Cosmic Ray Composition and Energy Spectrum:

Extending the Neural Network Analysis to IceTop/IceCube-40

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Sept. 22, 2009

Outline

- Data set
- Monte Carlo simulation
- K- and S- parameters
- Cut parameters
- Neural network
- Energy Spectrum
- Future

What's the Data Set?

- IT/I3 Coincident Events
- 2008 40-string/40-station config
- burn sample: September, Days 244-274
- # events (no cuts): 956184
- Livetime: 23.12 days

What's the Simulation?

- IT/I3 coincident events
- 40 string/40 station config
- Corsika: SibyII/Fluka
- Generated Radius at the surface: 1200m
- Oversampling: ~500 x (need to check for next mc set—likely way too many)
- Zenith Max: 65 degrees
- Energy Bins: 8-17. (10 TeV to 21.4 PeV)
- Primary Types: p and fe only
- Weighting: $E^{-2.7}$ below knee, $E^{-3.2}$ above
- ***NOTE****: the highest energy events were dying on the cluster, so quite a large deficit there. New MC being generated with fewer oversamples, higher energies, and more primaries.*

reco events p: 49712
reco events fe: 53934

Reconstructions

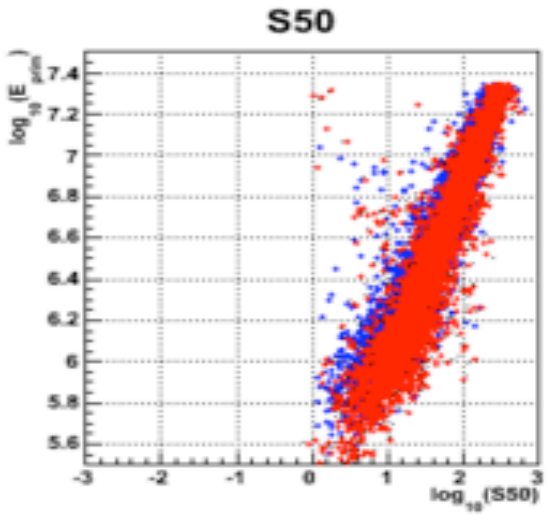
- ShowerCombined reco: uses timing and charge to fit shower front for core position and direction
- MuonBundleRecoLDF: seeded with core position → improved direction
- Second iteration between two gives further improvements in core position and direction.

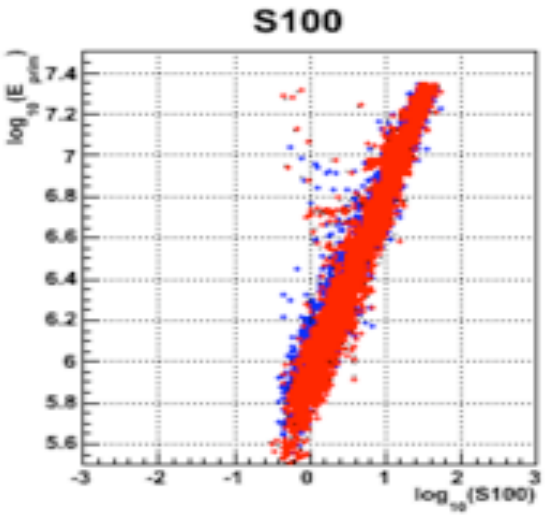
Choose Parameters using MC

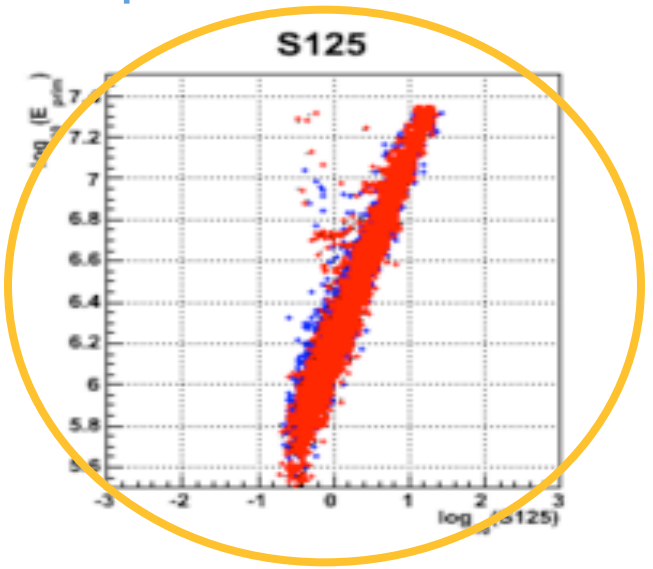
- To provide continuity/comparison with previous analyses, decide on K- and S-parameters.
- For choosing, make some very basic containment cuts:
  - Track within 75% IceTop area
  - Track within 75% IceCube volume

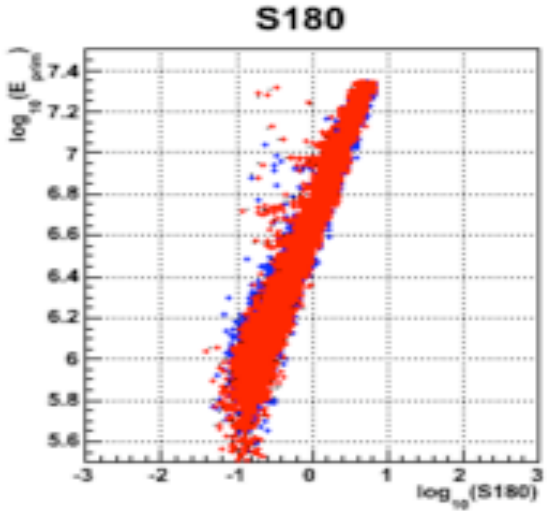
Choose S-Parameter: S125

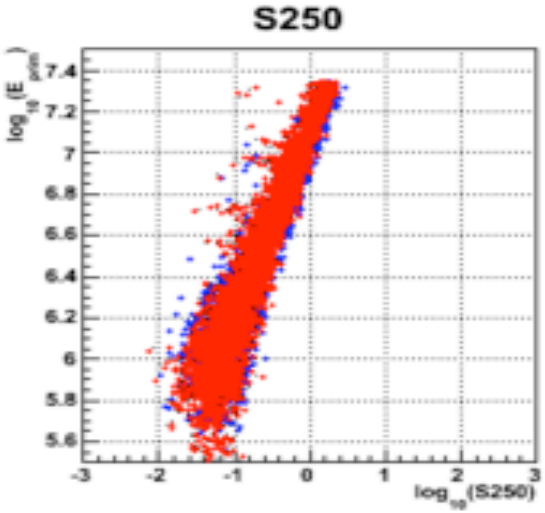
Want narrowest spread and least type dependence

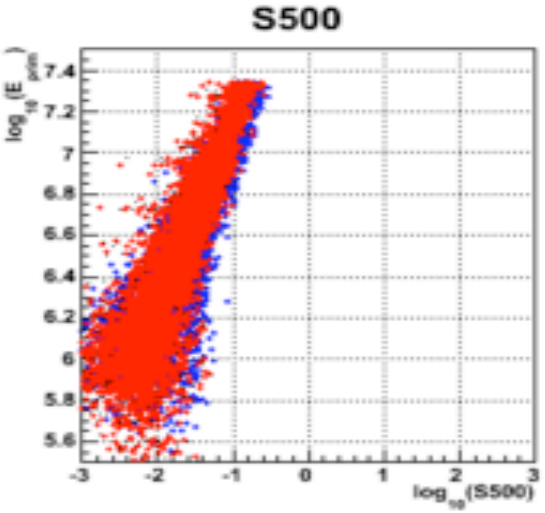








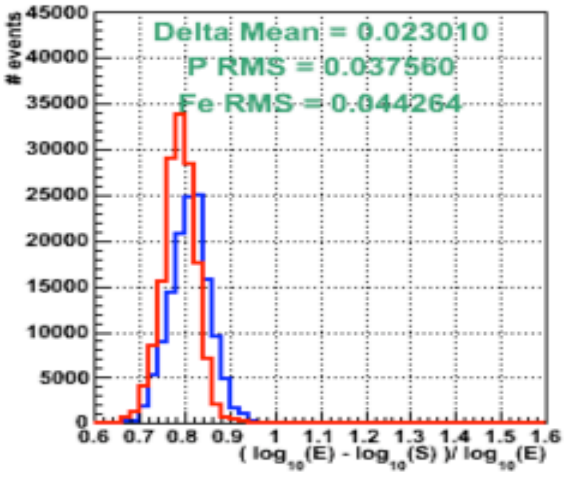




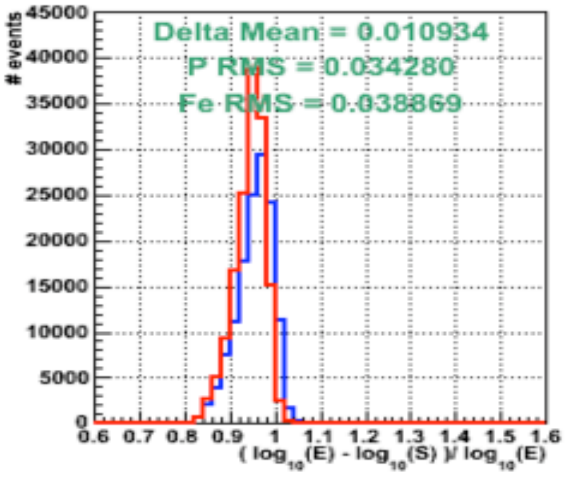
Choose S-Parameter: S125

Want narrowest spread and least type dependence

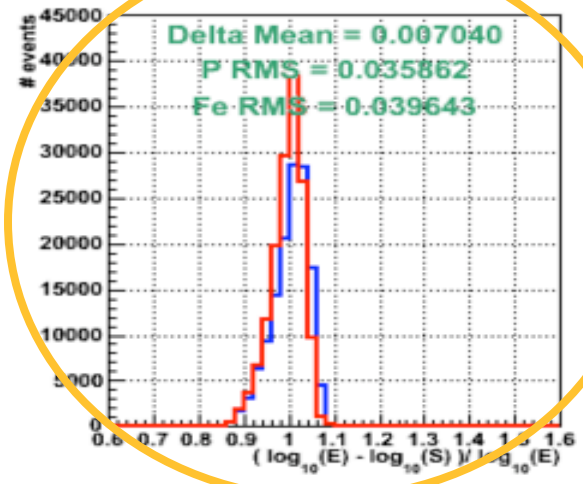
S50



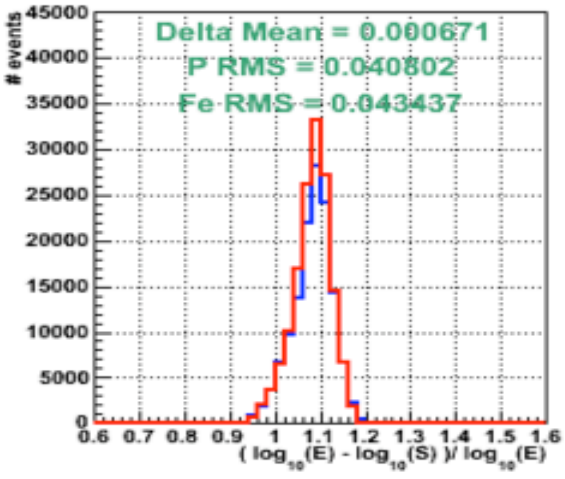
S100



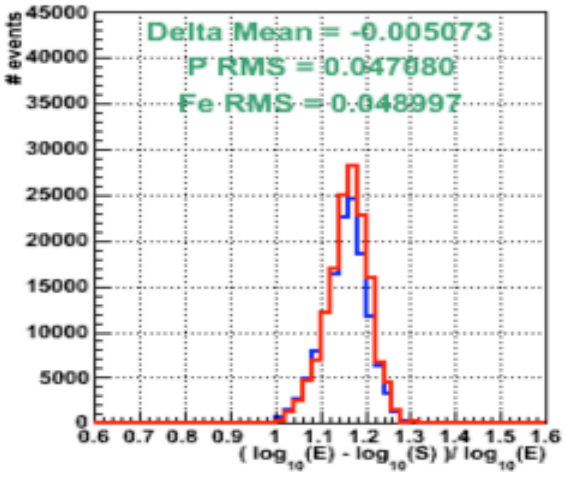
S125



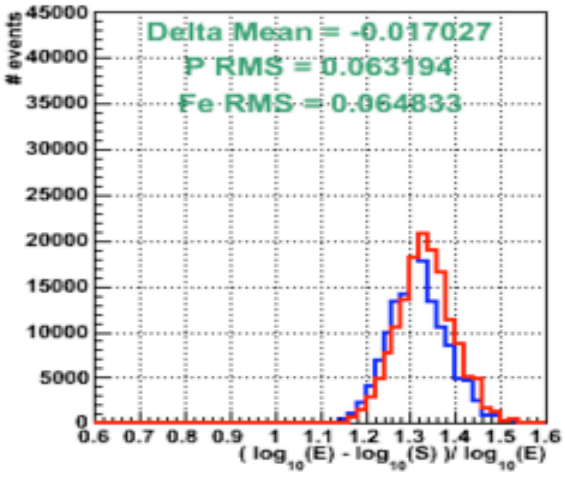
S180



S250

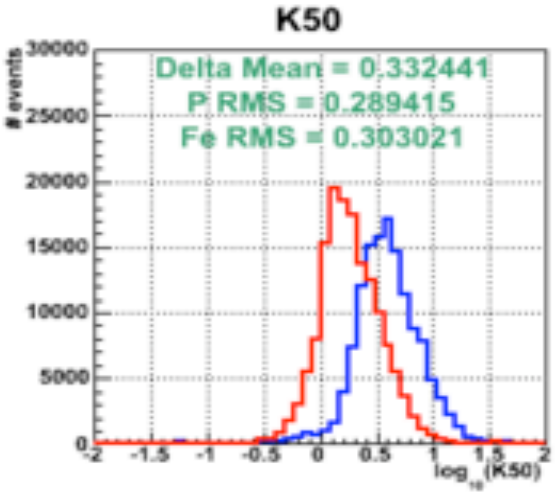


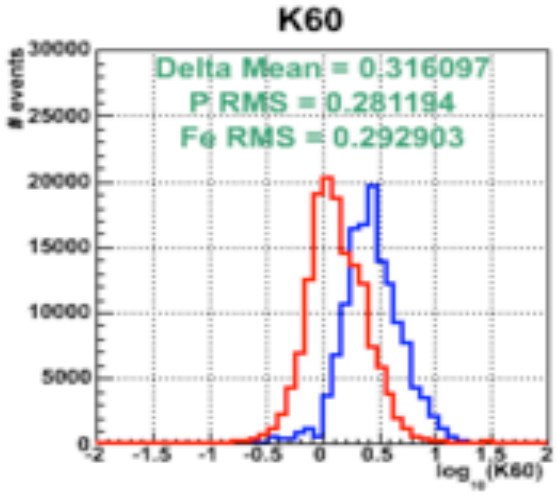
S500

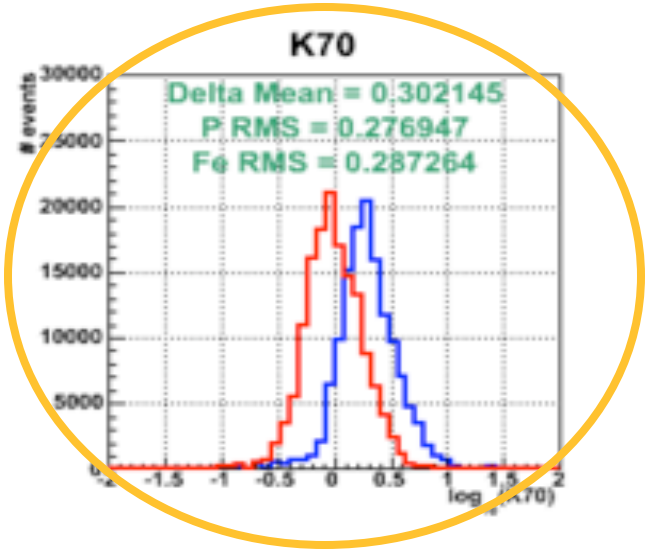


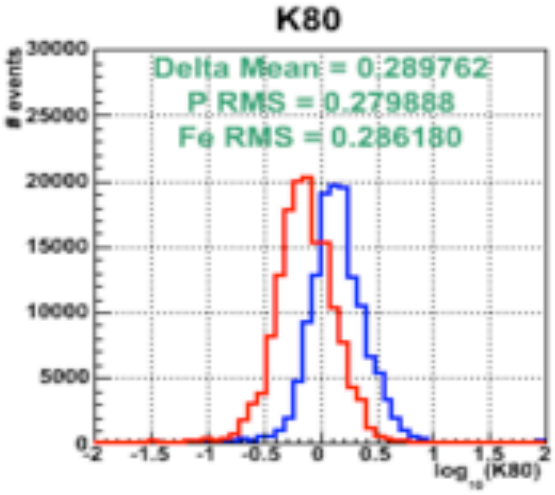
Choose K-Parameter: K70

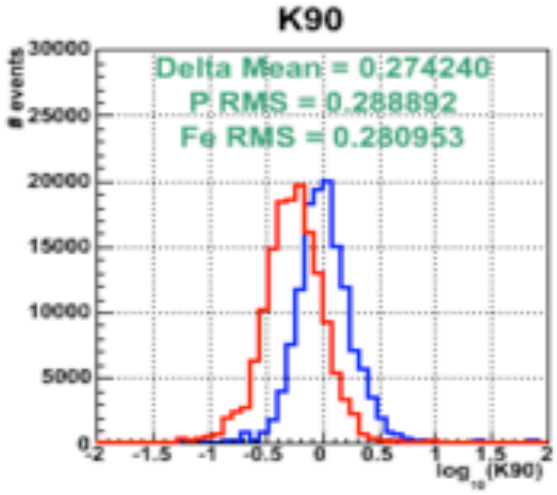
Best type (peak) separation with least overlap (narrow spread)

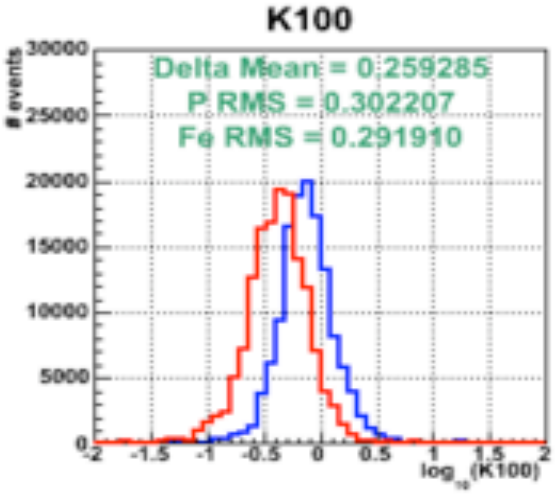


















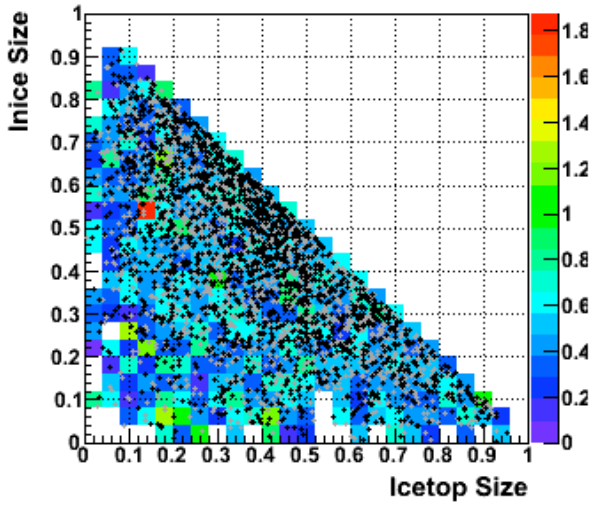
Establishing Cuts with MC

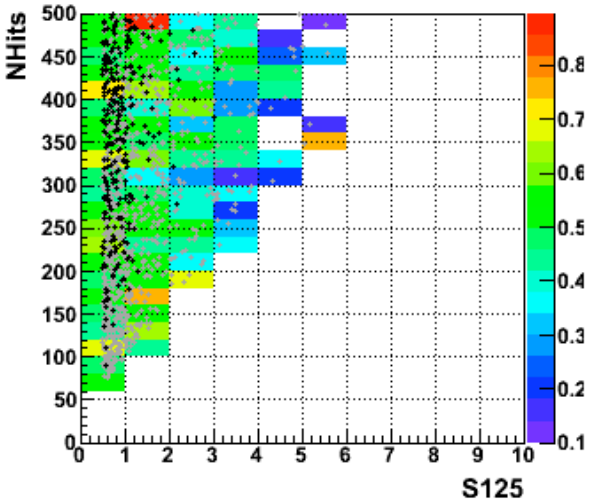
(prefer tight cuts for first check of technique)

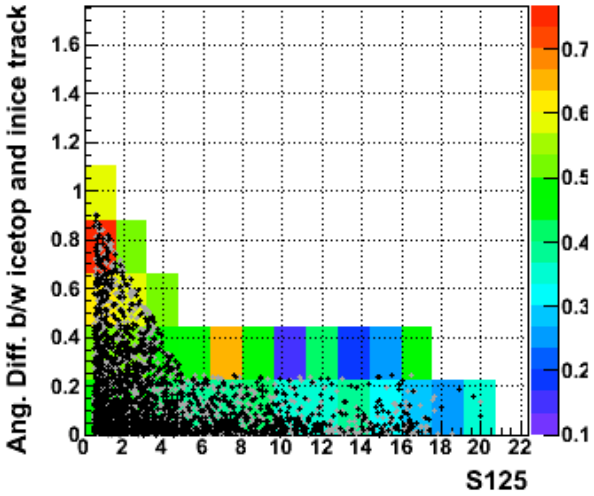
- Basic Cuts:
  - S125 > 0.5
  - Reco att. Length of light in ice < 90m
- 2-D Cuts:
  - Edge clippers in one detector must fall well w/in the other:
    Inice Size < -Icetop Size + 1
  - As S125 increses, Nhits should also increase:
    Nhits > 60*(S125) + 40
  - As S125 increases, the reco tracak length should increase to a certain point:
    LDirC > 80*(S125) + 400 for S125 < =5, otherwise LDirC > 850
  - Ang Diff b/w surface and inice track must be small and get smaller with higher S125:
    If S125 < 5, ang diff < -.15*(S125) + 1 or if S125 >= 5, ang diff < .25

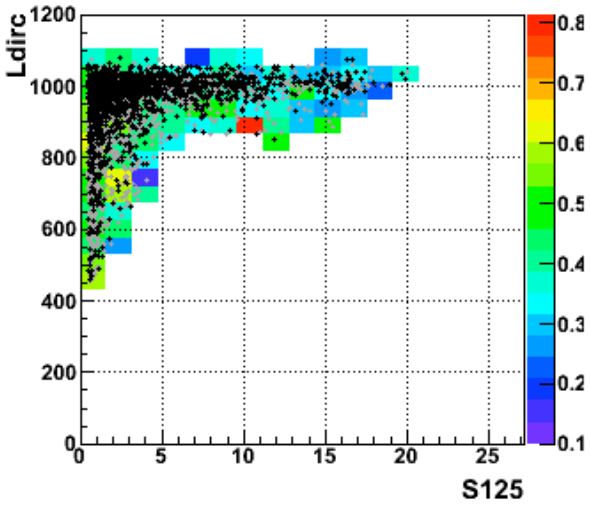
For reference, see:
http://wiki.icecube.wisc.edu/index.php/SPASE/AMANDA_Composition_Analysis/ITI3Cuts

2-D Cuts







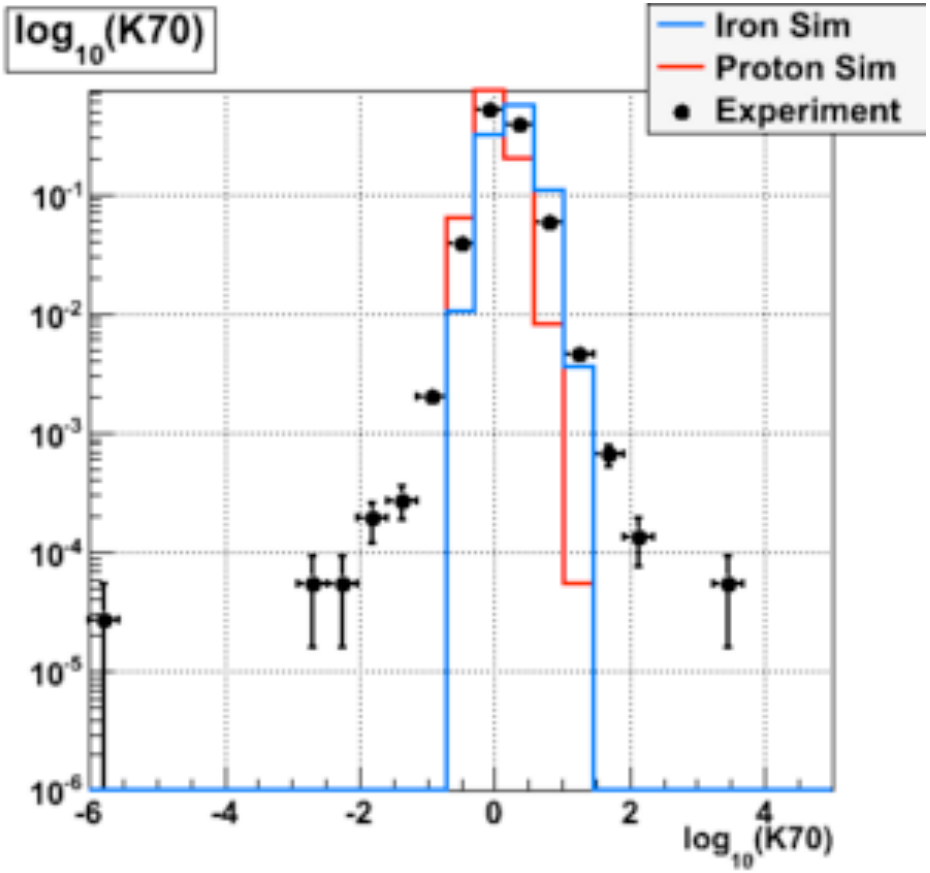


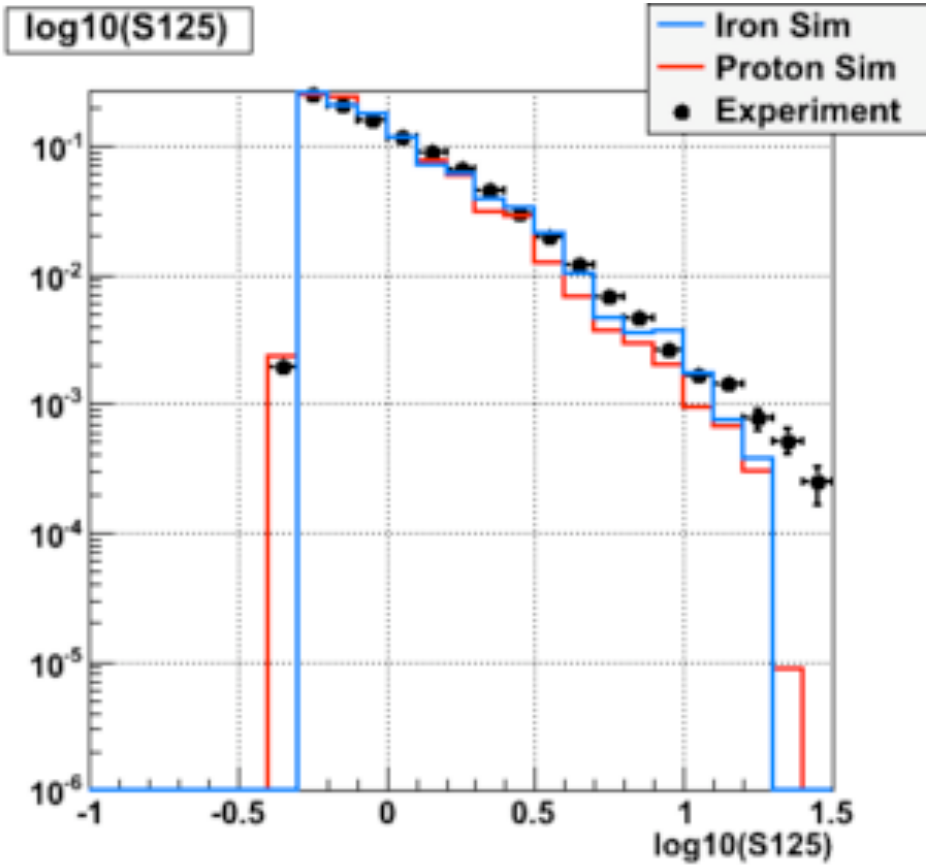
Gray Dots = proton

Black Dots = iron

Contours in angular resolution

Compare Data vs MC



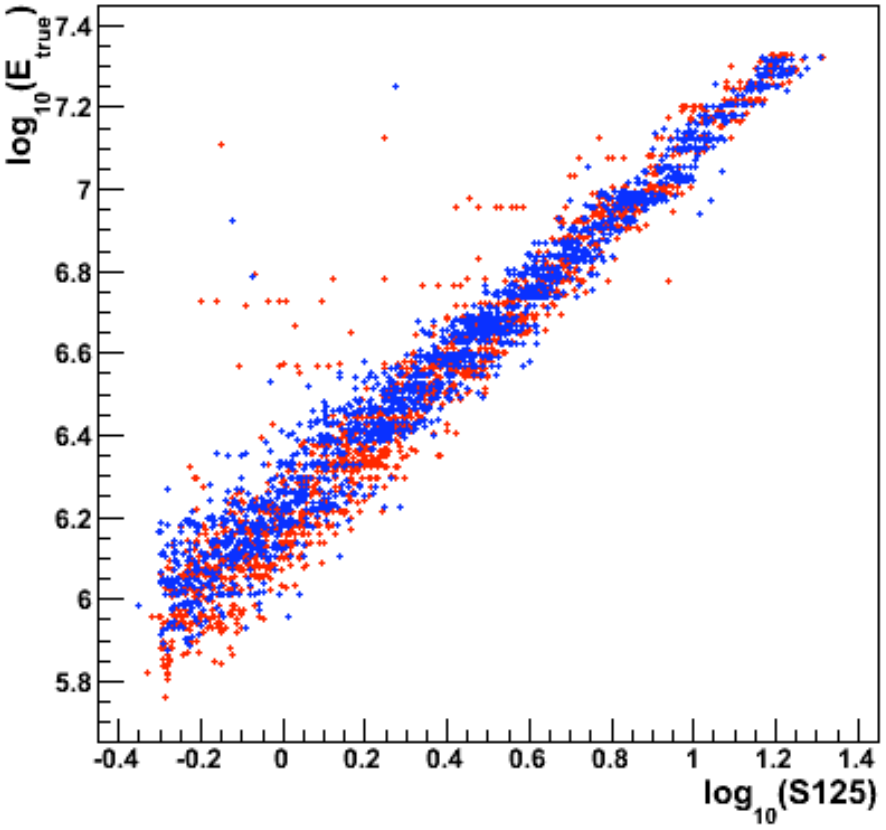


For more comparisons, see:

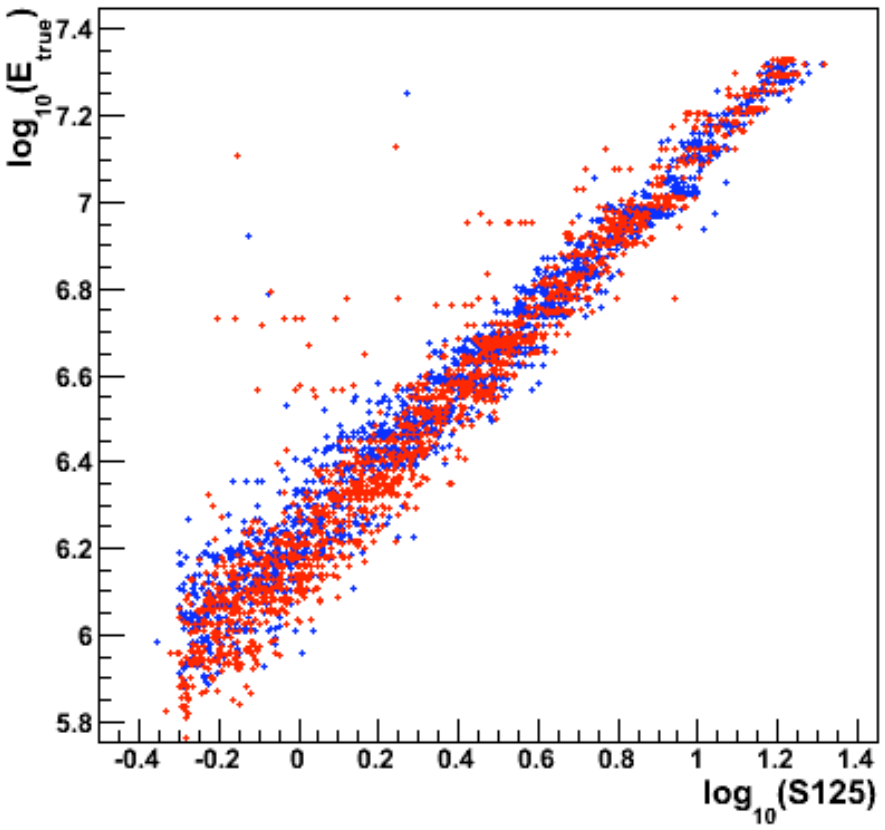
http://wiki.icecube.wisc.edu/index.php/SPASE/AMANDA_Composition_Analysis/ITI3Data_and_Monte_Carlo_Comparison_Studies

S125: Energy Estimator

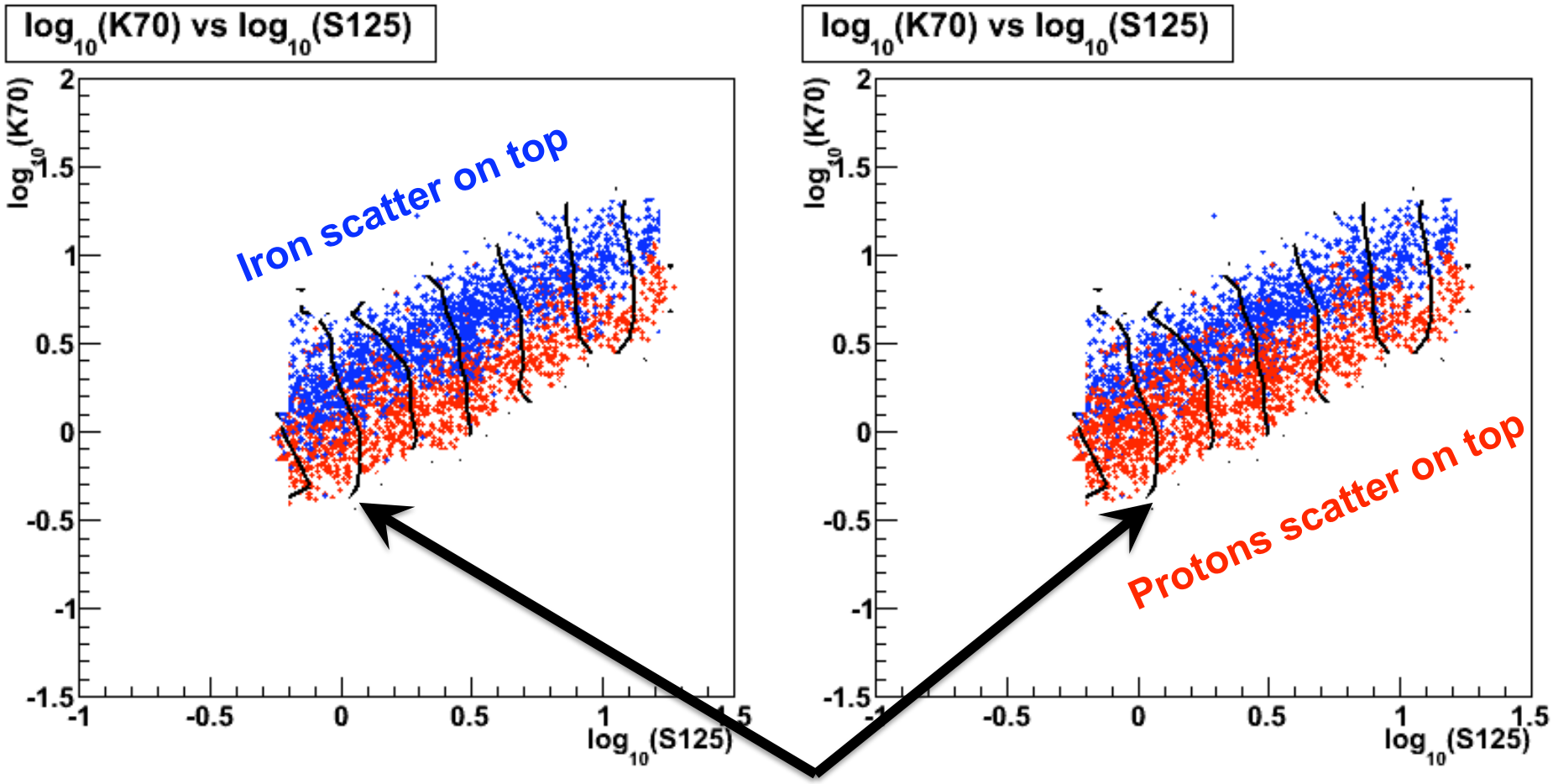
(Iron scatter on top)



(Protons scatter on top)

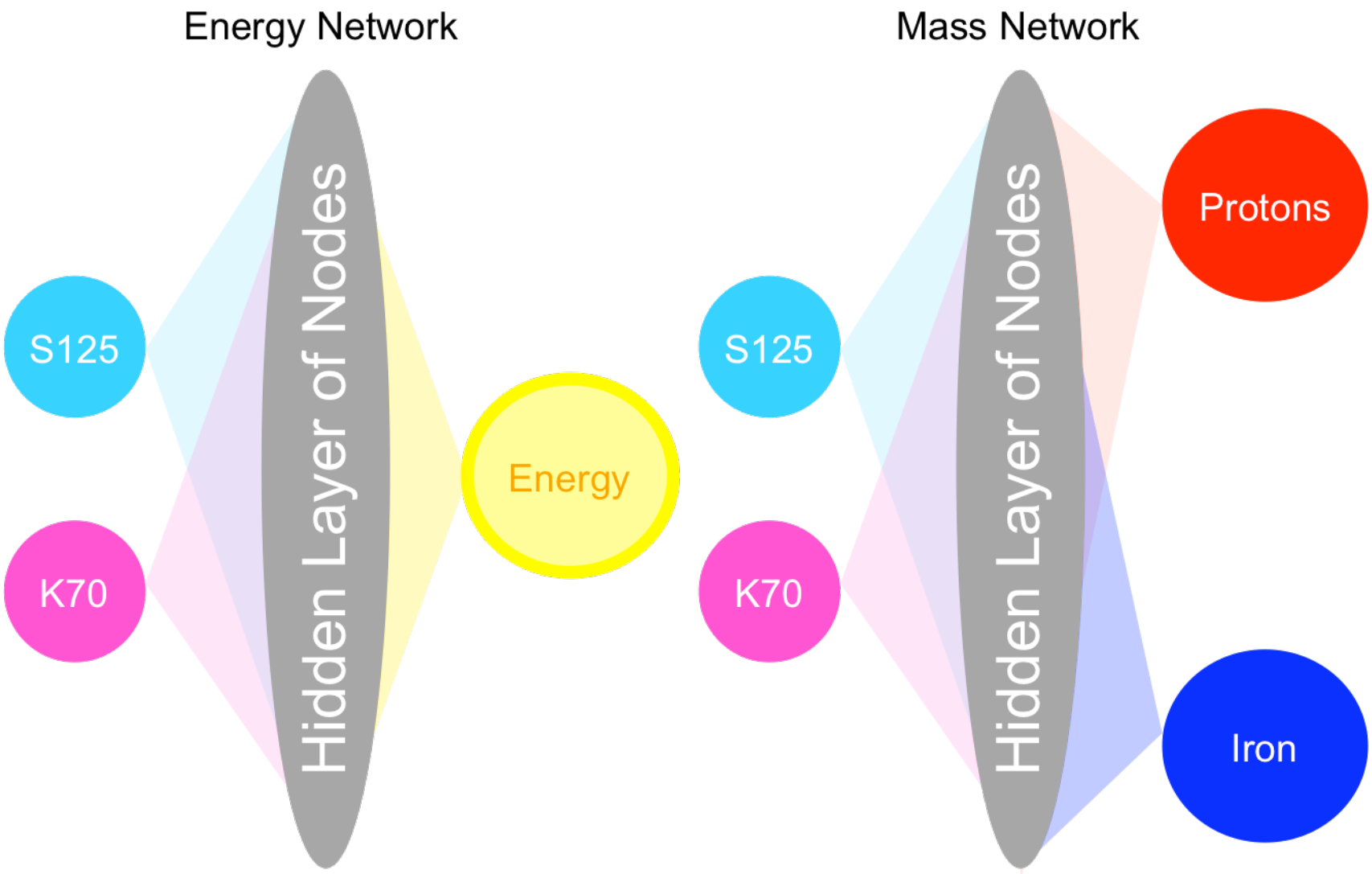


"Pig" Plot: contours in $\log_{10}E_{true}$



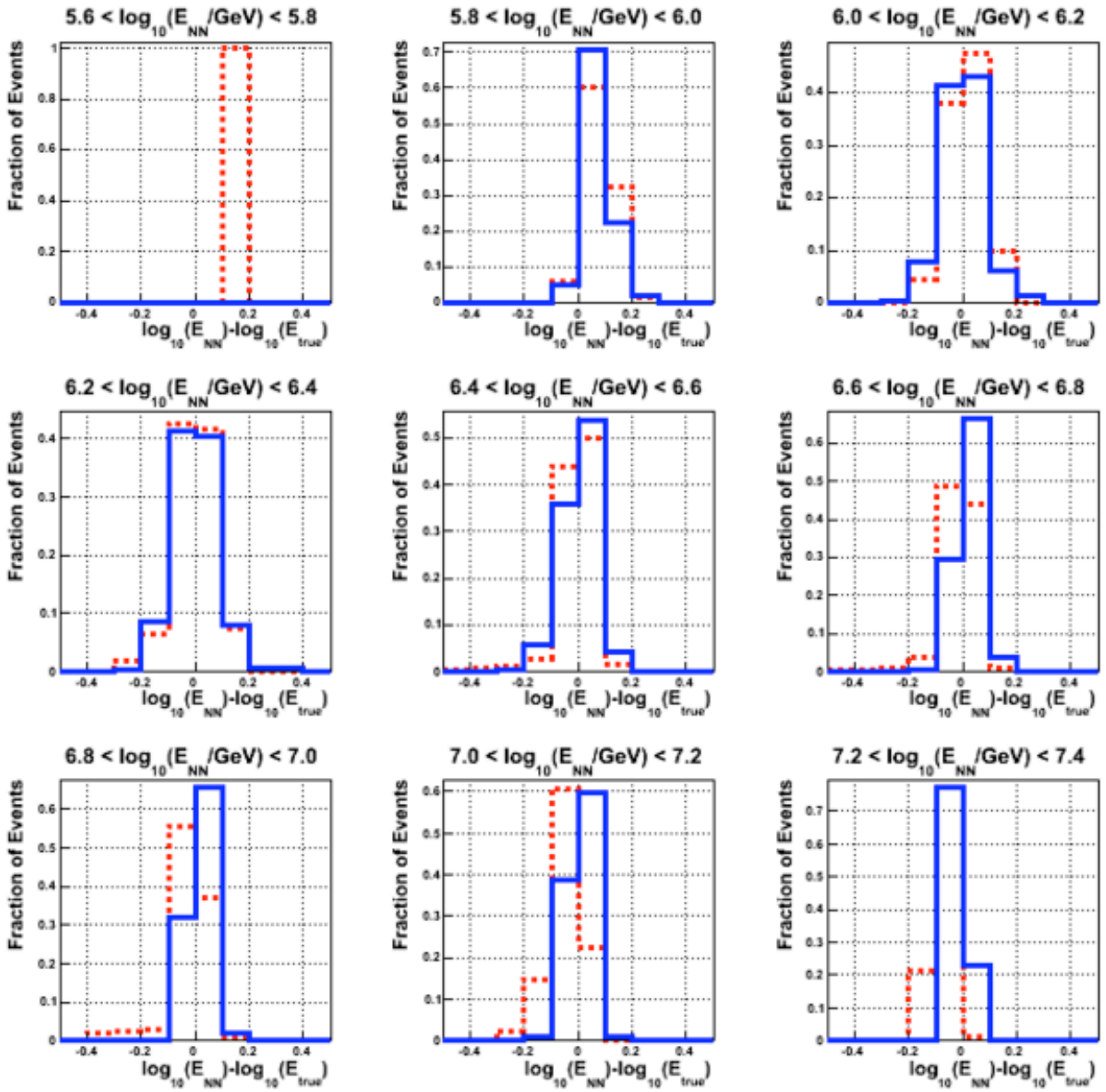
$\log_{10}(E_{true}) = 6.2$

Neural Networks



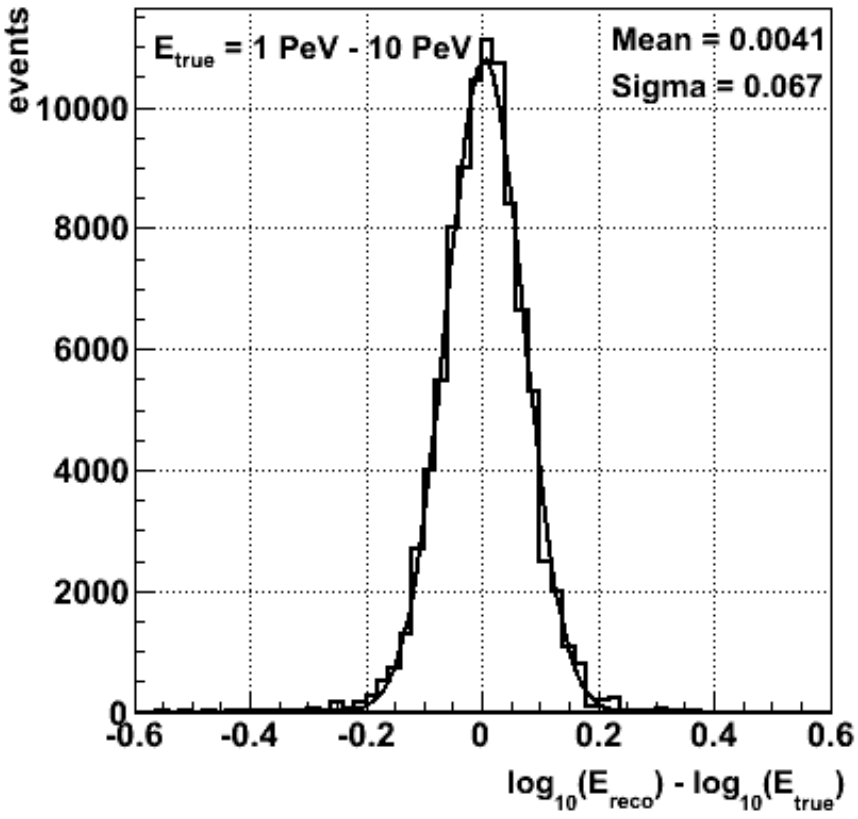
Still needs to be optimized: currently using 8 nodes for Energy, and 5 for Mass

Energy Output (Bins in $\mathrm{Log}_{10}E_{\mathrm{RECO}}$)

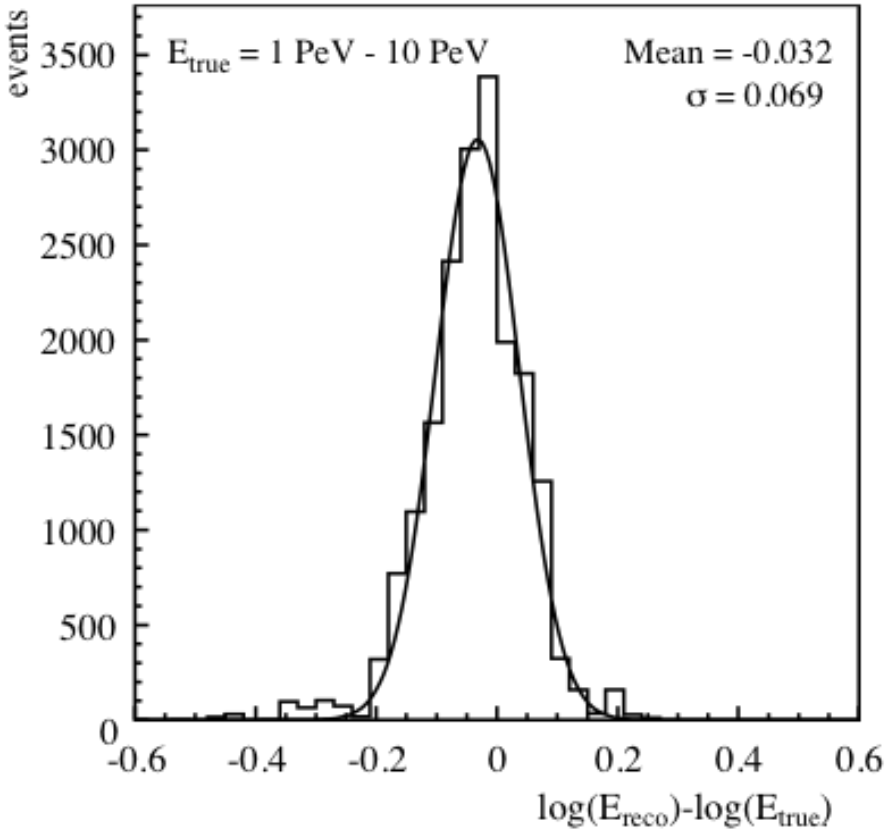


Energy Resolution 1-10 PeV

IT/IC 40



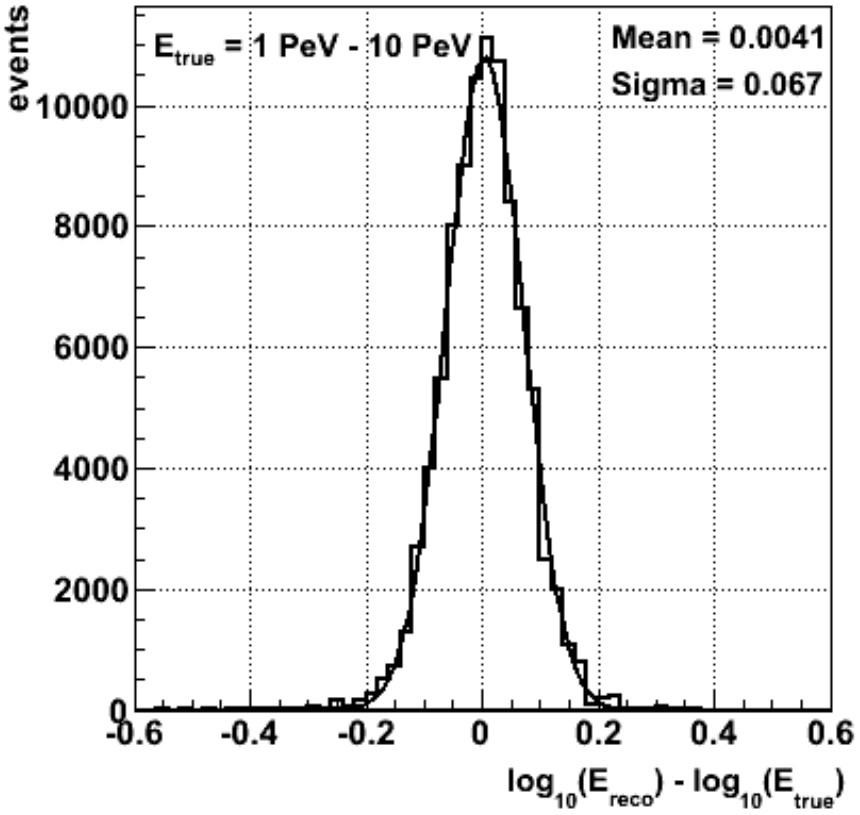
SPASE-2/AMANDA-B10

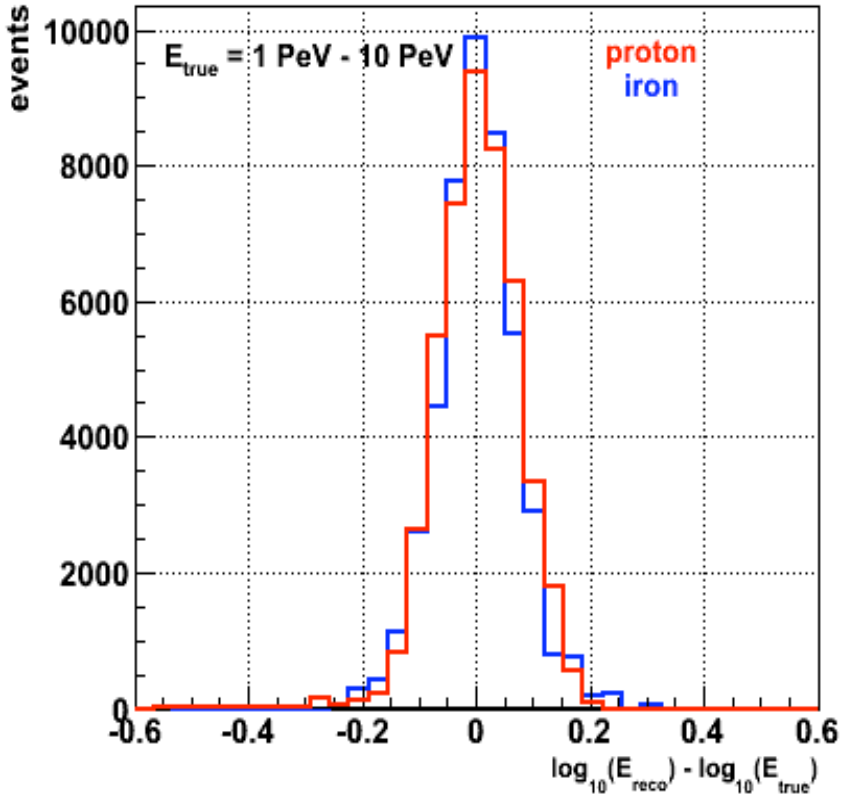


$\sigma_E \approx 7\% \log(E)$

Energy Resolution 1-10 PeV

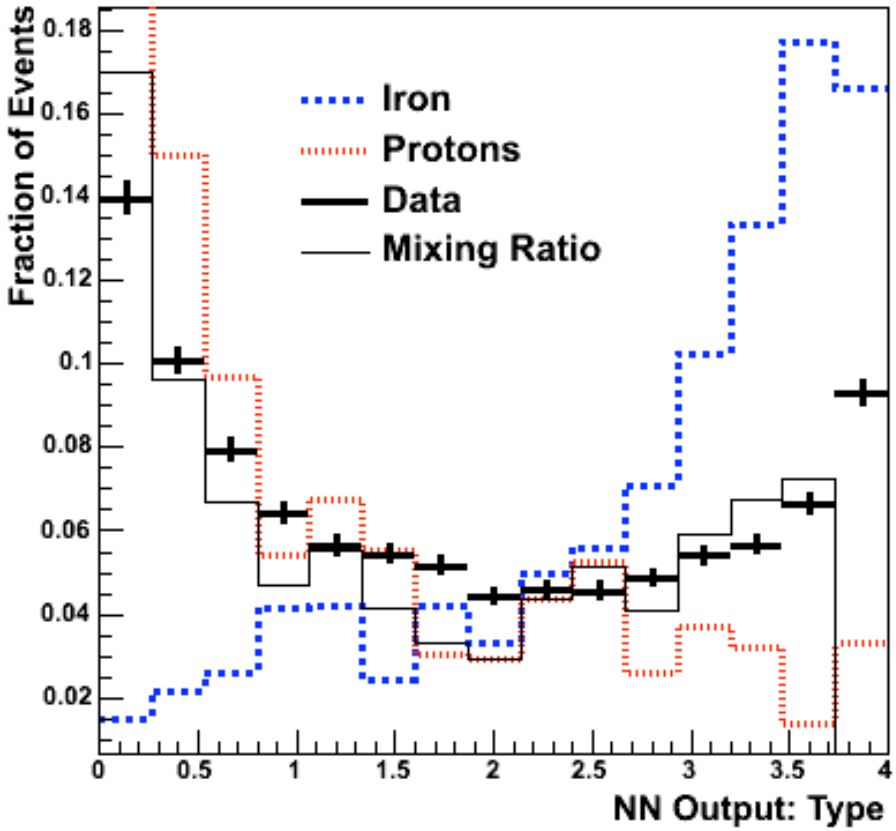
IT/IC 40





Protons: σ = 6.7% log(E), mean = 0.008
Iron: σ = 6.8% log(E), mean = 0.002

Mass Output, 6.2 < $\mathrm{Log}_{10}E_{\mathrm{TRUE}}$ < 6.4

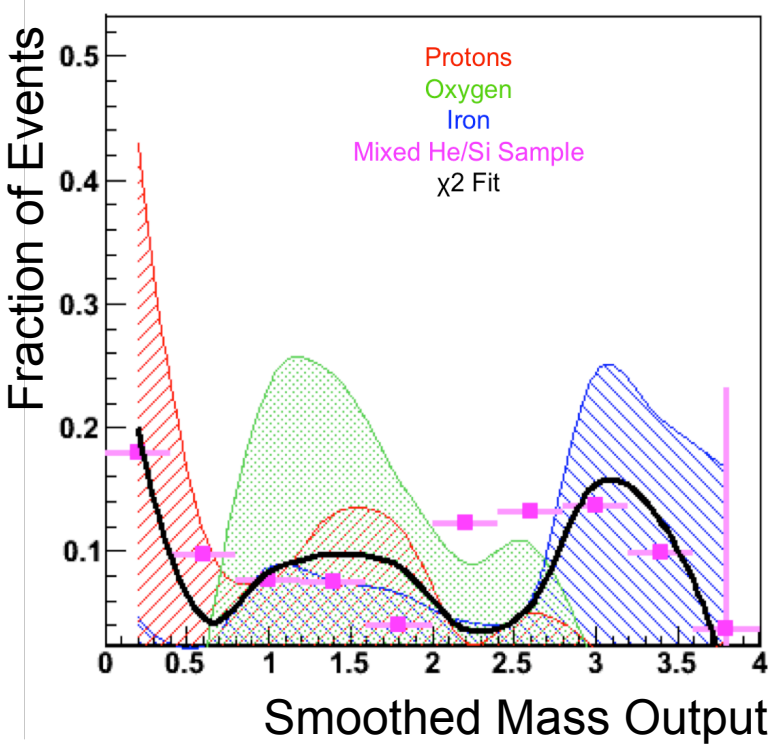


Mass Output and Minimization from Mass Network.

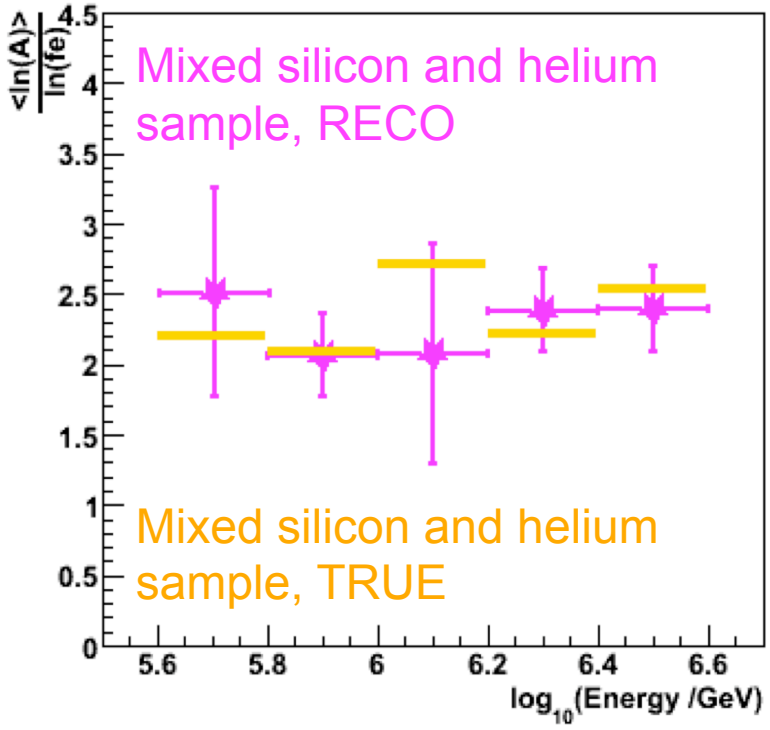
Can yield <lnA> result for each bin in energy

Due to mc jobs failing on the cluster at high energies there is an unknown bias in this particular set, so wait for new mc.

Prospects for Mass (from SP/AM, ICRC '09)

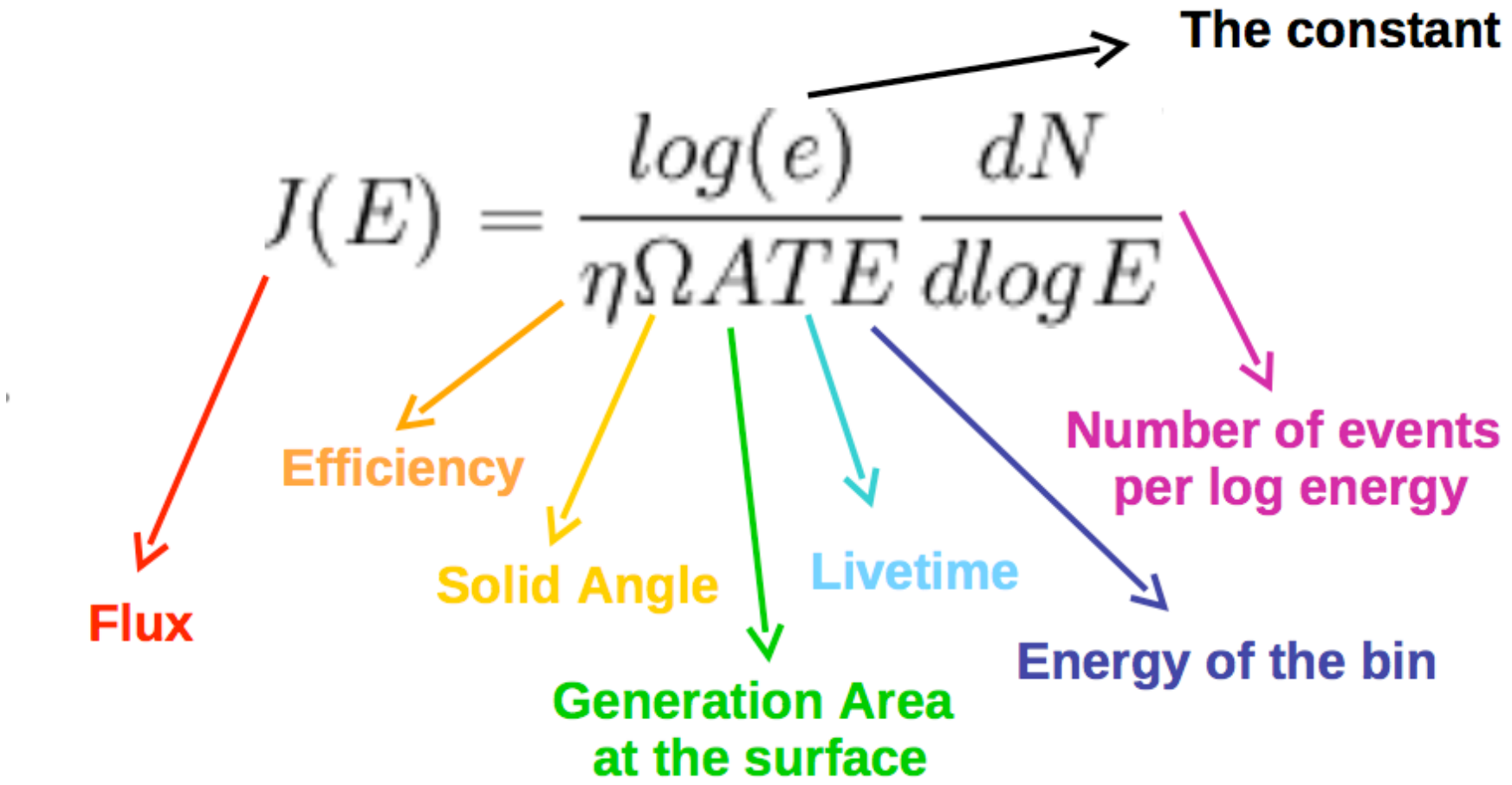


Minimization for one bin in $\log_{10}E_{true}$ for a network trained on three types: H, O, and Fe.

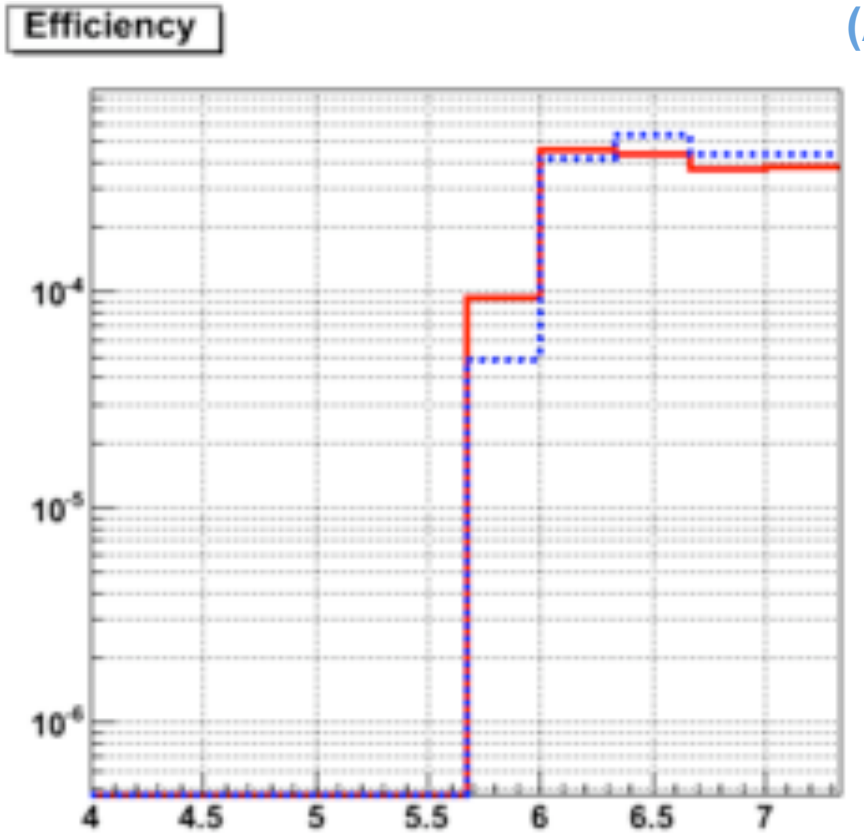


Test a network trained on three types. After training, network was "fed" mixture of He and Si. Reco and actual <lnA> vs Log_{10}(E) is shown. **(Note: very few He and Si were available)**

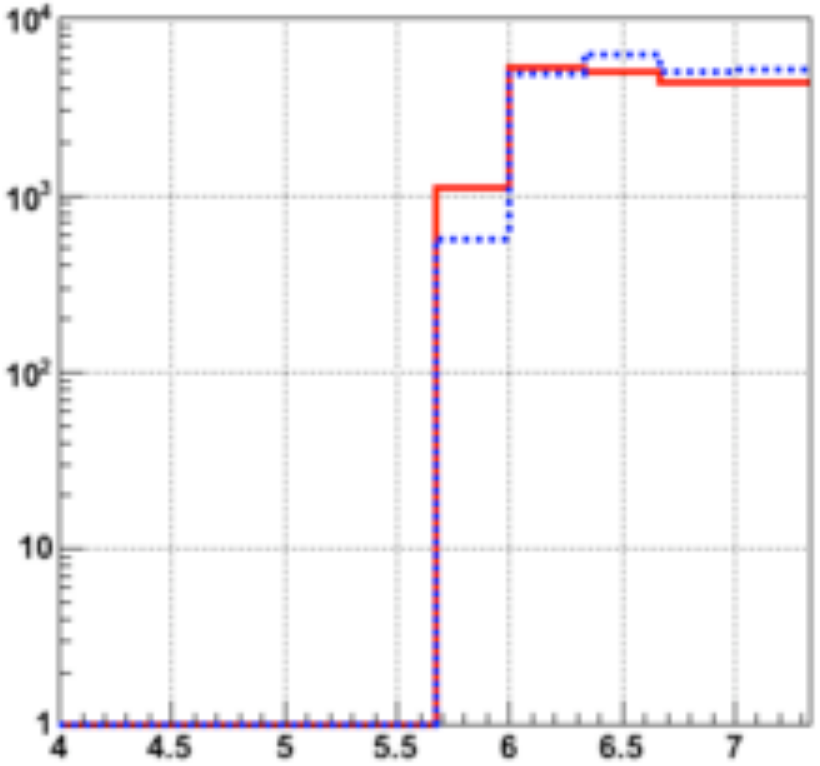
Energy Spectrum



Efficiency and Aperture w/Cuts



(Aperture = Efficiency * Generated Area * Ω)

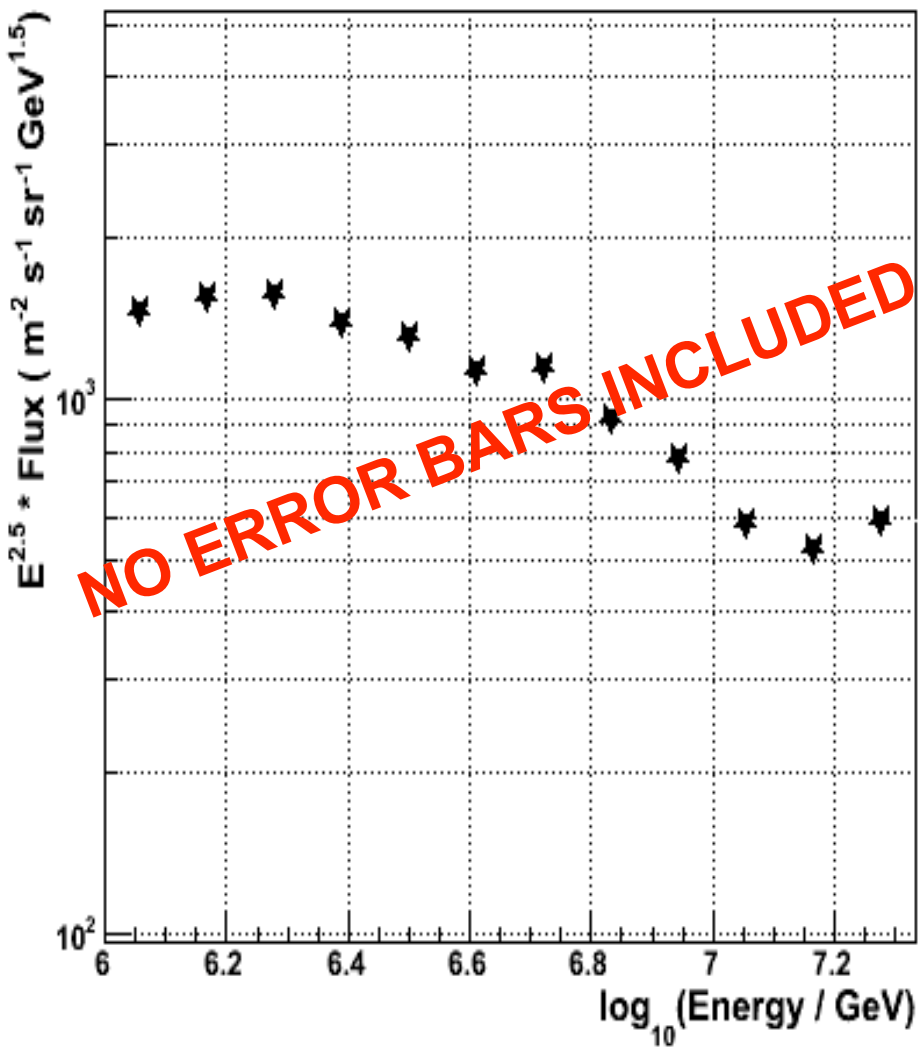


events after cuts:

- Protons: 1689 → 3.39% left
- Iron: 1825 → 3.38% left

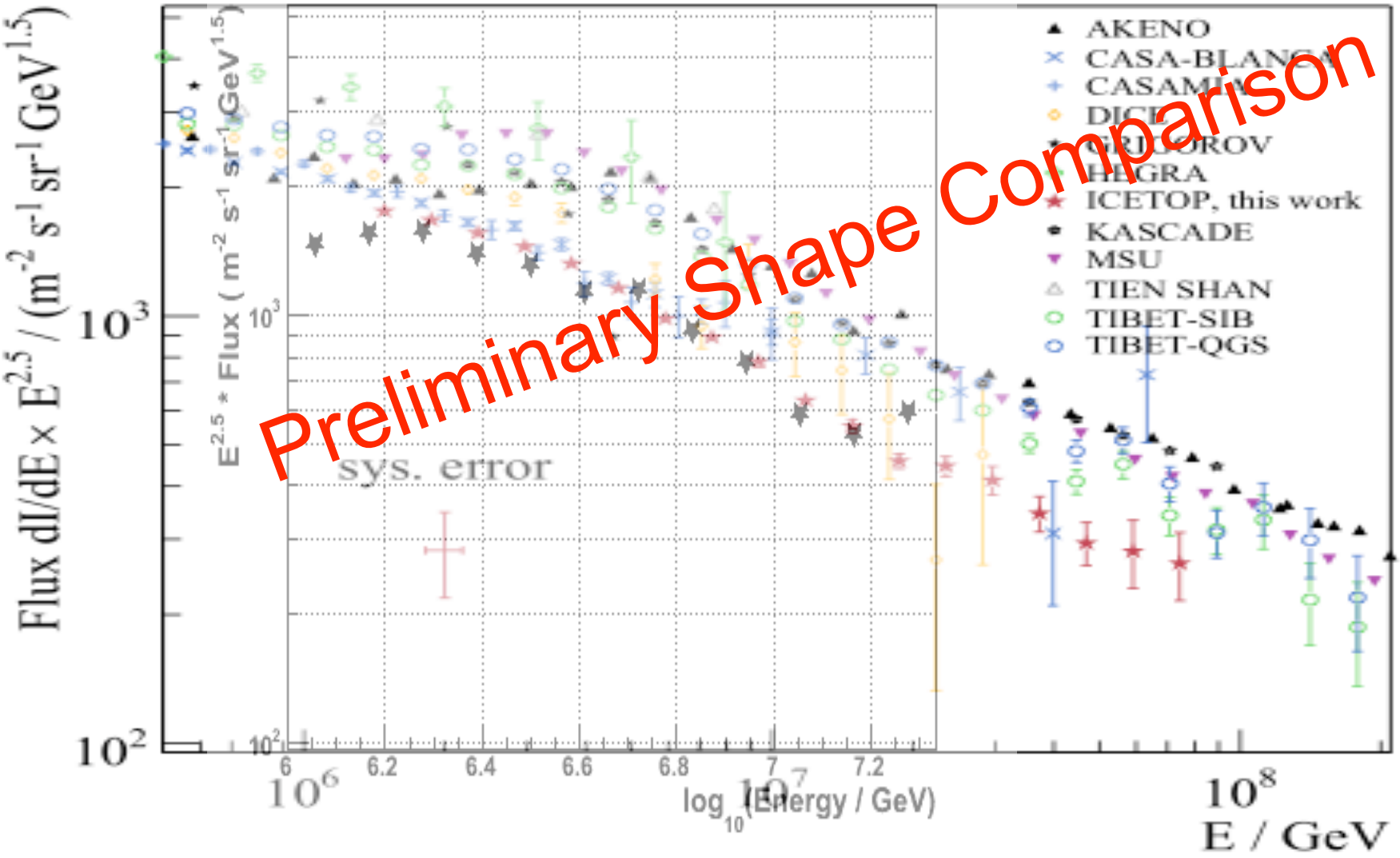
(NOTE: Lost all events with energies less than ~600 TeV—probably a little bit TOO tight!)

Energy Spectrum from NN Output



- Simple Energy Spectrum showing (Flux * $E^{2.5)}$ for shape comparison with other results
- No error analysis has been done
- **Remember, mc died on cluster at high energies→ spectrum shouldn't be completely trusted, esp at high energies.**

Order of Magnitude Simliar to Previous Results?



(S. Klepser, Thesis)

Future

- More mc primary types, higher energy
- Full year of IT/IC-40 data
- Optimize cuts → keep lower and higher energies
- Calibration to direct measurements?
- Automate optimization of neural network
- Systematic studies
  - Interaction models
  - Snow
  - VEM calibration
  - Ice Properties
  - Atmospheric Models

CONCLUSIONS

- NN analysis of IT/IC-40 looks very promising:
  - Clear separation of masses
  - Tight energy resolution
- K vs S NN analysis will provide bridge between previously published results (Rawlins) and new params/reco techniques for future composition analyses
- E-spectrum will provide independent comparison-for/validation-of IT-26 spectrum