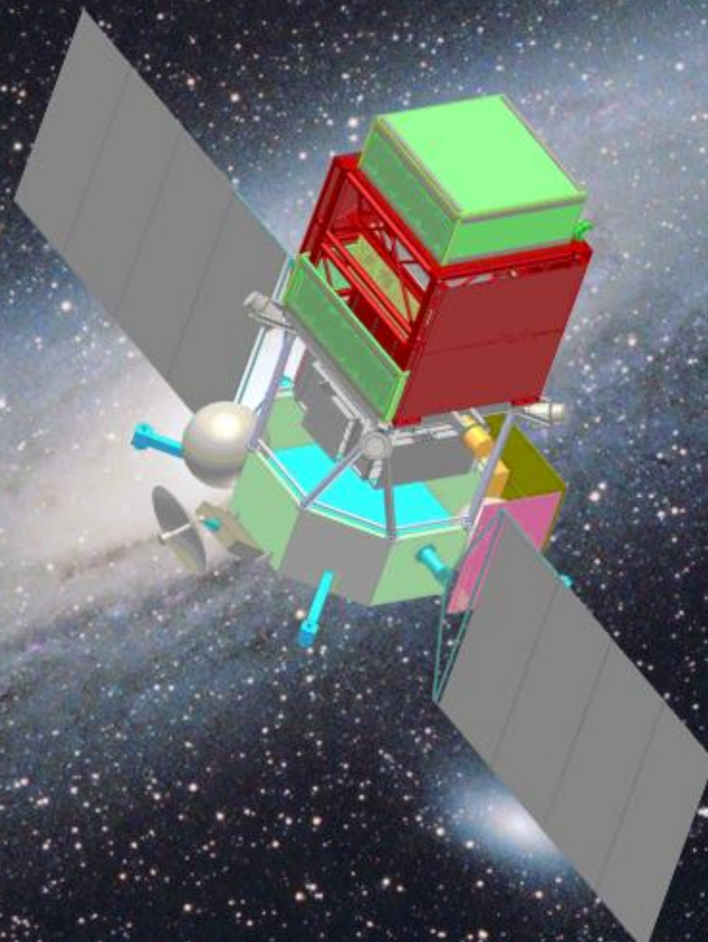
Presented by A.A. Leonov on behalf of Project Manager and Chief Designer N.P. Topchiev

The GAMMA-400 Space Mission for Measuring High-Energy Gamma Rays and Cosmic Rays



Национальный исследовательский ядерный университет МИФИ

INFN

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

14th Marcel Grossmann Meeting, Rome, July 12-18, 2015

GAMMA-400 collaboration

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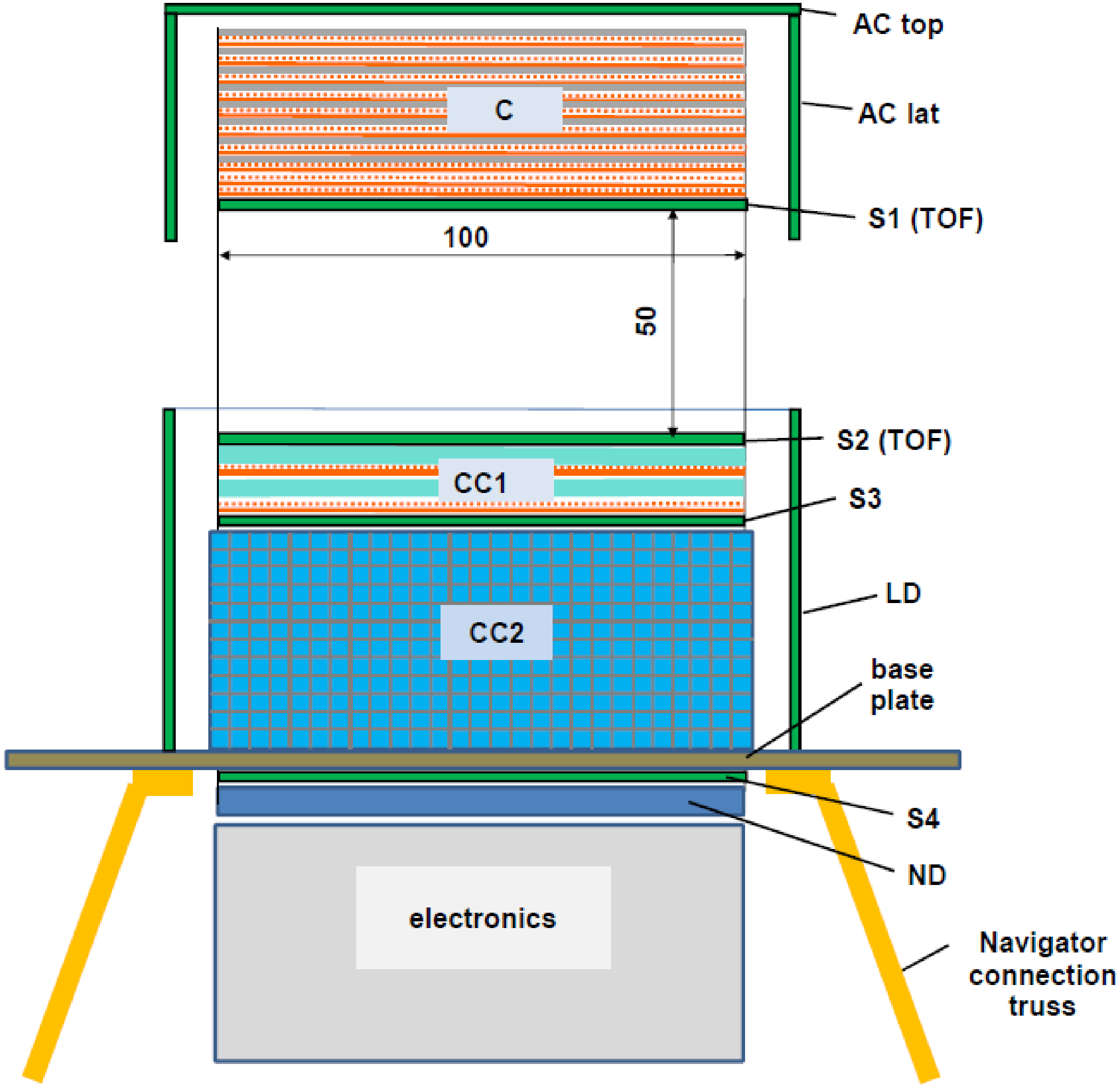
The current generation of gamma-ray space experiments with the advent of solid-state Silicon detector technology:
AGILE-GRID (Gamma-Ray Imaging Detector) – launch 2007,
FERMI LAT (Large Area Telescope) – launch 2008.
(arXiv:1507.01475v1 [astro-ph.HE] 6 Jul 2015)

Future gamma-ray mission:
GAMMA-400 – launch ~2023-2025,
Last GAMMA-400 workshop, 29-30th June, 2015, Barcelona (CIEMAT, ICCUB)
GAMMA-LIGHT – ???.
(Nuclear Physics B (Proc. Suppl.) 239–240, 193–198, 2014)

	Energy range, GeV	Angular resolution (68%)		
		100 MeV	10 GeV	100 GeV
AGILE	0.05÷10	4^0	0.2^0	-
FERMI (total)	0.2-300	5^0	0.2^0	0.13^0
GAMMA-400	0.02÷3000	2.5^0	0.1^0	0.017^0
GAMMA-LIGHT	0.05÷10	$\sim1.5^0$	0.1^0	-

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

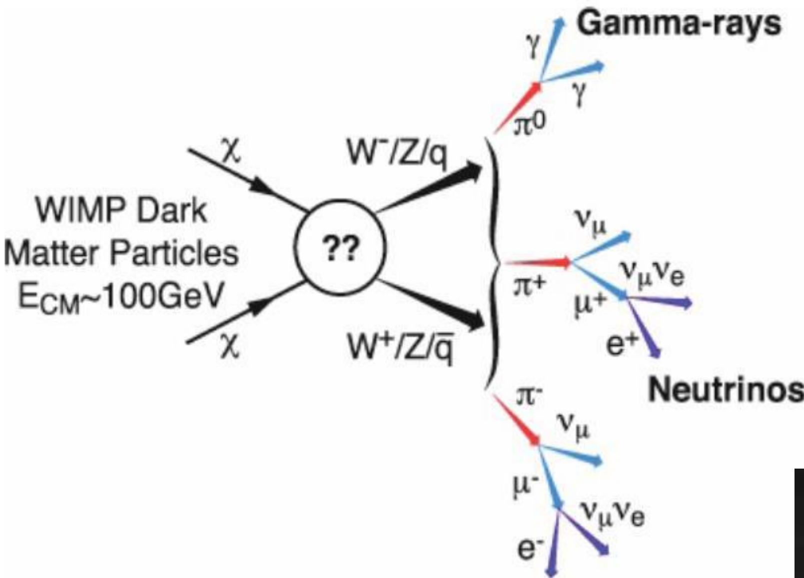
1.2 The variability of high energy γ-ray emissions from discrete sources in order to clarify the nature of particle acceleration in such sources

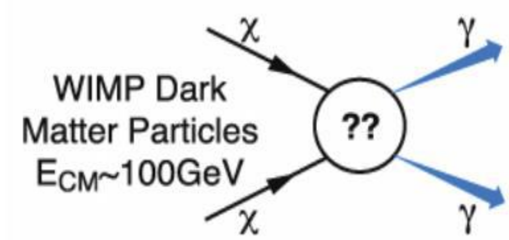
1.3 γ-ray bursts, including high-energy bursts

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 Production





Indirect search for dark matter in γ-ray and cosmic ray radiations

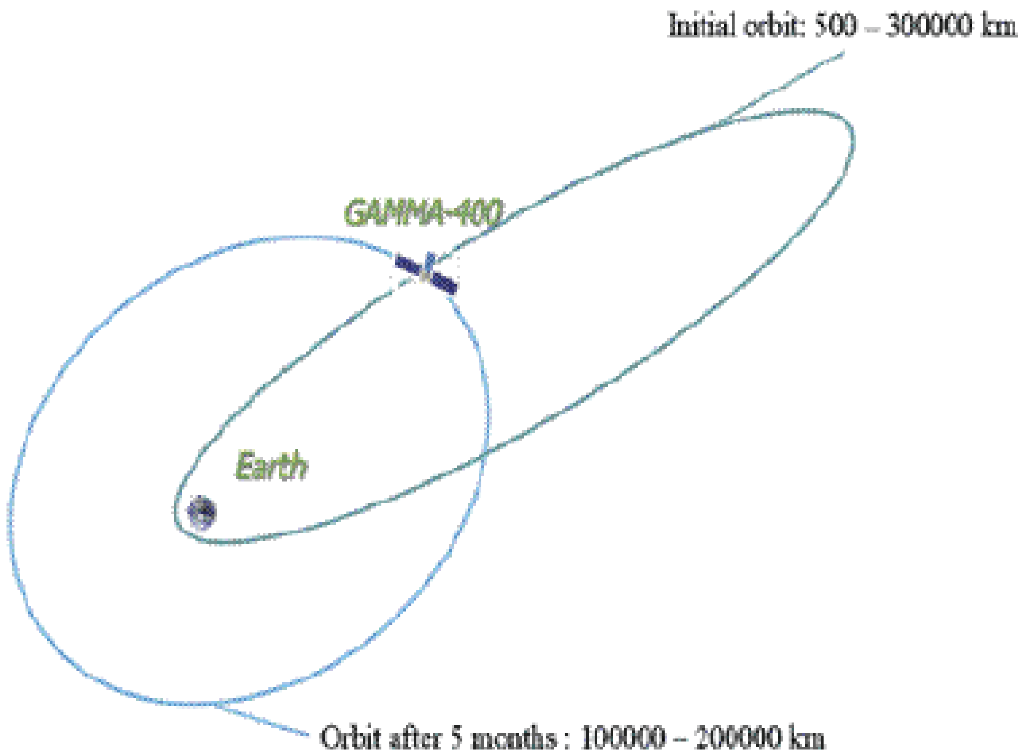
GAMMA-400 will conduct the search in the phase space of γ-rays with E > ~1 GeV and electron + positron spectrum above ~10 GeV.

General Approach: Search for disagreement / difference between observed and predicted by "classical" model CR / γ-ray flux / spectra / spatial distribution

Dark matter signature	=	Observed spectrum / spatial features	-	γ-ray sources	-	Known backgrounds (diffuse γ-radiation etc.)

The sensitivities to a DM signal depend critically on accurate estimates of the backgrounds: diffuse γ-rays, γ- rays from astrophysical sources, and charged particles detected as γ-rays

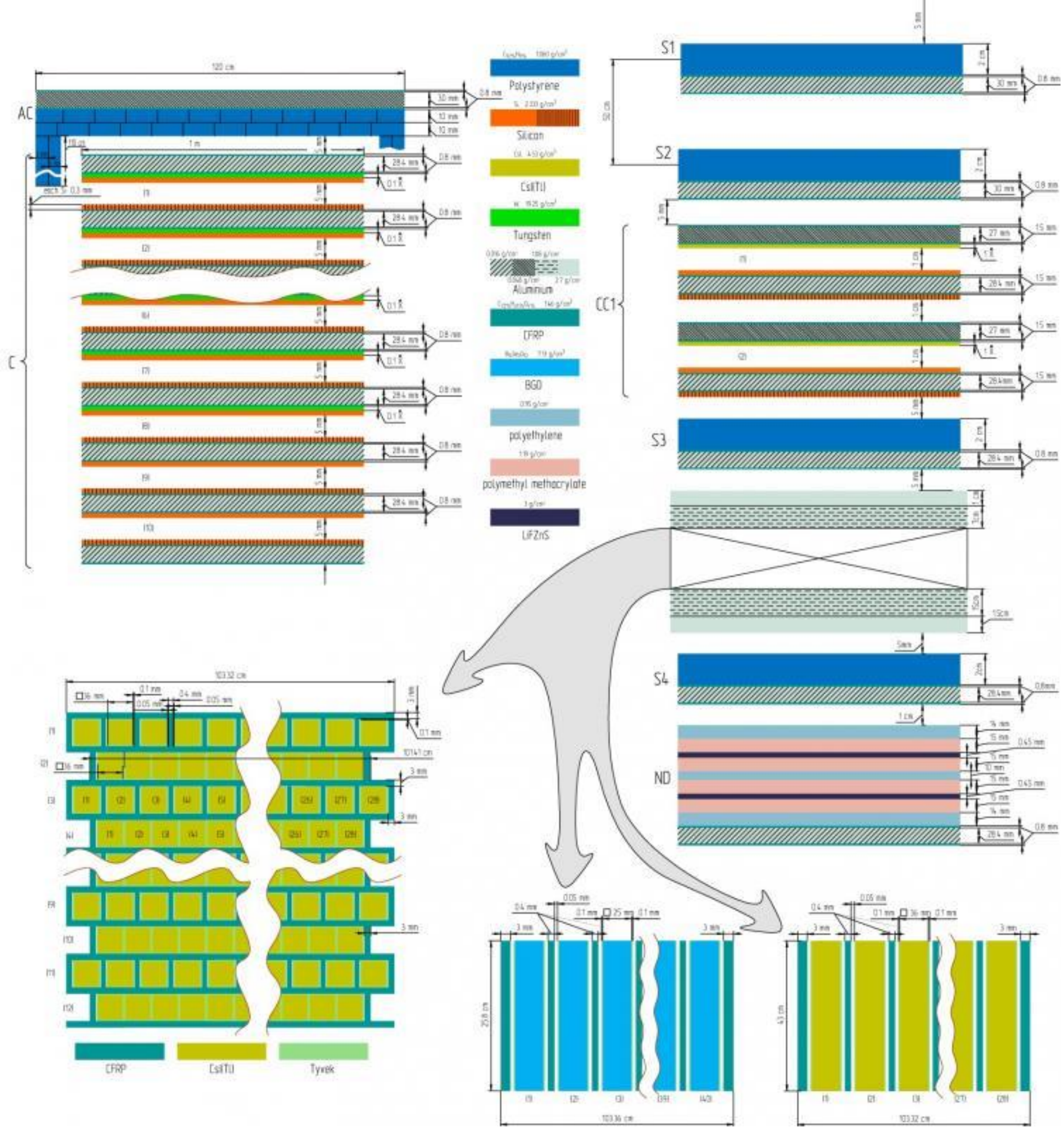
GAMMA-400 will be launched in highly elliptical orbit (500–300000 km) with an inclination angle of 51.8°. The initial orbit, after some months, evolves to a very high circular orbit (100.000 – 200.000 km) with an orbital period of about 7 days.



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

GAMMA-400 gamma-ray telescope simulation environment

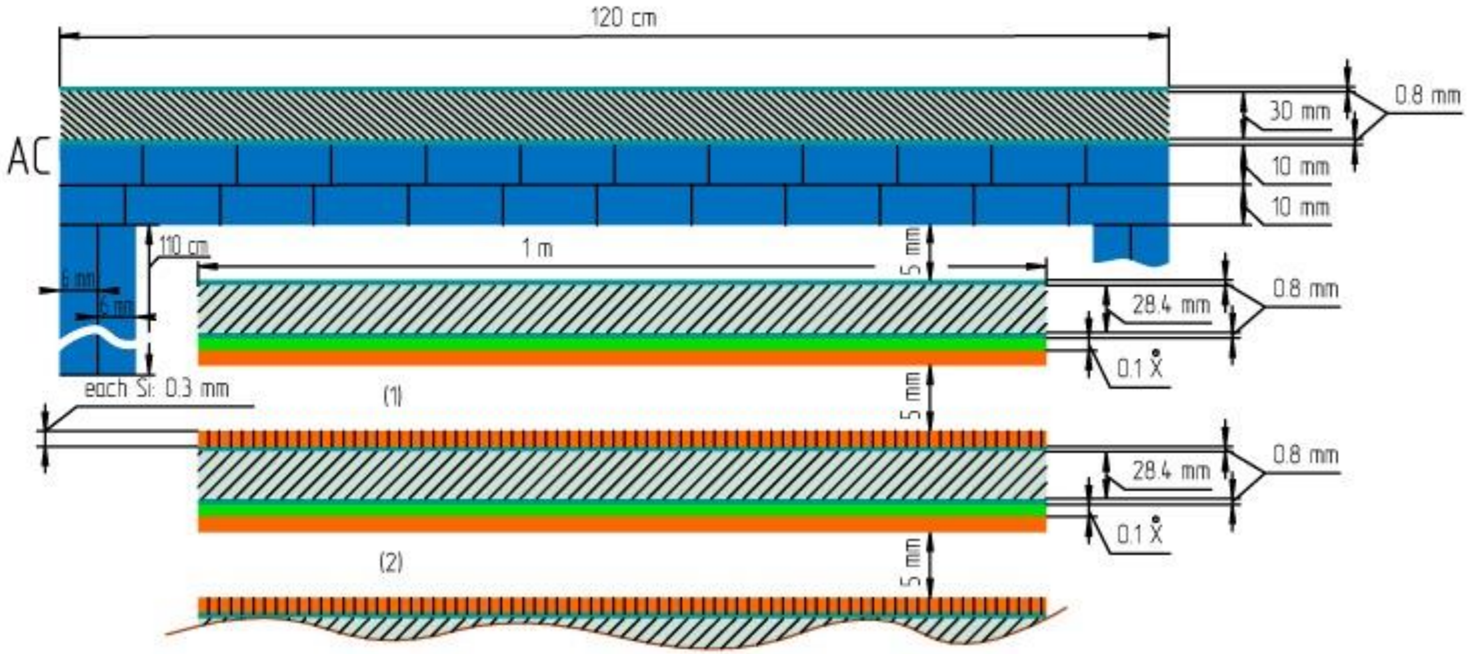
GEANT4 (4.9.4p02)
GLAST physical list



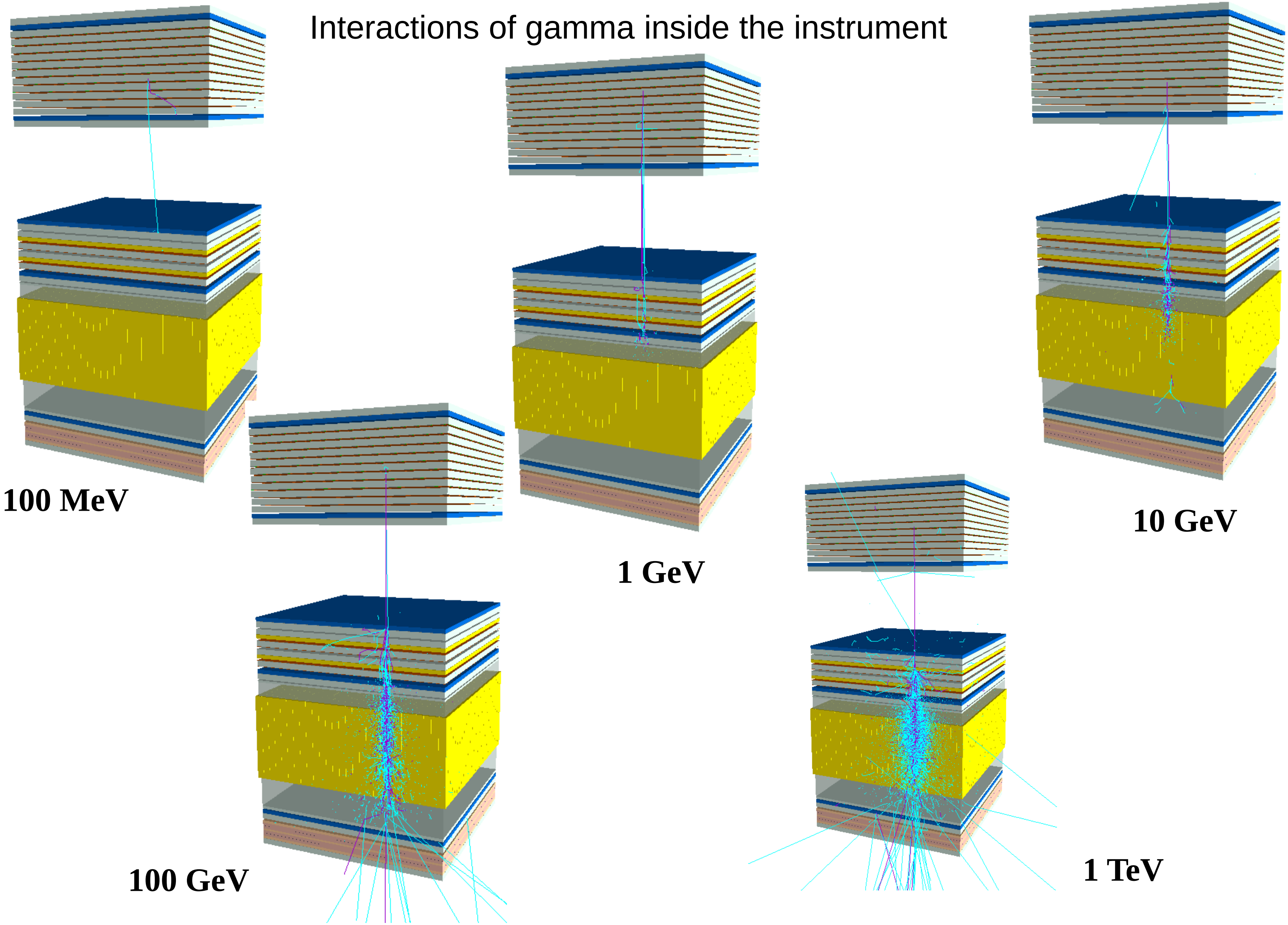
GAMMA-400 instrument layers

GAMMA-400 instrument layers

Magnified view of the top part



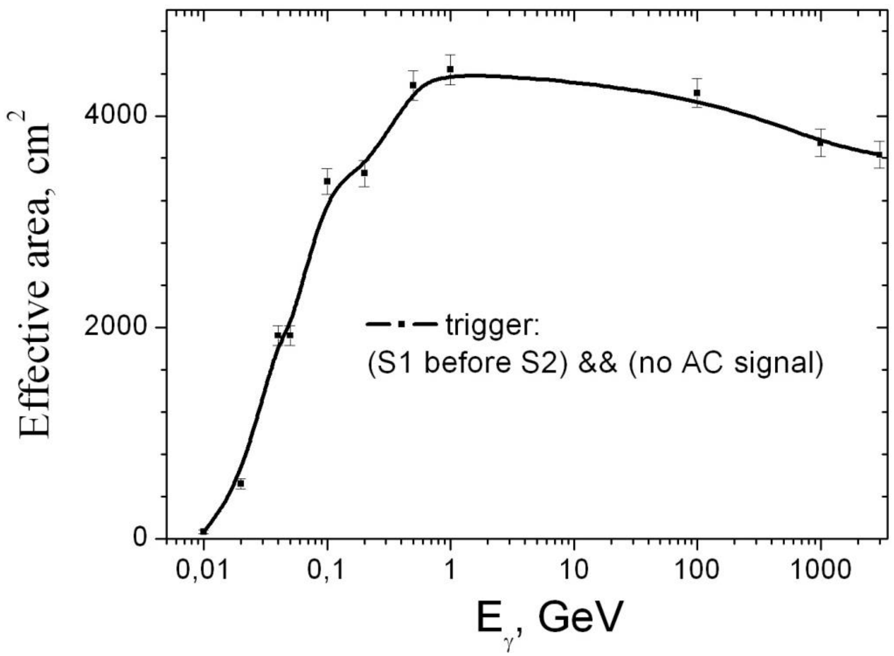
Interactions of gamma inside the instrument



GAMMA-400 performance

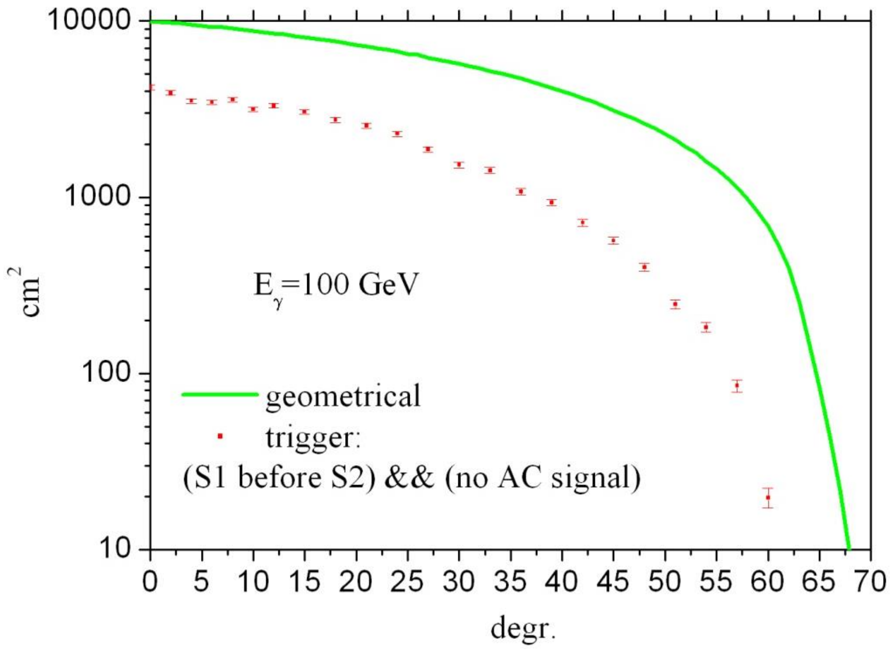
Effective area for vertical gamma.

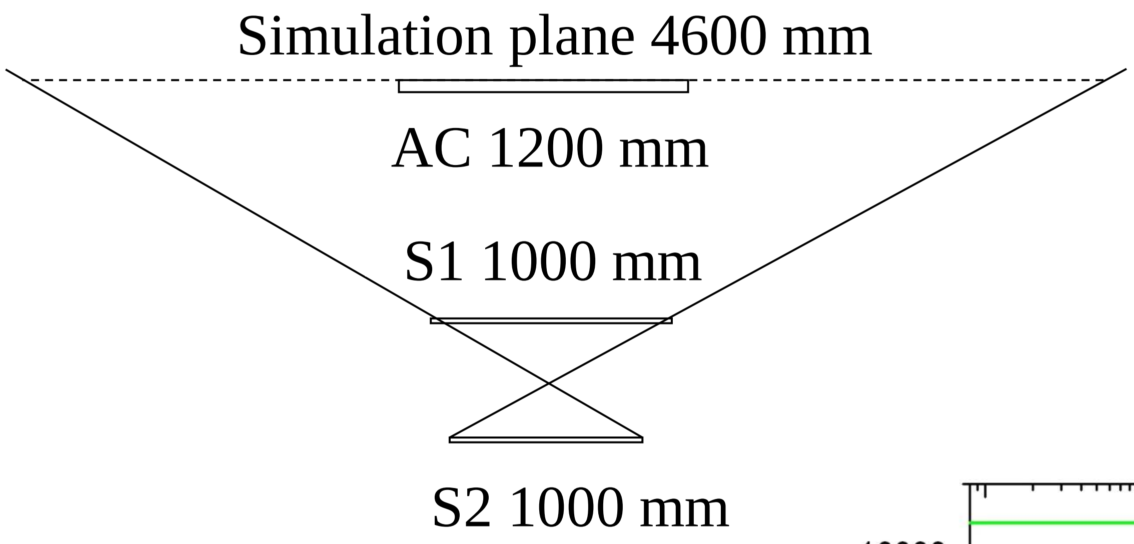
$$S_{EFF}(\theta) = \frac{N_{DET}}{N_0} \times S$$



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

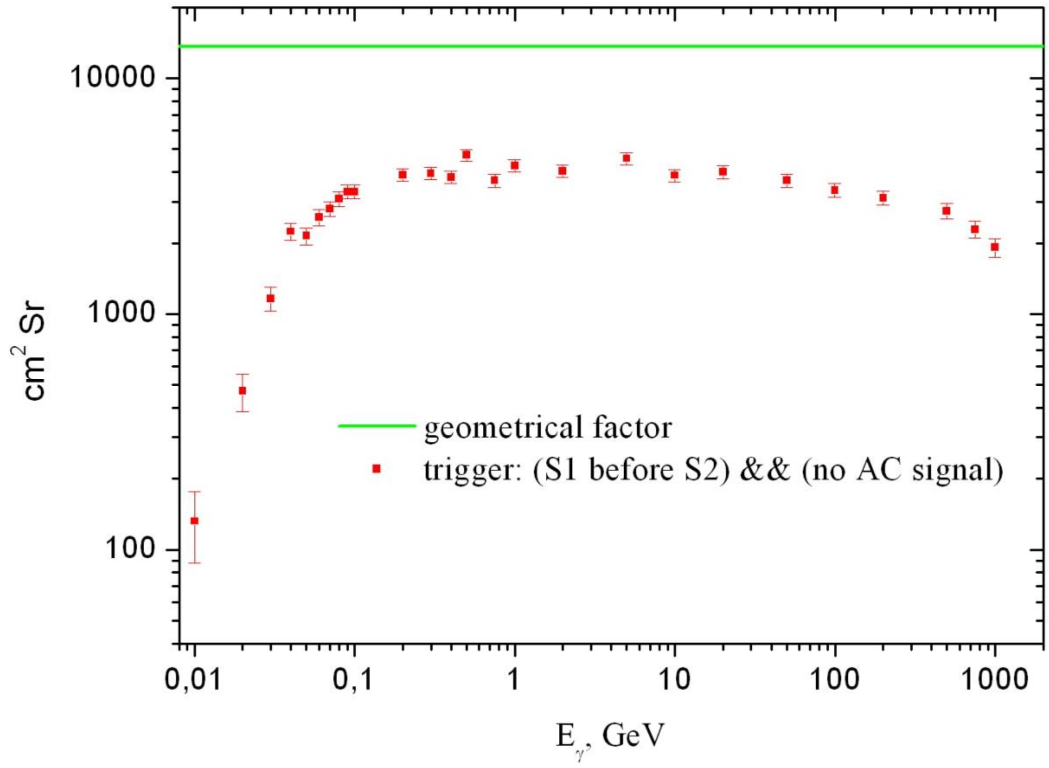
$$S_{EFF}(\theta) = \frac{N_{DET}}{N_0} \times S \times \cos\theta$$





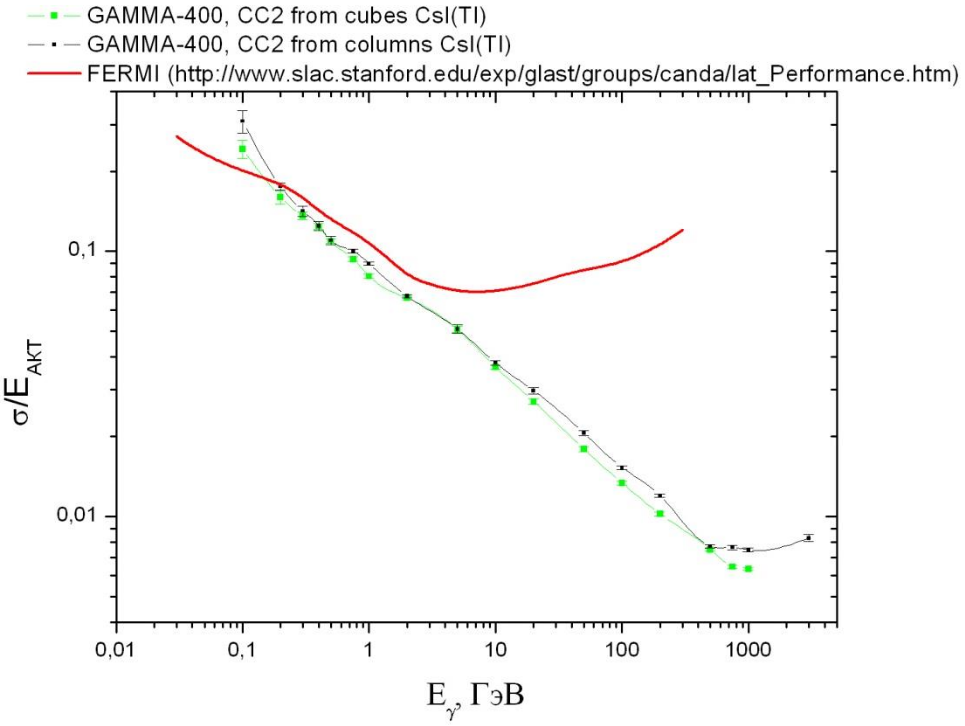
Acceptance.

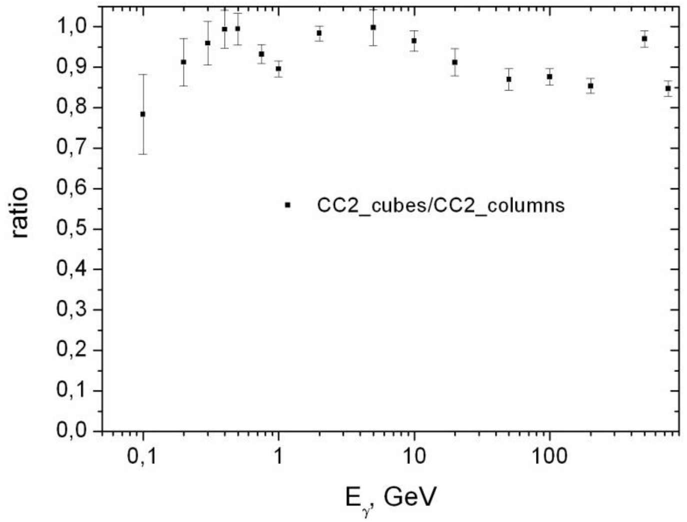
$$G(E) = \frac{N_{DET.}}{N_0} \times \pi S$$



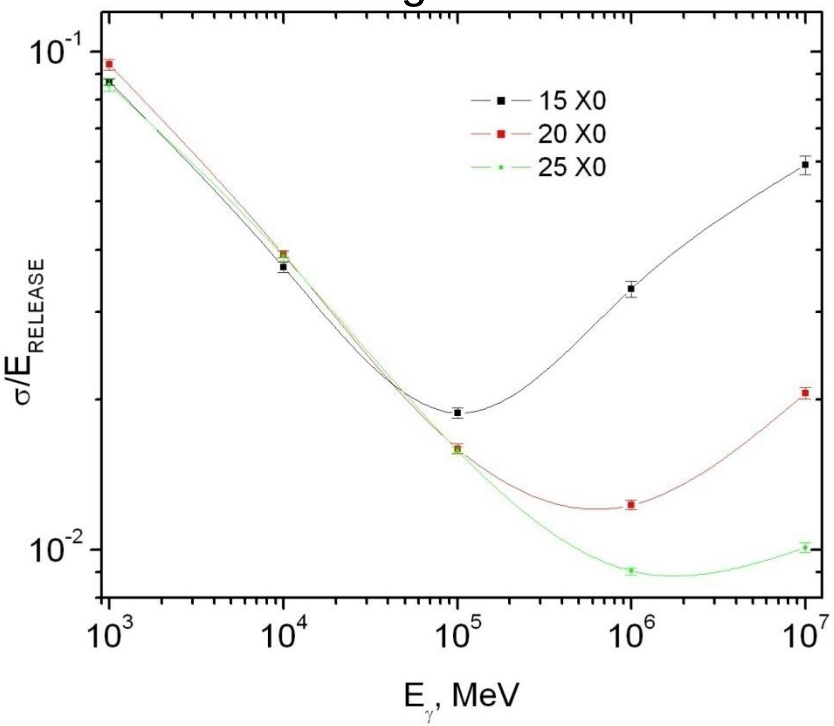
Energy resolution

Vertical flux in the center of surface

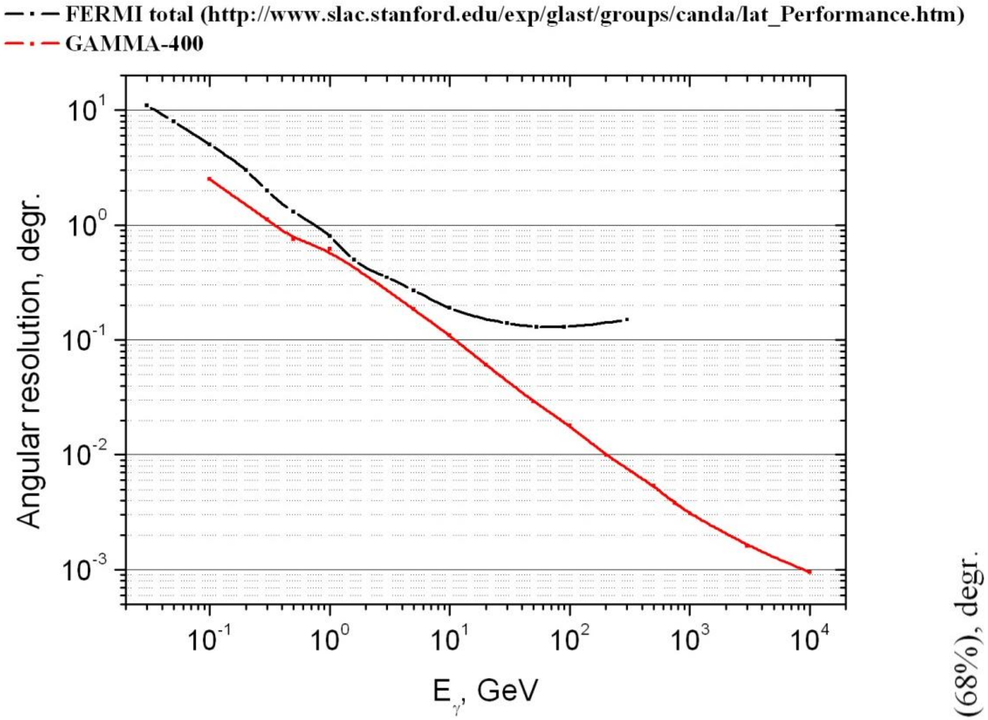


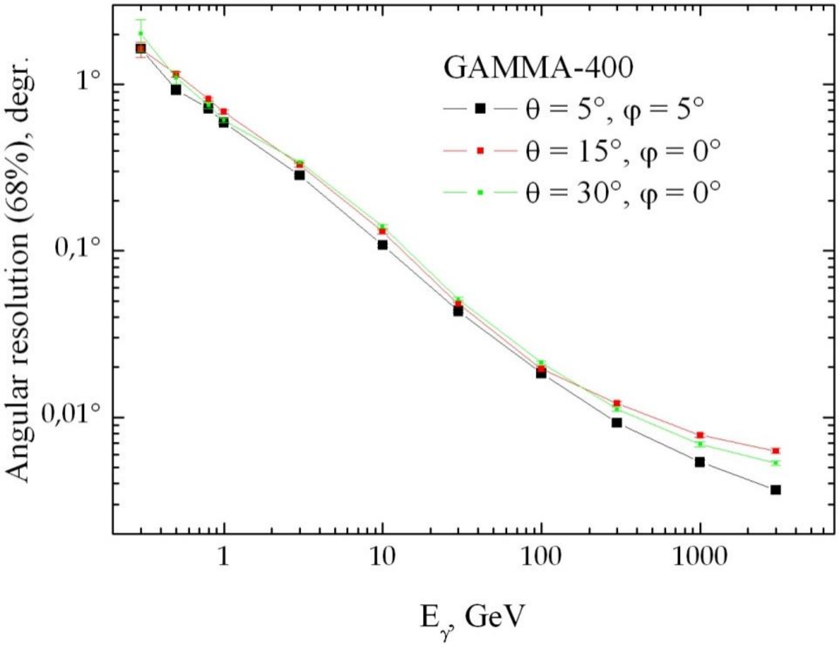


Different length of CC2

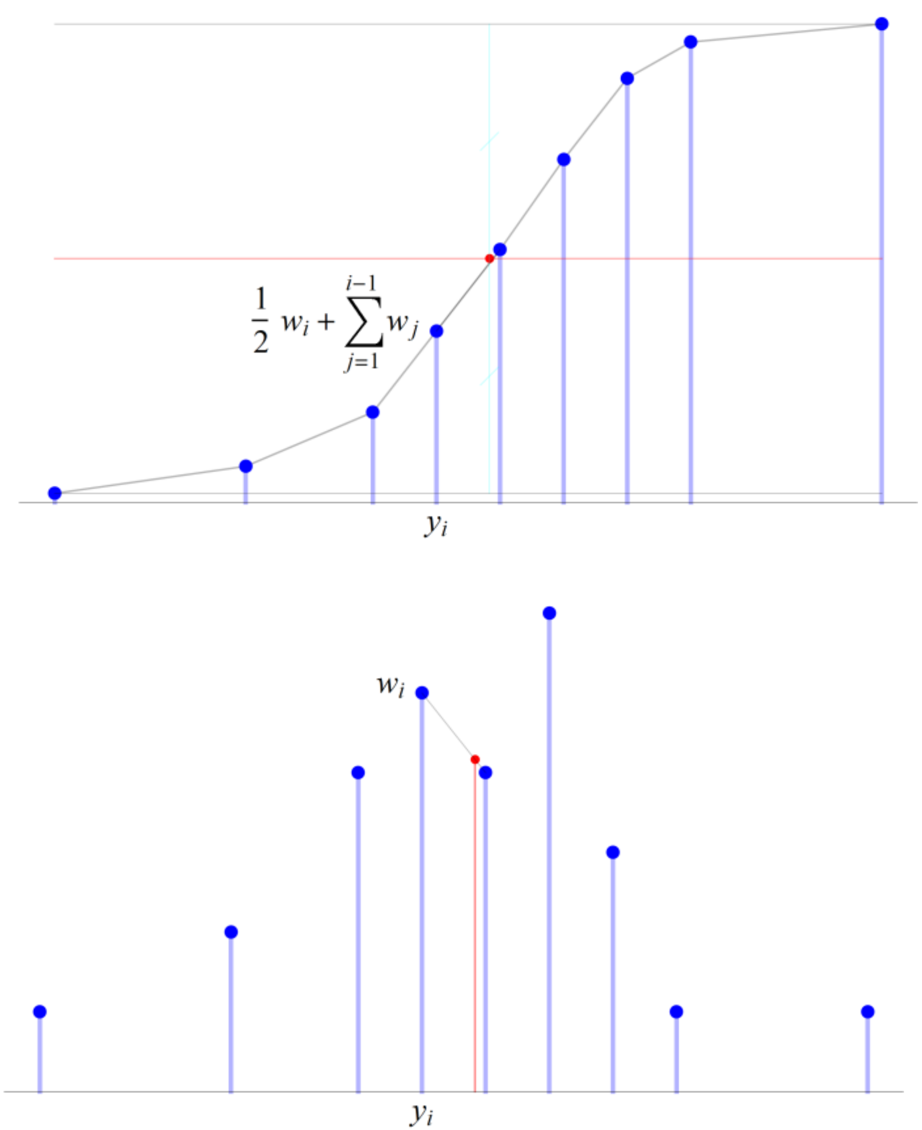


Angular resolution



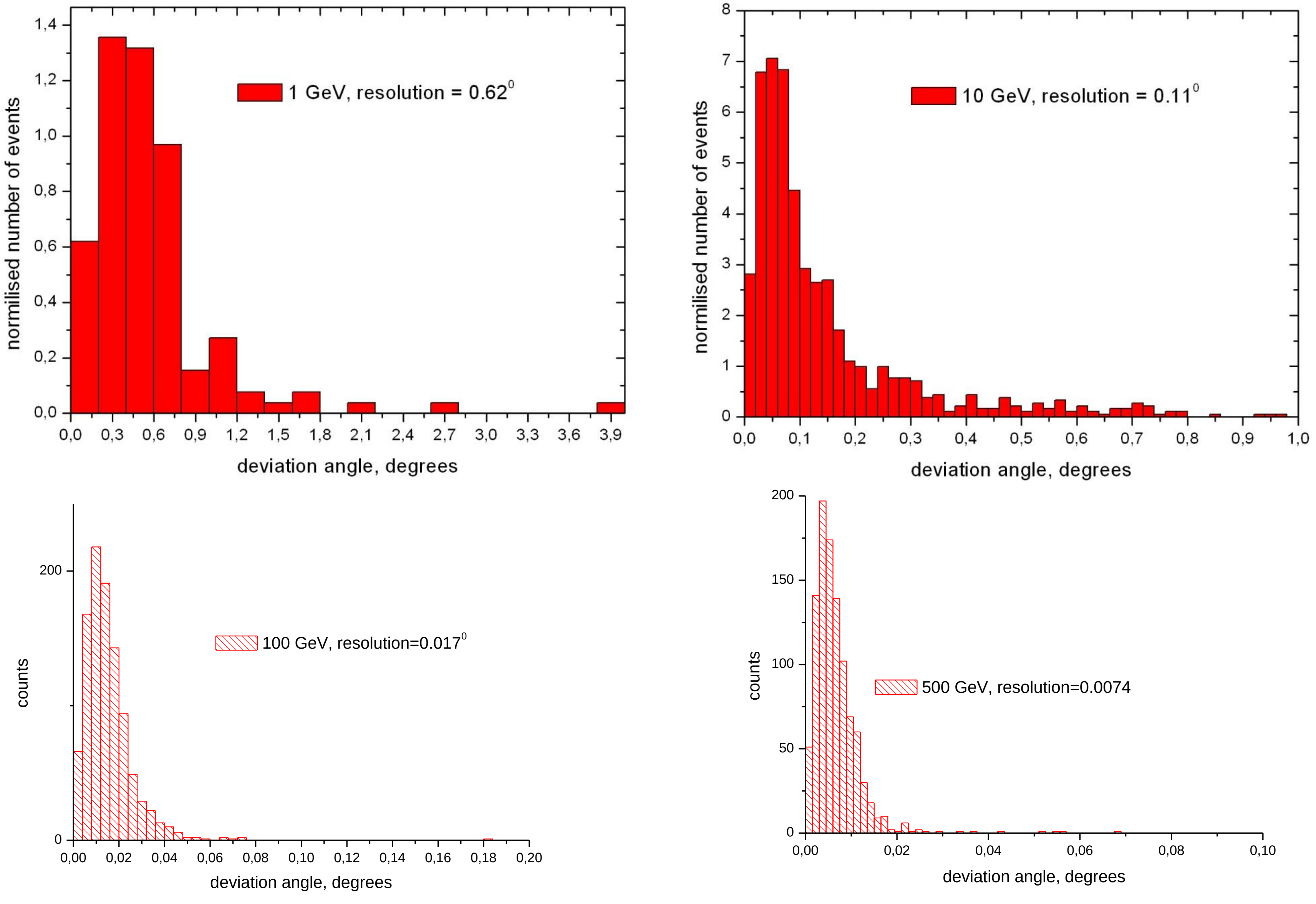


MEDIAN method, gamma > 1 GeV

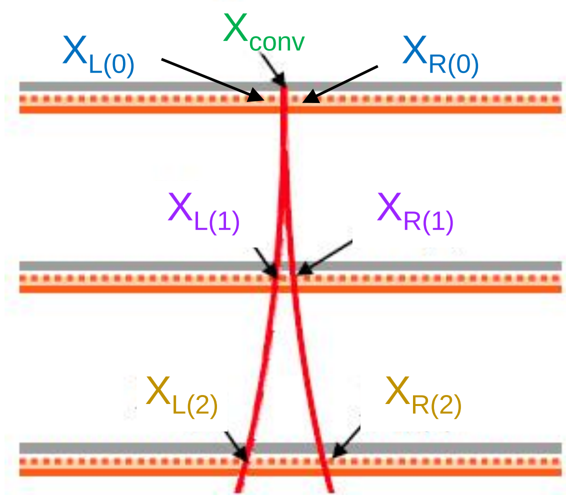


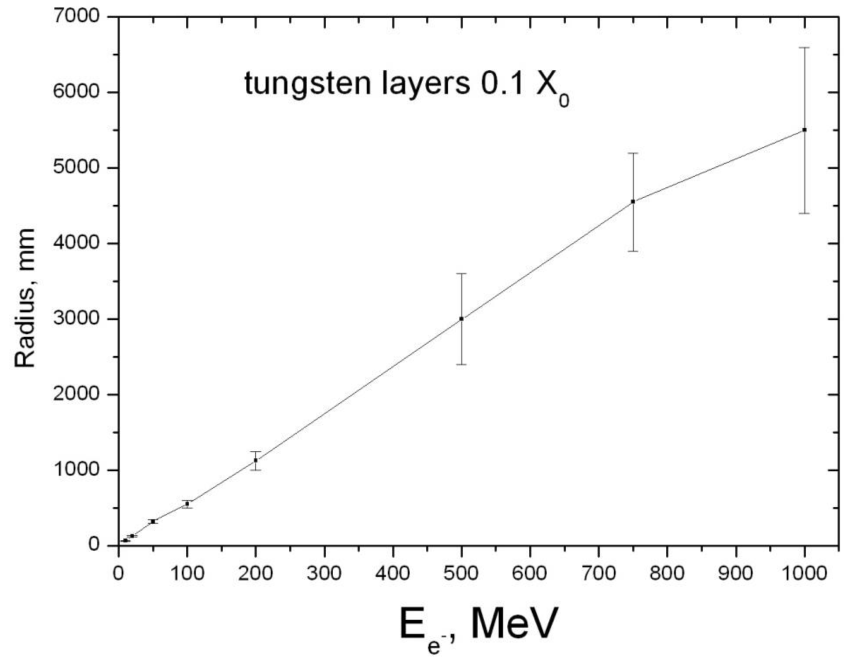
For each silicon-strip layer with energy release the distribution of the sum of energy deposited in strips is constructed.
The horizontal line is median, which is calculated as a half sum of the extreme points for constructed distribution.
The intersection point of median with piecewise continuous distribution gives the estimation of median energy location in silicon-strip layer.
To find the energy weight of the median the ordinary distribution of energy releases in strips is built.
The median energy weight is defined using the obtained median location on the piece line linking adjacent (respective median location) points of the obtained distribution.
The estimation of the initial direction is obtained using fitting procedure for the median locations in silicon-strip layers. Around the estimated direction the corridor from strips is constructed. The energy releases in strips outside the corridor are ignored. After that the iteration procedure starts, narrowing the corridor from strips in each silicon-strip layer, but not less, then 200 μm.

Angular resolution > 1 GeV



Imaginary curvature method, gamma < 500 MeV





Step 1: From the radius of track the pair component energies E_R and E_L are restored.

Step 2: Coordinate of $X_{L(W)}$ on conversion plate is restored from $X_{L(0)}$, $X_{L(1)}$, $X_{L(2)}$ and E_L .

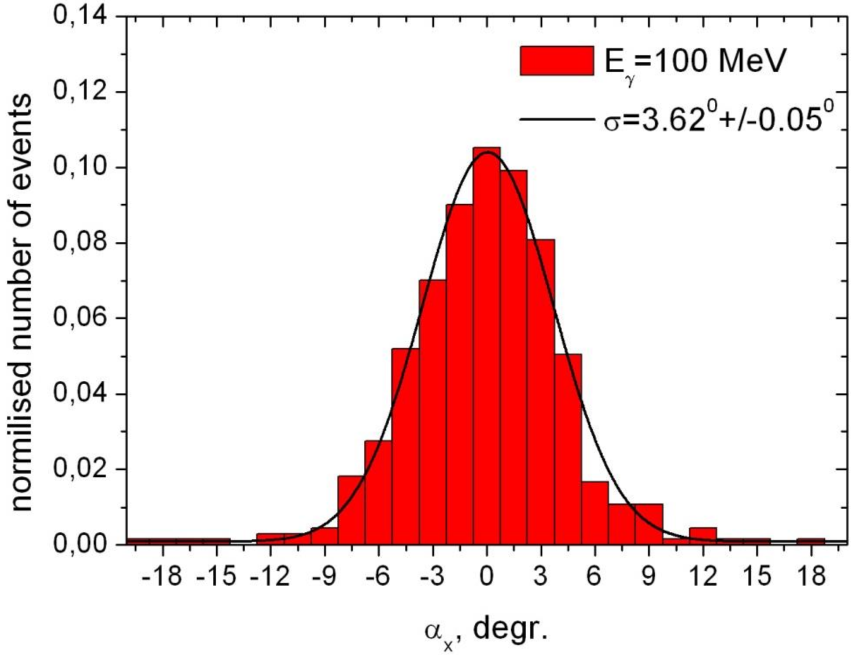
Step 3: Coordinate of $X_{R(W)}$ on conversion plate is restored from $X_{R(0)}$, $X_{R(1)}$, $X_{R(2)}$ and E_R .

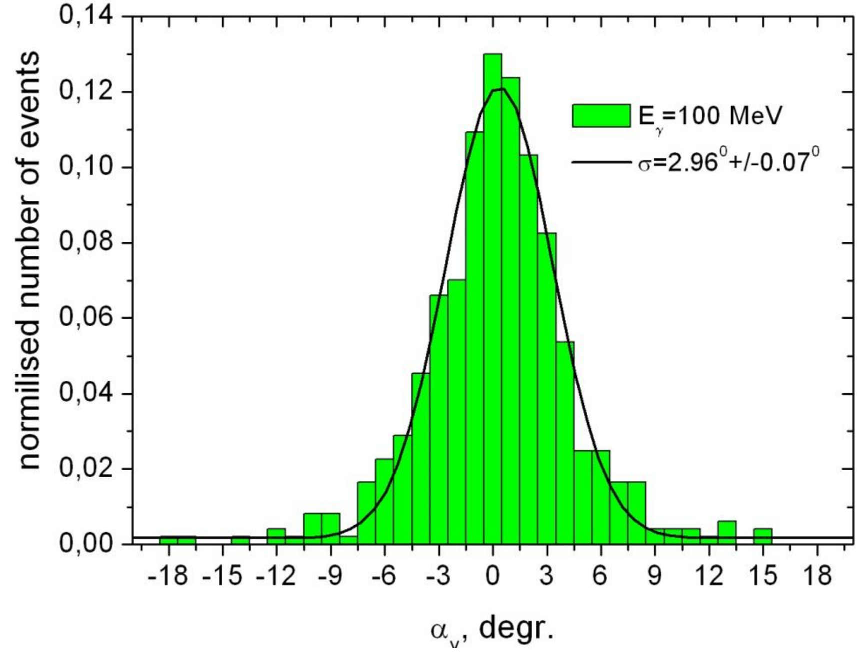
Step 4: Calculate middle point coordinate: $X_{conv} = X_{R(W)} \times (E_R/(E_L+E_R)) + X_{L(W)} \times E_L/(E_L+E_R))$.

Step 5: Repeat the steps 2, 3, 4 for (X_{conv}, $X_{R(0)}$, $X_{R(1)}$) and (X_{conv}, $X_{L(0)}$, $X_{L(1)}$).

Step 6: Calculate angles $\alpha_R(X_{conv}, X_{R(0)}, X_{R(1)})$ and $\alpha_L(X_{conv}, X_{L(0)}, X_{L(1)})$.

Step 7: Calculate 'weighted' plane angle $\alpha = \alpha_R \times E_R/(E_L+E_R) + \alpha_L \times E_L/(E_L+E_R)$.

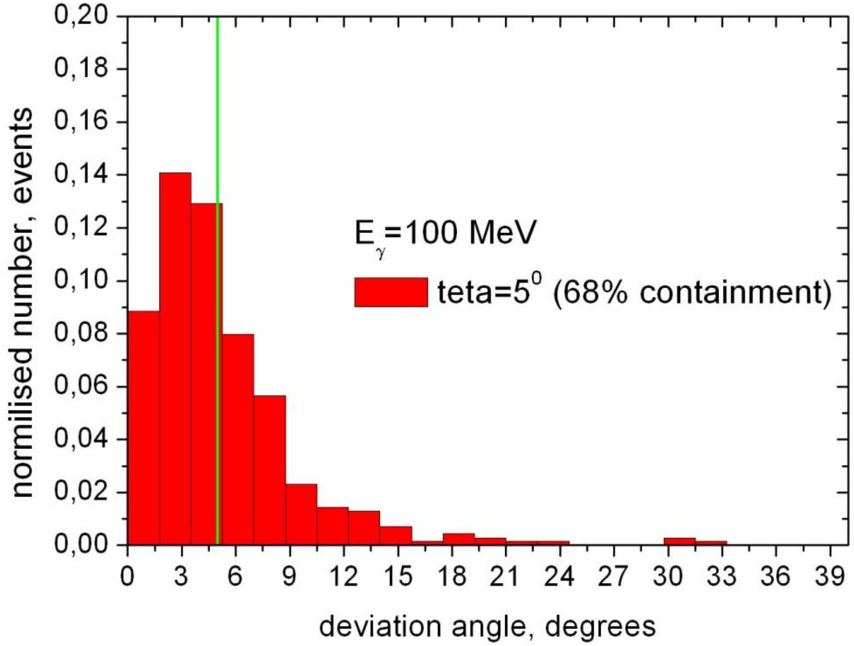




Relations of plane angles α_x and α_y with polar angle θ and azimuth angle φ:

$$\tan^2 \theta = \tan^2 \alpha_x + \tan^2 \alpha_y$$

$$\tan \varphi = \tan \alpha_y / \tan \alpha_x$$



The main influence on the angular resolution provides the thickness of first converter layer from tungsten, in which gamma conversion occurs. The investigation was done to look for the optimal thickness in the configuration of converter planes.
The configurations under study are the following:

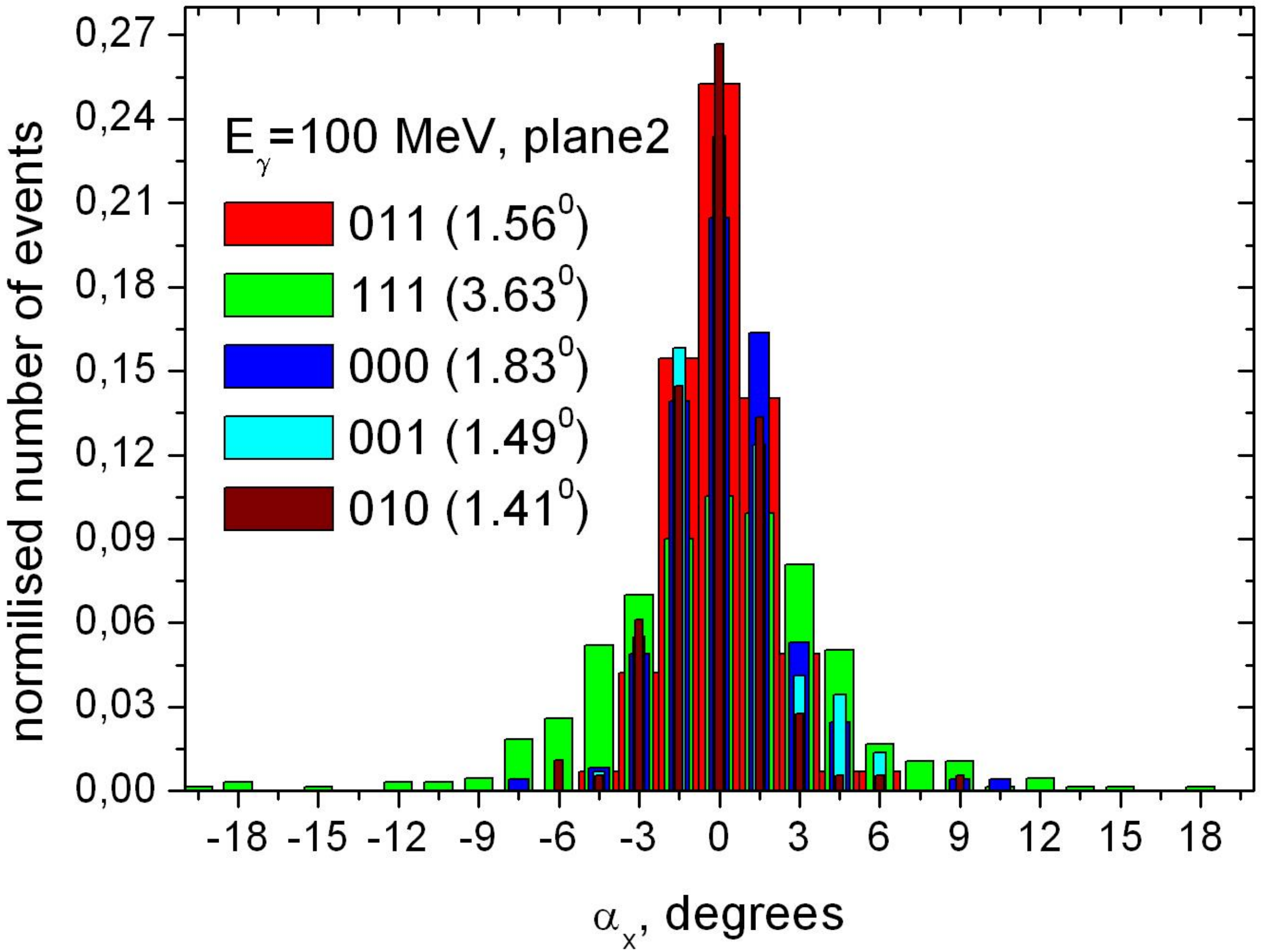
$0.01\ X_0$ - $0.1\ X_0$ - $0.1\ X_0$;
label '011';

$0.1\ X_0$ - $0.1\ X_0$ - $0.1\ X_0$;
label '111';

$0.01\ X_0$ - $0.01\ X_0$ - $0.01\ X_0$;
label '000';

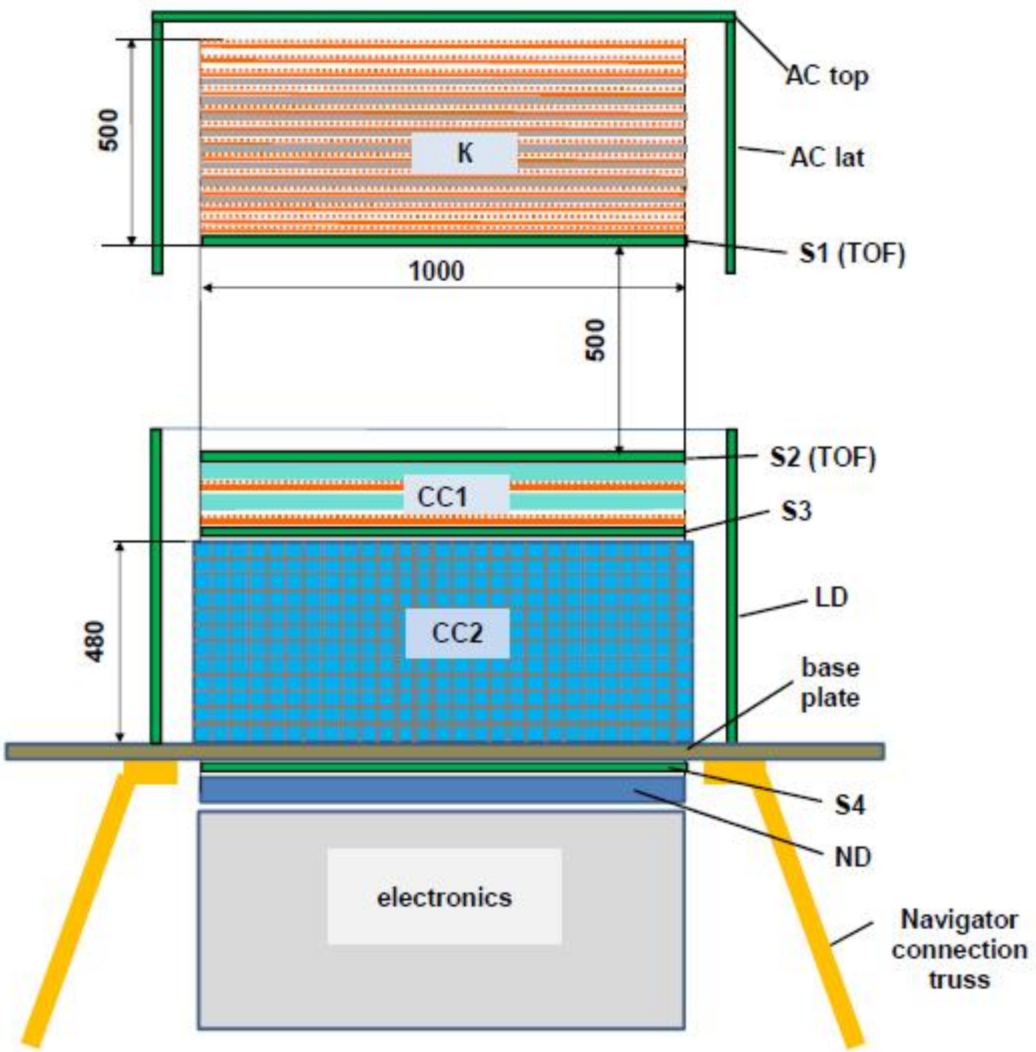
$0.01\ X_0$ - $0.01\ X_0$ - $0.1\ X_0$;
label '001';

$0.01\ X_0$ - $0.1\ X_0$ - $0.01\ X_0$;
label '010';



CFRP+Al honeycomb+Si ~ $0.013\ X_0$

Improvement of low energy angular resolution
Extension of energy range to 20 MeV

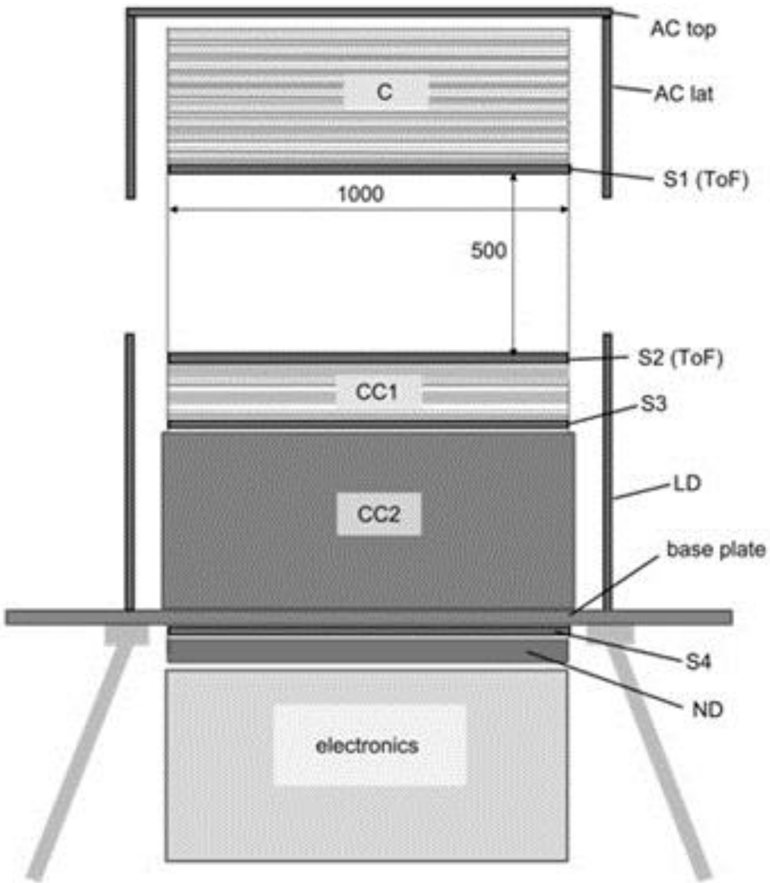


Separation of electrons and protons

The materials were accepted for publication in ASR

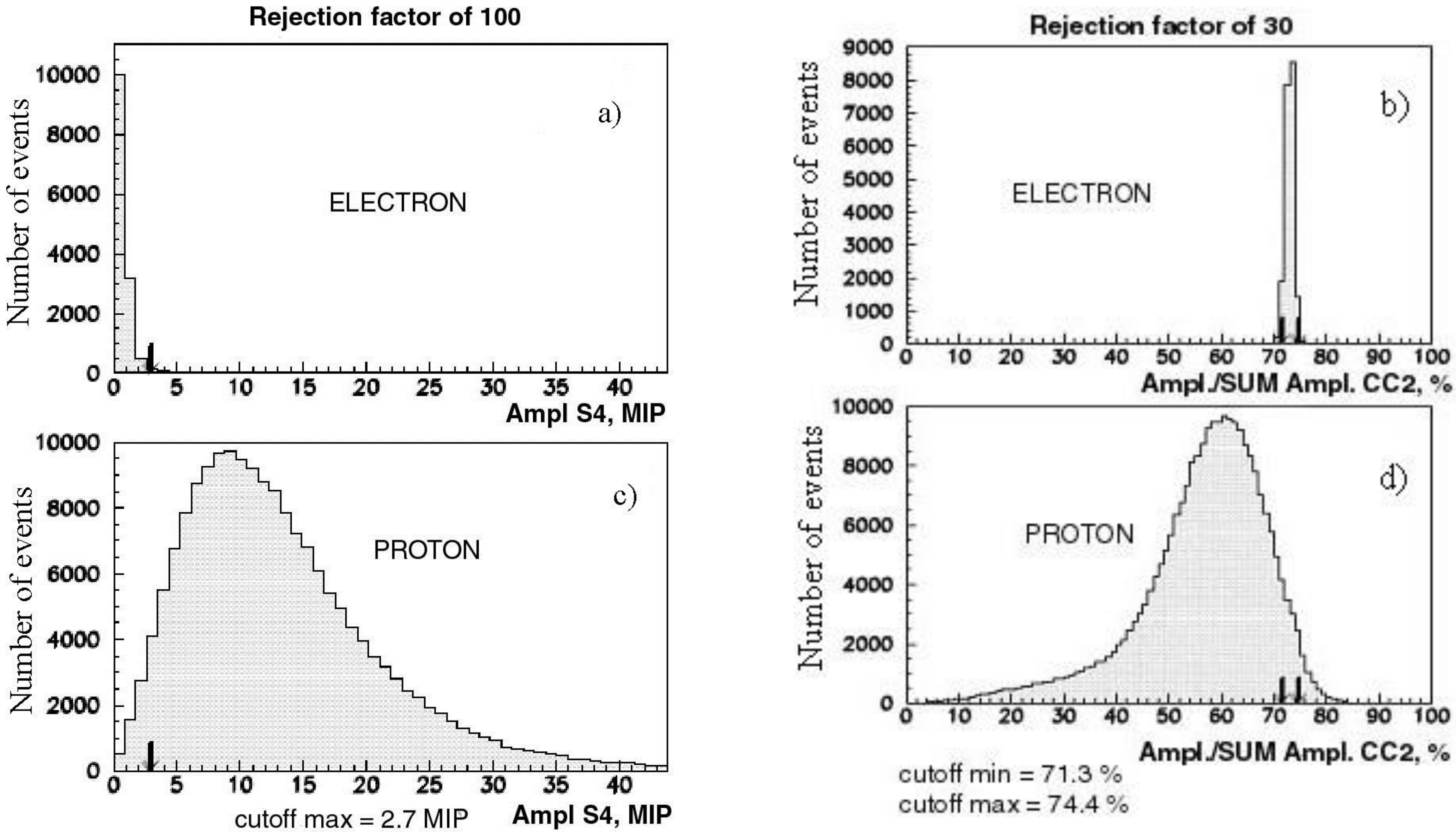
(Reference: JASR 12330, DOI: http://dx.doi.org/10.1016/j.asr.2015.06.040)

To reject protons from electrons, information from ND, S4, S3, S2, CC1, and CC2 is used.

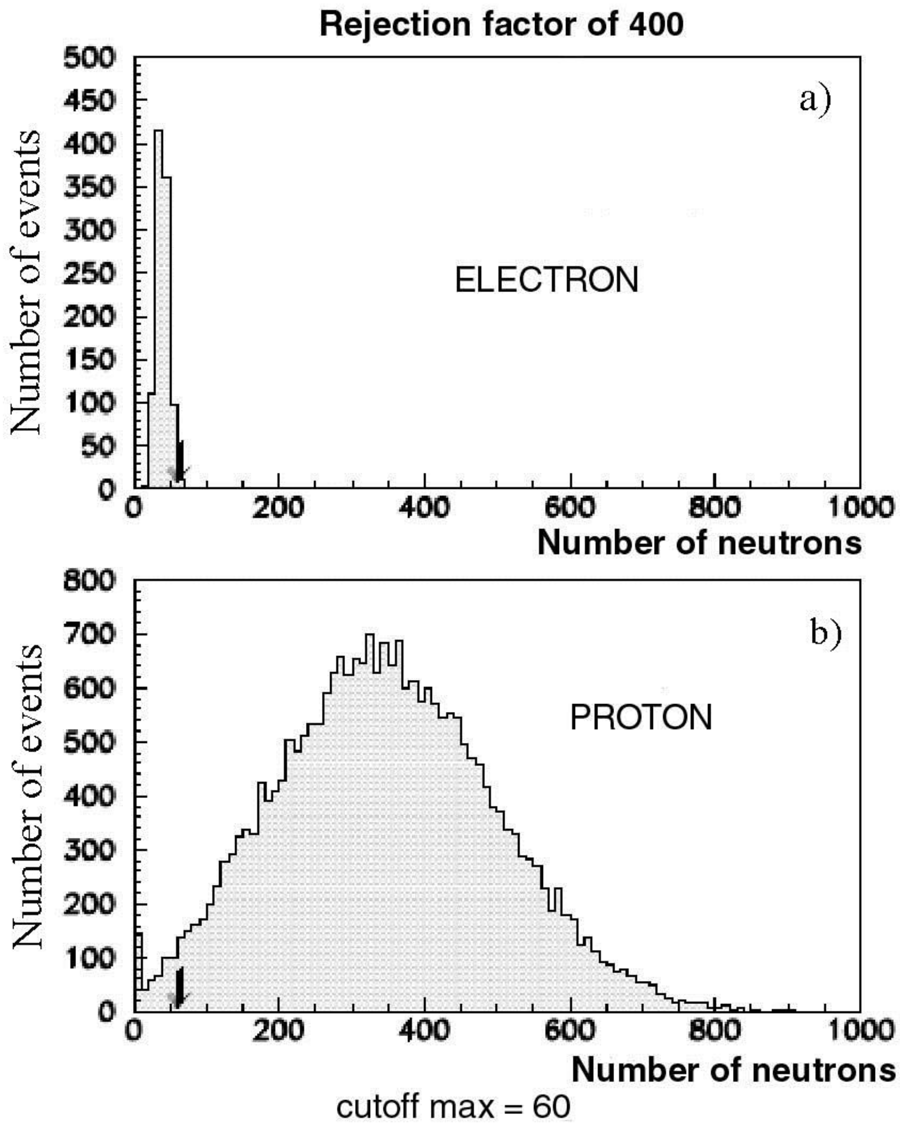


Every detector is considered as a “separate layer of a composite calorimeter”, and the ability of each layer to decrease the proton contamination in the different energy region is investigated individually.

The rejection factor at 100 GeV is calculated as the ratio of the number of initial protons with energy more than 100 GeV - assuming that the proton energy spectrum power-index is -2.7 - to the number of events identified as electrons with energy 100±2 GeV (taking into account that the GAMMA-400 energy resolution is equal to about 2%).



The cutoffs are determined in such a way to retain 98% of electrons.
In total, 25 cutoffs are used to reject protons.
Taking into account this selection, roughly 30% of electrons are also lost due to proton rejection.


Rejection factor of 400
a)
ELECTRON
Number of events
Number of neutrons
b)
PROTON
Number of events
Number of neutrons
cutoff max = 60

Intrinsic proton rejection factor for each detector taken individually, and the value of the decrease of the total rejection factor in case of elimination of a given detector from the analysis.

Detector, number of cutoffs	Intrinsic rejection factor	Decrease of the total rejection factor
S4 (2 cutoffs: 1 cutoff for each scintillation layer)	100	1.7
CC2 (2 cutoffs)	30	2.6
Strips in CC1 (4 cutoffs: 2 cutoffs for each X or Y silicon strip)	6	1.2
CsI(Tl) from CC1 (2 cutoffs: 1 cutoff for each layer of CsI(Tl) crystal)	3	1.3
S2, S3 (4 cutoffs: 2 cutoffs for each detector)	2	1.3
ND (1 cutoff)	400 (upper limit)	2

Total rejection factor to separate protons from electrons in energy range from 50 GeV to 1 TeV.

Energy, GeV	Total rejection factor
50	$(12.8\pm2)\times10^5$
100	$(4.0\pm0.4)\times10^5$
200	$(5.0\pm0.7)\times10^5$
1000	$(4.1\pm0.7)\times10^5$

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

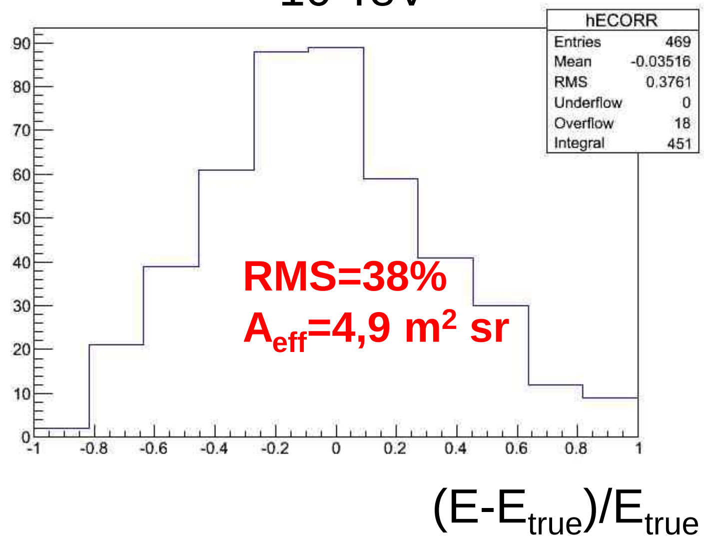
N×N×N cubes	28×28×12
L	3.6 cm
Size	$1\times1\times0.47$ m^3
X_0	54.6×54.6×23.4
λ_I	2.5×2.5×1.1
Mass	1683 kg

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

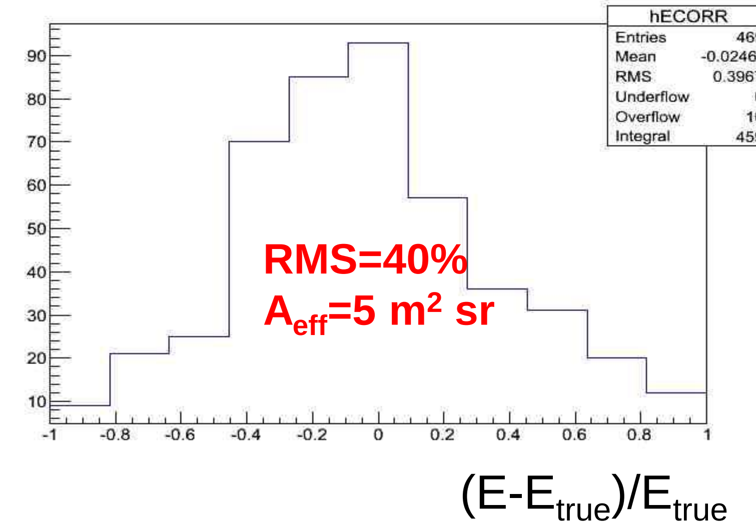
Expected number of proton and helium events in 10 years data taking, according to the Polygonato model

Calorimeter only proton energy resolution

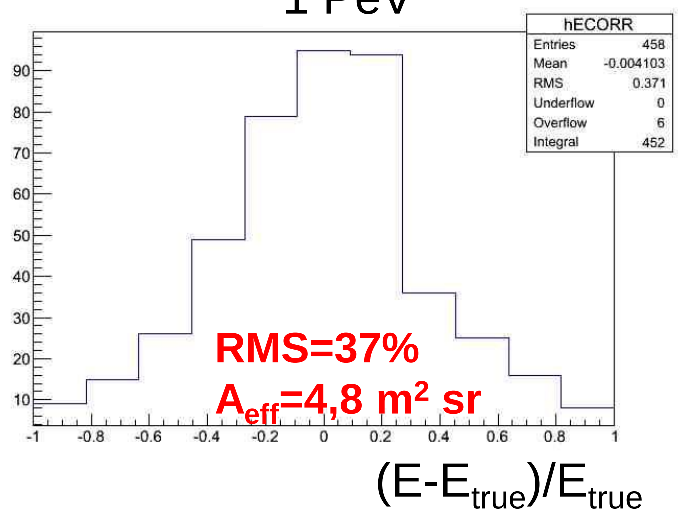
10 TeV



100 TeV

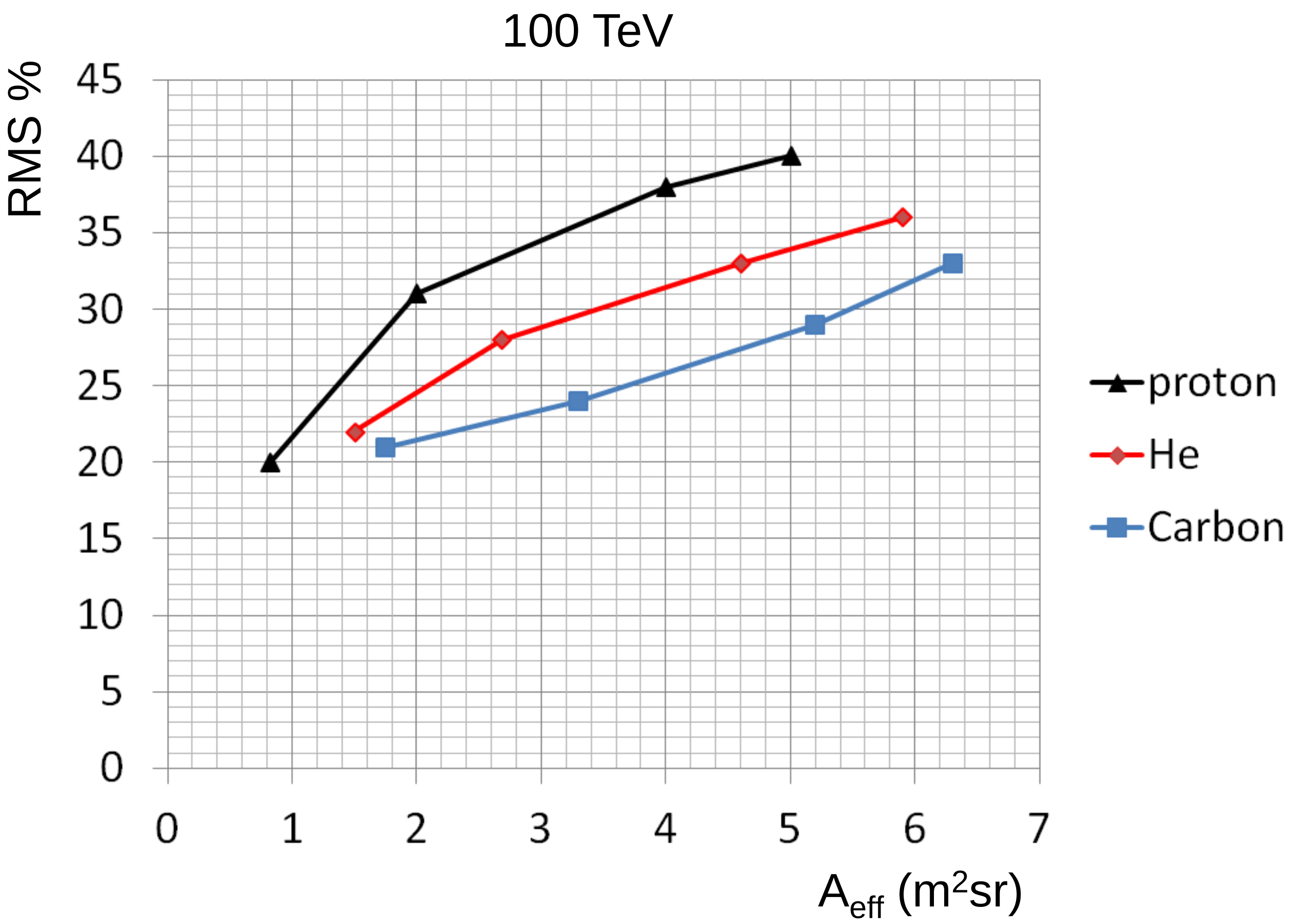


1 PeV



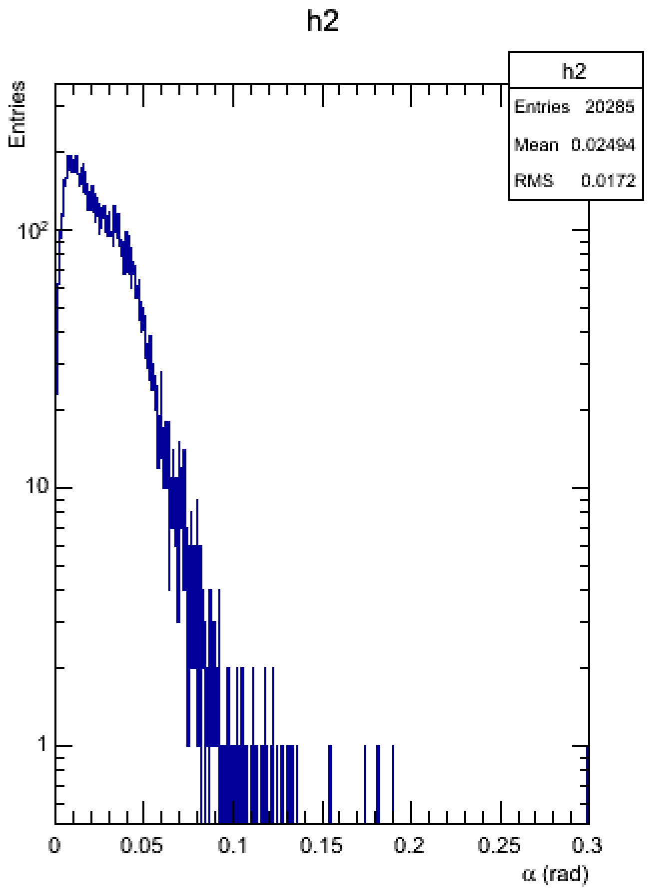
Resolutions and A_{eff} depend on cuts.
Optimizeation for large acceptance.

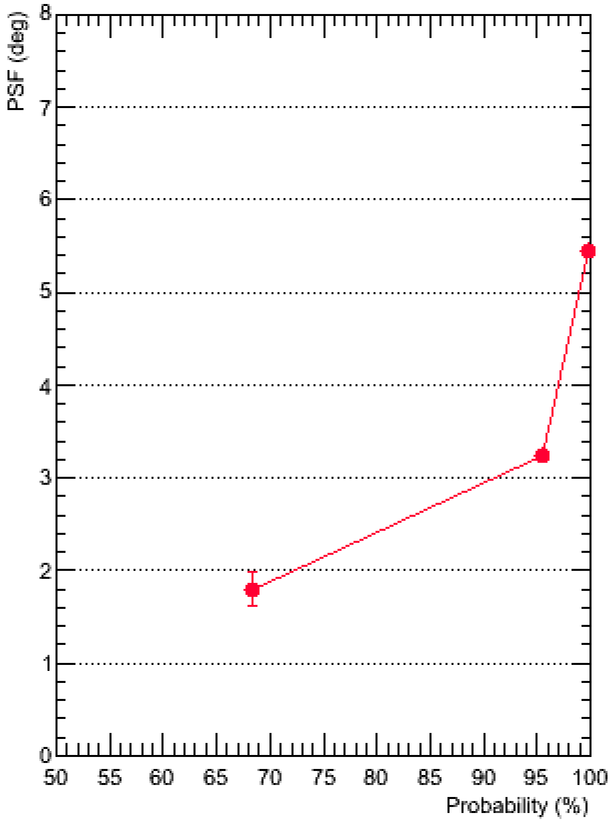
Nuclei energy resolution



Calorimeter only angular resolution (gamma 100 GeV)

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

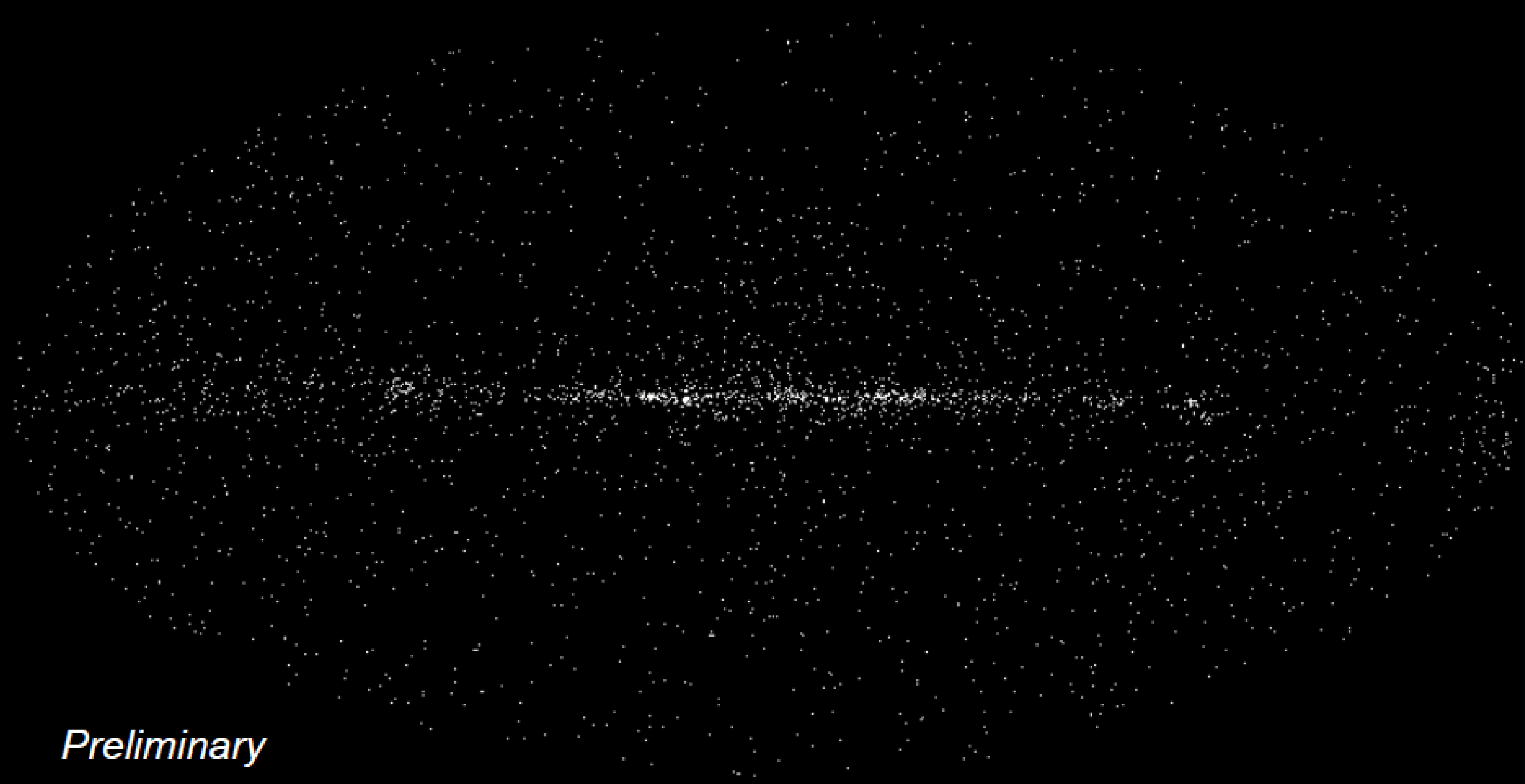




For HE (>1 TeV) protons and nuclei with 68% containment ~3^0 (Sergio Bottai, INFN, Florence)

the sky > 50 GeV

- 6 years of Pass8 data 50 GeV - 2 TeV
  ~ 51 000 γ at E > 50 GeV, ~ 18 000 γ at E > 100 GeV, ~ 2000 γ at E > 500 GeV
  => ~ 1 γ per square degree

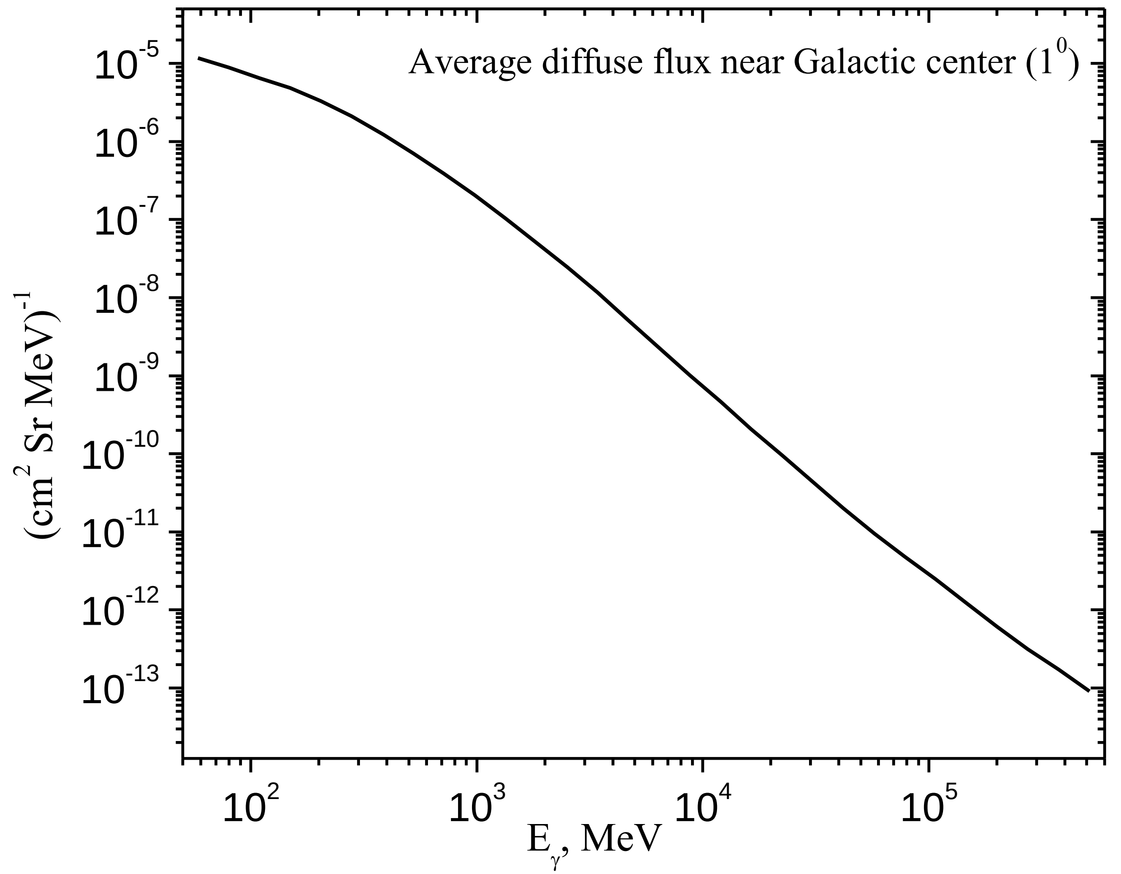


- reasonable angular resolution: 1 σ = 0.1°

Number of gamma from diffuse flux near Galactic center (1 deg. × 1 deg.) during 1 year of GAMMA-400 measurements.

Energy range, GeV	Number of gamma
10÷100	609
30÷100	103
50÷100	30
70÷100	16
100÷300	22

http://fermi.gsfc.nasa.gov/ssc/data/access/lat/BackgroundModels.html



1 year: Number of gamma from CRAB (1 FHL) neighborhood, 30 deg. × 30 deg.

	name(Y)	Long(Y)	LAT(Y)	gamma(Y)	F1030(Y)	N1030year(Y)	F30100(Y)	N30100year(Y)	F100500(Y)	N100500year(Y)
Long Name										
Units										
Comments										
Sparklines										
1	J0433.5+2905	170,5183	-12,6225	2,284	1,83197E-10	40	4,50988E-11	10	8,93355E-12	2
2	J0509.5+0542	195,4068	-19,5947	2,3122	3,36993E-10	74	1,32972E-10	29	1,32326E-11	3
3	J0515.9+1528	187,7041	-13,0348	2,0998	7,14822E-11	16	4,51862E-11	10	0	0
4	J0521.7+2113	183,6034	-8,6989	1,975	6,0817E-10	134	2,66758E-10	59	7,54143E-11	17
5	J0529.0+0937	194,5459	-13,4366	1,8668	5,87924E-11	13	2,46635E-11	5	7,35643E-12	2
6	J0534.5+2201	184,5515	-5,7856	2,3251	5,7145E-9	1261	1,35225E-9	299	3,83584E-10	85
7	J0601.0+3838	173,197	7,6461	1,3798	2,88338E-12	1	3,06052E-11	7	1,1627E-11	3
8	J0605.4+2726	183,4875	3,0152	1,9993	4,74008E-11	10	2,0574E-11	5	0	0
9	J0617.2+2234e	189,0481	3,0337	2,5587	2,57071E-9	567	4,71354E-10	104	1,17347E-10	26
10	J0622.9+3328	179,9088	9,1683	2,2901	2,87228E-10	63	6,45309E-11	14	0	0
11	J0633.9+1746	195,1354	4,2716	4,9967	2,69728E-9	595	3,74084E-11	8	0	0
12	J0648.9+1516	198,9922	6,3542	1,7296	1,51348E-10	33	3,81173E-11	8	2,63461E-11	6
13	J0650.4+2056	194,0331	9,1785	2,1553	7,01525E-11	15	0	0	1,27021E-11	3
14	--					--		--		--
15	СУММА					2826		558		145
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										
26										
27										
28										
29										
30										
31										
32										

1 year: Number of gamma from VELA (1 FHL) neighborhood, 30 deg. × 30 deg.

	name(Y)	Long(Y)	LAT(Y)	gamma(Y)	F1030(Y)	N1030year(Y)	F30100(Y)	N30100year(Y)	F100500(Y)	N100500year(Y)
Long Name										
Units										
Comments										
Sparklines										
1	J0718.7-4321	254,9564	-13,6576	2,4388	2,21977E-10	49	3,04927E-11	7	0	0
2	J0746.3-4757	261,3524	-11,3701	2,8377	1,30728E-10	29	0	0	1,10816E-11	2
3	J0822.6-4250e	260,3176	-3,2763	2,1399	2,93955E-10	65	1,15512E-10	25	1,5446E-11	3
4	J0833.1-4511e	263,3324	-3,106	2,7099	7,20484E-10	159	1,23507E-10	27	2,46924E-11	5
5	J0835.3-4510	263,5503	-2,7921	4,4792	9,63061E-9	2126	1,89385E-10	42	5,90132E-12	1
6	J0841.2-3556	256,8822	3,6885	2,3535	1,28532E-10	28	2,95141E-11	7	0	0
7	J0845.8-5553	273,1218	-7,9728	2,1417	5,33615E-11	12	1,48016E-11	3	1,08975E-11	2
8	J0852.7-4631e	266,4913	-1,233	1,7659	6,91791E-10	153	4,0703E-10	90	1,19312E-10	26
9	J0852.9-3656	259,1471	4,9197	1,9625	3,99433E-11	9	3,52297E-11	8	0	0
10	J0928.1-5252	275,0193	-1,3858	2,1631	1,0891E-10	24	3,24261E-11	7	0	0
11	J1023.9-4337	276,6036	11,5849	2,3918	1,31876E-10	29	7,37344E-11	16	0	0
12	--					--		--		--
13	СУММА					2683		232		41
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
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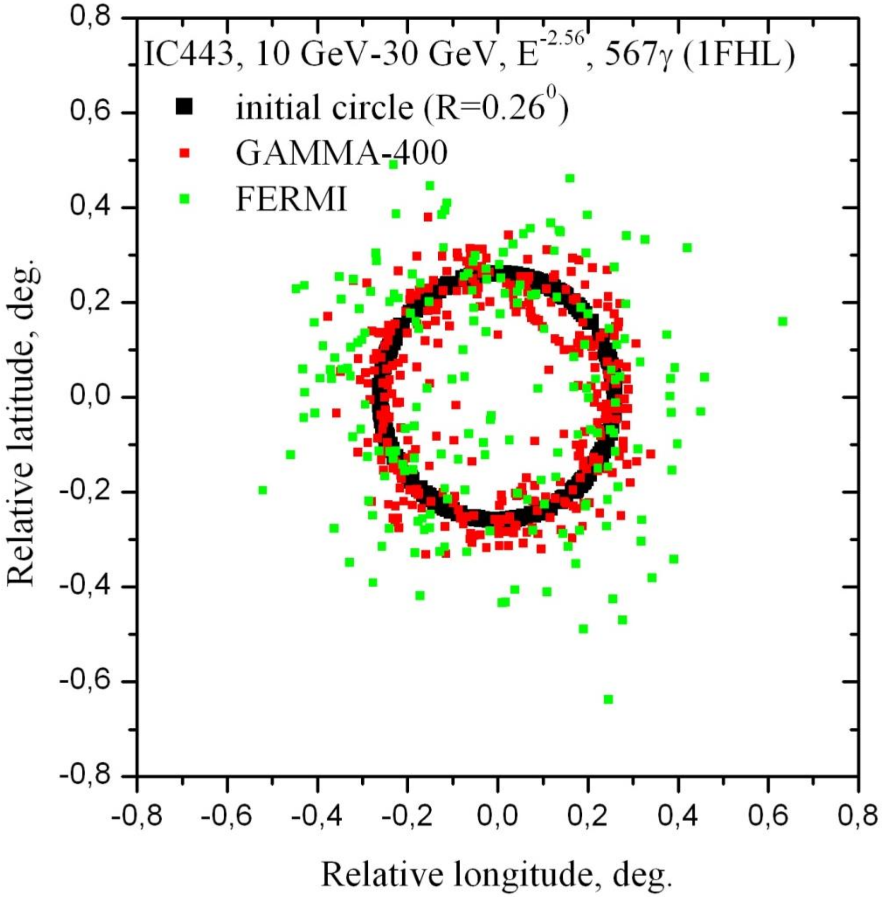
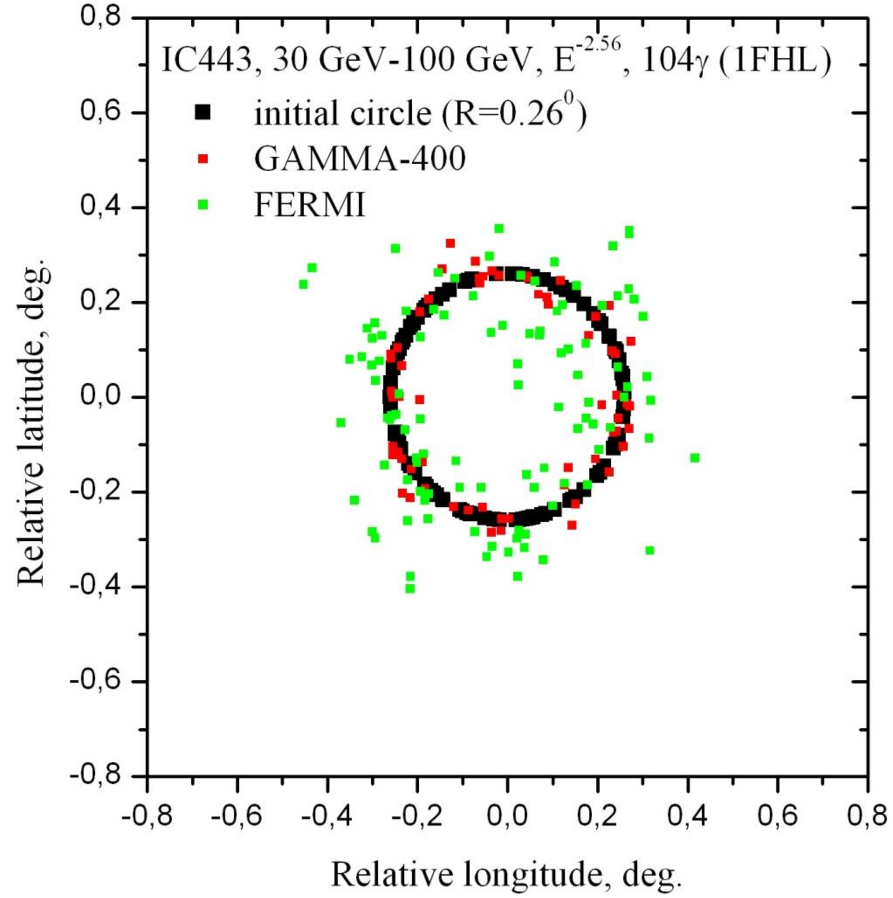
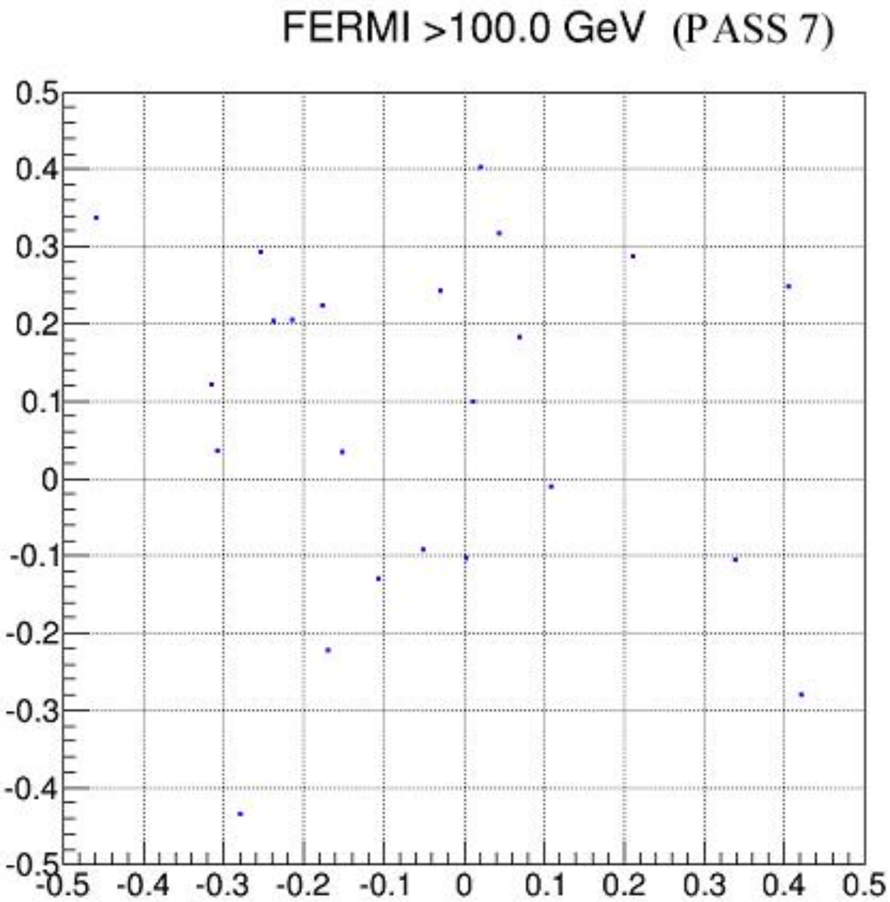
25										
26										
27										
28										
29										
30										
31										

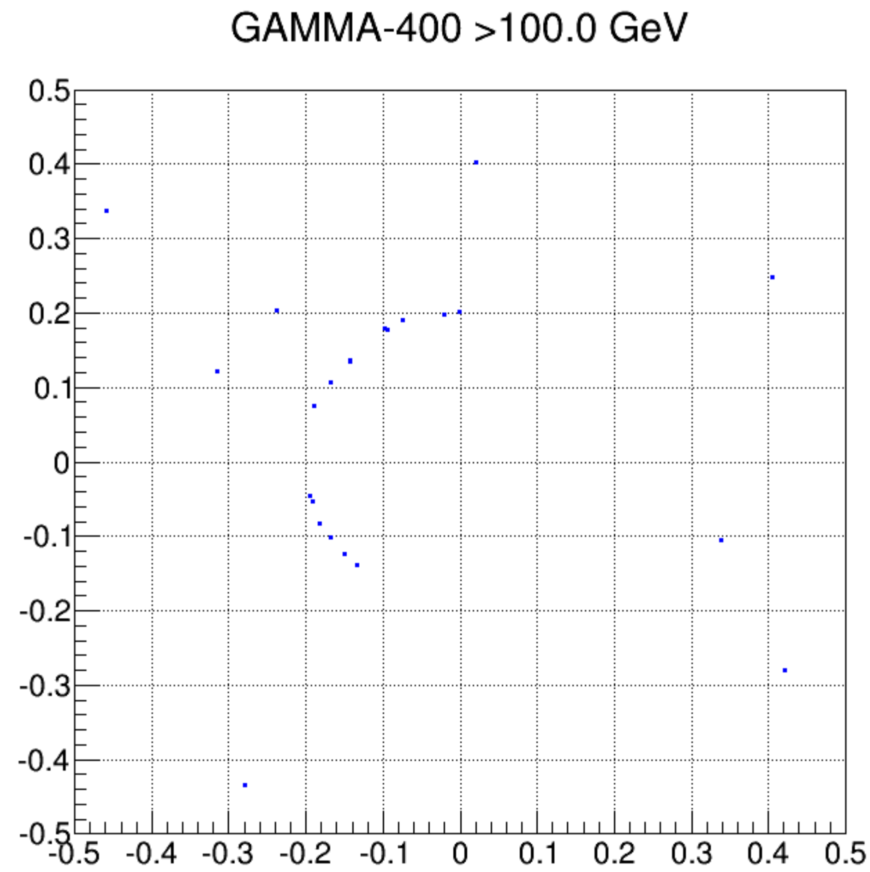
Initial circle distribution for supernova remnant IC 433 statistic



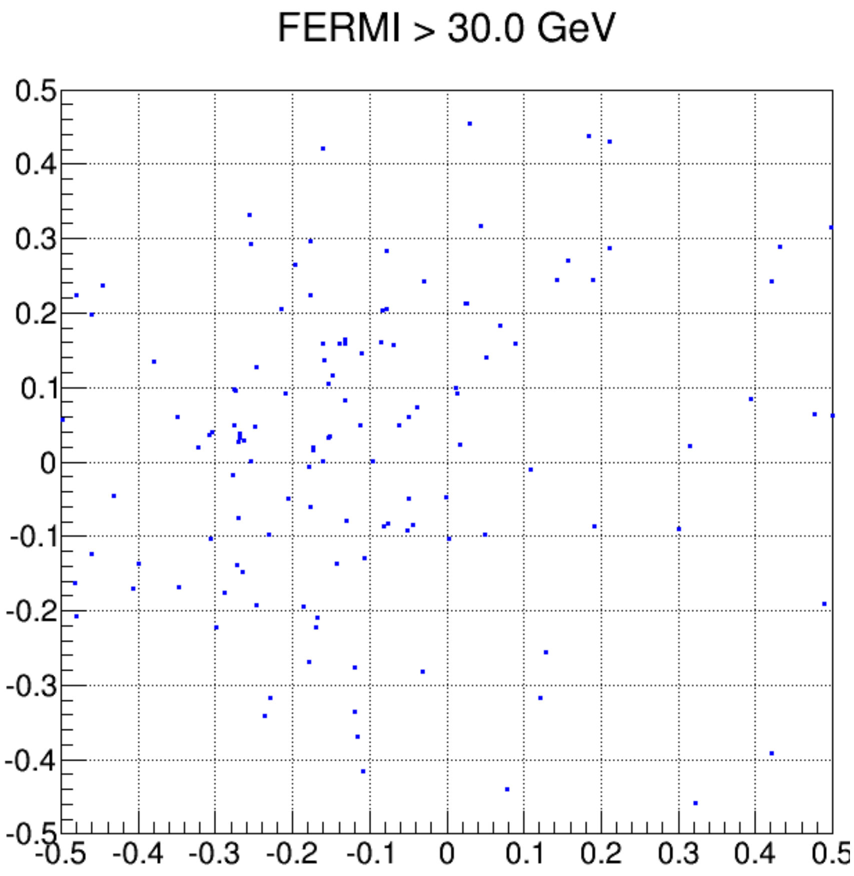


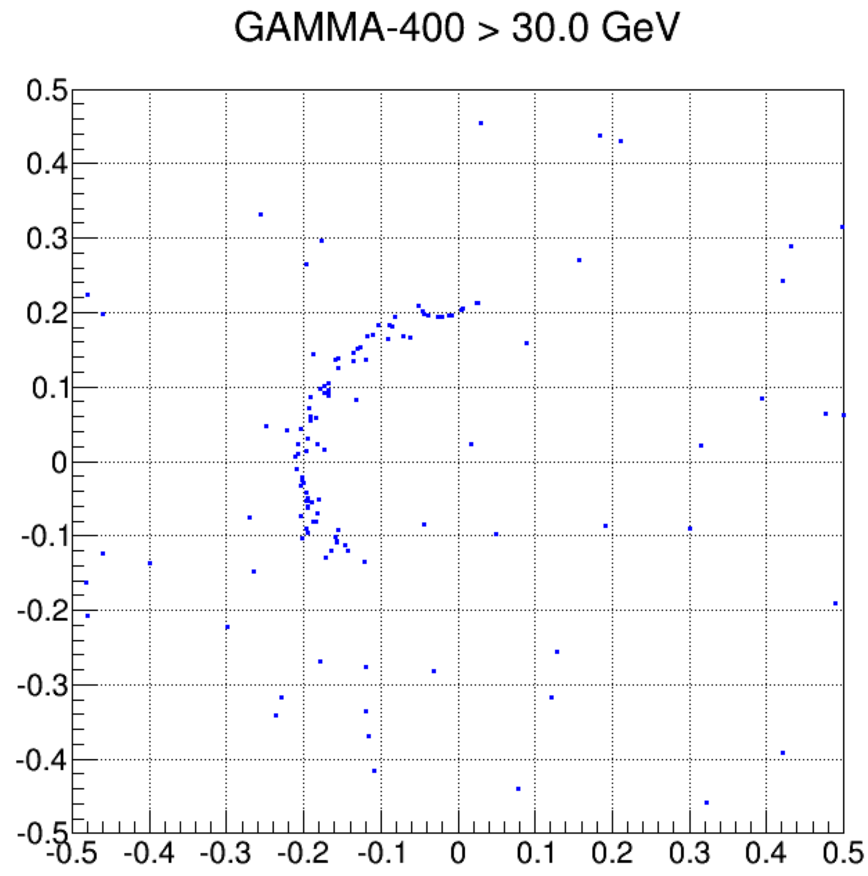
Initial arc distribution



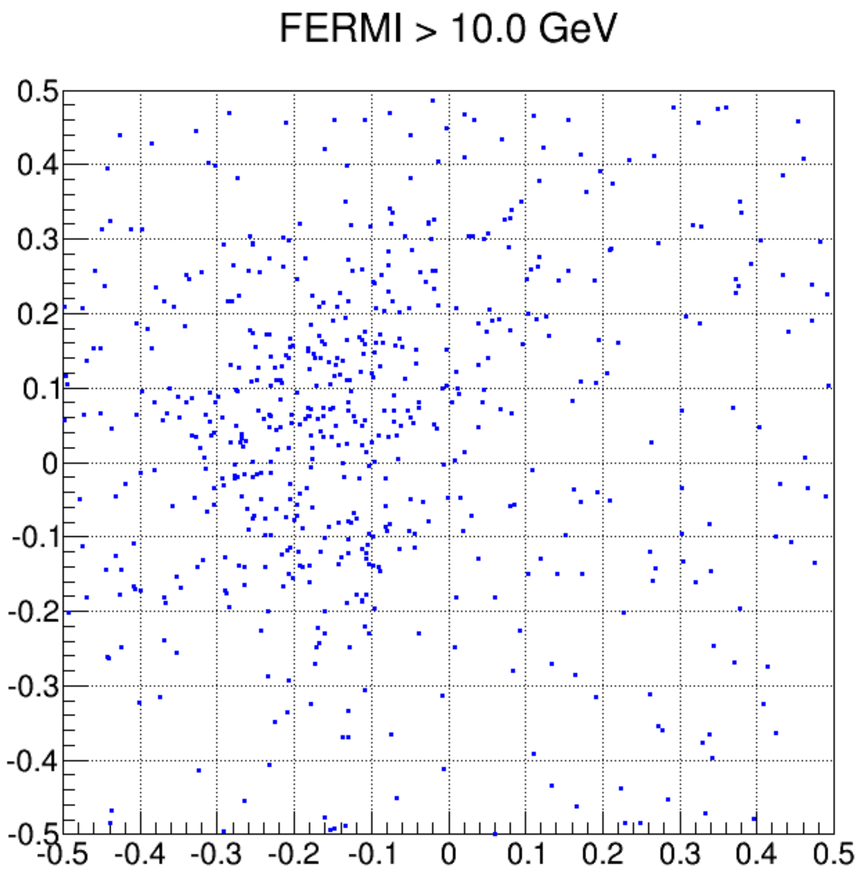


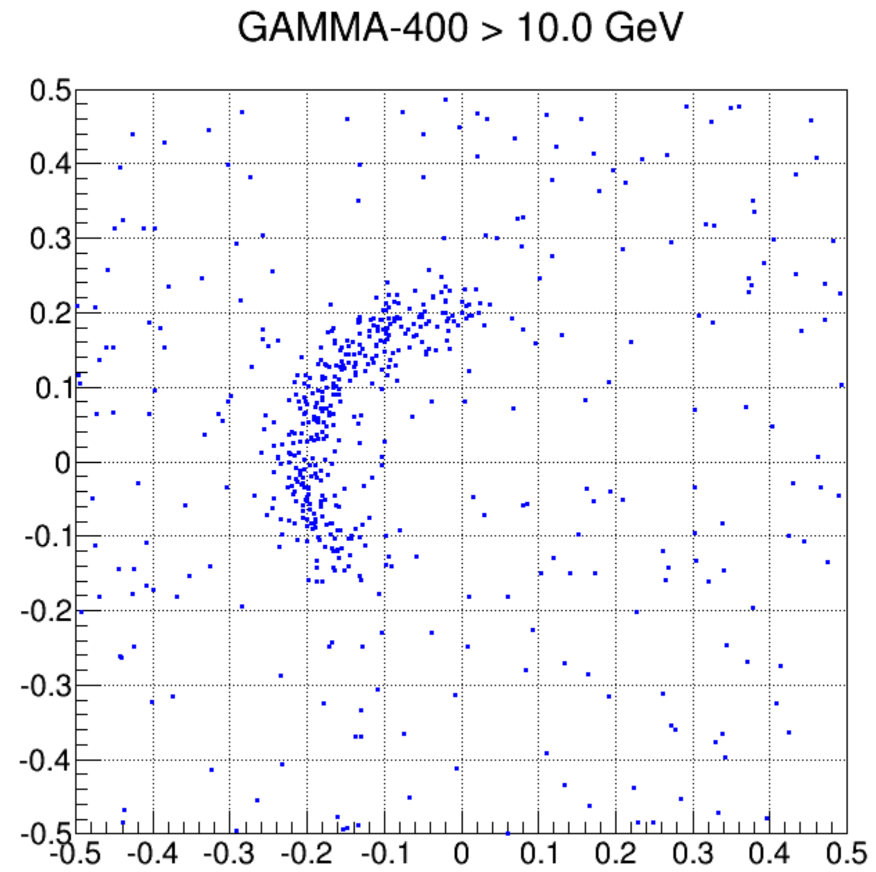
Initial arc distribution



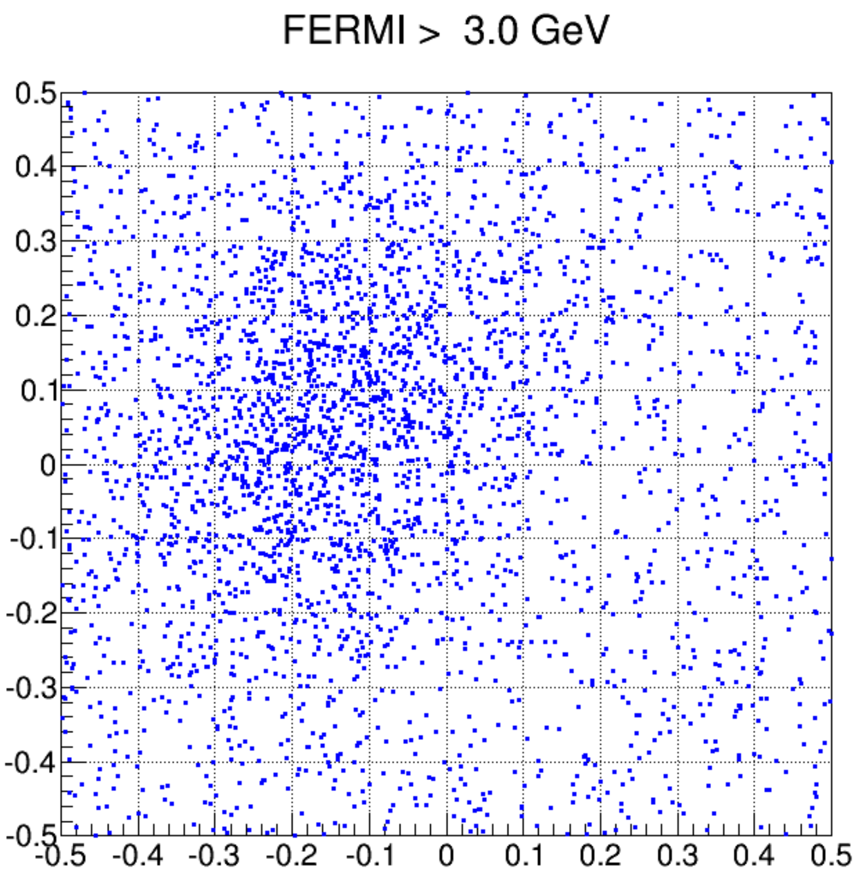


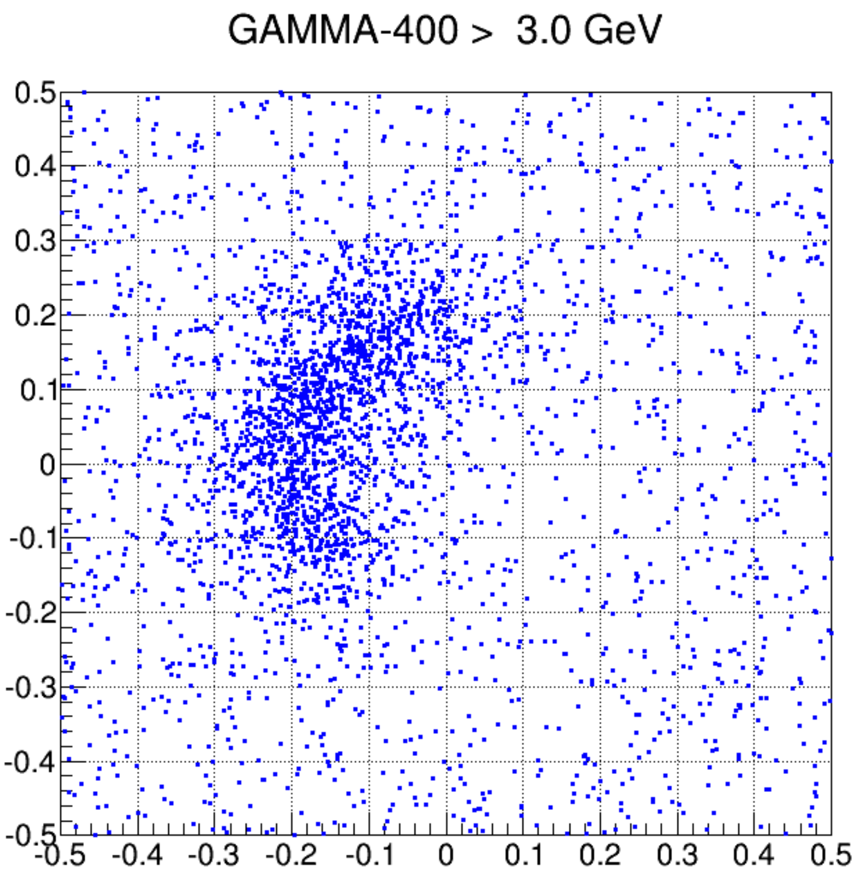
Initial arc distribution





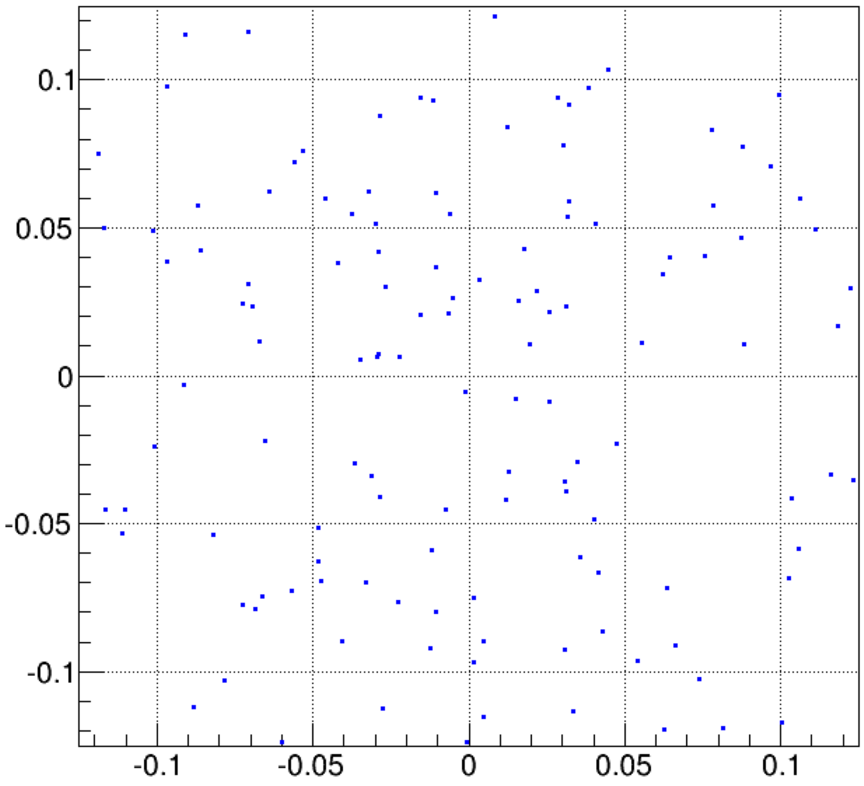
Initial arc distribution



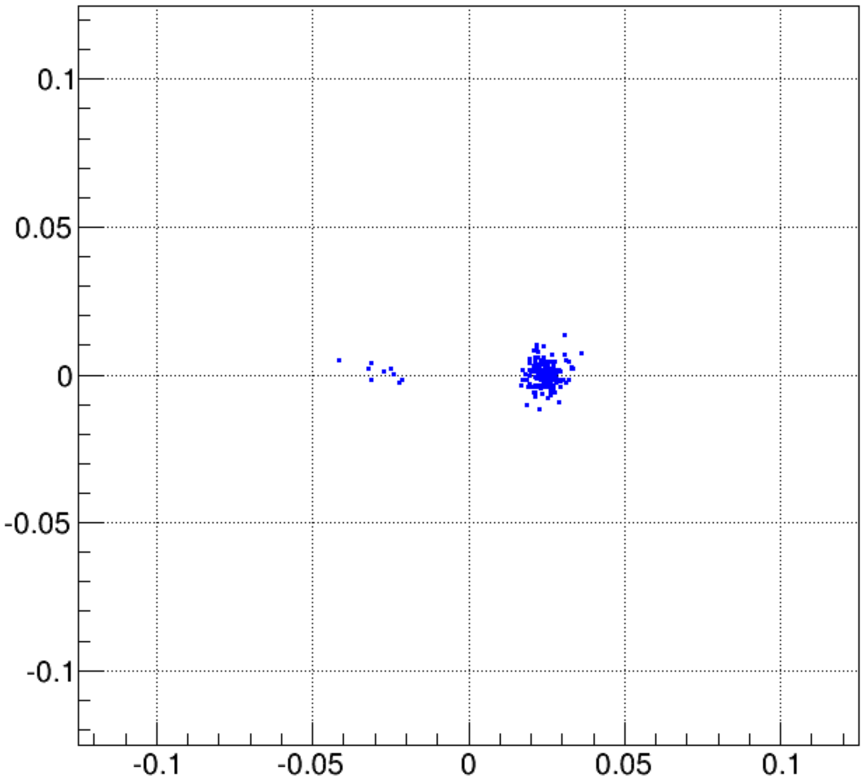


2 point sources (distance 0.05^0) to distinguish

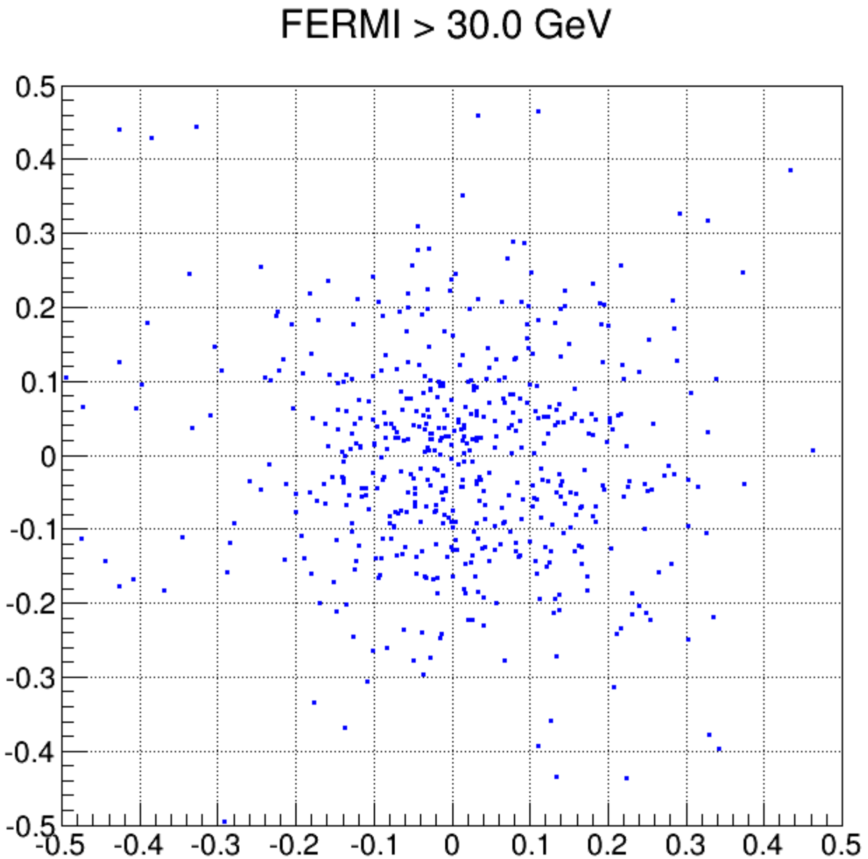
FERMI >100.0 GeV

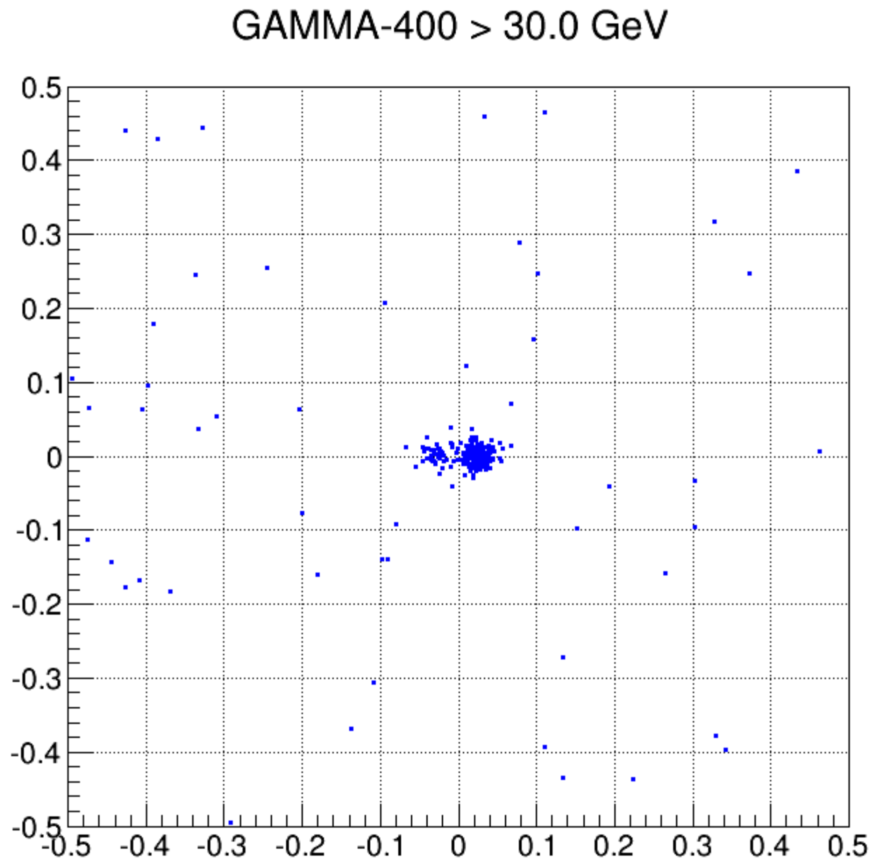


GAMMA-400 >100.0 GeV



2 point sources (distance 0.05^0) to distinguish





Conclusion

Werner Hofmann (CTA Spokesperson, private communications):
One of our worries in terms of maximising the science output of CTA is the coverage of the GeV domain - that is crucial for interpretation of sources - after the termination of Fermi. Obviously, GAMMA-400 is very well suited to fill that gap, and joint observations or joint projects seem very natural

- Scientifically, a precise, long duration experiment in space as GAMMA-400 will provide fundamental information with gamma rays and will allow to extend the range of direct measurements of cosmic rays beyond the TeV range

- The GAMMA-400 space observatory is scheduled to launch in about 2023-2025

Thanks for your attention

Spare slides

Nuclei count estimation

~knee

Experiment	Duration	GF (m^2 sr)	Calo $\sigma(E)/E$	Calo depth	ε sel	E>0.1 PeV		E>0.5 PeV		E>1 PeV		E>2 PeV		E> 4 PeV	
						^{3}Li to ^{9}F	^{10}Ne to ^{24}Cr	^{3}Li to ^{9}F	^{10}Ne to ^{24}Cr	^{3}Li to ^{9}F	^{10}Ne to ^{24}Cr	^{3}Li to ^{9}F	^{10}Ne to ^{24}Cr	^{3}Li to ^{9}F	^{10}Ne to ^{24}Cr
CALET	5 y	0.12	~30%	30 X_0 1.3 λ_0	0.8	136	140	9	10	3	3	1	1	0	0
CREAM	10 y	0.46	~45%	20 X_0 1.2 λ_0	0.8	51	53	4	4	1	1	0	0	0	0
ATIC	30 d	0.25	~37%	18 X_0 1.6 λ_0	0.8	5	5	0	0	0	0	0	0	0	0
TRACER	30 d	5	-	TRD	0.8	93	96	6	7	2	2	1	1	0	0
G400	10 y	3.9	~40%	25.4 X_0 1.2 λ_0	0.8	8830	9073	612	636	193	206	58	69	17	20

p and He count estimation

~knee

Experiment	Duration	GF (m^2 sr)	Calo $\sigma(E)/E$	Calo depth	ε sel	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
CALET	5 y	0.12	~40%	30 X_0 1.3 λ_0	0.8	292	276	17	19	5	6	1	2	0	0
CREAM	180 d	0.43	~45%	20 X_0 1.2 λ_0	0.8	103	97	6	7	2	2	0	1	0	0
ATIC	30 d	0.25	~37%	18 X_0 1.6 λ_0	0.8	10	9	1	1	0	0	0	0	0	0
G400	10 y	3.9	~40%	25.4 X_0 1.2 λ_0	0.8	18951	17921	1123	1242	300	374	69	106	11	24

Flux sensitivity.

Significance to identify point source in the presence of permanent background:

$$\sigma = \frac{N_{SOURCE}}{\sqrt{N_{SOURCE} + N_{BG}}}$$

N_{SOURCE} - gamma from point source during time T in energy range E_1, E_2;

N_{BG} - gamma from permanent background during time T in energy range E_1, E_2;

Source spectrum $J_{SOURCE}(E)\frac{1}{cm^2 \times sec \times MeV} \sim E^{-2}$

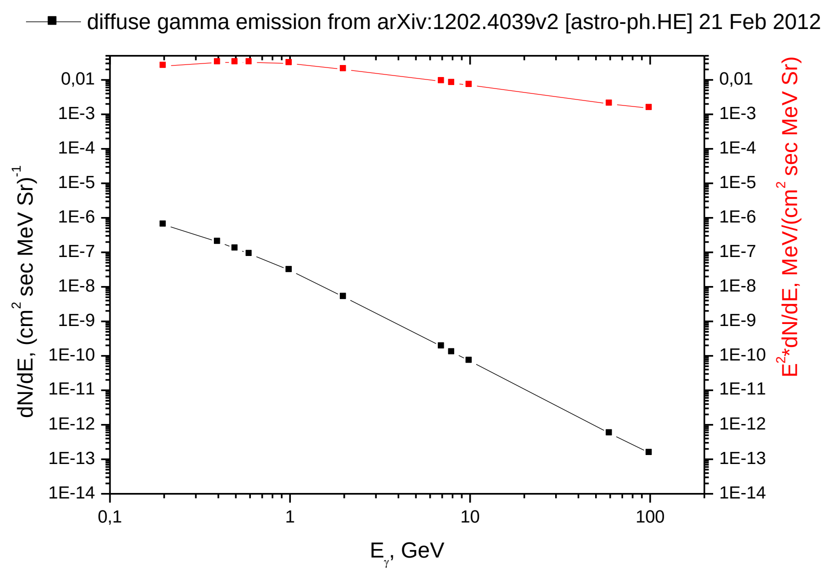
$$N_{SOURCE} = 0.68 \times \int_T \int_{E_1}^{E_2} A_{eff}(E) \times C_{MIN}(E_1, E_2) \times E^{-2}\, dE\, dt$$

$$\approx 0.68 \times T \times A_{eff} \times C_{MIN}(E_1, E_2) \times \left(\frac{1}{E_1} - \frac{1}{E_2}\right) = a \times C_{MIN}$$

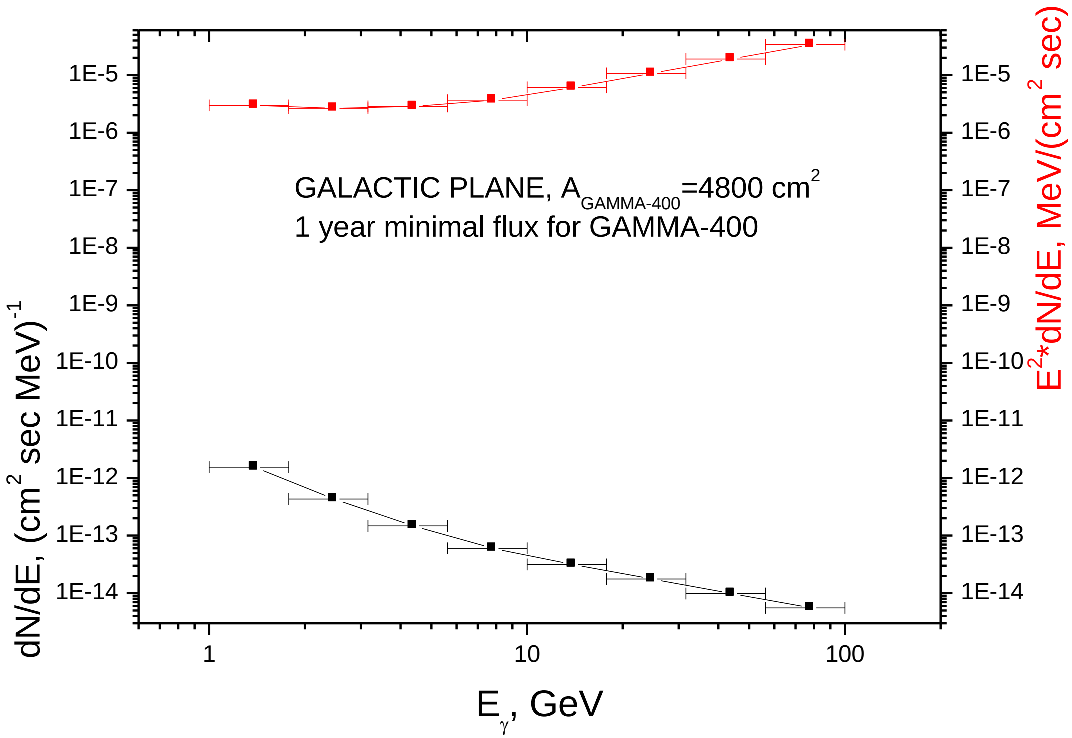
$$N_{BG} = \int_T \int_{E_1}^{E_2} J_{BG}(E) \times A_{eff}(E) \times \left(\int_{\Omega_{PSF}(E)} sin\theta cos\theta d\theta d\varphi \right) dE\, dt$$

$$\approx \pi T A_{eff} \times \int_{E_1}^{E_2} J_{BG}(E) \times \left(1 - cos^2\theta_{PSF}(E)\right) dE = b$$

$$\sigma = \frac{a \times C_{MIN}(E_1, E_2)}{\sqrt{a \times C_{MIN} + b}}$$

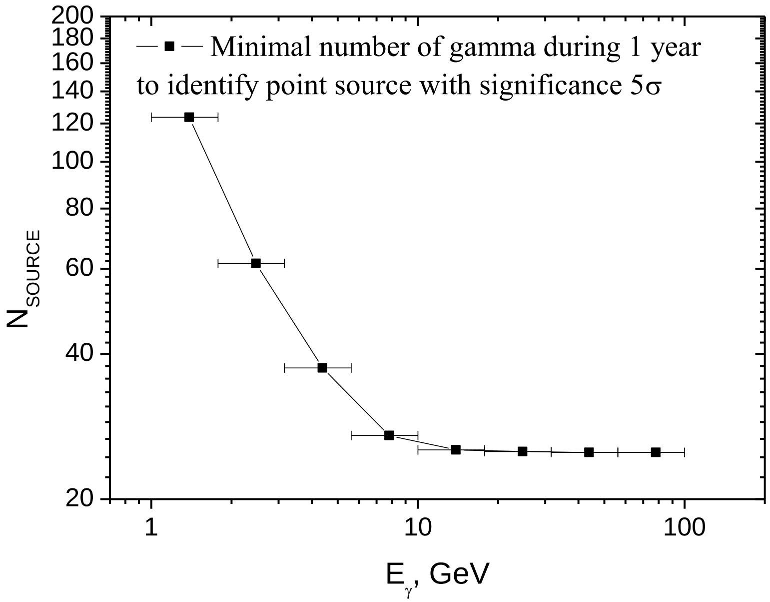


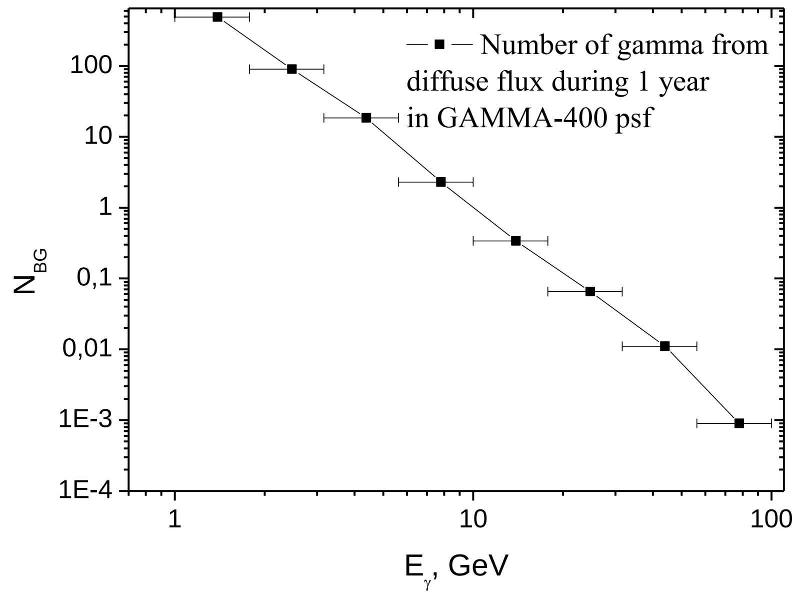
$$\langle J_{MIN}(E_1,E_2)\rangle = \frac{1}{E_2 - E_1} \times \int_{E_1}^{E_2} C_{MIN}(E_1,E_2) \times E^{-2}\, dE = \frac{1}{E_2 - E_1} \times C_{MIN}(E_1,E_2) \times \left(\frac{1}{E_1} - \frac{1}{E_2}\right)$$

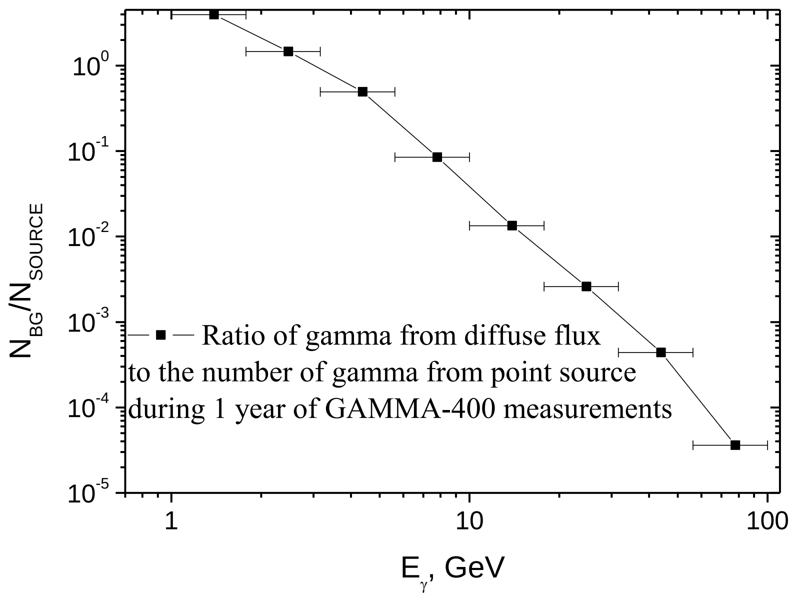


FERMI Point Source Sensitivity: $< 6 \times 10^{-9}$ cm^{-2} s^{-1}

http://fermi.gsfc.nasa.gov/science/instruments/table1-1.html


Minimal number of gamma during 1 year
to identify point source with significance 5σ
N_SOURCE
E_γ, GeV


Number of gamma from
diffuse flux during 1 year
in GAMMA-400 psf
N_BG
E_γ, GeV


Ratio of gamma from diffuse flux
to the number of gamma from point source
during 1 year of GAMMA-400 measurements
N_BG/N_SOURCE
E_γ, GeV

Thickness of GAMMA-400 instrument layers

Standard output of the simulation code

Material	thickness [cm]	thickness [g/cm2]	thickness [xo]	density [g/cm3]	xo [cm]
topAC					
psty	2.000000	2.120000	0.048416	1.060000	41.308608
Al	3.000000	0.144000	0.005997	0.048000	500.232534
CFRP	0.160000	0.233600	0.005091	1.460000	31.430273
T O T A L	5.160000	2.497600	0.059504		
C					
Si	0.600000	1.399800	0.064143	2.333000	9.354073
W	0.281060	5.410407	0.800000	19.250000	0.351325
Al	31.240000	0.499840	0.020817	0.016000	1500.697602
CFRP	1.760000	2.569600	0.055997	1.460000	31.430273
T O T A L	33.881060	9.879647	0.940957		
S1					
psty	2.000000	2.120000	0.048416	1.060000	41.308608
Al	3.000000	0.048000	0.001999	0.016000	1500.697602
CFRP	0.160000	0.233600	0.005091	1.460000	31.430273
T O T A L	5.160000	2.401600	0.055506		
S2					
psty	2.000000	2.120000	0.048416	1.060000	41.308608
Al	3.000000	0.048000	0.001999	0.016000	1500.697602
CFRP	0.160000	0.233600	0.005091	1.460000	31.430273
T O T A L	5.160000	2.401600	0.055506		
CC1					
Si	0.120000	0.279960	0.012829	2.333000	9.354073
	3.744110	16.960818	2.000000	4.530000	1.872055
Al	11.080000	0.350080	0.014580	0.016000	1500.697602
CFRP	1.200000	1.752000	0.038180	1.460000	31.430273
T O T A L	16.144110	19.342858	2.065588		
S3					
psty	2.000000	2.120000	0.048416	1.060000	41.308608
Al	2.840000	0.045440	0.001892	0.016000	1500.697602
CFRP	0.160000	0.233600	0.005091	1.460000	31.430273
T O T A L	5.000000	2.399040	0.055399		
CC2					
CsI(Tl) each	43.000000	194.790000	22.969411	4.530000	1.872055
T O T A L	43.000000	194.790000	22.969411		
T O T A L	113.505170	233.712345	26.201871		