Future plans for astro-particle physics activities (CSN2) at LNF

A. Paoloni

LNF Scientific Committee

November 13th 2015

CSN2 LNF groups

Group	Researcher FTE (pers)	Technologist FTE (pers)	Technician FTE (pers)	Closing activity
OPERA	2.0 (6)	0 (0)	2.5 (4)	*
Nessie.DTZ	0.1 (1)	0 (0)	0 (0)	
JUNO.DTZ	0.5 (3)	0 (0)	0 (0)	
ICARUS.DTZ	0.2 (3)	0 (0)	0.5 (1)	
T2K.DTZ	0.4 (1)	0 (0)	0 (0)	
CUORE.DTZ	0 (0)	1.6 (3)	0 (0)	*
KM3	1.2 (2)	0.6 (1)	0.5 (1)	
Wizard	1.8 (4)	0 (0)	0 (0)	*
Jem-EUSO-RD	2.1 (4)	0.6 (2)	0 (0)	
Limadou.DTZ	0.1 (1)	0.4 (1)	0 (0)	
ROG	1.6 (5)	0 (0)	1.3 (2)	*
Moonlight-2	6.5 (10)	2.0 (5)	1.7 (3)	

CUORE: technical support during installation, supposed to end in 2015.
T2K, ICARUS, LIMADOU: small contributions; no support required to the laboratory.

CSN2 LNF groups

Main On-going/future activities

Group	Researcher FTE (pers)	Technologist FTE (pers)	Technician FTE (pers)	Closing activity
OPERA	2.0 (6)	0 (0)	2.5 (4)	*
Nessie.DTZ	0.1 (1)	0 (0)	0 (0)	
JUNO.DTZ	0.5 (3)	0 (0)	0 (0)	
ICARUS.DTZ	0.2 (3)	0 (0)	0.5 (1)	
T2K.DTZ	0.4 (1)	0 (0)	0 (0)	
CUORE.DTZ	0 (0)	1.6 (3)	0 (0)	*
KM3	1.2 (2)	0.6 (1)	0.5 (1)	
Wizard	1.8 (4)	0 (0)	0 (0)	*
Jem-EUSO-RD	2.1 (4)	0.6 (2)	0 (0)	
Limadou.DTZ	0.1 (1)	0.4 (1)	0 (0)	
ROG	1.6 (5)	0 (0)	1.3 (2)	*
Moonlight-2	6.5 (10)	2.0 (5)	1.7 (3)	

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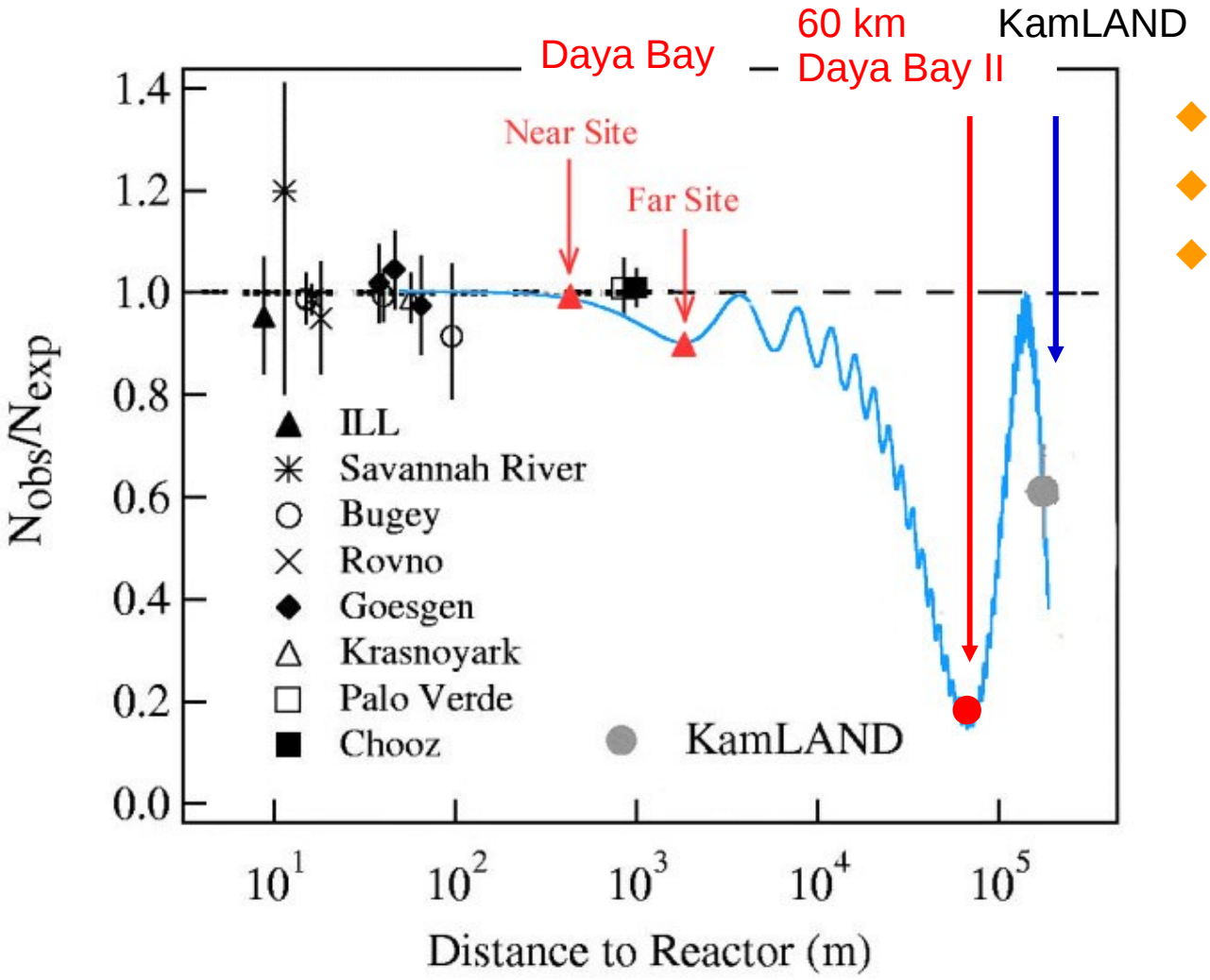
The JUNO Experiment



- 20 kton LS detector
- 3% energy resolution
- Rich physics possibilities
  - **Mass hierarchy**
  - **Precision measurement of 4 mixing parameters**
  - **Supernovae neutrinos**
  - **Geoneutrinos**
  - **Sterile neutrinos**
  - **Atmospheric neutrinos**
  - **Exotic searches**

Talk by Y.F. Wang at ICFA seminar 2008, Neutel 2011; by J. Cao at Nutel 2009, NuTurn 2012 ;
Paper by L. Zhan, Y.F. Wang, J. Cao, L.J. Wen, PRD78:111103,2008; PRD79:073007,2009

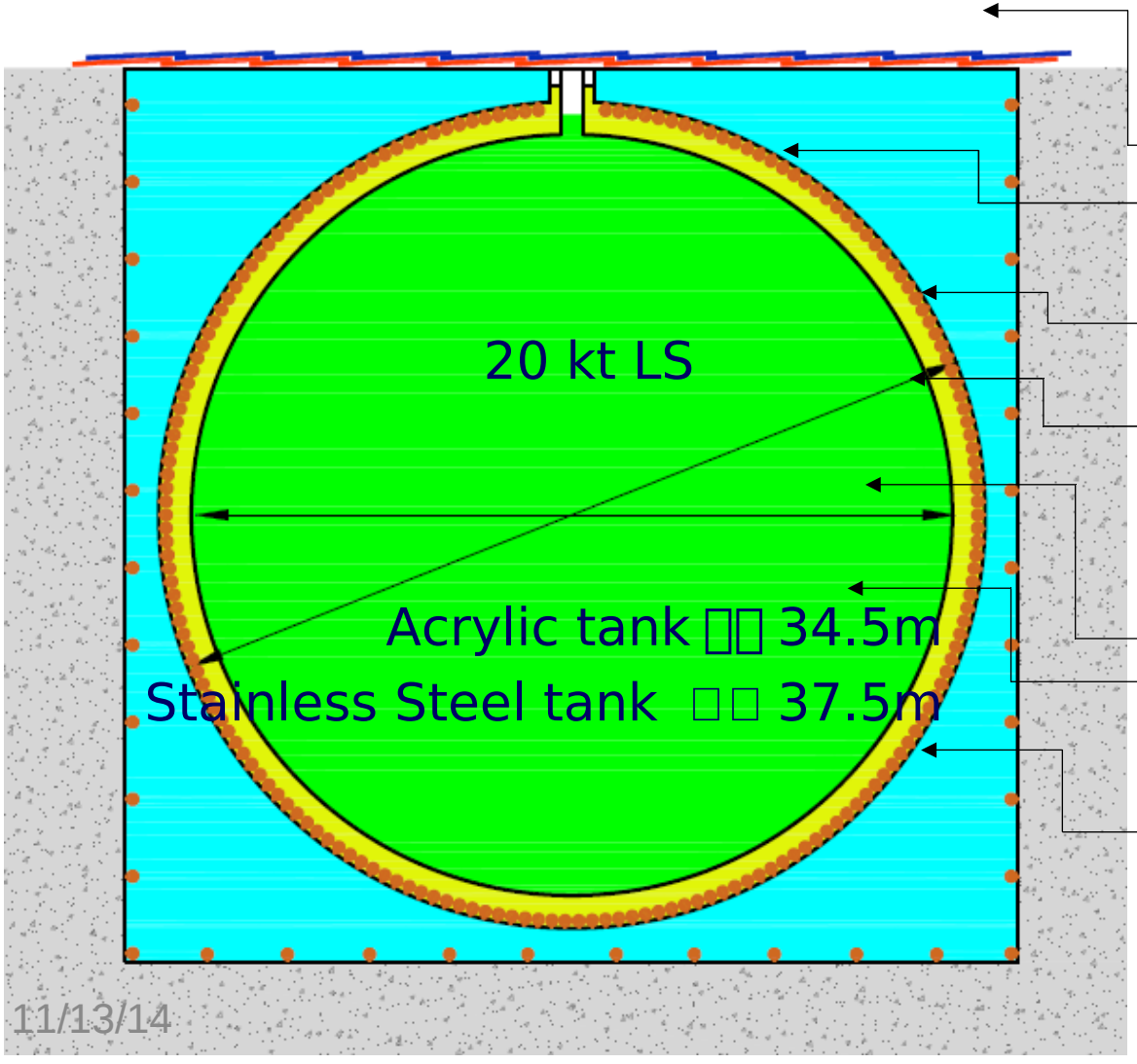
The Site

	Daya Bay	Huizhou	Lufeng	Yangjiang	Taishan
Status	Operational	Planned	Planned	Under construction	Under construction
Power	17.4 GW	17.4 GW	17.4 GW	17.4 GW	18.4 GW , 9.2 by 2020

The plan: a large LS detector

- LS volume: × 20➔ for more mass & statistics
- light(PE) × 5➔ for resolution

40 events/day



Muon detector

Steel Tank

Water seal

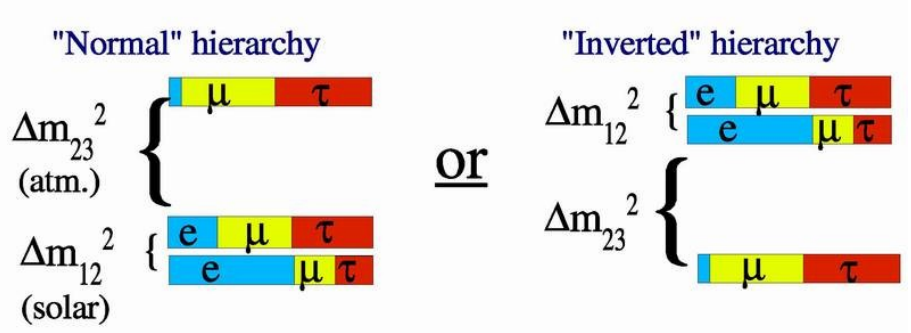
20kt water

6kt MO

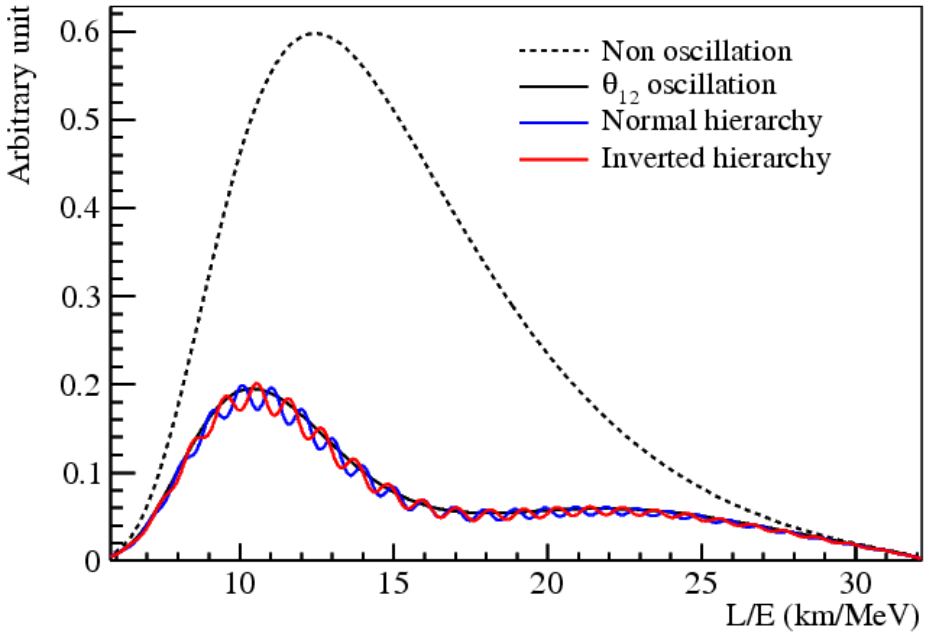
~15000 20” PMTs
coverage: ~80%

1500 20” VETO PMTs

Mass Hierarchy at Reactors



$$
\begin{aligned}
\Delta m^2_{31} &= \Delta m^2_{32} + \Delta m^2_{21} \\
\mathrm{NH}: \quad |\Delta m^2_{31}| &= |\Delta m^2_{32}| + |\Delta m^2_{21}| \\
\mathrm{IH}: \quad |\Delta m^2_{31}| &= |\Delta m^2_{32}| - |\Delta m^2_{21}|
\end{aligned}
$$



$$
\begin{aligned}
P_{ee}(L/E) &= 1 - P_{21} - P_{31} - P_{32} \\
P_{21} &= \cos^4(\theta_{13}) \sin^2(2\theta_{12}) \sin^2(\Delta_{21}) \\
P_{31} &= \cos^2(\theta_{12}) \sin^2(2\theta_{13}) \sin^2(\Delta_{31}) \\
P_{32} &= \sin^2(\theta_{12}) \sin^2(2\theta_{13}) \sin^2(\Delta_{32})
\end{aligned}
$$

Significance > 3 σ obtainable after 6 years exposure if target energy resolution is reached.
Better than 1% resolution on Δm^2_{21}, Δm^2_{32}, $\sin^2(\theta_{12})$.

Current Status & Brief Schedule

- Project approved by CAS for R&D and design
- Geological survey completed
- Granite rock, tem. ~ 31 °C, little water
- Engineering design underway, contract signed
- Land is acquired, civil construction approval underway

Schedule:

Civil preparation □ 2013-2014
Civil construction □ 2014-2017
Detector R&D □ 2013-2016
Detector component production □ 2016-2017
PMT production □ 2016-2019
Detector assembly & installation □ 2018-2019
Filling & data taking □ 2020

JUNO collaboration

JUNO is a chinese experiment with contributions from:

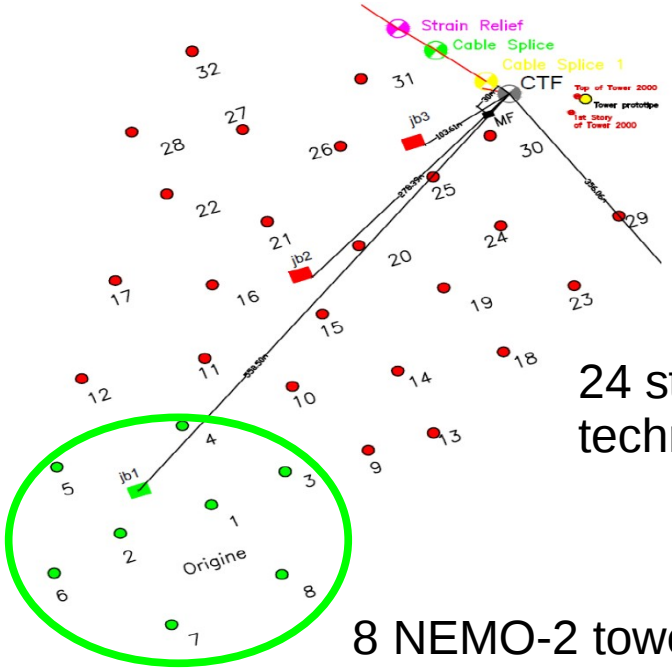
INFN (Milano, Ferrara, Perugia, Frascati, Padova, Roma3), France, Germany, Russia, Cech Republic and USA.

The participation is approved by INFN, with an extra-budget (besides CSN2 funding) of 7 MEuro for scintillator purification.

LNF contribution:
The OPERA Target Tracker will be employed as a Top Tracker in JUNO.
The Hamamatsu 64 ch MAPMT are INFN property.
New DAQ and trigger system for the Top Tracker is needed for the utilization in JUNO .

KM3 General Situation

20 Meuro budget from PON projects assigned for placing the orders of 8 towers (NEMO2-like), 24 strings (KM3net-like) and the relative infrastructures (before the end of November).
1 tower and 1 string prototypes are at present deployed and under test.

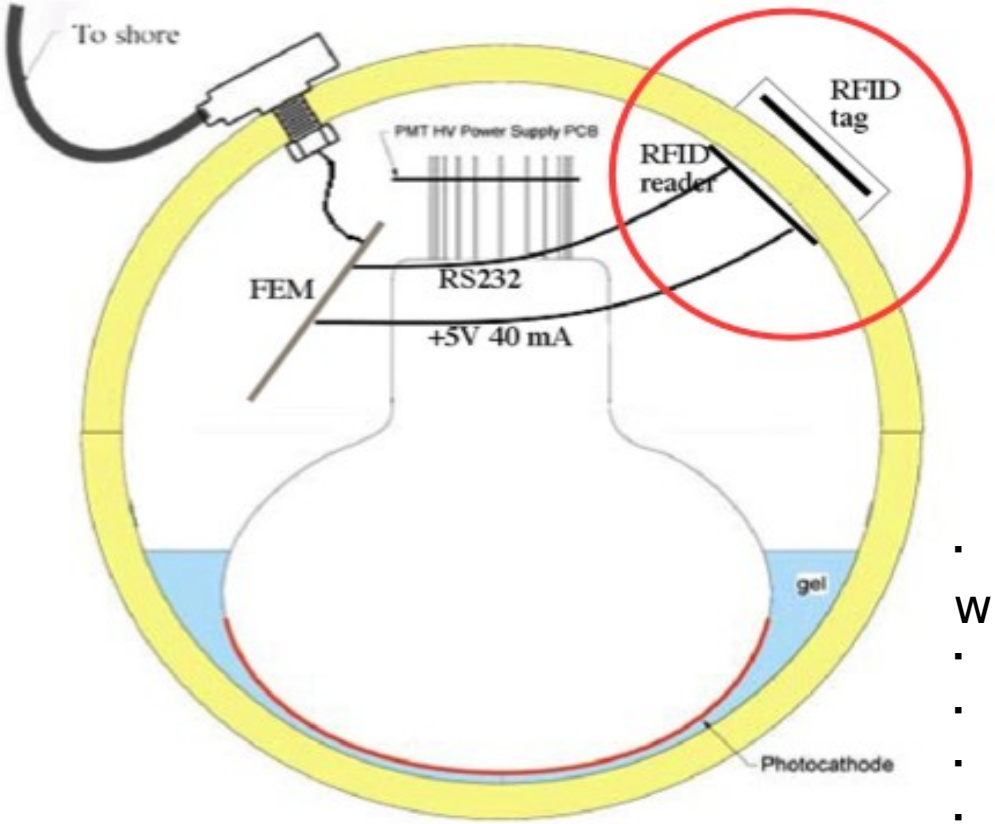


8 NEMO-2 towers

24 strings KM3net technology

Two of the eight towers will be assembled at LNF.

KM3 LNF group activity



PORFIDO

Physical Oceanography by RFID
Outlook

Use neutrino telescopes infrastructure
(power, communication)
for oceanographic measurements

(Temperature, salinity, water mass movements)

- RFID communication through OM glass without connectors
- Very little interference with detector
- Very little bandwidth to-from shore
- Very little power
- continuous data taking
- data rate controlled from shore

Jem-EUSO-RD

EUSO program:

Pathfinders:
EUSO-balloon
EUSO-TA
mini-EUSO

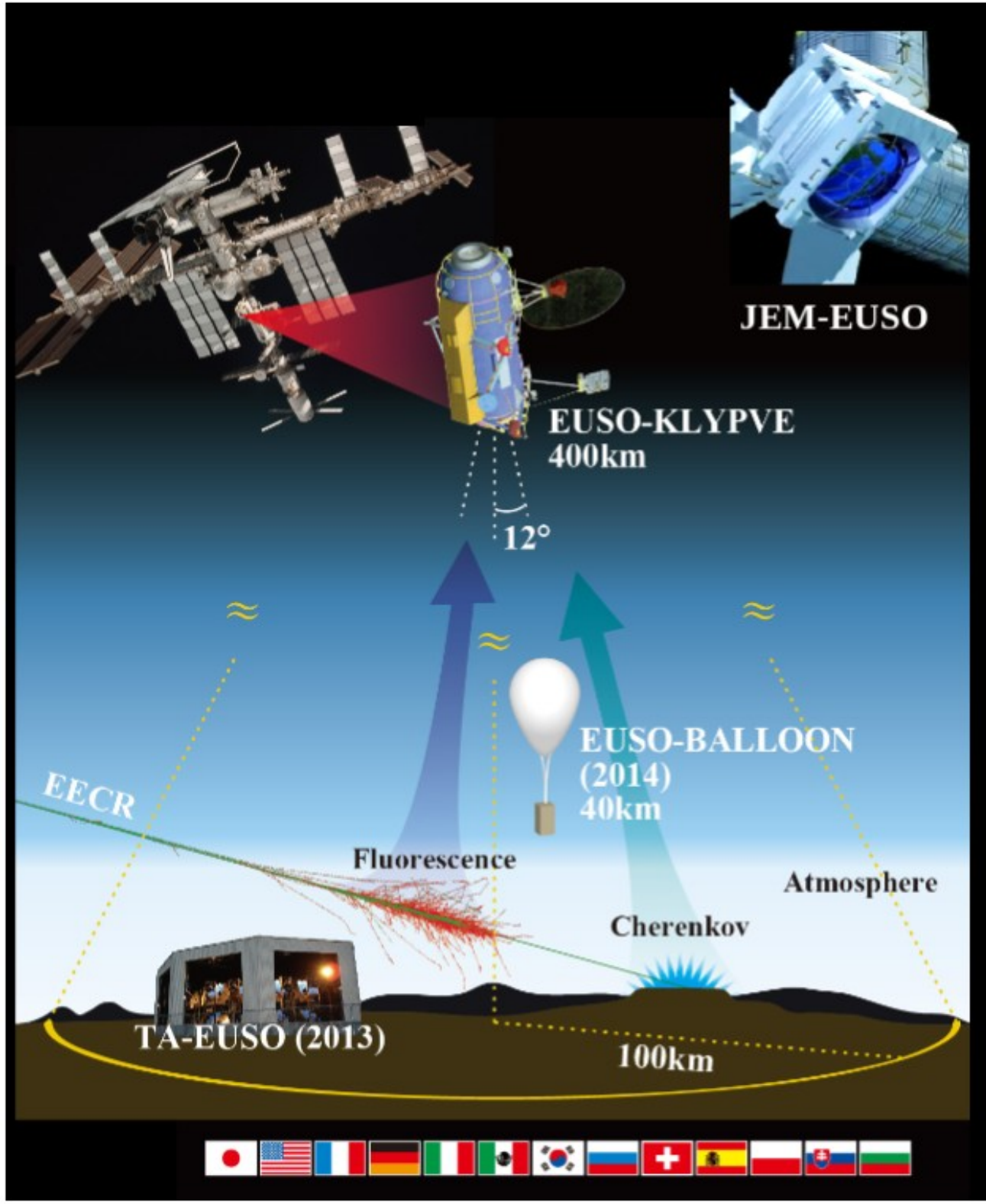
Klypve-EUSO on russian ISS module

LNF group activity:

PDM (Photo Detector Module) design (support by SPCM service).

Balloon tests.

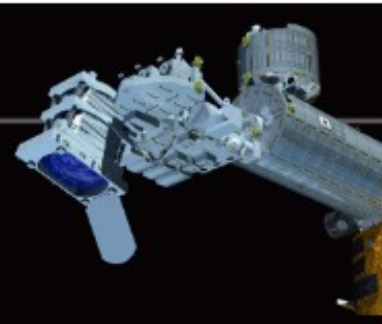
M. Ricci national responsible.



Jem-EUSO-RD pathfinders

EUSO-balloon: in August 2014 successful launch from Canada and data-taking.

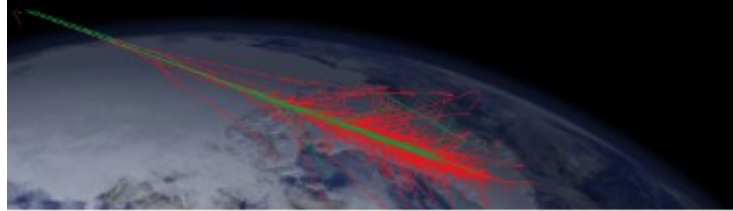
EUSO-TA: cross calibration tests on Telescope Array site (Utah) to start data-taking next year.



mini-EUSO
A precursor of JEM-EUSO on board ISS

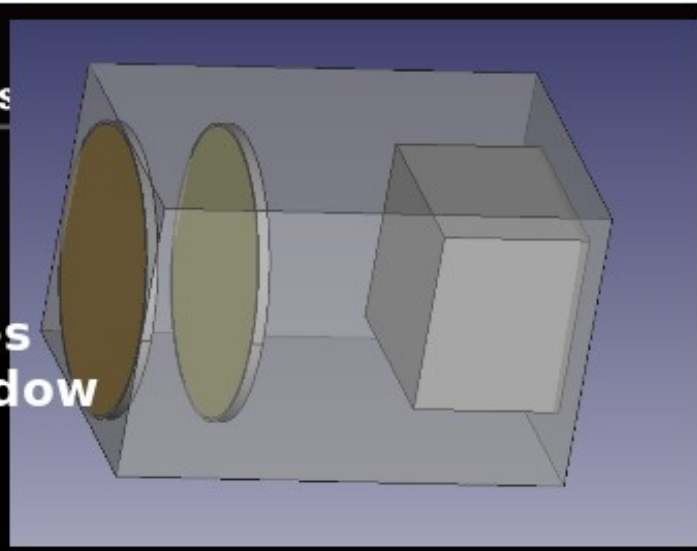
Proposed to ASI (Italian Space Agency) in response to a call 2012 for Human Spaceflight
Selected by ASI, July 2013 (Resources, upload mass, crew time)
Approved by Roscosmos/STAC Committee May 2014 and selected for UV window on Zvesda Module, Russian Segment ISS

Launch foreseen on 2016.



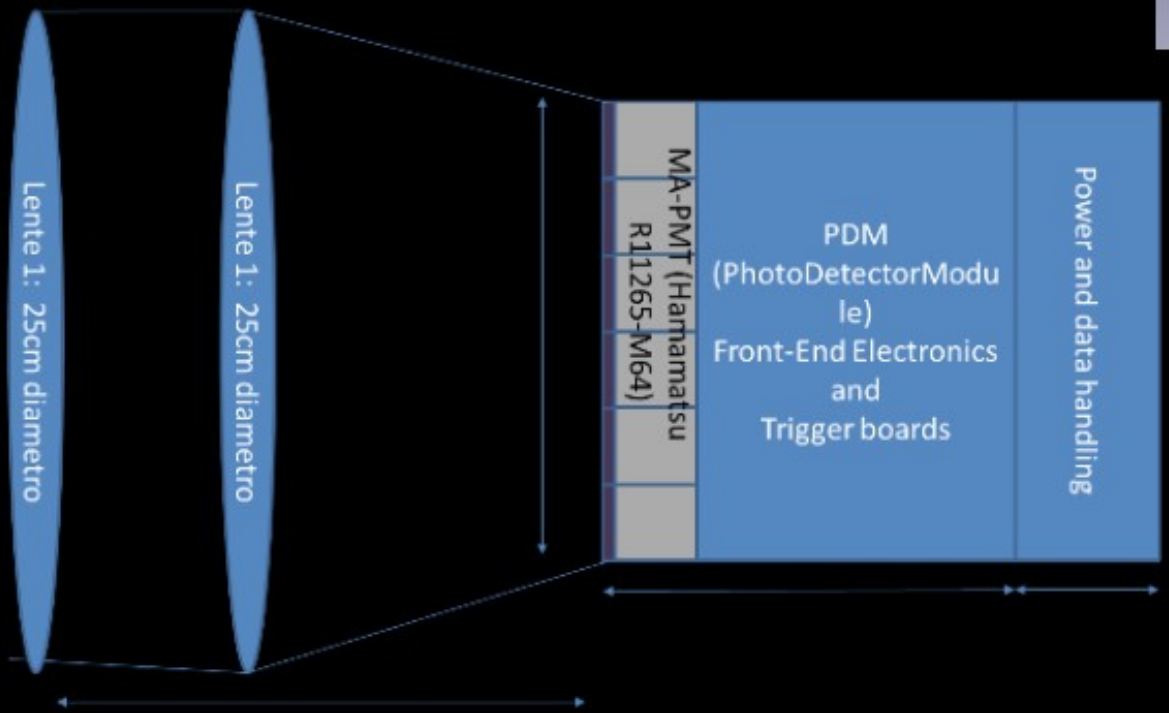
JEM-EUSO collaboration 13 Countries, 80 Institutes as of March, 2013

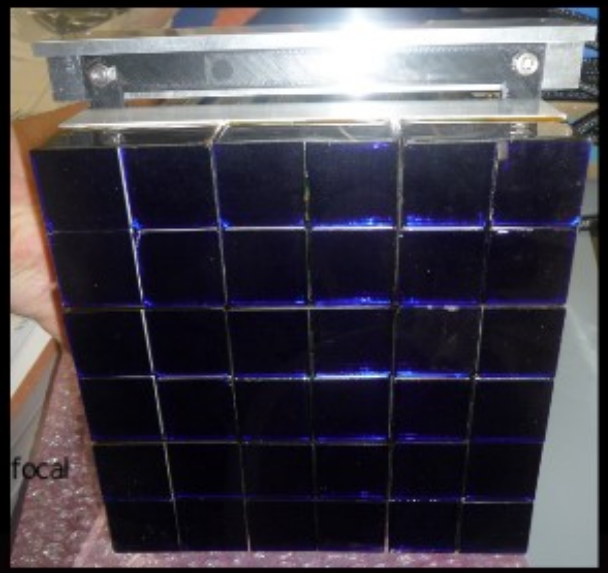
JEM-EUSO on ISS explores the origin of the highest energy particles



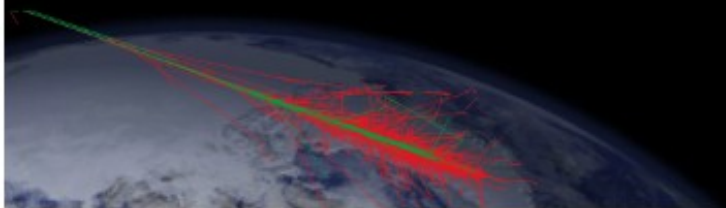
Mini-EUSO

Bring one PDM (36 PMTs) and two Fresnel lenses (25 cm diam.) to ISS and expose it to an ISS UV window





Unique opportunity to measure ultra-violet background.

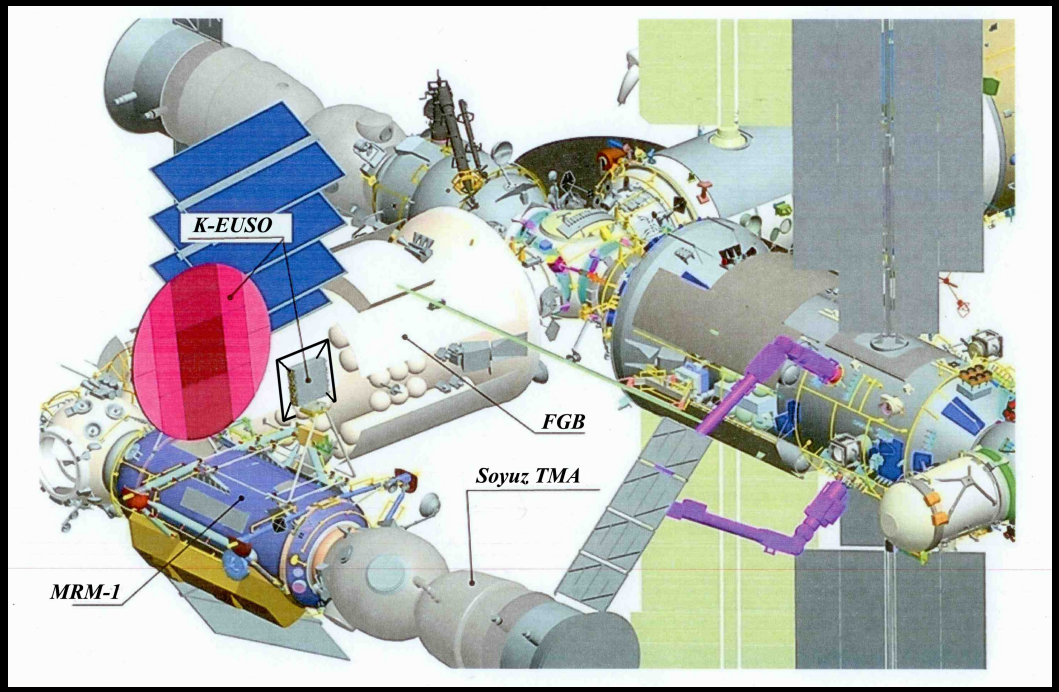


JEM-EUSO collaboration 13 Countries, 80 Institutes as of March, 2013

The Main Mission Intermediate Step JEM-EUSO on Russian Module KLYPVE-EUSO

- Included in the Russian Federal Space Program
- Passed the stage of preliminary design (pre-phase A)
- Technical requirements (specifications) defined, based of the preliminary design
- Optimization studies (mainly on the optics)

 K-EUSO Official Mission Name

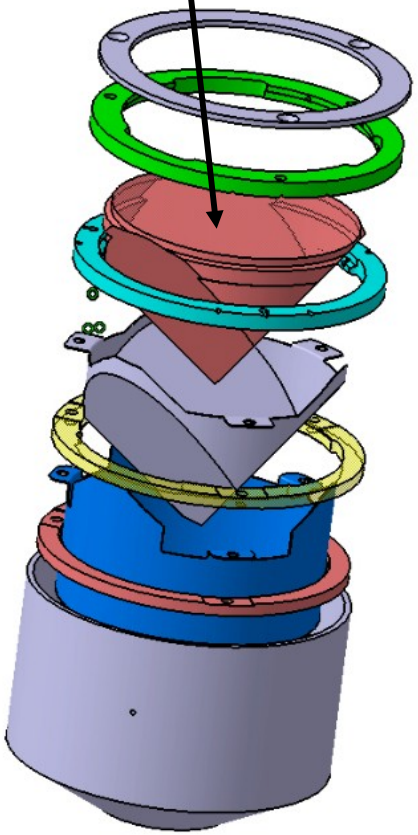


Under study.....

MoonLIGHT-2: 1-kg Lunar Reflector

- Goal: Precision tests of General Relativity
- Missions: Luna-27 (Russia, 2019), Chang'e-4/5 (China, 2016/2017); Moon Express (US, commercial, 2016)

MoonLIGHT& Apollo

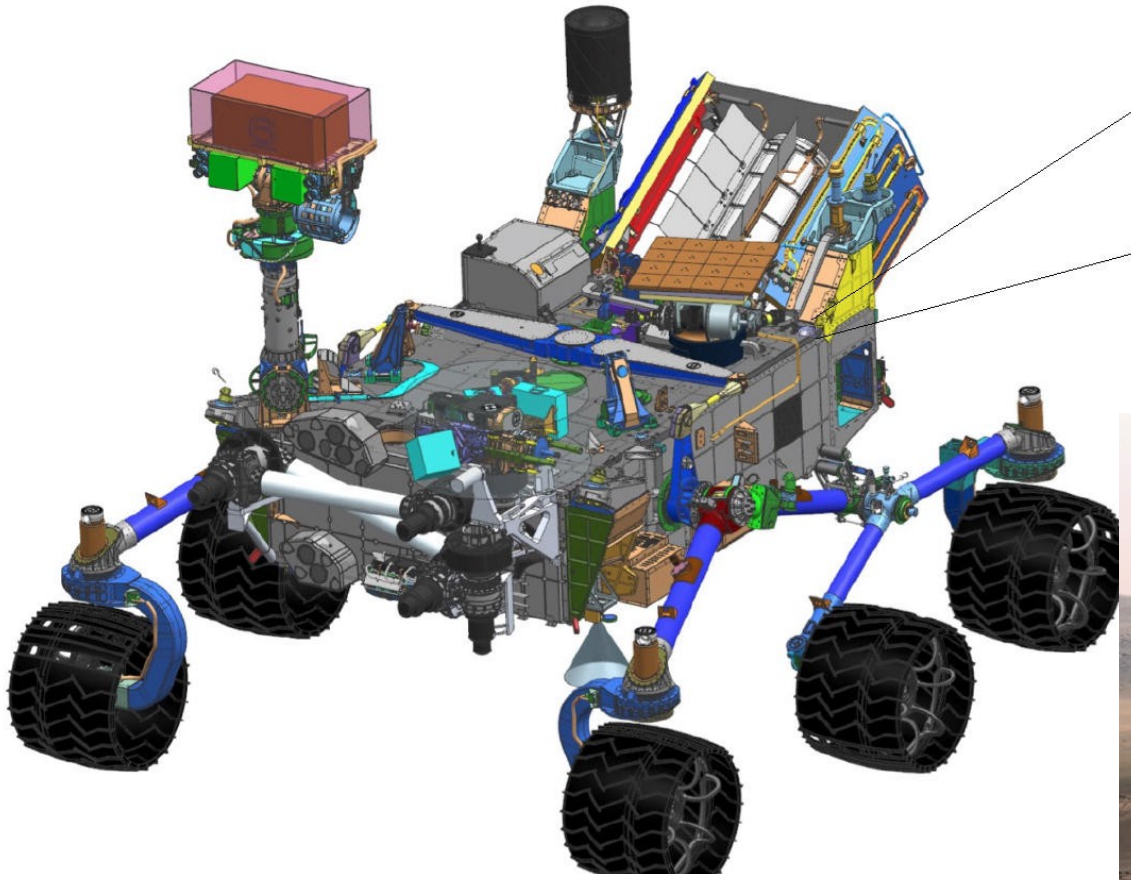


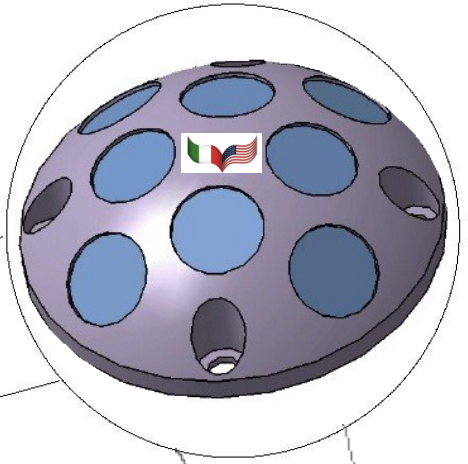
Precision test of General Relativity	Time scale	Apollo/Lunokhod few cm accuracy*	MoonLIGHT 1 mm	MoonLIGHT 0.1 mm
Parameterized Post-Newtonian (PPN) β	Few years	$\|\beta-1\|<1.1\times10^{-4}$	10^{-5}	10^{-6}
Weak Equivalence Principle (WEP)	Few years	$\|\Delta a/a\|<1.4\times10^{-13}$	10^{-14}	10^{-15}
Strong Equivalence Principle (SEP)	Few years	$\|\eta\|<4.4\times10^{-4}$	3×10^{-5}	3×10^{-6}
Time Variation of the Gravitational Constant	~5 years	$\|\dot{G}/G\|<9\times10^{-13}yr^{-1}$	5×10^{-14}	5×10^{-15}
Inverse Square Law (ISL)	~10 years	$\|\alpha\|<3\times10^{-11}$	10^{-12}	10^{-13}
Geodetic Precession	Few years	$\|Kgp\|<6.4\times10^{-3}$	6.4×10^{-4}	6.4×10^{-5}

INRRI: 50-gr reflectors for Mars Rovers

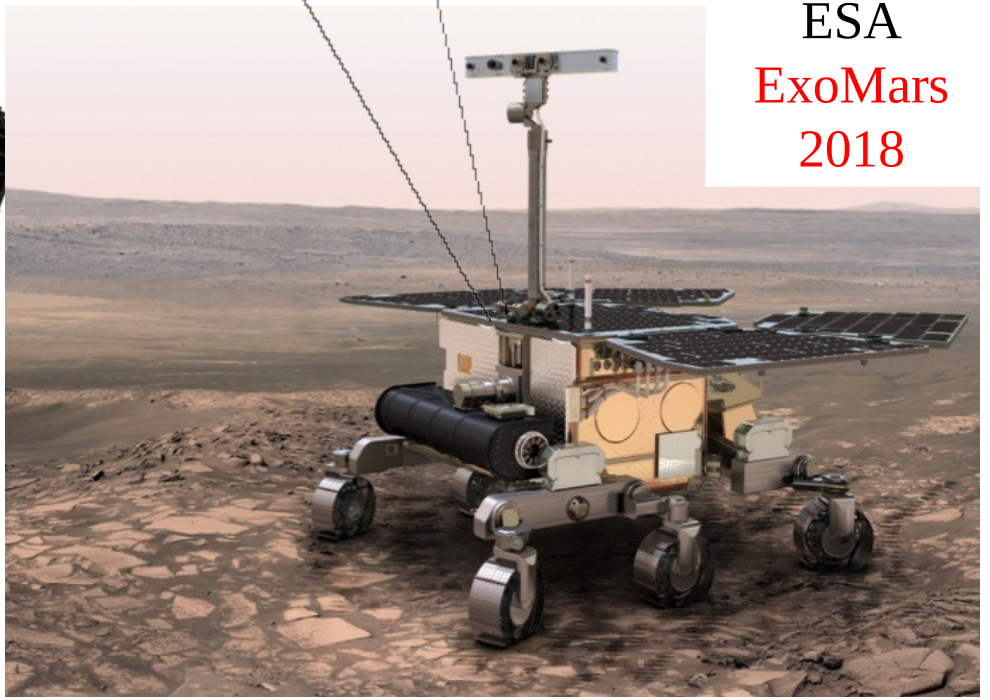
INRRI$2020:"
INstrument"for"landing1**R**oving"laser"**R**etroreflector"**I**nves5ga5ons"
"

for NASA Mars 2020





Science:
- Exploration
- Gravity
- Exolife

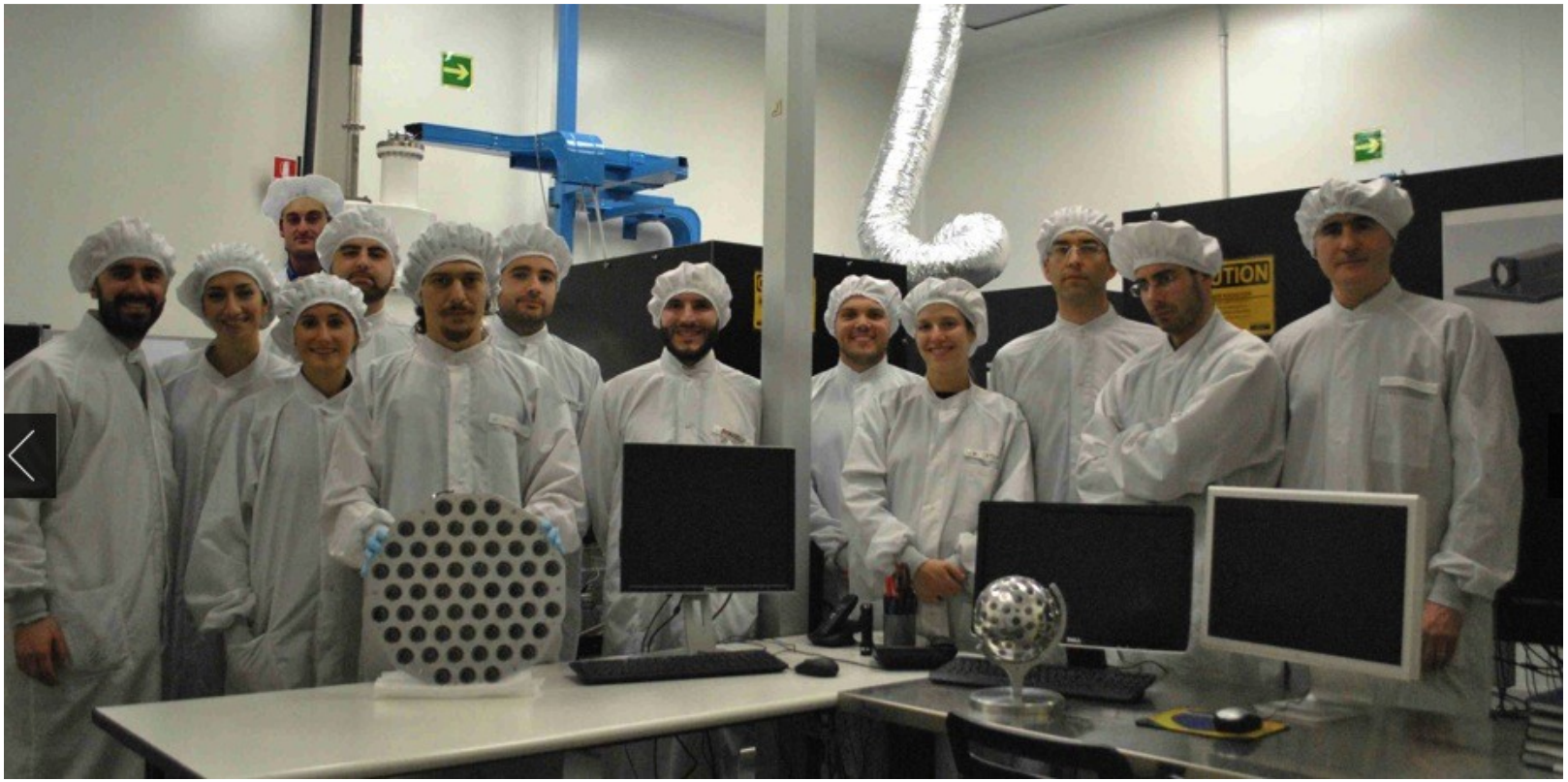


ESA
ExoMars
2018

SCF_Lab @INFN Frascati (Rome) next to ESRIN

SCF_Lab = Satellite/lunar/GNSS laser ranging/altimetry &
Cubesat/microsat Characterization Facilities Laboratory

2 unique **OGSE** (Optical Ground Support Equipment) in a clean room for thermal-optical-vacuum characterization of laser retroreflectors in representative, and (very) critical space environmental conditions



Affiliation of INFN to NASA/SSERVI

- SSERVI, **Solar System Exploration Research Virtual Institute**
  - Centrally managed by NASA-ARC, sservi.nasa.gov

- **Solar system Payloads of laser Retroreflectors of INfn for General reLativity, Exploration and planeTary Science**

- INFN: 1st Italian Partner of SSERVI
- Others: UK, Germany, Canada, Korea Netherlands, Israel, Saudi Arabia

CSN2 LNF group future activities summary

ν oscillation physics: 3.2 FTE (1.8 staff FTE).
OPERA will be closed in 2016. **ICARUS**, **T2K** small activities.
In the future, either **Nessie** (sterile ν at FNAL) or **Juno** (neutrino mass hierarchy).

Cosmic rays with ground based detectors: 1.2 FTE (0.8 staff FTE).
KM3 on-going.

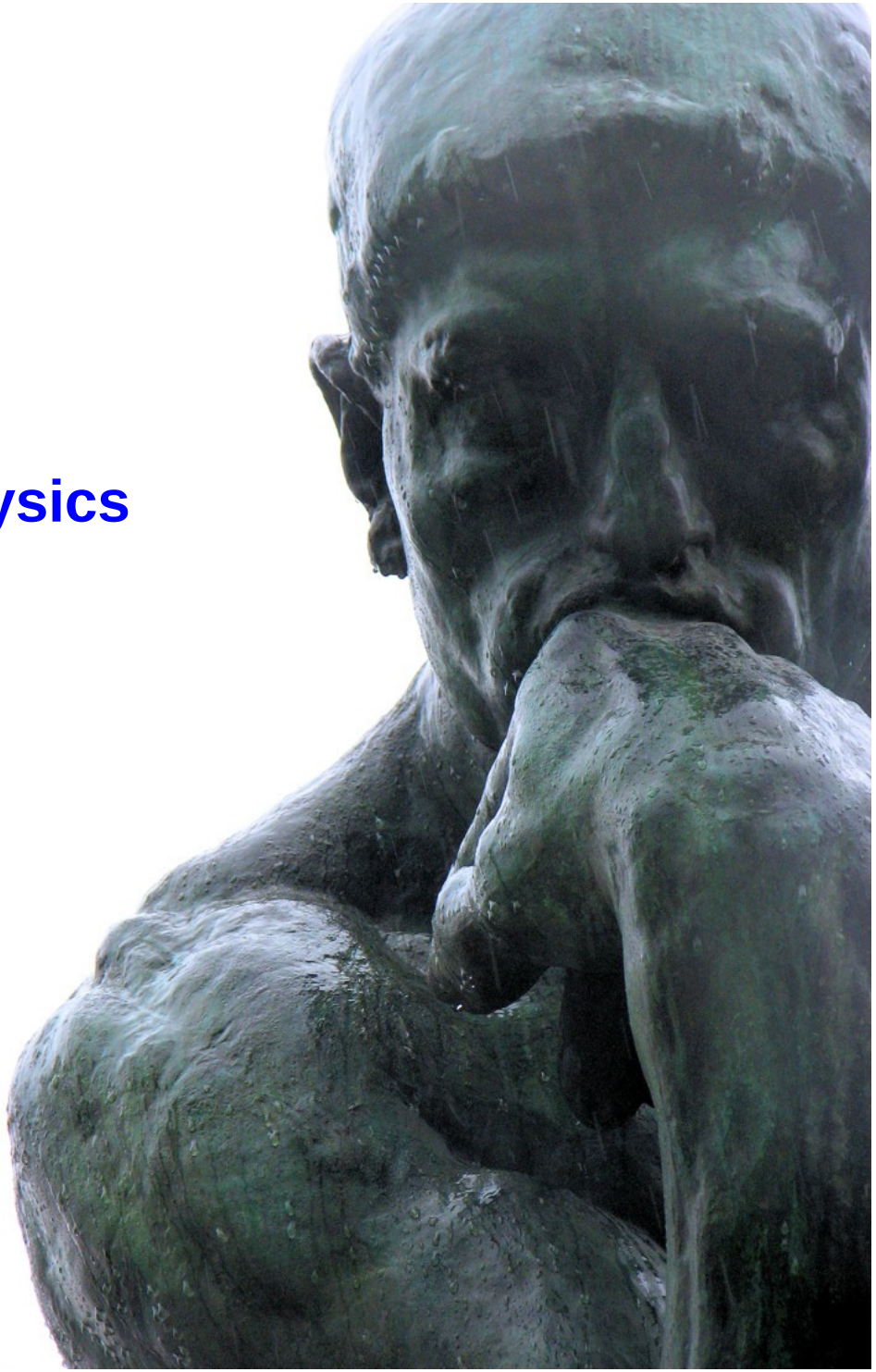
Cosmic rays with space based detectors: 5.0 FTE (2.6 staff FTE).
Wizard (PAMELA) in data analysis queue. **Limadou** small participation.
In the future, **Jem-EUSO-RD**.

General Physics: 8.5 FTE (1.2 staff FTE + 3.1 FTE associated from other institutions).
Moonlight-2 on-going.

Note: for the FTE calculations shown in this page, technicians have not been taken into account.

What next LNF:
Perspectives of fundamental physics at the Frascati Laboratory.

10-11 November 2014



INFN AND SPACE ACTIVITIES

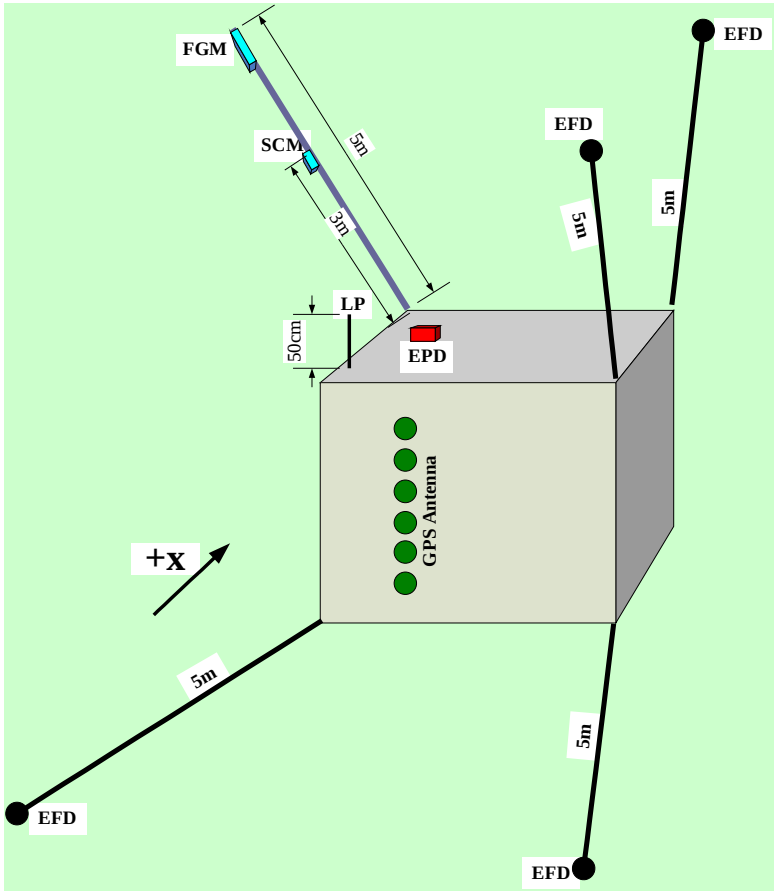
- **Proposal:**
  - LNF to support space based activities for INFN ?
  - Quite unique opportunity
    - Frascati could be the only place in which space detectors could be tested with particle beams and (maybe) laser in thermo-vacuum conditions
    - Frascati has already long experience and some infrastructures
      - 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!

Spares

LIMADOU - CSES

Study of perturbations on magneto-spheric perturbations and their correlation with seismic phenomena.

Satellite



Payload Instruments:

- **Particle Detector Analyser** (PDA).
  - Energy range: 300 KeV÷ 100 Mev
  - Pitch angle accuracy < 4° with particle identification

- **Electric Field Analyser** (EFA)
  - frequency range: ~DC ÷ 10 MHz
  - accuracy: 300 nV/m
  - dynamic range: 120 dB

- **Magnetic Field Analyser** (MAFA)
  - FLUX – GATE: • frequency range: ~DC ÷ 10 Hz
    - accuracy: a few (6-8) pT
    - resolution: 24 bit
  - SEARCH – COIL: • frequency range: ~10 Hz ÷ 100 kHz
    - sensitivity:10-2 pT /(Hz)½ (at 1 kHz)

- **Langmuir Probe & Retarding Potential Analyser**
  - LP: • electron temperature: 300 ÷ 15000 K
    - electron density: 102 ÷ 107 cm-3
  - RPA: • ionic temperature: 300 ÷ 10000 K
    - ionic density: 102 ÷ 107 cm-3