

China's Space Astroparticle Program

--Strong collaboration with DPNC

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Chinese Academy of Sciences

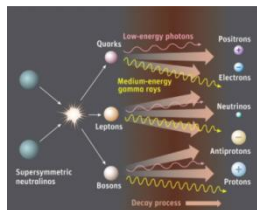
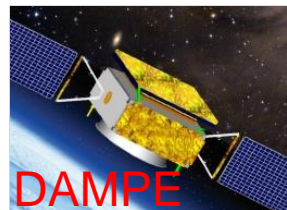
Physics vs. Astronomy: my perspective!

- Experimental physics (today):
 - Identifying problems and ask questions → design experiments to solve the problems and answer the questions.
 - **Strategies very important.**
- Astronomy (always):
 - Just build instruments with new capabilities → make unexpected discoveries.
 - **Opportunities very important.**

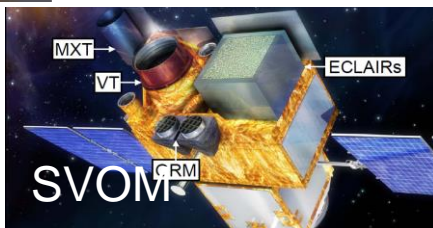
I am an astronomer and so
I will talk only about **opportunities** today!

China's Space HE Astrophysics Satellites

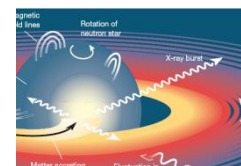
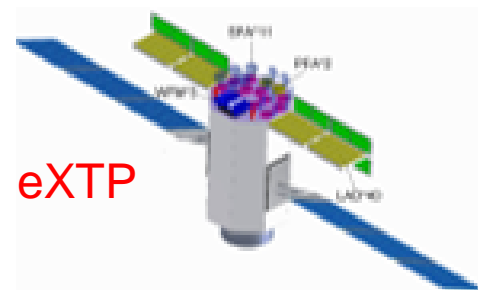
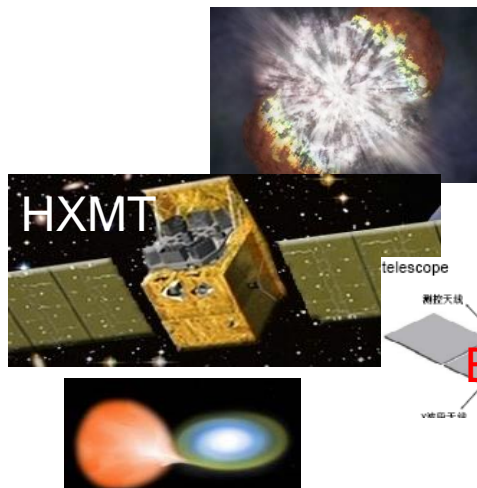
e/CR



γ-ray



X-ray



2015

2020

2025

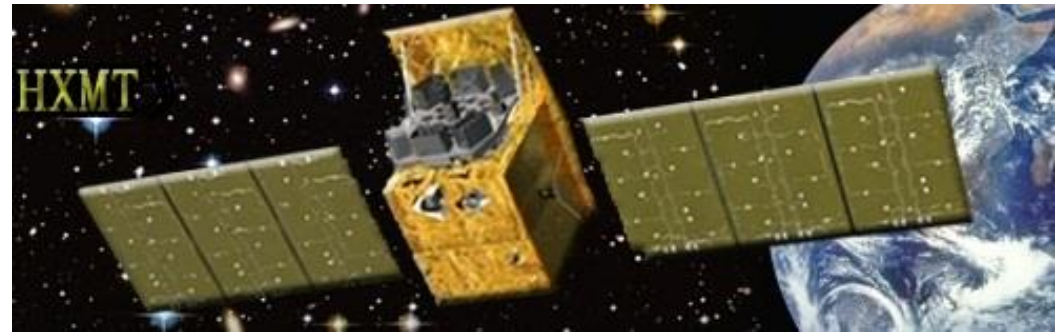
2030

Hard X-ray Modulation Telescope (HXMT)

- **Main scientific objectives (1-250 keV energy band)**
 - ✓ Scan monitoring of the Galactic plane → transients watch dog
 - ✓ Pointed observations → Black hole and neutron star x-ray binaries
 - ✓ Large MeV ASM → Gamma-ray bursts
- ✓ **Collaboration with ISDC** → Software and science operation

Satellite Facts:

- ✓ Mass: ~2500 kg
- ✓ Orbit: 550 km, 43°
- ✓ Lifetime: 4 yrs



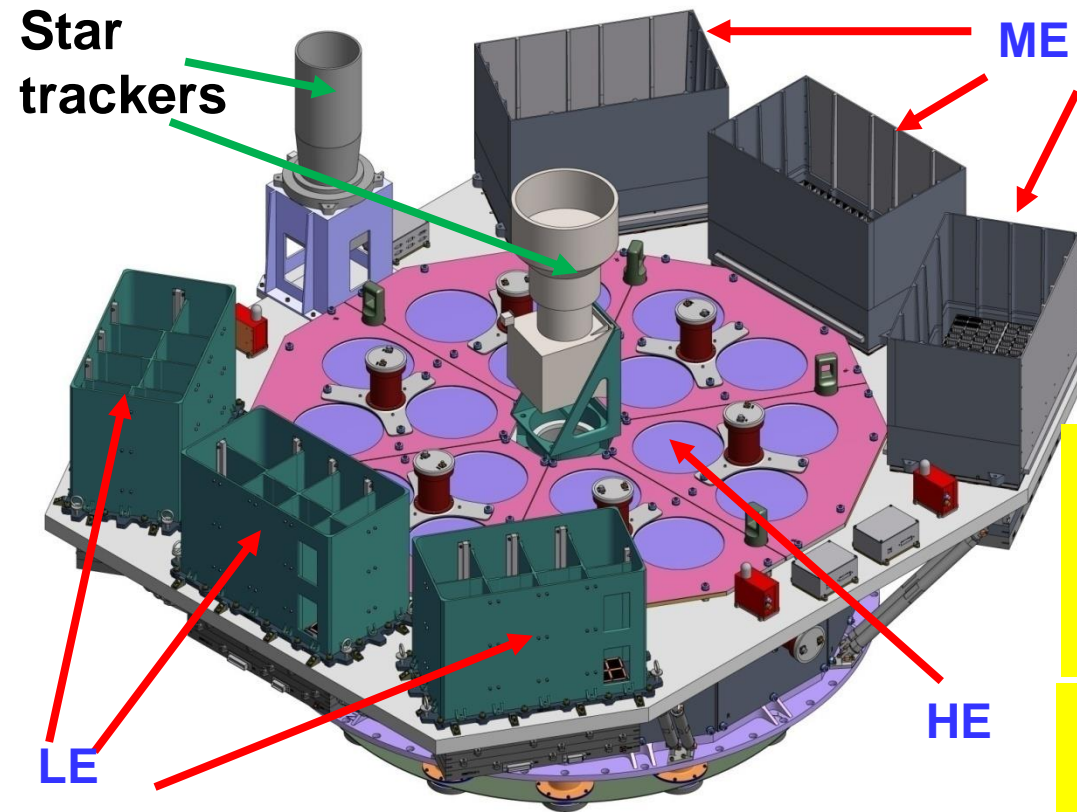
Officially approved in March 2011

Planned launch time: June 15, 2017

China's 1st X-ray satellite: open for international cooperation

PI: SNZ

HXMT Payloads



Medium (ME):
Si-PIN, 5-30 keV, 952 cm²

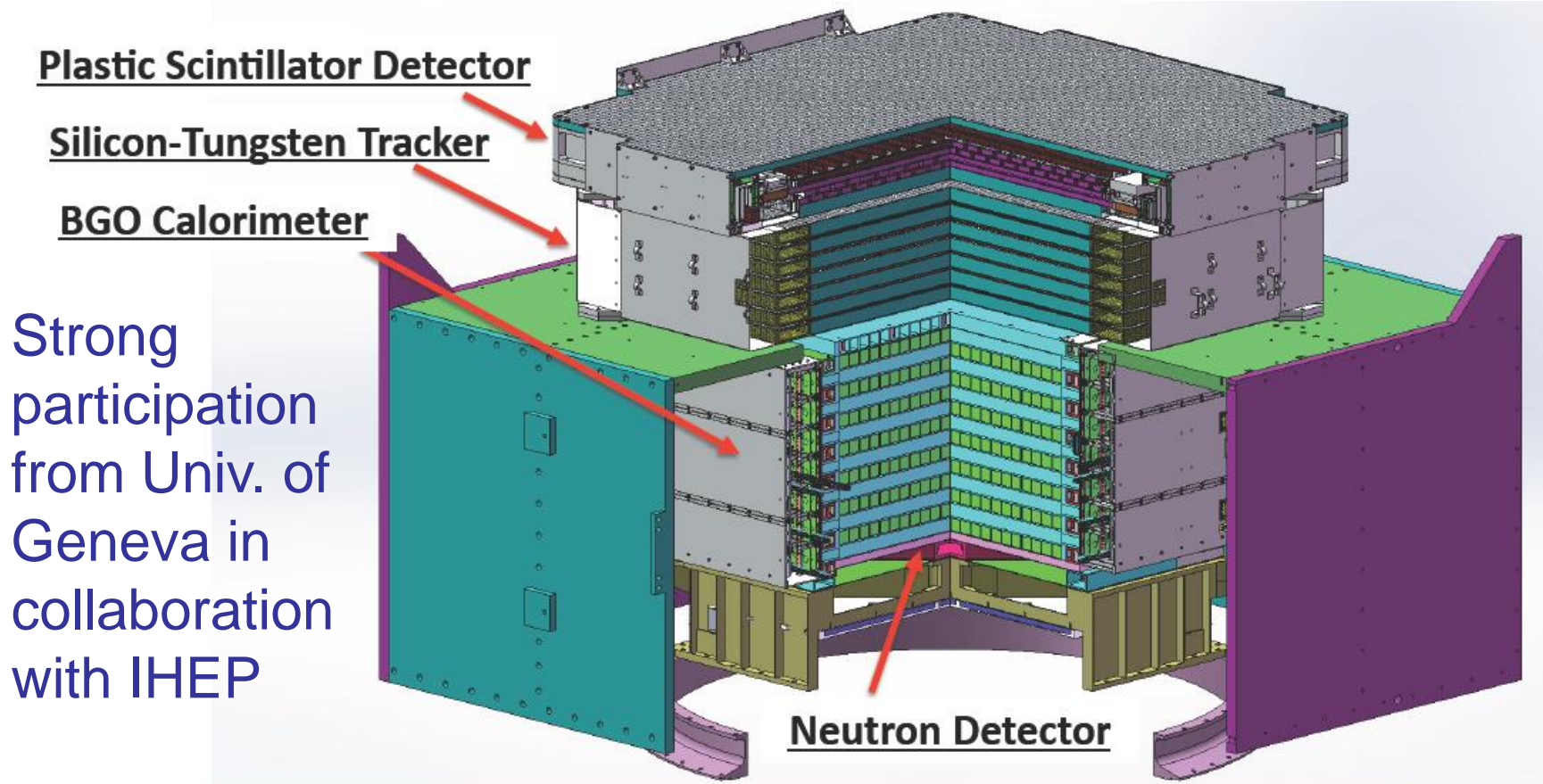
High Energy (HE): **Normal Mode**
NaI, 20-250 keV, ~5000 cm²
CsI, 50-700 keV, ~5000 cm²

High Energy (HE): **GRB Mode**
NaI, 100-300 keV, 5000 cm²
CsI, 200-3000 keV, 5000 cm²

Low Energy (LE):
SCD, 1-15 keV, 384 cm²

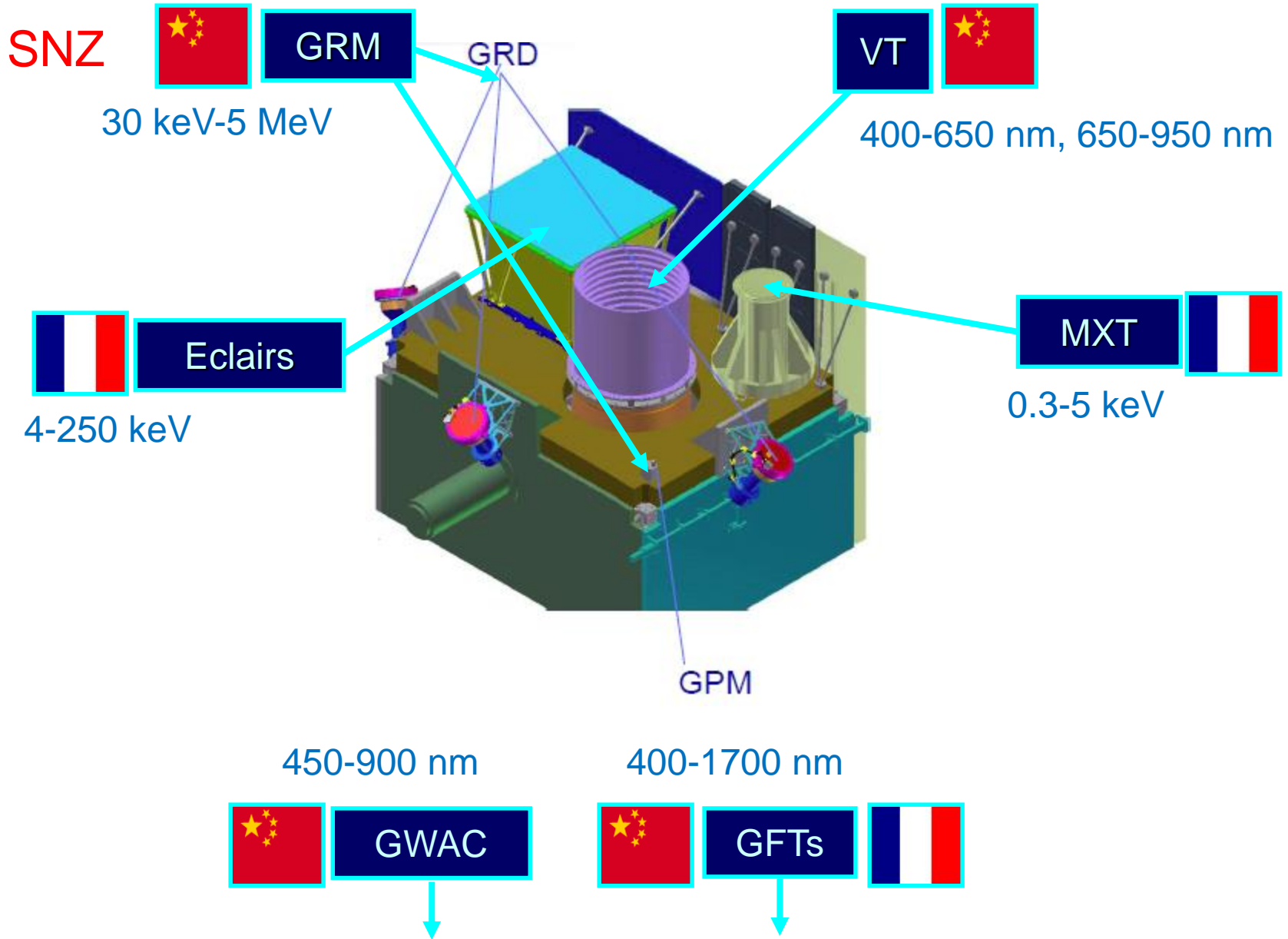
~200 GRBs/year

DAMPE: launched in Dec. 17 2015



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

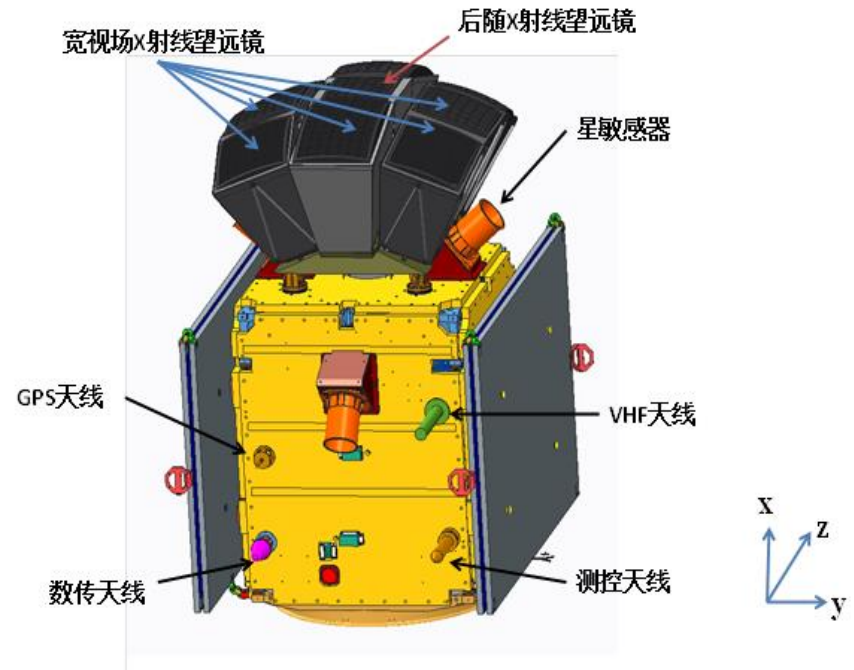
SVOM: ~2021 launch



Einstein Probe (EP)

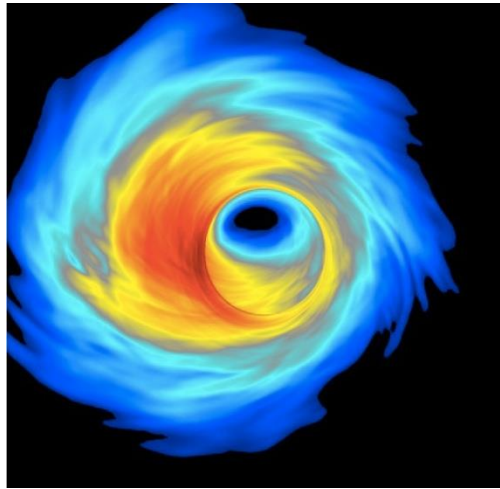


Lobster-eye optics

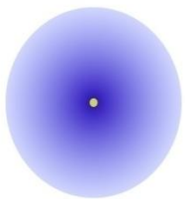
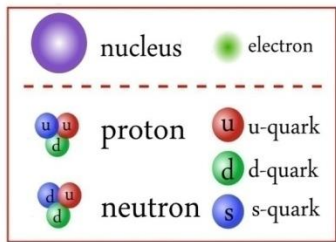


Selected for Phase 0/A in 2013, being approved for launch in 2020-2025.

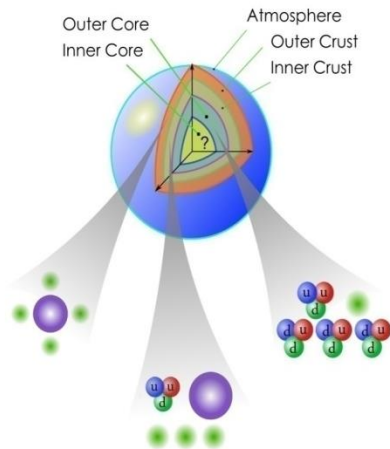
X-ray Timing and Polarization (XTP) mission



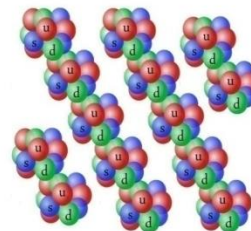
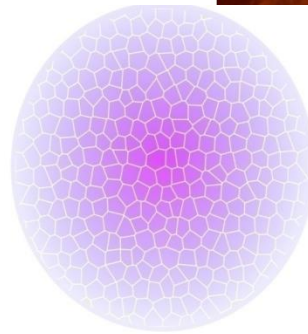
Singularity?
Neutron or Quark Star?
 Extreme gravity
 magnetism
 density



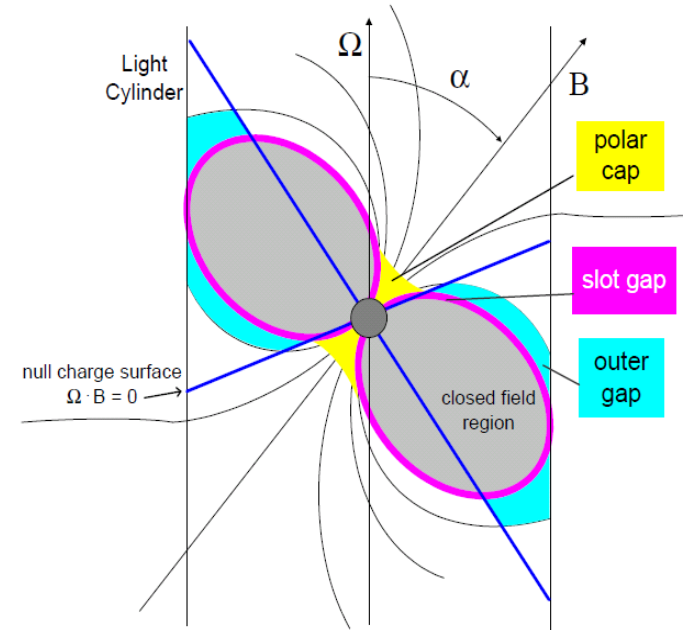
Landau's Gigantic Nucleus



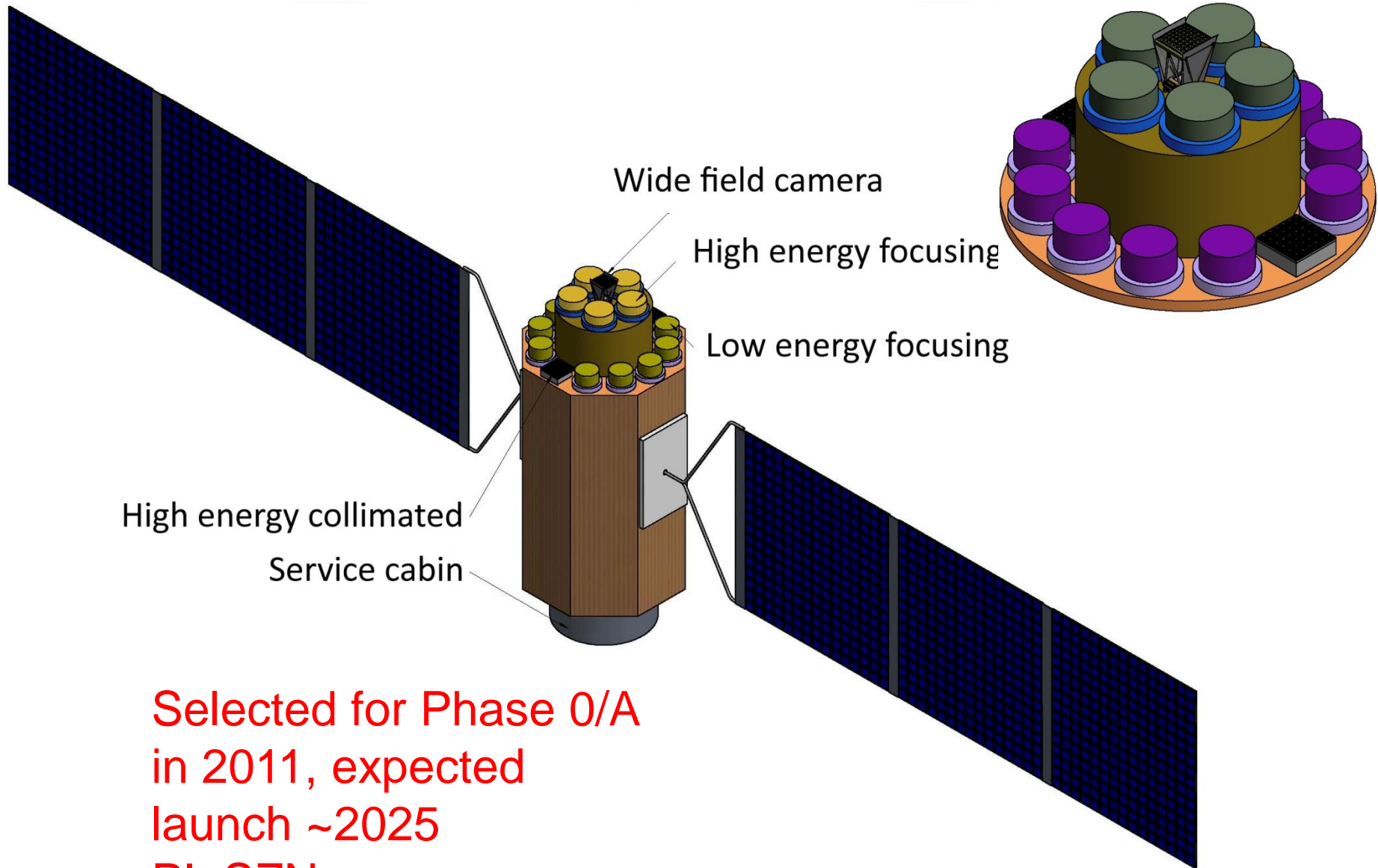
Normal Neutron Star



Quark Clustering Star



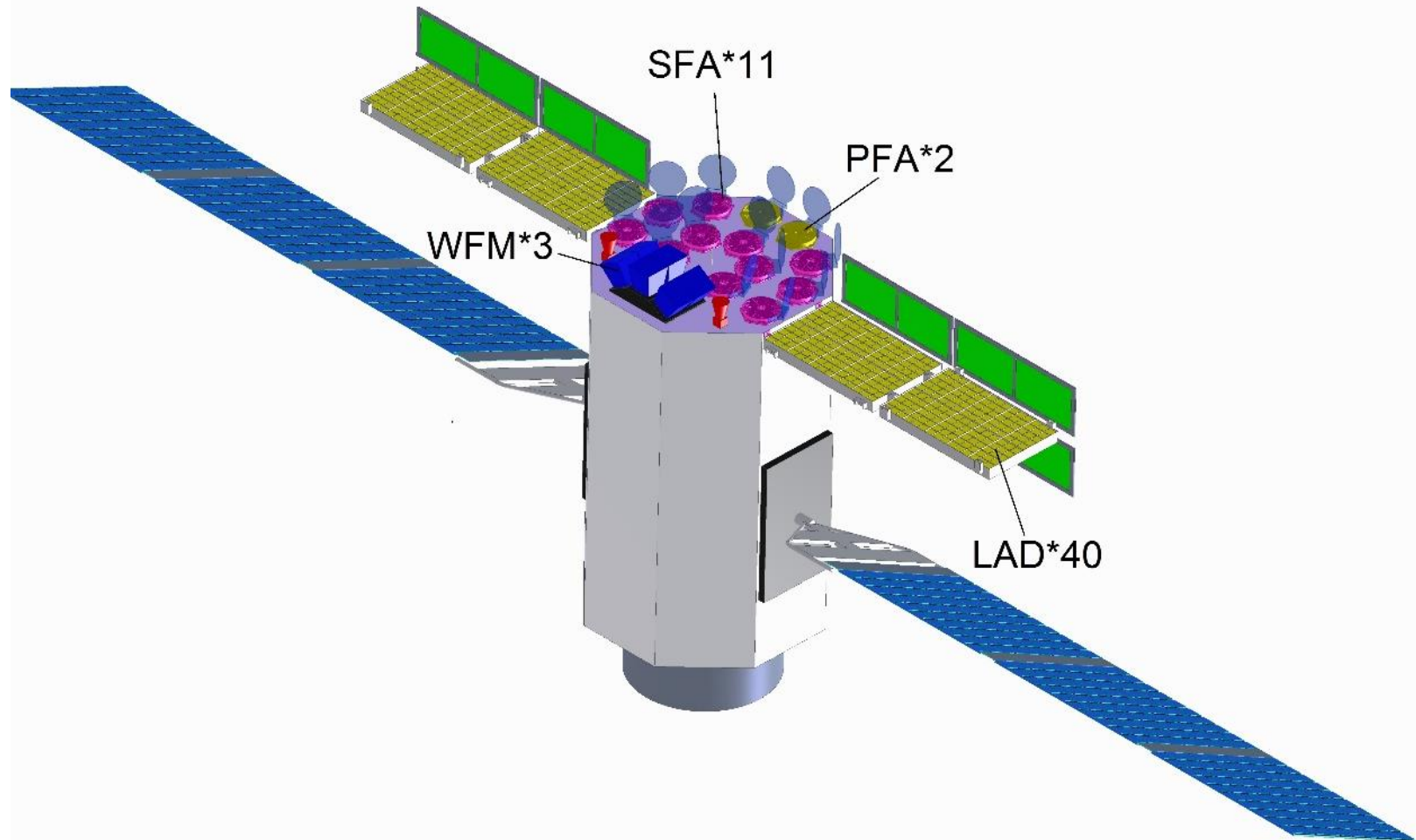
XTP satellite baseline design



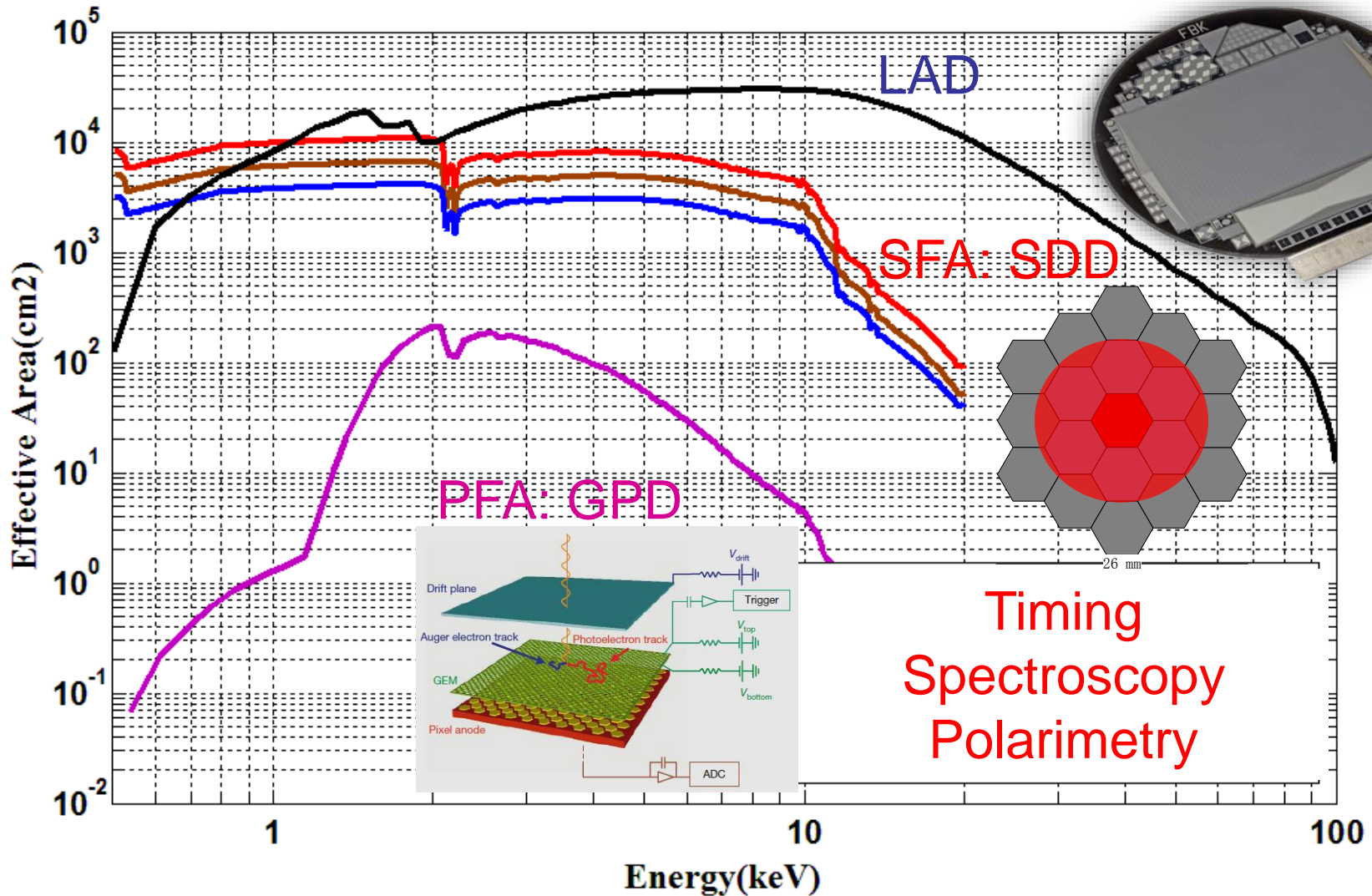
Selected for Phase 0/A
in 2011, expected
launch ~2025
PI: SZN

enhanced XTP (eXTP=XTP+LOFT)

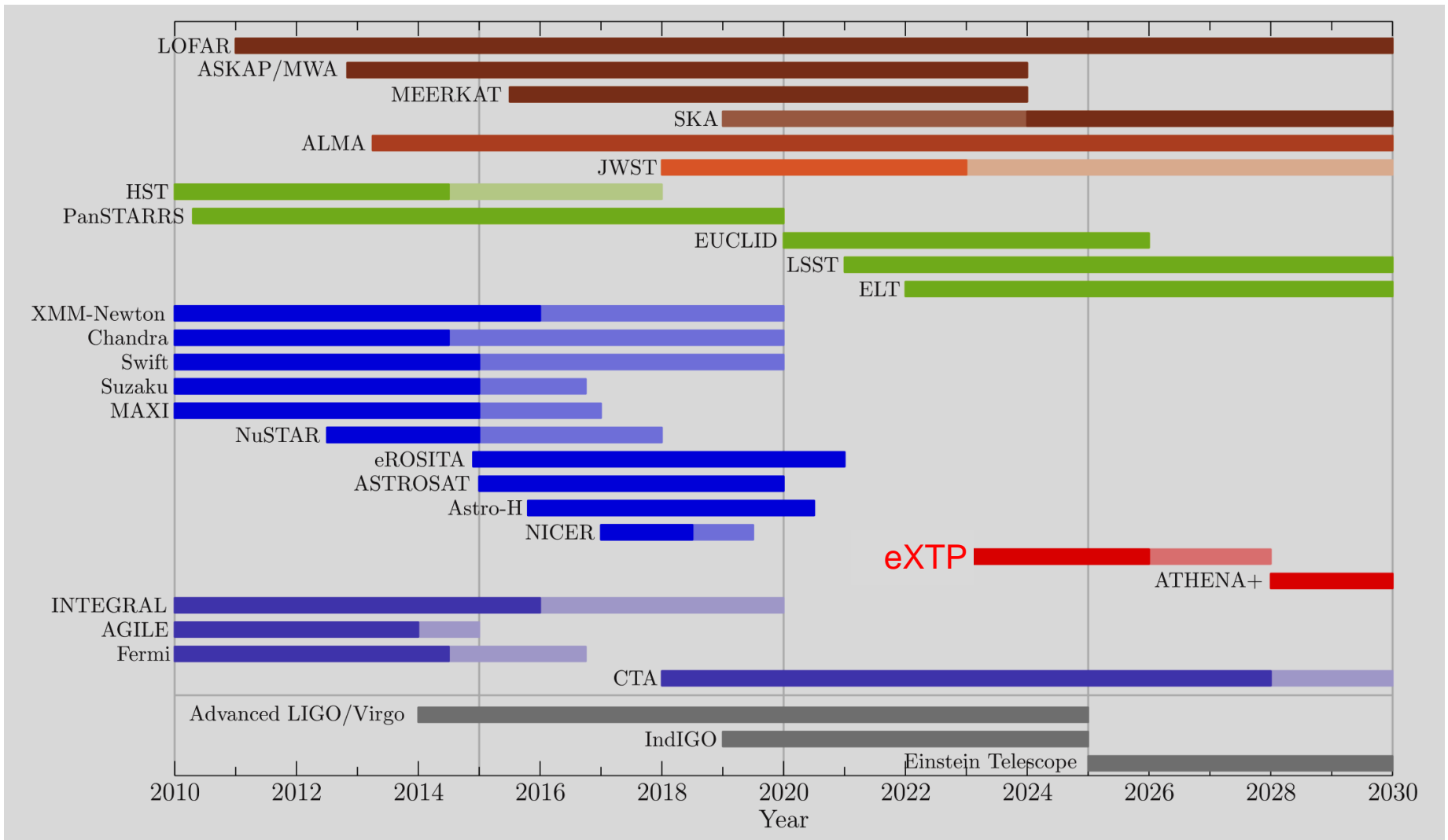
- 2 lines*5 columns*4 panels = 4 LAD (LOFT)
 - ~3 m² effective area for collimating detectors



Effective Area



eXTP in the Multi-wavelength and Multi-messenger Context of Time Domain Astronomy



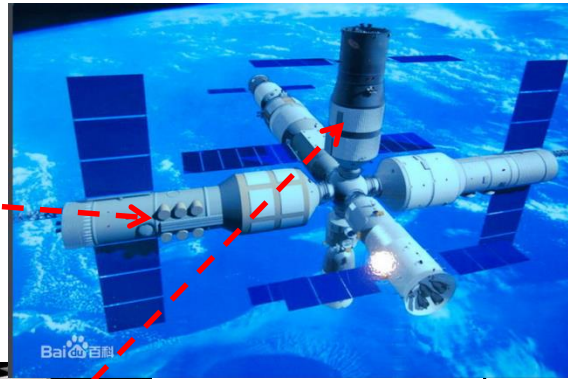
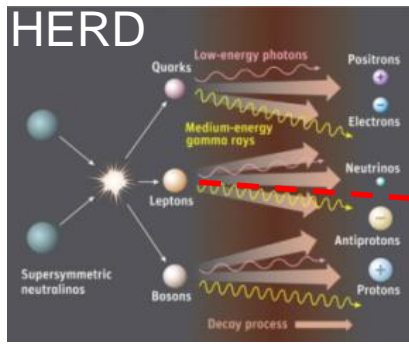
Potential European Participants



China's Space Station Program

2020

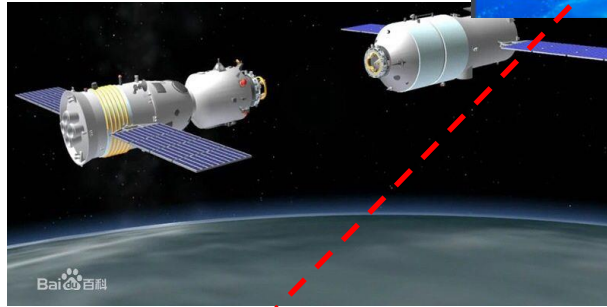
Phase -II



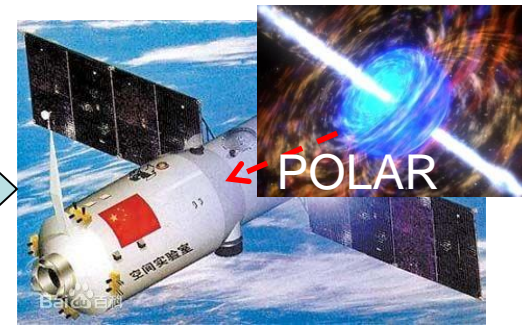
Space Station
3 large modules
+ 2 m telescope
~10-year lifetime

2016

Phase -II



Space lab:
no living cabin



2011

Phase -I



10 astronauts in 5 flights → **space walk**



2003

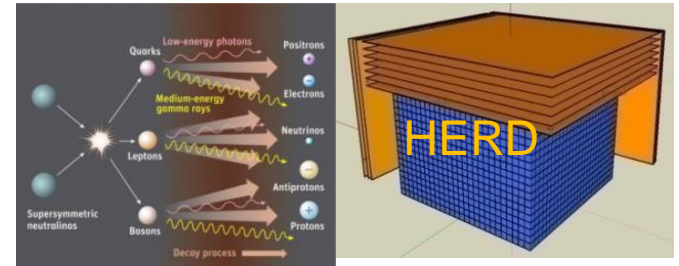
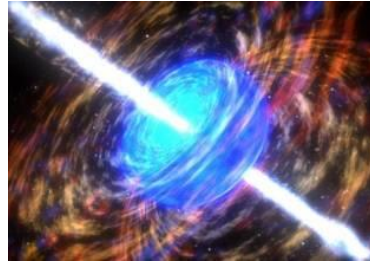
China's Space Station Astronomy Program

e/CR

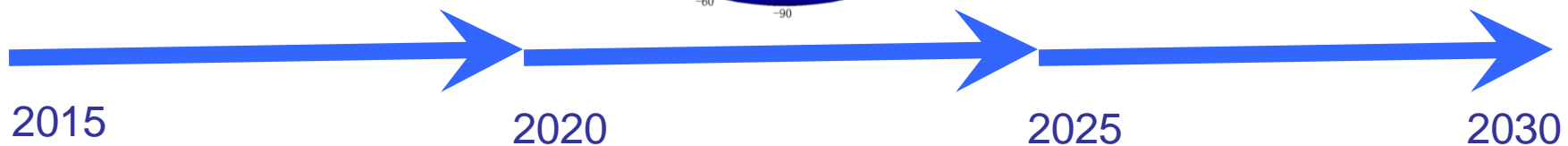
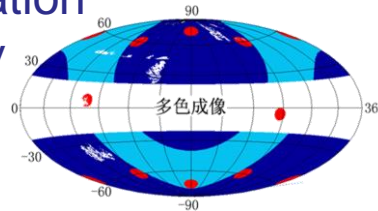
γ-ray

X-ray

IR/O

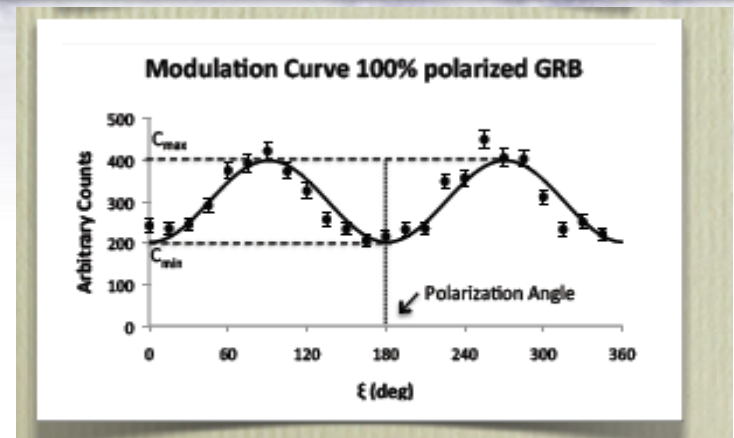
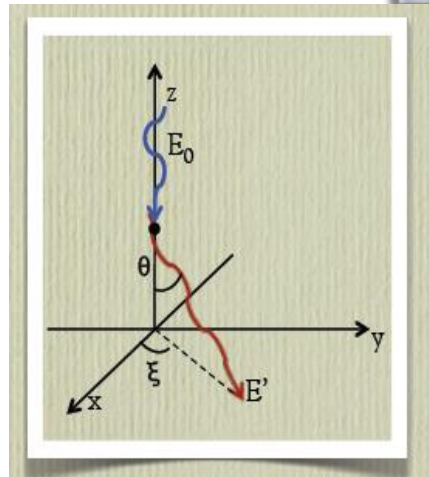
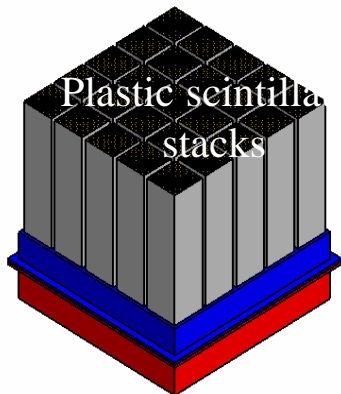
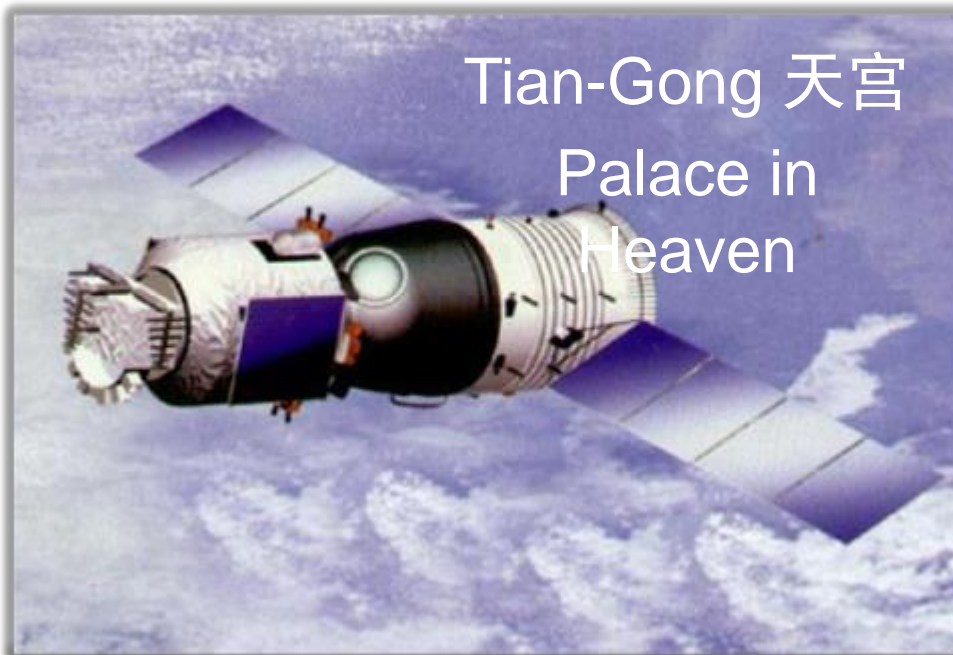


Chinese Space Station
2-m Optical Survey
Dark Energy



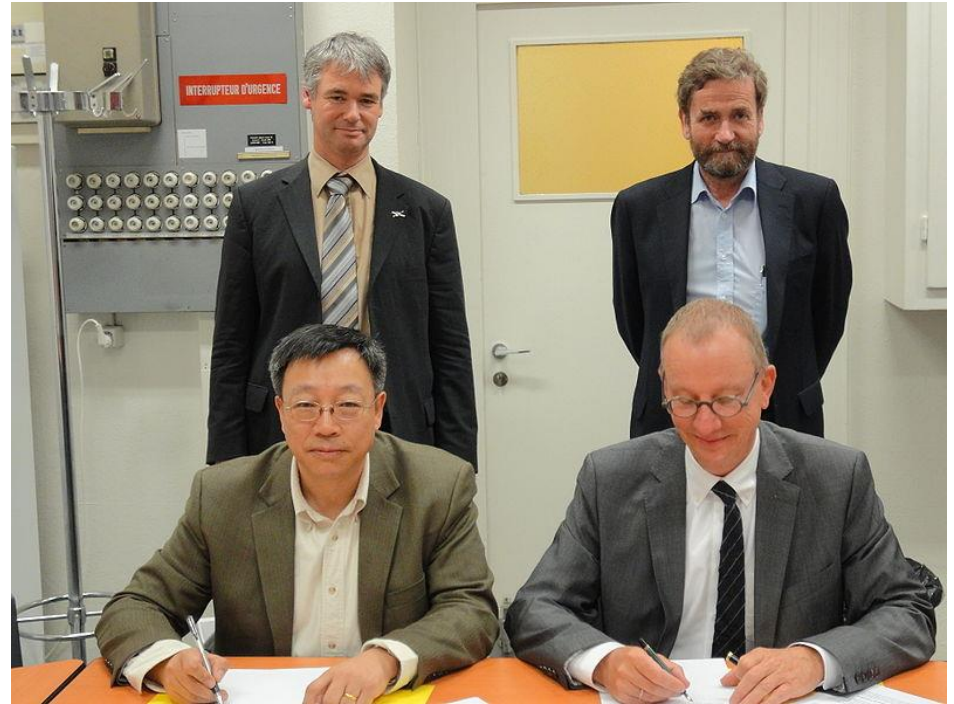
Gamma-ray burst polarization : POLAR

- China- Switzerland collaboration
 - Energy range: 50-350 keV;
FOV of POLAR: $\sim \frac{1}{2}$ sky
- Onboard China's spacelab TG-2: launch time Sept. 2016
- Main science: GRB jet & central engine; tests of quantum gravity theories



Collaborations of POLAR

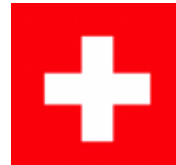
- PIs:
 - SNZ, IHEP, China
 - Martin Pohl, DPNC, Switzerland



China



Switzerland



Poland

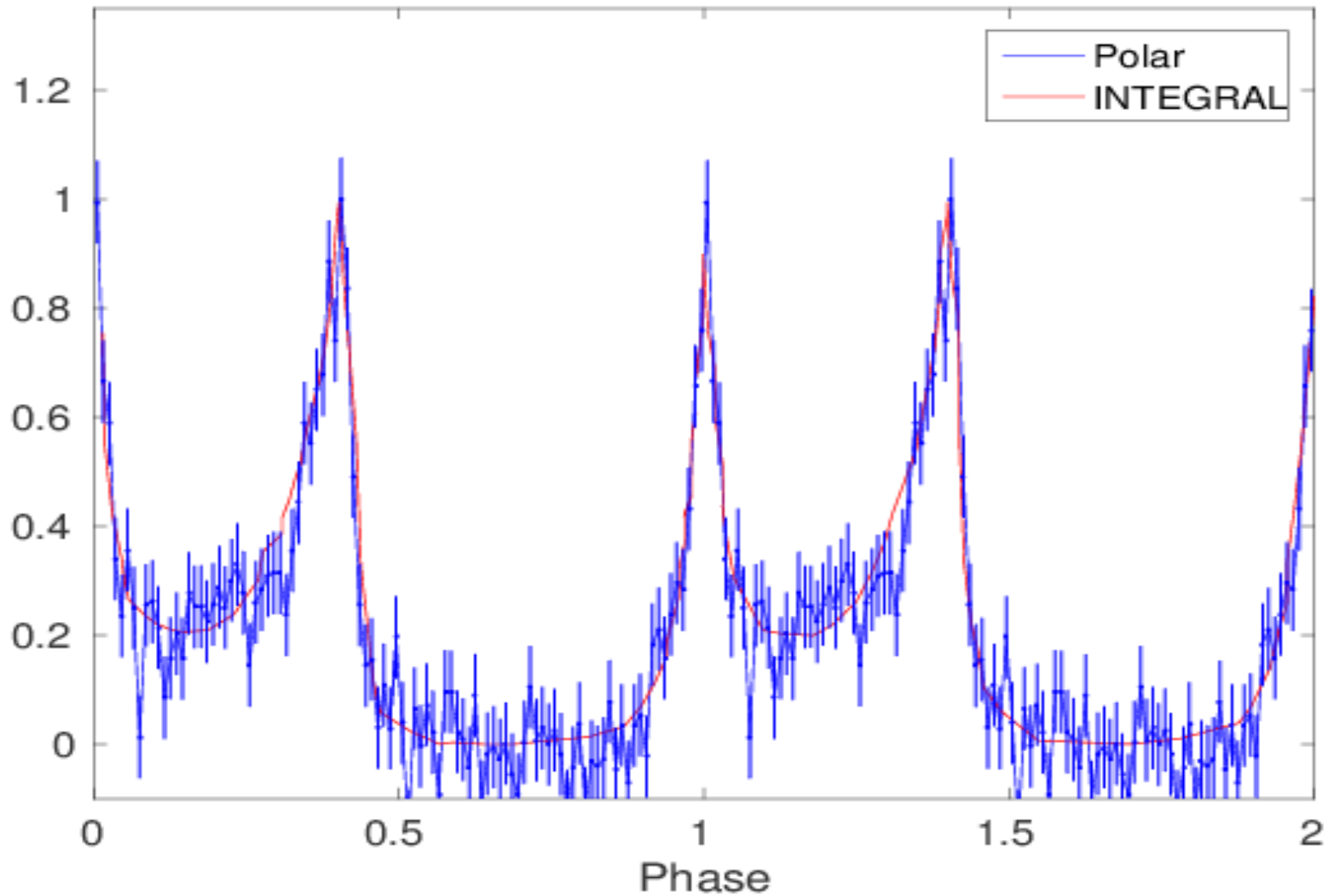


Current status

- Successfully launched on 15th/September
- Successfully powered-on on 22nd/September
- Powered-off on 14th/October for docking of TG-2 and Shenzhou-11
- Powered-on again on 18th/November...
- Powered-off since beginning of May for docking and refueling tests

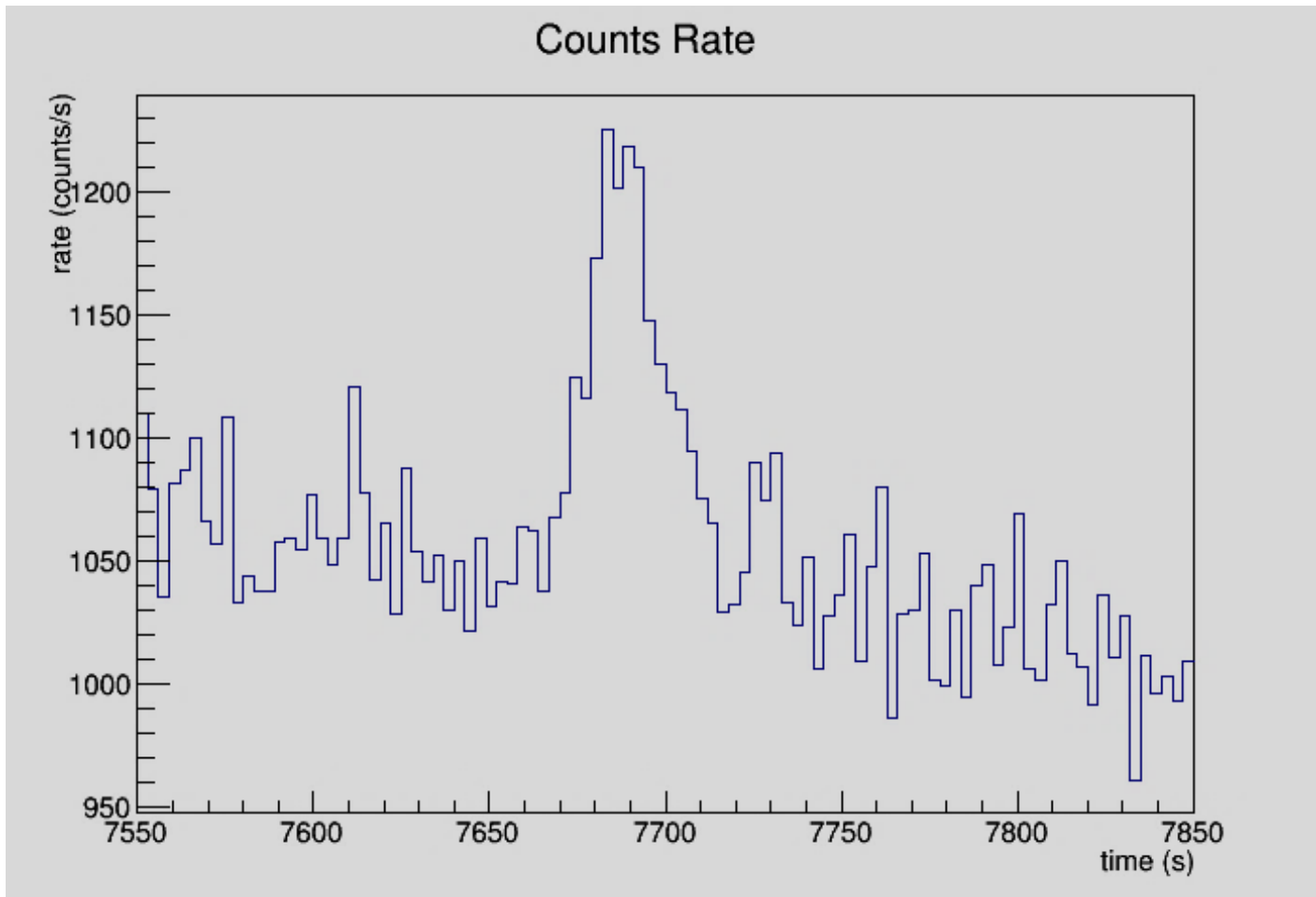


Preliminary results: Crab pulsar



First pulsar navigation study in China

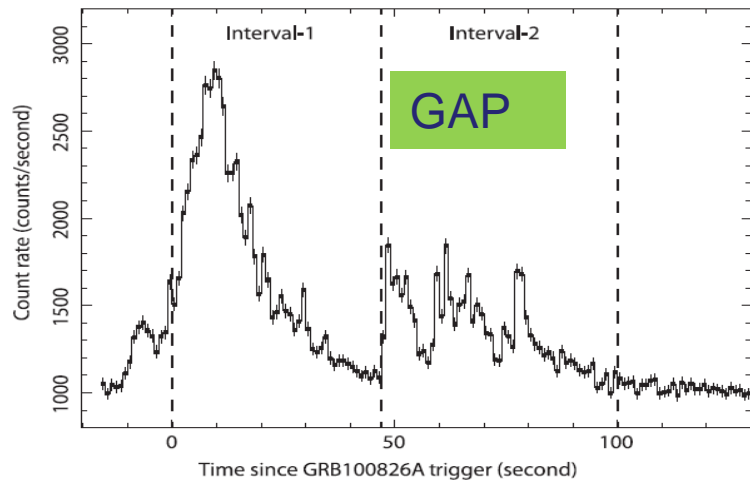
Preliminary results: solar flare



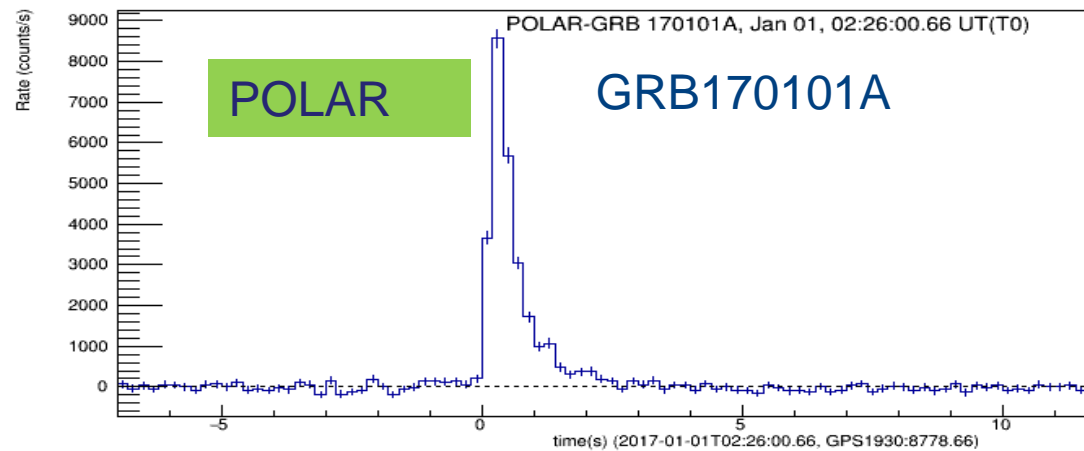
Oct. 12, 2016: consistent with RHESSI results

Best GRB polarization accuracy: GRB170101A

- MDP: 6-10% (1-sigma), best compared to previous reports
- Calibration in progress



Fluence: $3E-4$ erg/cm²
GAP: $27\% \pm 11\%$ (1-sigma)



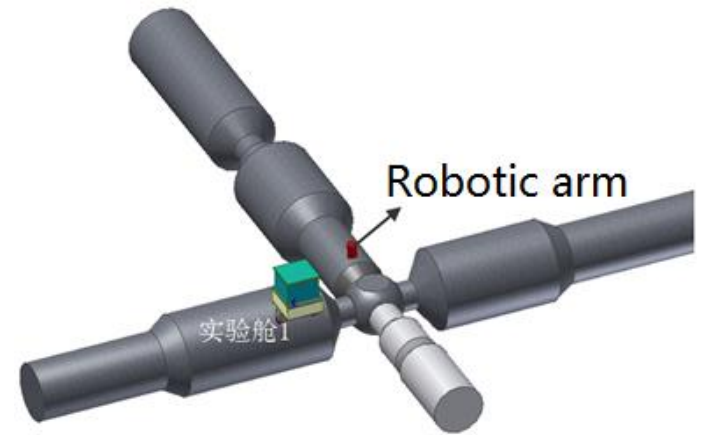
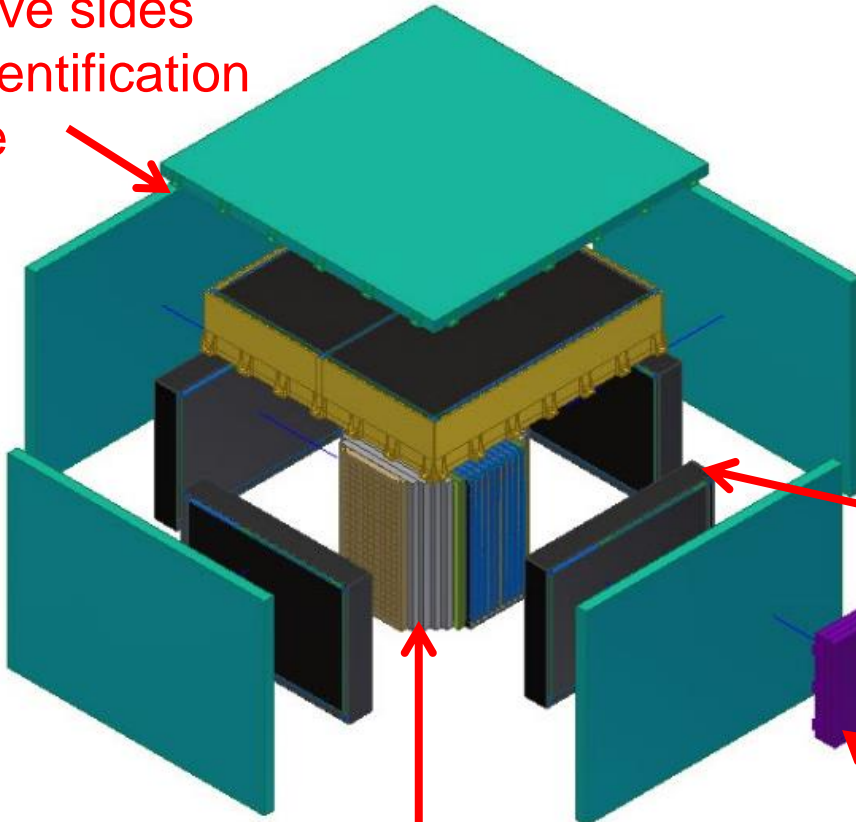
Fluence: $1.4E-5$ erg/cm²
POLAR: TBD $\pm 10\%$ (1-sigma)

High Energy cosmic-Ray Detector (HERD)

- Mission concept: a flagship and landmark scientific experiment onboard China's Space Station
- Sciences
 - Indirect DM search with unprecedented sensitivity
 - Precise CR spectrum and composition measurements up to the knee energy
 - Gamma-ray monitoring and survey
- Unique capabilities
 - Direct PeV CR observation with best energy resolution
 - Low energy gamma ray observation
 - Largest geometric factors for electrons and cosmic rays
- PI: SZN; Planned launch 2022-2025

HERD payload onboard China's SS

PSD, five sides
LE γ identification
Charge



STK (SSD), five sides
Charge
Trajectory
Gamma tracking

TRD
TeV proton calibration

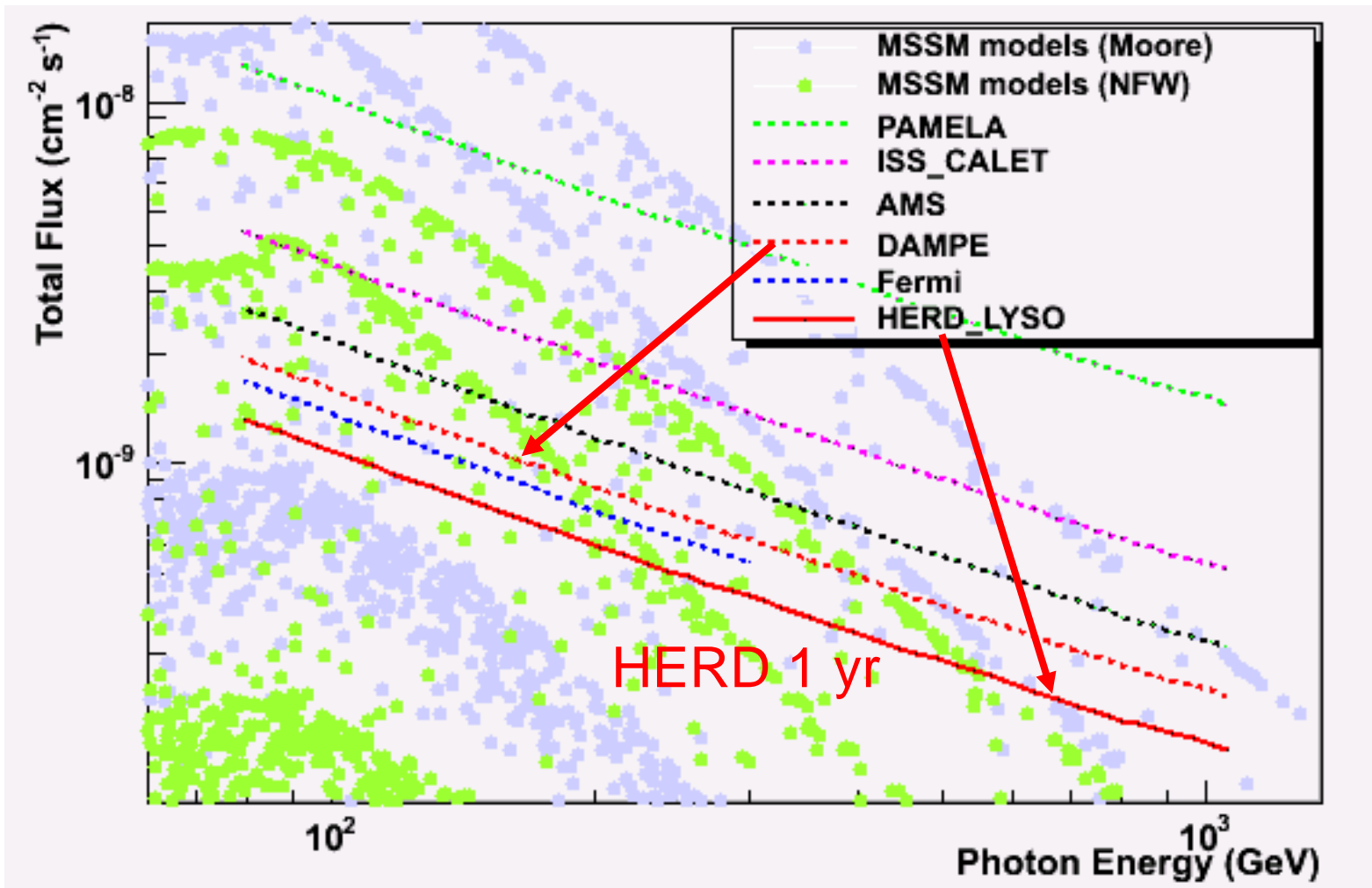
LYSO array
Trigger sub-system
ISCMOS sub-system

CALO, 3-d
e/ γ /CR energy
e/p discrimination

HERD specifications wrt DAMPE

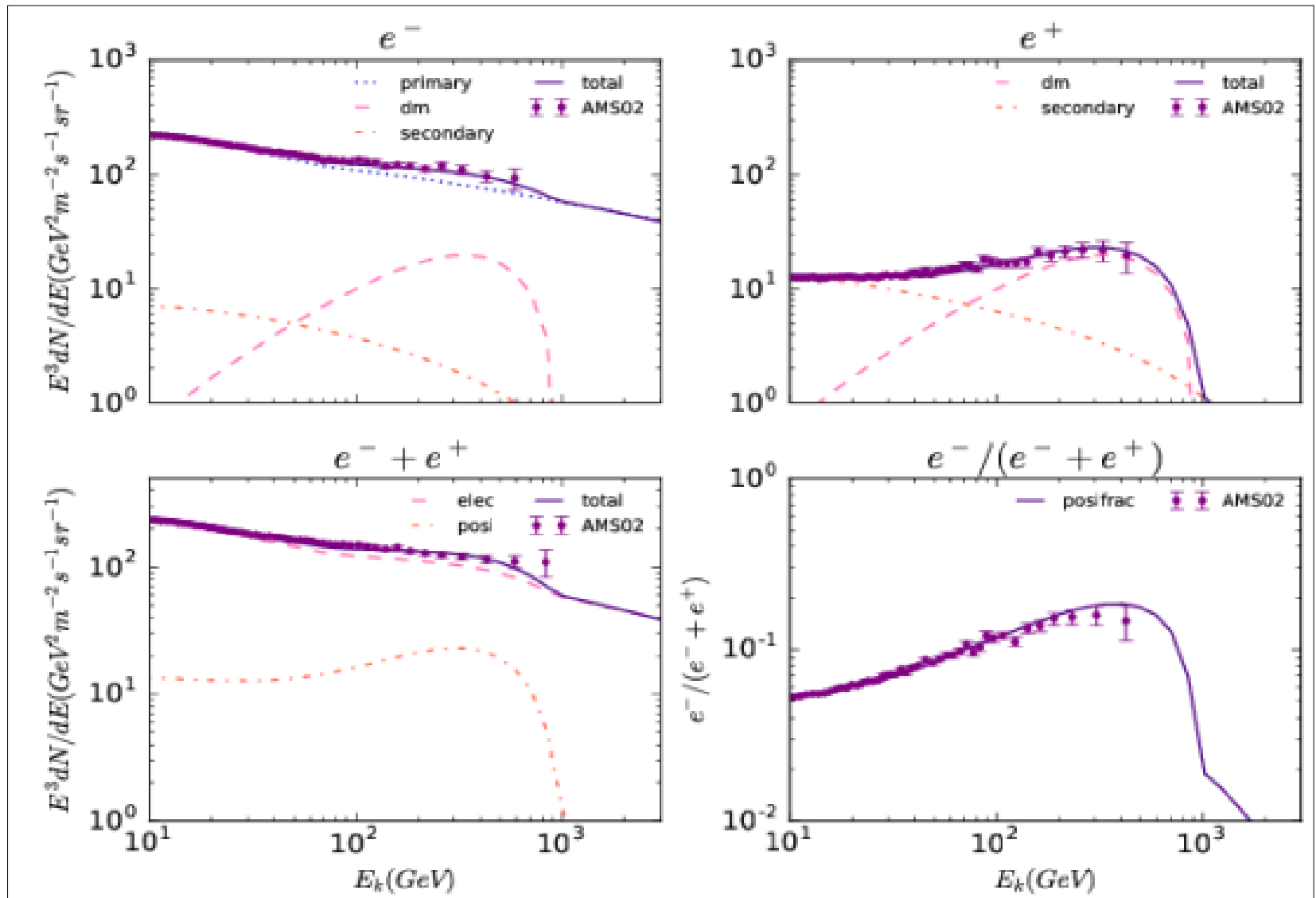
Item	HERD	DAMPE
Energy range(e/ γ)	10 GeV - 10 TeV (e/ γ) 0.5GeV - 10 GeV(γ)	10 GeV—10 TeV
Energy range (CR)	30 GeV - PeV	30 GeV—100 TeV
Angle resolution	0.1 deg.@10 GeV	0.1 deg.@10 GeV
Charge meas.	0.1-0.15 c.u	0.1-0.15 c.u
Energy reso.(e)	1%@200 GeV	1%@200 GeV
Energy reso.(p)	20%@100 GeV-PeV	50%@100GeV-100TeV
e/p discri.	$\sim 10^{-6}$	$\sim 10^{-5}$
G.F. (e)	$>3 \text{ m}^2\text{sr}@200 \text{ GeV}$	$0.3 \text{ m}^2\text{sr}@200 \text{ GeV}$
G.F. (p)	$>2 \text{ m}^2\text{sr}@100 \text{ TeV}$	$0.12 \text{ m}^2\text{sr}@100 \text{ TeV}$

Expected gamma-ray line sensitivity

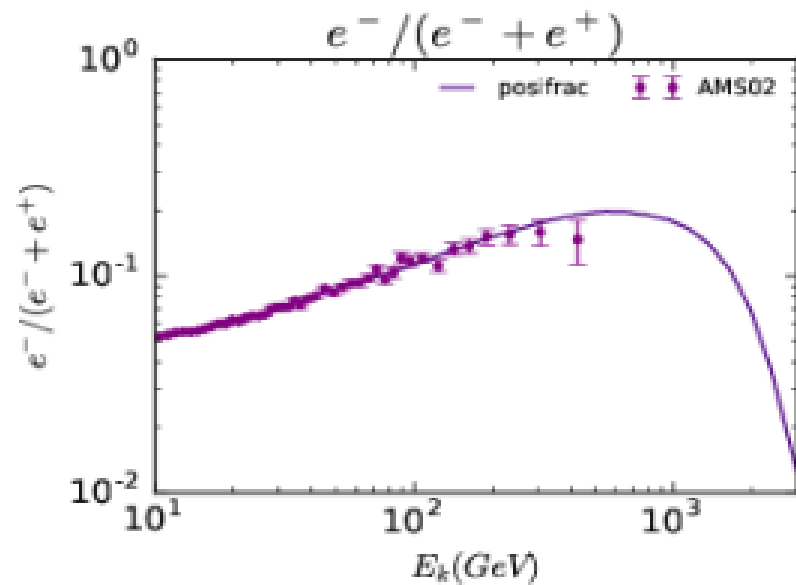
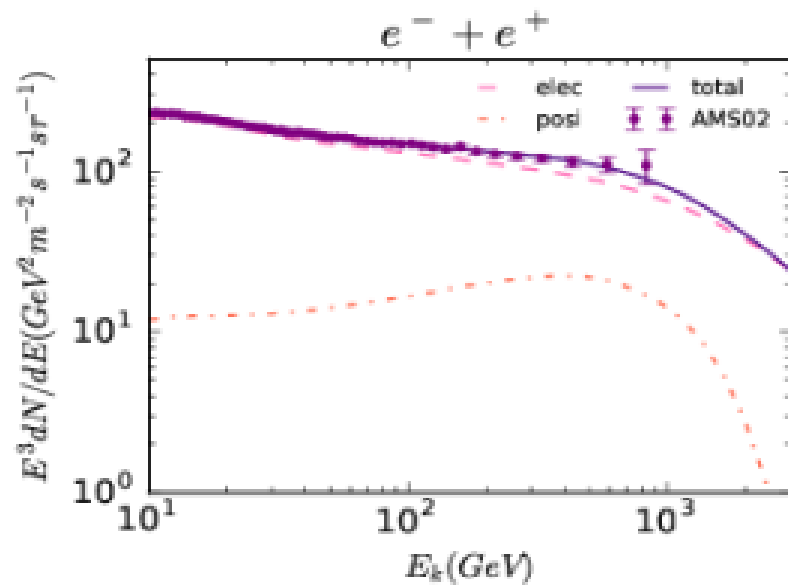
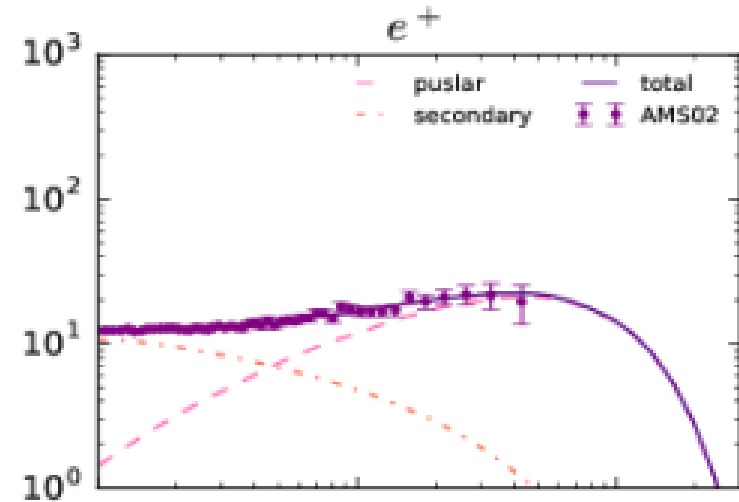
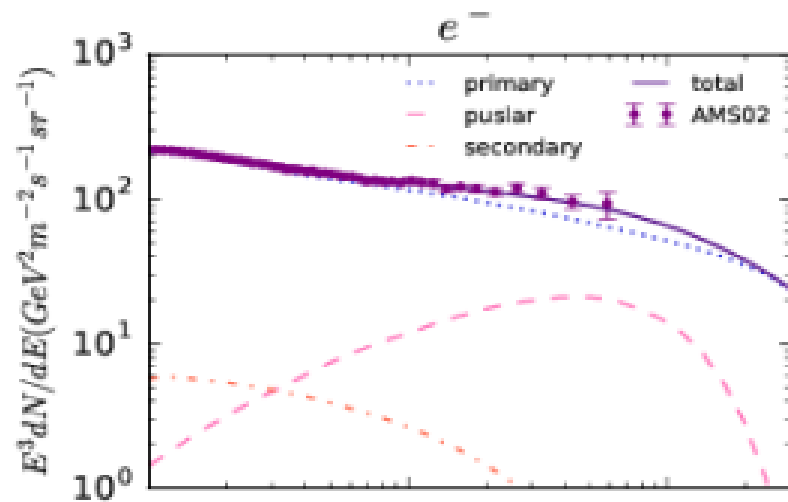


PAMELA: 2006-2016 CALET: 2015-2020; AMS: 2011-2024;
DAMPE: 2015-2020; Fermi: 2008-2018; HERD: 2023-

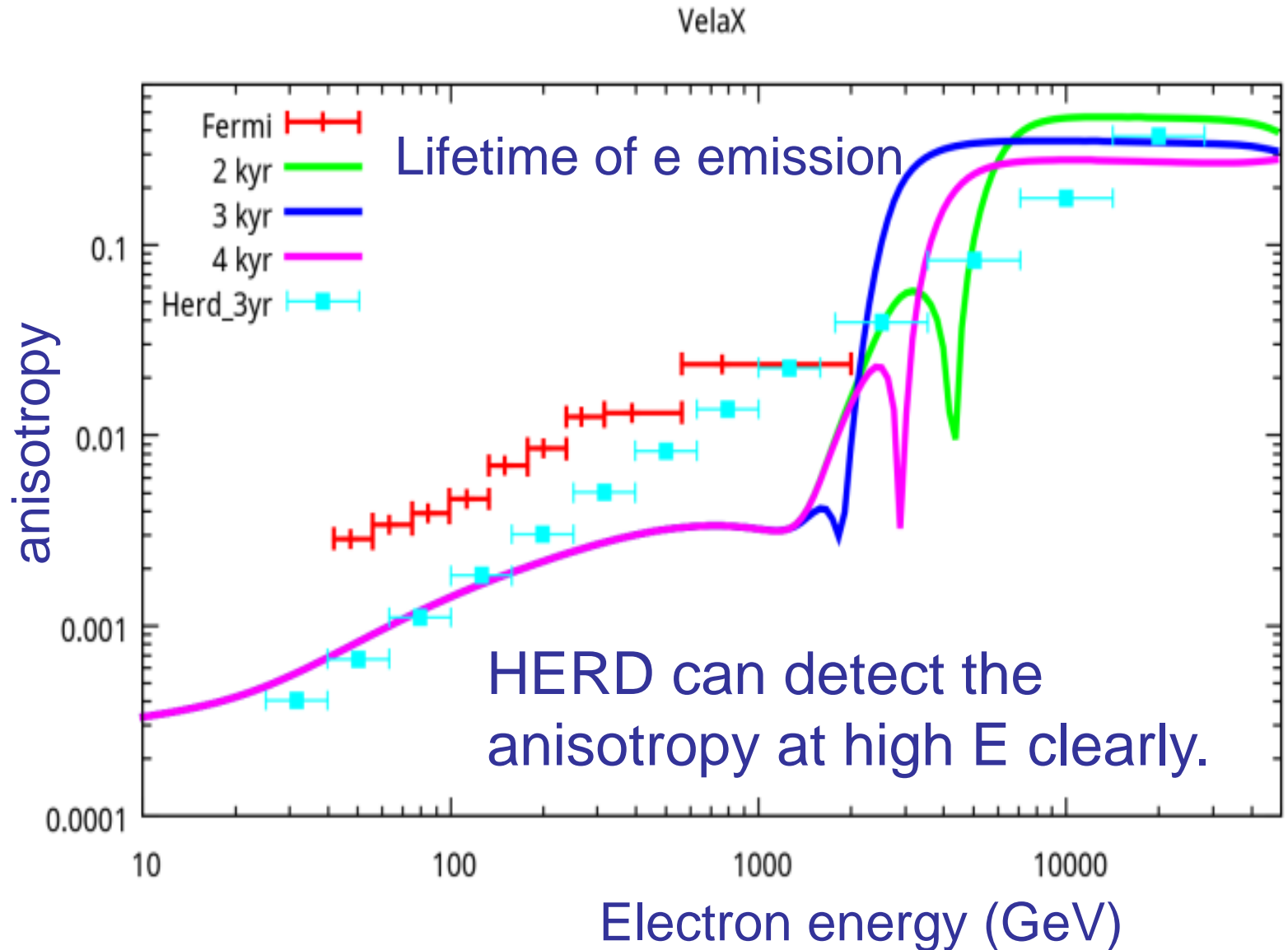
AMS02 data consistent with DM model...



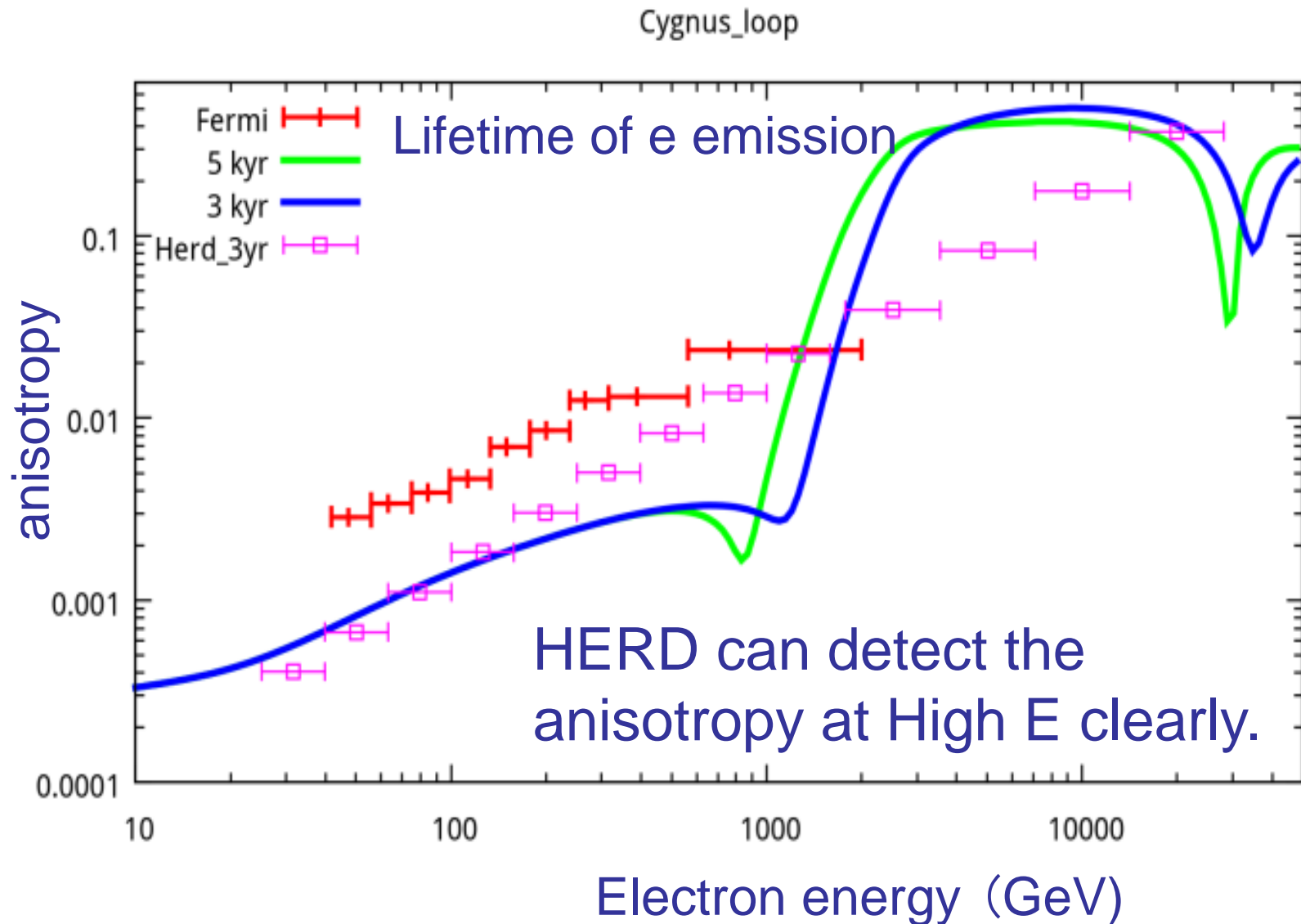
And also consistent with Pulsar model



Expected anisotropy of nearby high energy CR sources: Vela-X

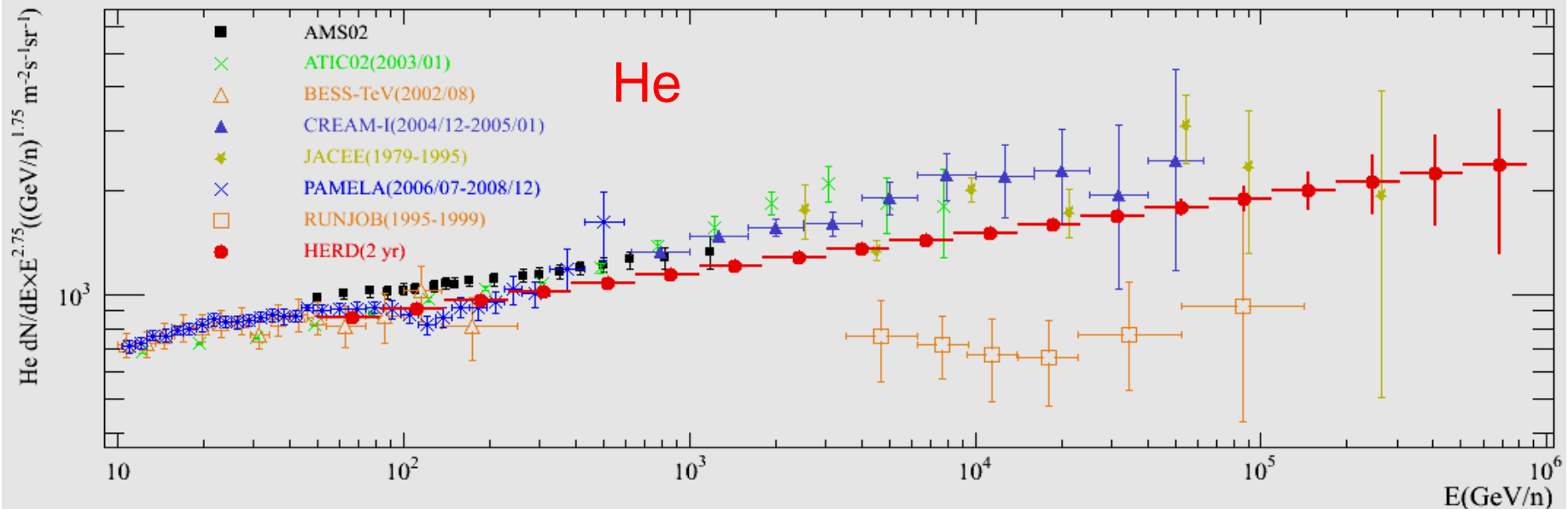
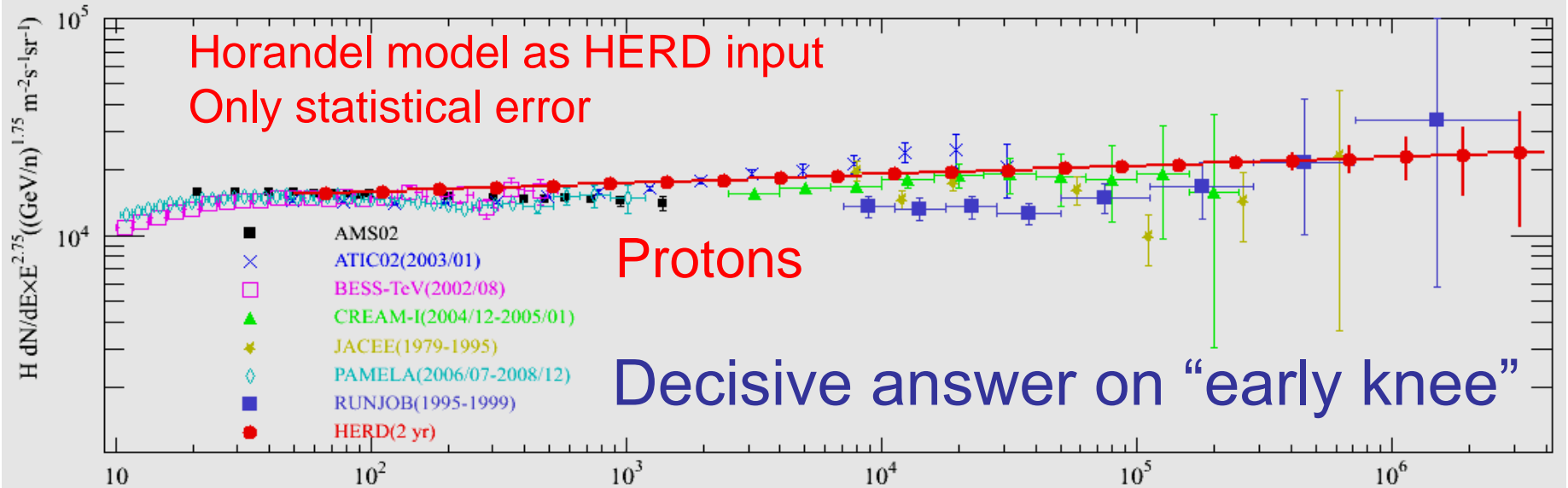


Expected anisotropy of nearby high energy CR sources: Cyg Loop

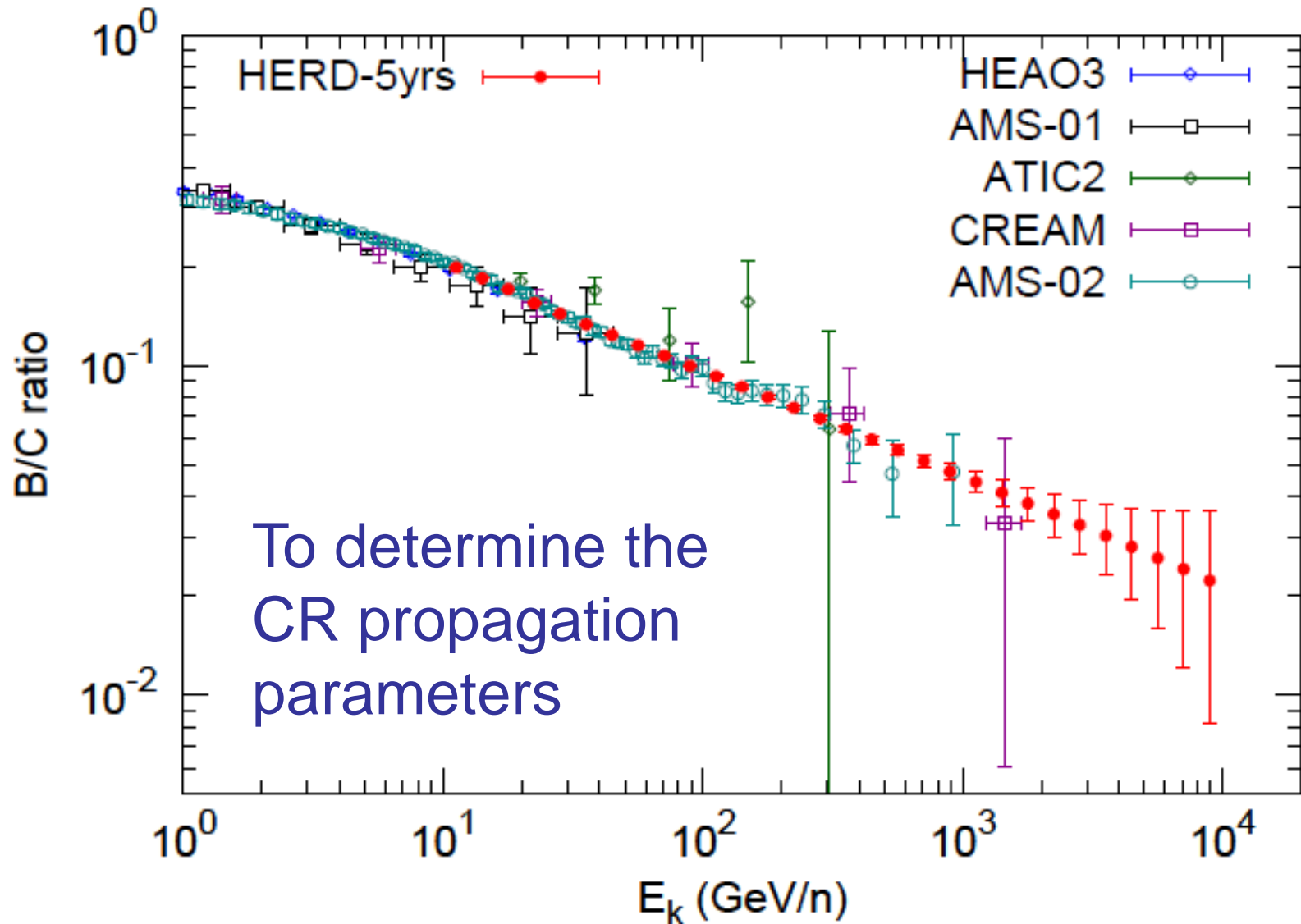


Expected HERD Proton and He Spectra

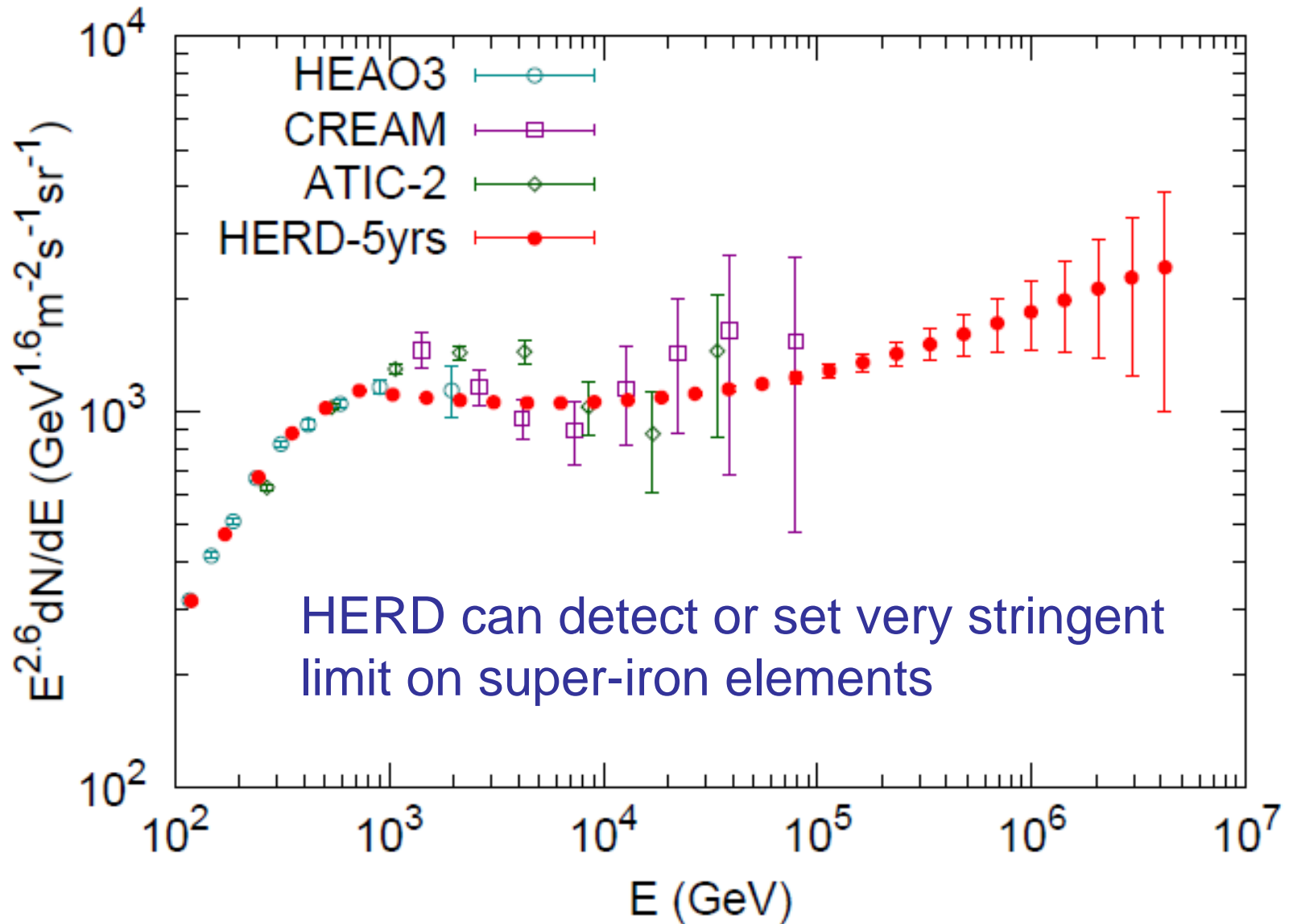
Horandel model as HERD input
Only statistical error



B/C measurement at HERD



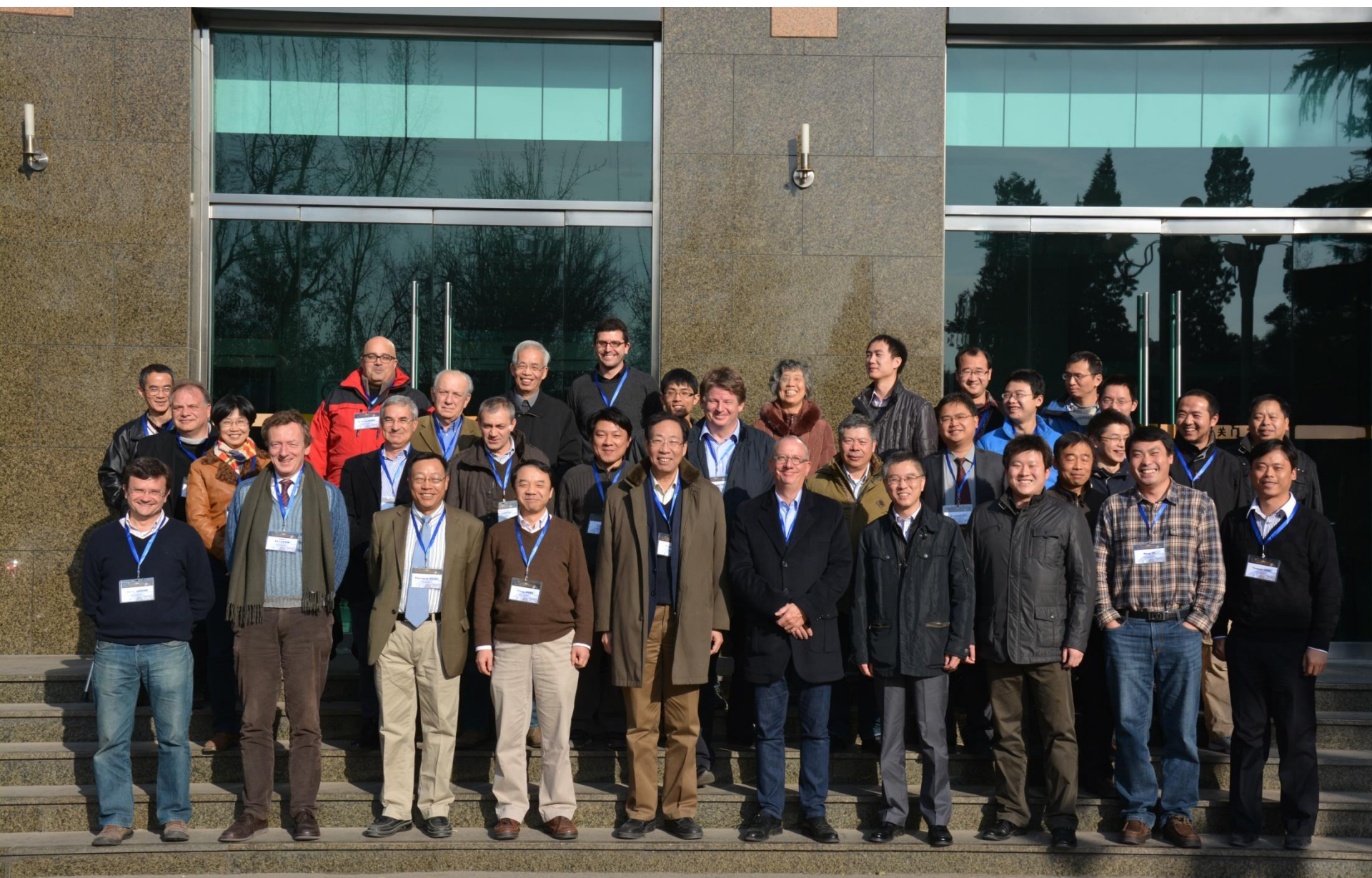
Iron nucleon and super-iron elements



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



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



3rd HERD Workshop @XIOPM 2016/1/18-21

The 3rd HERD Workshop

at XIOPM, Xi'an of China, Jan 18-21, 2016.



~20 international participants from Europe & US

International collaboration (120+ colleagues)

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



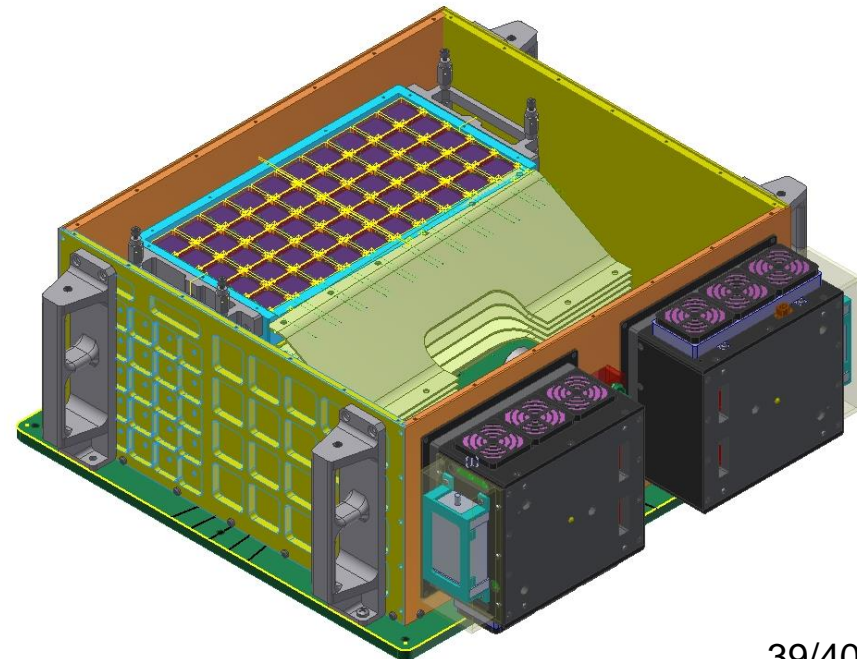
4th HERD workshop
ASI HQs, Roma, Italy 2017.2.9

HERD instrument teams -- tentative

Subsystem	Led by	Participated by
CALO	IHEP	XIOPM
STK	INFN	DPNC, CIEMAT, KTH, KIT
TRD	THU	GXU (RWTH Aachen)
PSD (+ND)	IHEP	PMO, USTC, IMP
Ground MIP cali.	GXU	IHEP
SPS cali.	INFN	DPNC, IHEP
Payload AIT	IHEP	

HERD beam tests @ CERN

- **1st beam test, Nov. 2015:** verified the 1st generation HERD calorimeter design and readout technique (coordinated by DPNC: Prof. Xin Wu)
- **2nd beam test, Oct. 2017:** 2nd generation HERD calorimeter (coordinated by DPNC : Prof. Xin Wu), to be followed by the 5th HERD workshop



Summary on China-DPNC collaboration

- Starting from AMS, China-DPNC collaboration on space astroparticle research has been uninterrupted and expanded.
- Current missions: DAMPE, POLAR, HXMT
- Future large missions: eXTP and HERD
 - DPNC participation crucial & encouraged by SSO
- Other possibilities on small-medium scale missions: PANGU, micro-PANGU or POLAR2

Fruitful past and bright future!

Great opportunities!