Primary cosmic-ray spectra and composition in the energy range from 50 TeV to 10^{16} eV observed with the new Tibet hybrid experiment

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CRI4a, (ICRC2019) 288, Jul 26th, Friday, 16:30, ICRC2019, MADISON, WISCONSIN, USA

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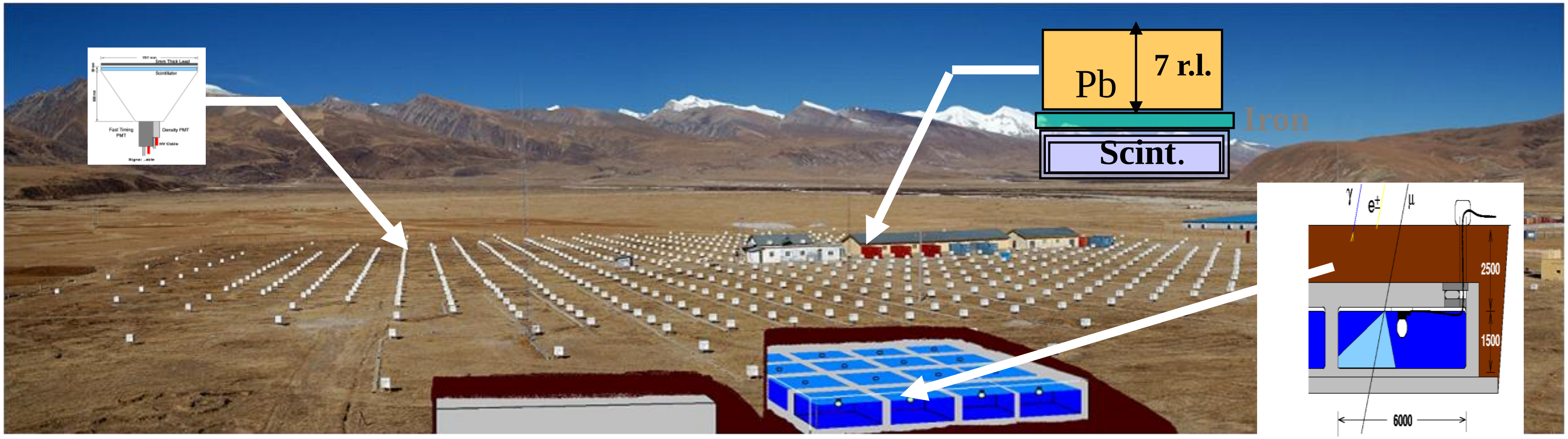
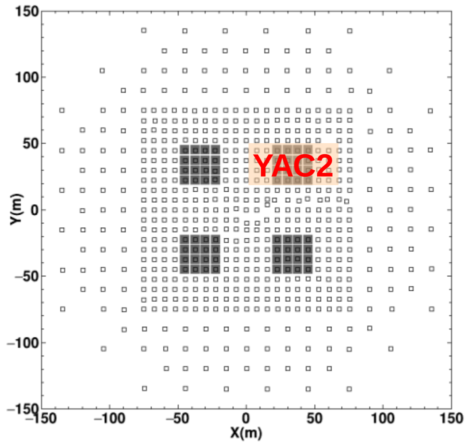
- Summary

Tibet hybrid experiment (YAC+Tibet-III+MD)

This hybrid experiment consists of low threshold Air shower core array (YAC) and Air Shower (AS) array and Muon Detector (MD) .





Tibet-III (65700 m^2) : Primary energy and incident direction.

YAC2 (500 m^2): High energy AS core within several x 10m from the axis.

Tibet-MD (3400 m^2) : Number of muon.

Detector Calibration

1.PMT linearity,

use of LED light source;

2. Linearity of PMT+scintillator,

a. probe calibration;

b. accelerator beam calibration.

- Full M.C. Simulation -

Hadronic interaction models

•CORSIKA (Ver. 7.5000)

– EPOS LHC–

– QGSJETII-04–

– SIBYLL 2.3 –

– SIBYLL 2.1 –

Primary composition models

- Helium poor model [1]
- Helium rich model [1]
- H4a model **[1]**

Ref. [1]. Astropart. Phys 66 (2015) 18.

= Air Shower simulation =

CORSIKA 7.5000 (EPOS –LHC, QGSJETII-04, SIBYLL2.3, SIBYLL2.1)

(1) Primary energy: E0 >1 TeV

(2) All secondary particles are traced until their energies become 1 MeV in the atmosphere.

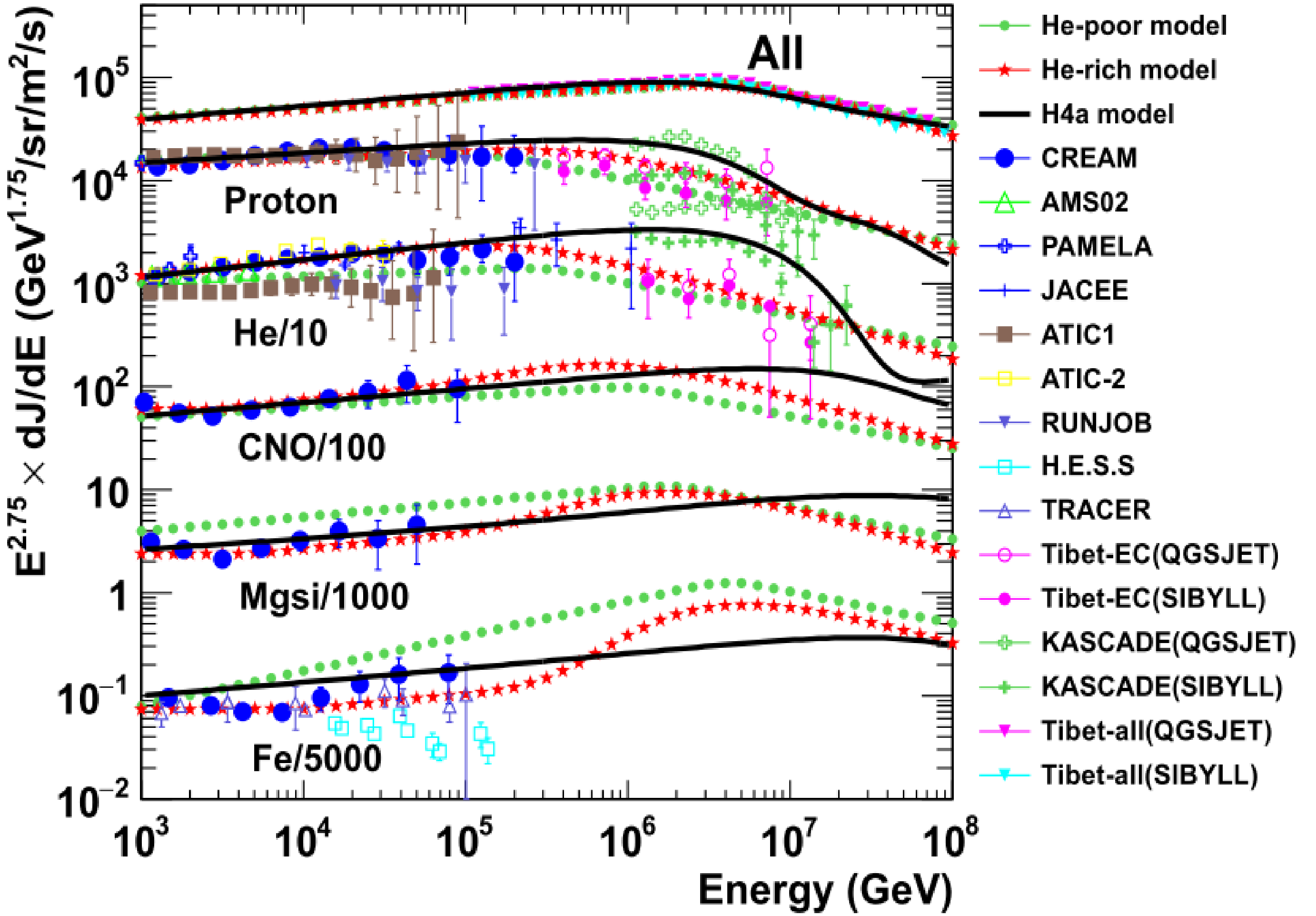
(3) Observation Site : Yangbajing (606 g/cm^2)

= Detector simulation =

(1) Geant 4 (Ver. 9.5)

Simulated air-shower events are reconstructed with the same detector configuration and structure as the Tibet-III and YAC array.

Primary cosmic-ray composition spectrum assumed in MC



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Primary proton, helium spectra analysis

Primary proton, He spectra analysis

Identification of proton+helium events

ANN (a feed-forward artificial neural network) is used.

Input event features:

N_e, ΣN_b, N_b^{top}, N_{hit}, $\langle R_b \rangle$, $\langle N_b R_b \rangle$, θ

Classification: (proton+helium)/others

Primary (proton+helium) energy determination

$E_0 = f(N_e, s)$ based on (P+He)-like MC events

Core event selection

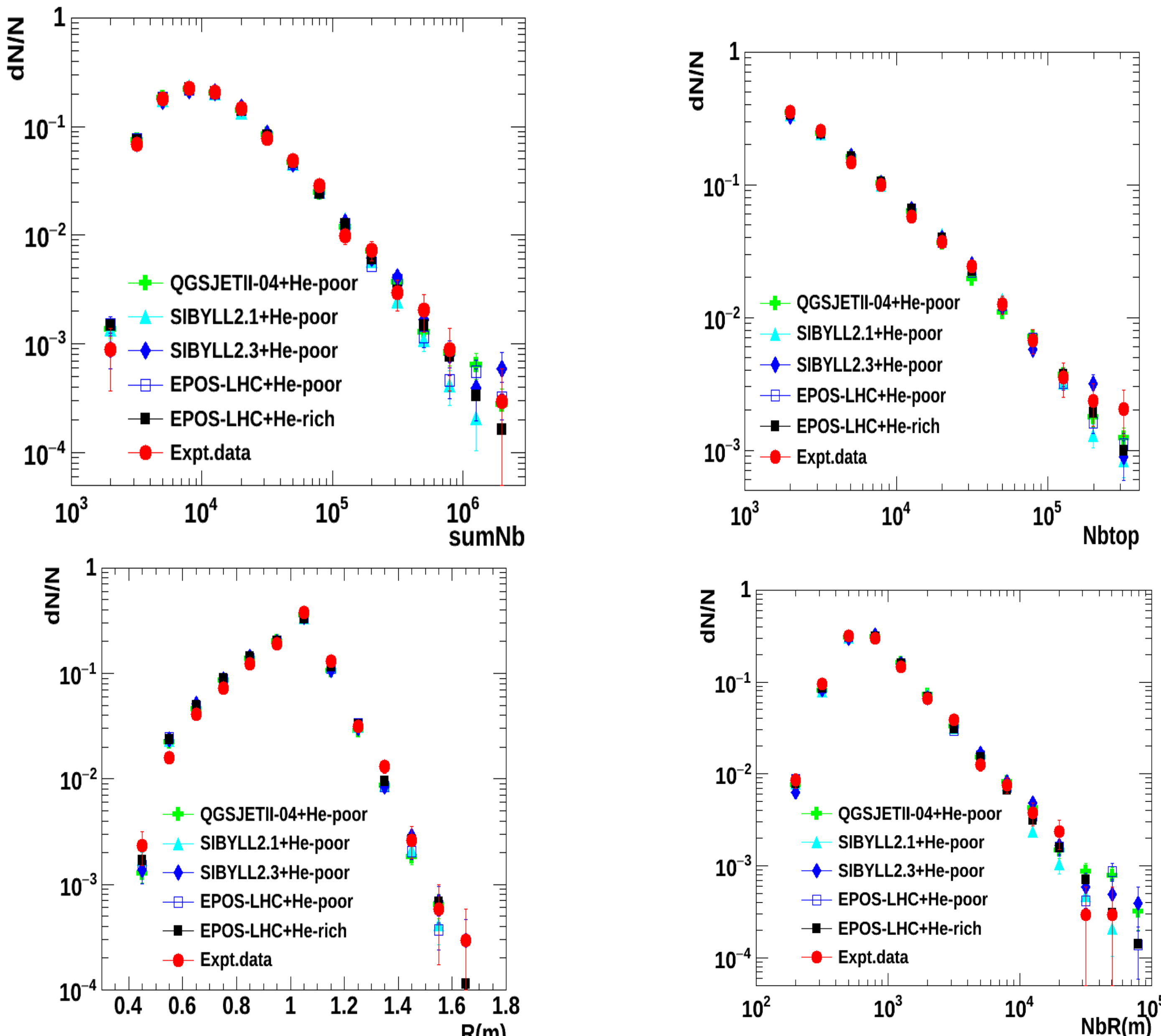
(Nb>200, N_{hit}≧4, Nbtop ≧1600, Ne>80000)

Statistics of core events in MC simulation and experiment

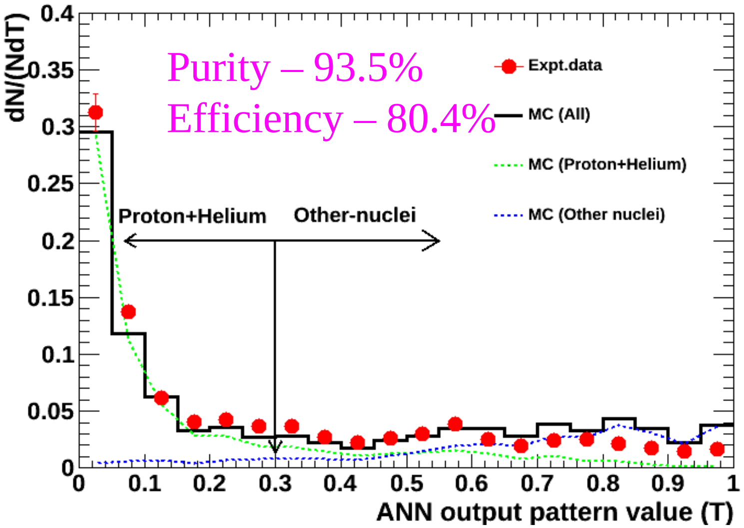
Live Time is 106.05 days.

	Selected core events
EPOS-LHC+He-rich	680989
EPOS-LHC-He-poor	21726
QGSJETII-04+He-poor	21856
SIBYLL2.3+He-poor	10152
SIBYLL2.1+He-poor	19176
Expt.data	3416

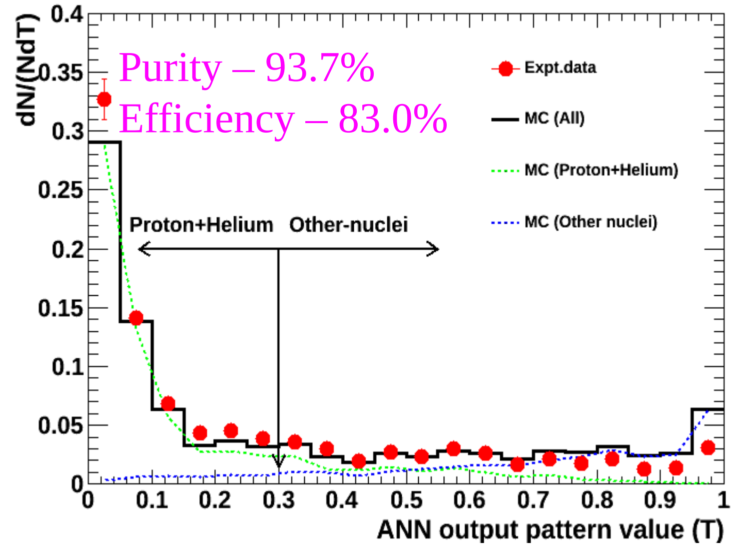
Interaction model dependence in (YAC+Tibet-III) experiment



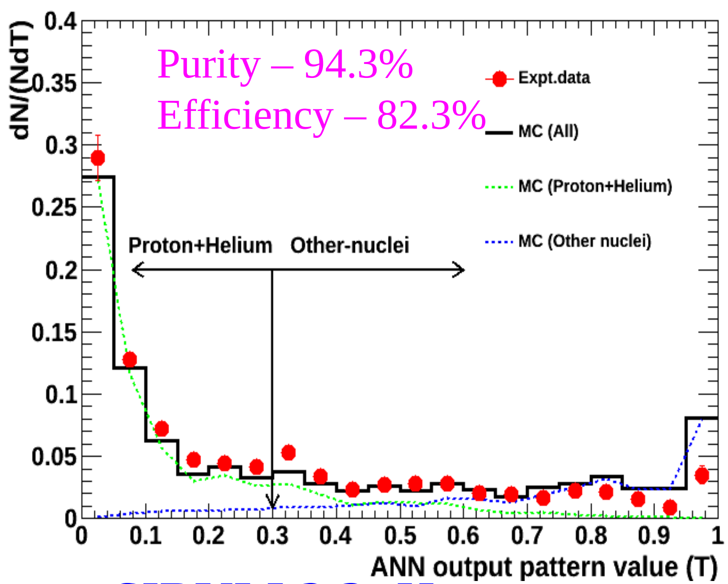
Primary (P+He) separation by ANN for MC events



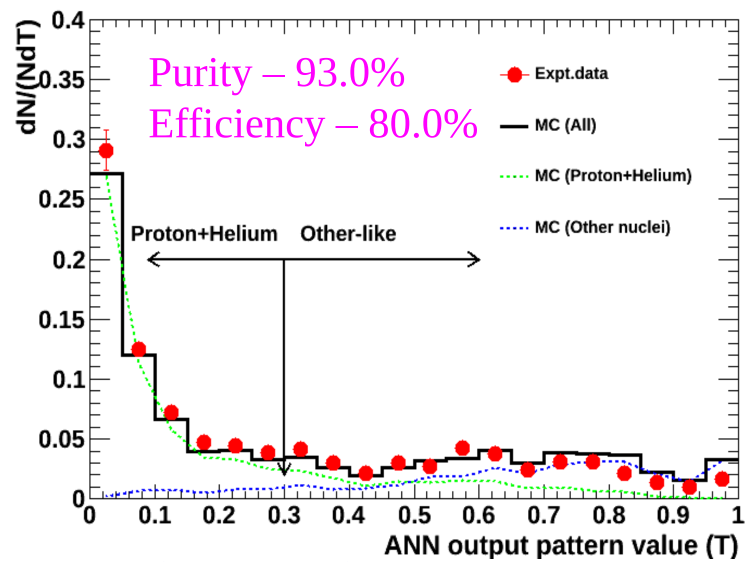
EPOS-LHC+He-poor



QGSJETII-04+He-poor



SIBYLL2.3+He-poor

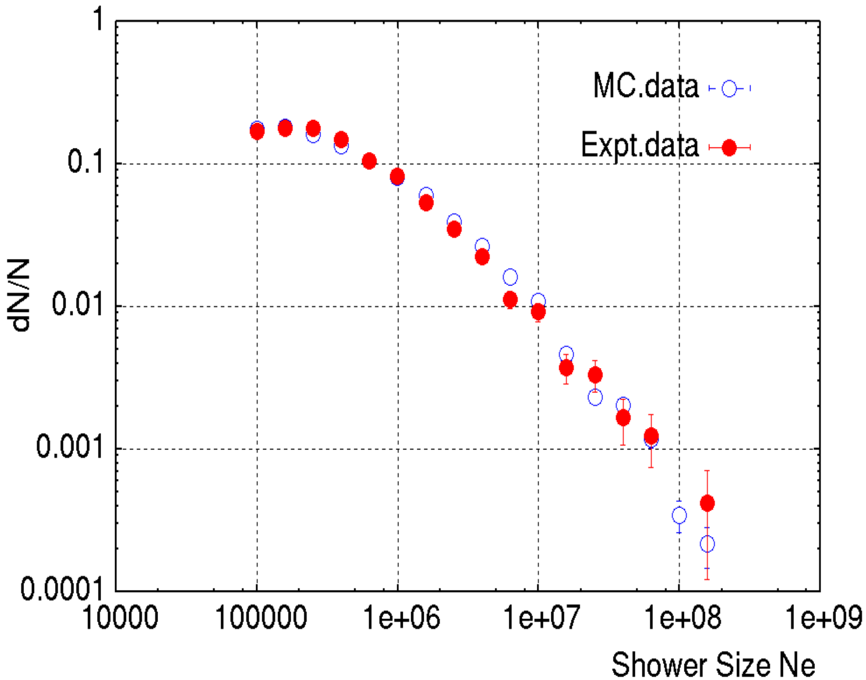


SIBYLL2.1+He-poor

Comparison of the air-shower size (Ne) between MC and Expt.data

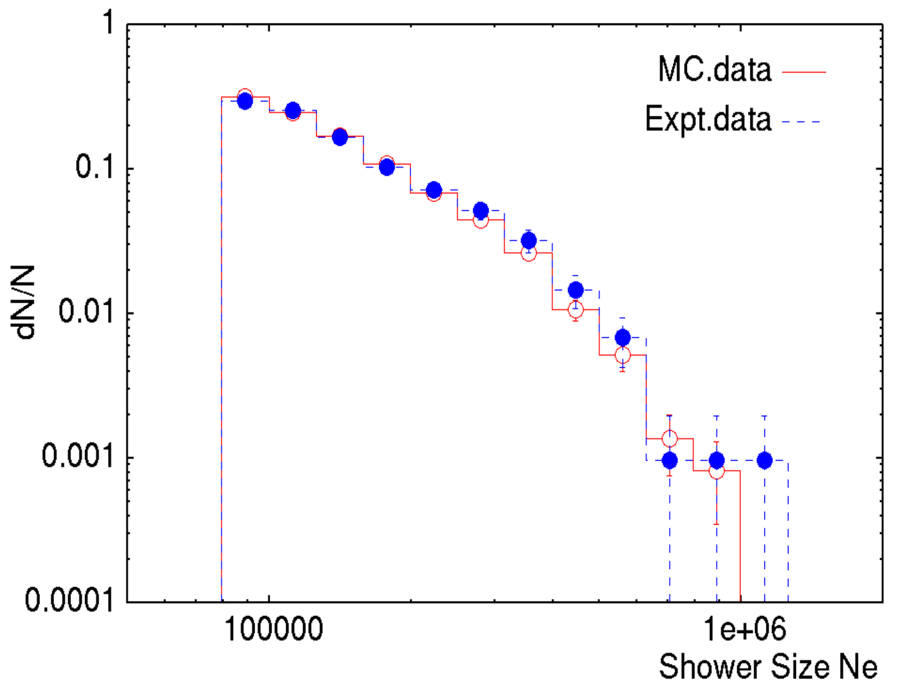
(From this two figures, we can see that, the air-shower size (Ne) has the shape very close to the MC prediction before and after ANN selection. Some other quantities have the same behavior as well.)

- Before ANN (all events)



Air shower size spectrum

- After ANN (Tcut<=0.3)
  (Proton+He)-like events



Air shower size spectrum

Air shower size to primary energy

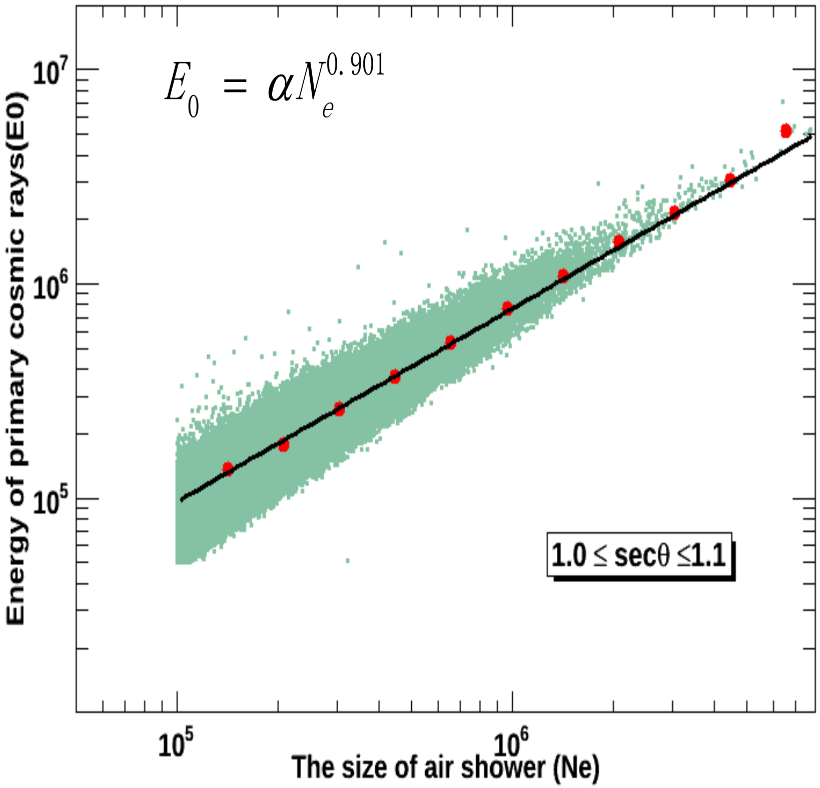
The primary energy (E0) of each AS event is determined by the air-shower size (Ne) which is calculated by fitting the lateral particle density distribution to the modified NKG function.

Modified NKG function

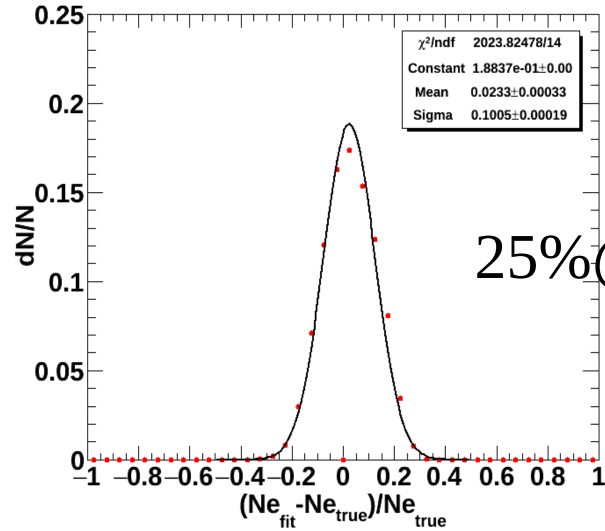
$$f(r) = \frac{1}{2\pi B(a(s,t)+2., -b(s,t)-a(s,t)-2)}(\frac{r}{r'_m})^{a(s,t)}(1+\frac{r}{r'_m})^{b(s,t)}/r'^2_m$$

$$t = \sec\theta - 1.$$

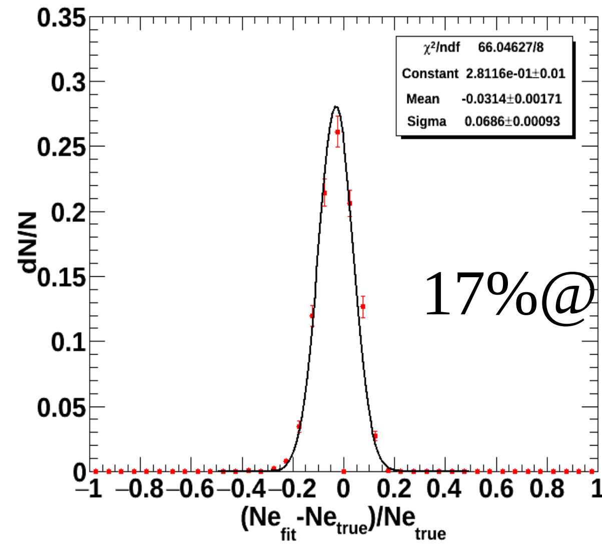
Air shower size to primary energy



Ne-E0

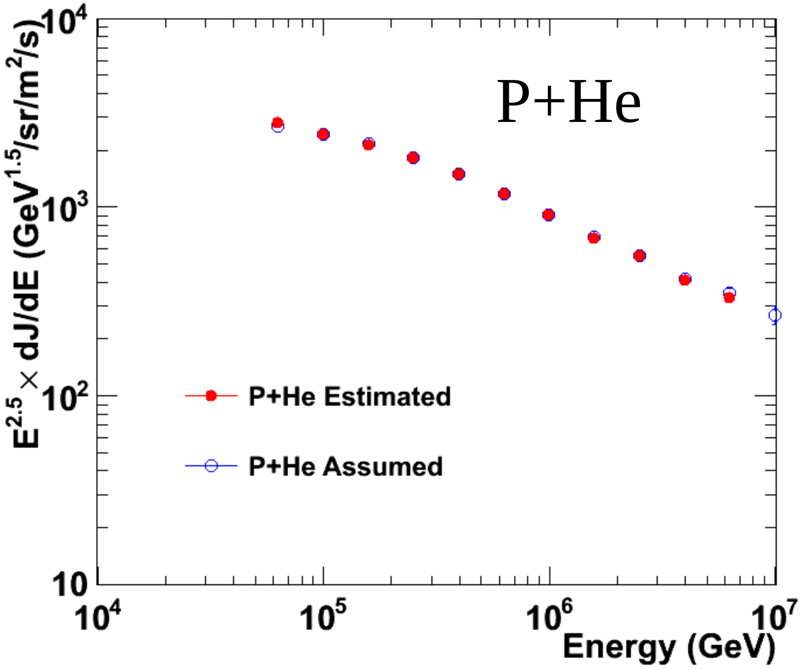


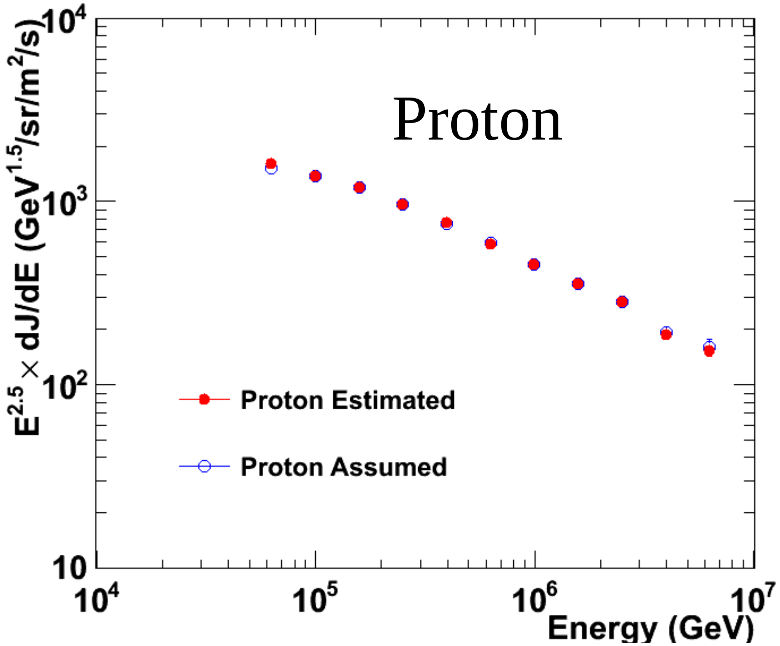
25%@200TeV



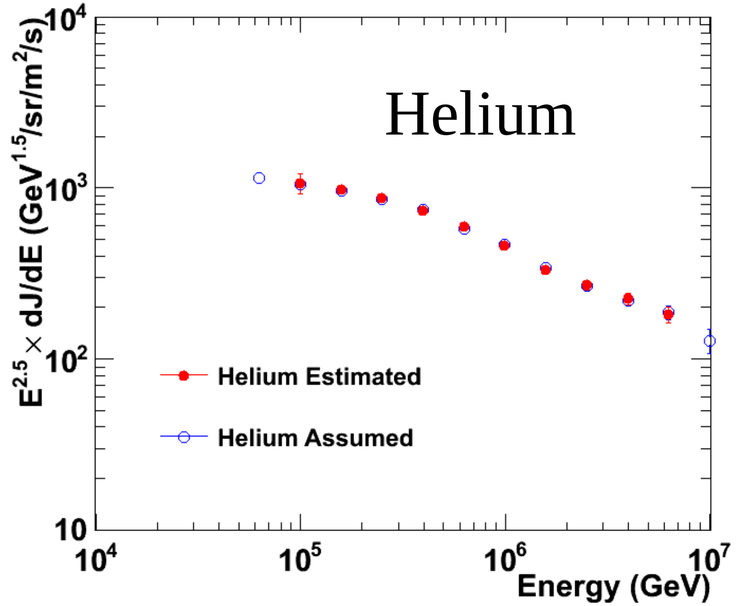
17%@1 PeV

Check the systematic errors by ANN

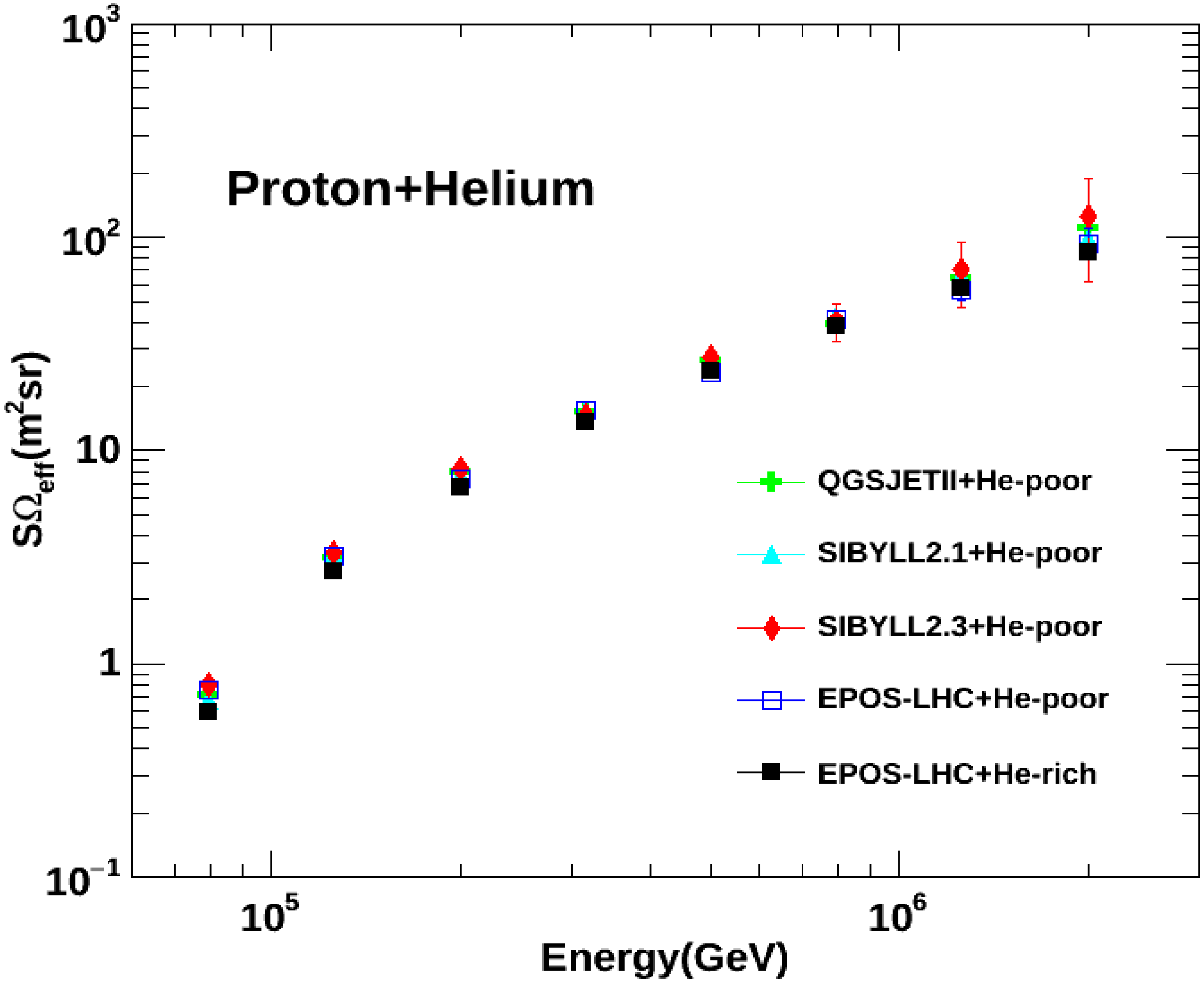




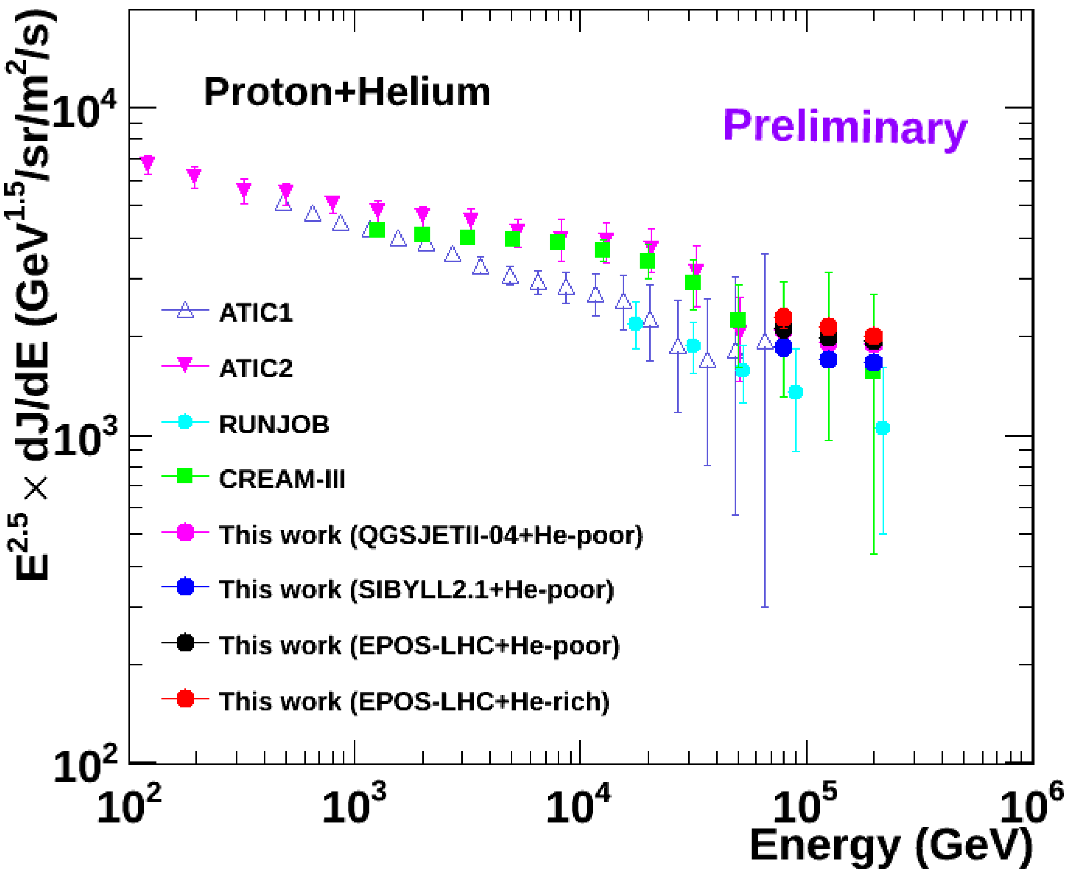
The primary energy of (P+He)-like or P-like or Helium-like events is in a good agreement with the true primary energy spectrum.



$(S\Omega)_{eff}$ calculated by MC



Results and discussions



(YAC+Tibet-III) could measure protons and heliums spectra from 50 TeV to 200TeV which is shown to be smoothly connected with direct observation data at lower energies. The results of the high energy above 200 TeV are under analysis.

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Summary

1. **YAC shows the ability and sensitivity in checking the hadronic interaction models. High energy core events are very sensitive to the light components in CRs and the core parameters of sum Nb, Nb_top, <R> and <Nb*R> are very useful to separate the light components from all the observed events using a ANN technique.**

2. **(Tibet-III+YAC) could measure (P+He) spectra from 50TeV to 200TeV which is shown to be smoothly connected with direct observation data at lower energies. The results of the high energy above 200 TeV are under analysis.**

3. **The interaction models dependence in deriving the (P+He) spectra are found to be small (less than 20%), and the composition model dependence is less than 10% in absolute intensity, and various systematic errors are under study now !**

Thank you for your attention !!