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Neutron background measurements

- 1. Neutron sources underground**
- 2. Past measurements**
- 3. Present and future measurements**
- 4. Conclusion and outlook**

Thanks to the deep location, neutron flux in the laboratory 10^4 times less than at sea level, remained neutrons are:

Low energy fast neutrons induced by U/Th activities

SF and (α, n) reactions in rock, shielding, construction materials, detectors itself

High energy neutrons induced by muons

Thermalized neutrons

For different experiments, different energy regions of neutron flux are important.

Efforts for good knowledge of neutron field at LSM are highly motivated:

Just MC or estimations of background is not enough any more for correct interpretation of experimental results of double-beta, neutrino or dark-matter search projects.

For dark matter experiments not only value of background but also fluctuations of it with time are key issue and critical for receiving of unbiased results.

Simulations for LSM

(thanks for data to Rachid LEMRANI)

Total flux

| $10^{-6} \text{ cm}^{-2} \text{ s}^{-1}$ | <300 eV | 300 eV-0.5 MeV | >0.5 MeV | >1 MeV | >2 MeV | Total |
|--|---------|----------------|----------|--------|--------|-------|
| Rock | 1.02 | 1.15 | 0.67 | 0,47 | 0,28 | 2,85 |
| Concrete | 1.18 | 1.19 | 0.76 | 0.53 | 0.31 | 3.14 |
| Very dry rock | 1.72 | 8.8 | 1.57 | 0.99 | 0.50 | 12.1 |
| Dry concrete | 1.48 | 2.10 | 1.06 | 0.76 | 0.44 | 4.64 |

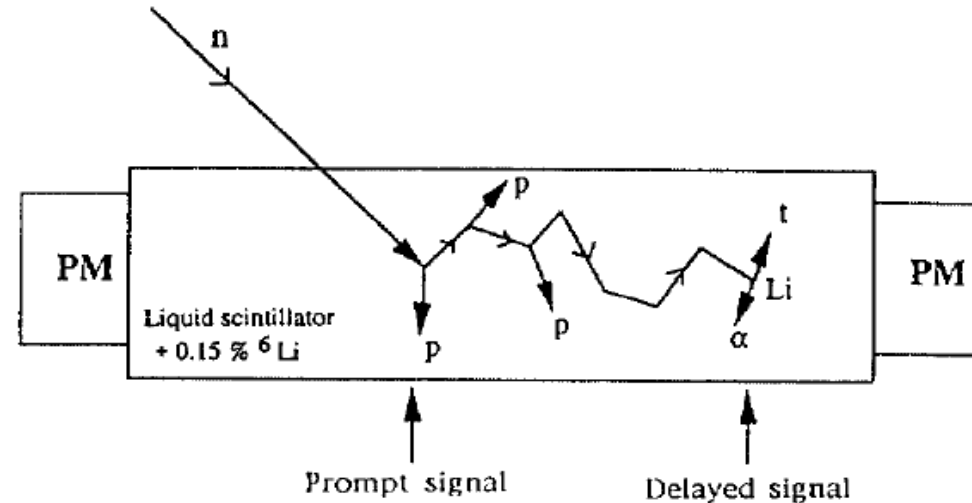
Direct flux (without backscattering)

| $10^{-6} \text{ cm}^{-2} \text{ s}^{-1}$ | <300 eV | 300 eV-0.5 MeV | >0.5 MeV | >1 MeV | >2 MeV | Total |
|--|---------|----------------|----------|--------|--------|-------|
| Rock | 0.32 | 0.43 | 0.49 | 0,38 | 0,24 | 1.2 |
| Concrete | 0.38 | 0.44 | 0.55 | 0.42 | 0.26 | 1.37 |
| Very dry rock | 0.34 | 1.79 | 0.96 | 0.69 | 0.41 | 3.08 |
| Dry concrete | 0.43 | 0.65 | 0.73 | 0.56 | 0.36 | 1.8 |

V. Chazal ^{a,1,2}, R. Brissot ^b, J.F. Cavaignac ^b, B. Chambon ^{a,1}, M. de Jesus ^{a,1}, D. Drain ^{a,1}
 Y. Giraud-Heraud ^c, C. Pastor ^{a,1}, A. Stutz ^b, L. Vagneron ^{a,1}

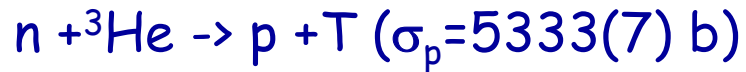
- Detector = ⁶Li loaded LS cell
- Signature : proton recoil as prompt + capture on ⁶Li as delay
- Counting time : 115 + 140 d
 - 1.15 count/day Pb + Cu
 - 0.38 count/day Pb + Cu + parafr
- Signal/noise = 2/1

⇒ $\Phi = 1,6 \cdot 10^{-6} / \text{cm}^2/\text{s} \ E > 2 \text{ MeV}$
 (revised 2001 value : initial value in 1998 paper = $4 \cdot 10^{-6} / \text{cm}^2/\text{s}$ but wrong simulation of propagation of neutrons through Pb/Cu shield)

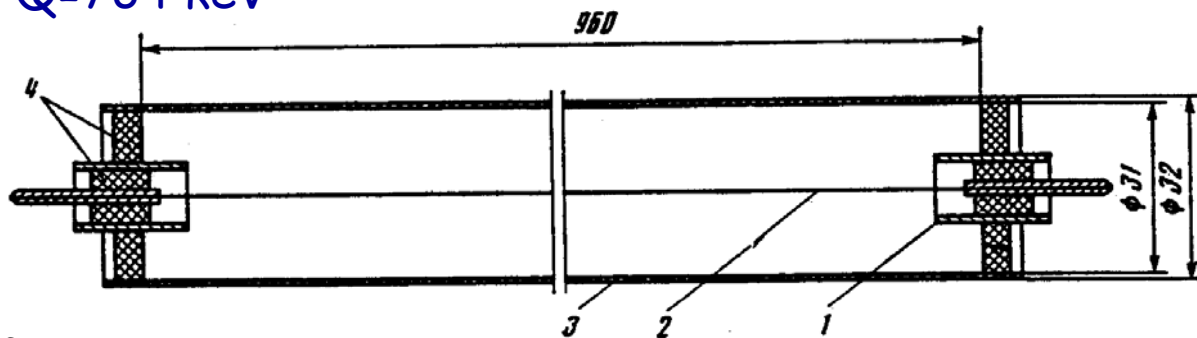


- in a first phase, the detector located inside a shielding of lead and copper (8 months);
- in a second phase, a 30 cm thick wax protection was installed all around the shielding, and 20 cm above the cover (5 months).

Neutron Monitor use proportional counters filled with ^3He



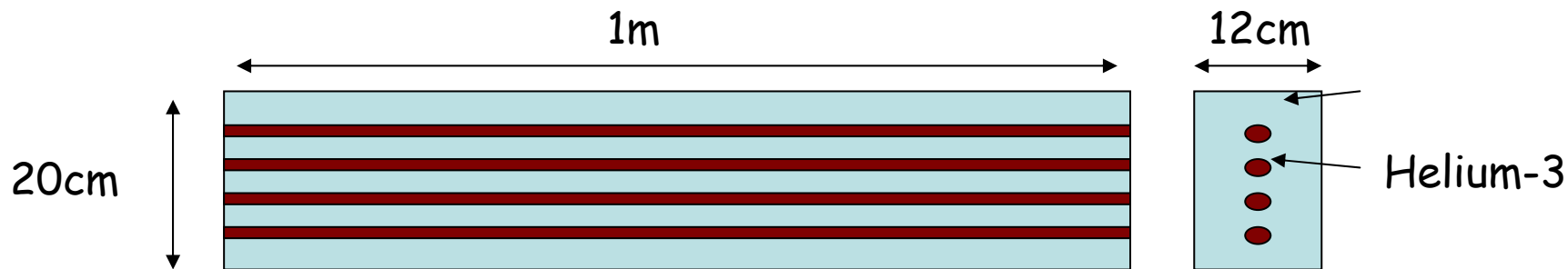
$$Q = 764 \text{ keV}$$



- 1 – guard ring;
- 2 – signal wire;
- 3 – body;
- 4 – glass isolators

^3He counters are excellent instrument for detection of thermalized neutrons (n peak is significantly higher of signal produced by gammas). The main background is due natural activity (alphas) in walls.

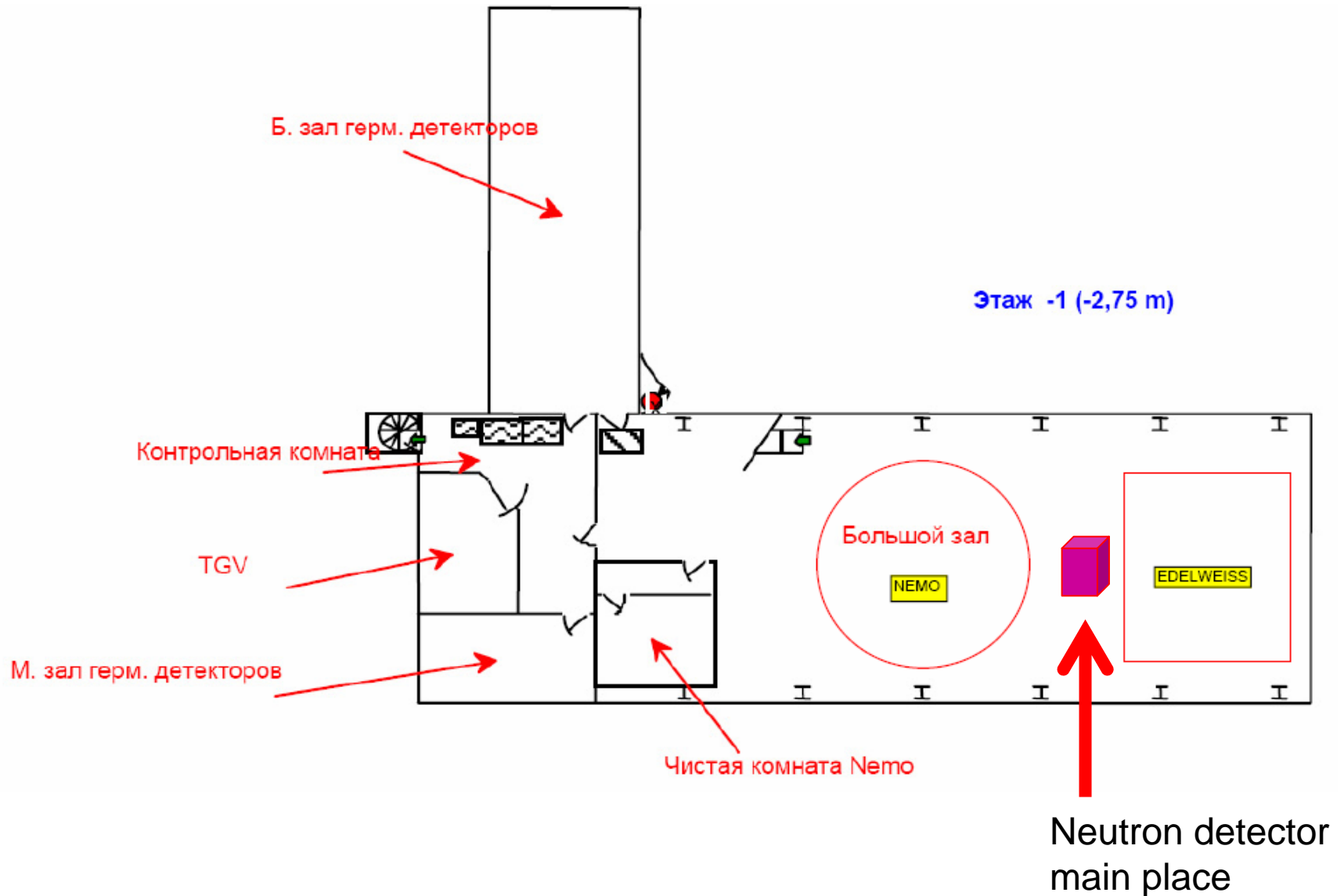
→ Against of the alpha background stainless tube covered inside by 50-60 μm Teflon and 1 μm electrolytic copper



→ Polyethylene moderator to measure fast neutrons
The module has 4 counters

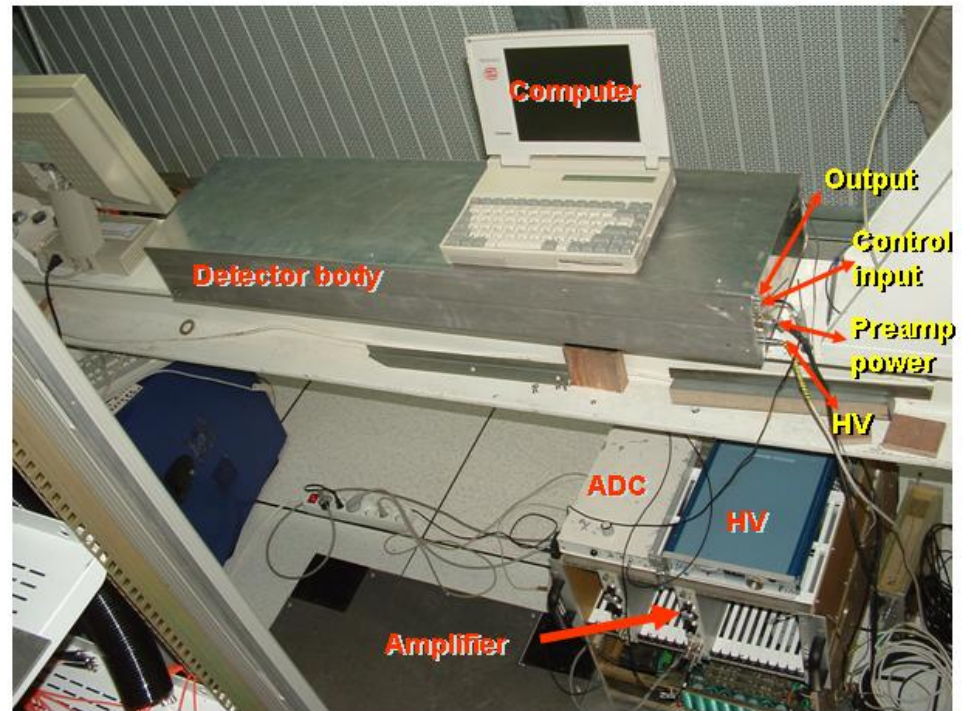
Detector has been delivered to LSM at end of June 2006

Installation at LSM

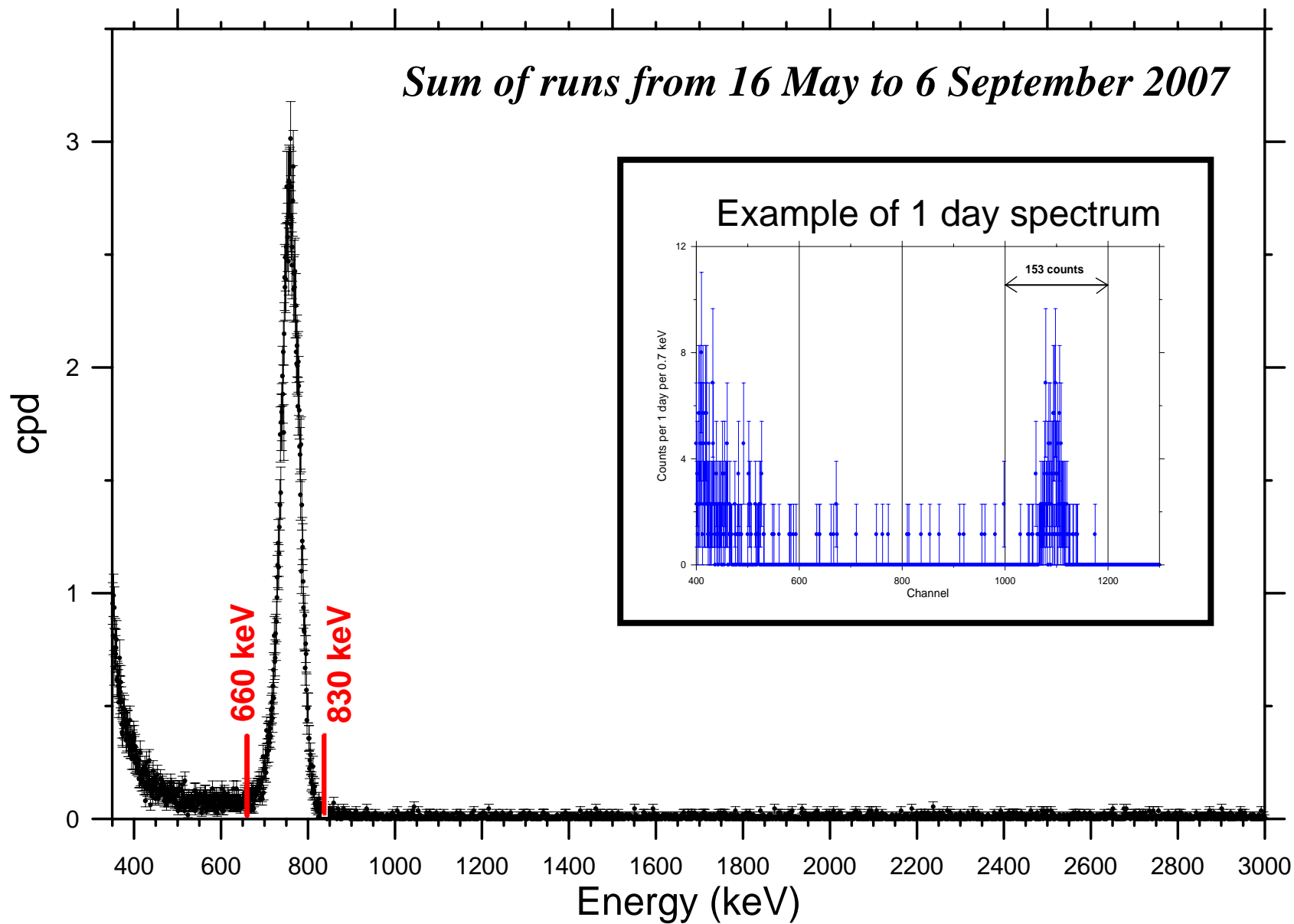


View of the module and it installation at LSM

Just under “NEMO” side
of EDELWEISS clean room



Measured spectrum / average rate in ROI is about 150 cpd



The detector:

Average signal: 150 cpd (70% - fast neutrons, 30% - thermalized neutrons)

Own background:

Neutrons in ROI (experimental): 2.0(7) cpd

Alphas (extrapolated): 0.6(1) cpd

Maximum of the detector efficiency(MC): 15% at 1 MeV

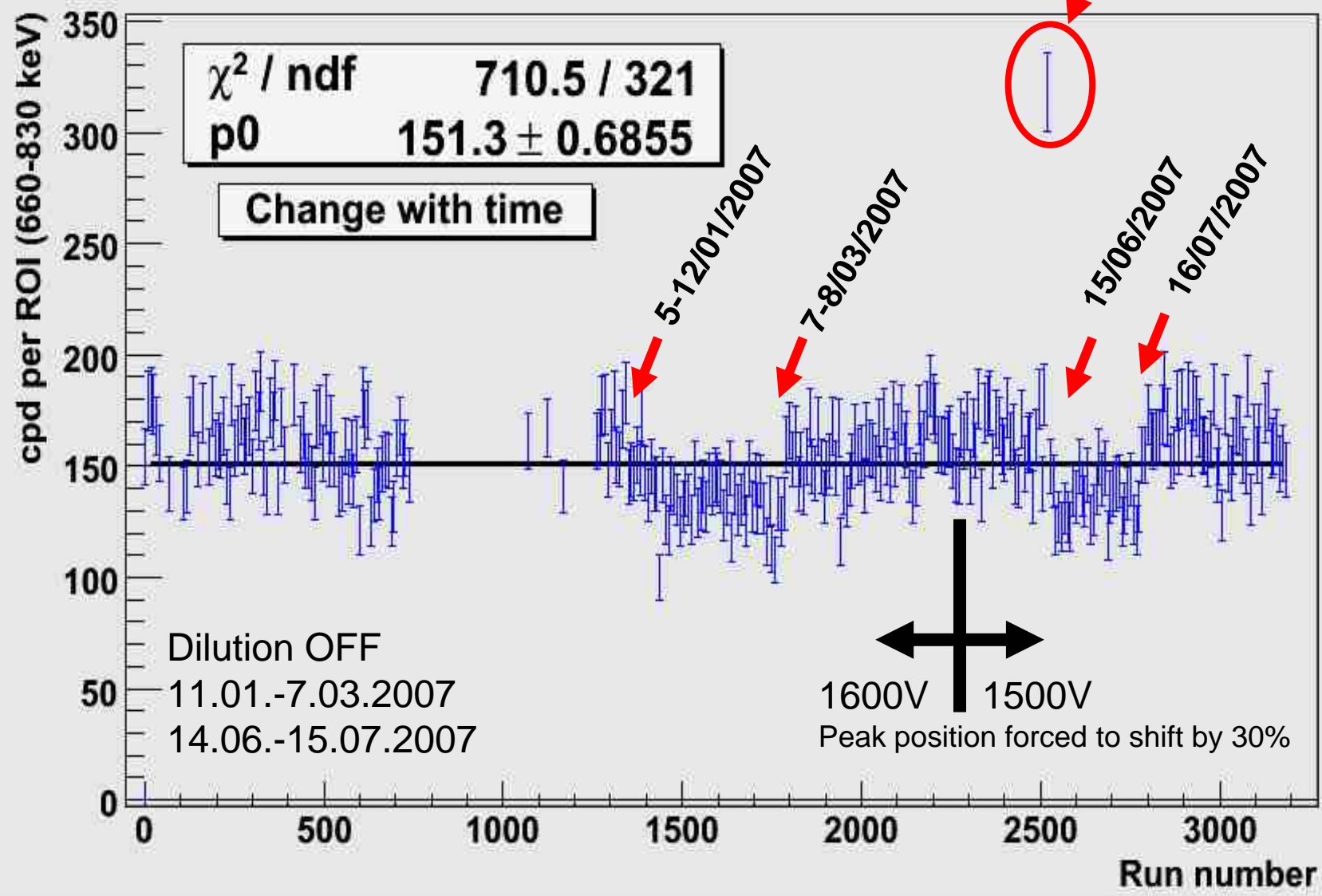
Sensitivity: 10^{-8} neutrons $\text{cm}^{-2} \text{sec}^{-1}$

Comparison of MC and experiment:

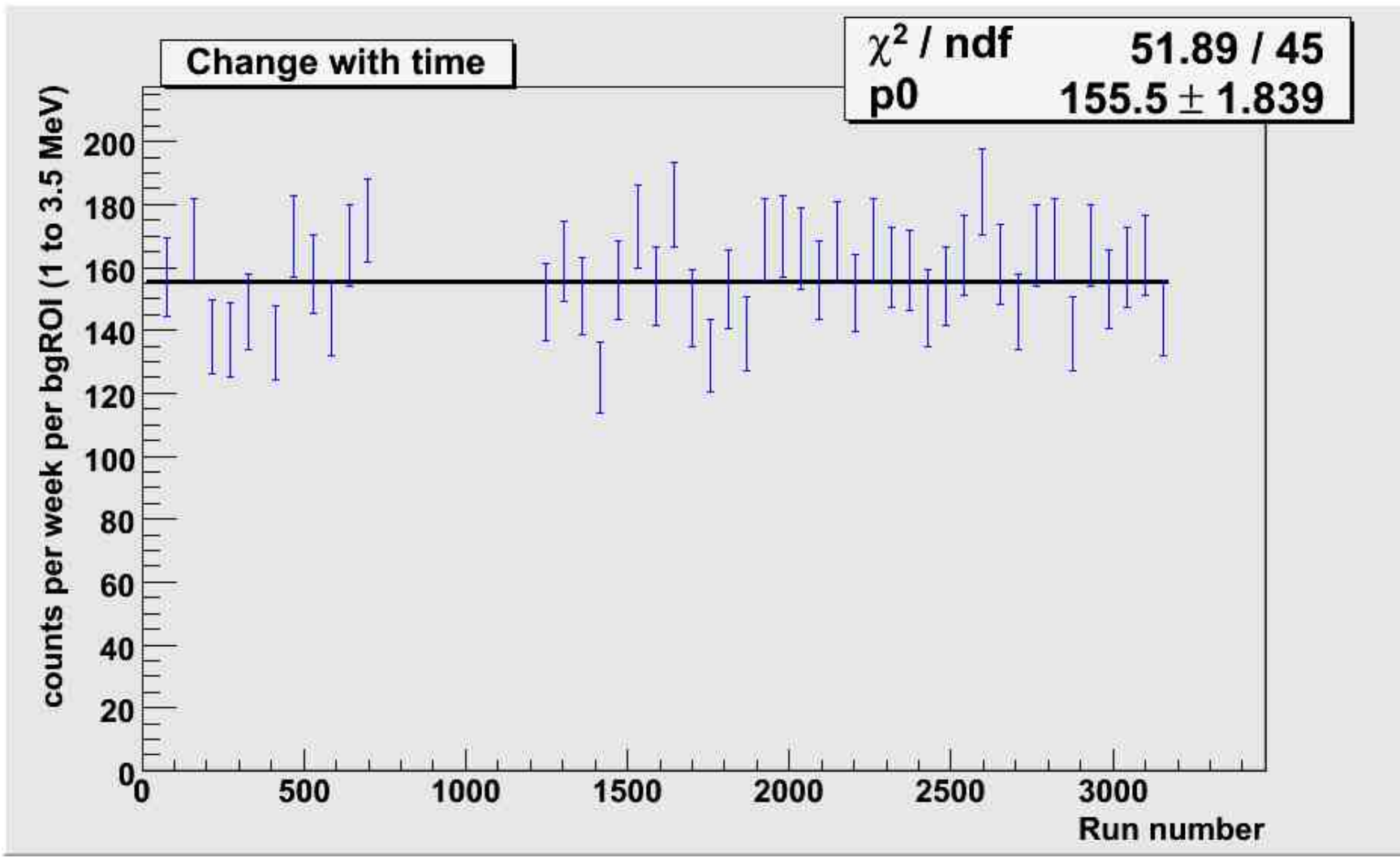
Flux: 2×10^{-6} neutrons $\text{cm}^{-2} \text{sec}^{-1}$

Day by day data for 2006-2007
Missed intervals corresponds to measurements at different locations

*operation with week
neutron calibration
source (20 n/sec) at
EDELWEISS area*



Day by day data / Background energy region



Interpretation

There are clear changes of detected neutron flux on a level +/- 10%

Possible sources of changes:

Electronics

seems to be unlikely since background due alpha particles is not affected

Wrong procedure for peak region treatment

seems to be non confirmed by forced change of the peak position

Water in rock underground

unhappily direct data is not available

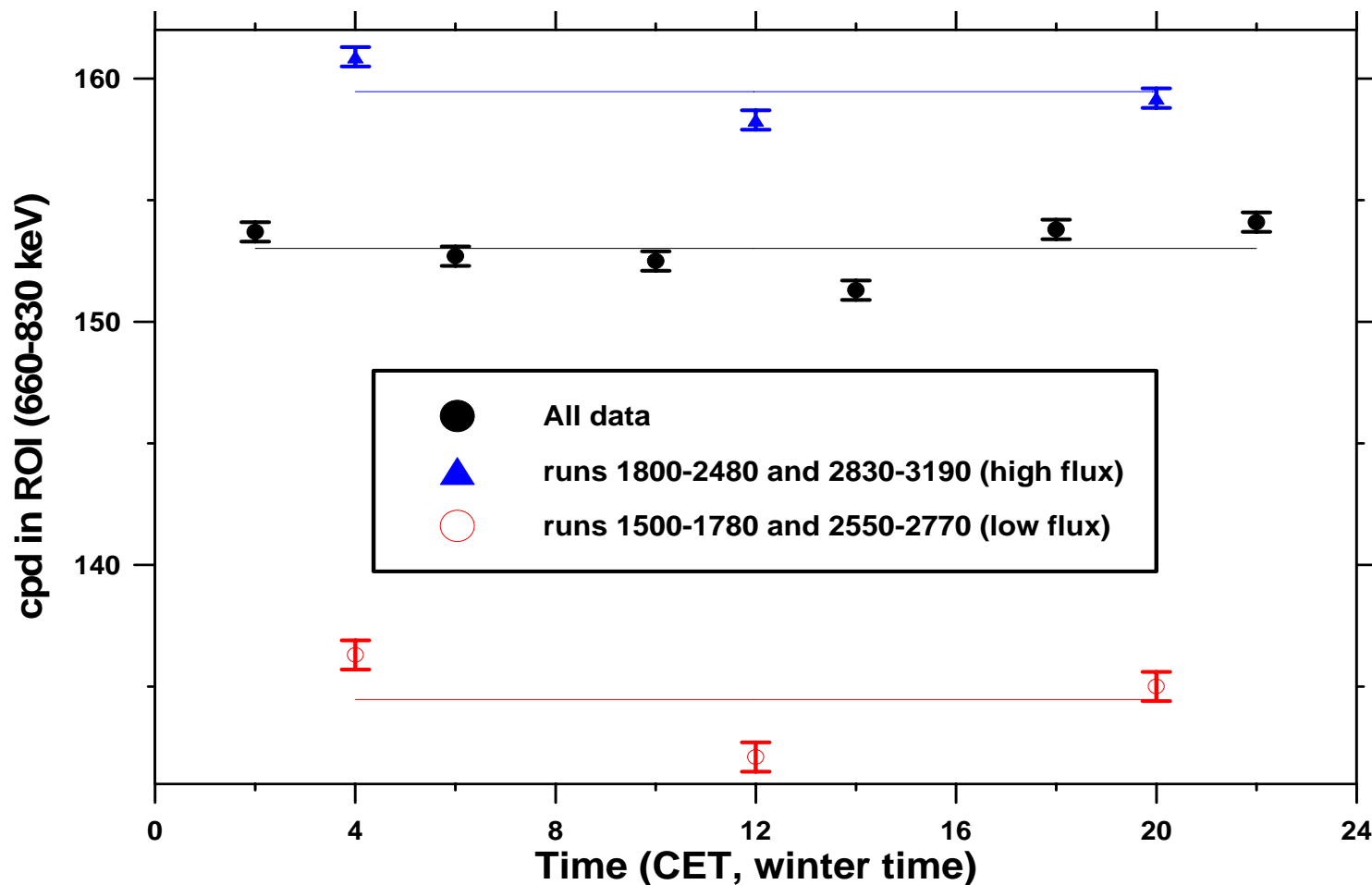
indirect data, as weather outside seems to be non in correlation

humidity in the lab was higher in winter time and this summer, but changes does not correlated directly with time of flux changes. (of course we don't know if humidity in the lab depends on water in rocks at all)

Position of EDELWEISS-II shields

When EDELWEISS experiment is not running, huge anti-neutron PE shield is widely open and stay above the detector. This is naturally introduce changes in the neutron flux at detector. Correlation between flux and shield position is clear.

Day – night variations

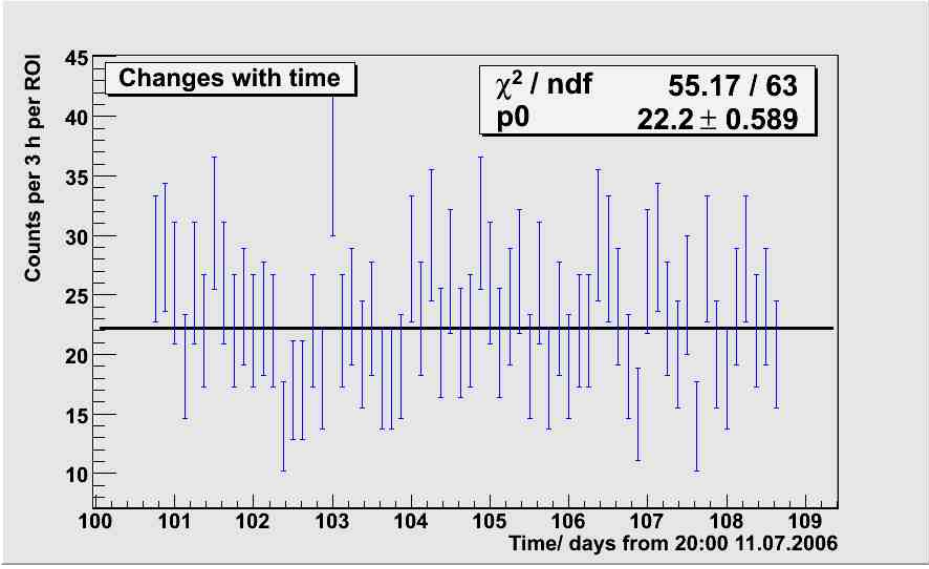
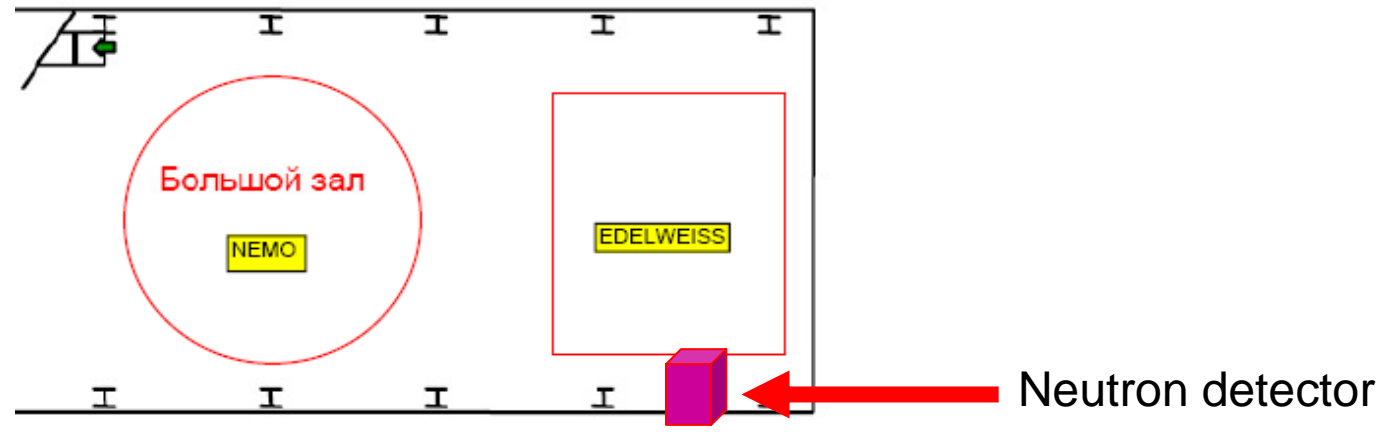


For all data $(\max - \min) / \max = 1.8\%$ (5σ), Max 20-24 h, Min 12-16 h

Usually more activity in the lab at "Min flux" time

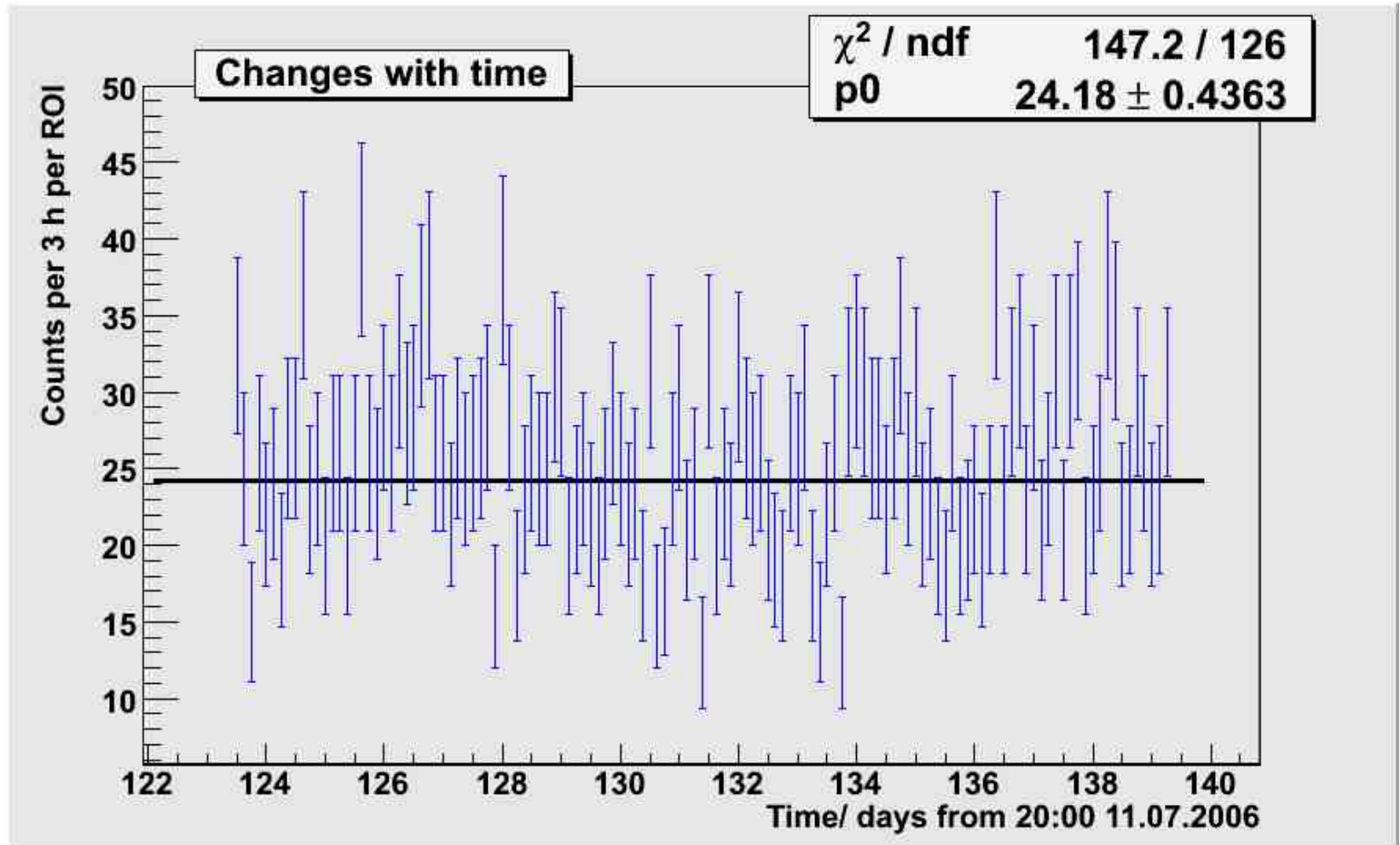
Possible influence: **shields positions (analysis of same condition data is in progress)**, effect of temperature of environment, pressure and humidity of air?

Between EDW and rock / horizontal



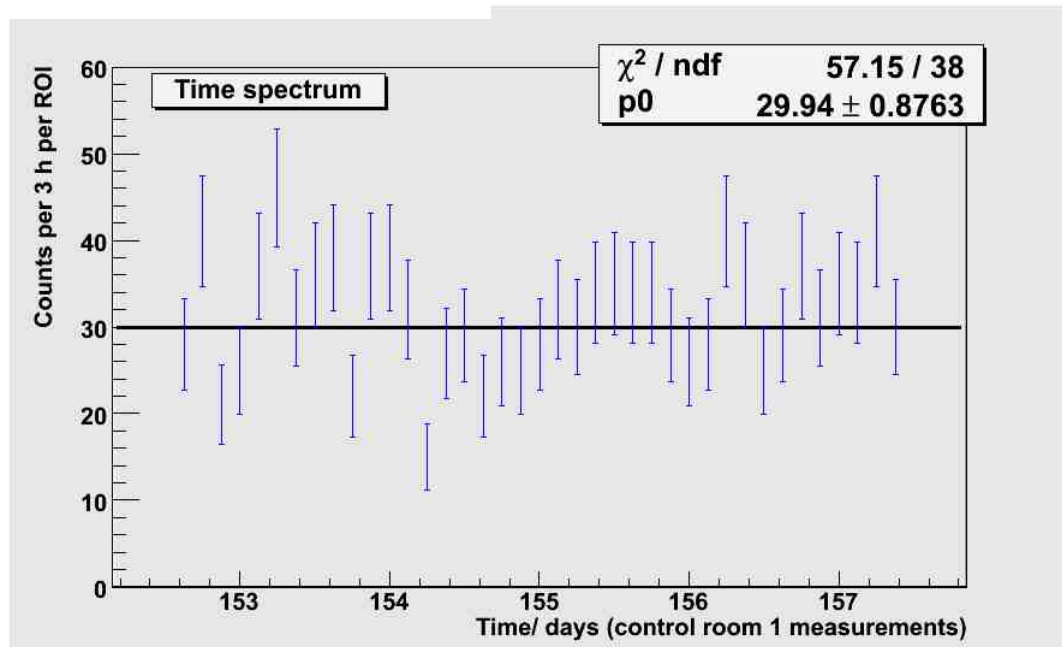
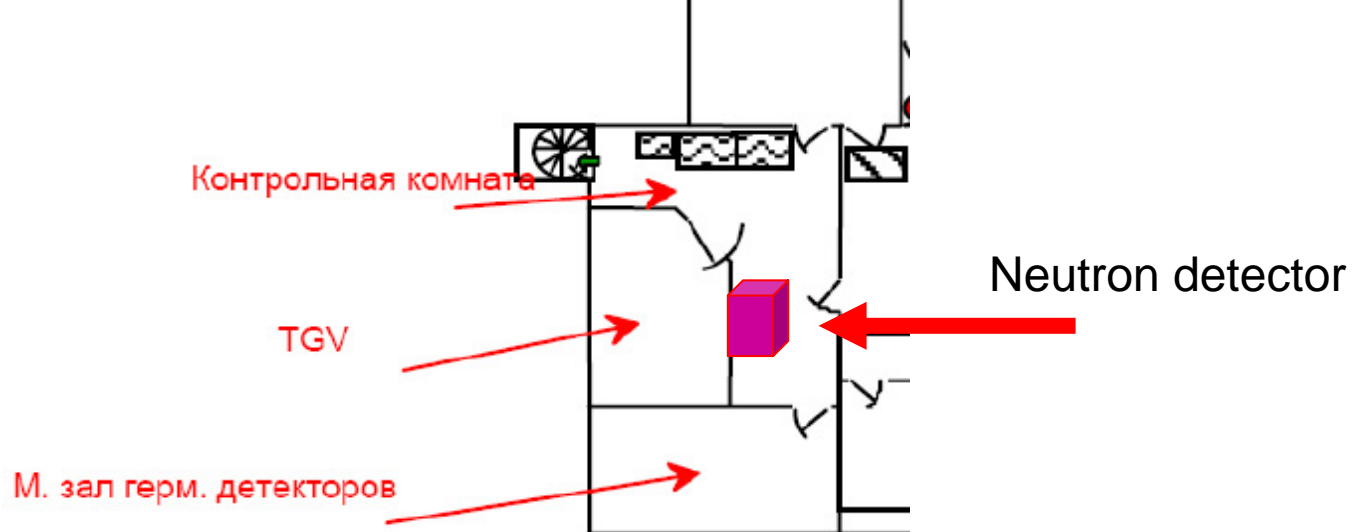
Result: 178(5) cpd

Between EDW and rock / vertical



Result: 193(4) cpd

Control room



Result: 240(7) cpd

SAS region



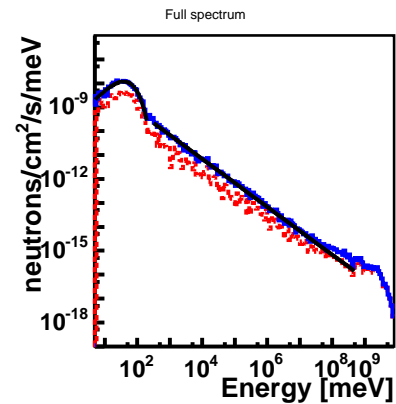
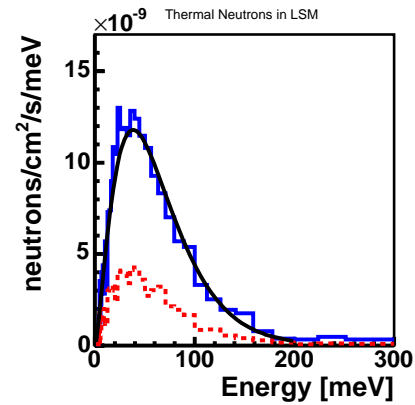
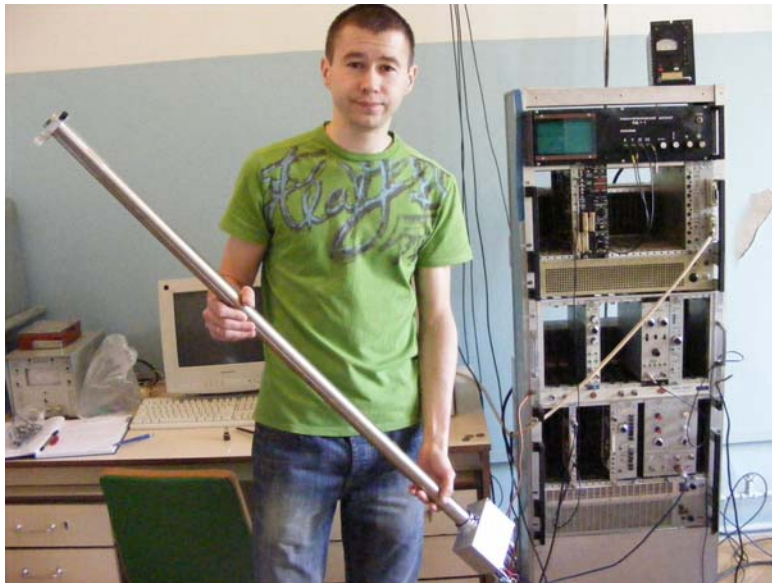
Result: 522(15) cpd
Investigation of influence
of AmBe source (20n/sec)
(located at lab entrance
inside of shield – can not detect)



Result: ~450(50) cpd
One counter was disconnected
Measurement will be repeated
later this year
Presented result is extrapolation for
4 counters

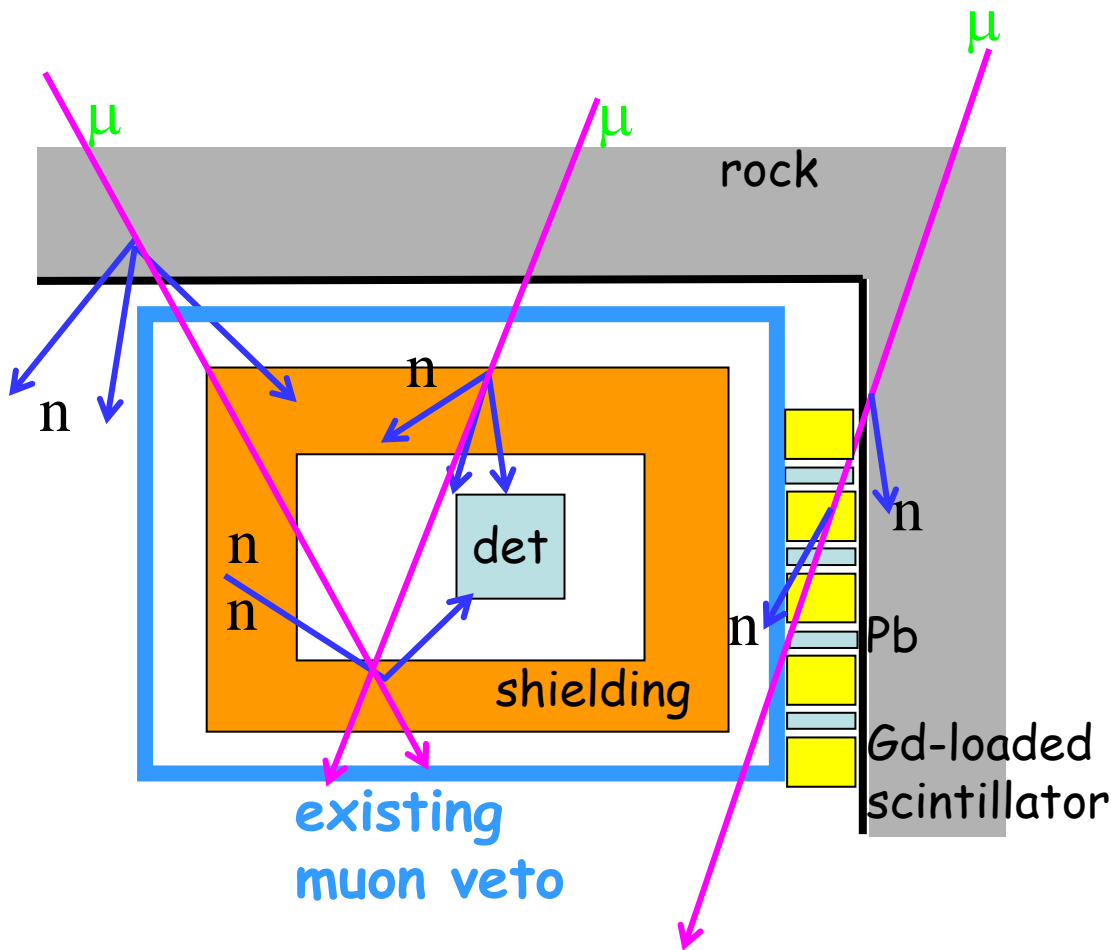
Monitoring of thermalized neutrons

| Energy | 0-0.3ev Thermal | 0.3ev-500ev Epithermal |
|--------------------------------------|--------------------|---------------------------|
| Flux 10^{-6} /s/cm ² | 1.0 | 0.52 |



**Detector is under test at
Dubna (and is working!)
Will be delivered to LSM
soon.**

Measurement of μ -induced neutrons with EDELWEISS-II



$$\Phi_{\mu} \sim 4 / \text{m}^2 / \text{day}$$

$$E_{\mu} = 300 \text{ GeV}$$

$$Y_n^{\mu} \sim 3 \times 10^{-4} \text{ n}/\mu / \text{gcm}^{-2} \text{ in rock}$$

n rate expected $\sim 1/\text{day}$
(Pb: $Y_n \sim 10$ times higher!)

e.g.

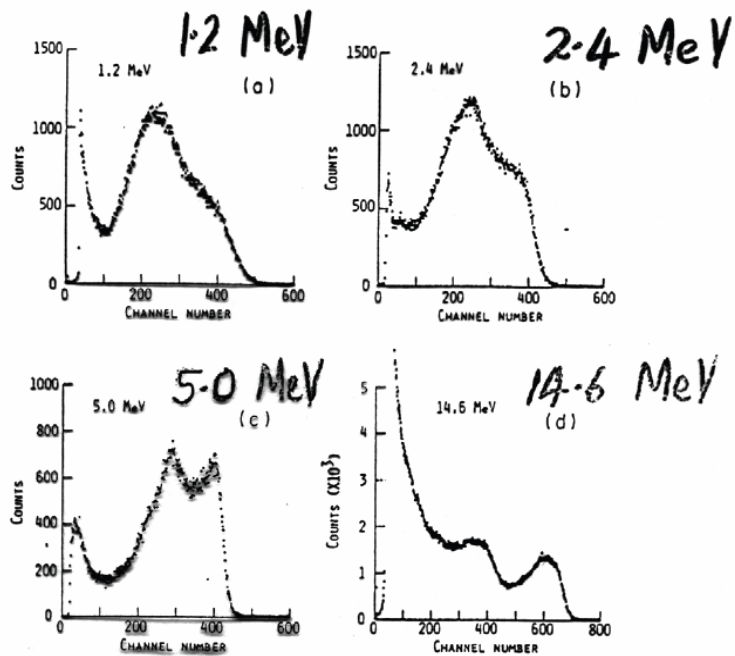
25 modules with 60l sc. each;
Pb bricks in between modules

triple-coincidences:

1. muon veto
 2. prompt neutron recoil
 3. delayed $\text{Gd}(n, \gamma)$ signal
- neutron yield & spectrum

Response of capture gated detectors

From J. Abdurashitov NANP2005 talk



Double peak is due to a multiplicity of recoils together with non-linear light yielding

- If n is captured $E_n \approx \sum E_{p_i}$
- Due to non-linear light yielding $\sum I(E_{p_i}) \neq I(\sum E_{p_i})$
- If one detects recoils separately

$$E_n \approx \sum E_p (I_i)$$

OPERA like scintillators around of counters – single recoil per cell

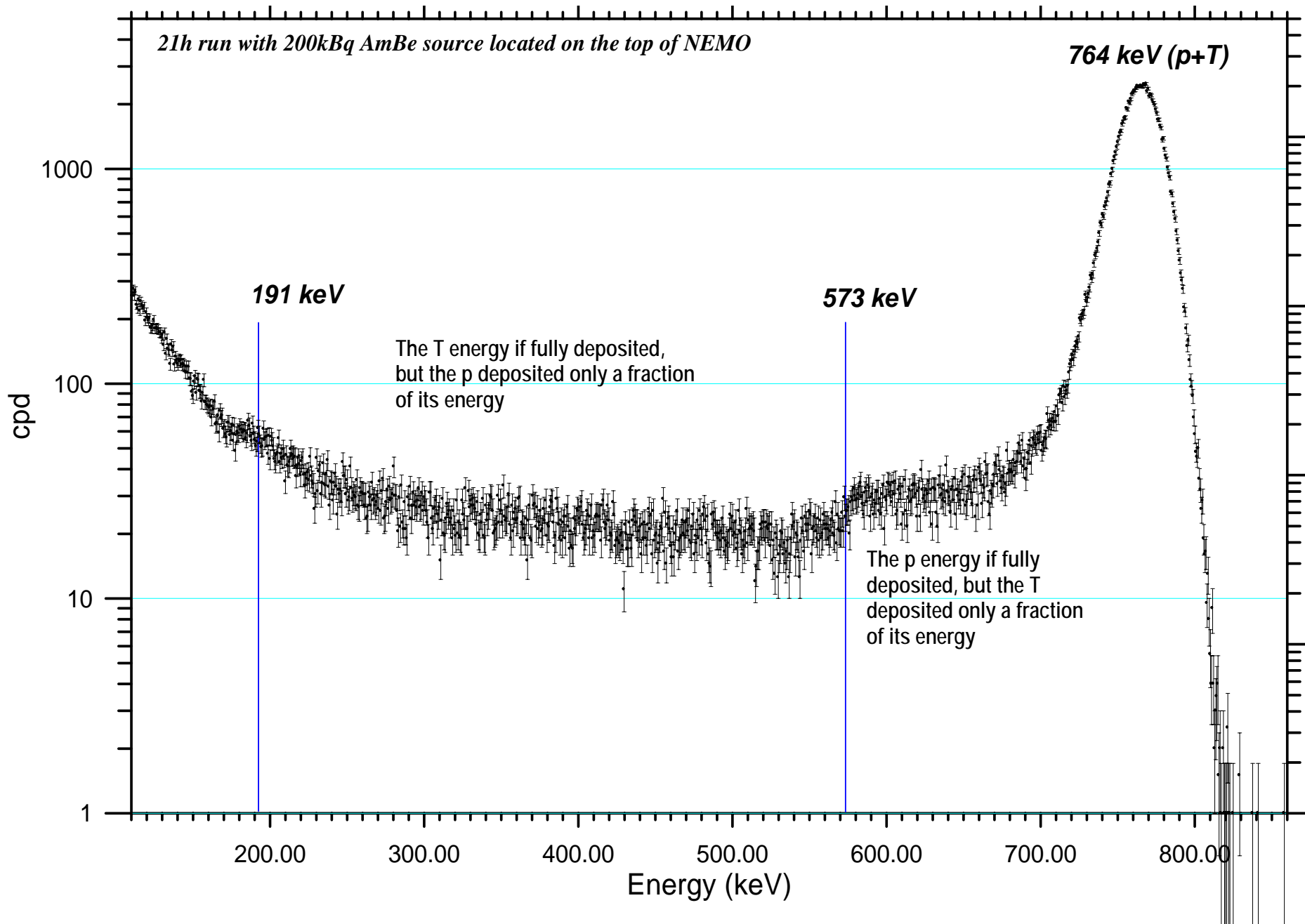


MC simulations at Dubna for optimal design, test of the cells for other projects

Outlook and plans

- **LSM laboratory and its future extension is the place for unique experiments requiring unprecedented understanding of backgrounds. Neutron and neutron induced backgrounds become more and more pronounced for each next generation of such experiments.**
- **First measurements of neutron flux at LSM: ratio signal/bkg = 2/1, now 100/1**
- **Continuous monitoring of neutron flux for last 2 years**
- **Detected variation for one place of measurement was found on a +/- 10% level. The reason is the influence of EDELWEISS PE shield on neutron flux. Variations of neutron flux in “stable” conditions is below 2%**
- **Significant difference of neutron flux for different places of the laboratory**
- **Measurements will be continued**
- **This year a new study of muon induced neutrons will be started by EDELWEISS collaboration**
- **This year we will start continuous monitoring of thermalized neutrons with a naked ^3He proportional counter**
- **R&D for construction of a neutron spectrometer will be continued**

Typical calibration spectrum / classical picture



Direct measurements of own background

To investigate own background, the detector has been placed underground (LSM) inside of a massive shield made from borated PE (30+ cm from all sides). By estimation it reduce neutron flux by 100 times. The used PE itself suppose to be relatively clean, because it has been used as part of shield of TGV experiment designated for double beta decay search.



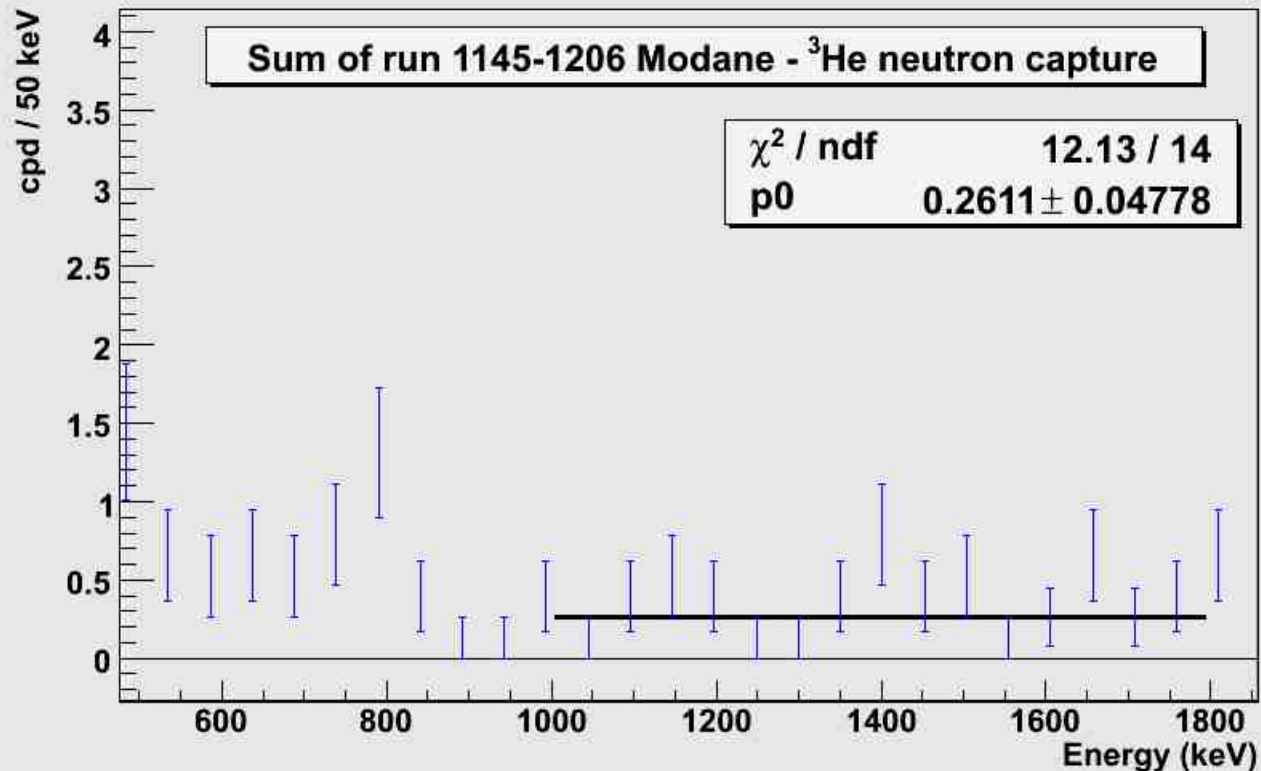
Direct measurements of own background/ results

Alpha background **0.26(5) cpd / 50 keV**

Alpha bg in n-ROI (140 ch, based on calibration with source) **0.6(1) cpd**

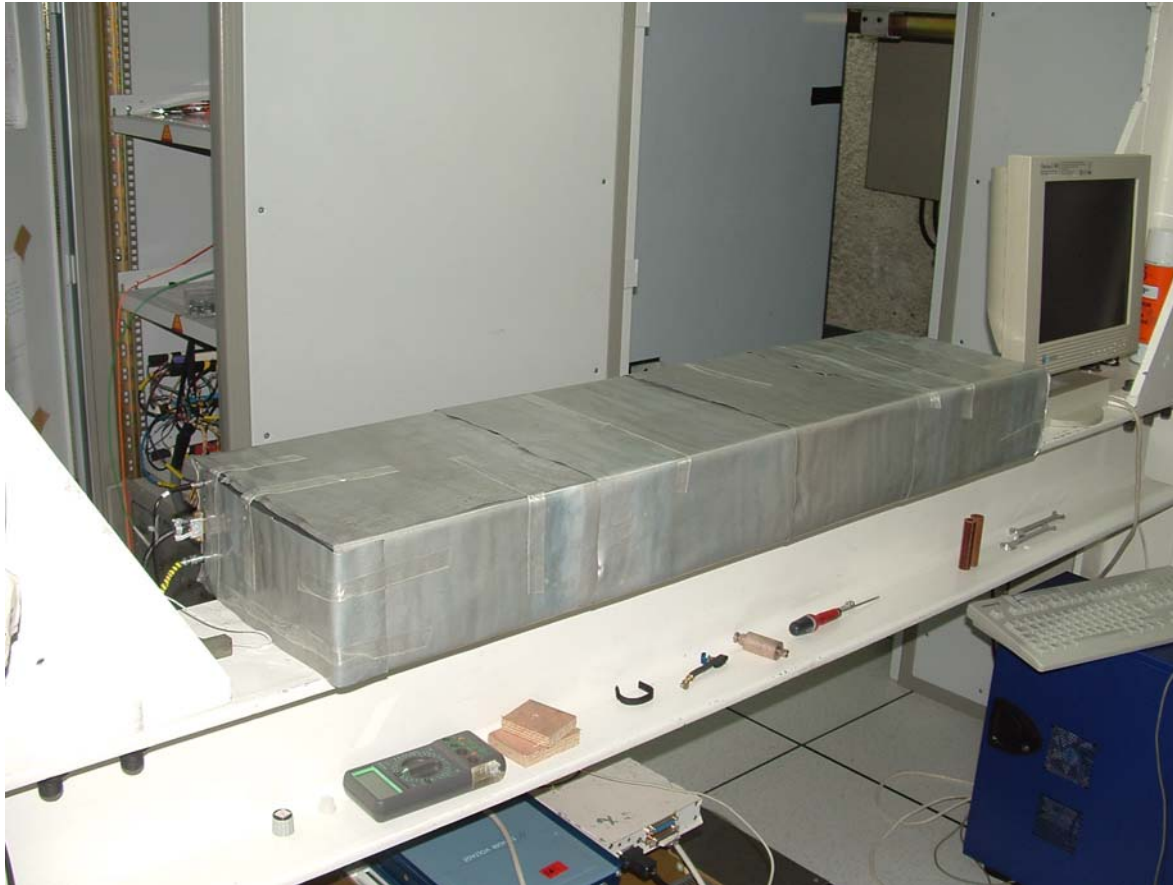
Signal with shield in neutron ROI **2.6(6) cpd**

Neutrons in n-ROI **2.0(7) cpd** / ~100 times lower than the signal without shield (these remained neutrons are mainly due inefficiency of the shield, own neutron background is probably negligible with respect to the alpha background)



Measurements at LSM / determination of thermalized neutrons yield

Measurements with detector wrapped all side around with Cd foil



42 h measurements before: 163 ± 10 cpd in ROI

27 h measurements with Cd: 112 ± 10 cpd in ROI

21 h measurements after: 157 ± 13 cpd in ROI

thermalized neutrons gives 49 ± 13 cpd (or 30% from all counts)

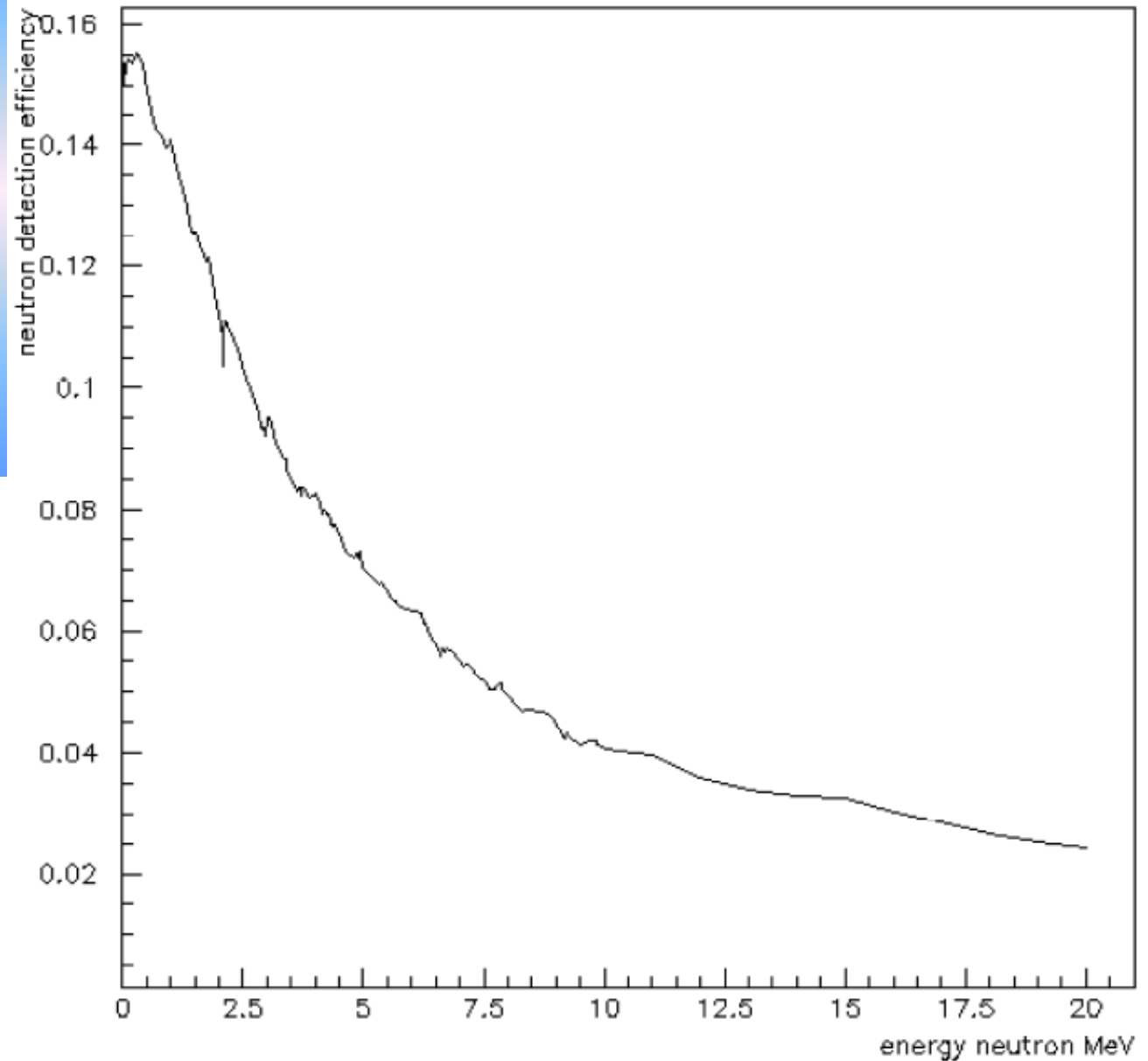
Efficiency

- **MC simulations with MCNPX**
- **Calibrations with PuBe source**
- **Calibration with 1 kg depleted uranium**

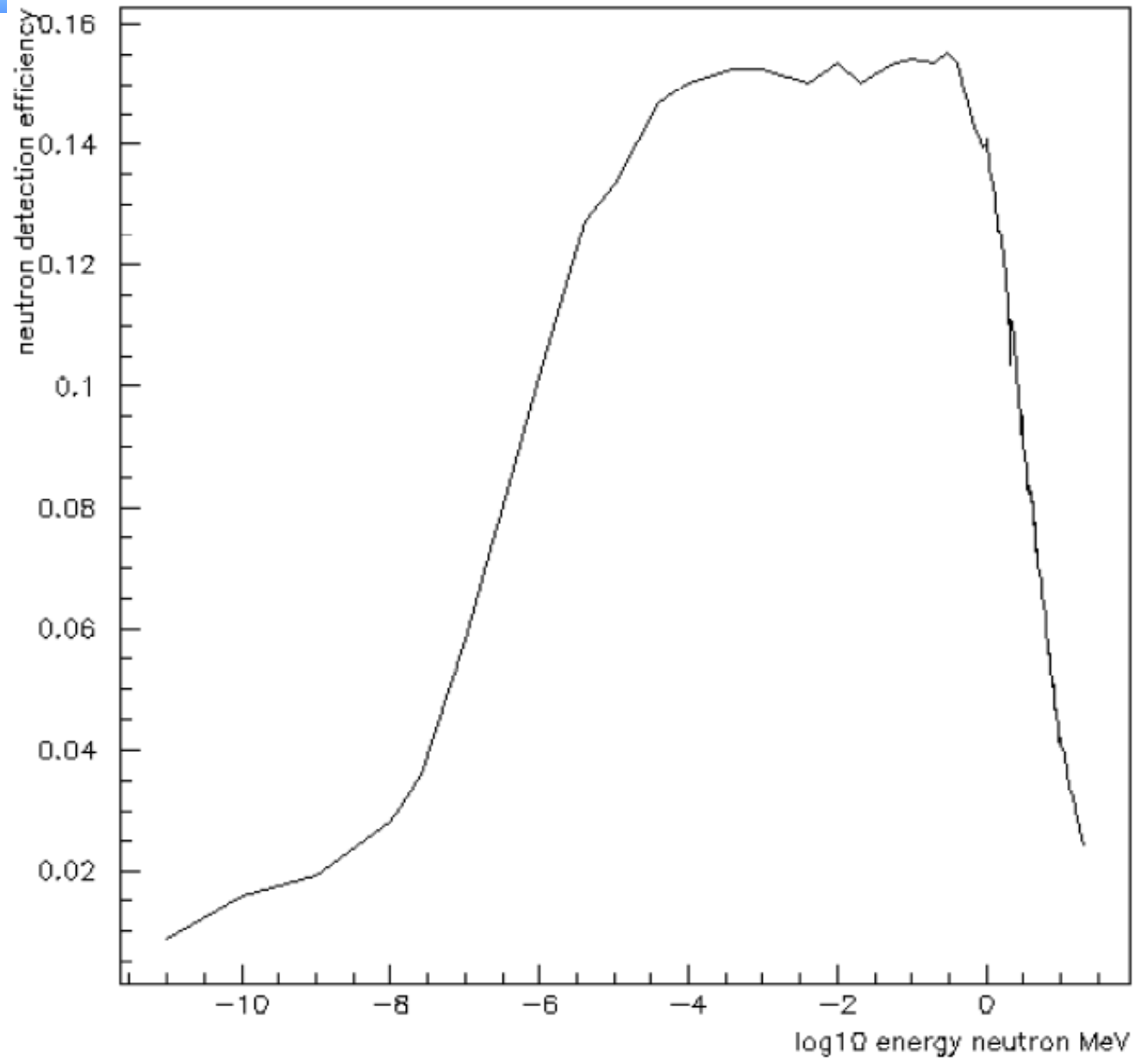
**MC / efficiency to 4π
All energies**

**Maximal efficiency
at 15%
around 1 MeV**

**Efficiency remained
above 2% even for
energies above 10
MeV**



MC / efficiency to 4π
Low energy region



Result of comparison of MC simulations with complete spectrum evaluated neutrons coming from Modane's rocks gives rate of 2×10^{-6} neutrons $\text{cm}^{-2} \text{sec}^{-1}$

With taking into account results of background measurements the detector can measure flux on a level as low as 10^{-8} neutrons $\text{cm}^{-2} \text{sec}^{-1}$