Highlights from the

GEANT4 Space Users' Workshop

Leuven, 3-7 Oct 2005

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@ Space Environments and Effects Analysis
ESA / ESTEC

Giovanni.Santin@esa.int

Joint Workshop

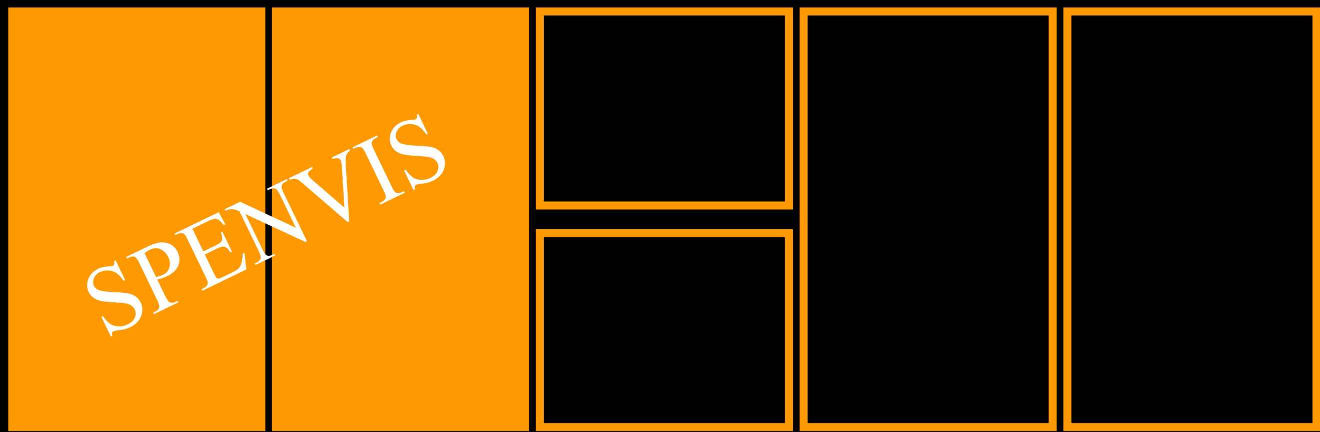
- SPENVIS: Space Environment Information System
- Geant4 Space Users

3 - 7 October 2005

Faculty Club Leuven, Belgium

SPENVIS workshop

- SPENVIS
  - Space Environment Information System
  - Sample from sessions
- Joint
- Geant4 Space Users

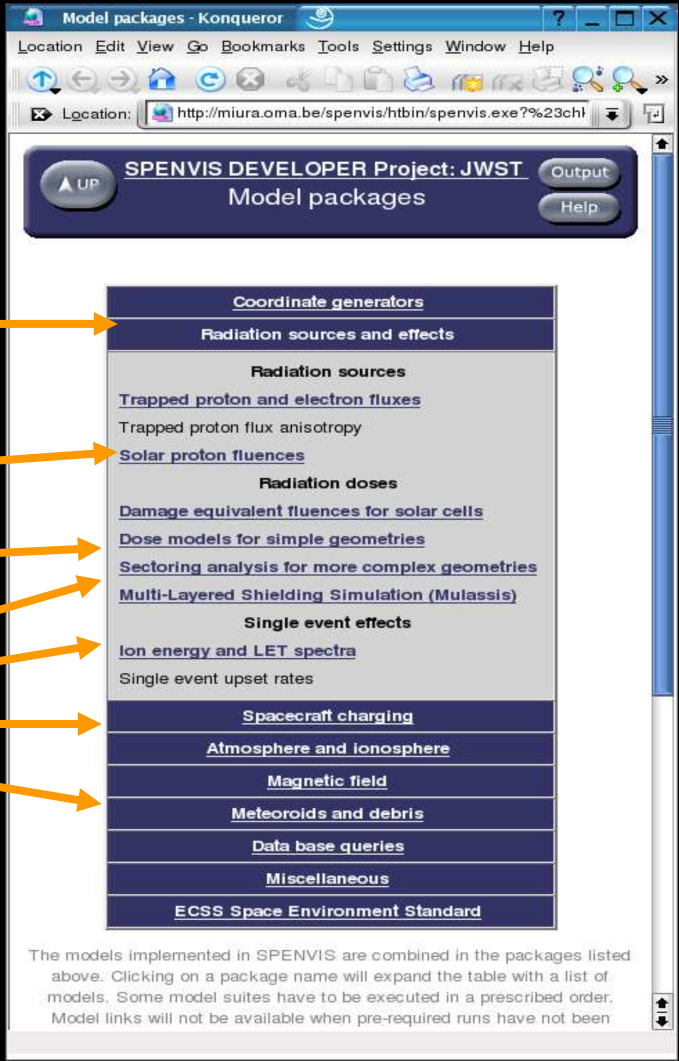


SPENVIS

Space Environment Information System

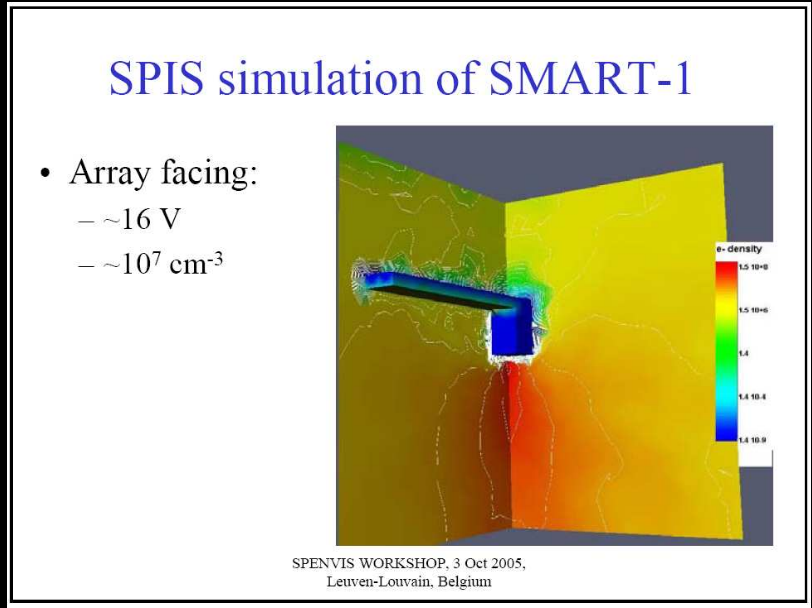
- Space Environment Information System
  - Models and tools for the space environments effects analysis
  - Also GEANT4-based models
- Web Interface

- Mission model
  - Orbit, attitude
- Space environment models
- Radiation transport
  - Simulation engine
- Effects Analysis
  - Damage mechanisms
  - Charging
  - SEE
  - Effects to humans



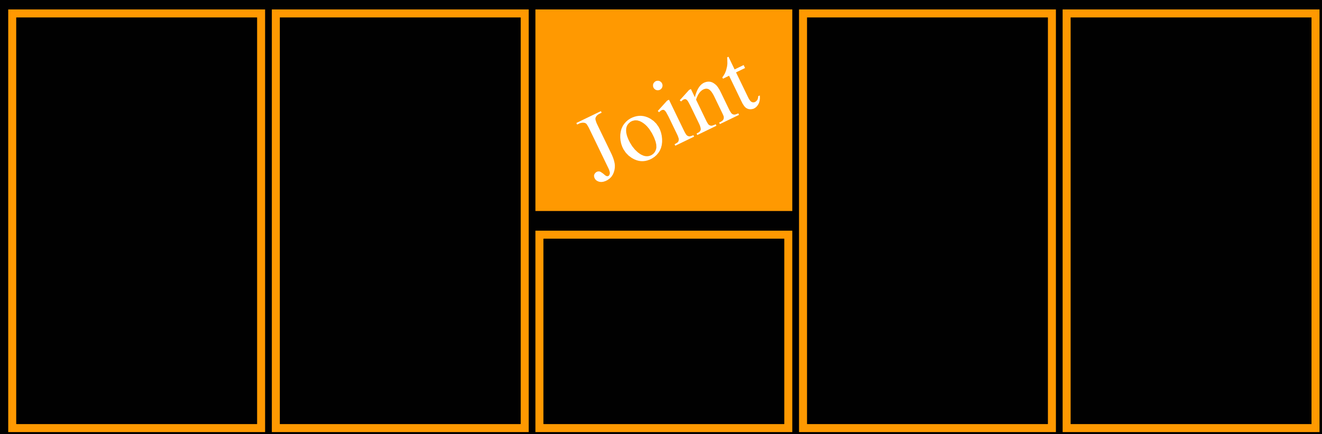
SPENVIS WS: highlights

- Plasma / Charging
- Solar Cell degradation: GEANT4/MULASSIS :NIEL and degr. models
- Radiation environment models: solar protons, radiation belts
- Single Event Effects (SEE) models

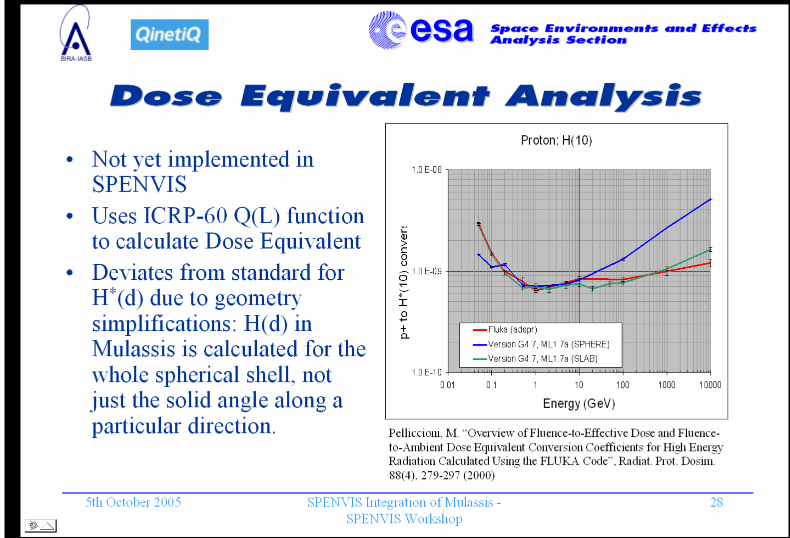


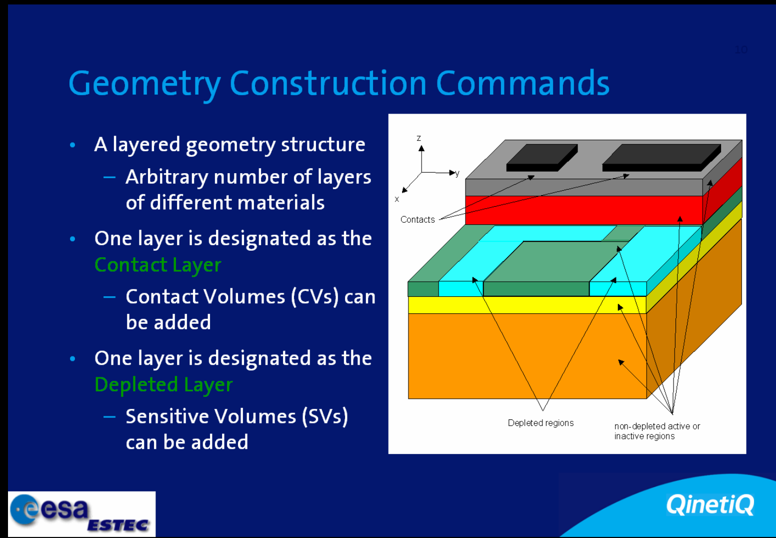
Joint session
SPENVIS / GEANT4 Space Users

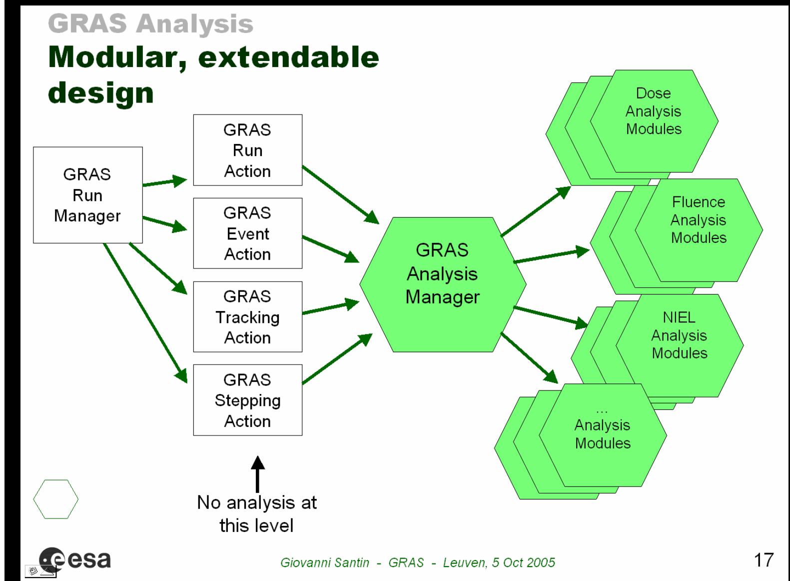
- SPENVIS
- Joint
  - Introduction to GEANT4 and recent developments
  - GEANT4 tools available within SPENVIS
    (now or in the near future)
  - MULASSIS , GEMAT, MAGNETOCOSMICS, GRAS
- Geant4 Space Users

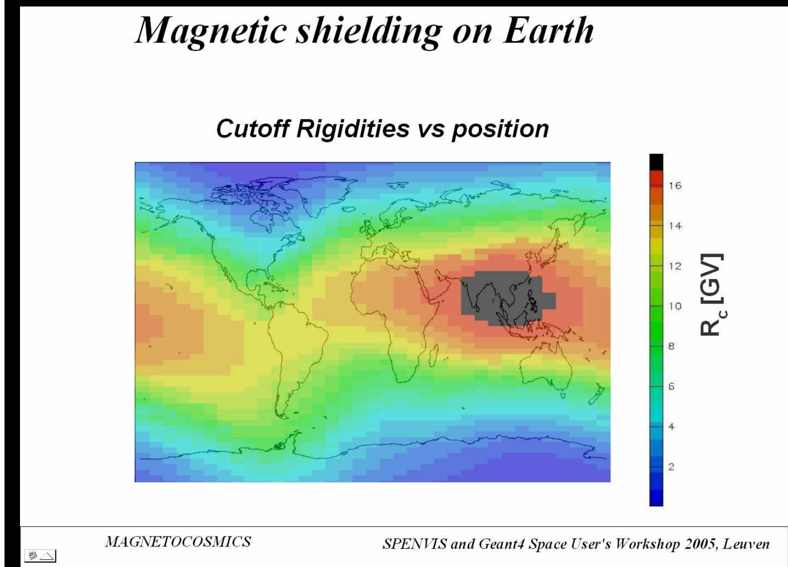


GEANT4 tools in SPENVIS









MULASSIS

GEMAT

MAGNETO-COSMICS

GRAS

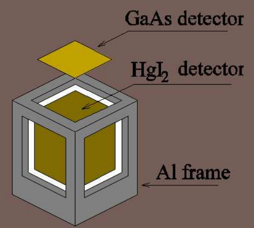
GEANT4 Space Users workshop

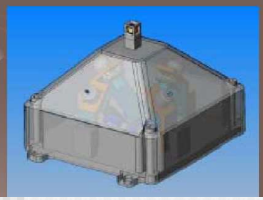
- SPENVIS
- Joint
- Geant4 Space Users
  - Radiation detectors / monitors
  - Effects to electronics
  - Model modeling
  - Exploration programme

GEANT4 Space Users

Space radiation detectors / monitors

SIXS Particle Instrument

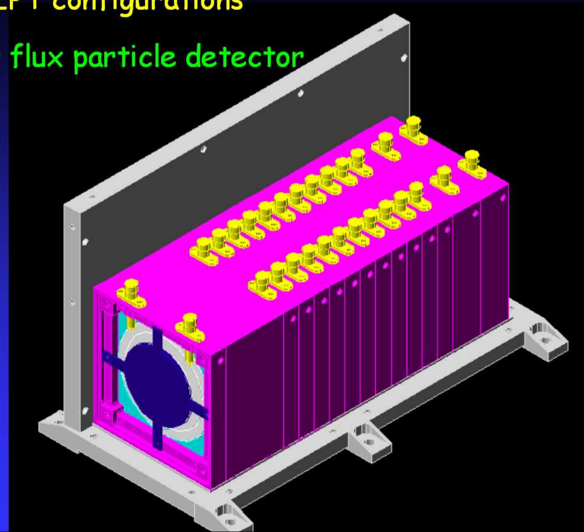




- SIXS Particle Instrument
  - 2π sr Field-of-View around anti-nadir with Geometric Factor of ~ 0.1 cm2 sr
  - Five GaAs surface detectors around a HgI2 core detector
  - Measures
    - 0.1 - 3 MeV electrons
    - 1 - 30 MeV protons
    - ΔE/E ~ 50 % energy channel separation
    - coarse directional resolution
    - 64-s/1-s time resolution

3. The EPT configurations

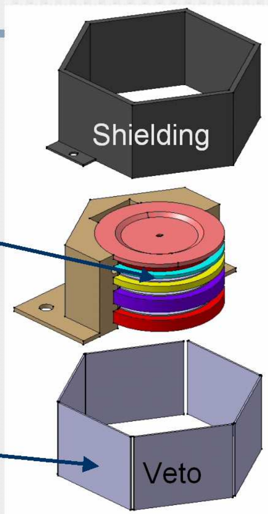
3.1. Low flux particle detector



The HEP Sensor System…

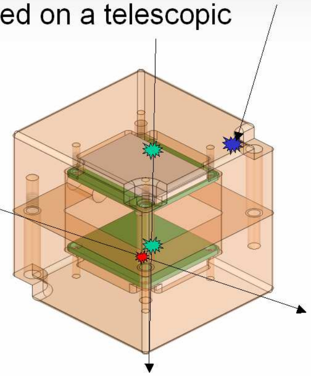
…Design Approach

- Range Telescope with:
  - Measured quantities:
    - Range
    - *dE/dx* in all layers
  - Stack of silicon PIN diodes and absorber layers
  - Size determined by rate about 2 cm diameter
  - Full digital readout
  - Active veto outside
  - Passive shield around Veto



LISA Pathfinder radiation monitor

- Variations in charging can compromise science goals of the mission
- Want to measure the flux responsible for charging
- A particle monitor is proposed based on a telescopic arrangement of PIN diodes.
- 5-10 g/cm^2 of shielding stops particles E<70-90MeV
- Count rates sufficient to detect small fluctuations in flux
- Energy resolution to distinguish GCR and SEP spectra.

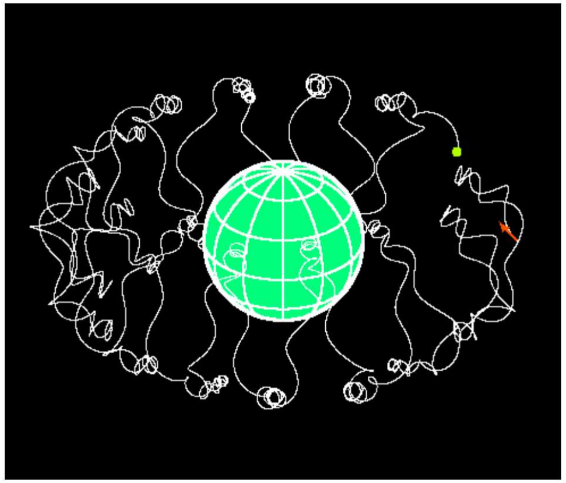


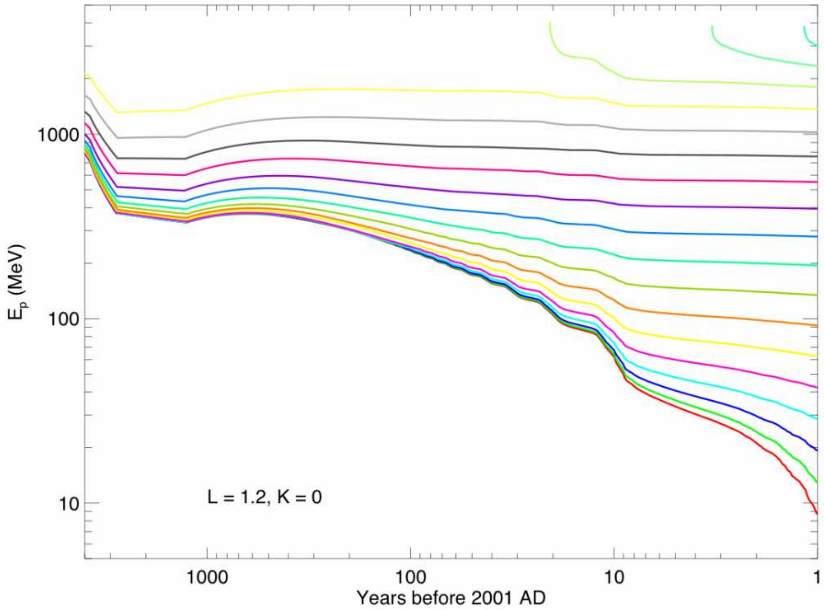
Model modeling...

Theoretical Modeling of the Inner Zone Using GEANT4 Simulations as Inputs

R. S. Selesnick and M. D. Looper
The Aerospace Corp., Los Angeles, CA USA

R. A. Mewaldt
Caltech, Pasadena, CA USA

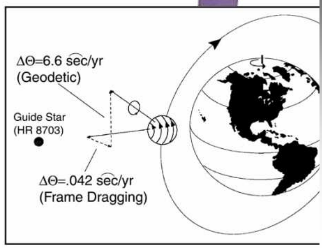




S/C Internal charge deposit

Gravity Probe B

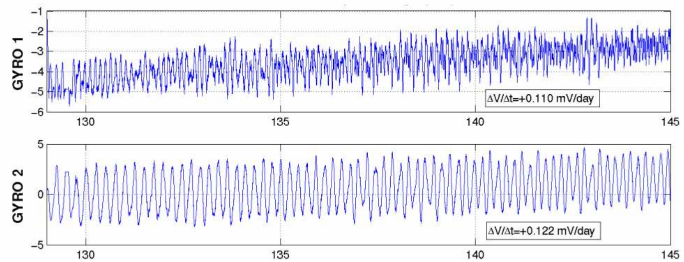
- Aims to detect geodetic and frame-dragging effects on free-falling gyroscopes in low earth orbit
- 600km polar orbit
- Gyroscopes accumulate charge from SAA
- GP-B payload also includes a high energy proton monitor (30-500MeV)



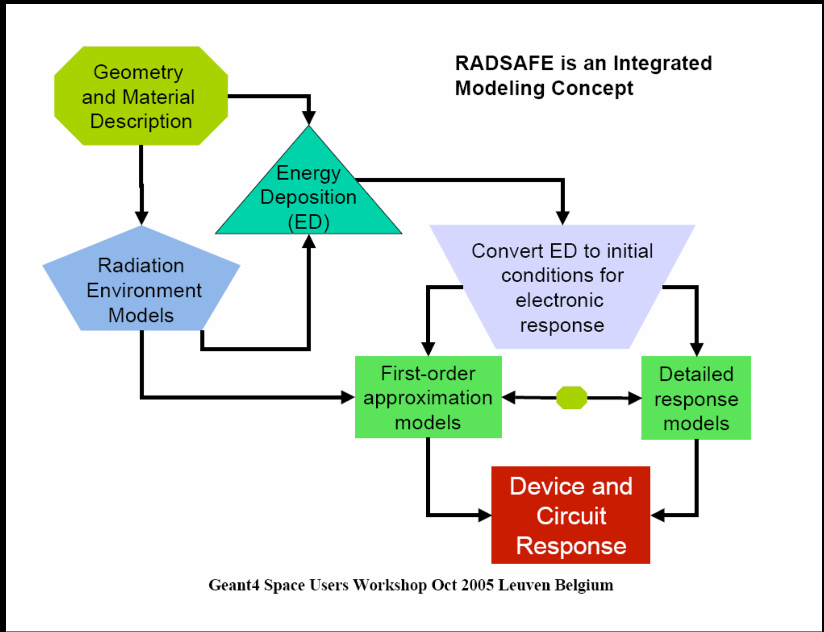
Peter Wass – Imperial College

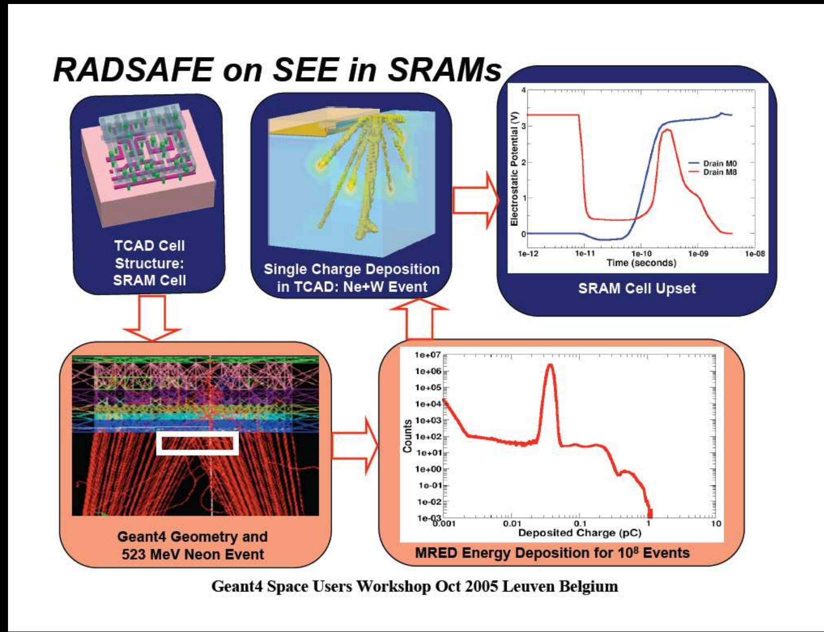
Results and data comparison

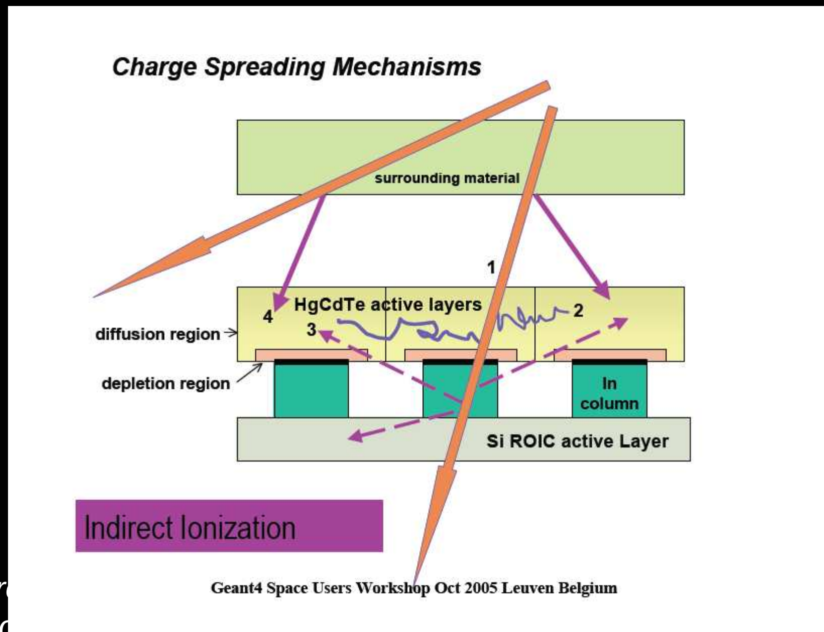
- The average charging rate, calculated from simulations is +12.5e/s
- Charging rate measured on orbit is +0.11mV/day or +8.0e/s



RADSAFE



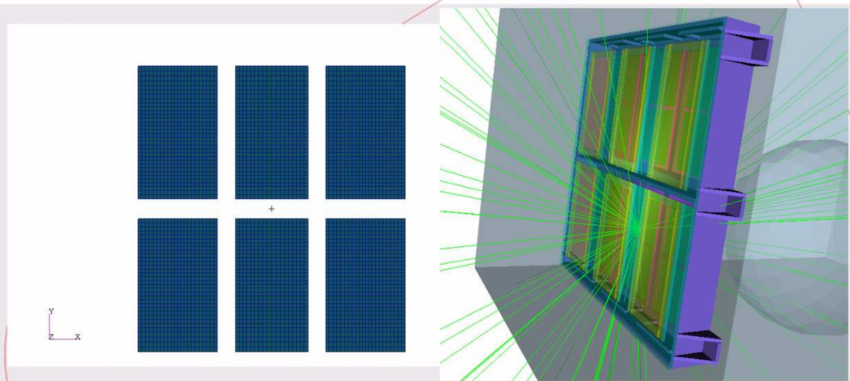




- SEE in microelectronics
- Detector response
- *R.Reed – Vanderbilt University*

Dose from ray tracing in CAD geometry models

Sectorial Analysis for the PCBs



- FEM Grids used as point target for the analysis
- Shielding and TID map for each PCB
- Very Fast and Efficient Method
  - From Geometry definition to post-process 3 days

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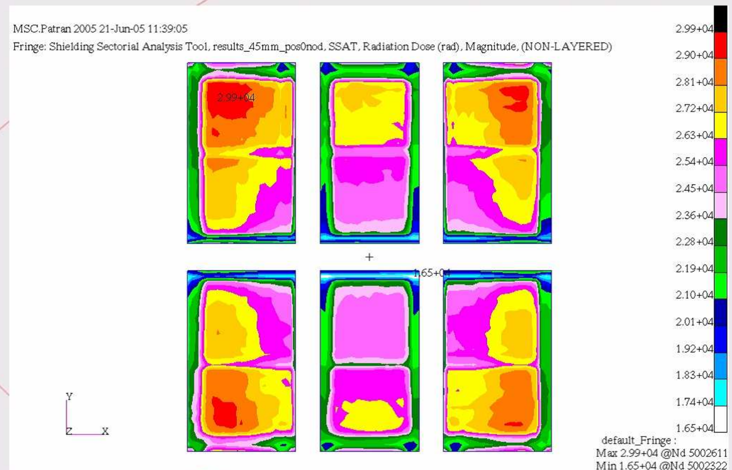
Post-Processed Results using PATRAN

- TID Maps obtained for each location of the PCB
- 3.5 mm (30krad) Al thickness reduced the mass



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Adolfo Aguilar - EFACEC

NIEL tool

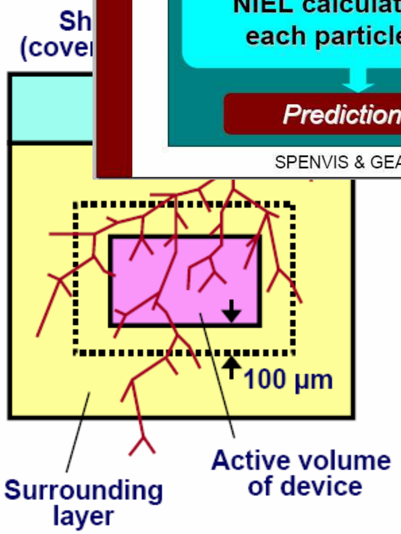
Tool Module "NIEL"

Uni Köln

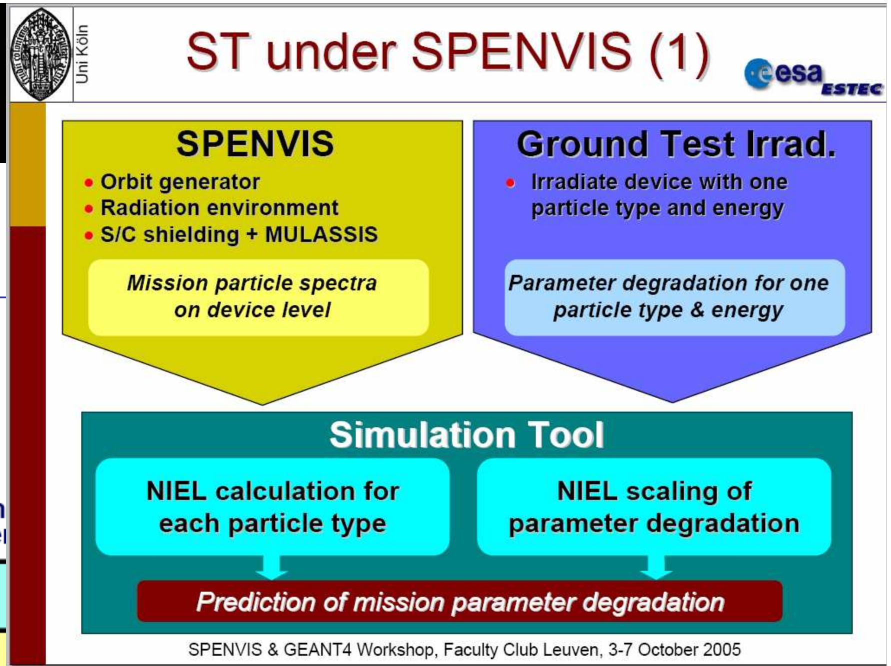
Two options of running module NIEL

(a) **NIEL calculation by applying the Lindhard partition function to the initial energy of the recoils** (not for high-energy projectiles, not for compounds with high ΔZ, no information about 3D defect distribution)

(b) **NIEL calculation by MC simulation of the damage cascade step by step in the vicinity of the active volume** (validity of algorithms and models in Geant4 limited at low energy; e.g. binary collision model rather should be replaced by a molecular dynamics code)



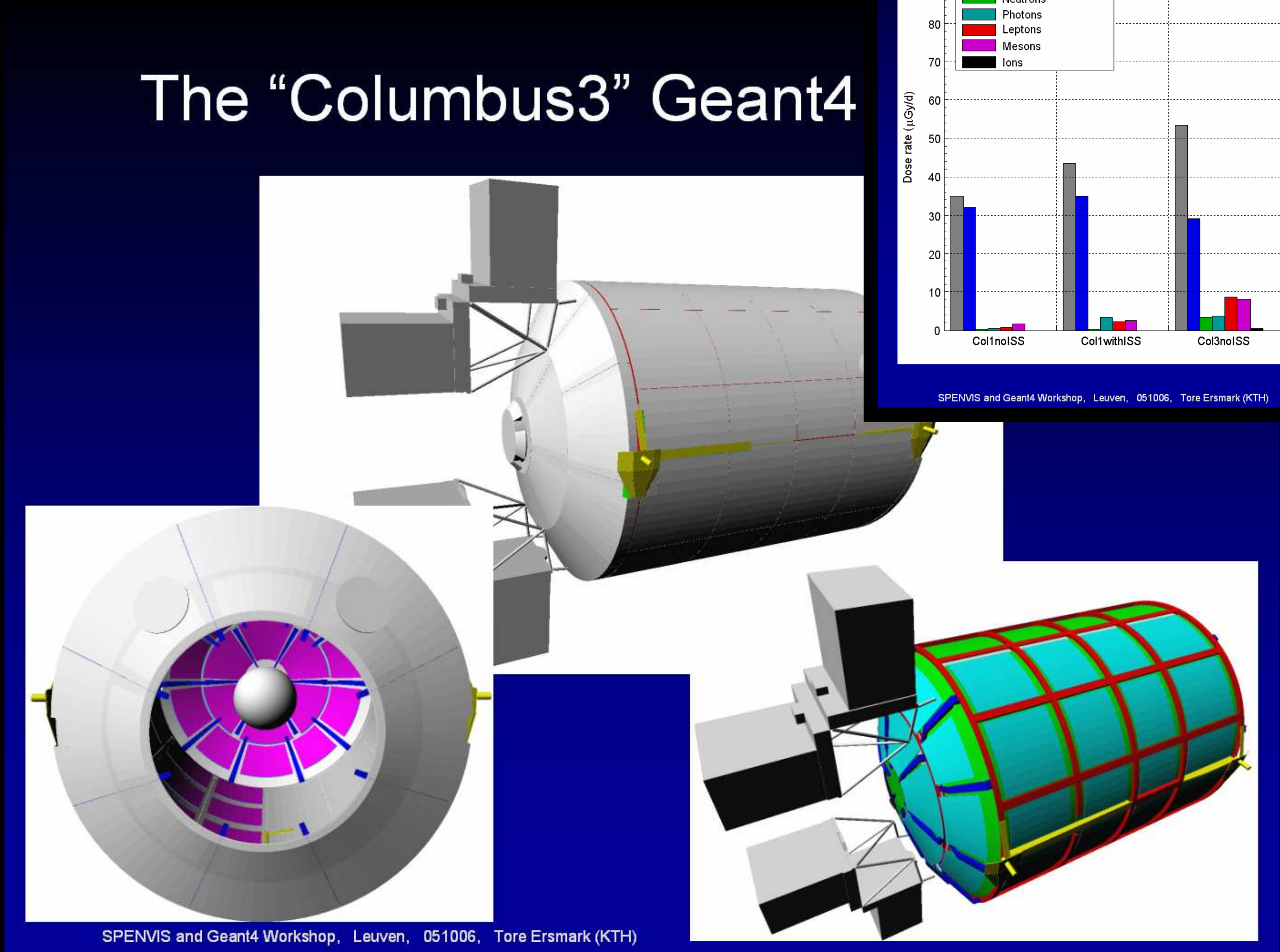
SPENVIS & GEANT4 Workshop, Faculty Club Leuven, 3-7 October 2005

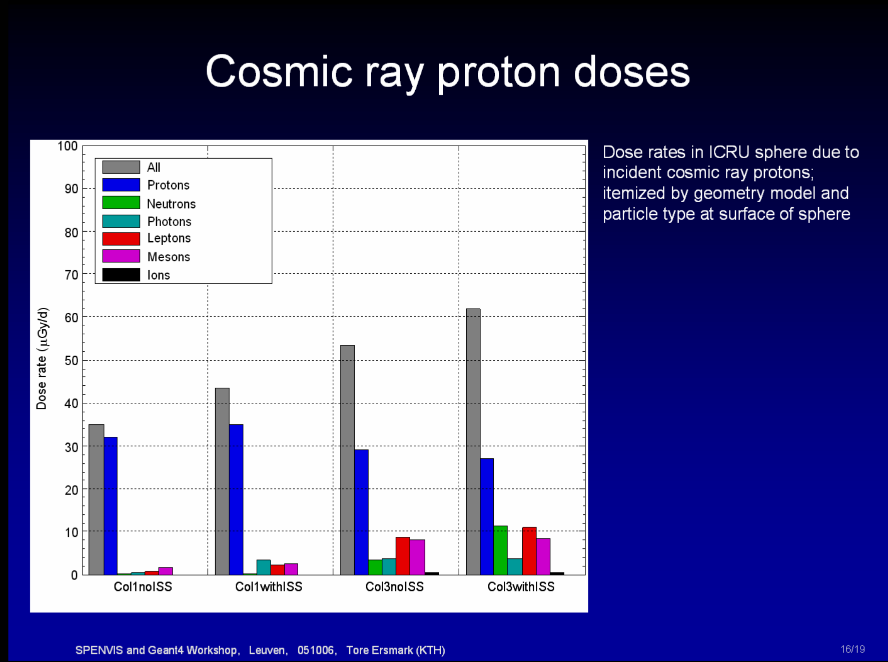


H.H.Fischer, K.Thiel
Cologne university

- Uses Screened Coulomb scattering
  - Implementation by Vanderbilt University
    Nucl Instr Meth B 227, Issue 3, 420-430 (2004)

DESIRE
Doses in ESA ISS/Columbus





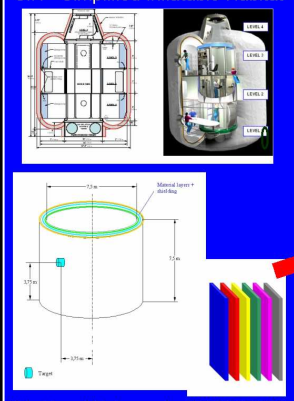
Tore Ersmark

KTH Stockholm

REMSIM

Radioprotection for interplanetary manned missions

SIH - Simplified Inflatable Habitat



Materials and thicknesses by ALENIA SPAZIO

Vehicle concepts

Two (simplified) options of vehicles studied

Simplified Rigid Habitat

A layer of Al (structure element of the ISS)

Simplified Inflatable Habitat

Modeled as a **multilayer structure**

- MLI: external thermal protection blanket
  - *Betacloth and Mylar*
- Meteoroid and debris protection
  - *Nextel (bullet proof material) and open cell foam*
- Structural layer
  - *Kevlar*
- Rebundant bladder
  - *Polyethylene, polyacrylate, EVOH, kevlar, nomex*

The Geant4 geometry model retains the essential characteristics of the vehicle concept relevant for a dosimetry study

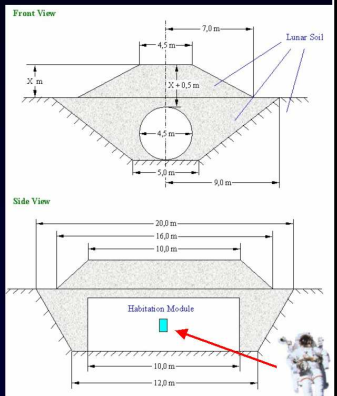
S. Guatelli, M.G. Pia – INFN Sezione di Genova

INFN Genova

Surface Habitats

- Use of local material
- Cavity in the moon soil + covering heap

The Geant4 model retains the essential characteristics of the surface habitat concept relevant to a dosimetric study

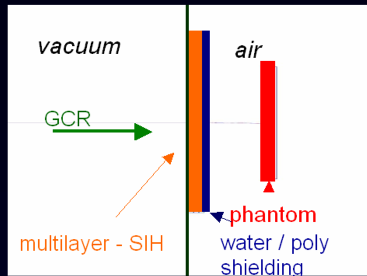


Sketch and sizes by ALENIA SPAZIO

S. Guatelli, M.G. Pia – INFN Sezione di Genova

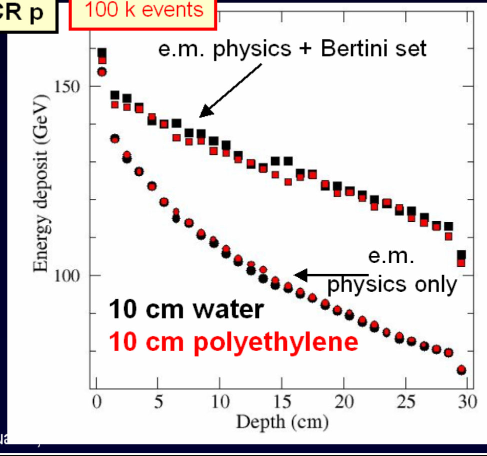
Shielding materials

- Comparison between
  - Water
  - Polyethylene
- Equivalent shielding results

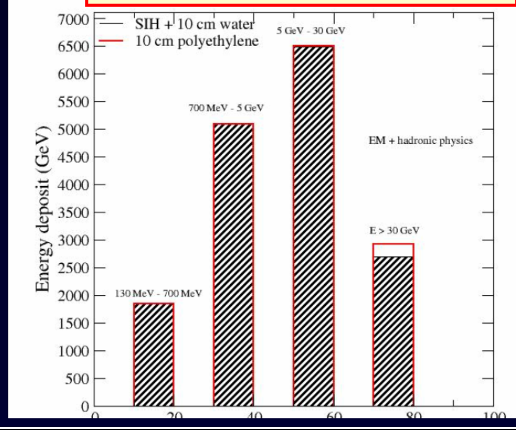


GCR p

100 k events



Energy deposit given by slices of the GCR p spectrum



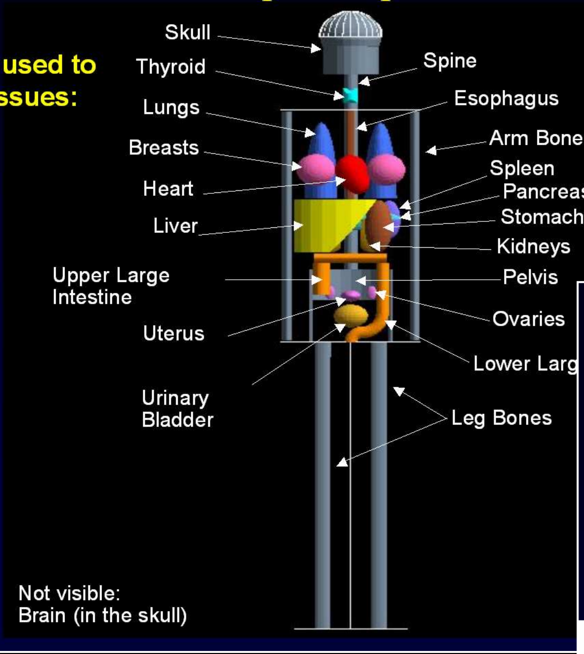
S. Gua...

Anthropomorphic phantoms

Female ORNL Anthropomorphic Phantom

Three materials used to model human tissues:

- **Skeleton,**
- **Lungs,**
- **Soft tissue**



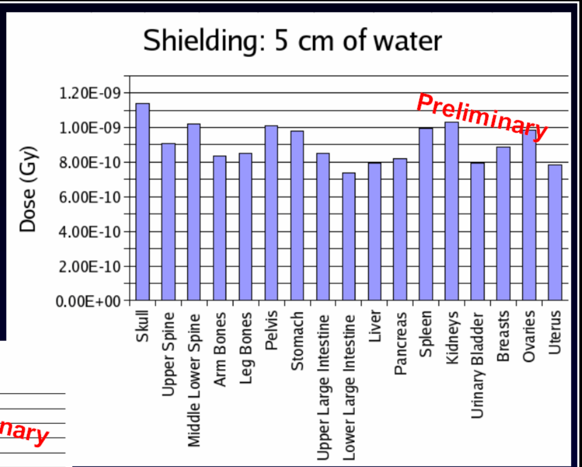
Susanna Guatelli

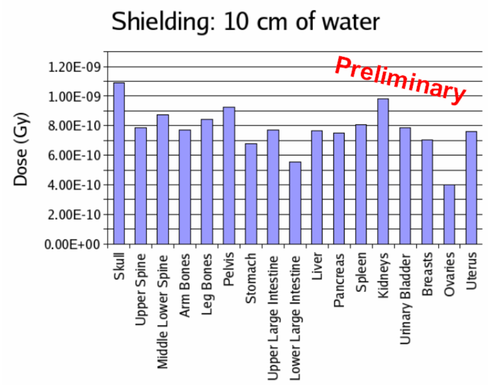
Not visible:
Brain (in the skull)

GEANT4 - DNA Collaboration

First results

- Calculation of the dose in the anthropomorphic phantom



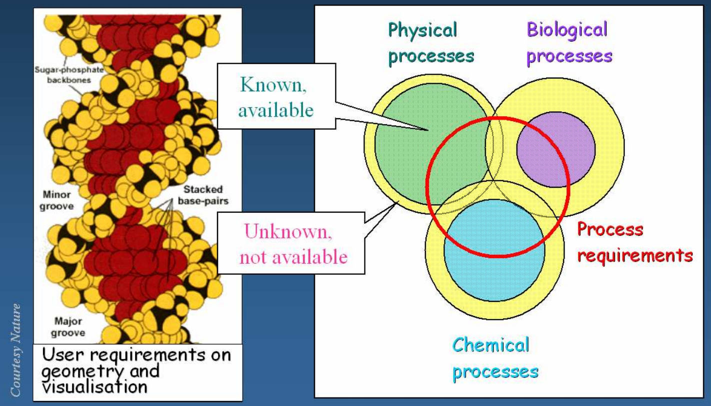


Preliminary

Geant4 Workshop

GEANT4 - DNA

Collection of User Requirements



Maria Grazia Pia, *INFN Genova*

TARGET THEORY	SINGLE-HIT	$S = e^{-D / D_0}$
TARGET THEORY	MULTI-TARGET SINGLE-HIT	$S = 1 - (1 - e^{-qD})^n$; REVISED MODEL: $S = e^{-q_1 D} [1 - (1 - e^{-q_n D})^n]$
MOLECULAR THEORY	RADIATION ACTION	$S = e^{-p(\alpha D + \beta D^2)}$
MOLECULAR THEORY	DUAL RADIATION ACTION	$S = S_0 e^{-k(\xi D + D^2)}$
MOLECULAR THEORY	REPAIR-MISREPAIR LIN REP / QUADMIS	$S = e^{-\alpha D}[1 + (\alpha DT / \varepsilon)]^{\varepsilon}$
MOLECULAR THEORY	REPAIR-MISREPAIR LIN REP / MIS	$S = e^{-\alpha D}[1 + (\alpha D / \varepsilon)]^{\varepsilon\Phi}$
MOLECULAR THEORY	LETHAL-POTENTIALLY LETHAL	$S = \exp[-N_{TOT}[1 + \frac{N_{PL}}{\varepsilon(1 - e^{-\varepsilon BAtr})}]^{\varepsilon}]$
MOLECULAR THEORY	LETHAL-POTENTIALLY LETHAL – LOW DOSE	$S = e^{-\eta_{AC} D}$
MOLECULAR THEORY	LETHAL-POTENTIALLY LETHAL – HIGH DOSE	$-\ln[S(t)] = (\eta_{AC} + \eta_{AB}) D - \varepsilon \ln[1 + (\eta_{AB} D/\varepsilon)(1 - e^{-\varepsilon BA\,tr})]$
MOLECULAR THEORY	LETHAL-POTENTIALLY LETHAL – LQ APPROX	$-\ln[S(t)] = (\eta_{AC} + \eta_{AB} e^{-\varepsilon BAtr}) D + (\eta^2_{AB}/2\varepsilon)(1 - e^{-\varepsilon BA\,tr})^2 D^2]$

In progress: calculation of model parameters from clinical data

Maria Grazia Pia, *INFN Genova*

- EM models in water down to ~7 eV
- Radiobiological models
- DNA models

GEANT4 – DNA Collaboration

Review of the work in progress[2/5]

- Total cross sections

	Electrons	Protons (H+)	Hydrogen (H)	Alpha (He++)	He+	He
Elastic	Brenner (7.5 - 200 eV) / Emfietzoglou (> 200 ev)	Neglected	Neglected	Neglected	Neglected	Neglected
Excitation	Emfietzoglou / Born (7 ev – 10 keV)	Miller and Green / Born (100 eV – 10 MeV)	Neglected	Miller and Green (1 keV – 15 MeV)	Miller and Green (1 keV – 15 MeV)	Miller and Green (1 keV – 15 MeV)
Charge decrease	Does not apply	Dingfelder (100 eV – 2 MeV)	Does not apply	To be done	To be done	Does not apply
Charge increase	Does not apply	Does not apply	Miller and Green / Dingfelder (0.1 Kev – 100 MeV)	Does not apply	To be done	To be done
Ionization	To be done	Rudd (0.1 - 500 keV) / To be done (> 500 keV)	Rudd (0.1 – 100 MeV)	To be done	To be done	To be done

- Final states

	Electrons	Protons (H+)	Hydrogen (H)	Alpha (He++)	He+	He
Elastic	Brenner (7.5 - 200 eV) / Emfietzoglou (> 200 ev)	Neglected	Neglected	Neglected	Neglected	Neglected
Excitation	Emfietzoglou / Born (7 ev – 10 keV)	Miller and Green / Born (100 eV – 10 MeV)	Neglected	Miller and Green (1 keV – 15 MeV)	Miller and Green (1 keV – 15 MeV)	Miller and Green (1 keV – 15 MeV)
Charge decrease	Does not apply	Dingfelder (100 eV – 2 MeV)	Does not apply	To be done	To be done	Does not apply
Charge increase	Does not apply	Does not apply	Miller and Green / Dingfelder (0.1 Kev – 100 MeV)	Does not apply	To be done	To be done
Ionization	To be done	Rudd (0.1 - 500 keV) / To be done (> 500 keV)	Rudd (0.1 – 100 MeV)	To be done	To be done	To be done

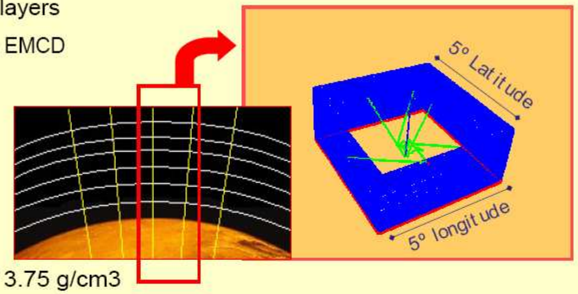
RESTEC
Fluxes and doses on Mars

- *Ana Keating*
  LIP Lisbon / ESA

Simulation Setup

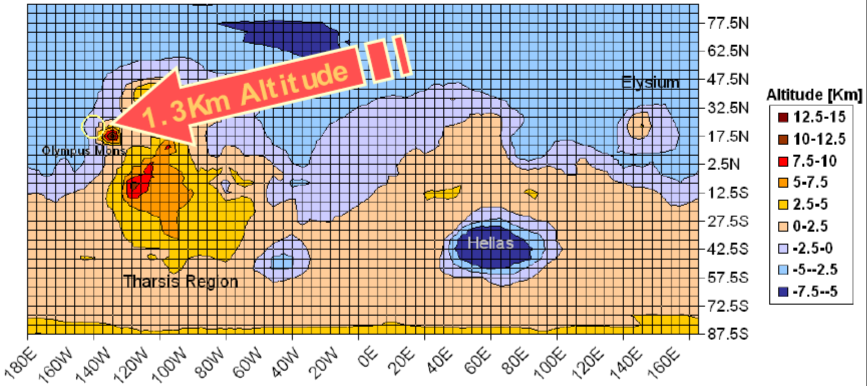
The geometry implemented in Geant4 program takes into account:

- 32 atmospheric layers
- Properties from EMCD
- Composition
  - 95% CO2
  - 2.5% N2
  - 1.25% Ar
  - 1.15% O2
  - 0.07% CO
  - 0.03% H2O
- Soil : Density of 3.75 g/cm3
- 30% Fe_2O_3 and 70% of SiO2



07/10/05 SPENVIS-GEANT4 Workshop 4

Olympus Mons Cliff (12h, Ls=180-210)



07/10/05 SPENVIS-GEANT4 Workshop 6

GCR: Radiation Environment at the Surface

At low energies:

- Neutrons
- Photons
- Electrons

At high energies (> 10^3MeV):

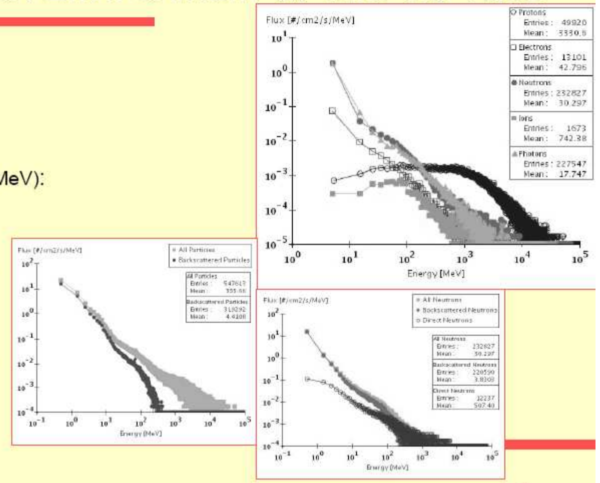
- Protons

The Ions are mainly:

- Deuteron, Triton
- Alpha

Backscattering

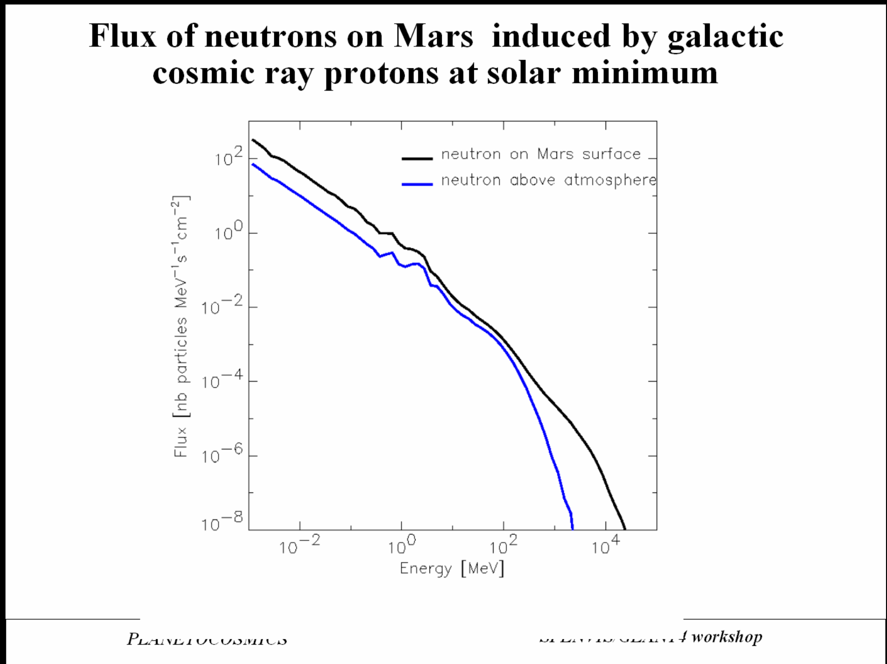
- 60% All particles
- 96% Neutrons

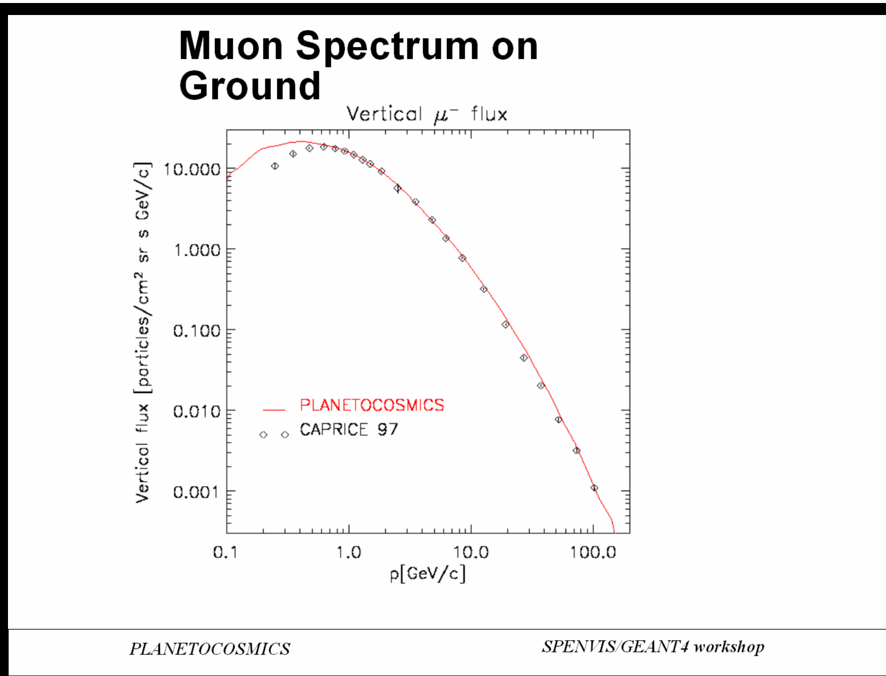


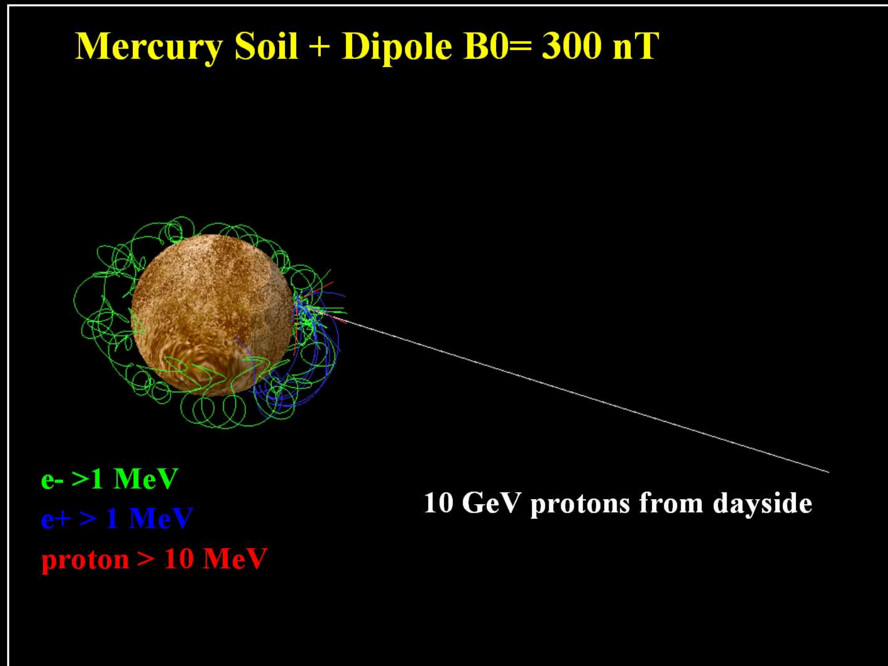
07/10/05 7

PLANETOCOSMICS

Earth, Mars, Mercury

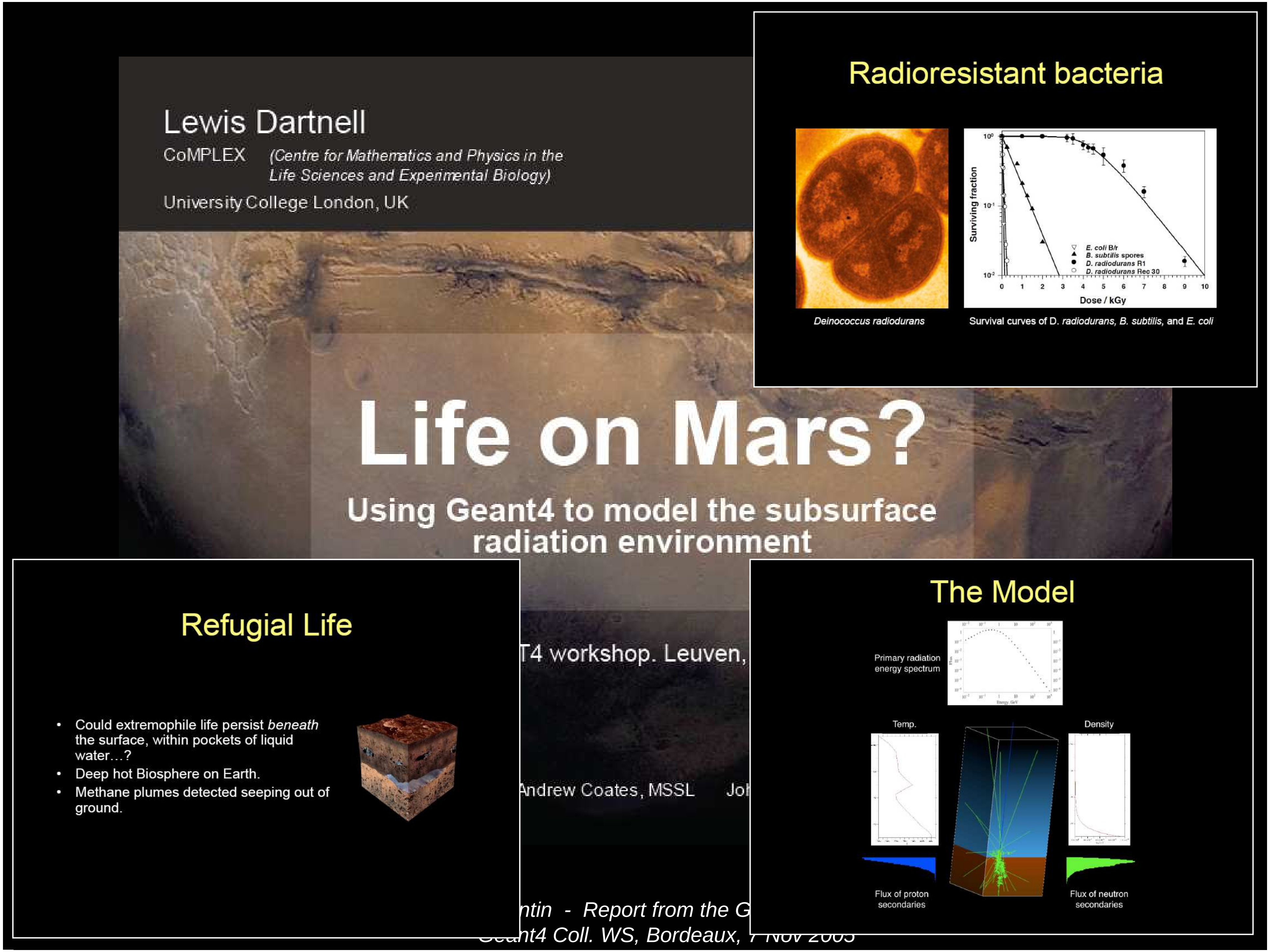






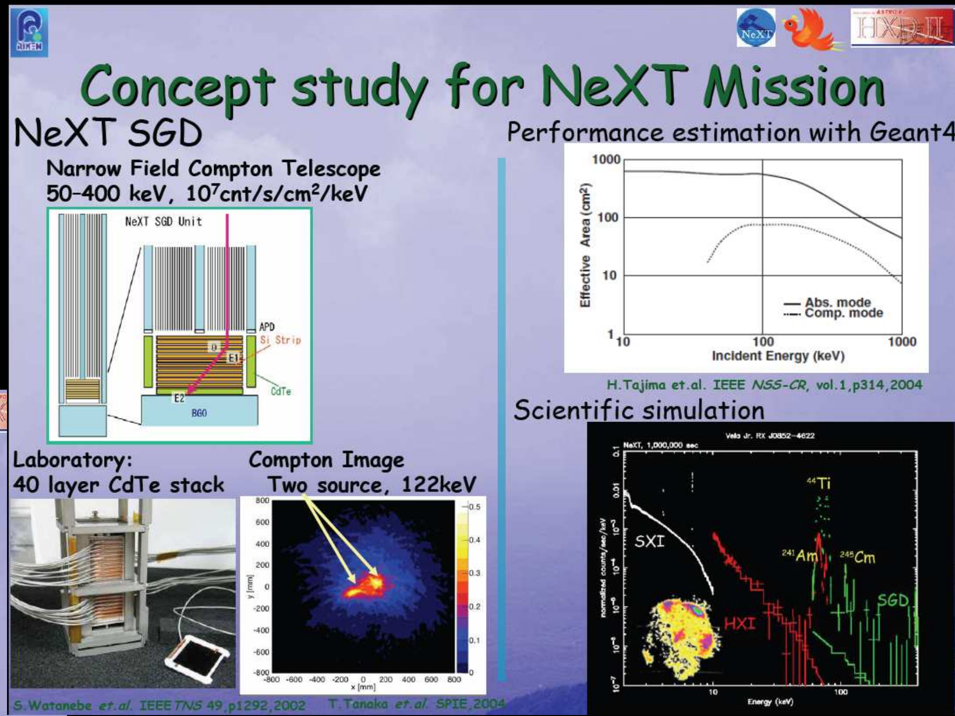
Laurent Desorgher

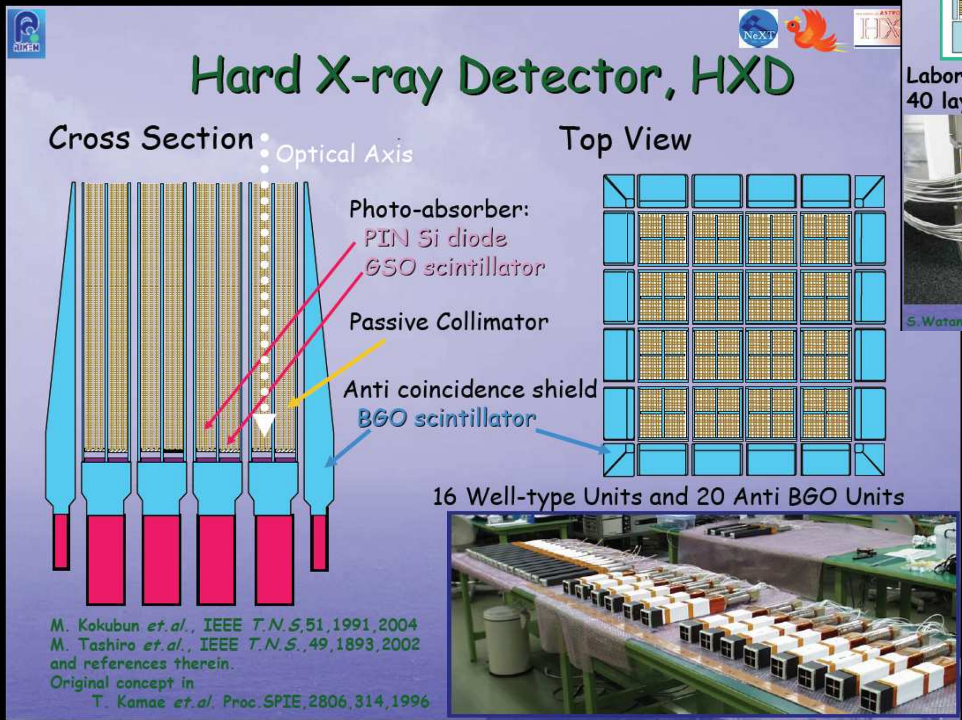
(Bern University)



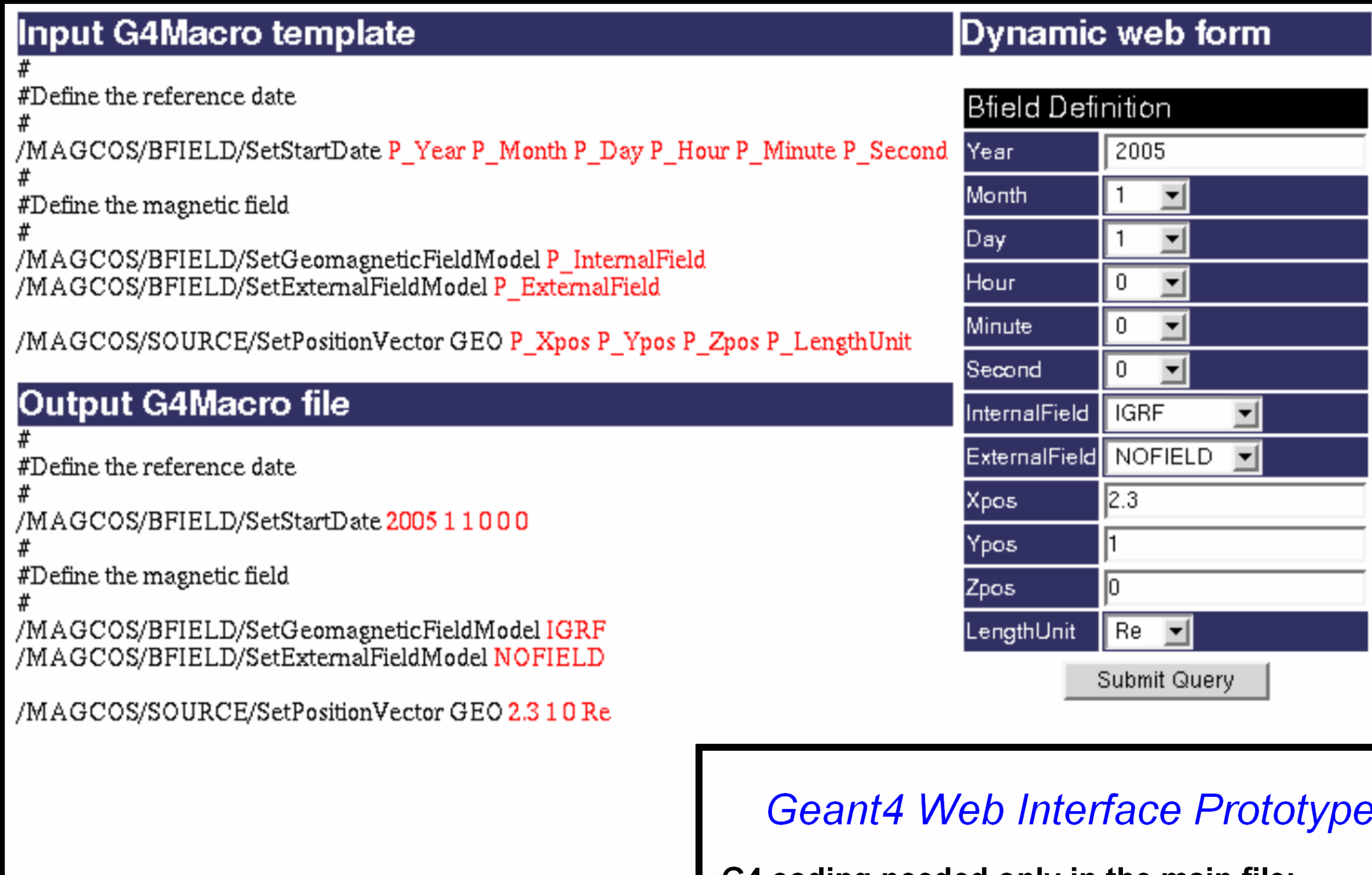
Lewis Dartnell
CoMPLEX (Centre for Mathematics and Physics in the Life Sciences and Experimental Biology)
University College London, UK
Life on Mars?
Using Geant4 to model the subsurface radiation environment
T4 workshop. Leuven,
Andrew Coates, MSSL
ntin - Report from the G
nt4 Coll. WS, Bordeaux,
Radioresistant bacteria
Surviving fraction
E. coli B/r
B. subtilis spores
D. radiodurans R1
D. radiodurans Rec 30
Dose / kGy
Deinococcus radiodurans
Survival curves of D. radiodurans, B. subtilis, and E. coli
Refugial Life
• Could extremophile life persist beneath the surface, within pockets of liquid water…?
• Deep hot Biosphere on Earth.
• Methane plumes detected seeping out of ground.
The Model
Primary radiation energy spectrum
Temp.
Density
Flux of proton secondaries
Flux of neutron secondaries

GEANT4 in Japan: NeXT and Suzaku





General purpose GEANT4 web interface



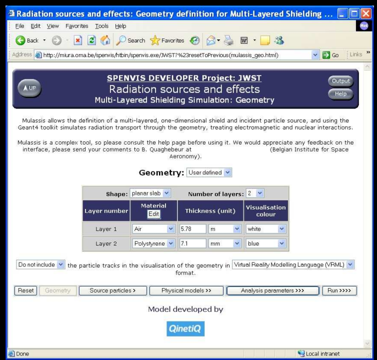
Set of PHP functions

- *Laurent Desorgher (Bern University)*

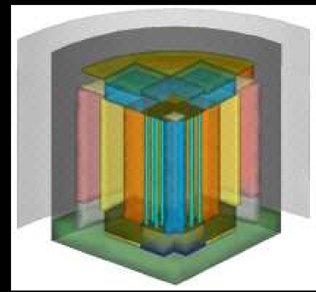
Geant4 Web Interface Prototype

- **G4 coding needed only in the main file:**
  G4UIsession* session
  = new G4UIGainPHPServer();

Interface GEANT4 to CAD GUI (or CAD GUI to GEANT$)



GUI tool

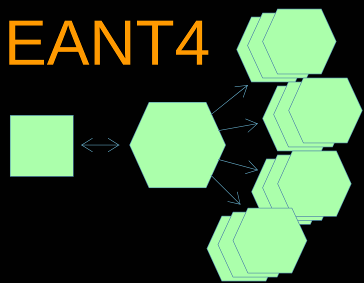


Geometry modeling

Script instructions:
- Physics
- Radiation Environment
- Analysis type

Geometry exchange format
- GDML
- CAD / STEP
- …

GEANT4



Conclusions

- Fruitful meeting of 2 communities (SPENVIS / GEANT4)
- Increasing use of GEANT4
- Usability
  Ready-to-use tools and interfaces
- Physics
  Improved EM models
  Need for further upgrade in hadronics

http://geant4.esa.int

http://www.spenvis.oma.be

Announcement: GDML session

- J.McCormick is trying to organize a parallel informal discussion session to discuss present use, trends, future developments related to GDML
- Please join if interested