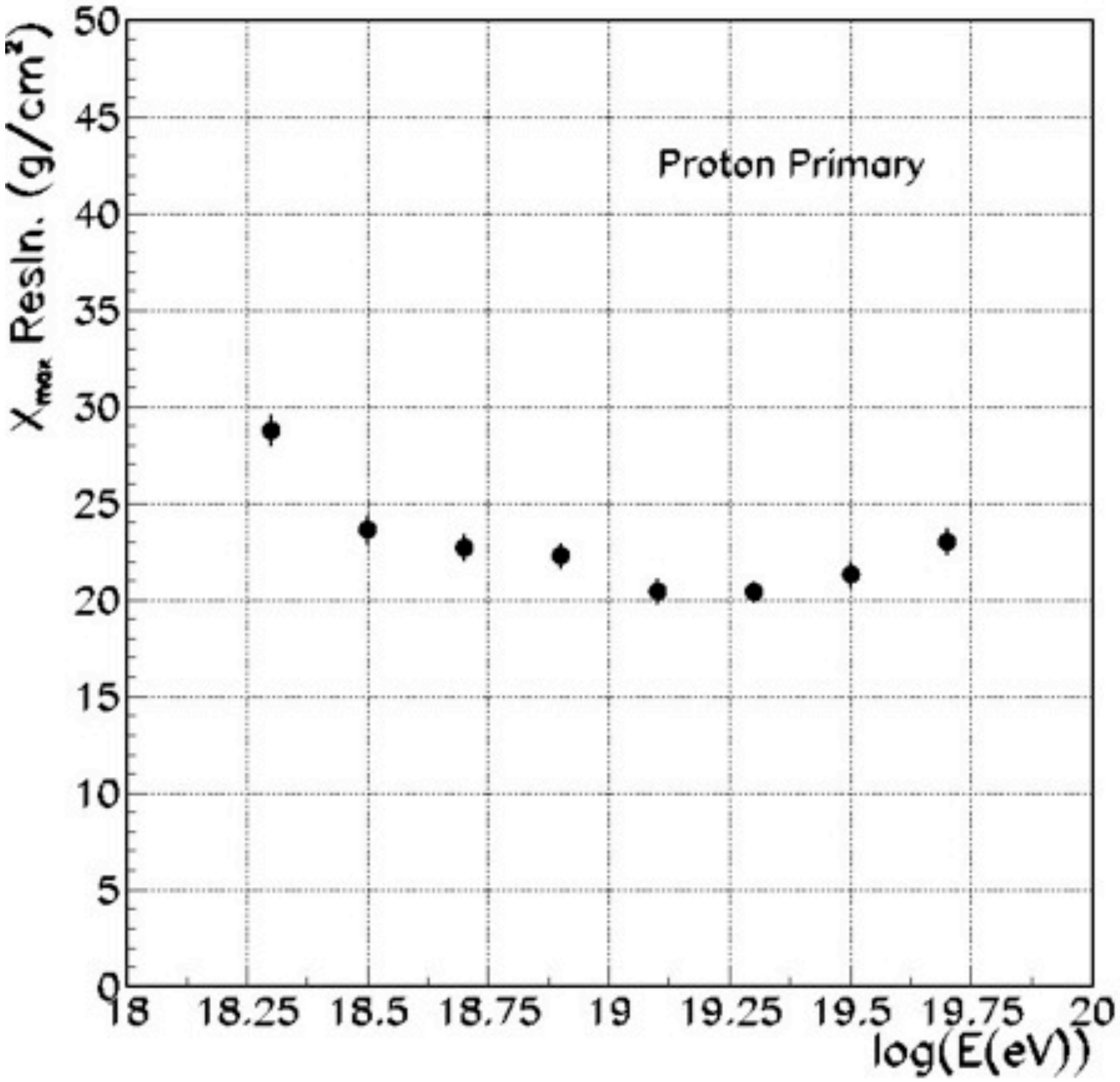
Elongation Rate (HiRes)

Acceptance bias is *energy independent*. Allows linear fit to determine E.R.

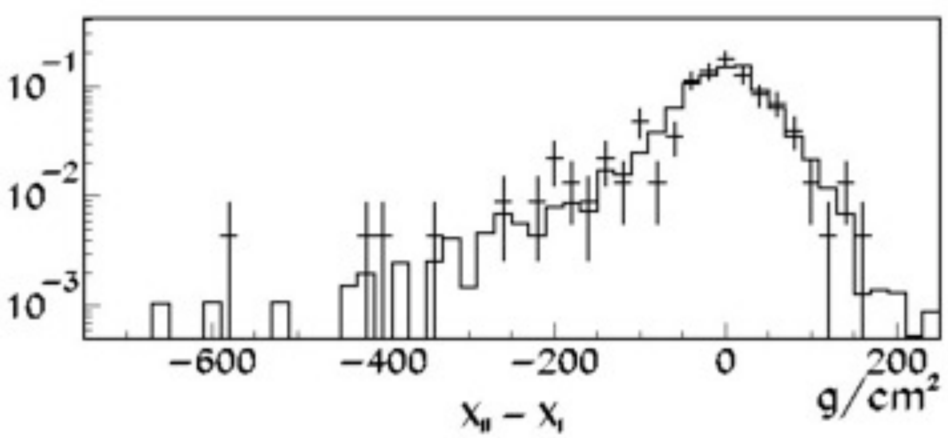
Linear fit consistent with constant elongation rate, i.e. *constant composition*.



Check of Xmax res. (HiRes)



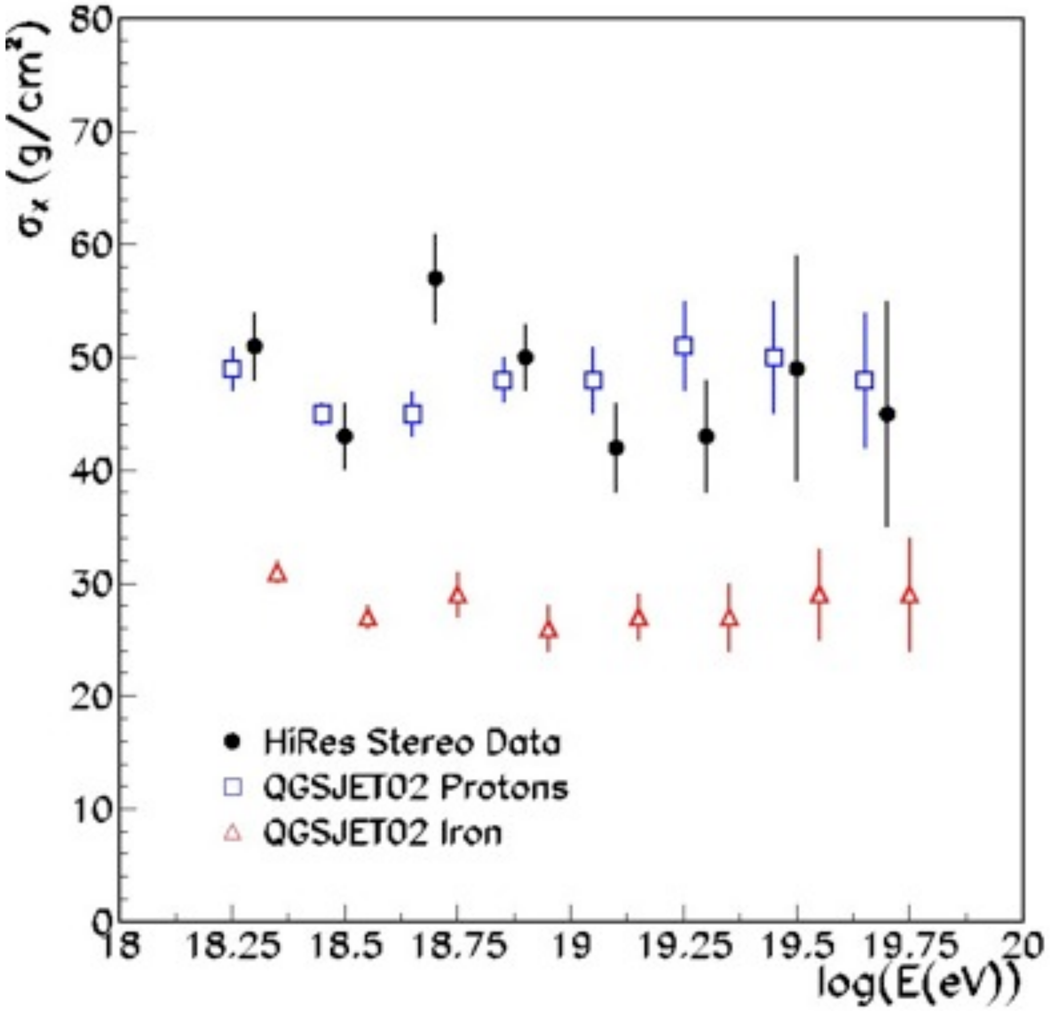
Compare X_{max} as measured by HiRes-I and HiRes-II



HiRes stereo data (points) vs QGSJET-II protons (histogram).

Width of Xmax vs Energy

Width of Xmax



HiRes:

- Define width as σ of Gaussian, truncated at 2xRMS
  - Focus attention on core of distribution
  - Avoid RMS undersampling bias
- Data consistent with QGSJET-II protons