Geant4 Space Users' Workshop 2017

ESA status report

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Hugh Evans, Dusan Budjas, Eamonn Daly, Maris Tali

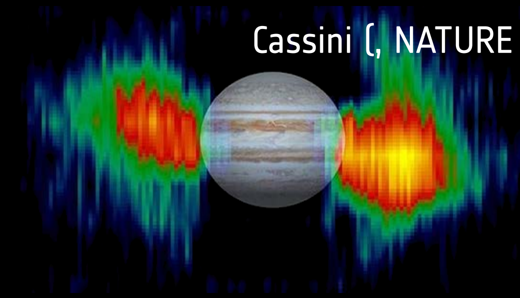
ESA/ESTEC and RHEA System

University of Surrey
10-12 April 2017

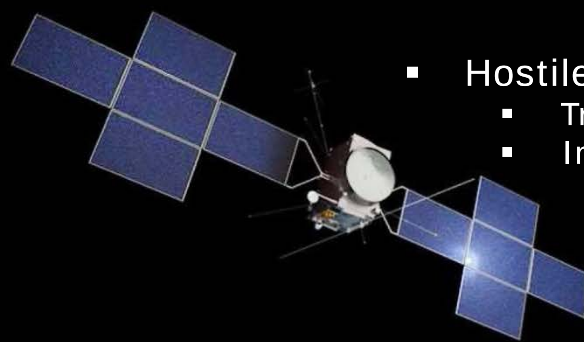
Outline

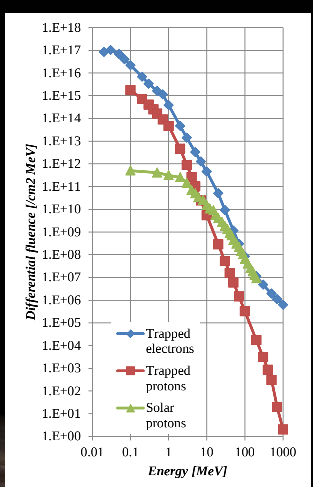
- ESA projects and Geant4 support
- Tool developments
- Perspectives

JUICE
(JUpiter ICy moons Explorer)



- ESA Cosmic Vision L-Class mission

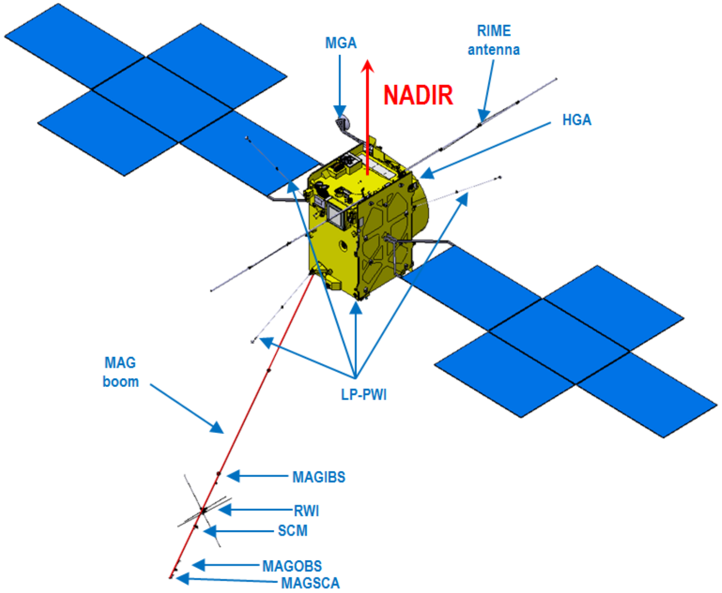


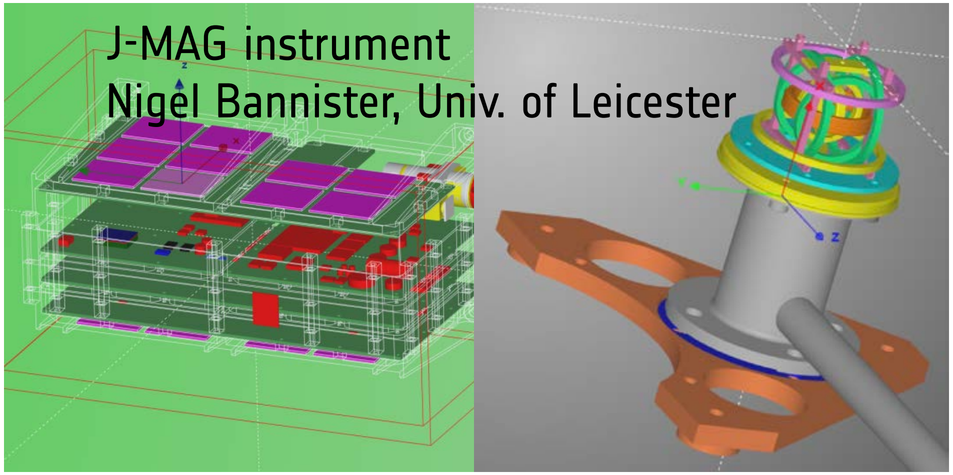


- Very intense magnetic field
  - Jupiter rotational period 9 h 56 min
  - Plasma torus and radiation belts wobble due to 7° tilt between Jupiter rotational and magnetic axes
- Hostile radiation environment
  - Trapped electrons with energies >100MeV
  - Intense, energetic, variable, difficult to predict
- Design driver for JUICE platform and payload
  - Sensor / component **degradation**
  - High **background** noise for science instruments
  - **Electron-induced SEE**
- Broad range of radiation analysis activities (TID, charging, DD, noise, SEE) for platform and instruments, **including Geant4 and GRAS**

JUICE
Status and new developments

- Launch planned for 2022, arrival 2030
- Airbus, Prelim. Design Review passed (March 2017)
- 11 science instruments to be flown
  - with Japanese and US collaborations
  - a few use Geant4 / GRAS
  - FASTRAD used by most instruments
    - Geant4 physics, GDML interface
- Radiation levels kept reasonable with careful shielding design
  - Vaults for sensitive electronics
  - Including **High-Z** materials
  - Models getting very detailed
- Geant4 has crucial role in **design and/or validation** of both FASTRAD and NOVICE

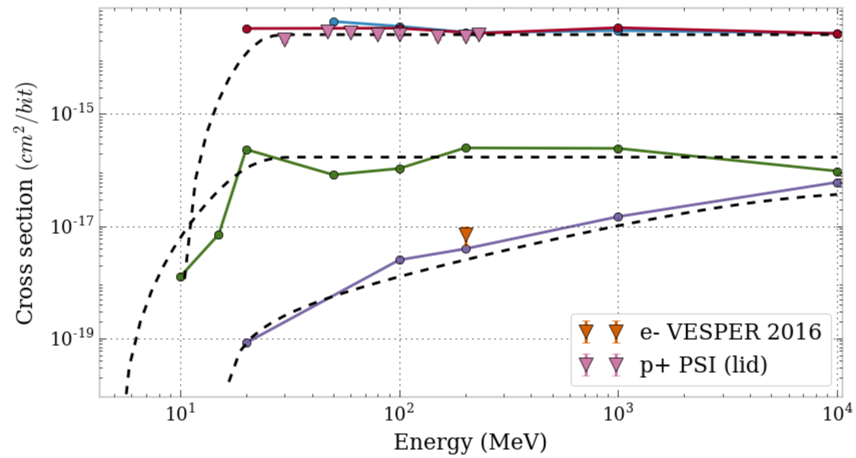


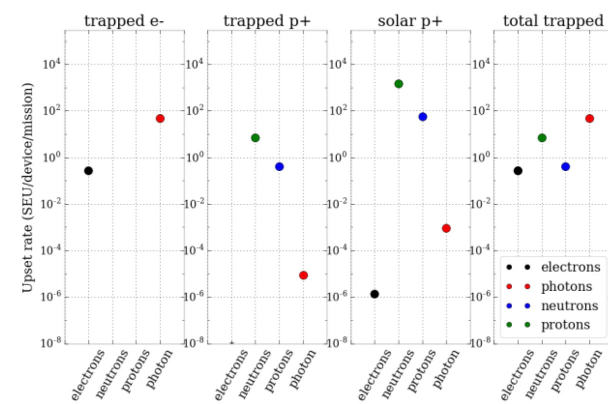


JUICE
Electron-induced Single Event Effects

- SEEs from single electrons recently reported in modern technologies (King, 2010 & 2013)
- Evidence of SEEs caused by higher energy electrons ~15-20 MeV (Samaras, 2014)
  - Not a big issue @ Earth, but potentially @ Jupiter
- Low energy → direct ionisation
- Higher energies → nuclear interactions
  - **Gamma-nuclear and electro-nuclear** processes
  - Cross section increasing with energy

- **CERN VESPER** tests @ **100-200 MeV** (Maris Tali, 2016)
  - Confirmed relevance for SEE @ Jupiter
  - For relatively old tech. (e.g. ESA SEU monitor)

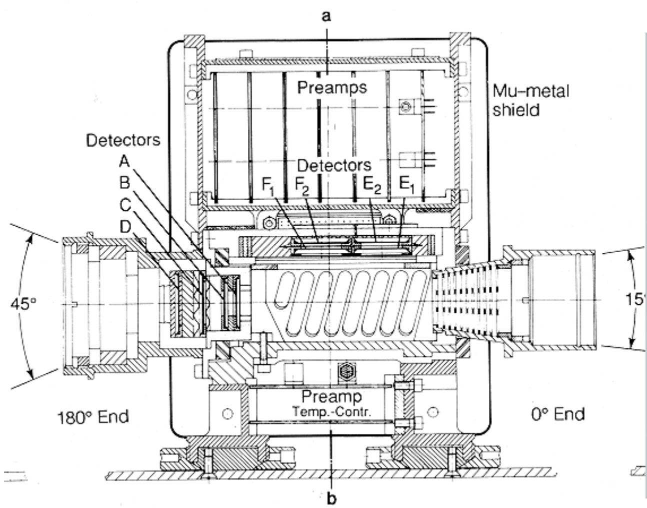


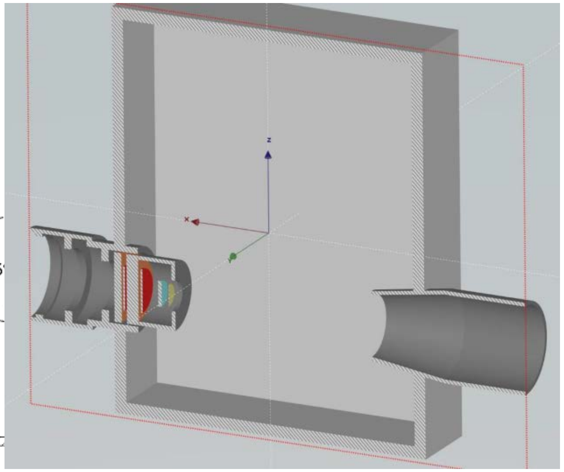


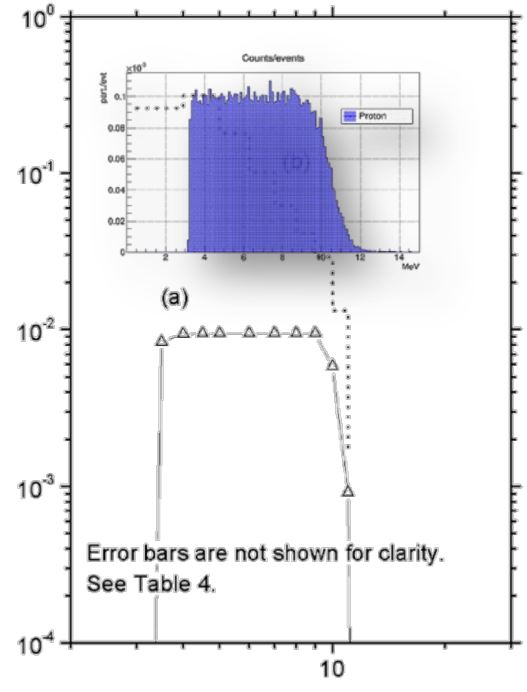
Maris Tali, RADECS 2016
IEEE Trans Nucl Sci, 2017

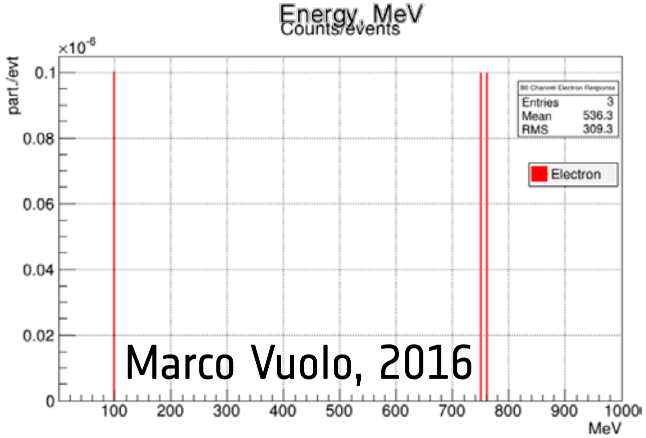
JUICE
Re-analysis of EPD radiation monitor data

- Galileo EPD B0 channel
- Previously erroneously assumed as contaminated by electrons
  - Precious interactions with I. Jun et al.
- GRAS simulations confirmed B0 as
  - pure proton channel
  - sensitive in the range 3 MeV < E < 10 MeV
- Important constraint for Jupiter trapped proton models









ESA Cosmic Vision L-class mission Athena

Primary goals:

- Mapping hot gas structures and determining their properties; searching for supermassive black holes

Launch 2028, with mission duration of 5 years

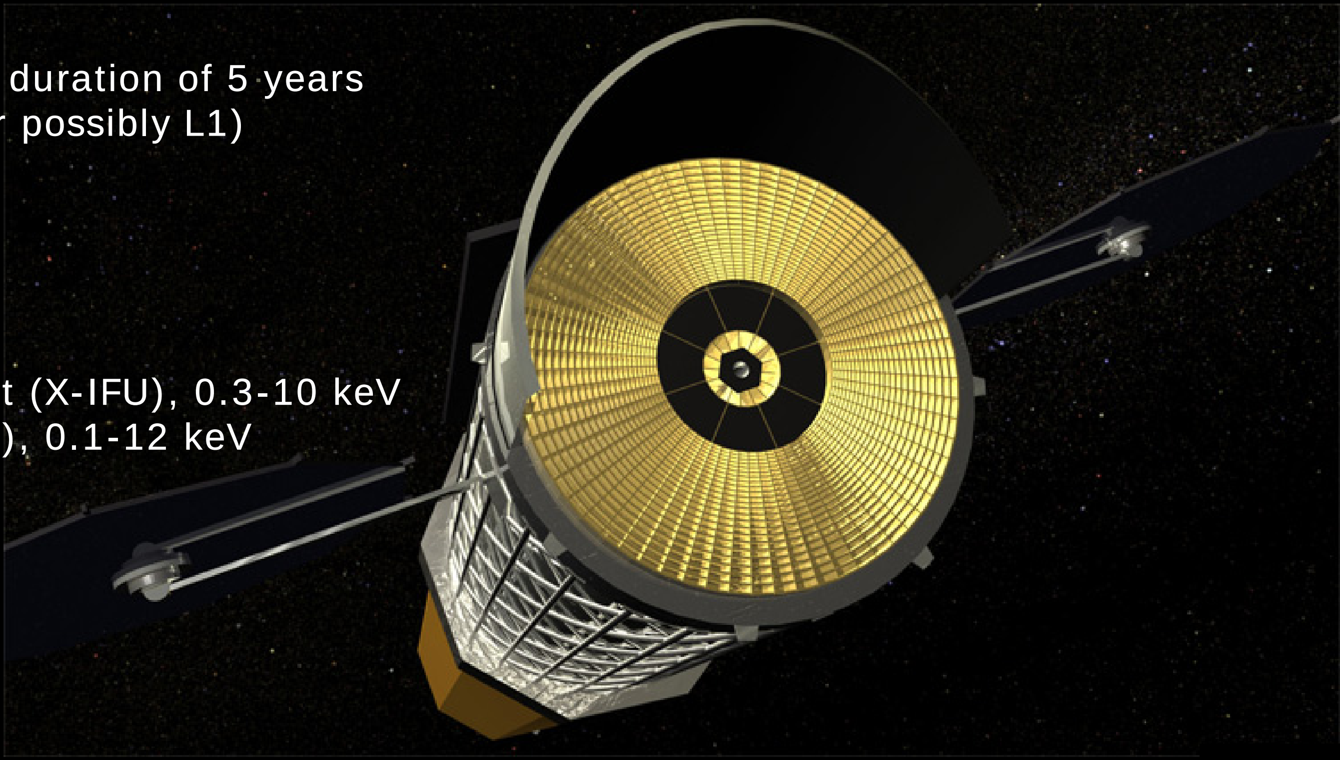
- Halo orbit around L2 (or possibly L1)

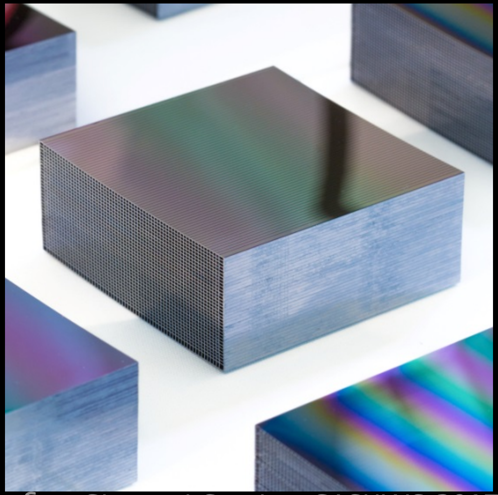
Mirror:

- Silicon Pore Optics

Two instruments:

- X-Ray Integral Field Unit (X-IFU), 0.3-10 keV
- Wide Field Imager (WFI), 0.1-12 keV

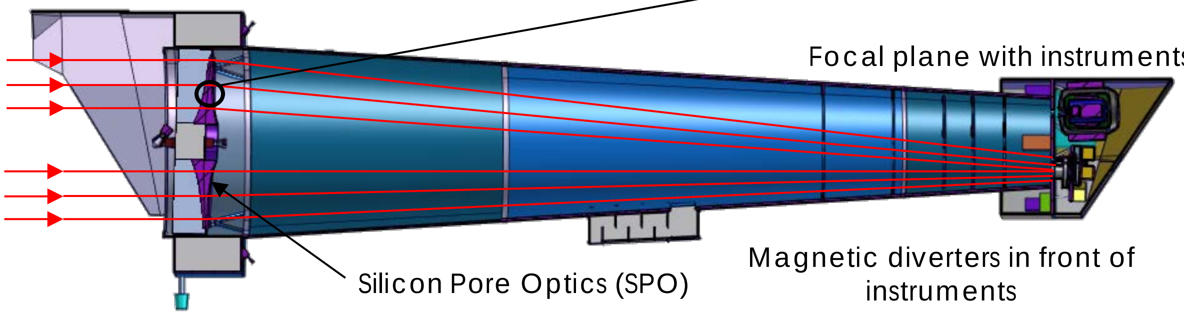


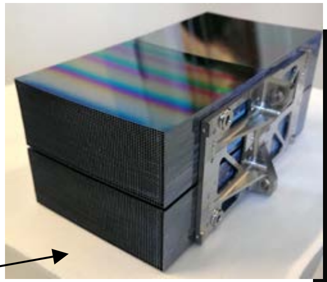


Particle background in the ATHENA X-ray telescope

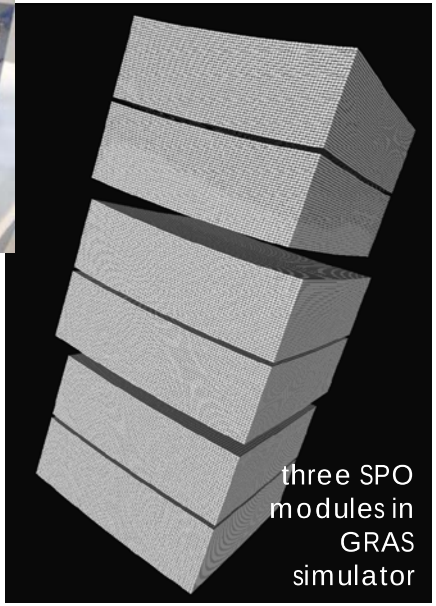
- Analysis of soft-proton measurements by Geotail, ACE and Artemis spacecraft, simulations using GRAS
  IEEE Trans. on Plasma Science V: 45 I: 5, 2017
- AREMBES: physics models and simulator

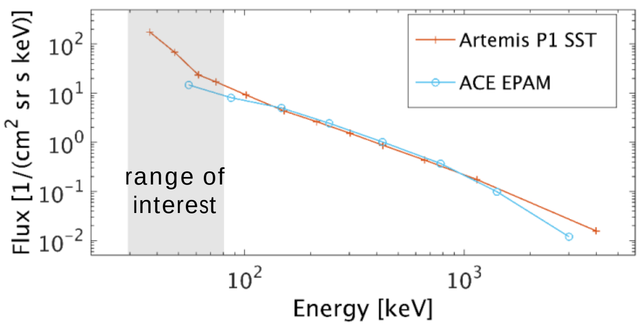
Soft protons focusing in Athena:



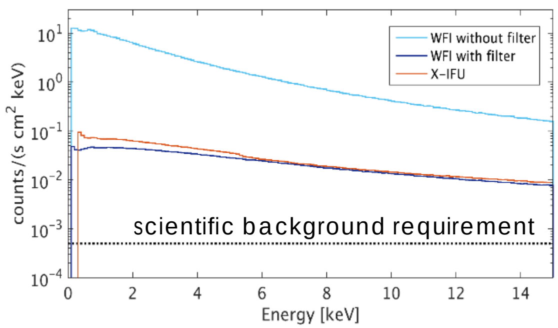


SPO module

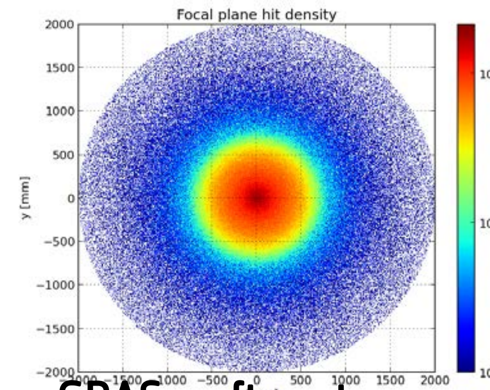




90% worst-case spectra for solar (from ACE) and solar + Earth magnetotail (from Artemis) proton flux

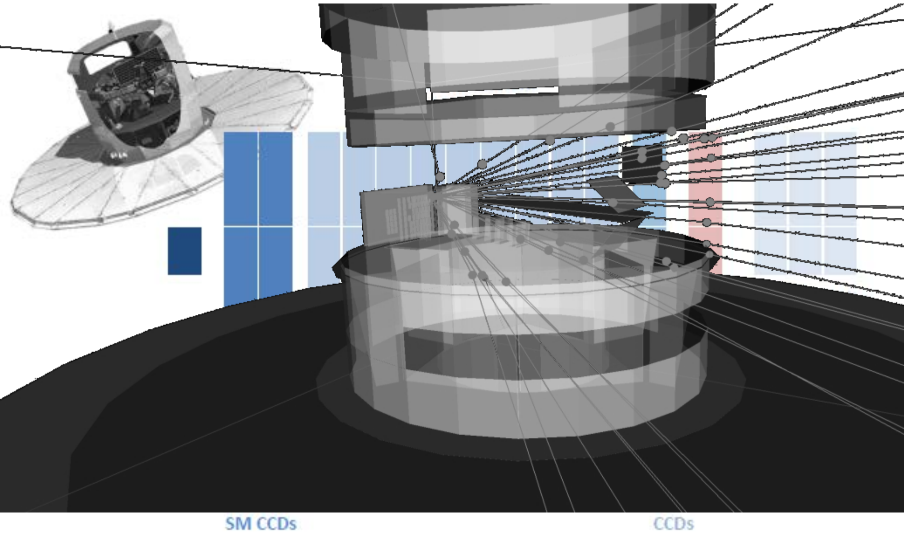


estimate of soft-proton background in Athena X-ray detectors without magnetic diverters

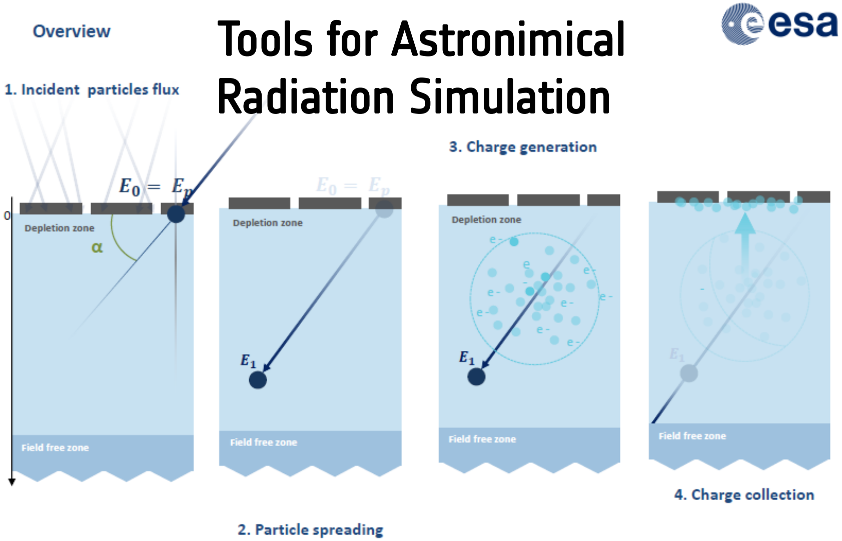


GRAS: soft proton focussing/diffusion

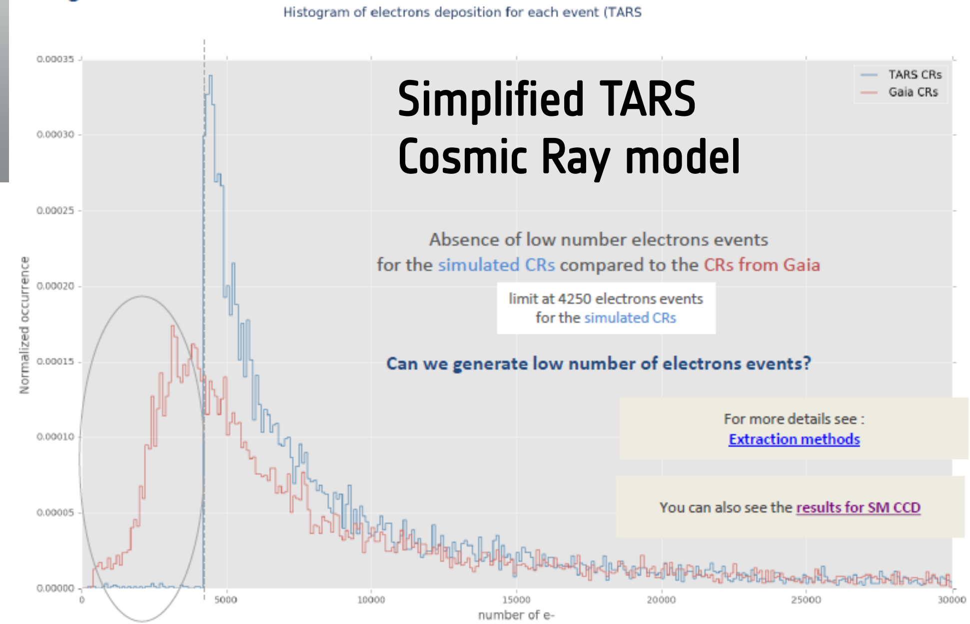
GAIA
CCD background studies



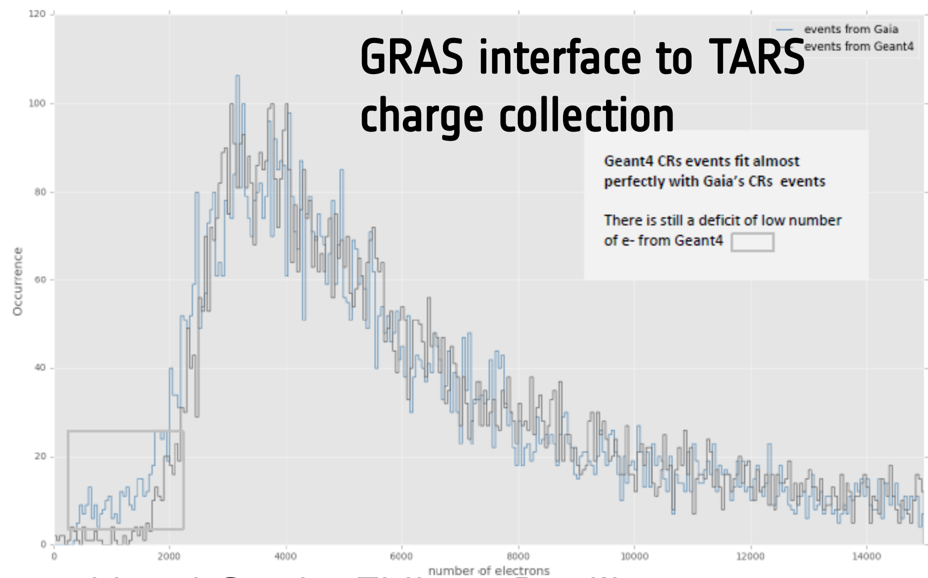
Tools for Astronimical Radiation Simulation



Firsts Results for BAM
Histogram



Simplified TARS Cosmic Ray model



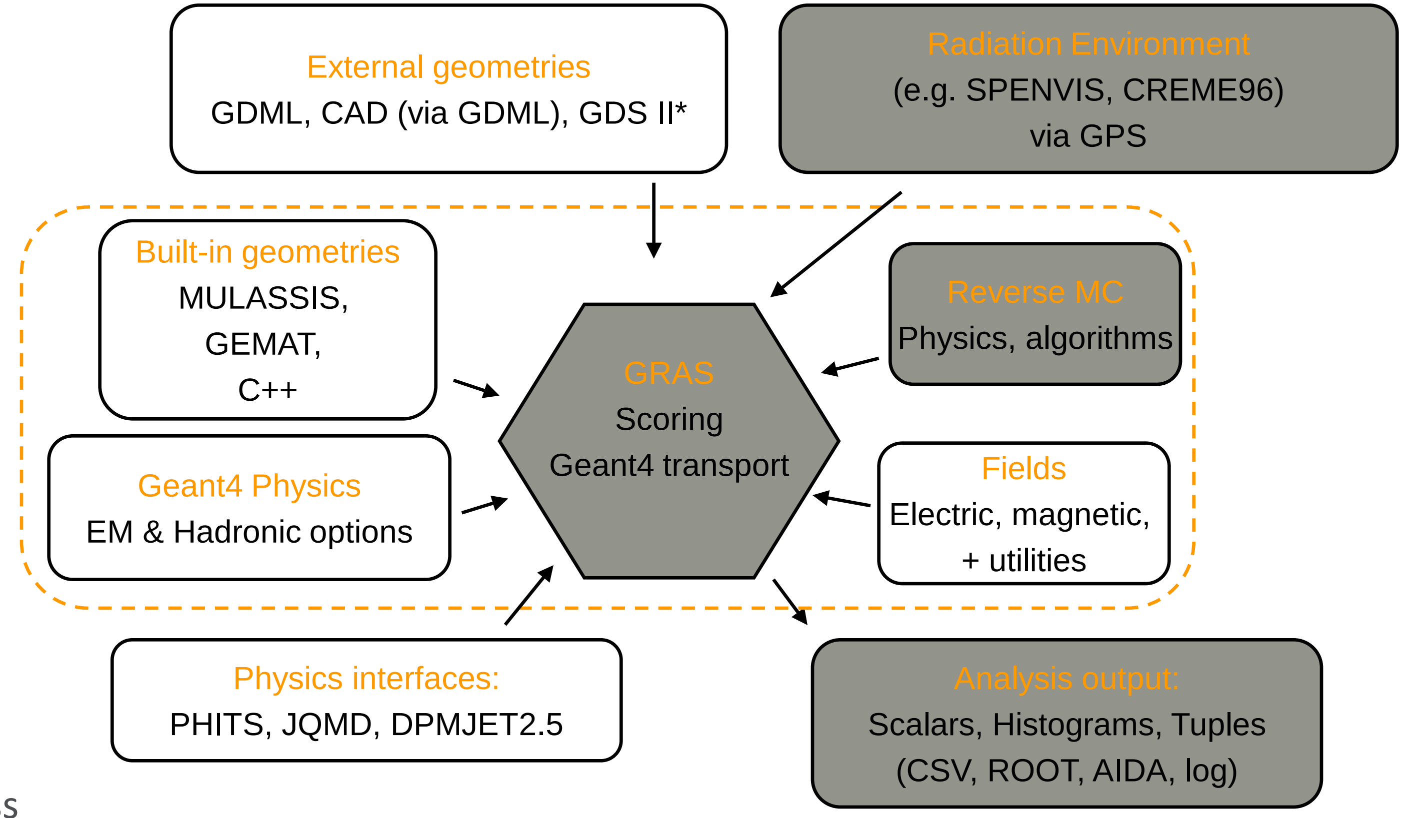
GRAS interface to TARS charge collection

Lionel Garcia, Thibaut Prod'homme, Marco Vuolo, Giovanni Santin

Geant4 tools integration: GRAS

Requirements:

- Ready-To-Use tool
  Multi-mission approach
- Modular progress
  Open to collaborations and contributions
- Currently GRAS v3.4
- GRAS v3.5 in preparation
- Ongoing study to assess Reverse Monte Carlo performance



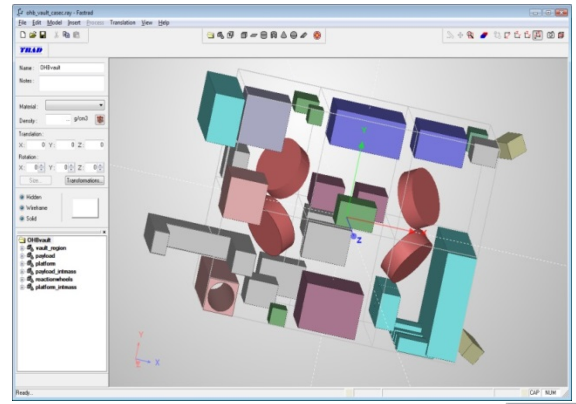
G Santin, V Ivantchenko et al, IEEE Trans. Nucl. Sci. 52, 2005

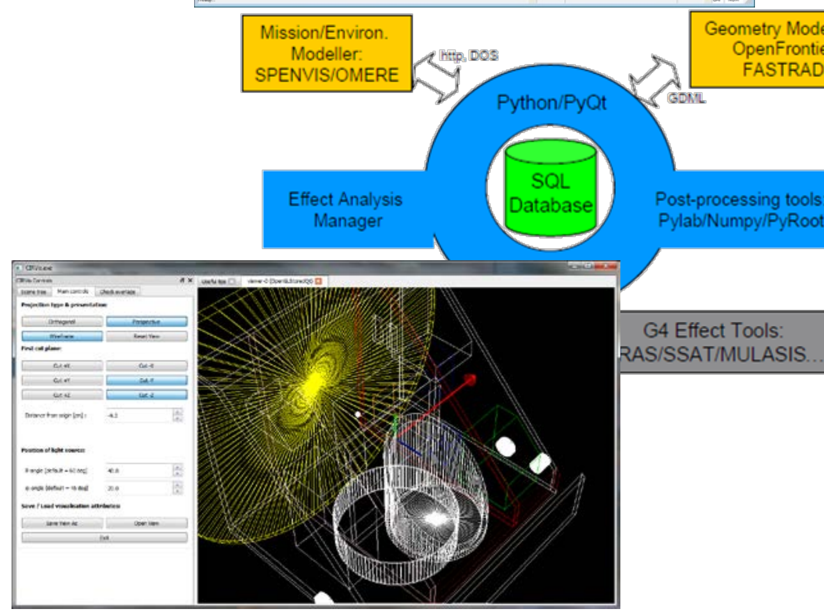
http://space-env.esa.int/index.php/geant4-radiation-analysis-for-space.html

CIRSOS
Collaborative Iterative Radiation Shielding Optimisation System

- Better interoperability of shielding analyses in multi-partner projects (e.g. JUICE, THOR, ATHENA, eLISA,)
- Integrated Modelling Environment
  - Mission specification and environment modeller
- Effects analysis tools
  - Geant4-based applications (GRAS, FMC and RMC, SSAT, MULASSIS)
  - Internal charging
- CIRvis visualisation
- Post-processing manager
  - Visualisation, plots
  - Response matrices / formulae / algorithms

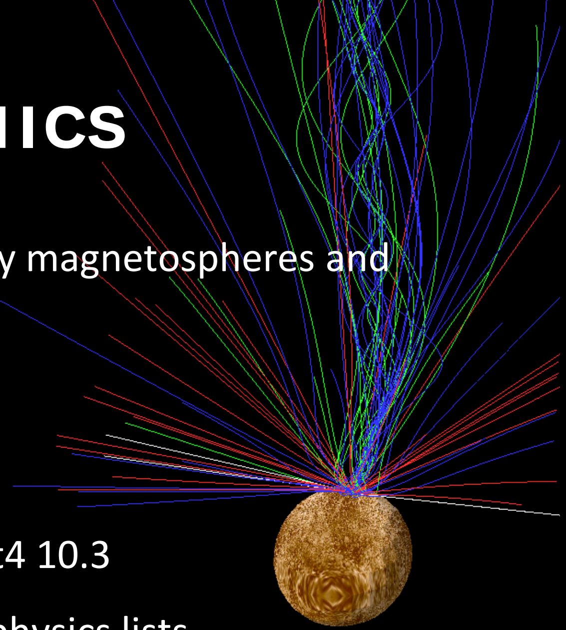
See the dedicated presentation



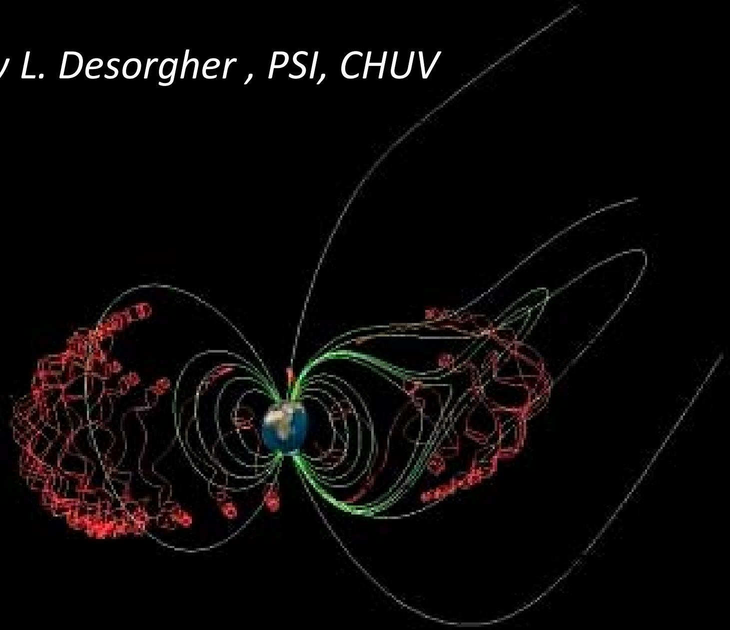


PLANETOCOSMICS

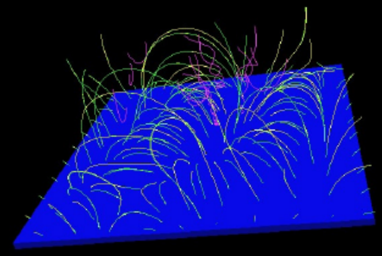
By L. Desorgher , PSI, CHUV



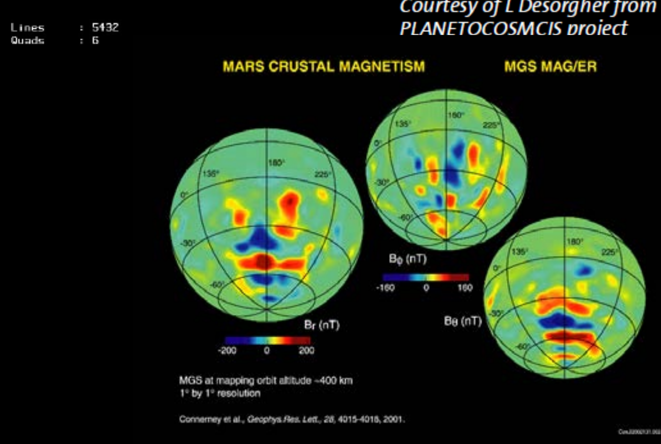
- Transport through planetary magnetospheres and atmospheres
- New version just released
  - Compliant with Geant4 10.3
  - Uses Geant4 built-in physics lists
  - New IGRF model for the Earth magnetic field
- Several forks by different groups
  - Joint effort proposed to merge all new features and extensions
- New open access webpage being discussed (maybe at ESA) for code repository and downloads



10 MeV e^- in the most magnetized region of Mars



Courtesy of L Desorgher from PLANETOCOSMCIS project



ROSSINI 1 & 2
Radiation Shielding by ISRU* & Innovative Materials for EVA, Vehicles and Habitats

- Thales Alenia Space Italy, GSI, INFN

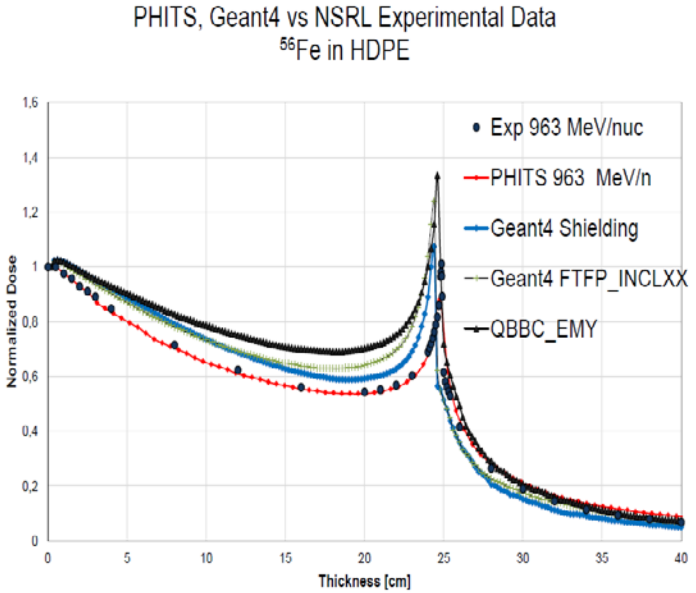
High-level objectives

- Select innovative shielding materials & systems
  - Hydrogen rich and ISRU* materials
- Test them under protons and heavy ions beams
- Use the experimental data to validate 3D simulations of deep space and moon habitat

** in-situ resource utilisation*

Space radiation shielding studies

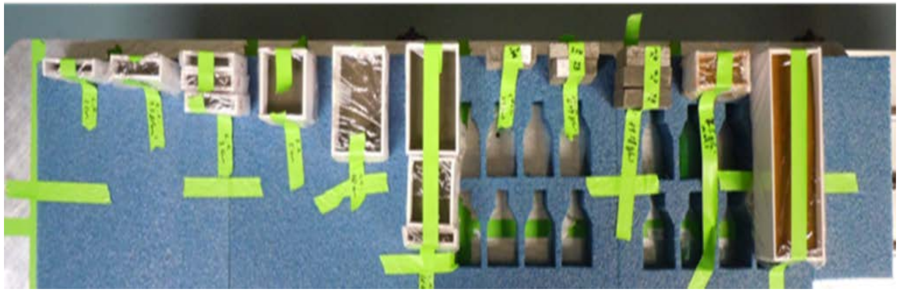
- Radiation tests including: dose reduction, beam fragmentation, lateral scattering, microdosimetry
- Simulations against experimental data and 3D simulations done with GRAS/Geant4 and PHITS

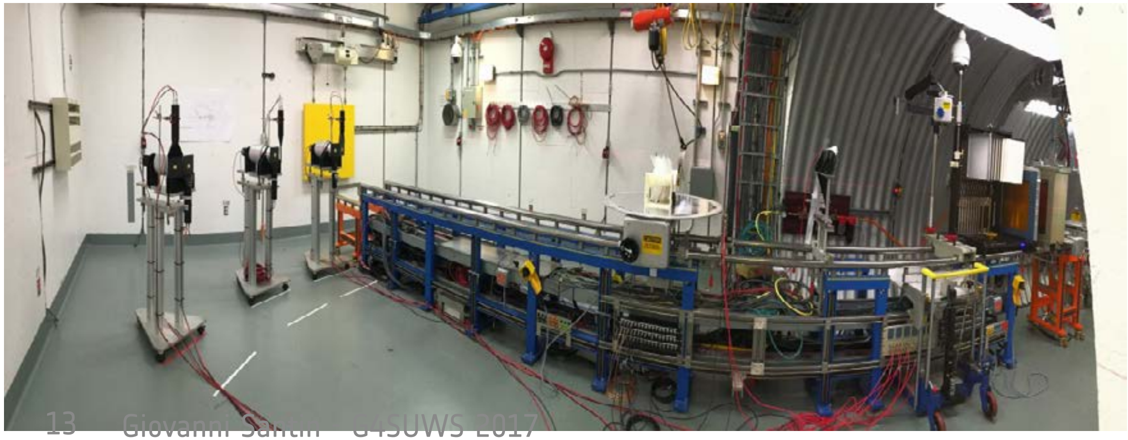


Lunar Regolith

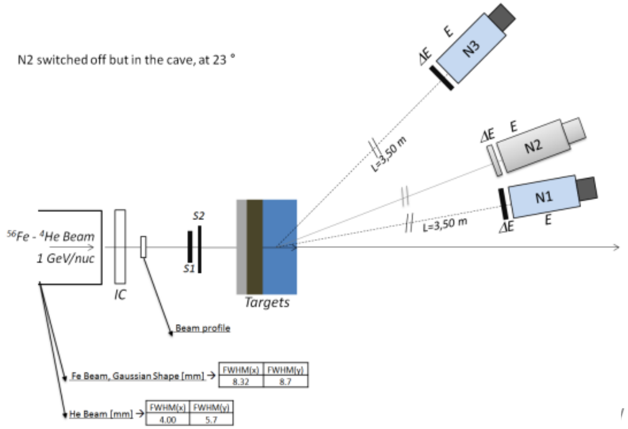
Lunar Concrete

Mars Regolith





Fragmentation Set up – June 2016 - NSRL



Summary and outlook

The near future is looking pretty grim, with significant cuts affecting basic R&D, to compensate for budgetary problems in other parts of the Galaxy

Nevertheless, all major ESA science missions continue to be major Geant4 users, through ESA developments or commercial tools

New easy to use tools for detailed calculations in collaborative environment are being finalized (see CIRSOS talk)

Geant4 physics models development for ESA "Moon village" concept: biological damage with Geant4-DNA, and shielding from HZE ions

Questions?

European Space Agency