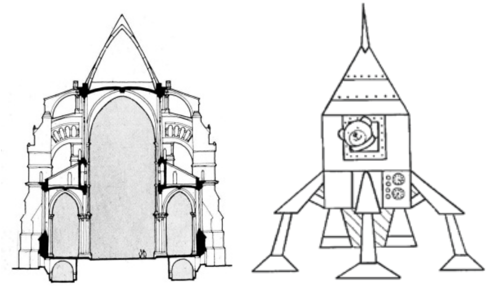
17th Geant4 Collaboration Workshop

Chartres, 10-14 Sep 2012

EM physics progress at ESA



Giovanni Santin*, Petteri Nieminen

Space Environments and Effects Analysis Section

European Space Agency

ESTEC

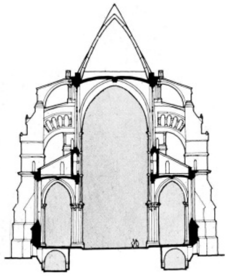
** on loan from RHEA Tech Ltd*

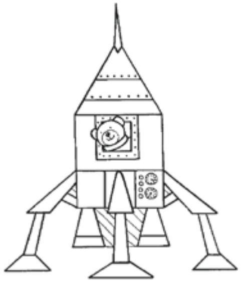
Outline

- ESA BioRad, Physics models for biological effects of radiation and shielding 2009-2011
  - Review of MC tools, improvements to ion physics, validation against data from LNS and GSI, Geant4 DNA

- Within the context of the ESA ELSHIELD project: Energetic electron shielding, charging and radiation effects and margins
  - Work Package on EM physics model improvement
  - Work packages on experimental test campaign for validation
    - Electron dose vs depth data in the range 1-10 MeV
    - Comparison to Geant4 and PENELOPE 2011

- Jupiter exploration and Galileo (navigation satellites)
  - Reverse MC performance
  - Comparison to Geant4 forward, NOVICE, FASTRAD MC





Geant4 standard EM model and interface development

Standard EM model developments:

New bremsstrahlung model for G4SeltzerBergerModel
- Base on evaluation of bremsstrahlung cross section by Seltzer and Berger

New version of L.Urban multiple scattering G4UrbanMscModel95
- Electron scattering benhcmarks

New model of photo-electric effect G4PEEffectFluoModel
- Atomic de-excitation added

New model of Compton scattering G4KleinNishinaModel
- Atomic de-excitation and Doppler broading added

New angular generator G4DipBustGenerator
- Fast sampling of angular distribution for bremsstrahlung

Extension of PAI and Moller-Bhabha ionisation models down in energy from 1 keV to 100 eV
- Important for micrometer scale simulation

Geant4 EM interface developments:

Universal interface to angular generator
- Interchange of angular generators between models

New universal interface to atomic de-excitation
- Standard EM package can use de-excitation module

New EM biasing framework
- Biasing options are available via UI commands

J.Allison
V.Grichine
A.Howard
V.Ivantchenko
M.Maire
L.Urban

INTERNAL THALES ALENIA SPACE
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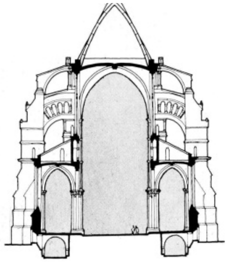
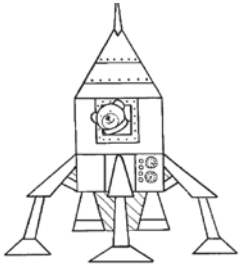
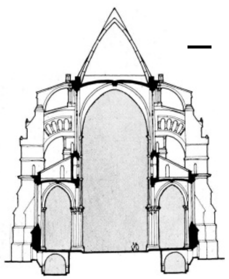


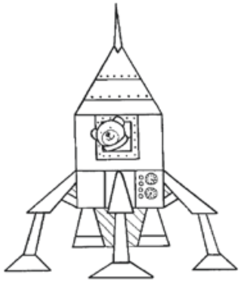


ELSHIELD e- experimental campaign

Context

- Navigation, telecommunication satellites in Earth orbits
  - High fluxes of penetrating energetic e- in the Earth's radiation belts
  - Significant Brem, dominant in well shielded S/C regions
- Jupiter missions
  - 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)
  - Significant Brem, but primary e- still dominate dose very deep in S/C
- Need of data for e- validation
  - Validation of dose vs depth in pure materials for 1MeV<E<10MeV
  - Dose enhancement effects in multi-layer structures
- Comprehensive experimental test campaign
  - Simple and complex layered-structures





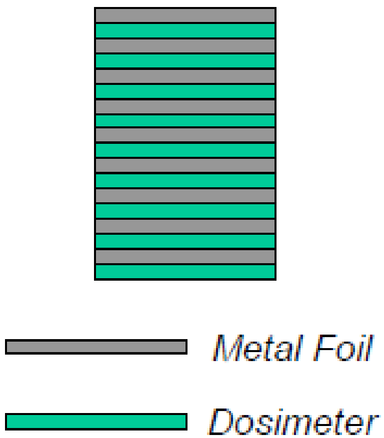
Samples

Electronic components

- 2N2222 Transistors in TO-18 package
  - Unshielded
  - Shielded with various metals and thicknesses
- pMOS in DFN-8 package
  - Unshielded

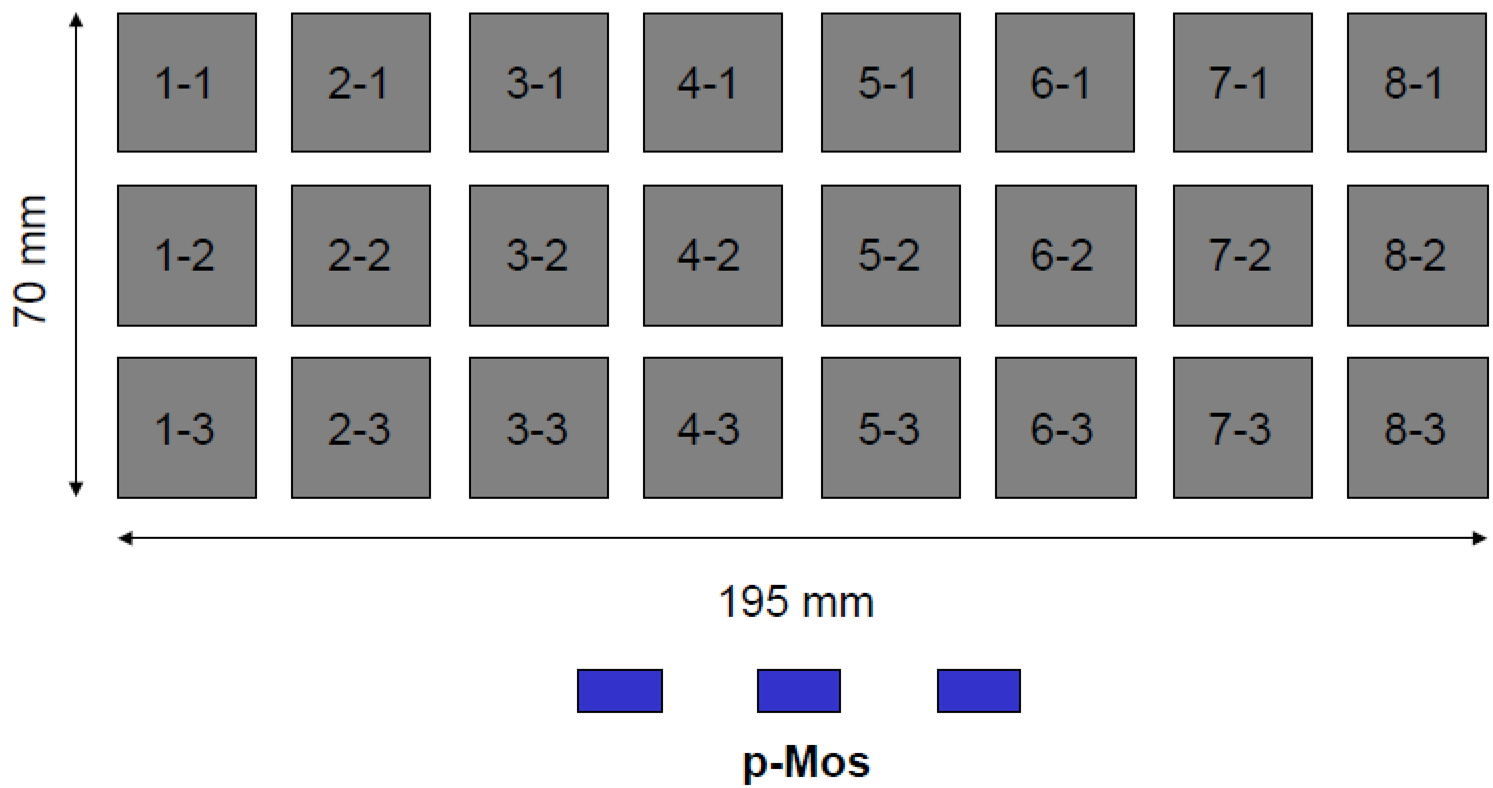
Metal stacks *(including thin film dosimeters)*

Material Configuration	Thickness (mm)	Composition
1	8	32.Al
2	5	20.Ti
3	2	8.Cu
4	1	4.Ta
5	4.25	Ta-16.Al
6	2.5	Ta-4.Al-Ta-4.Al
7	5	Ti-4.Al-Ti-4.Al-Ti-4.Al-Ti-4.Al
8	6.25	Cu-24.Al



Samples

2N2222



Dosimetry

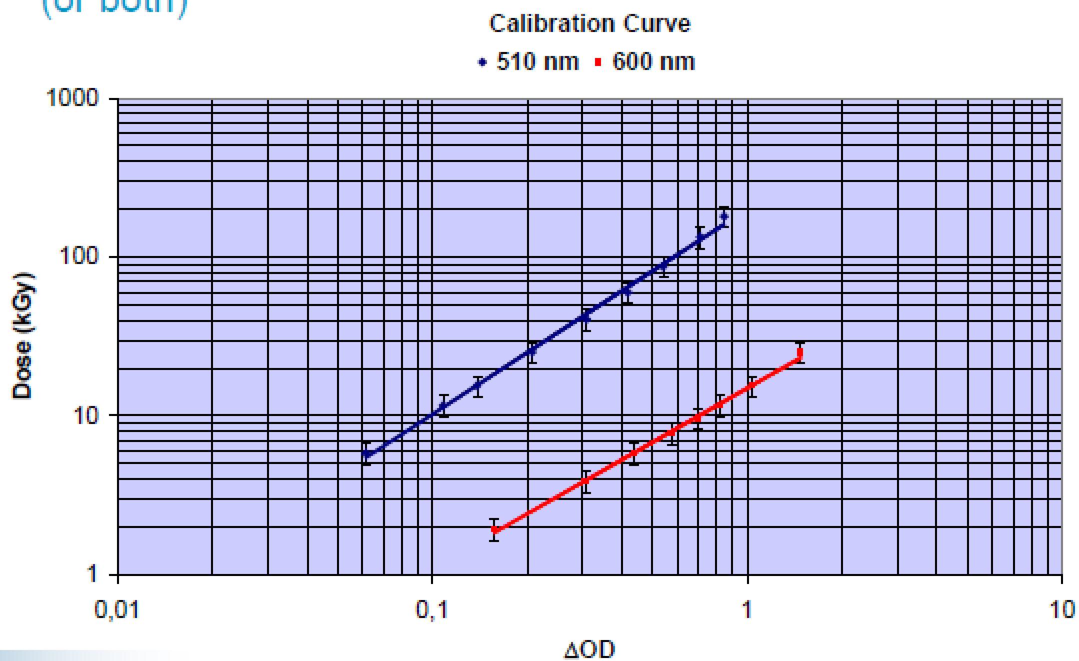
Dosimeters

- FWT-60-00 thin film dosimeters from Far West Technology
  - Density ~ 1.15 g/cm3
  - Mean thickness ~ 48.5 µm (batch #1106)
  - Change of optical density during irradiation
- FWT-92D digital radiachromic reader
  - Sensitivity function of the wavelength
  - For low dose (from 1 to 30 kGy), measurement at 600 nm
  - For high dose (from 10 to 200 kGy), measurement at 510 nm
- Uncertainties
  - Relative uncertainty estimated to remain within ±5%
  - Absolute uncertainty estimated to ±15% (T, %H, Dose)

Dosimetry

Dosimeters Calibration

- Calibration using a Co60 source (6 dosimeters)
  - Performed between 2 and 180 kGy
  - Optical density of the dosimeters measured either at 510 or 600 nm (or both)



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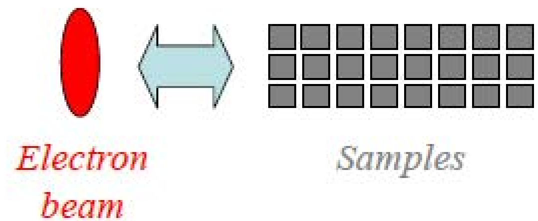
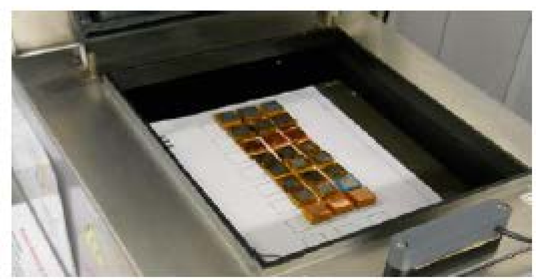
Irradiation Facilities

Scanning irradiation:

- 100 keV
  - Under flowing N_2

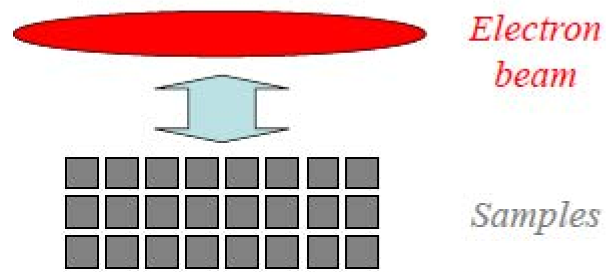


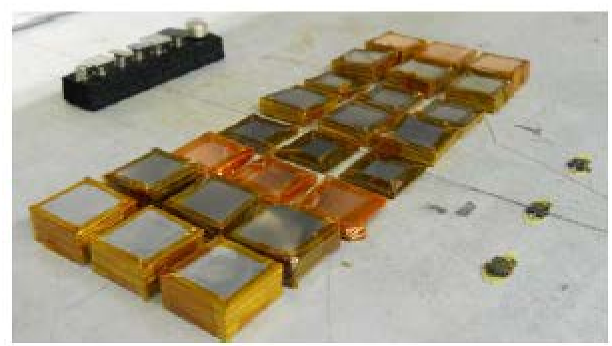


Irradiation Facilities

Scanning irradiation:

- 1 & 3 MeV
  - In Air (through Al window 100 µm)

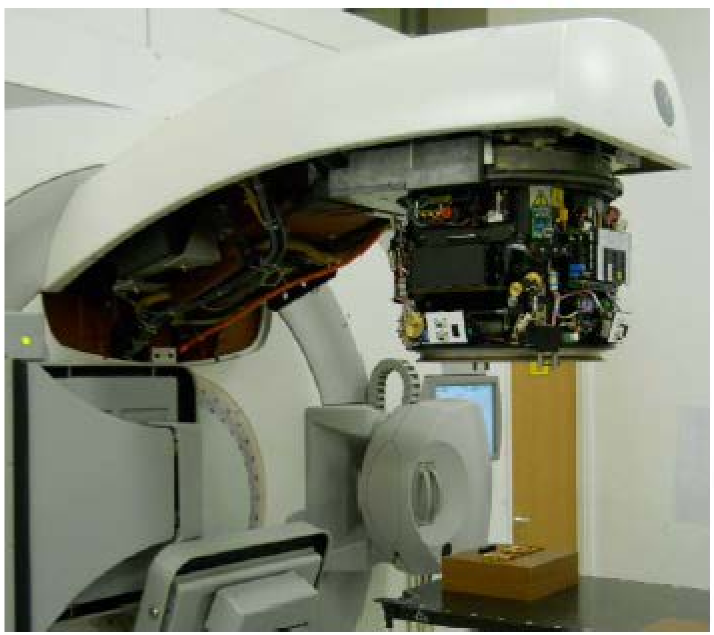




Irradiation Facilities

Stationary irradiation:

- 6 & 10 MeV
  - In Air
  - WTe Bottom & Top Layer (1.2 cm at 6 MeV, 2.3 cm at 10 MeV)



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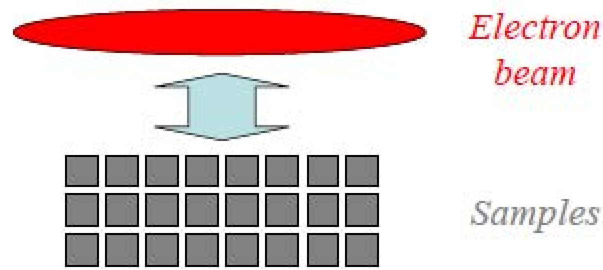

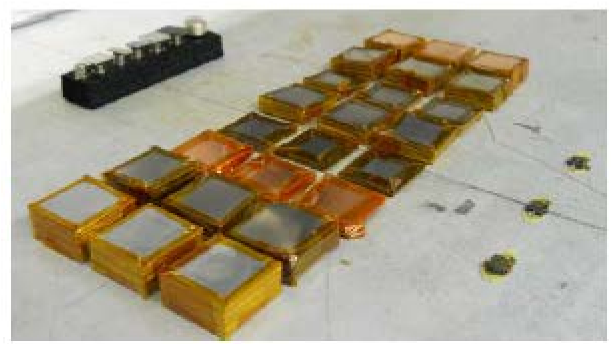

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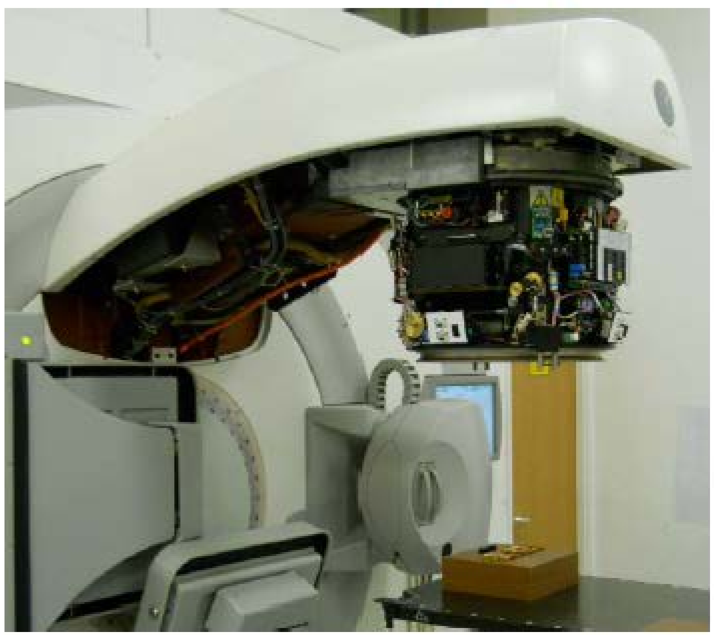
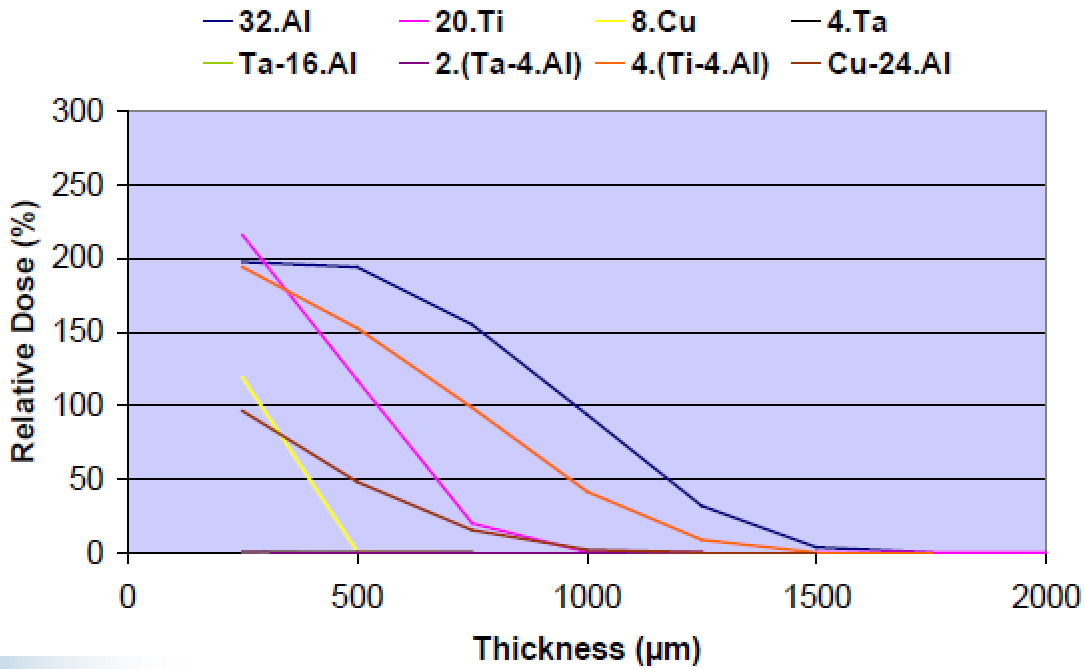


ThalesAlenia Space
A Thales / Finmeccanica Company

Test Results: Metal Stacks

1 MeV

- Dose up to ~1500 µm (Al)
- D_{Max} up to 215 % (Ti)
- Almost complete shielding with 250µm Ta



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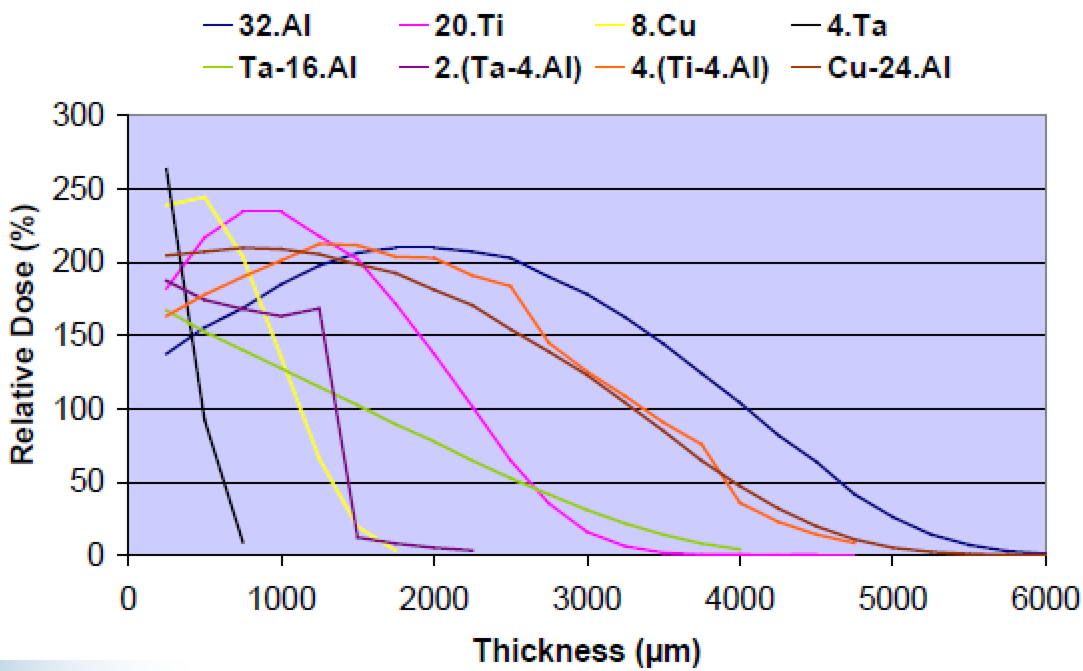
Test Results: Metal Stacks

3 MeV

- Dose up to ~6000 µm (Al)
- D_{Max} up to 260 % (Ta)
- Highest dose increase with Ta



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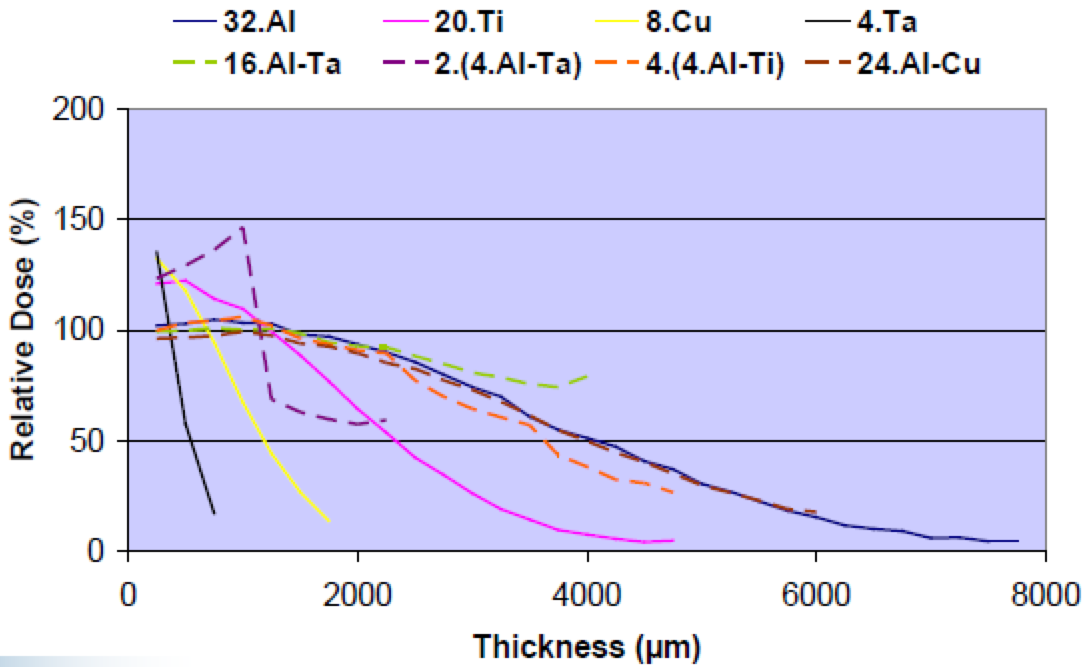
Test Results: Metal Stacks

6 MeV

- Dose on the whole sample depth (Al)
- D_{Max} up to 145 % (4.Al-Ta)
- Highest dose increase with Ta



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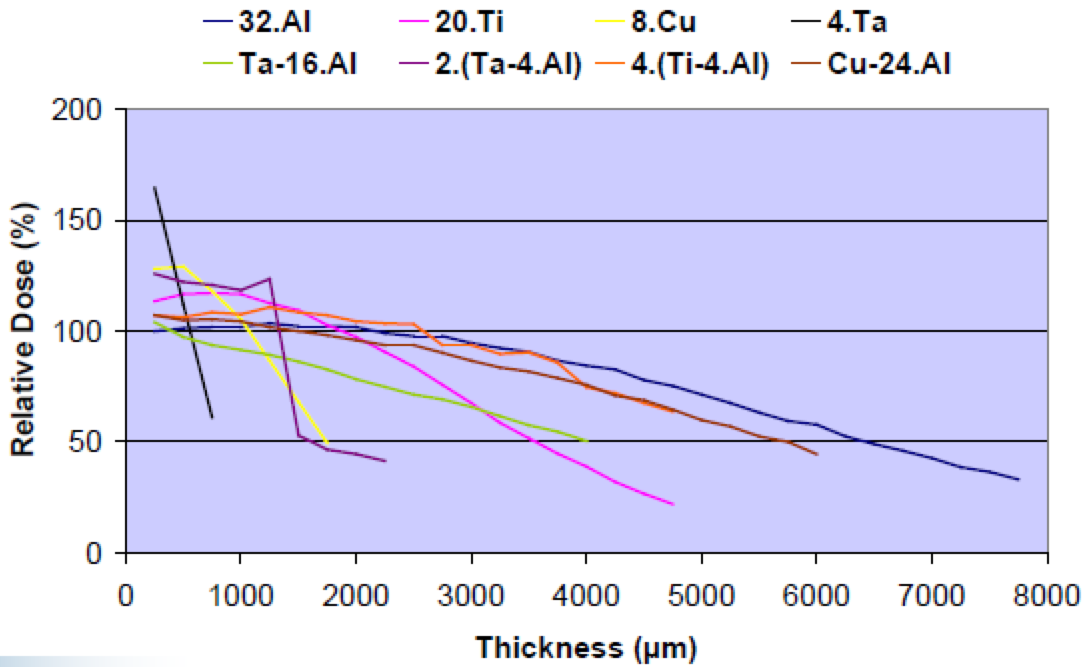
Test Results: Metal Stacks

10 MeV

- Dose on the whole sample depth (Al)
- D_{Max} up to 165 % (Ta - 4.Al)
- Highest dose increase with Ta



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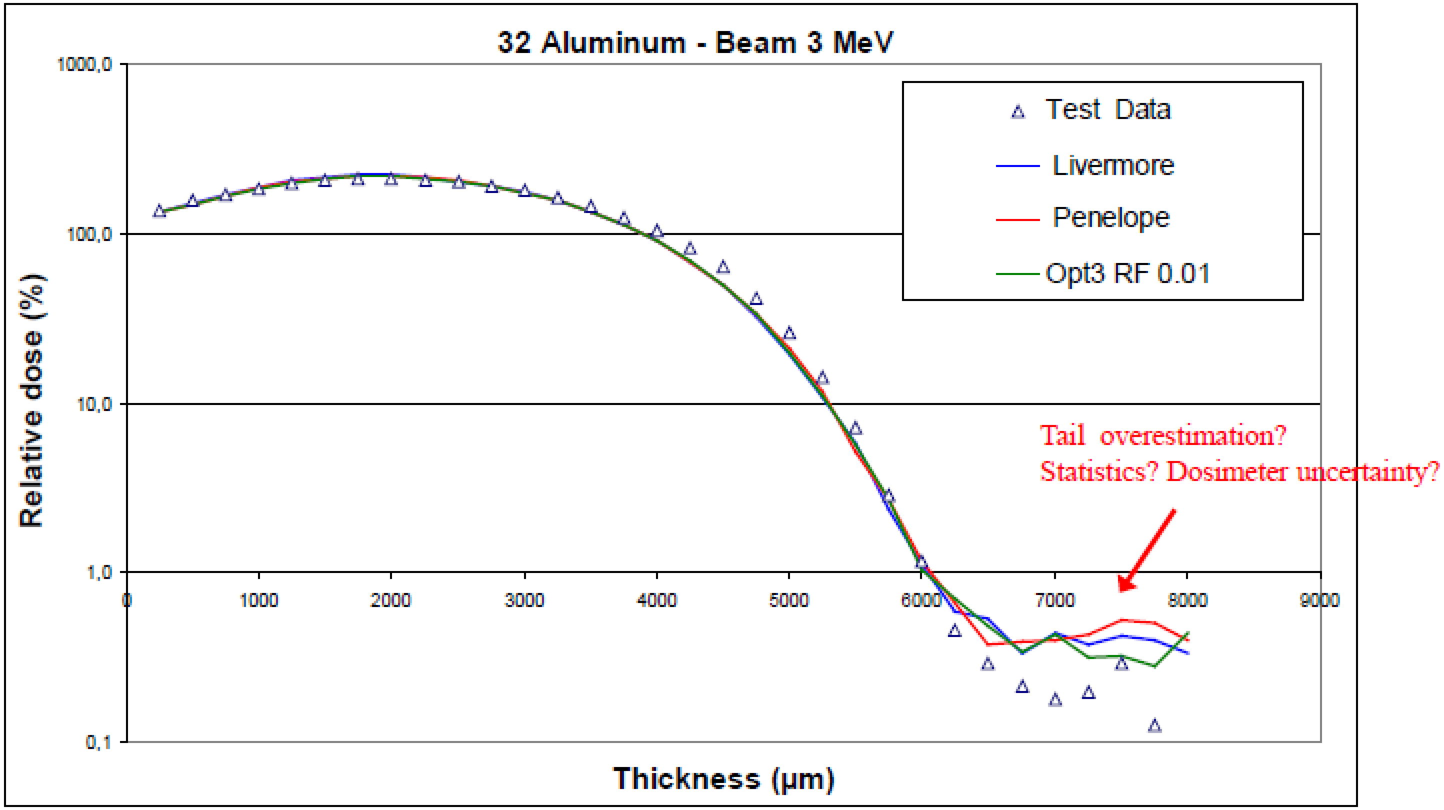
Validation of new models and tools

Preliminary validation results. 3 MeV case (G4.9.5)



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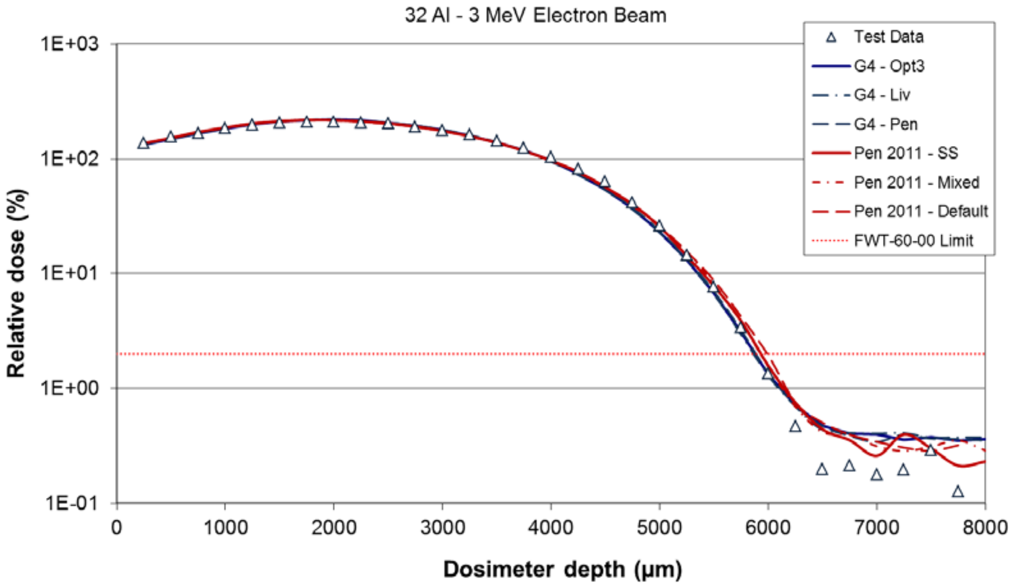
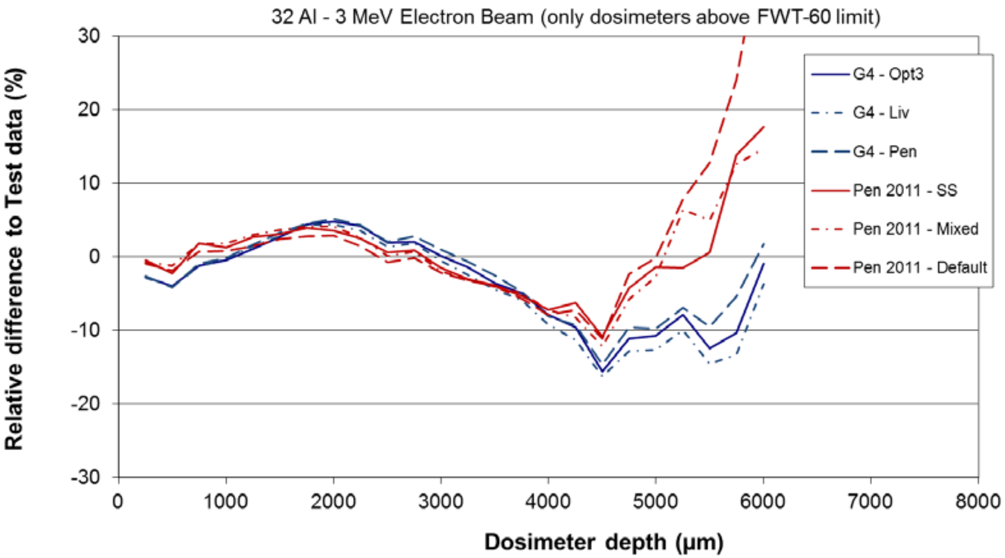
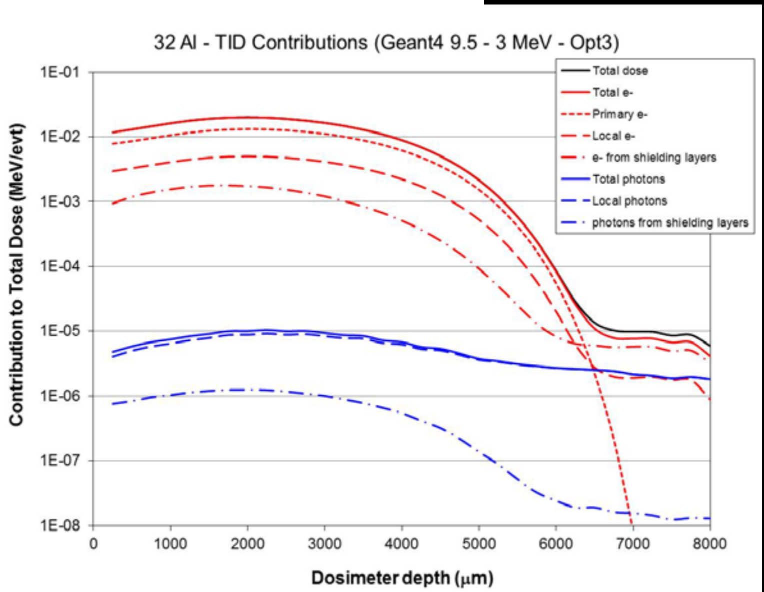
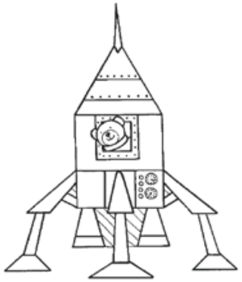
3MeV e⁻, sim.model w/ better exp.parameters Data v. Opt3, Liv, G4Pen and PENELOPE 2011







S.Ibarmia, INTA
V.Ivantchenko



3MeV e^- , various material sequences Data v. Opt3, Liv, G4Pen

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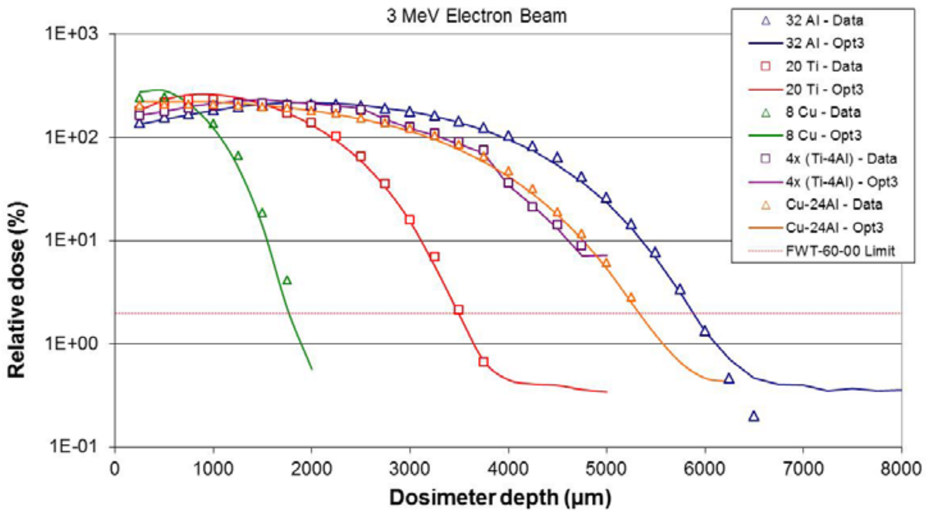
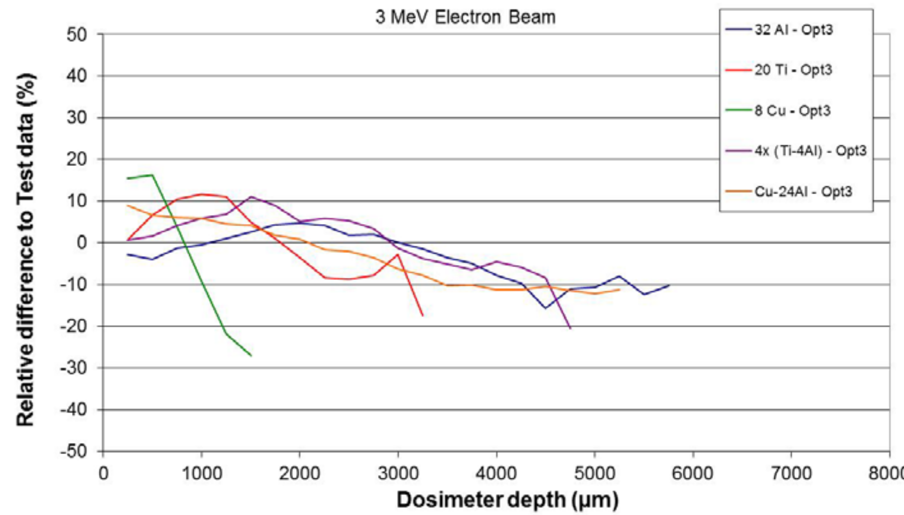
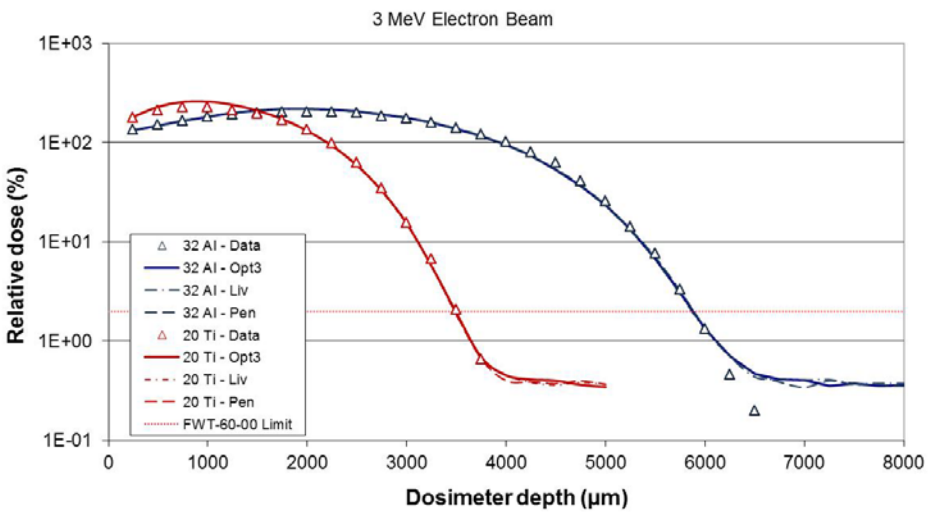
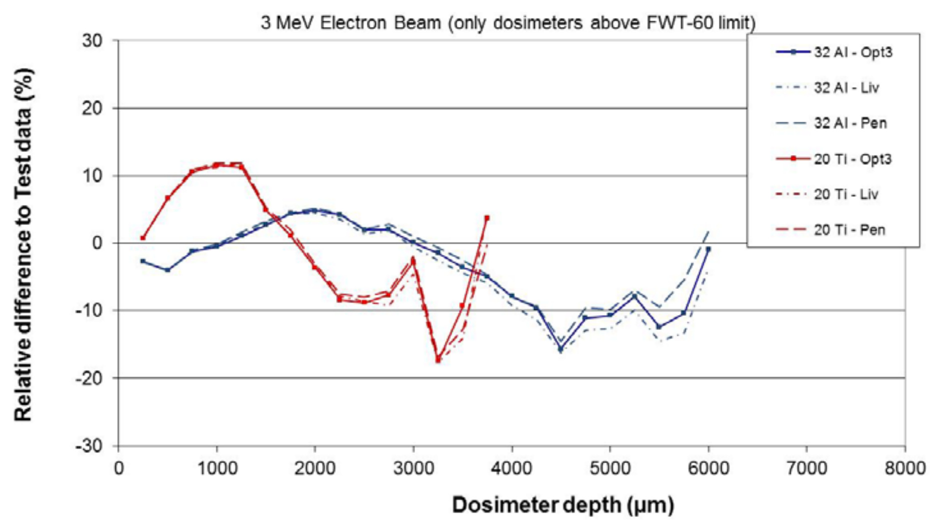
V.Ivantchenko





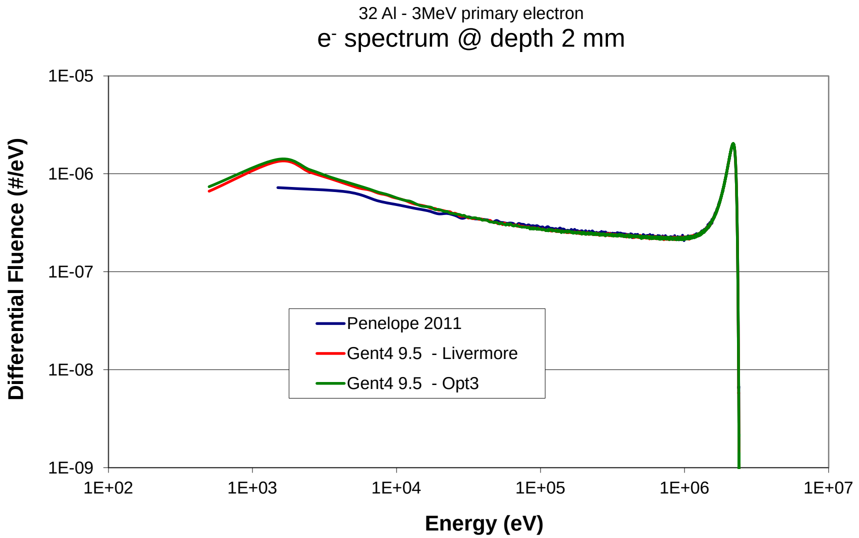


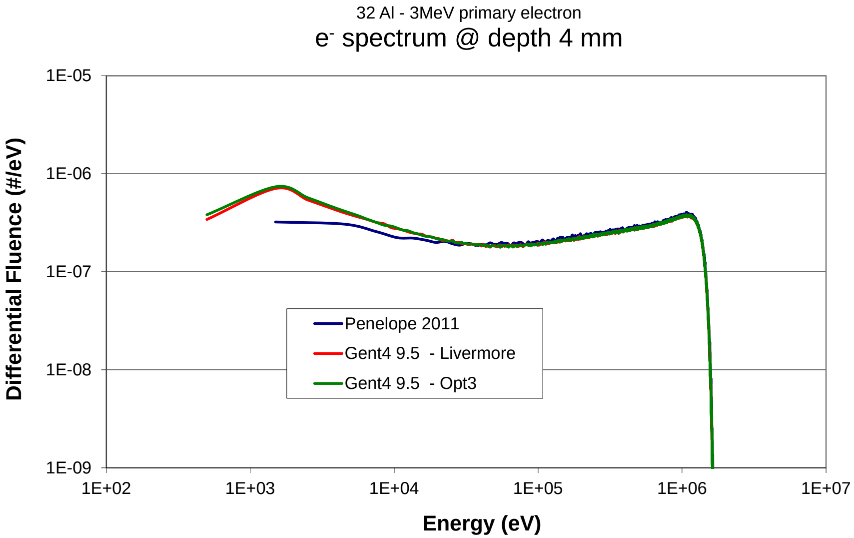


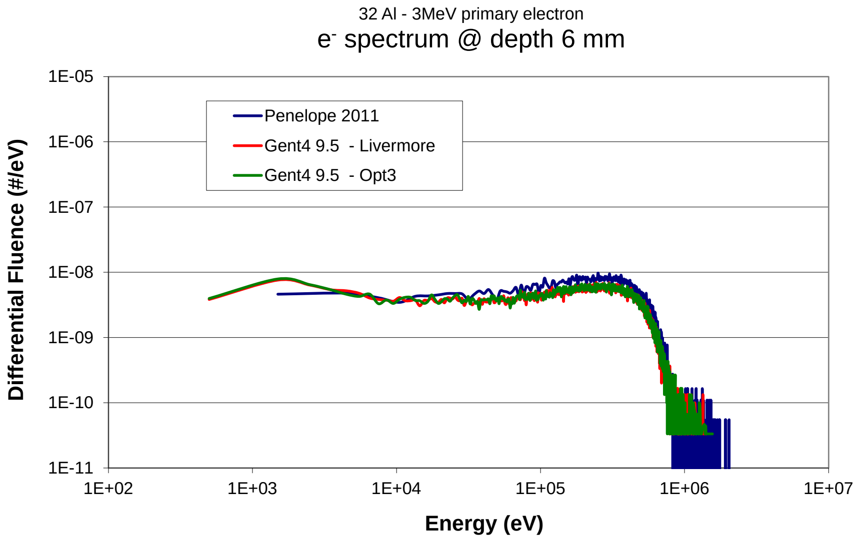
32 Al layers- 3MeV e^-
e^- spectrum @ various depths

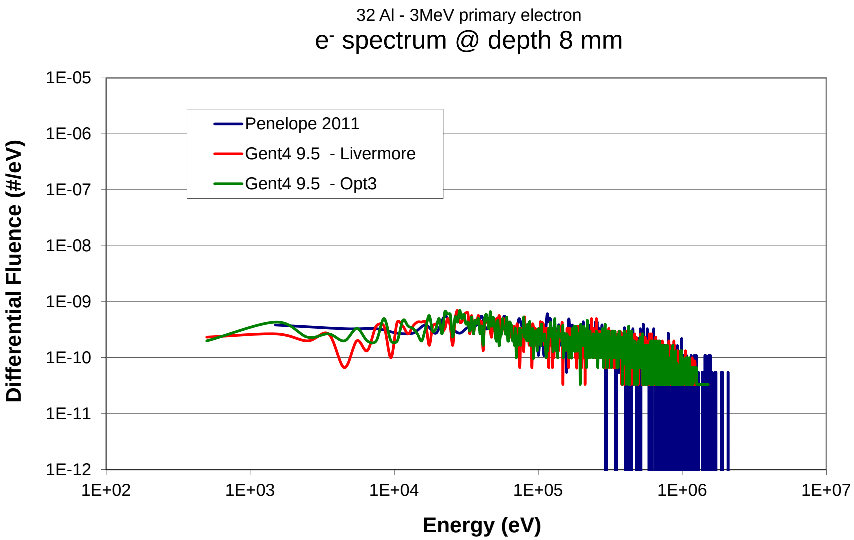
- Geant4 v. Penelope 2011. No window, vacuum, no table

S.Ibarmia, INTA
V.Ivantchenko





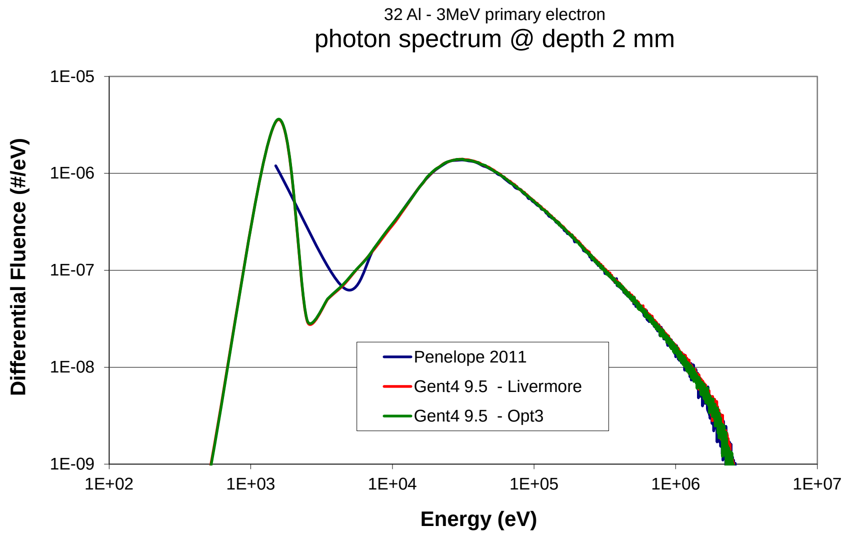


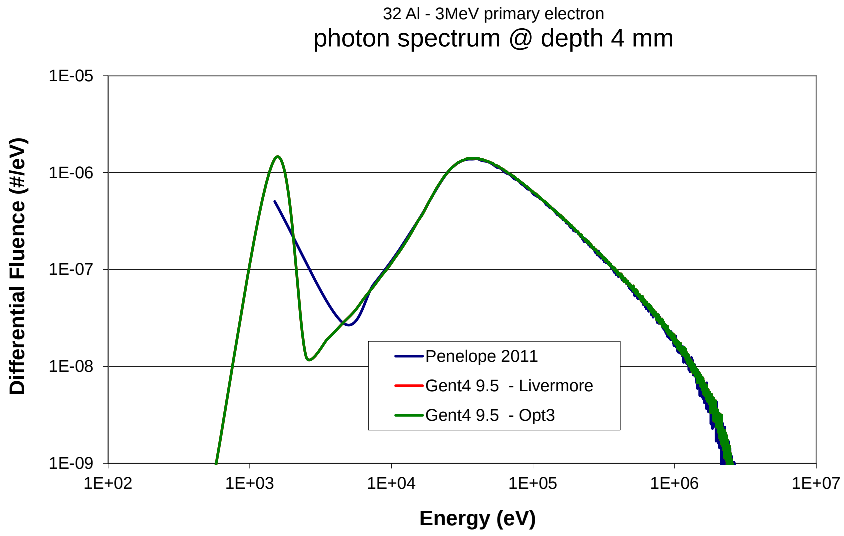


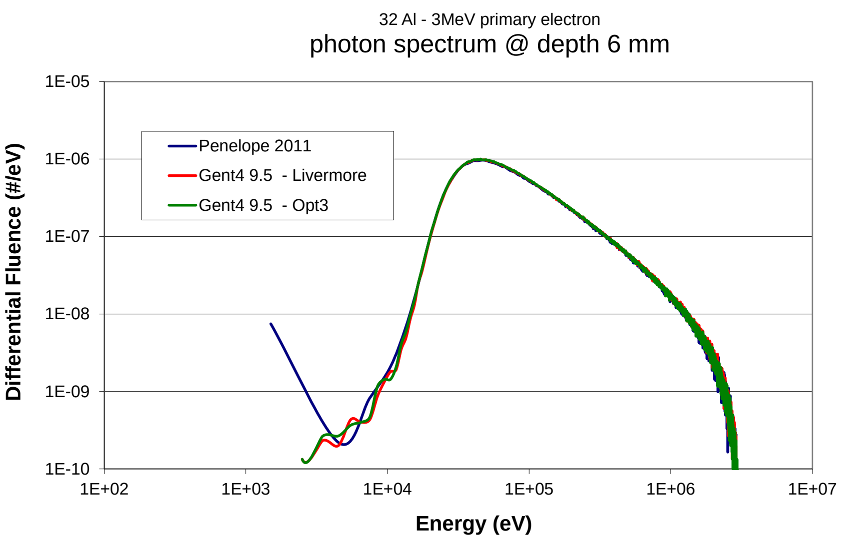
32 Al layers- 3MeV e-
gamma spectrum @ various depths

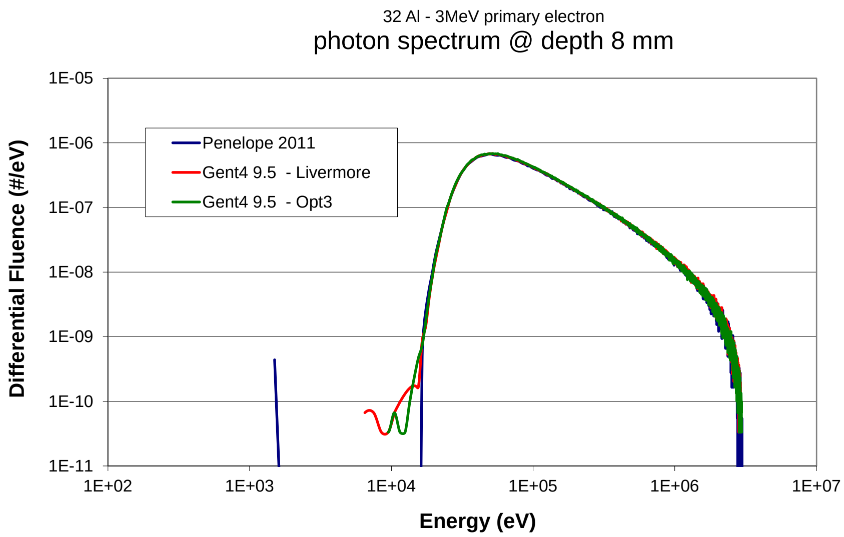
S.Ibarmia, INTA
V.Ivantchenko

- Geant4 v. Penelope 2011. No window, vacuum, no table



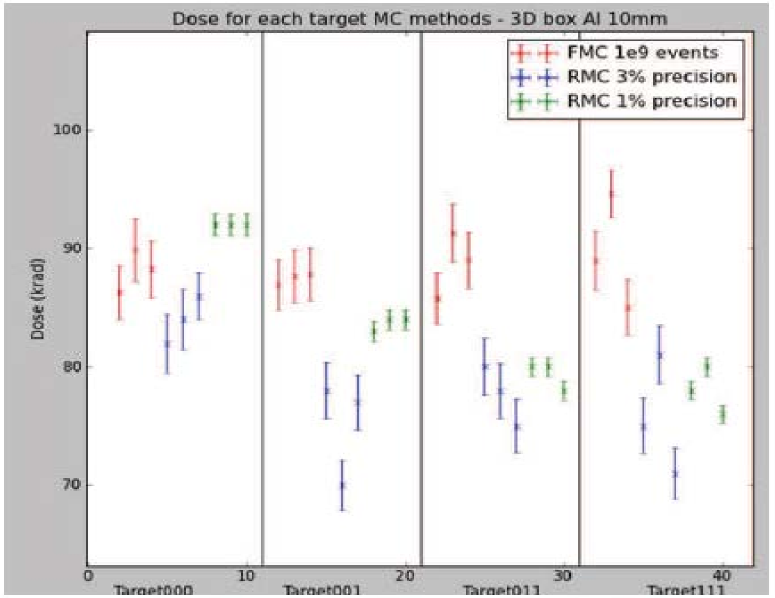


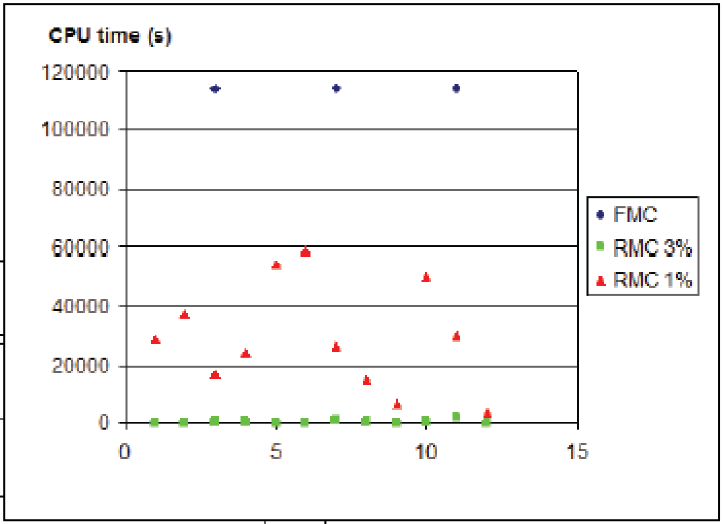


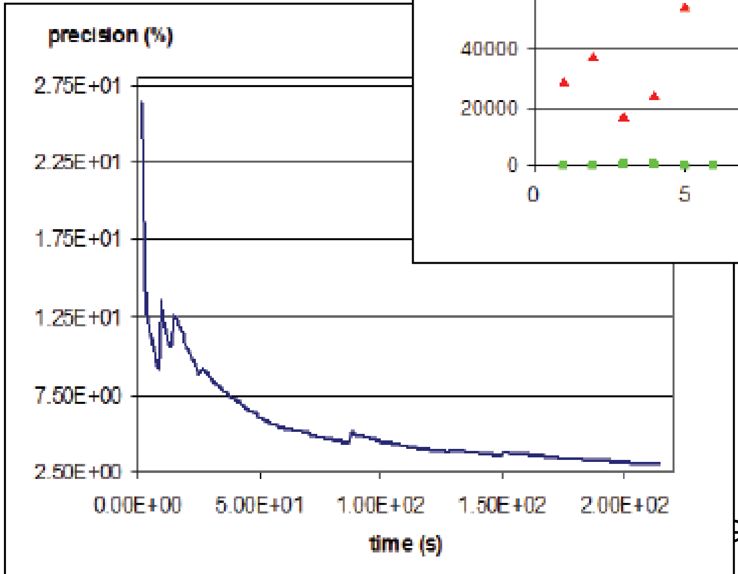


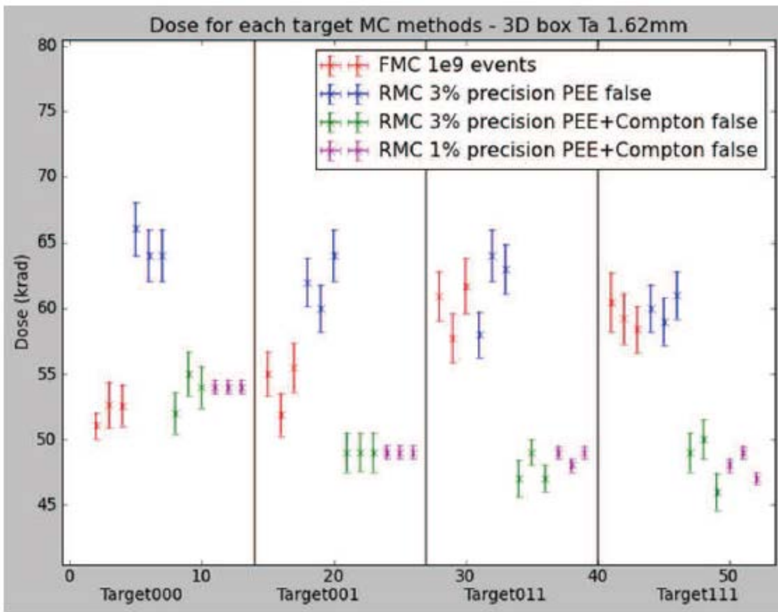
Reverse MC – some performance studies

- Geant4 RMC compared to FWD (GRAS 3.1, G4.9.5.1)
- Jupiter e- environment
- RMC can be stopped by convergence test
- Simulation time for RMC unexpectedly long
- Convergence time profile shows jumps







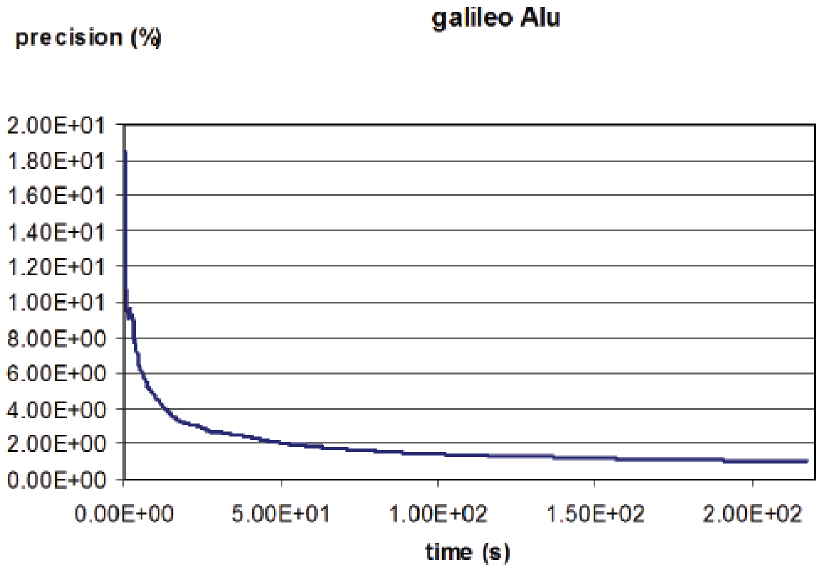


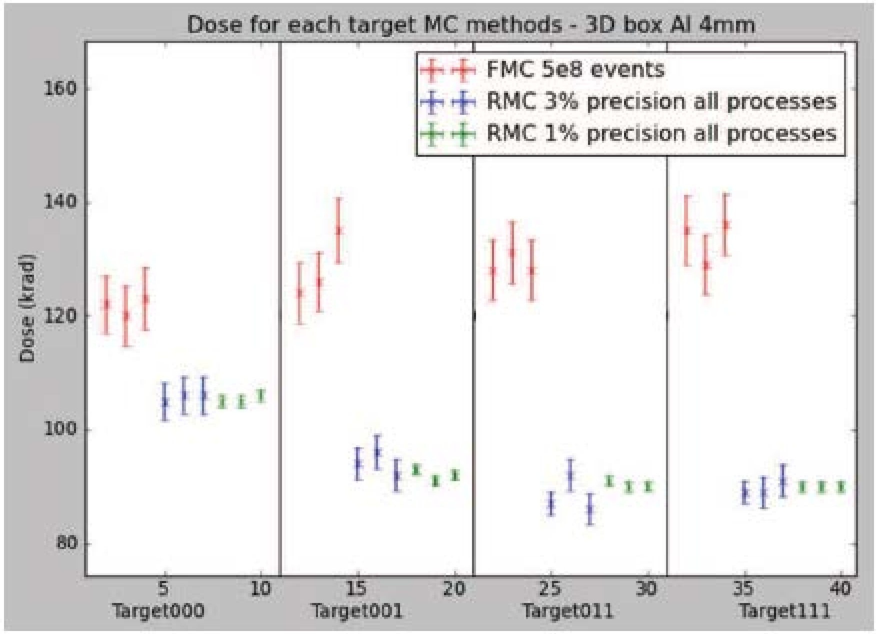
M.Ansart, ESA

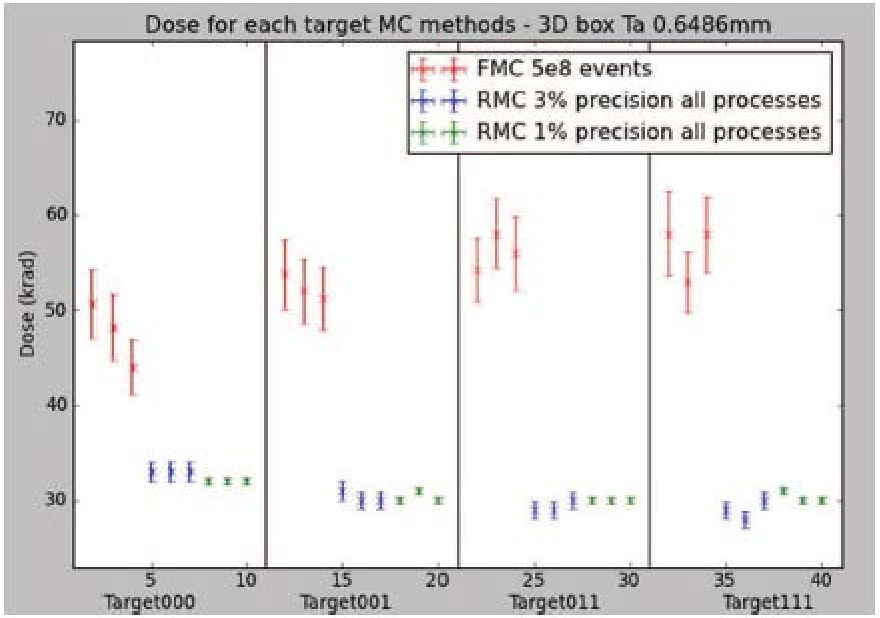
L.Desorgher, SpaceIT

Same for Galileo (Navigation) MEO spectrum (lower energy, E<7MeV)

- Convergence time profile smoother for MEO e- than for Jupiter e-
- Still some high weight events prevent RMC from quick convergence



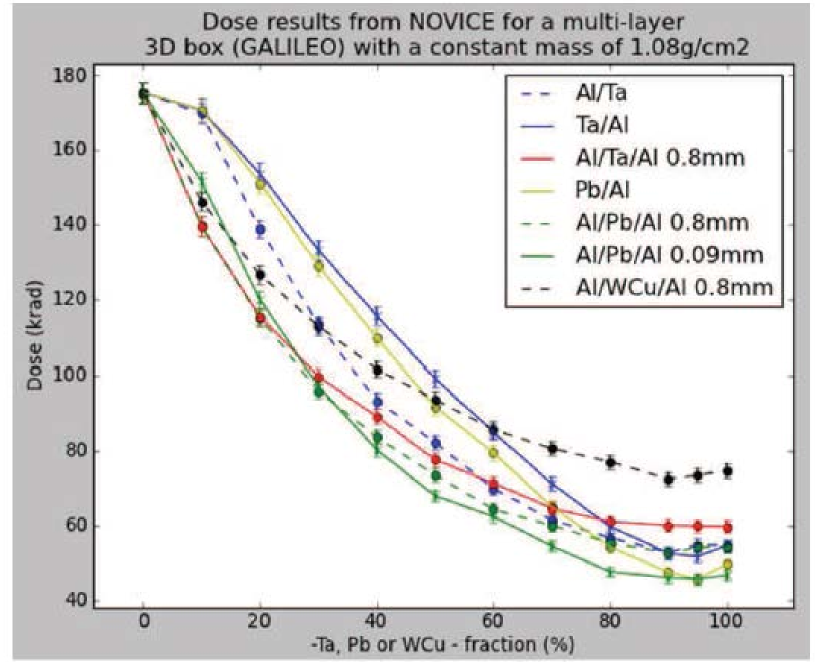


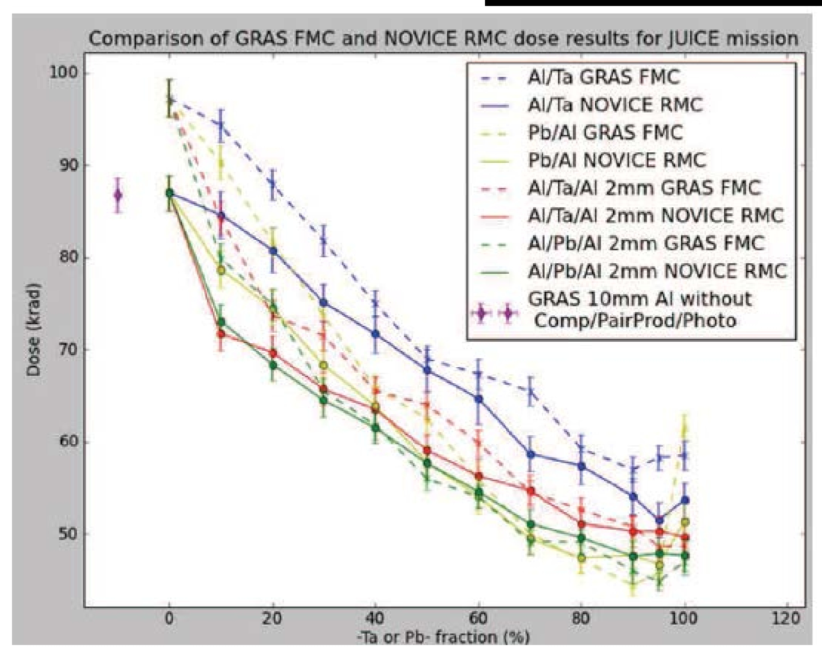


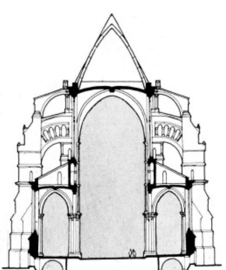
2012, Chartre

Geant4 FMC v. NOVICE

- NOVICE, developed by Tom Jordan (EMPC) was until very recently the only adjoint MC tool available to space industry
- Multi-layered shielding effects well reproduced
- Difference in absolute dose when compared to Geant4 FWD
- Physics models available in NOVICE not well documented. We hope to discuss discrepancies with Tom soon (maybe at RADECS 2012)







Engineering tool comparison Summary

- SHIELDOSE-2 (Seltzer, via SPENVIS)
- Geant4 FWD (GRAS, G4 9.5.p1)
- [MULASSIS (G4.9.4.p2 opt0)]
- FASTRAD FMC
- FASTRAD RMC (point or volume det)
- NOVICE RMC (point det)

- GRAS RMC not included
  - Ongoing work by Laurent
  - It will be interesting to see also with Geant4 RMC if any big difference between point and volume detector