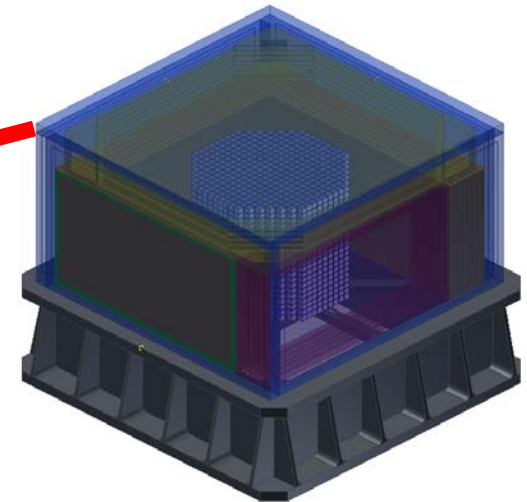
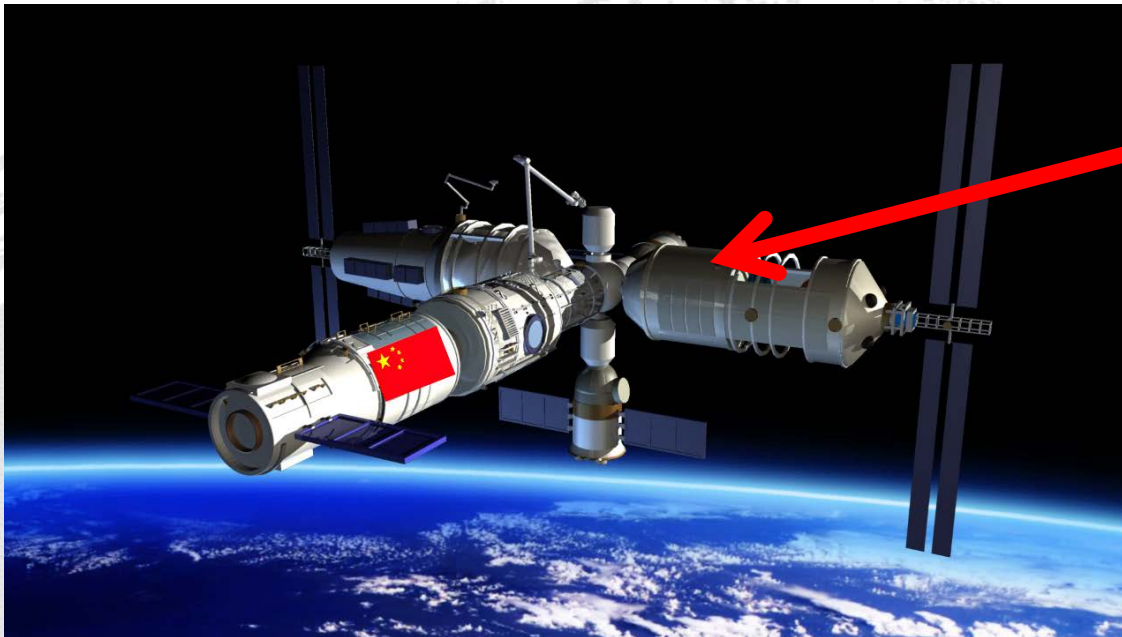


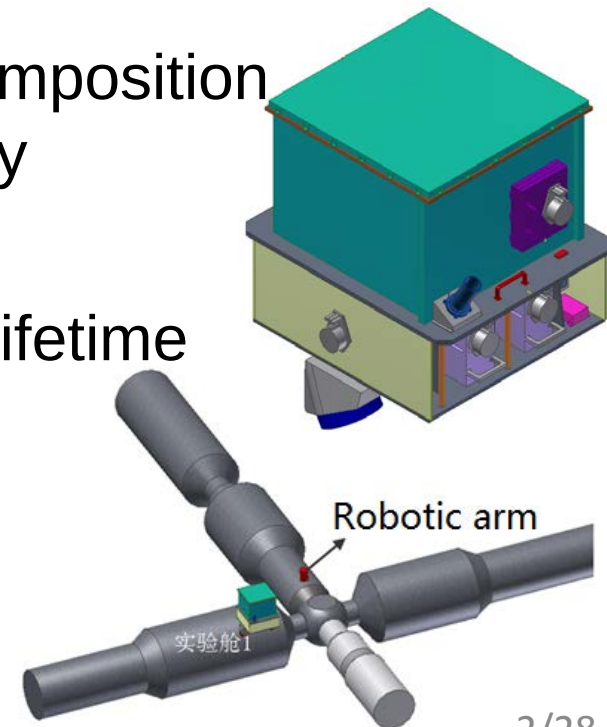
The High Energy cosmic-Radiation Detection (HERD) Facility onboard China's Future Space Station



Yongwei DONG, on behalf of HERD collaboration
Institute of High Energy Physics, CAS

HERD concept

- HERD is one of several space astronomy payloads of the cosmic light house program onboard CSS.
- Sciences
 - Indirect dark matter search with unprecedented sensitivity
 - Precise cosmic ray spectrum and composition measurements up to the knee energy
 - Gamma-ray monitoring and survey
- Planned launch 2022-2025; 10+ years lifetime

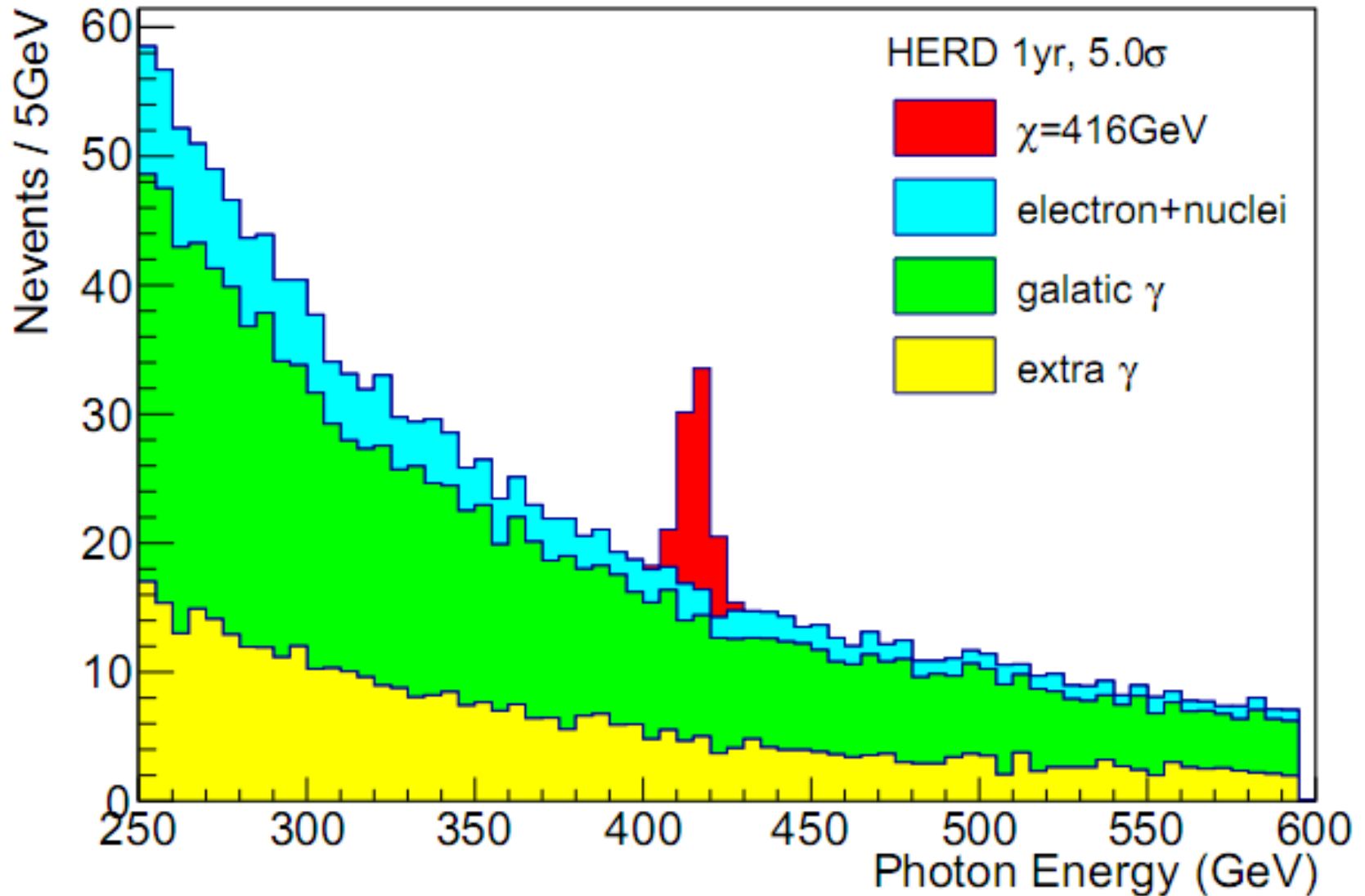


HERD specifications

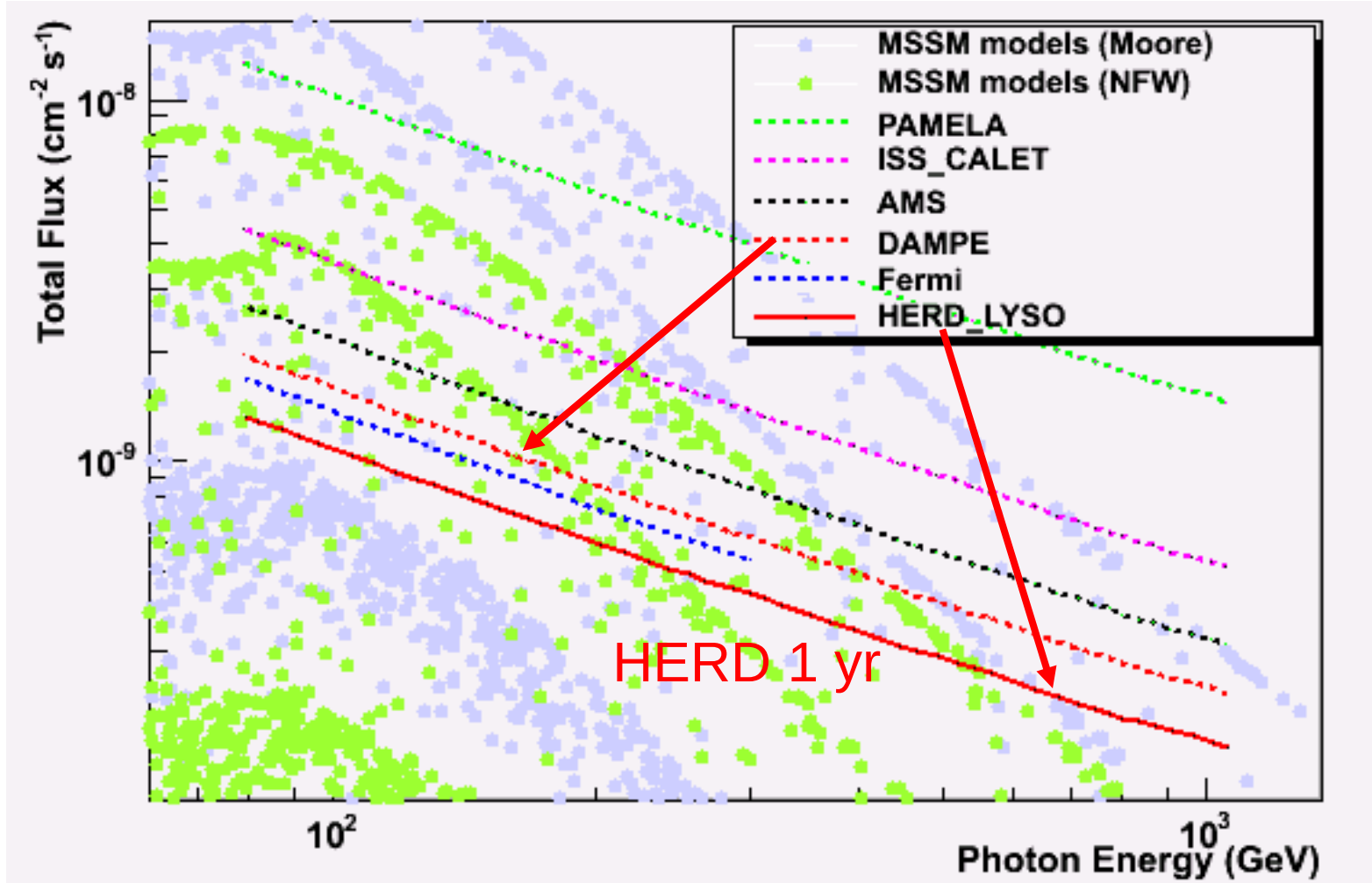
- Unique capabilities
 - Largest geometric factors for electrons and cosmic rays
 - Direct PeV CR observation with best energy resolution
 - Low energy gamma ray observation

Item	Value
Energy range (e/ γ)	10 GeV - 10 TeV (e/ γ); 0.5GeV - 10 GeV(γ)
Energy range (CR)	30 GeV - PeV
Angle resolution	0.1 deg.@10 GeV
Charge meas.	0.1-0.15 c.u
Energy resolution (e)	1% @200 GeV
Energy resolution (p)	20% @100 GeV-PeV
e/p separation	$\sim 10^{-6}$
G.F. (e)	>3 m ² sr @200 GeV
G.F. (p)	>2 m ² sr @100 TeV

Signal of monochromatic gamma-ray from DM annihilation



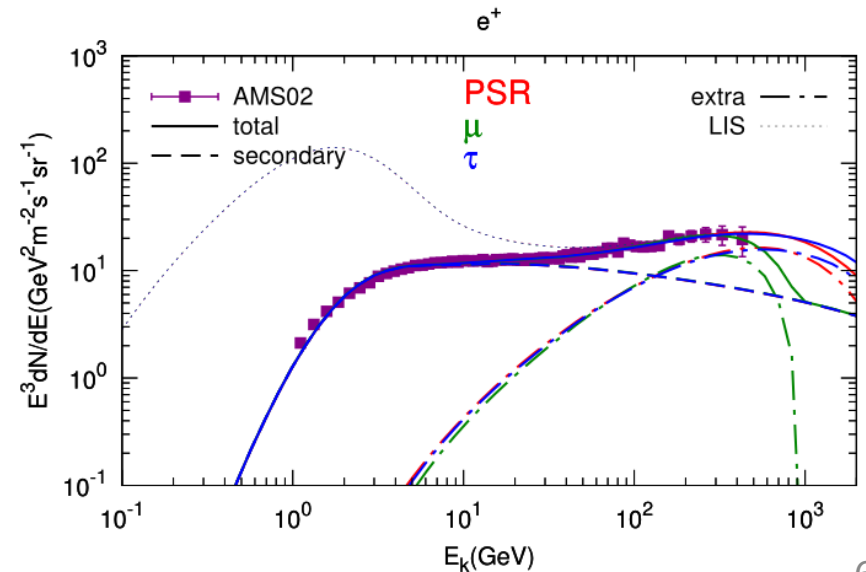
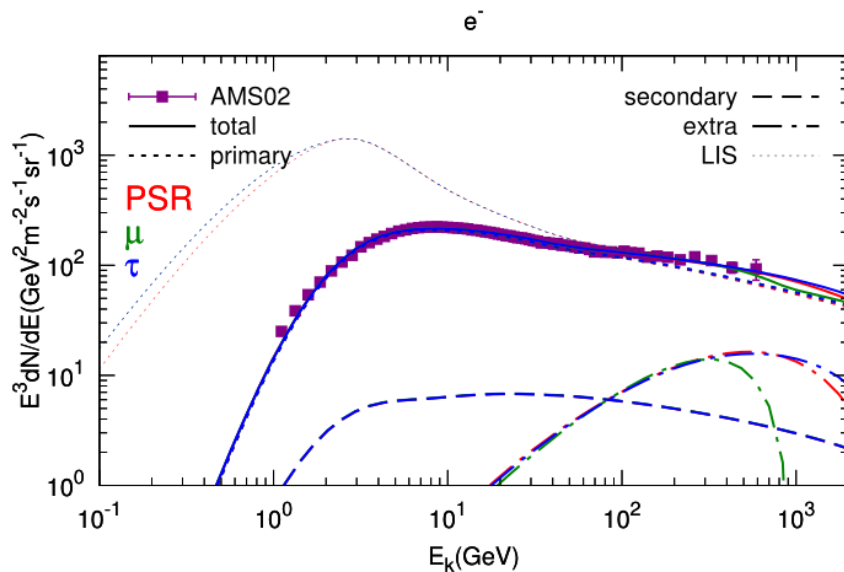
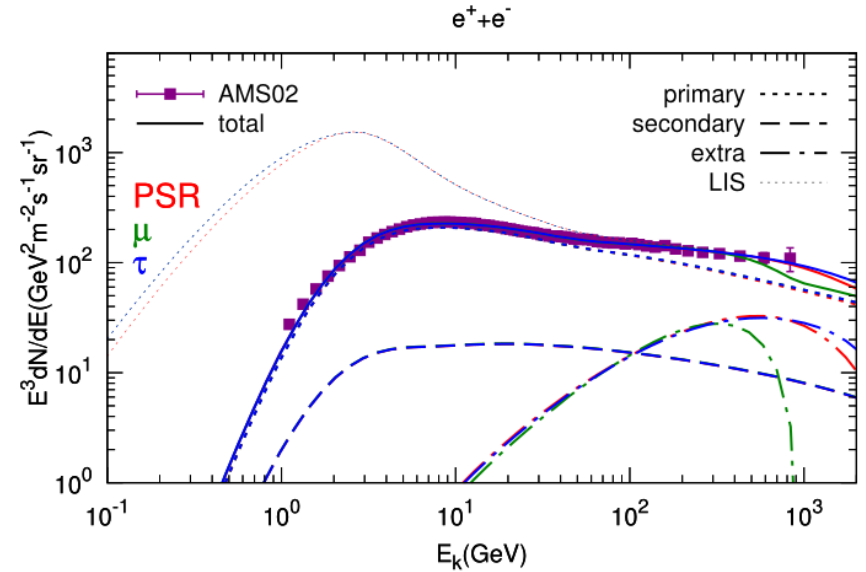
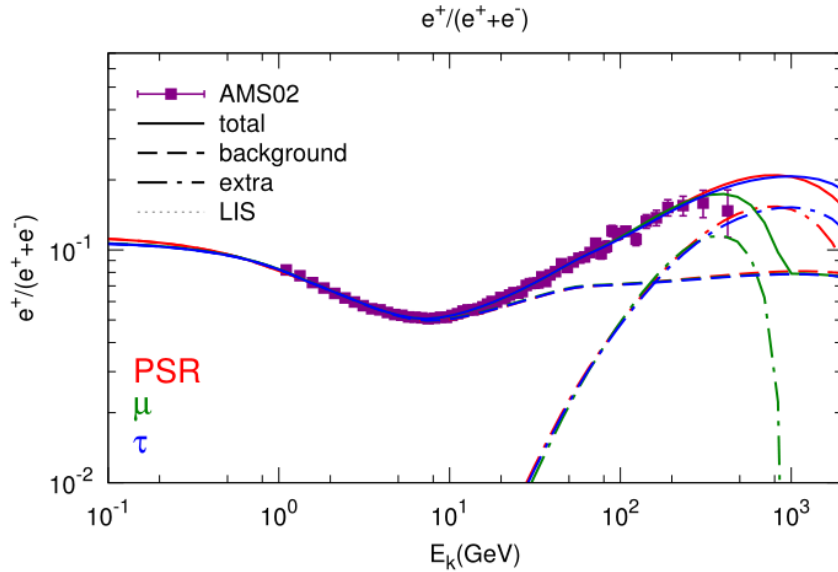
Expected gamma-ray line sensitivity



PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2024;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2023-

Positron/electron excess from DM annihilation or nearby pulsars

Lin SJ et al.
PRD91.063508, 2015

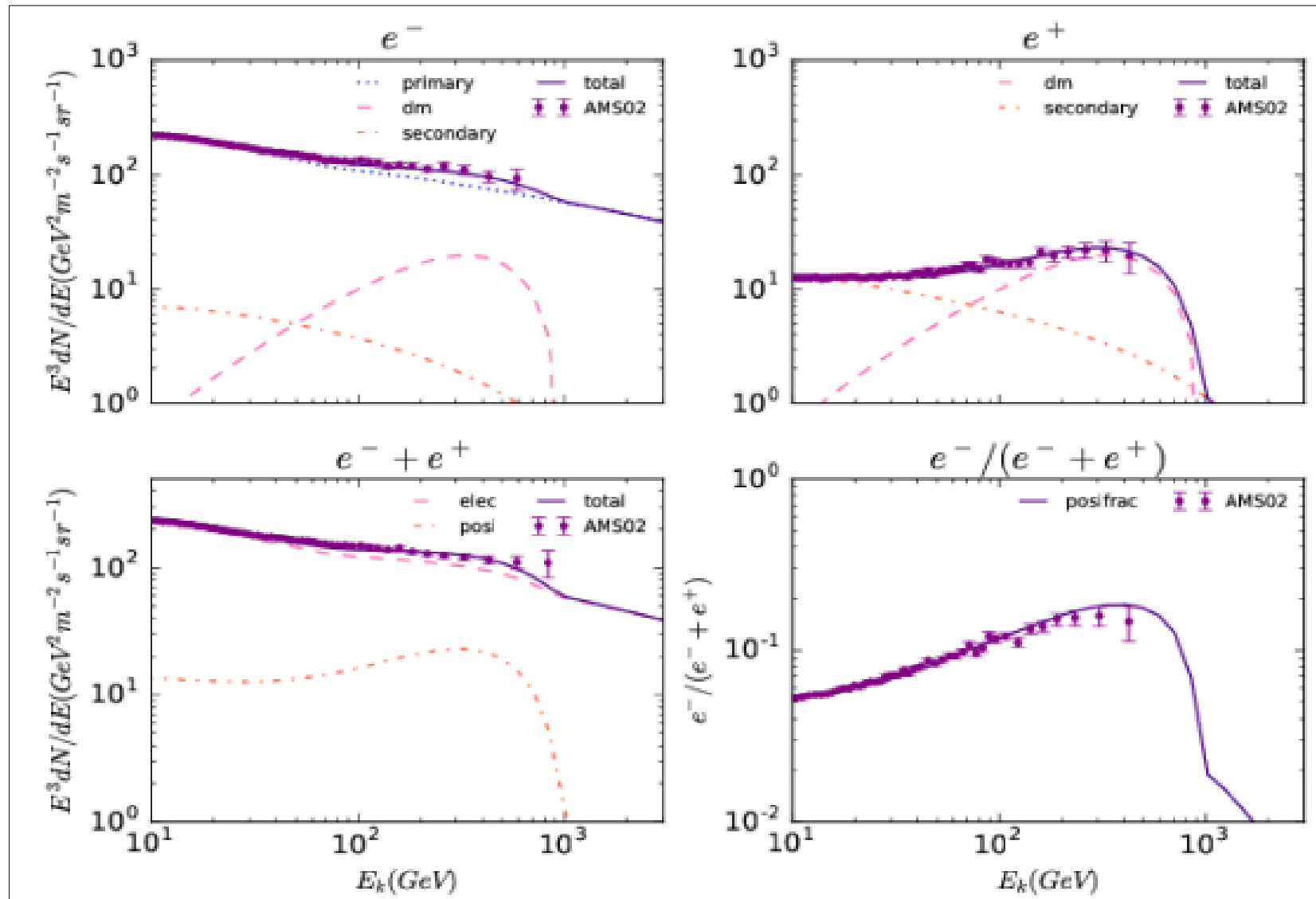


Contributions from nearby pulsars

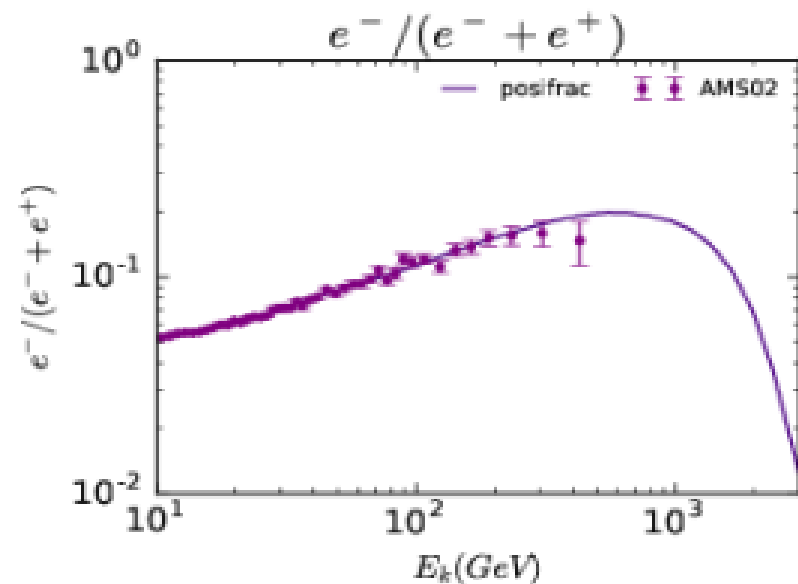
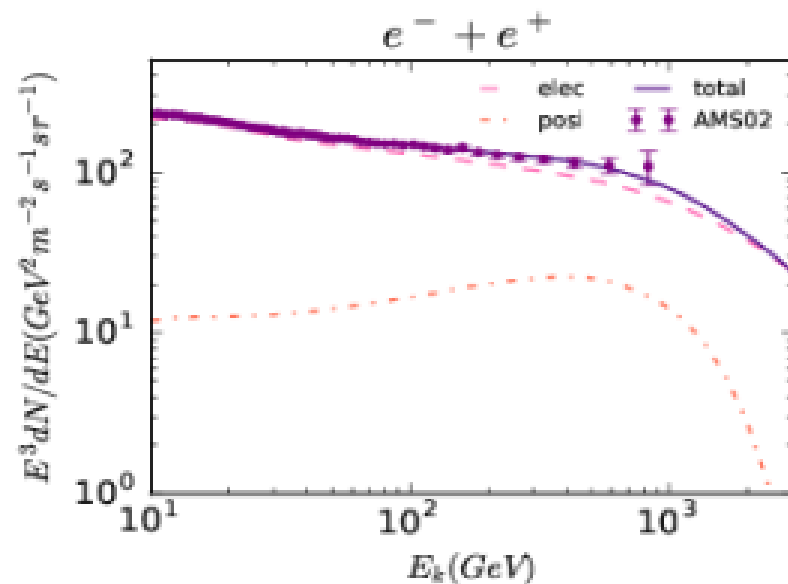
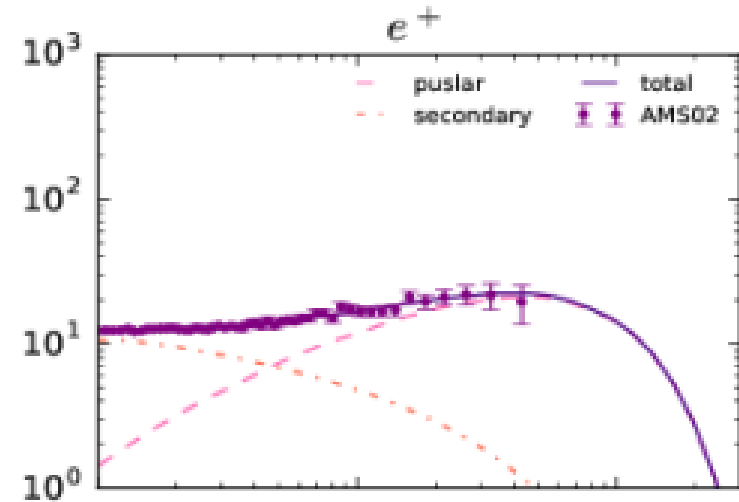
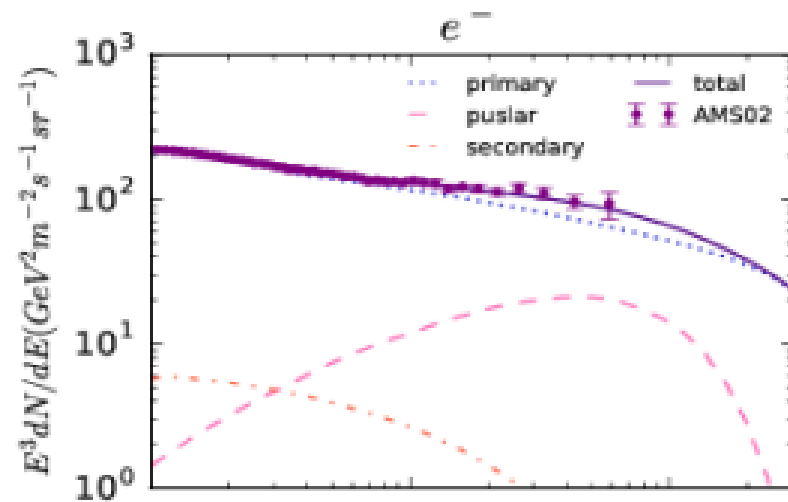
Fang,k. Wang, B. et al.
APJ 2017

Source	Other Name	$B_r^{1\text{GHz}}[\text{Jy}]$	α_r	Size[arcmin]	r[kpc]	t[kyr]	Ref.
G065.3+05.7	-	52	0.58	310×240	0.9	26	[21–24]
G074.0–08.5	Cygnus Loop	175	0.4	230×160	0.54	10	[21, 25, 26]
G114.3+00.3	-	6.4	0.49	90×55	0.7	7.7	[21, 27–29]
G127.1+00.5	R5	12	0.43	45	1	[20, 30]	[21, 27, 28, 30, 31]
G156.2+05.7	-	5	0.53	110	1.0	[15, 26]	[21, 28, 32–35]
G160.9+02.6	HB9	88	0.59	140×120	0.8	[4, 7]	[21, 27, 28, 36, 37]
G203.0+12.0	Monogem Ring	-	-	-	0.3	86	[38, 39]
G263.9–03.3	Vela YZ	varies	varies	255	0.29	11.3	[21, 40–43]
G266.2–01.2	Vela Jr.	50	0.3	120	0.75	[1.7, 4.3]	[21, 44–47]
G328.3+17.6	Loop I (NPS)	-	-	-	0.1	200	[48, 49]
G347.3–00.5	RXJ1713.7-3946	4	0.3	65×55	1	1.6	[21, 50, 51]

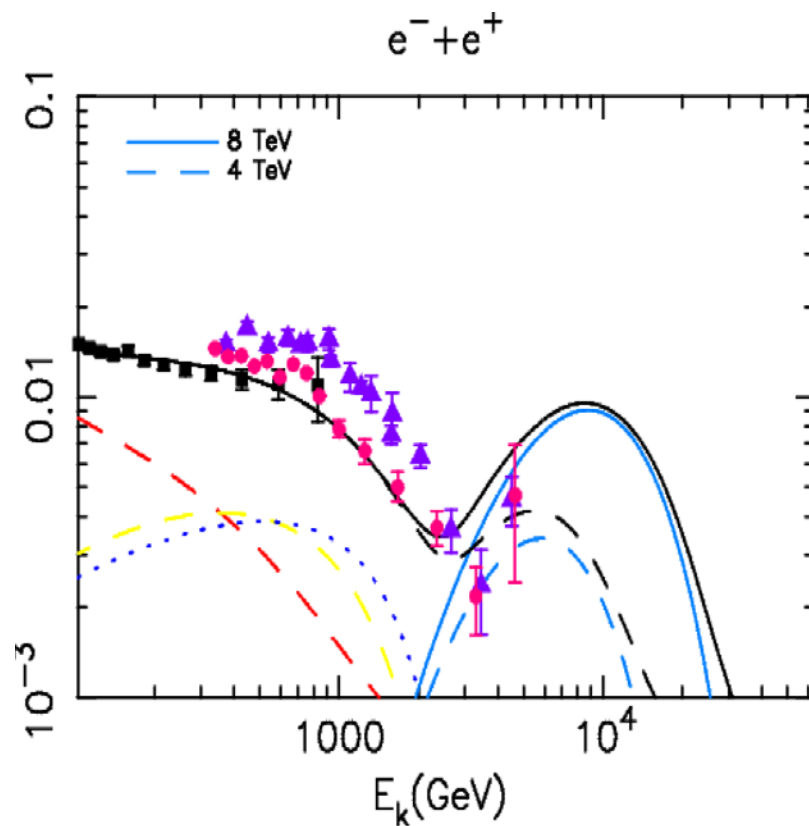
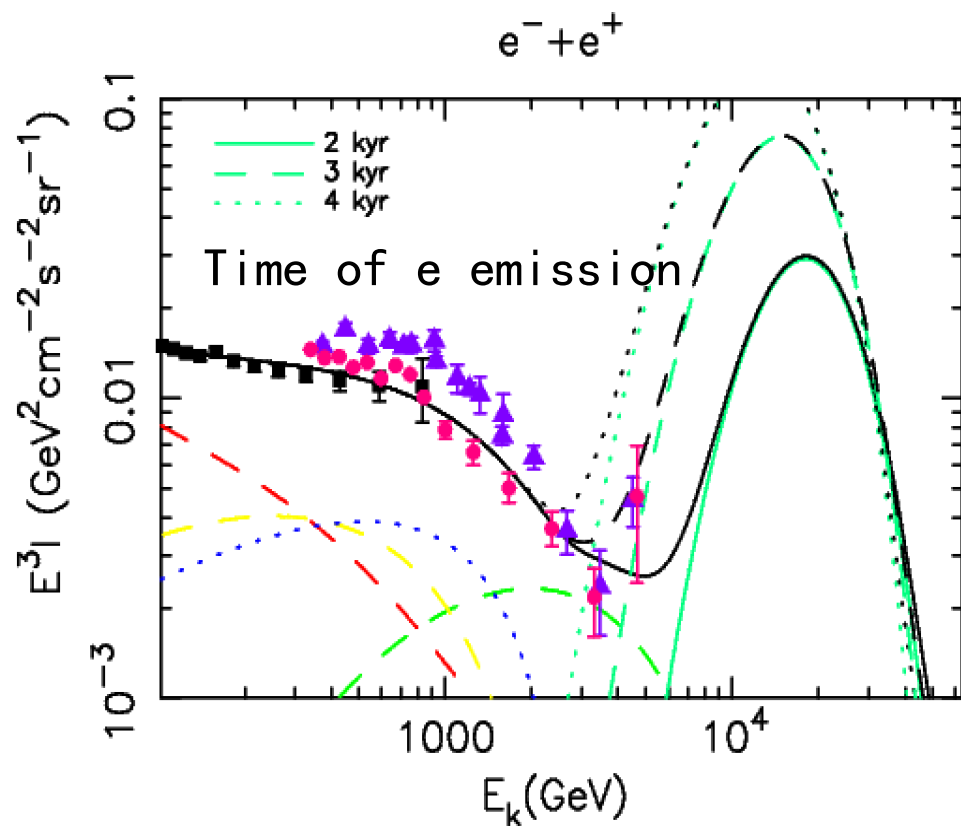
AMS02 data consistent with DM model...



And also consistent with Pulsar model

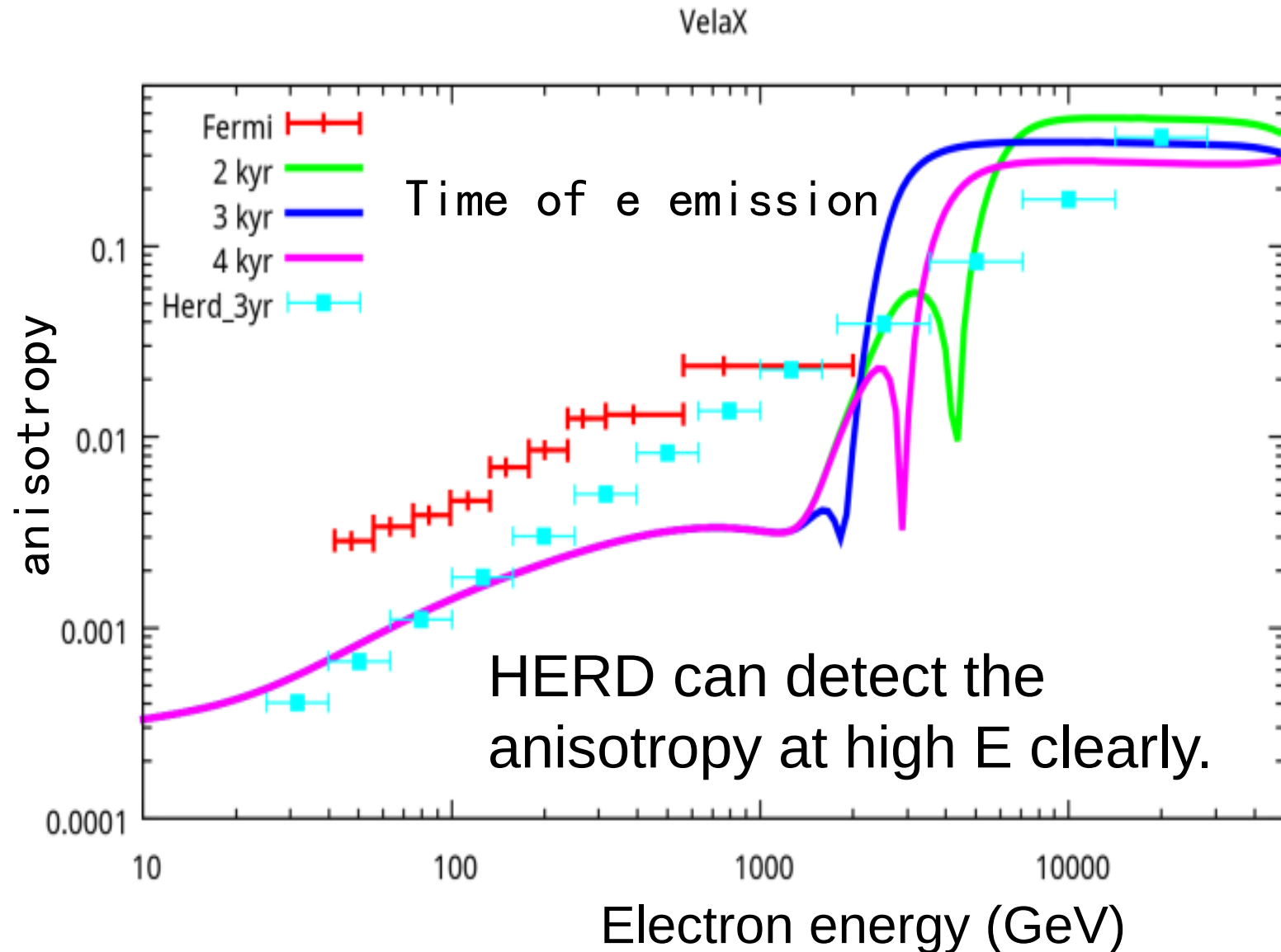


Spectra of nearby sources : Vela-X, Cygnus loop

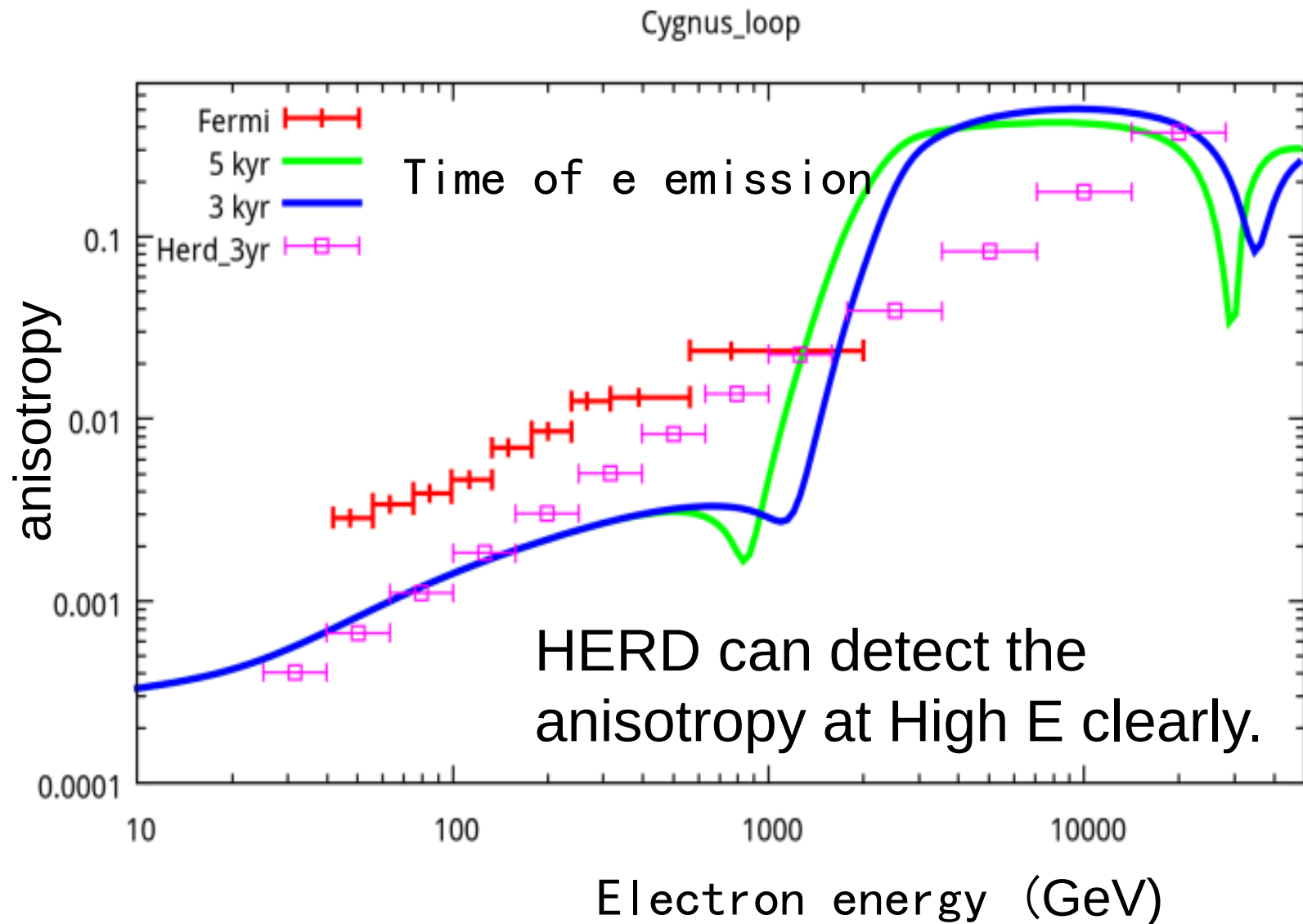


HERD can probe the bump around 10s TeV from the local sources. If this bump detected it Strongly favor a pulsar origin of positron excess

Anisotropy of nearby high energy CR sources: Vela-X

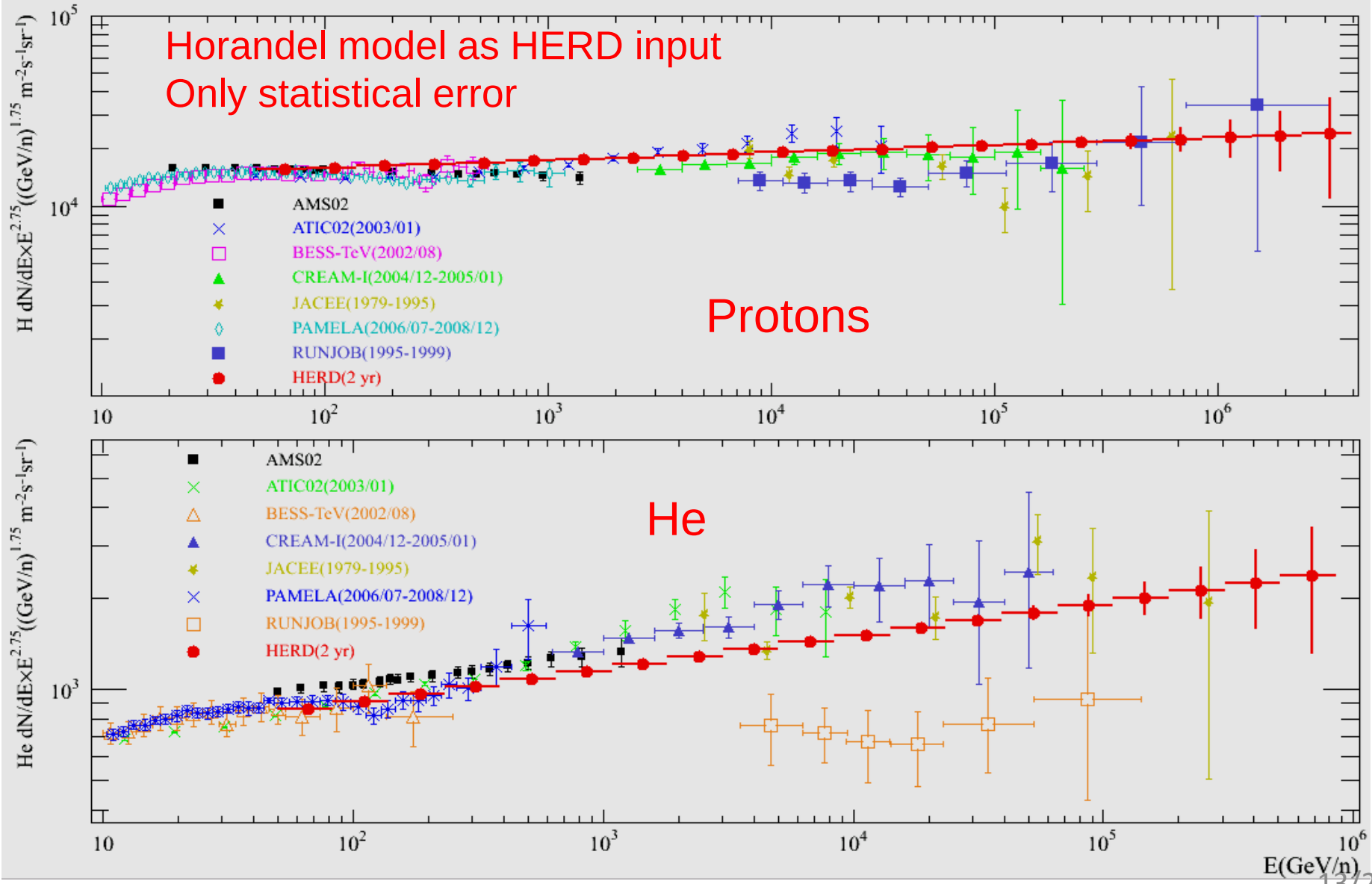


Anisotropy of nearby high energy CR sources : Cyg Loop

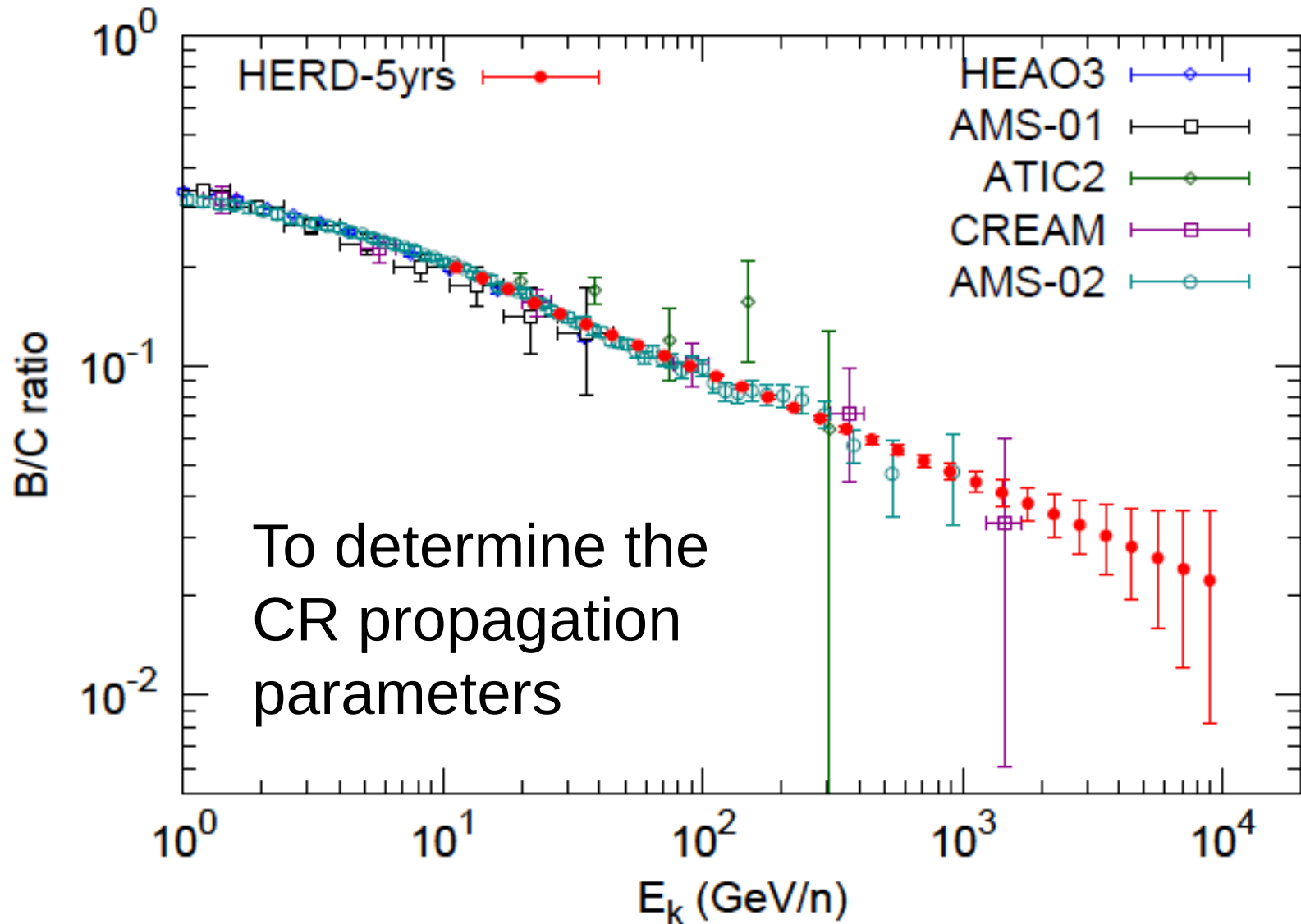


Expected HERD Proton and He Spectra

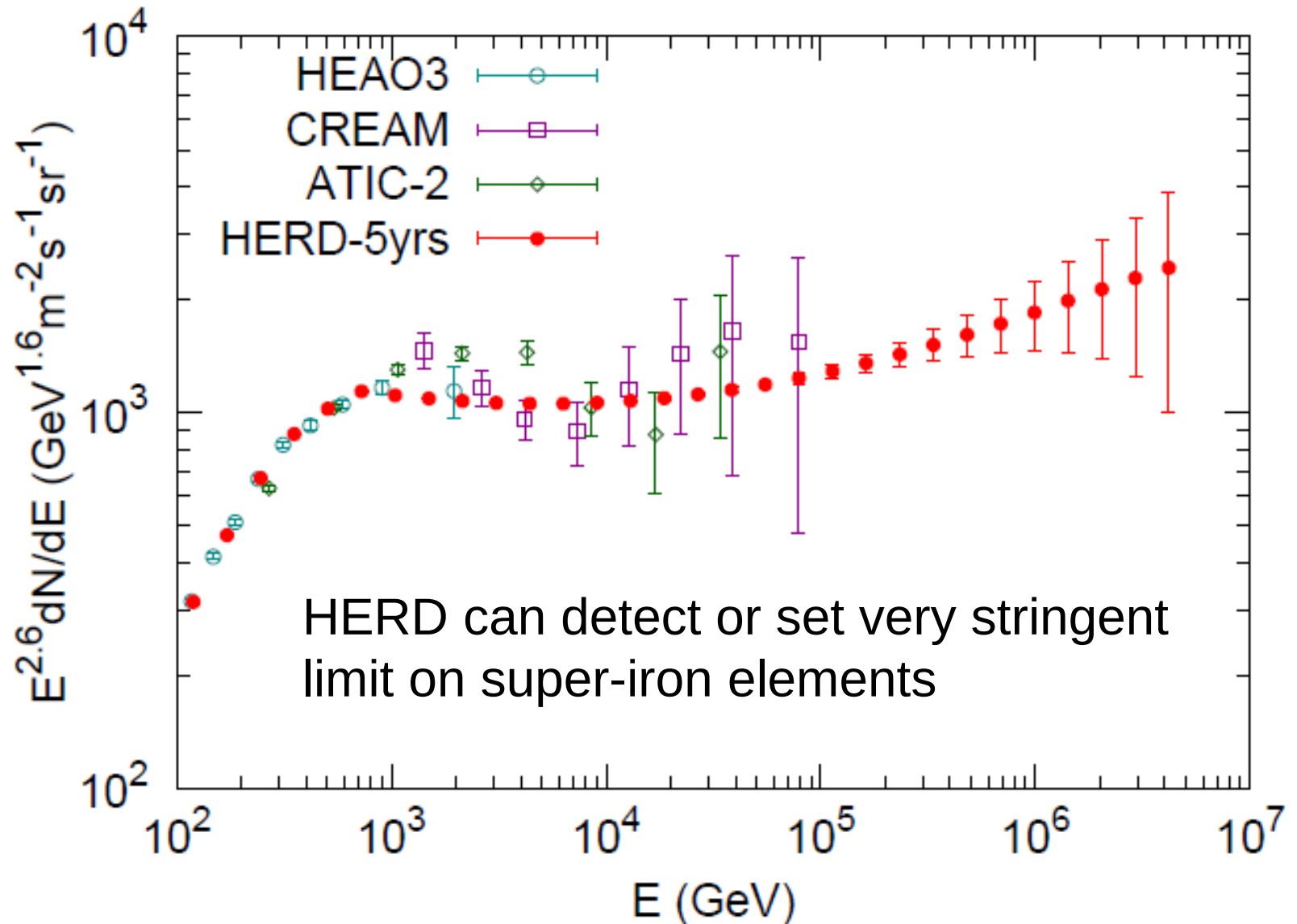
Horandel model as HERD input
Only statistical error



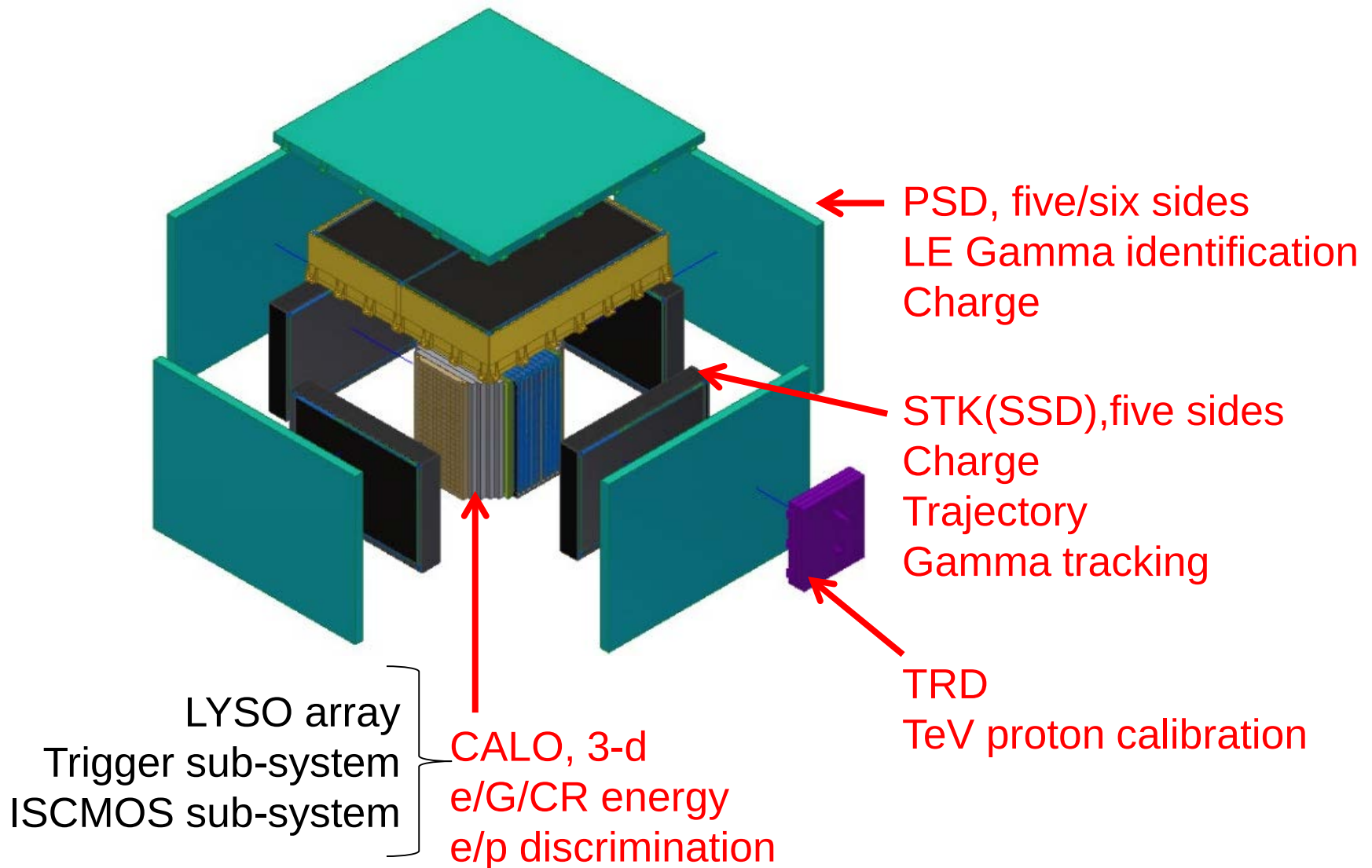
B/C measurement at HERD



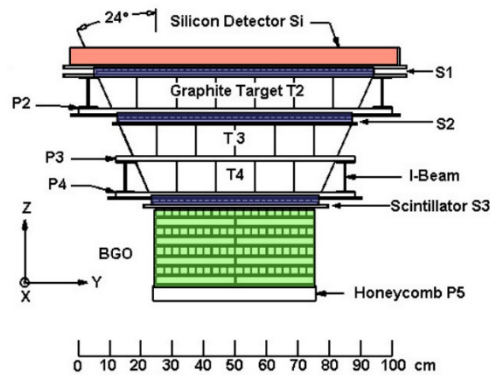
Iron nucleon and super-iron elements



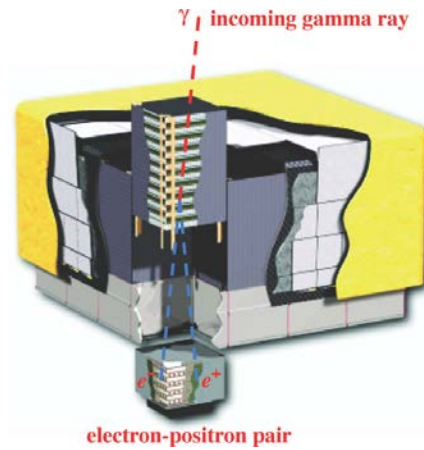
HERD payload



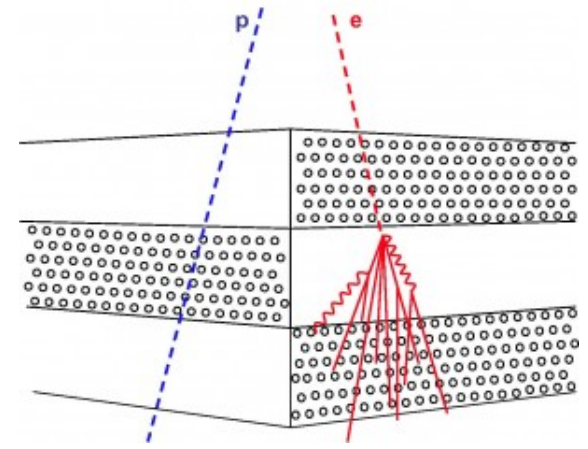
CALO - from bars to cubes



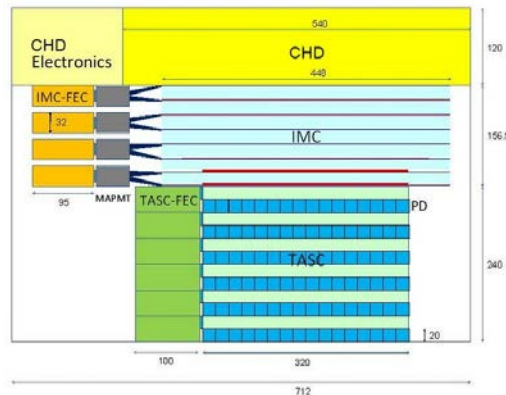
ATIC



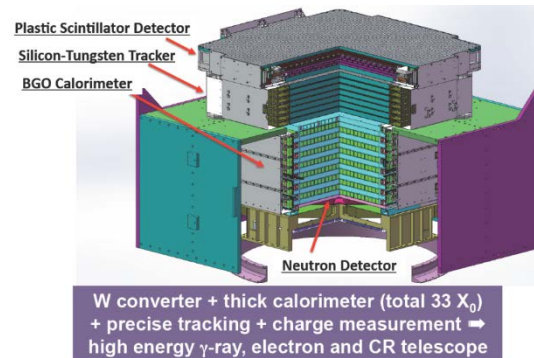
FERMI



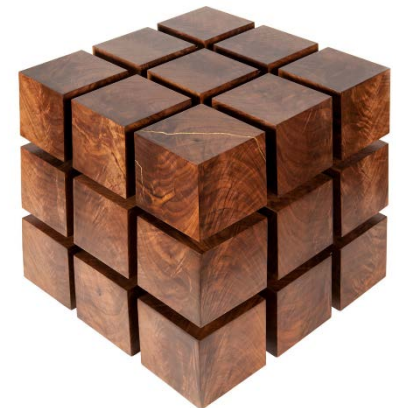
AMS-02



CALET



DAMPE

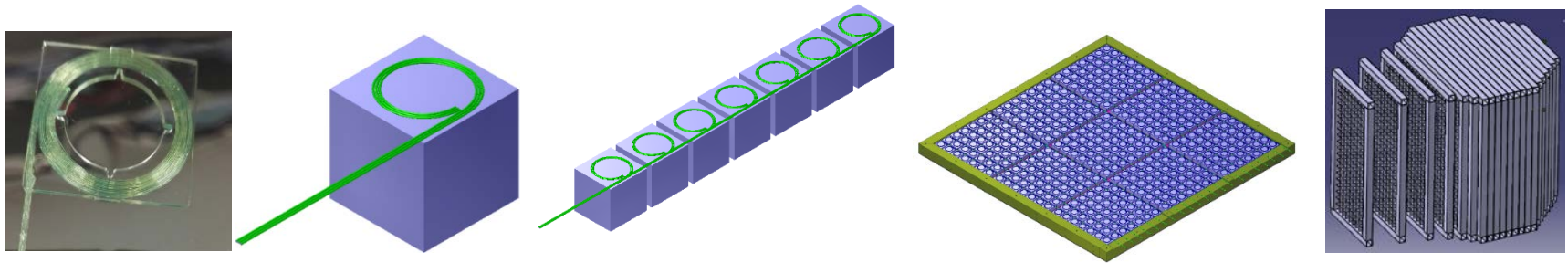


HERD

To increase significantly GF and improve particle discrimination

CALO – LYSO array

- Energy deposition of incident high energy particles
- **Wavelength shifting fibers** to read out crystal signals

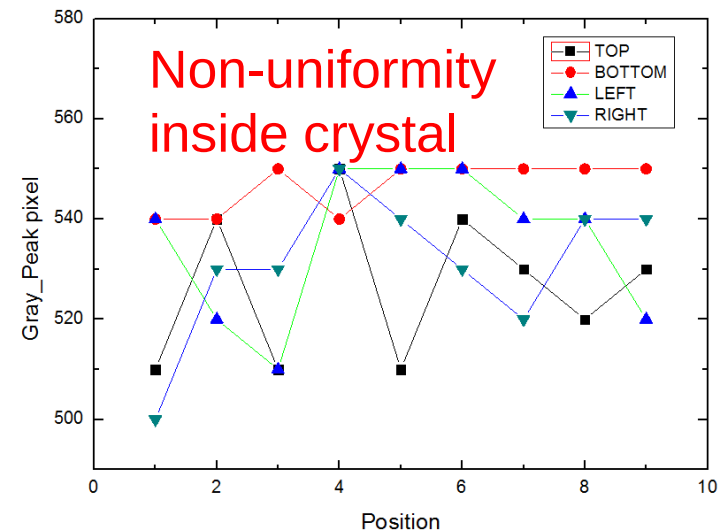
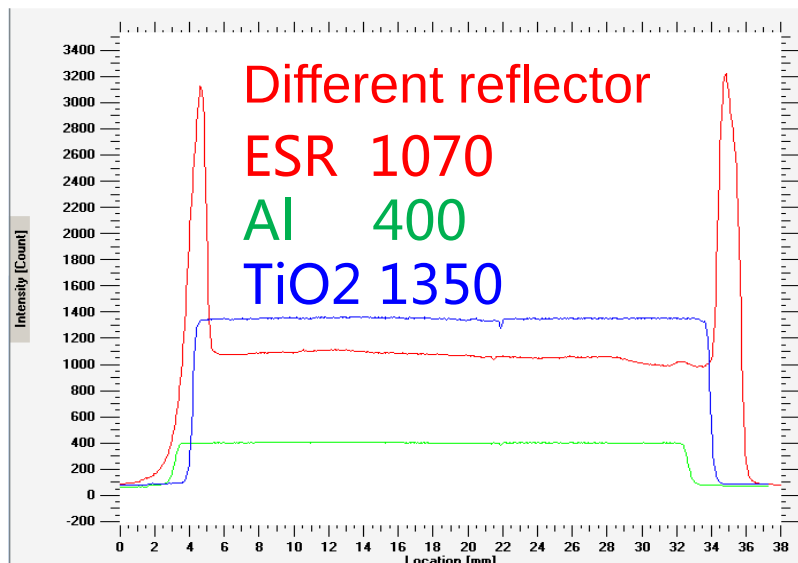
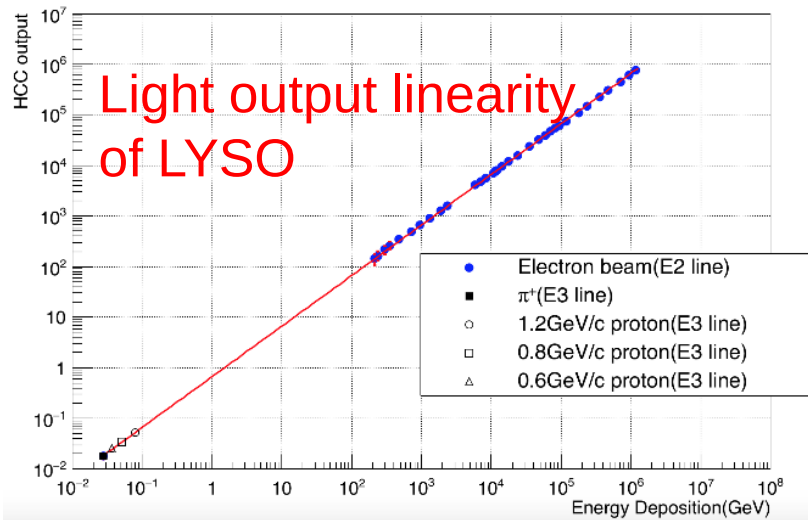


item	Value	Note
Type of crystal	LYSO	
Nuclear Interaction Length	3	Upper energy threshold
Number of crystals	~7500	
Crystal dimension	3cm*3cm*3cm	Energy reso.; e/p discri.
Fiber readout	3 WLSF/crystal	Large DR & trigger

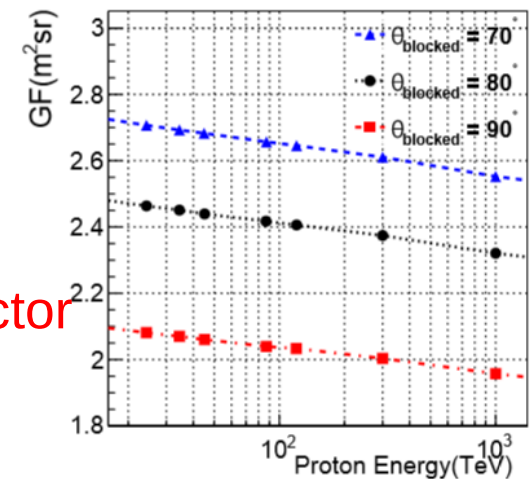
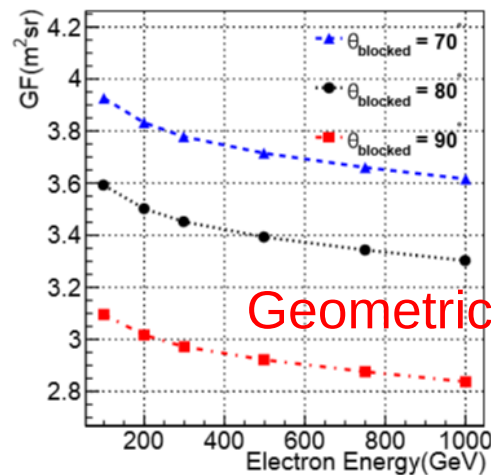
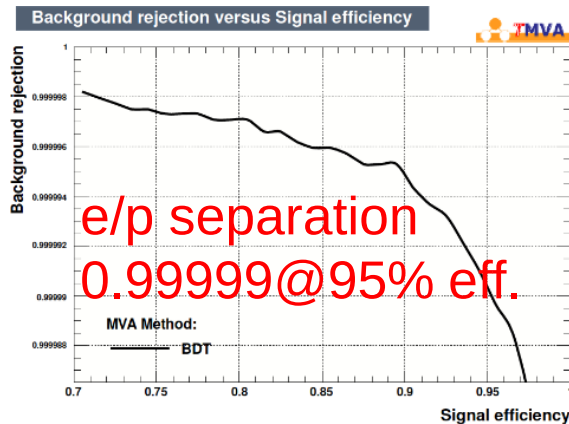
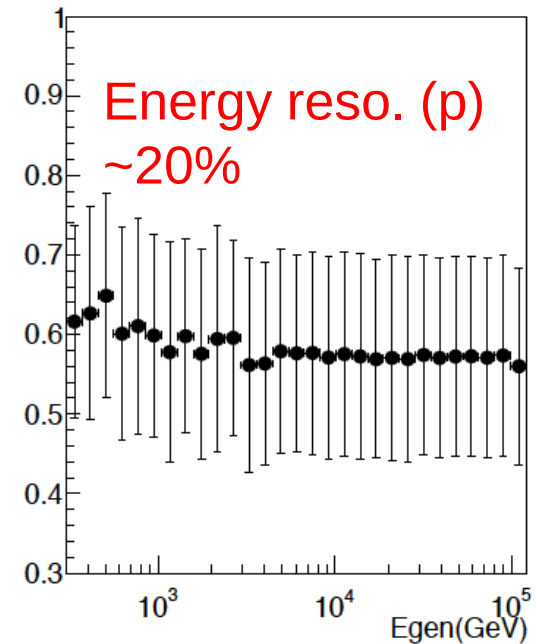
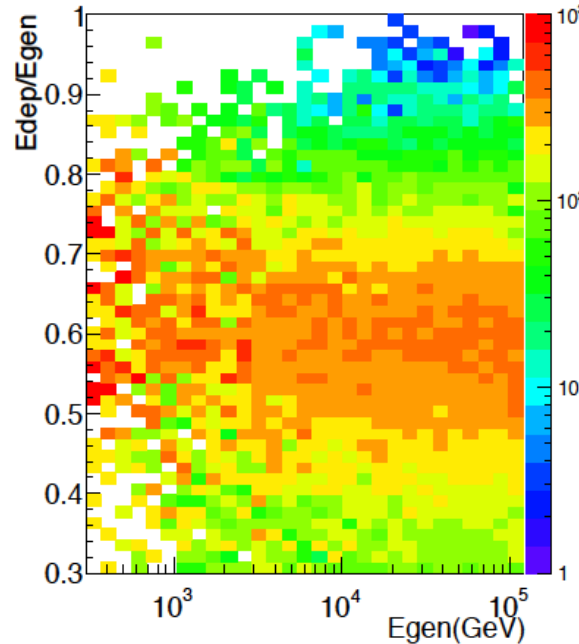
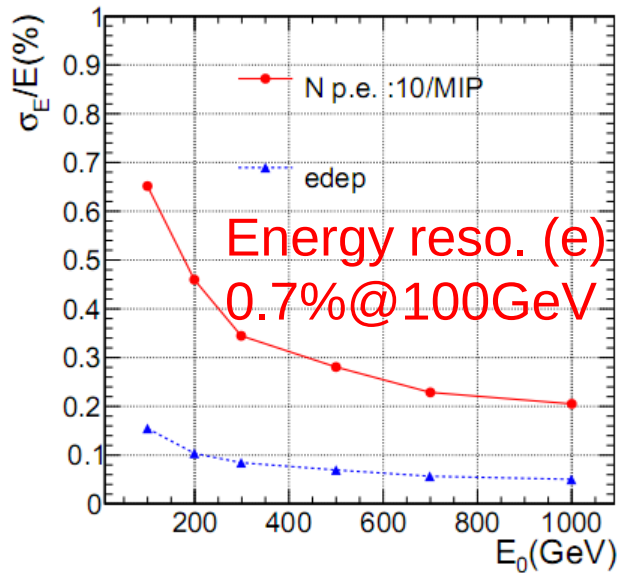
Trigger system

ISCMOS with low+high range

Crystal performances

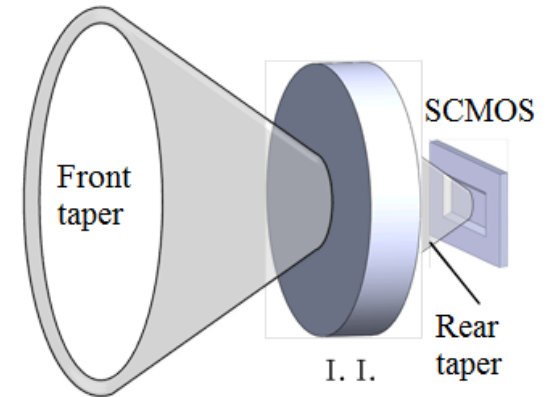


Expected CALO performances

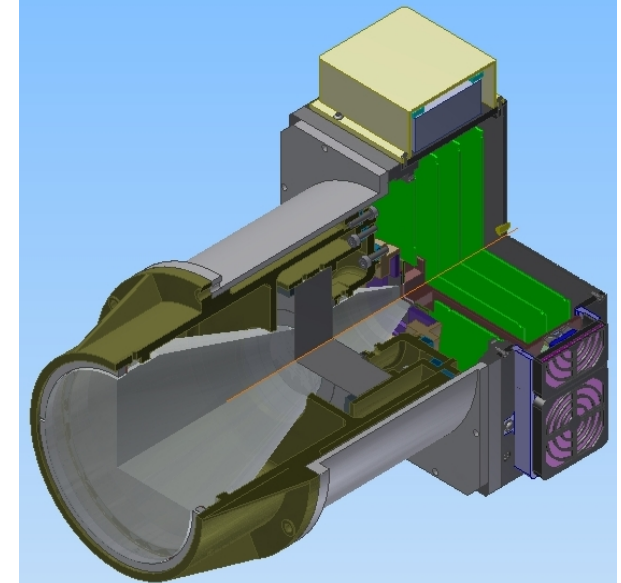


CALO – ISCMOS sub-system

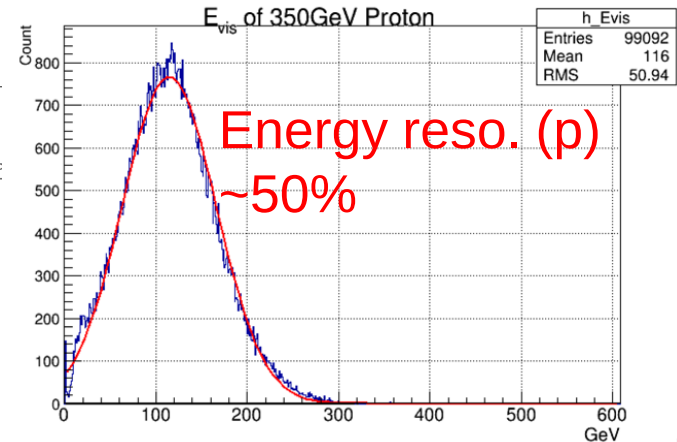
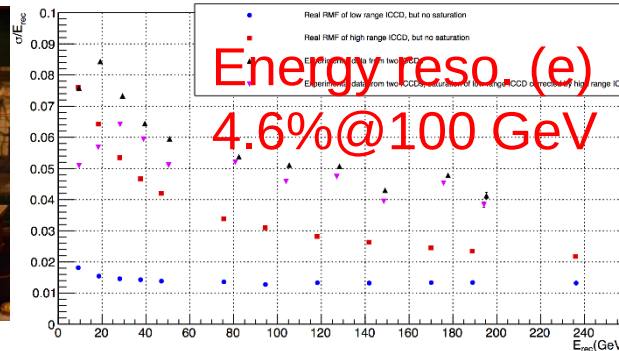
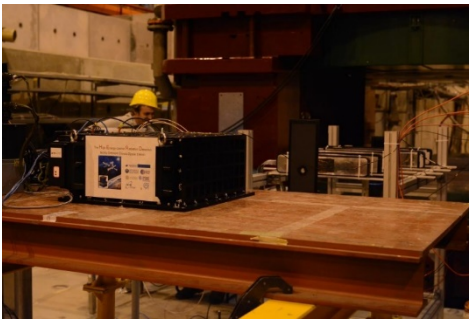
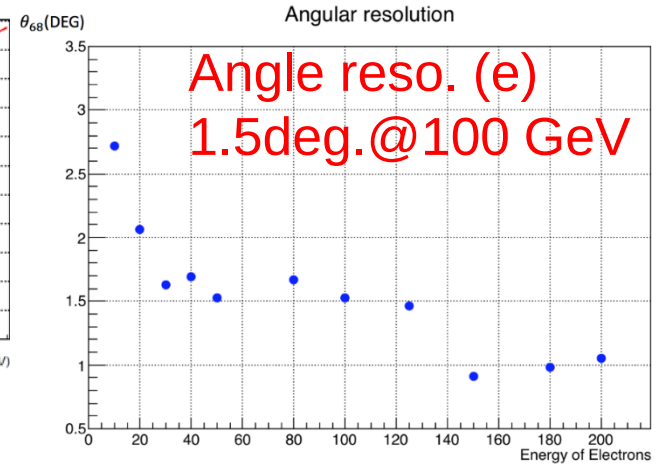
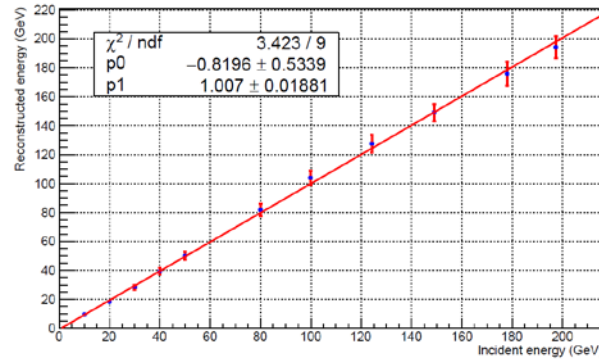
- **ISCMOS** to collect WLSF photons
- Accurate energy measurement
 - 1 fiber $\sim 20 \times 20$ pixels
 - Saturation effect to increase DR



Item	Value
Range	Low range & high range
Input fibers	~ 7500 WLSFs/range
Dynamic range	$\sim 10^7$ (equivalent to 30 - 10^8 p.e.)
Frame rate	~ 500 fps
Energy reso.	1% @ 200 GeV
Working mode	External trigger, scan mode, external trigger (CMOS)



2015 CERN SPS beam test

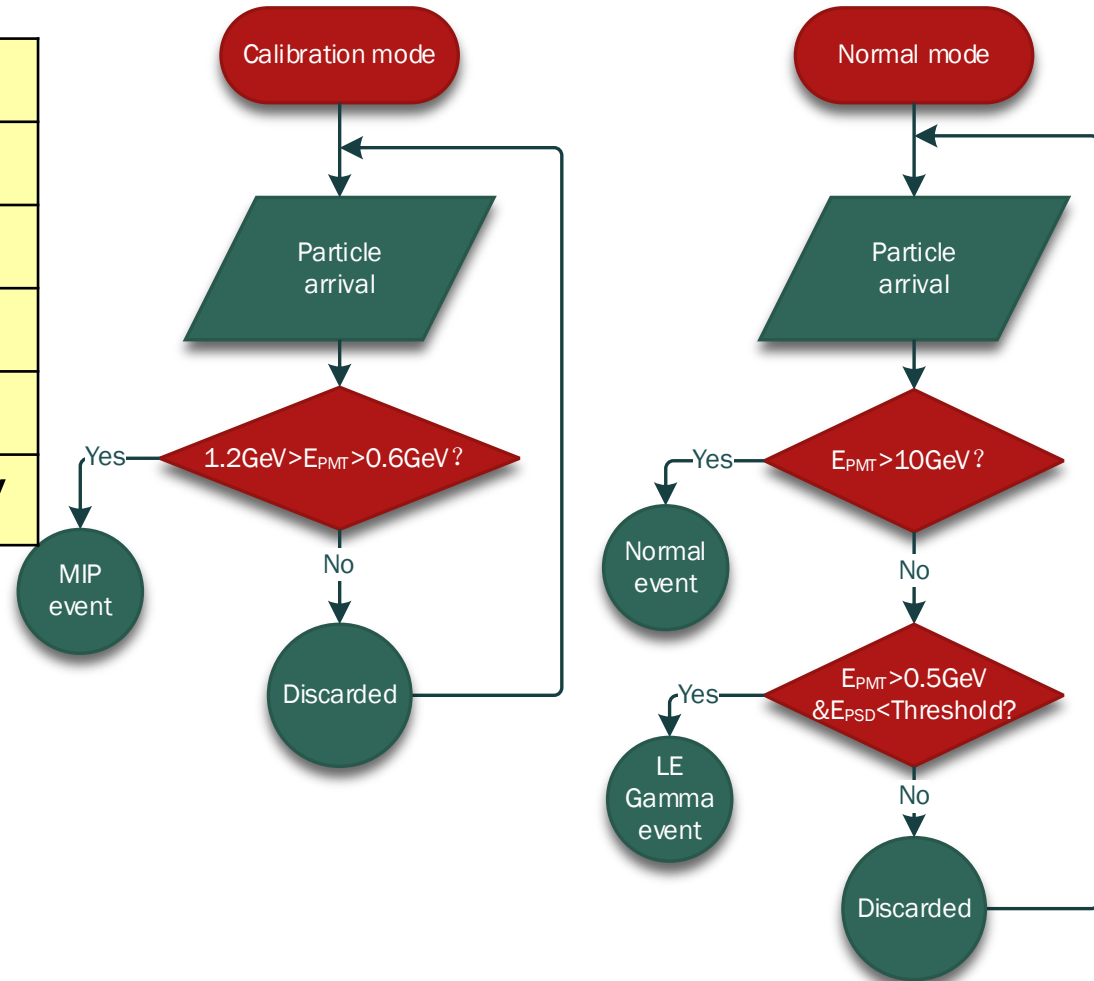


A 2nd beam test on upgraded prototype will be held Oct. 2017.

CALO – trigger sub-system

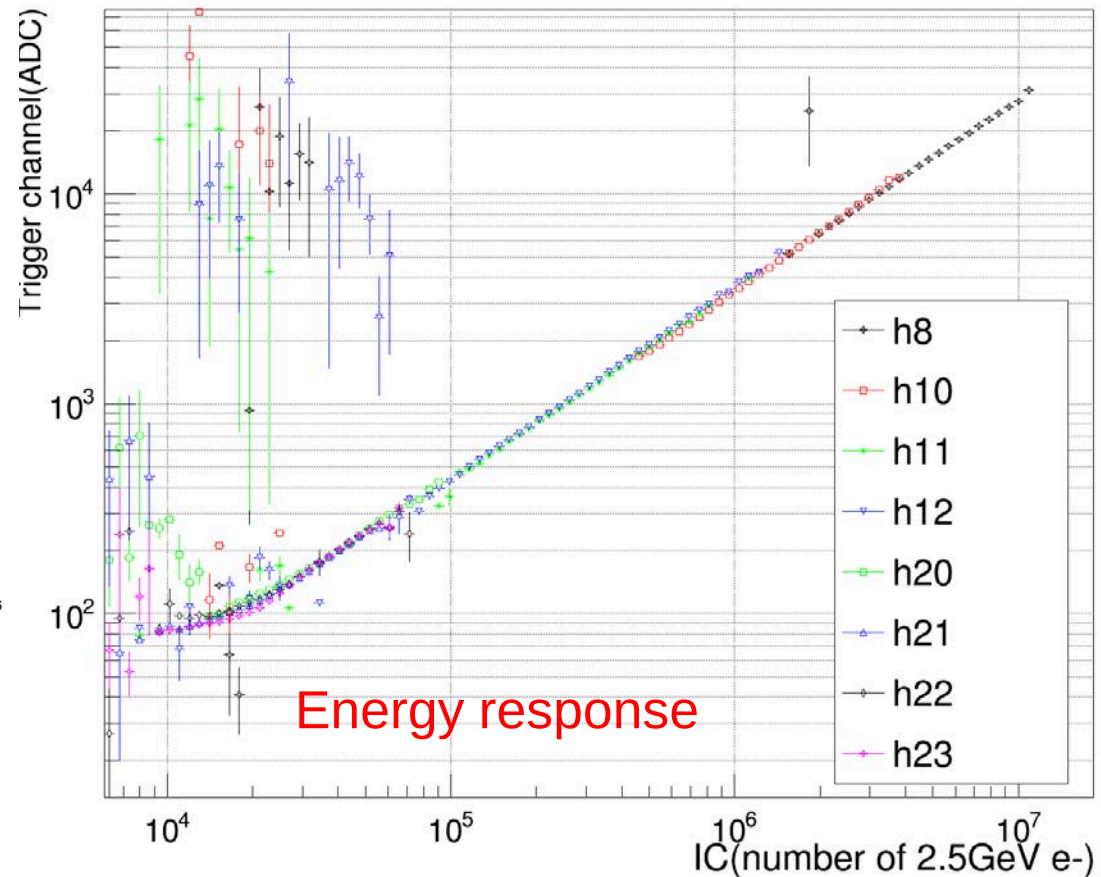
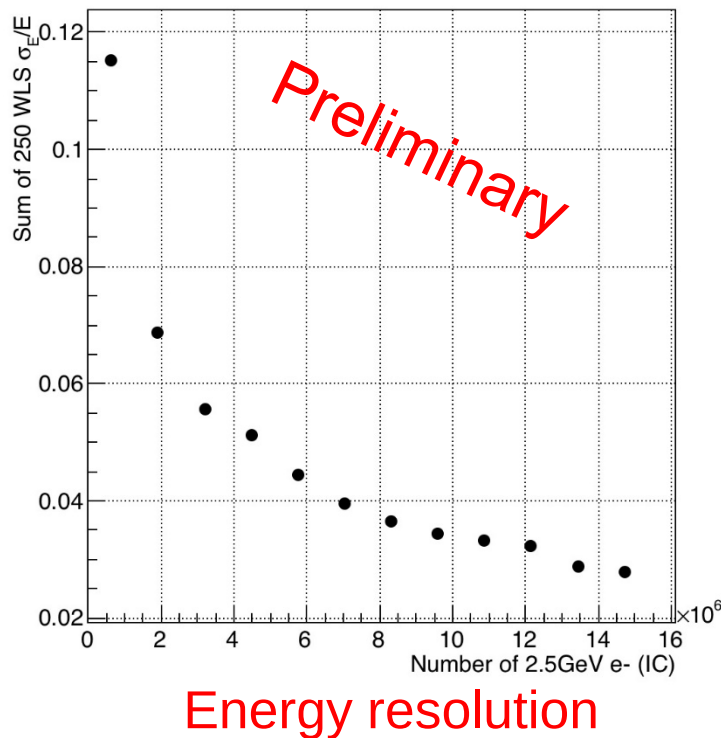
- To provide common trigger signal
- Coarse energy measurement

Item	Value
Input fibers	~7500 WLSFs
Trigger band	300 MeV - PeV
Trigger time	<100 ns
Dead time	<10 μ s
Energy reso.	~10% @ 200 GeV



CALO trigger - energy measurement

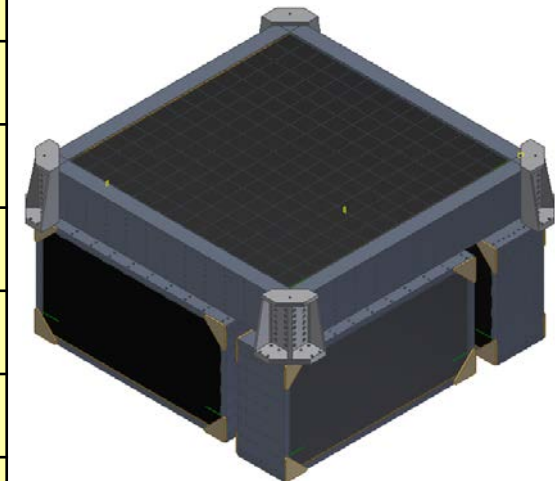
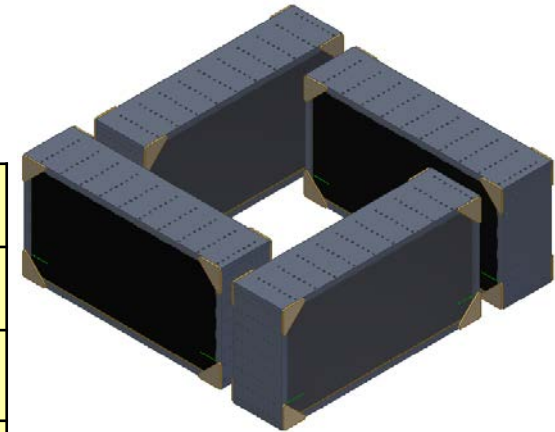
- Test on HERD prototype at BEPCII E2 by using calibrated electron bundles was taken in June, 2017.



STK payload

- Charge measurement
- CR/e trajectory
- Gamma ray conversion & tracking

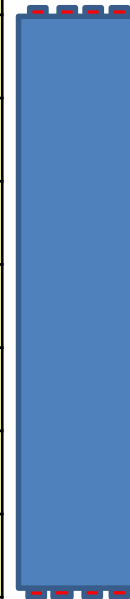
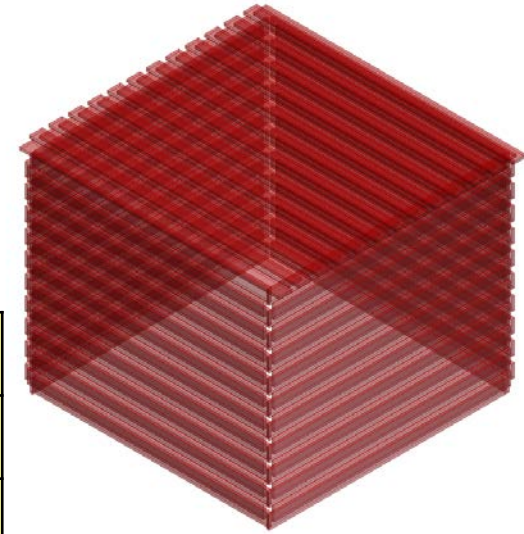
Item	Value
Coverage ratio	>80%
Charge measurement	Z = 1 - 20 (26); 0.1-0.15 c.u
Angle resolution	0.1 deg.@10 GeV
Layers of SSD	6 X/Y (top);3/6 X/Y (Lateral)
Active converter	1 R.L.
Dead time	<2 ms
Working mode	External trigger
Eff. Area (top)	~133 cm*133 cm
Eff. Area (lateral)	~114 cm*66.5 cm
Channels	~240,000/368,000



PSD payload

- Low energy gamma identification
- Coarse charge measurement
- Neutron detection on the bottom for particle discrimination

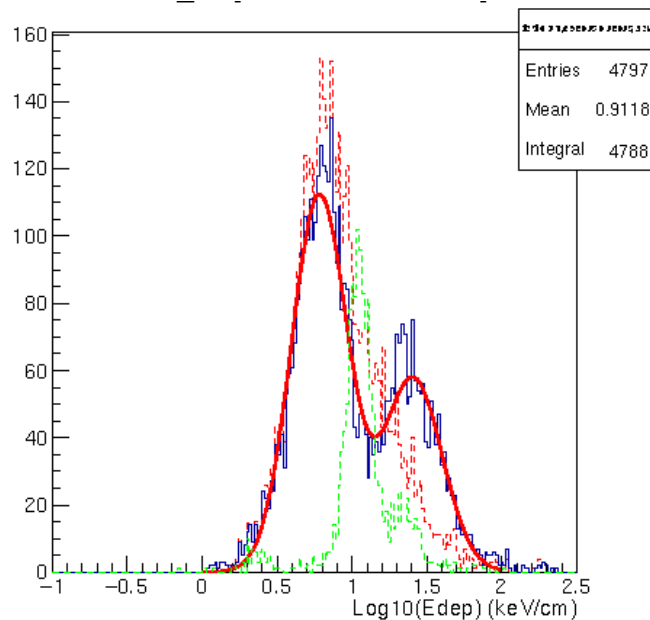
Item	Value
Coverage ratio	>99.9%
Layers	1 layer of PS bars
Charge measurement	1-10 (20)
Veto time	<100 ns
Dead time	<10 μ s
Working mode	External trigger; real-time veto
Eff. Area (top)	1.6m*1.6m
Eff. Area (lateral)	1.6m*1.2m
Channels	~608



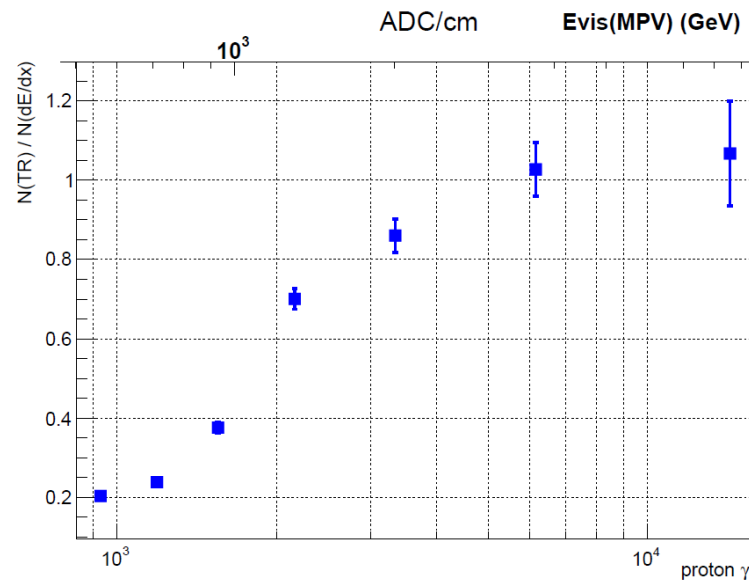
2*(3+1) SiPMs

TRD payload

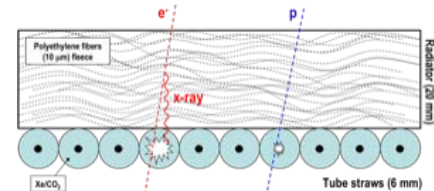
- Energy calibration of TeV protons and other nuclei
- A complete calibration in 2-3 months in-orbit operation



MWPC energy response
to [2.25, 2.5] TeV protons



2 months simulated
observation, $\sim 6300\text{cm}^2$ TRD.



Straw tube



Large area MWPC

Summary

- HERD, as a China-led mission with a large international collaboration, is a flagship and landmark scientific experiment onboard China's Space Station.
- Expected launch time before 2025; 10+ yrs lifetime.
- Advanced scientific objectives in DM search, CR observation and gamma-ray astronomy
 - May confirm the pulsar origin of positron/ electron excess measured at AMS-02
- Novel design of HERD
 - A 3-d crystal array to allow large GF and better particle discri..
 - A WLSF+ISCMOS read-out system to simplify electronics
 - Active converter to improve energy resolution of LE gamma
 - One-dimensional long PS bars to identify LE gamma in real time.
 - A TRD to calibrate TeV protons and other nuclei in orbit.

International collaboration (120+ scientists)

- **China:** CSU, IHEP, XIOPM, PMO, USTC, IGG, XAO, NAOC, TSU, GXU, PKU, NJU, YNU, NBU, SYSU, University of Hong Kong (HKU), National Central University (NCU)
- **Italy:** INFN Perugia, University & INFN Firenze, University & INFN Bari, University & INFN Pisa, University & INFN Trento, University of Salento and INFN Lecce, IAPS/INAF, University & INFN Catania, University & INFN Napoli, University & INFN Trieste
- **Switzerland:** University of Geneva; **Sweden:** KTH; **Spain:** CIEMAT
- **Germany:** KIT; **Russia:** Lebedev Physical Institute
- **Japan:** University of Tokyo



4th HERD workshop
ASI HQs, Roma, Italy 2017.2.9