The sensitivitity expectation of LHAASO on cosmic-ray electron at energy above 1 TeV

Reporter：Wusha

Coauthor: Hehuihai, Chensongzhan, Linsujie

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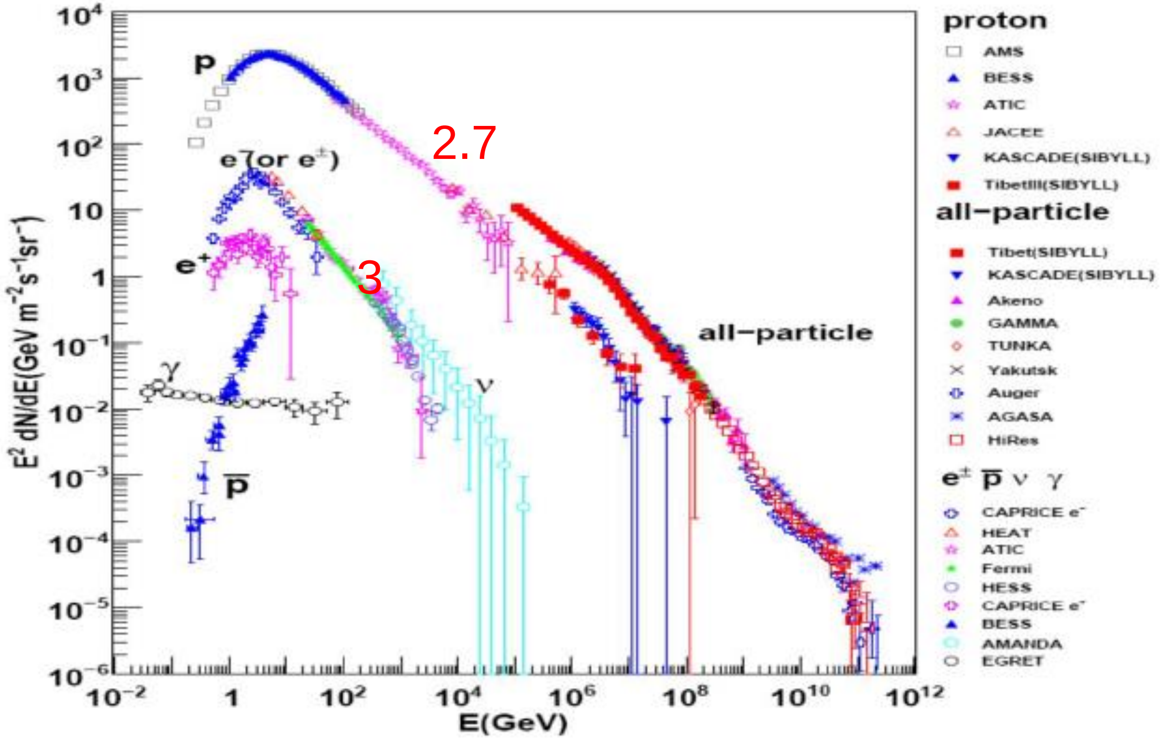
Content

1

Introduction of high energy cosmic ray electrons

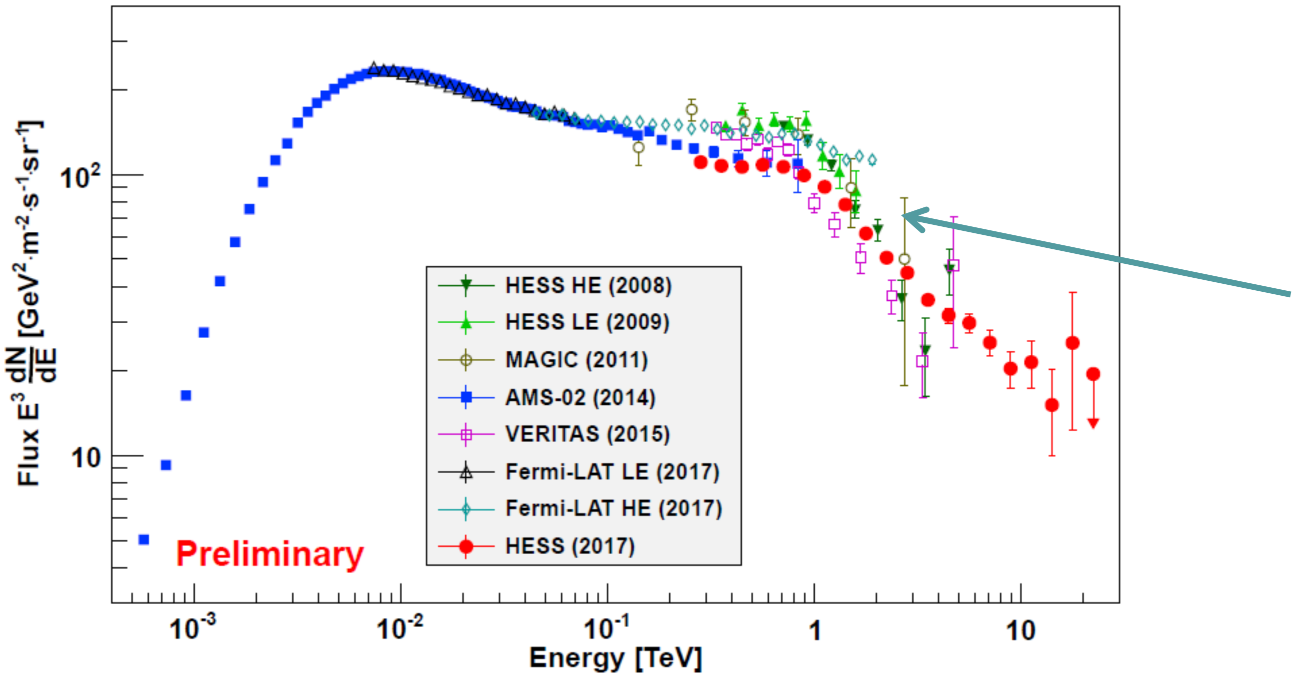
Electrons in Cosmic Ray



The $e^+ + e^-$ flux at 1 TeV is approximately **0.1%** of the flux of hadronic particles.

Above several hundred GeV, the electrons and positrons observed at Earth must originate in Galactic sources **< 1 kpc** from the solar system.

The measurement of cosmic-ray leptonic

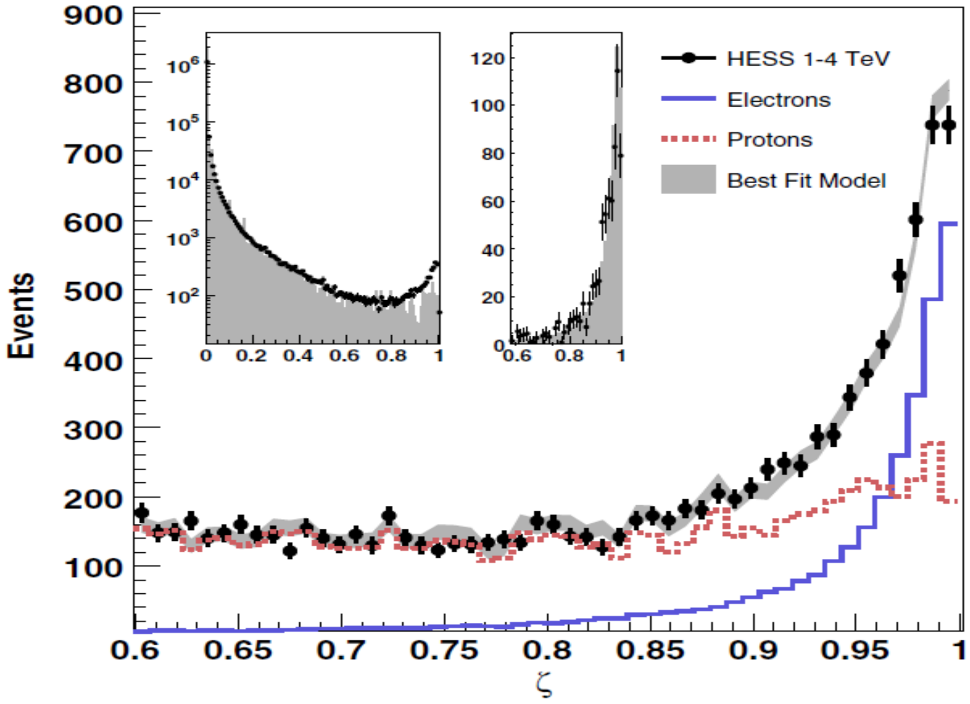


1、Below TeV
the electron-positron excess
Dark matter or astrophysical sources

2、Cut-off
1TeV cut-off
(HESS、VERITAS、DAMPE)
a single power law
(MAGIC、Fermi-LAT 5GeV-2TeV)

3、Above TeV
Local source、interesting structure (Dark matter or astrophysical sources)

Can LHAASO do it ?



HESS 2004 to 2007 Selection criteria :

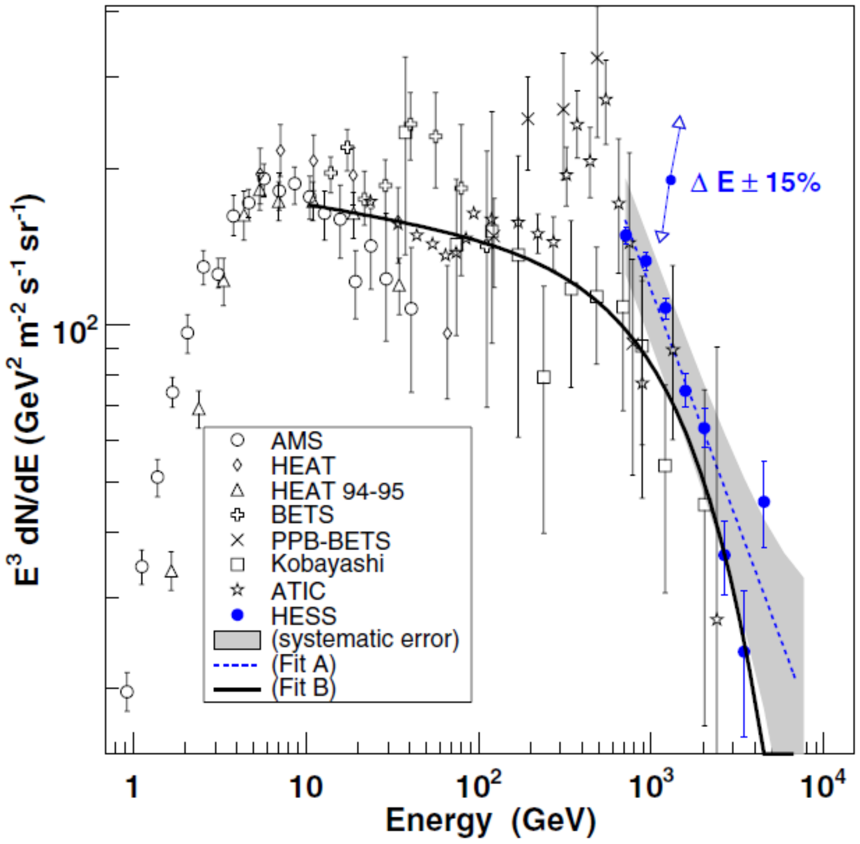
Only the central 3.0° of the field-of-view was utilized (8.6e-3)sr
239 h of live time~10 days
The effective area 5×10^4 m^2 at 1 TeV
10^{10} hadronic showers were simulated,10^{-2} of these showers trigger the array, 10^{-6} fall into the regime $\zeta > 0.9$

LHAASO one year simulation:

zenith angles smaller than 30°
The field-of-view ~8.4e-1 sr
The effective area 1×10^5 m^2 at 4TeV
The rejection efficiency of hadrons is about 1 × 10^3 at 4 TeV

DOI: 10.1103/PhysRevLett.101.261104

LHAASO can do it !



Electron:

$$\frac{\text{LHAASO one } year}{HESS\ 2004\ to\ 2007} = \frac{365}{10} \times \frac{8.4 \times 10^{-1}}{8.6 \times 10^{-3}} \times 2 \approx 7000$$

Background:

$$\frac{\text{LHAASO one } year}{HESS\ 2004\ to\ 2007} \approx 7000 \times 10 \approx 70000$$

Significance:

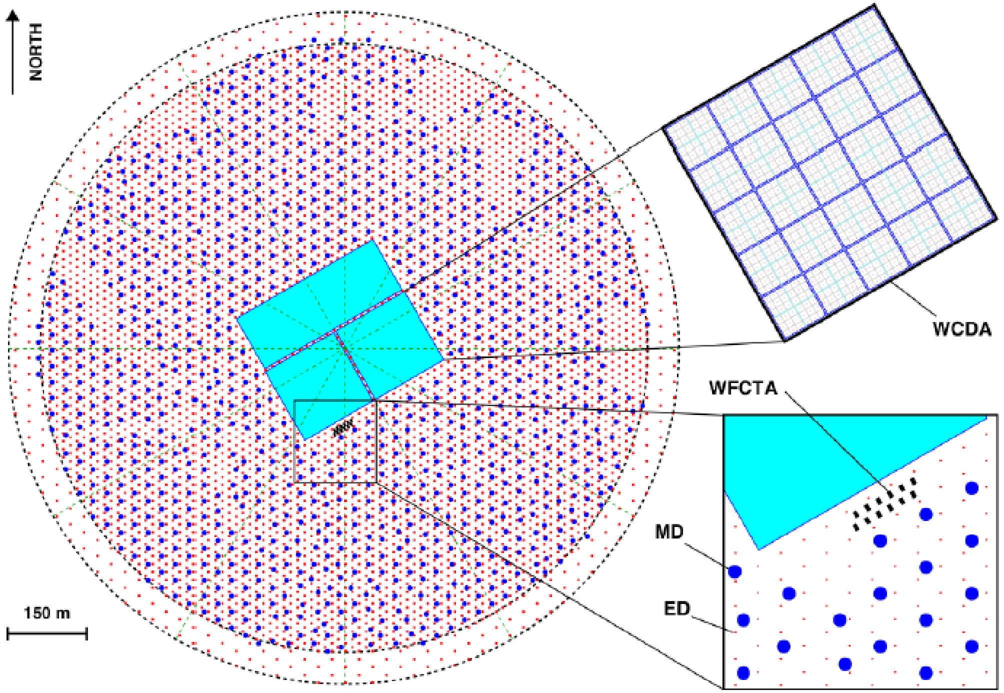
$$\frac{\text{LHAASO one } year}{HESS\ 2004\ to\ 2007} = \frac{7000}{\sqrt{70000}} \approx 26$$

DOI: 10.1103/PhysRevLett.101.261104

2

The LHAASO Detectors and Simulation

2.1. The LHAASO Detectors



- KM2A

  5195 EDs(2kHz)， 1171 MDs(6kHz)

  >5TeV (200ns&100m)

- WCDA

  150m × 150m， 900 detector(50 kHz)

  300m× 110m， 1320 detector

  100GeV - 20 TeV

- WFCTA

  12 wide-field-of-view Cherenkov telescopes

2.2. LHAASO Detector Simulation

Electron:

100GeV to 1PeV, zenith angles 0° to 60°

reweighted to measurement by AMS/HESS

Gamma-Ray Background:

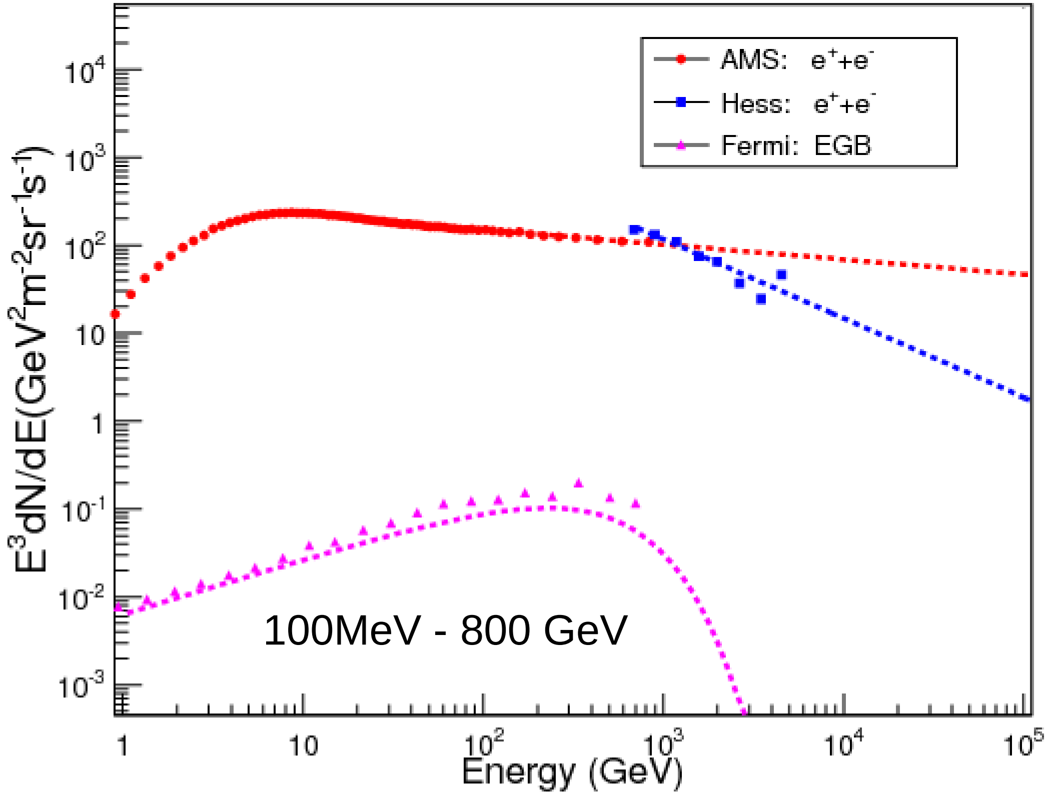
Galactic plane and potential gamma-ray sources are excluded.

diffuse extragalactic gammas is ignored

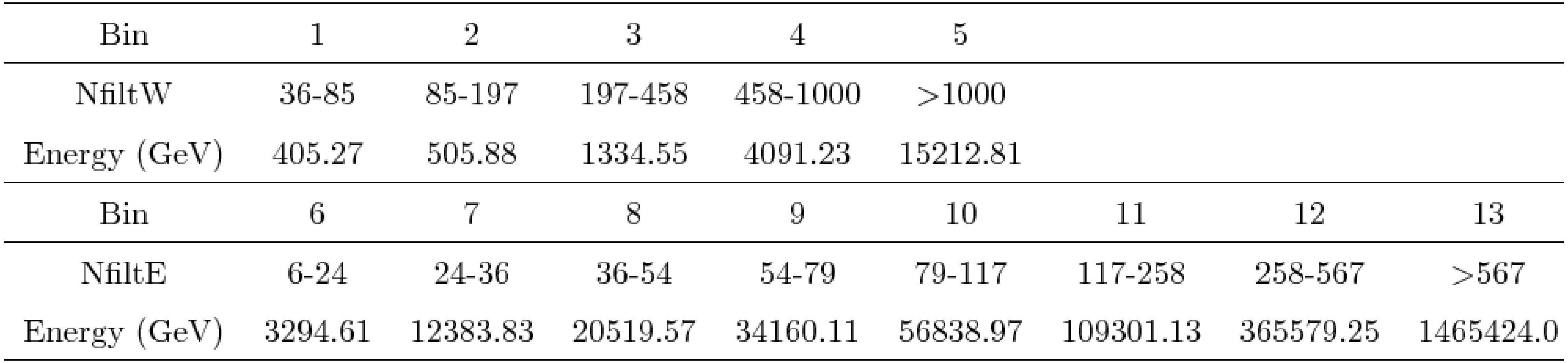
Hadronic Background:

proton,100GeV to 1PeV, zenith angles 0° to 60°

reweighted to all particle flux derived by Gaisser



2.2. LHAASO Detector Simulation

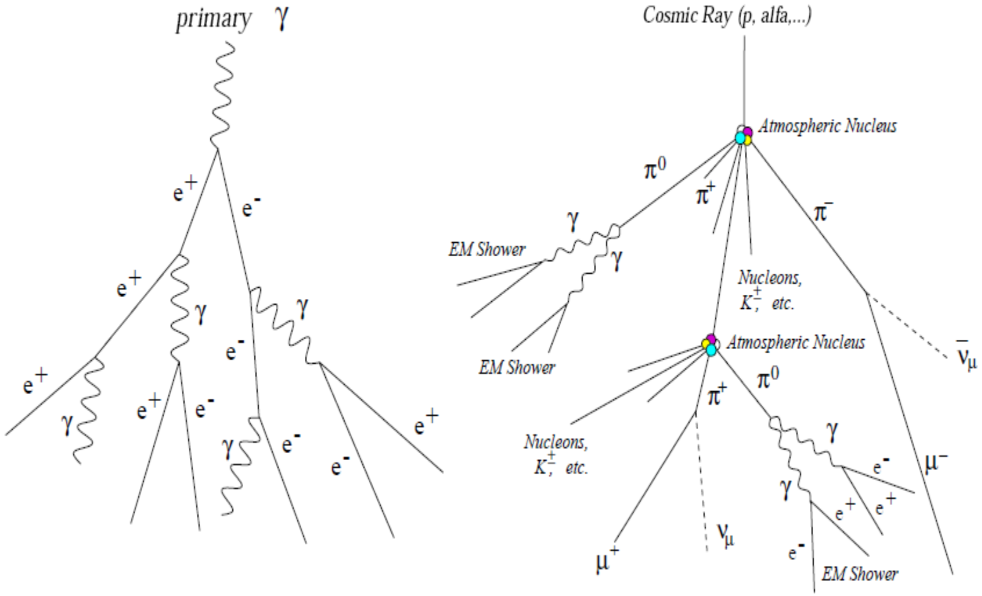


Bin	1	2	3	4	5			
NfiltW	36-85	85-197	197-458	458-1000	>1000			
Energy (GeV)	405.27	505.88	1334.55	4091.23	15212.81			
Bin	6	7	8	9	10	11	12	13
NfiltE	6-24	24-36	36-54	54-79	79-117	117-258	258-567	>567
Energy (GeV)	3294.61	12383.83	20519.57	34160.11	56838.97	109301.13	365579.25	1465424.0

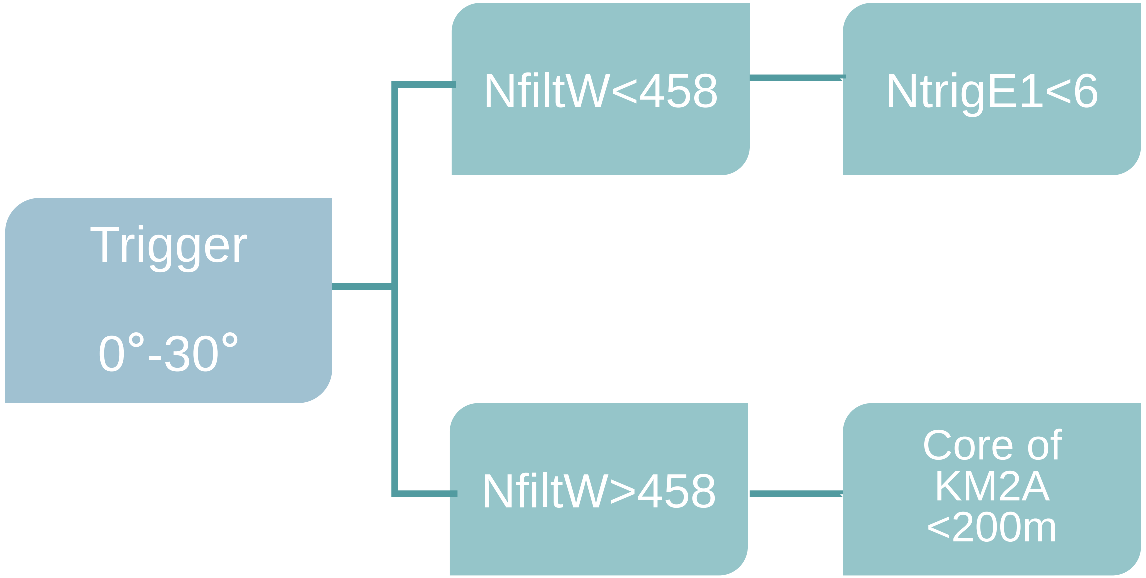
3

Electron-Hadron Separation

3.1. Electron-Hadron Separation in WCDA



Selection criteria :



Trigger

0°-30°

NfiltW<458

NtrigE1<6

NfiltW>458

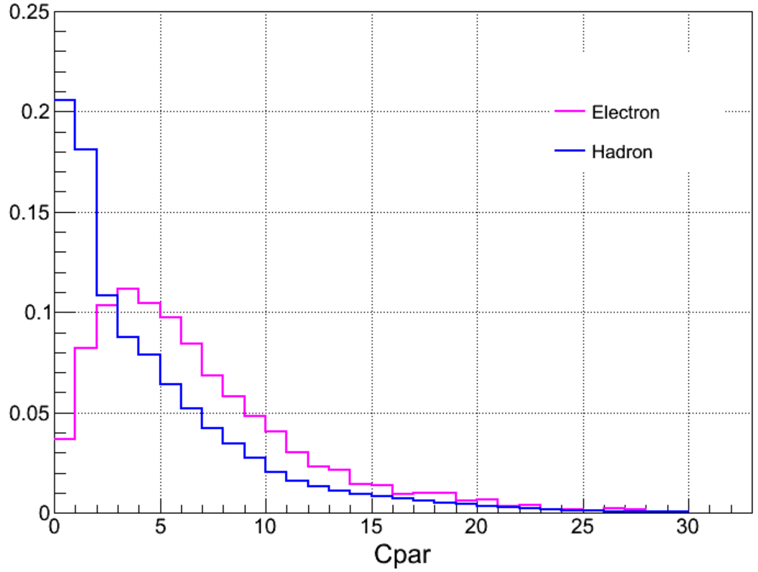
Core of KM2A <200m

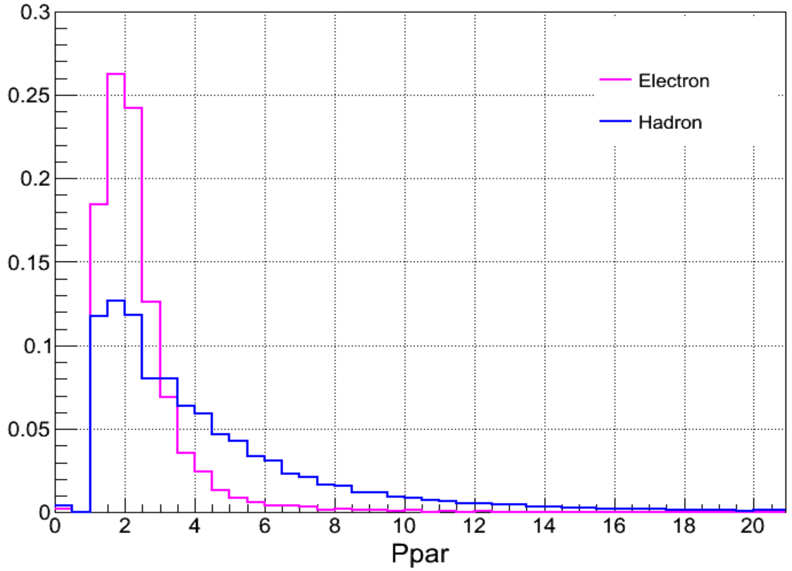
3.1. Electron-Hadron Separation in WCDA

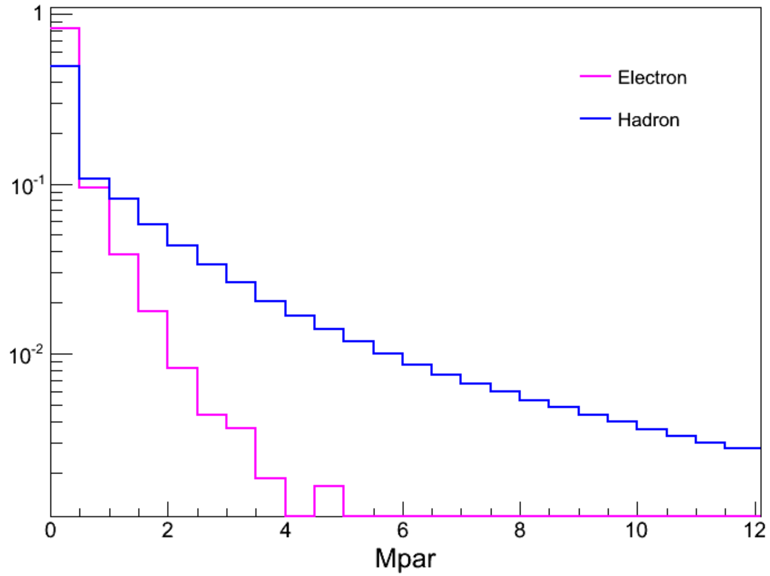
$$C_{par} = \frac{nFit}{cxPE_{45}}$$

$$P_{par} = \frac{\sum PE_{40}}{\sum PMT_{40}}$$

$$Mpar$$







Wenying Liao et al ,2017,ICRC

3.2. Electron-Hadron Separation in KM2A

- spacetimefilter
- planarfit, core_centre,
- noisefilter dt [-50,200]ns
- conicalfit, core_NKG
- MD : N_μ, ED : N_e

KM2A:rec_core
rec_theta

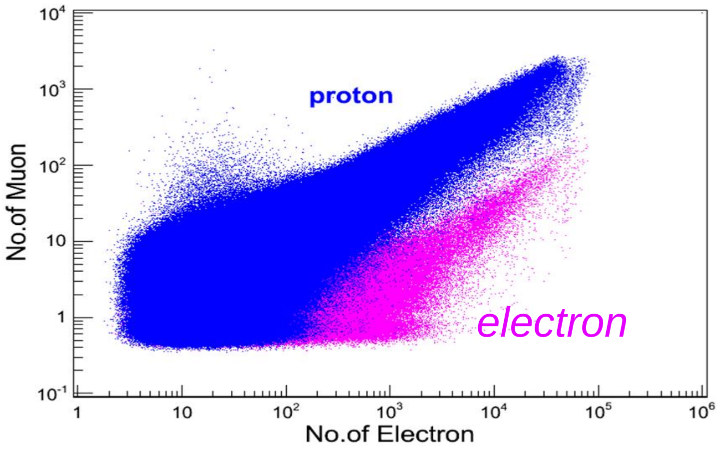
1 filter out the WCDA detectors away from the KM2A shower front

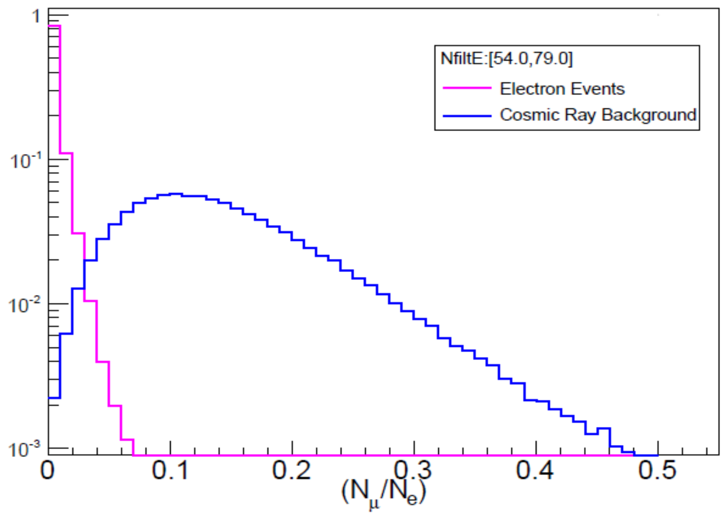
2 Electron-Hadron Separation:
Pe_{max} , Mpar

Selection criteria :

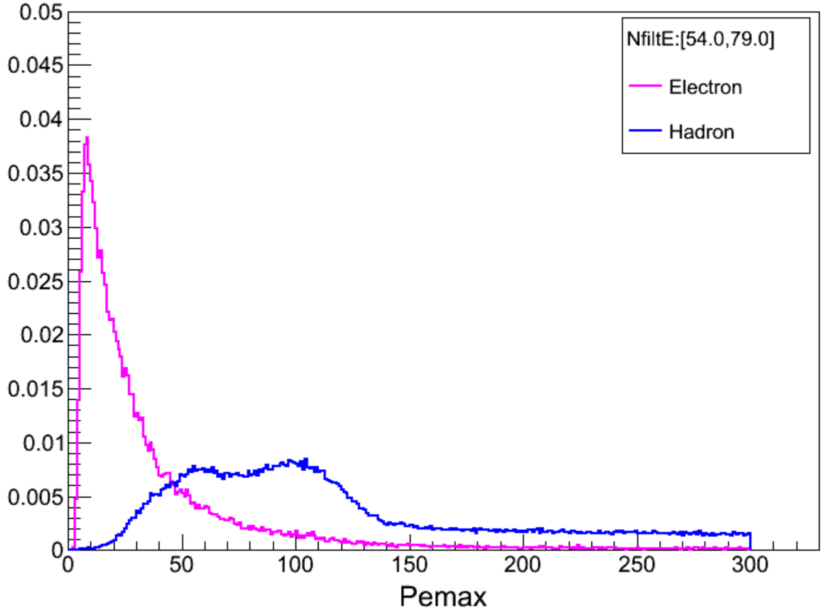
300ns&100m NtrigE>=6
rec_Etheta_c:[0°,30°]
Core:[200m,575m]

3.2. Electron-Hadron Separation in KM2A

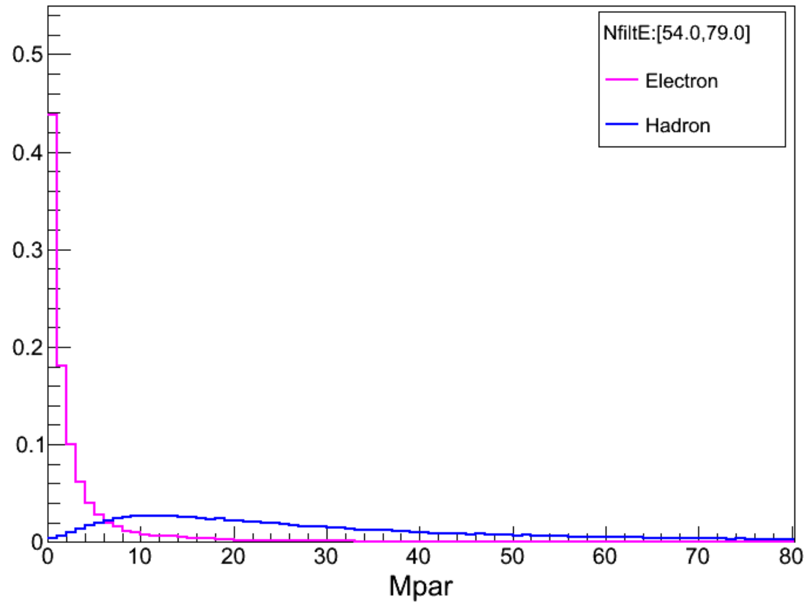




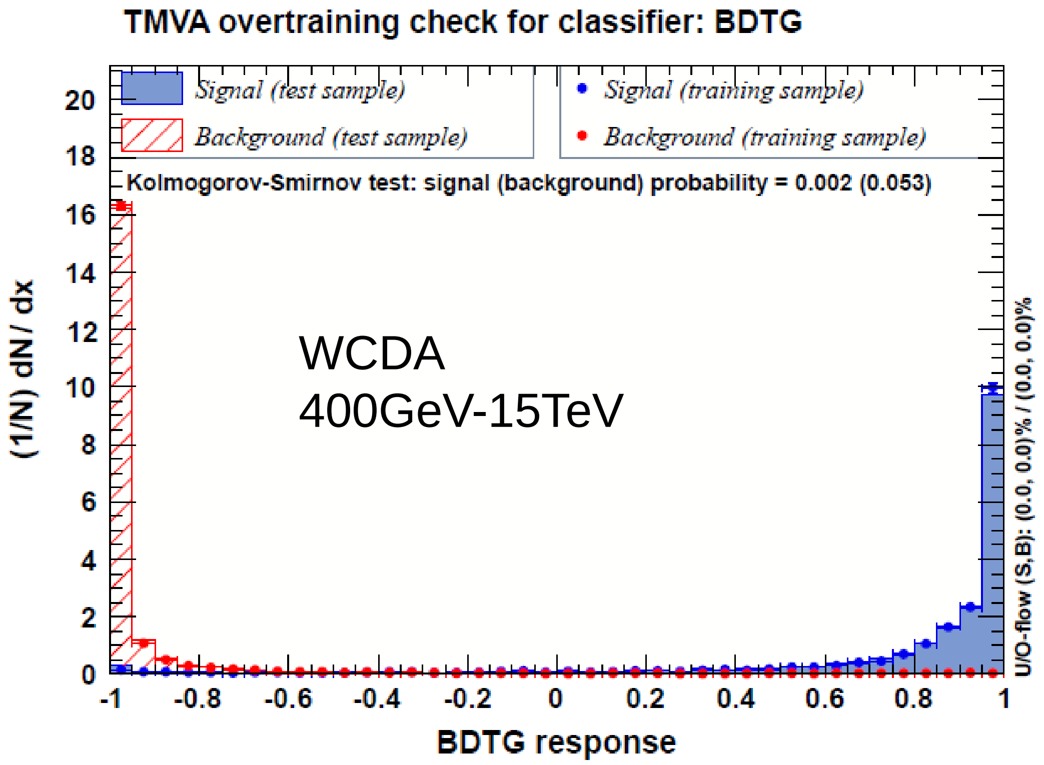
$Pe_{\max}$

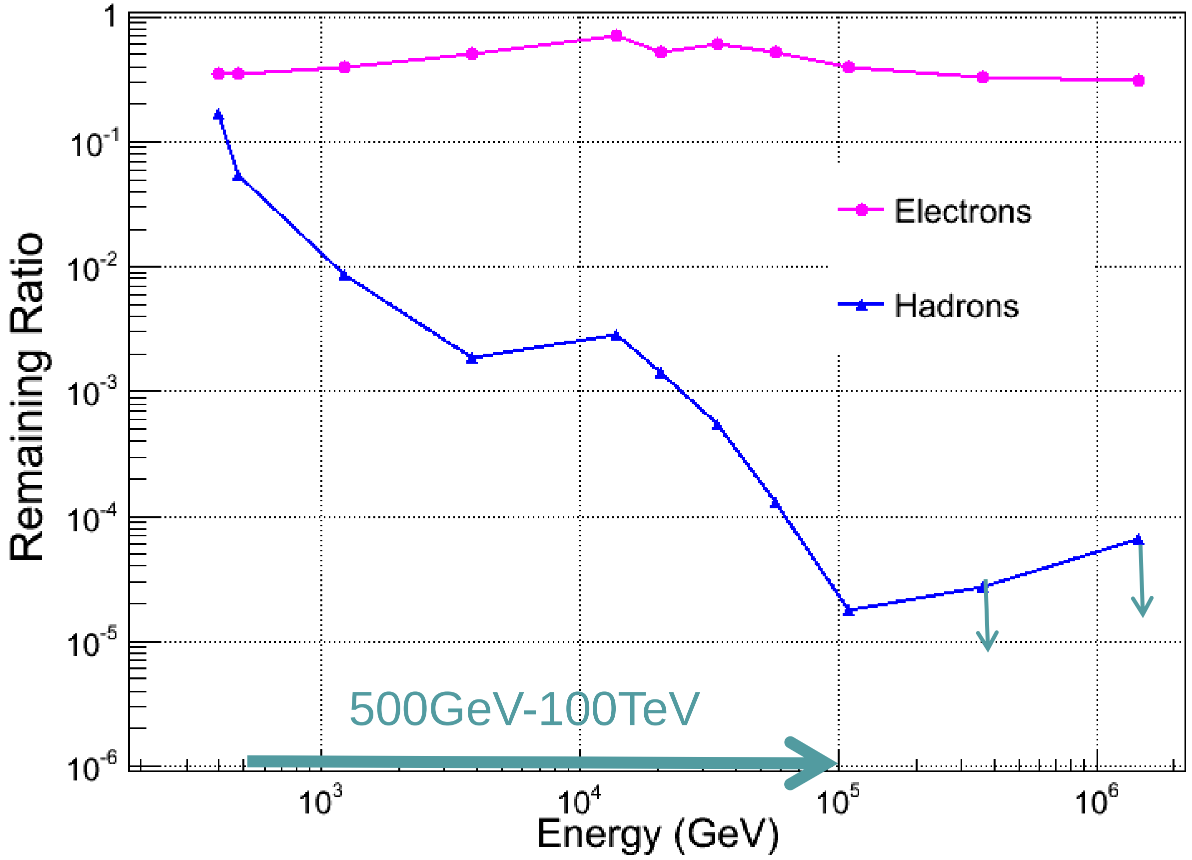


$Mpar$



Electron-Hadron Separation



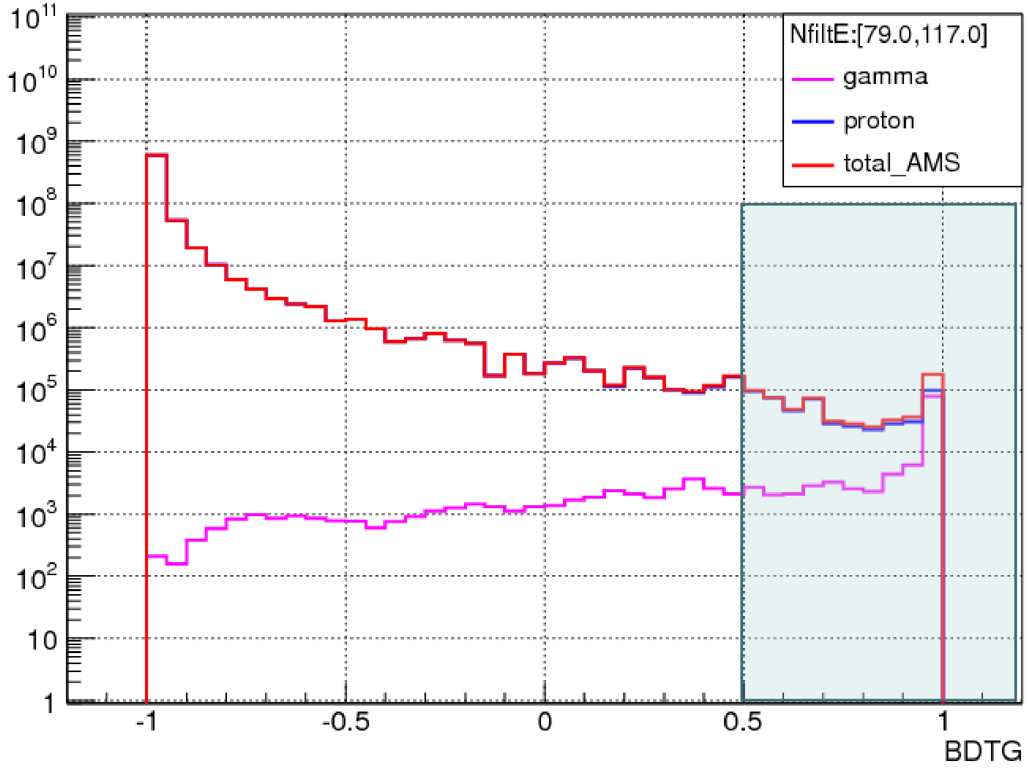


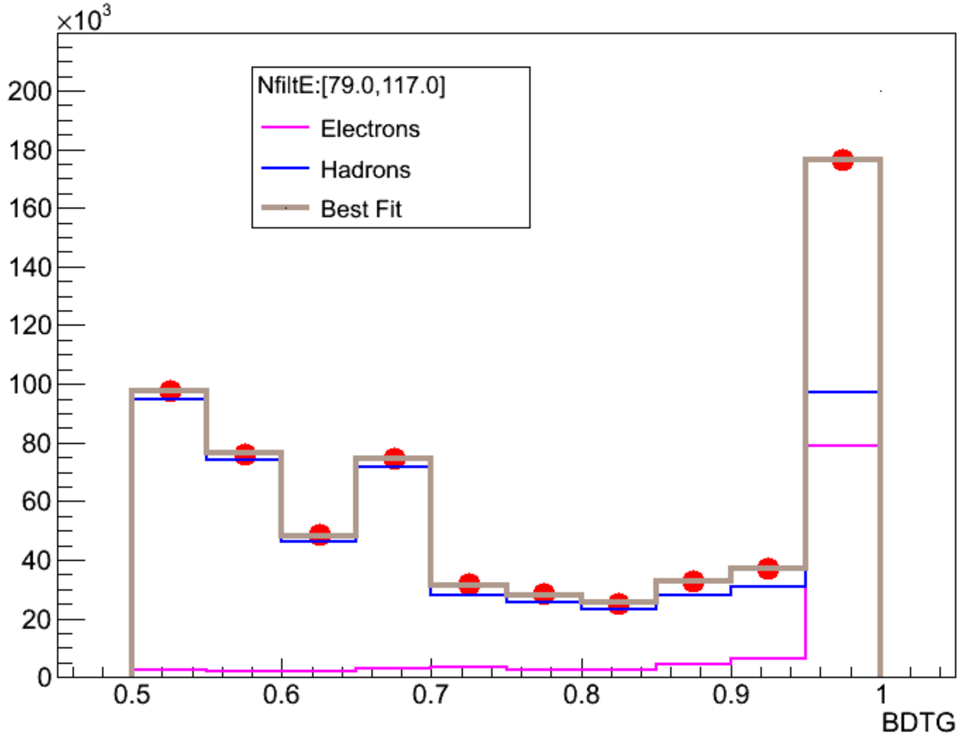
4

Result

4.1 Expect the Sensitivity of LHAASO for CREs

$$N_{t,i} = \mathrm{Poisson}(\mathrm{N}_{\mathrm{e,i}} + N_{p,i})$$





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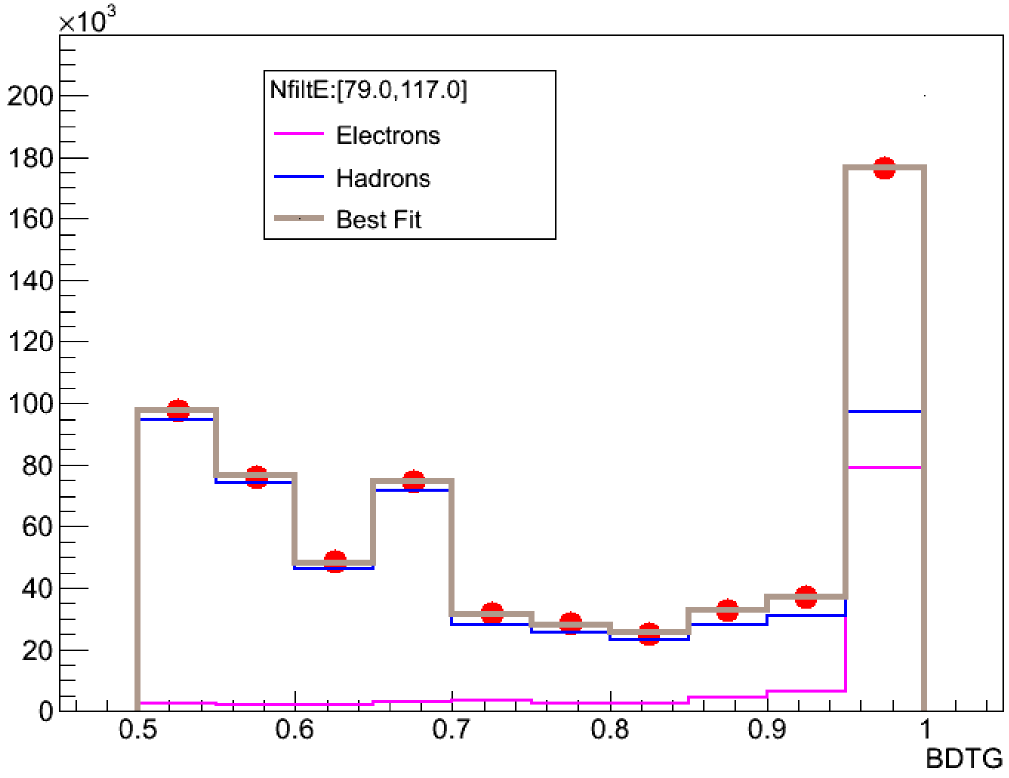
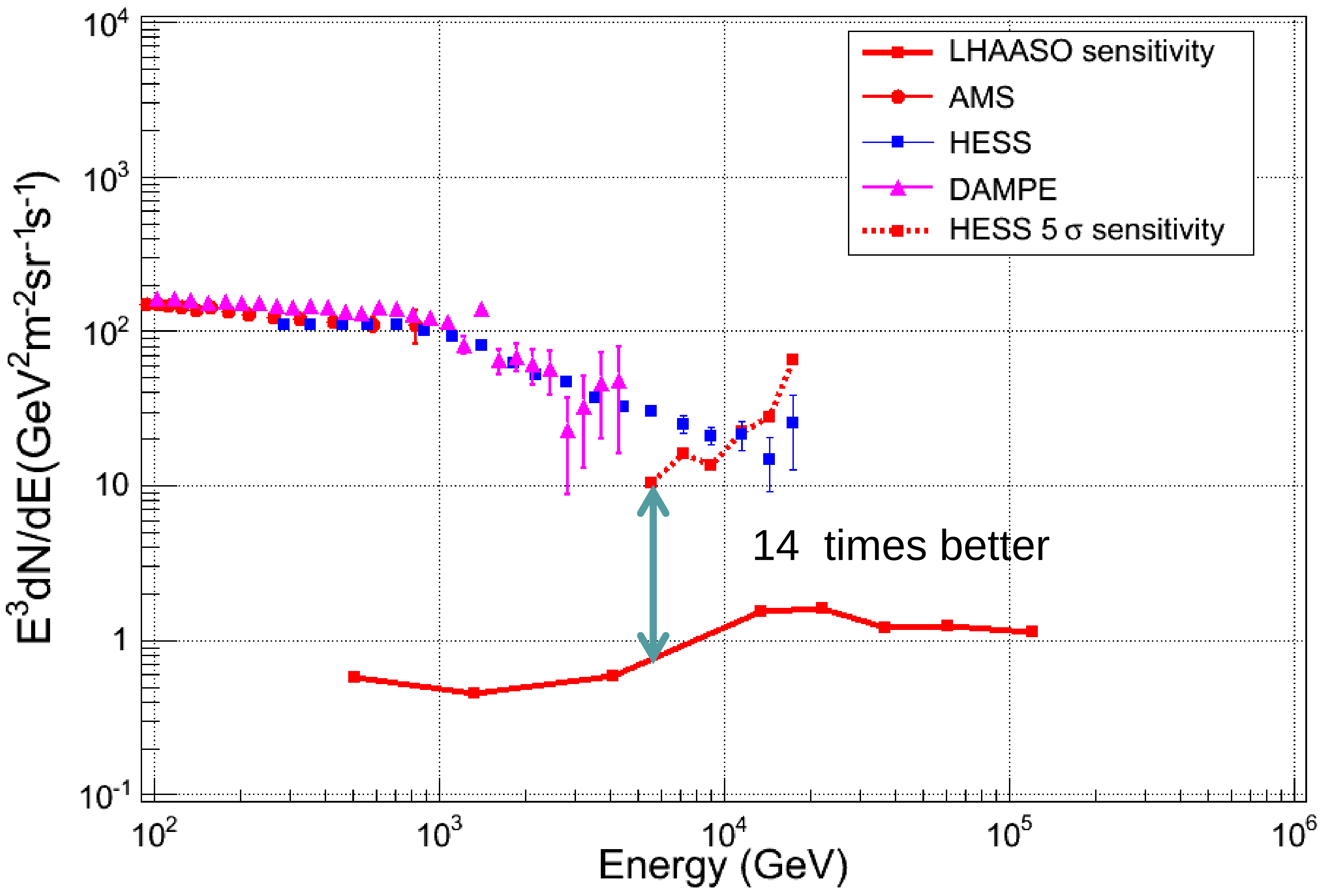


$$\xi = \frac{\sum N_{e,i}}{\sum N_{t,i}}$$

$$\chi^2 = \sum_{bins} \left(\frac{N_{t,i} - [\xi \sum N_{t,i} \frac{N_{e,i}}{\sum N_{e,i}} + (1-\xi) \sum N_{t,i} \frac{N_{p,i}}{\sum N_{p,i}}]}{\sigma_i} \right)^2$$

FCN	ξ	error	sig
5.70	1.71e-1	1.01e-3	1.69e2

4.1 Expect the Sensitivity of LHAASO for CREs



4.2 The expectant anisotropy spectrum of CREs

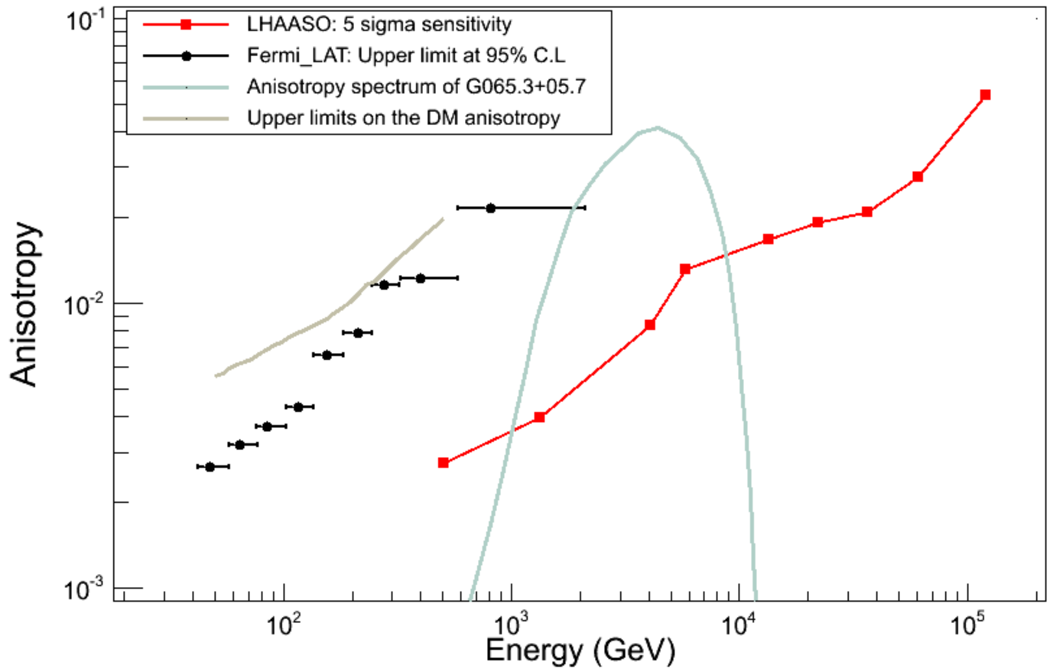
Suppose N±△ N is the number of particles

The minimum detectable anisotropy at n sigma is simply $\delta_{0,n\sigma} = n\Delta N/N.$

$$\delta_{e+p} = n / \sqrt{\sum N_{t,i}}$$

$$N_e = \xi \sum N_{t,i} \qquad N_{\mathrm{p}} = (1-\xi) \sum N_{t,i}$$

$$\delta_e = \frac{N_e + N_p}{N_e} \delta_{e+p}$$



Kun Fang et al, arXiv:1706.03745v1

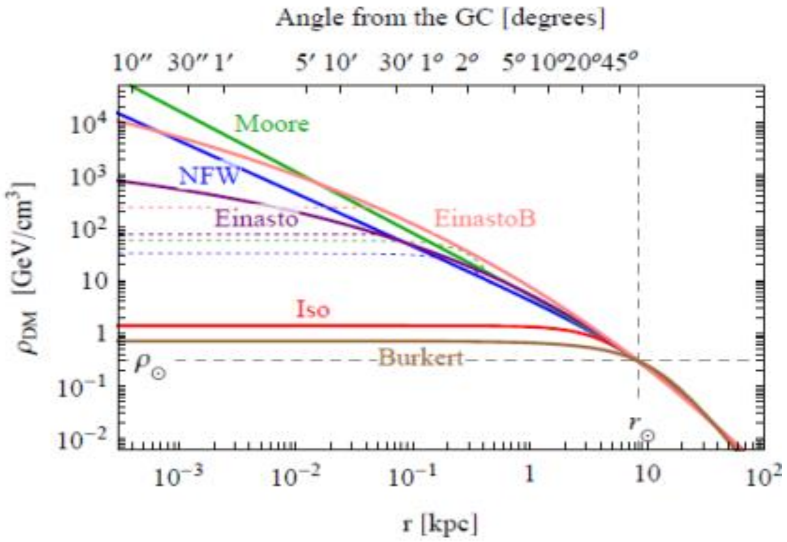
4.3 The limits on the annihilation cross section and decay lifetime

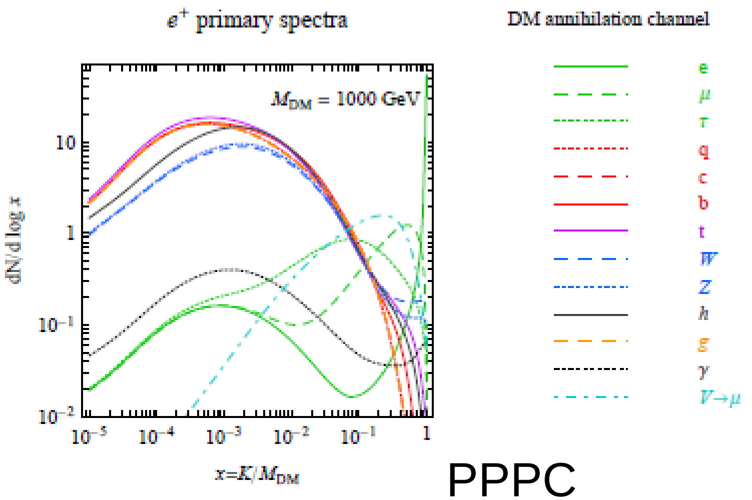
$$\frac{d\Phi_{e^\pm}}{dE}(E,\vec{x}) = \frac{v_{e^\pm}}{4\pi\, b(E,\vec{x})} \begin{cases} \frac{1}{2}\left(\frac{\rho(\vec{x})}{M_{\rm DM}}\right)^2 \sum_f \langle\sigma v\rangle_f \int_E^{M_{\rm DM}} dE_{\rm s}\, \frac{dN^f_{e^\pm}}{dE}(E_{\rm s})\, I(E,E_{\rm s},\vec{x}) & \text{(annihilation)} \\ \left(\frac{\rho(\vec{x})}{M_{\rm DM}}\right) \sum_f \Gamma_f \int_E^{M_{\rm DM}/2} dE_{\rm s}\, \frac{dN^f_{e^\pm}}{dE}(E_{\rm s})\, I(E,E_{\rm s},\vec{x}) & \text{(decay)} \end{cases}$$

The profiles of DM :NFW , 0.4GeV/cm^3

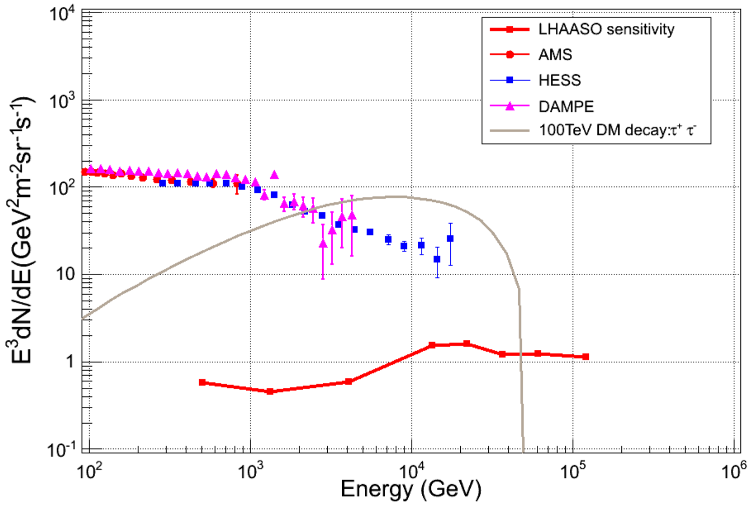
$$\frac{dN_e}{dE}$$

Propagation arxiv:1701.06149





PPPC



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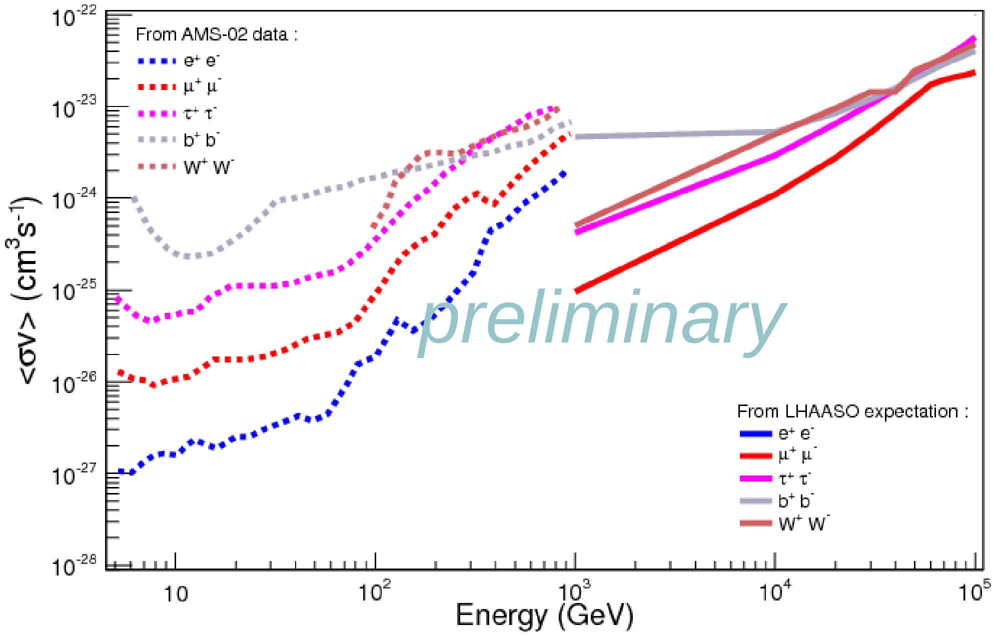

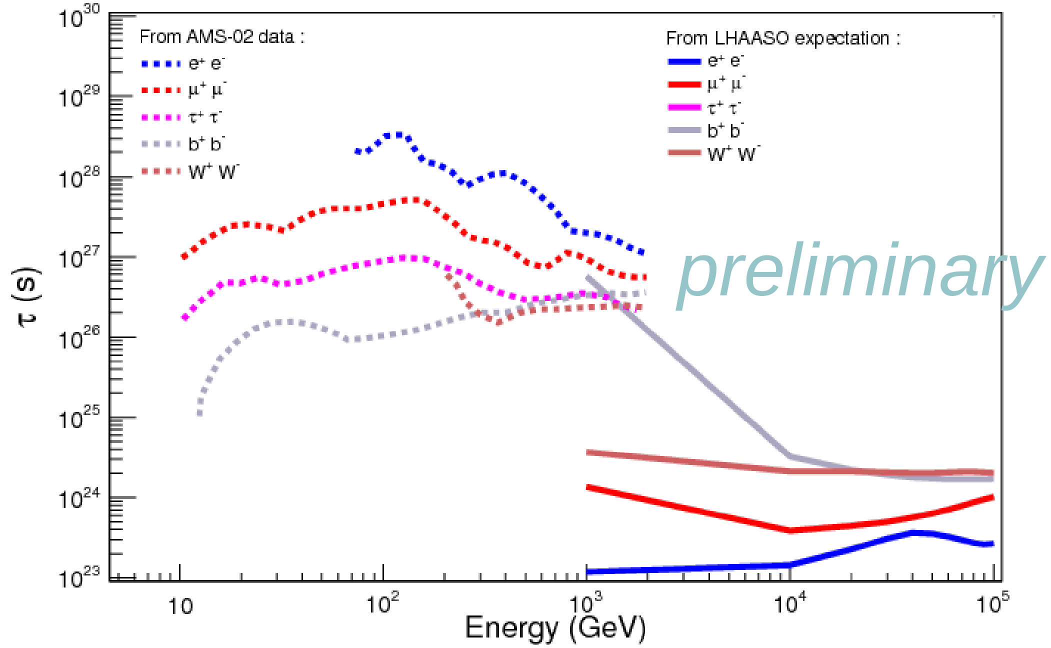

5 Conclusion

- With high electron-hadron discrimination capability, LHAASO may realize direct measurement of the CREs flux.

- LHAASO would provide a powerful distinction of different scenarios for cosmic ray electrons at energy above 1 TeV.

- LHAASO has the the potential to give limits on the dark matter model.

Thank you!