ESA STATUS REPORT

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ESA/ESTEC and RHEA System

Outline

- ESA projects and Geant4 support
- Tool developments
- Perspectives

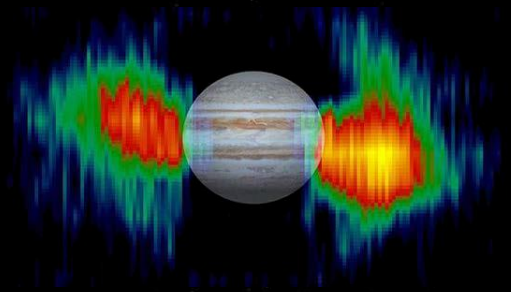
Space Center, Houston, TX
28-30 November 2018

Summary

- Introduction on ESA missions and related activities:
  - JUICE (Geometry debugging, code validation, etc.)
  - ATHENA (particle background study, AREMBES)
  - Additional ESA Cosmic Vision missions
- Overview on Radiation Monitors development (including some GRAS examples)
- Radiation Shielding activities: ROSSINI 1,2,3 and MUSRAS
- EDGE: Extended GDML Editor
- G4G : Geant4-based Particle Simulation Facility in Greece for Future Science Mission Support

JUpiter Icy moons Explorer (JUICE)

- JUICE is the first large-class mission in ESA's Cosmic Vision 2015-2025 programme.
- Planned for launch in 2022 and arrival at Jupiter in 2029,
- It will spend at least three years making detailed observations of the giant gaseous planet Jupiter and three of its largest moons, Ganymede, Callisto and Europa.



Cassini (NATURE 2002)

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

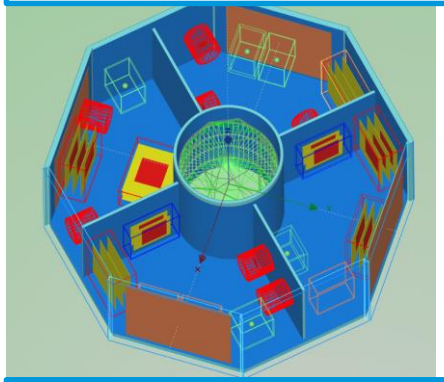
- Sensor / component **degradation**
- High **background** noise for science instruments
- **Electron-induced SEE**

Broad range of radiation analysis activities (TID, charging, DD, noise, SEE) for platform and instruments, **including Geant4 and GRAS**

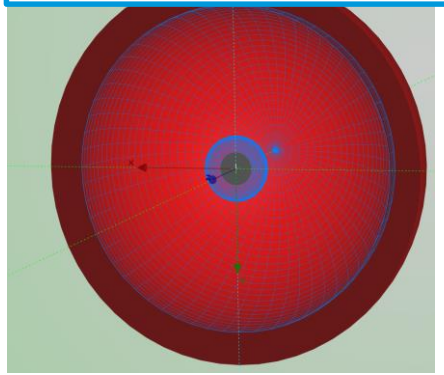
JUICE Geant4 related activities 2/2

- Radiation Shielding design: Vaults for sensitive electronics including **High-Z materials**
- RMC Tests and comparisons: Geant4 has crucial role in **design and/or validation** of both FASTRAD and NOVICE.
- Electron **back scattering** studied to explain some discrepancies between sectoring analysis and MC
- **Electron-induced Single Event Effects** studies (Maris Tali, RADECS 2016 IEEE Trans Nucl Sci, 2017):
  - Not a big issue @ Earth, but potentially @ Jupiter
  - Low energy ->direct ionization, Higher energies -> nuclear interactions
  - Gamma-nuclear and electro-nuclear processes
  - Need of **BIASING** techniques implementation into GRAS (started)

TEST Spacecraft for sharing info

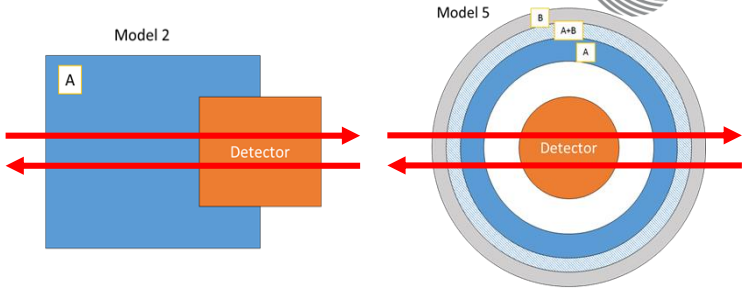


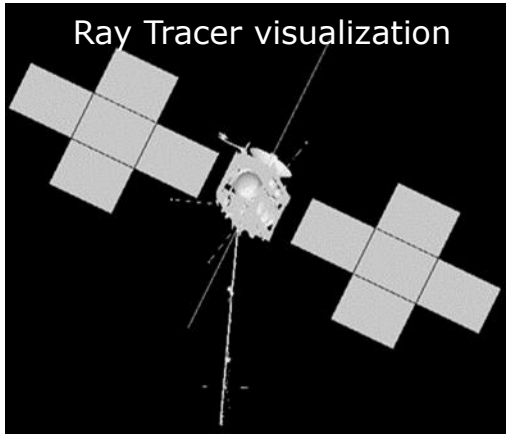
Sphere: 1mm Pb+4mm Al + Si det (0.5 mm r)

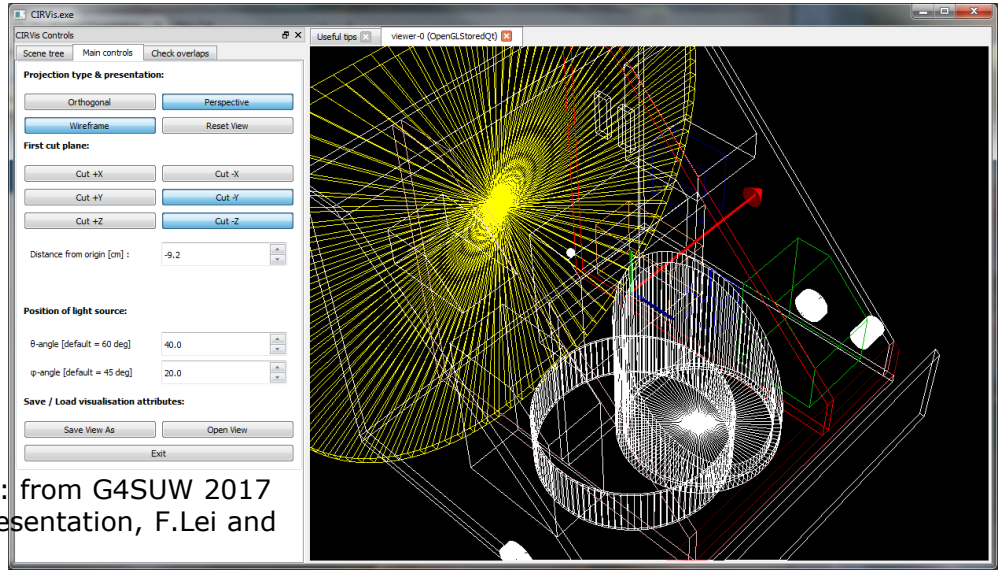


JUICE Geant4 related activities 1/2

- Models getting very detailed
- Evaluation of overlaps impact on 3D big models
  - In the most of the cases the overlaps are intentionally (to avoid gaps in the structures) or they are due to the step file conversion to tessellated geometry
  - Big models have thousands of very small overlaps, difficult geometry debugging







CIRVis tool: from G4SUW 2017 CIRSOS presentation, F.Lei and P. Truscott

ESA Cosmic Vision L-class mission Athena

ATHENA (Advanced Telescope for High Energy Astrophysics)

Primary goals:

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

Launch 2028, with mission duration of 5 years

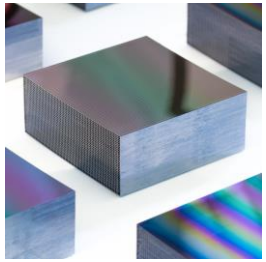
- Halo orbit around L2 (or possibly L1)

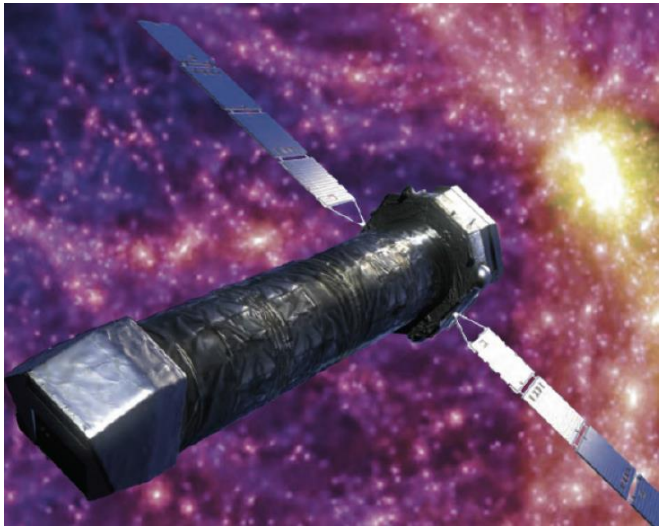
Mirror:

- Silicon Pore Optics

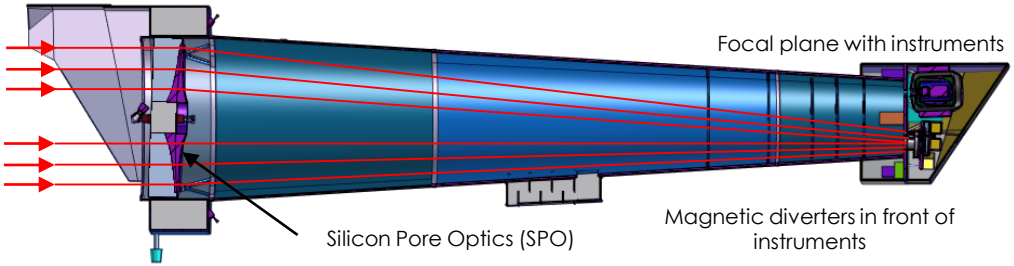
Two instruments:

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



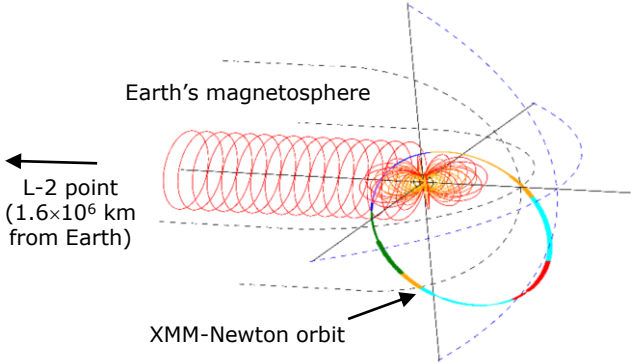


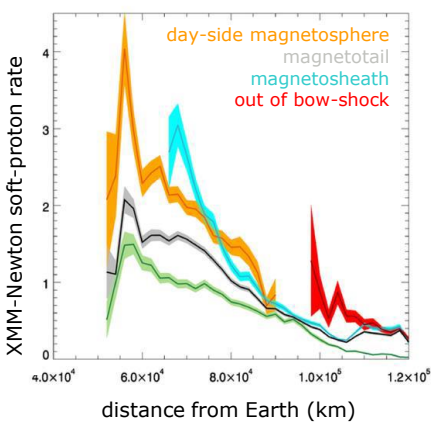
Soft protons focusing in Athena:

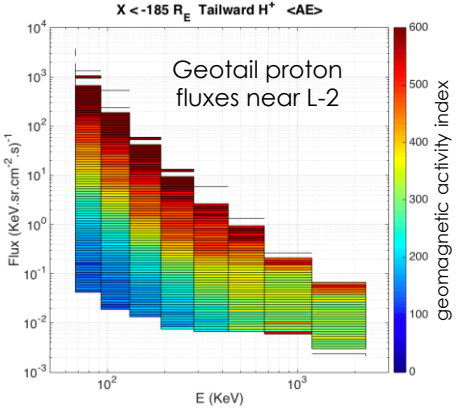


Particle background in the ATHENA X-ray telescope

- **AREMBES** (Athena Radiation Environment Models and x-ray Background Effects Simulator) :
  - Analysis of particle background in XMM-Newton data, measurements by Geotail, ACE and Wind spacecraft.
  - Development of a software simulator based on Geant4, capable of addressing all the background issues that the ATHENA mission will experience during its lifetime.
- **soft protons:** 10 keV to 100 keV energy range ("soft" compared to energetic particles causing SEE, TID, NIEL...)
  - ➢ potential limitation for astrophysical observations that require low background
  - ➢ ½ of XMM-Newton observations affected by "soft-proton flares"
  - ➢ ATHENA will operate at L-2 Lagrange point – new environment for X-ray telescopes



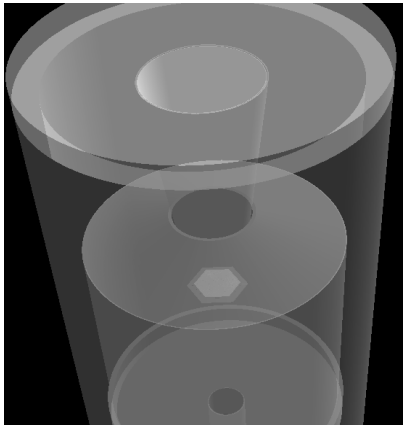




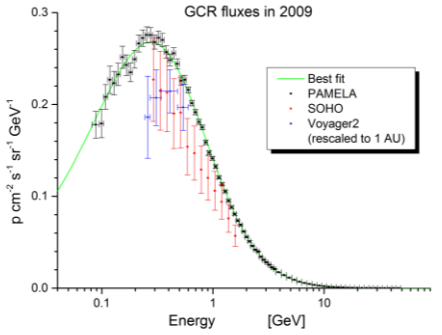
Athena Simulation Framework validation: X-IFU

- ASF validated against Geant4 simulation
- Input:
  - Same GCR protons spectrum
  - Same simplified mass model
  - Same Physics list (emstandard_opt4)
- Output:
  - Particle fluxes on X-IFU and CryoAC
- Results:
  - integrated fluxes compatible at 1σ level
  - spectra compatible at 2σ level
- Conclusion: the ASF can reproduce the particle fluxes predicted by a “traditional” Geant4 simulation and is a viable alternative

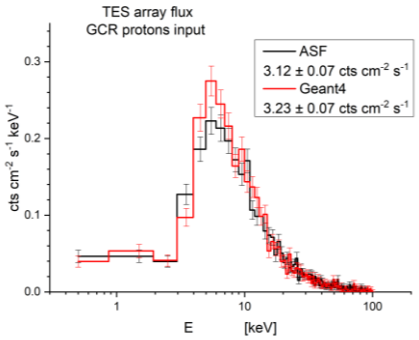
CREDIT: S.Lotti and C.Macculi (INAF)



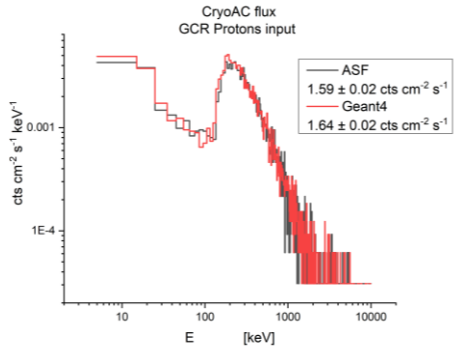
FPA and detector mass model



Input GCR protons spectrum



Background counts on X-IFU

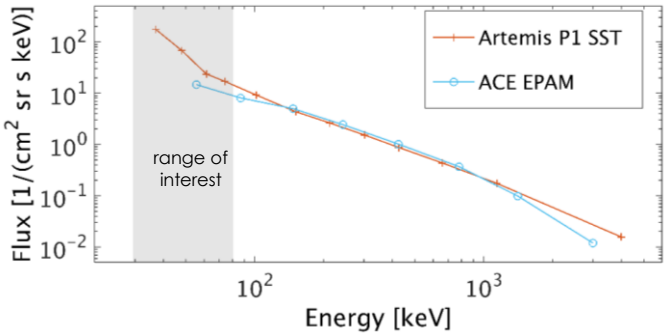


Particle fluxes on the CryoAC

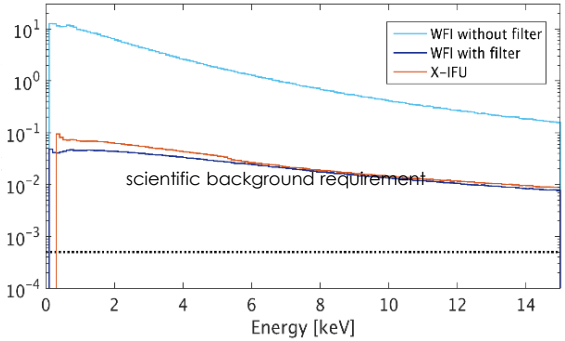
Particle background in the ATHENA X-ray telescope

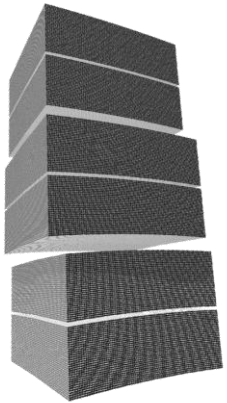
Soft Proton Fluxes in and Around the Earth's Magnetotail, D. Budjas et al. ,March 2017 IEEE Transactions on Plasma Science PP(99):1-7

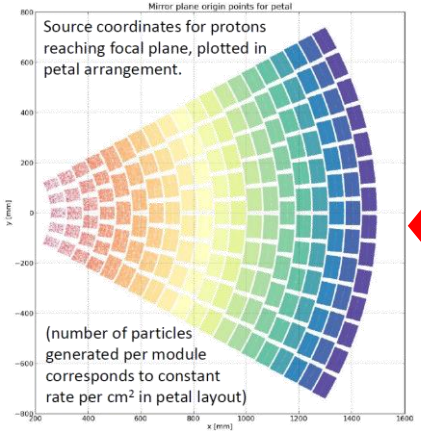
90% worst-case spectra for solar (from ACE) and solar + Earth magnetotail (from Artemis) proton flux

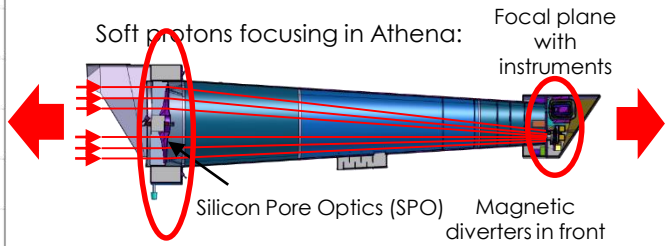


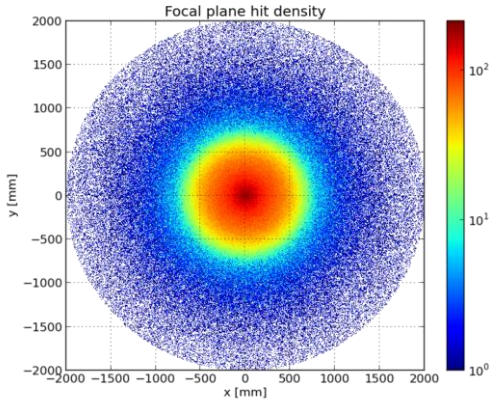
estimate of soft-proton background in Athena X-ray detectors without magnetic diverters







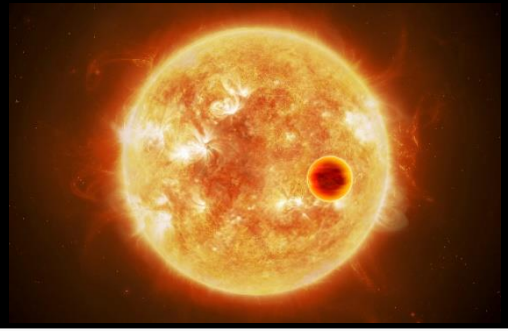




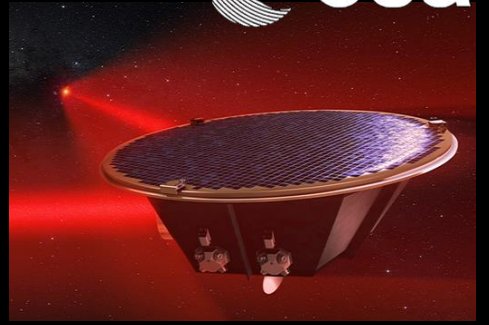
Future missions in ESA's Cosmic Vision programme

ARIEL, the Atmospheric Remote-sensing Infrared Exoplanet Large-survey

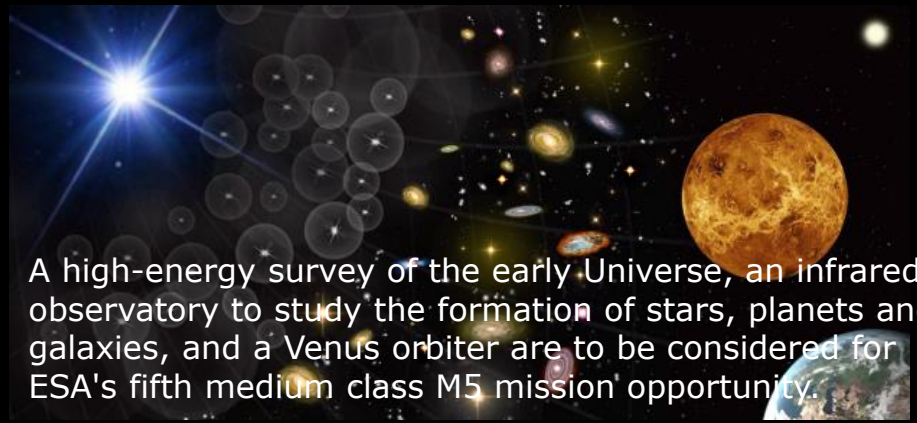
M4



LISA is a space-based observatory of gravitational waves consisting of a constellation of three spacecraft, with launch planned for 2034 **L3**



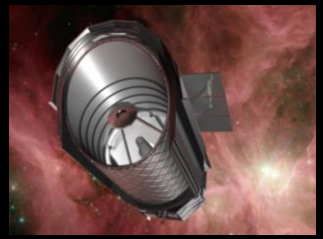
M5 selection:



A high-energy survey of the early Universe, an infrared observatory to study the formation of stars, planets and galaxies, and a Venus orbiter are to be considered for ESA's fifth medium class M5 mission opportunity.

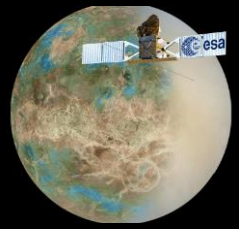
THESEUS:

Transient High Energy Sources and Early Universe Surveyor



SPICA:

Space Infrared Telescope for Cosmology and Astrophysics



EnVision:

Venus high-resolution radar mapping and atmospheric studies

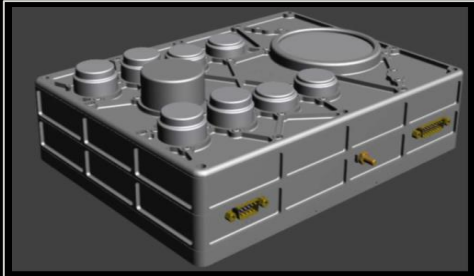
Space Environment Monitors Overview

- In this talk an overview on some of the past and present ESA developments in the domain is given
- There are various other, highly relevant activities by National Agencies, Industry and Institutes that are not reflected here
- Also, certain highly relevant activities that have recently been started or are in programmatic preparation (e.g. MIRAM, AIDA, MARS, NORM, various GSP activities, items in GSTP compendium...) are not yet reported here

Overview of past ESA Radiation Monitors

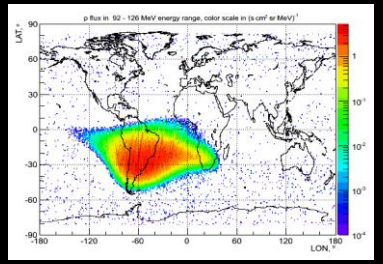
Contraves(RUAG→TAS-CH),PSI (CH)
Flights on STRV-1c, **Proba-1, INTEGRAL**, Rosetta, Giove-B, Herschel and Planck

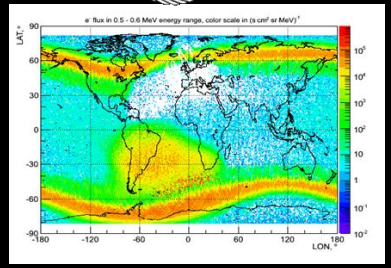
SREM Standard Radiation Environment Monitor



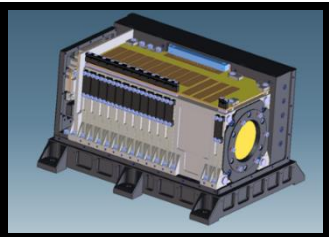
- RUAG (→TAS-CH), QinetiQ (UK)
- 2 Galileo FOC s/c equipped with the Environmental Monitoring Unit (EMU)
- Flying as 'SEDA' on two Himawari (Japan) satellites in GEO

EMU Environment Monitoring Unit





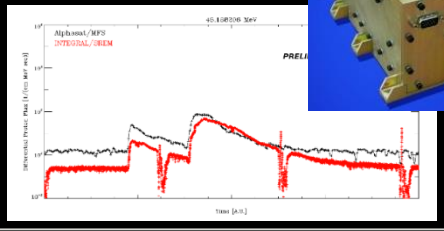
- UCL/CSR, QinetiQ Space, BISA, B.USOC (B), ASRO (FIN)
- Flying on Proba-V since May 2013

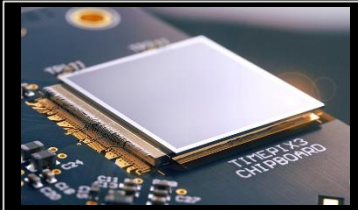


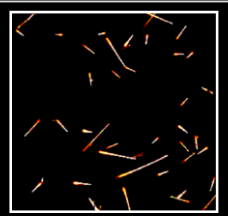
EPT Energetic Particle Telescope

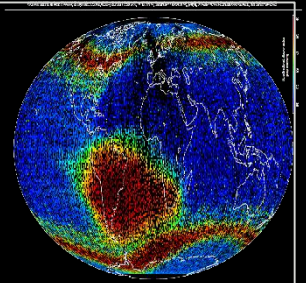
- EFACEC (P), LIP (P)
- Flying on AlphaSat (Inmarsat-4A F4) on GEO (July 2013 on), data analysis ongoing
- Similar instrument ("BERM") to be flown on BepiColombo

MFS Multifunctional Spectrometer







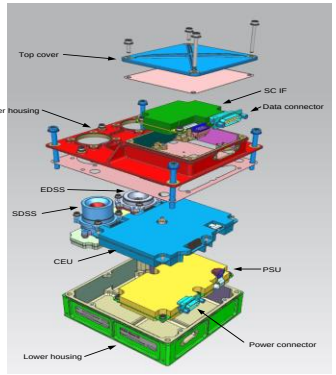


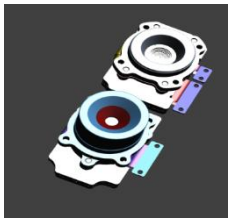
- IEAP CTU, CSRC (CZ)
- TimePix-based (CERN) imaging sensor
- One-chip demonstrator launched on Proba-V

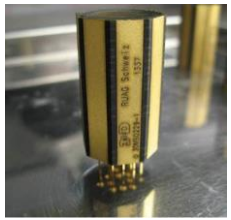
SATRAM Space Application of TimePix Radiation Monitor

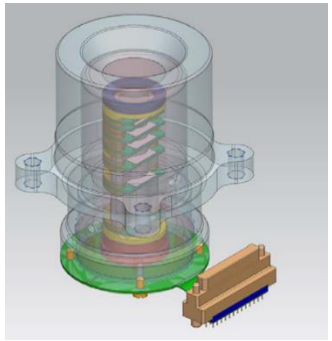
Next Generation Radiation Monitor (NGRM)

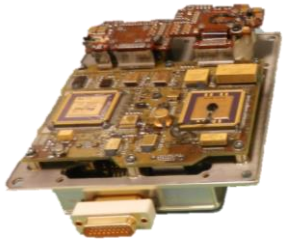
- TAS-CH, PSI (CH), IDEAS (N), EREMS (F), ONERA (F)
- Intended as follow-on for the SREM: Batch approach
- Mass 1.5 kg, power 2.5 W
- Dimensions 150 x 133 x 69 mm^3
- Two sensor heads, one for protons and heavy ions, the other for electrons
- Modular interface
- First demonstrator flight planned for EDRS-C (GEO)
- Further flights in preparation

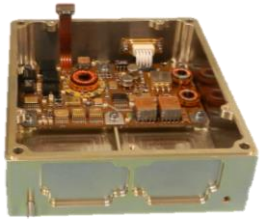






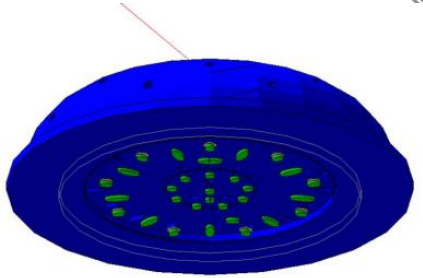


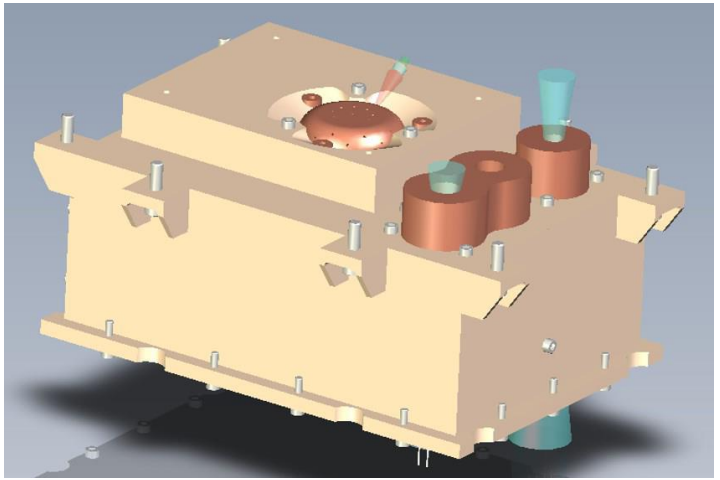


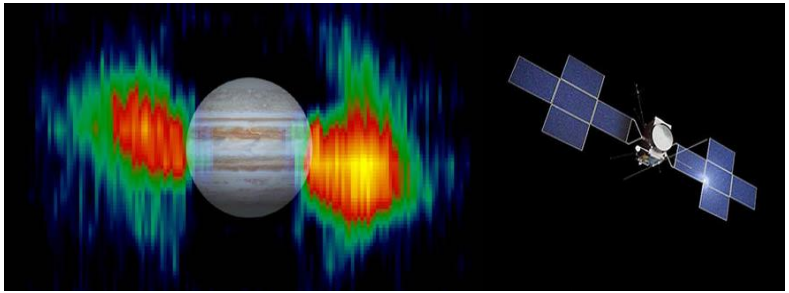


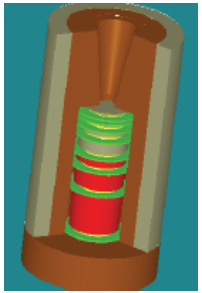
Rad-Hard Electron Monitor (RADEM)

- EFACEC, LIP (P), PSI (CH), GM-IDEAS (N)
- Radiation monitor dedicated to the high energy electron environment of Jupiter
- However, also detects protons and ions
- Aim: 2.6 kg, 3.2 W, 16 x 222 x 100 mm^3
- Interface SpW
- Platform instrument on the JUICE mission under Prime (Airbus) responsibility
- Undergone the CDR in July 2017



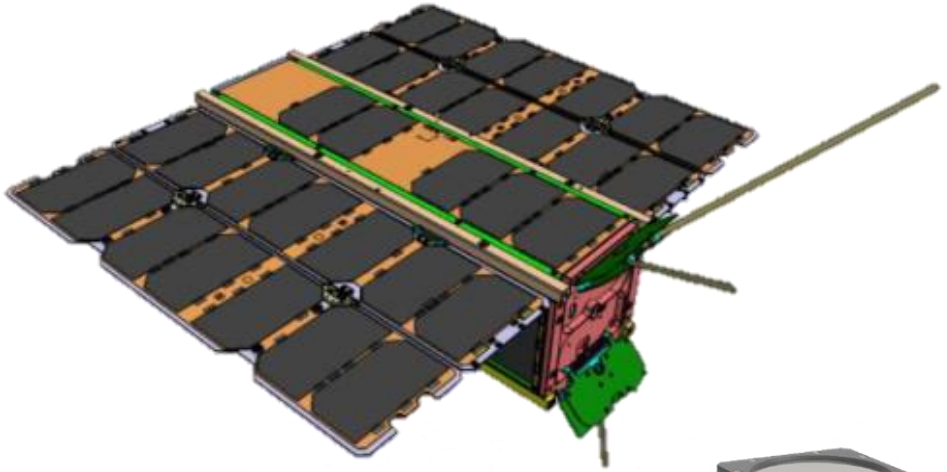


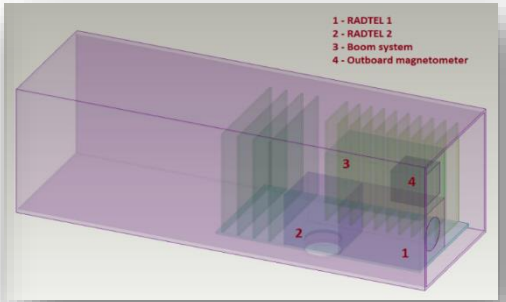




RadCube / RadMag

- RadCube: 3U cubesat by C3S (H)
- RadMag: Radiation monitor, MTA EK (H)
- Protons, electrons, heavy ion LET
- Inclusion of magnetic field measurement
- Phases B2-F kicked off in March 2017
- Launch planned in 2019 for 500-600 km Sun Synchronous Orbit
- 3 year operational life time





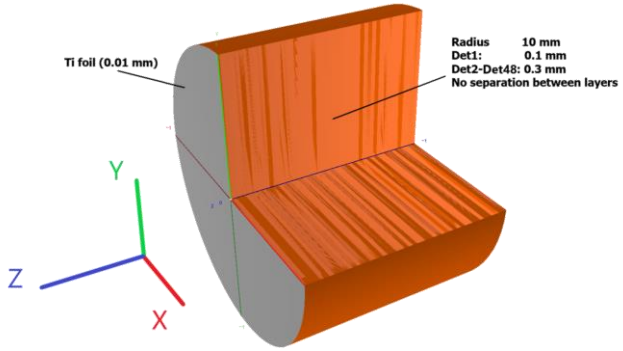
GRAS simulations for Radiation Monitor design

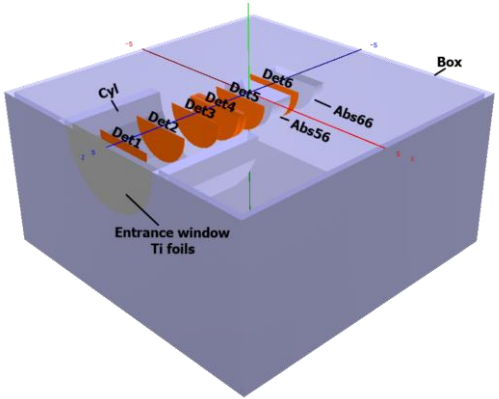
The "D3S RadMag" example by mta EK

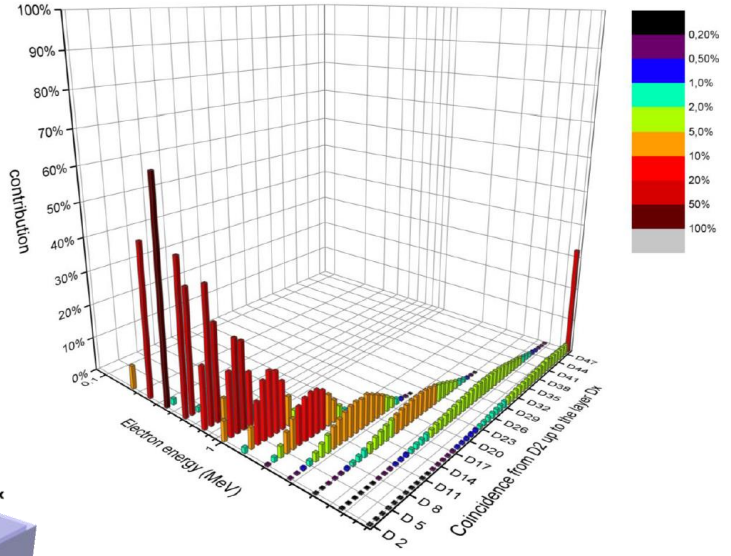
The activity aims to develop a complex instrument package combining the cosmic ray and magnetic field measurement capability for space weather service and directly applicable in the Distributed Space Weather Sensors System (D3S) concept of ESA.

- 1D slab geometry
- Species separation efficiency
- Identification of important layers

- Real design
- Absorber materials
- Channels definition







D2-Dx coincidence histogram for electrons

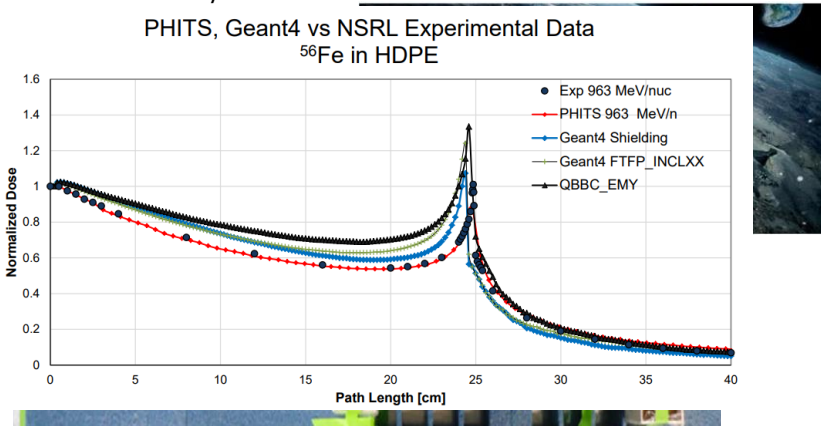
Credit: A.Hirn and B.Zabori (MTA EK)

Radiation Shielding R&D

ROSSINI 1, 2, 3

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

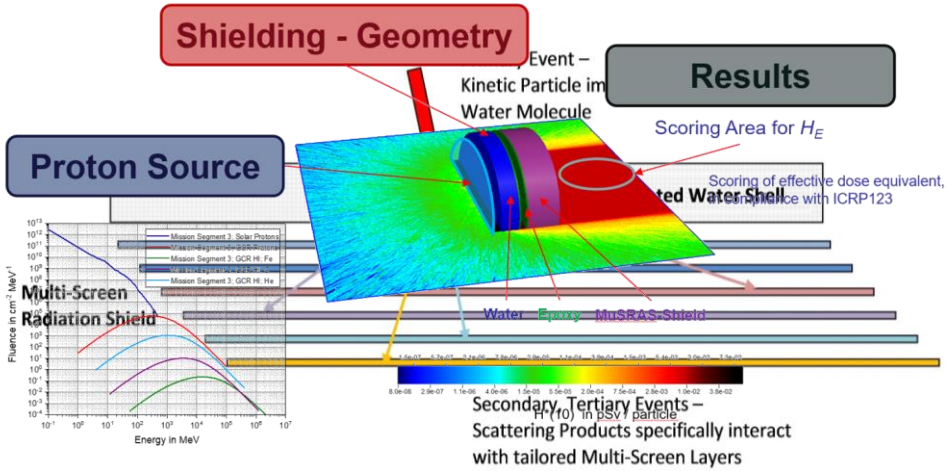
- Select innovative shielding materials & systems
- Hydrogen rich and ISRU* materials
- Test them under protons and heavy ions beams:
  - dose reduction
  - beam fragmentation
  - lateral scattering
  - microdosimetry
- Simulations against experimental data and 3D simulations done with GRAS/Geant4 and PHITS



MUSRAS

MultiScreen Radiation Shield:

- Application to interplanetary Human Spaceflight Missions by means of Monte Carlo Simulation and by manufacturing of material samples
- Demonstrator in radiation environment relevant for space mission
- Marketing study of a possible application for the MultiScreen radiation shielding including future aeronautic applications

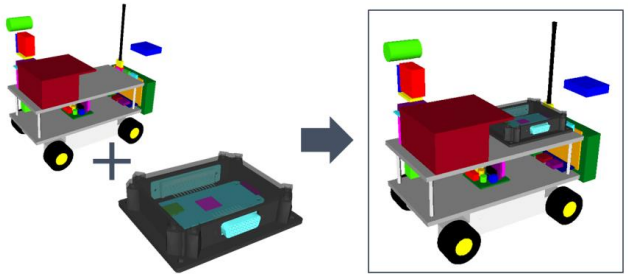


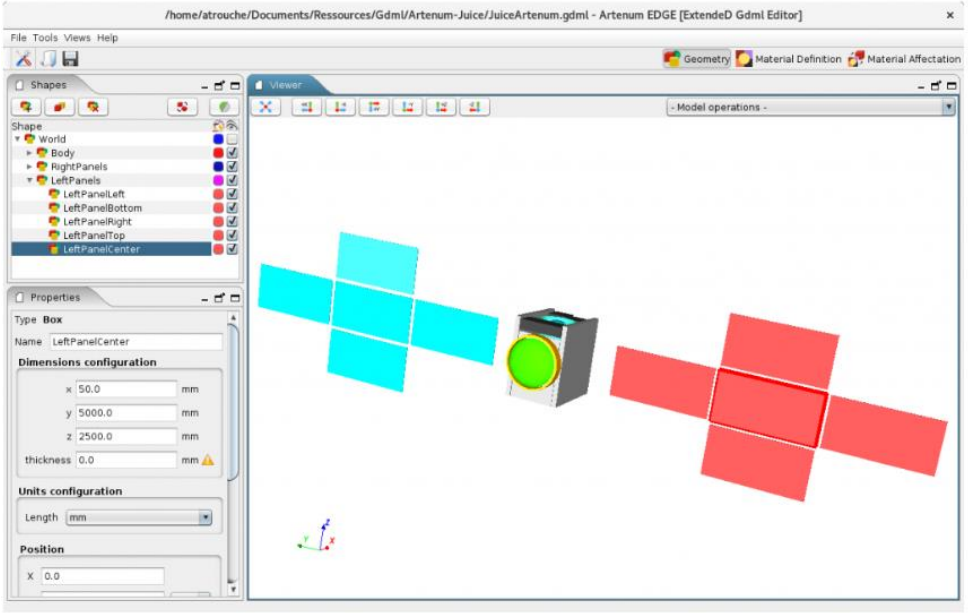
EDGE - ExtendeD Gdml Editor

ExtendeD Gdml Editor

User-friendly GUI to create/visualize and edit GDML based geometries with real-time 3D rendering

- GEOMETRY CHECKING :
  - Overlapping detection between elements
  - Geometry Hierarchy validation and correction
  - Volume and total mass computation
- MATERIAL PROPERTIES EDITION
- IMPORT/EXPORT CAPABILITIES (via tessellation)
  - STEP-AP 203-214
  - Gmsh .geo geometry format and .msh mesh format
  - Others B-Rep formats like .stl and .unv





More details on EDGE functions on: http://space-suite.com/edge

ESA contract 4000122289/17/NL/LF

G4G – Geant4 Greece

Geant4-based Particle Simulation Facility in Greece for Future Science Mission Support

- IASA - Institute of Accelerating Systems & Applications
- National Centre of Scientific Research "Demokritos"
- National Technical University Of Athens
- University of Ioannina

The objective is to establish a **strategic, complementary, long-term** capability as a key resource for space science-related simulation of particle "radiation" interactions with the payloads and systems, both for future missions and to aid data analysis from past and operating missions.

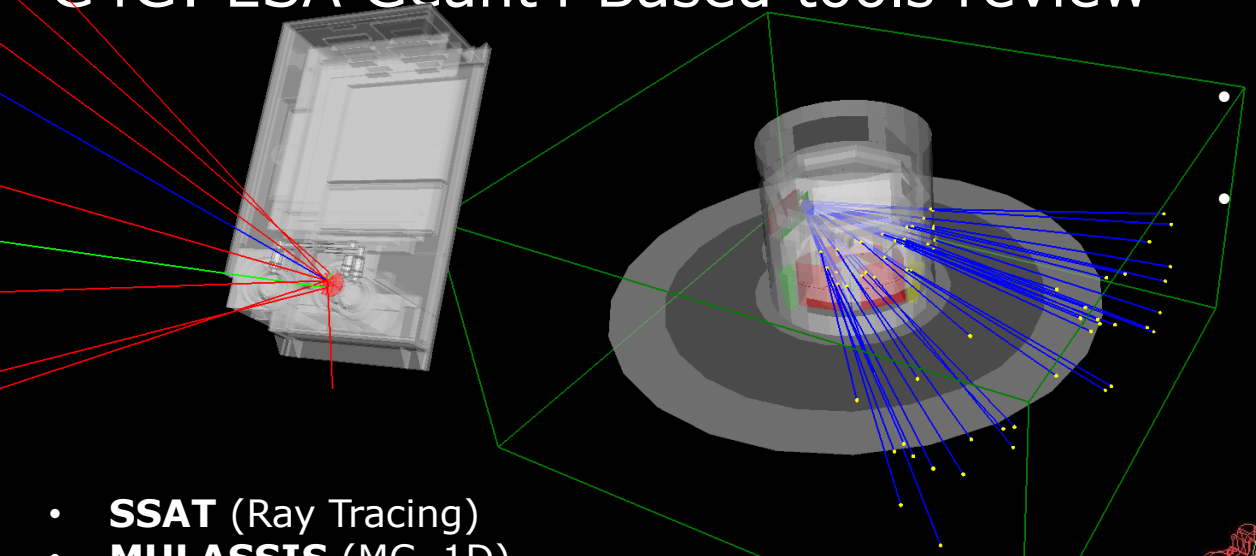
Main tasks:

REVIEW of existing Geant4 ESA developments

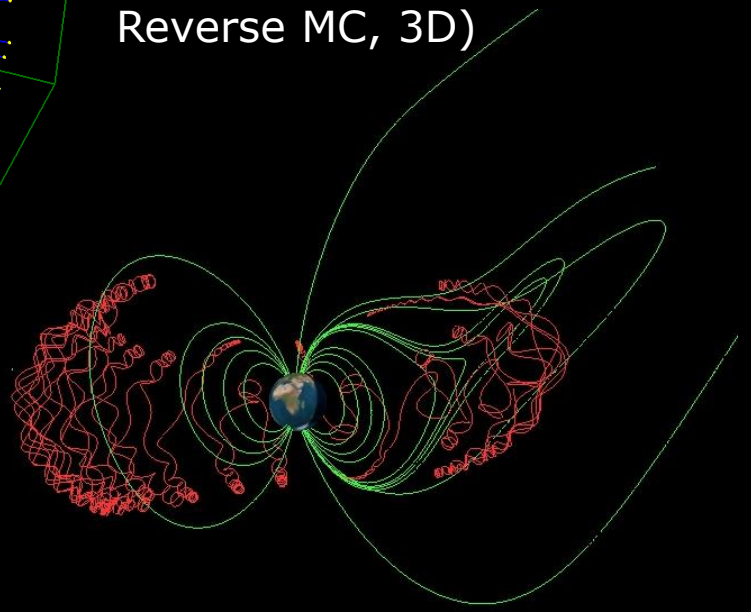
- Analysis and Improvement of Particle Transport and Effects Models for Electromagnetic Interactions
- Review of Particle Transport and Effects of Models for Hadronic Interactions

- ESA Geant4 tools general improvements and new implementation (GRAS, etc.)
- Improvements and extension for Planetocosmics-J
- Reverse Monte-Carlo improvements and validation for simulation speed-up
- ATHENA, JUICE and LISA related radiation analyses and tools development
- New Geant4 applications for SPENVIS
- New advanced examples for the Geant4

G4G: ESA Geant4 Based tools review



- **Geant4**: 20+ year in the collaboration
- **GRAS** (Forward and Reverse MC, 3D)



- **SSAT** (Ray Tracing)
- **MULASSIS** (MC, 1D)
- **GEMAT** (Geant4-based Microdosimetry Tool)
- **MAGNETOCOSMICS** (magnetosphere simulations)
- **ATMOCOSMICS** (atmosphere simulations)
- **PLANETOCOSMICS-J** (Extension to planets and moons)

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

By L. Desorgher , PSI, CHUV

Summary and outlook

In the past years some significant but temporary cuts affected basic R&D. Nevertheless, all major ESA science missions continue to be major Geant4 users, through ESA developments or commercial tools

Several ongoing or planned Geant4 related activities :

- **Support to scientific missions**
- **Radiation monitor developments**
- **Shielding materials**
- **Geant4 based tools review and improvement**
- **Geant4 physics models review development**
- **Future activity on new geometry editors are foreseen**

Young Graduate Trainee for Space Environment and Effects

Location
ESTEC, Noordwijk, The Netherlands

Our team and mission
The Space Environments and Effects Section supports the development of ESA missions and programmes by investigating the space environments within which they will operate, assessing likely effects and defining mitigation methods.

See its web page (http://space-env.esa.int) for more details.

Interested candidates are encouraged to visit the ESA website: http://www.esa.int

Field(s) of activities

- As part of this research, the Young Graduate Trainee will analyse radiation levels and effects in particular for planned human mission scenarios utilising available Geant4 frameworks and capabilities. Deficiencies in the existing codes shall be identified and solutions proposed.
- Young Graduate Trainee will evaluate and utilise these various European data sources, investigate and develop the different modelling approaches, and validate existing radiation environments and effects tools with in-flight data.

Thanks for your attention!

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