China's Future Space High Energy Astrophysical Missions

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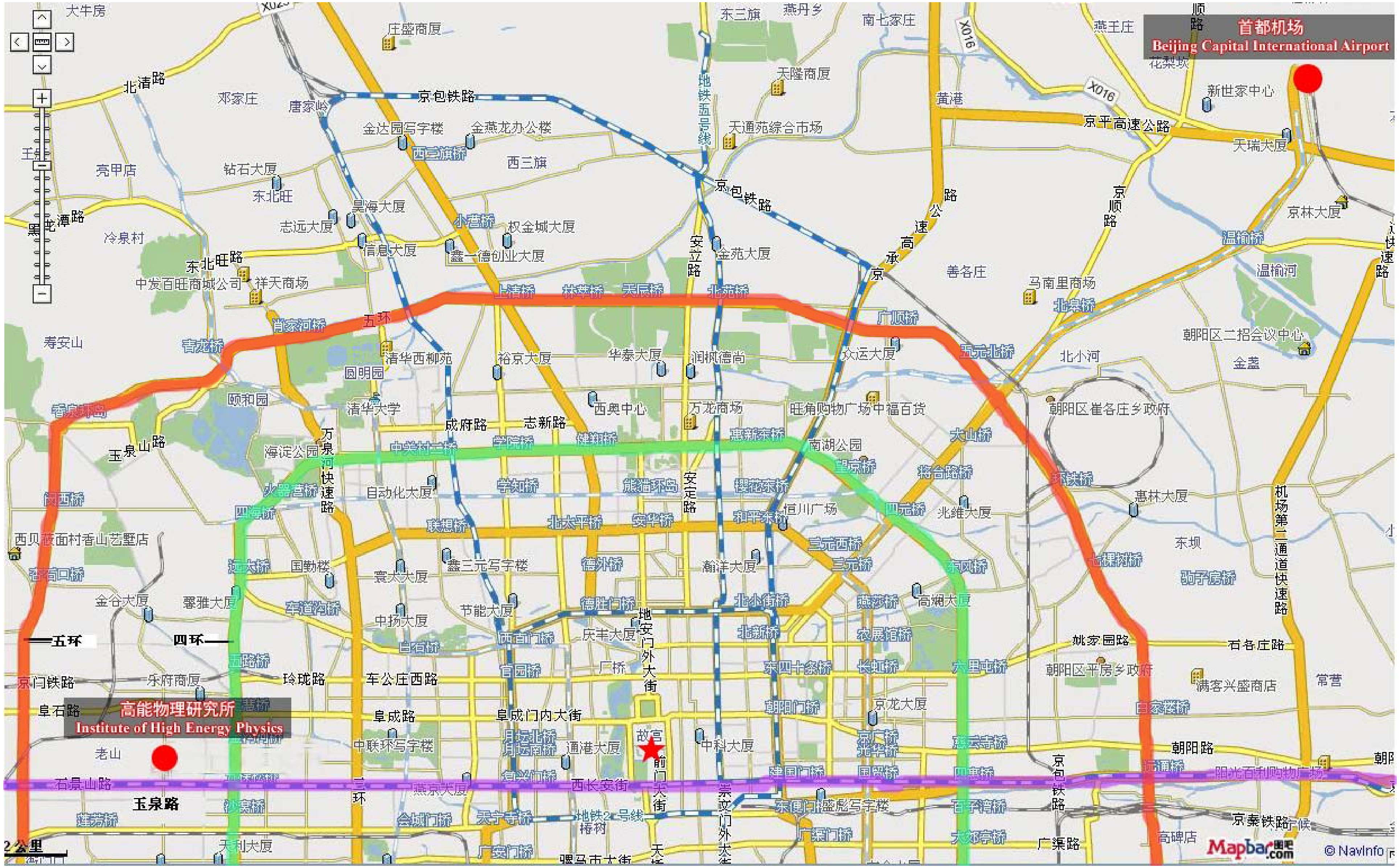
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马南里商场
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寰太大厦
鑫三元写字楼
瀚洋大厦
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金谷大厦
馨雅大厦
中扬大厦
节能大厦
庆丰大厦
地安门外大街
姚家园路
石各庄路
乐府商厦
玲珑路
车公庄西路
京门铁路
朝阳区平房乡政府
满客兴盛商店
常营
阜石路
阜成路
阜成门内大街
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朝阳路
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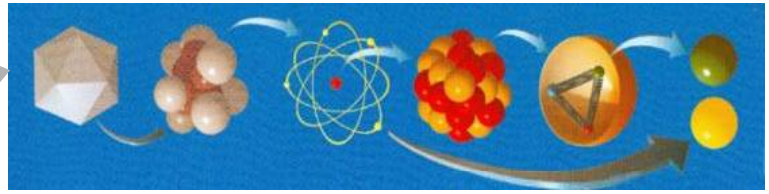
东便门盛彪写字楼
天利大厦
广渠路
高碑店
京秦铁路
机场第二通道快速路
2公里

IHEP Campus Map

Research in IHEP: >1300 fulltime staff

Science goals

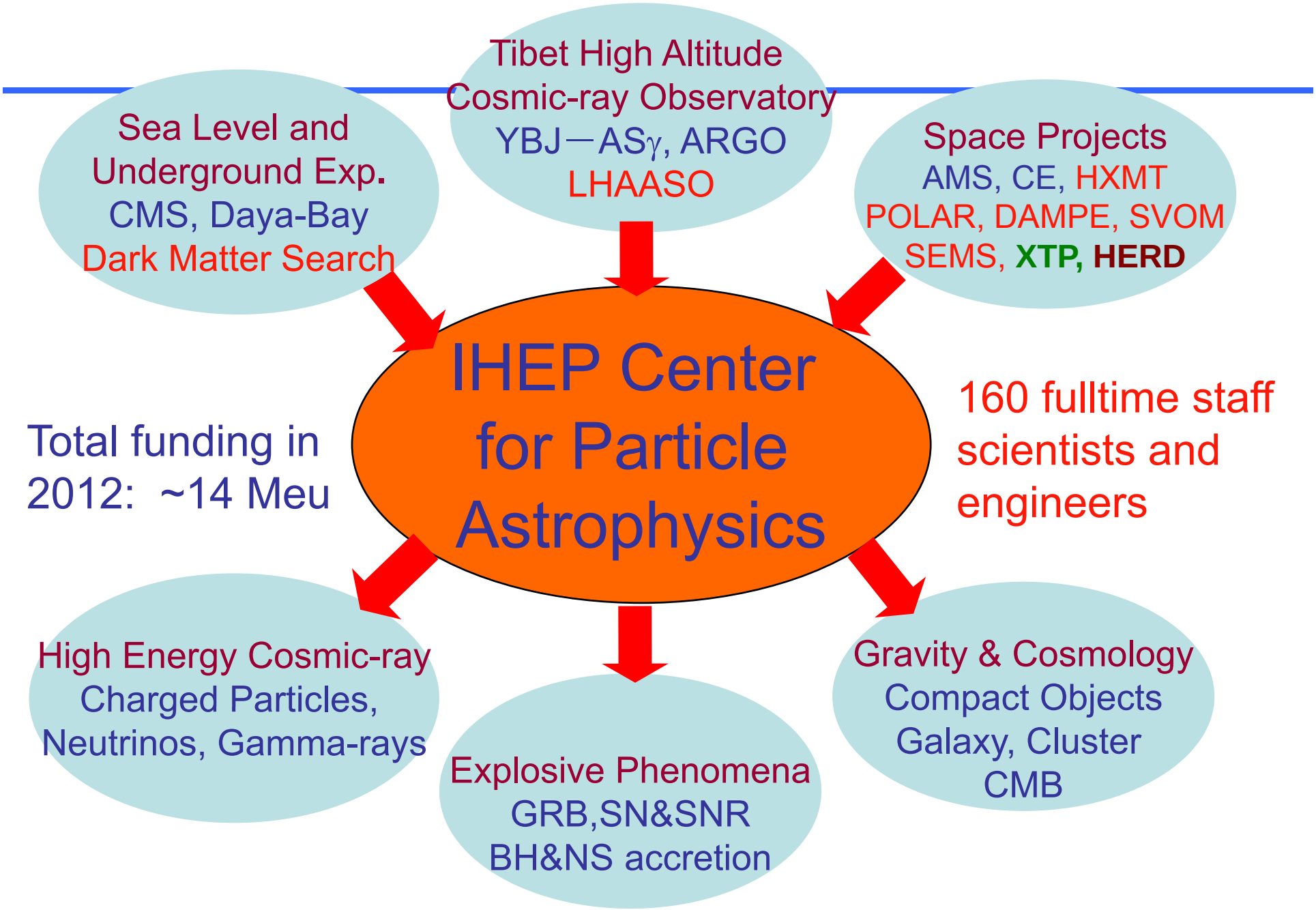


Fundamental structure of matter and evolution of the universe

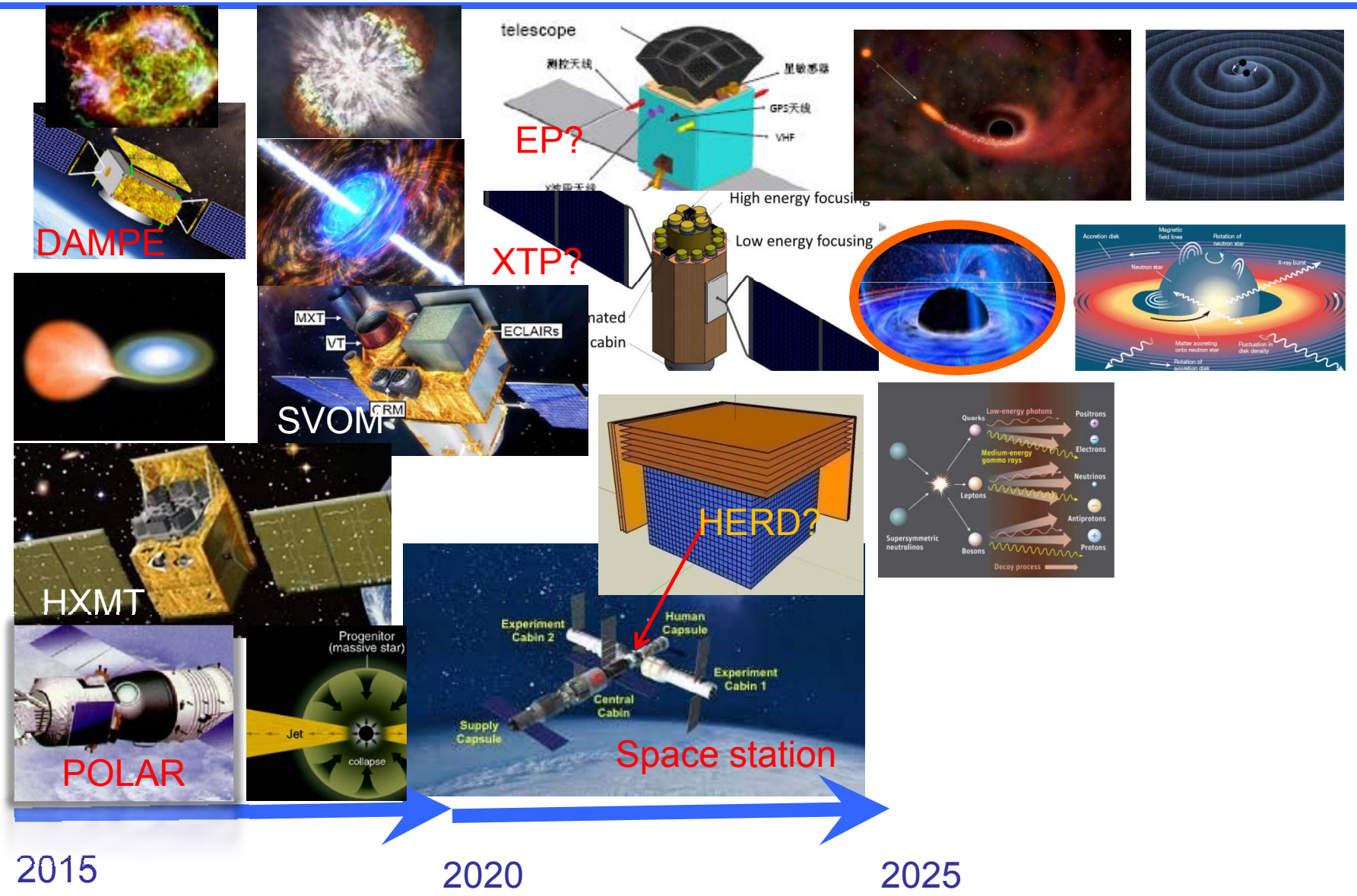
Total funding in 2012: ~140 Meu

Multi-discipline Platform

Collider, Synchrotron, Underground lab, high-altitude cosmic ray observatory, space instruments


Tibet High Altitude
Cosmic-ray Observatory
YBJ－ASγ, ARGO
LHAASO
Sea Level and
Underground Exp.
CMS, Daya-Bay
Dark Matter Search
Space Projects
AMS, CE, HXMT
POLAR, DAMPE, SVOM
SEMS, XTP, HERD
IHEP Center
for Particle
Astrophysics
Total funding in
2012: ~14 Meu
160 fulltime staff
scientists and
engineers
High Energy Cosmic-ray
Charged Particles,
Neutrinos, Gamma-rays
Explosive Phenomena
GRB,SN&SNR
BH&NS accretion
Gravity & Cosmology
Compact Objects
Galaxy, Cluster
CMB

China's High Energy Astrophysical Missions

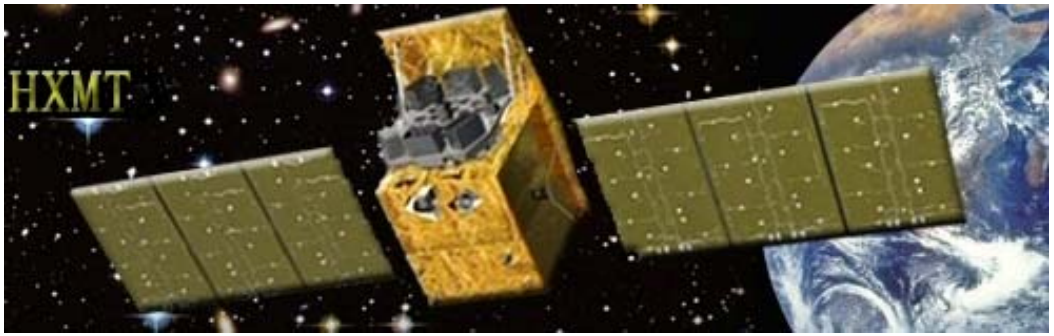


Hard X-ray Modulation Telescope (HXMT)

- 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

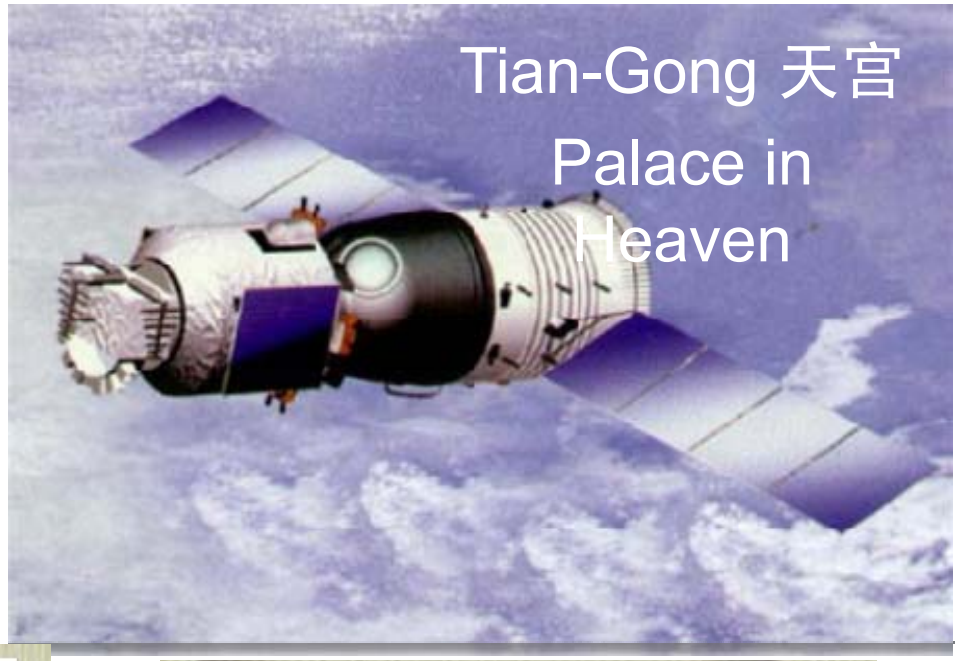
Entered Phase-B (Engineering model phase) in 12/2011

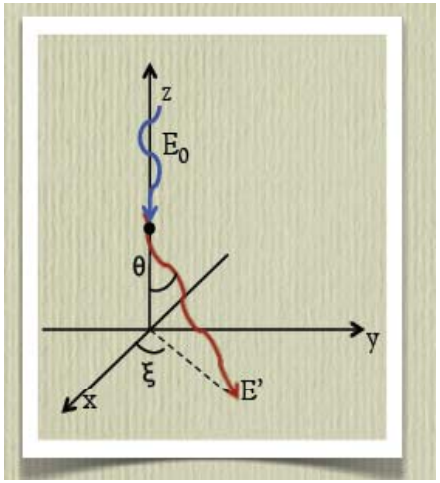
Now finishing the construction of the qualification models

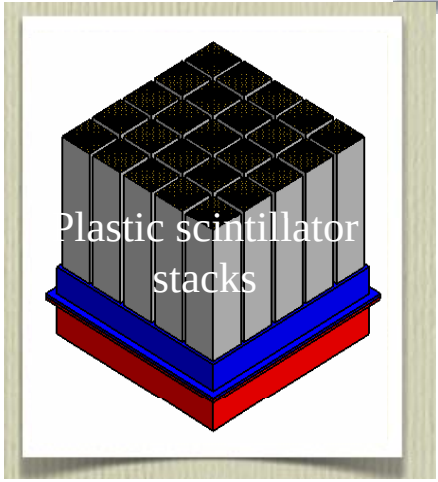
Planned launch time: Late 2014 or 2015

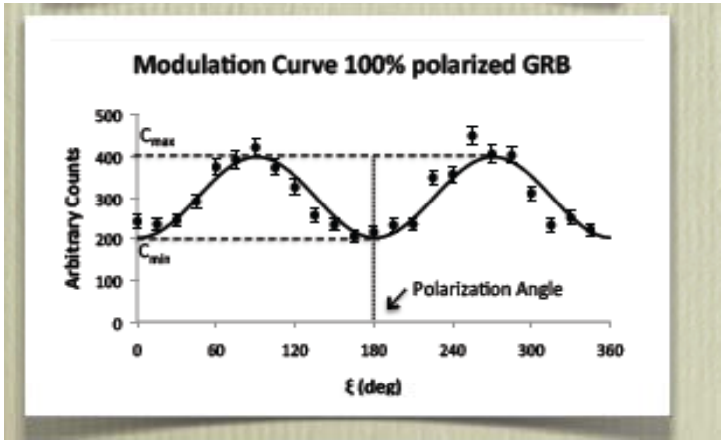
Gamma-ray burst polarization : POLAR

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



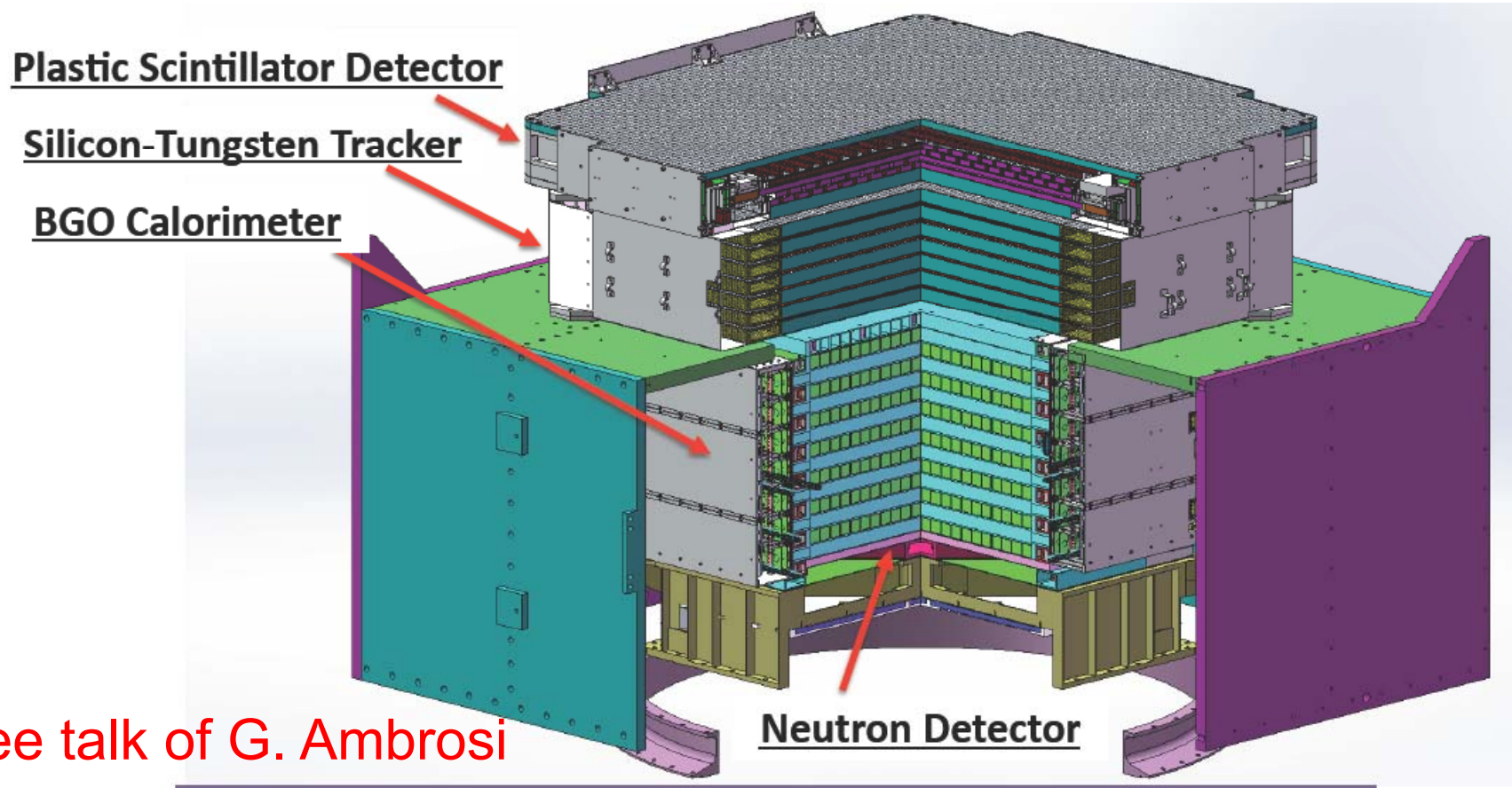






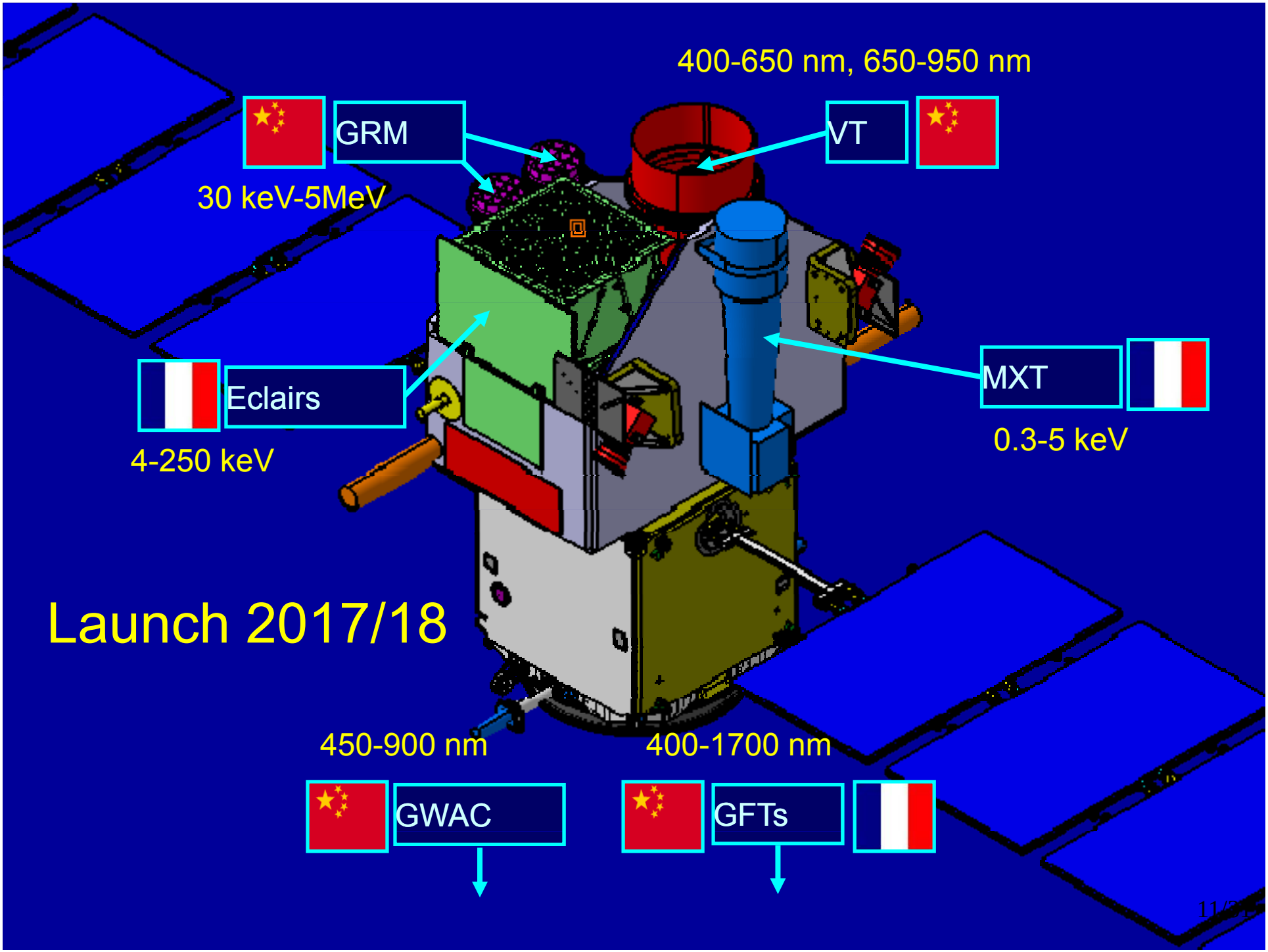
Instrument concept proposed by N. Produit, et al., NIM (2005)

DAMPE: launch in 2015



See talk of G. Ambrosi

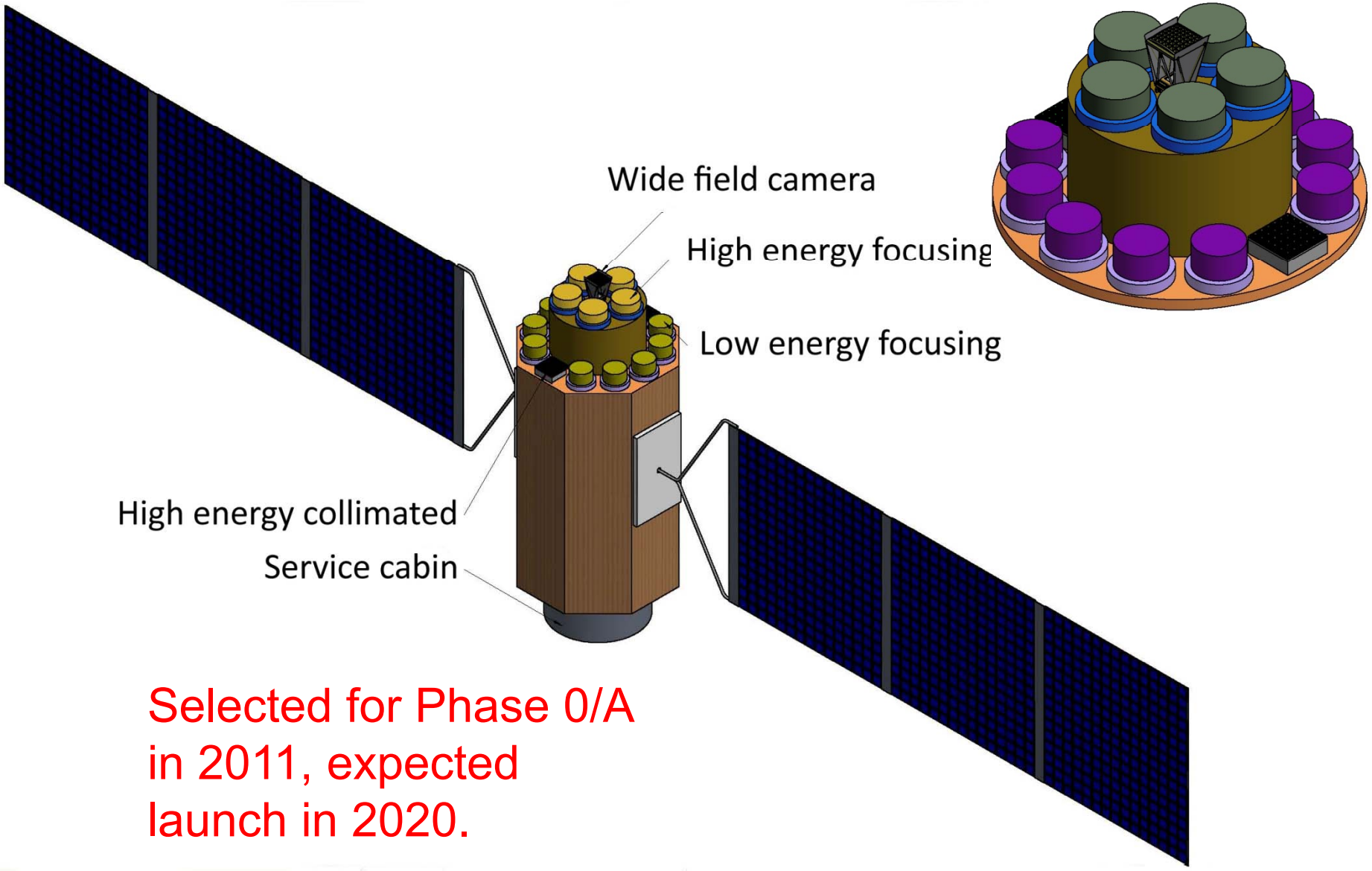
W converter + thick calorimeter (total 33 X_0) + precise tracking + charge measurement ➡ high energy γ-ray, electron and CR telescope


400-650 nm, 650-950 nm
GRM
VT
30 keV-5MeV
Eclairs
MXT
4-250 keV
0.3-5 keV
Launch 2017/18
450-900 nm
400-1700 nm
GWAC
GFTs

X-ray Timing and Polarization (XTP) mission

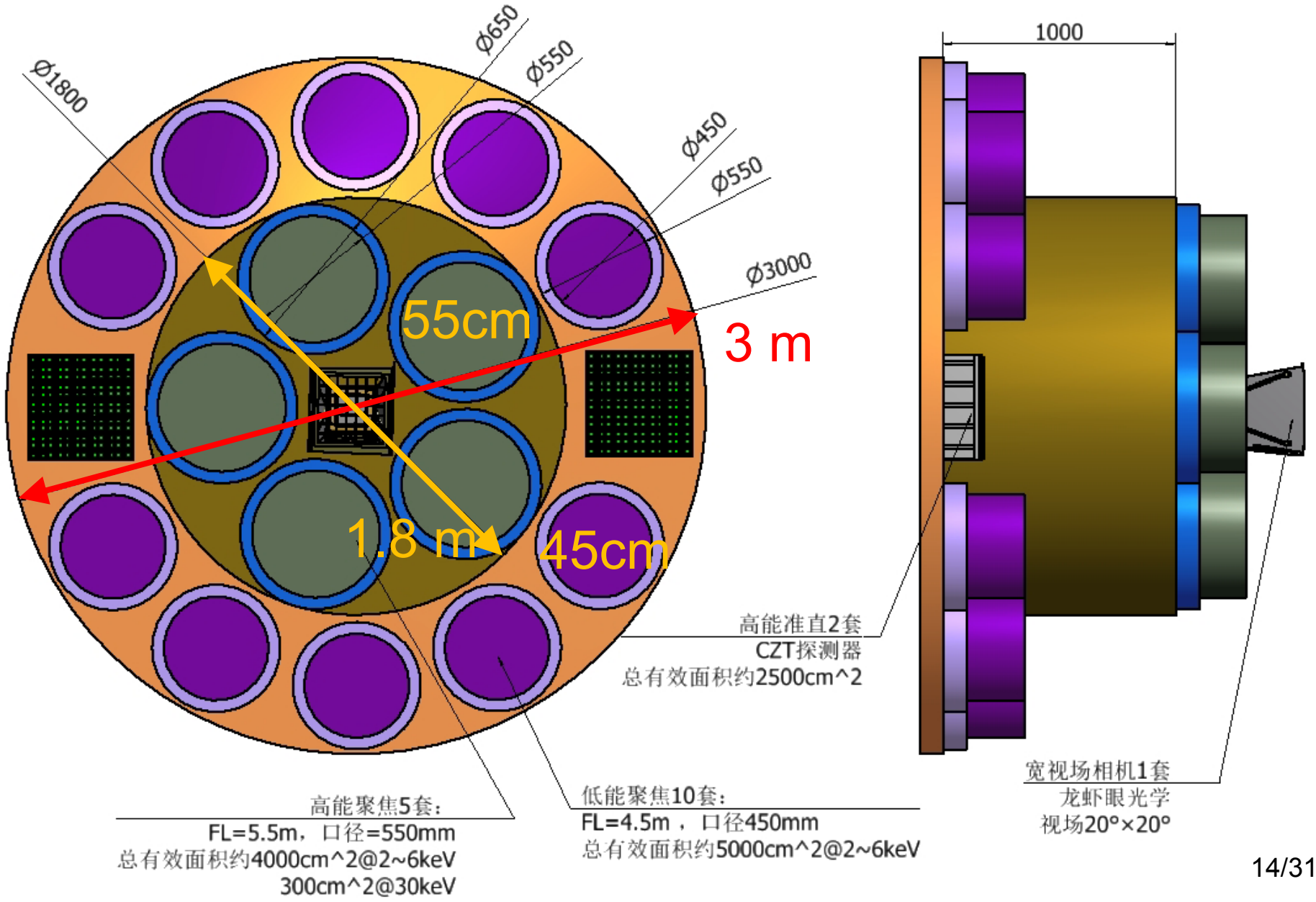
- Science: 1-singularity (BH); 2-stars (NS and QS); 3-extremes (gravity, density, magnetism) ($s^1s^2e^3$;1奇2星3极端）
  - Precise light curve + energy spectrum: Matter under extreme conditions, NS state equation, BH parameters
  - Polarization of X-ray: BH spin, nature of magnetars, pulsar radiation mechanism…
- 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
- CAS-MPG WG: explore possible China-Europe collaboration on an intermediate X-ray mission around 2020.

XTP satellite

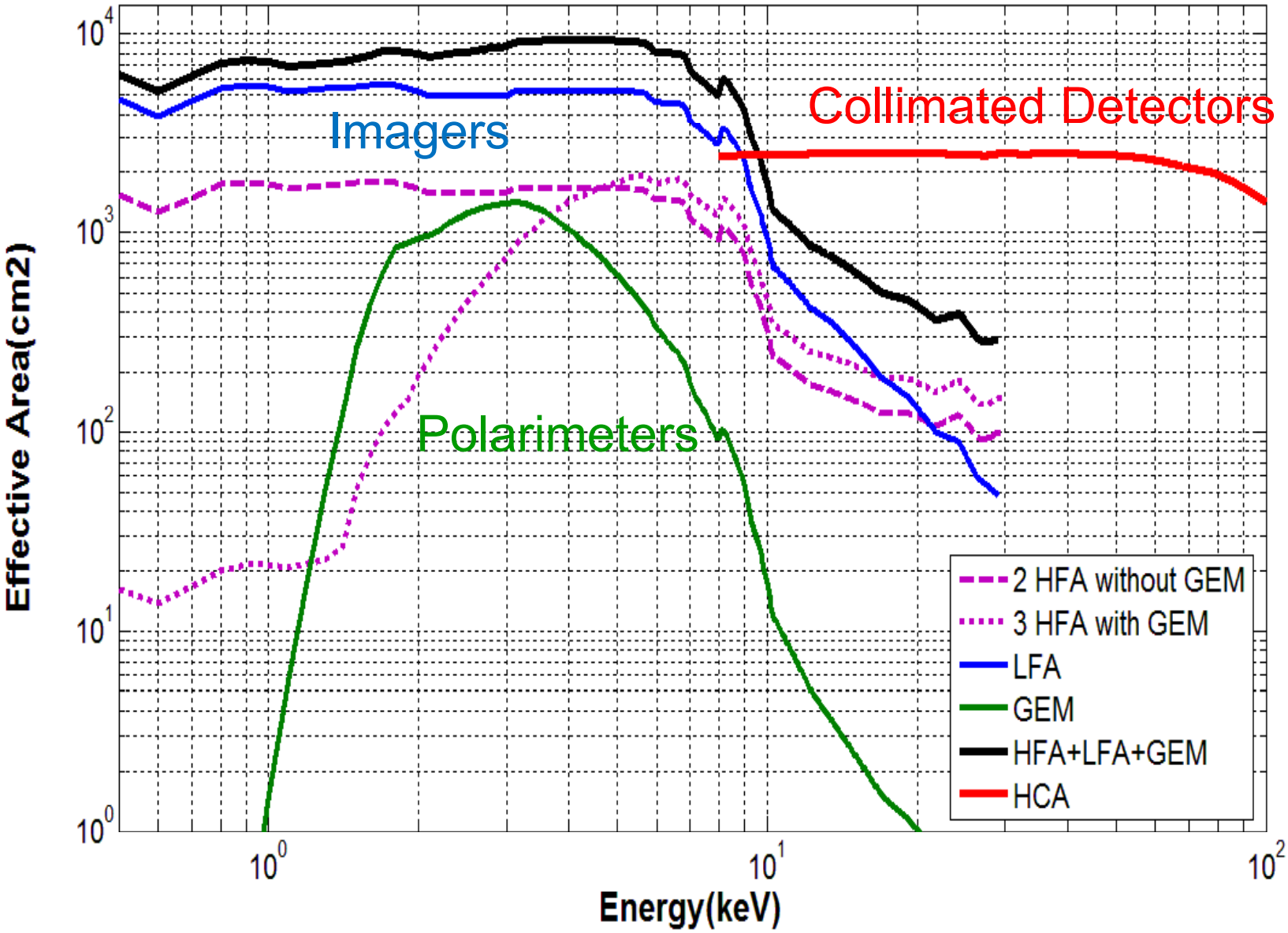


Selected for Phase 0/A in 2011, expected launch in 2020.

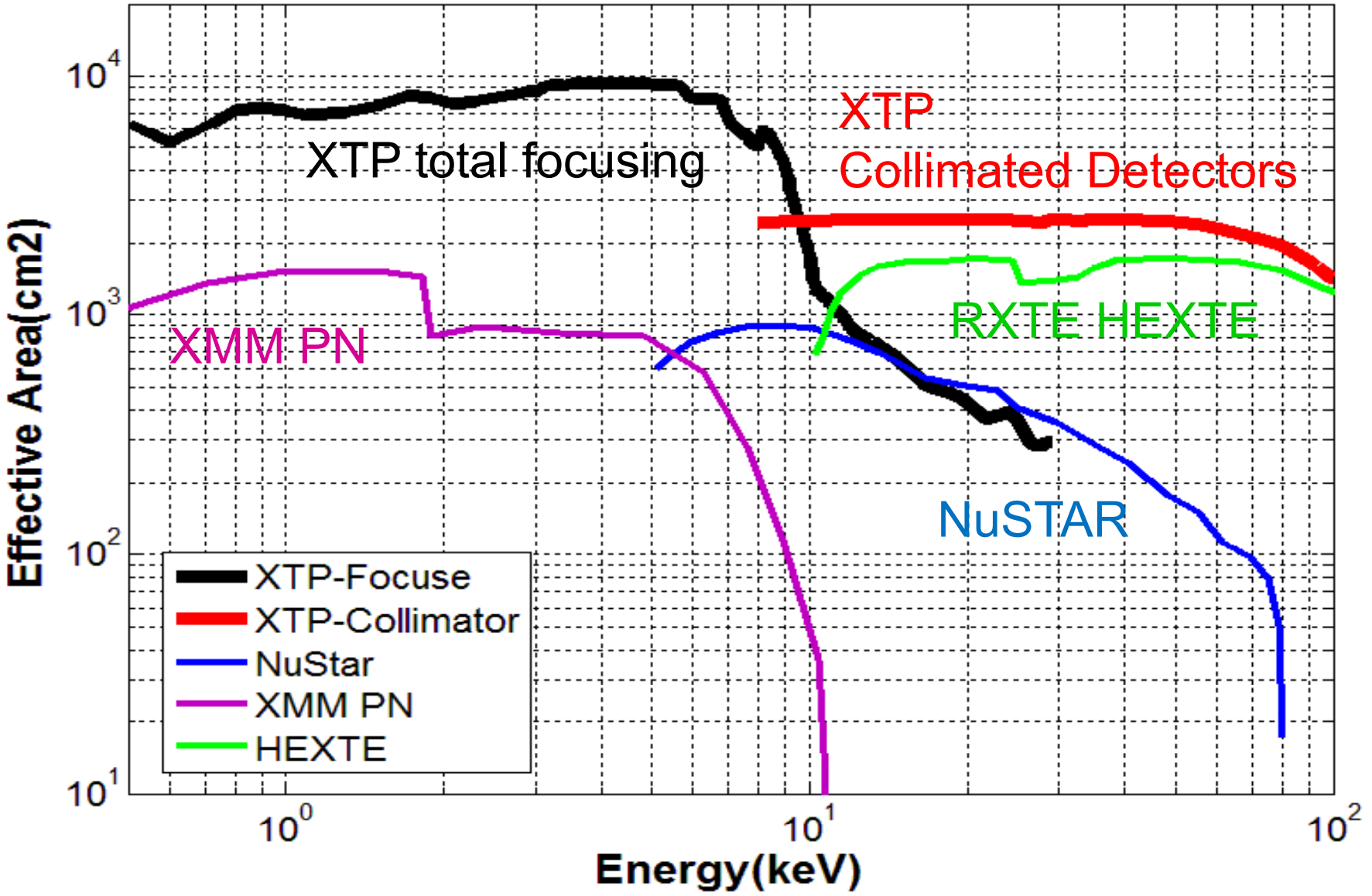
XTP payload layout

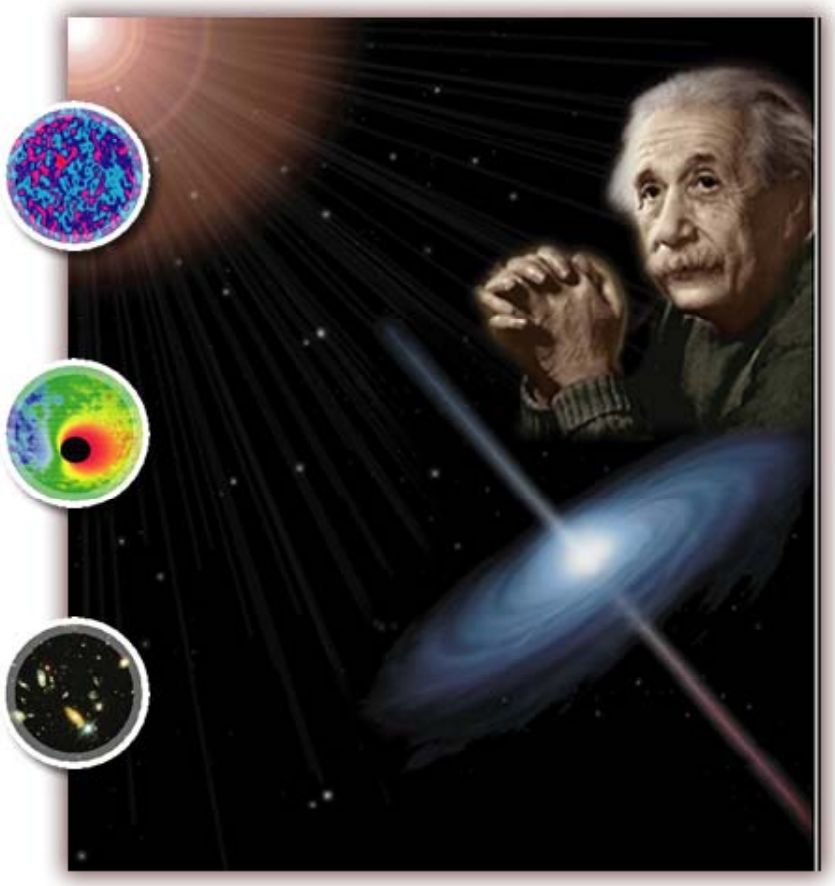


Effective Areas



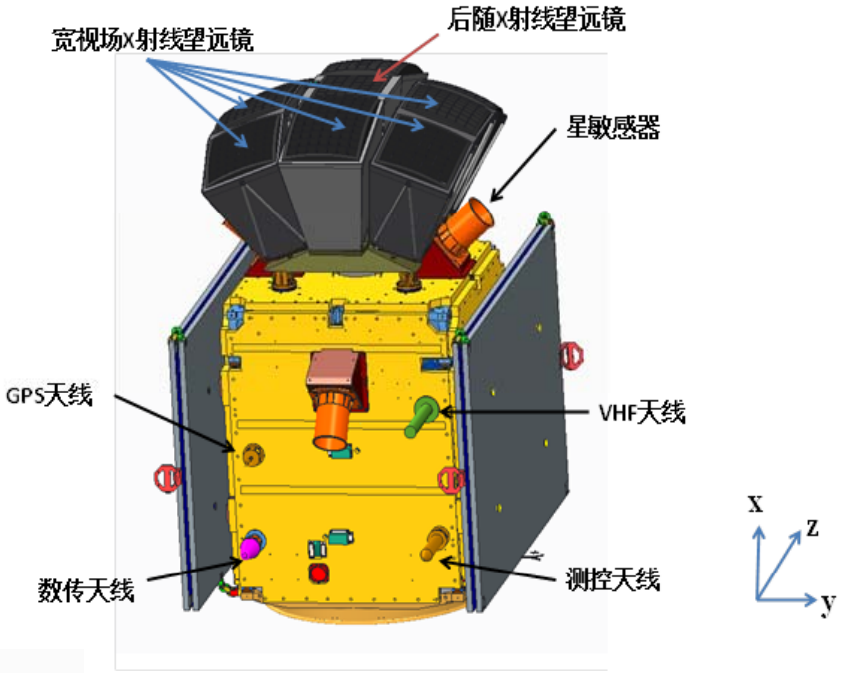
Effective Areas Comparison

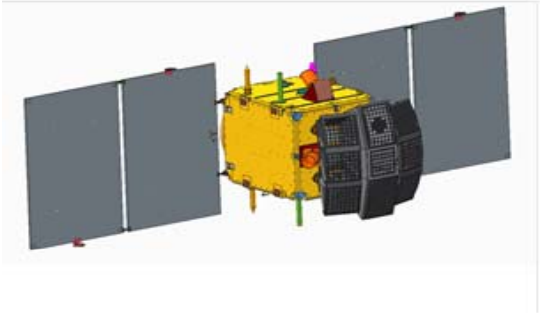


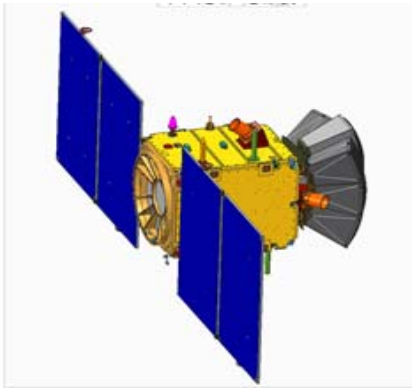


Einstein Probe (EP)

Lobster-eye optics

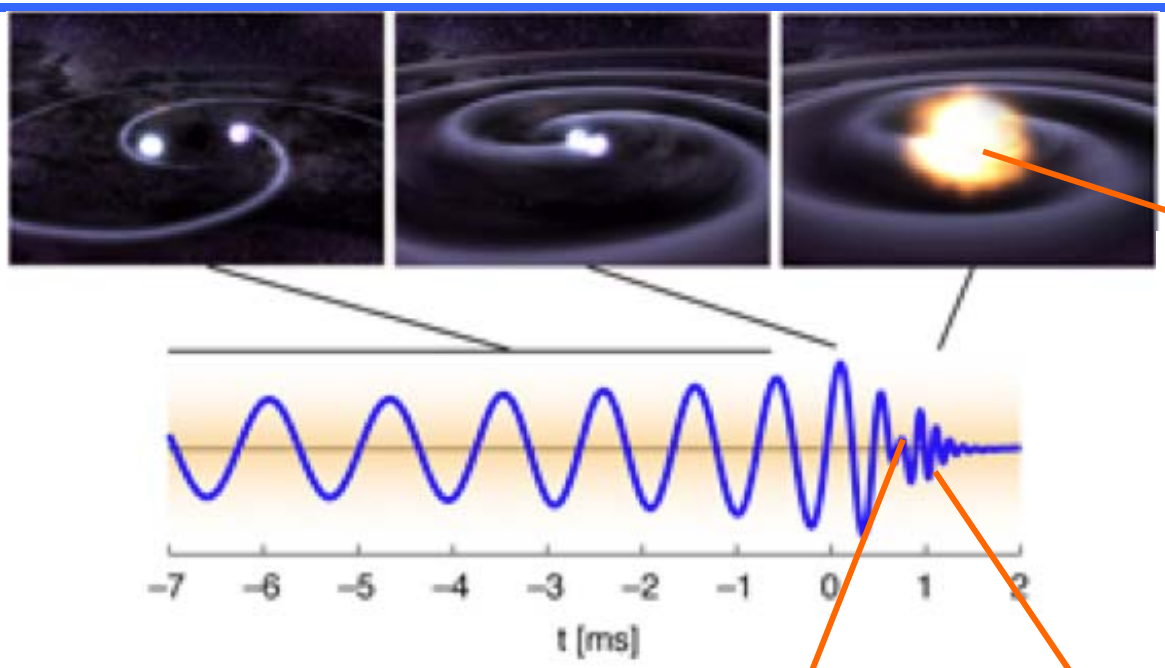


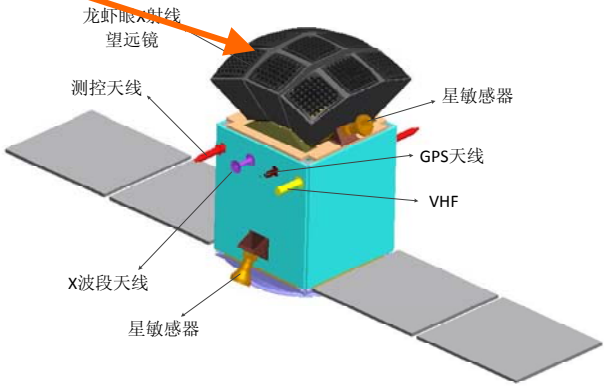




Selected for Phase 0/A in 2013, expected launch in 2020.

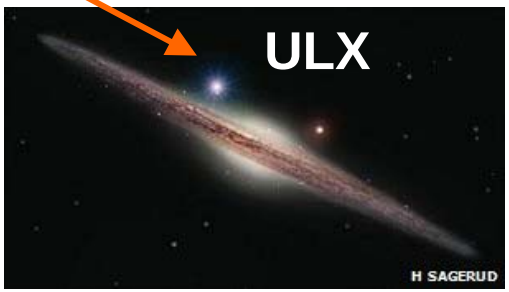
EM counterparts of GW explosions

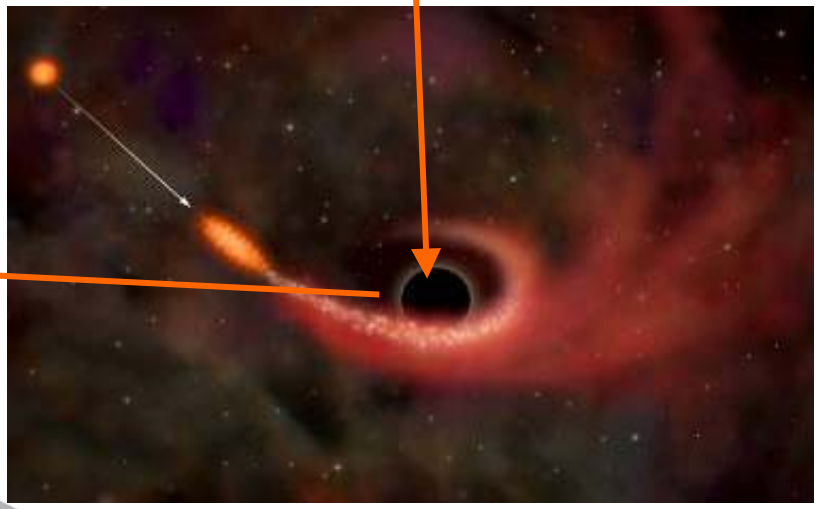


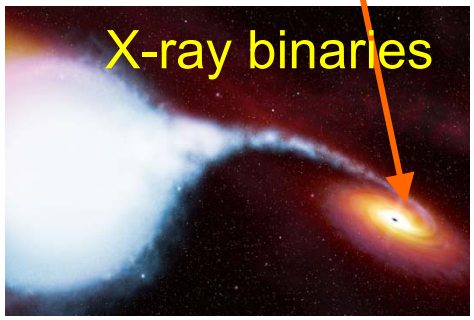


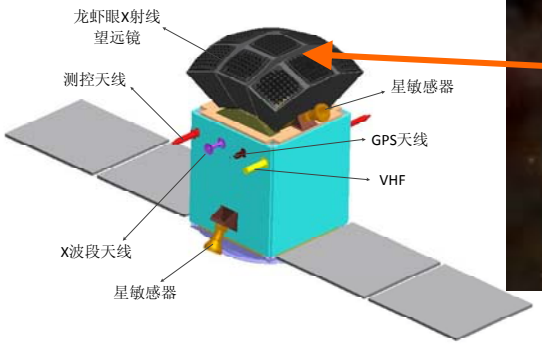
~2018

Black holes of all scales in the universe

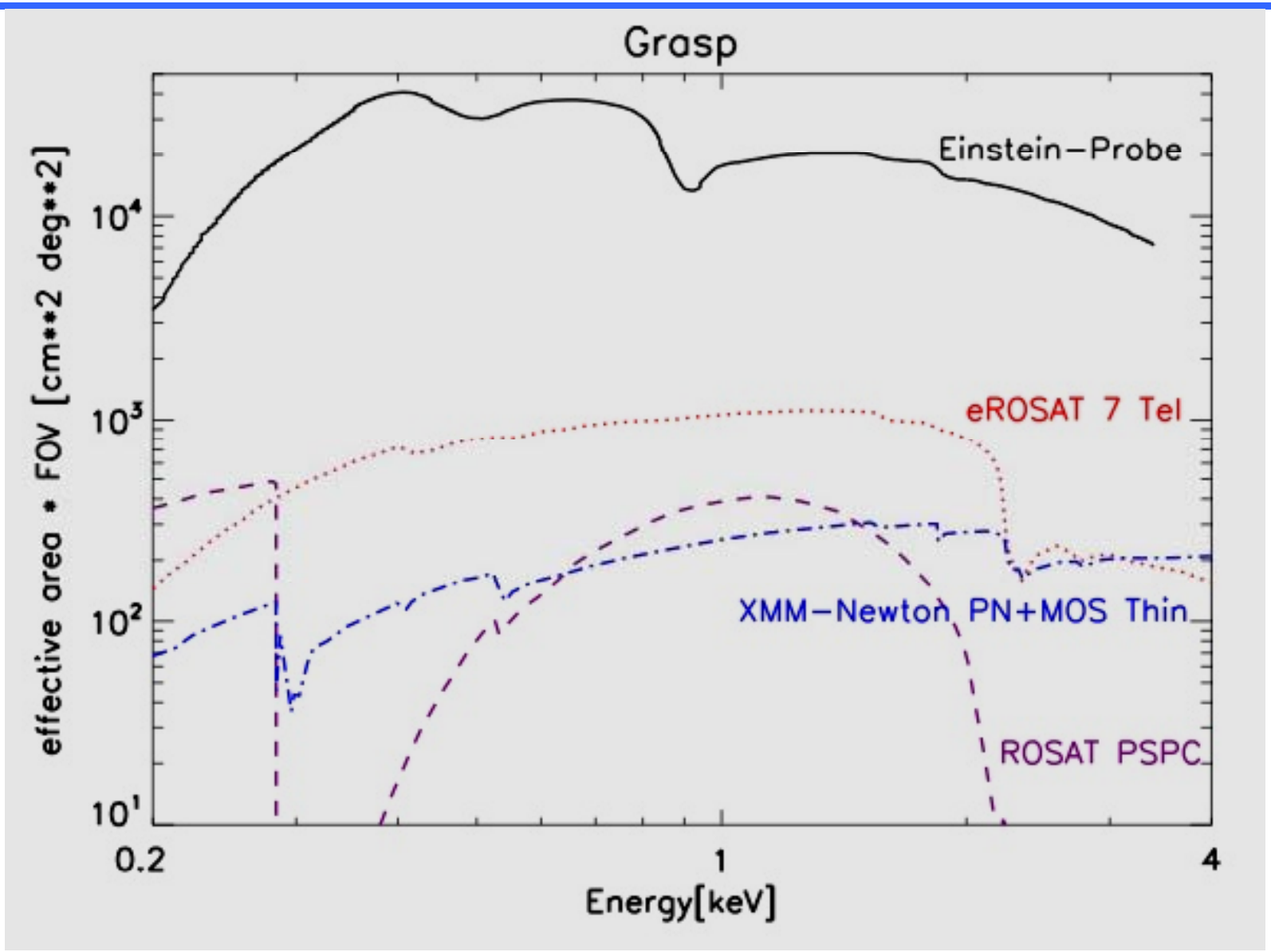








Capability of Einstein Probe



China's Space Station Program

- Three phases
  - 1st phase: so far 7 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 ~2018.

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

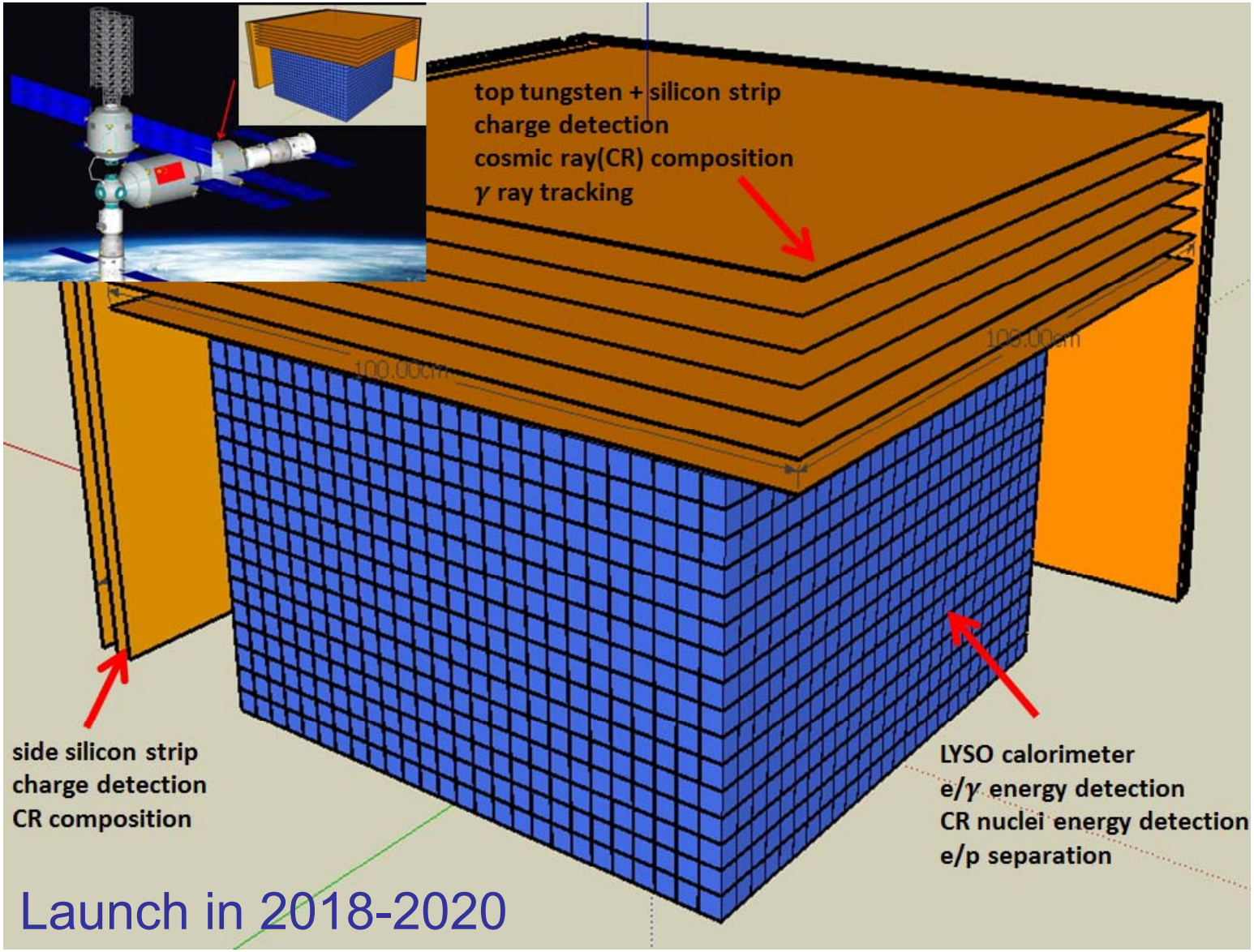

background
Gamma-ray
HERD
electron
proton
He
Dark matter particle

Science goals and requirements for HERD

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.

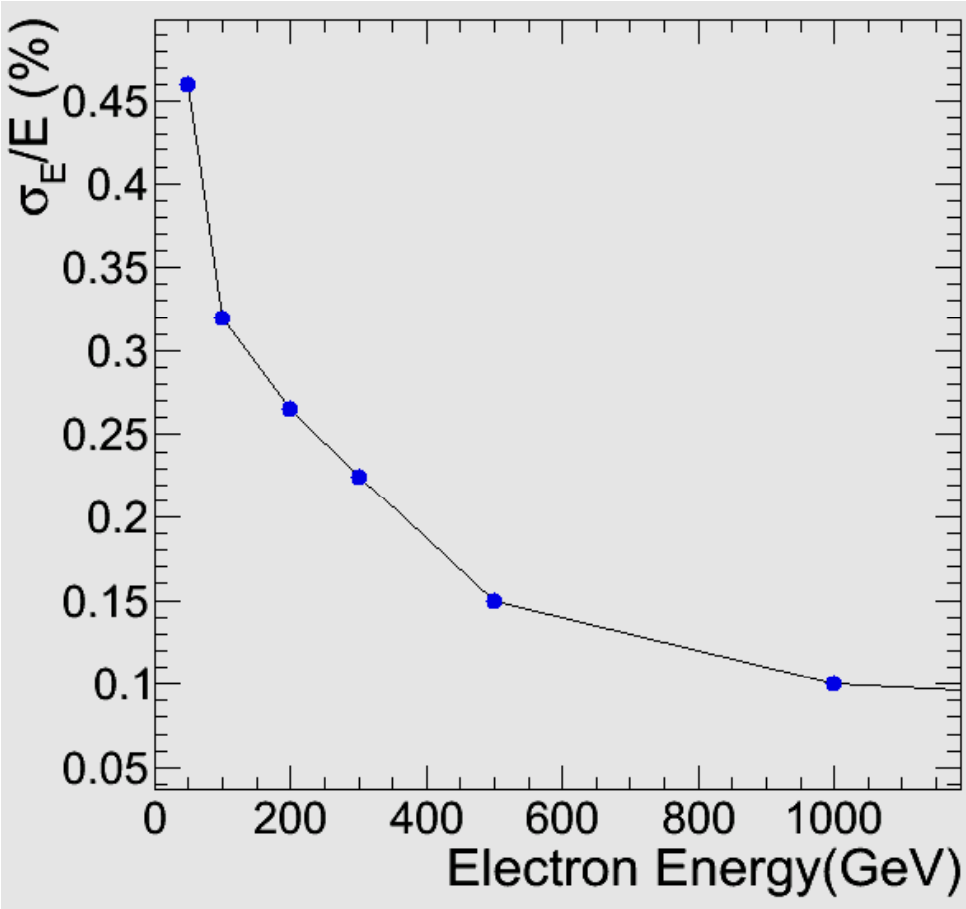
HERD Baseline design

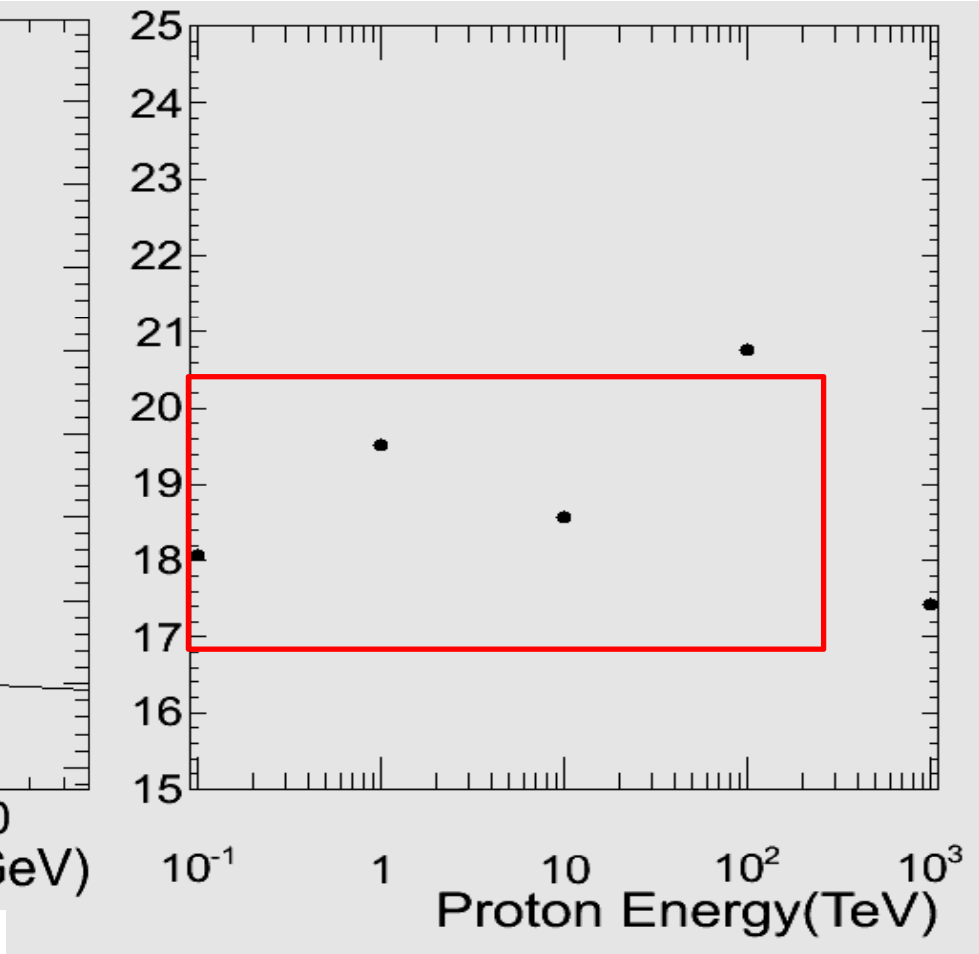


Characteristics of all components

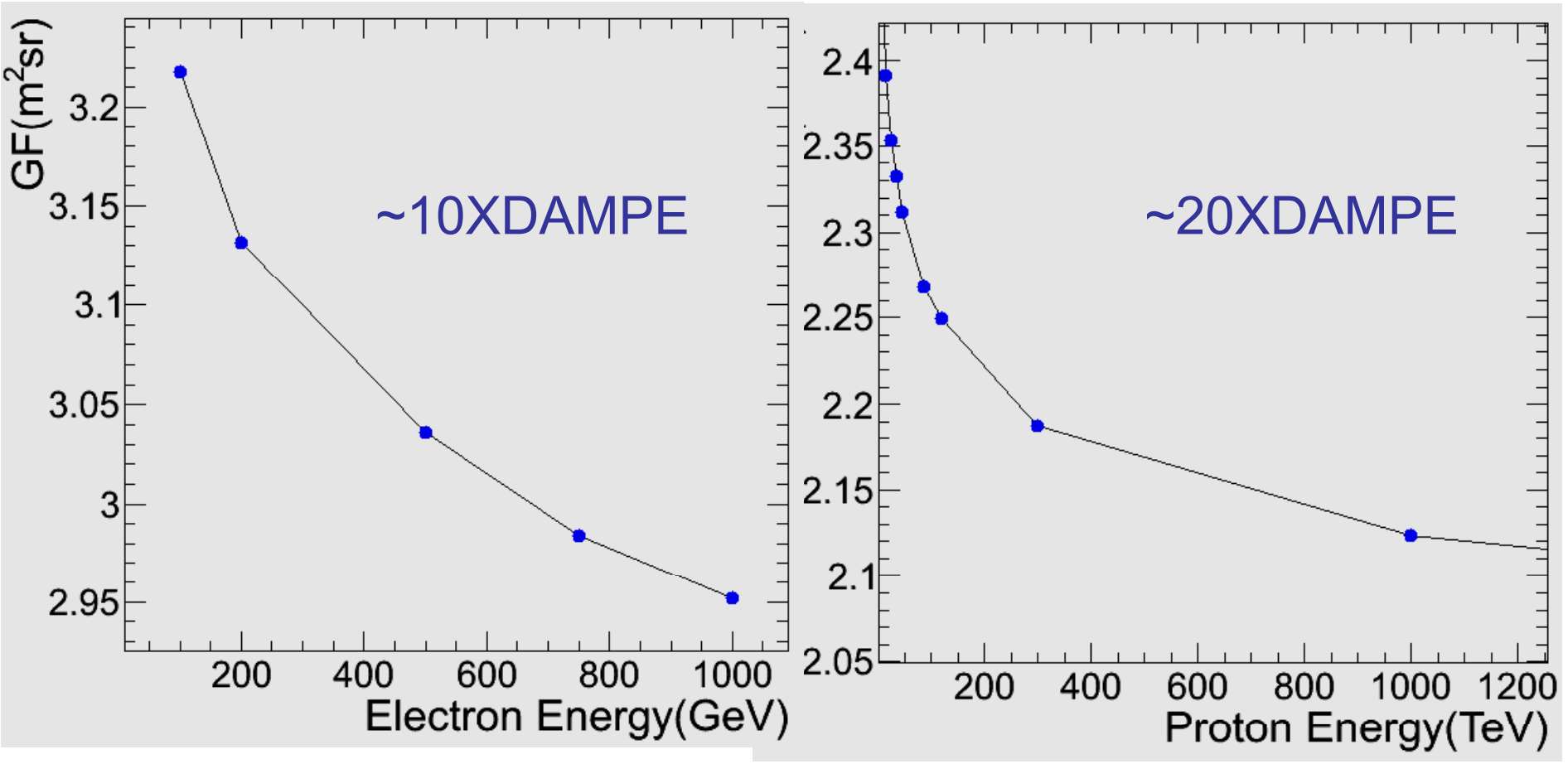
	type	size	X0,λ	unit	main functions
tracker (top)	Si strips	70 cm × 70 cm	2 X0	7 x-y (W foils)	Charge Early shower Tracks
tracker 4 sides	Si strips	65 cm × 50 cm	--	3 x-y	Nucleon Track Charge
CALO	9261 LYSO cubes	63 cm × 63 cm × 63 cm	55 X0 3 λ	3 cm × 3 cm × 3 cm	e/γ energy nucleon energy e/p separation

Simulation results: energy resolutions





HERD Geometrical Factor



Expected performance of HERD

γ (electron) energy range	tens of GeV-10TeV
nucleon energy range	up to PeV
γ angular resol. (silicon)	0.1^{o}
nucleon charge resol. (silicon)	0.1-0.15 c.u
γ (electron) energy resolution	1%@200GeV
proton energy resolution	20%
e/p separation power	10^{-6}
electron geometrical factor	3.1 m^2sr@200 GeV
proton geometrical factor	2.3 m^2sr@100 TeV

Performance Comparison

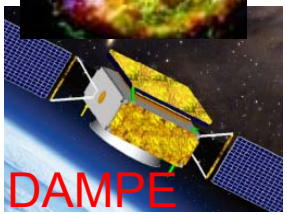
	X0(λ)	ΔE/E for e	e/p sep.	e GF* m^2sr@ 200GeV	p GF* m^2sr@ 100TeV
HERD (2020)	55(3)	1%	10^{-6}	3.1	2.3
AMS02 (2011)	17	2%	10^{-6}	0.12	0.12
DAMPE (2015)	31	1%	10^{-4}	0.3	0.12
ISS-CREAM (2015)**	20(1.5)	--	--	--	0.2

*Same event selections and cuts applied.

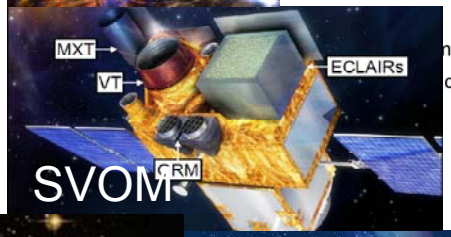
**~0.5 yr operation on SS approved.

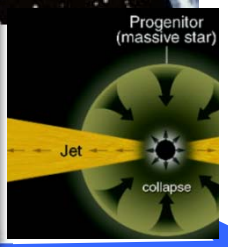
HERD can improve by at least ~10X for electrons and ~20X for cosmic rays over previous missions: this is necessary since it will operate much later.

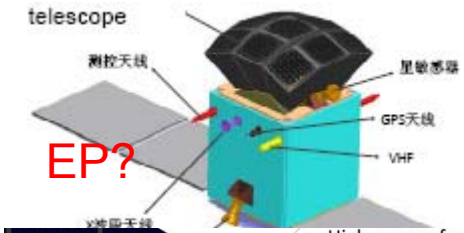
Summary: Collaborations Wanted!

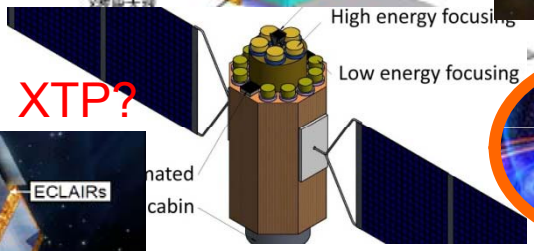



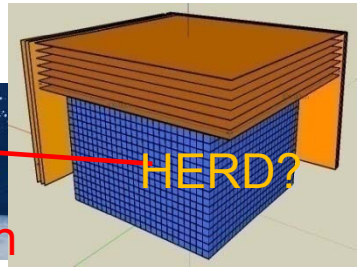


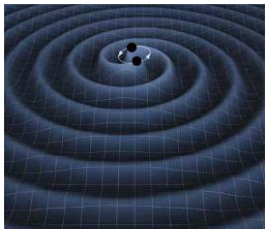



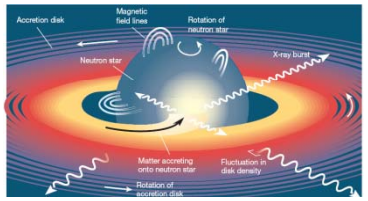


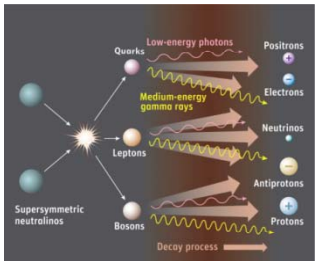


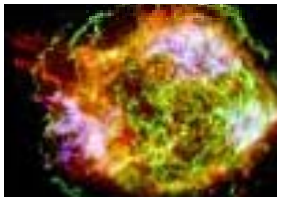










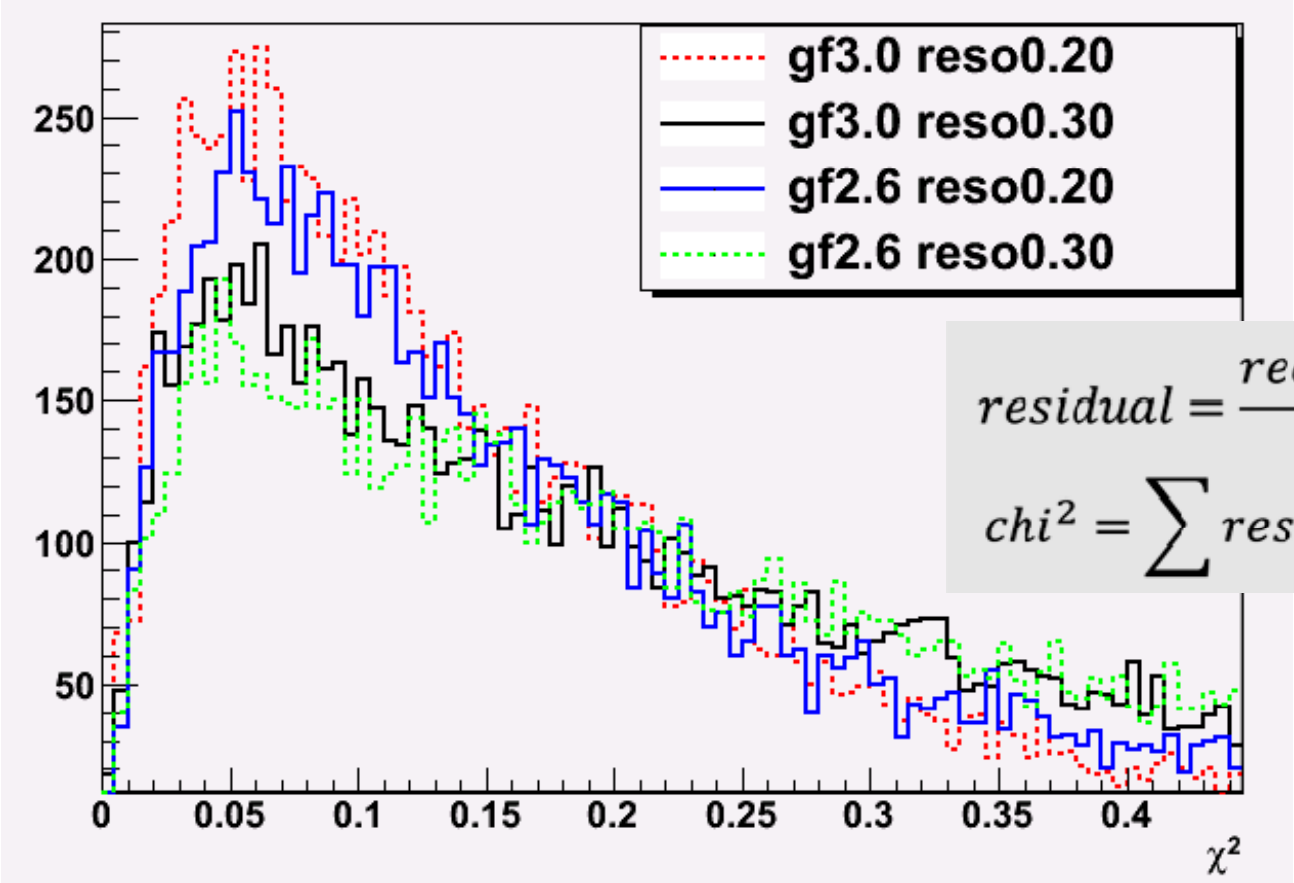
Wanted: international participations to EP, XTP and HERD at all levels!

zhangsn@ihep.ac.cn

2015 2020 2025

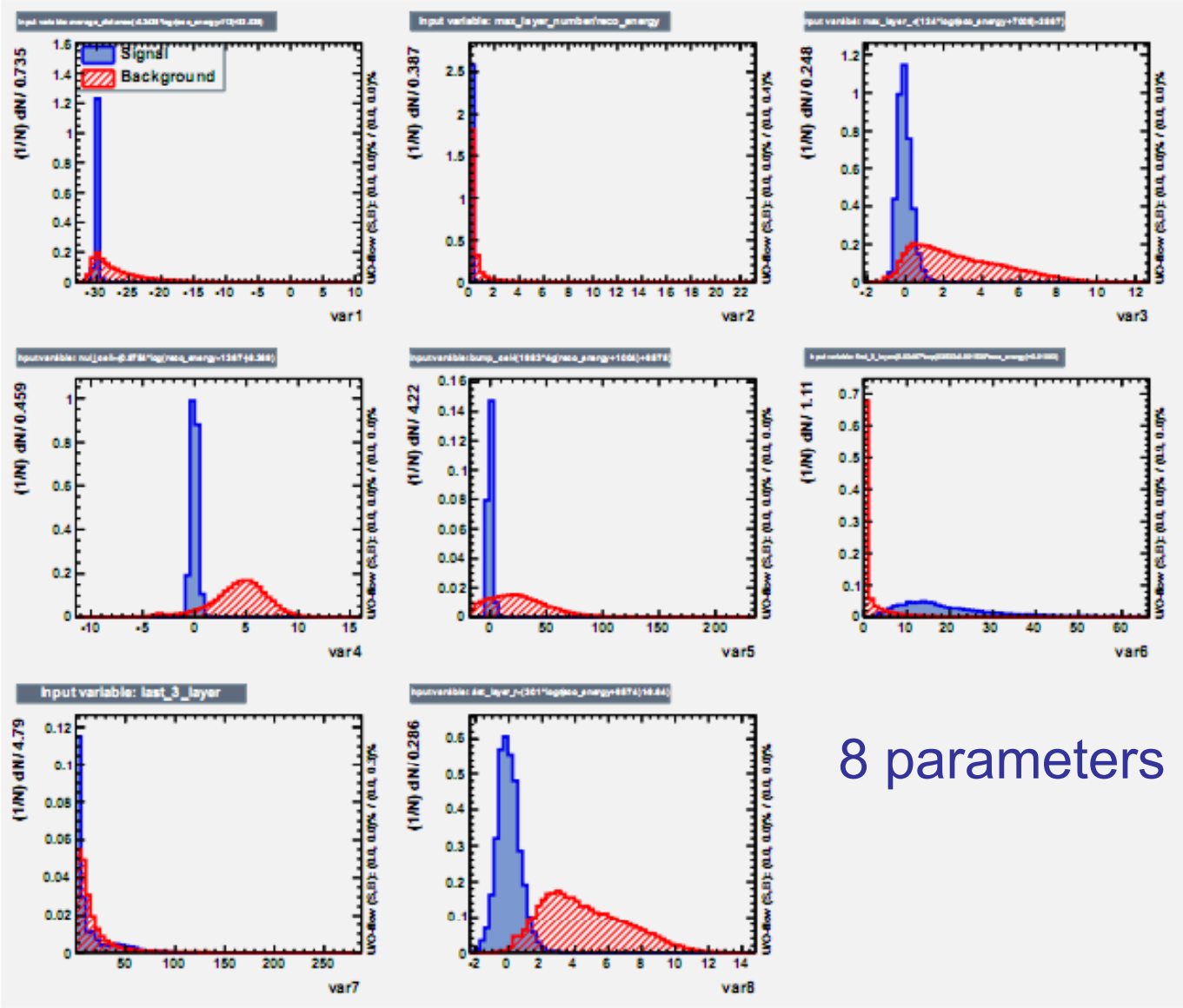
Backup Slides

HERD reconstruction vs. energy resol.



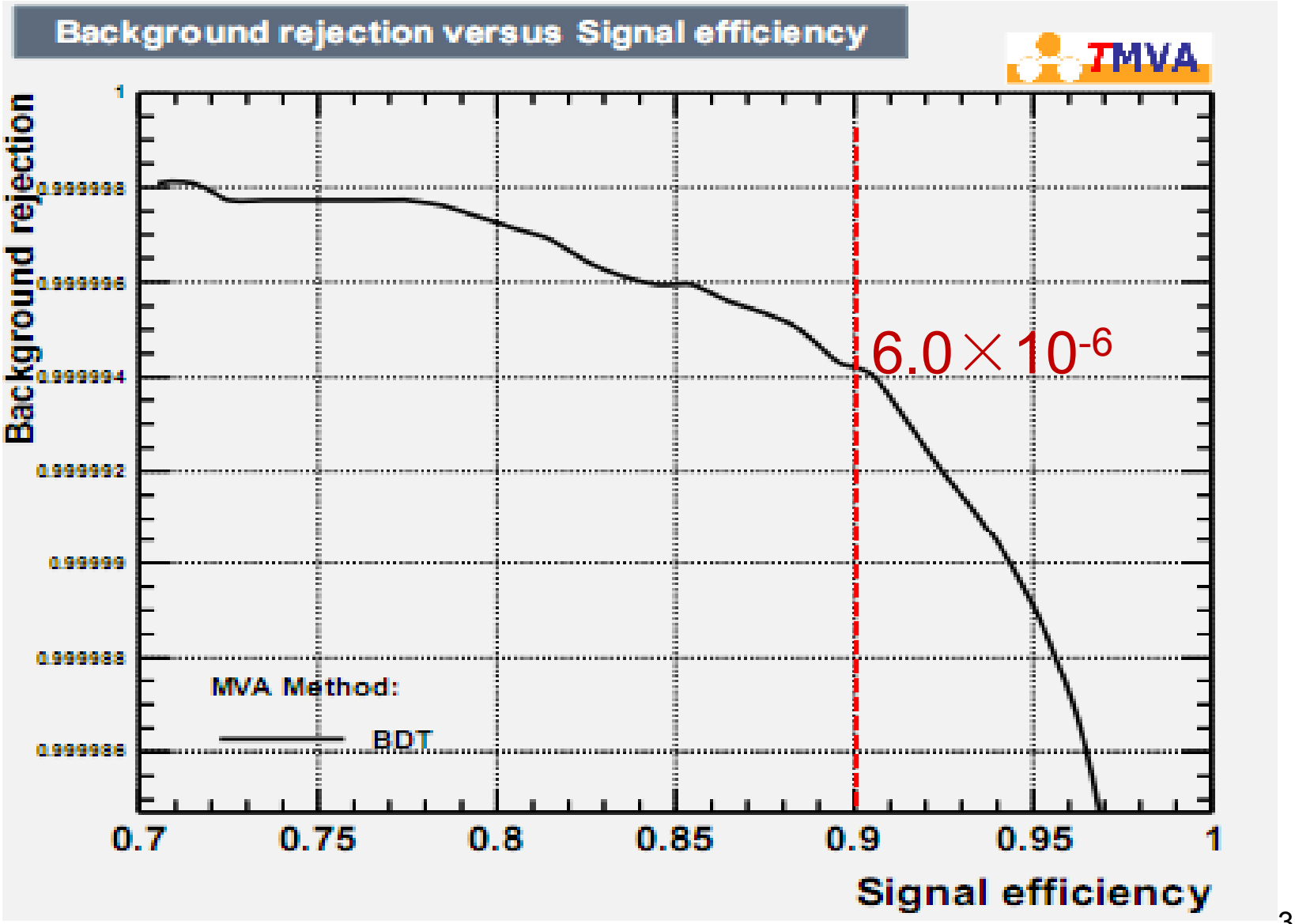
Under the weight limitation of 2 tons, resolution is more important for spectral reconstruction, based on the current design.

e/p separation (TMVA)

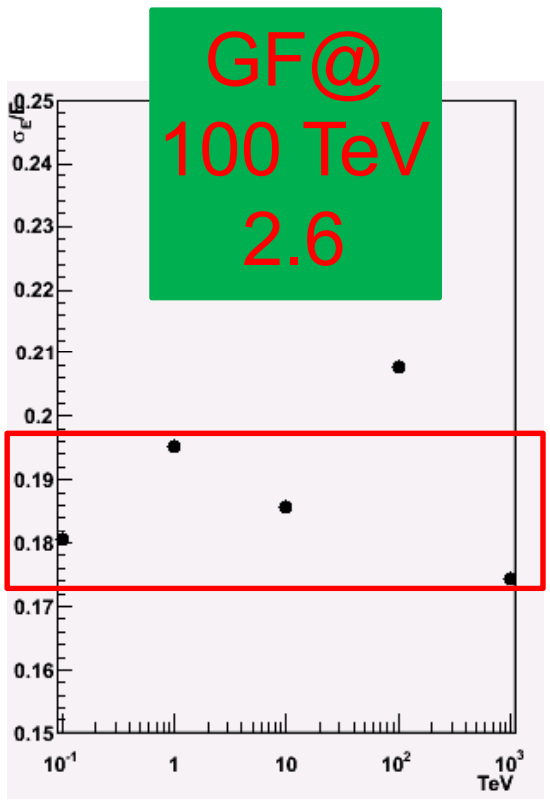


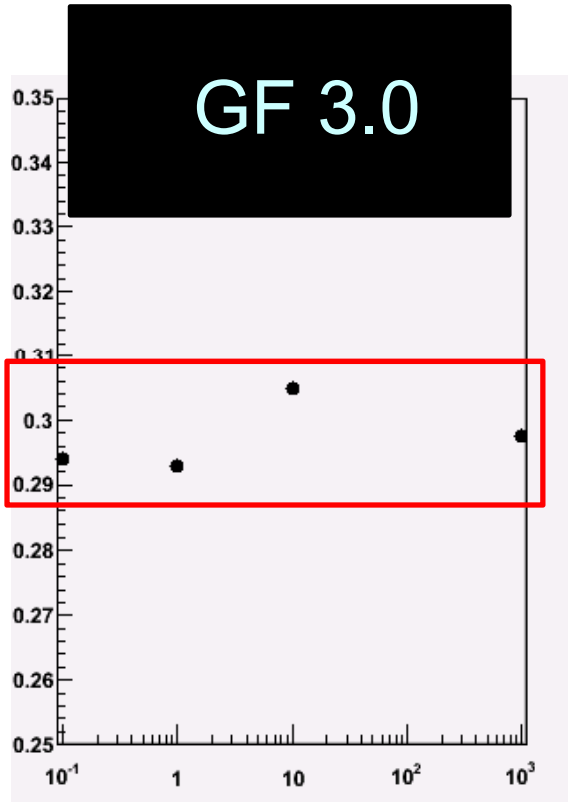
8 parameters

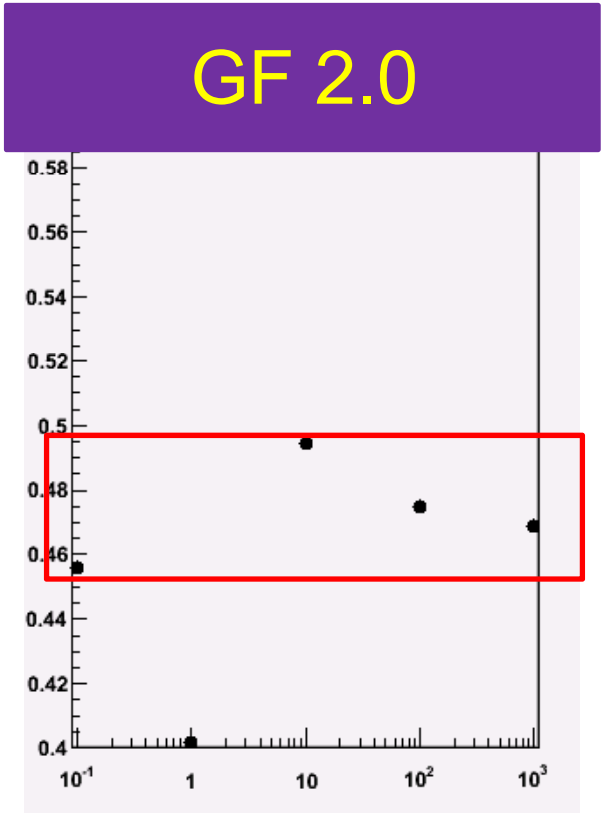
e/p separation (TMVA)



Proton energy resol. vs. detector thickness







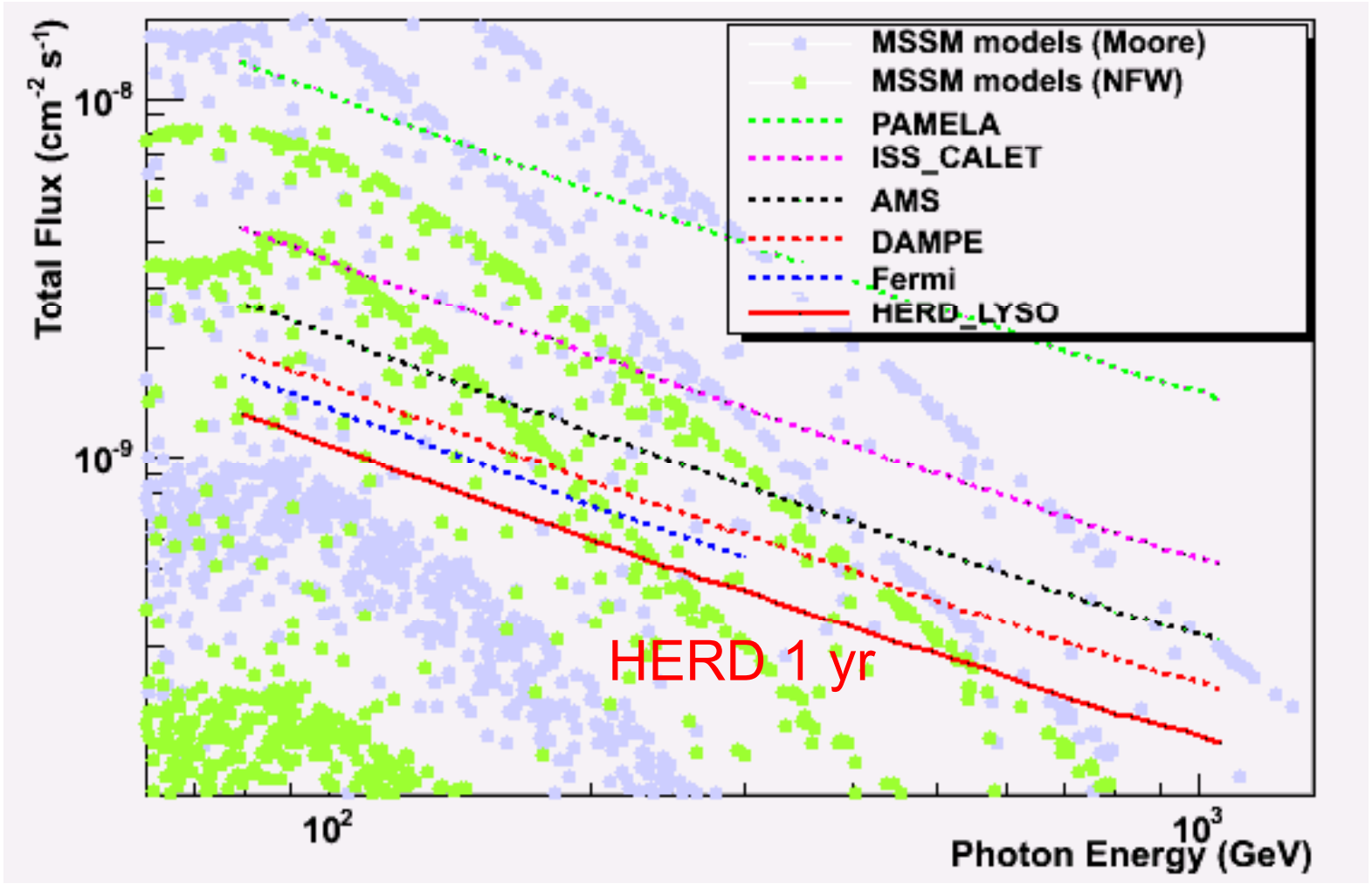
➔63*63*63cm
3 nucl.inter.length,
20% resolution

➔77*77*42cm
2 nucl.inter.length,
30% resolution

➔90*90*31cm
1.5 nucl.inter.length,
50% resolution

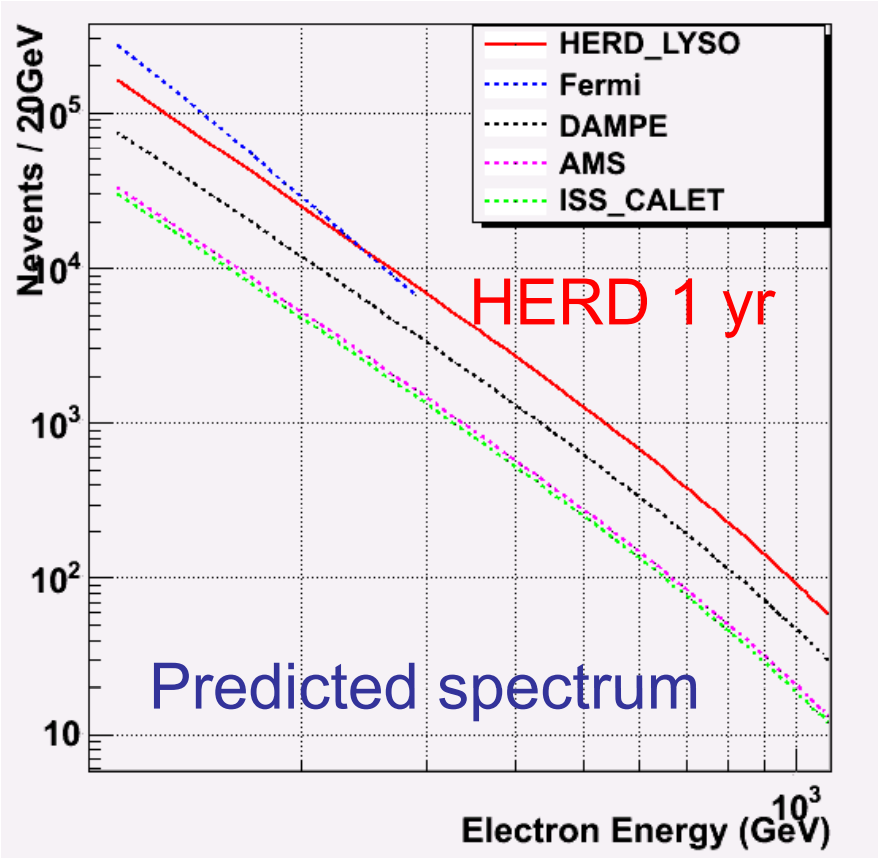
Total detector weight: 2000 kg

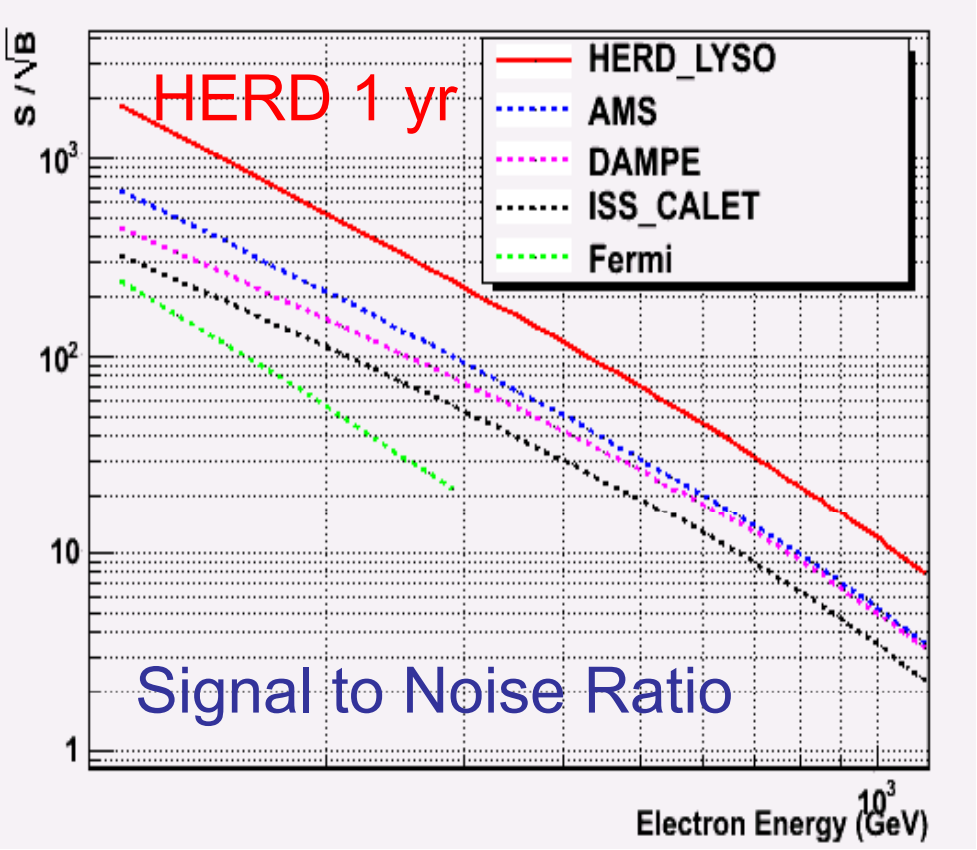
HERD sensitivity to gamma-ray line



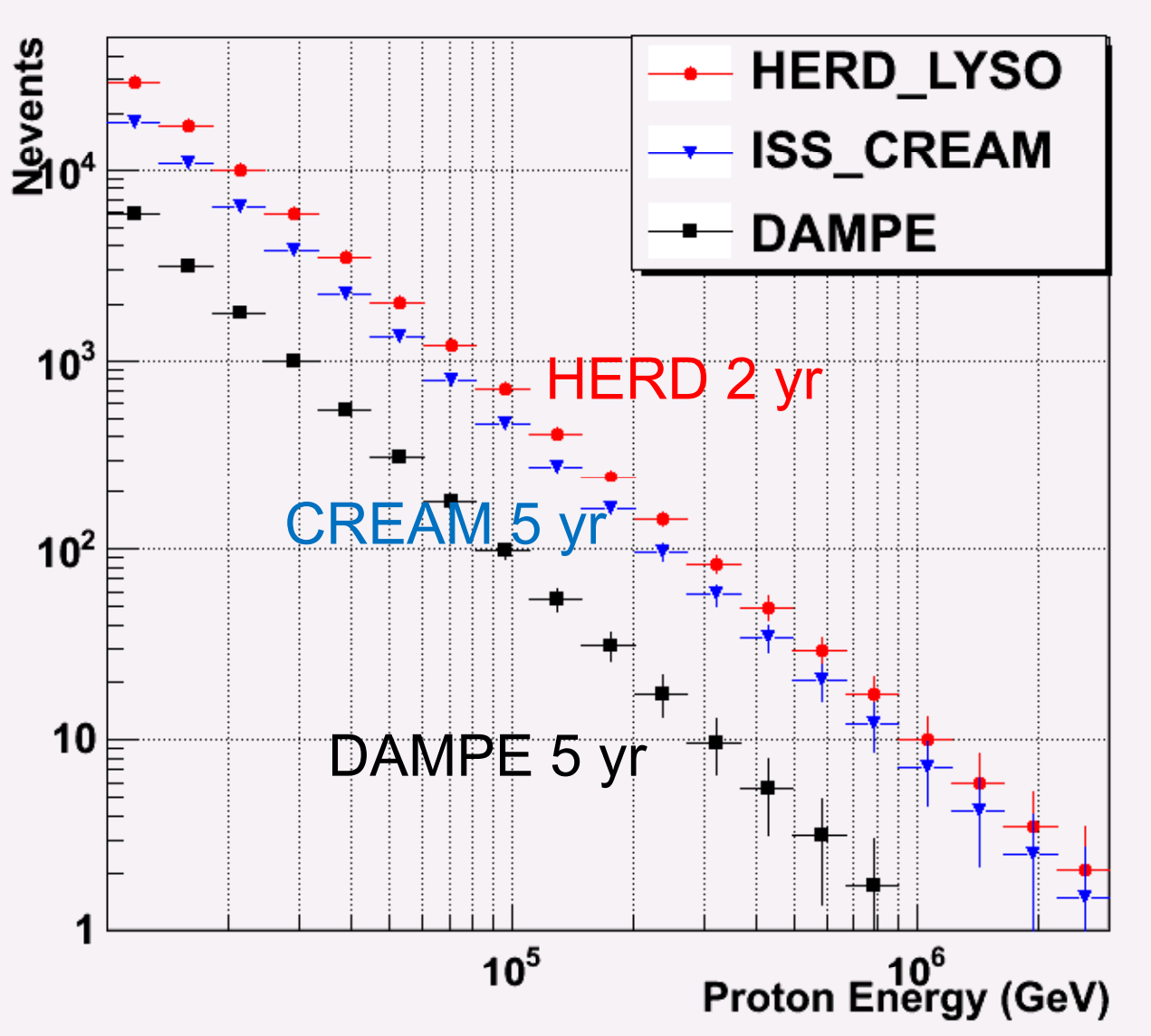
PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2021;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2020-2021

HERD electron detection capability: 2021





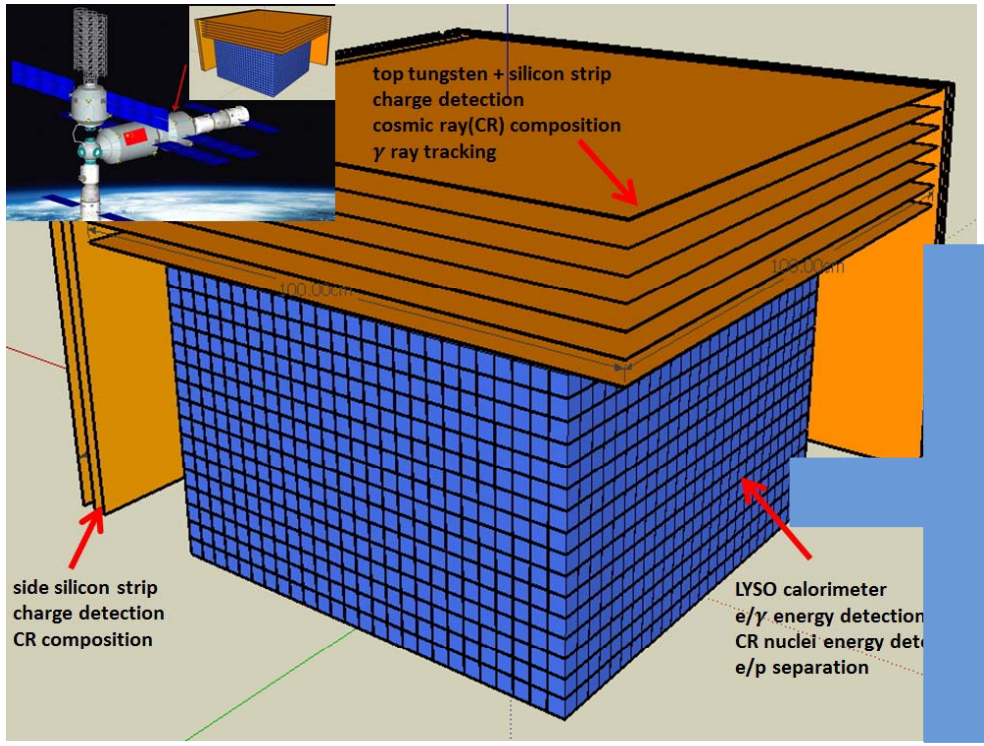
HERD proton (nucleon) detection capability



HERD：
2020-2022
CREAM：
2015-2020
DAMPE：
2015-2020

But CREAM is planned to operate only for several months on ISS.

New calorimeter readout technique



Direct Coupling

PD, APD, SiPM: Complicated system, high power consumption

MAPMT, SiPM: high power consumption

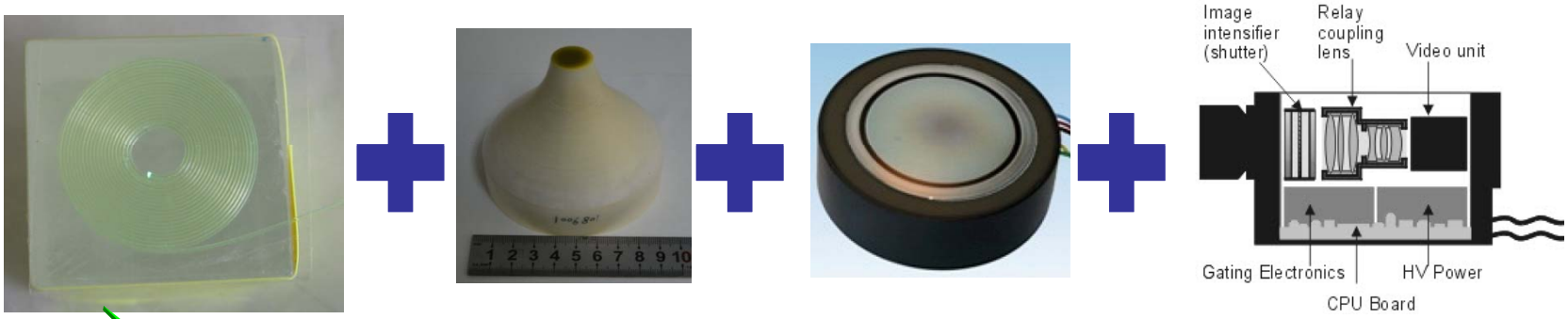
CCD: No single photon detection

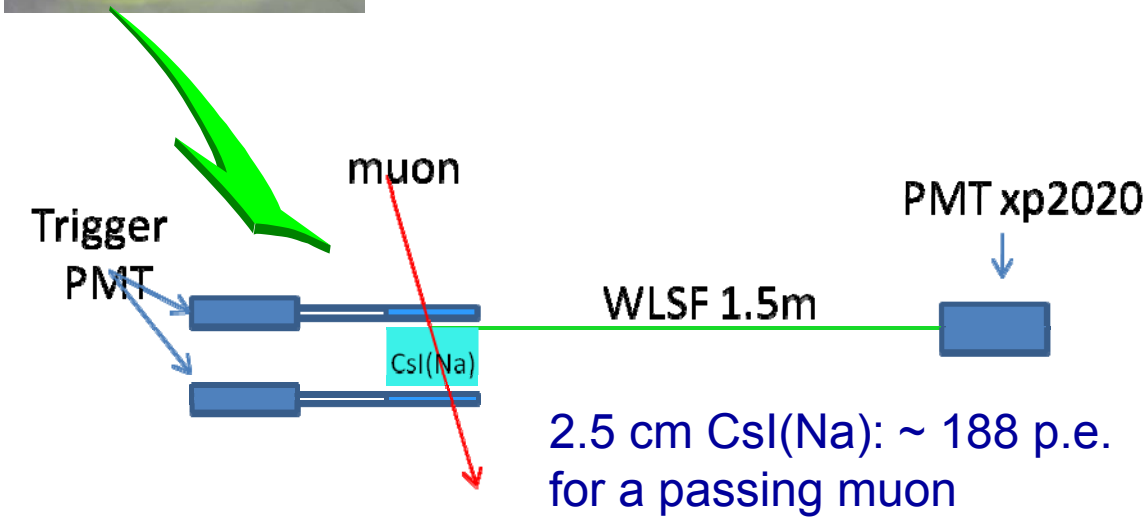
EMCCD, EBCCD: no ns gate control

ICCD: no above problems, but premature

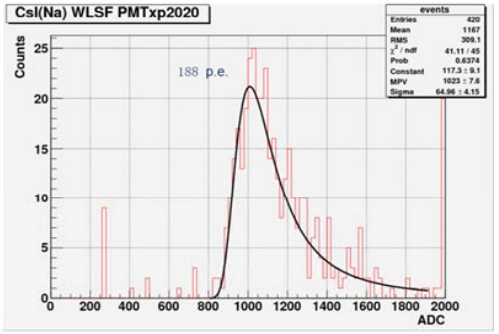
Wavelength shifter fiber readout

An example



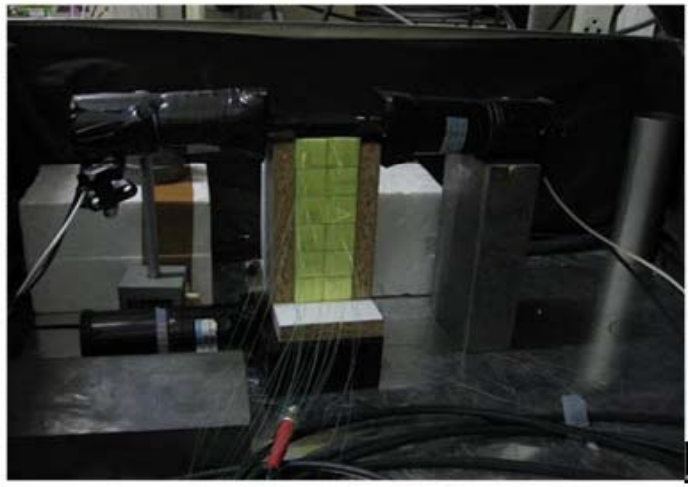


2.5 cm CsI(Na): ~ 188 p.e.
for a passing muon

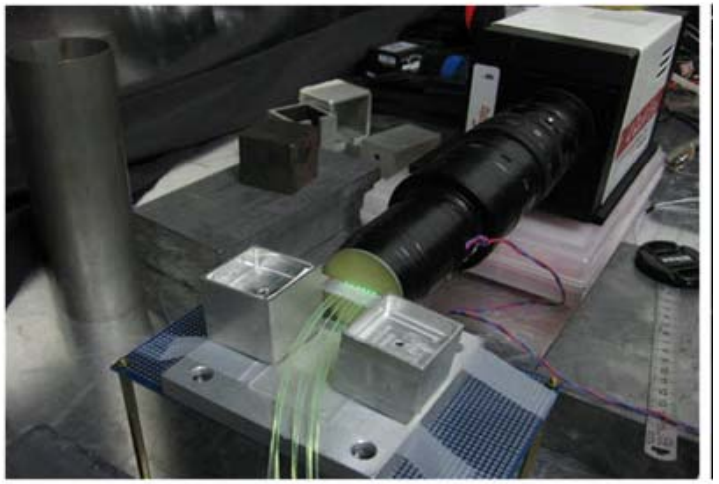


Sun, X. L. and et al. (2011). "A Digital Calorimeter for Dark Matter Search in Space." Journal of Physics: Conference Series **293(1): 012038.**

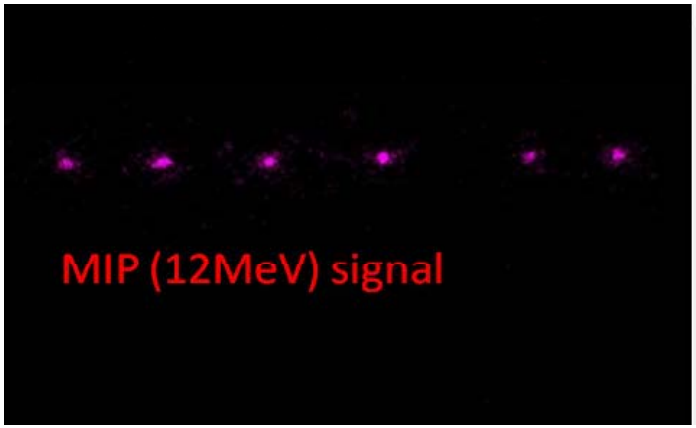
Test set-up and results

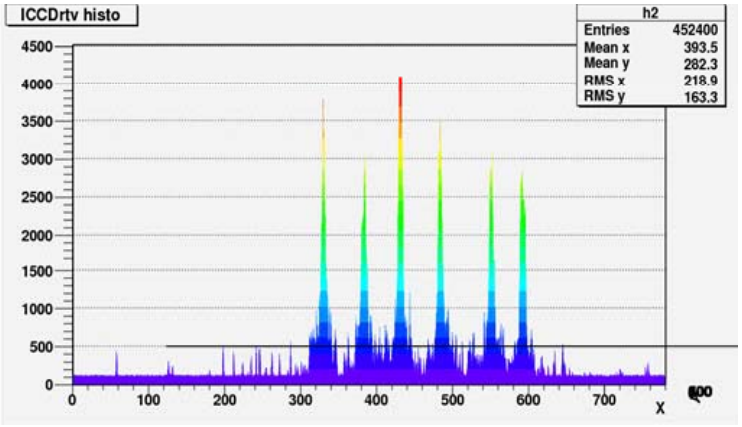


2×2×6 granular CsI with fibers sandwiched between two detectors



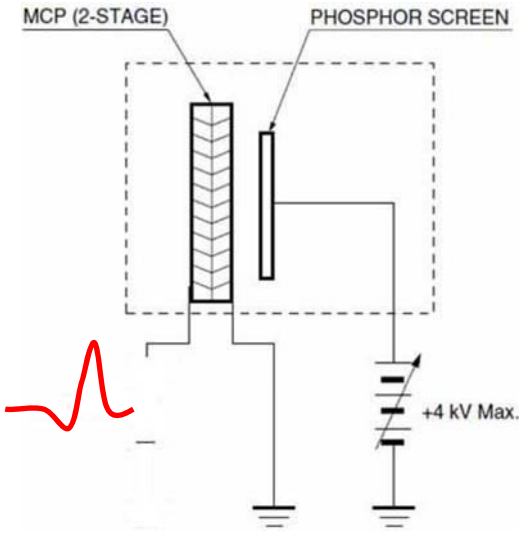
Taper +Imaging Intensifier + ICCD



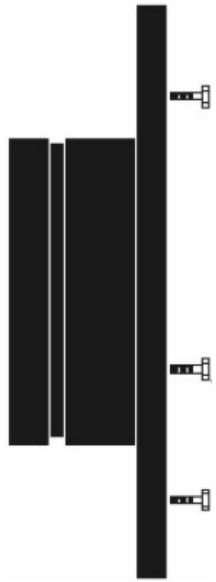


ICCD image of typical muon events

Concept of ICCD readout system



+



+

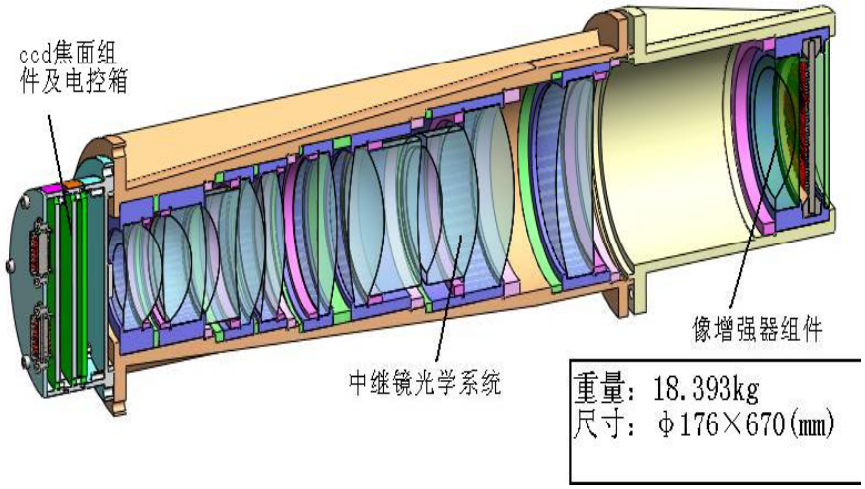
Cathode Triggered Intensifier

Optical Coupler

High frame rate and large format CCD

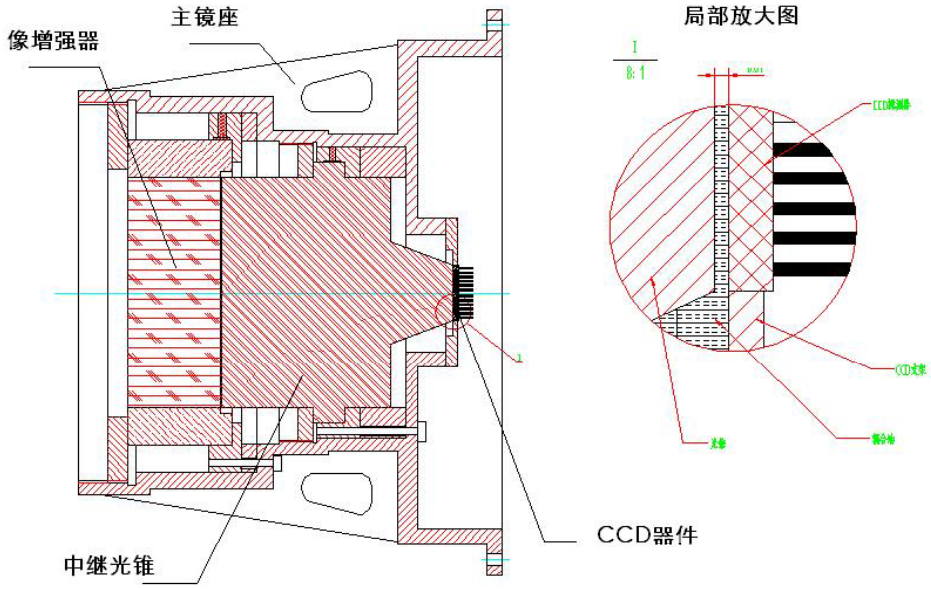
Two types of coupling

Relay mirrors



Single unit: weight of 18.393 kg, size， size of φ176×670(mm)。

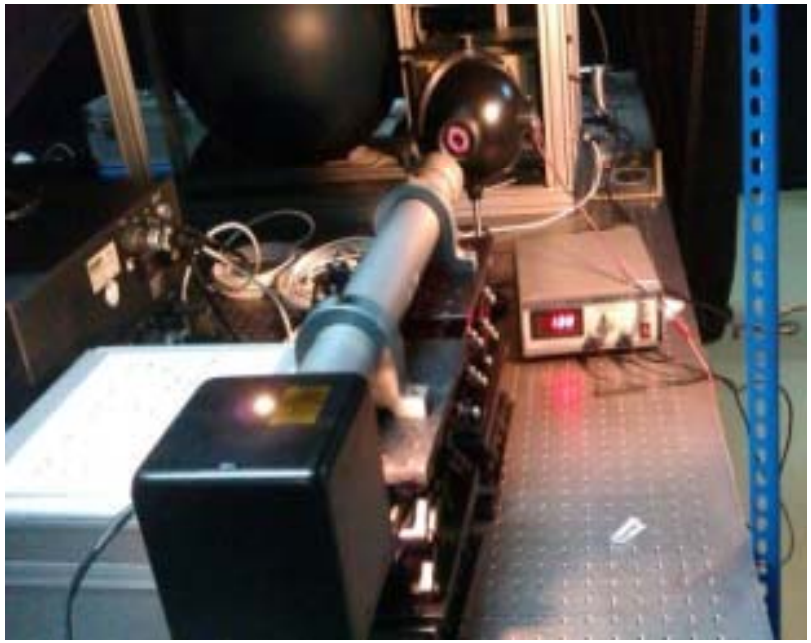
Taper

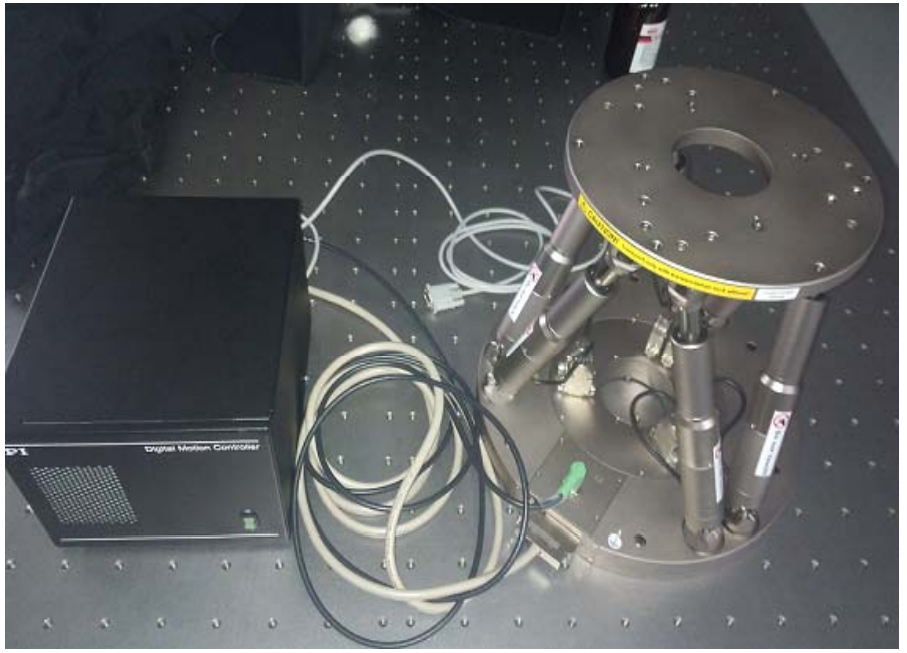


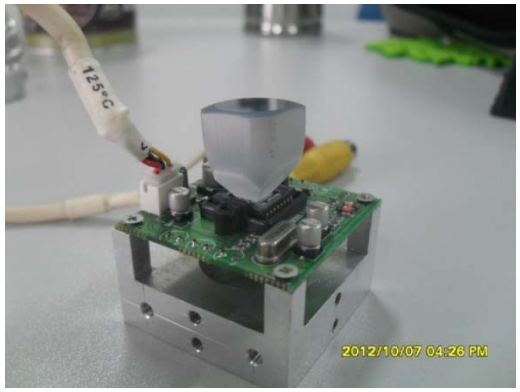
Technology development funded by XIOPM, CAS and NSFC.

Looking for collaborators in Italy.

ICCD readout R&D



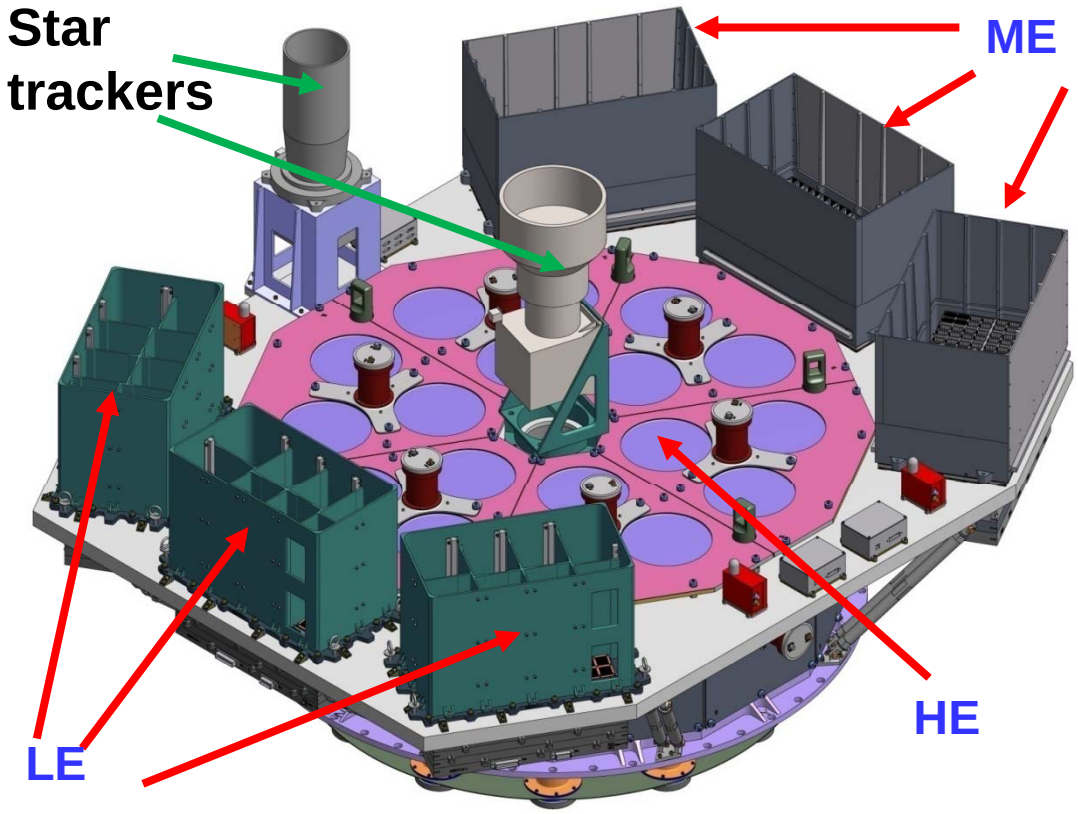




The HERD Team

- Current Chinese member institutions
  - Institute of High Energy Physics, China
  - Purple Mountain Observatory, China
  - Xi'an Institute of Optical and Precision Mechanics, China
  - University of Science and Technology of China
- Current international member institutions (tentative)
  - University of Geneva, Switzerland
  - Università di Pisa and INFN, Italy
  - IAPS/INAF, Italy
  - University of Florence and INFN Firenze, Italy
  - University of Perugia/Trento and INFN, Italy
  - University of Bari and INFN, Italy
  - KTH, Sweden

HXMT Payloads

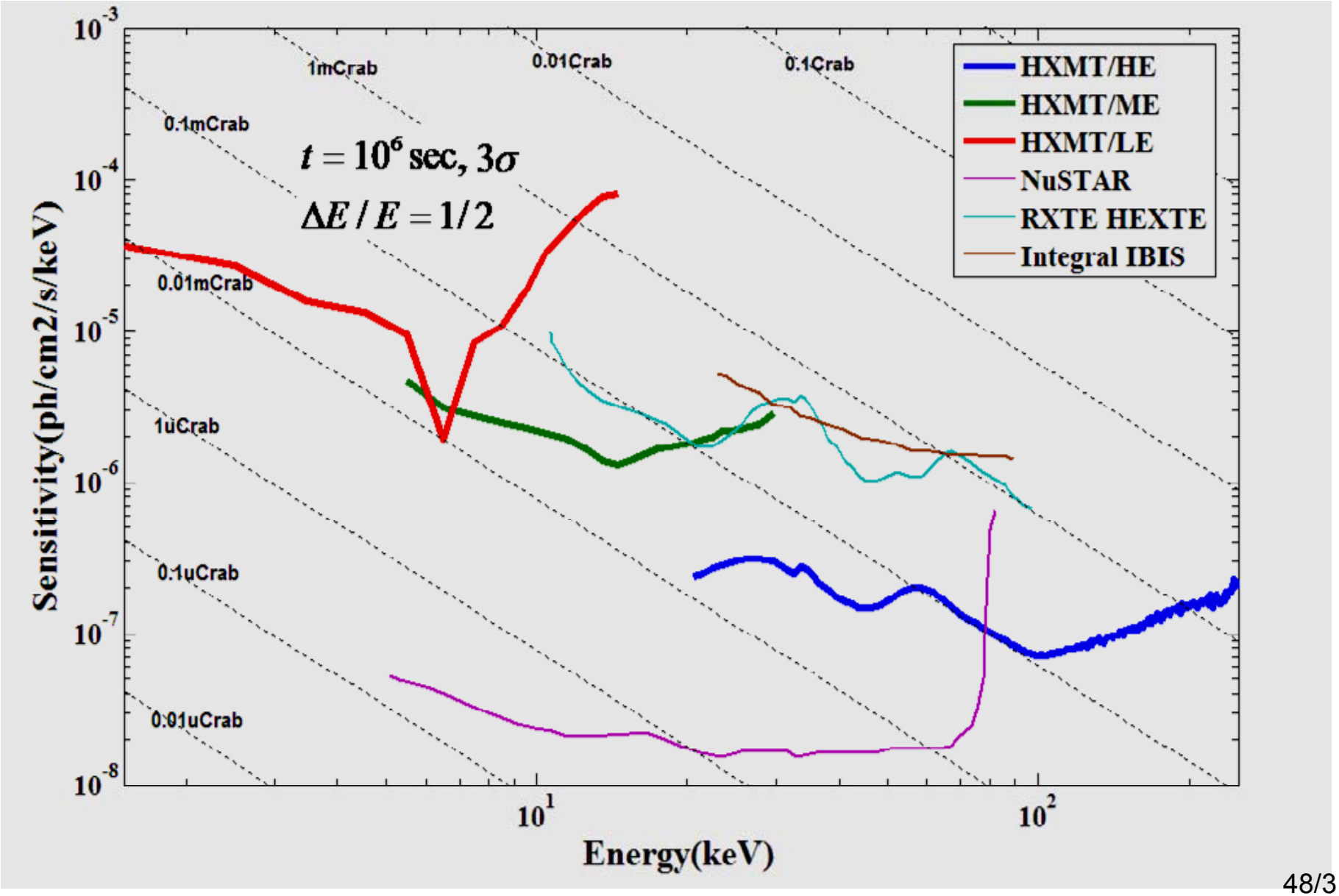


High Energg Telescope (HE):
NaI/CsI, 20-250 keV, 5000 cm^2

Medium Energy Telescope (ME):
Si-PIN,5-30 keV, 952 cm^2

Low Energy Telescope (LE):
SCD,1-15 keV, 384 cm^2

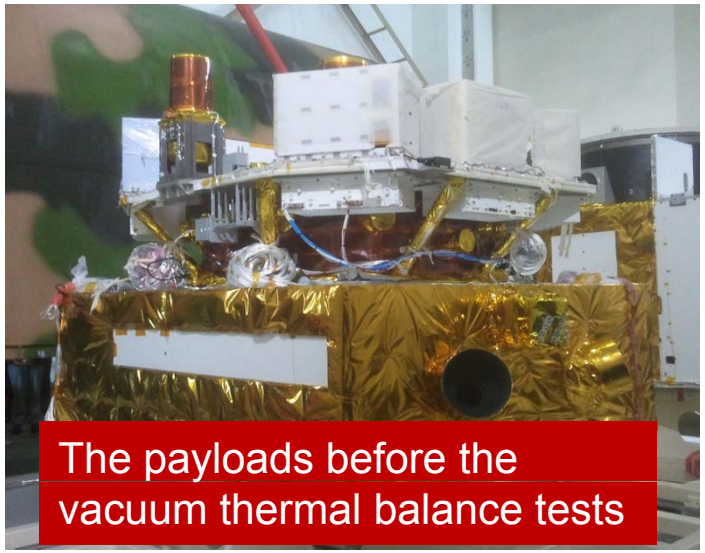
HXMT Sensitivity

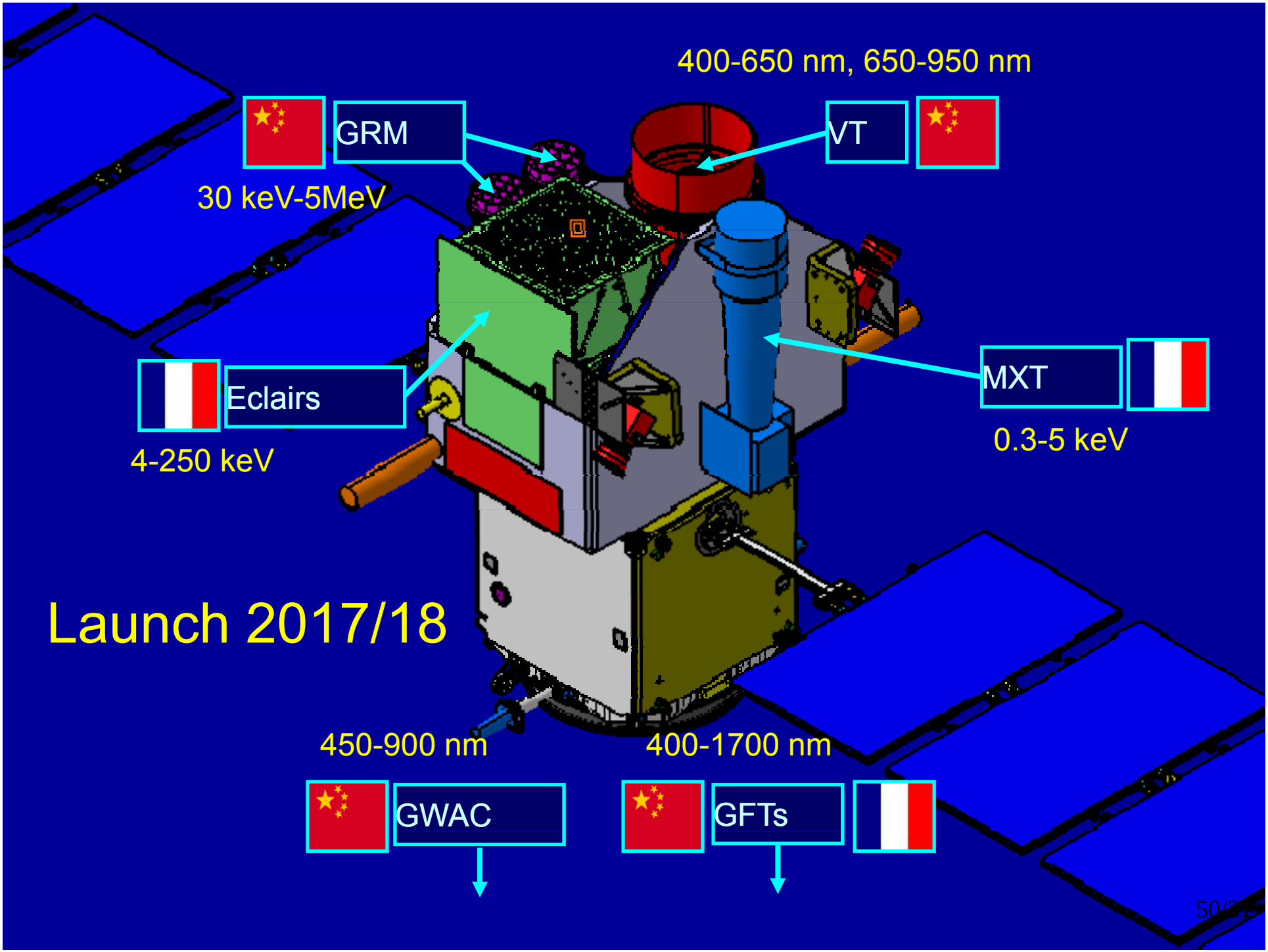


Current status of HXMT

The mechanical model of the satellite in dynamical environment tests (2012.11)


The electric model of HXMT's payloads in testing (2012.12).

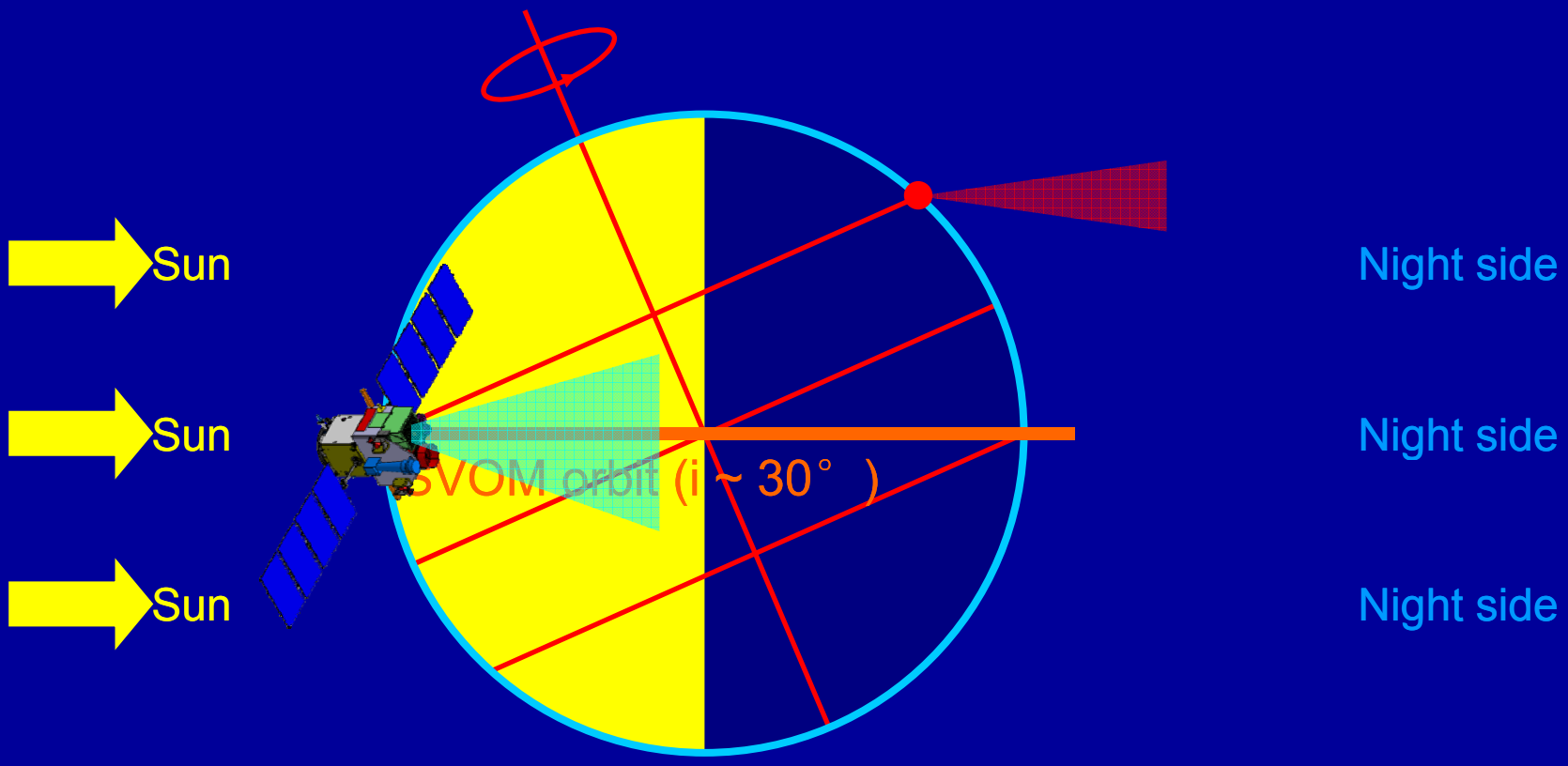

The payloads before the vacuum thermal balance tests


400-650 nm, 650-950 nm
GRM
VT
30 keV-5MeV
Eclairs
MXT
4-250 keV
0.3-5 keV
Launch 2017/18
450-900 nm
400-1700 nm
GWAC
GFTs

Space instrument performances

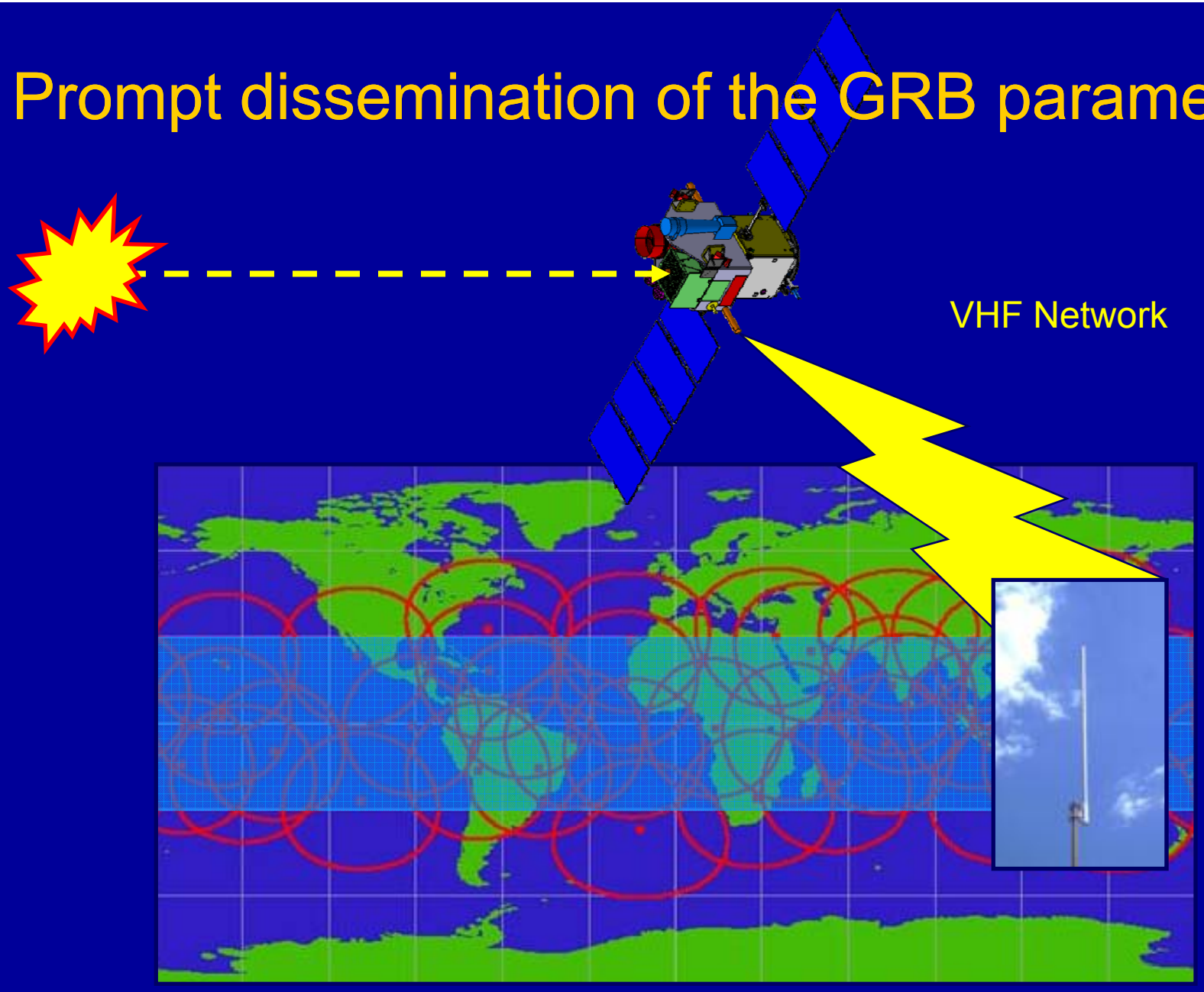
	Spectral band	Field of View	Allocation Accuracy	GRBs/yr (Dect. Rate)
GRM	30 keV-5 MeV	2 sr	2-5 deg	~80
ECLAIRs	4-250 keV	2 sr	10 arcmin	~70
MXT	0.3-5 keV	65× 65 arcmin	30 arcsec	~90%
VT	400-650 nm 650-950 nm	26 × 26 arcsec	1 arcsec	~80%

Pointing strategy: anti solar



About 75% of the GRBs detected by SVOM to be well above the horizon of large ground based telescopes all located at tropical latitudes

Prompt dissemination of the GRB parameters



GRB observation strategy

Space

GRB trigger provided by ECLAIRs at time T_0

T_0 + 5 min

VT (V & R band photometry)
MXT (Soft X-ray photometry)

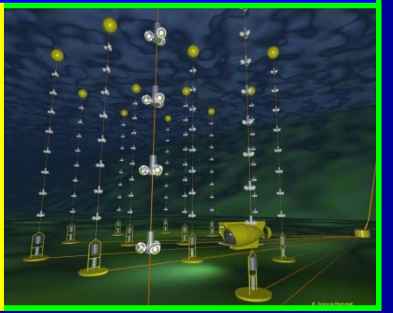
T_0 +1 min

Ground

GWAC
GFTs (g, r, i, J, H)

1-2 m robotic telescopes

Multi messenger follow-up



Multi-wavelength capabilities of SVOM