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

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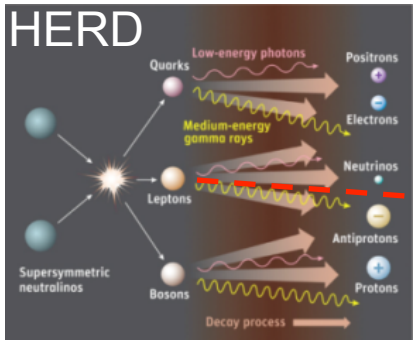
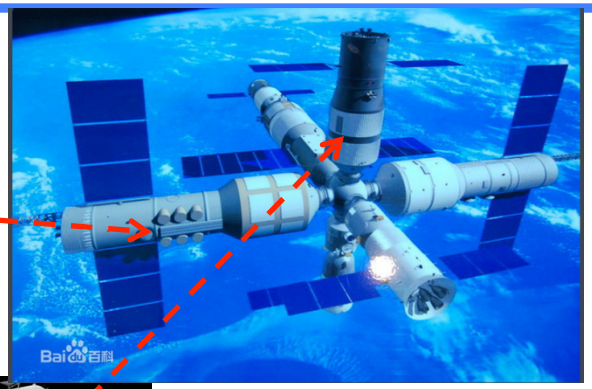
China's Space Station Program

2020

Phase -II

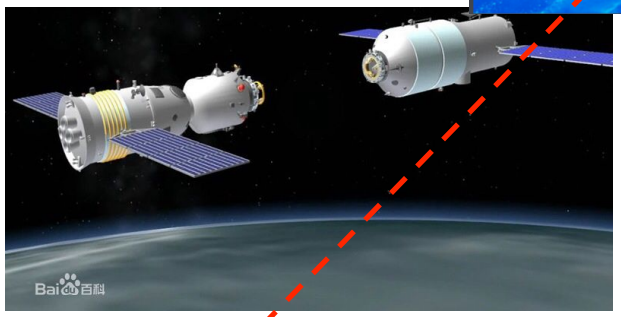




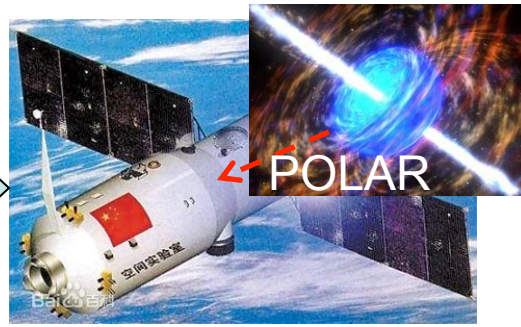
Space Station
3 large modules
~ 60 tons
~10-year lifetime

2016

Phase -II



Space lab:
no living cabin



2011

Phase -I

10 astronauts in 5 flights → space walk

2003

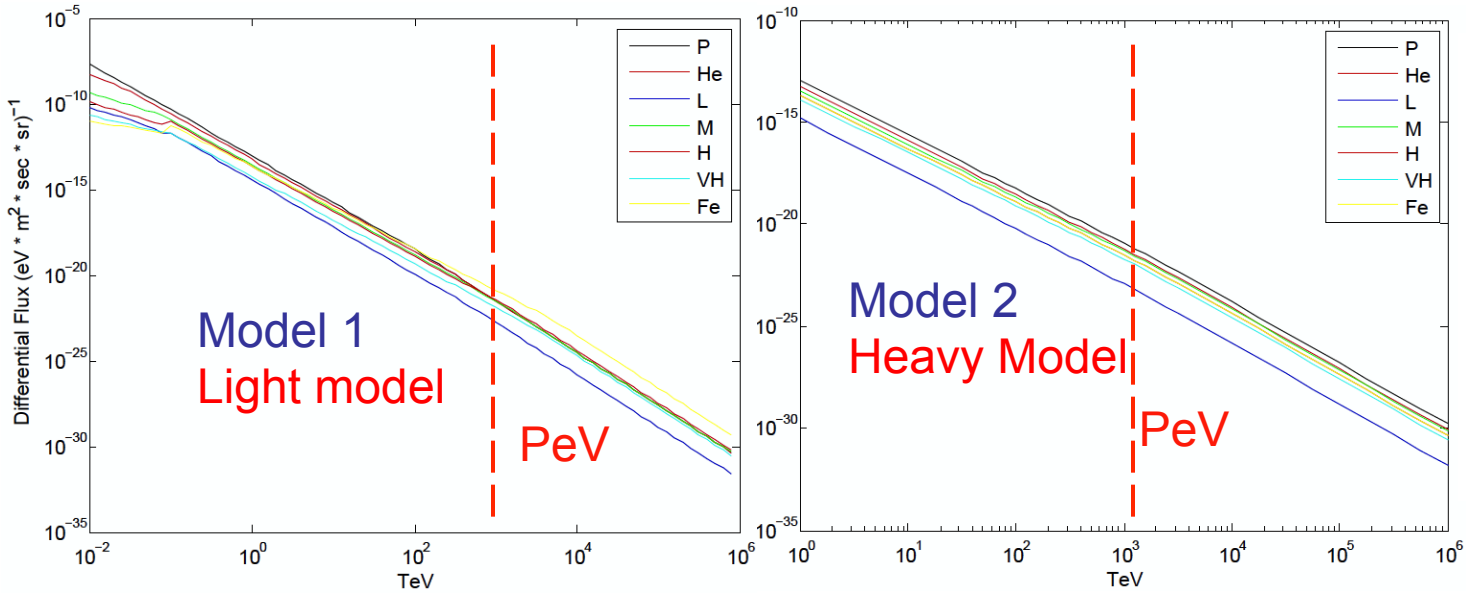
HERD: High Energy cosmic-Radiation Detector

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: γ-ray astronomy → monitoring of GRBs, microquasars, Blazars and other transients → down to 100 MeV for γ -rays → plastic scintillator shields for γ -ray selection

*complementary to high altitude cosmic-ray observations

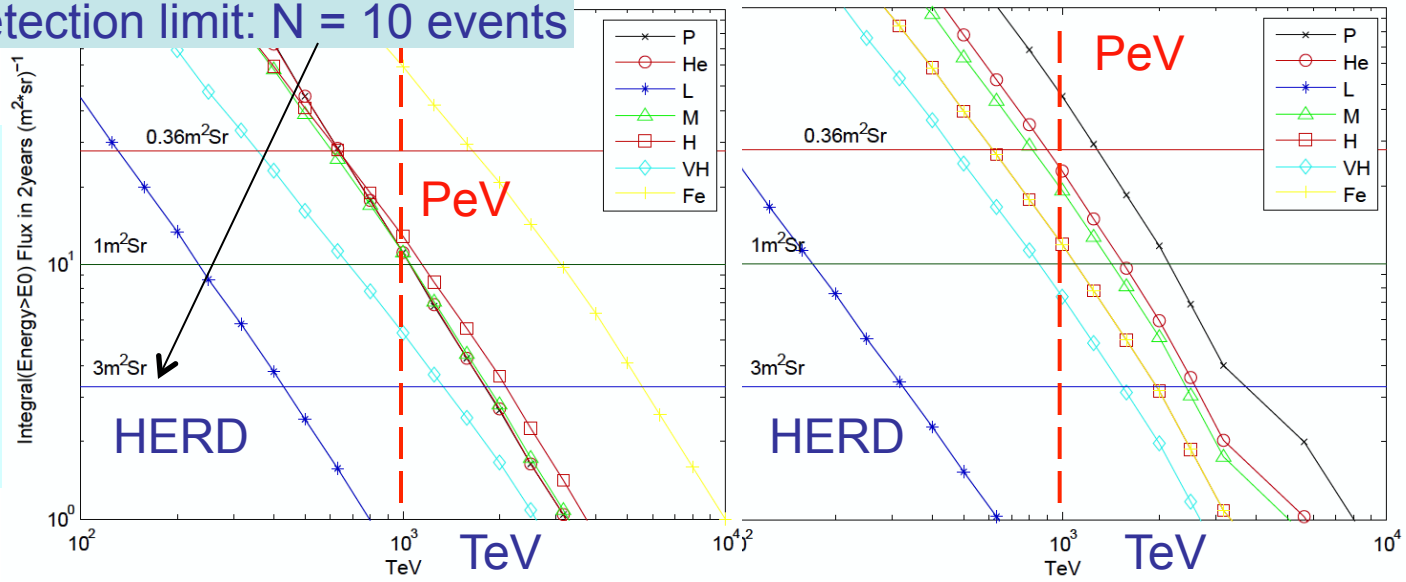
HERD Cosmic Ray Capability Requirement



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.

Characteristics of all components

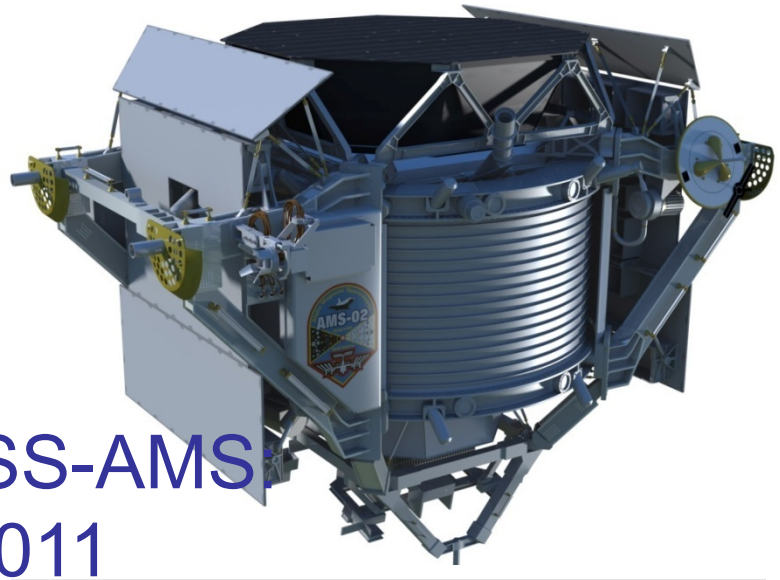
	type	size	X0,λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	2 X0	7 x-y (W foils)	Charge Early shower Tracks
CALO	~10K LYSO cubes	63 cm × 63 cm × 63 cm	55 X0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon energy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

Expected performance of HERD

γ/e energy range (CALO)	tens of GeV-10TeV
nucleon energy range (CALO)	up to PeV
γ/e angular resol. (STKs)	0.1°
nucleon charge resol. (STKs)	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

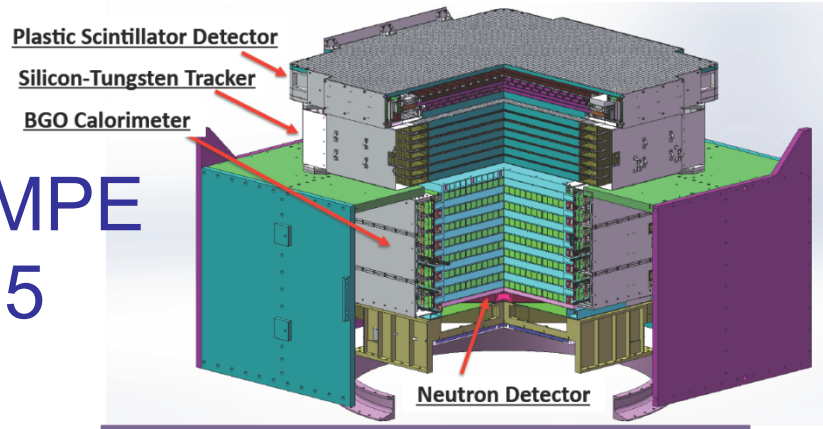
Acceptance & H-energy > n10X all others

Other detectors: Top down → "small" FoV

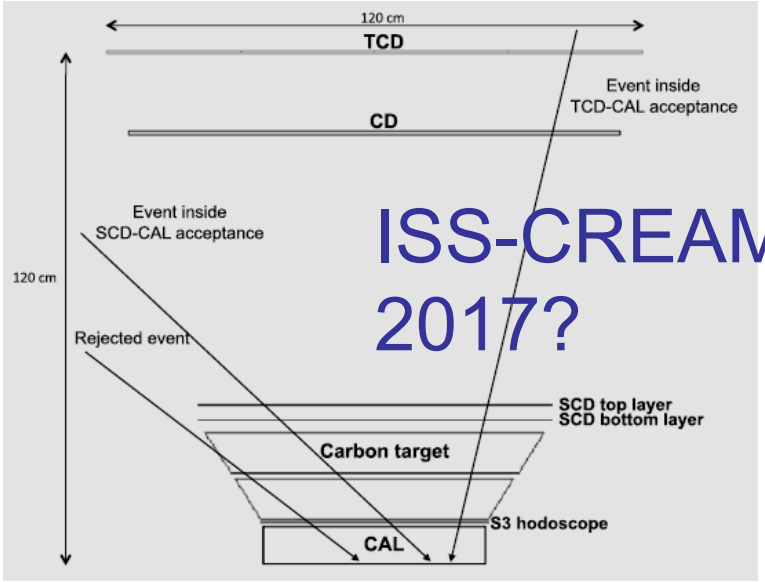


ISS-AMS: 2011

DAMPE 2015

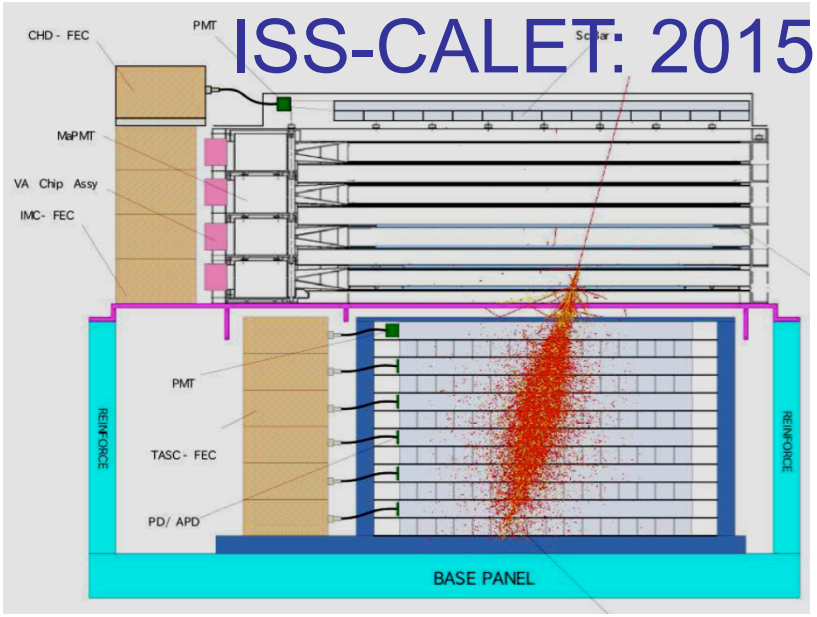


W converter + thick calorimeter (total 33 X_0) + precise tracking + charge measurement ➡ high energy γ-ray, electron and CR telescope



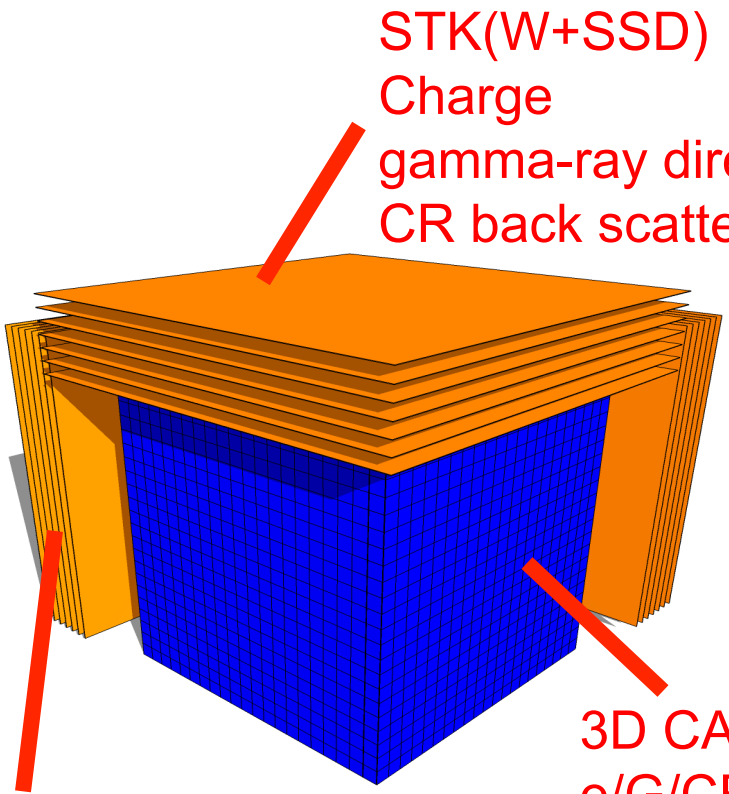
ISS-CREAM: 2017?

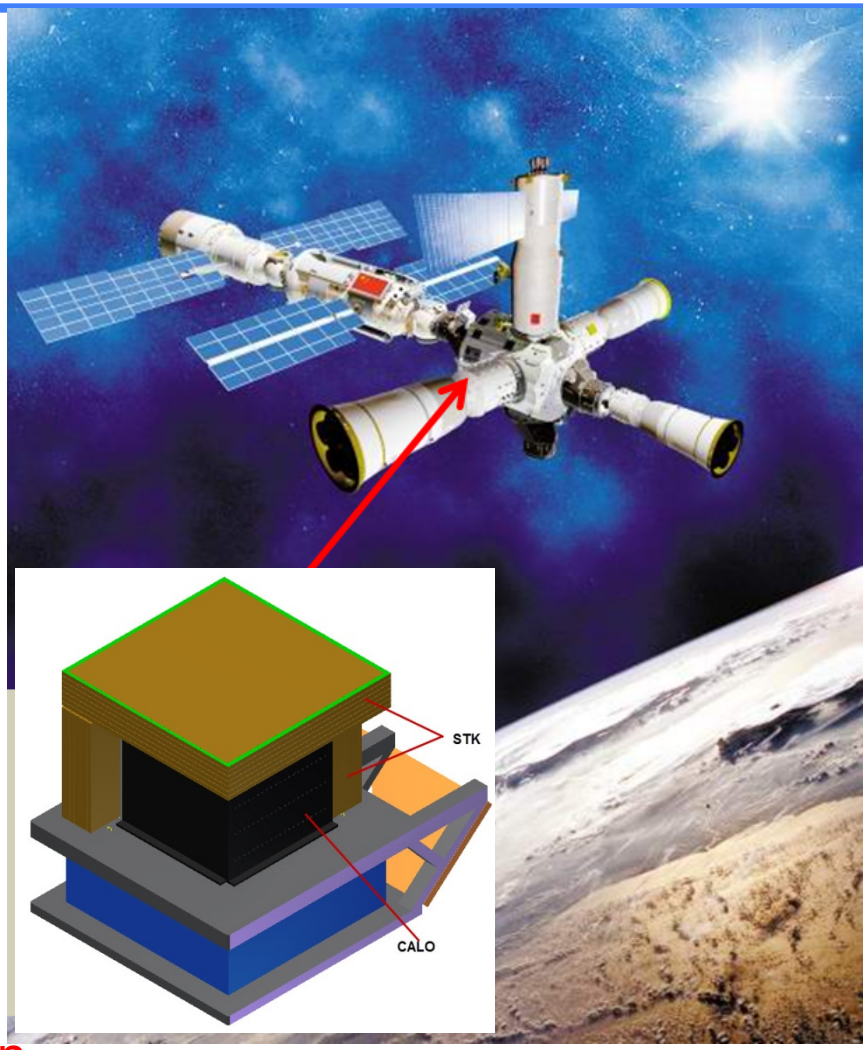
ISS-CALET: 2015



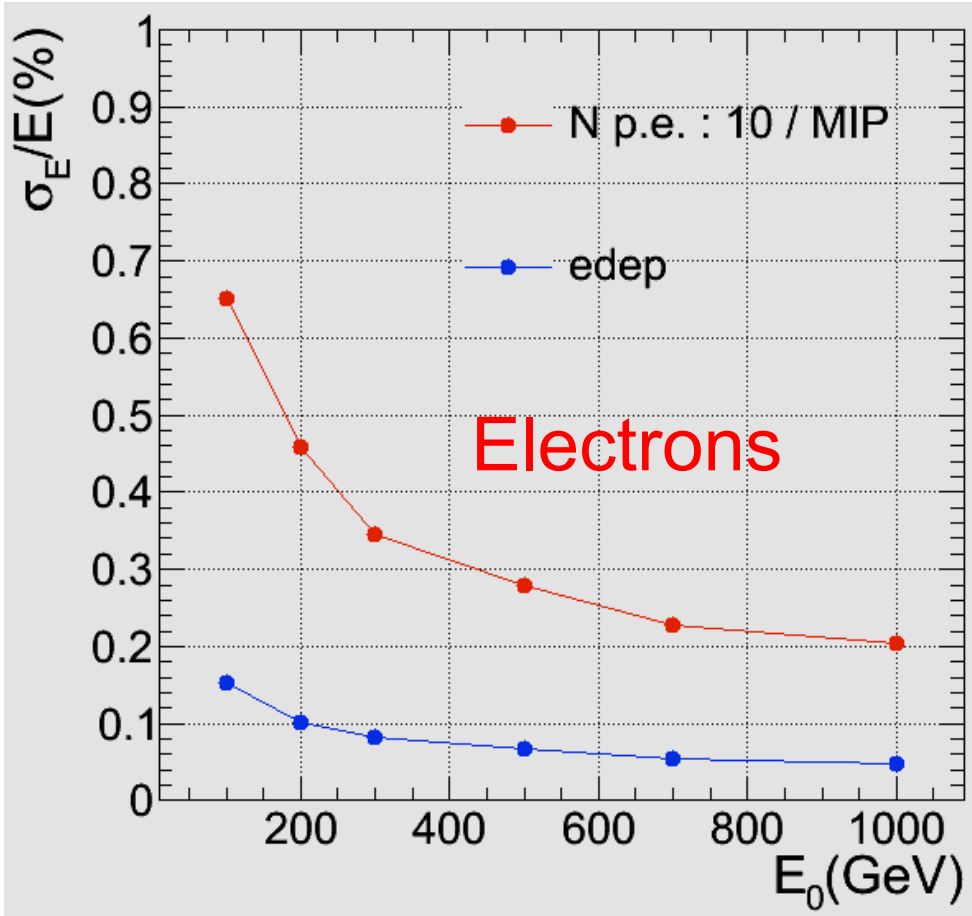
HERD Design：3D Calo & 5-Side Sensitive

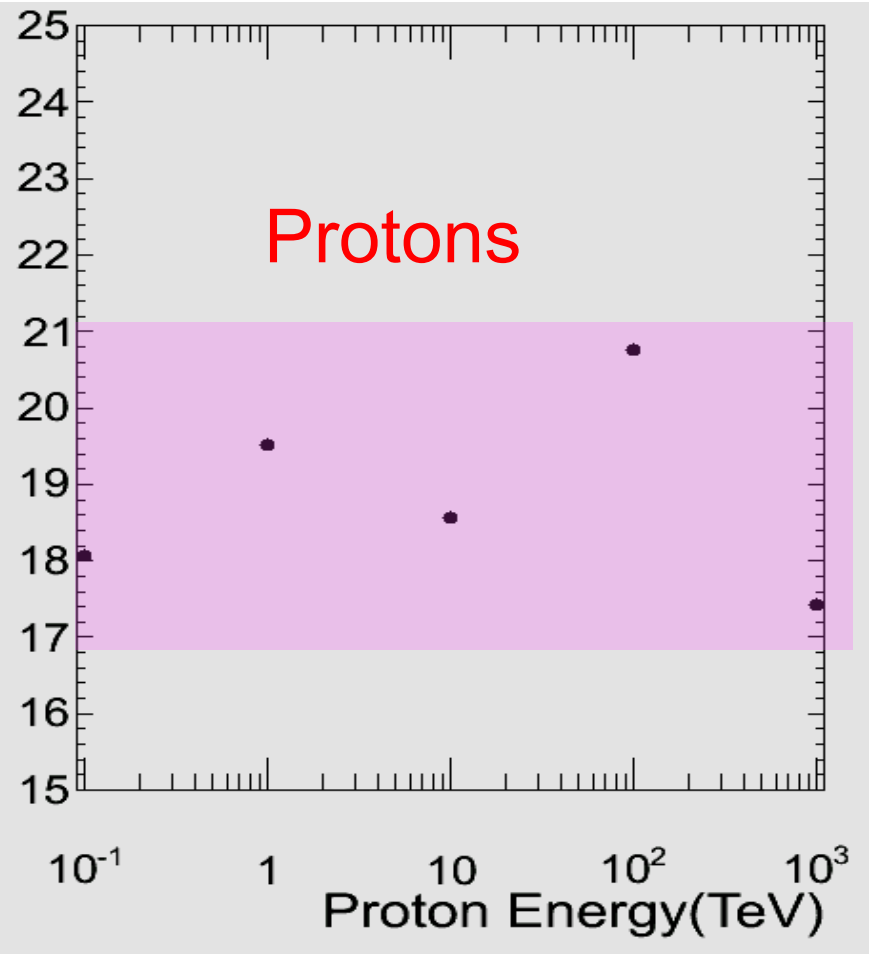
n10X acceptance than others, but weight 2.3 T ~1/3 AMS





Simulation results: energy resolutions

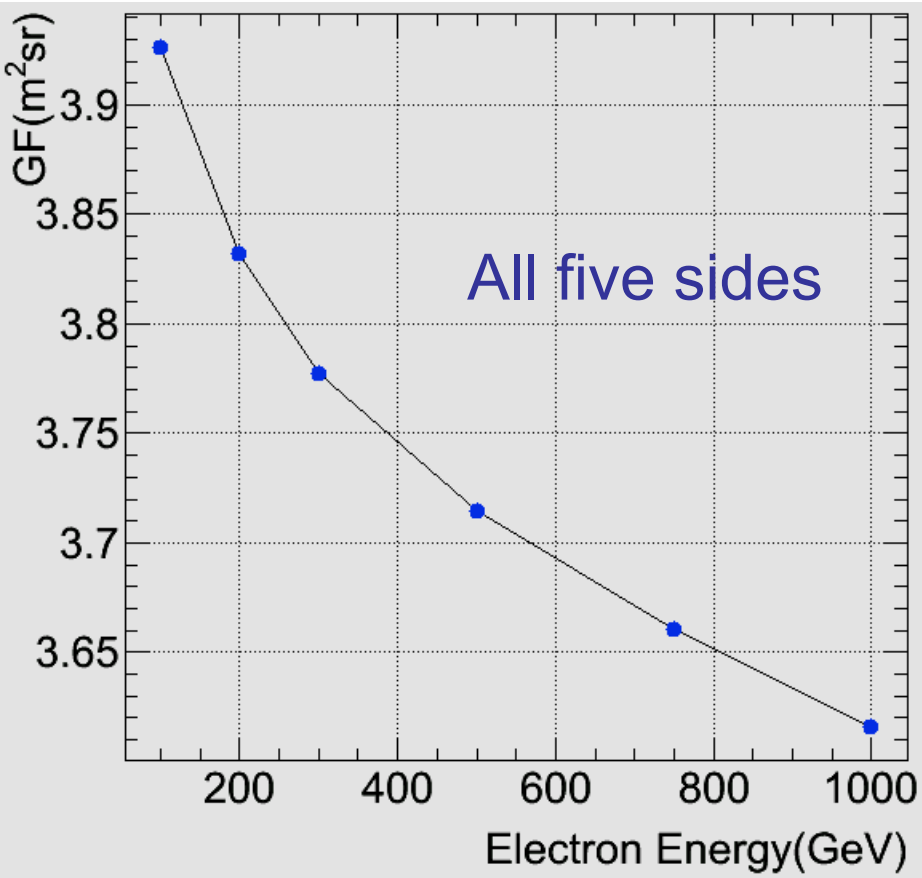


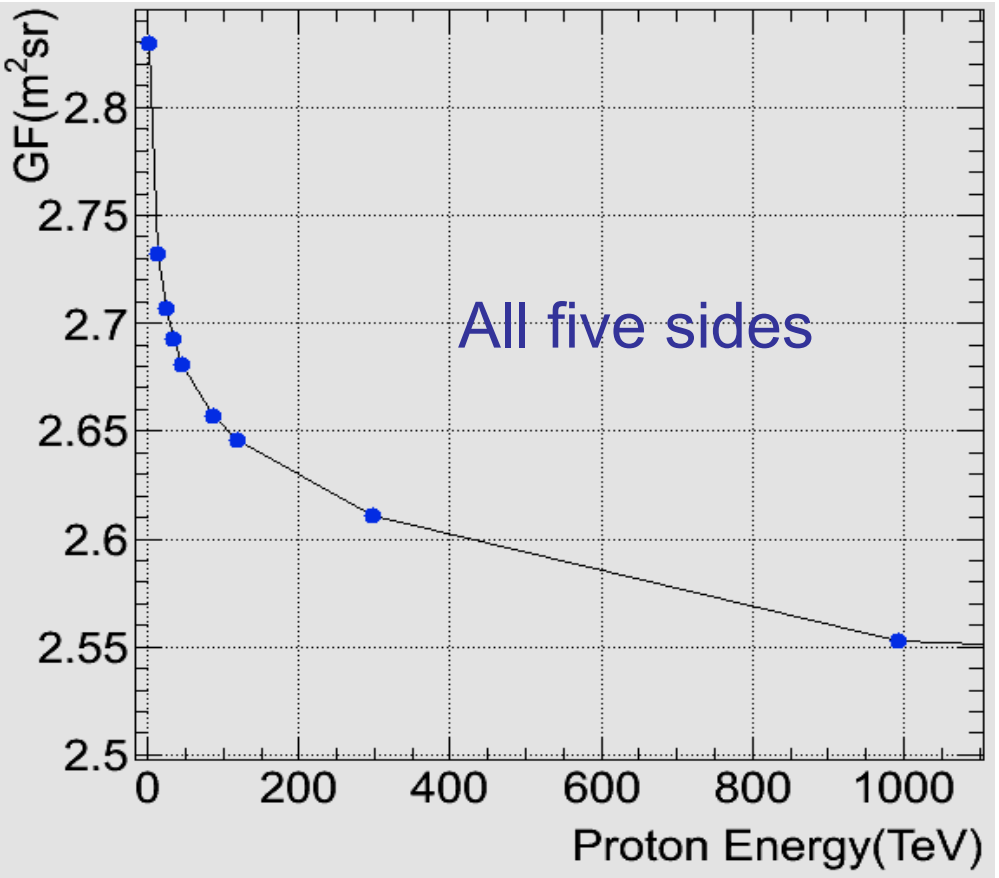


Electron < 1%; Proton: ~20%

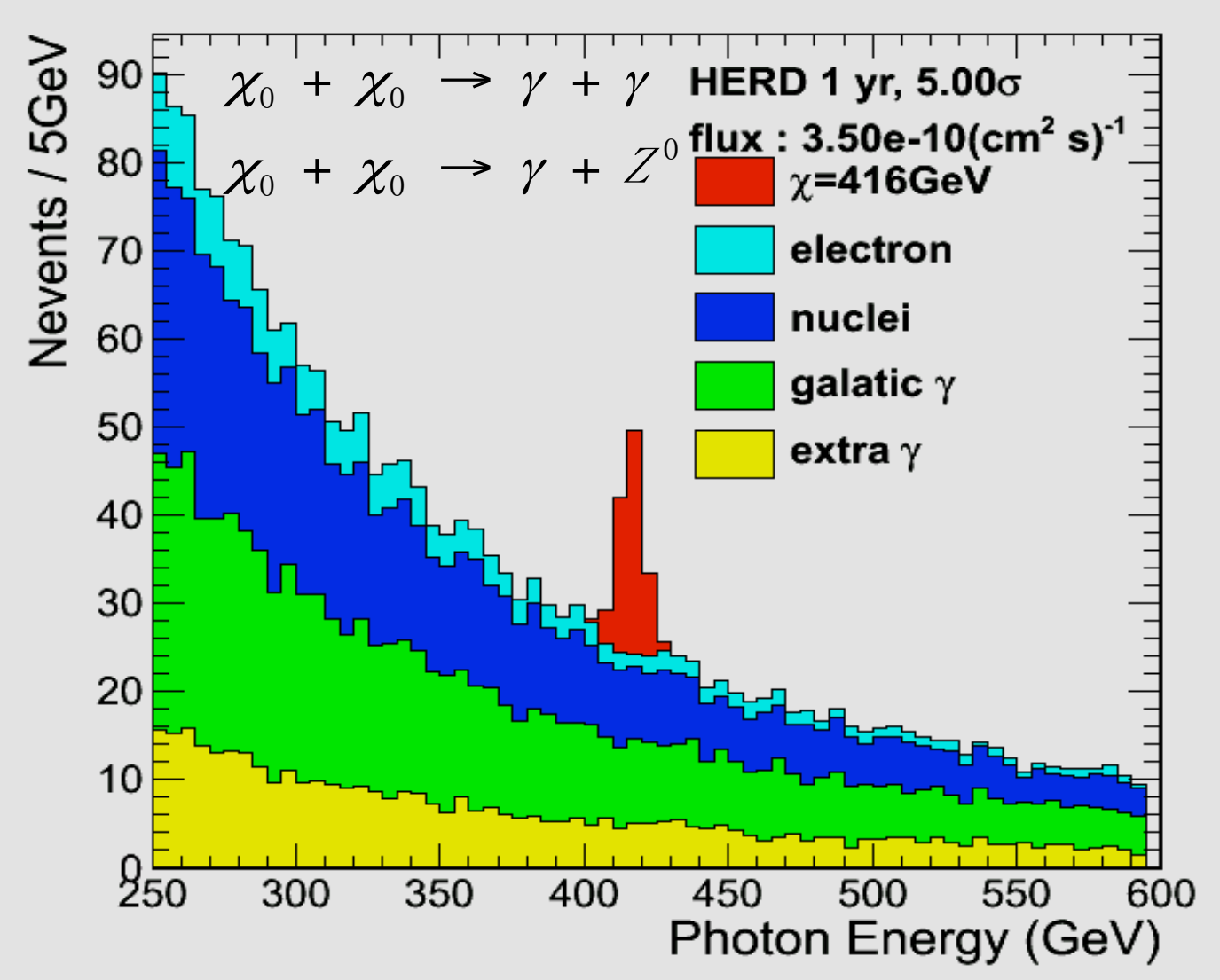
Essential for spectral features!

HERD Eff. Geometrical Factor: CALO

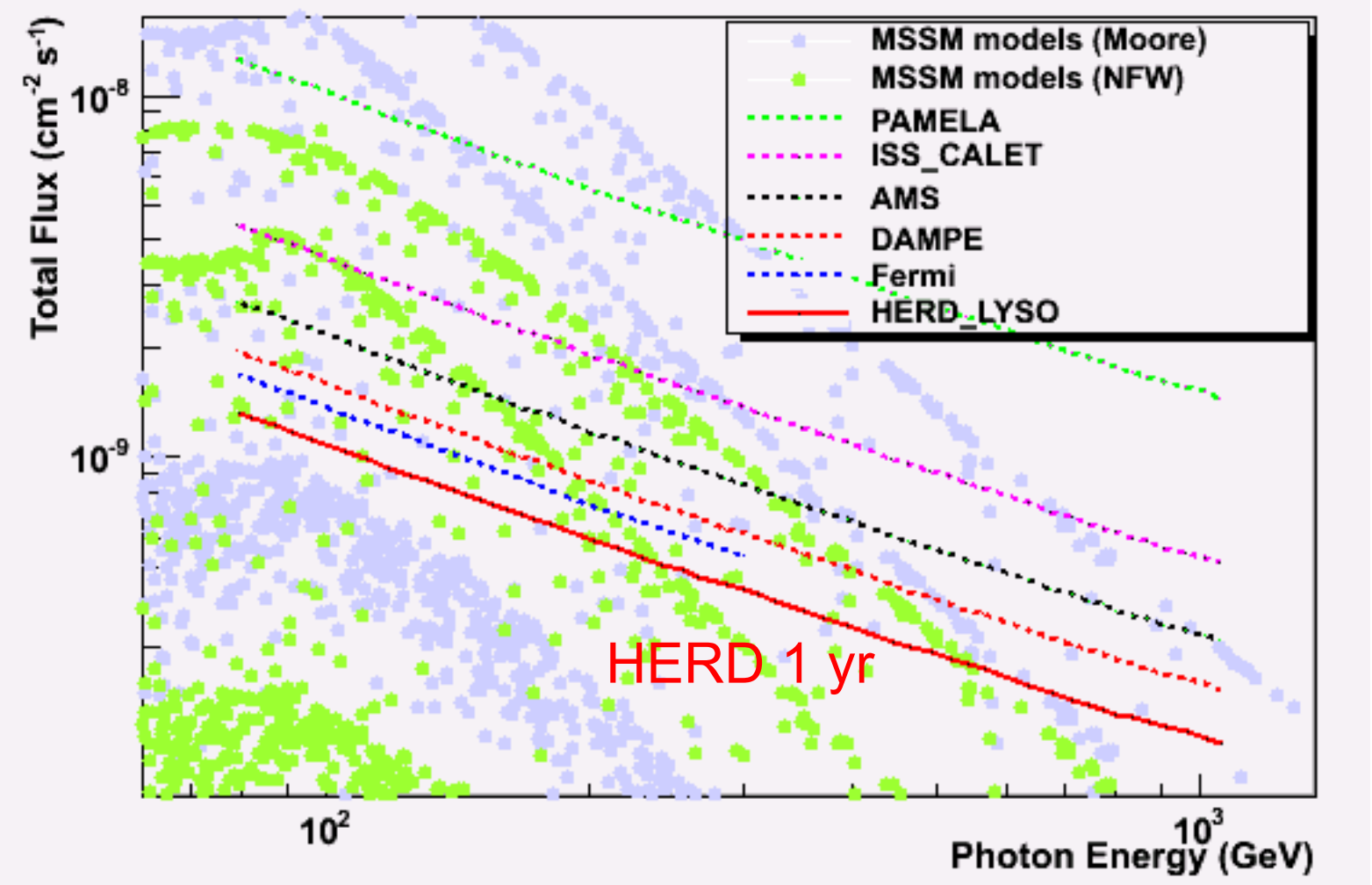




DM annihilation line of HERD

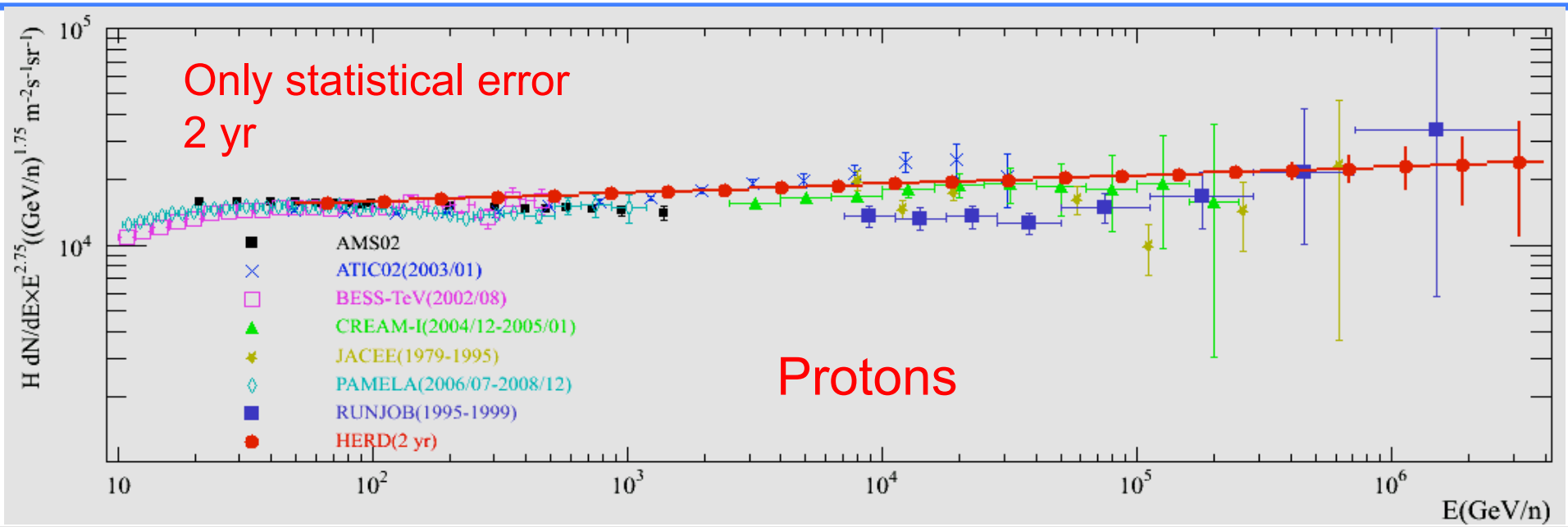


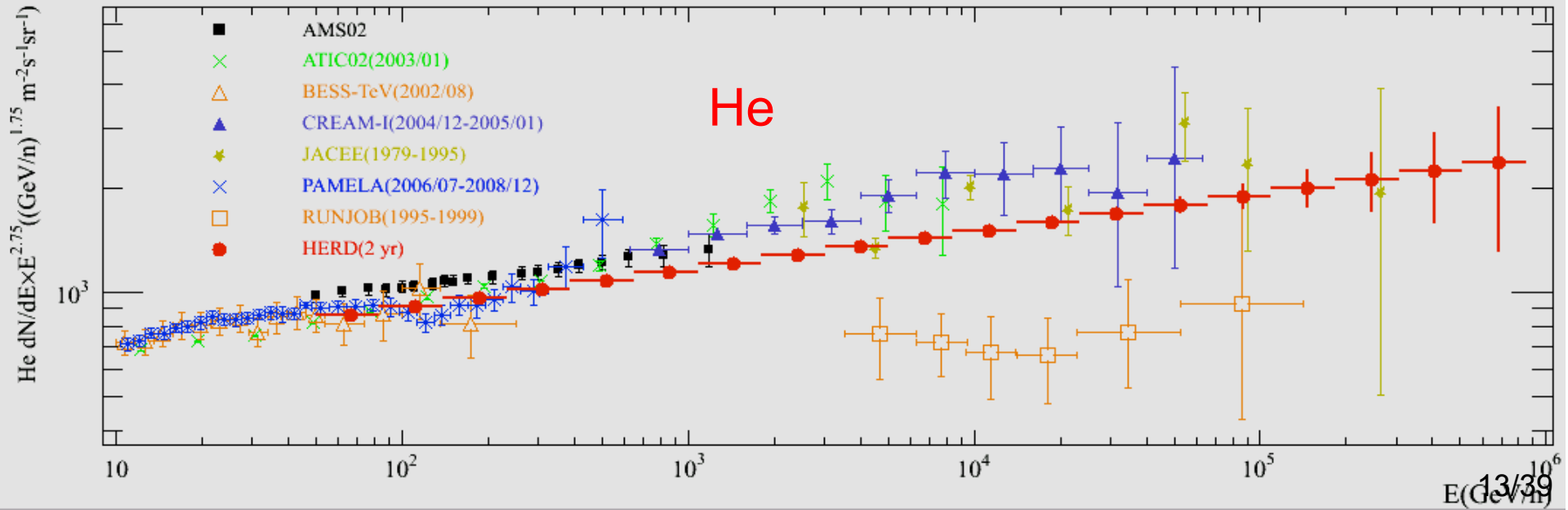
HERD sensitivity to gamma-ray line



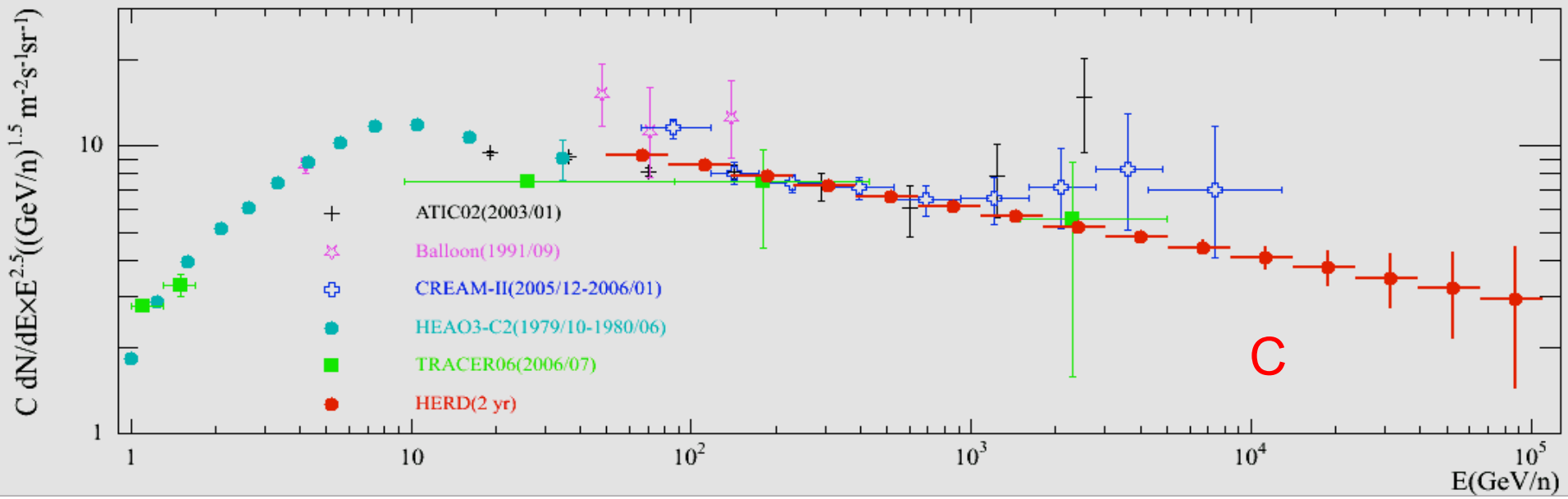
PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

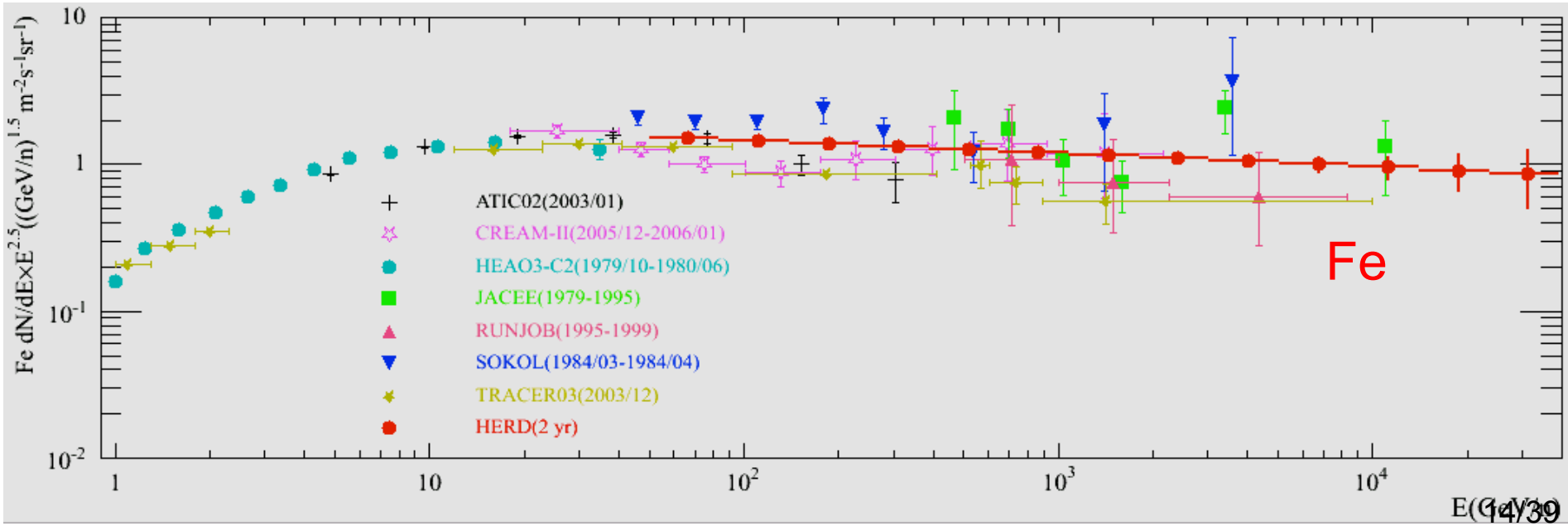
Expected HERD Proton and He Spectra



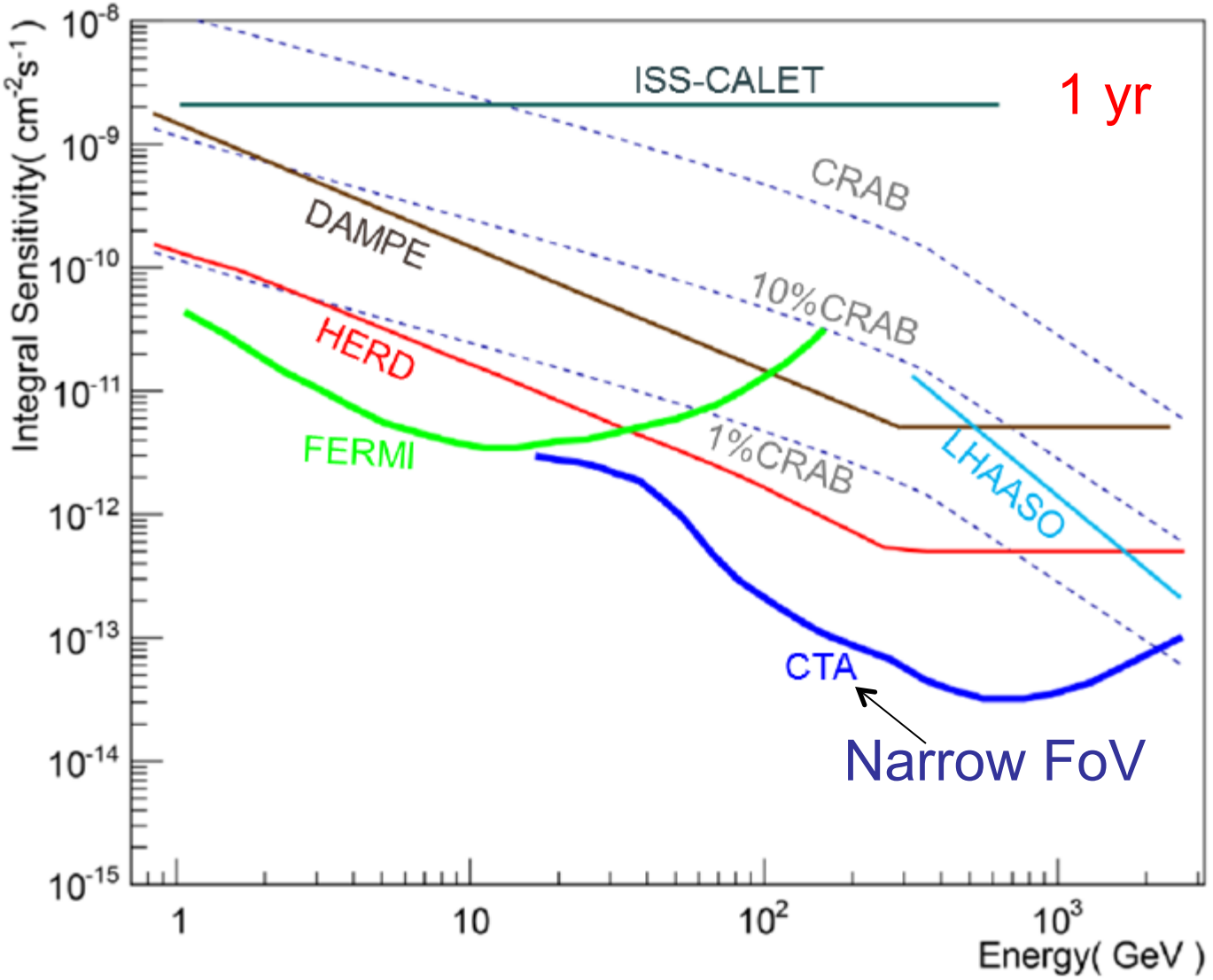


Expected HERD Spectra of C and Fe

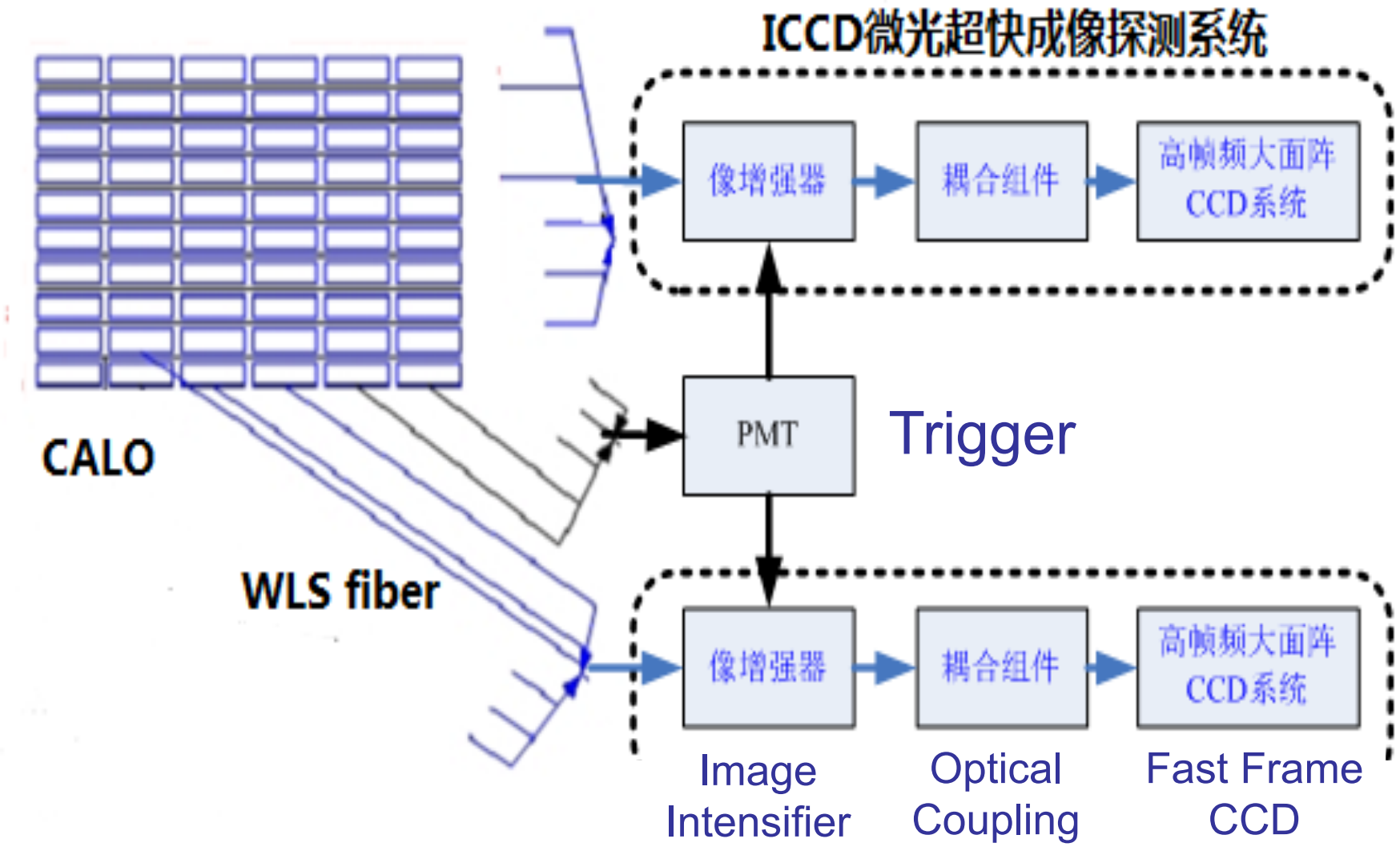




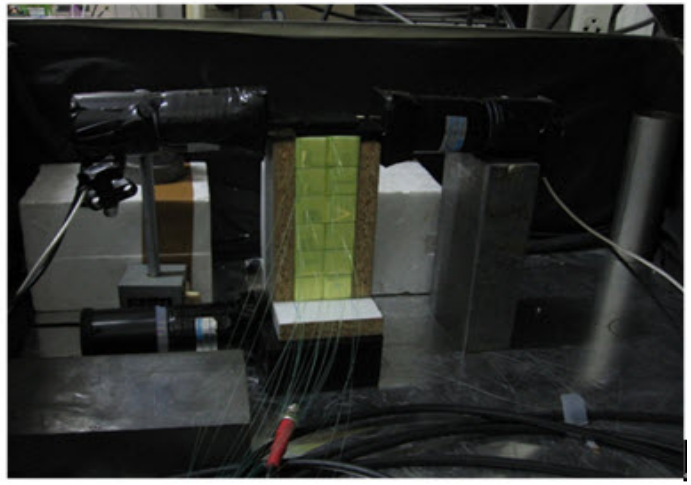
Gamma-ray Sky Survey Sensitivity



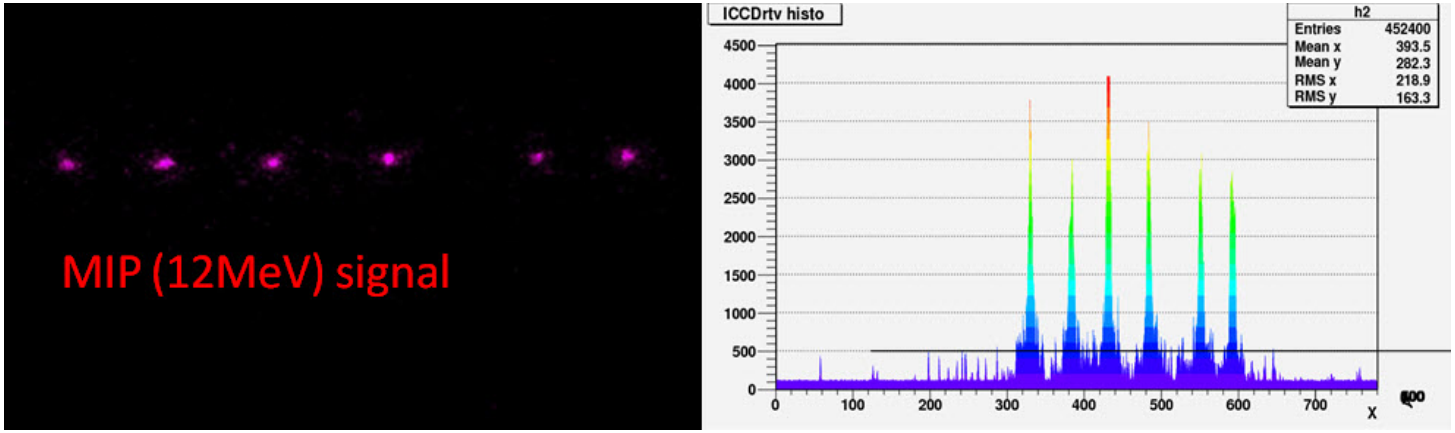
CALO readout



Proof of principle

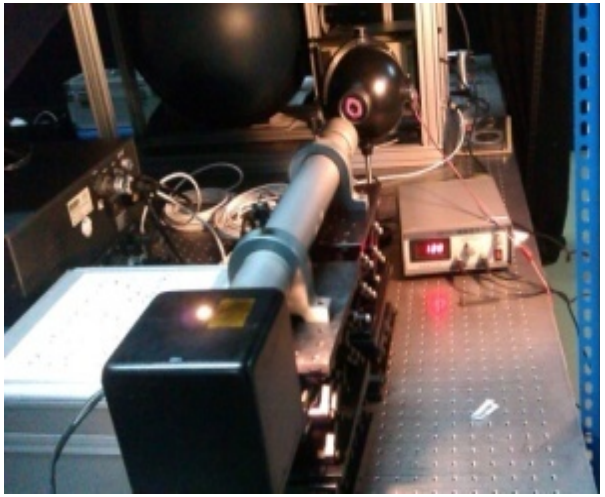


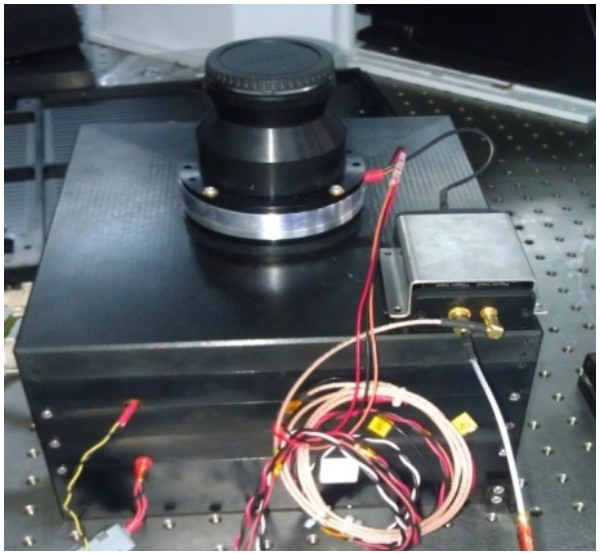
2×2×6 CsI crystal array



ICCD image of cosmic ray events

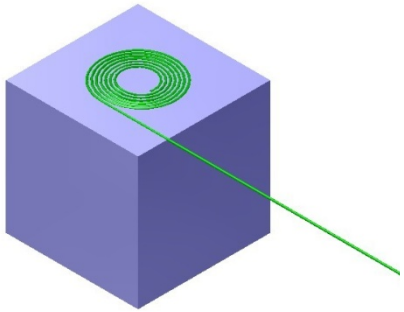
HERD progress – ICCD development

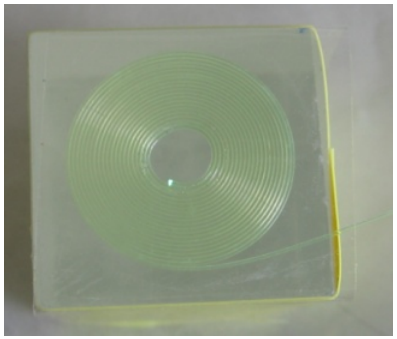


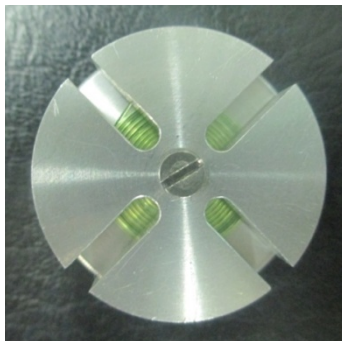


Scintillator signal readouts

- LYSO scintillator → WLSF







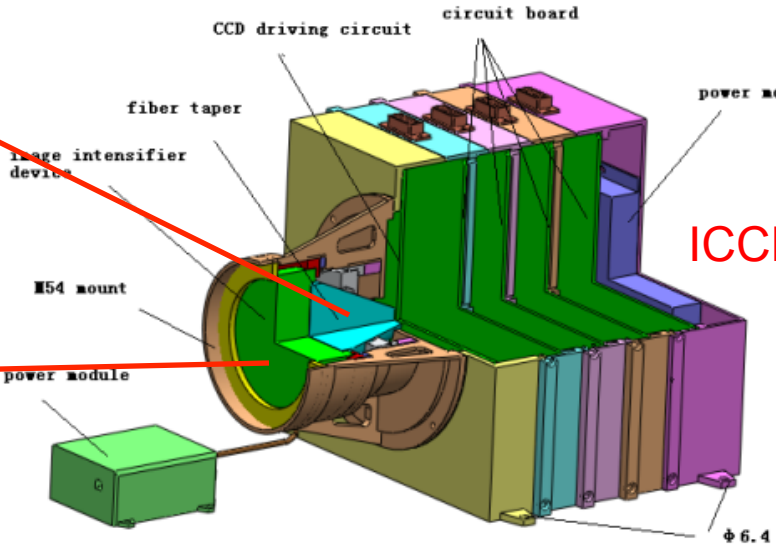
Optical fiber winding

Crystal packing

- Fiber to ICCD system

Image intensifier

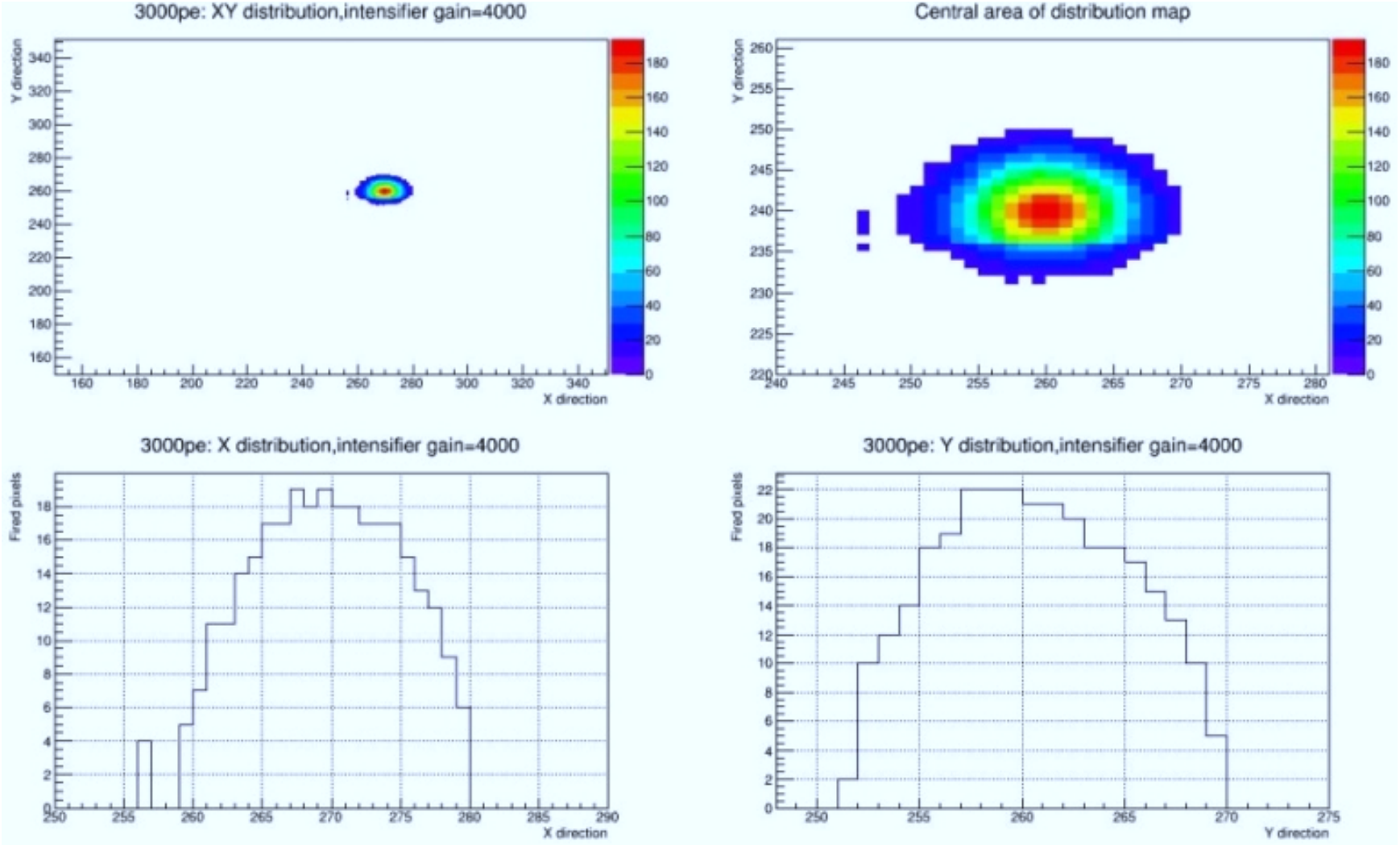
Taper



ICCD system

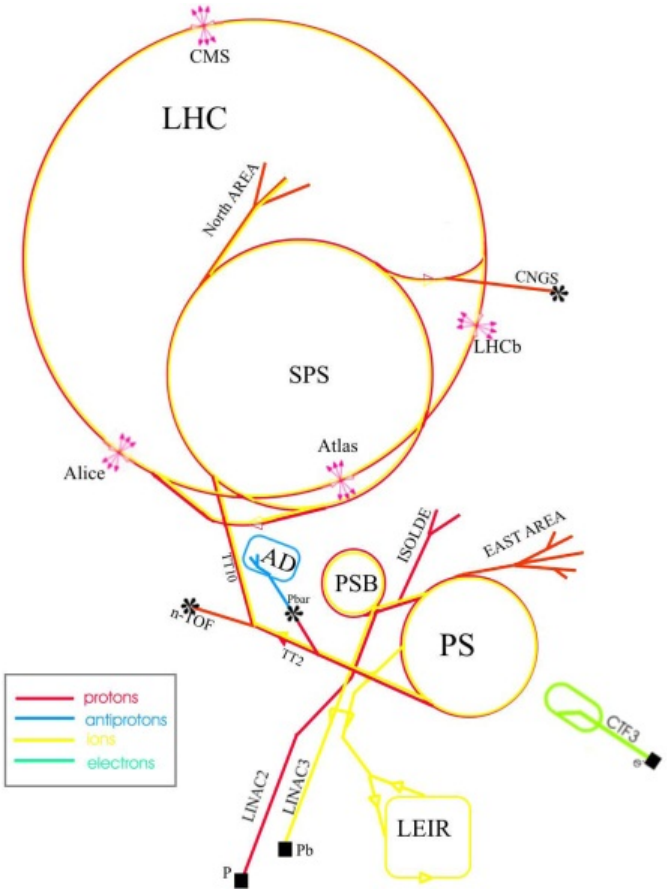
Fiber Image on CCD

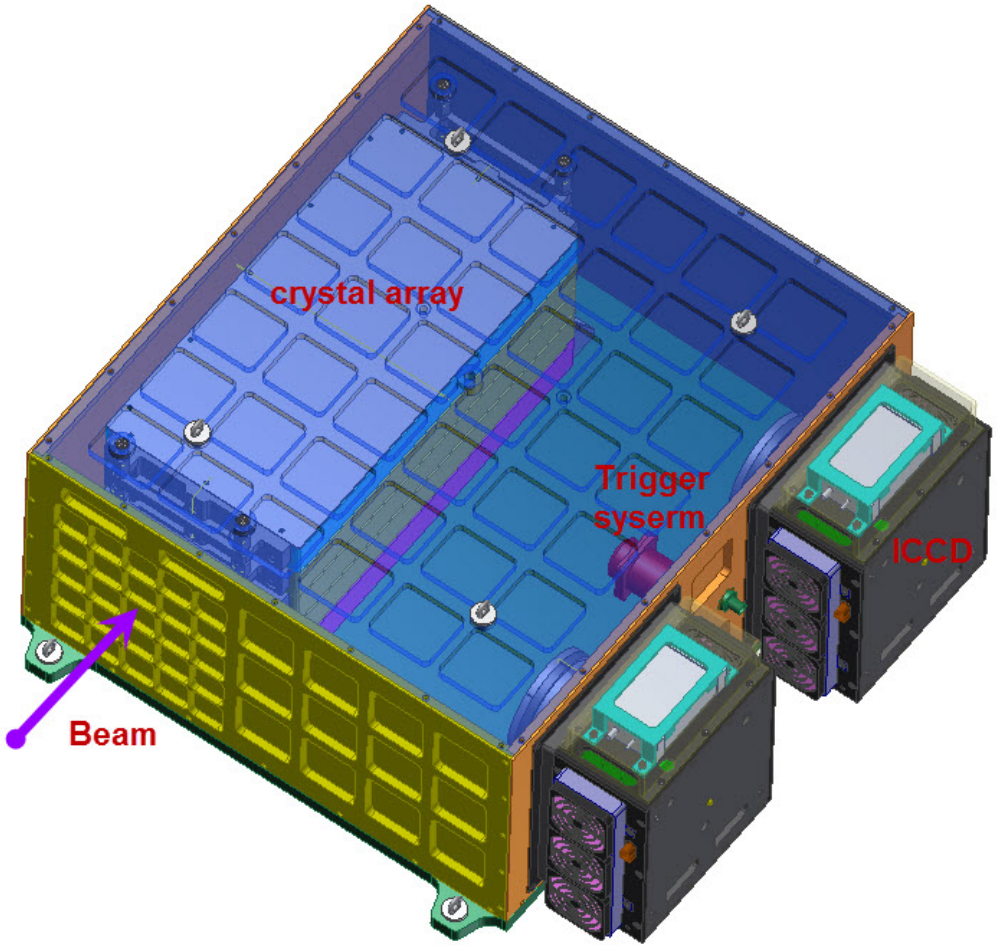
Signal: 3000 pe; gain of image intensifier: 4000



CERN Beam Test in Nov 10-20, 2015

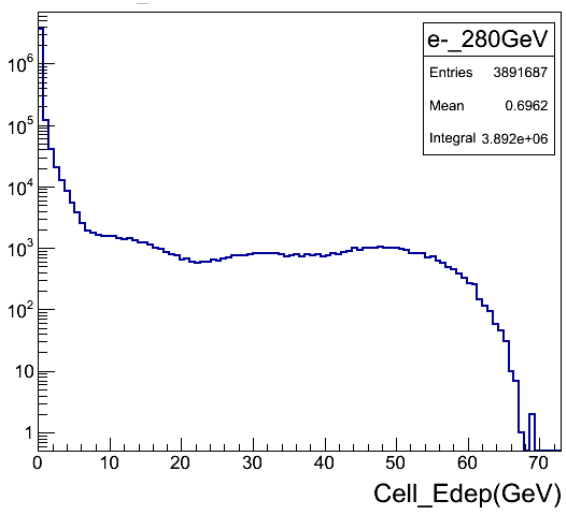
SPS H4: P & Pb

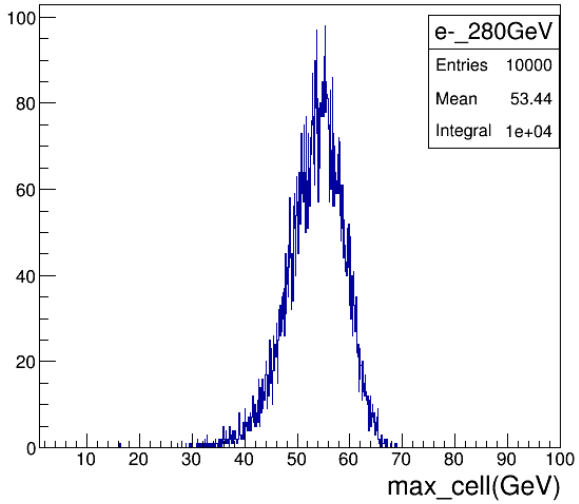


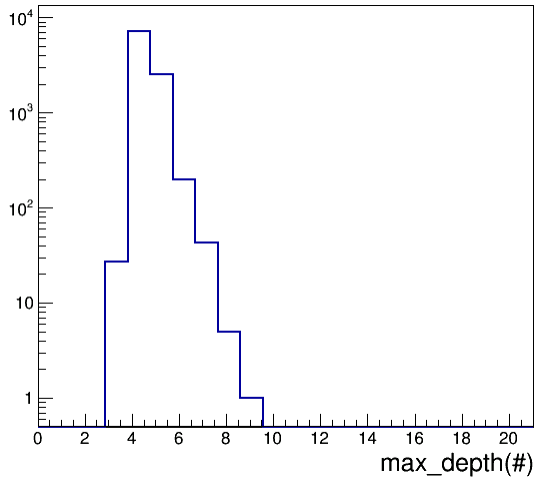


Requirements on the prototype

- Requirement on dynamic range: ~6000
  - Starting from 1/3 MIPs=10 MeV
  - Ending at max. energy deposition: 60 GeV



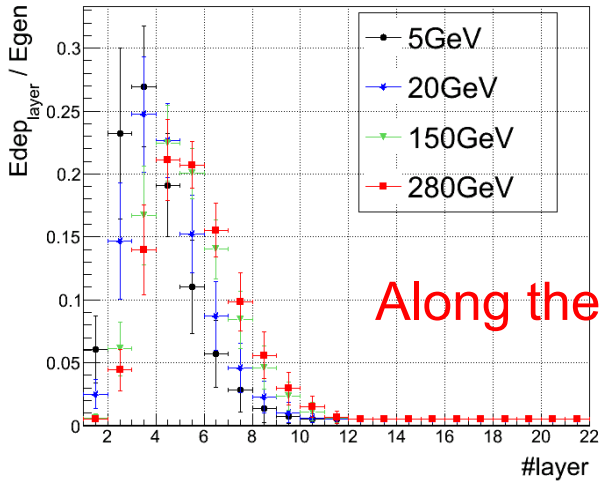


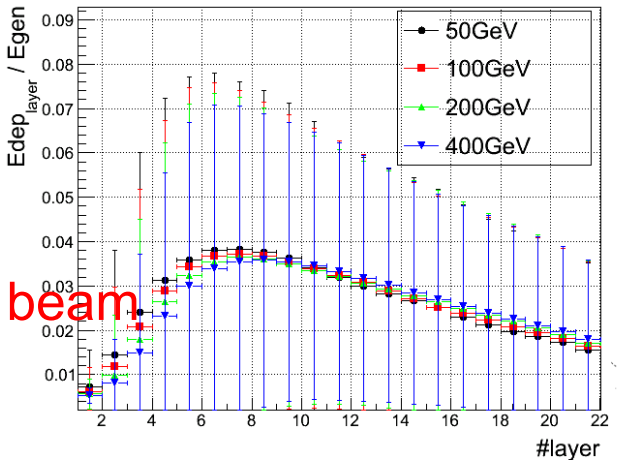


- Requirement on frame rate of ICCD: > 500 fps
  - Since the electrons arrive randomly in time

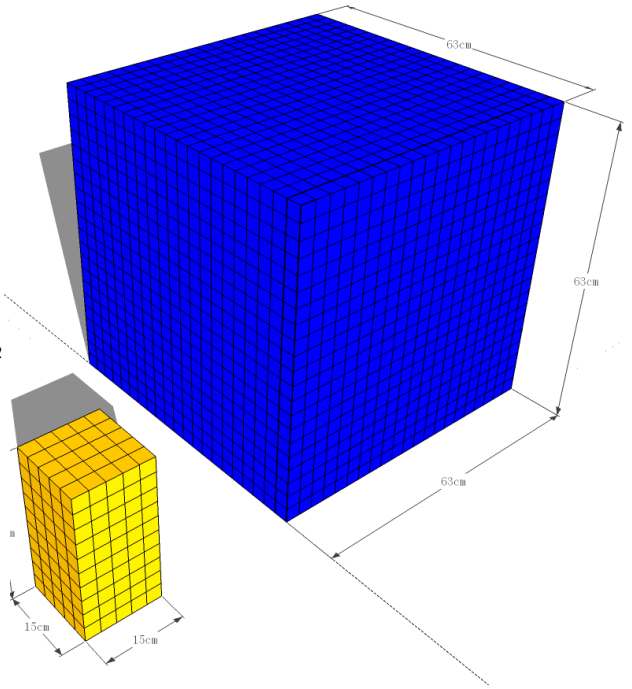
Requirements on the prototype

- Scale of the prototype：5×5×10, 3×3×3 cm^3
  - Larger than envelope of 280 GeV e- shower
  - 36% of the total energy for protons

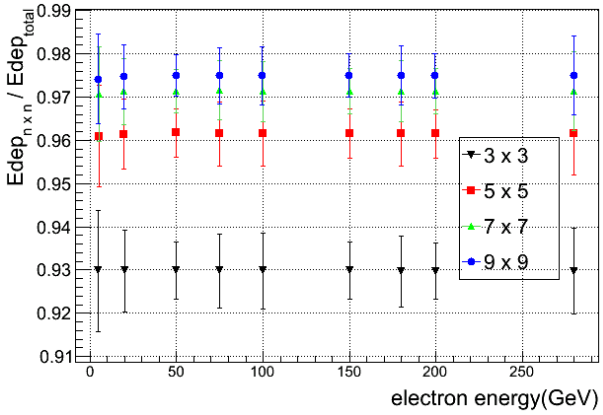


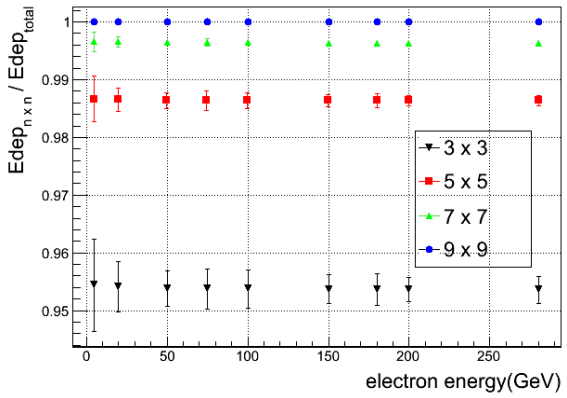


Along the beam



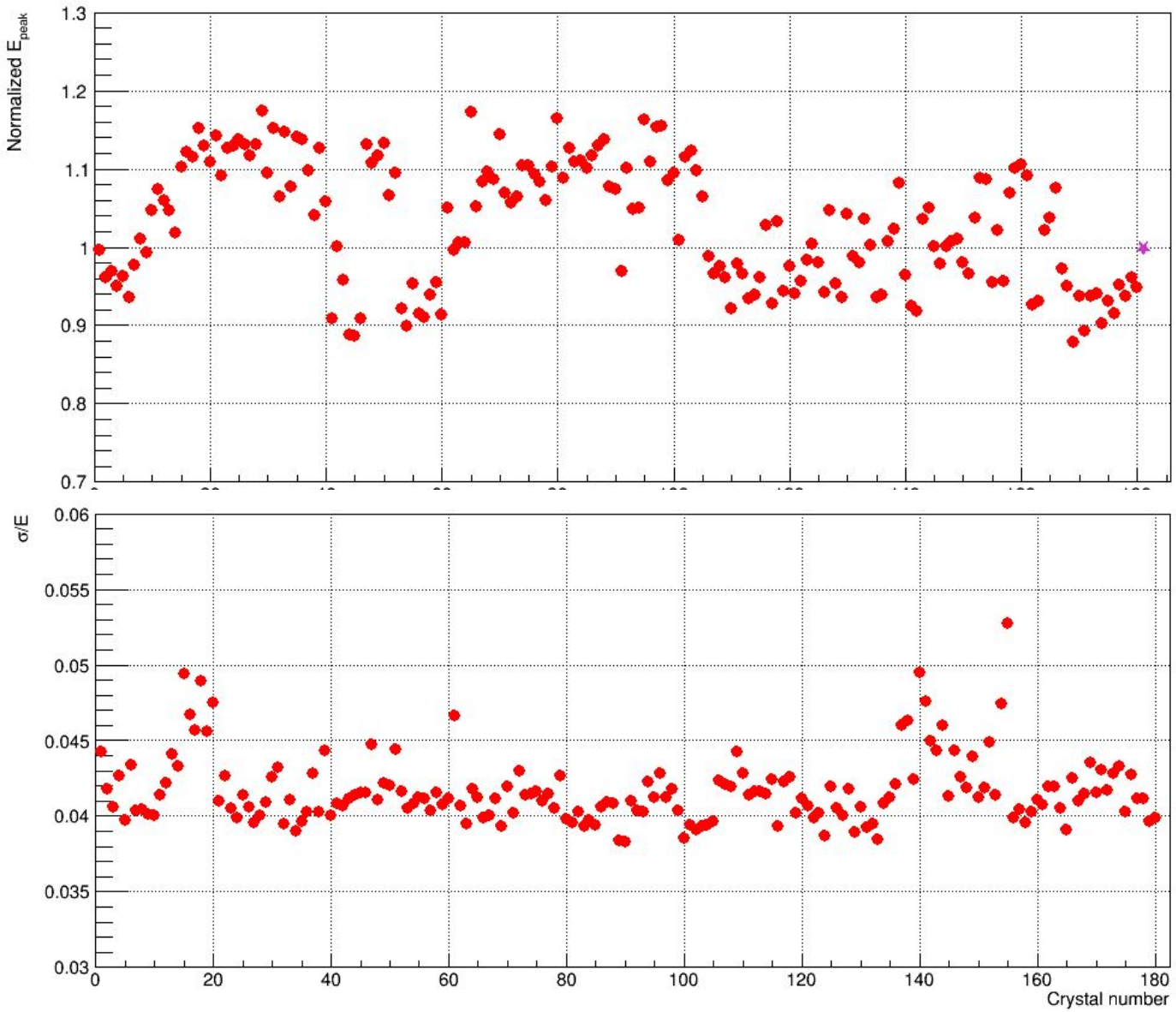
1/40 size of HERD





Transverse direction

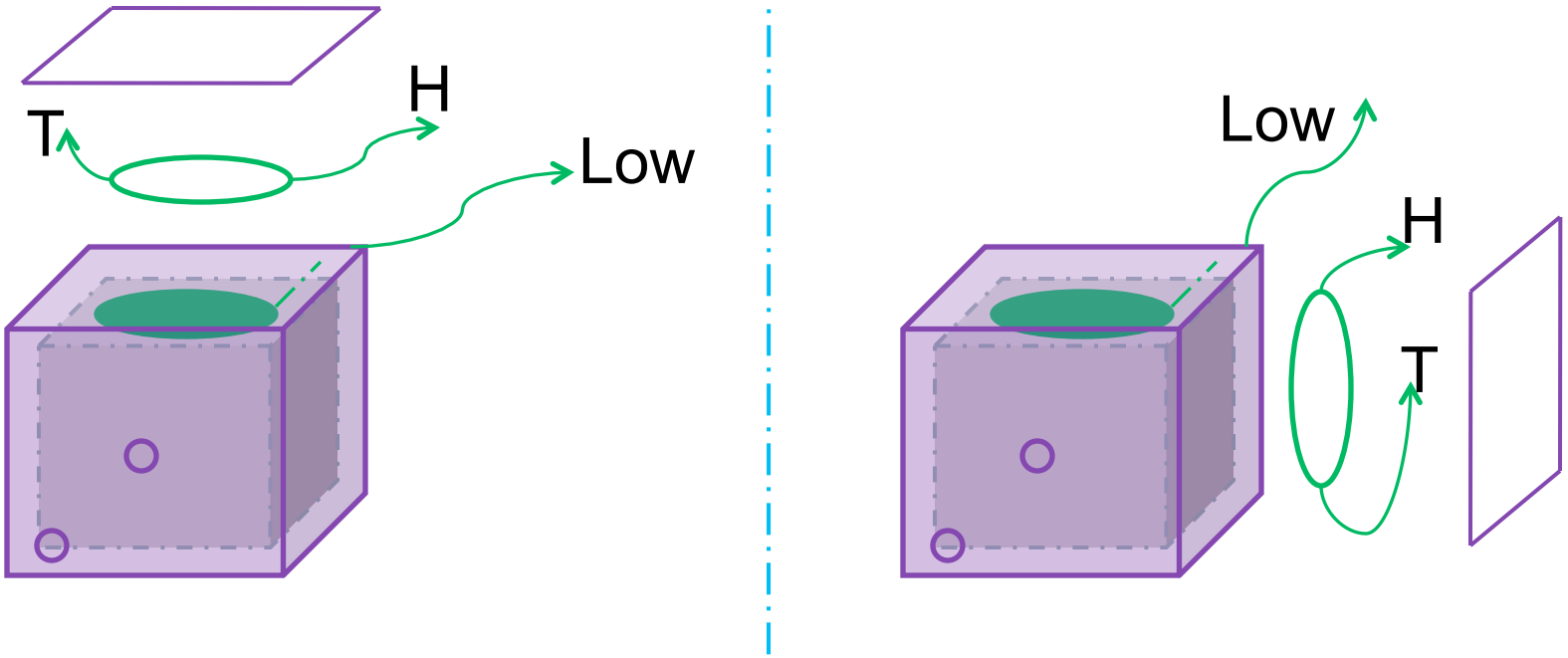
LYSO performance



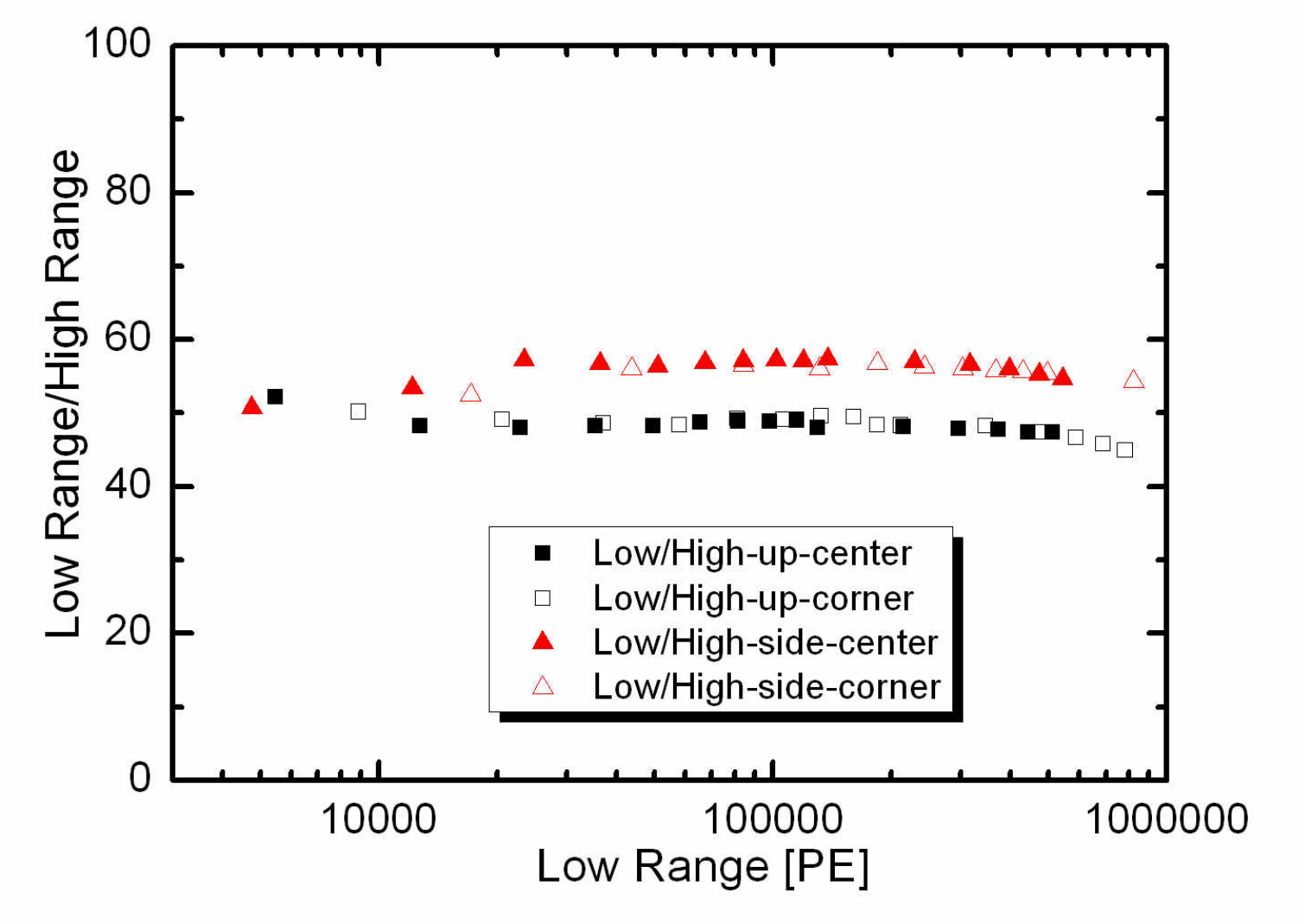
Variation of LYSO light output:
(Max-Min)/Mean
≈25%

Energy resolution (σ/E) for 662keV γ peak:
< 5%

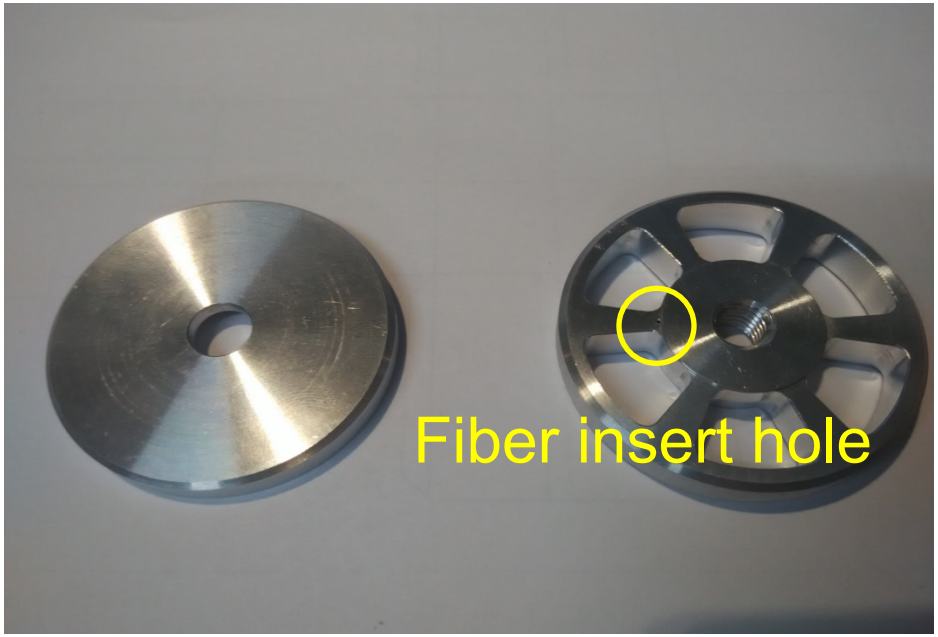
Realization of two readout ranges

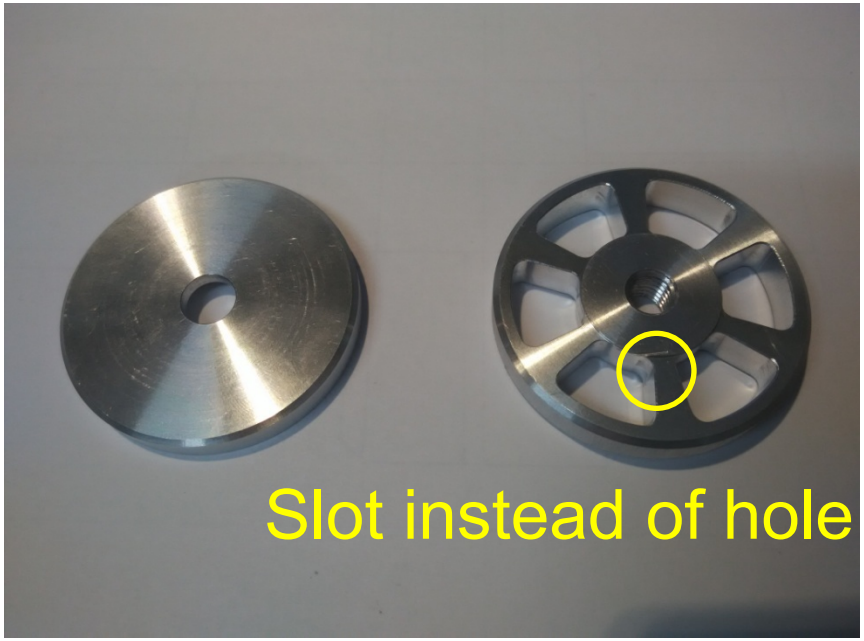


Signal ratios ~ 50:1



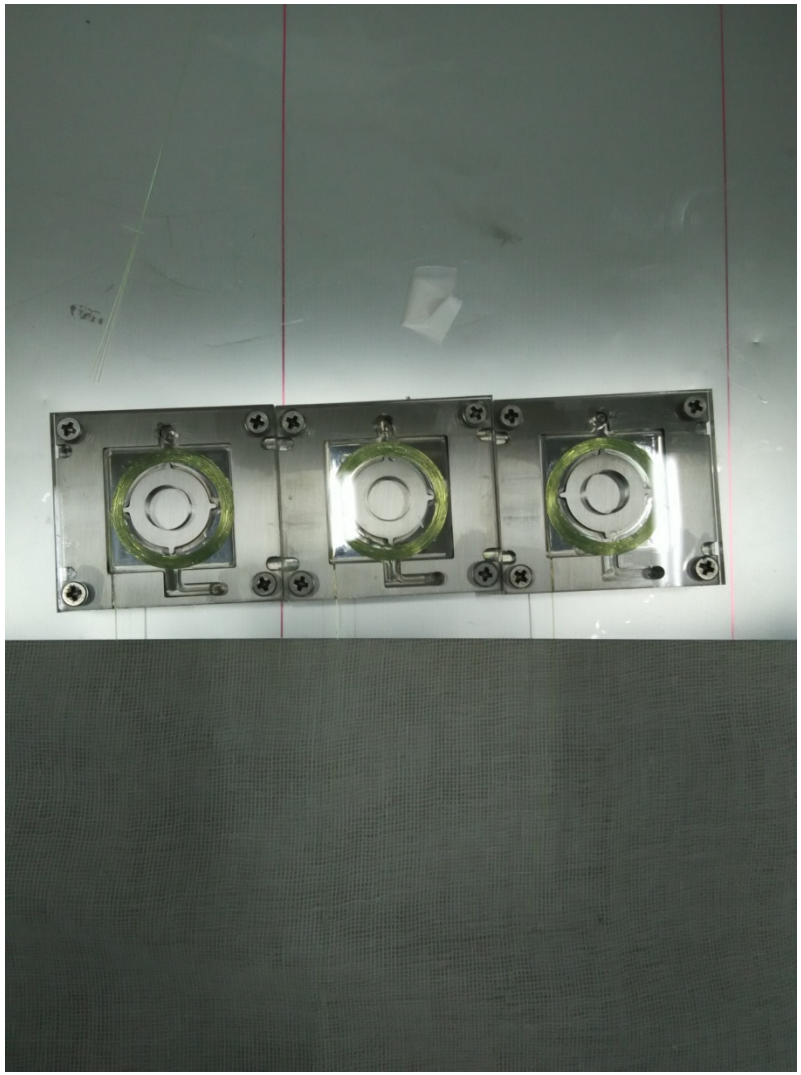
Fiber winding development



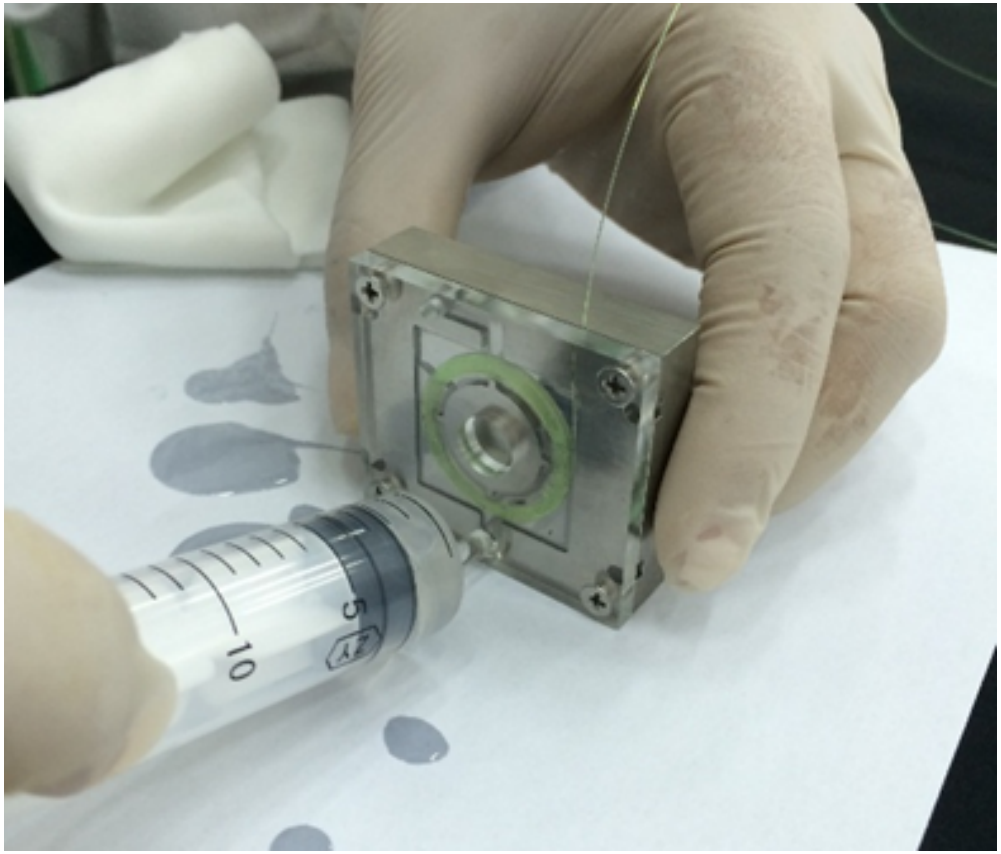


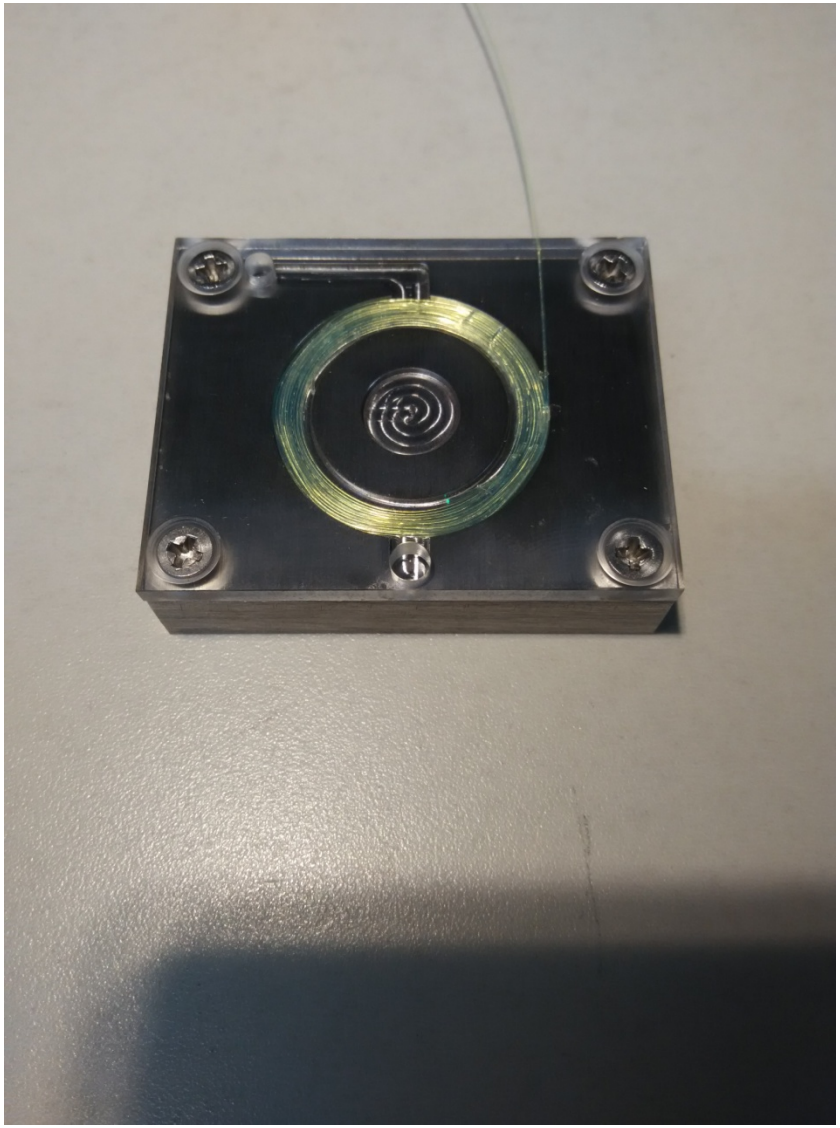
Fiber winding development

Fiber winding development

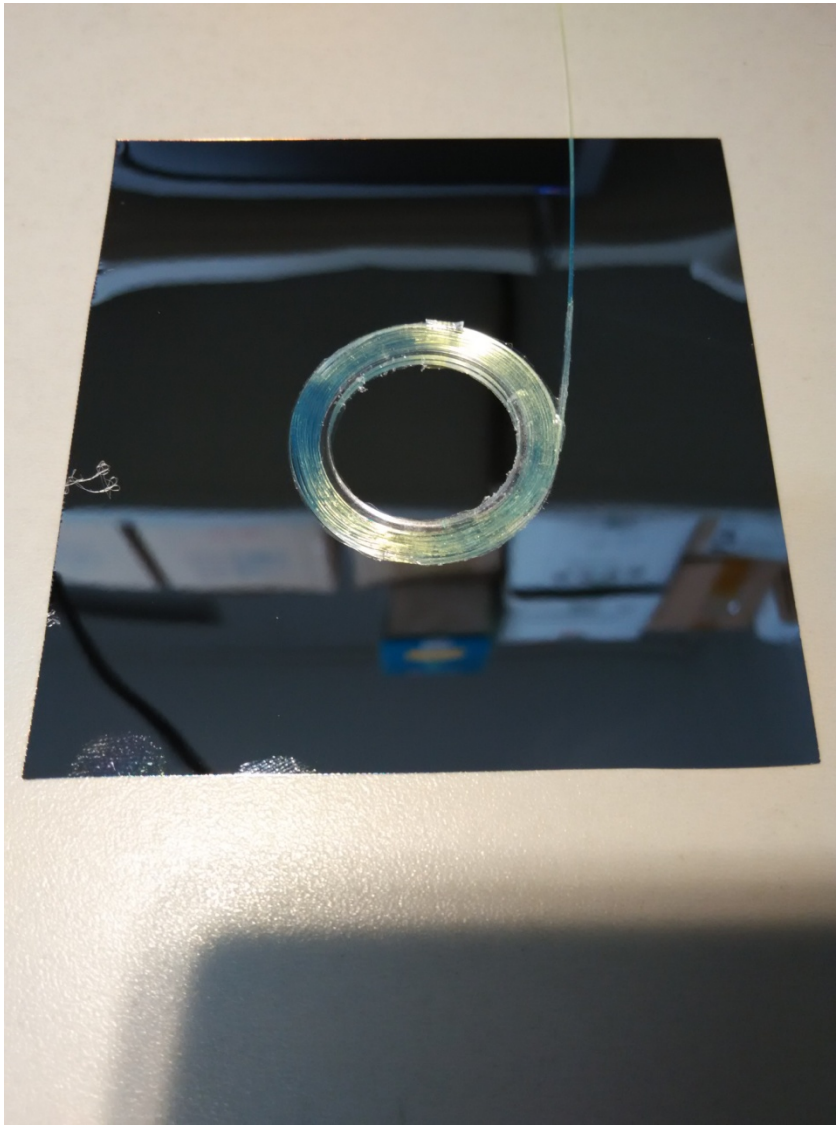


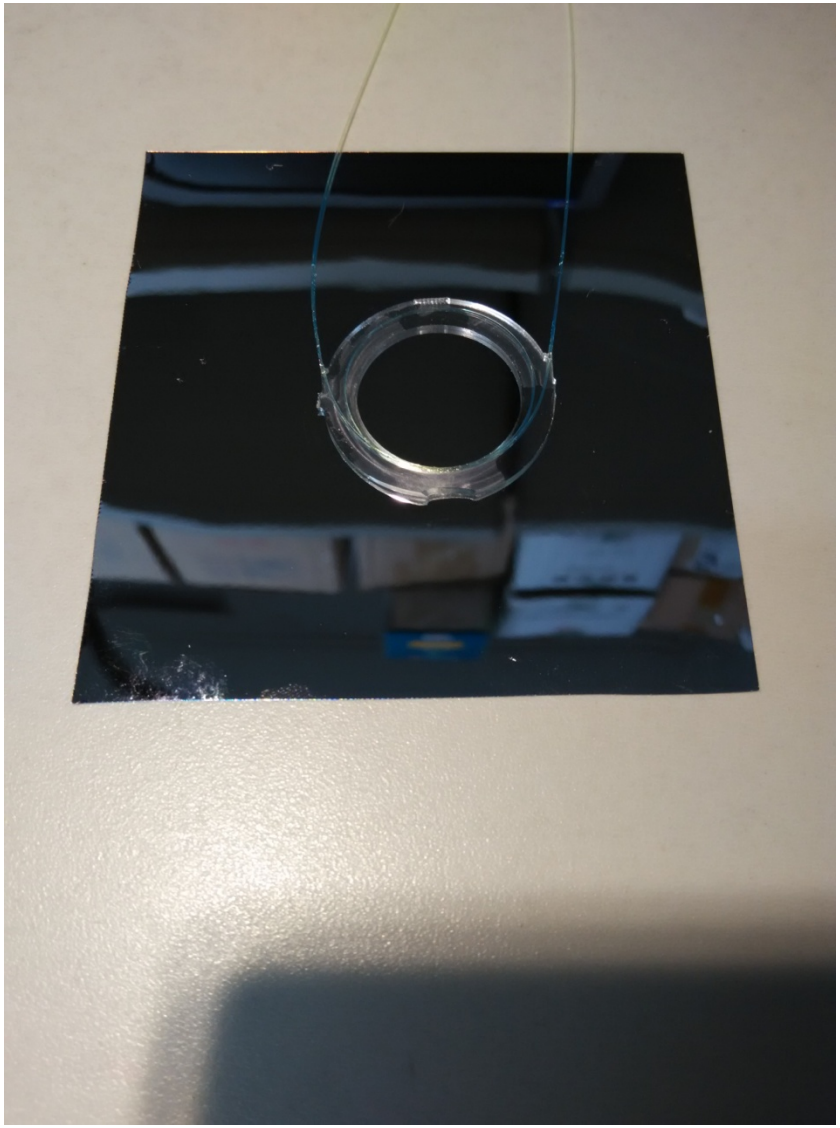
Fiber winding development





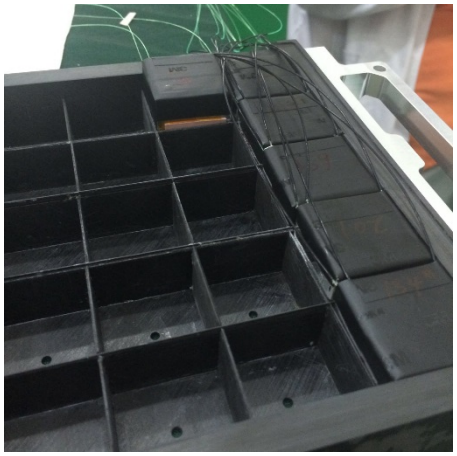
Fiber winding development

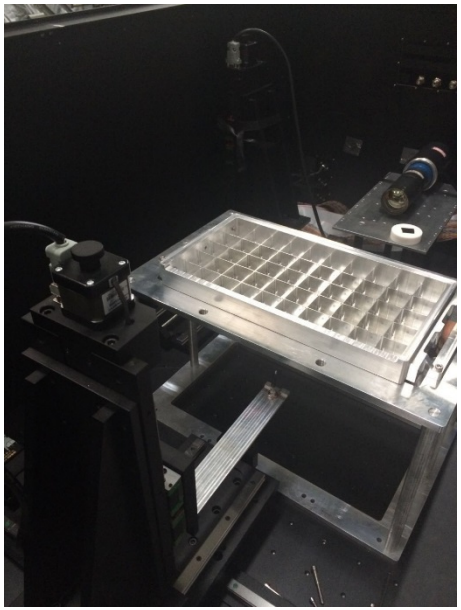




Making ESR wrapping

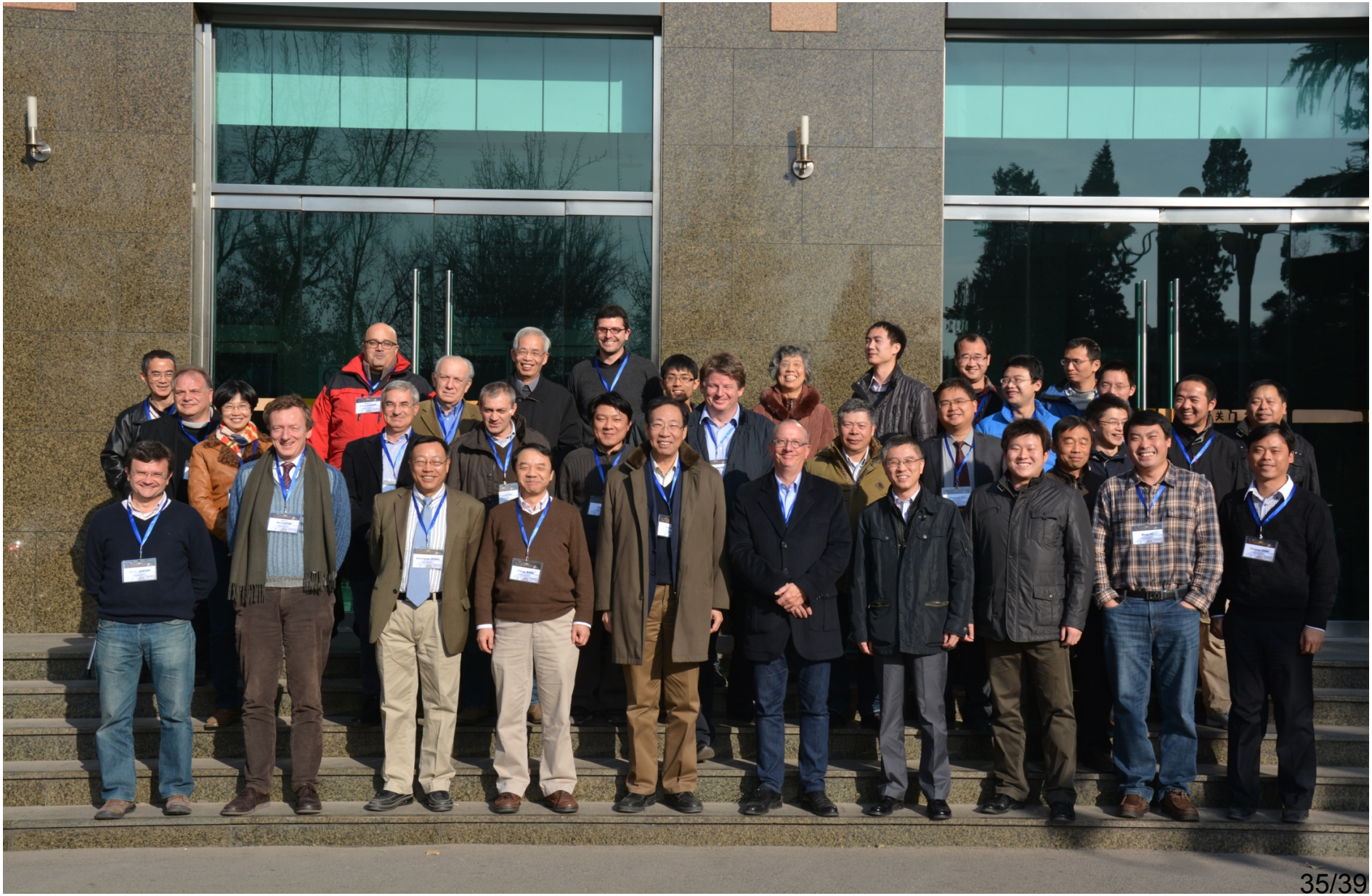
Assembly and lab test of the prototype





1st HERD workshop, Oct.17-18, 2012, IHEP, Beijing

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



The HERD Proto-Collaboration Team

- Chinese institutions (more welcome!)
  - Institute of High Energy Physics, Purple Mountain Observatory, Xi'an Institute of Optical and Precision Mechanics, University of Science and Technology of China, Nanjing University, Peking University, Yunnan University, China University of Geosciences, Ningbo University, Guangxi University
- International institutions (more welcome!)
  - Switzerland: University of Geneva
  - Italy: Università di Pisa/INFN, IAPS/INAF, University of Florence/INFN, University of Perugia/INFN, University of Trento/INFN, University of Bari/INFN, University of Salento/INFN-Lecce
  - Sweden: KTH
  - USA: MIT/Harvard