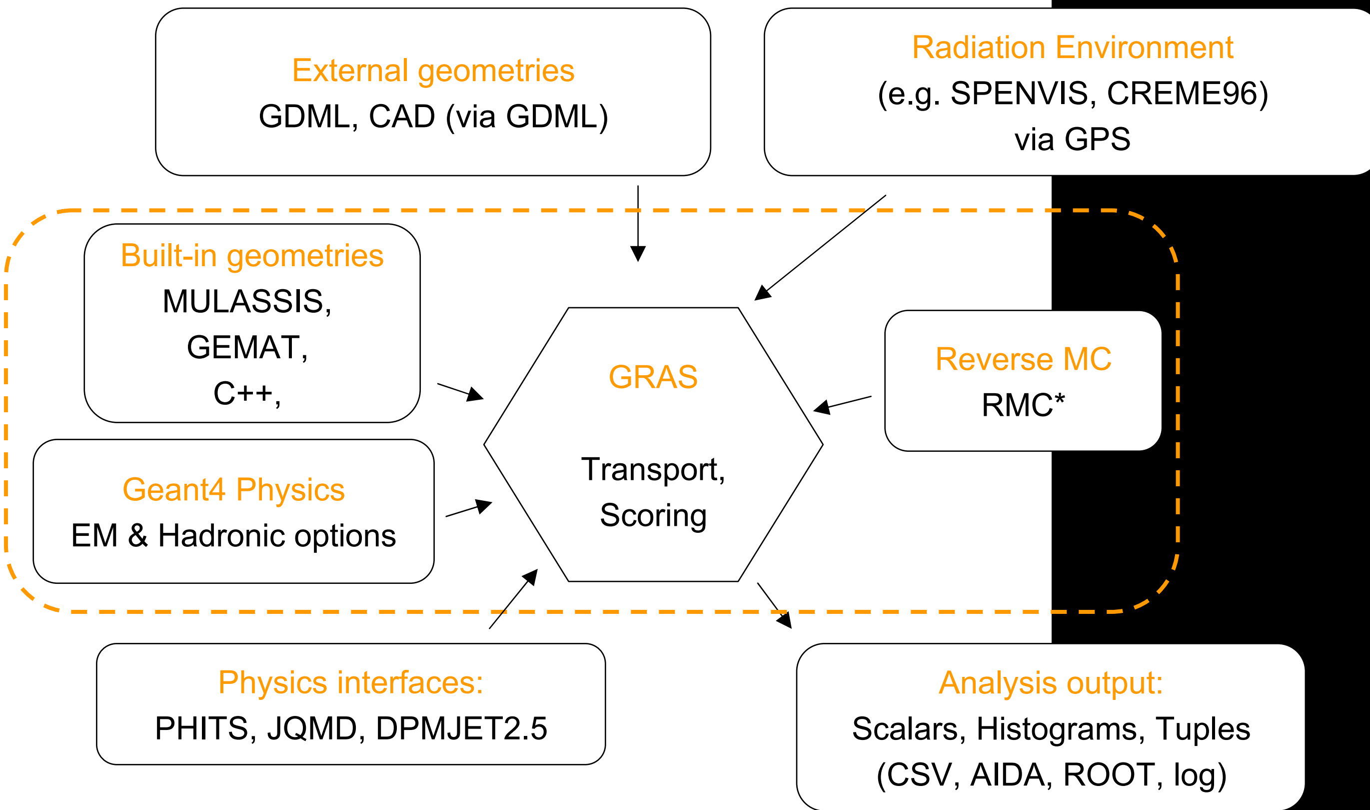
Geant4 Radiation Analysis for Space

GRAS – Motivation

- Widening of Geant4 application domain → multiplication of tools
  - Offer framework for coordinated extension and development
- Issues to address on geometry and transport
  - Ray-tracing VS MC
  - 1D VS 3D
  - EM VS EM+Hadronics
  - LET approach VS Actual energy deposition in microvolumes
- Analysis
  - Common tallies for standard support to engineering and scientific design
  - Human dosimetry for ESA exploration initiative
  - More detailed analysis for in depth studies
- Ready-To-Use tool
  - “Multi-mission” approach
  - Different analyses and geometries set without re-compilation
  - Integrated into SPENVIS

Santin et al, IEEE Trans. Nucl. Sci. 52, 2005

GRAS



Requirements:

- Ready-To-Use tool
  - Multi-mission approach
- Quick assessments
  - Ray-tracing ↔ MC
  - 1D ↔ 3D
  - EM ↔ Hadronics
  - LET ↔ SV details

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

** in progress*

GRAS: script driven

Santin et al, RADECS, 2005

Geometry

1

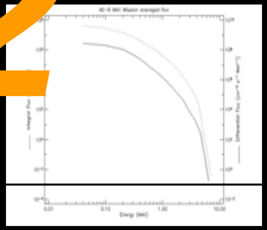
Parameters for
built-in geometries
or
External files

```
/gras/geometry/type gdml
/gdml/file geometry/conexpress.gdml
```

Source

2

RADIATION
ENVIRONMENT



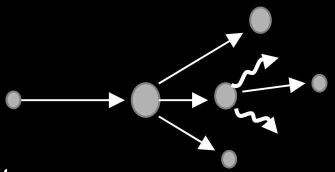
```
/gps/pos/type Surface
/gps/pos/shape Sphere
...
/gps/ang/type cos
/gps/particle e-

...
```

Physics

3

Physics lists

or single components

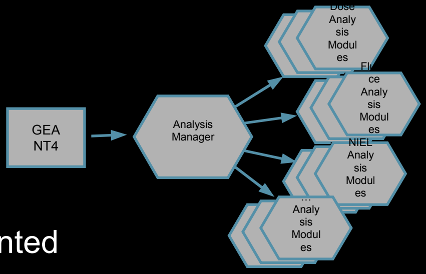


```
/gras/phys/addPhysics em_standard_opt3
/gras/phys/addPhysics QGSP_BIC_HP
/gras/phys/addPhysics raddecay

/gras/physics/setCuts 0.1 mm
/gras/physics/stepMax 0.01 mm
```

Analysis

4

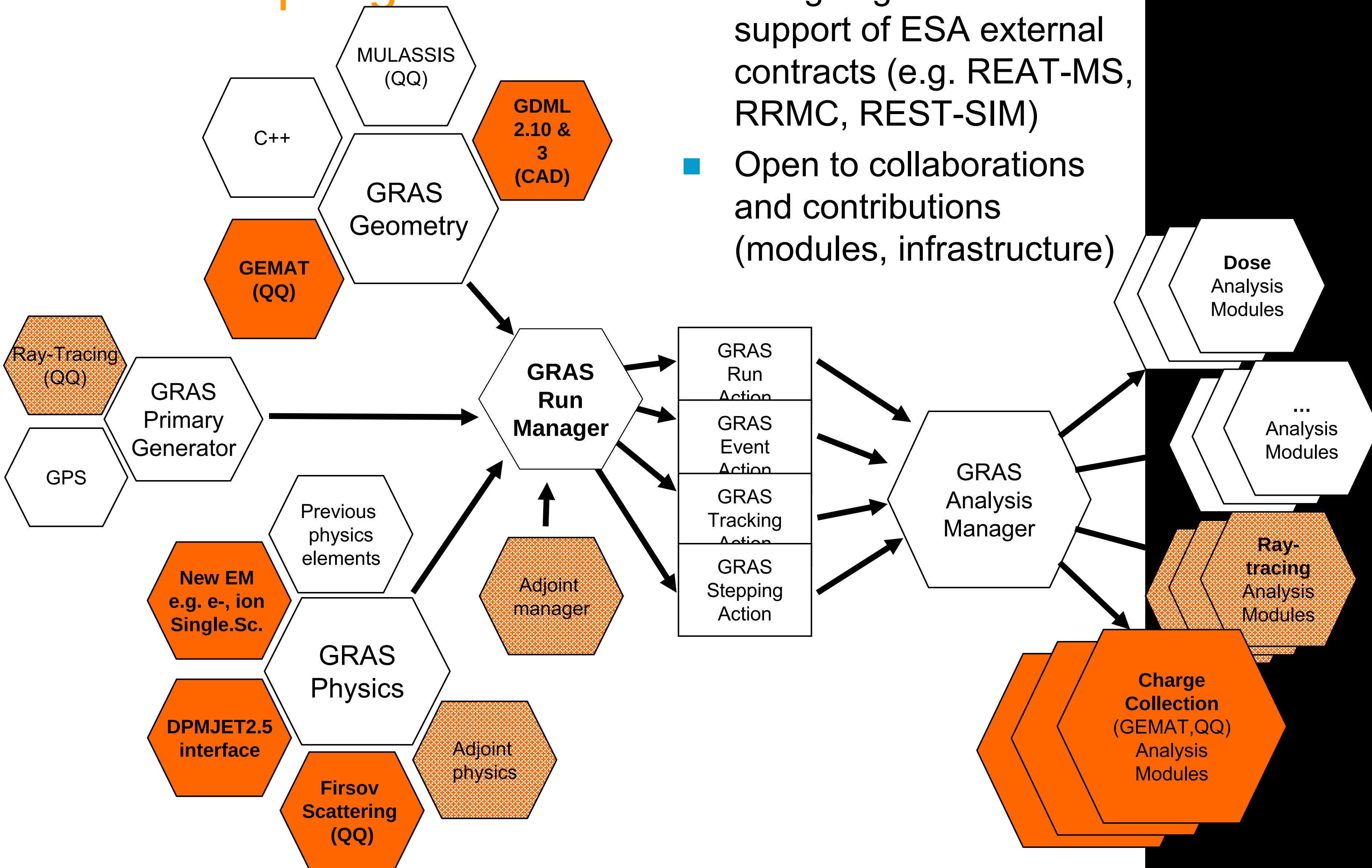
Object Oriented
scripting



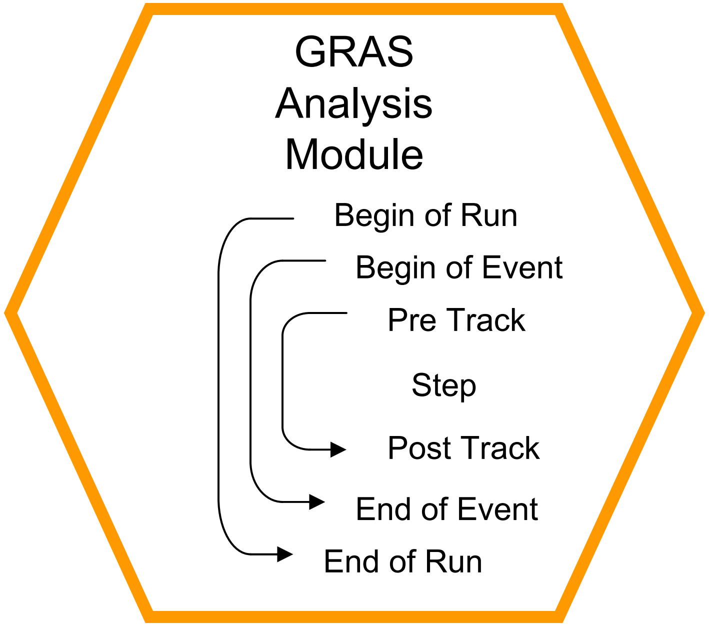

```
/gras/analysis/dose/addModule doseB12
/gras/analysis/dose/doseB12/addVolume b1
/gras/analysis/dose/doseB12/addVolume b2
/gras/analysis/dose/doseB12/setUnit rad
```

GRAS (v2.4) Modular progress

- ESA facility
- Being augmented with support of ESA external contracts (e.g. REAT-MS, RRMC, REST-SIM)
- Open to collaborations and contributions (modules, infrastructure)



Analysis Module "How-To"

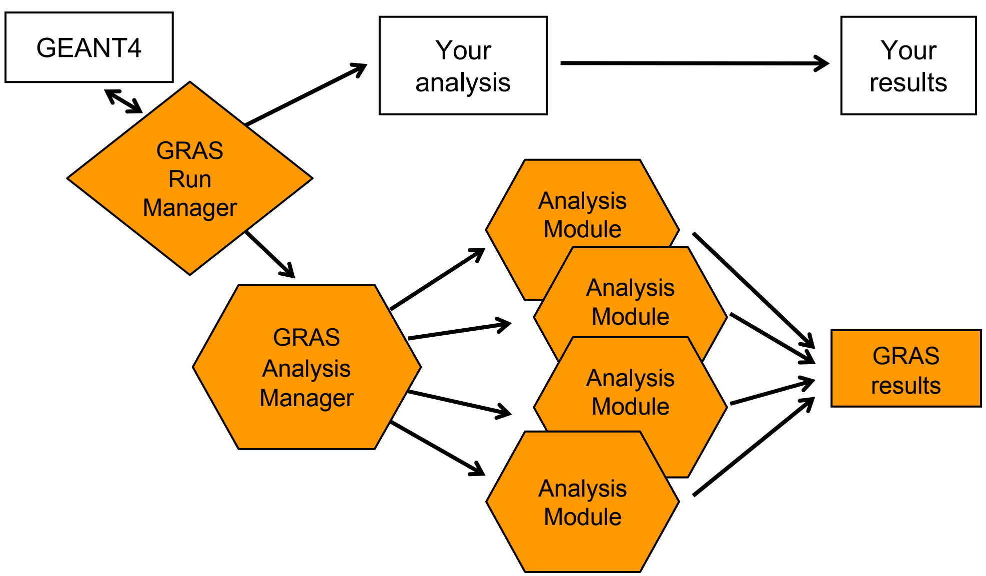


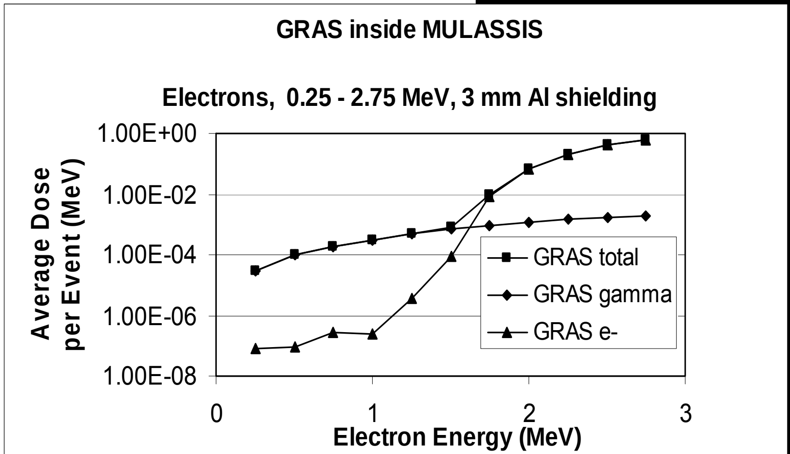
- Easy to implement:
  Self contained analysis element
  - Initialization, event processing, normalization, printout
- Only one class to create/derive in case a new type of analysis is needed
  - No need to modify Run+Event+Tracking+Stepping actions
- AIDA histogramming available "per module"
- G4 UI commands "per module"
  - Automatic module UI tree
  - *à la GATE*

```
/gras/analysis/dose/addModule doseCrystal
/gras/analysis/dose/doseCrystal/setUnit MeV
```

GRAS in existing applications

- 2 ways of adding GRAS output without discarding previous work
  A. Inserting C++ Geometry, Physics and/or Primary Generator classes inside GRAS
     - In the main gras.cc
  B. Inserting GRAS into your existing applications





R.Lindberg (ESA) IEEE-Trans Nucl Sci 53, 6 (2006)

GRAS Analysis modules:
Component degradation, background

- Total Ionizing Dose
  - Total accumulated dose
  - Also event Pulse Height Spectrum (signal in detectors / devices)
  - Also per “incident” particle type (with user choice of interface)
  - Units: MeV, rad, Gy

- Current / Fluence
  - Particle type, energy, direction, time, etc at surfaces
  - One/Both ways

- NIEL
  - Based on NIEL coeff.
  - Several curve sets available
    - CERN/ROSE (p, e-, n, pi)
    - SPENVIS/JPL (p)
    - Messenger Si (p, e-)
    - Messenger GaAs (p, e-)
  - Easy to add coeff. curves
  - Units: 95MeVmb, MeVcm2/g MeVcm2/mg, keVcm2/g

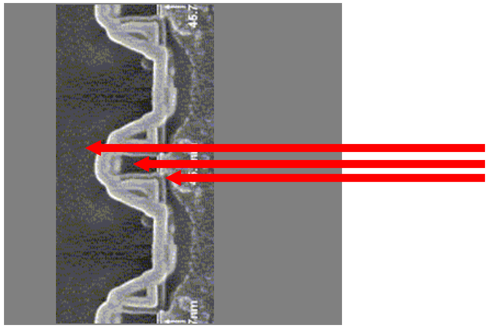
GRAS for component reliability

Ground testing aid, in-orbit prediction

- GEMAT charge collection analysis module (CCA)
- New accurate ion stopping power tables from ICRU73
- New ion straggling models and revised ionisation classes

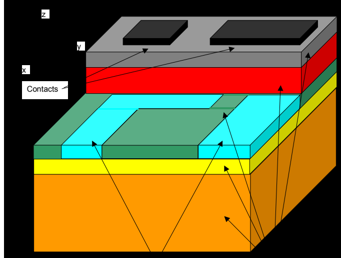
- LET
  - – Based on Geant4 dE/dx tables
  - – Computed at surface

- CCA (Charge Collection Analysis)
  - – QinetiQ development for GEMAT (ESA contract)
  - – Drift and diffusion parameterization
  - – Collection efficiencies for SV parts



Ongoing simulations of the ESA Standard SEU monitor

- Drift / diffusion contribution
- GRAS (A.Hedlund et al., ESA), GEMAT geometry, CCA analysis



GRAS Analysis modules:

Human Exploration Initiatives

GRAS Biological effects modules

- Dose equivalent
  - ICRP-60 and ICRP-92 LET-based coefficients
  - Units:
  - MeV, Sv, mSv, Gy, rad

- Equivalent Dose
  - ICRP-60 weights
  - User choice of weight interface
  - Units:
  - MeV, Sv, mSv, Gy, rad

GRAS used by G4-SESS

Space Environment Support System

SESS

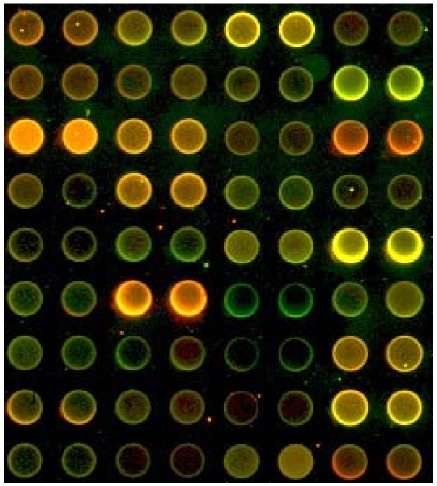
- Monitoring, analysis, warning
- Operators, project teams, development engineers and scientists
- "Space-Weather" application

G4SESS

- GRAS-based module (new GRAS module developed at INTA)
- Response matrix for radiation effects in sensors / electronics
- Near real-time computation based on external environment spectra
  - Python scripts (scipy, numpy) for GRAS data processing

- G4-SESS features
  - Multiplatform
  - Coded with Open Source Software
  - Modular structure
  - Geant4 and GRAS as radiation interaction and effects tools
  - Radiation effects data provider for SESS

GRAS for planetary exploration



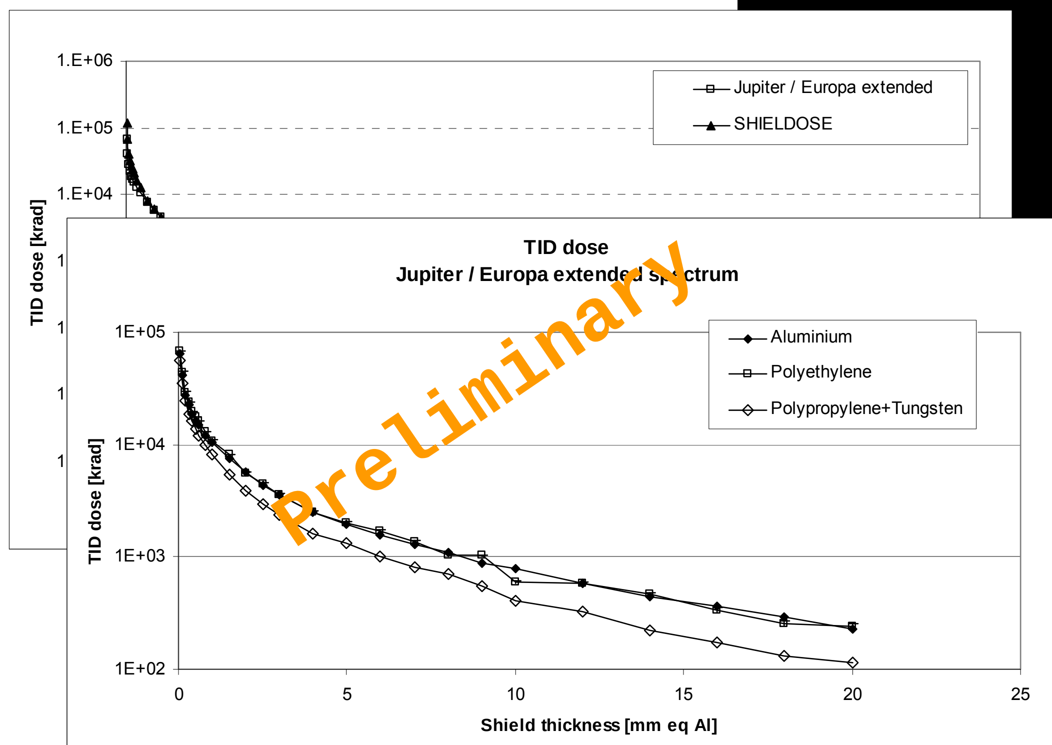
IRI - CNRS

Biochip development

LePostollec et al, Astrobiology. 2009

- Biological systems (ligands) to detect biomarkers
- Detection by fluorescence
- Radiation analysis for mission to Mars

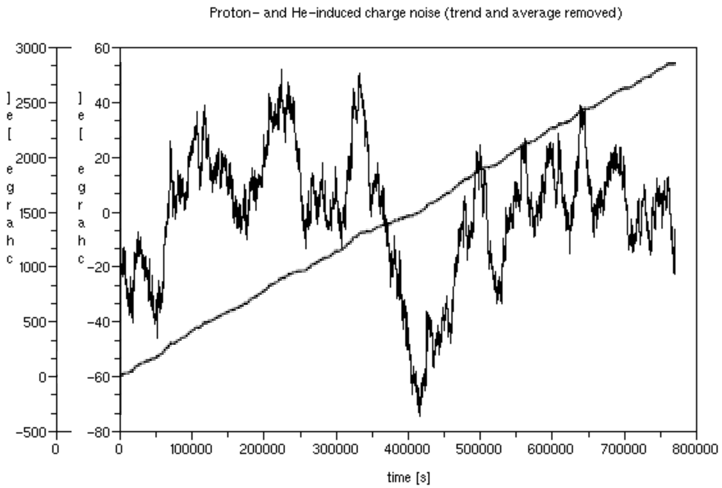
- Jupiter / Europa mission study
  - Internal ESA feasibility study
  - Divine-Garrett, GIRE and Salammbo-3D models

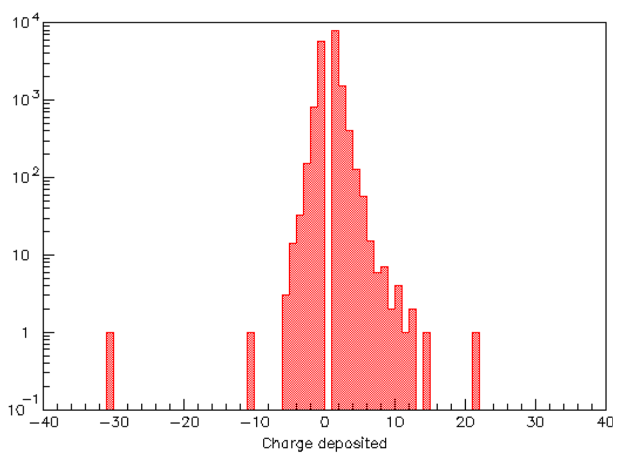


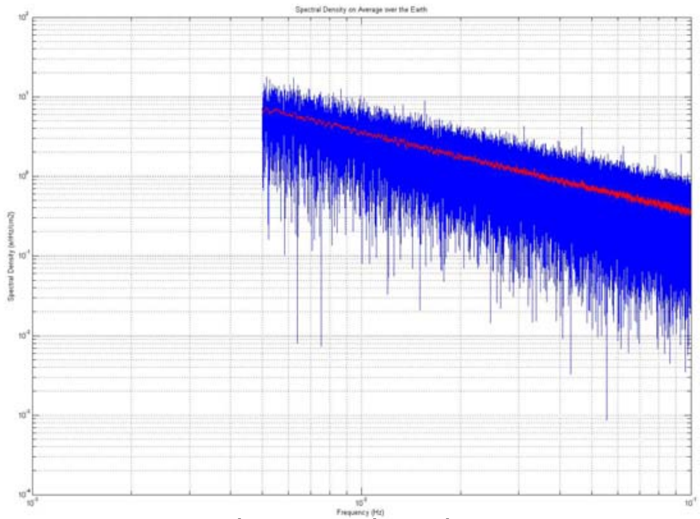
GRAS for GOCE

Gravity field
and steady-state Ocean Circulation Explorer

- Impact of electrode contact discontinuity on accelerometer performance
- Assessment of charging level and noise frequency content induced on the gold electrodes by cosmic-rays

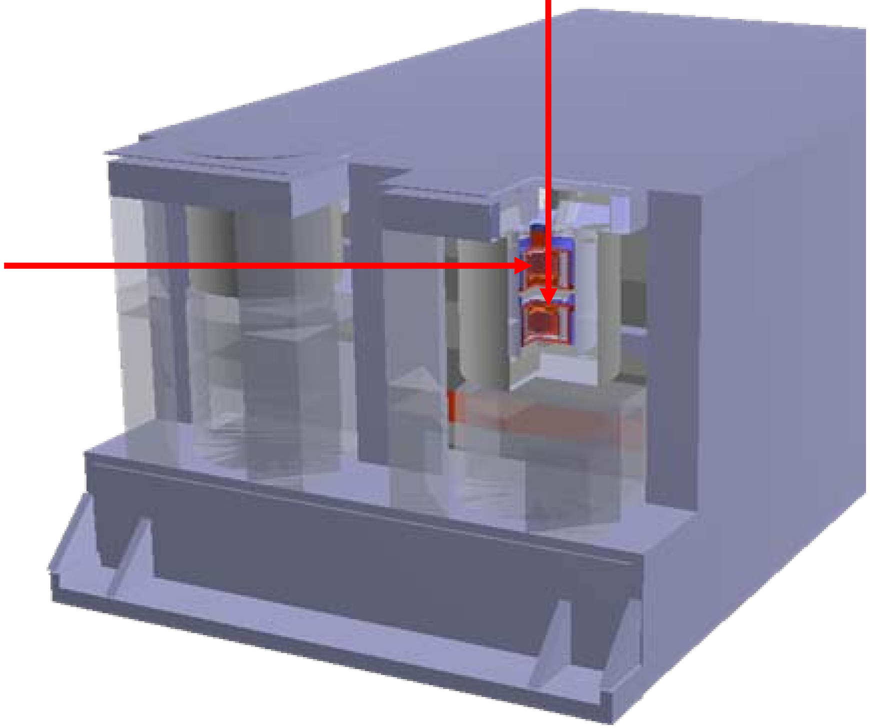


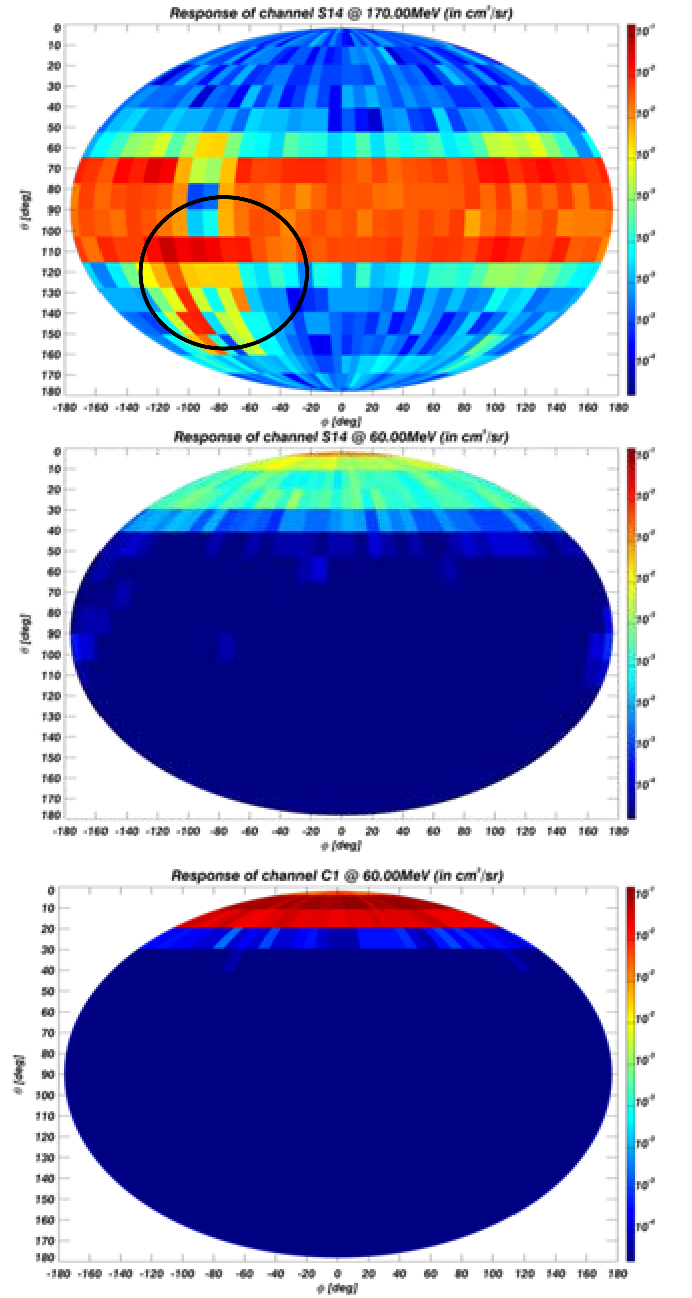




G.Santin, A.Menicucci, D.Lamarre, 2007

SREM Response (Proba-1)





Martin Siegl, ESA TEC-EES

- Detector response mapping
- Geant4 / GRAS simulations