DAMPE mission Introduction

Chinese Academy of Science

DAMPE International Collaboration Team

China:

Purple Mountain Observatory, CAS

Institute of High Energy of Physics, CAS

Institute of Modern Physics, CAS

National Space Science Center,CAS

University of Science and Technology of China

Swiss:

Geneva University

Italy:

I.N.F.N. Sez. di Perugia, Perugia University

I.N.F.N. Sez. di Bari, Bari University

DAMPE Observation

- Electron:2GeV-10TeV
- Gamma-rays:2GeV-10TeV
- Proton and Heavy Ions:30GeV-1000TeV

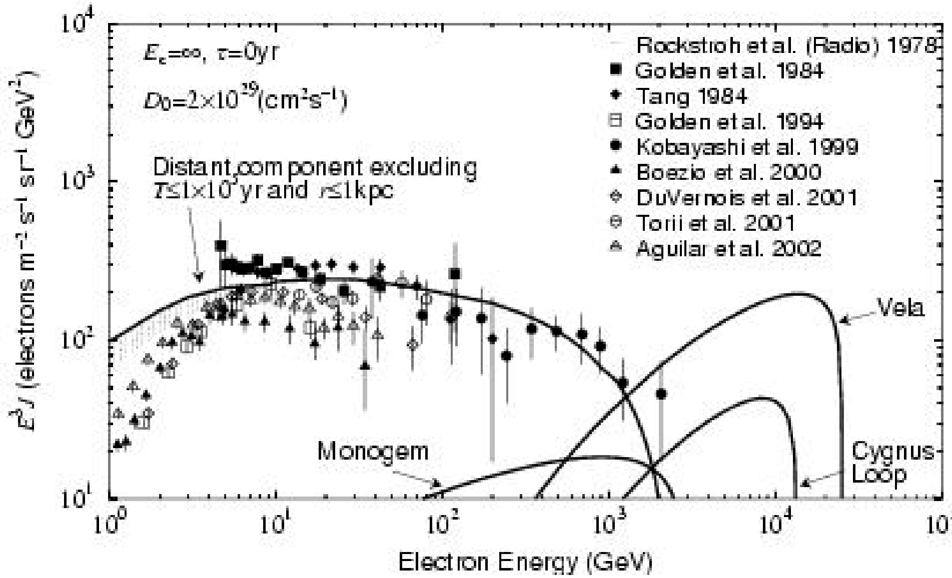
Scientific Objectives

Science Objectives	Observation Targets
Nearby Cosmic-ray Sources	Electron spectrum in trans-TeV region
Dark Matter	Signatures in electron/gamma energy spectra in 10GeV – 10 TeV region
Origin and Acceleration of Cosmic Rays	p-Fe above 30 GeV
Cosmic –ray Propagation in the Galaxy	B/C ratio up to several TeV /n
Gamma-ray Transients	Gamma-ray time profile
Gamma-ray Astronomy	Gamma-ray mapping

Nearby Cosmic-ray Sources

Trans-TeV electron spectrum observation

High energy electron lost energy ∝ $1/E^2$
Local TeV electrons:
Age < ~10^5 years, Distance < 1 kpc
Local TeV electrons → Vela, Monogem, Cygnus Loop



Electron spectrum depending on Vela and Cygnus Loop
Kobayashi, 1210.2813

Cosmic –ray Propagation in the Galaxy

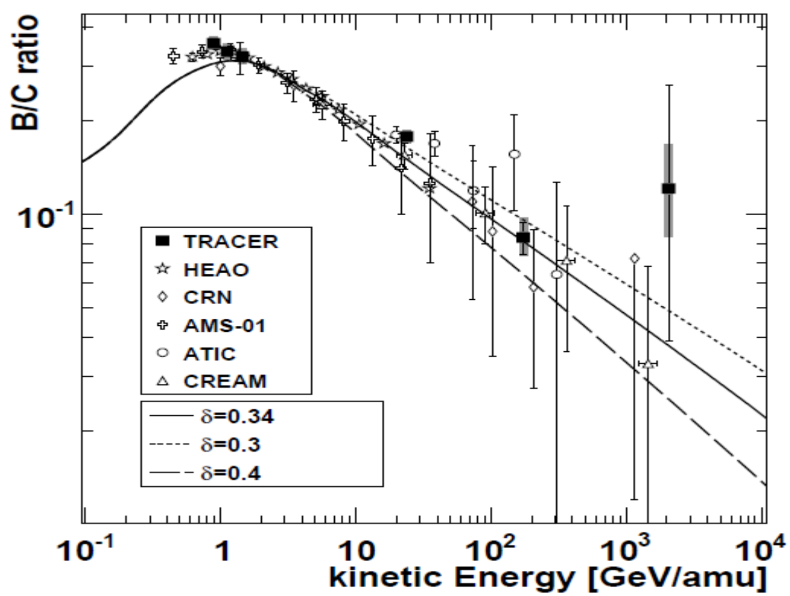
B/C ratio observation

- **B/C ratio: Secondary/Primay**

CNO+ISM→B

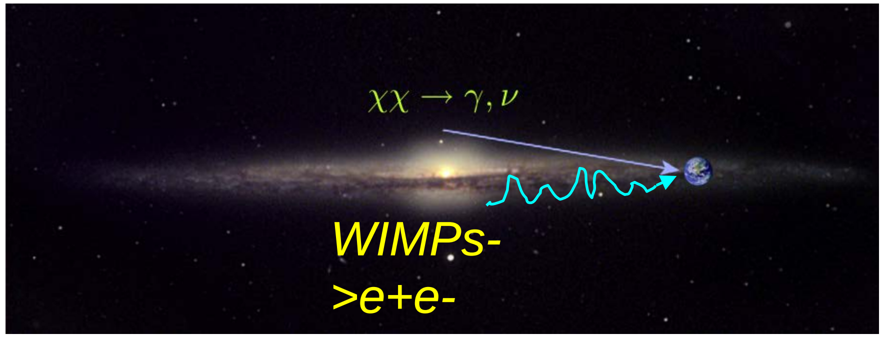
$N_B/N_C \propto \lambda_{esc} * \sigma_{CNO \rightarrow B}$

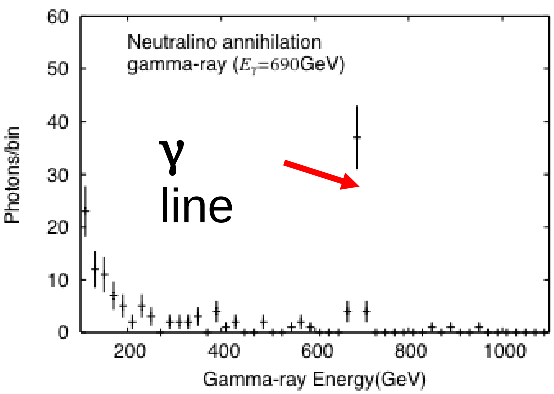
→Propagation in the Galaxy

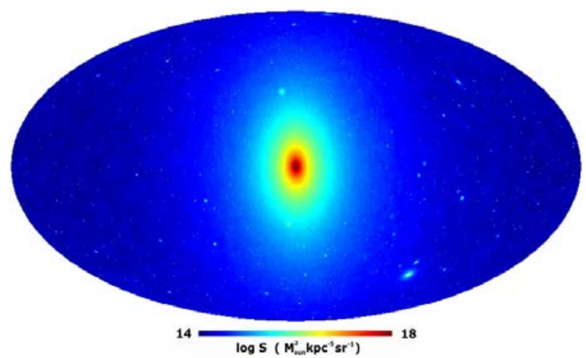


Dark Matter

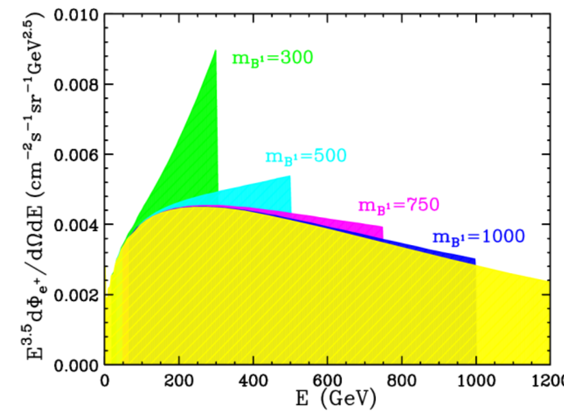
Signals in e&γ spectrum & space distribution







γ – ray Halo



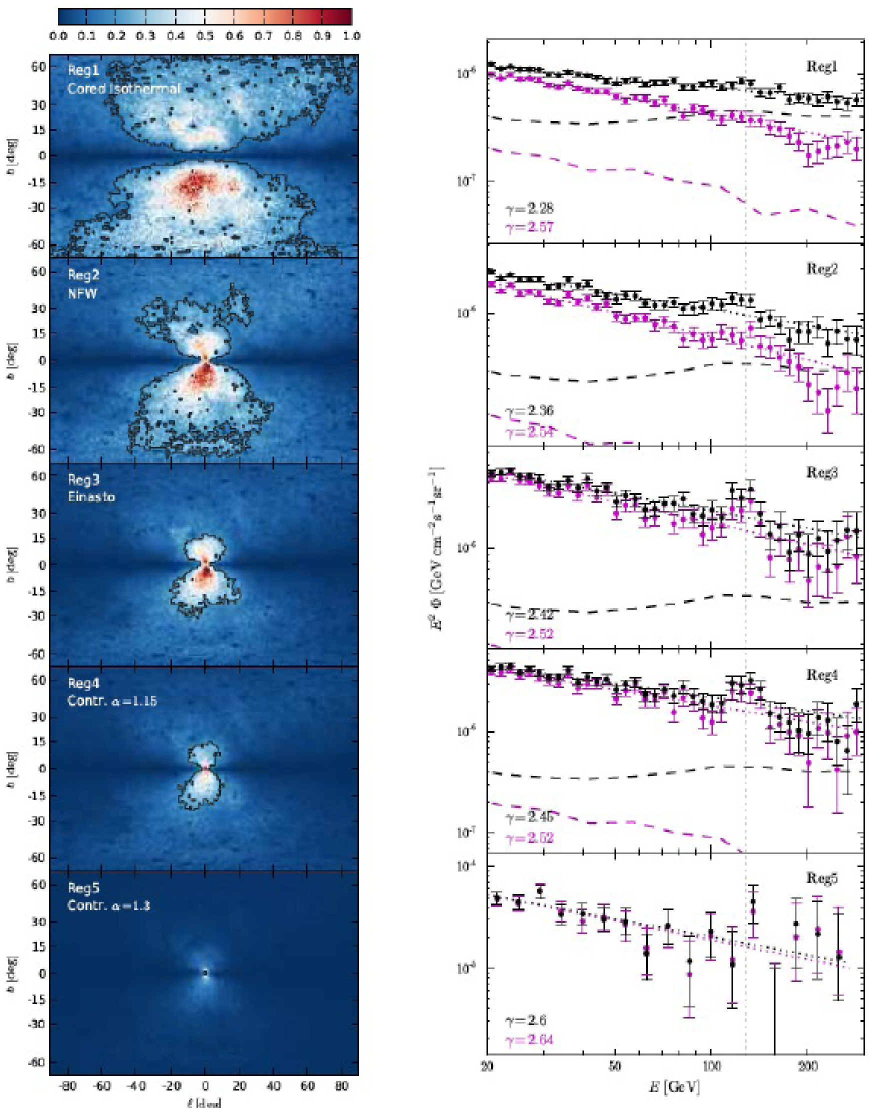
Cut-off in e^+ and e^-

These signals are smoking gun of dark matter particle

Present Observation

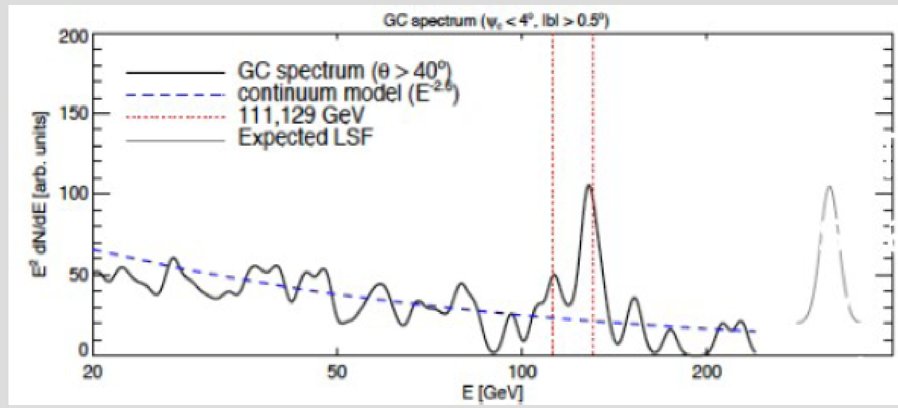
A gamma line at the GC?

Meng Su



Optimize search region around Galactic center based on signal-to-noise ratio for different dark matter halo models.

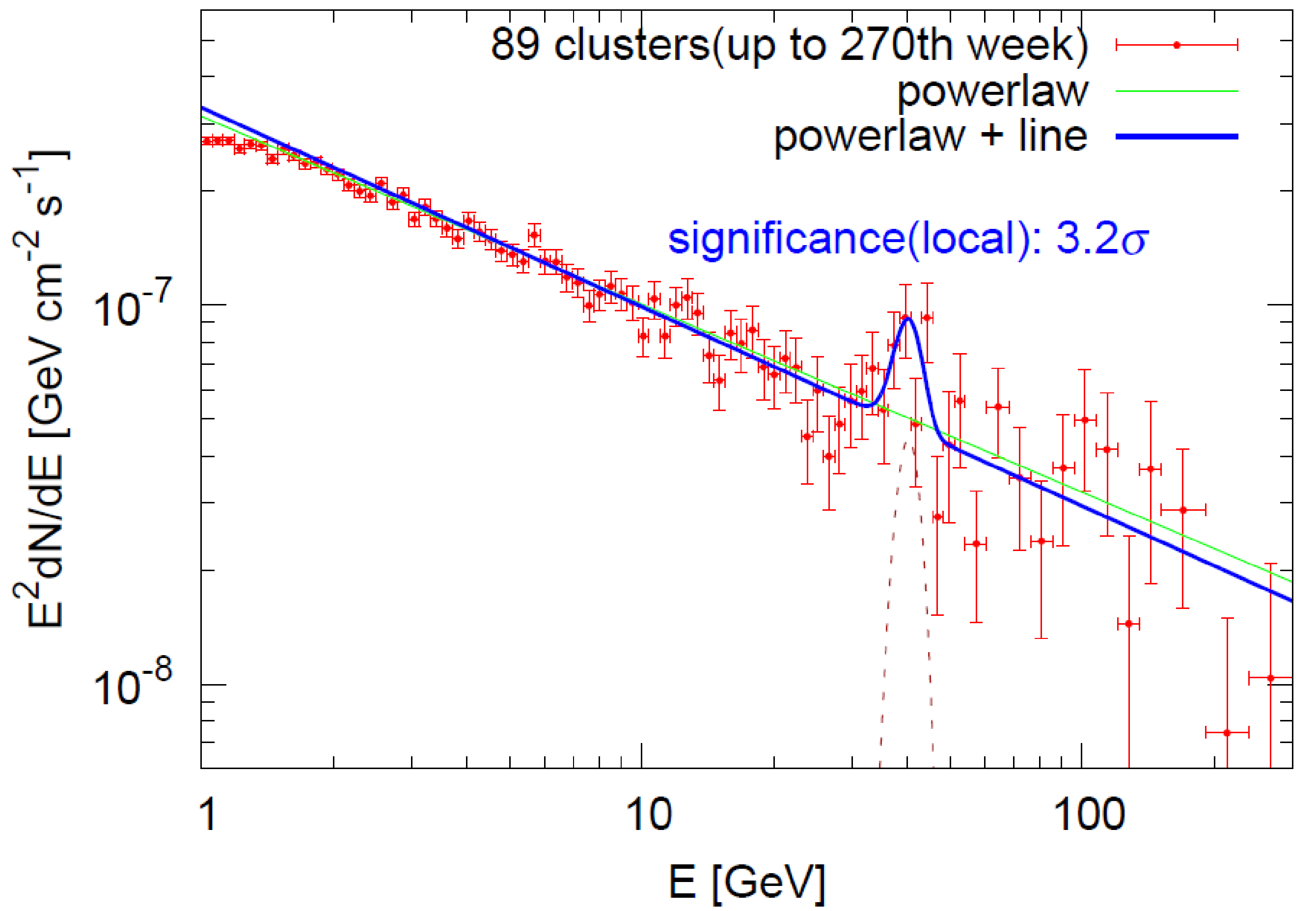
→ find excess in Galactic center around 110 GeV and 130 GeV



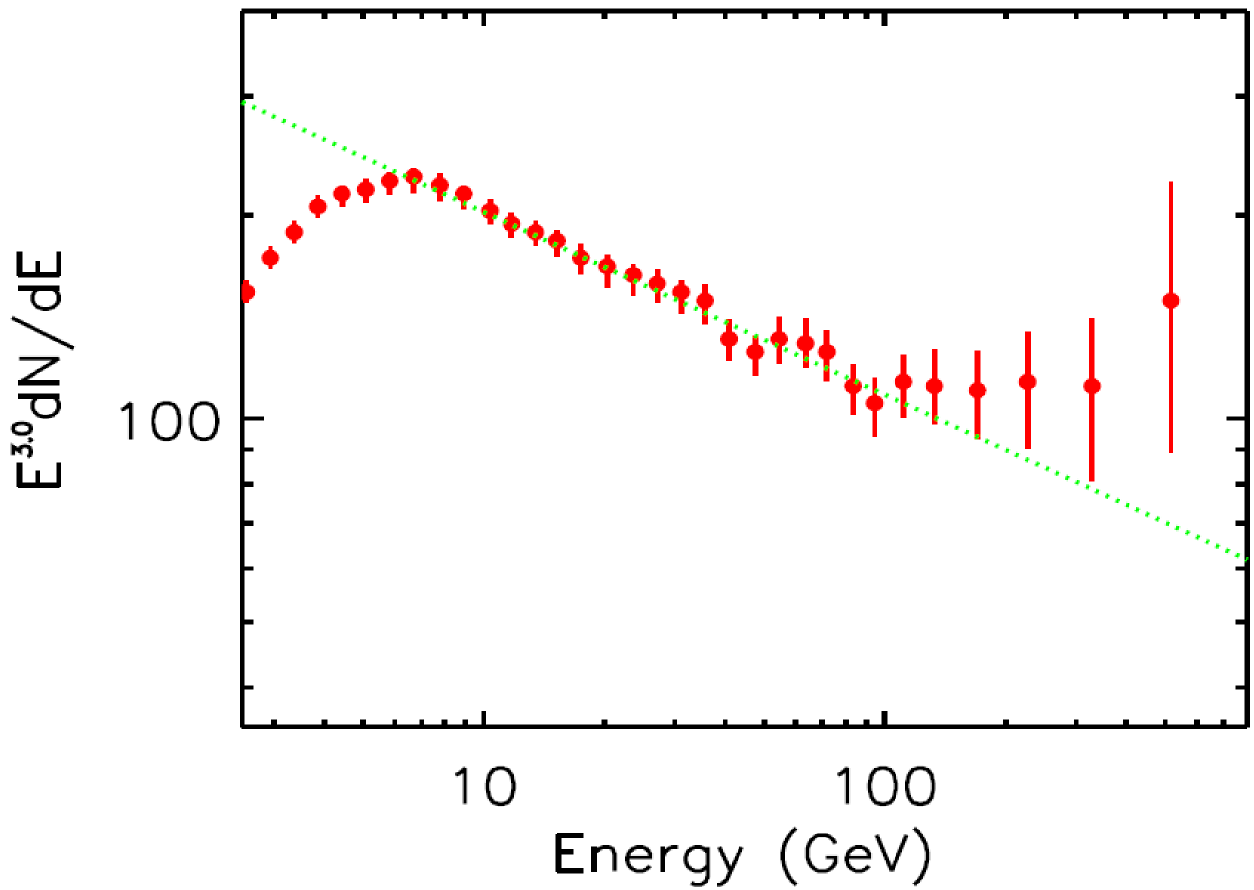
An offset-DM + Einasto model fits the data best:

6.6σ local, 5.1σ global significance

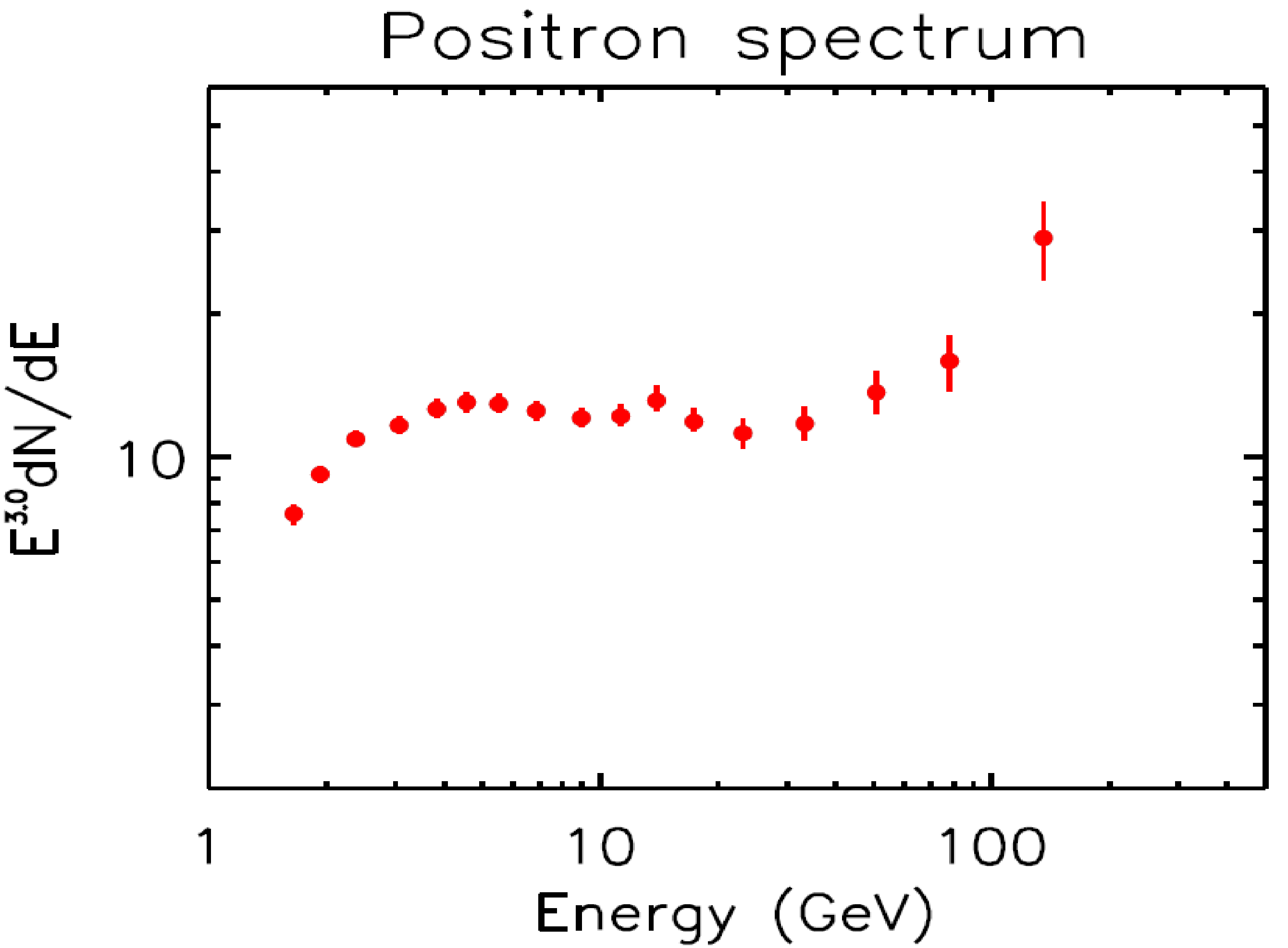
Gamma-ray line in Clusters?



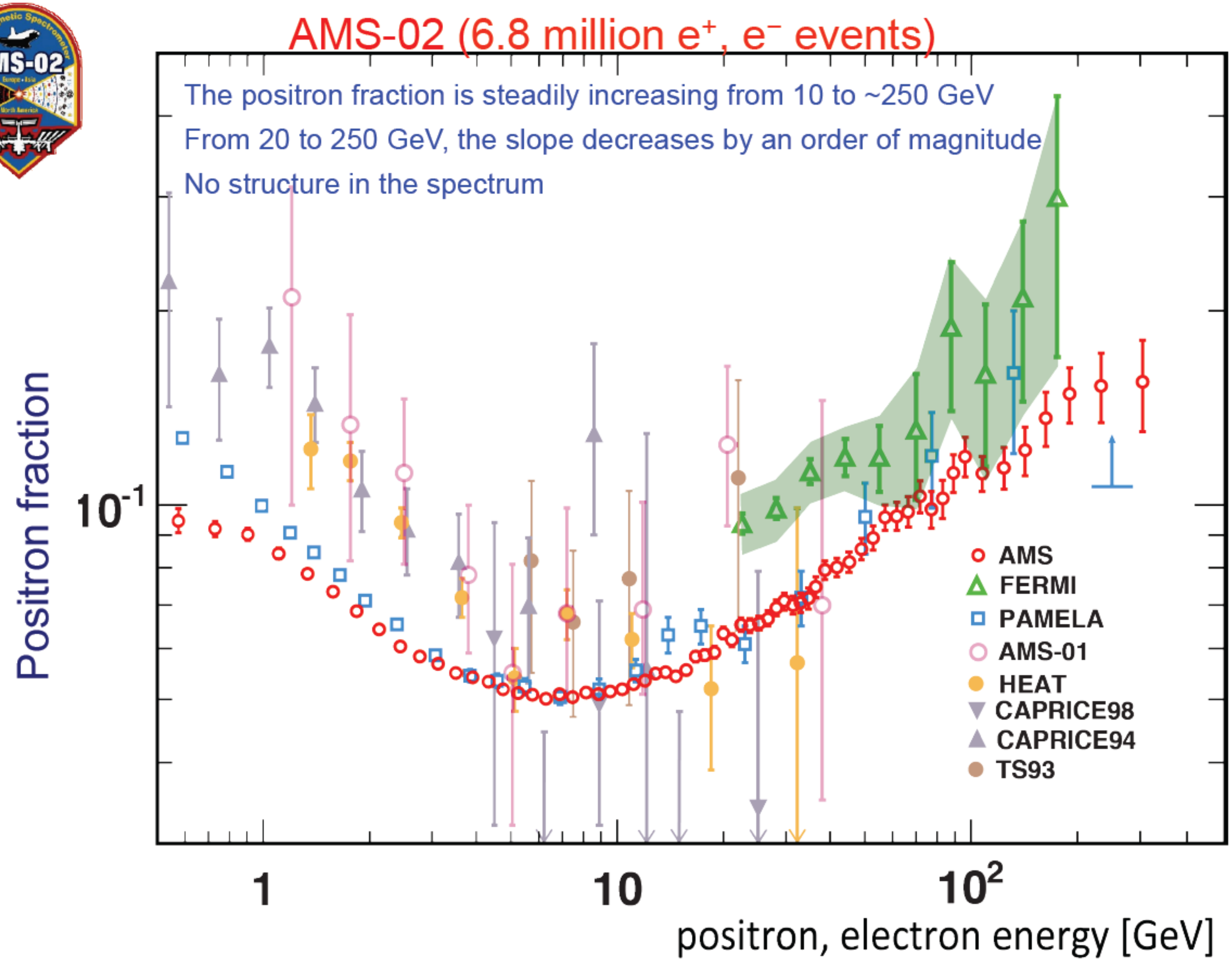
PAMELA 7 year e$^-$ Observation



PAMELA 7 year e^+ Observation

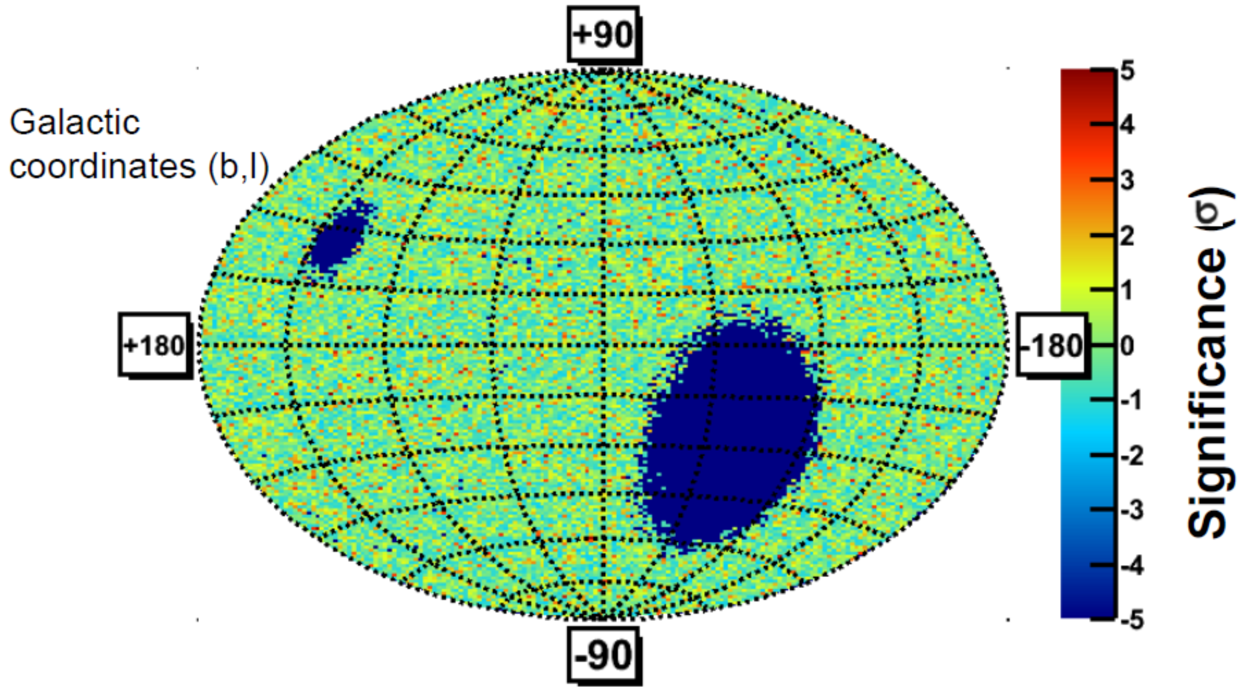


AMS02 e^+ fraction



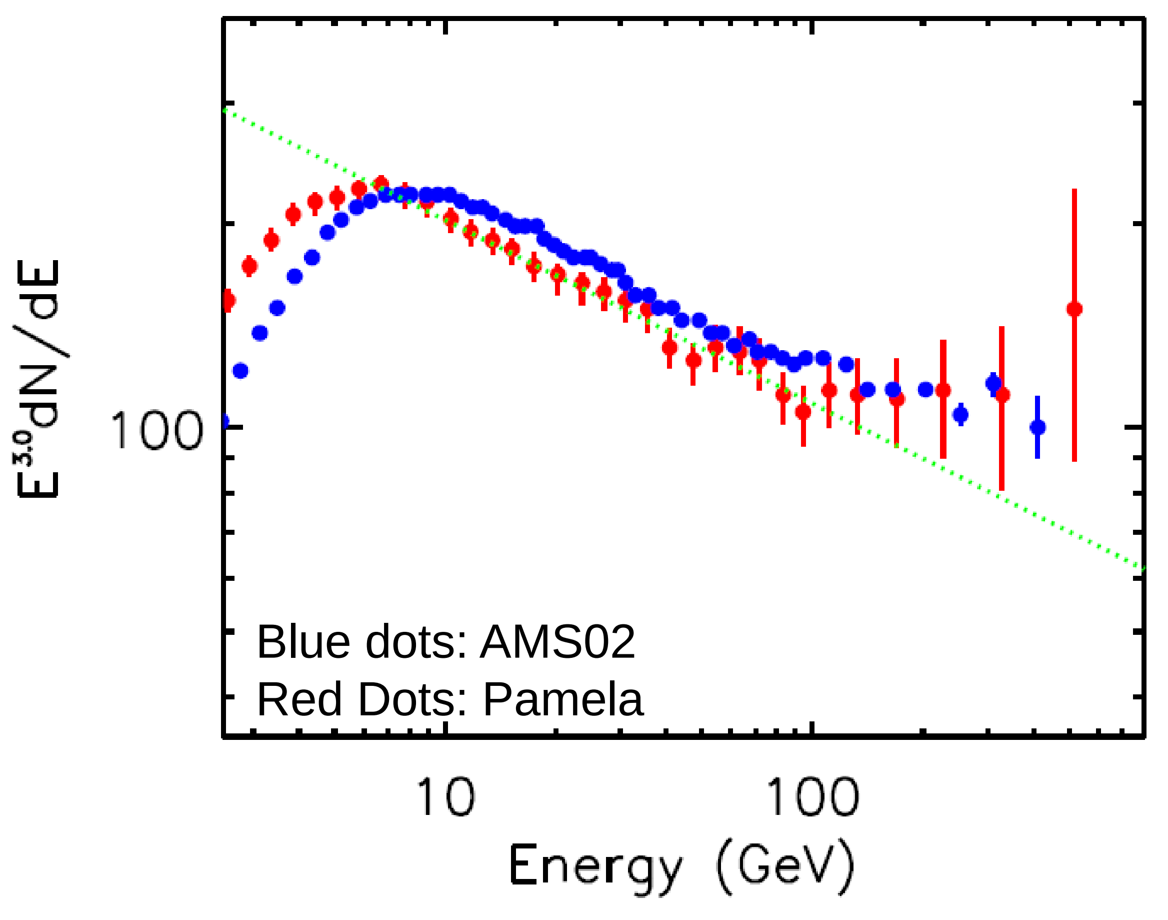
New results from AMS
1) On the origin of excess positrons

If the excess has a particle physics origin, it should be isotropic

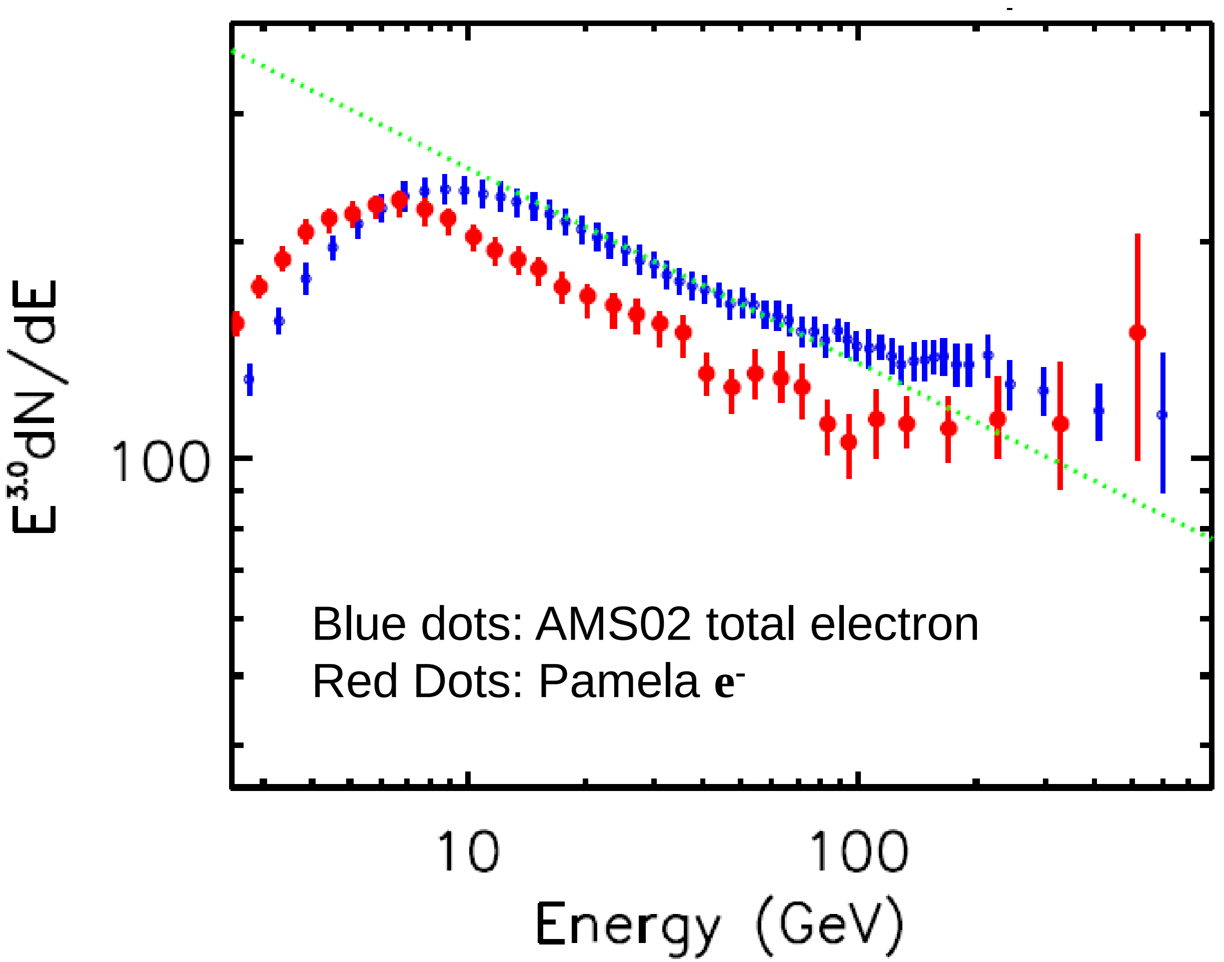


The fluctuations of the positron ratio e^+/e^- are isotropic

AMS02 and Pamela e^- spectrum



AMS02 e^-+e^+ & Pamela e^- spectrum



Present status

- Cosmic electrons:

No Space Observation above TeVs

- Cosmic ray Proton and Heavy Ions

from TeV to PeV, no direct element spectral measurement

- Gamma-ray astronomy

There is a gap between space and ground observation (10s GeV -100s GeV)

No High energy resolution observation in space

- Dark matter particle

No proof

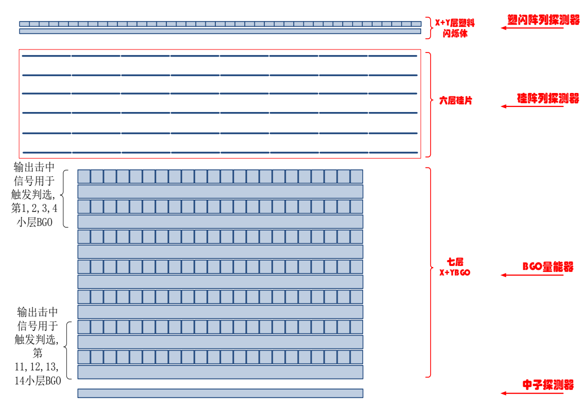
We need a new detector

- ❑Energy range >TeV
- ❑Energy resolution better than 1.5%
- ❑Background Rejection above 10^5

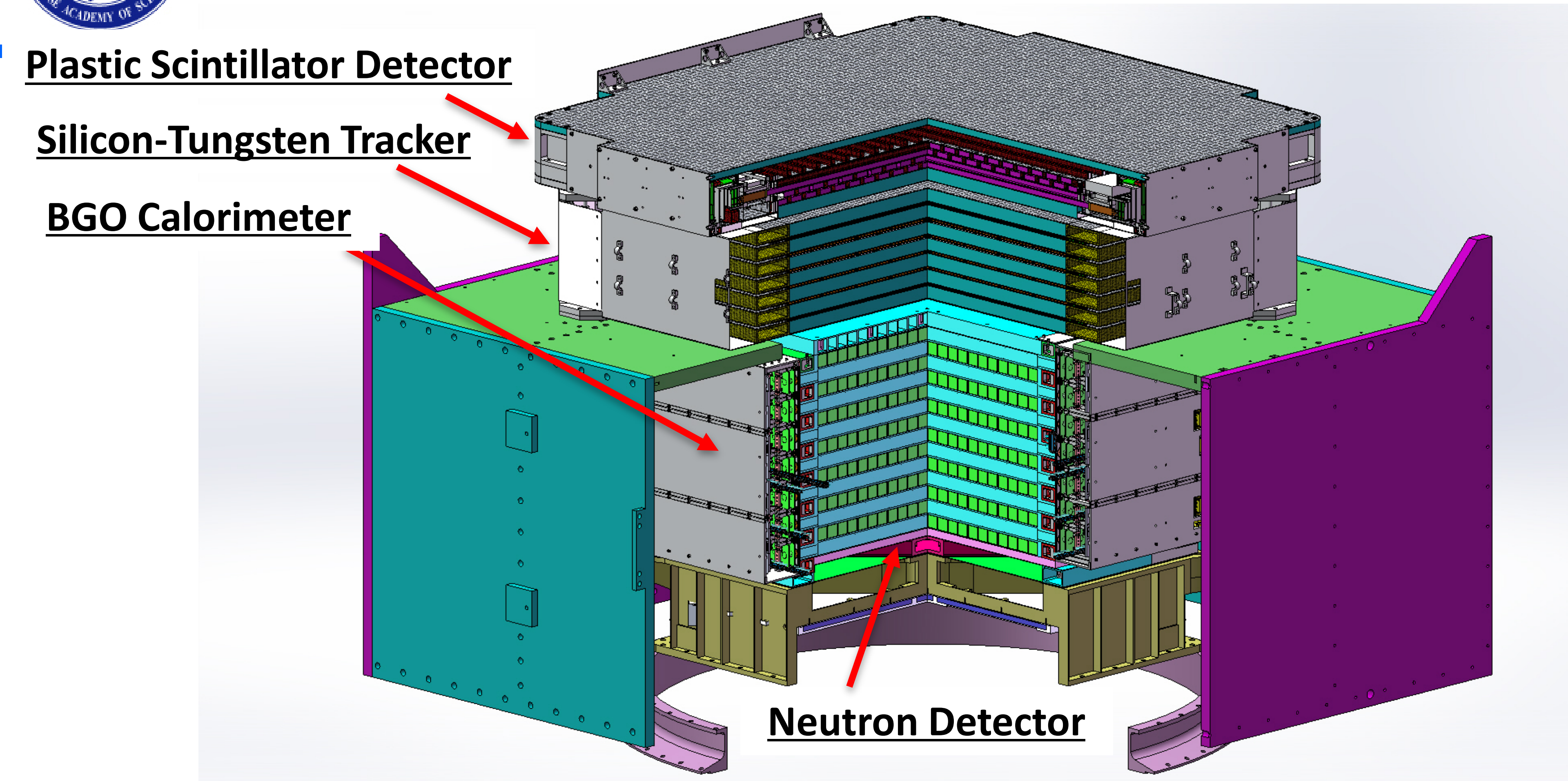
DAMPE Mission

Payload Overview

Measurement	Detector
Charge	Si-strip & Scintillation Hodoscope
Direction	Si-Stripe
Energy	BGO Calorimeter (31 r.l.)
Background Rejection	BGO Cal. Plus Neutron detector



The DAMPE Detector



W converter + thick calorimeter (total 33 X_0) + precise tracking + charge measurement ➡ high energy γ-ray, electron and CR telescope

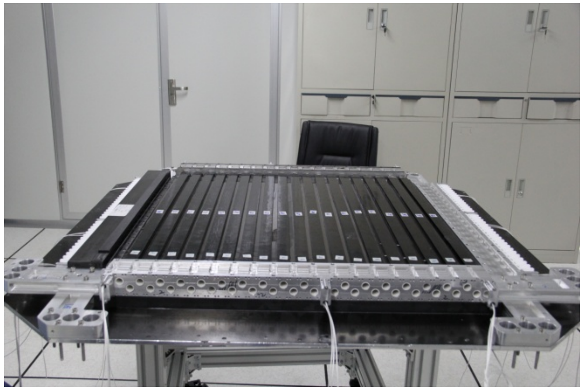
Comparison with AMS-02 and Fermi

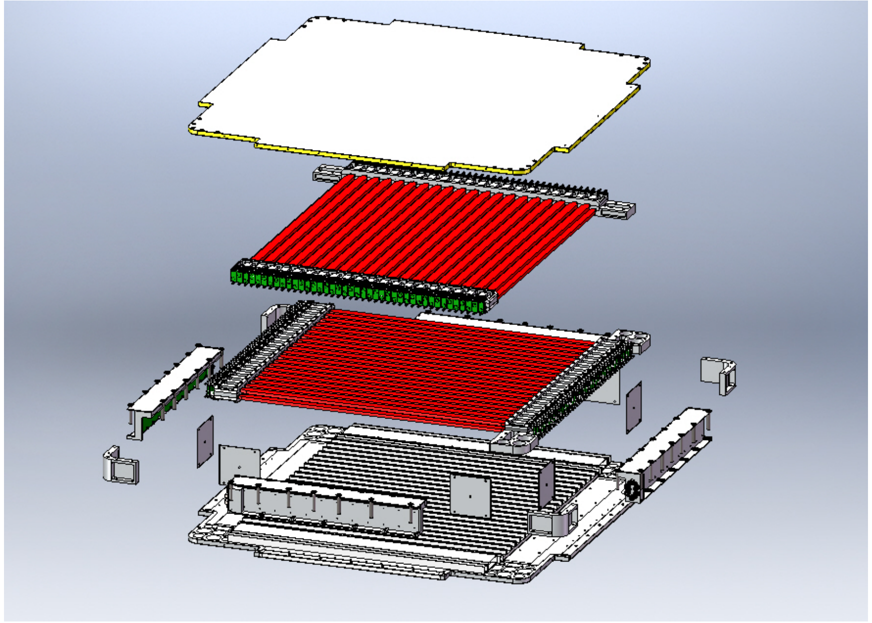
	DAMPE	AMS-02	Fermi LAT
e/γ Energy range (GeV)	5 - 10^4	0.1 - 10^3	0.02 - 300
e/γ Energy res.@100 GeV (%)	1.5	3	10
e/γ Angular res.@100 GeV (°)	0.1	0.3	0.1
e/p discrimination	10^5	10^5 - 10^6	10^3
Calorimeter thickness (X_0)	31	17	8.6
Geometrical accep. (m^2sr) (e)	0.29	0.06	0.15

- Geometrical acceptance with BGO alone: 0.36 m^2sr
  – BGO+STK+PSD: 0.29 m^2sr
  – First 10 layers of BGO (22 X_0) +STK+PSD: 0.36 m^2sr

Plastic Scintillator Detector (PSD)

- Two layers (x and y) of plastic scintillation strips of 1cm thick, 2.8 cm wide and 82 cm long
  - Strip staggered by 0.8 cm, fully covered area: 82cm × 82cm
- Readout both ends with PMT, use two dynode signals (factor ~40) to extend the dynamic range
  - FE ASIC VA160 with dynamic range up to 12 pC
- Expected performance
  - Position resolution ~6 mm
  - Charge resolution 0.25 u
  - Dynamic range Z = 1 - 20





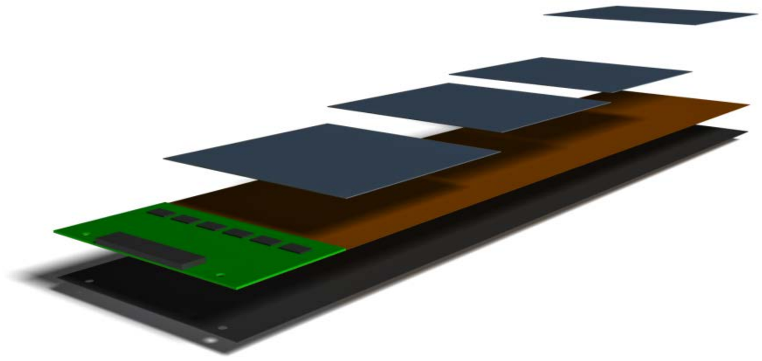
IMP, Lanzhou

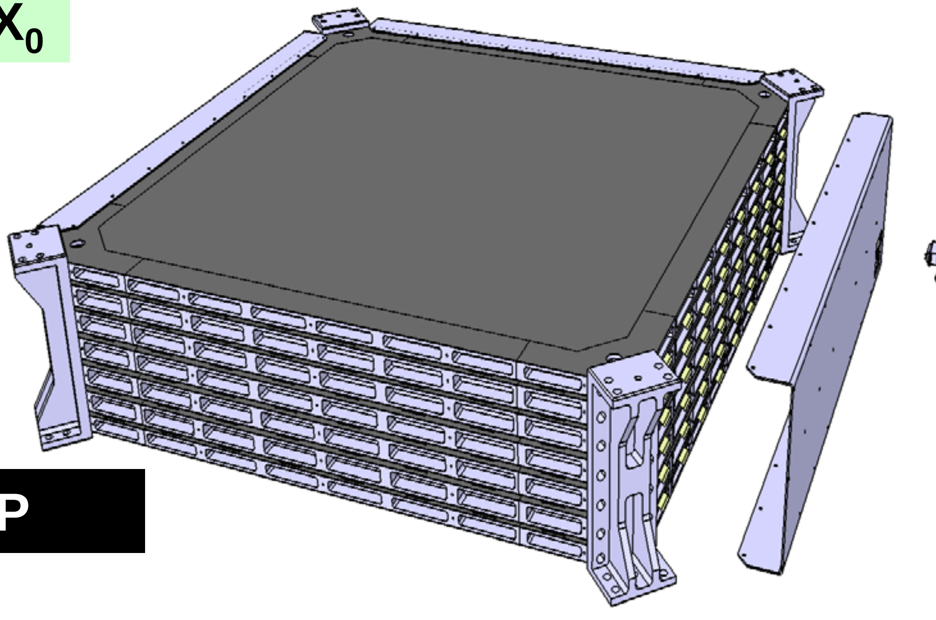
Silicon Tungsten Tracker (STK)

- 12 layers of silicon micro-strip detector, 7 support trays
  - Tray: carbon fiber face sheet with Al honeycomb core
  - Sensor 9.5 x 9.5 cm^2, 4 sensors bonded together to form a ladder
  - 16 ladders on each face of the support tray, x-view and y-view
    - Except top and bottom trays: only one face has ladders
- Tungsten plates integrated in trays 2, 3, 4 counting from the top
  - Total 1.43 X_0 for photon conversion

Detection area 76cm x 76cm

Consider to reduce to 0.86X_0

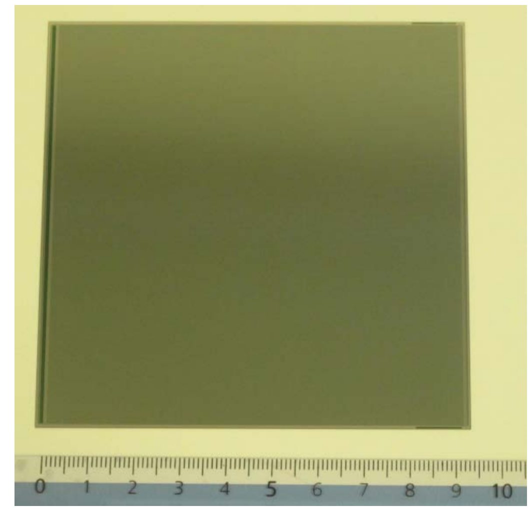




UniGE, INFN Perugia & Bari, IHEP

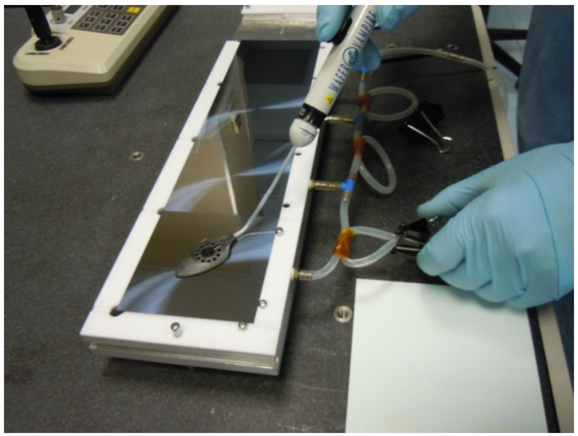
STK Silicon Sensor

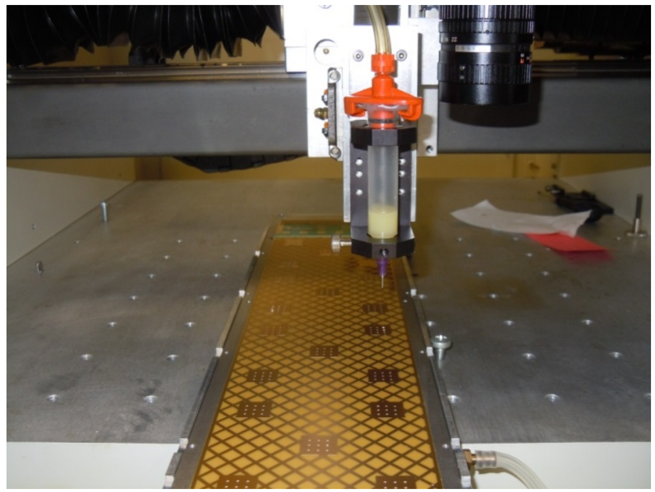
- Silicon strip detectors produced by Hamamatsu Photonics
  - 9.5 x 9.5 cm^2, 768 strips, 121 μm pitch (AGILE geometry)
  - 320±15 μm thick (AGILE: 410 μm)
- Two types of SSD being considered
  - Type A: resistivity 3-8 kΩ, V_{fd} 40-120 V
  - Type B: resistivity 5-8 kΩ, V_{fd} 10-80 V
- 30 Type A SSD delivered
  - V_{fd} 75-80 V
  - $<I_{leak}>$ ~150 nA, max 280 nA
  - 0 bad channels
- 81 Type B SSD delivered
  - 54 with Vfd 45-50 V, 26 with Vfd 65-70 V
  - $<I_{leak}>$ ~170 nA, max 400 nA
  - 1 bad channels

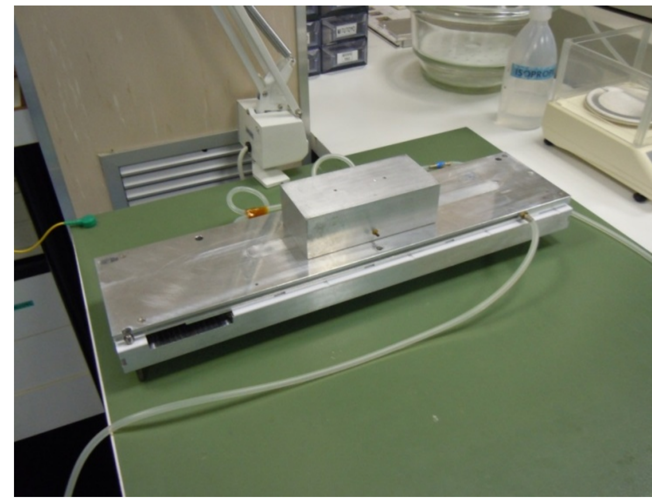


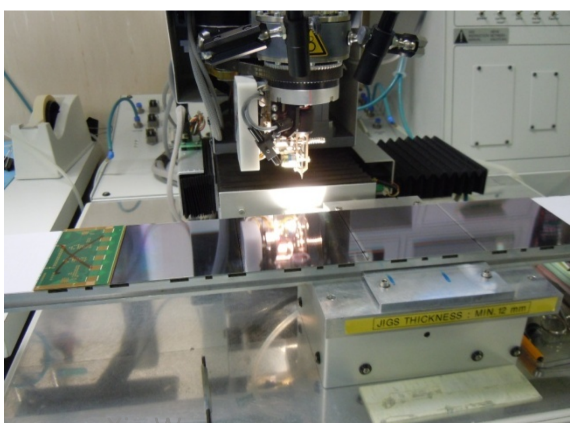
STK: Ladder Assembly

- Special jigs designed to assemble (align, glue and bond) 4 sensors on a TFH to produce a ladder
  - Specification: align 4 sensors to 40 μm, planarity to 50 μm





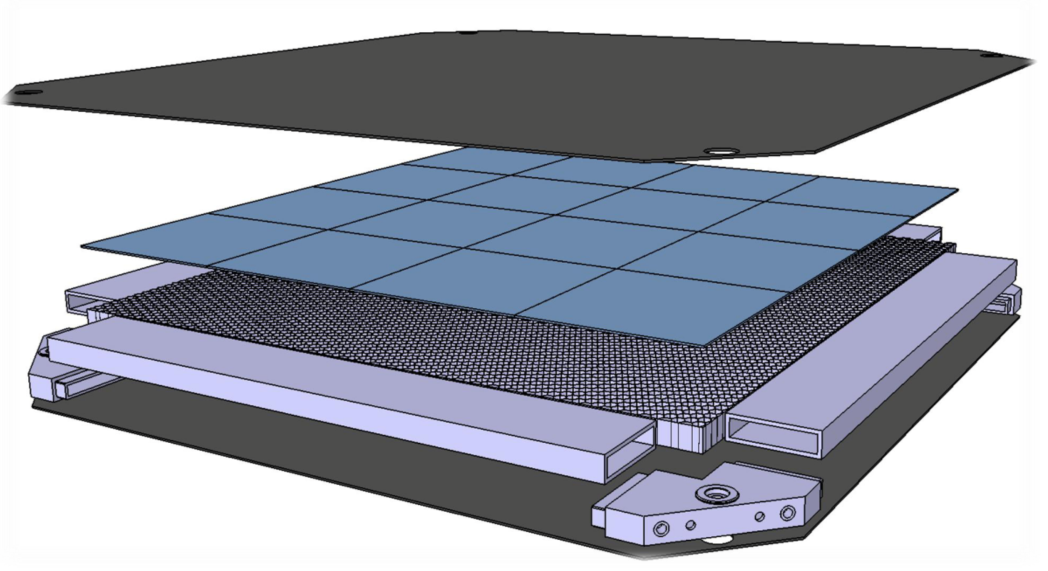


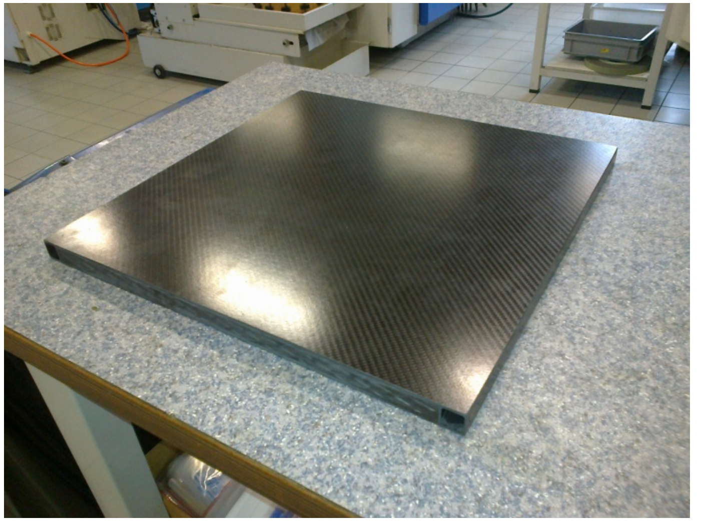


Gig design and prototyping in progress

STK: Support Tray

- 7 trays, 3 with tungsten plates
  - 22 kg of tungsten for trays with 2mm plates
  - CFRP side beams and corners to reduce total weight (~140 kg)





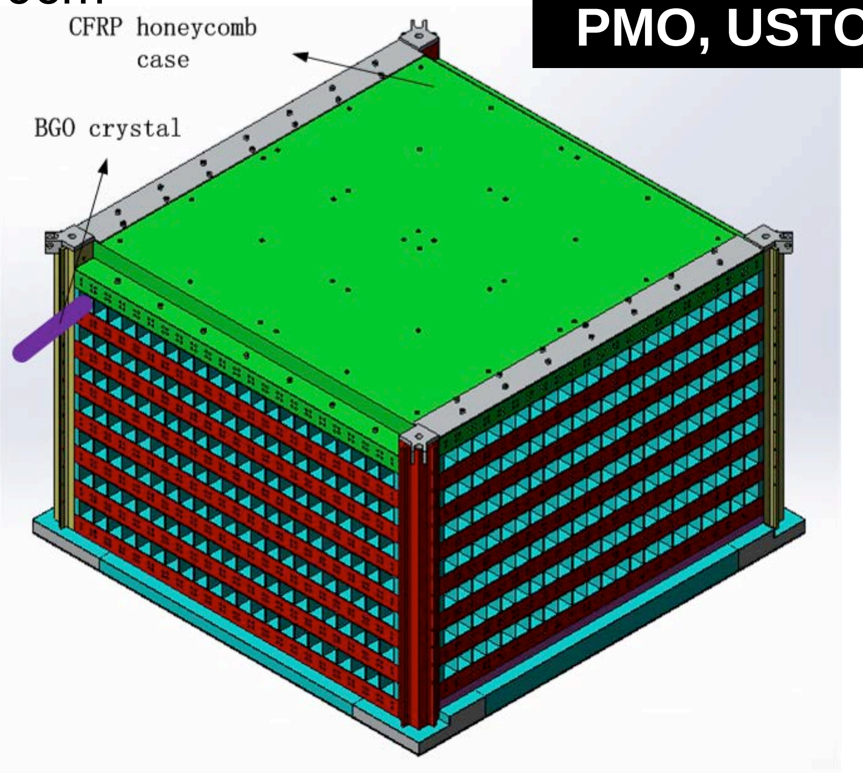
- A quarter size tray with 2mm tungsten plates have been produced by Composite Design (a Swiss company)
  - Being mounted with ladders and will go through vibration and thermal tests

BGO Calorimeter (BGO)

- 14-layer BGO hodoscope, 7 x-layers + 7 y-layers
  - BGO bar 2.5cm × 2.5cm, 60cm long, readout both ends with PMT
    - Use 3 dynode (2, 5, 8) signals to extend the dynamic range
  - Charge readout: VA160 with dynamic range up to 12 pC
  - Trigger readout: VATA160 to generate hit signal above threshold
    - Detection area 60cm × 60cm

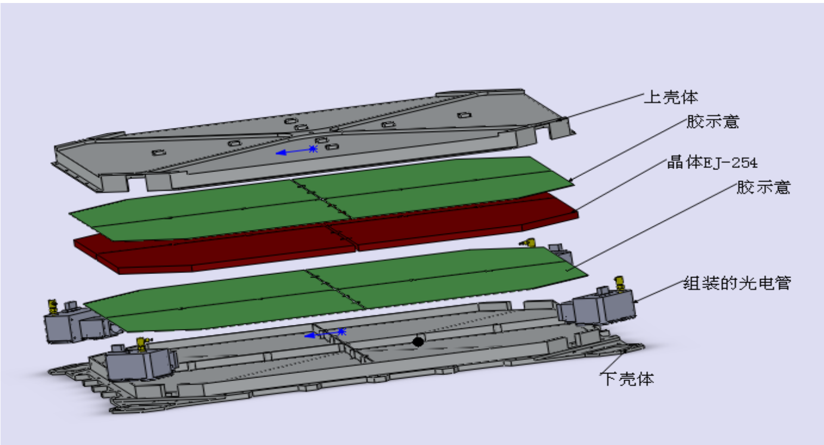
PMO, USTC

Total thickness $31X_0$

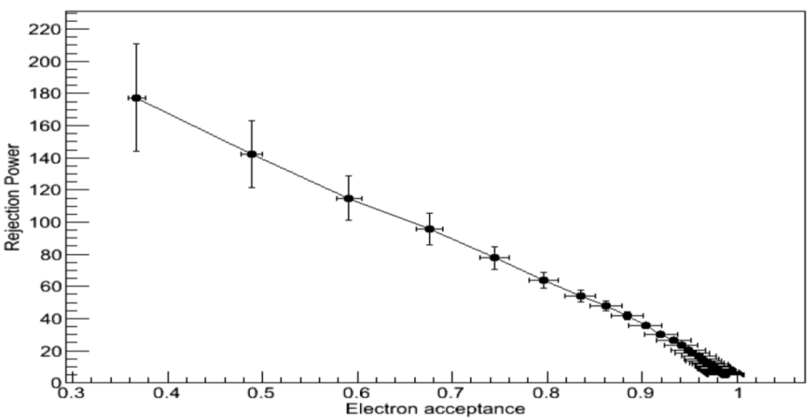


Measure electron/photon energy with great precision between 5 GeV - 10 TeV

Neutron Detector



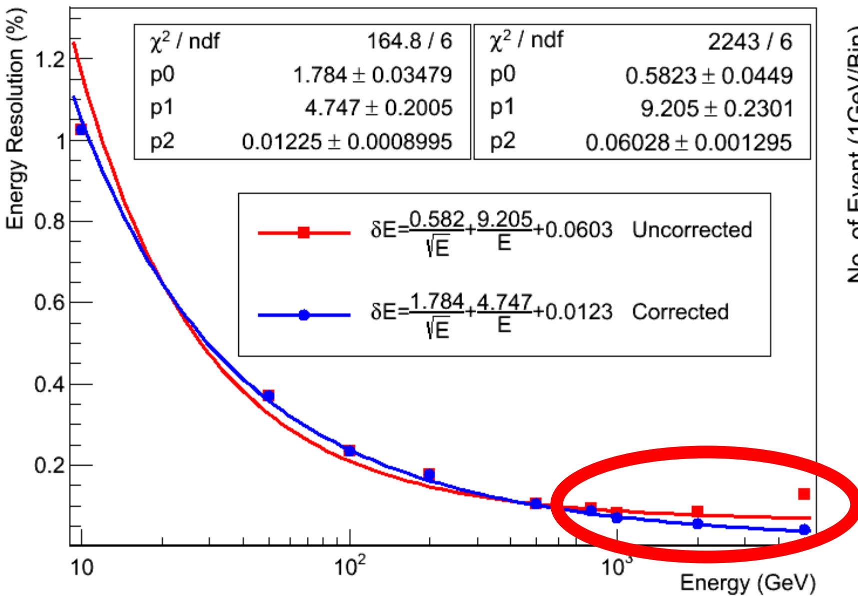
Size: 60cmX60cmX2cm
Boron density: 5%
4 PMT

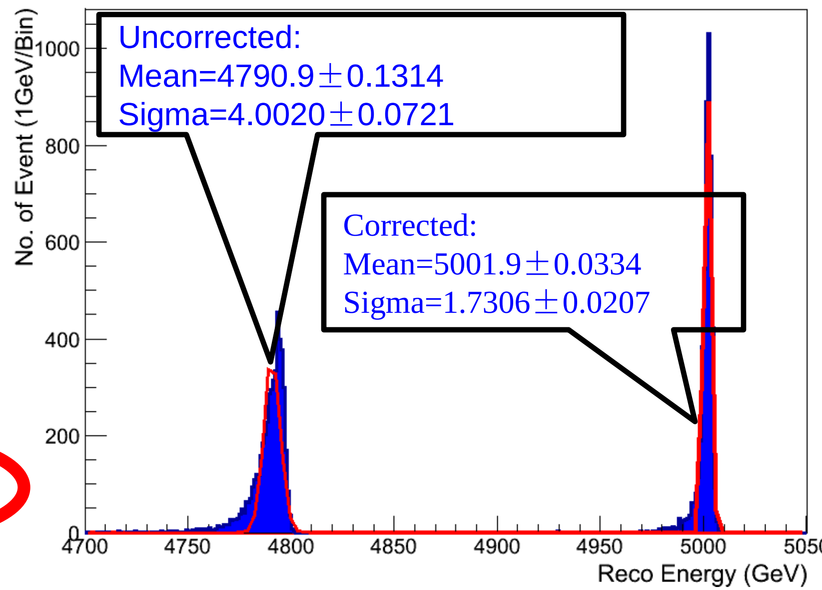


Neutron detector rejection power depending on electron selection eff.

Expected Performance from Simulation

Energy Resolution





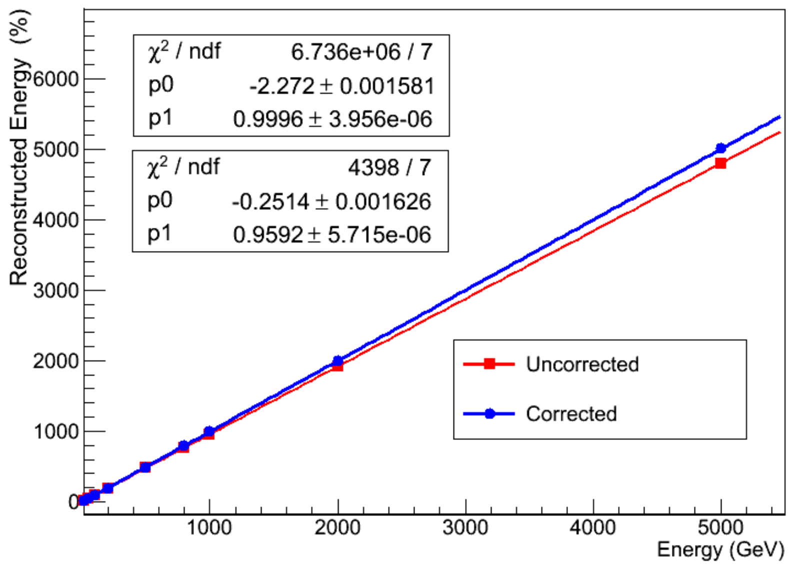
Energy resolution for electrons as a function of energy

Data was generated by G4 with particle vertically impacted on the center of ECAL(can ignore lateral leakage).

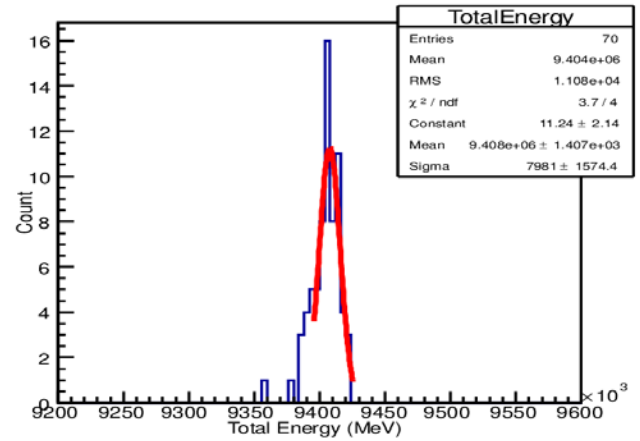
As shown in plots, Leakage Correction can give a better resolution.

Energy Resolution at 5TeV ~ 0.035%

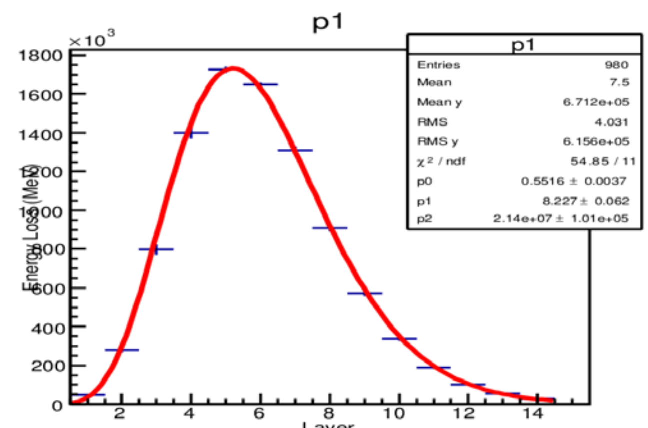
Energy Linearity



Leakage Correction can also give a better linearity. The gradient from 0.9592 to 0.9996. We wish it perfectly equal to 1.

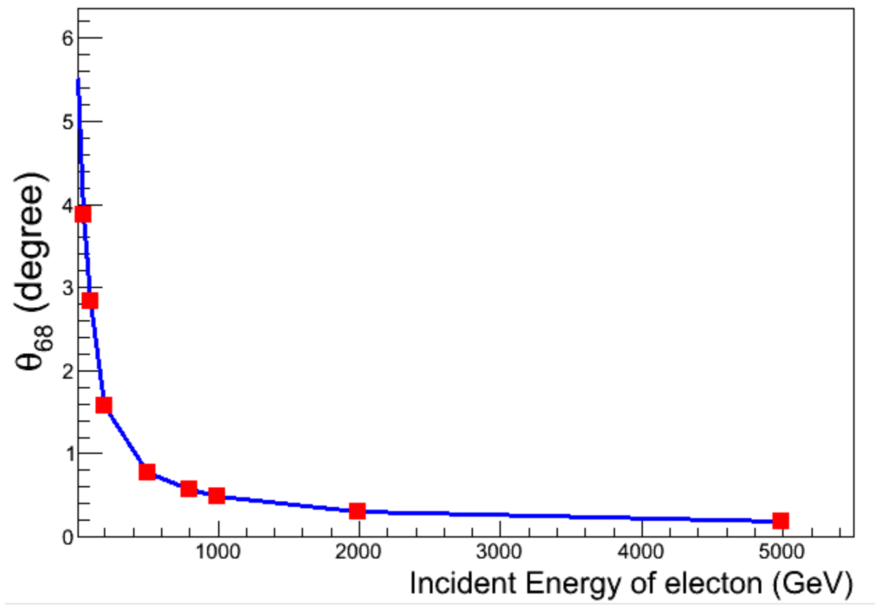


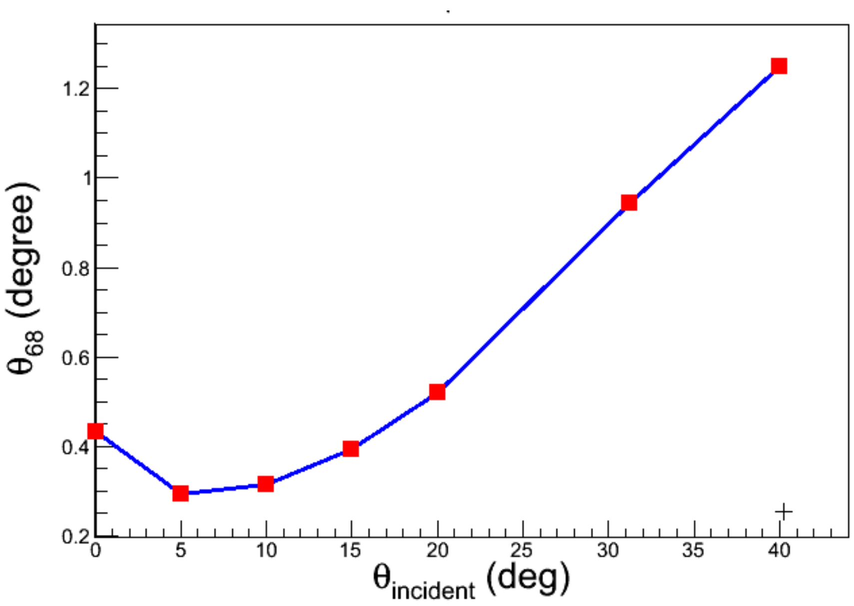
10TeV e, Energy deposit=9.4TeV



10TeV e shower profile, Only 0.3% energy leakage from bottom

Angular resolution just from BGO





Angle resolution for electrons as a function of energy and angle

With the energy increasing and angle decreasing, angle resolution became better.

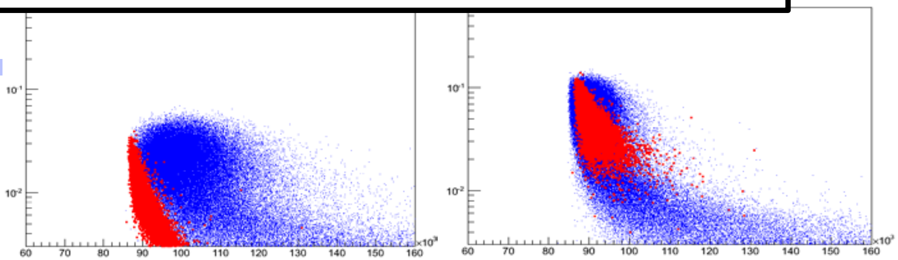
In high energy[500GeV,~], Θ_{68} can reach less than 1 degree (simulation result).

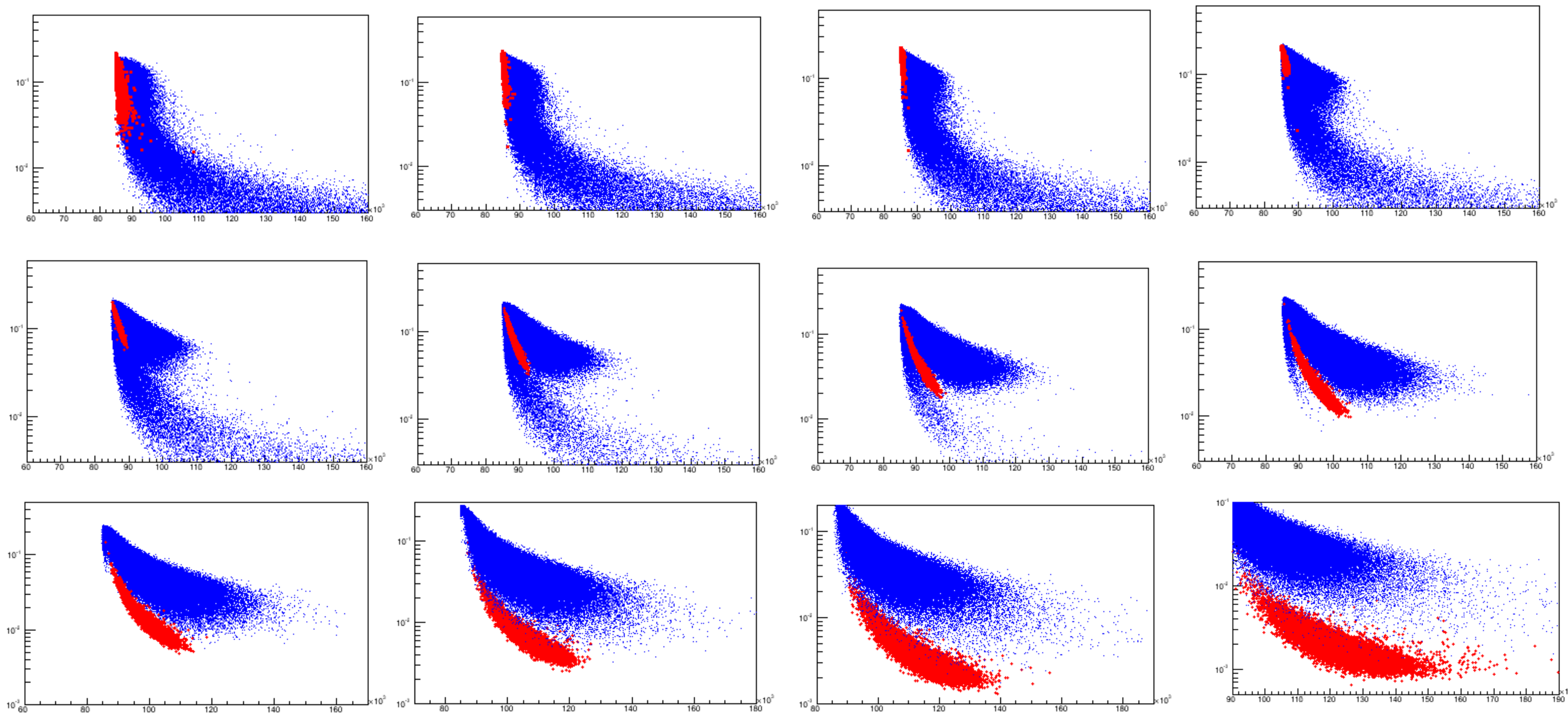
In low energy[~,200GeV], angle resolution is not so good, STK will provide better resolution.

e p seperation:
Shower development in BGO calorimeter

$$E_{frac} = \sum_{i=1}^{22} E_{li} / \sum_{i=1}^{22} \sum_{l=1}^{14} E_{li} \sim Y - Axis$$

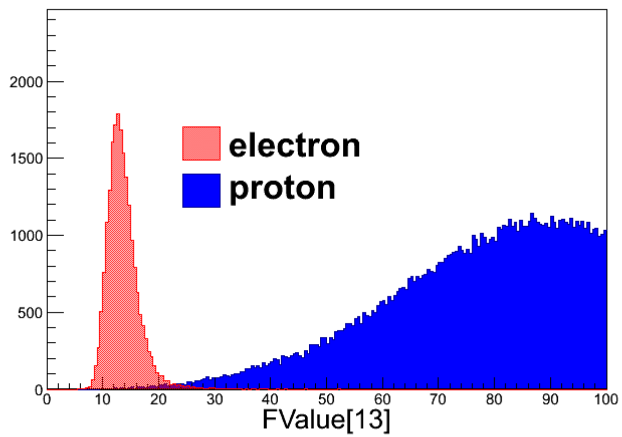
$$RMS^2 \sim X - Axis$$

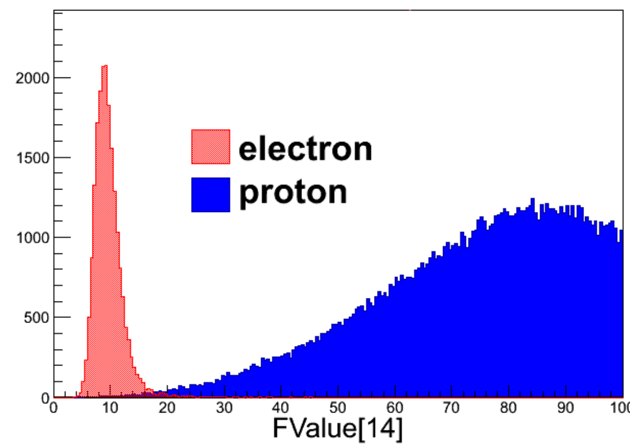




Shower Structure Parameter - *FValue*

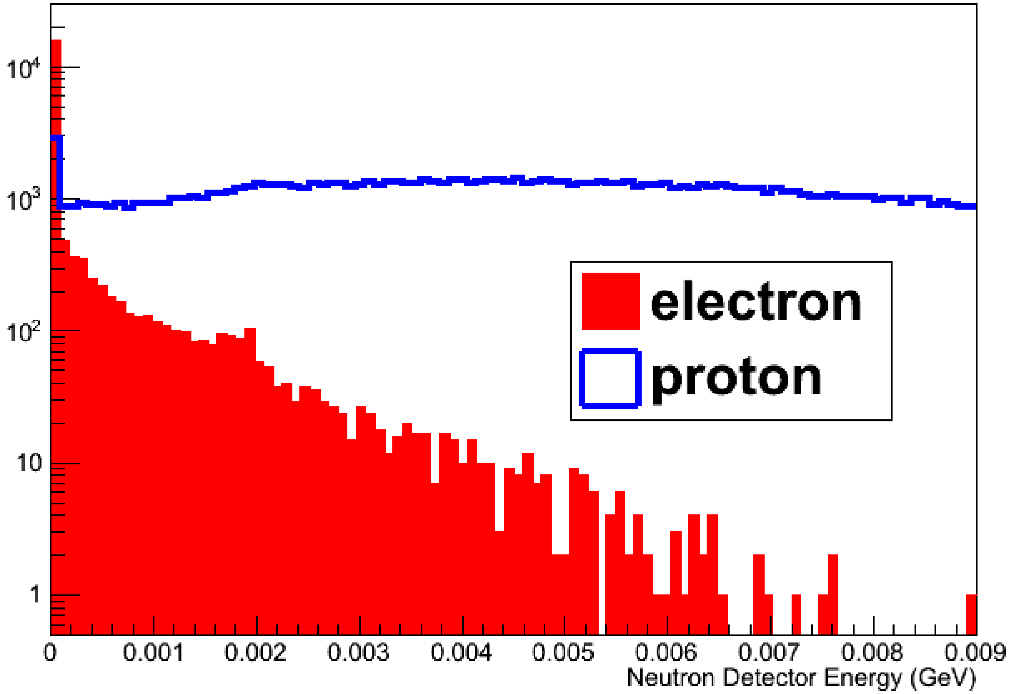
$$FValue = E_{frac} \cdot RMS^2$$

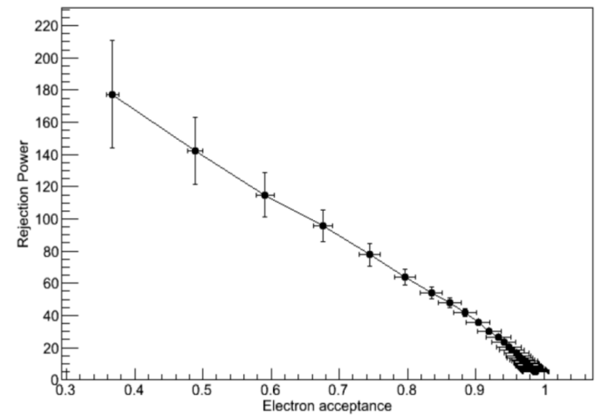




	Electron	**proton**
Energy Range [900,1000] GeV	19963	165617
F13<20&&F14<15	19060	108
Efficiency or False Rejection Rate	**95.48%**	**0.0652%(1.5e+03)**

e/p discrimination by neutron detector





Neutron detector rejection power depending on electron selection eff.

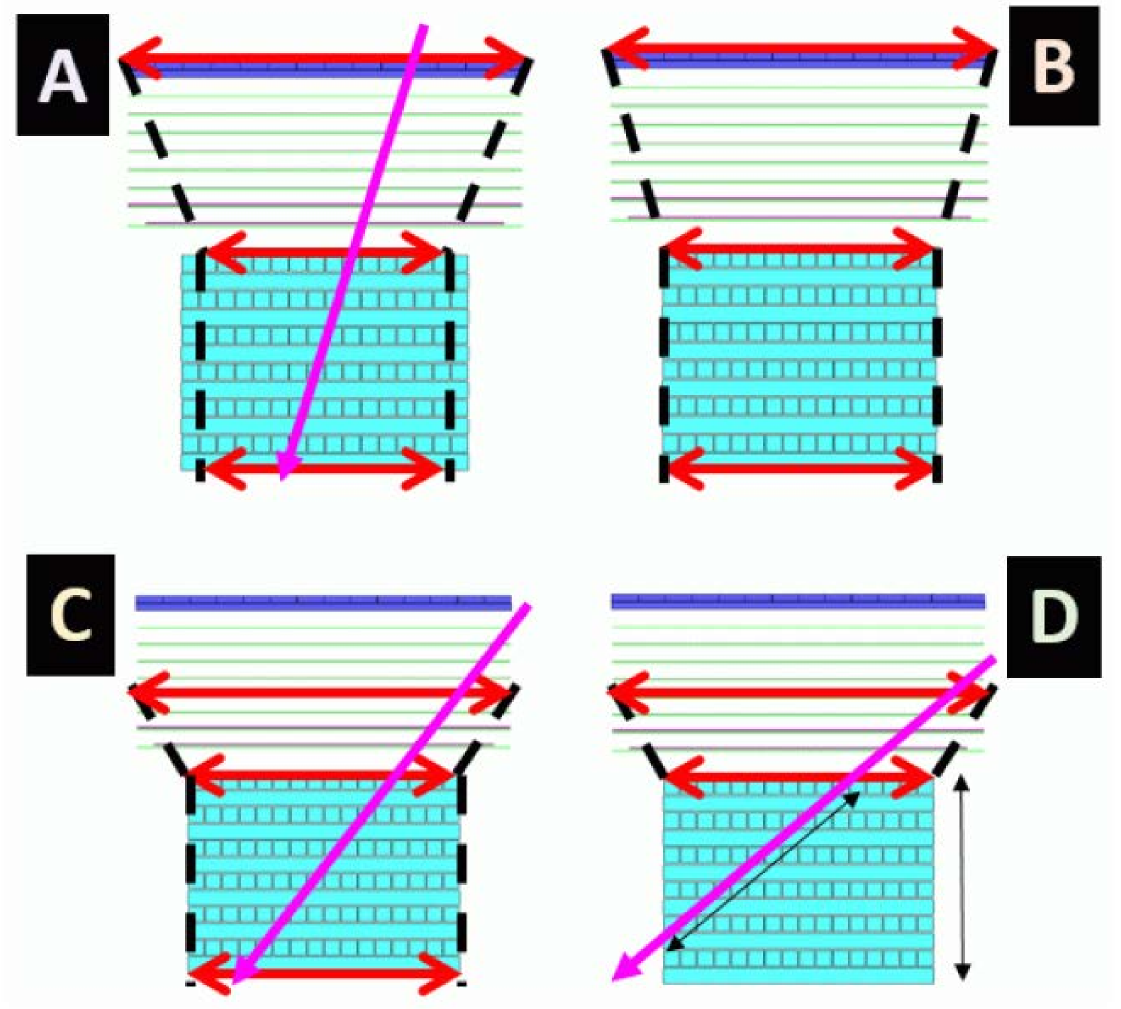
Deposited Energy at time window [1.5,10]μs in ND

◆**As plot, proton is obviously different with electron. we can use this difference to discriminate electron and proton.**

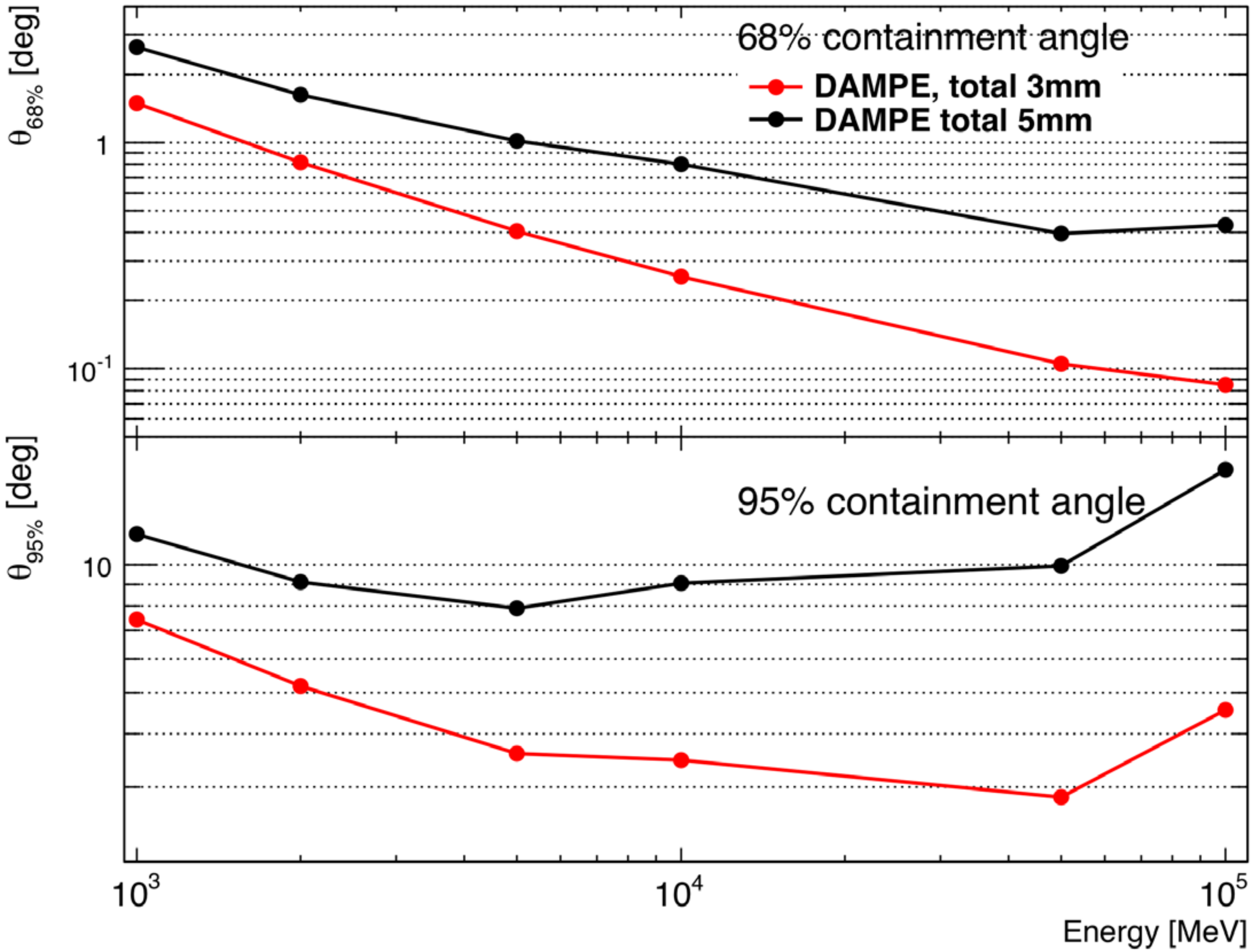
◆**Selection criterion: 3MeV.**

◆**Result: Reject 90% proton while keeping 98.3% electrons.**

Gamma FoV will be increased by side incident events



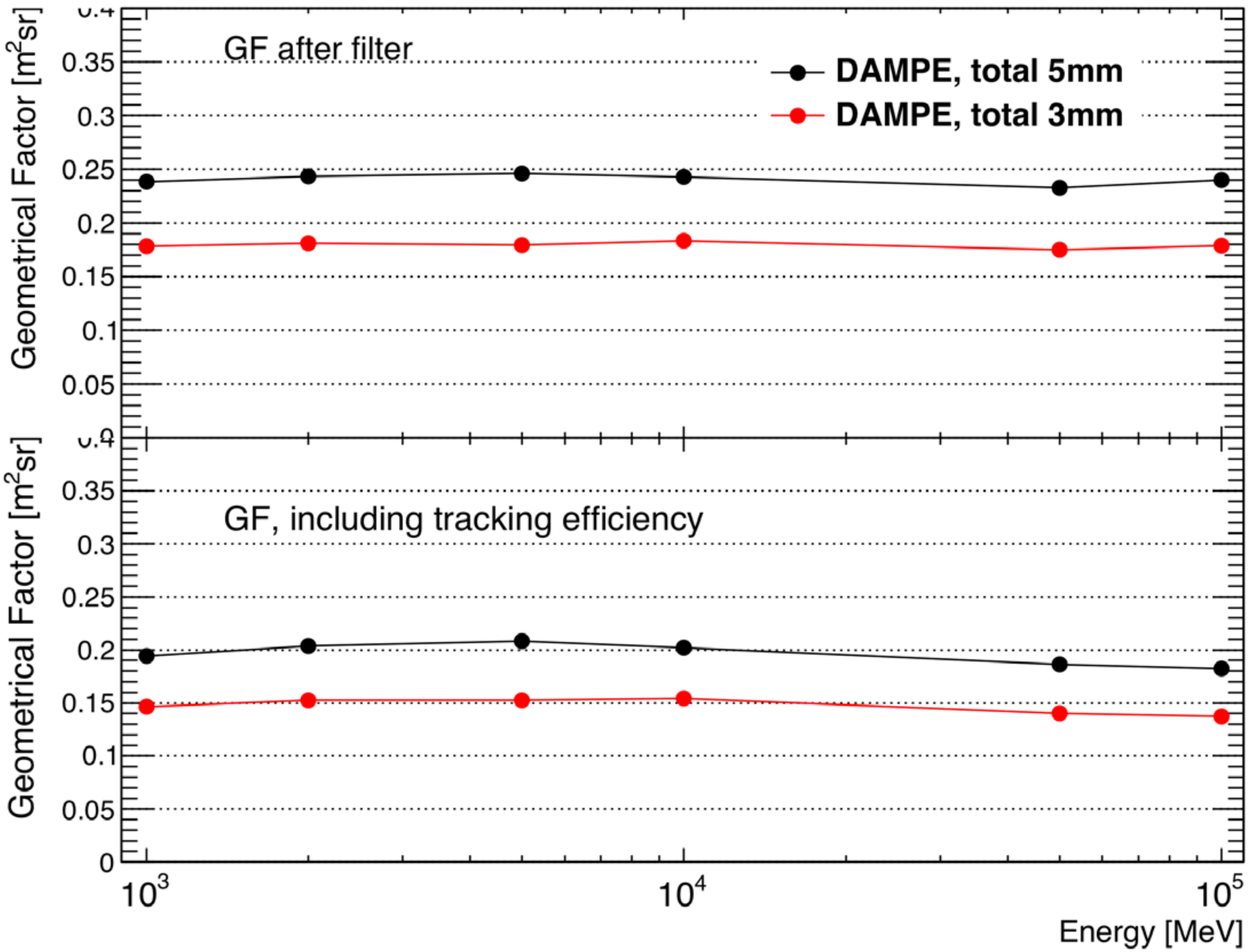
PSF depending on energy



Xin

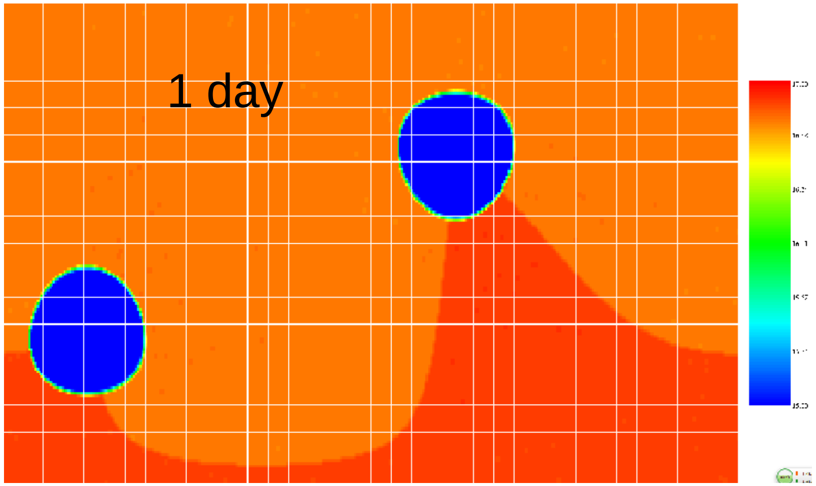
DAMPE is discussing to use 3mm W in total instead of 5mm

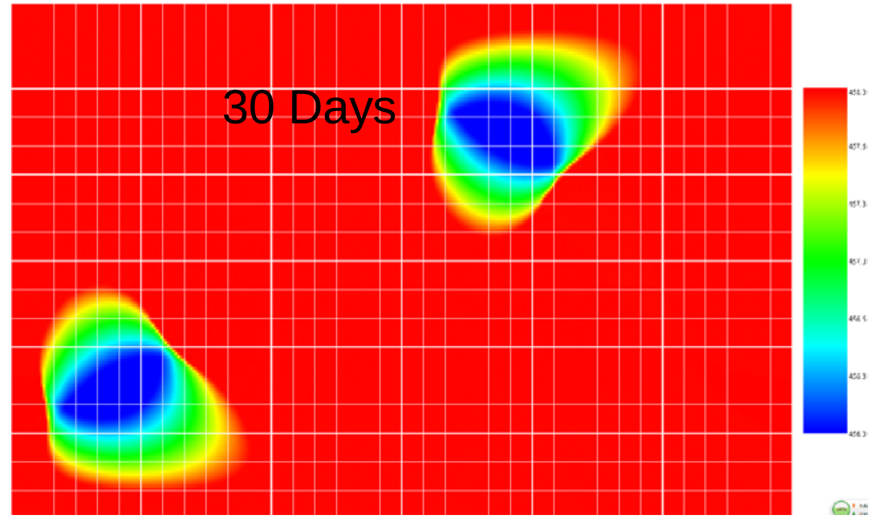
γ-ray GF for converted photon

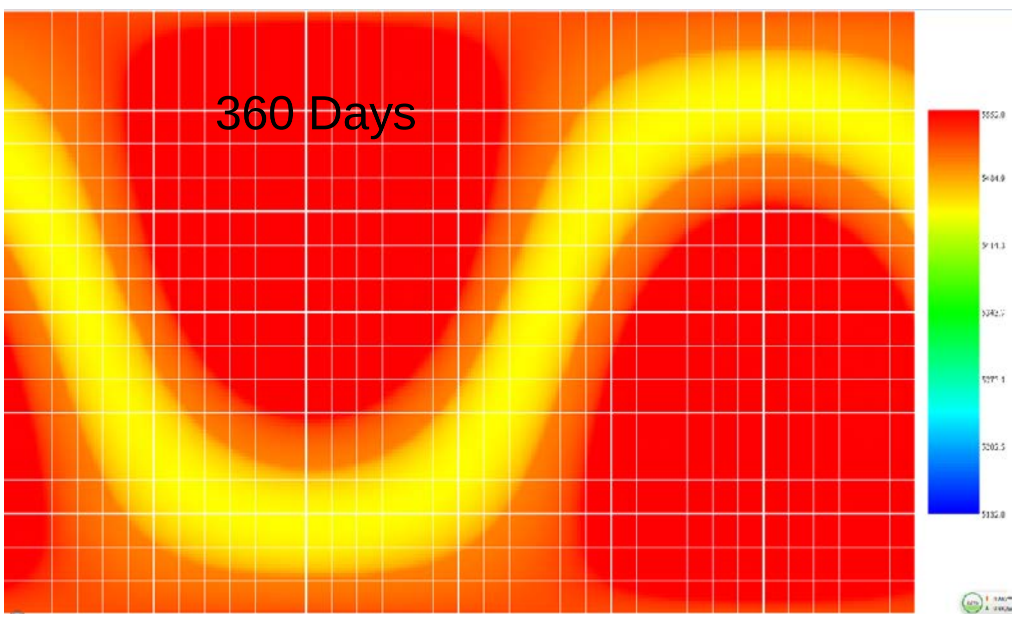


Xin **Note unconverted γ-ray at high energy can add to efficiency.**

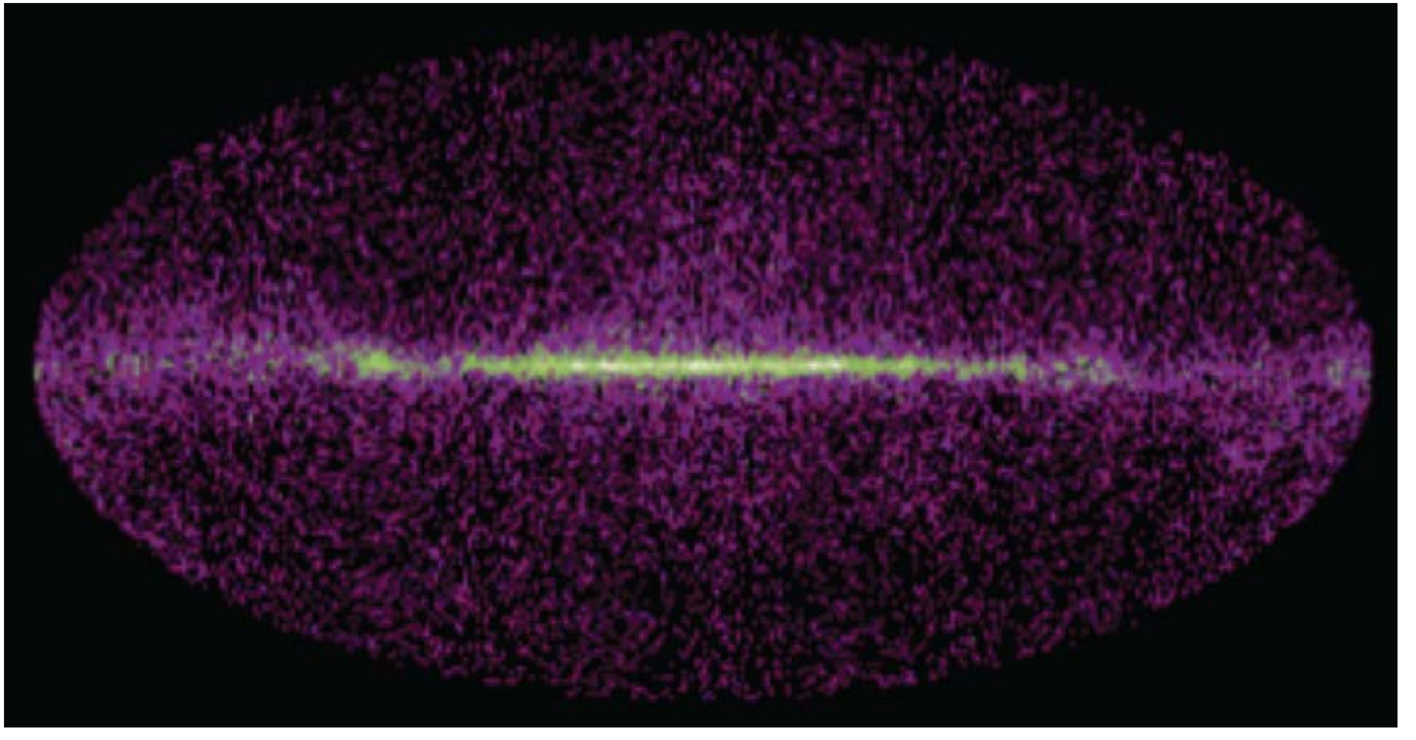
Exposure time



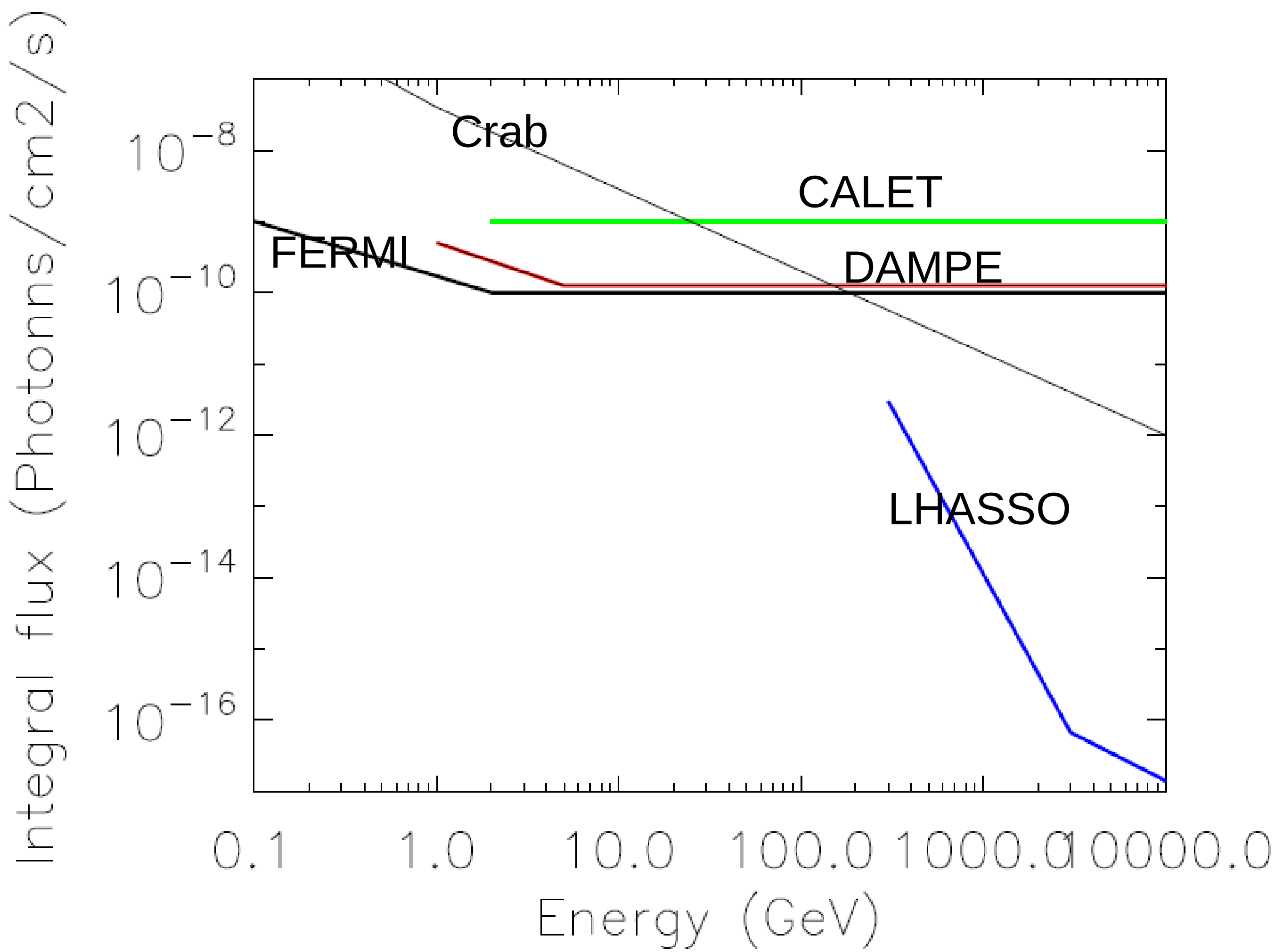




Gamma-ray mapping by 30 days

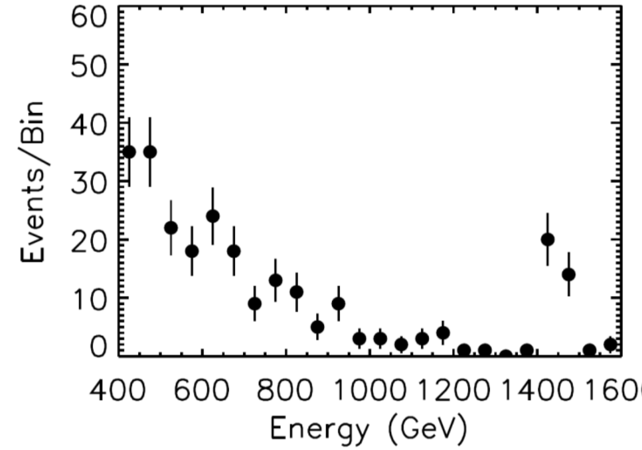


Gamma-ray Sensitivity

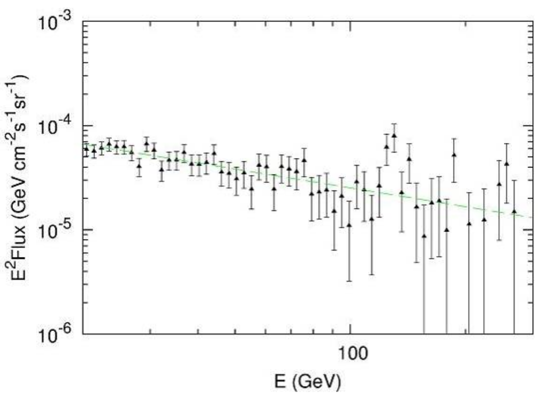


DAMPE for gamma-ray line observation

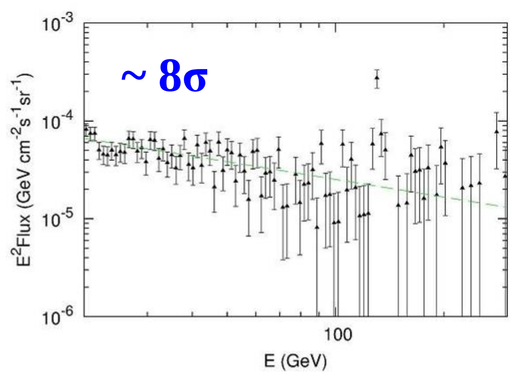
Monochromatic gamma-ray signals from WIMP dark matter annihilation would provide a distinctive signature of dark matter, if detected. Since gamma-ray line signatures are expected in the sub-TeV to TeV region, due to annihilation or decay of dark matter particles, DAMPE, with an excellent energy resolution of 1% above 100 GeV, is a suitable instrument to detect these signatures .



Simulated 1.4 TeV gamma-ray line from dark matter toward the Galactic center (300◦ < l < 60◦ , |b| <10◦) including the Galactic diffuse background for DAMPE 6 Months observations.
The annihilation cross-section is taken as $<\sigma v>_{\gamma\gamma} = 1\times10^{-25}$ cm^3s^{-1} with a NFW halo profile. The distinctive line signature is clearly seen in the gamma-ray spectrum.

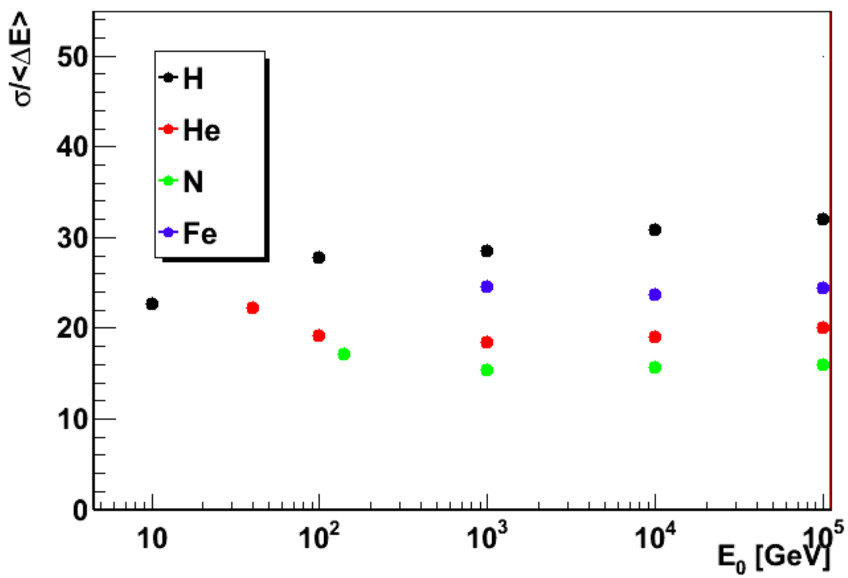


Fermi, 195 Weeks



DAMPE 3 years

Heavy Ion observation



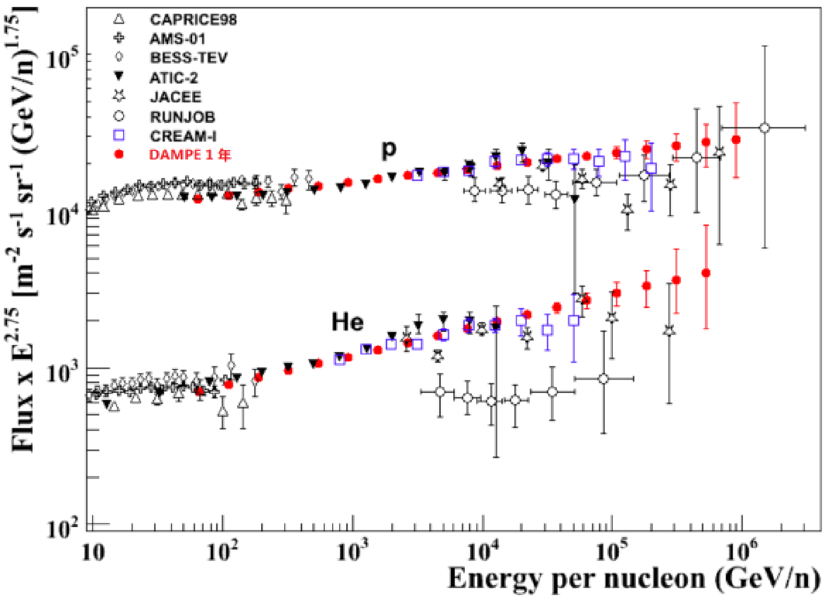
Energy resolution for nuclei

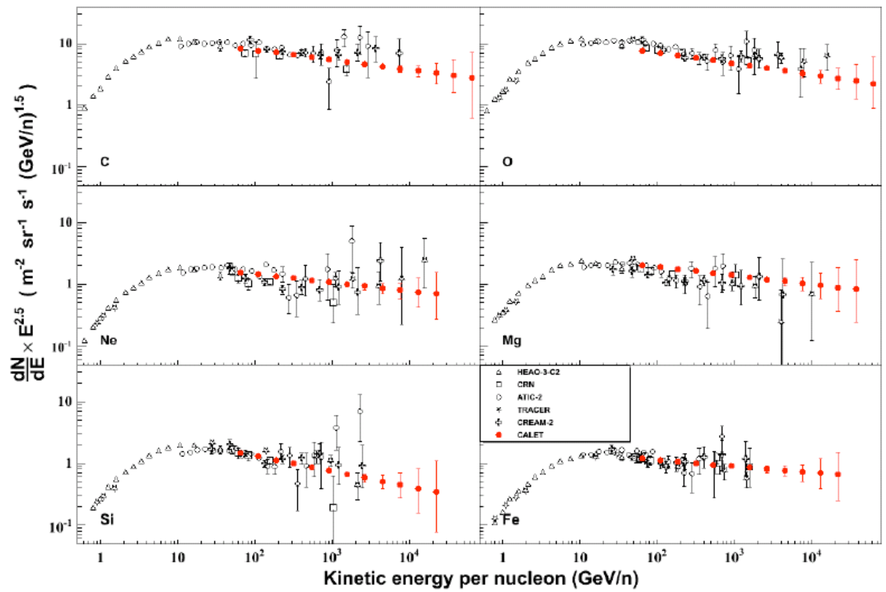
Requirements for calorimetry:

- Proton interaction requires > 0.5 λINT
- Energy Measurement at 100 TeV scale requires confinement of the e.m. core of the shower, i.e. > 20 X0

	λ_{INT}	X_0 (nominal incidence)
DAMPE	1.6	34
CREAM	0.5+0.7	20
AMS02	0.5	17

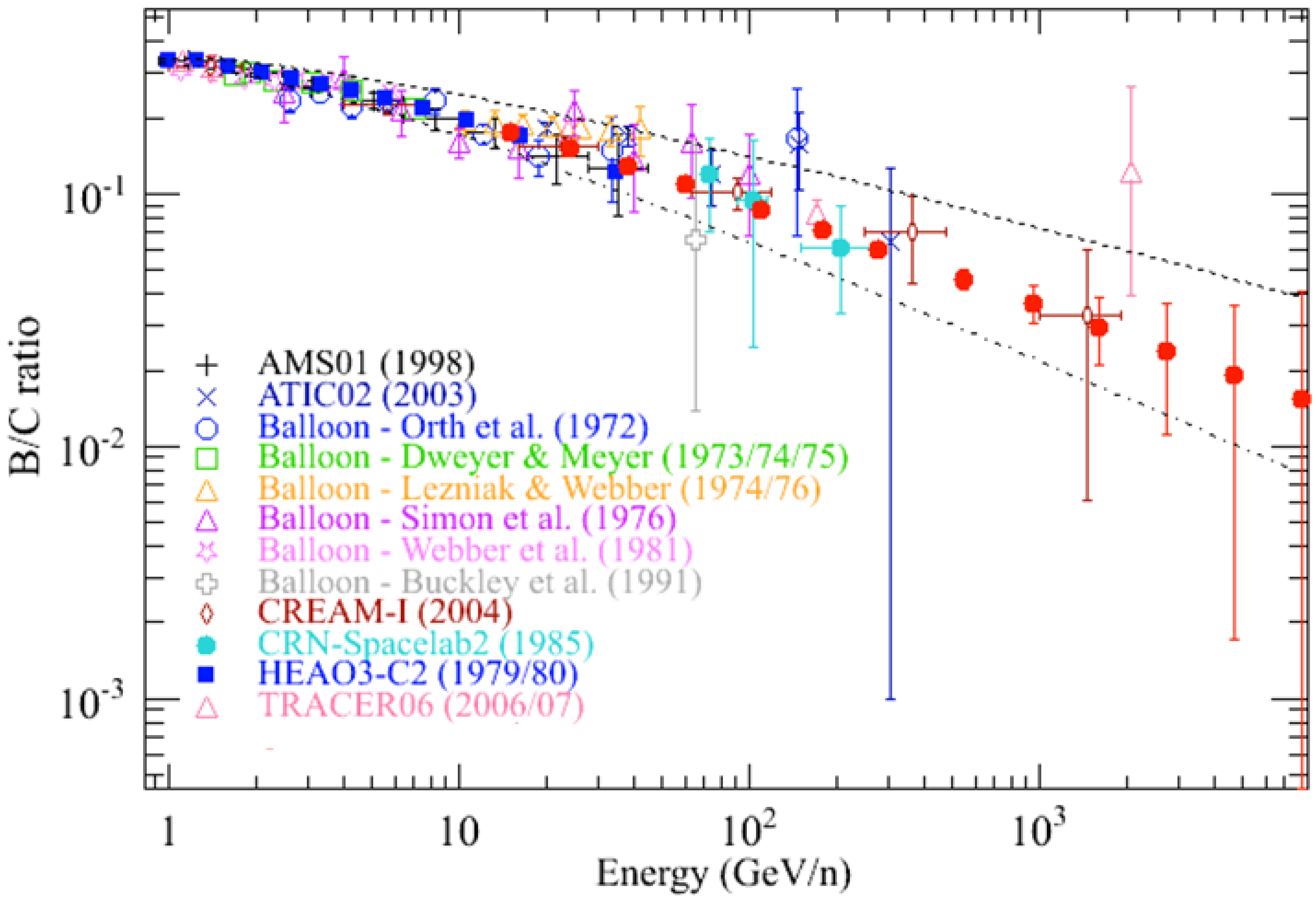
Heavy Ion results



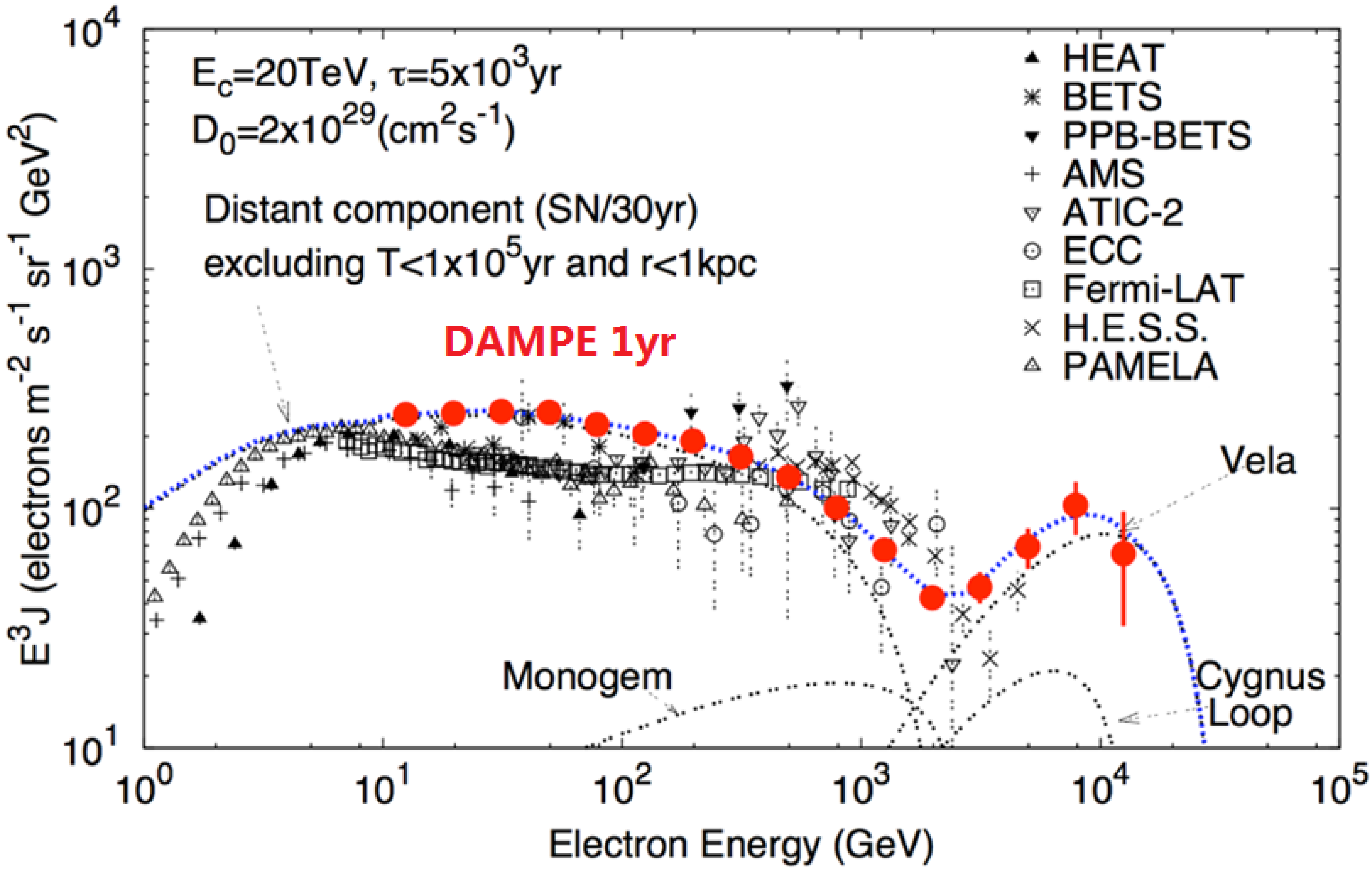


Proton spectrum to	≈ 900 TeV
He spectrum to	≈ 400 TeV/n
Spectra of C, O, Ne, Mg, Si to	≈ 20 TeV/n
B/C ratio to	≈ 4-6 TeV/n
Fe spectrum to	≈ 10 TeV/n

B/C ratio (1 year)



Expected electron spectrum (1yr) by Vela source



Expected performance for γ and e

γ performance

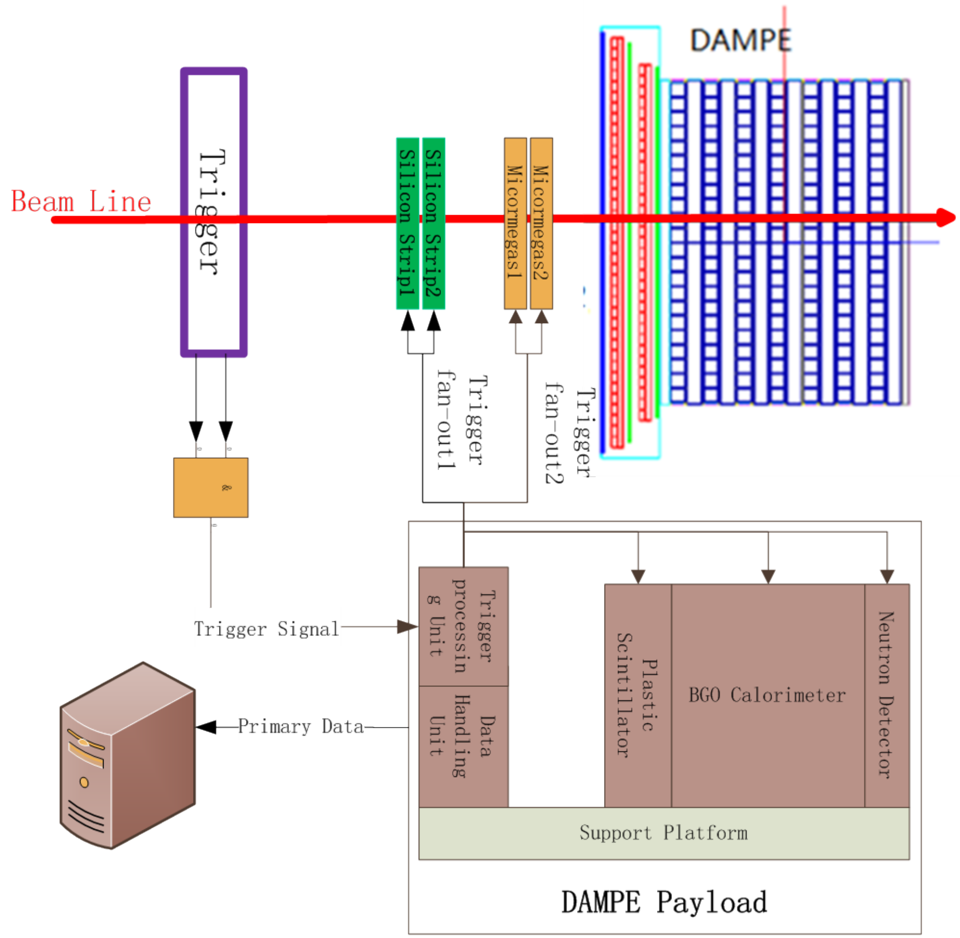
Range	2GeV-10TeV
Effective Area	$0.3m^2$@10GeV
Field of View	2.8 sr
Geometry Factor	$0.85m^2$.sr
Energy resolution	1.5%@100GeV
Angular resolution	0.1^O@10GeV%
Point source Sensitivity	$8.5X10^{-11}cm^{-2}s^{-1}$

e performance

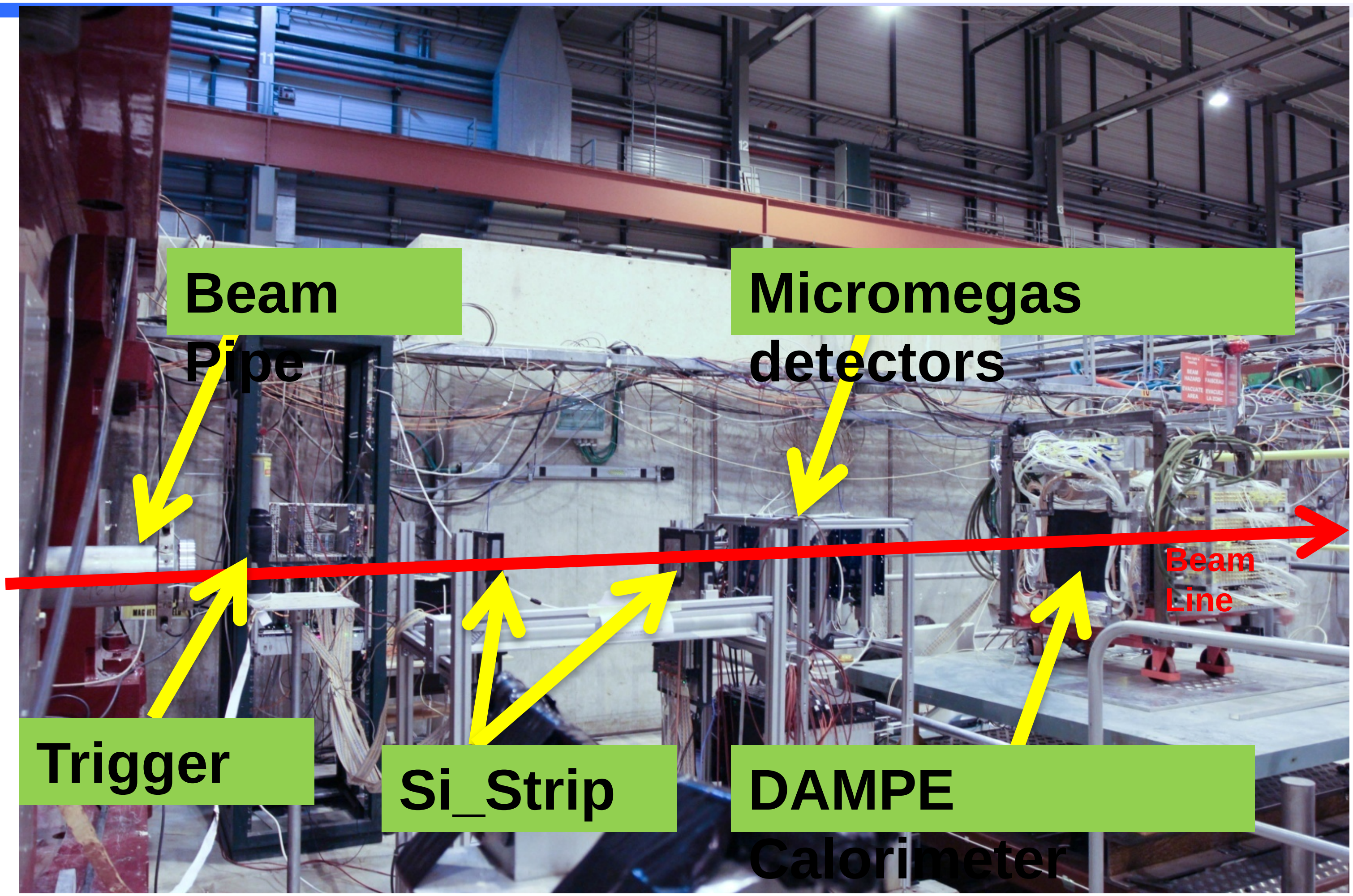
Range	2GeV-10TeV
Geometry Factor	$0.3m^2$.sr
Energy resolution	1.5%@100GeV
Angular resolution	0.1^O@10GeV%
Proton Rejection	10^5
Gamma sepeartion	100

DAMPE Beam Test

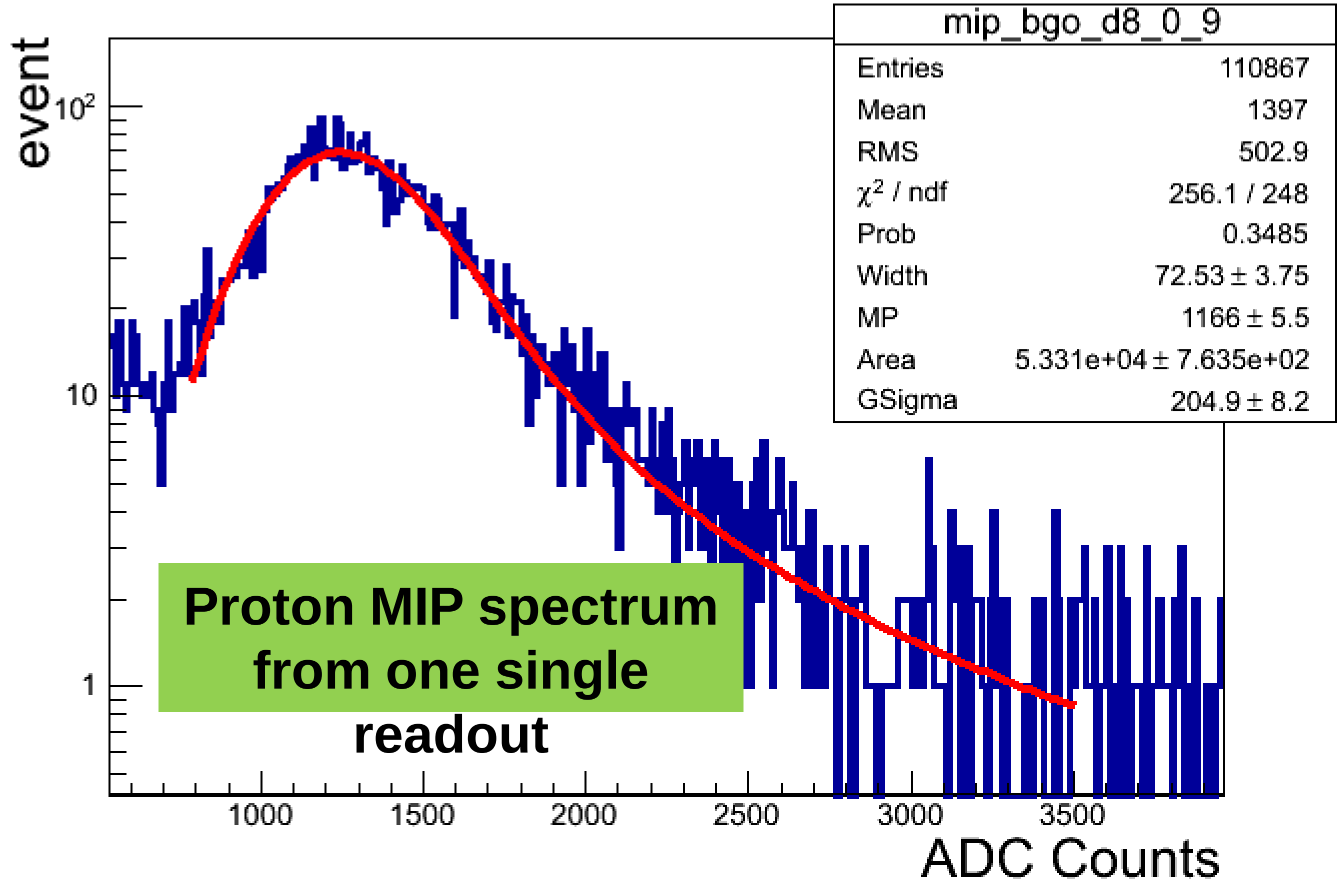
Beam Test Setup Scheme



12 Layer BGO Cal.

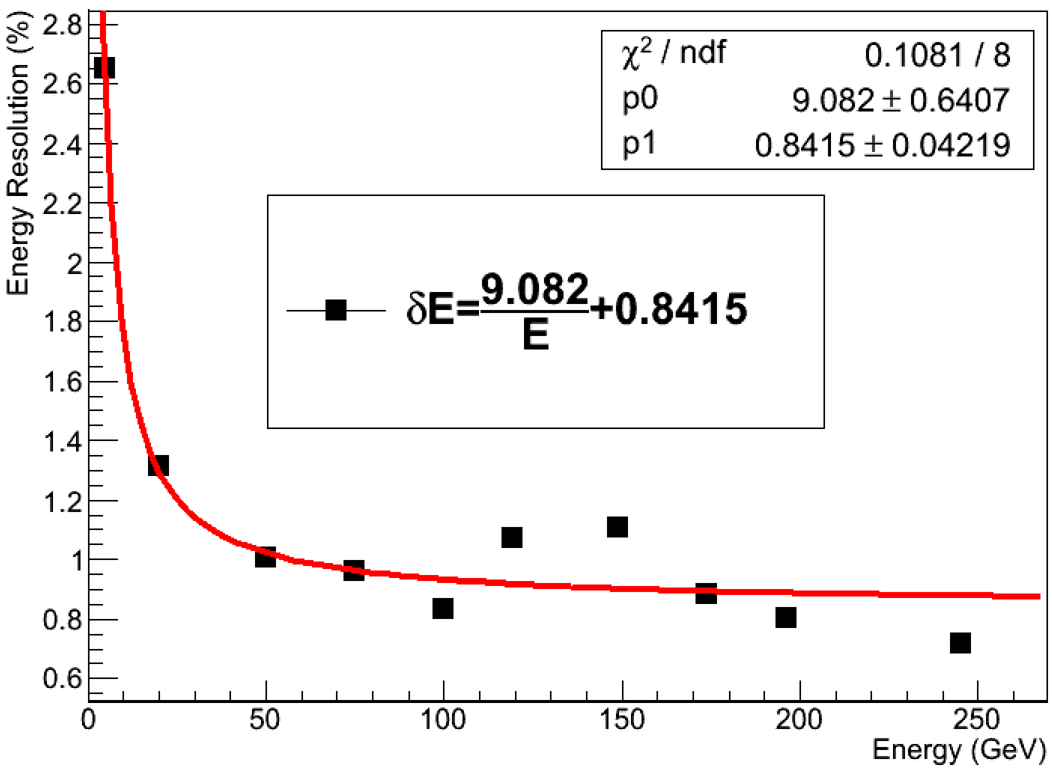

Beam Pipe
Micromegas detectors
Beam Line
Trigger
Si_Strip
DAMPE Calorimeter

Calibration with proton MIP



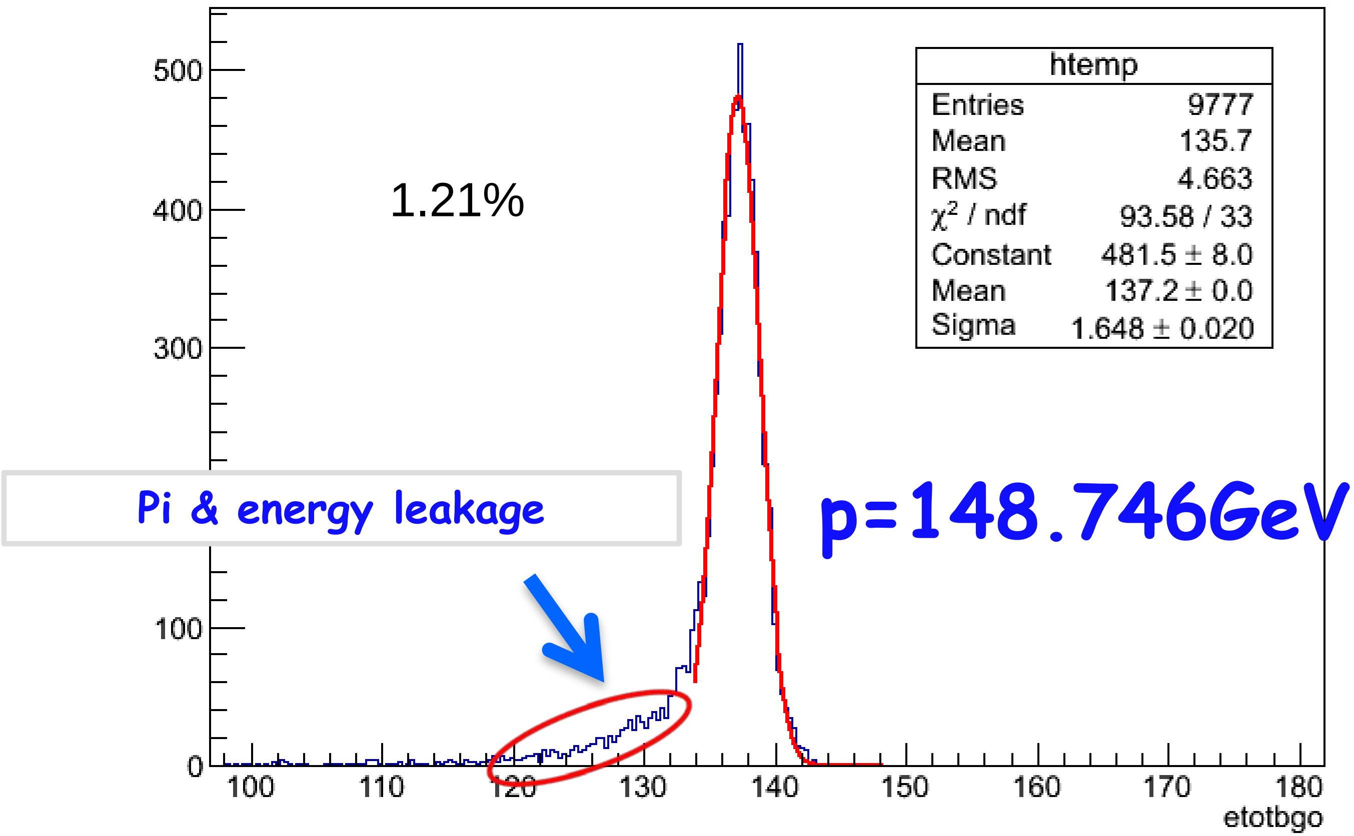
Fitting Function: Gaussian convolution landau

Energy Resolution

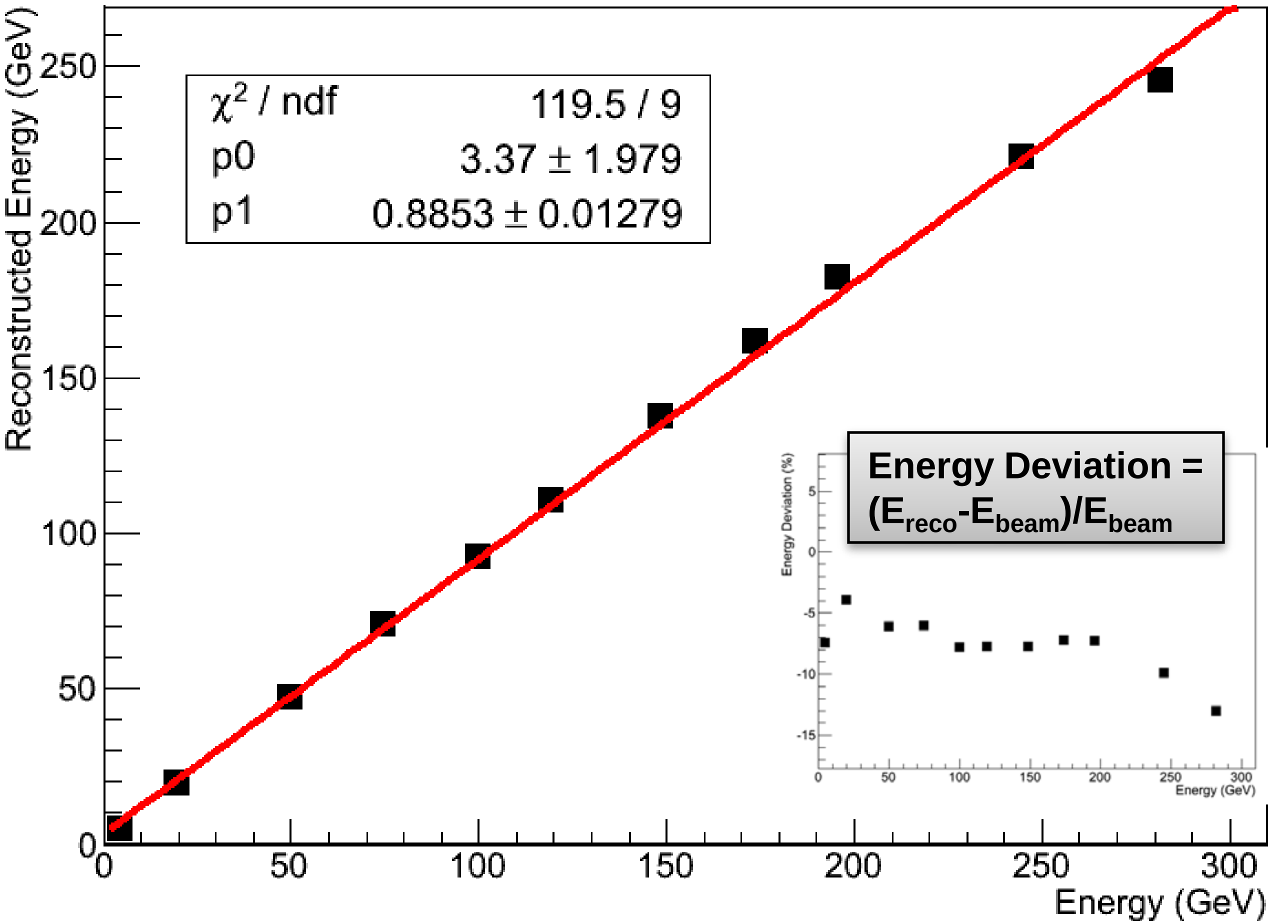


- Energy Resolution can reach 0.79%@ 250GeV

Electron Energy Spectrum



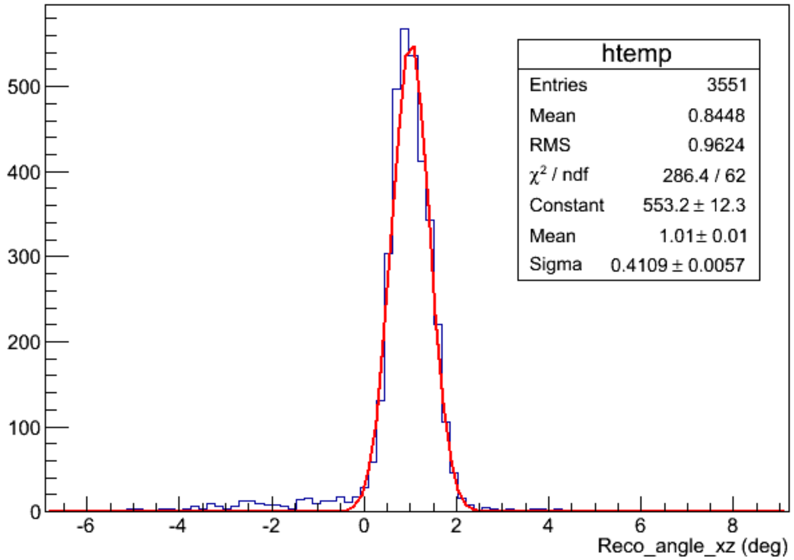
Energy Linearity

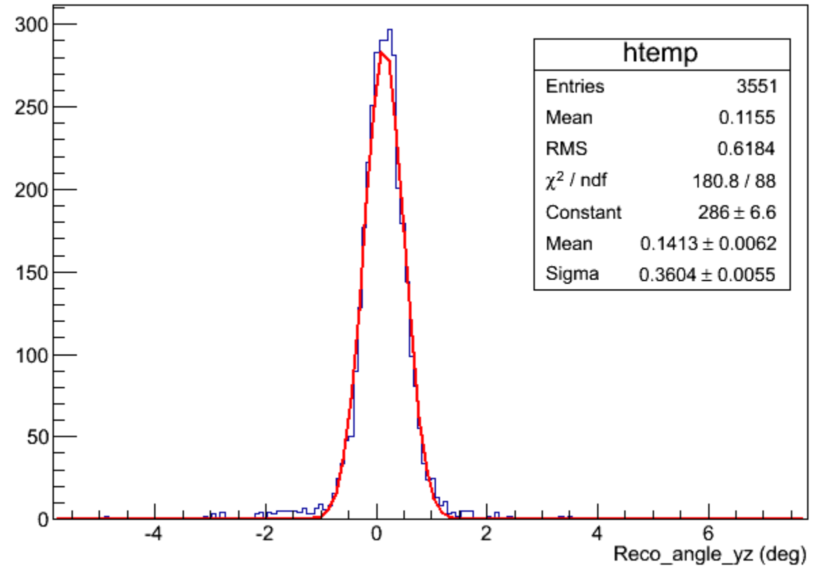


Energy Deviation = $(E_{reco}-E_{beam})/E_{beam}$

The gradient is equal to 0.885, which mainly caused by dead region.

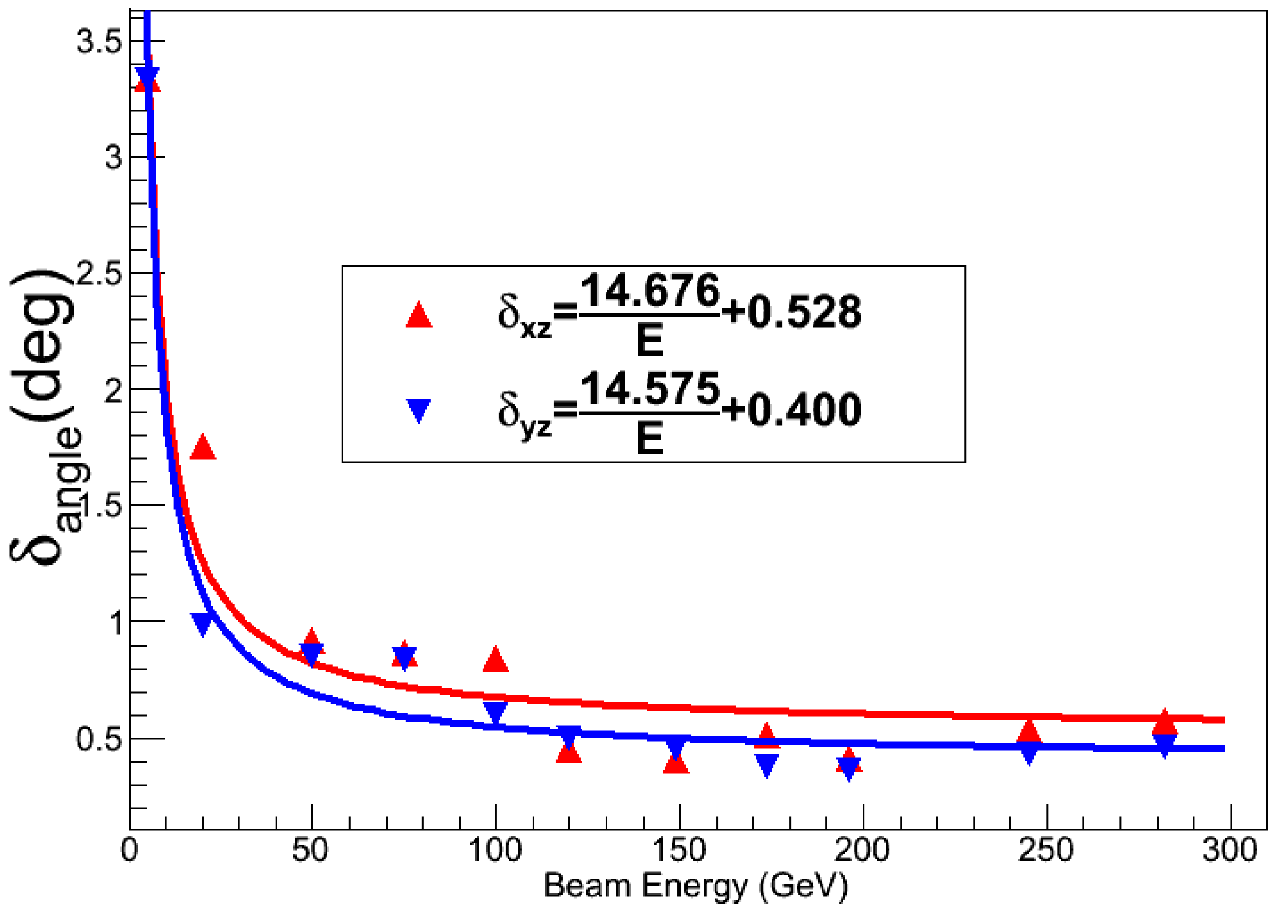
Reconstructed Angle distribution



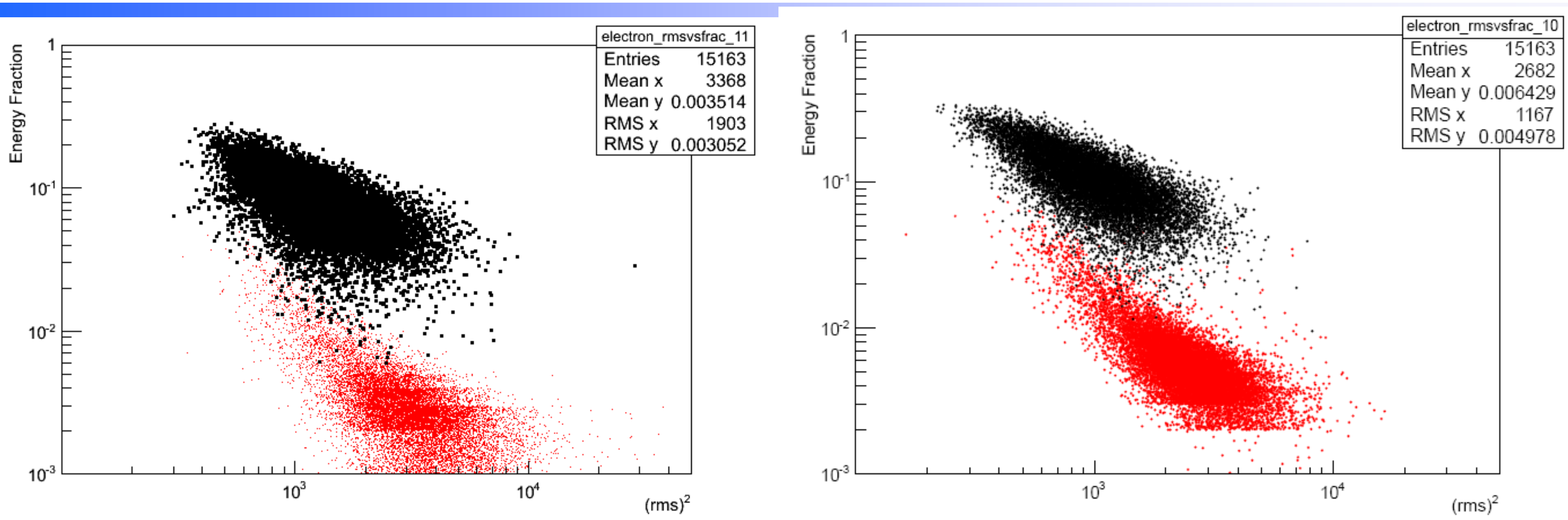


200GeV electron vertically injection.
Left: X-Z projection Right: Y-Z Projection
σ_{xz} = 0.4109° σ_{yz} = 0.3604

Angle Resolution δ_{angle}

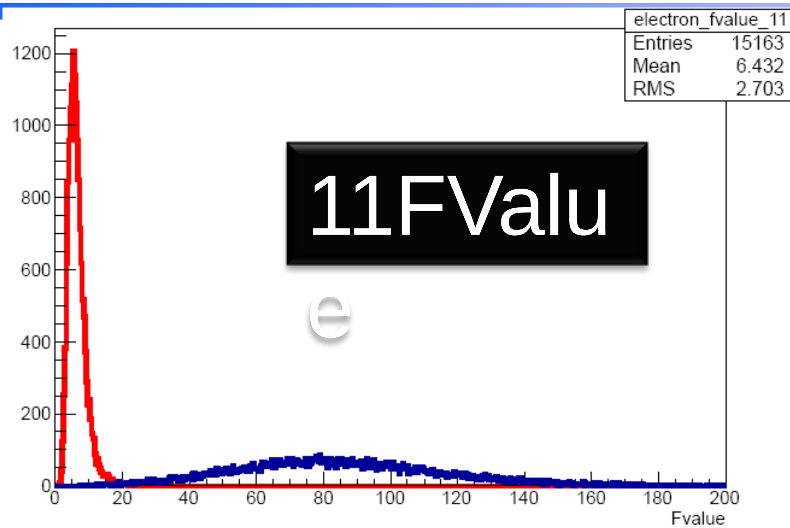


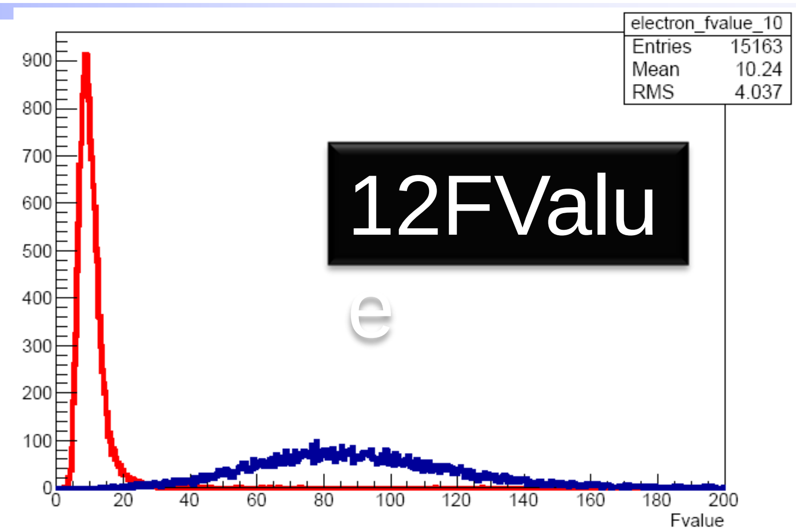
e/p discrimination



Shower development in 11、12 BGO Layer, Red dots: e, black dots: p

e/p seperation





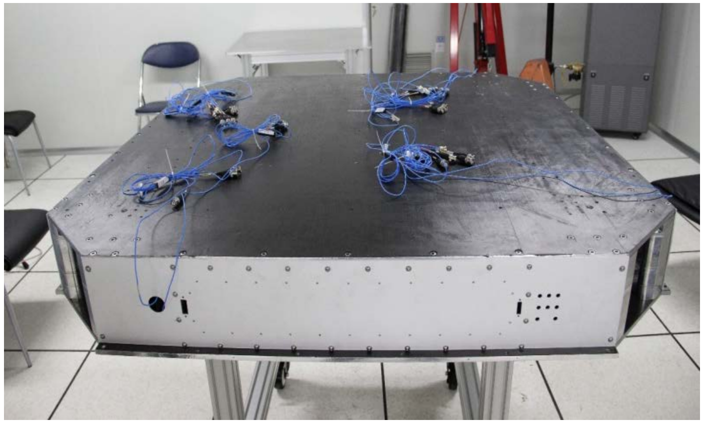
	e	p
Total events	24556	540145
energy [100,120]GeV	15163	12668
F11<14&F10<19	14462	5
Eff.	**95.38%**	**0.0395%**

These results agree with simulation very well

Present Status

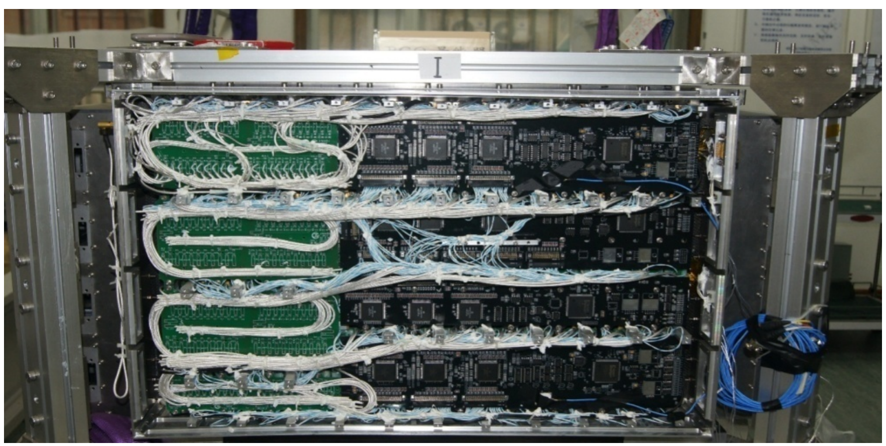
Vibration Test

Plastic
Hodoscope

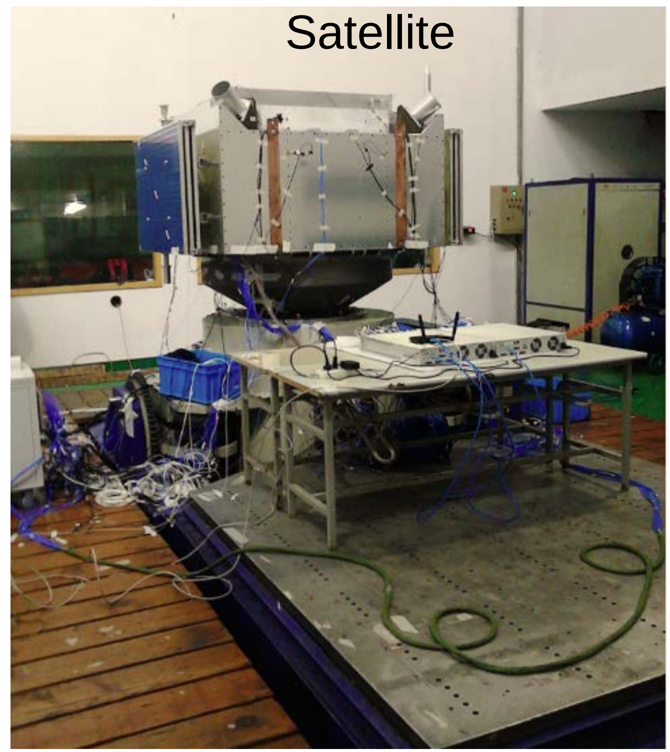


Neutron Detector

BGO Cal.



Satellite



Phase-C& D

- June, 2014, end of Phase C。
- Flight Model will be finished end of 2014
- Launch date: June, 2015

谢谢!