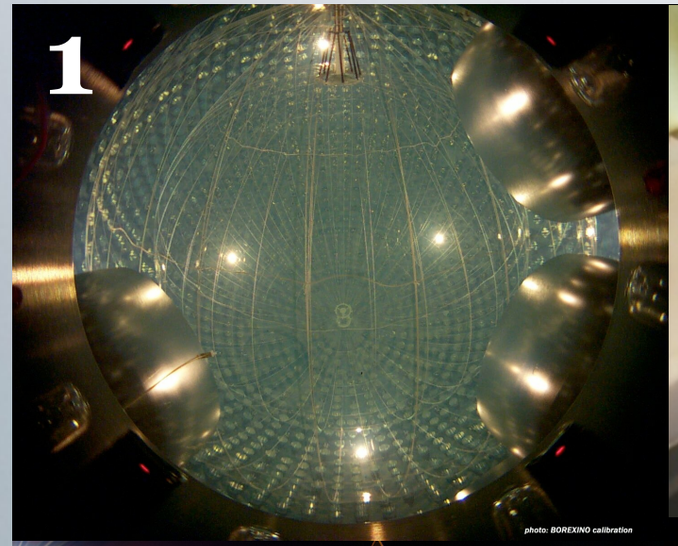
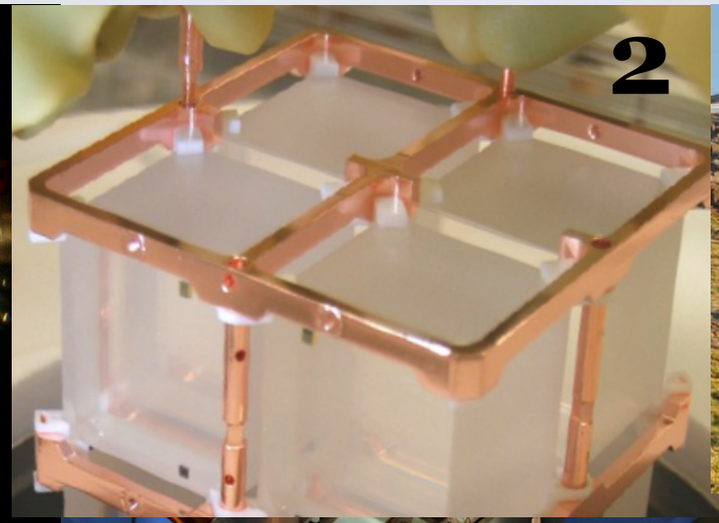
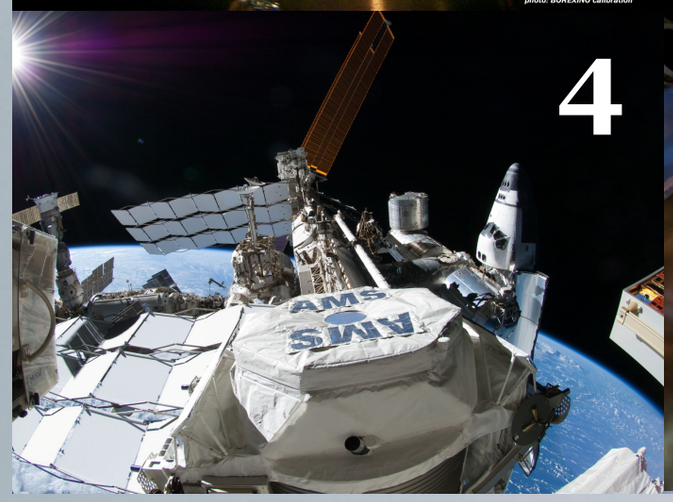
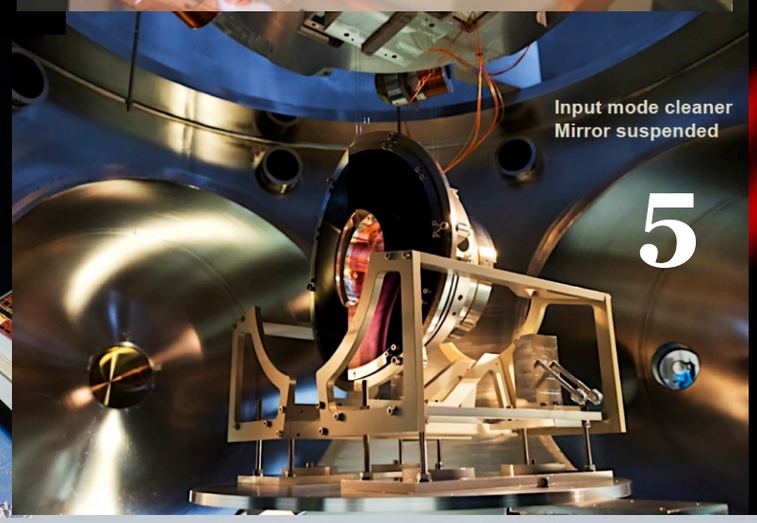
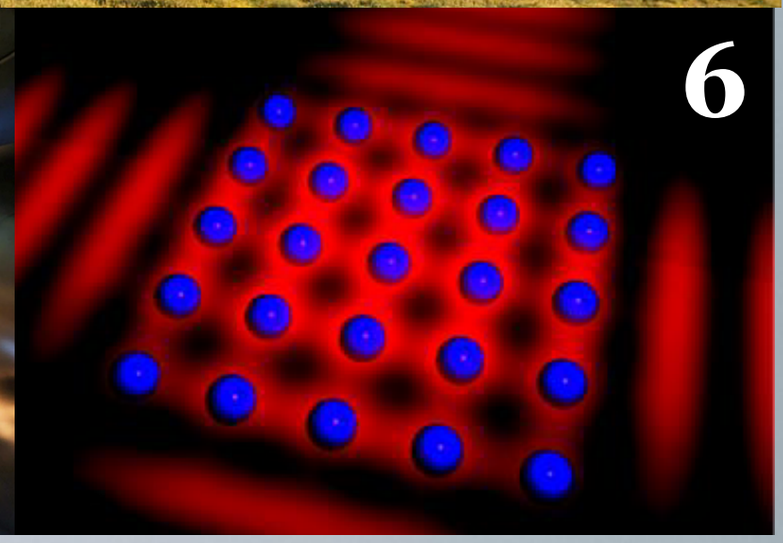










SPACE BASED ACTIVITIES OF THE CSN2

Frascati
Nov. 11th, 2014

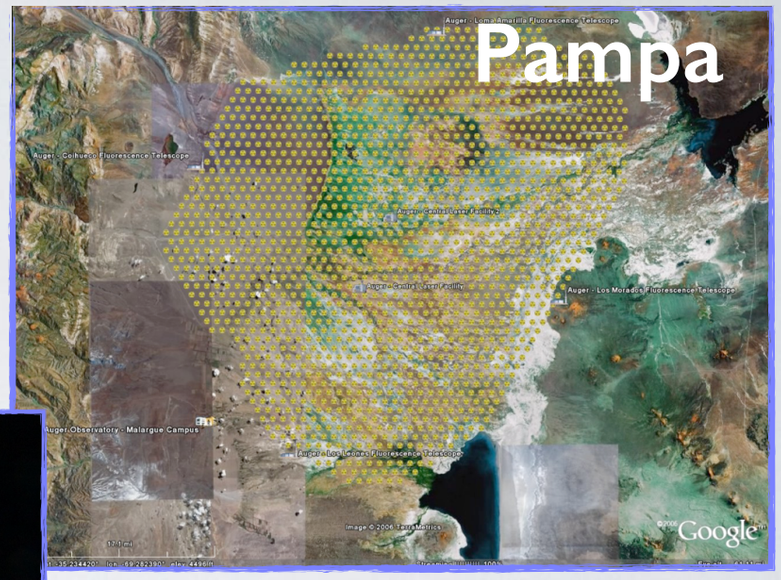
Marco Pallavicini
Università di Genova and INFN

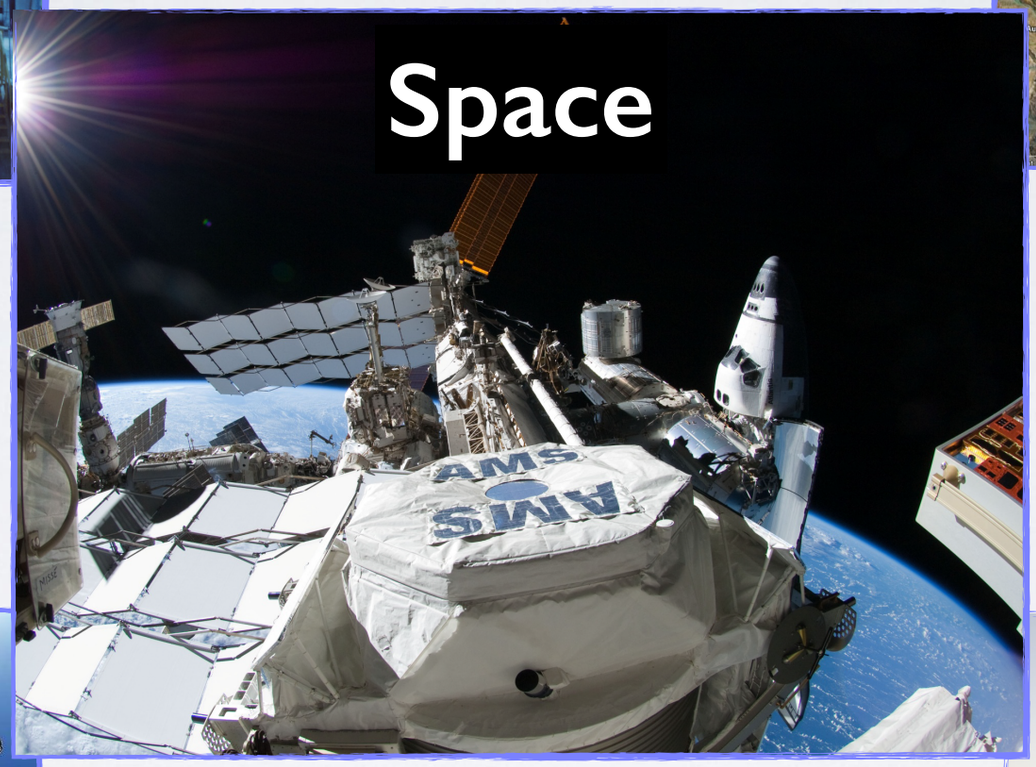
THE CSN2

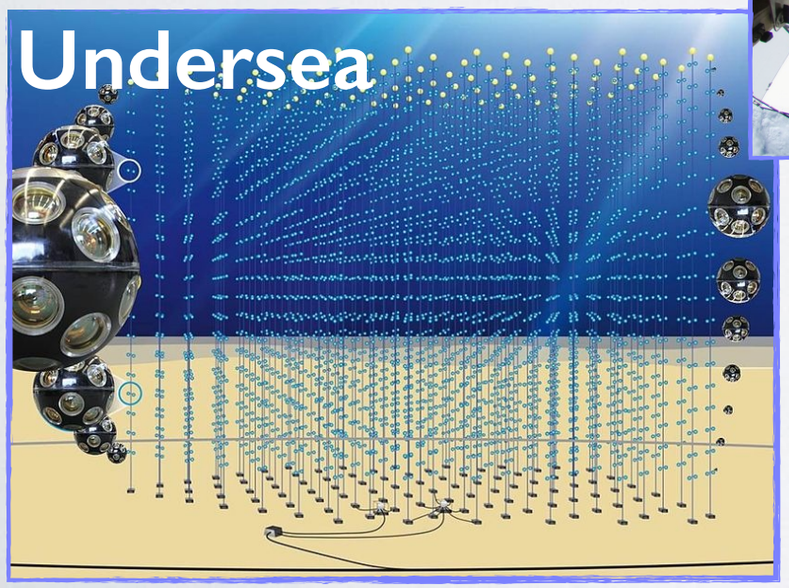
- The "Commissione Scientifica Nazionale 2"(CSN2) funds activities which have a broad and diverse scientific scope

	space ?
• Neutrino physics, with or without accelerator beams	no
• Underground physics	no
• Astro-particle physics	**yes**
• Astrophysics	**yes**
• General Relativity and Gravitational waves	**yes**
• Fundamental Quantum Mechanics	**yes**

MANY DIVERSE PLACES







WHY DO WE CARE ABOUT SPACE?

- **Answer 1: We want to do OUR science in space**
  - Fundamental questions addressed by the INFN community may be answered by studying natural particle fluxes not measurable at ground level or by performing high precision experiments in micro-gravity environments

- **Answer 2: We want to do NEW science in space**
  - Physics is changing, and many aspects of nature (dark matter, dark energy, inflation) are unlikely to be accessible by means of traditional INFN approaches

- **Answer 3: We want to make our skills available to other communities**
  - Other scientific questions which do not belong to the INFN mainstream can be answered by means of instruments based on INFN know-how, technology and available infrastructures

THE CSN2 BY QUESTIONS

- **Neutrinos**
  - What is ν mass ?
  - Are ν truly neutral fermions (Majorana vs Dirac) ?
  - What is the mass hierarchy ?
  - Are there light sterile ν mixed with SM ν ?
  - What can we learn with ν about the Sun, SN, high energy sources, and the cosmo itself ?
  - What is CP violation in lepton sector ?
- **Dark Matter and Dark Energy**
  - What is DM ?
  - Does it interact with matter non gravitationally ?
  - Does it scatter on nuclei ?
  - Can we observed its indirect evidence in the spectrum of astro-particle fluxes ?
  - Do axions exist ?
  - Can we understand and probe dark energy ?
- **Cosmic rays**
  - Where do the UHECR come from ?
  - How are they accelerated ?
  - Can we do fundamental physics ?
  - Can we get evidence of DM with CR ?
  - What can we learn with HE photons ?
  - Can we understand the matter-antimatter asymmetry of the Universe ?
- **Gravitation**
  - Can we detect gravitational waves ?
  - Can we do astronomy with them ?
  - Are the EP and GR correct ?
  - Can we understand and probe inflation ?
- **Fundamental physics**
  - Time-dependence of fundamental constants ?
  - Effects of quantum gravity in lab scale exp ?
  - Quantum simulator for non-abelian gauge theories ?

THE CSN2 BY QUESTIONS: WHAT DO WE DO IN SPACE ?

- **Neutrinos**
  - What is ν mass ?
  - Are ν truly neutral fermions (Majorana vs Dirac) ?
  - What is the mass hierarchy ?
  - Are there light sterile ν mixed with SM ν ?
  - What can we learn with ν about the Sun, SN, high energy sources, and the cosmo itself ?
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- **Fundamental physics**
  - Time-dependence of fundamental constants ?
  - Effects of quantum gravity in lab scale exp ?
  - Quantum simulator for non-abelian gauge theories ?

3 LINES OUT OF SIX INCLUDE SPACE ACTIVITIES

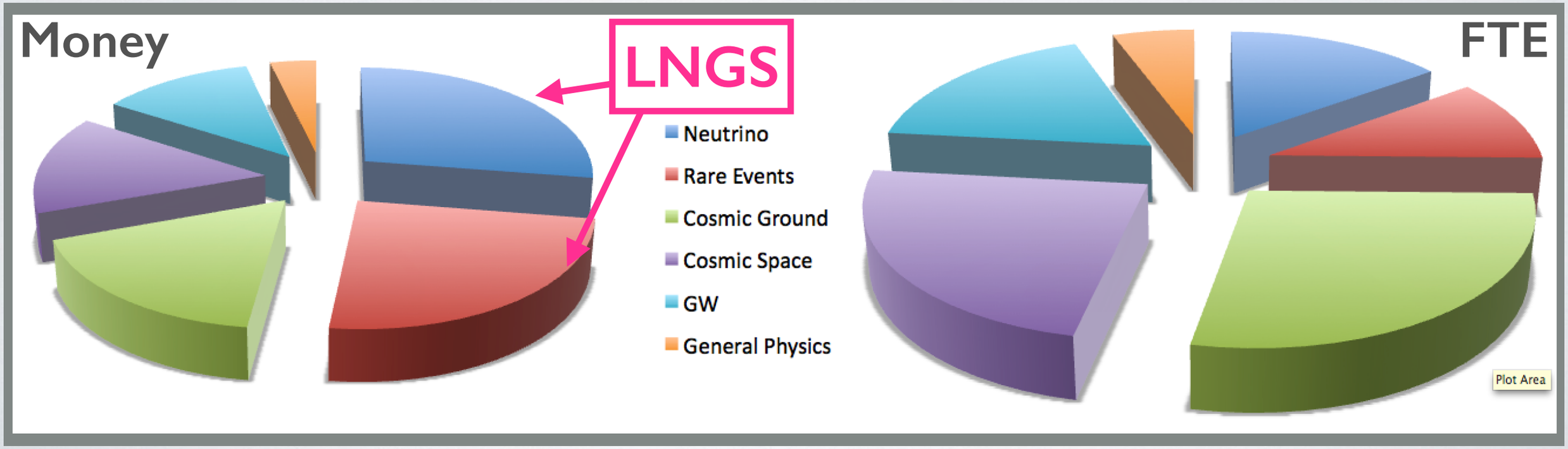
- Historically, CSN2 activities are divided into **6 lines**
  - Line 1: **Neutrino physics**
  - Line 2: **Search for rare events**
  - Line 3: Study of **Cosmic Rays and HE neutrinos** with detectors on **Earth**
  - Line 4: Study of **Cosmic Rays** (or other radiation) with **space detectors**
  - Line 5: **Gravitational waves** search
  - Line 6: **General physics, General Relativity, Fundamental QM**

RESOURCES AND THEIR USE

- **Budget**
  - 12.8 M€ 2015
  - **External**
    - 2014 14.5 M€
    - 2013 13.0 M€
    - 2012 13.0 M€
- **People**
  - 660 FTE in 2015 (589 ric. + 71 tec.)

CSN2 Sector 2	FTE	Budget
Neutrino Physics	14.8	27.5
Search for Rare Processes	10.3	24.5
Cosmic Rays (ground &u/water)	27.9	17.5
Cosmic Rays (space)	23.4	14.6
Gravitational Waves	17.7	12.2
General Physics	5.5	3.7

Table 2.3. CSN2 budget and personnel by research line (in %)



EXTERNAL FUNDS

- CSN2 projects have often **significant external fundings**
  - **Space agencies**
    - ASI: AMS2, Fermi, Limadou, LSPE, Pamela — 2 M€ / y
    - NASA: Moonlight2 (also CSN5) — 0.1 M€ / y + in-kind
    - Chinese CAS : DAMPE — 1 M€ / y INFN is paid !
  - **ERC:**
    - Rarenoise (completed), Lucifer, SOX, Holmes — 2 M€ / y
  - **PON**
    - Km3Net (end 2014) — 7.5 M€ / y
  - **PRIN MIUR**
    - Both at INFN and at associated universities — 0.7 M€/y
  - **"Progetti Premiali"** in collaboration with other italian agencies
    - Humor (CNR), Micra (CNR), Magia (CNR), Retroreflectors (ASI), Ringlaser (INRIM) — 2 M€ / y

Total ≈ 15.3 M€ / y

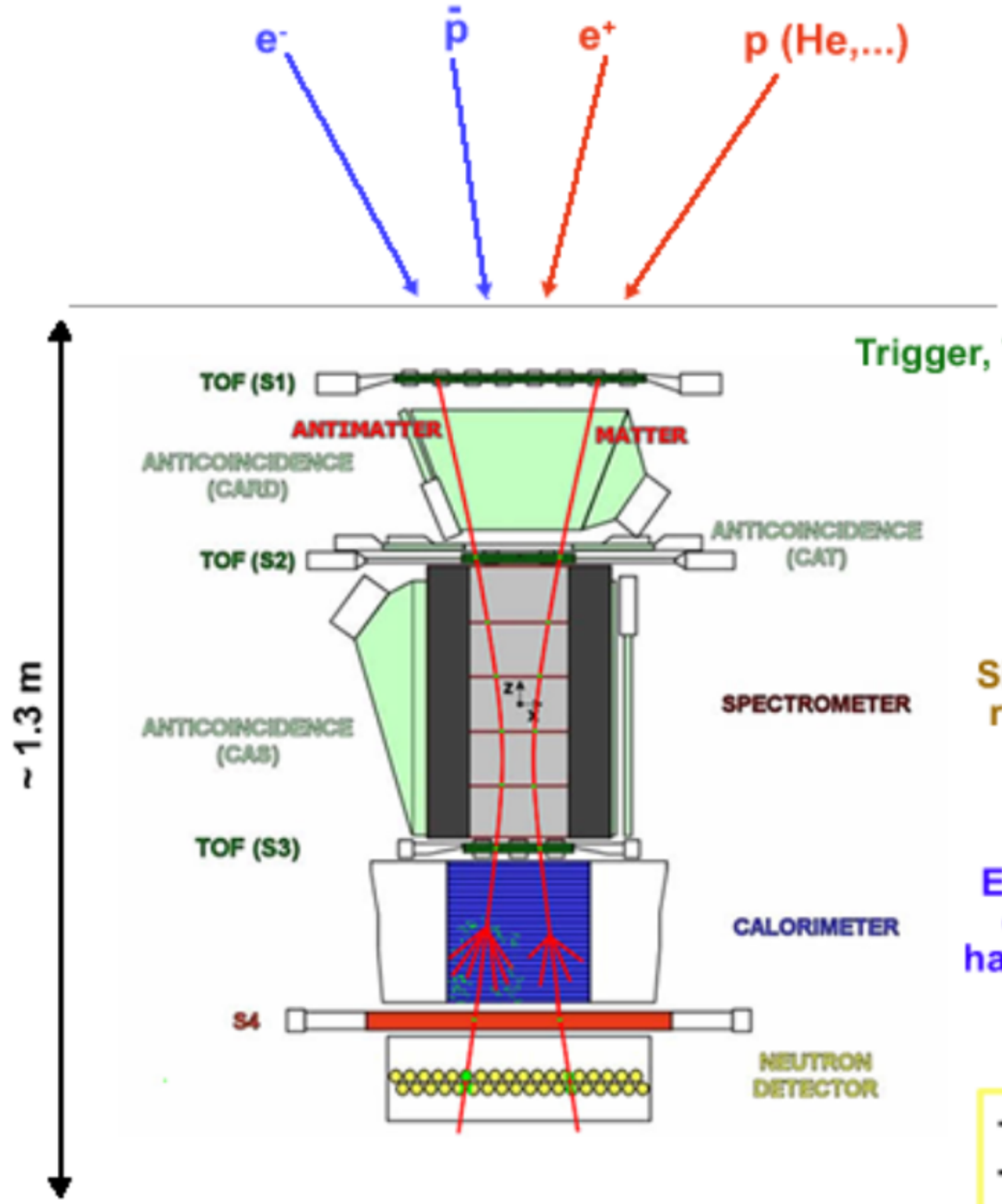
SPACE ACTIVITIES

- **Flying**
  - AMS02 — spectrometer+calorimeter for anti-matter and charged particles < 1 TeV
  - Fermi — high-energy gamma-ray and cosmic-ray space telescope
  - PAMELA — spectrometer+calorimeter for anti-matter and charged particles < 1 TeV

- **Construction**
  - DAMPE — deep calorimeter + silicon tracker for $\gamma, e^{\pm}$, nuclei, p 10-100 TeV scale
  - LSPE (balloon) — CMBR photons with polarisation, 5 frequencies
  - Moonlight2 — lunar ranging for general relativity
  - LISA-PF — technological demonstrator for GW detector LISA
  - Limadou — geophysics in the ionosphere

- **R&D or Long Term Activities**
  - Gamma-400 — deep calorimeter + silicon tracker for $\gamma, e^{\pm}$, nuclei, p 10-100 TeV scale
  - JEM-EUSO — UHECR fluorescence and Cherenkov from top view
  - Euclid (COSMO_WNEXT) — dark energy and cosmology (ESA mission)

FLYING EXAMPLE: PAMELA



~470 Kg / ~360 W

Trigger, ToF, dE/dx

- S1, S2, S3; double layers, x-y
- plastic scintillator (8mm)
- ToF resolution ~300 ps (S1-3 ToF >3 ns)
- lepton-hadron separation < 1 GeV/c
- S1.S2.S3 (low rate) / S2.S3 (high rate)

Sign of charge, rigidity, dE/dx

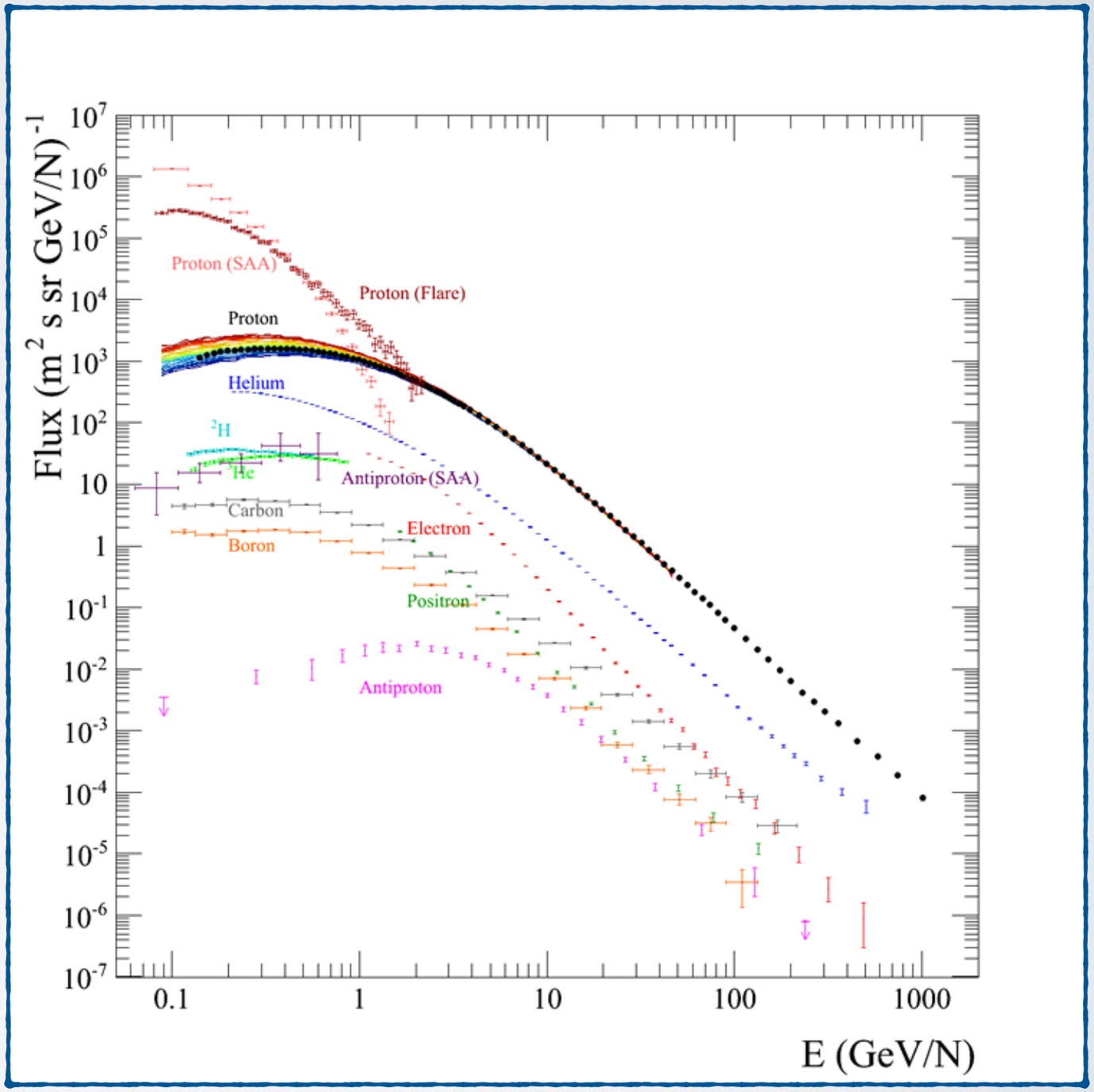
- Permanent magnet, 0.43 T
- 21.5 cm^2 sr
- 6 planes double-sided silicon strip detectors (300 μm)
- 3 μm resolution in bending view → MDR ~800 GV (6 plane) ~500 GV (5 plane)

Electron energy, dE/dx, lepton-hadron separation

- 44 Si-x / W / Si-y planes (380)
- 16.3 X0 / 0.6 L
- dE/E ~5.5 % (10 - 300 GeV)
- Self trigger > 300 GeV / 600 cm^2 sr

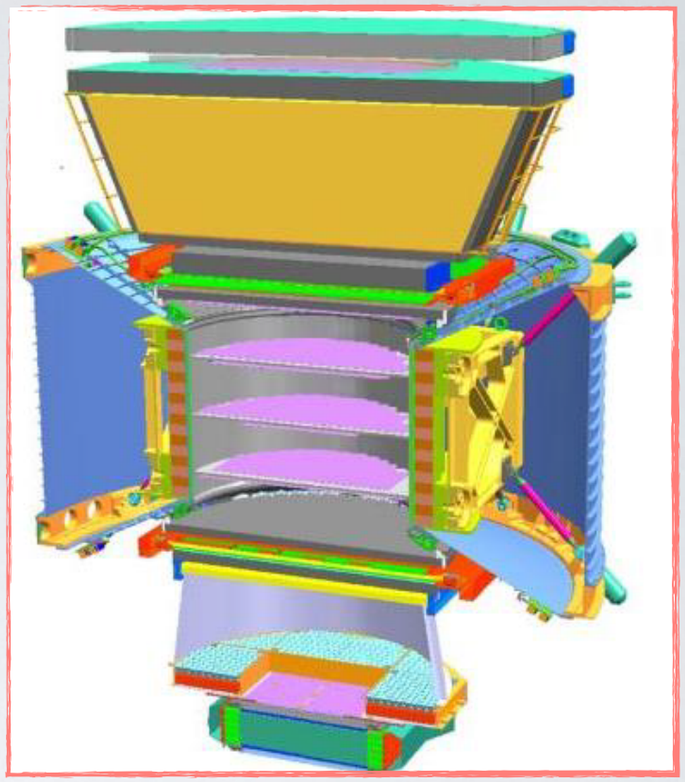
- 36 ^{3}He counters
- ^{3}He(n,p)T; E_p = 780 keV
- 1 cm thick poly + Cd moderator
- 200 μs collection

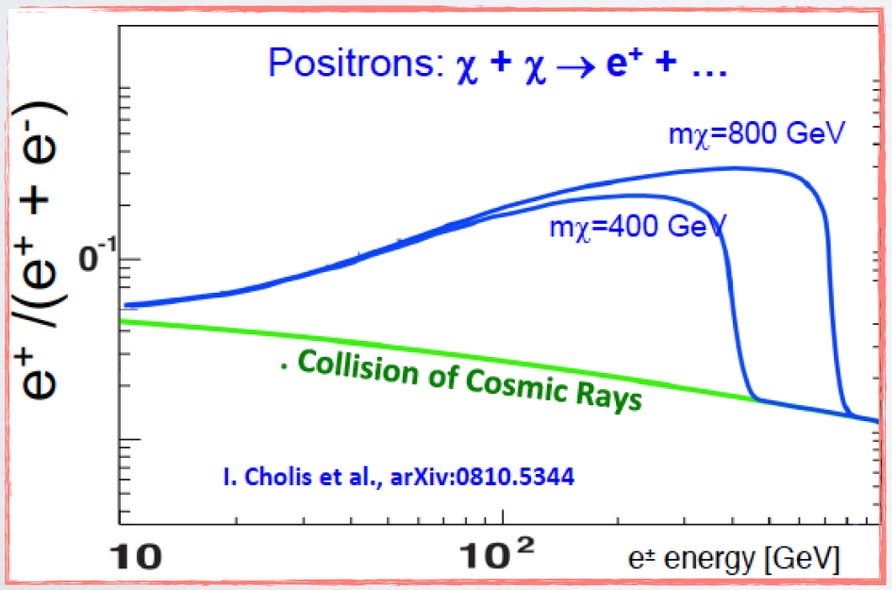
PAMELA RESULTS

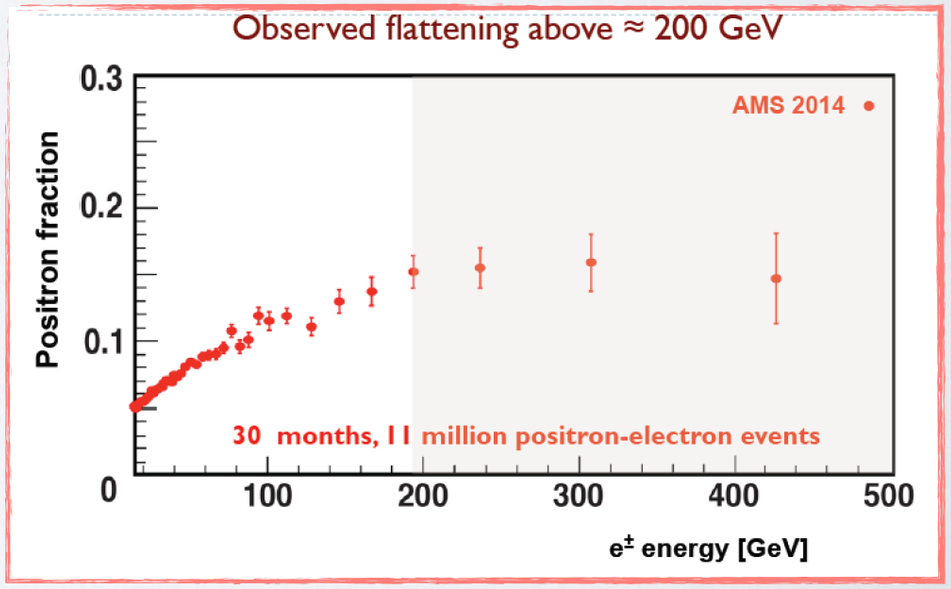


FLYING EXAMPLE: AMS02

- An "accelerator-like" particle detector in space
  - Tracker, TOF, TRD, Calorimeter, Magnet and RICH
  - Smooth data taking in progress
    - Events: 55 billions collected, 41 billions analysed
    - Man-power demanding operations: tracker alignment is done every minute because of constant temperature changes
- Most recent result: precise measurement of positron fraction
  - Main motivation: search for dark matter

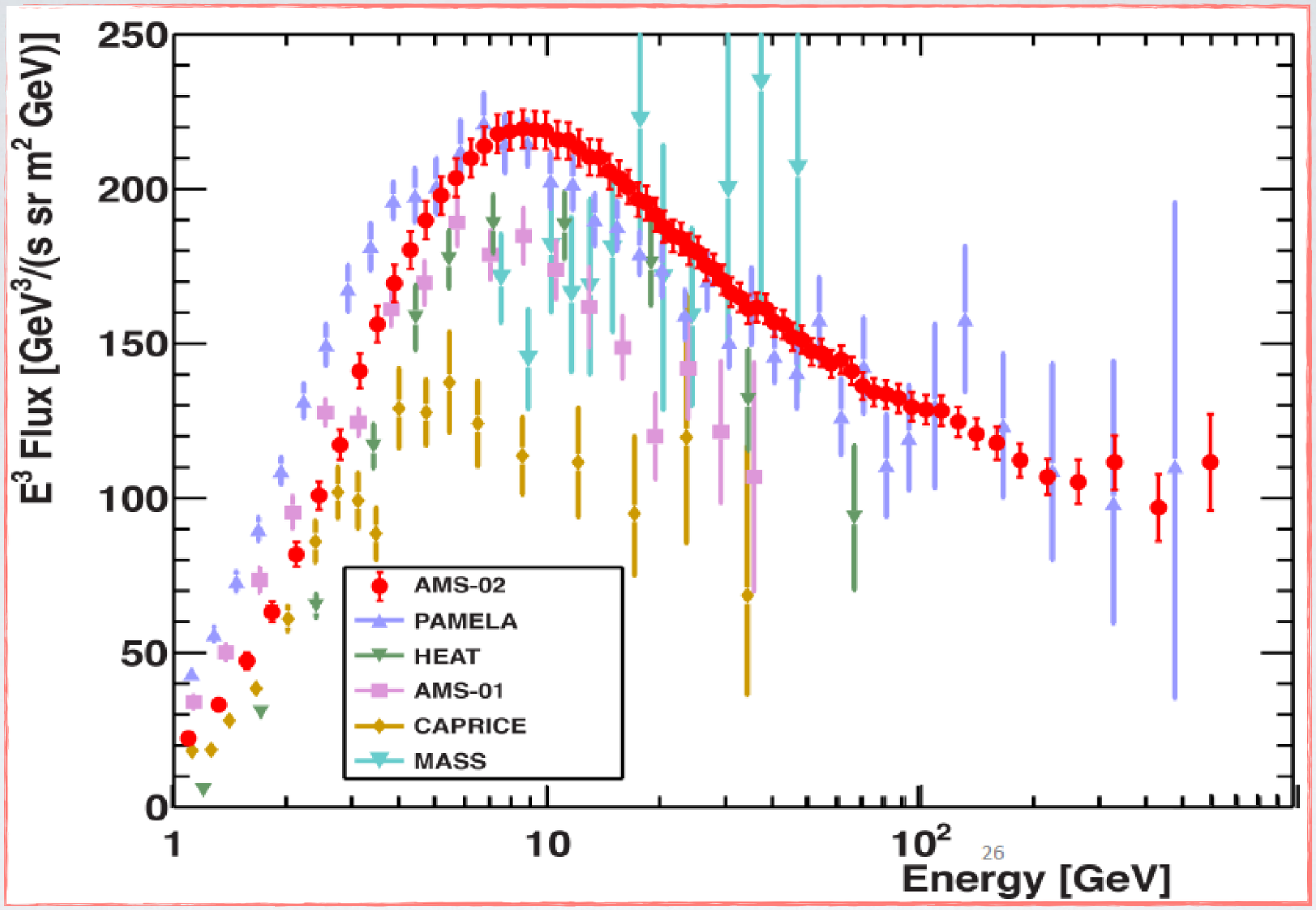






IMPACT OF AMS02 ON e^- FLUX KNOWLEDGE

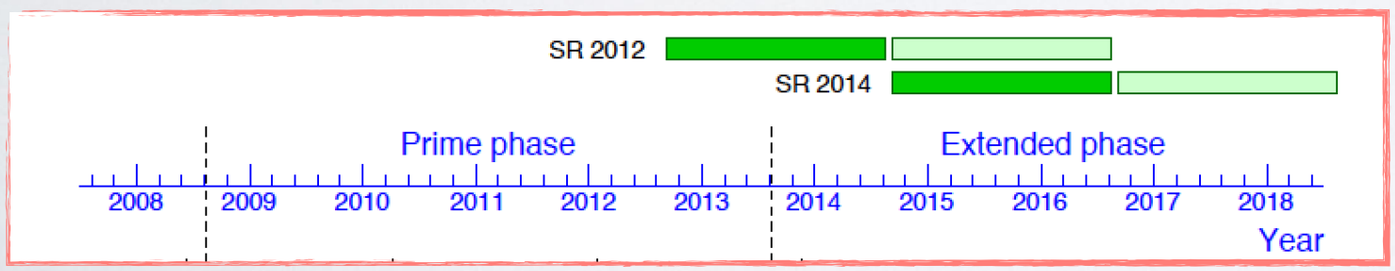
Electron flux after AMS02



FLYING EXAMPLE: FERMI

- Fermi has changed our knowledge of the γ sky
  - Very broad science scope
  - Very successful mission
  - Very **significant role of INFN**

- The mission is currently expected to continue until **2018**
  - Might be extended. Review in 2016.
  - 315 papers, 22 of which in Science/Nature
    - h_index of the experiment is 50



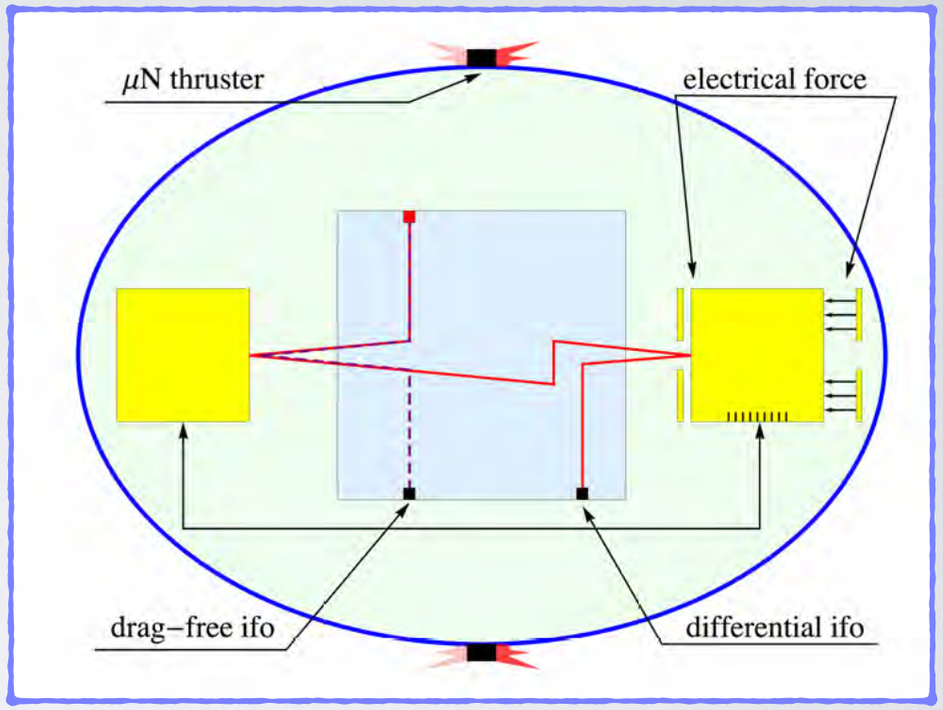
Science group	Coordinators
AGN and Blazars	Denis Bastieri
	Jeremy Perkins
Calibration and analysis	Carmelo Sgrò
	Matthew Wood
Catalogs	Elisabetta Cavazzuti
	Isabelle Grenier
Dark matter and new Physics	Luca Baldini
	Miguel A. Sànchez-Conde
Diffuse emission	Elena Orlando
	Johann Cohen-Tanugi
Galactic sources	Massimiliano Razzano
	Marianne Lemoine-Goumard
GRBs	Elisabetta Bissaldi
	Magnus Axelsson
Sources in the solar system	Melissa Pesce-Rollins
	Eric Grove

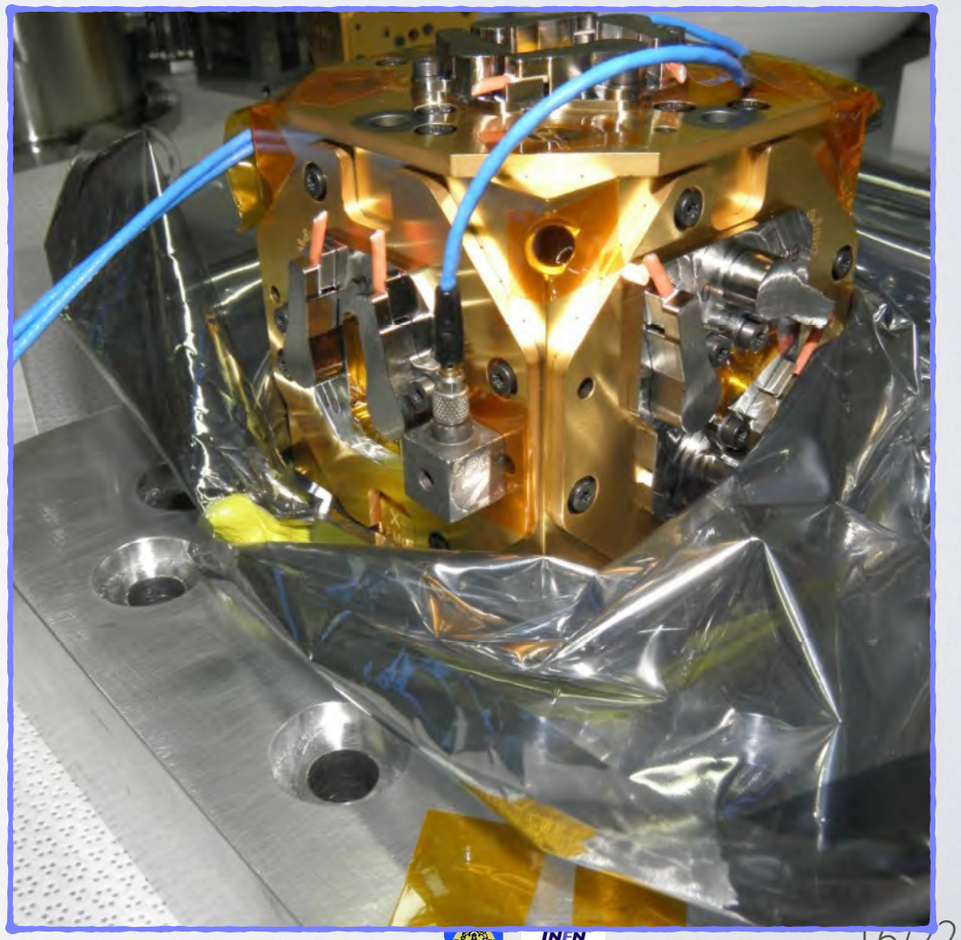
Category I and II papers in refereed journals

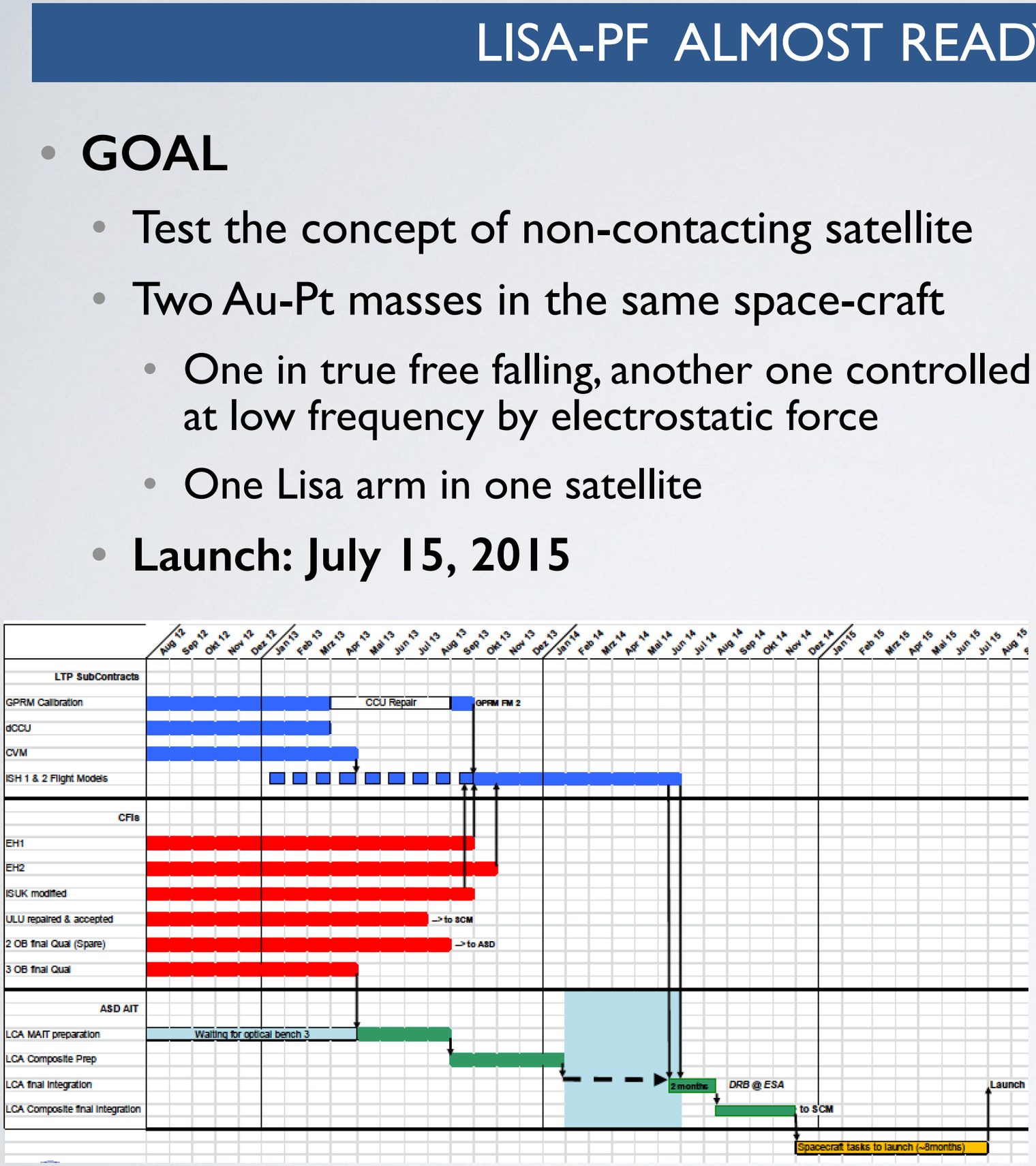
Journal	Published	In press	Total
Advances in Space Research	0+1=1	-	1
Astronomy and Astrophysics	6+29=35	0+3=3	38
Astroparticle Physics	2+6=8	-	8
Astrophysical Journal	81+59=140	0+2=2	142
Astrophysical Journal Letters	22+20=42	-	42
Astrophysical Journal Supplement	8+2=10	-	10
Journal of Cosmology and Astroparticle Physics	3+4=7	-	7
Journal of Geophysical Reserch	0+1=1	-	1
Monthly Notices of the RAS	0+25=25	-	25
Nature	2+1=3	-	3
Nuclear Instruments and Methods	0+1=1	-	1
Physical Review D	8+2=10	-	10
Physical Review Letters	7+0=7	-	7
Publications of the ASJ	0+1=1	-	1
Science	18+0=18	1+0=1	19
Total	157+152=309	1+5=6	315

LISA-PF ALMOST READY TO GO

- **GOAL**
  - Test the concept of non-contacting satellite
  - Two Au-Pt masses in the same space-craft
    - One in true free falling, another one controlled at low frequency by electrostatic force
    - One Lisa arm in one satellite
  - **Launch: July 15, 2015**

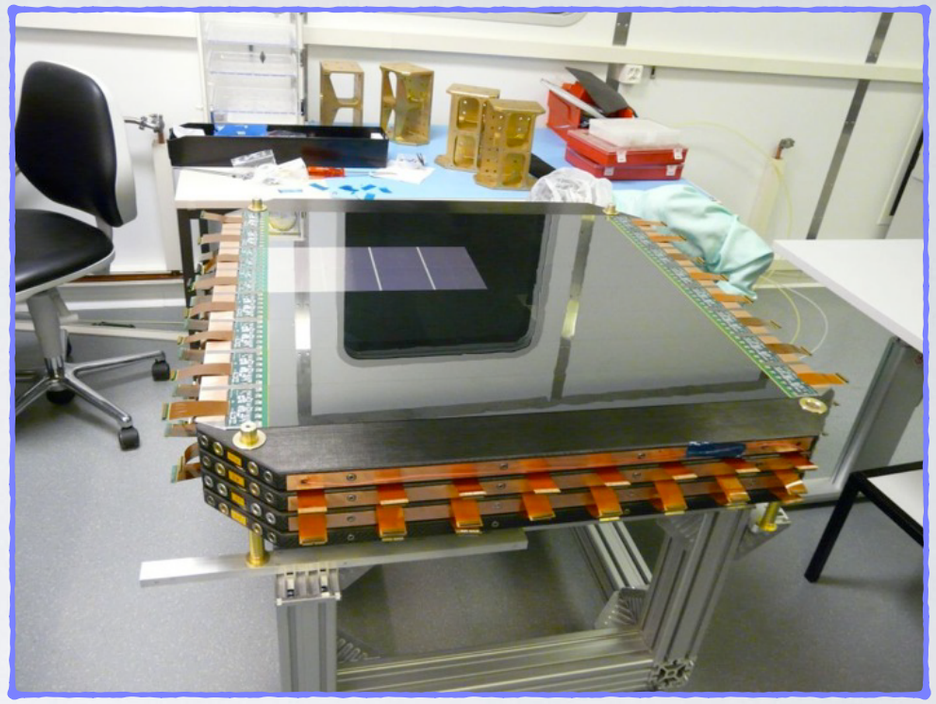




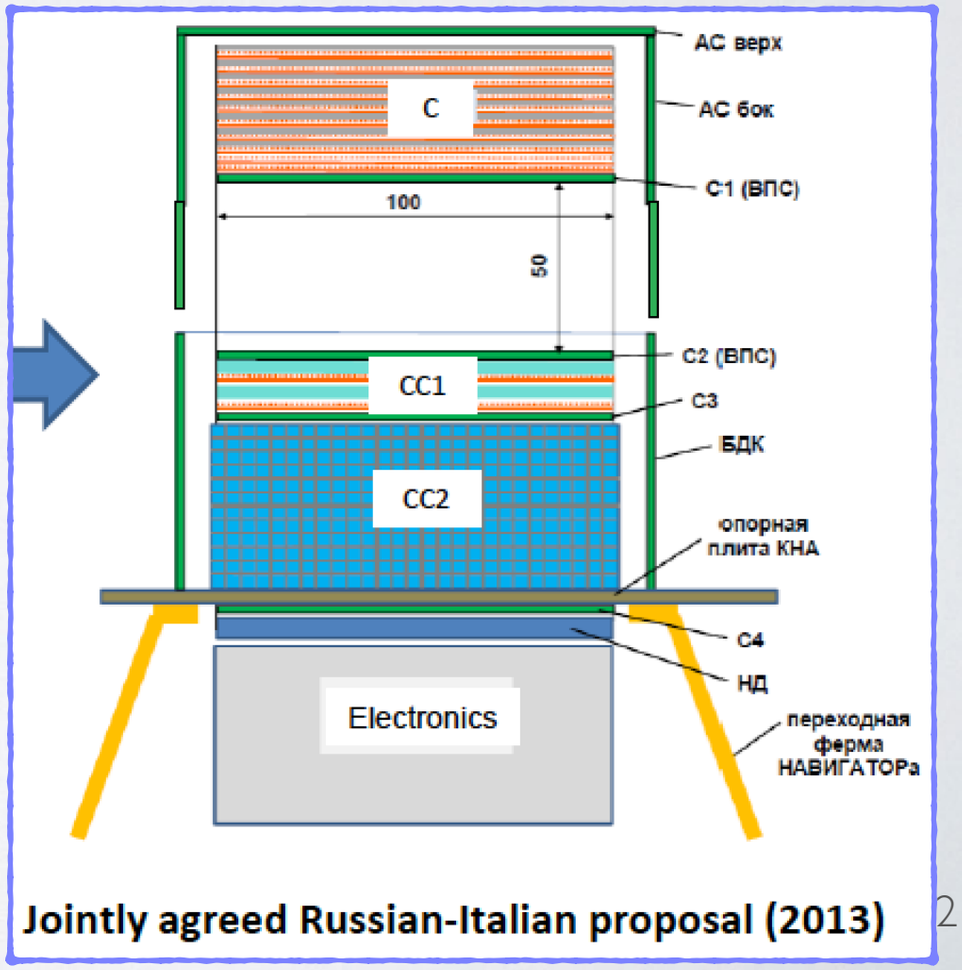


DAMPE AND GAMMA-400

- Two future cosmic rays and gamma missions
  - **Dampe:** an innovative financial path (follow-up of Fermi and AMS02)
    - 2 GeV - 10 TeV e/γ 30 GeV - 100 TeV CR
    - We are scientists AND industrial partner for the Chinese Space Agency
    - Construction in advanced stage. Good test beam results of the tracker.



  - **Gamma-400:** Mission approved by ROSCOMOS for launch in 2020
    - 100 MeV - 1 TeV **e/γ** 2% energy resolution
      Electrons 10 TeV
      Light Nuclei up to the knee 1000 TeV
      - Great capability to separate electrons/hadrons



Jointly agreed Russian-Italian proposal (2013)

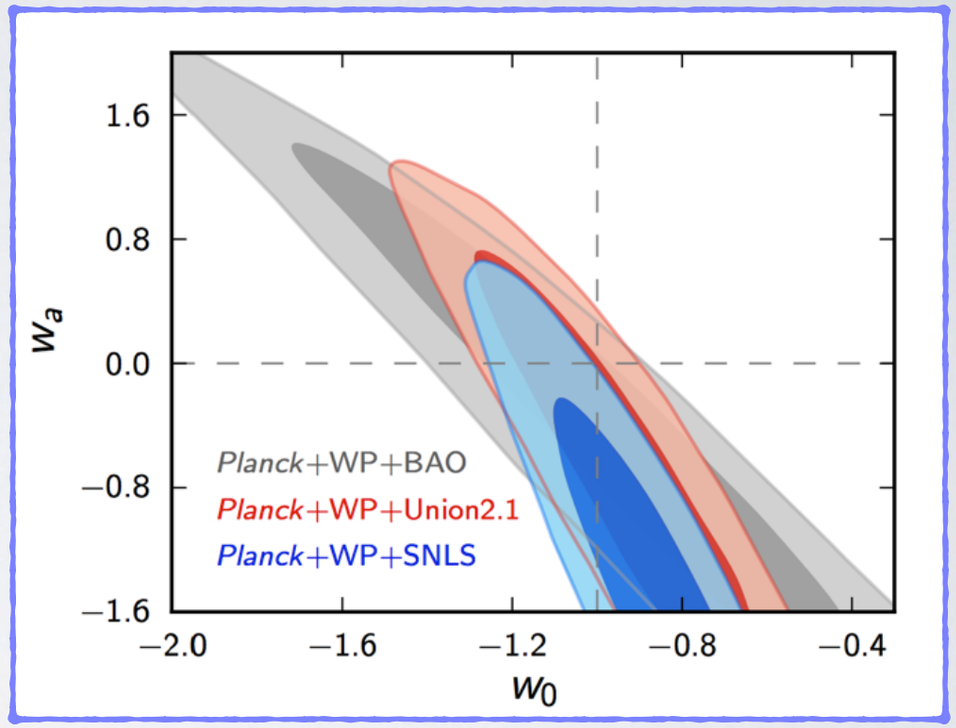
See O. Adriani's talk

What Next

EUCLID: STUDY OF DARK ENERGY

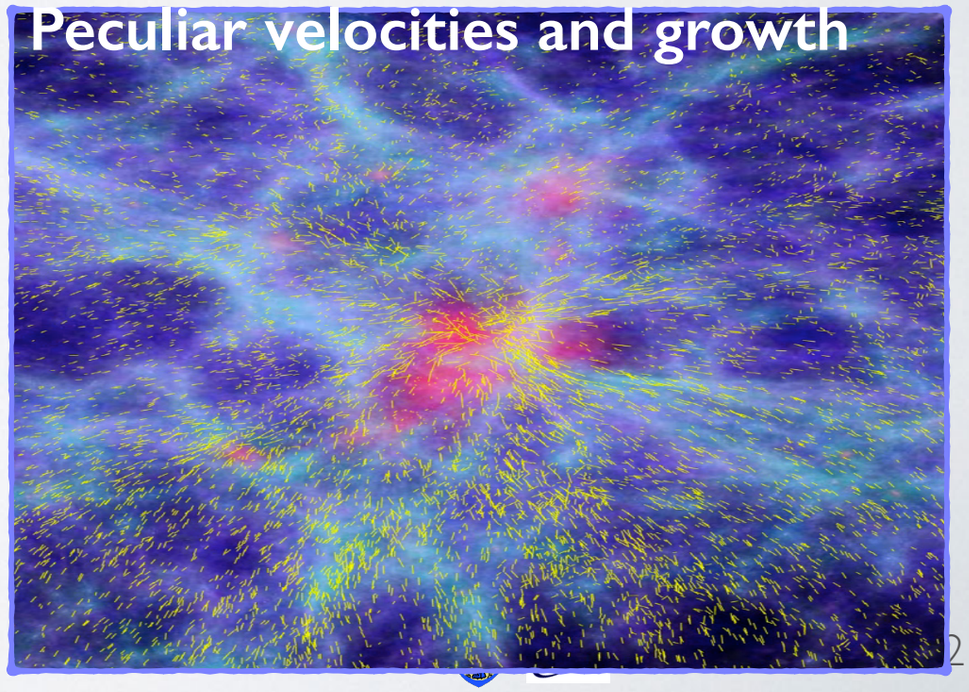
- **EUCLID:** mapping the universe with sufficient precision to disentangle different dark energy models (and much more)
  - High precision Barionic Acoustic Oscillations
  - High precision weak gravitational lensing
  - Measure the growth of structures
  - Launch: ~ 10 y from now

$$w(a) = w_0 + w_a\,(1 - a)$$



- **One of the main fundamental scientific questions for the next decades**
  - INFN should indeed play a role
    - A small exploratory group in place (PD and BO so far)
    - Discussion in progress

the future

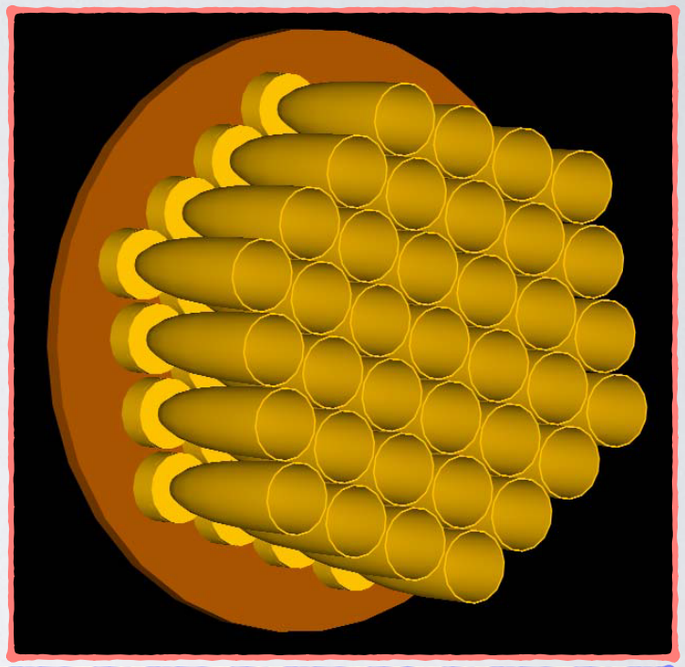


What Next

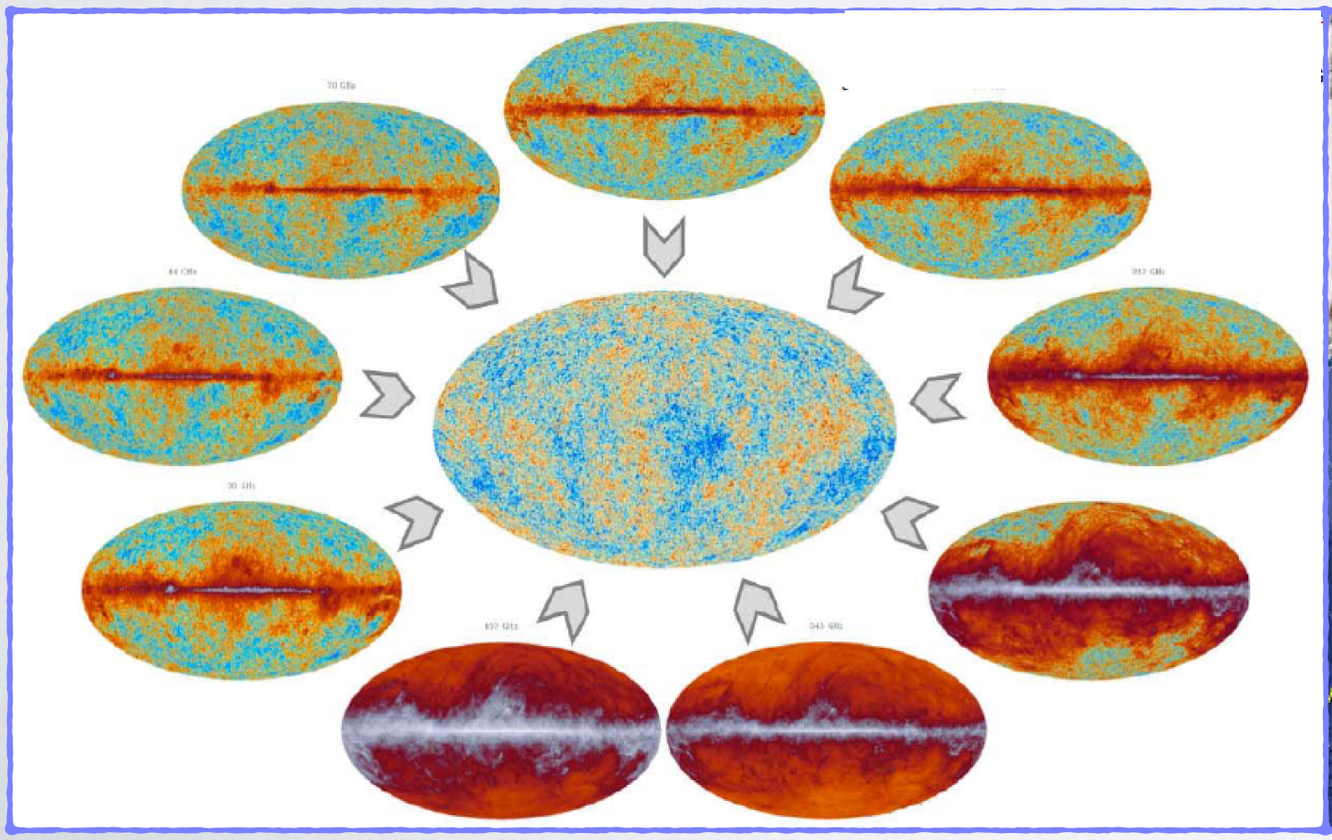
LSPE: SEARCH FOR COSMIC INFLATION

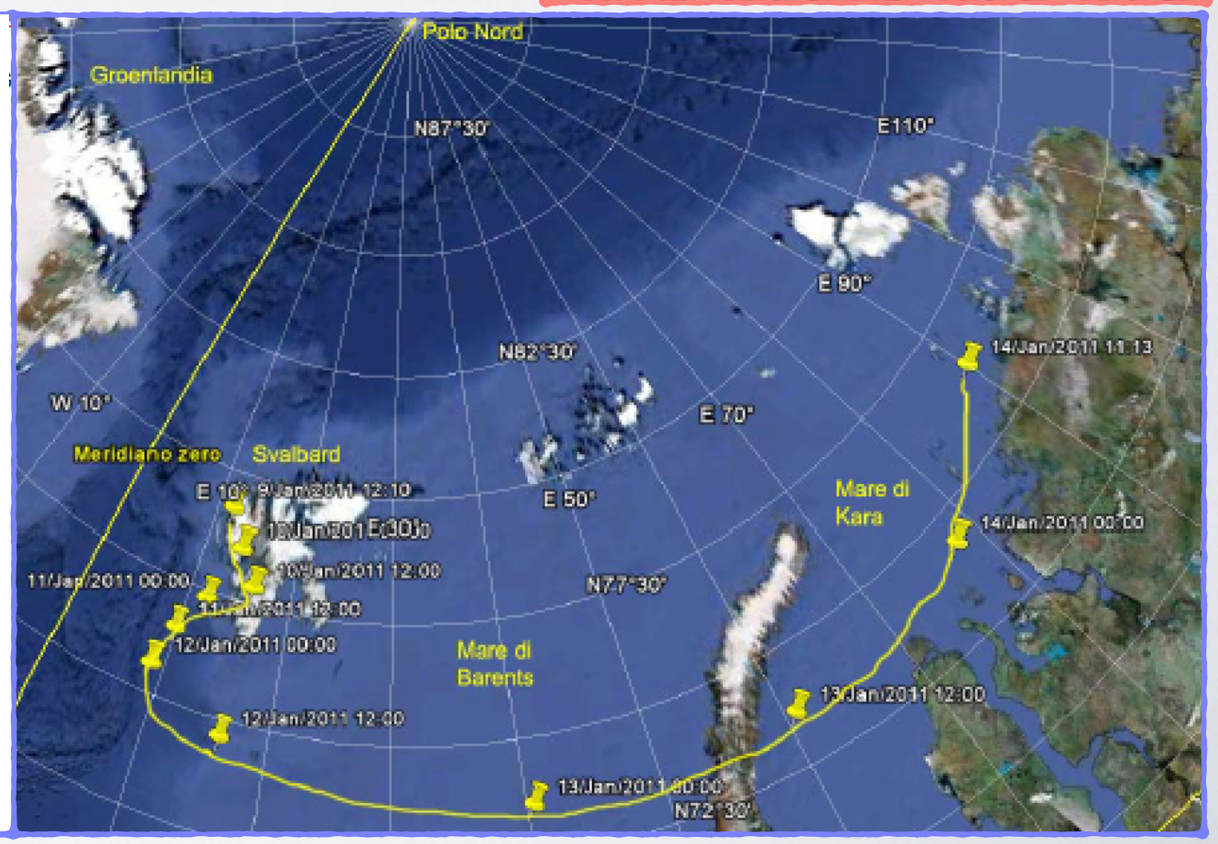
- **LSPE: Large Scale Polarisation Explorer**
  - Balloon mission for polarised CMB photons
  - Search for B-modes in a multi-wavelength approach
  - Re-use of technology R&D for neutrino mass measurement **(μ-bolometers) + TES + KIDs**
    - **5 channels (40 - 250 GHz) on spinning payload**
    - **Angular resol. 1.5°-2.3° Sky coverage: 20-25%**
    - **Sensitivity: about 10 μK**

P. De Bernardis
A. Baldini, F. Gatti



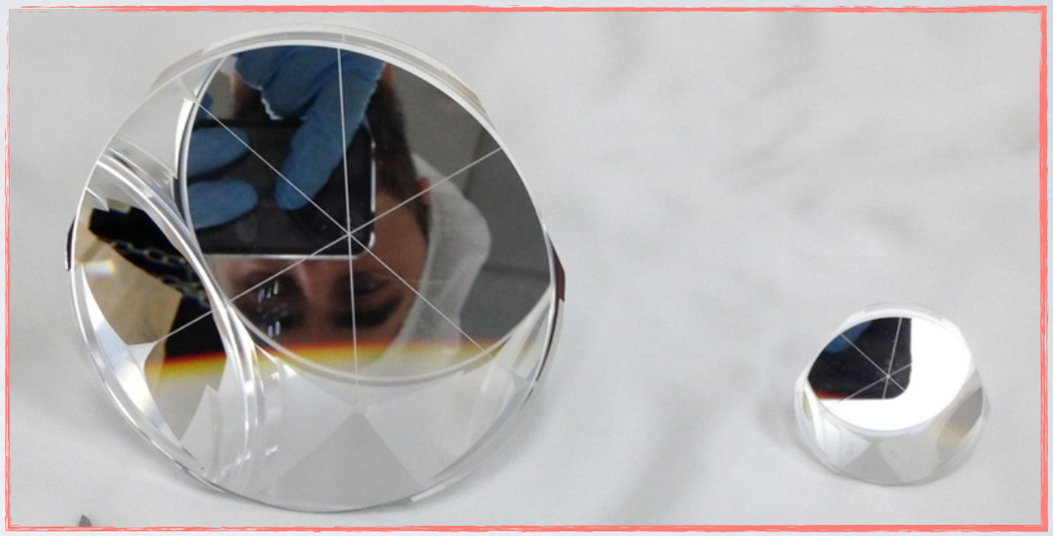
See P. De Bernardis' talk

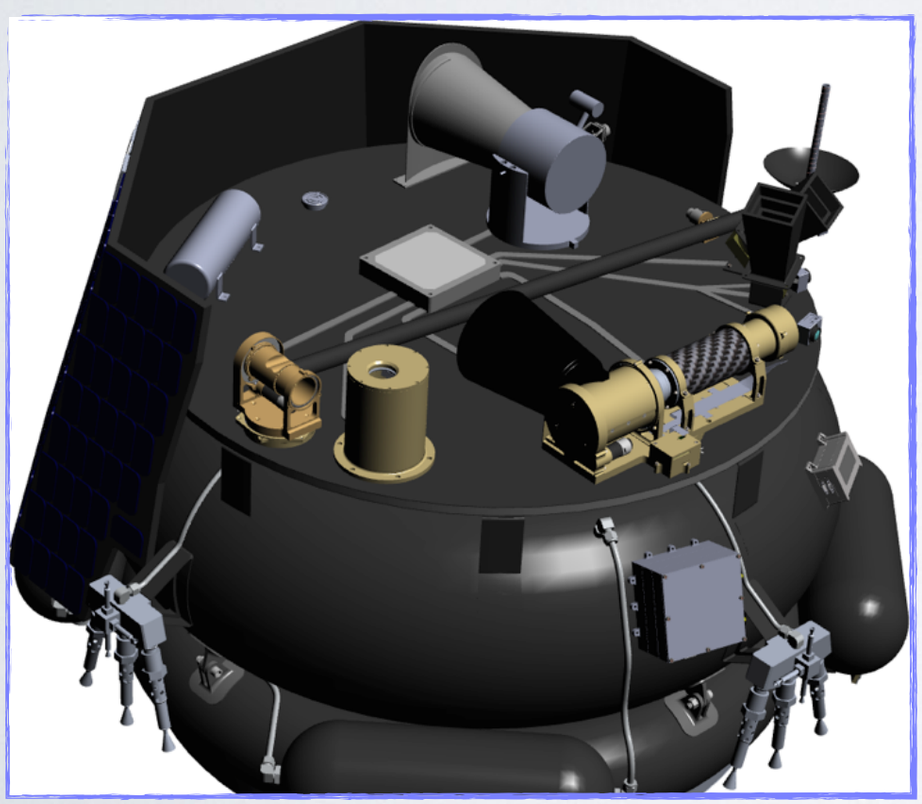




HIGHLIGHTS : MOONLIGHT-2

- Test of **General Relativity** with Laser Retroreflector
  - INFN/NASA agreement NASA-SSERVI
  - Laser Retroreflector on the MOON
    - General relativity
    - Geo-physics. Other fundamental science.
    - INRRI: **IN**strument for landing-**R**oving laser **R**etroreflector **I**nvestigations





See S. Dell'Agnello's talk

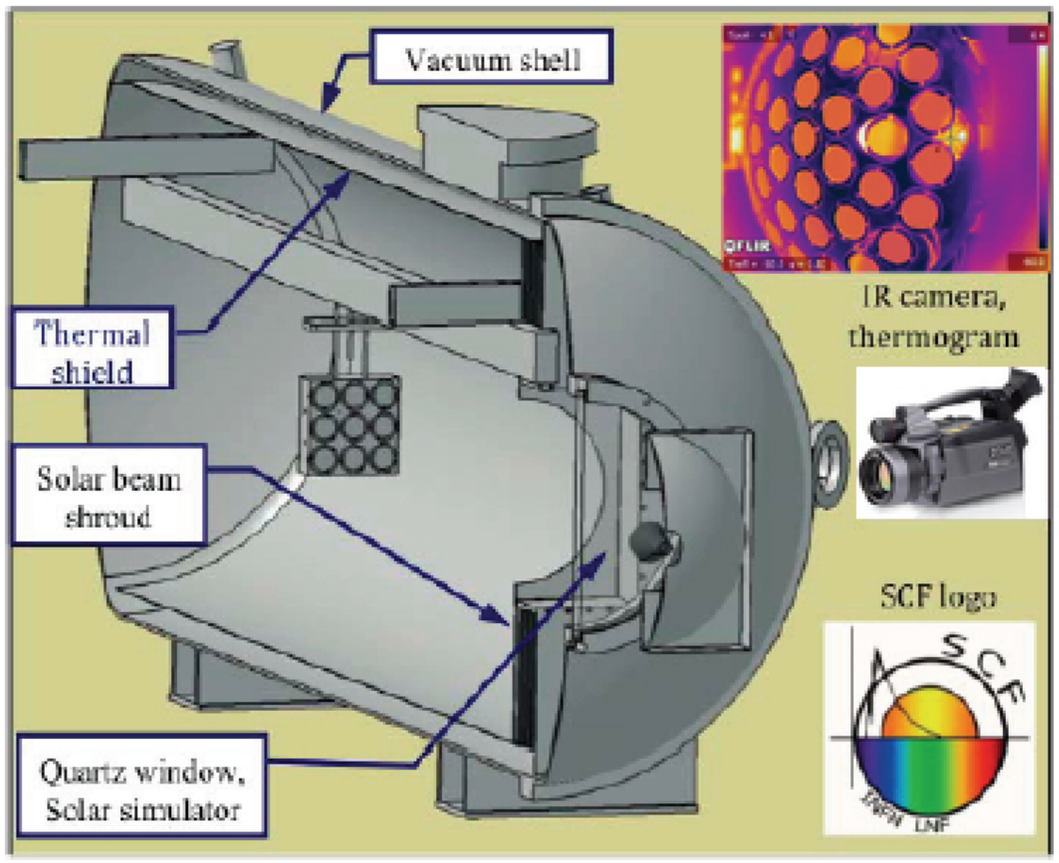
SIGNIFICANT INFRASTRUCTURE AT LNF

SCF_LAB

Satellite/Lunar/GNSS laser ranging
Characterization **F**acility **LAB**oratory

Two unique and unprecedented OGSEs (Optical Ground Support Equipments) facilities in a clean room to characterize the SLR/LLR/GNSS space segments

SCF for SLR/LLR (RD-1, RD-2)



SCF-G for GNSS (RD-10)

INFN AND SPACE ACTIVITIES

- **Proposal:**
  - LNF to support space based activities for INFN ?
  - Quite unique opportunity
    - Frascati could be the only place in which space detectors could be tested with particle beams and (maybe) laser in thermo-vacuum conditions
    - Frascati has already long experience and some infrastructures
    - A good opportunity, in my opinion, for the future of the main INFN laboratory
  - Frascati may play a role for management of Svalbard balloon launch facilities under ASI contract (later)
- Of course:
  - We should not duplicate existing facilities in Perugia/Terni, Tor-Vergata and everywhere else in Italy (I do not have yet a global view. I am working on it).
- We need a global plan!