D E S I R E

Dose Estimation by Simulation of the ISS Radiation Environment

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

Status of the DESIRE project:

Geant4 Physics Validation Studies and Columbus/ISS Radiation Simulations

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Outline

1. The DESIRE Project
2. Geant4 Physics Validation Studies
3. Tentative Columbus/ISS 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 dose / risk estimations.

ISS / Columbus

Completed

Columbus

Launch date: ?

Circular orbit

380-400 km altitude

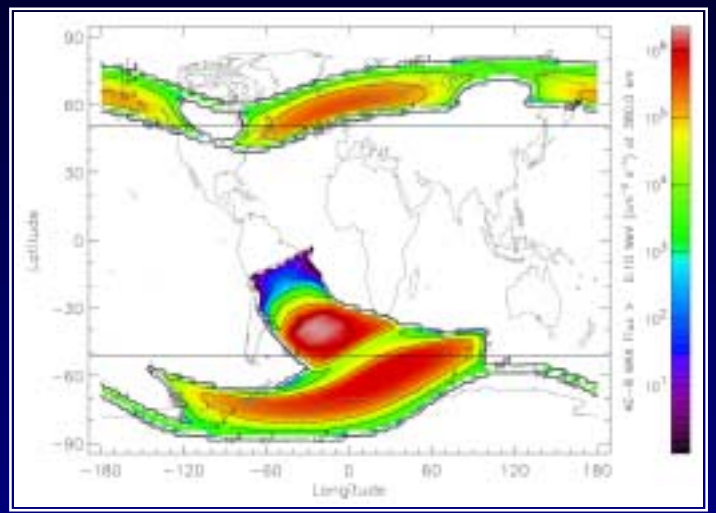
51.6º inclination (~London)

Dec. ’02

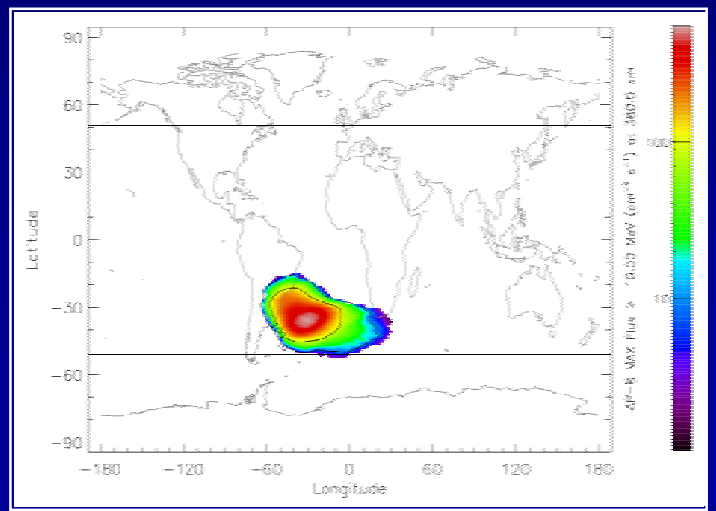
Radiation Environment

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

Trapped e-



Trapped p



Radiation Transport

- Why Geant4?
  - Aims to provide all necessary physics.
  - Designed to be easily extendable.
- Why a MC approach (vs. transport eq.)?
  - All information of the radiation fields, fewer approximations.

2. Validation studies

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

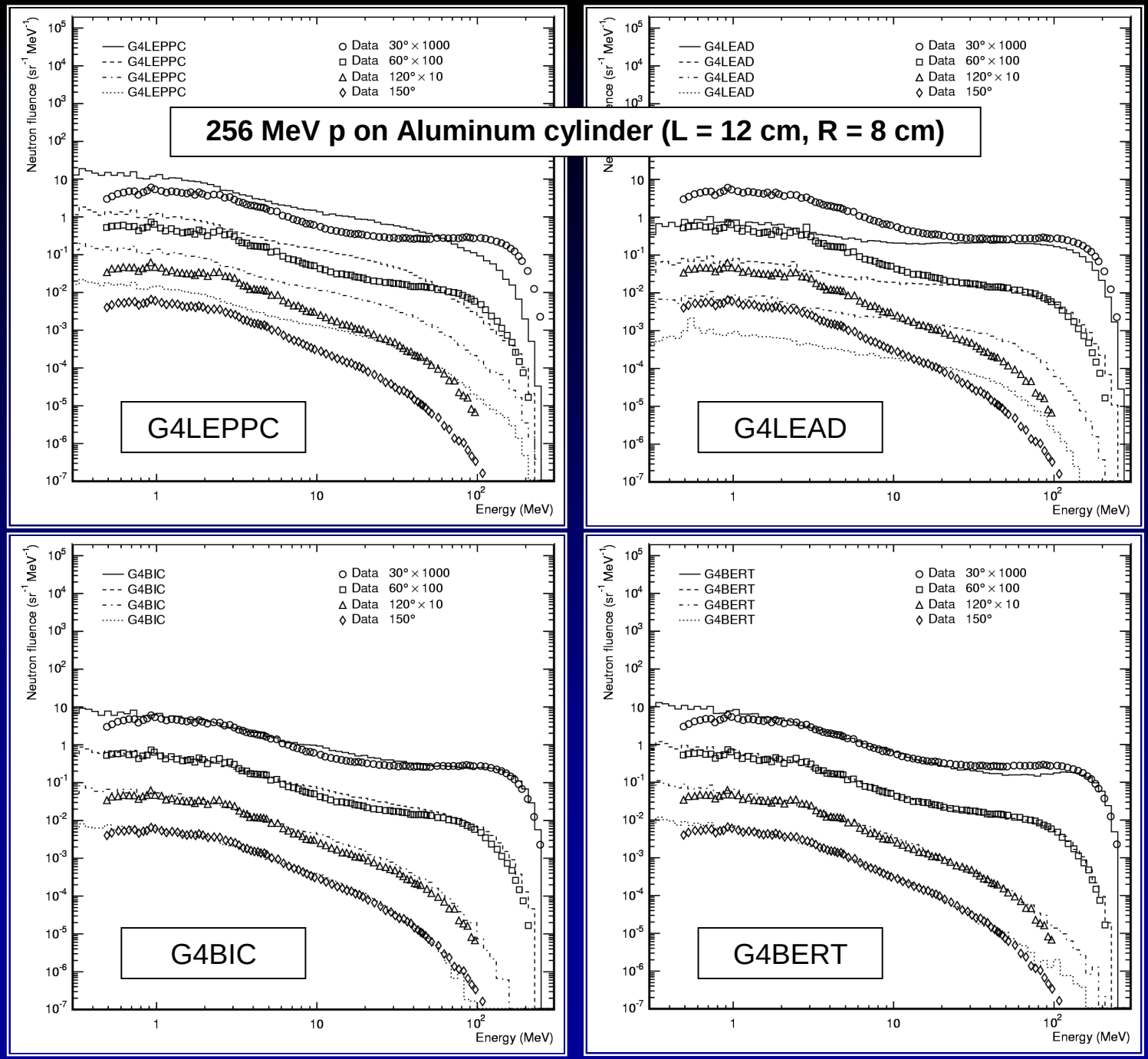
- Comparisons to Los Alamos exp. data
  - M.M. Meier, et al. Nucl. Sci. Eng. 102, 310-321 & 104, 339-363
- Comparisons to SHIELD-HIT
  - SHIELD has been used previously for space applications (Mir).
- Comparisons to BRYNTRN
  - Similar codes used in the NASA manned space program.

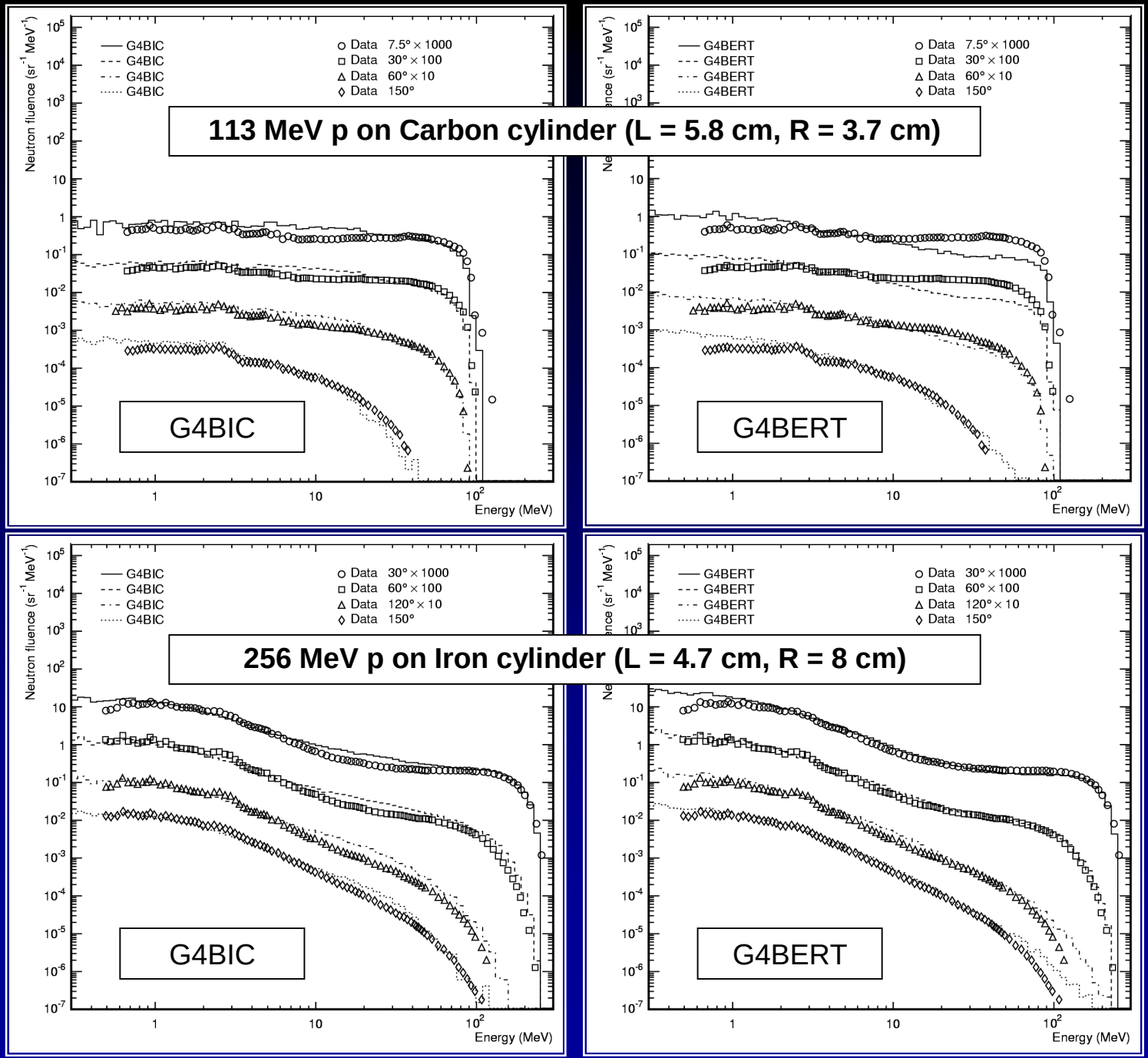
Test details

- Geant4 6.1
- Using the physics lists:
  - G4LEPPC (LHEP_PRECO_HP)
  - 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

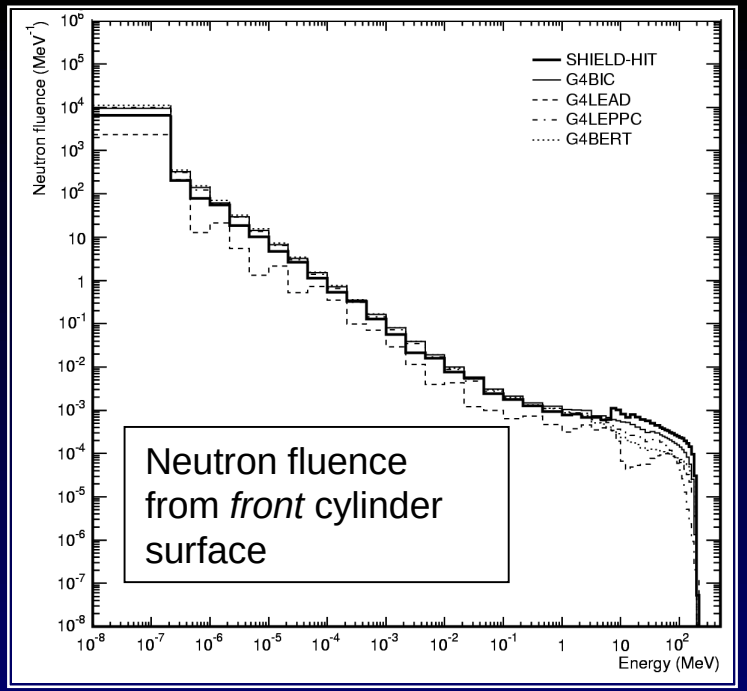
- Extended target comparisons
- Proton pencil beam incident on cylinder along axis
  113 MeV, 256 MeV
- Cylinder targets of different sizes
- Materials
  Beryllium, Carbon, Aluminum, Iron, Uranium
- Looking at neutron spectra from different directions
  7.5º, 30º, 60º, 120º, 150º

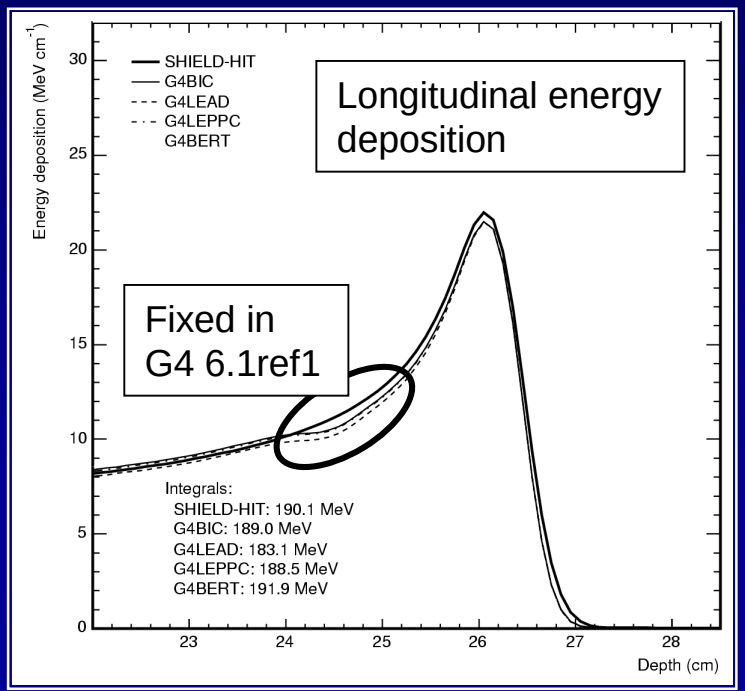

256 MeV p on Aluminum cylinder (L = 12 cm, R = 8 cm)
G4LEPPC
G4LEAD
G4BIC
G4BERT
Neutron fluence (sr^{-1} MeV^{-1})
Energy (MeV)
Data 30° × 1000
Data 60° × 100
Data 120° × 10
Data 150°

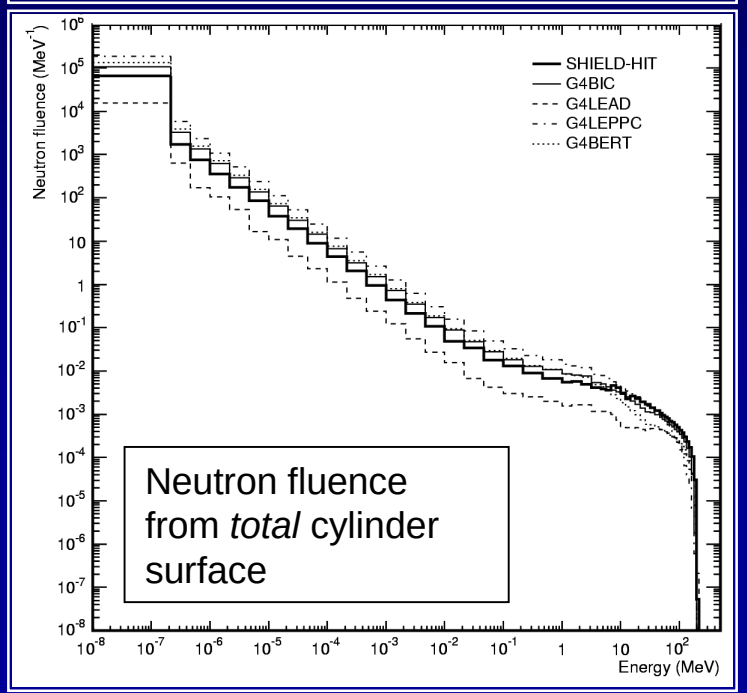

113 MeV p on Carbon cylinder (L = 5.8 cm, R = 3.7 cm)
G4BIC
G4BERT
256 MeV p on Iron cylinder (L = 4.7 cm, R = 8 cm)
Neutron fluence (sr^{-1} MeV^{-1})
Energy (MeV)
G4BIC
G4BERT
Data 7.5° × 1000
Data 30° × 100
Data 60° × 10
Data 150°
Data 30° × 1000
Data 60° × 100
Data 120° × 10
Data 150°

Comparisons with SHIELD-HIT

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

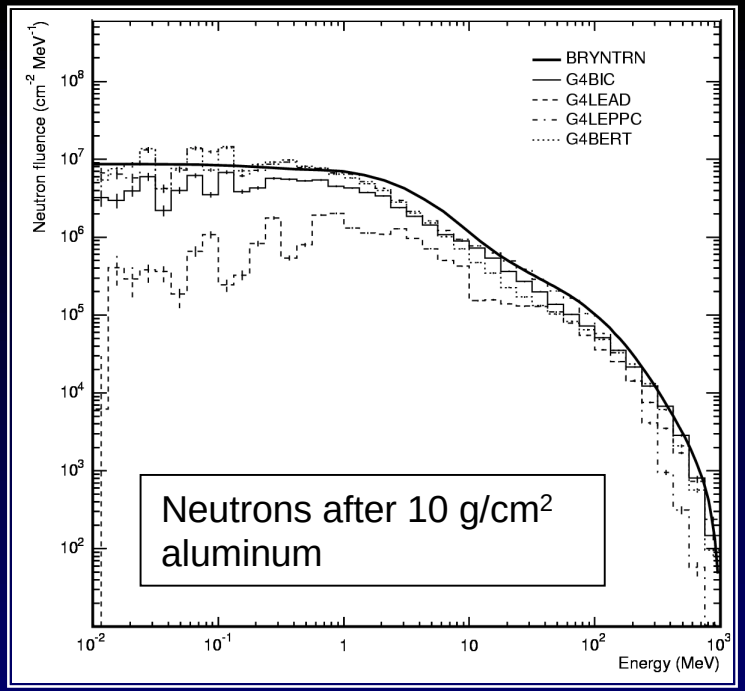


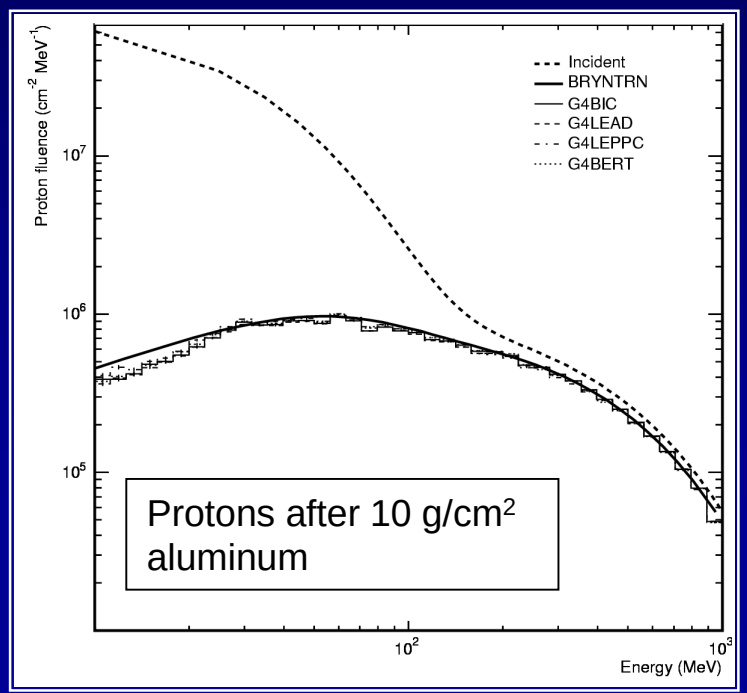


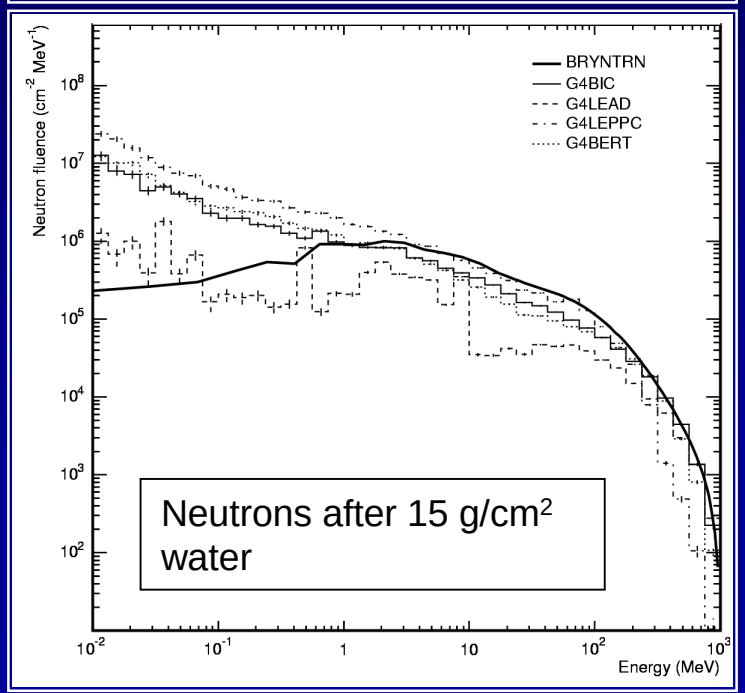


Comparisons with BRYNTRN

- ”Semi-infinite slab” geometry. 0-20 g/cm^2 aluminum + 0-30 g/cm^2 water.
- Irradiated with protons according to the frequently-used 1956 SPE.



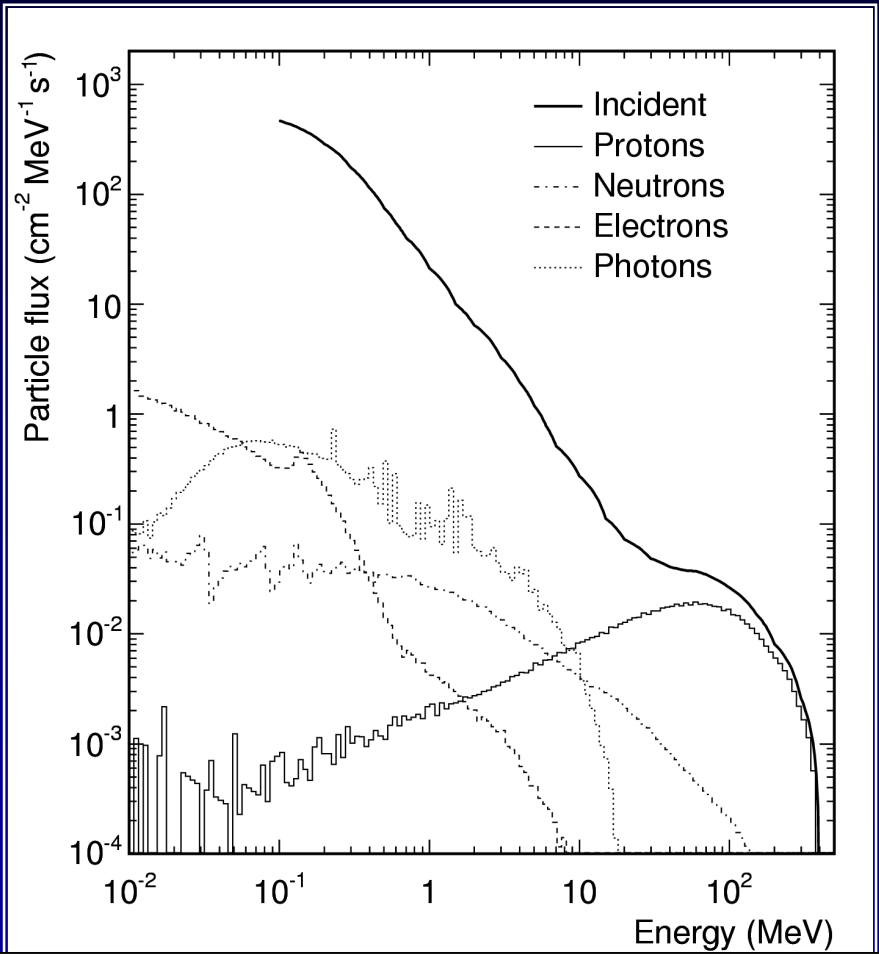




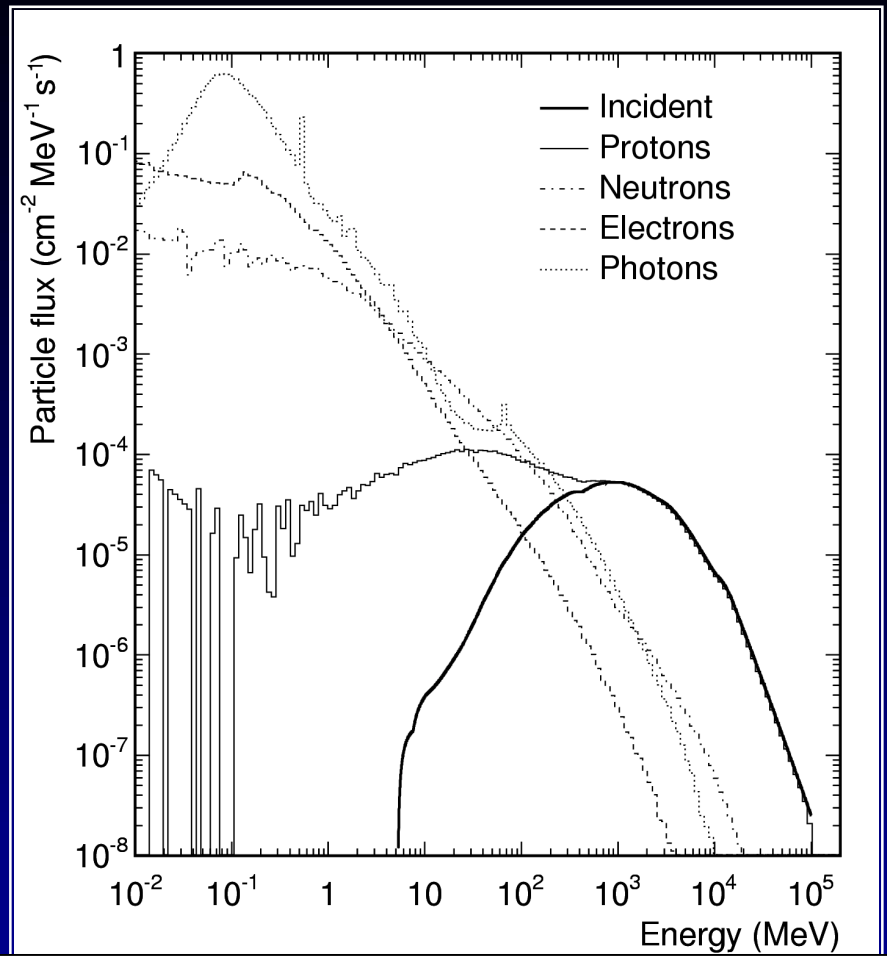
3. Tentative Results from Columbus/ISS Radiation Simulations

- Simple model of the Columbus implemened in Geant4.
  - Aluminum hull.
  - Aluminum/Kevlar/Nextel MDPS layer.
  - Total mass thickness ~2-3 g/cm^2 (vs. ~10 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/ISS Radiation Simulations



Penetrating *trapped* protons and secondaries.



Penetrating *cosmic ray* protons and secondaries.

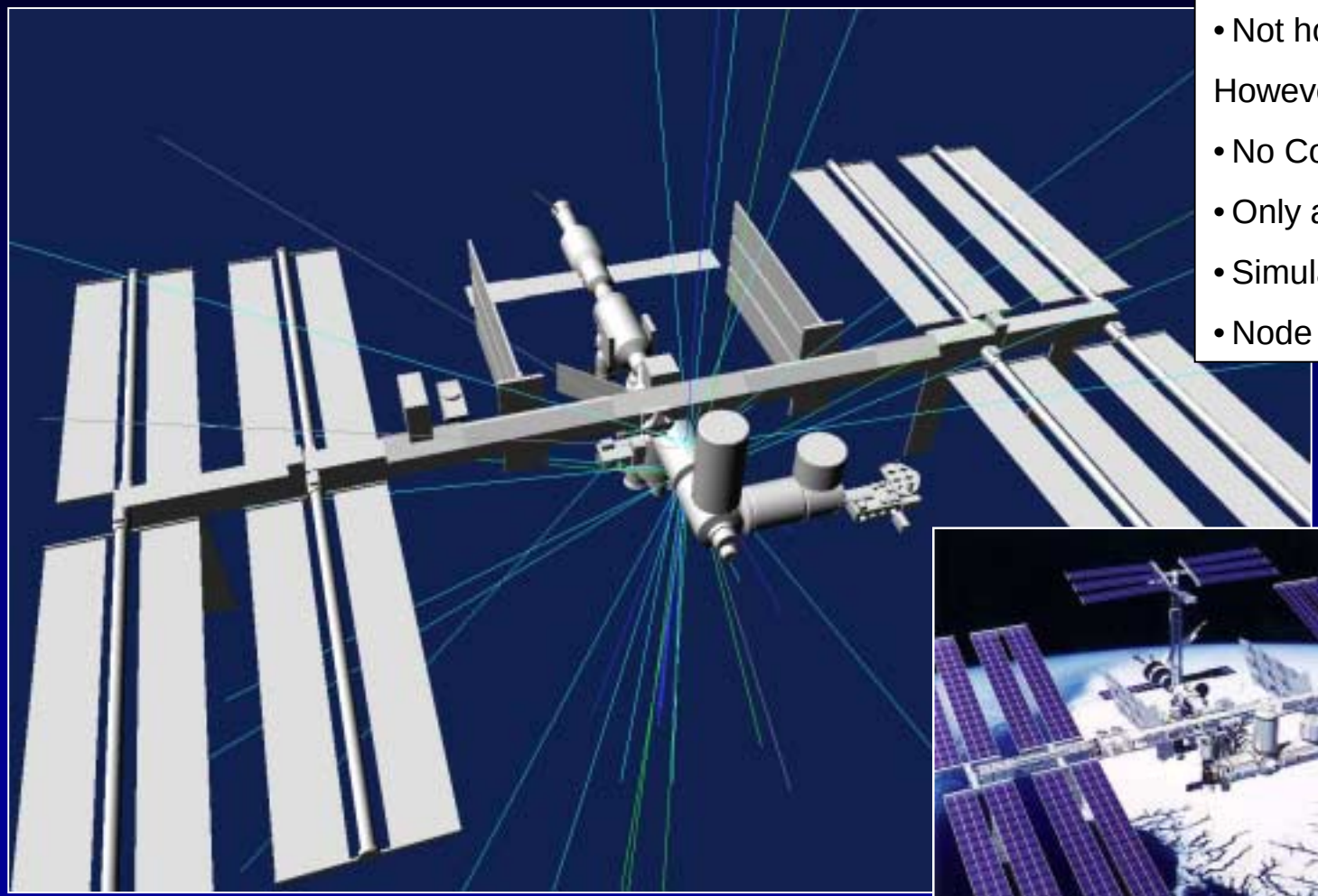
Calculated dose: ~430 μGy/d
vs. 300-400 μGy/d for STS/Mir

New ISS Geometry (14A)

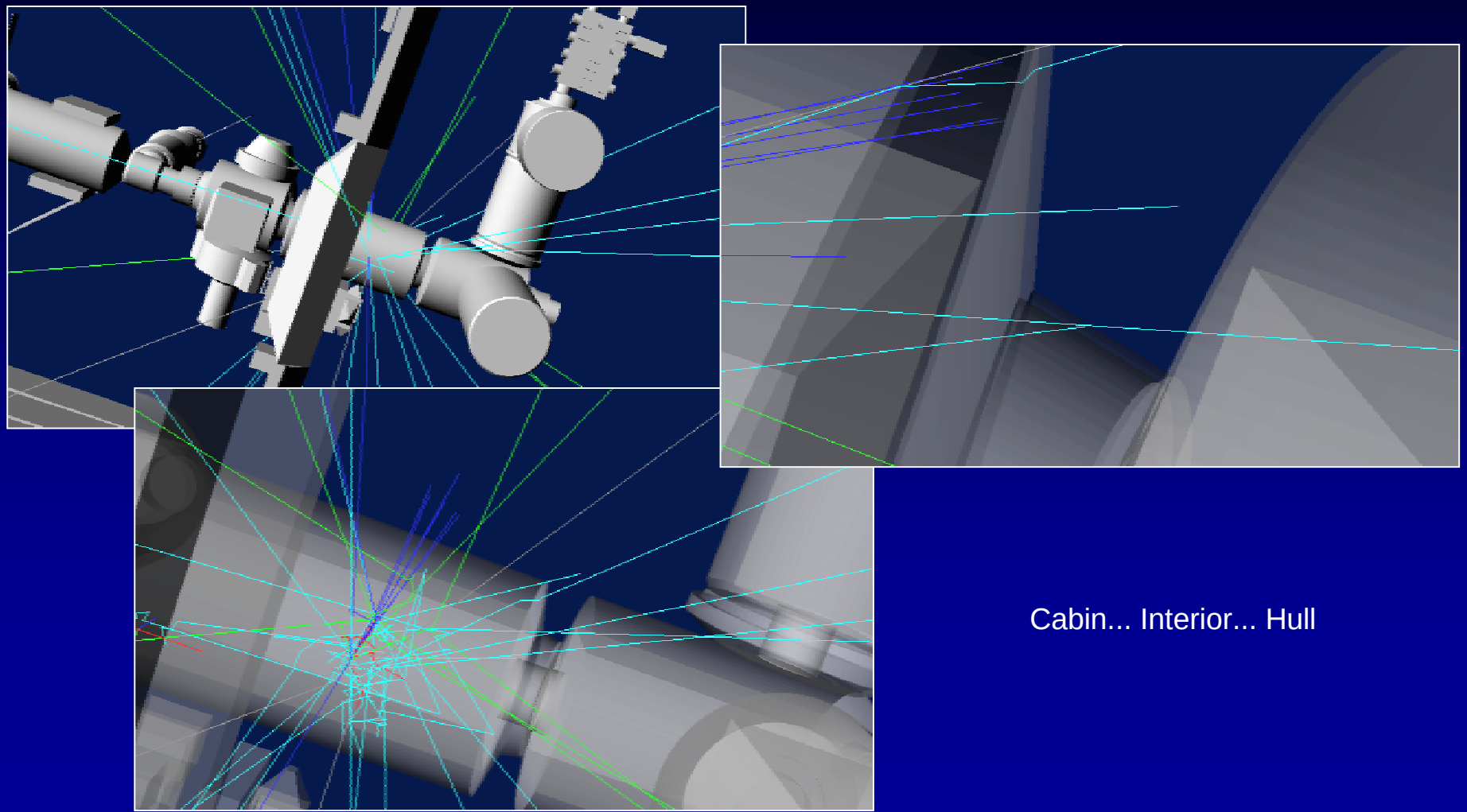
- From SEMDA-NASA spec.
- ~300 volumes and
- All mass accounted for (~350 ton)
- Not homogeneuous

However..

- No Columbus
- Only aluminum
- Simulation speed?
- Node 2 detail?



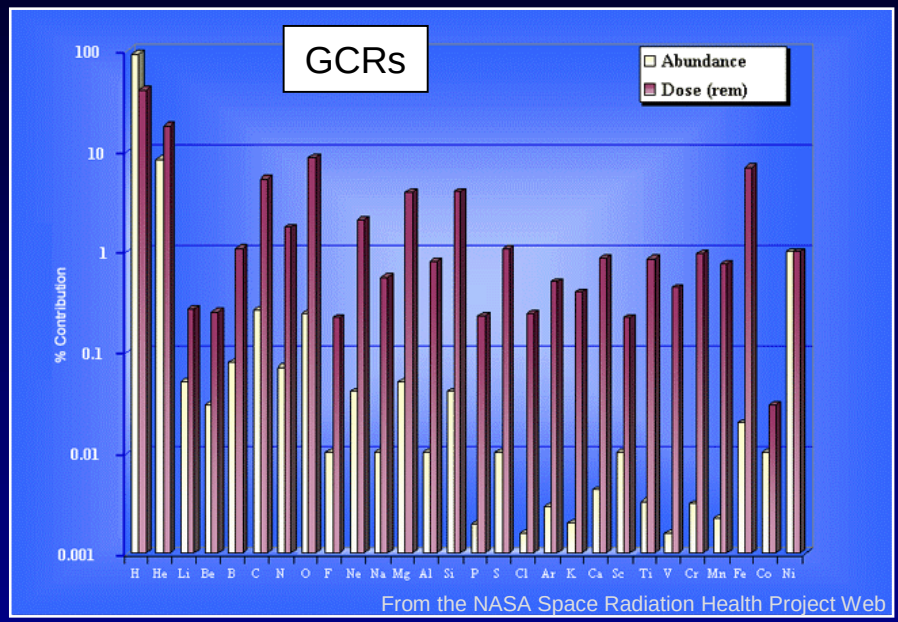
New ISS Geometry (14A), details



Cabin... Interior... Hull

Conclusions and Outlook

- Geant4 using the Binary- or Bertini Cascade models performs very well. Sufficient agreement with data and other codes.
- Reasonable calculated dose for Columbus.



- Work on more realistic geometry underway.
- Validation studies of light ions.
- Heavy ions...

Acknowledgment:

- F. Cucinotta: BRYNTRN data.
- The Göran Gustafsson Foundation: Computing resources.