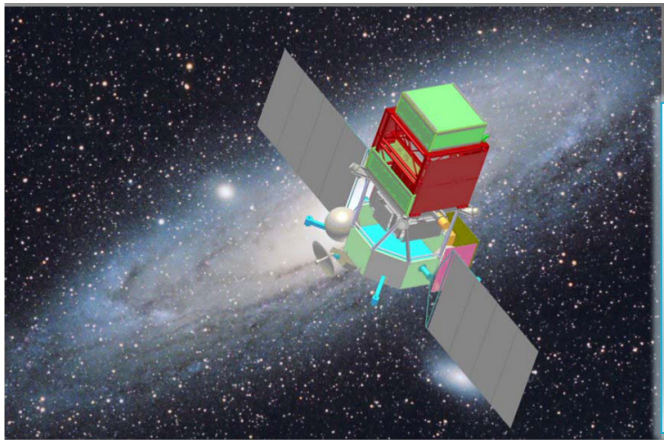
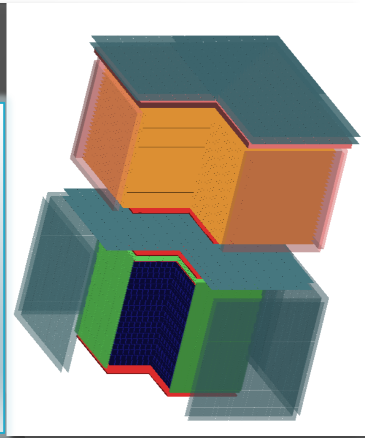


beyond the current generation of scientific space missions



GAMMA-400

INFN: Firenze, Pisa, Pavia, Roma II, Trieste
INAF: Roma, Bologna Milano

Address all current front edge CR science tasks

Challenging high performance instrument

Complementarity to ground experiments

SUMMARY

- THE PRESENT SITUATION
- POSSIBLE SCIENTIFIC PERSPECTIVES
- INSTRUMENT EVOLUTION
- REACH OF THE PROPOSED INSTRUMENT

11th AGILE Science Workshop:
"Gamma-rays and Galactic Cosmic Rays", May 16-17, 2013
ASI Headquarters, Via del Politecnico, Rome

УТВЕРЖДАЮ
Директор
Учреждения Российской академии наук
Физического института
им. П.Н. Лебедева РАН
академик
Месяц Г.А.
2009 г.

ПРОЕКТ ГАММА-400

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

От ФИАН

Руководитель научного направления
академик
Гинзбург В.Л.
2009 г.

Научный руководитель проекта
ГАММА-400
профессор, г.н.с.
Гальпер А.М.
21 мая 2009 г.

Москва, 2009 г.

Translation

APPROVED
the director of the
ution of the Russian
demy of Sciences
ev Physical Institute
an
Mesyats G.A.

THE GAMMA-400 PROJECT

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

From LPI

Director of scientific branch
academician
Ginzburg V.L.

Scientific director of the
GAMMA-400 project
professor
Galper A.M.

Moscow, 2009

Gamma-400

Approved mission by ROSCOSMOS

Originally devoted Gamma rays study (30 GeV – 1 TeV)
& high-energy electrons and positrons.

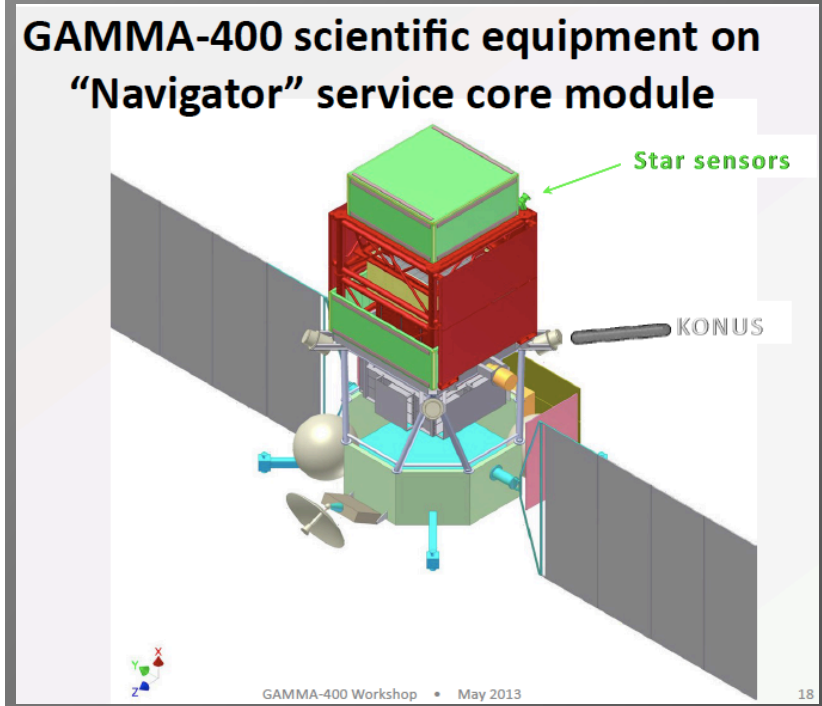
APPROVED
by the decree of the Russian Government
of December 28, 2012 No. 2594-R

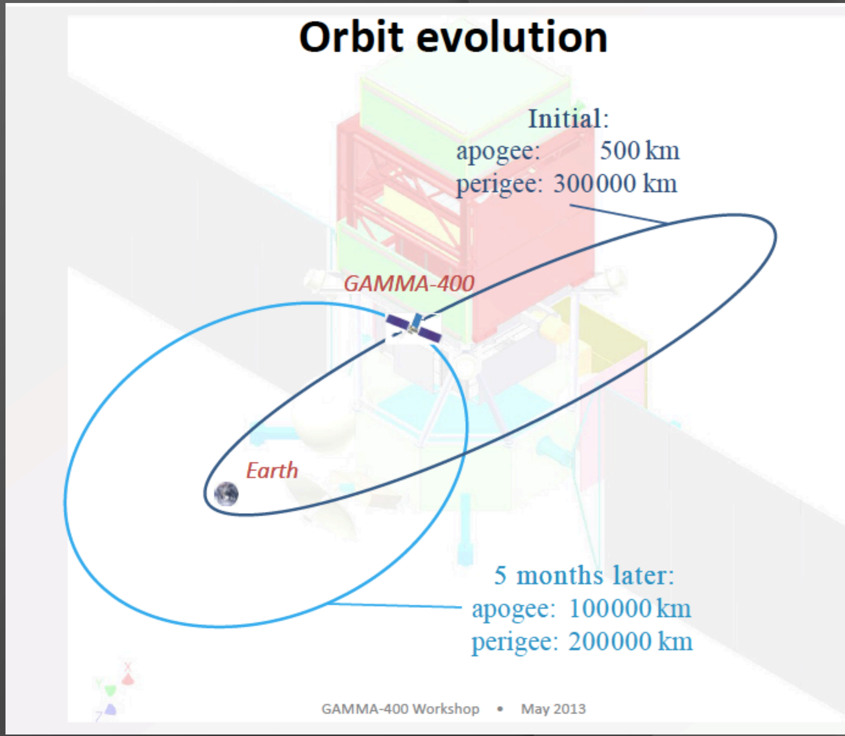
Russian Government program
“Russian Cosmic Activity in 2013–2020”

In project:
Making of three space observatories: “WSO-UV”, “Spectrum-M” (“Millimetron”) and “GAMMA-400” for the purpose of execution of research of astrophysical objects in various electromagnetic ranges and high energy gamma rays.

GAMMA-400 Workshop • May 2013 5

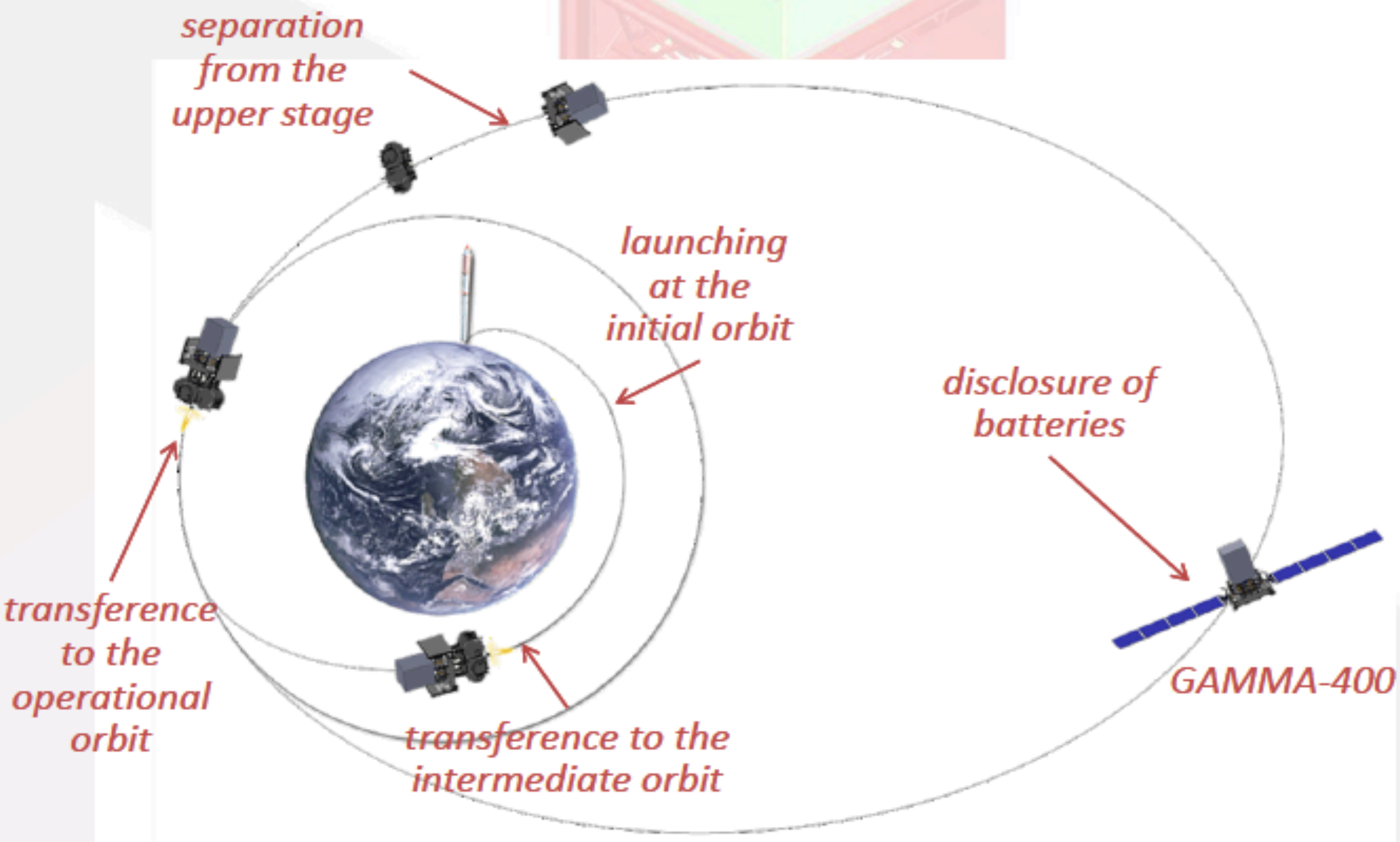
GAMMA-400 WILL BE INSTALLED ON SPACECRAFT "NAVIGATOR", MANUFACTURED BY LAVOCHKIN.





- Characteristics of the satellite:
  - scientific payload > 2600 kg,
  - power budget 2 kW,
  - expected lifetime ≈ 10 years
  - Pointing without earth occultation

Launching scheme

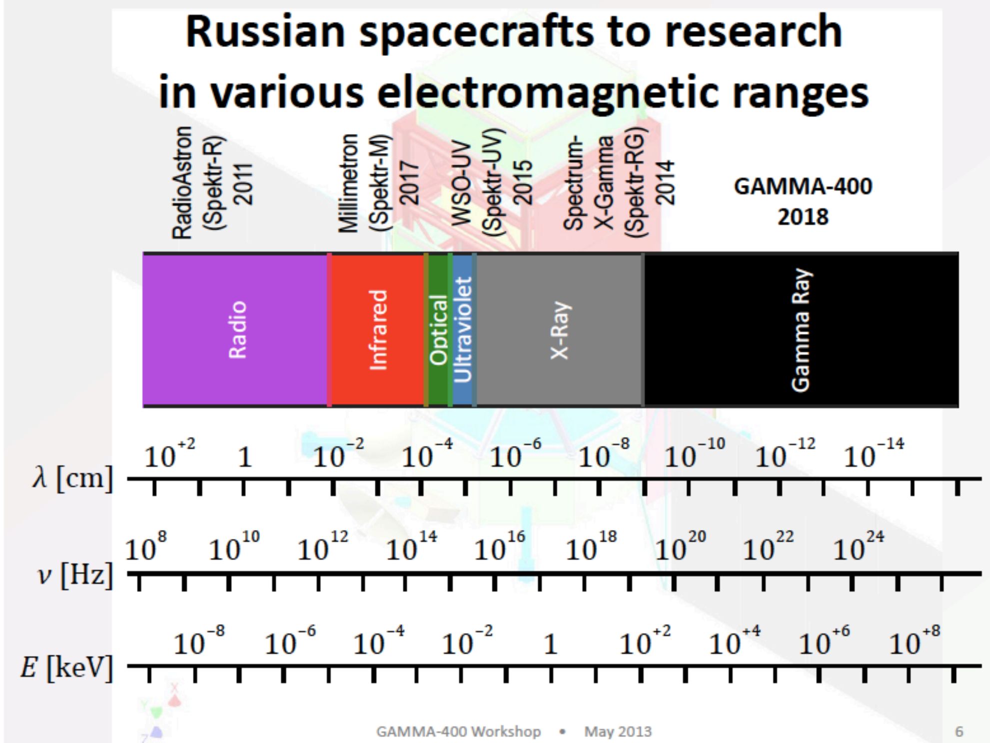


The original GAMMA400 Instrument

Primary tasks of the project

a) Study of the origin of the dark matter by means of gamma-ray astronomy;
b) Precise measurements of discrete astrophysical sources in the Milky Way;
c) Research of high energy gamma-ray bursts;
d) Research of high energy $e^{-}e^{+}$-fluxes;
e) Research of high energy light nuclei fluxes.

GAMMA-400 Workshop • May 2013



Launch foreseen by end 2018

- unique opportunity to configure the apparatus for :
- **gamma-rays from 100 MeV < up to 300 GeV**
- **proton & nuclei in cosmic-rays up to the "knee"**
- **electrons/positrons beyond TeV energy range**

The collaboration

* Firenze, Pisa, Pavia, Roma2, Trieste =>=>=> PAMELA FERMI AGILE community

- At present:
  - Russian, Italian, US collaboration
  - Expressed interest from France, Spain and Sweden (KTH & OKC theorists and experimentalists)
  - Current scientific interest from the TeV community (CTA, Hofmann)
  - Ongoing contacts with the multi-wavelength community
  - Open possible contribution and collaborations

Centenary Symposium 2012: Discovery of Cosmic Rays Denver, June 2012

Space Gamma-Ray Telescope GAMMA-400

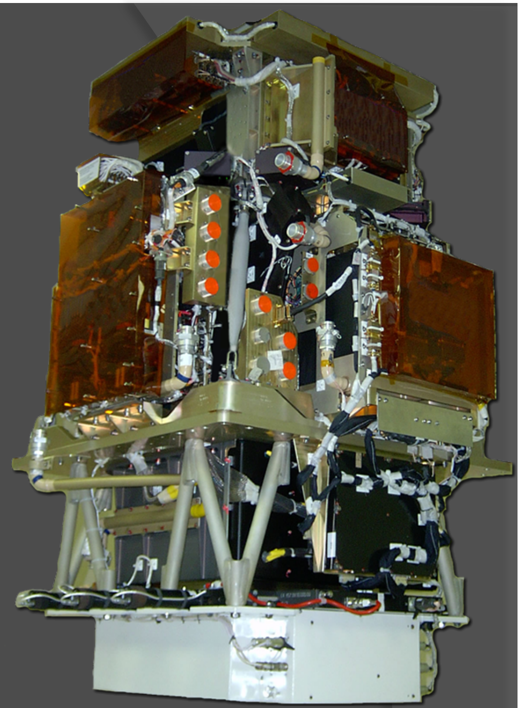
A.M. Galper[1,2], O. Adriani[3], R.L. Aptekar[4], I.V. Arkhangelskaja[2], A.I. Arkhangelskiy[2], M. Boezio[5], V. Bonvicini[5], K.A. Boyarchuk[6], Yu.V. Gusakov[1], M.I. Fradkin[1], V.A. Kachanov[7], V.A. Kaplin[2], E.N. Korchagin
P. Marrocchesi[8], E.P. Mazets[4], I.A. Mereminskiy[2], E. Mocchiutti[5], A.A. Moiseev[9], N. Mori[3], I. Moskalenko[10], P.Yu. Naumov[2], P. Papini[3], P. Picozza[11], V.G. Rodin[12], M.F. Runtso[2], R. Sparvoli[11], P. Spillantini[3]
E. Vannuccini[3], Yu.T. Yurkin[2], N. Zampa[5], V.N. Zirakashvili[14], V.G. Zverev[2]

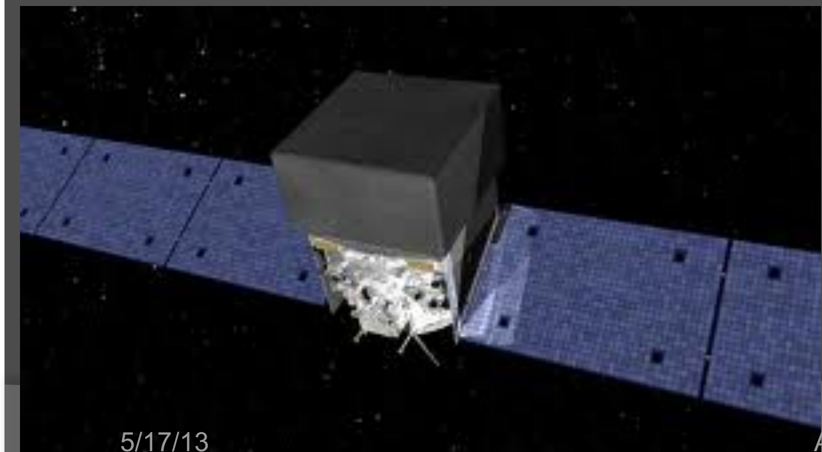
[1] Lebedev Physical Institute, Russian Academy of Sciences, Moscow, Russia;
[2] National Research Nuclear University MEPhI, Moscow, Russia;
[3] Istituto Nazionale di Fisica Nucleare, Sezione di Firenze and Physics Department of University of Florence, Florence, Italy;
[4] Ioffe Physical Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia;
[5] Istituto Nazionale di Fisica Nucleare, Sezione di Trieste, Trieste, Italy;
[6] Open Joint Stock Company "Research Institute for Electromechanics", Istra, Moscow region, Russia;
[7] Institute for High Energy Physics, Protvino, Moscow region, Russia;
[8] Istituto Nazionale di Fisica Nucleare, Sezione di Pisa and Physics Department of University os Siena, Siena, Italy;
[9] NASA Goddard Space Flight Center and CRESST/University of Maryland, Maryland, USA;
[10] Hansen Experimental Physics Laboratory and Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, Stanford, USA;
[11] Istituto Nazionale di Fisica Nucleare, Sezione di Roma 2 and Physics Department of University of Rome "Tor Vergata", Rome, Italy;
[12] Space Research Institute, Russian A
[13] Istituto Nazionale di Astrofisica – IAS
Rome, Italy.
[14] Pushkov Institute of Terrestrial Magn
Moscow region, Russia;
[15] Lavochkin Association, Khimki, Mos

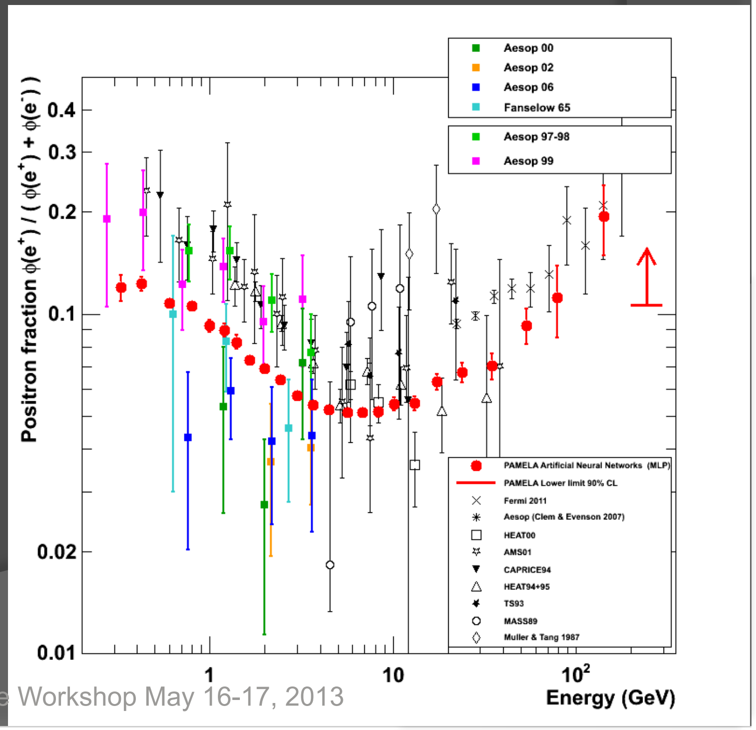
Abstract

The preliminary design of the new space gamma-ray telescope GAMMA-400 for the energy range 100 MeV – 3 TeV is presented. GAMMA-400 will be installed on the Navigator space servi

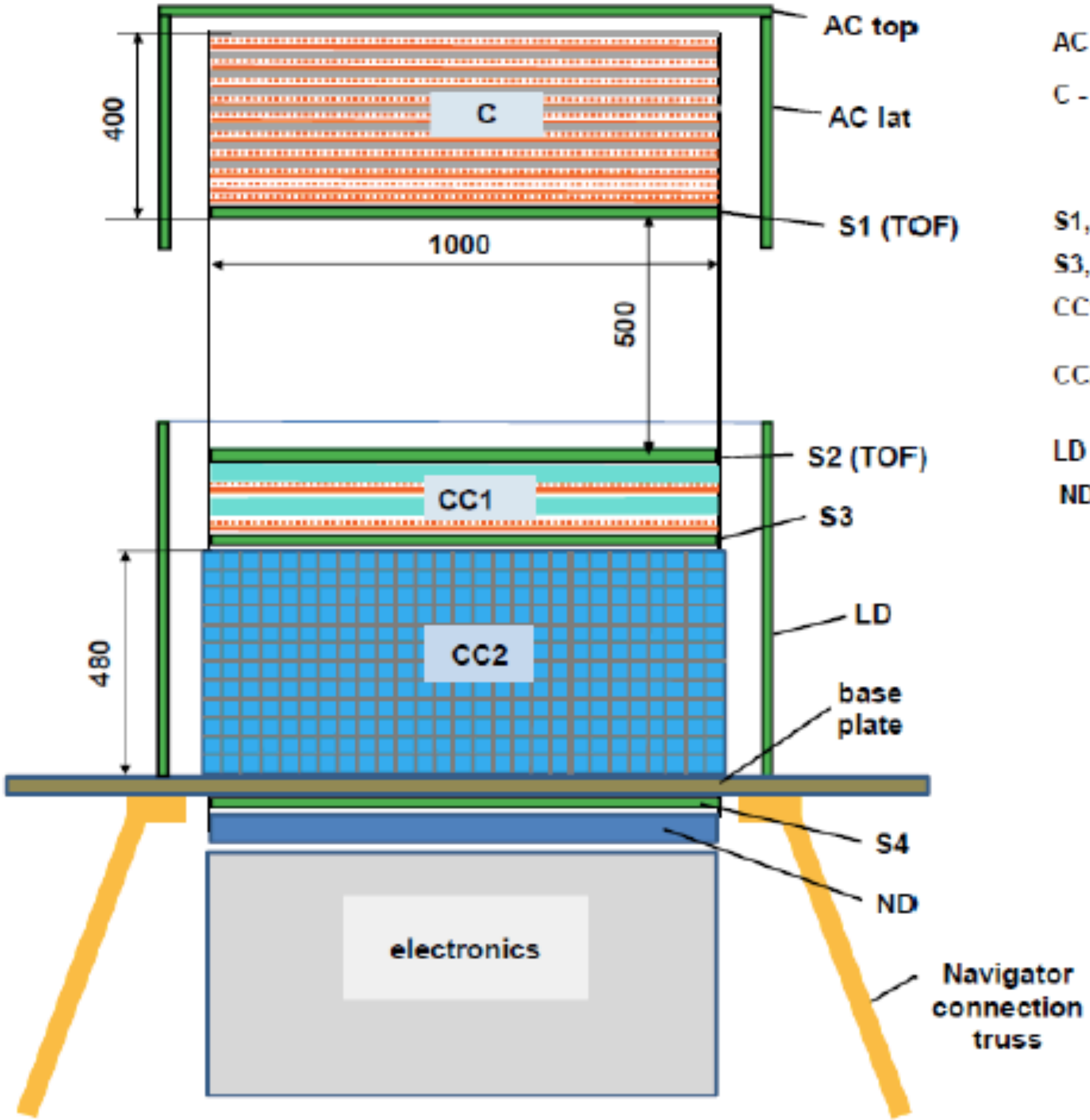
Collecting experienced researchers from Pamela + Agile + Fermi







Physical diagram of the GAMMA-400 scientific equipment



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 0.5 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

Comparison between characteristics of existing and planned gamma-ray telescopes

	space gamma-ray telescopes			ground gamma-ray telescopes		
	Fermi	AMS-2	GAMMA-400	H.E.S.S.-II	MAGIC	CTA
energy range [GeV]	0.02–300	10–1000	0.1–3000	> 30	> 50	> 20
acceptance [m² sr]	2.4	0.4	1.2	0.01	0.01	0.1
effective area [m²]	0.8	0.2	0.6	10^5	10^5	10^6
angular resolution (E_γ > 100 GeV)	0.2	1.0	< 0.02	0.07	0.05	0.06
energy resolution (E_γ > 100 GeV)	10%	3%	1–2%	15%	15%	10%

GAMMA400 possible evolution

1. Study p and nuclei spectra up to the “knee” $10^{14} – 10^{15}$ eV

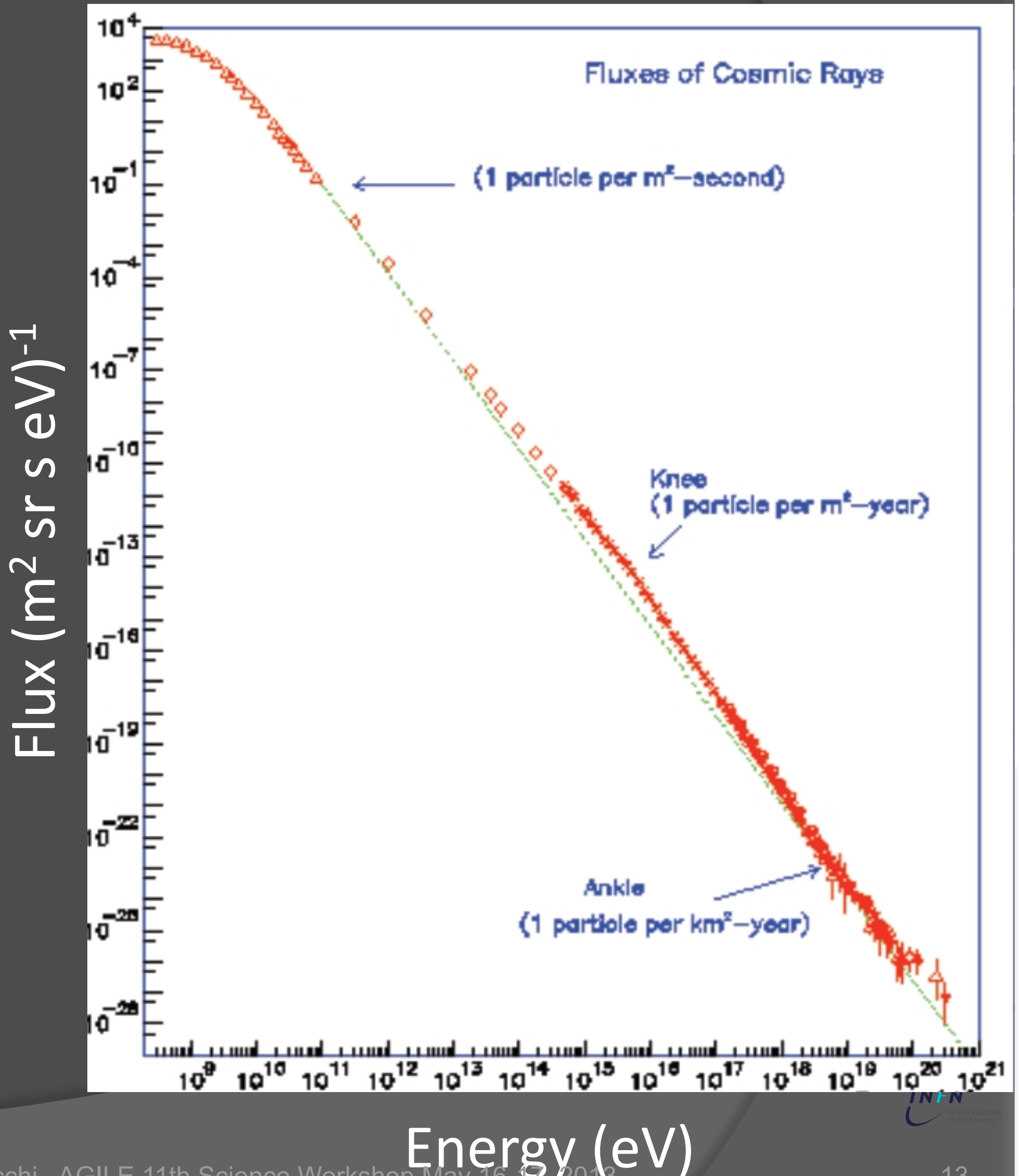
   - Calorimeter of new conception (39 X_0), high L&T granularity, homogeneous and isotropic, with optimal energy resolution and particle discrimination
     - Electron/positron detection up to TeV energies
     - Nuclei detection up to 10^{15} eV energies

2. Gamma detection capability extension to the 30 – 300 MeV region, to reach a detection band of 30 MeV- 300GeV.
     - breakthrough angular resolution, at 1 GeV 3-4 times better than existing expt.
     - improved *sensitivity* by a factor of 5 -10 in the energy range 30 MeV–10 GeV;

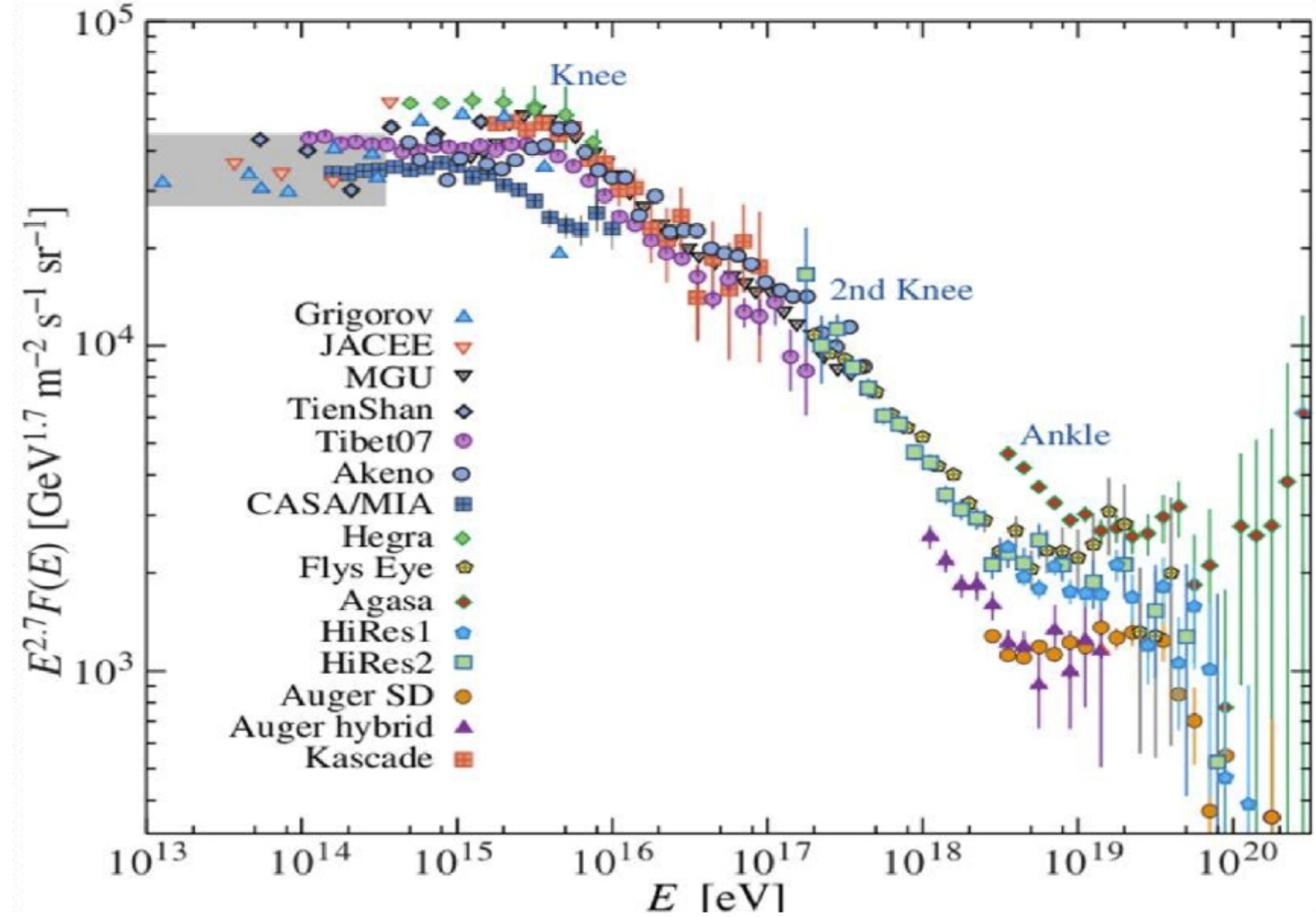
     (a combination of: effective area, Point Spread Function, and pointing strategy)

cosmic rays

- Composition: ca. 90% protons, 10% helium, heavier ions and “electrons”, only 0.01% photons, neutrinos?
- Energy spectrum: power law with some features
- What are the sources of these cosmic rays?
- How are they produced?
- How are they accelerated?

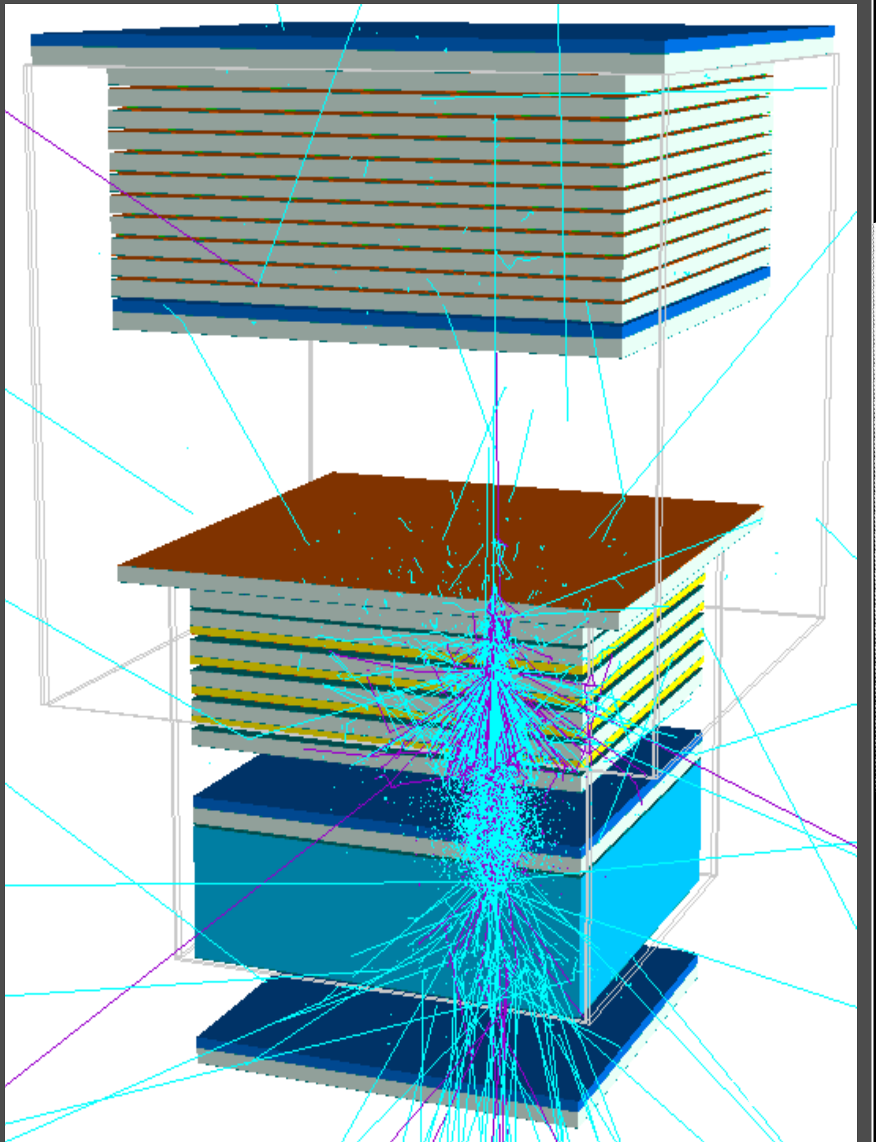


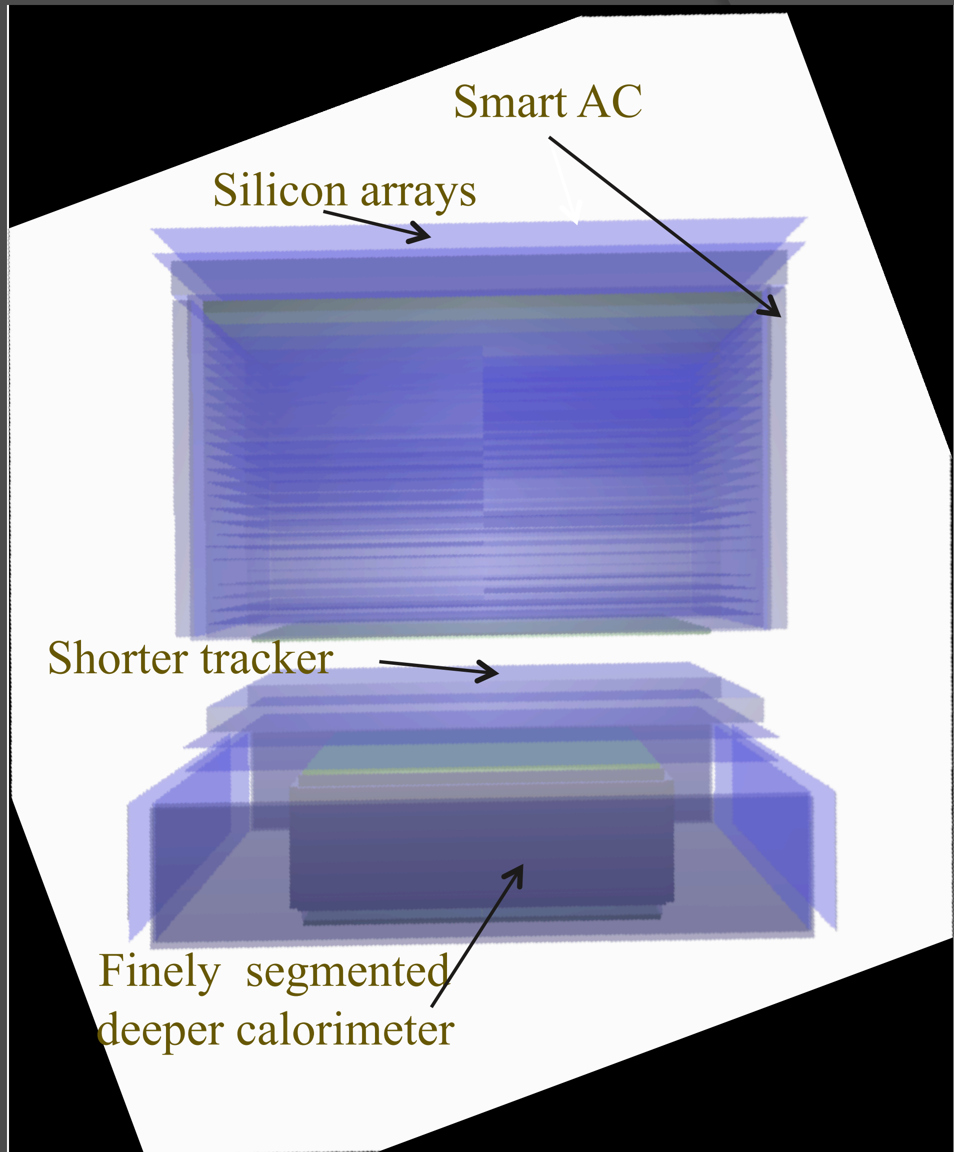
General Agreement between instruments



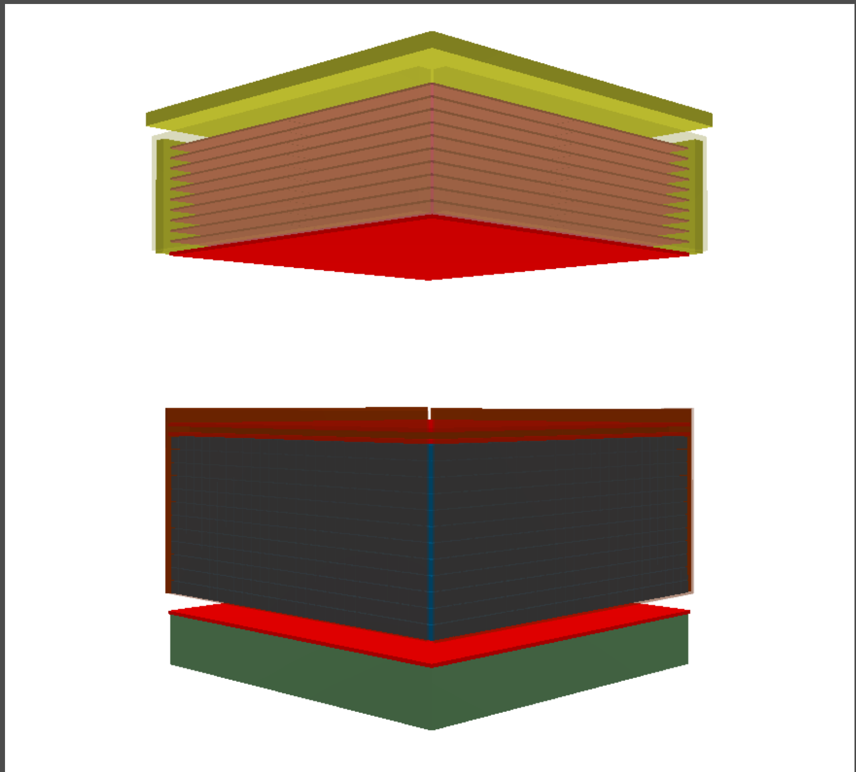
Halzen, ISVHECRI 2010

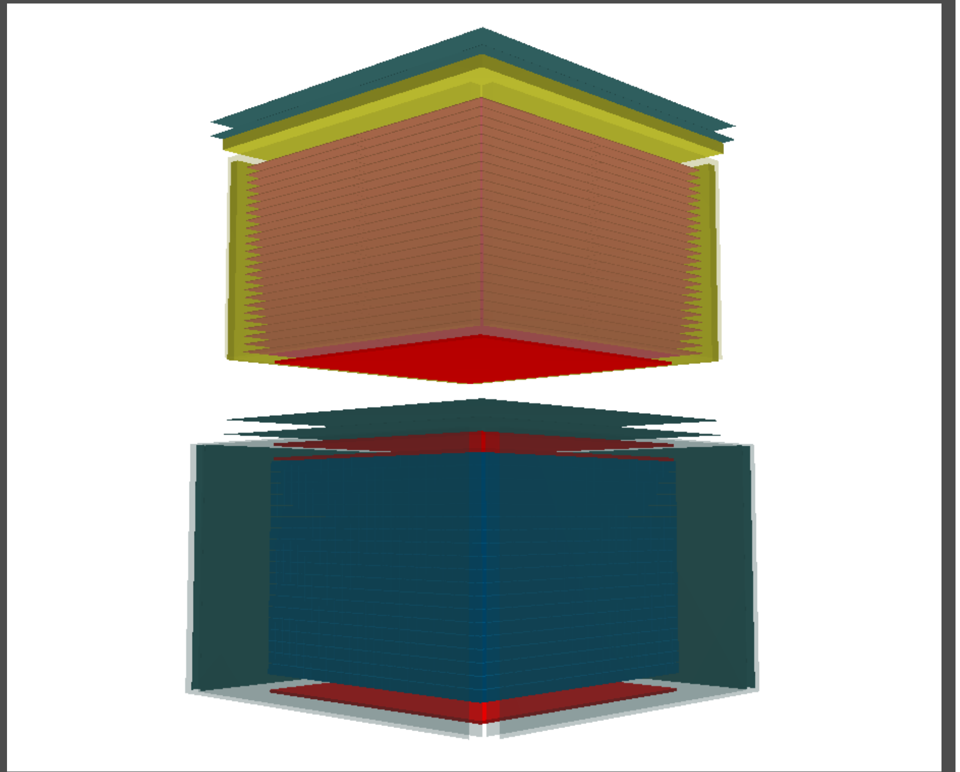
G-400: Present vs. Possible New Design





Possible evolution



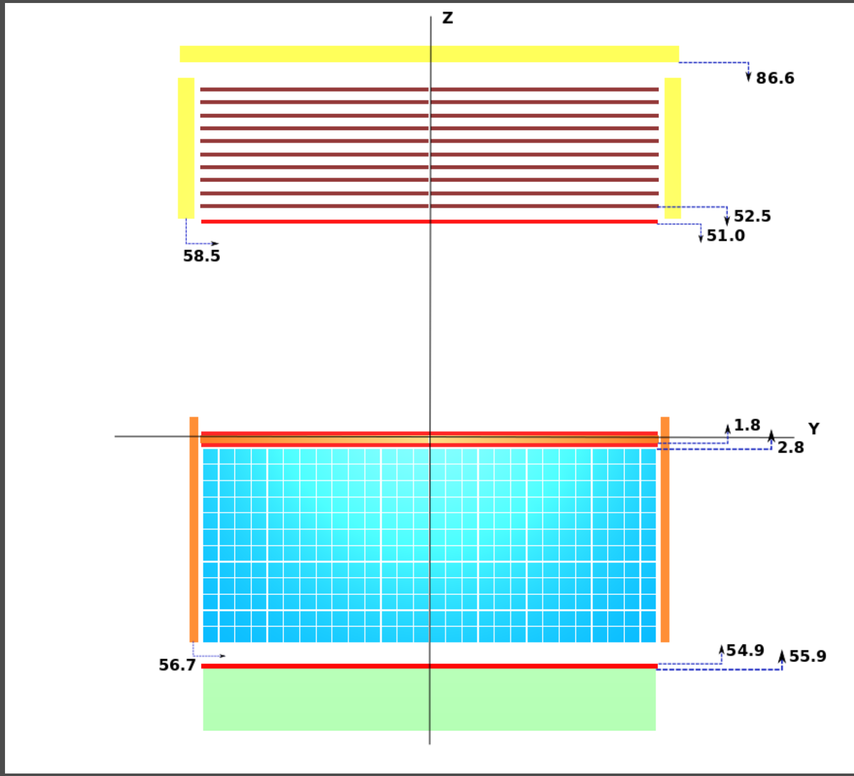


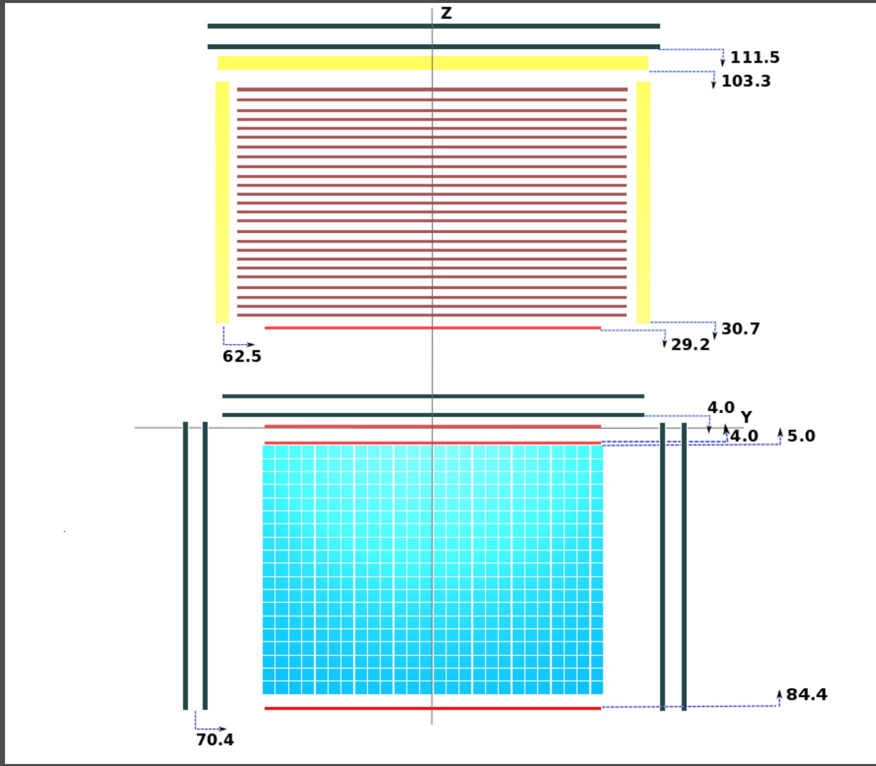
-10 tracker planes and

-28x28x12 CsI cubes in the homogeneous calorimeter with sampling calo at the top and 4 sides.

- Tracker: 25 planes with Tungsten;
- Calorimeter: 26x26x19 CsI cubes of 3.6 cm with gap 0.3 cm (i.e, 50.32 and 36.77 X0 in horizontal and verticaldirection respectively).

Possible evolution





10 tracker planesand 28x28x12 CsI cubes in the homogeneous calorimeter with sampling calo at the top and 4 sides.

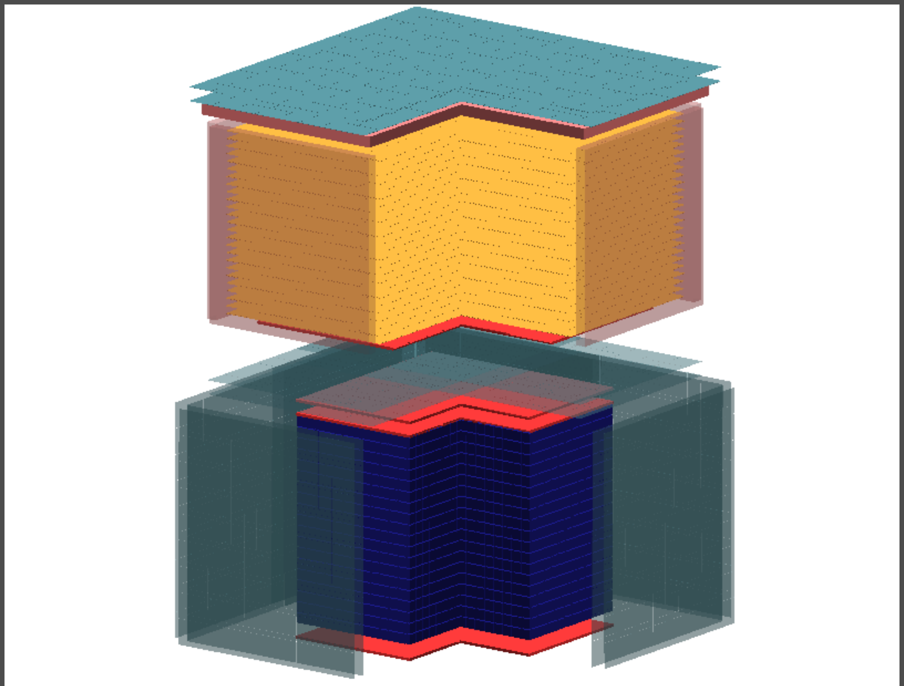
- Tracker: 25 planes with Tungsten;

- Calorimeter: 26x26x19 CsI cubes of 3.6 cm with gap 0.3 cm (i.e, 50.32 and 36.77 X0 in horizontal and verticaldirection respectively).

GAMMA400 a "dual" instrument:

state-of-the-art imaging Silicon Tracker

very deep homogeneous and isotropic calorimeter, with large acceptance, excellent granularity in all directions and energy resolution;



Gamma-rays from 30 MeV up to 300 GeV to be studied with substantial improvements concerning the angular and energy resolution, the broad-band sensitivity, and the continuous exposure of sources without Earth occultation;

Proton/nuclei cosmic-rays up to the"knee", whose spectrum and composition is to be studied with unprecedented detail up to 1 PeV/nucleon:

Electrons/positrons in the TeV energy range and beyond, to be measured with much improved sensitivity compared with current space, balloon-borne, and ground measurements.

- No Earth occultation

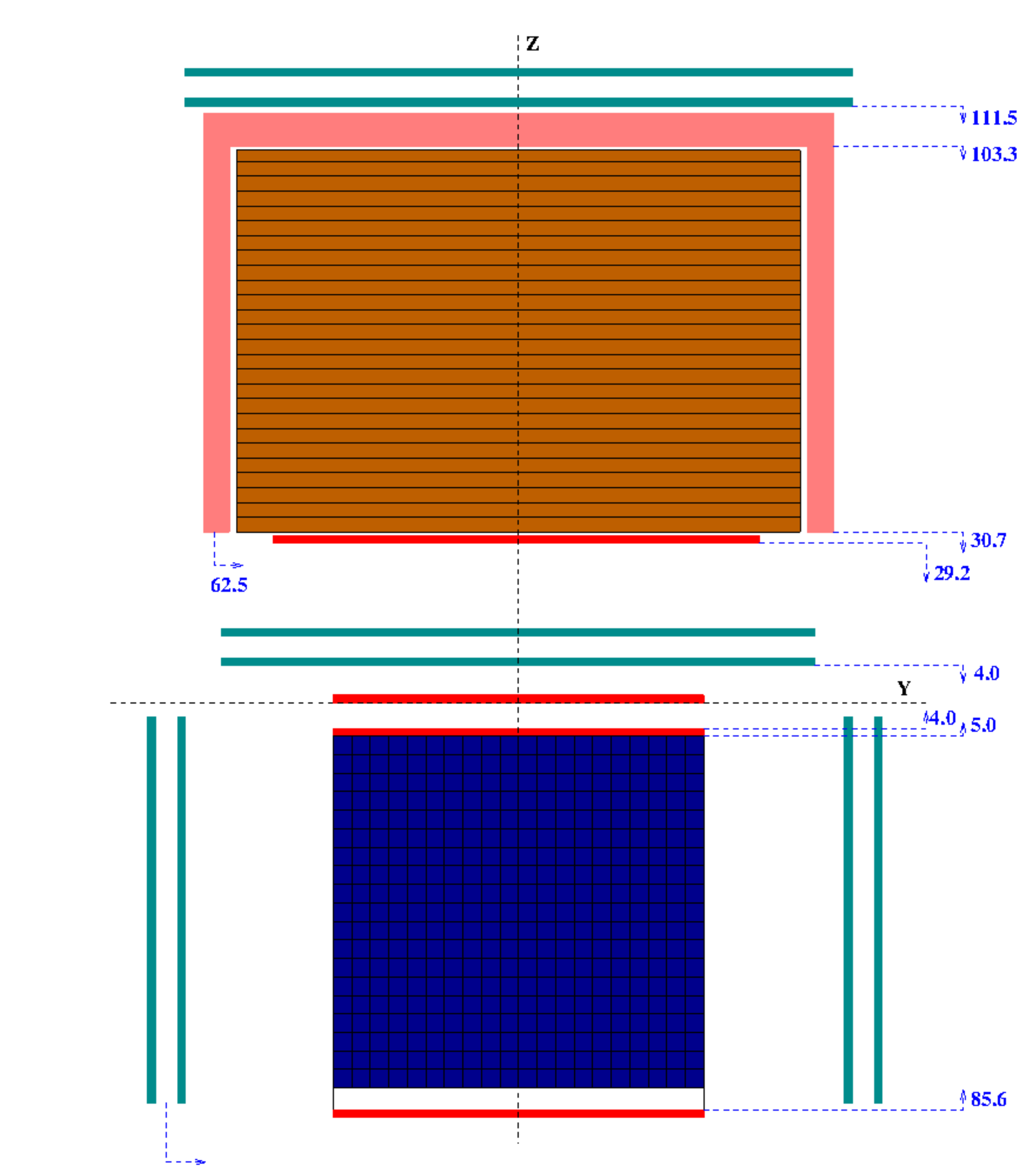
  pointing strategy with a very large exposure per unit time for extended monitoring (months) of individual sources;

- Excellent Pointing Capabilities
  - angular *0.2 degrees* and
  - *energy resolution 1%*, at 1 GeV,
  - best sensitivity in the 30 MeV – 300 GeV,

it allows to resolve the diffuse emission and the ultimate search for Dark Matter.

Gamma-400: a multi-purpose mission
Important points
Addresses some of the most fundamental scientific tasks

- The GAMMA-400 homogeneous and isotropic calorimeter design gives unique energy resolution and depth for electrons&nuclei. The Gamma-400 proposed tracker is an evolution of AGILE and FERMI-LAT
  - search for DM,
  - origin of galactic CR,
  - CR acceleration mechanism(s),
  - studies of galactic and extragalactic gamma-ray sources
  - Galactic center
  - photons also @ low energy;
  - pointing strategy without Earth occultation.



TRACKER

no. of tower = 2x2

no. of plane = 25

(plane =>

W-Kap-Cu-Si-Gap-Si-Cu-Kap-AlSupport)

W = 0.013 cm

Kap = 0.005 cm

Cu = 0.001 cm

Planes gap = 2.5 cm

no. of tile = 6x6

tile dim = 9.5x9.5x0.03 cm^3

gap = 0.1

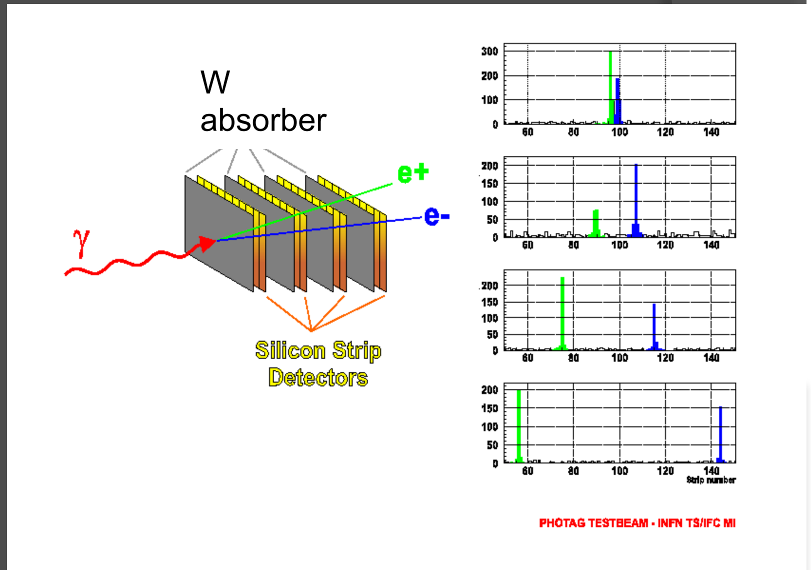
tot dim = 115.7x115.7x72.12 cm^3

tot dim with frame = 116.5x116.5x72.12

Tracker Parameters influencing the PSF

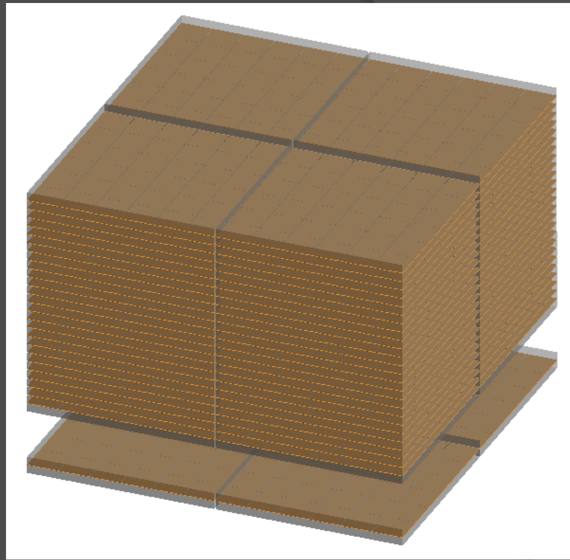
In the current configuration of Silicon-Trackers (based on AGILE & Fermi-LAT experience), the parameters that mainly affect the angular resolution are:

1. the converter thickness X_0 per plane;
2. the spacing between the planes (D);
3. the Si micro-strip pitch and thickness;
4. the readout system;
5. filtering, event topology, noise;



Readout mode - AGILE pre-flight calibrations **(Prest M., et al., 2002)**

Possible Tracker configuration



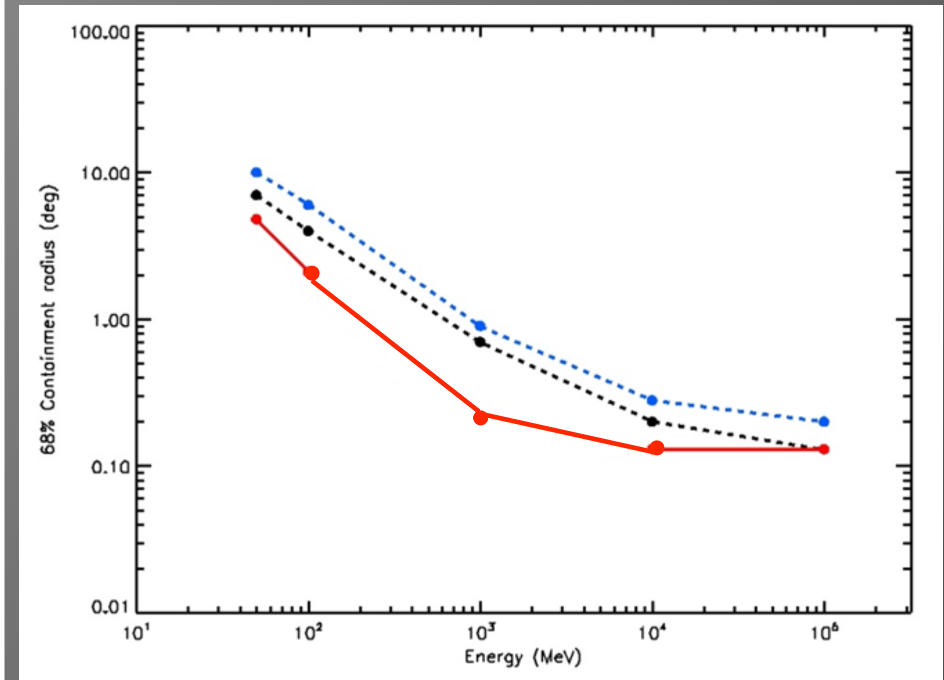
- Baseline 25 planes:
  - 4 towers
  - 25 planes,

    each plane 2 array (view) of the silicon tiles
  - Tungsten converter with < 3% of X0
  - Silicon microstrip, 120 micron pitch, analog readout
  - CLUSTER POSITIONING: energy-weighted
  - ANALOG READOUT
  - READ OUT PITCH: 240 Microns

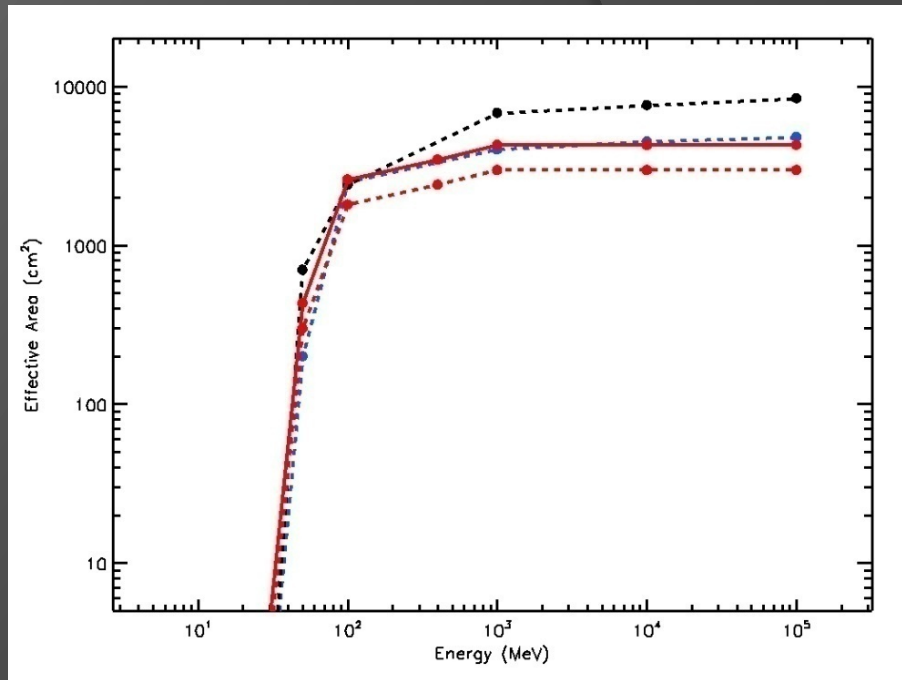
- Option-1 > 25 planes
  - Reduced/no Tungsten converter
  - > 25 planes
  - lever arm + Si thickness optimization

G-400 SIMULATED PERFORMANCE
work in progress

PSF



Effective Area

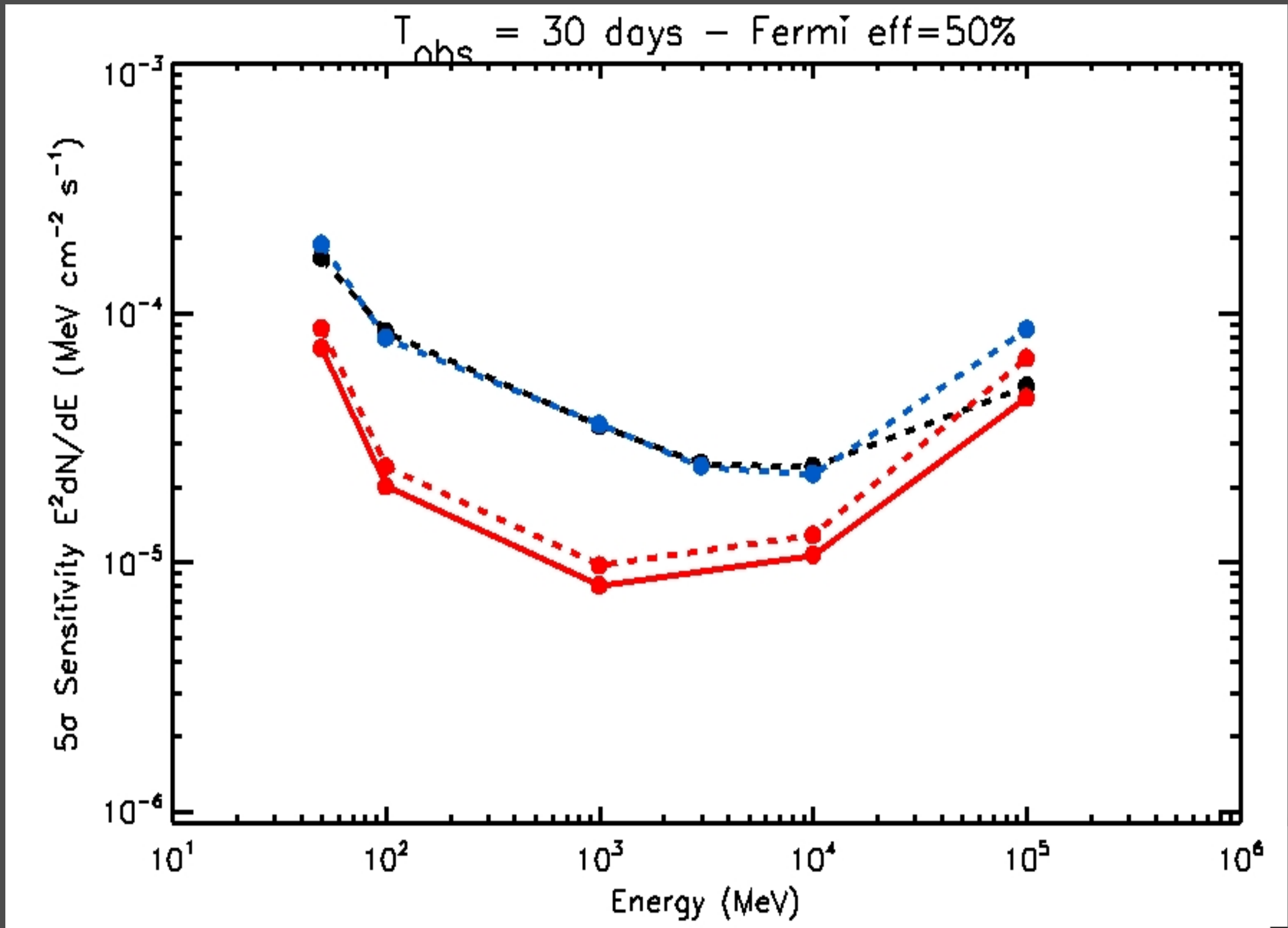


G-400: (red solid line)
Fermi (black dotted: upper LAT, PASS7)
Fermi (blue dotted : total LAT, PASS7)

G-400: 120x120 cm^2(red solid line)
G-400: 100x100 cm^2 (red dotted line) .
Fermi (black dotted: total LAT, PASS7)
Fermi (blue dotted: upper LAT, PASS7)

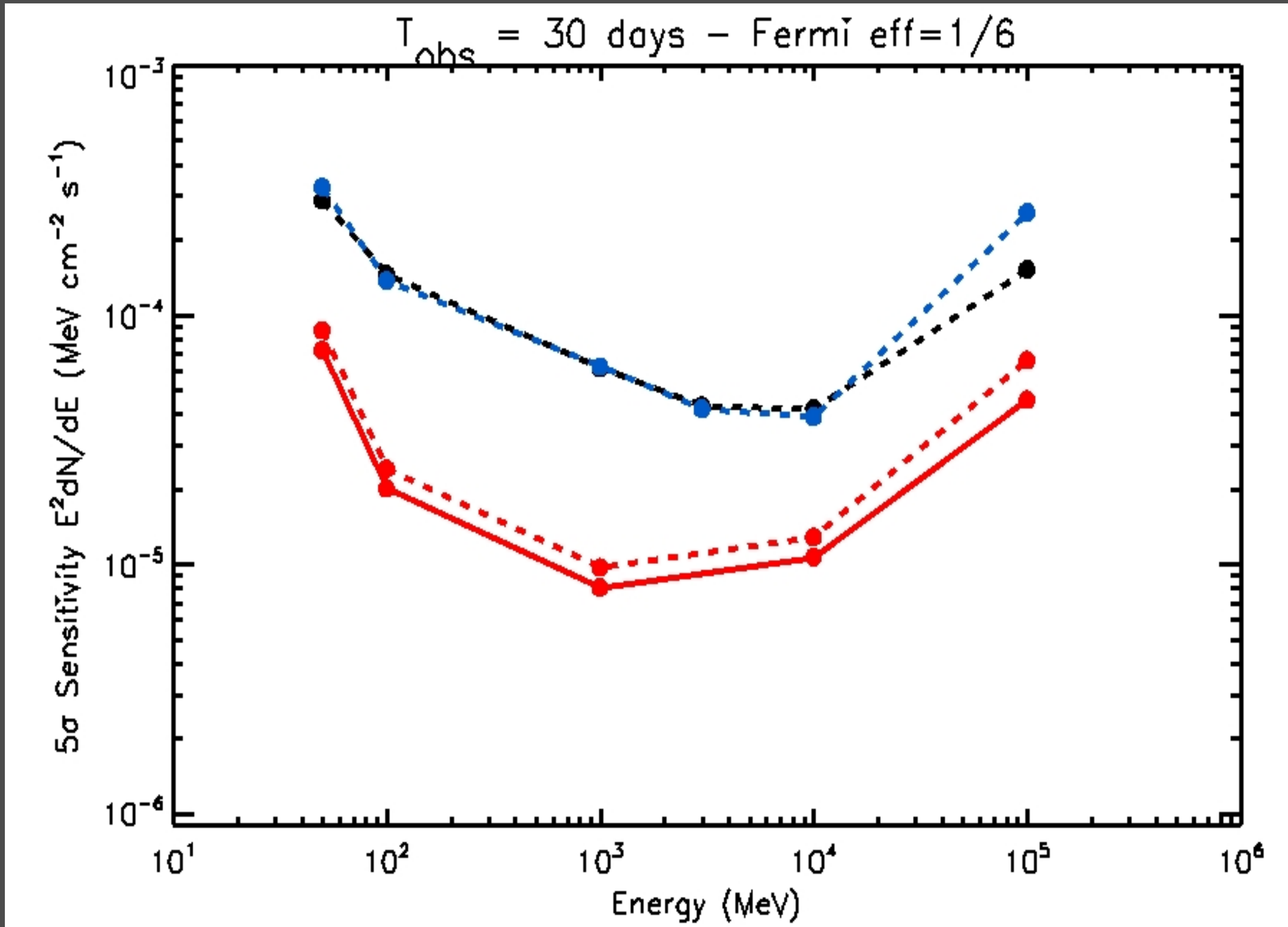
G-400 sensitivity

30-day observation – Fermi exp. Eff=50% (E.occultation)
Galactic Centre



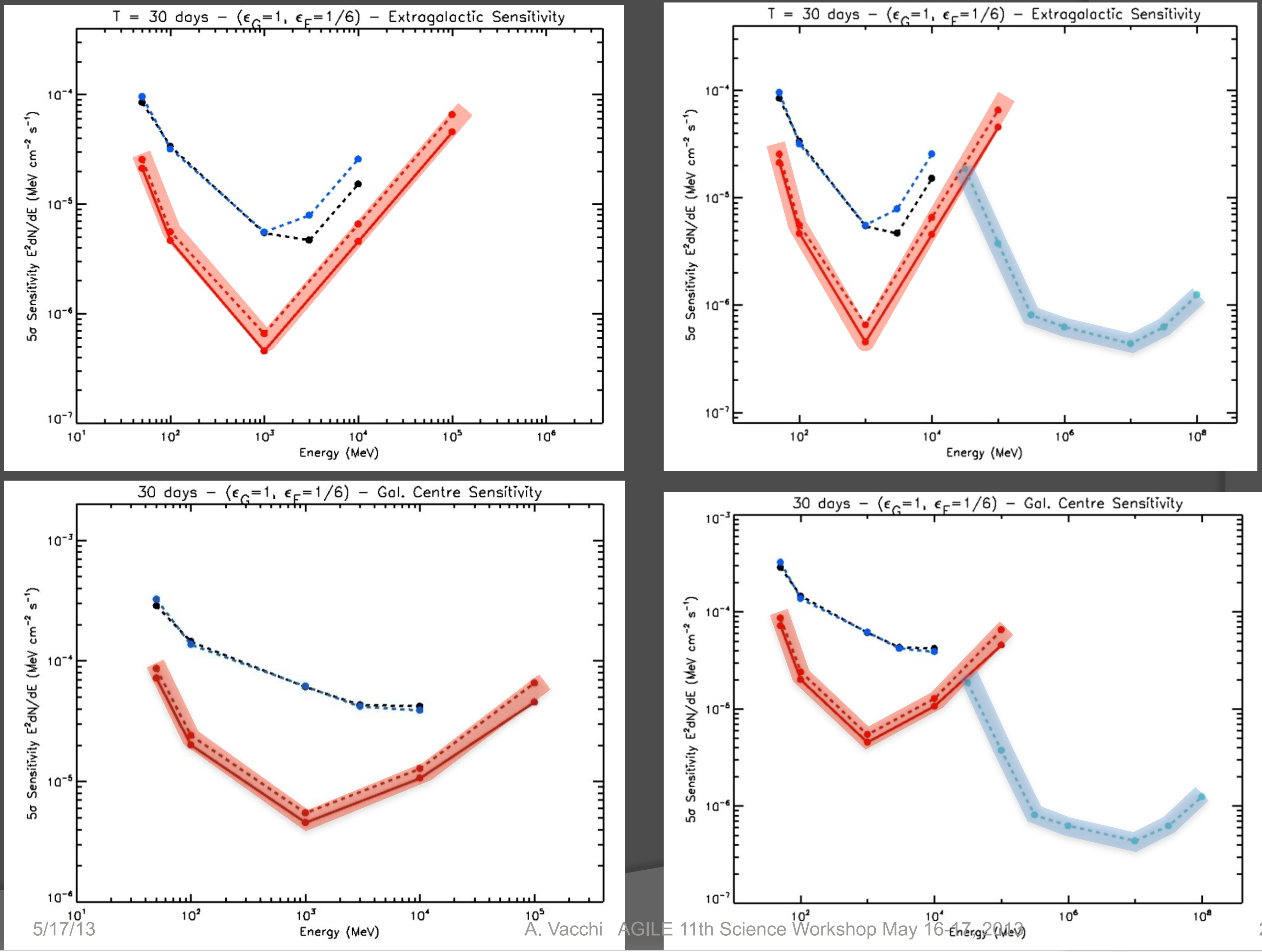
G-400: 120x120 cm²(red solid line) ; G-400: 100x100 cm² (red dotted line) . Fermi (black dotted: total LAT, PASS7); Fermi (blue dotted: upper LAT, PASS7)

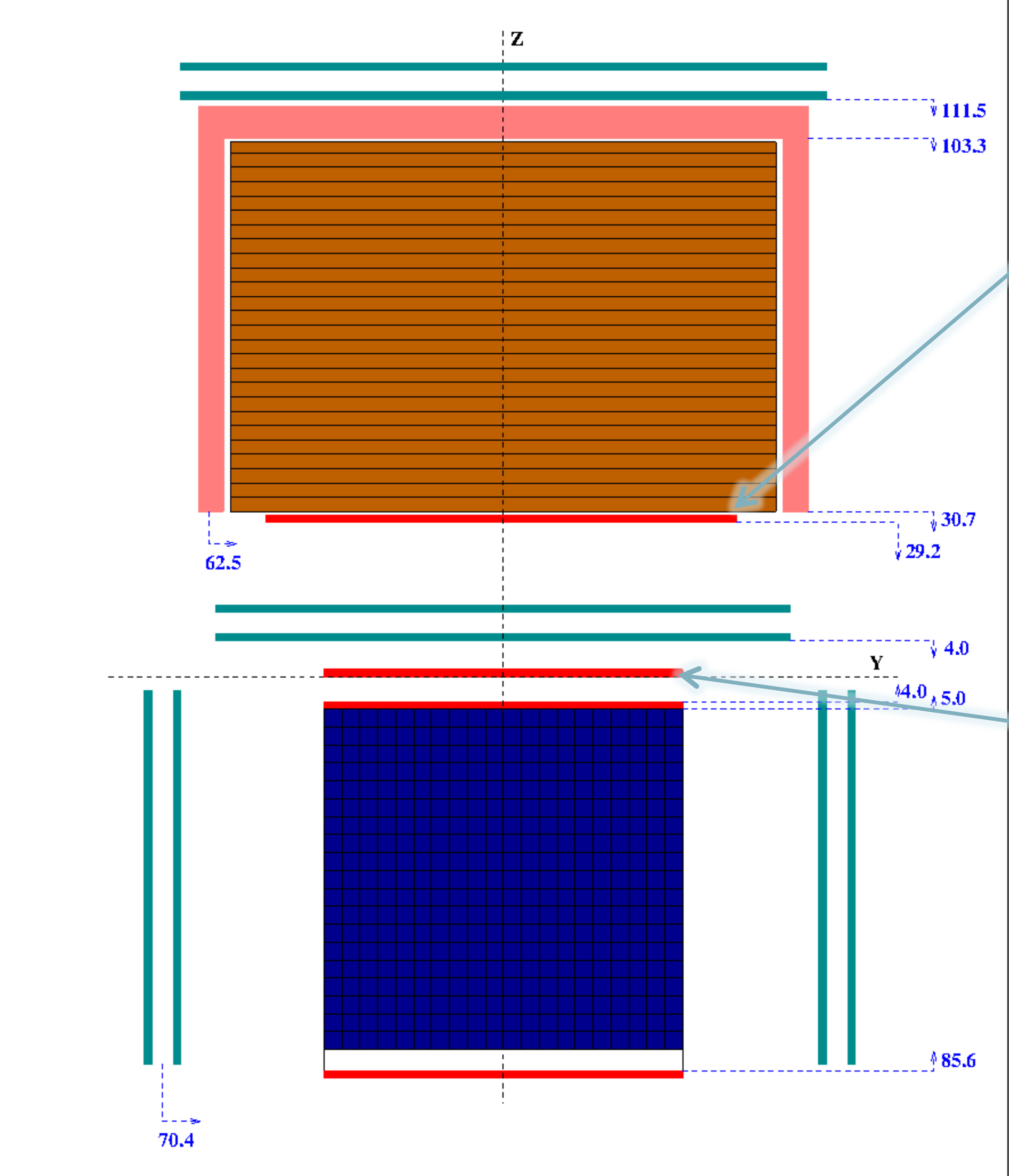
G-400 sensitivity
30-day observation – Fermi exp. eff=1/6 (sky-scanning)
Galactic Centre



G-400: 120x120 cm²(red solid line) ; G-400: 100x100 cm² (red dotted line) .
Fermi (black dotted: total LAT, PASS7); Fermi (blue dotted: upper LAT, PASS7)

Sensitivity – 30 days





TOF (S1):
no. of tower = 1
no. of paddle = 10
paddle dim = 100x10x0.5 cm^3
tot dim = 100x100x1 cm^3
tot dim with frame = 101x101x1 cm^3
bottom at z = 29.2 cm

TOF (S2,S3,S4):
no. of tower = 1
no. of paddle = 8
paddle dim = 80x10x0.5 cm^3
tot dim = 80x80x1 cm^3
tot dim with frame = 81x81x1 cm^3
S2 bottom at z = 0.0 cm
S3 bottom at z = -4.0 cm
S4 bottom at z = -85.6 cm

Top and middle SIAR:

no. of tower = 1

no. of plane = 2

(Each plane contains 2 Si layers separated by 5 cm)

no. of tile (top) = 14x14

no. of tile (middle) = 13x13

tile dim = 9.5x9.5x0.05 cm3

tile gap = 0.1 cm

tot dim (top)= 134.4x134.4x5.3 cm^3

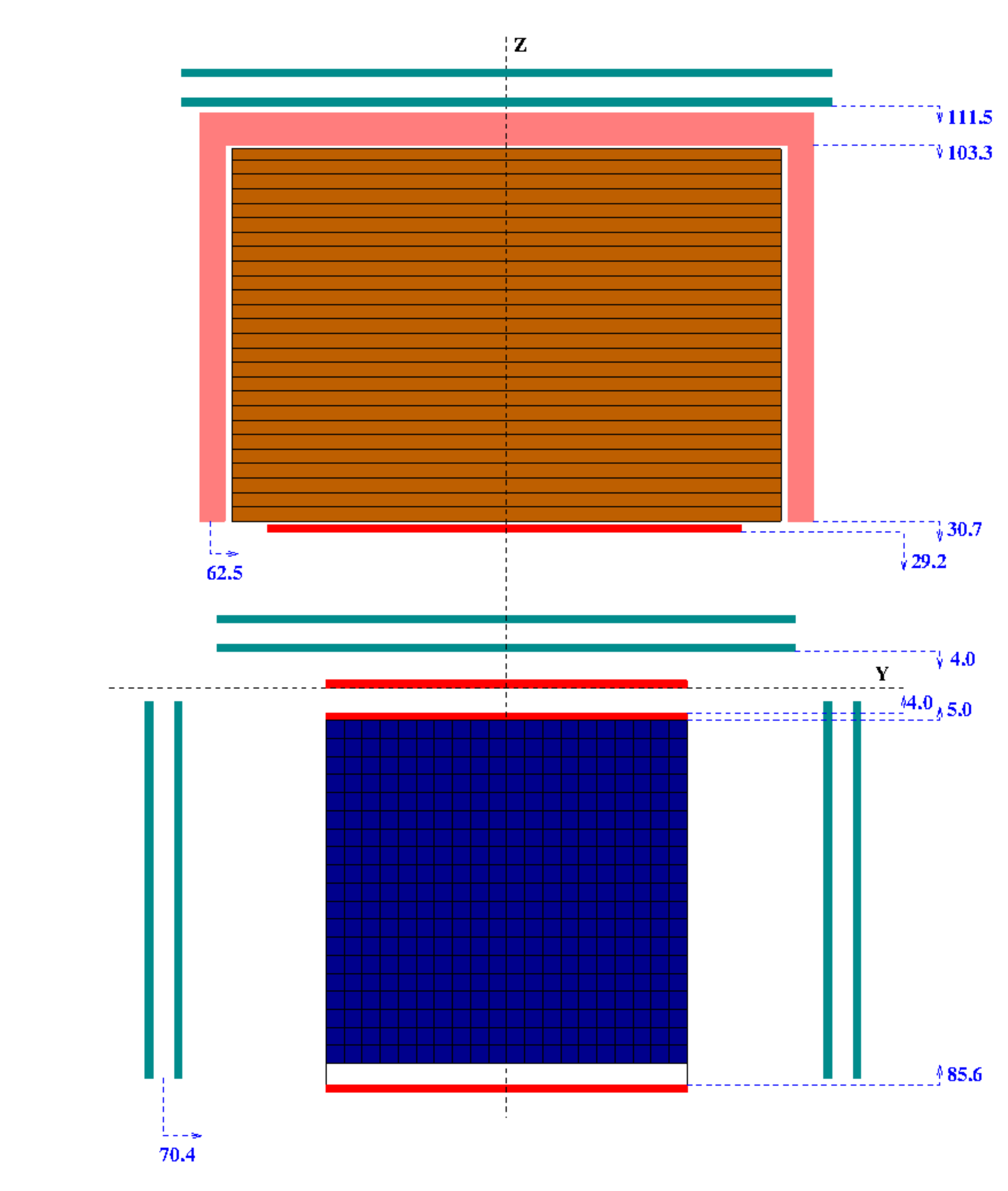
tot dim with frame (top) = 135.4x135.4x5.2 cm^3

(SIAR top) bottom at z = 111.485 cm

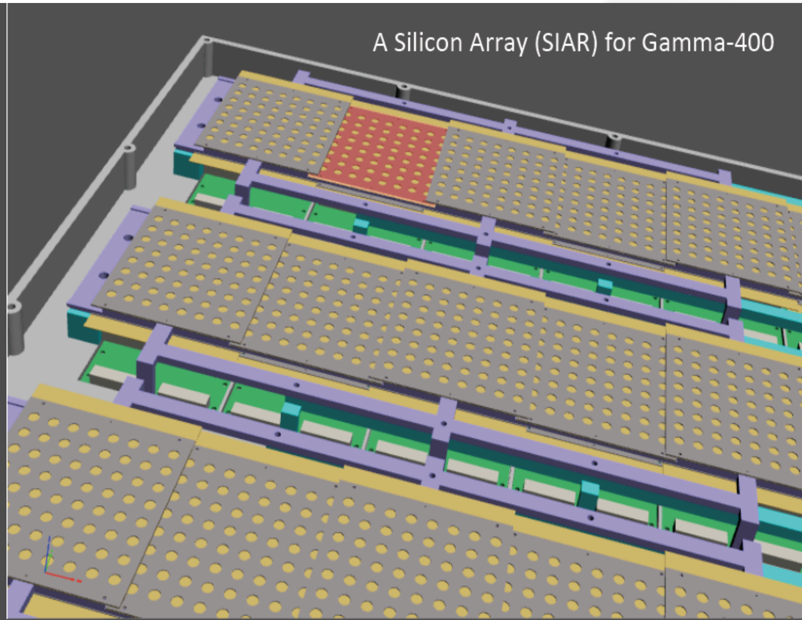
tot dim (middle)= 124.8x124.8x5.3 cm^3

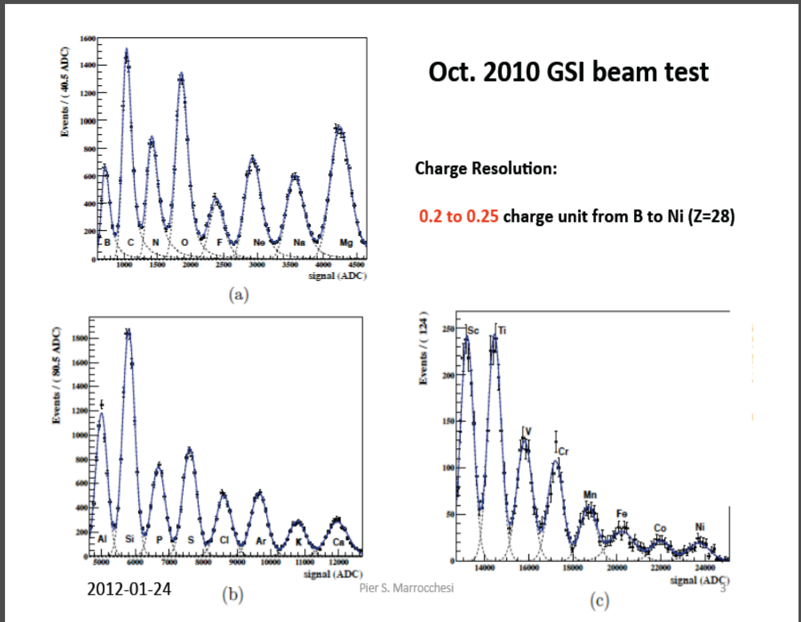
tot dim with frame (middle) = 125.8x125.8x5.2 cm^3

(SIAR middle) bottom at z = 4.0 cm



Silicon Array





CALORIMETER:

no. of tower = 1

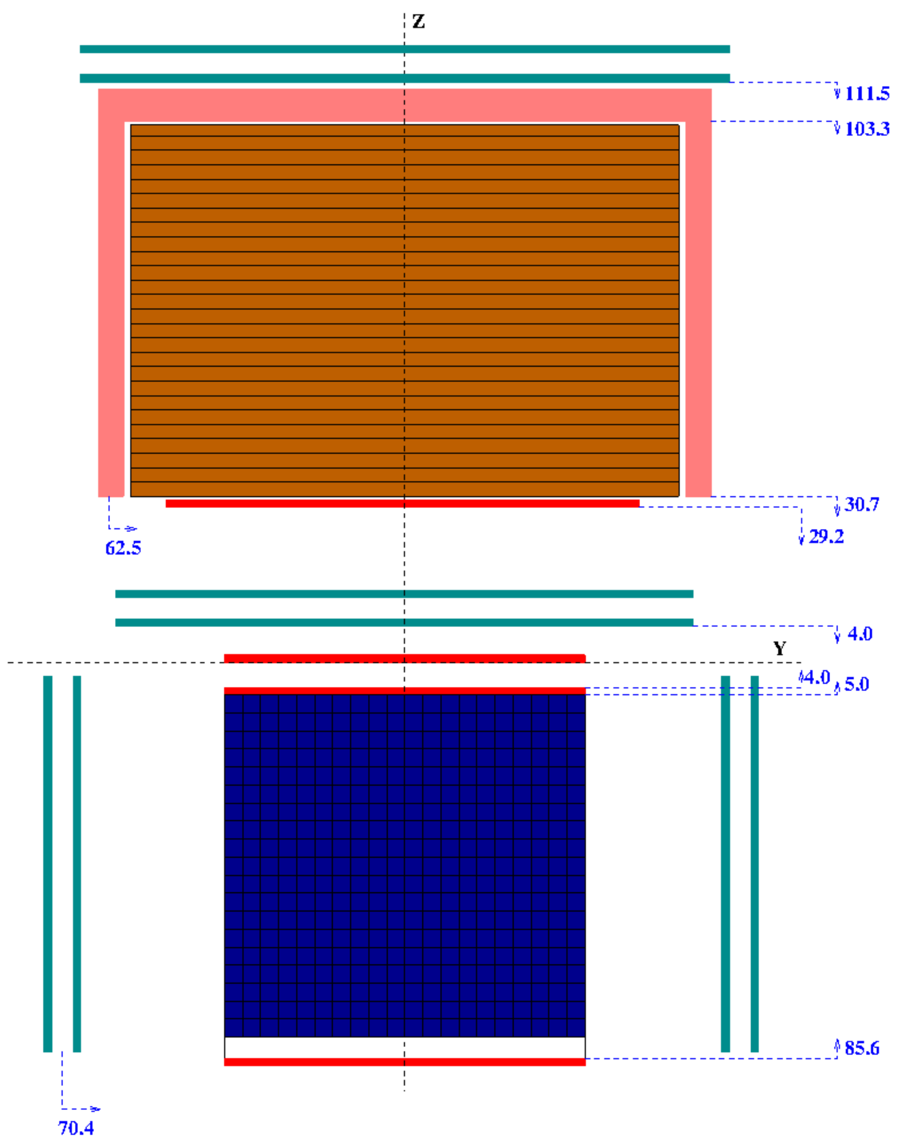
no. of crystals = 20x20x19

crystal (CsI cube) = 3.6 cm each side

gap = 0.4 cm

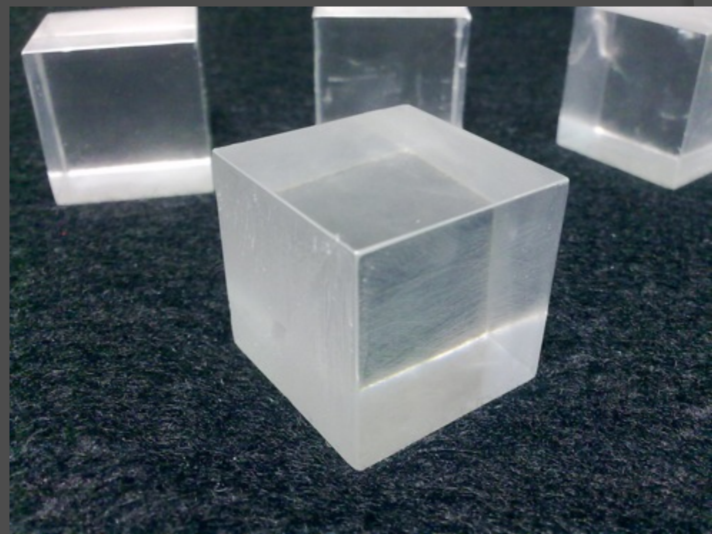
tot dim = 80x80x76 cm^3

tot dim w frame = 80.6x80.6x80.6 cm^3



Basic idea Small CsI(Ta) cubic crystals, cubic homogeneous calorimeter

- Homogeneous calorimeter
- Completely symmetric, to maximize the Geometric Factor
- Finely segmented in every direction
- Gaps in between crystals to increase GF
- Total weight < 1600 kg
- Very high dynamic range



- This type of photodiode have 9,2x9,2 mm^2 active area and quantum efficiency at 550 nm is about 0,65, bias voltage 45V.

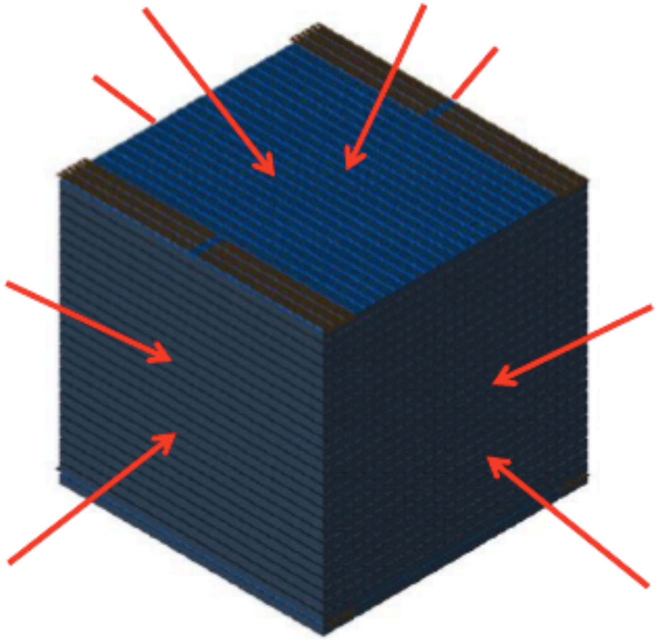
Gamma-400: Calorimeter Geometry

- Homogeneous calorimeter
- Symmetric, to maximize the Geometric Factor:

  $100 \times 100 \times 52\ cm^3$

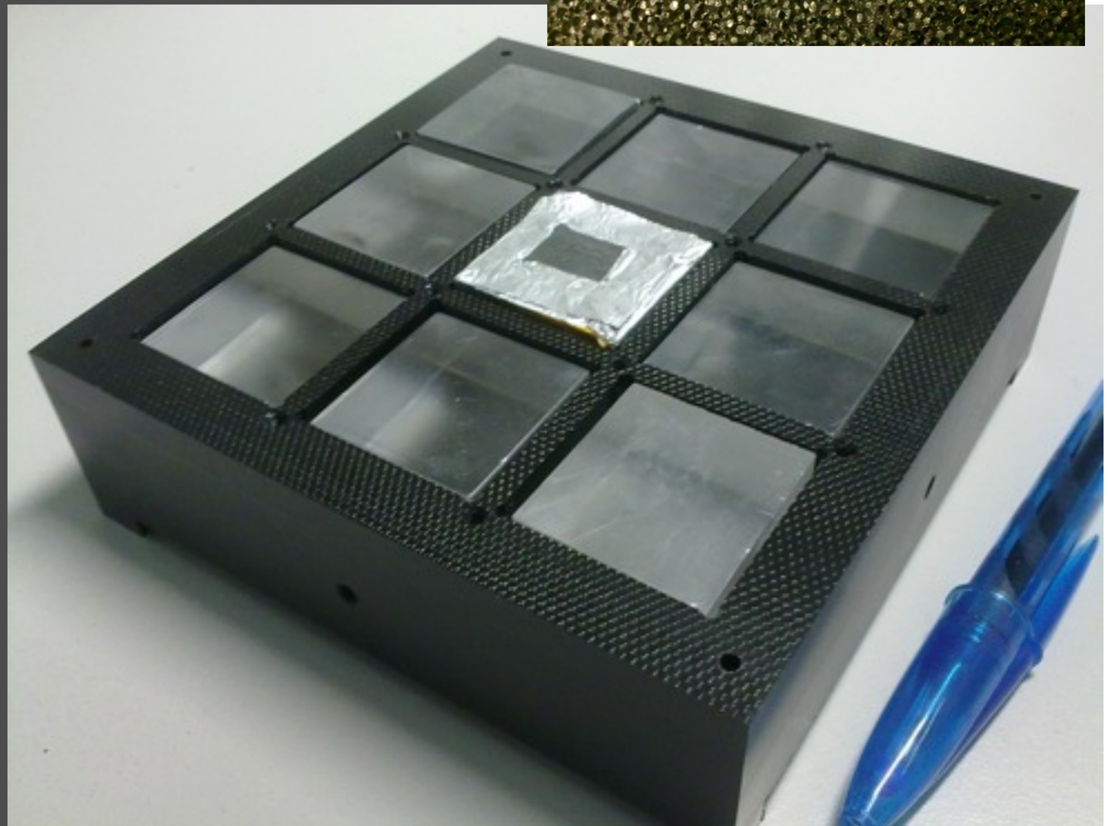
  $(50X_0 \times 50X_0 \times 26X_0)$
- Total weight ~ 1800 kg
- Very high dynamic range
- Finely segmented in every direction

  $1\ R_M \times 1\ R_M \times 1\ R_M$ small CSI crystals, cubic shape
- Few mm gap between crystals

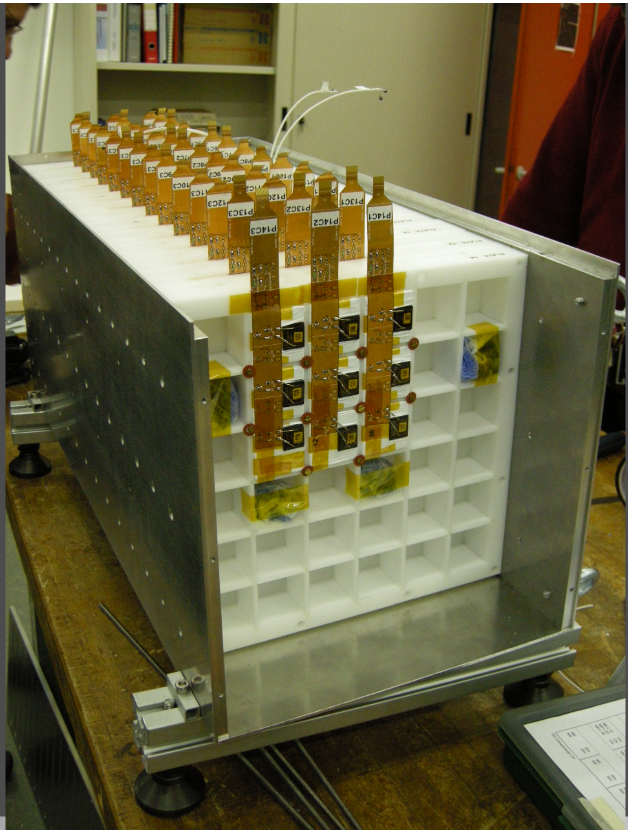


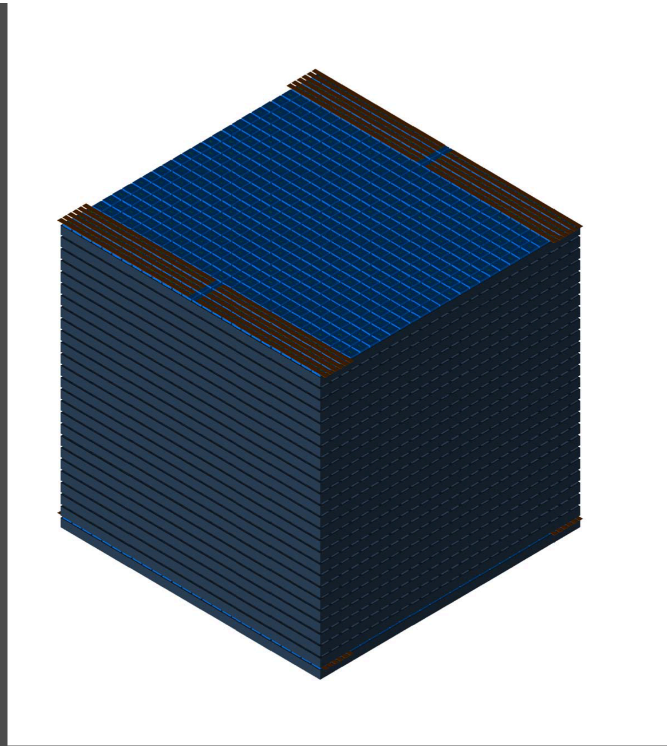
The chosen configuration: CsI(Tl) ~1600 kg

	Cubes
N×N×N	**20×20×20**
L (cm)	3.6*
Crystal volume (cm³)	46.7
G (cm)	**0.3**
Mass (Kg)	1683
N.Crystals	8000
Size (cm³)	78.0×78.0×78.0
Depth (R.L.) " (I.L.)	39×39×39 1.8×1.8×1.8
Planar GF (m²sr) (fiducial**)	1.72×1.72×1.72



(* one Moliere radius)
(** on the 3 sides within a reduced perimeter of size (N-1)*L)





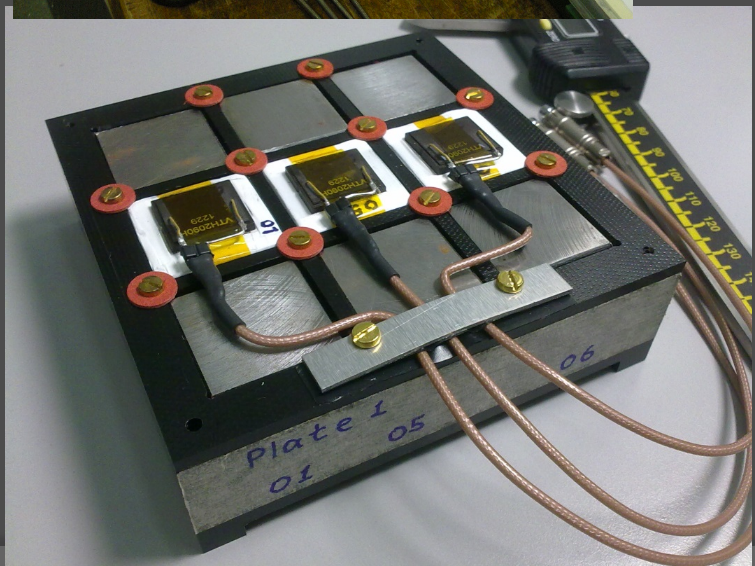
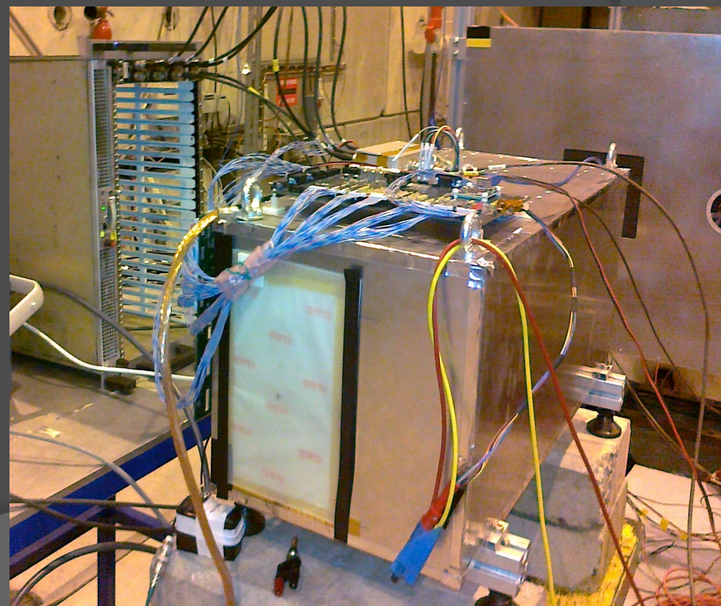


Plate 1
01
05
06



DRS4 + SiPM = Cerenkov

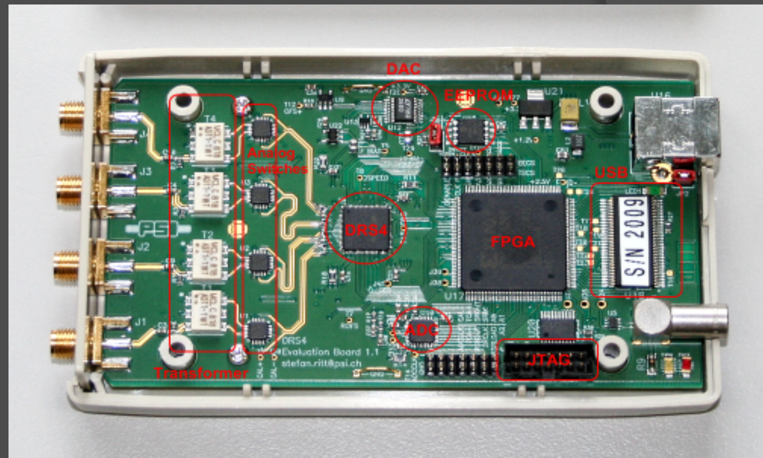
The DRS4 is high speed digitizer developed at PSI for high precision timing. It includes 8 channels sampling and storing 1024 cells each.

It has been used extensively in MEG (Mu to EGamma).

Sampling frequnecy 0.5 – 6 GPS
Bandwidth ~ 1GHz
Consumption 40 mW/ch
Cost 83 euro/ch

Optimal for discriminating fast Cherenkov light from slow scintillating light

DRS4 evaluation board: 4 channels (2048 sample depth)



DRS4 can be operated from VME crate or stand alone with the DRS4 evaluation board

For more info: http://drs.web.psi.ch/

Overall Geometric Factor: 5 x (1.72 m^2s sr) = 8.5 m^2 sr

- For electrons with selection criteria allowing an efficiency of 33% :
  - resolution1%.
  - GF 8.5 x 0.33 = 2.84 m^2 sr

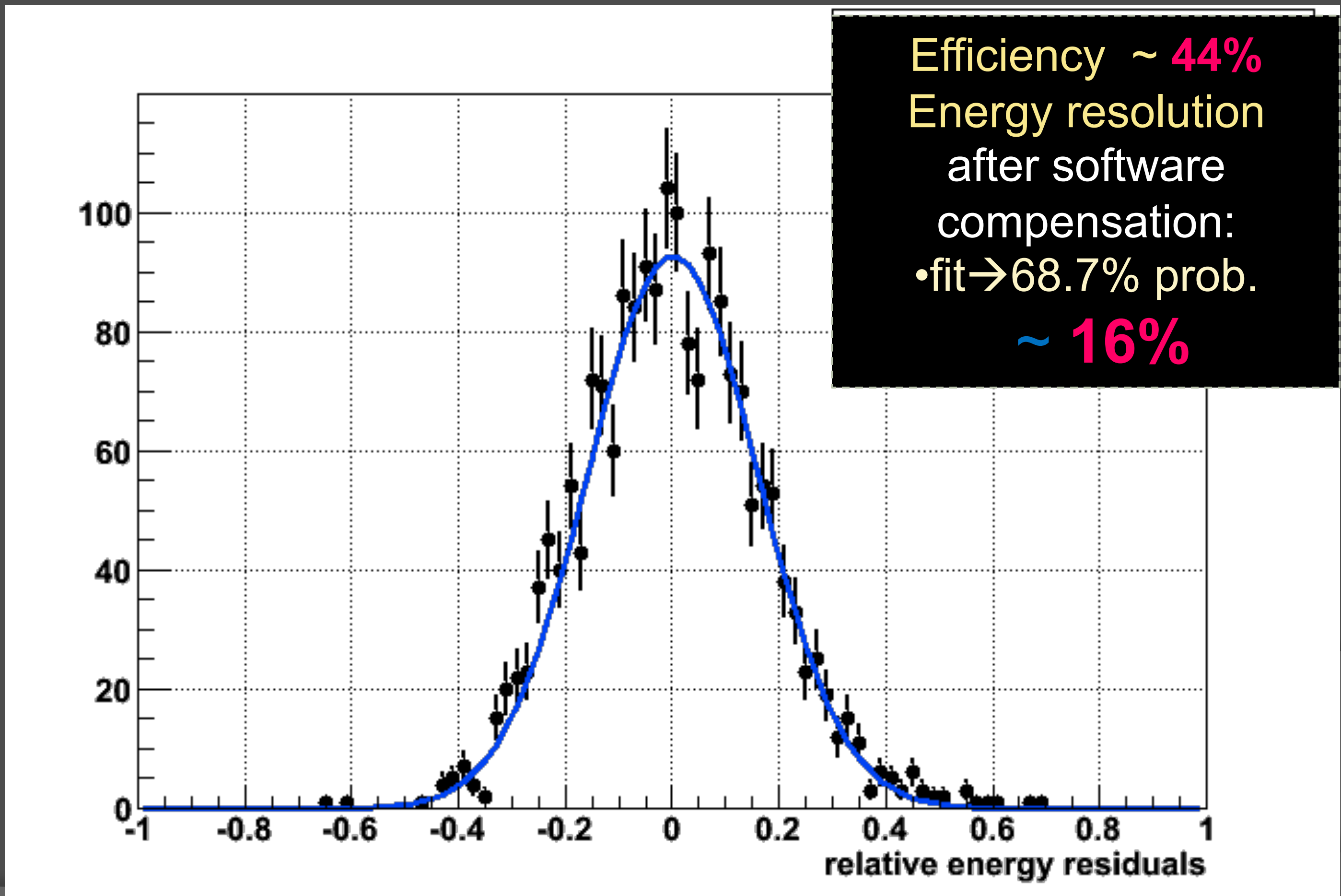
- For protons allowing for an adapted shower development and containment:
  - Efficiency 44% corresponding to an effective GF3.75 m^2 sr
  - In absence of software and hardware compensation the energy resolution for protons is of about 33%. By applying those compensations simulations indicates that 16% is reachable.

- Rejection power for protons to select electrons is >10^5 simulation work is ongoing.

80x80 Calorimeter resolution: Protons (1 TeV)

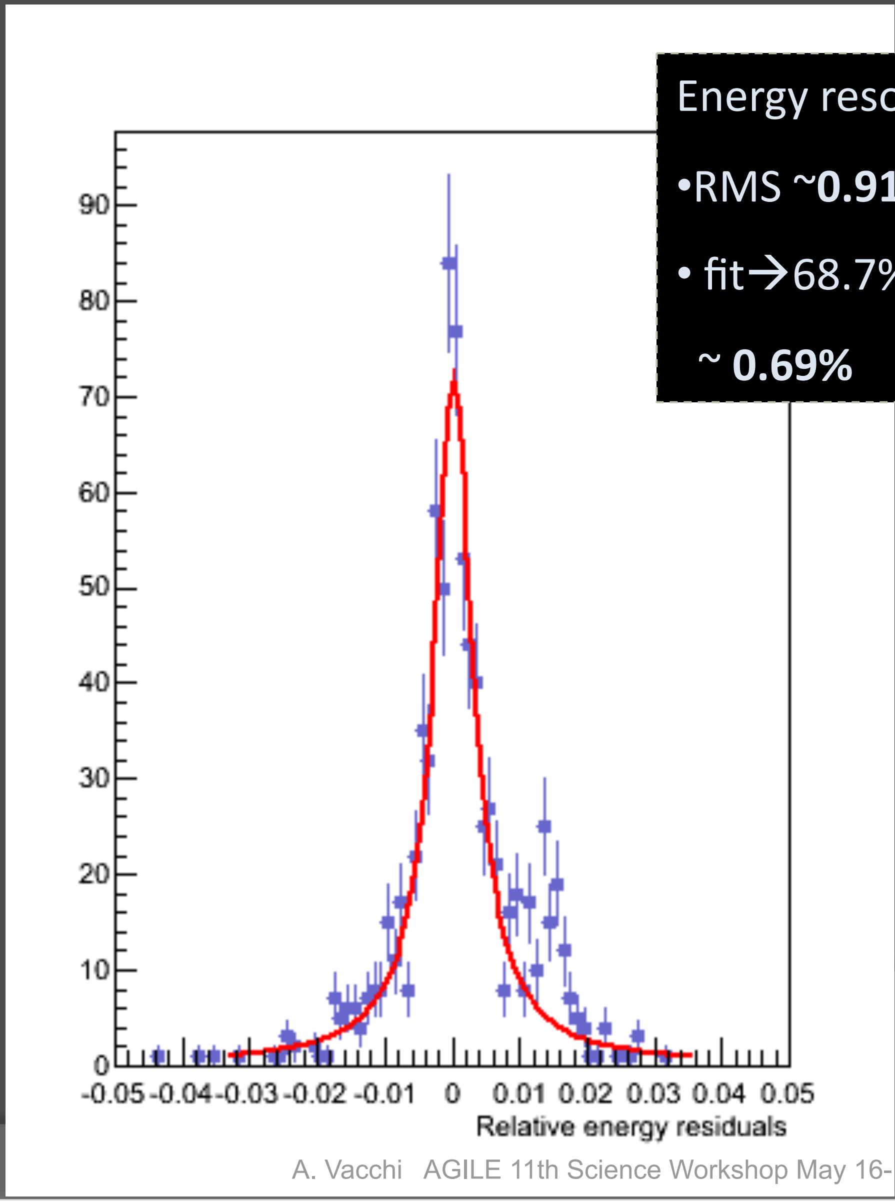
GF=8.5 m^2 sr & GF_{eff}= 3.75 m^2 sr

ΔE/E 16%



Calorimeter resolution: Electrons (1 TeV)

0.7%



Energy resolution:

•RMS ~**0.91%**

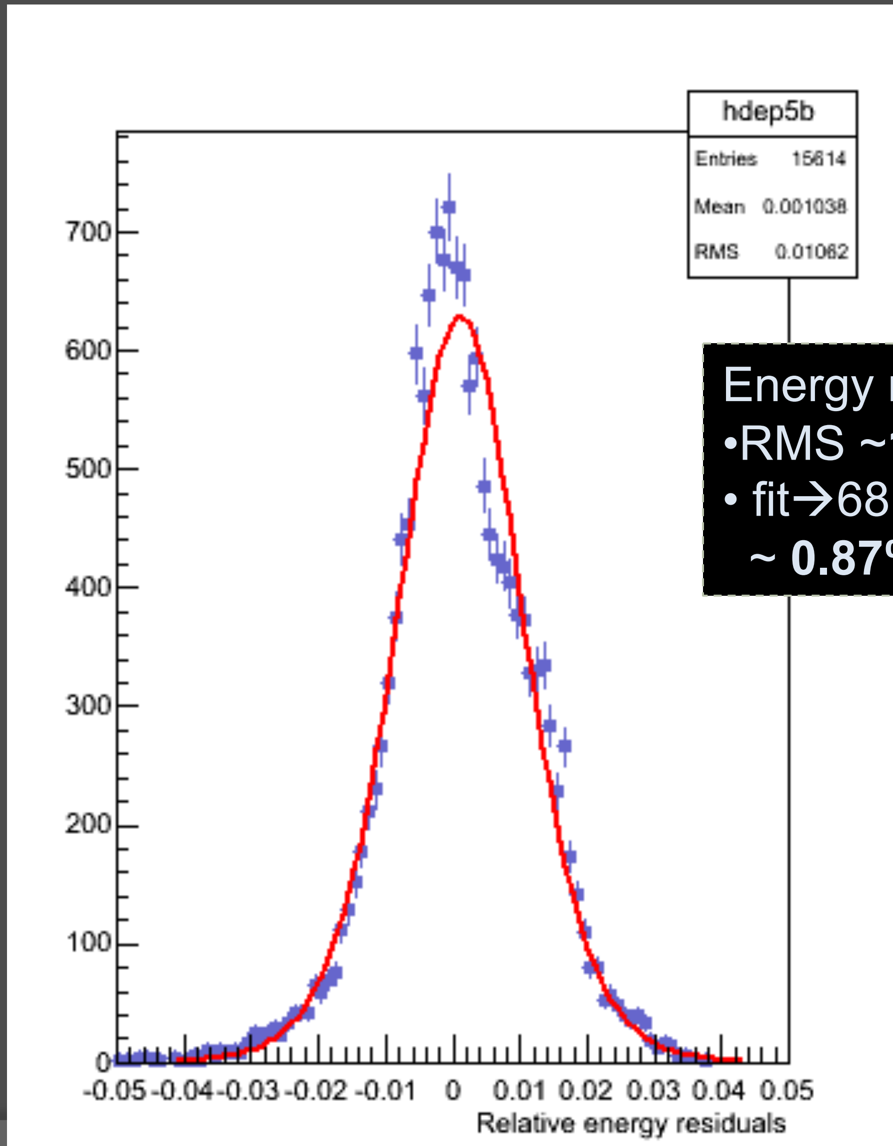
• fit→68.7% prob.

~ **0.69%**

Electrons from every direction (2π), traversing the top calorimeter surface, with contained shower maximum

Calorimeter resolution: Photons (100 GeV)

0.8%



Energy resolution:
- RMS ~**1.26%**
- fit→68.7% prob. ~ **0.87%**

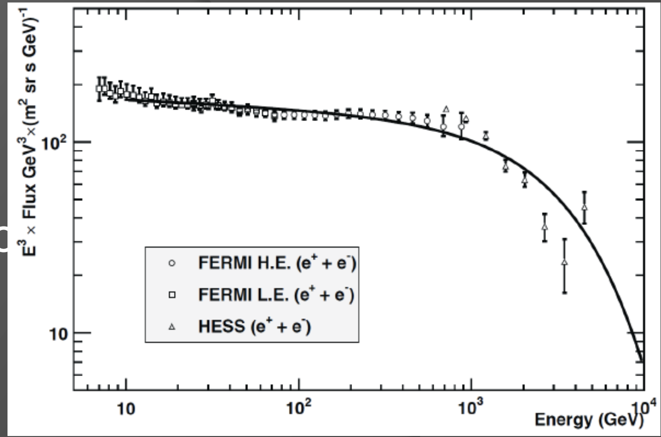
Gamma rays traversing the top detectors (AC) and the top calorimeter surface, with contained shower maximum

Calorimeter summary

Geometry	Electrons E (TeV)	Electrons GF_{eff} (m^2sr) (top)	Electrons $\frac{\sigma(E)}{E}$	Gamma rays E (TeV)	Gamma rays $\frac{\sigma(E)}{E}$	Protons E (TeV)	Protons GF_{eff} (m^2sr) (tot)	Protons $\frac{\sigma(E)}{E}$
CsI 20×20×20 (3.6+0.5)cm	1	0.573	0.69%	0.1	0.87%	1	3.75	16%

Counts estimation, *electrons*

G400 configuration: CsI(Tl), 20x20x20 crystals
Size: 78.0x78.0x78.0 cm^3 – gap
Taking into account: geometrical factor and exp. duratio
selection efficiency 80%



Experiment	Dura tion	Planar GF (m^2 sr)	Calo σ(E)/E	Calo depth	e/p rejection factor	E > 0.5 TeV	E > 1 TeV	E > 2 TeV	E > 4 TeV
CALET	5 y	0,12	~2%	30 X_0	10^5	3193	611	95	10
AMS02	10 y	0,5**	~2%	16 X_0	10^3 **	26606	5091	794	84
ATIC	30 d	0,25	~2%	18 X_0	10^4	109	21	3	0
FERMI	10 y	1,6@300 GeV * 0,6@800 GeV *	~15%	8,6 X_0	10^4	59864	2545	0	0
G400	**10 y**	**8,5**	**~0,9%**	**39 X_0**	**10^6**	**452303**	**86540**	**13502**	**1436**

* efficiencies included ** calorimeter standalone

Counts estimation, protons and helium nuclei

Polygonato model
G400 configuration: CsI(Tl), 20x20x20 crystals
Size: 78.0x78.0x78.0 cm^3 – gap 0.3 cm
Taking into account: geometrical factor and exp. duration + selection efficiency 80%

~ knee ↓ (E > 4 PeV)

Experiment	Duration	Planar GF (m^2 sr)	ε sel ε conv	Calo σ(E)/E	Calo depth	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	0,8 0,5	~40%	30 X_0 1,3 λ_0	146	138	9	10	2	3	1	1	0	0
CREAM	180 d	0,43	0,8 0,4 CT*	~45%	20 X_0 1,2 λ_0	41	39	3	3	1	1	0	0	0	0
ATIC	30 d	0,25	0,8 0,5 CT*	~37%	18 X_0 1,6 λ_0	5	5	0	0	0	0	0	0	0	0
G400	**10 y**	**8,5**	**0,8** **0,4**	**~17%**	**39 X_0** **1,8 λ_0**	**16521**	**15624**	**979**	**1083**	**261**	**326**	**60**	**92**	**10**	**21**

* carbon target

Counts estimation, heavier nuclei ($3 \leq Z \leq 24$)

Polygonato model

G400 configuration: CsI(Tl), 20x20x20 crystals

Size: 78.0x78.0x78.0 cm^3 – gap 0.3 cm

Taking into account: geometrical factor and exp. duration + selection efficiency 80%

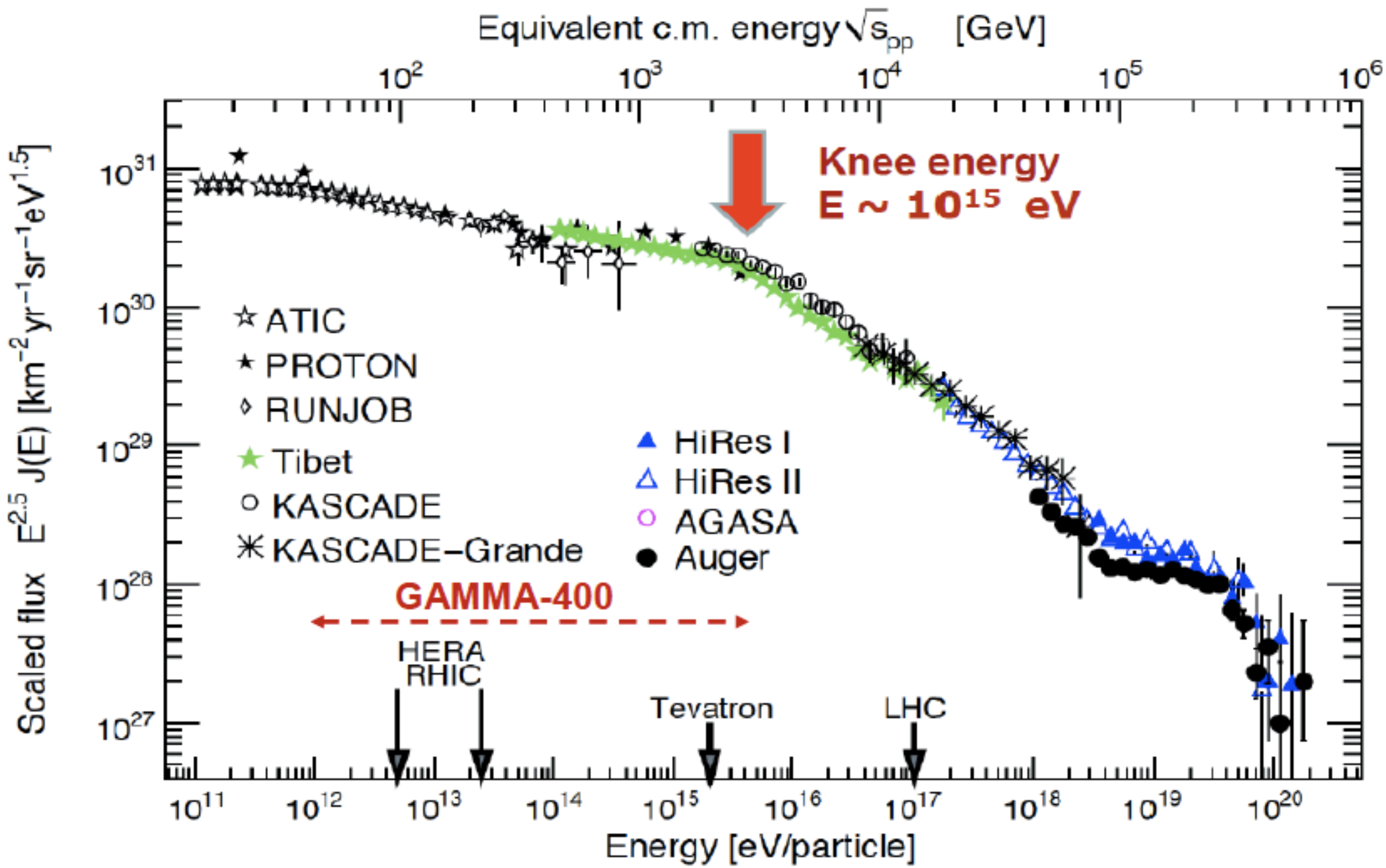
~ knee ↓

Experiment	Duration	Planar GF (m^2 sr)	ε sel / ε conv	Calo σ (E)/E	Calo depth	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	0,8 / 0,5	~30%	30 X_0 1,3 λ_0	68	70	5	5	1	2	0	1	0	0
CREAM	180 d	0,46	0,8 / 0,4 CT*	~45% **	20 X_0 1,2 λ_0	21	21	1	1	0	0	0	0	0	0
ATIC	30 d	0,25	0,8 / 0,5 CT*	~37%	18 X_0 1,6 λ_0	2	2	0	0	0	0	0	0	0	0
TRACER	30 d	5	0,8 / -	TRD	TRD	93	96	6	7	2	2	1	1	0	0
G400	**10 y**	**8,5**	**0,8 / 0,4**	**~17%**	**39 X_0 1,8 λ_0**	**7698**	**7910**	**533**	**555**	**169**	**180**	**51**	**60**	**15**	**17**

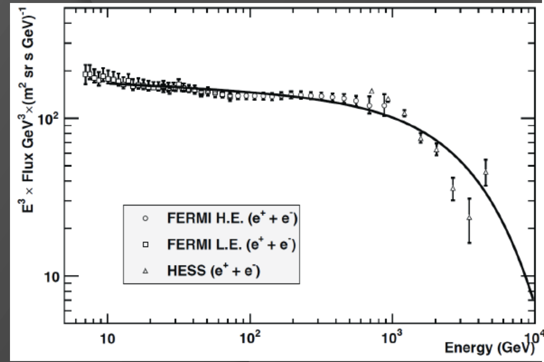
*carbon target

** better than 20% using TRD

Gamma-400: Nuclei



Comparison to other experiments, electrons How better is GAMMA400?



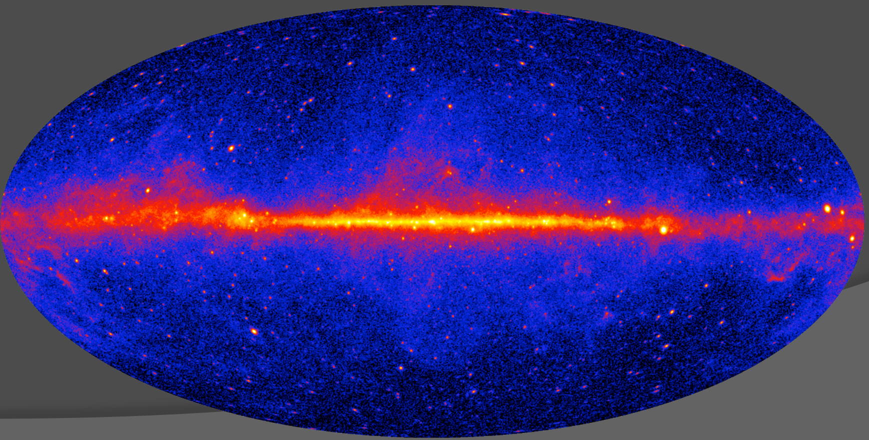
G400 configuration: CsI(Tl), 20x20x20 crystals
Size: 78.0x78.0x78.0 cm^3 – gap 0.3 cm
Taking into account: geometrical factor and exp. duration + selection efficiency 80%

Experiment	Duration	Planar GF (m^2 sr)	Calo σ (E)/E	Calo depth	Statistics (>1 TeV)
CALET	1,4	16	2,2	1,3	142
AMS02	1	20	2,2	2,3	17
ATIC	122	20	2,2	2,2	4120
FERMI	1	1,2@300 GeV 3@800 GeV	16,6	4,5	34

* efficiencies included

DM Indirect search with gamma-ray

- Ground-based Imaging Atmospheric Cherenkov telescopes
  - MAGIC, HESS, VERITAS, CTA, …
  - sensitive to γ's from 50 GeV – 50 TeV (>100 TeV for CTA)
- Gamma-ray space telescopes
  - EGRET, AGILE, FERMI/LAT,
  - GAMMA-400, …
    - sensitive to γ's 30 MeV - 300 GeV, excellent pointing, mapping capability
    - Signature: Mono-energetic γ-line from direct annihilation or continuum through annihilation into intermediate states
    - search in galactic dark matter halo, dwarf galaxies, galaxy clusters, galactic dark matter satellites, …



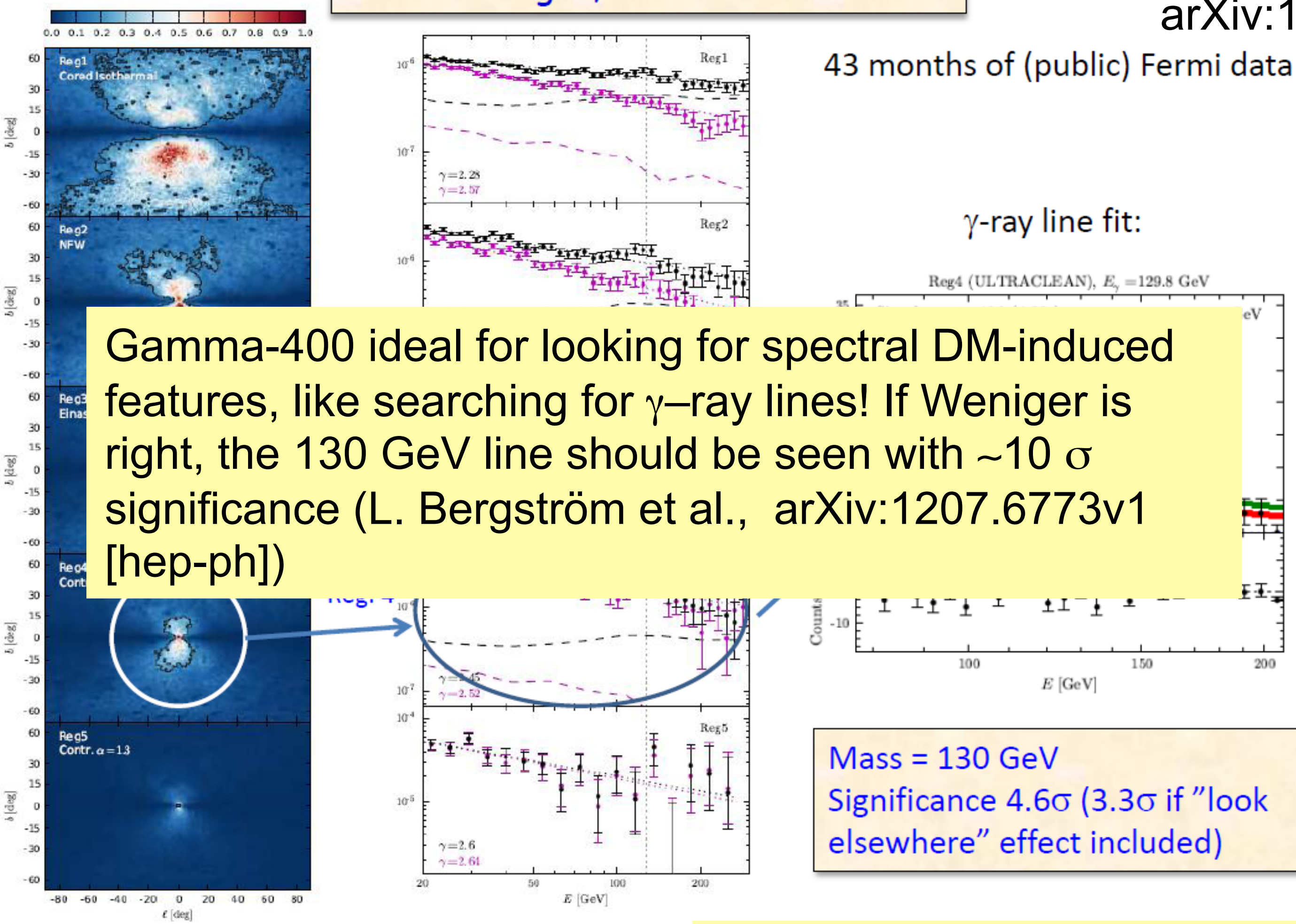
Scientific goals: high-energy γs

C. Weniger, arXiv:1204.2797

\+ arXiv:1205.1045
arXiv:1206.1616

43 months of (public) Fermi data

γ-ray line fit:



Gamma-400 ideal for looking for spectral DM-induced features, like searching for γ–ray lines! If Weniger is right, the 130 GeV line should be seen with ~10 σ significance (L. Bergström et al., arXiv:1207.6773v1 [hep-ph])

Mass = 130 GeV
Significance 4.6σ (3.3σ if "look elsewhere" effect included)

L. Bergström, , Stockholm 2012

No other planned space experiment active for mid-2020 when many other facilities/observatories will be operating from radio to TeV will have gamma-ray capability.

- G-400 will point to specific targets but with a large FOV:
  - 2.5 sr, i.e., 1/5 of the whole sky e.g.,
    - Galactic plane and Center,
    - SNRs;
    - DM candidates;
- G-400 is complementary to TeV instruments
    - Many problems need to be solved by joint GeV and TeV observations (e.g., CR origin in SNRs and propagation).
    - The international community is showing great interest in G-400.
    - Explicit synergy with CTA

Concluding
G-400 will address crucial scientific problems

- G-400 will have optimal angular and energy resolution and statistics to address
  1. Fundamental physics (Dark Matter searches)
  2. Cosmic-Ray origin, propagation and detection up to the knee.
  3. High-energy Astrophysics
  4. Galactic-center