

ESA Geant4 R&D activities

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Space Environments
and Effects Section
European Space Agency
ESTEC

Geant4 Space Users' Workshop,
Hiroshima, 26 August 2015



European Space Agency

- ESA Programmes status and outlook 2015 on
- Main ESA missions where Geant4 is applied
- Geant4-based radiation engineering tools and models
- (Some) ongoing and planned R&D activities
- Outlook and Conclusions

ESA Programmes Outlook (in context of energetic particle interactions)



- Demanding Science missions
 - ✓ Rosetta, GAIA ongoing
 - ✓ In preparation: **JUICE**, **Athena**, **Solar Orbiter**, ExoMars, Cheops
 - ✓ **LISA Pathfinder to be launched by end of 2015**; BepiColombo in 2017
- Human missions:
 - ✓ ESA will construct service module for Orion (needs high immunity from radiation effects): **Airbus design selected in May 2014**
 - ✓ Preparation for missions beyond LEO (shielding, biological effects), **possibly Moon**
- Earth observation missions with considerable on-board processing (susceptibilities, especially **SEE**)
- Telecom and Navigation (Galileo) in highly severe outer radiation belt environment
- Technology spacecraft ("Proba" series), next **Proba-3**

Radiation Engineering tools: SPENVIS

<https://www.spenvvis.oma.be/>



- 10,000 + registered users
- Models and tools for the space environments effects analysis
- Web Interface
- A range of **Geant4-derived tools and models** (MULASSIS, SSAT, GEMAT,...)
- Link to GRAS
- Jupiter-related models and tools to target the JUICE mission under “JOREM”: JOSE environment, shielding assessment. **Now also Ganymede environment “GREET”**
- New **NIEL models** (INFN Milan) implemented to SPENVIS in 2015

**Next Generation SPENVIS**
ESTEC Contract No. 4000104812

| | |
|------------------|---|
| Consortium | The Space Environment Information System (SPENVIS) had been under continual development since 1996 for ESA by BIRA, providing the world community with an on-line resource for evaluating the space environment. SPENVIS-4 is a World Wide Web based interface to a comprehensive set of models of the space environment. It has been operational for more than ten years now and has a mature international user community of about 2000 registered users who use the system for various purposes, e.g. mission analysis and planning, educational support, and running models for scientific applications. |
| Contact | |
| Public documents | Within the ESA/GSTP-5 programme, funding has been provided for the development of a next generation of this resource. The informatics technology available today has evolved considerably from what was state of the art in 1995, where web servers were limited to basic html pages and cgi-scripts. Within the scope of this development the framework and models of the SPENVIS system will be reviewed, restructured and reengineered using current web design techniques and programming methodologies, providing a new, extensible and open framework for the integration of current and future space environment models. |
| Links | Distributed architectures for space data analysis and collaborative engineering have been investigated through several ESA activities (SAAPS, SEDAT, VISPLANET, SEPEN, REST-SIM) from which potential requirements and solutions for the SPENVIS-5 project may emerge. The advantages of a distributed approach are that the resources are acquired, developed and maintained at an "expert centre" where the competences and necessary supporting facilities reside and are available as needed by a "coordination node" in response to end-user needs and in compliance with any access restrictions that may apply. The new system is foreseen to be operated in the context of ESA's SSA programme. |

Consortium

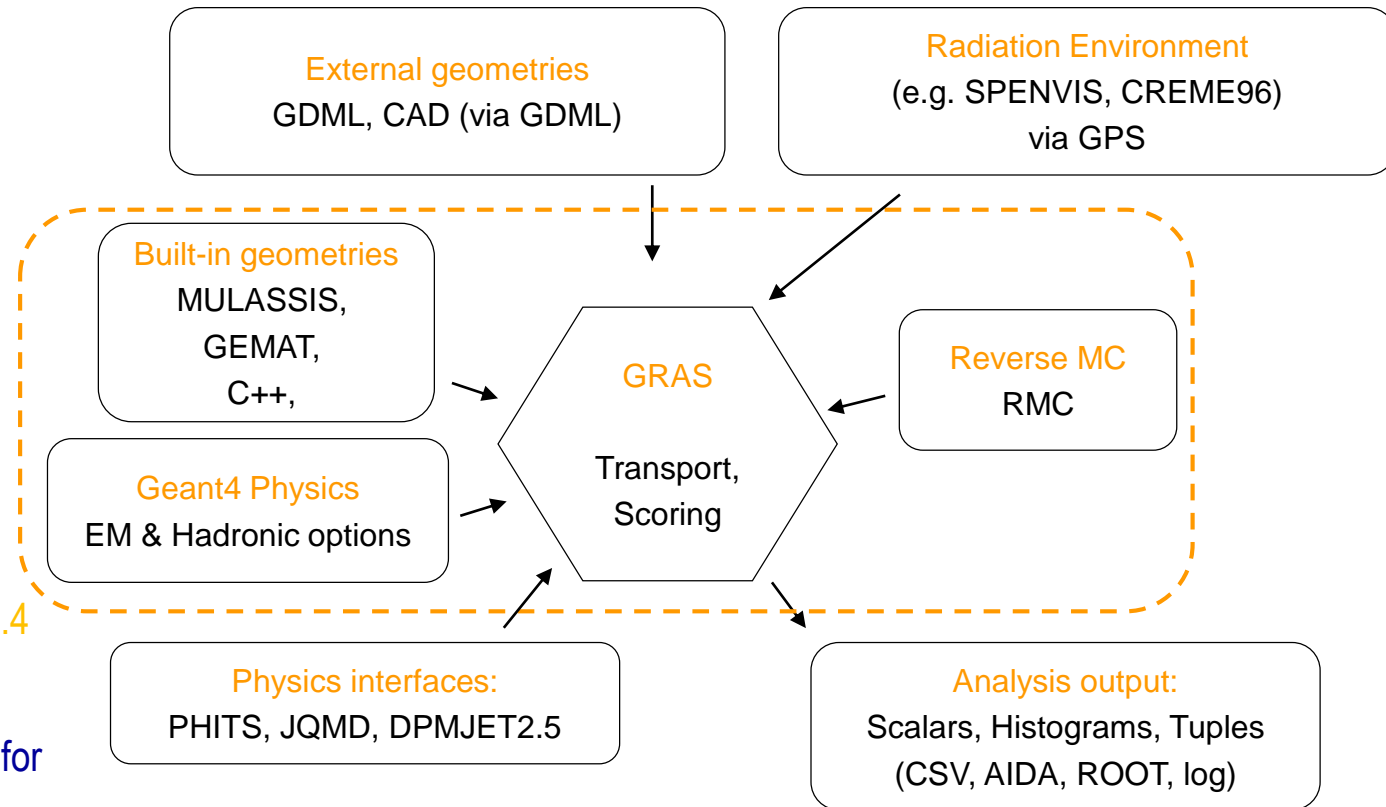

Under development: Next Generation of the system “(“SPENVIS-NG”), **to be deployed in 2015**

Geant4 tool integration: GRAS

(Geant4 Radiation Analysis for Space)



- Ready-To-Use tool
Multi-mission approach
- Quick assessments
Ray-tracing ↔ MC
1D ↔ 3D
EM ↔ Hadronics
LET ↔ SV details
- Modular progress
Open to collaborations and contributions
- Currently GRAS v3.3, v.3.4
in preparation 2015-2016
- Increasingly the baseline for
much of ESA analyses
- **Reverse MC**: Substantial
effort by Laurent Desorgher
in 2014-2015



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>

<https://www.spenvvis.oma.be/help/models/gras.html>

ESA Cosmic Vision M-class mission Solar Orbiter



- Examine how the Sun controls the heliosphere
- Launch planned for October 2018; mission of 7 years (+3 years extended)
- High-latitude ($>25^\circ$) observations between 0.28 and 0.94 AU
- Combination of remote sensing and in situ observations, with 10 instruments
- Highly demanding mission environment
- Various Geant4 instrument analyses

[Journal of Instrumentation](#) > Volume 10 > February 2015

O. Grimm et al 2015 *JINST* **10** C02011 doi:10.1088/1748-0221/10/02/C02011

Performance and qualification of CdTe pixel detectors for the Spectrometer/Telescope for Imaging X-rays

7TH INTERNATIONAL WORKSHOP ON SEMICONDUCTOR PIXEL DETECTORS FOR PARTICLES AND IMAGING

O. Grimm^{a,d}, M. Bednarzik^b, G. Birrer^b, N. Arnold^d, V. Commichau^d, G. Hurfurd^d, S. Krucker^d, O. Limousin^c and A. Meuris^c

[Show affiliations](#)



11. Juni 2013
11. Juni 2013

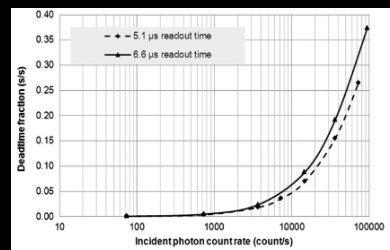
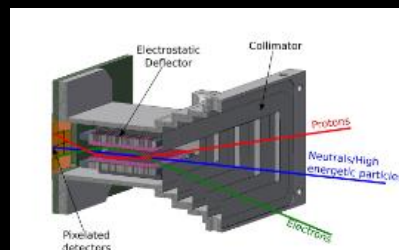
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Christian-Albrechts-Universität zu Kiel
Mathematisch-naturwissenschaftliche Fakultät
EAP
Extraterrestrische Physik

The SupraThermal Electrons, Ions and Neutrals (STEIN) detector for Solar Orbiter

Christoph Terasa^a for the Solar Orbiter STEIN team^a, Robert P. Lin^b, Dong-Hun Lee^c, Ho Jin^d, Olivier Limousin^d

^a Christian-Albrechts-Universität, Kiel, Germany; ^b Space Sciences Laboratory, University of California, Berkeley, CA, United States; ^c Kyung Hee University, Yongsu, Seongnam, Republic of Korea; ^d CEA Saclay, DSM/IRAP/SP-1913, Gif-sur-Yvette, France



Dissertation (Metadaten)

Titel (original): Developments and Numerical Simulations for the Electron-Proton-Telescope Onboard Solar Orbiter
(übersetzt): Vorarbeiten und numerische Simulationen für das Electron-Proton-Teleskop an Bord von Solar Orbiter

Autor: Rolf Paspigilis

URN:NBN: urn:nbn:de:gbv:8-diss-104689

Fakultät: Mathematisch-Naturwissenschaftliche Fakultät
DDC Sachgebiet: 530 Physik

Caliste-SO X-ray micro-camera for the STIX instrument on-board Solar Orbiter space mission

A. Meuris^a, G. Hurfurd^d, M. Bednarzik^b, O. Limousin^a, O. Gevin^a, I. Le Mer^a, J. Martignac^a, B. Horeau^a, O. Grimm^d, R. Resanovic^c, S. Krucker^d, P. Orleński^d

[Show more](#)

EP 4.42: Poster

Dienstag, 26. Februar 2013, 11:15-12:45, Poster OG

Auswahlstatus für diesen Beitrag:

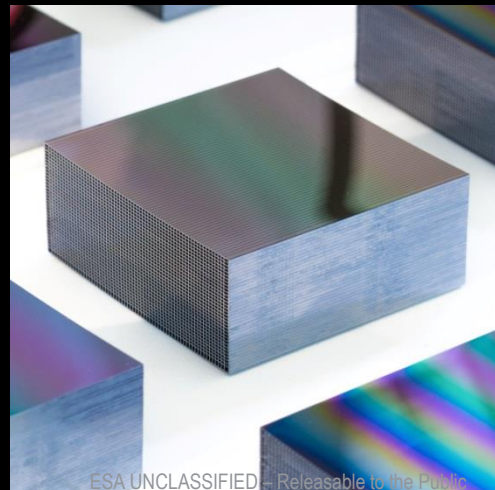
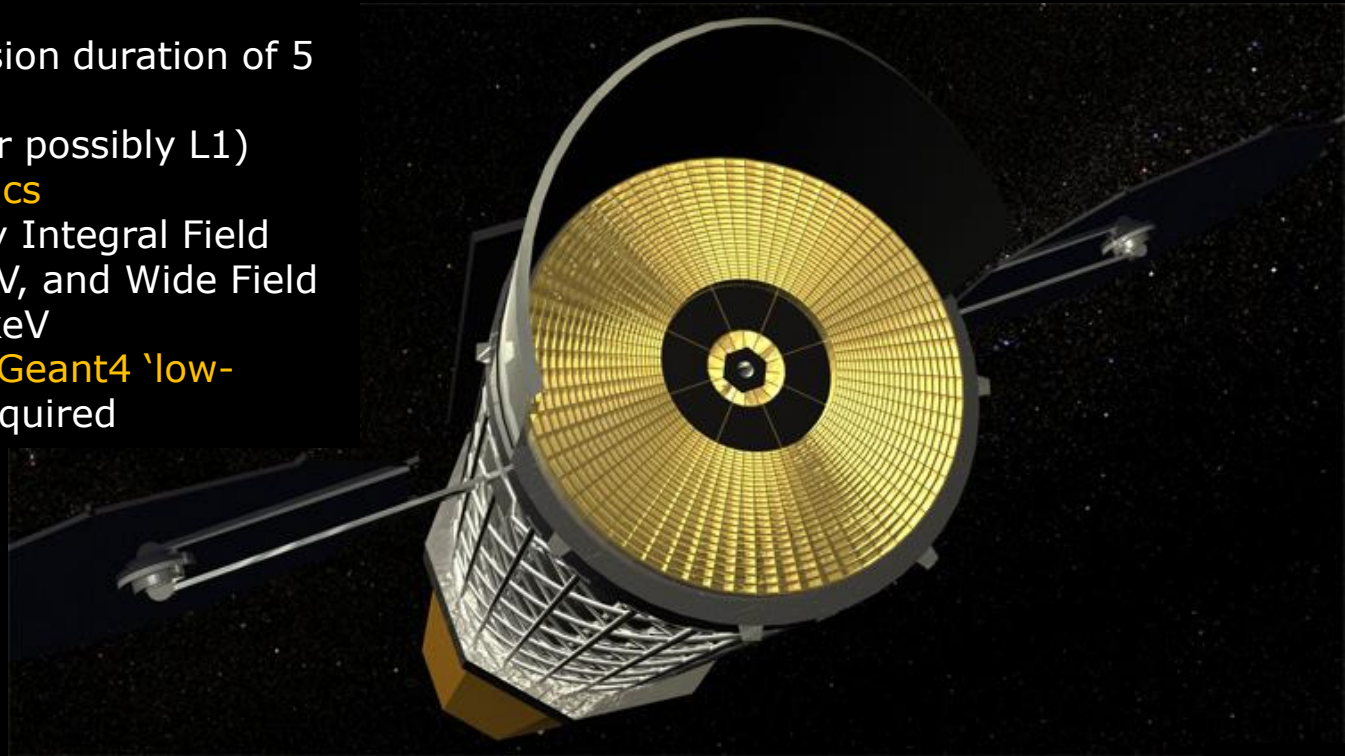
Scintillation quenching in BGO crystal of the Solar Orbiter HET – J. GRUNAU, S.R. KULKARNI, C. MARTIN, S. BOETTCHER, L. SEIMETZ, B. SCHUSTER, A. KULEKZIN, and R.F. WIMMER-SCHWEINGRUBER – IEAP, Christian-Albrechts-Universität zu Kiel, Germany

The High-Energy Telescope (HET) on ESA's Solar Orbiter mission will measure electrons from 300 keV up to about 30 MeV, protons from 10 to 100 MeV and heavy ions from approximately 20 to 200 MeV/nuc. These measurement capabilities are reached by a combination of solid-state tracking detectors and a scintillator calorimeter. This setup can perform particle identification via the dE/dx vs total E technique. The scintillator approach provides a good resolution over the complete energy range but the total energy deposition has to be corrected for the scintillation quenching. The quenching lowers light output depending on the type and energy of the incident particle. We measured the crystal response for different heavy ions and energies and compared them to simulated values. Simulations were carried out using the GEANT4 toolkit provided by CERN. From comparison of simulated and measured data we were able to calculate quenching factors for the BGO crystals for ions up to iron. The results are of great interest for later data analysis with the HET telescope.

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)
- Utilises **silicon pore optics**
- Two instruments: X-Ray Integral Field Unit (X-IFU), 0.3-10 keV, and Wide Field Imager (WFI), 0.1-12 keV
- Radiation background: **Geant4 'low-energy' e.m. physics** required



- Athena Radiation Environment Models and Effects Simulators (AREMBES): ITT closing on 25.9.2015
- Other R&D with Geant4 context in planning

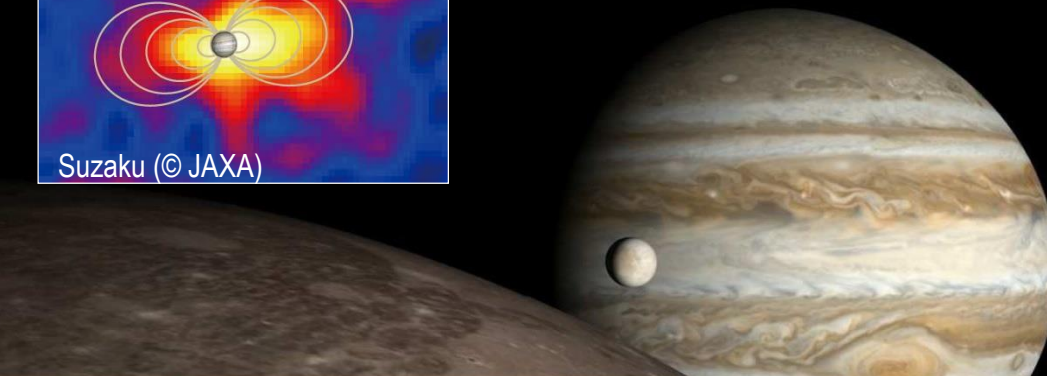
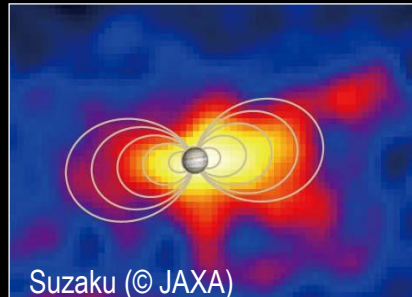
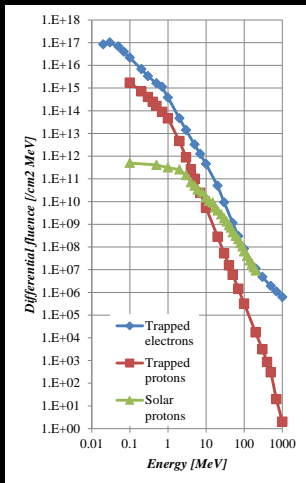
ESA Cosmic Vision L-Class mission JUICE (Jupiter ICy moons Explorer)



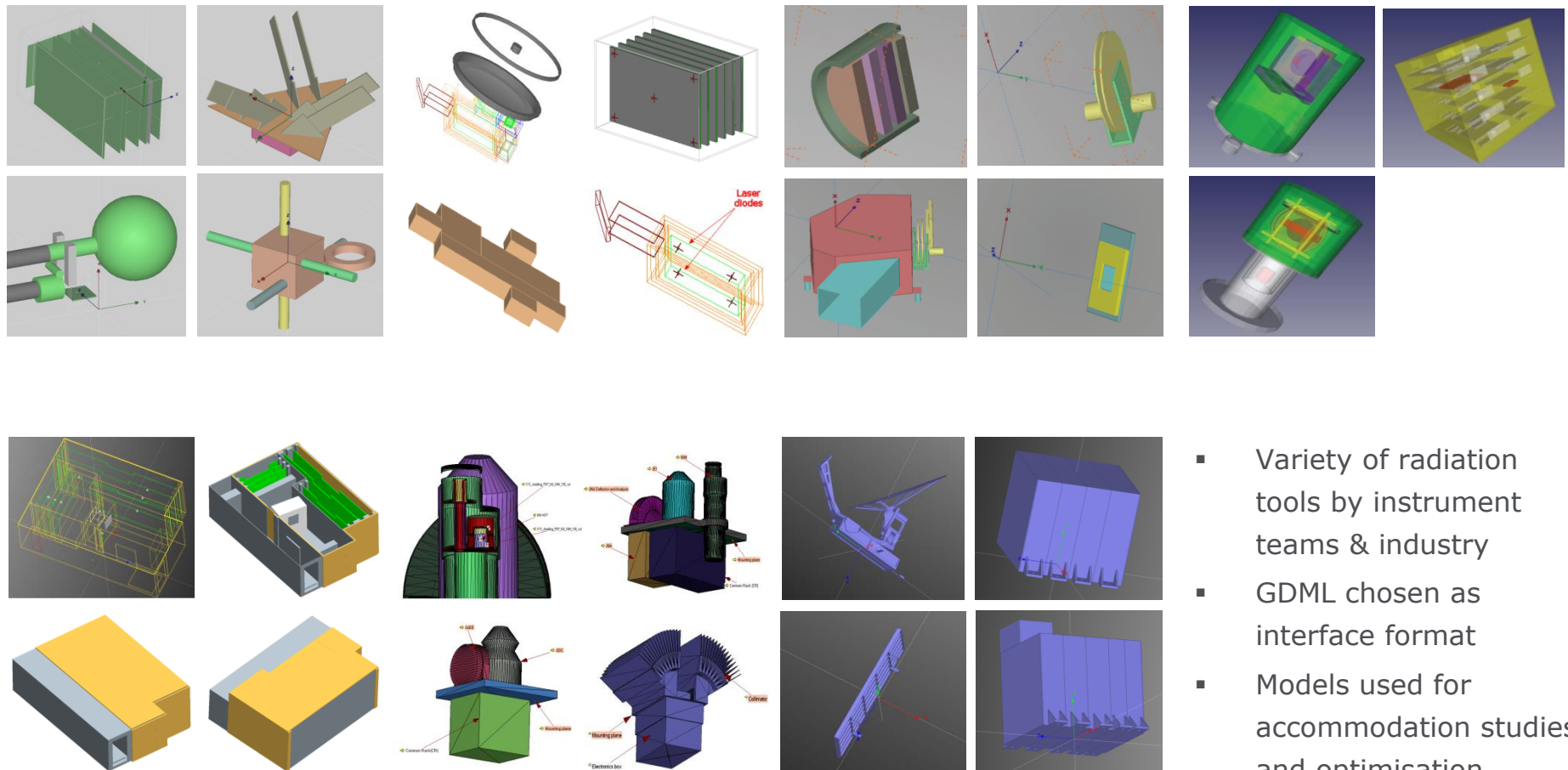
- Launch planned for 2022, arrival 2030
- **Prime (Airbus) selected** 17 July 2015
- 11 science instruments to be flown:
<http://sci.esa.int/juice/50073-science-payload/>
- Japanese and US collaborations
- Giant Jovian magnetosphere and e- radiation belts up to several tens of MeV; protons
- Substantial **shielding and background issues**
- Broad range of radiation analysis activities (TID, charging, DD, noise, SEE) for platform and instruments, including Geant4 and GRAS



(c) Airbus Defence and Space



JUICE Instrument radiation models (GDML)



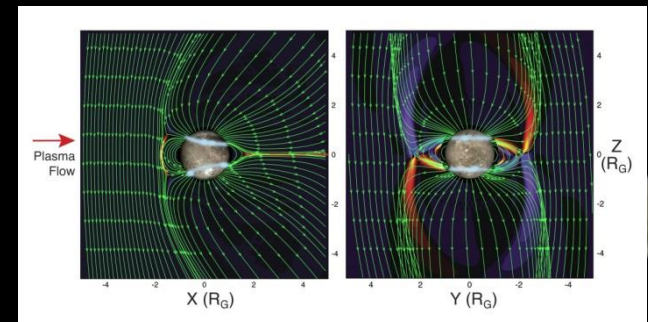
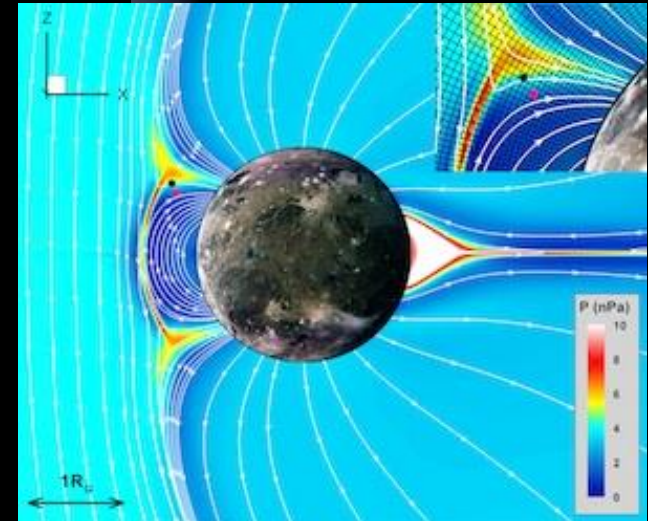
- Variety of radiation tools by instrument teams & industry
- GDML chosen as interface format
- Models used for accommodation studies and optimisation

<https://www.esa.int/ESA/missions/juice>

Ganymede



- Deep ocean
- Internal dynamo
- “Magnetosphere within a magnetosphere” → modification to local radiation environment
- PLANETOCOSMICS-J

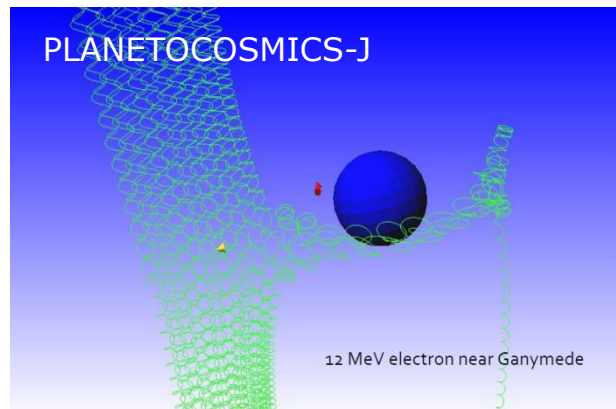
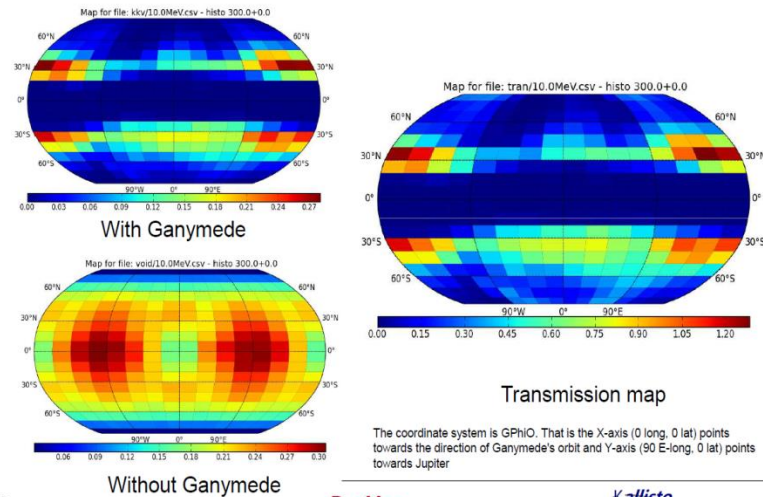


HST, April 9 2007

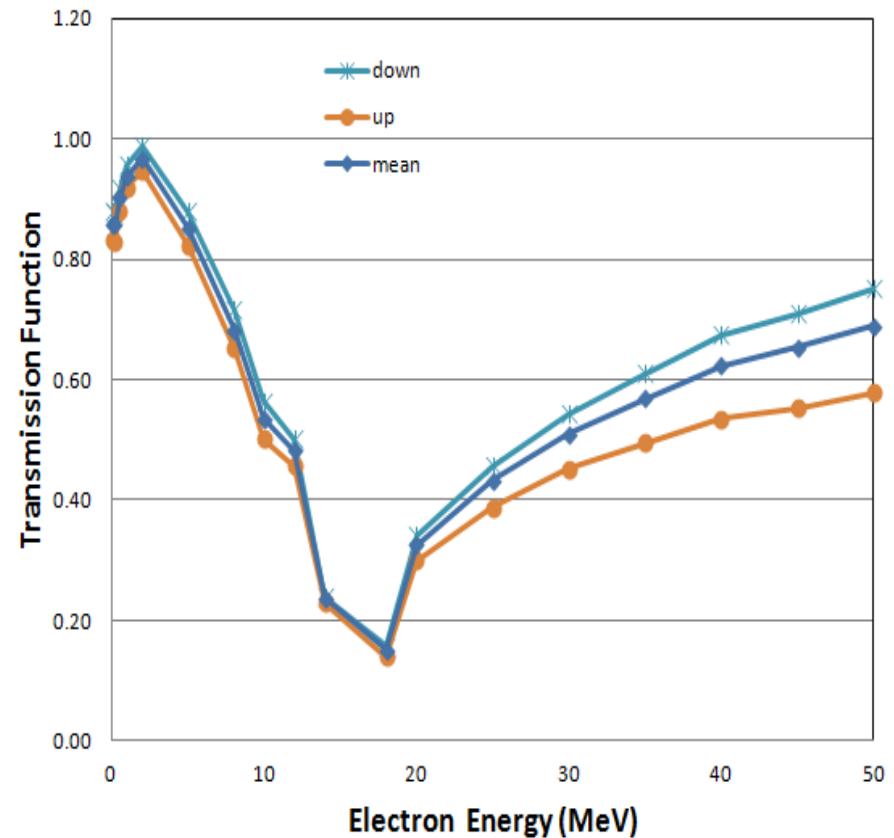
European Space Agency

Ganymede Radiation Environment Engineering Tool (GREET)

Transmission map calculation example



JUICE T-F for Ganymede orbiting Phase

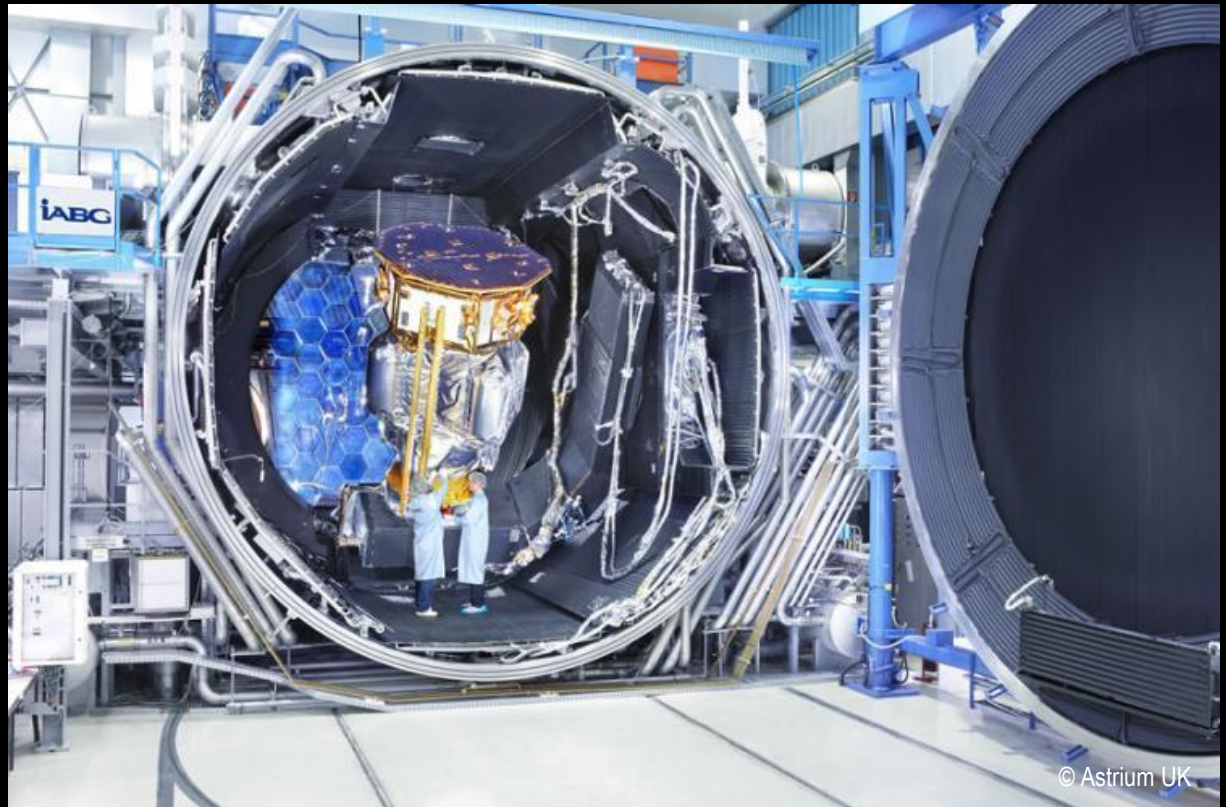
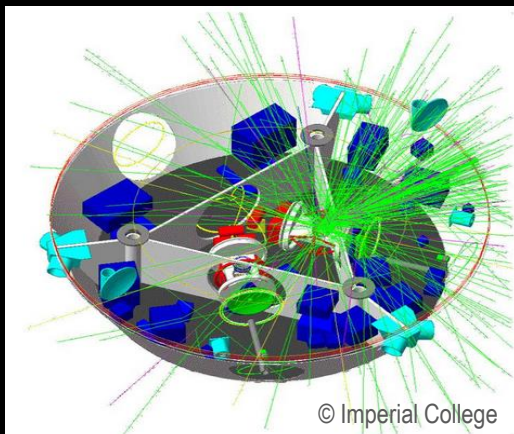


P. Truscott, D. Heyndericks, R. Nartallo, Fan Lei, A. Sicard-Piet, S. Bourdarie, J. Sorensen, L.Desorgher, "Application of PLANETOCOSMICS to Simulate the Radiation Environment at the Galilean Moons", Vol. 5, EPSC2010-808, 2010

LISA Pathfinder



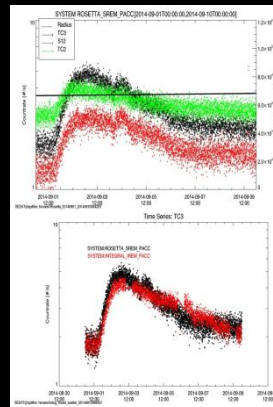
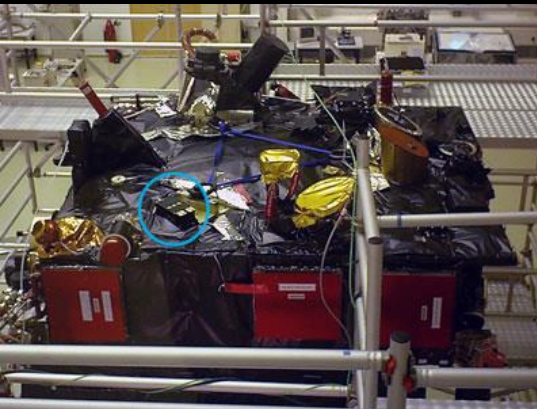
- Launch scheduled for **autumn 2015**
- Precursor to the potential ESA L3 mission (“**eLISA**”) for gravitational waves
- Highly sensitive gravitational proof mass technology
- Detailed **charging / radiation monitor simulations** by MC, including Geant4



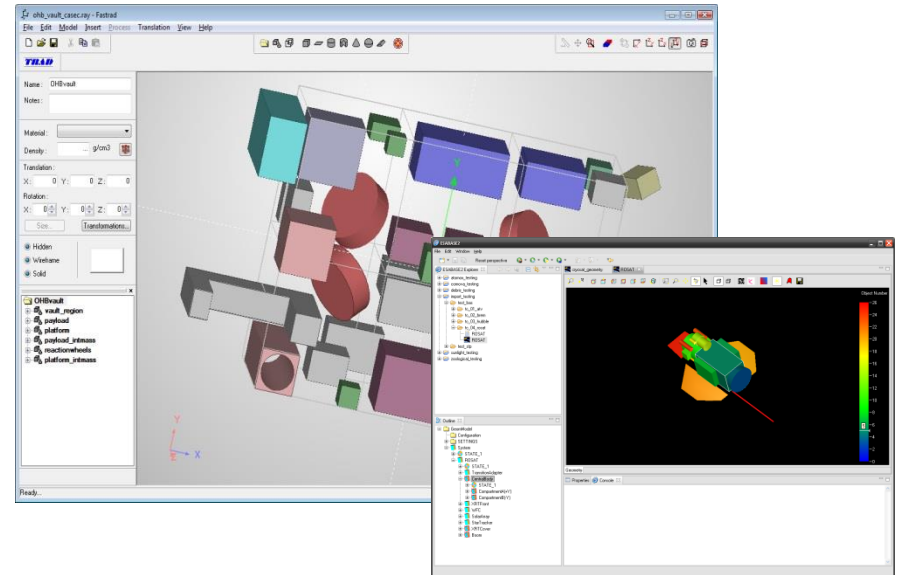
Rosetta



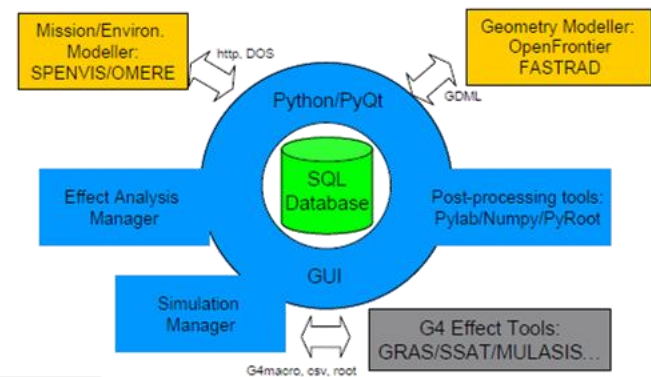
- **Perihelion** of Comet 67P/Churyumov–Gerasimenko on **13 August 2015**
- Some (minor) **SPEs** observed by the onboard SREM instrument
- SREM response functions obtained by Geant4



- Better interoperability of shielding analyses in **multi-partner projects** (e.g. JUICE)
- Mission specification and environment modeller based on REST-SIM reported in previous G4 SUWSs
- Integrated Modelling Environment
- Effects analysis tools
 - Internal charging (link also to ELSHIELD outcome)
 - **Geant4-based applications** (GRAS, FMC and RMC, SSAT, MULASSIS)
- Post-processing manager
 - Visualisation, plots
 - Response matrices / formulae / algorithms
- See the **dedicated presentation**



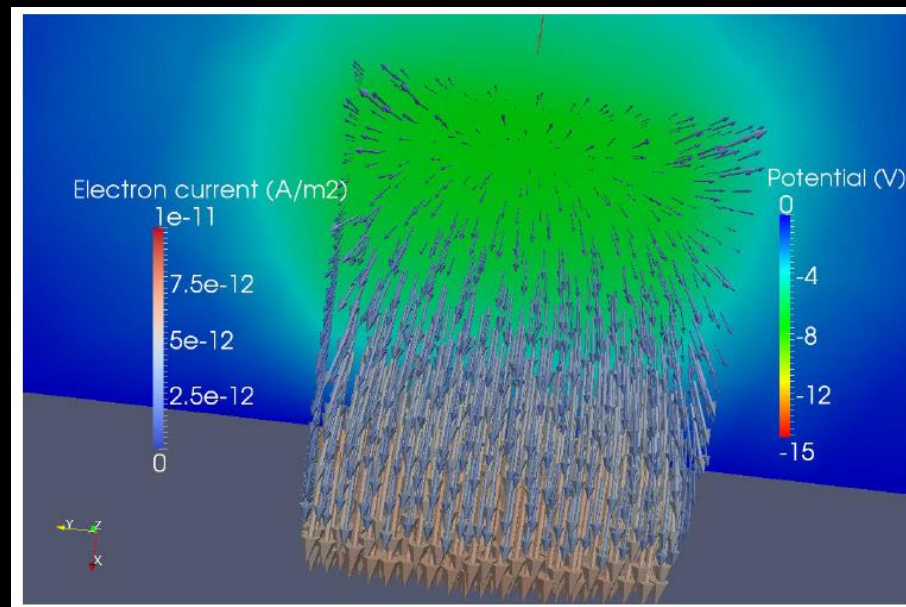
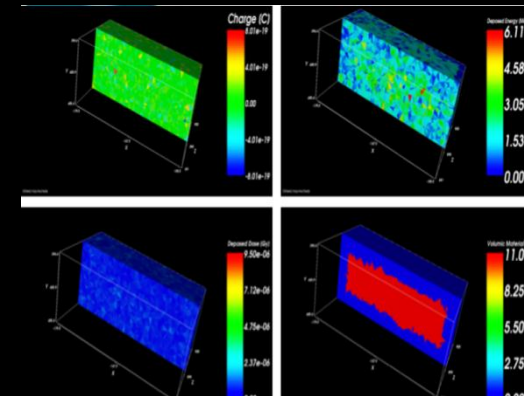
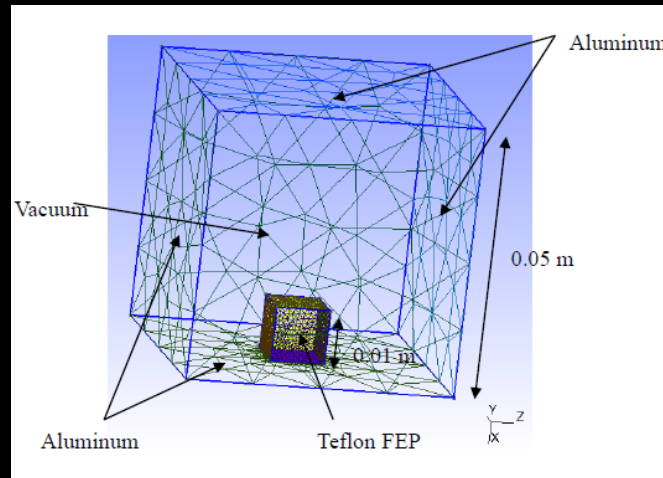
Simulation Framework



ELSHIELD 3D internal charging tool



- New 3D deep charging analysis capability, based on novel interfaces between CAD, SPENVIS, FASTRAD, Geant4 / GRAS particle transport, SPIS and circuit solvers
- Used as input to the 3D-MIX project (ONERA), to be completed in 2015

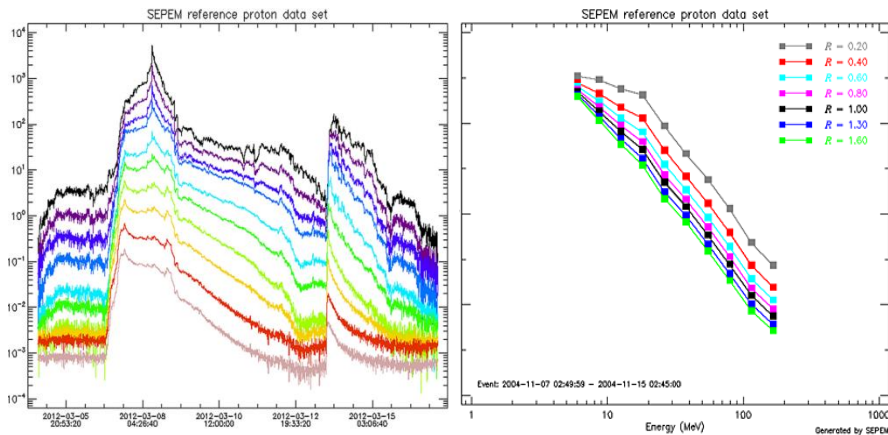


SEP-EM

Solar Energetic Particle Environment Modelling



- Cross-calibrated SEP data from 1973 to 2013
- New modelling tools, statistical and physical modelling techniques
- 1 AU + inner heliosphere from 0.2 to 1.6 AU
- Peak flux and integrated fluence statistics, but also durations of high SEP flux periods
- Geant4-based effects analysis tools:
 - MULASSIS for dose and shielded particle fluxes
 - GEMAT for SEU analysis



SEP-EM

Home

Data Access

Browsing & plotting

Data Table Manager

Copy

Data Processing

Median filtering

De-spiking

Gap filling

Manual cleaning

Energy re-binning

Cross-calibration

Event List Manager

Generate event lists

Event spectra

Effects tools

Mulassis geometry

Mulassis response function

SEU geometry

SEU response function

Build statistical models

Fluence and peak flux

Time above threshold

Event duration analysis

Use statistical models

Models at 1 AU

Away from 1 AU modelling

Event spectra

Fluence and peak flux

Login

Username:

Password:

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Welcome to ESA's Solar Energetic Particle Environment Modelling (SEP-EM) application server, a WWW interface to solar energetic particle data and a range of modelling tools and functionalities intended to support space mission design.

The system provides an implementation of several well known modelling methodologies, built on cleaned datasets. A large number of datasets have been combined into an SQL database for easy access. SEP-EM also gives the user increased flexibility in his/her analysis and allows generation of mission integrated fluence statistics, peak flux statistics and other functionalities. It also integrates effects tools that calculate single event upset rates and radiation doses for a variety of scenarios; the statistical methods can further be applied to these effects parameters.

Furthermore, SEP-EM makes use of a newly developed physics-based shock-and-particle model to simulate particle flux profiles of gradual SEP events from Mercury to Mars orbits (SOLPENCO2).

A contiguous reference proton data set was constructed using data ranging from 1973 to 2013, by means of data cleaning and processing tools available on the server. Using this dataset, a reference event list was constructed and also made available on the server.

An extensive set of help pages is available, including background material, information on the datasets and processing, and context sensitive help for each application page. Please consult the help pages before using the system!

Use of SEP-EM is free of charge, but registration is required and can be done from the homepage using the link at the bottom of the left-hand menu. For further information please contact **N. Crosby**. Please consult the **server usage** help page before registering for an account; registration implies acceptance of the terms and conditions outlined there.

Copyright

The European Space Agency remains the exclusive owner of all rights of the SEP-EM software.

All publications and presentations using data obtained from this site should properly acknowledge the service.

ESA Contract No: 20162/06/NL/JD
Project Manager: Norma B. Crosby
IT Development and Data Processing: Daniel Heynderickx
ESA Technical Officer: Piers Jiggins (formerly Alexi Glover)
ESA Technical Responsible: Alain Hilgers, **ESA Space Environments and Effects**
SEP-EM Team Members and Names of the Consortium

Background material

Overview

SEP events

Event lists

Statistical models

SOLPENCO2

SEP Effects

Geant4 effects tools

System help

Server usage

Site map

Context help

How to ...

Plot data

Edit model runs

Tips and tricks

Browser timeouts

Data information

Data sources

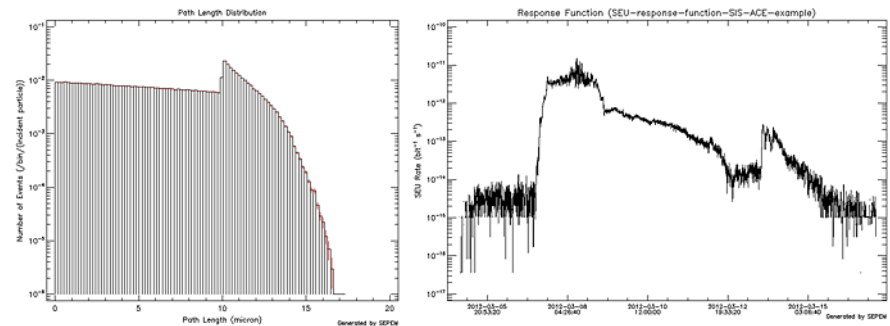
SEP-EM reference proton dataset

SEP-EM reference event list

Help page authors

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 N. Crosby,
 D. Heynderickx,
 P. Jiggins,
 B. Sanahuja,
 I. Sandberg,
 R. Truscott

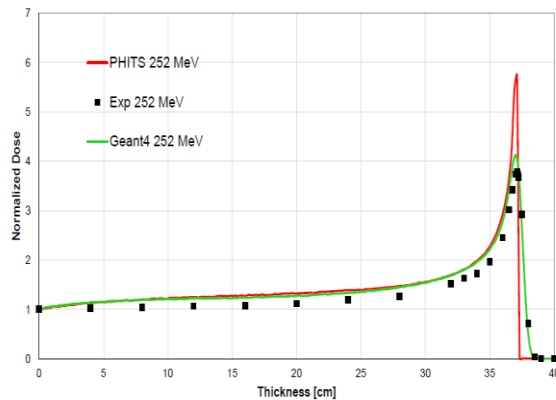
<http://dev.sepem.oma.be/>



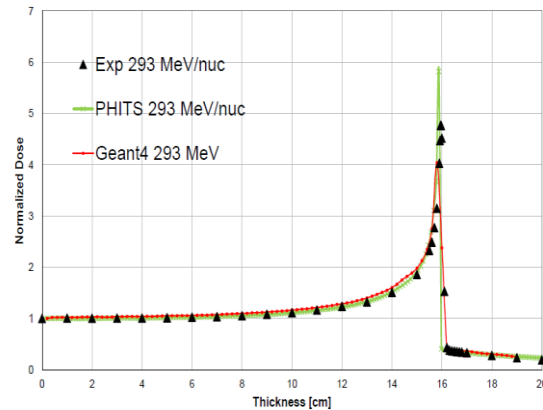
Radiation Shielding by ISRU and Innovative Materials for EVA, Vehicles and Habitats (ROSSINI2)



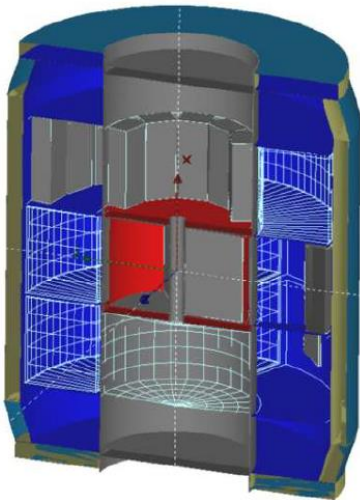
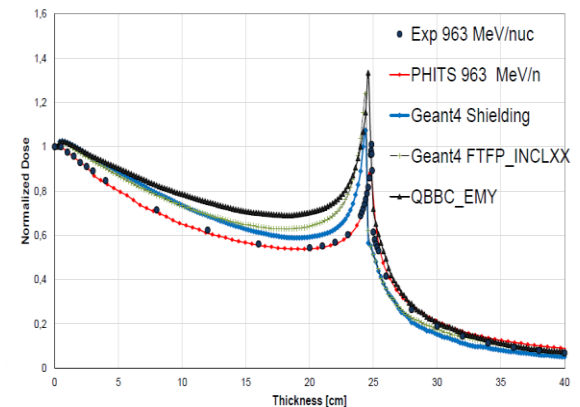
PHITS, Geant4 vs NSRL Experimental Data
H in HDPE



PHITS, Geant4 vs NSRL Experimental Data
 ^{12}C in HDPE



PHITS, Geant4 vs NSRL Experimental Data
 ^{56}Fe in HDPE



- TAS (Torino), GSI and INFN
- Goal: Design, develop, build and test innovative passive shielding solutions to be adopted in future human exploration missions
- High-Z, high-energy particles: GSI closure impacts the project; other facilities are sought (GSI discussions e.g. with NASA NSRL)
- Simulation framework developed based on Geant4 and PHITS – some discrepancies between the codes investigated
- Evaluation of radiation doses absorbed in human tissue, given the particle species and energy spectra observed behind the shields considered
- Design of eventual shielded refuges on lunar/planetary surfaces, habitats and deep space missions, starting in 2016

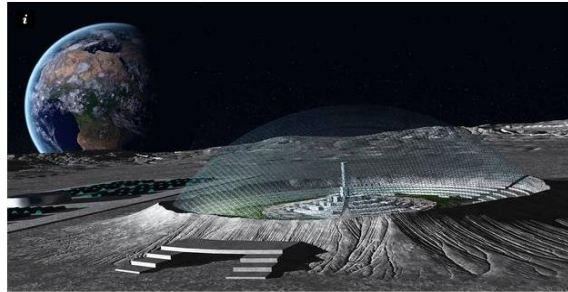
Long-term (2024 →) future: “Moon village” ?



THE INDEPENDENT Tuesday 14 July 2015

News > World > Europe Frontpage >

The new director of the ESA wants to build a village on the Moon



'I propose a Moon village on the far side of the Moon'

BBC

future

Home Tech Science Health Columns

DISCOVER: The Genius Behind...
REINSPIRED BY: World-Changing Ideas



Should we build a village on the Moon?

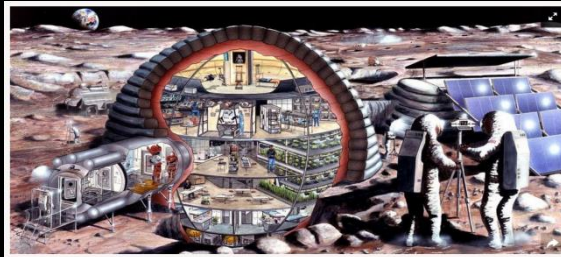
The new head of the European Space Agency has a plan – for humanity to build a 'village on the Moon'. Richard Hollingham asks him why.

Popular Mechanics

JUL 11, 2015 @ 2:03 PM

Europe's Space Chief: Let's Build a Moon Village

Humanity can, should, must, and will settle on the far side of the moon.



Jan Wörner, ESA Director General.

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News & Comment | News | Q&A | 2015 | August | Article

NATURE | NEWS: Q&A

Moon village would host first class research

Europe's new space chief Johann-Dietrich Wörner explains his lunar ambitions.

Elizabeth Gibney

- ESA Large-class Science missions JUICE and ATHENA are major Geant4 tool, model and application customers at ESA. For ATHENA simulator, dedicated WP for low-E e.m. physics updates
- Planned call for L3 mission (“Gravitational Universe”) concepts in 2016
- Other Science missions (e.g. Solar Orbiter) also face radiation issues
- Human spaceflight beyond the ISS? Shielding of the lunar radiation environment, Geant4-DNA
- Continued importance of easy-to-use and rapid tools (e.g. reverse MC, GRAS, SPENVIS(-NG), SEPTEM Web-based applications, SEE models and tools) for spacecraft and instrument development
- Radiation instruments and Geant4: See separate presentation
- Some personnel changes and challenges created

THANK YOU