D E S I R E

Dose Estimation by Simulation of the ISS Radiation Environment

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

Geant4 simulations of the Columbus/ISS radiation environment

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Outline

1. The DESIRE project
2. Geant4 physics validation studies
3. Columbus and ISS geometries
4. Radiation environment models
5. Simulation results
6. Conclusions and future

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 European ISS laboratory Columbus.
- Utilizes Geant4 for radiation transport.
- Funded by ESA (15613/NL/LvH) and SNSB.

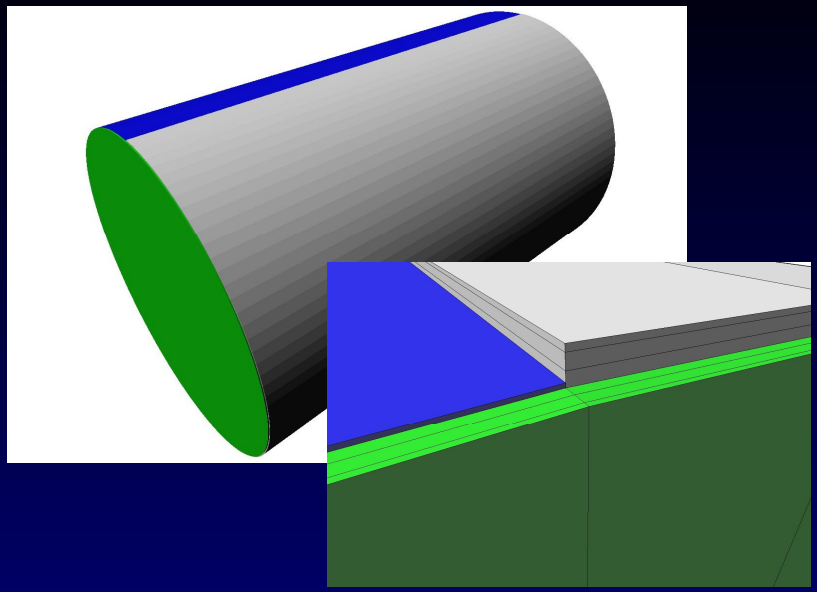
1. Validation of Geant4 physics models by comparisons to…
   - Experiments
   - NASA BRYN-/HZETRN programs
   - SHIELD-HIT Monte Carlo program
2. Implementation of Columbus and ISS geometries in Geant4.
3. Evaluation of incident radiation environment models.
4. Full simulations of particle fluxes and doses inside Columbus.

Geant4 physics validation studies

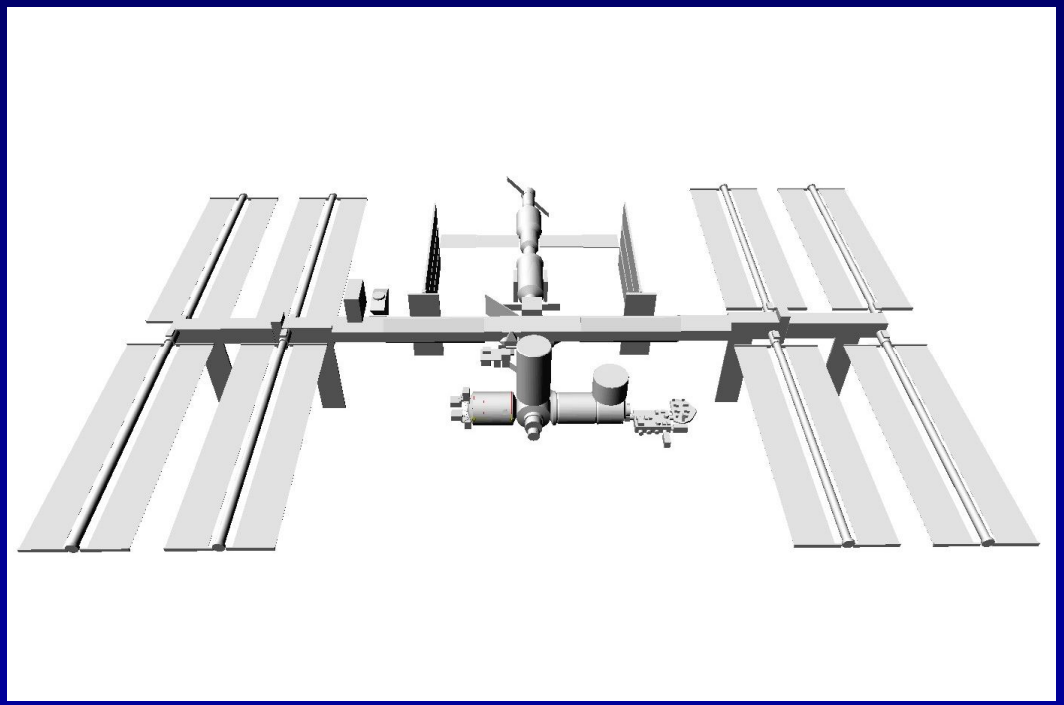
- Incident protons with energies 10-1000 MeV.
  - Neutron production
  - Energy deposition
  - Proton penetration
  - Water, Beryllium, Carbon, Aluminum, Iron, Uranium
- Comparisons to Los Alamos experimental data, SHIELD-HIT, BRYNTRN.
- Published in IEEE Trans. Nucl. Sci. 51,1378 (2004).

Summary: Energy deposition/proton penetration ok. Neutron production ok after release of cascade models (since 2003).

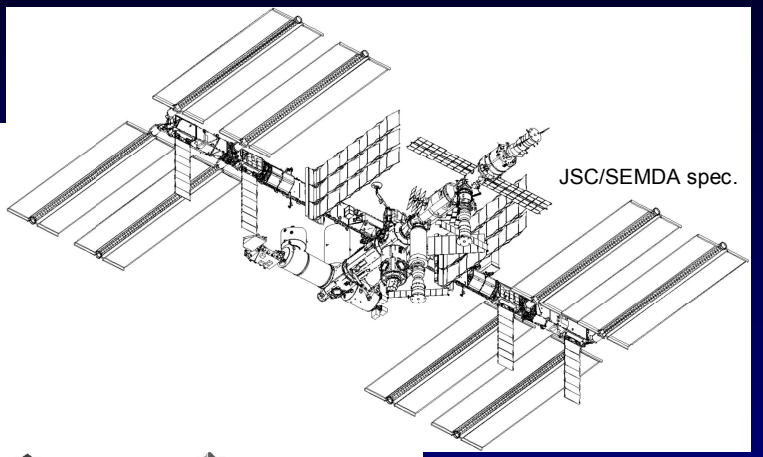
Columbus and ISS geometries

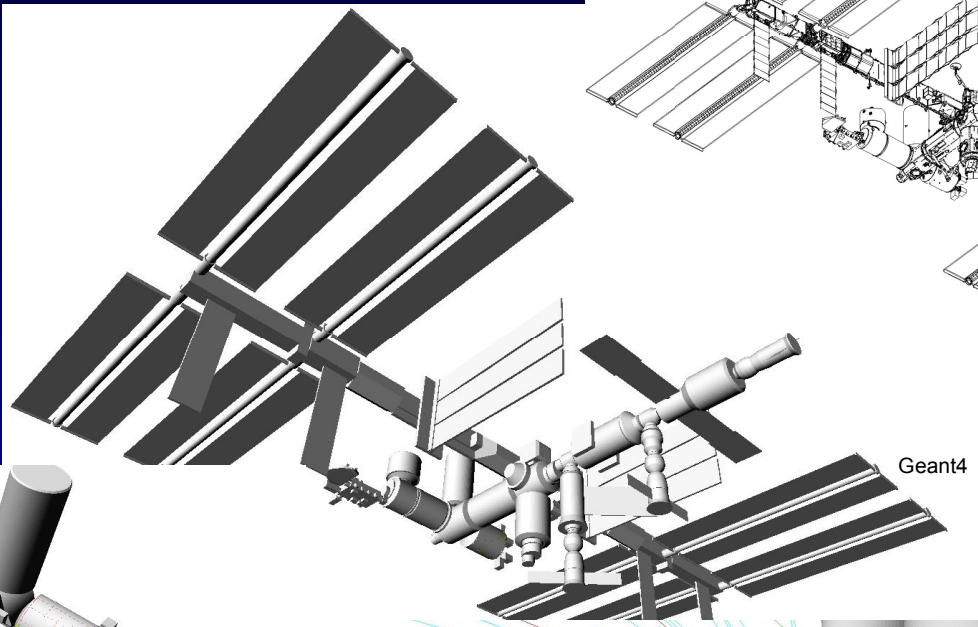


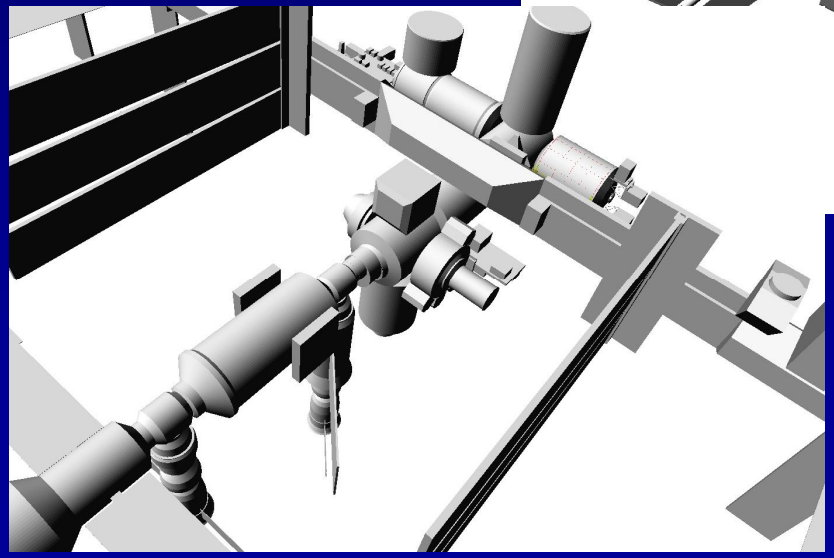
- "Columbus1"
  - Simple cylinder-like geometry
  - 10 volumes; MDPS1/2/3 + hull
  - 4200 kg
- "Columbus3"
  - Detailed geometry
  - 800 volumes
  - 16750 kg
- ISS
  - 350-400 volumes
  - 352 tons (369 tons)

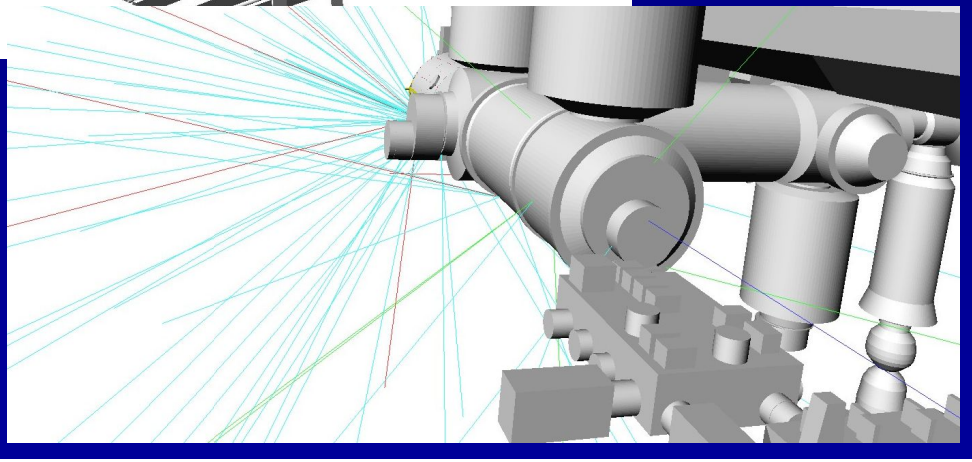


The ISS Geant4 geometry

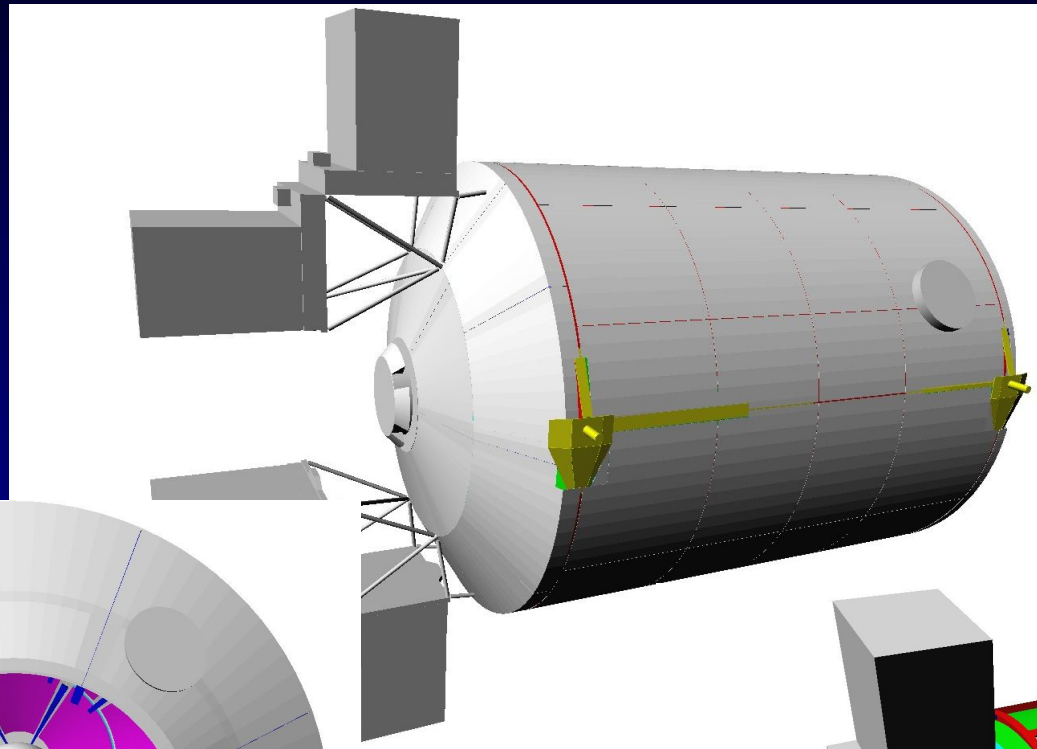


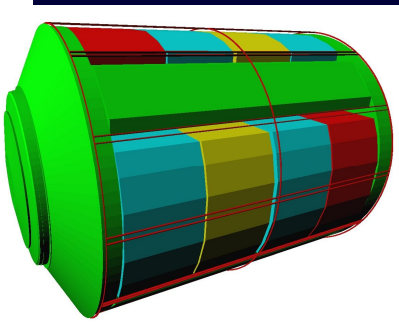


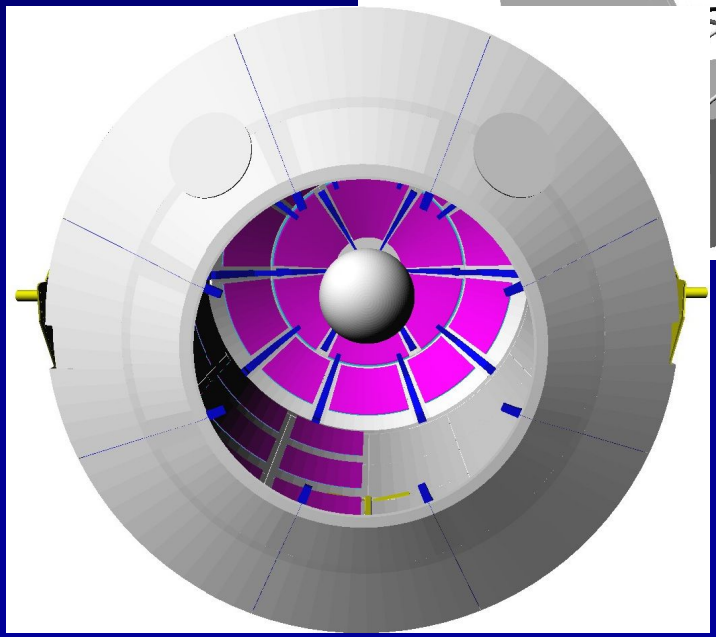


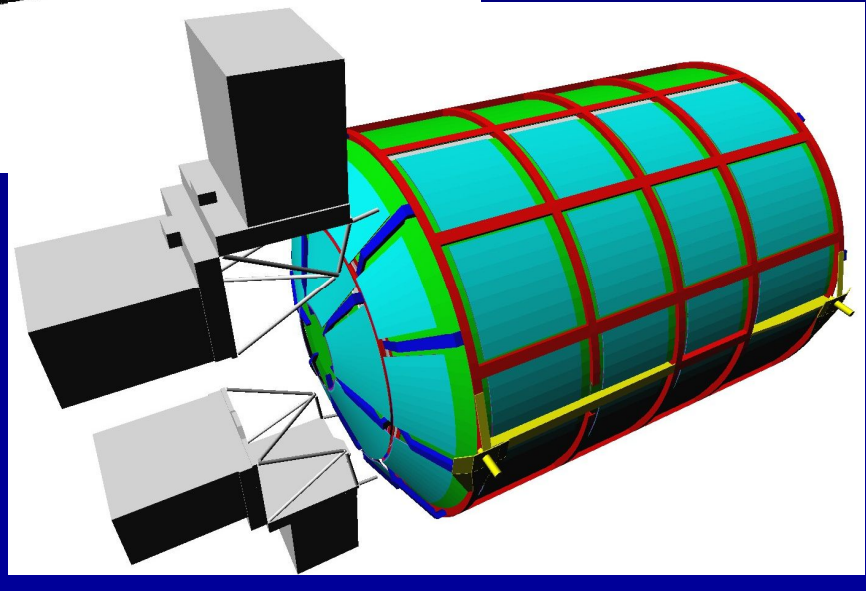


The “Columbus3” Geant4 geometry







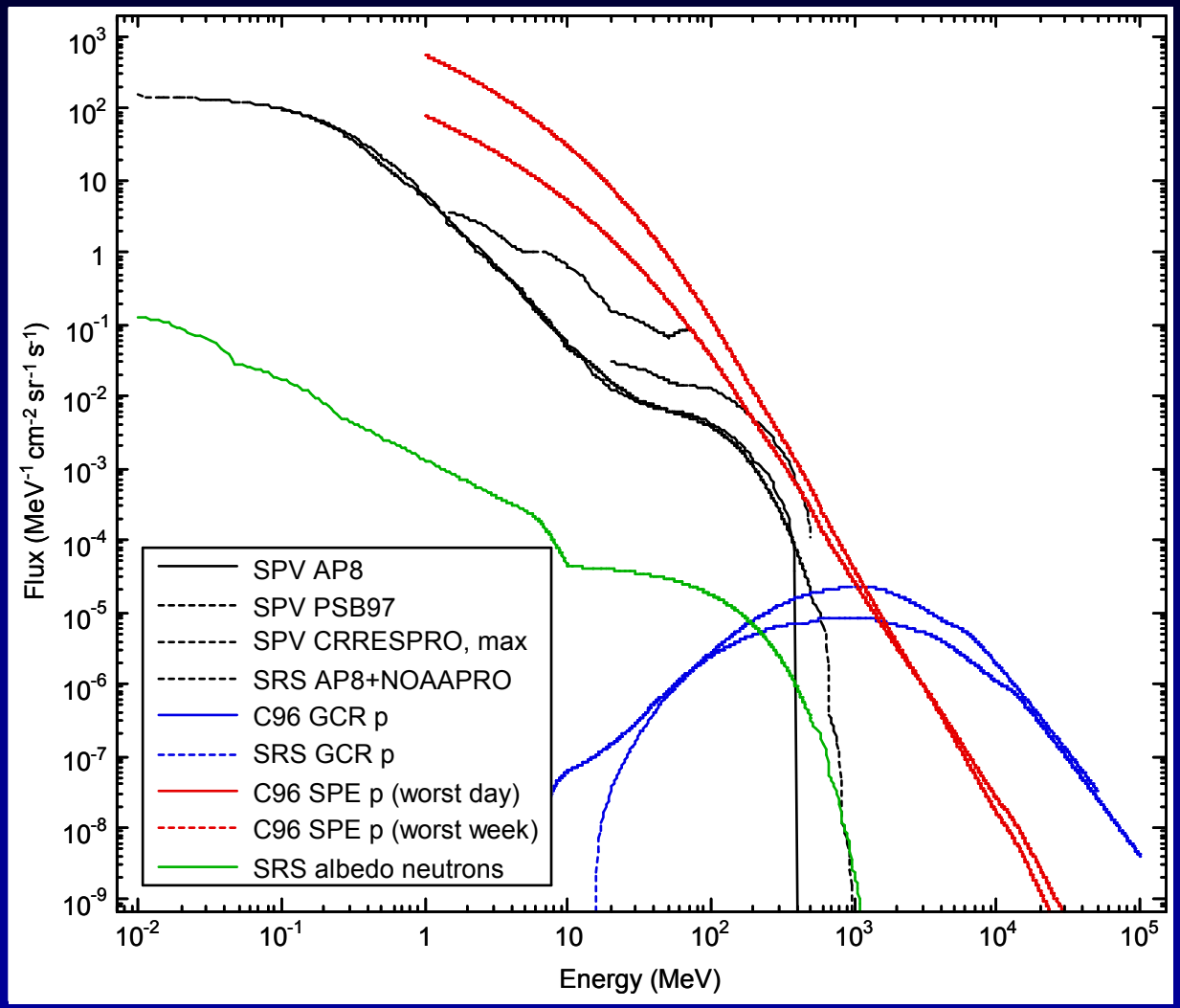


Radiation environment models

- Studied incident radiation fields
  - Trapped protons (isotropic and anisotropic)
  - GCR protons
  - SPE protons
  - Cosmic ray albedo neutrons
- Other radiation fields
  - GCR ions
  - Solar ions

- Web interfaces to models
  - SPENVIS (”SPV”) (http://www.spenvis.oma.be/spenvis/)
  - CREME96 (”C96”) (https://creme96.nrl.navy.mil)
  - SIREST (”SRS”) (http://sirest.larc.nasa.gov)

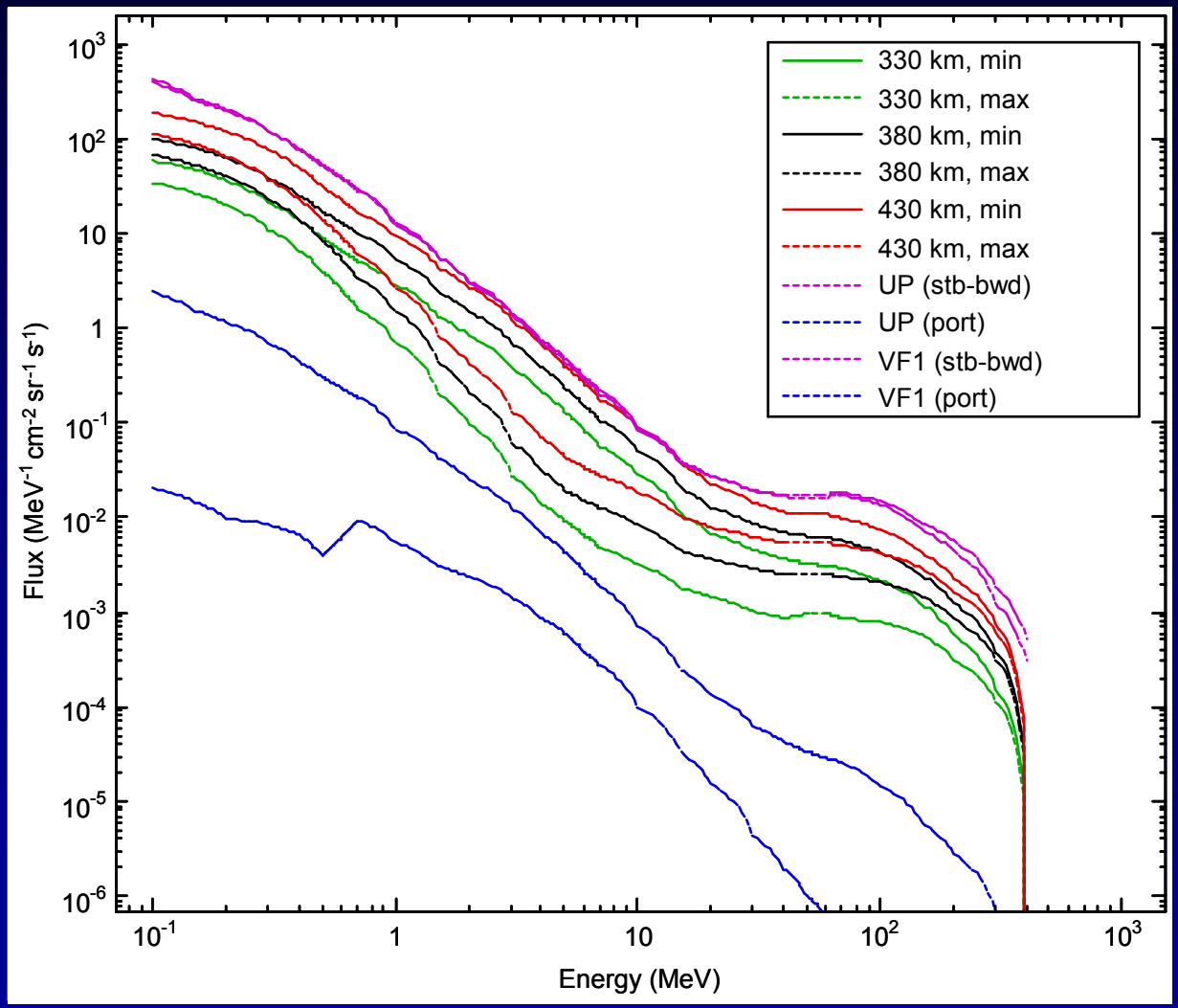
Incident spectra



Incident particle spectra at 380 km

- Belt protons
- GCR protons
- SPE protons
- CR albedo neutrons

Belt proton altitude dependence and anisotropy

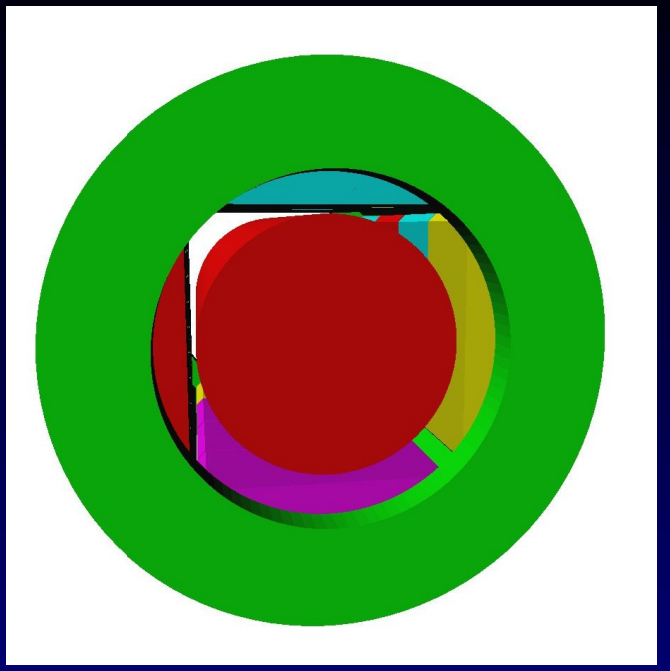


Incident proton spectra at 330 km, 380 km, 430 km

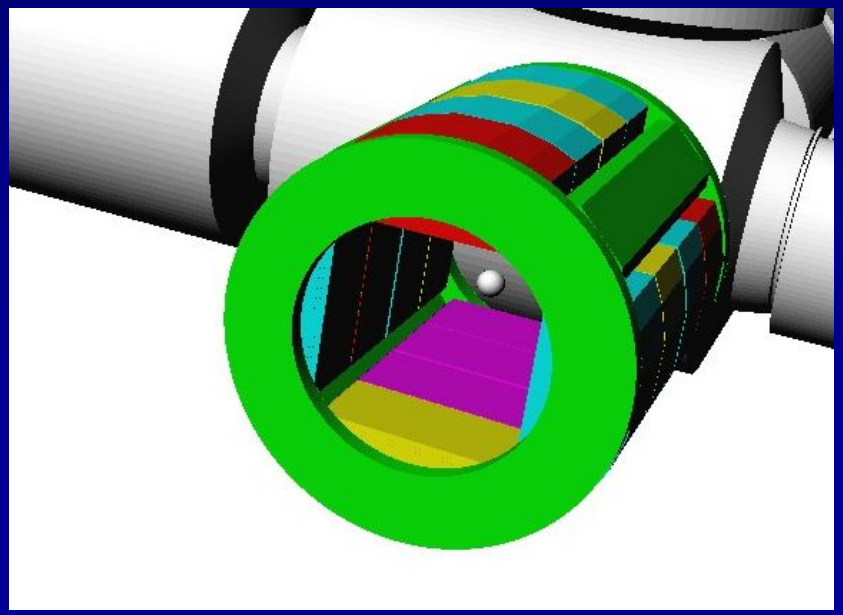
- Solar minimum/maximum
- Anisotropy; spectra for protons coming from *port* and *startboard-backward* (at solar-minimum and 380 km)

Simulation results

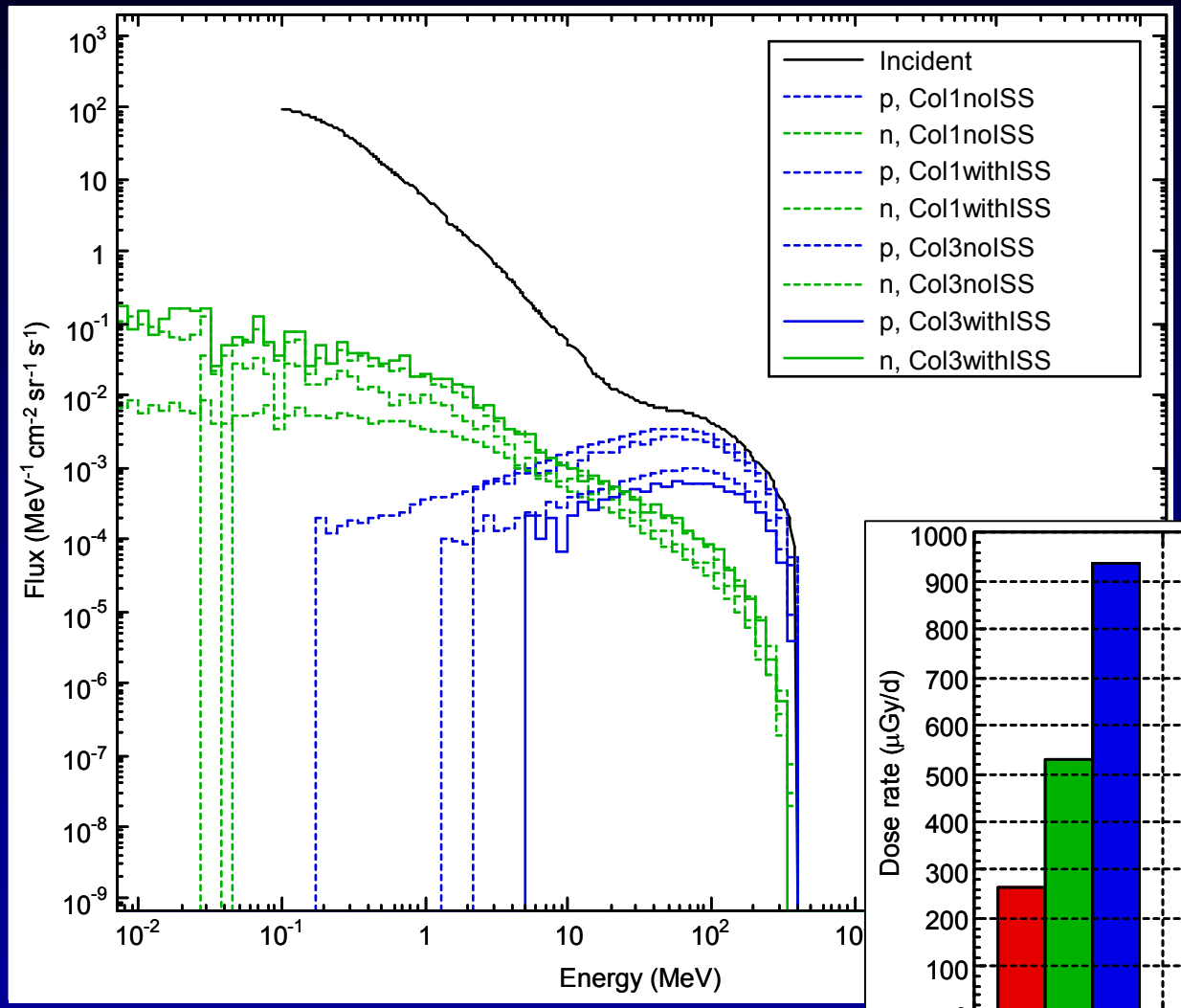
- Spectra of particles entering Columbus



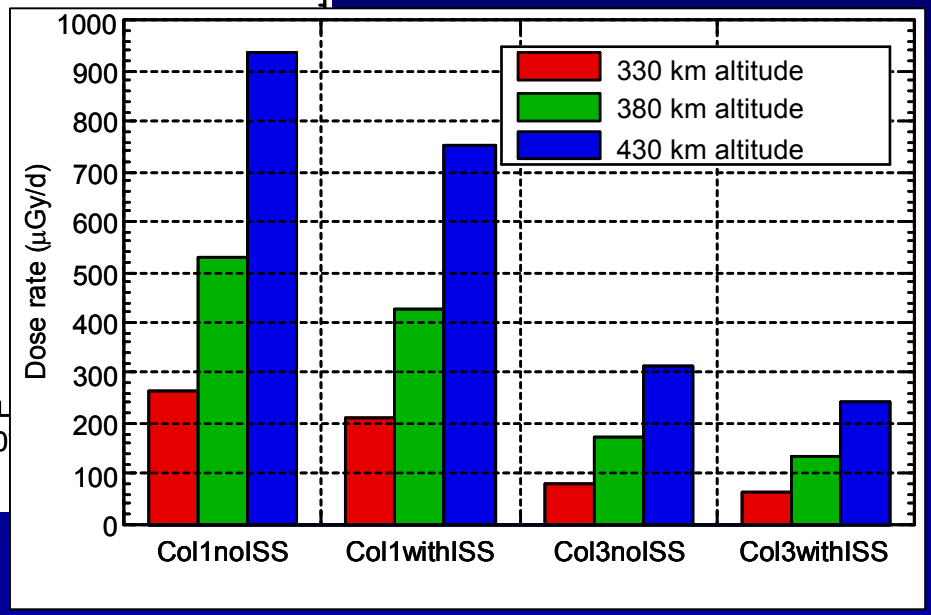
- Doses at 10 mm depth in ICRU sphere
  - Statistics...
- 380 km and sol-min unless noted



Belt protons

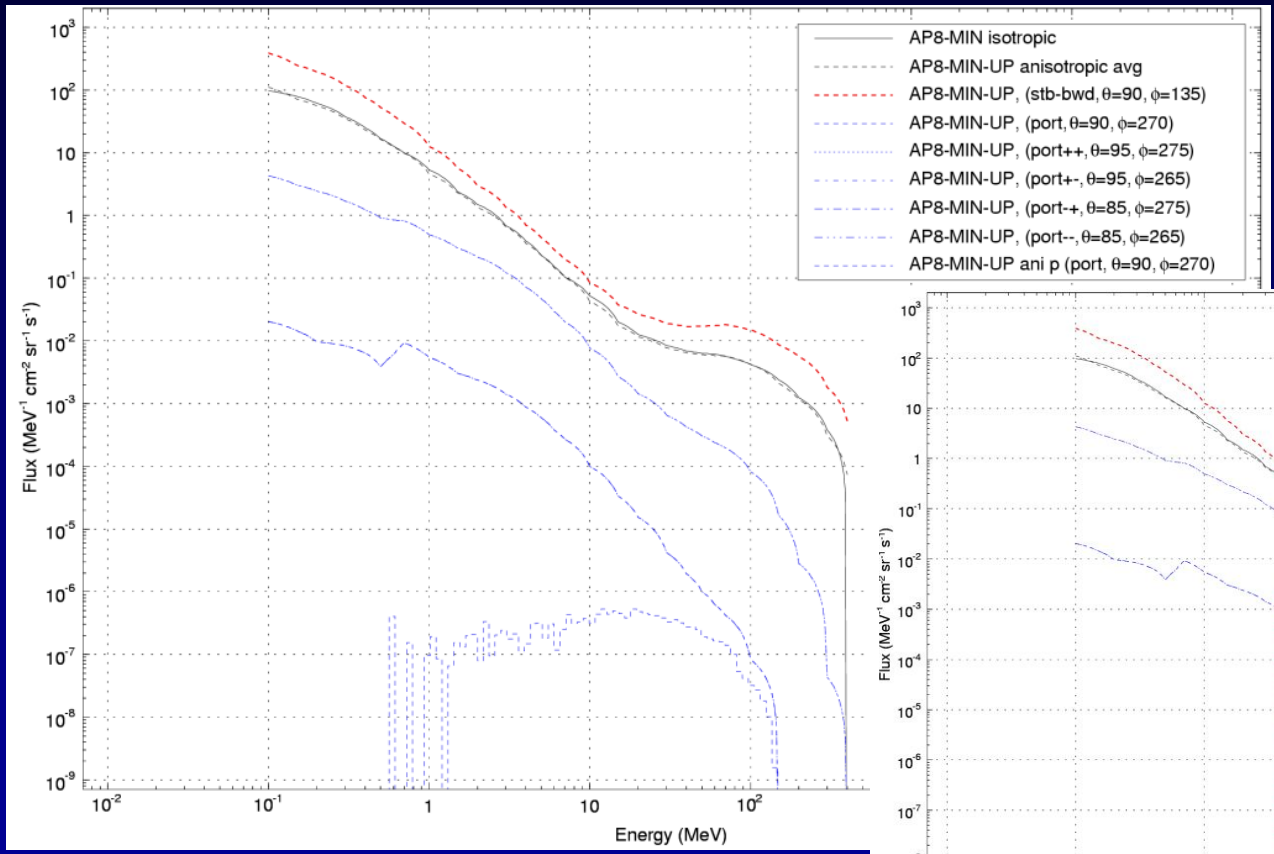


Incident belt (AP8-MIN) protons at 380 km.
Penetrating protons and neutrons.

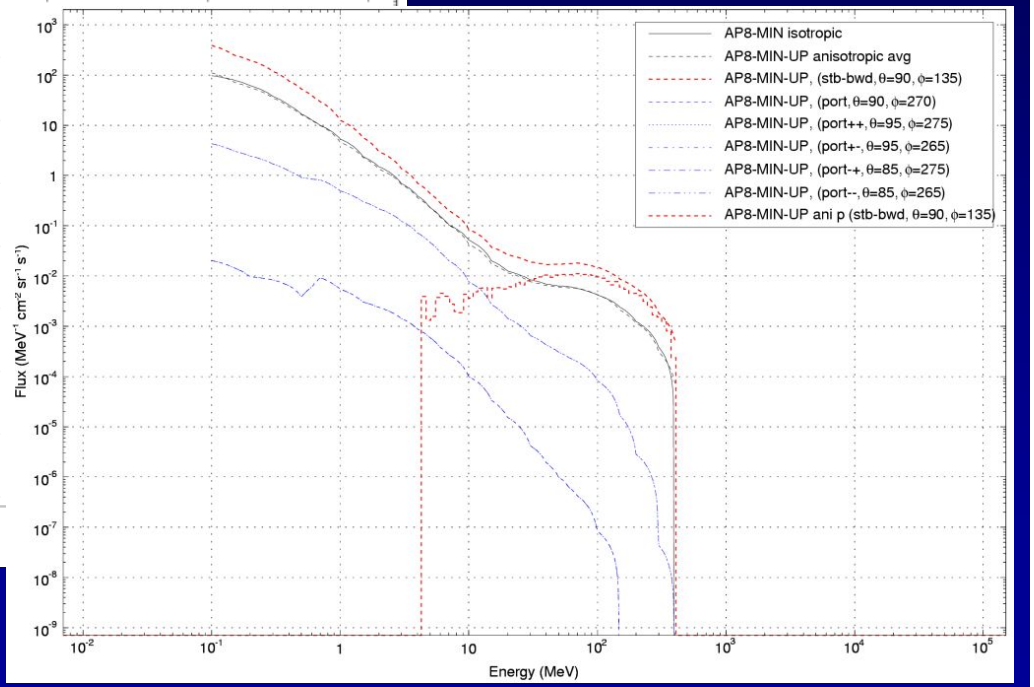


Belt proton doses at three altitudes for different geometry configurations.

Preliminary study of belt proton anisotropy

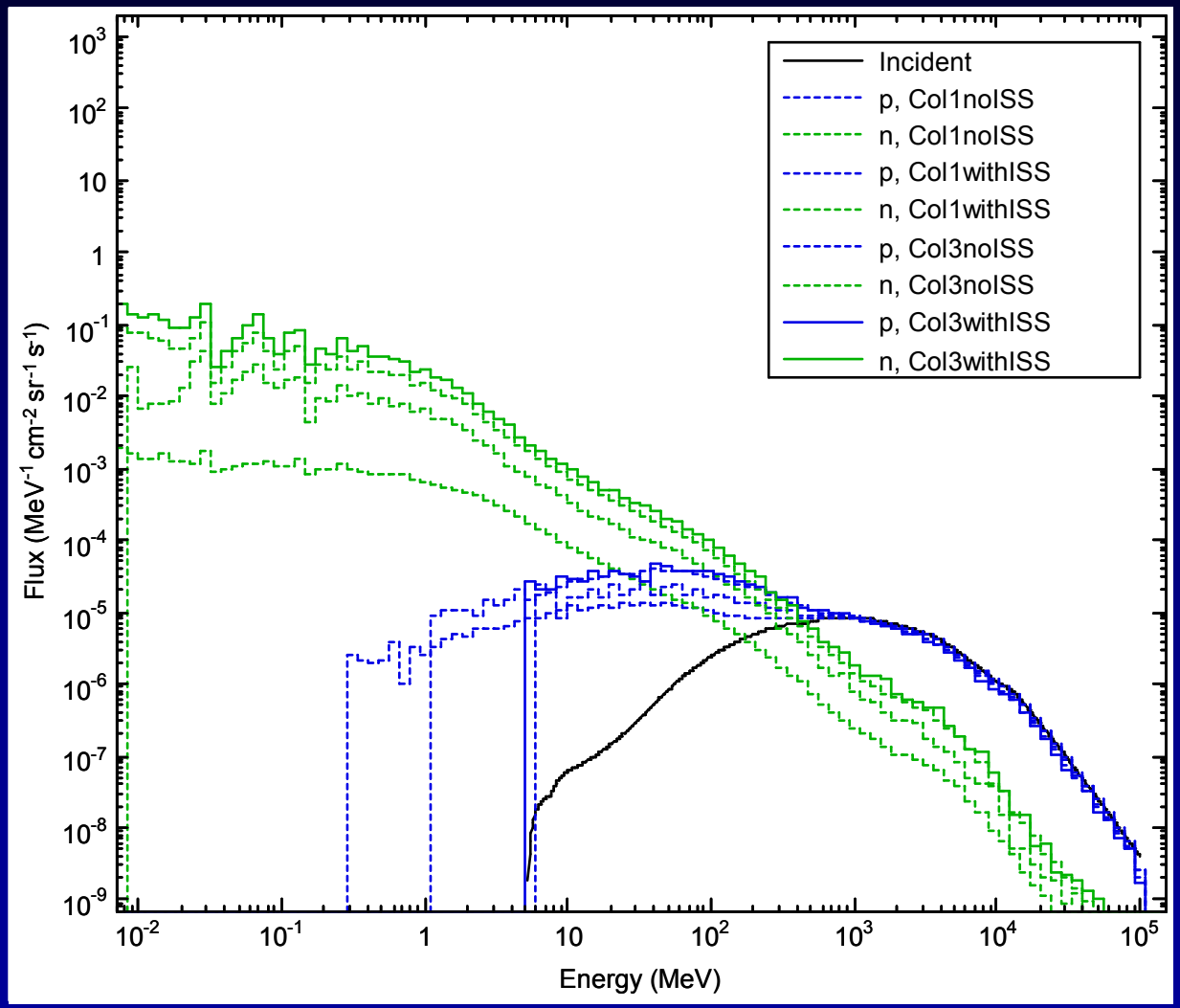


Incident belt protons. Anisotropy from SPENVIS "ANI-UP" model. Penetrating protons from *port* direction.



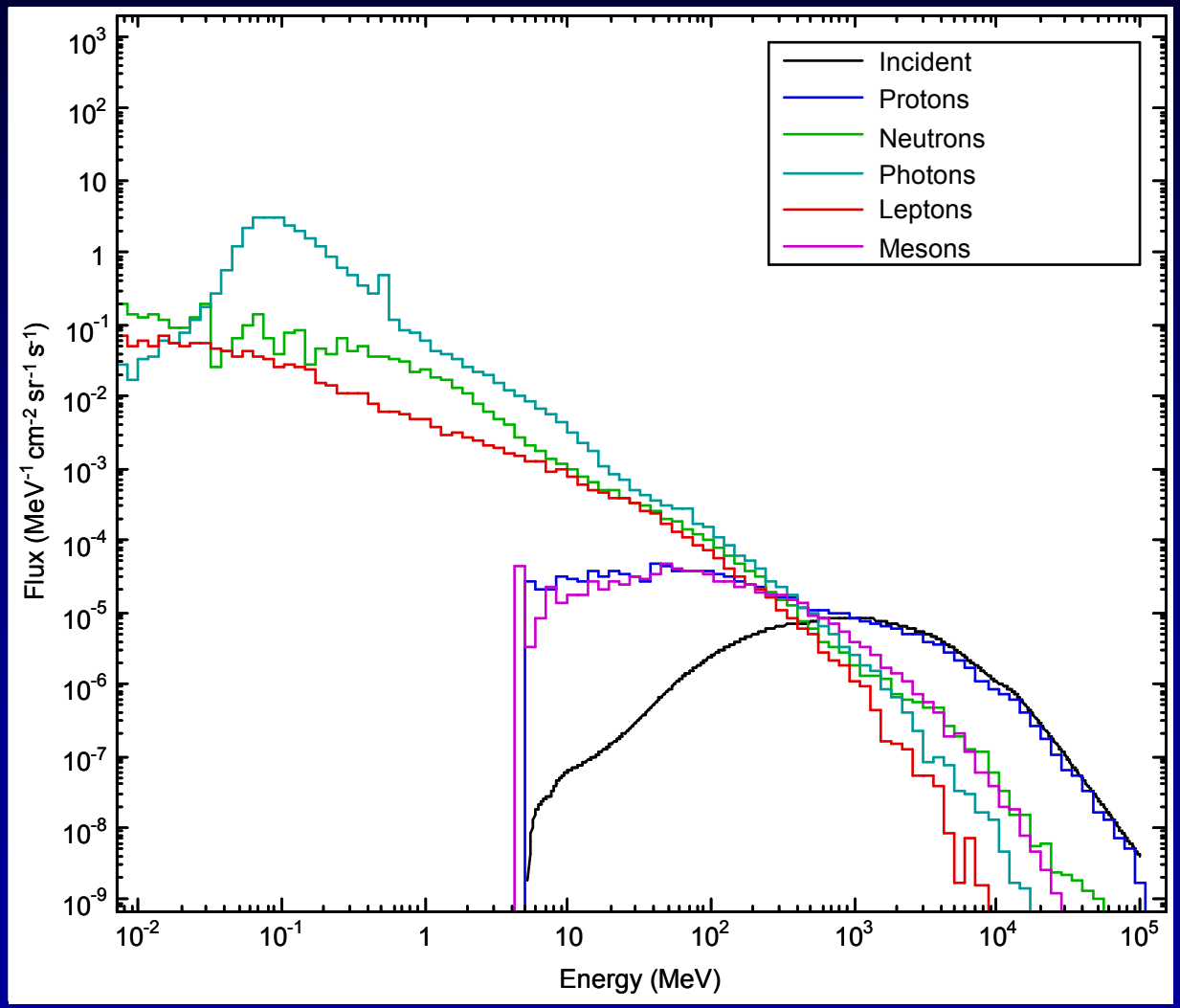
Penetrating protons from *starboard-backward* direction.

Cosmic ray protons



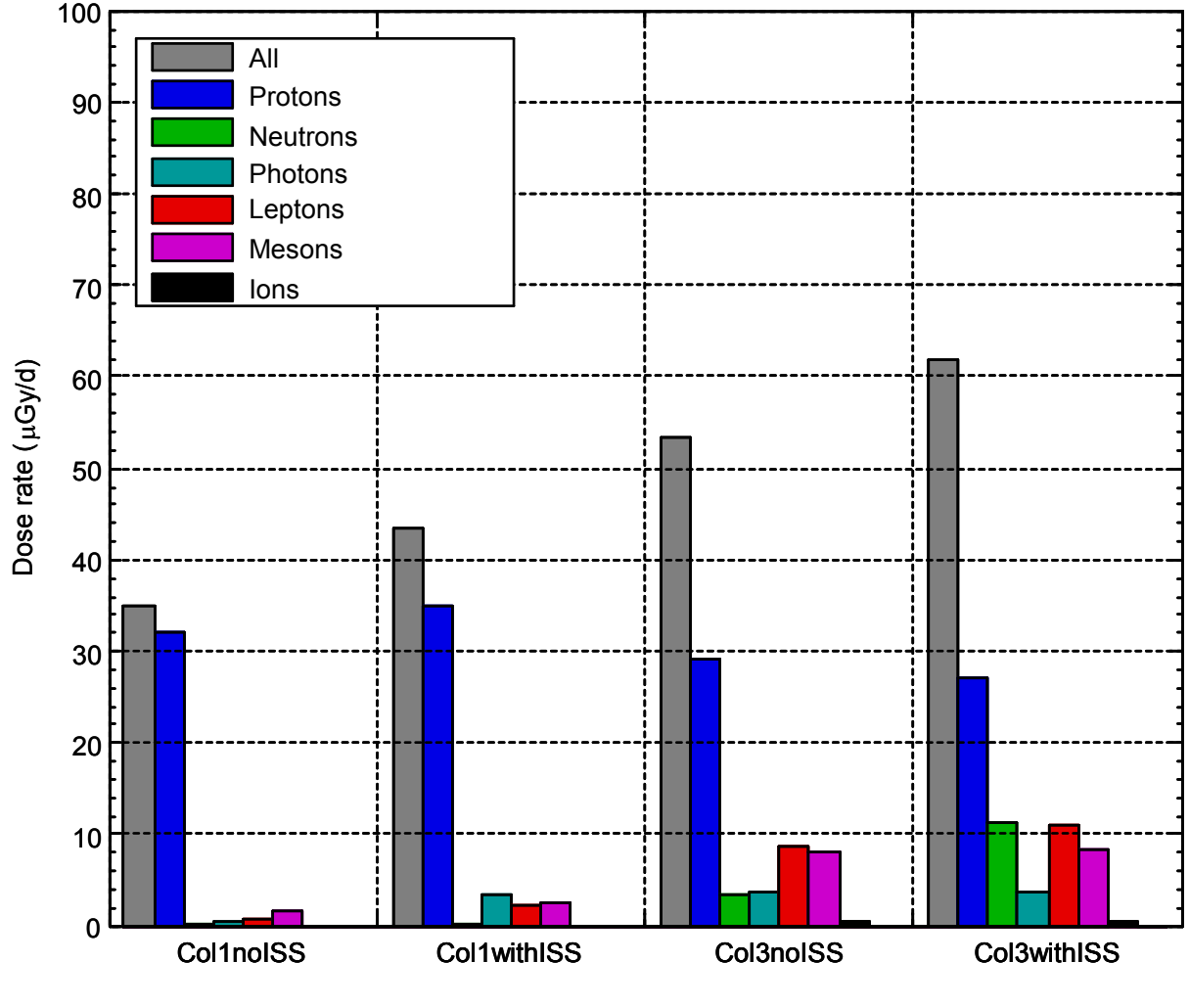
Penetrating primary/secondary protons and secondary neutrons due to incident cosmic ray protons (CREME96-min, 380 km)

Cosmic ray protons; Col3withISS



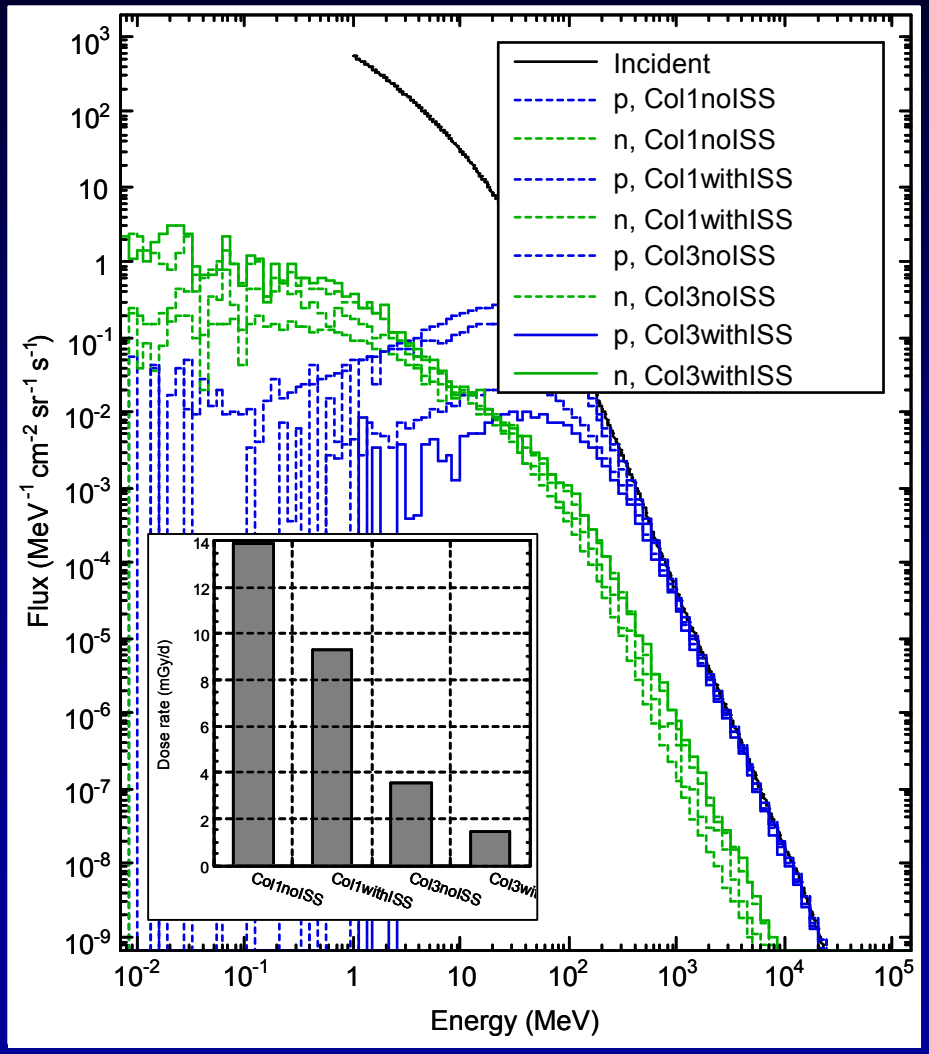
Spectra of various particle species entering Columbus in the ”Col3withISS” geometry

Cosmic ray proton doses

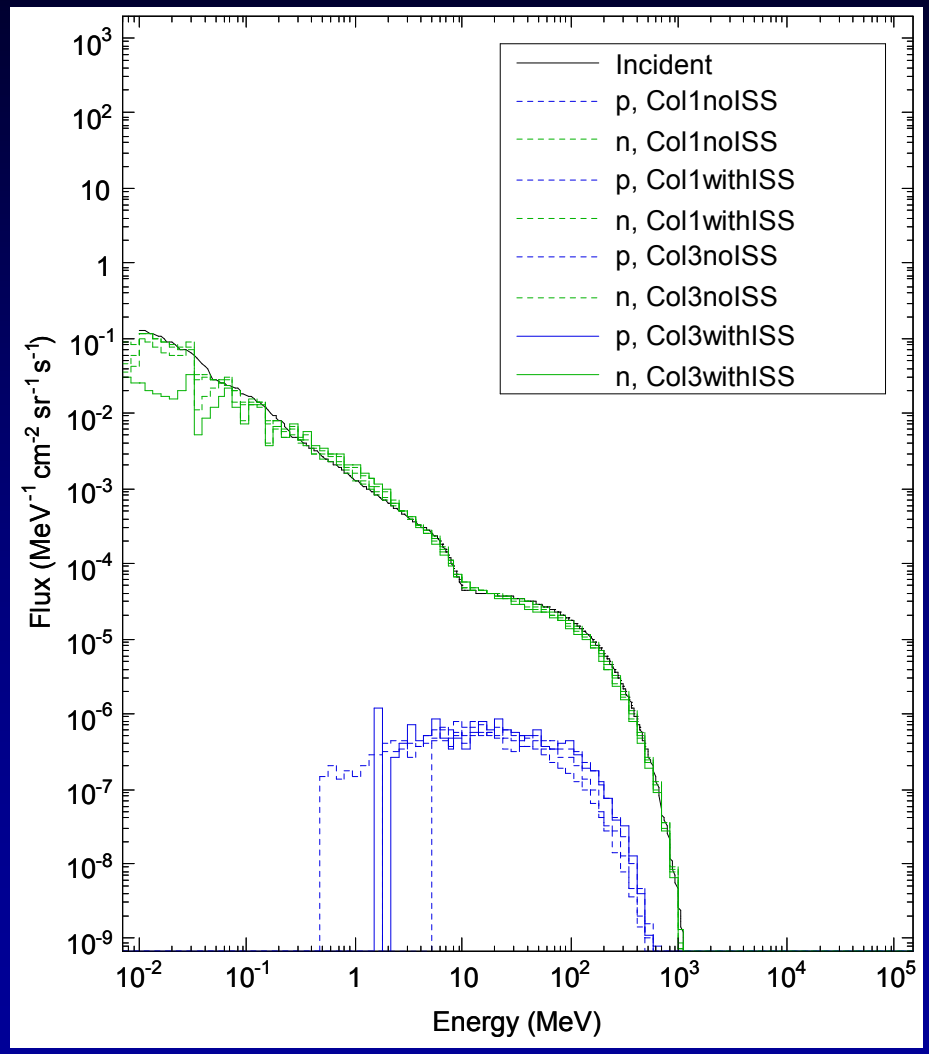


Dose rates in ICRU sphere due to incident cosmic ray protons; itemized by geometry model and particle type at surface of sphere

SPE protons & albedo neutrons

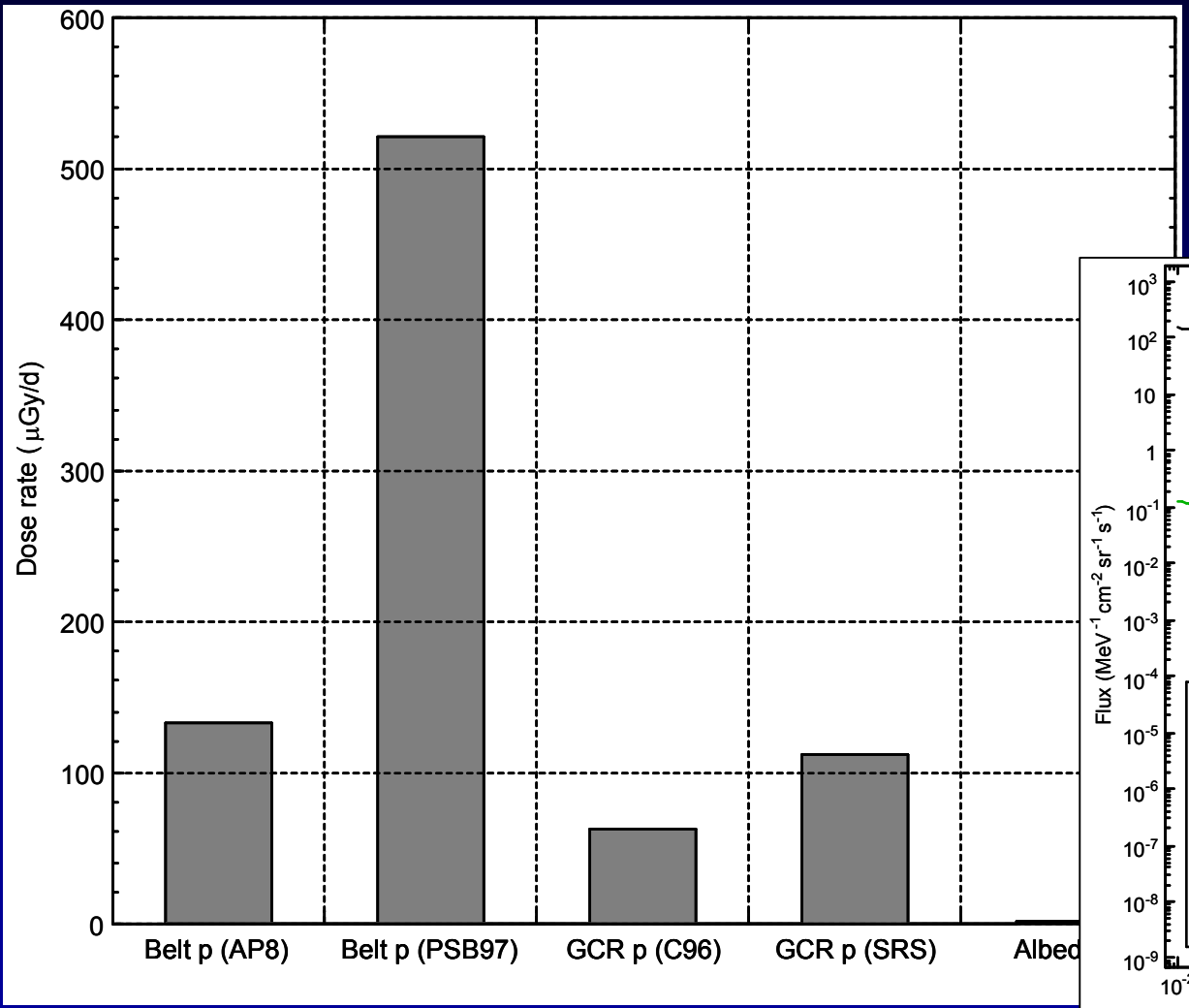


SPE particle spectra and resulting doses

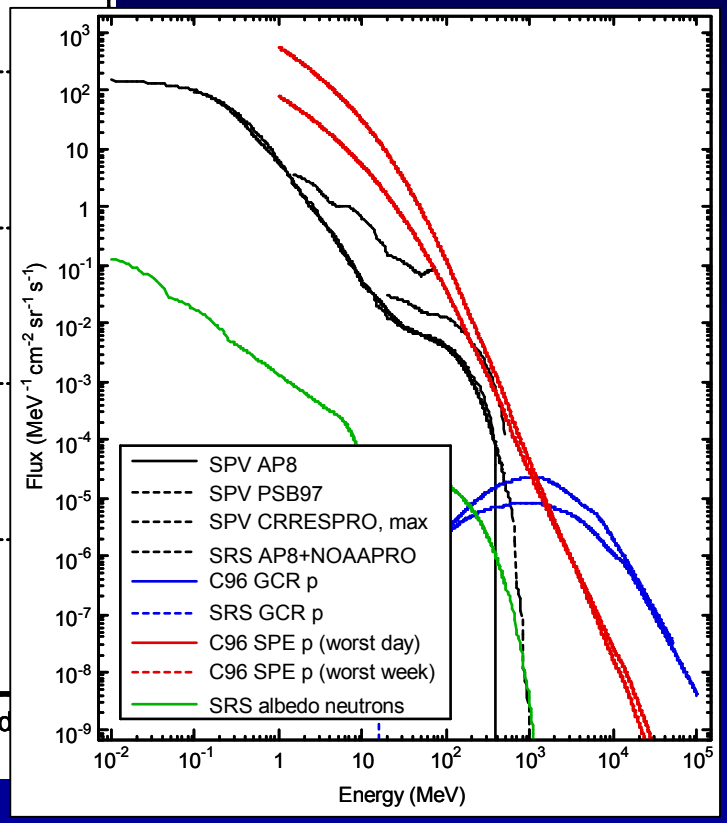


Albedo neutron spectra and secondary protons

Modell comparisons; Col3withISS



- Belt protons: 135 vs. 520 μGy/d (!)
- CR protons: 60 vs. 115 μGy/d
- Albedo neutrons unimportant (several previous studies)



Conclusions and future

- A detailed model of Columbus and ISS (14A) has been implemented as Geant4 geometries.
- Dose rates has been calculated for standard incident radiation field models
  - Belt protons (AP8-MIN): 135 μGy/d
  - Cosmic ray protons (CREME96, min): 60 μGy/d
  - Cosmic ray albedo neutrons (SIREST): 0.5 μGy/d
- Study of the influence of belt proton anisotropy in progress.

GCR- and solar ions will be studied the next few months.

Acknowledgment:

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