



## MONitor for Neutron Dose in hadrONtherapy

**Coordinator:** Michela Marafini

### Participants:

- Valentina Giacometti, *CF, Assegno di ricerca from SIR (01/02/2017=>31/01/2018)*;
- Michela Marafini, *CF, INFN Roma, RTD (02/2016 => 22/09/2018)*;
- Riccardo Mirabelli, *Università Roma, INFN Roma, Dottorando (01/11/2016 => 30/10/2019)*;
- Vincenzo Patera, *SBAI, INFN Roma, CF, Professore Associato*;
- Davide Pinci, *INFN Roma, Ricercatore*;
- Alessio Sarti, *SBAI, LNF, CF, Ricercatore* ;
- Adalberto Sciubba, *SBAI, INFN Roma, CF, Professore Ordinario*;



### Place of Work & Collaborations:

The Laboratory is at SBAI Department - Sapienza Università di Roma

We collaborate with:

- TIFPA - Proton Therapy Centre, Trento
- CNAO - Centro Nazionale di Adroterapia Oncologica, Pavia
- FBK – Fondazione Bruno Kessler, Trento
- INFN – Sezione di Roma

#### Affiliations:

**CF** = Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi

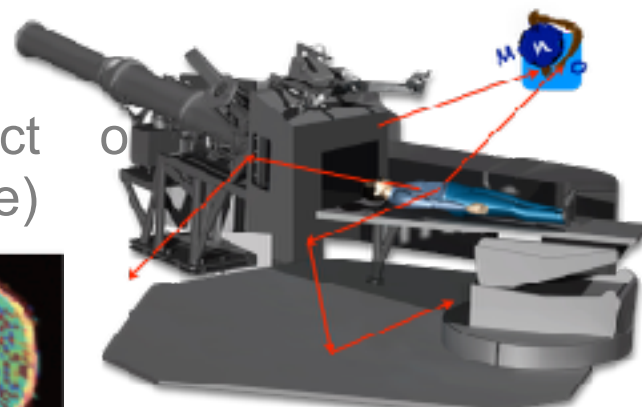
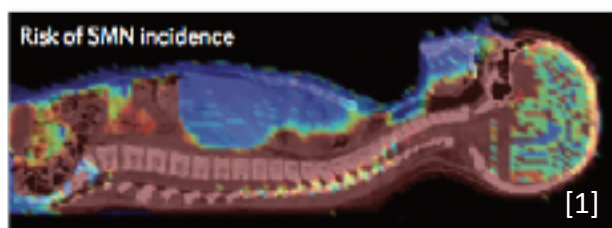
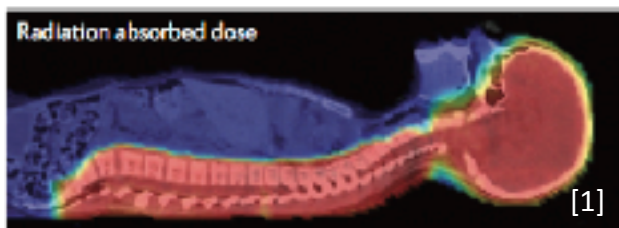
**INFN** = Istituto Nazionale di Fisica Nucleare

**SBAI** = Dipartimento di Scienze di Base e Applicate per l'Ingegneria - Università degli Studi di Roma *La Sapienza*

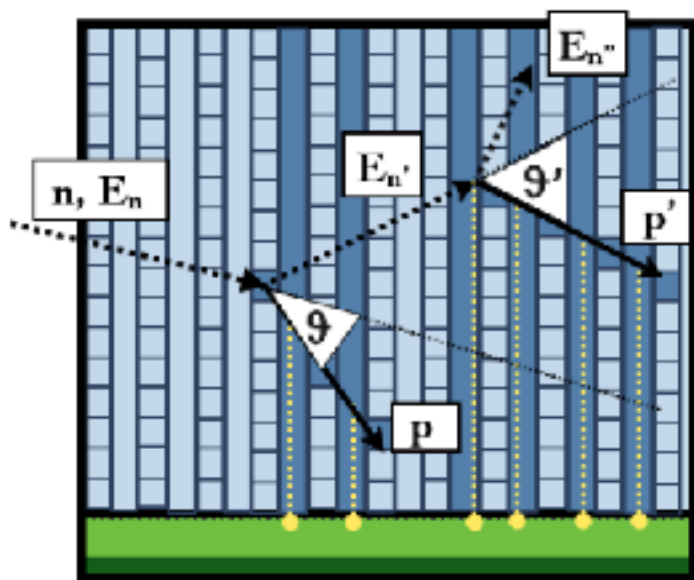
**LNF** = Laboratori Nazionali di Frascati



**Project main goal:** characterization of the secondary neutrons produced in PT and their impact additional dose released on patient (SNM incidence)



[1] M.Durante W.D. Newhauser  
doi:10.1038/nrc3069



### Tracking detector:

Matrix of scintillation fibres (x-y oriented) readout with a dedicated SPAD-CMOS sensor

- size: 10 x 10 x 20 cm<sup>3</sup>
- squared scintillating fibres 250 μm double cladding

### Measure principle:

Double Elastic Scattering

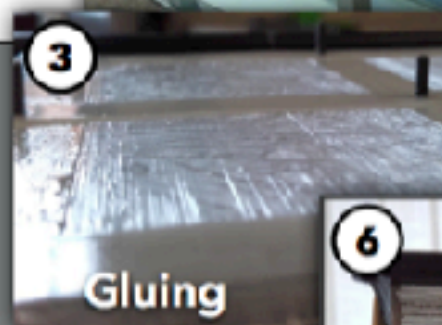
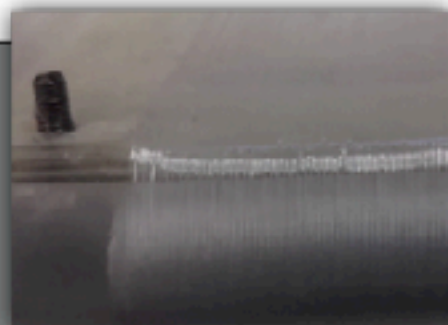
### Goal:

spectrum and angular distribution

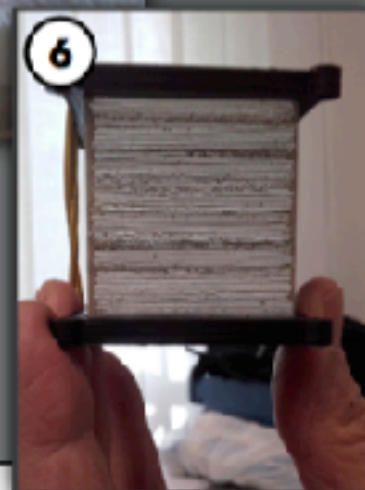
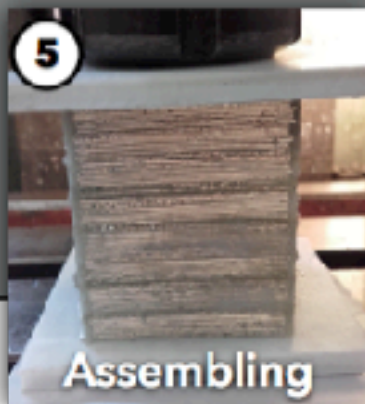
## MONitor for Neutron Dose in hadrONtherapy

### Project main results so far achieved

- First tracker prototype realization
- Test with cosmic rays, sources and BTF electrons



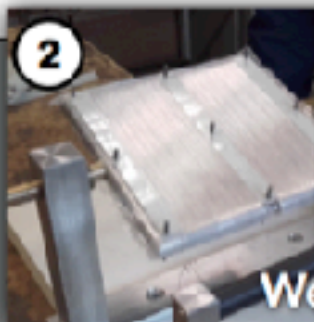
~ 45 hors of work



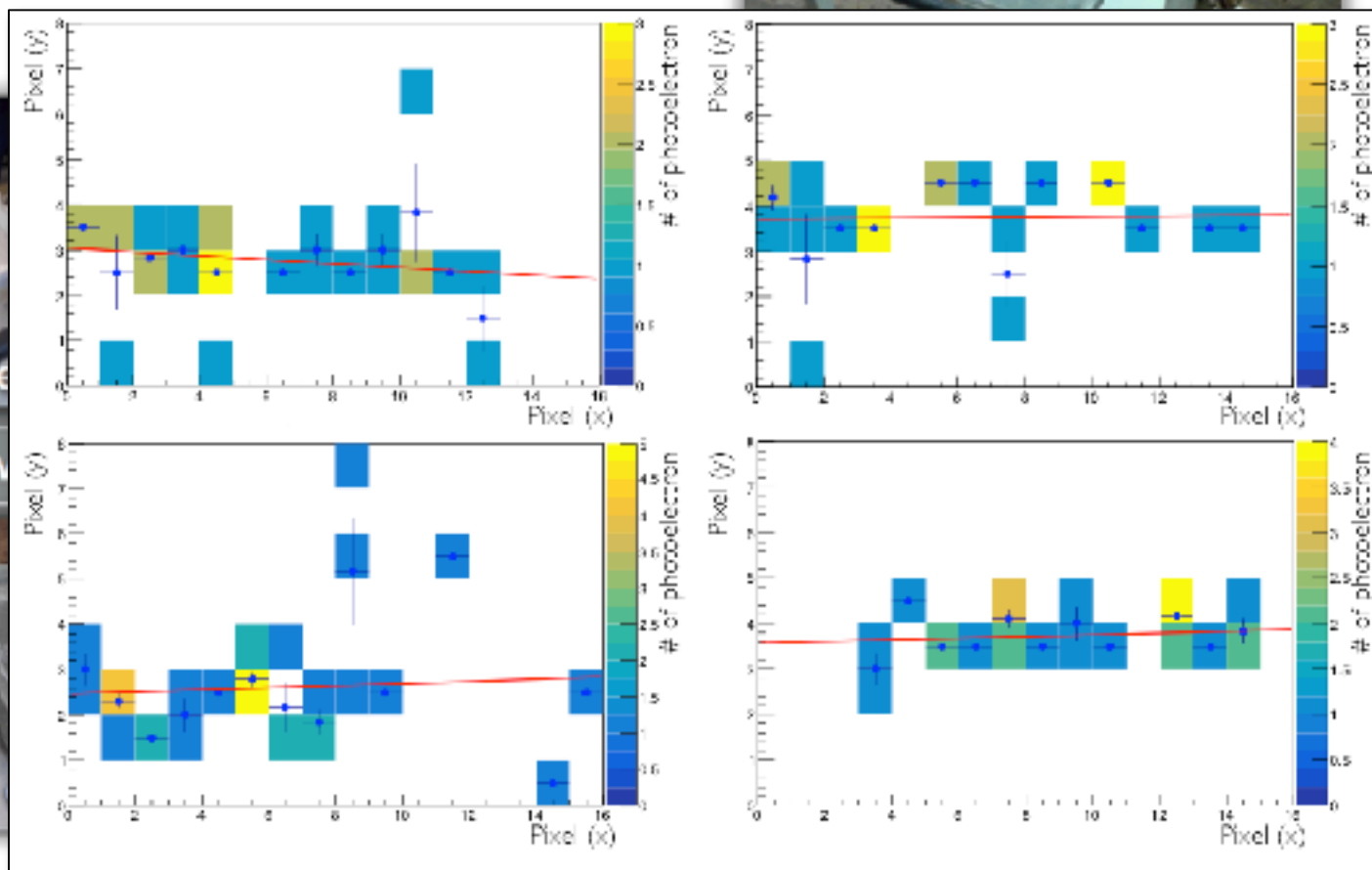
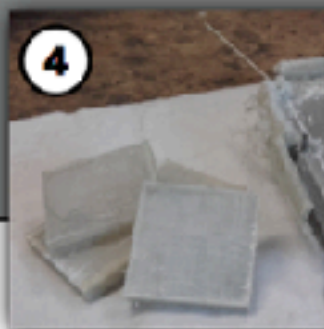
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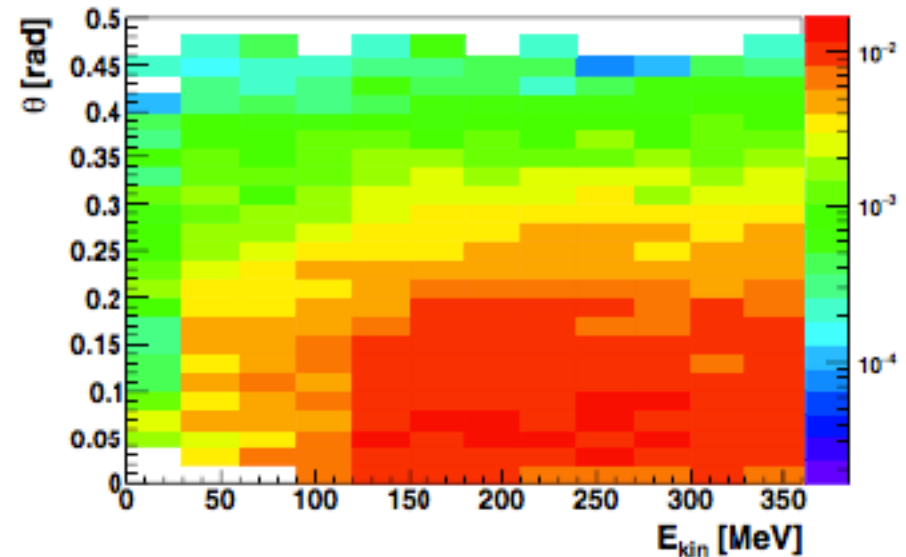
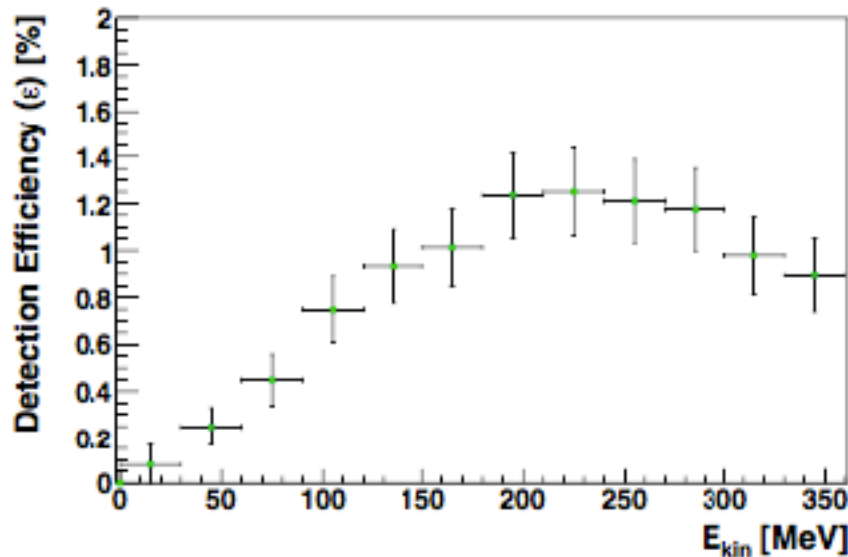
~ 45 hours of work



## MONitor for Neutron Dose in hadrONtherapy

### Project main results so far achieved

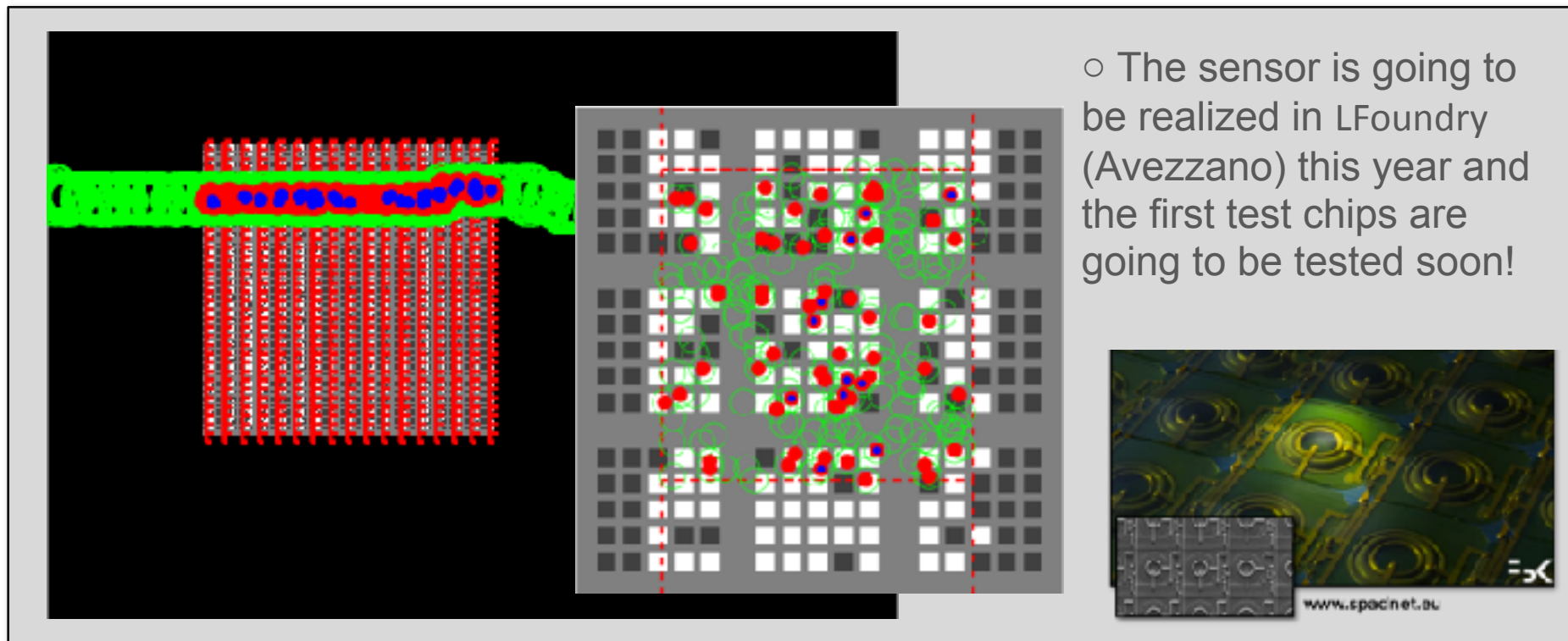
- MonteCarlo Simulation in FLUKA of the detector 10 x 10 x 20 cm<sup>3</sup>
- Development of the Reconstruction Software for single and double neutron



- Set up simulator, analysis of optimal sensor features and definition of target sensor architecture: Design and identification of the most suitable sensor architectures: SBAM sensor.

## MONitor for Neutron Dose in hadrONtherapy

### Project main results so far achieved



- The sensor is going to be realized in LFoundry (Avezzano) this year and the first test chips are going to be tested soon!



- Set up simulator, analysis of optimal sensor features and definition of target sensor architecture: Design and identification of the most suitable sensor architectures: SBAM sensor.



## MONitor for Neutron Dose in hadrOntherapy

### Scientific Publication for MONDO in 2016

- M.Marafini et al. "MONDO: a neutron tracker for Particle Therapy secondary emission characterization" accepted by Phys. Med. Biol. 2016 DOI:
- S.Valle, M.Marafini et al. "The MONDO project: A secondary neutron tracker detector for particle therapy" NIMA 845, 556–559 (2017) DOI: 10.1016/j.nima.2016.05.001
- M.Marafini et al. "SBAM Sensor: a SPAD Matrix in CMOS Technology for the MONDO experiment" TNS in preparation;

### Conference for MONDO in 2016

- IEEE2016 – Strasbourg – Poster Contribution. *Conference Record*: L. Gasparini et al. "MONDO: a neutron tracker for Particle Therapy secondary emission measurements";
- ATTRACT TWD Symposium 2016 – Barcelona – Poster Contribution "MONDO: a neutron tracker for Charged Particle Therapy secondary emission measurements";
- SIF2016 – Pavia – Oral Contribution. *Proceeding*: R. Mirabelli "MONDO: Un tracciatore per neutroni per misure di flussi di secondari in terapia con particelle";

### Science communication in 2016

- M.Marafini "Il segreto dei neutroni" Platinum (Il Sole 24 Ore) Rubrica: Ricerca e l'Innovazione - Luglio (2016) [www.platinum-online.com](http://www.platinum-online.com)



## MONitor for Neutron Dose in hadrONtherapy

### Plan of activities 2017 - 2018

#### ■ 2017

- 1) Scintillating Matrix construction:  $4 \times 4 \times 4.8 \text{ cm}^3 \Rightarrow 10 \times 10 \times 20 \text{ cm}^3$
- 2) SBAM sensor test chips realization (2 FPGA evaluation board  $2 \times 0.5 \text{ cm}^2$ )
  - 1) test of the sensors in FBK
  - 2) evaluation of the sensor as fibers readout at SBAI
- 3) Test of the prototype with protons (TIFPA)
- 4) Simulation:
  - 1) Reconstruction software for neutron back-tracking with the implementation of the with the real readout system;
  - 2) evaluation of the energy resolution of the reconstructed neutrons;
  - 3) evaluation of the resolution in angle;

#### ■ 2018

- 1) Simulation:
  - 1) Evaluation of the background
  - 2) Other applications of MONDO detector will be investigated (Ex. Neutron in space, neutron beam monitor)
- 2) New SBAM sensors (full run)
- 3) Preliminary measurements of neutrons produced in PMMA during Carbon ion (CNAO) and proton (TIFPA) irradiation





## MONitor for Neutron Dose in hadrOntherapy

### Plan of activities 2019

#### ▪ 2019 (Request of extension of the project)

=> Test of neutron in paediatric Particle Therapy

- Flux, energy spectrum and angular emission distribution measurements for secondary neutrons:
  - 1) C,N,O,C<sub>A</sub> target;
  - 2) body measurements;

### Possible Collaborations

- TIFPA: Trento proton therapy centre => proton beam

- CNAO => Carbon ion beam

- FRED Project: A fast Monte Carlo platform on GPU for treatment plan dose recalculation in proton therapy

[<https://agenda.infn.it/getFile.py/access?contribId=23&resId=0&materialId=slides&confId=12790>]



## MONitor for Neutron Dose in hadrONtherapy

### Impact of the research and outreach initiatives

Any contribution to the secondary neutron flux and spectra knowledge would drastically improve the Treatments Planning Systems and, as a consequence, reduce the Secondary Malign Neoplasm incidences with the immediate feedback of increase the number of treatable patients.

*According to the new upgrade of the L.E.A\*. the Particle Therapy is going to be offered by Italian national sanitary service for 10 different type of tumours (for example, paediatric solid tumours and brainstem cancers) and the interest in this technique is growing up exponentially.*

\* LEA [Definizione e aggiornamento dei livelli essenziali di assistenza (LEA) - Novembre 2016 - Atti del Governo n. 351: <http://www.senato.it/service/PDF/PDFServer/BGT/00994183.pdf>]

### Outreach initiatives

- Presentation of the results to international conference;
- Several papers (2/year) are expected to be published on refereed journals in the next few years: Monte Carlo evaluation of the performances of the detector, sensor development reports and secondary neutron measurements results;



### Expected funding in the 3-year period (2017-2019):

The Project is funded by MIUR for 3 years starting from September 2015 thanks to the **SIR2014** program. **The CF is the host institution of the project.** The total funding is about 539k€ .



- **Co-funding:** The Grant Giovani Ricercatori Gruppo V of **INFN** funded the proof of concept of the project (539k€). For the 2017: ~2 k€ from INFN for PhD mission and services.



### - Request of funding by Centro Fermi

- o *Up to 2018 no other request will be addressed to CF;*
- o *For the 2019 the request is to extend the project and the PI contract;*

### - Potential external funding

- o Progetto premiale 2016 ASI-INFN-Centro Fermi "Space Radiation Shielding"

"SPARE: