Preventivi Gruppo II

A. Paoloni

Consiglio di Laboratorio

30 Giugno 2017

LNF gruppo II: Anagrafica

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

Note:
Nella tabella non sono esplicitate le percentuali degli associati (quiescenza+altri enti) e degli afferenti ad altre commissioni scientifiche, pur essendo contate negli FTE.
RTD=ricercatore a Tempo Determinato.
1 RTD + 3 ADR pagati su fondi ASI. 1 ADR pagato dalla presidenza (NASA/SSERVI).
L'anagrafica di QUAX e' scorporata dalla call di gruppo V. Per QUAX e' stata bandita una borsa per laureati.
Soglia per apertura sigla in CSN2 = 1.5 FTE.

LNF gruppo II: Anagrafica

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

CUORE + Darkside: Contributo tecnico da parte LNF (technical management).
CUORE e' in presa dati, percio' a prescindere dai FTE allocati (per la firma degli articoli), l'attvita' del nostro gruppo diminuira'.
Non sono previste richieste ai servizi per il 2018.

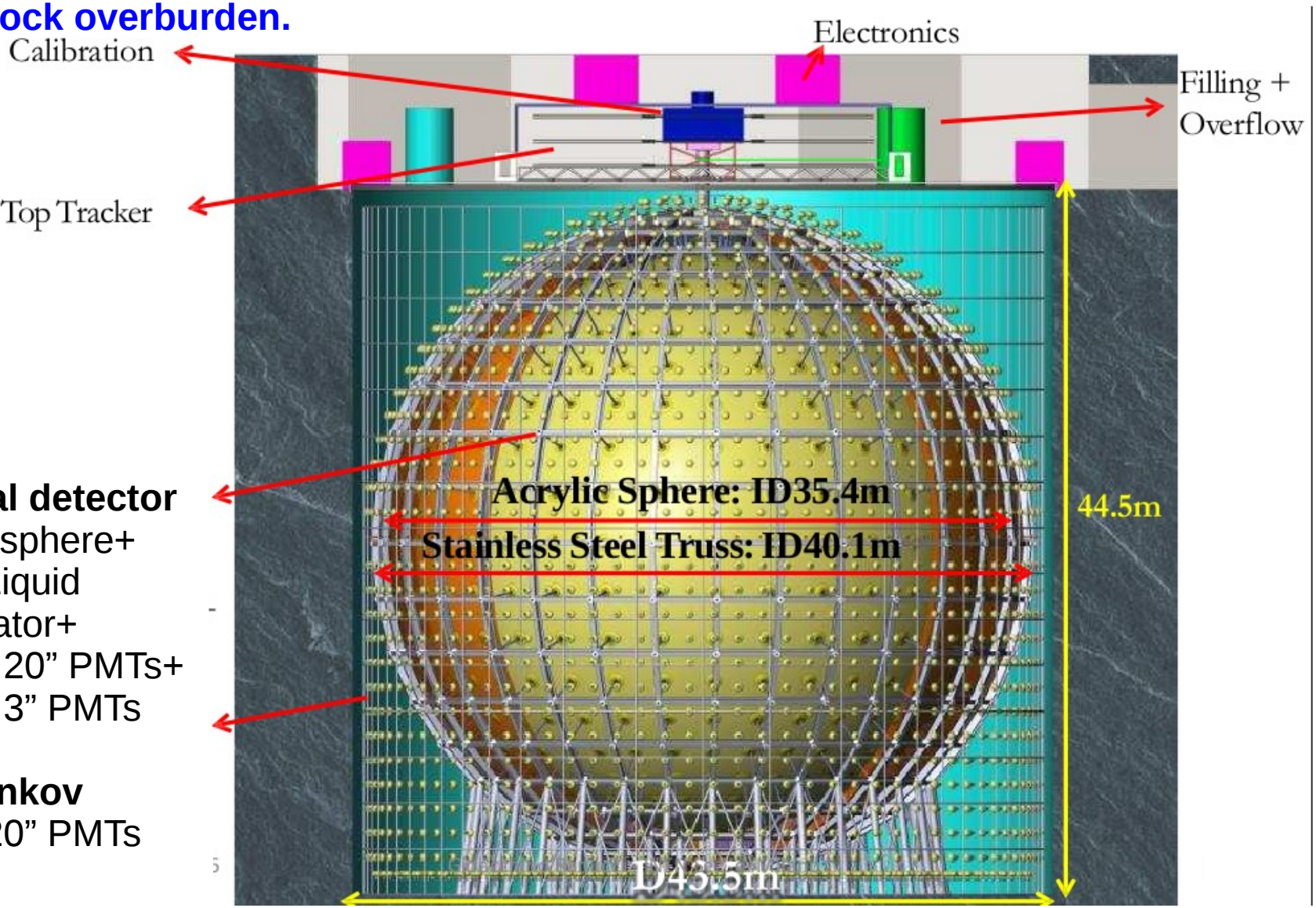
LNF gruppo II: Fisica del neutrino

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

Assestamento delle percentuali per raggiungere la soglia di apertura almeno su JUNO.

JUNO experiment

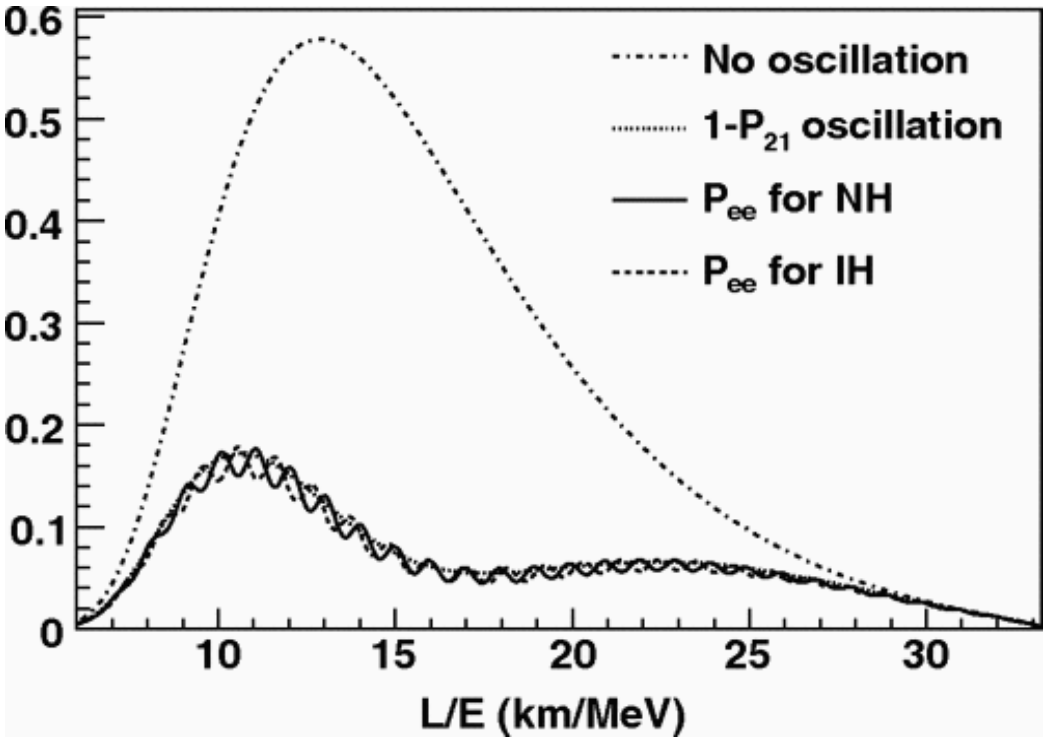
Oscillation experiment: anti-ν_e disappearance for mass hierarchy measurement.
50 km baseline from 2 nuclear power plants (power=26-36 Gw).
700 m rock overburden.



Central detector
Acrilic sphere+
20 kt Liquid scintillator+
17000 20” PMTs+
25000 3” PMTs
Water Cherenkov
2000 20” PMTs

Multi-purpose experiment: Determination of Δm^2_{21}, Δm^2_{31}, θ_{12} at sub % level.
Observation of neutrinos from natural sources (Sun, geo-neutrinos, Supernovae).

JUNO experiment



Mass hierarchy determination through interference with two oscillating amplitudes (solar and atmospheric). Not dependent on θ_{23} and δ_{CP} like other competitors (Nova, ORCA, PINGU, Dune, INO) using ν_{μ} beams or atmospheric neutrinos.

3-4 σ can be reached in 6 years of operation, provided a factor of 2 improvement is achieved in the energy resolution of current Liquid Scintillator experiments.

INFN contributions:
Liquid scintillator purification (Mi/Pg)
FE electronics (Pd/RM3)
Top Tracker electronics (LNF)
Computing (RM3/CT)
Low activity (MiB)

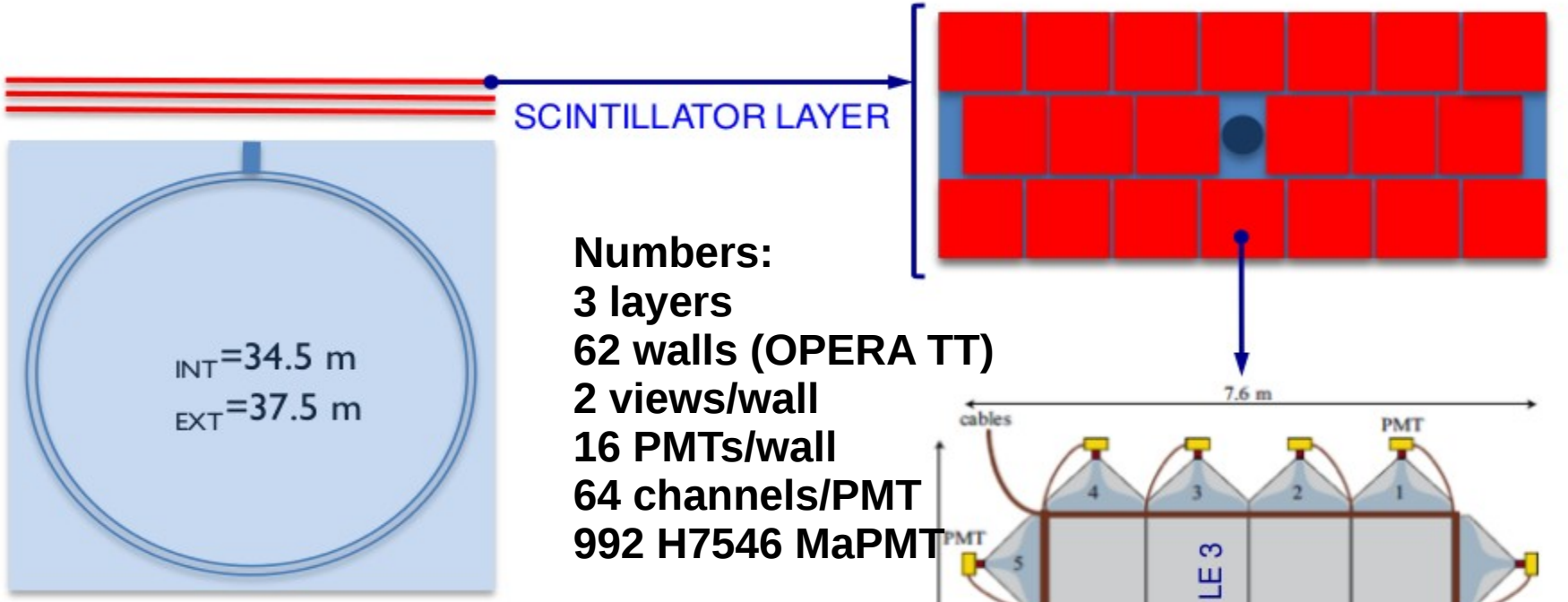
Energy resolution needed:
3% / √ E(MeV) + 1%

Statistic term:
Scintillator light yield: 10.4 kγ/MeV
Attenuation length: 20 m @430 nm
PMT coverage: 75%
PMT quantum efficiency: 35%

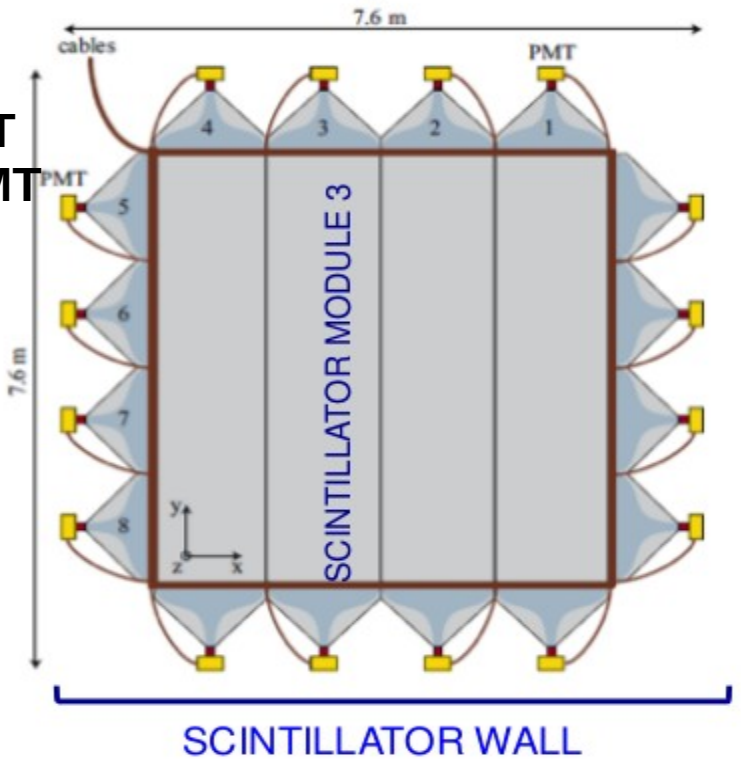
Systematic term:
Dedicated calibration system
Small PMT system (linearity at high energy values and peripheral events)

JUNO experiment Top Tracker

Background dominated by cosmogenic production of ^{9}Li and ^{8}Be.
Top Tracker for: tagging (50% coverage), precision study of background, Central Detector performances monitoring.
Plastic scintillator strips read-out with WLS fibers from OPERA experiment.



Numbers:
3 layers
62 walls (OPERA TT)
2 views/wall
16 PMTs/wall
64 channels/PMT
992 H7546 MaPMT

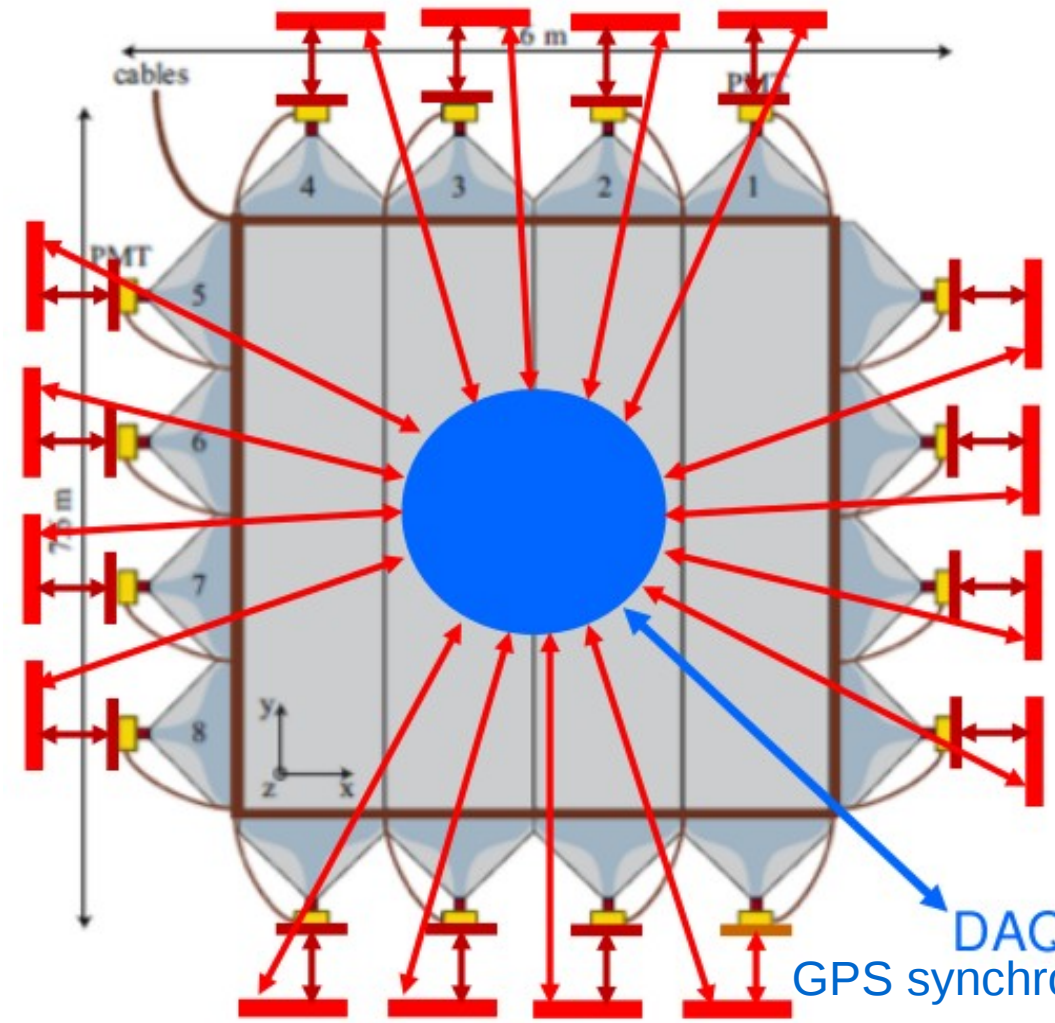


Single PMT maximum rate = 50 kHz
L1 (wall) trigger rate = 10 kHz (100 ns shaping)
Signal multiplicity = 6 fired strip/hit
Charge resolution = 8 bit
Time-stamp resolution = 1 ns

L1 (wall) trigger = AND of x and y views.

JUNO Top Tracker electronics

OPERA electronics and DAQ, designed for low rate, need to be replaced.
A. Paoloni L3 responsible for the electronics of the Top Tracker, realized in collaboration with Strasbourg and LLR-Paris groups.



MAROC3 board (FEC):
It hosts MAROC3 chip and logic strictly required to make it work.
(Strasbourg: prototype validated)

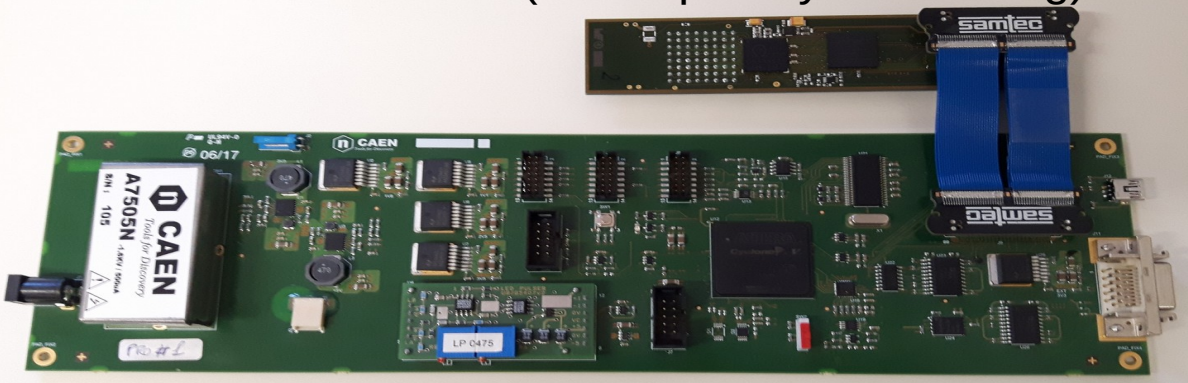
Read-out board (ROB):
Manages MAROC3 setting and read-out.
Hosts PMT HV power supply.
Hosts FADC for charge read-out.
(INFN-LNF: prototype ready)

Concentrator board:
Generates wall trigger.
Trigger time-stamp with respect to GPS signal.
Collect read-out data and send them to DAQ.
Deliver DCS commands to read-out boards.
(LLR-Paris-under development)

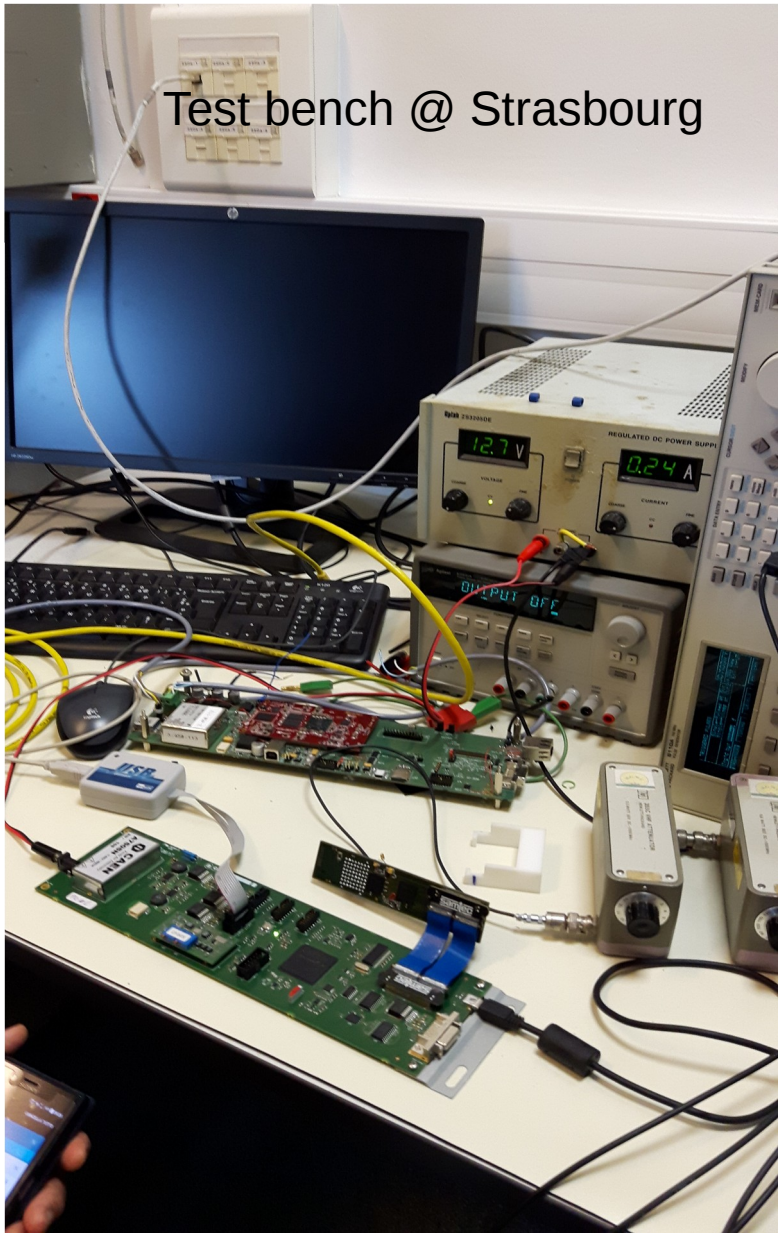
Installation foreseen in second half of 2020. Data taking expected in 2021.

Top Tracker electronics prototypes

Front-End board (developed by Strasbourg)



Read-Out board (developed by CAEN and AgeScientific)



FE + RO boards integration test in Strasbourg successful:
FE and RO boards design frozen.
First prototypes at LNF (already with second version of firmware).
In the next months: test of the prototypes on detector for fine tuning.
Prototype of concentrator (LLR Paris) expected next year.
Next year start of the tender for 1000 RO boards.

Other activities of LNF group: shifts on liquid scintillator purification facilities and on PMT testing.

LNF gruppo II: Raggi cosmici

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

Un gruppo su due esperimenti, in stretta collaborazione con il gruppo di Tor Vergata.
M. Ricci responsabile nazionale di Jem-EUSO-RD.
Contributo dell'SPCM alla progettazione meccanica del PDM (Photo-Detector Module) di mini-EUSO e realizzazione dell'engineering model.

The EUSO program: *Ultra-High Energy cosmic rays from space.*

EUSO-TA:

Ground test detector installed in 2013 at Telescope Array site: currently operational. Future option for AUGER site.

EUSO-BALLOONS:

Balloon flight from Timmins, Canada (French Space Agency) Aug 2014.
NASA Ultra long duration balloon flights: SPB April 2017 and NASA SPB-2 2020.

TUS (Tracking Ultraviolet Setup):

Russia (launched 2016 on Lomonosov satellite)

MINI-EUSO (2018):

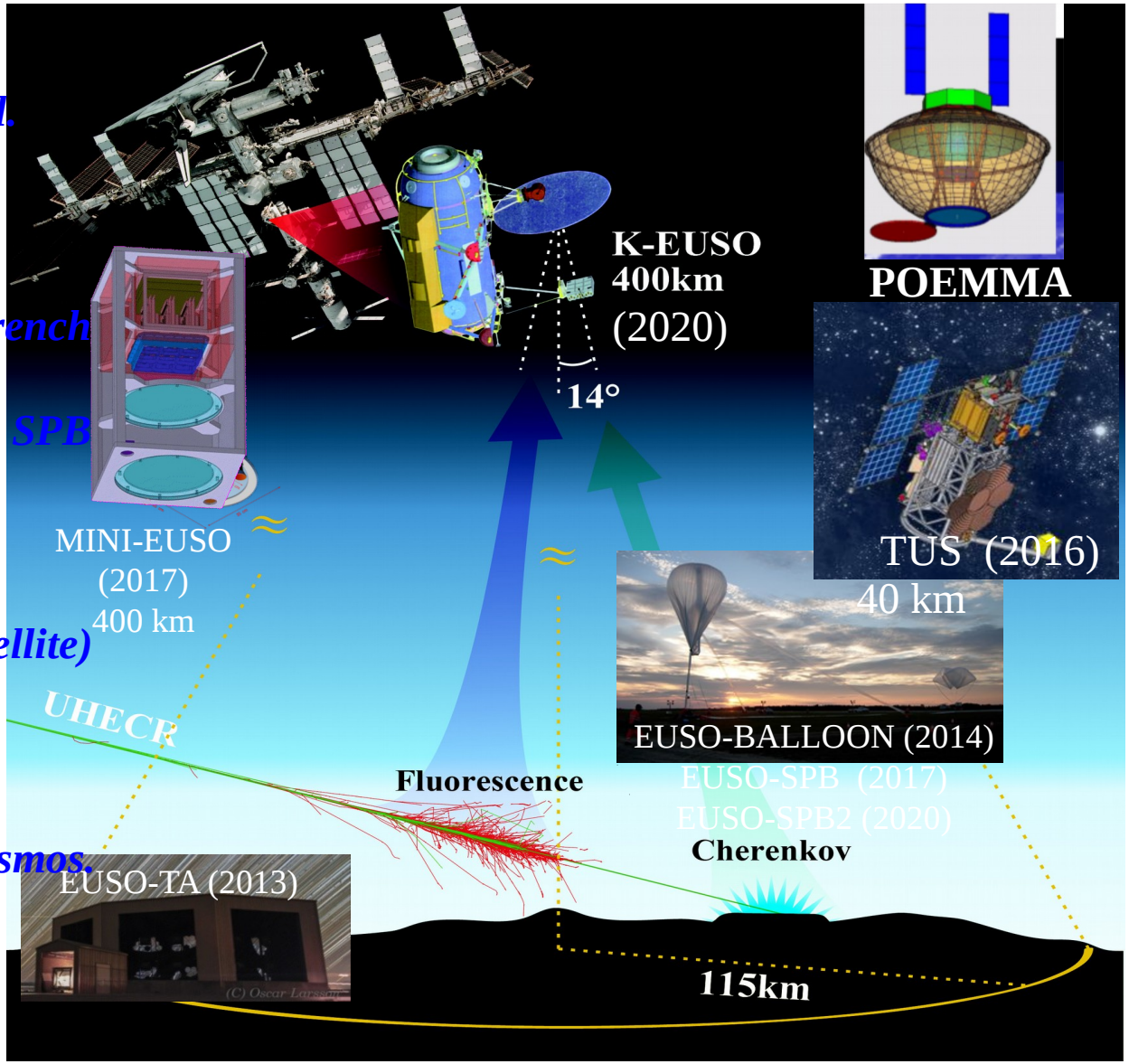
Precursor mission at International Space Station (ISS); approved by ASI and Roscosmos.

K-EUSO (2022):

ISS Approved by Roscosmos.

POEMMA (2025)-:

NASA twin free-flyer: UHECR and cosmic neutrinos. (Probe Of Extreme Multi-Messenger Astrophysics)



JEM-EUSO collaboration 16 Countries, 93 Institutes, 351 people

MINI-EUSO/UV-Atmosphere

A precursor of EUSO on board ISS Russian Modulefor the observation of Atmosphere and Earth in the UV spectrum

Approved by Italian Space Agency

Approved by Russian Space Agency

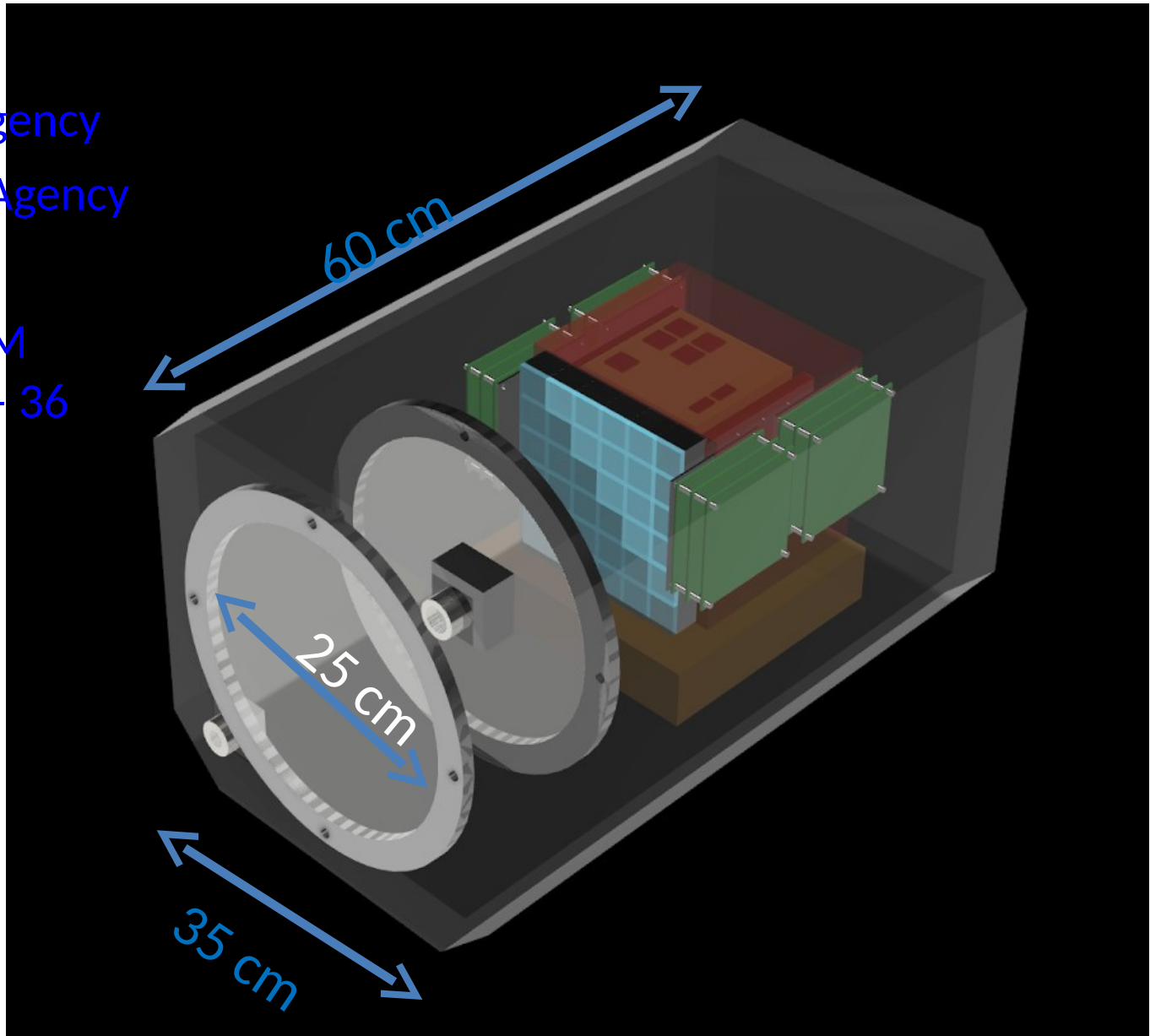
Inside the ISS late 2017

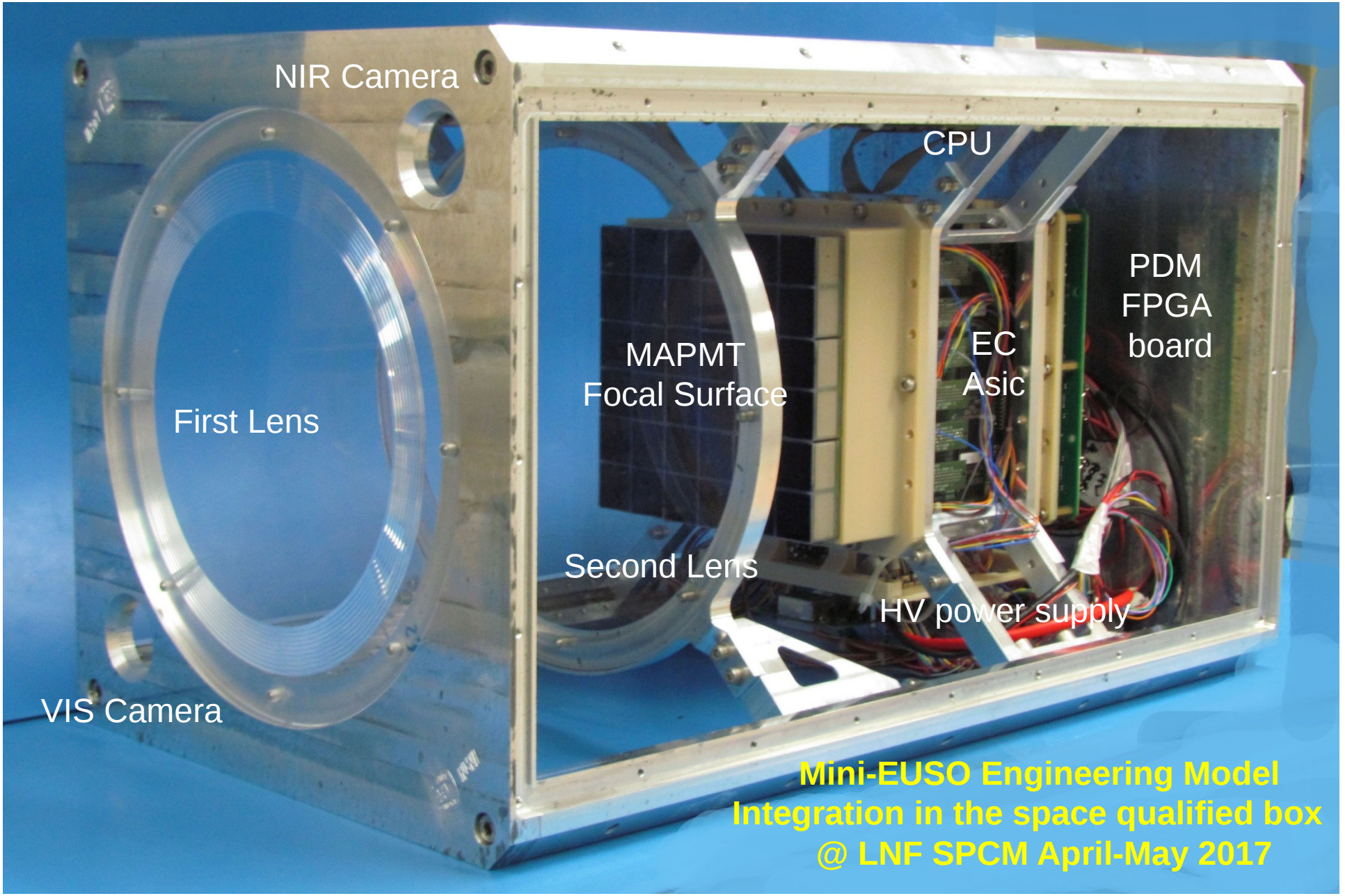
2 Fresnel lenses and one PDM (Photo Detector Module – 36 PMT's)

FoV: ± 19°

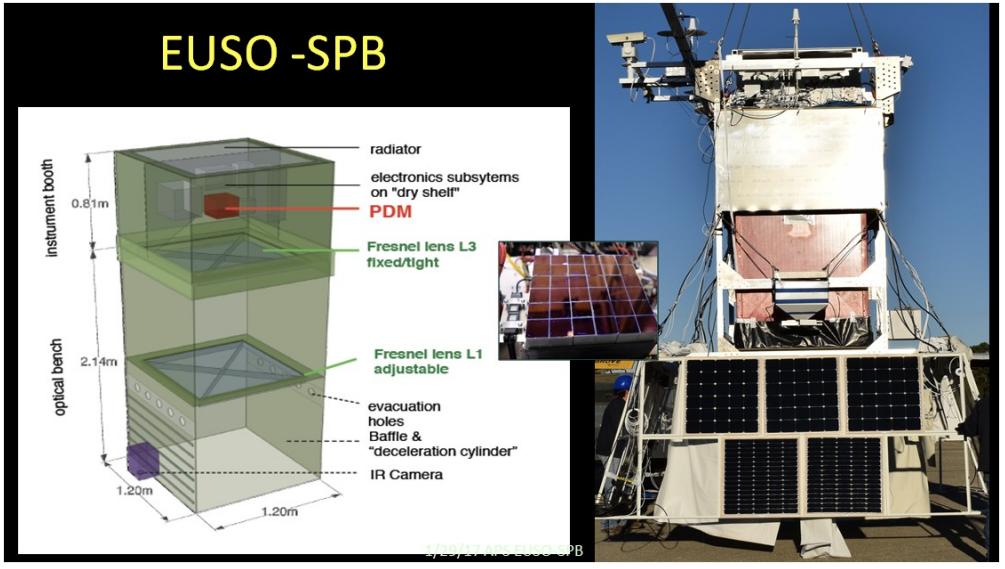
Power: 60 W @ 27 V

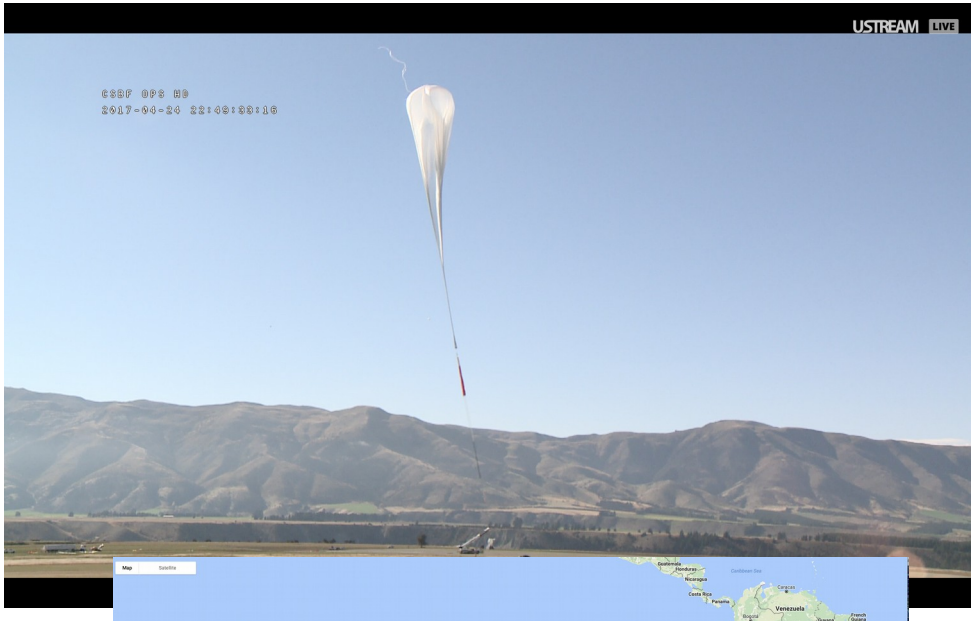
Weight: 30 kg

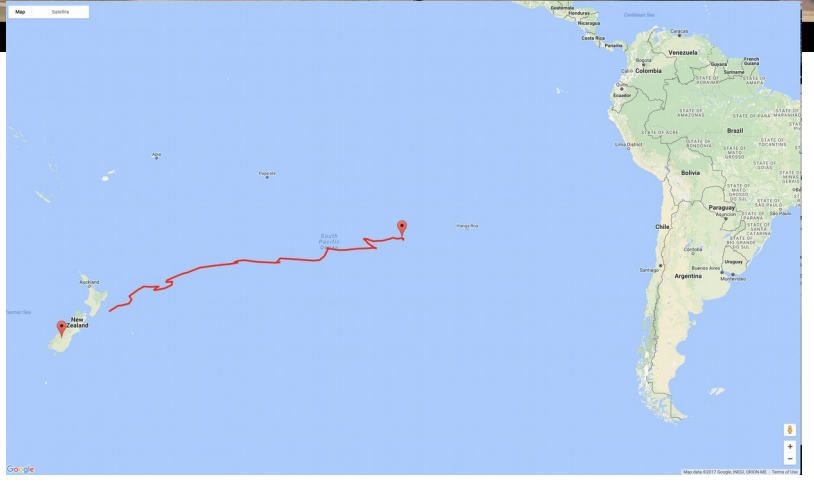



NIR Camera
CPU
PDM
FPGA
board
EC
Asic
MAPMT
Focal Surface
First Lens
Second Lens
HV power supply
VIS Camera
Mini-EUSO Engineering Model
Integration in the space qualified box
@ LNF SPCM April-May 2017

EUSO-SPB Balloon flight, launched 25 April, 2017
Wanaka, New Zealand



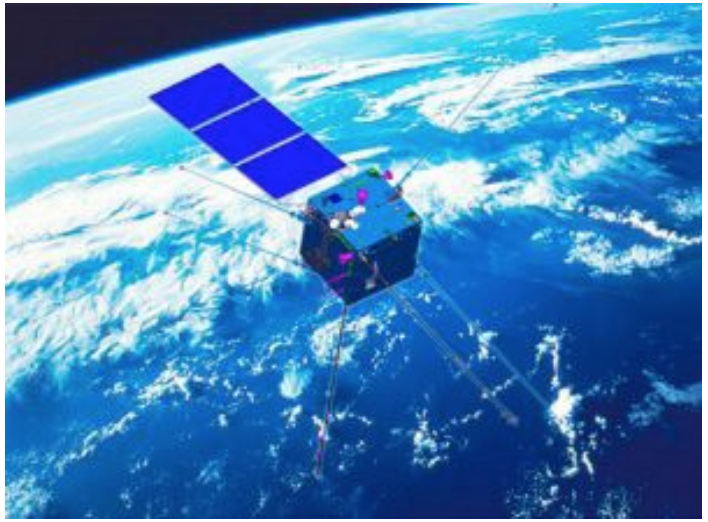




NASA-CSBF Mission

2nd Payload built by the JEM-EUSO Collaboration.
New lenses, Focal Surface, Improved Electronics.
Approved by ASI.
Flight terminated after 12 days.

Main Goal: First UV UHECR shower observation from top of atmosphere



LIMADOU-CSES

(Chinese Seismo-Electromagnetic Satellite)

ASI INFN INGV project
Chinese National Space Agency
China Earthquake Administration

INFN group composition: Bologna, LNF, Tor Vergata, Trento, Perugia, UniNettuno Roma.

Main Scientific Objectives:

- Measurement from space of magnetospheric perturbations and correlations with seismic phenomena
- Interactions between Magnetosphere, Ionosphere and Earth

Instruments on board CSES Satellite:

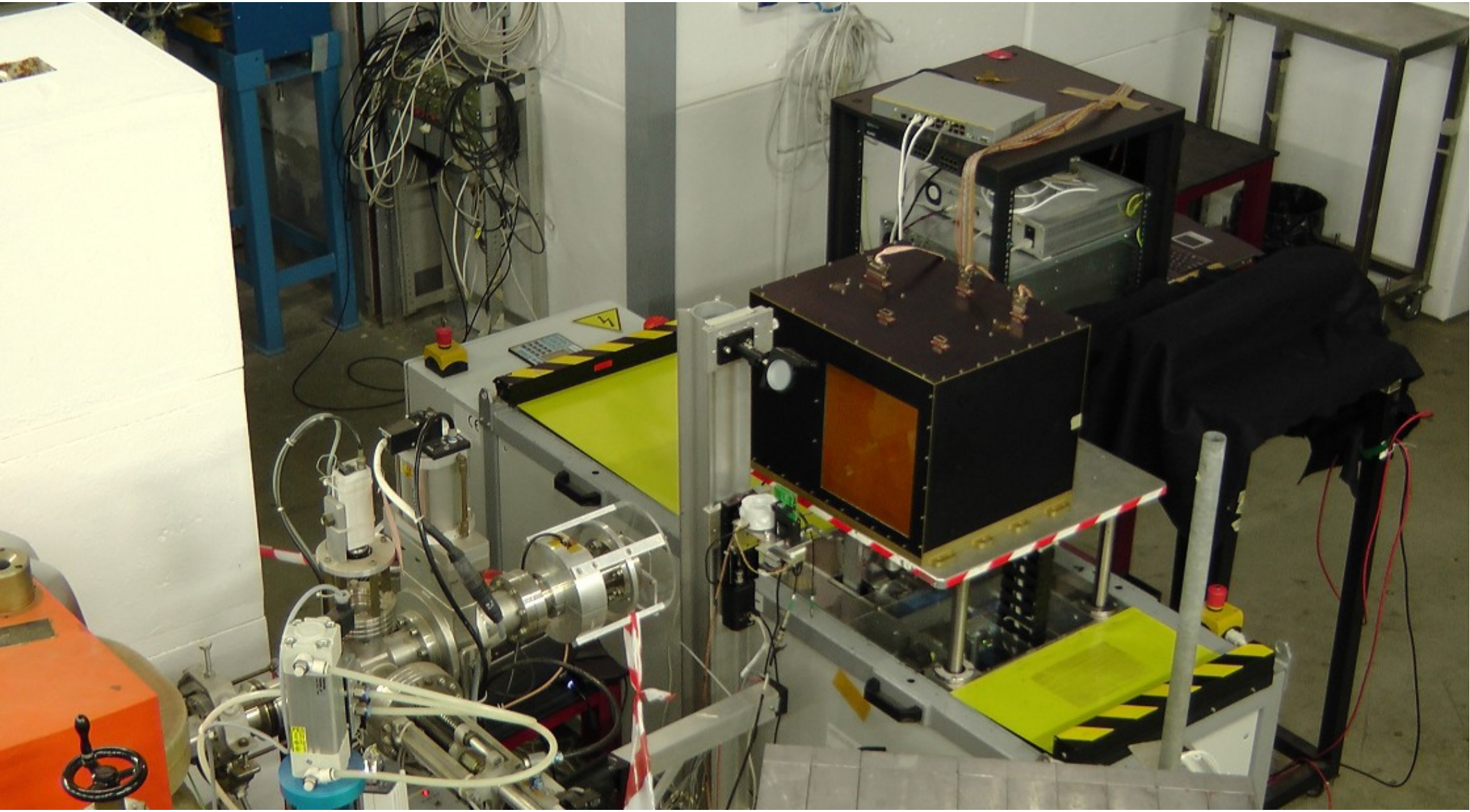
- Magnetic Spectrometer
- Electric Field Detector
- High Energy Particle Detector
- Magnetic Field Detector
- Low-frequency e.m. wave detector

Launch mid-August 2017

Jiuquan Satellite Launch Center, Gansu (Inner Mongolia)

CSES- LIMADOU High Energy Particle Detector (HEPD) Flight Model
Electron Beam Test @ BTF, Frascati, 3-5 October 2016

→ **Energy: 30 MeV, 45 MeV, 60 MeV, 120 MeV**



LNF gruppo II: Gravitazione

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

Moonlight2: Laser ranging per test della legge di gravita'.
S. Dell'Agnello e' Responsabile nazionale.
Il gruppo include anche ricercatori dall'universita' e dall'osservatorio di Matera per il Laser Ranging.

INFN solar system science assets

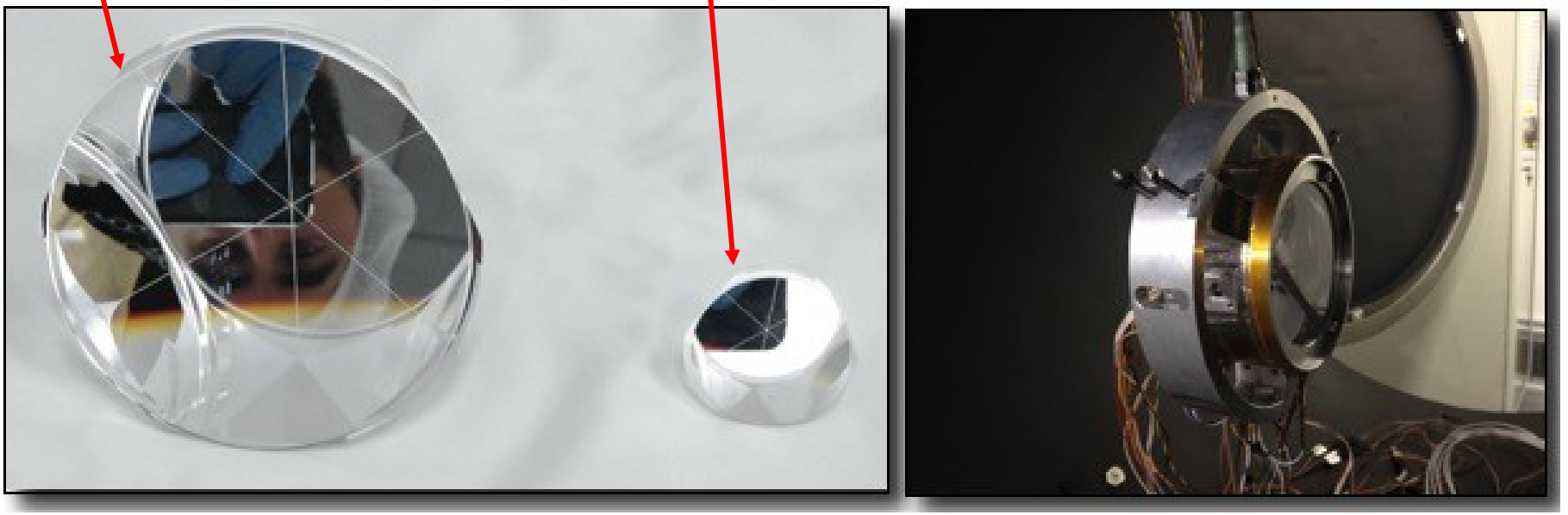
- MoonLIGHT, the *big* Lunar laser retroreflector
  - Moon Laser Instrumentation for General relativity High accuracy Tests, next-generation lunar (see D. Currie's talk)
- INRRI, the Solar System *micro*reflector
  - Instrument for landing-Roving laser Retroreflector Investigations
- PEP, the Planetary Ephemeris Program *orbital SW*
  - Lunar/Martian positioning data: with PEP, developed in USA at the Harvard-Smithsonian Center for Astrophysics (CfA), by Shapiro, Reasenberg, Chandler since 1960/70s

MoonLIGHT, next-generation

Lunar Laser Ranging (LLR) Retroreflector

- INFN-Frascati, U. Maryland, INFN/Univ. Padua
- Lunar stations: ASI-MLRO (Italy), APOLLO (US), OCR (France)

MoonLIGHT (100 mm) **GNSS (33 mm)** **MoonLIGHT package**



Lunar Laser Ranging test of General Relativity

- Improvements of the space segment up to ×100 with MoonLIGHTs on near side in addition to Apollo/Lunokhods

Science measurement / Precision test of violation of General Relativity	Apollo/Lunokhod * few cm accuracy	MoonLIGHTs ** sub-mm	mm
Parameterized Post-Newtonian (PPN) β	$\lvert\beta-1\rvert < 1.1\times10^{-4}$	10^{-5}	10^{-6}
Weak Equivalence Principle (WEP)	$\lvert\Delta a/a\rvert < 1.4\times10^{-13}$	10^{-14}	10^{-15}
Strong Equivalence Principle (SEP)	$\lvert\eta\rvert < 4.4\times10^{-4}$	3×10^{-5}	3×10^{-6}
Time Variation of Gravitational Constant	$\lvert\dot{G}/G\rvert < 9\times10^{-13}\mathrm{yr}^{-1}$	5×10^{-14}	5×10^{-15}
Inverse Square Law (ISL) - Yukawa	$\lvert\alpha\rvert < 3\times10^{-11}$	10^{-12}	10^{-13}
Geodetic Precession	$\lvert K_{gp}\rvert < 6.4\times10^{-3}$	6.4×10^{-4}	6.4×10^{-5}

* J. G. Williams et al PRL 93, 261101 (2004)

** M. Martini et al Plan. & Space Sci. 74 (2012) 276–282; M. Martini PhD thesis 2016

MEDIA RELEASE

Daven Maharaj / 650-241-8577
media@moonexpress.com

FOR RELEASE: May 15th, 2015 @ 2:00PM GMT

Moon Express Announces First International Multi-Mission Payload Agreement with The INFN National Laboratories of Frascati and the University of Maryland

"MoonLIGHT" Lunar Laser Ranging Array Will Bring New Insights into General Relativity

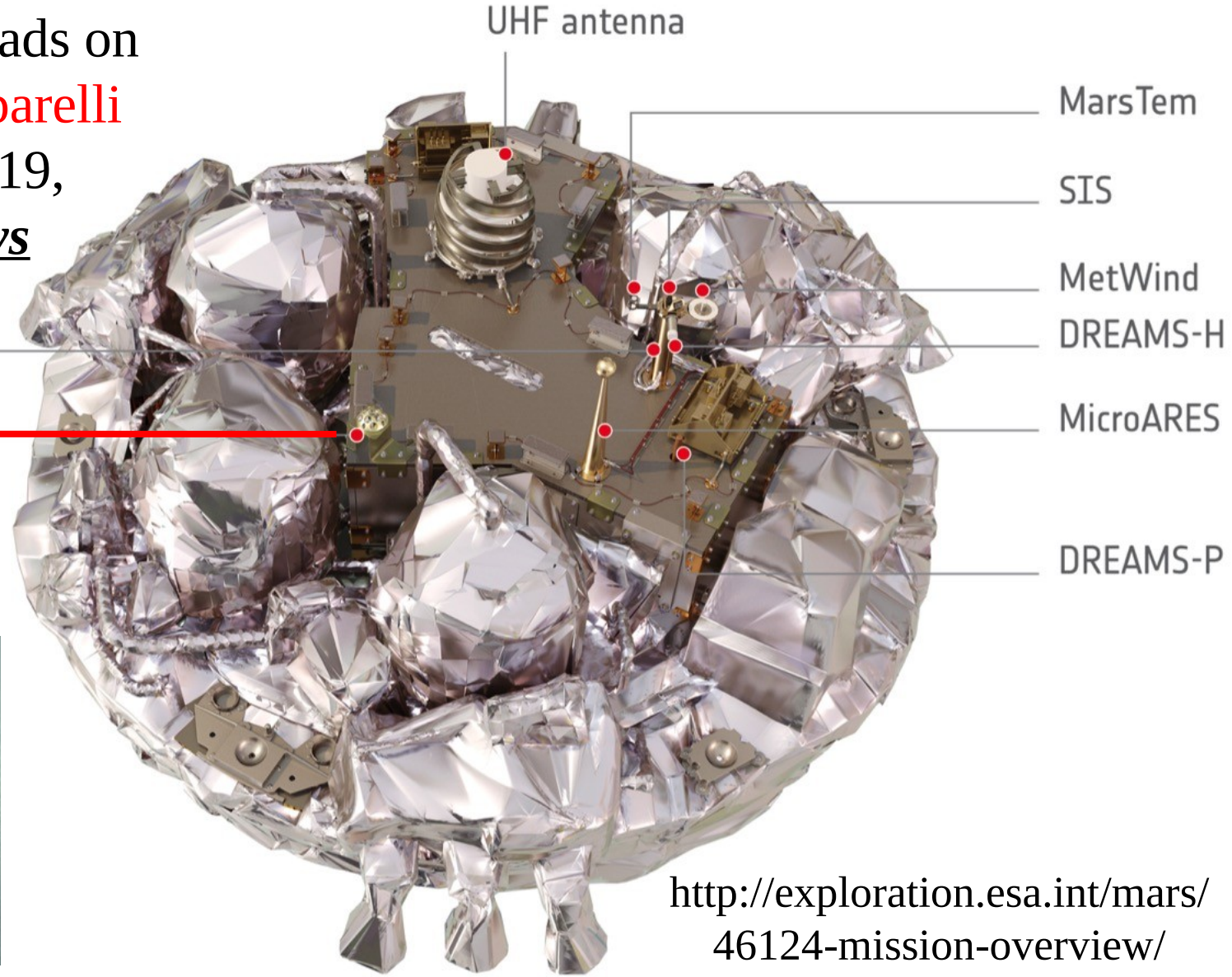
Frascati, Italy (May 15th, 2015) – Moon Express, Inc. (MoonEx) has announced a multi-mission payload agreement with The National Laboratories of Frascati (INFN-LNF) and the University of Maryland to deliver a new generation of lunar laser ranging arrays to the Moon. Under the agreement, "MoonLIGHT" instruments will be carried on the first four Moon Express missions and used in conjunction with Apollo Cube Corner (CCR) Retroreflector arrays to test principles of Einstein's General Relativity theory, add to international scientific knowledge of the Moon, and increase lunar mapping precision that will support the company's future lander missions.

"MoonLIGHT" Payload Agreement Announcement in Frascati, Italy. L-R: Jack Burns, CU; Doug Currie, UMD; Simone Dell'Agnello, INFN-LNF; Bob Richards, Moon Express

The payload announcement was made today in Frascati, Italy, right after the European Lunar Symposium, during a Global Exploration Roadmap workshop of the International Space Exploration Coordination Group (ISECG), attended by officials

ExoMars 2016: 1st laser retroreflector on Mars

Science payloads on Lander Schiaparelli
Landing: Oct 19, 2016, ***in 6 days***



INRRI
25 gr
~5cm×2cm

http://exploration.esa.int/mars/46124-mission-overview/

National Aeronautics and Space Administration

Headquarters
Washington, DC 20546-0001

July 14, 2016

SMD/Mars Exploration Program

Dr. Enrico Flamini
Chief Scientist
Agenzia Spaziale Italiana
Via del Politecnico snc
00133 Rome
Italy

Dear Dr. Flamini:

NASA is agreeable to hosting the Agenzia Spaziale Italiana (ASI) Laser Retroreflector Array (LRA) on the Mars 2020 rover, as we see the instrument to be of mutual benefit, holding the potential to improve the accuracy of geospatial maps that the scientific community has been building for the last several decades. We are also exploring the possibility of including an ASI LRA on NASA's Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission.

InSight lander launch in May 2018.
Readiness Review @LNF, with NASA-JPL and ASI.

Mars test of GR (PEP simulations)

- MGN, Mars Geo/physics Network of INRRIs
- Test of non-ideal MGN (~all north, weather/accuracy limitations)

  Phoenix Lander (68N, 234E), Curiosity Rover (4S, 137E), Opportunity Rover (2S, 354E), Viking1 lander (22N, 50W), Viking 2 Lander (48N, 258W)
- Data: 1 laser normal point (NP) every 7 Sols for 10 years
  - Or >1 NP every 7 Sols for < 10 years
- Preliminary, but based on consolidated lunar PEP analysis
- Accuracy: 10cm–10m (current ephemeris ~50m)

INRRI: Time/Accuracy	Accuracy on β-1	Accuracy on γ-1	Accuracy on $\dot{G}/G$
10 years / 10 m	1.7 x E-04	7.2 x E-04	3.8 x E-14
10 years / 1 m	3.7 x E-05	1.6 x E-05	1.4 x E-14
10 years / 10 cm	7.4 x E-07	3.2 x E-06	2.9 x E-15
Best accuracy now Data *Analysis group*	**1 x E-04** Lunar Laser Ranging *JPL, Harvard-INFN*	**2.3 x E-05** Cassini *Bertotti et al*	**9 x E-13** Lunar Laser Ranging *JPL, Harvard-INFN*

LNF gruppo II: Universo oscuro

Experiment	FTE (persone)	Afferenti gruppo II	postdoc
JUNO	1.5 (5)	1 R (ricercatore) + 1 T (anche KM3)	
KM3.DTZ	0.5 (1)	1 T (tecnologo)	
CUORE.DTZ	1.5 (3)	3 T	
Darkside.DTZ	0.8 (2)	2 T (anche CUORE)	
Jem EUSO RD	2.1 (6)	1 R + 2 T (anche CUORE)	1 ADR (ToV)
Limadou.DTZ	0.2 (2)	1 R (anche Jem EUSO RD)	
Moonlight2	7.2 (12)	2 T + 1 RTD	3 ADR
QUAX	1.55 (5)	2 R + 1 T (anche CUORE)	

QUAX: ricerca di assioni, attivita' partita l'anno scorso a Frascati, portando FTE dai gruppi I e V.
Possibile che partano anche altre nuove attivita' sulla dark matter nei prossimi anni.

Axion: CP violation in QCD

$$\mathcal{L}_{QCD} = ... + \theta \frac{\alpha_s}{8\pi} G_{a\mu\nu} \tilde{G}_a^{\mu\nu}$$

This term violates T (CP) symmetry and induces a neutron electric dipole moment (EDM)

Predicted:

$$d_n \simeq \theta \frac{m_q}{M_n} \frac{e}{M_n} \sim \theta \times 10^{-3} e \text{ GeV}^{-1} \sim \theta \times 10^{-15} e \text{ cm}$$

Measured:

$$d_n < 2.9 \times 10^{-26} e \text{ cm} \qquad \theta < 10^{-10}$$

PRL 82(5) (1999) p.904ß

Moreover θ gets further contributions from quark mass matrix. Why so small?

Axion Solution

$$\mathcal{L}_{QCD} = ... + \frac{\alpha_s}{8\pi}(\theta - \frac{a}{f_a})G_{a\mu\nu}\tilde{G}_a^{\mu\nu}$$

"a" is a new scalar field.

Peccei Quinn Weinberg Wilczek

Axions Cold Dark Matter

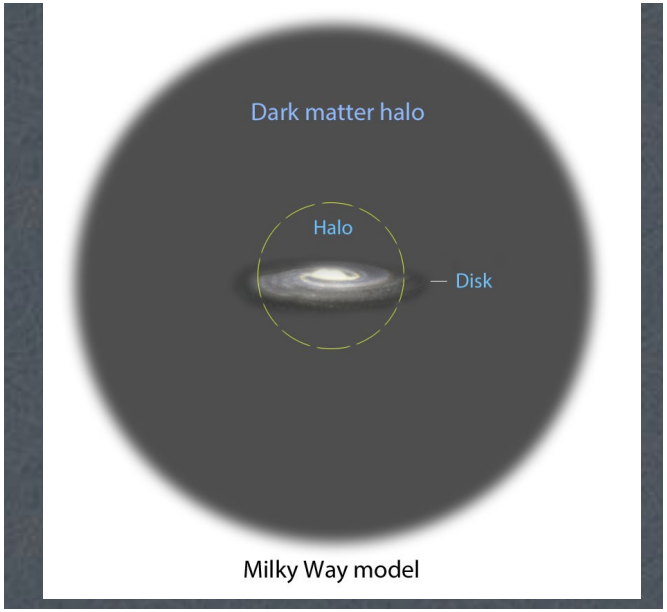
$$\rho \simeq 0.3 GeV/cm^3$$

$$n_a \simeq 3 \times 10^{12} \left(\frac{100\mu eV}{m_a}\right) 1/\mathrm{cm}^3$$

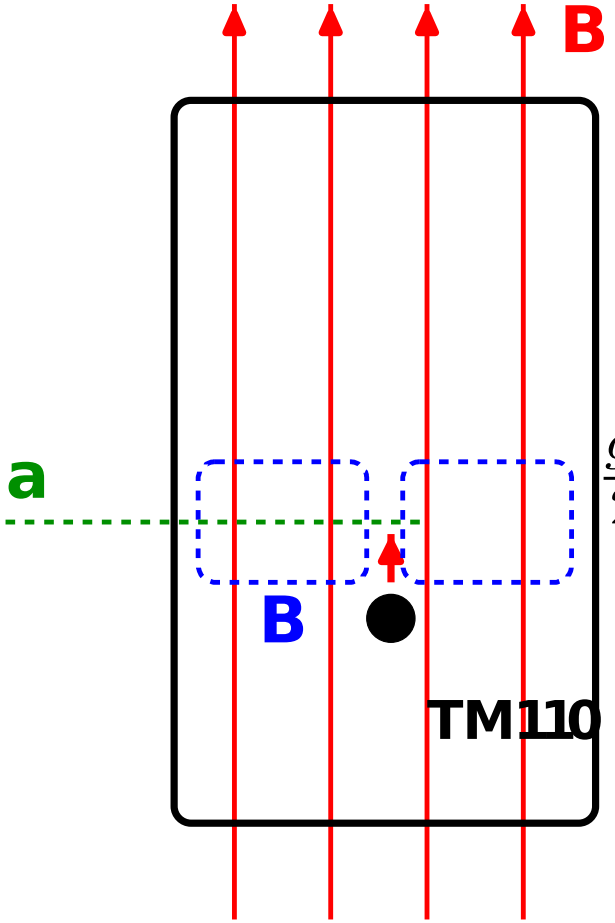
$$\beta_a \sim 10^{-3}$$

$$\frac{\delta\omega}{\omega} \sim 10^{-6} \qquad \frac{\omega}{2\pi} = 24(\frac{m_a}{100\mu eV})\mathrm{GHz}$$

$$a = a_0 \cos\omega t$$



Quax Experiment



$\frac{g_p \hbar}{2m} \sigma \cdot \nabla a$

Search for galactic axions through their coupling to electrons: axion “wind” flips an electron spin inside a resonant cavity exciting its mode TM110.
Very low power signals expected, measurebale with a single microwave photon counter.

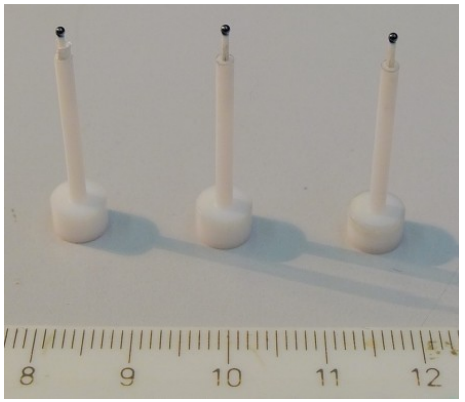
$$P_S \sim 5 \times 10^{-26} \mathrm{W}$$

$$R_S \sim 1 \times 10^{-3} \mathrm{Hz}$$

$$m_a = 200 \mu \mathrm{eV}$$

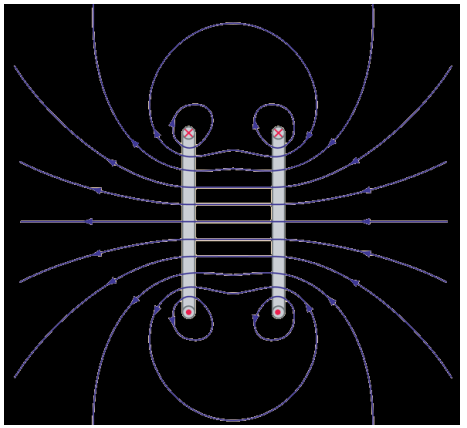
Physics of the Dark Universe 15 (2017), 135-141

Quax R&D

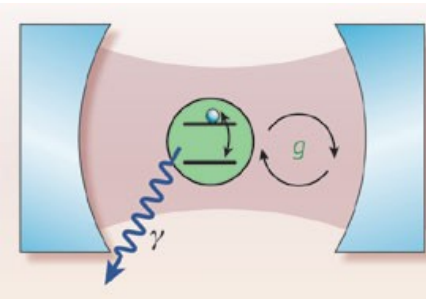


1) R&D on paramegnetic/ferrimagnetic materials (high spin density $10^{28}/m^3$) (Pd/LNL/To)

2) R&D on SC resonant cavities operating in strong B field (LNF)



3) R&D on magnets with strong (2T) and uniform (10 ppm) magnetic field. (Na/Salerno)



4) R&D on Single microwave photon counters (LNL/Pd/LNF/ Trento)

Request of LNF services:
Research division mechanical workshop.
1 month*person for cavity project.
Support for cryogenics (He liquefier).

LNF gruppo II: richieste ai laboratori

JUNO: **supporto tecnico per test prototipi, disegno della scheda di distribuzione LV.**

Jem-EURO-RD: **2 mu SPCM per produzione di supporti per PDM (Photo-Detector Module) con la stampante 3D, per le attività in corso e in fase di sviluppo.**

Moonlight2: **in linea con quelle di quest'anno.**

Quax: **supporto tecnico per la criogenia (run del liquefattore di elio), officina meccanica e progettazione della cavita' superconduttrice.**