Neutron background measurements at the Modane Underground Laboratory

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Motivations for this work:

1) Neutrons and neutron induced background becomes more and more important, for each next generation of neutrino, double beta and dark matter experiments. Just MC or estimations of background is not enough any more.
2) For dark matter experiments not only value of background but also fluctuations of it with time are key issue and critical for correct interpretation of data.
3) Particular interest for LSM for new neutron measurements
   a) Configuration of the laboratory significantly changed from last measurements, thus neutron flux is quite probably not the same.
   b) Investigations of both long (year) and short (day/night) fluctuations is important.
   c) It is interesting to make a map of neutron flux at LSM, so to perform measurements in many places.

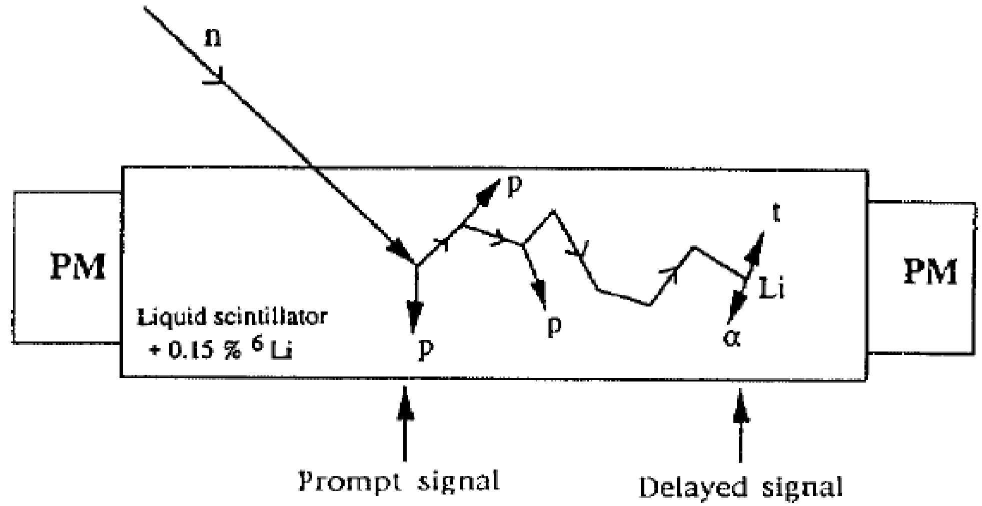
Previous measurement

Astroparticle Physics 9 (1998) 163–172

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

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

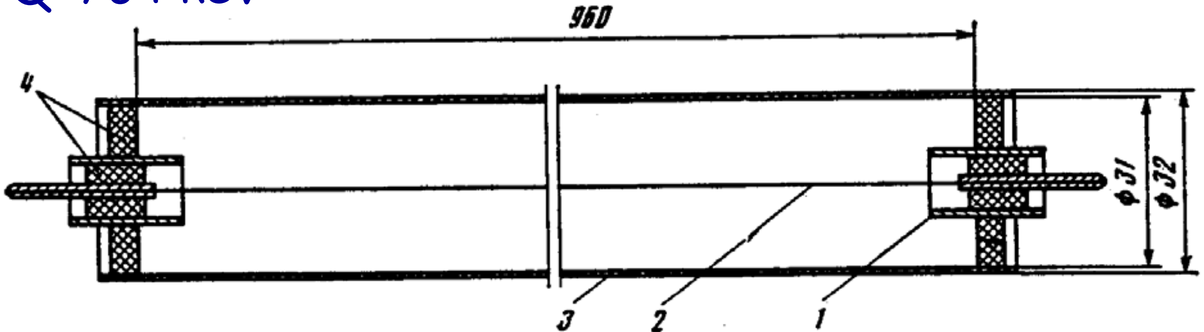


- in a first phase, the detector located inside a shielding of lead and copper (8 months);
- in a second phase, a 30 cm thick wax protection was installed all around the shielding, and 20 cm above the cover (5 months).

JINR Neutron Detector

$n + {}^3He \rightarrow p + T$ (σ_p=5333(7) b)

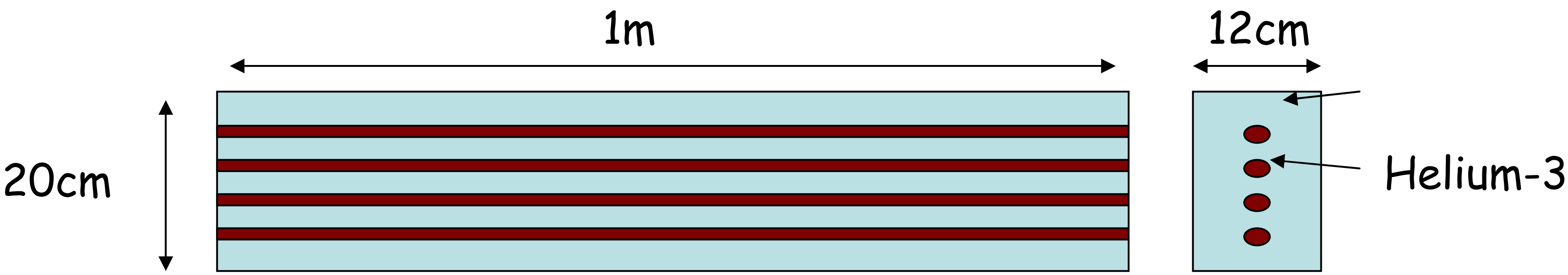
Q=764 keV



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

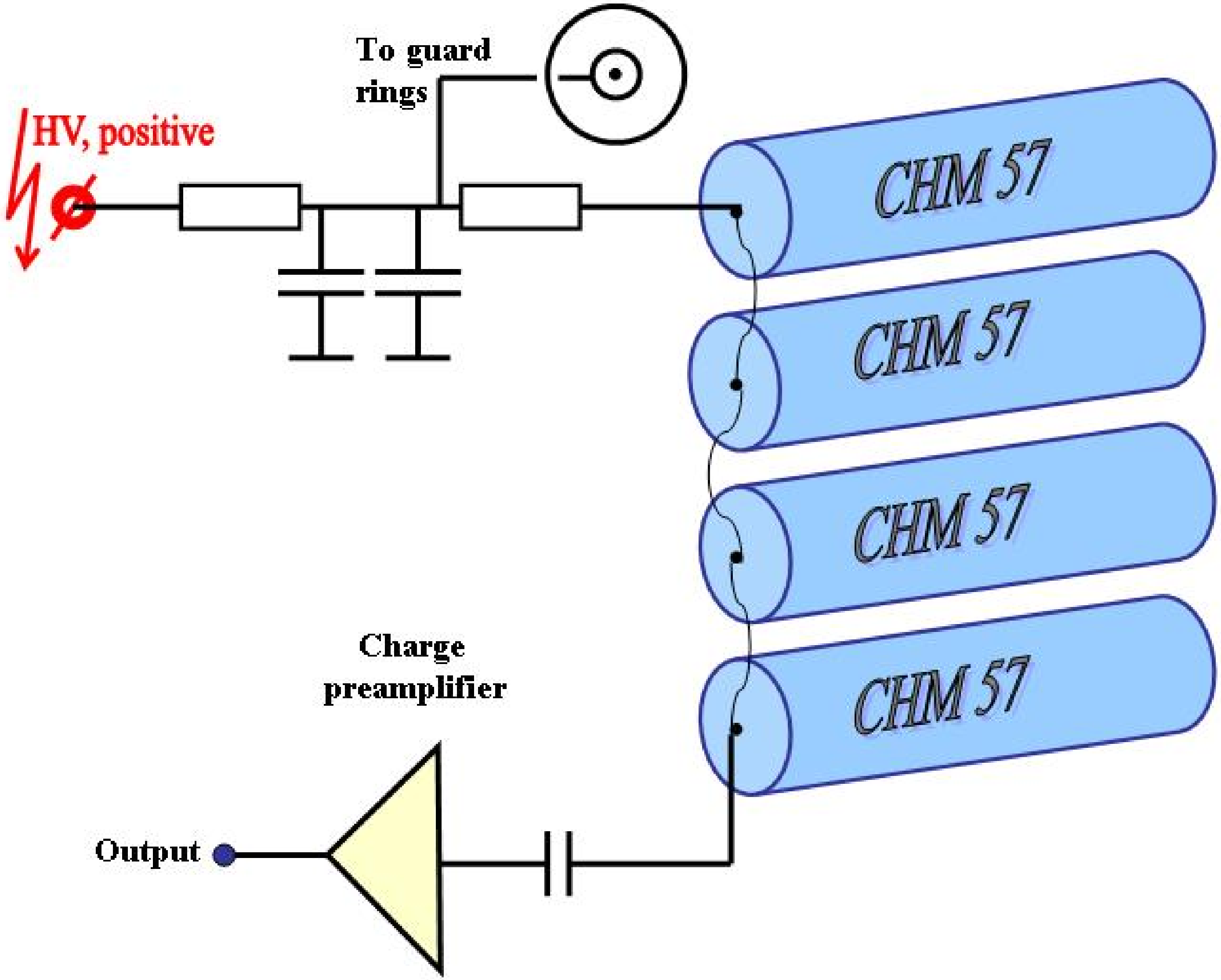
^{3}He counters are excellent instrument for detection of termolized neutrons (n peak is significantly higher of signal produced by gammas). The main background is due natural activity (alphas) in walls.

→ Stainless tube covered inside by 50-60 μm Teflon and 1μm electrolytic copper against alpha background



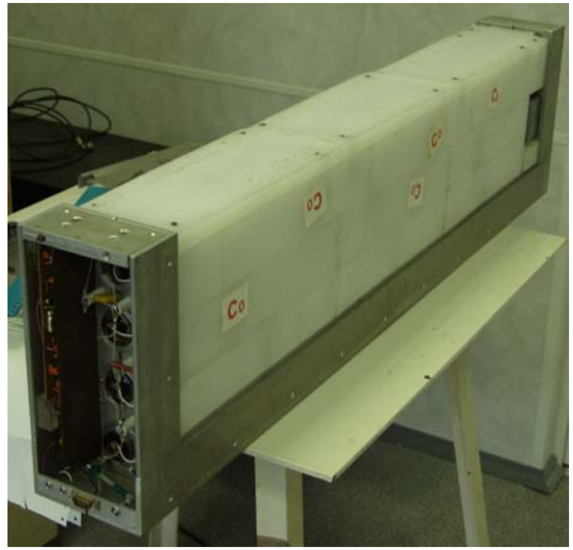
→ Polyethylene moderator to measure fast neutrons
The module has 4 counters

Electrical scheme of the module



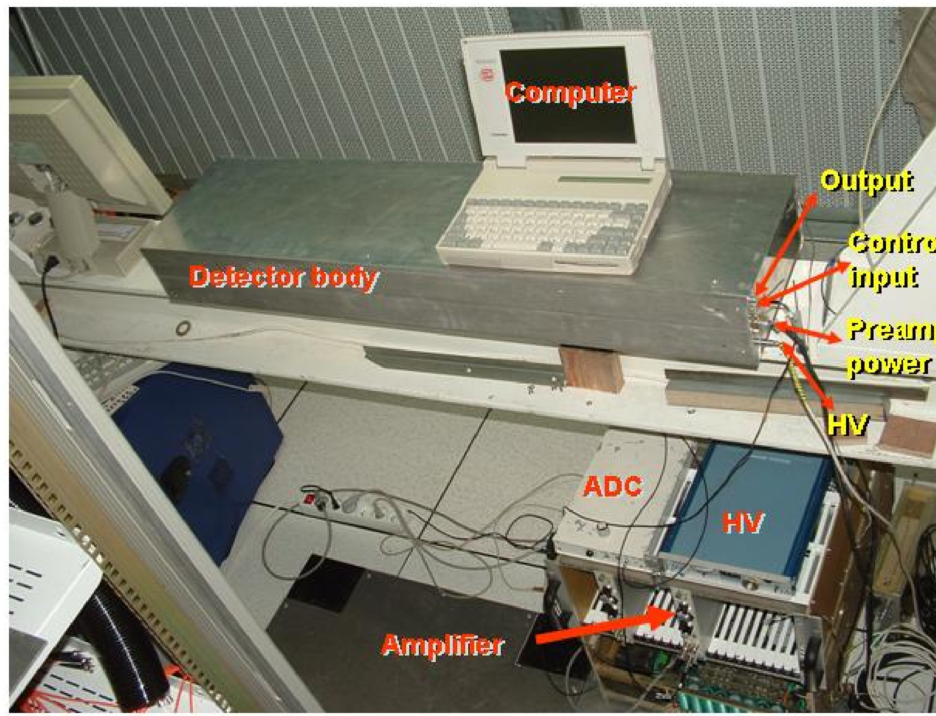
Counters chosen to have identical with each other response, so tandem connection can be used.

View of the module and it present installation at LSM

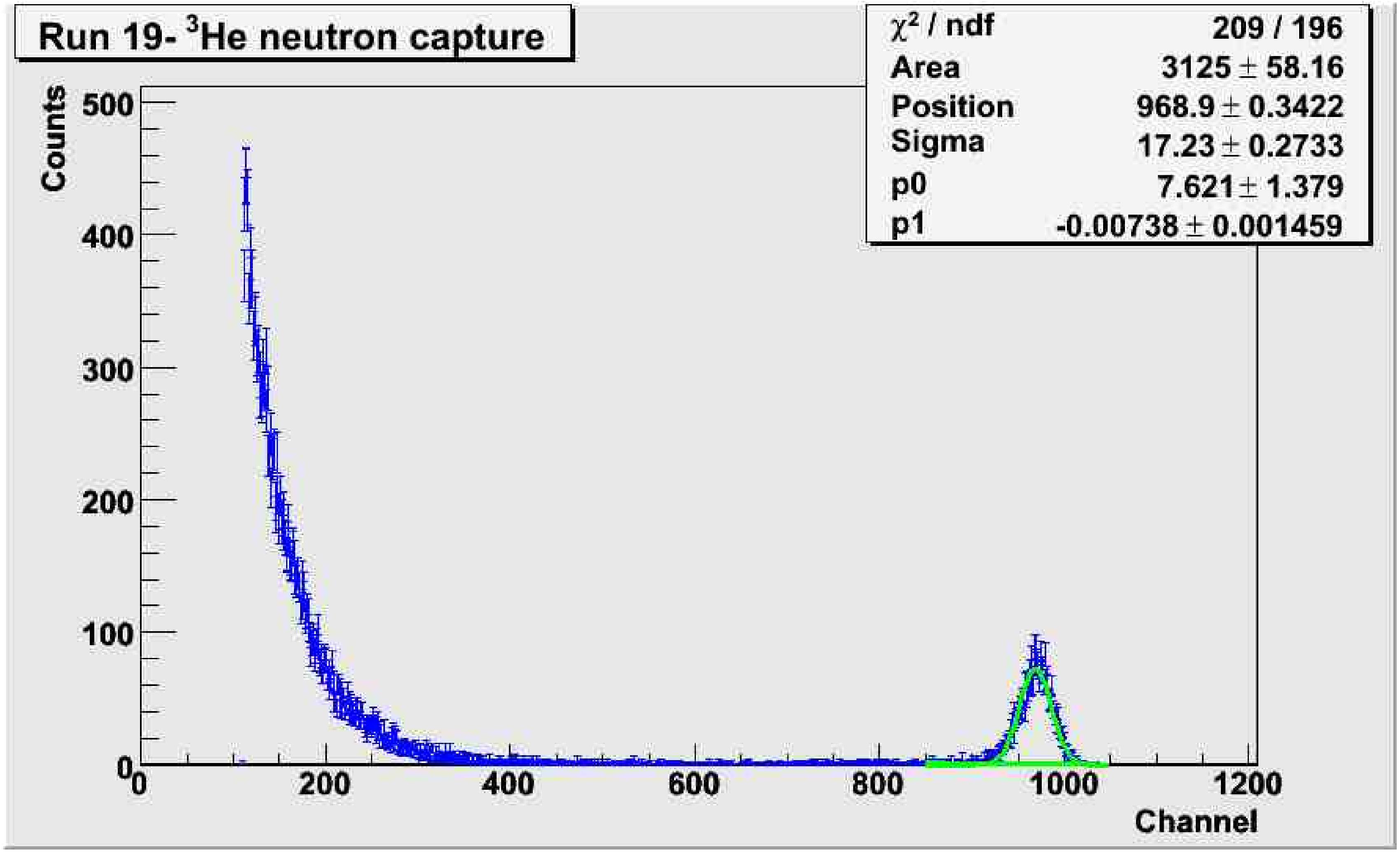


Front

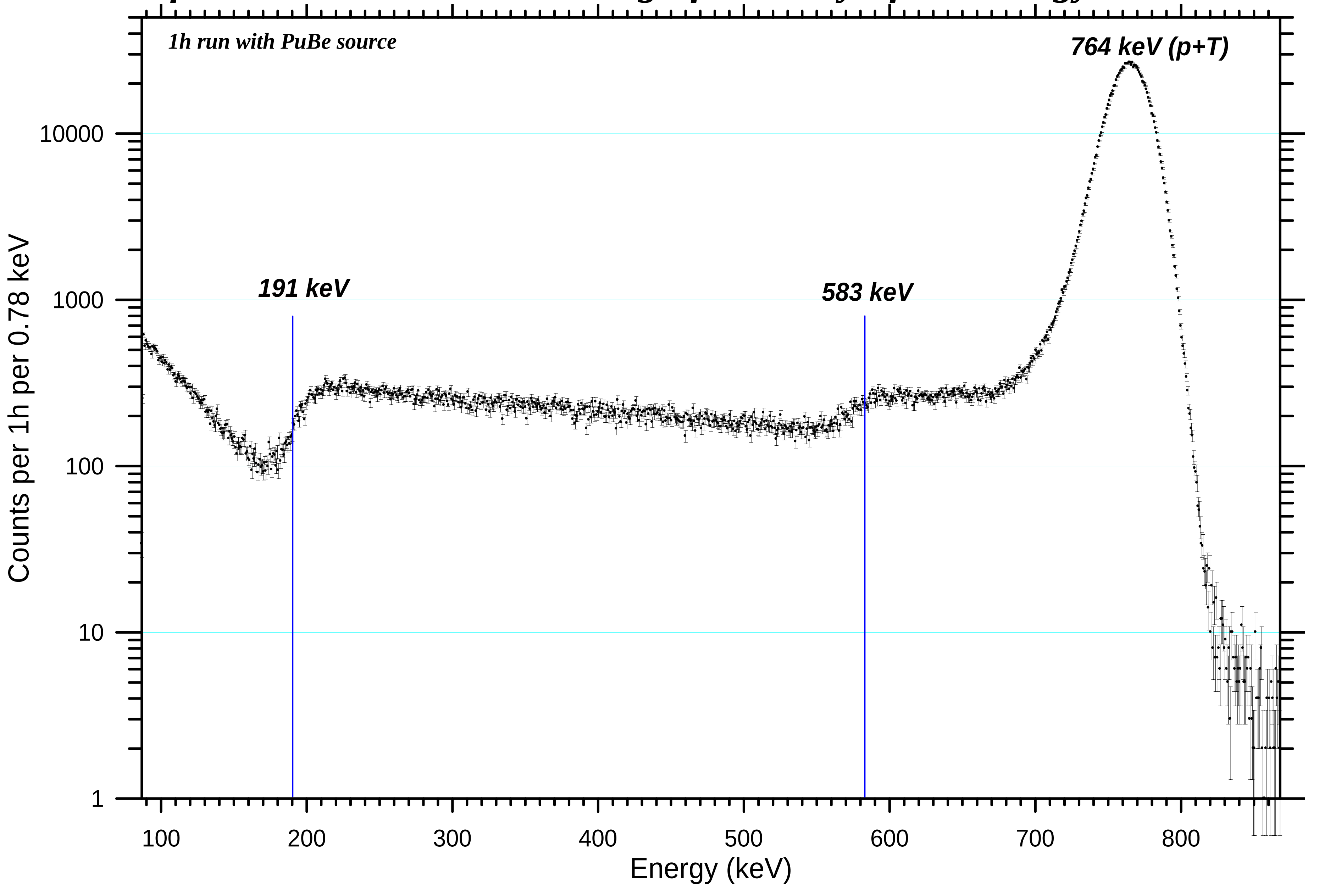
Back



Typical 1h background at Dubna laboratory
Counting rate at 764 keV peak – 0.87(2) Hz
That has to be compared to neutron flux on the ground (see level) which is about 60 n/sec/m²
Achieved resolution (FWHM) is 4.2%



Spectrum recorded by the detector under one hour exposition on strong neutron flux at Dubna lab. Checking of linearity of the energy scale.



Efficiency calibrations

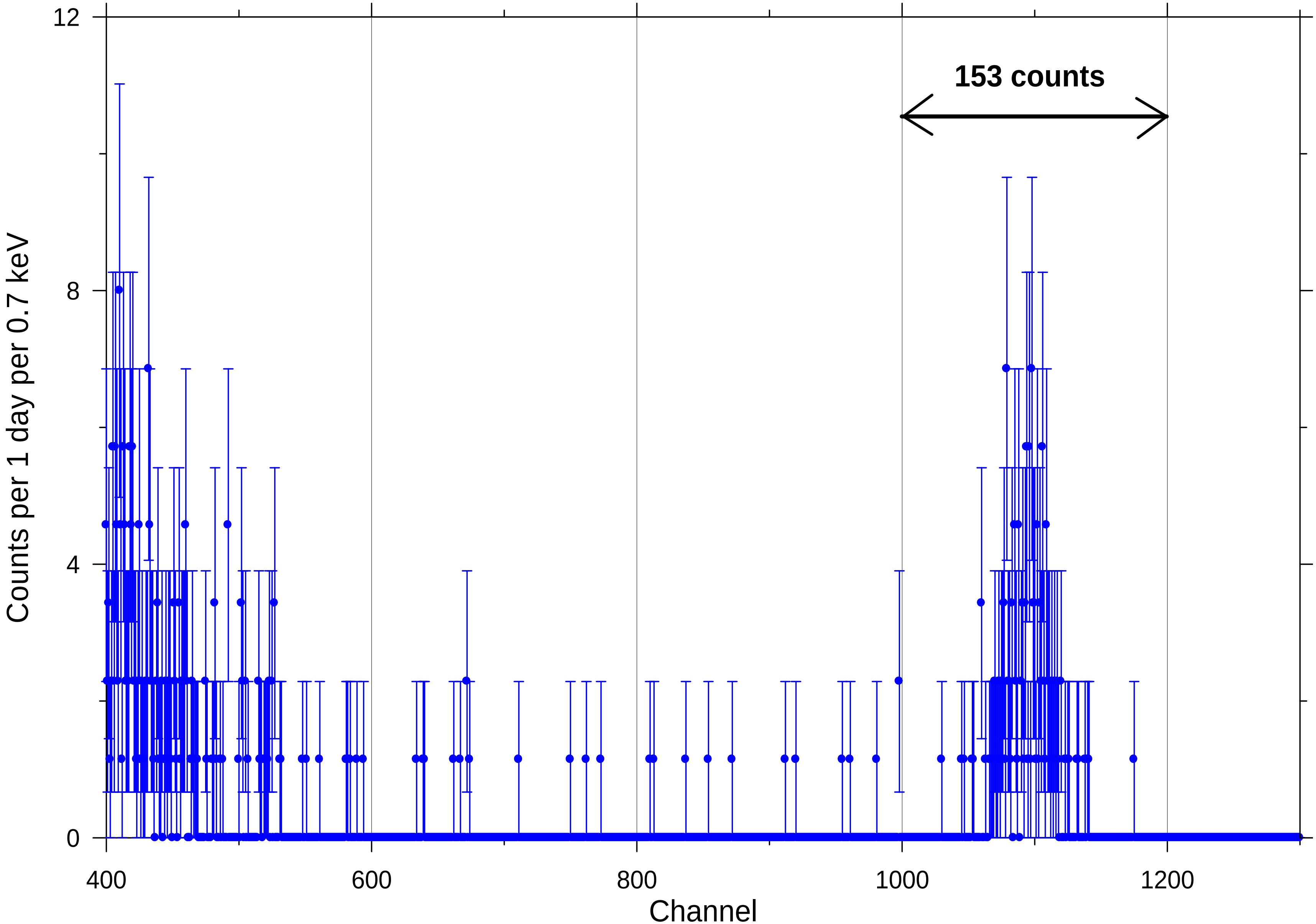
For determination of efficiency of detection MC simulation has to be performed (future plans)

Experimental data for such simulations was accumulated:

1) PuBe source located at different positions (also distanses) with respect to the detector was used.
2) 1 kg of depleted uranium 238 (neutrons due SF) at different places on surface of the module.

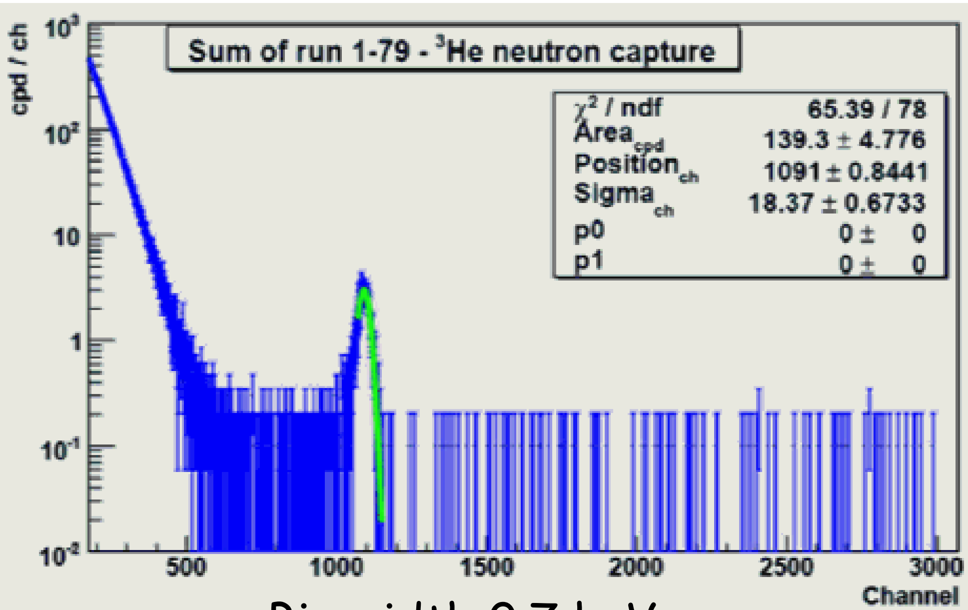
From preliminary estimations, it seems that efficiency is not bad for neutrons with energy bellow 10 MeV
For example, ^{238}U source of activity 15.2±1.3 n/s
placed directly on the surface of the module gives 1.00(6)Hz in the detector

Detector has been delivered to LSM at July
First 1 day measurement at LSM

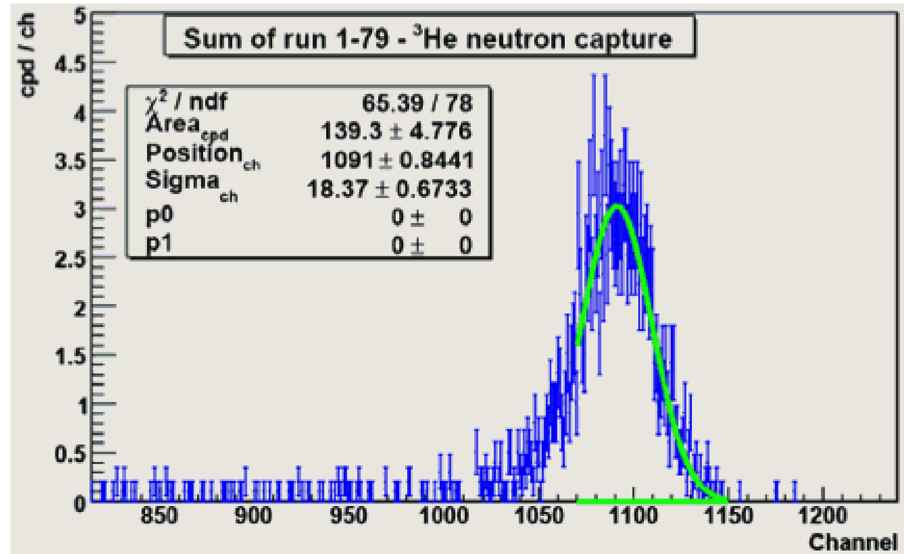


Measurements at LSM/ July 2006

First 237 hours (about 10 days)



Bin width 0.7 keV

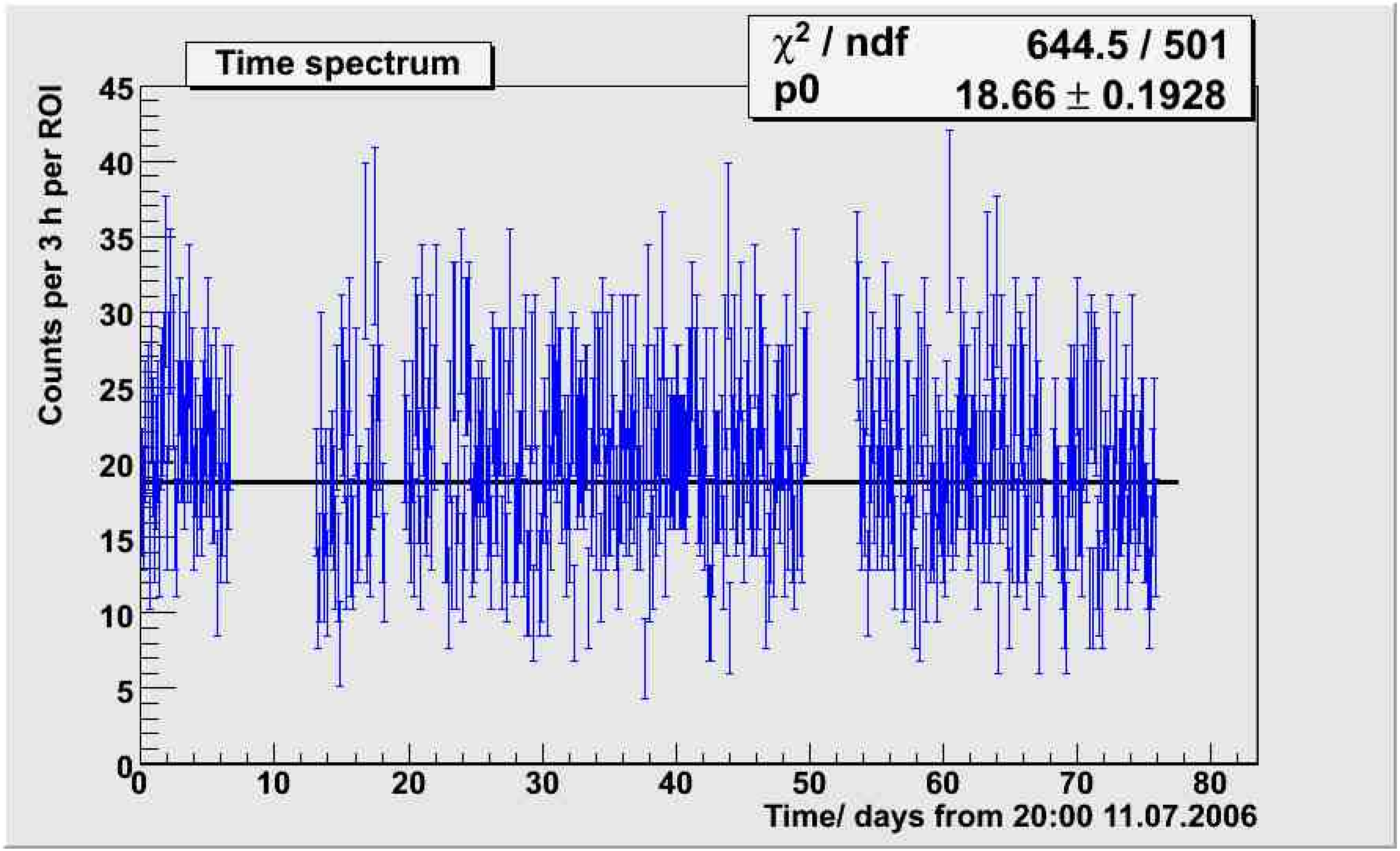


Resolution = 4%

-> Clearly identified peak with low background
-> 150±2 detected neutrons per day !
-> 2 σ level variations: 16% daily, 6% weekly, 3% monthly, 1% half year

Measurements at LSM

Neutron rate each 3 hours

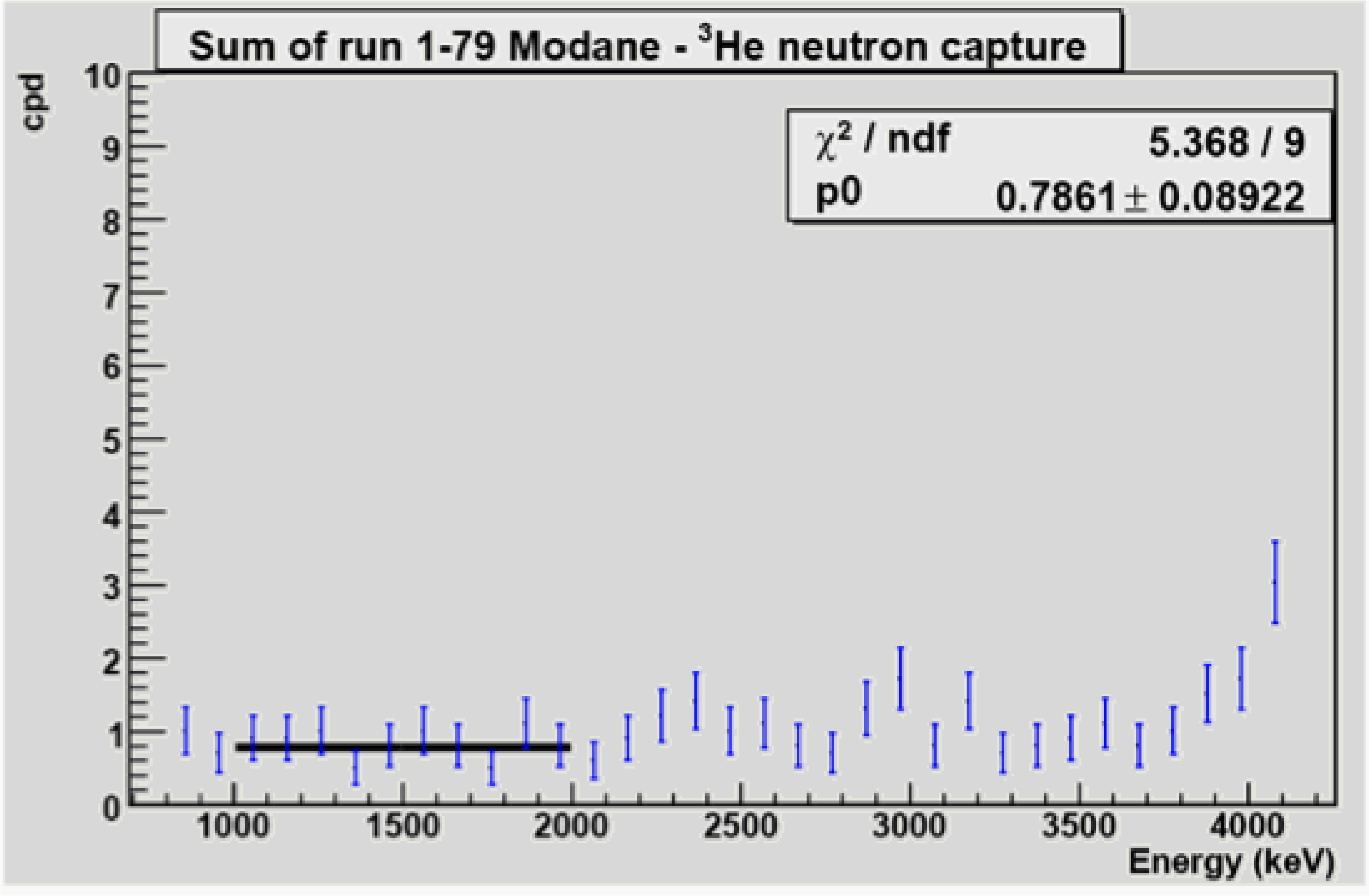


Measurements at LSM/ July 2006

From extrapolation of region above peak

-> 0.8(±0.1) counts per day in the peak region : 764±46 keV (ROI for neutron peak)

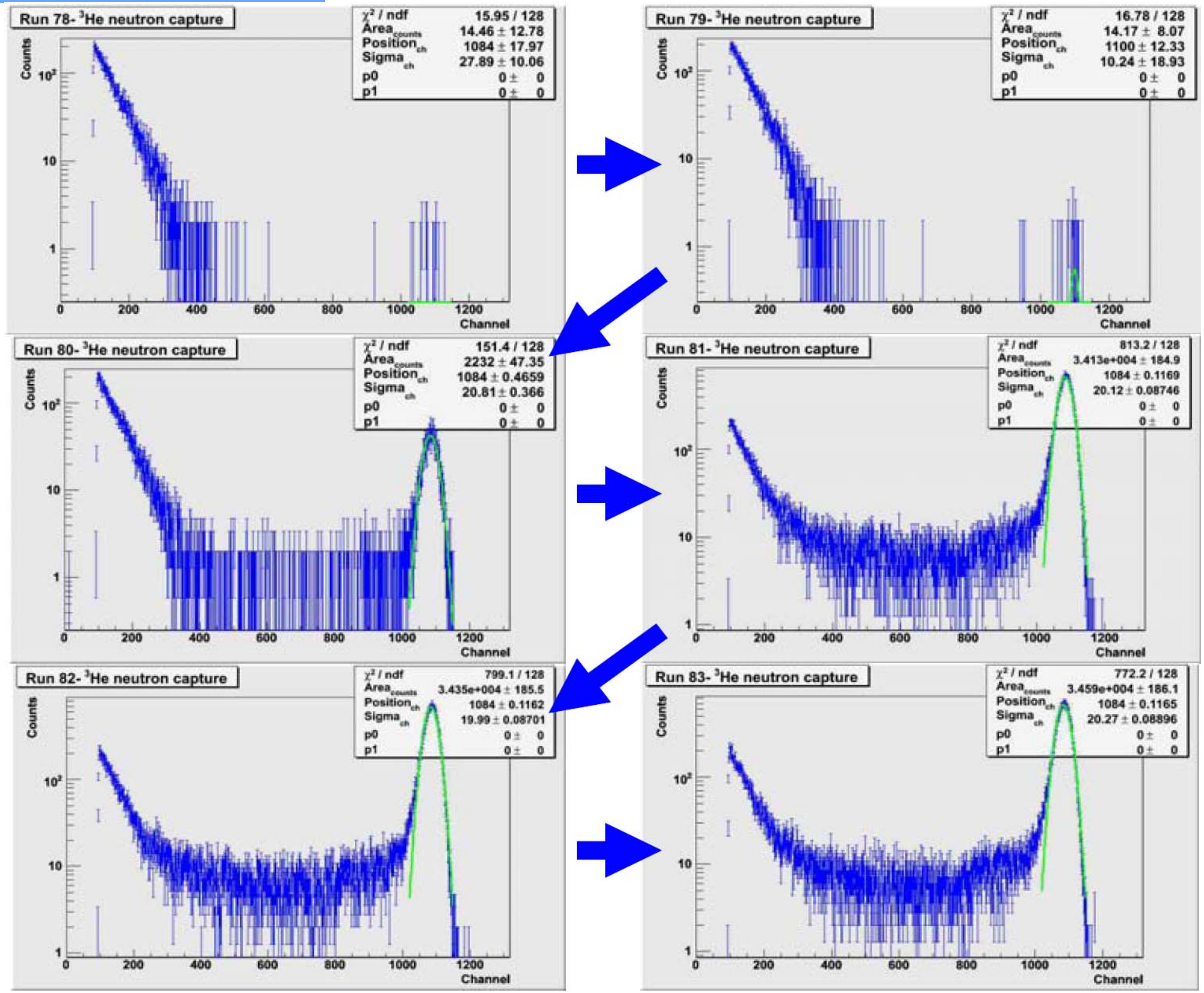
-> background 200 times lower than signal



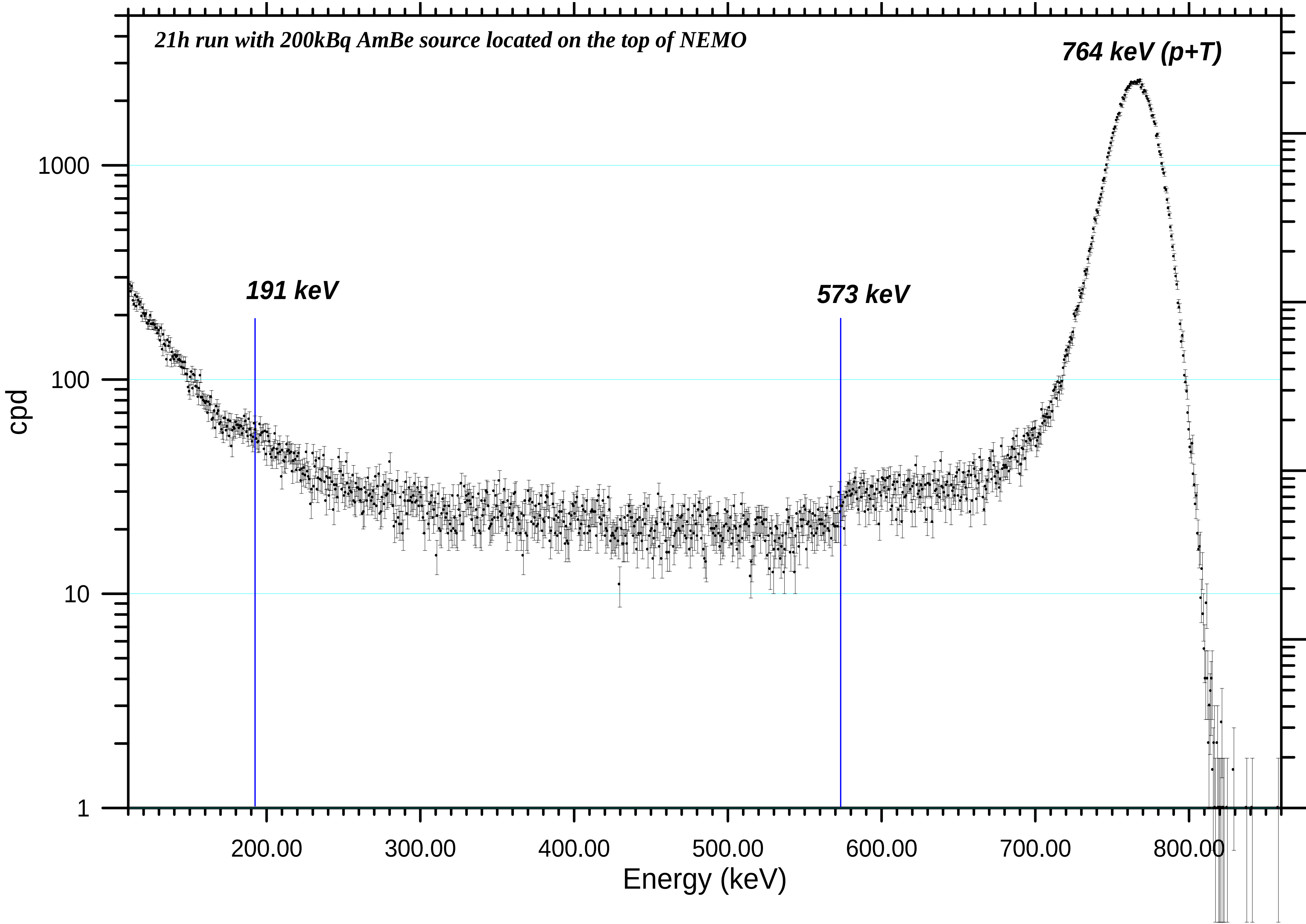
Bin width is 93 keV

Measurements at LSM

21-23 July 200kBq neutron source



Measurements at LSM



Future plans and things to do

-Use of Cd foil to disentangle thermal and fast neutrons

-Long term measurements to search for neutron flux variations (seasonal, day/night, etc)

- Neutron flux at different places of LSM

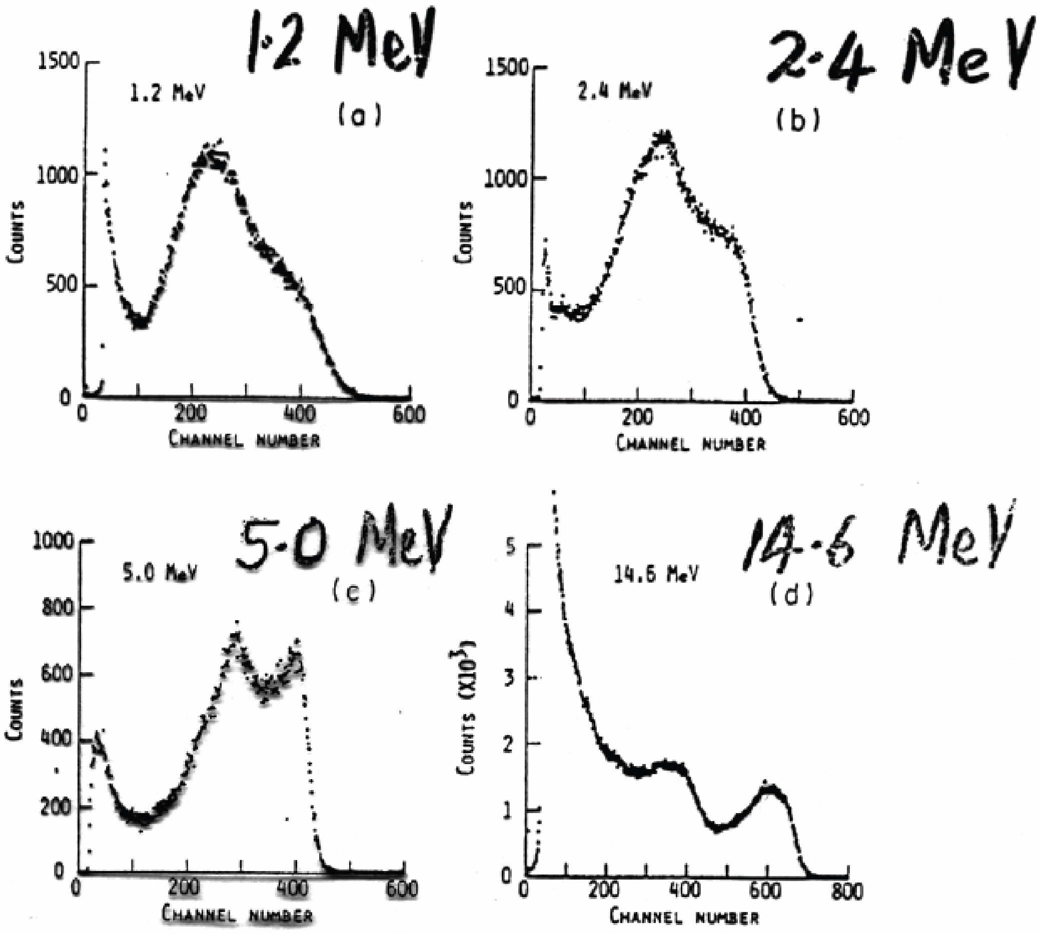
- Monte-Carlo simulation of the detector to estimate neutron flux with using calibration data available

- Use scintillator around of counters to measure neutron spectrum

- Muon/neutron correlation measurement with EDW μ-veto

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

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

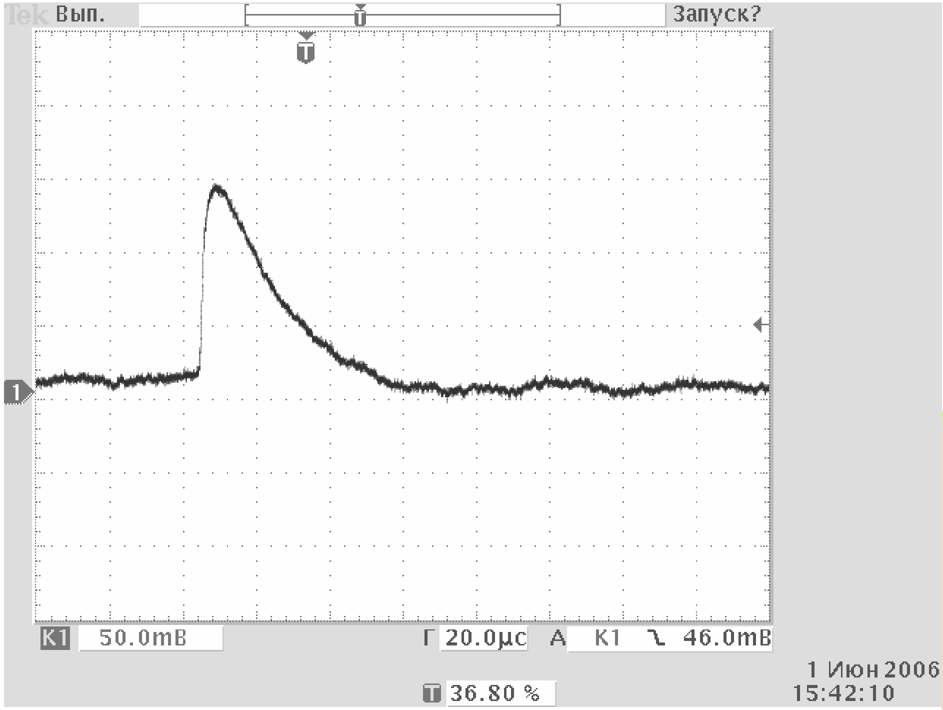
OPERA like scintillators around of counters – single recoil per cell

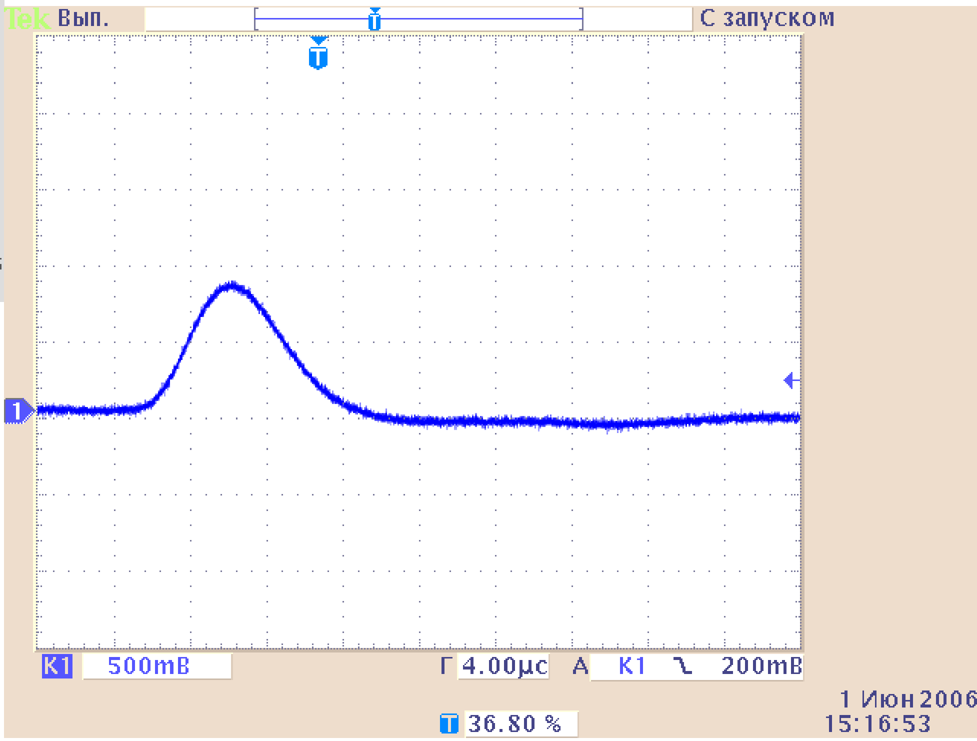
Conclusion

- A neutron detector based on ^{3}He counters has been successfully tested at LSM and demonstrated good performance.
- Continuous data taking from July. New results soon.
- We are still in beginning and a lot of work has to be done
- Precise neutron measurements is a hard task, we have to develop right methods if we want to know our tomorrow background.

The work conducting in cooperation with Institut für Kernphysik, Karlsruhe and EDELWEISS collaboration

Shape of signal after preamplifier (HV=1600V)





Shape of signal after ORTEC572 amplifier (gain 100, shaping time 2μs)

Neutron background sources underground

Low energy neutrons induced by U/Th activities

- fission and (α,n) reactions in the surrounding rock/concrete
- fission reactions in detector shield

High energy neutrons induced by muons