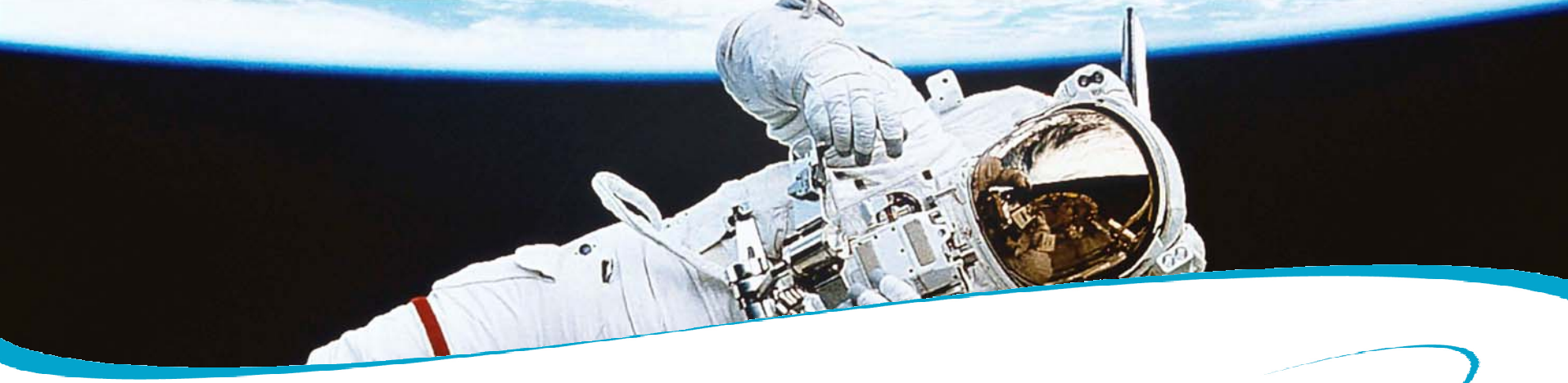

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Space Radiation Shielding for Human Mission: materials and concepts

Authors: Emanuele Tracino, Marco Silvestri

Co-Authors: Cesare Lobascio, Roberto Destefanis, Vincenzo Guarnieri, Maurizio Belluco, Mauro Briccarello

Presenter: Emanuele Tracino

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Template reference : 100181685K-EN

- Shielding development
- Ground Tests
- Flight Tests
- Simulations
- Conclusions

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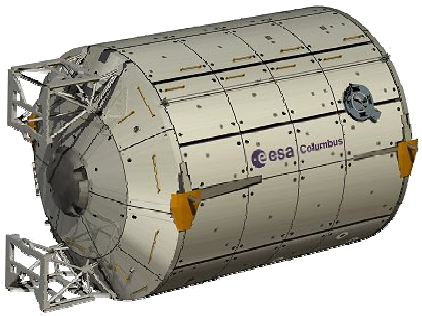
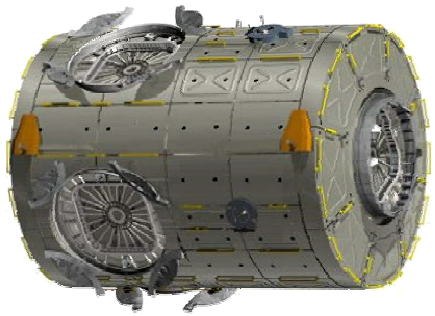
Shielding development (1/4)

Adding 1g/cm^2 for radiation protection means…



COLUMBUS:
ΔM = 1,04 tons
Δ $ = 52 M$



NODE 2,3:
ΔM = 1,1 tons
Δ $ = 55M$

MPLM:
ΔM = 1,05 tons
Δ $ = 52,5M$

- **Use multipurpose materials (integrated approach)**
- **Shielding optimization through mass distribution**
- **Research for new materials**
- **Active shielding ?**

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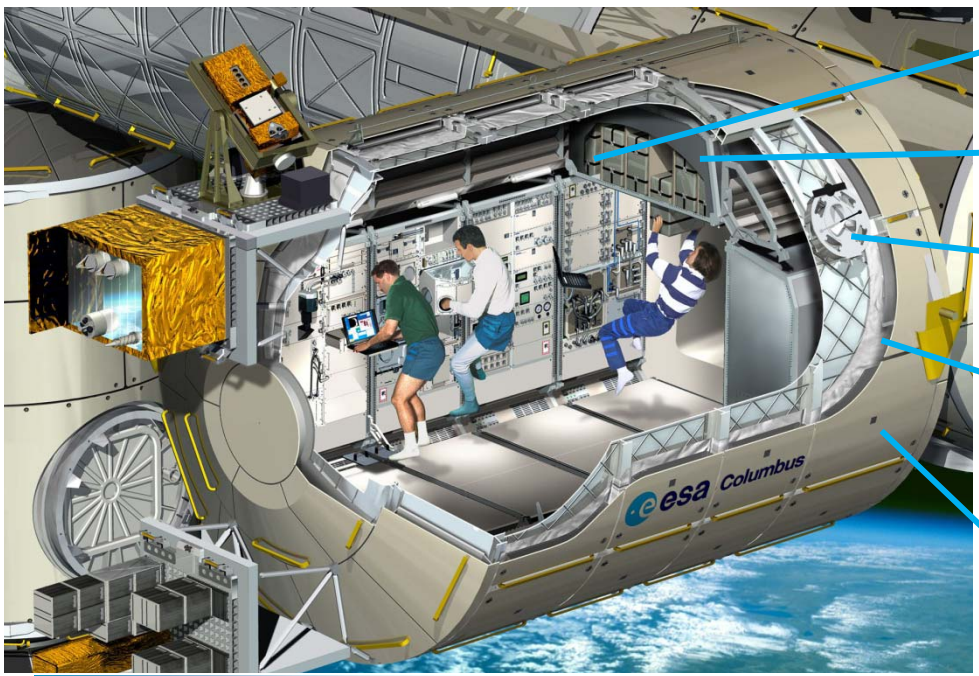
Shielding development (2/4)

Integrated approach:

- Using materials good not only as radiation shield (e.g. Kevlar)
- Integrate the radiation protection with other subsystems (e.g. ECLS)
- Considering the internal mass distribution and materials



Internal out-fit

Secondary Structure

Primary Structure

Thermal protection

Micro-Meteoroids and Orbital Debris (MMOD) protection system

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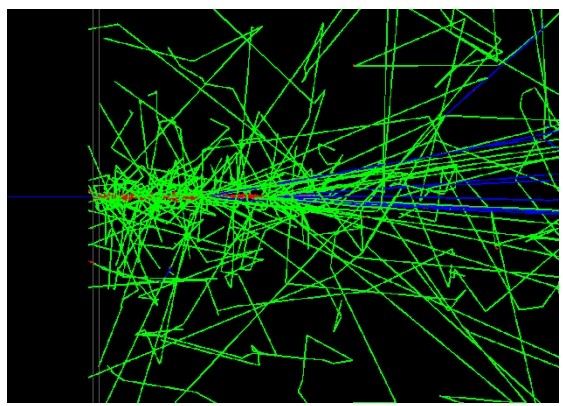
Shielding development (3/4)

Phase 1 - Concepts validation by means of:

- on ground tests (accelerator p+, 56Fe)
- on flight tests (ISS, Foton)
- simulations (Geant4) and correlations → **just started (2 weeks)**

Goals:

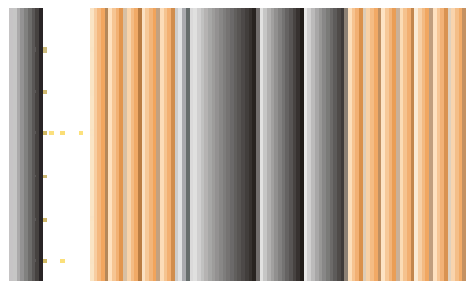
- gain experimental know-how
- familiarization with Monte Carlo Tools for radiation transport
- Acquire expertise to predict shielding behaviour of materials and multilayers in simple geometries

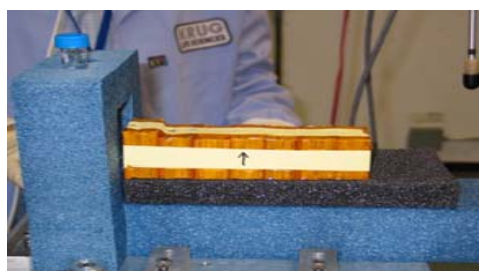


Shielding development (4/4)

Phase 2

1. Material selection - optimization
2. Shielding performance prediction
3. Multilayer selections - optimization
4. Shielding performance prediction
5. Best candidate selection
6. Beam tests
7. Long duration flight tests





PATENT **PRODUCTS**

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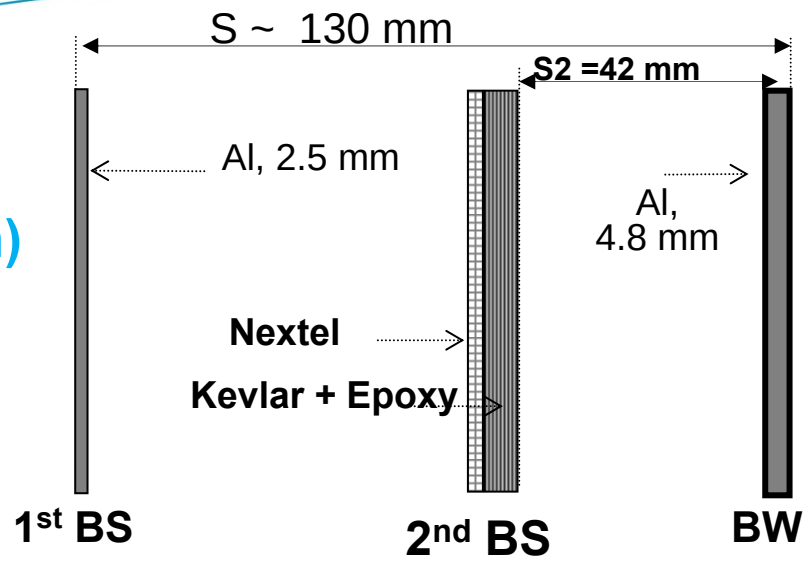
Materials Tested

- Kevlar (36% epoxy resin)
- Nextel (Al2O3, B, SiO2)
- Polyethylene
- Aluminium



- Kevlar and Nextel are used in MMOD shielding for they ballistic properties and also as structural materials in inflatable module
- No literature data on shielding properties for Kevlar and Nextel

Characterisation of candidate materials irradiating them with a 1 GeV/n ^{56}Fe beam measuring:

- Dose Reduction
- Bragg peak position

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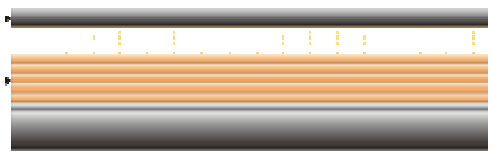
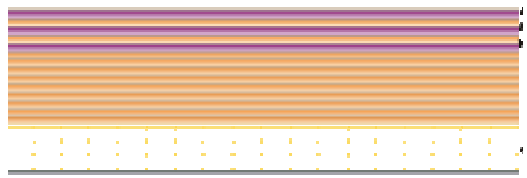
COLUMBUS
Rigid module concept



Composition:
- Nextel
- Kevlar epoxy
- Kapton
- Aluminium

"Columbus" Target aims to reproduce the High Resistance MMOD Shielding of the actual Columbus Module on the ISS

REMSIM
Inflatable module concept



Composition:
- Nextel
- Kevlar
- Kapton
- Air bladder
- Beta-cloth
- Nomex

This configuration refers to the multi-layer target selected during the REMSIM study

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ESCHILO and ALTCRISS (collaboration with Univesity of Napoli and Tor Vergata)

Spacecraft: ISS

Experiment: ALTEINO – particle detector

2 identical tiles composed by KEVLAR, NEXTEL and HDPE

SOFOCLE (collaboration with DLR)

Spacecraft: ISS

Experiment: Matroska – human phantom with various dosimeter

Shielding tiles made by KEVLAR, NEXTEL and Polyethylene accomodated in the Matroska poncho

PARIDE (collaboration with University of Napoli and INFN Torino)

Spacecraft: Foton (12 days, 61° altitude between 262 - 304 km)

Experiment: PARIDE

Neutron dose comparison behind Kevlar and Aluminium shield (Using Bubble Detector Neutron Dosimeter - BDND)

Kevlar show a reduction in Neutron dose of about the 21% vs. Unshilded

Aluminium show an increasing of the dose of 6% vs. Unshilded

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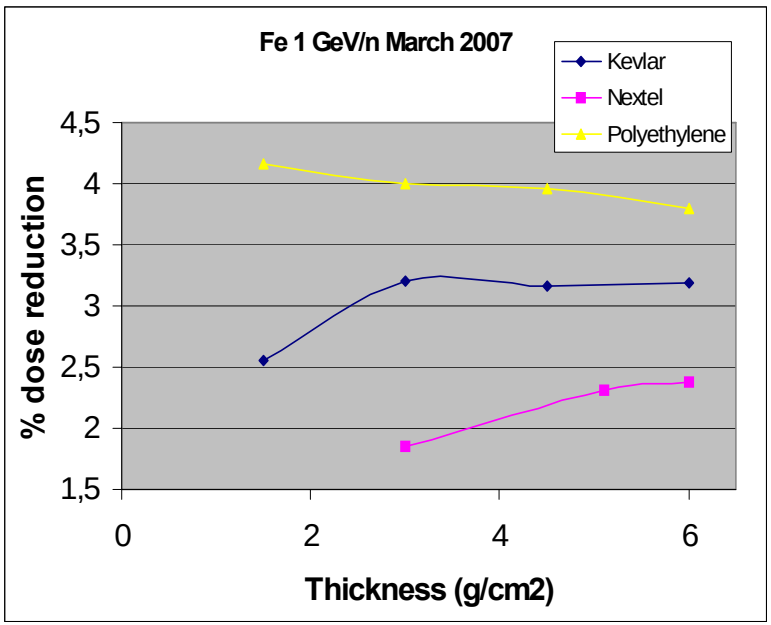
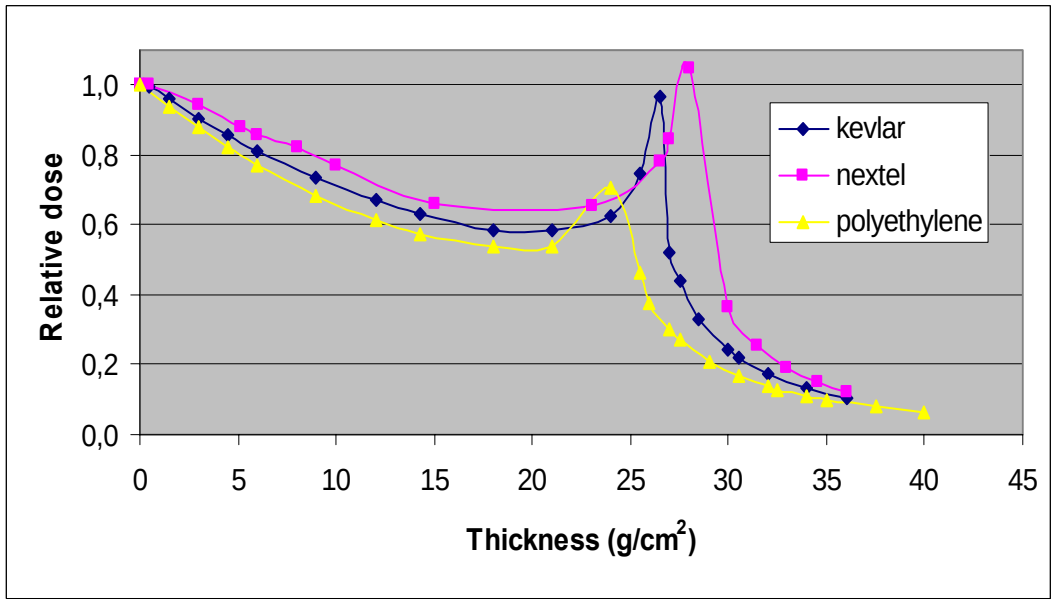


Percent dose reduction per g/cm^2



Bragg peak for different materials

Performed experiments confirmed hydrogen-rich materials and light atoms like carbon are effective radiation shields

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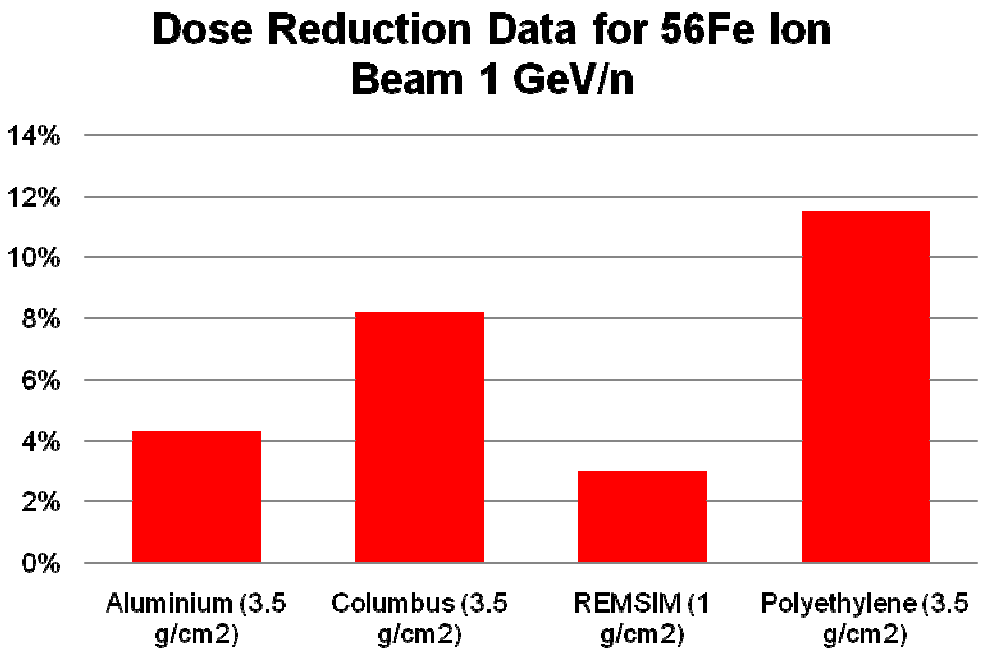
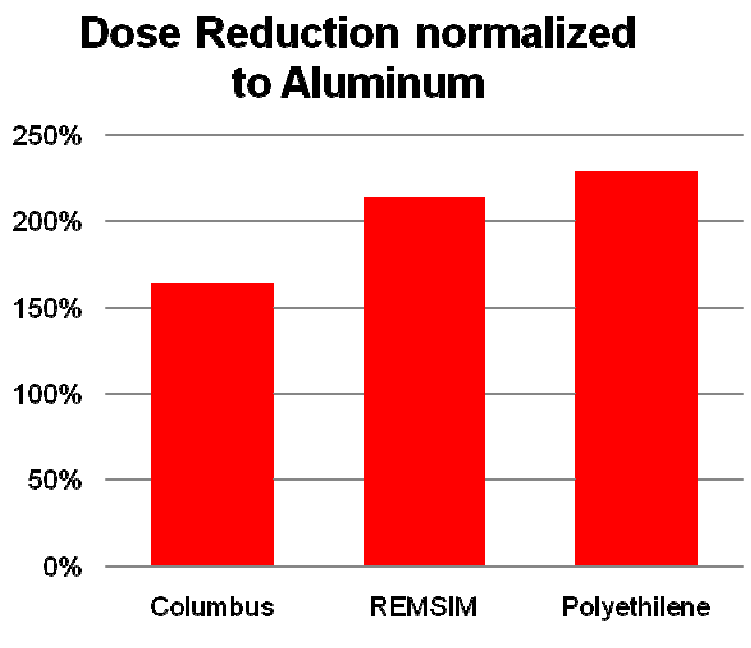
Dose reduction offered by multilayers
1 GeV/nucleon ^{56}Fe beam tests





Experimental data show that for a given mass, hydrogen-rich materials and multilayers have better shielding performance compared to metallic ones.

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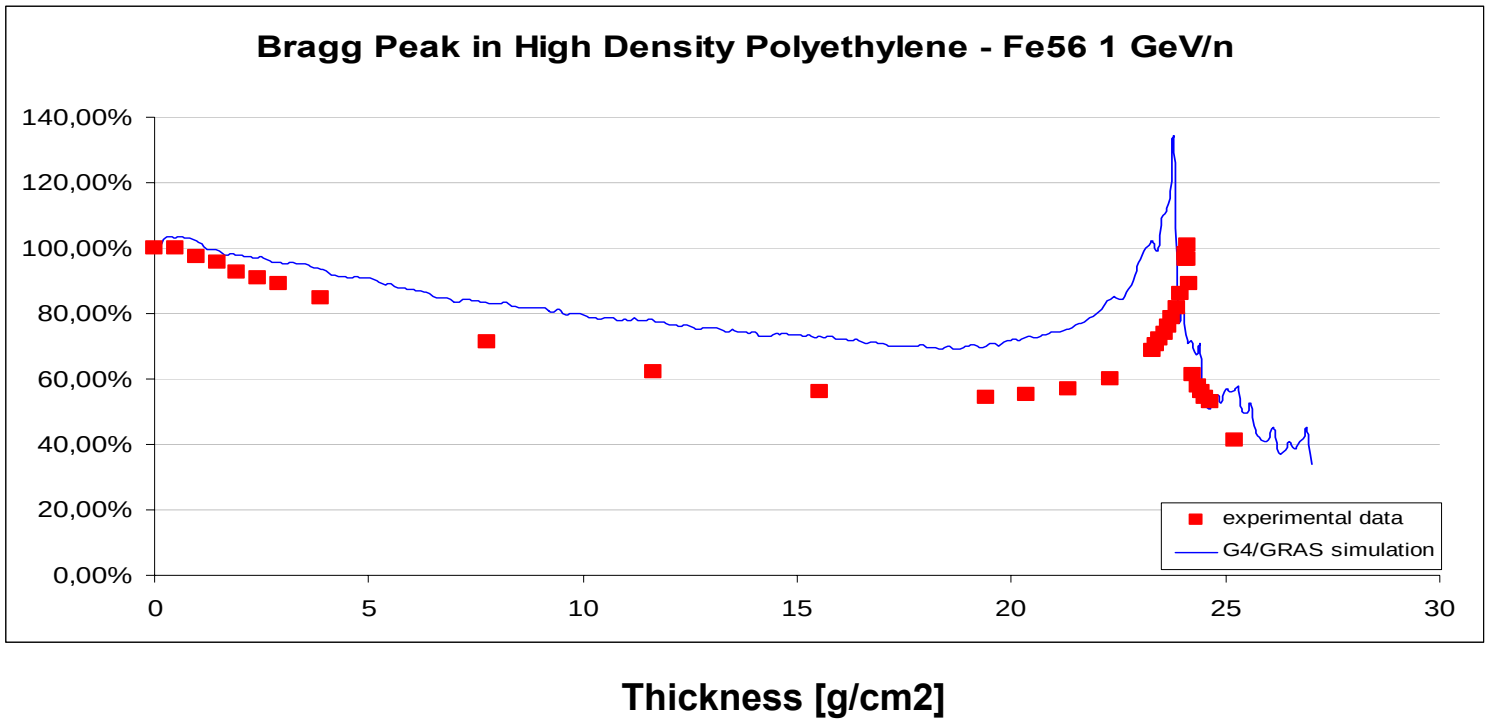
Dose reduction preliminary simulations vs. Experimental data



- Preliminary simulation results show about 15% larger dose
- Good agreement with the Bragg peak position and the ion range
- Work in progress to improve the simulation accuracy

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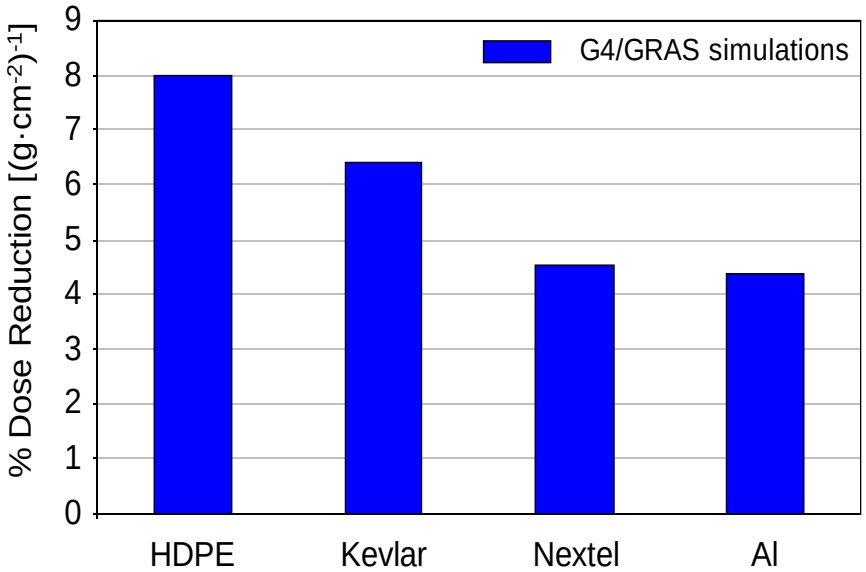
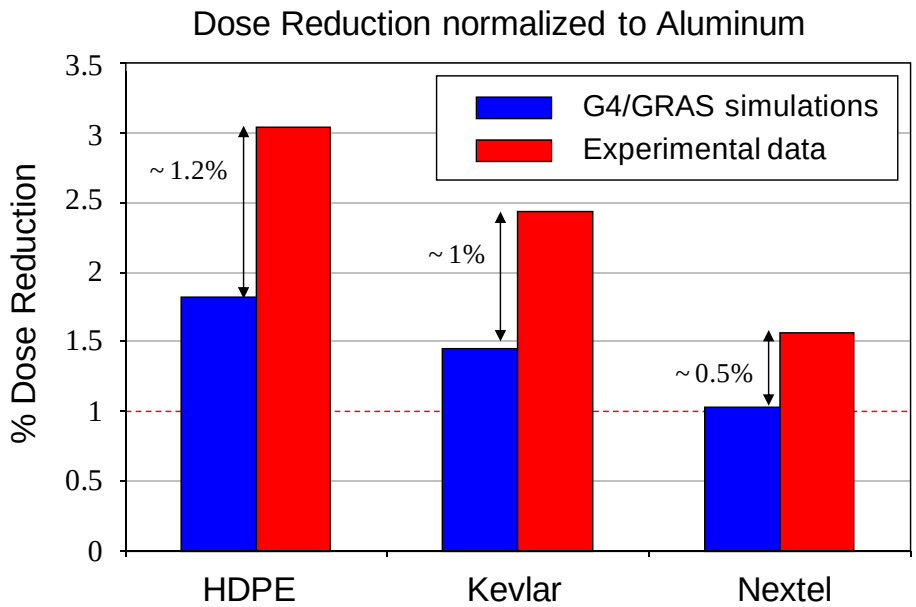
Dose reduction simulations vs. Experimental data





- **Preliminary simulations confirm the dose reduction trend**
- **We are still working on:**
  - **Materials modellization**
  - **G4 Physics**
  - **Target geometry**

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Conclusions

- Investigation on absolute and relative radiation shielding effectiveness of pure and composite multi-layered materials
- Acquisition of know-how in Geant4 / GRAS simulations and correlation with experimental results

Future outlook

- Improving modeling and simulation know-how
- extend investigations to other materials for inflatable modules and to regolith for surface habitats shielding
- Optimization of the different shielding layouts and calculation of the effects on crew and electronics

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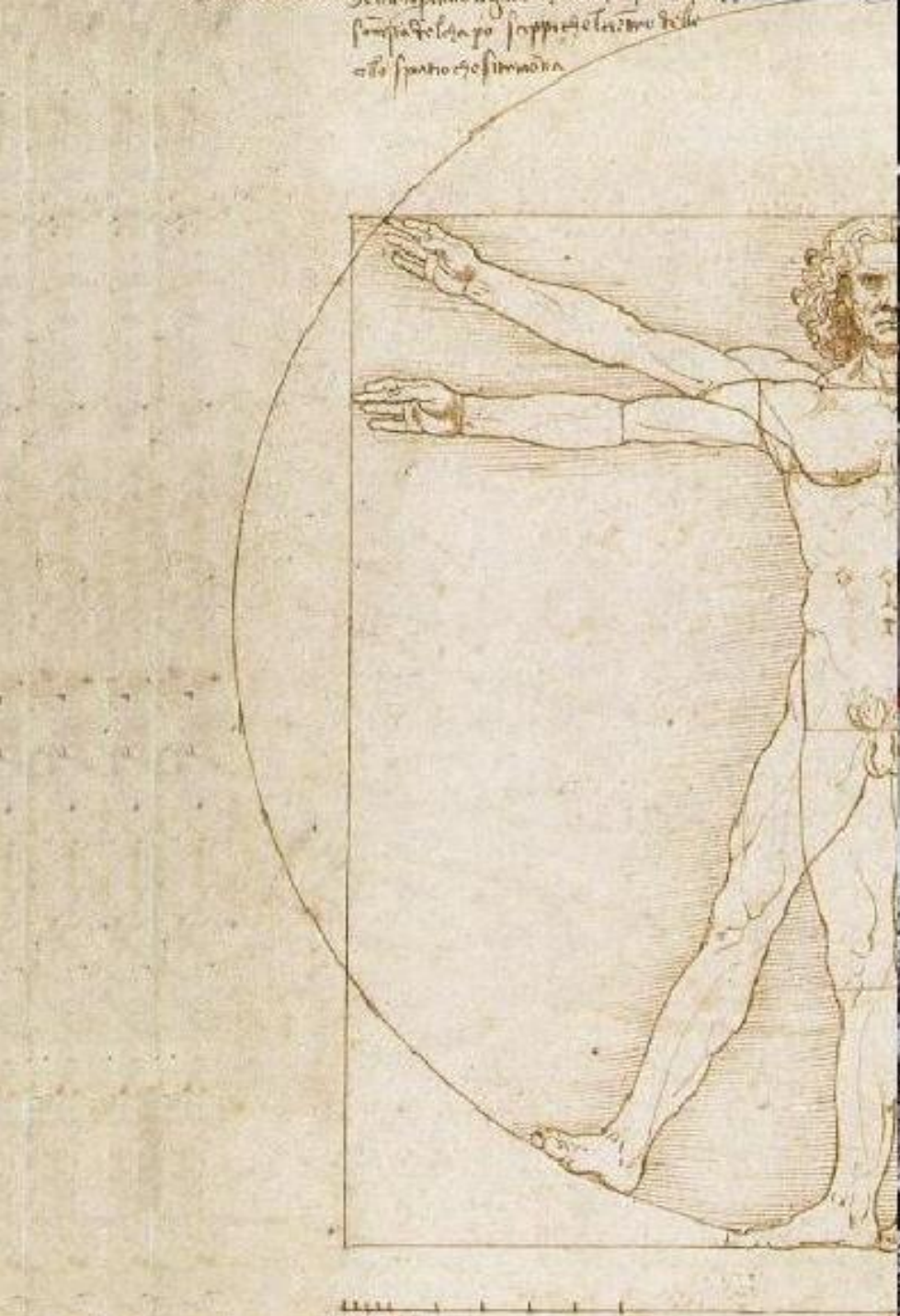

Thank you for attention

- Back-Up Slides

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PARIDE : PARticle & Ion Dosimetry Experiment *

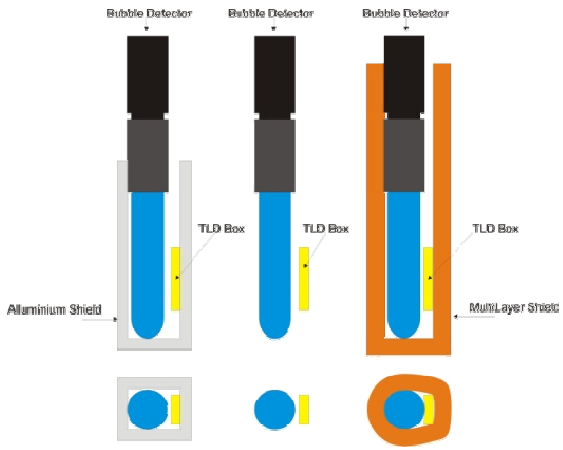
On board the last Foton mission (Sep. 2007) to study the effectiveness of different radiation shelters

Detectors to evaluate the **neutron component** of the radiation field: Bubble Detectors Neutron Dosimeter **(BDND)**

Detectors to evaluate the **ionizing component** of the radiation field: Thermo-luminescence Detectors **(TLD)**

Aluminum and Kevlar shelters to assess their shielding capability

Main parameters	
max altitude	304 km
min altitude	262 km
Orbit Inclination	63°
Mission Duration	12 days



* Close cooperation with Marco Durante, Università Federico II, Napoli and Alba Zanini Università degli studi di Torino

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ESCHILO (“Esperimento di SCHermatura In Low Orbit - Shielding Experiment in Low Orbit”) during the ENEIDE mission;

ALTCRISS (Alteino Long Term monitoring Cosmic Ray on the International Space Station), the long duration campaign for measuring the effect of shielding against cosmic radiation in different locations and orientations of the Space Station;

SOFOCLE (“Shielding Options FOr Crew in Low Earth orbit”), long term experiment aimed at evaluating the effect of shielding tiles fitted on a “poncho” on the anthropomorphic phantom Matroshka.

Additional results on the radiation environment have been obtained in September 2007 with the experiment PARIDE (PARticle & Ion Dosimetry Experiment) onboard the 12-day long mission of the unmanned spacecraft Foton.

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Why Space ?

Space is an **extreme** environment (µg, radiation, confined volumes, prolonged isolation..)

Lack of defences because of the absence of a Darwinian selection

Series of molecular and cellular **damages** very close to those due to aging

The early **aging effect** is taken into account for space applications

Bio-Technological application to be used both in **space** and on **Earth**

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Ground Tests(1/11)

Astronauts are spending more and more time in space

NASA is working with Brookhaven National Laboratory and others here on Earth to learn about the possible risks to human beings exposed to space radiation

Courtesy from Brookhaven National Laboratories, USA. Adam Rusek .

TAS-I chose NASA Space Radiation Labs at Brookhaven to tests and characterize the behaviour of different material as radiation shields

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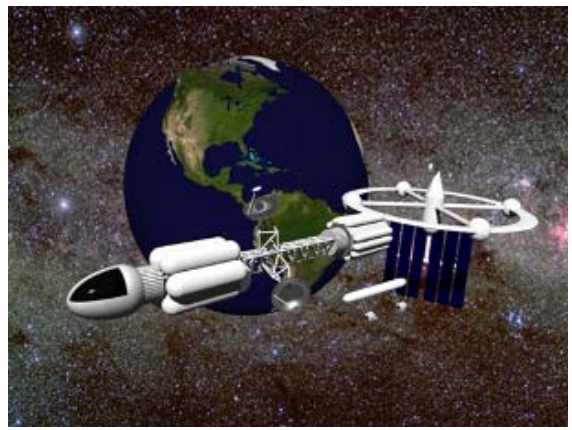
TAS-I Activities (1/2)

Activity : development of methods and materials (flexible, rigid) to be used as radiation shielding

Goal: designing passive radiation shielding means to be used as effective physical countermeasures against radiations for

- **Interplanetary vehicles**
- **Surface habitat design concepts**



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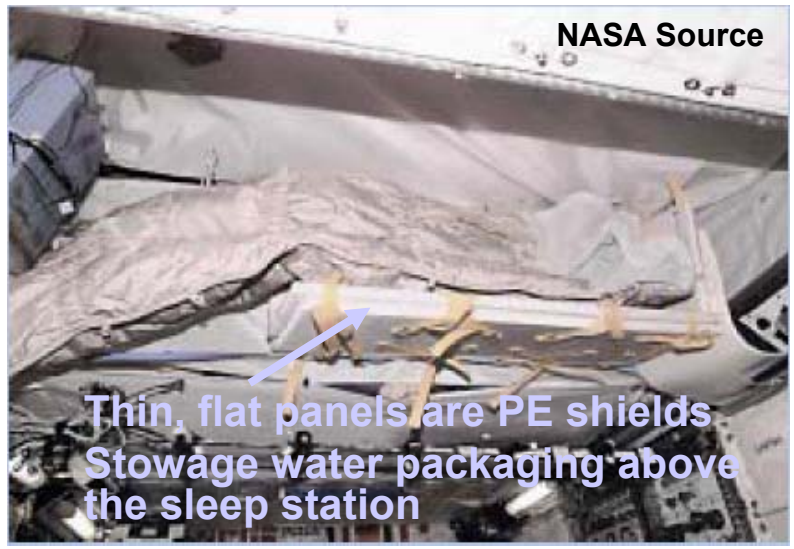
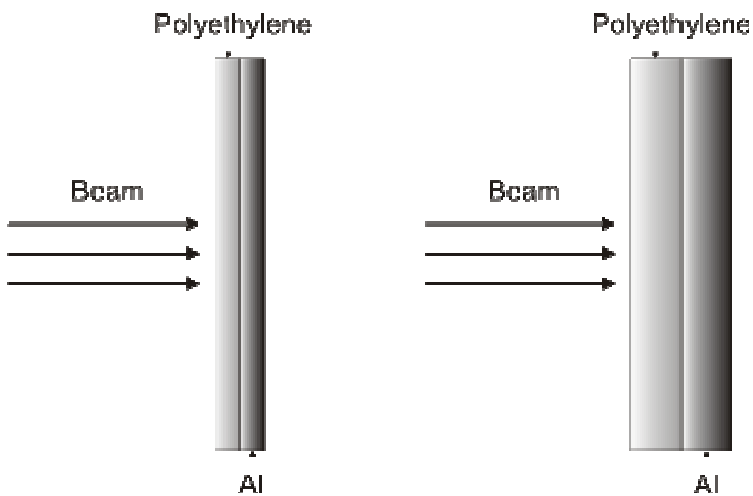
"Aluminium & Polyethylene" Target

Space structures make a massive usage of aluminium

Polyethylene is used on ISS to lower the dose the astronauts are exposed to

Effects evaluation of multi-layers composed by Aluminium and Polyethylene





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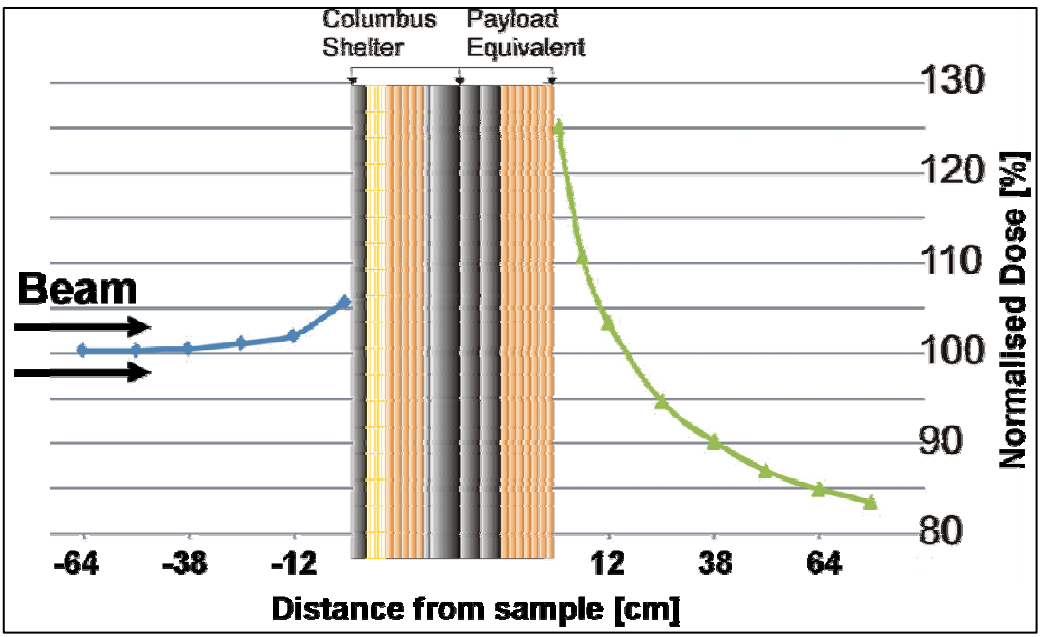
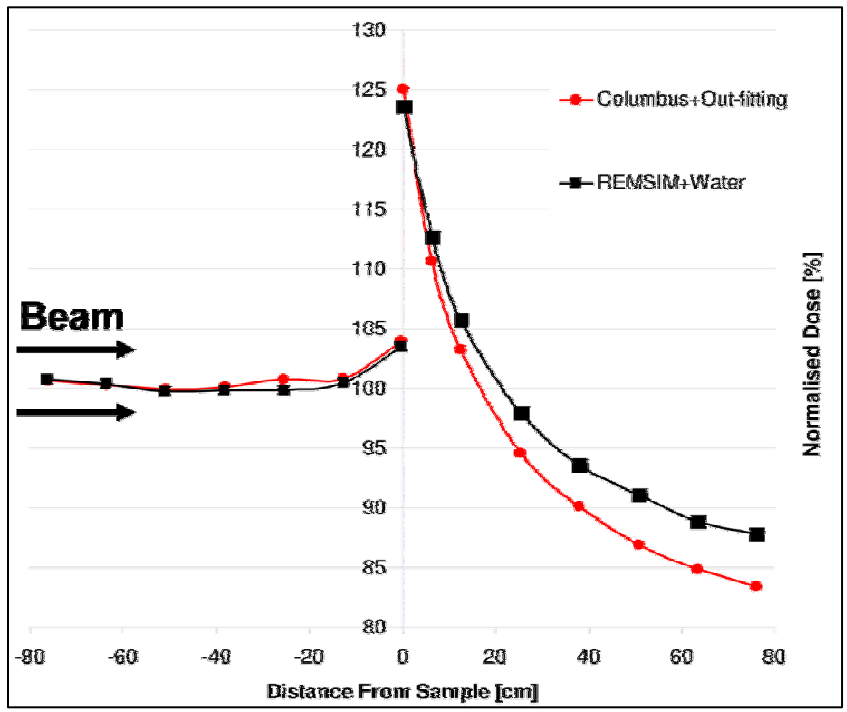
Ground Tests(10/11)

Second test series summer 2007

Results 1 Proton beam tests





"Columbus" and "REMSIM"

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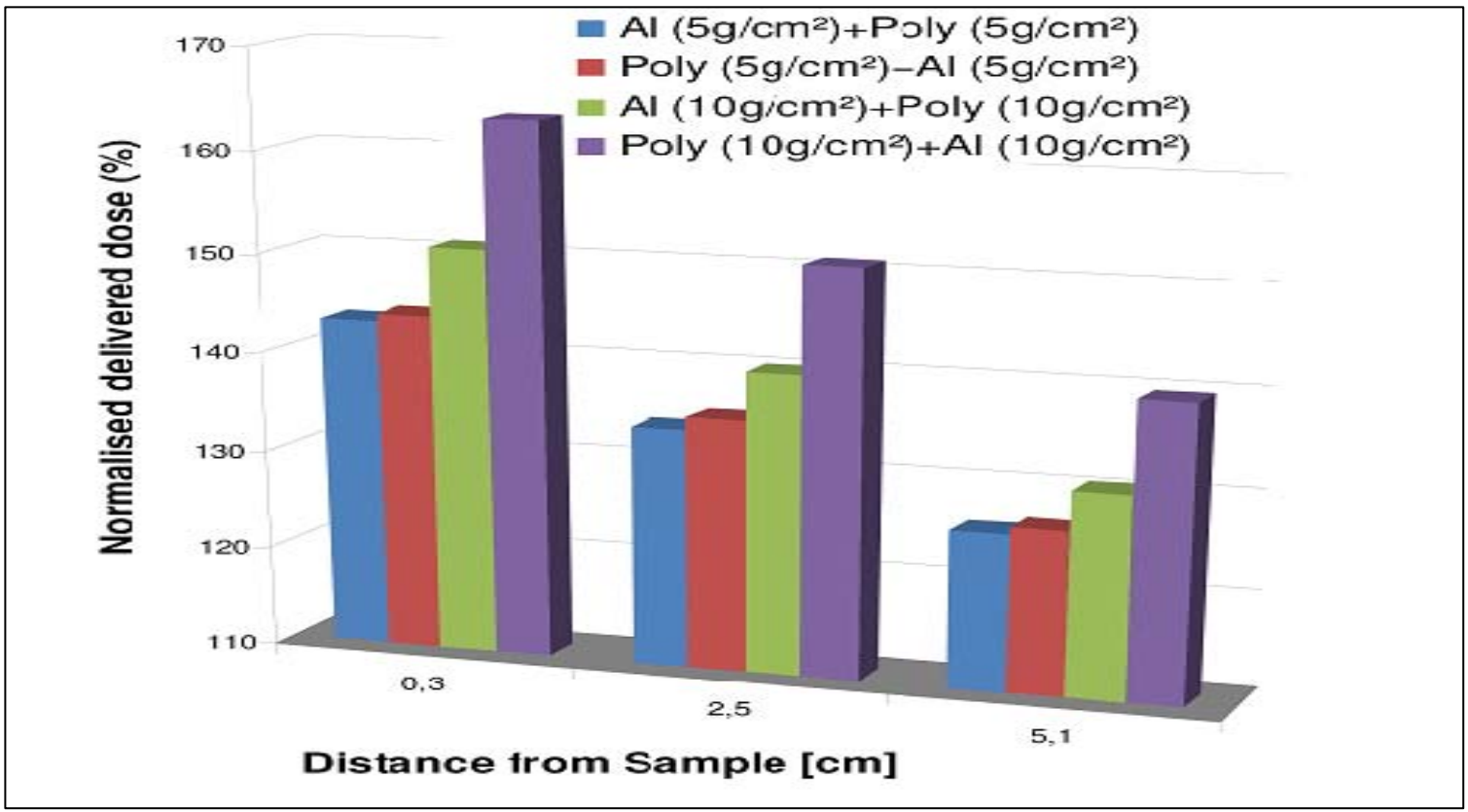
Ground Tests(11/11)

Second test series summer 2007

Results 1 Proton beam tests



Aluminium and Polyethylene Multi-layer

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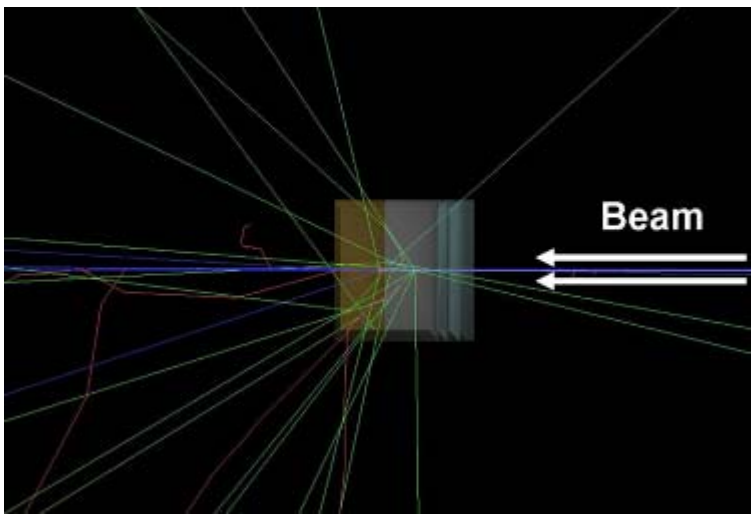
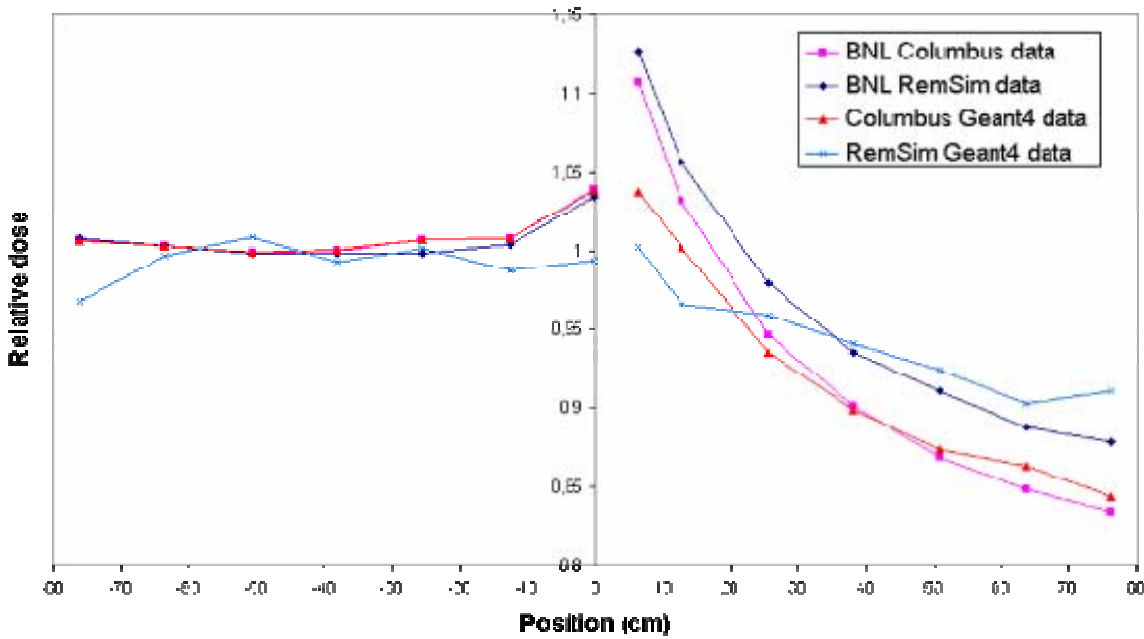
Ground Tests Simulation



TAS-I simulation campaign

Simulated target models the real target used to perform the beam test



GEANT4 simulations results vs real data

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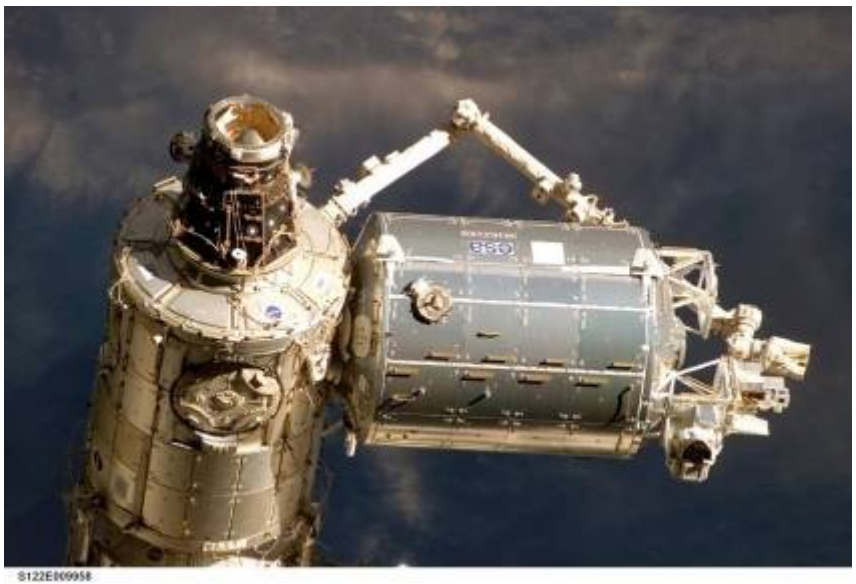
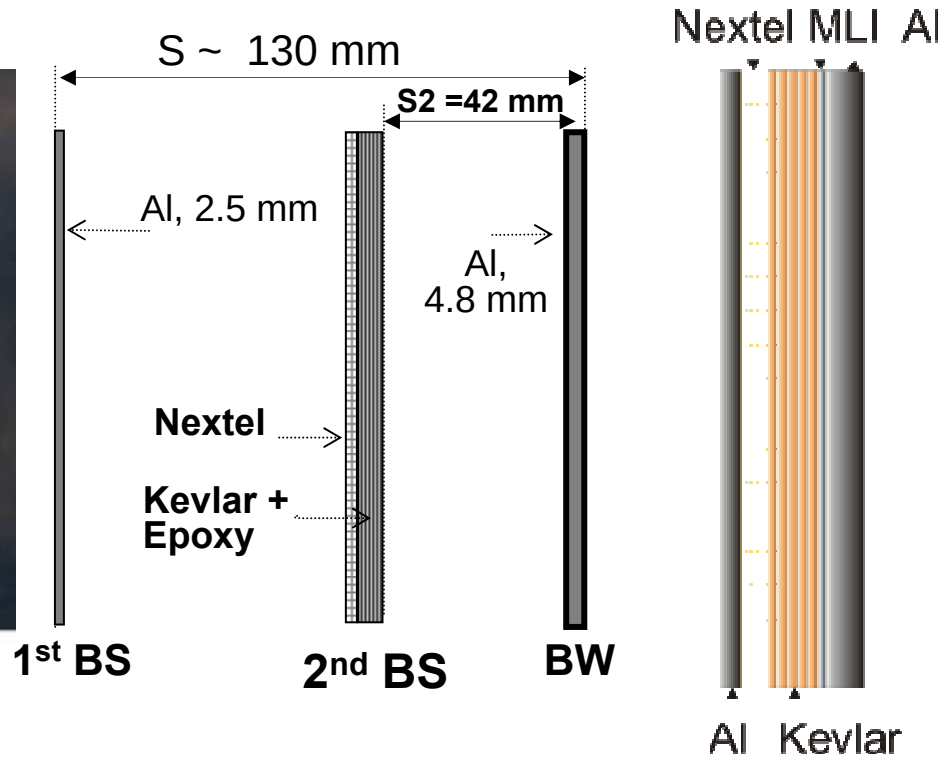
Ground Tests(5/11)

Second test series summer 2007

"Columbus" Target





"Columbus" Target aims to reproduce the High Resistance MMOD Shielding of the actual Columbus Module on the ISS

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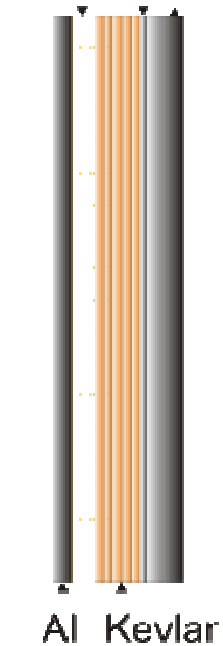
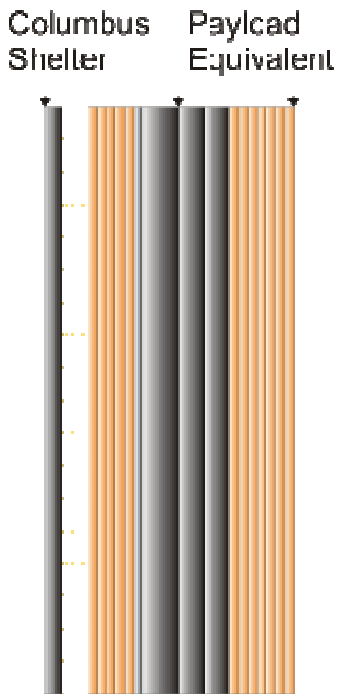
Ground Tests(6/11)

Second test series summer 2007

“Columbus” Target: two configurations tested



Only MMOD



MMOD + internal outfitting equivalent

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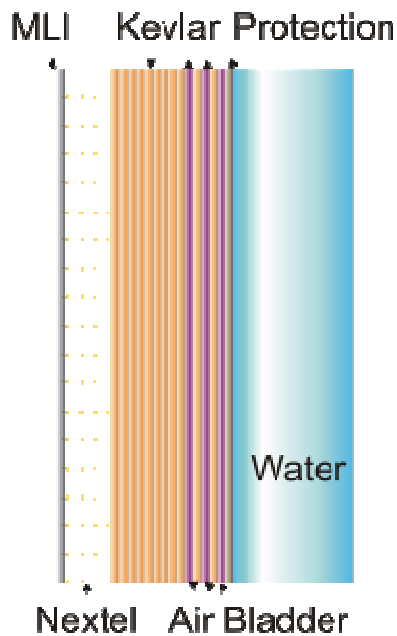
Ground Tests(7/11)

Second test series summer 2007

"Remsim" Target

This configuration refers to the multi-layer target selected during the REMSIM study

Material	Layers [#]	Areal Density [g/cm²]
MLI + Betacloth	21	0.04
Nextel	4	0.40
Kevlar	17	0.35
Air Bladder	3	0.05
Nomex	1	0.014
Total "REMSIM"		**1**
Water flasks	2	0.3
plus additional Water		**8.06**



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Ground Tests(4/11)

Second test series summer 2007

Tested Targets

- "Columbus"
- "Remsim"
- Aluminium & Polyethylene

Courtesy from Brookhaven National Laboratories, USA

Tests were performed irradiating targets with a 1 GeV/nucleon ^{56}Fe ions beam and 1 GeV protons beam

… to represent significant components of the GCR

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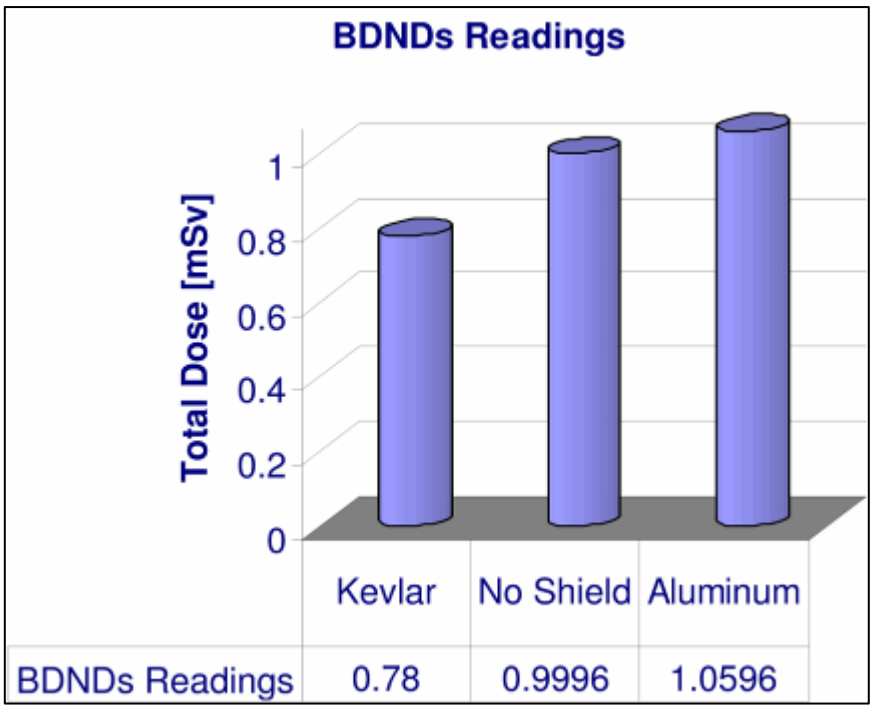
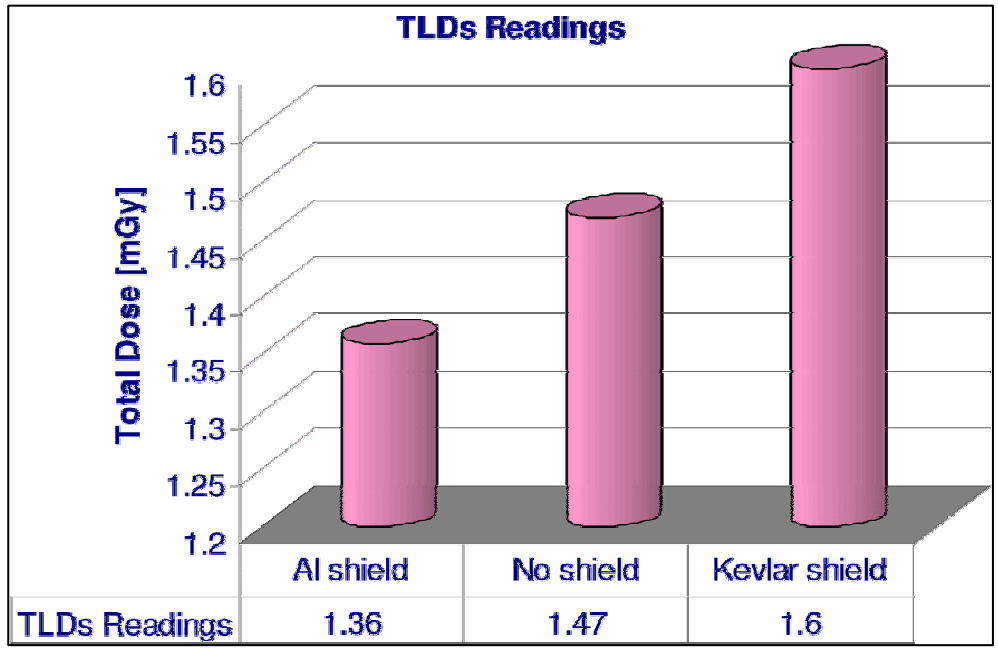
On Flight Tests(2/2)

PARIDE : Results





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