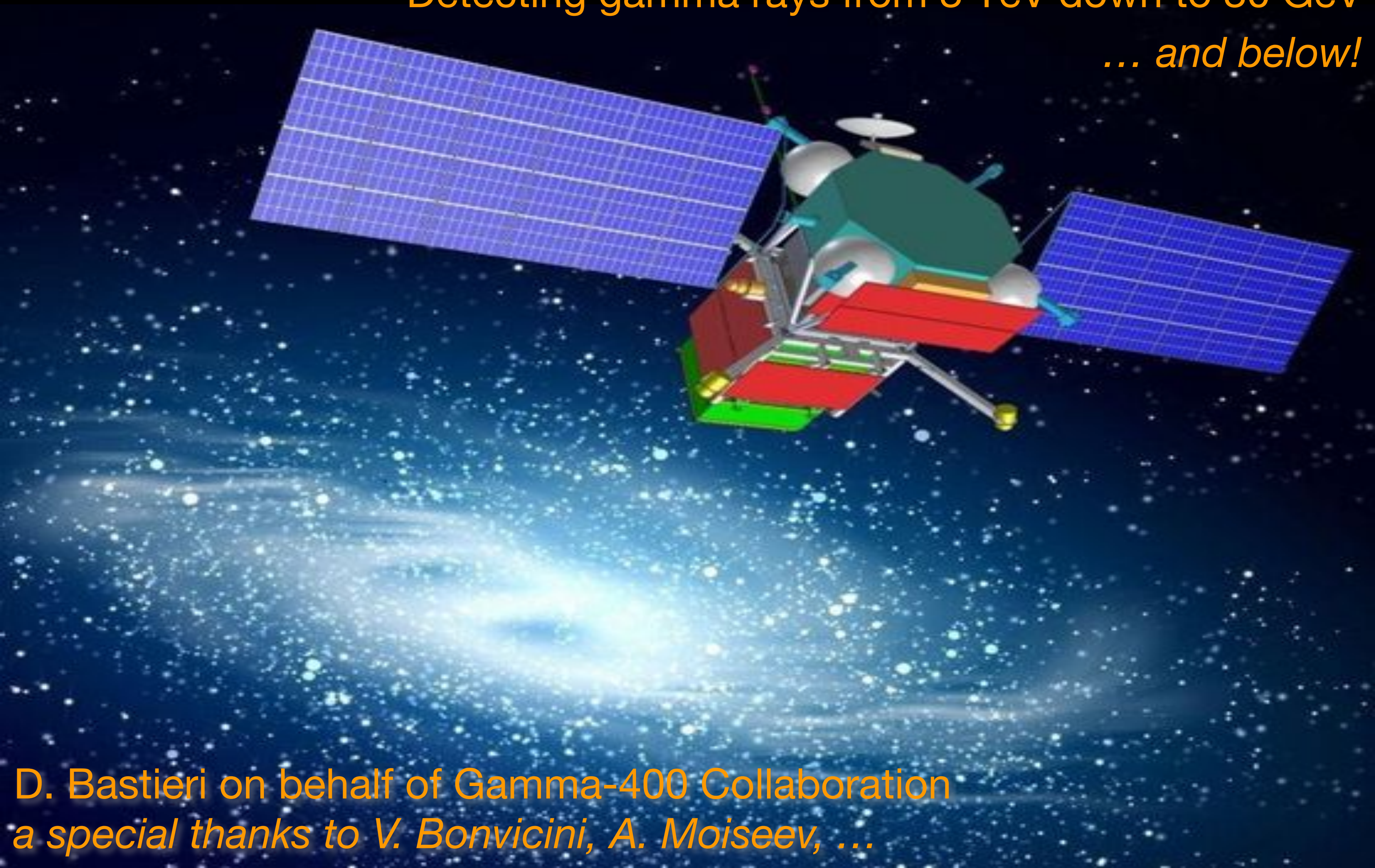
GAMMA-400

Detecting gamma rays from 3 TeV down to 30 GeV

… and below!



D. Bastieri on behalf of Gamma-400 Collaboration

a special thanks to V. Bonvicini, A. Moiseev, …

The origins

SOME TASKS OF OBSERVATIONAL GAMMA-RAY ASTRONOMY IN THE ENERGY RANGE 5–400 GeV

V. A. DOGIEL, M. I. FRADKIN, L. V. KURNOSOVA, L. A. RAZORENOV, M. A. RUSAKOVICH, and N. P. TOPCHIEV

Proc. 20th ICRC (Moscow, 1987), Space Science Reviews, 49, 215

The GAMMA-400 project studying space γ rays and electron + positron fluxes in the energy range of 1-3000 GeV

Proposal signed on May 21st, 2009 by GAMMA-400 PI, Prof. A. Galper, academician V. Ginzburg, and LPI head, academician G. Mesyats

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.

29/V 2009 г.

Научный руководитель проекта

ГАММА-400

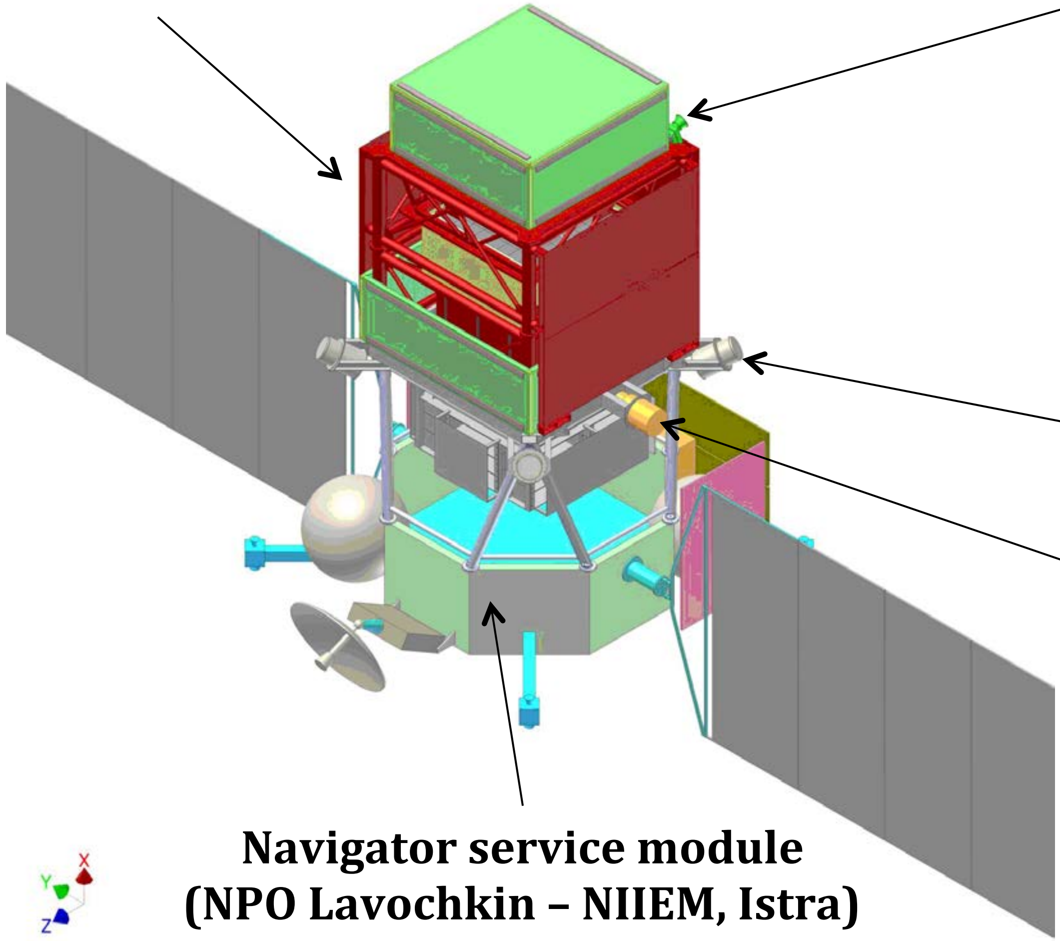
профессор, г.н.с.

Гальпер А.М.

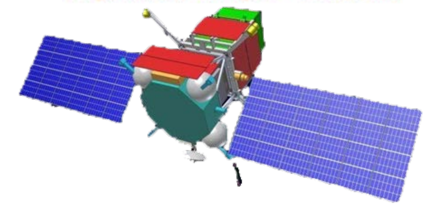
21 мая 2009 г.

Москва, 2009 г.

The Satellite



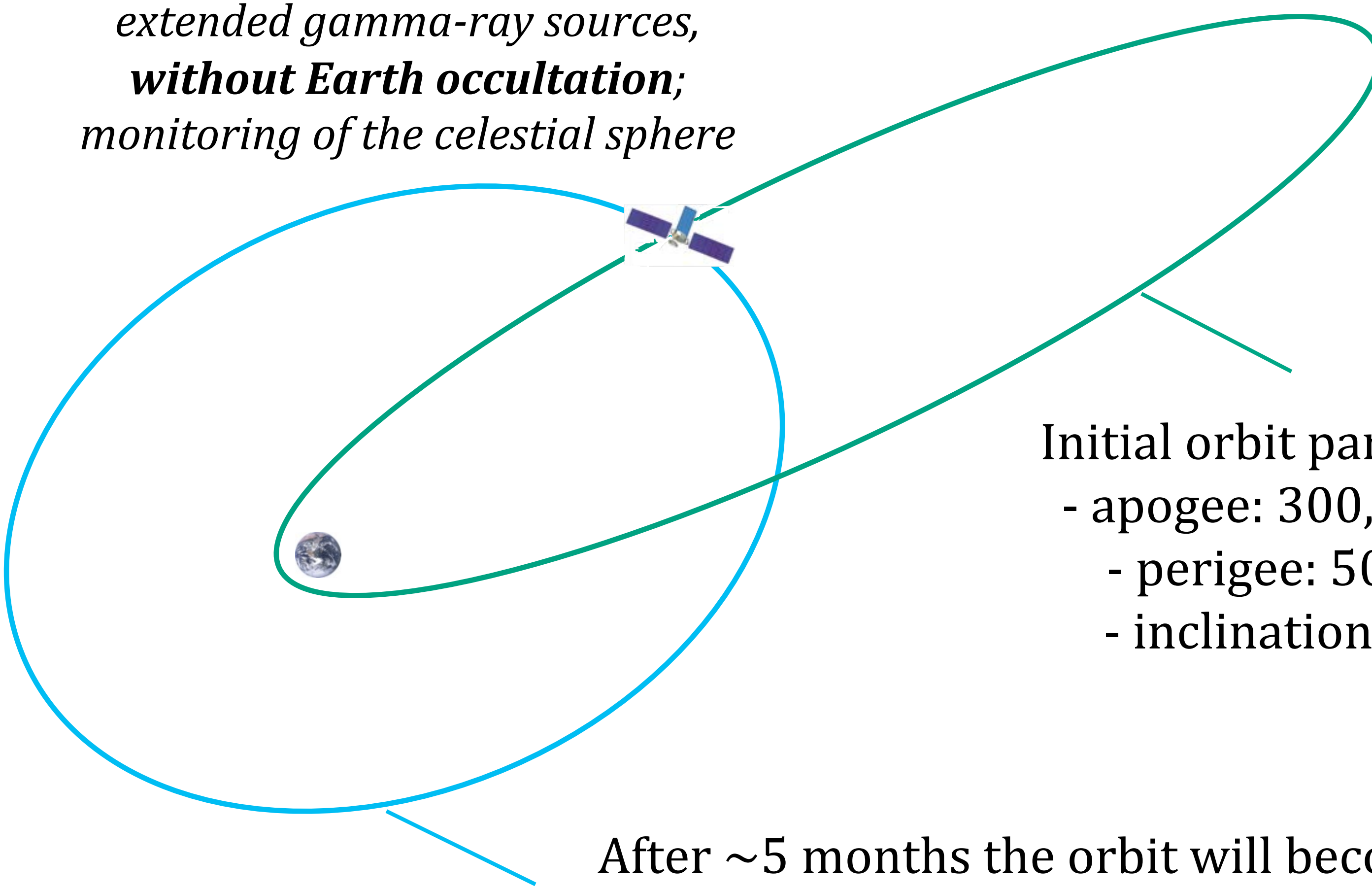
Гамма-400



The Orbit

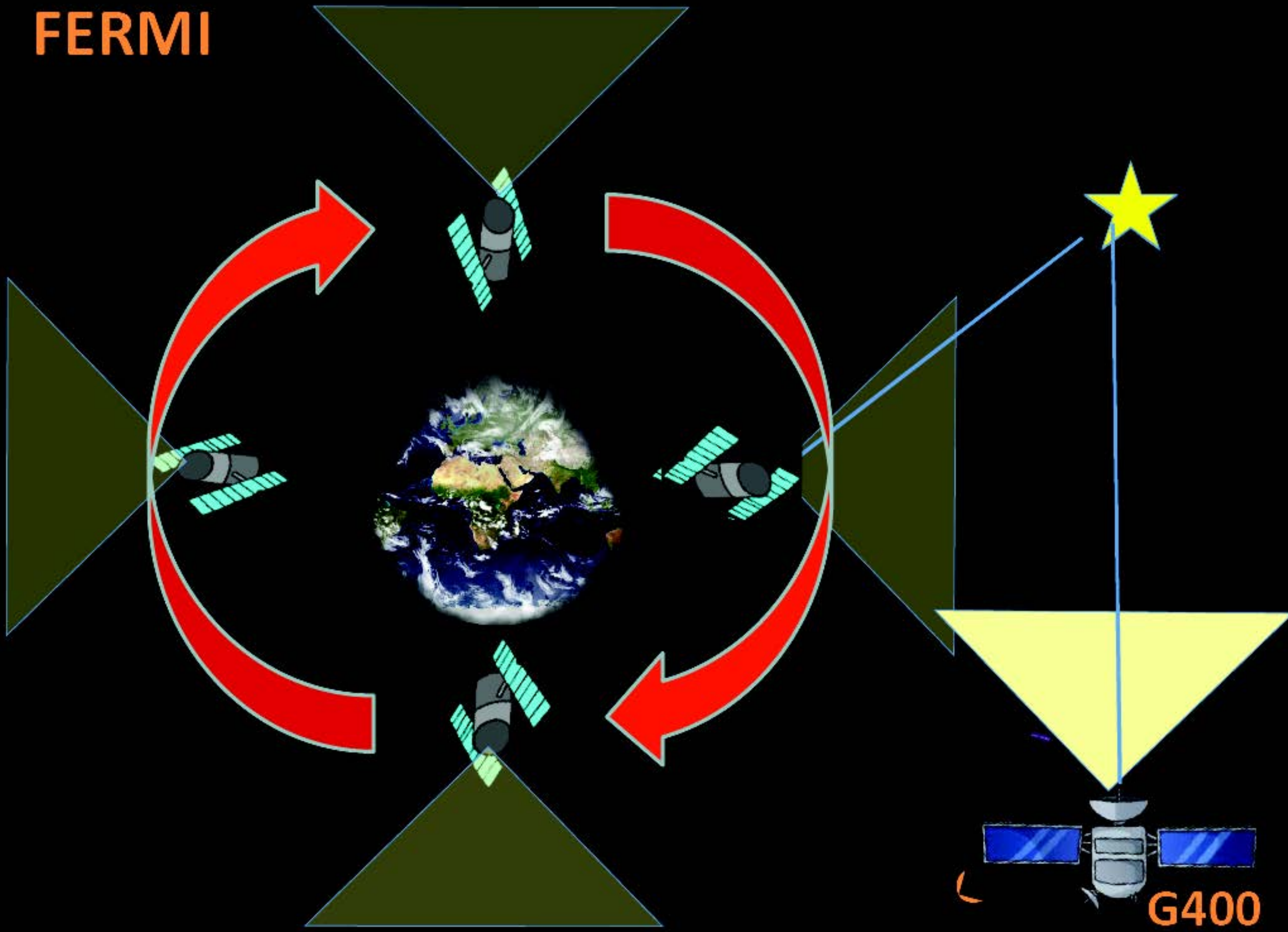
Observation modes:

Continuous long-duration (~100 days) observation of specific regions of celestial sphere, including point and extended gamma-ray sources,
without Earth occultation*;*
monitoring of the celestial sphere

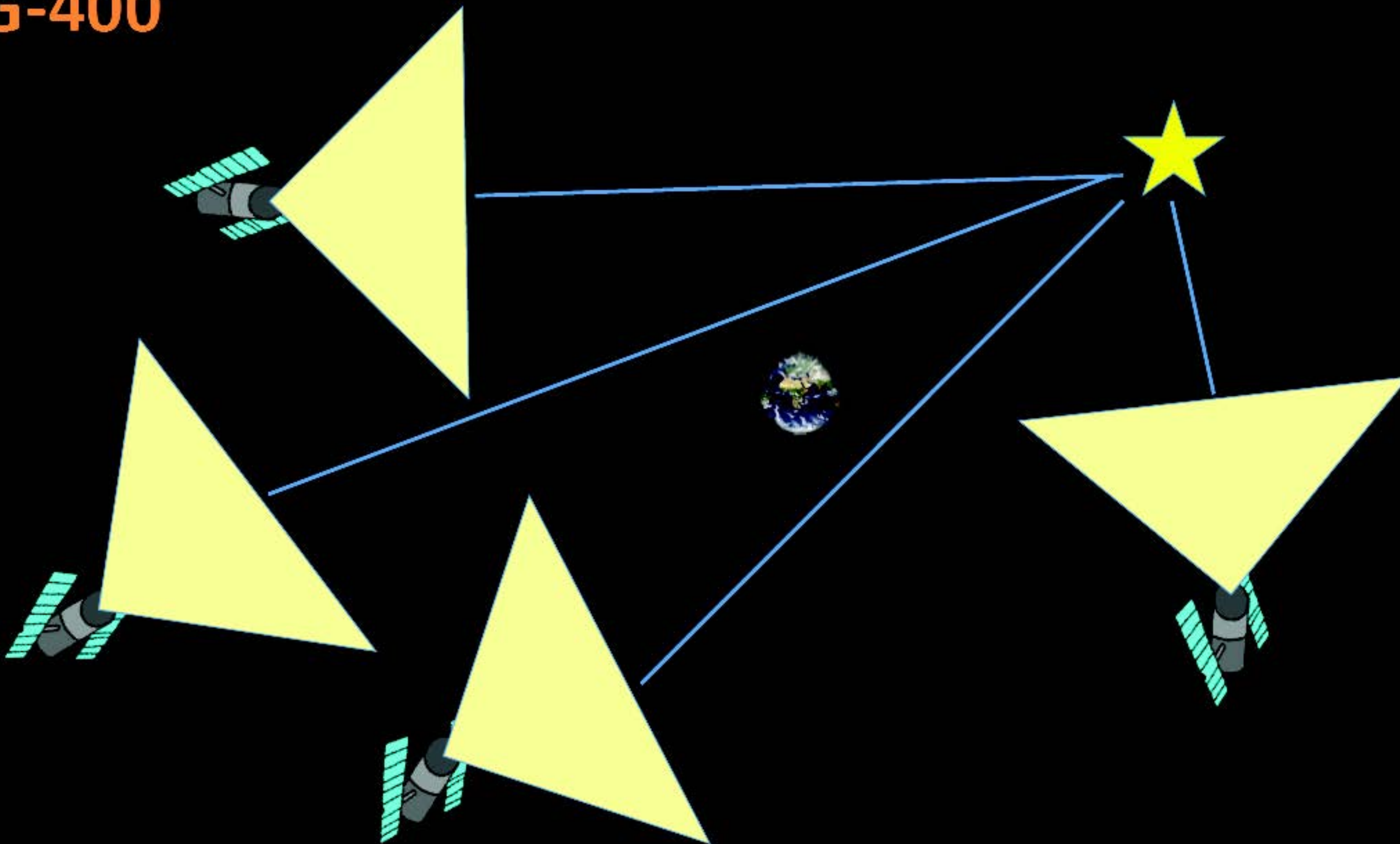


Initial orbit parameters:
- apogee: 300,000 km:
- perigee: 500 km;
- inclination: 51.8°

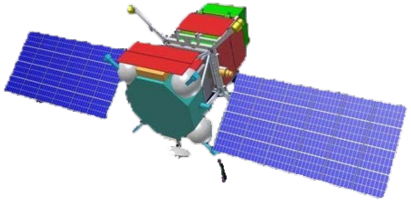
After ~5 months the orbit will become more circular with a radius of ~200,000 km.


FERMI
G400

G-400



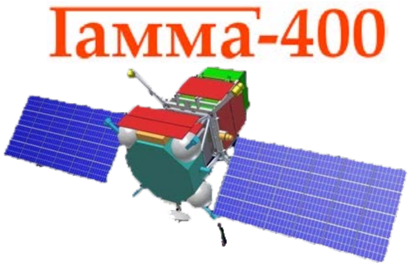
Гамма-400



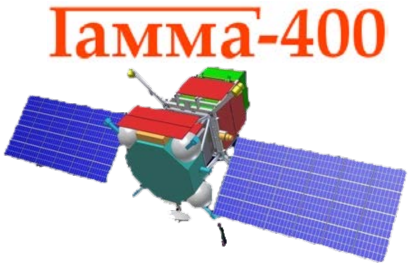
Evolution of the design

	1st stage 2009-2010	2nd stage 2011-2012	3rd stage 2013-2014
Ang. Resolution (E_γ > 100 GeV)	0.2°	~0.01°	~0.01°
Energy resolution (E_γ > 10 GeV)	~3%	~1%	~1%
Energy range (γ)	30-1000 GeV	0.1-3000 GeV	0.1-3000 GeV
Sensitive area	0.44 m^2	0.64 m^2	1.0 m^2
Mass	1700 kg	2600 kg	4100 kg
Power consumption	800 W	2000 W	2000 W
Telemetry downlink volume	500 MB/day	100 GB/day	100 GB/day
Particles	gamma rays, electrons + positrons, protons, nuclei		

The GAMMA-400 project



- Mission is approved by ROSCOSMOS (launch currently scheduled in the first 20ies)
- GAMMA-400:
  - Scientific payload mass: 4100 kg
  - Power budget: 2000 W
  - Telemetry downlink capability: 100 GB/day
  - Lifetime: > 7 years
  - Orbit (initial parameters): apogee 300000 km, perigee 500 km, orb. period 7 days, inclination 51.8°
  - GAMMA-400 will be installed onboard the platform "Navigator" manufactured by NPO Lavochkin



GAMMA-400 Principal Investigator

Prof. Arkadiy M. Galper

(Lebedev Physical Institute, NRNU MEPhI)

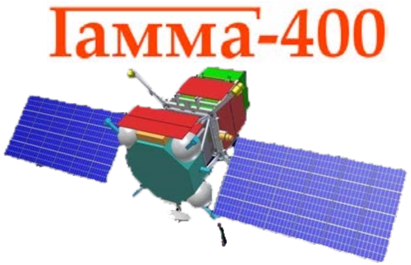
GAMMA-400 Deputy PI

Dr. Nikolay Topchiev
(LPI, Russia)

Dr. Valter Bonvicini
(INFN, Italy)

Dr. Yuriy Yurkin
(NRNU MEPhI, Russia)

INFN & science in space

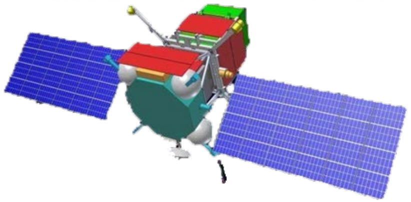


- World-renowned experience in designing, assembling and operating particle detectors. In particular, INFN is the world leader in Silicon Strip Detectors and associated low-noise/low-power Front-End Electronics for space applications (*Fermi* LAT: 170μW/channel).
- INFN designed, built, tested and operated converter-tracker instruments and imaging calorimeter in space for:
  - **NINA (1998)**
  - **Sil-Eye1…3 (2000/03)**
  - **PAMELA (2006 – …)**
  - ALTEA (2008)
  - AGILE (2007 – …)
  - Fermi LAT (2008 – …)
  - AMS-01 (1998) & AMS-02 (2011 – …)
  - DAMPE (2016)

Support by agencies and research institutes

- 2013: INFN Proposal to provide CVT/TKR + SSD for the calorimeter
- 2014: general agreement between ASI & ROSCOSMOS, details on a specific MoU between LPI and INFN (both documents still under drafting)
- 2015: IFAE/UB/CIEMAT willing to join?

Гамма-400



Scientific payload

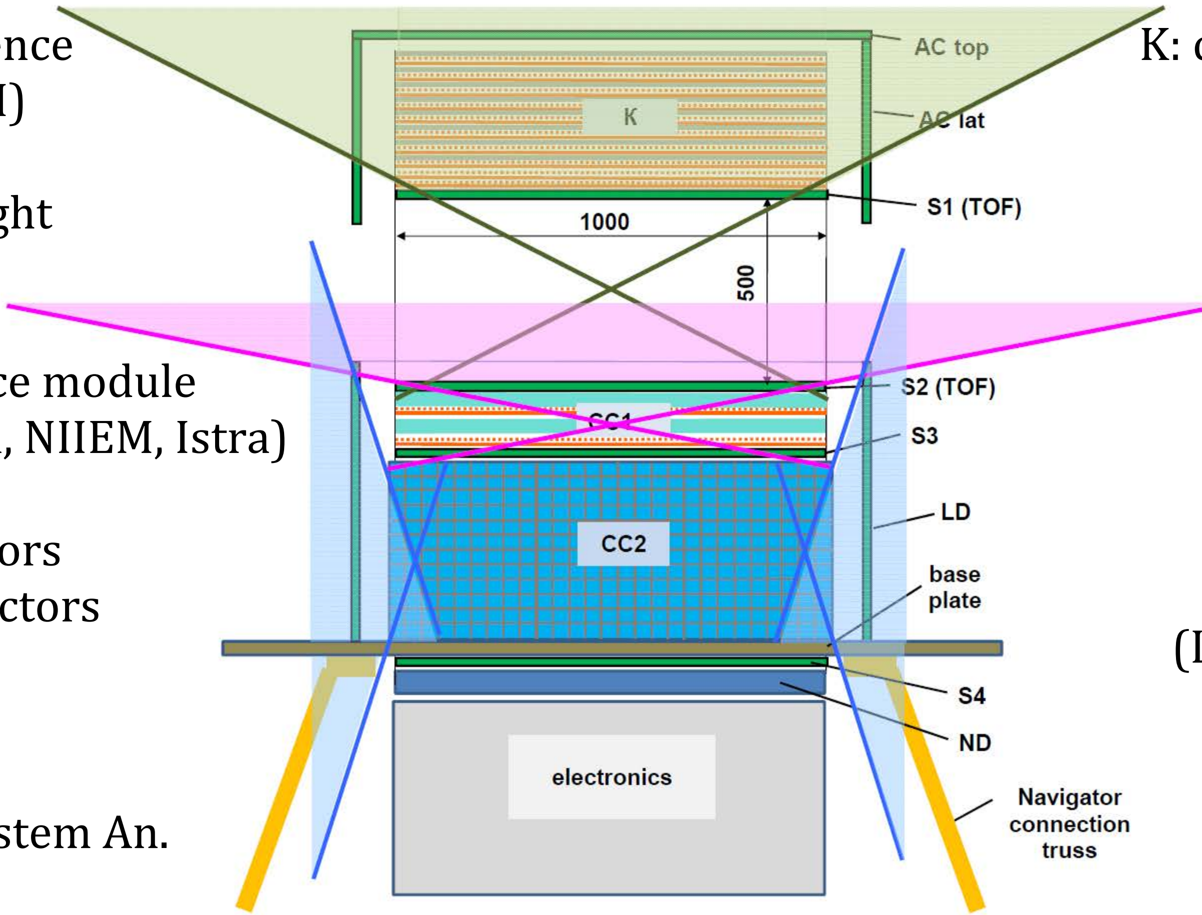
AC: anticoincidence detector (MEPhI)

TOF: time-of-flight (MEPhI)

Navigator service module (NPO Lavochkin, NIIEM, Istra)

S3, S4: Scintillators
LD: Lateral detectors (MEPhI)

Scientific DAQ
Sci. Res. Inst. System An.
SRISA – RAS



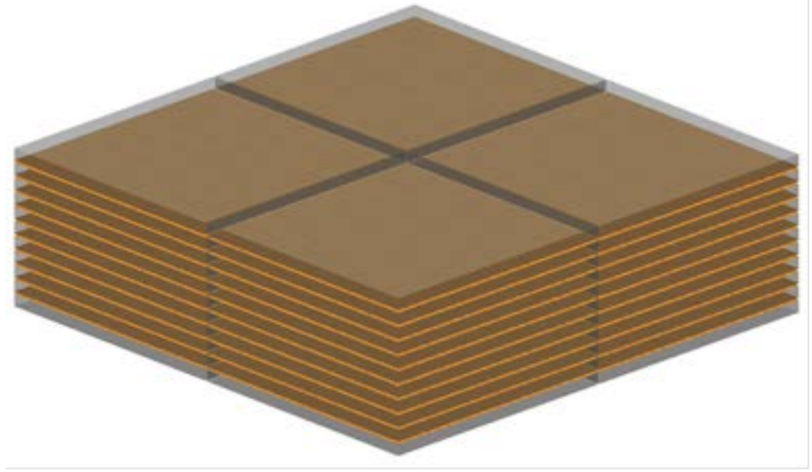
K: converter/tracker (W)+Si strips (INFN) (1 X_0)

CC1: calorimeter +Si strips (LPI+INFN) (2 X_0)

CC2: calorimeter *CaloCube* (LPI+INFN) (23 X_0)

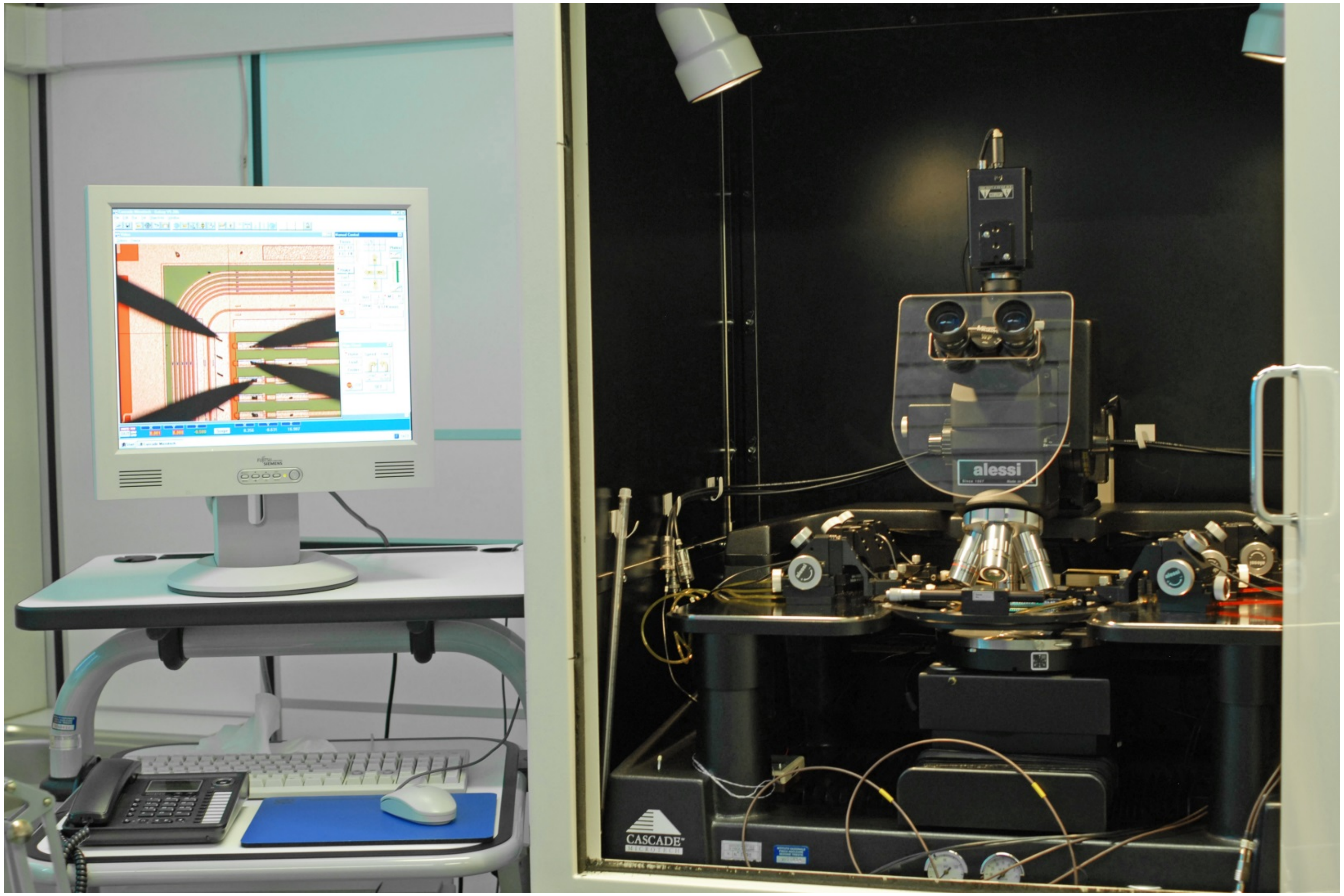
ND: neutron detector (MEPhI)

Converter/Tracker

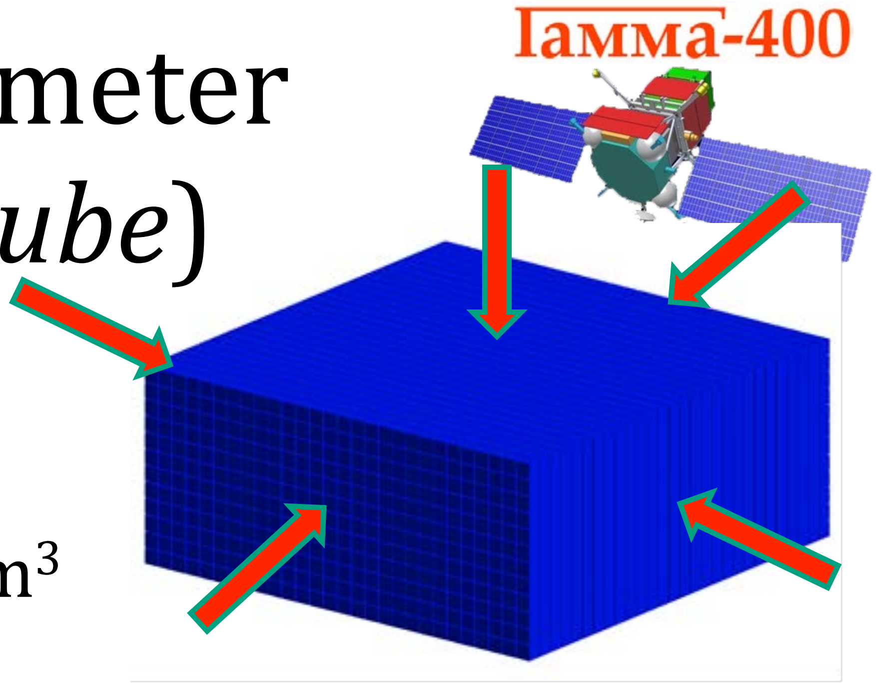


- Homogeneous Si-W Tracker
- 4 towers (50 cm × 50 cm each)
- 8 W/Si-*x*/Si-*y* planes + 2 Si-*x*/Si-*y* planes
- Thickness of each plane 0.1 X_0
- Each die: 9.7 cm × 9.7 cm from 6” wafers
- Sensors arranged in *ladders* (5 detectors/ladder), 1 *ladder* ≈ 50 cm
- Implant pitch 80 μm (fine segmentation)
- Read-out pitch 240 μm (capacitive charge division, one strip every 3 is read-out), 384 read-out strips/ladder
- 2000 silicon detectors
- 153600 readout channels, 2400 front-end ASICs (64 channels/ASIC)
- Power consumption (FE only): ≈ 80 W (520 μW/channel)

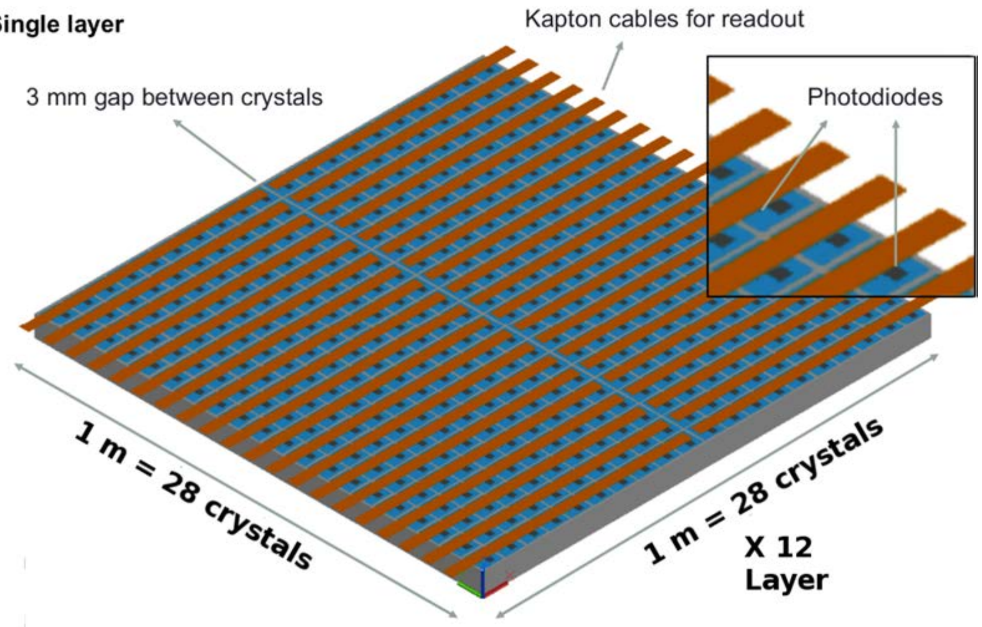
Detectors under test in Trieste



CC2 Calorimeter
(→ *CaloCube*)

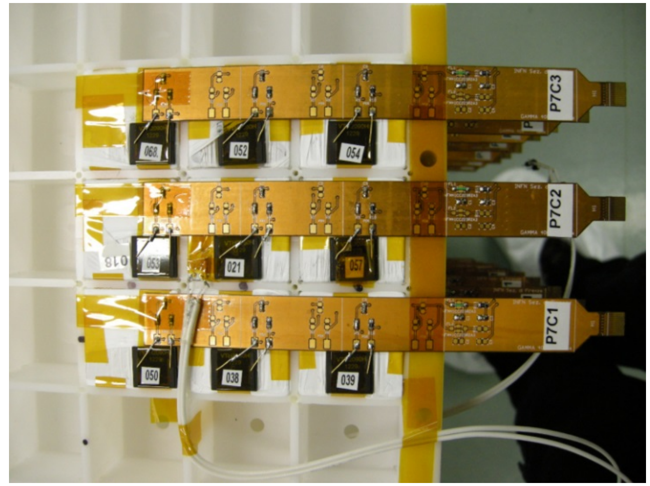


- 28×28×12 CsI(Tl) cubes
- ℓ_{cube} = 3.6 cm
- CC2 dimensions: 1×1×0.47 m^3
- X_0: 54.6×54.6×23.4
- λ_I: 2.5×2.5×1.1
- Mass = 1980 kg
- Planar GF: 9.5 m^2sr
- $GF^{0.1\text{-}1\ TeV}_{eff,\ el} \approx 3.4\ m^2sr$
- $GF^{1\ TeV}_{eff,\ prot.} \approx 3.9\ m^2sr$



Calorimeter prototype

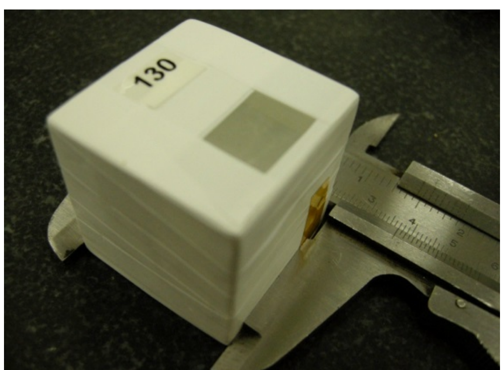
- 14 Layers
- 9 crystals/layer
- xtal dim: $(3.6\ \text{cm})^3$
- 126 Crystals in total
- 126 Photodiodes
- 50.4 cm of CsI(Tl)
- 27 X_0, 1.44 λ_I
- Photodiodes read-out by 9 CASIS1.2A (16-chan ASICs)

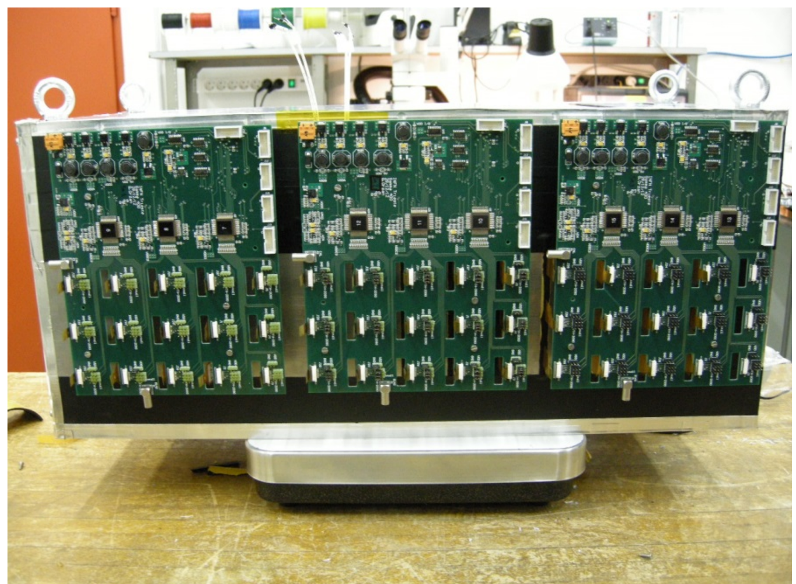


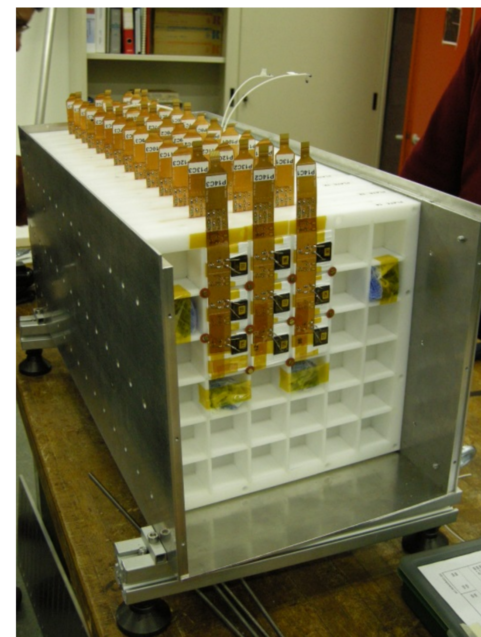
Mechanics:
INFN Pisa

Front-end electronics:
INFN Trieste

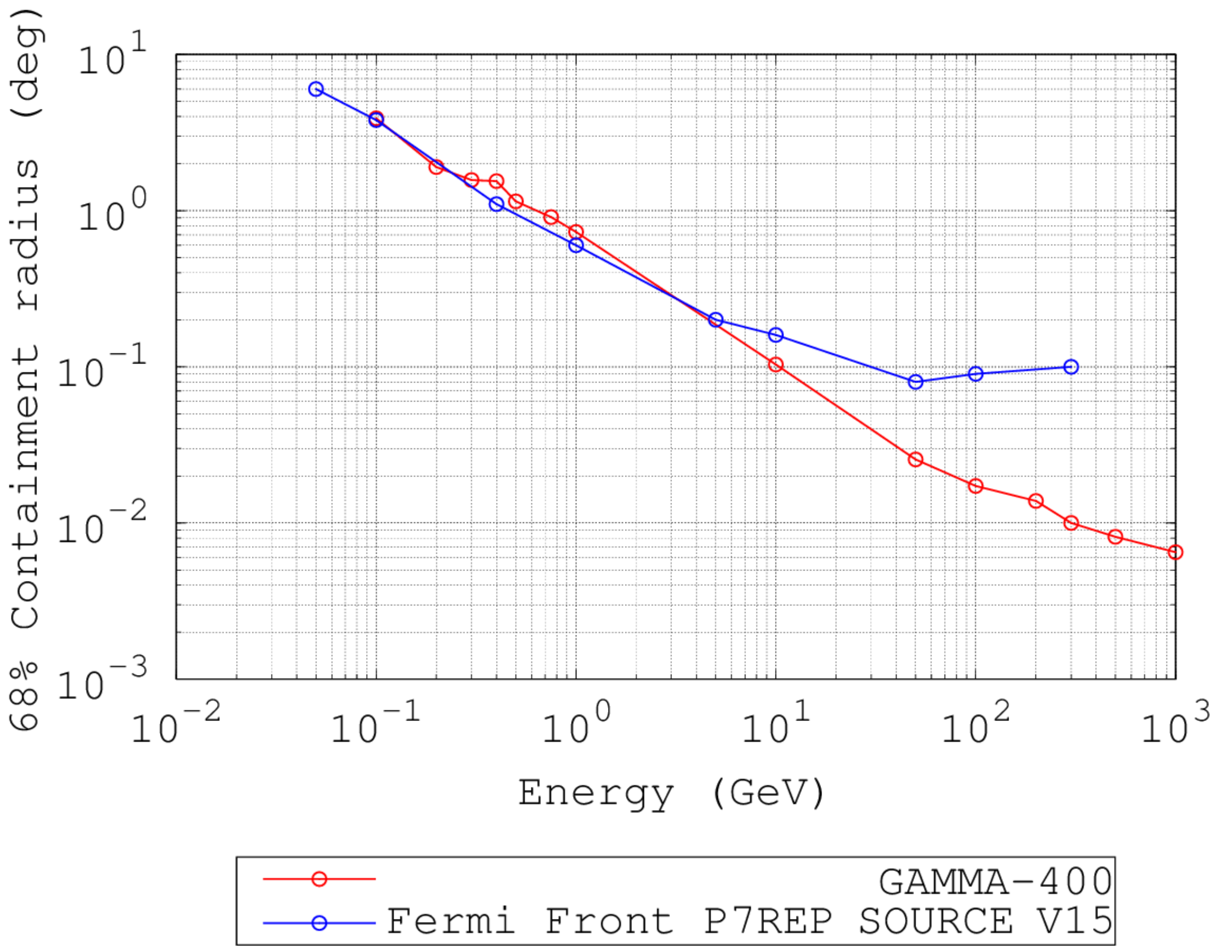
Crystals, photodiodes, DAQ, assembly:
INFN Florence



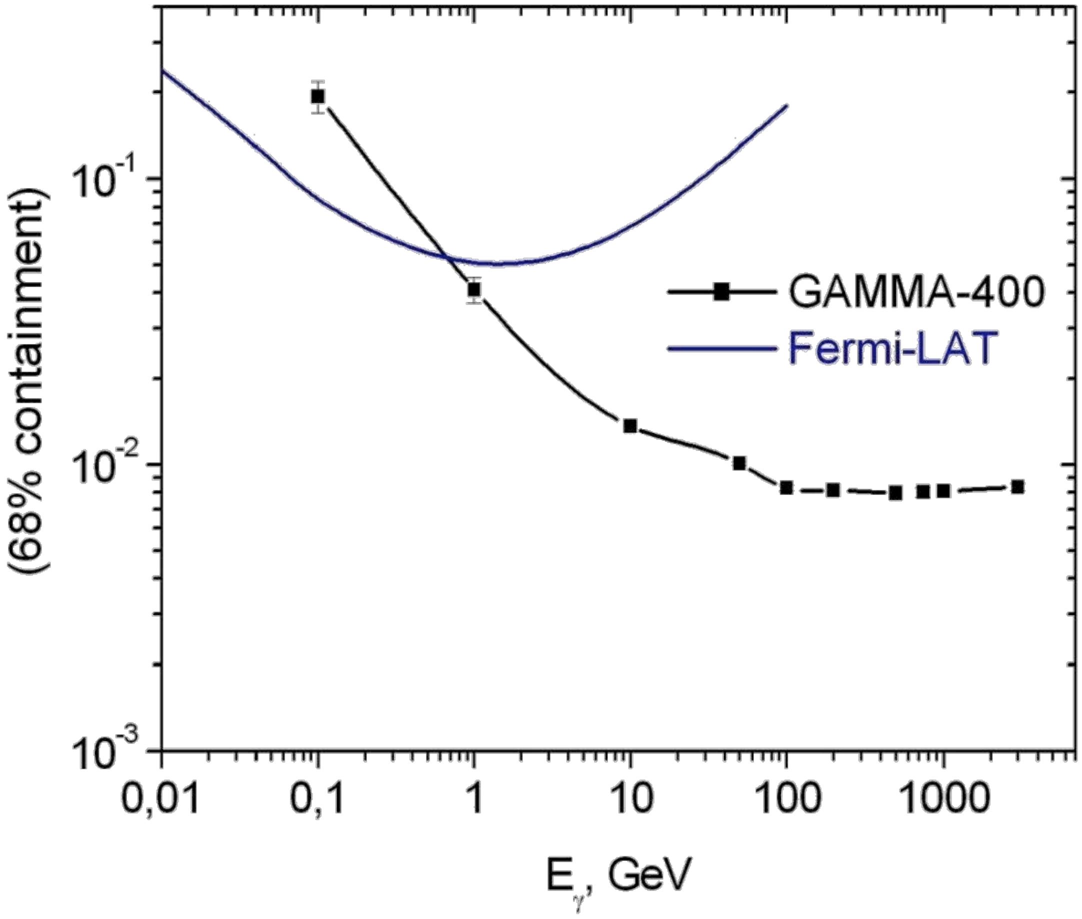


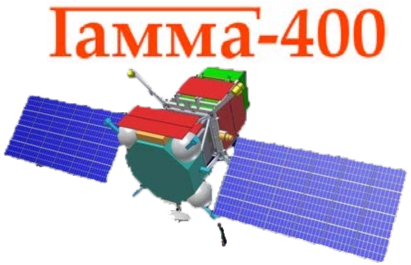


Angular resolution

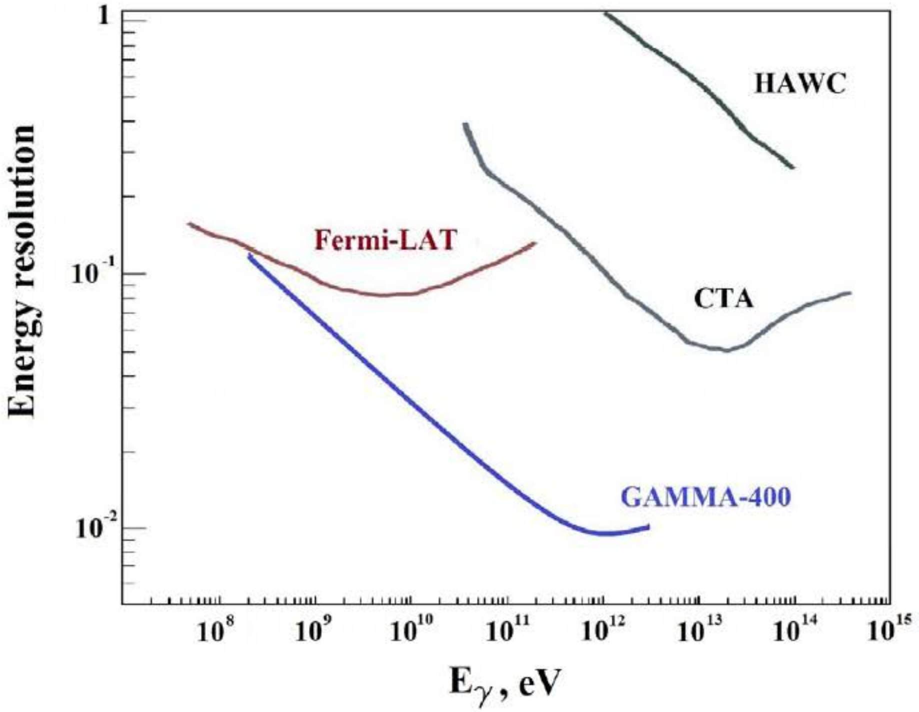


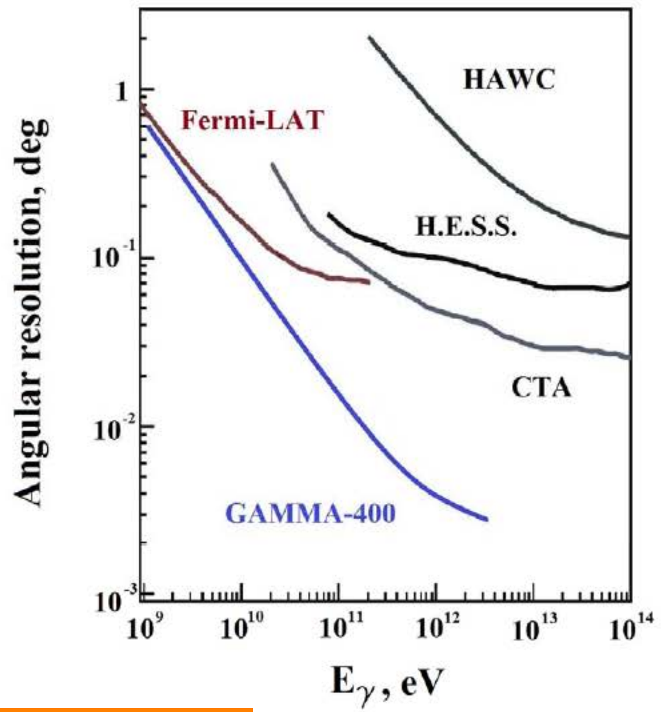
Energy resolution





GAMMA-400 and CTA





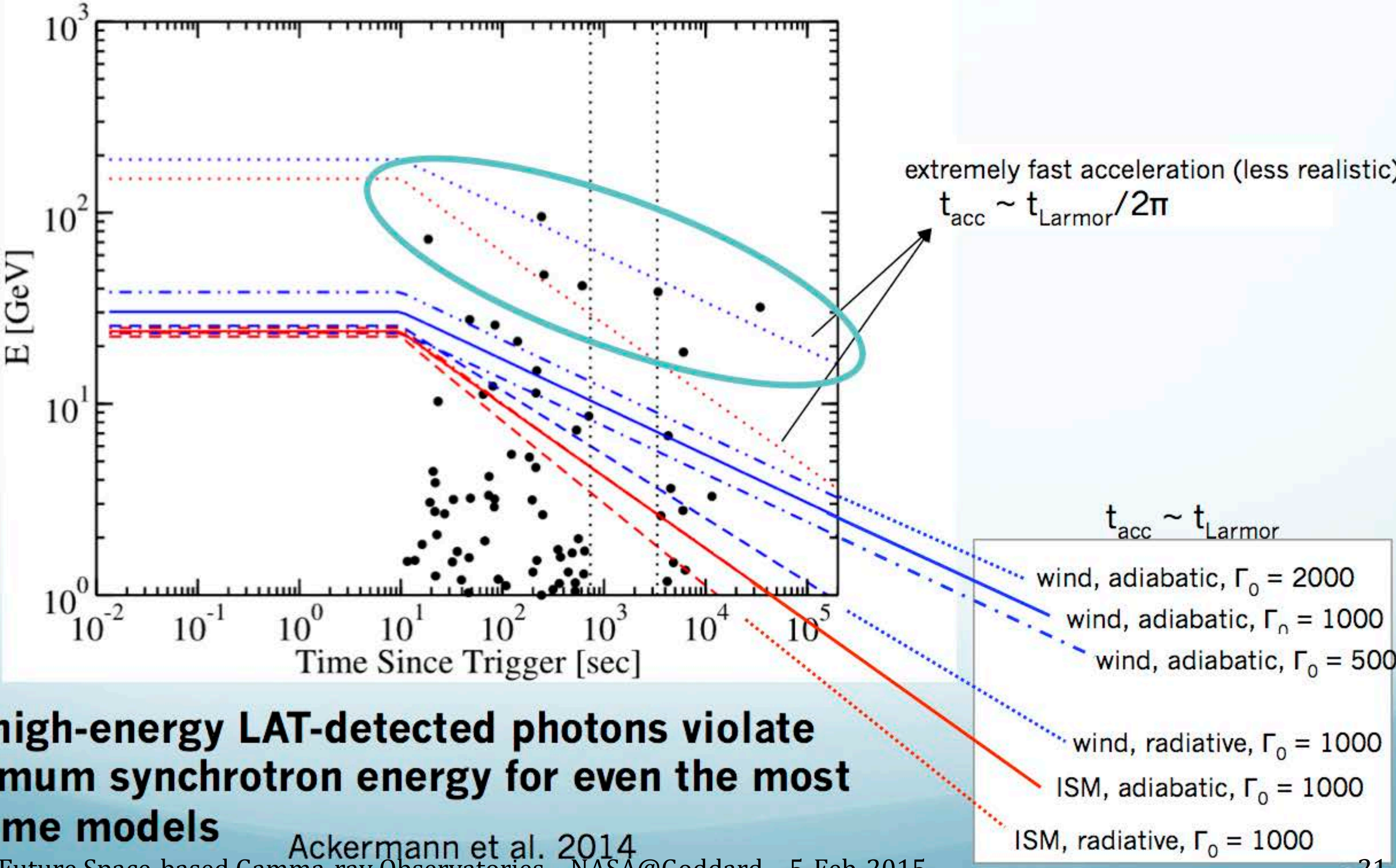
68% Containment

S.Funk, J.A. Hinton/Astroparticle Physics 43(2013) 348-355

HE & VHE

- Publications
  - *Fermi* LAT + MAGIC — 16 articles
  - *Fermi* LAT + HESS — 12 articles
  - *Fermi* LAT + Veritas — 7 articles
- ATel (since 8/2008), trg'd by LAT/not trg'd:
  - MAGIC — 17 after LAT (+1 AGILE) vs. 12
  - Veritas — 13 after LAT vs. 8
  - HESS — 3 after LAT vs. 2

GRB 130427A Challenges Synchrotron Shock Physics?



The high-energy LAT-detected photons violate maximum synchrotron energy for even the most extreme models

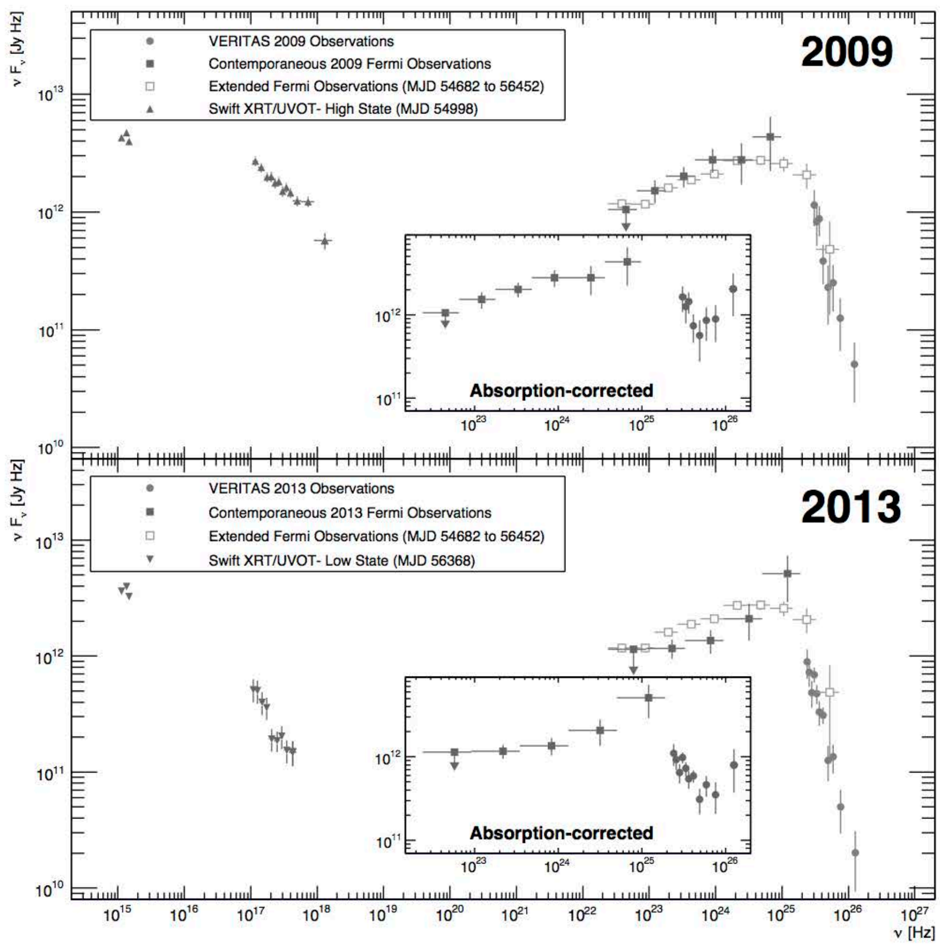
Ackermann et al. 2014

Open Questions in GRBs

- What is the true shape of the the prompt emission spectum, and therefore also emission mechanism(s)?
  - How common are multiple components?
  - Temporal and spectral evolution of components?
  - This would benefit from simultaneous keV-10's of MeV sensitive spectral coverage
- Is the afterglow of synchrotron origin and a single component from radio to GeV?
  - Bridging gap between few MeV and GeV would help
- When is the transition between prompt emission and afterglow? What radius from the central engine does that occur? What are the implications for jet composition (magnetic vs baryonic)?

PKS 1424+240

- Blazar detected < 750 GeV @ z>0.6035
- Relative high state in 2009, low state in 2013
- Flux is lower in 2013 by about a factor of 2
- Both absorption-corrected spectra show low-significance indication of hardening at high energy
- Inconclusive whether the high energy (>310 GeV flux) is variable, (5.6±3.6) vs. (3.6±1.8) x 10^{-9} m^{-2} s^{-1}
- Lower state in 2014 as compared to 2013 - analysis ongoing

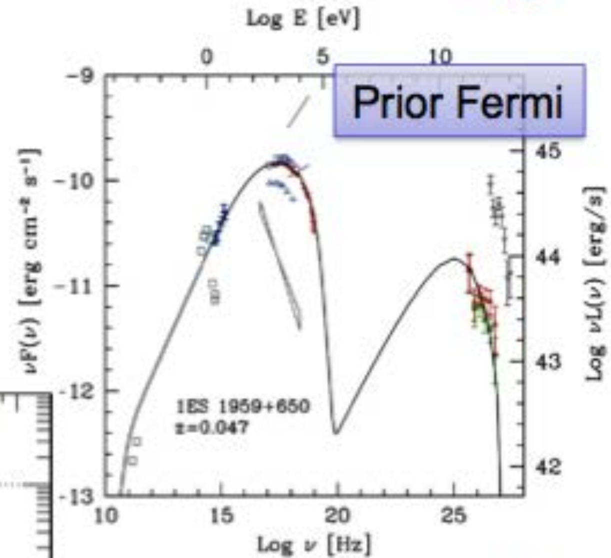


Figures from S. Archambault et al. 2014 (VERITAS Collaboration), ApJL 785, L16

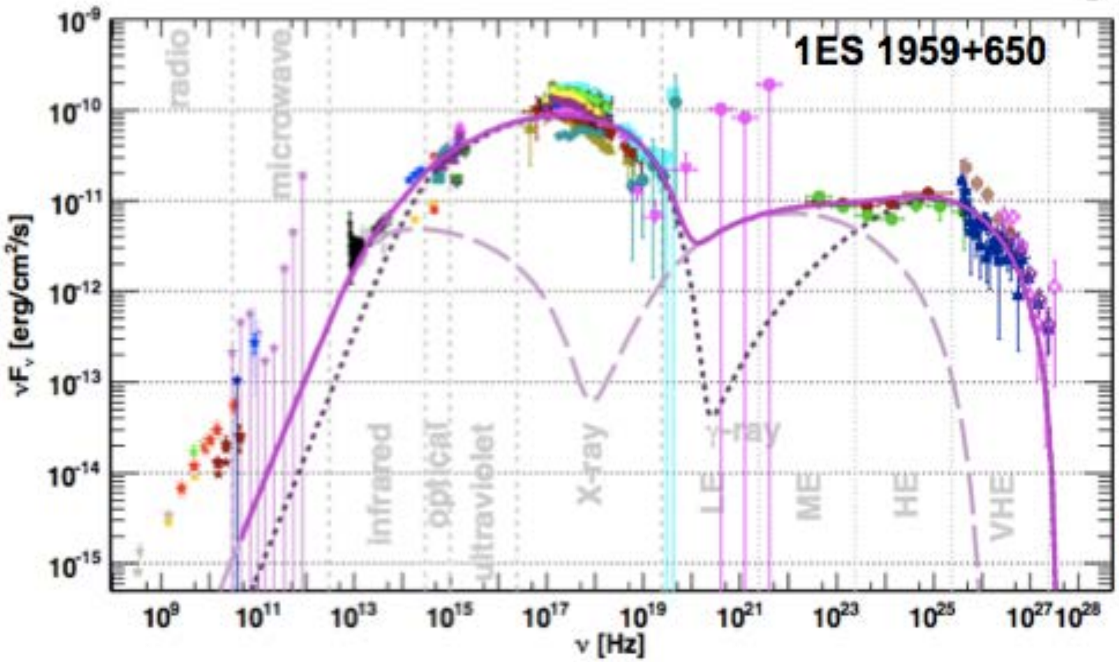
GeV-TeV Connection: 1ES 1959+650

Challenging the one zone leptonic model:
Flat VHE spectrum

A "standard" blazar (no EBL, no hard TeV,....)
- A HSP with an hadronic VHE bump?
- Leptonic Multi-zones emission?

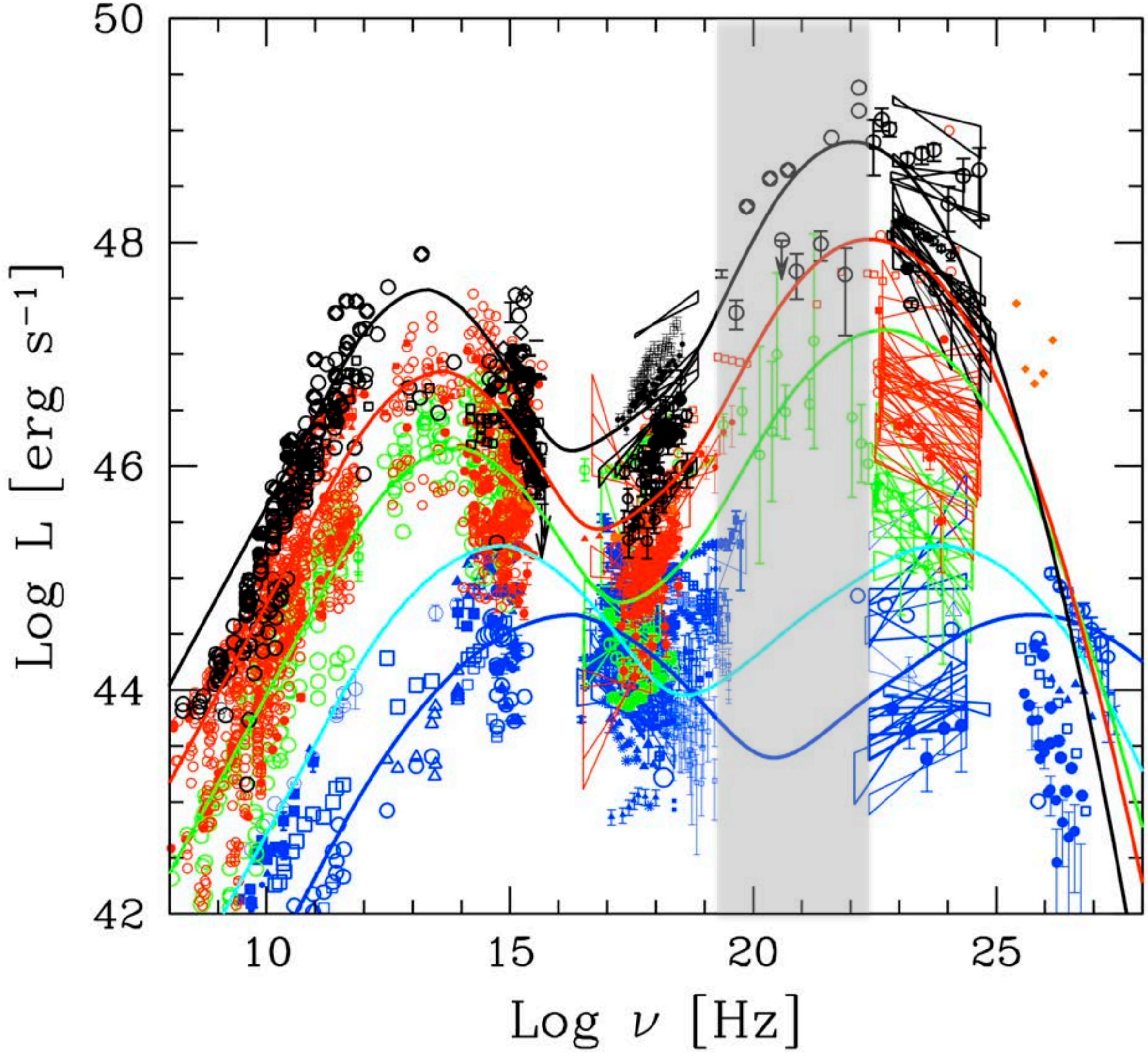


Tagliaferri+ 2009



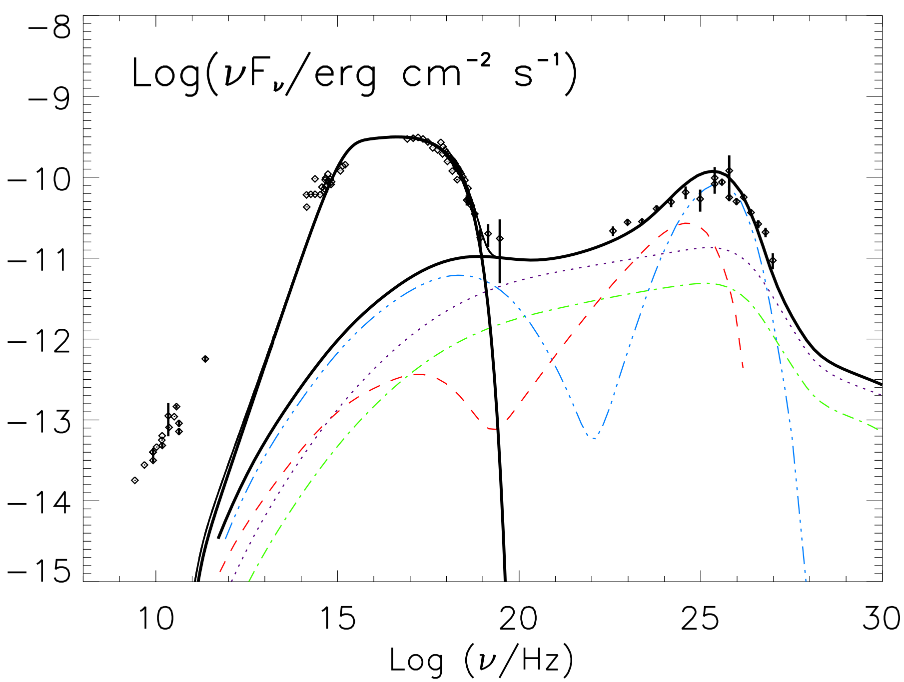
M. Backes, PhD thesis

Missing pieces



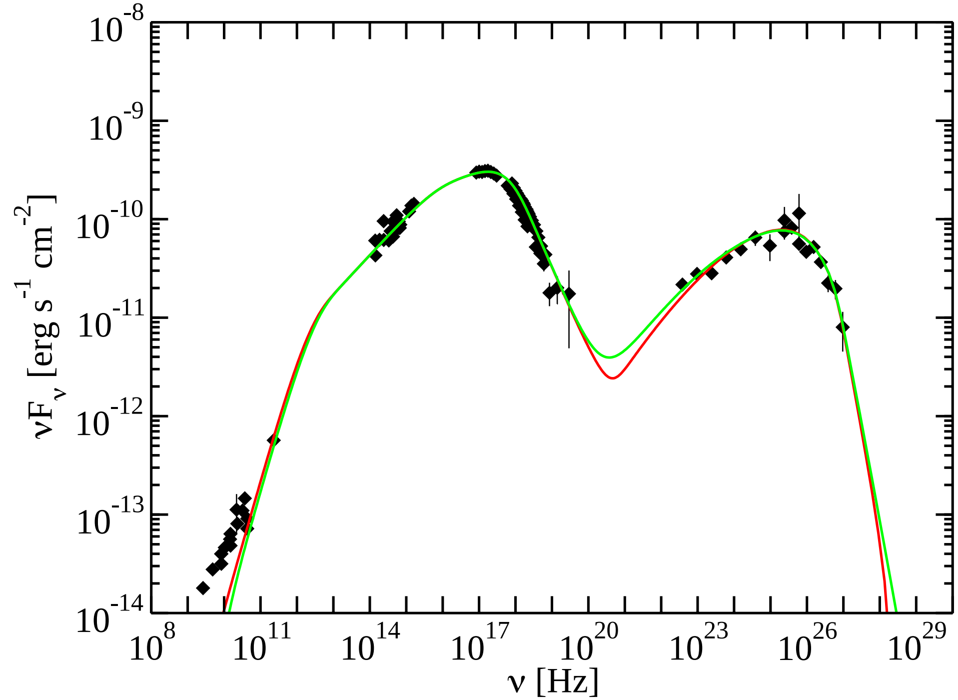
Mkn421 SED
Abdo++, ApJ 736 131 (2011)

Hadronic model

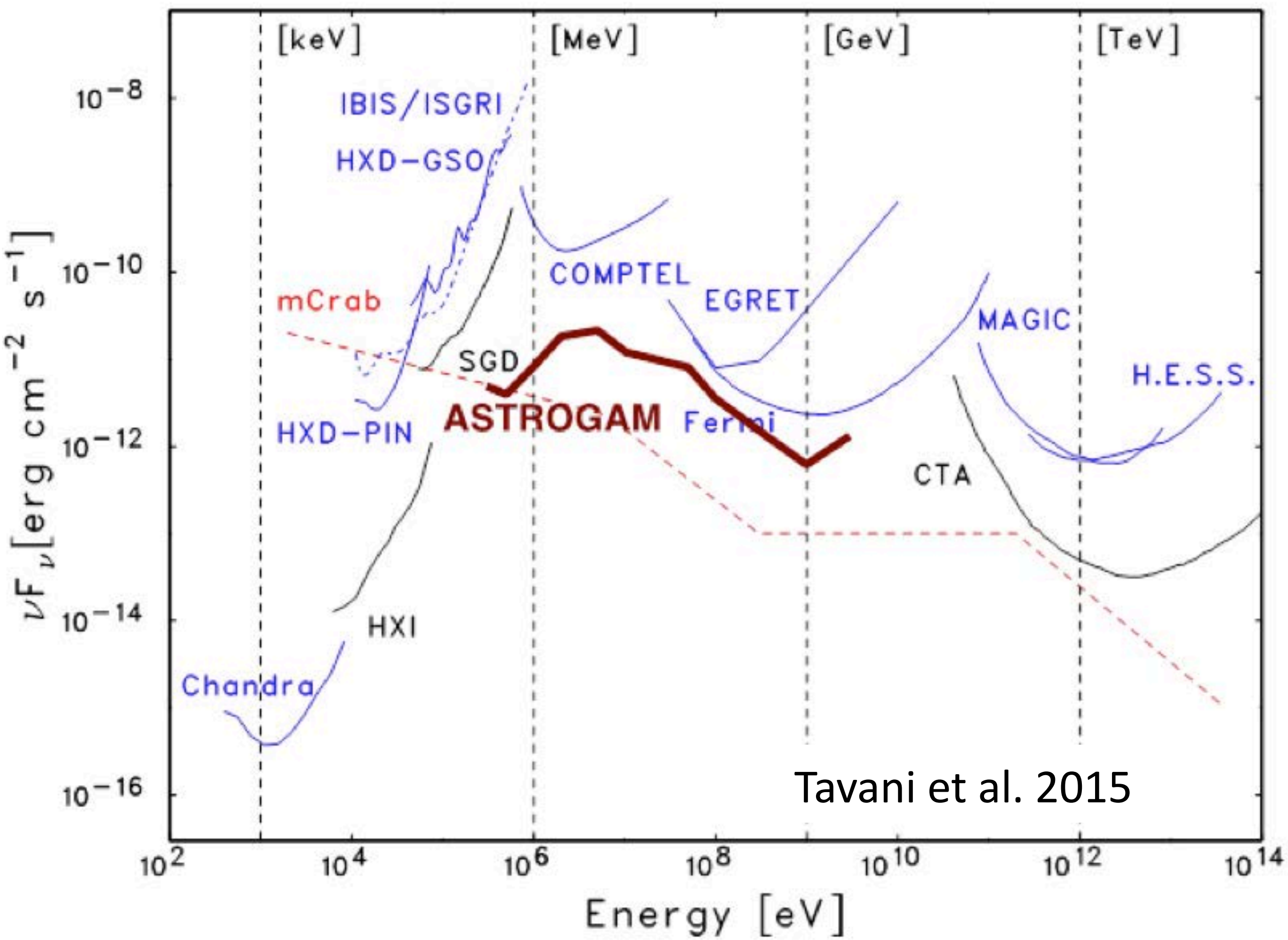


dotted line: π^0 decay

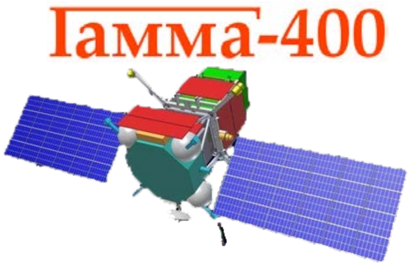
Leptonic model



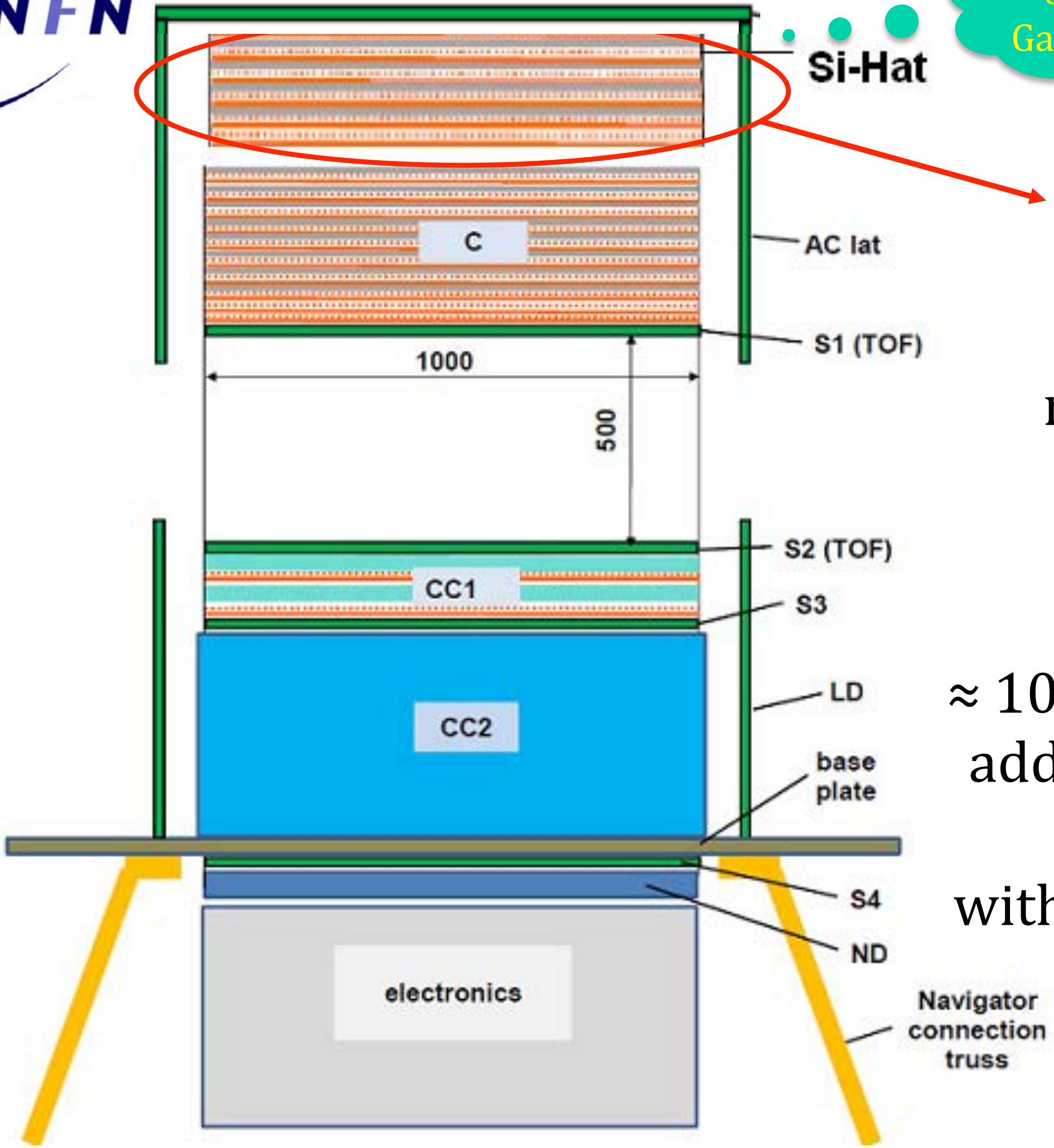
Missing info
Hard X-rays/Soft γ rays



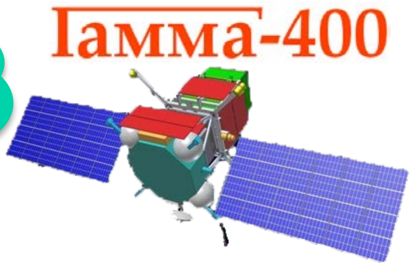
Silicon Hat



- The less-known region of the e.m. spectrum is the HE region spanning 10 to 100 MeV. It is the typical transition region between synchrotron radiation and the inverse Compton region, crucial to discriminate between *hadronic* and *e.m.* origin.
- Several projects have been proposed to fill this window, but it could also be envisaged to add to GAMMA-400 a *top* detector sensitive between 10 and 100 MeV, given the weight budget of few tons for the satellite scientific payload.
- A possible solution, with good angular resolution in this region, could be the use of SSD (either single-sided or double-sided) with no converter. In principle, if double-sided, it could also allow the measurement of polarization from the correlation of the plane of conversion with the axis of polarization.

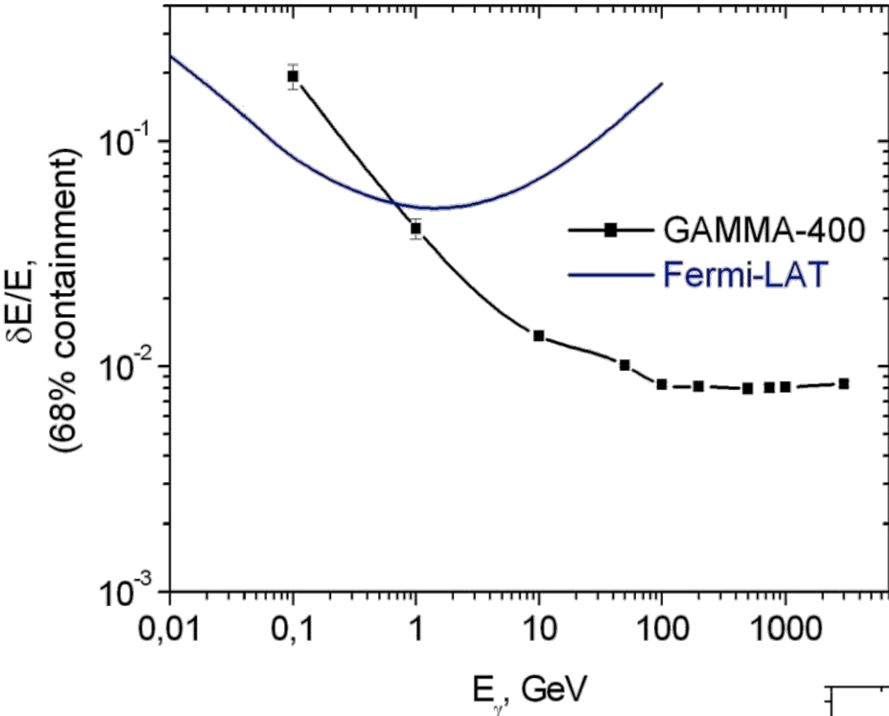


Add a Si-Hat on top of Gamma–400



10-30 *x-y* Si-planes
(thickness: 0.5 mm)
+ electronics
no passive converter

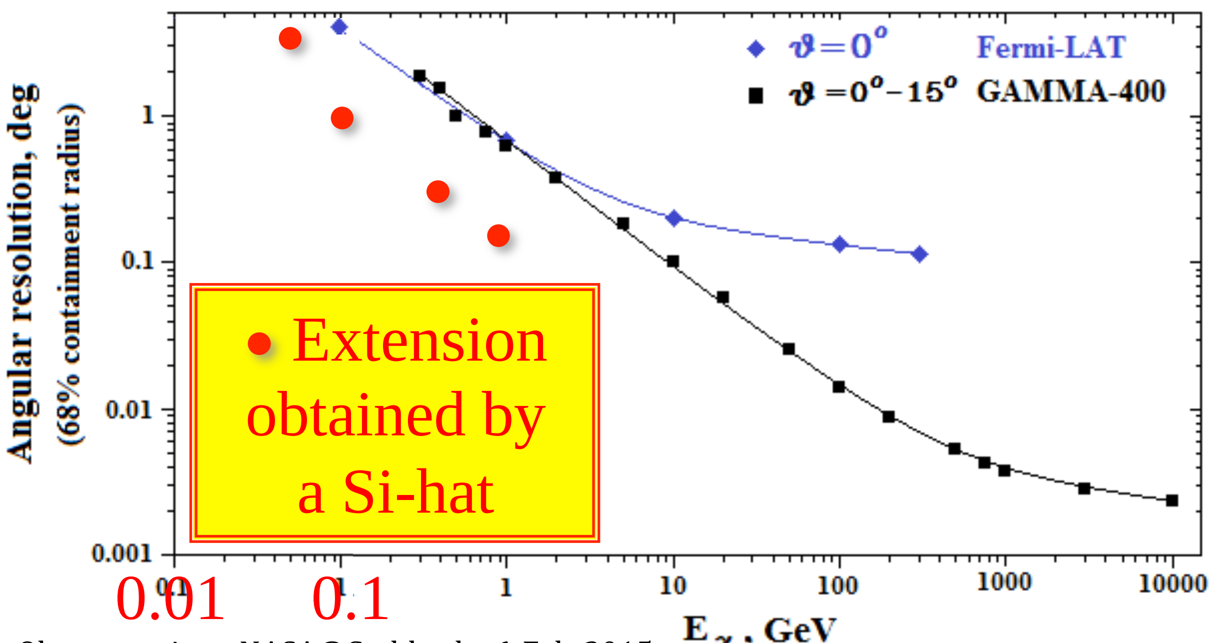
≈ 10% X_0 of total conversion
additional ∼400 cm² of A_{eff}
at E ∼100 MeV
with ∼1° of *PSF* at 100 MeV.



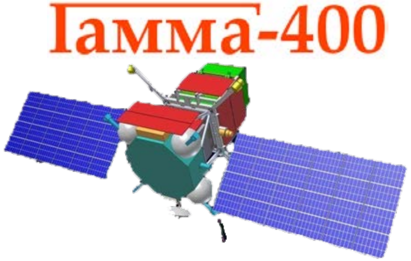
Energy resolution vs. energy for normal incidence for Fermi-LAT and GAMMA-400

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

Angular resolution vs energy for Fermi-LAT (for normal incidence) a GAMMA-400 (for θ=0°-



Conclusions



- Gamma–400 is approved by ROSCOSMOS
  - Energy range 30 GeV – 3 TeV
- Due to fly at the beginning of 2020’s
- Provide a calibration for CTA
- Provide a scientific trigger for CTA
- Will provide also $e^{\pm}$ and CR observation
- An extension to lower energies (?30 MeV):
  - Is feasible
  - The technology has already flown many times
  - Could provide info also on the polarization of γ rays