Space experiment "BTN-Neutron" on Russian segment of International Space Station

V.Tretyakov [1]; F. Fedosov [1]; Kozyrev [1]; M. Litvak [1]; V. Lyagushin [2]; A. Malakhov [1]; I.Mitrofanov [1]; M.Mokrousov [1]; A.Sanin [1]; A.Vostrukhin [1]

1) Space Research Institute RAS, Moscow, Russia
2) Rocket and Space Corporation «Energy», Korolev, Russia
3) and other cooperation, Russia

16th WRMISS
"Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University
Brehova 7, 110 00, Prague1"
6-8th September 2011

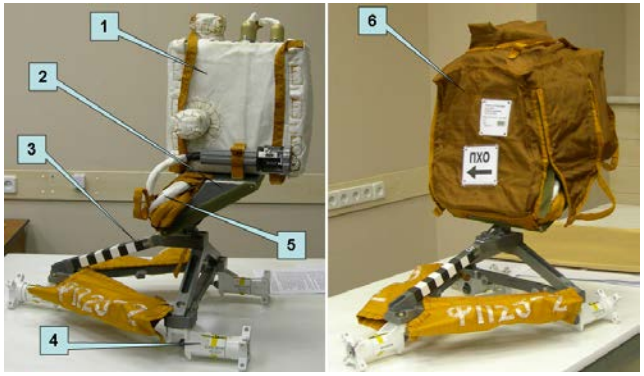
Content

1. Goals, equipment, data
2. Neutron spectra and doze rate
3. Gamma radiation
4. Solar cycle and neutron flux trends
5. Next experiment on ISS

Science goals

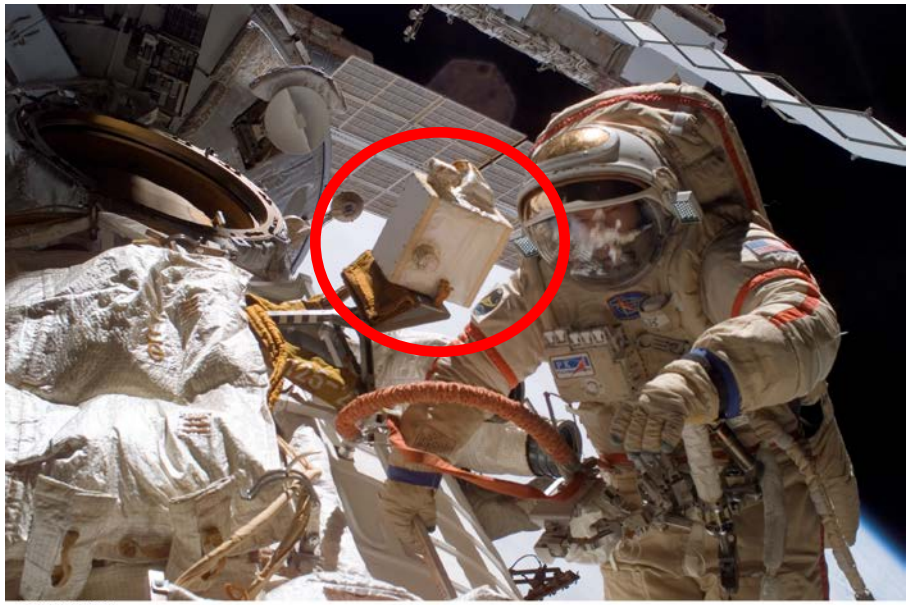
1. Measurements of neutron environment for to obtain the neutron spectra and neutron dose rates outside of Russian Service Module of ISS (Zvezda) for different latitude/longitude/altitude of station, time, solar activity and others parameters. IN PROGRESS
2. (additional 1) Study of radiation hardness the new perspective scintillation crystals for future space science applications. DONE
3. (additional 2) Detecting of Gamma Ray Bursts "simultaneously" with HEND/Mars Odyssey and other spacecrafts. IN PROGRESS
4. (additional 3) Study of GCR trend during solar cycle. IN PROGRESS

Equipment and allocation



Detectors unit
(in space)

Electronics unit
(inside)



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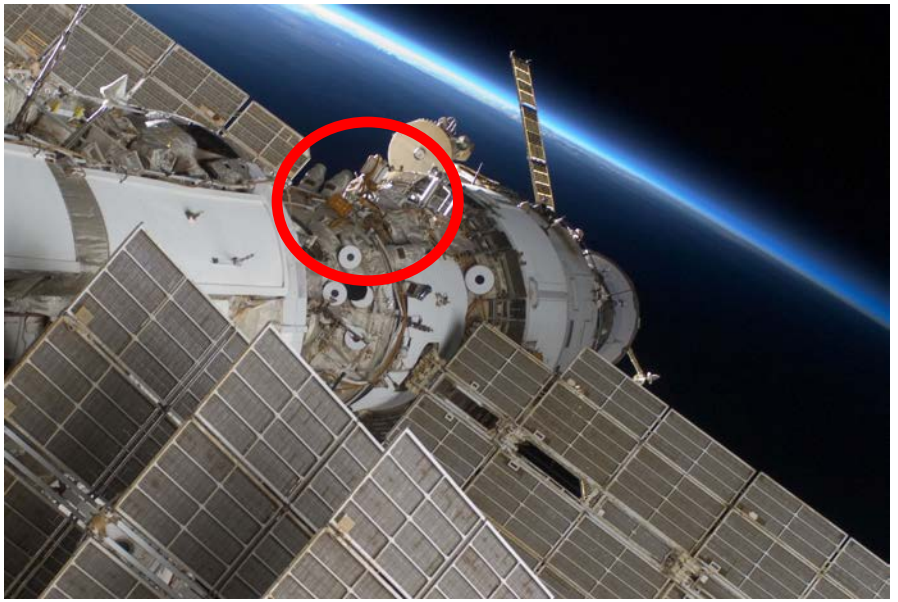


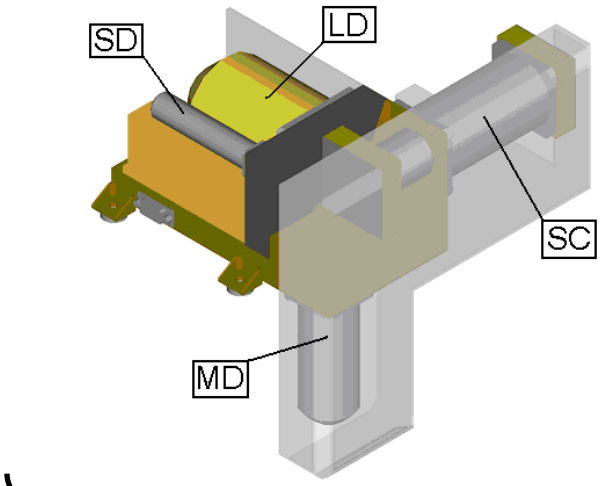
Neutron & Gamma detection technique

NEUTRONS:

measurements of fluxes of neutrons in wide energy range: from epithermal (~0.4 eV) up to fast (~ 10 MeV) neutrons by means of ^{3}He counters with Cd shields + polyethylene moderators and stylbene scintillation detector;

GAMMA:

measurements of gamma and X-ray in energy range 30 keV-10 MeV by means stylbene scintillation detector and CsI:Tl^{+3} scintillation detector.

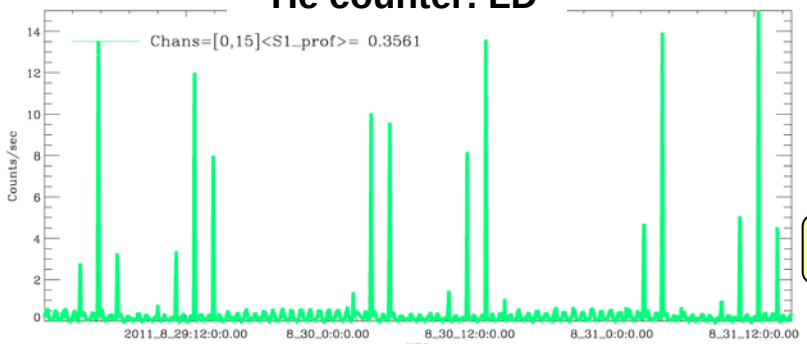


5 detectors = 6 signals:

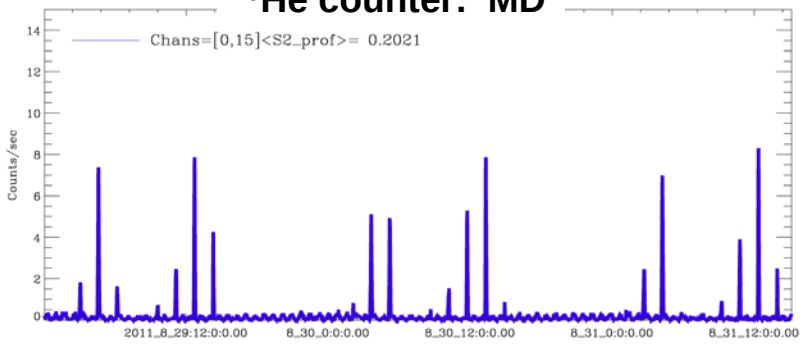
- 4 "neutron signals"
  - ^{3}He counters – (SD, MD, LD)
  - stylbene (SC/IN/N)
- 2 "gamma signals"
  - stylbene (SC/IN/G)
  - CsI:Tl^{3+} (SC/OUT/G)

Neutron & Gamma profiles

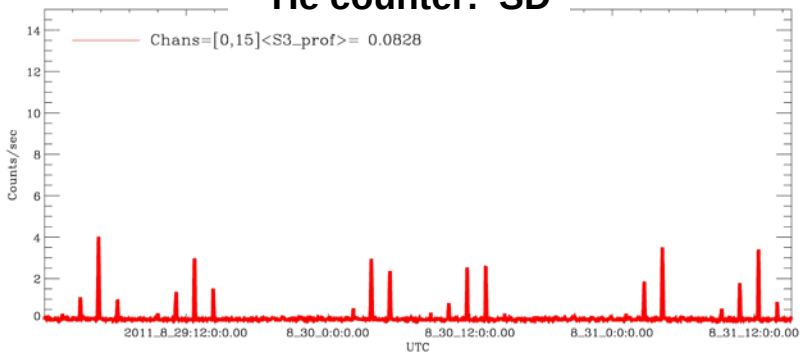
^{3}He counter: LD



^{3}He counter: MD



^{3}He counter: SD

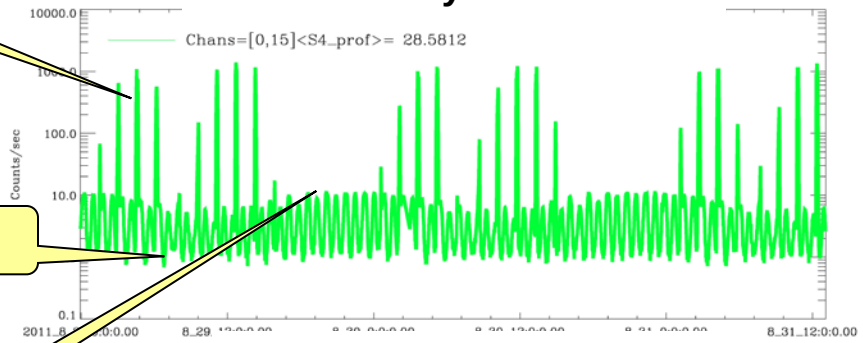


SAA

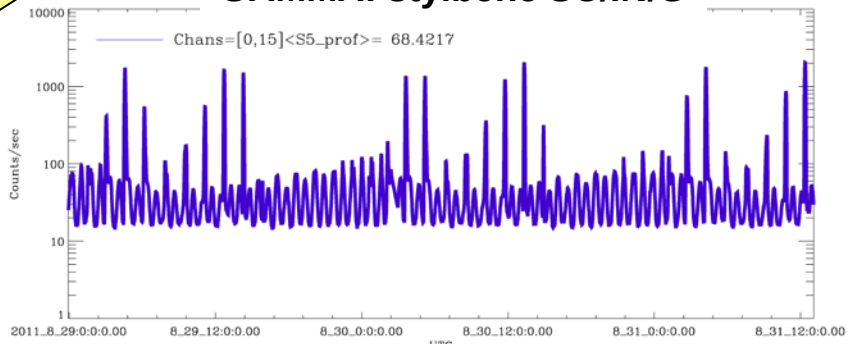
Equator

Polar area

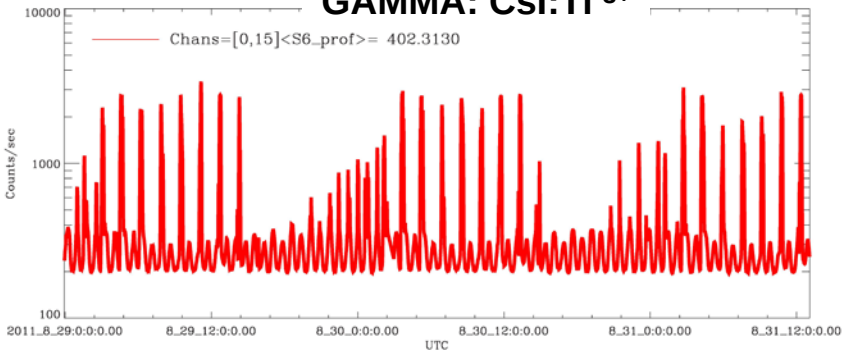
NEUTRON: stylbene SC/IN/N



GAMMA: stylbene SC/IN/G

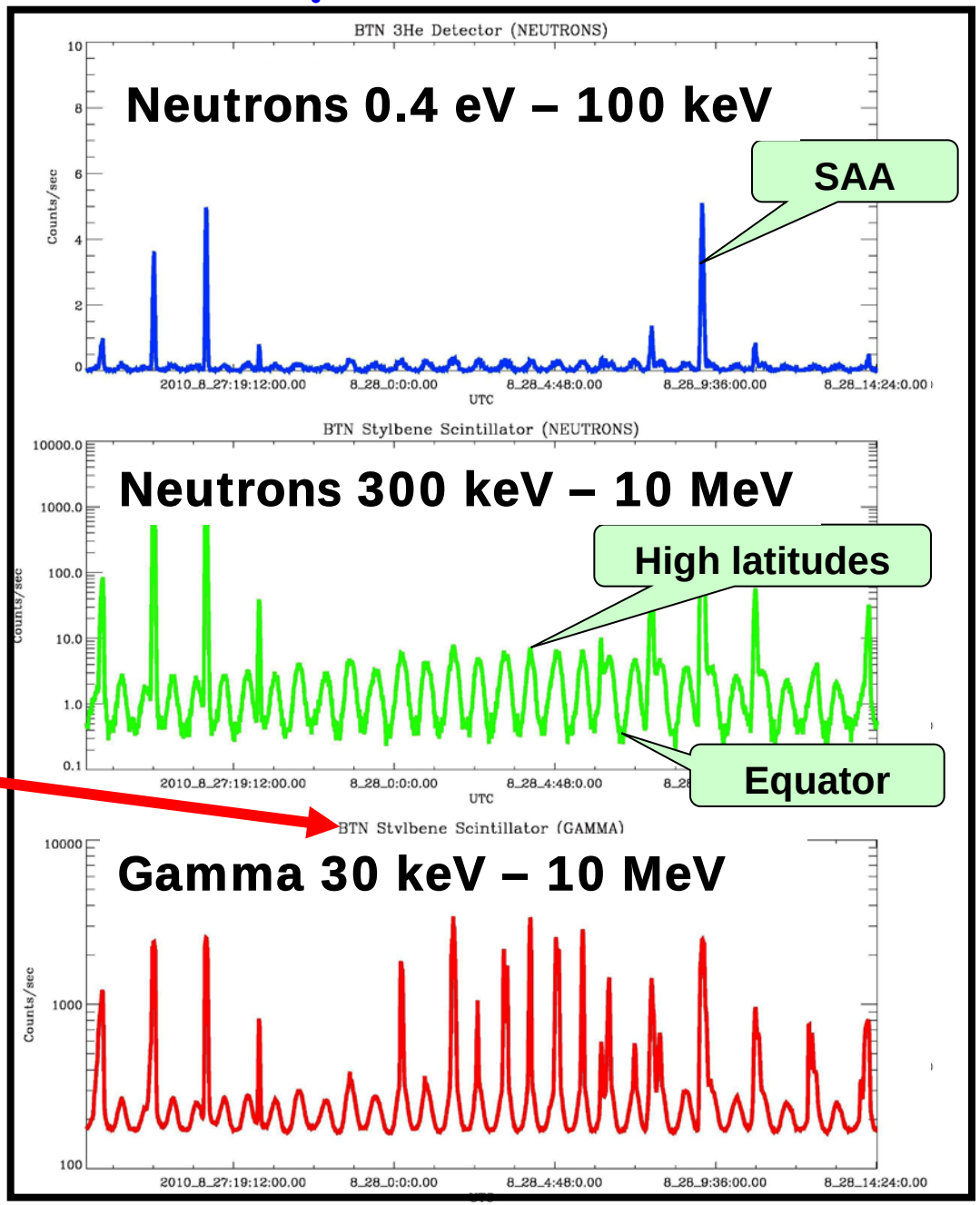


GAMMA: CsI:Tl $^{3+}$



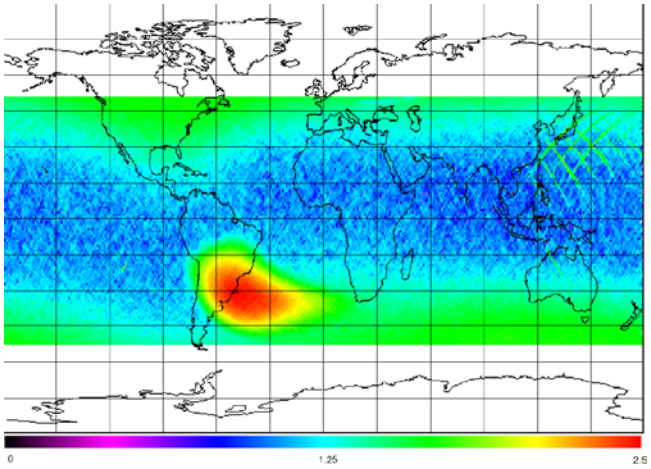
Neutron & Gamma profiles

2011 15WRMISS

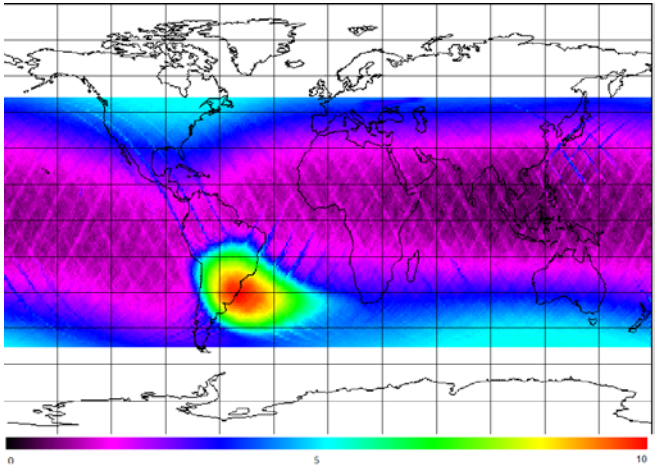


NOT stylbene but CsI:Tl^{+3} !

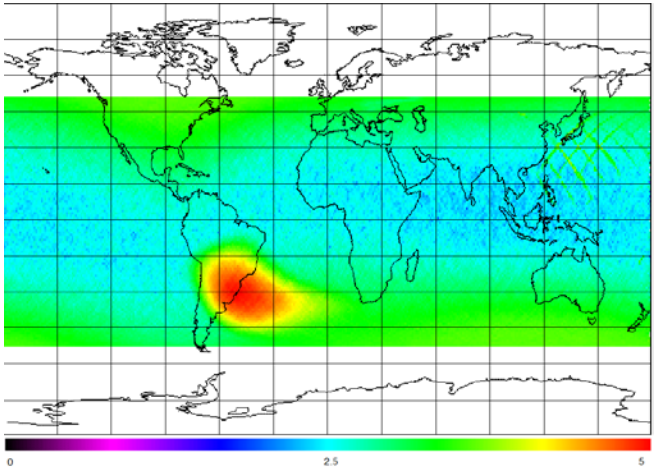
Neutron maps (counts/sec)



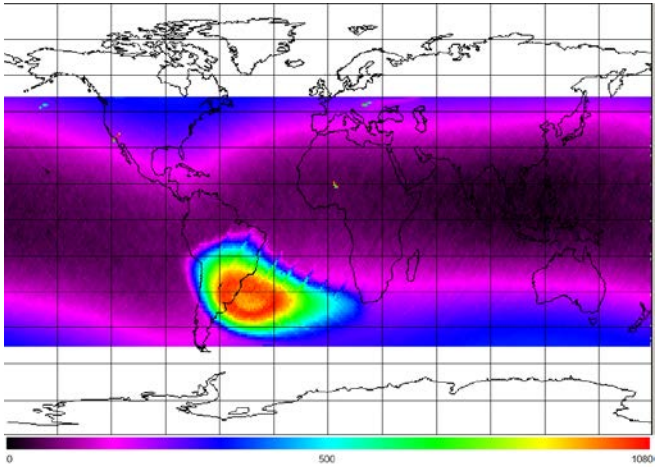
Neutron map for ^{3}He Detector SD
(0,4 eV – 1 keV)



Neutron map for ^{3}He counter LD
(0,4 eV – 1 MeV)

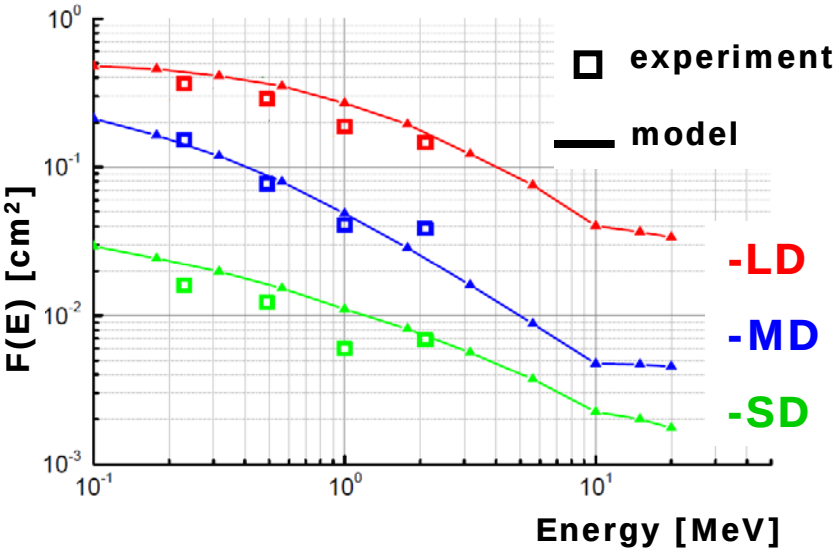


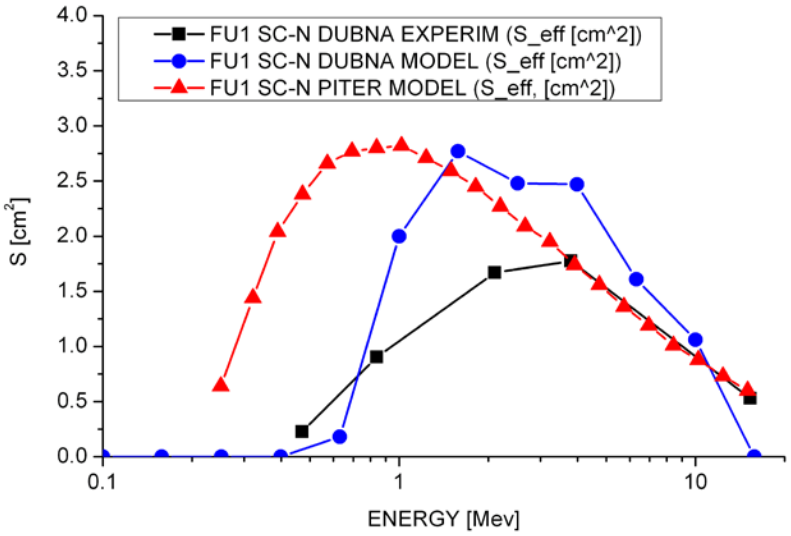
Neutron map for ^{3}He counter MD
(0,4 eV – 100 keV)

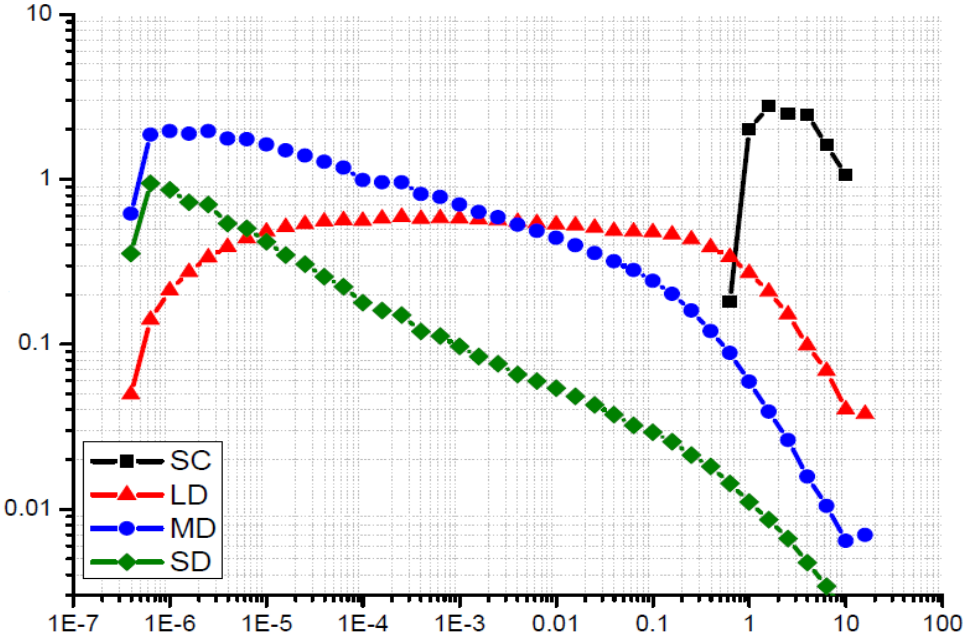


Neutron map for Stylbene Detector
(300 keV – 10 MeV)

Calibration on neutron sources







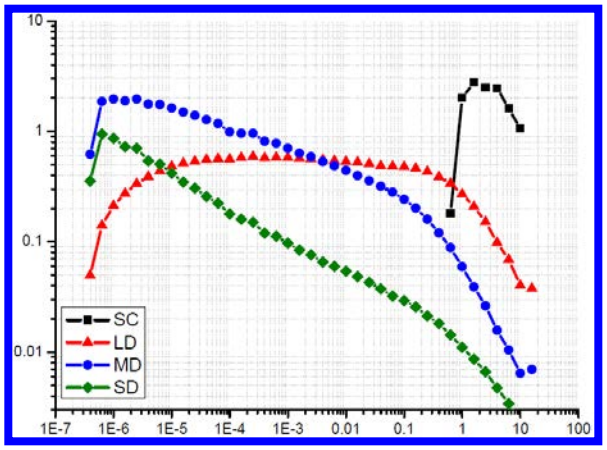
JNRI (Dubna) : Experiment + Model

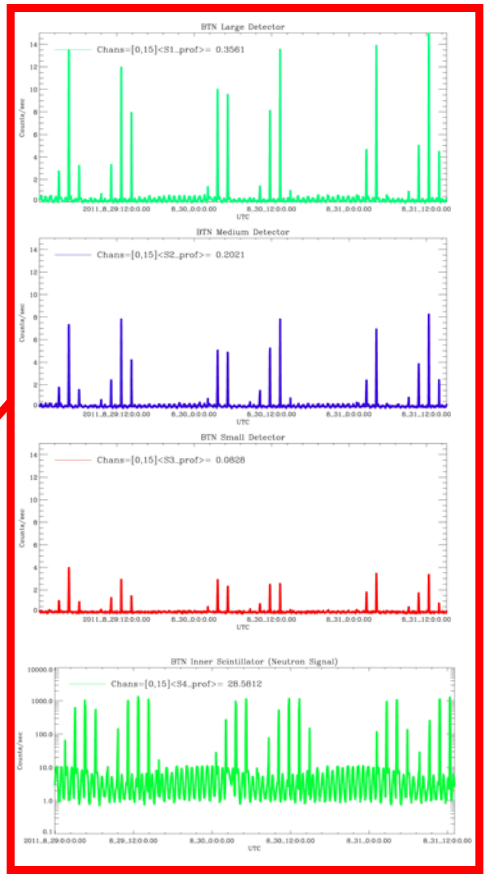
VNIIEF (Sarov): Experiment

Kurchatov INE (Moscow): Experiment

Khlopin RI (S-Petersburg) – Model

Spectra deconvolution



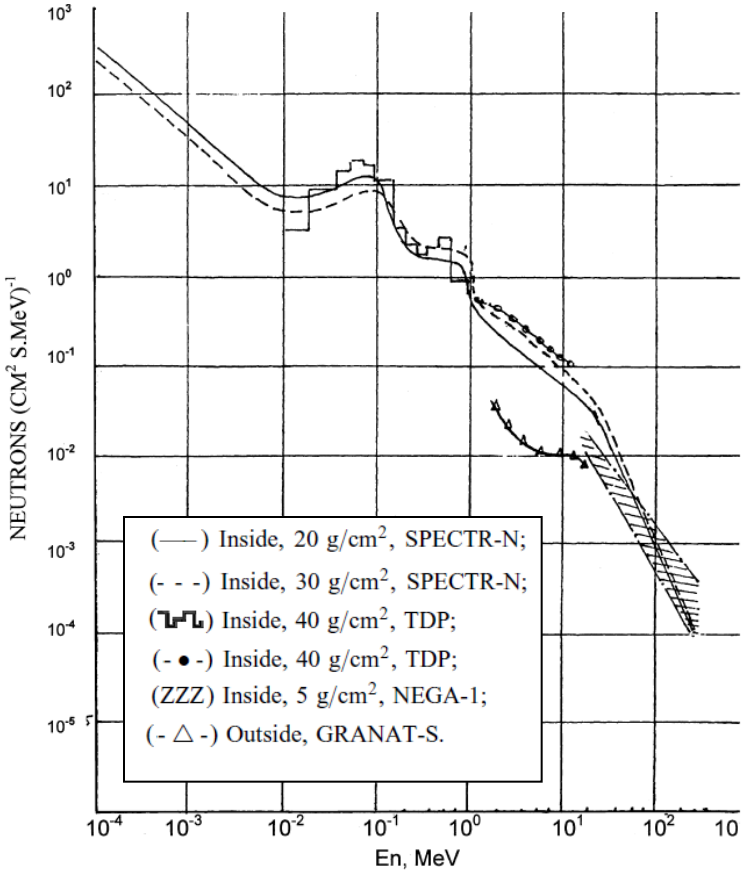


$$C_{model} = \int dN/dE \times F(E)\, dE$$

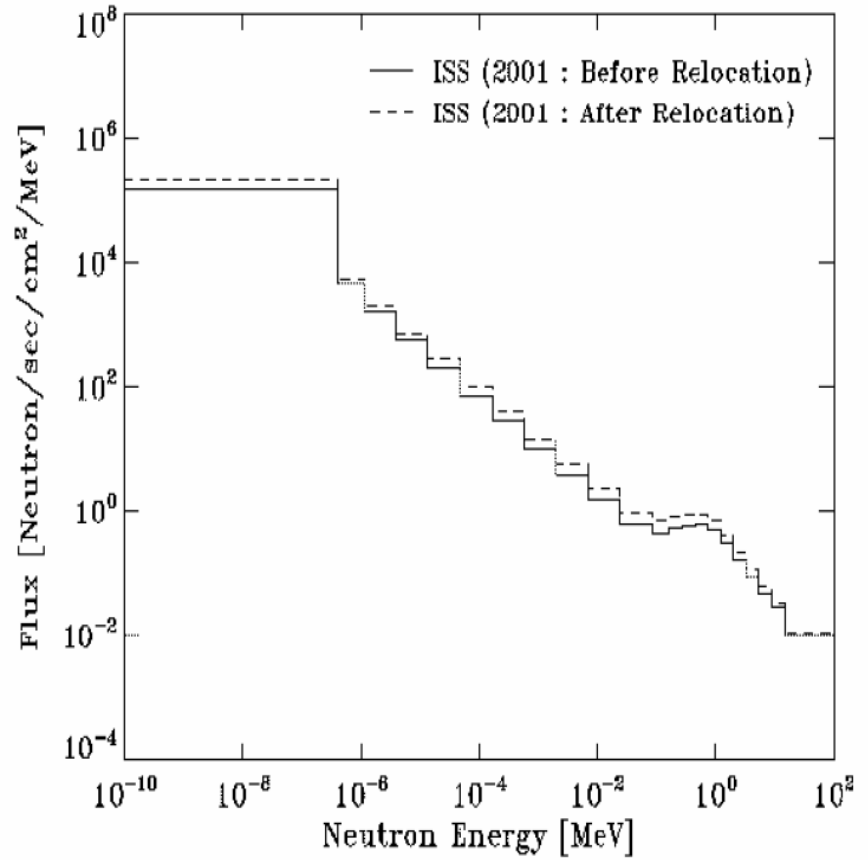
$$\chi^2 = \frac{\sum (C_i - C_{i\,model})^2}{Err(C_i)^2}$$

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

Neutron spectra

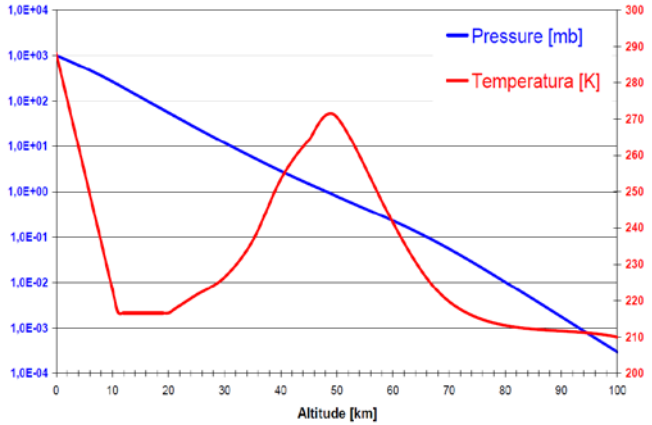


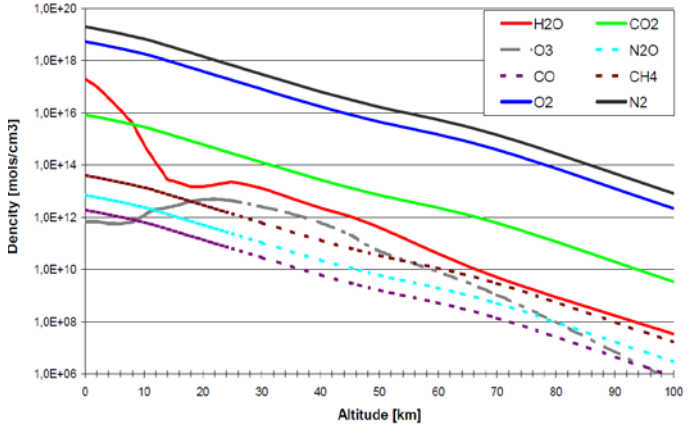
Neutron spectra inside and outside Mir station measured with different instruments, V. I. Lyagushin, V.E. Dudkun et al., Radiation Measurements, 33 (2001), 313-319

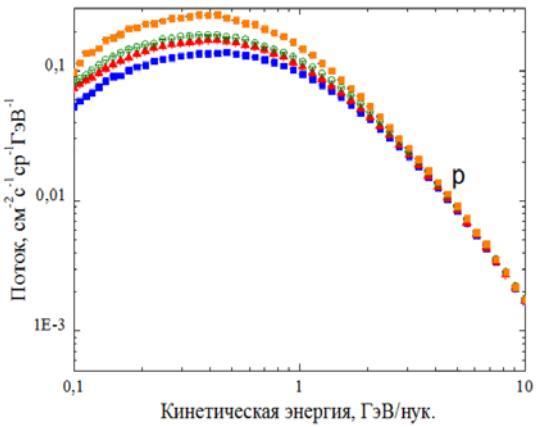


Evaluation of neutron radiation environment inside the ISS based on Bonner Ball Neutron Detector Experiment (H. Koshiishi, H. Matsumoto, et al., Proc. 9th WRMISS, 2001)

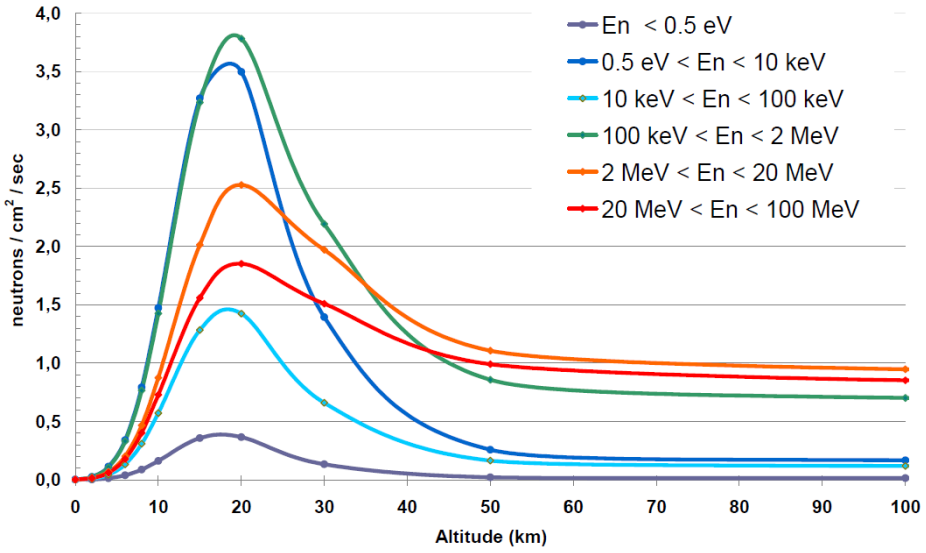
Neutron albedo formation



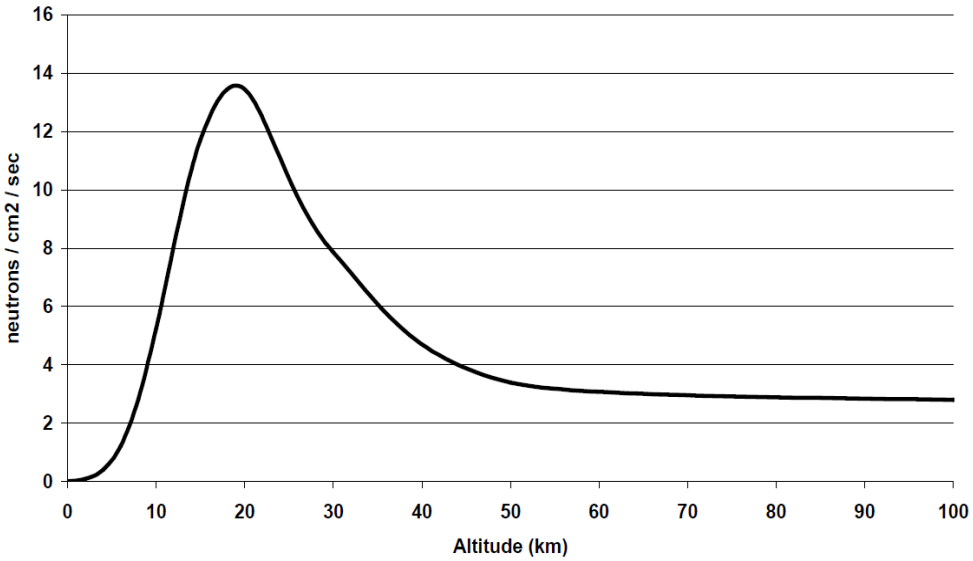




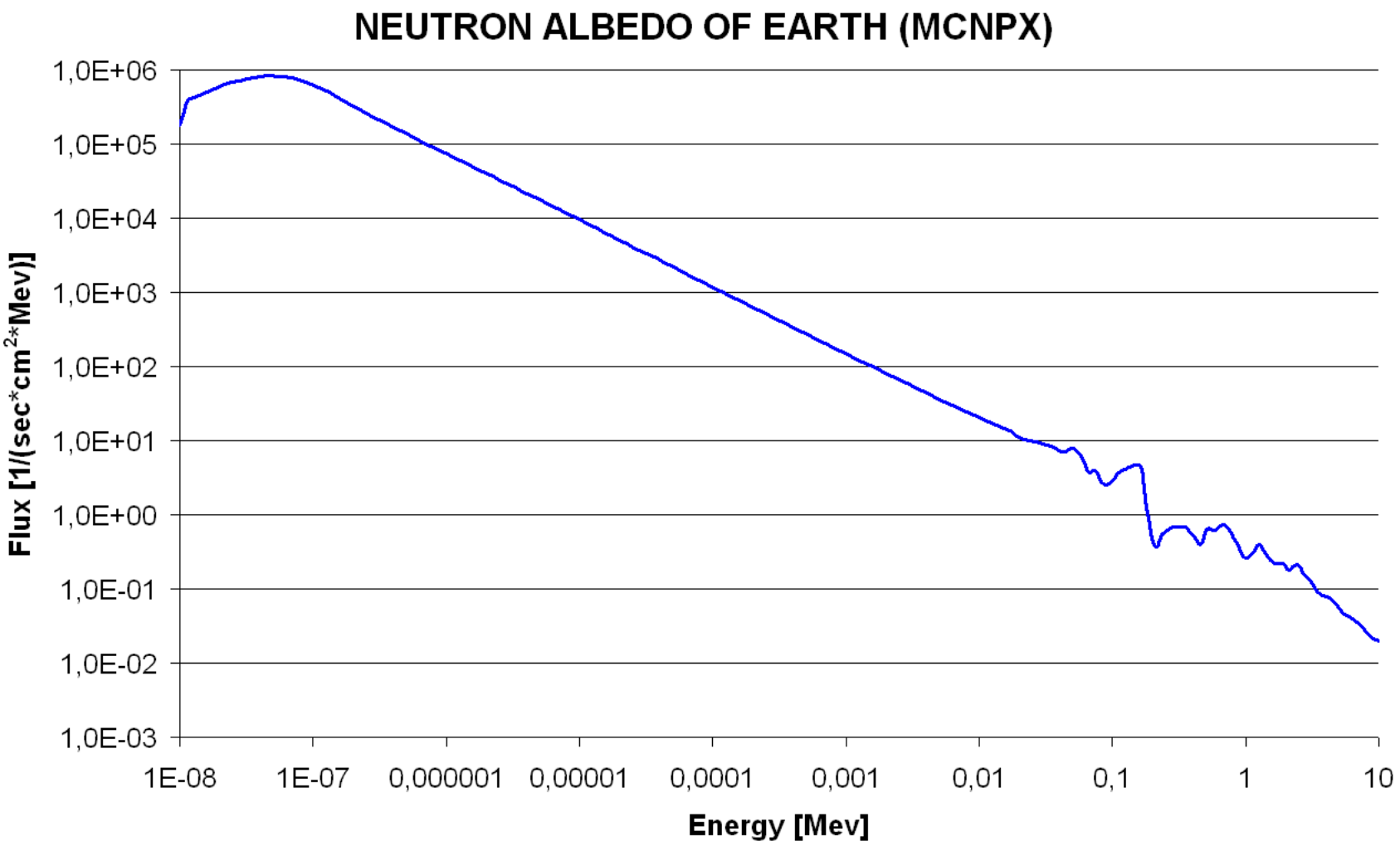
Flux of neutrons with energy E_n crossing the surfaces at specified amplitudes



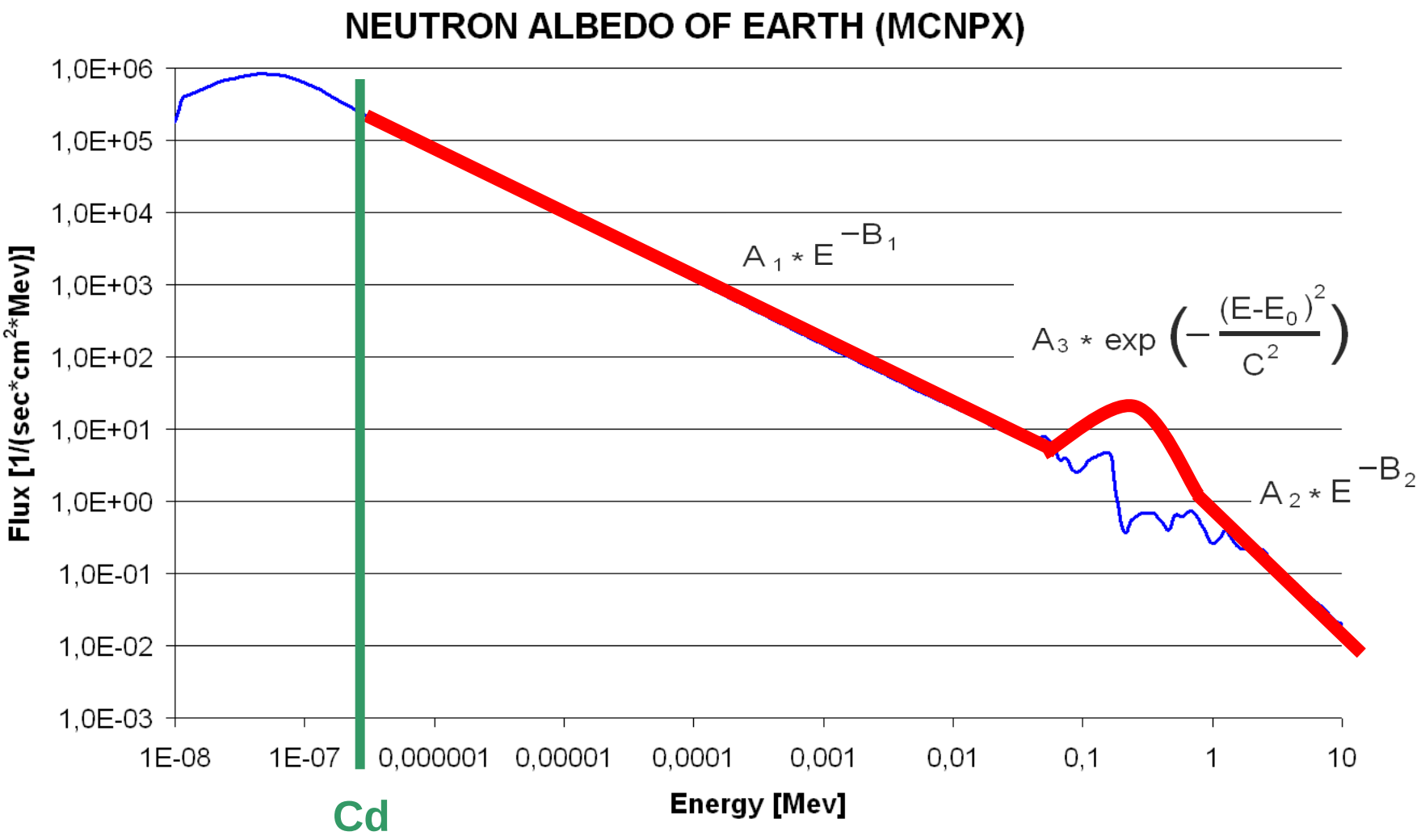
Total flux of neutrons for all energy crossing the surfaces at specified amplitudes



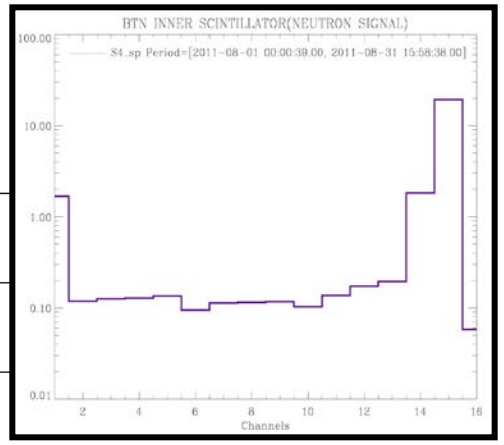
Neutron spectra



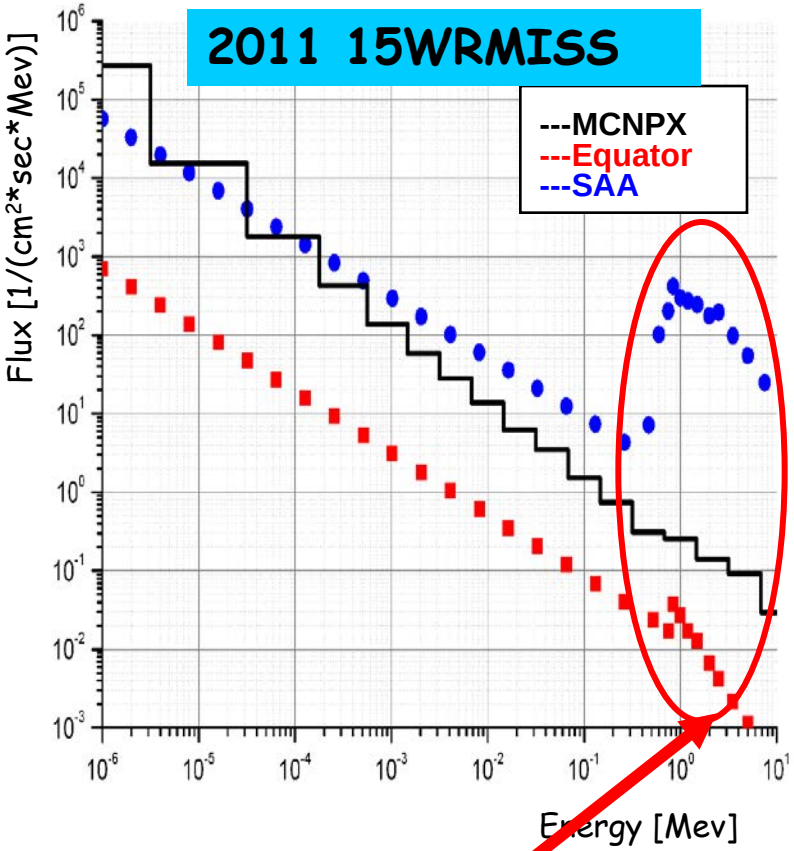
Neutron spectra



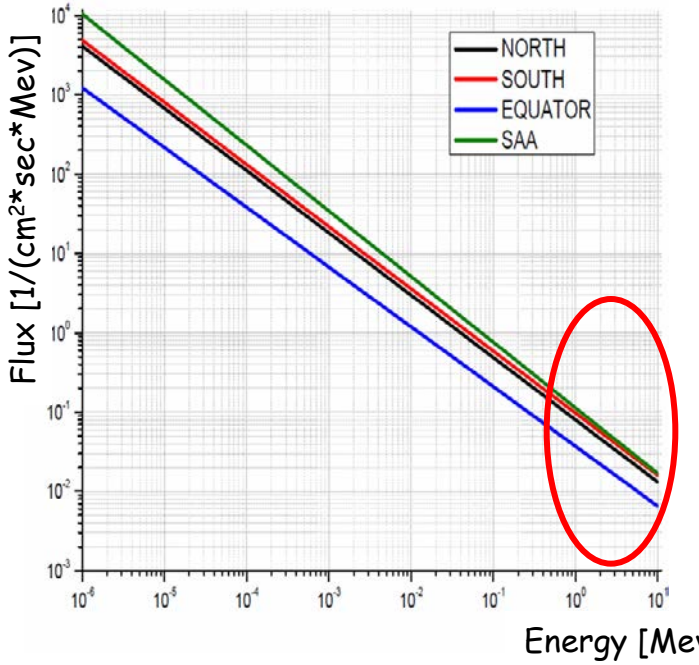
Neutron spectra

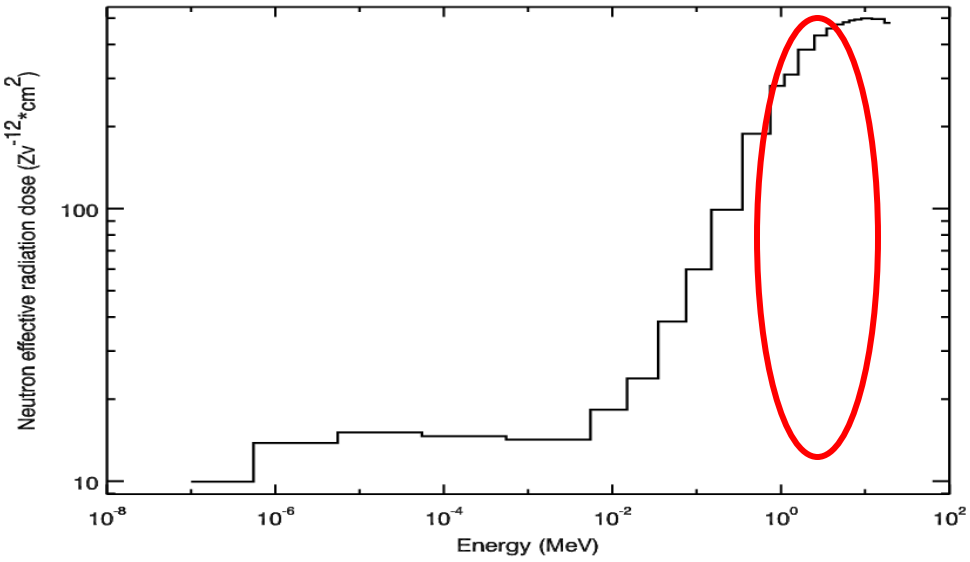


Neutron spectra

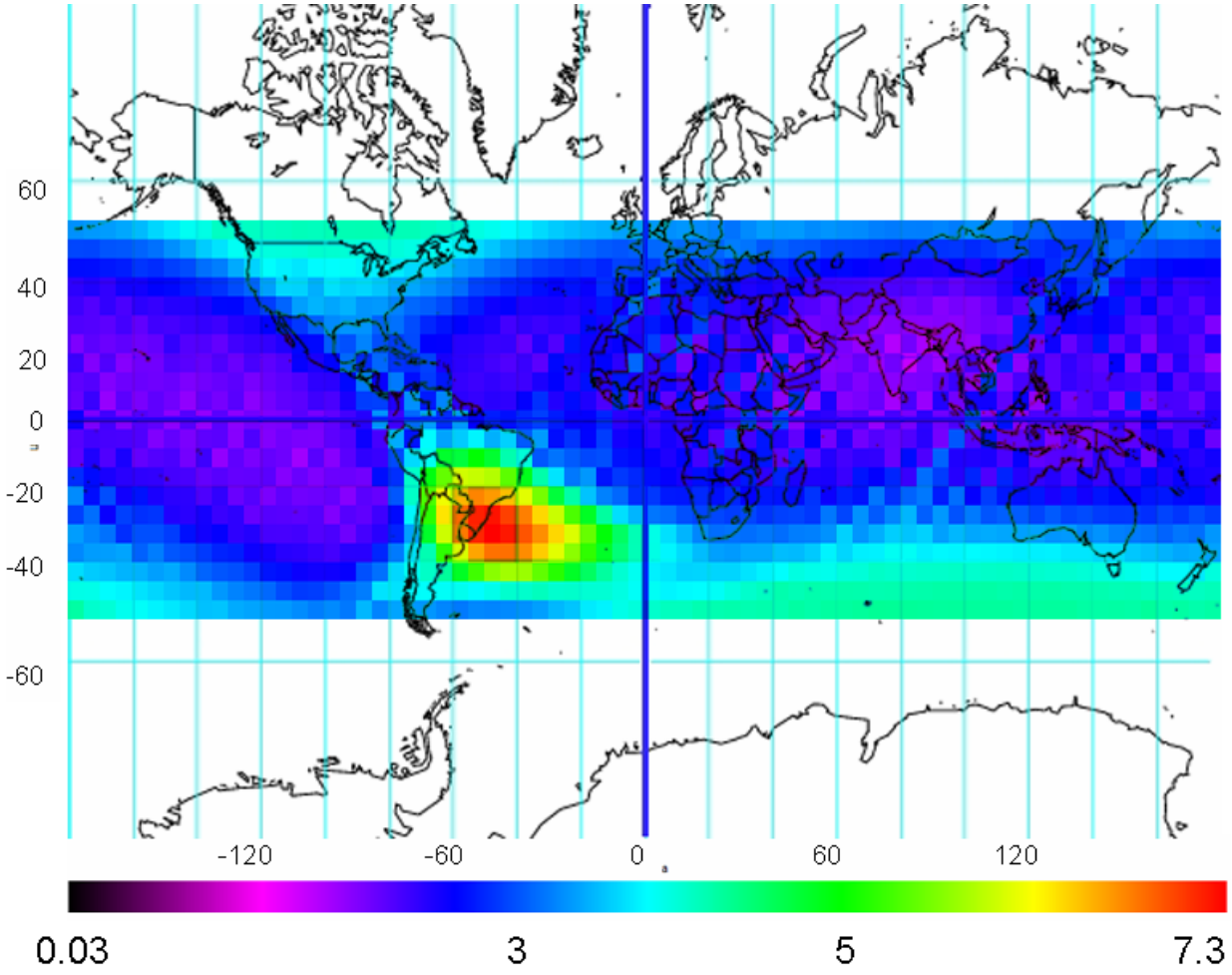


OVERESTMATION ?



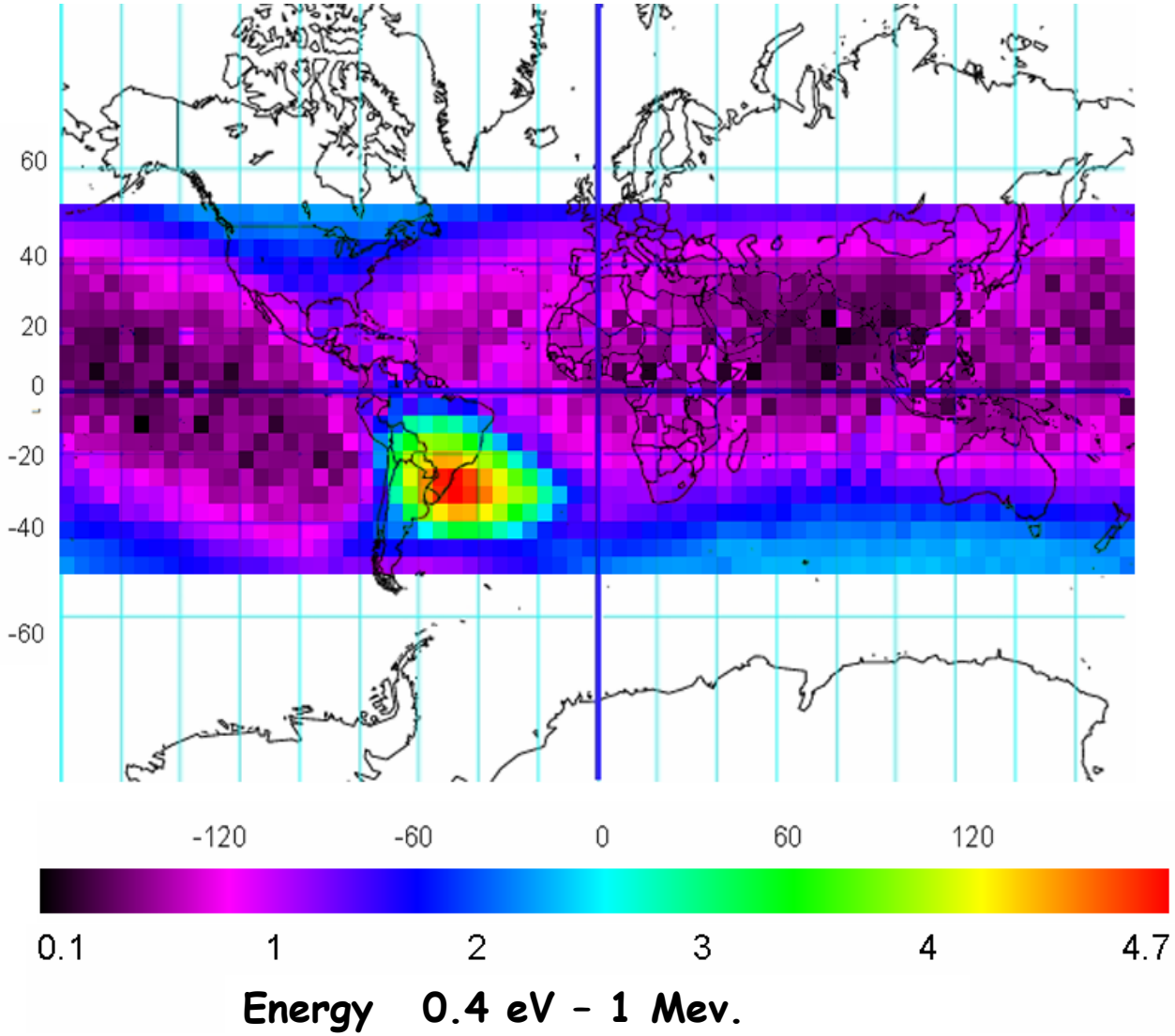


Neutron flux map (n/sec/cm^2)



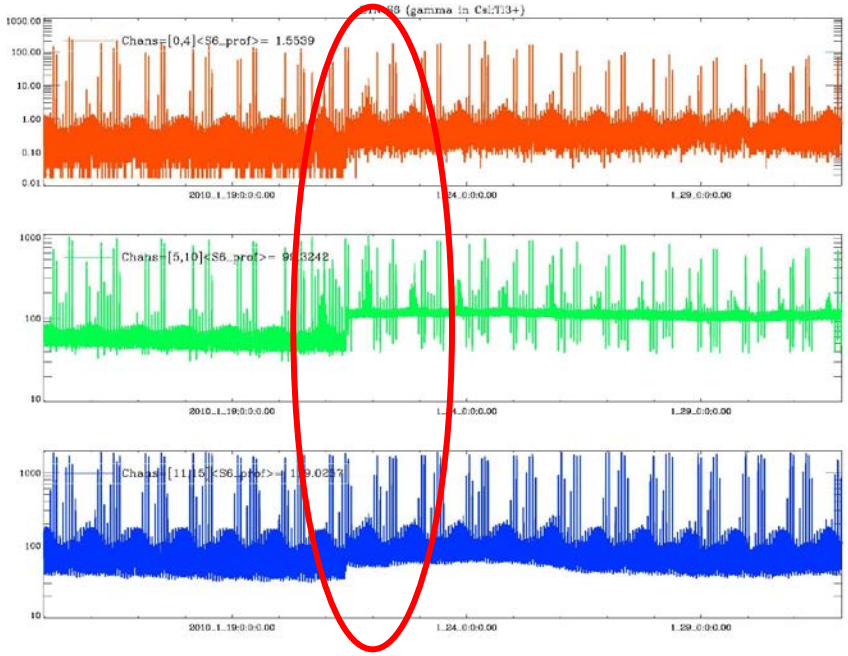
Energy 0.4 eV – 1 Mev.
Time 01 Jun. – 01 Oct. 2010

Doze rate map (μZv/hour)

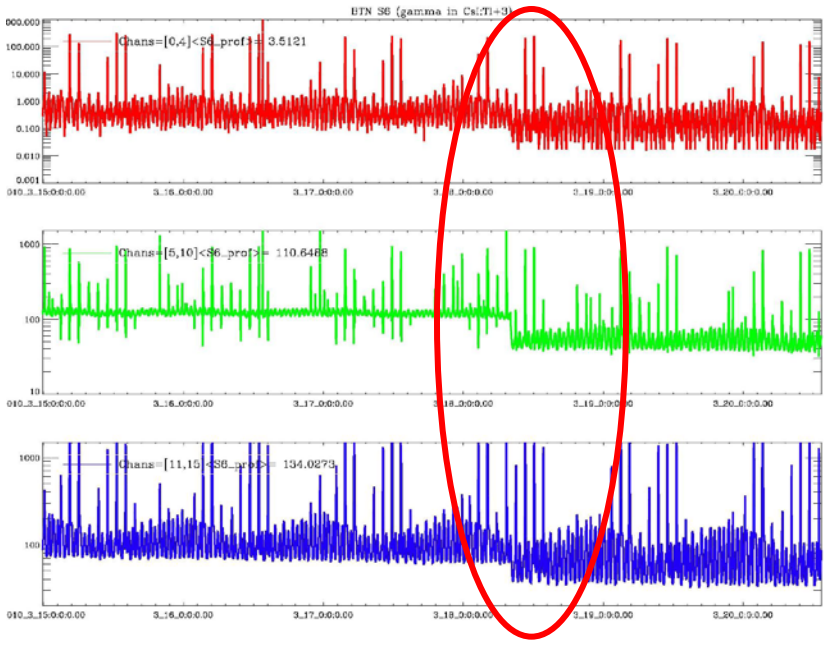


Energy 0.4 eV – 1 Mev.
Time 01 Jun. – 01 Oct. 2010

Gamma Radiation - Artificial from "Soyuz"

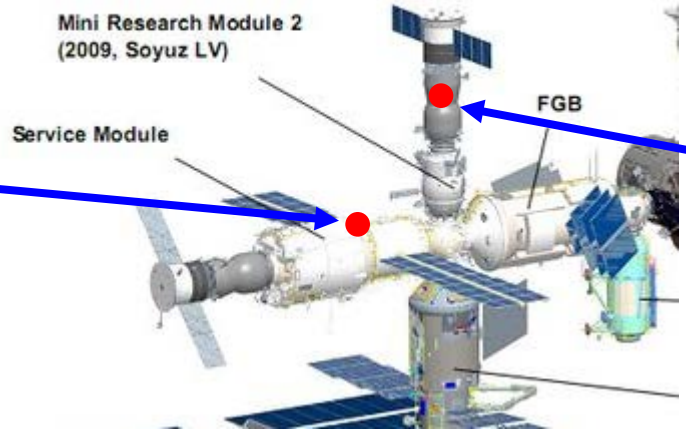


21 Jan. 2010 drop in gamma background ~ 10:30 UT
Upper plot - channels 0- 4 of CsI:Tl
Central plot - channels 5 - 10 of CsI:Tl
Low plot - channels 11 - 16 of CsI:Tl



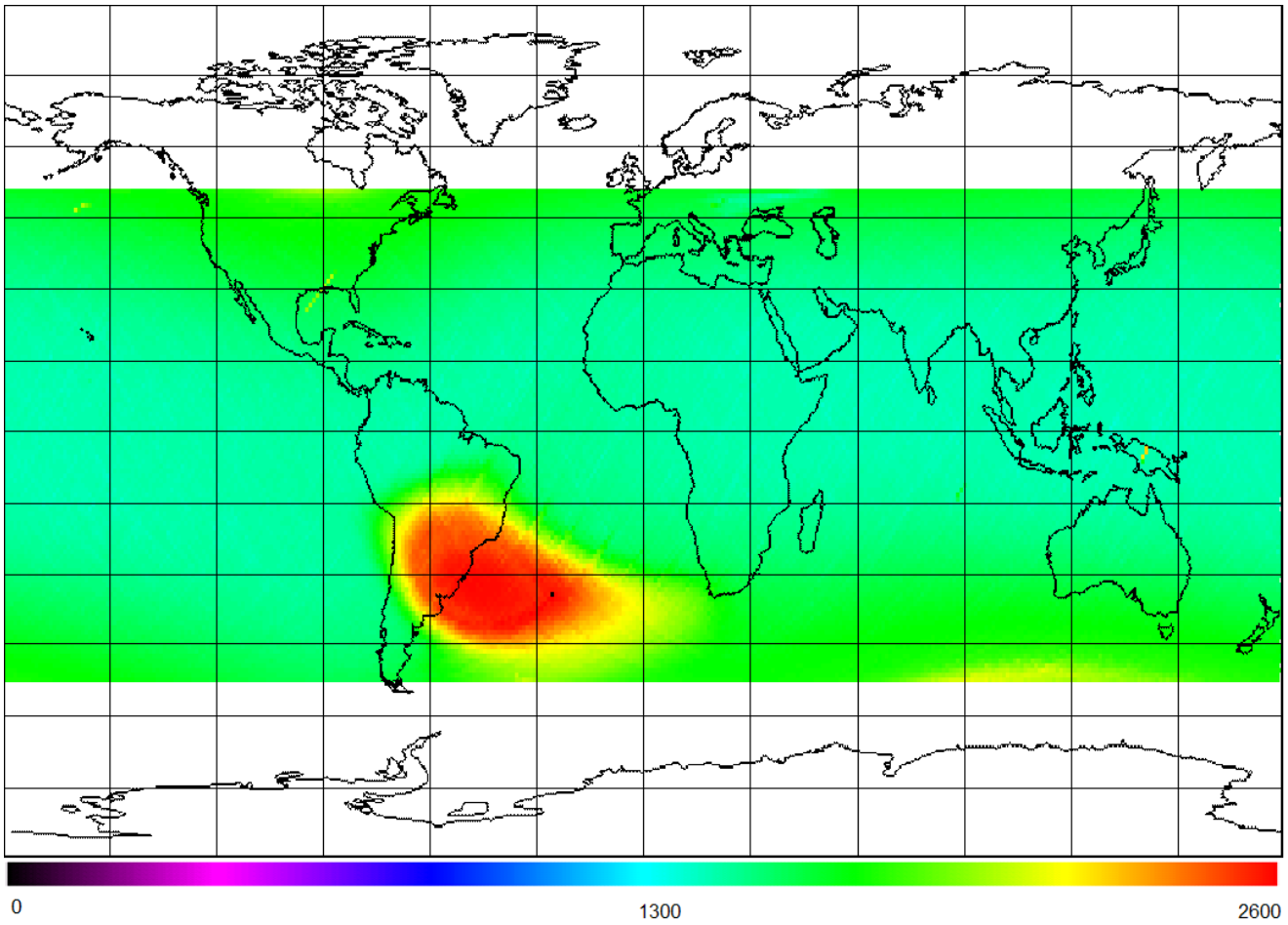
18 Mar.2010 drop in gamma background ~ 08:00 UT
Upper plot - channels 0 - 4 of CsI:Tl
Central plot - channels 5 - 10 of CsI:Tl
Low plot - channels 11 - 16 of CsI:Tl

BTN-M1 detectors



Gamma ray altimeter
«KAKTUS-2B» with Co-60,

Gamma Radiation - Natural from Space



Gamma map [counts/sec] for CsI:Tl $^{3+}$ detector (*SC/OUT/G*) for 30 keV – 10 MeV

Gamma Radiation from neutrons: test in JNRI

References isotopic source Cs-137

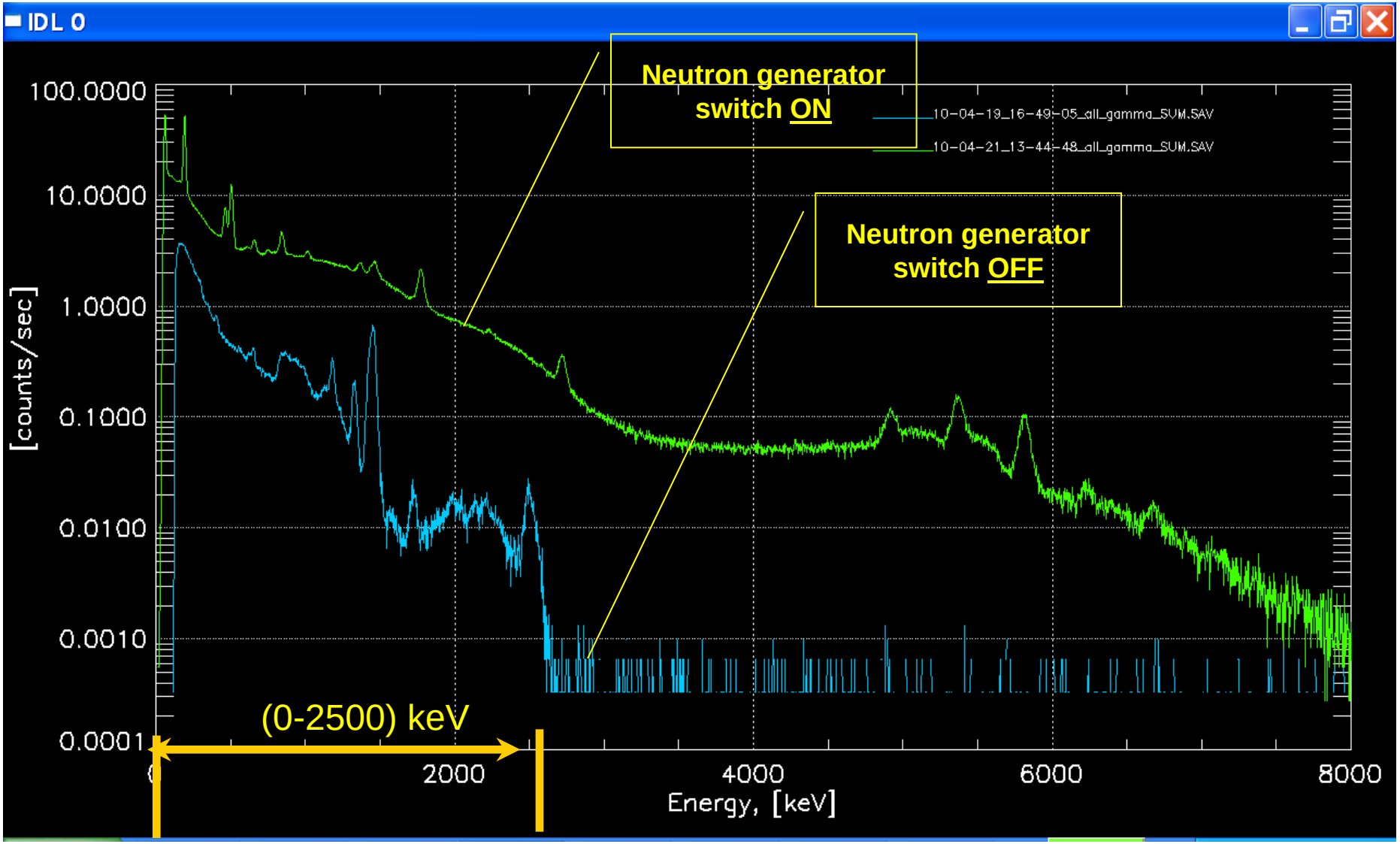
Geometry of measurements

Place for samples and moderator

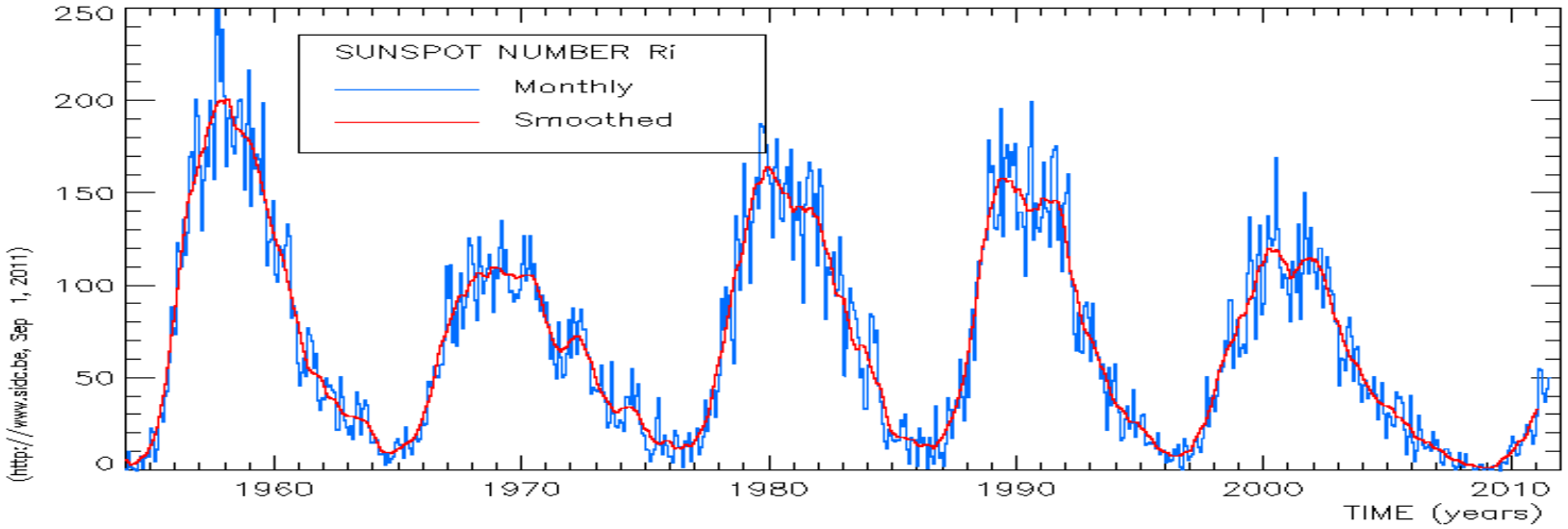
Gamma-ray and neutron spectrometer NS HEND

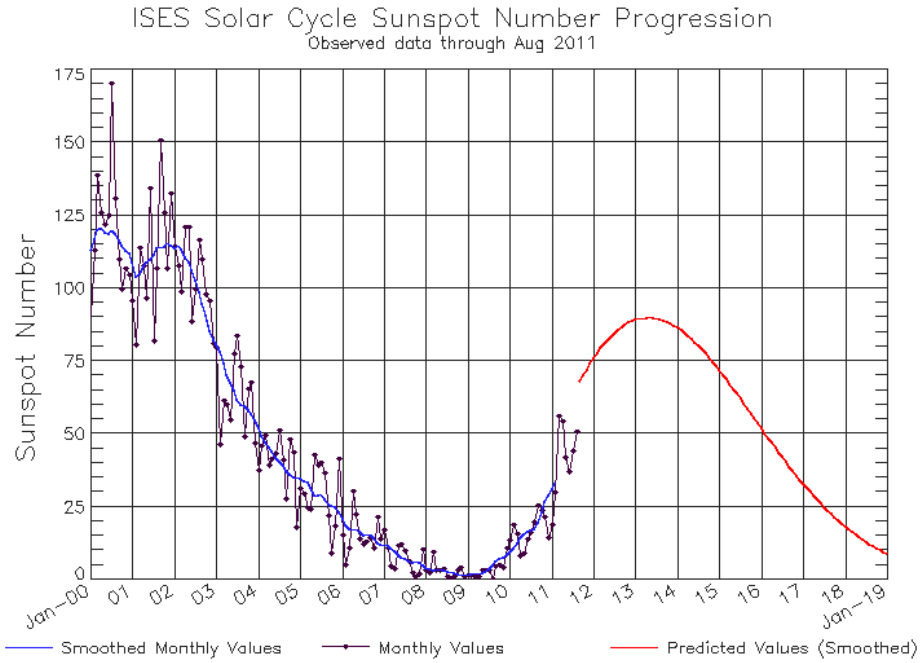
Pulsing neutron generator DAN/PNG

Gamma Radiation from neutrons: results



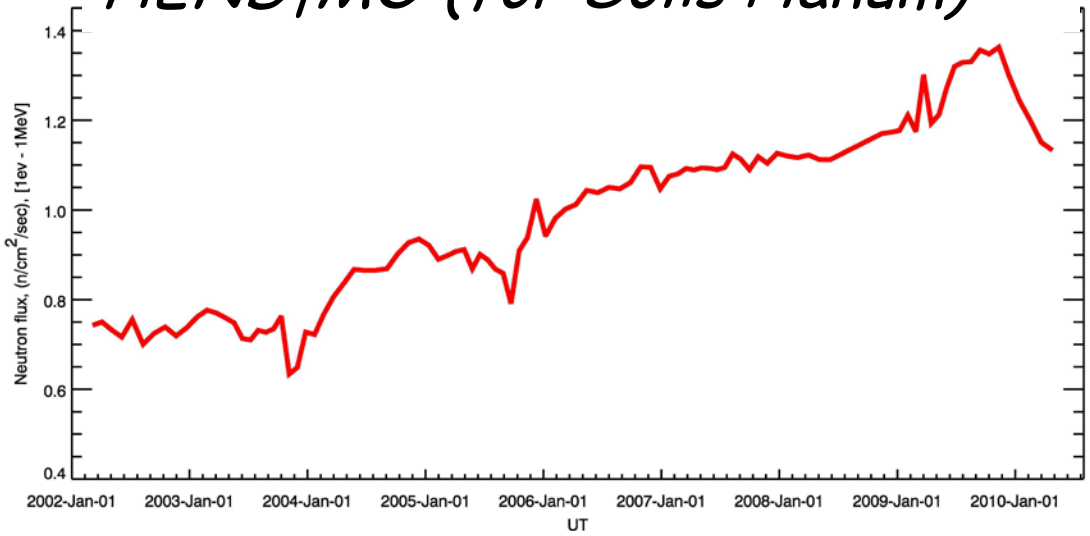
GCR trend

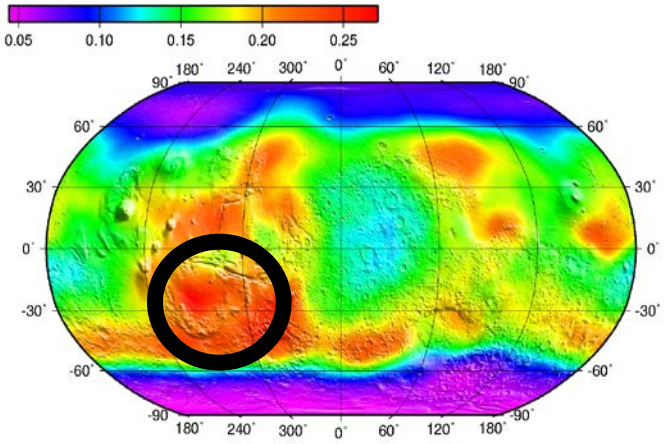

SUNSPOT NUMBER Ri
Monthly
Smoothed
250
200
150
100
50
0
1960
1970
1980
1990
2000
2010
TIME (years)
(http://www.sidc.be, Sep 1, 2011)


ISES Solar Cycle Sunspot Number Progression
Observed data through Aug 2011
Sunspot Number
175
150
125
100
75
50
25
0
Jan-00
01
02
03
04
05
06
07
08
09
10
11
12
13
14
15
16
17
18
Jan-19
Smoothed Monthly Values
Monthly Values
Predicted Values (Smoothed)
Updated 2011 Sep 6
NOAA/SWPC Boulder,CO USA

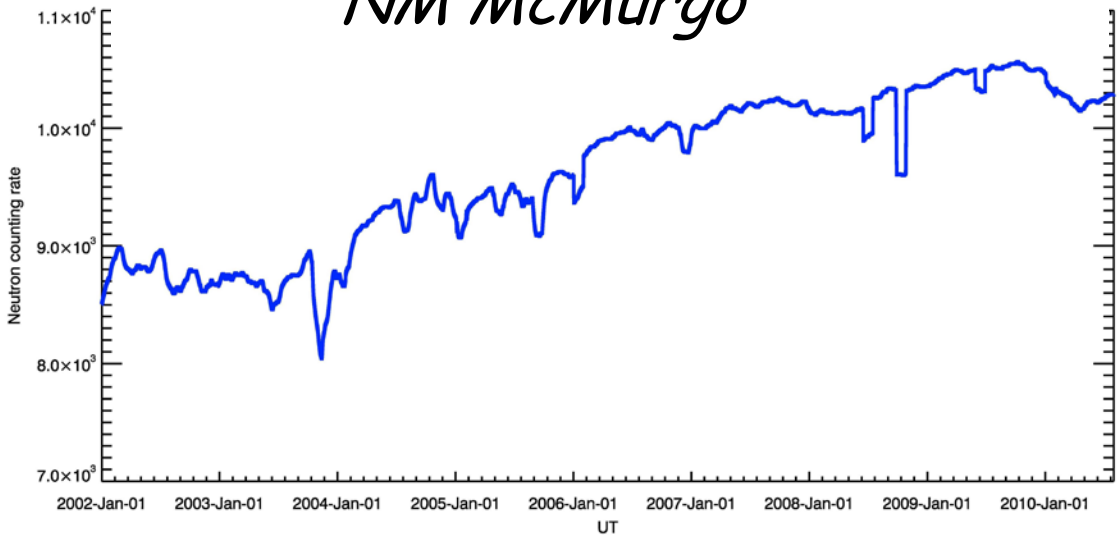
GCR trend on Earth and near Mars

HEND/MO (for Solis Planum)





NM McMurgo

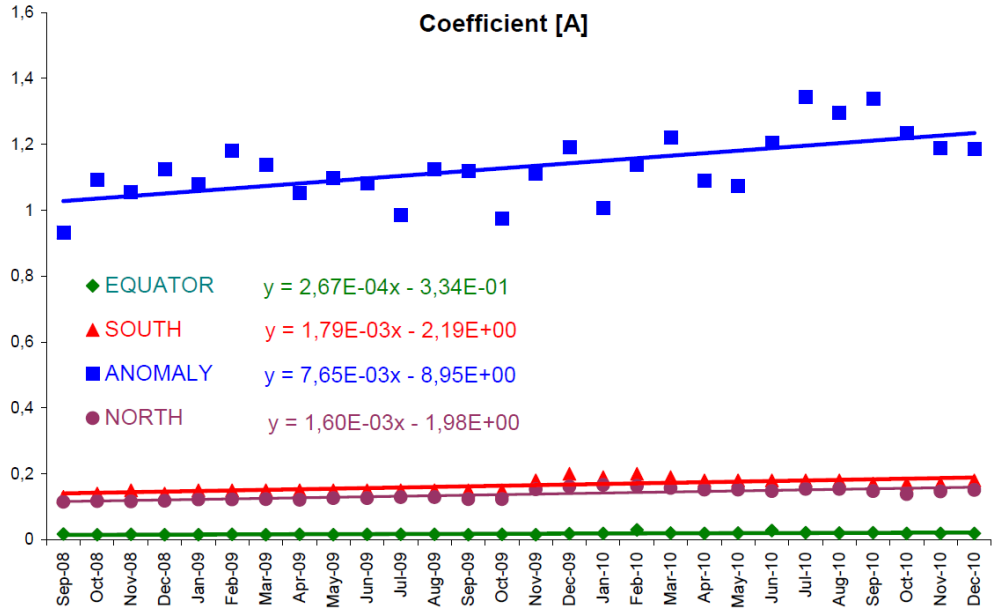


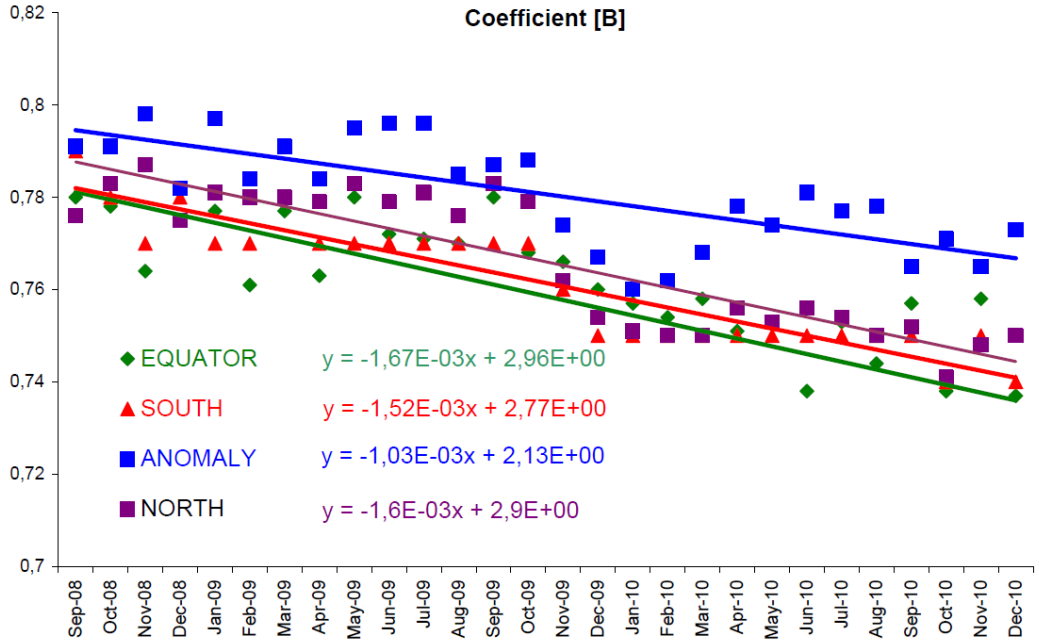
Station: McMurdo
Longitude: 77.9 S
Latitude 166.6 E
Altitude: 48 m

GCR trend on ISS

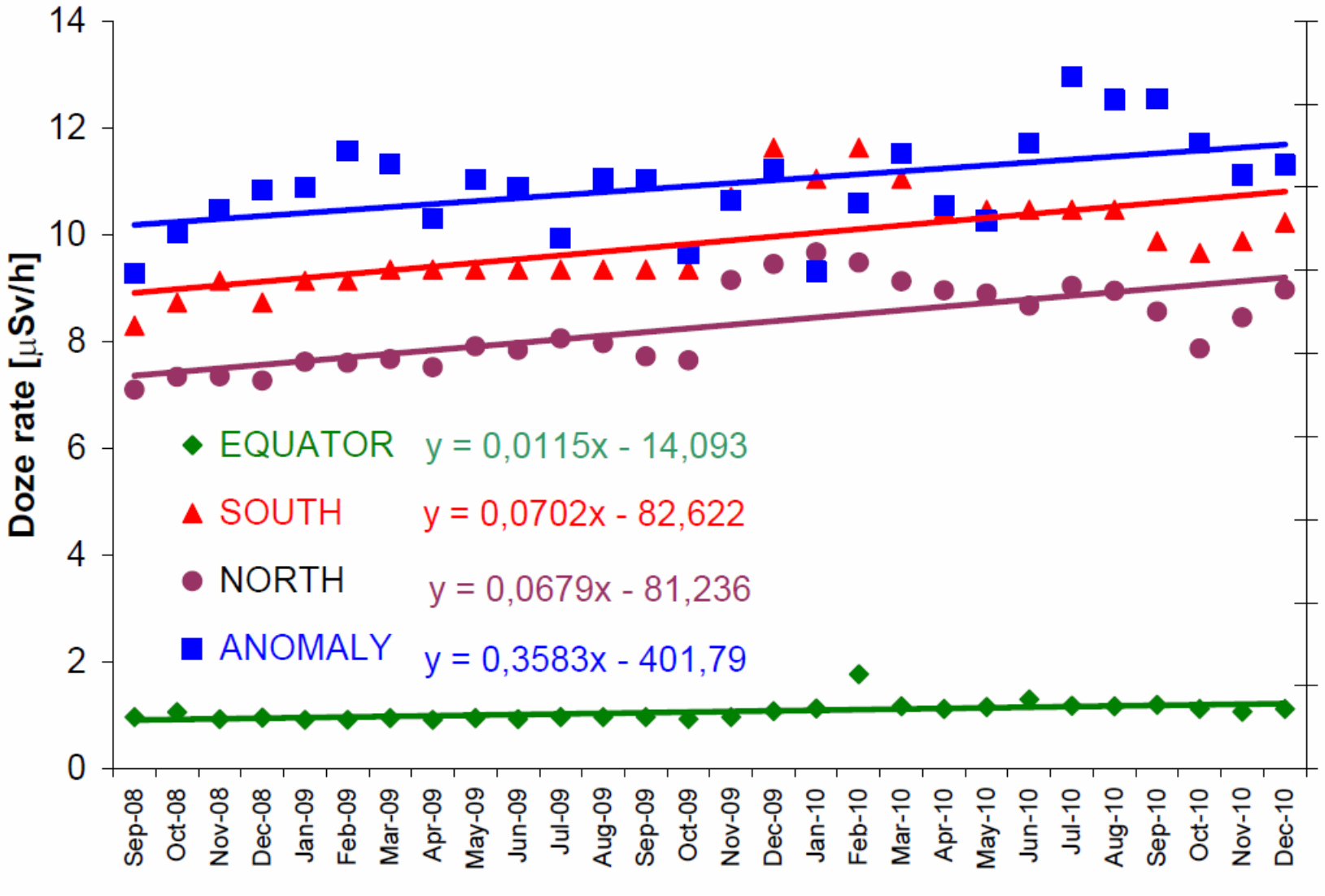
BTN near Earth

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





Trend of doze rate (μZv/hour)



Energy 0.4 eV – 1 Mev.
Time 01 Sep 2008 – 01 Jun. 2011

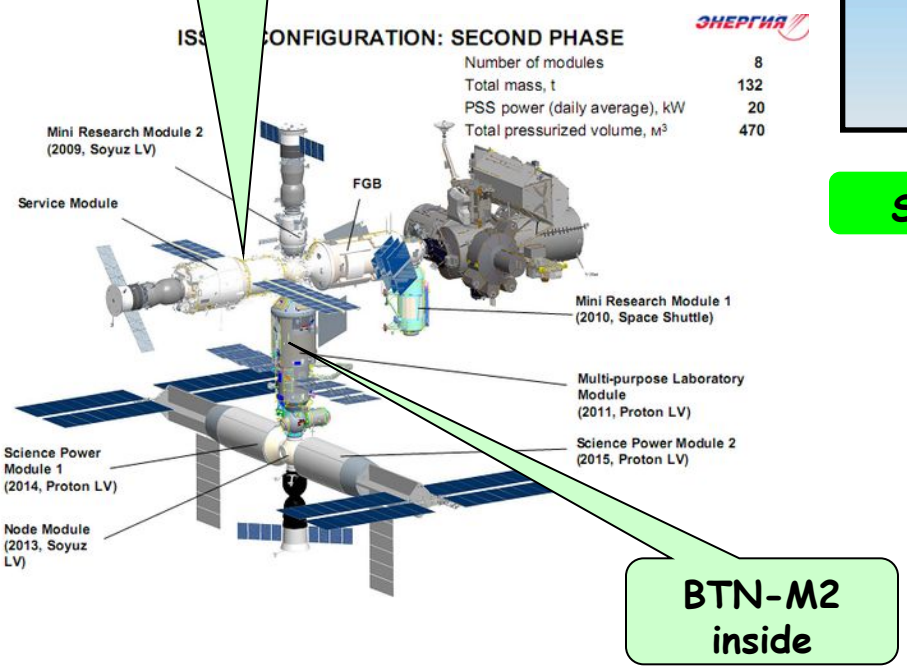
Next experiment BTN-M2: scientific goals

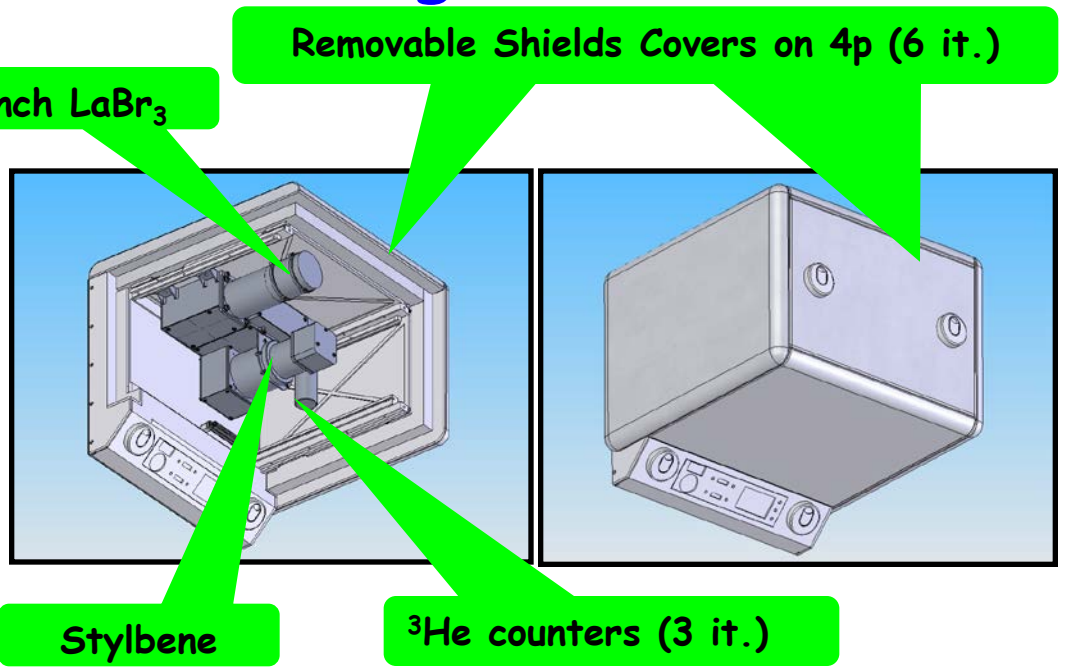
1. Measure inside of SM ISS of fluxes of neutrons in energy range from thermal energy (0.025 eV) up to fast (10 MeV) for radiation background study and comparison with data outside of ISS (from BTN-M1);

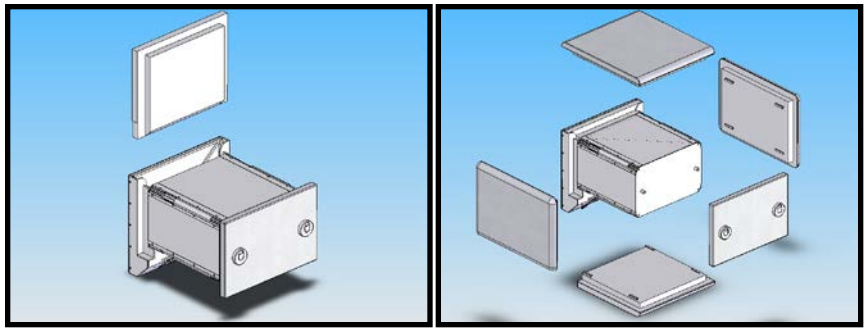
2. Measure of gamma ray spectra with high energy resolution (~3%) in energy range from 50 keV up to 10 MeV;

3. Tests of new materials for radiation shielding and safety approaches during future deep space mission and for design of collimated detectors for nuclear planetology and astrophysics.

Next experiment BTN-M2: design

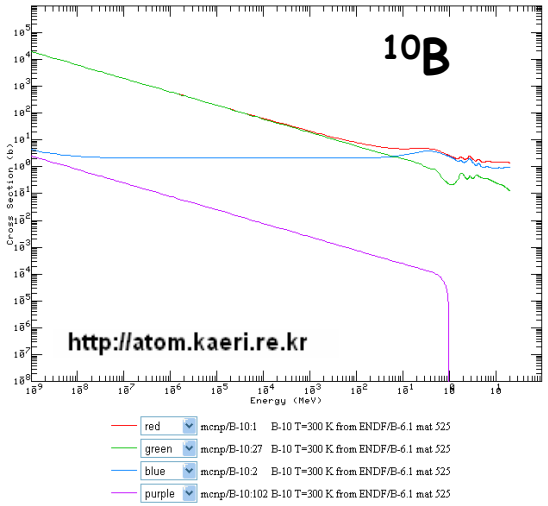


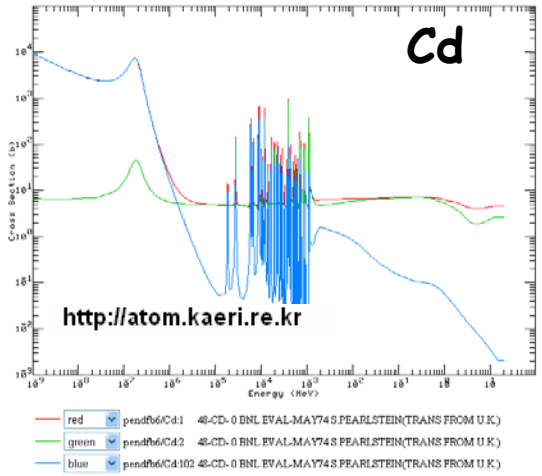


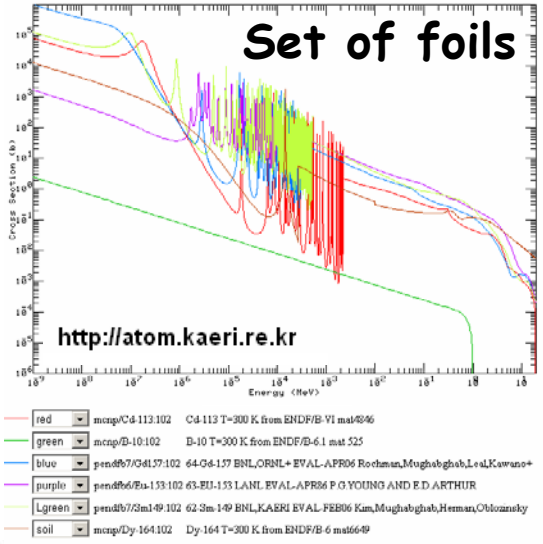


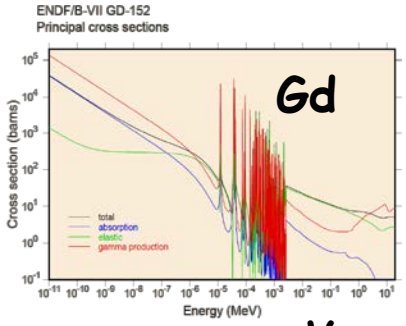
Measurements in different shielding covers combinations

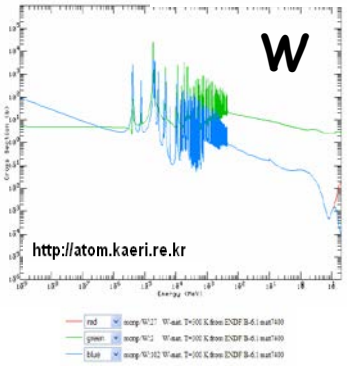
Next experiment BTN-M2: physics



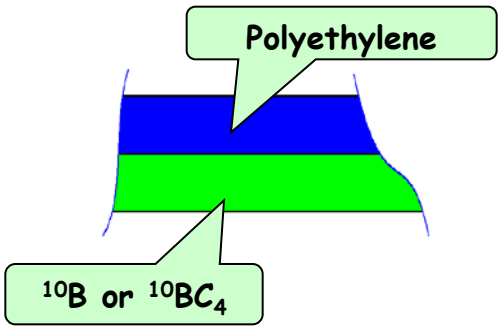




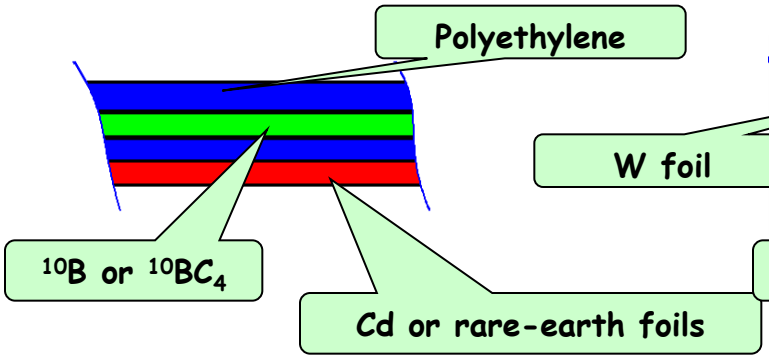




Var. 1



Var. 2



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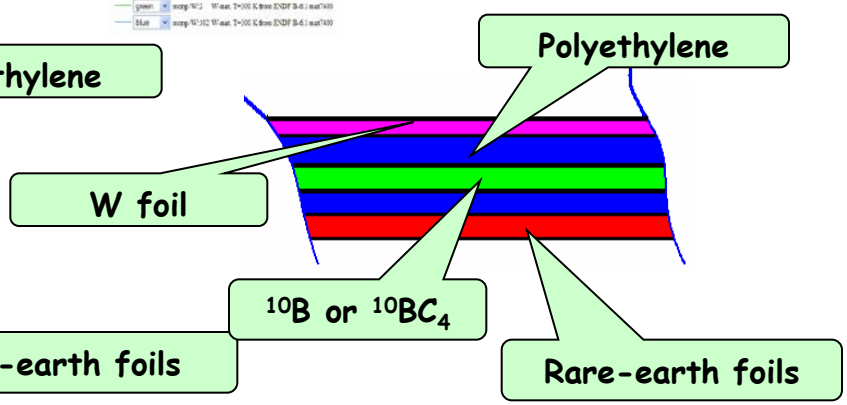

CONCLUSION

RESULTS

1. All devices are operated successfully !!!
2. Neutron spectra and doses estimation obtained for 0.4 ev – 1 Mev
3. $LaBr_3$:Ce detector studied during 2006 – 2007 in BTN selected for the space nuclear physics devices:
   - BTN-M2/ MLM of ISS (2014) – in design
   - MGNS/BepiColombo (Mercury orbital SC, ESA, 2014) – in hardware
   - NS-HEND/Fobos-Grunt (Phobos Lander, Russia, 2011) – ready to flight
   - ADRON-LR/Luna-Resurs+Chandrayana-2 (Moon Lander, Russia + India, 2013) - in design
   - ADRON-LG/Luna-Glob (Moon Lander, Russia, 2014) - in design

TASKS

1. Obtain high energy spectra (> 1 Mev) and doses from BTN stylbene data
2. Compare dozes in 3 point of Solar System (HEND, BTN-M1, LEND) for future mission
3. Modeling of Earth' neutron albedo generation and structure
4. Modeling of local neutron background ('Zvezda' mass and elements model - ?)
5. Comparison HEND, BTN-M1, LEND, GOES and ACE, measurements for SPE and SF
6. Continue monitoring of GCR (flux and dozes) trend