Description of CR data from 200GeV to 200EeV:

update on Global Fit (GST)

with the latest composition results from experiments

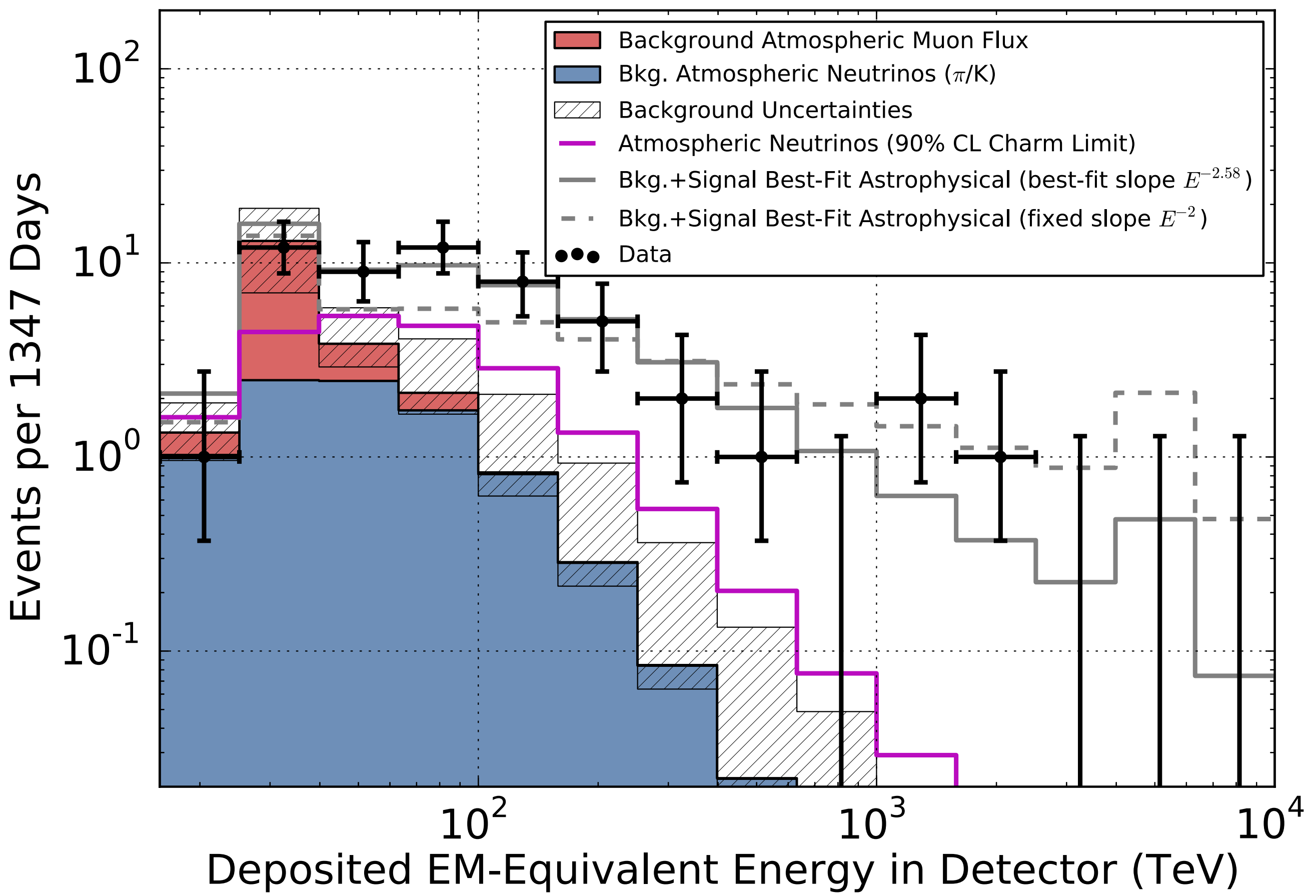
Serap Tilav

Bartol Research Institute

University of Delaware

CR Origin –beyond the standard models   Sep /18-24/2016 San Vito di Cadore

It is essential to describe the observed features of the CR spectrum and mass composition in order to extract IceCube's astrophysical neutrino signal out of the background of atmospheric neutrinos

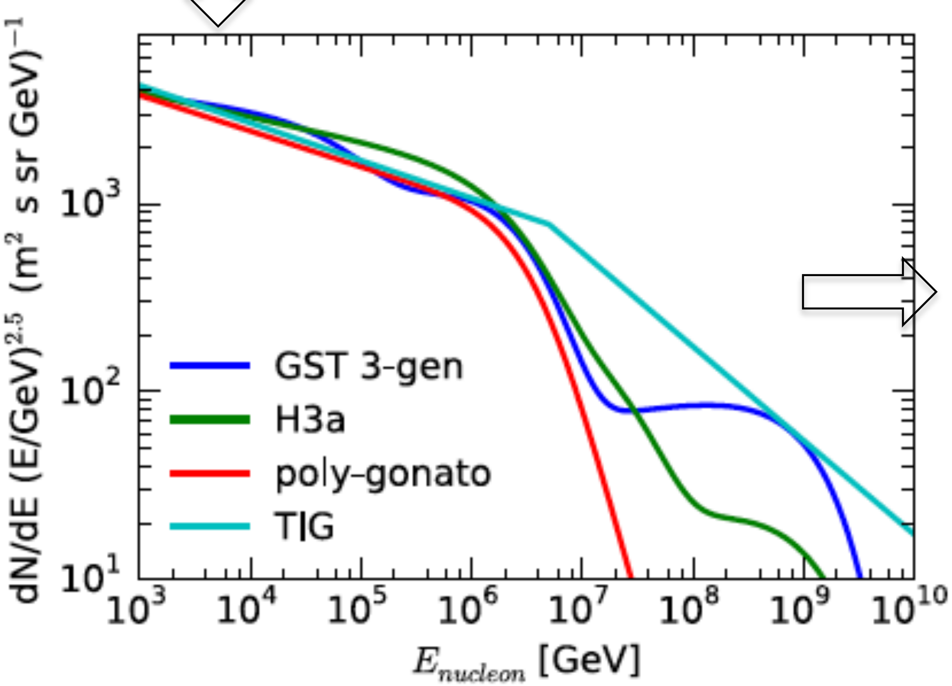


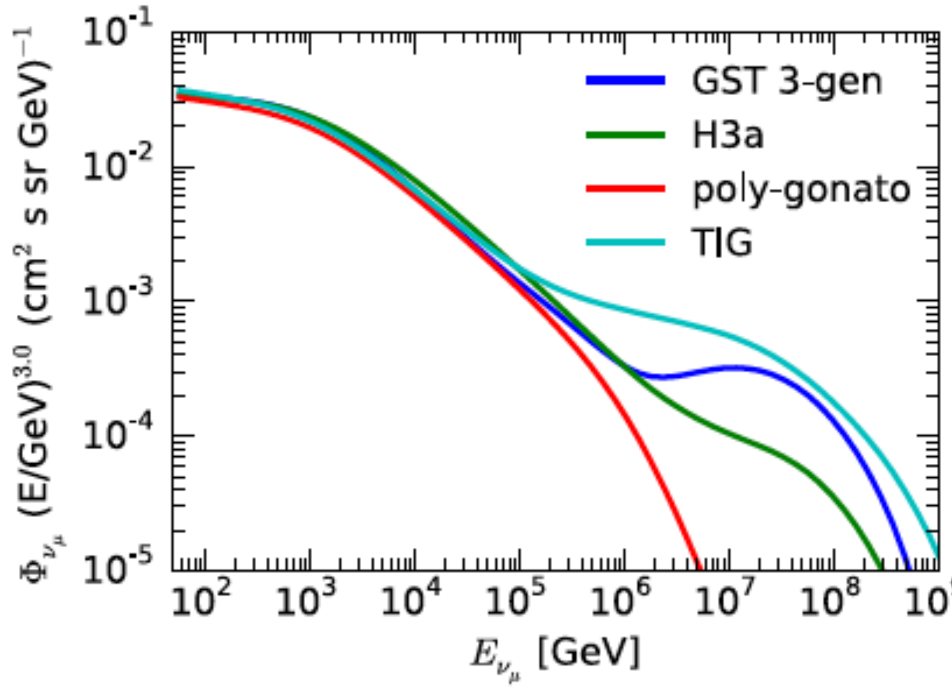
IceCube 4yr (2010-2014) HESE (High Energy Starting Event) Analysis

ICRC 2015 arXiv:1510.05223

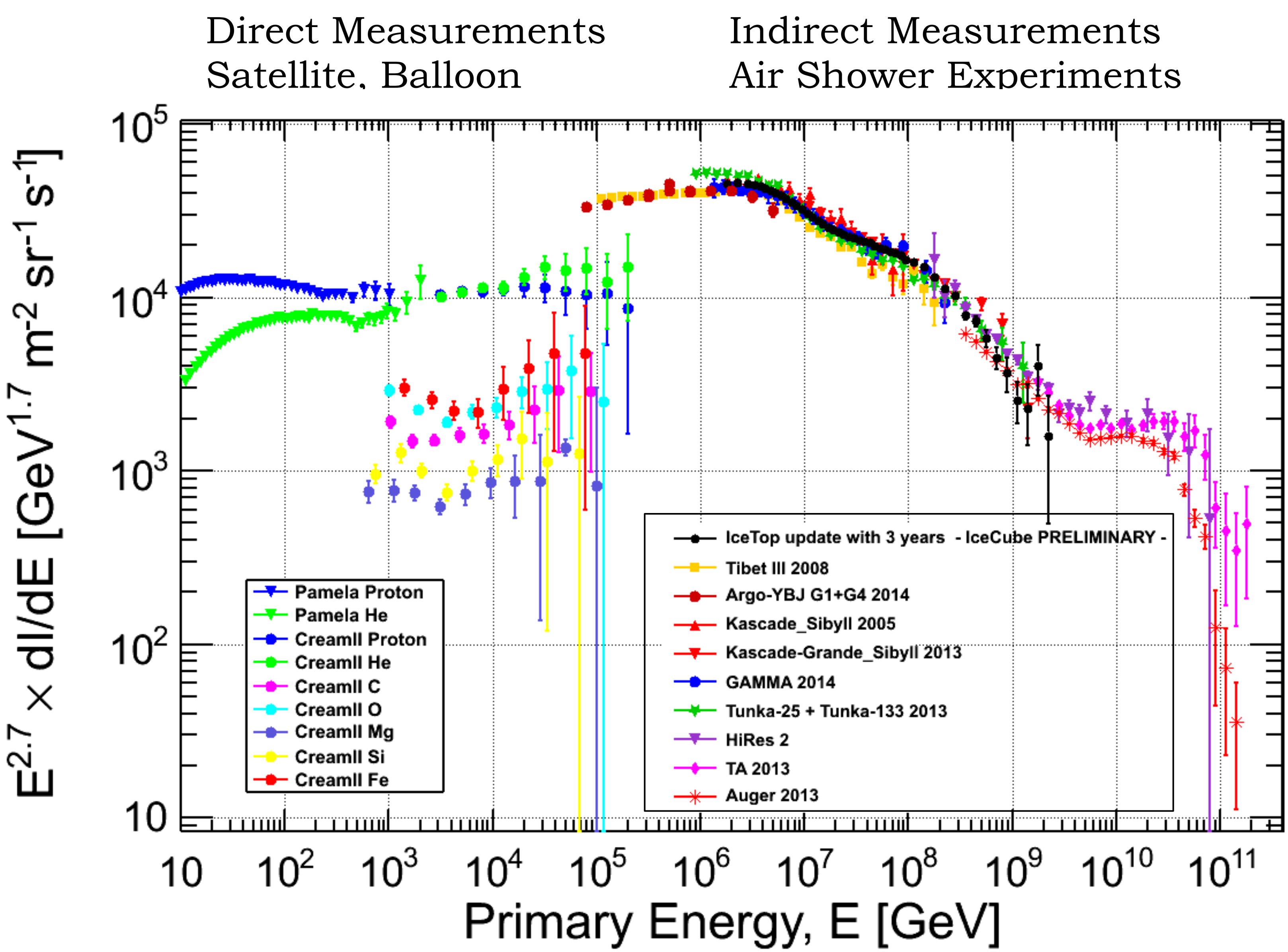
Calculation of conventional and prompt lepton fluxes at very high energy
Anatoli Fedynitch, Ralph Engel, Thomas K. Gaisser, Felix Riehn, and Todor Stanev
ISVHECRI 2014
arXiv:1503.00544v2

Primary Spectrum and Composition



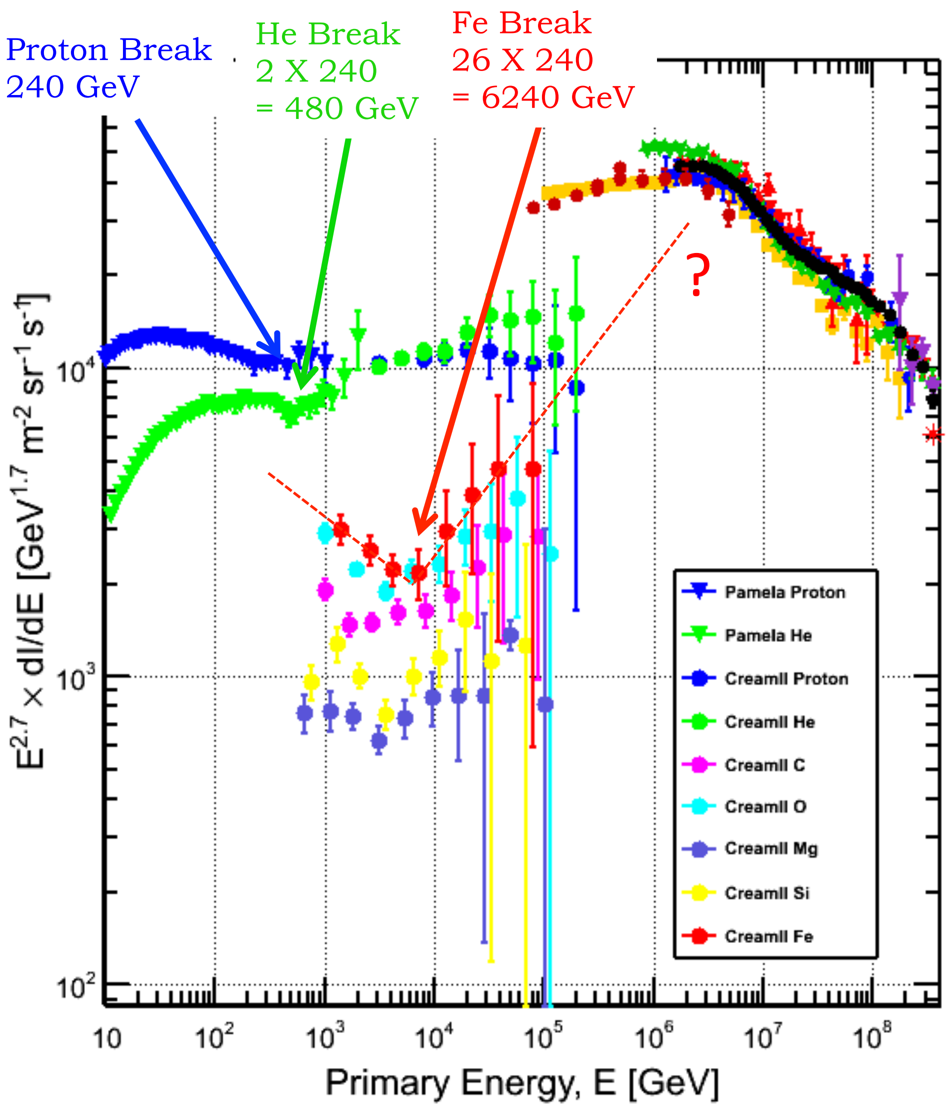


When looked in detail the CR spectrum is not a simple power law



GST-2013 [arXiv:1303.3565 Gaisser , Stanev ,Tilav]
is a data driven phenomenological fit to the CR spectrum and <lnA> together

Inspired by the rigidity dependent spectral breaks and the hardening observed in elemental spectra above ~200 GeV

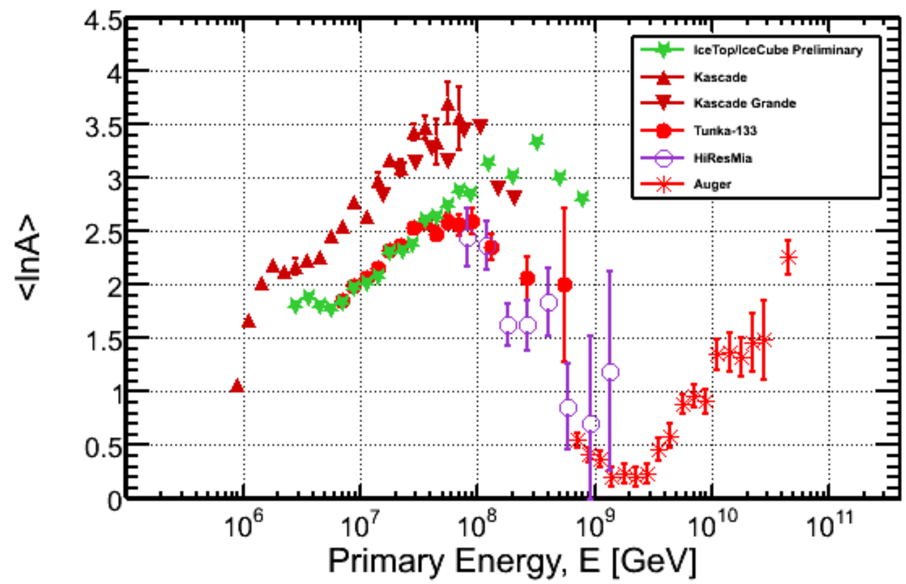


This hard component has to cut somewhere much before the knee,
otherwise the knee becomes all Iron!

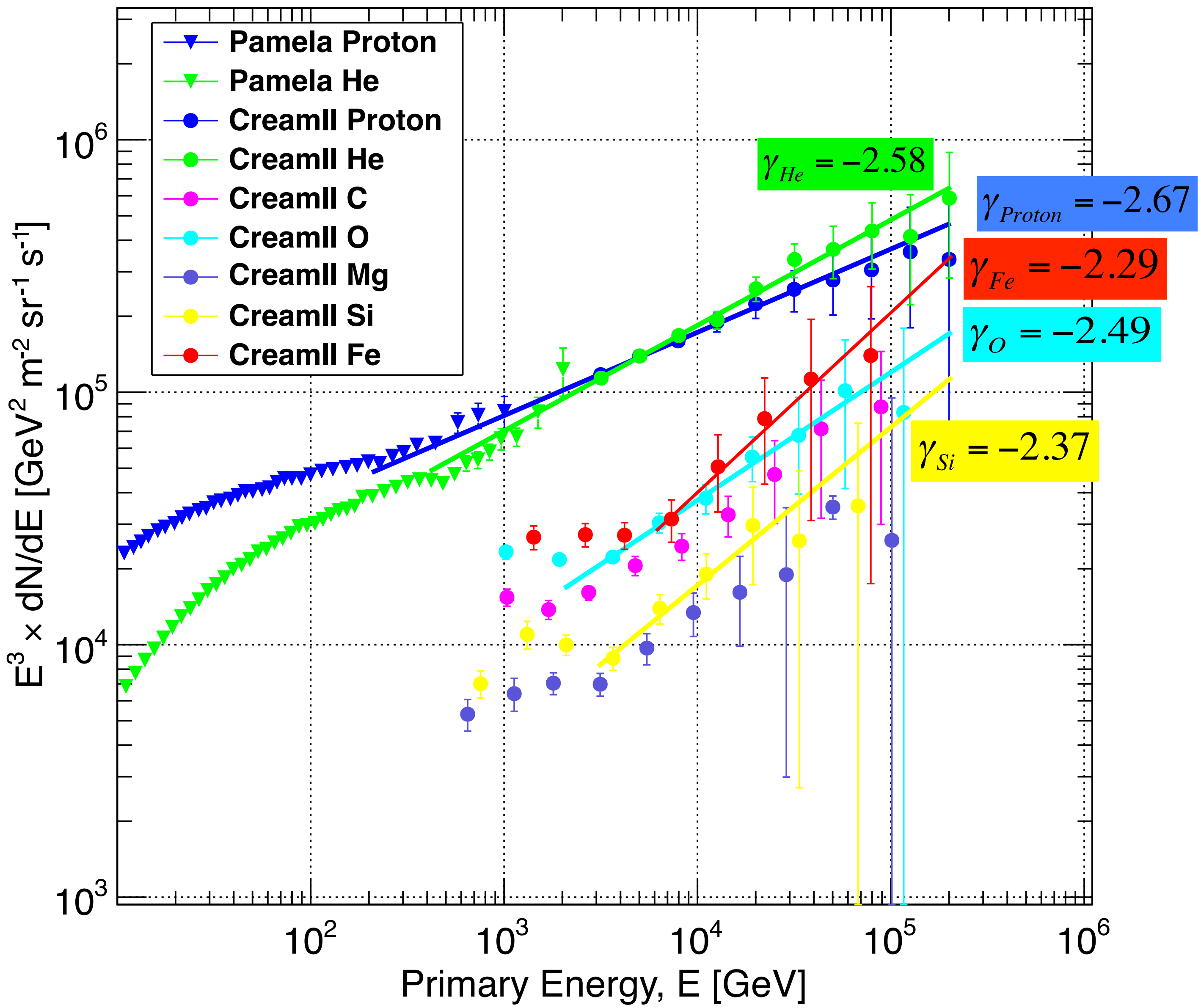
Use a functional form to describe a population of particles cutting off with rigidity as

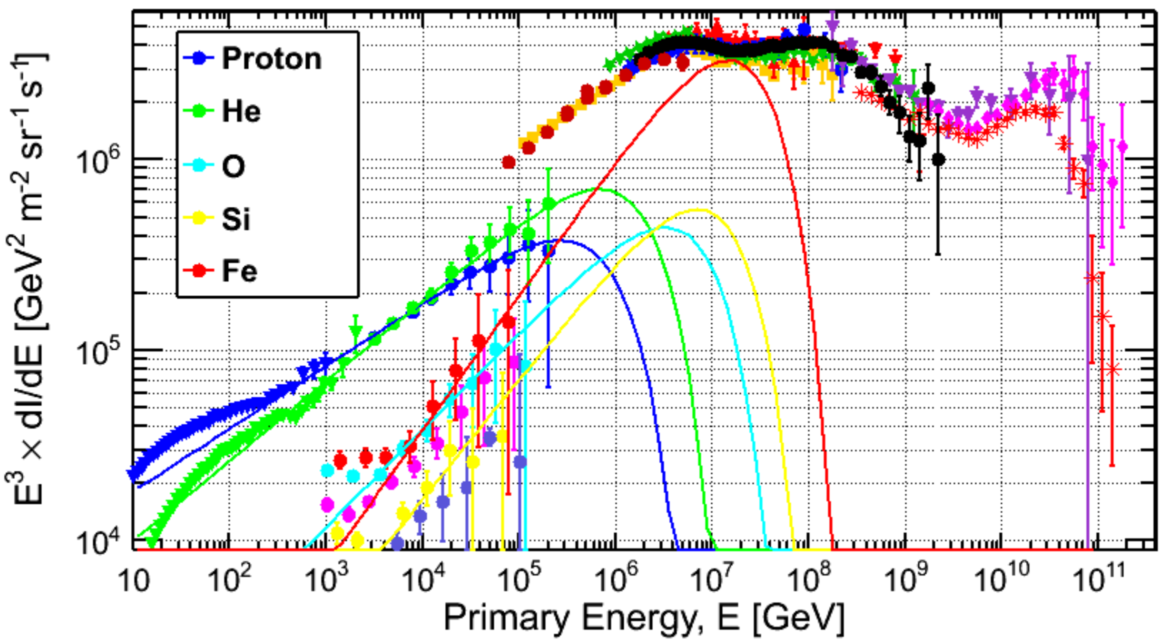
$$E\frac{dN}{dE} = \sum_{i\ \text{elements}} A_i E^{-\gamma_i} e^{-\frac{E}{Z_i E_{cutoff}}}$$

Above the knee use <lnA> as guidance



Spectral Indices of the hard component



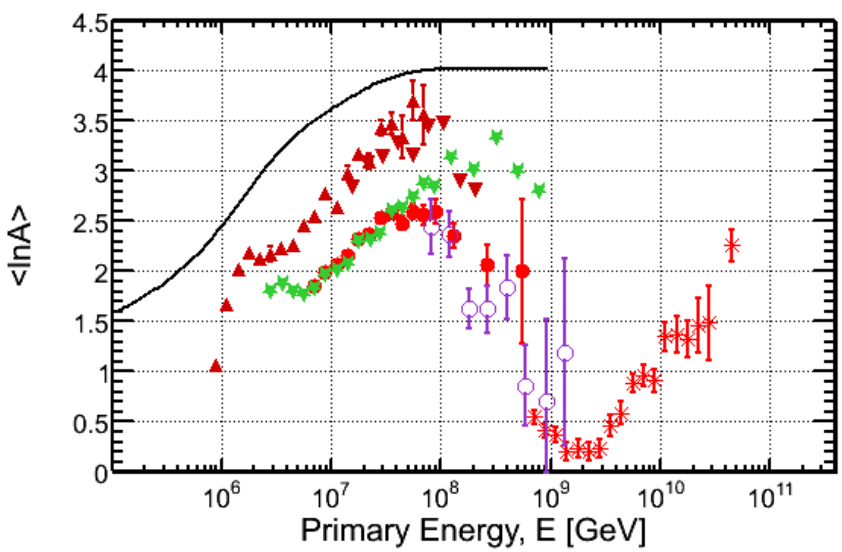


Fe spectrum is the key to the whole puzzle.

The CreamII Fe data, when extended with the same index up to an energy where it makes 100% of the all particle spectrum, defines the maximum cut off energy for Fe.

This point turns out to be 20.8 PeV.

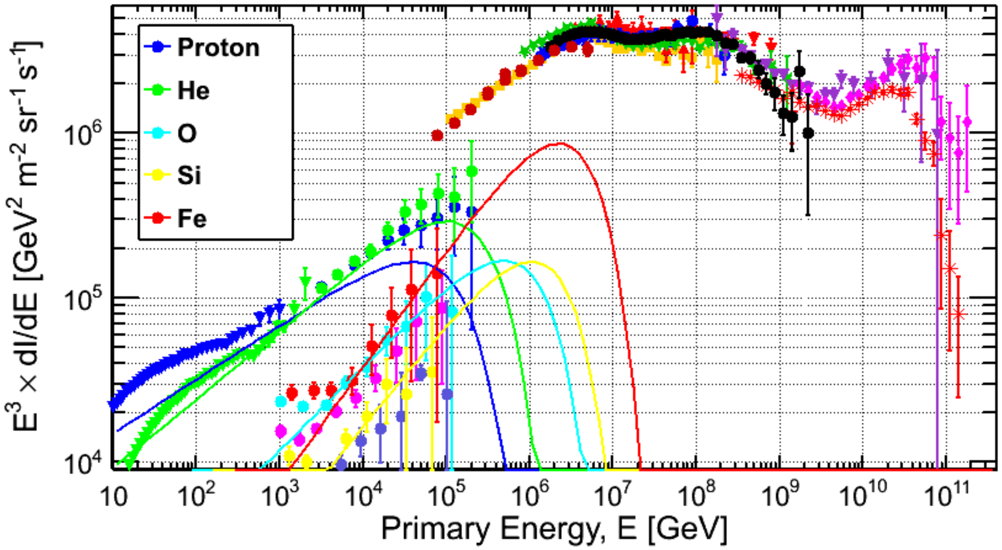
If Fe cuts off at 20.8 PeV
➔ Proton will cut off at
20800/26 = 800 TeV

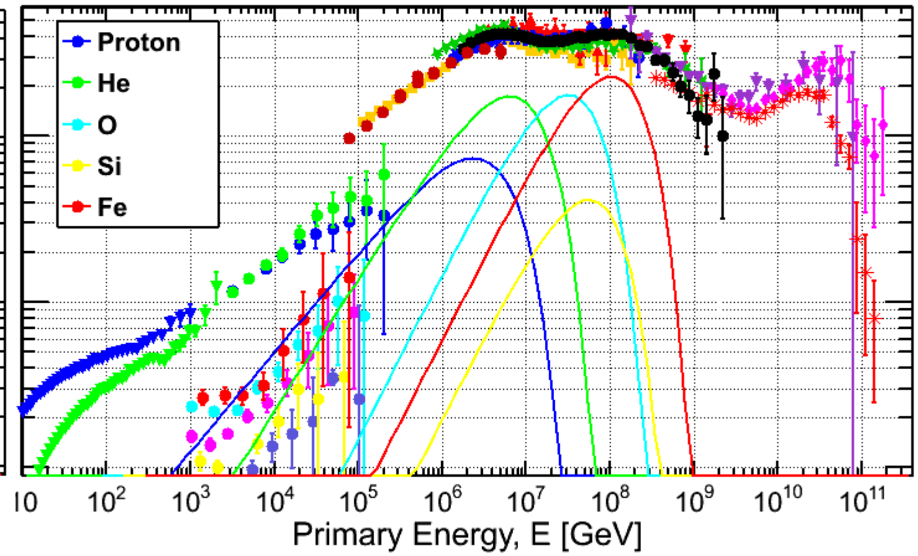


However:

<lnA> data tells us the knee is not 100% Fe.

➔ the cutoff energy has to be lower





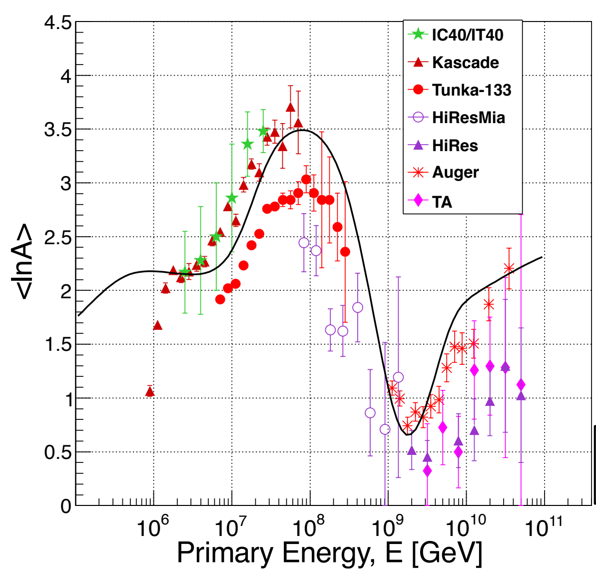
Population 1

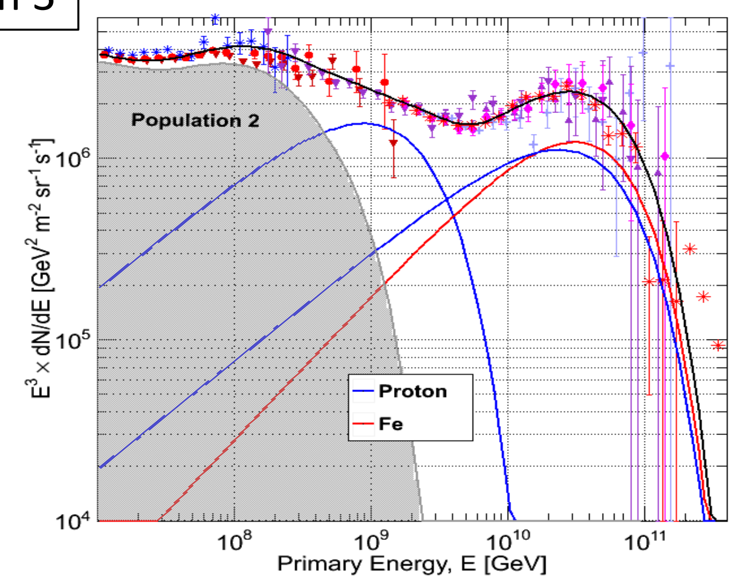
E^{p}_{cutoff} = 120 TeV
E^{Fe}_{cutoff} = *26 x* 120 TeV = 3.1 PeV
↓
The CR Knee

Population 2

E^{p}_{cutoff} = 4 PeV
E^{Fe}_{cutoff} = *26 x* 4 PeV = 104 PeV
↓
The 2nd Knee

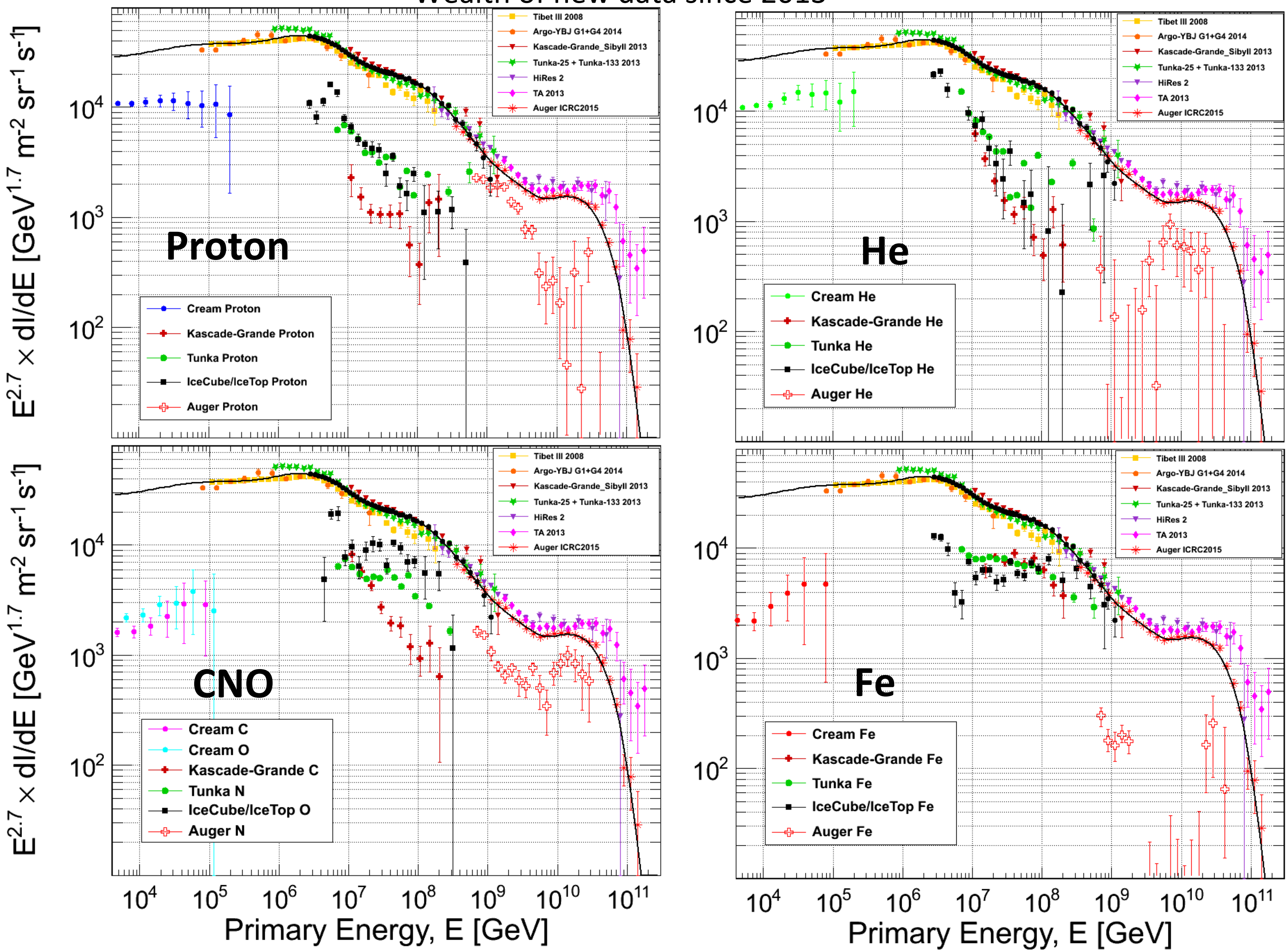
Population 3



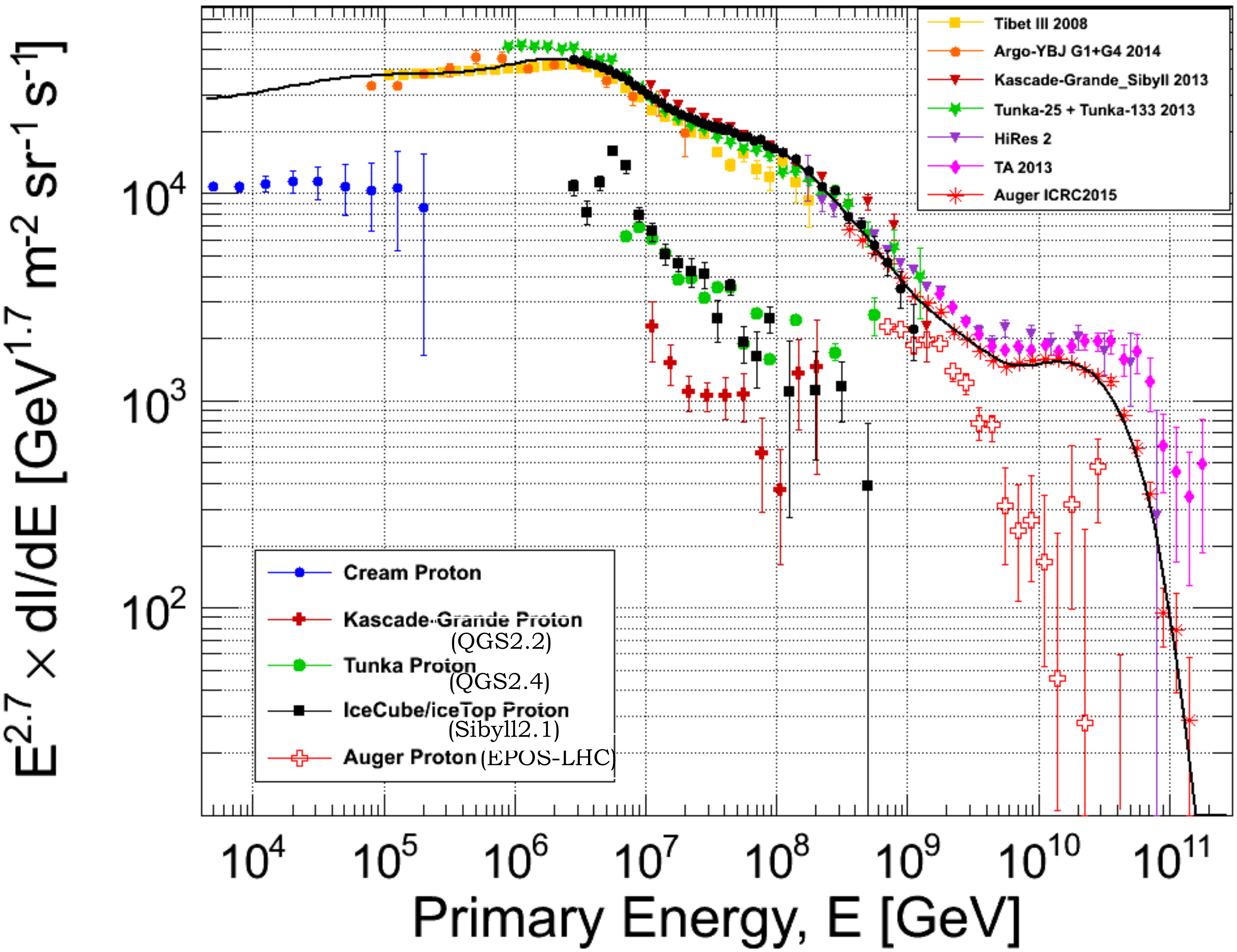


<lnA> fit result

Wealth of new data since 2013



Proton Measurements



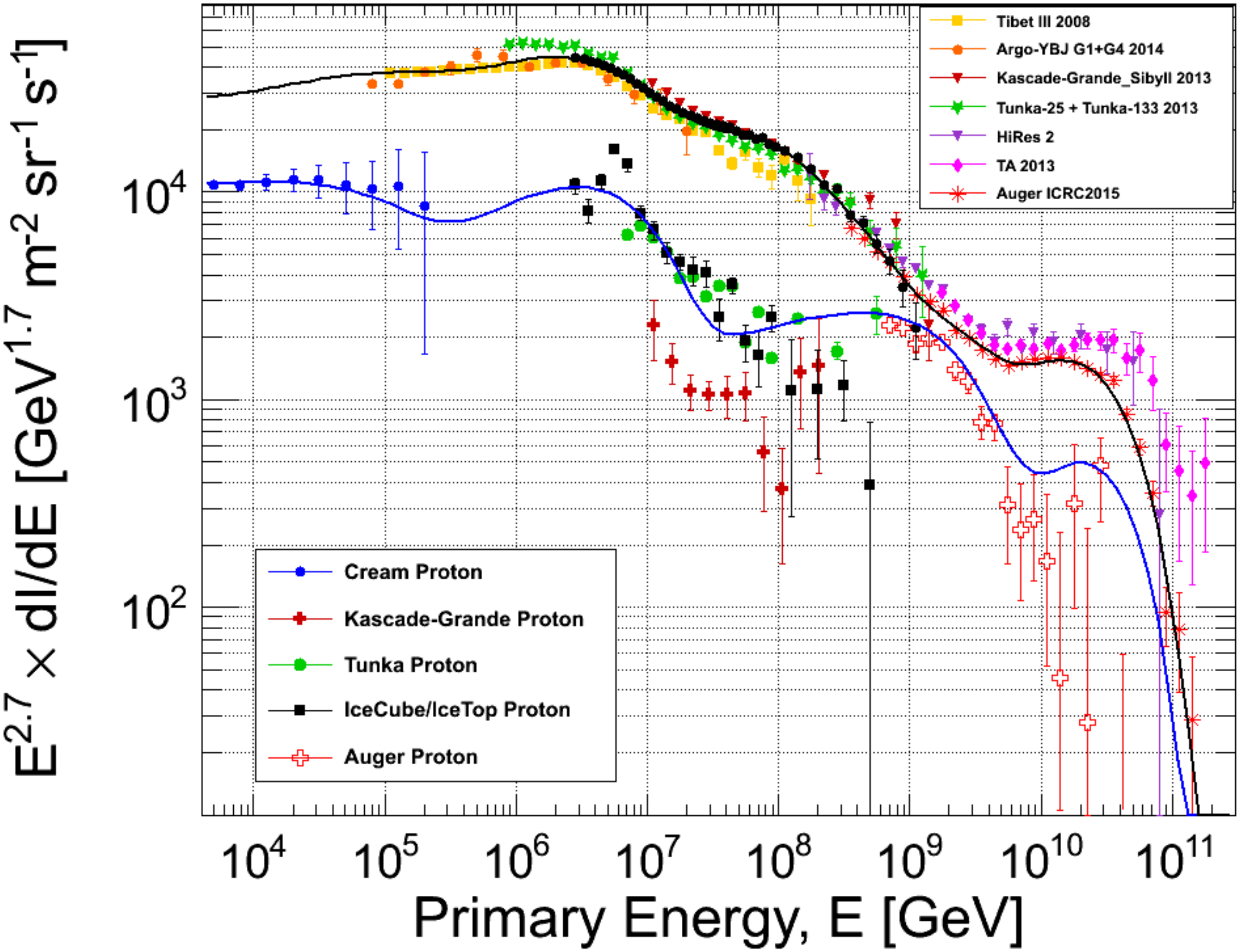
Kaskade-Grande
- sea level (1022 g/cm^2)
- Scintillator/muon detectors on surface
- uses EM and GeV muons

Tunka
- 938 g/cm^2
- wide FOV air Cherenkov array
- measures X_{max} and photon distribution on surface

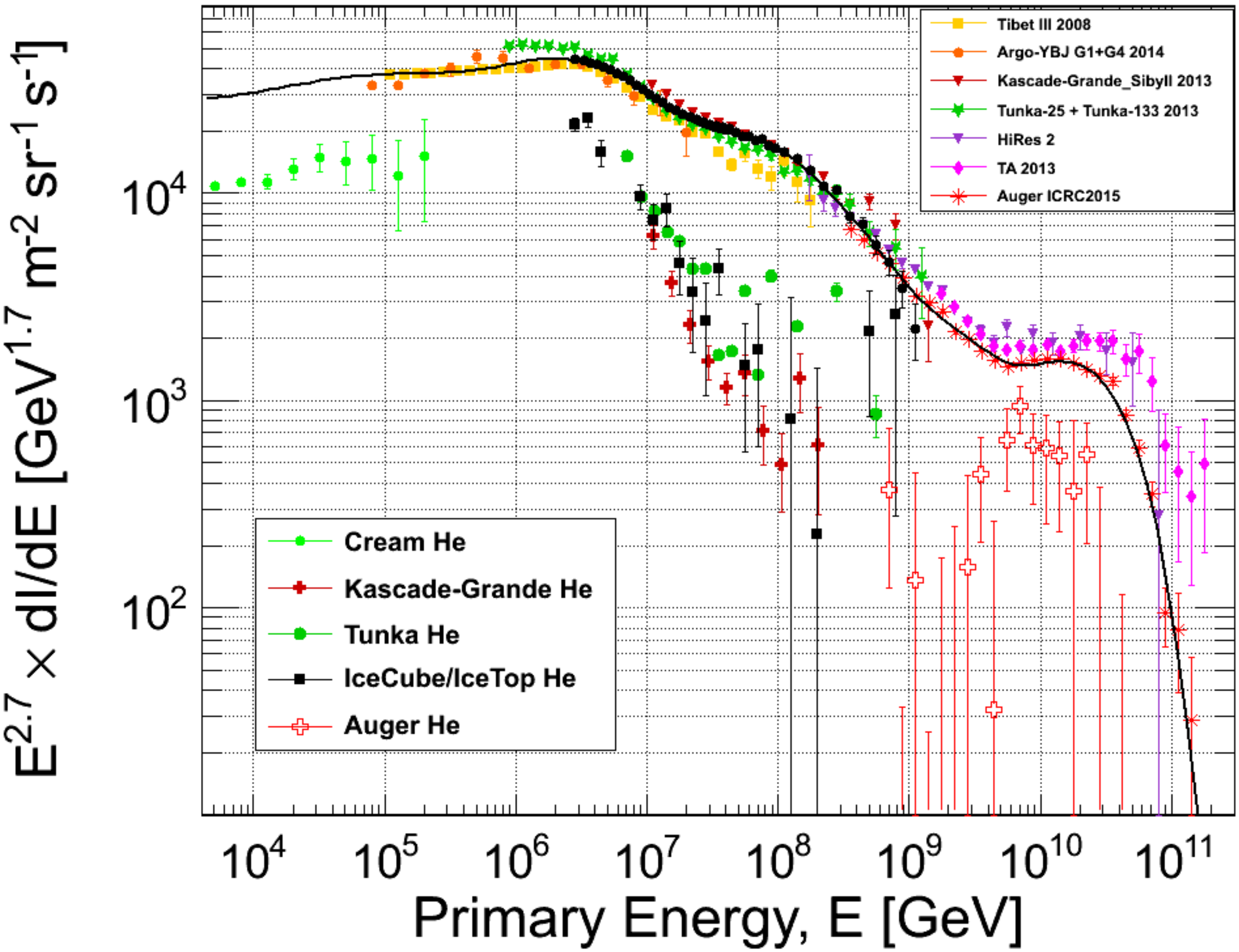
IceTop/IceCube
- 680 g/cm^2
- ice Cherenkov tanks on the surface => EM and TeV muon bundles at 1.5-2.5 km dept in ice

Proton Measurements and the fit

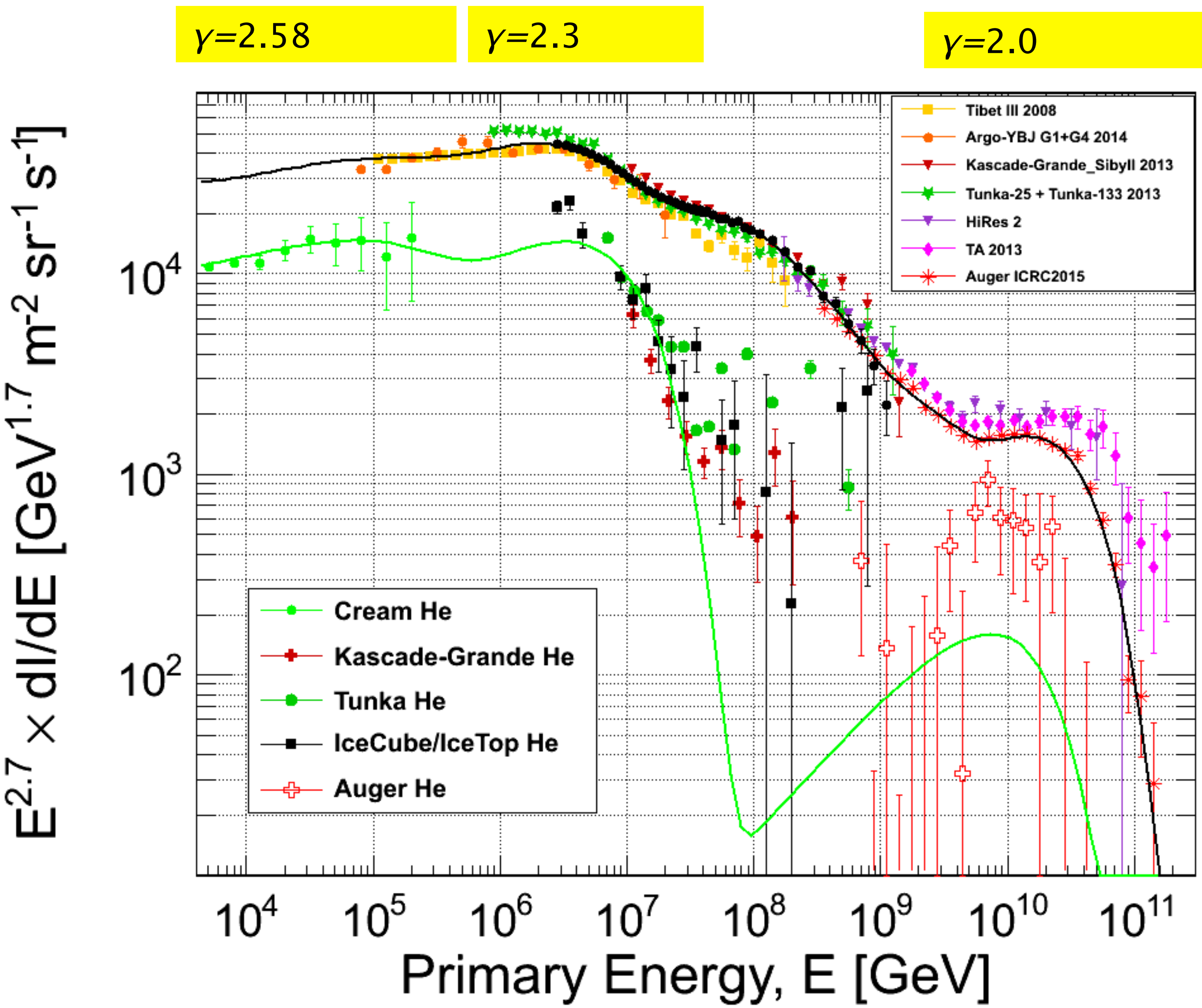
γ=2.67 E_{cutoff}=120TeV	γ=2.3 E_{cutoff}=7 PeV	γ=2.5 E_{cutoff}=2.1 EeV	γ=1.5 E_{cutoff}=17 EeV



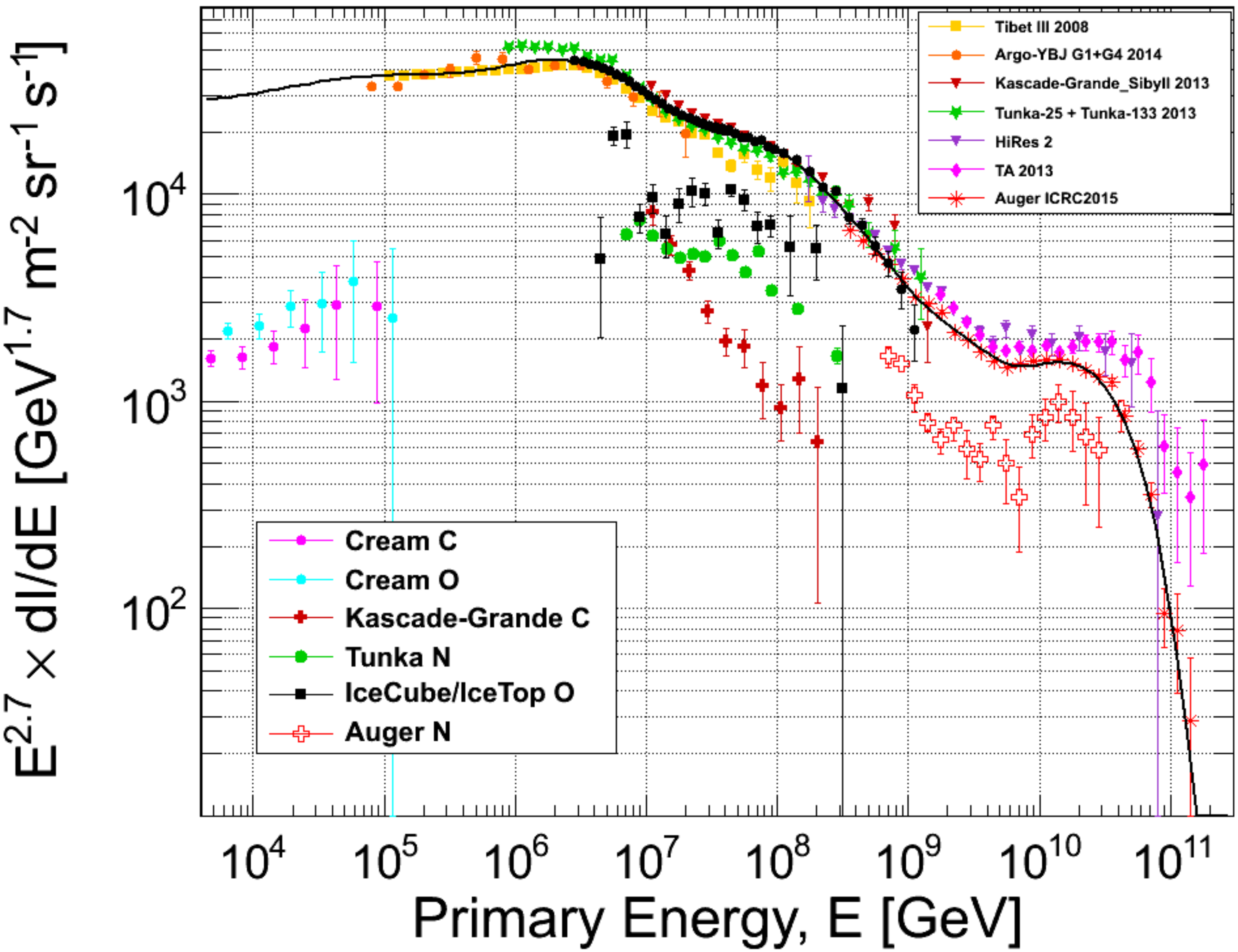
He Measurements



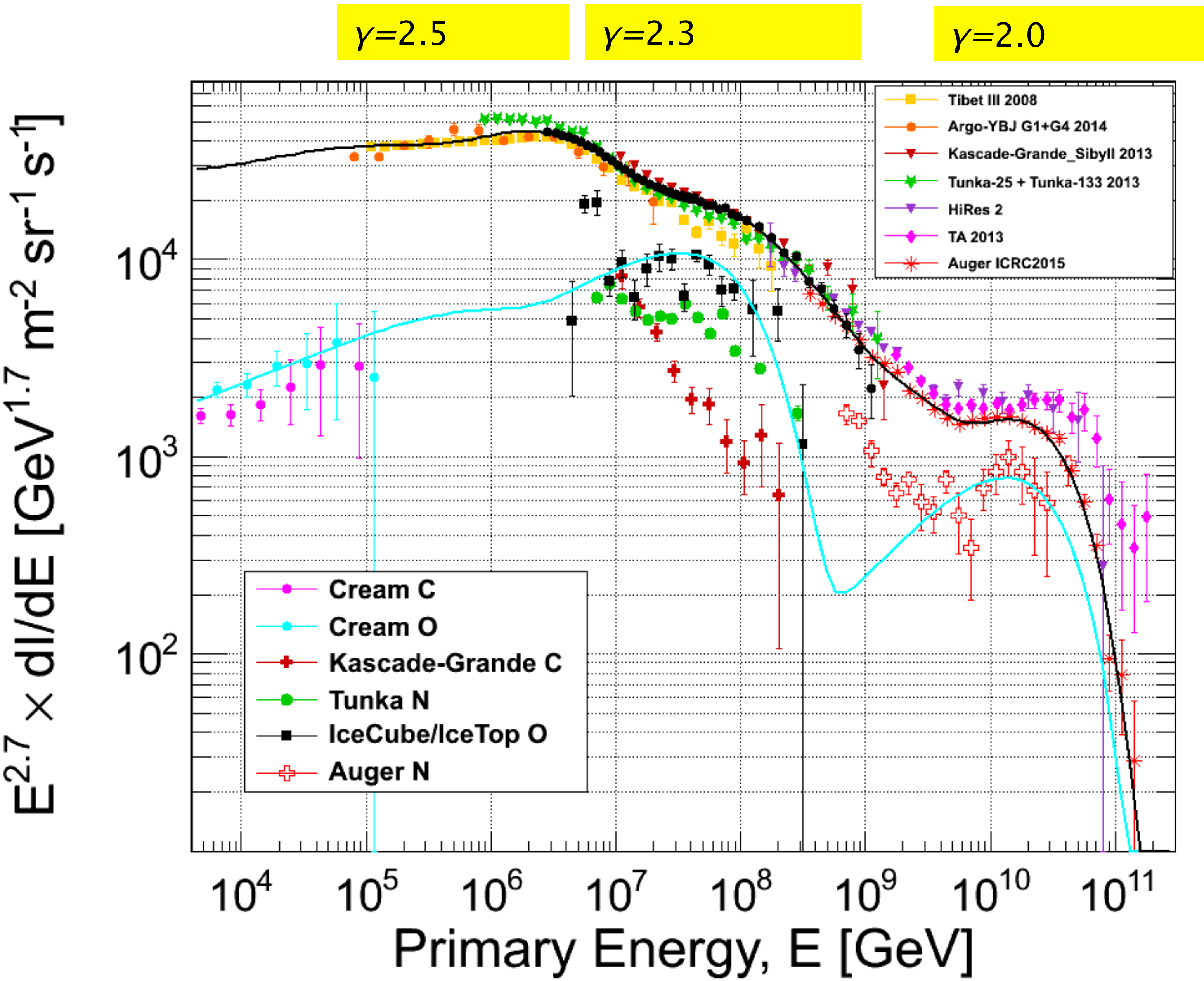
He Measurements and the fit



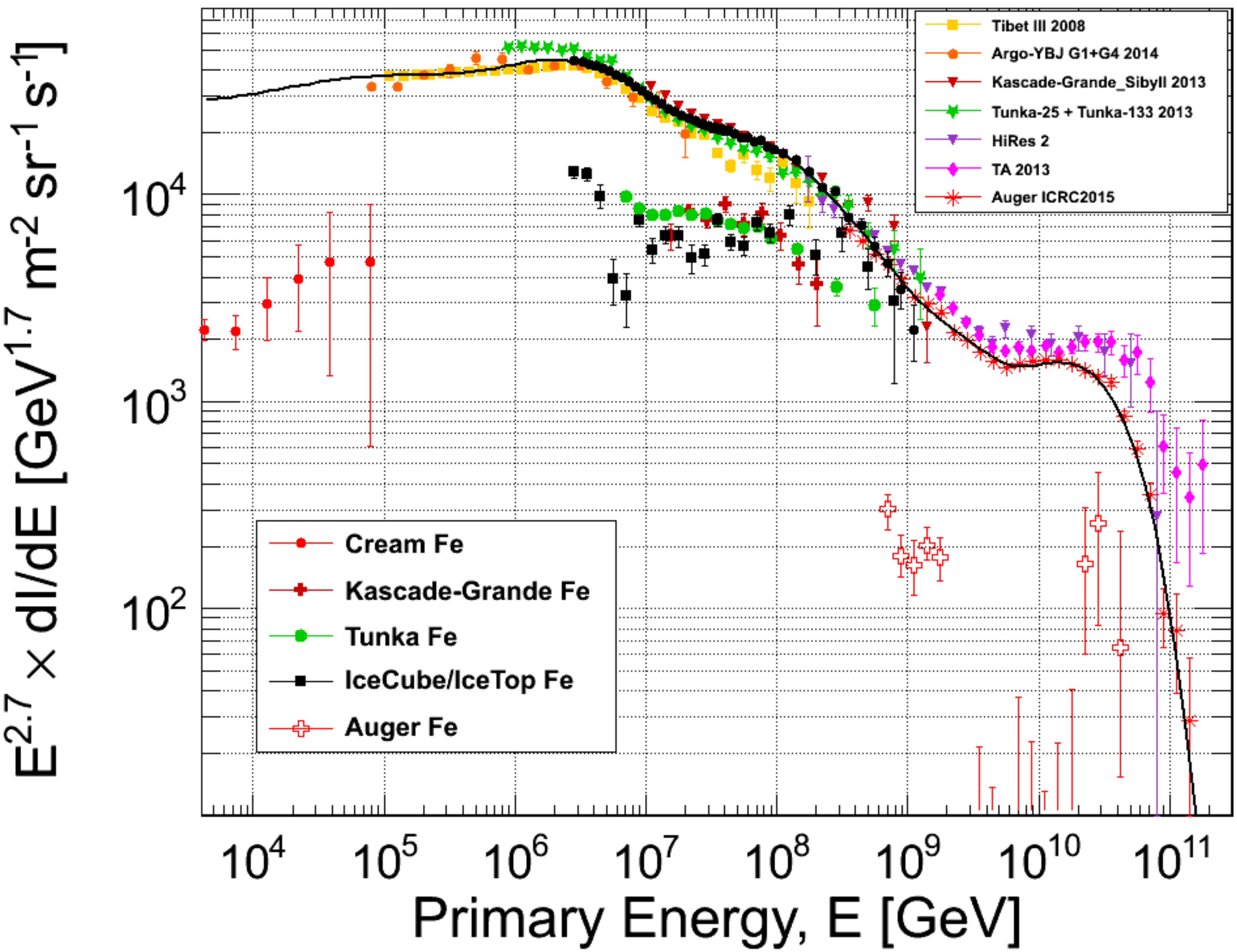
CNO Measurements and the fit



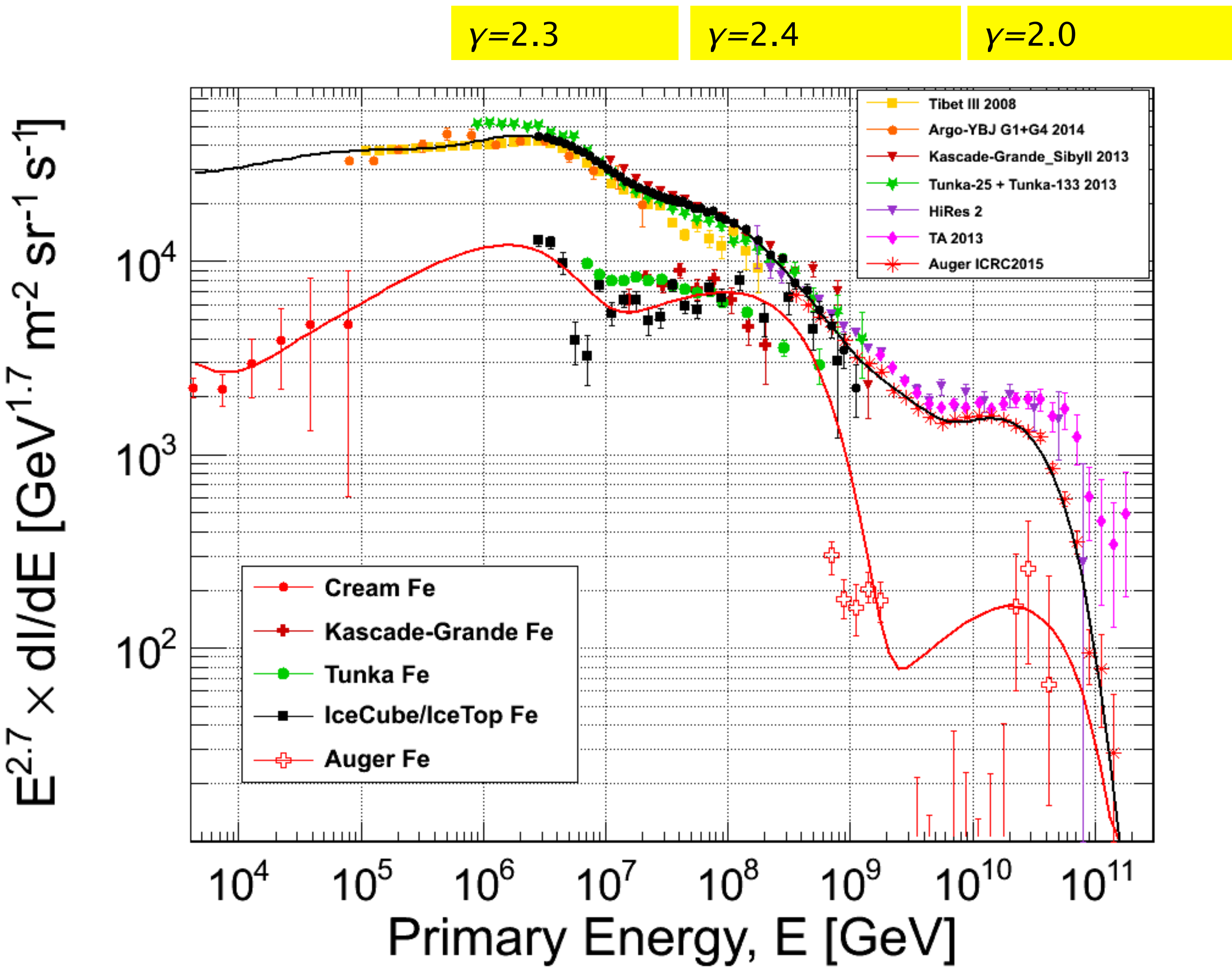
CNO Measurements and the fit



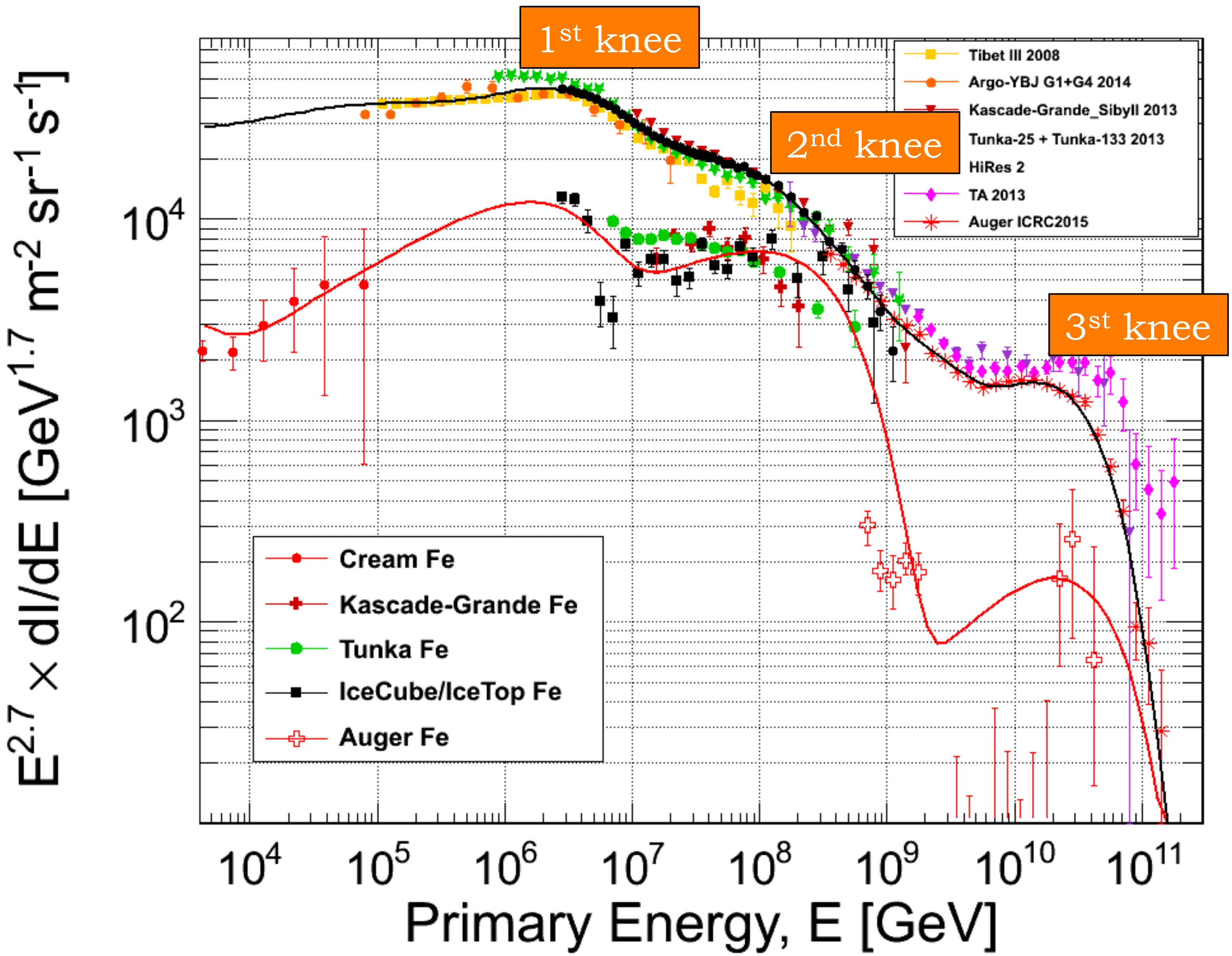
Fe Measurements



Fe Measurements and the fit

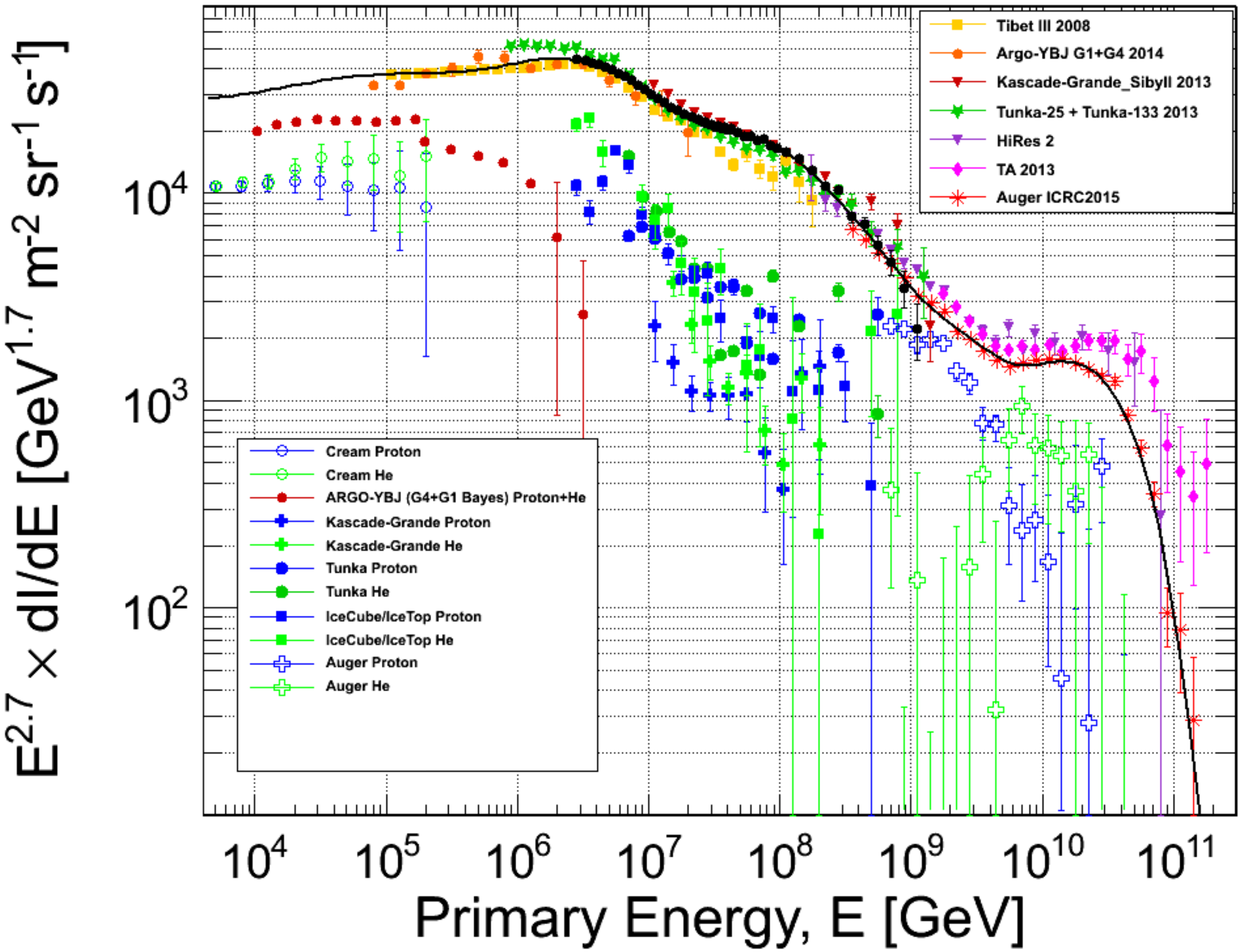


iron under every knee



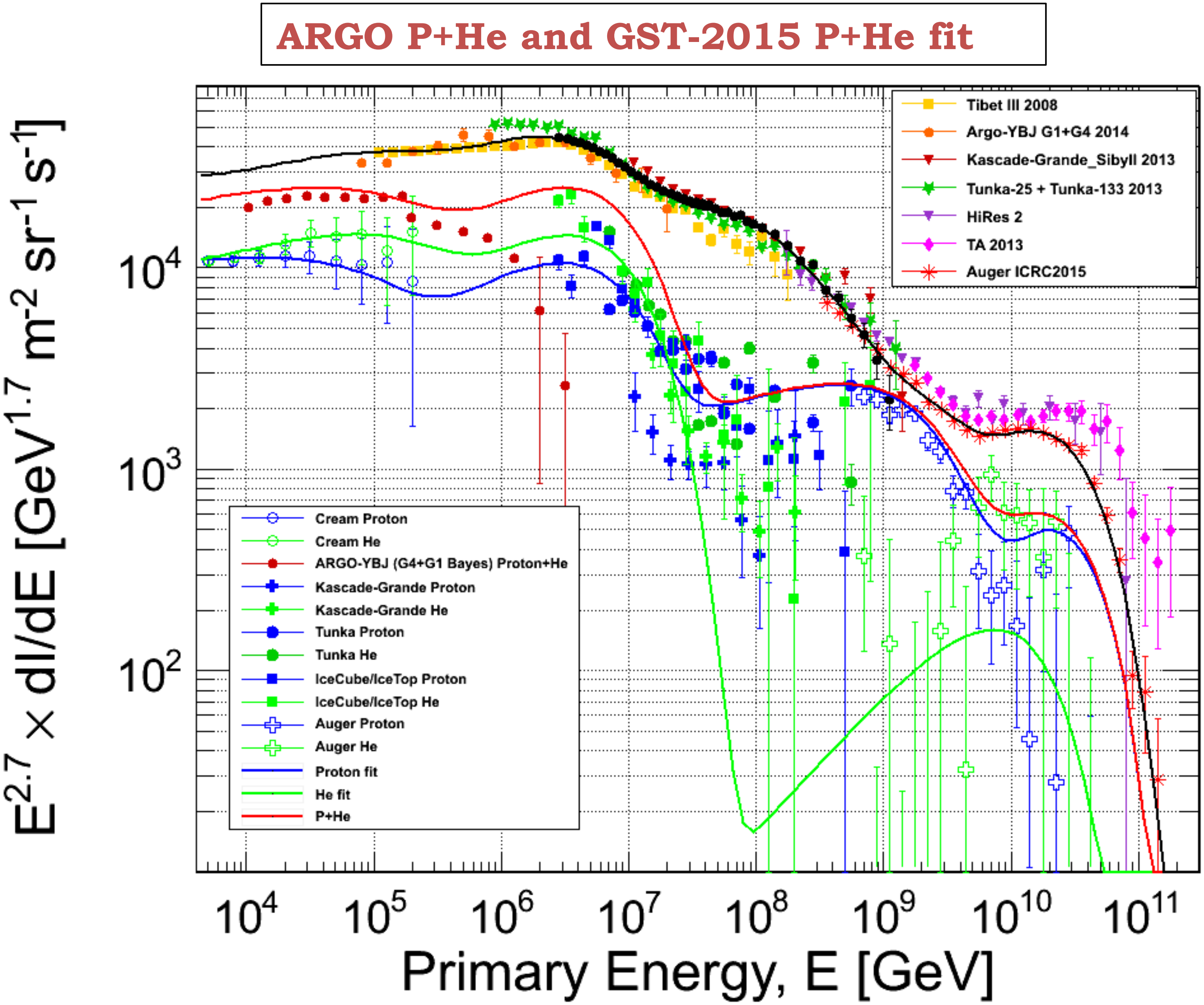
Proton and He Measurements

and ARGO P+He



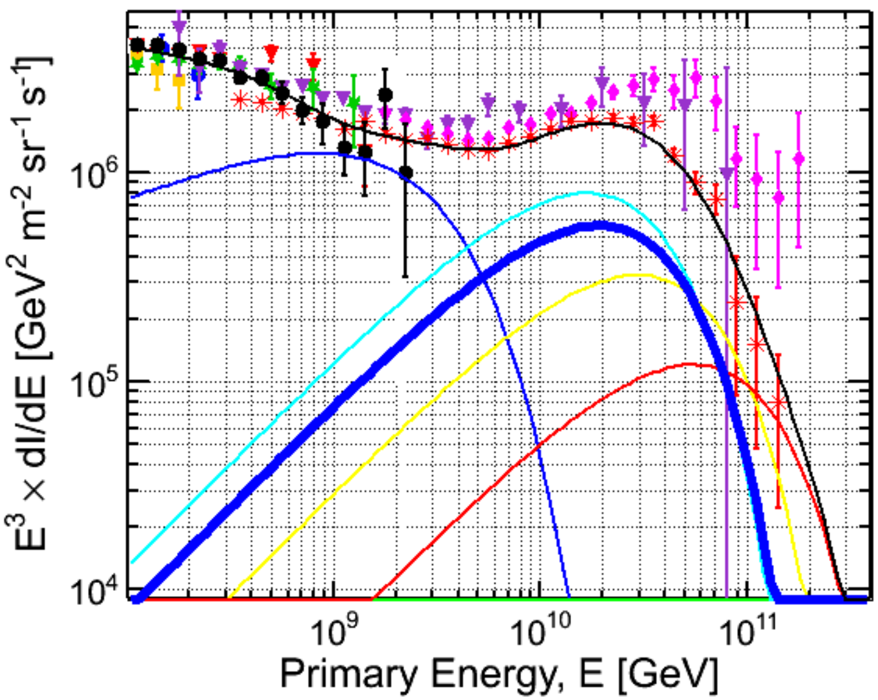
Blue: Proton
Green: He

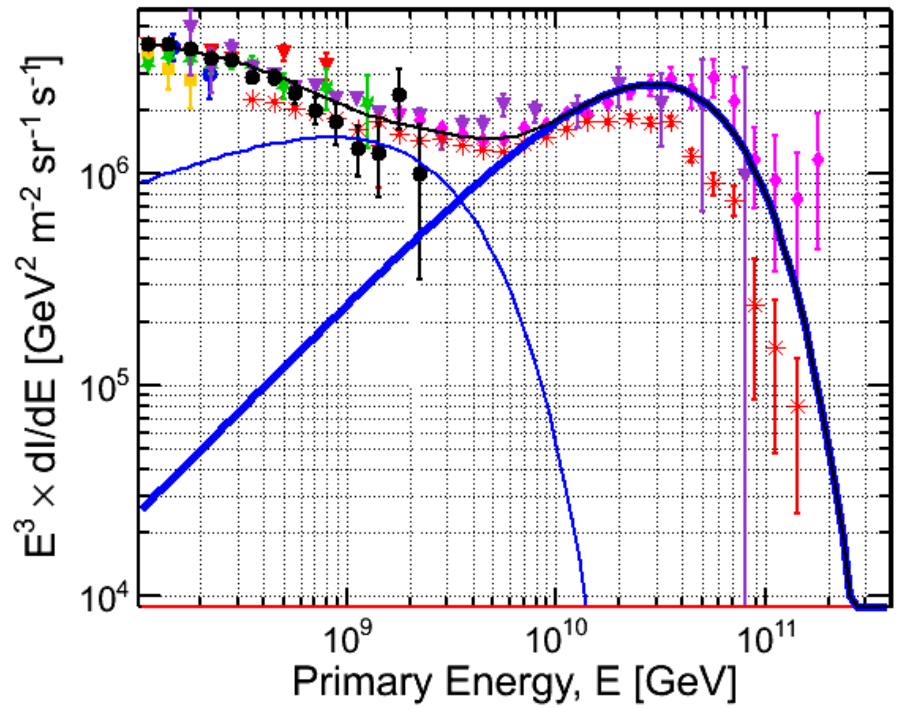
Proton and He Measurements and fits



Blue: Proton
Green: He

Compare Auger and TA

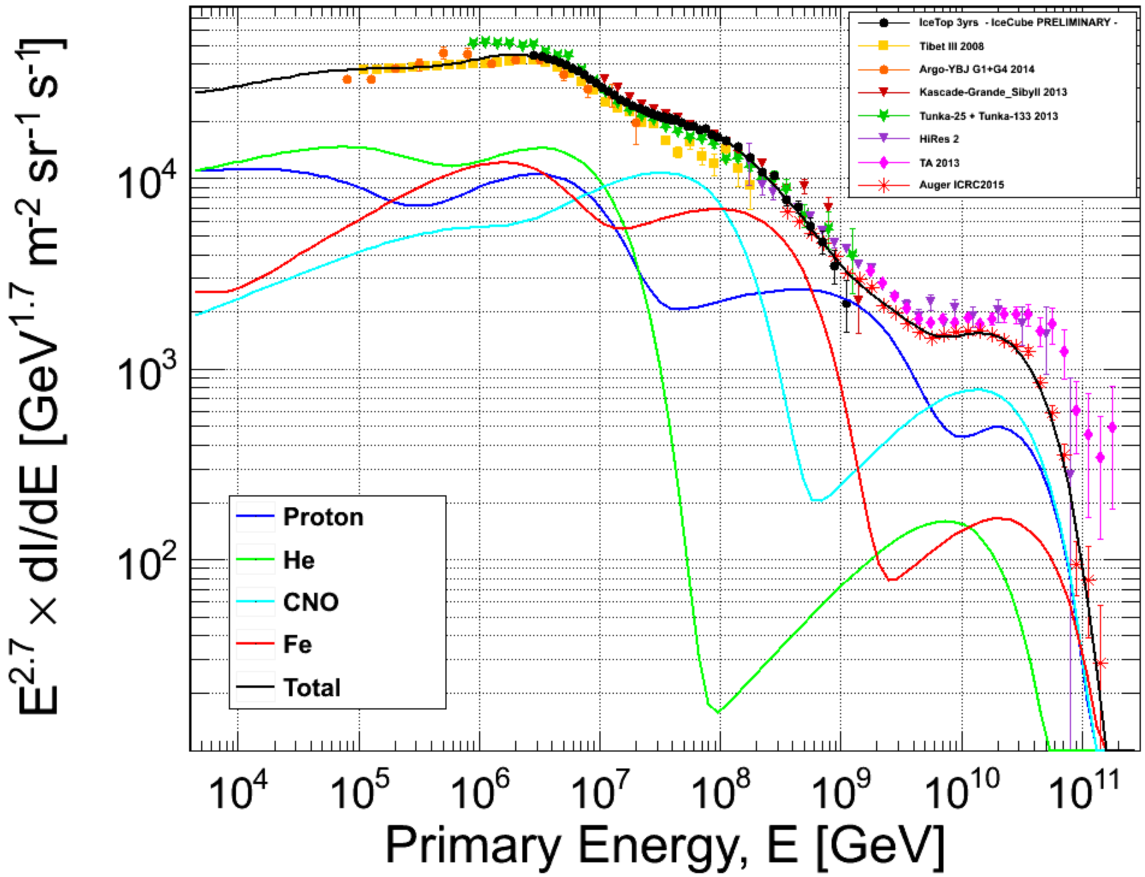


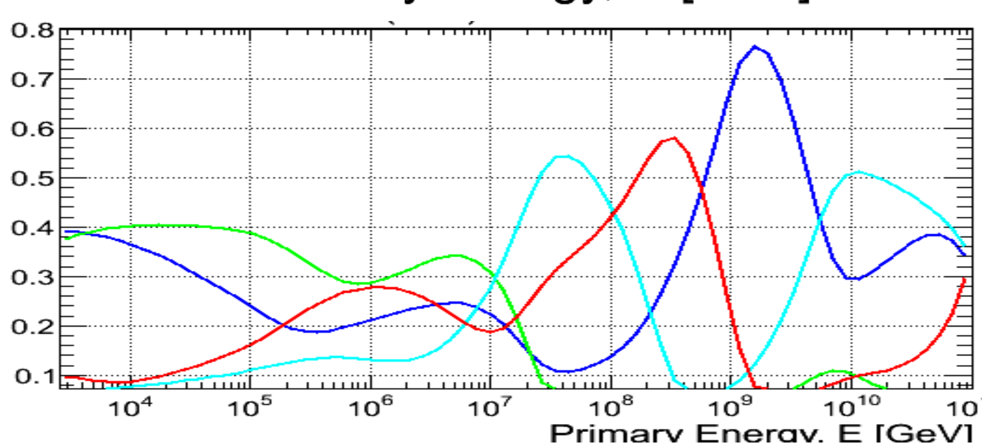


Auger sees heavy elements
under the second Proton

TA sees all Proton
(are the elements there
in undetectable levels?)

Here is the resulting picture: WAY BEYOND THE STANDARD MODEL





Fractions

Concluding Remarks:

1^{st} population: Classical Supernovae cutting off around ~100 TeV

2^{nd} population: Much harder ~2.3 spectral index

A different source population or a boosted version of the ambient supernovae particles???

3^{rd} and 4^{th} population: Are they really extra-galactic???