Brief Report on the Current Status of HERD and the 2nd HERD workshop

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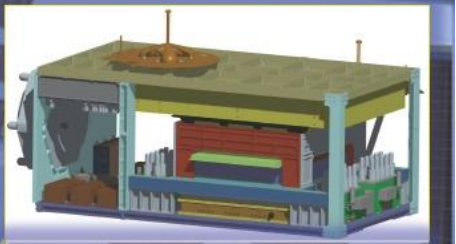
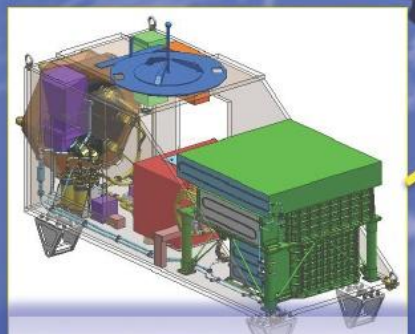
View from NASA: “Cosmic Ray Observatory on the ISS”

AMS Launch
May 16, 2011



ISS-CREAM
Sp-X Launch 2014



CALET on JEM
HTV Launch 2014

JEM-EUSO
Launch Tentatively
planned for 2017

From G. Ambrosi

China's Space Station Program

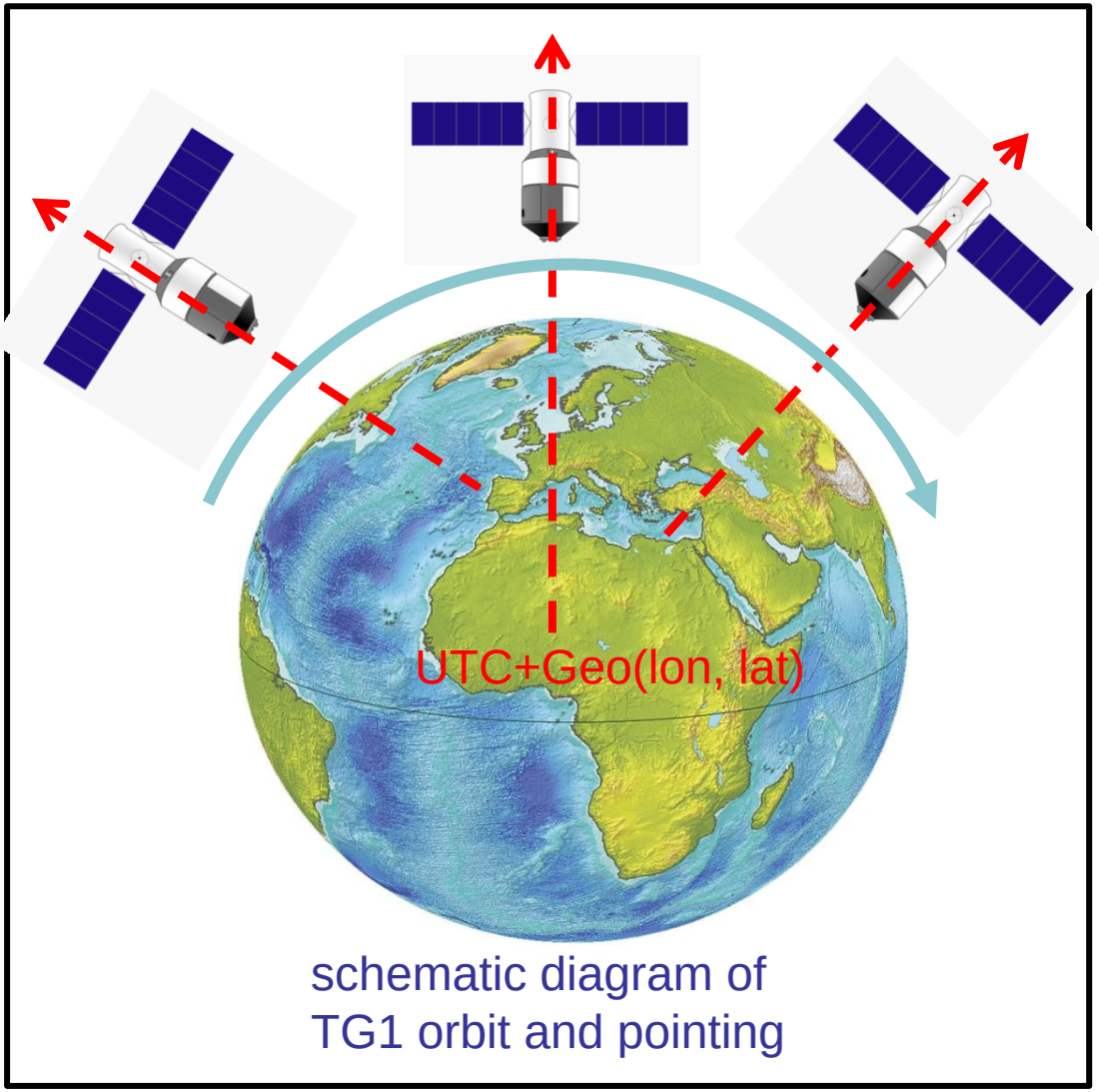
- Three phases
  - 1st phase: so far 10 Chinese astronauts have been sent out and returned back successfully; many space science research has been done. Completed successfully.
  - 2nd phase: spacelab: docking of 3 spaceships with astronauts delivering and installing scientific instruments. 1st launch on Sept. 29, 2011.
  - 3rd phase: spacestation: several large experimental cabins with astronauts working onboard constantly. 1st launch ~2020.

International collaborations on space science research have been and will continue to be an important part.

Cosmic Lighthouse Program: China's Space Station

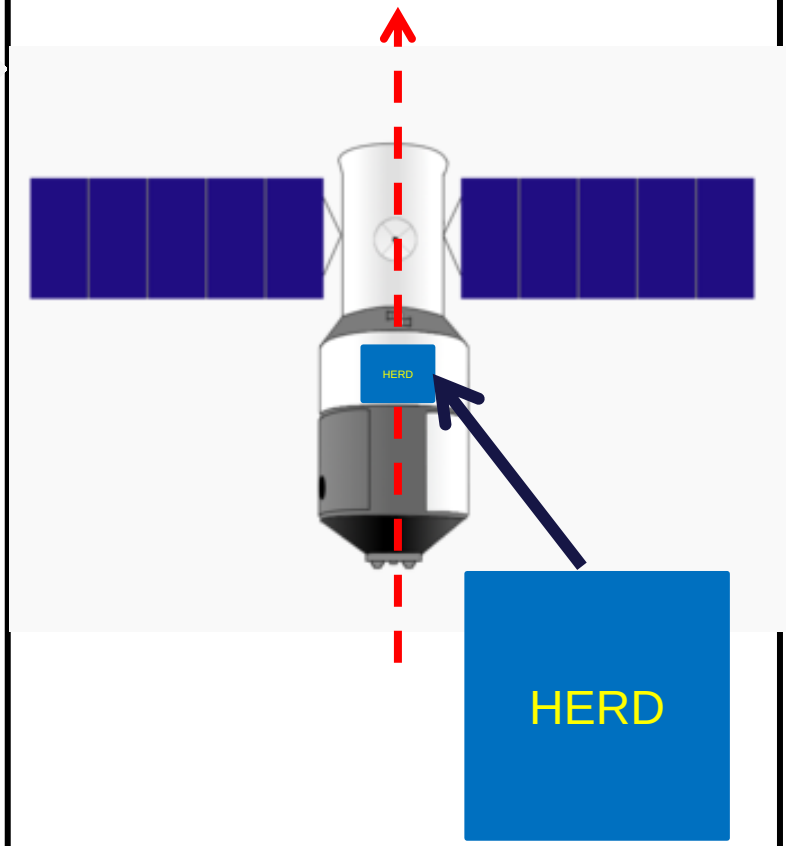
Candidate Projects	Main Science Topics
Large scale imaging and spectroscopic survey facility (**approved**)	Dark energy, dark matter distribution, large scale structure of the universe
HERD (**concept**)	Dark matter properties, cosmic ray composition, high energy electron and gamma-rays
Soft X-ray-UV all sky monitor (?)	X-ray binaries, supernovae, gamma-ray bursts, active galactic nuclei, tidal disruption of stars by supermassive black holes
X-ray polarimeter (?)	Black holes, neutron stars, accretion disks, supernova remnants
Galactic warm-hot gas spectroscopic mapper (?)	The Milky Way, interstellar medium, missing baryons in the Universe
High sensitivity solar high energy detector (?)	Solar flares, high energy particle acceleration mechanism, space weather
Infrared spectroscopic survey telescope (?)	Stars, galaxies, active galactic nuclei

HERD in Space



schematic diagram of
TG1 orbit and pointing

schematic diagram of
HERD onboard TG1




background
Gamma-ray
HERD
electron
proton
He
Dark matter particle

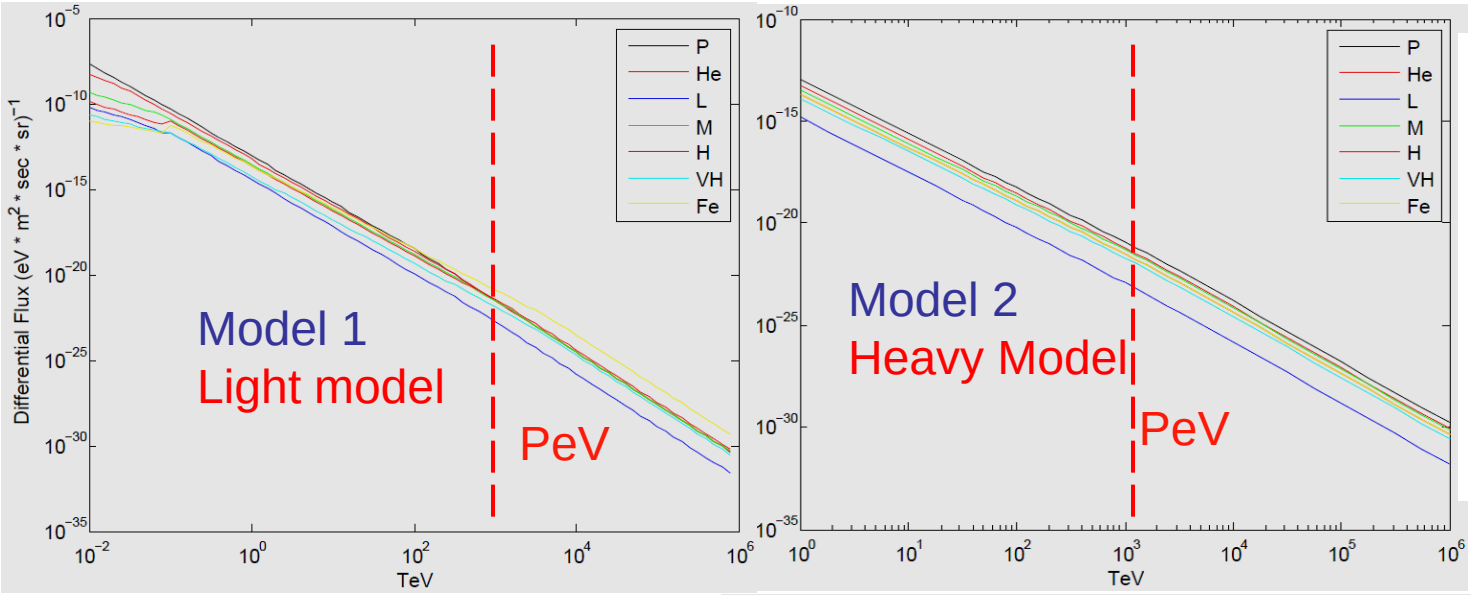
HERD: High Energy cosmic-Radiation Detector

Science goals	Mission requirements
Dark matter search	R1: Better statistical measurements of e/γ between 100 GeV to 10 TeV
Origin of Galactic Cosmic rays	R2: Better spectral and composition measurements of CRs between 300 GeV to PeV* with a large geometrical factor

Secondary science: monitoring of GRBs, microquasars, Blazars and other transients.

*complementary to LHAASO

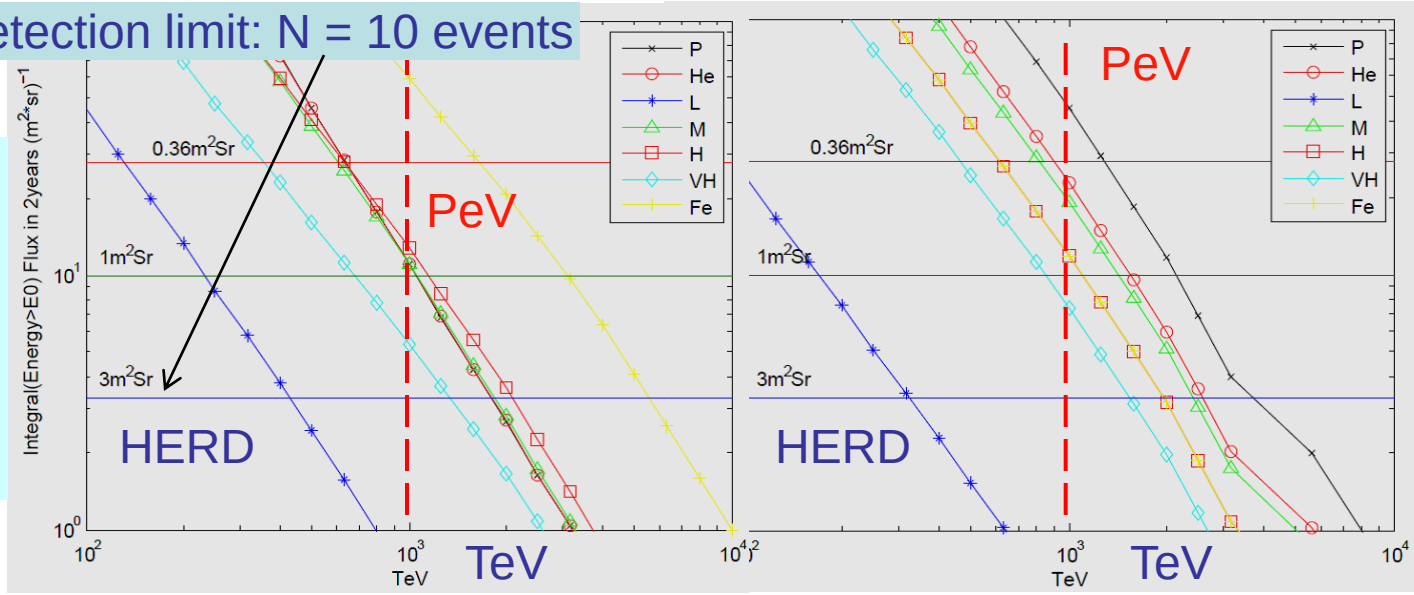
HERD Cosmic Ray Capability Requirement



P (<A> ~ 1)
He (<A> ~ 4)
L (<A> ~ 8)
M (<A> ~ 14)
H (<A> ~ 25)
VH (<A> ~ 35)
Fe (<A> ~ 56)

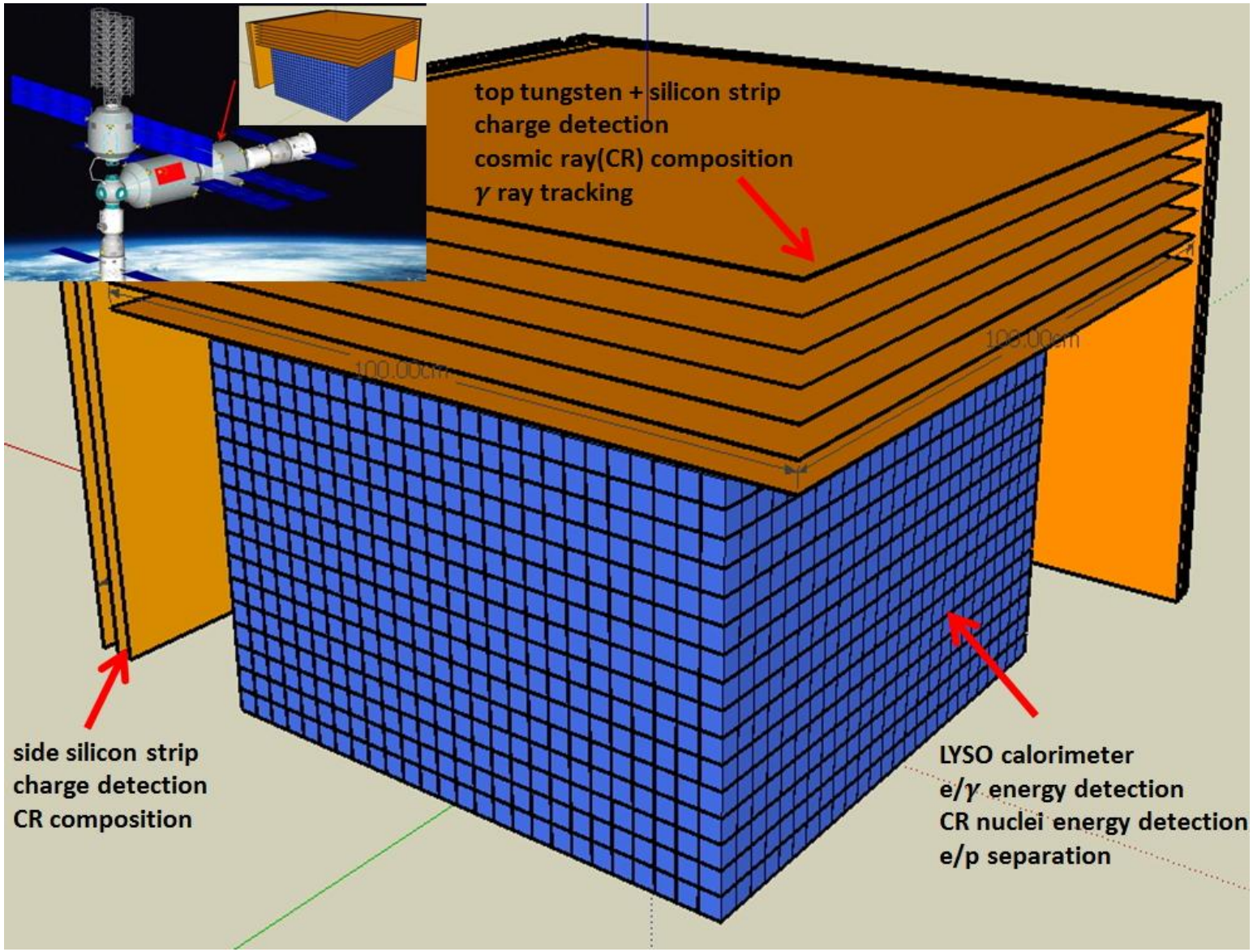
Detection limit: N = 10 events

N(E>E0; 2 yr)



Except for L, up to PeV spectra feasible with GF~2-3 in ~years: discriminate between models.

Baseline design of HERD



Characteristics of all components

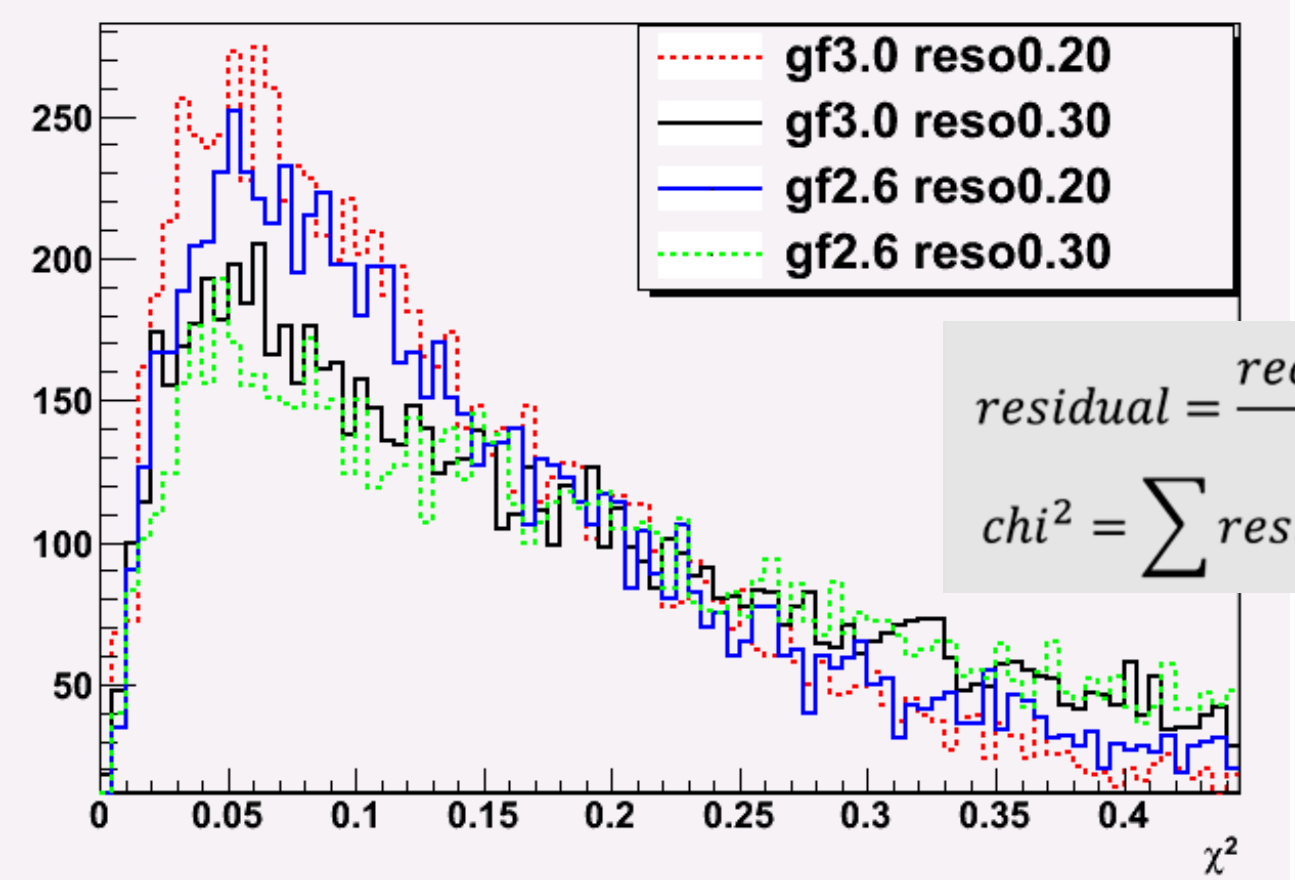
	type	size	X0,λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	--	3 x-y	Nucleon Track Charge
CALO	~10K LYSO cubes	63 cm × 63 cm × 63 cm	55 X0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon energy e/p separation

Total detector weight: ~2000 kg

Expected performance of HERD

γ/e energy range (CALO)	tens of GeV-10TeV
nucleon energy range (CALO)	up to PeV
γ/e angular resol. (top Si-strips)	0.1^{o}
nucleon charge resol. (all Si-strips)	0.1-0.15 c.u
γ/e energy resolution (CALO)	<1%@200GeV
proton energy resolution (CALO)	20%
e/p separation power (CALO)	$<10^{-5}$
electron eff. geometrical factor (CALO)	3.7 m^2sr@600 GeV
proton eff. geometrical factor (CALO)	2.6 m^2sr@400 TeV

HERD reconstruction vs. energy resol.

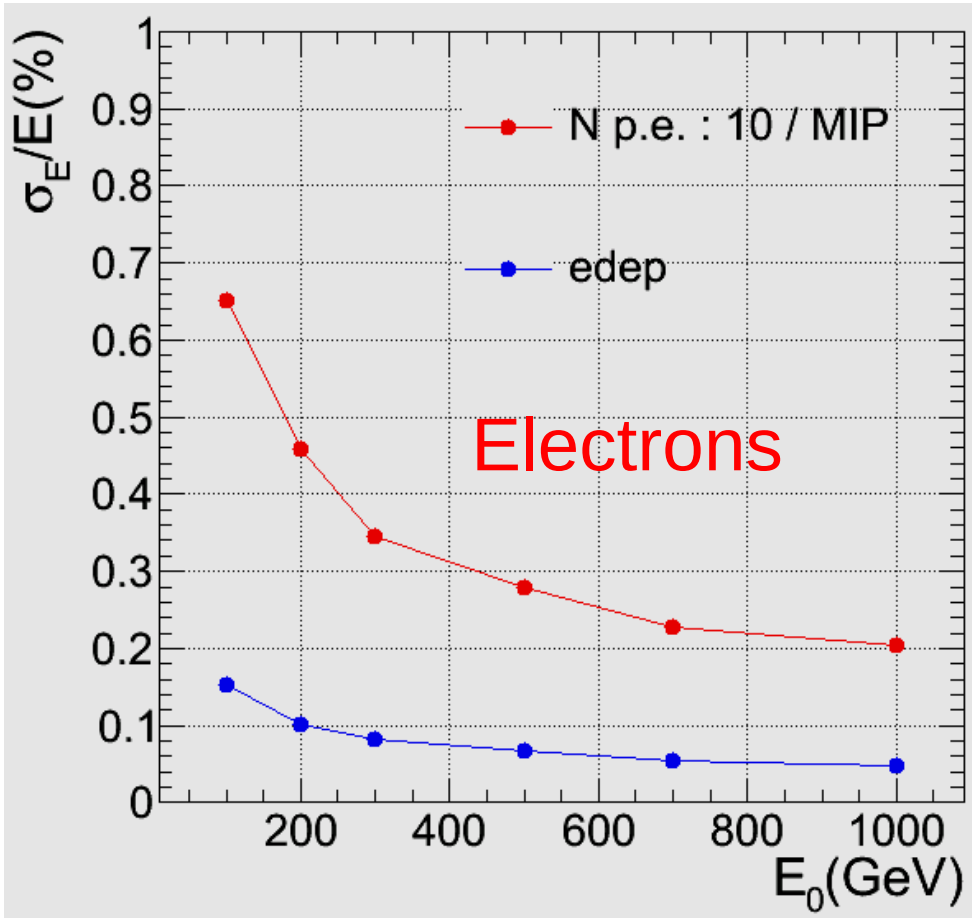


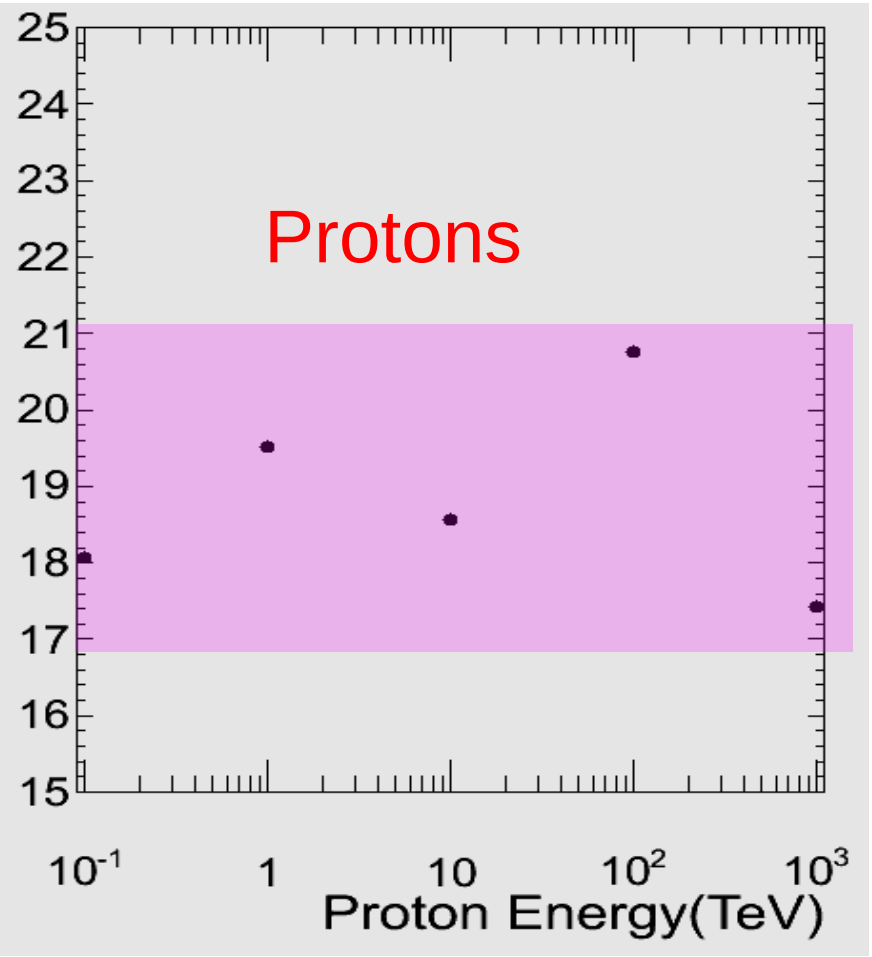
$$residual = \frac{reco - truth}{truth}$$

$$chi^2 = \sum residual^2$$

Under the weight limitation of 2 tons, resolution is more important for spectral reconstruction, based on the current design.

Simulation results: energy resolutions

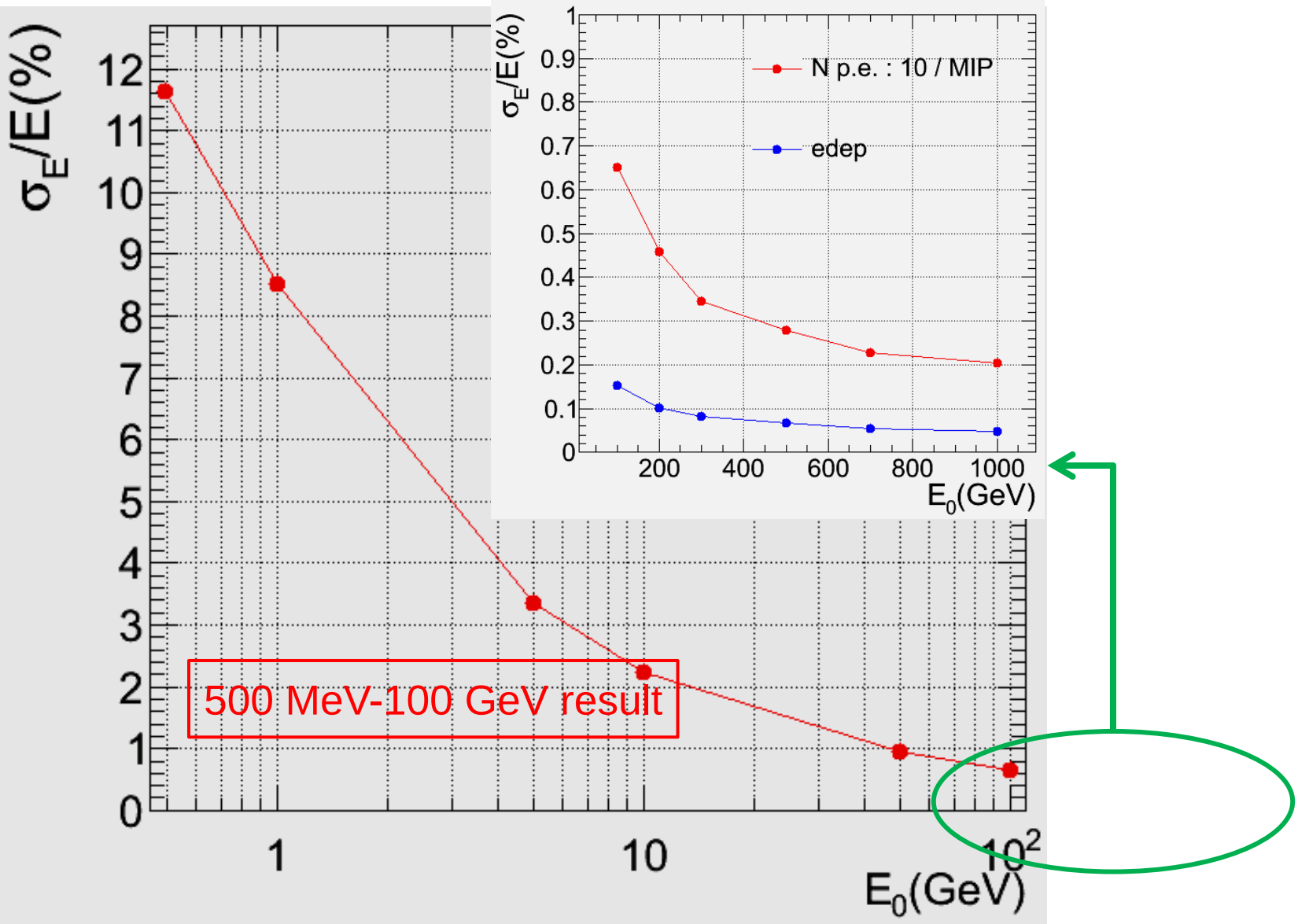




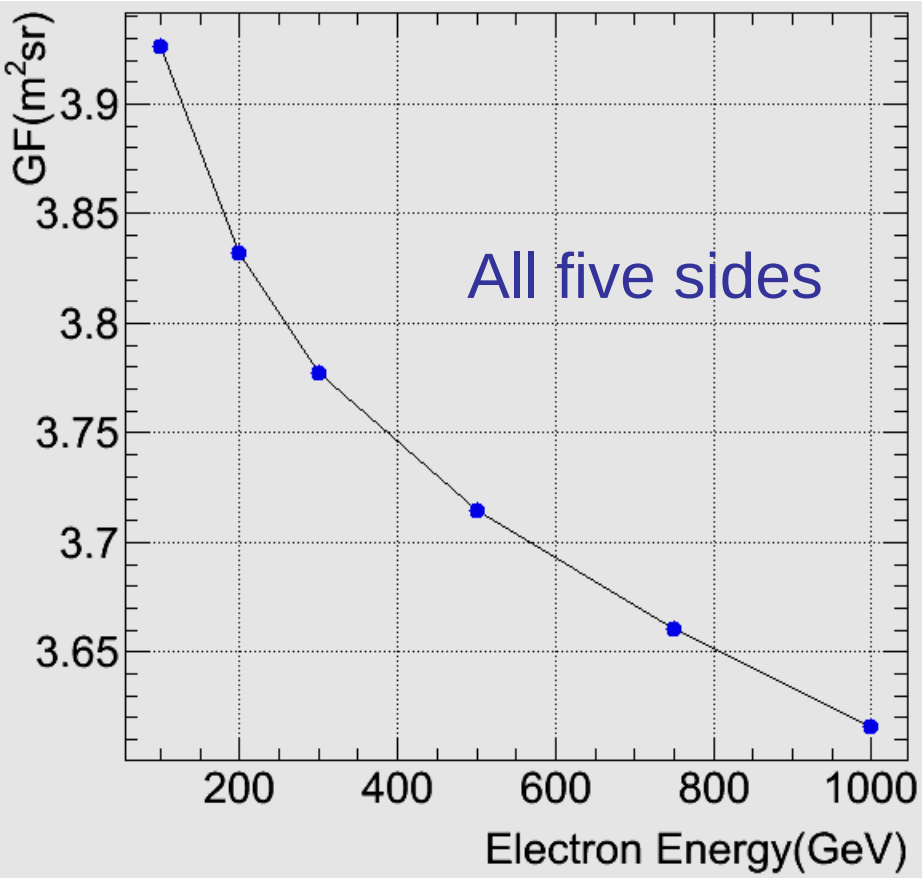
Electron < 1%; Proton: ~20%

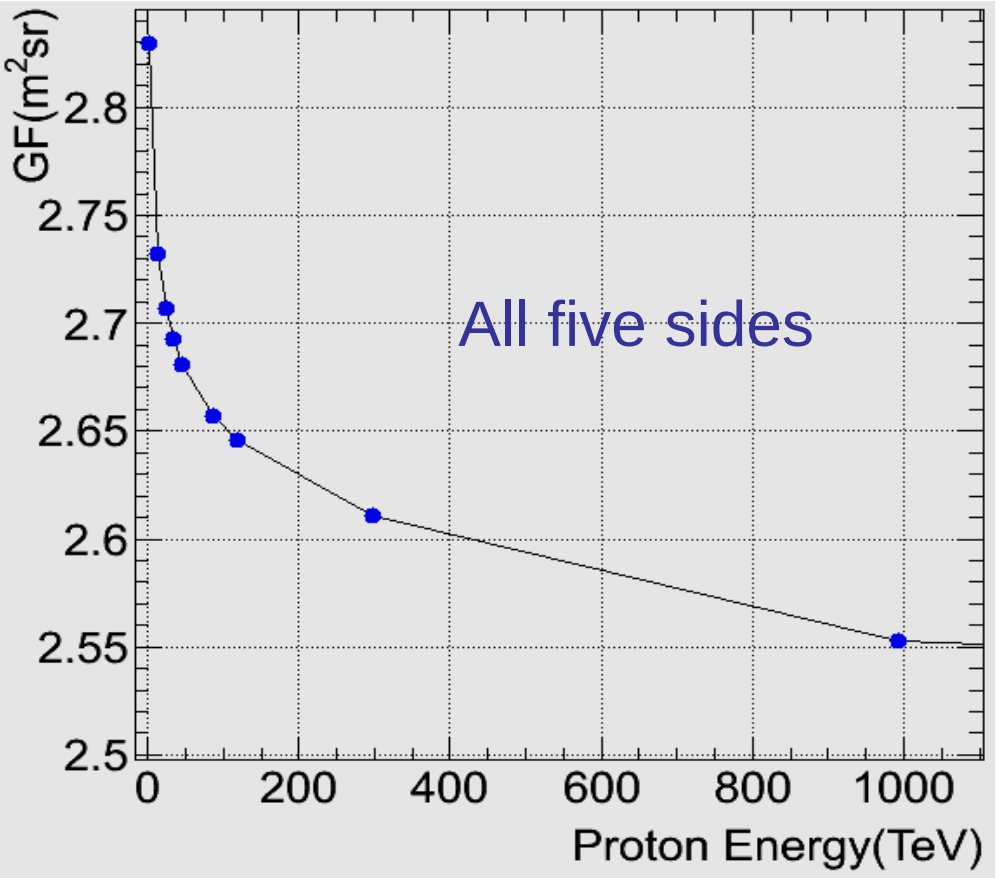
Essential for spectral features!

Energy Resolution for gamma-rays



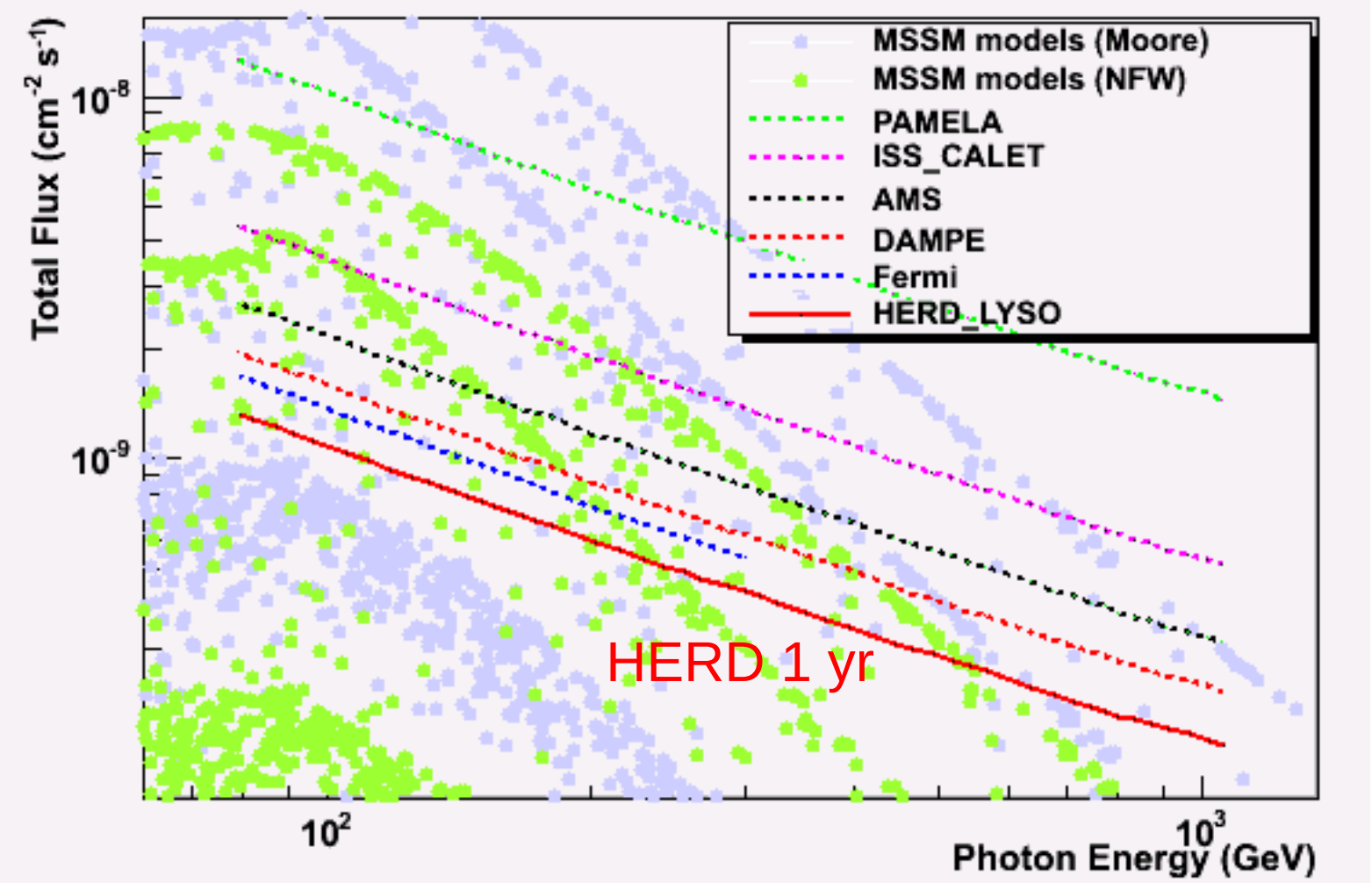
HERD Eff. Geometrical Factor: CALO





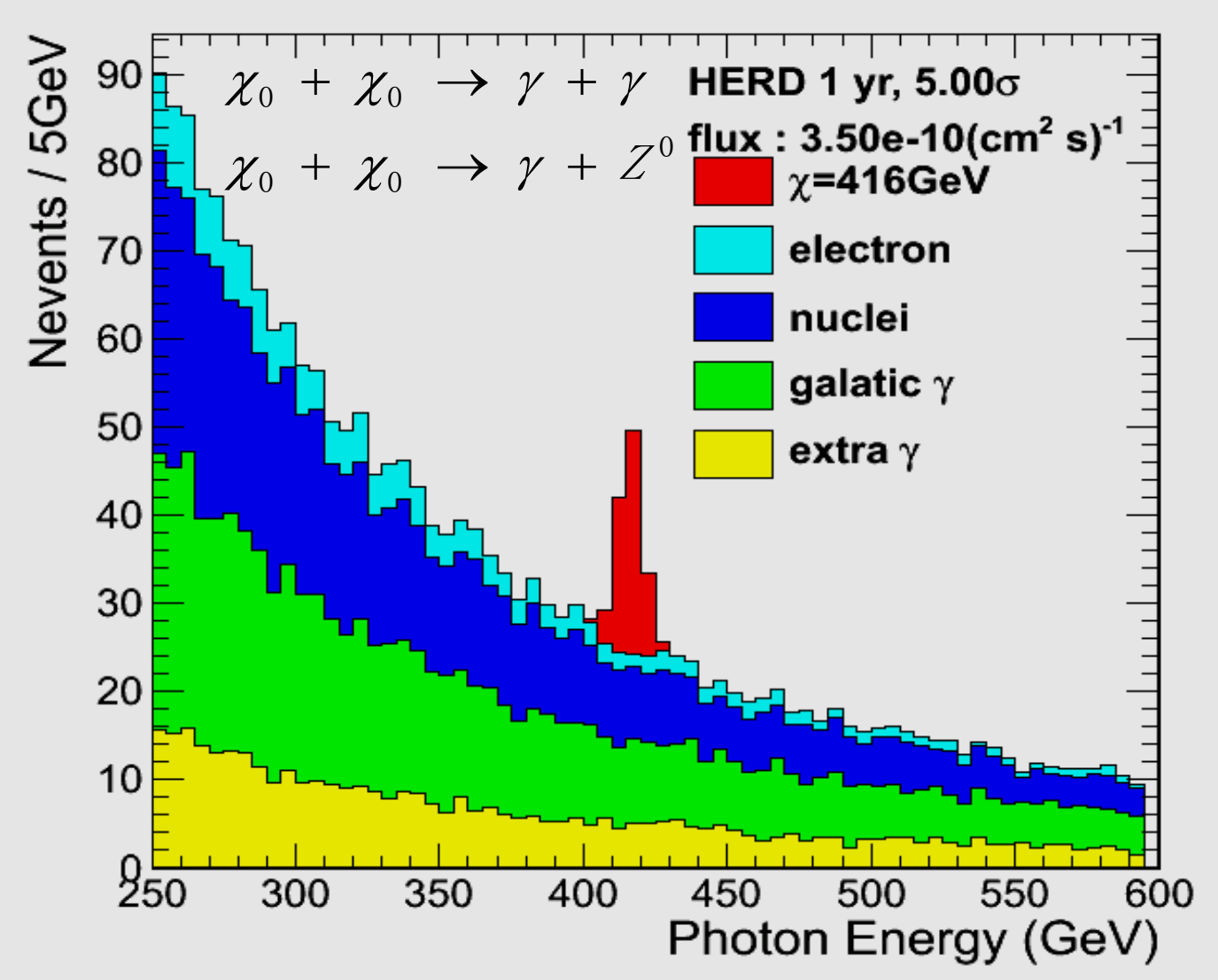
$$N_{obs} = F \times G_{eff.} \times T_{exp.} \times \eta_{pid} \times \eta_{reco}$$

HERD sensitivity to gamma-ray line

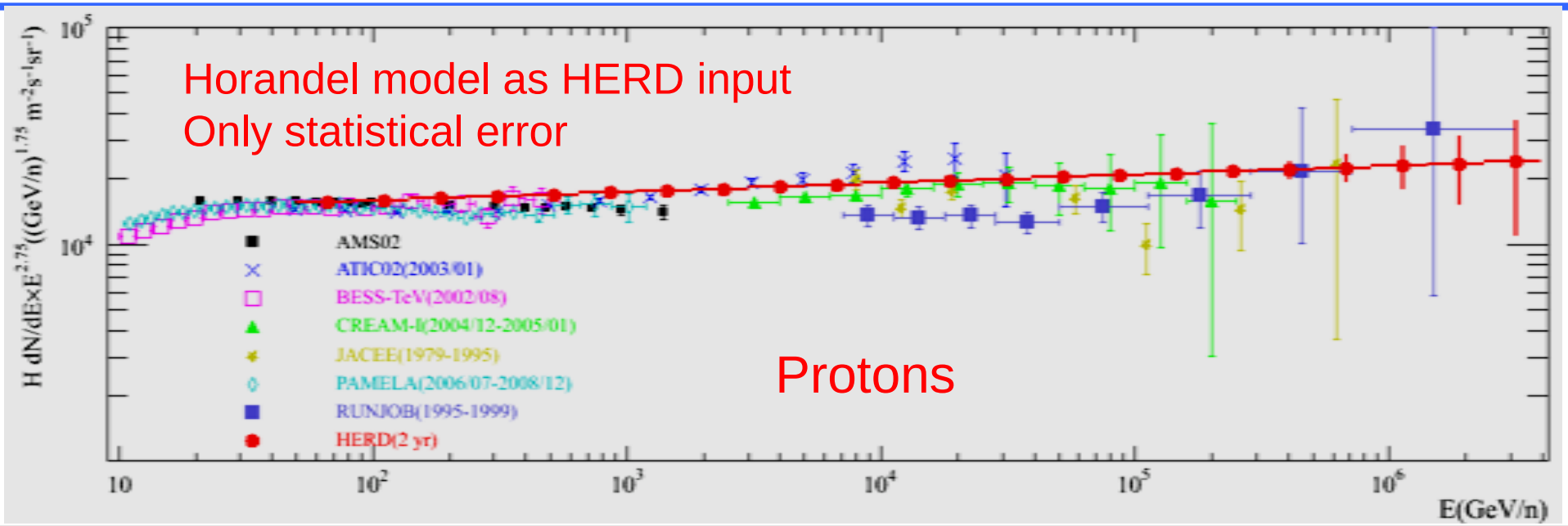


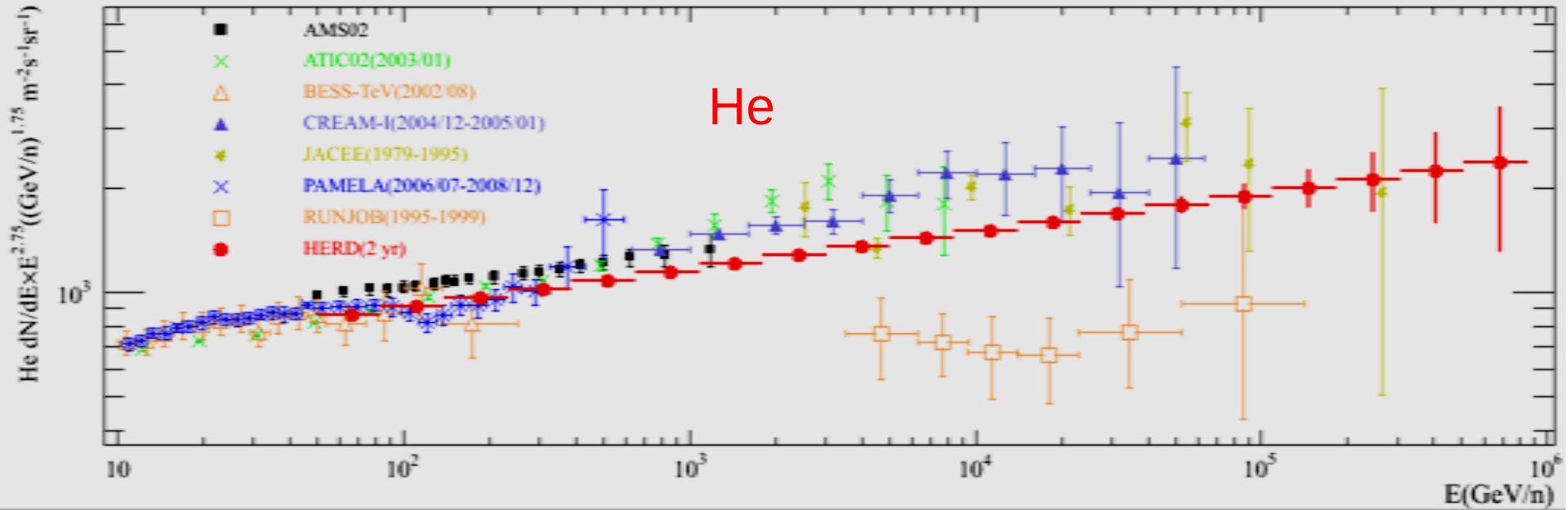
PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

DM annihilation line of HERD

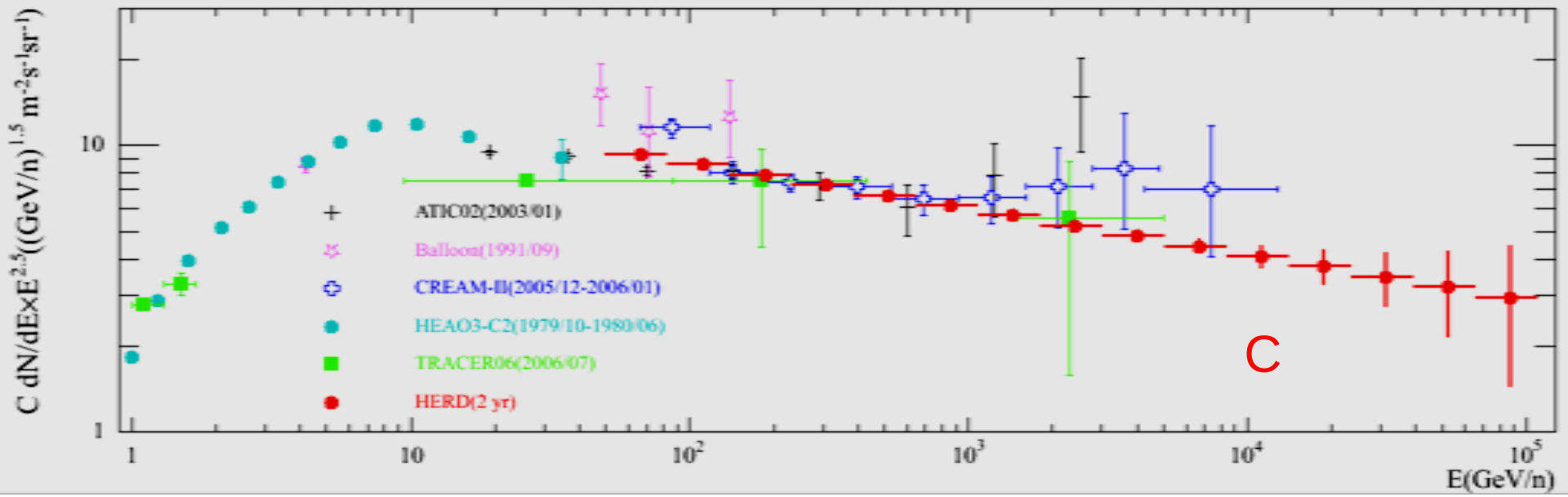


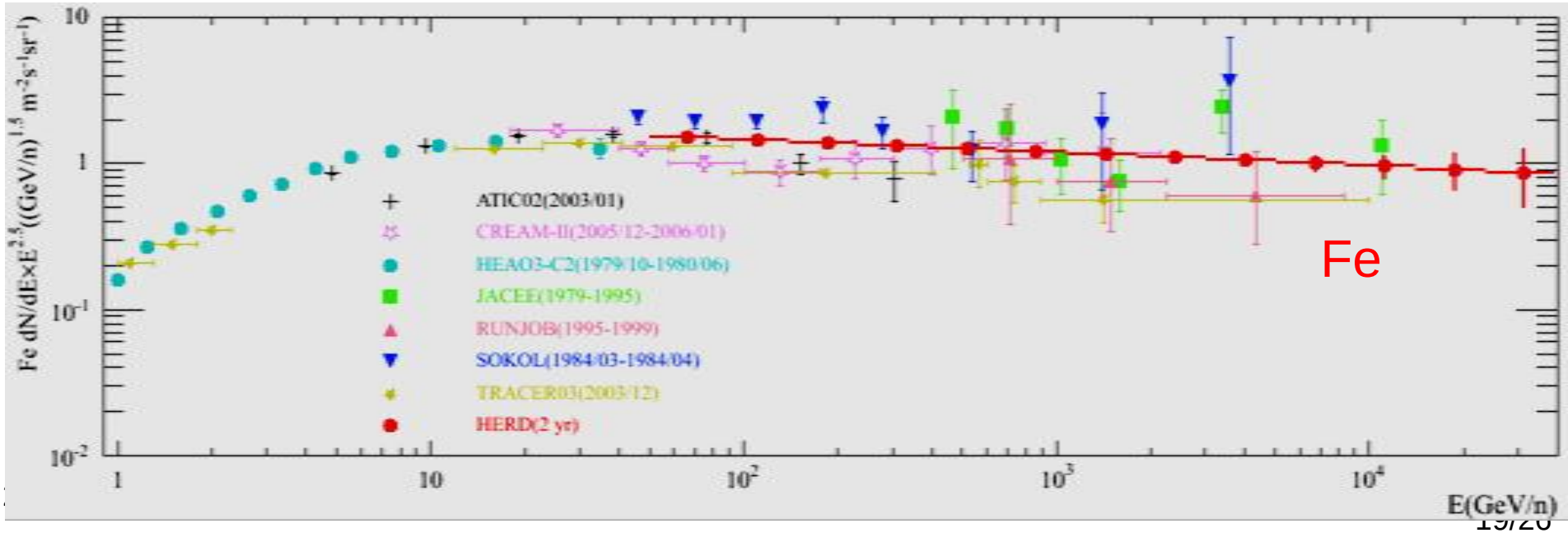
Expected HERD Proton and He Spectra



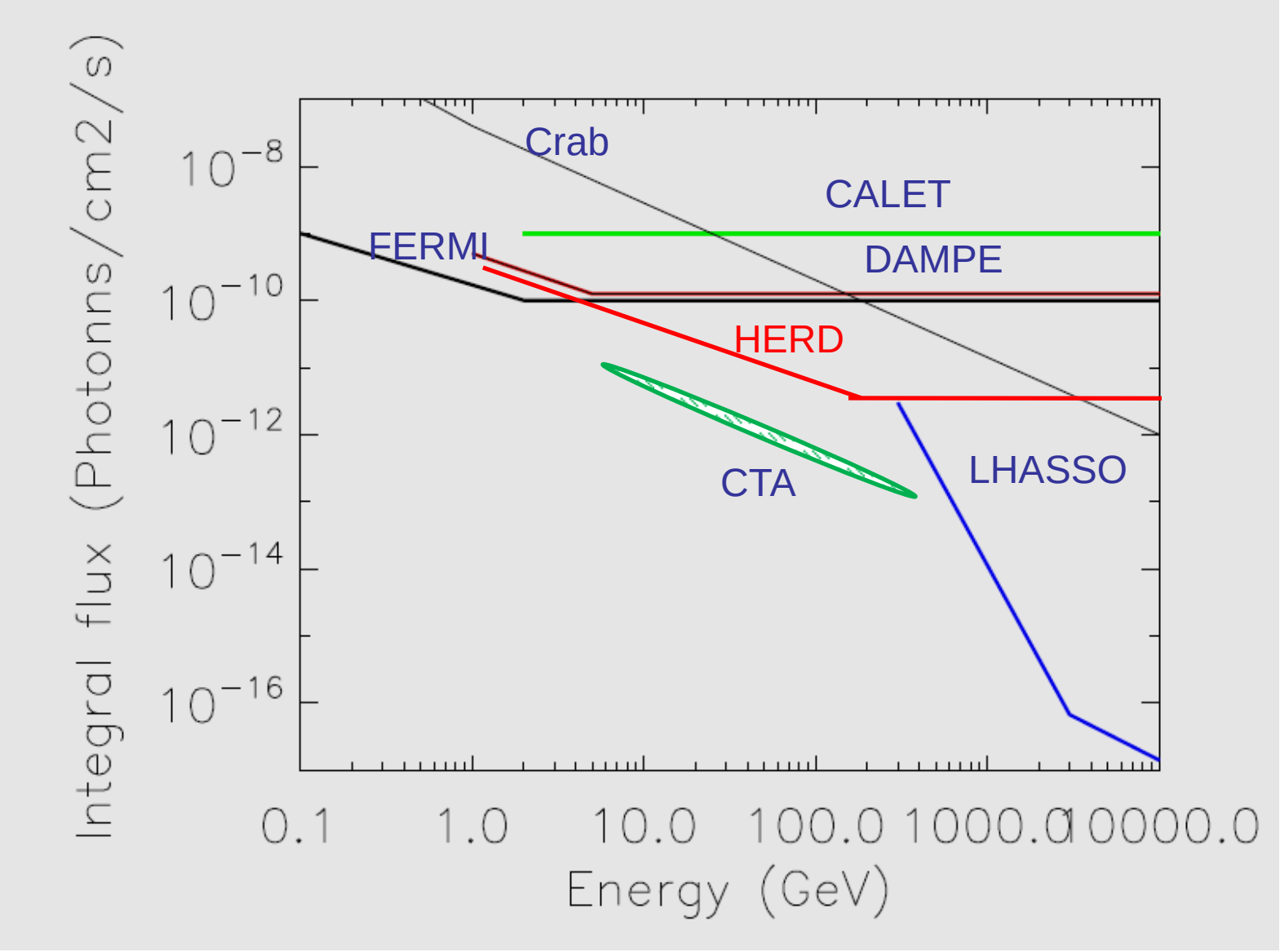


Expected HERD Spectra of C and Fe



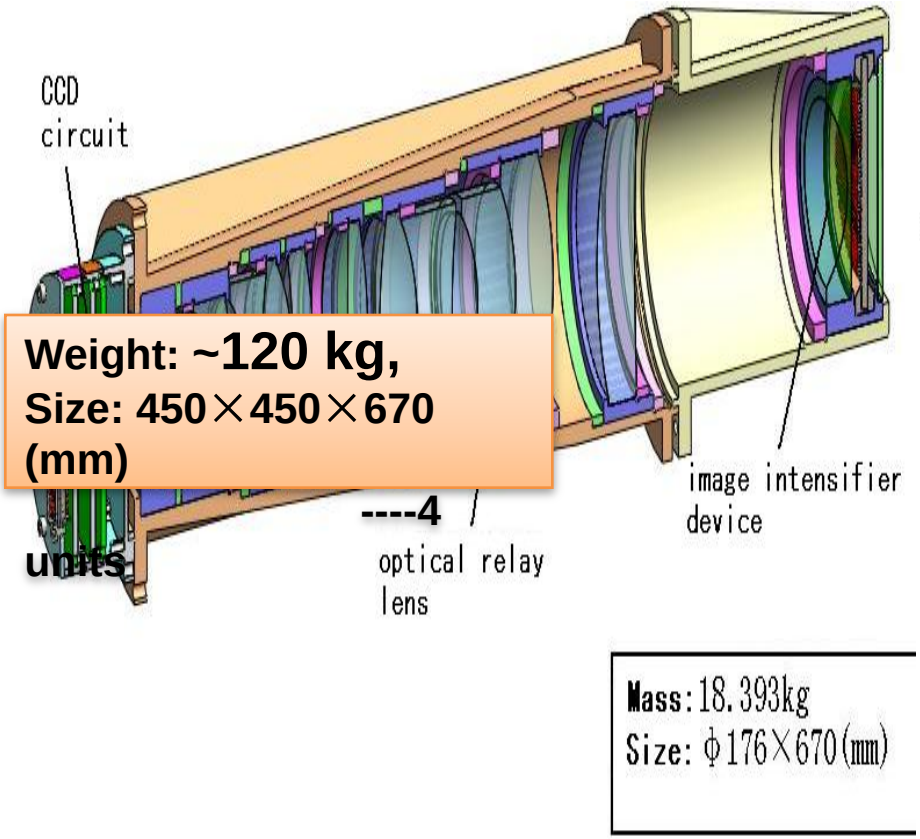


Gamma-ray Sky Survey Sensitivity



Signal Readout: Two Types of Coupling

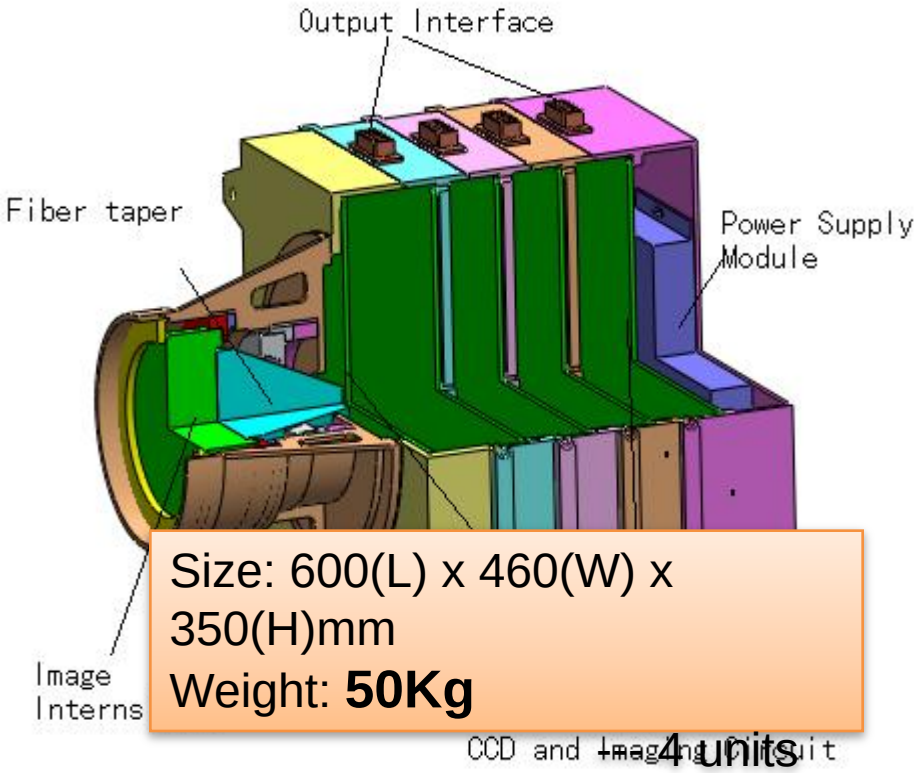
Relay Lens



Weight: ~120 kg,
Size: 450×450×670 (mm)

----4 units

Taper



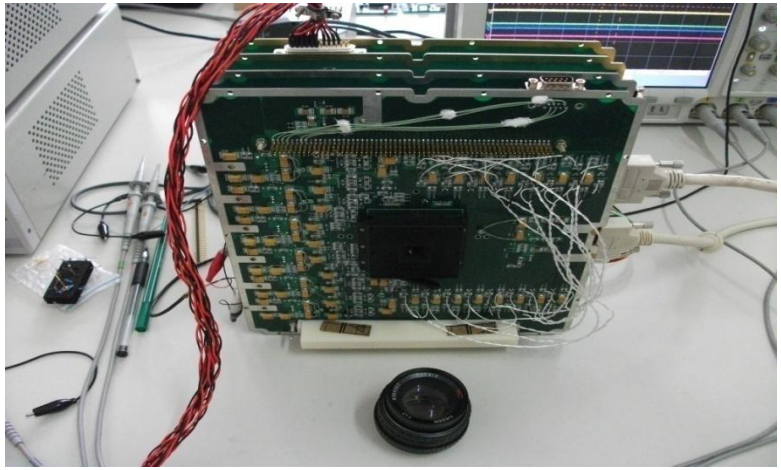
Size: 600(L) x 460(W) x 350(H)mm
Weight: **50Kg**

4 units

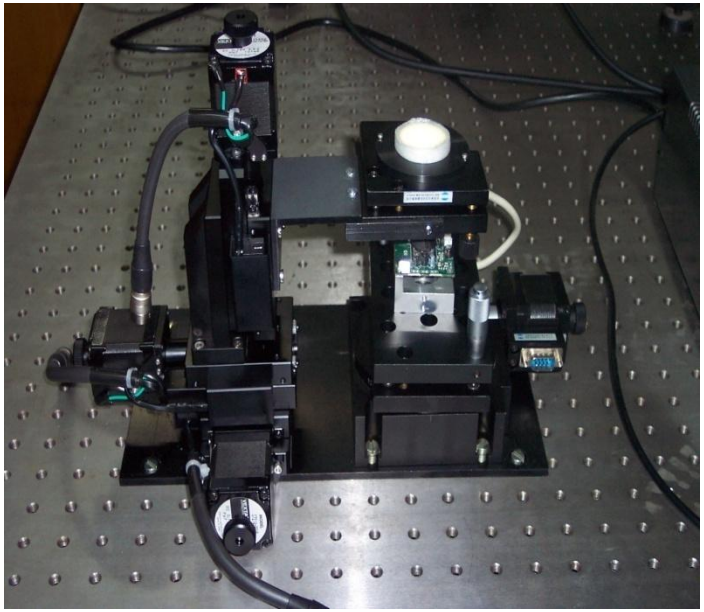
Relay Lens Tests

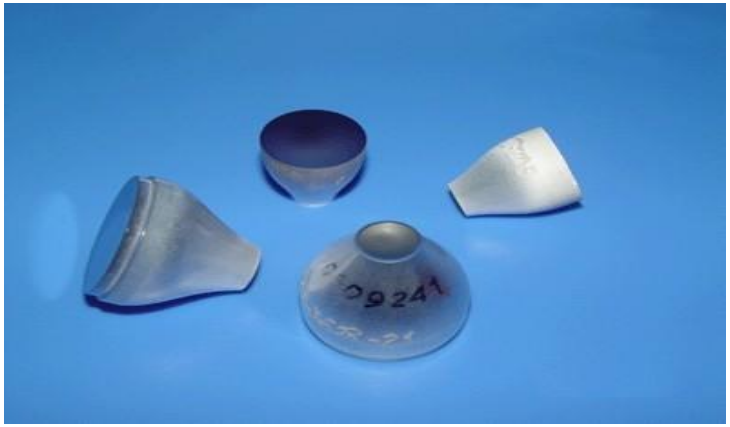
Performance Characteristics of Principle Prototype :

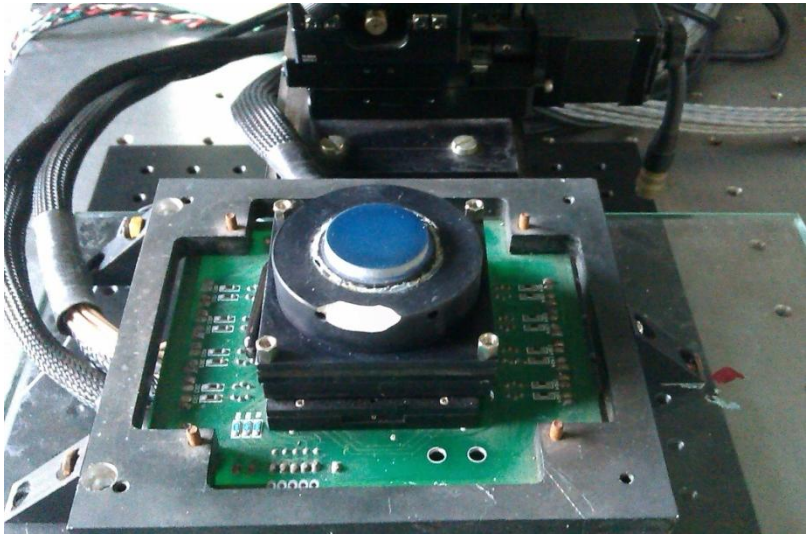
- ➢512×512 back illuminated CCD;
- ➢Adjustable CCD gain and MCP gain ;
- ➢Fame rate : 280 frame/second;
- ➢External trigger mode



Taper Coupling Tests

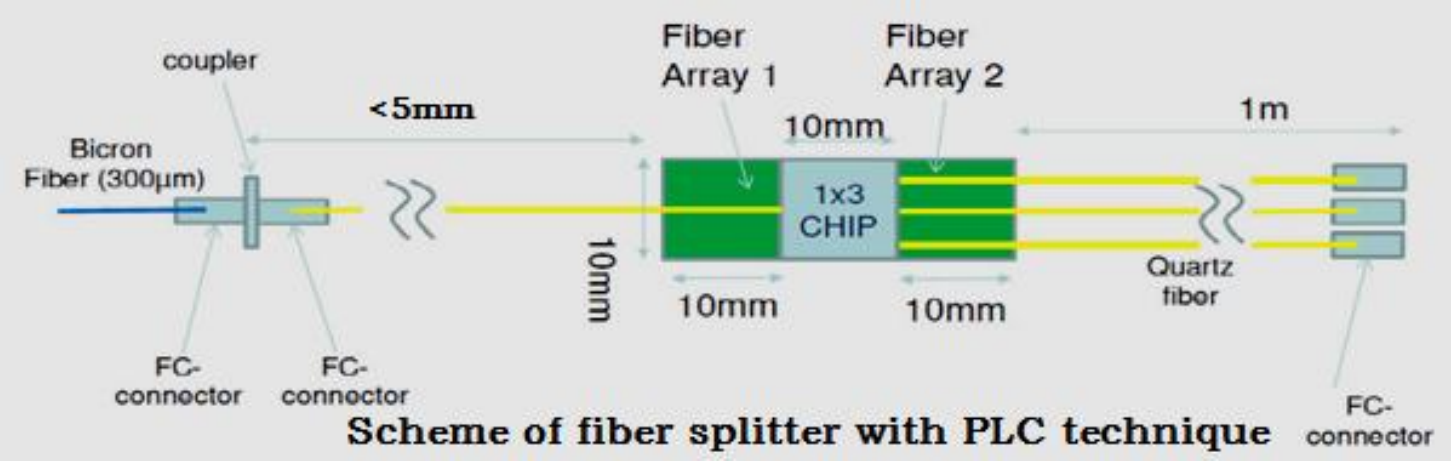






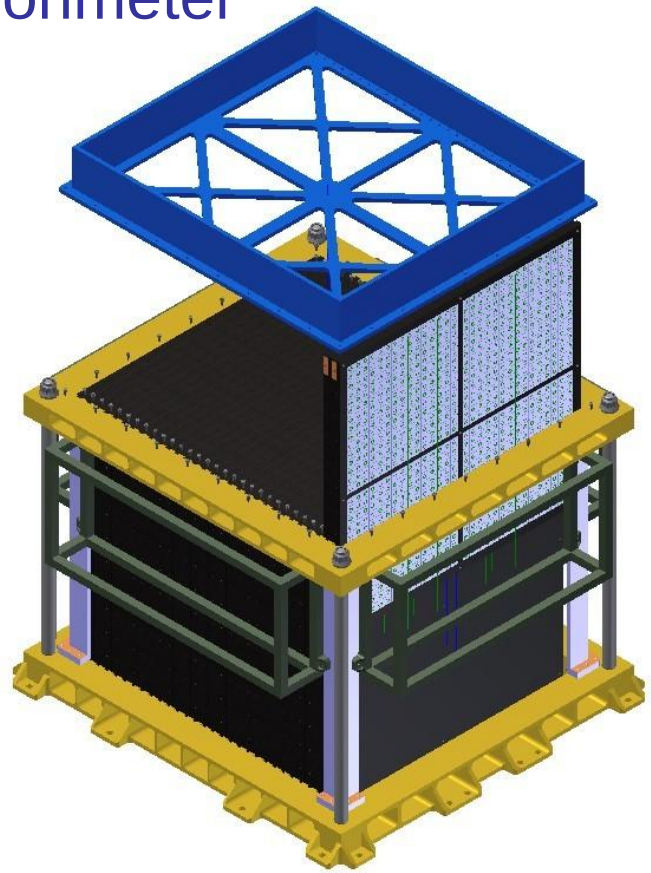
Requirement of dynamic range

- Simulation → dynamic range of 10^6
  - Crystal's linearity is OK: To be verified in BEPC beam test
  - Image intensifier: ~ 10^4
  - CCD: FWC/sqrt(ENC) < 10^4 (FWC=full well charge)
- 3 outputs with different energy ranges from crystals
  - 3 fibers on the surface of crystals – too complicated!
  - Fiber splitter outside the calorimeter – working on it!

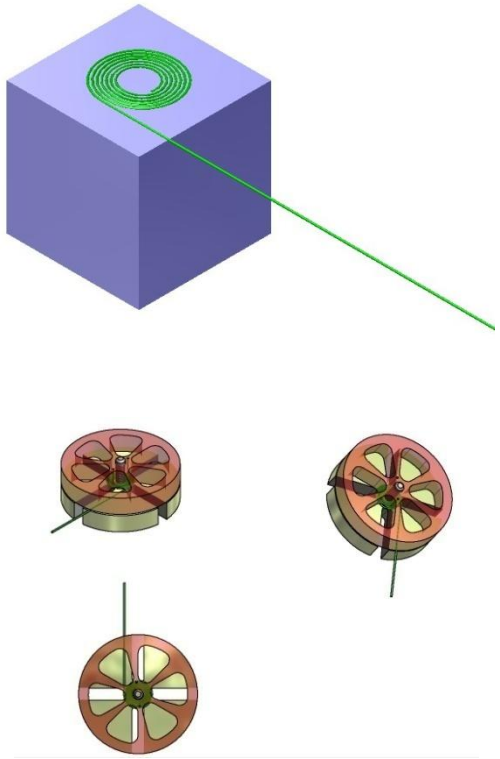


Prototype of one layer of calorimeter

Structural design of HERD calorimeter



Mold for the spiral WLS fiber



2nd HERD Workshop @IHEP 2013/12/2-3