MEASUREMENTS OF NEUTRON ENVIRONMENT INSIDE AND OUTSIDE the ISS

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Timetable and Conditions of the Space Experiment for Neutron Measurements

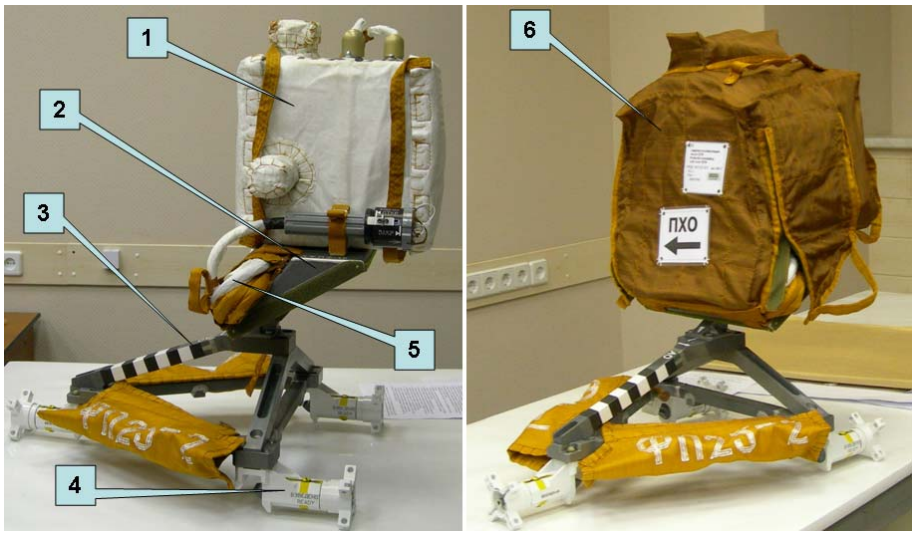
Bubble dosimeter (Matroshka-R Space experiment)	2006 - 2007, inside ISS
BTN-M1 (BTN-Neutron Space experiment)	2007 – 2010, outside ISS
Average radio emission flux, Ja	80
Wolf's number W	32
Planetary geomagnetic activity index, Ap	9
Average geostationary orbit flux, [$cm^{-1}ster^{-1}day^{-1}$]: Protons > 100 MeV Electrons > 2 MeV	 $3.6 * 10^3$ $1.5 * 10^8$
Amplitude of the ring current, Dst	51
Solar activity	Anomalously long solar activity decay period at the end of 23 solar cycle

Science goals of BTN-NEUTRON experiment [on Board Telescope of Neutron]

1. Study of Earth' neutron albedo for different latitude / longitude / altitude of ISS, time, solar activity, Earth' atmosphere conditions and others
2. Build the physical model of neutron background on ISS for different flying configuration, orientations and environment condition
3. Accumulate data for model of neutral particles generation on Sun during Solar Particle Events

BTN-M1: Equipment

Detection unit (in space)



Interface electronics unit (inside)

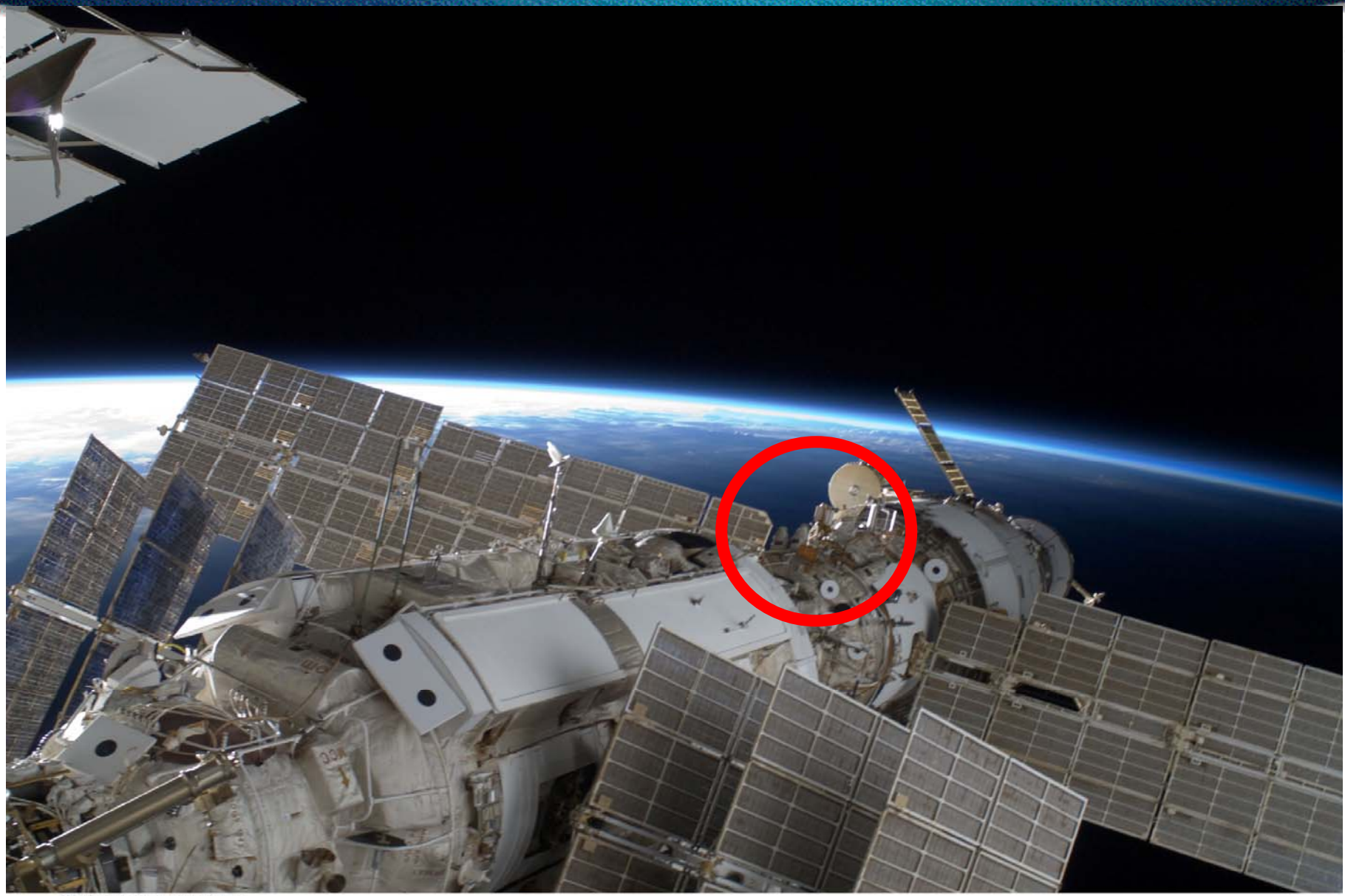
DETECTION UNIT (BTN-MD+BTN-MF)
Location: in space
Sizes BTN-MD: 245 x 280 x 330 mm
Mass: 6,4 kg
Power: 8,7 Wt (28 V)

ELECTRONICS UNIT (BTN-ME)
Location: inside station
Sizes: 255 x 265 x 115 mm
Mass: 3,4 kg
Power: 3,4 Wt (28 V)

BTN-M1: Detectors

Detector	Name	Thickness of moderator [cm]	Energy range	Sensitivity [cm2]
^{3}He	**SD (small)**	**0,2**	**0,4 eV -1 keV**	**0,5**
^{3}He	**MD (middle)**	**1,5**	**0,4 eV – 100 keV**	**1,1**
^{3}He	**LD (large)**	**3**	**0,4 eV – 1 MeV**	**0,1**
Stilbene	**SC**	**-**	**0,3 MeV - 10 MeV**	**2**

BTN-M1: Allocation on ISS



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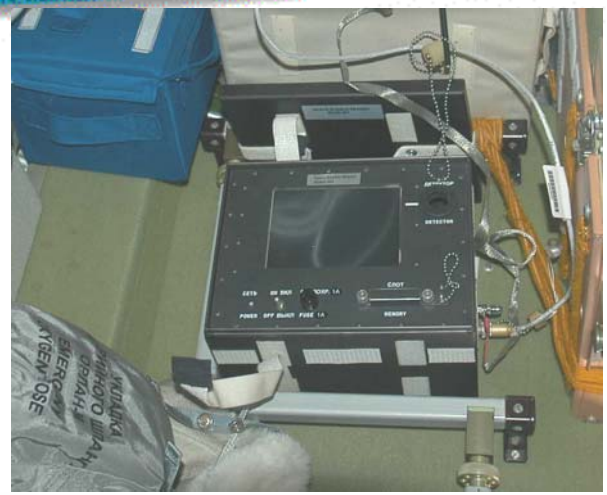
Science Goals of Space Experiment with Bubble Dosimeter on ISS

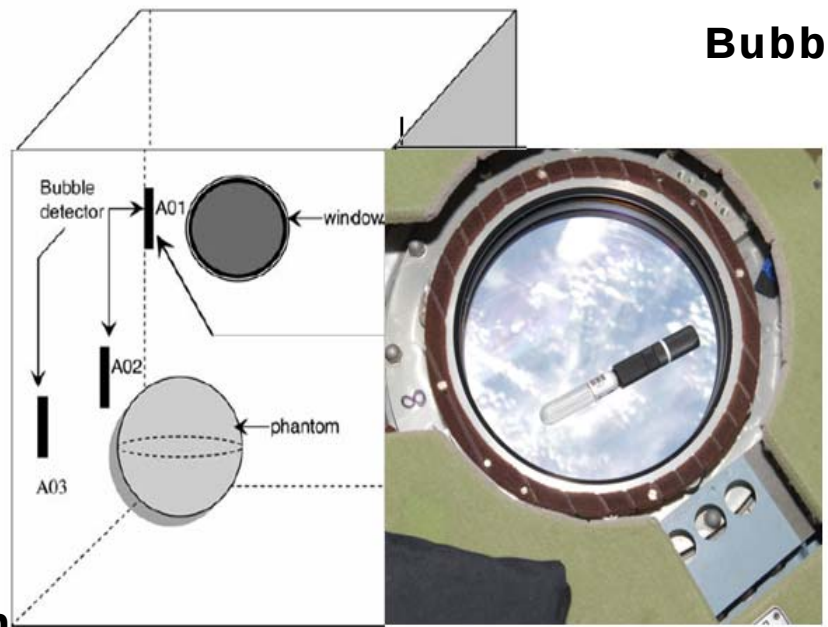
- **Neutron dose measurements in ISS compartments**
- **Neutron dose measurements inside and on the outer surface of Matroshka-R spherical phantom**

Bubble Dosimeter Experiment Equipment

Spherical phantom



Bubble reader



Bubble
detectors in
the crew cabin

Bubble equipment characteristics

The spherical phantom:

- **Diameter is 35 cm,**
- **Mass is 32 kg**

Bubble detector:

- **Diameter is 1.6 cm,**
- **Mass is 0.03 kg,**
- **Sensitivity is from 140 to 200 bubbles / mSv**
- **Energy range is from 200 keV to 10 MeV**

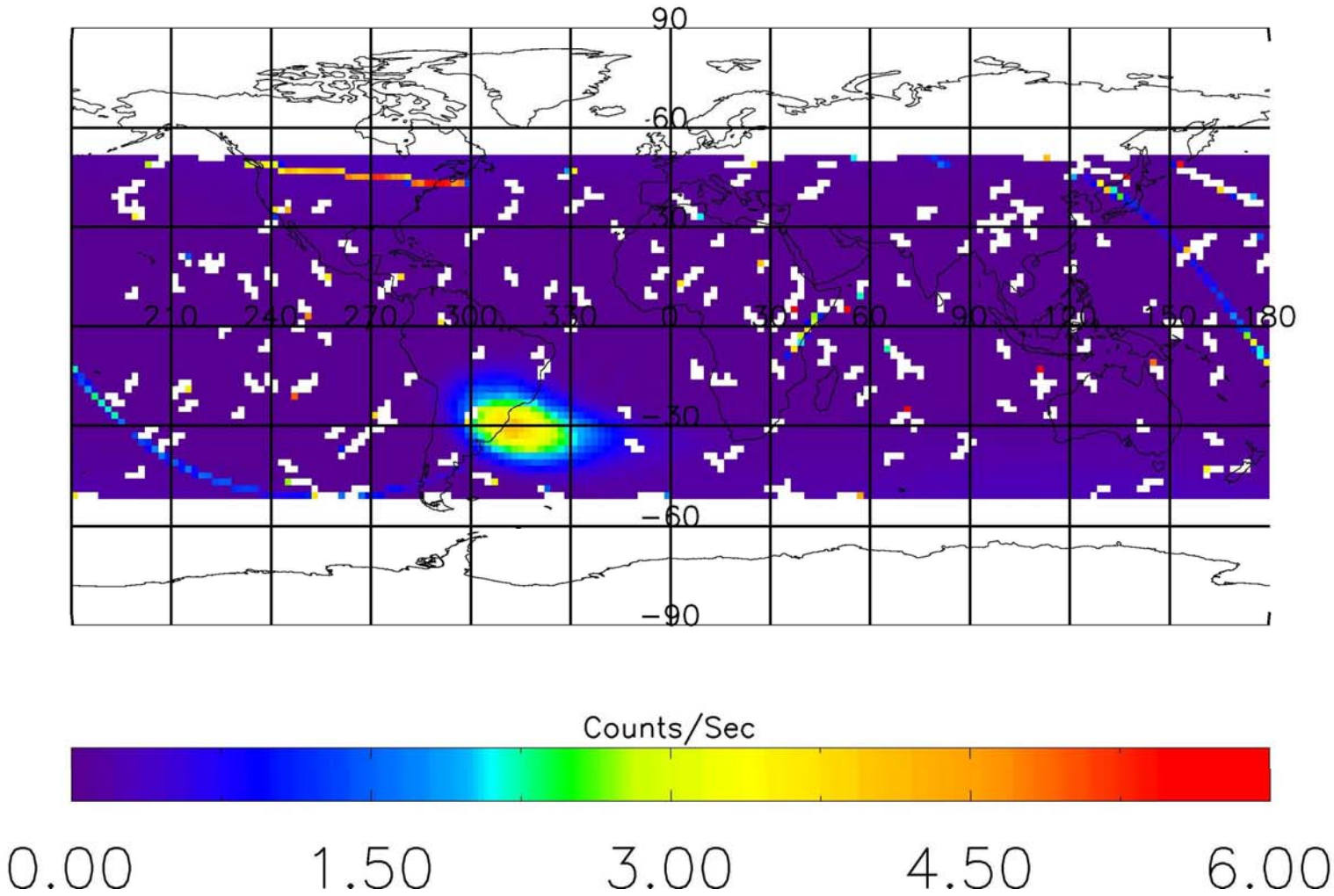
The Bubble reader

- **Size is 300*200*180 mm**
- **Mass is 4.5 kg**

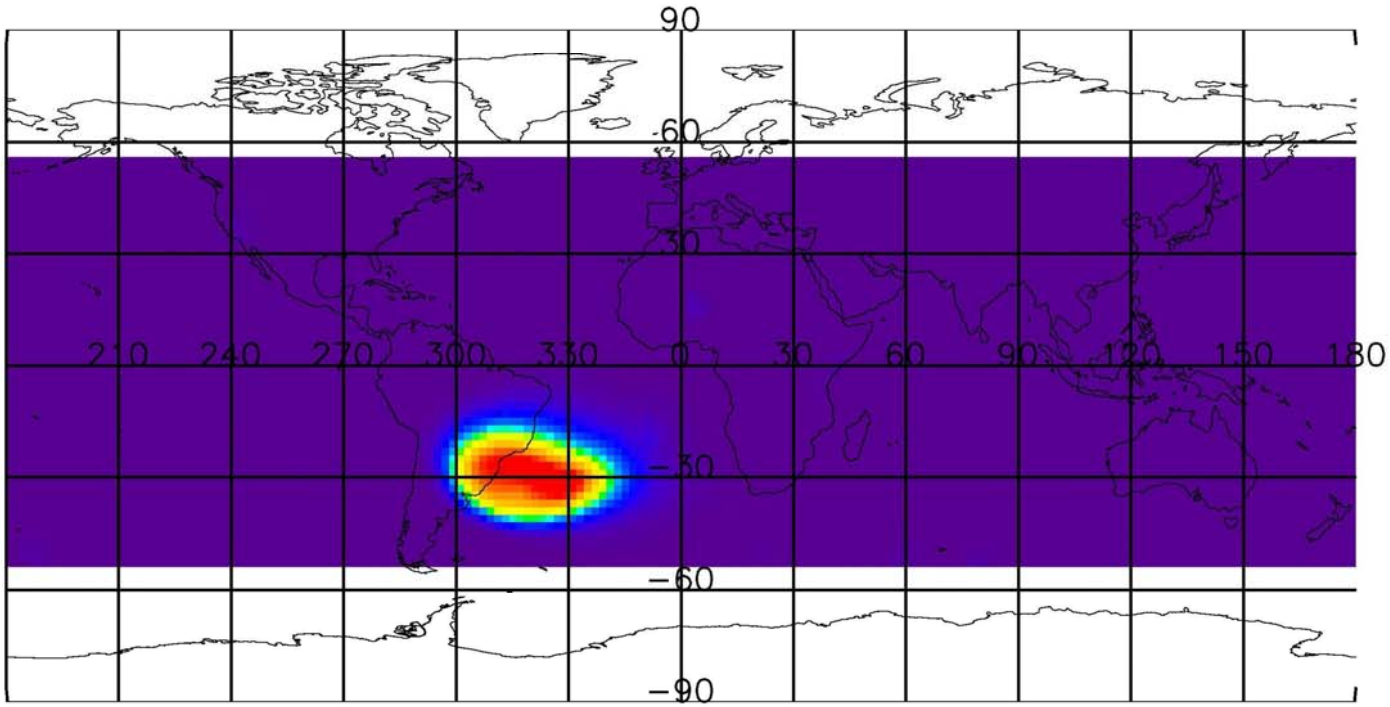
Data downloading by crew via voice channel and with memory card

Data and Measurements with BTN-M1

BTN-1: Neutron Medium ^{3}He Detector (0.4 eV – 100 keV)



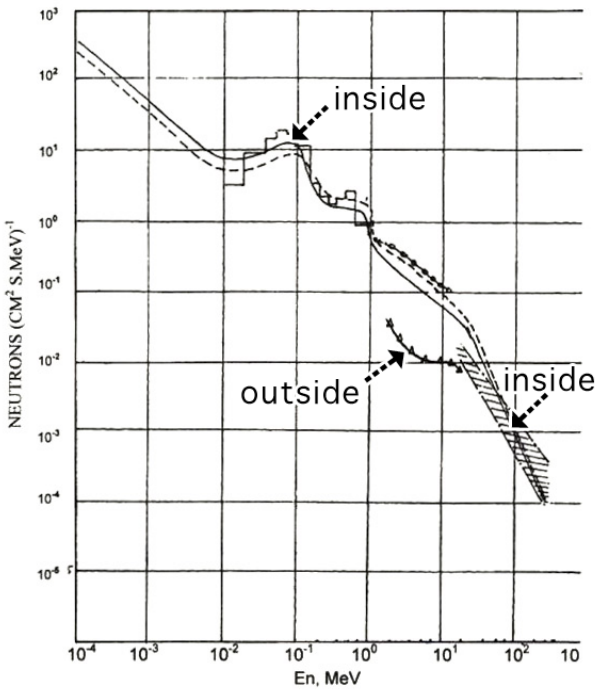
BTN-1: Stilbene Detector: Neutrons (300 keV - 10 MeV)



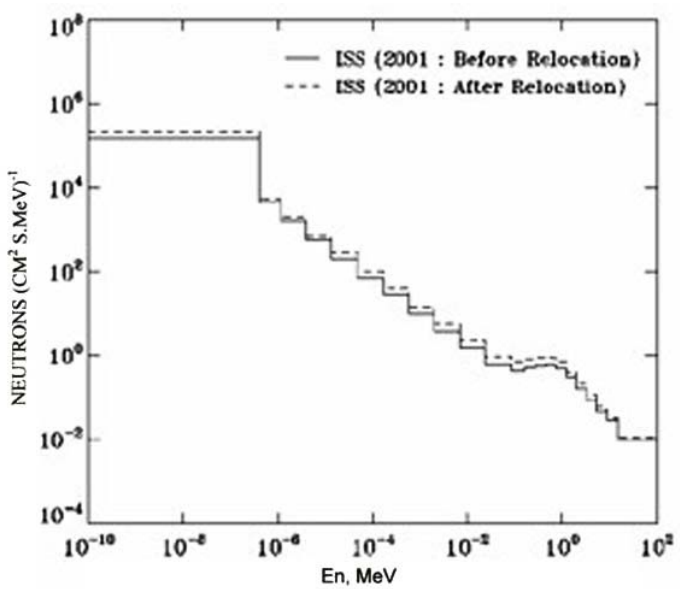
Counts/Sec

0.28 157.66 315.05 472.43 629.81

Measured neutron spectra on Mir station and ISS

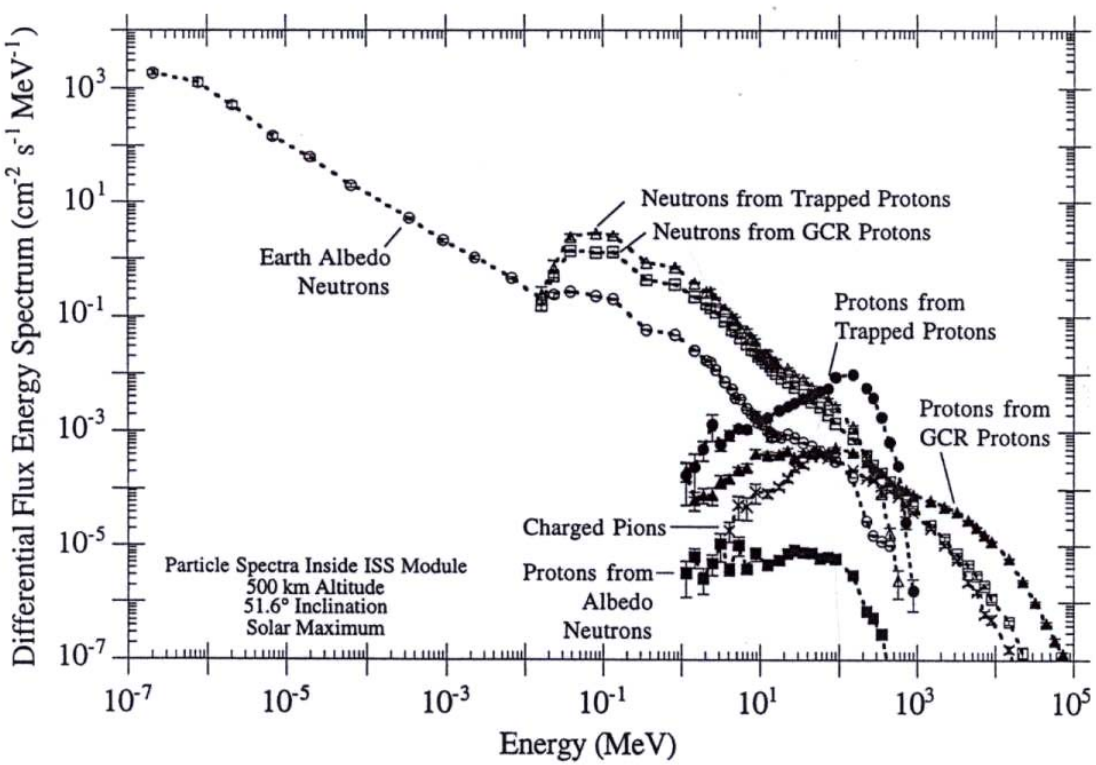


Neutron spectra inside and outside Mir station measured with different instruments.
V. I. Lyagushin, V.E. Dudkun et al.,Radiat. Meas., 33 (2001), 313-319



Evaluation of neutron radiation environment inside the ISS based on Bonner Ball Neutron Detector Experiment. H. Koshiishi et al., Proc. 9th Workshop on Radiation Monitoring for ISS, 2001

Predicted spectra on ISS



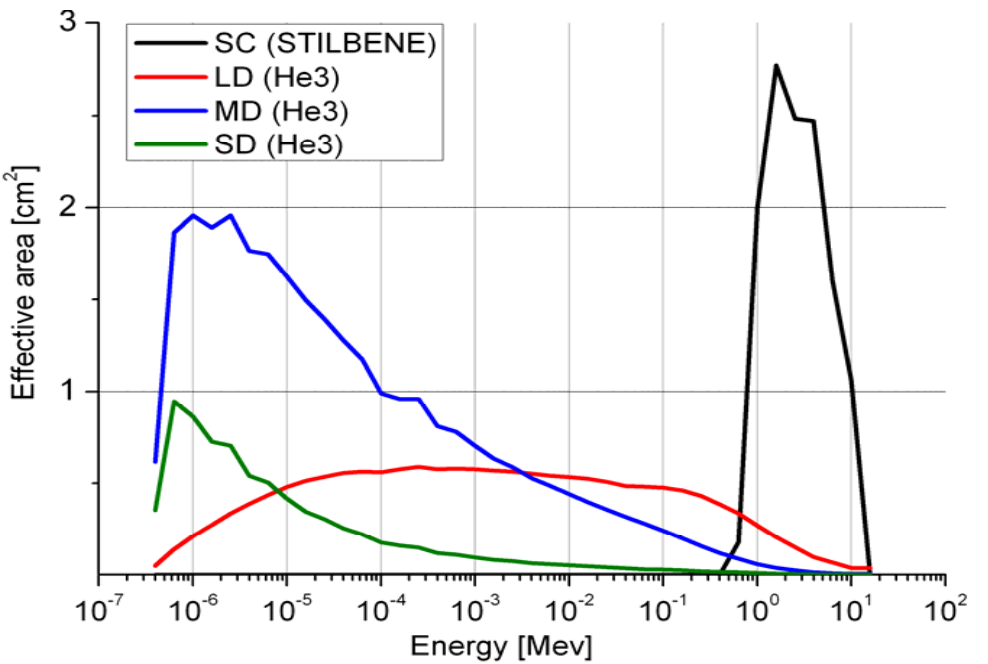
Predicted different particle spectra inside ISS. T. W. Armstrong and B.L. Colborn. Radiat. Meas., 33 (2001), 229-234

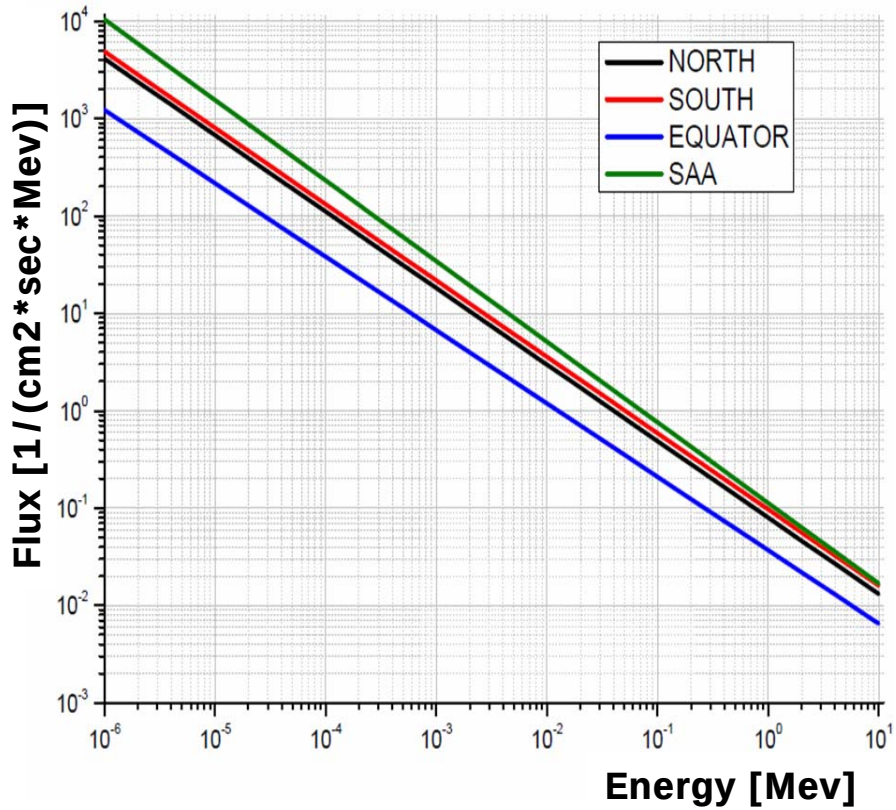
BTN-1 neutron spectra on ISS

$$dN/dE = A \times (E / E_0)^{-B}$$

$$C_{model} = \int dN/dE \times F(E)\, dE$$

$$\chi^2 = \frac{\sum (C_i - C_{i\,model})^2}{Err(C_i)^2}$$





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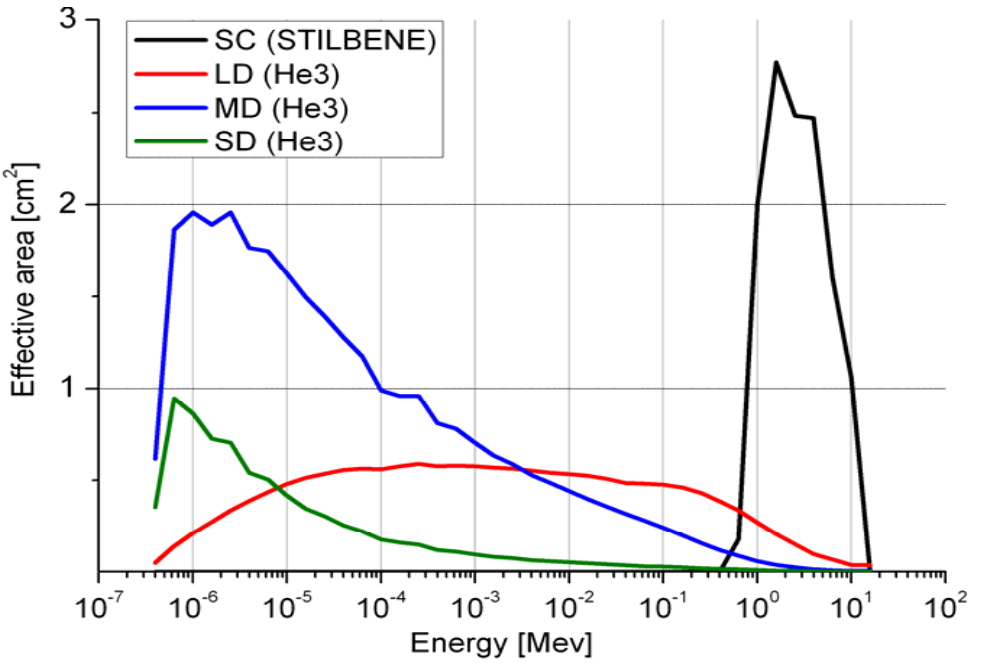

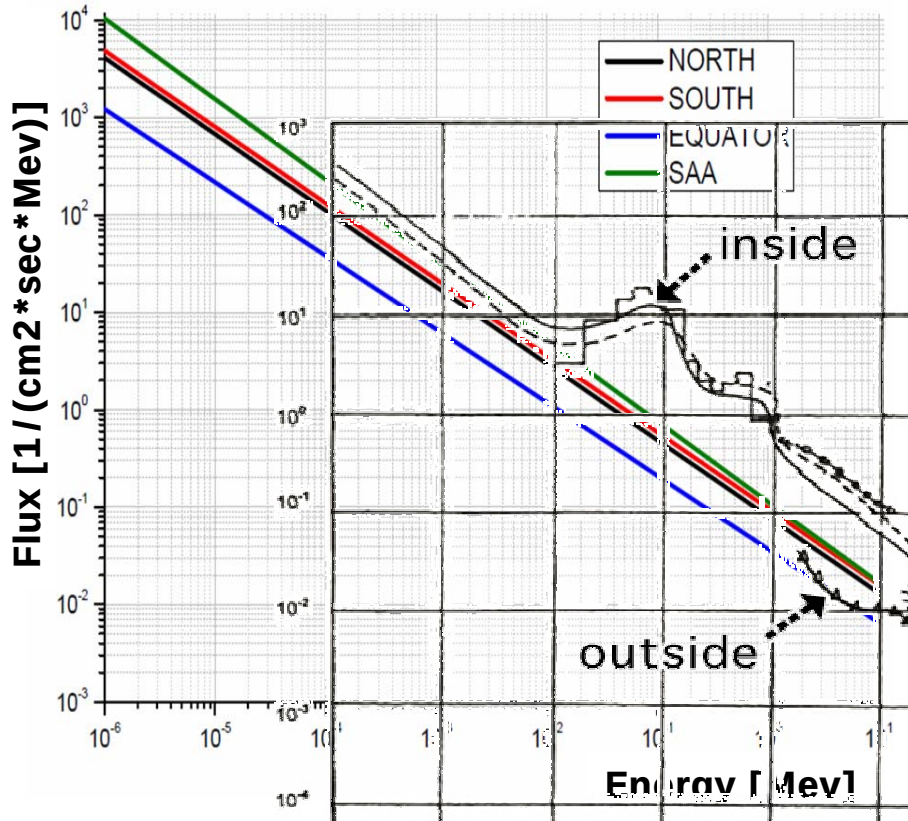

Neutron Doses Measured with BTN-M1 on the Outer Surface of ISS

Orbit Region	Neutron Dose Rate, mSv/day
Equatorial	**0.005**
High latitude	**0.05**
South-Atlantic Anomaly	**0.125**

Data and Measurements with Bubble Detectors

Exposure locations of Bubble-dosimeters	Ambient dose rate, mSv/day	Period of experiments
1. Module "Zvezda"		
1.1 Crew cabins		
Surface of the spherical phantom to the center of Service Module (max shielding thickness)	0.11 ± 0.03	ISS -13,14,15
Surface of the spherical phantom to the wall side (min shielding thickness)	0.08 ± 0.02	ISS -13,14
1.2 Working compartments		
On the floor near the central axis of the module (max thickness)	0.13 ± 0.03	ISS -14, 15
On the module panels in the big diameter compartment (min thickness)	0.09 ± 0.02	ISS -14,15
2. Module "Piers"		
On surface of the spherical phantom	0.12 ± 0.03	ISS -15
Inside the spherical phantom at the depth of 10-15 cm	0.09 ± 0.02	ISS -15

Conclusions

1. Neutron dose rate on the outer ISS surface in the energy range from 0.4 eV to 10 MeV is:
   - 0.005 mSv/day in Equator area,
   - 0.05 mSv/day in high latitude region,
   - 0.125 mSv/day inside SAA.
2. Neutron dose rate inside ISS in the energy range from 0.2 to 10 MeV is:
   - Inside worker compartment from 0.08 to 0.13 mSv/day as dependent on shielding and increasing with thickness,
   - On the surface of spherical phantom is practically the same to dose inside worker compartments,
   - Inside the spherical phantom at the depth of 10-15 cm the dose rate is 1.2-1.3 times lower than on the surface.
3. The neutron field profile inside and outside ISS is of difficult character and it should be studied in future.