Future Gamma Ray Satellite Experiments

Mirko Boezio
INFN Trieste, Italy

"Latest Results in Dark Matter Searches" Workshop
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Satellite Experiments with Capabilities for γ-ray Detection

- **CALET (Calorimeter Electron Telescope), Japanese-led international mission, launch by march 2016**

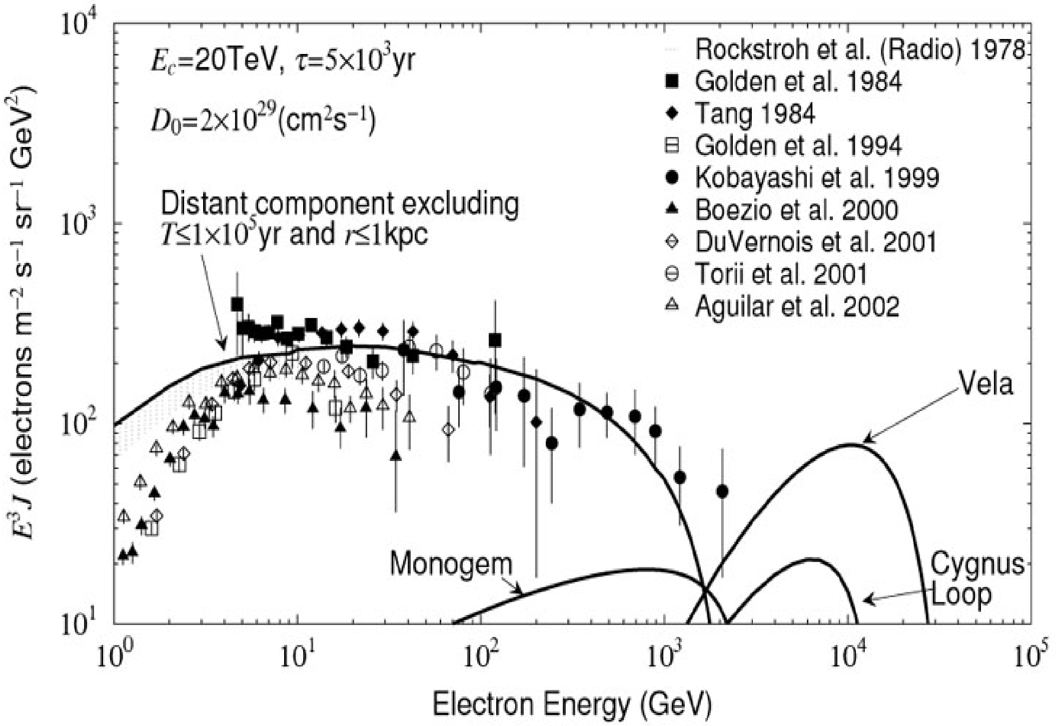
- **DAMPE (Dark Matter Particle Explorer), Chinese-led international mission, launch 2015-2016 (HERD High Energy Cosmic Radiation facility, launch ~2020?)**

- **GAMMA-400, Russian-led international mission, launch 2019**

Electrons can tell us about local GCR sources

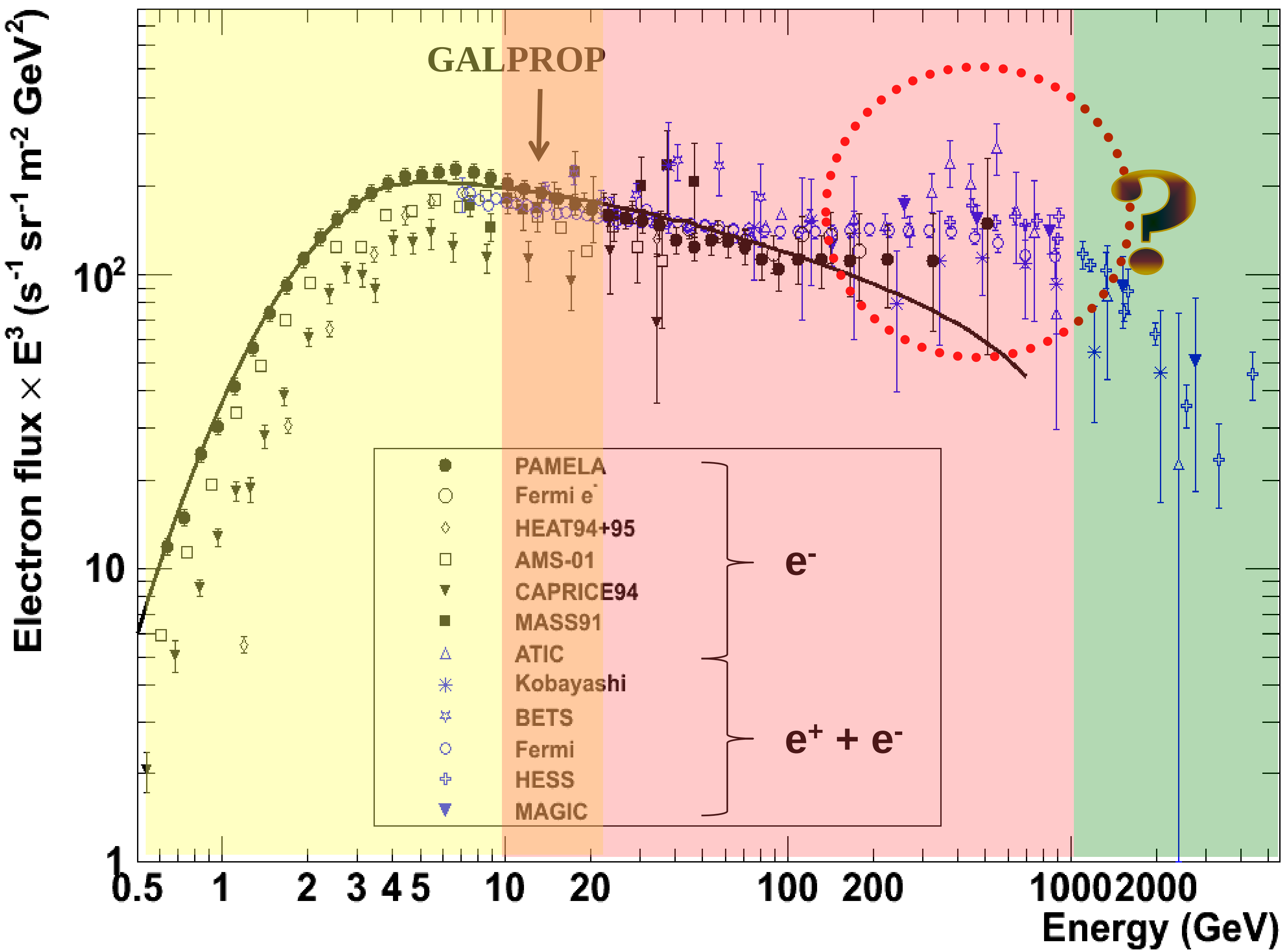
- **High energy electrons have a high energy loss rate ∝ E^2**
  - **Lifetime of ~10^5 years for >1 TeV electrons**
- **Transport of GCR through interstellar space is a diffusive process**
  - **Implies that source of high energy electrons are < 1 kpc away**

Only a handful of SNR meet the lifetime & distance criteria
Kobayashi et al., ApJ 601 (2004) 340 calculations show structure in electron spectrum at high energy

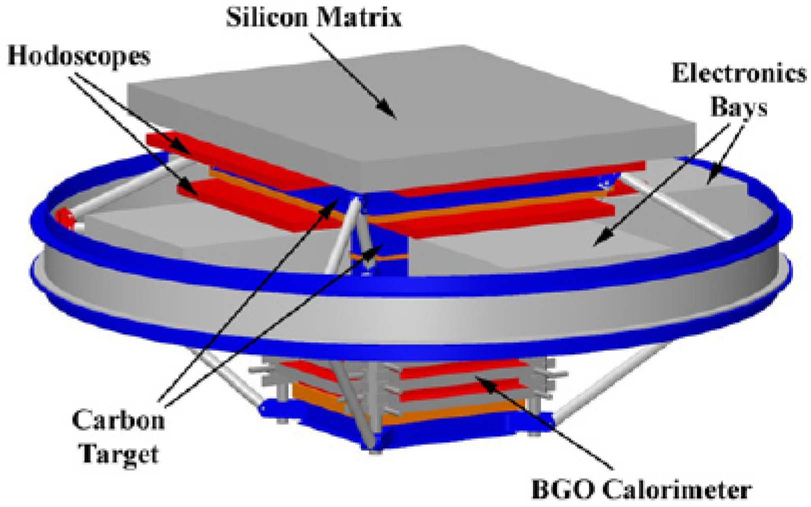


J. P. Wefel, TevPA 2011, Stockholm (2011)

Electron Spectrum

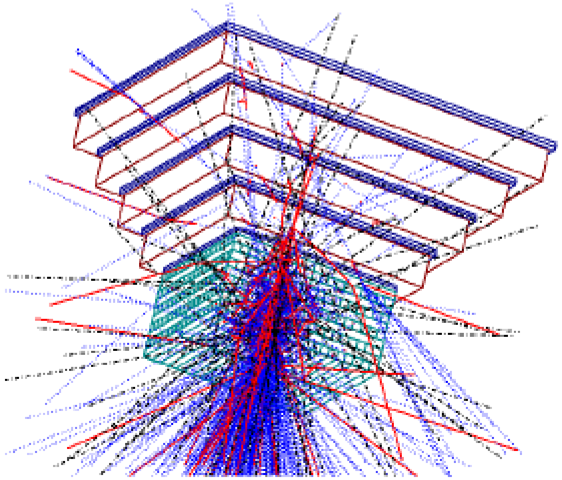


ATIC Instrument

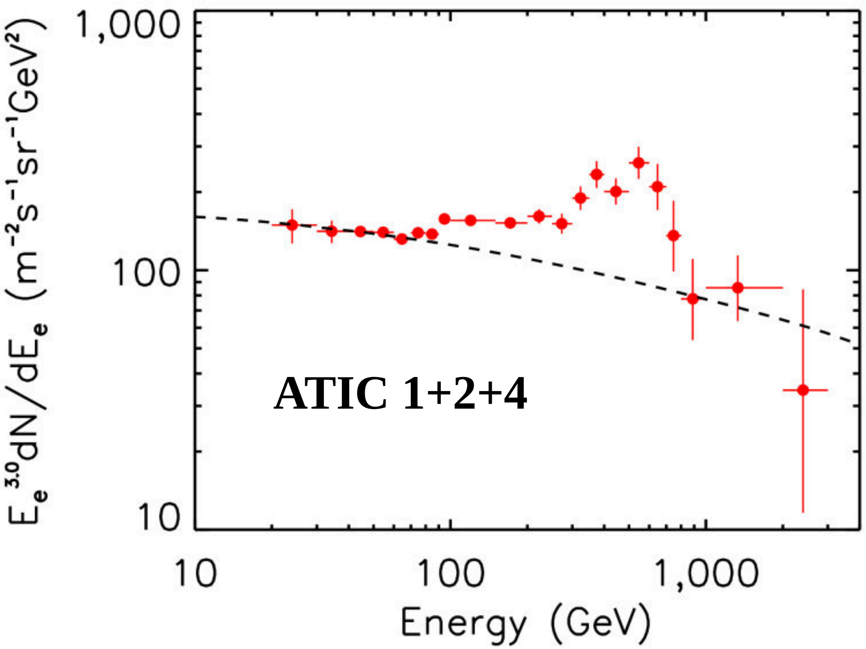


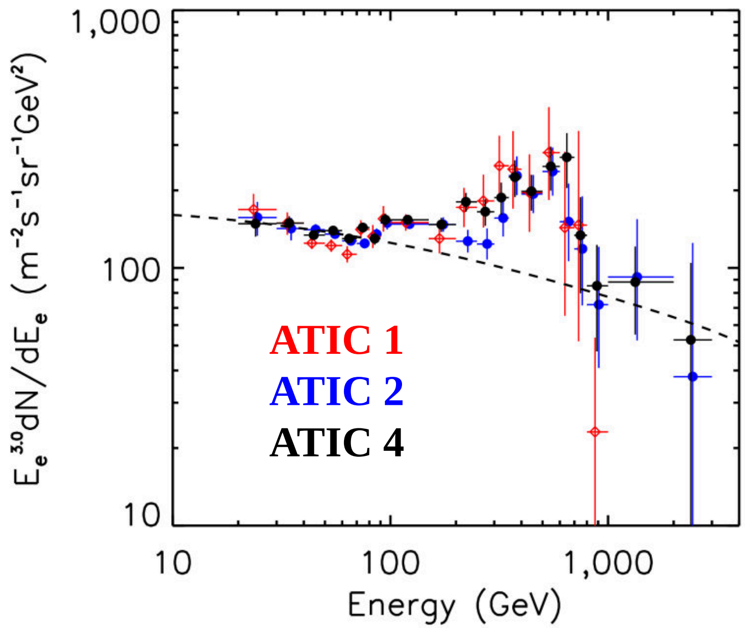
Antarctic Flights:

- <u>12/28/00 - 1/13/01</u>
- <u>12/29/02 – 1/18-03</u>
- 12/27/07 – 1/15/08



Results from three ATIC flights





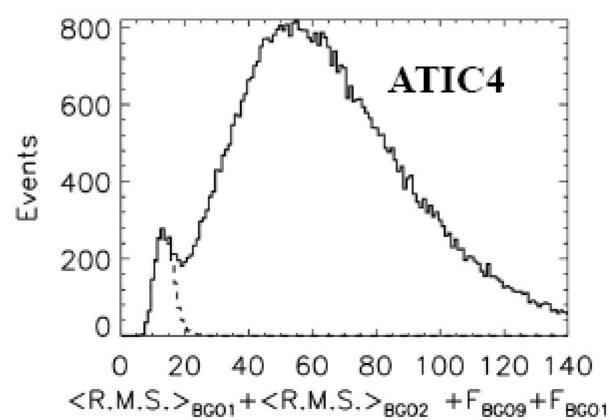
"Source on/source off" significance of bump for ATIC1+2 is about 3.8 sigma

J Chang *et al. Nature* **456**, 362 (2008)

ATIC-4 with 10 BGO layers has improved e , p separation. **(~4x lower background)**

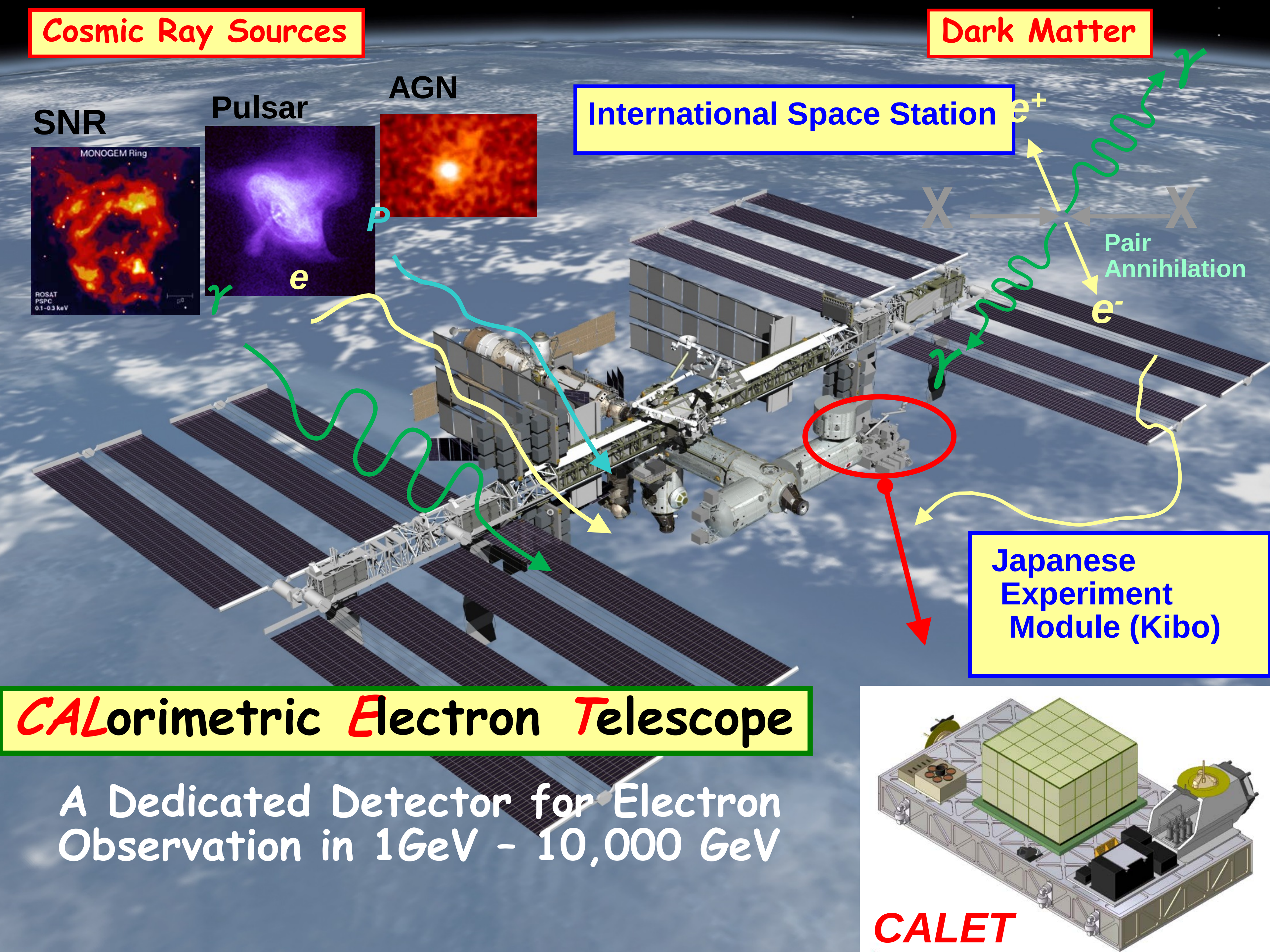
"Bump" is seen in all three flights.

Significance for ATIC1+2+4 is 5.1 sigma



J. P. Wefel, TevPA 2011, Stockholm (2011)

CALET


Cosmic Ray Sources
Dark Matter
SNR
MONOGEM Ring
ROSAT PSPC 0.1–0.3 keV
Pulsar
AGN
P
e
γ
International Space Station
e+
γ
X
X
Pair Annihilation
e-
γ
Japanese Experiment Module (Kibo)
CALorimetric Electron Telescope
A Dedicated Detector for Electron Observation in 1GeV – 10,000 GeV
CALET

CALET Collaboration Team

O. Adriani[19], Y. Akaike[3], K. Asano[17], M.G. Bagliesi[22], G. Bigongiari[22], W.R. Binns[24], M. Bongi[19], J.H. Buckley[24], G. Castellini[19], M.L. Cherry[9], G. Collazuol[26], K. Ebisawa[5], V. Di Felice[21], H. Fuke[5], A. Gherardi[19], T.G. Guzik[9], T. Hams[10], N. Hasebe[23], M. Hareyama[5], K. Hibino[7], M. Ichimura[2], K. Ioka[8], M.H. Israel[24], A. Javaid[9], E. Kamioka[15], K. Kasahara[23], Y. Katayose[4,25], J. Kataoka[23], R. Kataoka[17], N. Kawanaka[8], M.Y. Kim[22], H. Kitamura[11], Y. Komori[6], T. Kotani[23], H.S. Krawczynski[24], J.F. Krizmanic[10], A. Kubota[15], S. Kuramata[2], T. Lomtadze[20], P. Maestro[22], L. Marcelli[21], P.S. Marrocchesi[22], V. Millucci[22], J.W. Mitchell[10], S. Miyake[28], K. Mizutani[14], A.A. Moiseev[10], K. Mori[5,23], M. Mori[13], N. Mori[19], K. Munakata[16], H. Murakami[23], Y.E. Nakagawa[23], S. Nakahira[5], J. Nishimura[5], S. Okuno[7], J.F. Ormes[18], S. Ozawa[23], P. Papini[19], B.F. Rauch[24], S. Ricciarini[19], Y. Saito[5], T. Sakamoto[1], M. Sasaki[10], M. Shibata[25], Y. Shimizu[4], A. Shiomi[12], R. Sparvoli[21], P. Spillantini[19], M. Takayanagi[5], M. Takita[3], T. Tamura[4,7], N. Tateyama[7], T. Terasawa[3], H. Tomida[5], S. Torii[4,23], Y. Tunesada[17], Y. Uchihori[11], S. Ueno[5], E. Vannuccini[19], J.P. Wefel[9], K. Yamaoka[4,23], S. Yanagita[27], A. Yoshida[1], K. Yoshida[15], and T. Yuda[3]

1) Aoyama Gakuin University, Japan
2) Hirosaki University, Japan
3) ICRR, University of Tokyo, Japan
4) JAXA/SEUC, Japan
5) JAXA/ISAS, Japan
6) Kanagawa University of Human Services, Japan
7) Kanagawa University, Japan
8) KEK, Japan
9) Louisiana State University, USA
10) NASA/GSFC, USA
11) National Inst. of Radiological Sciences, Japan
12) Nihon University, Japan
13) Ritsumeikan University, Japan
14) Saitama University, Japan
15) Shibaura Institute of Technology, Japan
16) Shinshu University, Japan
17) Tokyo Technology Institute, Japan
18) University of Denver, USA
19) University of Florence, IFAC (CNR) and INFN, Italy
20) University of Pisa and INFN, Italy
21) University of Rome Tor Vergata and INFN, Italy
22) University of Siena and INFN, Italy
23) Waseda University, Japan
24) Washington University-St. Louis, USA
25) Yokohama National University, Japan
26) University of Padova and INFN, Italy
27) Ibaraki University, Japan
28)Tokiwa University, Japan

CALET Observation Targets

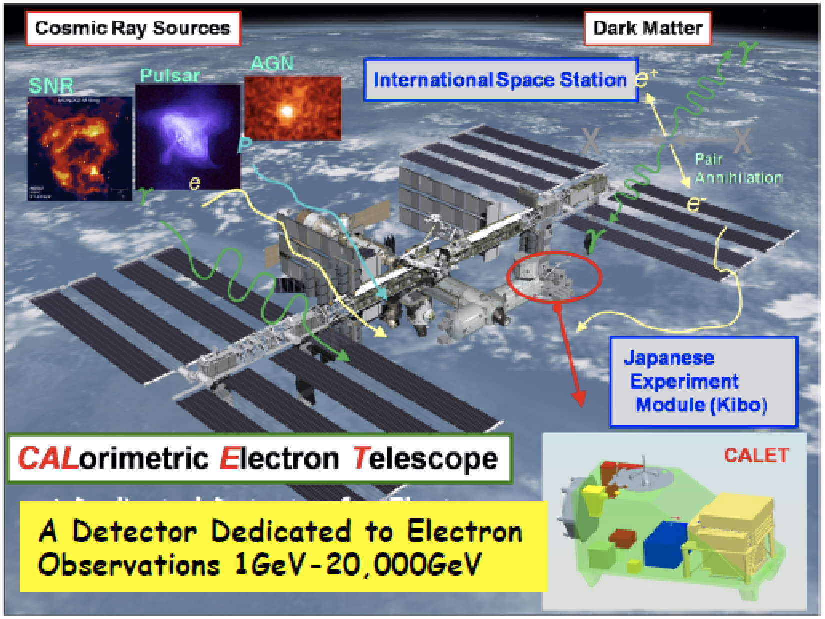
Calorimeter (CALET/CAL)

- Electrons: 1 GeV - 20 TeV
- Gamma-rays: 4 *GeV - 10 **TeV
  (Gamma-ray Bursts: > 1 GeV)
- Protons and Heavy Ions:
  10's of GeV - 1,000** TeV
- Ultra Heavy (Z>28) Nuclei:
  E> 600 MeV/nucleon

(* 50% efficiency, ** statistical dependent)

Gamma-ray Burst Monitor (CGBM)

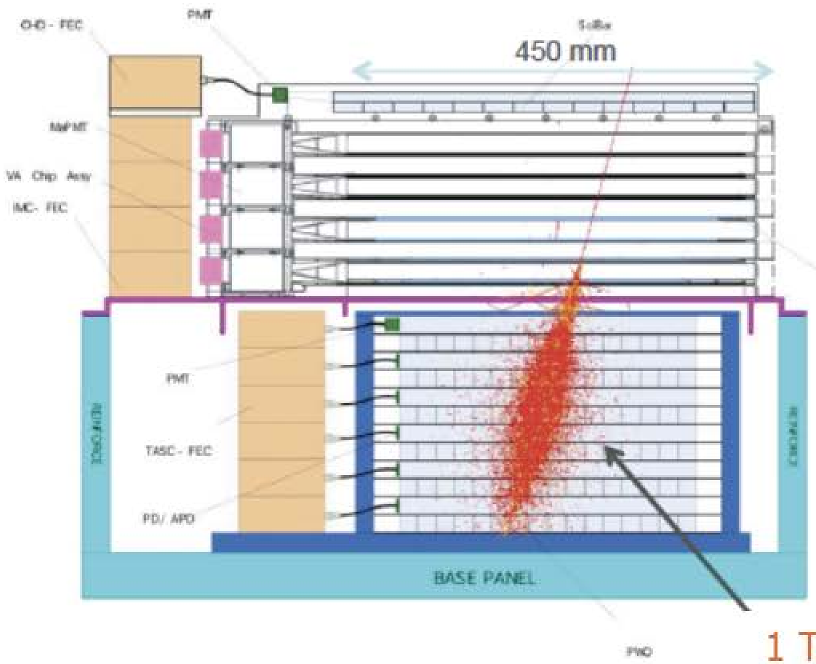
- X-rays/Soft Gamma-rays:
  7keV - 20MeV



Science Objectives	Observation Targets
Nearby Cosmic-ray Sources	Electron spectrum into trans-TeV region
Dark Matter	Signatures in 10 GeV - 10 TeV electron and gamma energy spectra
Origin and Acceleration of Cosmic Rays	p-Fe above several tens of GeV, Ultra Heavy Nuclei
Cosmic-ray Propagation in the Galaxy	B/C ratio to several TeV /nucleon
Solar Physics	Electron flux below 10 GeV
Gamma-ray Transients	Gamma-rays and X-rays 7 keV - 20 MeV

S. Torii, TeVPA 2013, Irvine, USA

Overview of the CALET Instrument



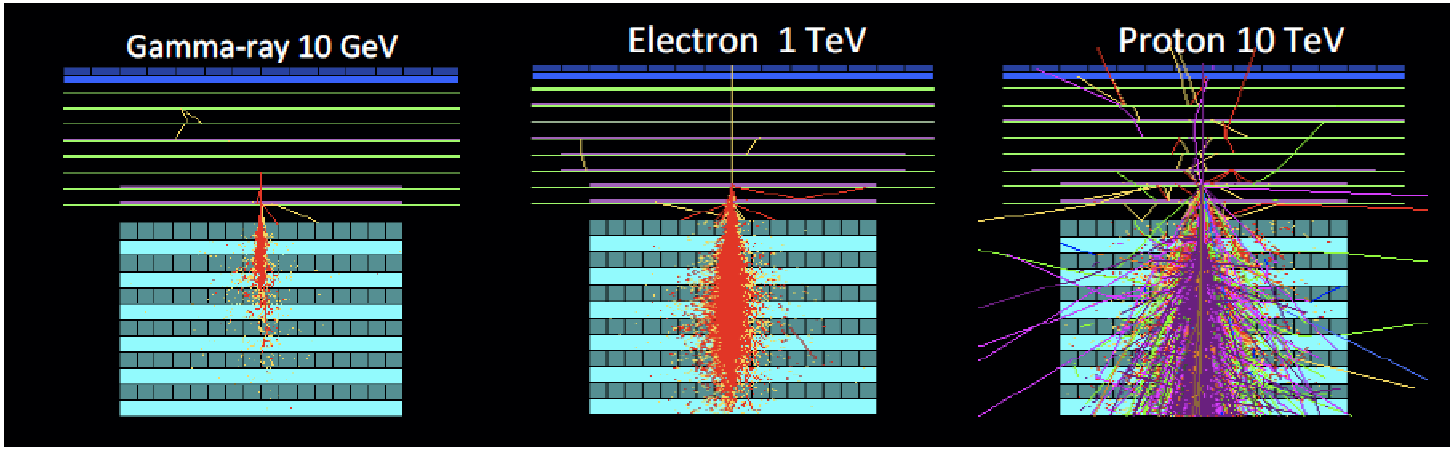
- **CHarge Detector (CHD)**
  (Charge Measurement in Z=1-40)
- **Imaging Calorimeter (IMC)**
  (Particle ID, Direction)
  Total Thickness of Tungsten (W): $3X_0$, $0.11\ \lambda_I$
  Layer Number of Scifi Belts: 8 Layers × 2(X,Y)
- **Total Absorption Calorimeter (TASC)**
  (Energy Measurement, Particle ID)
  PWO 20mm x 20mm x 320mm
  Total Depth of PWO: $27\ X_0$ (24 cm), $1.35\ \lambda_I$

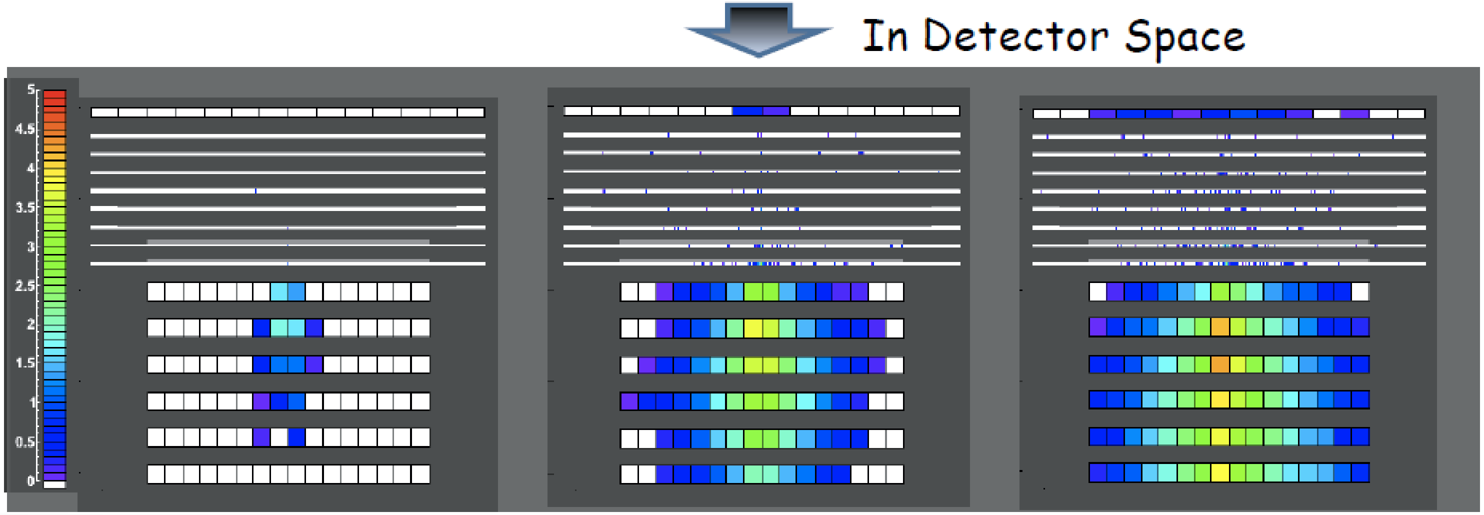
1 TeV electron shower

	CHD (Charge Detector)	IMC (Imaging Calorimeter)	TASC (Total Absorption Calorimeter)
Function	Charge Measurement (Z=1-40)	Arrival Direction, Particle ID	Energy Measurement, Particle ID
Sensor (+ Absorber)	Plastic Scintillator : 2 layers Unit Size: 32mm x 10mm x 450mm	SciFi : 16 layers Unit size: $1mm^2$ x 448 mm Total thickness of Tungsten: $3\ X_0$	PWO log: 12 layers Unit size: 19mm x 20mm x 326mm Total Thickness of PWO: $27\ X_0$
Readout	PMT+CSA	64 -anode PMT+ ASIC	APD/PD+CSA PMT+CSA (for Trigger)

S. Torii, TeVPA 2013, Irvine, USA

CALET/CAL Shower Imaging Capability (Simulation)

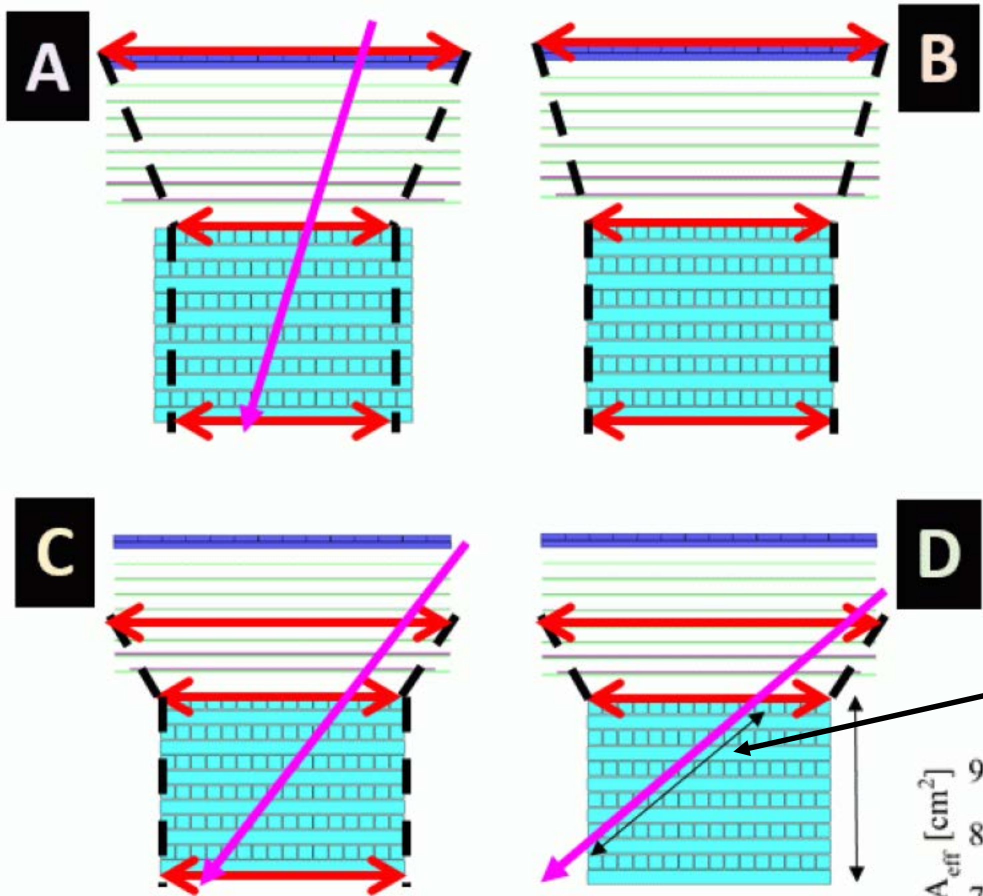


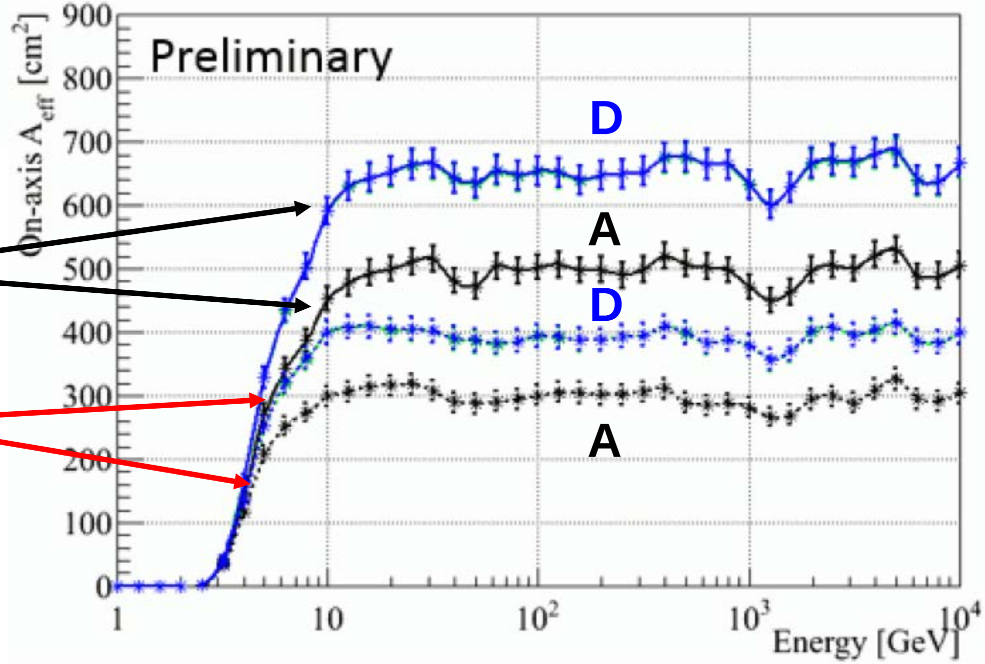


- Proton rejection power of 10^5 can be achieved with IMC and TASC shower imaging capability.
- Charge of incident particle is determined to σ_Z=0.15-0.3 with the CHD.

S. Torii, TeVPA 2013, Irvine, USA

CALET Performance for γ-rays



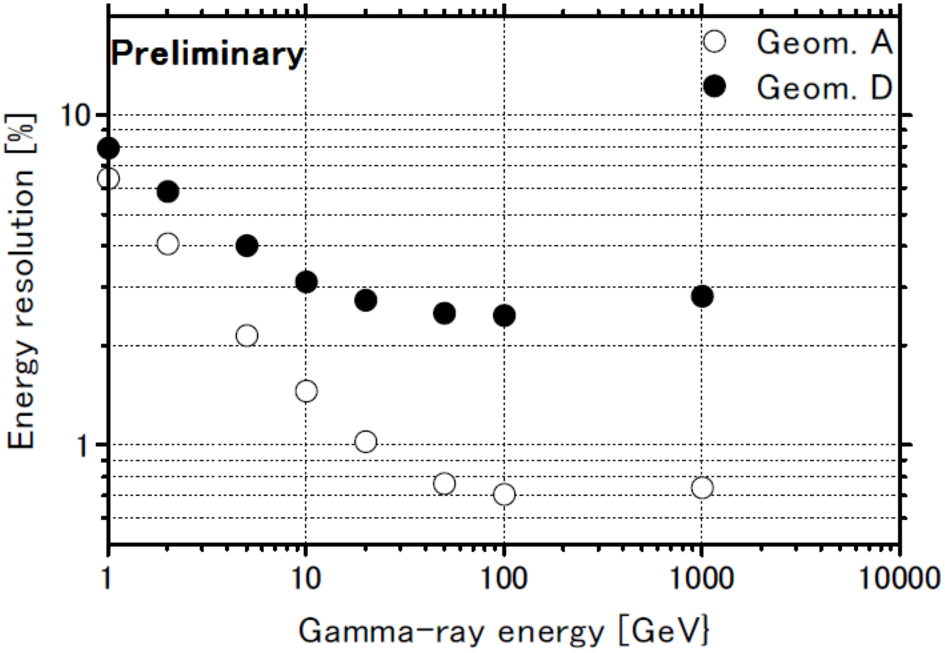


Conversion in any layers

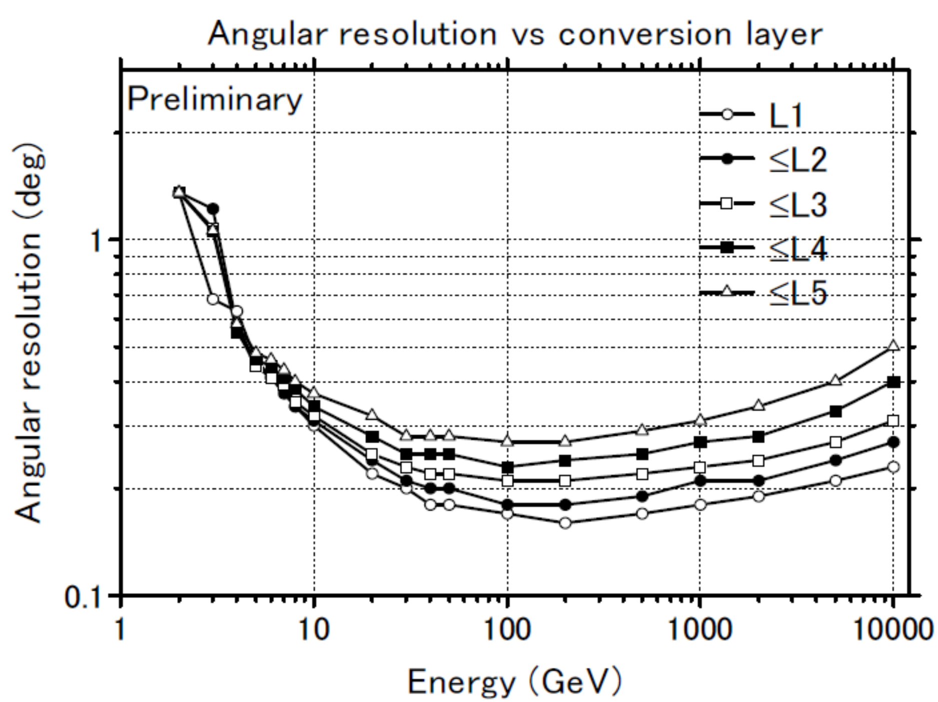
Conversion in upper layer

M. Mori, ICRC 2013, Rio de Janeiro

CALET Performance for γ-rays



CALET energy resolution for gamma rays of normal incidence.

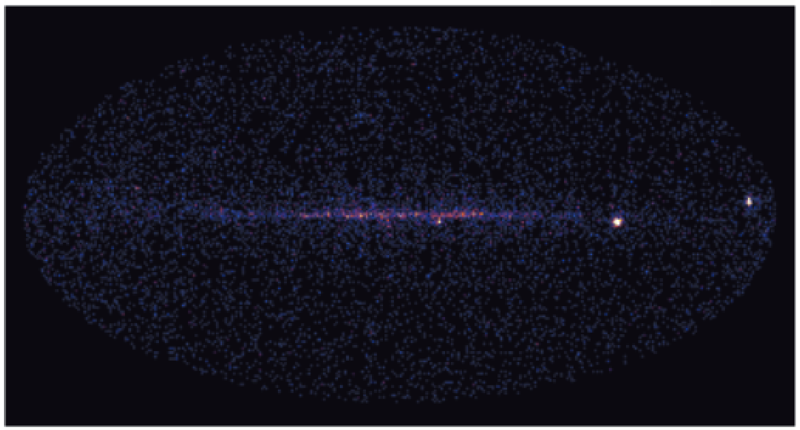


CALET angular resolution for γ-rays of normal incidence. The curve 'L1' is for gamma-rays converted in L1, '≤L2' is those in L1 or L2, etc.

M. Mori, ICRC 2013, Rio de Janeiro

CAL: Gamma-ray observation performance

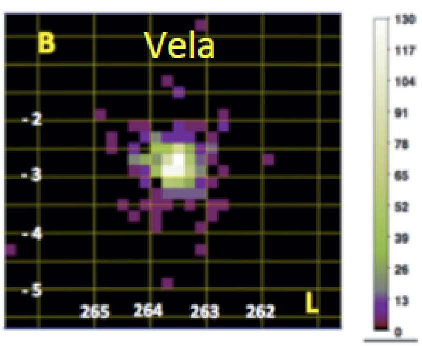
CALET simulation (>10 GeV; 3 year)



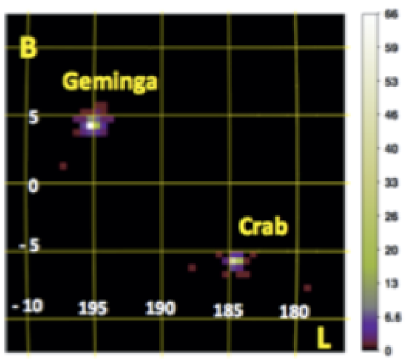
Gamma-ray performance

	CAL
Energy range (photon)	10 GeV-10 TeV
Effective area	600 cm^2 (@ 10 GeV)
Angular resolution	2.5°@1 GeV 0.35°@10GeV
FOV	~2 sr

Simulation of point source observations in one year



Vela: ~ 300 photon above 5 GeV

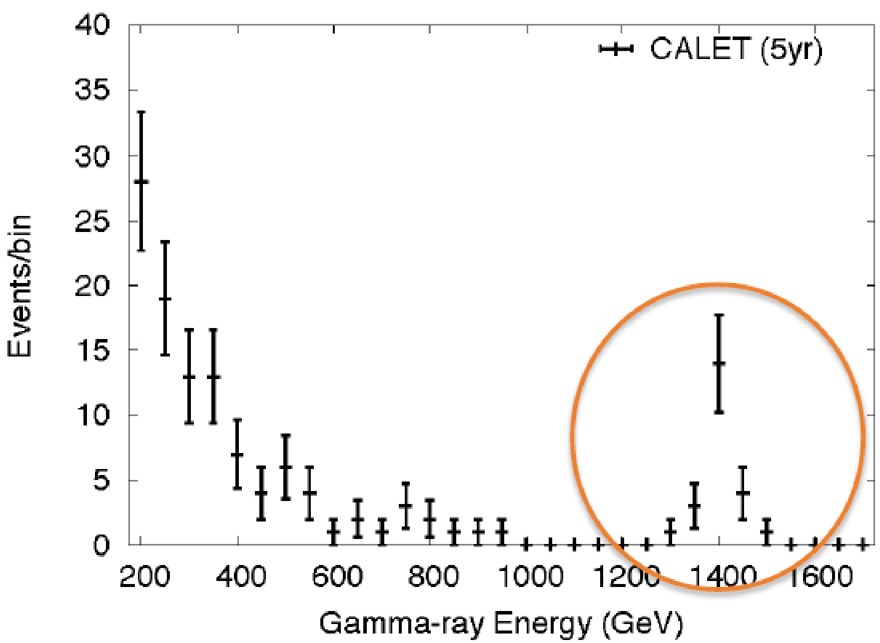


Geminga: ~150 photons above 5 GeV
Crab: ~ 100 photons above 5 GeV

Greece)

CALET Capability for Detection of Gamma-ray Lines from Dark Matter

Monochromatic gamma-ray signals from WIMP dark matter annihilation would provide a distinctive signature of dark matter, if detected. Since gamma-ray line signatures are expected in the sub-TeV to TeV region, due to annihilation or decay of dark matter particles, CALET, with an excellent energy resolution of 1 - 3 % above 100 GeV, is a suitable instrument to detect these signatures .



- Simulated 1.4 TeV gamma-ray line from dark matter toward the Galactic center (300° < l < 60° , |*b*| < 10°) including the Galactic diffuse background for CALET 5 year observations.
- The annihilation cross-section is taken as $\langle \sigma v \rangle_{\gamma\gamma} = 1\times10^{-25}\ cm^3 s^{-1}$ with a NFW halo profile. The distinctive line signature is clearly seen in the gamma-ray spectrum.

S. Torii, TeVPA 2013, Irvine, USA

DAMPE

(and HERD)

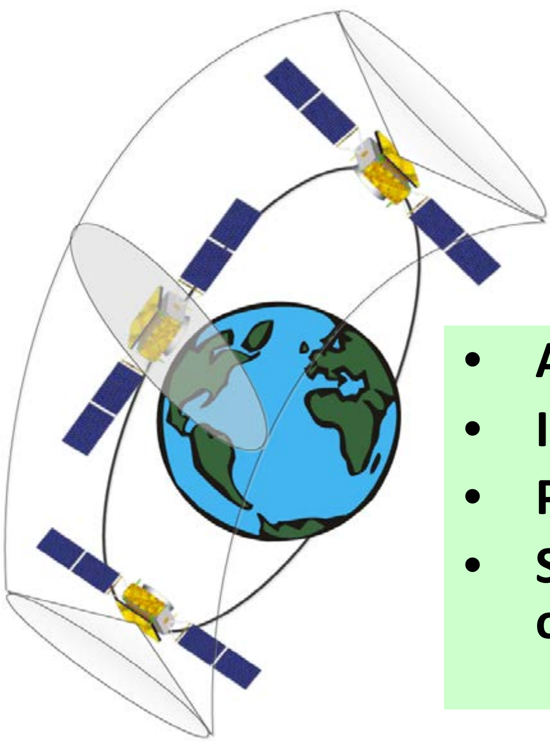
DAMPE Collaboration

- CINA
  - Purple Mountain Observatory, CAS, Nanjing
    - Responsabile dell'esperimento: Prof. Jin Chang
  - Institute of High Energy Physics, CAS, Beijing
  - National Space Science Center, CAS, Beijing
  - University of Science and Technology of China, Hefei
  - Institute of Modern Physics, CAS, Lanzhou
- SVIZZERA
  - Università di Ginevra
- ITALIA
  - INFN Perugia
  - INFN Bari

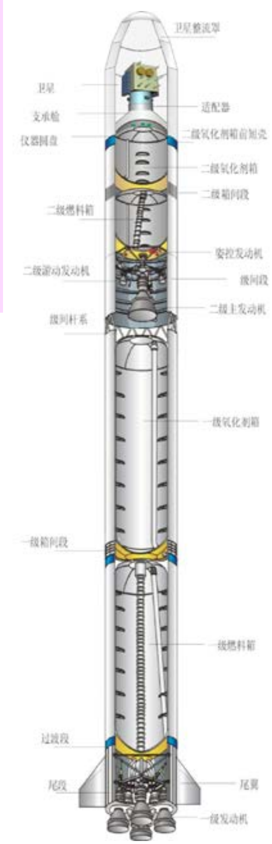
Dark Matter Particle Explorer Satellite

- **One of the 5 satellite missions of the Chinese Strategic Priority Research Program in Space Science of CAS**
  - **Approved for construction (phase C/D) in Dec. 2011**
  - **Scheduled launch date late 2015**

- **Satellite ≈ 1900 kg, payload ≈1300kg**
- **Power consumption ≈640W**
- **Lifetime > 3 years**
- **Launched by CZ-2D rockets**



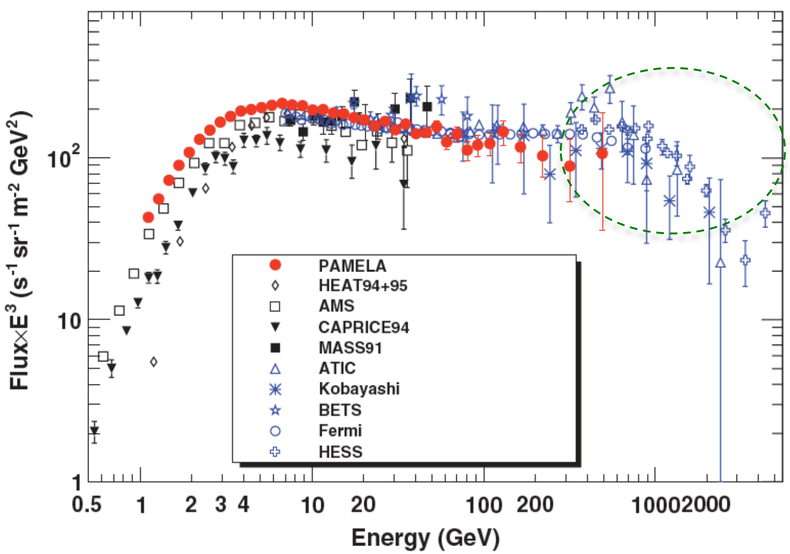
- **Altitude 500 km**
- **Inclination 97.4°**
- **Period 95 minutes**
- **Sun-synchronous orbit**

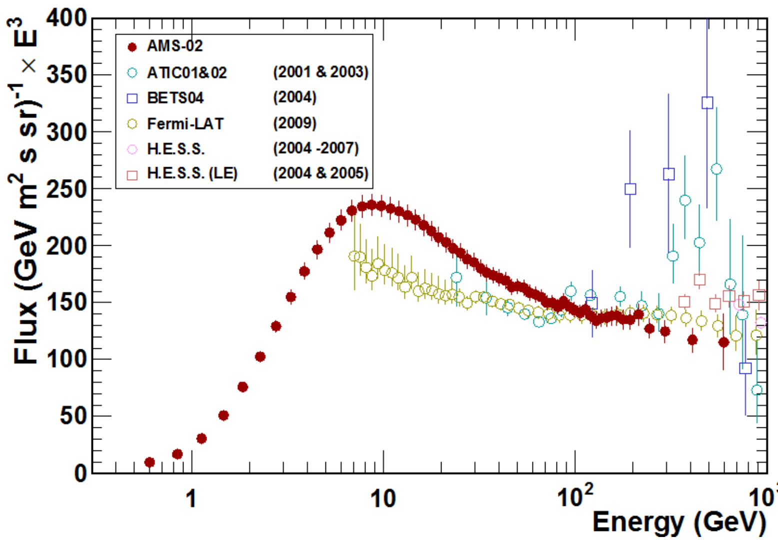


Scientific Objectives of DAMPE

- **High energy particle detection in space**
  - **Search for Dark Matter signatures with e, γ**
  - **Study of cosmic ray spectrum and composition**
  - **High energy gamma ray astronomy**

Covering 2 GeV - 10 TeV e/γ, 30 GeV - 100 TeV CR
Excellent energy resolution and tracking precision
Complementary to Fermi, AMS-02, CALET, ISS-CREAM, …

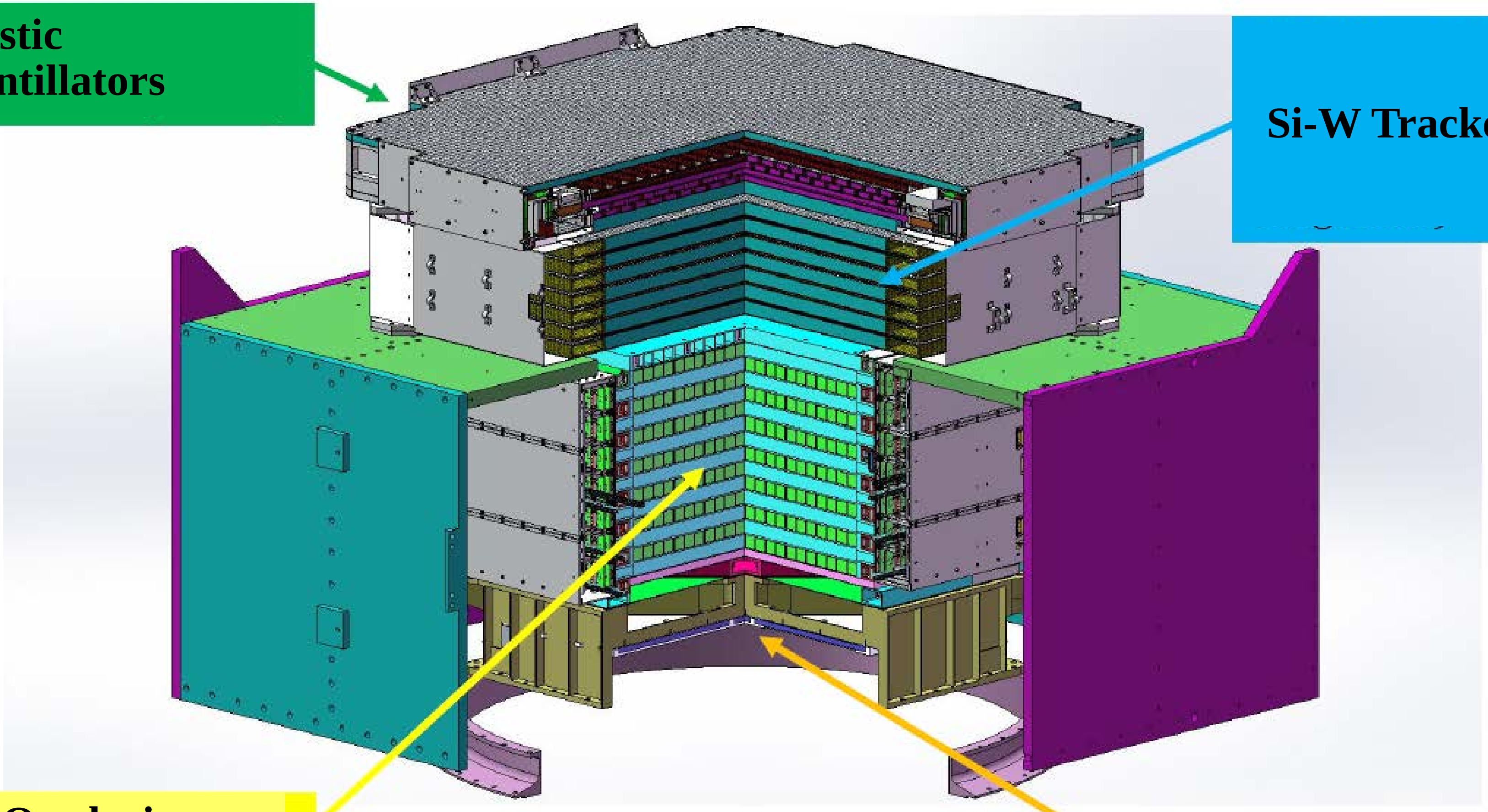




DAMPE APPARATUS

Plastic Scintillators

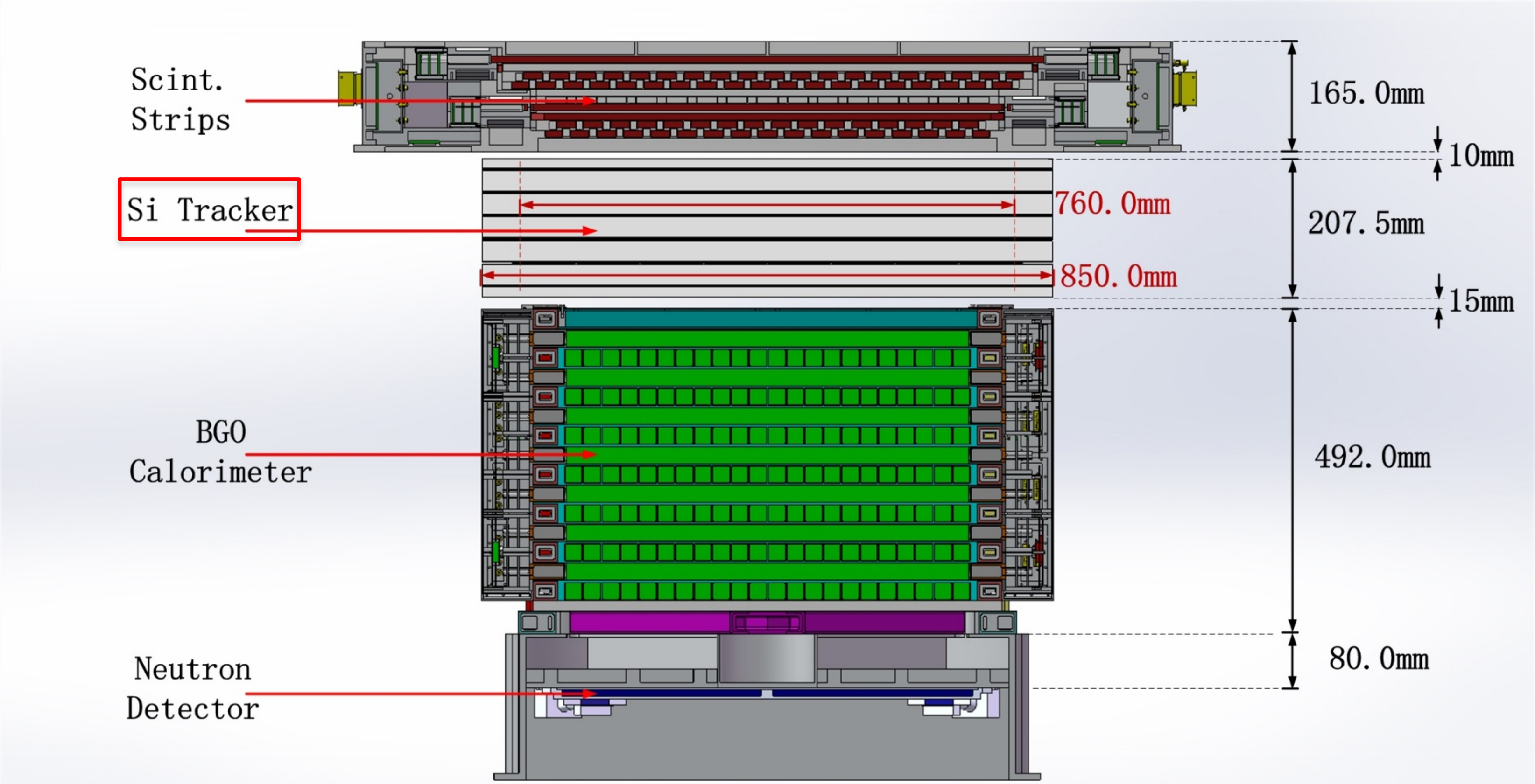
Si-W Tracker



BGO calorimeter

Neutron Detector

DAMPE Detector Layout



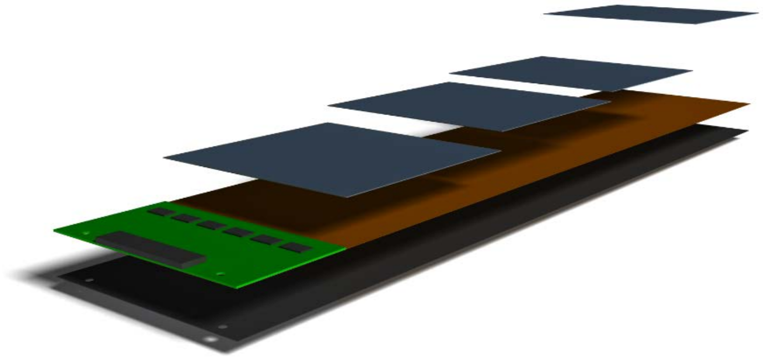
- **Scintillator strips, Silicon tracker, BGO calorimeter, neutron detector**
- **Combine a γ-ray space telescope with a deep imaging calorimeter**
  - **Silicon tracker/converter + BGO imaging calorimeter**
    - **Total ~33 X_0 → deepest detector in space**

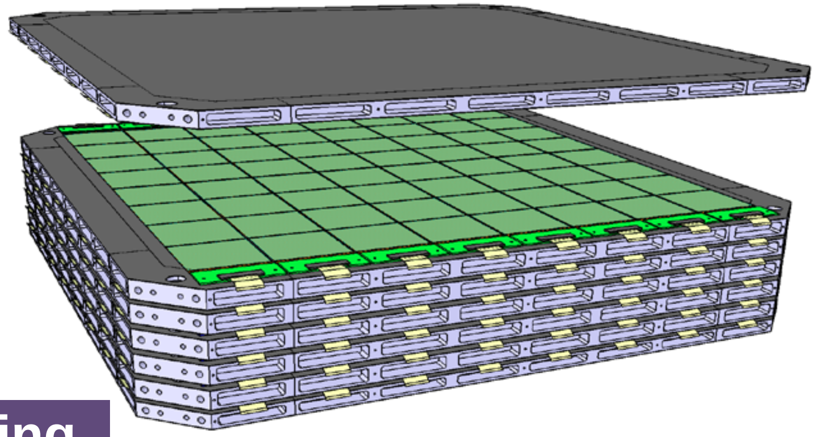
Silicon Tungsten Tracker (STK)

- 12 layers of silicon micro-strip detector, 7 support planes
  - o Plane: carbon fiber face sheet with Al honeycomb core
  - o Sensor 9.5 x 9.5 cm^2, 4 sensors bonded together to form a ladder
  - o 16 ladders on each face of the support plane, x-view and y-view
    - Except top and bottom planes: only one face has ladders
    - Readout every other channel, readout pitch 242μm

- Tungsten plates integrated in trays 2, 3, 4 counting from the top
  - o Total 1.43 X_0 for photon conversion

Detection area 76cm x 76cm





UniGE, INFN Perugia & Bari, IHEP Beijing

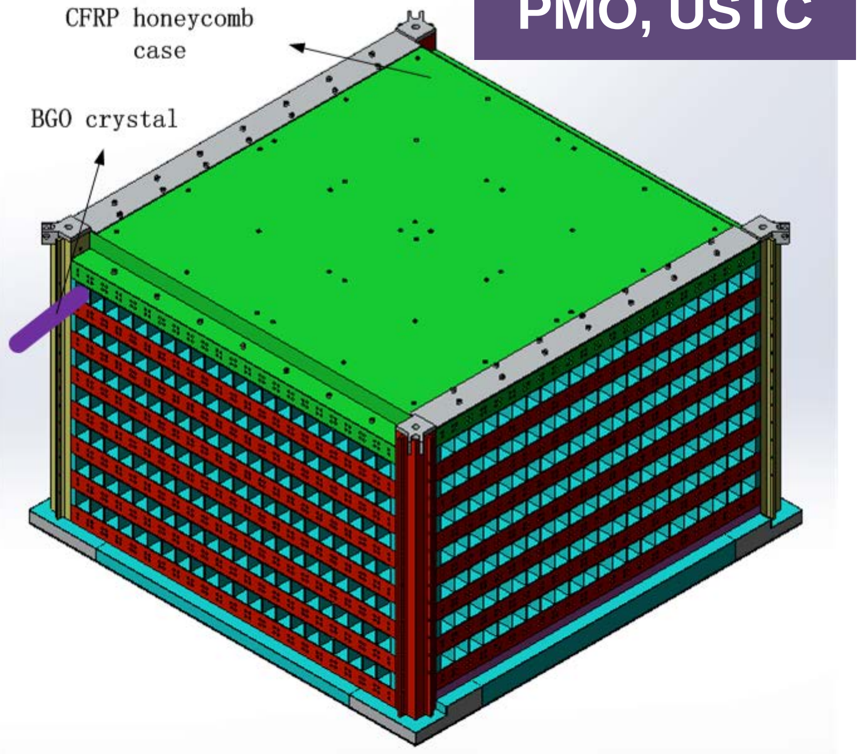
BGO Calorimeter (BGO)

- **14-layer BGO hodoscope, 7 x-layers + 7 y-layers**
  - **BGO bar 2.5cm × 2.5cm, 60cm long, readout both ends with PMT**
    - Use 3 dynode (2, 5, 8) signals to extend the dynamic range
  - **Charge readout: VA160 with dynamic range up to 12 pC**
  - **Trigger readout: VATA160 to generate hit signal above threshold**
    - Detection area 60cm × 60cm

PMO, USTC

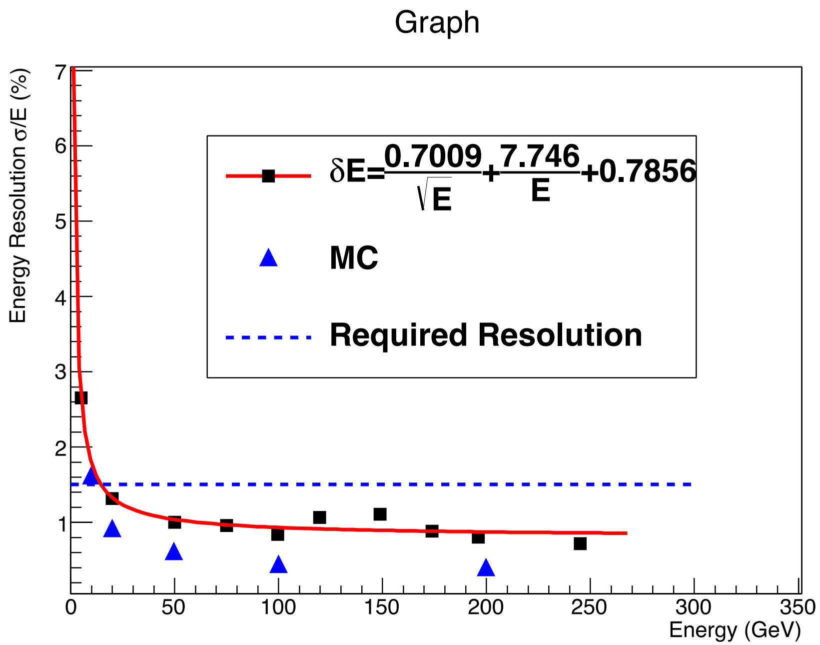
Total thickness $31X_0$

Measure electron/photon energy with great precision between 5 GeV - 10 TeV

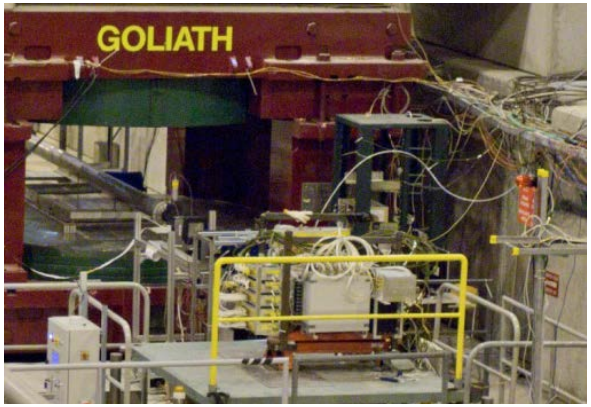


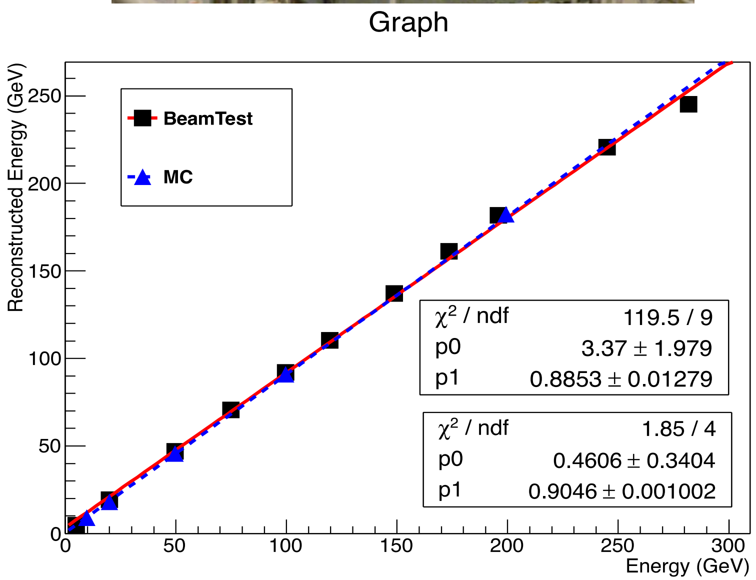
BGO Performance

- **A prototype calorimeter (12 layers, 30cm × 30cm) was tested with high energy electrons and protons beams at CERN in October 2012.**
  - **Resolution <1.2% above 20 GeV (requirement 1.5% at 100 GeV)**



Goal 1% at 800 GeV





good linearity

DAMPE e/γ Performances

Photons

Range	5GeV-10TeV
Effective Area	$3000cm^2$@10GeV
Field of View	2.8 sr
Geometry Factor	$0.81m^2sr$
Energy resolution	1.5%@100GeV
Angular resolution	0.1°@10GeV
Point source Sensitivity	$8.5\times10^{-11}cm^{-2}s^{-1}$

Electrons

Range	5GeV-10TeV
Geometry Factor	$0.3m^2sr$
Energy resolution	1.5%@100GeV
Angular resolution	0.1°@10GeV
Proton rejection	10^5
Gamma separation	100

F. Loparco, BOHEME 2014, Italy

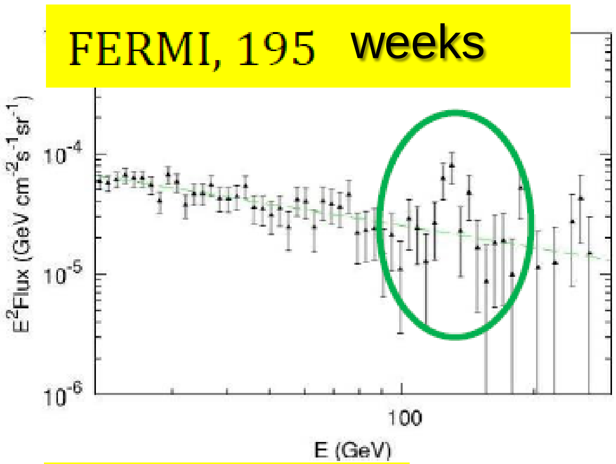
DAMPE compared to AMS-02 and Fermi

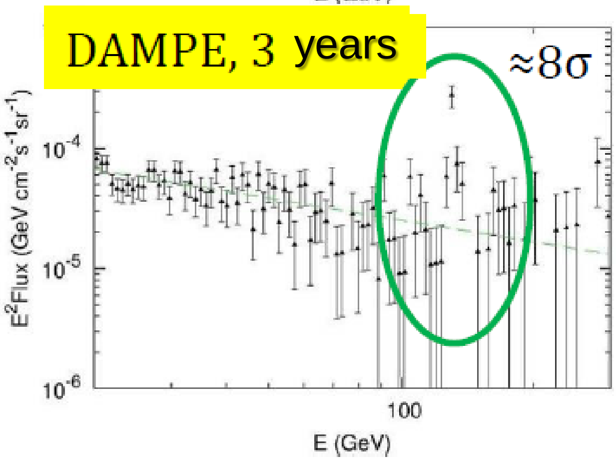
	DAMPE	AMS-02	FERMI-LAT
Energy Range (GeV)	5 - 10^4	0.1 - 10^3	0.02 - 300
Energy resolution for e/γ @100 GeV	1.5%	3%	10%
Angular resolution for e/γ @100 GeV	0.1°	0.3°	0.1°
Proton rejection factor	10^5	10^5 - 10^6	10^3
Calorimeter depths (X_0)	31	17	8.6
Acceptance (m^2sr)	0.29 (0.36 per il solo BGO)	0.09 (ECAL)	1

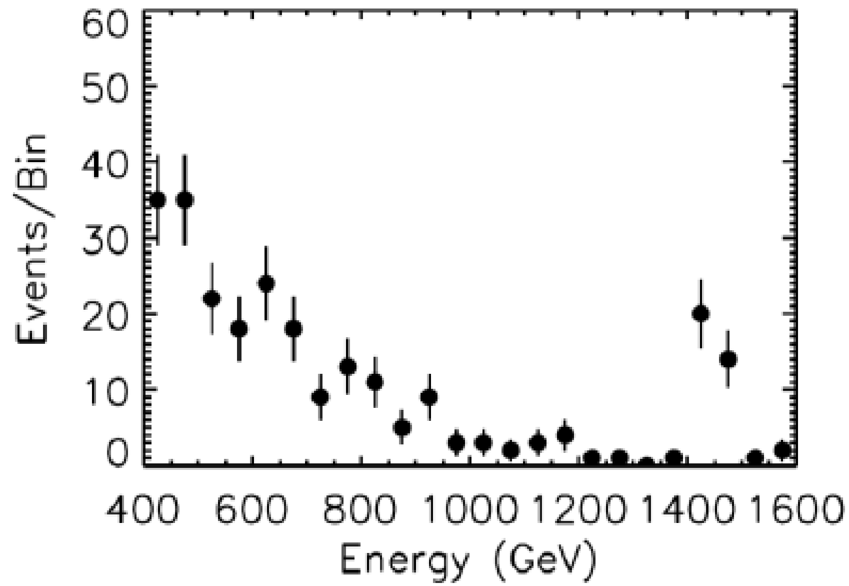
F. Loparco, BOHEME 2014, Italy

Search for γ lines

- **Energy resolution of 1% for E>100 GeV allows DAMPE to detect possible lines due to WIMP annihilations in the γ-ray spectrum**





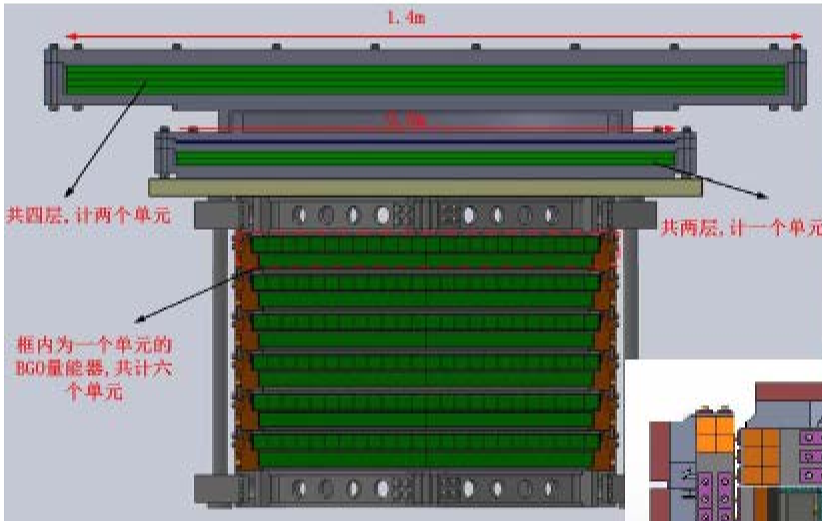


Simulation of a γ line at1.4TeV due to DM annihilation from the galactic center (300° <l<60° , |b|<10°):
- Annihilation cross section <σv>γγ= 10^{-25}cm^{3}s^{-1}
- NFW DM profile
- The simulation includes the diffuse galactic background

Expected results for six months of data taking.

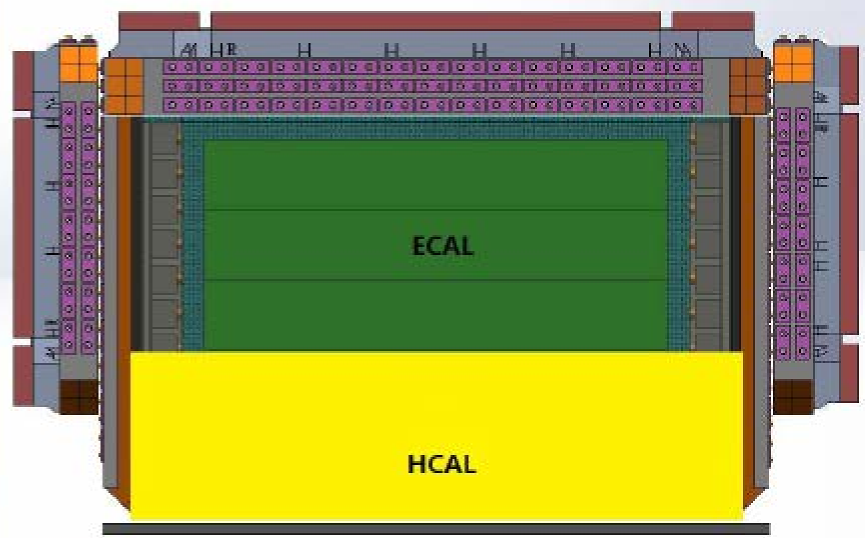
F. Loparco, BOHEME 2014, Italy

Two Dark Matter Detection Experiments

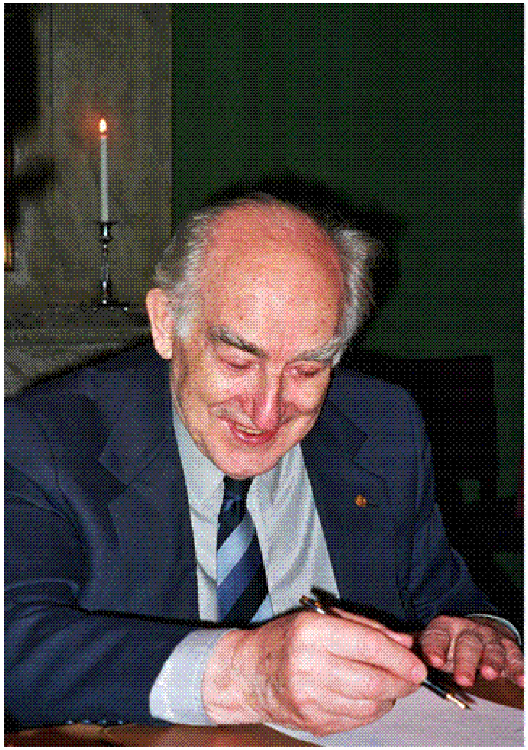


High Energy cosmic Radiation Detection facility (HERD) onboard China's space station: ~2000 kg payload. Launch time ~2020

China's dark matter detection satellite experiment: 1200 kg payload. Expected launch time ~2015



GAMMA-400



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) proposed the GAMMA-400 project in Russia to search for indirect signals of dark matter particles studying the gamma-ray sky. Within the framework of this project, which has become international, the precision gamma-ray telescope GAMMA-400 has been designed.

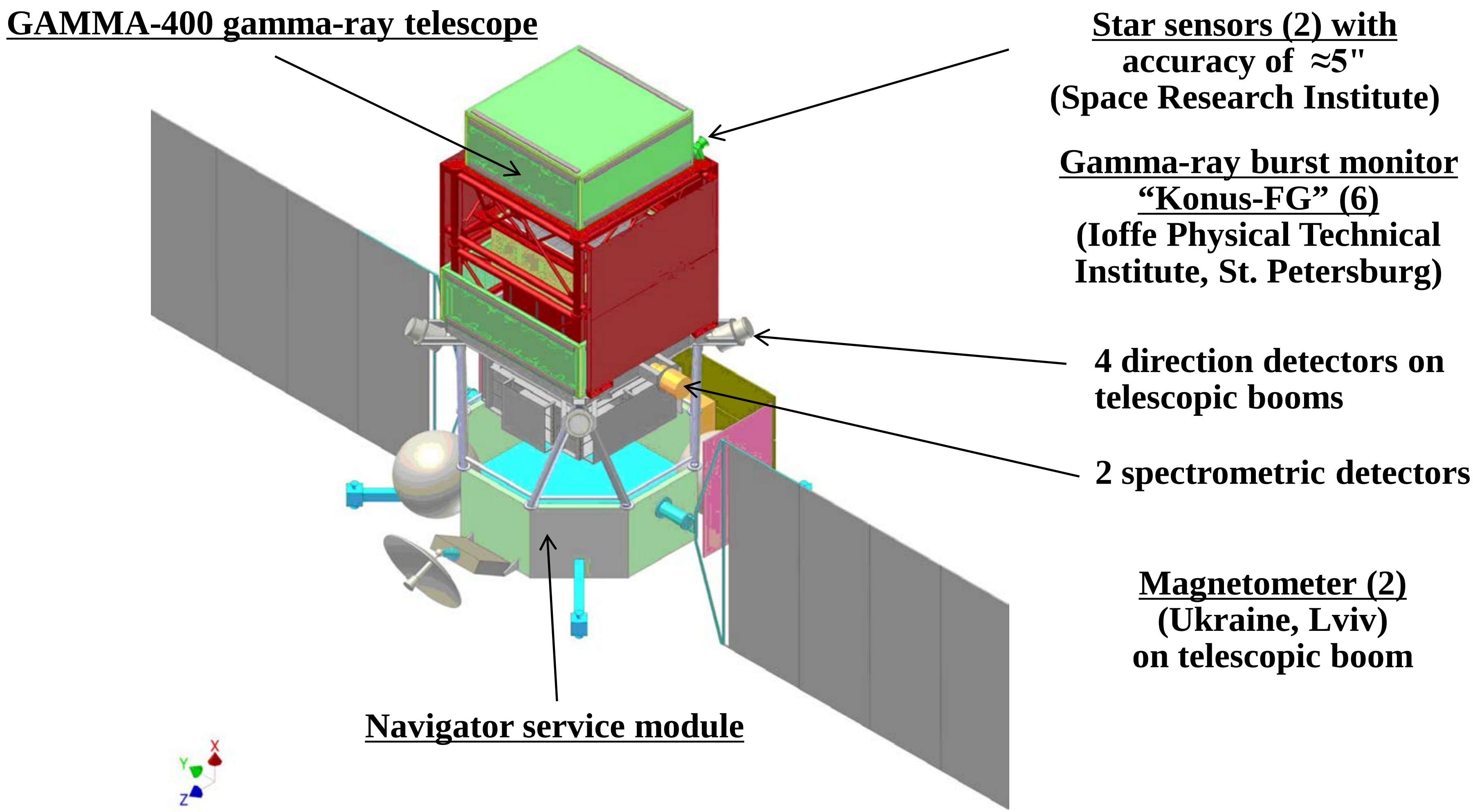
Cooperation in the design and production of scientific equipment

Russian scientific organizations	Foreign scientific organizations
LPI RAS – Leading Institute	INFN (Italy) – Converter/Tracker and Calorimeter
NRNU MEPhI – TOF and A/C detectors	INAF (Italy) – Converter/Tracker
NIIEM — design, temperature control system	Taras Schevchenko National University (Ukraine) — Ukrainian main collaborator
NIISI RAS — electronics	CrAO (Ukraine) — ground-based observatio
Ioffe Institute — Konus-FG burst monitor	IKI (Ukraine) — magnetometer
IKI — star sensor	ISM (Ukraine) — scintillators
IHEP — calorimeters, scintillators	KTH (Sweden) — anticoincidence
TsNIIMASH — space qualification	

GAMMA-400

- **Mission approved by ROSCOSMOS (launch currently scheduled by 2019)**
- **GAMMA-400 will be installed onboard the platform “Navigator” manufactured by Lavochkin**
  - **Scientific payload mass 4100 kg (rocket changed from Zenith to Proton-M)**
  - **Power budget 2000 W**
  - **Telemetry downlink capability 100 GB/day**
  - **Lifetime ~ 10 yrs**

GAMMA-400 SCIENTIFIC COMPLEX ON THE NAVIGATOR SERVICE MODULE



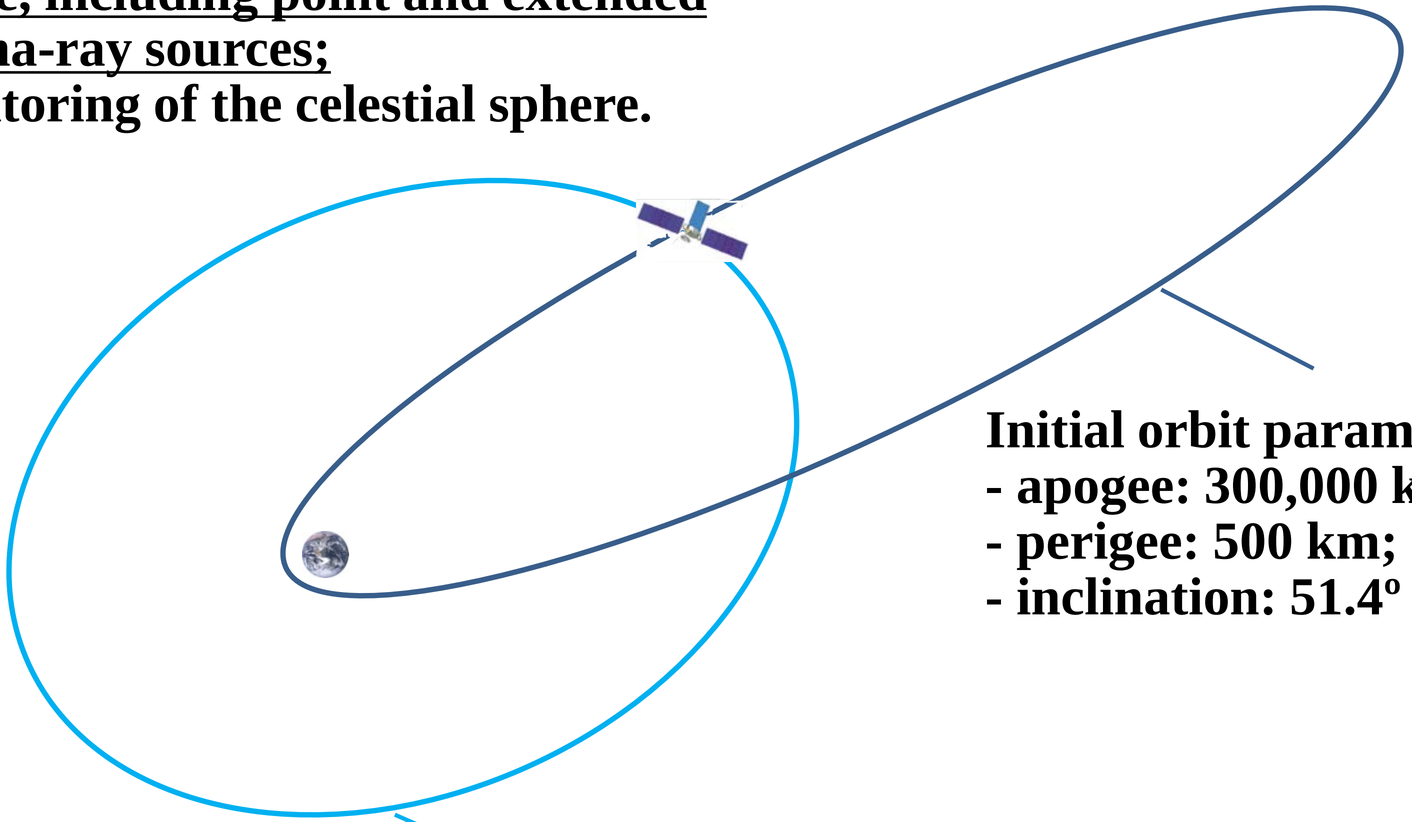
The GAMMA-400 spacecraft and Navigator service module are designed by Lavochkin.

OBSERVATION MODES AND THE GAMMA-400 ORBIT EVOLUTION

Observation modes:

- continuous long-duration (~100 days) observation of some regions of celestial sphere, including point and extended gamma-ray sources;

-monitoring of the celestial sphere.



Initial orbit parameters:
- apogee: 300,000 km:
- perigee: 500 km;
- inclination: 51.4º

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

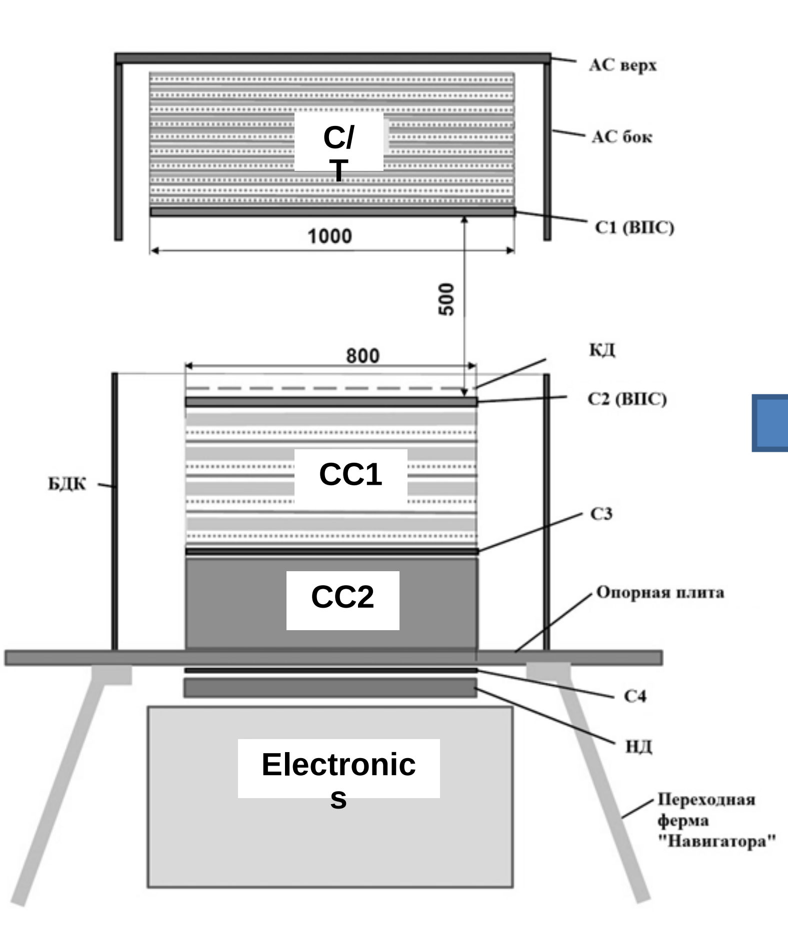
GAMMA-400

- **Original Russian design focused on:**
  - **High Energy Gamma-rays (~ 10 GeV – 3 TeV)**
  - **High energy electrons (e^+ and e^-) up to TeV**
- **Scientific objectives (from Russian proposal):**
  - **"To study the nature and features of weakly interacting massive particles, from which the Dark Matter consists"**
  - **"To study the nature and features of variable gamma-ray activity of astrophysical objects, from stars to galactic clusters"**
  - **"To study the mechanisms of generation, acceleration, propagation and interaction of cosmic rays in galactic and intergalactic spaces"**

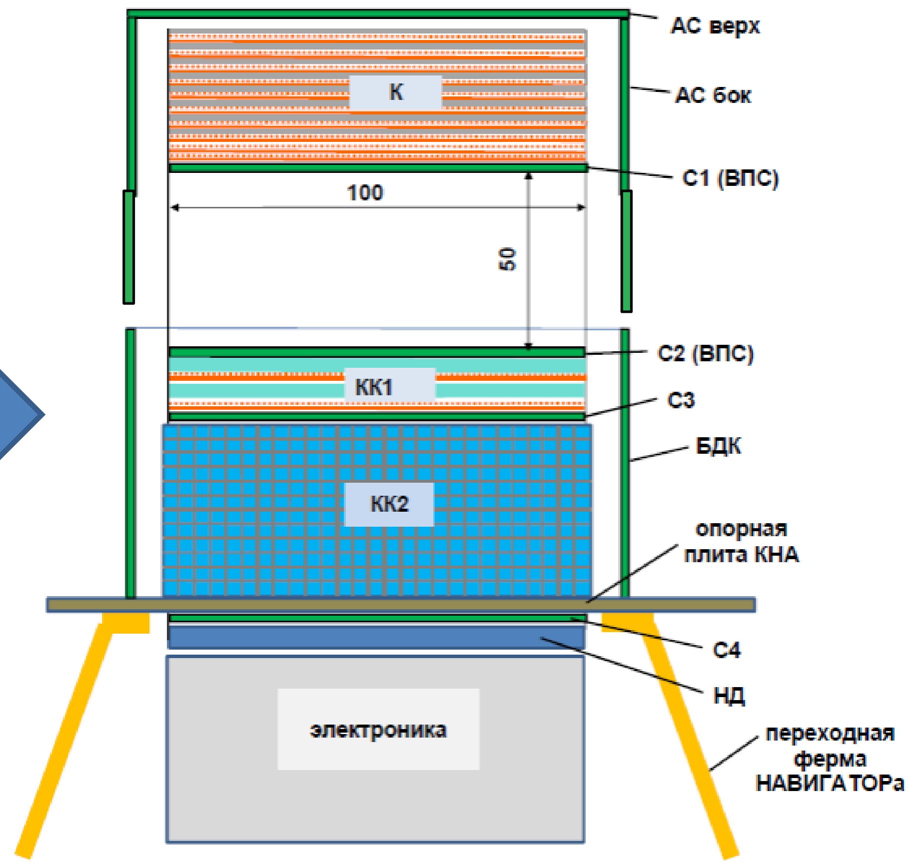
Improvements in the GAMMA-400 design and performance

- **During the last years, the collaboration between Italian and Russian groups have resulted in a new version of the apparatus for the G-400 mission. The guidelines of this work have been:**
  - **to develop a jointly defined dual instrument that, taking into account the currently available financial resources, optimizes the scientific performance and improves them with respect to the B1 version: this new "baseline" version, called B2, has been agreed upon by both (Russian and Italian) sides during a collaboration meeting held in Moscow in February 2013.**

GAMMA-400

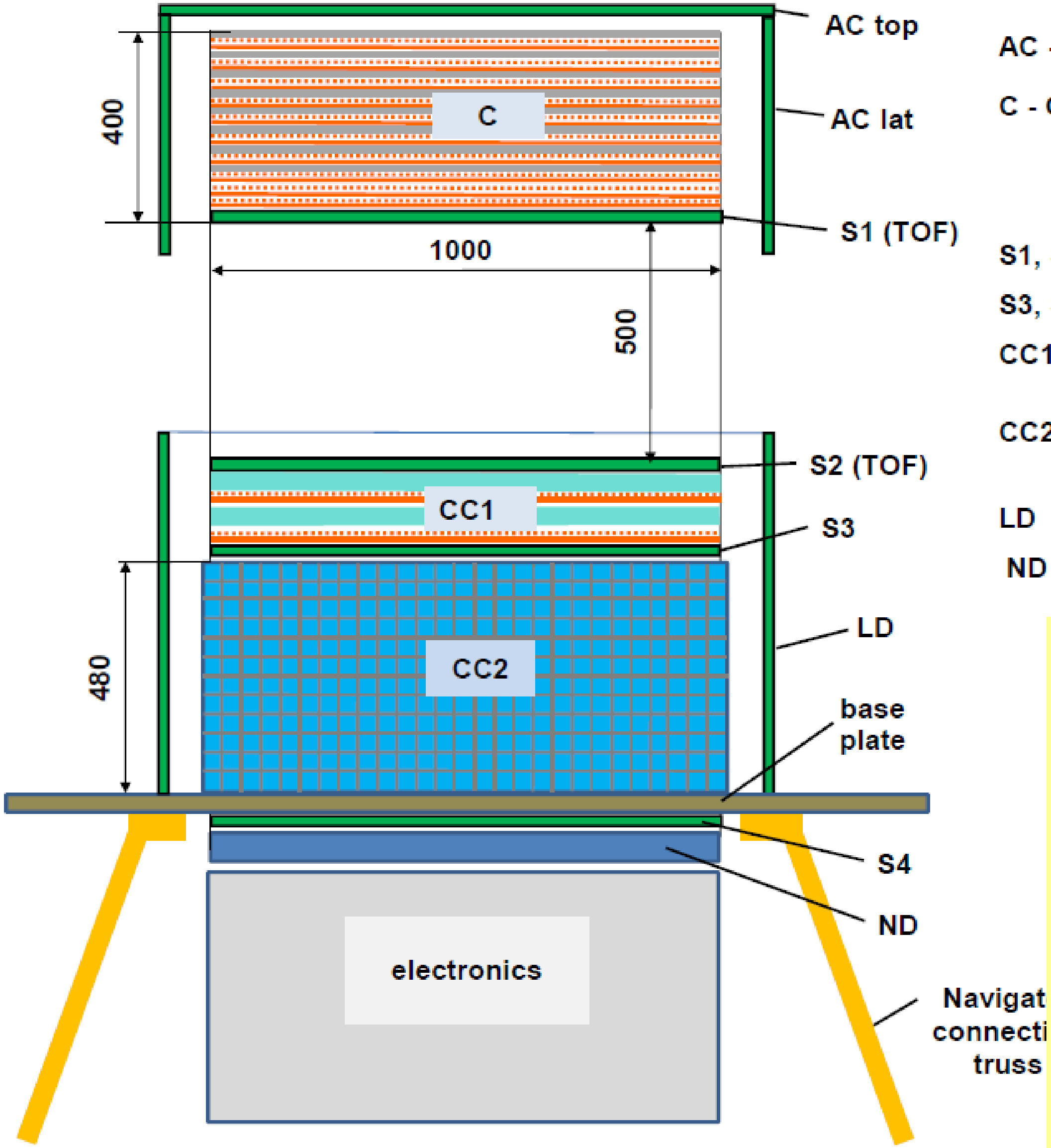


Original Russian proposal (2011)



Jointly agreed Russian-Italian proposal (2013)

The new B2 baseline



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

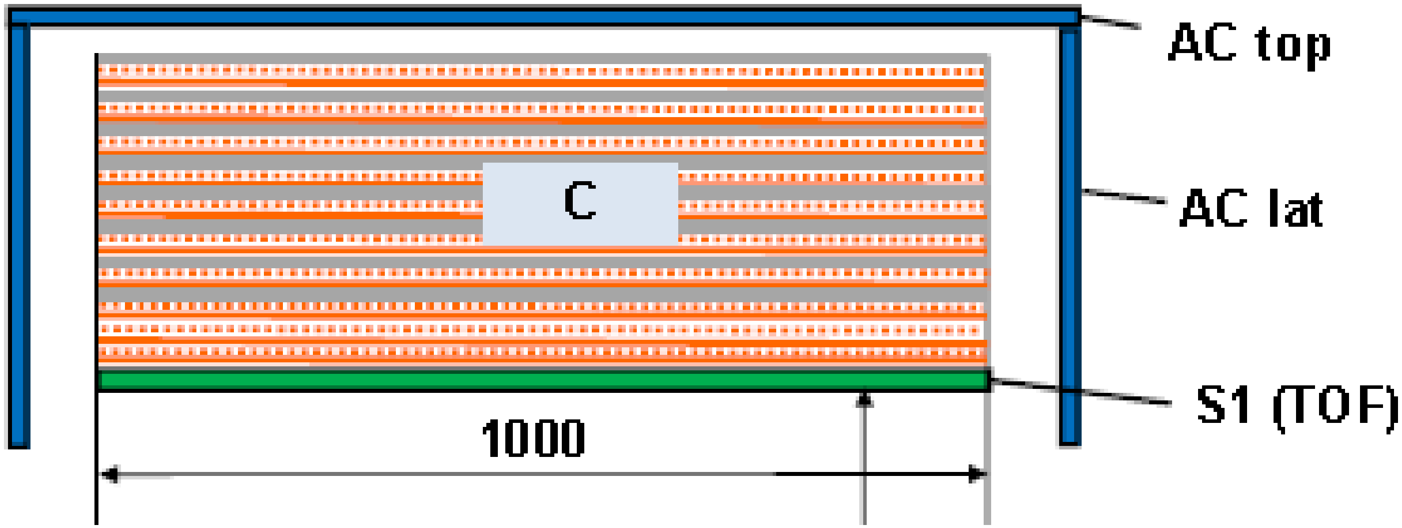
LD - 4 lateral calorimeter detectors

ND - neutron detector

B2 over B1 improvements:

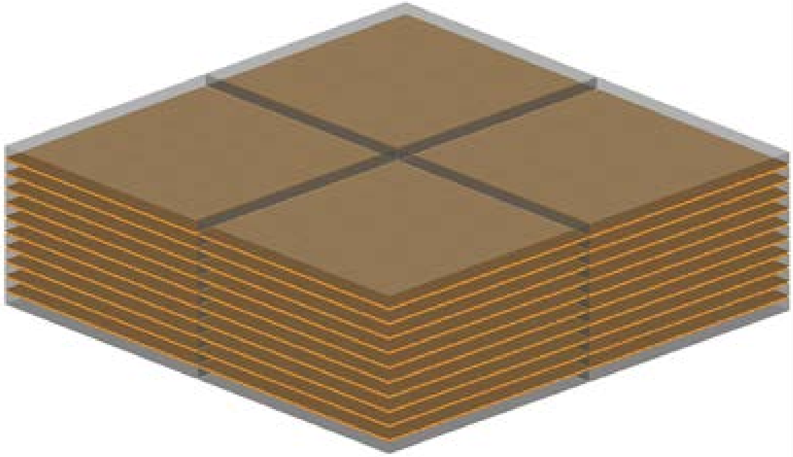
- **Introduction of the highly segmented homogeneous calorimeter with CsI cubes ⇒ improved energy resolution, extended GF with lateral particle impingement, nuclei capability**
- **Increase of the planar dimensions of the calorimeter (from 80 cm x 80 cm to 100 cm x 100 cm) ⇒ larger A_{eff}**
- **Si strip detector pitch of the 2 CC1 layers decreased from 0.5 mm to 0.1 mm**

B2 detectors: Converter/Tracker



- 8 layers W $0.8X_0$ + 8 planes Si (x,y)
- 2 layers of Si (x,y), no W

B2 detectors: Converter/Tracker



- Homogeneous Si-W Tracker
- 4 towers (~ 50 cm x 50 cm each);
- 8 W/Si-x/Si-y planes + 2 Si-x/Si-y planes (no W);
- Thickness of each plane 0.1 X_0
- Each sensor ~ 9.7 cm x 9.7 cm from 6" wafers;
- Sensors arranged in ladders (5 detectors/ladder), 1 ladder ~ 50 cm;
- Read-out pitch 240 μm (capacitive charge division), 384 strips/ladder
- Implant pitch:
  - Either 120 μm (one strip every 2 is read-out)
  - Or 80 μm (one strip every 3 is read-out)
- 2000 silicon detectors;
- 153600 readout channels, 2400 front-end ASICs (64 channels/ASIC)
- Power consumption (FE only): ~ 80 W

V. Bonvicini, CSN2 2013, Trento, Italy

B2: Converter/Tracker

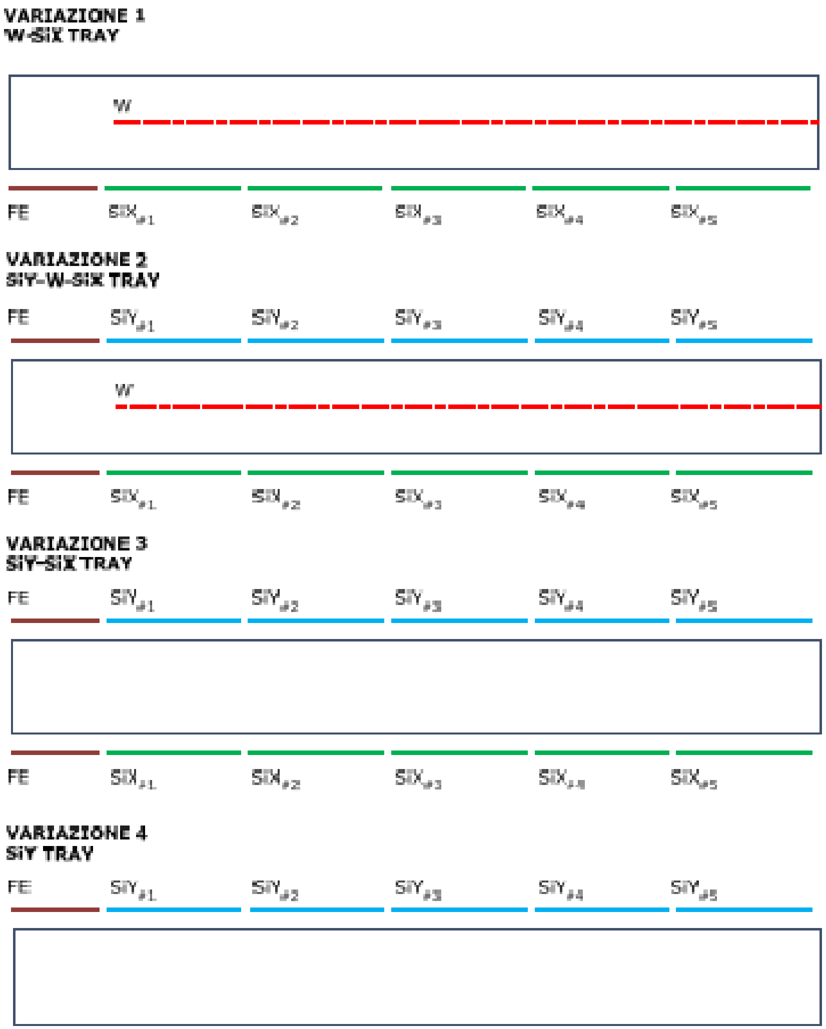


Figura 1 – Tray Type

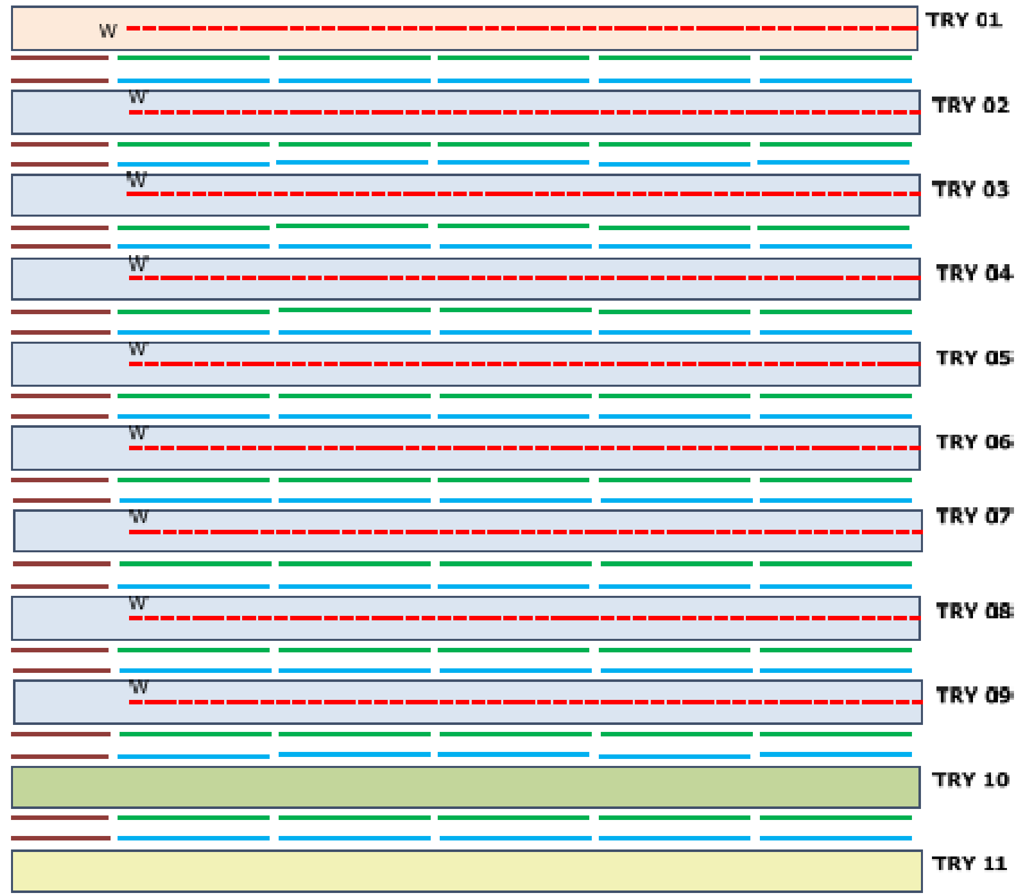
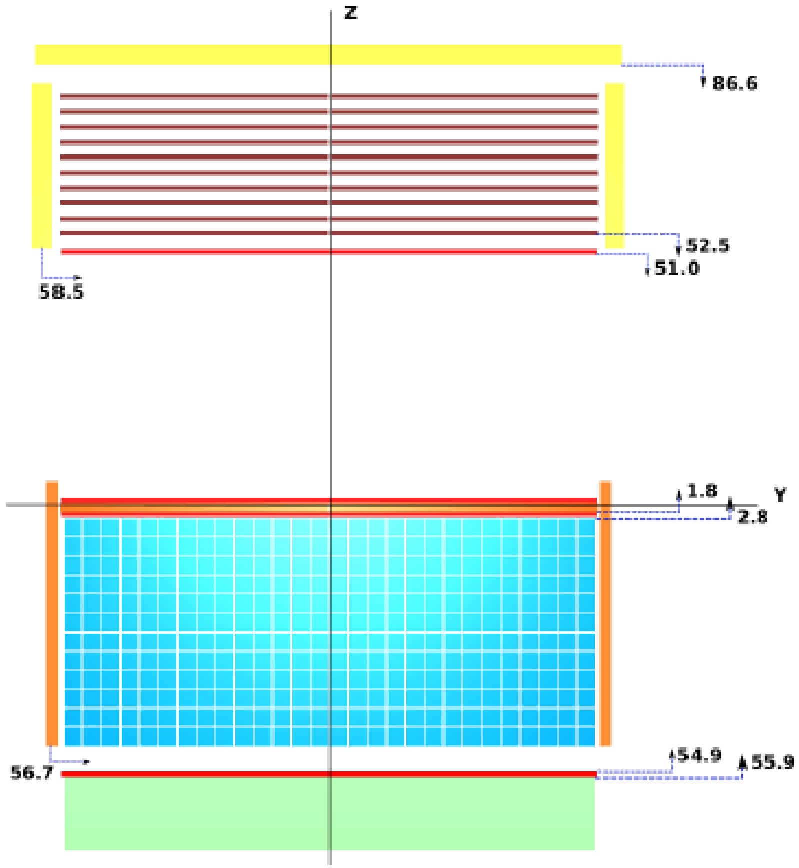


Figura 2 – Tower Assembly

V. Bonvicini, CSN2 2013, Trento, Italy

B2: Calorimeter

GAMMA-400: Calorimeter



Calorimeter CC1 (Si-CsI(Tl))

N layers	2
Si pitch	0.1 mm
Size	1x1x0.04 m^3
X_0	2
λ_I	0.1

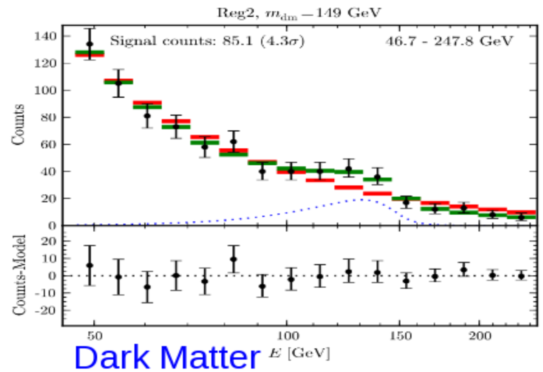
Calorimeter CC2 (CsI(Tl))

NxNxN	28x28x12
L	3.6 cm
Size	1x1x0.47 m^3
X_0	54.6x54.6x23.4
λ_I	2.5x2.5x1.1
Mass	1683 kg

V. Bonvicini, CSN2 2013, Trento, Italy

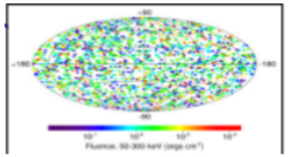
Physics with GAMMA-400

Galactic/ Extragalactic gamma-ray sources

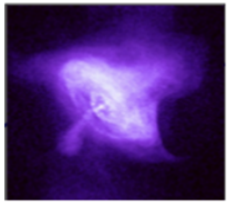


Dark Matter

CR propagation

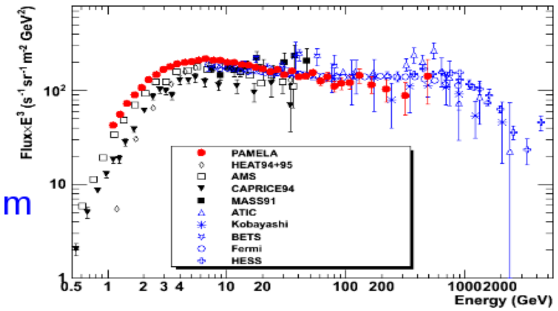


GRBs

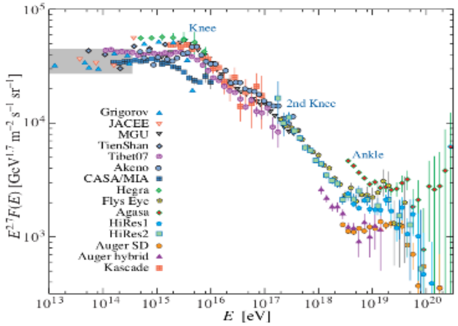


Pulsars

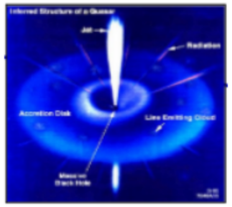
Electron spectrum



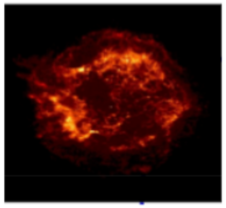
Knee origin



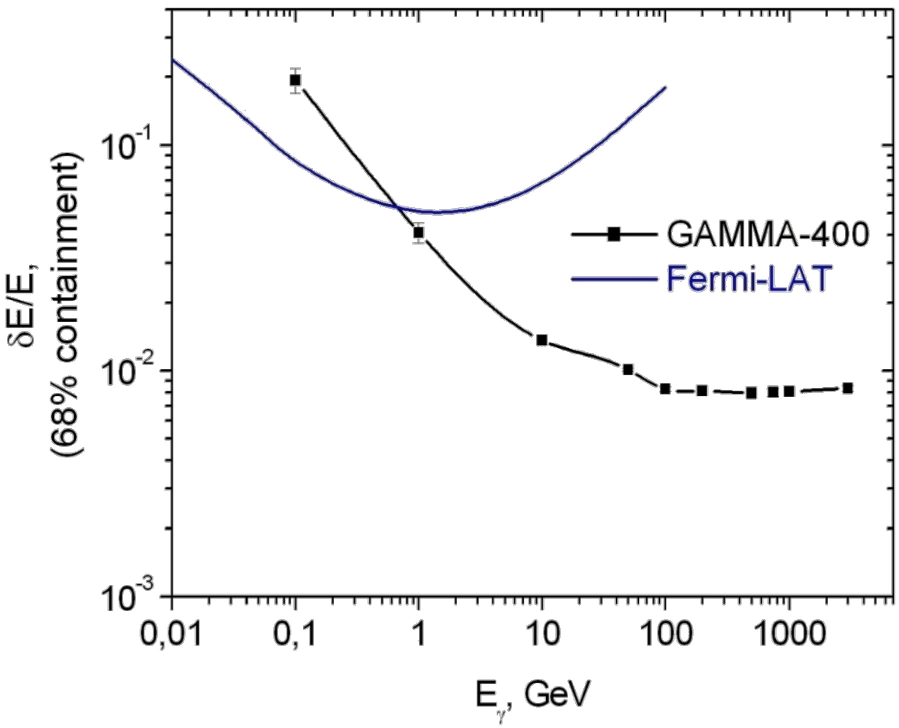
CR origin and acceleration mechanisms



AGNs

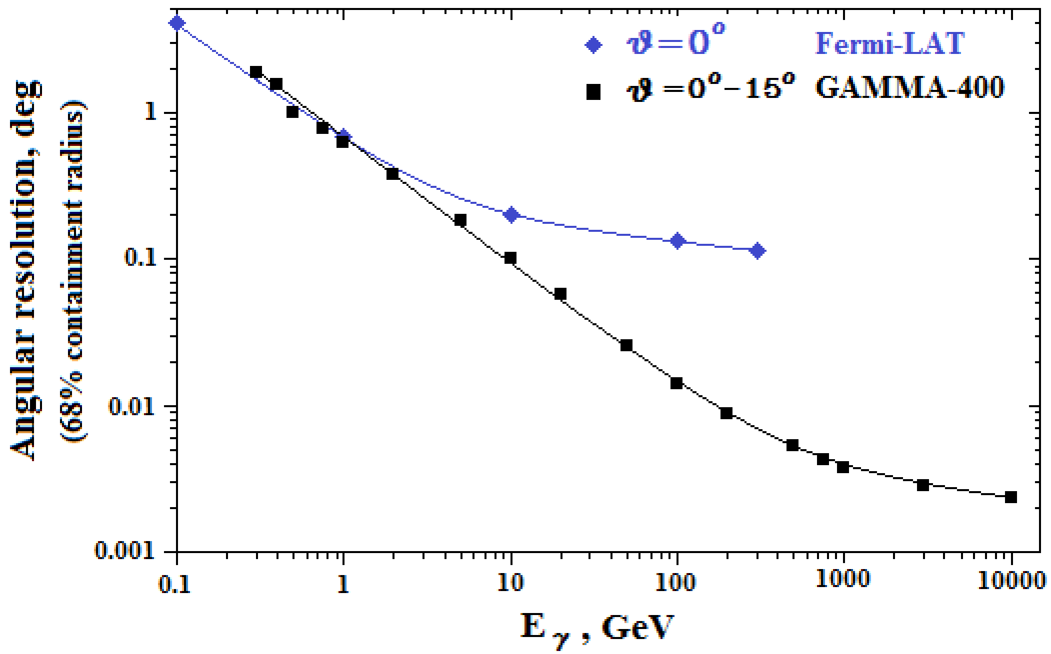


SNRs



Energy resolution vs. energy for normal incidence for Fermi-LAT P7 V6 and GAMMA-400

Angular resolution vs. energy for Fermi-LAT P7 V6 (for normal incidence) and GAMMA-400 (for θ=0° -15°)



A. Galper, Workshop on the Future of Dark Matter Astroparticle Physics 2013, Trieste, Italy

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_γ > 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_γ > 100 GeV)	~0.1°	~0.01°
Calorimeter - thickness	CsI ~8.5X_0	CsI(Tl)+Si strips ~25X_0
Energy resolution (E_γ > 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

A. Galper, Workshop on the Future of Dark Matter Astroparticle Physics 2013, Trieste, Italy

γ-ray lines in diffuse radiation : Perspectives for GAMMA-400

Back-on-envelope estimate:

Sensitivity to the γ-ray line (flux) in the diffuse radiation can be expressed in simplified form as: $I_\gamma = \frac{n_\sigma}{0.68}\sqrt{\frac{2F_{bck}\eta E_\gamma}{GT}}$

where n is a number of σ , F_{bck} is a (diffuse) background, ηEγ is an energy bin width, which depends on η (energy resolution), G is a geometric factor, T is an observation time

Comparison of Fermi LAT and GAMMA-400 sensitivity:

- ηEγ for GAMMA-400 is 10X less than that for Fermi LAT at E>100 GeV,
- G for GAMMA-400 is ~ 0.5 of that for Fermi LAT,
- the sensitivity for GAMMA-400 for the same observation time is expected to be ~ 2 better than for Fermi LAT.

γ-ray line from source : Perspectives for GAMMA-400

Assumption: the line is a δ-function in energy spectrrum

Confidence estimate: Confidence of the line detection can be taken similarly to the confidence in detection of point source (probability for the background to fluctuate to create a "feature")

$$C = \frac{N_{sig}}{\sqrt{N_{bkg}}}$$

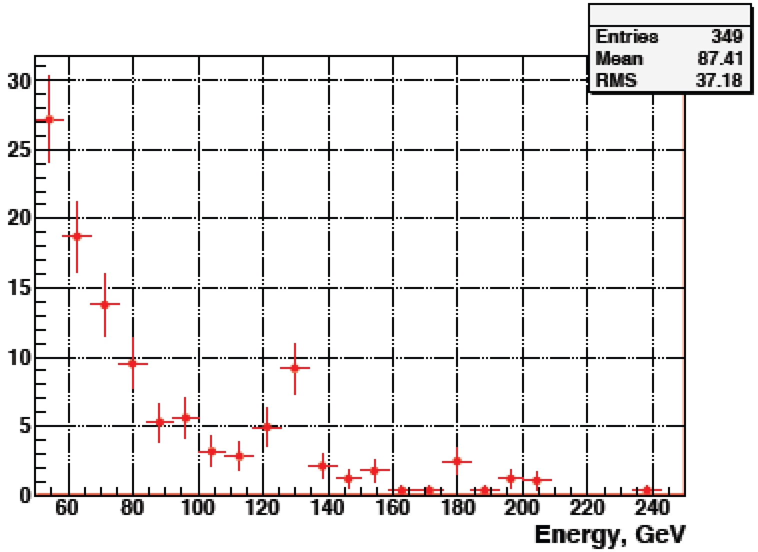
where N_{sig} is a number of events from the "line" (source), and N_{bkg} is a number of background (diffuse) events

With 10X better PSF for Gamma-400:

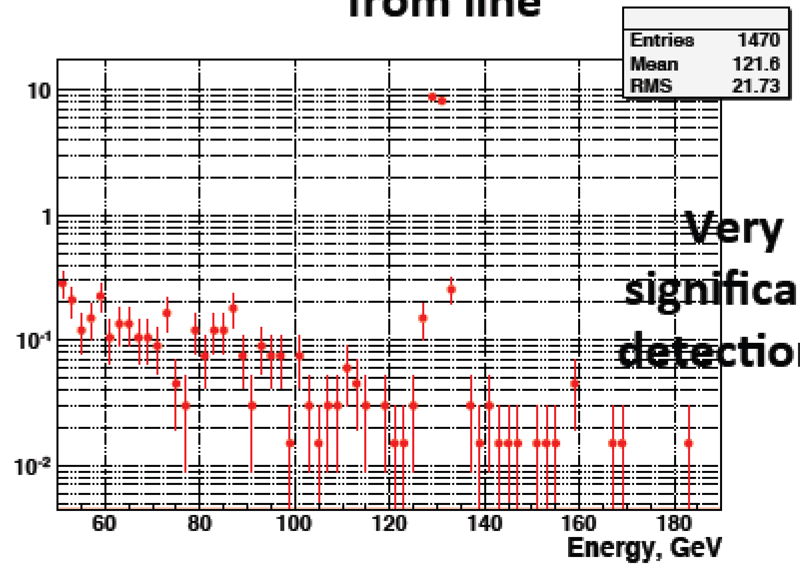
- N_{bkg} can be 100X less,
- detection confidence C will be ~5X larger, assuming twice less events from the "line" N_{sig} detected (due to smaller A_{eff})
- **All this works only for the point source!**

Increasing the energy resolution

LAT-like instrument, 300 events



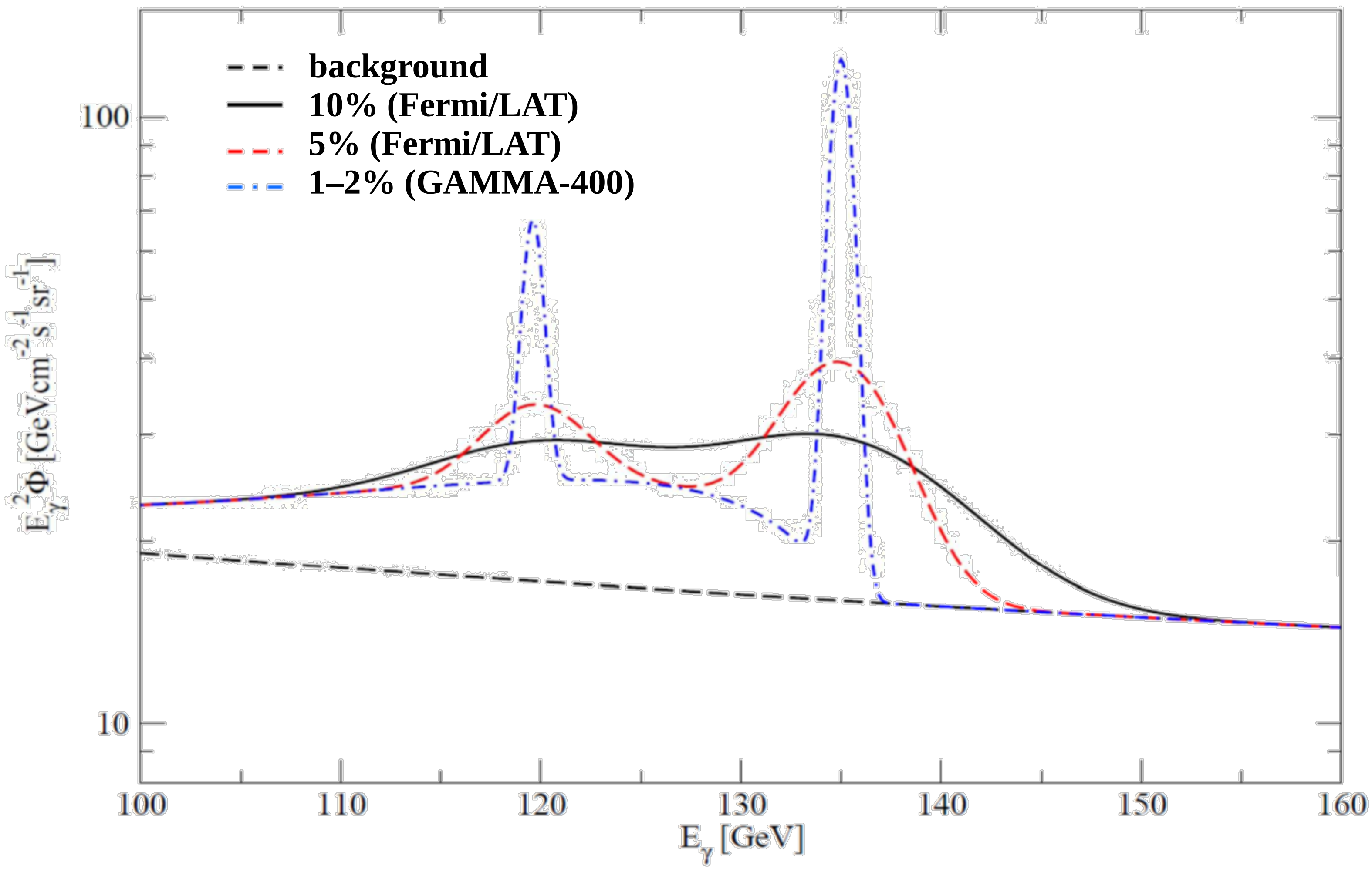
Gamma-400, 10X better dE/E, 10X better PSF (100X less background), same # of events from line



Very significant detection !

Alexander Moiseev Aspen 2013 Closing in on Dark Matter

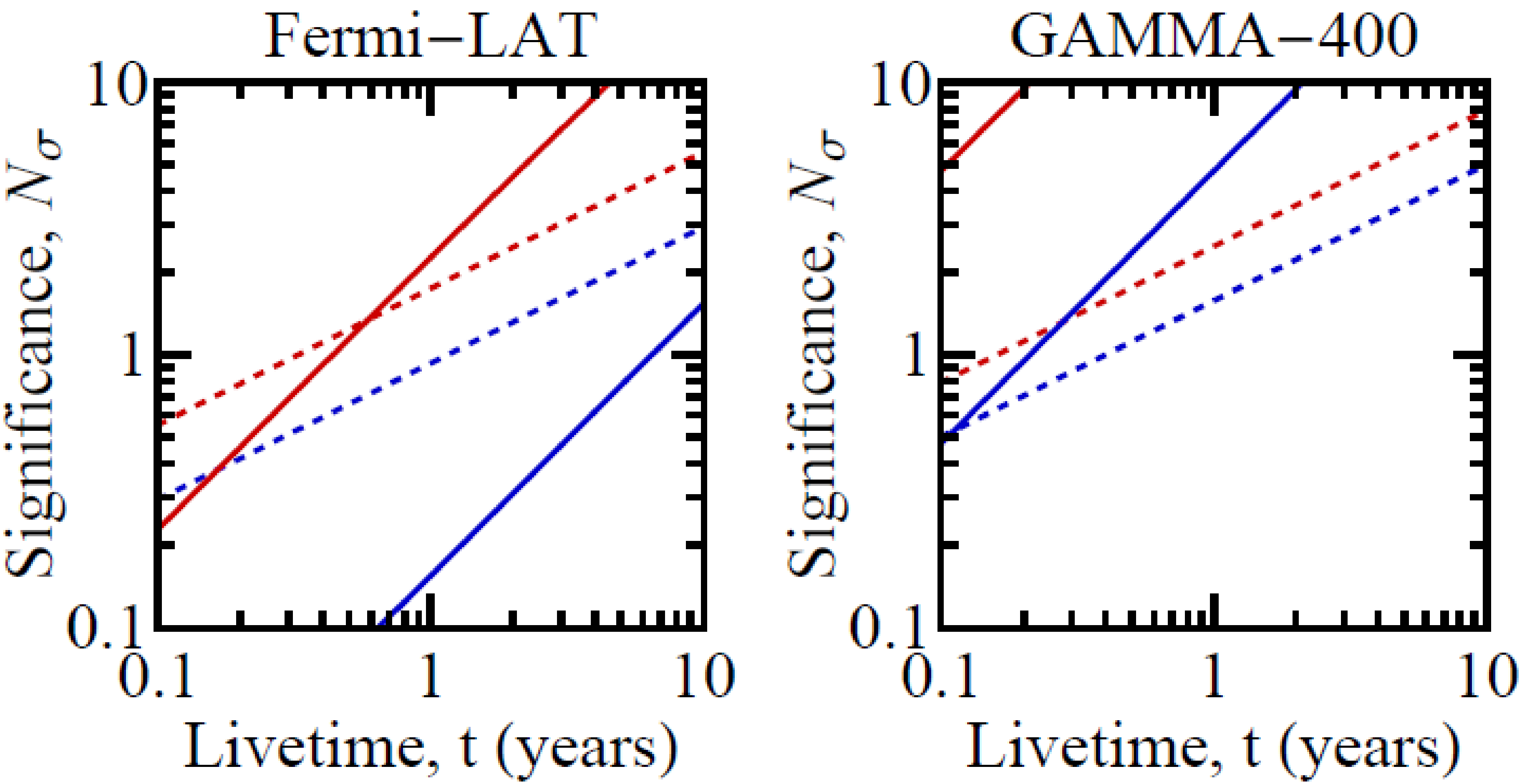
Increasing the energy resolution



The γ-ray differential energy results for a 135 GeV right-handed neutrino dark matter candidate.

L. Bergström, Phys.Rev. D86 (2012) 103514, arXiv:1208.6082

Increasing the angular and energy resolution



The expected significance of 135 GeV line in the flux spectrum (dashed lines) or the fluctuation angular power spectrum (solid lines) analysis of the diffuse γ-ray background with the Fermi-LAT or GAMMA-400 experiments.
S. S. Campbell and J.F. Beacom (2013) arXiv:1312.3945

Galactic Center

- **Expected to be the strongest source of γ-rays from DM annihilation. "EGRET GeV excess" has been in the center of DM discussion for years, until it was closed by Fermi LAT results**
- **Intense background from unresolved sources remains the main problem, assuming that the part of background created by CR interactions with the matter, is much better known and can be accounted for**
- **Potential perspectives for GAMMA-400: having >10 times better angular resolution at high energy, faint sources in dense GC area can be localized and their radiation can be removed as a background, and better model of diffuse radiation can be built. Concern: smaller effective area can make this analysis more difficult and not efficient**

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)	0.2° (E_γ~0.5 GeV)	0.1° (E_γ~1 GeV)	0.1°	0.1°	**~0.01°**	0.07°	0.07° (E_γ = 300 GeV)	0.1°	0.1° (E_γ = 100 GeV) 0.03° (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)

A. Galper, Workshop on the Future of Dark Matter Astroparticle Physics 2013, Trieste, Italy

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

Thanks!

Overview

- PANGU (PAir-productioN Gamma-ray Unit)
  - An unprecedented high resolution ($\lesssim 1°$) γ-ray space telescope dedicated to the sub-GeV (~100 MeV to ~1 GeV) region

An unique instrument to open up a frequency window that has never been explored with great precision

- A wide range of topics of Galactic and extragalactic astronomy and fundamental physics can be attacked
  - Extreme physics of extended/compact objects (extensive targets)
  - Galactic and extragalactic cosmic rays (origin, acceleration mechanism)
  - Search for Dark Matter (unique capability)
  - Detect and determine the high-energy behavior of gamma-ray transients.
  - Fundamental Physics, e.g. Baryon asymmetry in early universe
  - Solar and terrestrial high energy phenomena
- Innovative instrument concept
  - Thin target material (scintillating fiber) with magnetic spectrometer

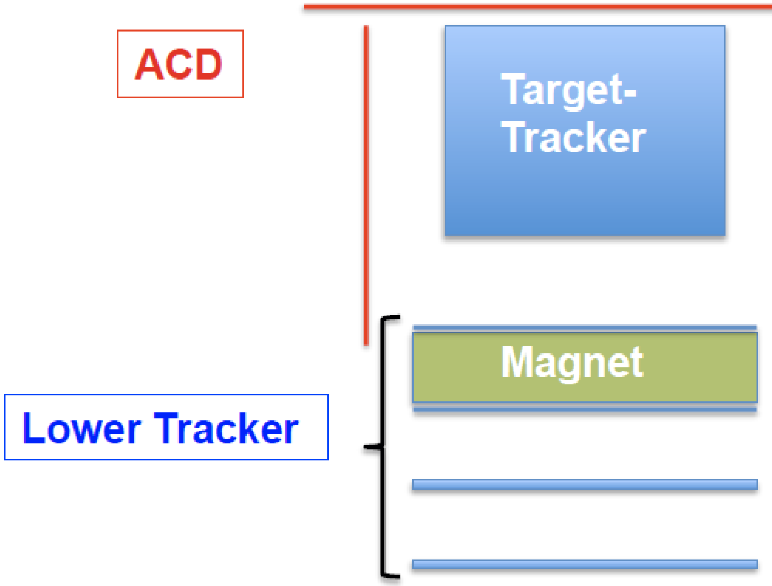
X. Wu, First Workshop on a CAS-ESA Joint Scientific Space Mission, 2014, Chengdu, Cina

Mission Concept

- Low earth orbit
- All-sky survey and pointed observations
  - With possibility to rotate the payload to study systematic effect of polarisation measurement
- Minimum lifetime three years
- Science data open to the world community

X. Wu, First Workshop on a CAS-ESA Joint Scientific Space Mission, 2014, Chengdu, Cina

Sketch of a Possible PANGU Layout

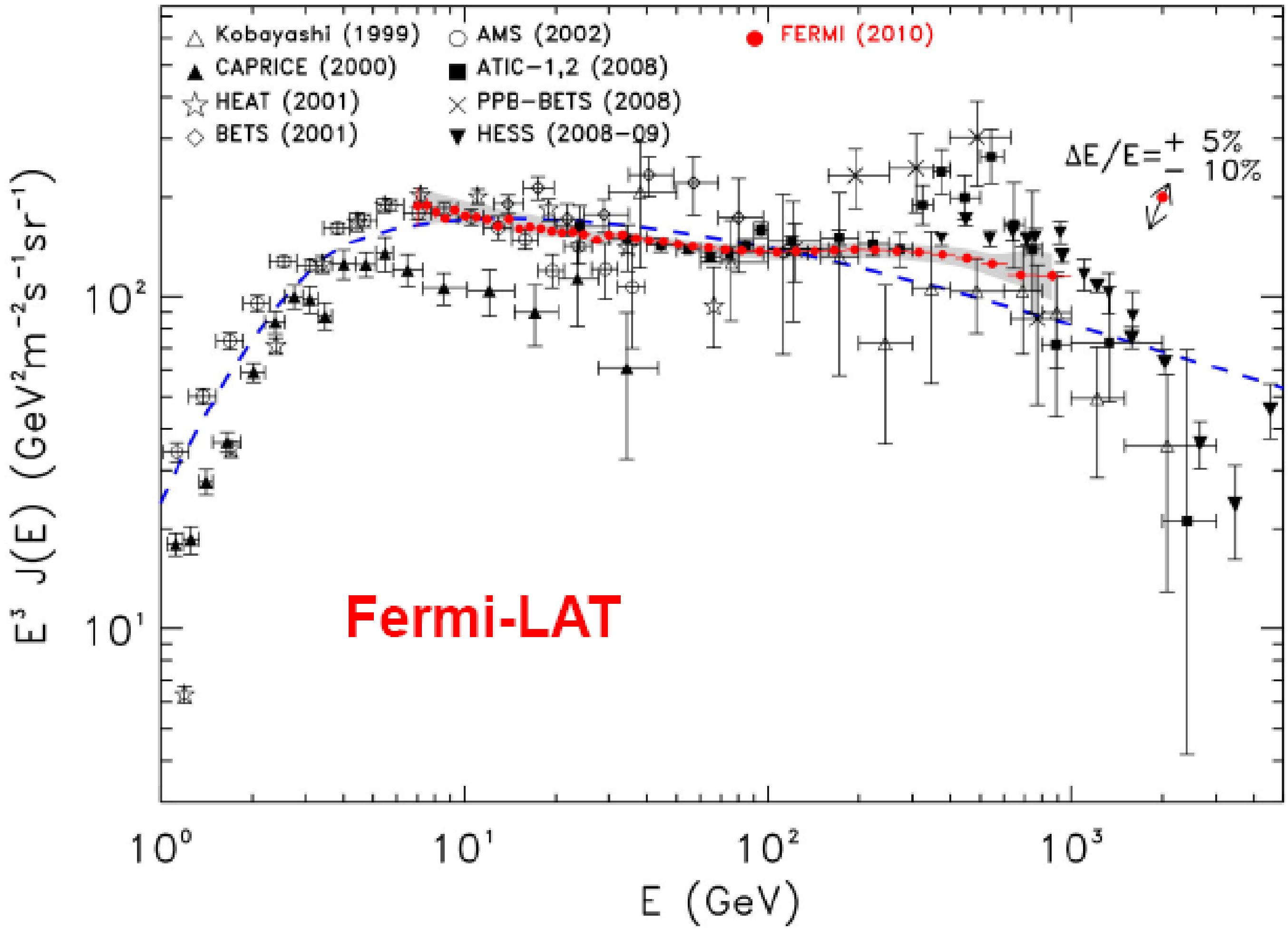


Target and magnet sizes can be easily scaled to fit with resource constraints!

- 3 sub-systems: target-tracker, magnet + lower tracker, Anticoincidence
  - Target-tracker : ~ 40 x 40 x 40 cm^3
  - Magnet: r_2 = 26 cm, r_1 = 25 cm, height 10 cm, field in +y direction
  - Lower tracker: one X-layer above, one X-layer, and two X-Y layers below, ~10 cm between layers
  - Anticoincidence detector (ACD) on 5 sides

X. Wu, First Workshop on a CAS-ESA Joint Scientific Space Mission, 2014, Chengdu, Cina

FERMI All Electron Spectrum

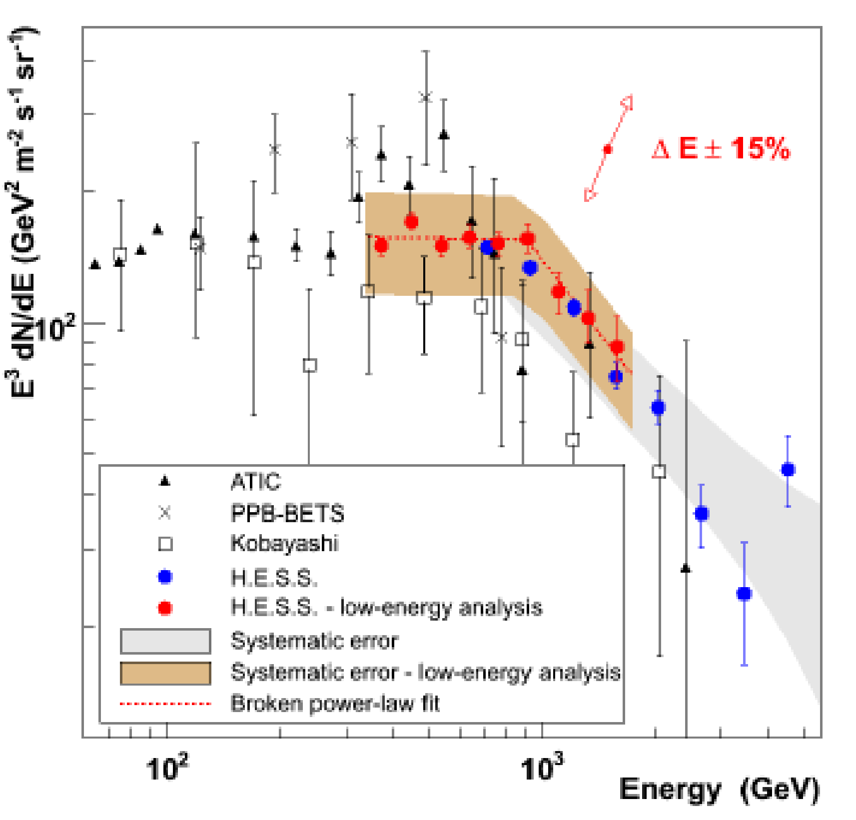


A. Abdo et al., Phys.Rev.Lett. 102 (2009) 181101
M. Ackermann et al., Phys. Rev. D 82, 092004 (2010)

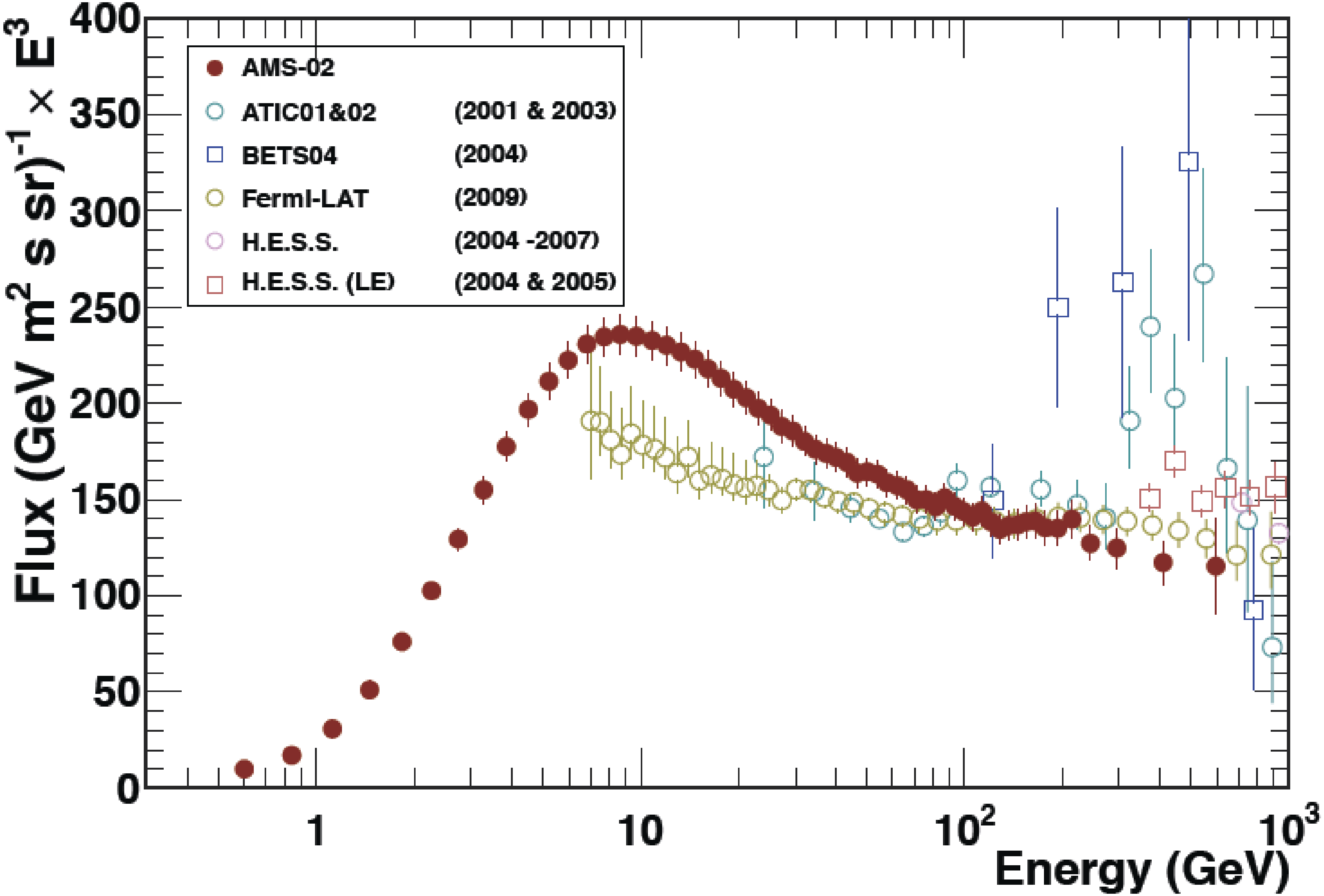
Electrons measured with H.E.S.S.

Results: Low-Energy Spectrum

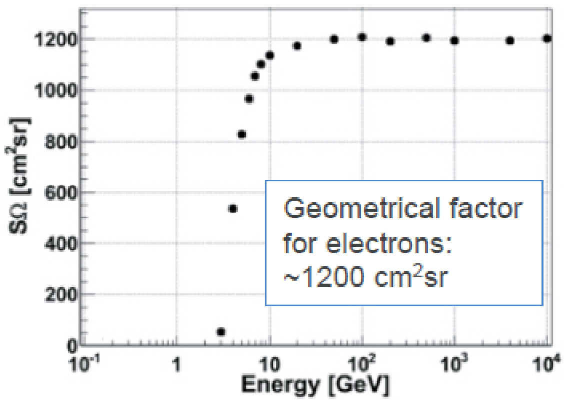
- Cuts:
  - impact distance < 100 m
  - image size in each camera > 80 photo electrons
  - Data set of 2004/2005
- Syst. uncertainty: atmospheric variations + model dependence of proton simulations (SIBYLL vs. QGSJET-II)
- Spectral index:
  $\Gamma_1 = 3.0 \pm 0.1(\text{stat}) \pm 0.3(\text{syst.})$
  $\Gamma_2 = 3.9 \pm 0.1(\text{stat}) \pm 0.3(\text{syst.})$

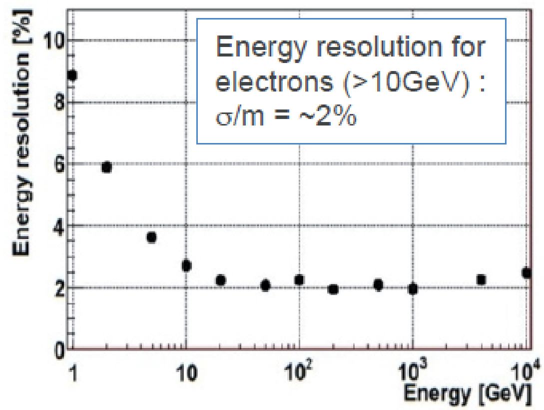


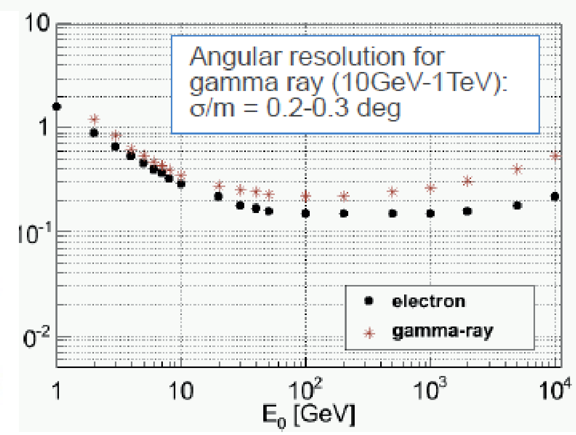
(Electron plus Positron) Spectrum
comparison with recent measurements

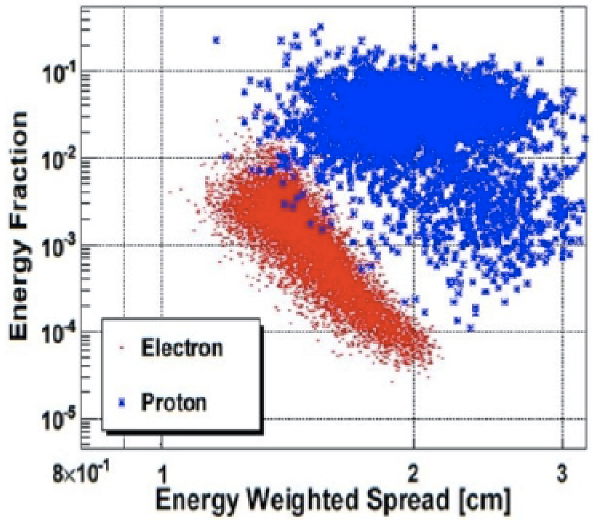


CALET Expected Performance by Simulations

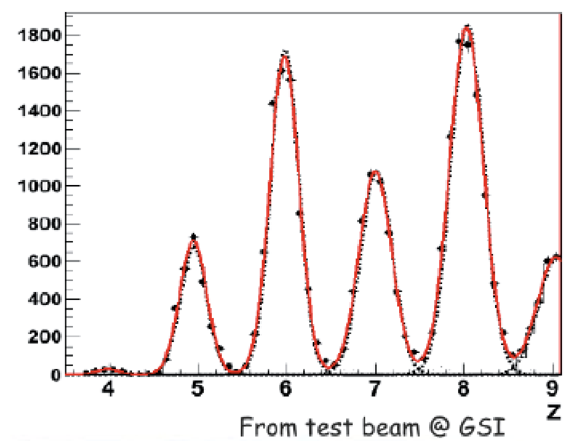








Proton rejection power at 1TeV $\approx 10^5$ with 95% efficiency for electrons



Experiment CHD

Charge resolution: $\sigma_Z = 0.15 - 0.3$

S. Torii, TeVPA 2013, Irvine, USA

CALET GRB performance

Broad energy range (from few keV X-rays to GeV-TeV gamma-rays):
long-duration GRBs, short-duration GRBs, X-ray flashes and GeV GRBs.
Sensitivity of CGBM: ~10^{-8} ergs cm^{-2} s^{-1} (1-1000 keV) for 50 s long bursts.

Parameters	CAL	CGBM
Energy range	1 GeV - 10 TeV (GRB trigger)	HXM: 7 keV - 1 MeV (goal 3 keV - 3 MeV) SGM: 100 keV - 20 MeV (goal 30 keV - 30 MeV)
Energy resolution	3% (10 GeV)	HXM: ~3% (662 keV) SGM: ~15% (662 keV)
Effective area	~600 cm^2 (10 GeV)	68 cm^2 (2 HXMs), 82 cm^2 (SGM)
Angular resolution	2.5° (1 GeV) 0.35° (10 GeV)	-
Field of view	~45° (~2 sr)	~3 sr (HXM), ~4π sr (SGM)
Dead time	2 ms	40 μs
Time resolution	62.5 μs	GRB trigger: 62.5 μs (event-by-event data) Normal mode: 125 ms with 8 ch, 4 s with 512 ch (histogram data)

S. Torii, TeVPA 2013, Irvine, USA

Clumps : Perspectives for GAMMA-400

Features to search for:

- Hard (Not power-law) energy spectrum
- Extended spatial dimensions
- Lack of counterparts in other wavelengths

Approach:

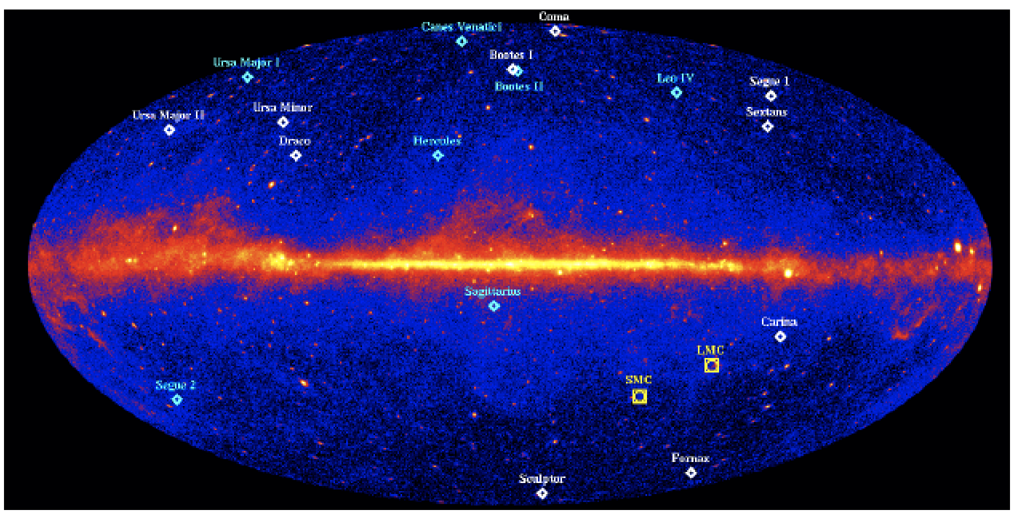
- Check among available by that time non-ID Fermi LAT and GAMMA-400 (if found) γ-sources to meet the above criteria

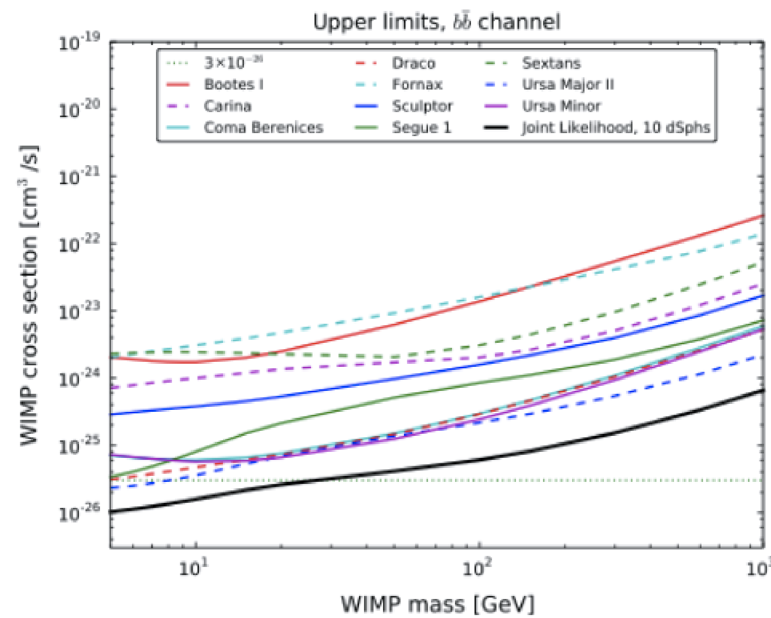
Perspectives:

- Better energy resolution will allow to better distinguish between power-law "normal source" and hard DM spectra, potentially increasing the number of satellite candidates
- Better angular resolution will allow to better distinguish between point and extended sources, also potentially increasing the number of satellite candidates
- Larger number of available by that time non-ID Fermi LAT sources shall also increase the number of satellite candidates

Dwarf Spheroidal Galaxies: prominent DM candidates

- Search for γ–ray emission from Dwarf Spheroidal Galaxies (satellite galaxies) with large J-factor (line-of-sight integral of the squared DM density)
- Fermi LAT applied a joint likelihood analysis to 10 satellite galaxies: no dark matter signal was detected. Upper limit for <σ *v*> is set to ~10^{-26} cm^3 s^{-1} at 5 GeV and 5 x 10^{-23} cm^3 s^{-1} at 1 TeV (Ackermann et al. PRL 107, 241302, 2011)





Dwarf Spheroidal Galaxies: Perspectives for GAMMA-400

Joint likelihood (for 10 dSphs) of agreement between observed γ-radiation and that predicted by DM model:

Energy-binned γ-ray data; should be better for Gamma-400

$$L(D|\mathbf{p}_W, \{\mathbf{p}\}_i) = \prod_i L_i^{\mathrm{LAT}}(D|\mathbf{p}_W, \mathbf{p}_i) \times \frac{1}{\ln(10) J_i \sqrt{2\pi}\sigma_i} e^{-[\log_{10}(J_i) - \overline{\log_{10}(J_i)}]^2/2\sigma_i^2},$$

Binned Poisson likelihood fully accounting of the PSF (E); should be better for Gamma-400

Improved dE/E and PSF for GAMMA-400 should provide better sensitivity for this analysis