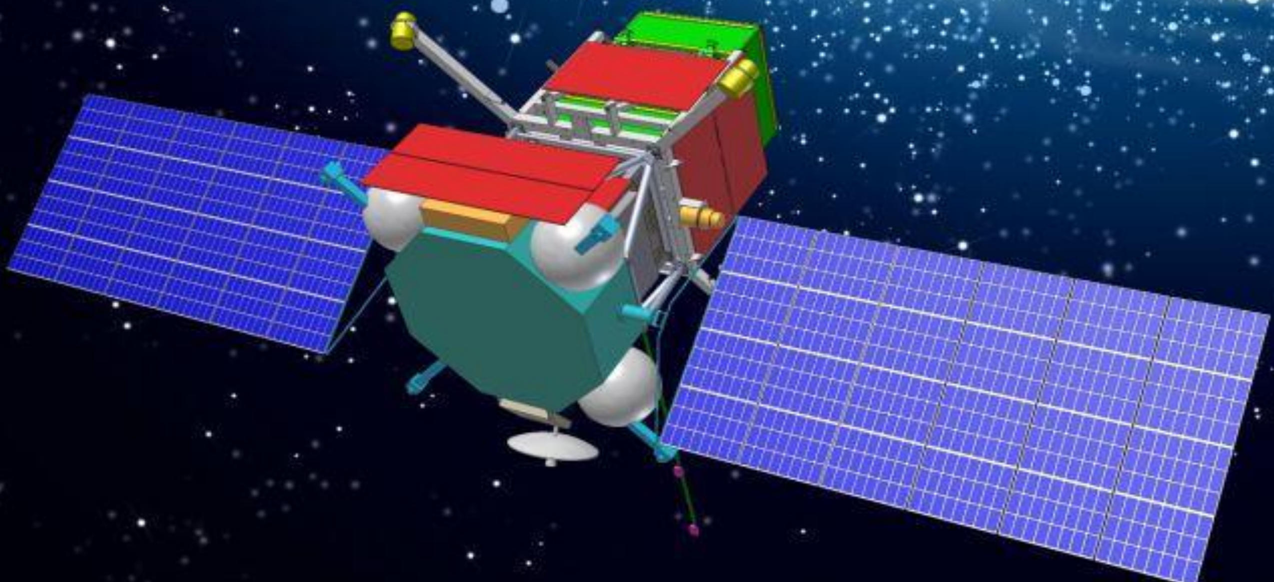
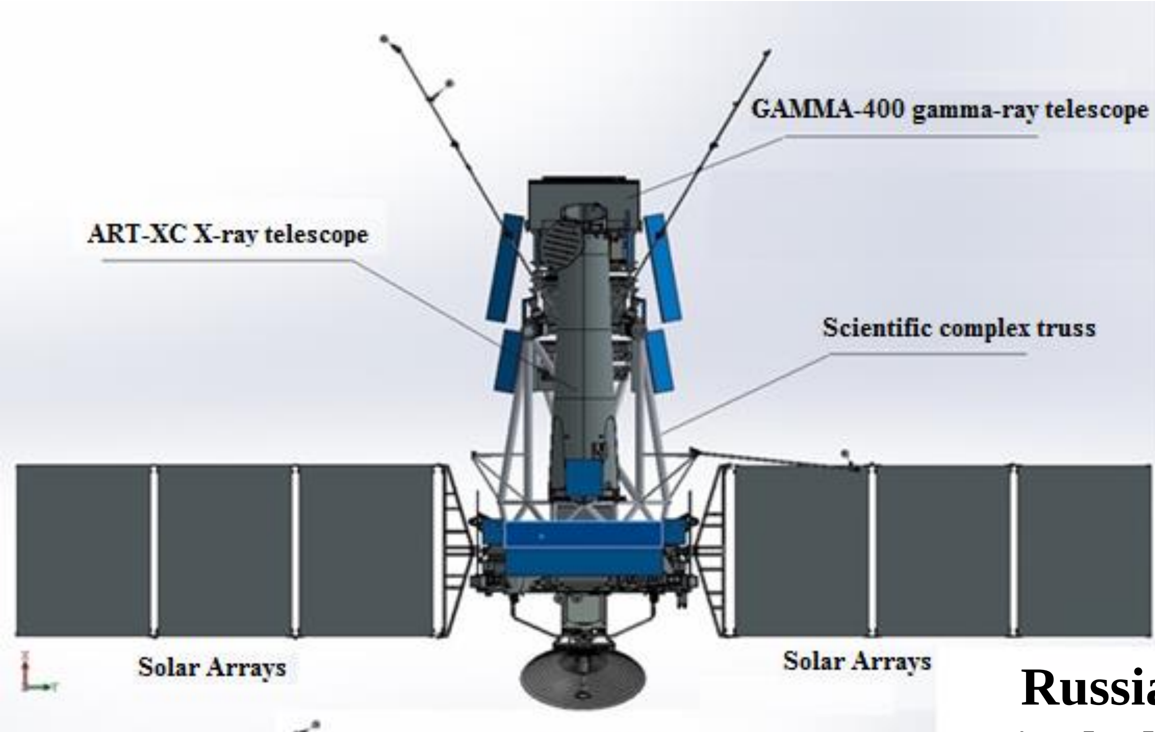
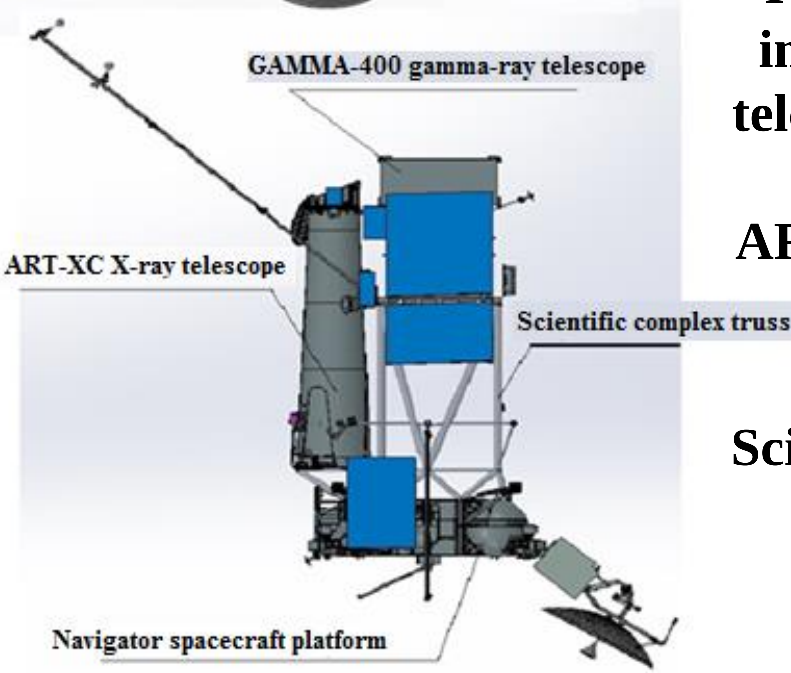
Nikolay Topchiev
for the GAMMA-400 Collaboration

GAMMA-400 gamma-ray observations in the GeV and TeV energy range



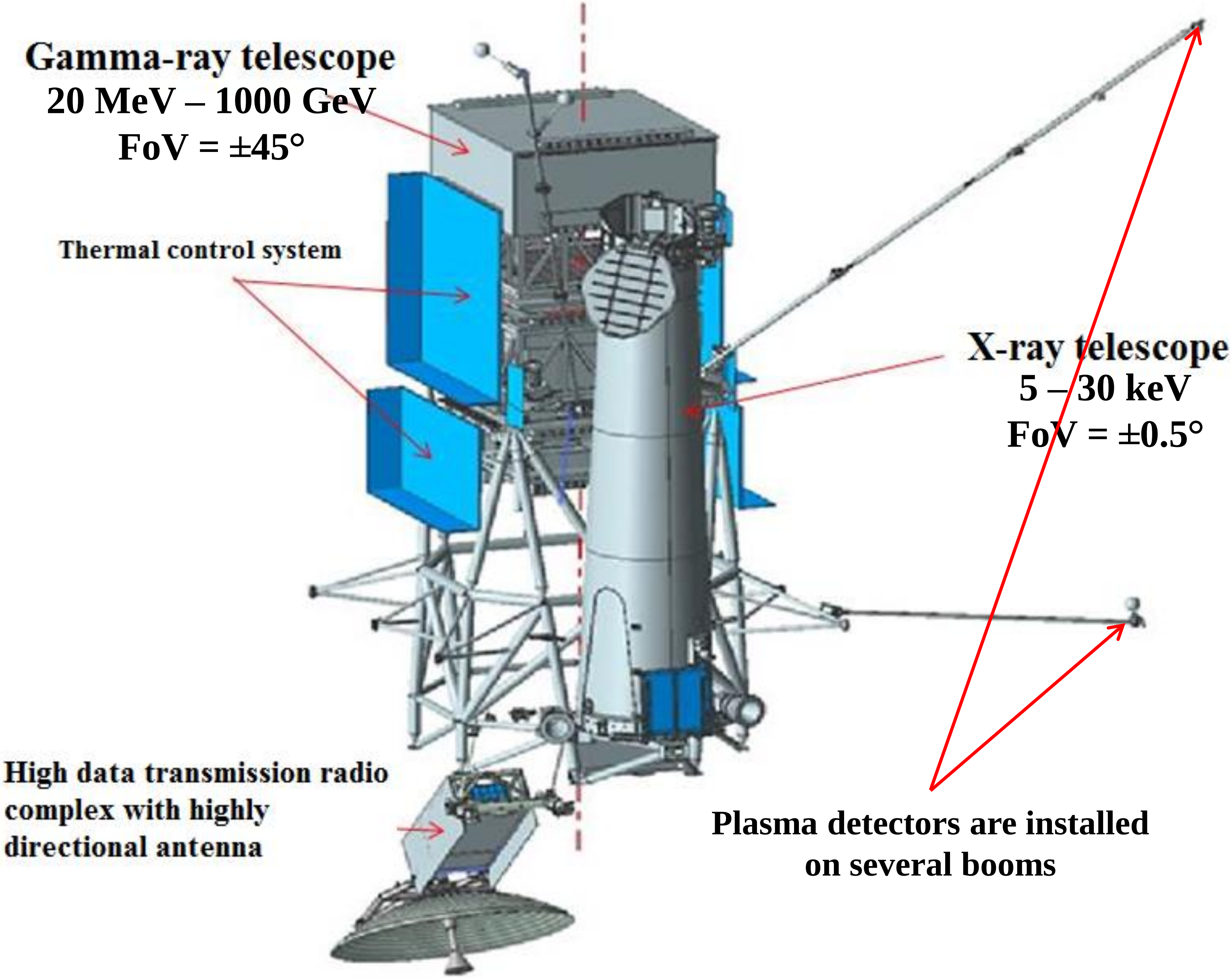
ISCRA-2021, June 10, 2021





Russian astrophysical observatory includes GAMMA-400 gamma-ray telescope (mainly, LPI + MEPhI) and additional instruments:
ART-XC X-ray telescope and plasma detectors (IKI)

Scientific complex will be installed on Navigator space platform (Lavochkin Association)



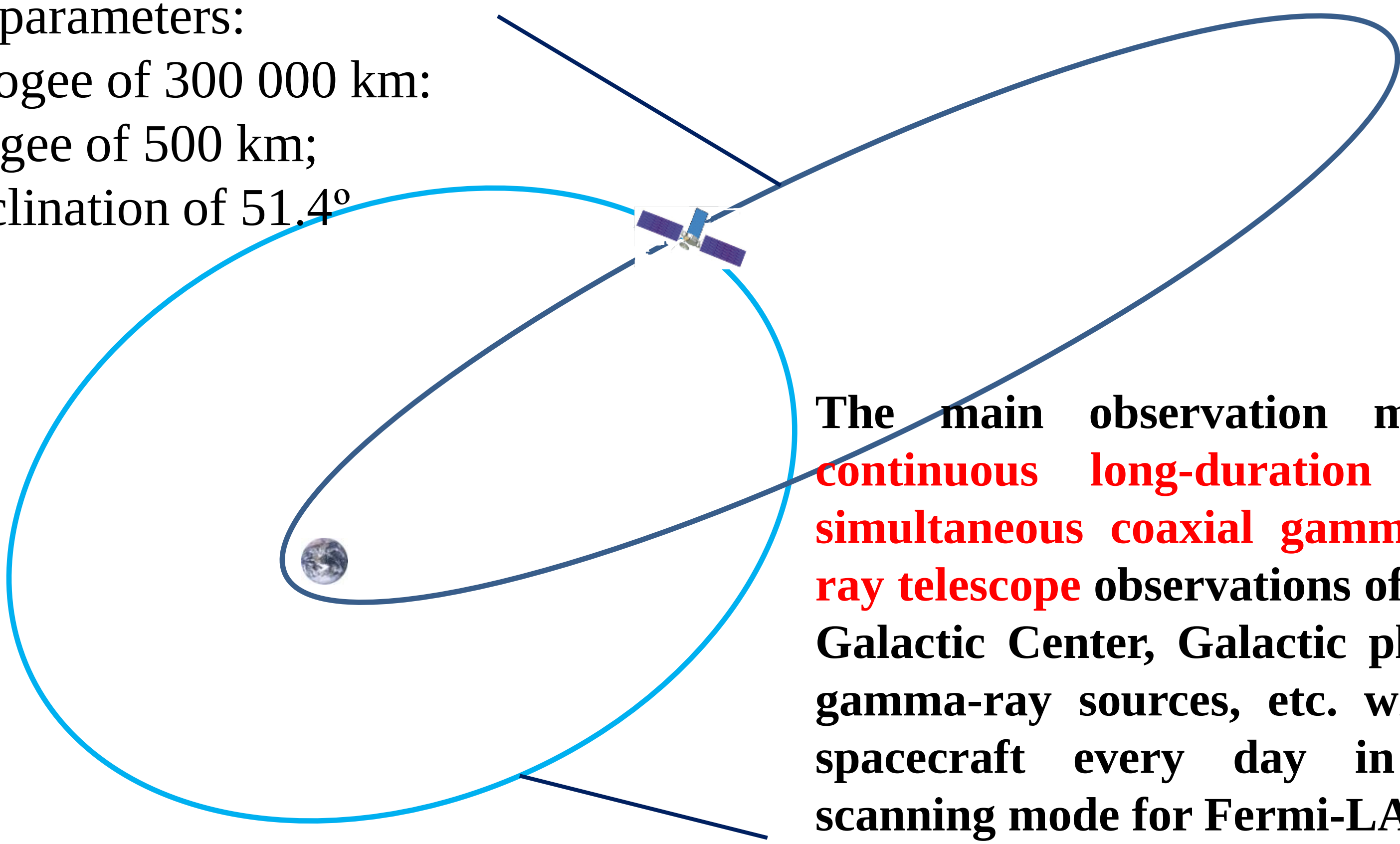
GAMMA-400 scientific complex.

Gamma- and X-ray telescopes are installed coaxially without overlapping fields of view

The GAMMA-400 orbit evolution and observation modes

The highly elliptic orbit of the **GAMMA-400 astrophysical observatory** will have the following initial parameters:
-an apogee of 300 000 km:
-a perigee of 500 km;
-an inclination of 51.4°

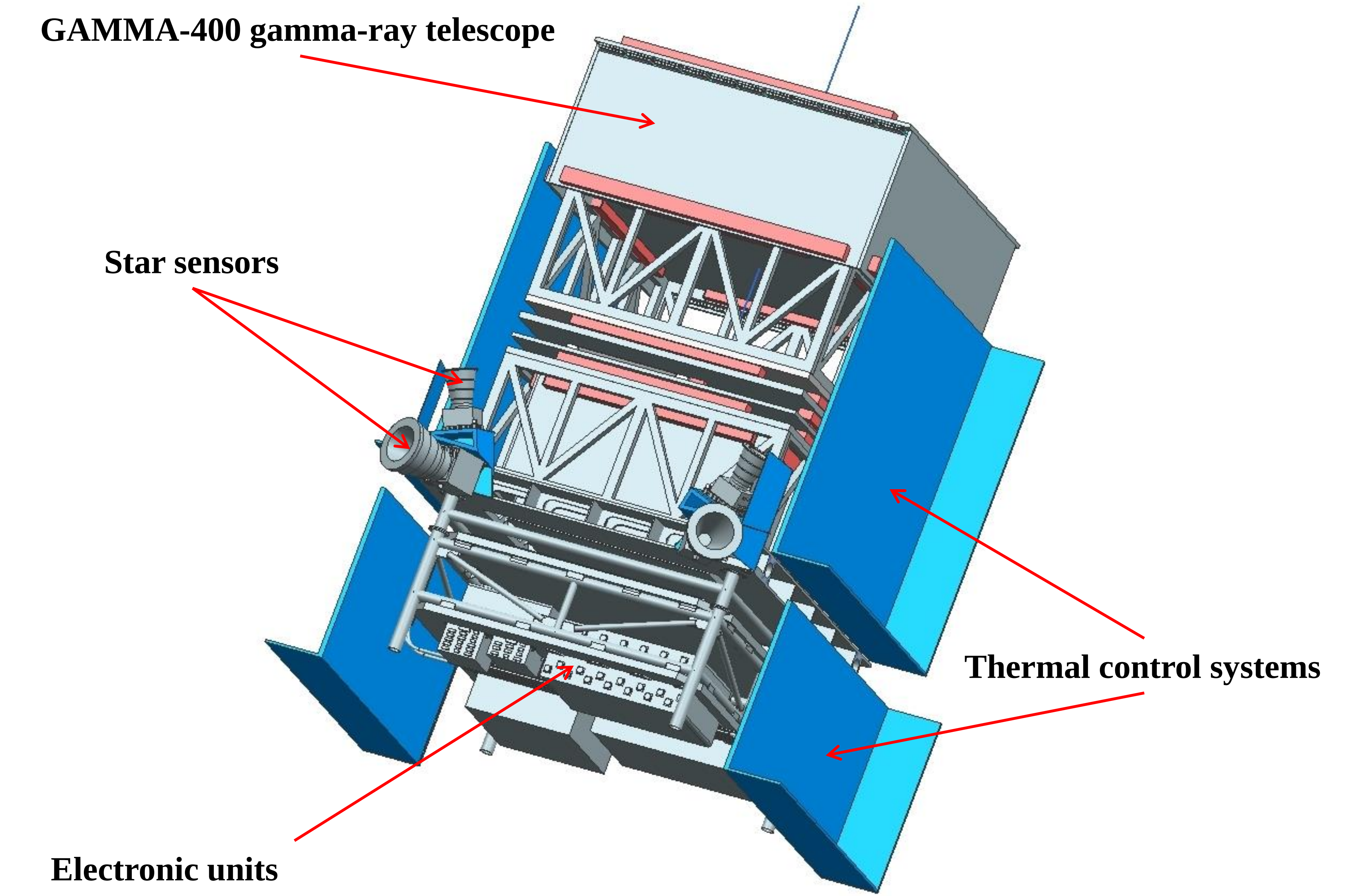
Time of operation will be 7 years



The main observation mode will be continuous long-duration (~100 days) simultaneous coaxial gamma-ray and X-ray telescope observations of sources in the Galactic Center, Galactic plane, extended gamma-ray sources, etc. with 1°-shift of spacecraft every day in contrast to scanning mode for Fermi-LAT.

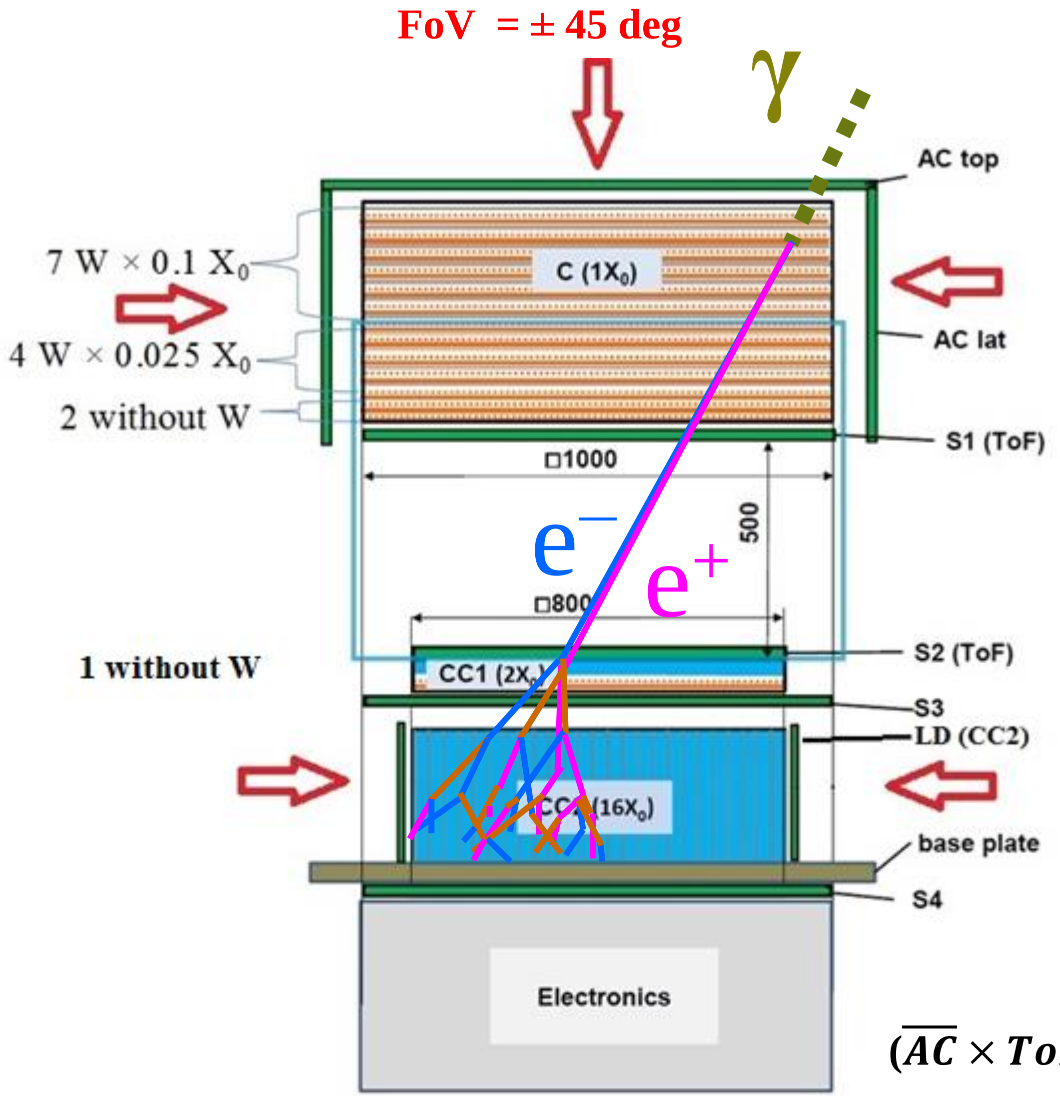
Under the action of gravitational disturbances of the Sun, Moon, and the Earth after ~6 months the orbit will transform to about circular with a radius of ~200 000 km and will be without the Earth’s occultation and out of radiation belts.

As a ground receiving station, it is proposed to use the radio-astronomy complex based on the RT-22 radio-telescope in Pushchino (Lebedev Physical Institute), the same station as for Radioastron mission (Spectr-R).



View of the GAMMA-400 gamma-ray telescope

The GAMMA-400 physical scheme



AC – anticoincedence scintillation system

C - SciFi converter-tracker ~1 X_0

S1, S2 – TOF scintillation detectors

CC1, CC2 – CsI(Tl) calorimeter vertical thickness
2+16=18 X_0

CC2 – lateral thickness
~43 X_0

S3, S4 – scintillation detectors

E_γ = ~20 MeV – ~1 TeV

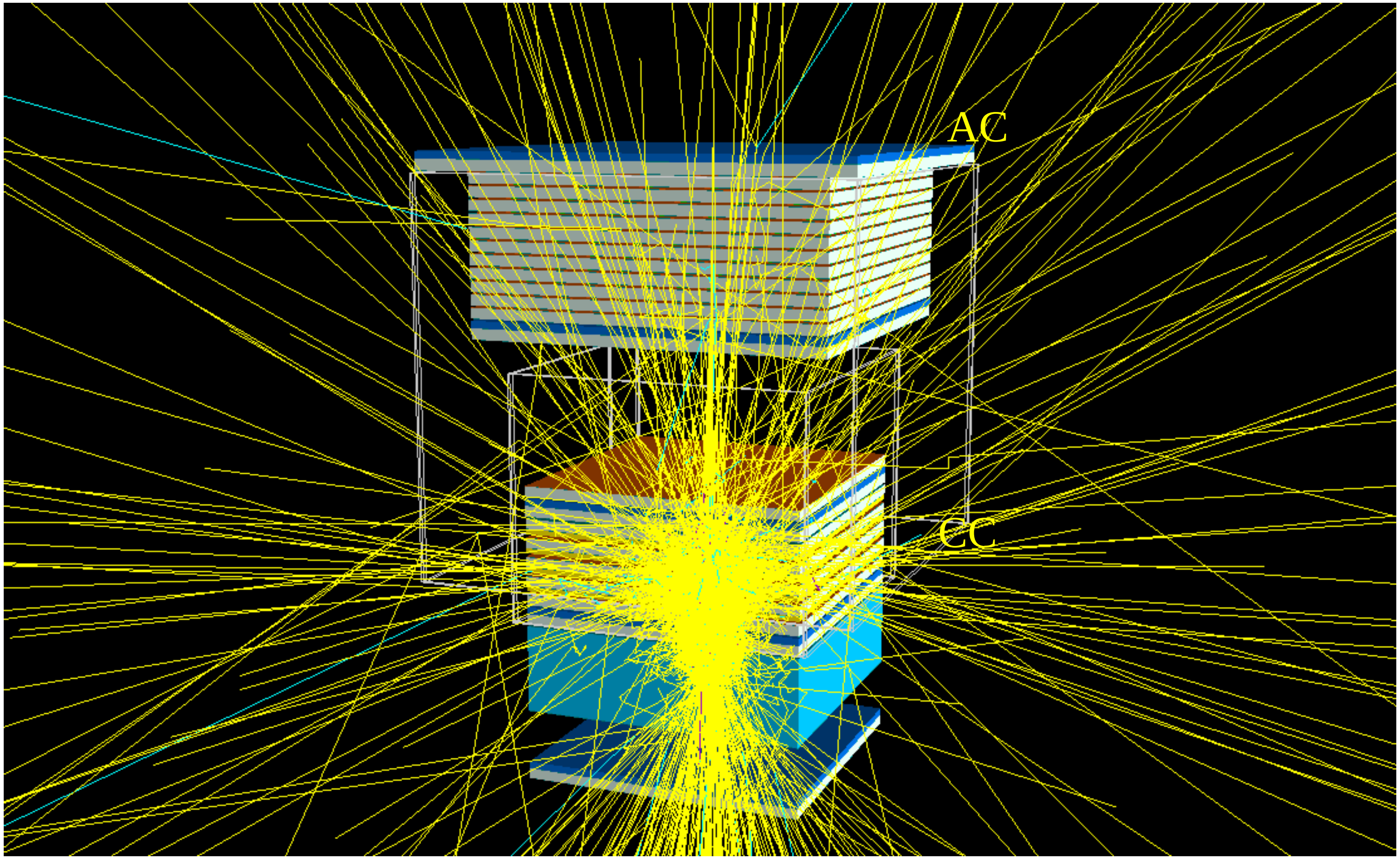
$\Delta\theta$ = ~0.01° (E_γ = 100 GeV)

$\Delta E/E$ = ~2% (E_γ = 100 GeV)

Main trigger:

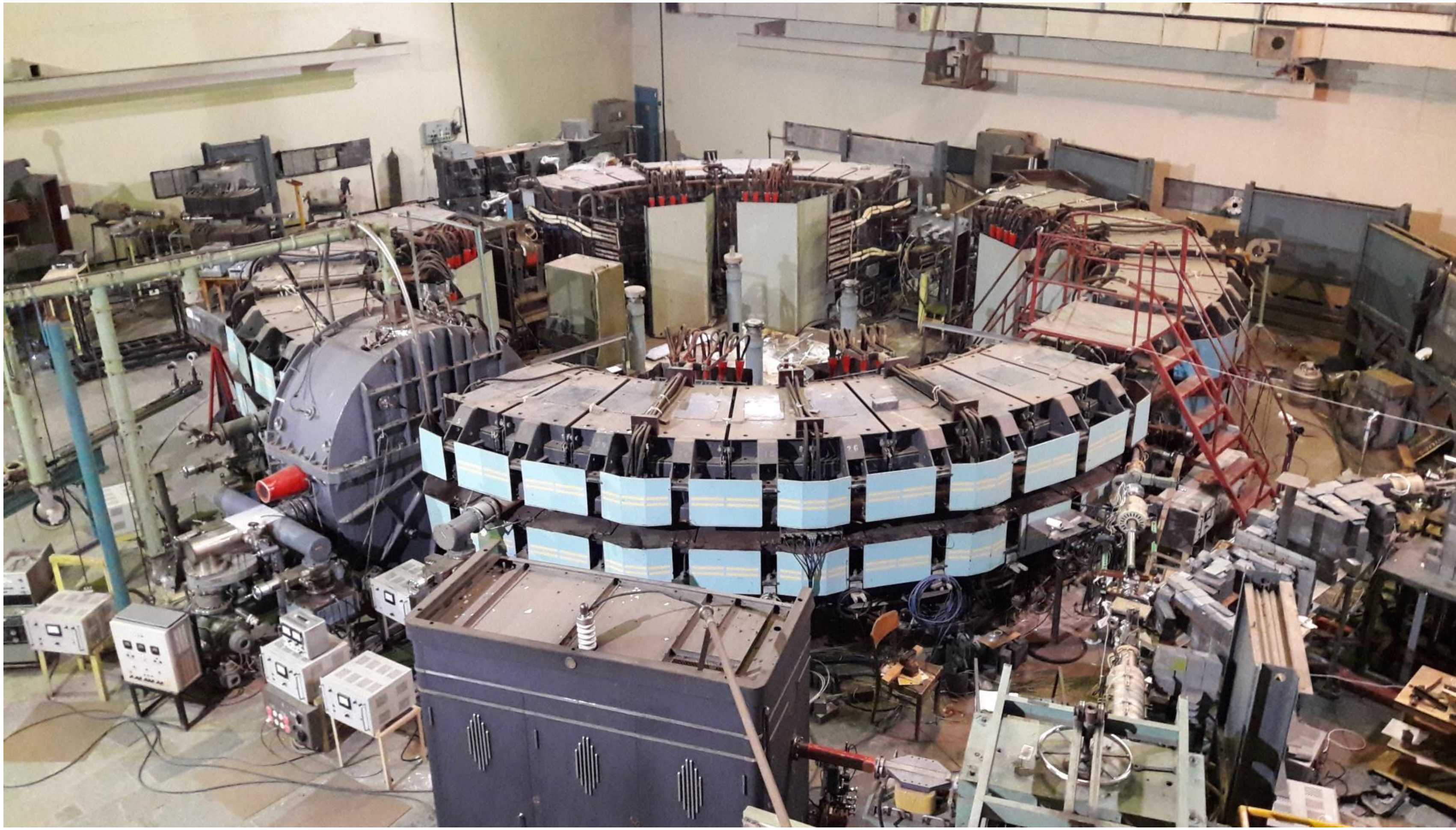
$(\overline{AC} \times ToF)|(S3(E_{RELEASE} > E_{THRESHOLD})ToF)$

GAMMA-400 will detect gamma rays from top-down and lateral directions



When interacting high-energy (> 5 GeV) gamma rays with calorimeter (CC) matter, backsplash particles (mainly 1-MeV photons) are formed, which can interact in AC and exclude real gamma rays. To eliminate this effect all scintillation detectors are constructed as double 100-mm strips and time-of-flight methods are used.

S-25R electron synchrotron
(Lebedev Physical Institute, Troitsk)

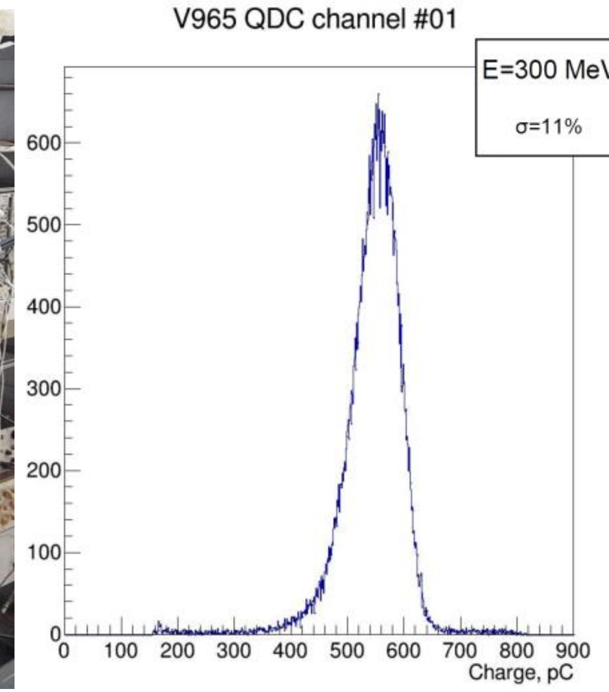


Prototypes of some detector systems were tested and calibrated on positron beams at S-25R electron synchrotron (LPI, Troitsk) in the energy range of 100-300 MeV.

Prototype of AC detector
(L = 1300 mm, time resolution = ~200 ps)


CC2

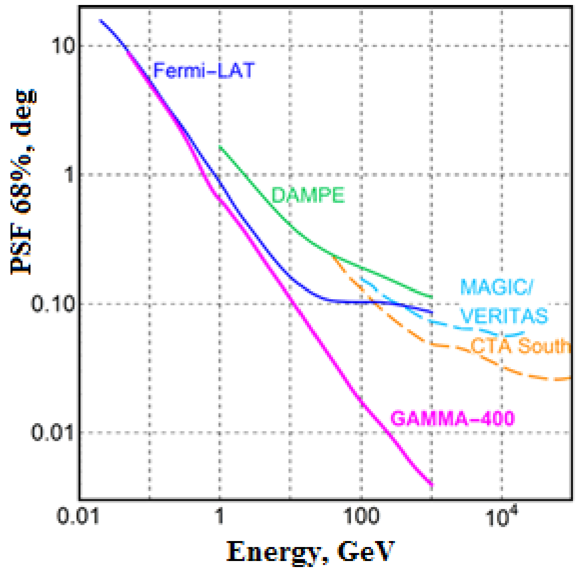

Калориметр КК2


V965 QDC channel #01
E=300 MeV
σ=11%
0
100
200
300
400
500
600
0
100
200
300
400
500
600
700
800
900
Charge, pC

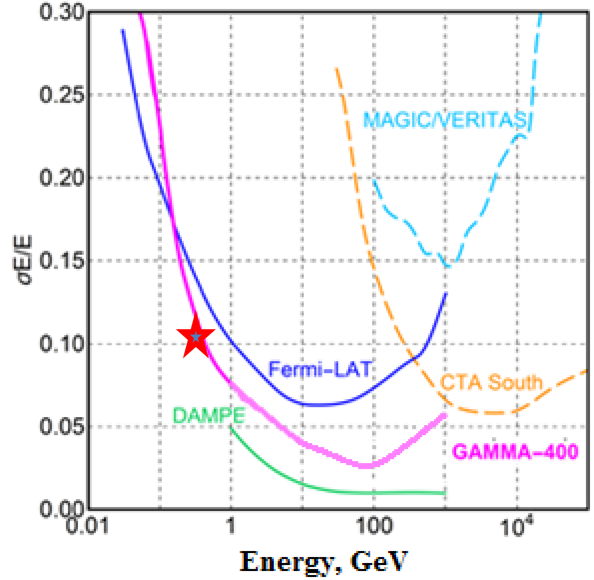

CC2

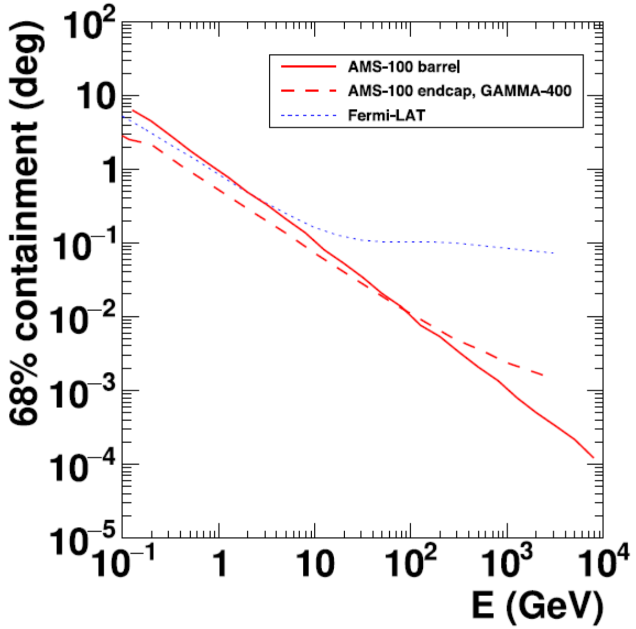

CC2

Angular resolution



Energy resolution





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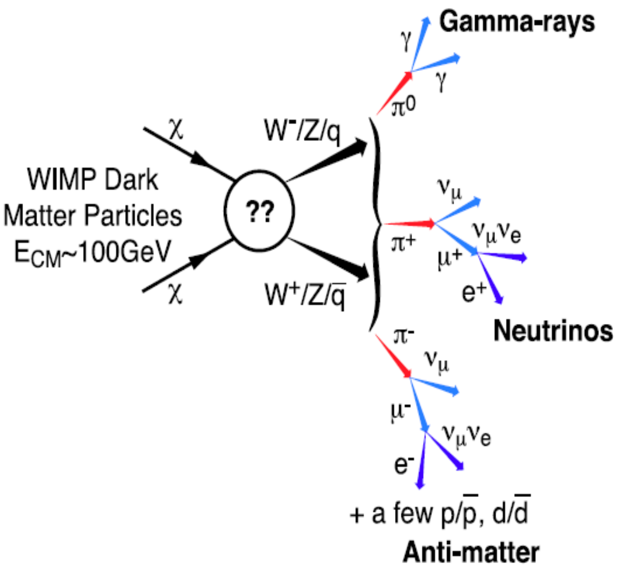
GAMMA-400 calculated angular and energy resolutions vs energy.

★ GAMMA-400 experimental energy resolution for the energy of 300 MeV at LPI electron synchrotron in Troitsk.

Main scientific goals of the GAMMA-400 gamma-ray telescope

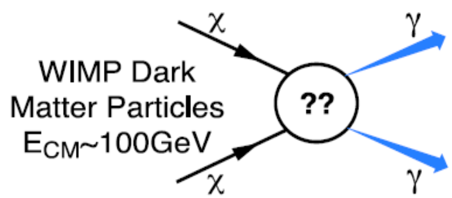
with unprecedented angular **(~0.01° at E_γ = 100 GeV)** and energy resolutions **(~2% at E_γ = 100 GeV)**

1. Dark matter searching (WIMP and ALP particles) by means of gamma-ray astronomy in the energy range ~20 MeV - 1000 GeV

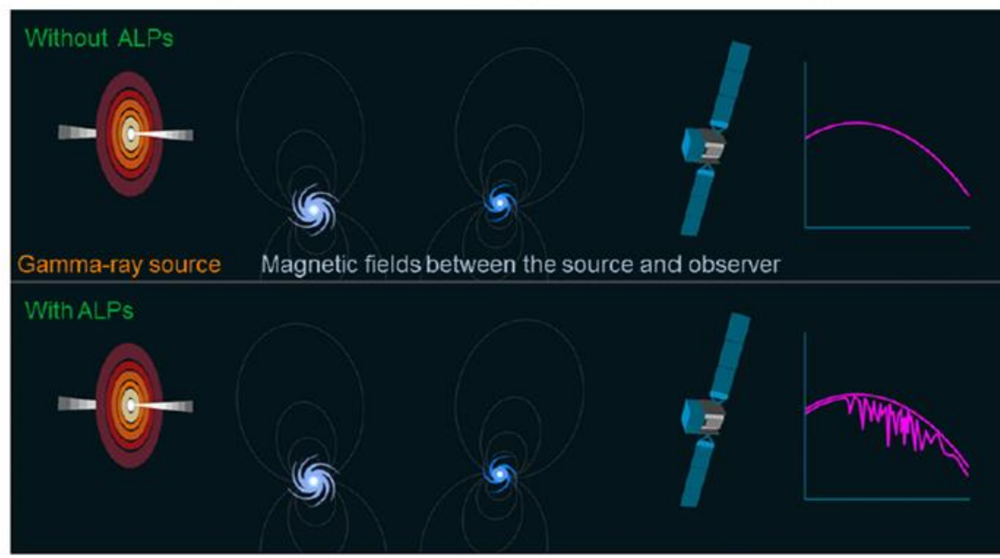


secondary gamma rays

primary monoenergetic gamma rays



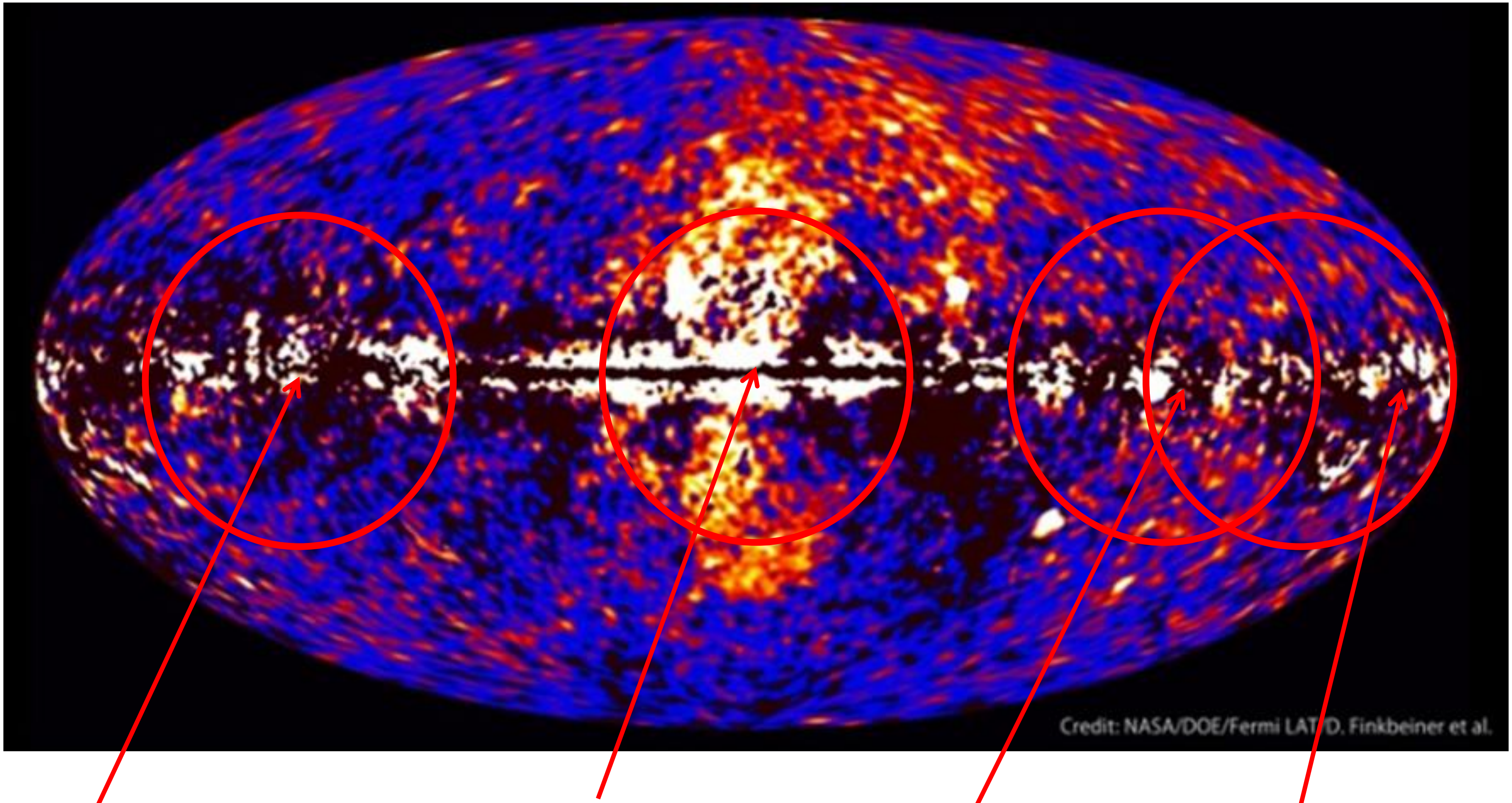
ALP signature searches in pulsar and blazar spectra



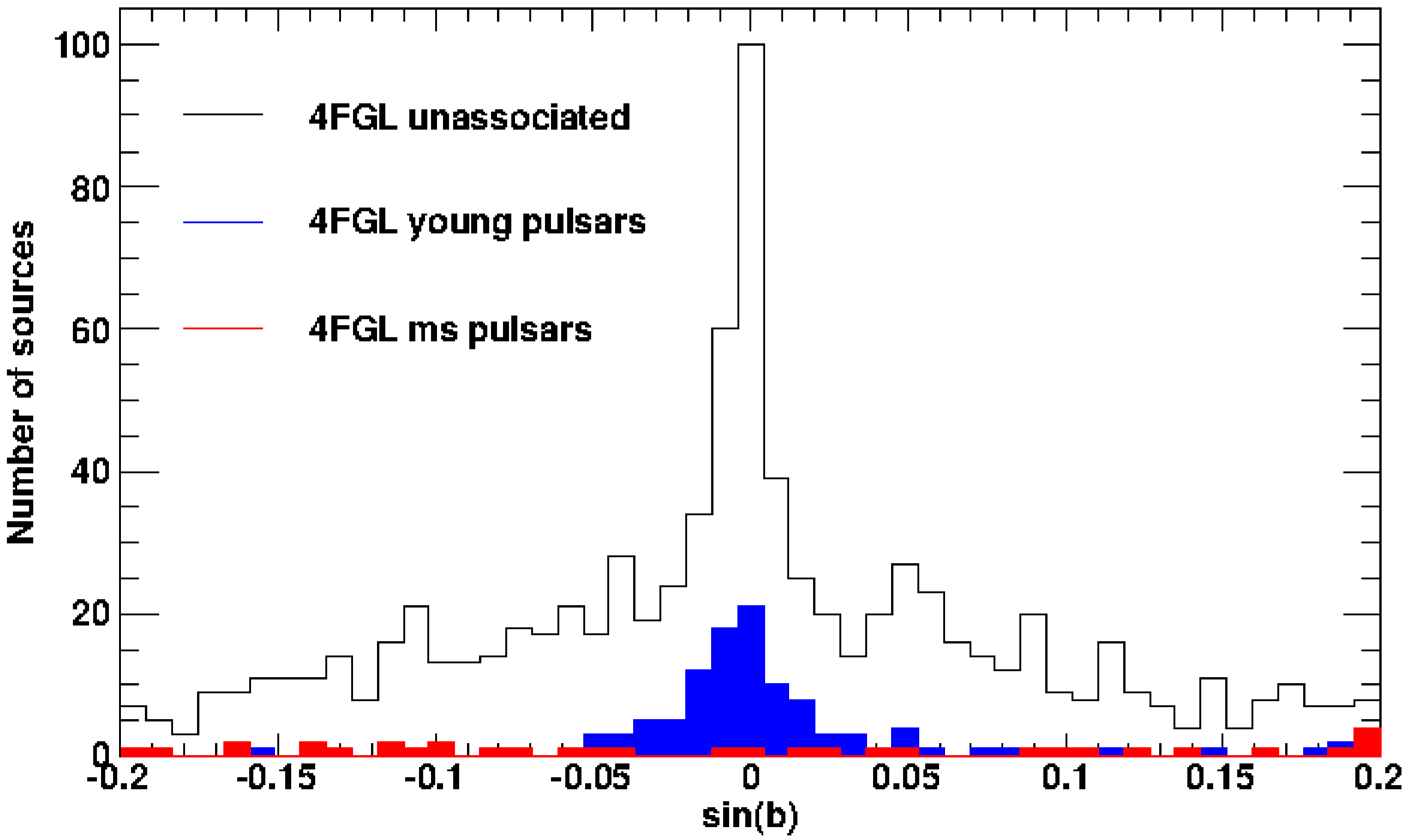
$\gamma + \boldsymbol{B} \leftrightarrow \gamma + ALP$ — conversion

The key relevant parameters of ALP are its mass m_a and electromagnetic coupling constant $g_{a\gamma}$. These parameters define the character of spectral features due to conversion.

2. Precise and detailed observations of Galactic plane, especially, Galactic Center, Fermi Bubbles, Crab, Vela, Cygnus, Geminga, and other regions with aperture of ±45°

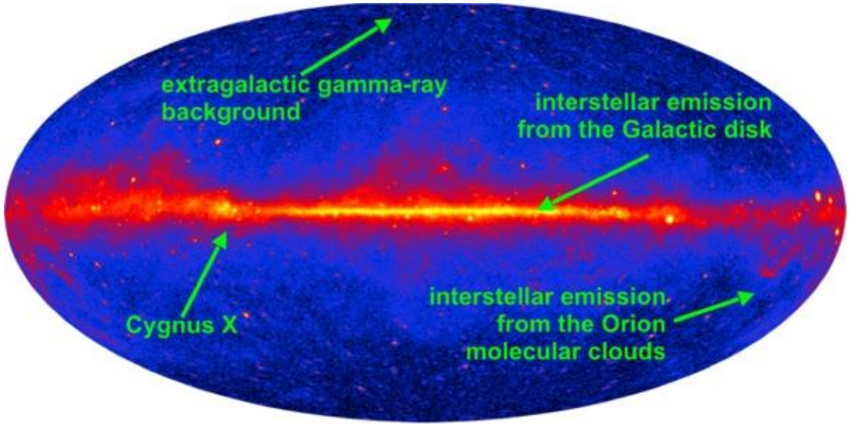


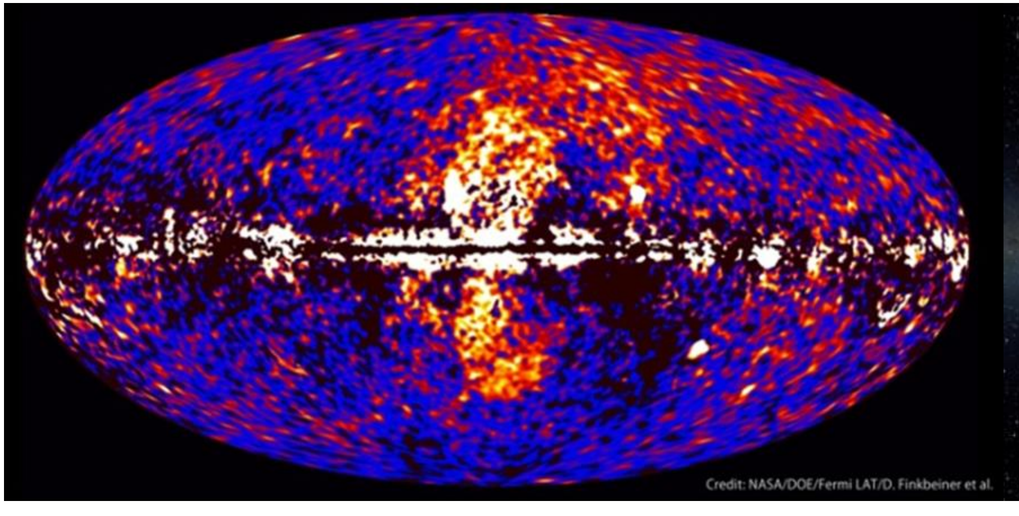
3. Identification (especially in the Galactic plane) of ~1350 from 5064 discrete sources (according to 4th Fermi-LAT catalog), precise studying extended sources, studying detail structure and HE processes in active sources, studying gamma rays from the Sun

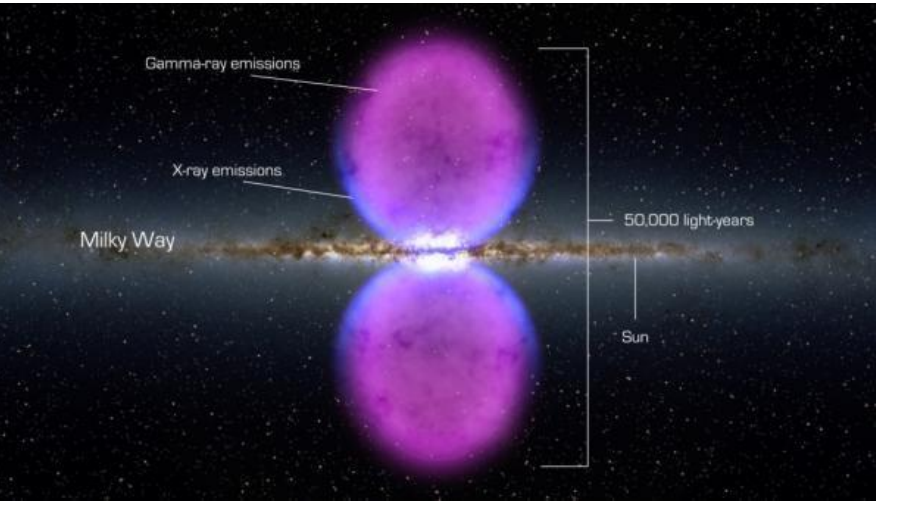


4. Searching for and studying gamma-ray bursts from top-down and lateral directions

5. Studying diffuse gamma rays







	Space-based gamma-ray telescopes						Ground-based facility
	Medium energy			High-energy			
	e-ASTROGAM	AMEGO	Fermi-LAT	**GAMMA-400**	HERD	AMS-100	CTA
Country	Europe	USA	USA	**Russia**	China	Europe +USA	
Energy range	0.3 MeV – 3 GeV	0.2 MeV - 10 GeV	50 MeV – 1000 GeV	**20 MeV – 1 TeV**	0.5 GeV – 10 TeV	1 GeV – 10 TeV	> 50 GeV
Observation mode	Scanning	Scanning	Scanning	**Point-source**	Scanning	Scanning	Scanning
Orbit	Circular, ~550 km	Circular, ~550 km	Circular, ~550 km	**Highly elliptical, 500-300 000 km**	Circular, ~400 km	L2	
Angular resolution	0.1°	1°	0.1°	**~0.01°**	0.1°	~0.01°	0.1°
Energy resolution	20%	10%	10%	**~2%**	1-2%	1-2%	15%

Performance of future gamma-ray telescopes in comparison with Fermi-LAT

Conclusions

- **After Fermi-LAT the GAMMA-400 mission will greatly improve the direct data of LE+HE gamma rays due to unprecedented angular and energy resolutions, large area, and continuous long-term simultaneous coaxial gamma-ray and X-ray telescope observations. GAMMA-400 space observatory is scheduled to launch for ~2030.**

GAMMA-400 site - http://gamma400.lebedev.ru/