11th Collaboration Meeting of the BM@N Experiment at the NICA Facility

Neutron energy reconstruction with HGND prototype in Xe+CsI@3.8 AGeV run

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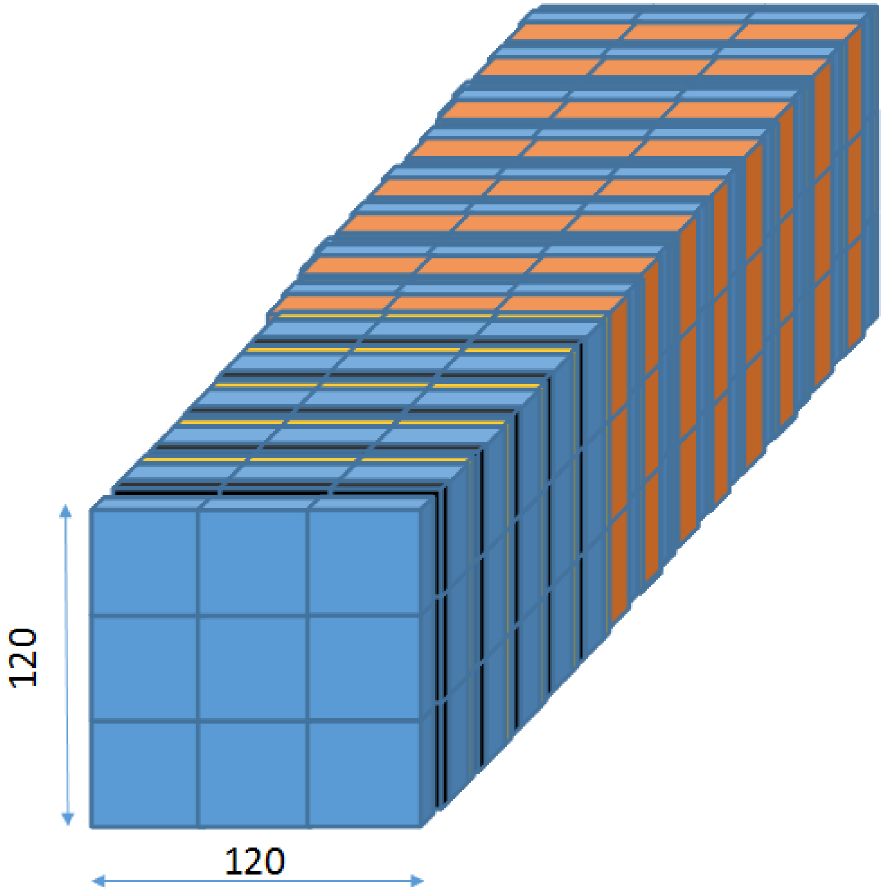
Introduction

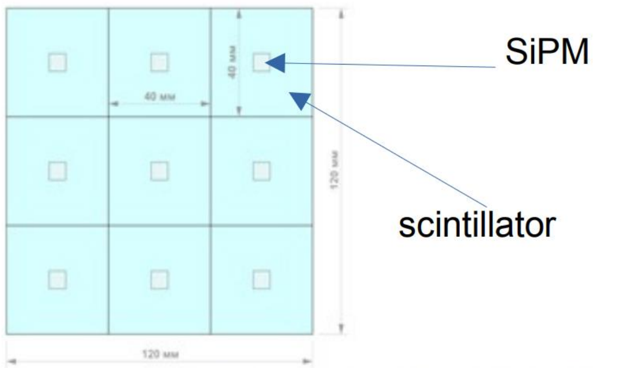
- The High Granular Neutron Time-of-Flight Detector (HGND) at the BM@N experiment is under development for measuring the energy of neutrons produced in nucleus-nucleus collisions.
- For the first time, small prototype of the HGND was used in Xe+CsI at 3.0 and 3.8 AGeV run at the BM@N.
- The multilayer (absorber/scintillator) and high granular structure of the ToF HGND makes it possible to identify and measure the energies of neutrons.
- Neutron energy reconstruction with HGND prototype at 0° and 27° positions in Xe+CsI@3.8 AGeV run will be discussed.

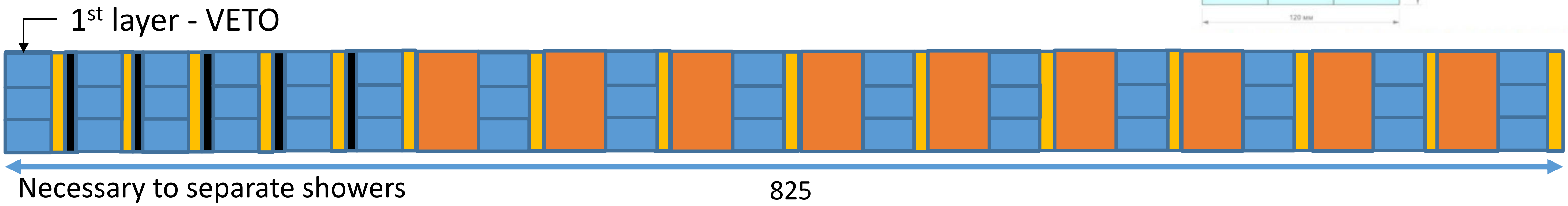
HGND prototype design



- Scint. layer **Veto** 120x120x25 (мм)
- 1^{st} (electromagnetic) part:
  5 layers: Pb (8mm) + Scint. (25mm)
  + PCB + air
- 2^{nd} (hadronic) part:
  9 layers: Cu (30mm) + Scint. (25mm)
  + PCB + air

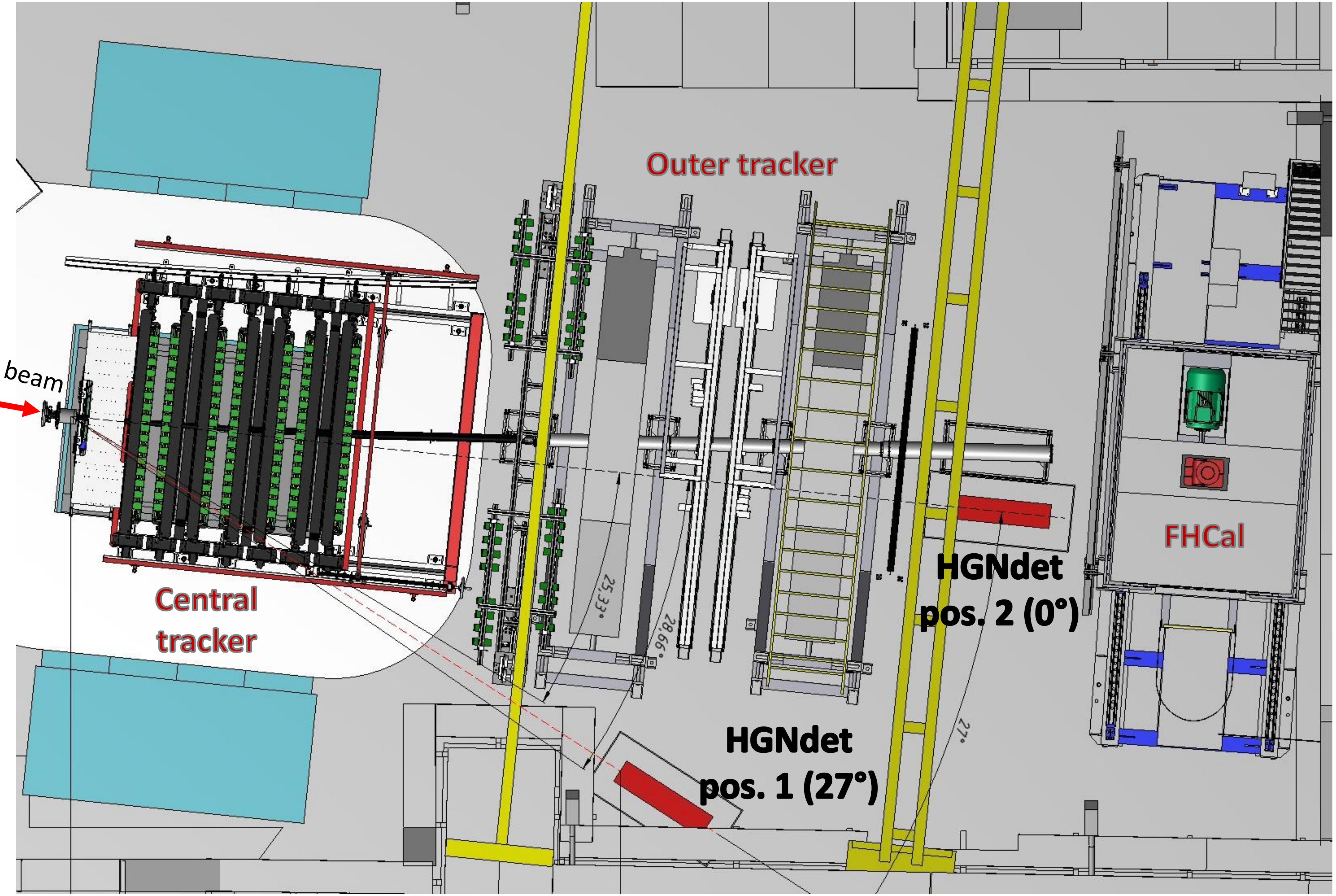
Scint. cell – 40 x 40 x 25 mm^3
Total number of cells – 9+45+81=135
Total size – 12 x 12 x 82.5 см^3
Total length ~ 2.5 λ_{int}





Necessary to separate showers from gamma quanta

HGND prototype in the Xe run of BM@N on Xe ion beam



27° position:

Measurements of the neutron spectrum at ~ midrapidity.

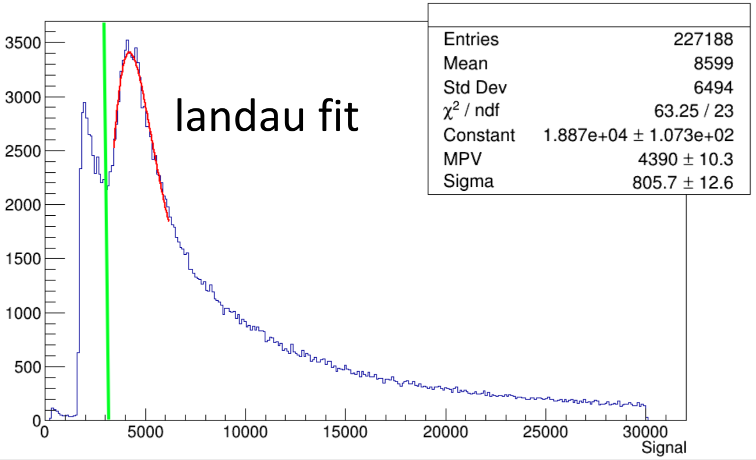
0° position:

Test and calibration with known neutron energy (energy of a beam of spectator neutrons)

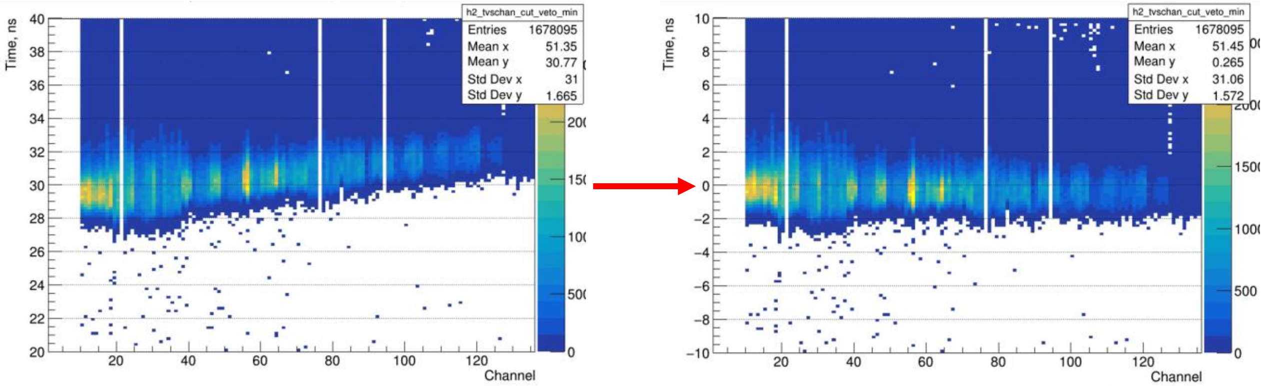
HGND calibration

1. Amplitude normalization

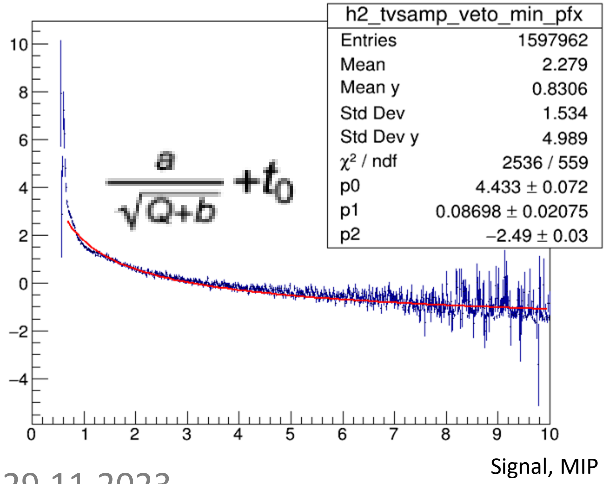
$$Ampl = Ampl \cdot \frac{1}{MPV}$$



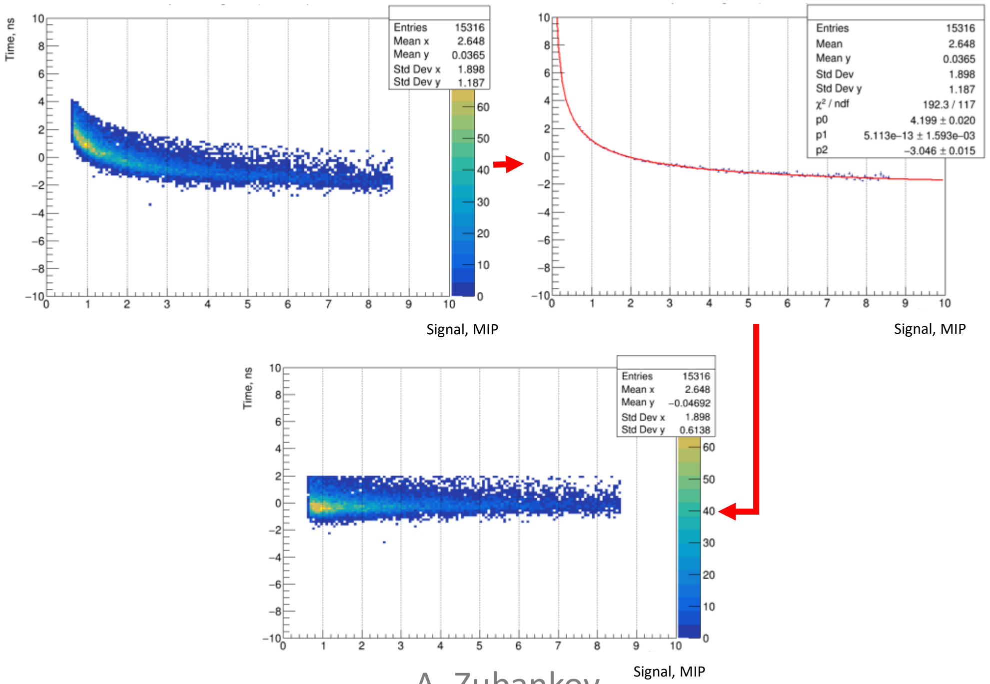
2. Time shift for all channels by the average fit value



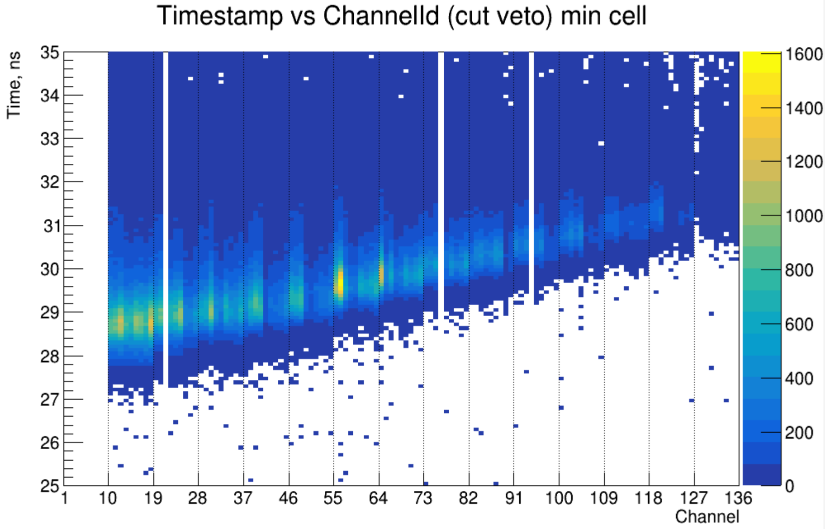
3. Determination of parameters of the approximating function for all channels & time limit



4. Time-amplitude correction

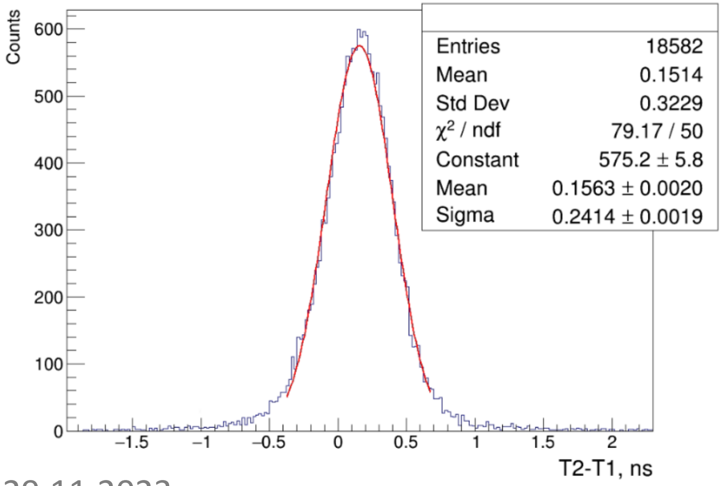


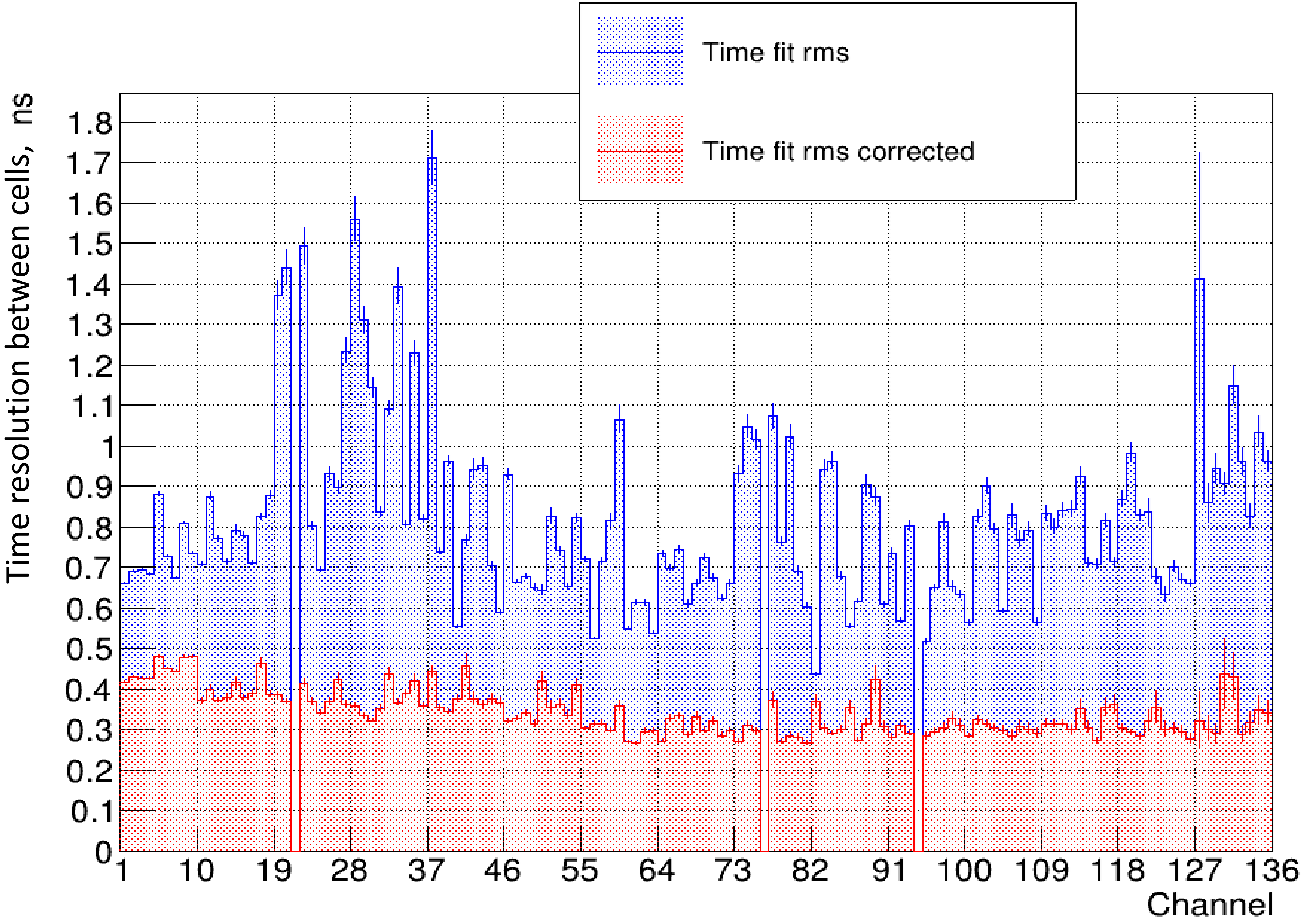
5. Time shift



HGND calibration

Time-amplitude correction of signals made it possible to get rid of the dependence of time on signal amplitude, which improved the time resolution by ~2.4 times.





Estimating the time resolution of cells

Selection – hits in 4 consecutive layers: (i) & (i+1) & (i+2) & (i+3),
3 of which are used to calculate the time resolution of the cell in layers 6 – 11.

Xe + CsI (2%) @ 3.8 AGeV
1 Xe ion, BC1S, CCT2
HGN 0 deg. pos., Veto cut

1st step 1-3 layers

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

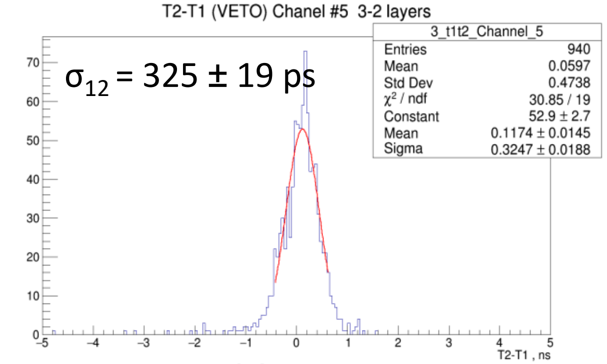
2nd step 1-3 layers

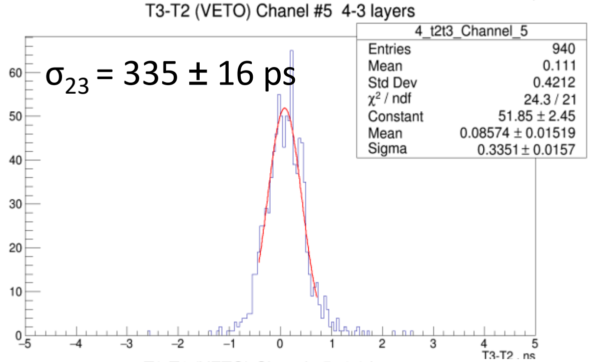
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

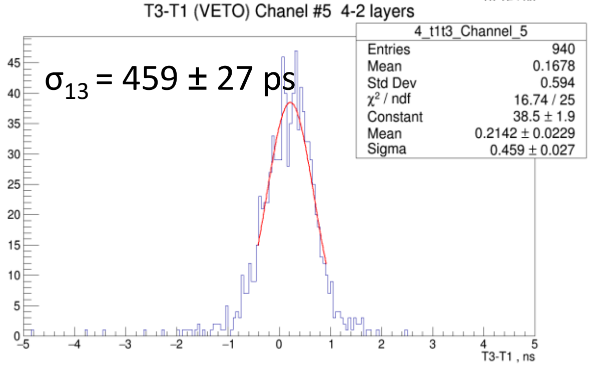
$$\sigma_1^2 + \sigma_2^2 = \sigma_{12}^2$$
$$\sigma_2^2 + \sigma_3^2 = \sigma_{23}^2$$
$$\sigma_1^2 + \sigma_3^2 = \sigma_{13}^2$$

$$\sigma_1 = \sqrt{((\sigma_{12}^2 + \sigma_{13}^2 - \sigma_{23}^2)/2)}$$
$$\sigma_2 = \sqrt{((\sigma_{12}^2 + \sigma_{23}^2 - \sigma_{13}^2)/2)}$$
$$\sigma_3 = \sqrt{((\sigma_{13}^2 + \sigma_{23}^2 - \sigma_{12}^2)/2)}$$

Average time resolution $\overline{\sigma_2}$ = 134±29 ps







Estimation of γ-background

Criterion for selecting events with "γ-quanta":

- Veto == 0
- Ampl > 0.5 MIP
- Hits in 2 & 3 & 4 layers in module

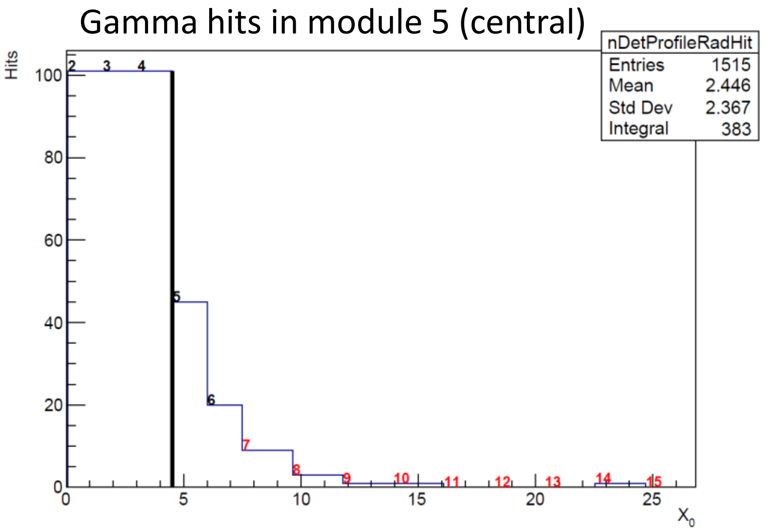
=> 4.52 X_0 or 0.266 λ_{int}

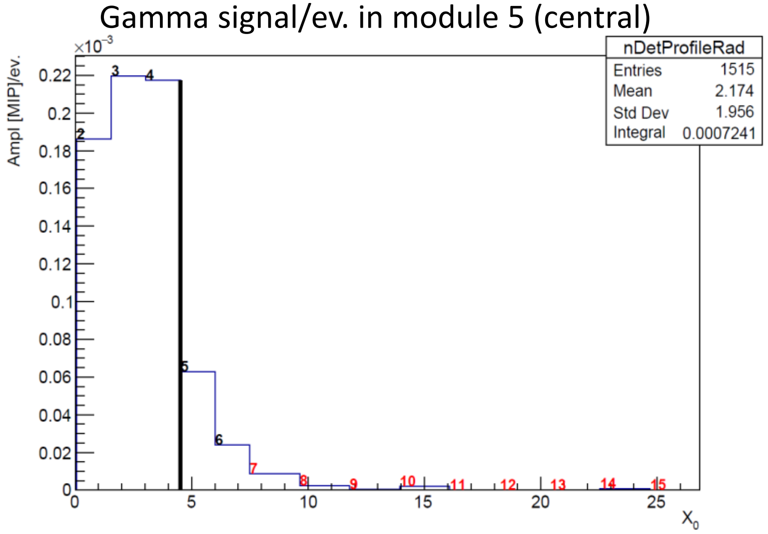
layer

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

For inverted HGND prototype:

- Hits in 14 & 13 layers in module => 4.36 X_0





Fraction of γ-ev. in single individual cells

Beam ⊗

Cell 1 (layer 3 didn't work)	***Cell 2*** **0.0092%** ±0.0009%	***Cell 3*** **0.0097%** ±0.0009%
Cell 4 **0.0202%** ±0.0013%	***Cell 5*** **0.0084%** ±0.0008%	***Cell 6*** **0.0099%** ±0.0009%
Cell 7 **0.0221%** ±0.0014%	***Cell 8*** **0.0118%** ±0.0010%	***Cell 9*** **0.0102%** ±0.0009%

Fraction of γ-ev. for inverted HGND prot.

Beam ⊗

Cell 3 **0.0287%** ±0.0015%	***Cell 2*** **0.0131%** ±0.0010%	***Cell 1*** **0.0117%** ±0.0010%
Cell 6 **0.0287%** ±0.0015%	***Cell 5*** **0.0131%** ±0.0010%	***Cell 4*** **0.0227%** ±0.0013%
Cell 9 **0.0340%** ±0.0016%	***Cell 8*** **0.0117%** ±0.0010%	***Cell 7*** **0.0146%** ±0.0011%

Xe + CsI (2%) @ 3.8 AGeV
HGN 27 deg. pos.
Total number of events:
1 Xe ion, BC1S + CCT2 – 1.2M (100%)
+ Veto cut – 68.2k (5.67%)

Fraction of γ-ev. in full HGND prototype (all cells):
0.173 %

Comparable to simulation (0.1–0.2%)

Gamma rejection efficiency is the same in both configurations

Reconstruction of the neutron energy spectrum

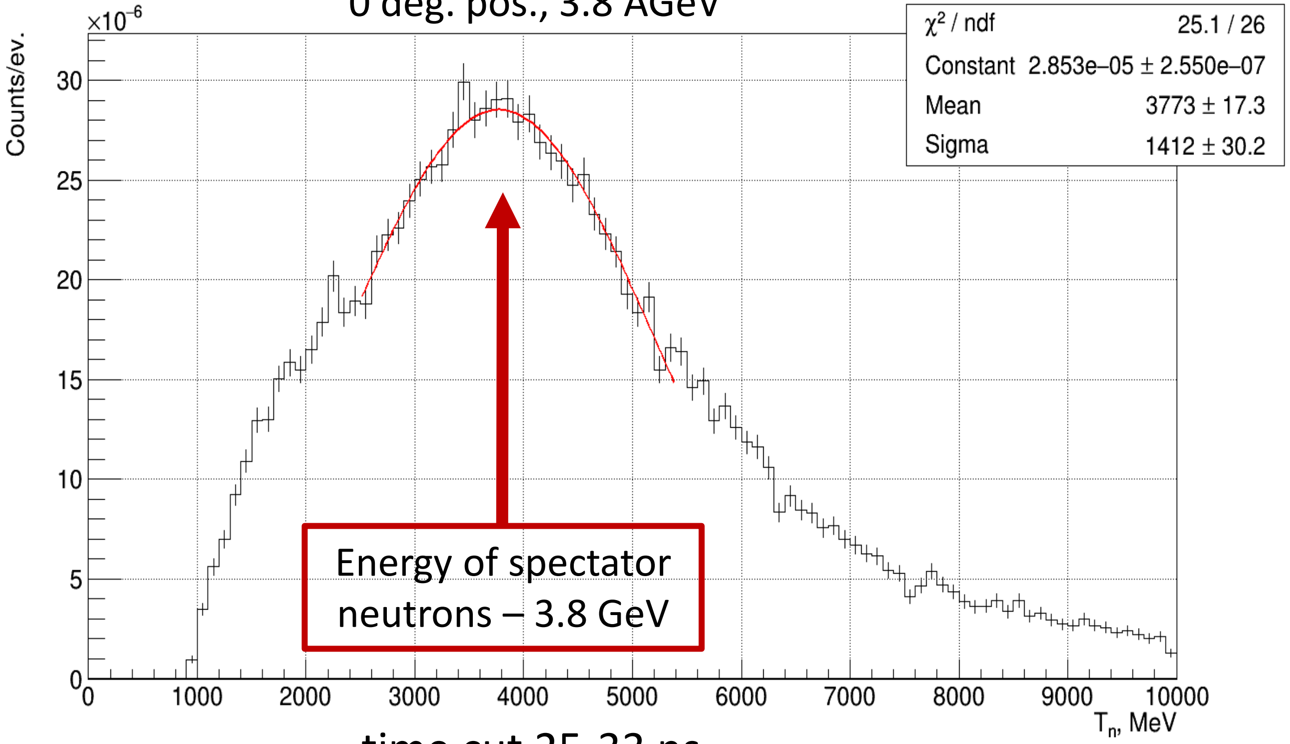
Criteria for selecting events with neutrons:

- 1 Xe ion, BC1S + CCT2
- Veto == 0, Ampl > 0.5 MIP, time cut

Reconstruction of energy by maximum speed

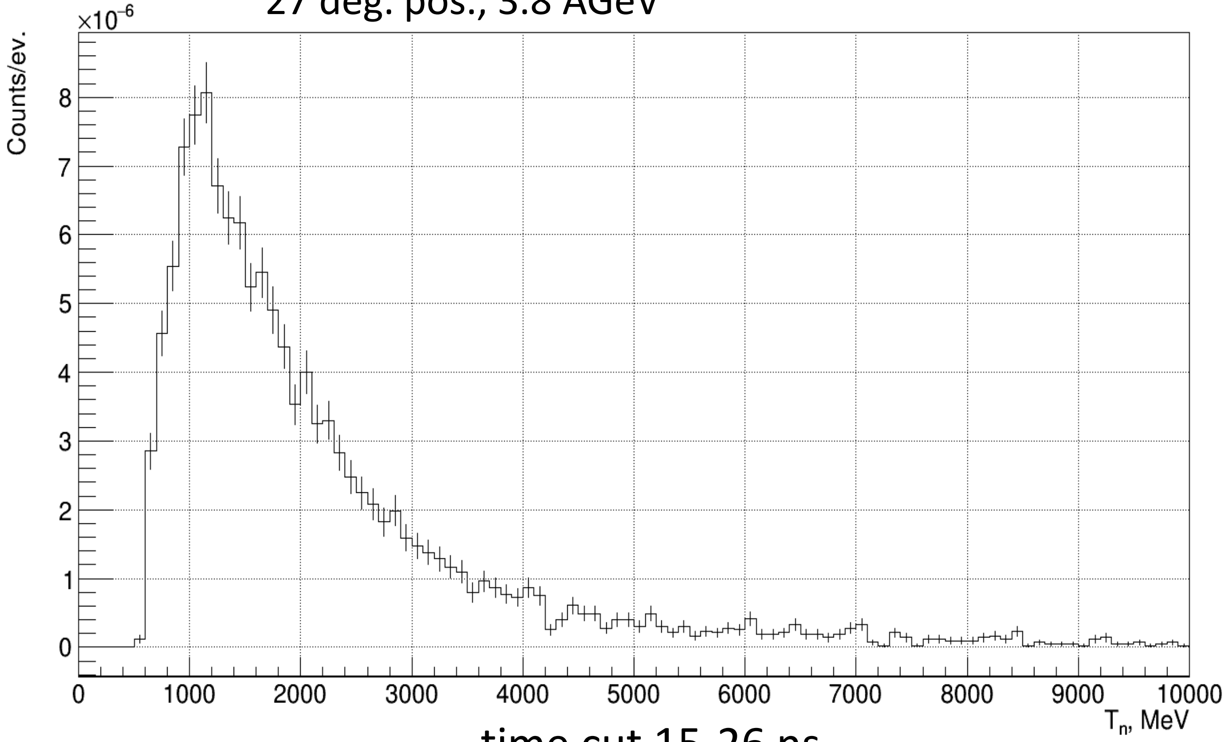
Without efficiency correction

0 deg. pos., 3.8 AGeV



time cut 25-33 ns

27 deg. pos., 3.8 AGeV



time cut 15-26 ns

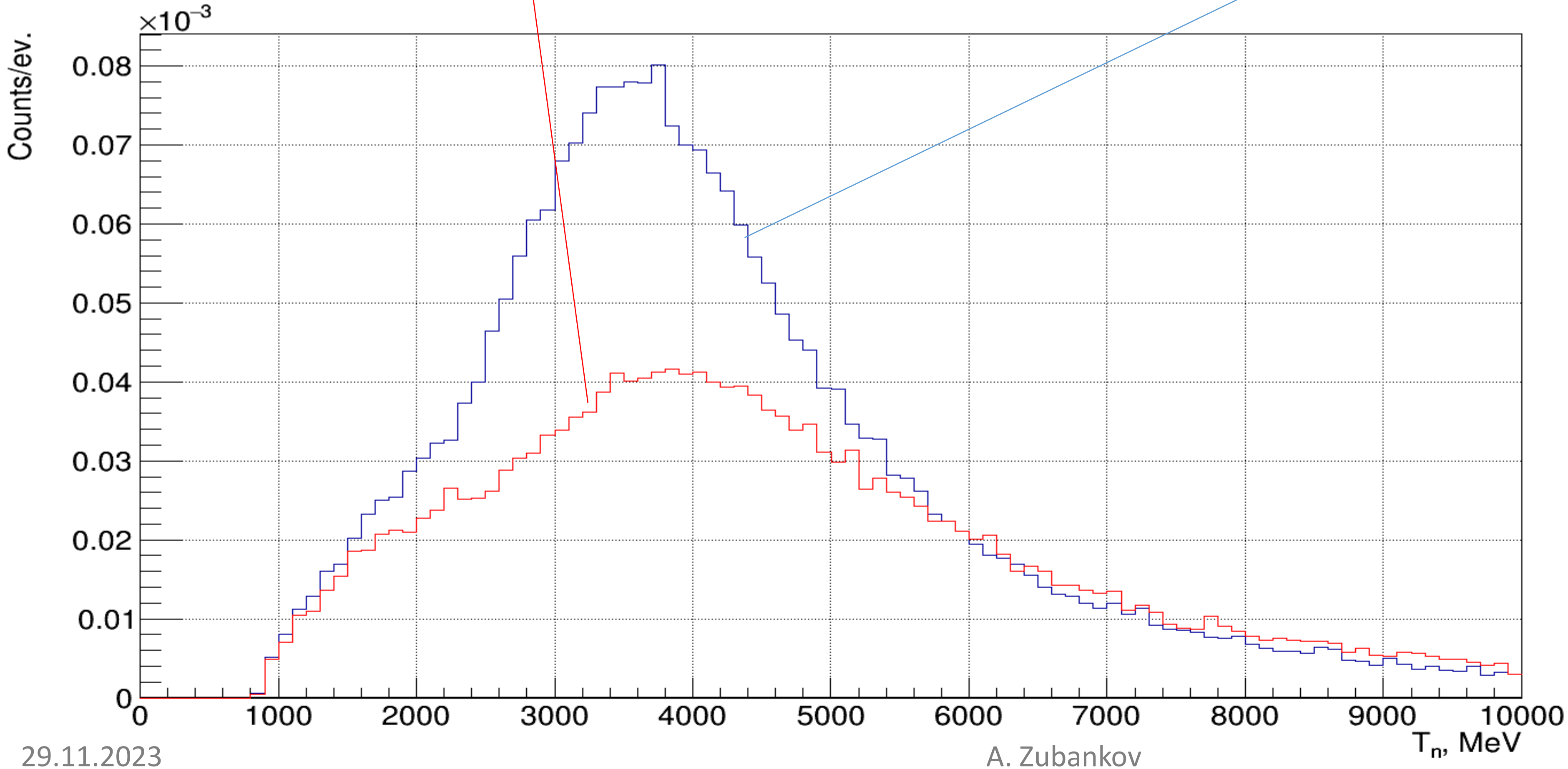
Position	n/ev. (BC1S+CCT2)
0 deg.	29,35%
27 deg.	2,33%

Reconstruction of the neutron energy spectrum at 0 deg.

Runs 7513, 7514 - **0 deg. pos.**
CsI 2%
Total number of events - 755k
BC1S + CCT2 – 252k
Vertex ± 1.5 – 177k
Veto – 74k
BT*(prescale factor+1) – 18k*2k

Reco
Max speed
Time cut 25-33 ns
Scaled by BT*(prescale factor+1)

Run 8300 - **0.7 deg pos.**
CsI 2%
Total number of events – 889k
BC1S + CCT2 – 319k
Vertex ± 1.5 – 234k
Veto – 104k
BT*(prescale factor+1) – 19k *2k



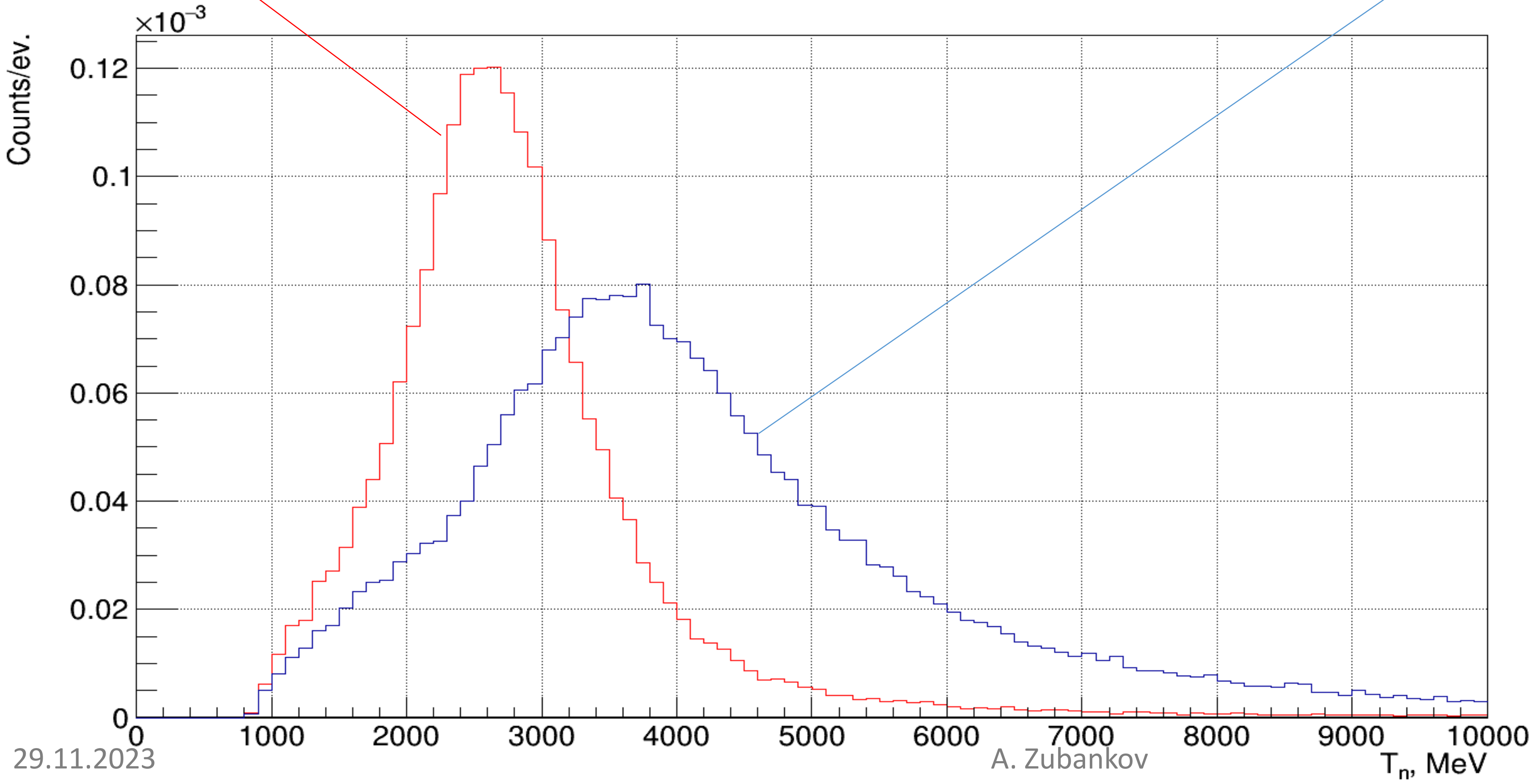
Position	n/ev. (BC1S+CCT2)
0 deg.	29,35%
0.7 deg.	32,61%

Reconstruction of the neutron energy spectrum at 0 deg.

Run 8320 – **3 AGeV**
CsI 2%
Total number of events – 579k
BC1S + CCT2 – 212k
Vertex ± 1.5 – 165k
Veto – 62k
BT*(prescale factor+1) – 15k*2k

Reco
Max speed
Time cut 25-33 ns
Scaled by BT*(prescale factor+1)

Run 8300 – **3.8 AGeV**
CsI 2%
Total number of events – 889k
BC1S + CCT2 – 319k
Vertex ± 1.5 – 234k
Veto – 104k
BT*(prescale factor+1) – 19k *2k



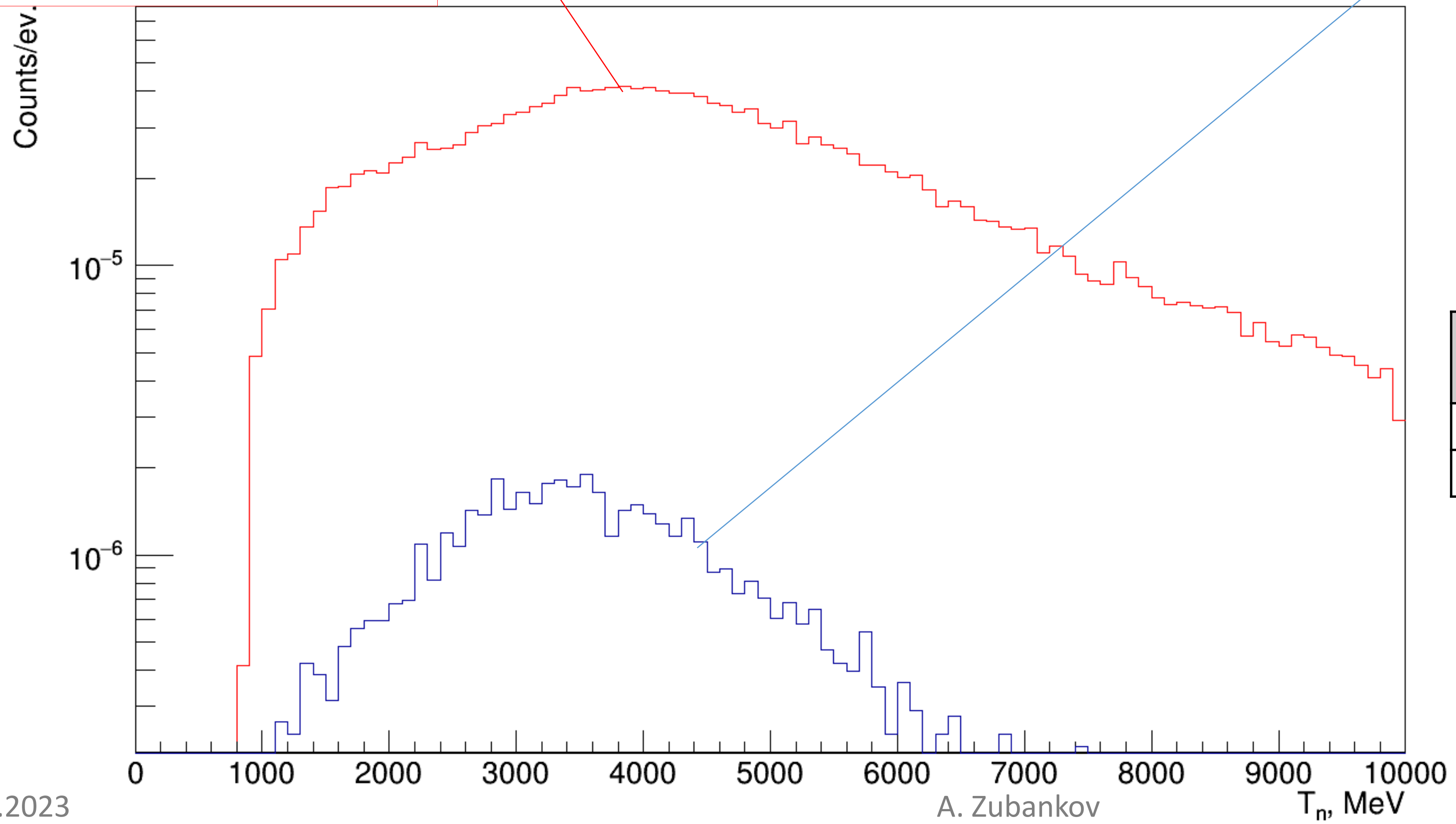
Position	n/ev. (BC1S+CCT2)
0.7 deg. 3 AGeV	29,43%
0.7 deg. 3.8 AGev	32,61%

Reconstruction of the neutron energy spectrum at 0 deg.

Runs 7513, 7514
CsI 2%
Total number of events - 755k
BC1S + CCT2 – 252k
Vertex ± 1.5 – 177k
Veto – 74k
BT*(prescale factor+1) – 18k*2k

<u>Reco</u>
Max speed
Time cut 25-33 ns
Scaled by BT*(prescale factor+1)

Runs 7527, 8224, 8237, 8243, 8249
Empty target
Total number of events – 498k
BC1S + CCT2 – 109k
Vertex ± 1.5 – 10k
Veto – 4.5k
BT*(prescale factor+1) – 41k *2k



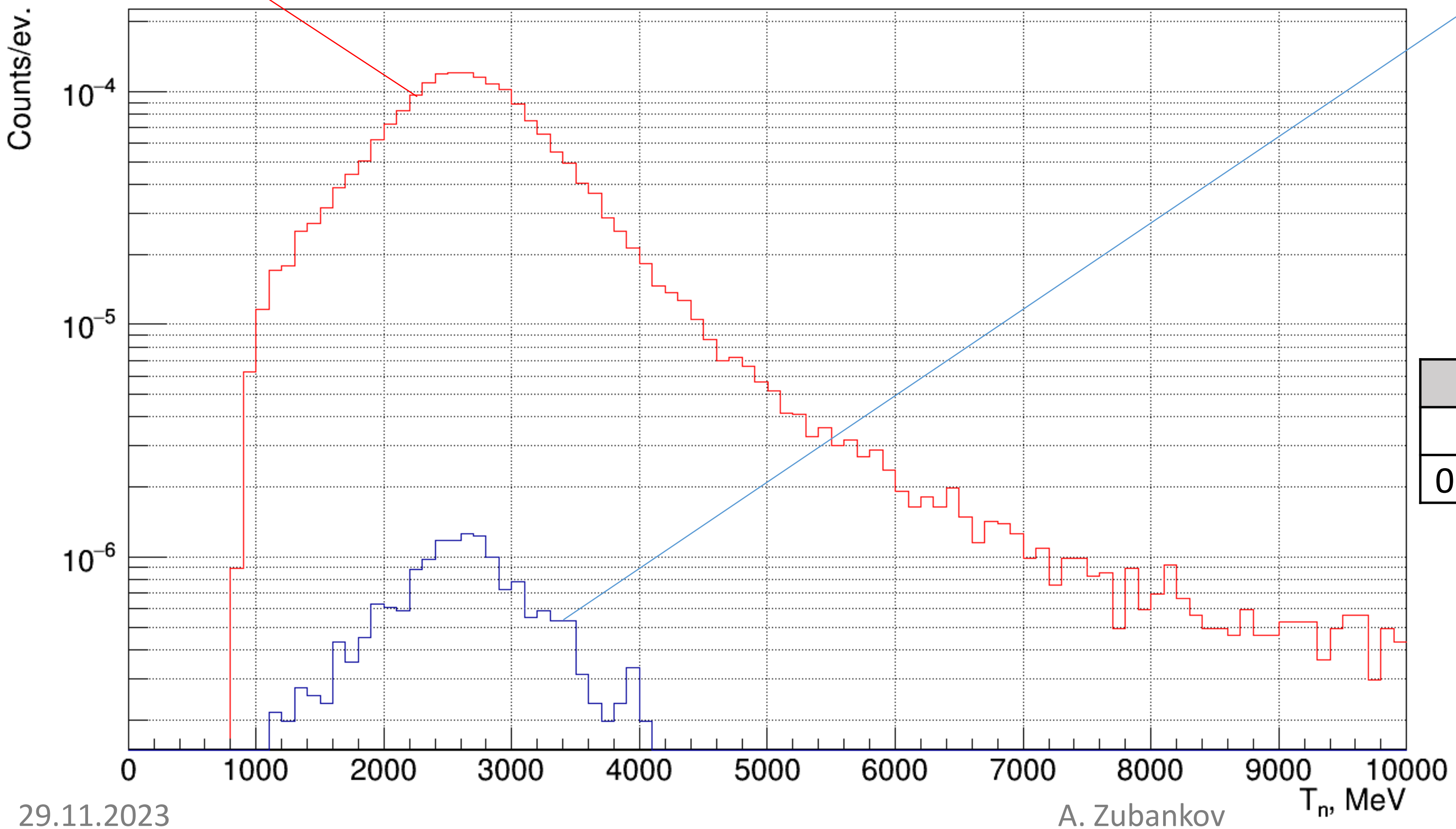
Position	n/ev. (BC1S+CCT2)	
0 deg.	29,35%	100%
0 deg. empty	4,11%	14%

Reconstruction of the neutron energy spectrum at 0 deg.

Run 8320 3 AGeV
CsI 2%
Total number of events – 579k
BC1S + CCT2 – 212k
Vertex ± 1.5 – 165k
Veto – 62k
BT*(prescale factor+1) – 15k*2k

<u>Reco</u>
Max speed
Time cut 25-33 ns
Scaled by BT*(prescale factor+1)

Runs 8327, 8333, 8336
Empty target
Total number of events - 319k
BC1S + CCT2 – 33k
Vertex ± 1.5 – 2.5k
Veto – 1k
BT*(prescale factor+1) – 25k*2k



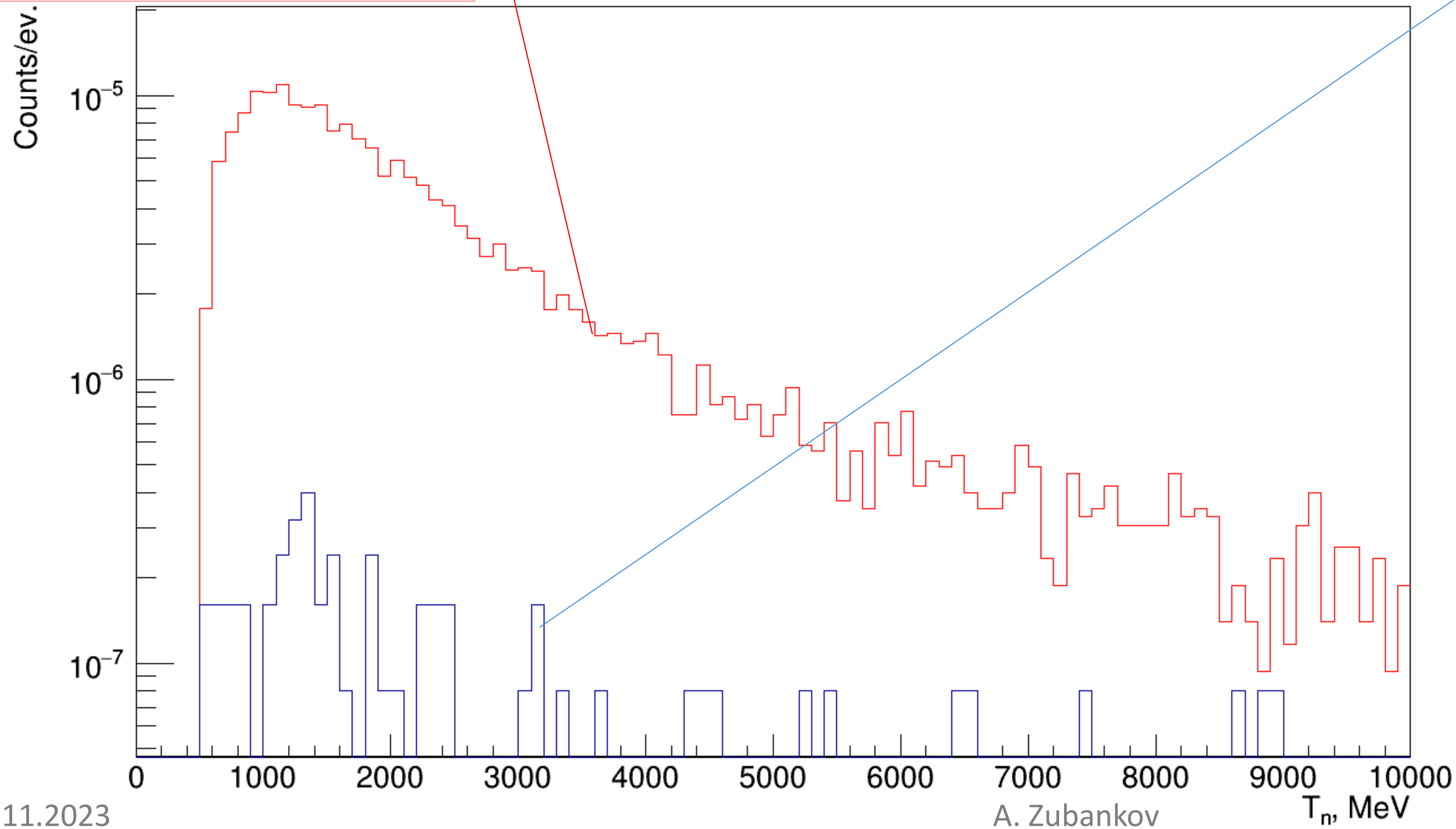
Position	n/ev. (BC1S+CCT2)	
0.7 deg. 3 AGeV	29,43%	100%
0.7 deg. 3 AGeV empty	2,91%	9,9%

Reconstruction of the neutron energy spectrum at 27 deg.

Run 7549
CsI 2%
Total number of events – 1M
BC1S + CCT2 – 386k
Vertex ± 1.5 – 269k
Veto – 9k
BT*(prescale factor+1) – 21k*2k

Reco
Max speed
Time cut 15-26 ns
Scaled by BT*(prescale factor+1)

Run 7548
Empty target
Total number of events – 100k
BC1S + CCT2 – 18k
Vertex ± 1.5 – 1.3k
Veto – 58
BT*(prescale factor+1) – 6k*2k



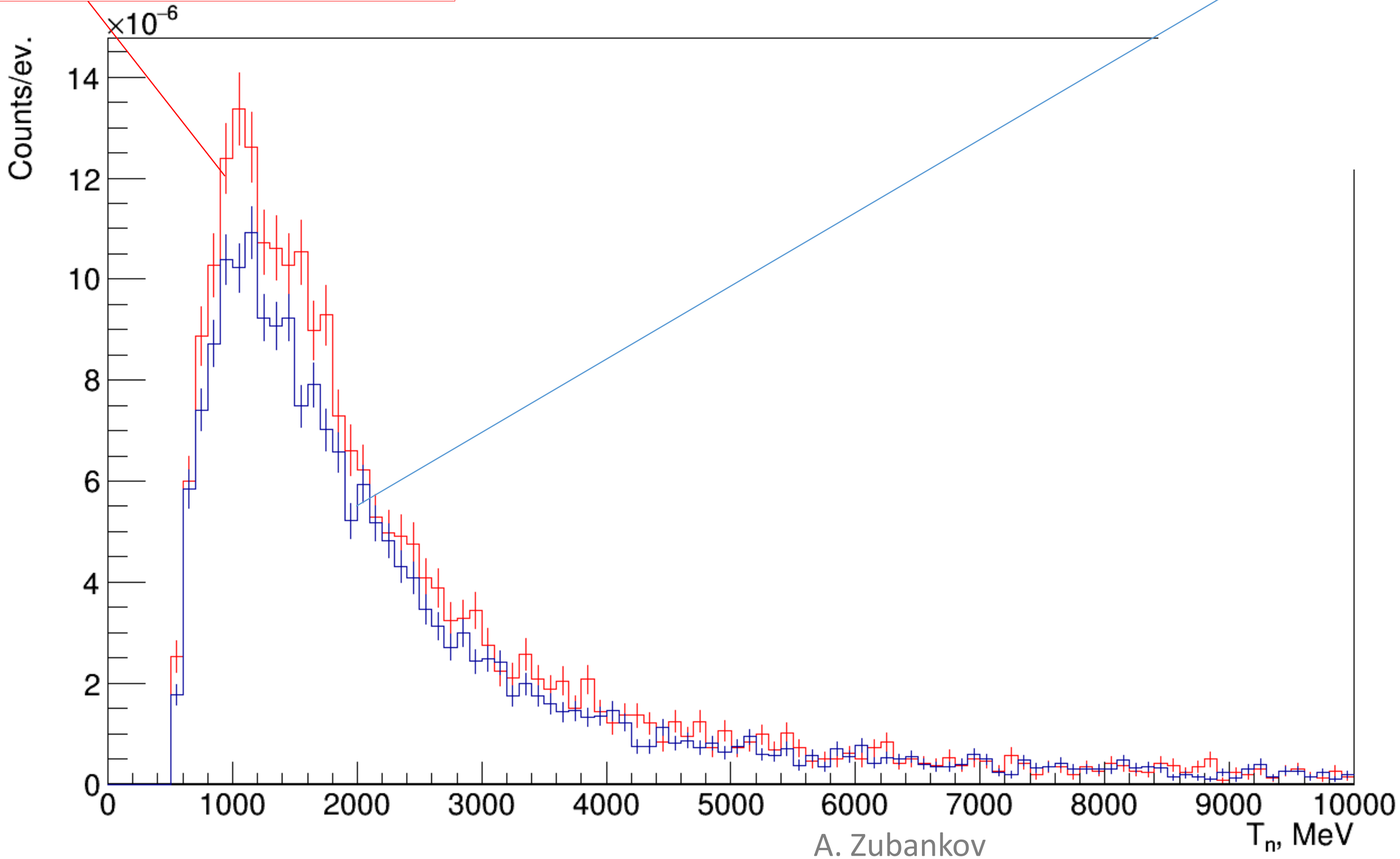
Position	n/ev. (BC1S+CCT2)	
27 deg.	2,33%	100%
27 deg. empty	0,32%	13,5%

Reconstruction of the neutron energy spectrum at 27 deg.

Run 7566 - **HGND rotated by 2/70 radians**
CsI 2%
Total number of events – 687k
BC1S + CCT2 – 336k
Vertex ± 1.5 – 196k
Veto – 6.5k
BT*(prescale factor+1) – 13k*2k

Reco
Max speed
Time cut 15-26 ns
Scaled by BT*(prescale factor+1)

Run 7549
CsI 2%
Total number of events – 1M
BC1S + CCT2 – 386k
Vertex ± 1.5 – 269k
Veto – 9k
BT*(prescale factor+1) – 21k*2k



Position	n/ev. (BC1S+CCT2)
27 deg.	2,33%
27 deg. 2/70 rad.	1,93%

Conclusions

- Time-amplitude correction of signals improved the time resolution by 2.4 times
- The average time resolution of cells was 134±29 ps
- The number of events with γ-quanta was 0.173%, which is comparable to simulation
- The energy spectrum of neutrons was reconstructed for 2 positions of HGND prototype
- Events with detected neutrons from an empty target are only 14% of the number of events with detected neutrons from the CsI(2%) target

Thank you for your attention!