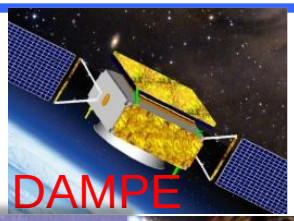
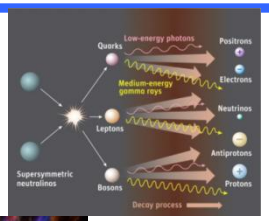
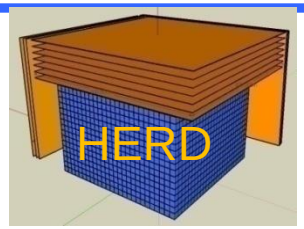
China's Future Space High Energy Astrophysical Missions

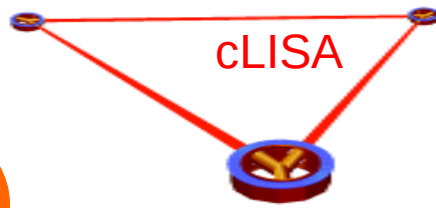
Shuang-Nan Zhang
zhangsn@ihep.ac.cn
Center for Particle Astrophysics
Institute of High Energy Physics
Chinese Academy of Sciences

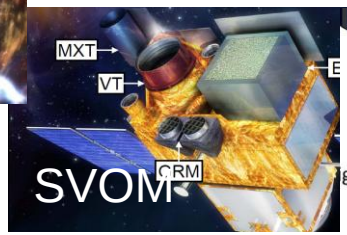
China's Future Space Astronomy Missions

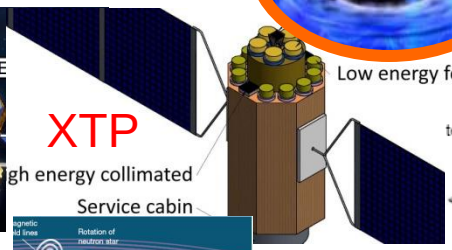


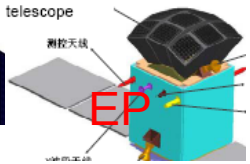


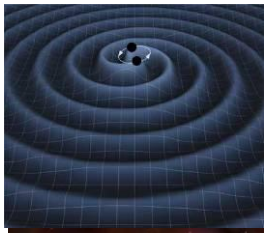


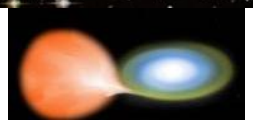


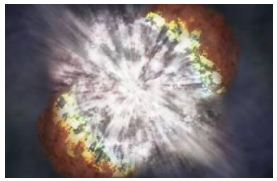


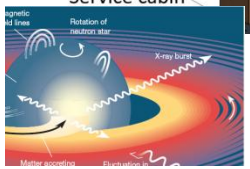


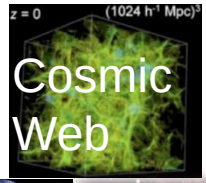


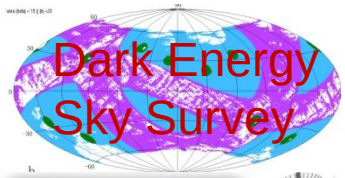


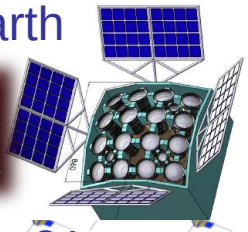


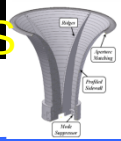












e/CR /GRW

γ-ray

X-ray

UV

IR/O

radio

2015

2020

2025

2030

China's Future Space Astronomy Missions

e/CR /GRW

γ-ray

X-ray

UV

IR/O

radio

DAMPE

HERD

Candidates

cLISA

POLAR

HXMT

SVOM

MXT

VT

CRM

XTP

Low energy focusing

telescope

EP

Fully funded & in progress

R&D funded & in queue

Dark Energy Sky Survey

STEP

Cosmic Web

NEarth

mmVLBI

JEEEDIS

21cm COME

21cm SULFRO

2015

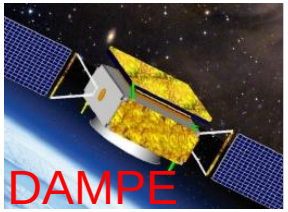
2020

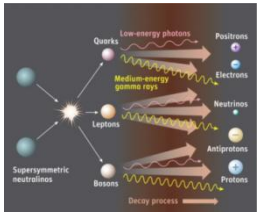
2025

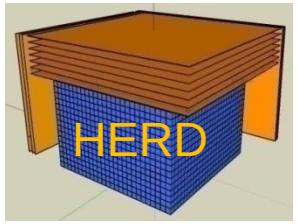
2030

China's Future SHE Astrophysics Missions

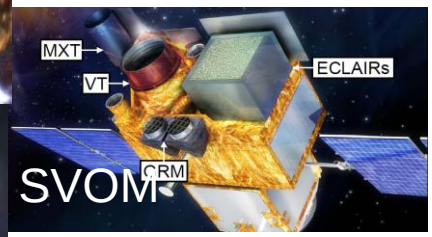
e/CR



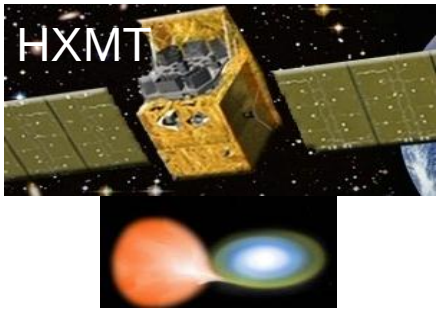


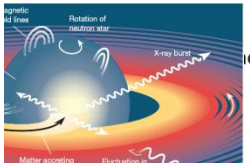


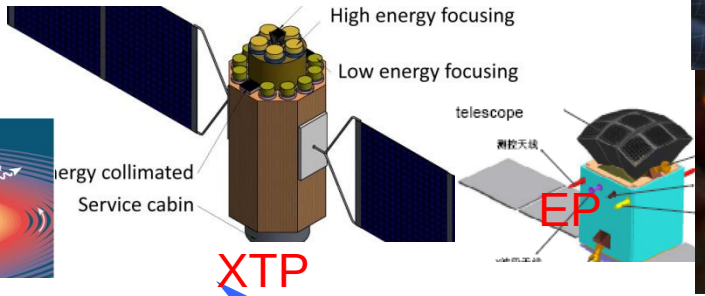
γ-ray

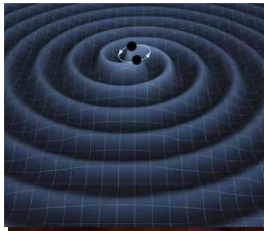


X-ray









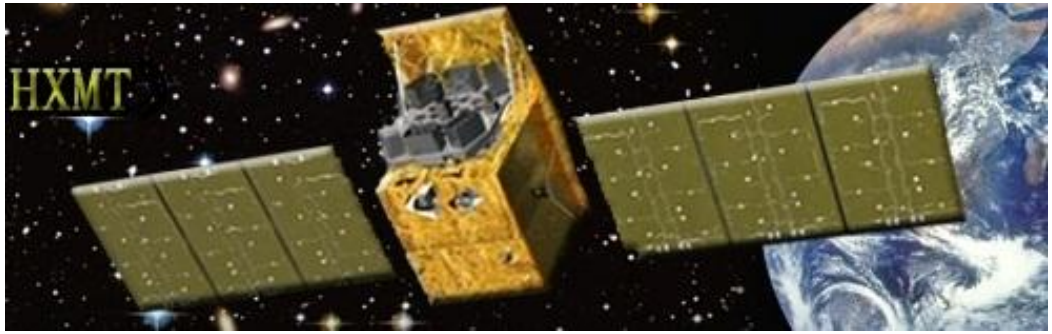
2015 2020 2025 2030

Hard X-ray Modulation Telescope (HXMT)

- Main scientific objectives (1-250 keV energy band)
  - ✓Scan monitoring of the Galactic plane → transients watch dog: need ground follow-up observations.
  - ✓Pointed observations → Black hole and neutron star x-ray binaries: need coordinated ground observations

Satellite Facts:

- ✓ Mass: ~2800 kg
- ✓ Orbit: 550 km, 43°
- ✓ Lifetime: 4 yrs



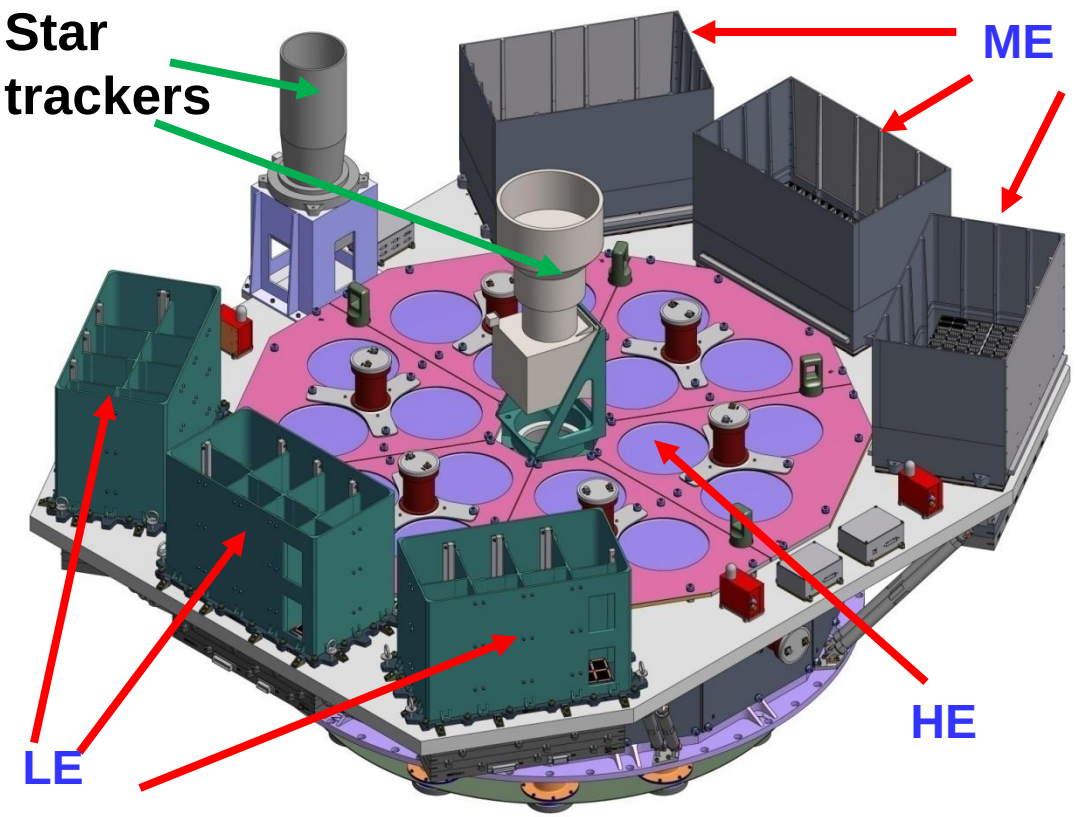
Officially approved in March 2011

Entered Phase-B (Engineering model phase) in 12/2011

Now finishing the construction of the qualification models

Planned launch time: Dec. 2015

HXMT Payloads



High Energg (HE):

NaI/CsI, 20-250 keV, 5000 cm^2

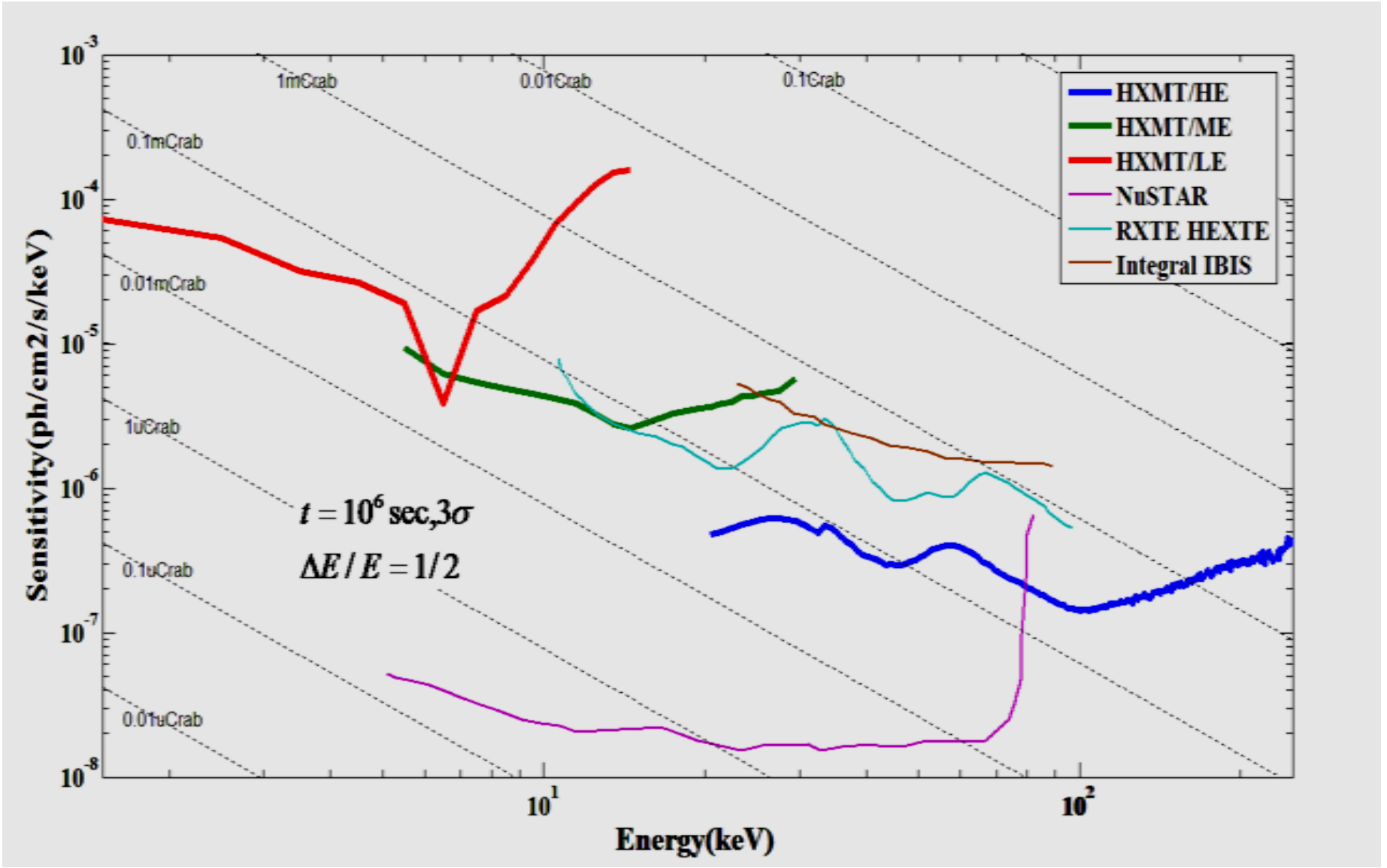
Medium (ME):

Si-PIN,5-30 keV, 952 cm^2

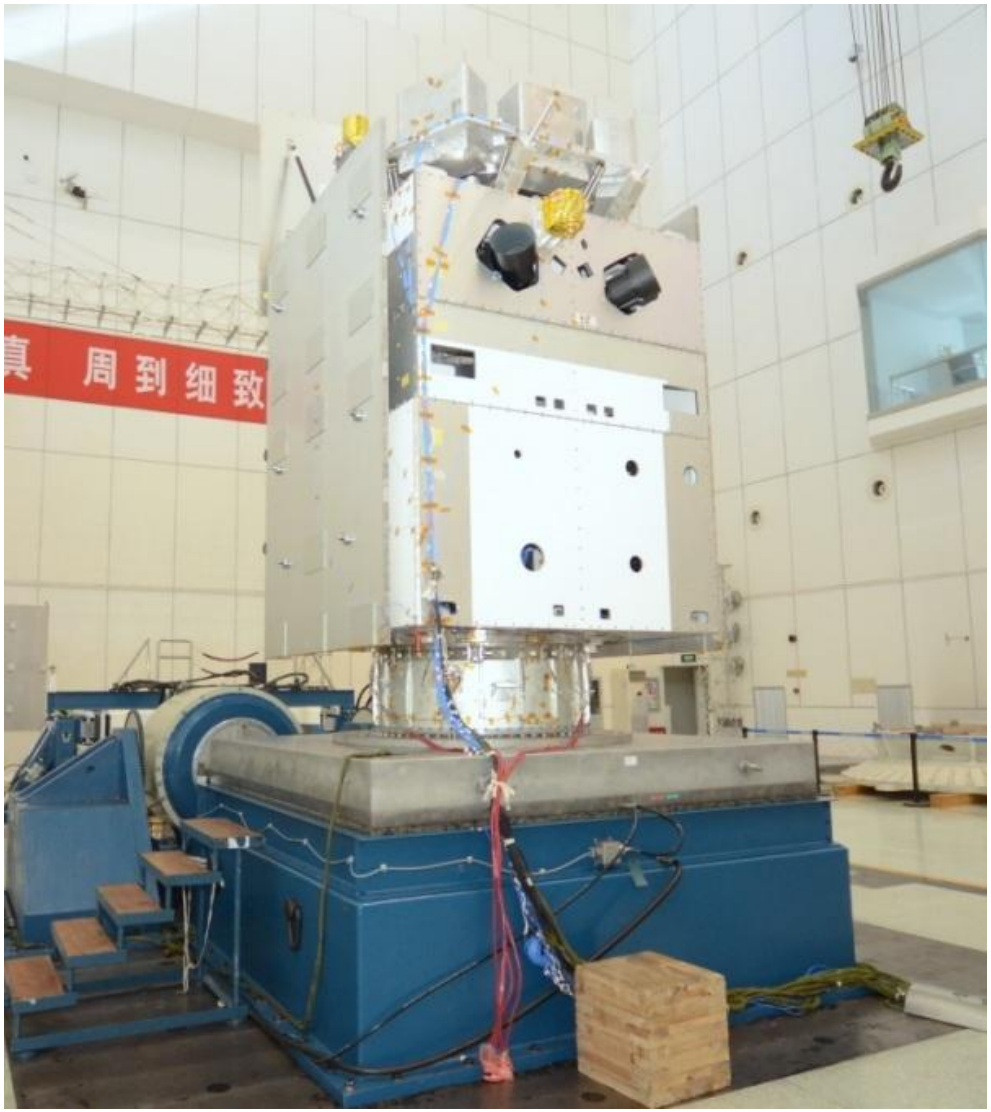
Low Energy (LE):

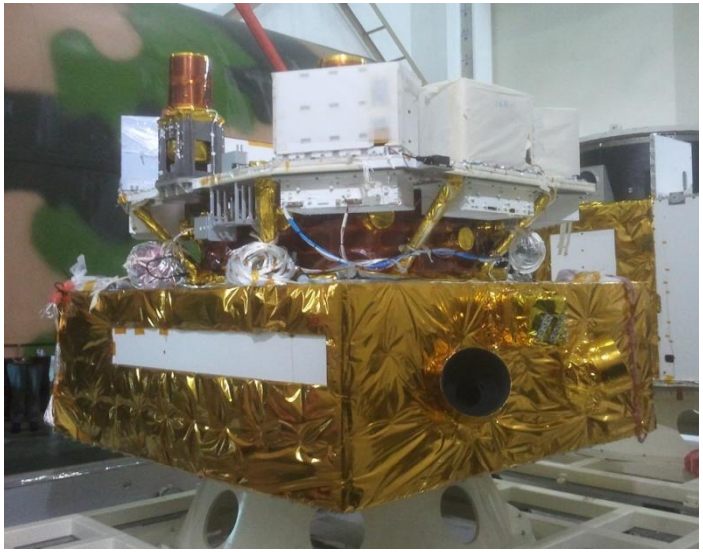
SCD,1-15 keV, 384 cm^2

HXMT Sensitivity



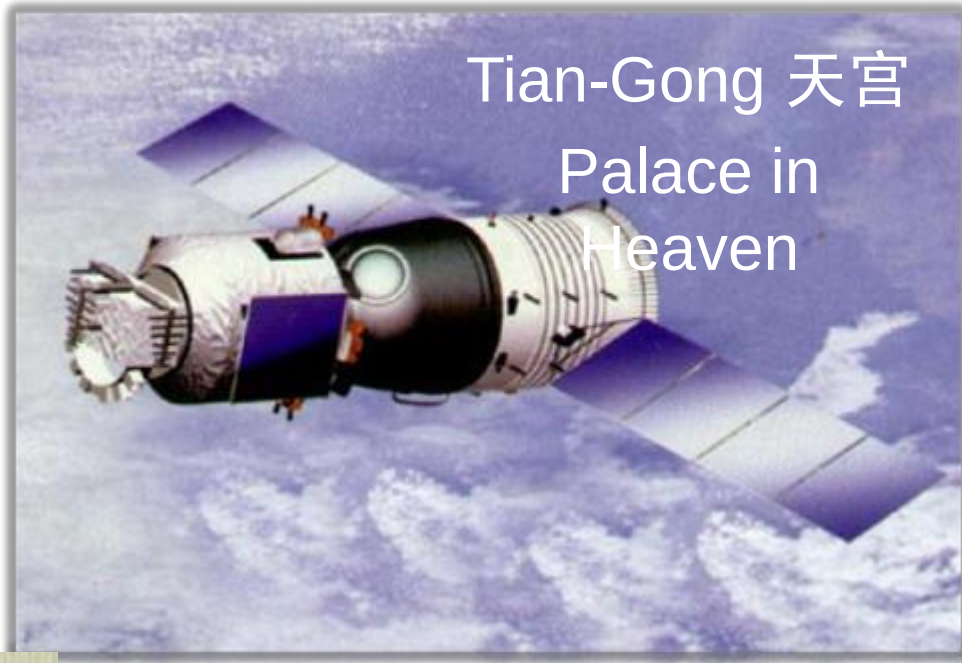
Current status of HXMT

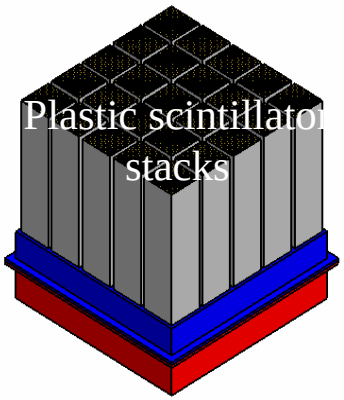


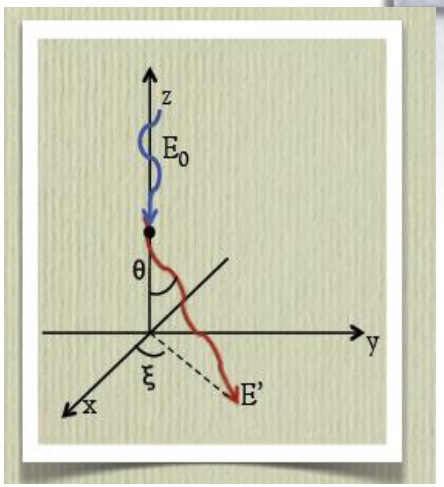


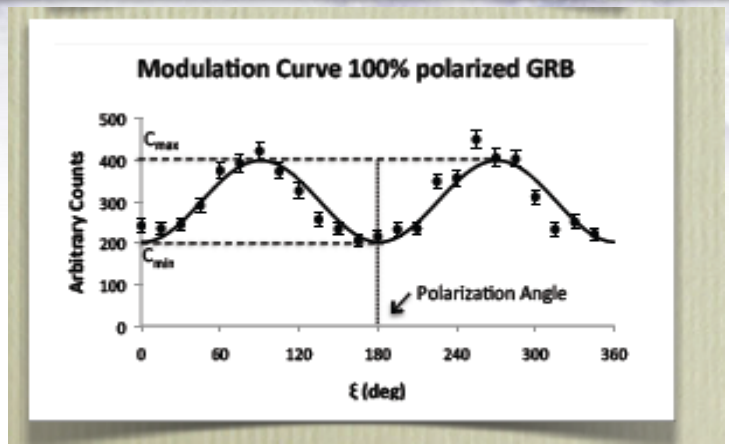
Gamma-ray burst polarization : POLAR

- China- Switzerland collaboration
  - Energy range: 50-350 keV; FOV of POLAR: ~½ sky
- Onboard China's spacelab TG-2: launch time Dec. 2015
- Main science: GRB jet & central engine; tests of quantum gravity theories

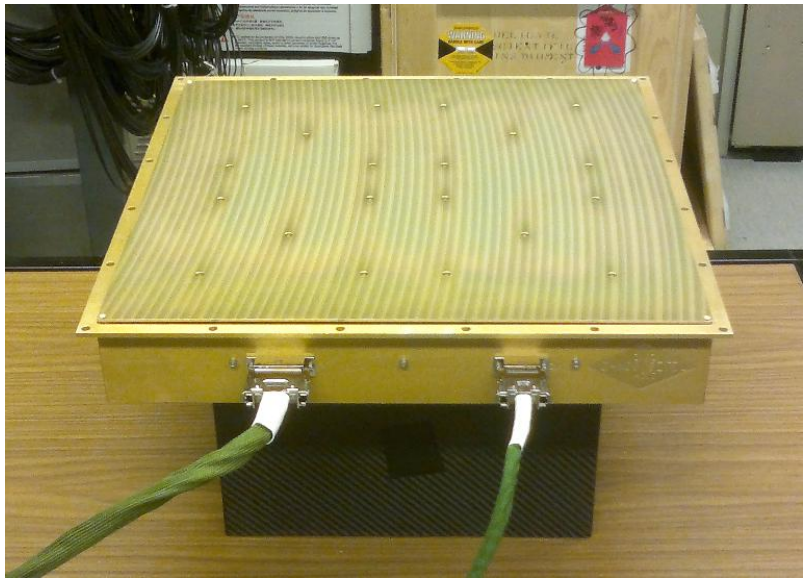


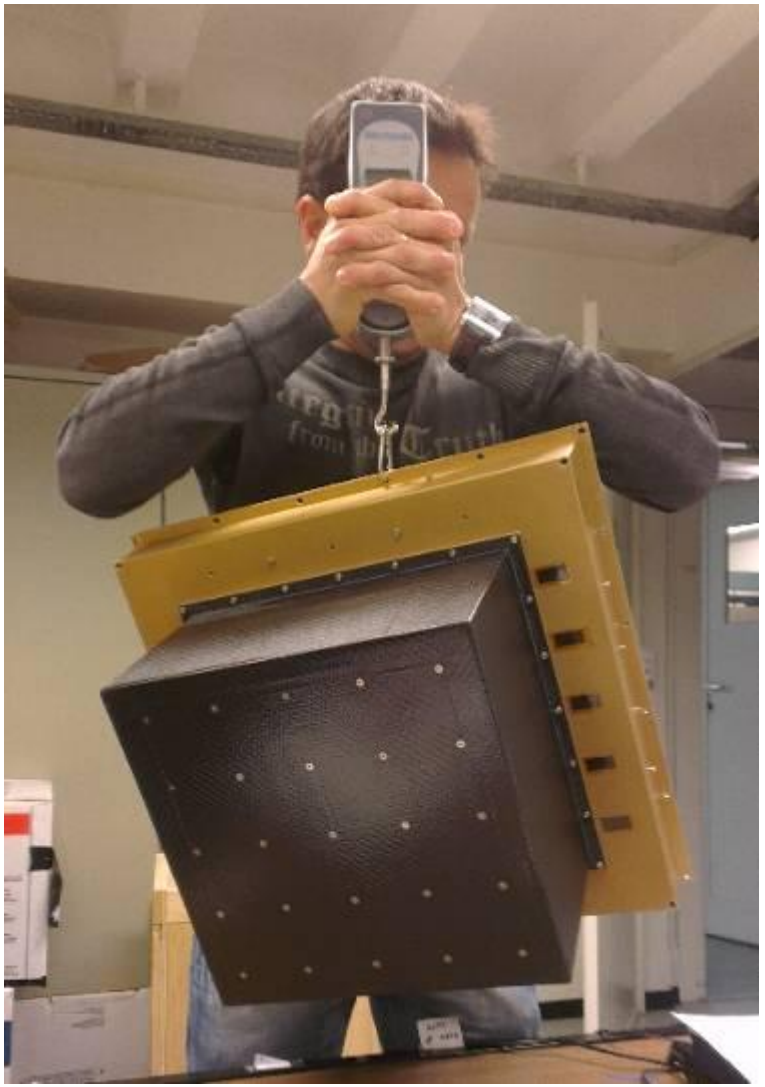




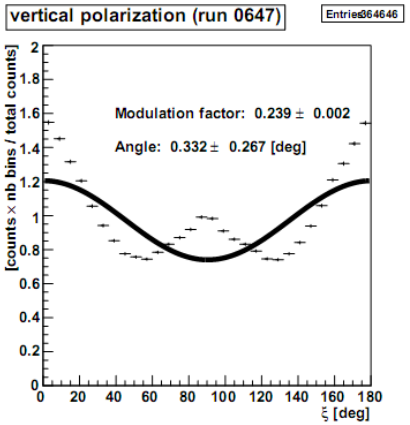


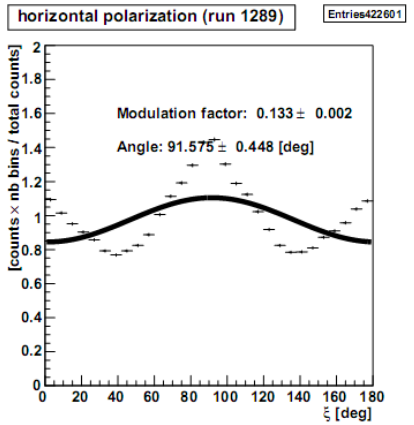
POLAR Qualification Modules

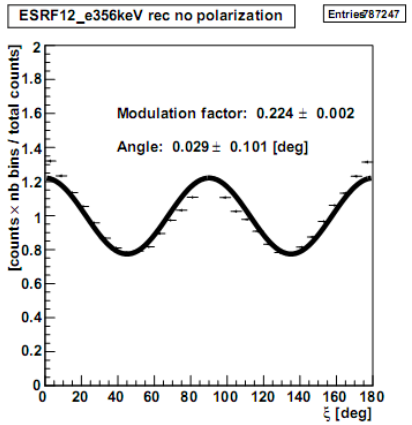


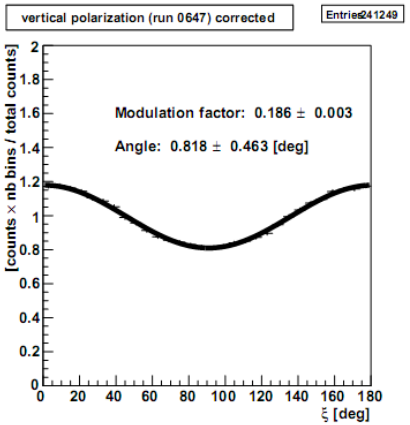


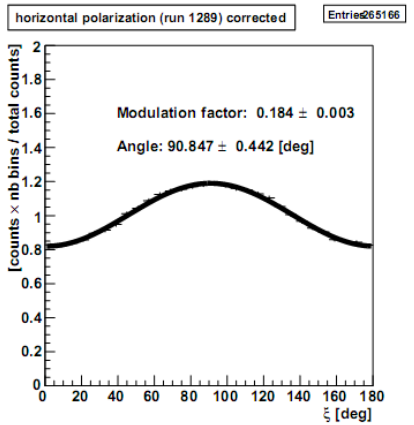
POLAR ESRF Calibration





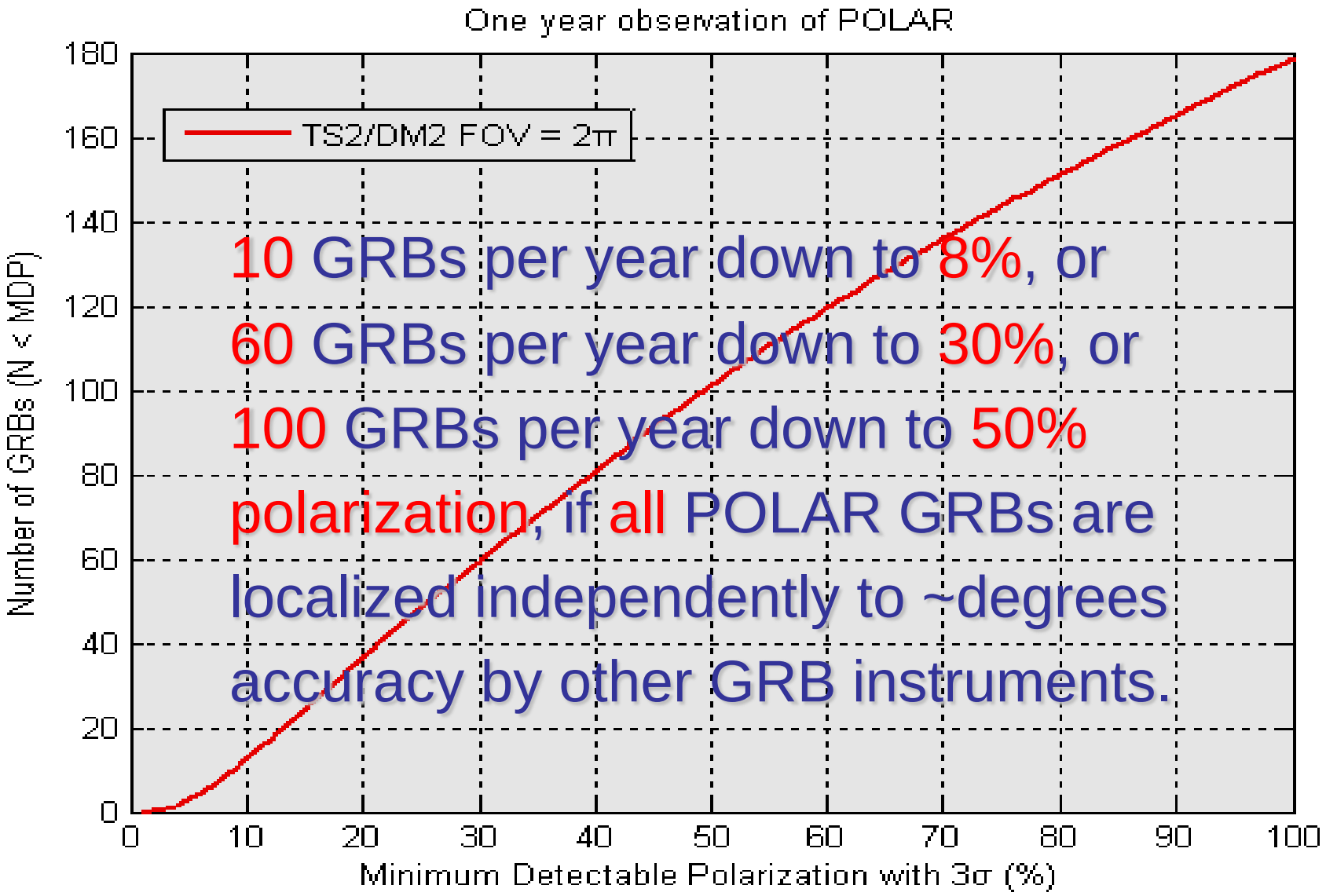






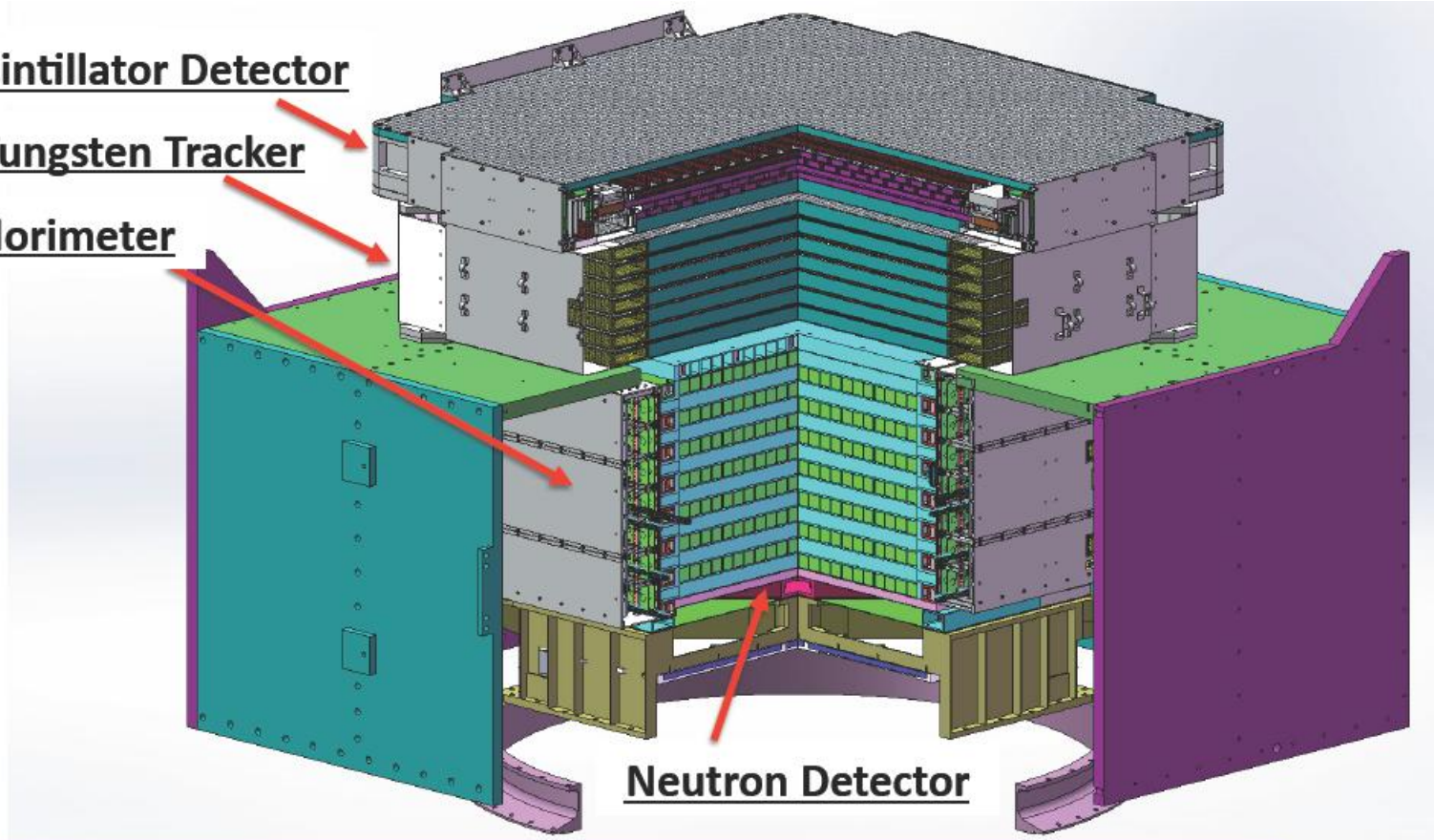
Results agree with Monte-Carlo simulations

POLAR capability



10 GRBs per year down to 8%, or
60 GRBs per year down to 30%, or
100 GRBs per year down to 50% polarization, if all POLAR GRBs are localized independently to ~degrees accuracy by other GRB instruments.

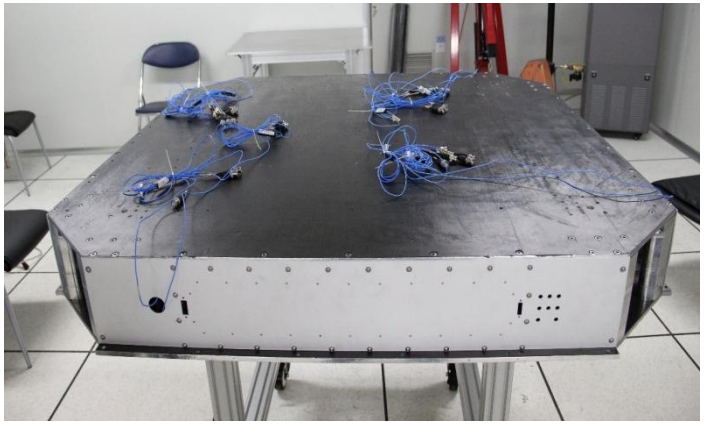
DAMPE: launch in ~2015



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

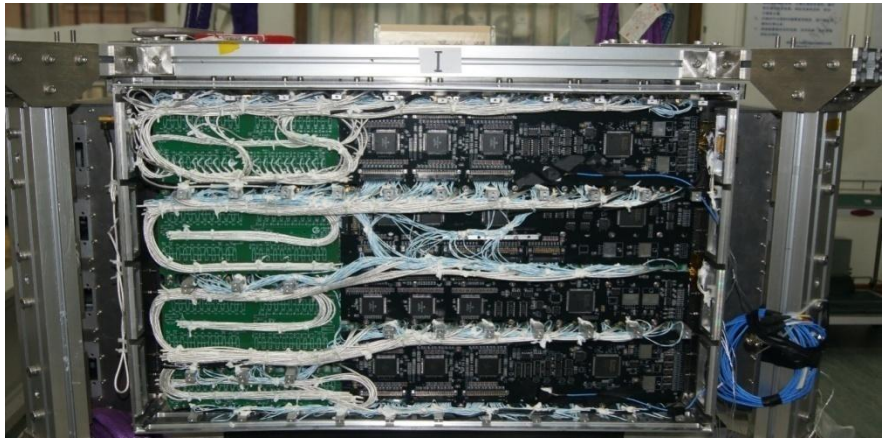
Vibration Test

Plastic Hodoscope

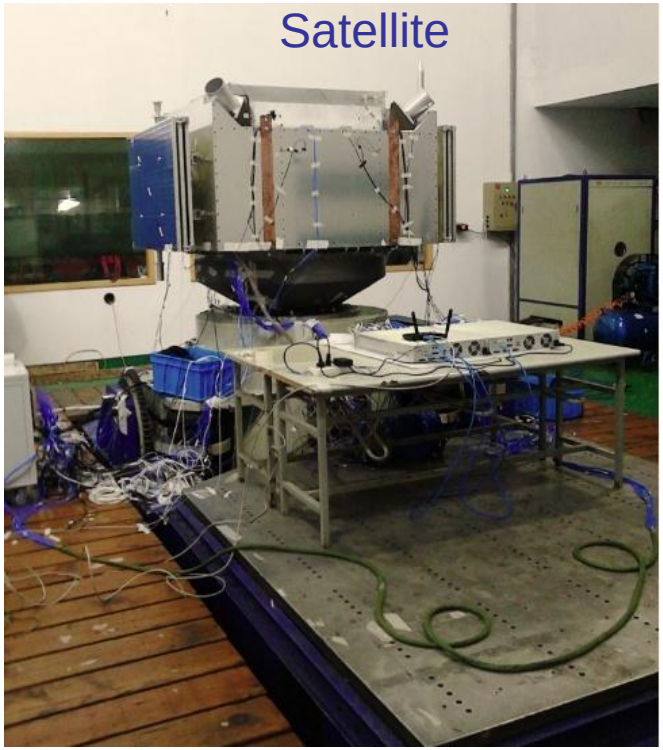


Neutron Detector

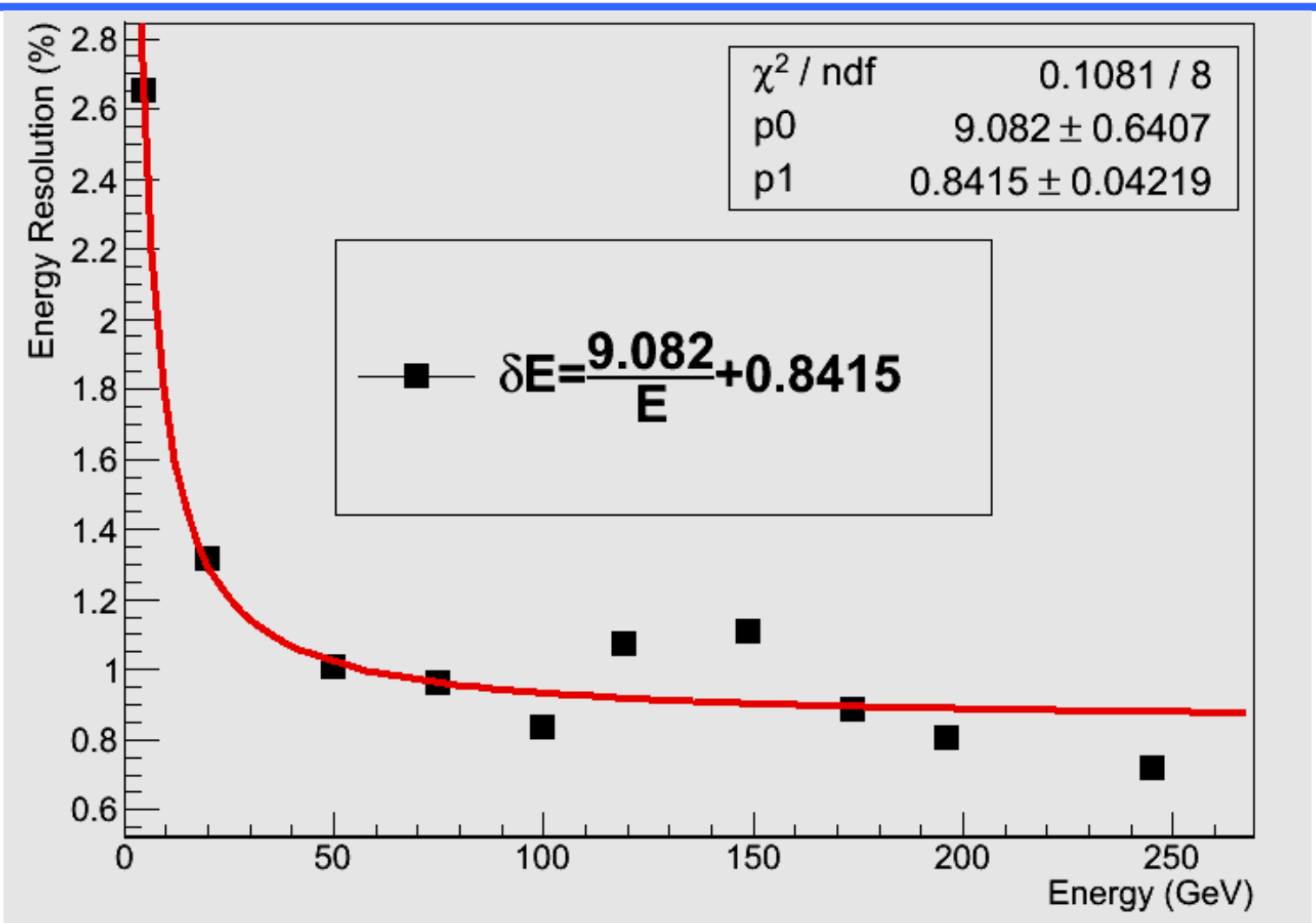
BGO Cal.



Satellite

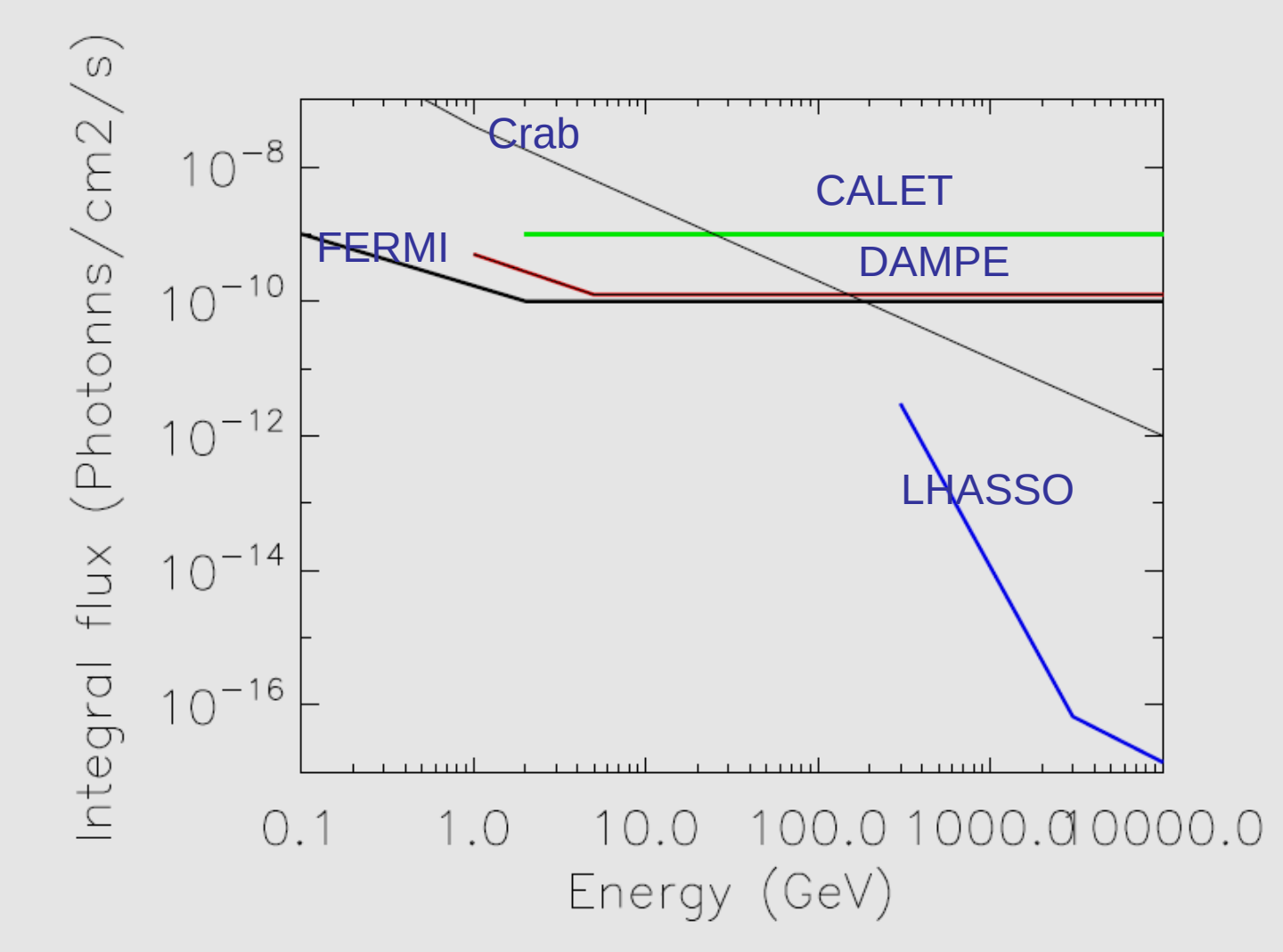


Energy Resolution

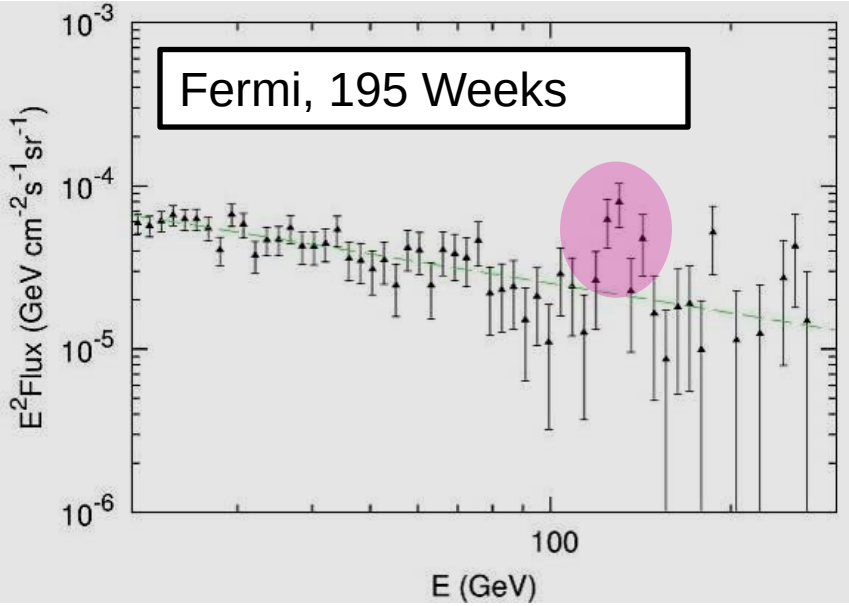


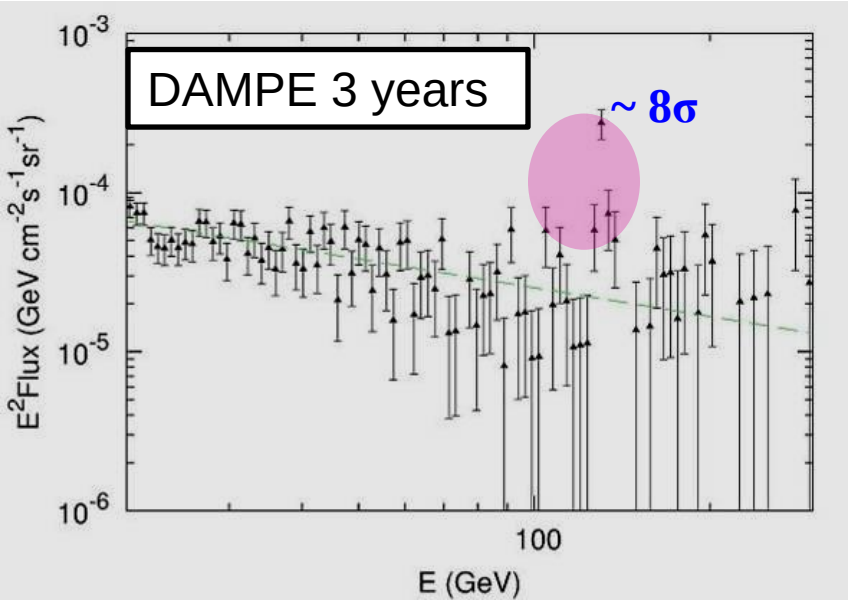
Energy Resolution can reach 0.79%@ 250 GeV

Gamma-ray Sensitivity



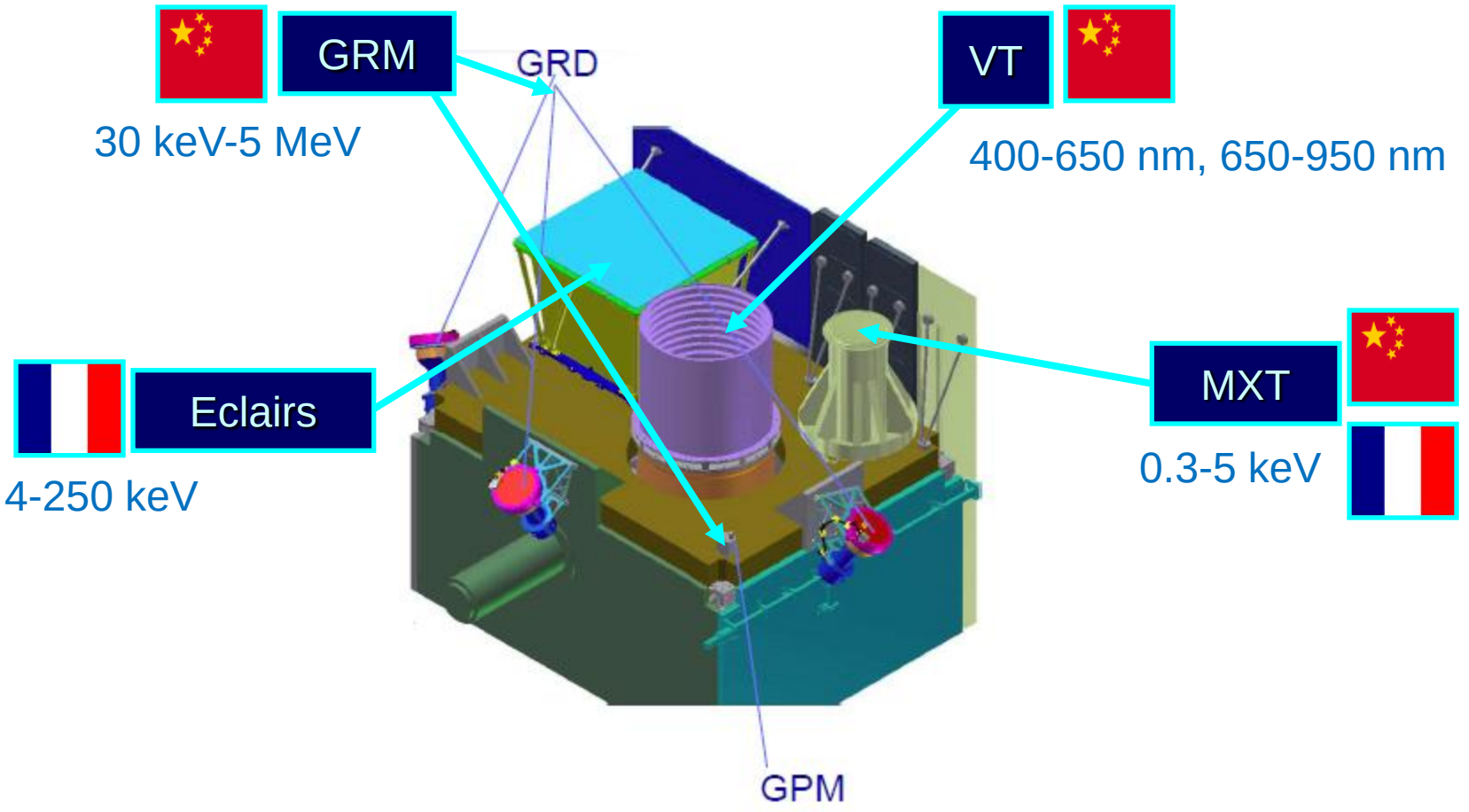
DAMPE for gamma-ray line observations





DAMPE will confirm or deny the “suspicious” dark matter annihilation line of Fermi with high significance

SVOM: ~2020 launch



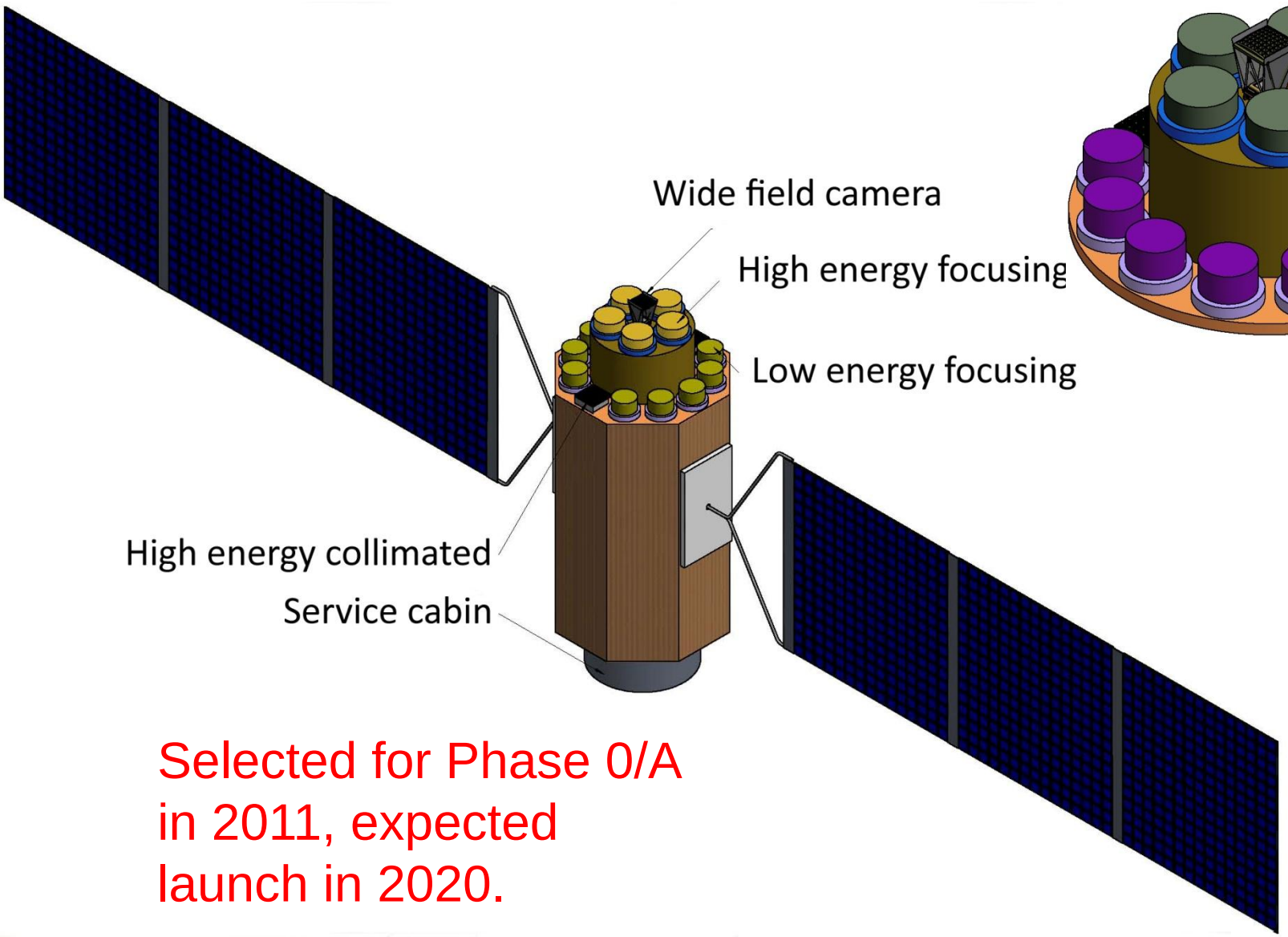
Space instrument performances

	Spectral band	Field of View	Allocation Accuracy	GRBs/yr (Dect. Rate)
GRM	30 keV-5 MeV	2 sr	2-5 deg	~80
ECLAIRs	4-250 keV	2 sr	10 arcmin	~70
MXT	0.3-5 keV	65× 65 arcmin	30 arcsec	~90%
VT	400-650 nm 650-950 nm	26 × 26 arcsec	1 arcsec	~80%

X-ray Timing and Polarization (XTP) mission

- Science: 1-singularity (BH); 2-stars (NS and Magnetar); 3-extremes (gravity, density, magnetism)
  - Precise light curve + energy spectrum: Matter under extreme conditions, NS state equation, BH parameters
  - Polarization of X-ray: BH spin, nature of magnetars, pulsar radiation mechanism…
- Instrument Design Goal
  - The most sensitive light curve with good energy resolution and polarization at 1-30 keV → from faint X-ray binaries to bright AGNs

XTP satellite



Selected for Phase 0/A in 2011, expected launch in 2020.

Satellite fitting in launcher

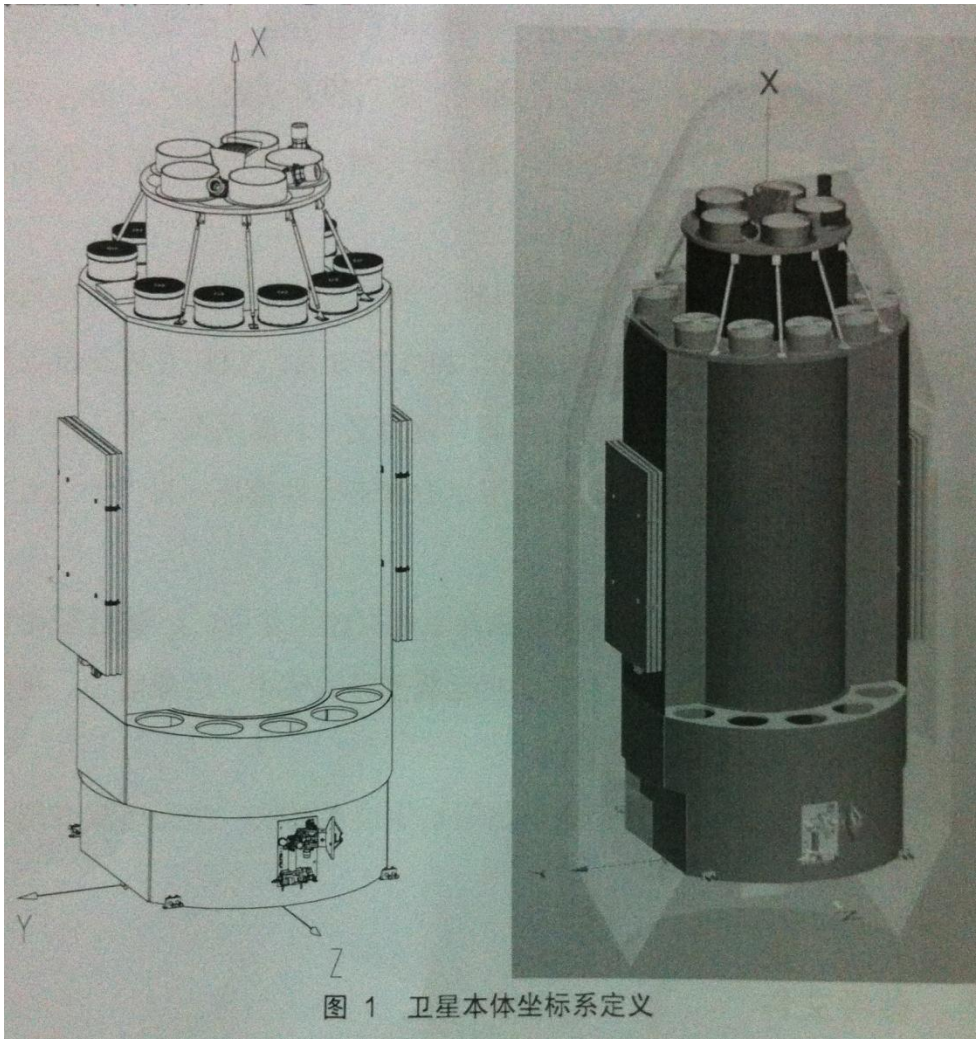
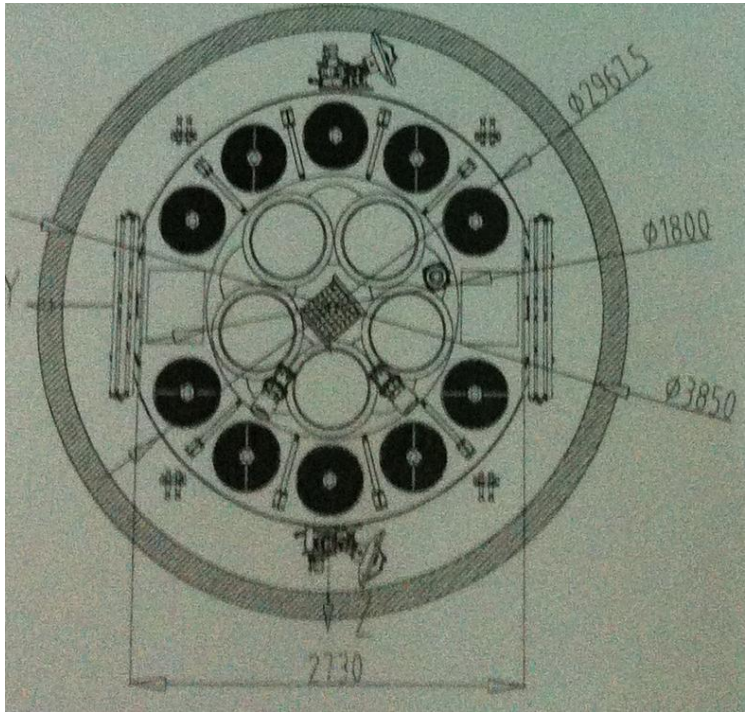
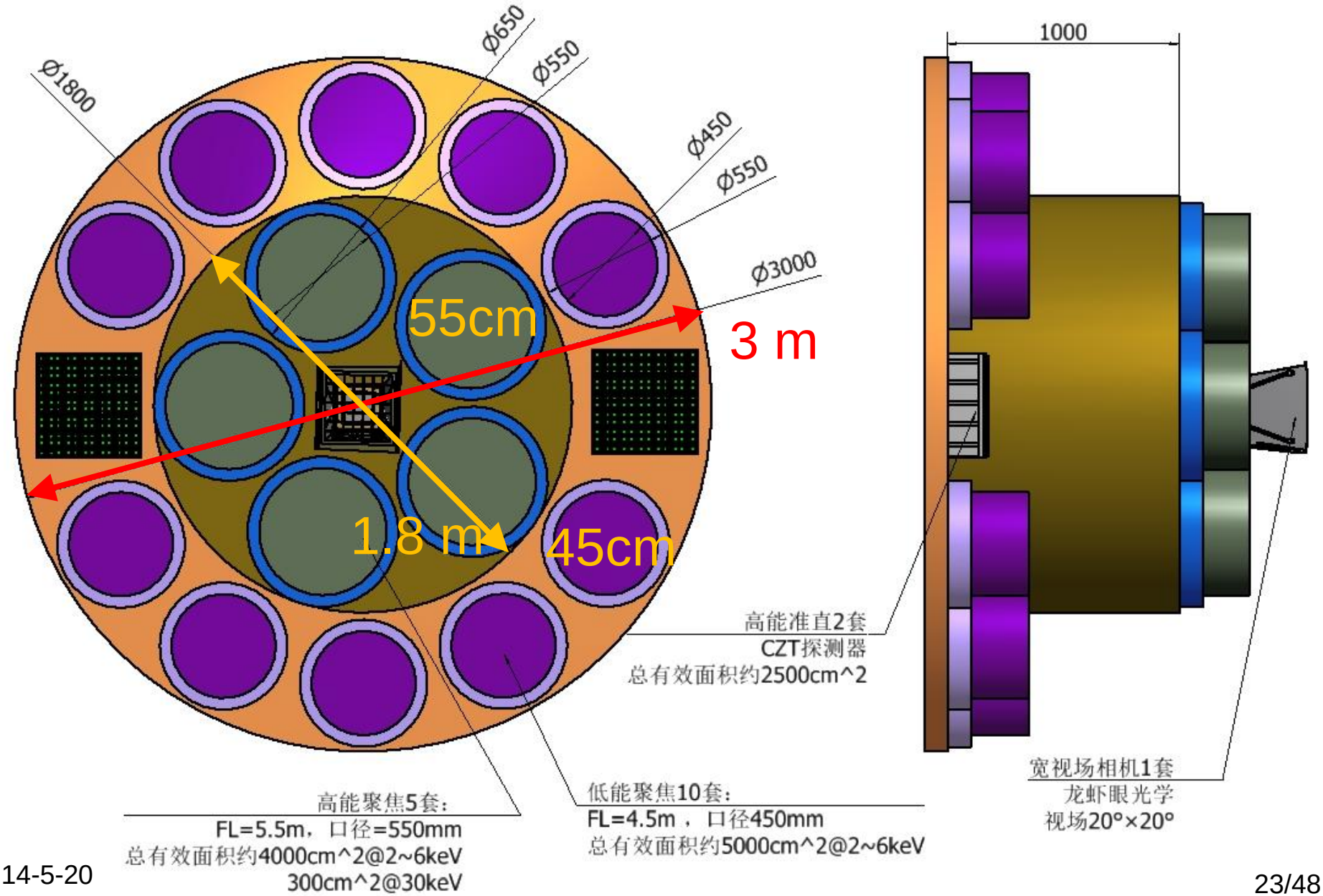


图 1　卫星本体坐标系定义

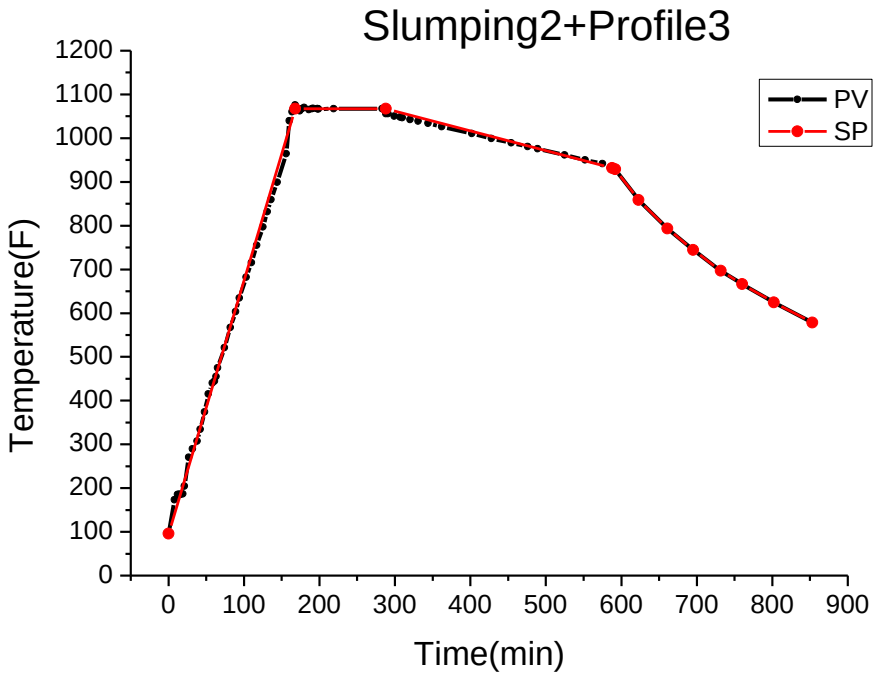


XTP payload layout



Slumped glass mirror

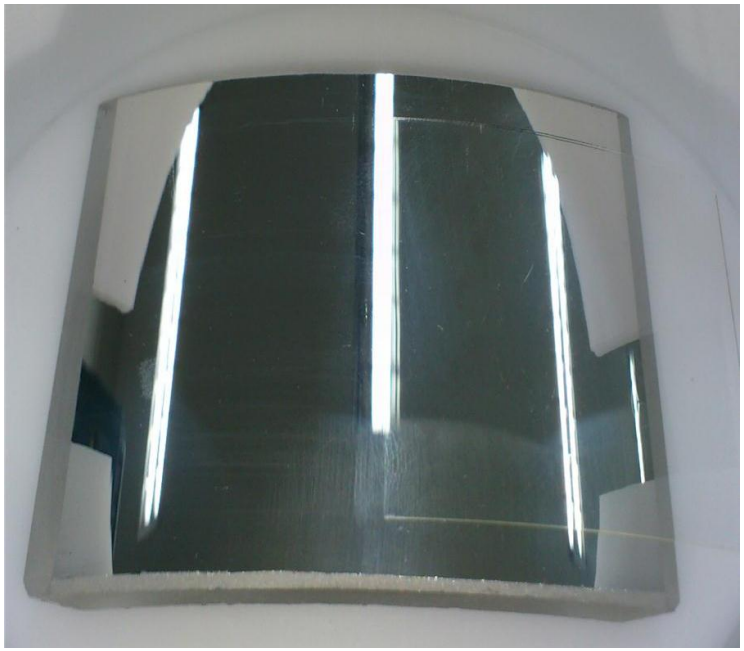
L&L Furnace



Temperature curve

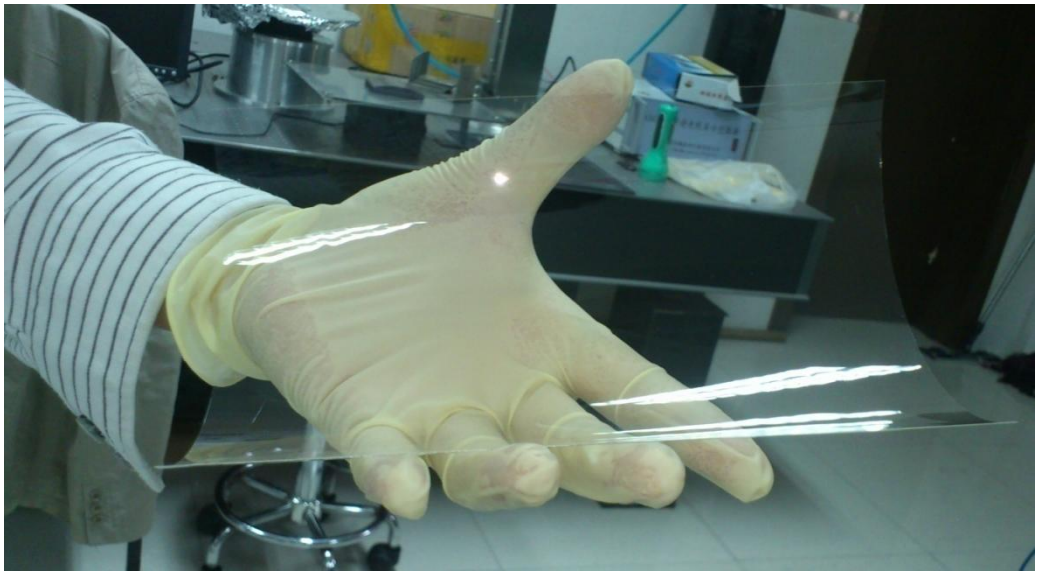
Before

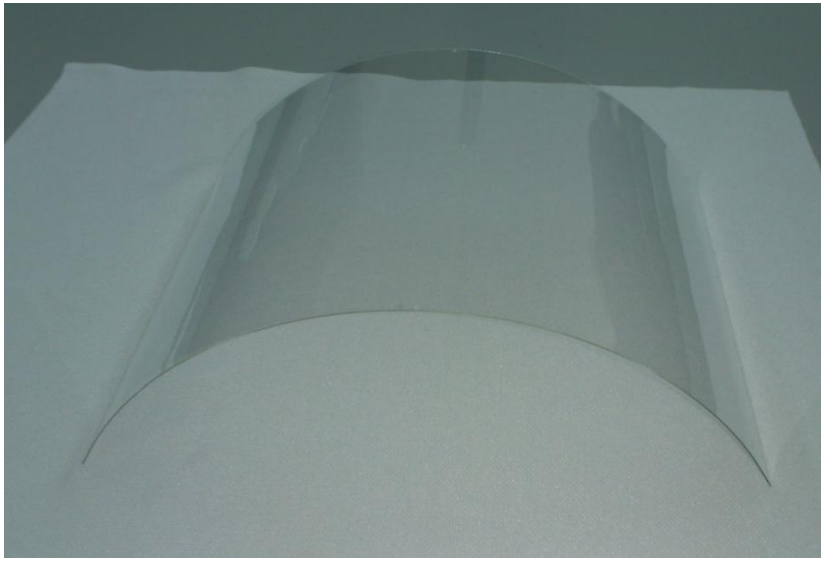
D263 & Mandrel



After

Mirror & Mandrel

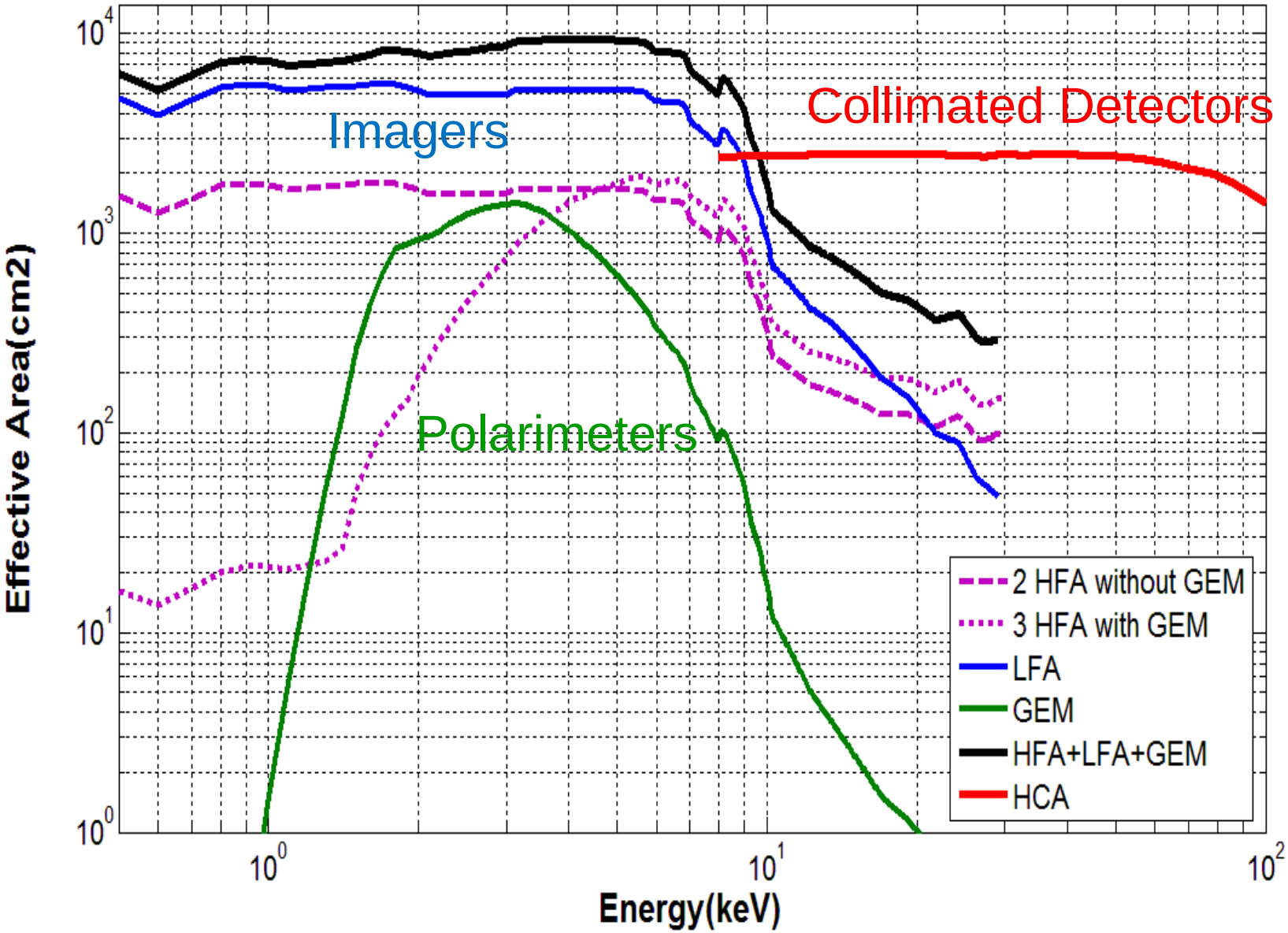




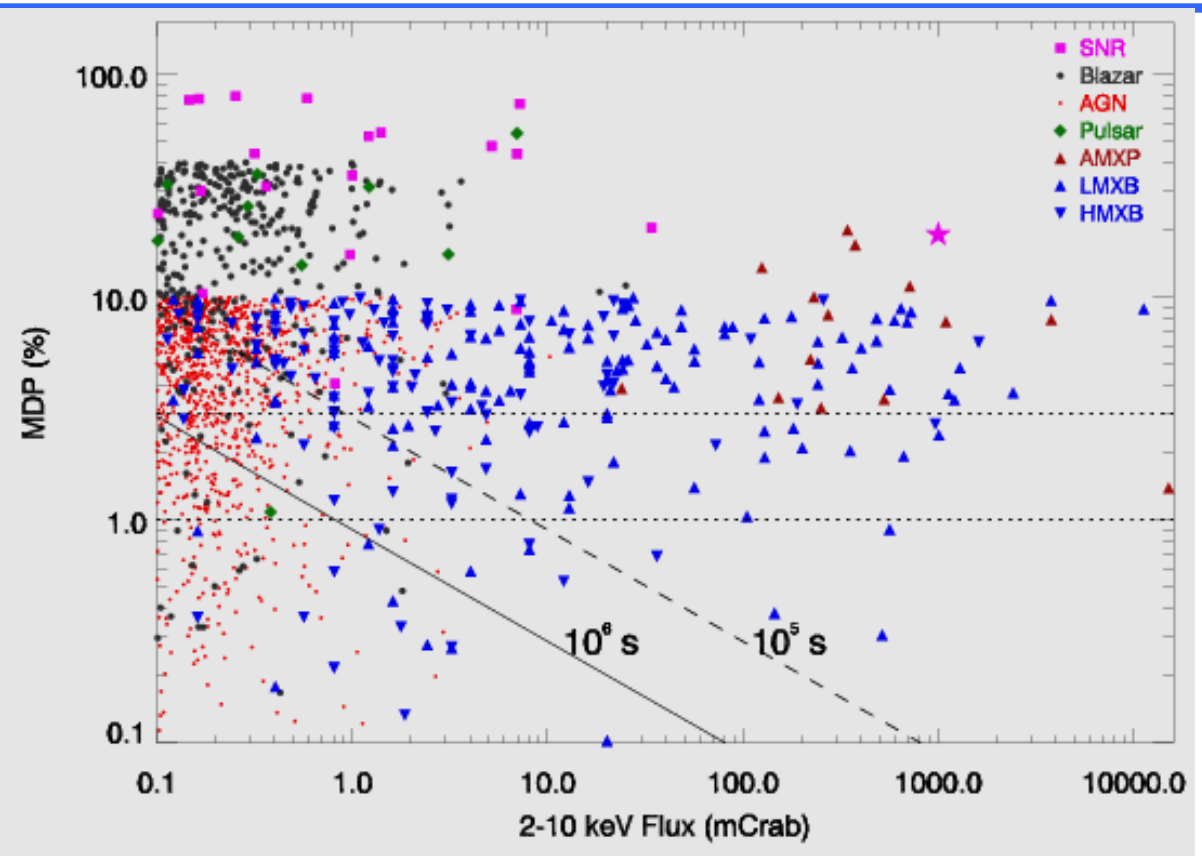
T= 200μm L=200mm Material: D263

Surface roughness: 0.3 nm → arcmin angular resolution

Effective Areas



XTP Polarimetry Sensitivity



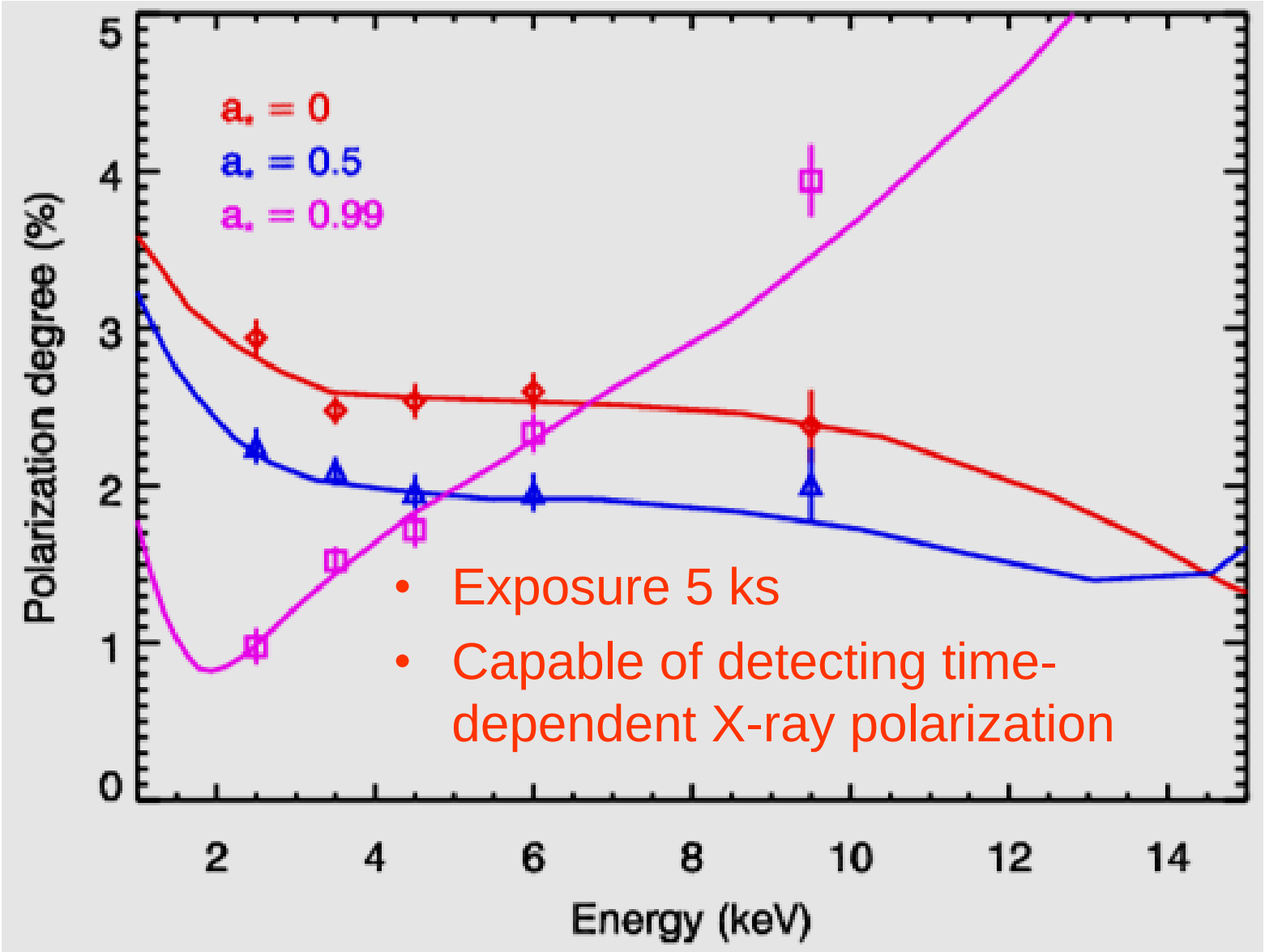
	total	P>1%		P>3%	
		10^5 s	10^6 s	10^5 s	10^6 s
SNR	19	19	19	19	19
Blazar	314	264	292	264	285
AGN	990	362	773	360	674
Pulsar	10	9	9	9	9
AMXP	14	14	14	13	13
LMXB	139	119	126	99	103
HMXB	102	77	89	68	73

Current situation: only 1 detection!

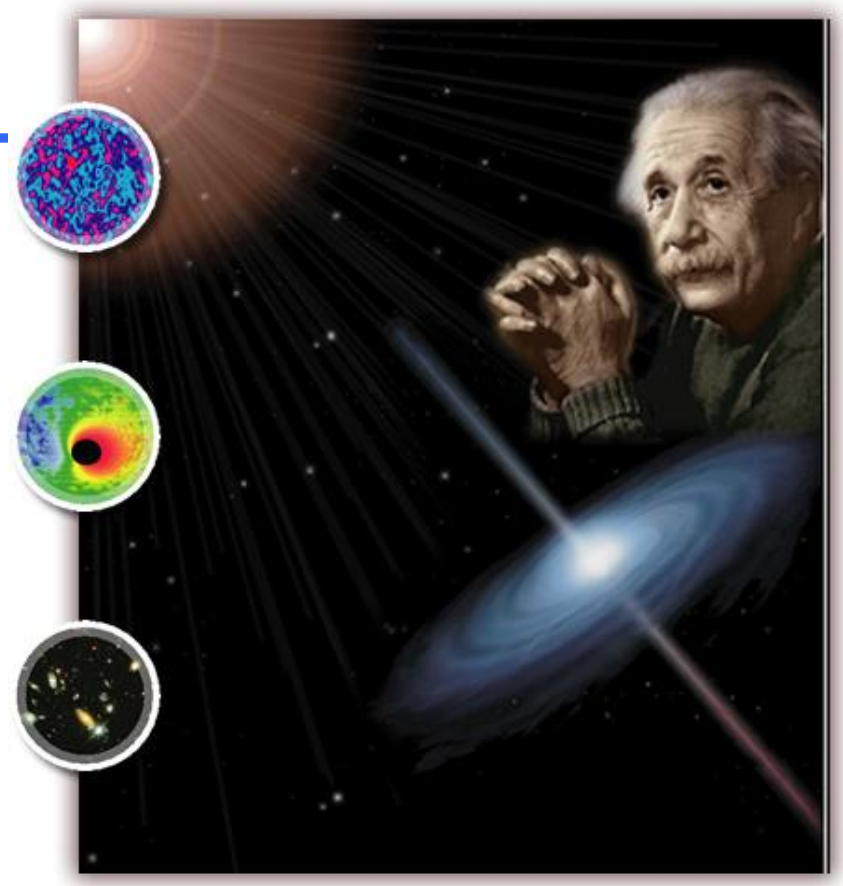
P = 15%±5% (Novick et al. 1972)

P = 19%±1% (Weisskopf et al. 1976, 1978)

XTP Polarimetry: GRS 1915+105

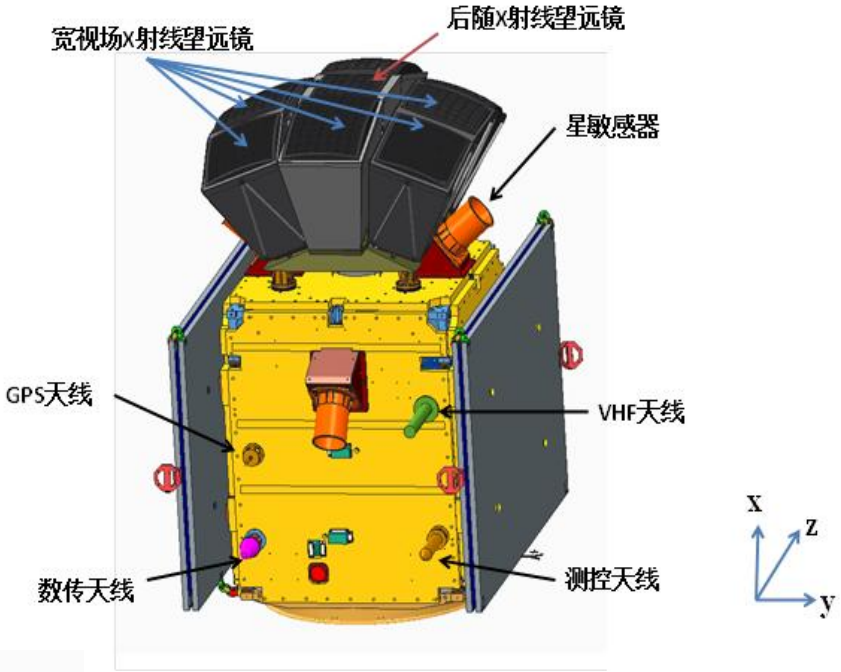


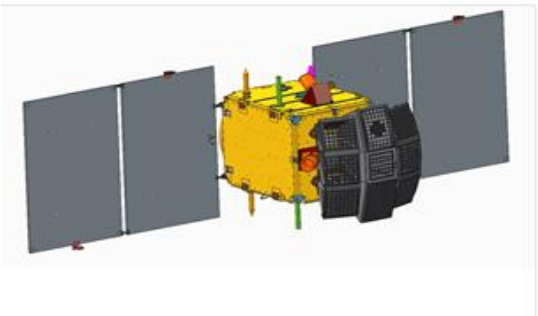
- Exposure 5 ks
- Capable of detecting time-dependent X-ray polarization

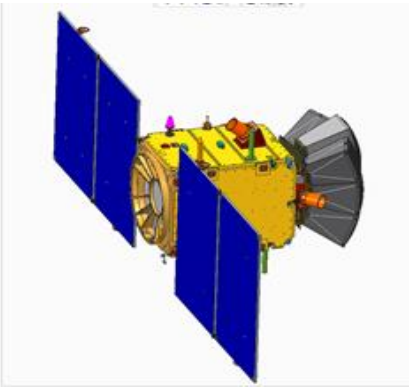


Einstein Probe (EP)

Lobster-eye optics

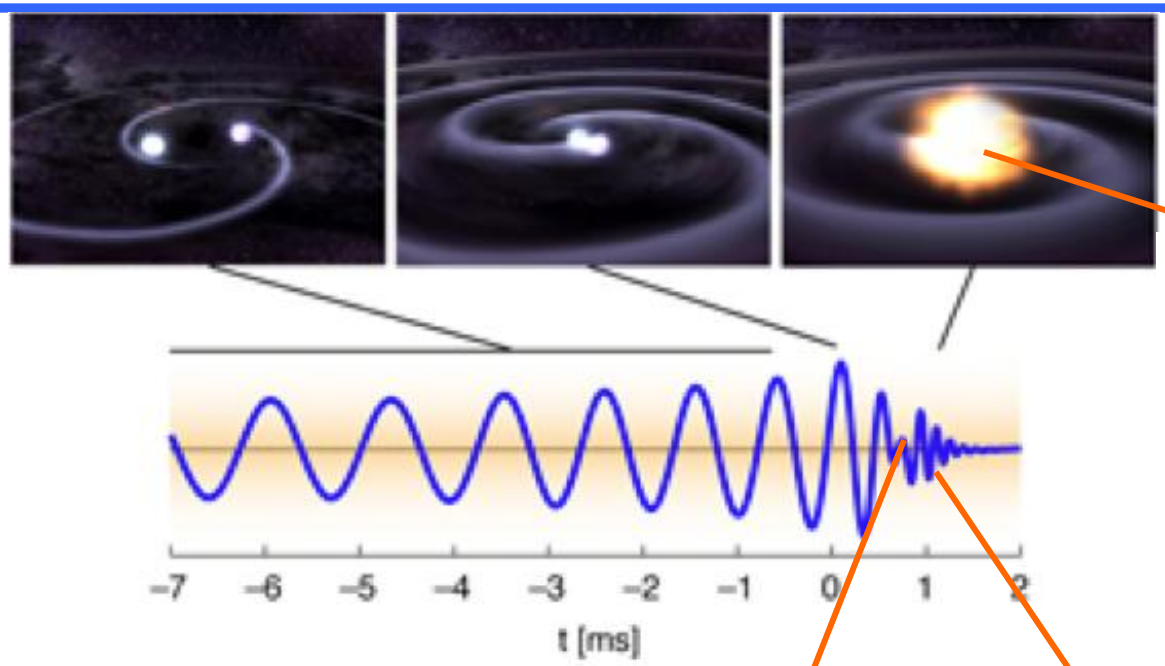


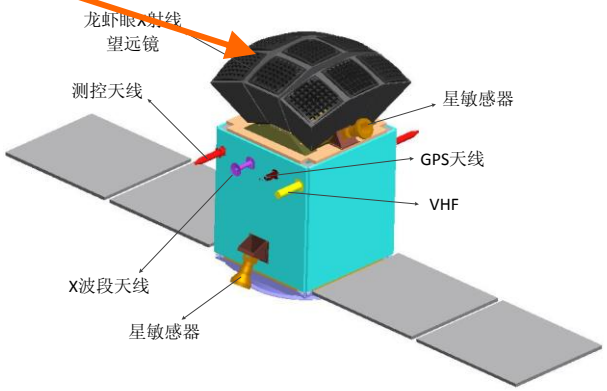




Selected for Phase 0/A in 2013, expected launch in 2020-2025.

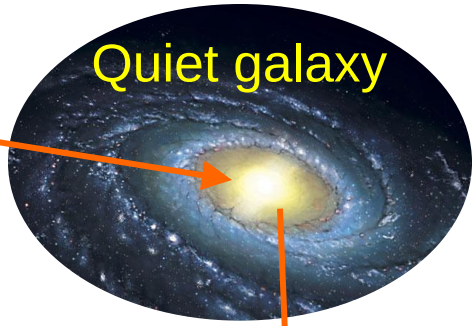
EM counterparts of GW explosions

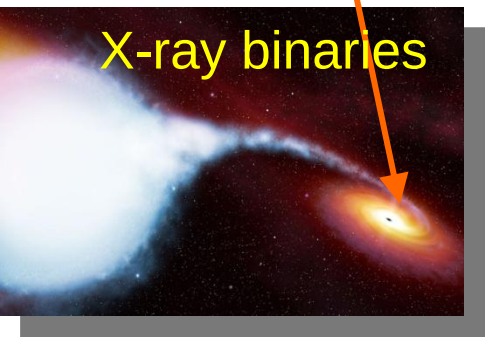


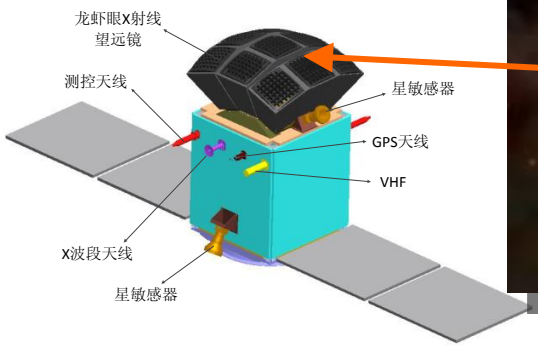


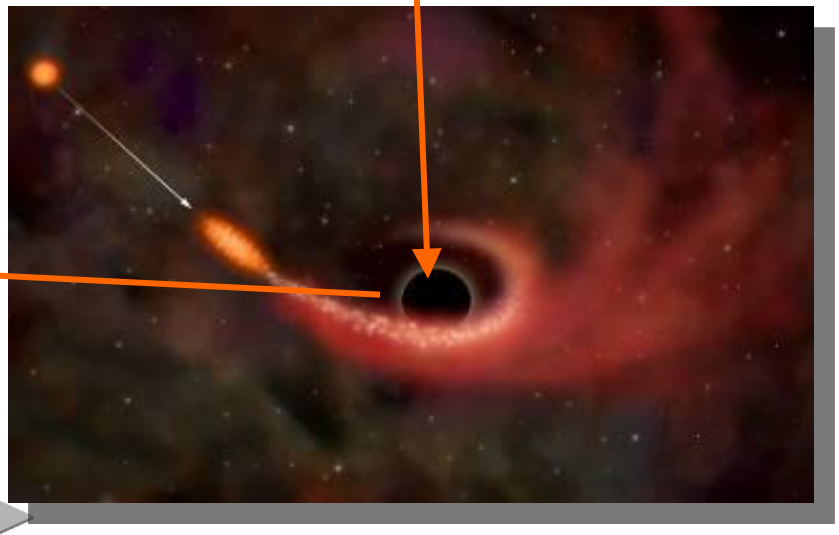
~2018

Black holes of all scales in the universe

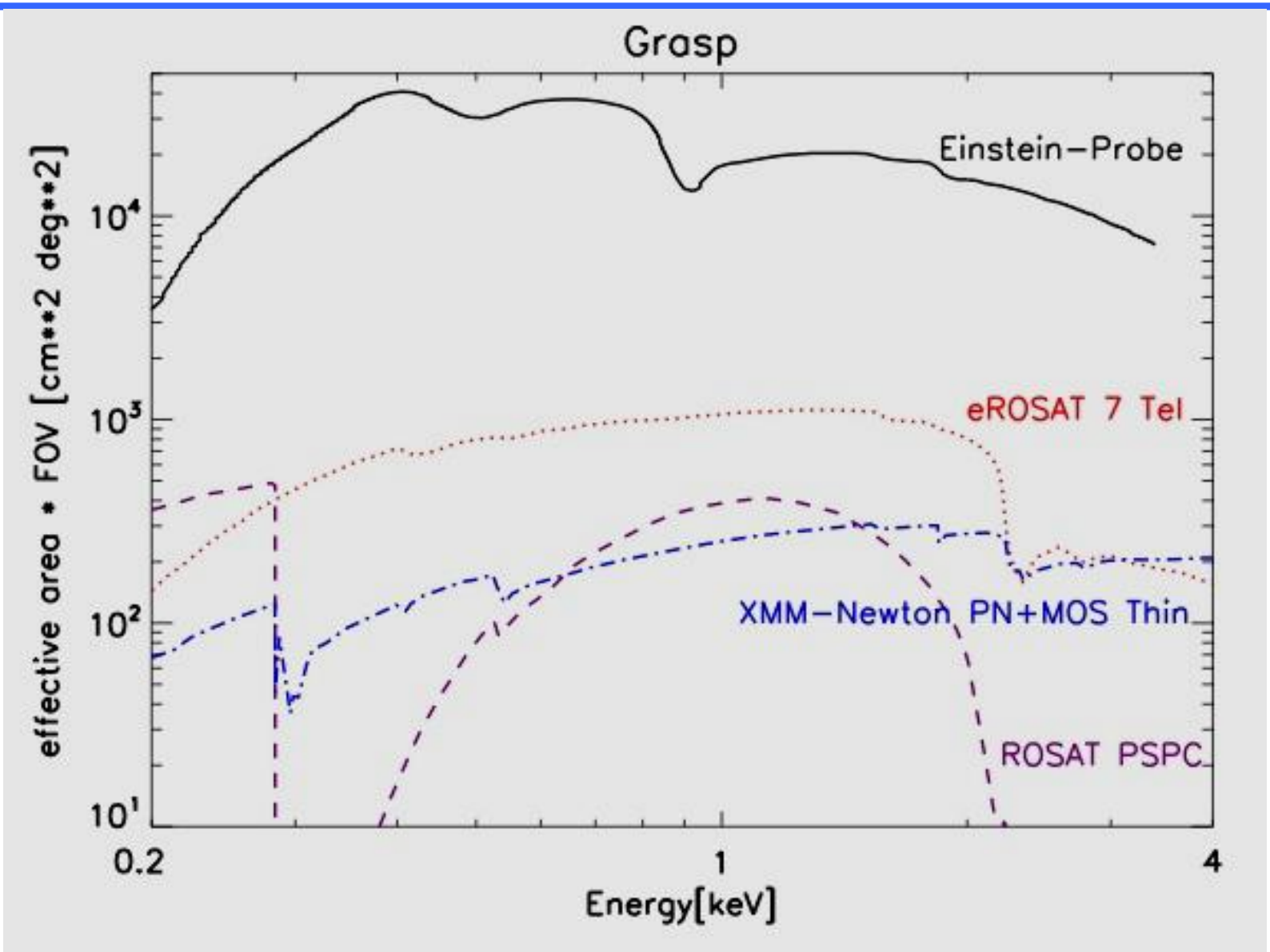








Capability of Einstein Probe



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

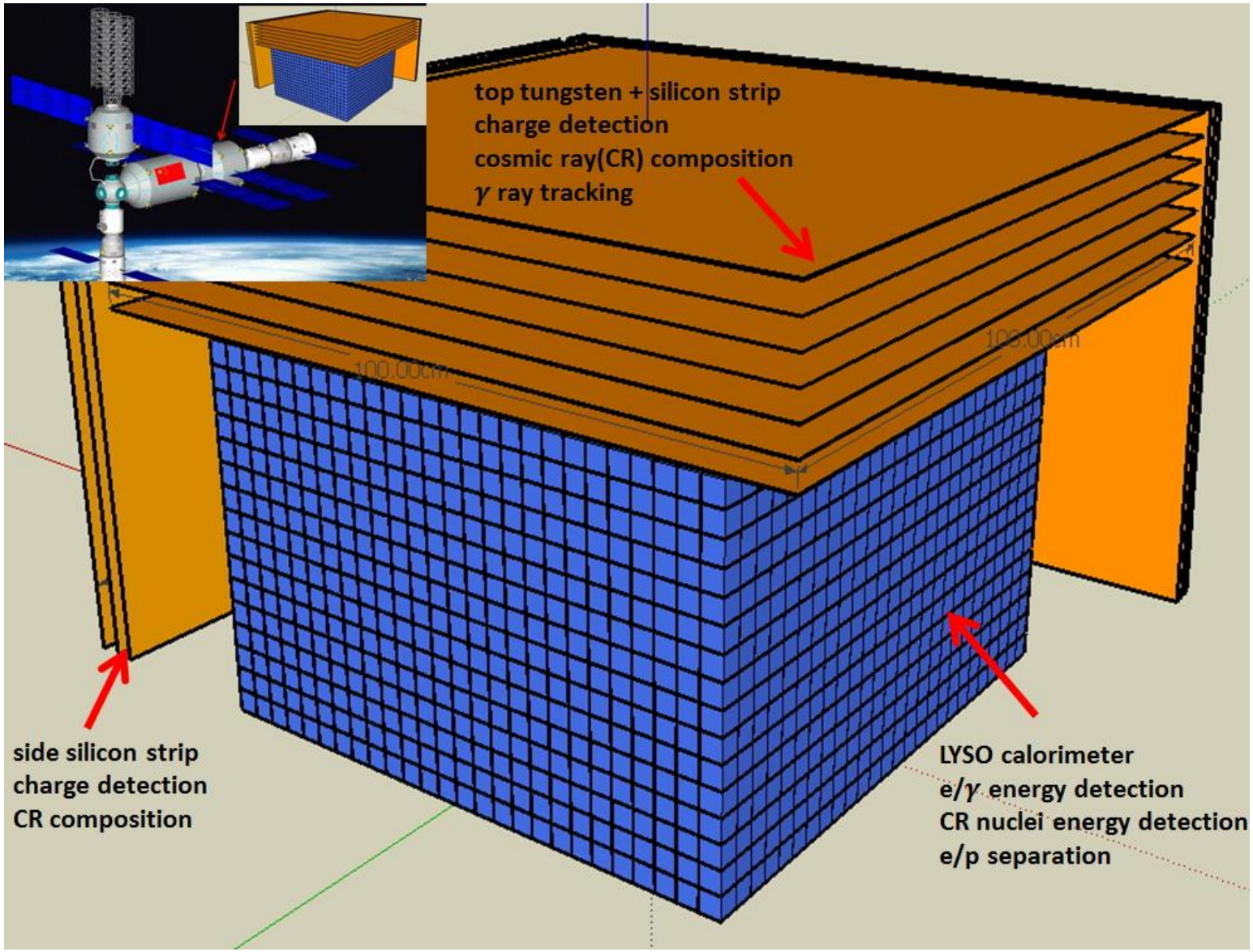

background
Gamma-ray
HERD
electron
proton
He
Dark matter particle

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.

Baseline design of HERD



Characteristics of all components

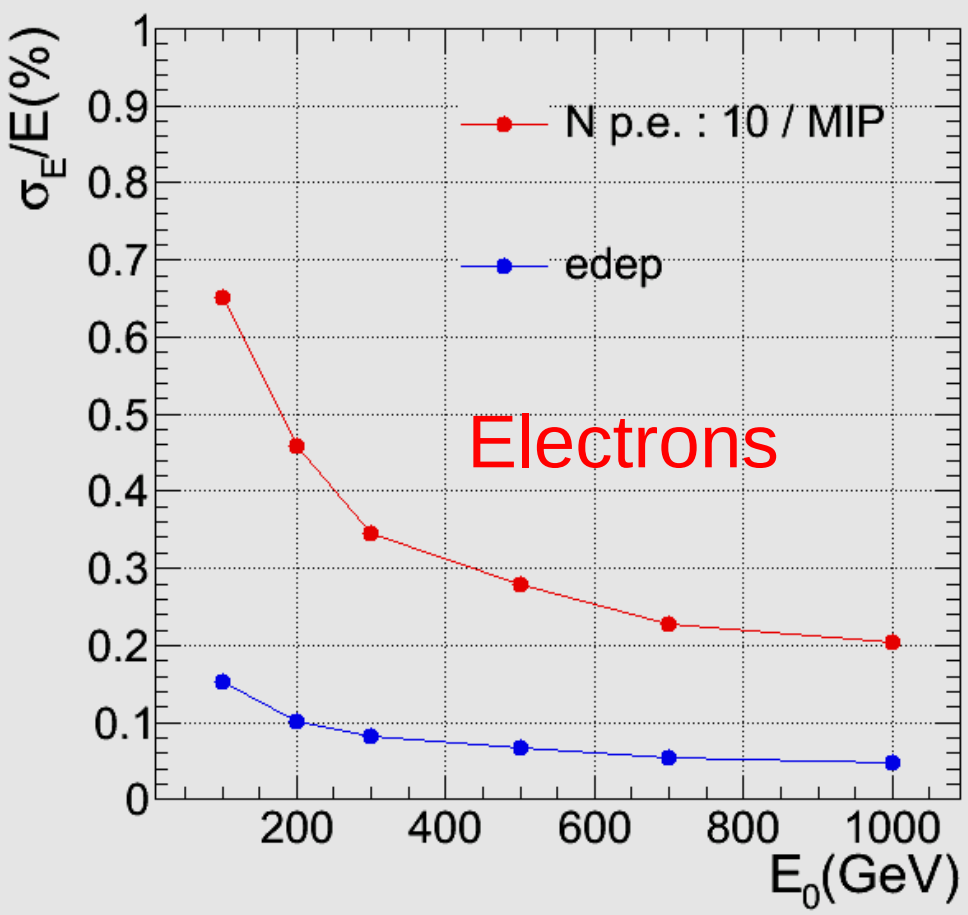
	type	size	X0,λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	--	3 x-y	Nucleon Track Charge
CALO	~10K LYSO cubes	63 cm × 63 cm × 63 cm	55 X0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon energy e/p separation

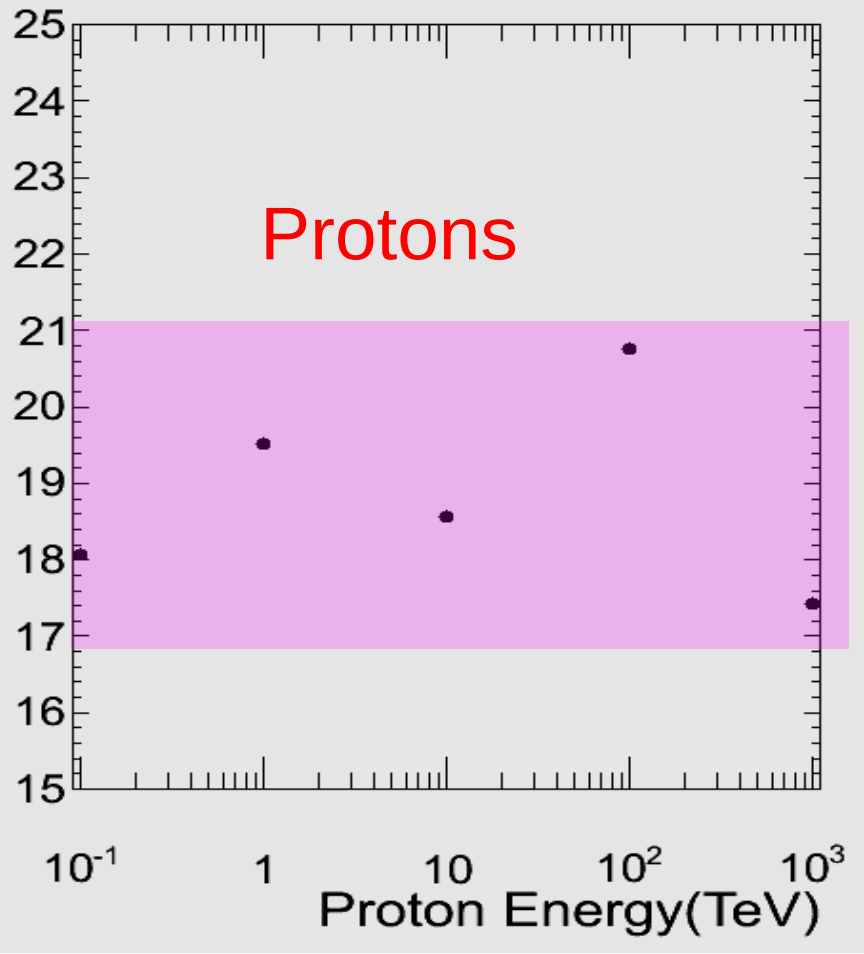
Total detector weight: ~2000 kg

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

Simulation results: energy resolutions

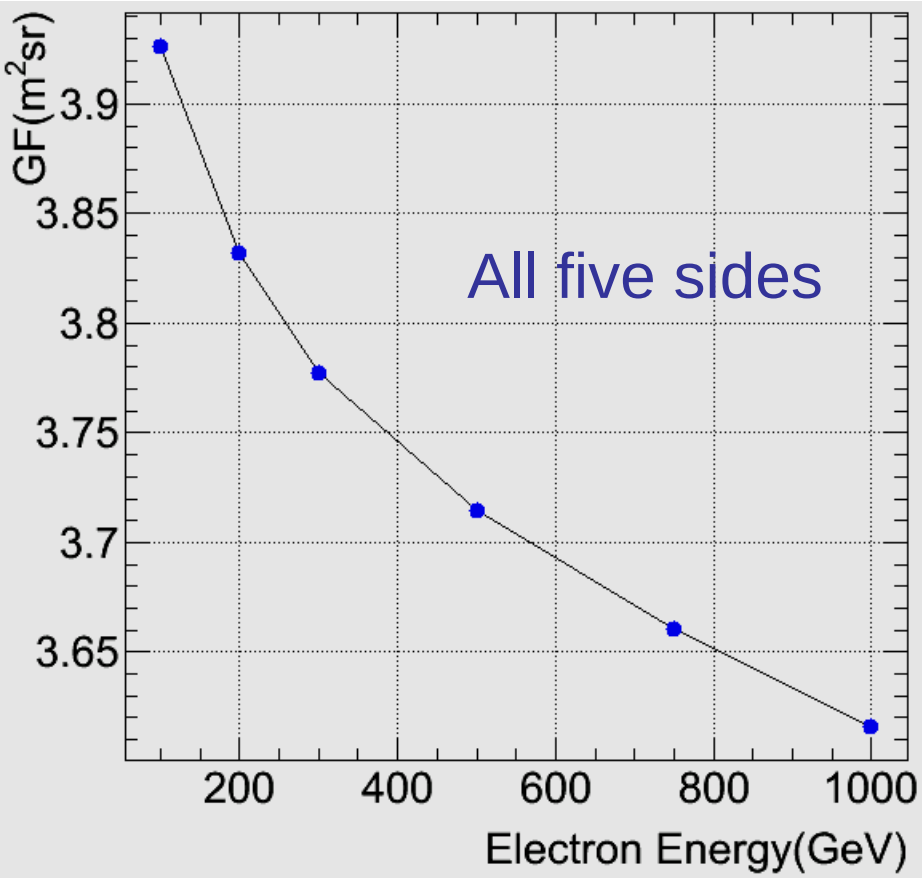


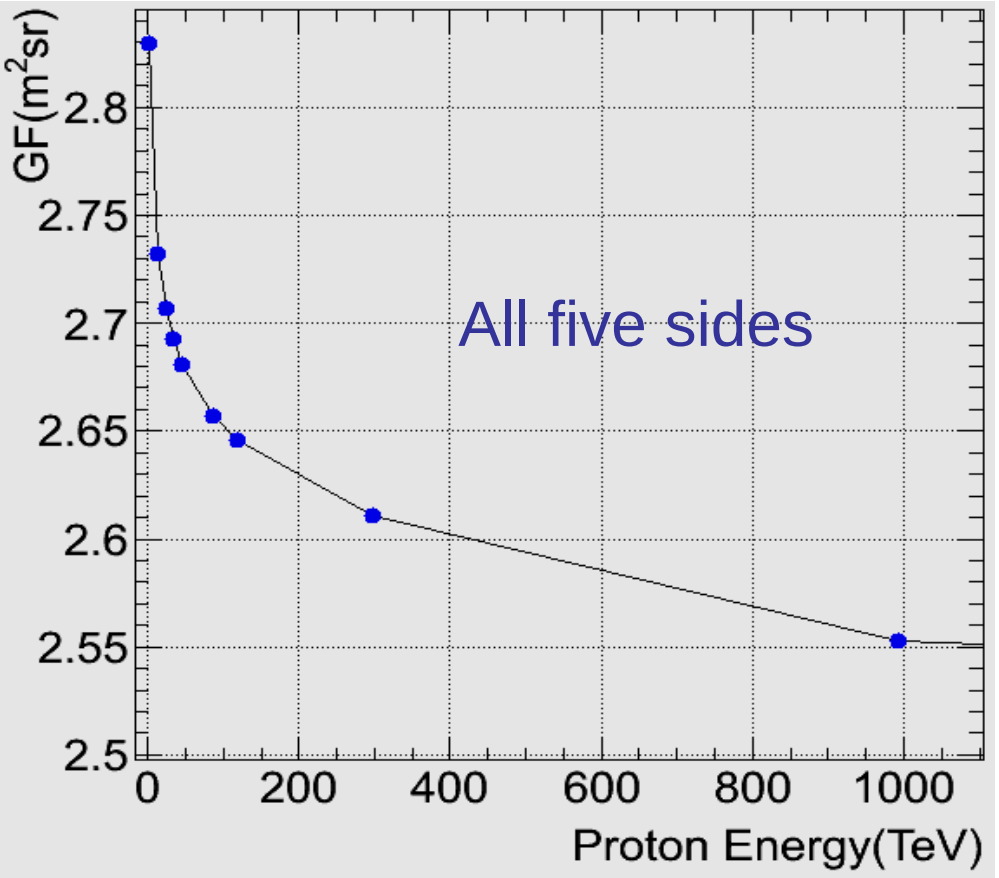


Electron < 1%; Proton: ~20%

Essential for spectral features!

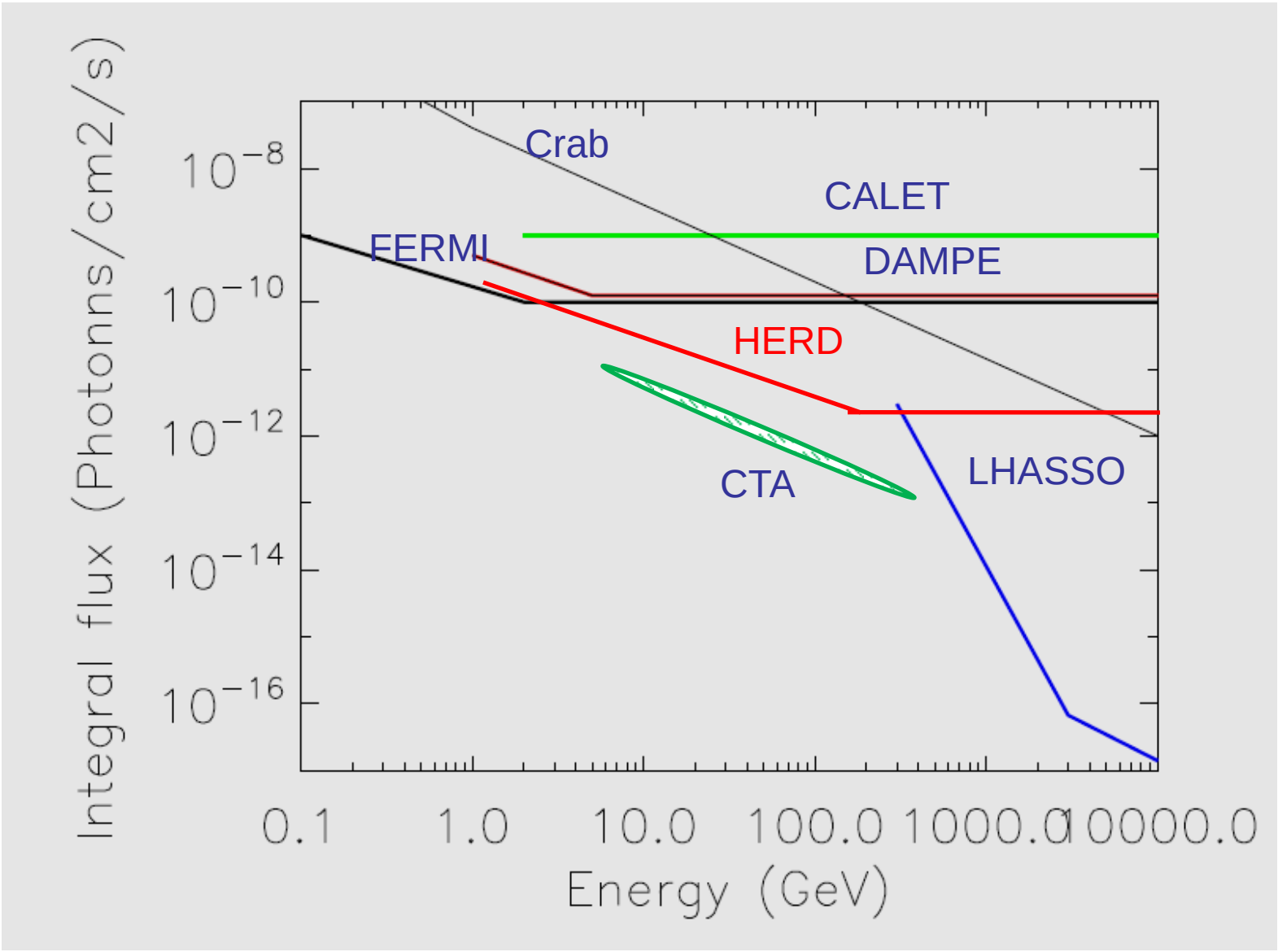
HERD Eff. Geometrical Factor: CALO



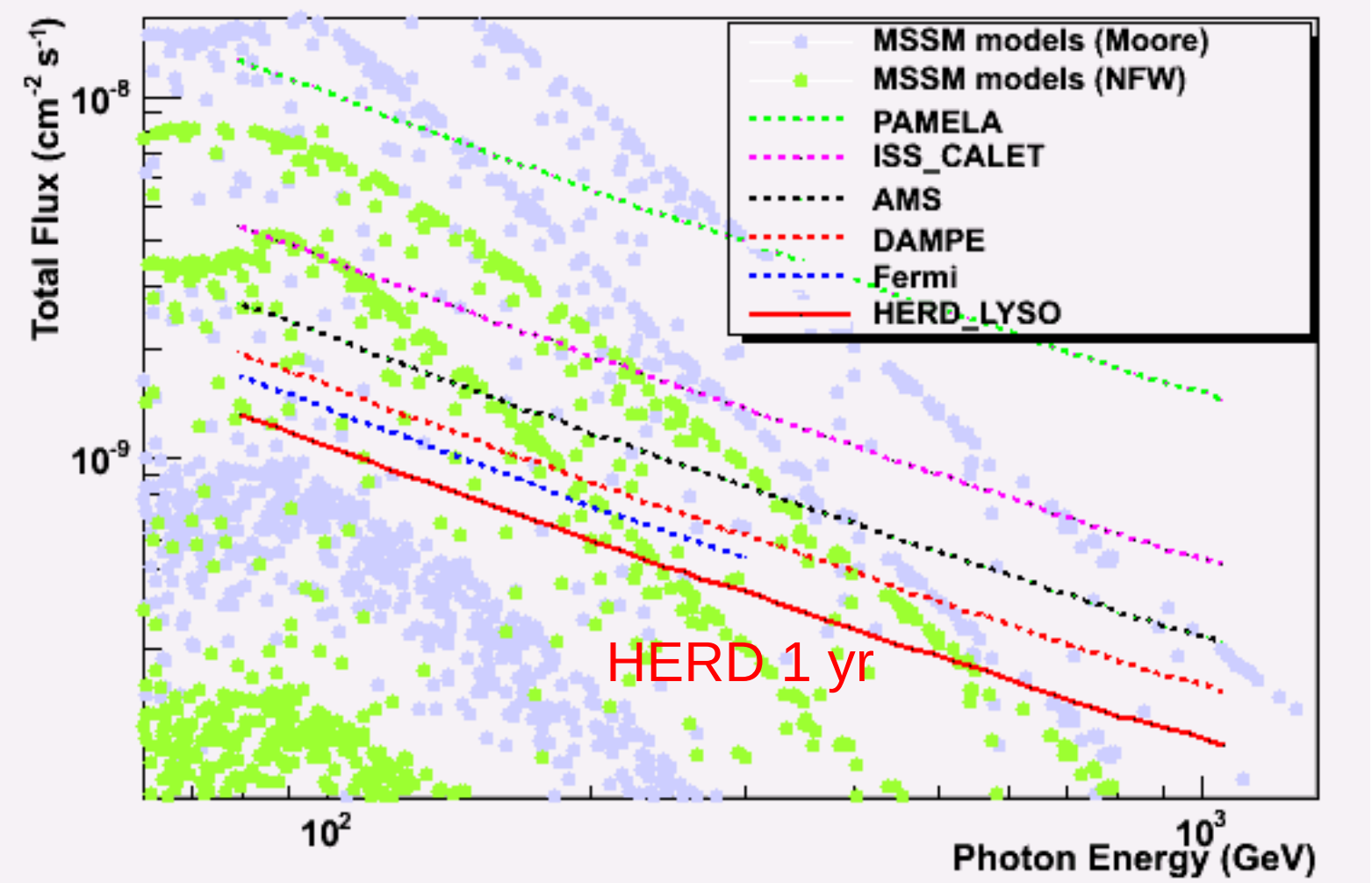


$$N_{obs} = F \times G_{eff.} \times T_{exp.} \times \eta_{pid} \times \eta_{reco}$$

Gamma-ray Sky Survey Sensitivity

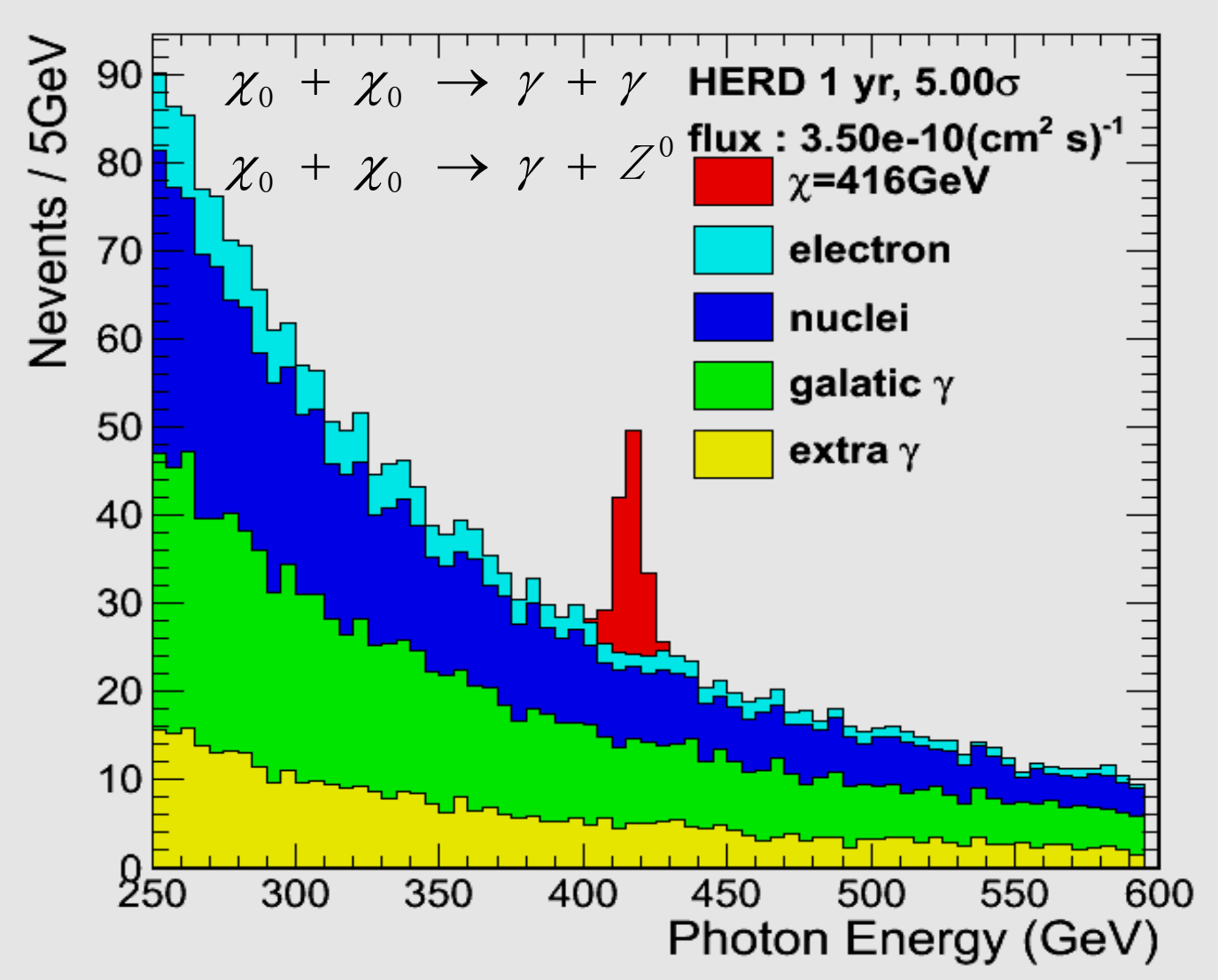


HERD sensitivity to gamma-ray line

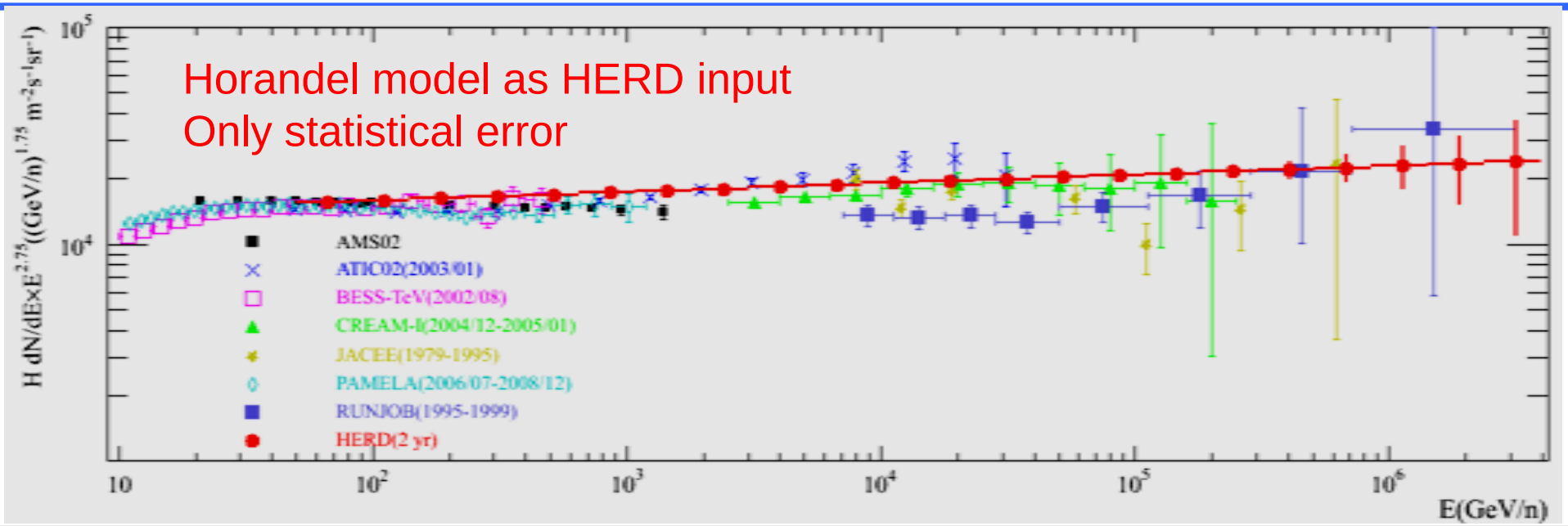


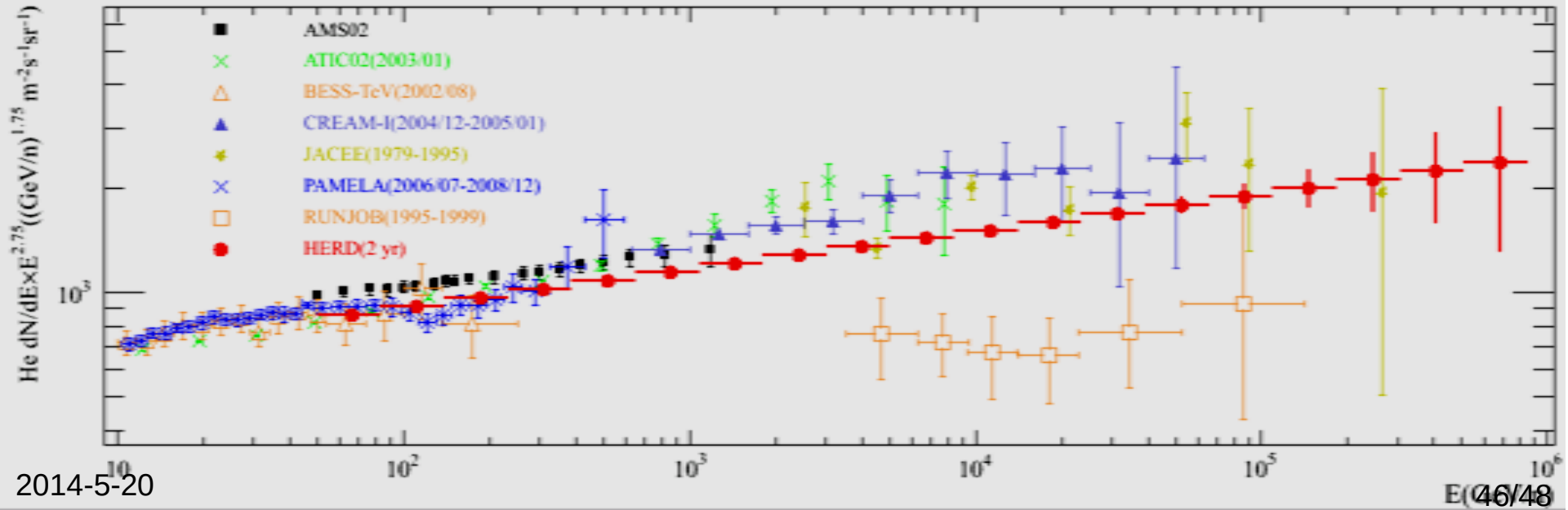
PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

DM annihilation line of HERD

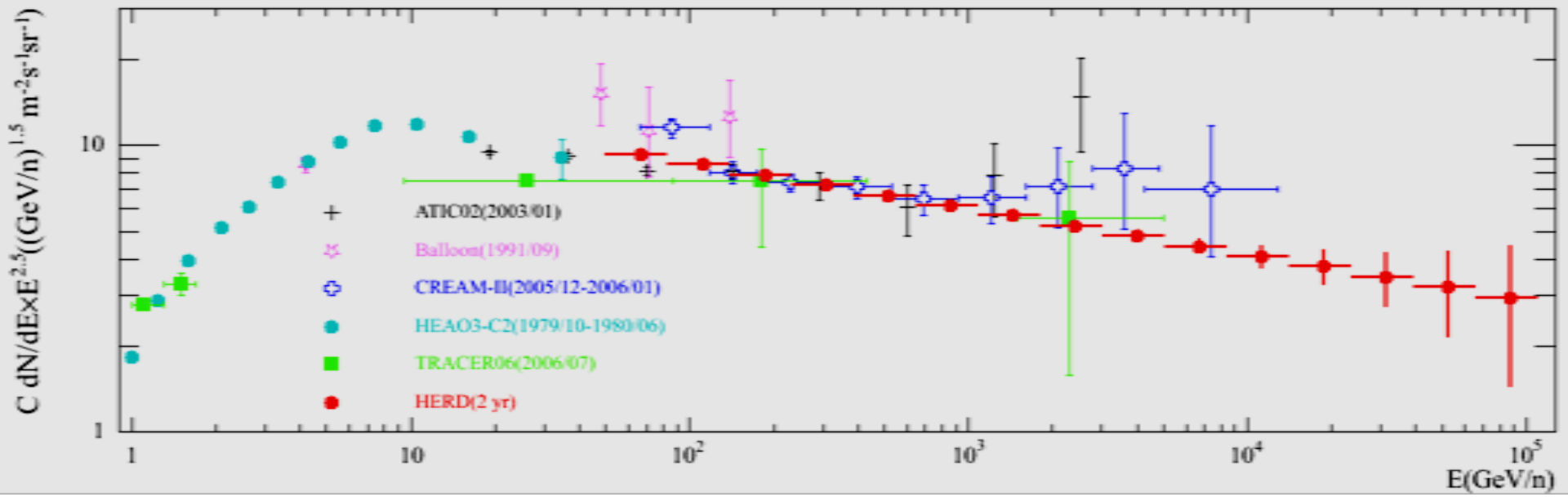


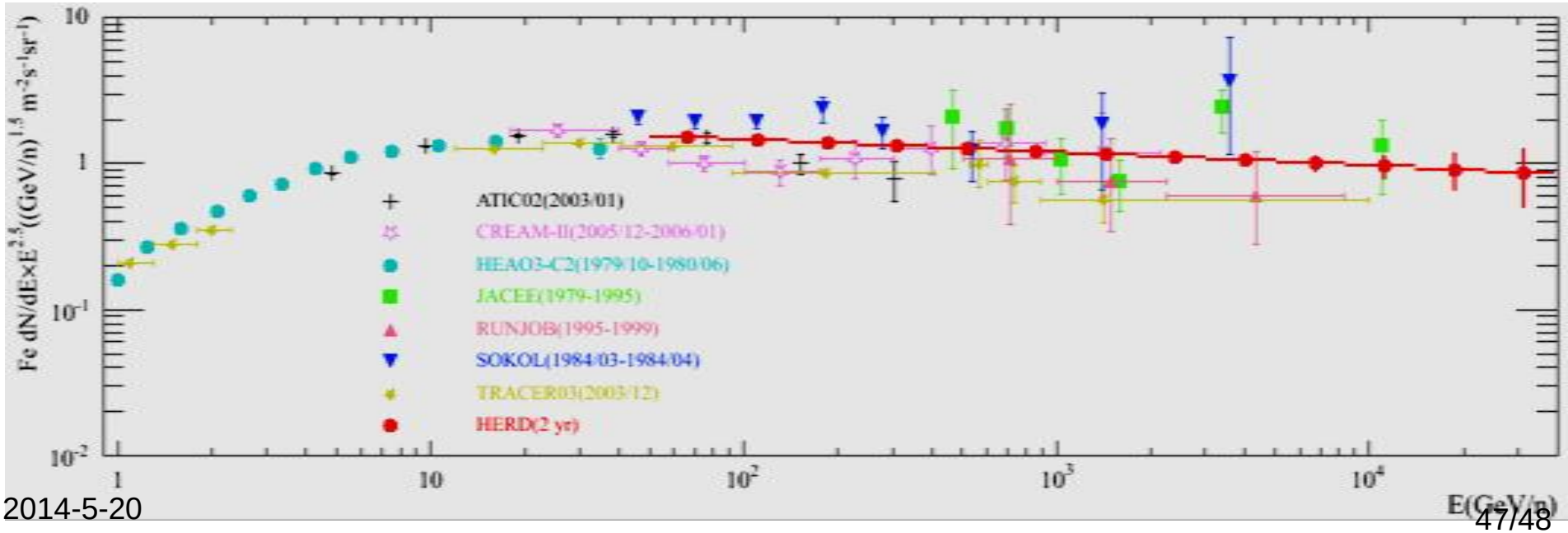
Expected HERD Proton and He Spectra



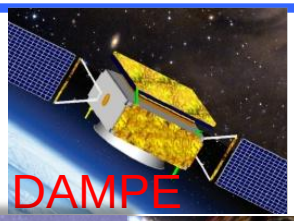


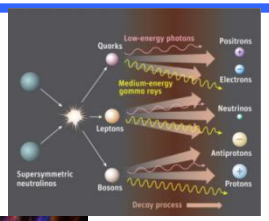
Expected HERD Spectra of C and Fe

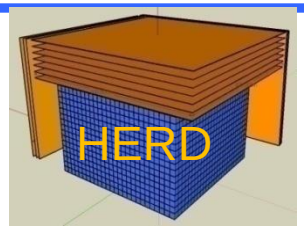


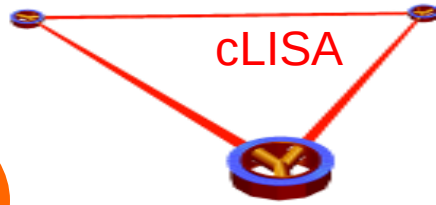


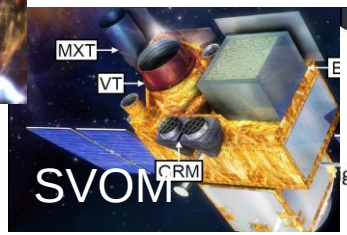
good economy + international collaboration

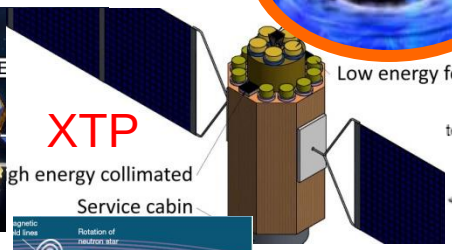


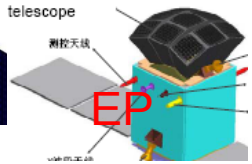


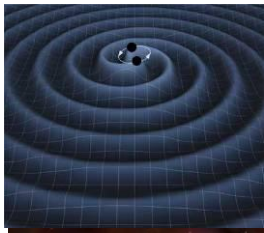


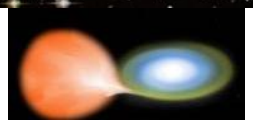


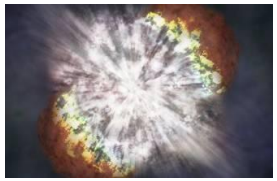


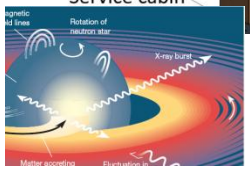


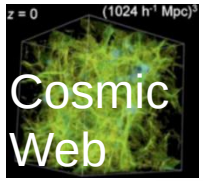


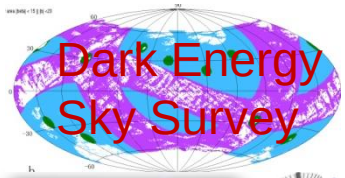


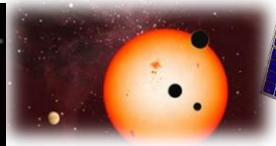


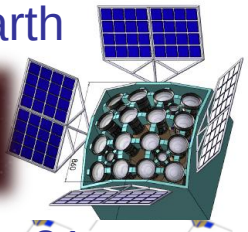


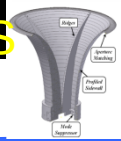












e/CR /GRW

γ-ray

X-ray

UV

IR/O

radio

2015

2020

2025

2030