Space experiment BTN-Neutron on Russian Segment of International Space Station

15th WRMISS
"Villa Mondragone Conference Center",
via Frascati 51, Monte Porzio Catone
7-9th September 2010

Authors

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[1)] Space Research Institute, Russia

[2)] Rocket and Space Corporation «Energy», Russia

and cooperation

Science goals of BTN-NEUTRON experiment

[Board Telescope of Neutron]

SOURCES OD NEUTRON IN SPACE

- **Earth' neutron albedo.**
- **Local neutron from spacecraft materials**
- **Solar neutron from Solar Particle Events.**

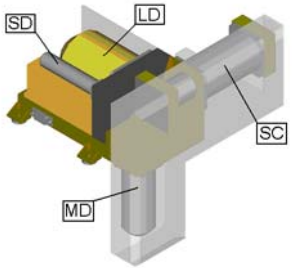
BIG GOALS

1. **Study of Earth' neutron albedo for different latitude/longitude/altitude of ISS, time, solar activity, 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.**

PROJECT: History

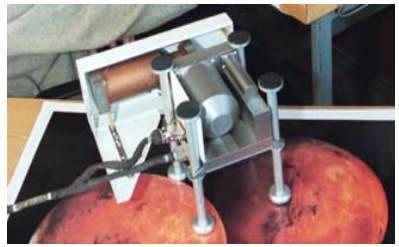
1997

1998



HEND
Laboratory unit

1999



HEND
Technological unit

2000

HEND
Flight units

2007

Flight spare unit
on ISS

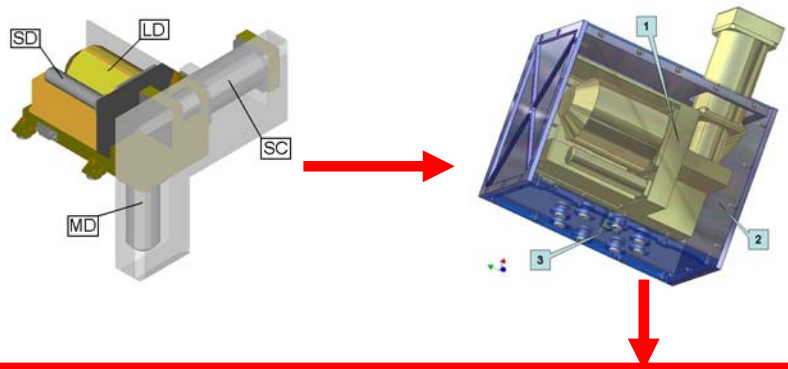
2001

Flight unit
on Mars Odyssey

PROJECT: BTN-M1 Equipment

Detection unit

(in space)



- measure of fluxes of neutrons in wide energy range: from epithermal (~0.4 eV) up to fast (~ 10 MeV) neutrons;
- measure X-ray and gamma radiation in energy range 30 keV-10 MeV.

Electronics unit

(inside)

- power supply and control;
- command transmission;
- science data and telemetry transmission on board;
- temporary storage of data and telemetry in case of unexpected delay in transmission;
- allocation of samples of scintillation crystals.

PROJECT: Allocation onboard ISS

Detection unit

(in space)

ISS014E14536_1

Electronics unit

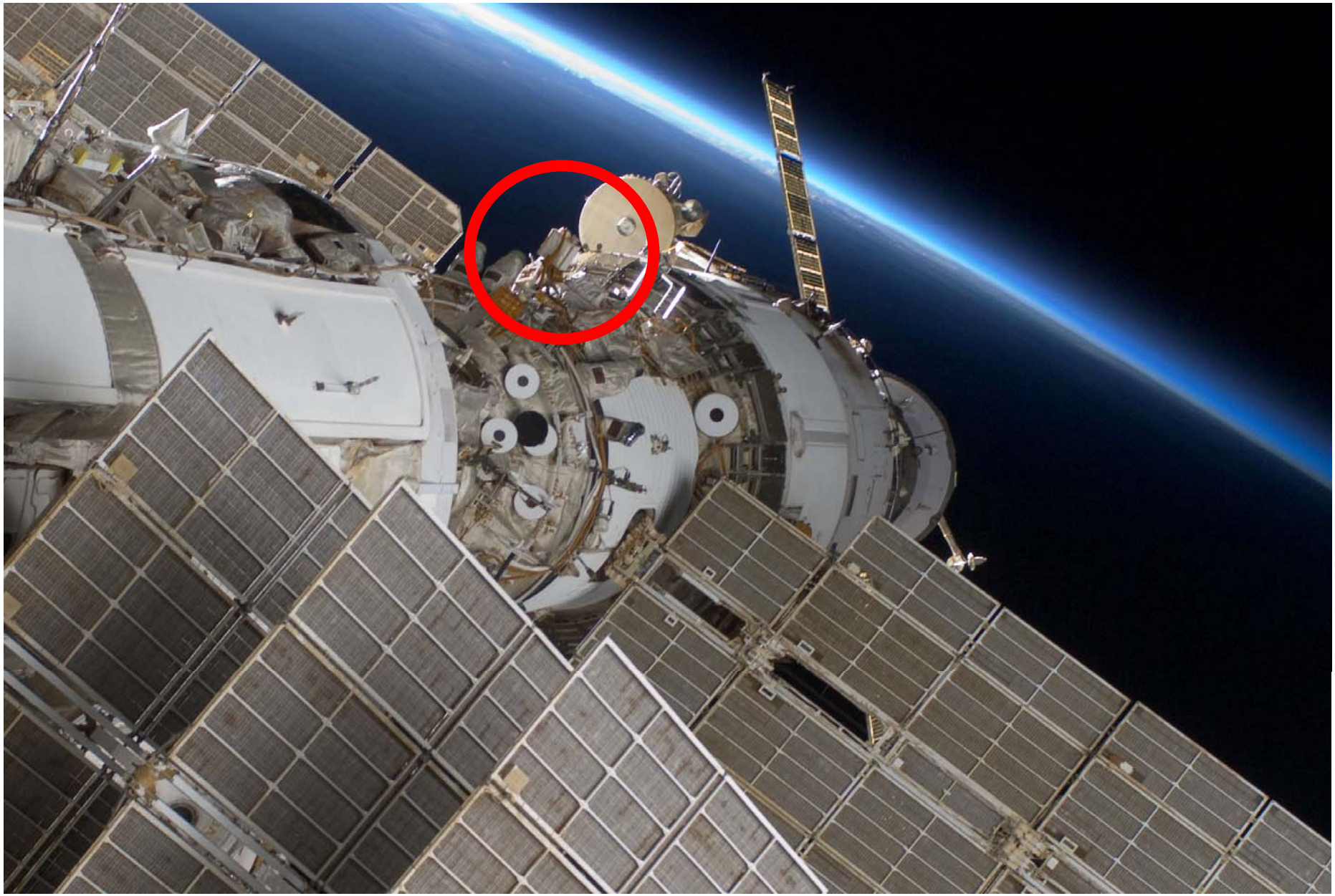
(inside)

23 November 2006 (EVA-17)

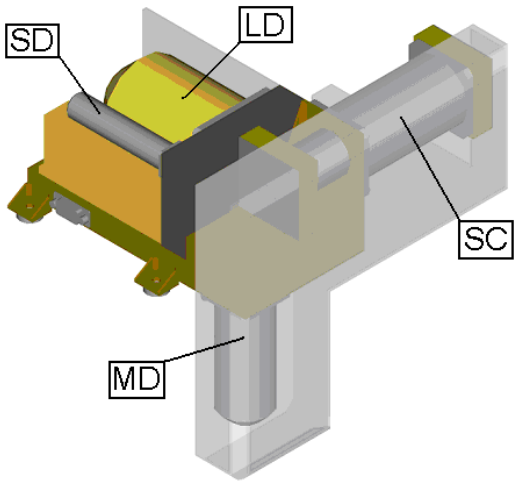
26 February 2007 (EVA-17A)

03 November 2006

PROJECT: Allocation onboard ISS

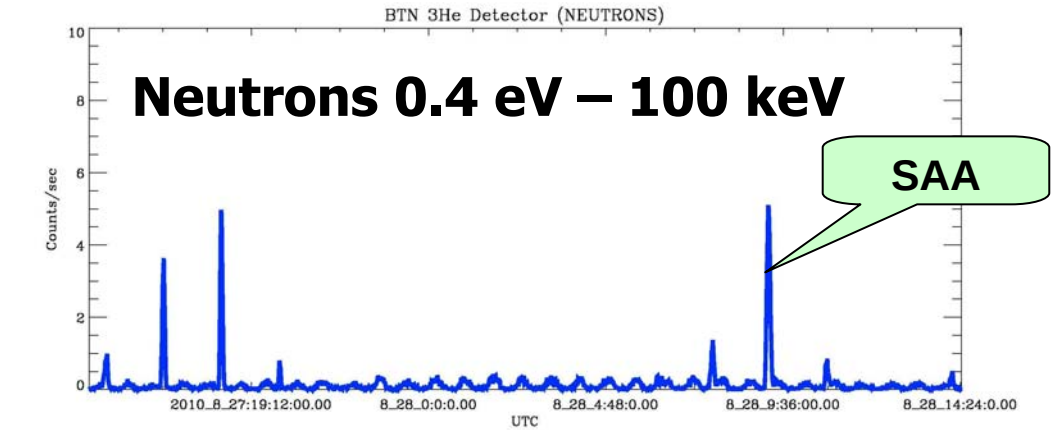


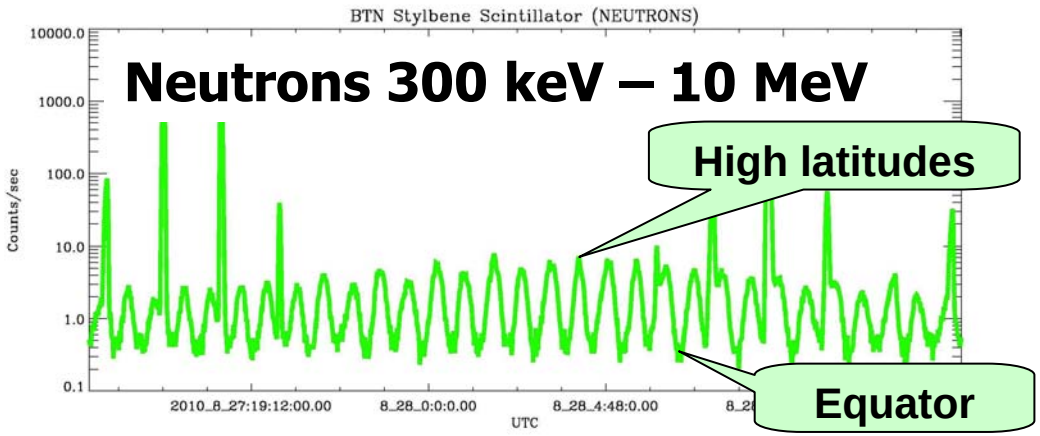
PROJECT: Neutron & Gamma profiles

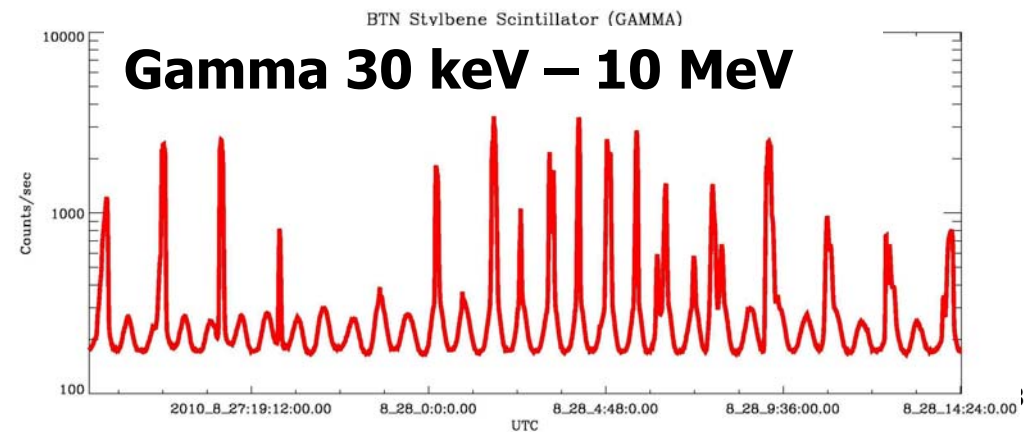


5 detectors = 6 signals:

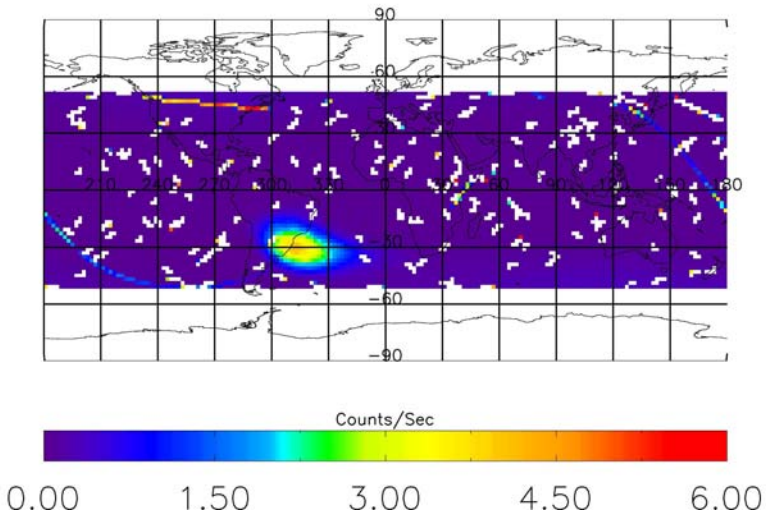
- **4 “neutron signals”**
  - ***^{3}He* counters - SD, MD, LD**
  - **stylbene SC/IN/N**
- **2 “gamma signals”**
  - **stylbene SC/IN/G**
  - ***CsI:Tl $^{3+}$***



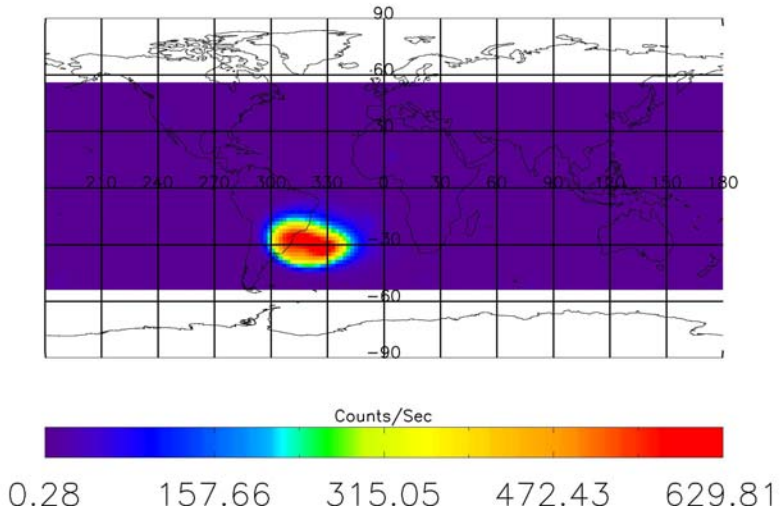




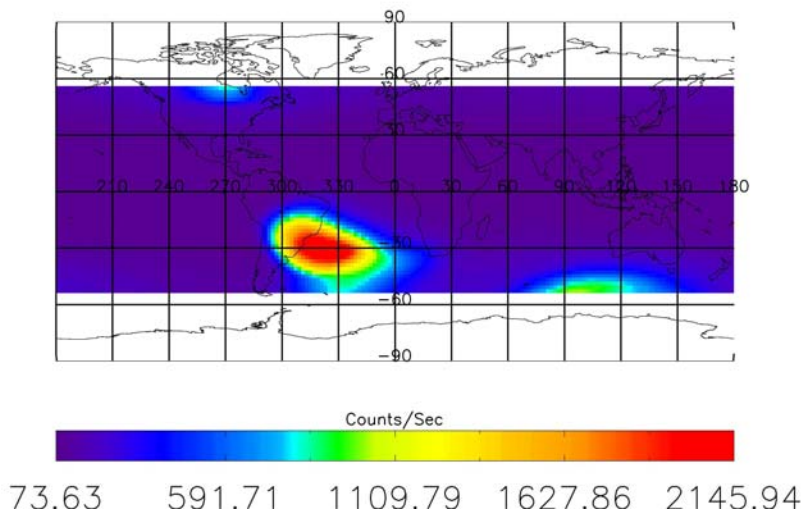
PROJECT: Neutron $ Gamma map (in counts rate)



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



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

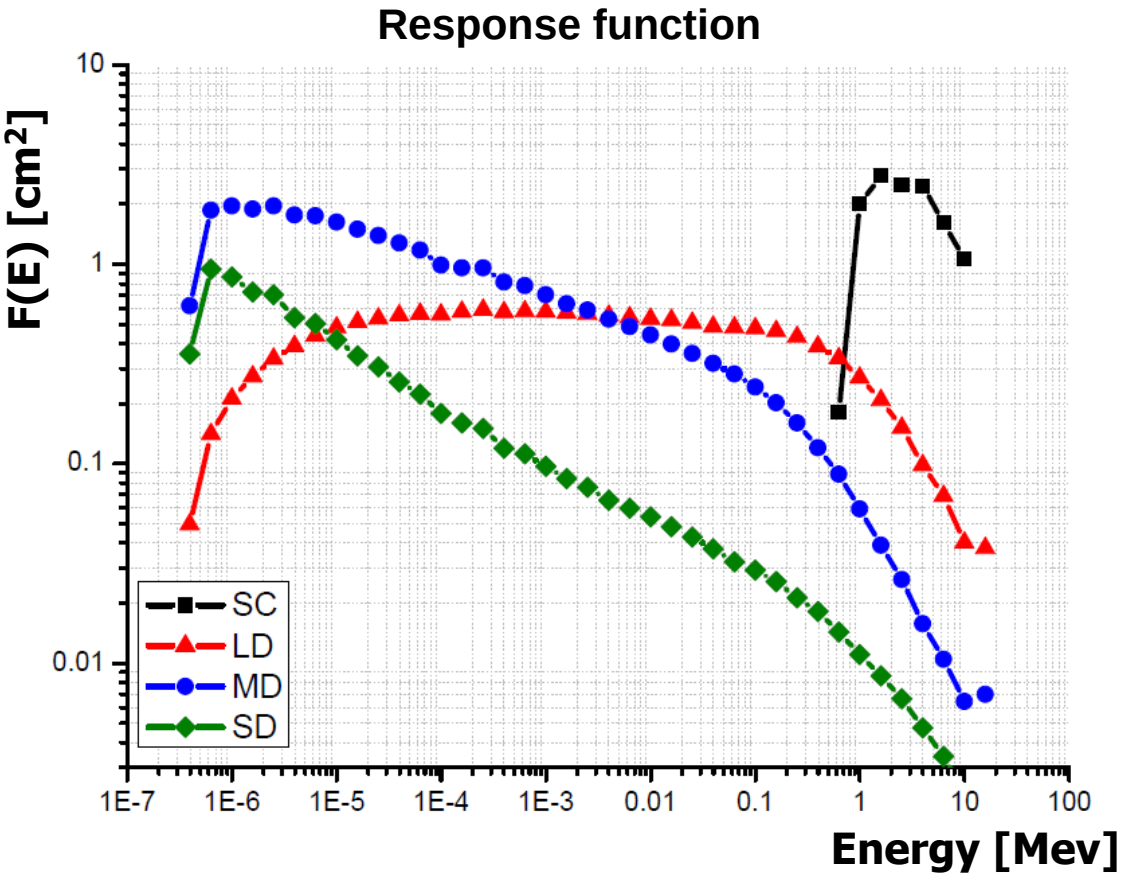


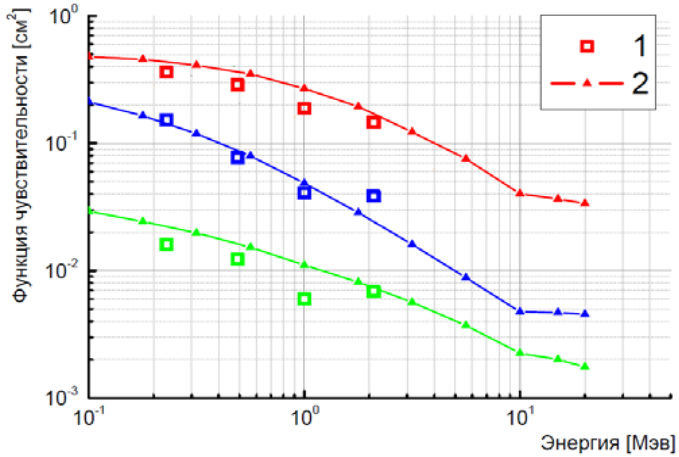
Gamma map for CsI:Tl^{+3} Detector (100 keV – 10 MeV)

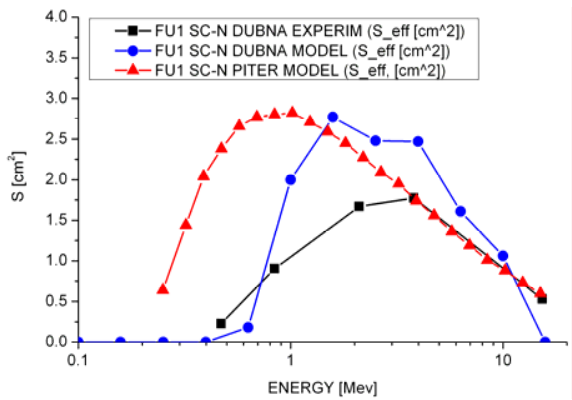
Science goals of 1st stage of experiment

1. **Study of neutron distribution, neutron spectra and estimate dose rates outside of Russian 'Zvezda' module of ISS for different latitude/longitude/altitude of ISS, time, solar activity and others. IN PROGRESS!**
2. **(additional 1) Study of radiation damage and degradation the new perspective scintillation crystals for future space science applications DONE**
3. **(additional 2) Detect of Gamma Ray Bursts "simultaneously" with HEND/Mars Odyssey and other spacecrafts. IN PROGRESS!**

1. Spectra: Calibration







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

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

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

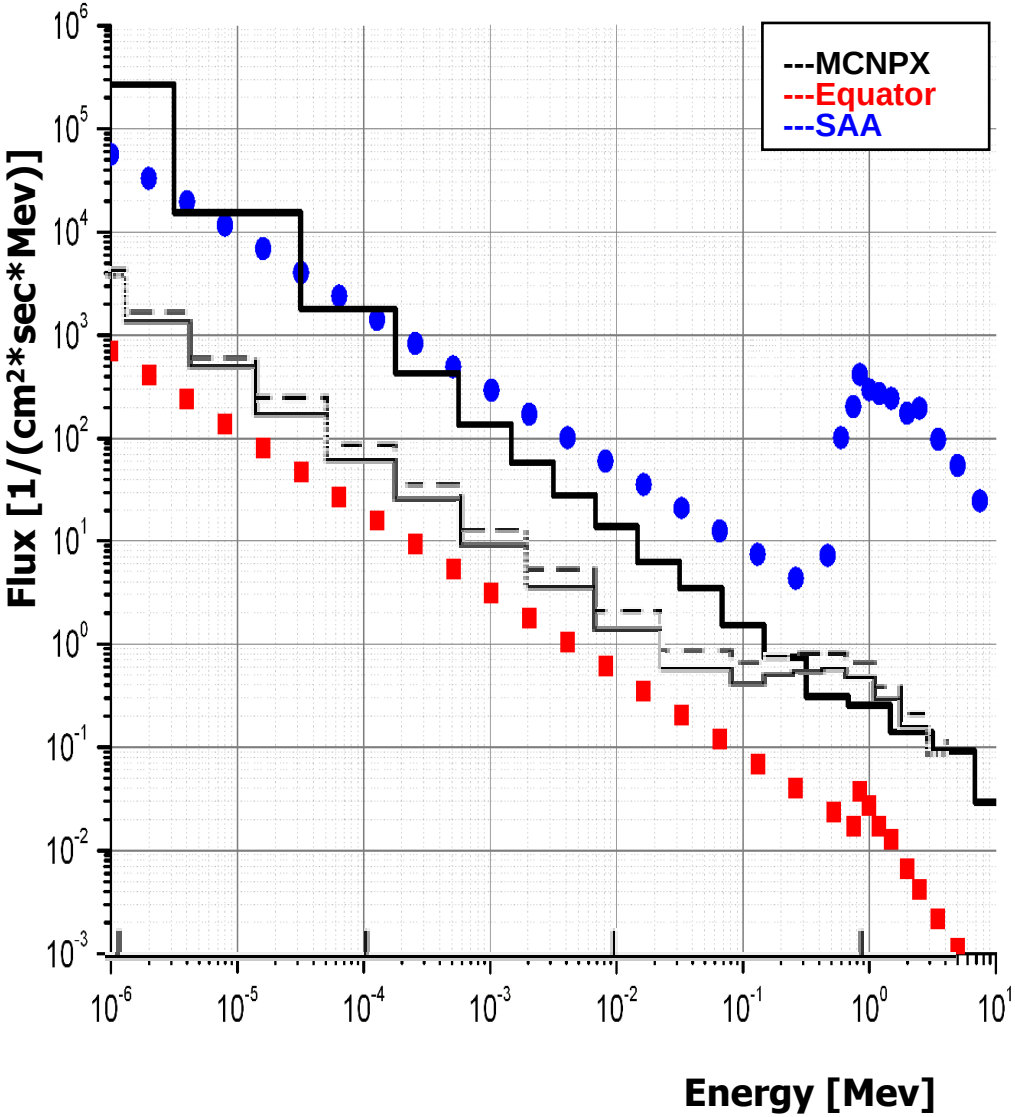
JNRI (Dubna),

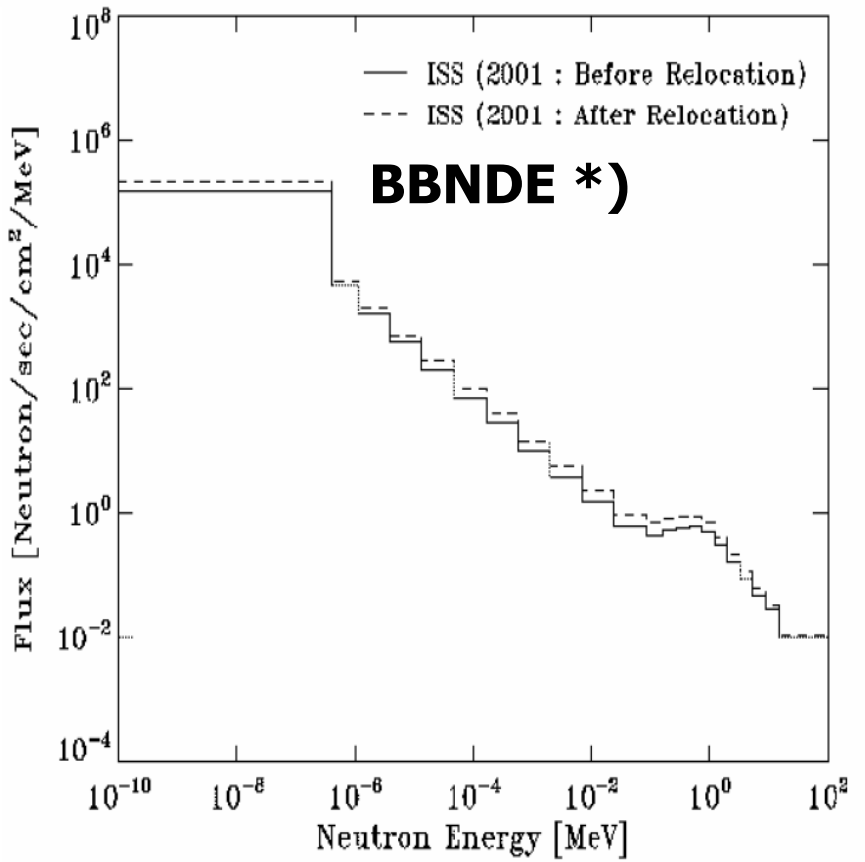
VNIIEF (Sarov),

Kurchatov INE (Moscow)

Khlopin RI (Sankt- Petersburg)

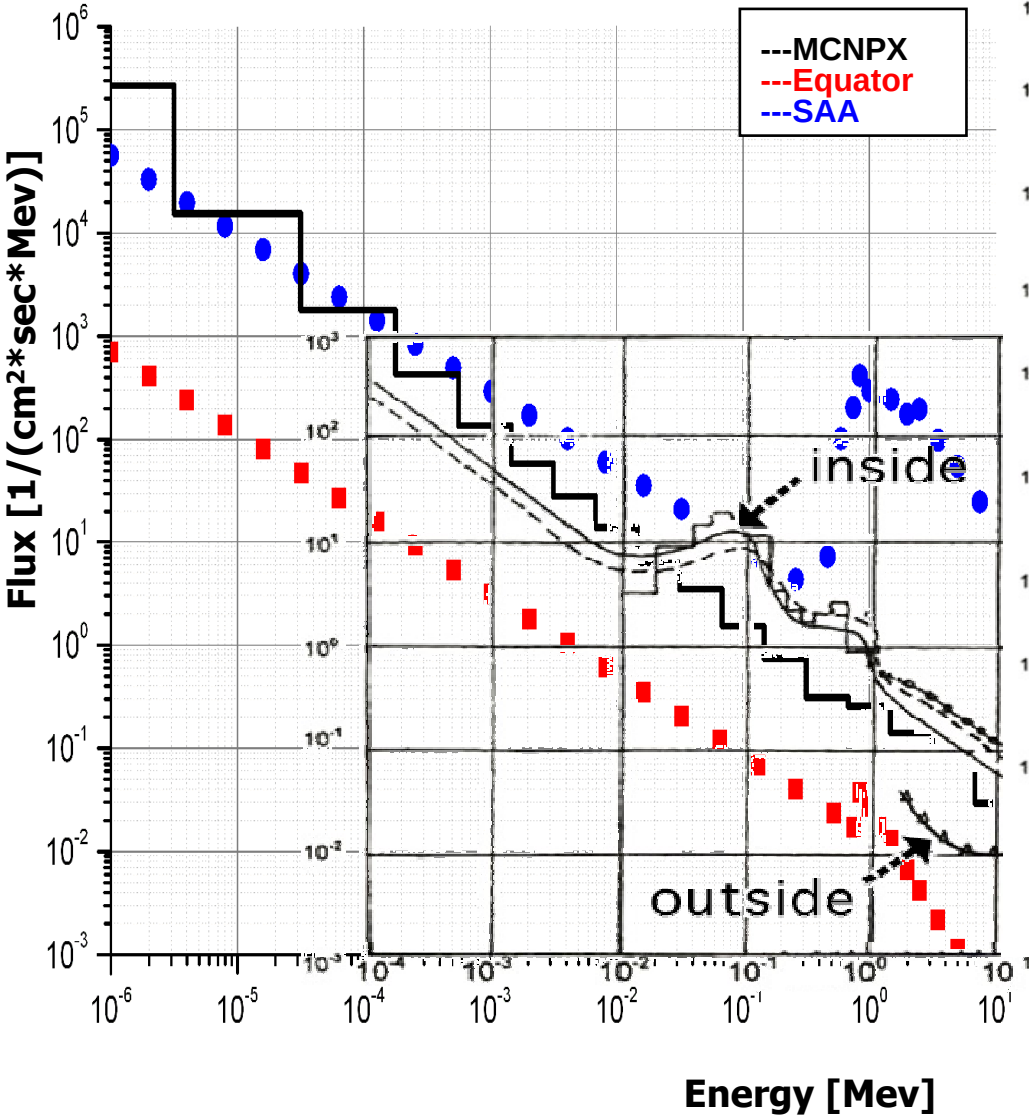
1. Spectra: Neutron spectra convolution

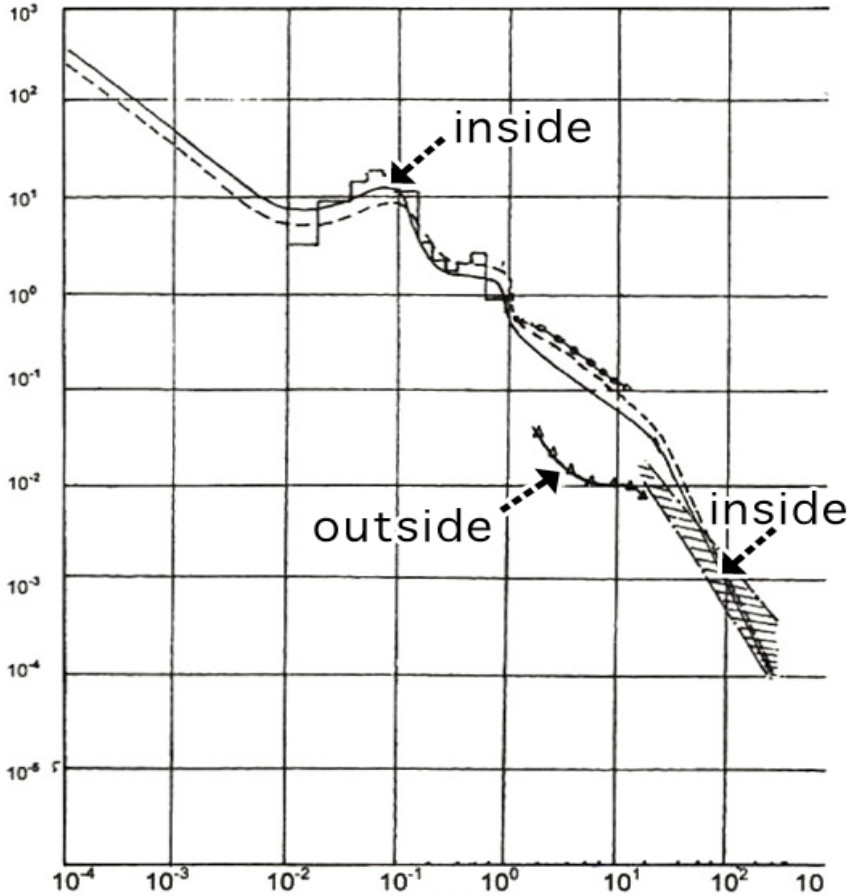




***) Evaluation of neutron radiation environment inside the ISS based on Bonner Ball Neutron Detector Experiment (H. Koshiishi, H. Matsumoto, e.c., // Proc. 9th WRMISS, 2001)**

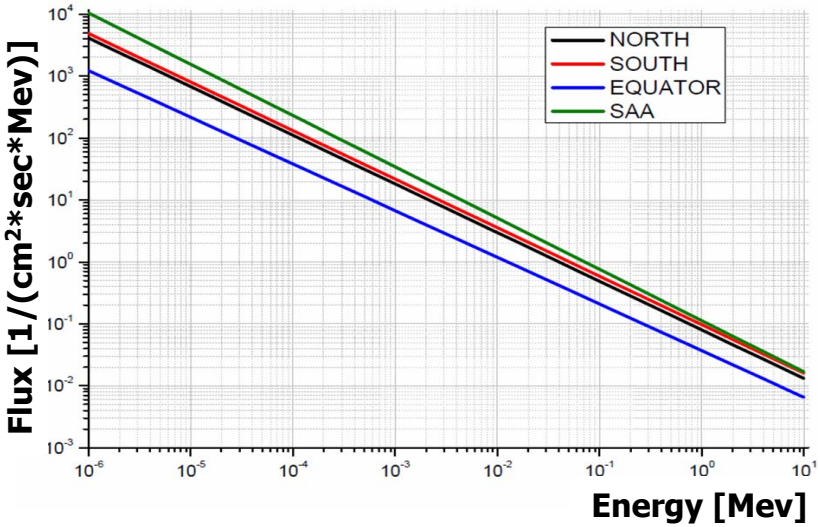
1. Spectra: Neutron spectra convolution

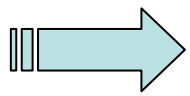


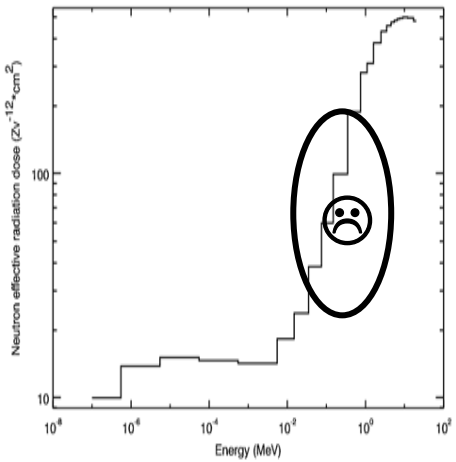


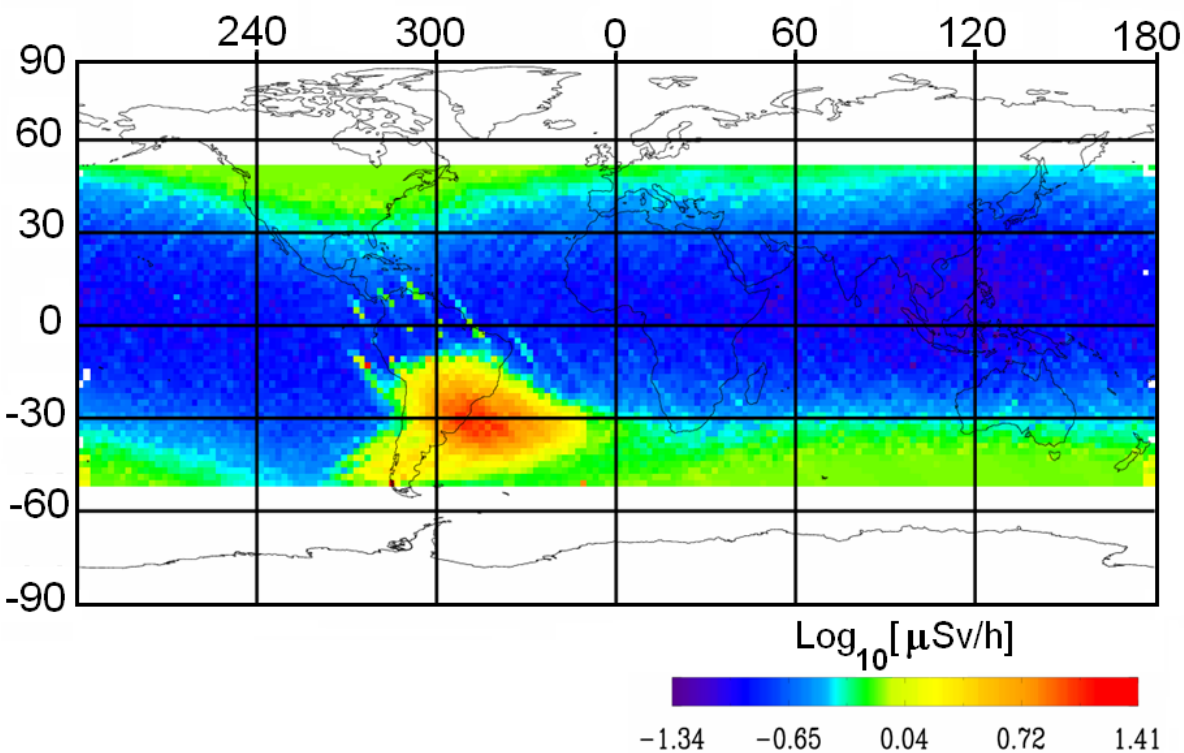
Neutron spectra inside and outside Mir station measured with different instruments, V. I. Lyagushin, V.E. Dudkun et al., Radiation Measurements, 33 (2001), 313-319

1. Radiation: Neutron dozes near Earth

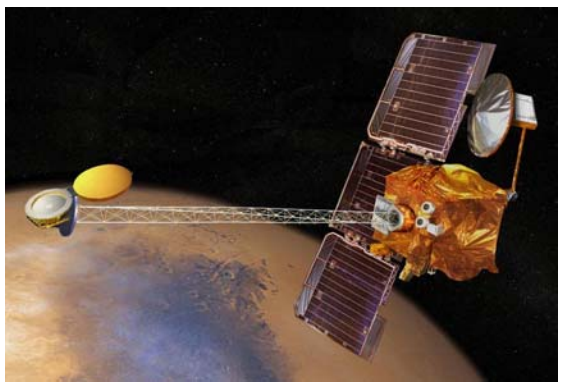








1. Radiation: Neutron dozes near Earth, Mars and Moon



HEND/MO 2001

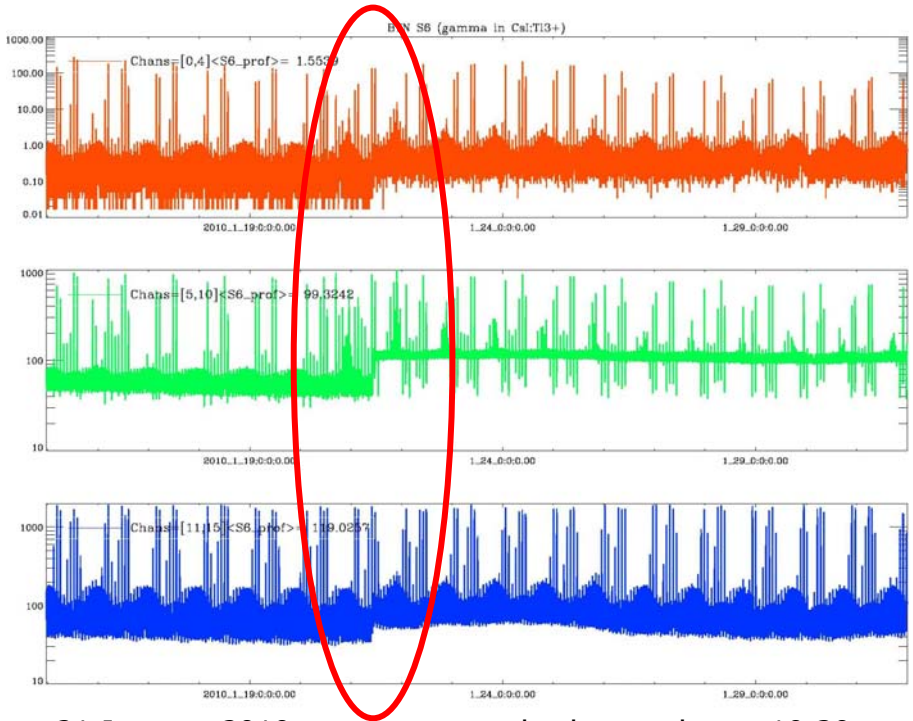
BTN-M1/ISS 2006

LEND/LRO 2009

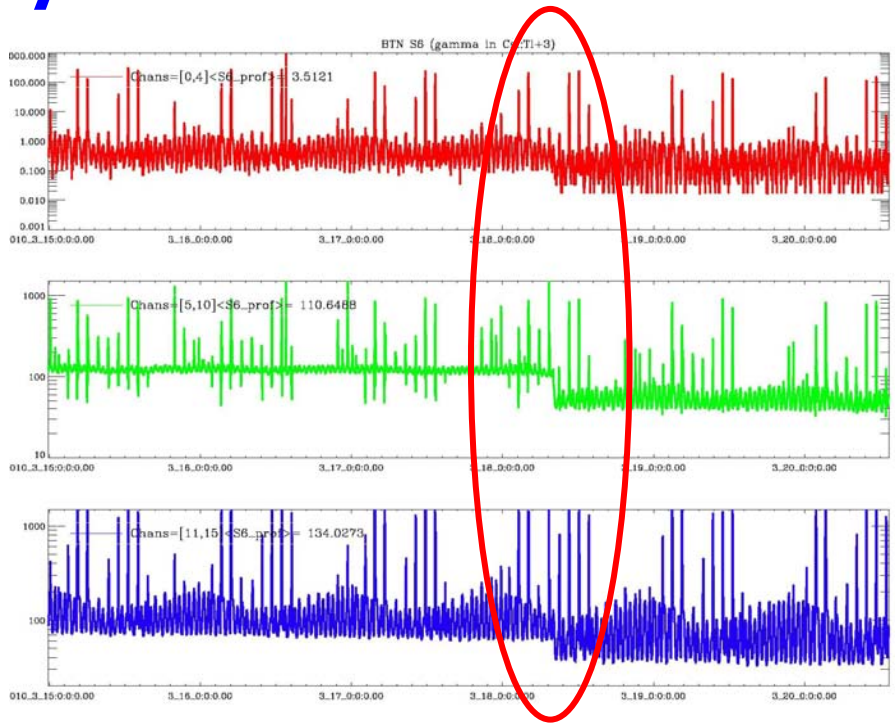
1. Radiation: Neutron dozes near Earth, Mars and Moon

Experiment	Conditions & Detectors	Neutron doze rate [μSv/h]
BTN / ISS	Outside ISS 3 He^3+SC (Stylbene) 0,4 eV- 10 MeV	0.2 (Equator) 2.0 (High latitude areas) 5.0 (SAA)
HEND / MO	Outside MO 3 He^3+SC (Stylbene) 0,4 eV- 10 MeV	1,1 (Solis Planum) 0,8 (High latitude areas) Rem.!
LEND / LRO	Outside LRO 8 He^3+SC (Stylbene) 0,025 eV - 10 MeV	5.0 (on orbit) Rem.!

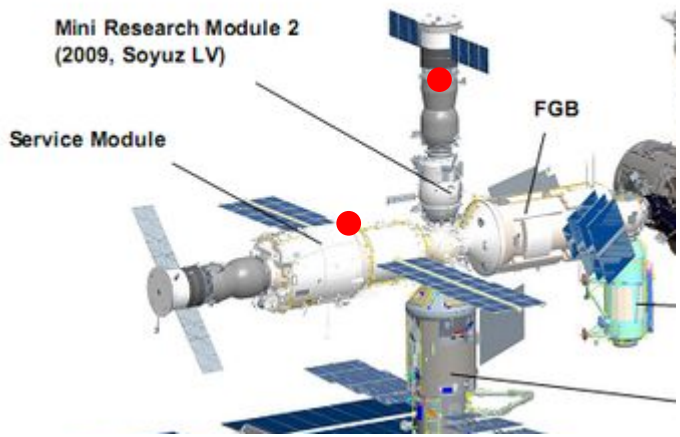
1. Radiation: Gamma from "Soyuz"



21 January 2010 step in gamma background near 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 March 2010 step in gamma background near 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



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

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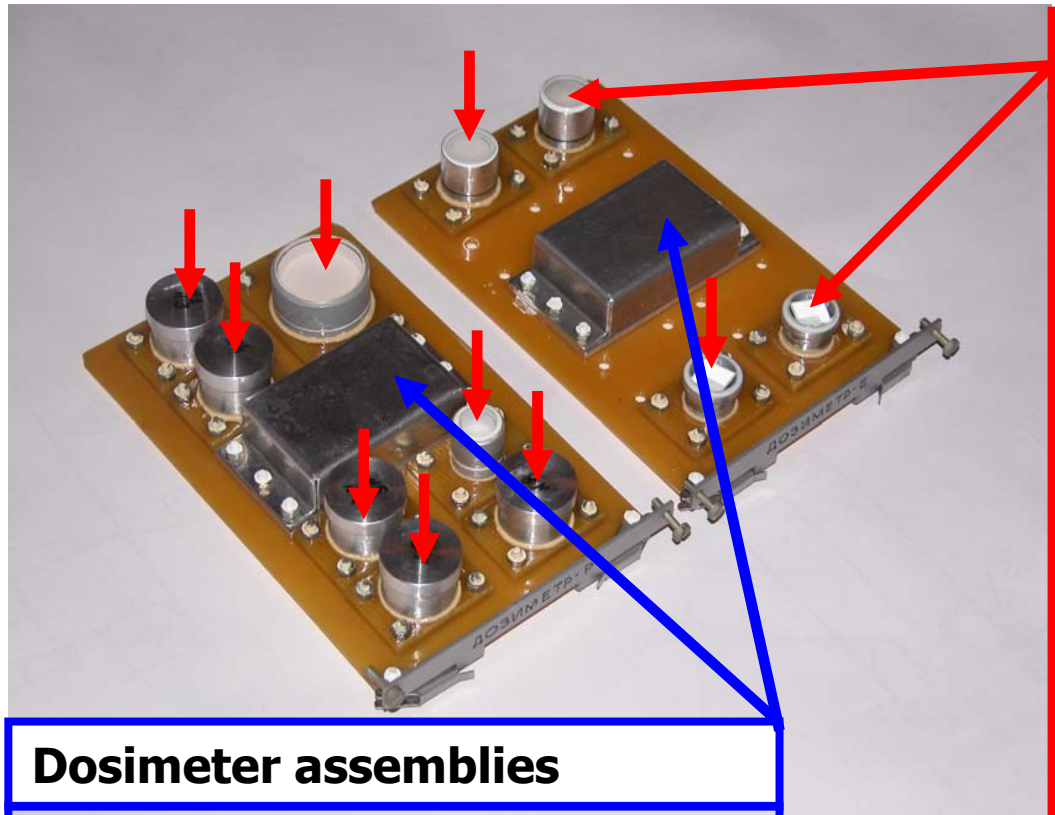
2. **(additional 1) Study of radiation damage and degradation the new perspective scintillation crystals for future space science applications DONE**
3. **(additional 2) Detect of Gamma Ray Bursts "simultaneously" with HEND/Mars Odyssey and other spacecrafts. IN PROGRESS!**

2. Scintillator samples: Design



Dosimeter assemblies

Solid state thermo luminescent dosimeters DTG-4 (IMBP, Russia)

Plastic track detectors TASTRACK (IMBP, Russia & TASL Co, UK)

Samples of scintillator

Board # 1 (Europe)

$(LuAl)O_3:Ce^{3+}$

$LaBr_3:Ce^{3+}$

$(LuY)SiO_5:Ce^{3+}$

$LaC1_3:Ce^{3+}$

(Delft University of Technology, Netherlands)

Board # 2 (Russia)

$(Lu_{0.5}Y_{0.5})\ AlO_3:Ce^{3+}$

$(Lu_{0.7}Y_{0.3})\ AlO_3:Ce^{3+}$

$(Lu_2SiO_5):Ce^{3+}$

$(Lu_2SiO_5):Ce^{3+}$

$(YAlO_3):Ce^{3+}$

$CsI:Tl^{3+}$

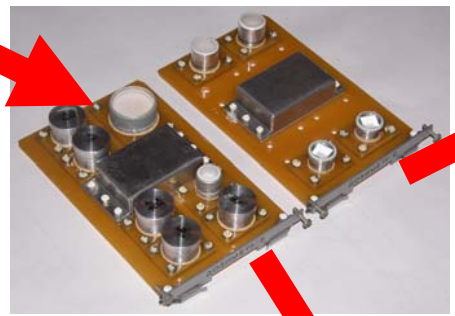
$NaI:Tl^{3+}$

(VIMS, Russia)

3 November 2006 - 22 October 2007

2. Scintillator samples: Return and Processing

Assemblies were returned onboard «Soyuz-TMA-10» 23 October 2007

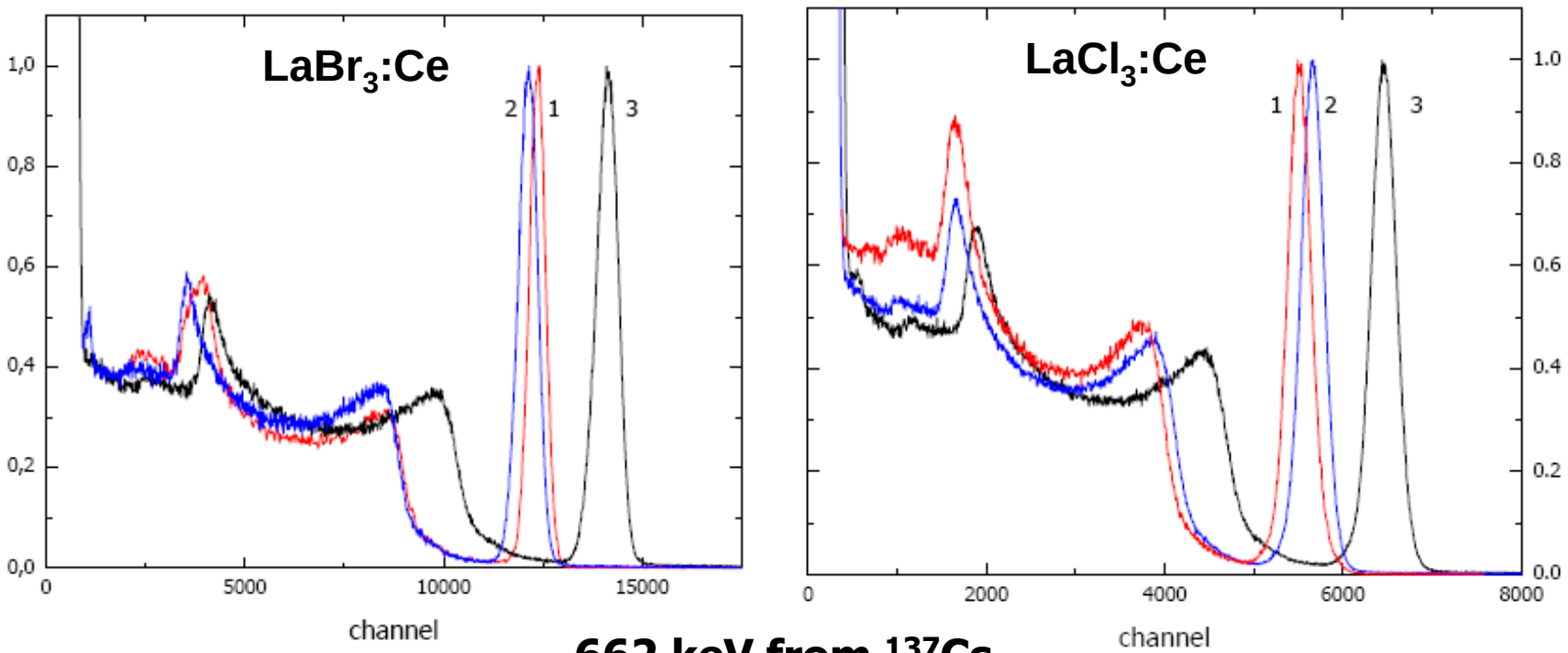


Radiation Measurement Research Section
Fundamental Technology Center
National Institute of Radiological Sciences,
Chiba, Japan

59.2 мГр

IMBP(Rus) **VIMS (Rus), ESTEC**

2. Scintillator samples: Results



662 keV from ^{137}Cs

Curve 3 – after manufacturing in 2004

Curve 2 – before assembling in IKI in 2005

Curve 1 – after returning from ISS in 2008 год

2. Scintillator samples: Results

Samples	Before flight		After flight	
	2004 year		2008 year	
	Yield [pho/MeV]	Resolution [%]	Yield [pho/MeV]	Resolution [%]
$LaBr_3$:5%Ce	**15800**	**3.4**	**12850**	**3.9**
$LaCl_3$:10%Ce	**7200**	**5.1**	**5617**	**5.7**
LYSO:Ce	**4730**	**9.5**	**4283**	**9.7**
LuAP:Ce	**800**	**13.0**	**772**	**14.4**

Delft University of Technology, Netherlands + ESTEC

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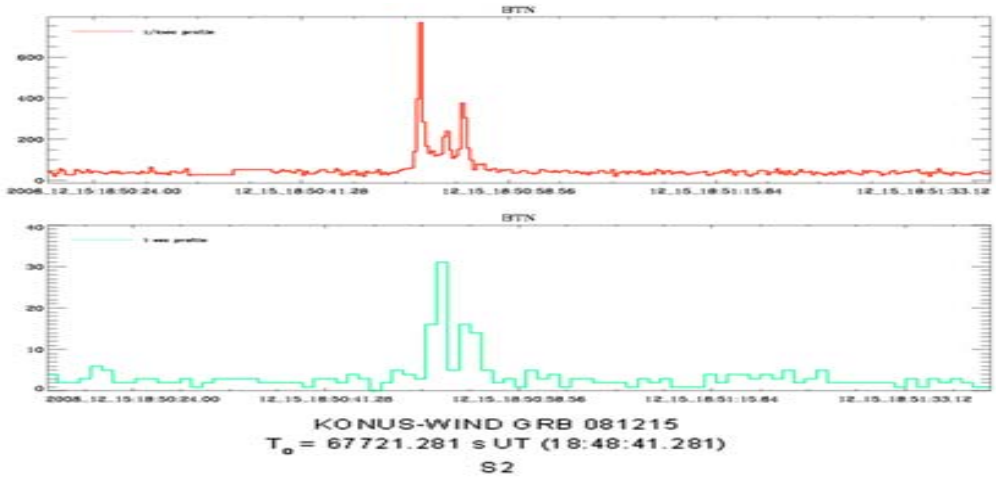
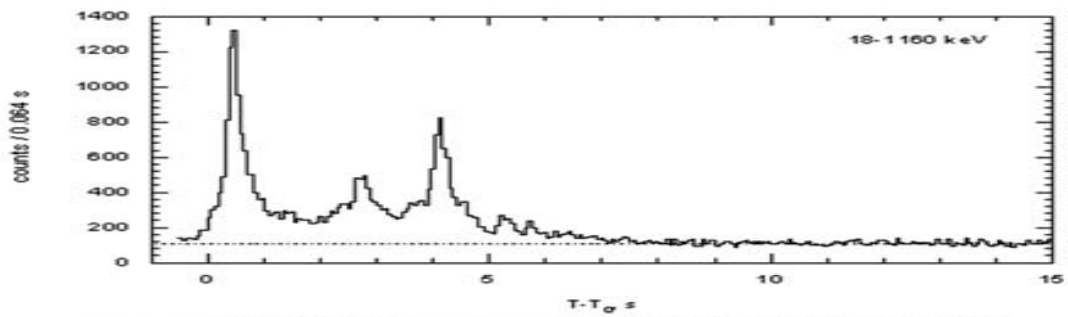
3. GRB registration

15 December 2008

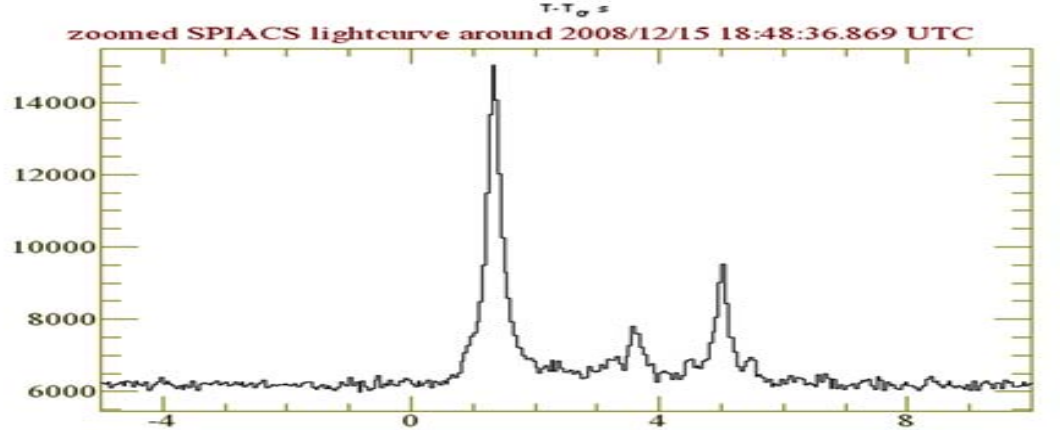
BTN / ISS



Konus / Wind



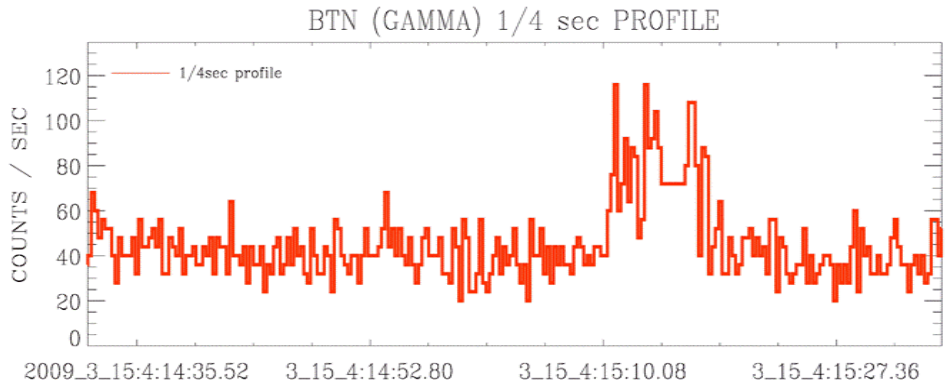
SPIACS/Integral



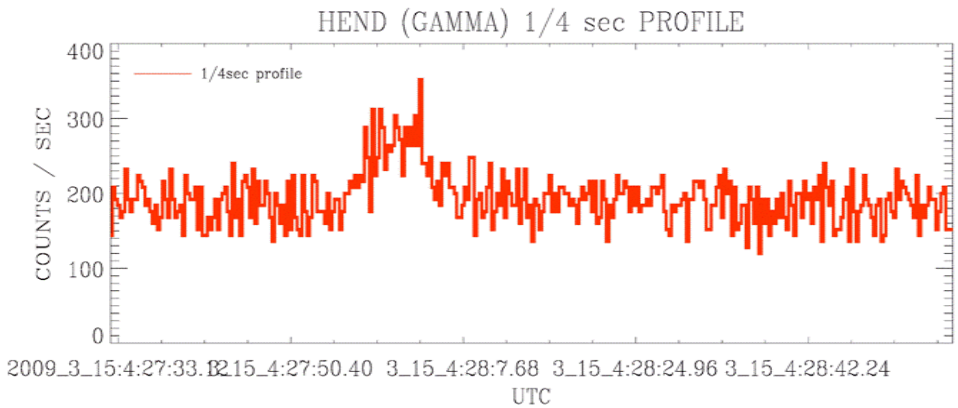
3. GRB registration

15 March 2009

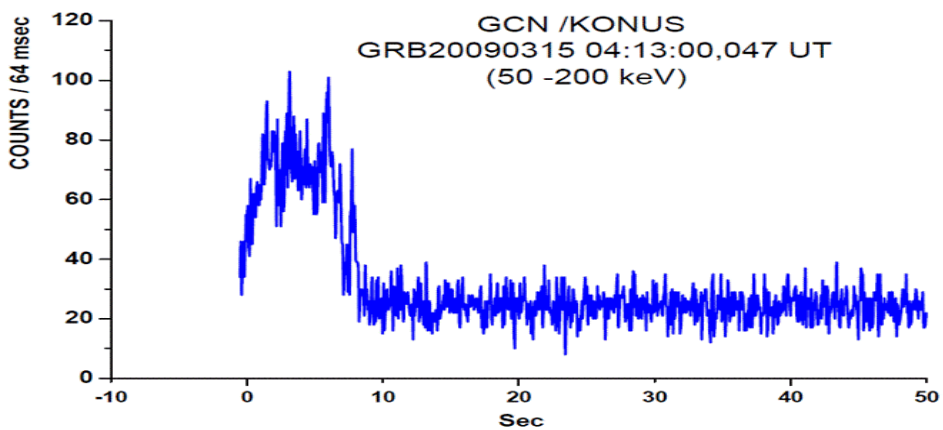
BTN / ISS



HEND / Mars Odyssey



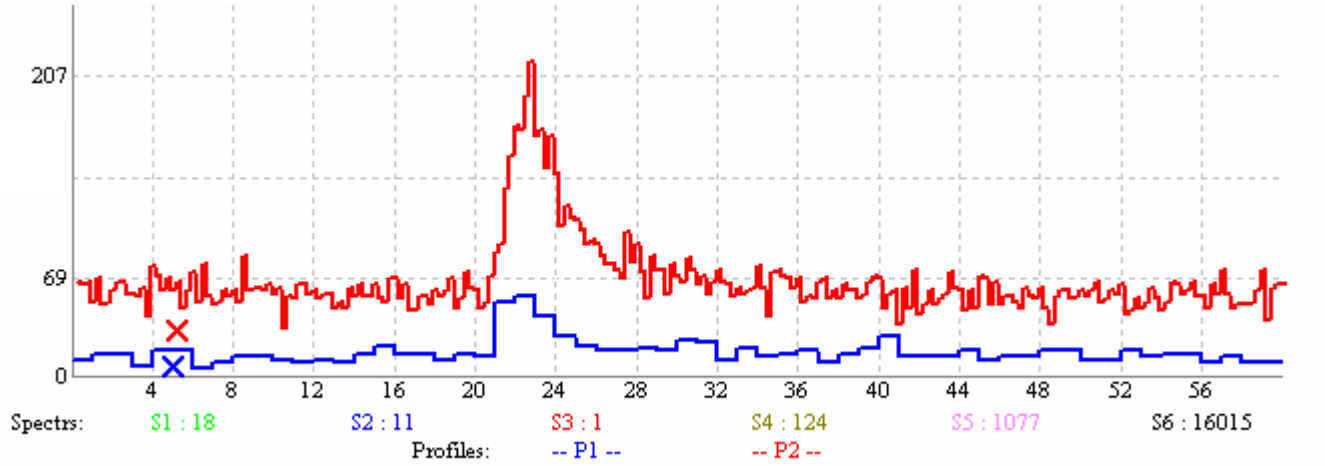
Konus / Wind



3. GRB registration

07 July 2010

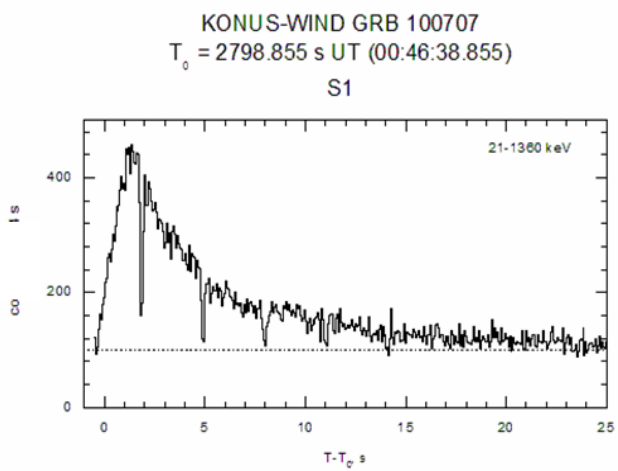
BTN / ISS



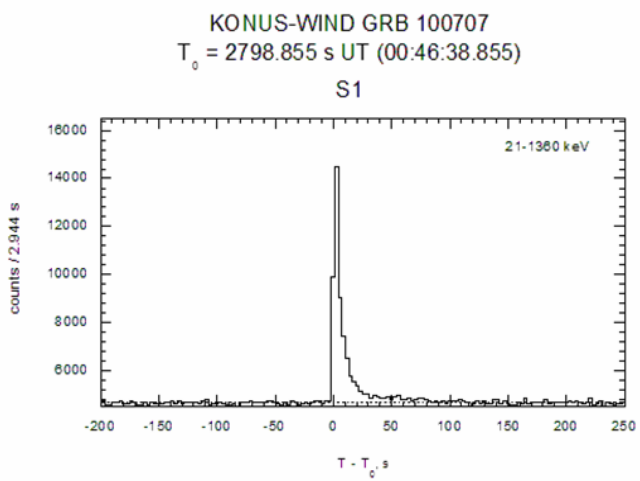
GRB 100707A Konus-Wind trigger time T_0=02798.855 s UT (00:46:38.855)

Konus / Wind

K-W light curve with 64 ms resolution (eps-file)



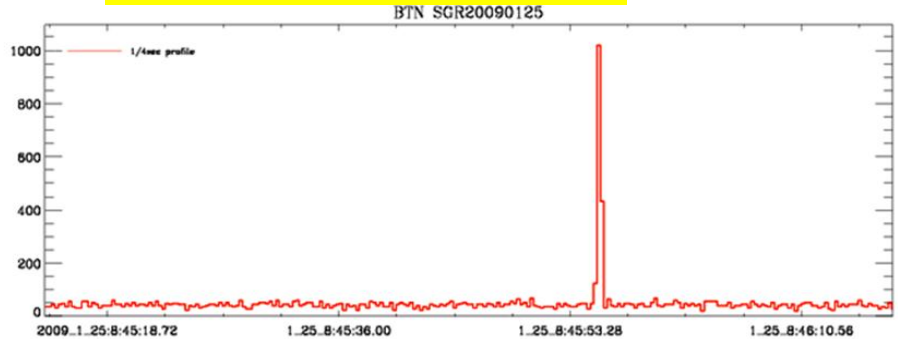
K-W light curve in Background Mode (eps-file)



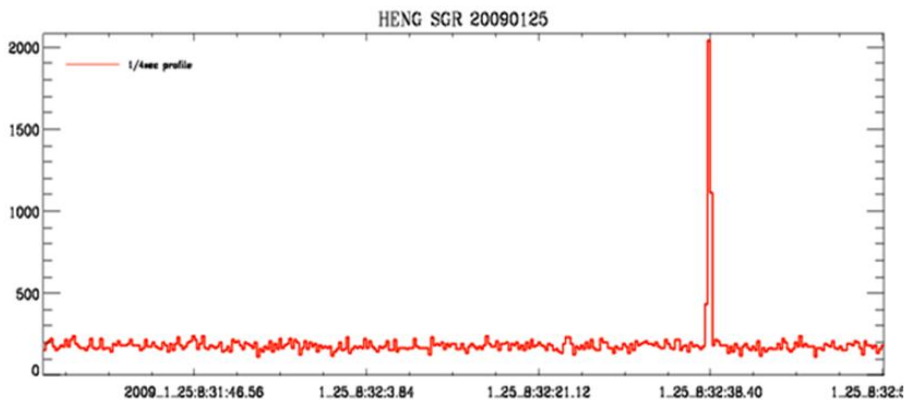
3. SGR registration

25 January 2009

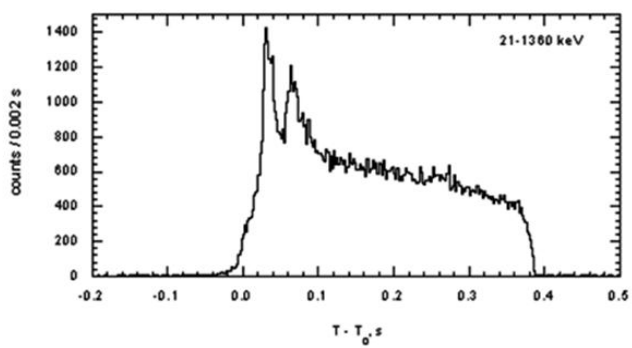
BTN / ISS



HEND / Mars Odyssey



Konus / Wind



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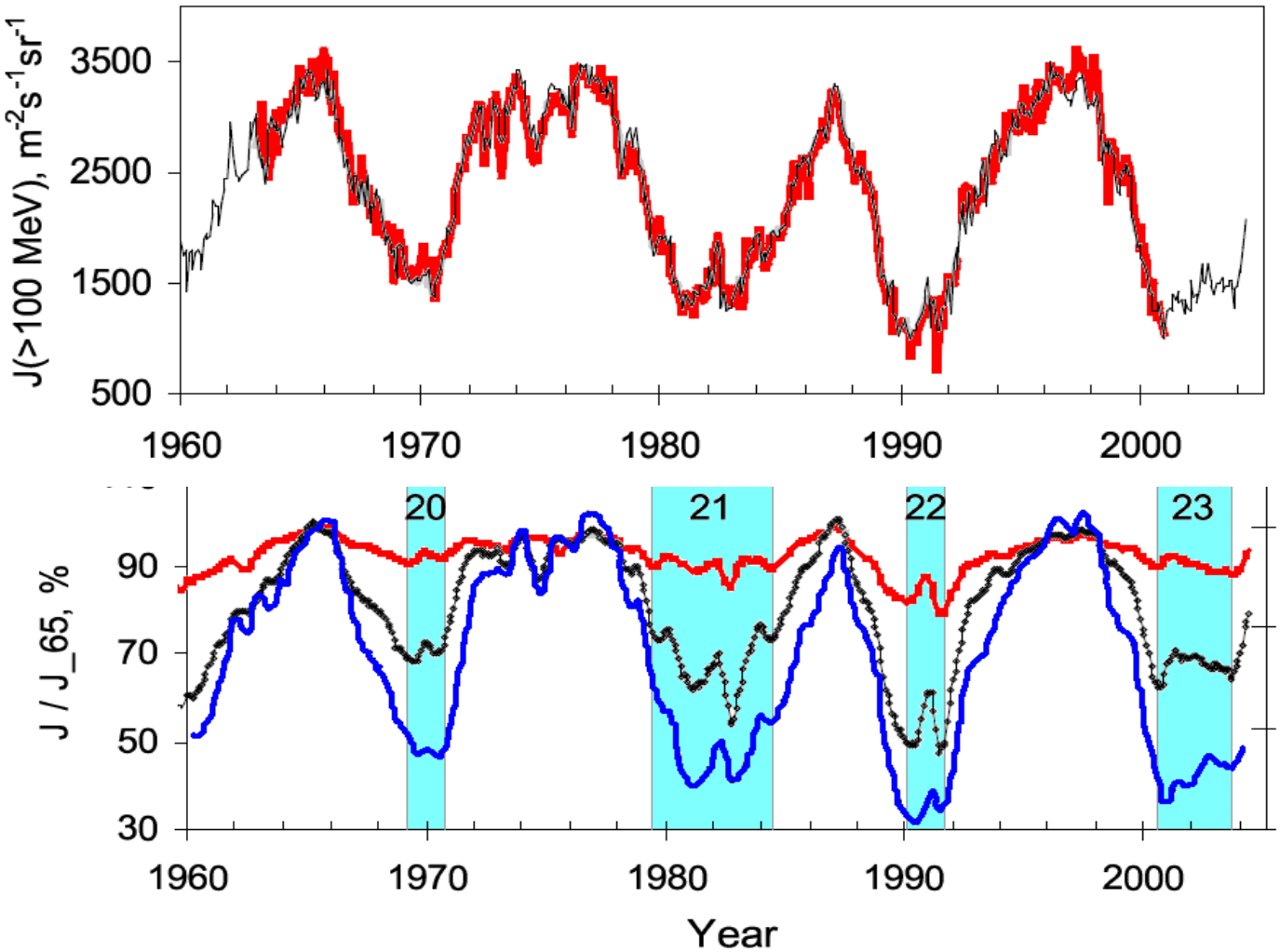
2. **(additional 1) Study of radiation damage and degradation the new perspective scintillation crystals for future space science applications DONE**
3. **(additional 2) Detect of Transient Gamma Ray Phenomena (GRB, SGR) "simultaneously" with HEND/Mars Odyssey and other spacecrafts. IN PROGRESS!**
4. **(additional 3 - new) Study of GCR trend. IN PROGRESS!**

4. GCR trend near Earth and Mars



Monthly averaged intensity of primary CRs with $E > 100$ MeV (balloon experiments in Arctic (Black-Murmansk) and Antarctic (Red - Mirniy)

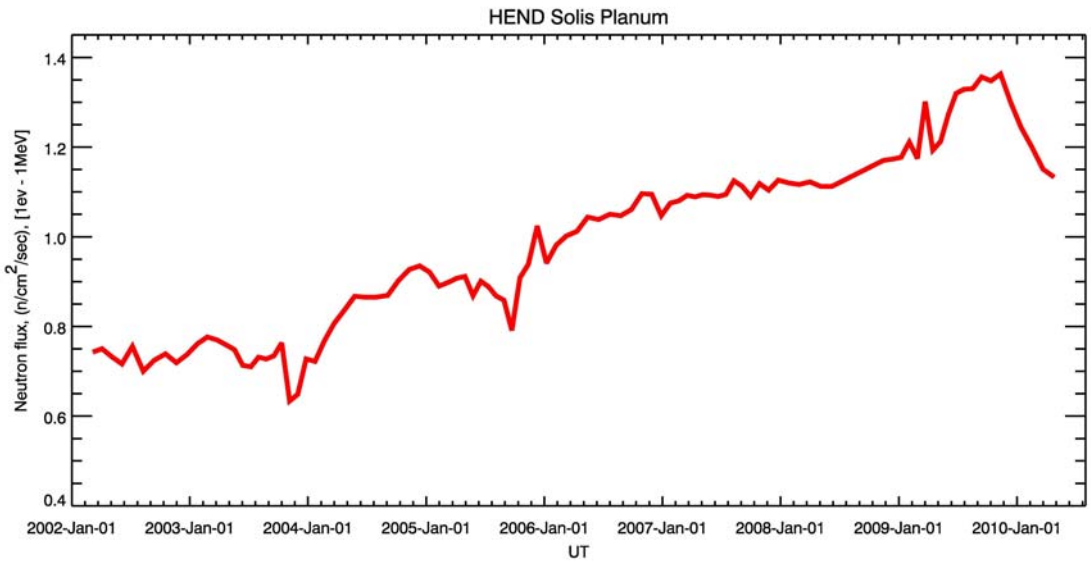
Blue: balloons experiment

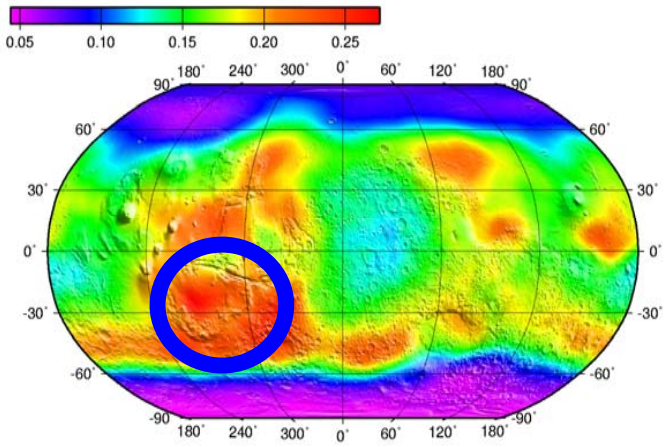
Red : NM Haleakala
Longitude : 203.72
Latitude:20.72
Altitude: 3030 m

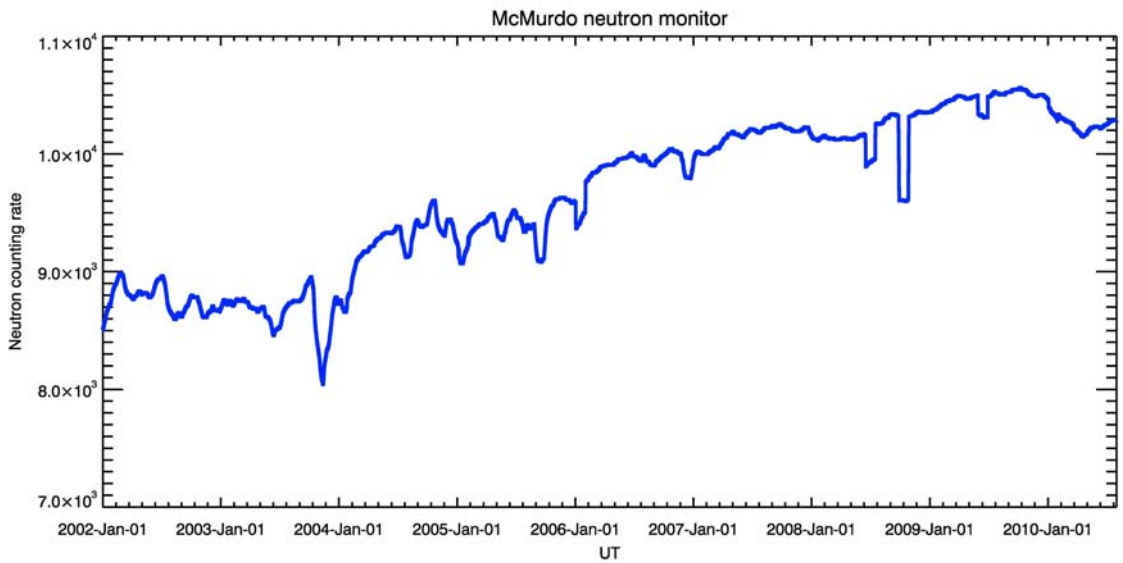
Black : NM Climax
Longitude : 253.82
Latitude:39.37
Altitude: 3400 m

CR intensity divided by its average value in 1965 and smoothed over 7 months. From "Cosmic ray fluxes in the maximum phase of solar activity cycles", G. A. Bazilevskaya, et al, International Journal of Modern Physics A, Vol. 20, No. 29, 2005

4. GCR trend near Earth and Mars

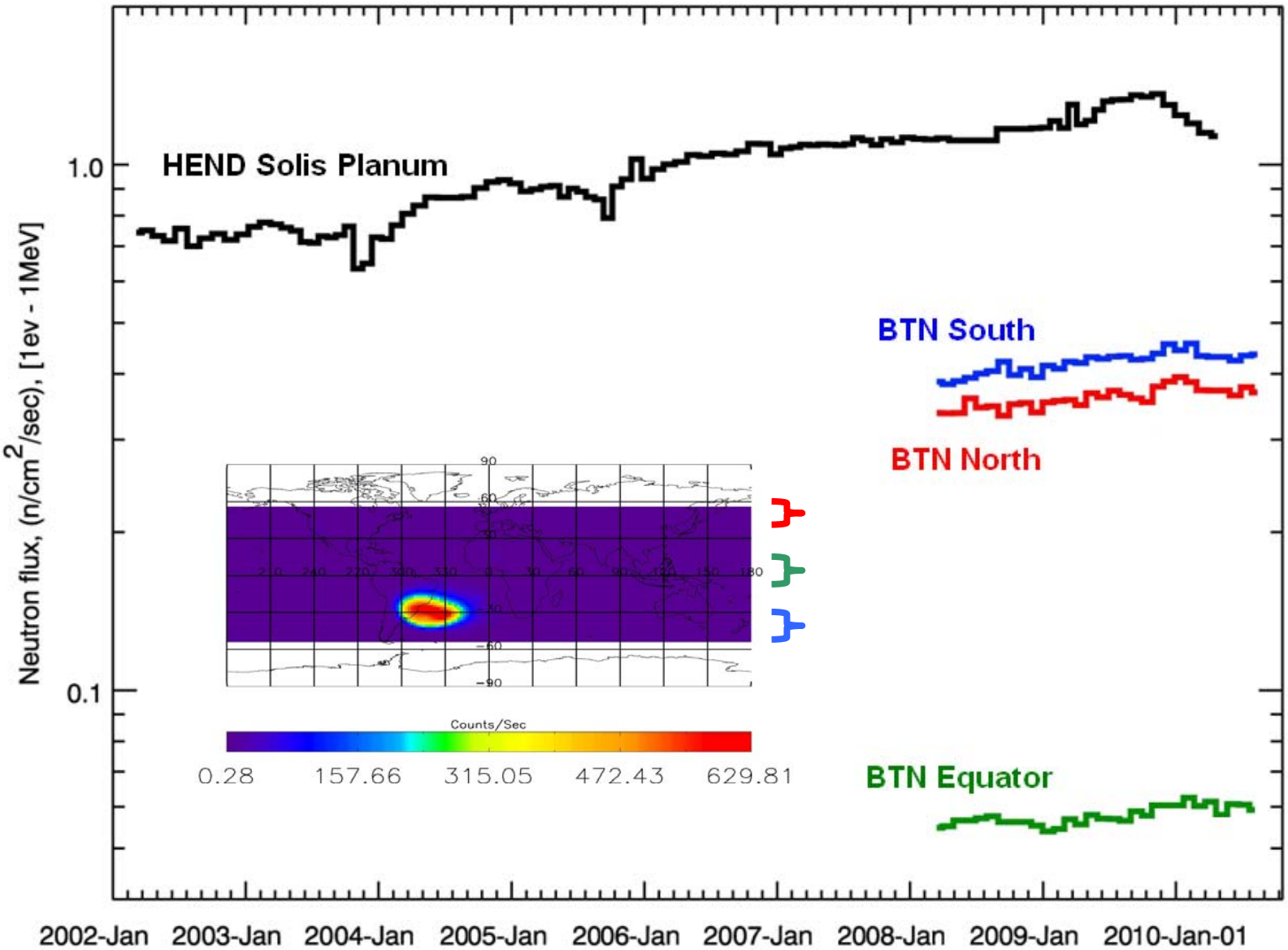






Station : McMurdo
Longitude : 77.9 S
Latitude 166.6 E
Altitude: 48 m

4. GCR trend near Earth and Mars



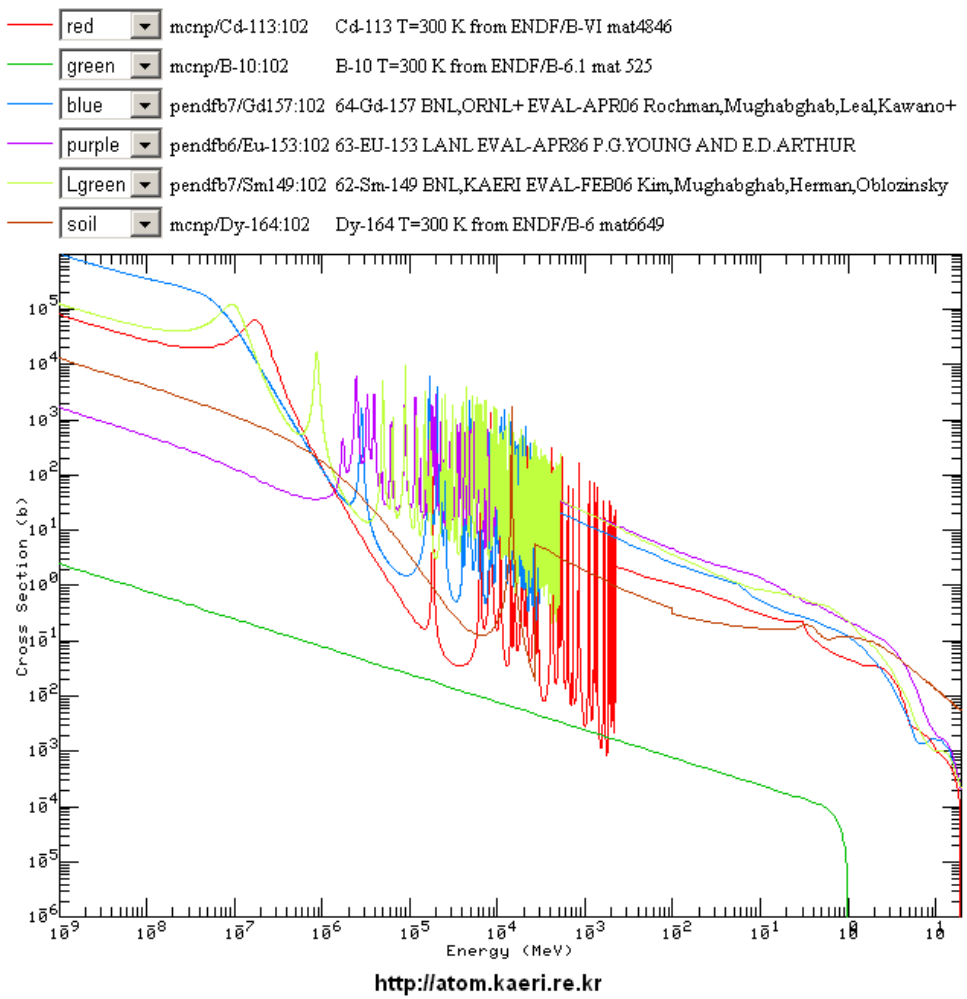
5. BTN-M2: scientific goals

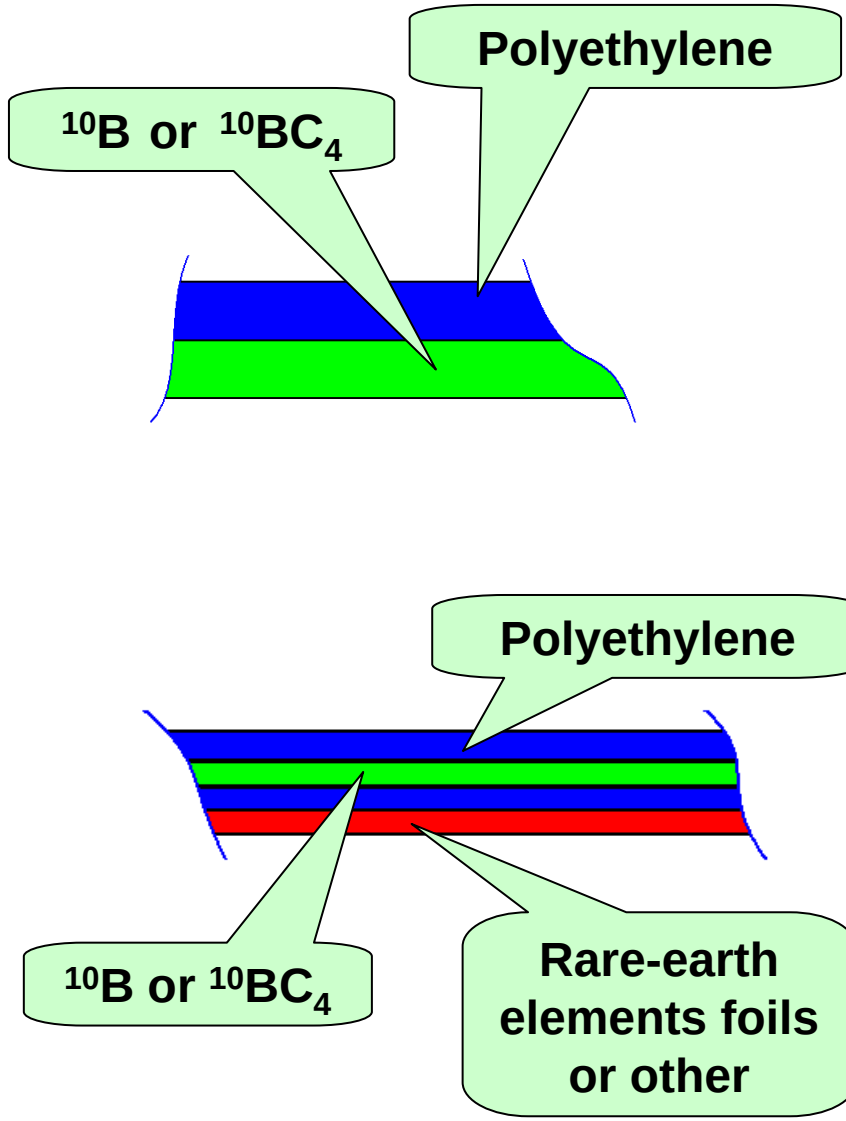
• **Measure of fluxes of neutrons in energy range from thermal energy (0.025 eV) up to fast (10 MeV) for radiation background study and comparison with data outside of ISS (from BTN-M1) for full neutron environment understanding;**

• **Measure of fluxes of gammas with high energy resolution (~3%) in energy range from 50 keV up to 10 MeV;**

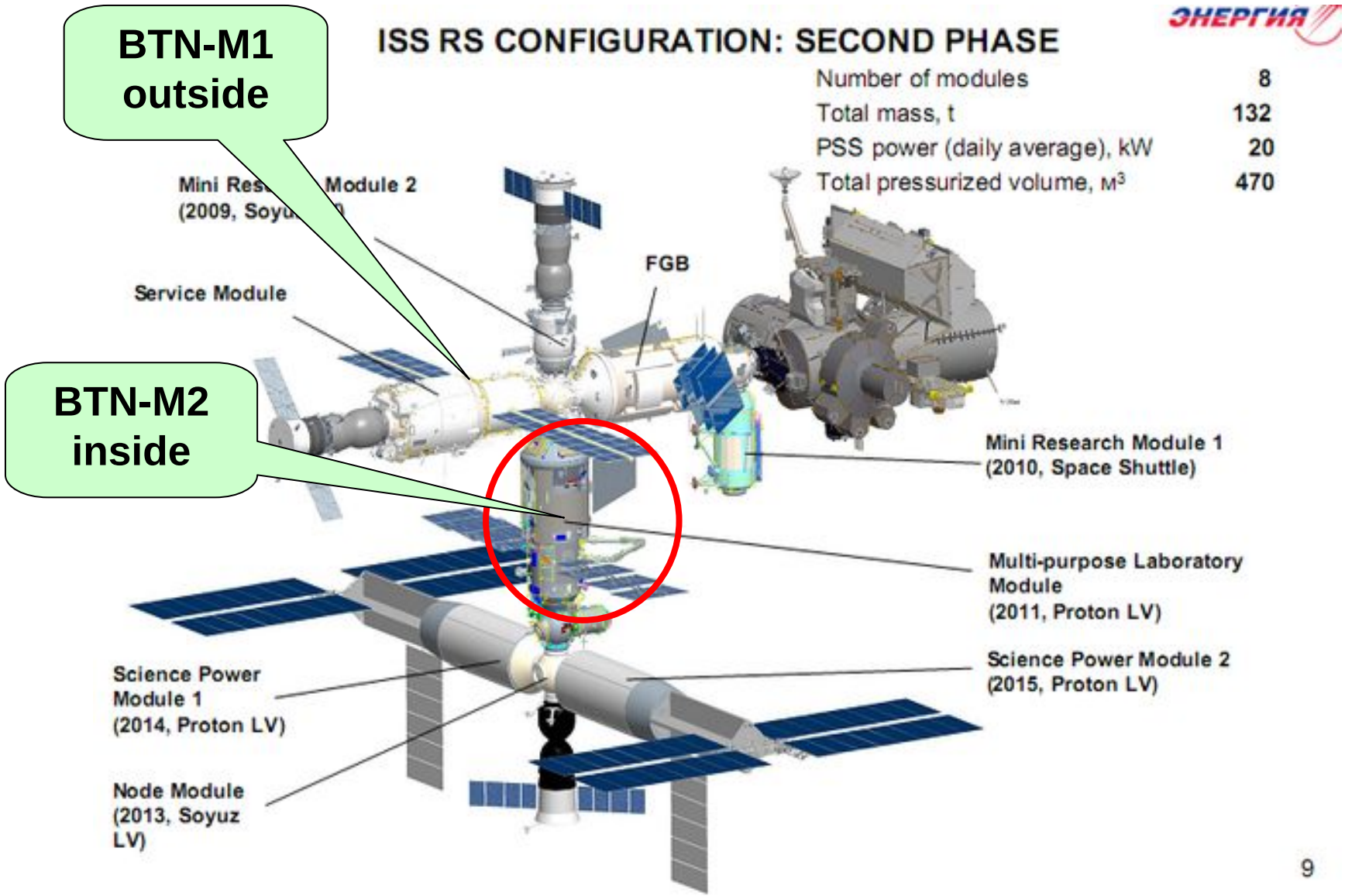
• **Tests of new materials and approaches for radiation shielding and safety during future deep space mission, astrophysics experiments and collimated detectors for nuclear planetology.**

5. BTN-M2: physics of shielding

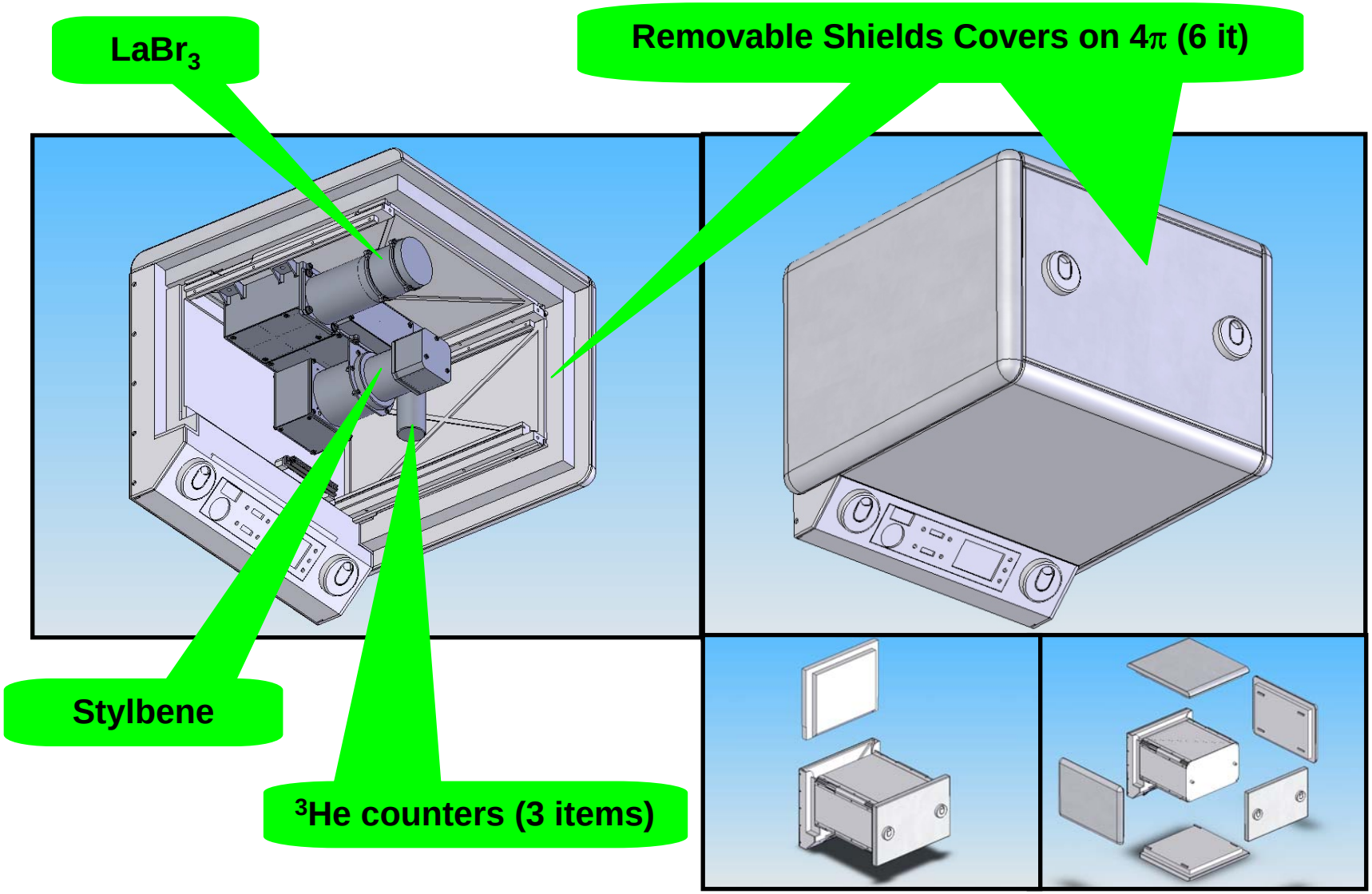




5. BTN-M2: allocation on ISS



5. BTN-M2: design



Measurements without shielding covers

Measurements in different shielding covers combinations

CONCLUSION & FUTURE TASKS

RESULTS

1. **All devices are operated successful !!!**
2. **Neutron spectra and doses estimation done (0.4 ev – 1 Mev)**
3. **$LaBr_3$:Ce detector selected for:**
   - **BTN-M2/ MLM of ISS (2014)**
   - **MGNS/BepiColombo (Mercury orbital SC, ESA, 2014)**
   - **NS-HEND/Fobos-Grunt (Phobos Lander, Russia, 2011)**
   - **ADRON-LR/Luna-Resurs+Chandrayana-2 (Russian Moon Lander, 2013)**

TASKS

1. **Obtain high energy spectra (> 1 Mev) from BTN stylbene data**
2. **Convolution of spectra for all energy range of device and doses too**
3. **Compare dozes in three point of Solar System for future space mission**
4. **MCNPX-modeling of Earth' neutron albedo with more accuracy**
5. **MCNPX-modeling of local neutron background ('Zvezda' mass model - ?)**
6. **Include BTN-M1 data to GCN (The Gamma-ray bursts Coordinates Network, http://gcn.gsfc.nasa.gov/)**
7. **Comparison GOES, ACE, HEND, BTN-M1 and LEND measurements for Solar activity**
8. **Continue monitoring of GCR trend**
9. **BTN-M2 design and manufacturing**

Thank you!