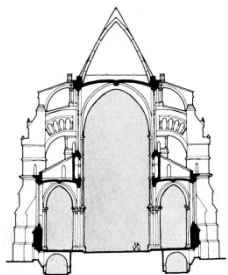# Report from user domains: space
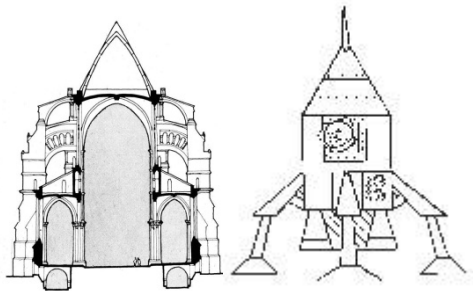
Giovanni Santin*

Space Environments and Effects Analysis Section
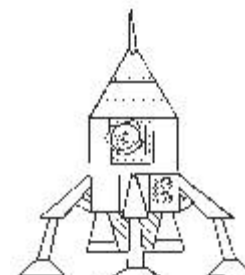*European Space Agency*
ESTEC
* on loan from RHEA Tech Ltd

- Non comprehensive presentation of use cases in the space domain
- Trying to capture trends, problem areas, requirements

X- and gamma-ray observatories

MONACO framework

- (XMM,) ASTRO-H, SymbolX, XEUS/IXO/ATHENA,…
- Very active user community
  - New attempt on X-ray mirror modelling
  - New development on CdTe detector activation
  - MONACO framework modelling X-ray source
  - Particle induced background
    - direct → veto, magnetic deflection,…
    - indirect – activation/fluorescence – JAXA

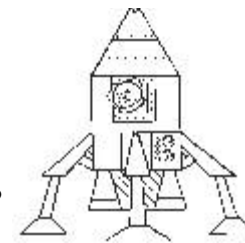Vela X-1 (orbital phase = 0.5)
Chandra HETG
Simulation
Fe
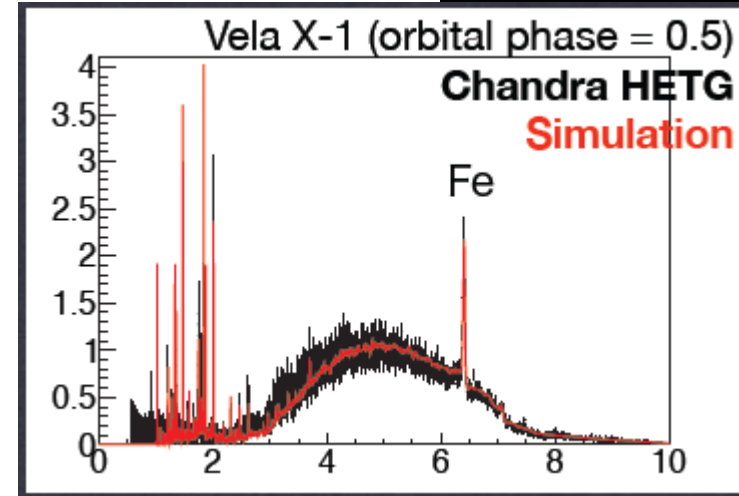
- User report (ISAS/JAXA ASTRO-H mission)
  - Fluorescence lines
    - […] "the accuracy of the fluorescence line cente (Livermore) model is insufficient […] only a few accuracy is sub-eV"
    - Geant4 doc. refers to database and energy cons

Astro-H

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

3
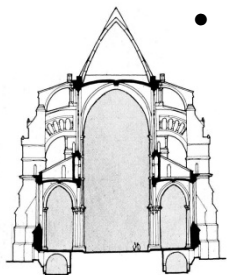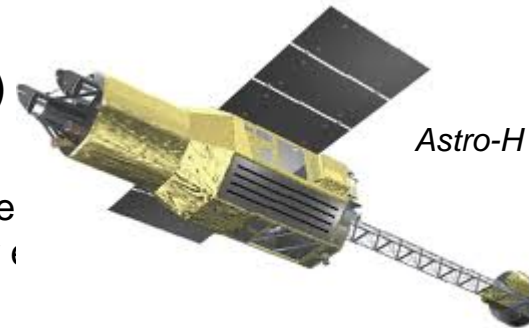
Moon, Mars, Jupiter

- **Moon, Mars**
  - ESA MARSREM suite of tools (in SPENVIS). NASA Curiosity rover (RAD instr.) will hopefully provide some first validation data
    - Geant4 relatively new to the field
    - Thin or no atmosphere, hadronics, lots of albedo neutrons from soil

  - Recent ESA human dosimetry study with comparison to Cucinotta et al. (NASA, HZETRN) and Sato (PHITS) for ISS and interplanetary routes (Chavy-Macdonald, RADECS 2012).
    - Here shielding might make things worse. HZE ions physics for cosmic rays play important role, FTF only Geant4 option.
   - Geant4 DNA – New upcoming related ESA project

- **Jupiter missions**
  - ESA JUICE mission selected, phase A-B1 starting, instrument AO open
    - Harsh electron environment: LEO E < 7 MeV → Jupiter E<1000 MeV
    - Multi-layered shielding and new techniques to limit dose, lower background (quite a challenge)
    - GRAS heavily used for mission feasibility, now also payload instrument
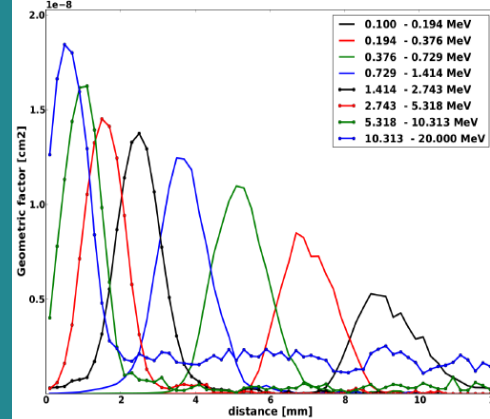   - Geant4 focus: material effects, local dose enhancements, Brem, MSC

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

4
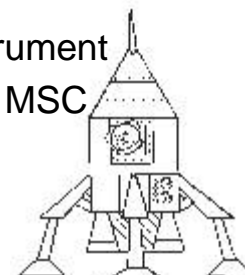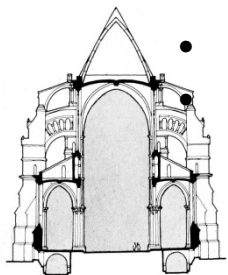
Radiation monitors
ESA: RADEM, HMRM
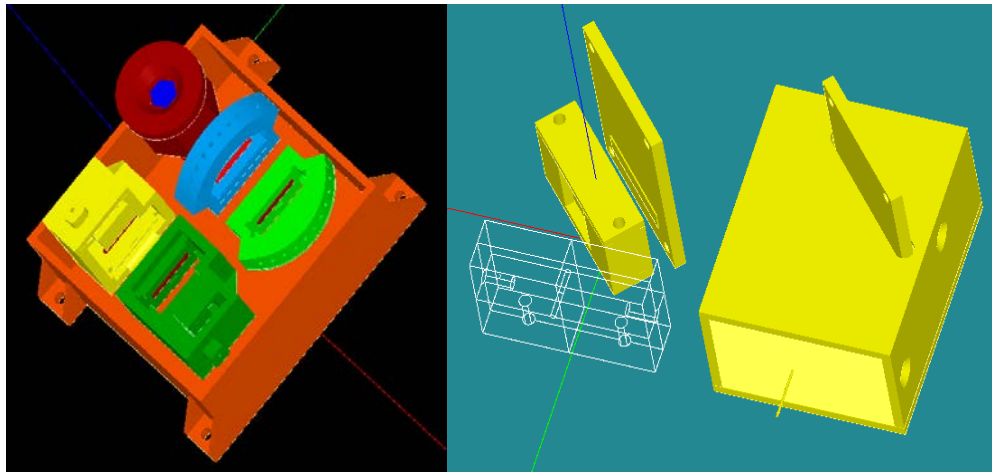
B=0.2 T, collimator L=1.8 cm, Ø=0.4 mm

- RADEM for Jupiter mission – e⁻ magnetic spectrometer response

- HMRM: 52g instrument, conceptual design to optimisation and validation with full simulation geometry

G4HMRM v1.0
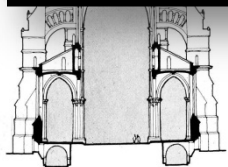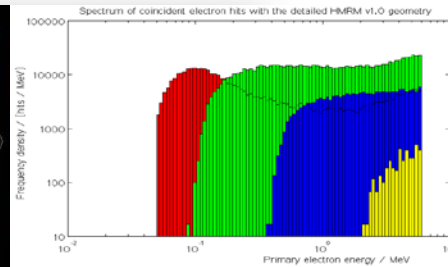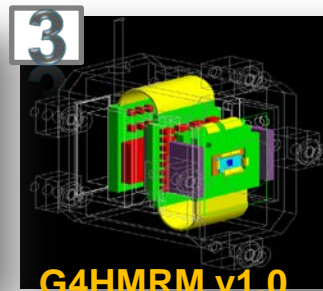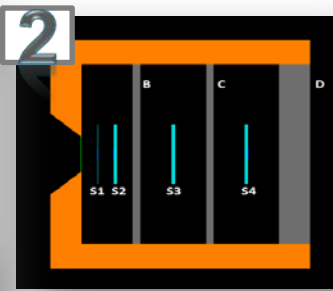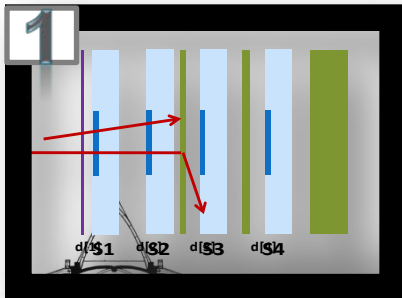
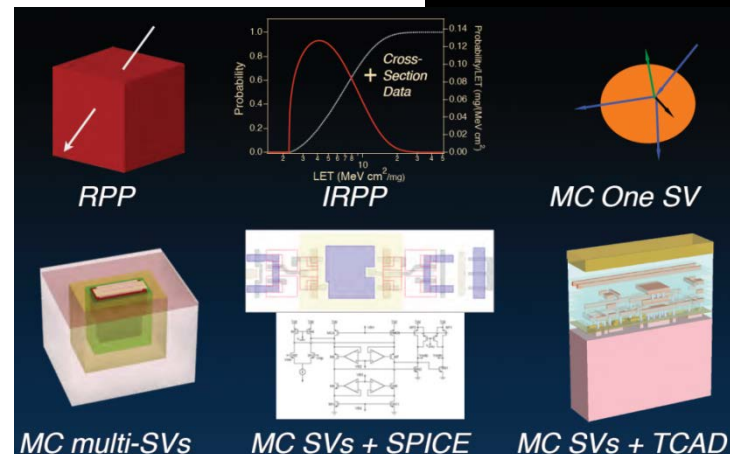*Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012*
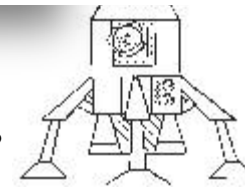
Single Event Effects

- Renewed interest in Geant4 for detailed response of semiconductor devices
    - Interest in very low energy EM (track structure),
    - but also very high energy hadronics for GCR

- Tools
    - MRED, NanoTCAD
    - ESA DESMICREX, Global TCAD Solutions (GTS)
        - GDSII import, (modified) GRAS simulation
    - Cogenda VisualTCAD
        - Includes GDSII import, GDML export
        - GSeat/VisualParticle: Geant4 application
    - Similar recent Chinese developments also appeared

- User input (INTA)
    - "it would be desirable to develop [open] geometry interfaces to link microelectronic standard formats, such as GDSII, CIF, etc, in order to import device layouts into G4"

MRED approach to SEE analysis

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

6
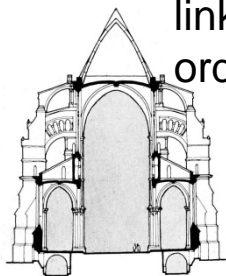
News on SEE

- Recent developments: Geant4 to extract radial profiles, SiliconDNA to extend this to lower energies in Si → new nanometer technologies
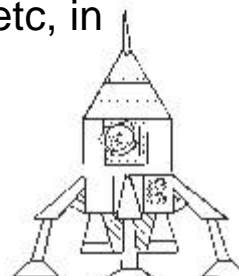 - Note: key developments from new Geant4 collaborators from space microelectronic domain

- Role of G4DNA
  - User input: "Initiatives such as G4DNA should be supported. […] integration scale of technology […] SEE are going to be (or they already are) the main concern in the near future"

- Not only space: recent focus on ground effects:
  - New microelectronic tech.
  - Pervasive automation in high reliability devices (e.g. automotive industry)
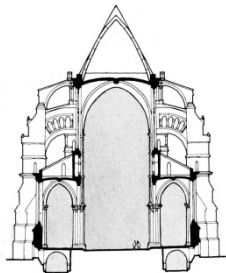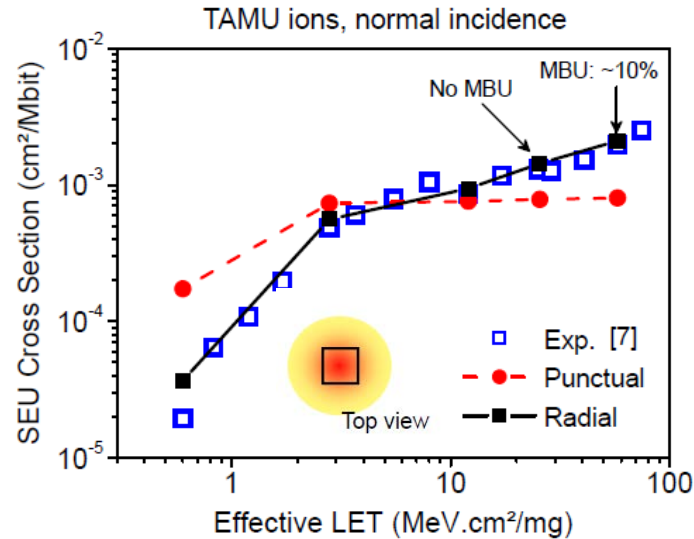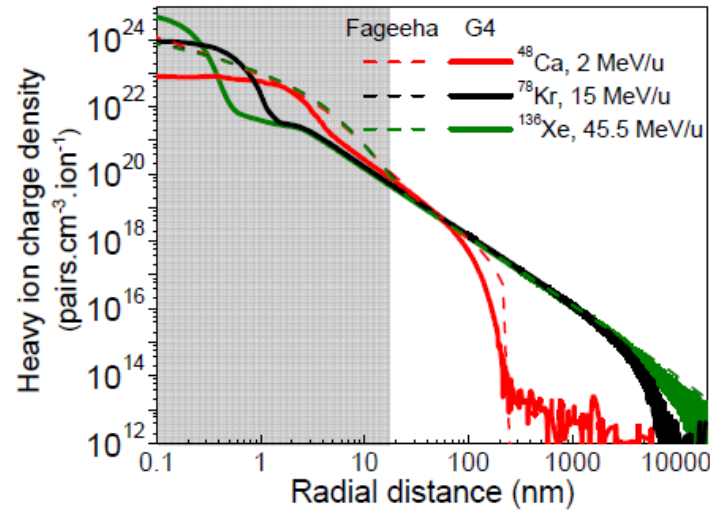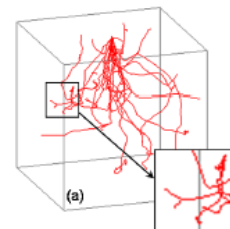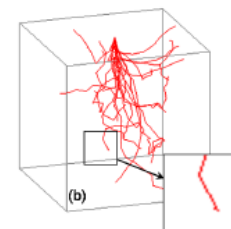
Mélanie Raine, CEA
Geant4 Space Users WS 2011

See dedicated talk

Report from space user domain - Geant4 2012, Chart

EM and hadronic physics validation at ESA

- Support to SEE and human exploration

- New fragmentation data at GSI
  - Generally Geant4 doing OK
  - Comparison with FLUKA, which performs better in some areas
  - Experimental activities continuing in new ROSSINI project
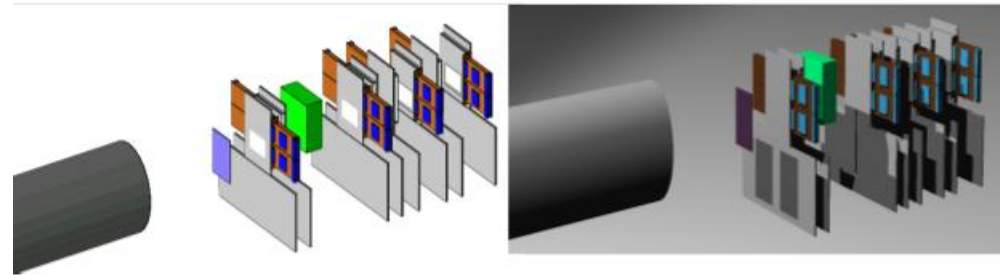
- ELSHIELD
  - some results tomorrow

Total charge changing cross sections

Legend:
- GSI exp
- FLUKA
- G4 QMD
- G4 BINARY
- G4 ABRASION
- G4 ABLATION

Relative difference to experimental value
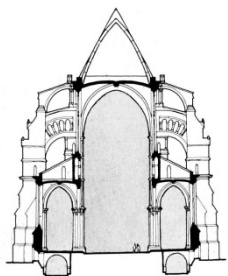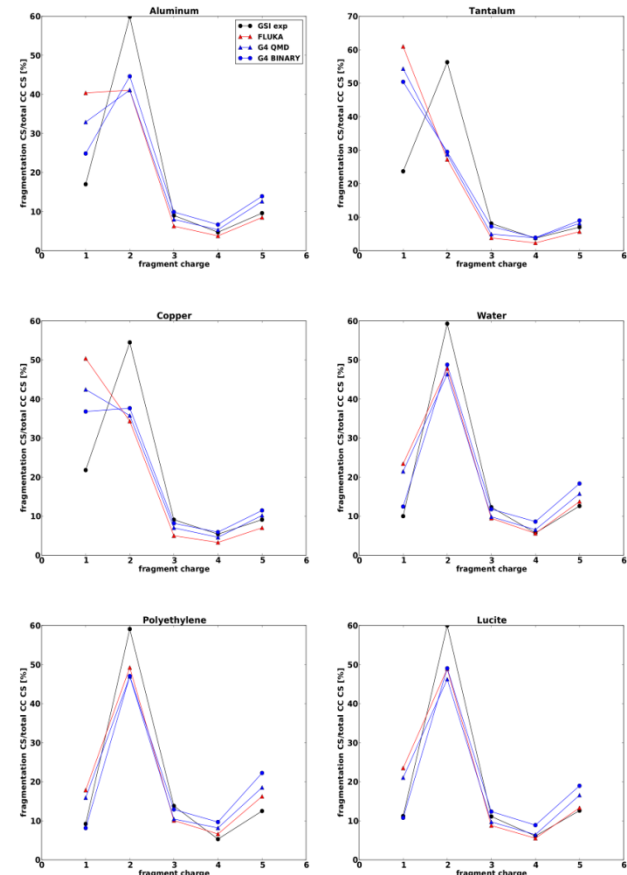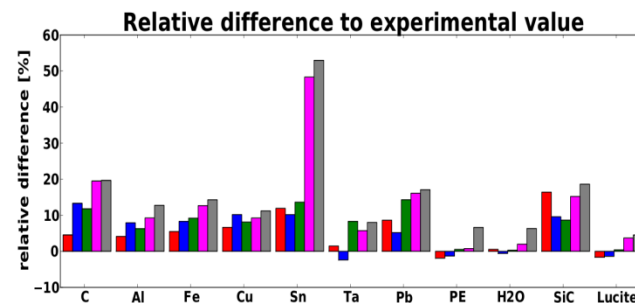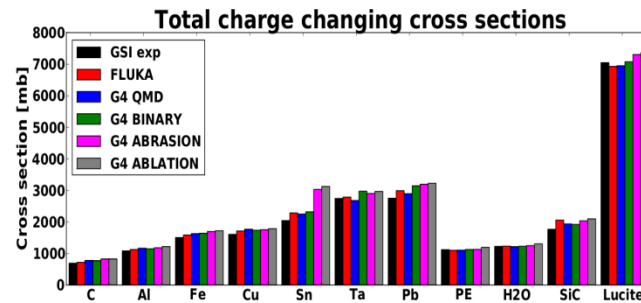
Report from spac

Speed: Reverse MC

- Development by Laurent Desorgher
  - 2008: prototype, 2010: consolidation for e-, extension to p, ions (no had.)
  - Some recent validation exercises, some minor problems to be fixed (more details on this tomorrow, EM validation)
- Major novel Geant4 capability from space user
  - Enabling Geant4 use by space industry
  - Used through GRAS in FASTRAD, REST-SIM
- Space users' input:
  - High interest in space engineering for obvious computational speed gain
  - INTA (E): simulations over realistic S/C geometries to assess radiation levels and support system design […] long CPU times […] even if biasing techniques are applied. […] We would like to encourage the collaboration to keep developing it.

Parallel computing

several alternatives, G4MPI, Geant4+TOP-C, Geant4MT, require extra knowledge, re-coding of exiting applications, third-party S/W, etc.

We encourage the collaboration to define a standard solution to "parallelize" the code

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

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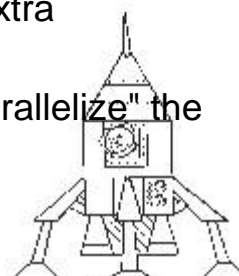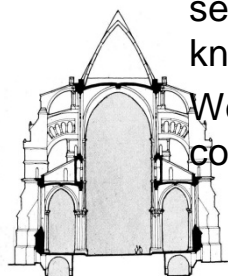
Usability: CAD to GDML interfaces

- Directly or via STEP, STL – to GDML or directly Geant4
  - **FASTRAD** www.fastrad.net, **ESABASE2** www.esabase2.net
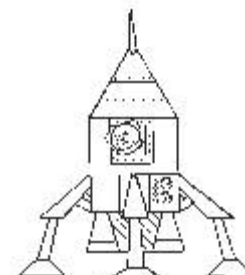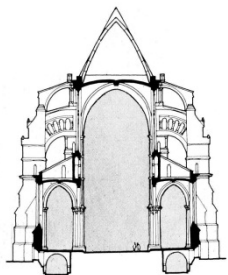   - Space environment analysis w/ CAD)
    - Basic modules free for academic non commercial use
    - Some minor glitches but basically working
  - **Cogenda** STEPtoGDML
  - **SALOME** (open source computational platform w/ CAD) http://www.salome-platform.org/
    - Existing closed source development by CEA (for TRIPOLI MC)
    - Recent new developments by Laurent Desorgher
  - **FreeCAD** (new open source CAD tool)
    - Emmanuel Delage, internal module http://cad-gdml.in2p3.fr/
    - Juan Cabrera via STL with FreeCAD, CADMesh, no GDML http://csrsrv1.fynu.ucl.ac.be/csr_web/geant/step-gdml.php
  - **Solveering** via STL, F.Garcia http://www.solveering.com/products/products_stl2gdml.html
  - JAXA reported conversion **Gmsh** → GDML
  - Editing, error detection, hole filling, etc in **MeshLab** http://meshlab.sourceforge.net/
  - Last but not least: **mesh2gdml** by N.Graf

*Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012*

CAD interfaces: GDML "standard"

- GDML widely used and adopted for many interfaces, becoming *de facto* a standard for MC geometries
    - CAD (←)→ Geant4
    - Geant4 ←→ ROOT
    - CAD → TRIPOLI (MC, neutrons)
    - SPIS (plasma, charging) → Geant4

- Industry interest in Geant4 makes GDML perfect candidate for exchange format
    - Industry looks for standard formats, no experiments
    - XML is an excellent choice
    - Documentation is rather poor, examples outdated, …

- Evolution of GDML ?
    - Consolidation where needed (doc, …)
    - Extensions such as LCDD promising, but not widely adopted. Maybe too specific?
   - Discussion / convergence needed to new standard
        - GDML 4.0 ?

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

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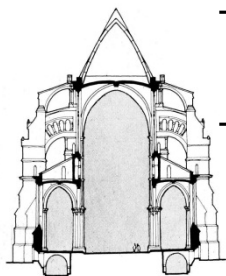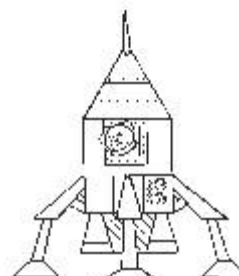
Usability:
Integrated Modelling Environments

- IME's for G4 applications for experts and non experts
    - Geometry, pre-processing, simulation, post-processing
    - Get new Geant4 (space) users quickly up to speed for quick but accurate radiation assessment studies
    - Integrate Geant4 in engineering development process, beyond the SPENVIS Geant4 tools
    - Interface scientific payload developer teams to space industry
    - ESA tool usability: GRAS → REST-SIM → …

- Looking for input: any experience on (open source) IME's from Geant4 developers and users is welcome
    - Many options: **SALOME** (CEA, EDF, OpenCascade), **Keridwen** (used for SPIS plasma sim.), **Eclipse** RCP, **Netbeans,…**
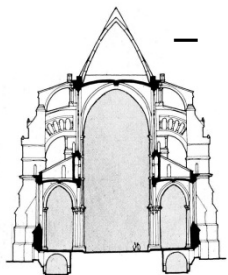
    - Similar but different subject: IDE development platforms
        - Eclipse, xcode,… the coll. does not offer guidance to Geant4 developers nor to users for use of these platforms

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012

12
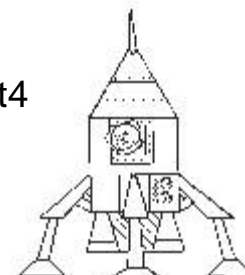
Tentative summary

Payload / spacecraft analyses

- Pervasive use in space science: difficult to find who does not use Geant4
- Extending from scientific performance studies to engineering feasibility
- Other S/C: advanced G4 modules in commercial tools, reverse MC is key
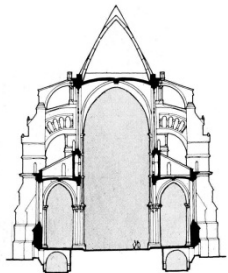
Radiation effects

- Geant4 physics evolving with technology
- Ground-based applications experiencing previously "space only" effects

Usability & speed

- User experience (tool availability, scripting, GUI, web access, Windows)
- Still exchange formats: more solutions available (GDML, CAD/TCAD)
- Reverse MC key for speed (scoring in nano-volumes in macroscopic S/C

Next Geant4 Space Users' Workshop
Barcelona, 3 days in the week 4-8 March 2013

Report from space user domain - Geant4 2012, Chartres, 10-14 Sep 2012