15th Workshop on Radiation Monitoring for the International Space Station
7-9 September 2010, University of Rome "Tor Vergata"

Portable High-Energy Neutron Spectrometer (PHENS) for Active Diagnostics of Radiation Environment in Spacecraft

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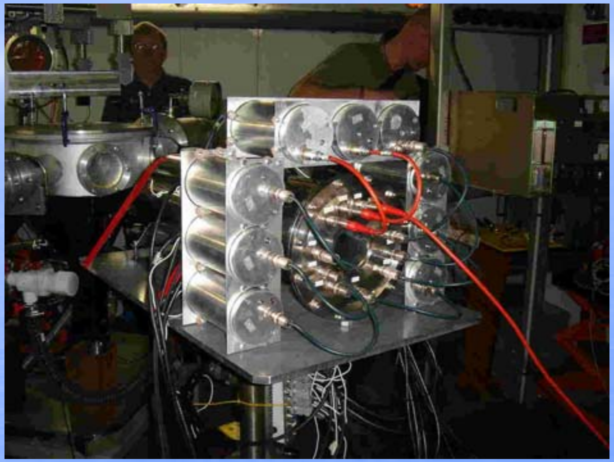
Outline

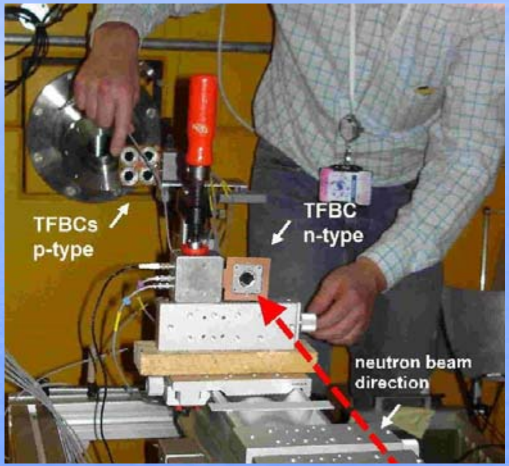
- Introduction
  - The brief historical note
  - Methodical approach
- PHENS design
  - Detector module
  - Preliminary calibration
- Future development

The KRI detectors for space experiments

- He-3 counters (Tsvetkov, 1975)
- Nuclear photoemulsions (Dudkin, 1991)
- Nuclear track detectors (Nikolaev, 2002)
- Gamma Spectrometer SPIN-6000 (Rimski-Korsakov, 1989-1990) for orbit space station “Mir”

The KRI detectors for neutron flux monitoring at the European high energy neutron beam facilities





The Svedberg Laboratory (TSL), Uppsala, Sweden.

Quasimonoenergetic and "white" spectrum neutron beams up to 180 MeV.

Since 1998 neutron monitors based on the TFBC and IC are permanently installed

The Université Catholique de Louvain (UCL), Louvain-la-Neuve, Belgium.

Quasimonoenergetic neutron beams up to 60 MeV.

Since 2002 measurements and neutron flux monitoring by means of MIC .

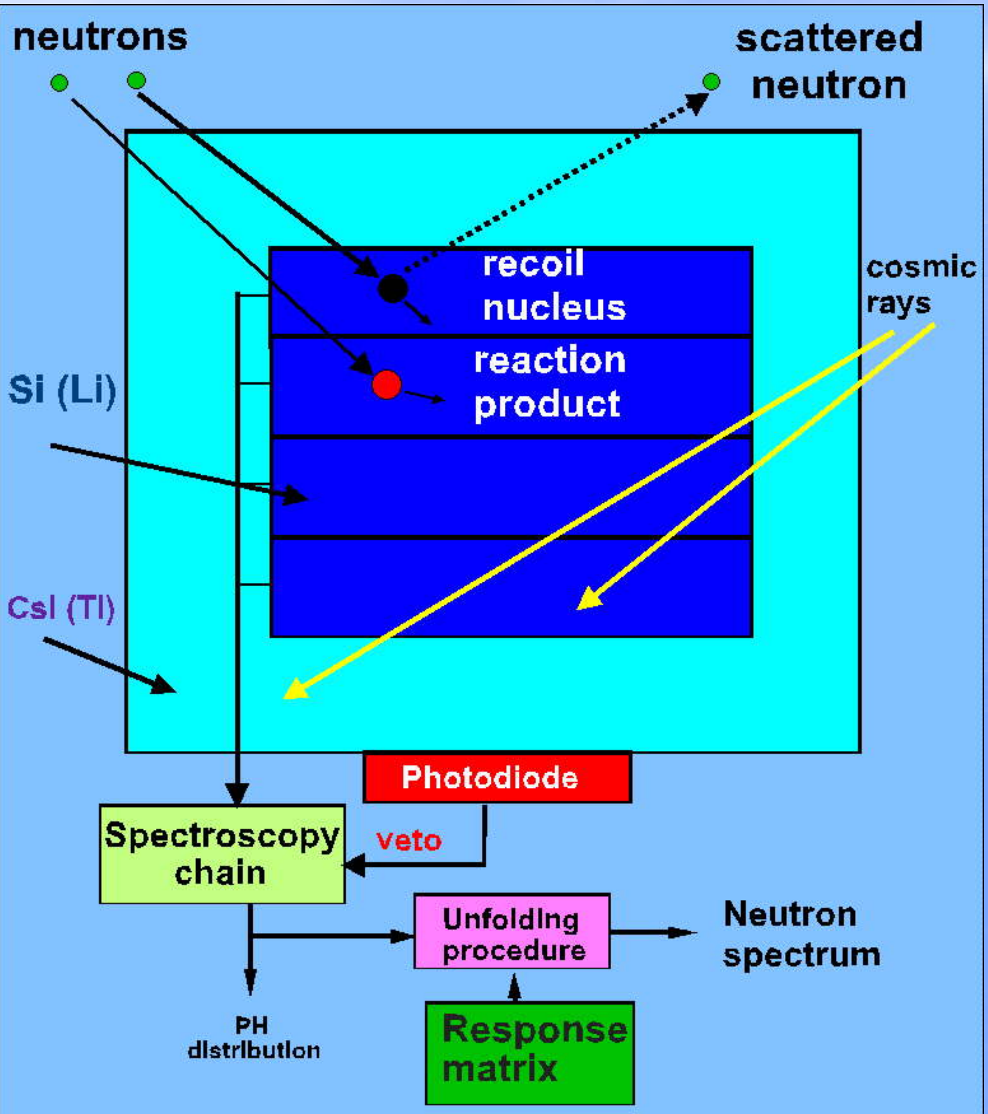
Fast Neutron Irradiation ISIS Facility, Rutherford Appleton Laboratory, UK.

"White" spectrum neutron beam up to 800 MeV.

Characterization of high energy neuron field by means of the TFBC technique (2009).

PHENS: principle of operation

Presented work follows an idea suggested by Maurer et al. [Acta Astronautica 52 (2003) 405] for the Mars Neutron Energy Spectrometer (MANES).



Neutrons colliding with silicon nuclei undergo elastic (n,n') and nonelastic (n,p), (n,a) … interactions.

The number of counts at a given deposited energy $C(E_D)$ is:

$$C(E_D) = \int R(E_D, E_N)\Phi(E_N)\mathrm{d}E_N$$

where $\Phi(E_N)$ is the neutron spectral fluence and $R(E_D,E_N)$ - response function of the detector

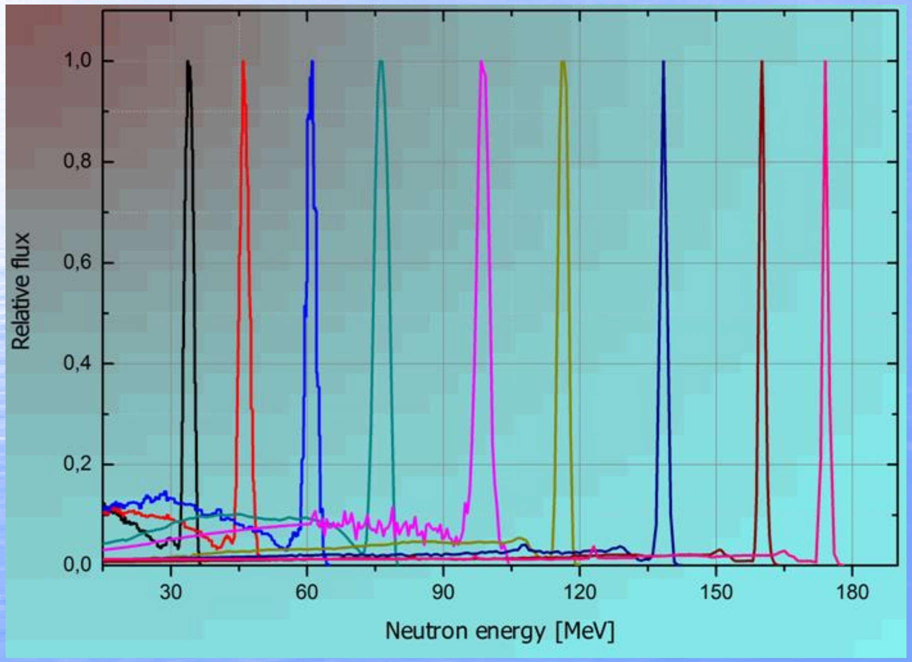
Neutron spectrum $\Phi(E_N)$ is determined by means of unfolding procedure using the accurately known response function

For this purpose, accurately characterized monoenergetic, quasimonoenergetic or "white" spectrum neutron reference beams are necessary.

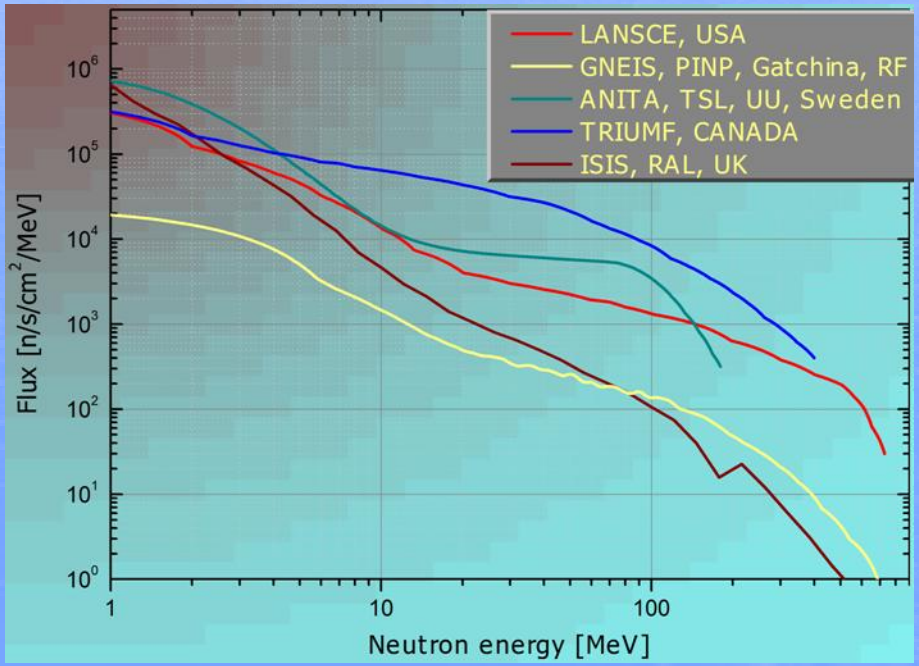
Available neutron beams for calibration measurements

Quasimonoenergetic neutrons

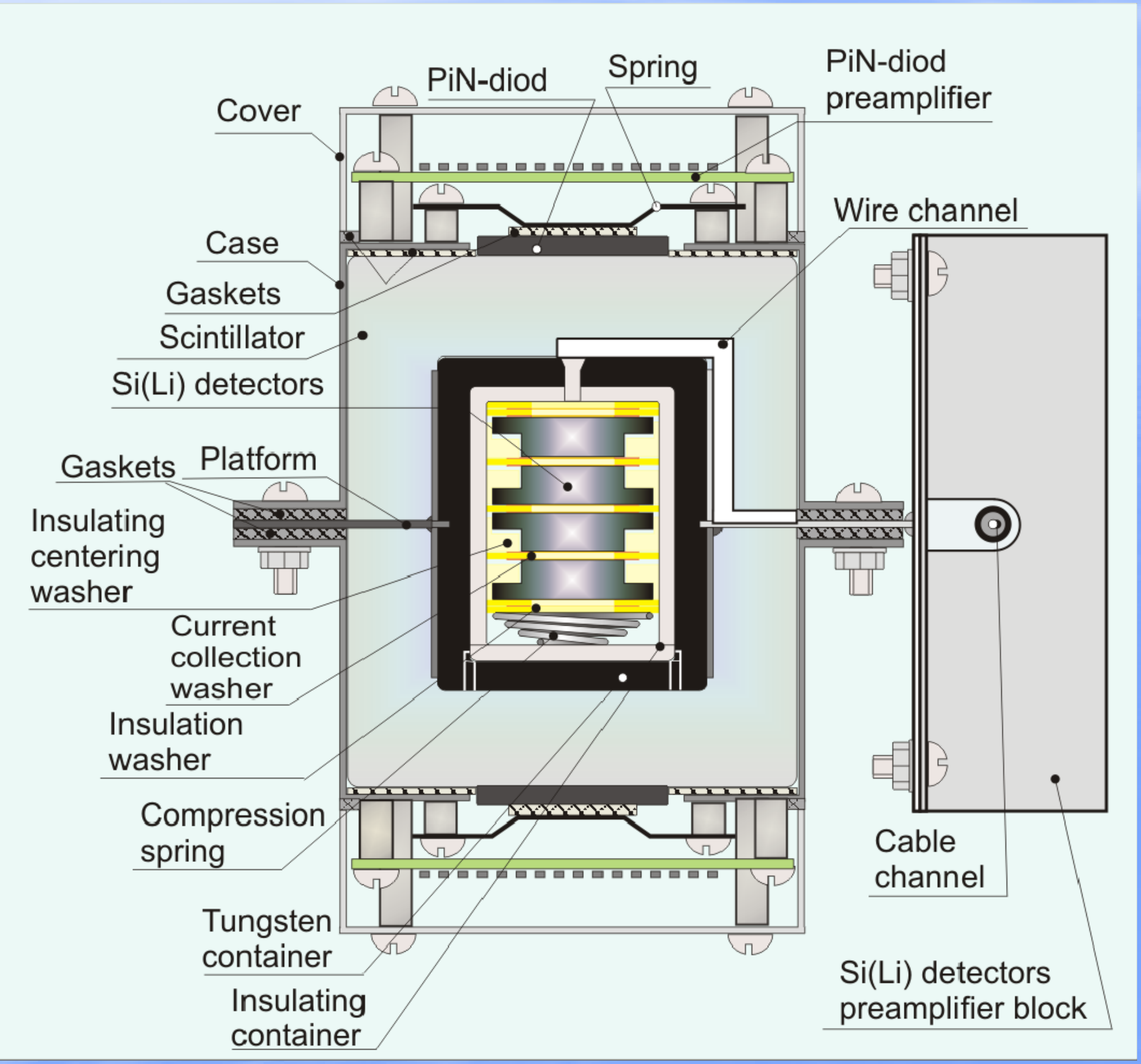
TSL, UCL, iTL, RIKEN, RCNP etc.



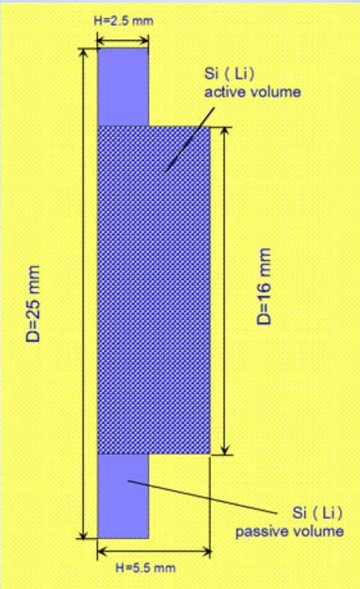
"White" spectrum neutrons

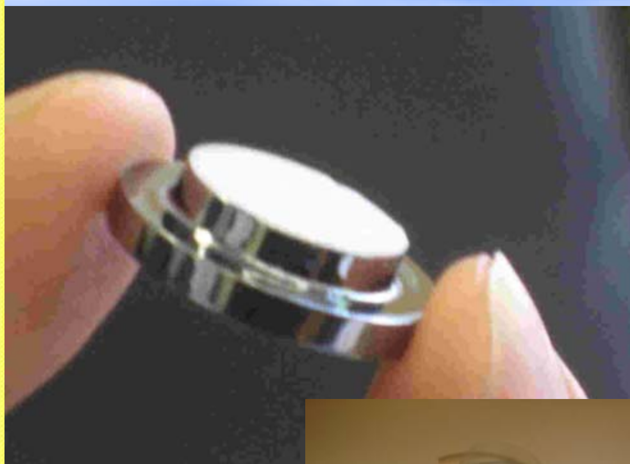


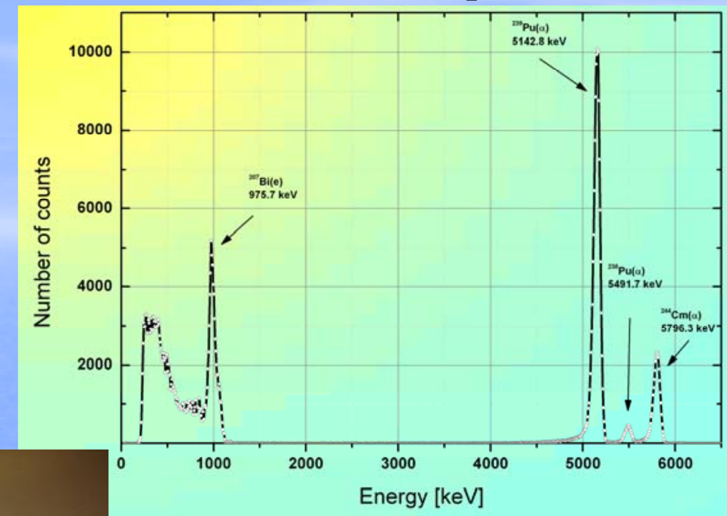
PHENS: design of the detector module



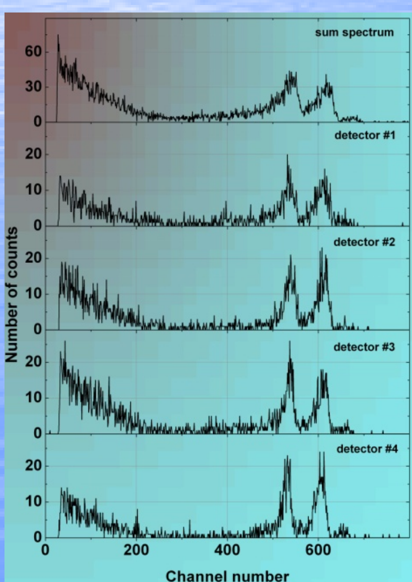
PHENS: device and spectrometry characteristics of the Si(Li) detector (producer – PINP, Gatchina)





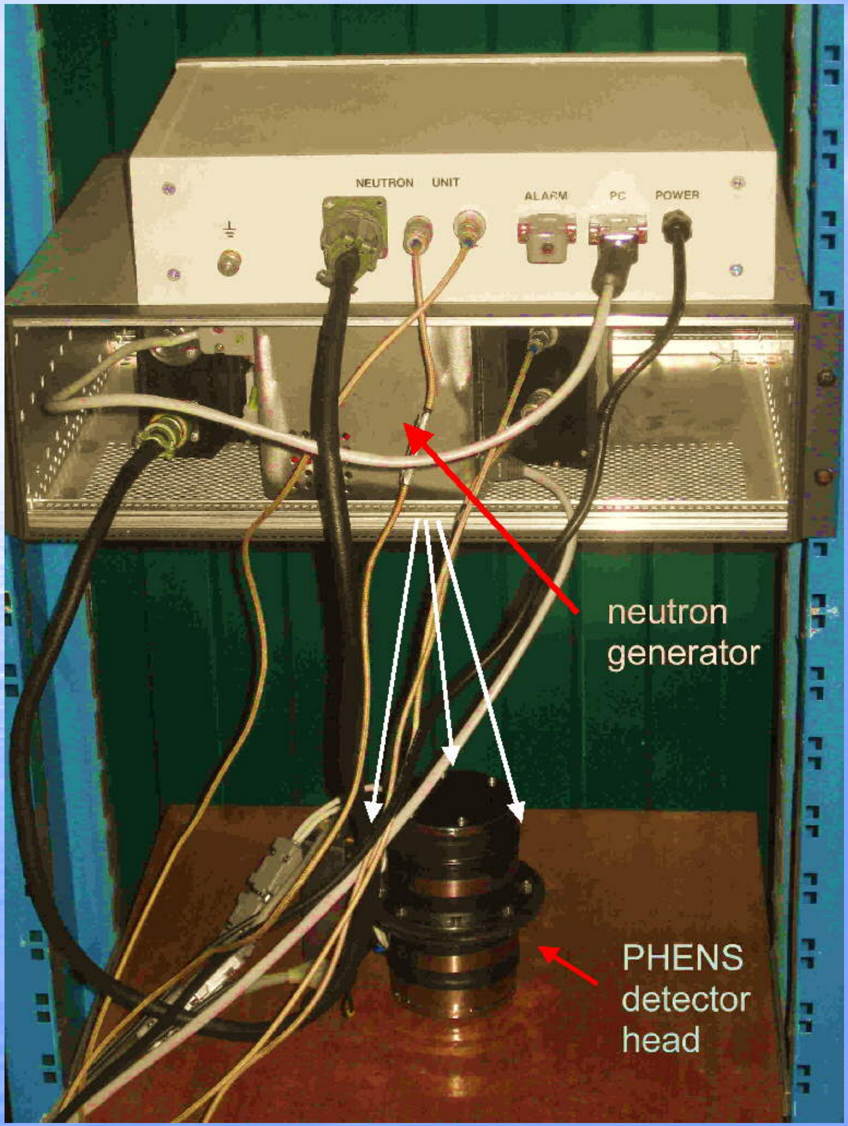


Total sensitive volume – 4 cm^3



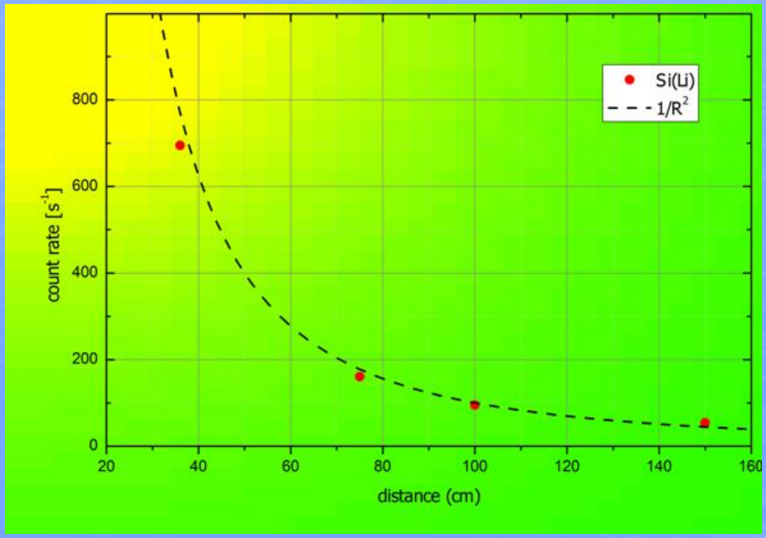
Four internal ^{nat}U α-particle sources (6 Bq each) provide checks of operationability and gain stability and energy calibration

PHENS: test measurements at 14 MeV neutrons (June 2010)



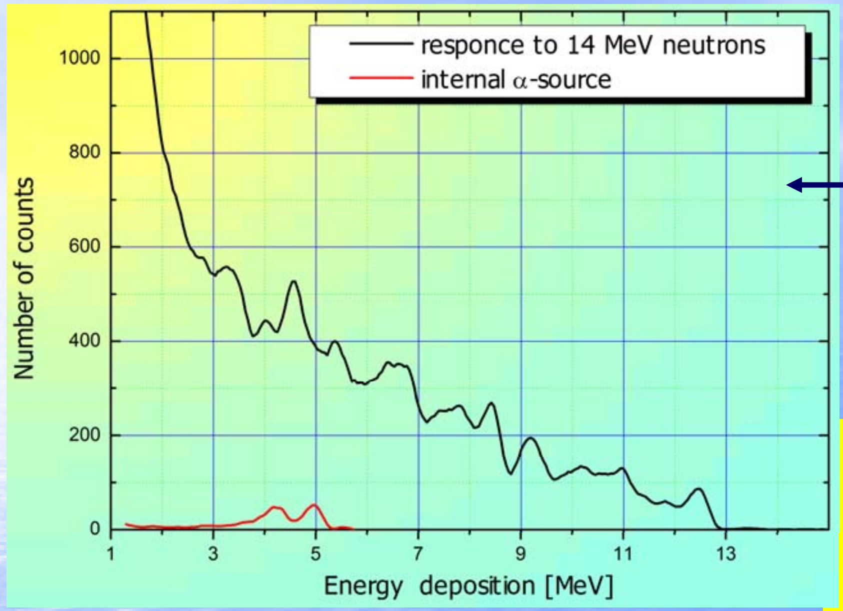
First calibration measurements at 14 MeV neutrons were performed using a D-T neutron generator. Neutron flux intensity was about $7x10^7$ s^{-1} in 4π.

Count rates and pulse height distributions of the Si(Li) detector were measured at different distances (30 – 150 cm) from the neutron source.



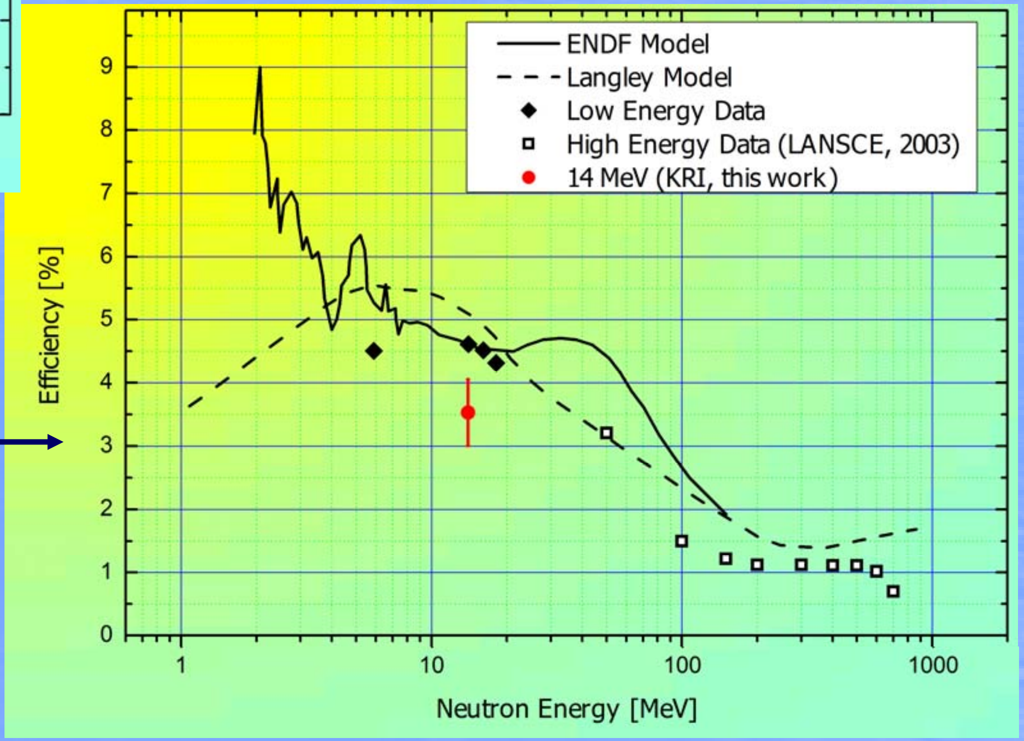
Neutron flux was measured by means of the generator internal counter of accompanying α-particles and external monitor based on $^{238}U(n,f)$ reaction.

PHENS: spectrum of energy deposition and efficiency of Si(Li) detector to 14 MeV neutrons

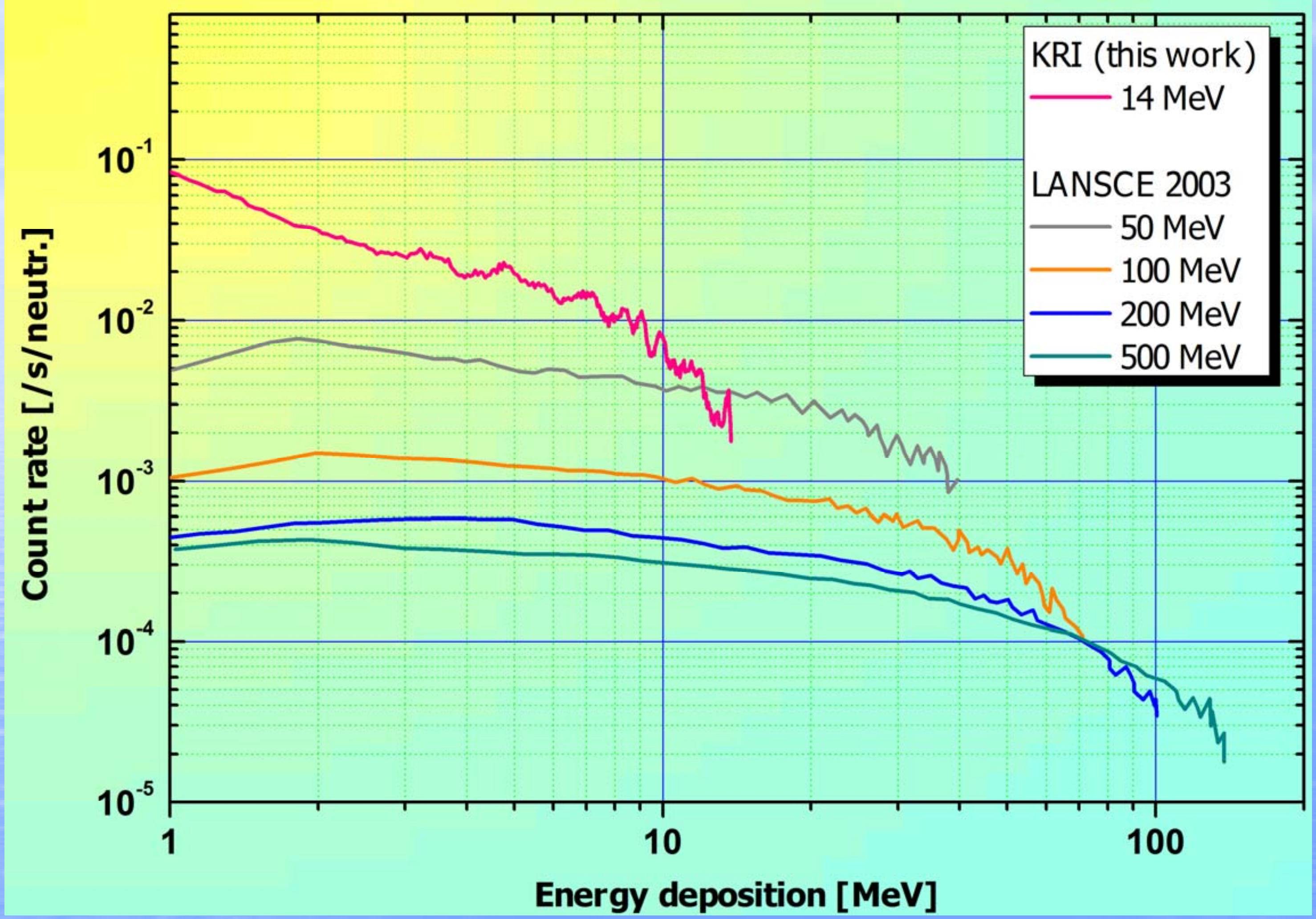


Spectrum of energy deposition from monoenergetic 14 MeV neutrons

Efficiency of Si(Li) detector to 14 MeV neutrons

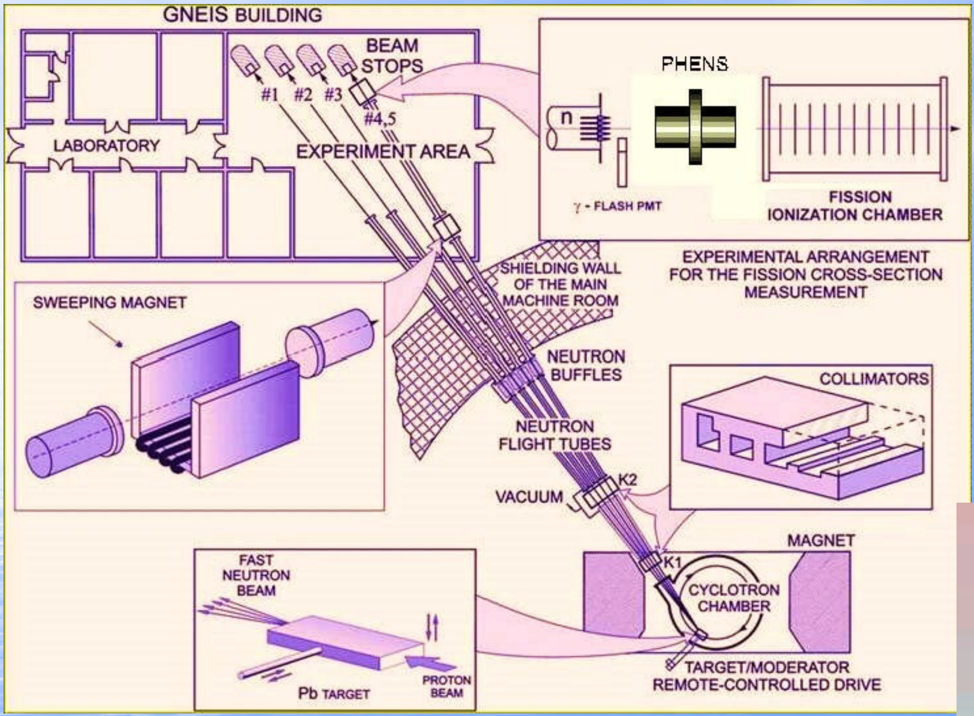


Spectra of energy deposition in Si(Li)-detector



Spectra of energy depositions from monoenergetic 14 MeV neutrons and monoenergetic slices of the LANSCE neutron beam [Maurer et al. *Radiation Research* 159 (2003) 154–160].

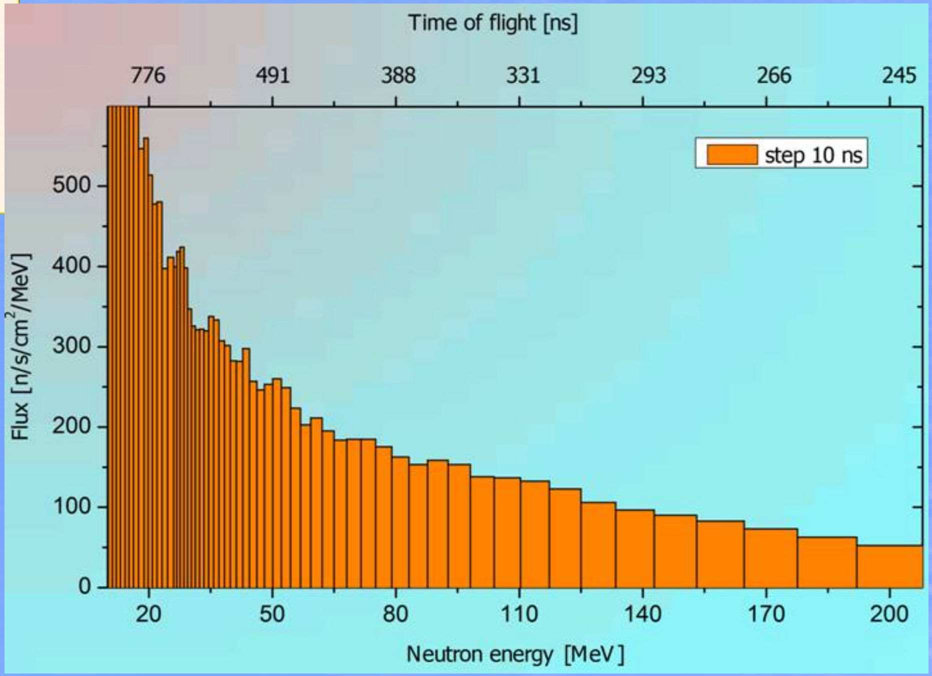
PHENS: calibration measurements at the GNEIS facility (scheduled to the end of 2010)



TOF measurements at the GNEIS facility:

- Energy of primary protons – 1 GeV
- Neutron production target - lead
- Start from γ-flash
- Minimal time step – 10 ns
- Flight distance – 48 m
- Neutron flux monitor – IC, and TFBC

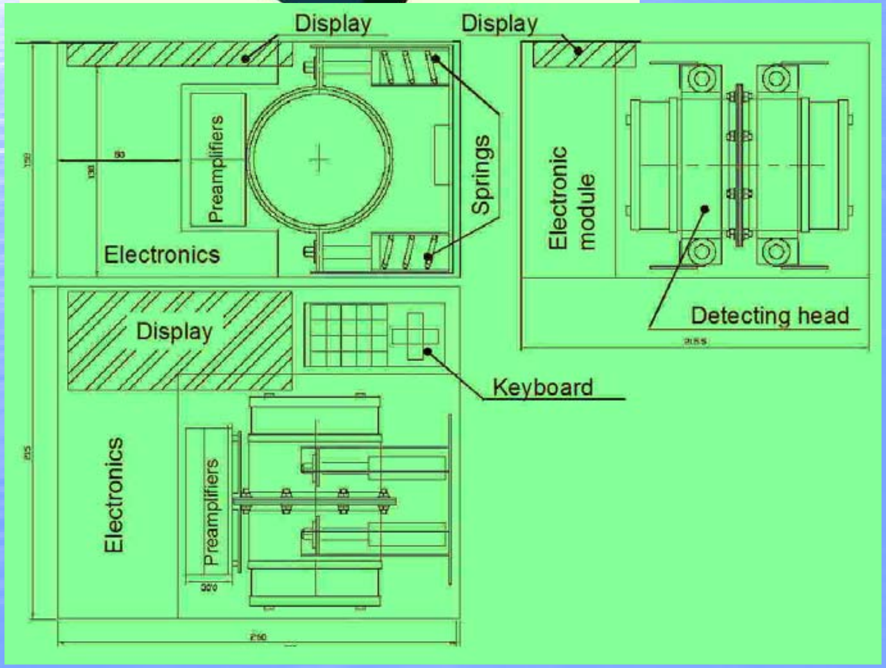
Spectra of energy deposition in Si(Li) detector will be obtained for about 60 neutron energy bins in the enery range 10 – 200 MeV



PHENS: final design and tests (2011)

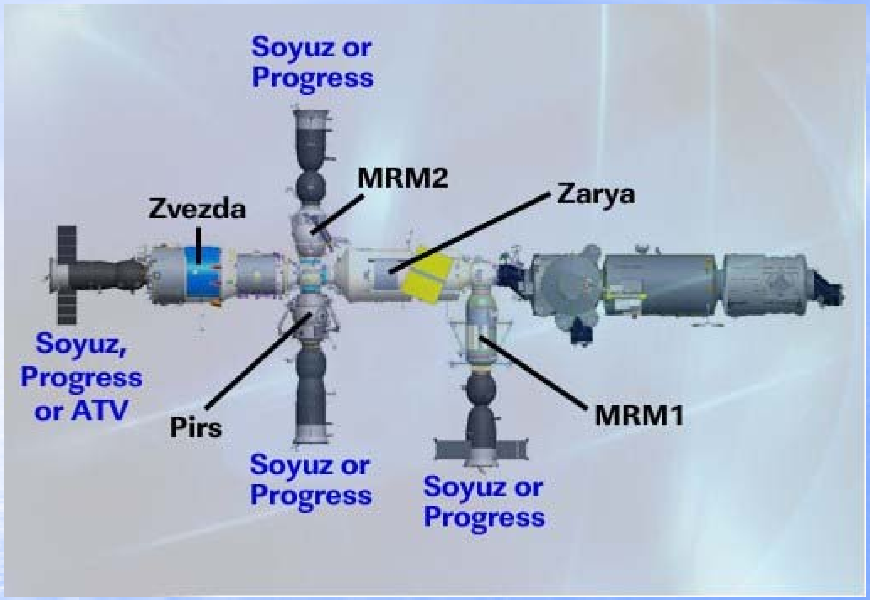
Technical parameters:

- Max weight - 6 kg
- Overall dimensions - 260x220x160 mm
- Max power consumption - 6 W

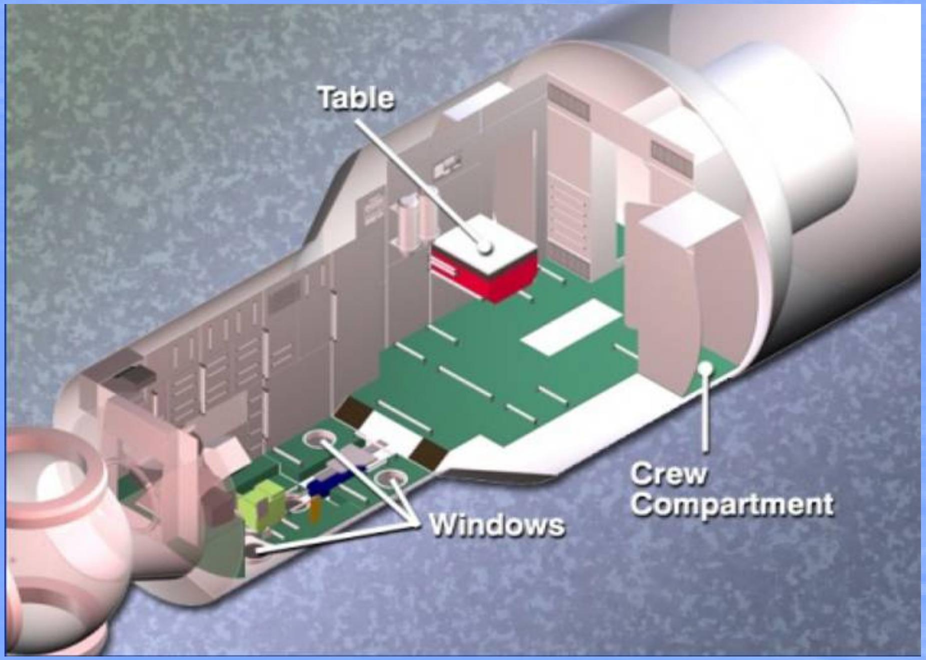


The final engineering operational development and all necessary bench tests including mechanical, climatic, electromagnetic and etc. will be executed at the Institute of Biomedical Problems.

PHENS: planned space experiment (Matroshka-R, 2012)



PHENS will be placed inside the **Zvezda** Service Module of the Russian segment of the ISS



Main tasks:

- Studying the dynamics of the energy spectra of neutrons
- Studying the dynamics of neutron doses
- Studies of radiation-protective properties of various materials to reduce the neutron dose

PHENS: expected count rates

Estimation of the neutron count rates (s^{-1}) in the energy range 10 – 200 MeV
for 5 MeV energy threshold of CsI active screen
Thickness of radiation shielding 20 g/cm^2

Energy threshold of Si(Li) detector	Measurement condition, source of radiation		
	Solar min Earth Radiation Belts (average on orbit)	Solar min Earth Radiation Belts, South Atlantic Anomaly	Solar max (peak)
1 MeV	0.35	22.4	2.8E+03
5 MeV	0.20	12.6	1.6E+03

Acknowledgment

The work is partly supported:

- by the International Science & Technology Center (ISTC), Moscow, Project #3779
- by the Contracts with the Rocket and Space Corporation «Energy» and Institute of Biomedical Problems (#100-2008/2, #100-2010/1).