Progress report on nuclei flux

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Outline

- Energy and mass reconstruction method
- Progress on all particle flux
- Progress on light nuclei flux

Energy and Mass reconstruction method

MC Sample:

WFCTA(6 telescopes)+KM2A half array

Components: Proton, Helium, CNO, MgAlSi, Iron

Energy range: 10^{13}~10^{16} eV

Zenith Angle: 20^{o}~40^{o}

Azimuth Angle: -85^{o}~95^{o}

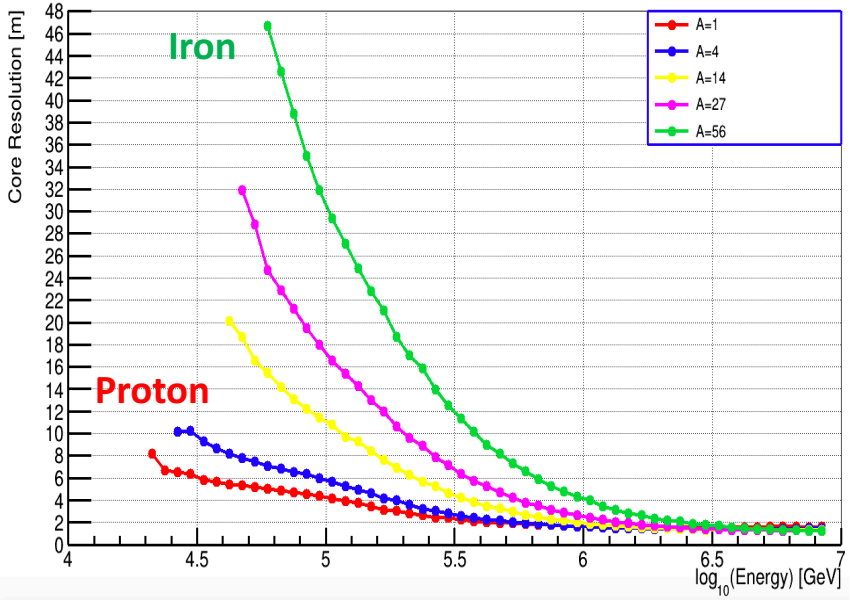
Core Range: 600m X 600m, zero is the center of 6 telescopes

Hadronic interaction model: QGSJET+FLUKA

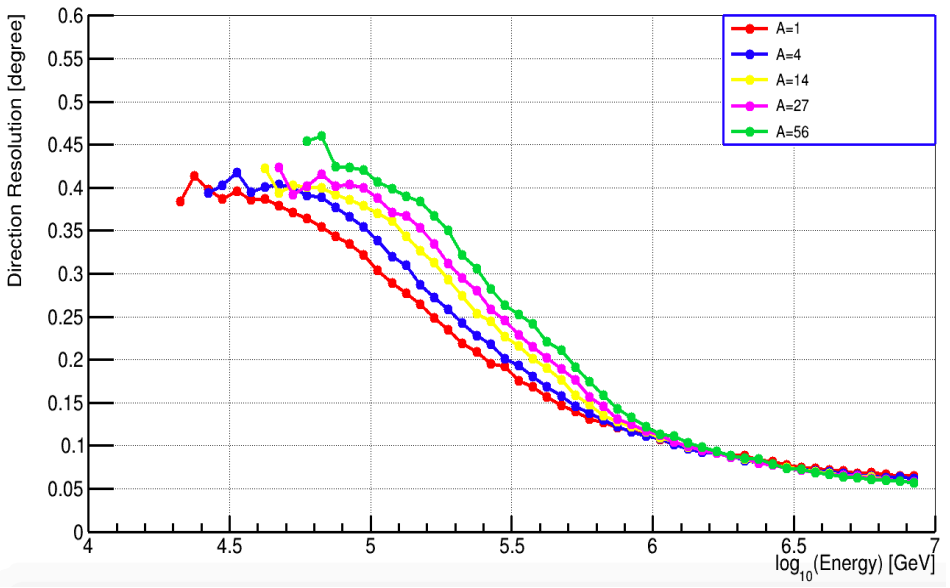
Core and Direction Resolution

NKG-like function for lateral distribution of nuclei: $\rho(r) = n_e(\frac{r}{r_m})^{s-2.5}(1+\frac{r}{r_m})^{s-4.5}, r_m = 130m$

Core Resolution



Direction Resolution



Core resolution<2m, direction resolution<0.1° @ few PeV

Principle of the method

- Two variables are used.

  Nsize (integration of NKG-like function)

  Nu (NuM4, 15~400m to the core)

- Correct for the zenith angle and age dependences

  zenith angle: different amount of material traversed

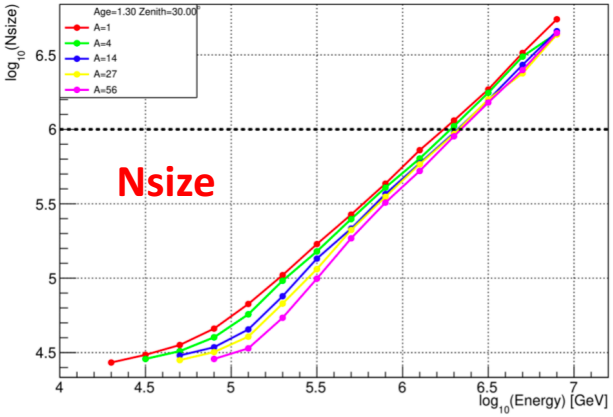
  age(from lateral distribution): shower to shower fluctuation

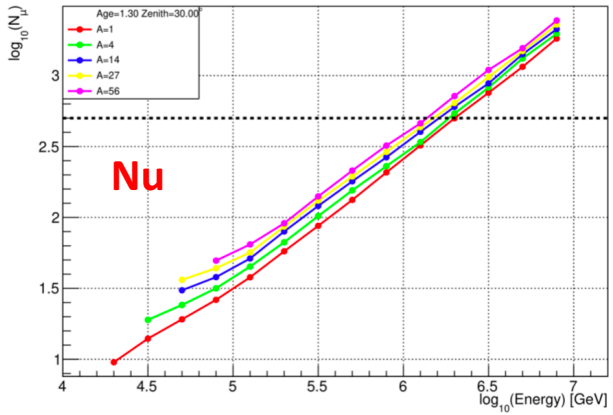
- E and logA reconstruction

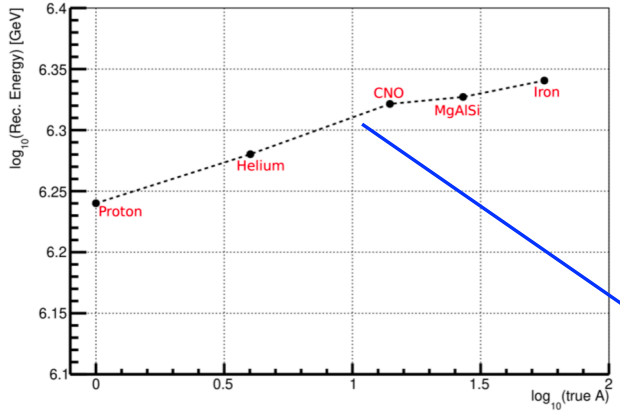
  Nsize and Nu are dependent on energy and mass (after correcting other effects)

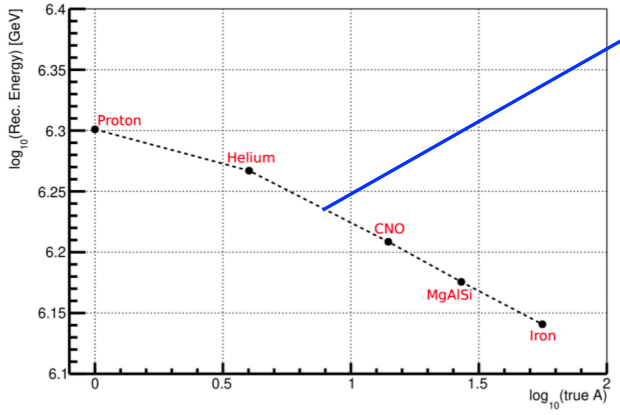
  E and logA is reconstructed from Nsize and Nu

E and logA from Nsize and Nu





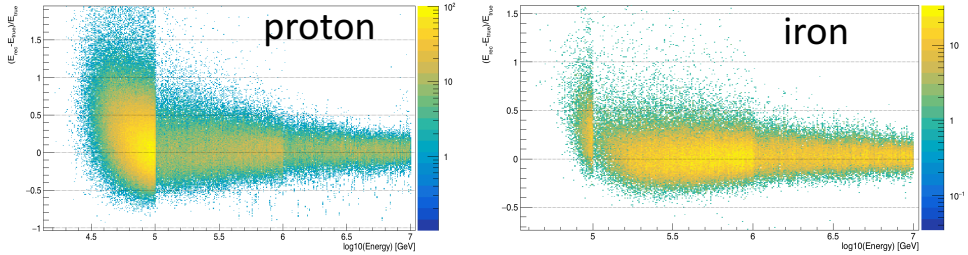




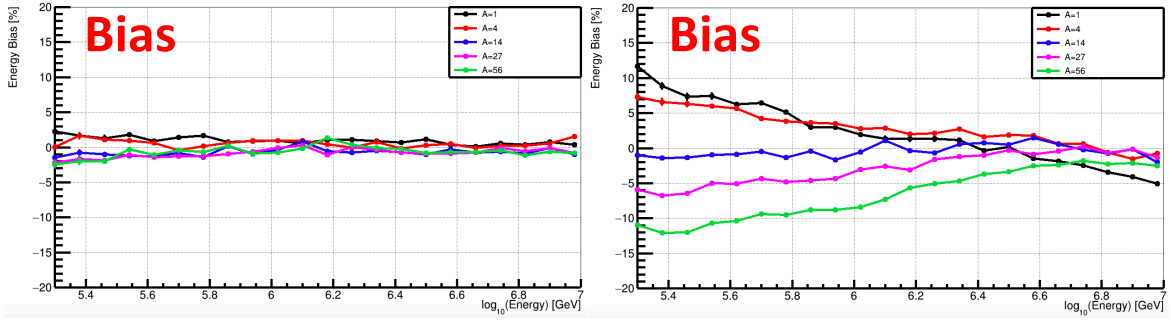
The cross point of the two lines are the reconstructed E and logA

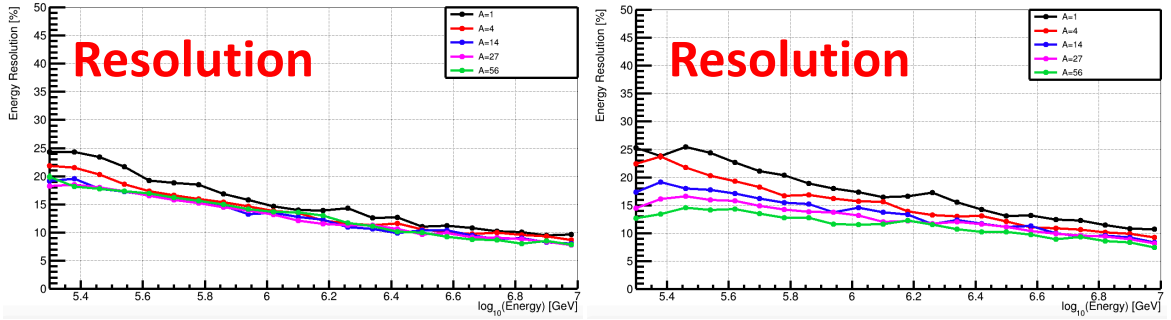
Performance of the method

Energy



this method

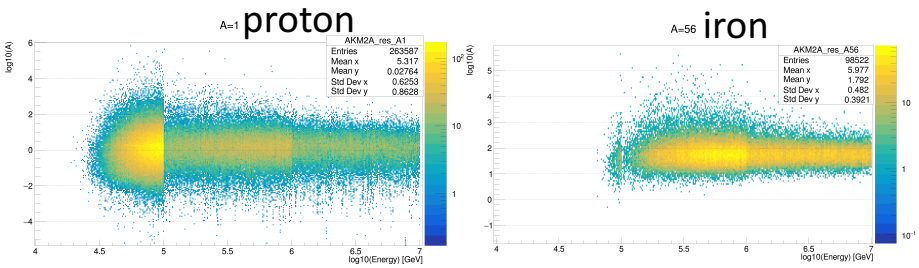


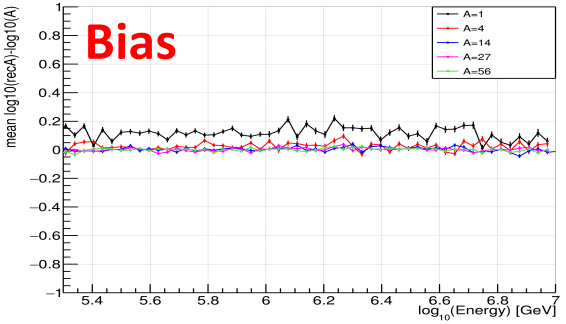


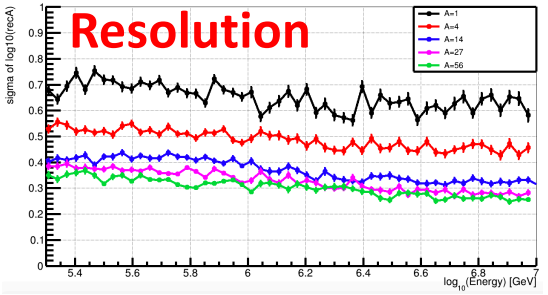
sqrt(ρ_{50}*nu)

Energy bias<3%, energy resolution: 15%@1PeV, 10%@10PeV

log10(A)



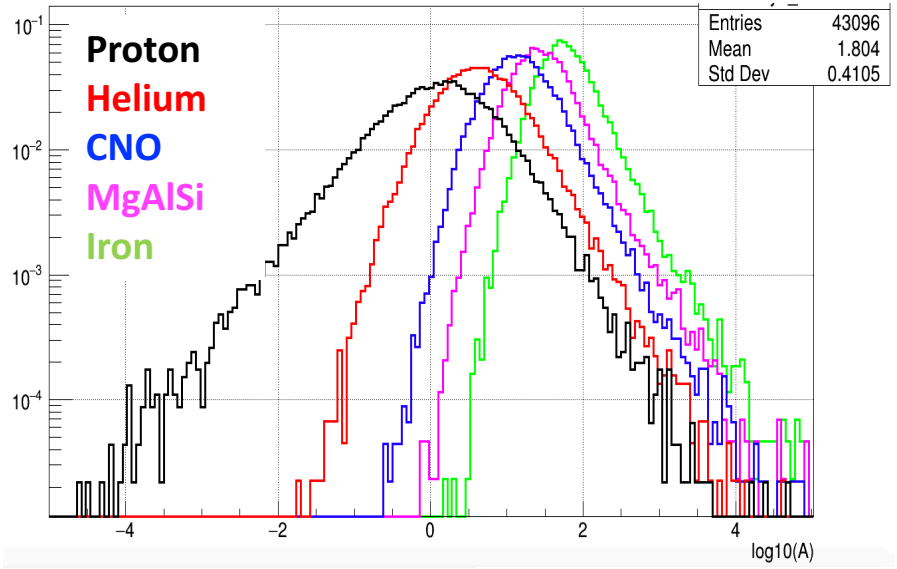




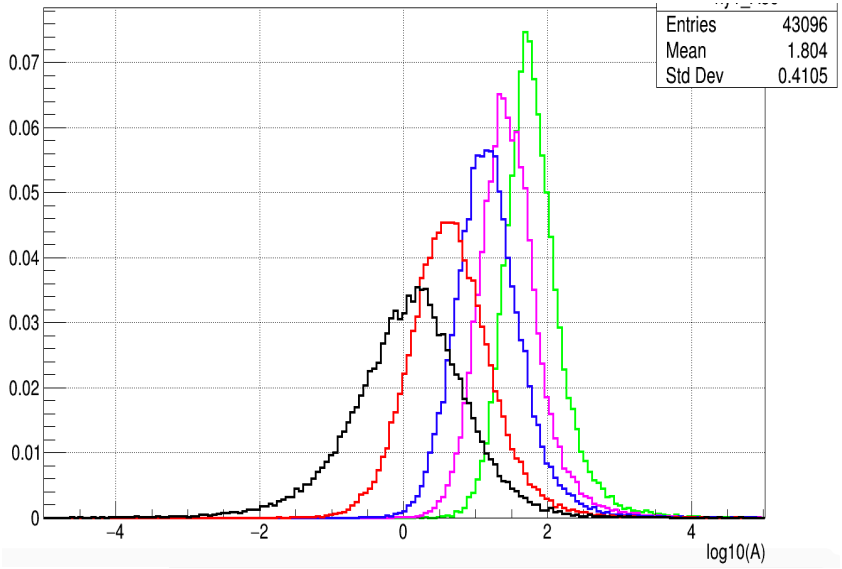
Mass bias ~0, resolution: 0.65 for proton, 0.3 for iron

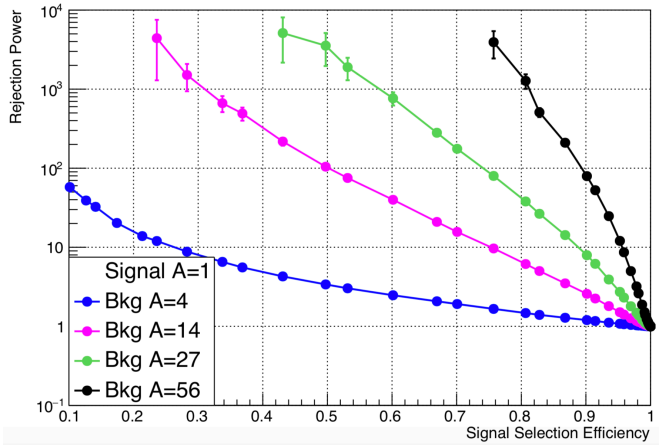
Particle Identification @1PeV

Log scale



Linear scale





Rejection power vs efficiency

All particle flux

Data: KM2A half array,~1 year's data (2019-12~2020-11)

Selection:

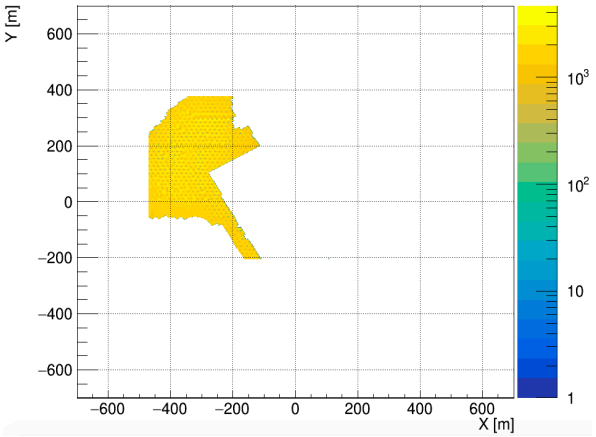
core range: Dr>60m, +-290m from center of WFCTA

direction: 21°<zenith<39°, -84°<azimuth<94°

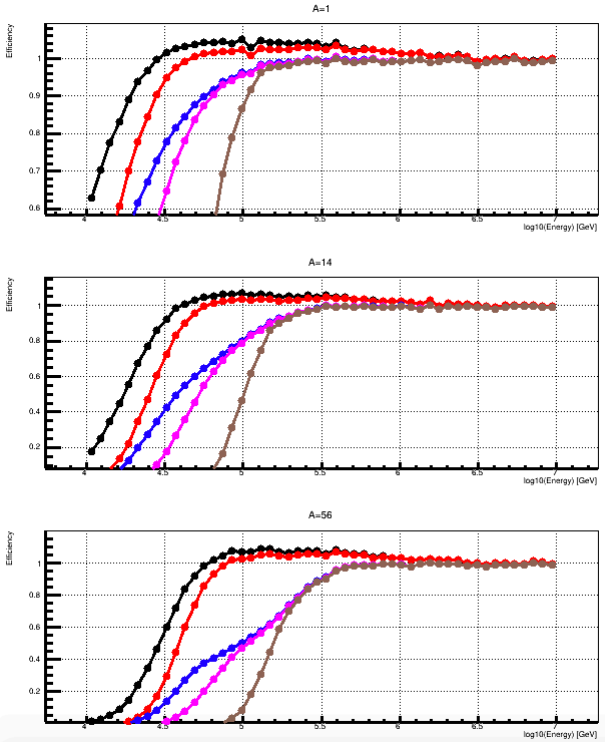
NtrigE>20 && NfiltE>50, NuM4>0

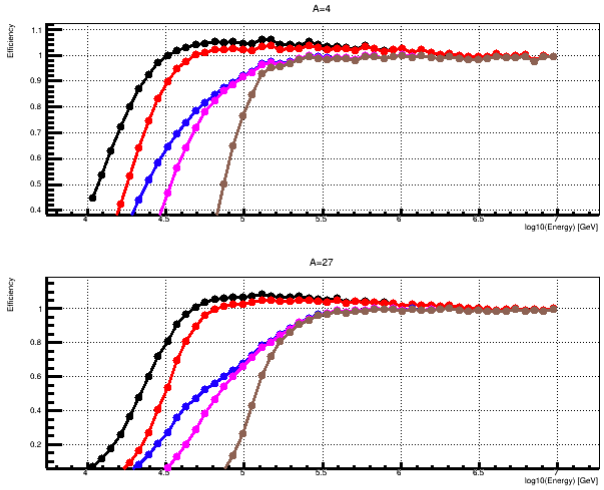
NpE1/NpE2>2

0.8<age<2.2

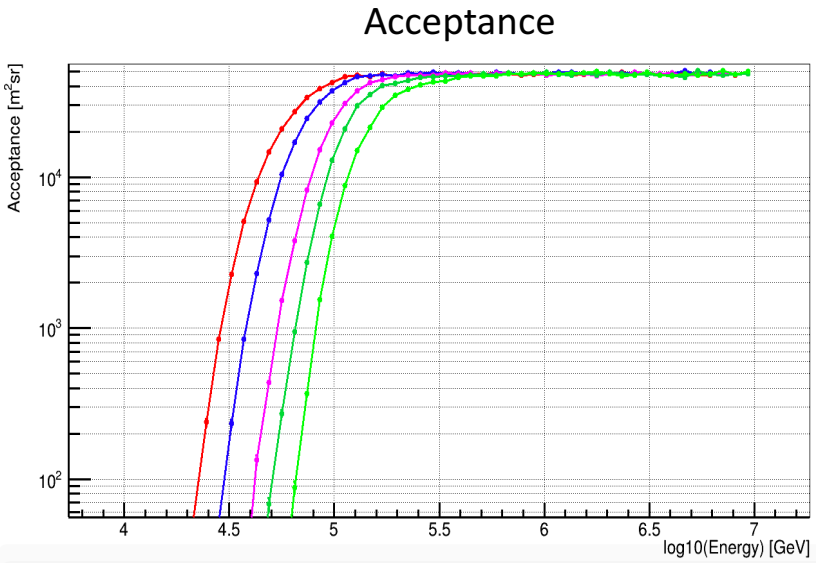


Selection efficiency and Acceptance





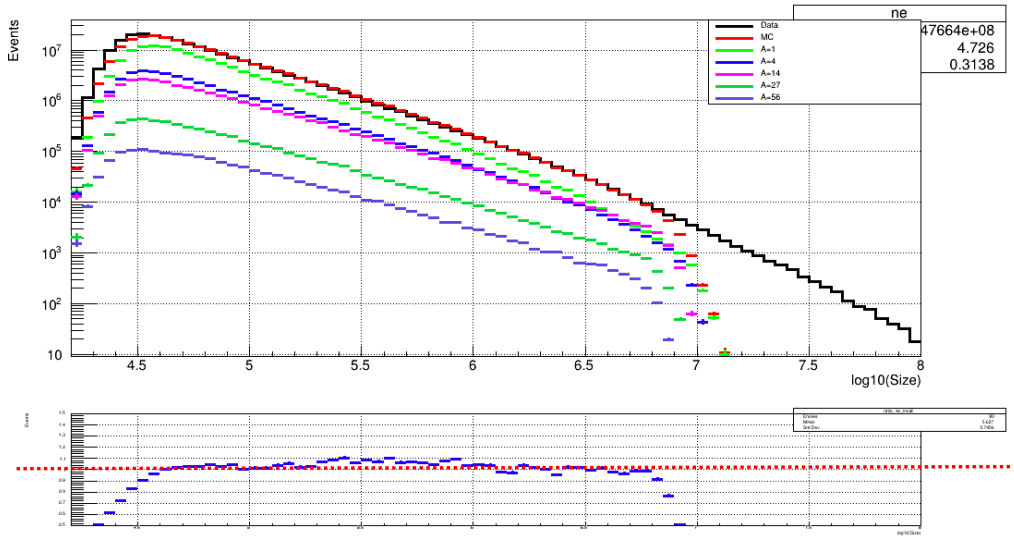
Efficiency:
denom: events inside the geometry
num: events after selection



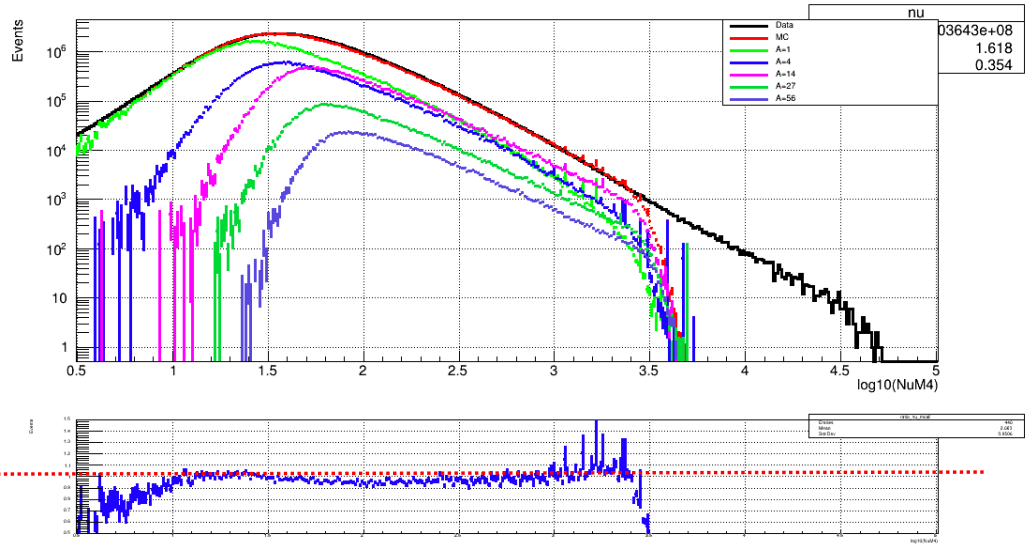
Efficiency is 100% after logE=5.7 for all nuclei
Acceptance at high energy is 4.85*10^4 m^2 sr (due to limited core&direction region in MC)
Exposure time is 2.6*10^7 s

Data MC comparison

Nsize



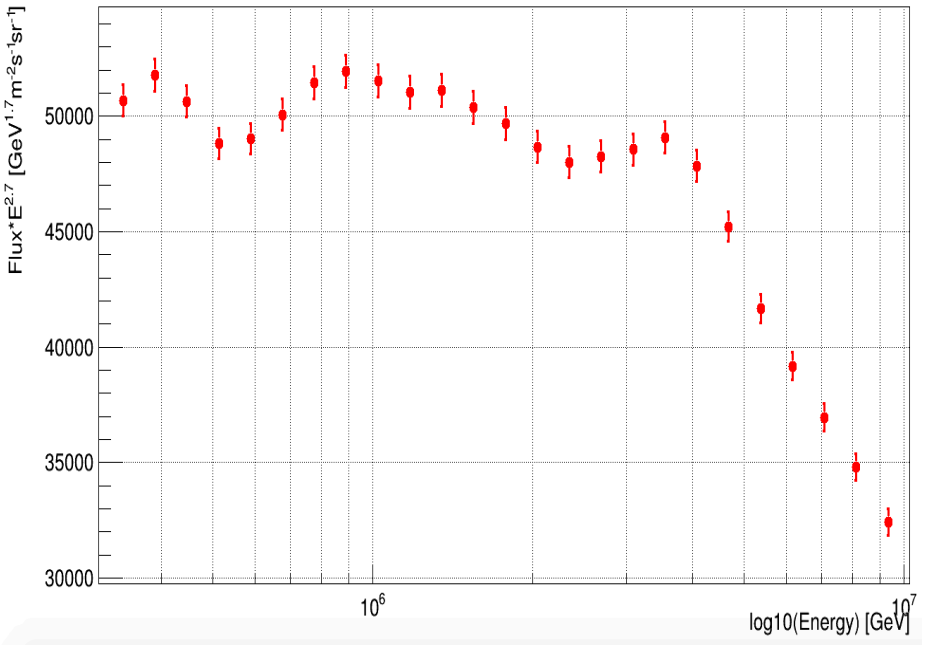
Nu

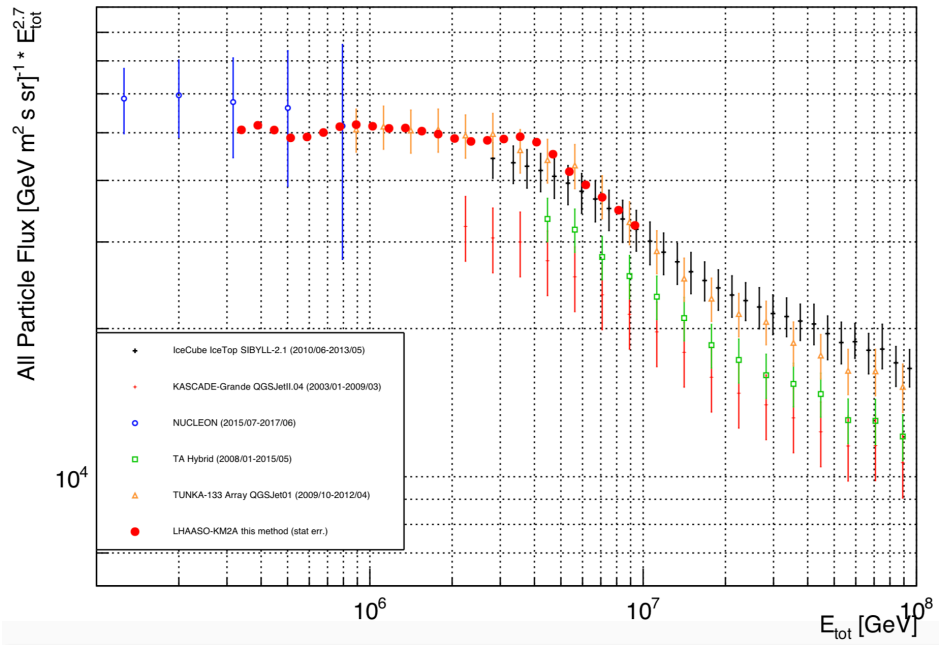


Nsize and Nu agree with each other within 10% between data and MC, except for low energy.

Preliminary All Particle Flux

this work

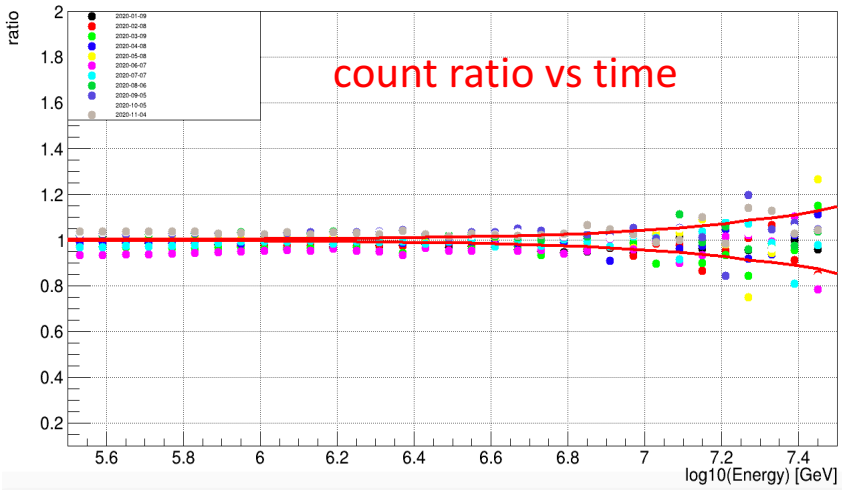


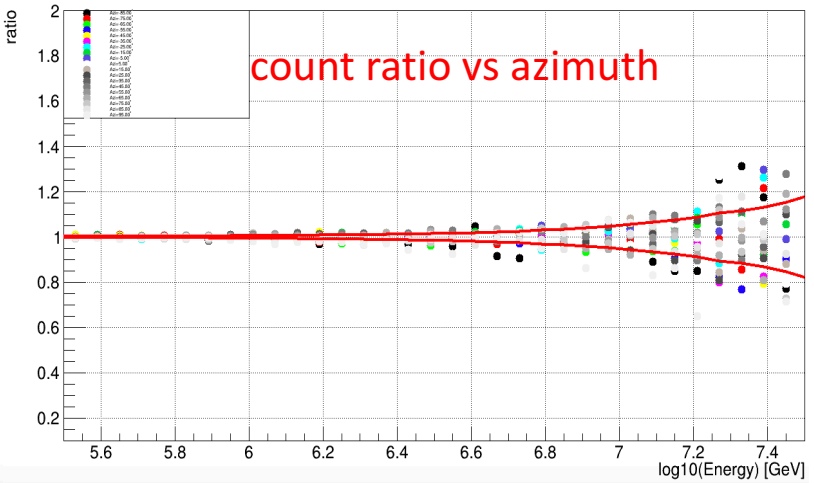


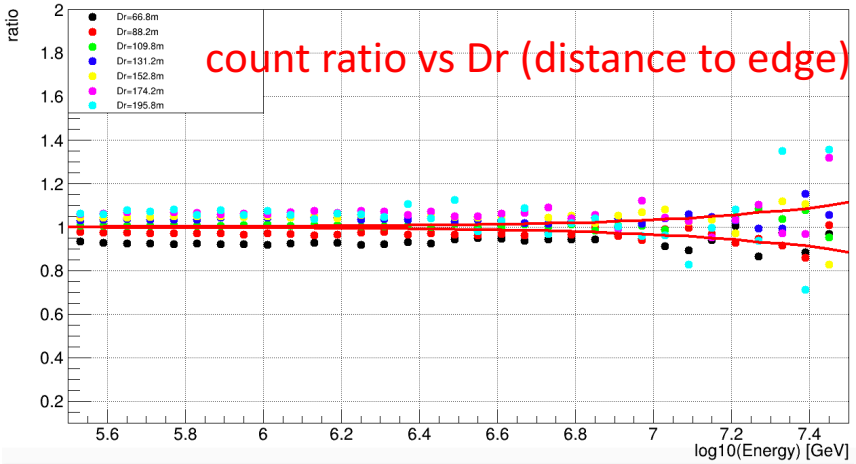
The knee of all particle spectra located at ~4PeV

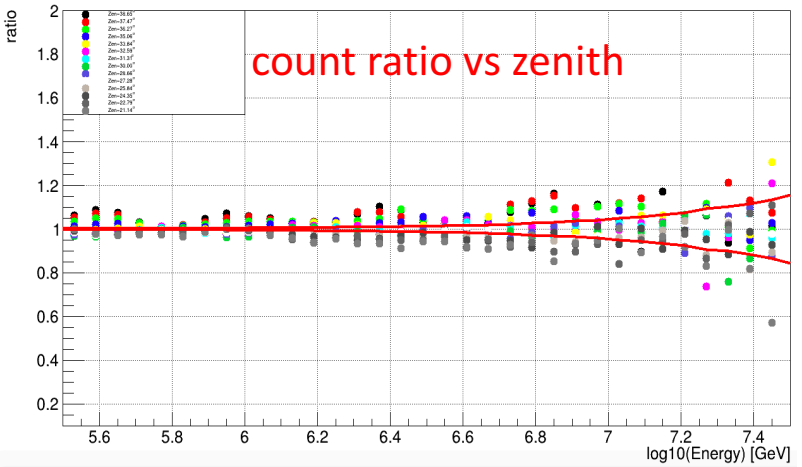
the fluctuation below few PeV may due to overfitting during reconstruction

Flux Check





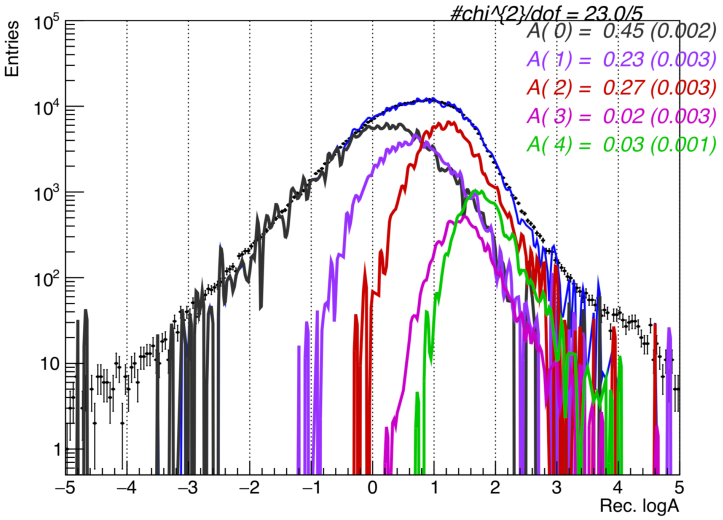




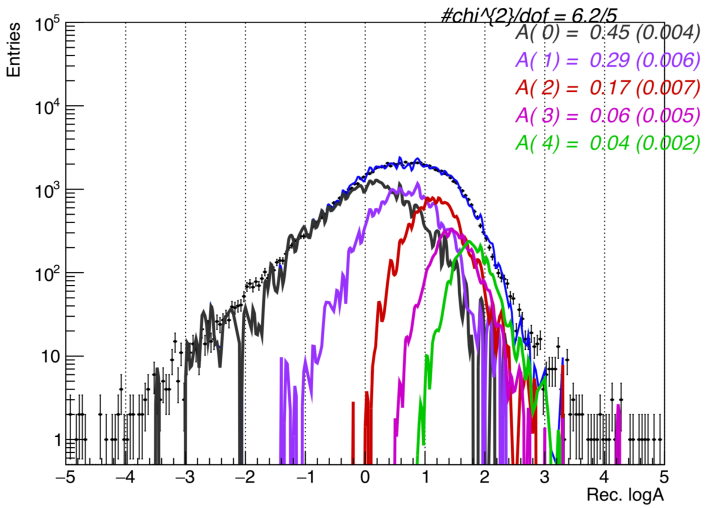
There are variations within maximum of ~8%, except azimuth angle. Still checking…

Light Nuclei Counting: Template Fitting

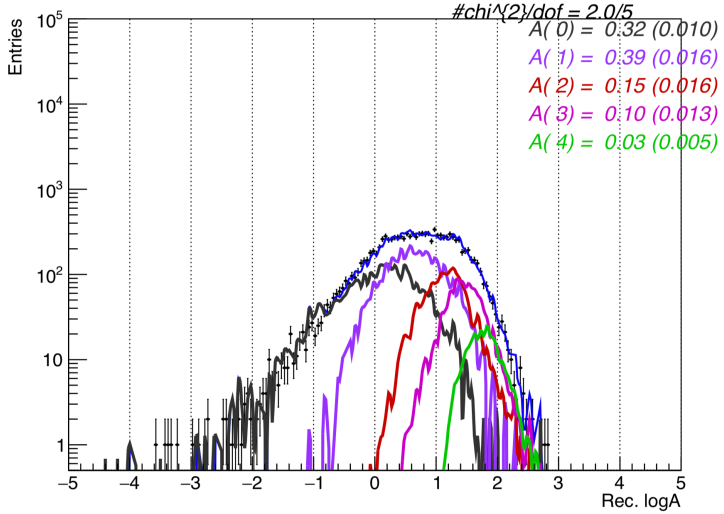
log10(E)=6.04~6.10



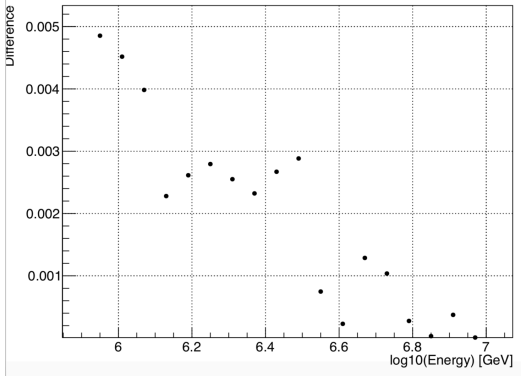
log10(E)=6.46~6.52



log10(E)=6.88~6.94

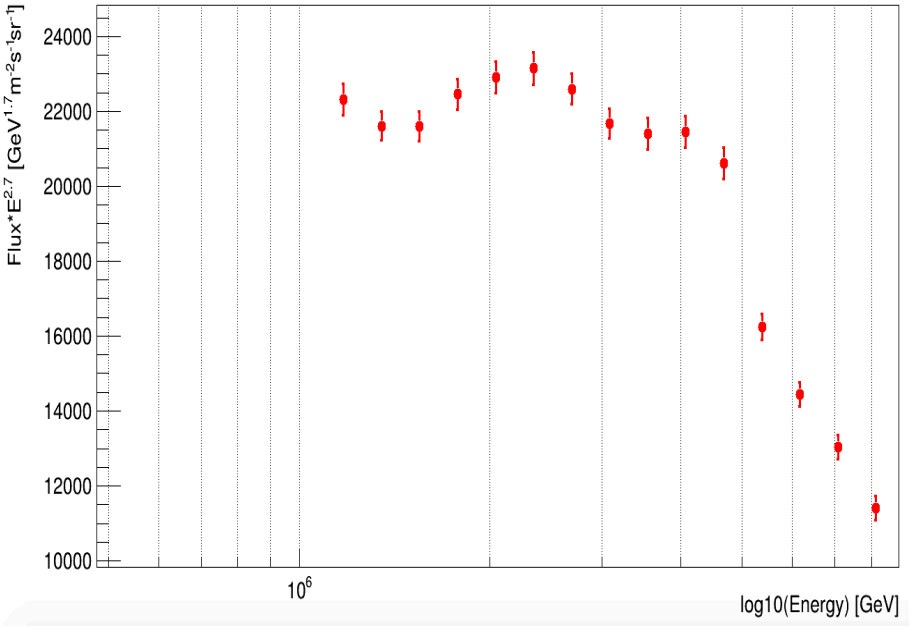


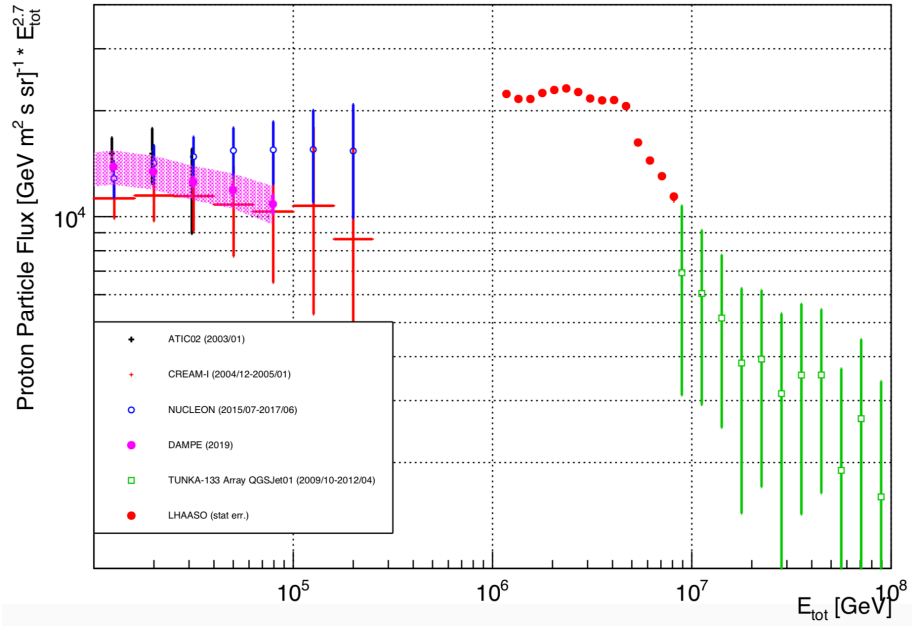
difference of events between data and MC



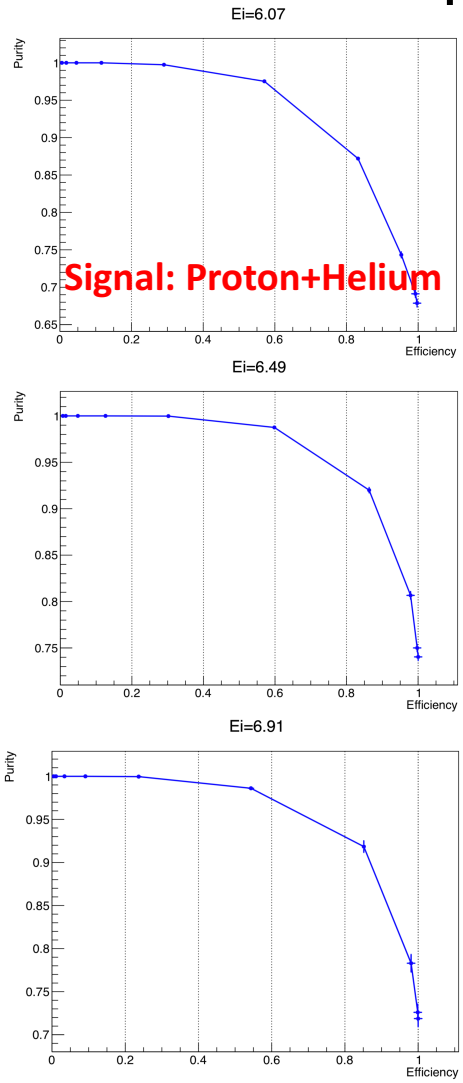
The number of proton are mainly defined by the left tail of data

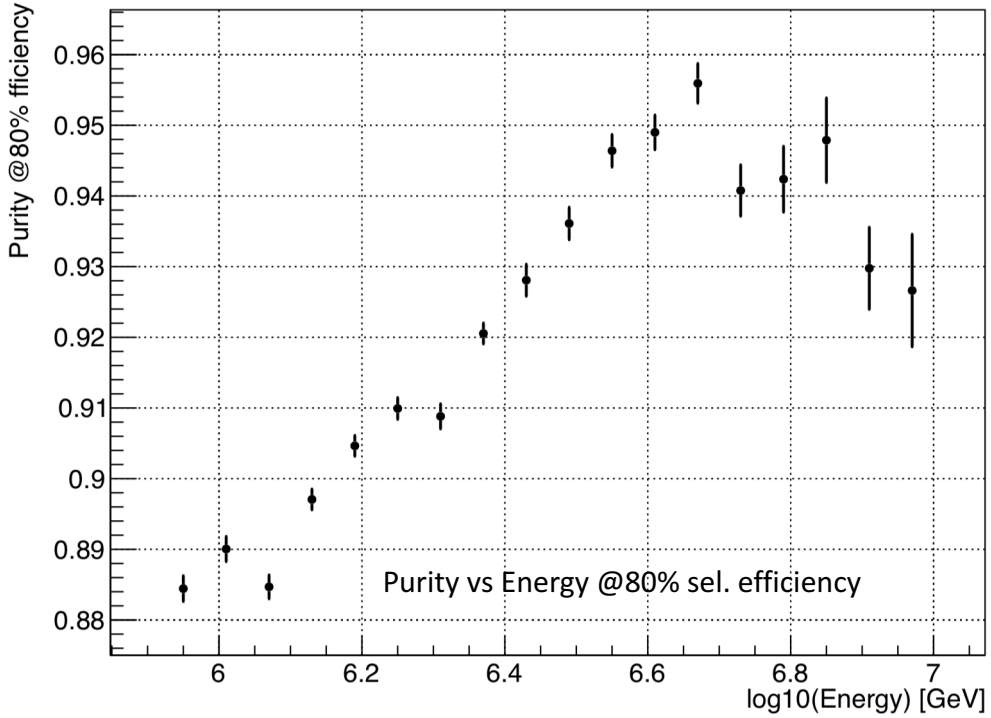
Preliminary Proton Flux





Purity vs Selection Efficiency





The Helium(or proton+helium) flux is possible, the coupling of N_{He} and N_{CNO} is studying.

Summary

- A new unbiased energy and mass reconstruction method is provided
- Preliminary all particle and proton flux is shown
- These measurements provide independent results besides WFCTA

Light Nuclei Flux: unfolding method

Difficulties: migration between different energy bins and different mass bin

reference: DOI:https://doi.org/10.1103/PhysRevLett.123.181102
AMS02 He3,He4 flux measurements

$$m = \frac{ZR}{\beta\gamma}$$

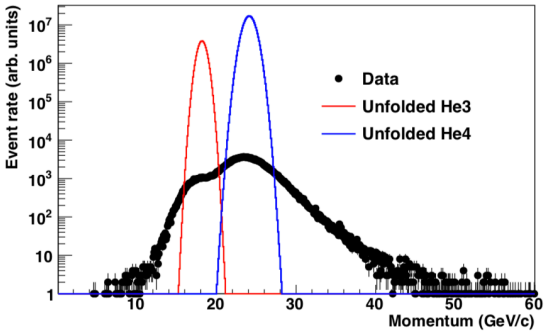


Figure 8: Unfolded momentum distributions for events near $E_{k/n} = 5$ GeV/n compared with measured momentum for those events. Unfolded distributions are multiplied by an arbitrary factor for plotting on the same axes.

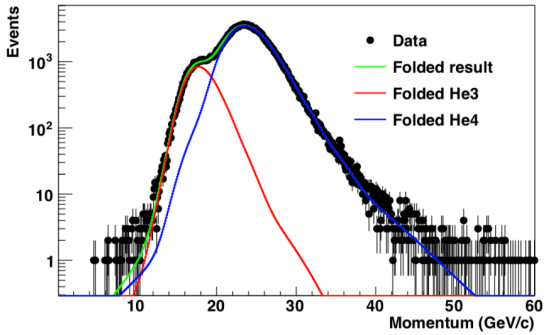


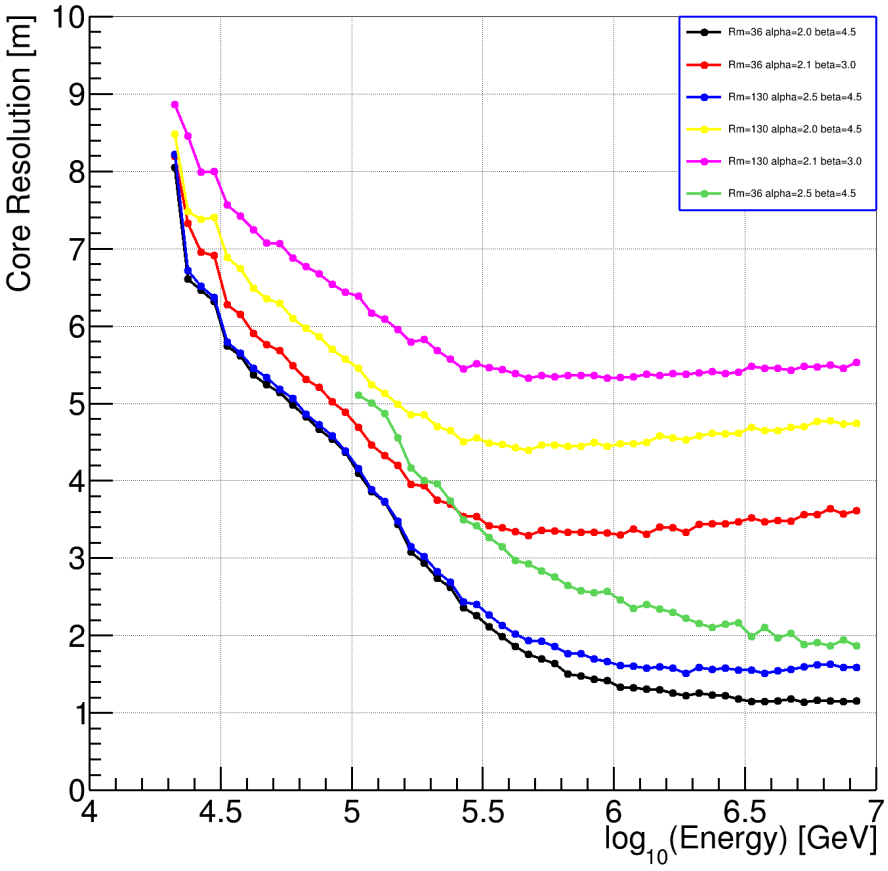
Figure 9: Re-folding of the distributions shown at left, along with their sum (in green), for comparison with data in $E_{k/n} = 5$ GeV/n bin.

1. select narrow rec. energy bin (to avoid the effect of nuclei flux on true energy distribution) , reconstruct the true energy distribution, based on MC
2. reconstruct mass distribution from true energy distribution, based on MC
3. fit the data mass distribution with the templates from MC with previous step. Derive the fraction of each component
4. adding the true energy distribution of each rec. energy bin, derive the counts of each component vs true energy

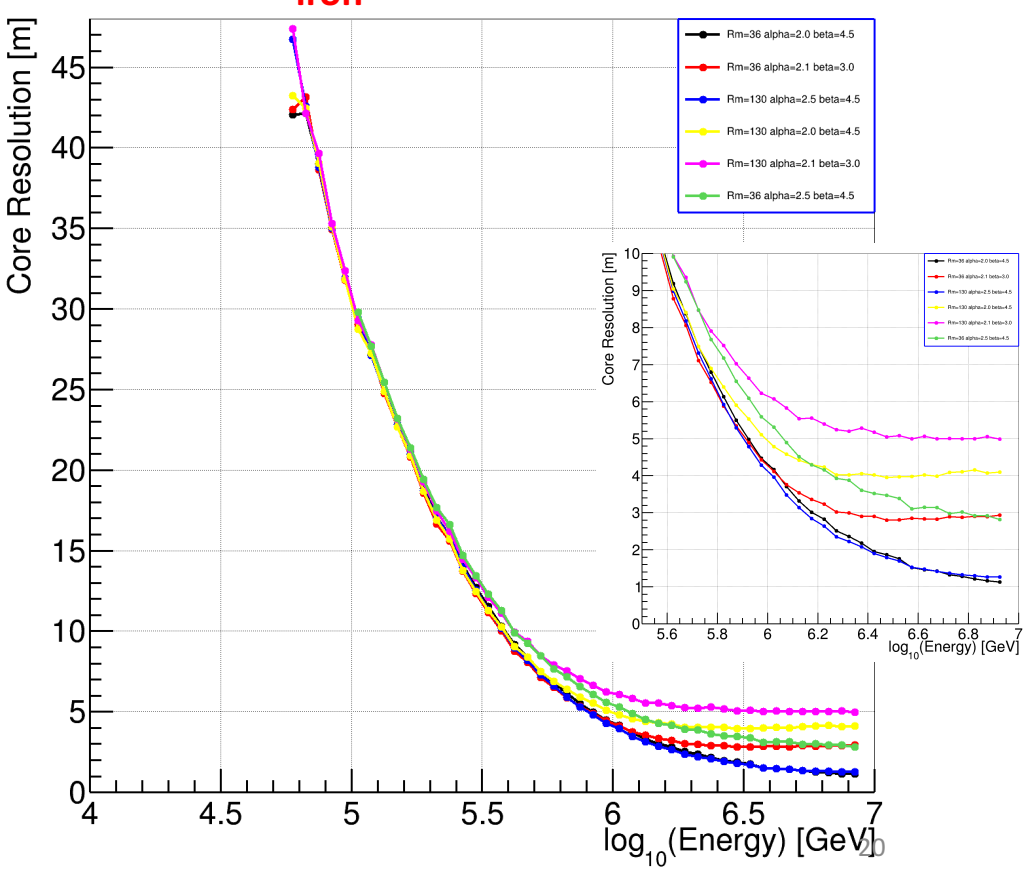
Core Resolution

NKG-like function for lateral distribution of nuclei: $\rho_2(r) = N_e C(s)\left(\frac{r}{r_m}\right)^{s-\alpha}\left(1+\frac{r}{r_m}\right)^{s-\beta}$

proton

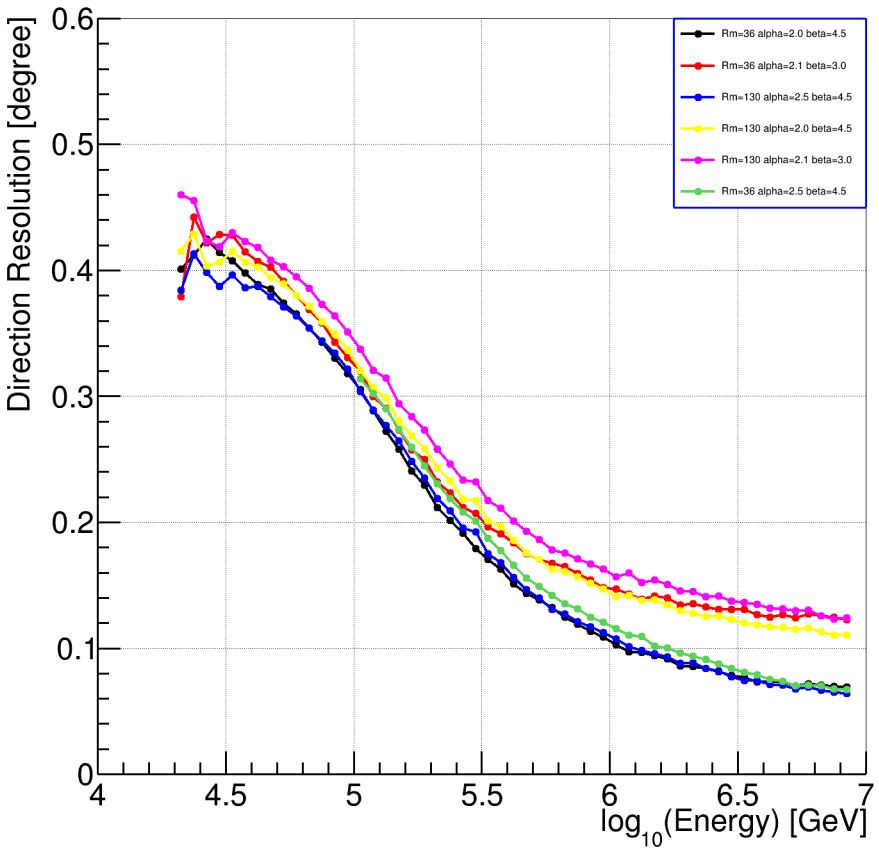


iron



Direction Resolution

proton



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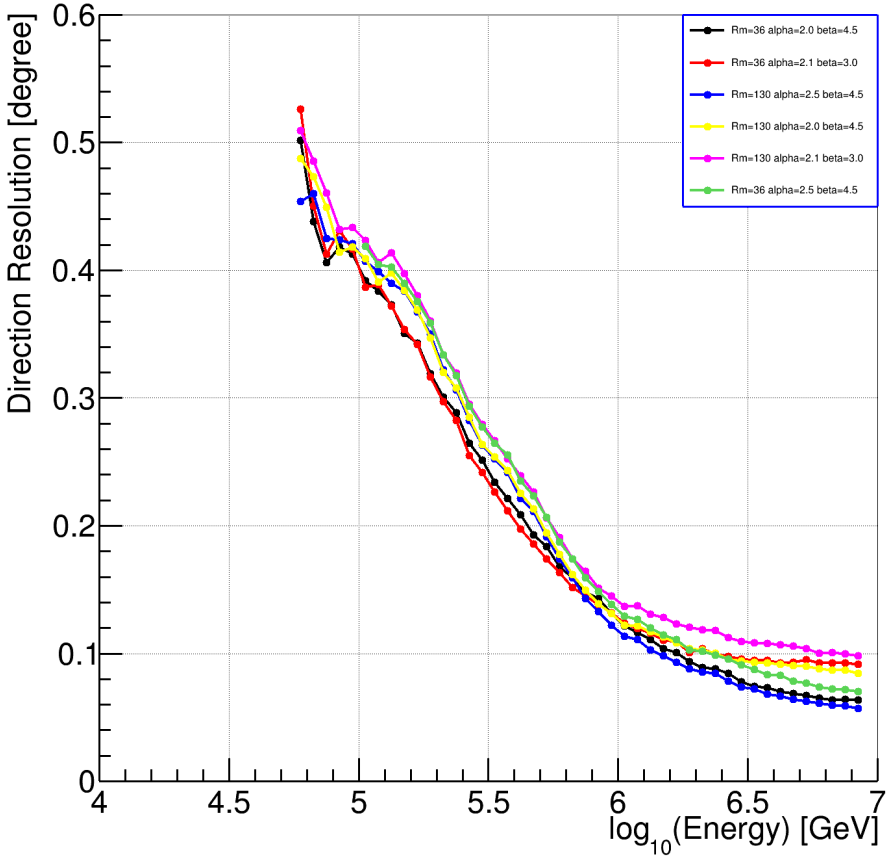
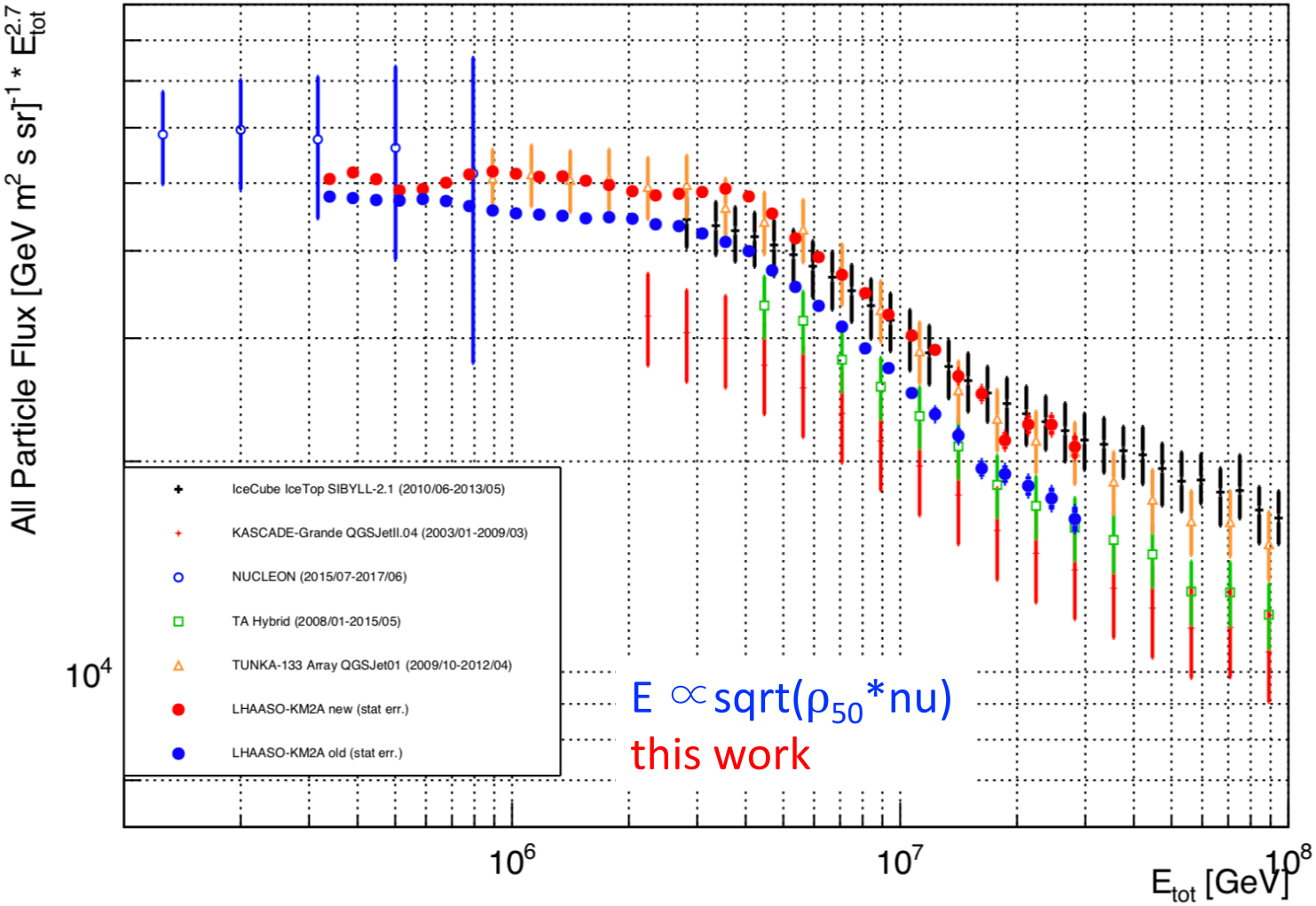
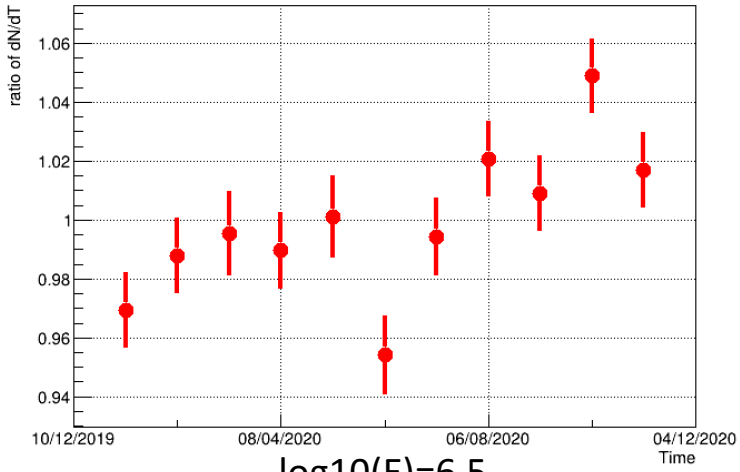


All Particle Flux

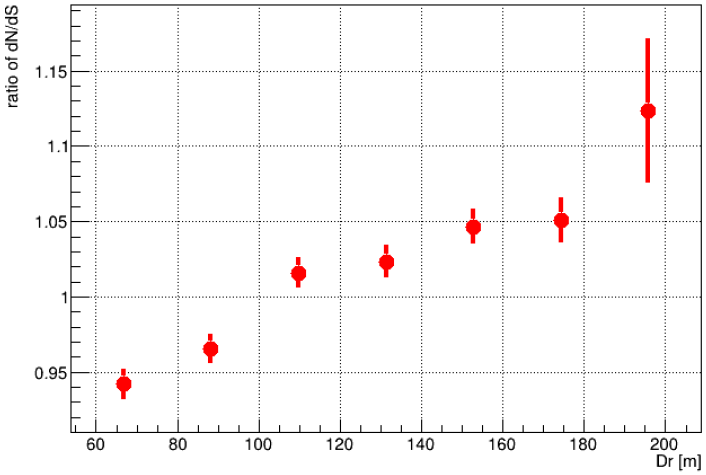


Flux Check

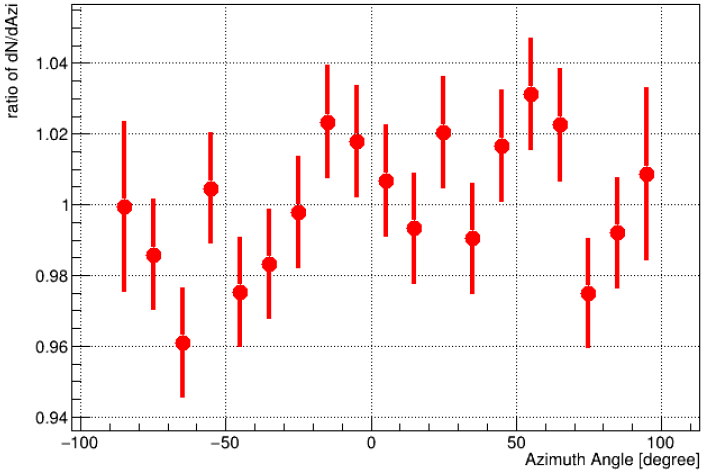
log10(E)=6.5



log10(E)=6.5



log10(E)=6.5



log10(E)=6.4