

# Ground-based Testing of ISS Elements and EVA Suites:

A Status Report – 12/99

Presented to NCRP Committee

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SRHP

# Overview

- Recent tests conducted at BNL
  - Heavy ion beams (Si, Fe)
  - ISS elements
    - Node-2 wall and DCQ layers
  - EVA suit swatches
    - EVA suit layers of EMU (US) and Orlan-M (Russian)
- Planned tests at the LLU facility
  - Proton and Electron beams
  - EVA suits
    - EMU and Orlan-M suits with an instrumented torso

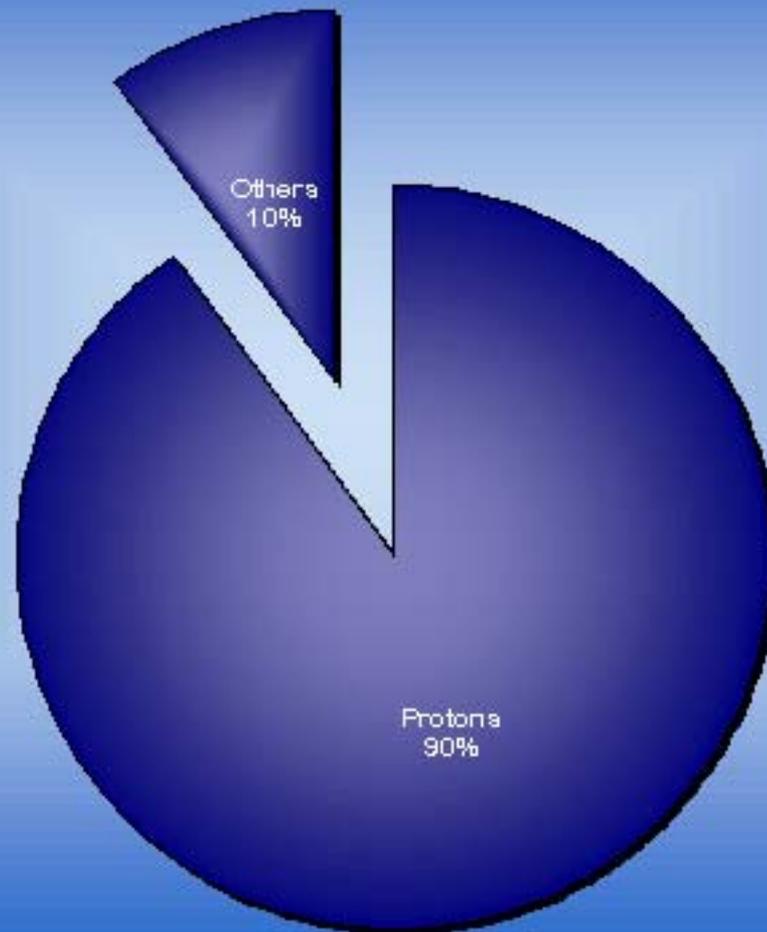
# Rationale and Objectives

- To develop more validation to our models
- To estimate radiation doses
- To simulate and study radiation damage
- To test the existing design limitations
- To initiate the requirements
- To negotiate shielding needs
- To yield improved safety

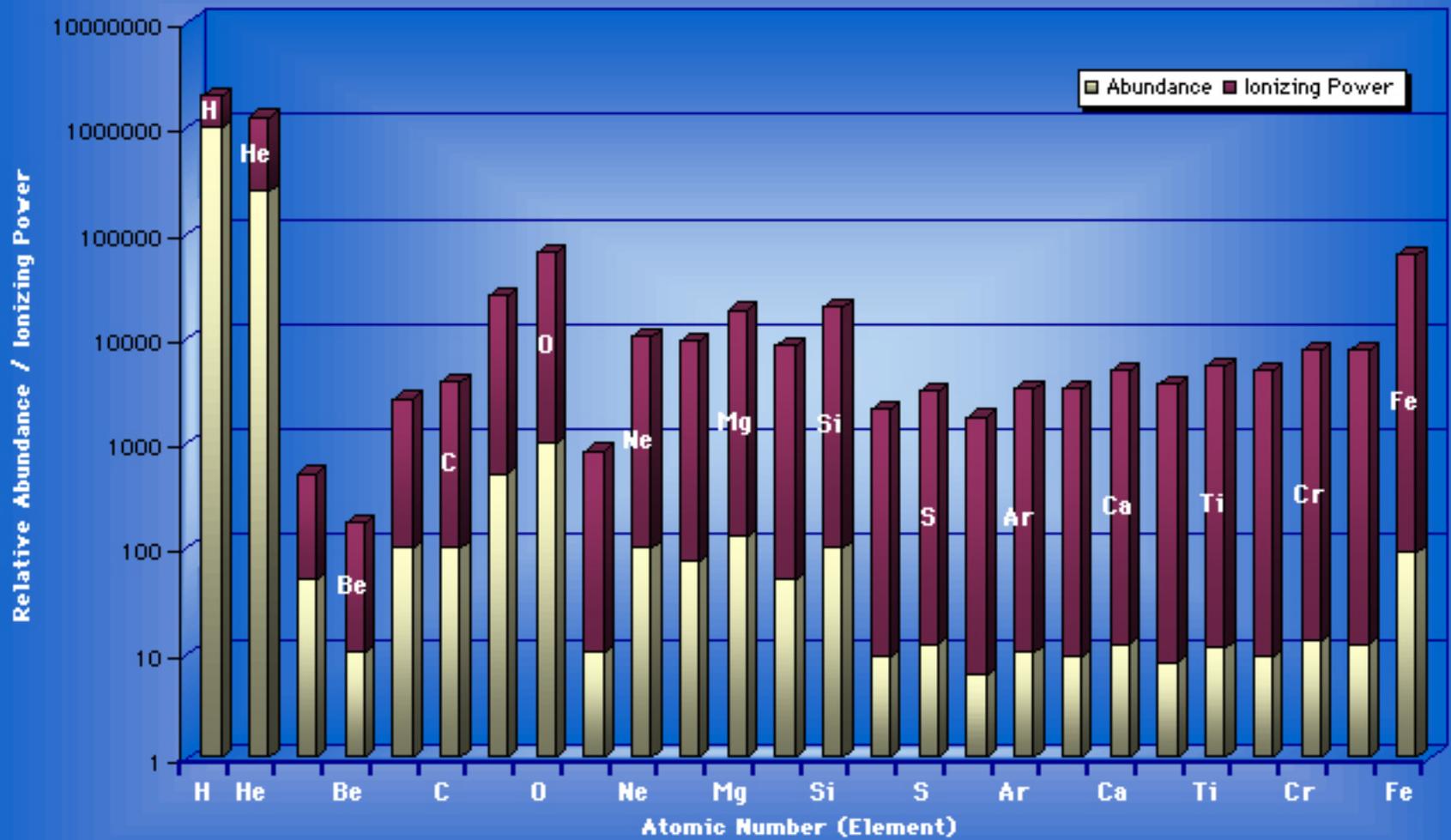
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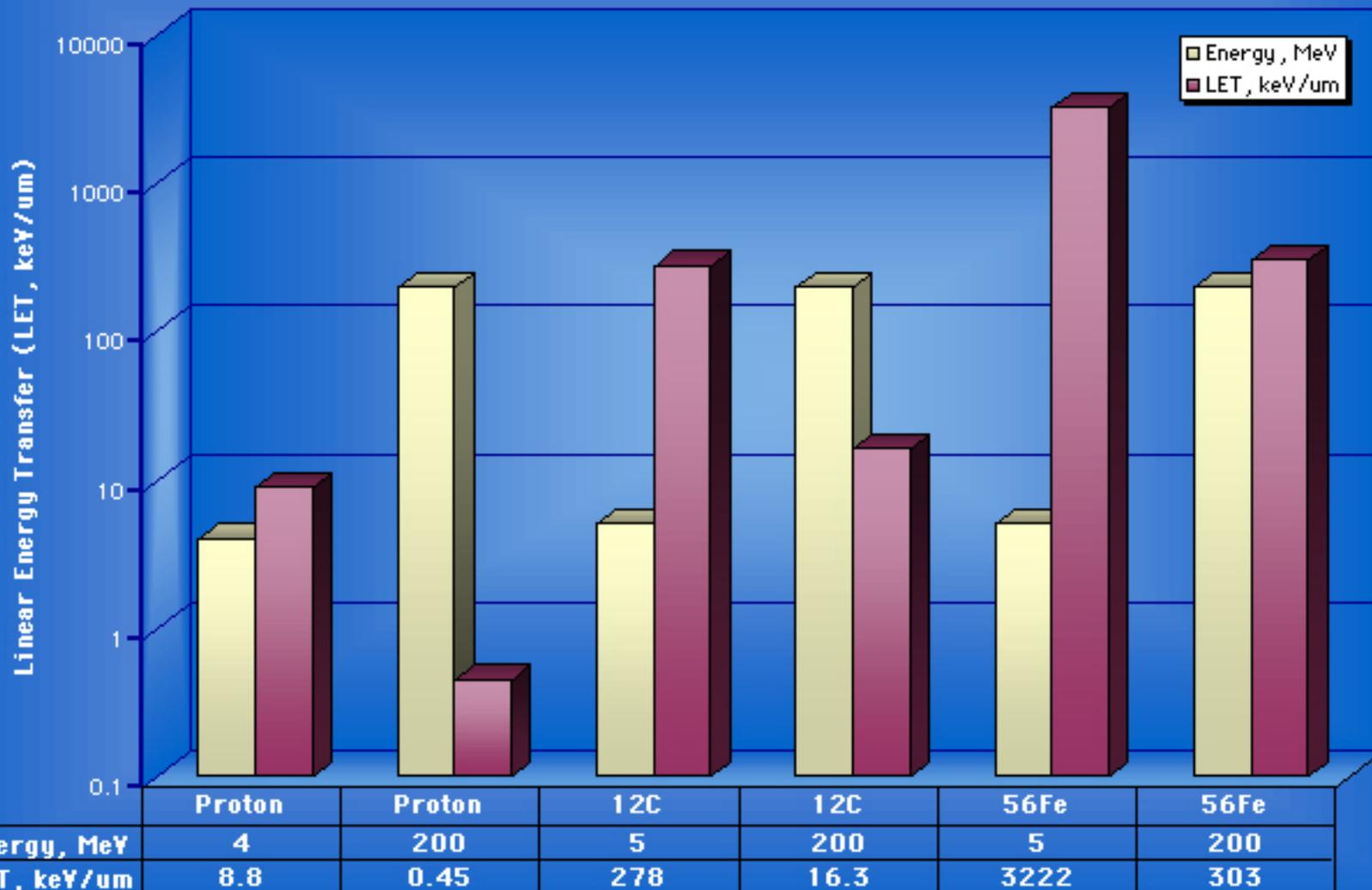
## Radiation Dose Contribution from SPE



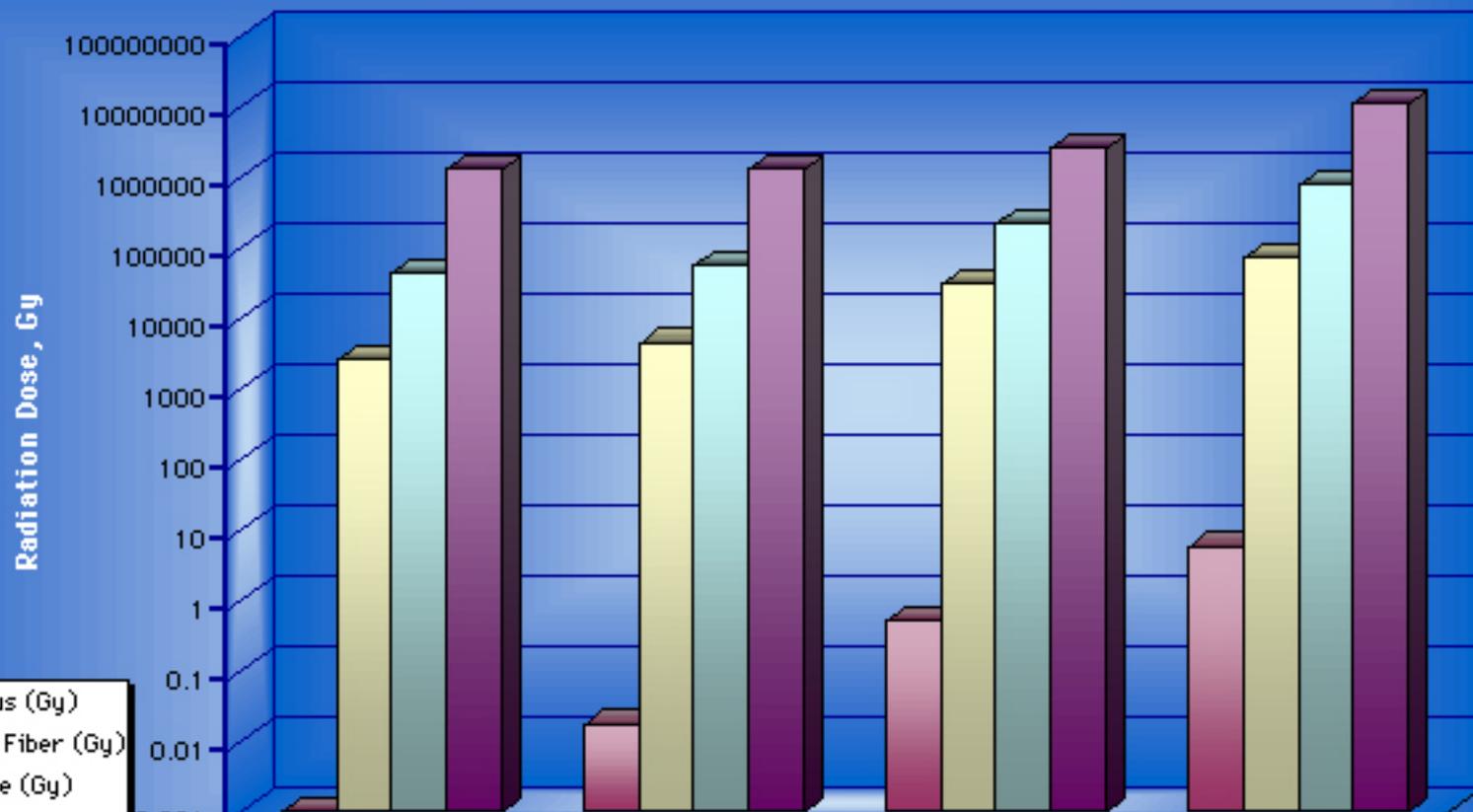
## Relative Abundance and Ionizing Power of GCR



### Energy Deposition at Cell Level



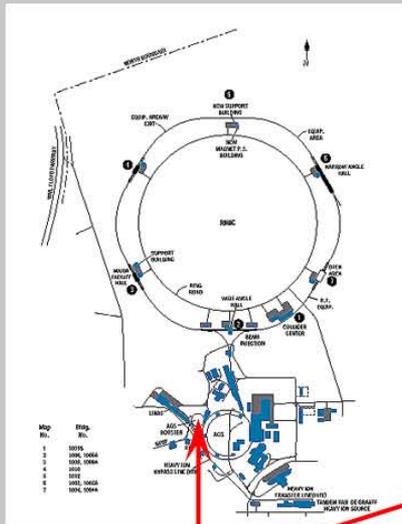
## Radiation Doses in Cellular Targets



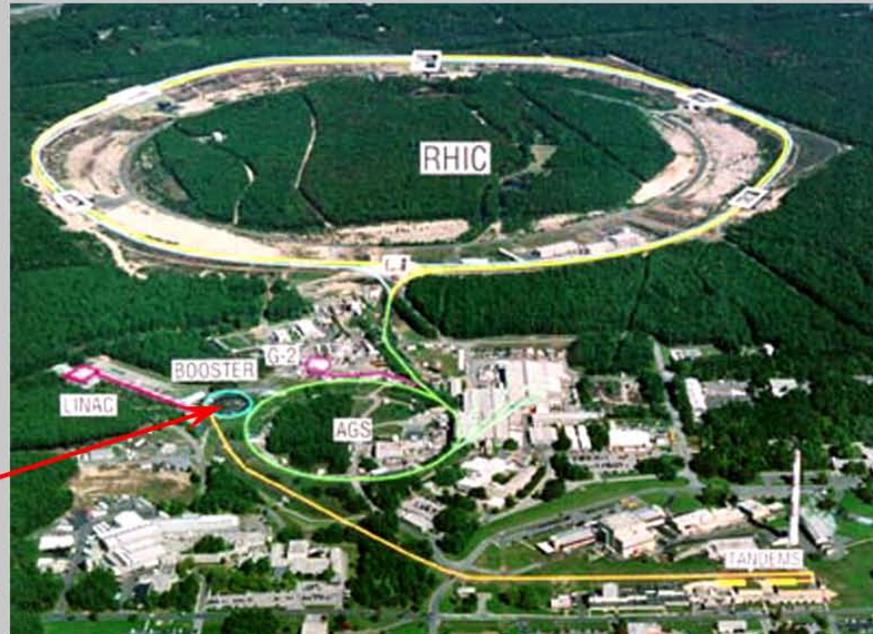
- Cell Nucleus (Gy)
- Chromatin Fiber (Gy)
- Nucleosome (Gy)
- DNA (Gy)

Cell Nucleus (Gy)	0.001	0.017	0.5	5.8
Chromatin Fiber (Gy)	2600	4500	30600	70200
Nucleosome (Gy)	44000	56000	218000	800000
DNA (Gy)	1310000	1300000	2570000	11100000

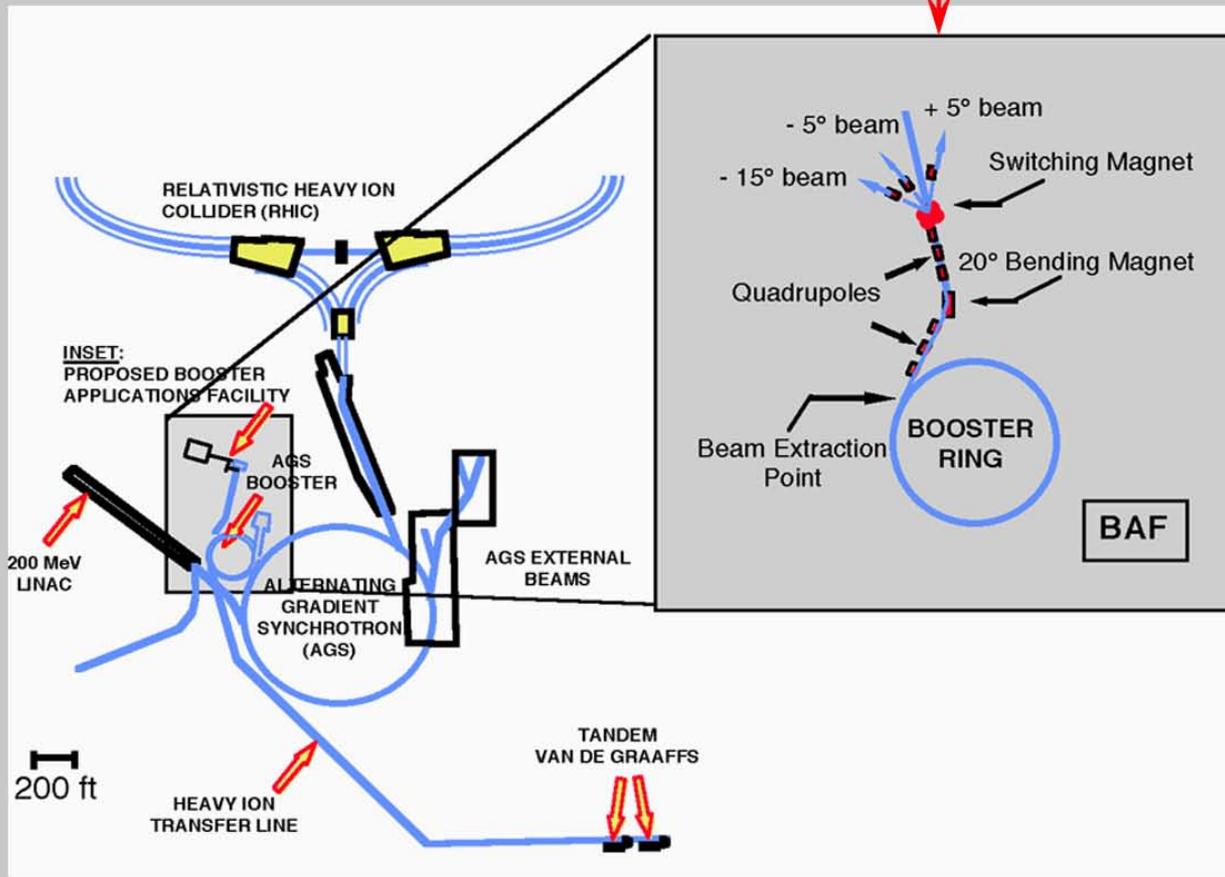
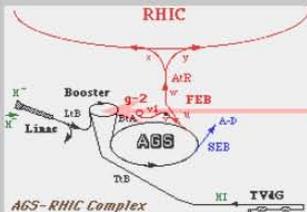
# Tests Completed at BNL (November 1999)



**Booster Applications Facility  
BAF (NASA)**

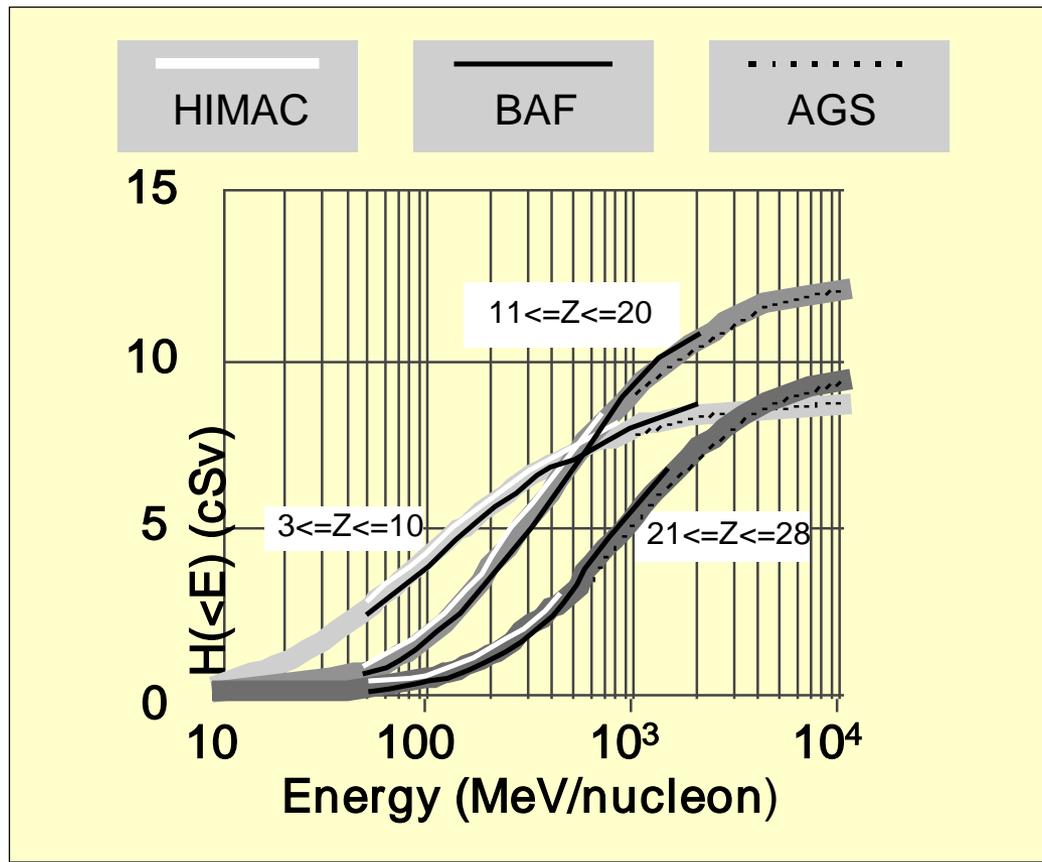


# Booster Applications Facility BAF (NASA)

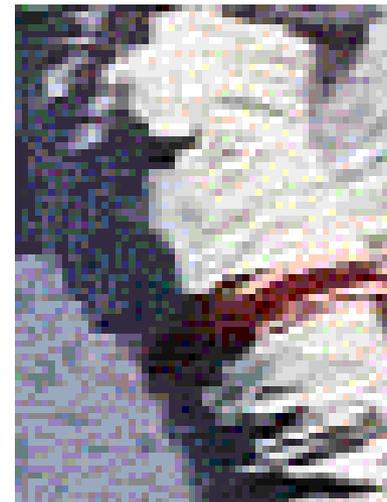
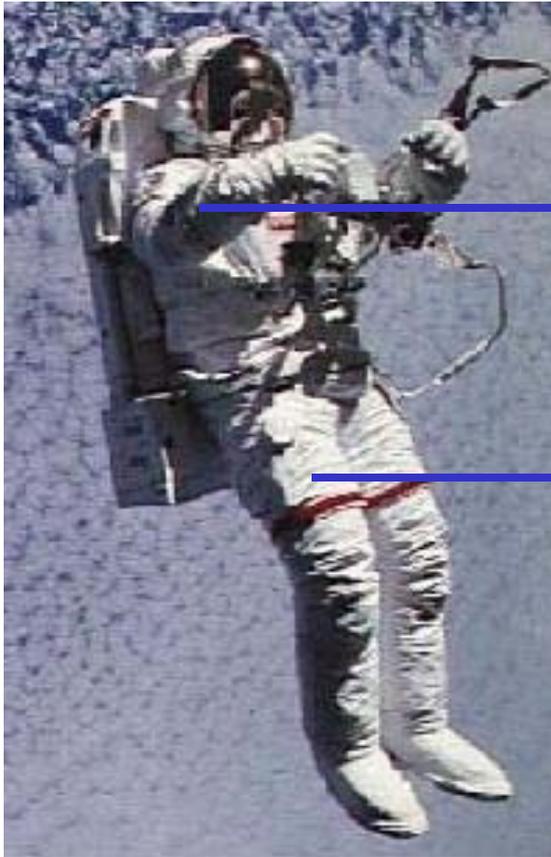


# Particle Energy Range Available for Research

BNL: AGS (current) and BAF (2003)  
(HIMAC in Japan)



# EMU Sample Swatches



# EMU Suit Layers

EMU (US EVA Suit - Layers)		
1	Thermal Micro Meteoroid Garment	Cloth - NOMEX Type
2	Insulation	Reflective - Reinforced Foil Type
3	Insulation	Reflective - Reinforced Foil Type
4	Insulation	Reflective - Reinforced Foil Type
5	Insulation	Reflective - Reinforced Foil Type
6	Insulation	Reflective - Reinforced Foil Type
7	Lining	Thick Latex Type
8	Pressure Garment Restraint	White - NOMEX Type
9	Bladder	Yellow - NOMEX Type
10	Restraint Liquid Cooling Garment	Nylon Stretch Type
11	Lining	Nylon Stretch Type
12	Inner Garment	

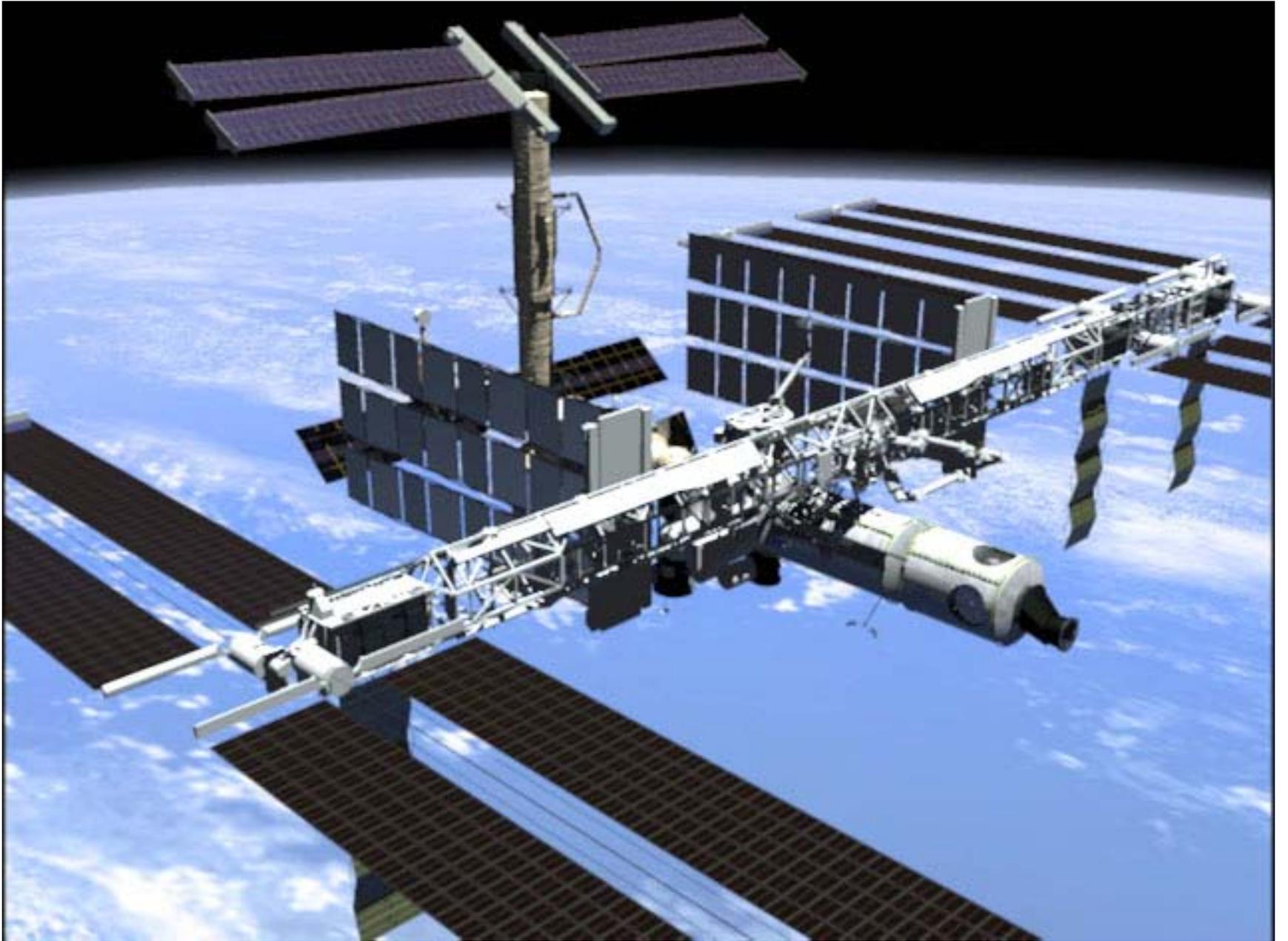
# EMU Suit Layers

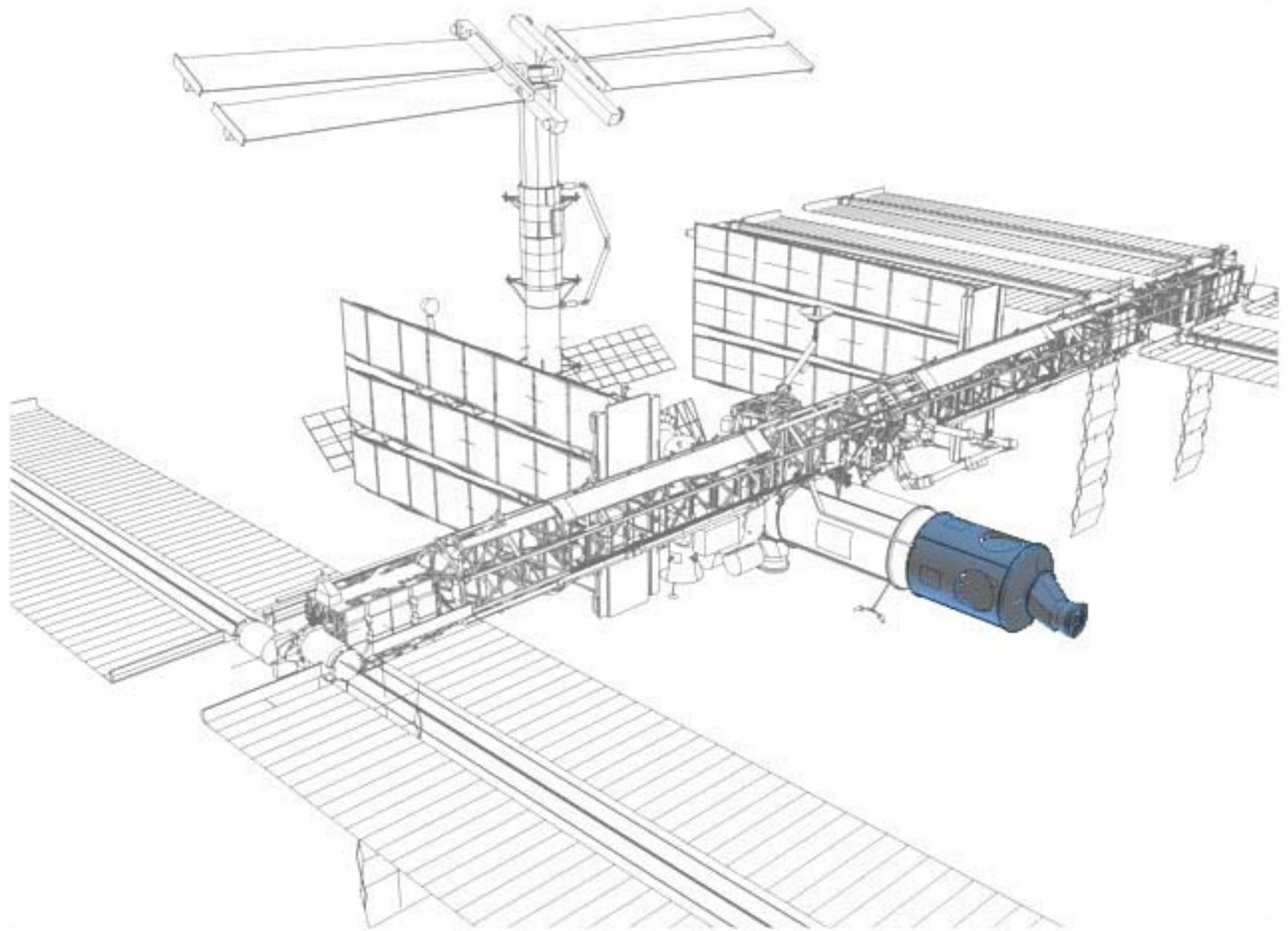
Updated: 12/16/99

EMU (US EVA Suit - Layers)			
1	Thermal Micro Meteoroid Garment	Teflon-impregnated Ortho-fabric with Kevlar grid backing	Cloth Type
2	Insulation	Aluminized Mylar	Reflective
3	Insulation	Aluminized Mylar	Reflective
4	Insulation	Aluminized Mylar	Reflective
5	Insulation	Aluminized Mylar	Reflective
6	Insulation	Aluminized Mylar	Reflective
7	Lining	Neoprene coated nylon ripstop	Thick Cloth Type
8	Pressure Garment Restraint	Dacron	White - Cloth Type
9	Bladder	Urethane coated nylon	Yellow - Thick Cloth Type
10	Liquid Cooling and Ventilation Garment	Nylon Spandex	Porous Stretch Type
11	Lining	Nylon Chiffon	Nylon Stretch Type
12	Thermal Control Undergarment	Capilare	Cotton Cloth Type

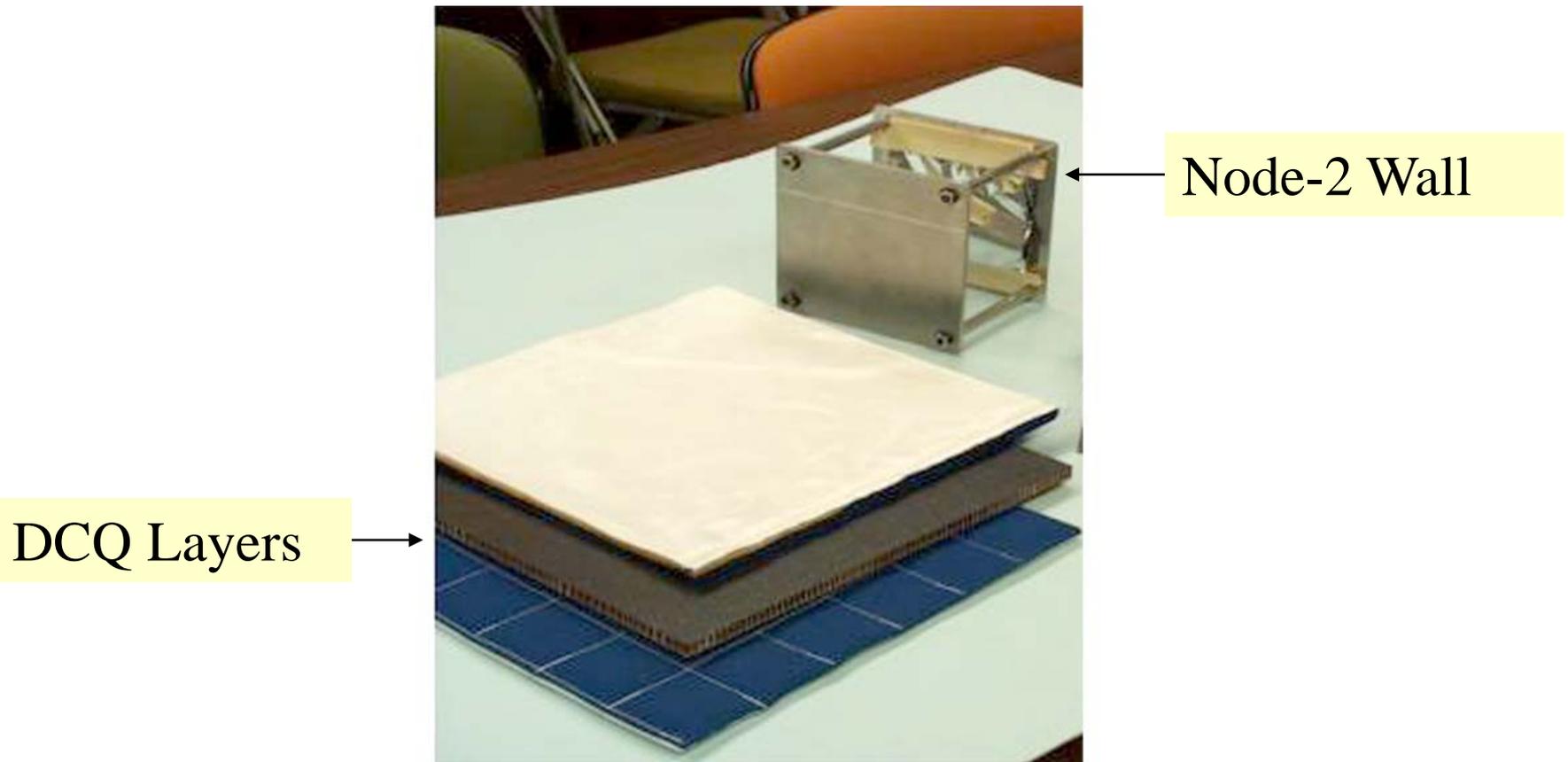
# Orlan-M Suit Layers

Orlan-M (Russian EVA Suit - Layers)			
1	Protective Garment	PHENILON	NOMEX type
2	Radio Fabric	CAPRON + Silver	Mesh Type
3	PETF Film	Polyethylentereftalat	Porous Type
4	PETF Film	Polyethylentereftalat	Reinforced Porous
5	PETF Film	Polyethylentereftalat	Porous Type
6	PETF Film	Polyethylentereftalat	Reinforced Porous
7	PETF Film	Polyethylentereftalat	Thick Layer
8	Radio Fabric	CAPRON + Silver	Mesh Type
9	Lining	CAPRON	Nylon Type
10	Restraint Layer	LAVSAN (Polyphir, DACRON)	Thick Cloth Type
11	Primary Bladder	Natural Latex Type	Rubber Stretch Type
12	Redundant Bladder	Rubber Coating Capron	Metallic Rubber
13	Lining	CAPRON	Nylon Type
14	Liquid Cooling Garment	SPANDEX + CAPRON tricot	Porous Stretch Fabric
15	Inner Garment		





# Node-2 Test Articles



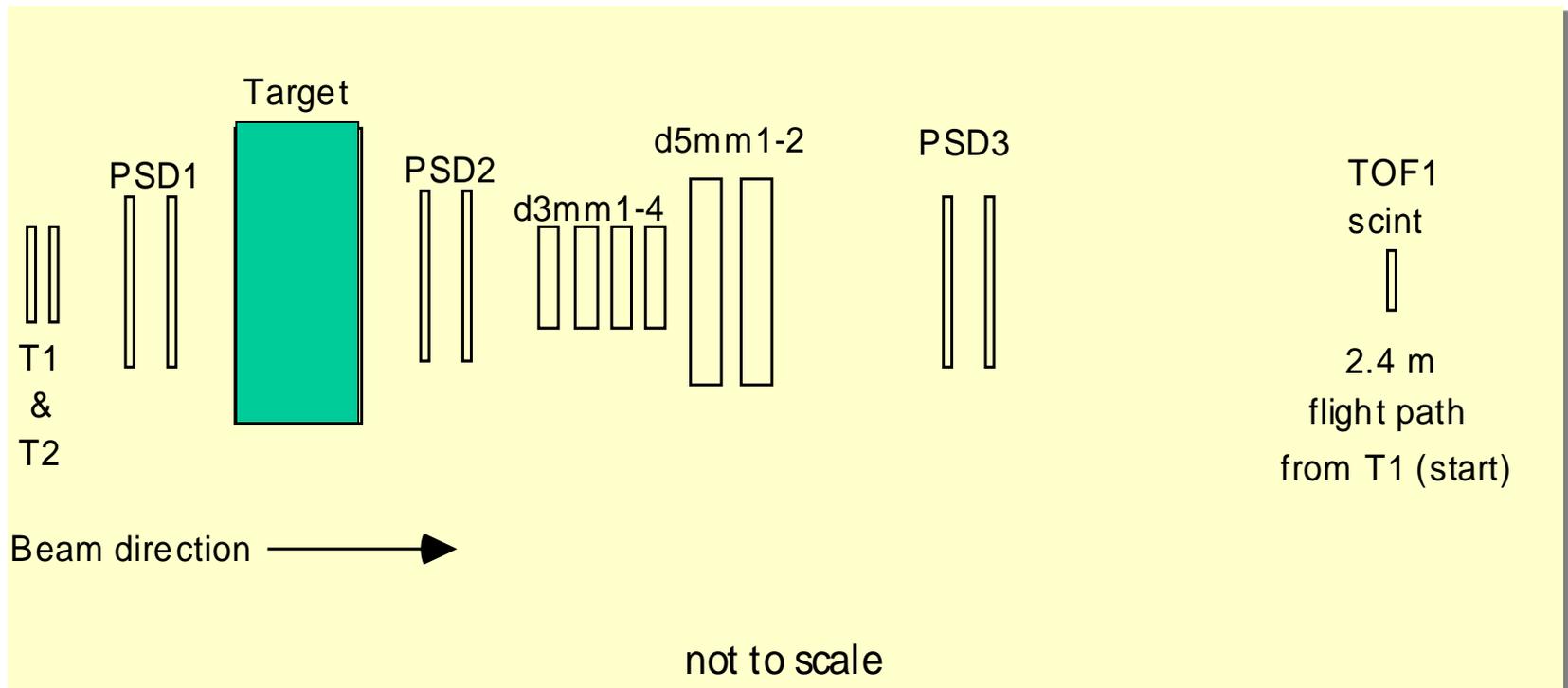
# Node-2 Test Article Layers

Node-2 Wall	
Outer Bumper	Several Layers
Stand-off	Gap
Pressure Vessel	Thick Layer

DCQ Outer Layer		
1	NOMEX	Cloth Type
2	Bisco	Rubber Stretch Type
3	Durrett	Felt Type
4	Bisco	Rubber Stretch Type
5	NOMEX	Cloth Type
Honey Comb Material		
DCQ Inner Layer		
1	NOMEX	Cloth Type
2	Durrett	Felt Type
3	NOMEX	Cloth Type

# Test Targets and Various Detectors Used for Data Collection at BNL Testing

Detectors used to measure fragmentation cross sections and fragment fluences from 1.08 GeV/nucleon  $^{56}\text{Fe}$  incident on a variety of targets. The detectors include plastic scintillation counters (T1, T2, TOF1), position sensitive solid state detectors (PSD1,2,3) and 3 and 5 mm solid state energy loss detectors (d3mm1-4, d5mm1-2).



# Results

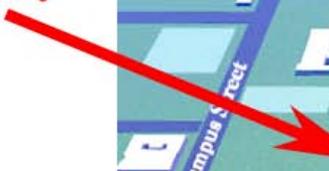
- Irradiation tests were completed (November 11-17, 1999)
  - Fe: 600 MeV/nucleon
  - Fe: 1000 MeV/nucleon
  - Si: 600 MeV/nucleon
- Data analysis is in progress with the PIs
  - Singleterry, Wilson, Thibeault, Bryant (LaRC)
  - Miller, Zeitlin, Heilbronn (LBNL)
  - Cucinotta (JSC)
- Preliminary results for the “1GeV Fe” beam indicate very little of fragmentation in either of the Swatches (~2%) [Zeitlin et al, 1999]

# Tests Planned for LLU (January 2000)



# LOMA LINDA UNIVERSITY & MEDICAL CENTER

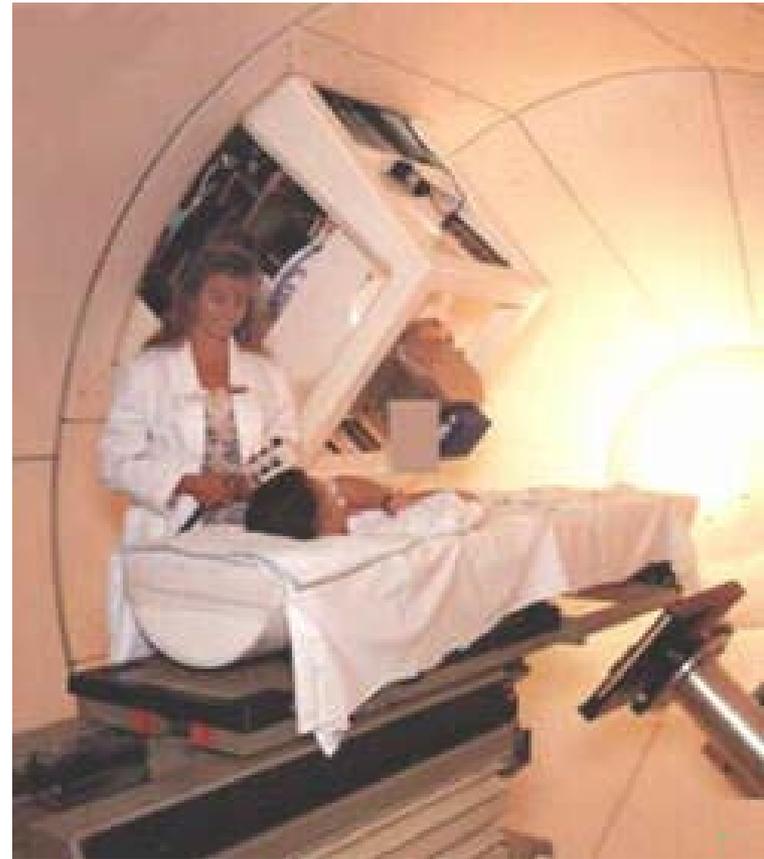
**NASA Supported Research Facility  
At the Loma Linda University  
(Proton Beam)**



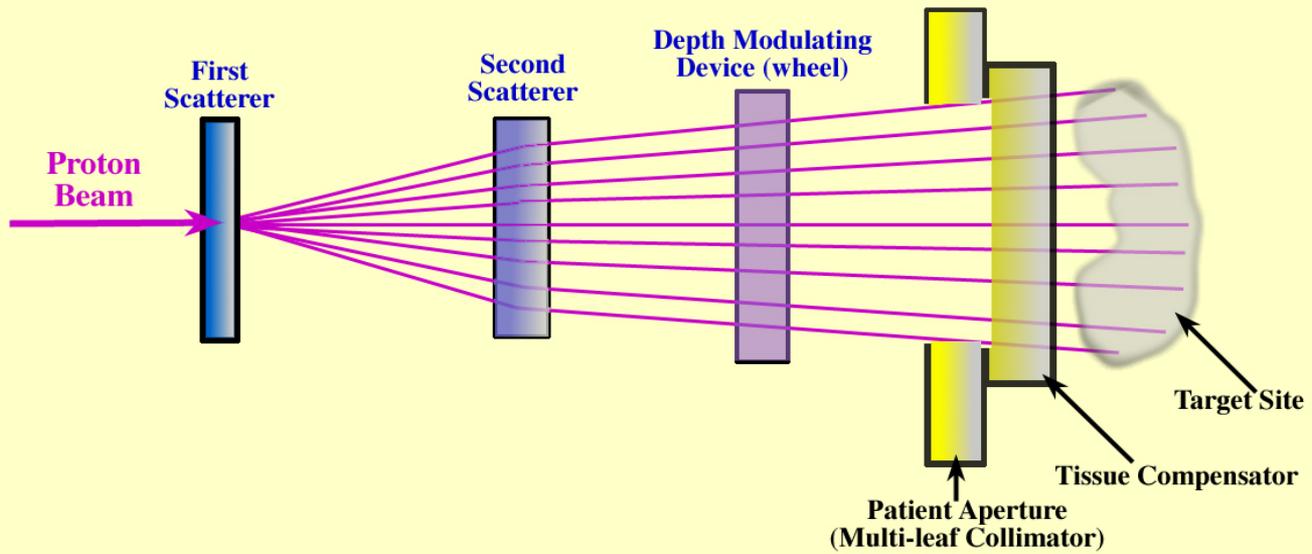
# LLU Proton Therapy Info

## LLU Proton Treatment Facility

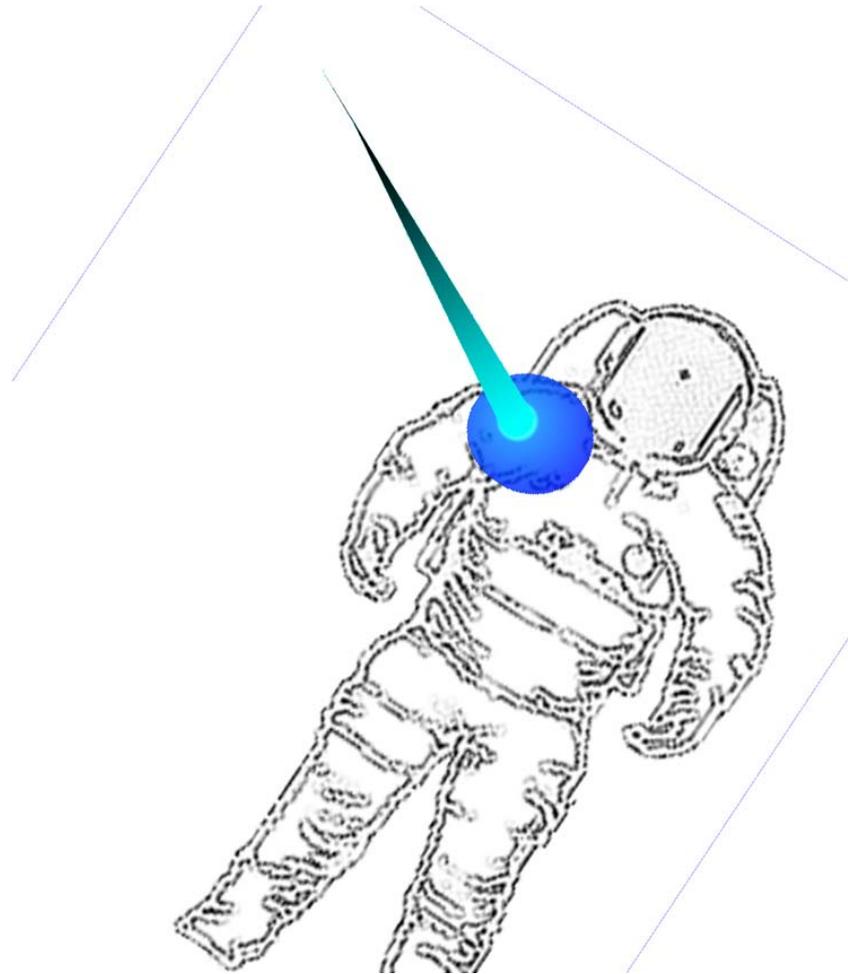
Gantry rotation capability	359 degrees
Proton beam diameter	20 - 52 cm
Proton beam energy	70 - 250 MeV
(mono energetic or modulated with a 300 rpm propeller)	(with a maximum capability of 235 MeV at the target)
Proton dose rate	0.7 Gy/min (~ 20 cm dia)
	0.01 Gy/min (~50 cm dia)



*Spread-out Bragg peak configuration  
for treating the entire depth of the target volume.*



# Proposed Plan for the *Proton Beam* at LLU



# Test Objectives

## 1. **Measurements with proton and electron beams (skin depth):**

- Threshold limits (energy cut-off) of the EMU at various sections of the suit
- Threshold limits (energy cut-off) of the Orlan-M at various sections of the suit

## 2. **Measurements of energy deposition at critical organs (several proton energies):**

With proton beam for the EMU and Orlan-M suits:

- Measurements at BFO (hip, thigh, spine)
- Measurements at Eye
- Measurements at Skin (head, face, neck)

With electron beam for the EMU and Orlan-M suits:

- Measurements at BFO (hip, thigh, spine)
- Measurements at Eye
- Measurements at Skin (head, face, neck)

## 3. **Energy deposition along the trajectory in the torso**

With proton beam at various sites for the EMU

With proton beam at various sites for the Orlan-M

With electron beam at various sites for the EMU

With electron beam at various sites for the Orlan-M

# Current Plans

- PI: Miller et al (LBNL, LLU, and JSC)
- Detectors: TLD, Si, and CR-39
- Other info
  - Both the suits (EMU and Orlan-M) will be imaged with CT scans (with the instrumented torso) prior to irradiation tests for data analysis and reference
  - Nominal proton energies 40-250 MeV
  - Nominal electron energies 1-5 MeV, obtained by range-shifting a 6 MeV beam
  - Doses and dose rates TBD, but particle fluxes must be on the order of  $10^3/\text{cm}^2$  for Si and  $10^4/\text{cm}^2$  for CR-39.

# Future Work

- TransHab Module
  - Testing of the outer layers
  - Testing of the crew quarters
  - Dose estimations at various locations

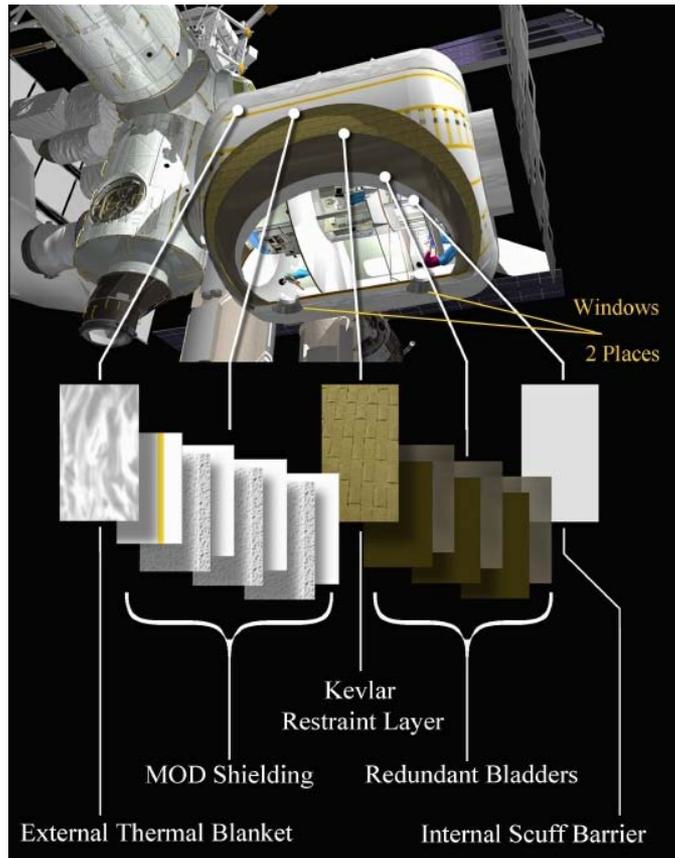


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# TransHab



# Conclusion





# ISS Expeditions

## – Expedition 1

- Flight 2R - Soyuz / Return Flight 6A - STS 100
- Jan 2000 (TBD) through Apr 2000 (TBD) (~ 110 days)

## – Expedition 2

- Flight 6A - STS 100 / Return Flight 7A.1 - STS 102
- After Apr 2000 through TBD (about 120 days)

## – Expedition 3

- Flight 7A.1 - STS 102 / Return Flight 8A - STS 105
- TBD

## – Expedition 4

- Flight 8A - STS 105 / Return Flight 9A - STS 109
- TBD