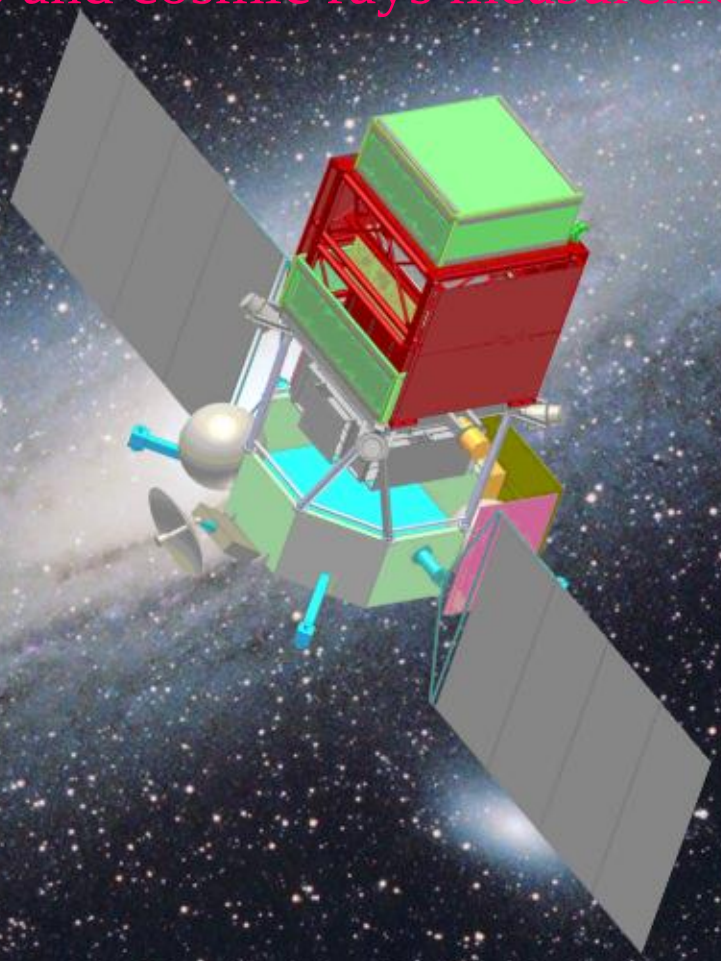
Presented by A.A. Leonov on behalf of GAMMA-400 collaboration

Perspectives of the GAMMA-400 space observatory for high-energy gamma rays and cosmic rays measurements



ICCPA, Moscow, October 9, 2015

GAMMA-400 collaboration

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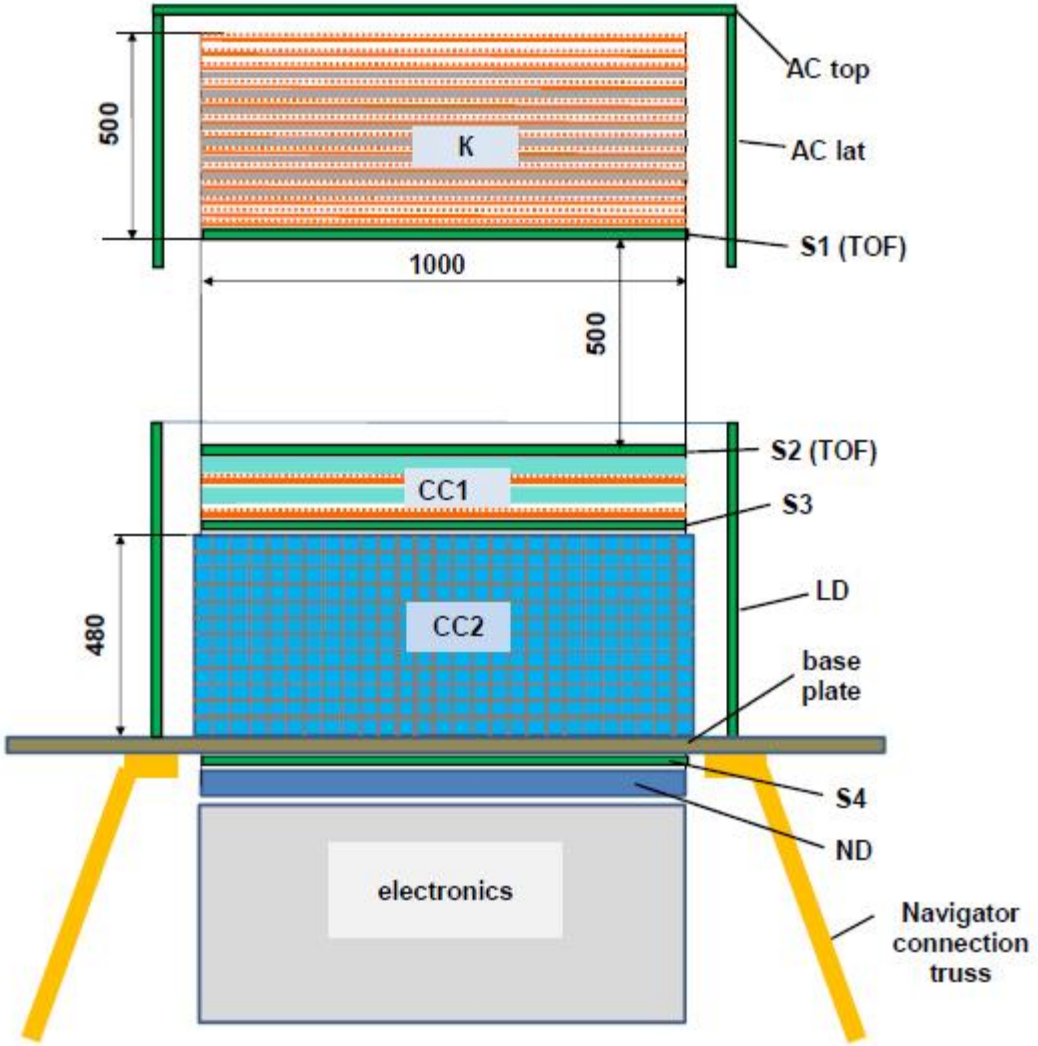
ICCPA, Moscow, October 9, 2015



Physical scheme

Scientific goals

Physics goals for total telescope acceptance (~4200 cm^2 sr)

1.1 The features in the energy spectra of high energy γ-ray emissions from discrete and extended sources associated with particles of dark matter

1.2 The variability of high energy γ-ray emissions from discrete sources in order to clarify the nature of particle acceleration in such sources

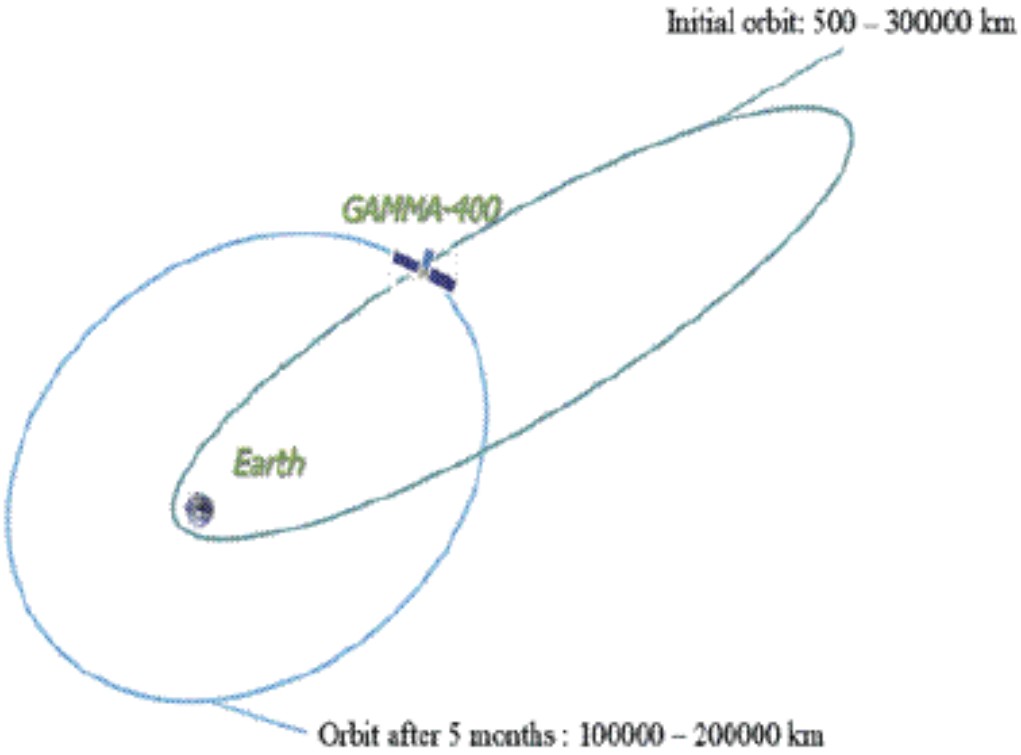
1.3 γ-ray bursts, including high-energy bursts

1.4 high-energy γ-ray emissions, fluxes of electrons and positrons, and nuclei in solar flares

Physics goals for calorimeter only acceptance (~4 m^2 sr)
2.1 HE e+, e- from Dark Mater annihilation
2.2 HE e+, e- acceleration mechanisms
2.3 HE protons and nuclei (>>GeV)
- PAMELA has revealed a break in proton and He spectrum (different slope)
- the knee of proton and helium
- the spectral hardening of nuclei (E>TeV)

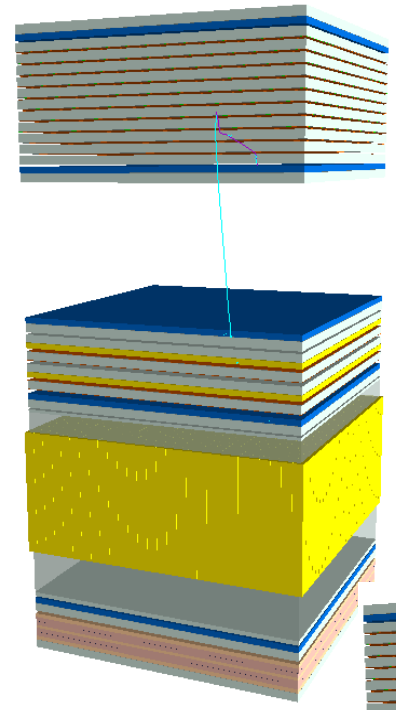
2.4 CR propagtion in the Galaxy

GAMMA-400 will be launched in highly elliptical orbit (500–300000 km) with an inclination angle of 51.8°. The initial orbit, after some months, evolves to a very high circular orbit (100.000 – 200.000 km) with an orbital period of about 7 days.

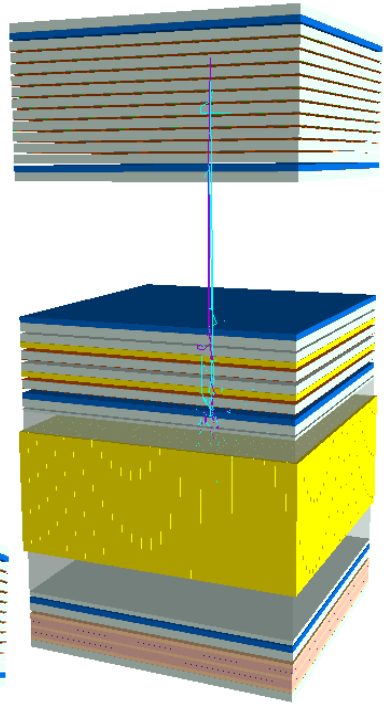


GAMMA-400 is less as survey and more as “pointing telescope” (without occultation of the Earth).

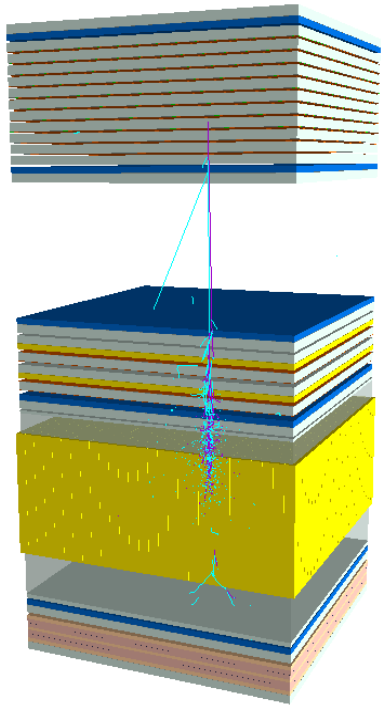
Interactions of gamma inside the instrument



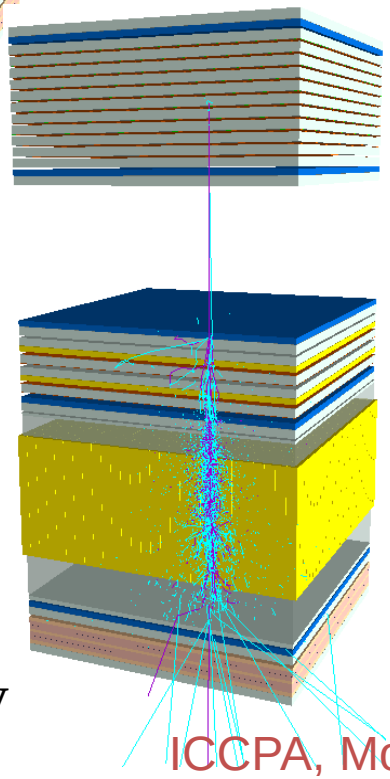
100 MeV



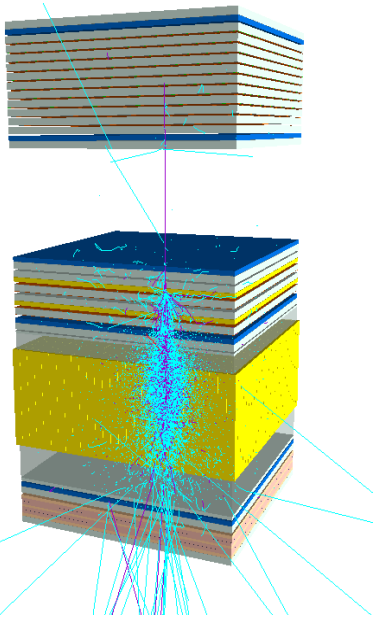
1 GeV



10 GeV



100 GeV

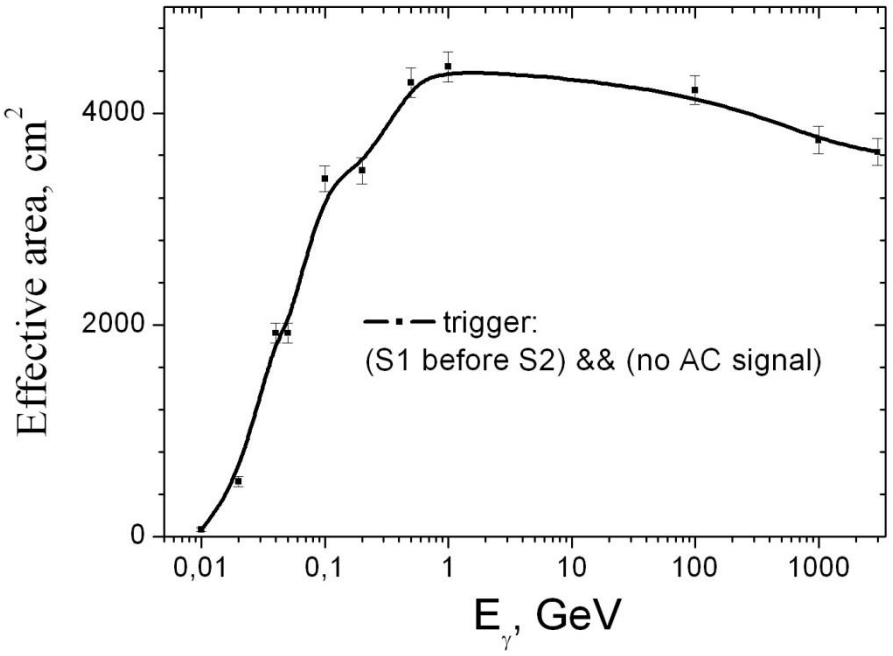


1 TeV

GAMMA-400 performance

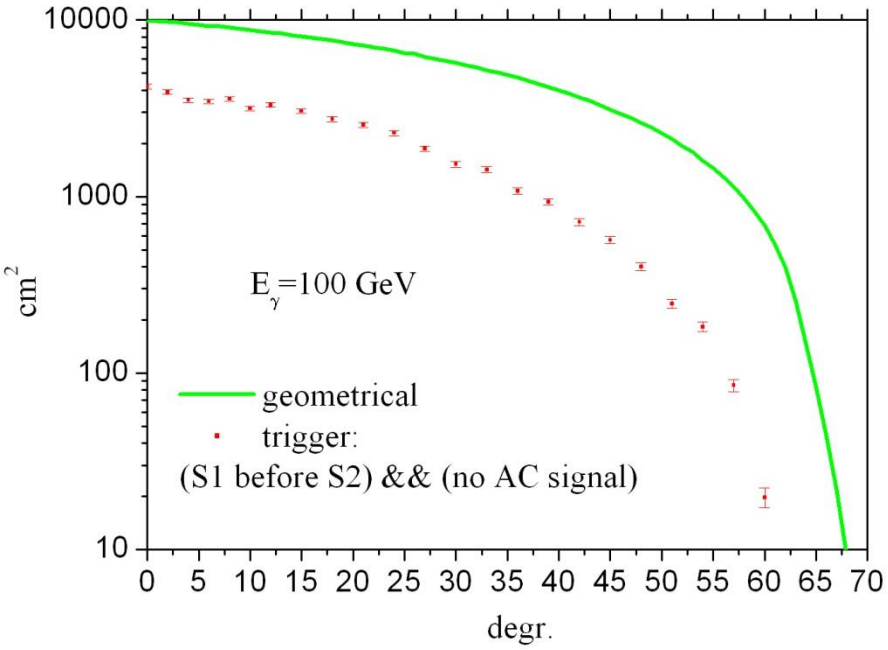
Effective area for vertical gamma.

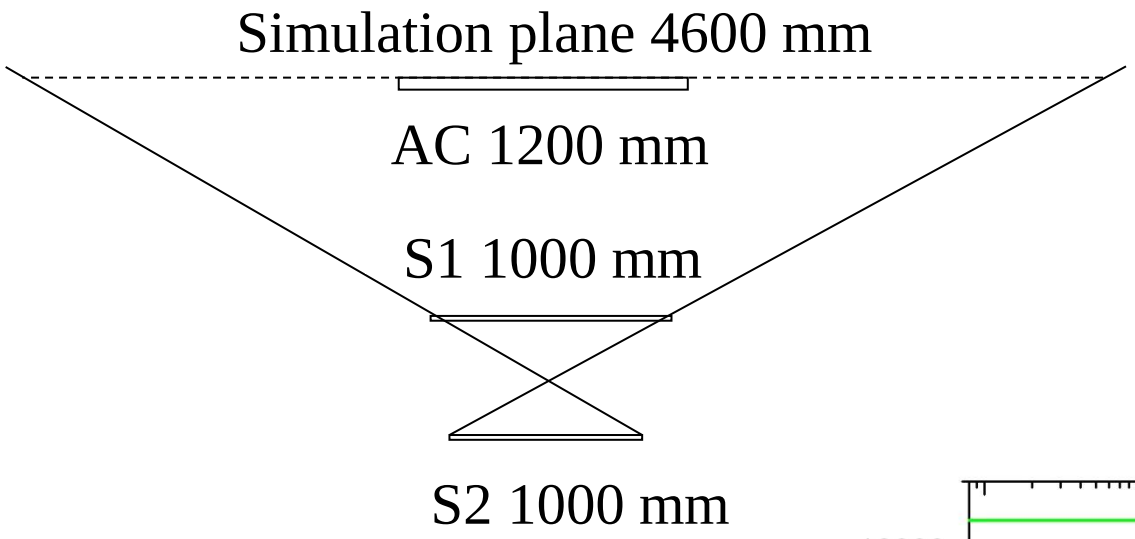
$$S_{EFF}(\theta) = \frac{N_{DET}}{N_0} \times S$$



Effective area as a function of 100 GeV gamma incidence angle.

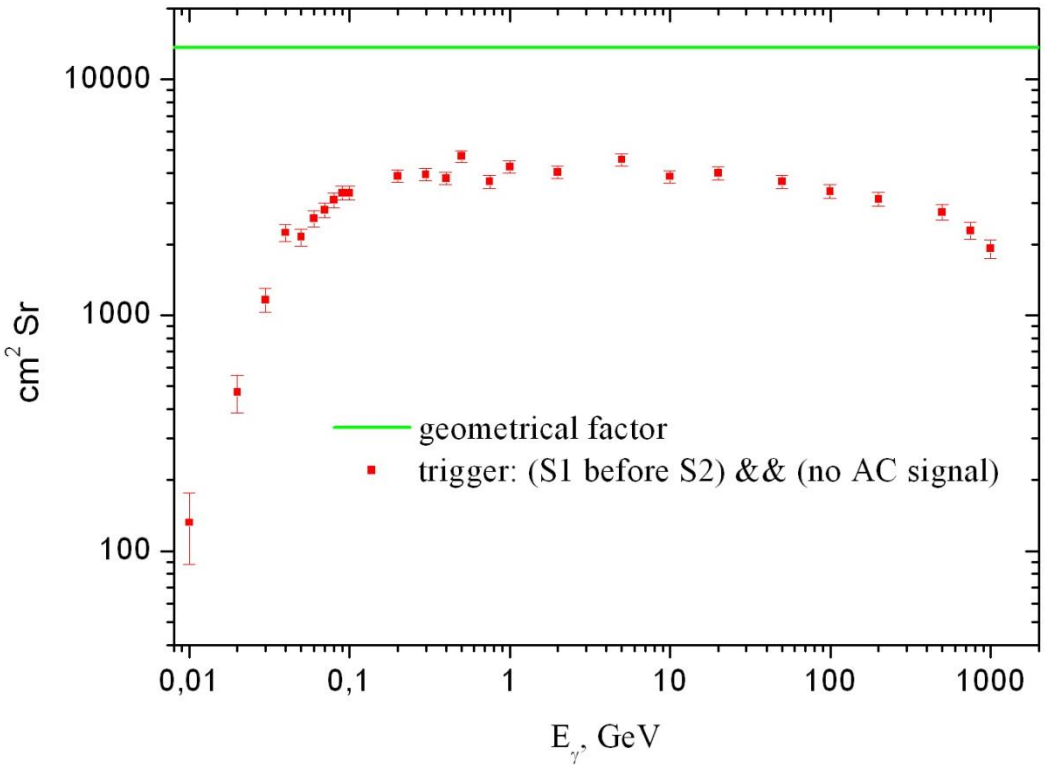
$$S_{EFF}(\theta) = \frac{N_{DET}}{N_0} \times S \times \cos\theta$$





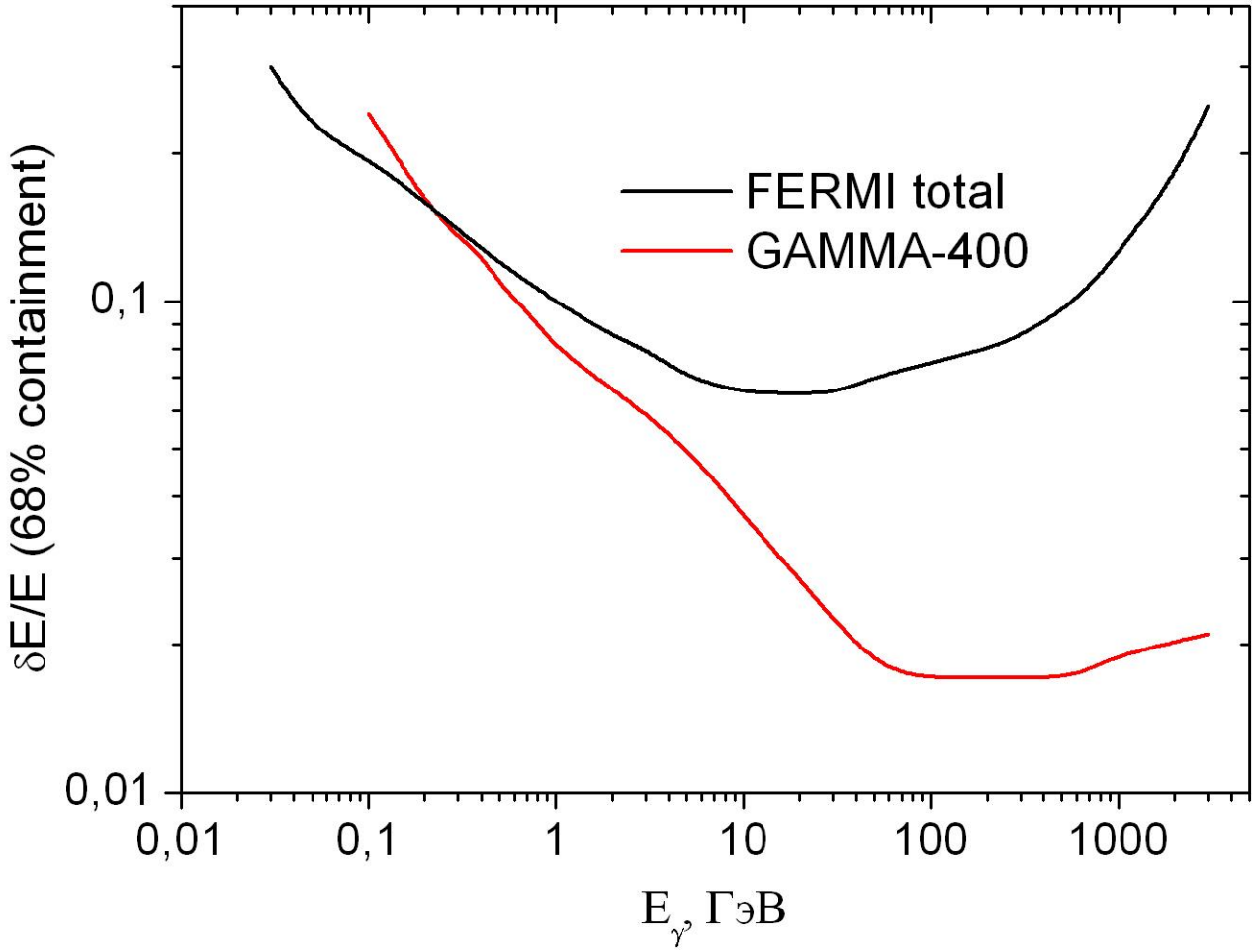
Acceptance.

$$G(E) = \frac{N_{DET.}}{N_0} \times \pi S$$

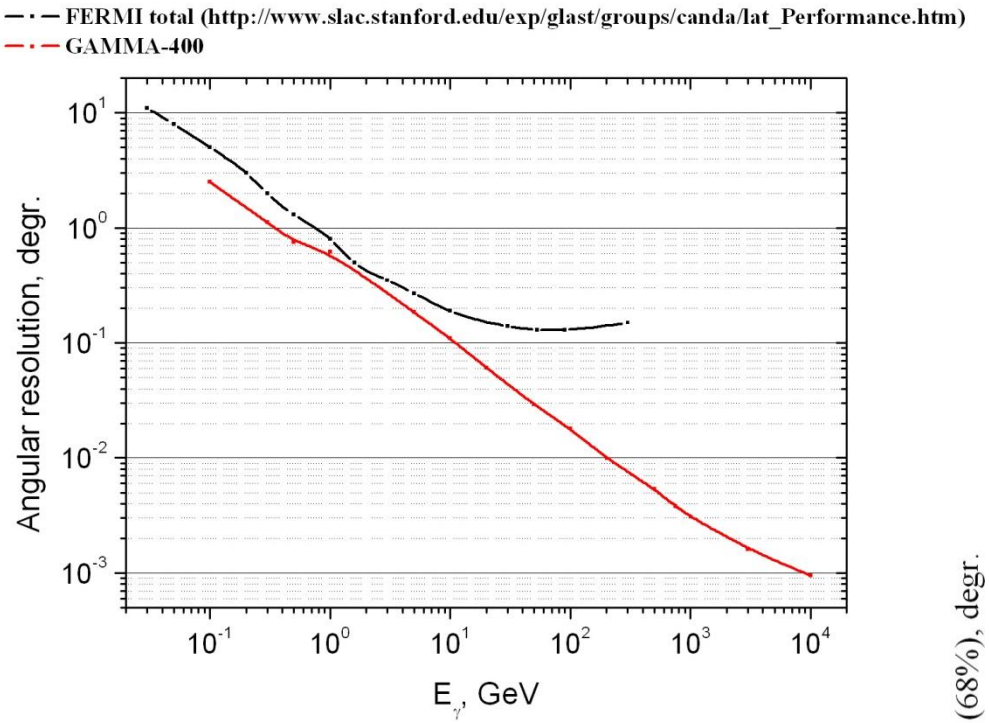


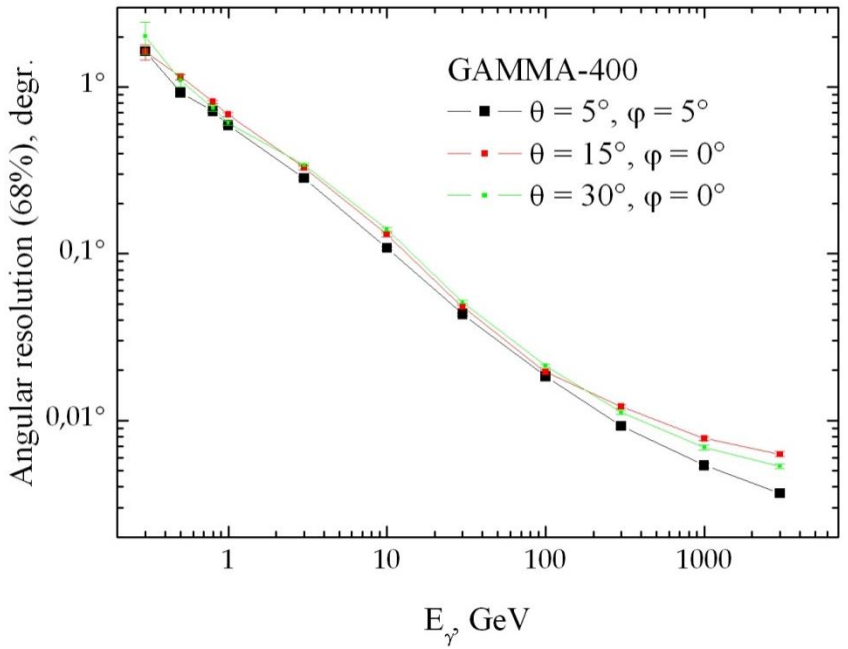
Energy resolution

FERMI (http://www.slac.stanford.edu/exp/glast/groups/canda/lat_Performance.htm)

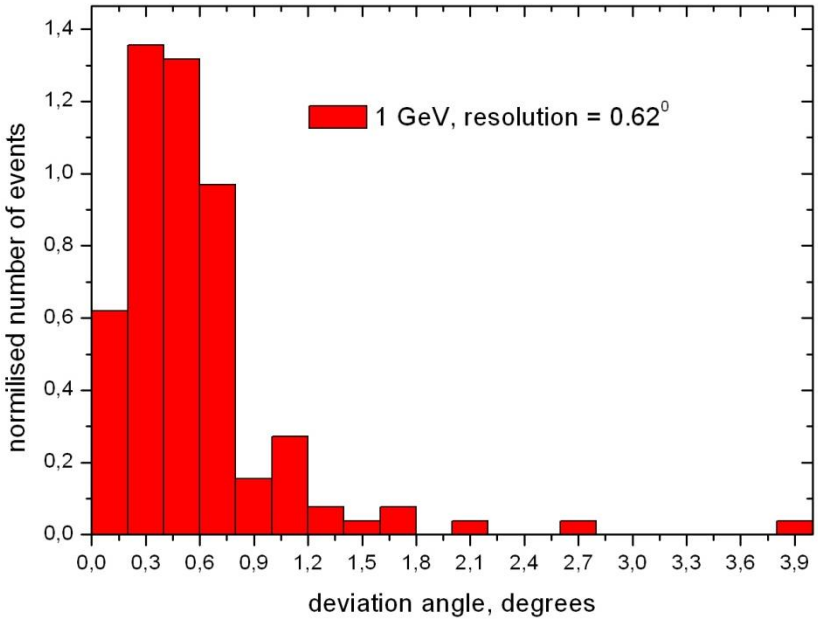


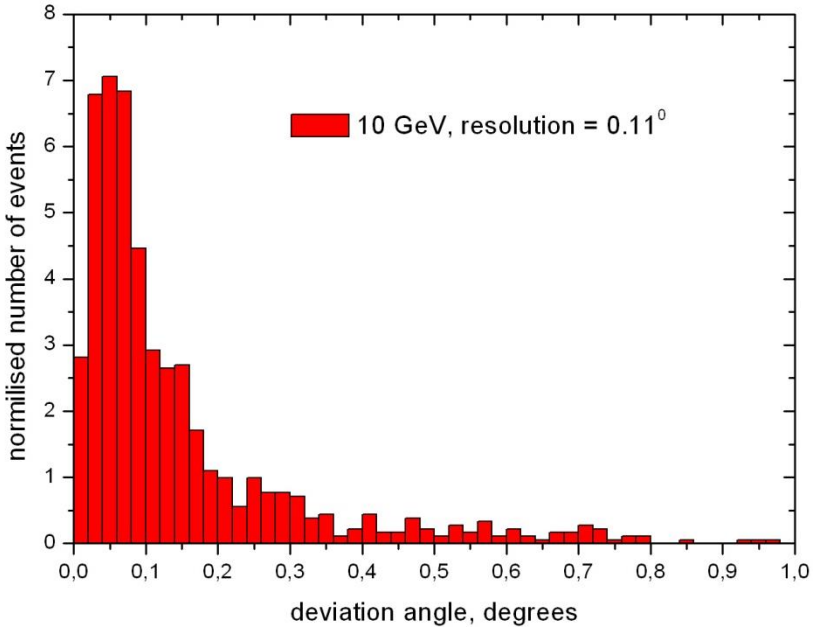
Angular resolution

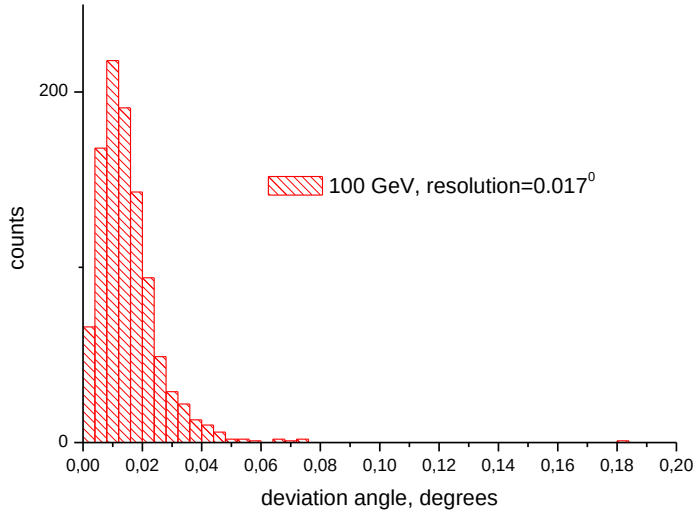


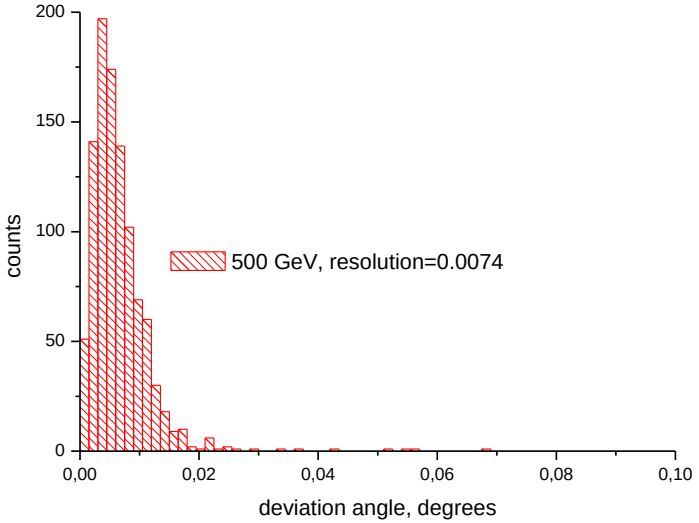


Angular resolution > 1 GeV

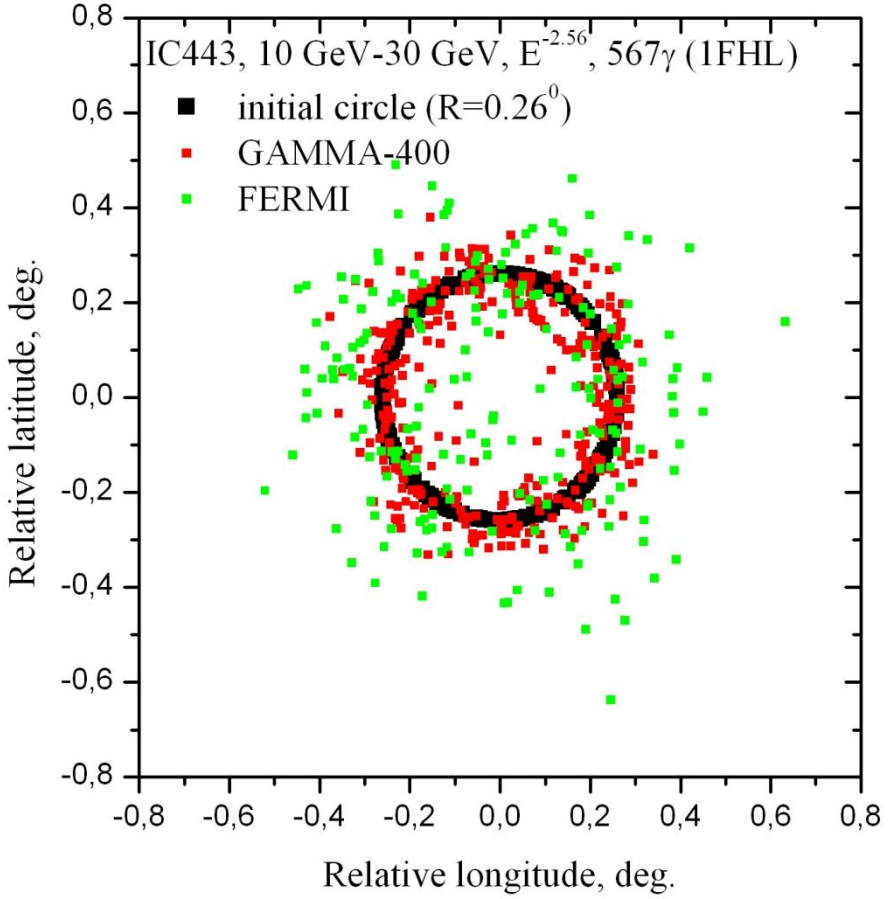


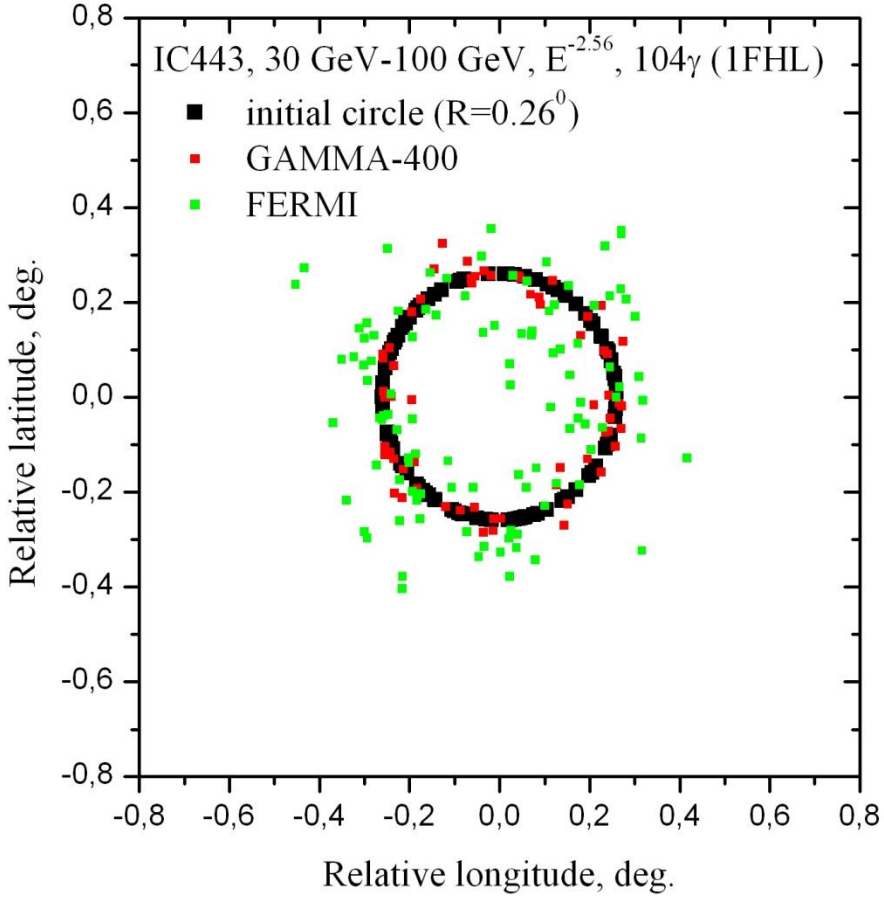




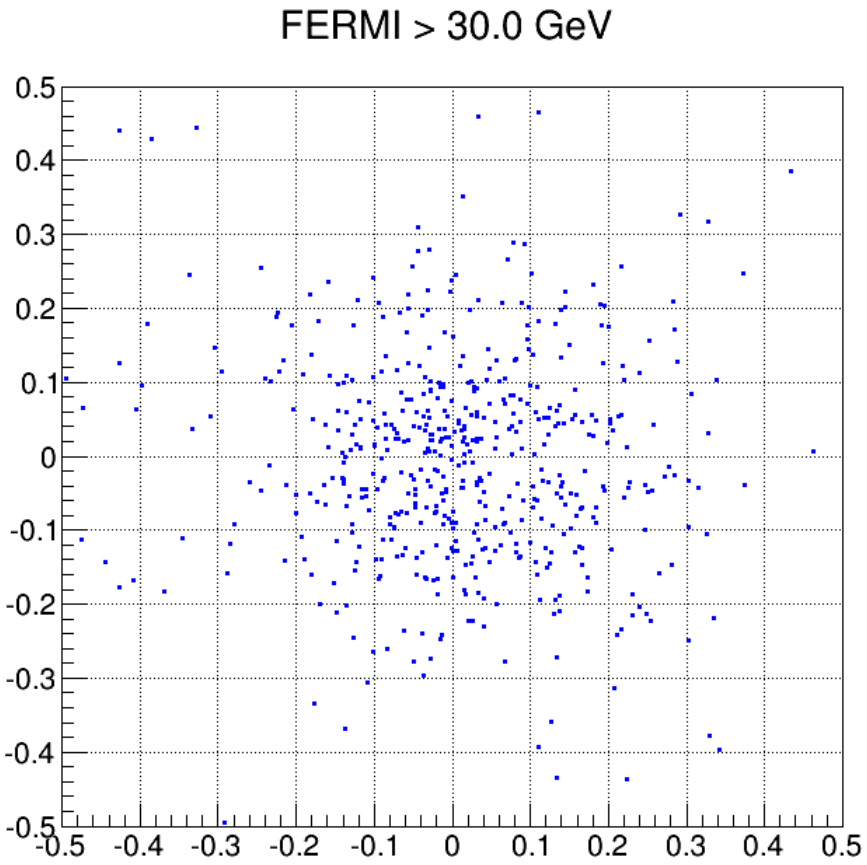


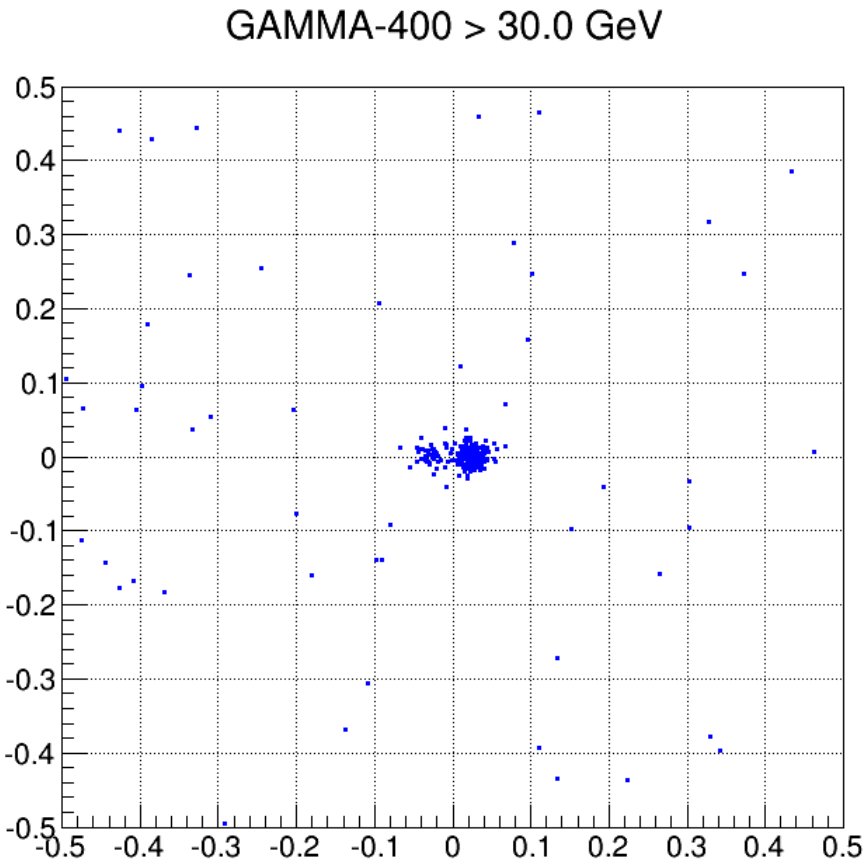
Initial circle distribution for supernova remnant IC 433 statistic



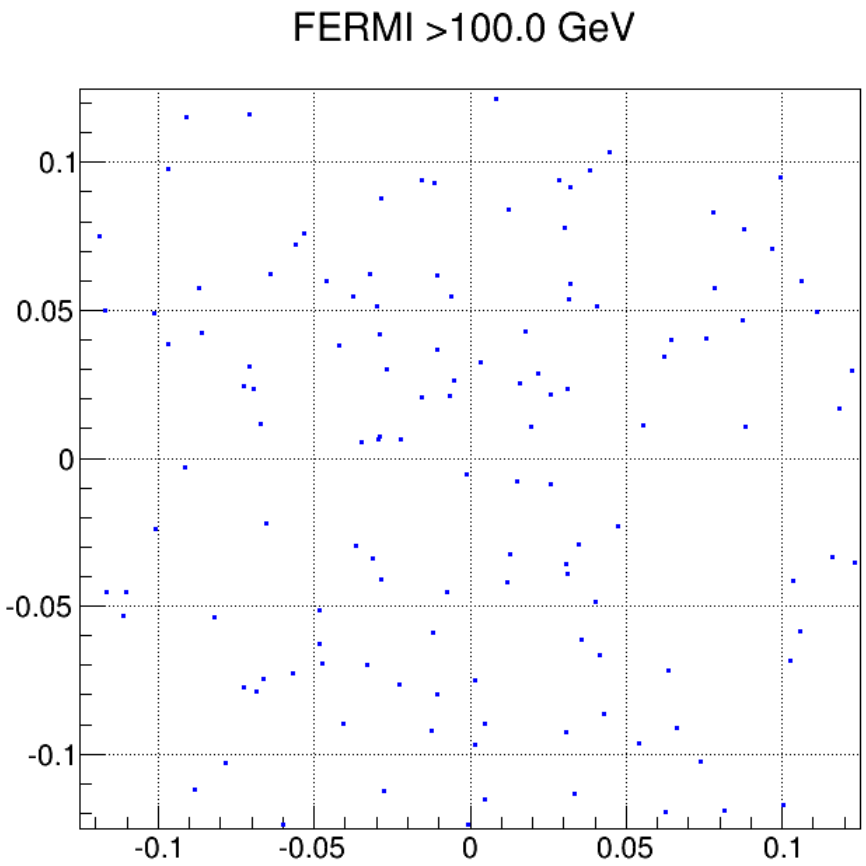


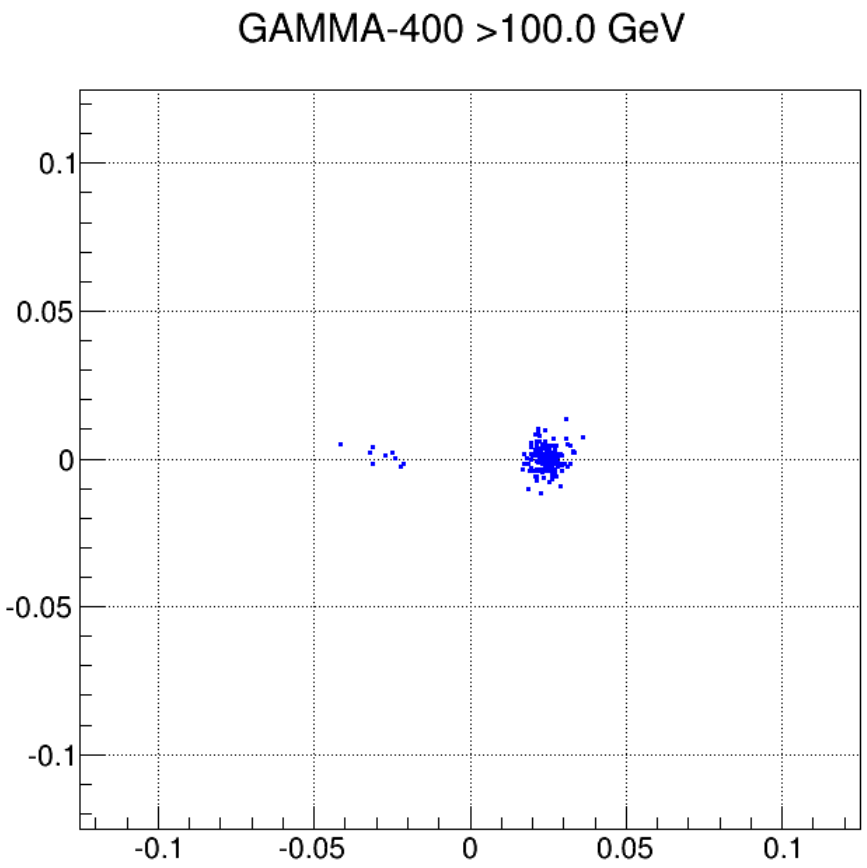
2 point sources (distance 0.05^0) to distinguish





2 point sources (distance 0.05^0) to distinguish





Модели распределения темной материи в Галактике

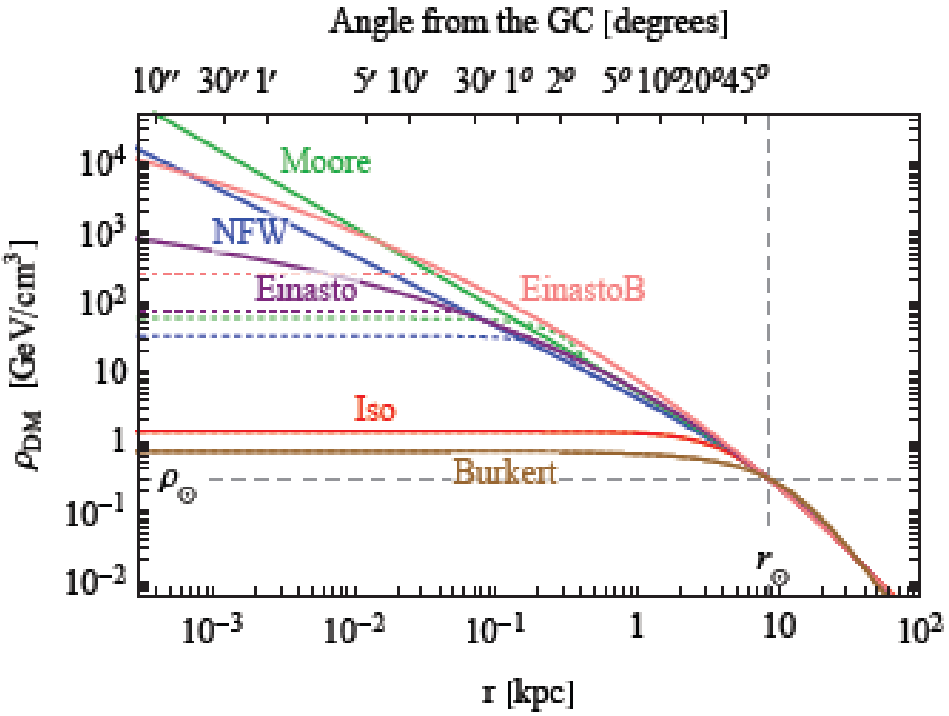
$$\text{NFW}: \quad \rho_{\text{NFW}}(r) = \rho_s \frac{r_s}{r}\left(1+\frac{r}{r_s}\right)^{-2}$$

$$\text{Einasto}: \quad \rho_{\text{Ein}}(r) = \rho_s \exp\left\{-\frac{2}{\alpha}\left[\left(\frac{r}{r_s}\right)^{\alpha}-1\right]\right\}$$

$$\text{Isothermal}: \quad \rho_{\text{Iso}}(r) = \frac{\rho_s}{1+(r/r_s)^2}$$

$$\text{Burkert}: \quad \rho_{\text{Bur}}(r) = \frac{\rho_s}{(1+r/r_s)(1+(r/r_s)^2)}$$

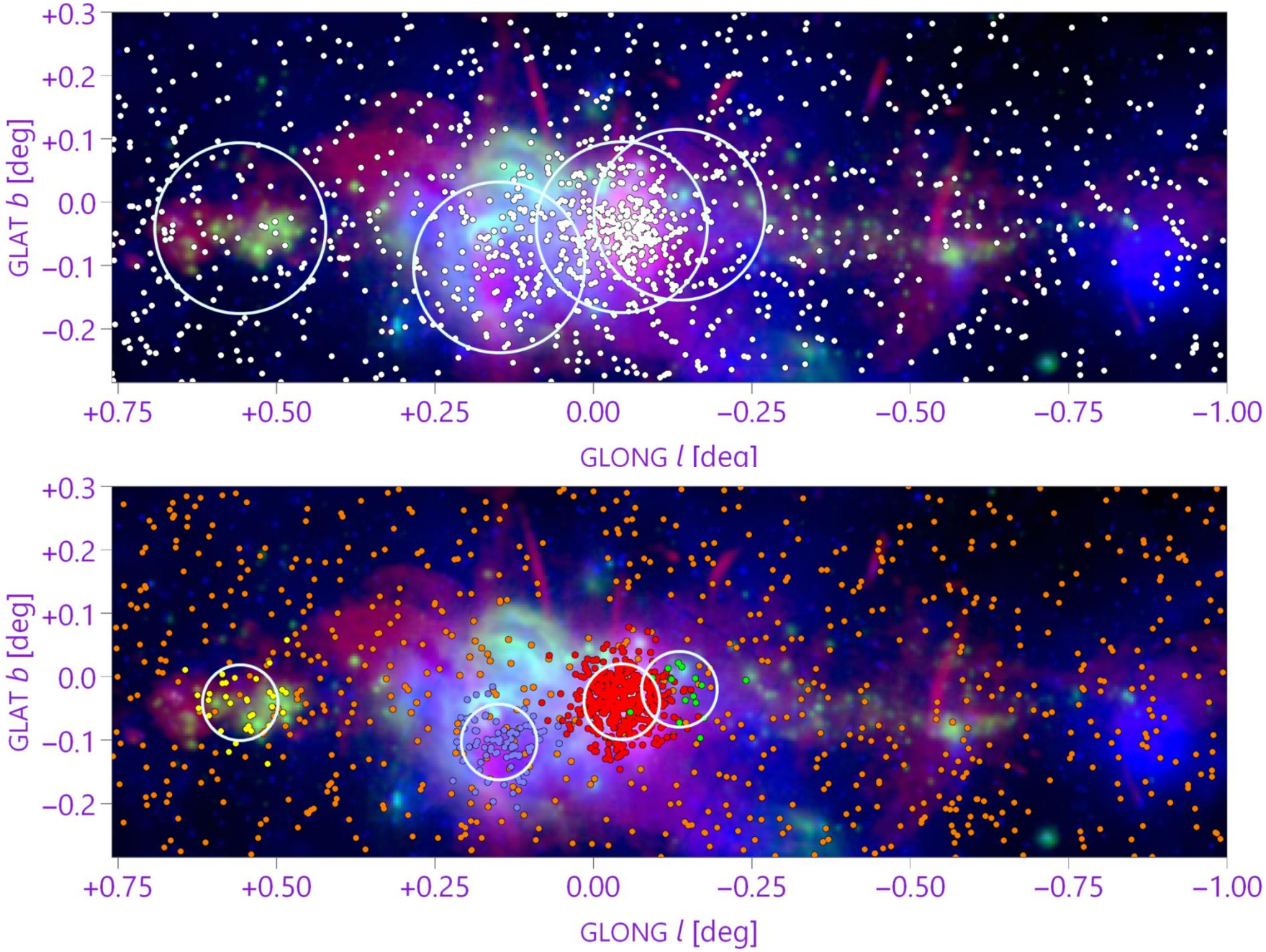
$$\text{Moore}: \quad \rho_{\text{Moo}}(r) = \rho_s \left(\frac{r_s}{r}\right)^{1.16}\left(1+\frac{r}{r_s}\right)^{-1.84}$$

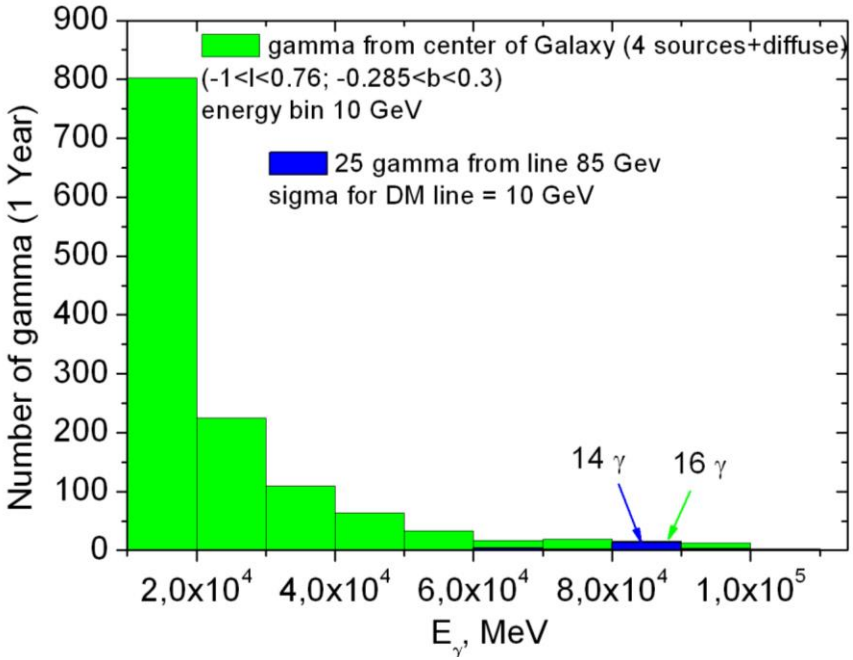


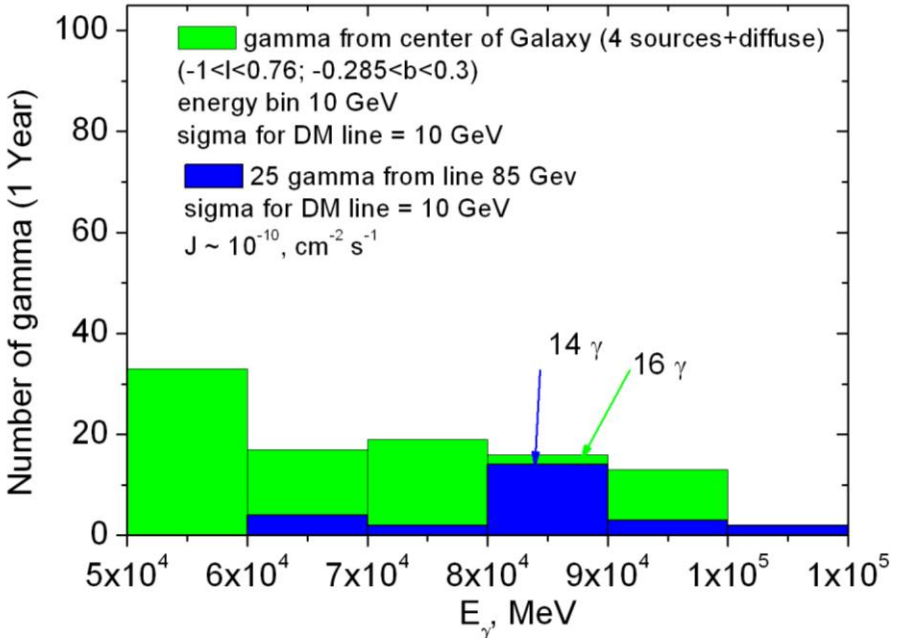
DM halo	α	r_s [kpc]	ρ_s [GeV/cm^3]
NFW	–	24.42	0.184
Einasto	0.17	28.44	0.033
EinastoB	0.11	35.24	0.021
Isothermal	–	4.38	1.387
Burkert	–	12.67	0.712
Moore	–	30.28	0.105

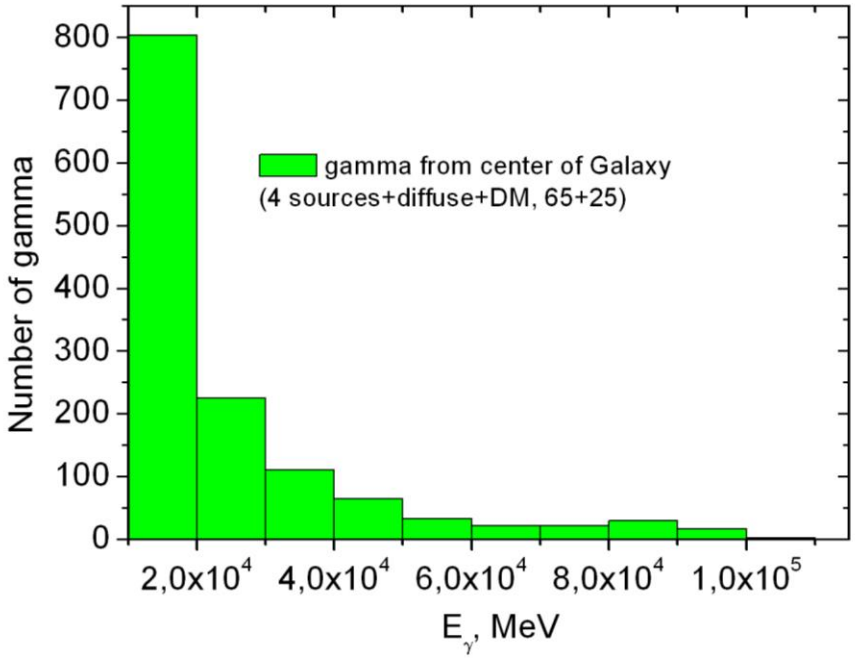
Galactic center (*-0.87<l<1; -0.285<b<0.3*).
3FGL catalog

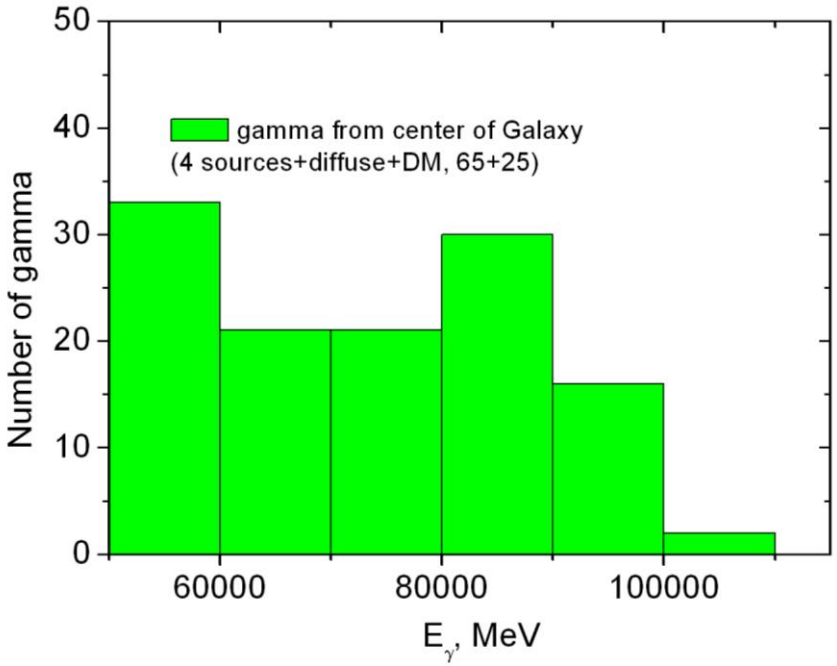
Name	Longitude	Latitude	Flux, 10-100 GeV, gamma/(cm^2 sec)	Power index	Number of gamma (FERMI LAT)
J1745.6-2859c	-0,0444	-0,0393	$9{,}998 \times 10^{-10}$	2,32	252
J1745.3-2903c	-0,136	-0,0201	$3{,}06 \times 10^{-10}$	2.29	77
J1746.3-2851c	0,1492	-0,1032	$4{,}57 \times 10^{-10}$	2,32	115
J1747.0-2828	0,5572	-0,0413	$6{,}65 \times 10^{-11}$	2.43	17

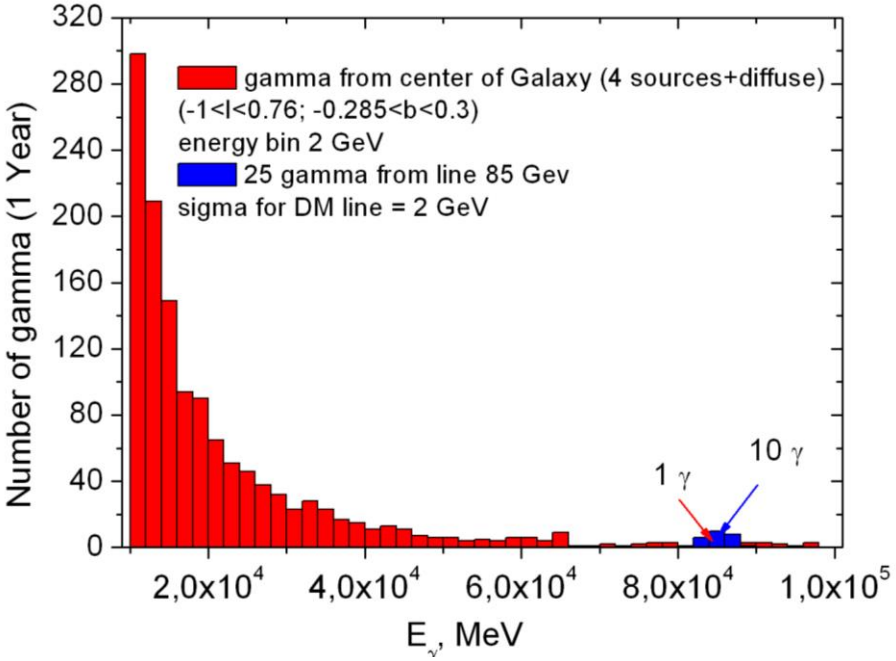

+0.3
+0.2
+0.1
0.0
−0.1
−0.2
GLAT b [deg]
+0.75
+0.50
+0.25
0.00
−0.25
−0.50
−0.75
−1.00
GLONG l [deg]

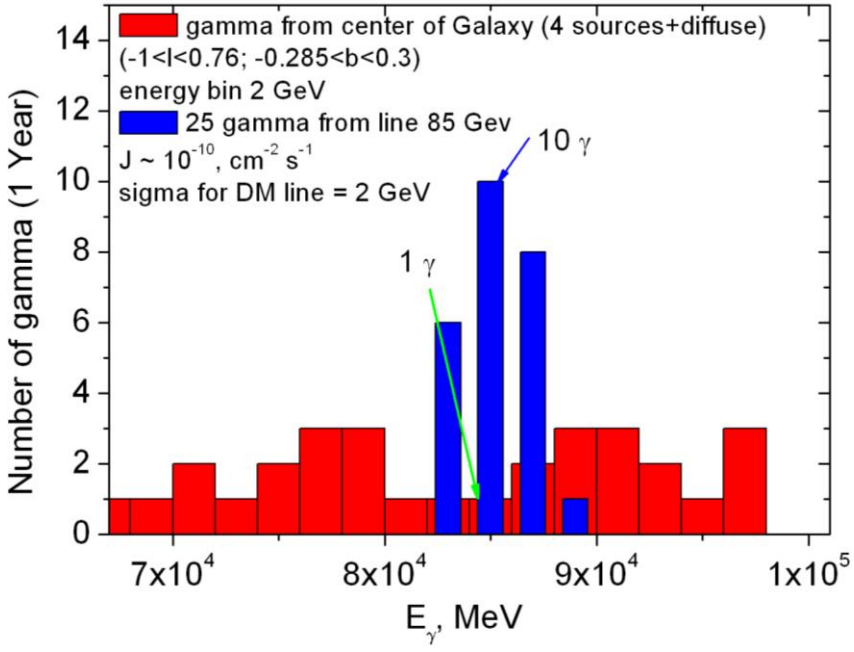

gamma from center of Galaxy (4 sources+diffuse)
(-1<l<0.76; -0.285<b<0.3)
energy bin 10 GeV
25 gamma from line 85 Gev
sigma for DM line = 10 GeV
14 γ
16 γ
Number of gamma (1 Year)
E_γ, MeV

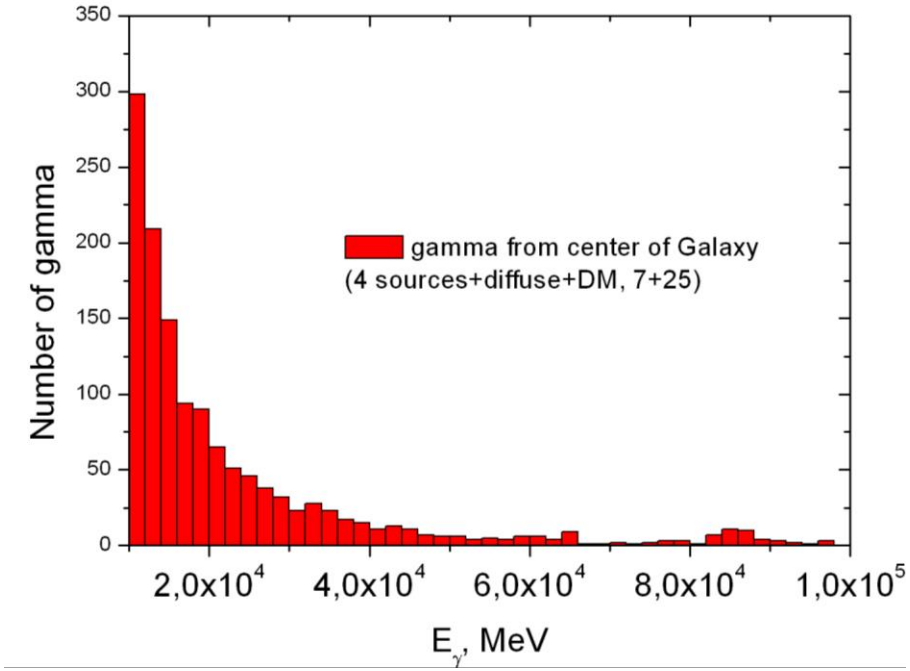

gamma from center of Galaxy (4 sources+diffuse)
(-1<l<0.76; -0.285<b<0.3)
energy bin 10 GeV
sigma for DM line = 10 GeV
25 gamma from line 85 Gev
sigma for DM line = 10 GeV
J ~ 10^-10, cm^-2 s^-1
14 γ
16 γ
Number of gamma (1 Year)
E_γ, MeV

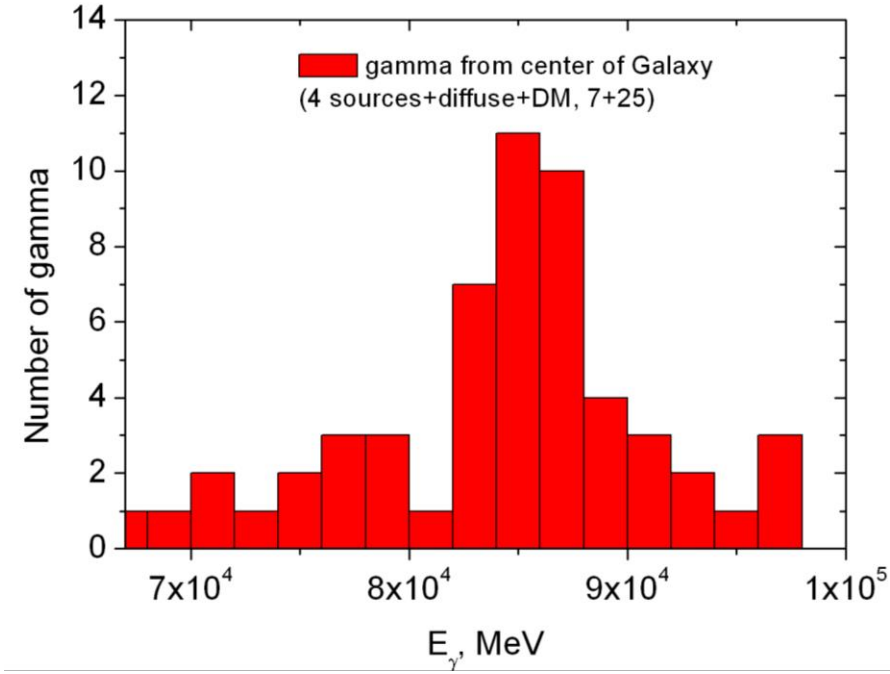

gamma from center of Galaxy
(4 sources+diffuse+DM, 65+25)
Number of gamma
E_γ, MeV


gamma from center of Galaxy
(4 sources+diffuse+DM, 65+25)
Number of gamma
E_γ, MeV


gamma from center of Galaxy (4 sources+diffuse)
(-1<l<0.76; -0.285<b<0.3)
energy bin 2 GeV
25 gamma from line 85 Gev
sigma for DM line = 2 GeV
1 γ
10 γ
Number of gamma (1 Year)
E_γ, MeV


gamma from center of Galaxy (4 sources+diffuse)
(-1<l<0.76; -0.285<b<0.3)
energy bin 2 GeV
25 gamma from line 85 Gev
J ~ 10^-10, cm^-2 s^-1
sigma for DM line = 2 GeV
1 γ
10 γ
Number of gamma (1 Year)
E_γ, MeV


gamma from center of Galaxy
(4 sources+diffuse+DM, 7+25)
Number of gamma
E_γ, MeV


gamma from center of Galaxy
(4 sources+diffuse+DM, 7+25)
Number of gamma
E_γ, MeV

GAMMA-400 only calorimeter CC2 (CsI(Tl)) performance

N×N×N cubes	28×28×12
L	3.6 cm
Size	$1\times1\times0.47$ m^3
X_0	54.6×54.6×23.4
λ_I	2.5×2.5×1.1
Mass	1683 kg

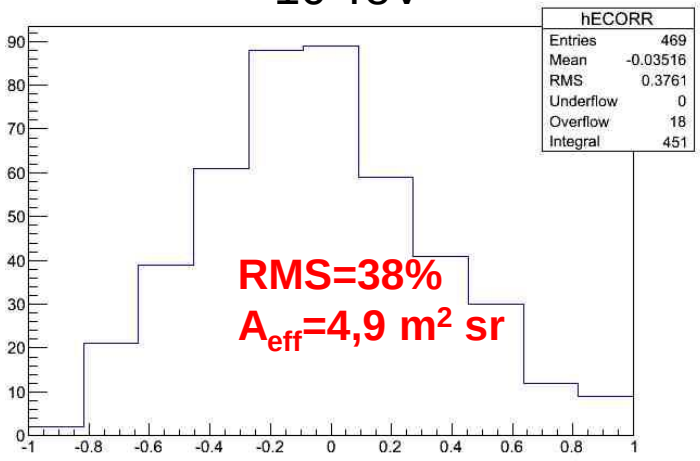
Protons and Helium (Polygonato model)

Effective GF (m^2 sr)	σ(E)/E	E>0.1 PeV		E>0.5 PeV		E>1 PeV		E>2 PeV		E>4 PeV	
		p	He	p	He	p	He	p	He	p	He
~4	35%	7.8×10^3	7.4×10^3	4.6×10^2	5.1×10^2	1.2×10^2	1.5×10^2	28	43	5	10

Expected number of proton and helium events in 10 years data taking, according to the Polygonato model

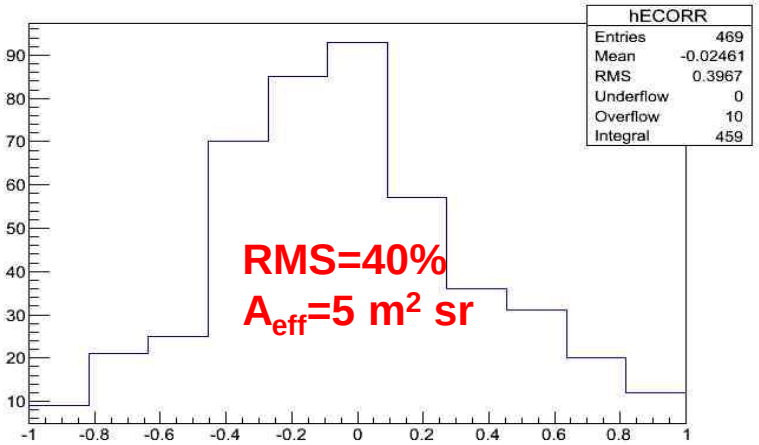
Calorimeter only proton energy resolution

10 TeV



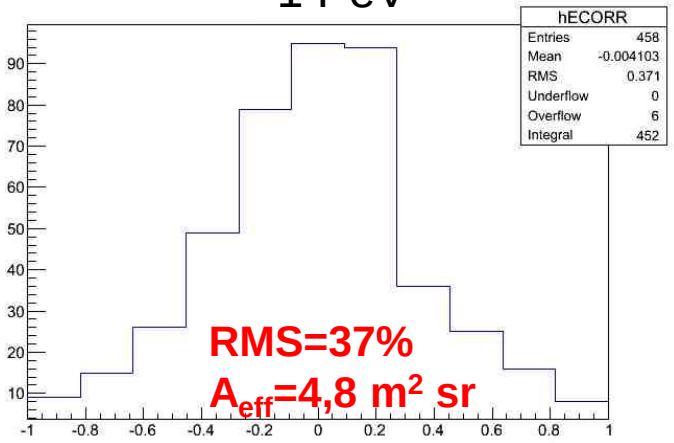
$(E-E_{true})/E_{true}$

100 TeV



$(E-E_{true})/E_{true}$

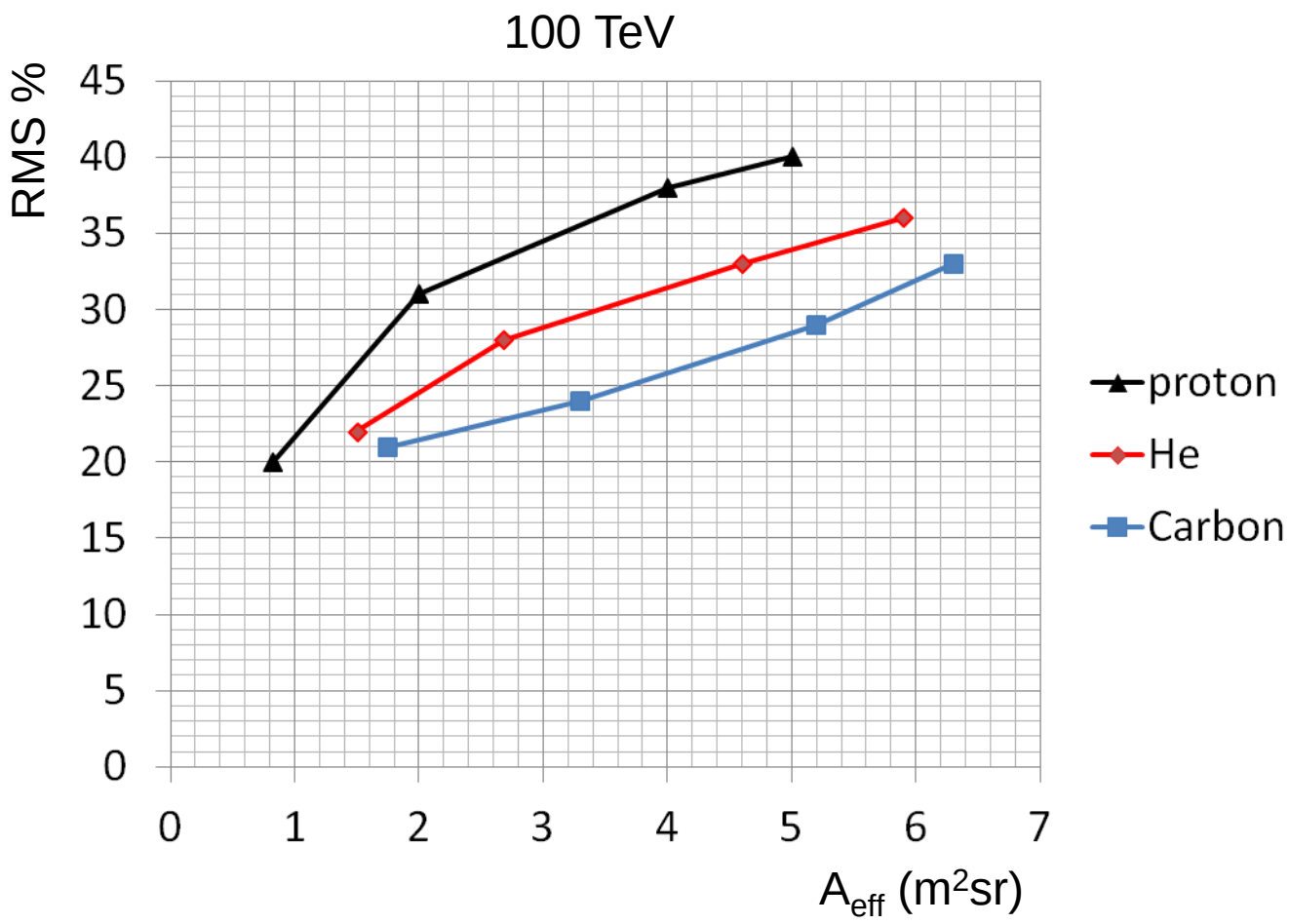
1 PeV



$(E-E_{true})/E_{true}$

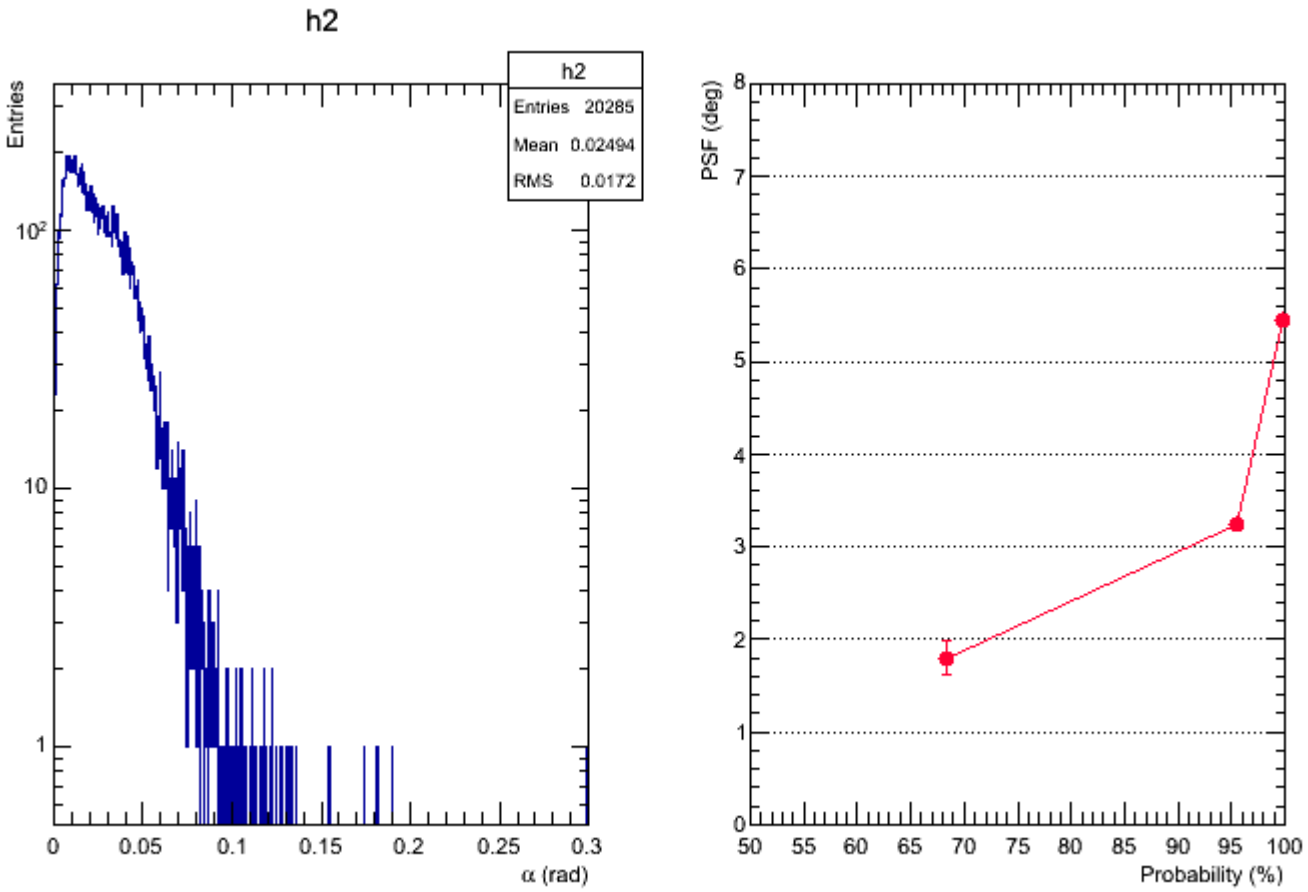
Resolutions and A_{eff} depend on cuts.
Optimizeation for large acceptance.

Nuclei energy resolution



Calorimeter only angular resolution (gamma 100 GeV)

68% containment: $1.7^0 \pm 0.2^0$ (Elena Vannuccini, INFN, Florence)



For HE (>1 TeV) protons and nuclei with 68% containment ~3^0 (Sergio Bottai, INFN, Florence)

Conclusion

The instrument has been designed for the optimal detection of gamma rays in a broad energy range (from 100 MeV up to 3 TeV), with excellent angular and energy resolution.

The observatory will also allow precise and high statistic studies of the electron component in the cosmic rays up to the multi TeV region, as well as protons and nuclei spectra up to the knee region.

GAMMA-400 will allow to address a broad range of science topics, like search for signatures of dark matter, studies of Galactic and extragalactic gamma-ray sources, Galactic and extragalactic diffuse emission, gamma-ray bursts and charged cosmic rays acceleration and diffusion mechanism up to the knee.

Thanks for your attention