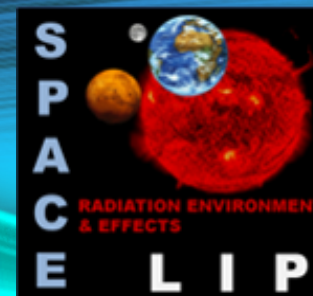


# SPACE RADIATION ENVIRONMENT & EFFECTS @ LIP

Marco Pinto, Ana Luísa Casimiro, Filipe Máximo  
Luísa Arruda, Jorge Sampaio & Patrícia Gonçalves



# RADIATION ENVIRONMENT IN THE SOLAR SYSTEM

## Galactic Cosmic Rays

low flux but highly penetrating

protons & nuclei

## Solar Particle Events

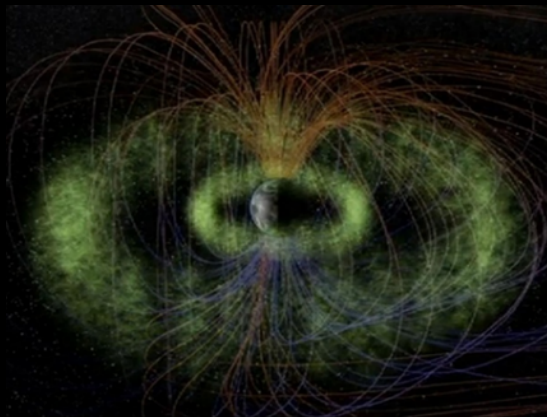
sporadic, intense & dangerous

electrons & protons

## Radiation Belts

high radiation dose

electrons , protons & ions



# RADIATION ENVIRONMENT MEASUREMENT TECHNOLOGIES

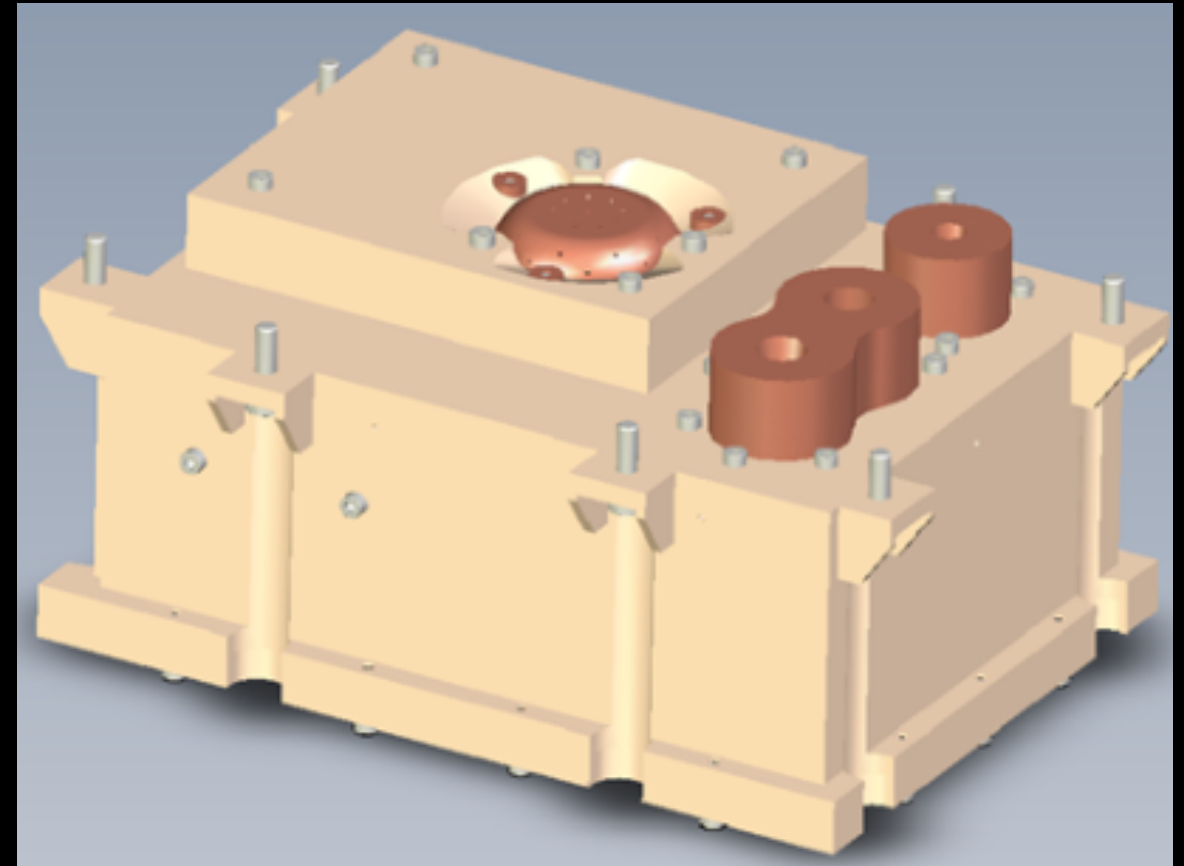
## RADEM

### Main Objectives

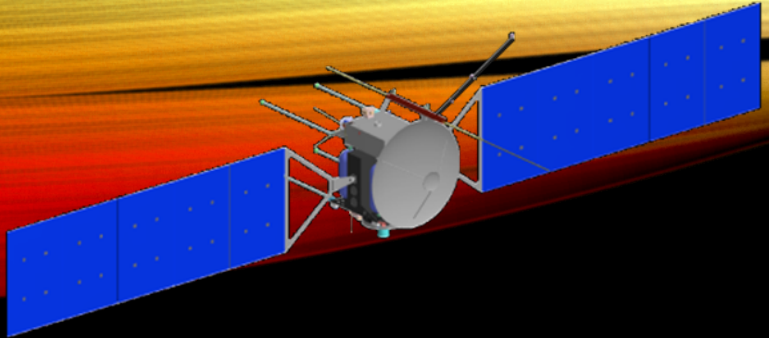
- Ensure mission safety
- Provide valuable scientific data

### Requirements

- Electron detector
  - Spectral range 300 keV – 40 MeV
  - Peak Flux  $10^9$  e/cm<sup>2</sup>/s
- Proton Detector
  - Spectral range 5 MeV– 250 MeV
  - Peak Flux  $10^9$  e/cm<sup>2</sup>/s
- Particle Separation
  - From Helium to Oxygen
- Dose determination
- Low mass
- Low power consumption



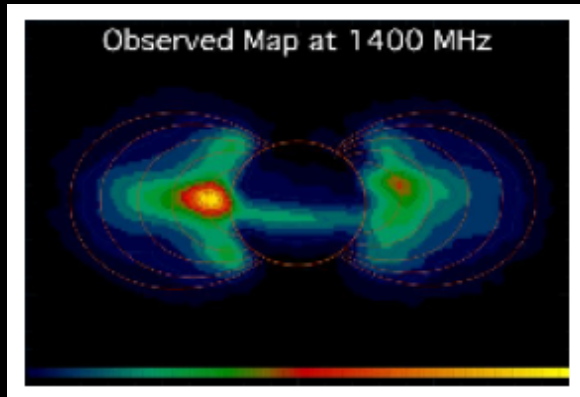




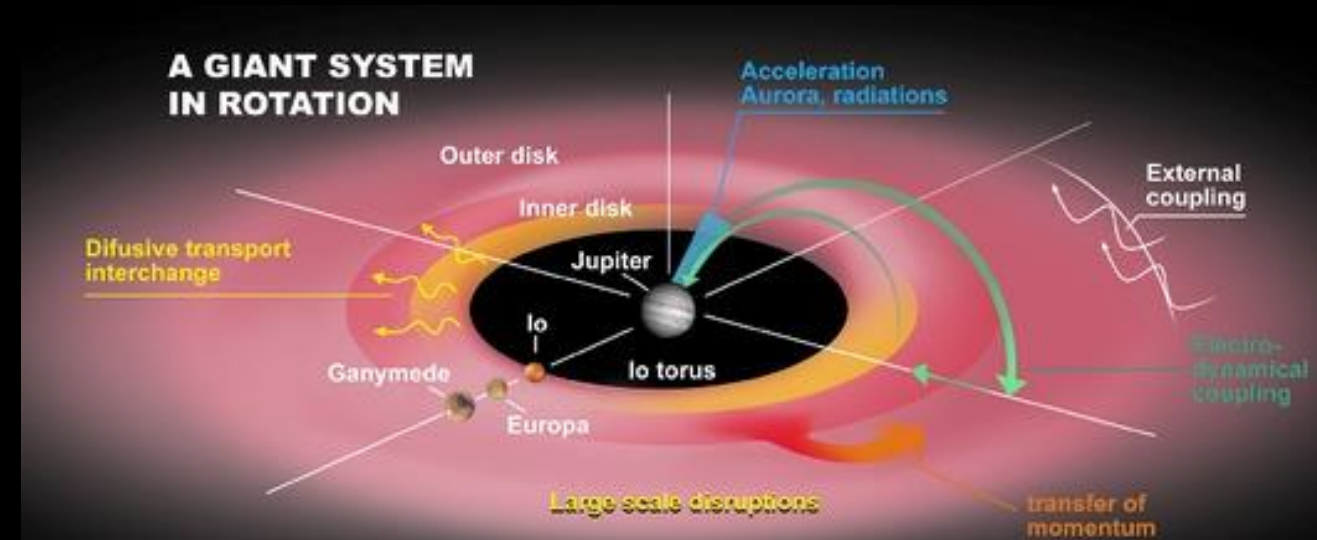
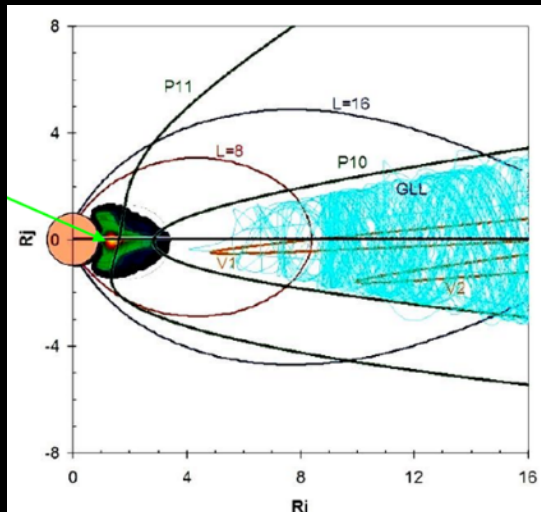
# THE JUPITER ICY MOONS EXPLORER<sup>4</sup>

Next Class-L (Large) ESA Mission

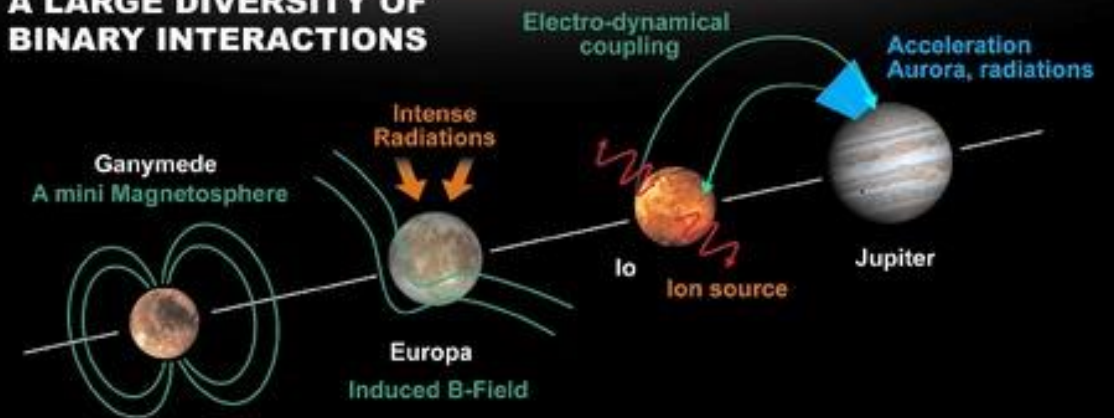
Synchrotron emission observations



& data from Voyagers, Pioneer, Galileo, Cassini



## A LARGE DIVERSITY OF BINARY INTERACTIONS



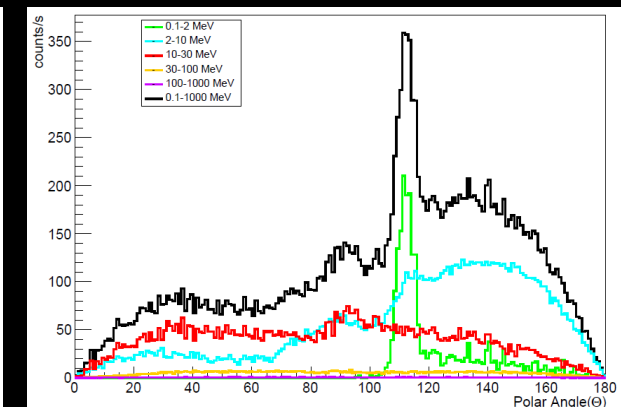
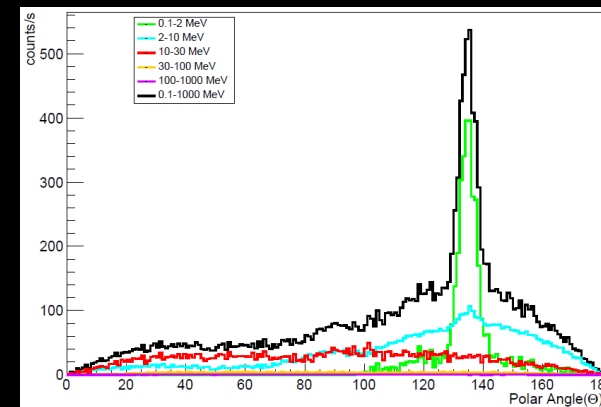
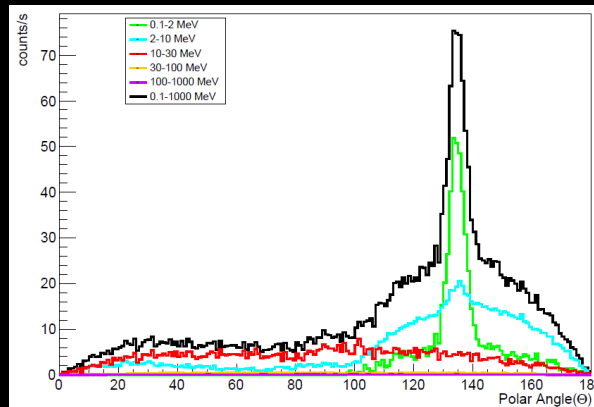
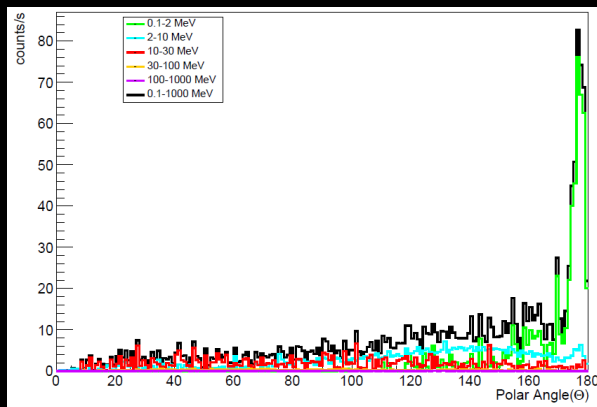
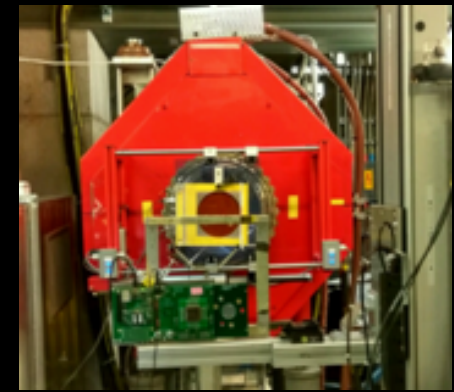
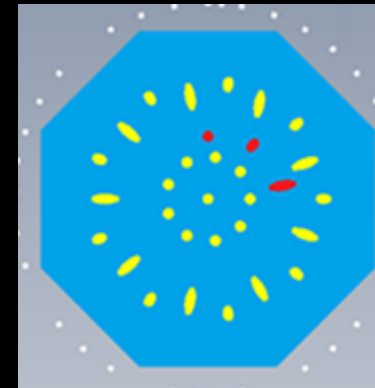
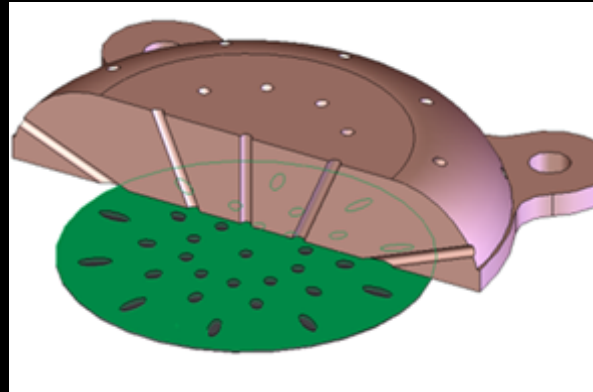


# DEVELOPMENT OF THE RADEM DIRECTIONALITY DETECTOR

**Marco Pinto**

Design, testing and performance:

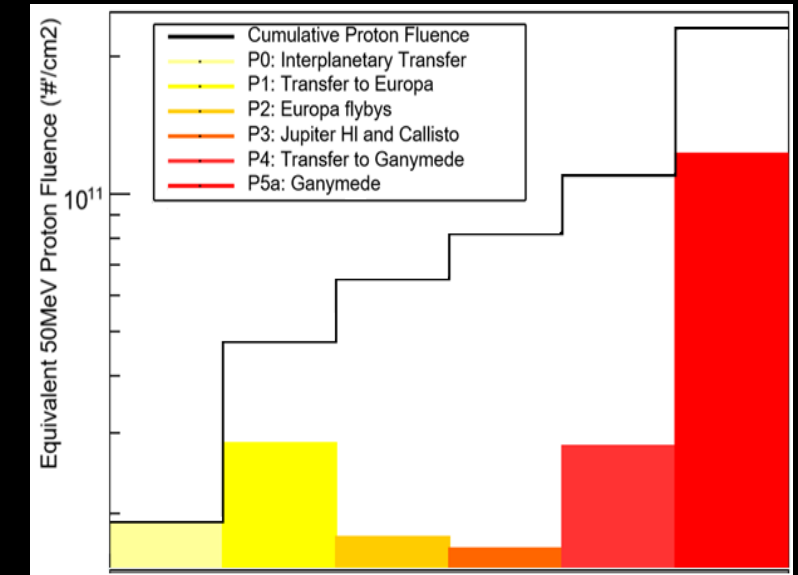
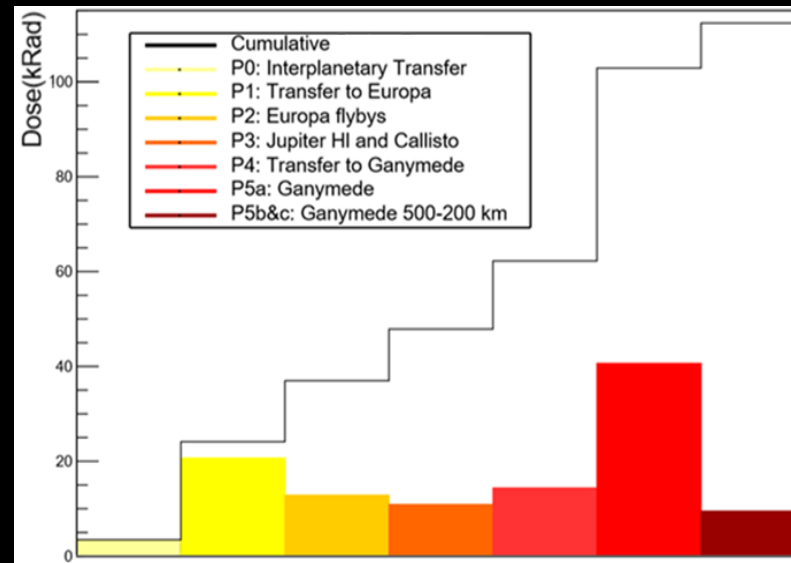
- Copper Collimator - 28 directions
- Single 505 $\mu$ m Kapton Absorber
- Single Detection Plane
- 28 Si Diodes
- 3 Blind Sensors



# RADEM RADIATION ANALYSIS

Marco Pinto

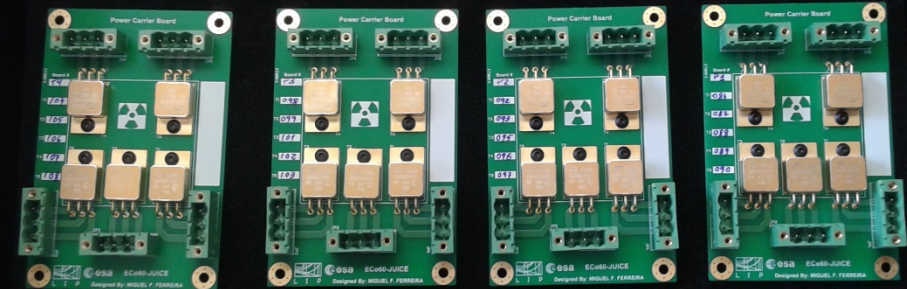
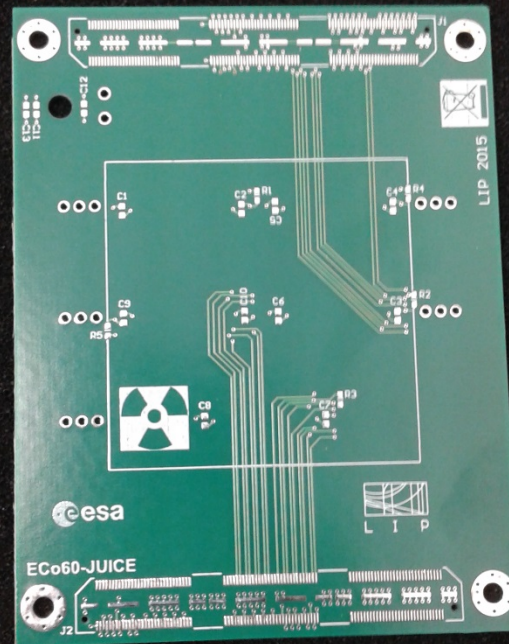
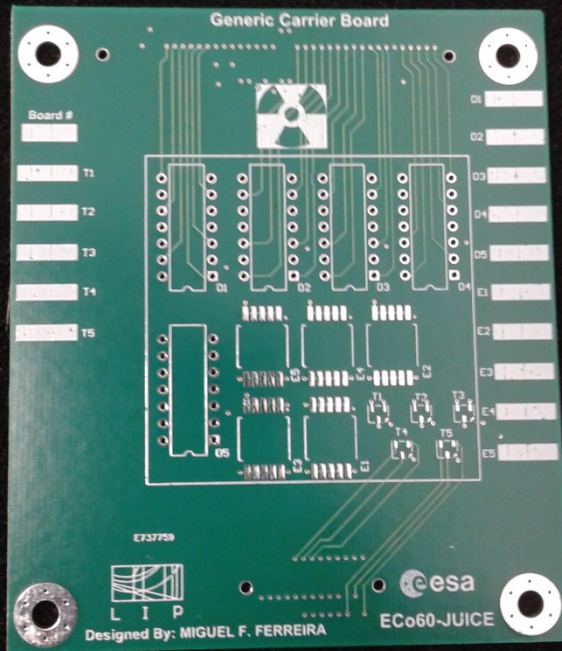
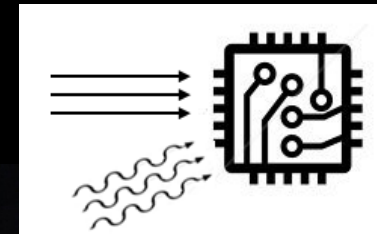
- Analysis at component level:
  - 119 components
  - TID; TNID and SEE for the whole JUICE mission
- Shielding optimization
- ASIC TID testing
  - To be performed



TID and TNID phase evolution in two critical EEE components



# TEST, CHARACTERIZATION AND RADIATION HARDNESS ASSURANCE OF EEE COMPONENTS





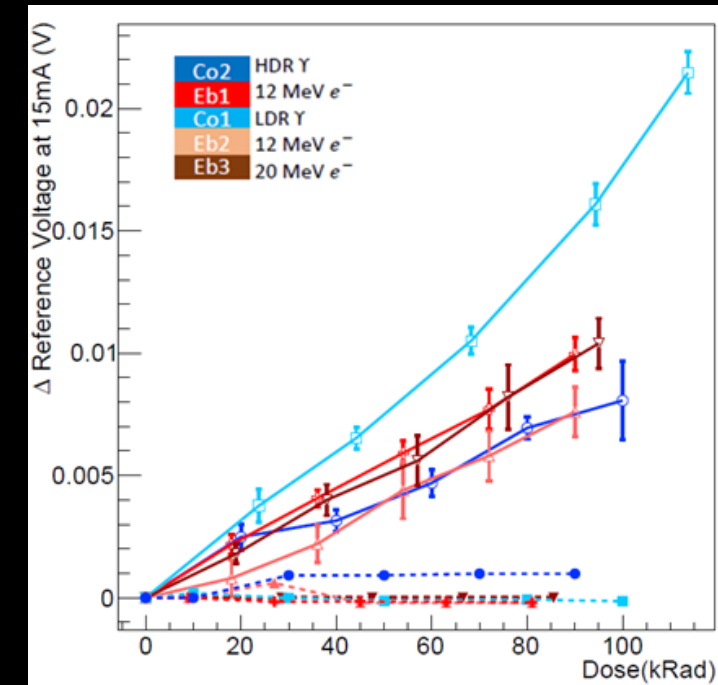
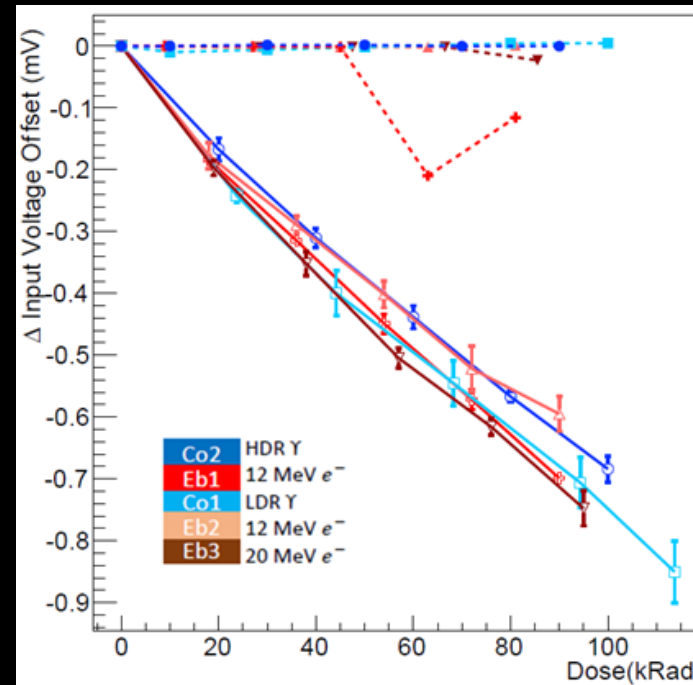
# ECO-60

## REPRESENTATIVENESS OF $^{60}\text{Co}$ TESTING FOR EEE COMPONENTS FLOWN TO THE JOVIAN SYSTEM

1. Circuit design and testing
2. Measurement automation
3. Radiation campaigns
4. Annealing
5. Data analysis

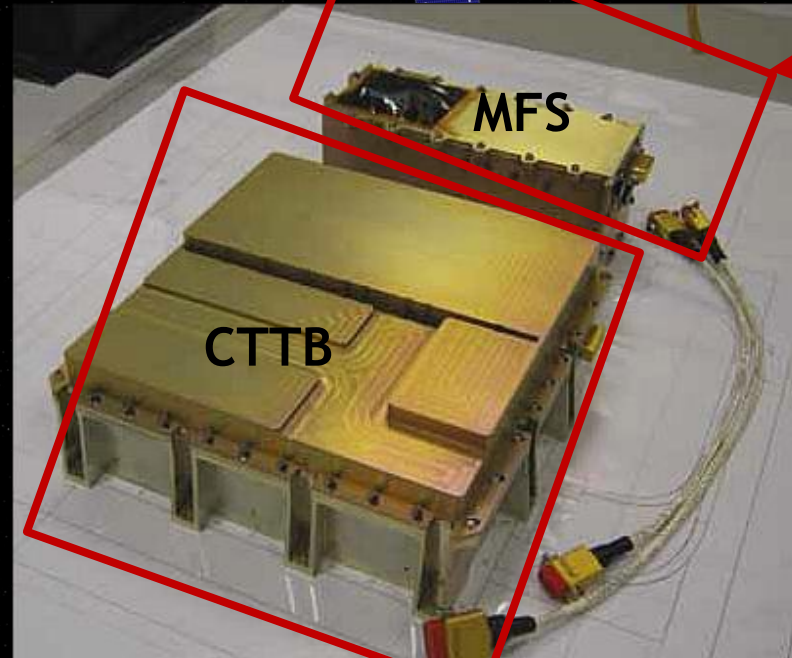


- ✓ Co60 testing representativeness verified – project concluded
- ✓ Results published in NSREC RDW 2017
- ✓ LIP lead project
- ✓ Collaboration between SPACE group and ECRLab

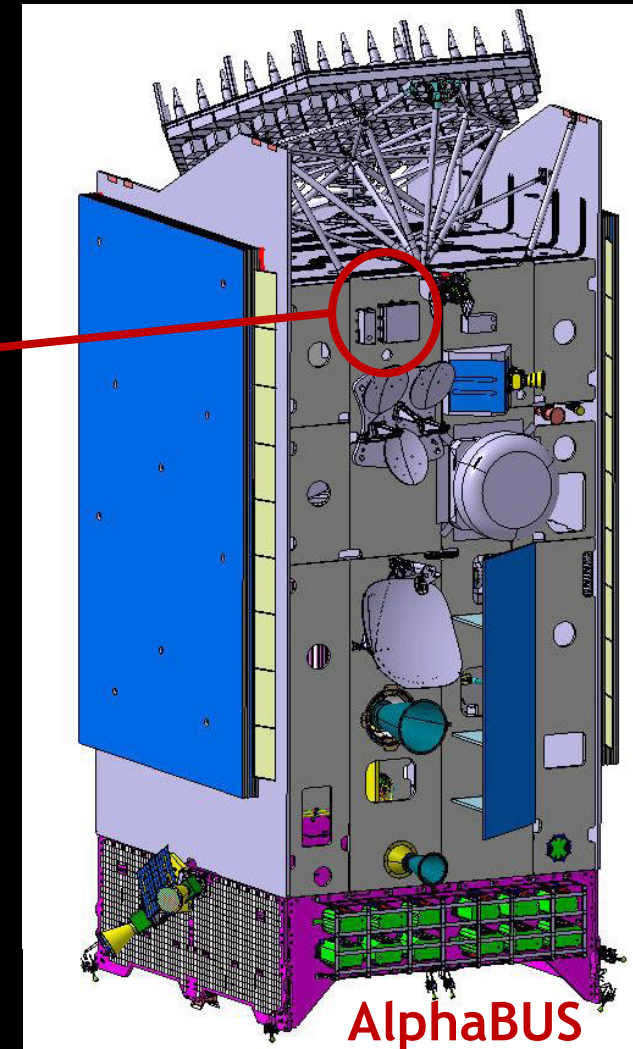


## DATA ANALYSIS & TOOLS: THE MFS & THE CTTB ON ALPHASAT

- The AlphaSat was launched to GEO July 2013 carrying the AEEF
- AEEF (TDP8) = MFS + CTTB
- The two units are installed on X-panel of the AlphaSat



MFS: MultiFunctional Spectrometre  
CTTB: Component Technology Test Bed

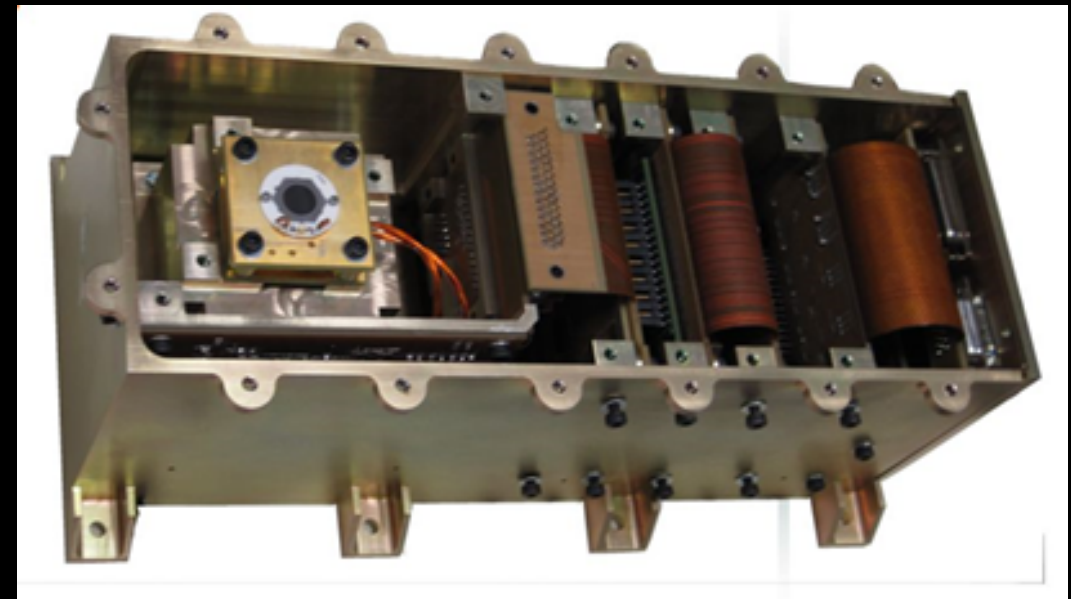
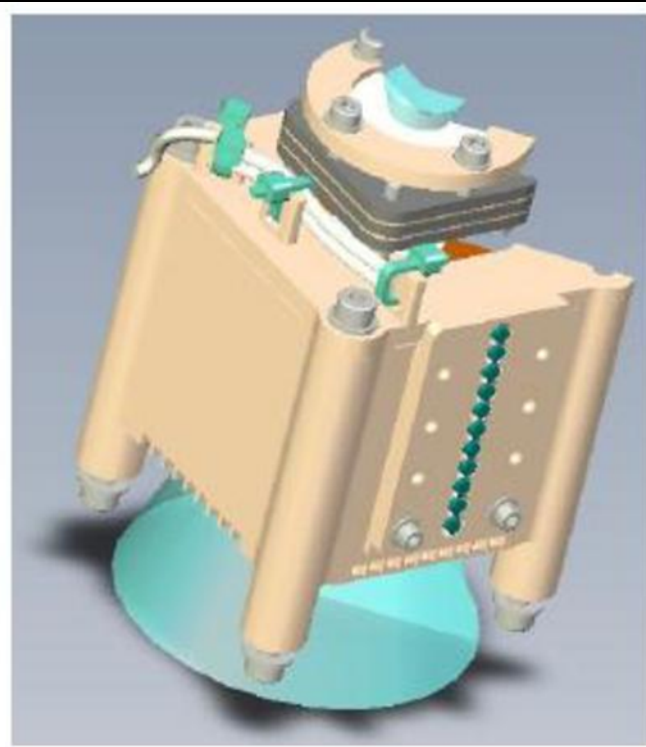
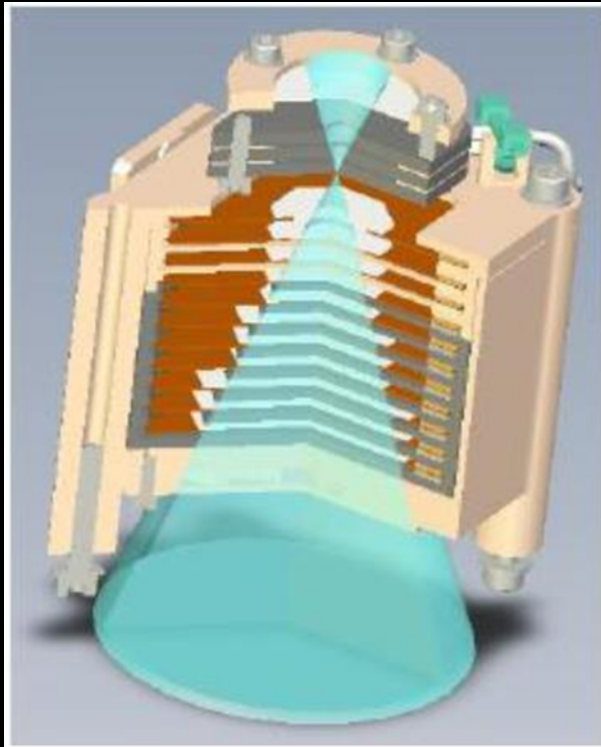




# THE MULTIFUNCTIONAL SPECTROMETER

## MFS requirements

- Electrons 300 KeV – 7 MeV
- Protons 1 MeV – 200 MeV
- Alpha particles 5 MeV – 200 MeV
- Heavy Ions 5 MeV/nuc – 50 MeV/nuc

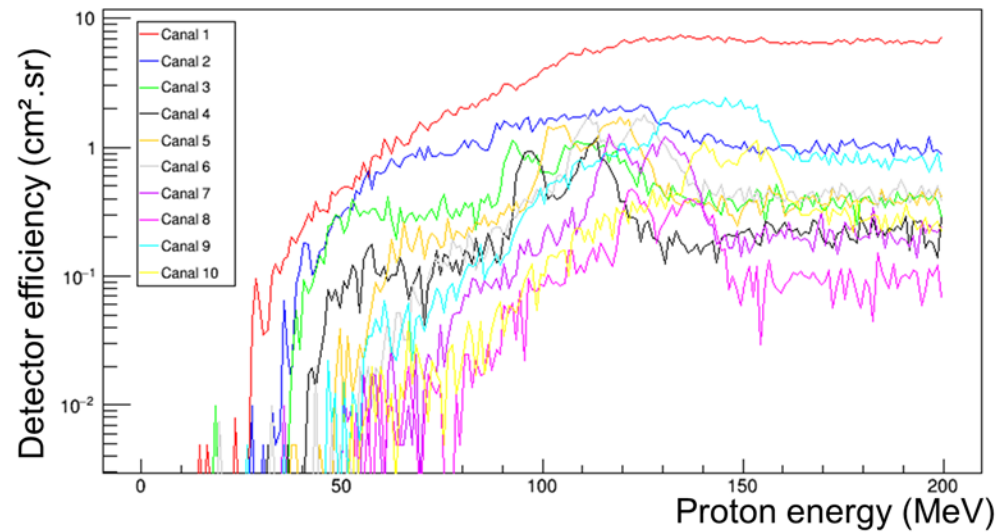




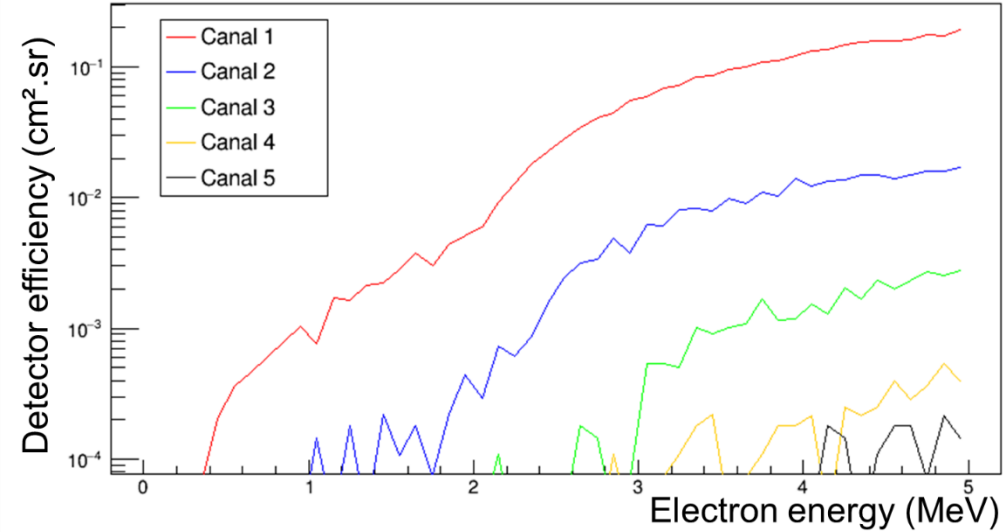
# MFS RESPONSE FUNCTIONS

Obtained with Geant4 detailed simulation and analysis of the MFS response

Response function of proton channels to incoming protons



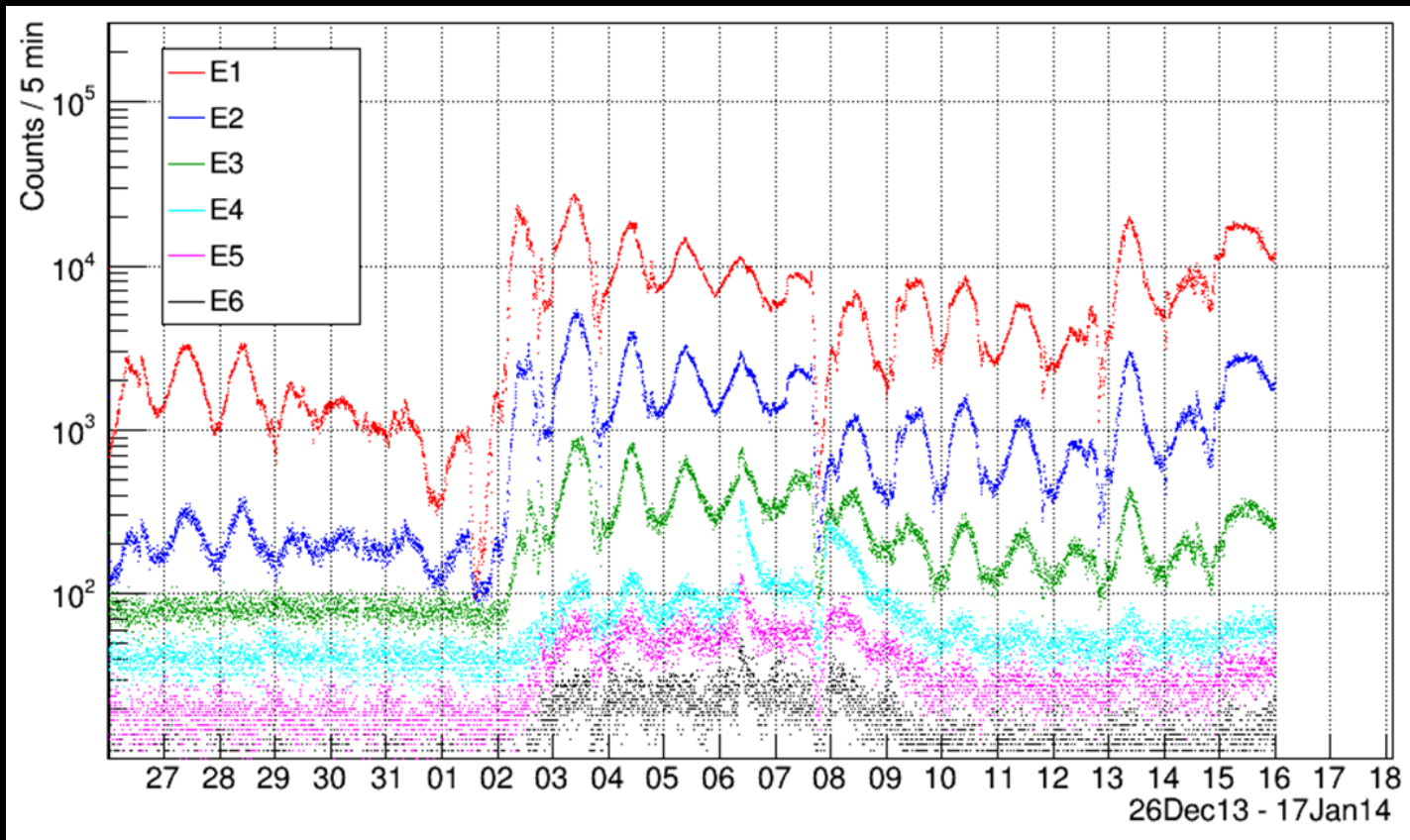
Response function of electron channels to incoming electrons



# ELECTRONS DURING JANUARY 2014 SEP EVENT

MFS Electron counts

Filipe Máximo

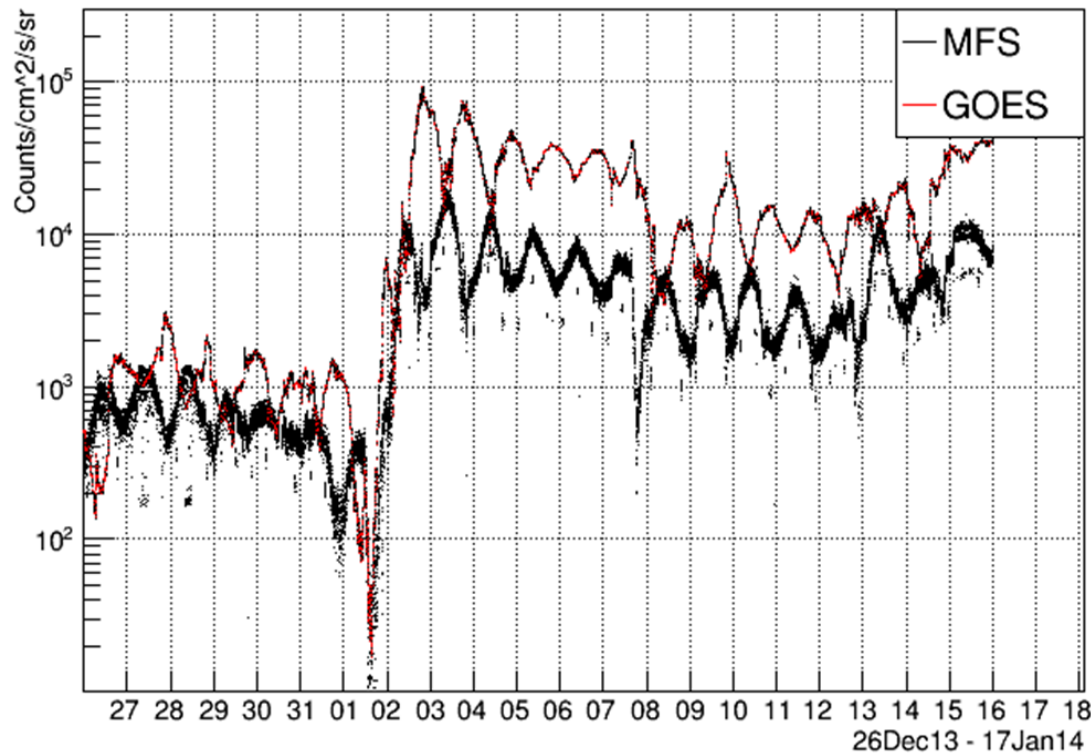


# ELECTRON FLUX DURING JAN 2014<sup>13</sup> SEP EVENT

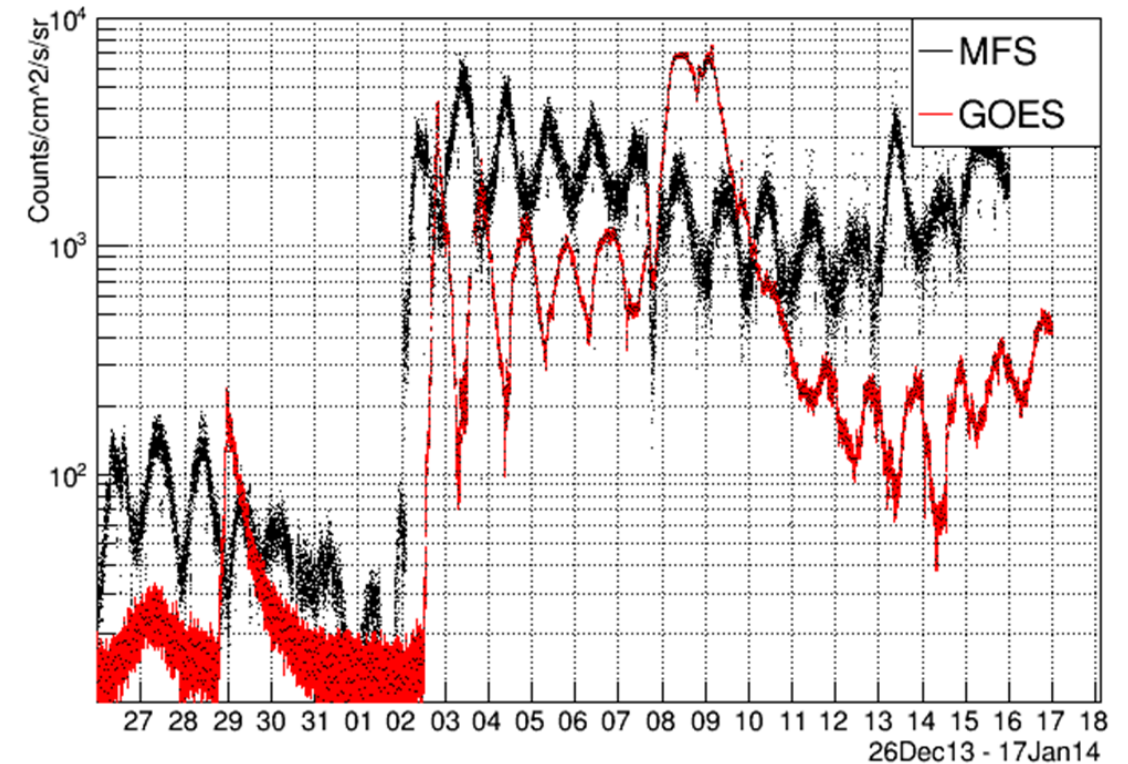
Electron Integral Fluxes vs Time :  
electron channel data deconvoluted from detector electron response functions

Filipe Máximo

> 0.8 MeV



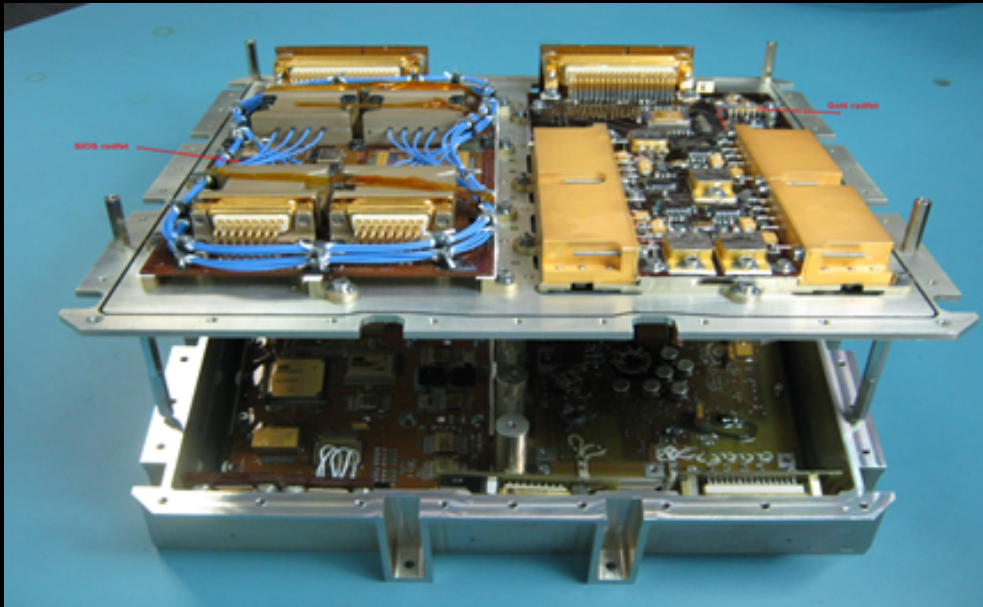
> 2 MeV





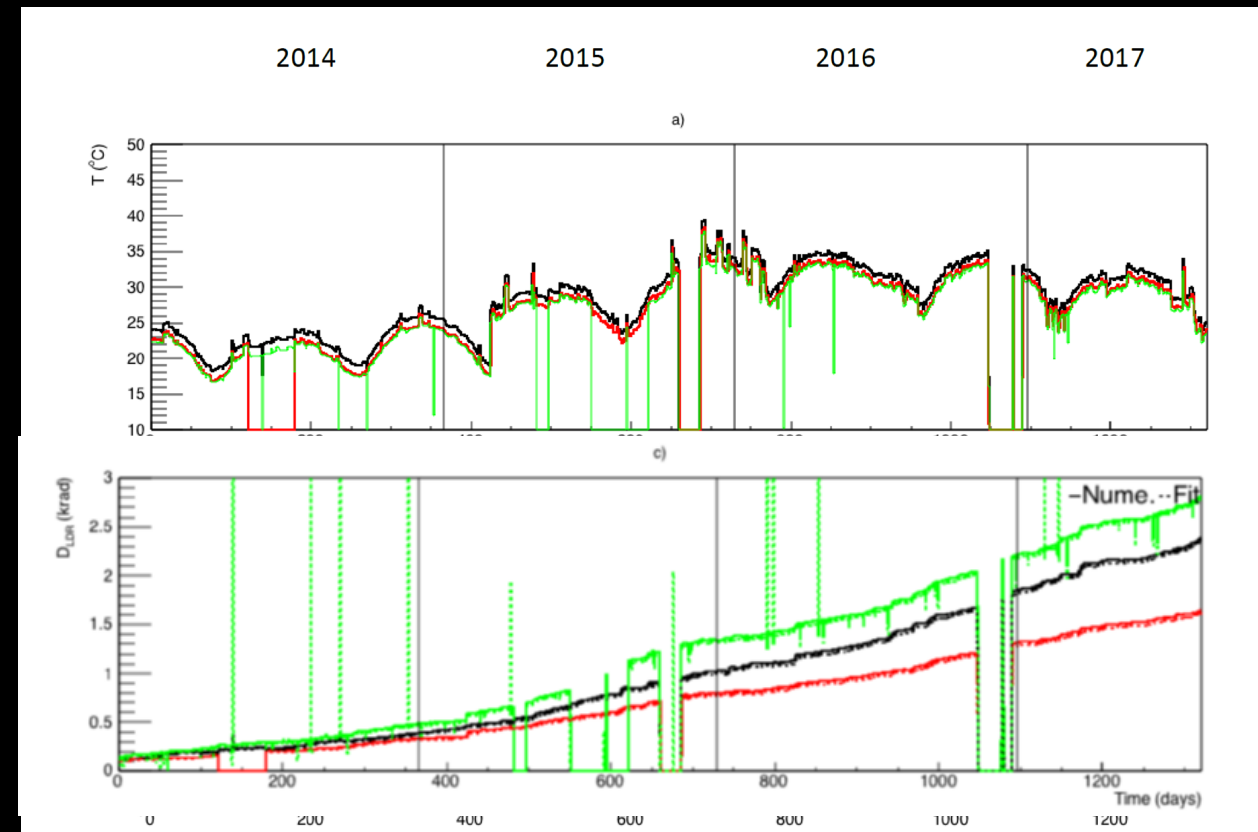
# CTTB DATA ANALYSIS

## Component Technology Test Bed



3 experiments:

- GaN Sensors (Aveiro)
- Optical Links (Valencia)
- Memories



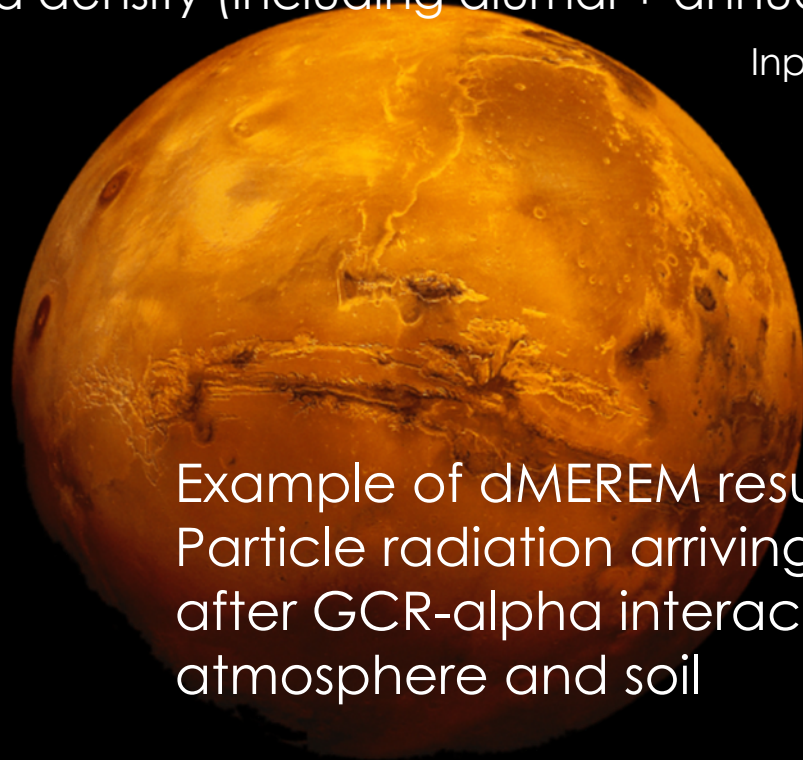
RADFET Total Ionizing Dose for each CTTB experiment  
January 2014-September 2017

# RADIATION ENVIRONMENT MODELING

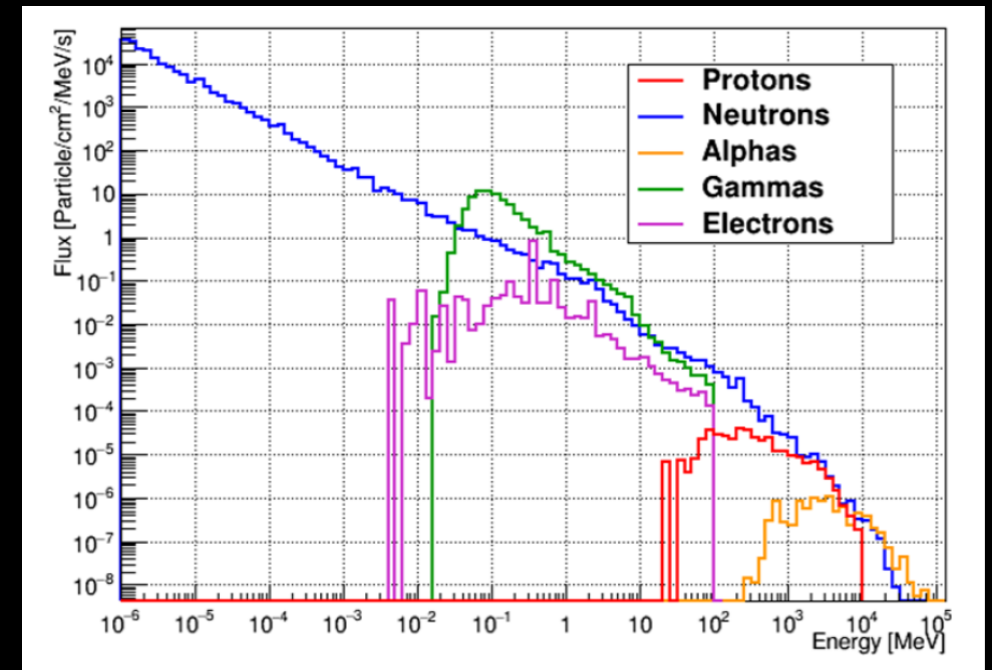
## MARSREM: THE MARS ENERGETIC RADIATION ENVIRONMENT MODELS

LIP developed **dMEREM**, a **Geant4** based model for the radiation environment on Mars, Phobos and Deimos, including local treatment of surface topography and composition, atmospheric composition and density (including diurnal + annual variations) and local magnetic fields.

Inputs given as a function of latitude, longitude, in a 5 x 5 degree grid, and season.



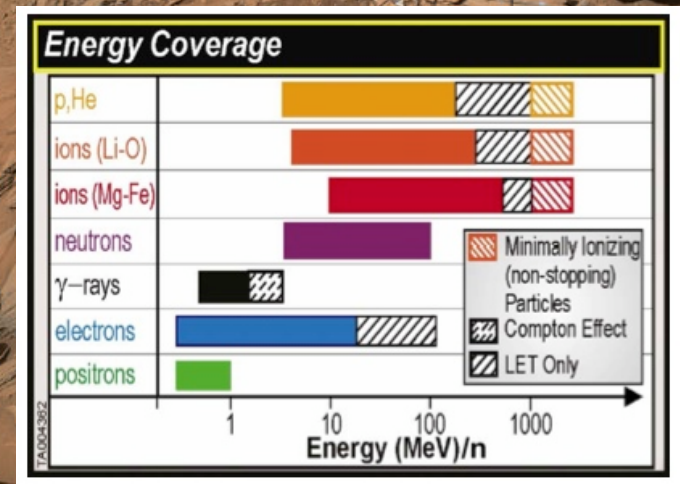
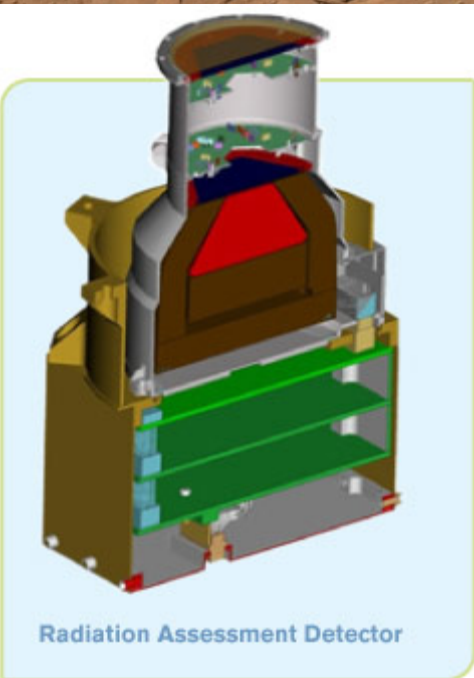
Example of dMEREM results:  
Particle radiation arriving on Mars surface  
after GCR-alpha interaction with  
atmosphere and soil





# CURIOSITY ROVER ON MARS

## RADIATION ASSESSMENT DETECTOR



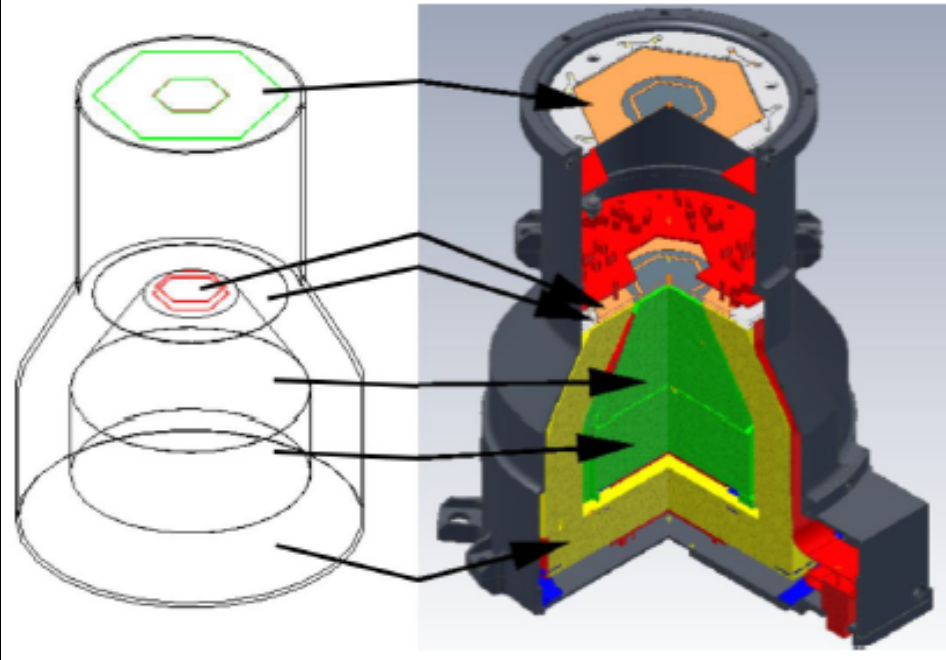


# ASSESSMENT OF RADIATION EXPOSURE IN MANNED MISSIONS TO MARS

**Ana Luísa Casimiro**

Using dMEREM and RAD data (aboard Curiosity) to predict radiation hazards in manned missions to Mars

## RAD/MSL Geant4 detailed simulations



Ongoing Geant4 simulation of RAD/MSL

- Replicate previous spectra and obtained new spectra during transit and on Mars' surface
- Use published spectra results to re-do previous simulations using 2 phantoms:
  - ICRU sphere
  - ICRP reference anthropomorphic models

# FROM CAD TO GDML TO G4 GUIMESH

## GUI Mesh

A Graphical User Interface to convert STEP files into GDML

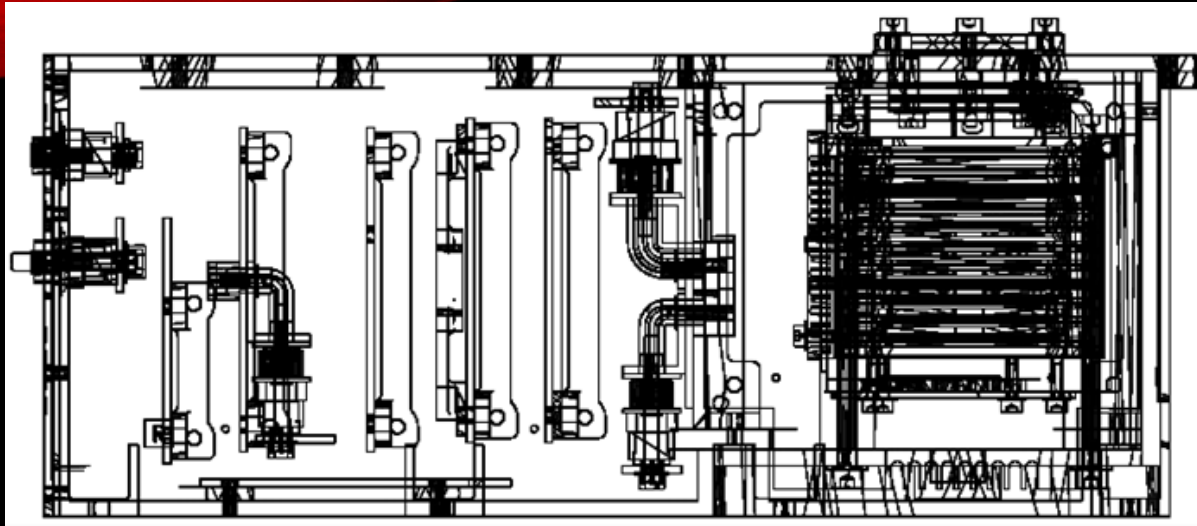
Menu	Volume List	Material List	Editing Options
Find FreeCAD Dir	1. JUI-EFA-RDM-ML-268 1.0 Top Ta Plate C	1. G4_Si	<b>Volume Options</b>
Open STEP	2. Socket Head Cap Screw_ISO_ISO 4762 M3 x 16 --- 16N	2. G4_Si	JUI-EFA-RDM-ML-019 2.0 PCB 11R
Update Lists	3. Socket Head Cap Screw_ISO_ISO 4762 M3 x 6 --- 6N	3. G4_Si	Change Material G4_Si
Save Lists	4. Socket Head Cap Screw_ISO_ISO 4762 M3 x 12 --- 12N	4. G4_Si	Change Density 2.33
Load Materials	5. Socket Head Cap Screw_ISO_ISO 4762 M3 x 12 --- 12N	5. G4_Si	<b>Meshing Options</b>
Create Material	6. Socket Head Cap Screw_ISO_ISO 4762 M3 x 16 --- 16N	6. G4_Si	Surface Deviation 0.1
Mesh it!	7. JUI-EFA-RDM-ML-208 1.0 CEU-Flex B Spacer	7. G4_Si	Warning: Changing this parameter can severely damage your tessellation
Exit Program	8. Socket Head Cap Screw_ISO_ISO 4762 M3 x 12 --- 12N	8. G4_Si	G4_H
	9. Socket Head Cap Screw_ISO_ISO 4762 M3 x 12 --- 12N	9. G4_Si	G4_He
	10. Socket Head Cap Screw_ISO_ISO 4762 M3 x 12 --- 12N	10. G4_Si	G4_Li
	11. JUI-EFA-RDM-ML-028 2.0 P&I-Stack Abs A1 1	11. G4_Si	G4_Be
	12. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	12. G4_Si	G4_B
	13. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	13. G4_Si	
	14. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	14. G4_Si	
	15. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	15. G4_Si	
	16. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	16. G4_Si	
	17. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	17. G4_Si	
	18. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	18. G4_Si	
	19. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	19. G4_Si	
	20. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	20. G4_Si	
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	22. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	22. G4_Si	
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	26. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	26. G4_Si	
	27. JUI-EFA-RDM-ML-128 1.0 P&I-Stack Cable Dummy	27. G4_Si	

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File loaded

Created by: Marco Pinto

# MFS



# CTTB



# RADEM

