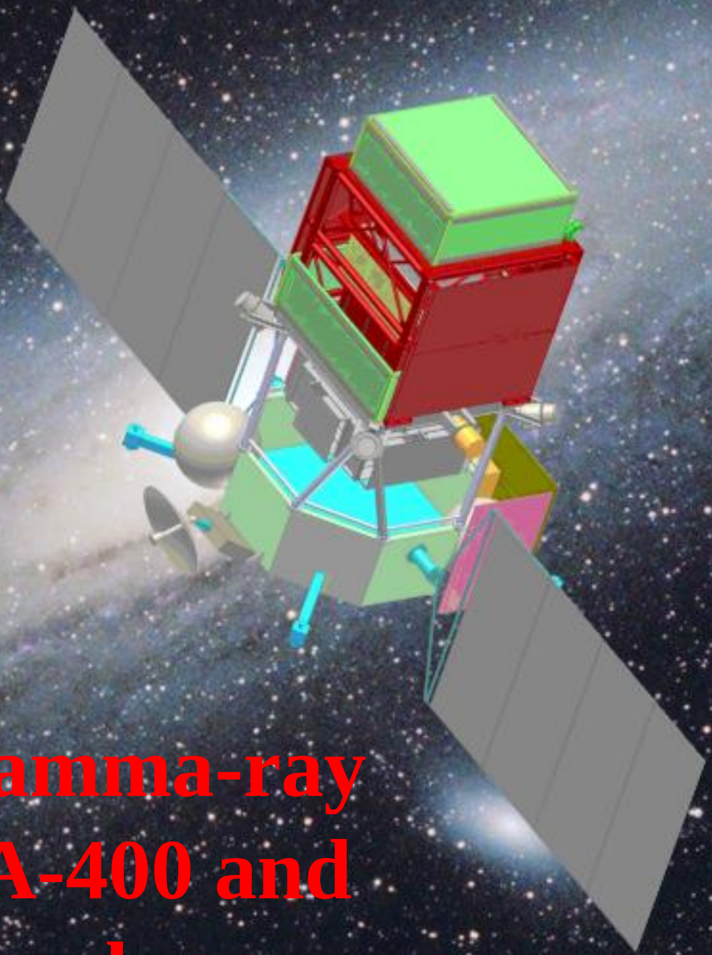
Russian Academy of Sciences
P.N.Lebedev Physical Institute
L P I

Arkadiy M. Galper
for the GAMMA-400 Collaboration



The space-based gamma-ray telescope GAMMA-400 and its scientific goals

"Workshop on the Future of Dark Matter Astroparticle Physics", Trieste, October 8, 2013

GAMMA-400 TEAM

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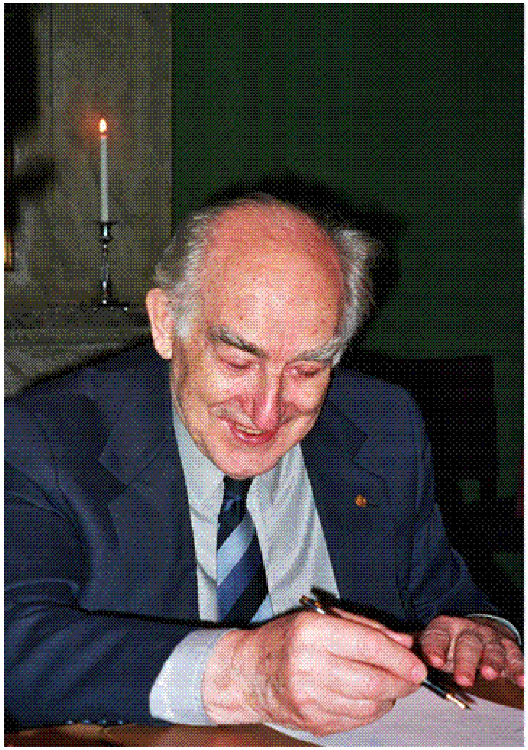
Taras Shevchenko National University of Kyiv (Kiev, Ukraine): B.I. Hnatyk

Lviv Center of Institute of Space Research, Lviv (Lviv, Ukraine): V. Korepanov

APPROVED
by the decree of the Russian Government
of December 28, 2012   No. 2594-R

Russian Government program
"Russian Cosmic Activity in 2013–2020"

In project:
Creation of three space observatories: "Spectrum-UV", "Spectrum-M" ("Millimetron"), and "GAMMA-400" to research astrophysical objects in various bands of the electromagnetic spectrum and high-energy gamma rays.



Vitaly Ginzburg (1916-2009)

Lidiya Kurnosova (1918-2006)

At the end of the last century the Nobel laureate academician Vitaly Ginzburg (LPI) and professor Lidiya Kurnosova (LPI) were initiated the GAMMA-400 project in Russia to search for dark matter particles using the gamma-ray astronomy methods. Within the framework of this project, which has become international, the precision gamma-ray telescope GAMMA-400 with high physical and technical characteristics is designed.

УТВЕРЖДАЮ

Директор

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им. П.Н. Лебедева РАН

академик

Месяц Г.А.

_____________ 2009 г.

ПРОЕКТ ГАММА-400

ИССЛЕДОВАНИЕ КОСМИЧЕСКОГО ГАММА-ИЗЛУЧЕНИЯ И ПОТОКОВ ЭЛЕКТРОНОВ И ПОЗИТРОНОВ В ДИАПАЗОНЕ ЭНЕРГИЙ 1-3000 ГэВ

От ФИАН

Руководитель научного направления

академик

Гинзбург В.Л.

_____________ 2009 г.

Научный руководитель проекта

ГАММА-400

профессор, г.н.с.

Гальпер А.М.

21 мая 2009 г.

Москва, 2009 г.

APPROVED

by the director of

Lebedev Physical Institute

academician

Mesyats G.A.

THE GAMMA-400 PROJECT

THE RESEARCH OF COSMIC GAMMA RAYS AND ELECTRON+POSITRON FLUXES IN THE ENERGY RANGE OF 1–3000 GeV

From LPI

Director of scientific branch

academician

Ginzburg V.L.

Principal Investigator of the Gamma-400 project

professor

Galper A.M.

Moscow, 2009

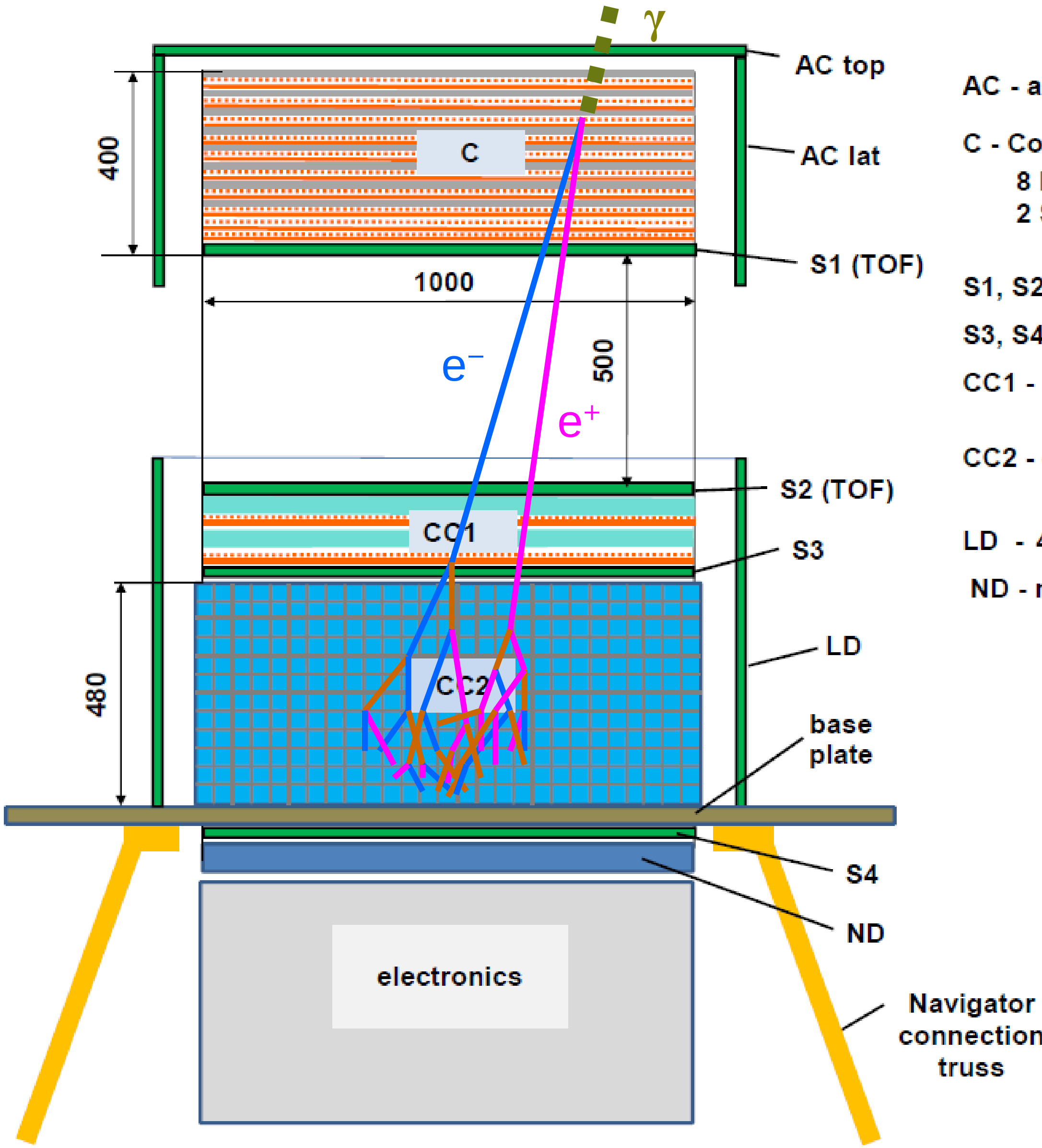
GAMMA-400 SCIENTIFIC GOALS

The GAMMA-400 main scientific goals are: study of the origin of the dark matter by means of gamma-ray astronomy; precise measurements of Galactic and extragalactic discrete astrophysical sources; research of high-energy gamma-ray bursts; research of high energy electron + positron fluxes; research of high-energy nuclei fluxes.

GAMMA-400 GAMMA-RAY TELESCOPE

GAMMA-400 is optimized for the energy 100 GeV with the best parameters: the angular resolution ~0.01°, the energy resolution ~1%, and the proton rejection factor ~10^6, but is able to measure gamma-ray and electron + positron fluxes in the energy range from 100 MeV to 10 TeV. The GAMMA-400 effective area is ~5000 cm^2 at $E_{\gamma} > 1$ GeV, the total mass is 4100 kg, the power consumption is ~2000 W, and a telemetry downlink capability is 100 GB/day. Together with the gamma-ray telescope GAMMA-400, the space observatory will include two star sensors for determining the GAMMA-400 axes with accuracy of approximately 5'', two magnetometers, and the KONUS-FG gamma-ray burst monitor.

GAMMA-400 PHYSICAL SCHEME



AC - anticoincidence detectors (AC top , AC lat)

C - Converter-Tracker - total 1 Xo
8 layers W 0.1 Xo +Si (x,y) (pitch 0.1mm)
2 Si(x,y) no W

S1, S2 - TOF detectors

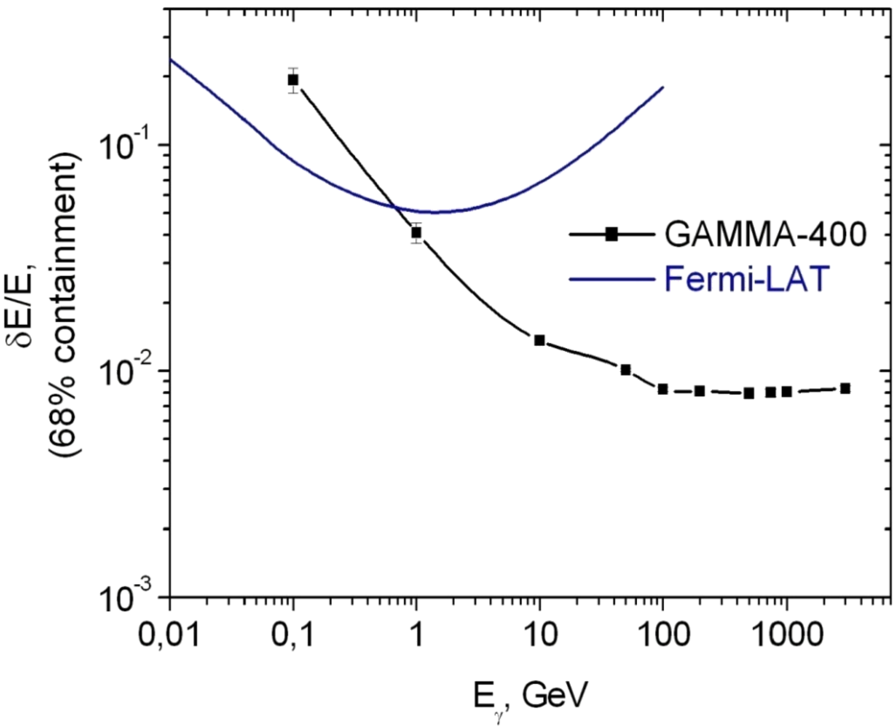
S3, S4 calorimeter scintillator detectors

CC1 - imaging calorimeter (2Xo)
2 layers: CsI(Tl) 1Xo + Si(x,y) (pitch 0.1 mm)

CC2 - electromagnetic calorimeter
CsI(Tl) 23 Xo 3.6x3.6x3.6 cm^3 - 28x28x12=9408 crystals

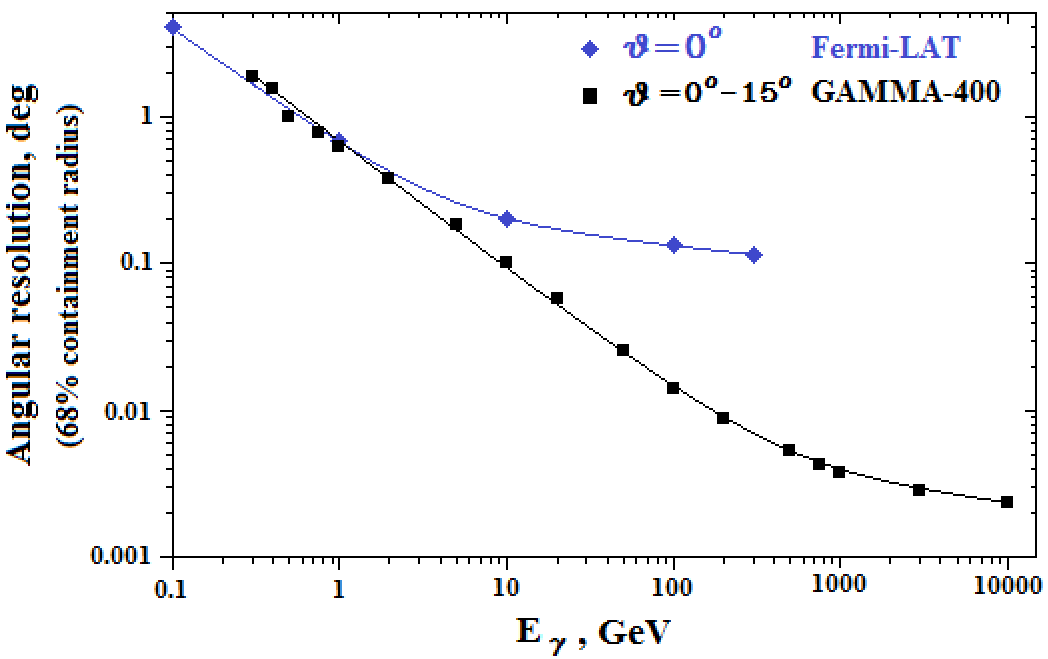
LD - 4 lateral calorimeter detectors

ND - neutron detector



Energy resolution vs. energy for normal incidence for Fermi-LAT and GAMMA-400

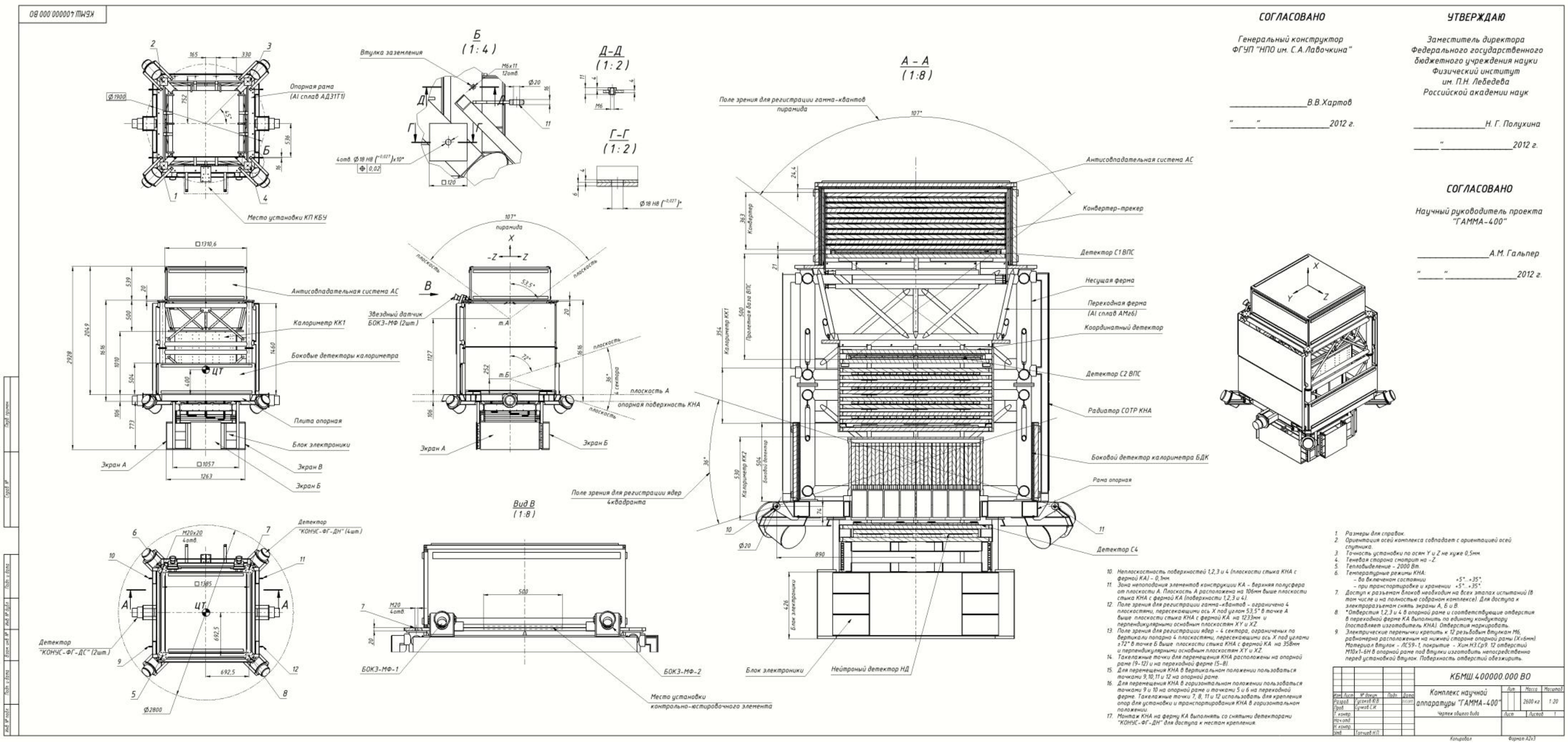
Angular resolution vs. energy for Fermi-LAT (for normal incidence) and GAMMA-400 (for θ=0°-15°)



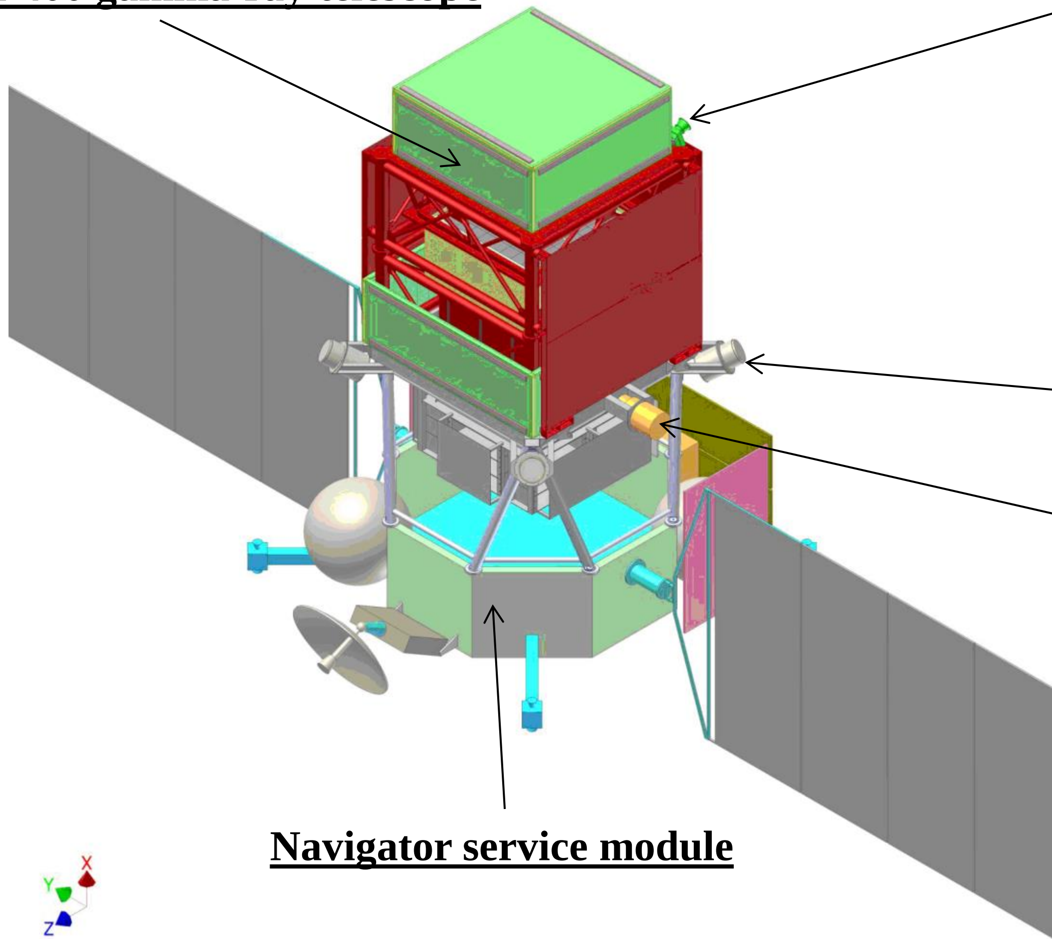
Comparison of the main parameters for GAMMA-400 and Fermi-LAT

	Fermi-LAT	**GAMMA-400**
Orbit	circular, 565 km	high-elliptical, 500-300 000 km
Energy range	20 MeV - 300 GeV	100 MeV – 10 000 GeV
Effective area ($E_\gamma > 1$ GeV)	~8000 cm^2	~5000 cm^2
Coordinate detectors	Si strips (pitch 0.23 mm)	Si strips (pitch 0.1 mm)
Angular resolution ($E_\gamma > 100$ GeV)	~0.1°	~0.01°
Calorimeter - thickness	CsI ~8.5X_0	CsI(Tl)+Si strips ~25X_0
Energy resolution ($E_\gamma > 100$ GeV)	~10%	~1%
Proton rejection coefficient	~10^4	~10^6
Mass	2800 kg	4100 kg
Telemetry downlink capability	15 GB/day	100 GB/day

General view drawing of the GAMMA-400 scientific complex

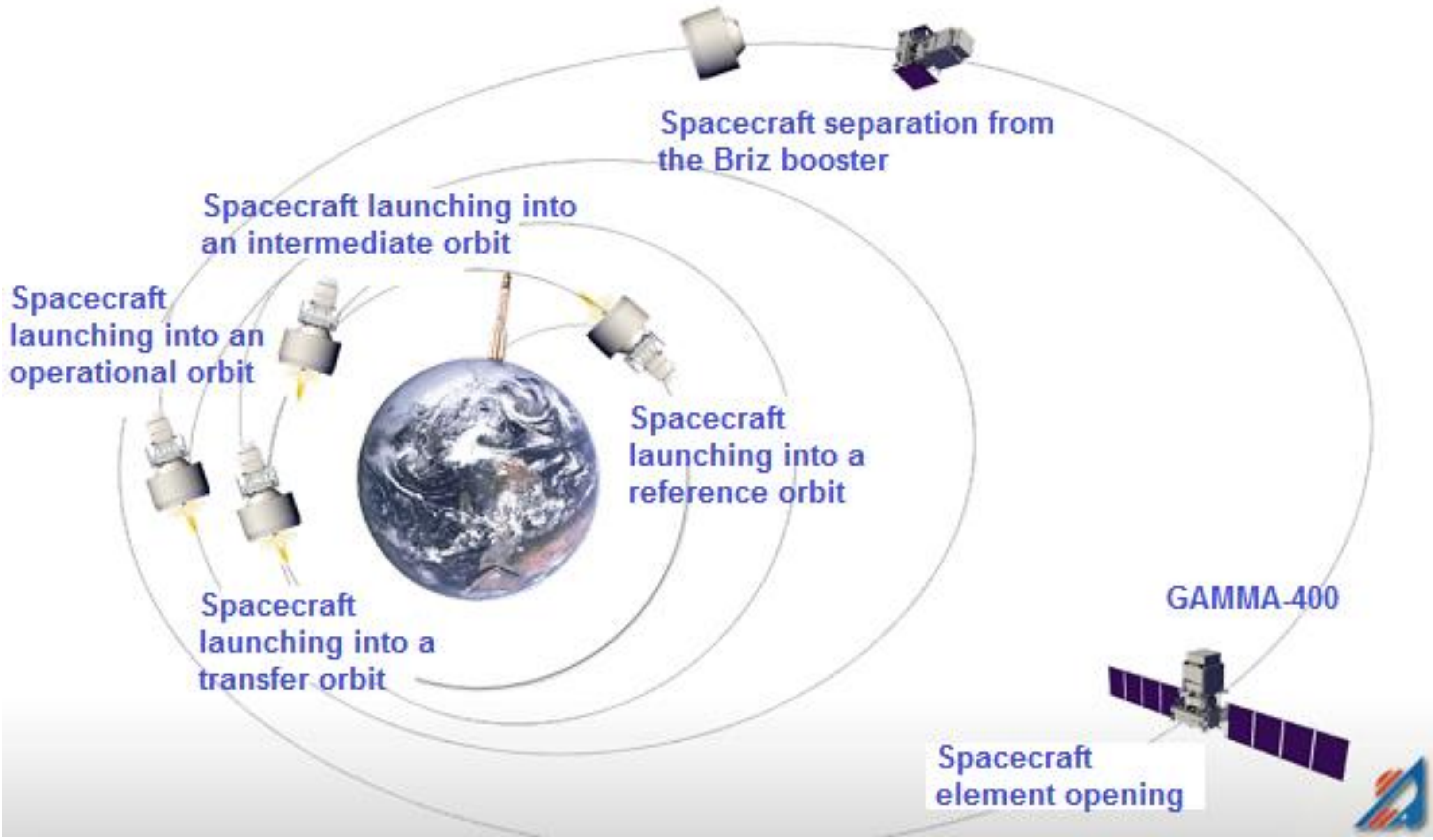


GAMMA-400 SCIENTIFIC COMPLEX ON THE NAVIGATOR SERVICE MODULE



The GAMMA-400 spacecraft and Navigator service module are designed by Lavochkin Association

THE GAMMA-400 SPACECRAFT LAUNCHING SCHEME



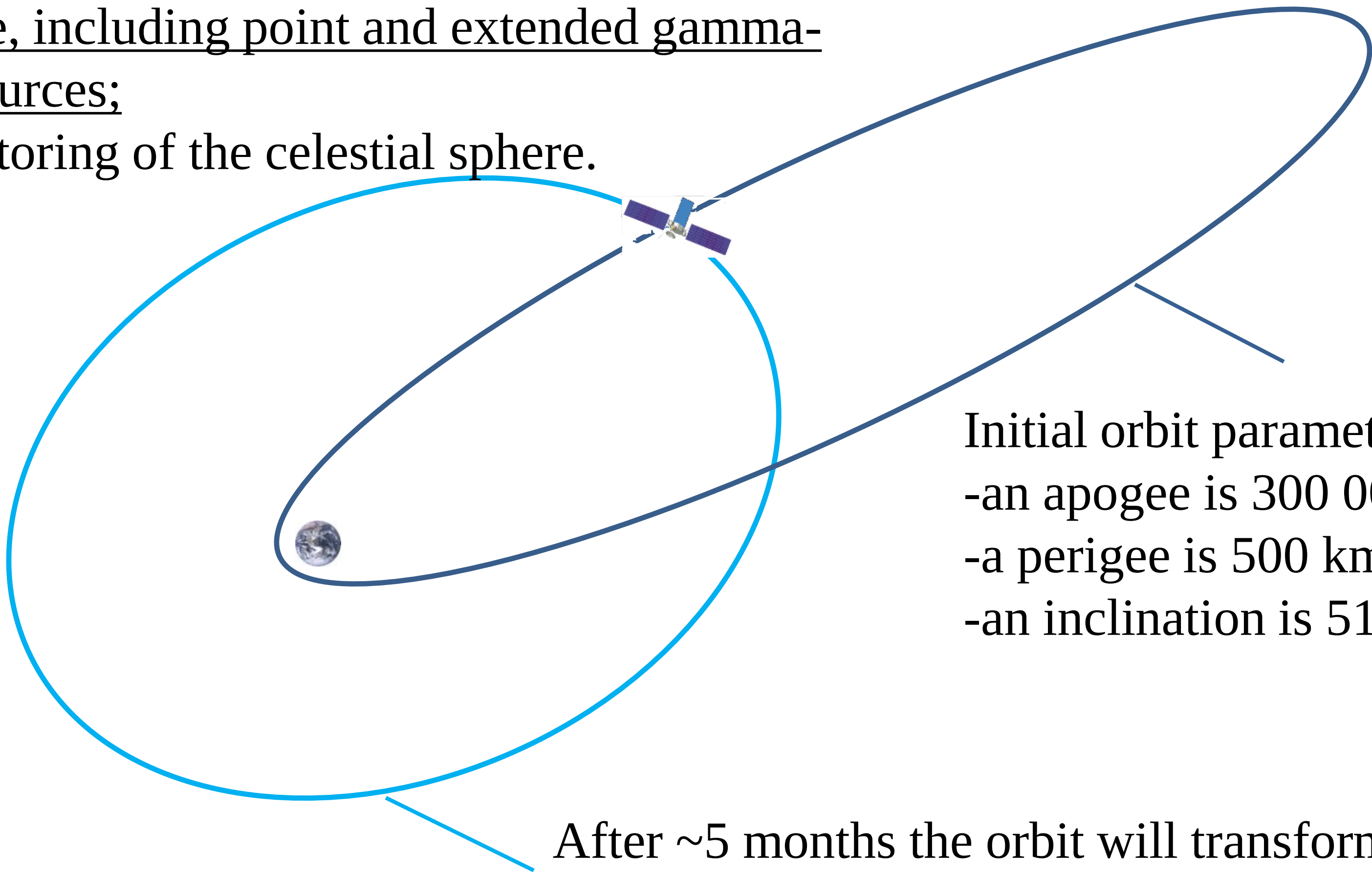
The GAMMA-400 project is included in the Russian Federal Space Program and funded by the Russian Space Agency. The launch of the GAMMA-400 space observatory is planned in 2019 using the more powerful Proton launch vehicle + Briz booster instead of Zenit launch vehicle + Fregat booster.

The expected mission duration is more than 7 years.

OBSERVATION MODES AND THE GAMMA-400 ORBIT EVOLUTION

Observation modes:

- <u>continuous long-duration (~100 days) observation of some regions of celestial sphere, including point and extended gamma-ray sources;</u>
- monitoring of the celestial sphere.



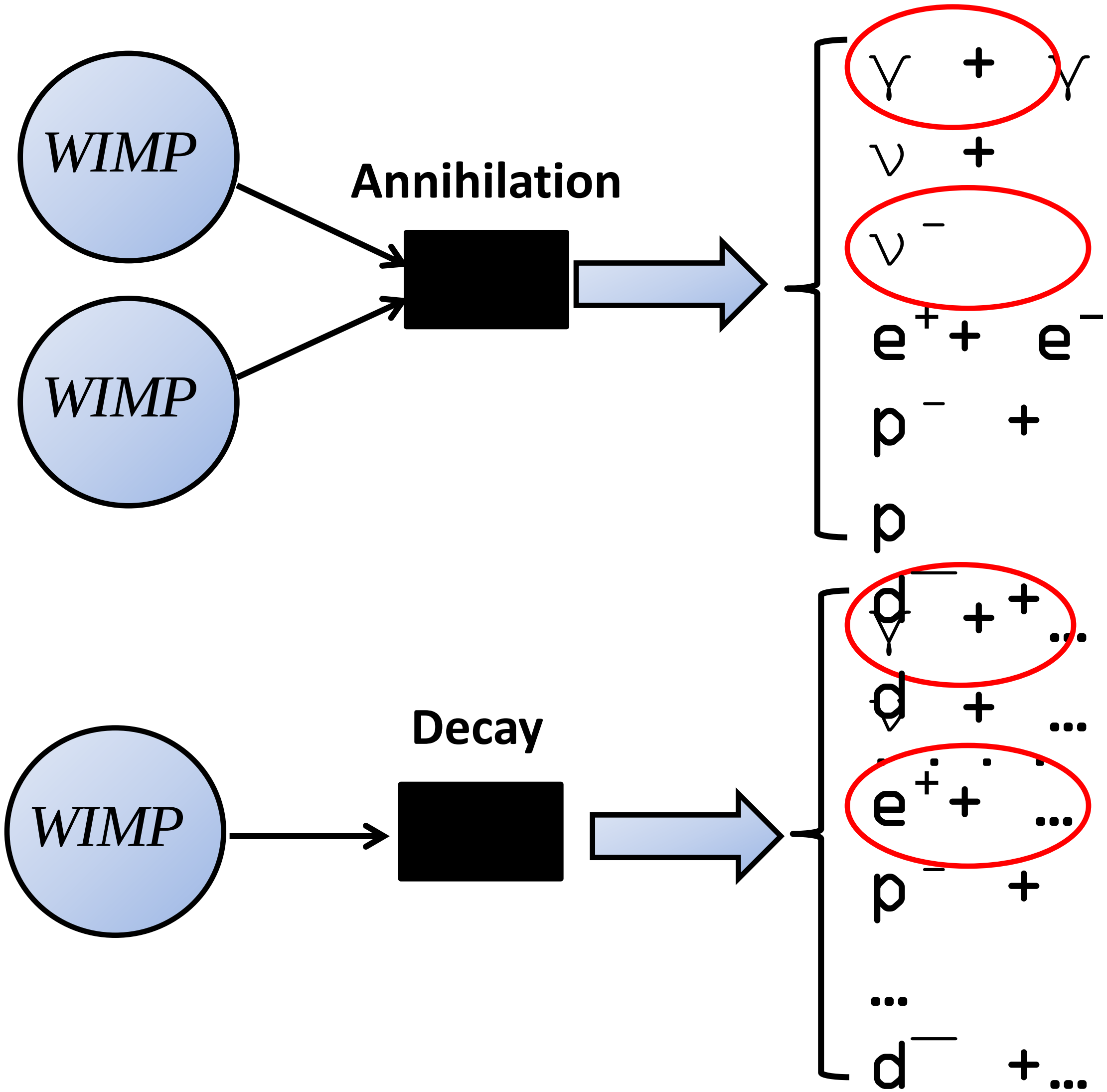
Initial orbit parameters:

- an apogee is 300 000 km:
- a perigee is 500 km;
- an inclination is 51.4º

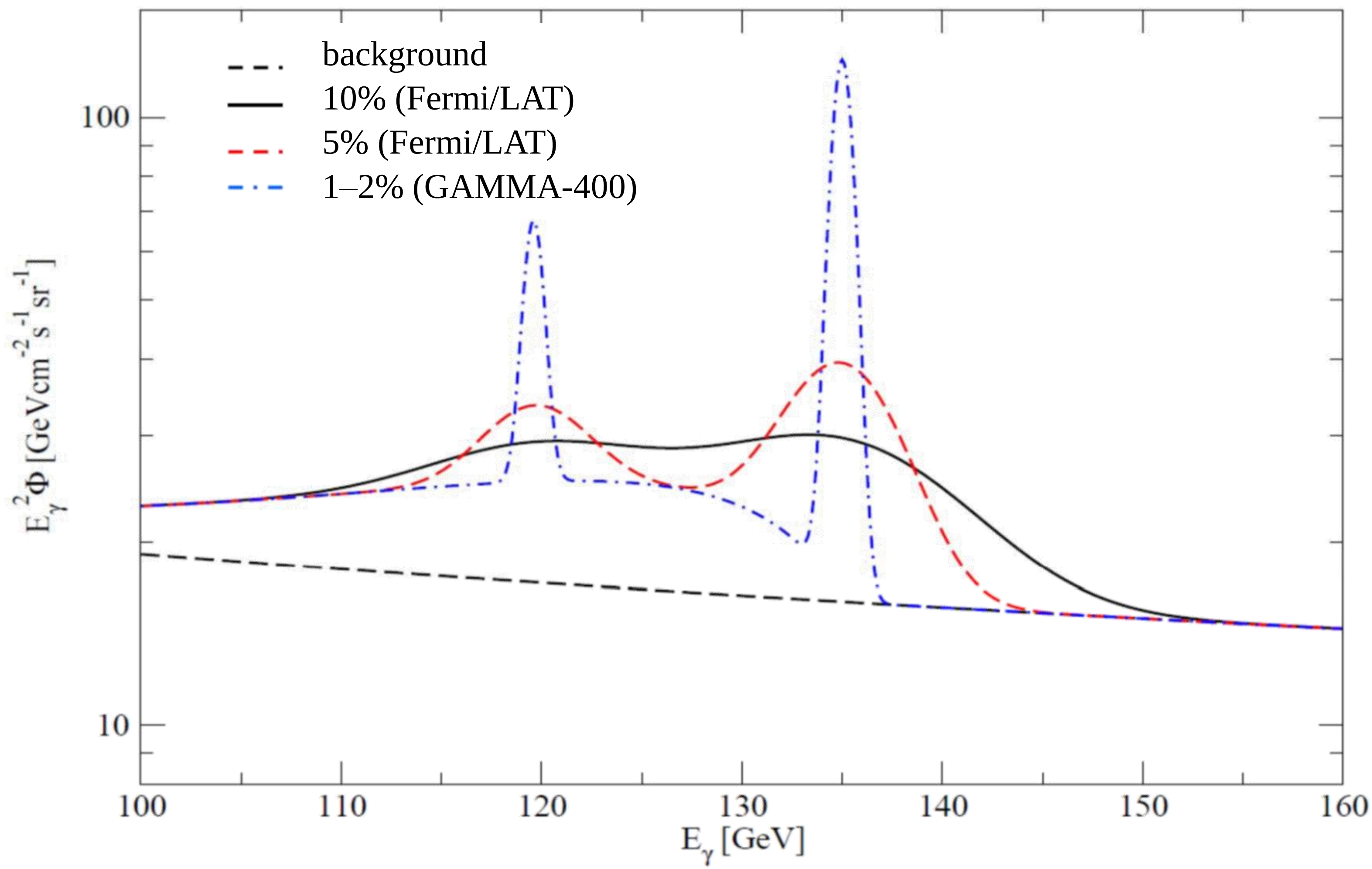
After ~5 months the orbit will transform to circular with a radius of ~150 000 km.

STUDY OF THE NATURE OF THE DARK MATTER BY MEANS OF GAMMA-RAY ASTRONOMY

Indirect methods of detecting dark matter particles



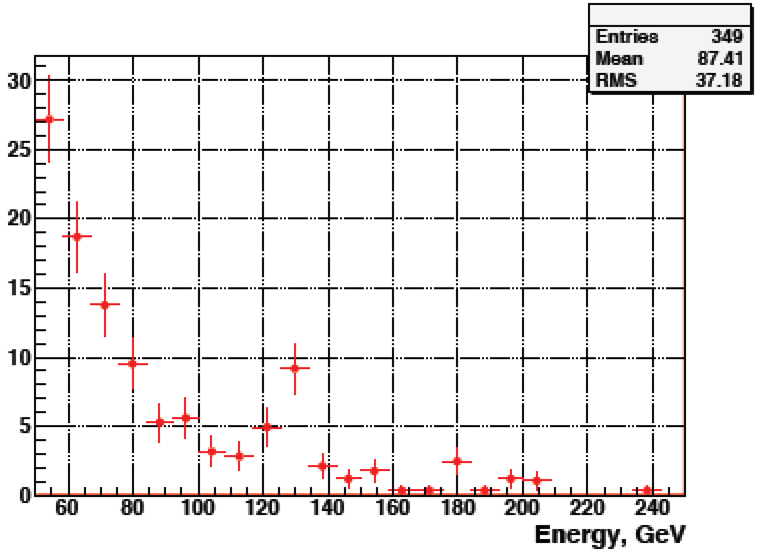
Increasing the energy resolution



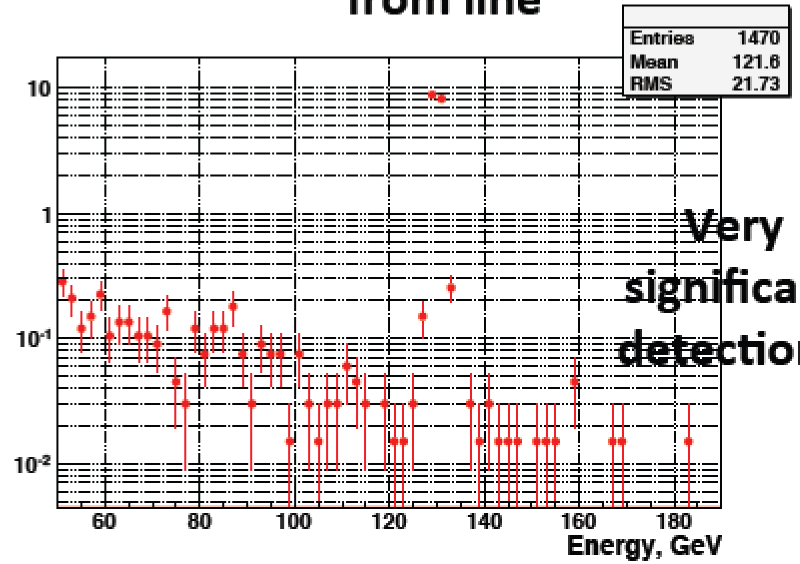
Bergström L., arXiv:1208.6082 (2012)

Increasing the energy resolution

LAT-like instrument, 300 events



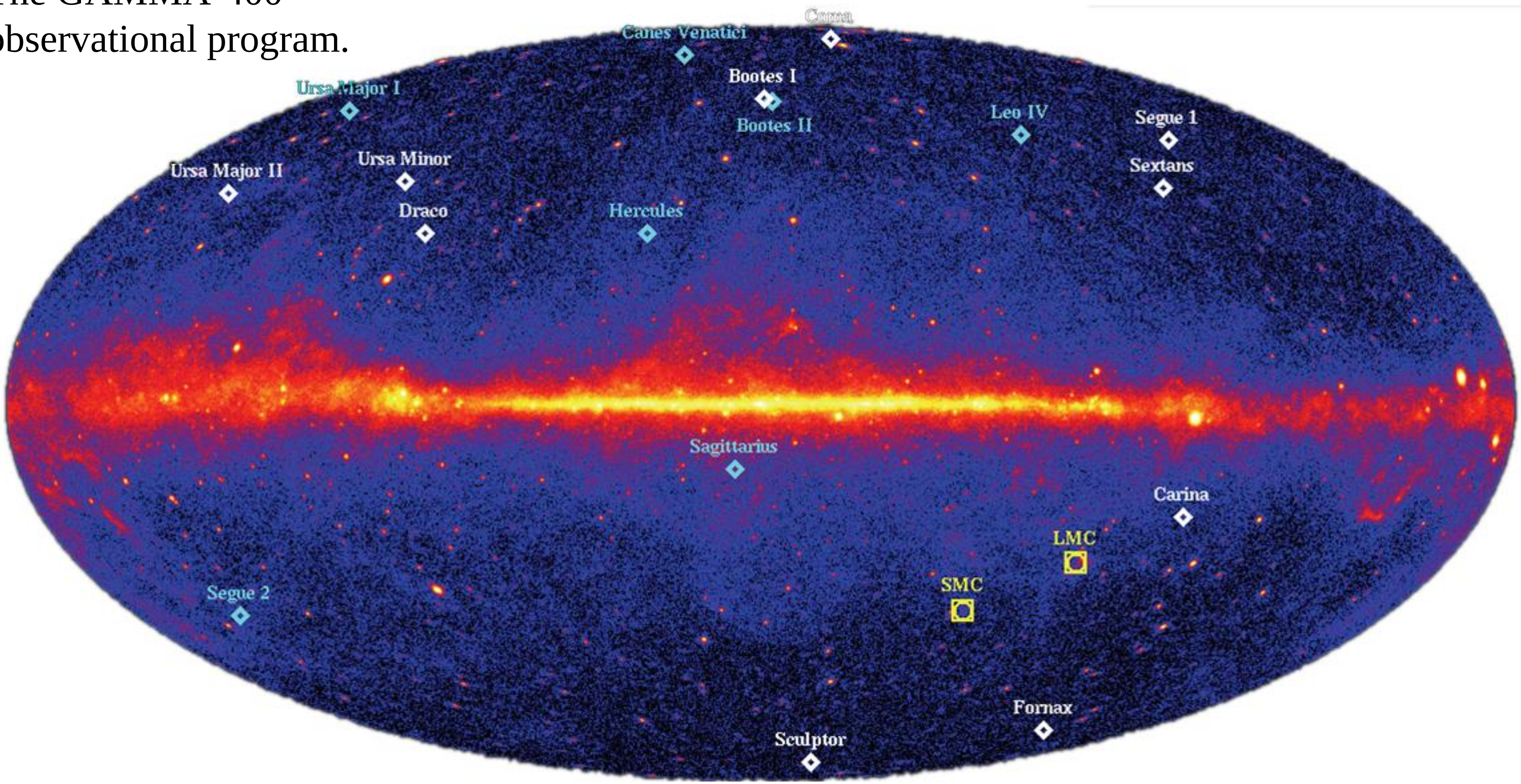
Gamma-400, 10X better dE/E, 10X better PSF (100X less background), same # of events from line



Very significant detection !

Gamma-ray sky map by the Fermi-Lat data

The GAMMA-400 observational program.



Наблюдение карликовых сферических галактик

PRECISION MEASUREMENTS OF HIGH-ENERGY GAMMA-RAY EMISSION OF GALACTIC DISCRETE SOURCES

LAT 2FGL Source Classes

Description	Identified		Associated	
	Designator	Number	Designator	Number
Pulsar, identified by pulsations	PSR	83	...	...
Pulsar, no pulsations seen in LAT yet	...	...	psr	25
Pulsar wind nebula	PWN	3	pwn	0
Supernova remnant	SNR	6	snr	4
Supernova remnant / Pulsar wind nebula	...	...	†	58
Globular cluster	GLC	0	glc	11
High-mass binary	HMB	4	hmb	0
Nova	NOV	1	nov	0
BL Lac type of blazar	BZB	7	bzb	429
FSRQ type of blazar	BZQ	17	bzq	353
Non-blazar active galaxy	AGN	1	agn	10
Radio galaxy	RDG	2	rdg	10
Seyfert galaxy	SEY	1	sey	5
Active galaxy of uncertain type	AGU	0	agu	257
Normal galaxy (or part)	GAL	2	gal	4
Starburst galaxy	SBG	0	sbg	4
Class uncertain	...	...	...	1
Unassociated	...	...	...	575
Total	...	127	...	1746

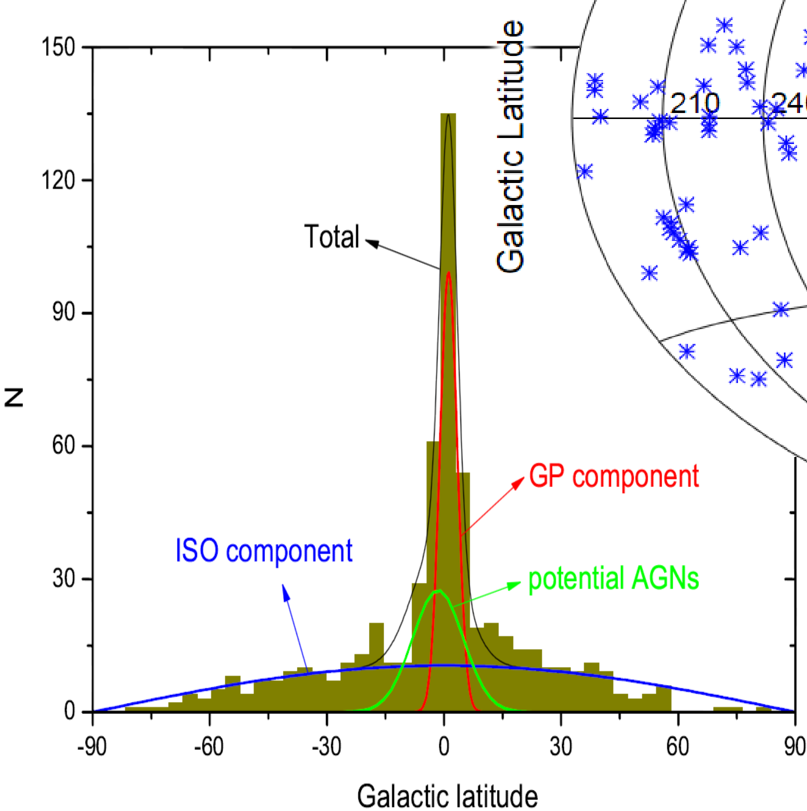
Cosmic-ray high-energy sources

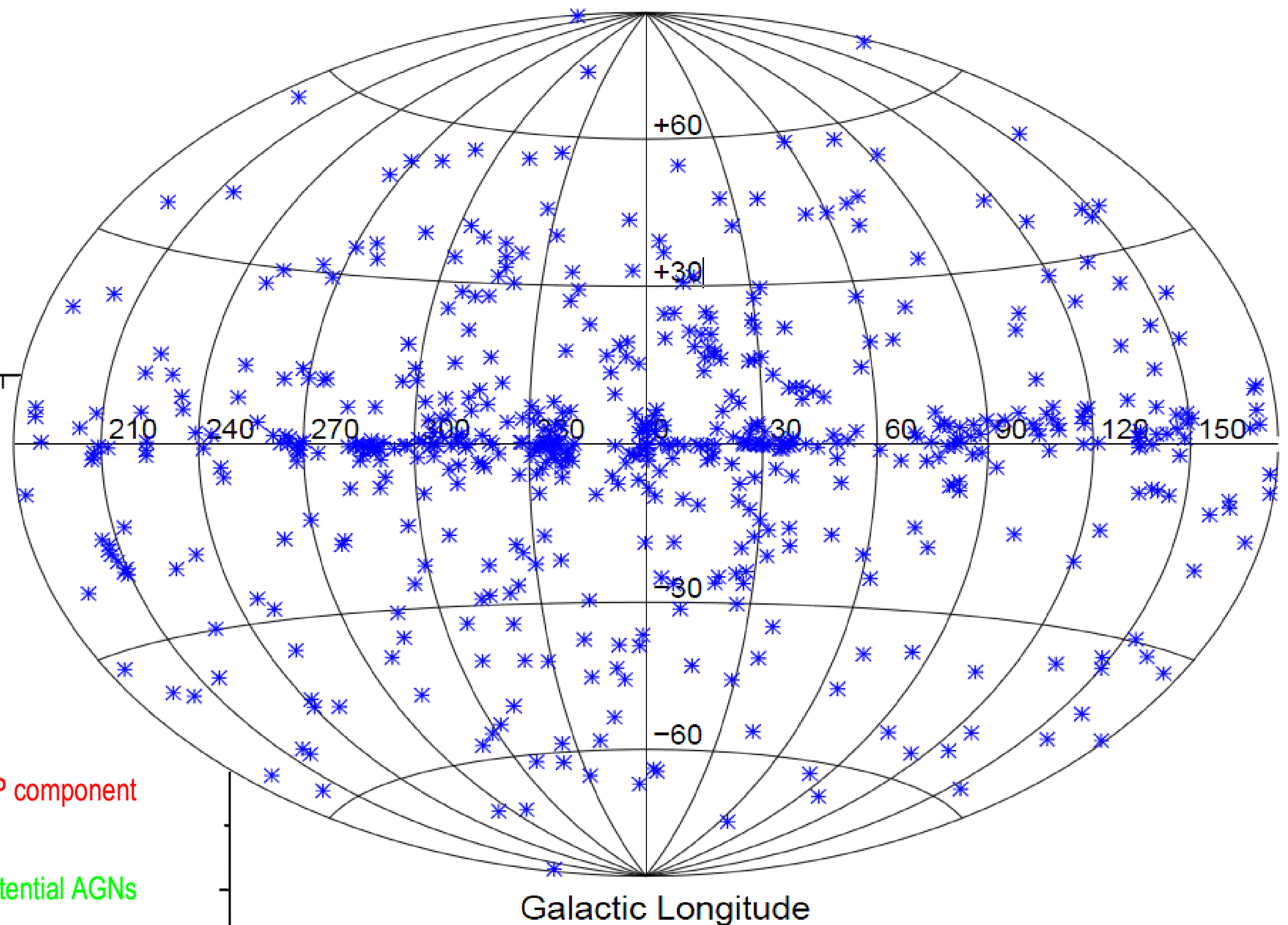
- Galactic
  - PWN — plerions
  - SNR — SuperNova Remnants
  - Binary gamma-ray objects
- Extragalactic
  - Star formation galactics
  - AGN — active galactic nuclei

[arXiv:1307.5560]

Distribution of 573 nonidentified sources from 2FGL

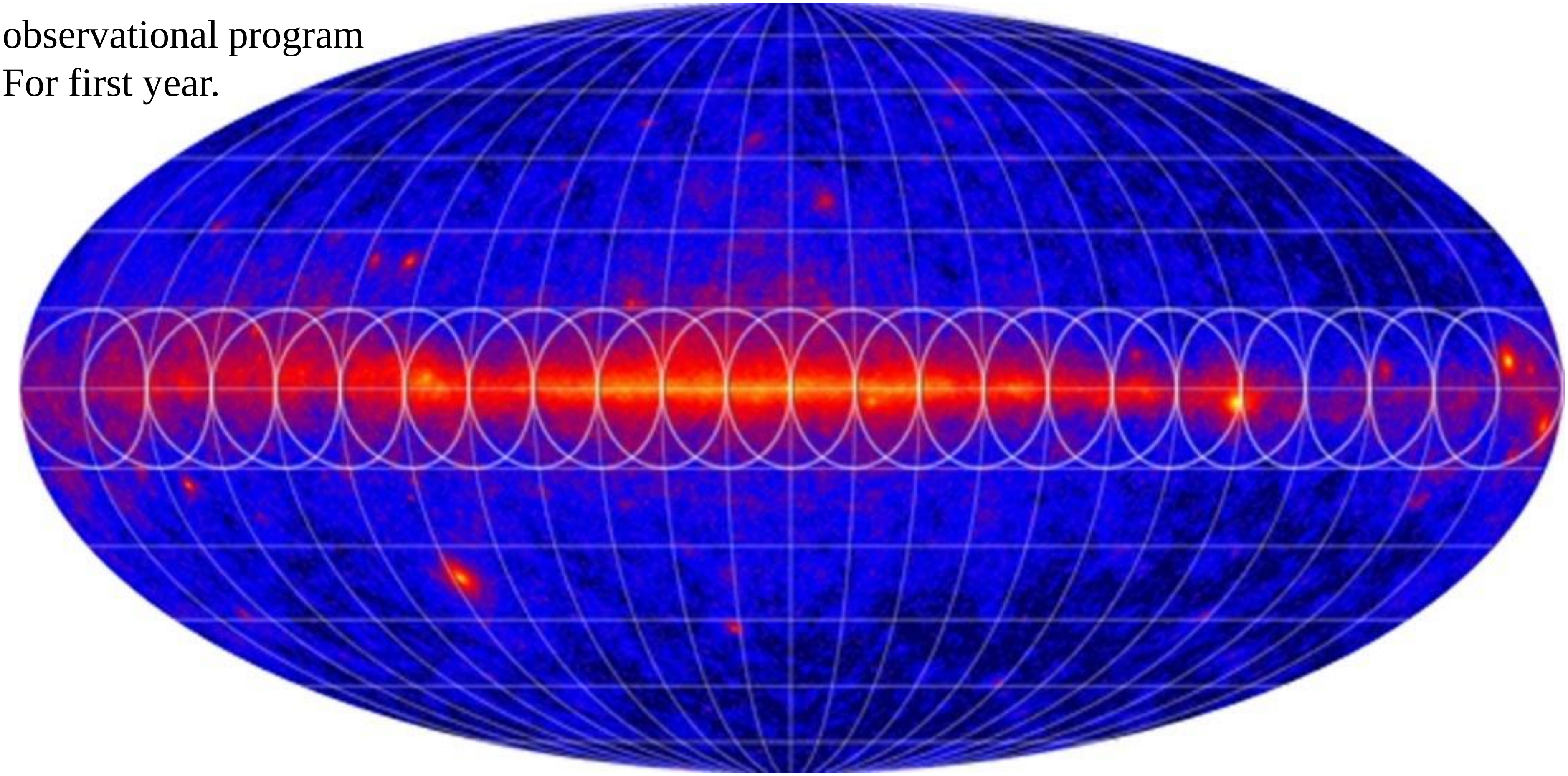
Zhu Mao, Yun-Wei Yu,
arXiv:1304.3989v1





Gamma-ray sky map by the Fermi-Lat data

The GAMMA-400
observational program
For first year.



Galactic scanning mode

Using the data from the TeV Gamma-Ray Source Catalogue (from the ground-based facilities), we can calculate expected number of gammas, which GAMMA-400 will detect during 100 days of observation (the GAMMA-400 effective area is 5000 cm^2).

Name	**Facility**	**Spectr. index**	**Integr. flux F(> 100 GeV), 10^{-9} $cm^{-2}s^{-1}$**	**Expected gammas N(> 100 GeV) per 100 days**
1ES 1011+496	MAGIC	4.0	67.7	2921
1ES 1218+304	MAGIC	3.0	4.09	177
1ES 1959+650	MAGIC	2.78	5.805	251
1ES 2344+514	MAGIC	3.3	1.67	72
3C 279	MAGIC	4.11	219.0	9458
BL Lac	MAGIC	3.64	3.18	138
Crab	H.E.S.S., MAGIC	2.48	11.7	504
MAGIC J0616+225	MAGIC, VERITAS	3.1	0.605	26
Mkn 180	MAGIC	3.25	3.60	155
Mkn 421	H.E.S.S., MAGIC	3.2	6.05	261
Mkn 501	MAGIC	2.28	10.7	463
PG 1553+113	H.E.S.S., MAGIC	4.01	204.0	8833
PKS 2155-304	H.E.S.S., MAGIC	3.53	69.0	2983
RX J0852.0-4622	H.E.S.S.	2.2	0.331	14
RX J1713.7-3946	H.E.S.S.	2.84	0.618	27
W Com	VERITAS	3.8	4.570	198

COMPARISON OF BASIC PARAMETERS OF OPERATED, EXISTING, AND PLANNED SPACE-BASED AND GROUND-BASED INSTRUMENTS

	SPACE-BASED INSTRUMENTS					GROUND-BASED GAMMA-RAY FACILITIES			
	EGRET	**AGILE**	**Fermi-LAT**	**CALET**	**GAMMA-400**	**H.E.S.S.-II**	**MAGIC**	**VERITAS**	**CTA**
Operation period	1991-2000	2007-	2008-	2014	2019	2012-	2009-	2007-	2018
Energy range, GeV	0.03-30	0.03-50	0.02-300	10-10000	**0.1-10000**	> 30	> 50	> 100	> 20
Angular resolution (E_γ > 100 GeV)	0.2º (E_γ~0.5 GeV)	0.1º (E_γ~1 GeV)	0.1º	0.1º	**~0.01º**	0.07º	0.07º (E_γ = 300 GeV)	0.1º	0.1º (E_γ = 100 GeV) 0.03º (E_γ = 10 TeV)
Energy resolution (E_γ > 100 GeV)	15% (E_γ~0.5 GeV)	50% (E_γ~1 GeV)	10%	2%	**~1%**	15%	20% (E_γ = 100 GeV) 15% (E_γ = 1 TeV)	15%	20% (E_γ = 100 GeV) 5% (E_γ = 10 TeV)

THANK YOU FOR ATTENTION