Capabilities of GAMMA-400 telescope for observation of electrons and positrons in TeV energy range.

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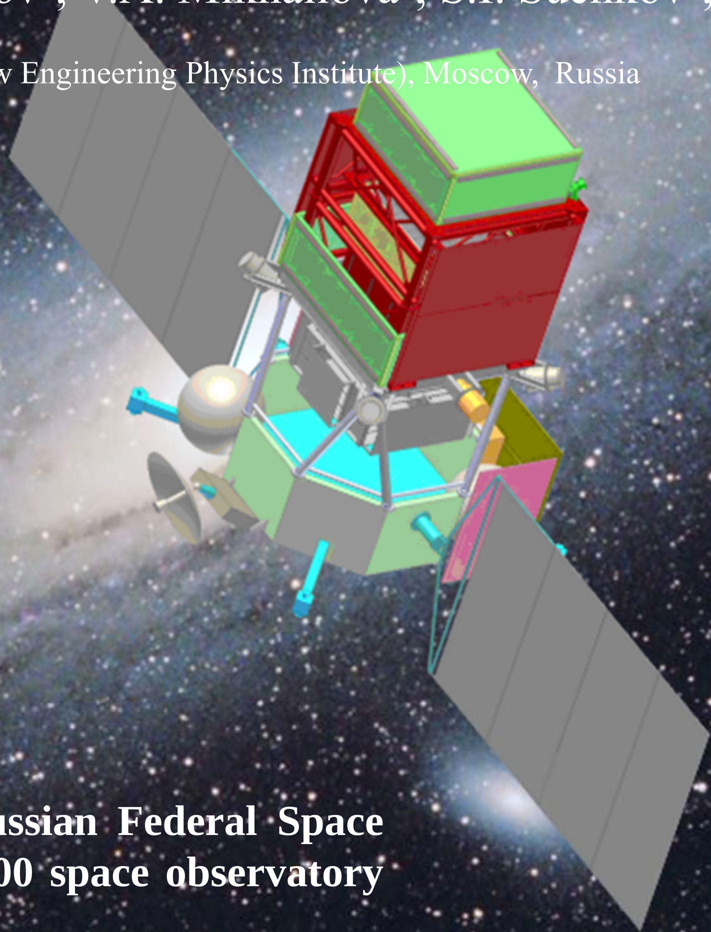


According to the new approved Russian Federal Space Program 2016-2025 the GAMMA-400 space observatory is scheduled to launch in 2025-2026.

ISCRA, MEPHI, Moscow, 28 June, 2019

GAMMA-400: **G**amma **A**stronomical **M**ultifunctional **M**odular **A**pparatus

GAMMA-400 main scientific goals

-Searching for gamma-ray lines for the energy range of 20 MeV - several TeV in the discrete source, diffuse, and isotropic gamma-ray emission when annihilating or decaying dark matter particles;

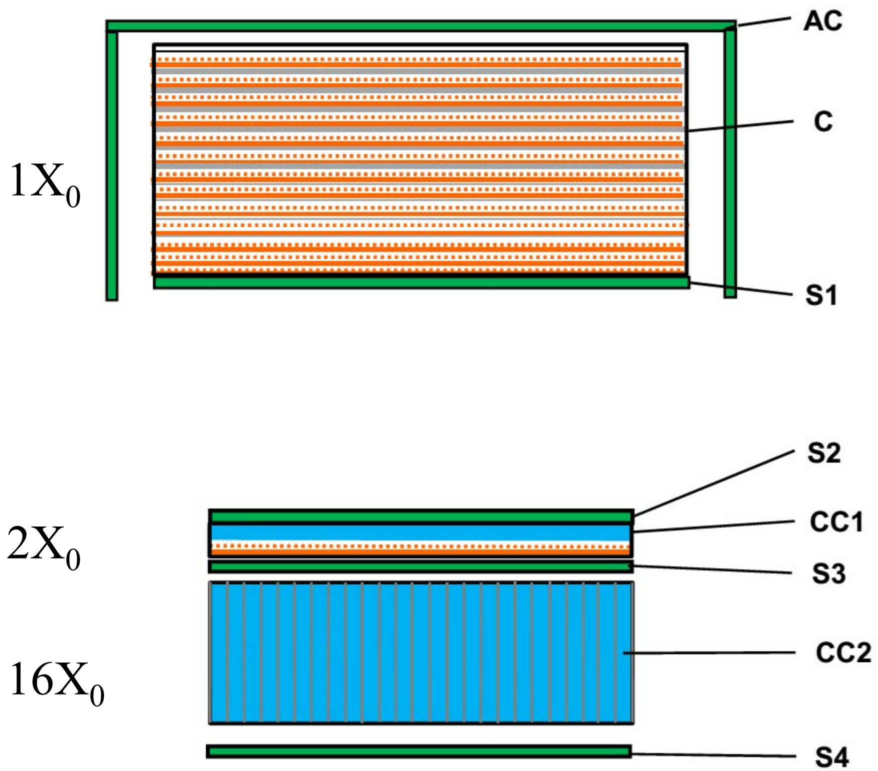
-Searching for new and study of known Galactic and extragalactic discrete high-energy gamma-ray sources: supernova remnants, pulsars, accreting objects, microquasars, active galactic nuclei, blazars, quasars;

- Studying the structure of extended sources with high angular resolution and measuring their energy spectra and luminosity with high energy resolution;

-Identifying discrete gamma-ray sources with known sources in other energy ranges;

-High-precision measurements of the high-energy electrons and positrons spectra

GAMMA-400 physical scheme



AC – Anticoincidence System
C - Fiber converter- tracker $1X_0$ of W
S1,S2 – ToF scintillator counters
S3,S4– Shower scintillator counters

CC1-CC2 are two parts of CsI calorimeter
22×22 vertical bars $2X_0+16X_0$

The energy range:
from ~ 20 MeV - till almost ~ 10 TeV

Main trigger: $M = \overline{AC} \times ToF$

$$ToF = S_1 \times S_2 \times (time_{S_1} < time_{S_2})$$

High energy γ and charged particle trigger:

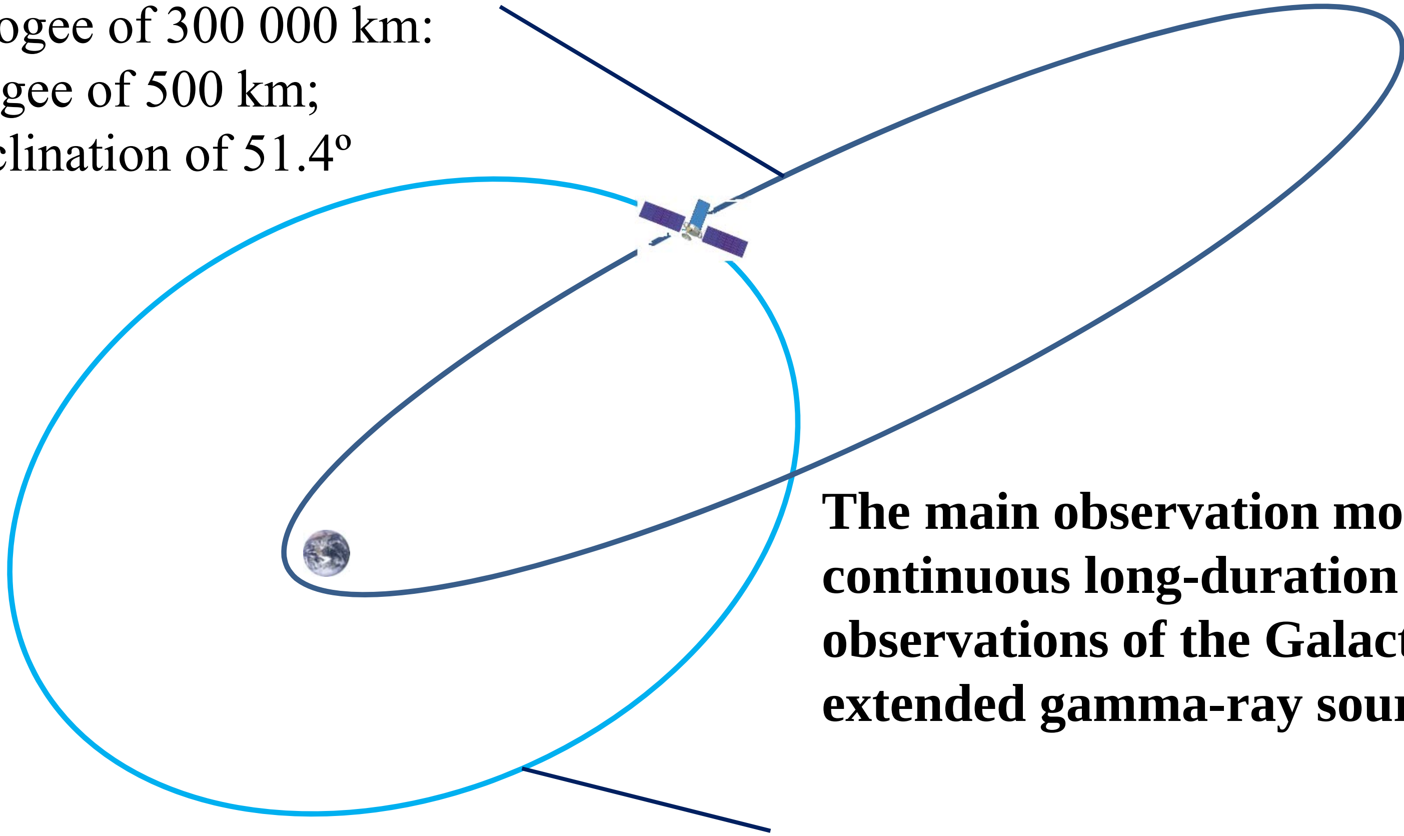
$$H = S1 \times S2 \times S3$$

The GAMMA-400 orbit evolution and observation modes

The orbit of the GAMMA-400 space observatory will have the following initial parameters:
- an apogee of 300 000 km:
- a perigee of 500 km;
- an inclination of 51.4º

Time of operation will be 7-10 years

Downlink rate   up to 100 GB per day

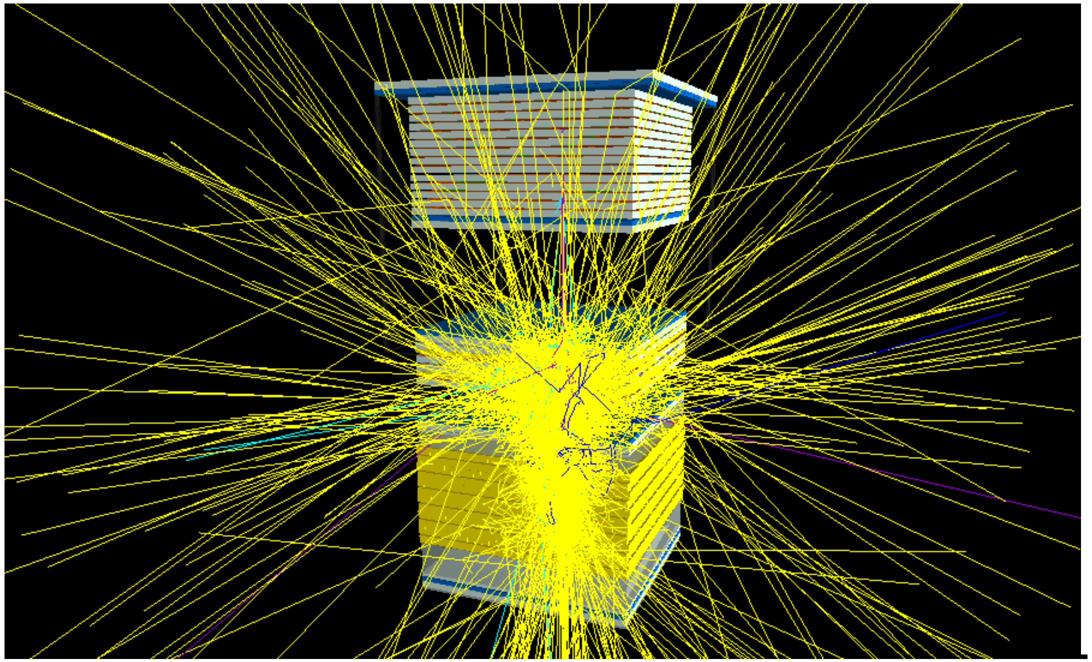


The main observation mode will be continuous long-duration (~100 days) observations of the Galactic Center, extended gamma-ray sources, etc.

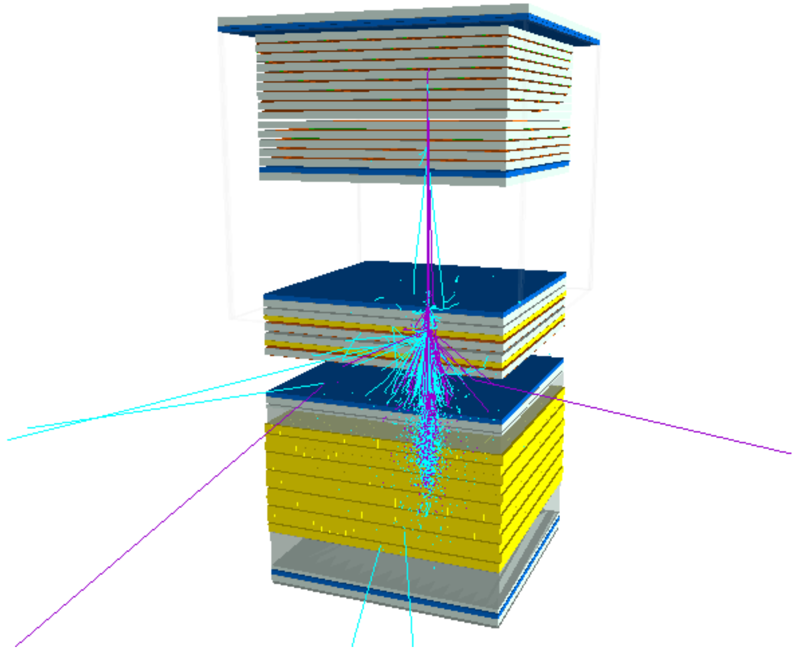
Under the action of gravitational disturbances of the Sun, Moon, and the Earth after ~6 months the orbit will transform to about circular with a radius of ~200 000 km and will be without the Earth's occultation and out of radiation belts.

Simulation environment: GEANT4 (4.10.01p02)

100 GeV gamma



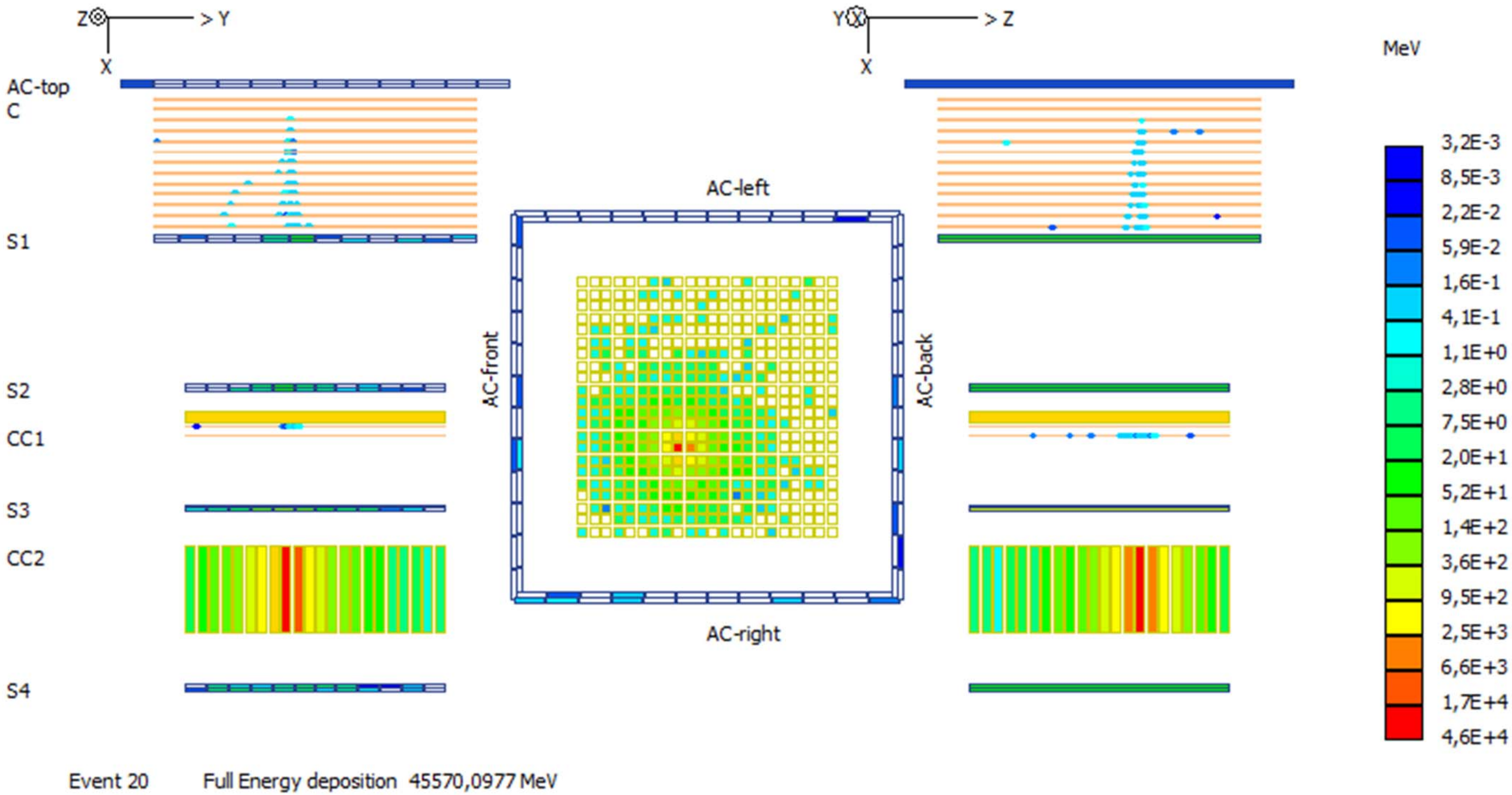
with secondary gamma visualization



no secondary gamma visualization

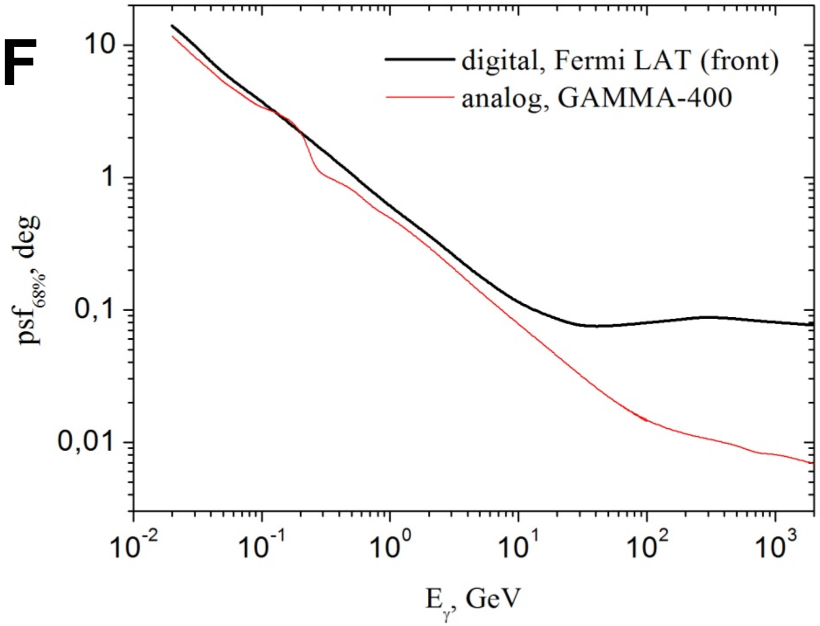
Back scattering photons ~ 1 MeV

Moddeling gamma-ray detection with energy 50 GeV

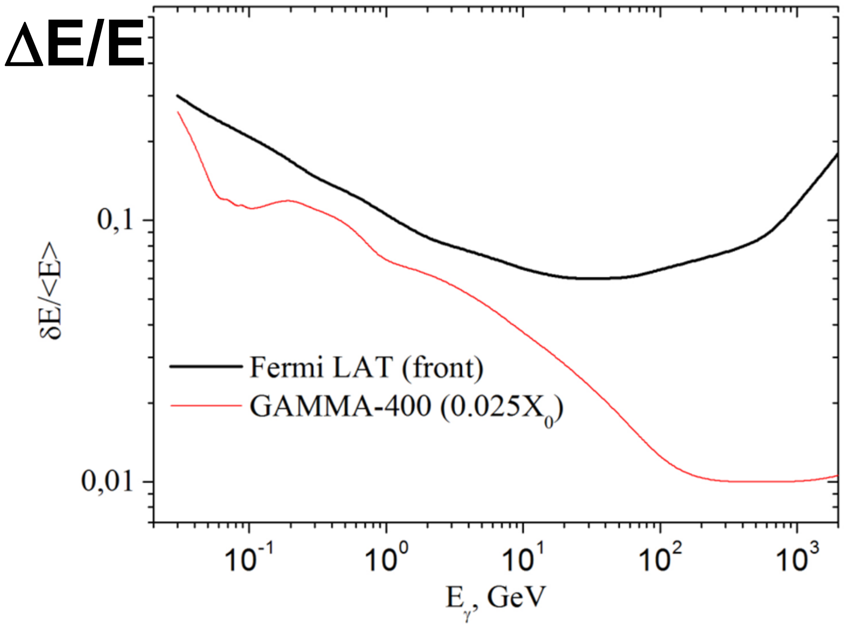


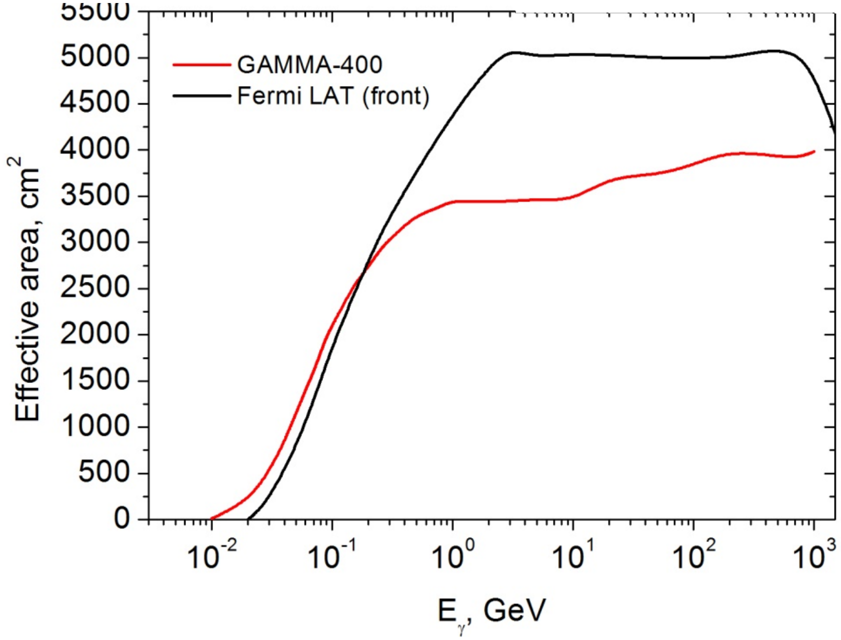
GAMMA-400 performance

PSF



ΔE/E



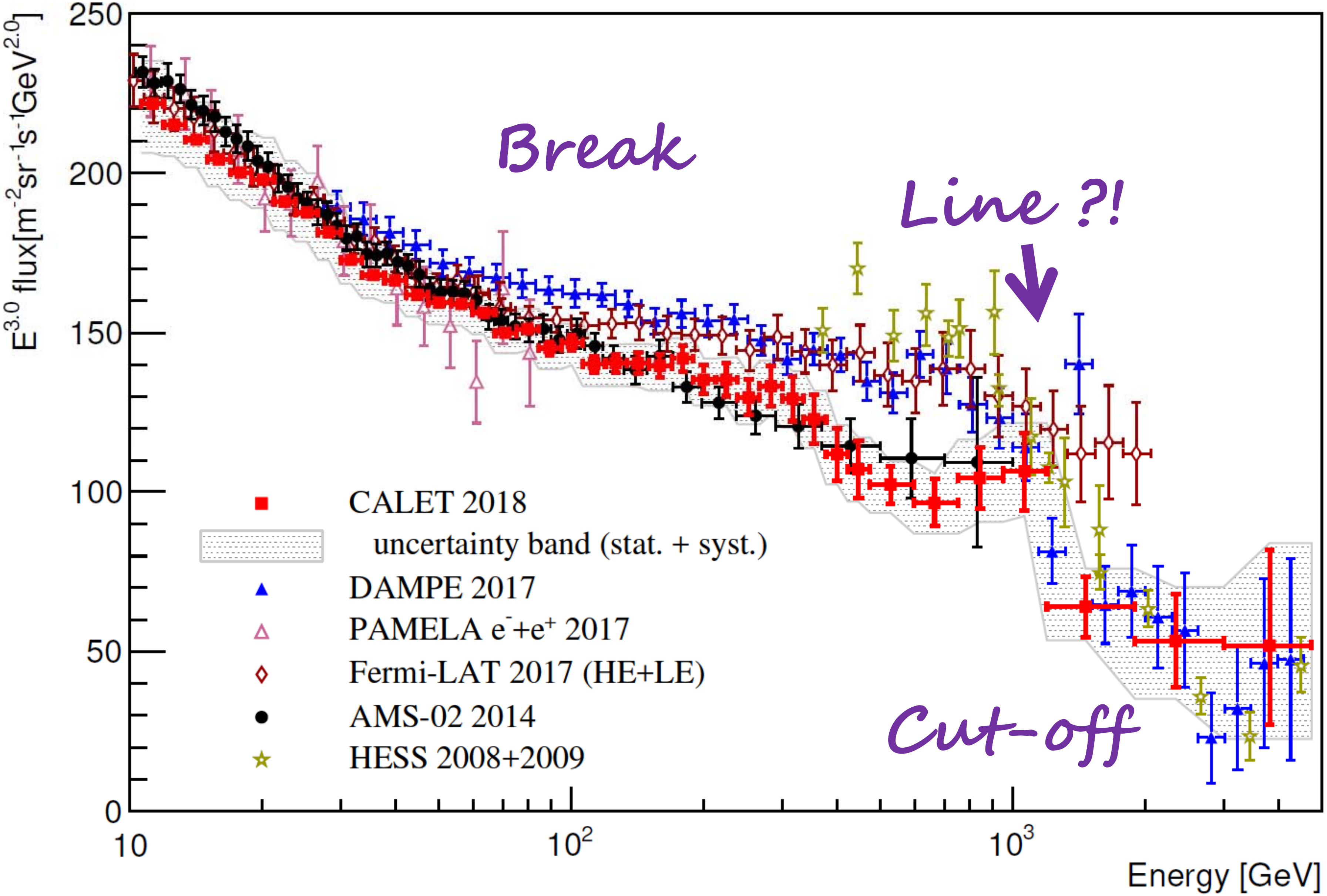


Better angular resolutions above ~10 GeV then existing instruments

Instruments comparison

	SPACE-BASED INSTRUMENTS					GROUND-BASED FACILITIES			
	AGILE	**Fermi-LAT**	**DAMPE**	**CALET**	**GAMMA-400**	**H.E.S.S.-II**	**MAGIC**	**VERITAS**	**CTA**
particles	γ	γ	e, nuclei, γ	e, nuclei, γ	γ, e	γ	γ	γ	γ
Period of work	2007-	2008-	2015	2015	~2026	2012-	2009-	2007-	~2020
Mode of observation	Continuous monitoring of sky				Continuous pointing up to 100 days	Several hours observation intervals			
Energy intervals, GeV	0.03-50	0.02-300	5-10000	10-10000	**0.02-~400**	> 30	> 50	> 100	> 20
Angular resolution (E_γ = 100 GeV)	0.1° (E_γ~1 GeV)	0.1°	0.1°	0.1°	**0.01-0.02°**	0.07°	0.07° (E_γ = 300 GeV)	0.1°	0.1° (E_γ = 100 GeV) 0.05° (E_γ > 1 TeV)
Energy resolution (E_γ = 100 GeV)	50% (E_γ~1 GeV)	10%	1.5%	2%	**2-3%**	15%	20% (E_γ = 100 GeV) 15% (E_γ = 1 TeV)	15%	20% (E_γ = 100 GeV) 5% (E_γ = 10 TeV)
Effective area, m^2	0.36	1.8	0.36	0.1	**0,64**				

Total electron + positron spectrum



arXiv:1806.09728

Comparison of characteristics for different experiments

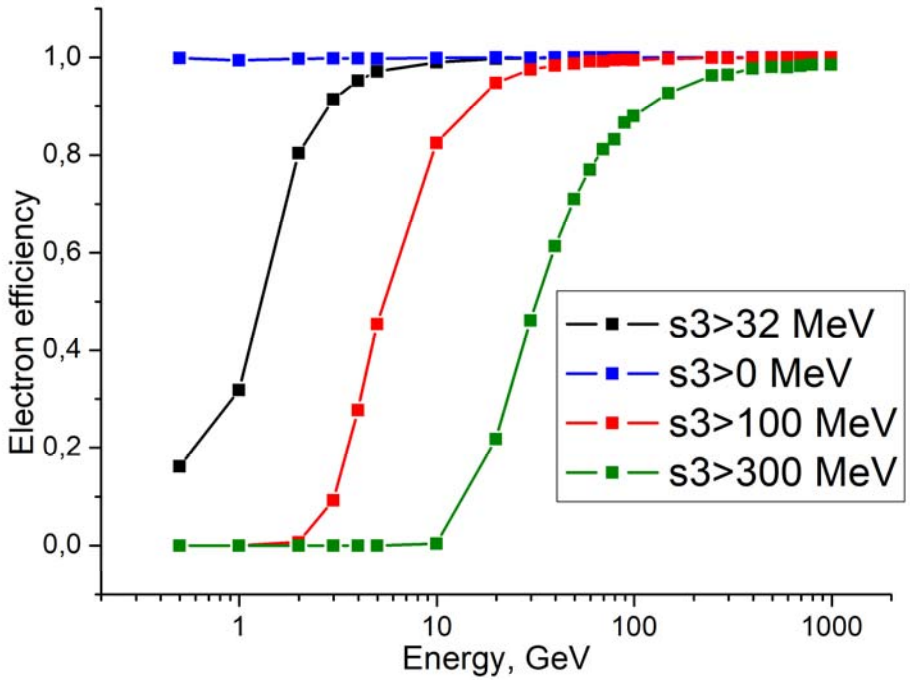
Instrument	GAMMA-400	CALET	DAMPE	AMS-02	Fermi-LAT
Aperture, m^2 sr	1.00 (E>1 GeV)	0.1040 (E>10 GeV)	0.3 (E>30 GeV)	0.05 (E>10 GeV)	2.8* (E~50 GeV)

* - additional selection long-range particle

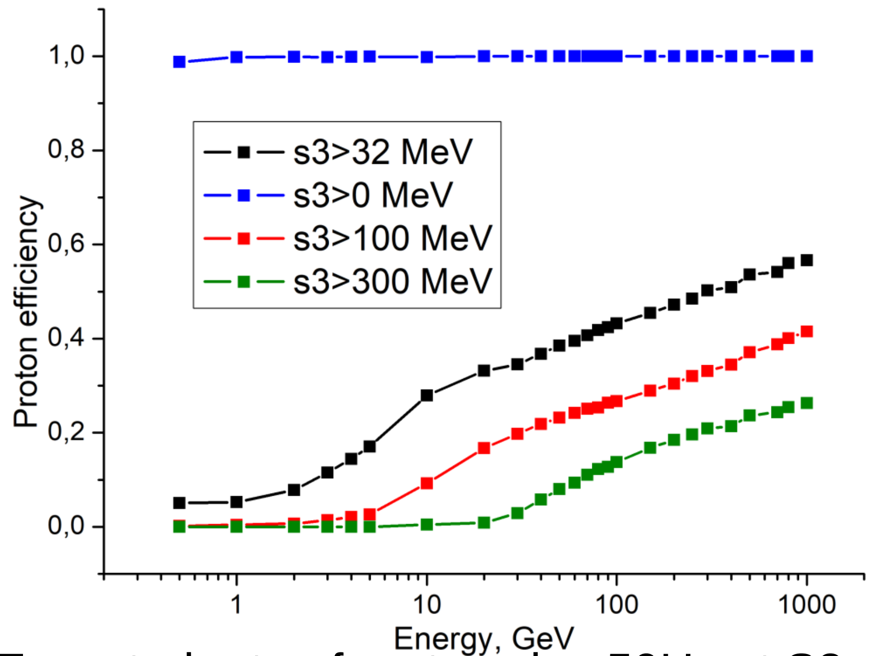
Trigger efficiency for charged particles

High energy trigger H = S1 × S2 × S3(E>Eth)

electrons



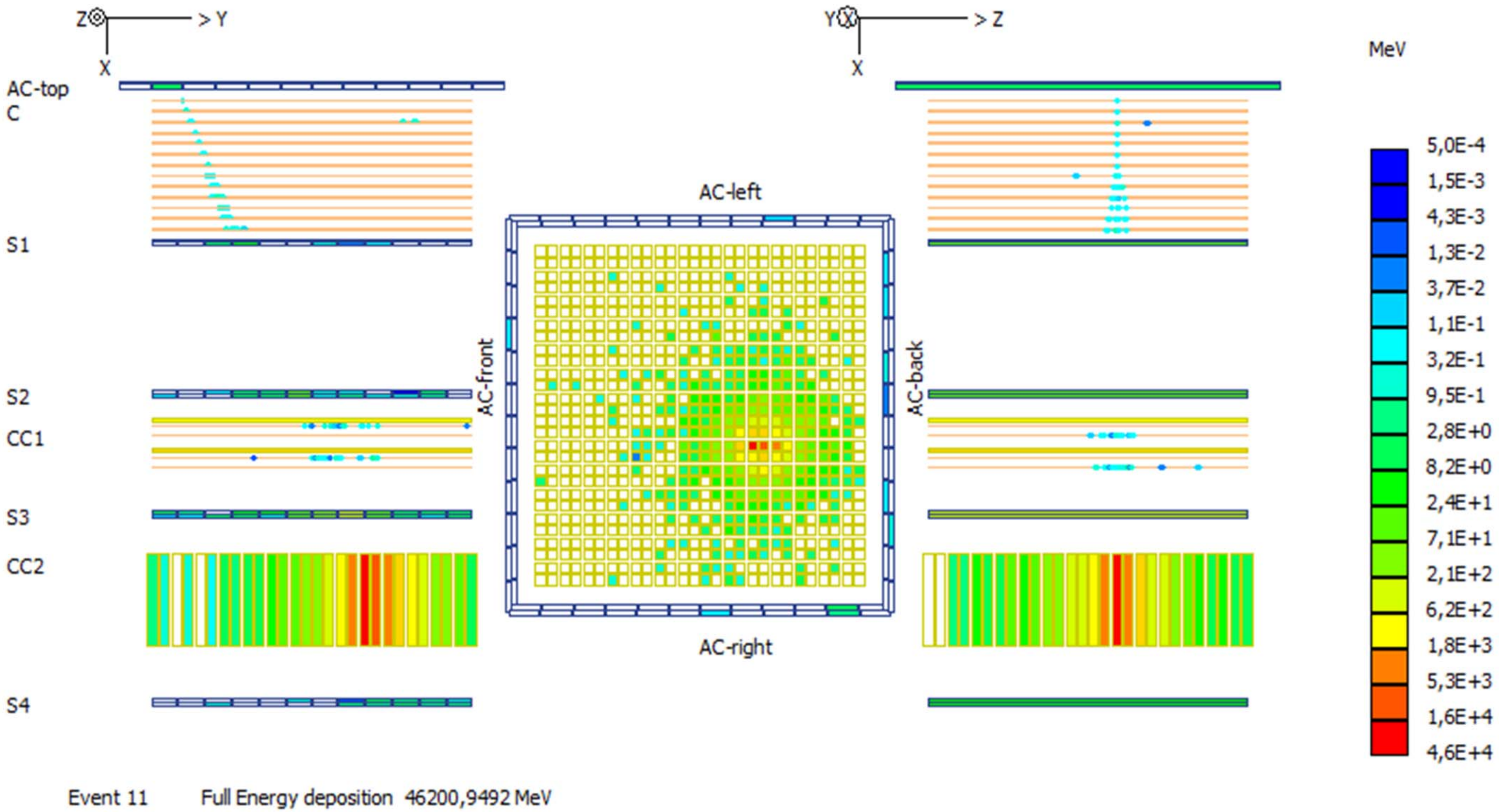
protons



Expected rate of protons is ~50Hz at S3 threshold E_{th}=100 MeV

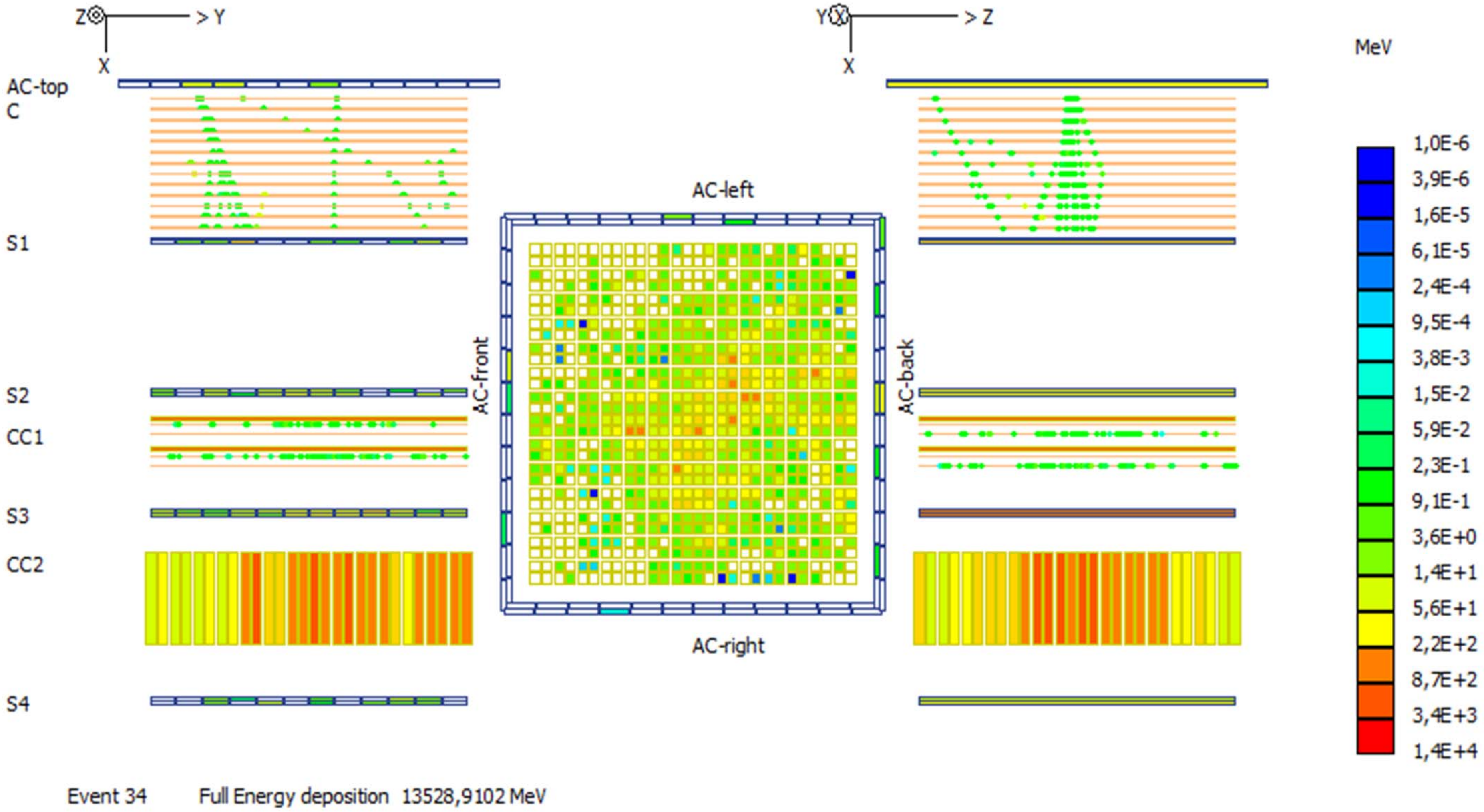
To keep high gamma-ray efficiency and low rate of background protons
Optimal S3 threshold is about 60-100 MeV

Electron E=50 GeV



Electrons interact in C and CC1, they release almost all energy in 1-3 bars of CC2

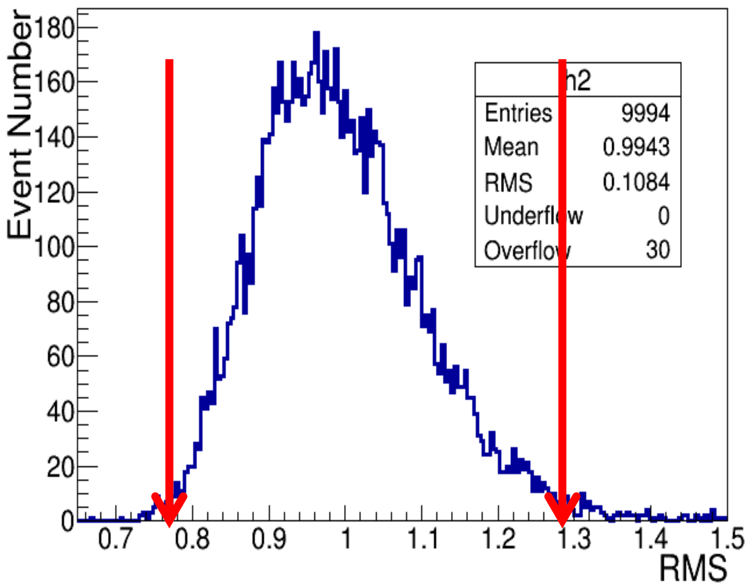
Proton E=50 GeV



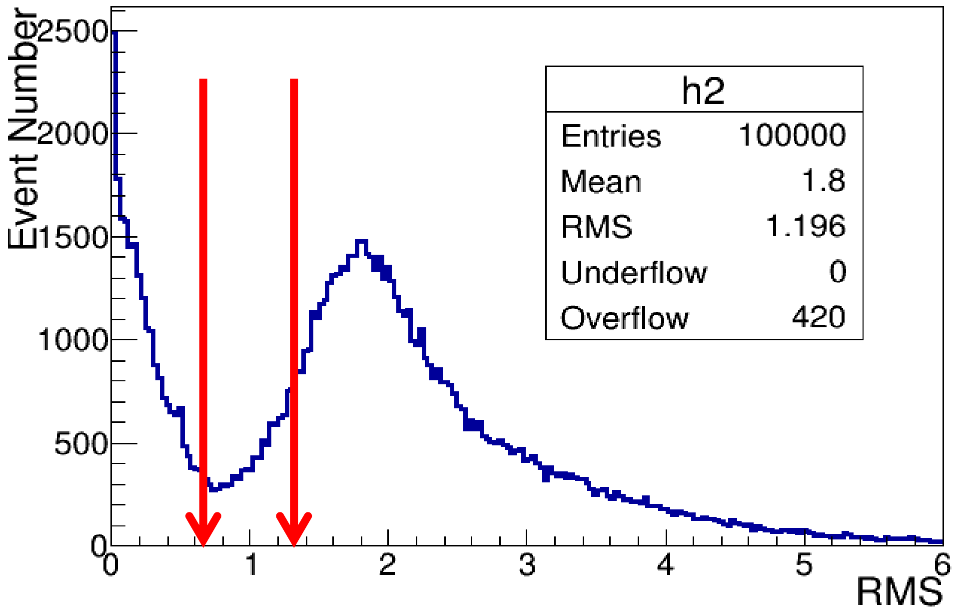
Examples of selection criteria

RMS of showers in calorimeter CC2:

Electrons E = 50 GeV



Protons E > 50 GeV



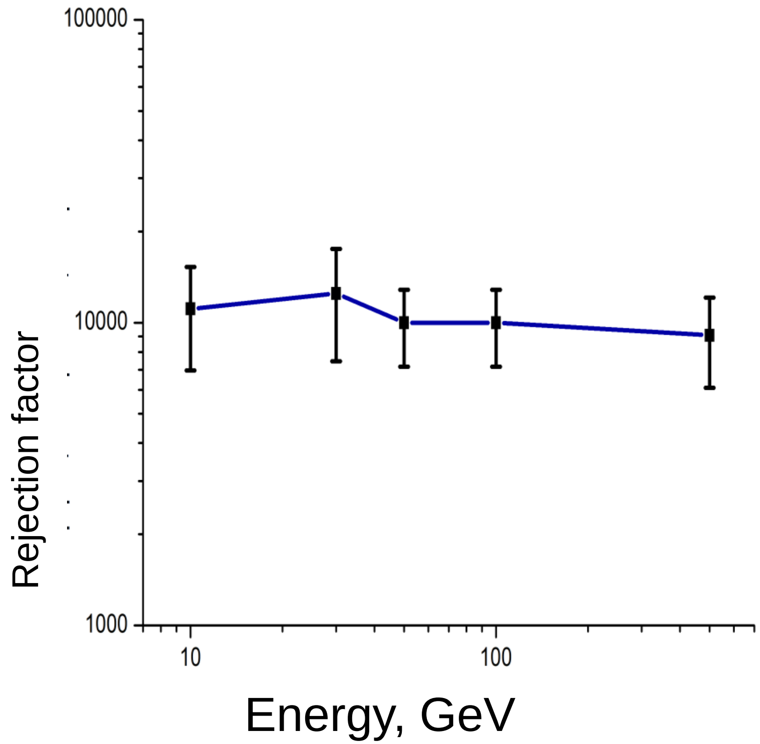
Electron efficiency ε =0.9, proton rejection factor f~50

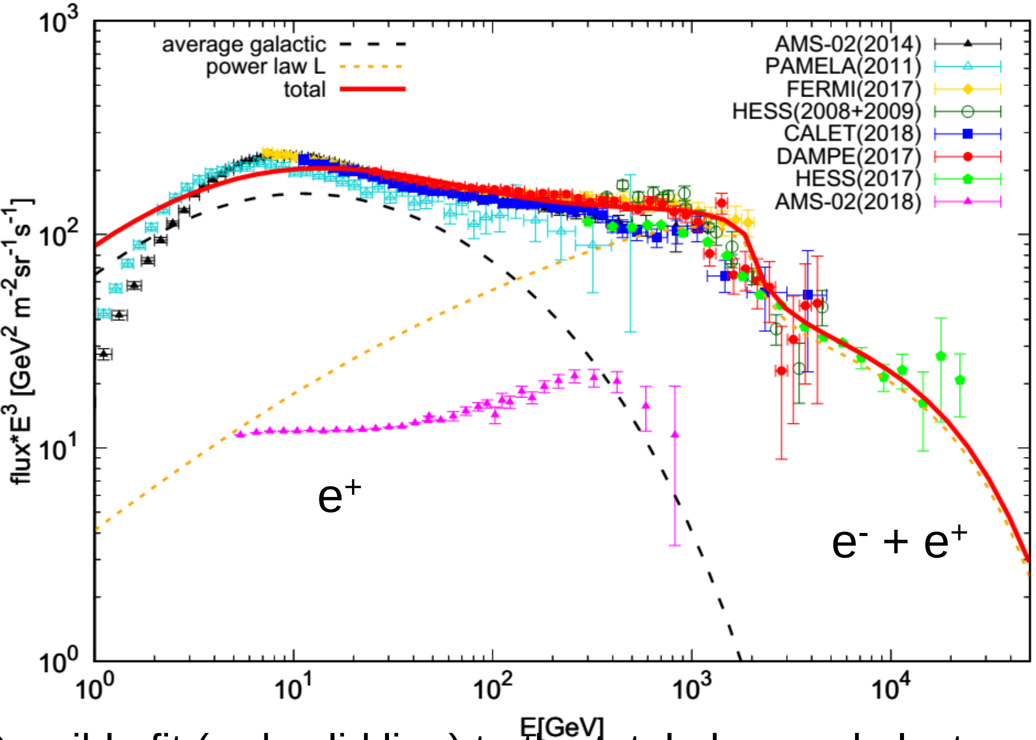
Intrinsic weight of rejection criteria

Criteria	Electron efficiency	Proton rejectionв
Amplitude C1	0.93	2.46
Amplitude S3	0.97	4.22
Amplitude C4	0.91	2.37
EC4/ECC2	0.95	20.05
Total energy	0.97	12.69
Emax/ECC2	0.99	1.83
RMS in CC2	0.98	12.54

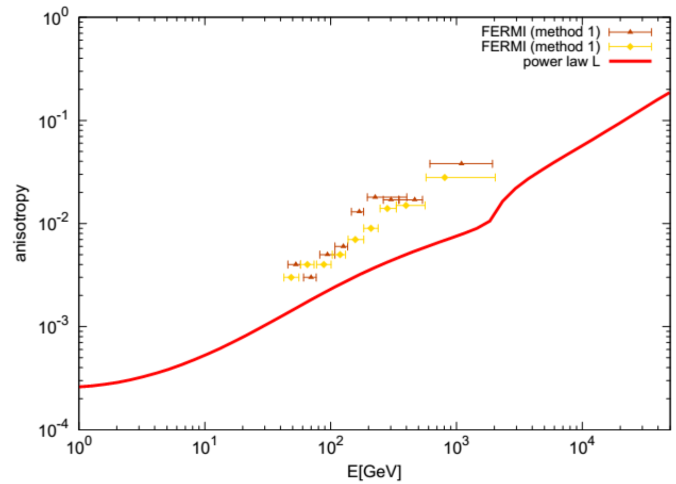
Total rejection coefficient

Energy, Gev	Proton rejection	Electron efficiency, %
10	$(1.11\pm0.42)\cdot10^4$	72
30	$(1.3\pm0.5)\cdot10^4$	77
50	$(1.0\pm0.3)\cdot10^4$	78
100	$(1.0\pm0.3)\cdot10^4$	81
500	$(9\pm3)\cdot10^3$	84





Anisotropy



Possible fit (red solid line) to the total observed electron spectrum due to distant sources (black line) and one local continuous fading source (orange dotted line) with $t/\tau=0.08$
arXiv:1811.07551

For fadding local source:
$L(t)=Lo\ \exp(-t/\tau)$

Conclusion:

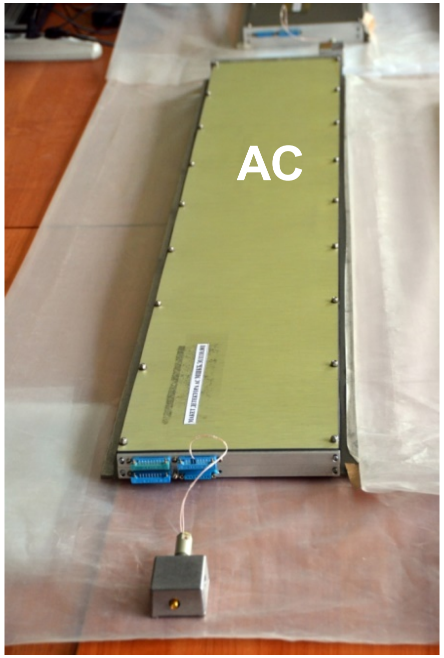
Expected count rate of HE electrons is 1Hz

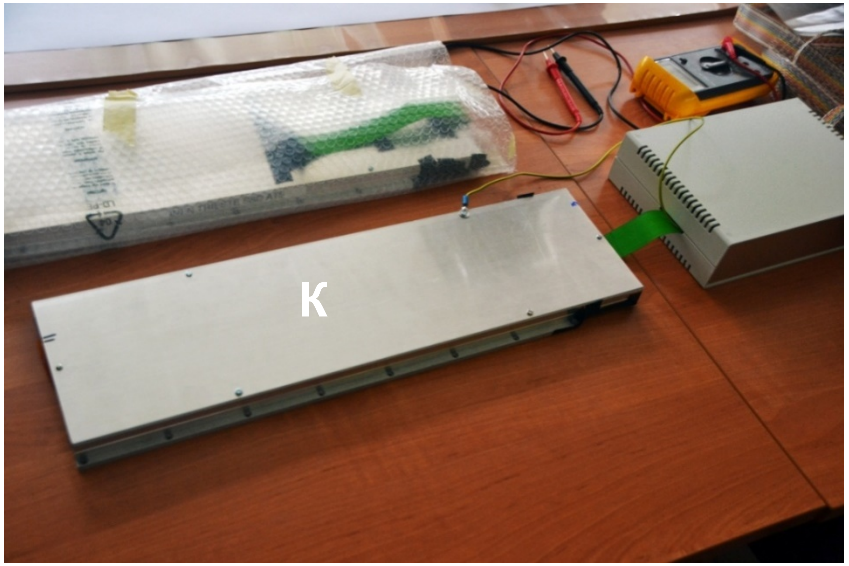
After 5 yeas of observations Gamma-400 will be able

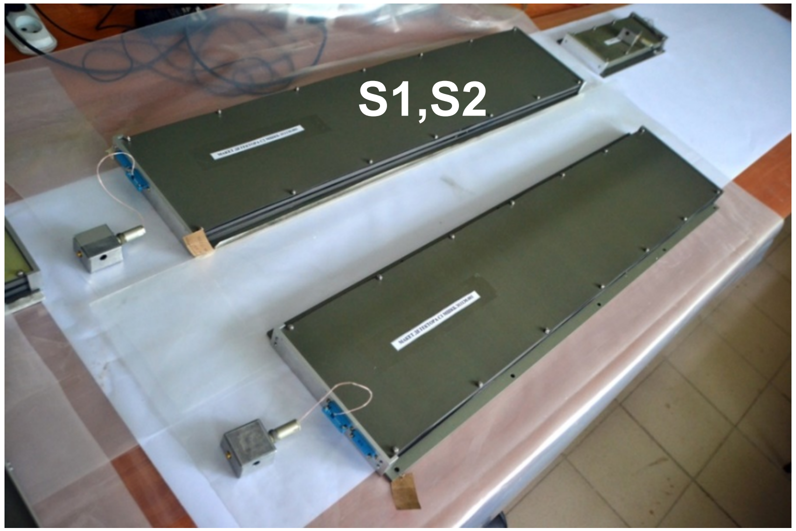
1) **to measure anisotropy of possible local sources of electrons**
2) **To find time variations of local source with $\tau < 10^3$ years**

Data for electrons can be used for calibration of gamma-ray channel

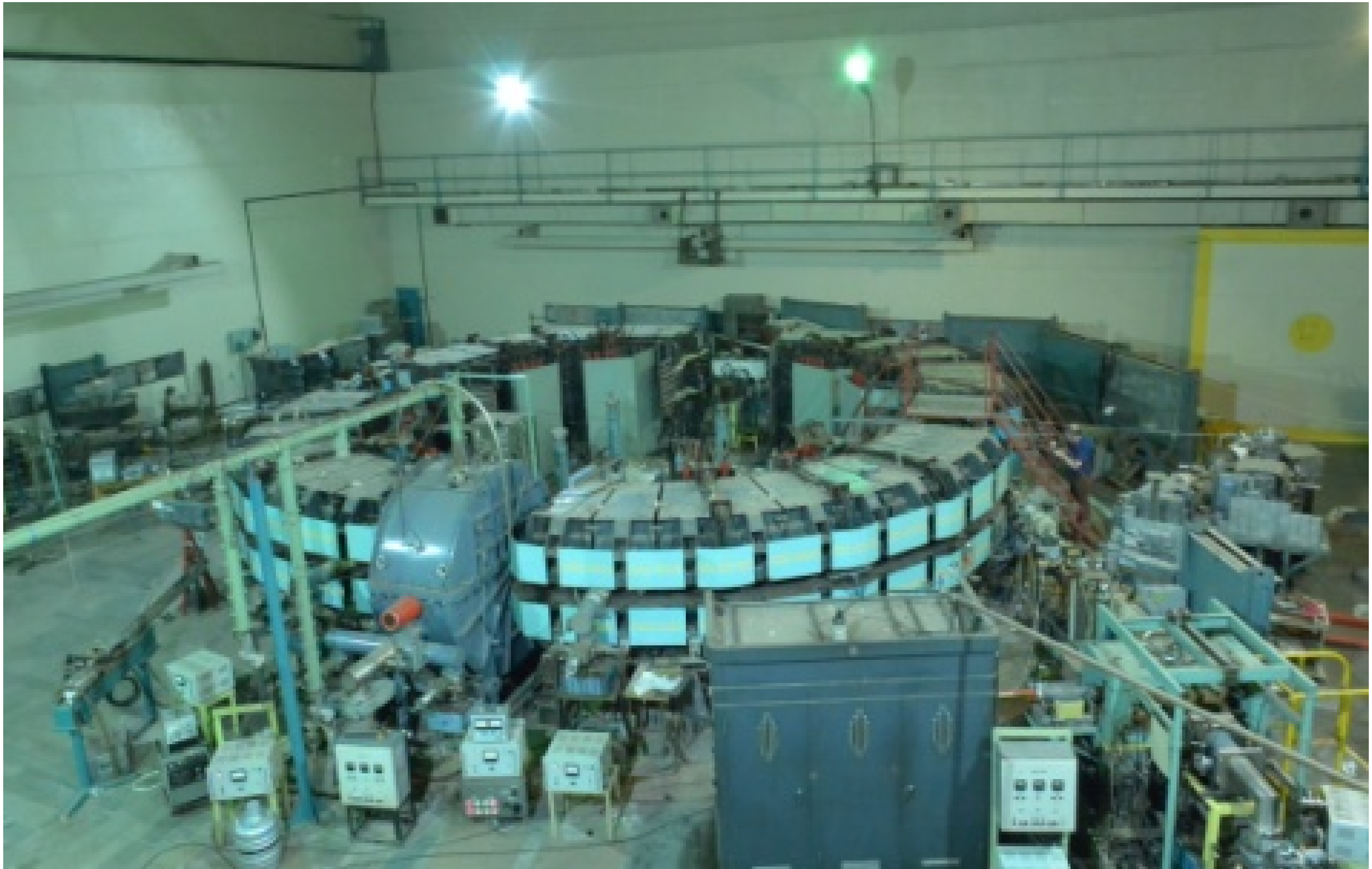
Models of gamma telescope detector systems





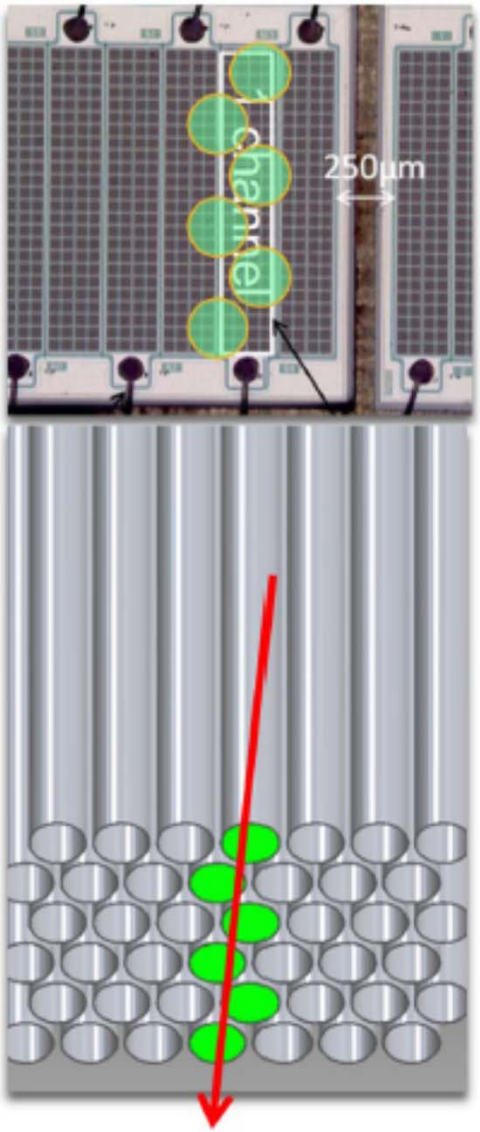


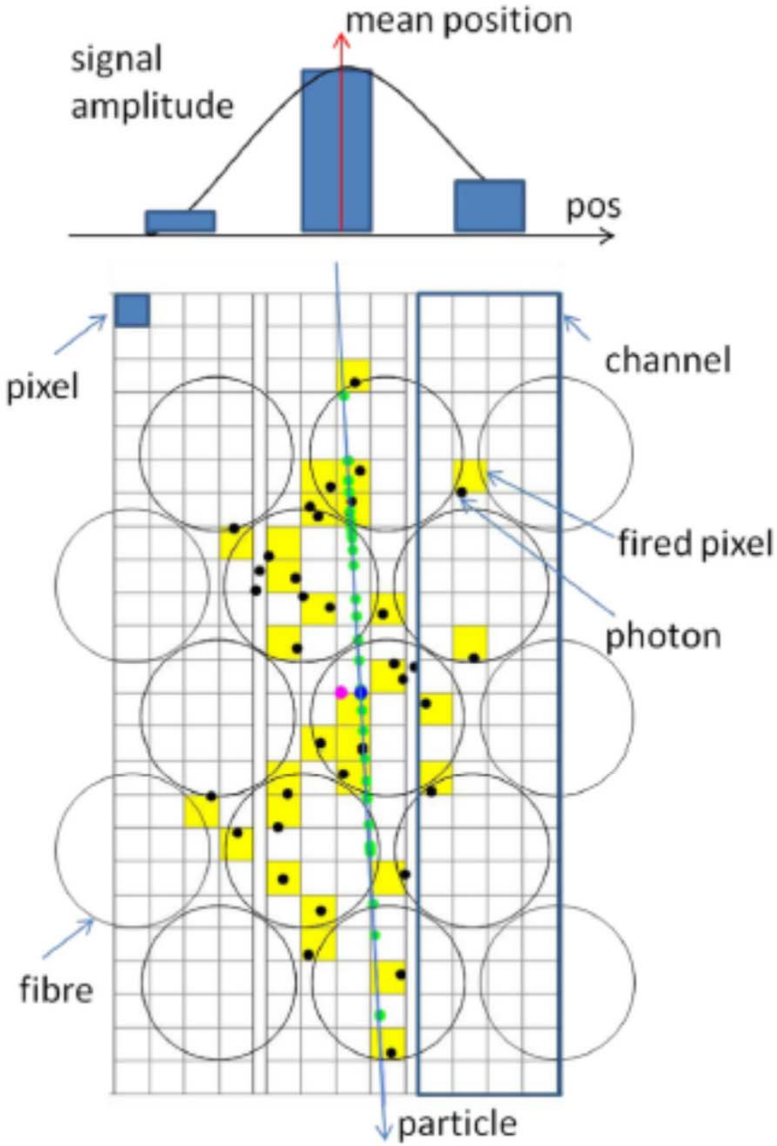
General view of the C-25P synchrotron accelerator (FIAN, Pakhra)



Positron beam

Tracker: from silicon strips to fibers





Thank you