Dark Matter Particle Search by High Energy Electron and Gamma-ray Observation

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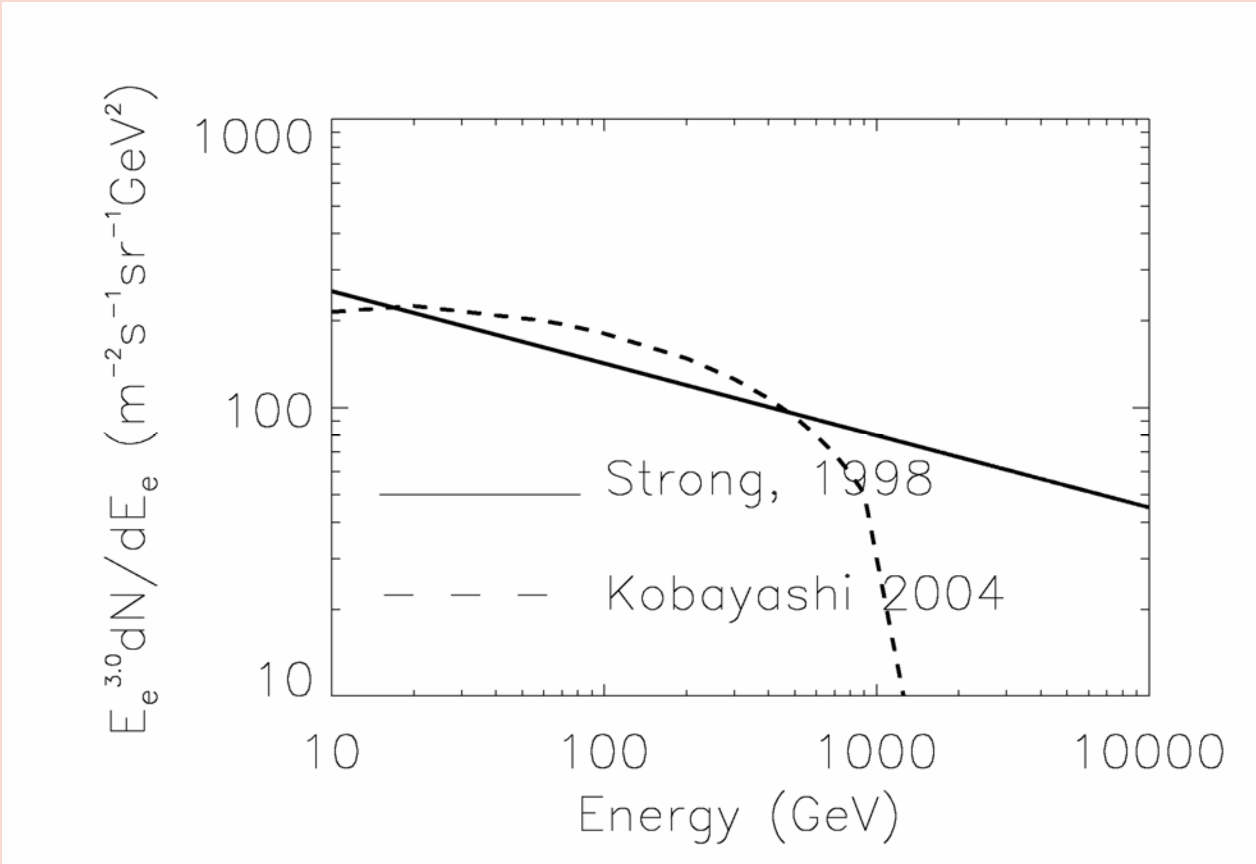
Outline

- Astrophysical Significance
- ATIC Results
- Chinese missions for high energy electron
- Summary

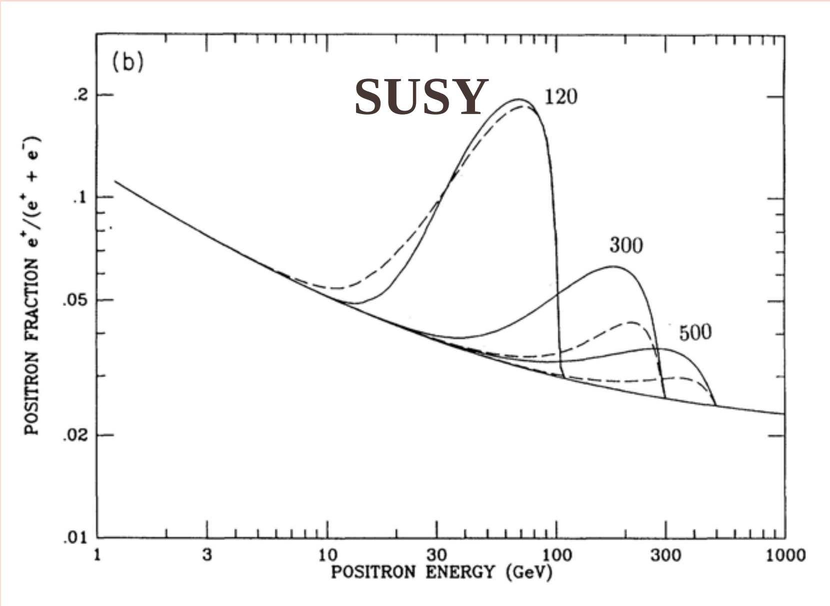
Astrophysical Significance

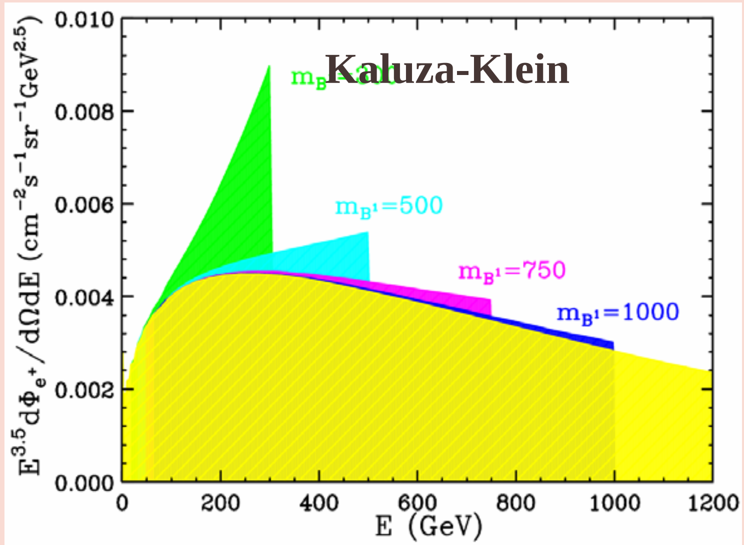
- Dark Matter Signatures
- Nearby Sources of Cosmic Particles



$E_e^{3.0} dN/dE_e$ ($m^{-2}s^{-1}sr^{-1}GeV^2$)
1000
100
10
10
100
1000
10000
Energy (GeV)
Strong, 1998
Kobayashi 2004

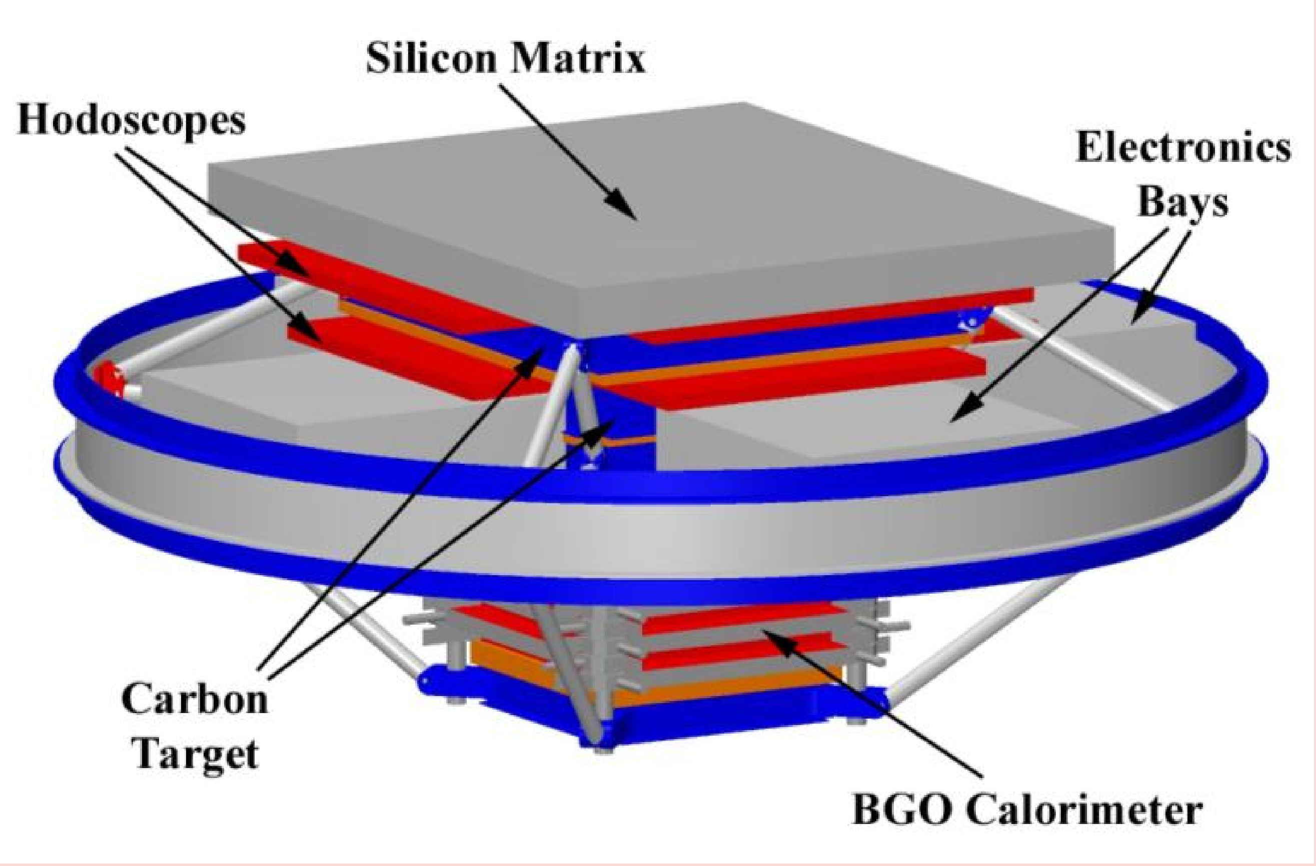
Dark matter particle can produce some structures in smooth electron spectra!





ATIC Results

ATIC


Silicon Matrix
Hodoscopes
Electronics
Bays
Carbon
Target
BGO Calorimeter

Flight Results

The ATIC long duration balloon test flight from McMurdo, Antartica occurred between 2000-12-28 and 2001-01-13 (~16 days) and the first science flight occurred between 2002-12-29 and 2003-01-18 (~20 days)

Total observation time: about 36 days

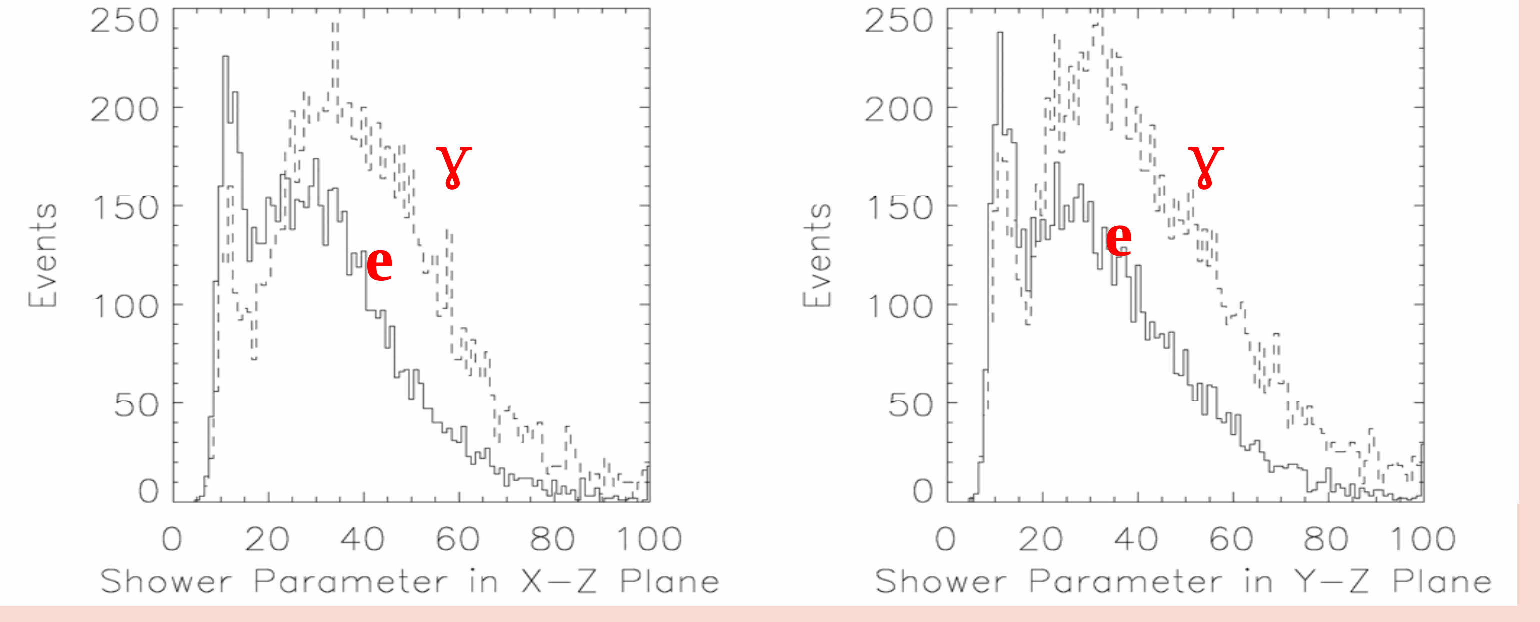
How to select ‘electron events’ from flight data

- According to Gamma-ray

We use top Scn as segmented anticoincidence

Gamma-ray showers are similar to electron showers

We use the same method (as for electrons) to choose gamma-ray events

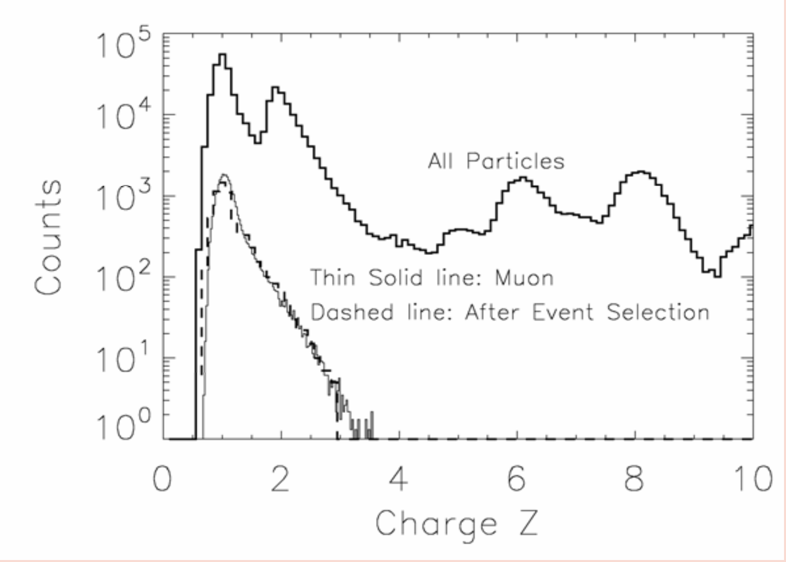


The ‘gamma-ray’ like events and ‘e like events’

Background Level

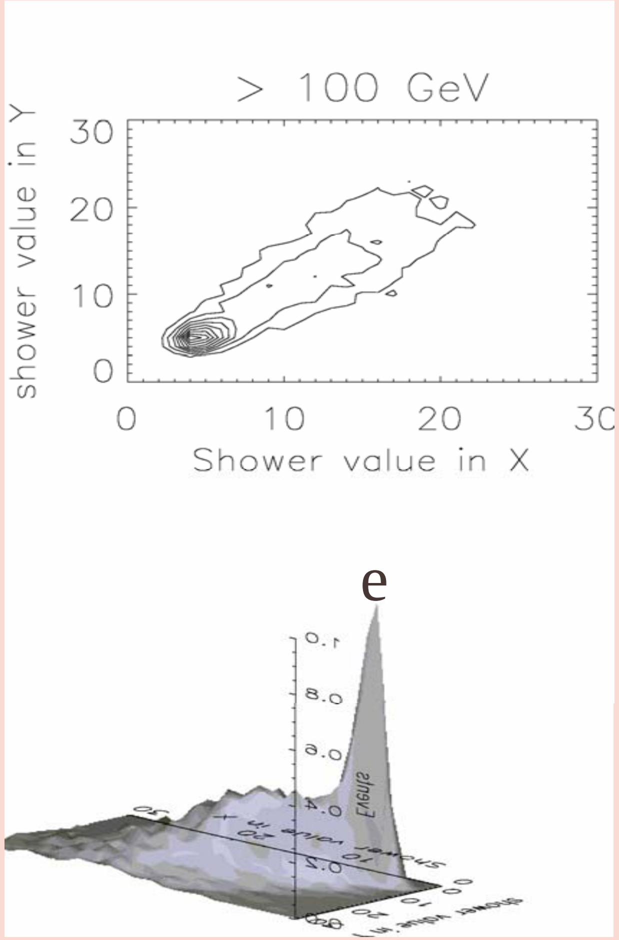
The proton shower development is similar to heavy primary
According to: + The ratio of protons/heavy primaries, and
+ The ratio of false e-events (from heavies)/ heavy primary events,

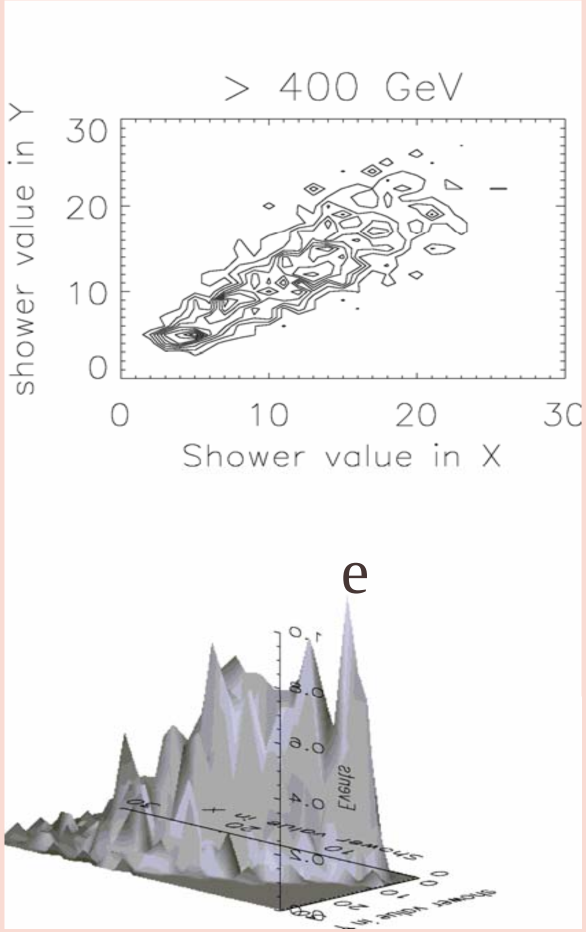
we can, after considering the shower difference between protons and heavy primaries, estimate how many protons are mistaken for electrons



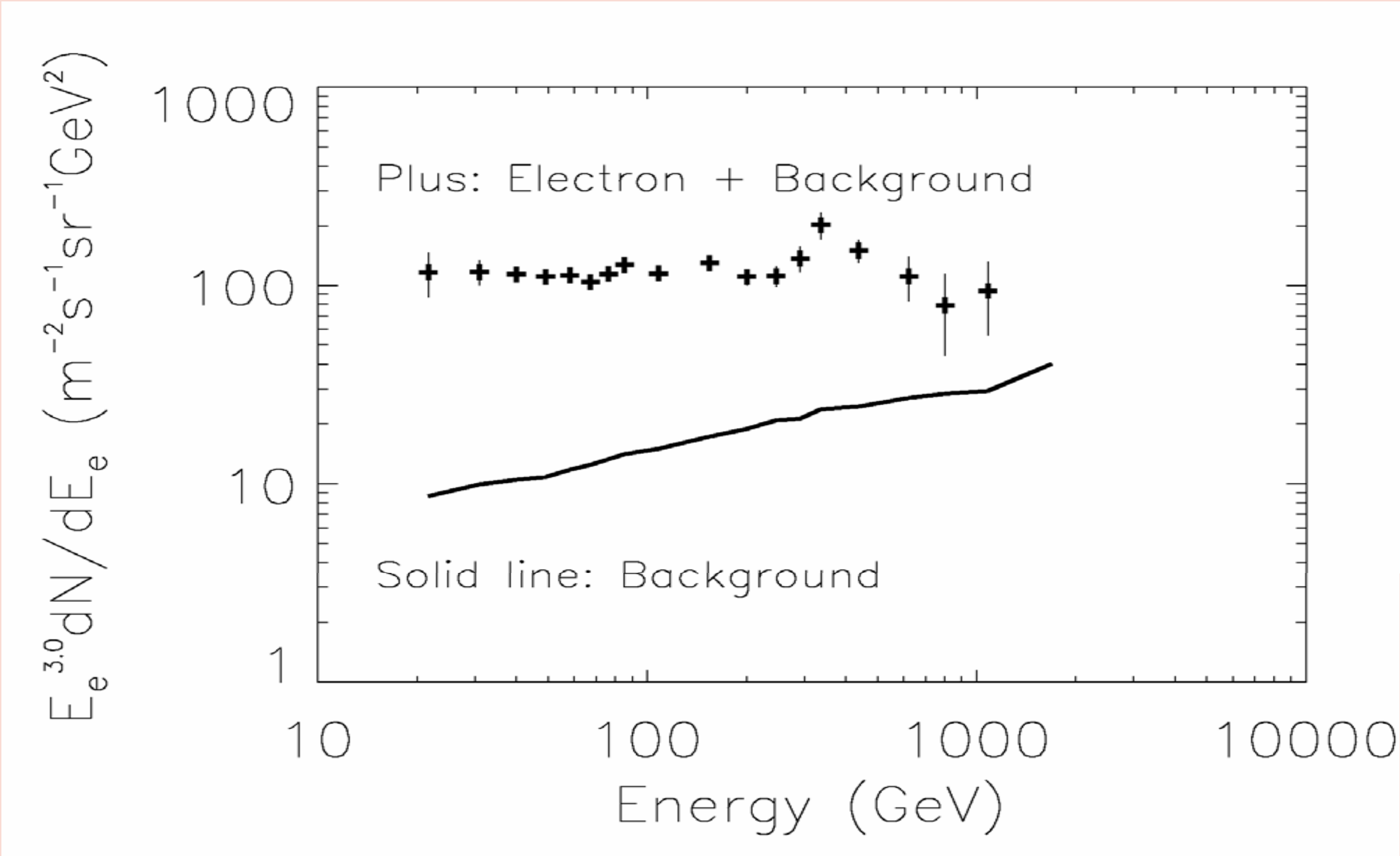
For the flight data proton rejection power is about 6000

Electron signal from flight data

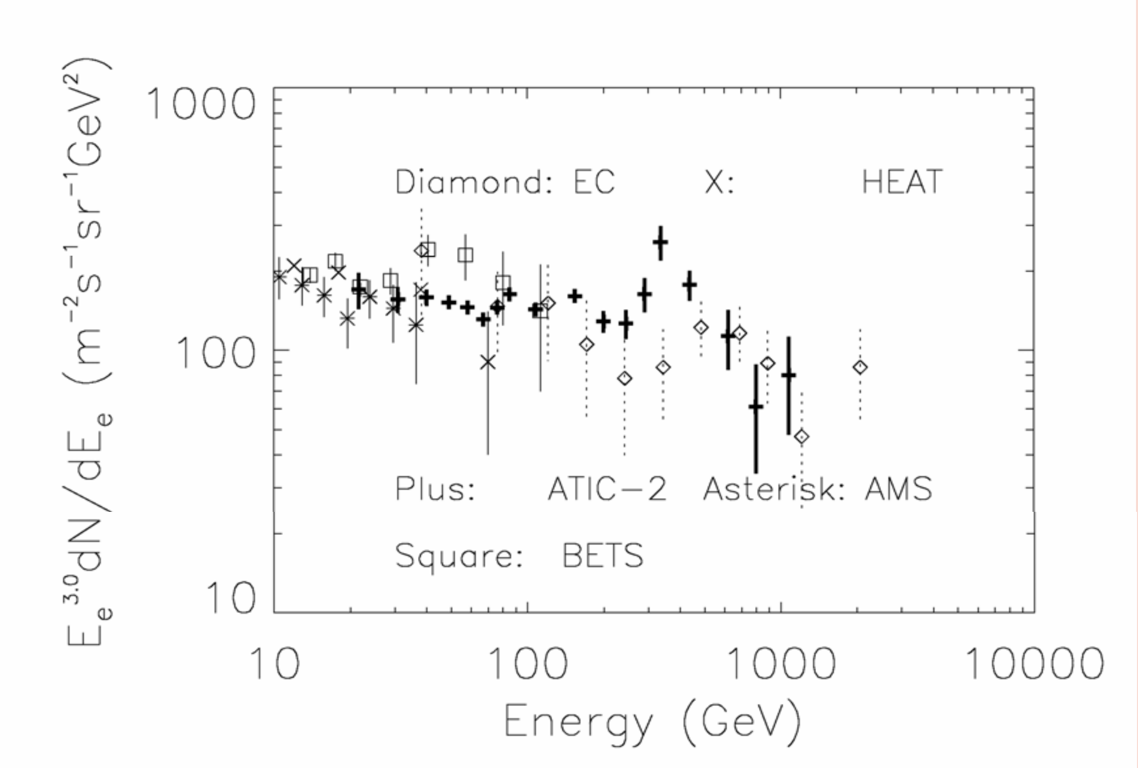




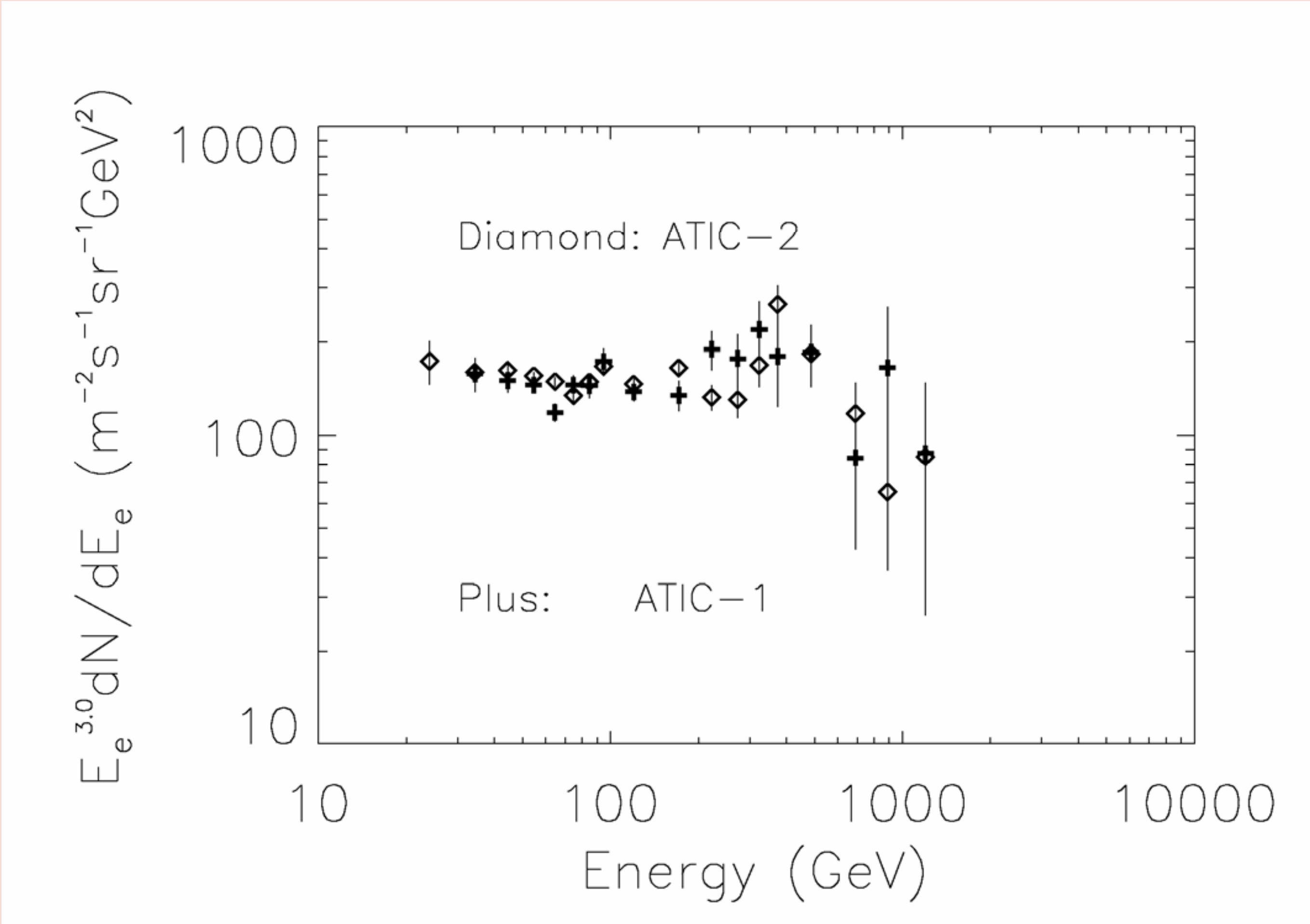
Flight Result



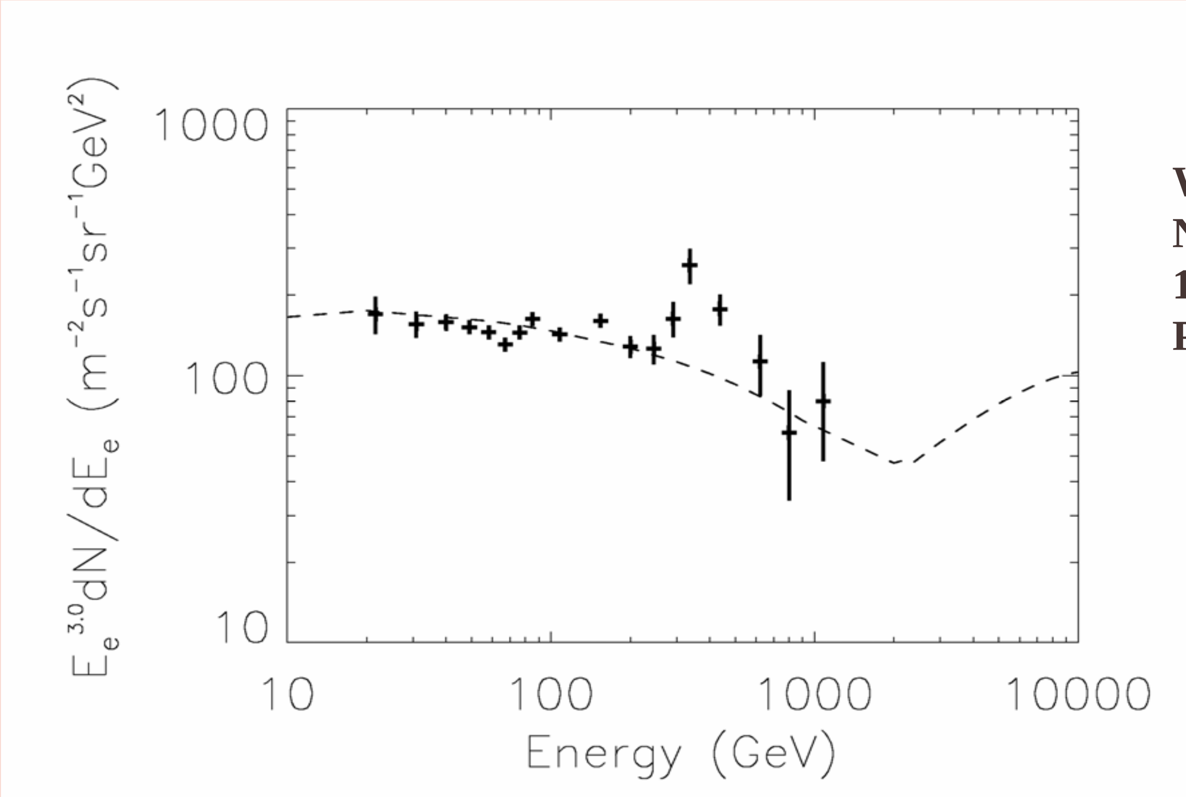
Electron Spectrum from ATIC-2



Electron Spectrum ATIC-1 and ATIC-2



Comparing with electron models

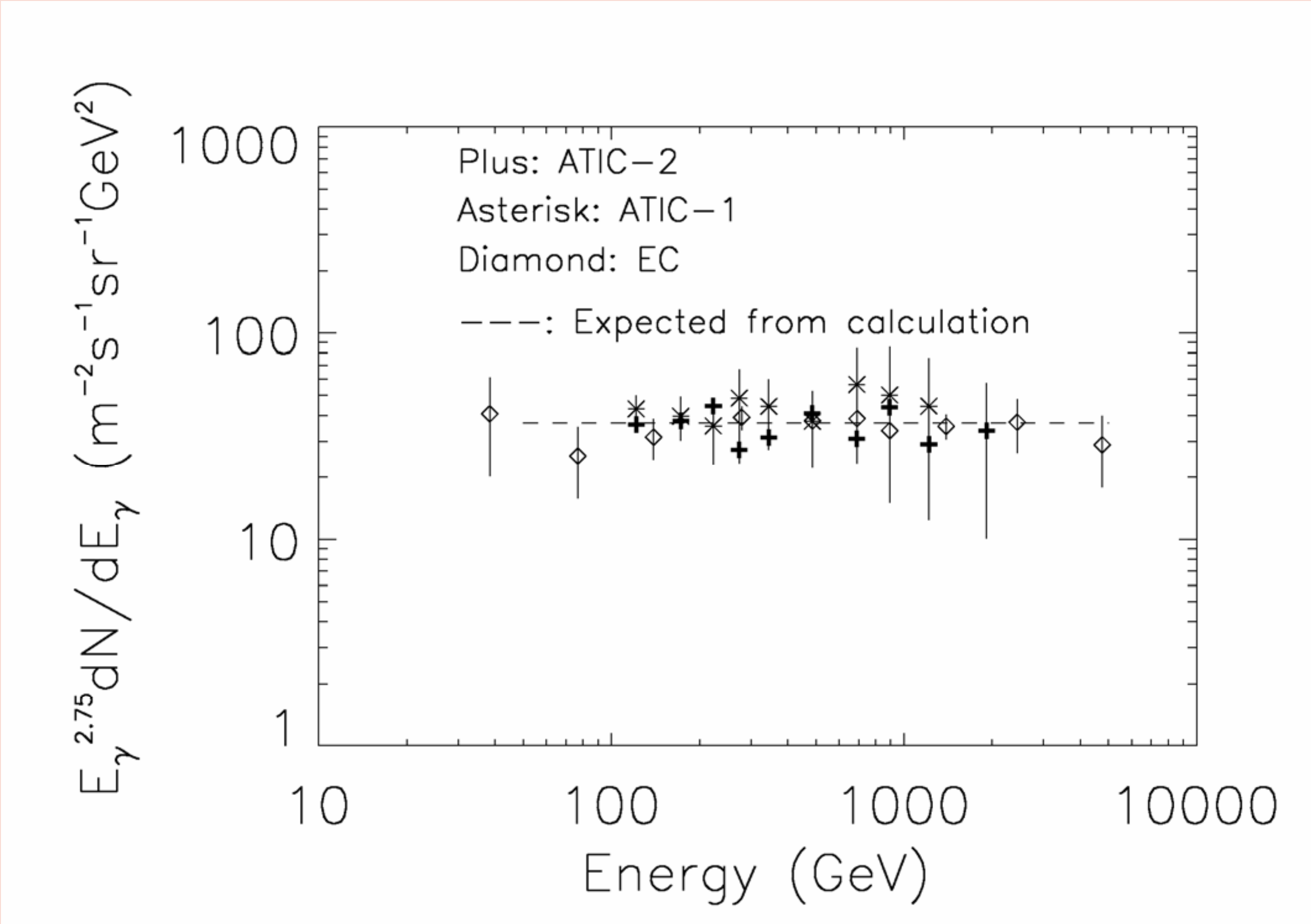


We have checked all Nearby sources within 1kpc, sources can not Produce this bump!

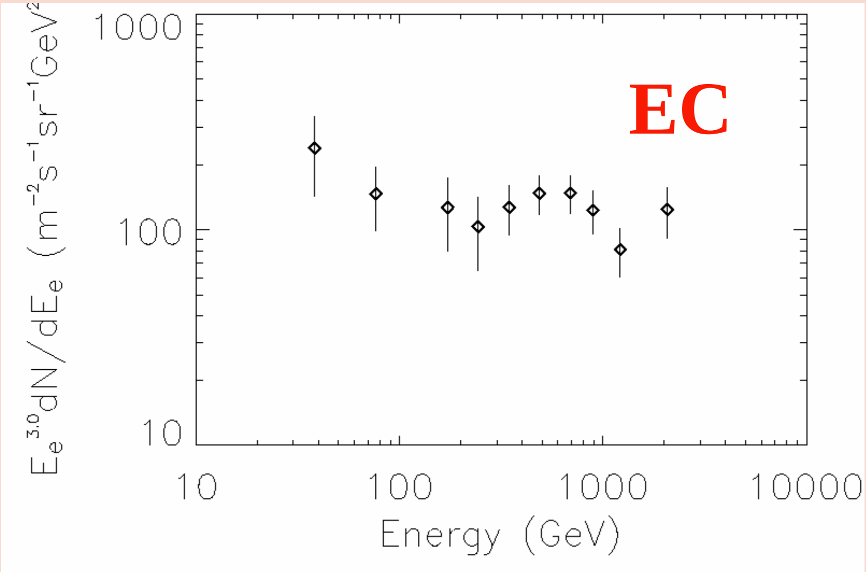
Absolute electron spectrum spectrum comparison with calculated model by a diffusion coefficient of $D=2.0X10^{29}(E/TeV)^{0.3}cm^2s^{-1}$ and a power index of injection spectrum 2.4

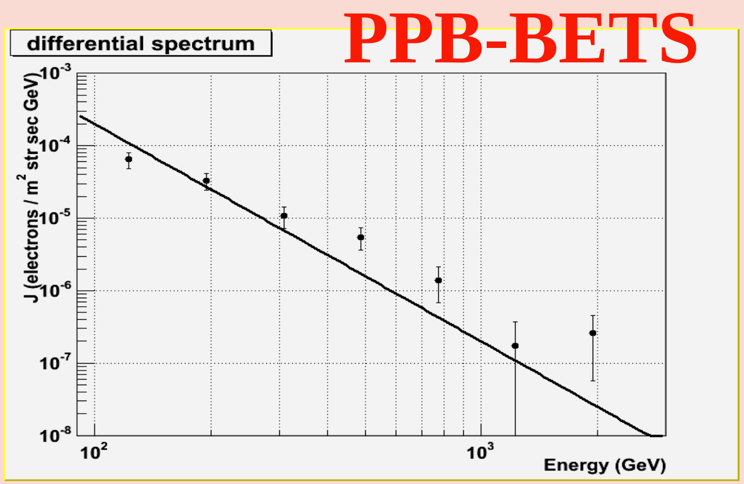
T. Kobayashi, et al.; Astrophys. J. 601 , 340 (2004)

Atmos. Gamma-ray results



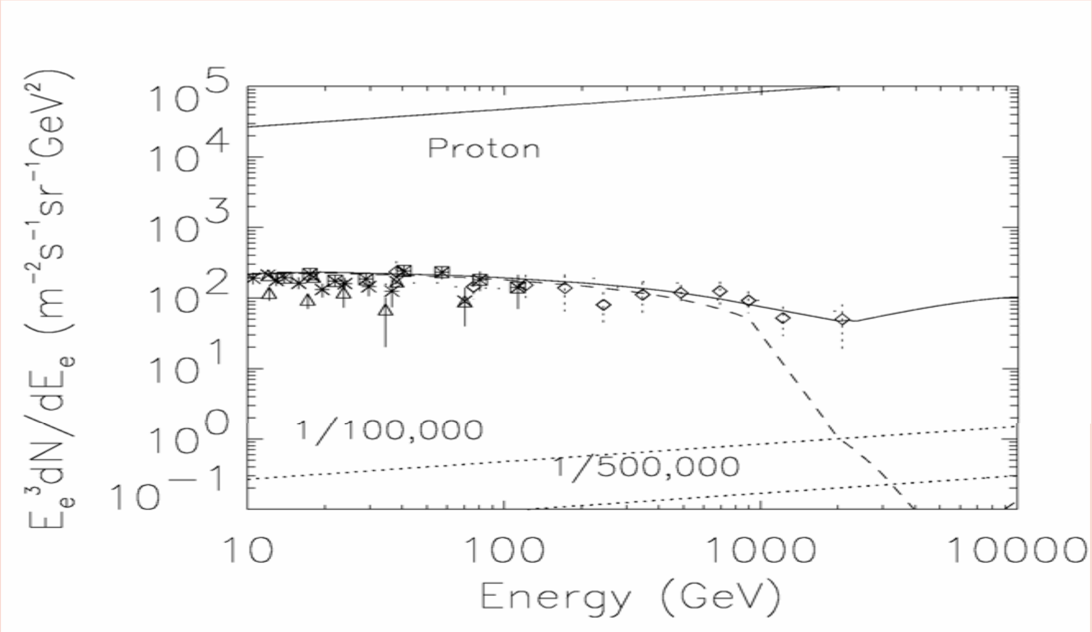
Other Experiment





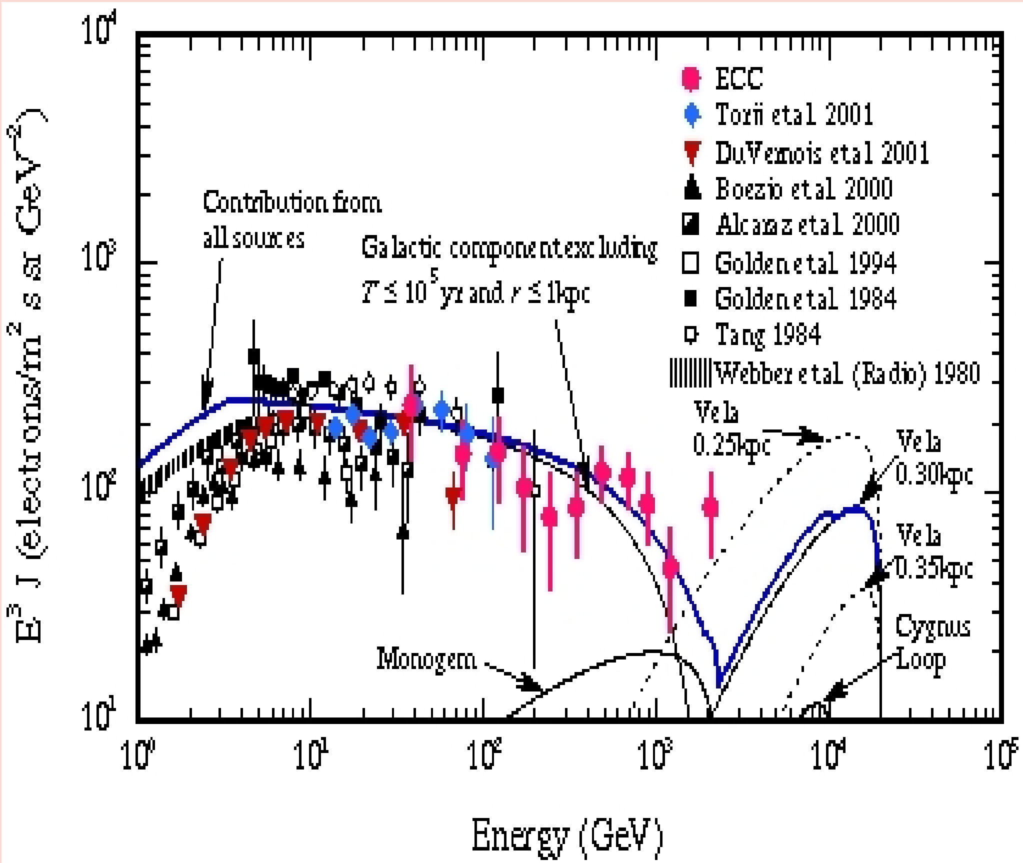
High Energy Electron Observations in China

For electron Observation：Background Rejection
Electron spectrum: 1/100 of P (-3.3)



P e seperation>10^4

Present Electron Observations



Below 100 GeV
200% difference

Above 100 GeV:
Only EC and ATIC
PPB-BETS

Present Technique

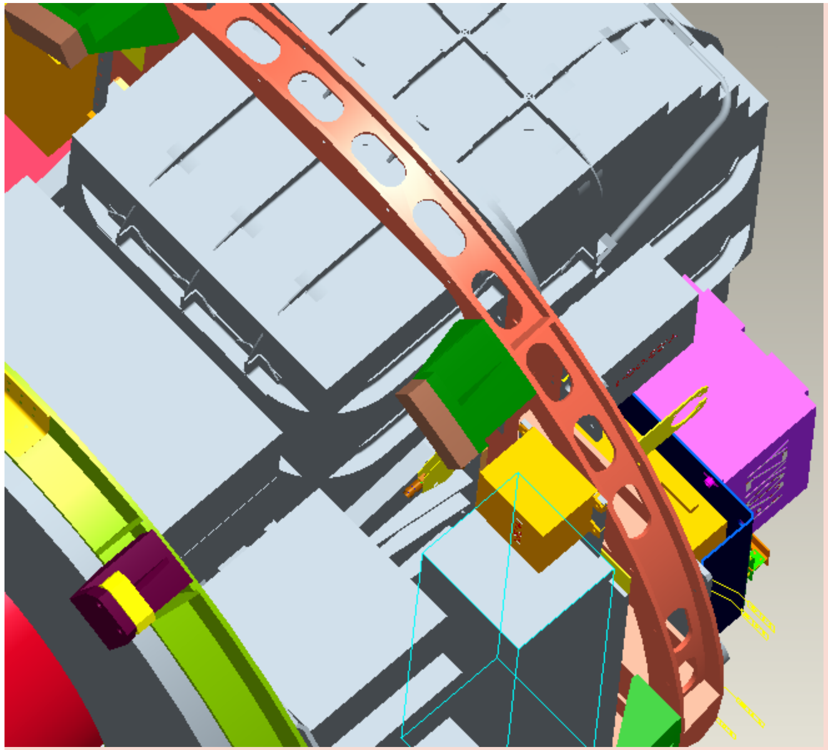
- Magnet Spectrometer
- Emulsion Chamber
- High Resolution Calorimeter

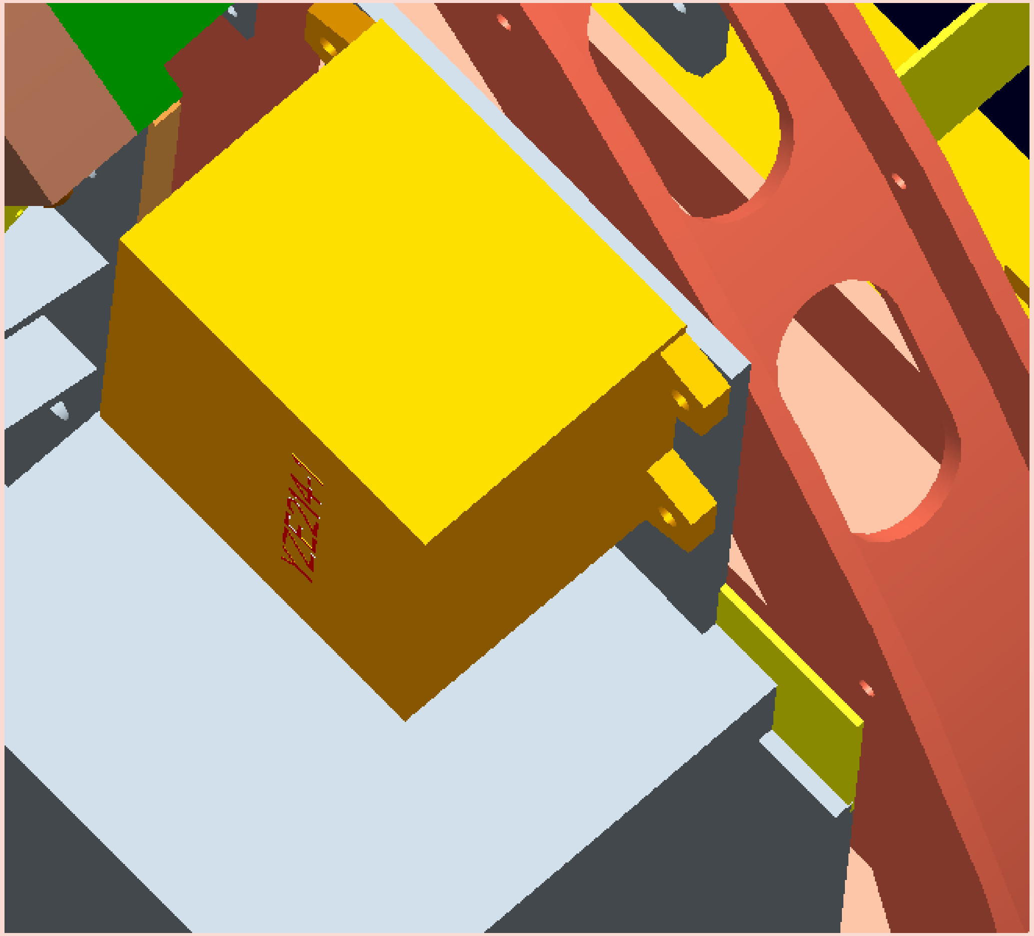
Emulsion Experiment

Purple Mountain Observatory,China
Institute of High Energy Physics, China
Waseda Univ. Japan
Aoyamagakuin Univ.,Japan
ISAS,Japan

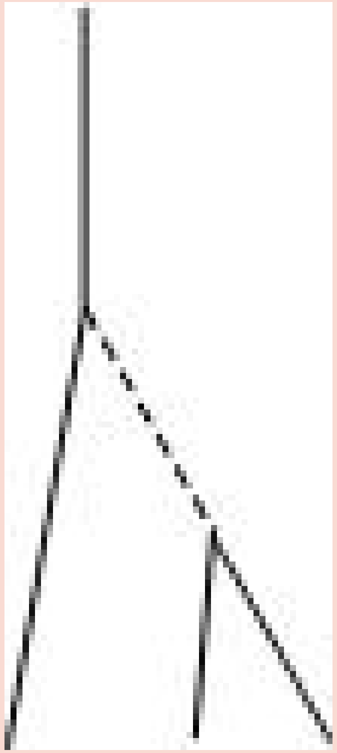
EC in Zhongzi Mission

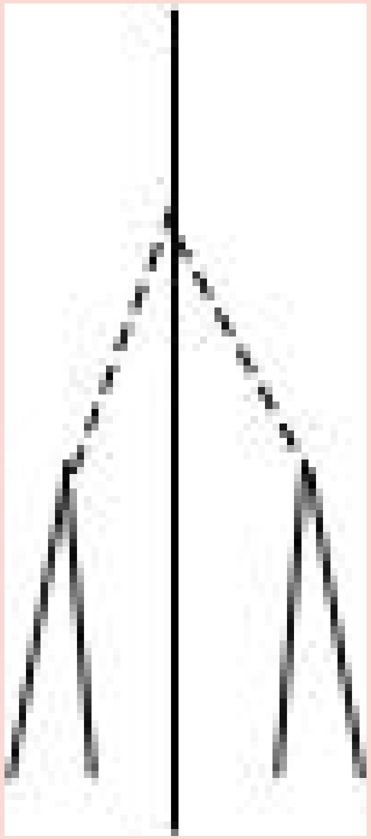
- Return Capsule
- 14 days
- 5 kg for EC test
- Launch time: Sept. 2006
- Launch place:Jiuquan
- Recovery Place:Suining
- First EC experiment in the space
- If successful, large experiment!

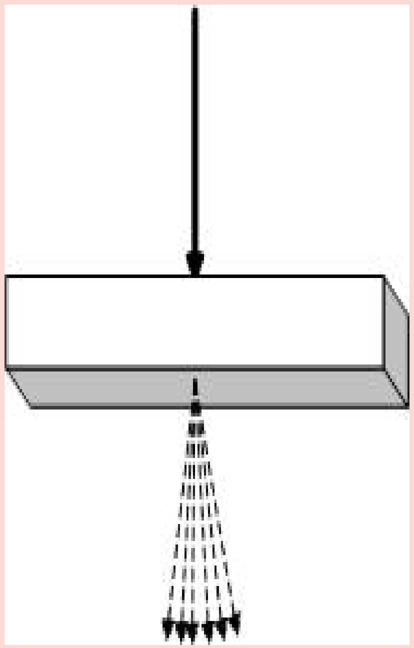




EC e p separation
1/50000, ApJ 280

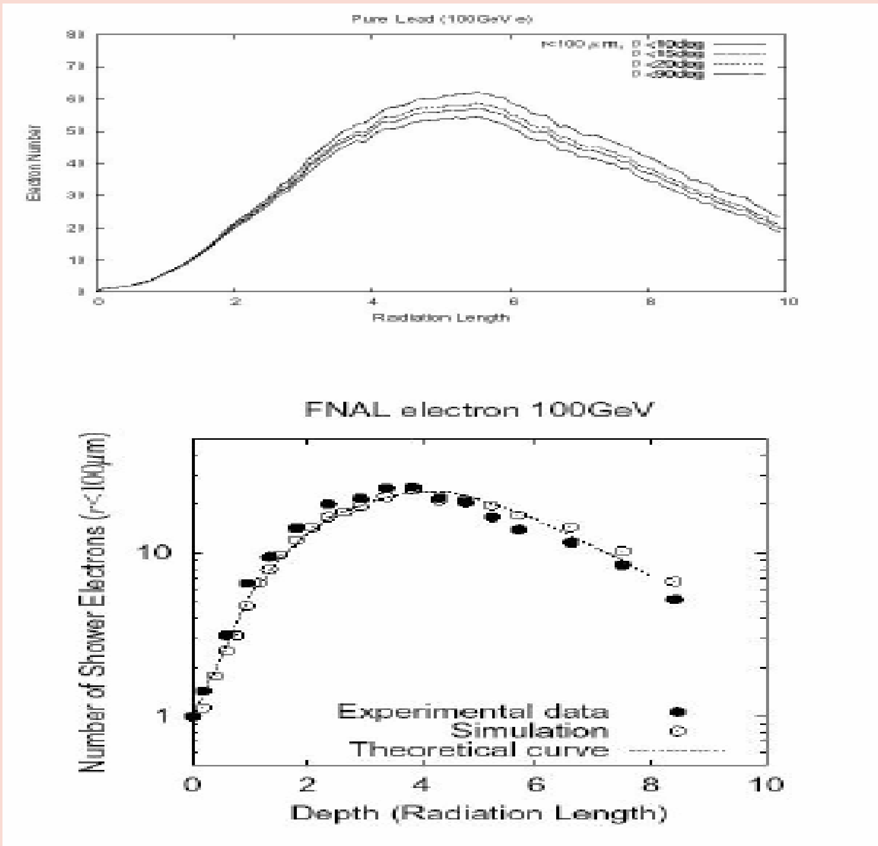




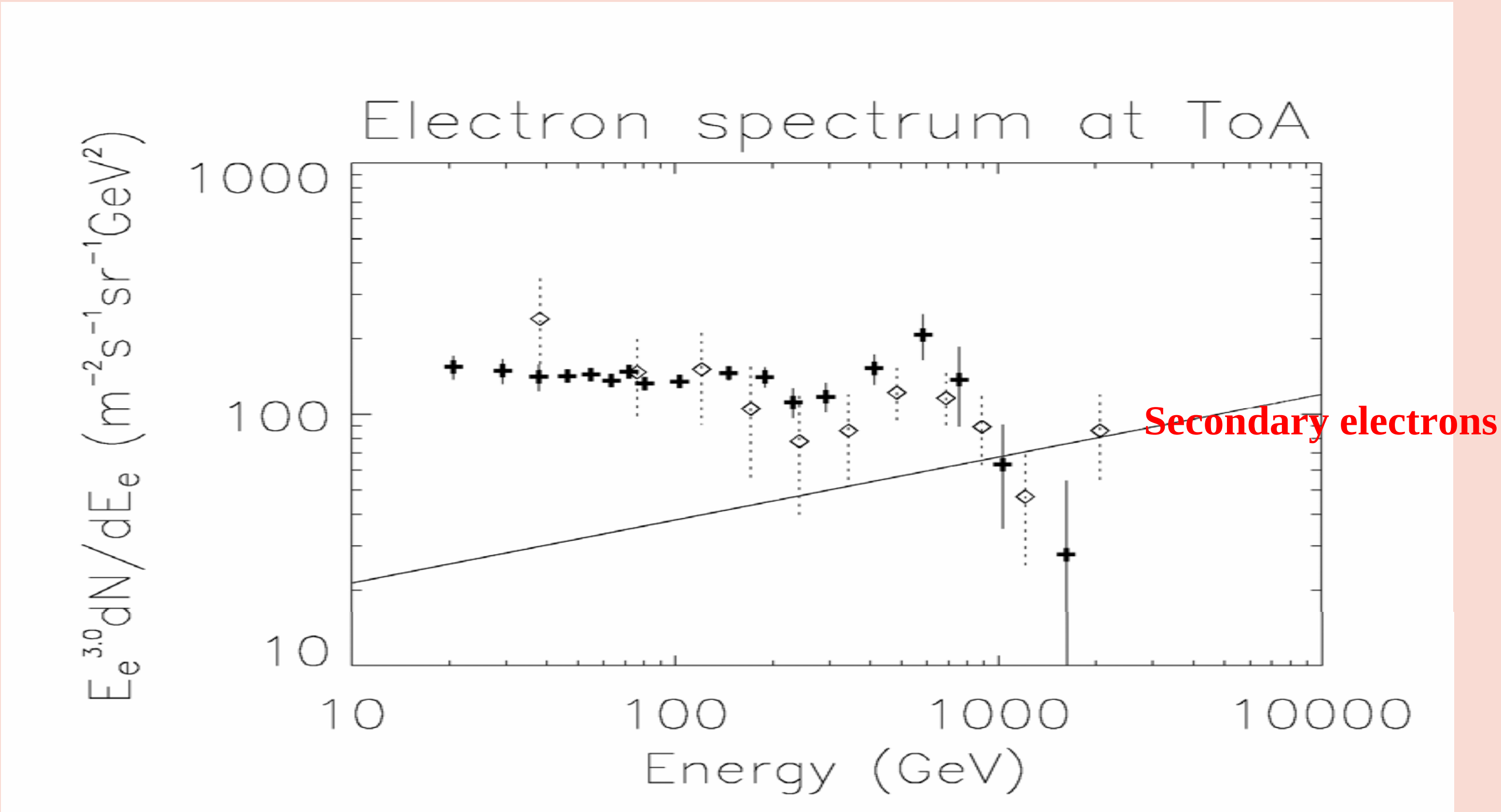


Energy measurements

- Shower profile analysis, energy resolution=15%



Present EC measurements



Go to space!

EC Mission

- 5kg
- >100 GeV, 30
- >200 GeV, 7.6
- >400 GeV, 2.2

100Kg EC

- >100 GeV, 3000
- >200 GeV, 800
- >400 GeV, 230

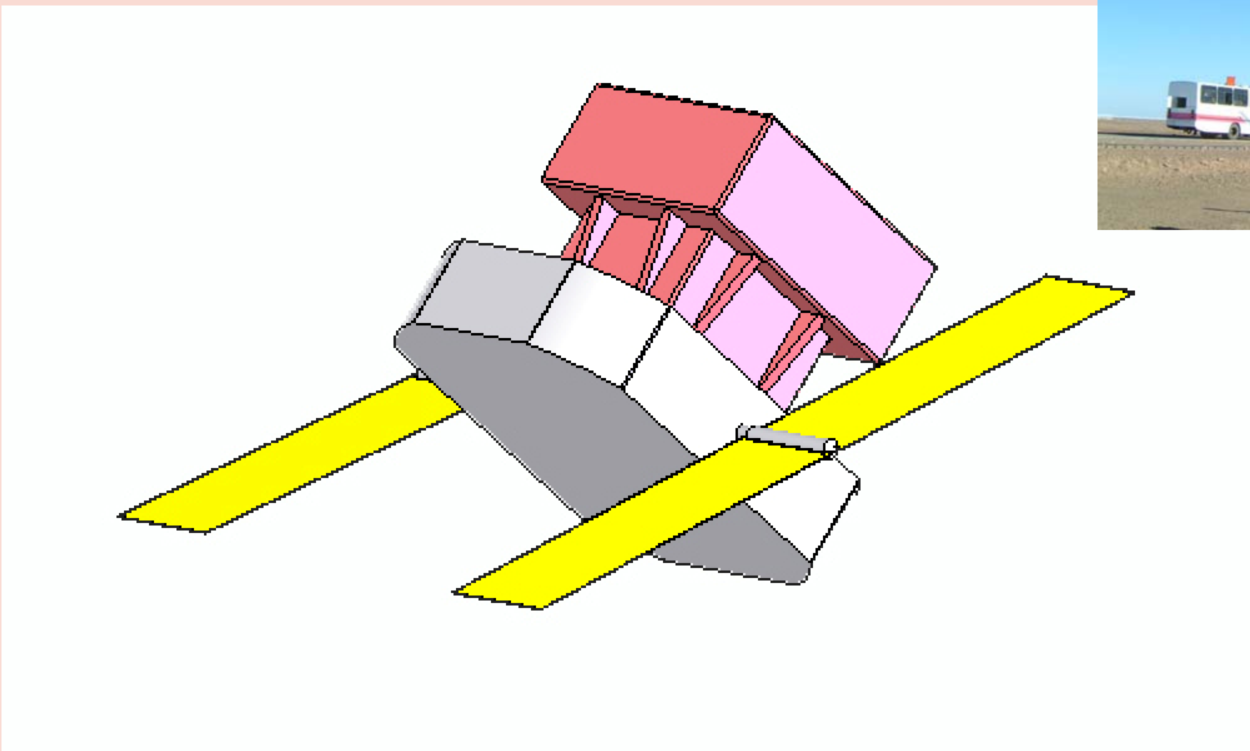
Weight & Geo. Factor

AREA	400	900	1225	1600	2500
G. F. (m^2.Sr)	0.073	0.2	0.28	0.38	0.63
Weight (kg)	21	46	63	82	128
Events (>300GeV)	70	200	280	380	630

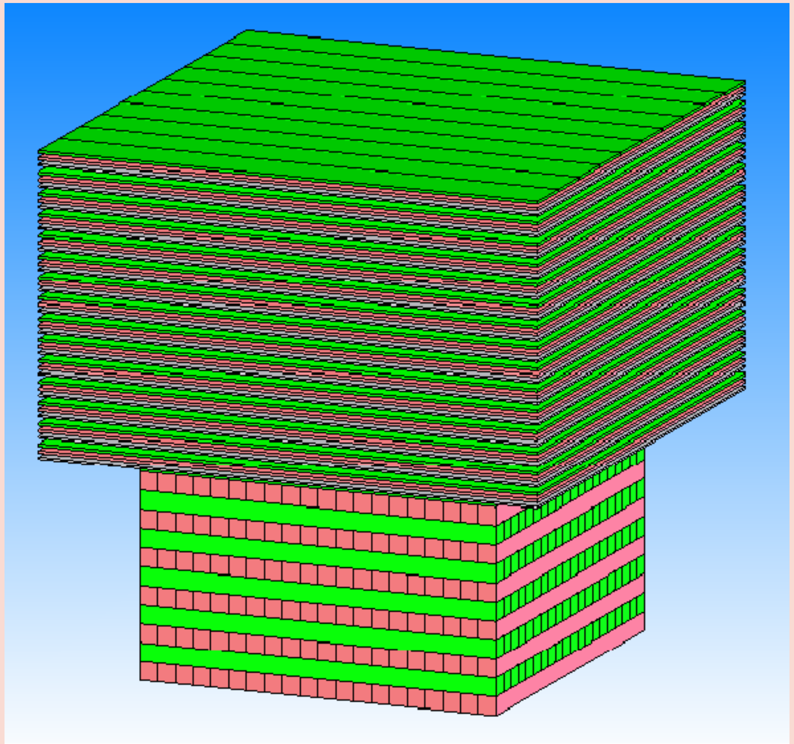
ATIC 36 days, only about 140

High energy electron and Gamma-ray Telescope (HEGAT-DMS)

PMO, IHEP, CSSAR
WU, ISAS, Kanagawa Uni. …



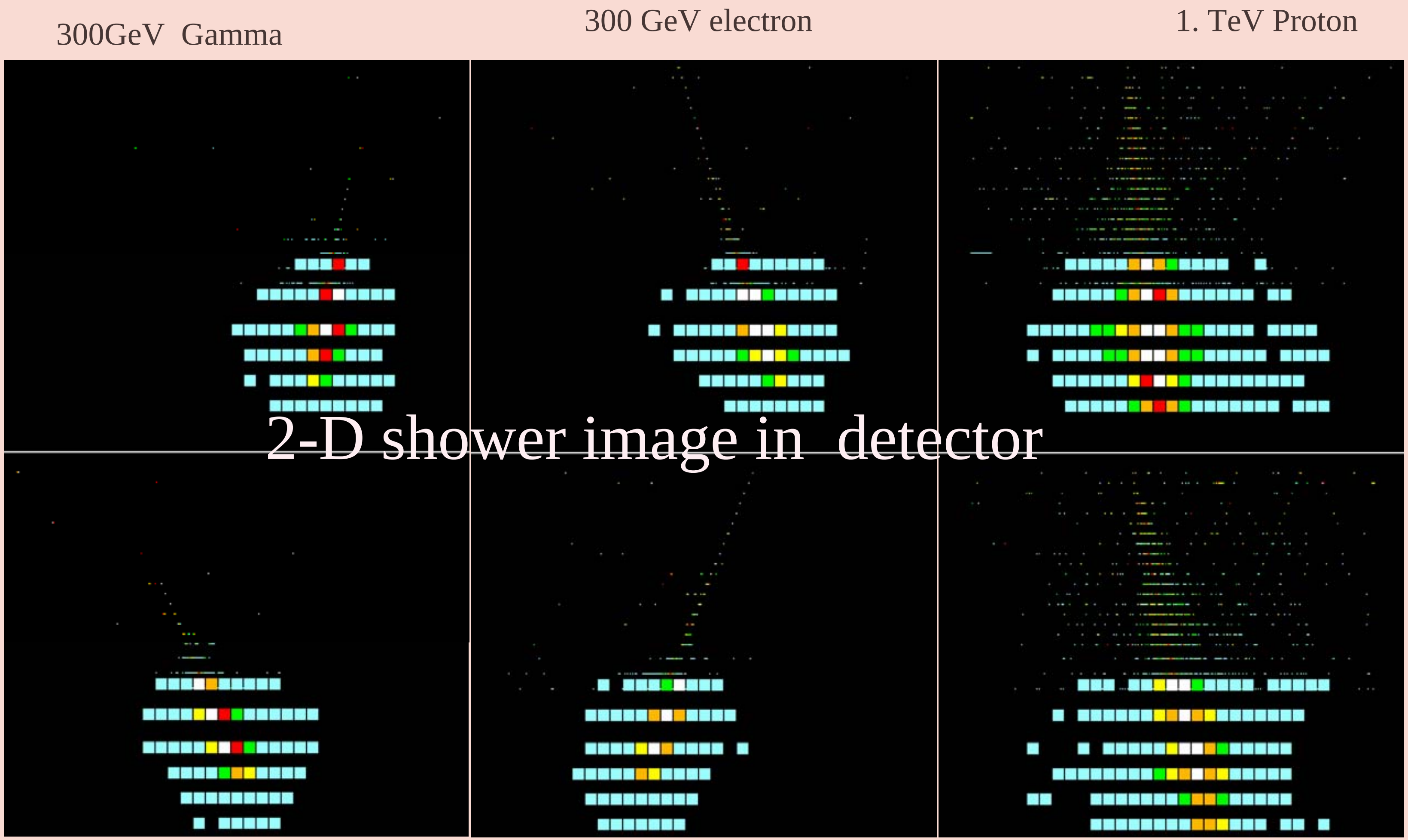
IMC + BGO



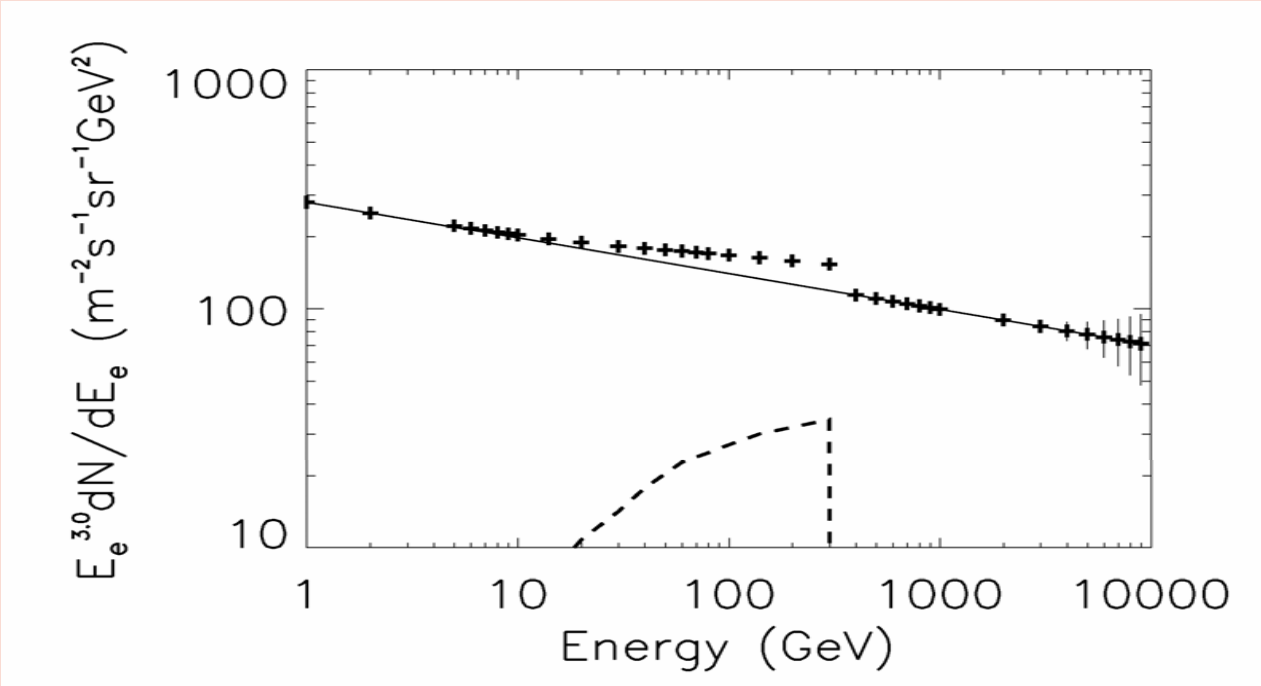
Size: 70cmX70cm for IMC
50cmX50cm for BGO
IMC: 3 r.l. (1mm)
BGO: 22.3 r.l.
Resolution: 2%@100GeV
Energy Range: 1GeV-5TeV

Weight: 650Kg
Power: 300W

Shower image detector

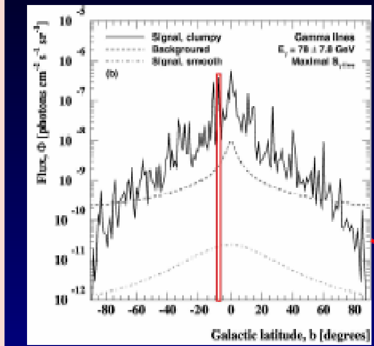


Expected Results



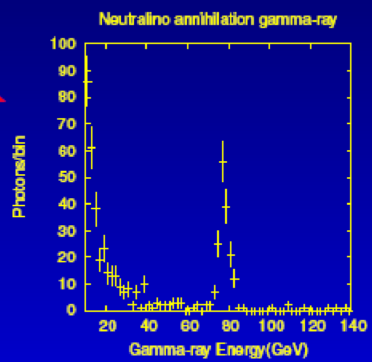
Simulated electron flux enhancement due to dark matter particle signal (Annihilation of 300 GeV dark matter particle produce equal fraction of $\tau^+\tau^-$, $\mu^+\mu^-$ and e^+e^- pairs, a NFW dark matter distribution with a boost factor 5 and ρ_{local}=0.4GeV/cm^3 [4], solid line is fitted from present electron observation data.)

Expected Results

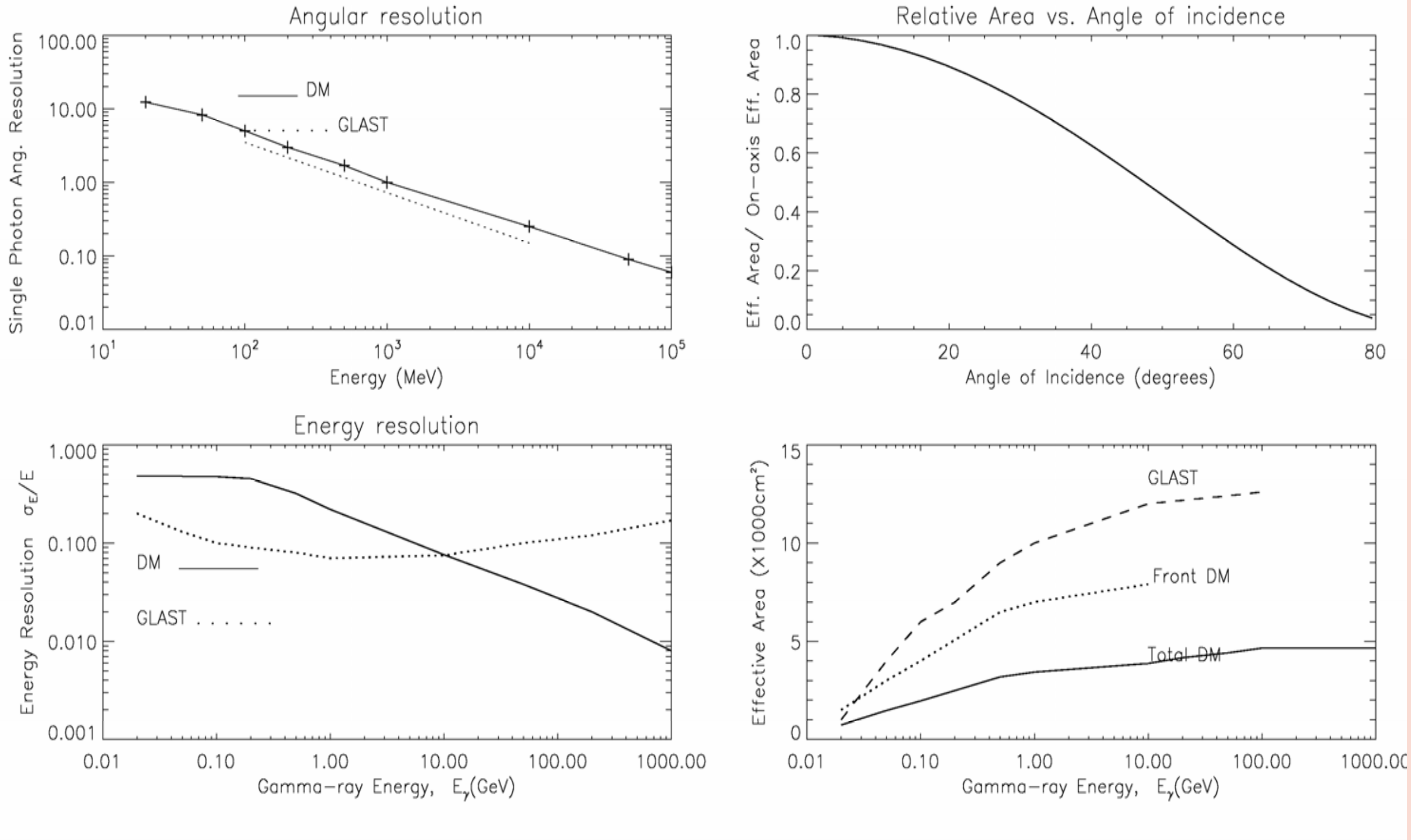


- Neutralino gamma-ray line signals of 78GeV from accreting Galactic halo dark matter (Bergström et al., Phys.ReV.D (2001))
- The flux of 3×10^{-7} (cm^{-2} s^{-1} sr^{-1}) in a field of $44° \times 1°$ at $b \simeq -10°$

Expected energy spectrum of a gamma-ray line at 78GeV from neutralino annihilation for 3 years, including the background of the Galactic diffuse emission.



Gamma-ray Astronomy

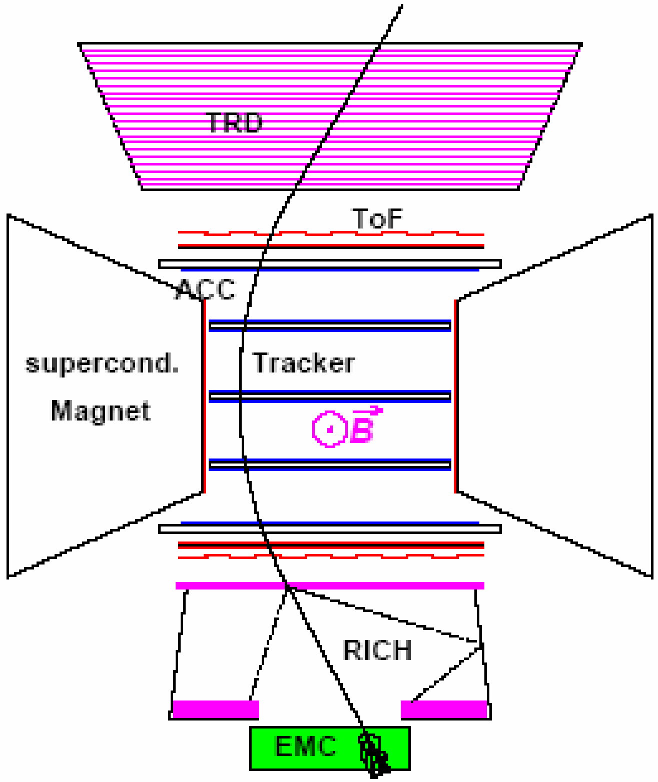


Summary

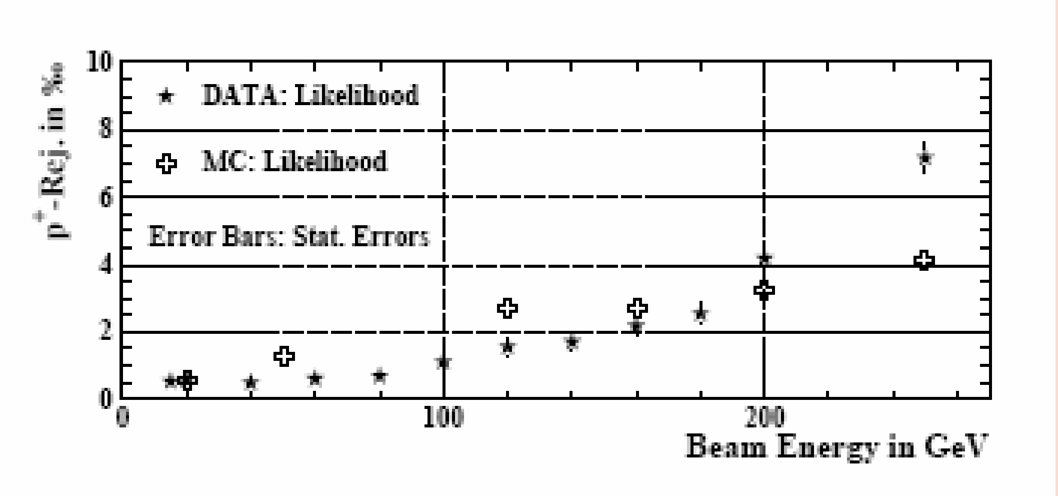
- **Electron observation is very important for high energy astrophysics**
- **DM can produce detectable signal in electron spectrum**
- **Space EC experiment (2006)**
- **HEGAT-DMS** in future

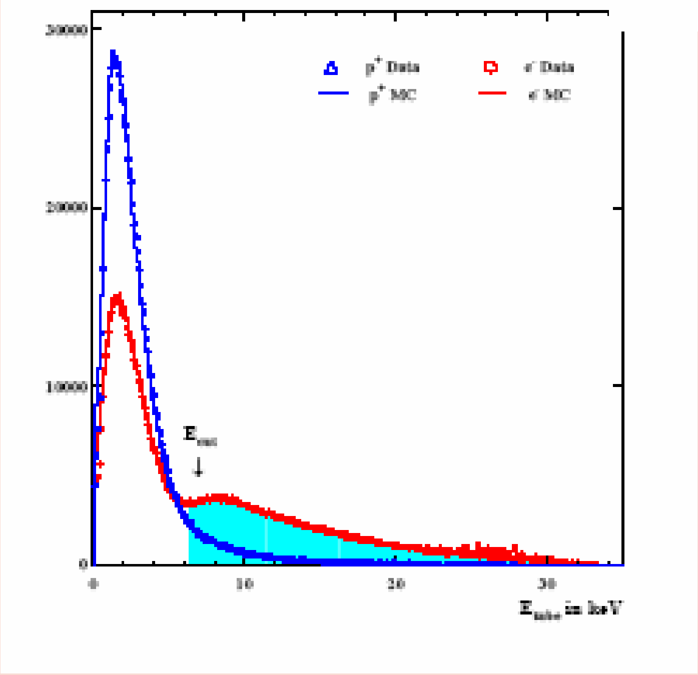
Thanks !

AMS-2 Particle Identification



- ToF & Tracker:
  rigidity p/q and charge q
- reject protons from positrons with:
  shower shape in EMC: 10^{-4}
  (no) transition radiation in TRD: $< 10^{-2}$
  Efficiency for $e^{\pm}$: 90%, Momentum $p < 300$ GeV


DATA: Likelihood
MC: Likelihood
Error Bars: Stat. Errors
Beam Energy in GeV


E_cut
E_tube in keV

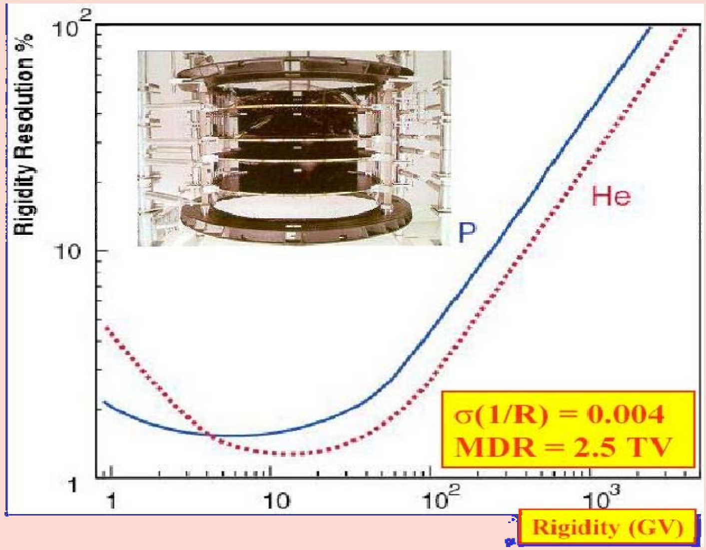
AMS

- 探测器：TRD E-M IC
- TRD β >1000

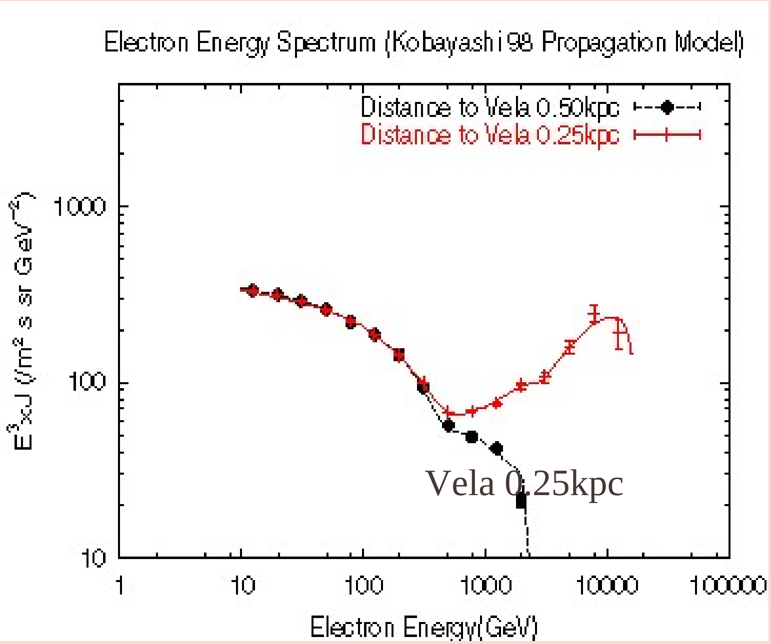
  电子1000 β =0.5GeV

  质子1000 β =1TeV

E-M



E (GeV)	Expected Numbar	p/e
10	7.4×10^7	120
100	3.8×10^5	420
1,000	1.8×10^3	1,500



Vela 0.50kpc

The method to select electron events:

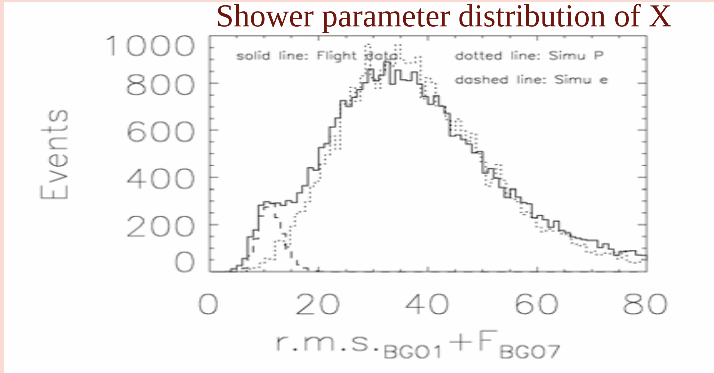
1. **Rebuild the shower image, get the shower axis, and get the charge from the Si-detector ($\chi^2 < 1.5$)**

2. **Shower analysis in Y-Direction (r.m.s. & F, BGO1 and BGO7, resp.)**

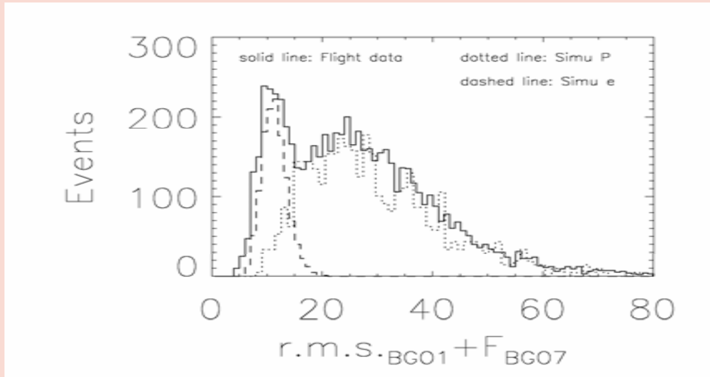
3. **Shower analysis in X-Direction (BGO2 and BGO8)**

From what is left we find that flight data agree with simulation results!!

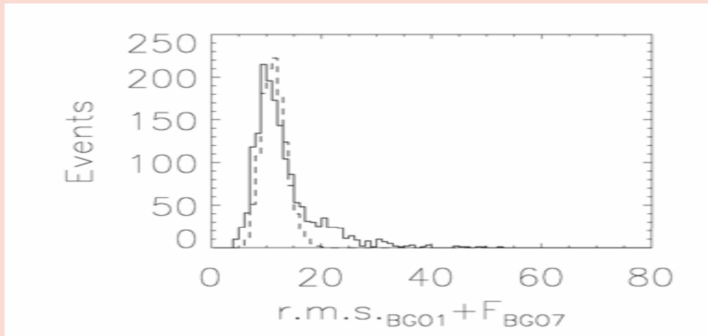
Single charge good geo. >50GeV



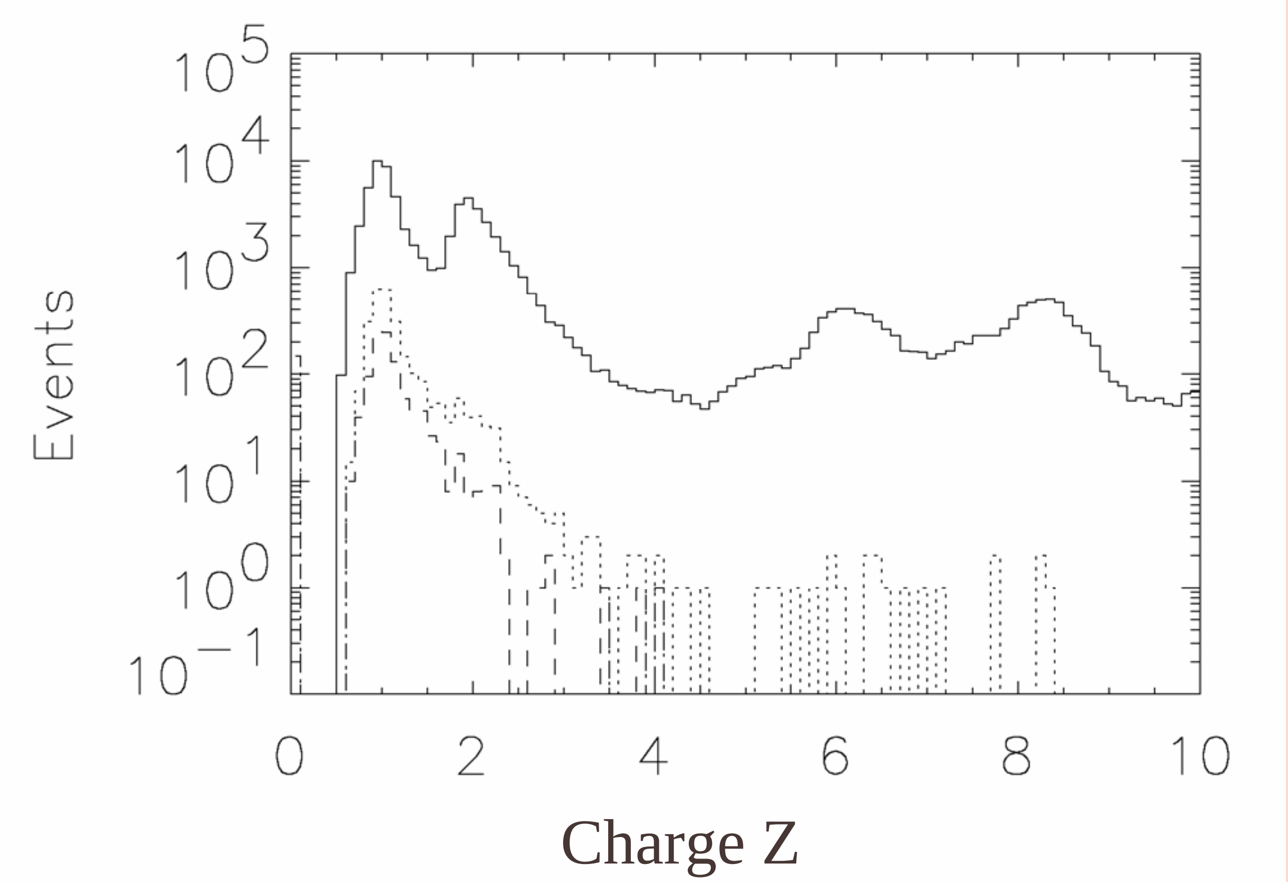
After shower axis fitting cut



After Y-direction cut



Consider the charge spectrum of heavy primaries: We apply our electron selection method without making use of the charge information. We find that almost all heavy primaries are rejected.

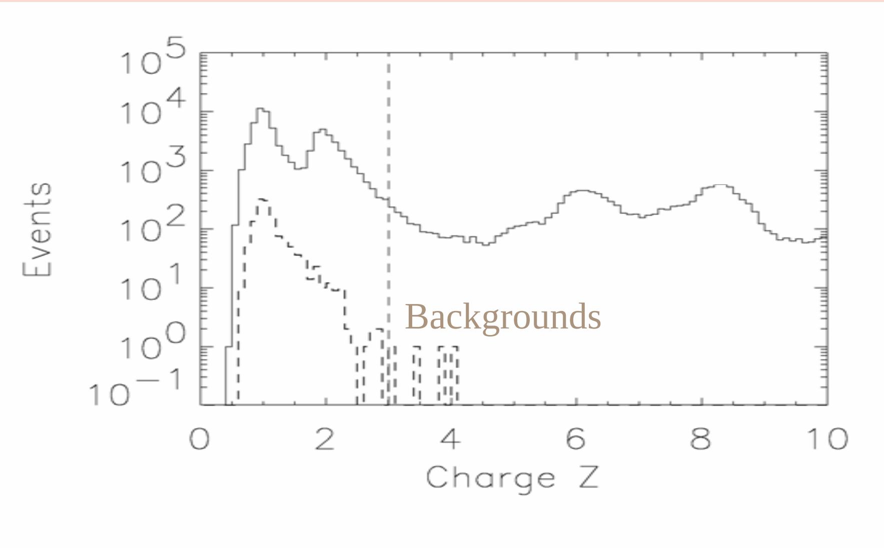


Background Level

The proton shower development is similar to heavy primary

According to: + The ratio of protons/heavy primaries, and
+ The ratio of false e-events (from heavies)/ heavy primary events,

we can, after considering the shower difference between protons and heavy primaries, estimate how many protons are mistaken for electrons



Proton rejection power is about 6000

The background level determined from the charge distribution agrees with the result determined from the shower parameter distribution.