

DESIRE

Dose Estimation by Simulation of the ISS Radiation Environment

<http://www.particle.kth.se/desire/>

The DESIRE project:

Studies of the Columbus/ISS radiation environment using Geant4

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Outline

1. The DESIRE Project
2. Geant4 Physics Validation Studies
3. Tentative Columbus Radiation Simulations and Recent ISS Modeling

1. The DESIRE Project

- "Dose Estimation by Simulation of the ISS Radiation Environment"
- Aimed at accurate calculations of the radiation flux and doses to astronauts inside the Columbus/ISS.
- Utilizes Geant4 for radiation transport.
- Funded by ESA (15613/NL/LvH) and SNSB.

Project outline

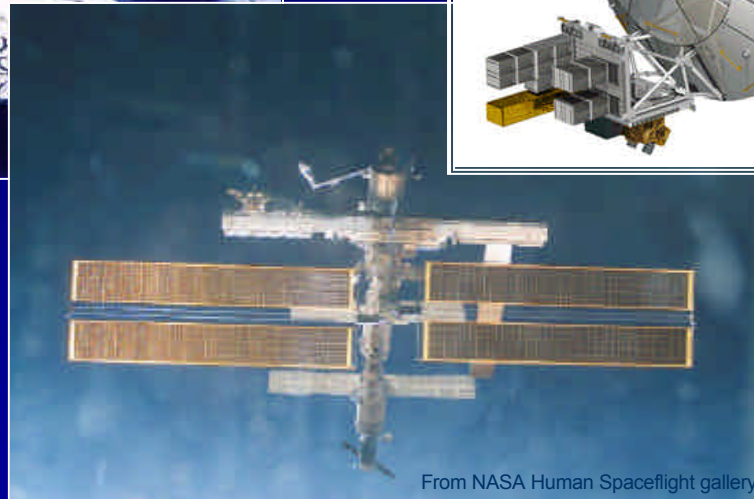
- Benchmark studies of Geant4. Comparisons to experiments and other codes (BRYN-/HZETRN, SHIELD-HIT).
- Geometry modeling; simpler tests.
- Evaluation of incident radiation fields; full simulations. Comparisons to data from Mir, SilEye and, if available, another ISS module.
- Equivalent doses. Human phantoms in Geant4?

ISS / Columbus

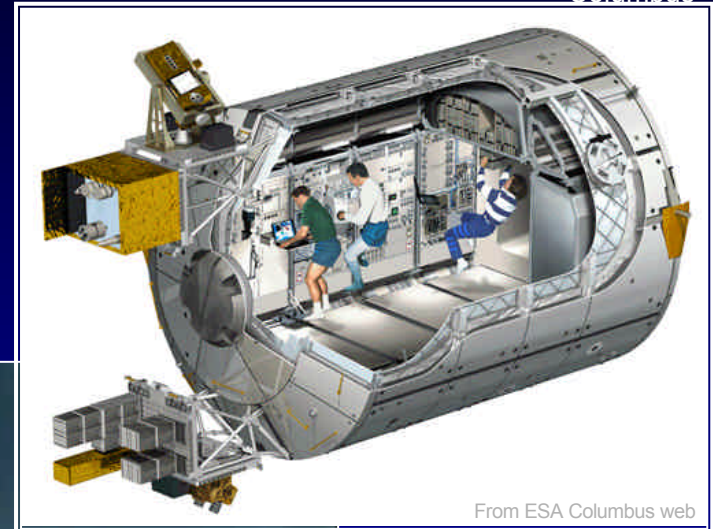
Completed



Circular orbit
380-400 km altitude
51.6° inclination (~London)



Columbus



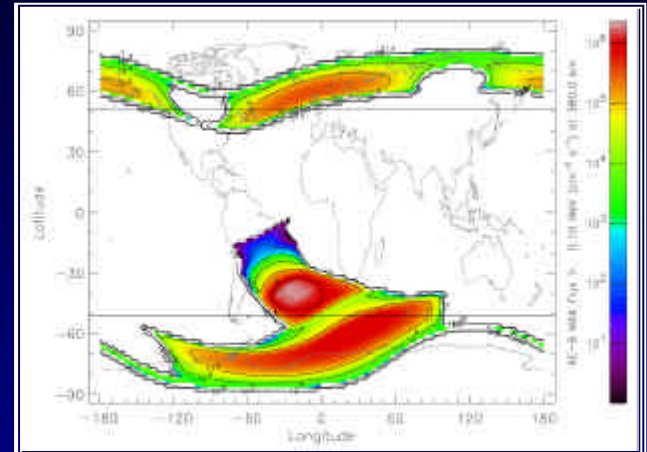
Launch date: ?

Dec. '02

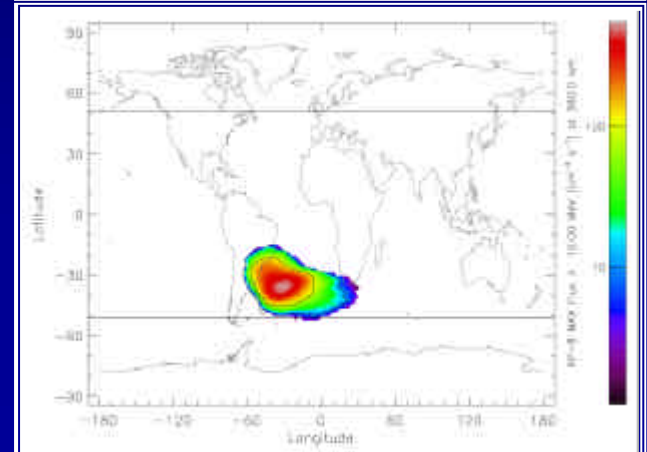
Radiation Environment

- GCRs (protons, ions)
- Trapped particles (electrons, protons)
- Solar Particle Events

Trapped e⁻



Trapped p



Radiation Transport

- Why Geant4?
 - Aims to provide all necessary physics.
 - Heavy ion transport still missing (?)
 - Designed to be easily extendable.

2. Validation studies

Incident protons, energy 10-1000 MeV; neutron production, energy deposition, proton penetration.

- Comparisons to Los Alamos exp. data
 - M.M. Meier, et al. Nucl. Sci. Eng. 102, 310-321 & 104, 339-363
- Comparisons to SHIELD-HIT
 - SHIELD has been used previously for space applications (Mir).
- Comparisons to BRYNTRN
 - Similar codes used in the NASA manned space program.

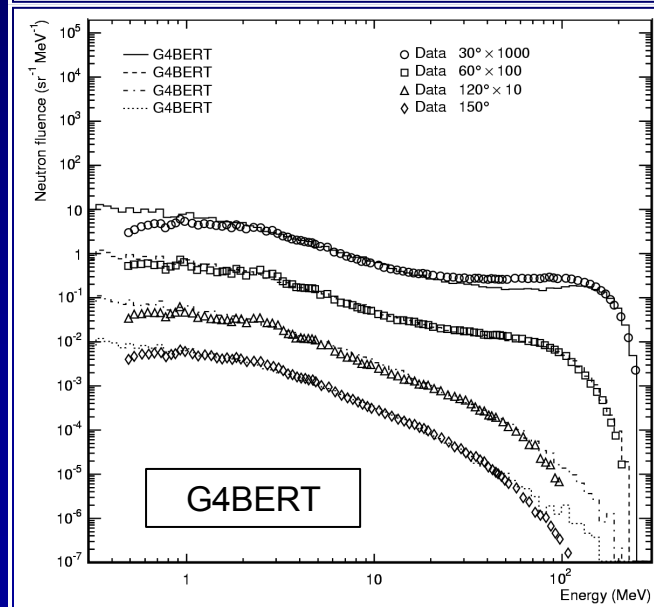
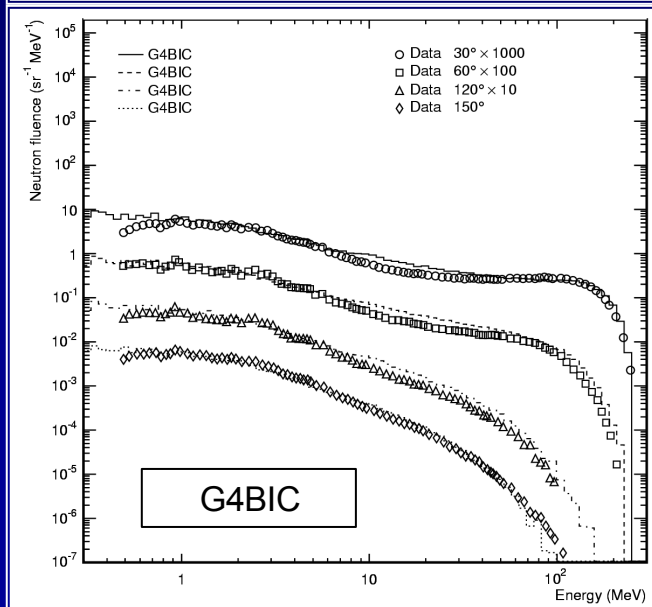
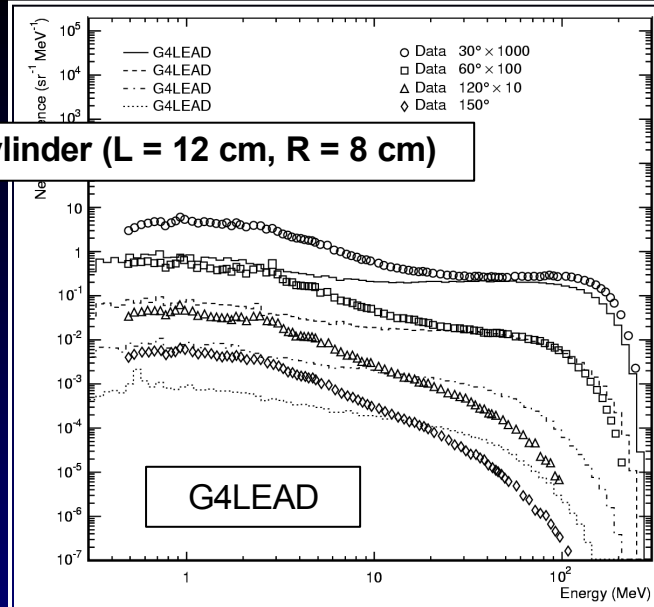
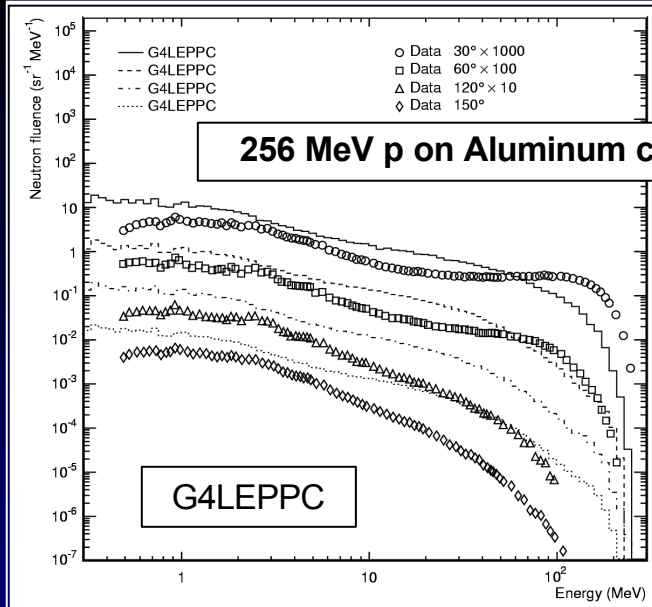
Test details

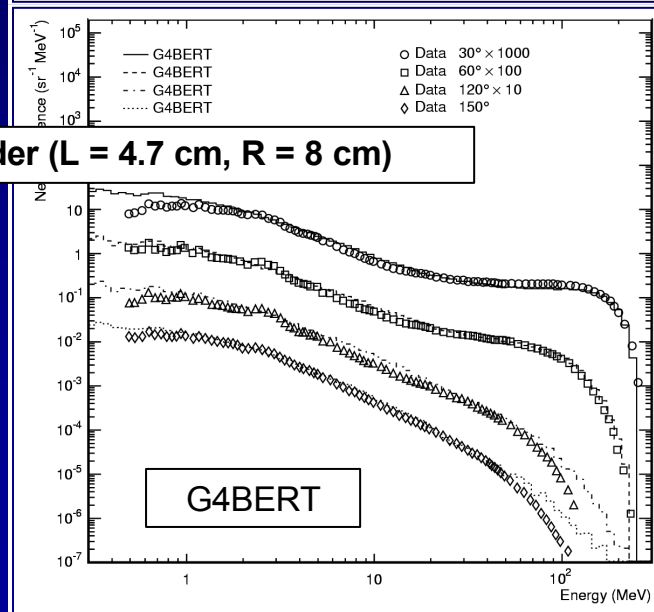
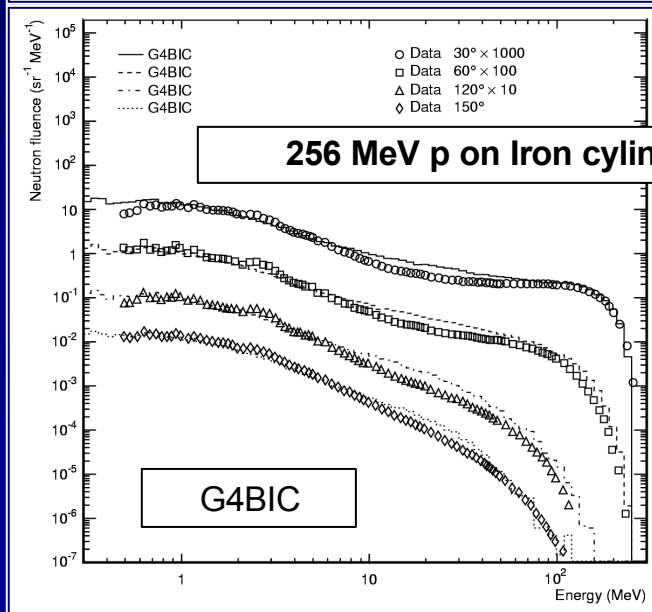
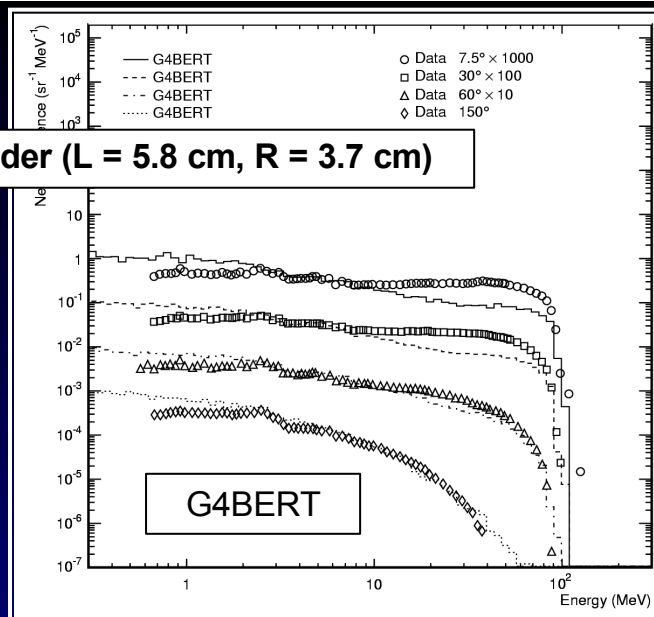
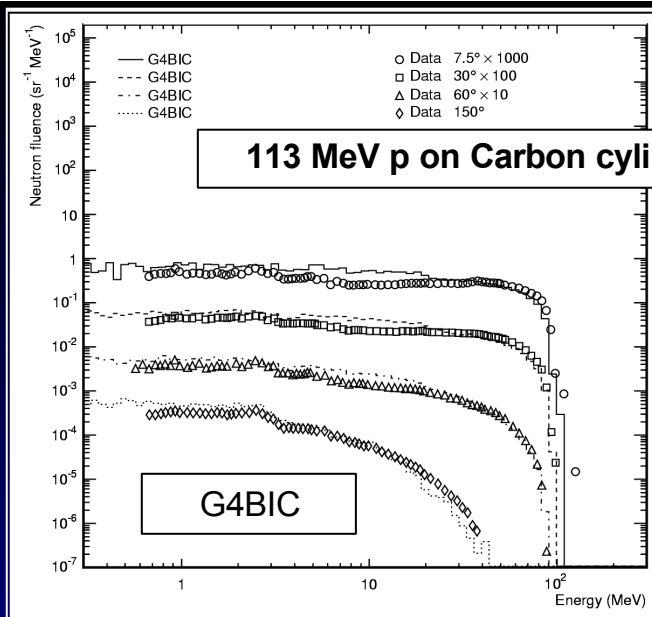
- Geant4 6.1
- Using the physics lists:
 - G4LEPPC (LHEP_PRECO_HP)
 - "GEISHA-like"
 - G4LEAD (LHEP_LEAD_HP)
 - G4Mars5GeV
 - G4BIC (LHEP_BIC_HP)
 - G4BERT (LHEP_BERT_HP)
- Standard EM physics
- Data driven low energy neutron models

Neutron Spectra Comparisons with Exp. Data

- Extended target comparisons
- Proton pencil beam incident on cylinder along axis
113 MeV, 256 MeV
- Cylinder targets of different sizes
- Materials
Beryllium, Carbon, Aluminum, Iron, Uranium
- Looking at neutron spectra from different directions
7.5°, 30°, 60°, 120°, 150°

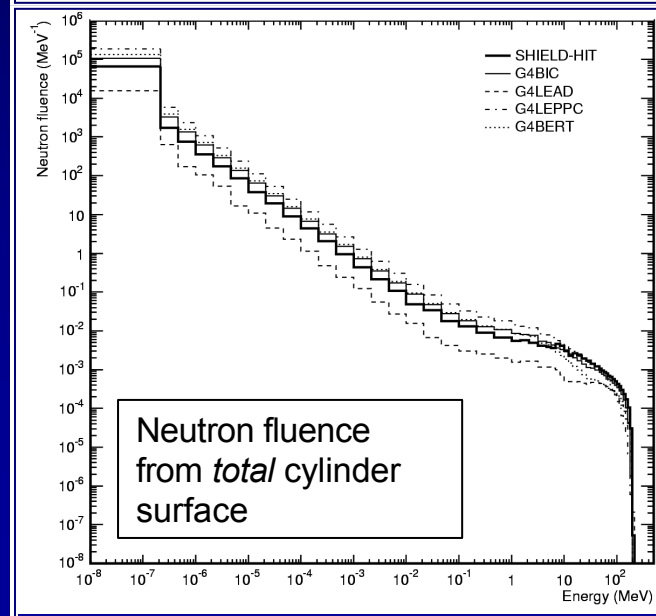
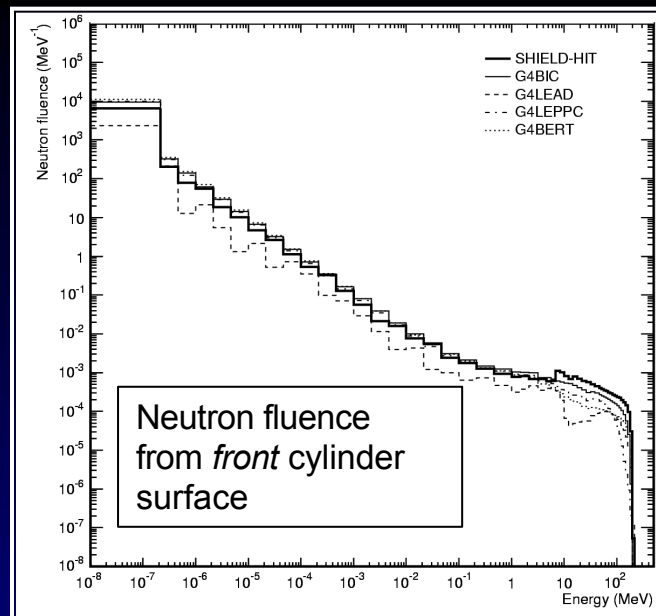
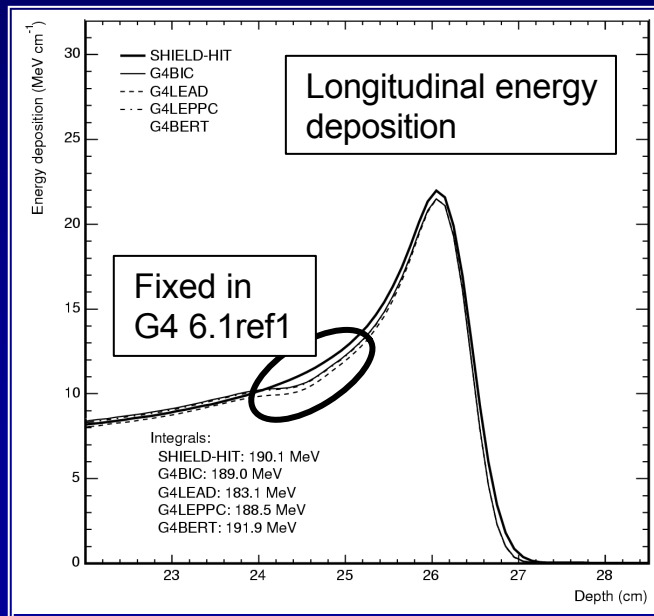
256 MeV p on Aluminum cylinder (L = 12 cm, R = 8 cm)





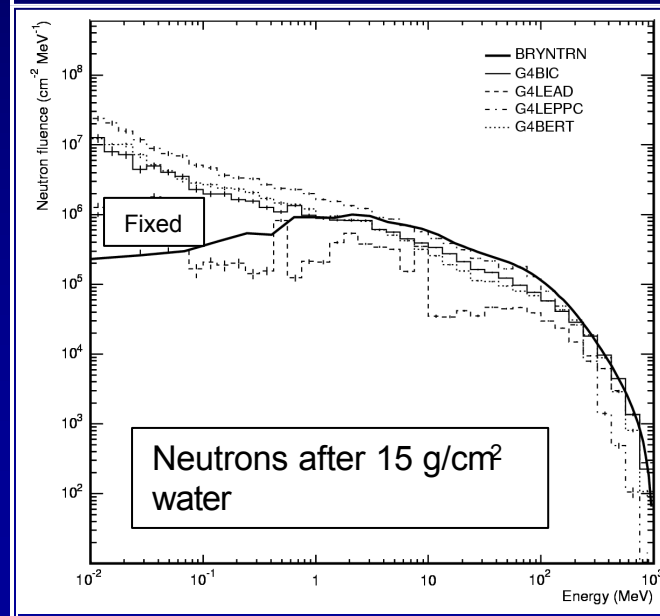
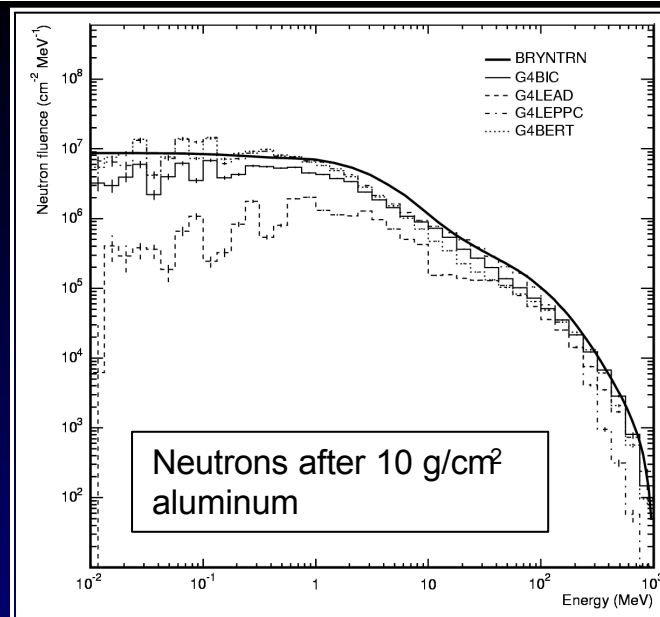
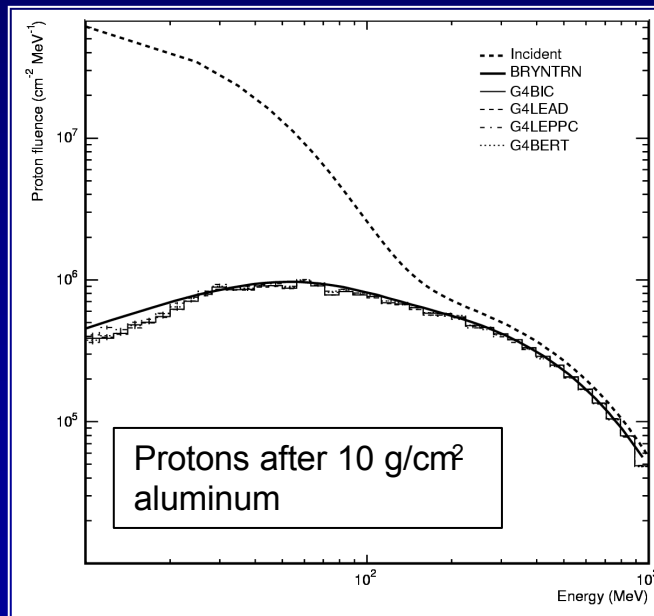
Comparisons with SHIELD-HIT

- Proton (202 MeV) pencil beam incident on water cylinder along axis.
- Cylinder radius 10 cm, length 30 cm.



Comparisons with BRYNTRN

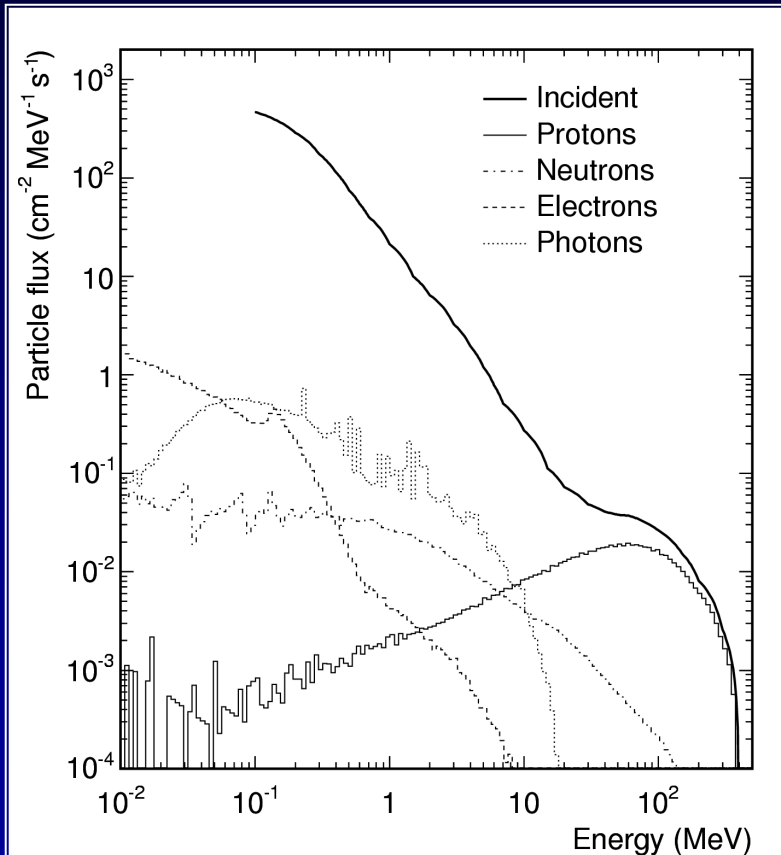
- Semi-infinite slab geometry.
0-20 g/cm² aluminum +
0-30 g/cm² water.
- Irradiated with protons according to the frequently-used 1956 SPE.



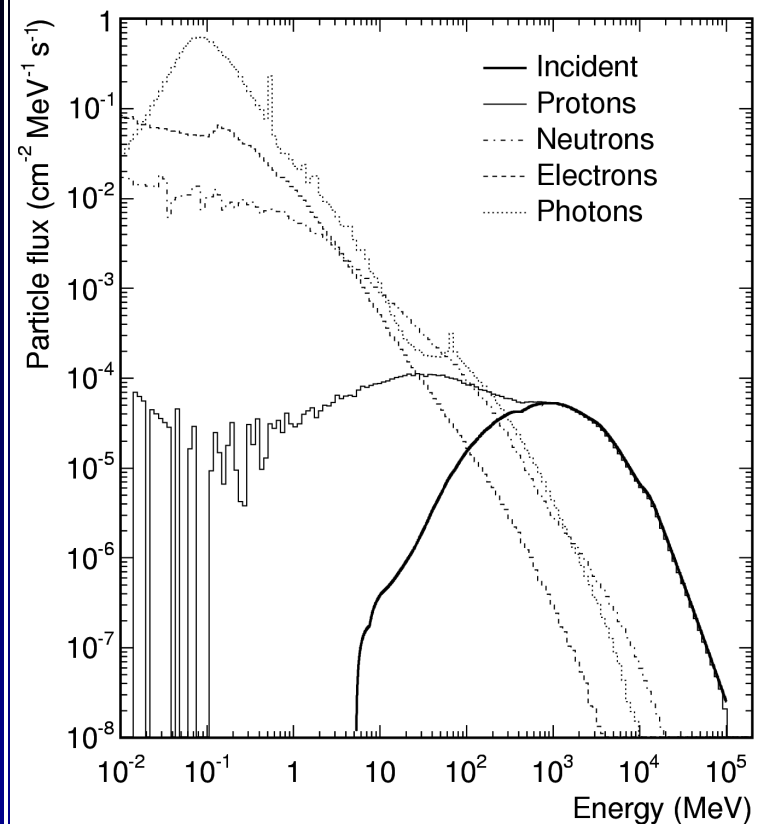
3. Tentative Results from Columbus Radiation Simulations

- Simple model of the Columbus implemented in Geant4.
 - Aluminum hull.
 - Aluminum/Kevlar/Nextel MDPS layer.
 - Total mass thickness $\sim 2\text{-}4 \text{ g/cm}^2$.
 - Water tank for dose measurement.
- Incident radiation fields:
 - Trapped electrons, AE8-min (SPENVIS)
 - Trapped protons, AP8-min (SPENVIS)
 - Cosmic ray protons, solar minimum (CREME96)
- Geant4 5.2p2

Columbus Radiation Simulations



Penetrating *trapped* protons and secondaries.



Penetrating *cosmic ray* protons and secondaries.

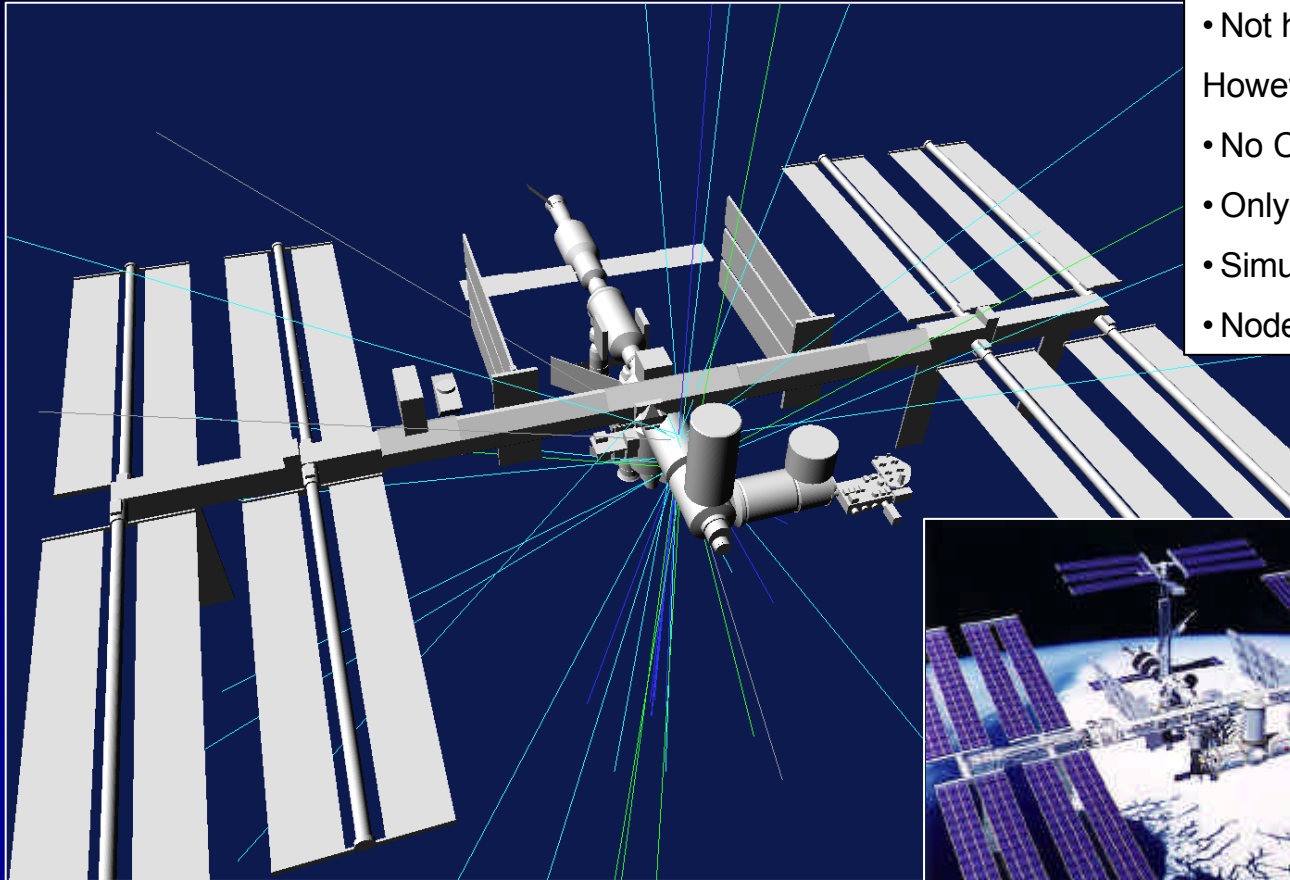
Calculated dose: $\sim 430 \mu\text{Gy/d}$

New ISS Geometry (14A)

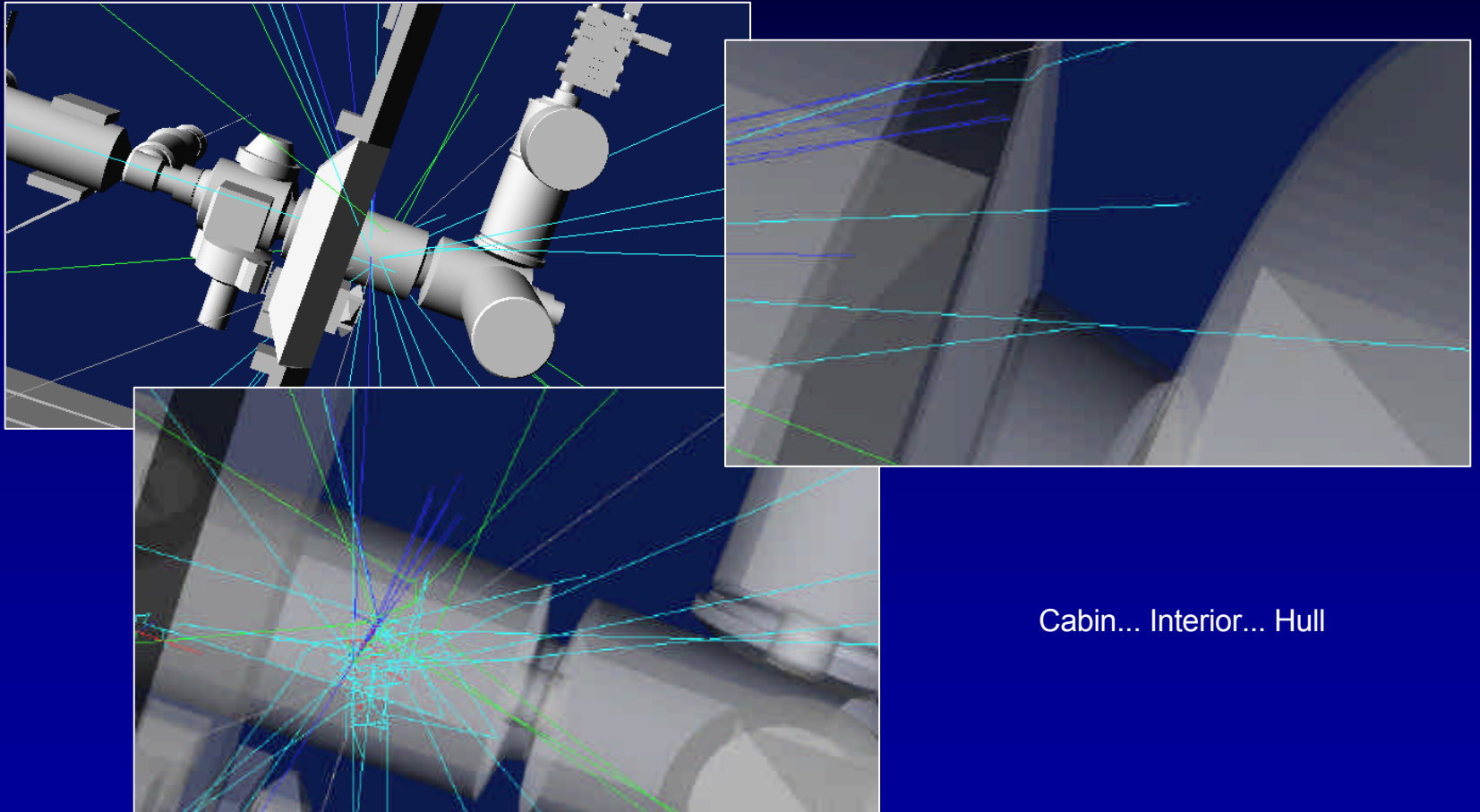
- From SEMDA-NASA spec.
- ~300 volumes
- All mass accounted for (~350 tons)
- Not homogeneous

However...

- No Columbus; iterations...
- Only aluminum
- Simulation speed?
- Node 2 detail?



New ISS Geometry (14A), details



Cabin... Interior... Hull

Conclusions and Outlook

- Geant4 using the Binary- or Bertini Cascade models performs very well. Sufficient agreement with data and other codes.
- Calculated dose for Columbus not unrealistic.
- Work on more realistic geometry underway.
 - Iterations...
- Validation studies of light ions. (Binary, Bertini, Abrasion-ablation)
- Heavy ions...

Acknowledgment:

- F. Cucinotta: BRYNTRN data.
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