Project PRES (Proton Radius in Electron Scattering)
The results of the test runs at MAMI(2017 and 2018)

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Experiments with Active Targets on elastic ep- and μp-scattering

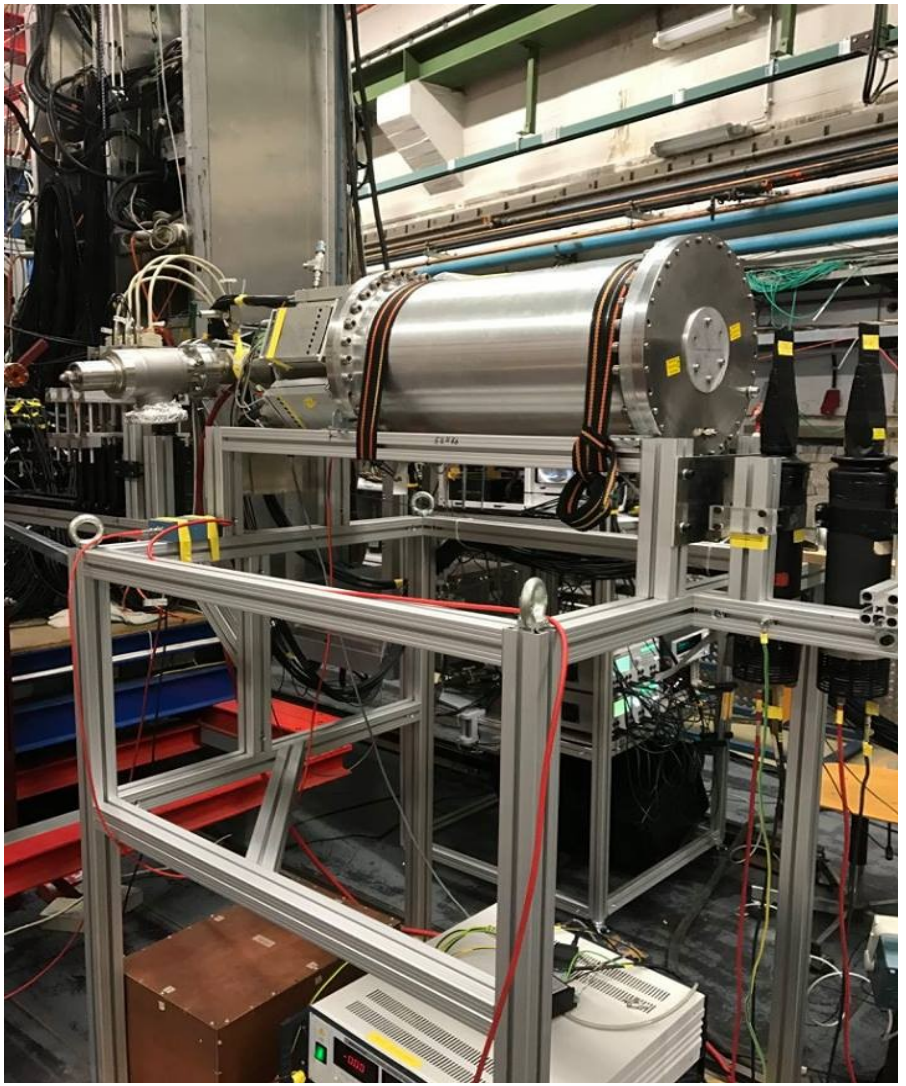
- Beam: e^- (MAMI, Mainz)
- E = 720 MeV
- H_2, p = 20 and 4 bar
- Tp=0,5–20 MeV
(-t = 0,001—0,04 ГэВ²/c²)
- 40–260 mrad

- Beam: μ (CERN)
- E = 100 Mev
- H_2, p = 20 and 4 bar
- Tp=0,5–20 MeV
(-t = 0,001—0,04 ГэВ²/c²)
- 0,3–2mrad

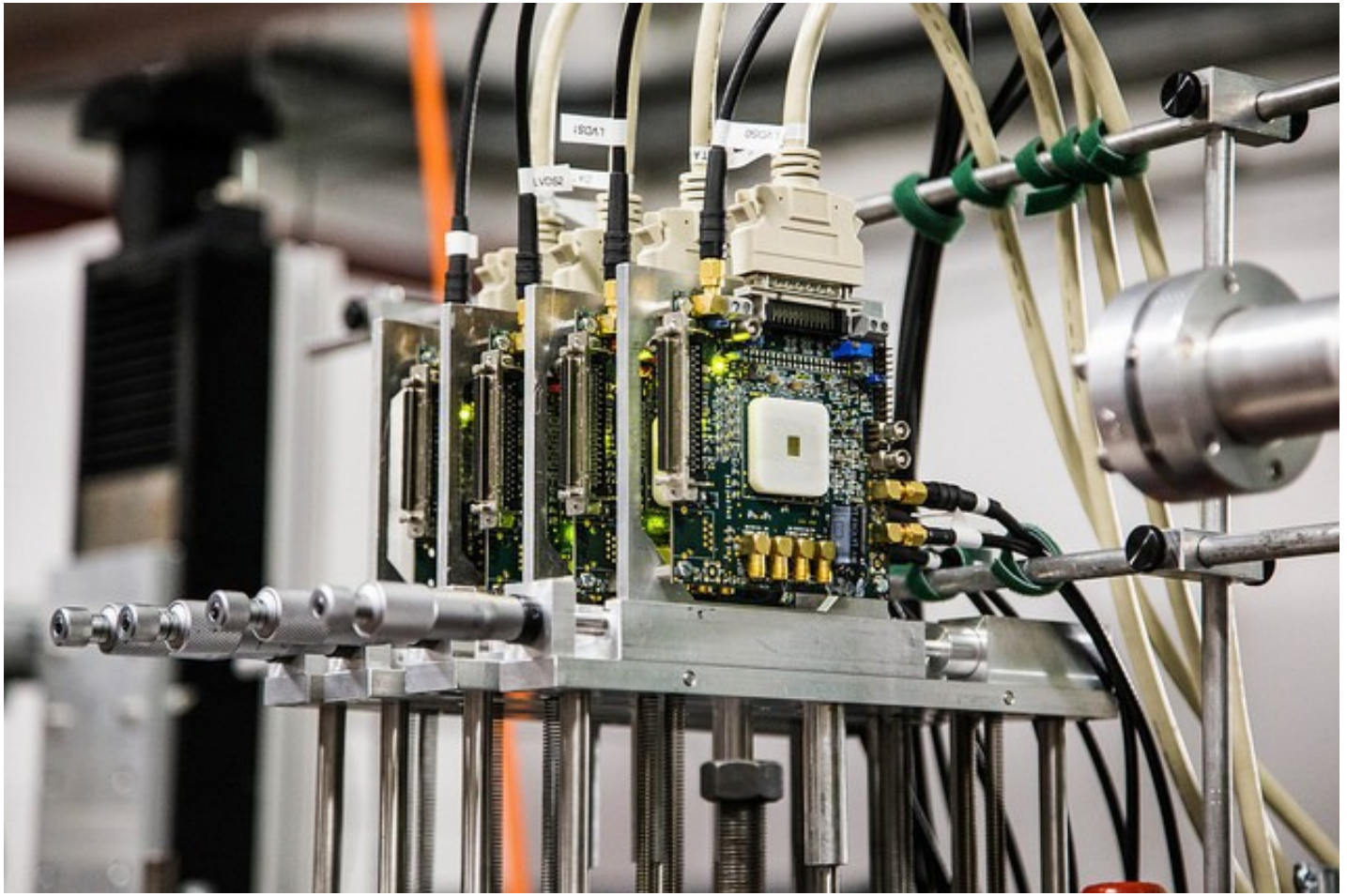
Test runs with TPC prototype

The main goals of the test runs:

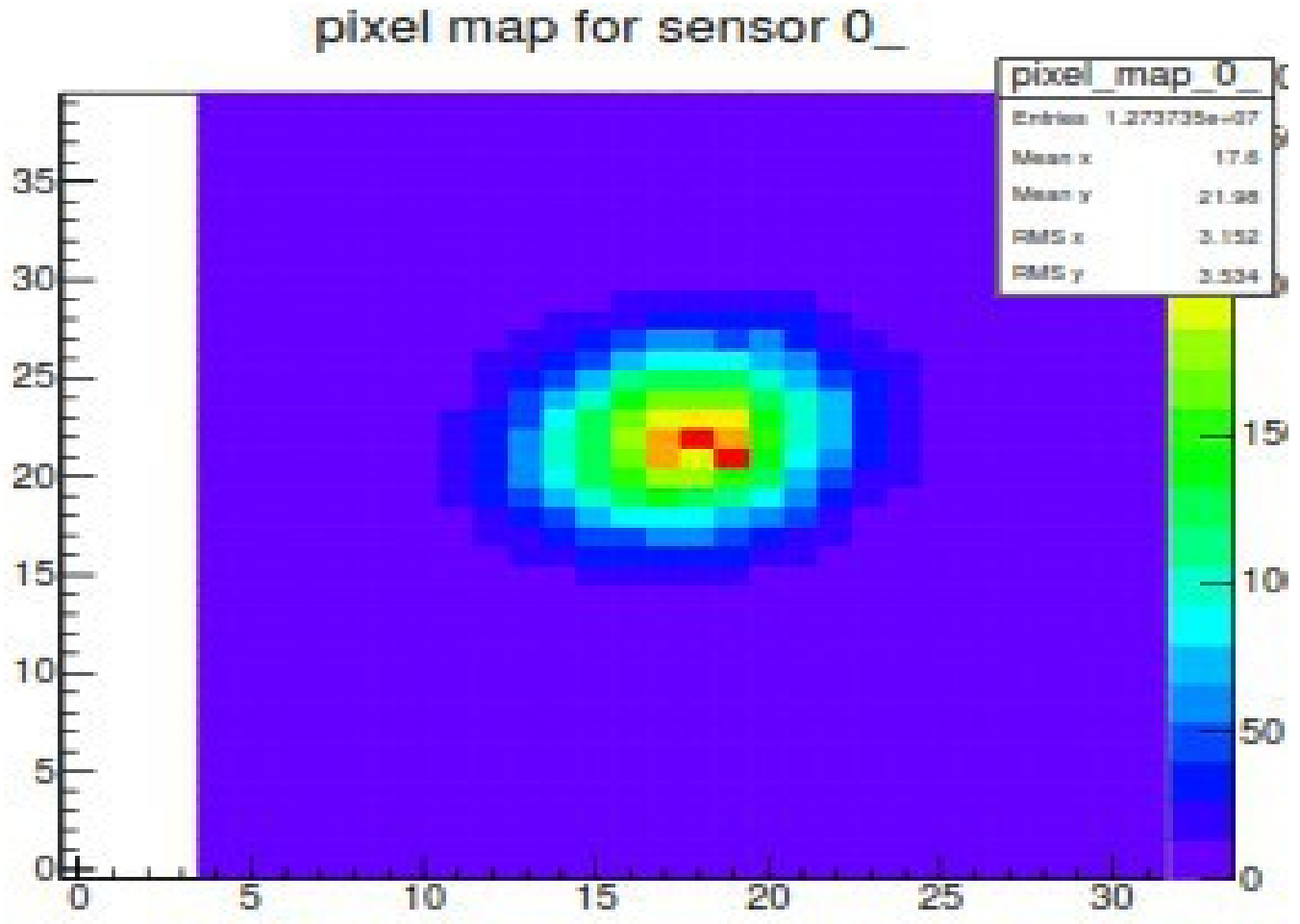
- The recoil proton energy resolution.
- The background in TPC.
- The possibility to operate TPC in the self triggering mode.
- The electron beam with requested parameters.



ACTAF2 prototype is installed down stream of the Cristal Ball /Taps setup.
A temporary electron beam line was constructed for this test run.

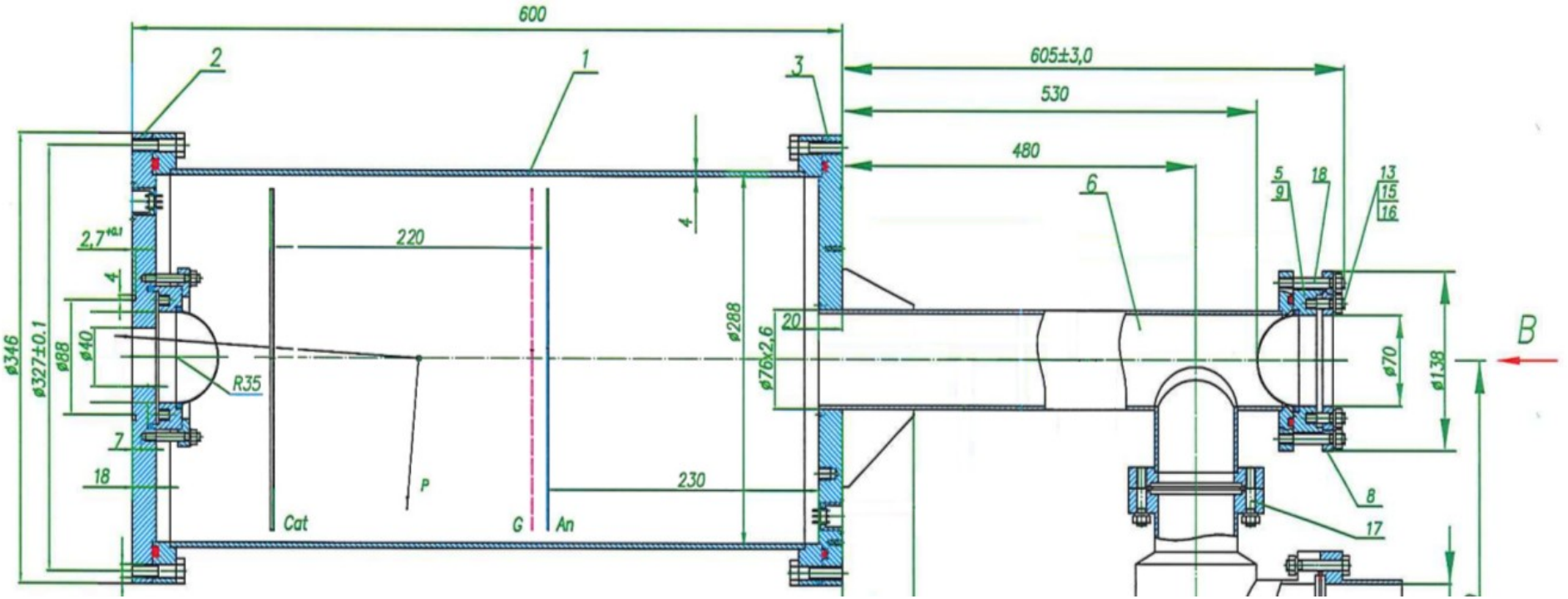


Beam telescope - four planes of pixels before ACTAF2 prototype



Beam spot (two dimension distribution of the electron beam).
The x (y)- axis is the pixel numbers (the pixel width is 100 (80)mkm

Experimental set up (prototype of ACTAF2)

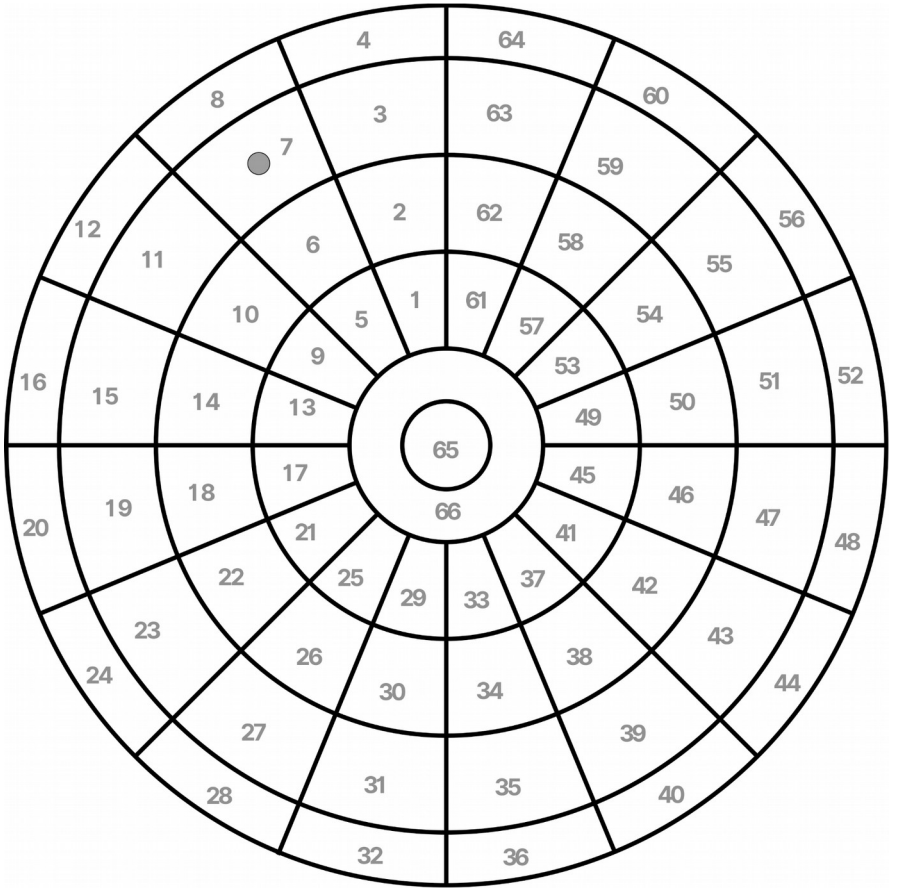


Schematic view of the ACTAF2 prototype (side view).

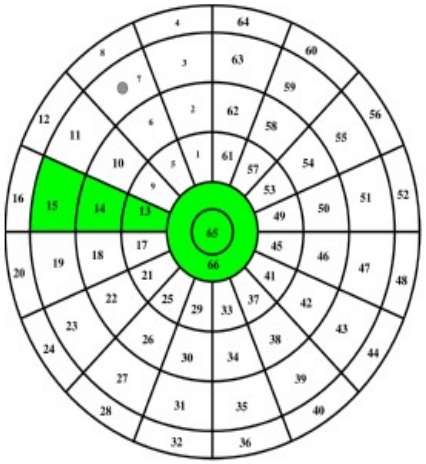
Active Target (TPC)

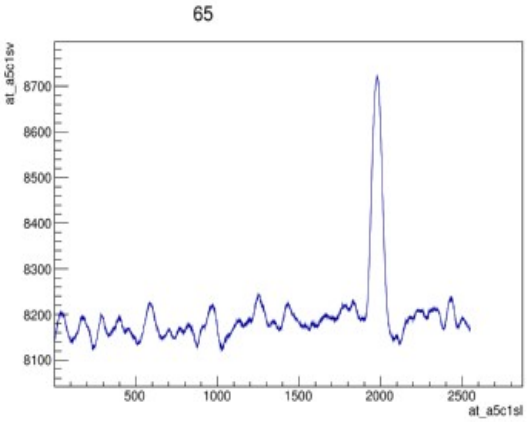
- Gas: He +4%N_2
- pressure =10 (5)bar
- L_{CG} = 220 mm
- V_C =-14 (9) κV
- V_G =- 0.8 (0.5) κV
- t_{CG} ≈ 80 mks

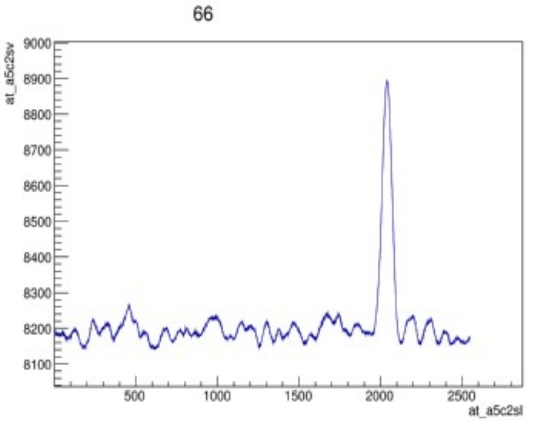
Gas: Hydrogen
pressure= 1.25 bar
V_C =-3kV
V_G = -0.2 kV
t_{CG} =55mks

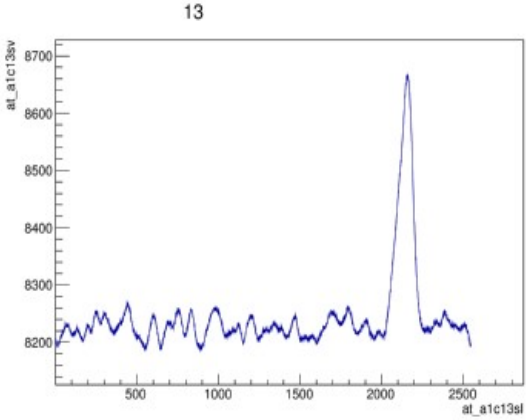


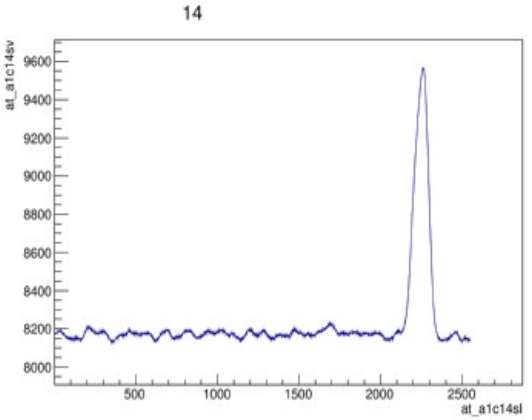
200 mm

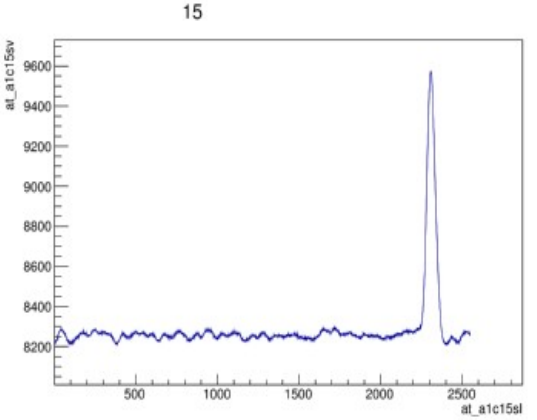




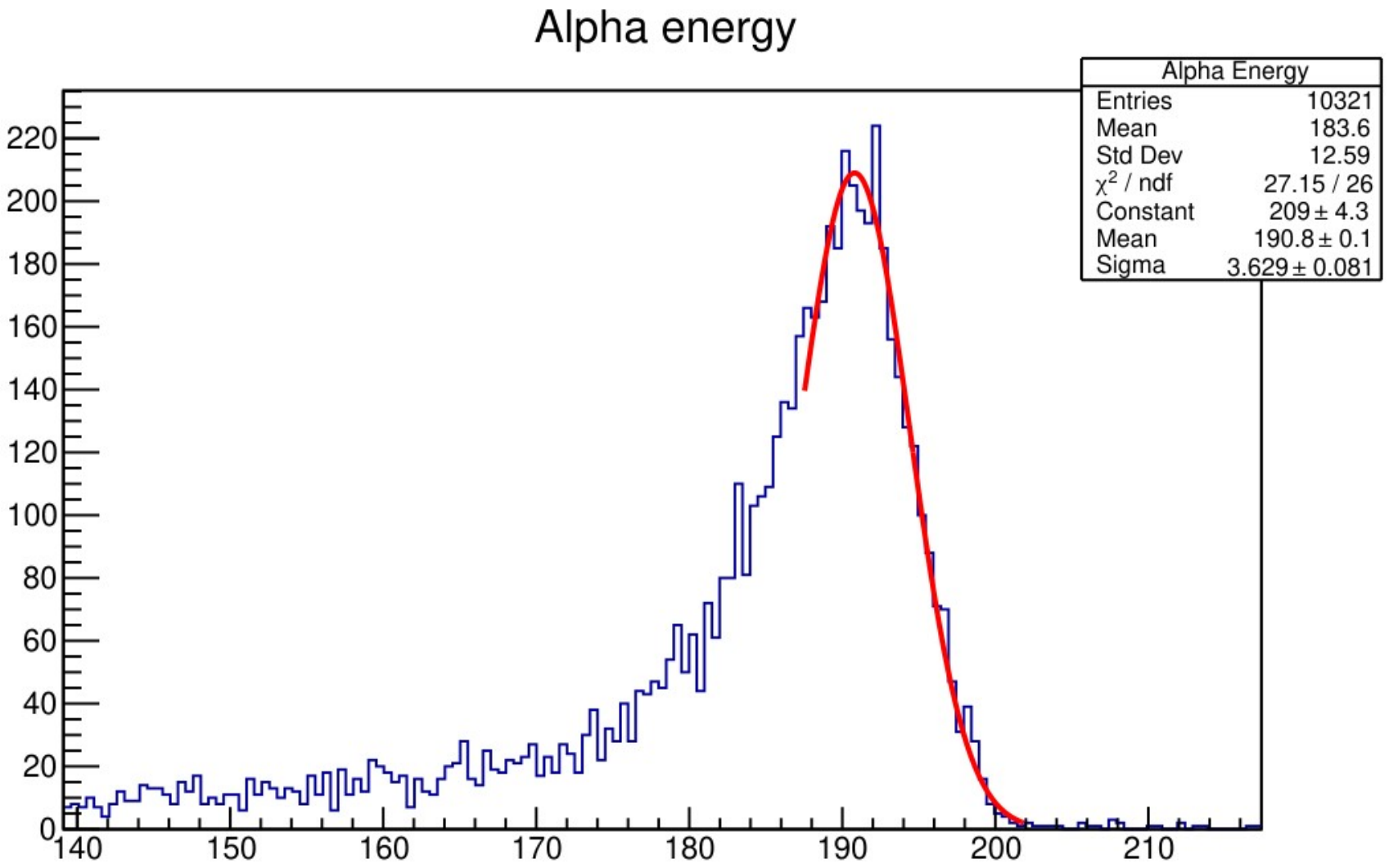




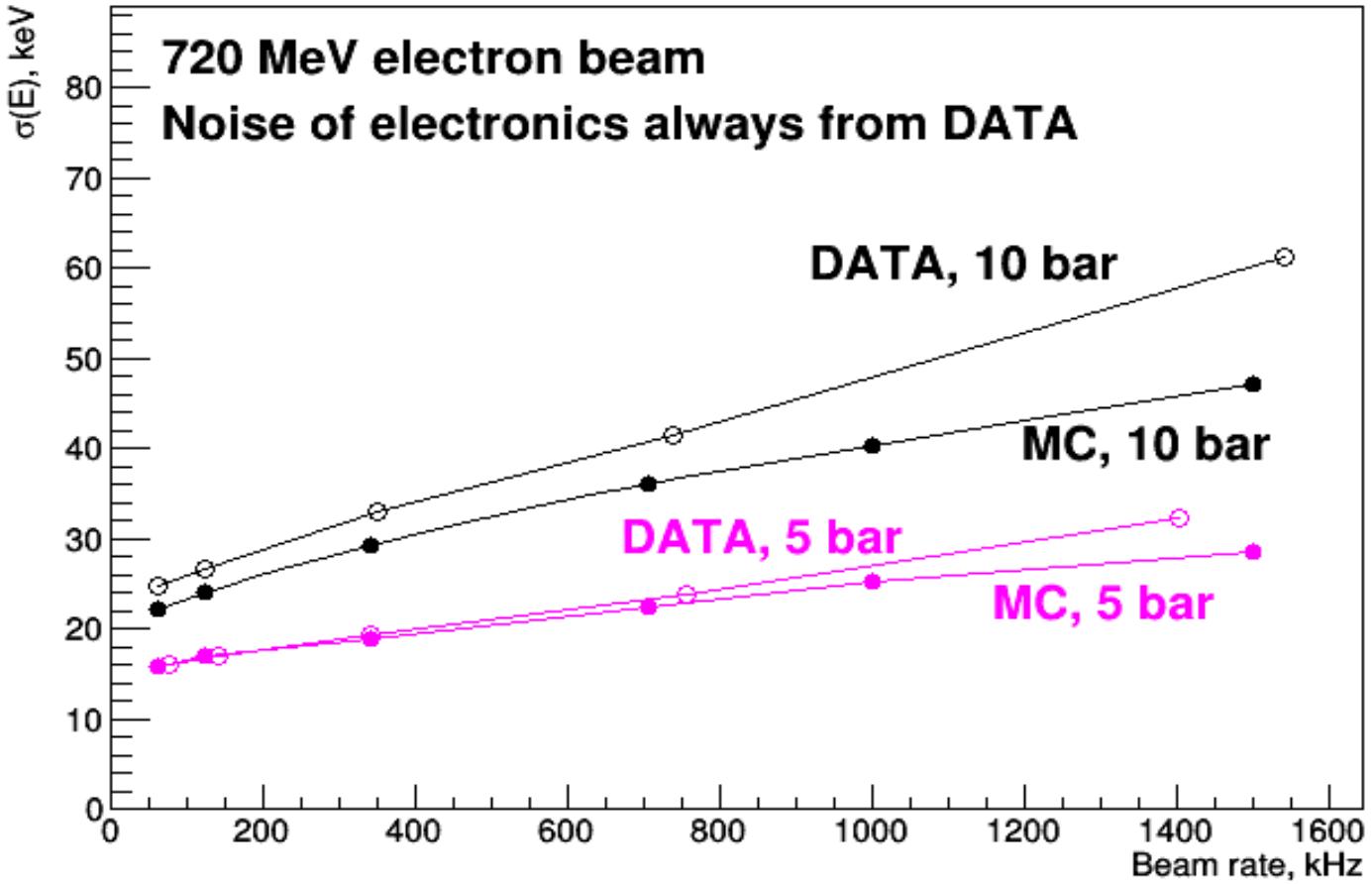




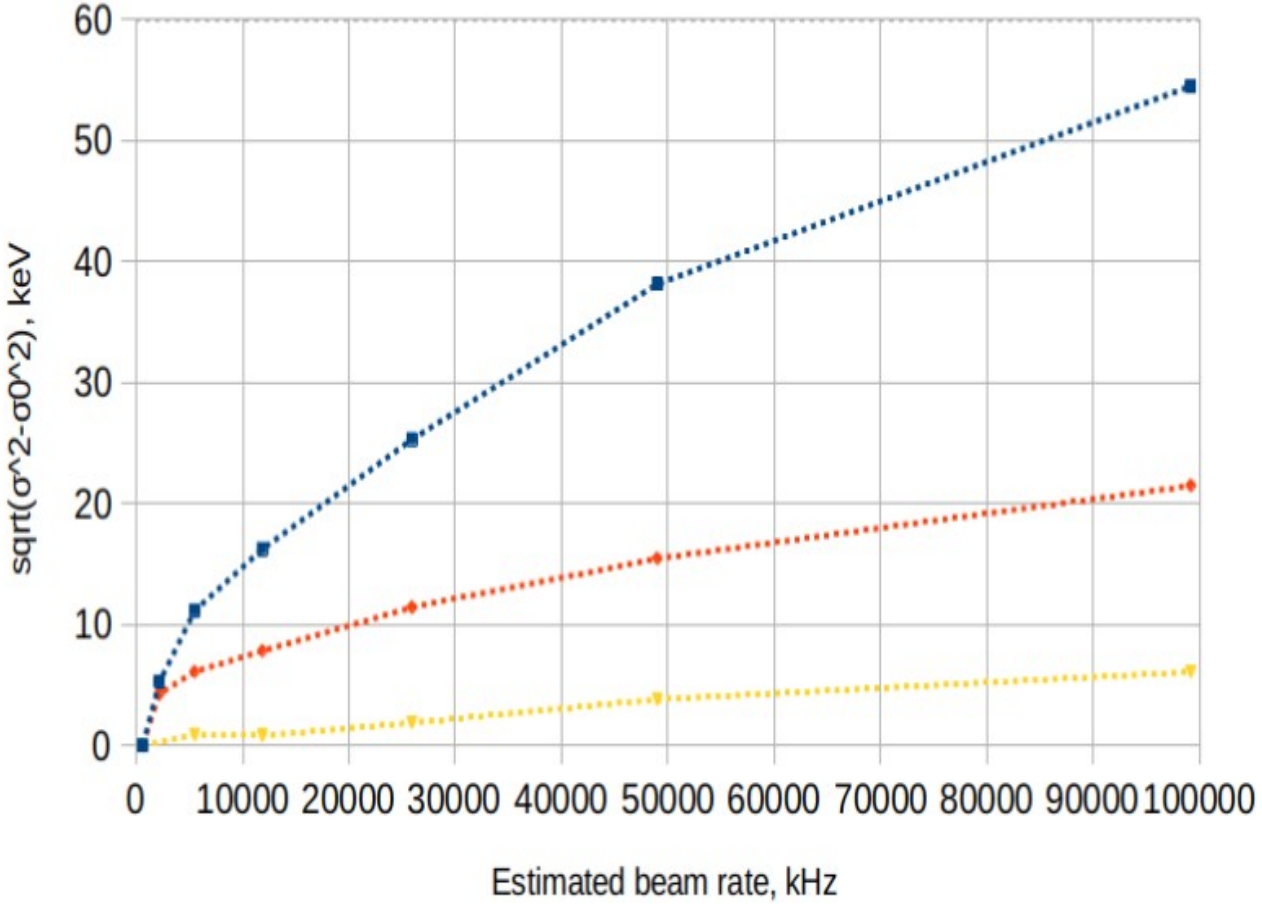
Display of a long range track observed in the TPC (He +4%N_2, 10 bar)



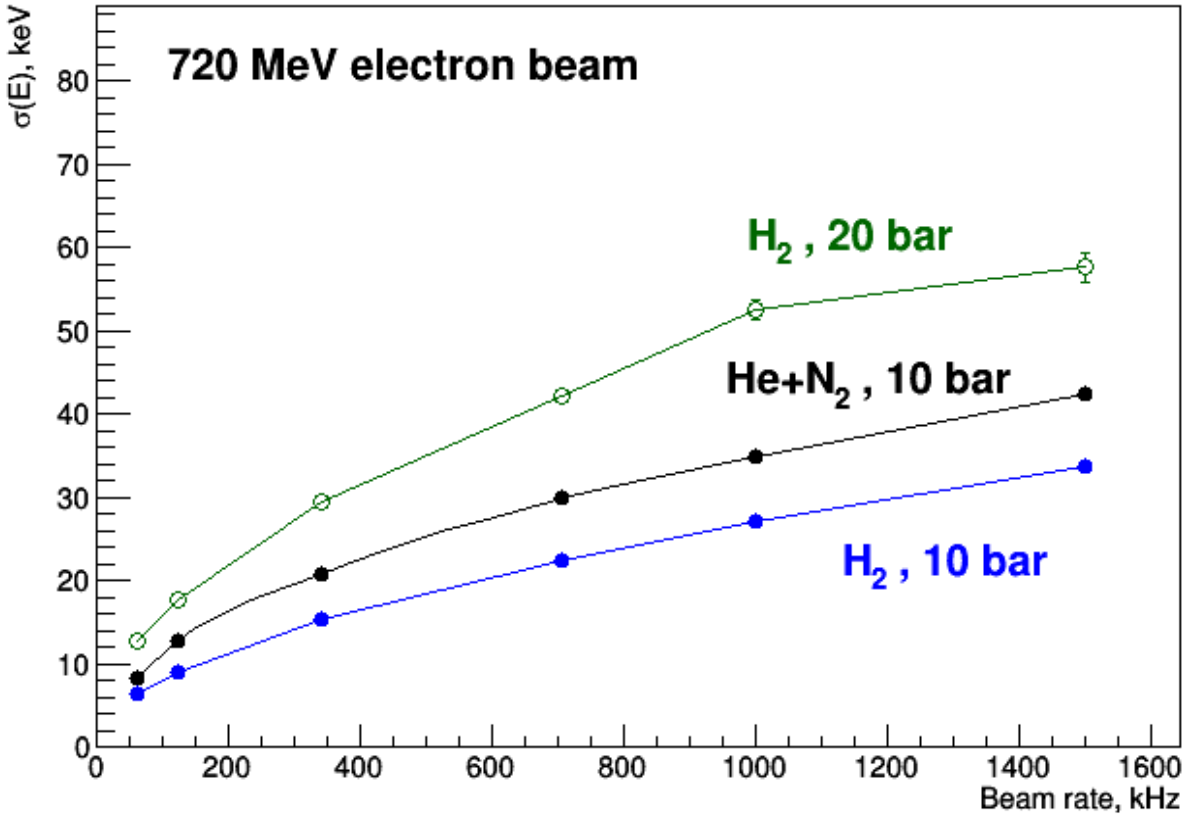
Energy distribution of the signals from the alpha source(Am-241, E=5.486 MeV



Comparison of the noise at the central pad measured at various beam rates with MC calculations. He + 4%N2 gas mixture (5bar and 10bar). Drift gap 220mm. Drift velocity 2.75 mm/μs for 10 bar and 3.14 mm/μs for 5 bar gas pressure.



Beam ionization noise in function on the beam rate for the pure hydrogen at the pressure 1.25 bar . The measurements were done at different pads (blue – *central pad #65, red*-nearest ring #66*, yellow-one next segmented pad #33).*
Note that on this figure is shown only the beam ionization noise (the electronics noise was subtracted from the total measured noise).



Beam ionization noise in function on the beam rate calculated for the He + 4%N2 gas mixture(10 bar) and for pure hydrogen (10 bar and 20 bar).Drift gap 220 mm. Drift velocity 2.75mm/μs.

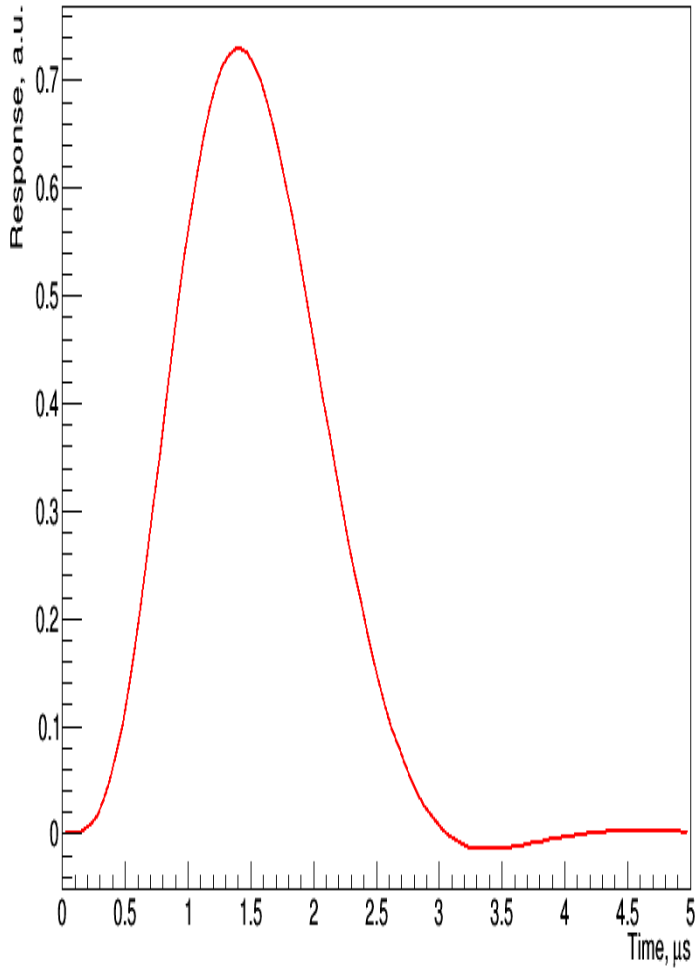
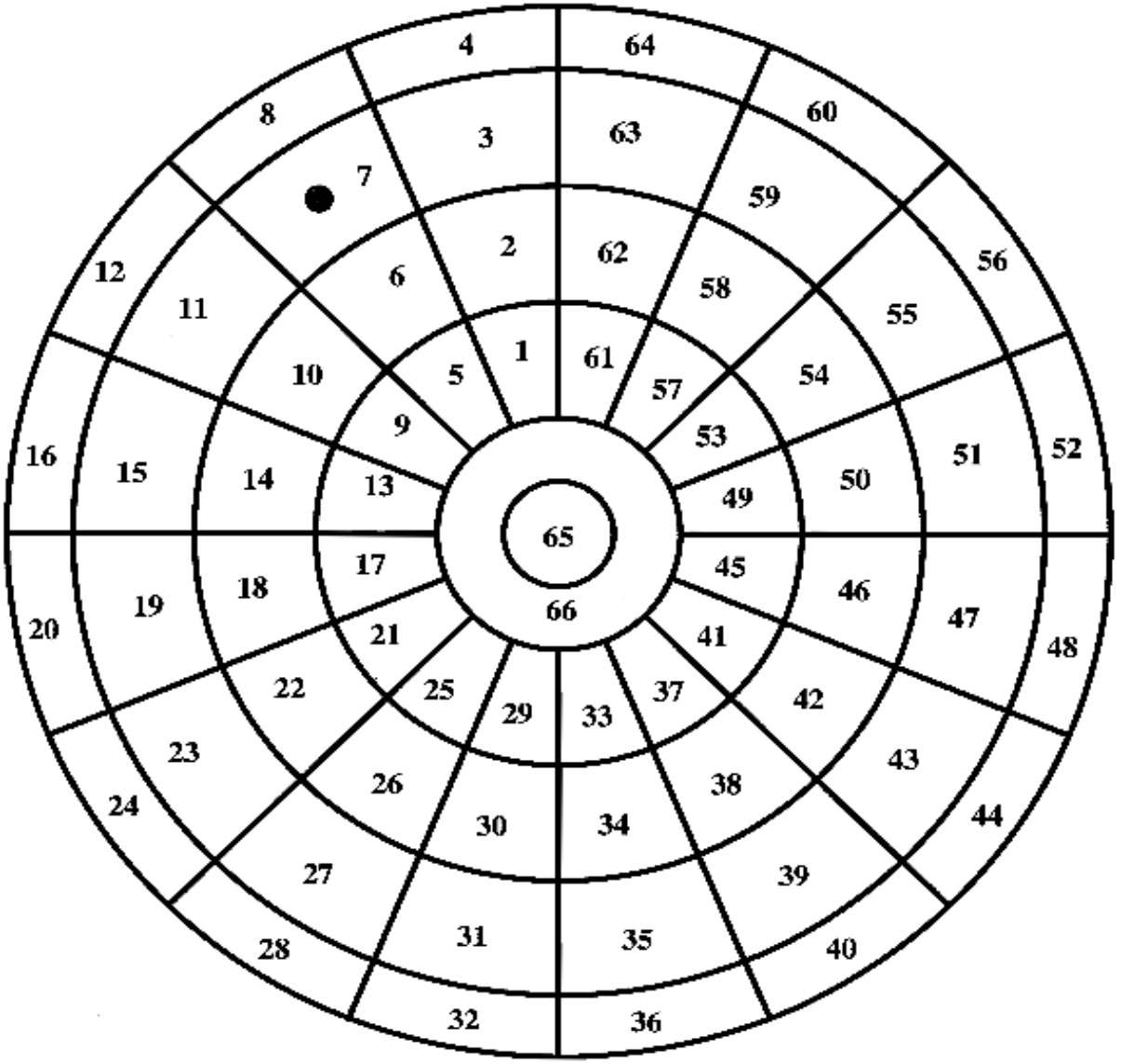


Fig.3
Signal at the output of the amplifier corresponding to a delta fuction input signal.

The signal at the output of the amplifier (shaping time is 1.4μs)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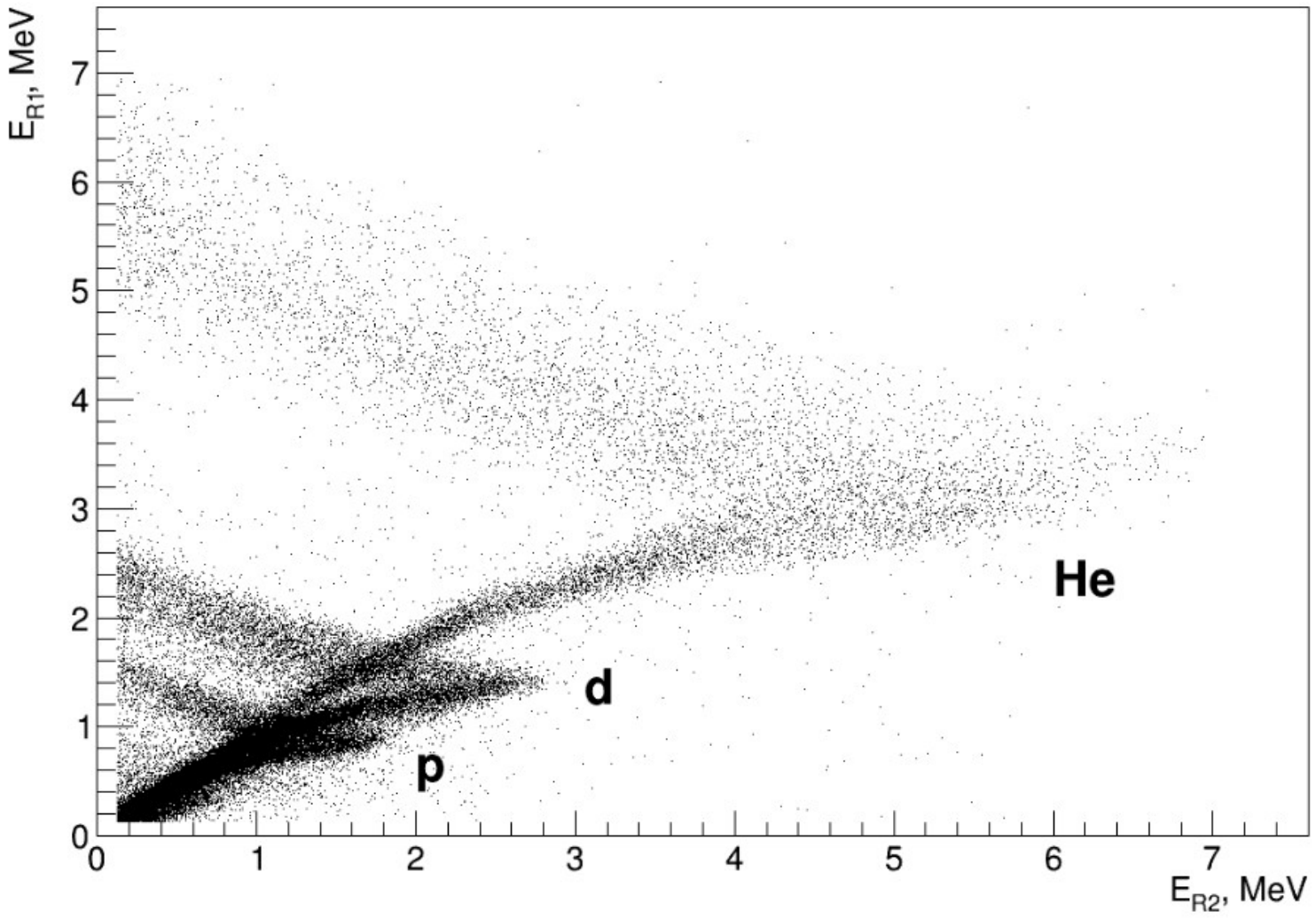
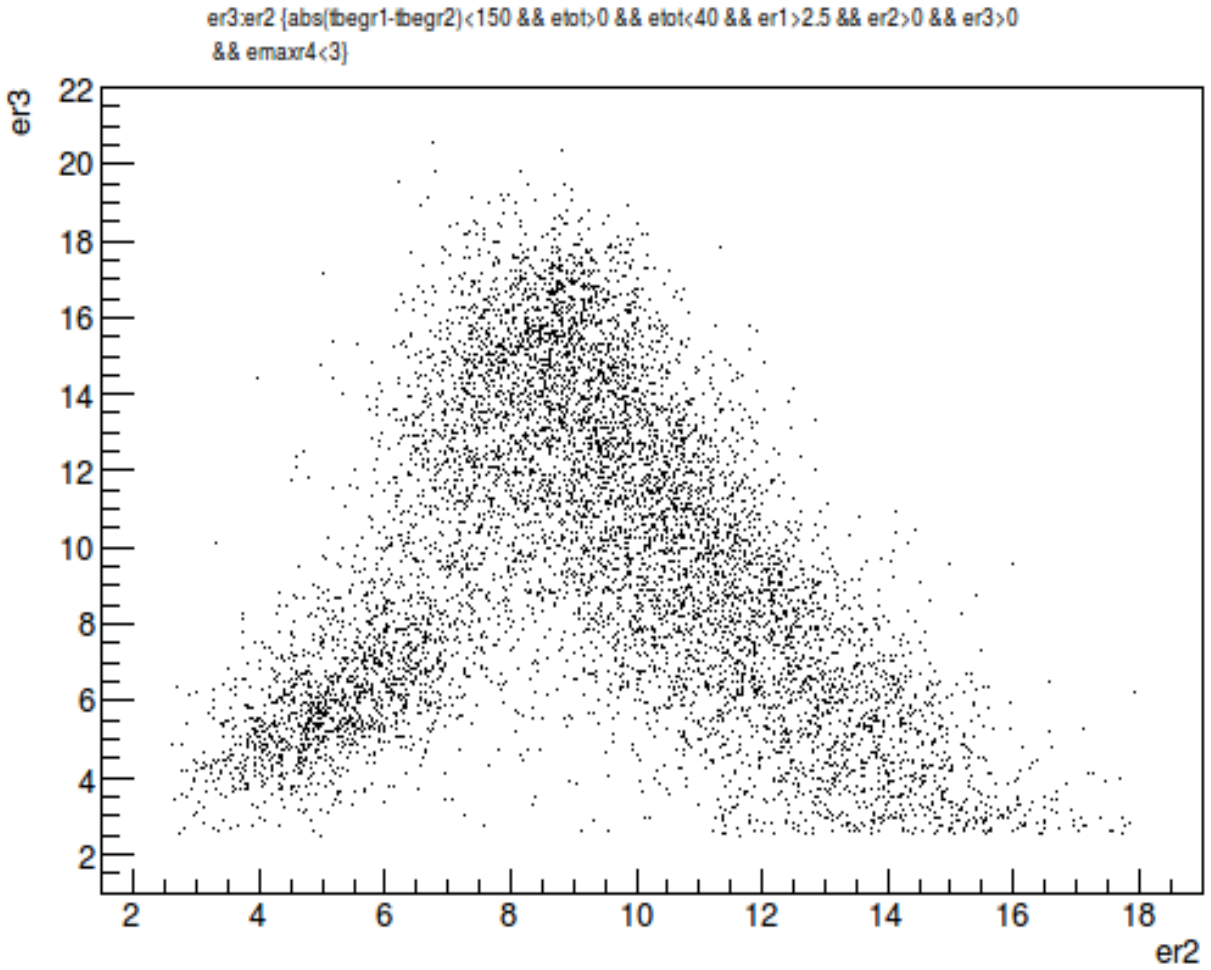
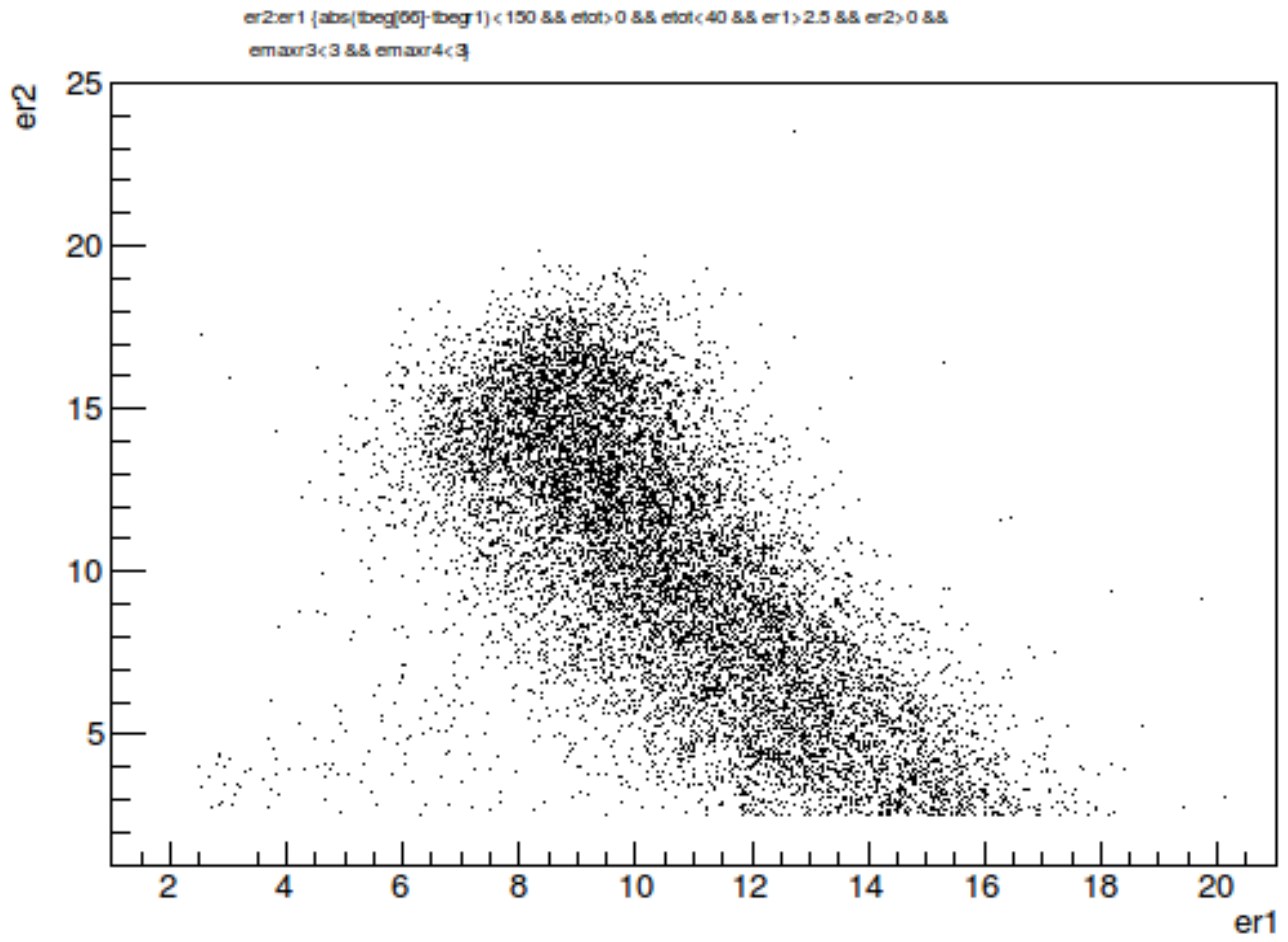


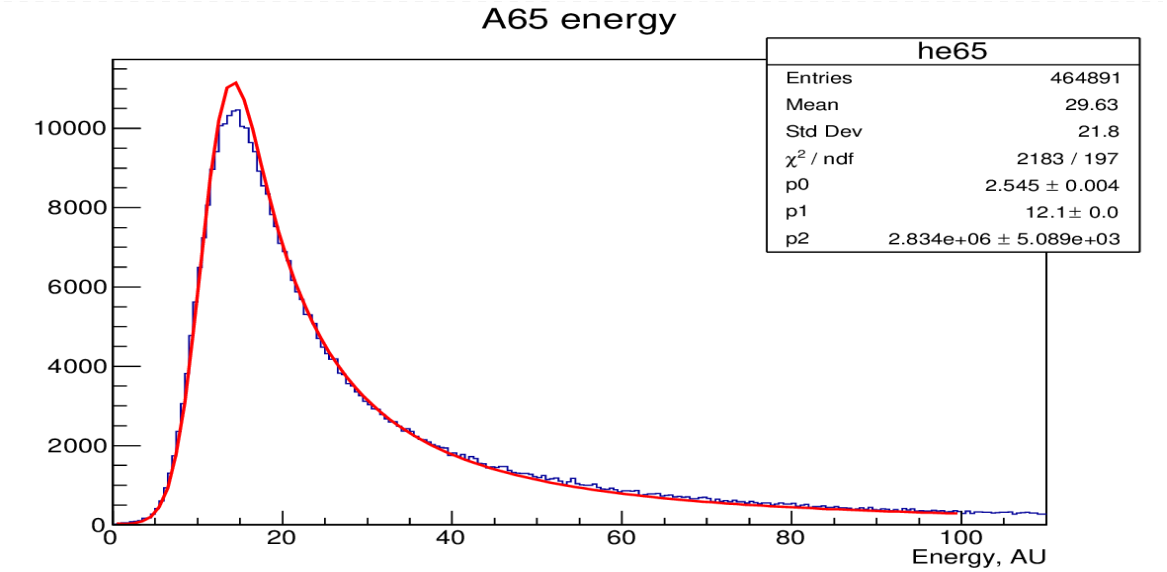
The recoil particles deposit energy correlations between neighbors anode rings R1 and R2 (He+4%N_2, 10 bar). The energy scale is in the FADC channels, 1ch=22keV.



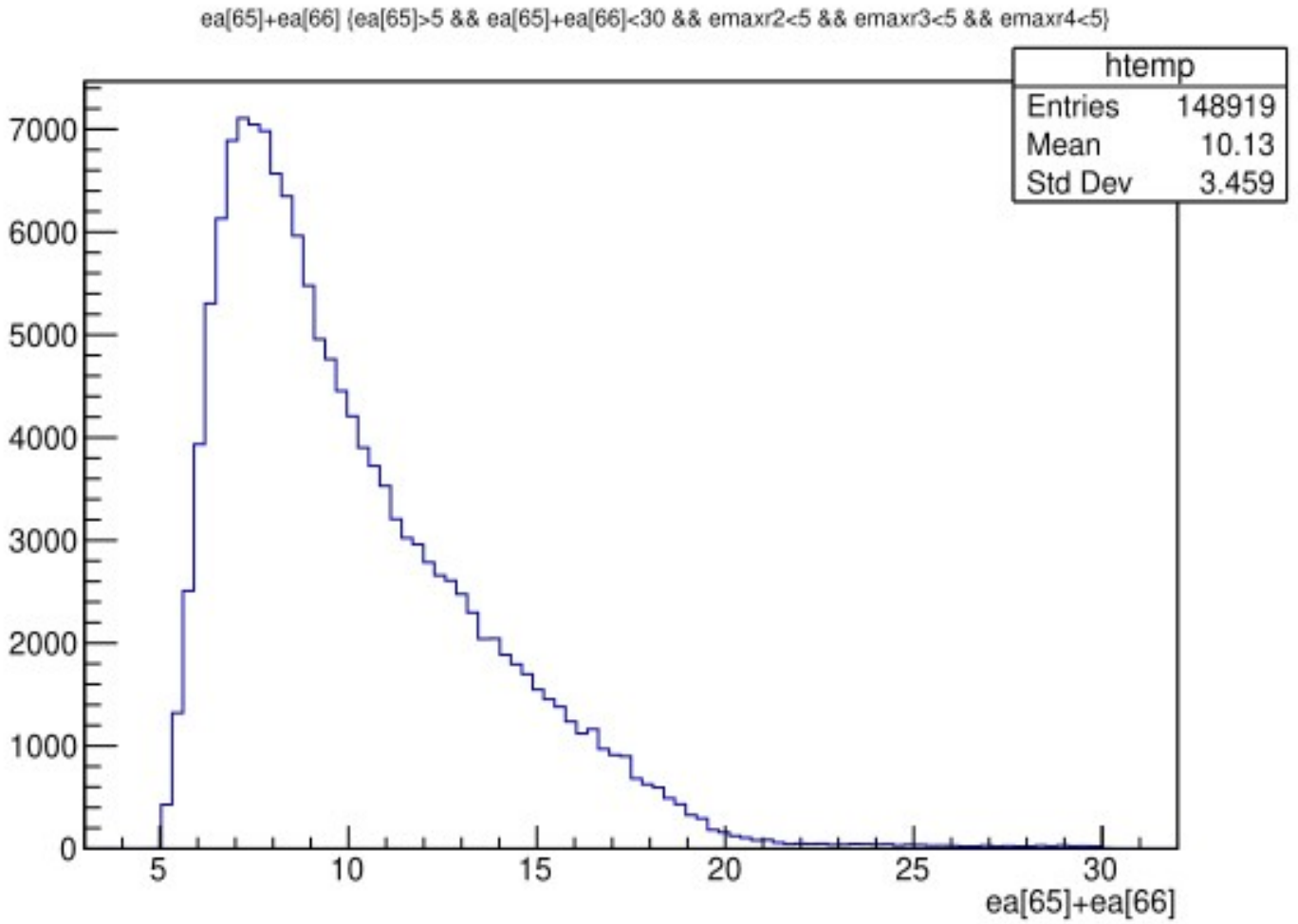
The recoil proton deposit energy correlation between neighbors anode rings R2 and R3 (H2, 1.25 bar). The energy scale is in the FADC channels, 1ch=27keV.



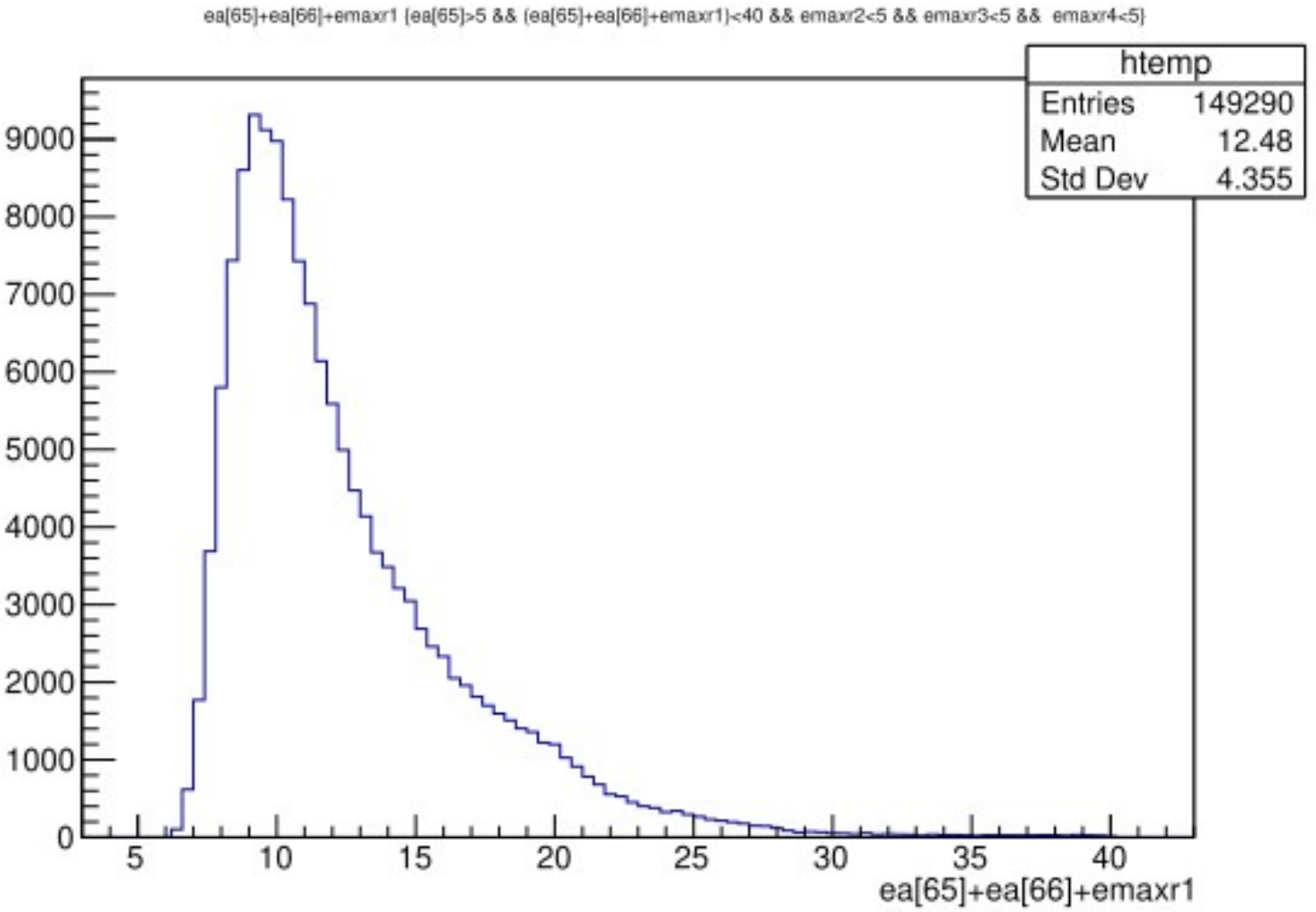
The recoil proton deposit energy correlation between neighbors anode rings R1 and R2 (H2, 1.25 bar). The energy scale is in the FADC channels, 1ch=27keV. Now signal on ring R3.



Energy distribution of the signals from the central pad (He+4%N2 ,10 bar,1ch=22keV). The red curve – fit with 1/t2 distribution combined with a Gaussian centered at 300keV.



Energy distribution of the signals on the two central anodes #65 and#66.
Energy channel - 1 ch=27keV , hydrogen pressure- p= 1.25 bar .



Energy distribution of the signals on the central anodes #65 and#66 and first rung R1.
Energy channel - 1 ch=27keV , hydrogen pressure- p= 1.25 bar .

The estimation of the e-p elastic cross section

For the preliminary estimation of the elastic e-p differential cross-section (ds/dt) we have used the data from hydrogen run at pressure1.25 bar:

It was analyzed ~ 1800 files. The average electron beam intensity was ~ 600 kHz.

The total number of the beam electron (N_e) is equal ~$2.9 \cdot 10^{11}$.

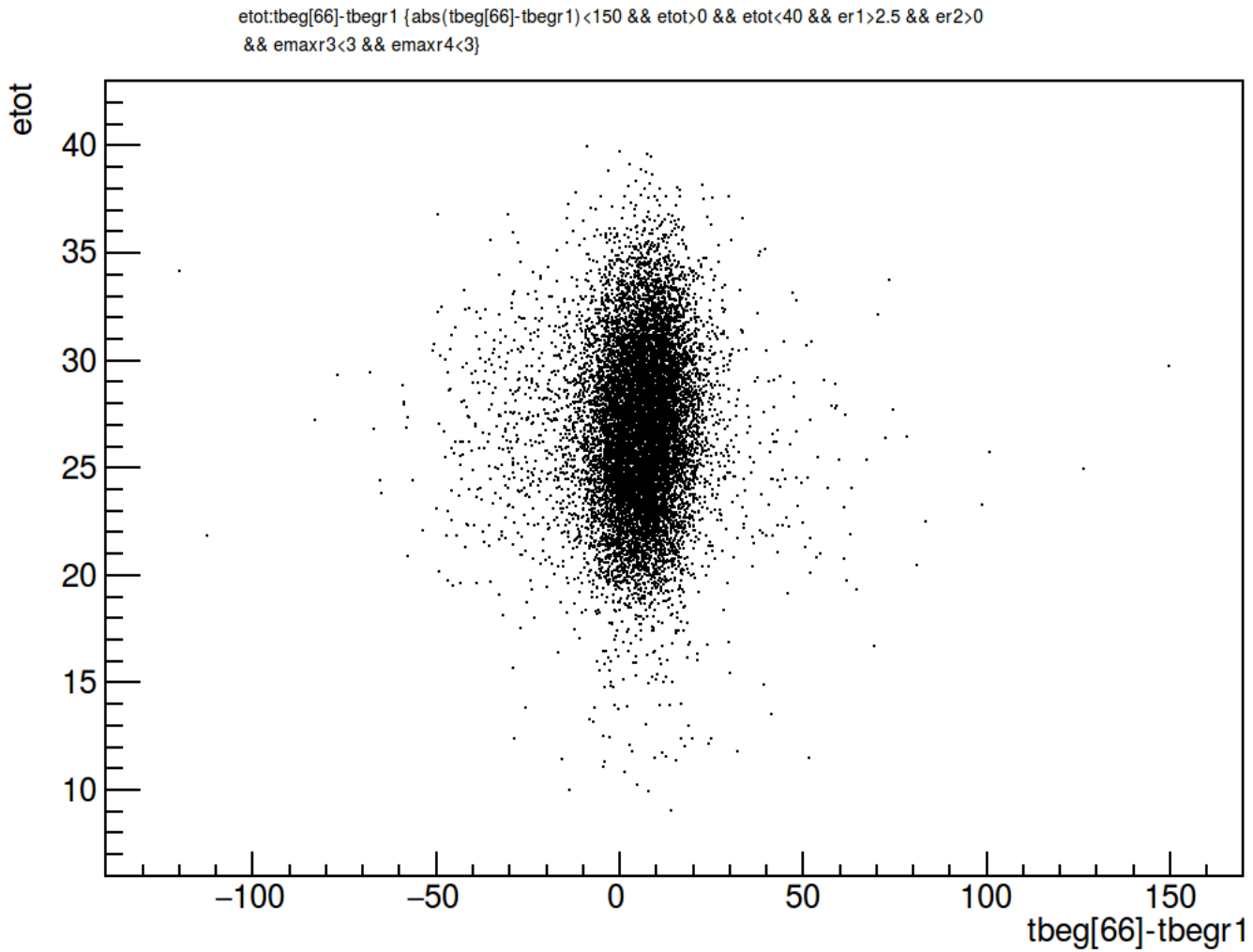
The number of the protons (N_p) in the fiducial (L=22cm) volume of the TPC is equal ~1.4×10^{21}. The luminosity (L) is equal: $L=N_e \cdot N_p \sim 4 \cdot 10^{32}$.

The number of the recoil protons (N_{ep}) detected on the central anodes # 65 and 66 (in the energy region 200-500keV) is equal ~$1.5 \cdot 10^5$.

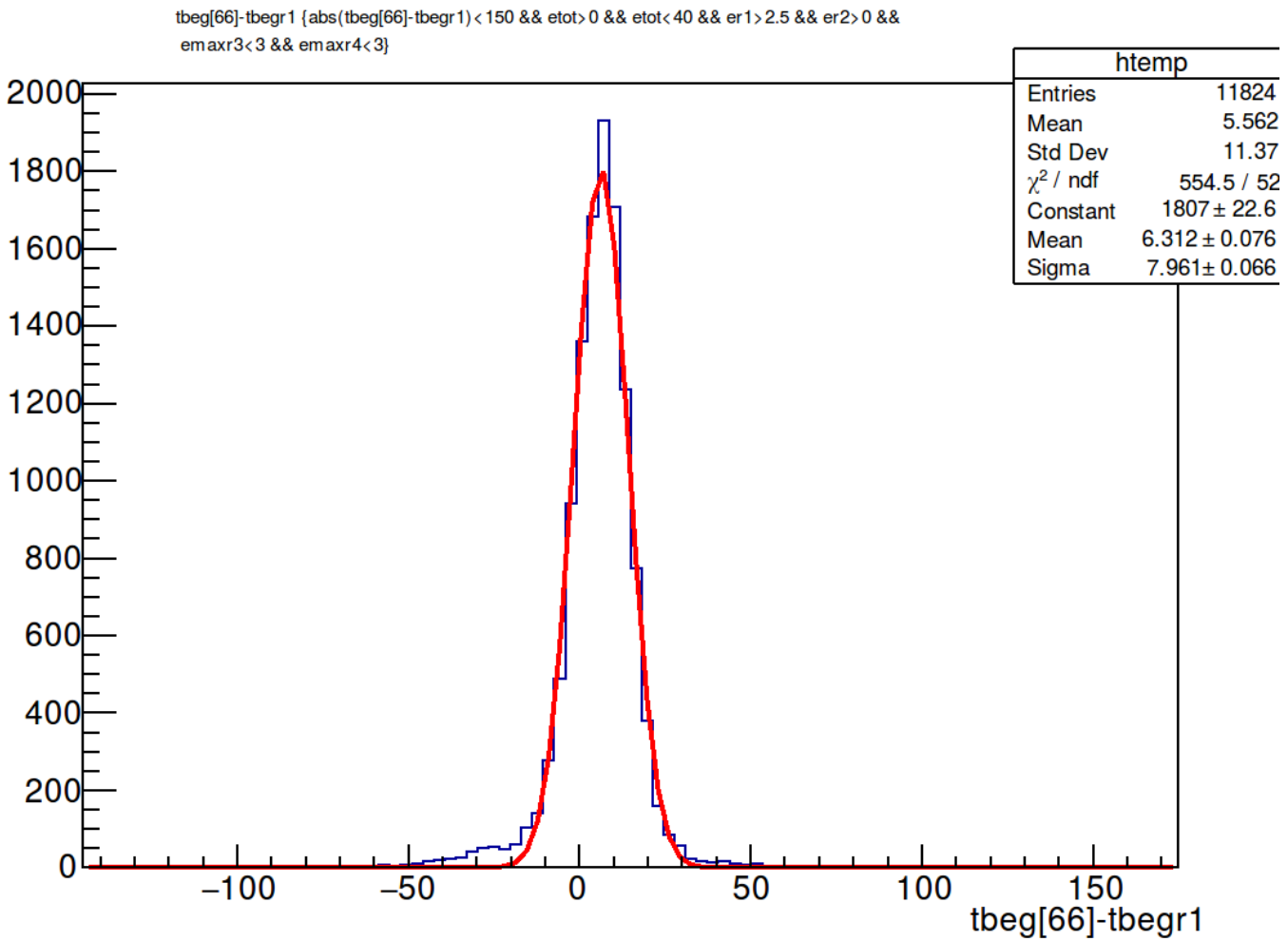
From these number is possible to estimate the elastic e-p differential cross-section:

$ds/dt = N_{ep}/L \sim 3.7 \cdot 10^{-28}$ $cm^2 \sim 0.37$ mbar.

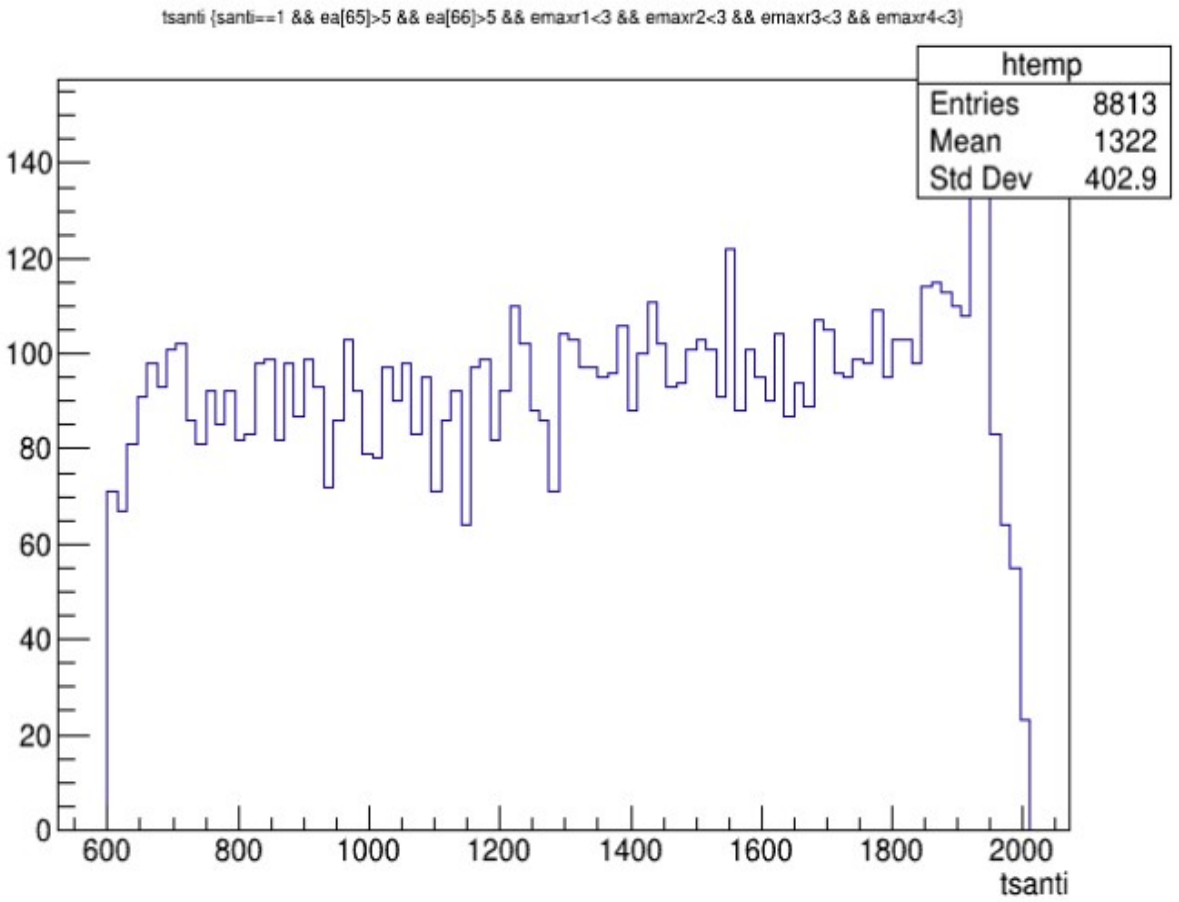
The theoretical calculation of the elastic e-p differential cross-section for the recoil energy 200-500keV is ~0.36 mbar. This value is in the good agreement with the experimental estimation.



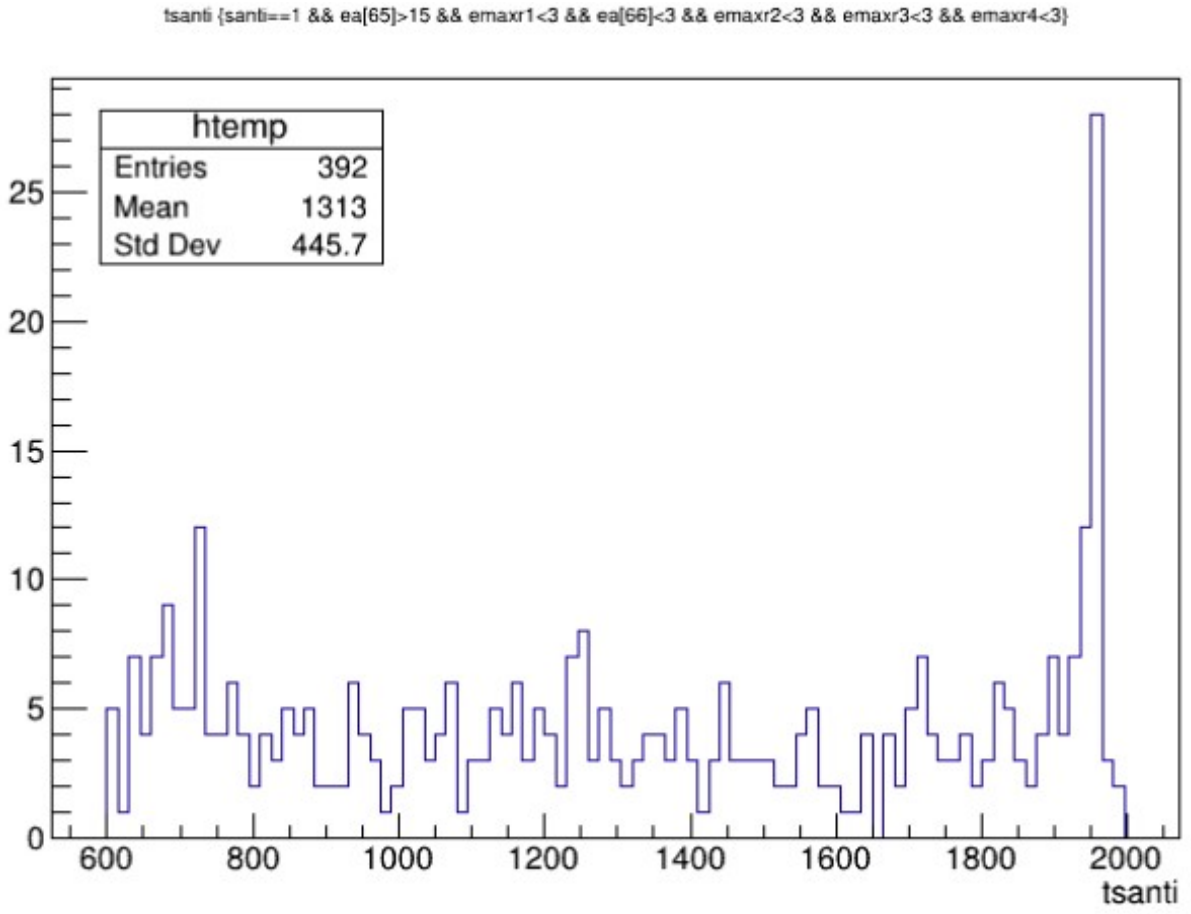
The correlation between the time differences (ΔT66-R1) of the signals on the two neighbor's anodes (#66 and first ring (R1) and the total recoil proton energy (Etot). Scale time channels,1ch=40ns. The proton energy scale is in the FADC channels,1ch=27keV.



Time differences (ΔT66-R1) distribution of the signals on the two neighbors anodes (#66 and first ring (R1). Scale time channels, 1ch=40ns.



Time distribution of the *signals anti-coincidence(S1·S2 (anti)) from scintillator counters*. *Scale time channels, 1ch=40ns. Signals from TPC are on the two central anodes #65 and#66.*



Time distribution of the *signals anti-coincidence(S1·S2 (anti)) from scintillator counters*. Scale time channels,1ch=40ns. *The conditions: one Tr signal in the total time window* (108 μs) *and signal from TPC with energy more 450keV is only on the central anode #65.*

Test runs with TPC prototype

MAIN CONCLUSIONS:

- The beam ionization is in agreement with Monte Carlo simulations.
- The experimental estimation of the elastic e-p cross section is in agreement with theoretical calculations .
- For triggering can use the self triggering mode.
- MAMI accelerator provides practically ideal electron beam for the proton radiusmeasurements.

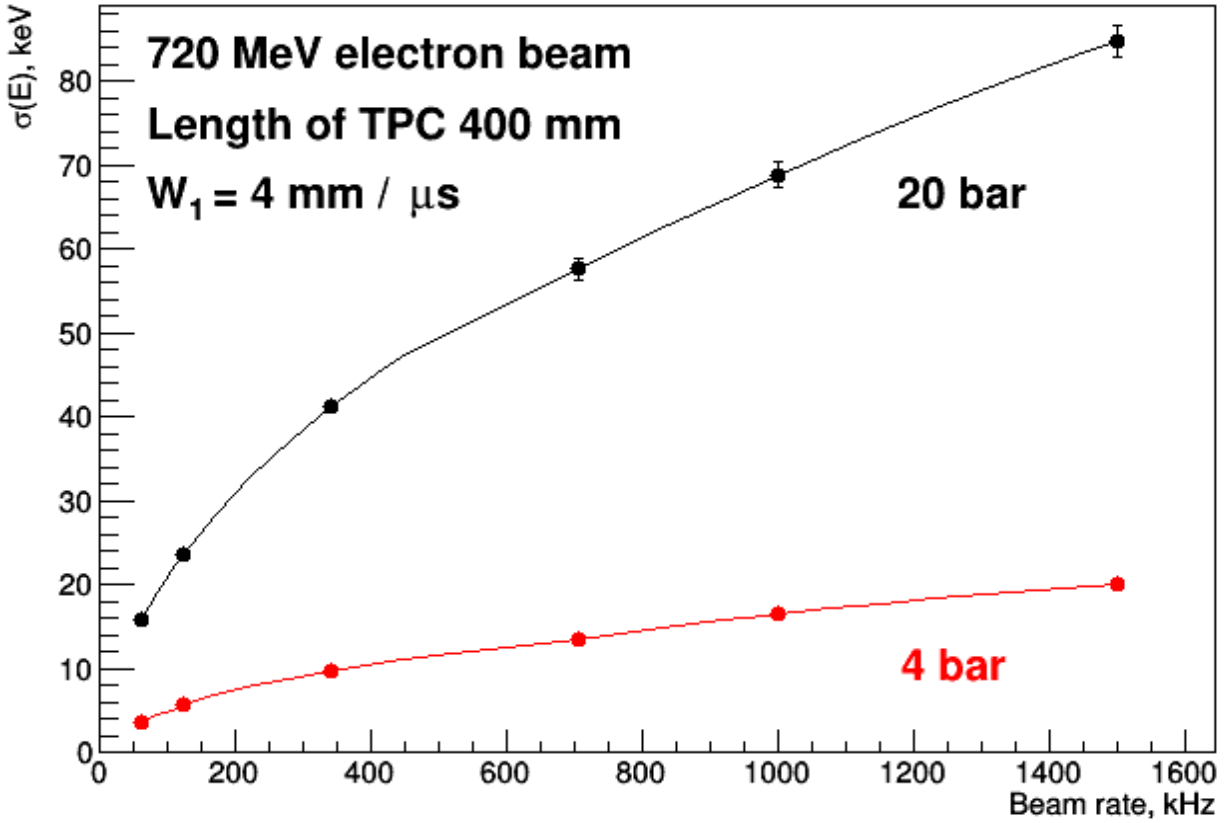
Thank you for attention !

Results of the Monte Carlo simulations

The results of the MC simulations could be summarized as follows:

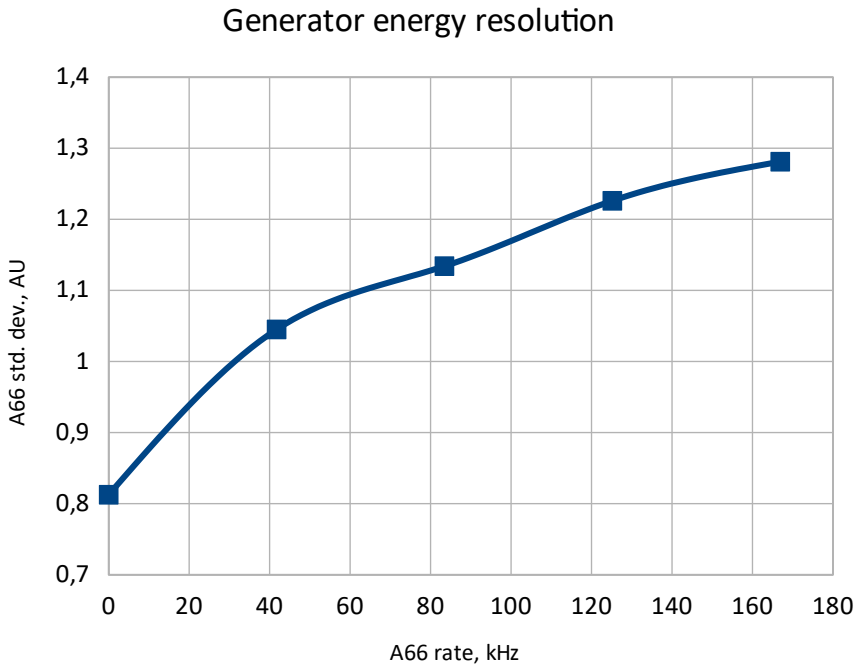
-
- The beam noise is increasing with beam rate as root square of the rate;
- The beam noise is nearly proportional to the gas pressure;
- The beam noise is increasing slightly with the total drift gap;
- The beam noise is increasing slightly with the drift velocity;
- The beam noise in hydrogen is less than in the He+4%N2 mixture by ~ 20%.
-

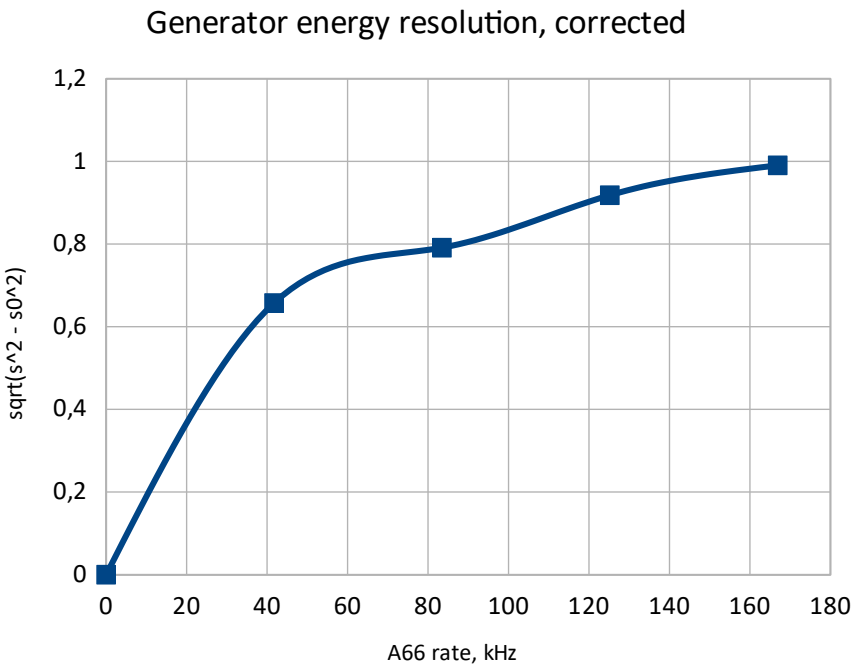
The measurements of the noise in the test runs have been done with pulse generator



MC prediction of the beam ionization noise on the central pad for the main experiment. Pure hydrogen at 20 bar and 4 bar gas pressure. Drift gap 400 mm. Drift velocity 4 mm/μs.

Energy resolution on the beam (CERN)





1 AU ≈ 28 кэV

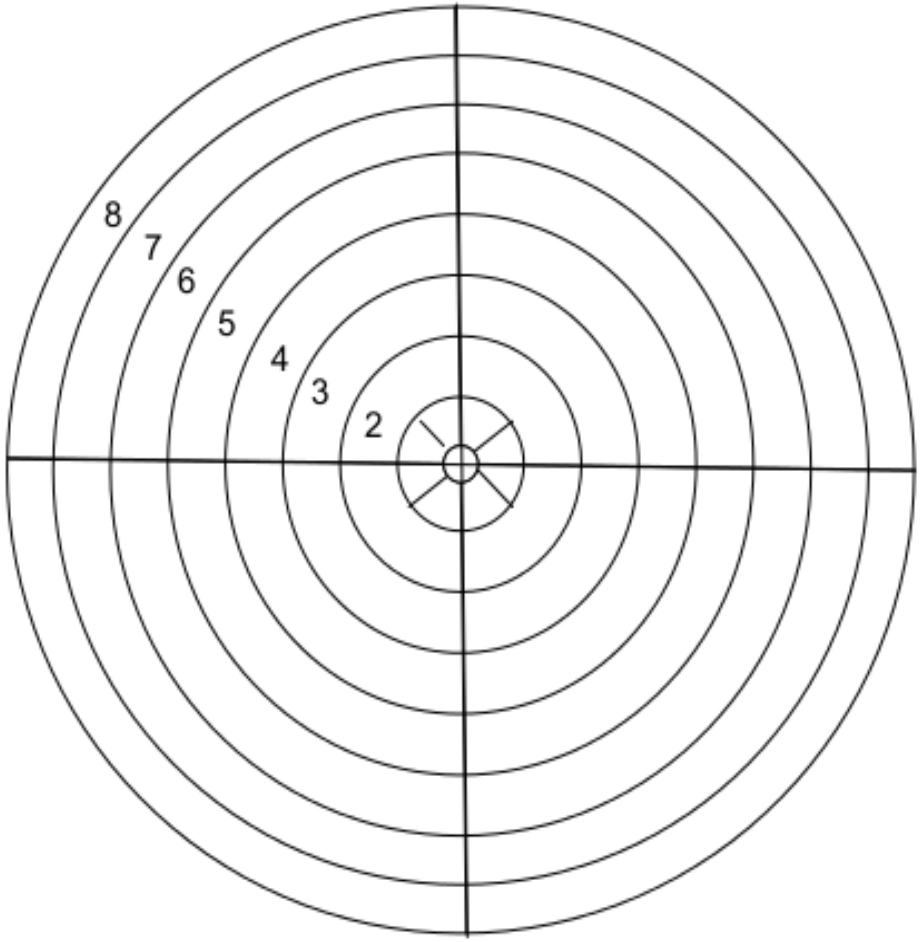
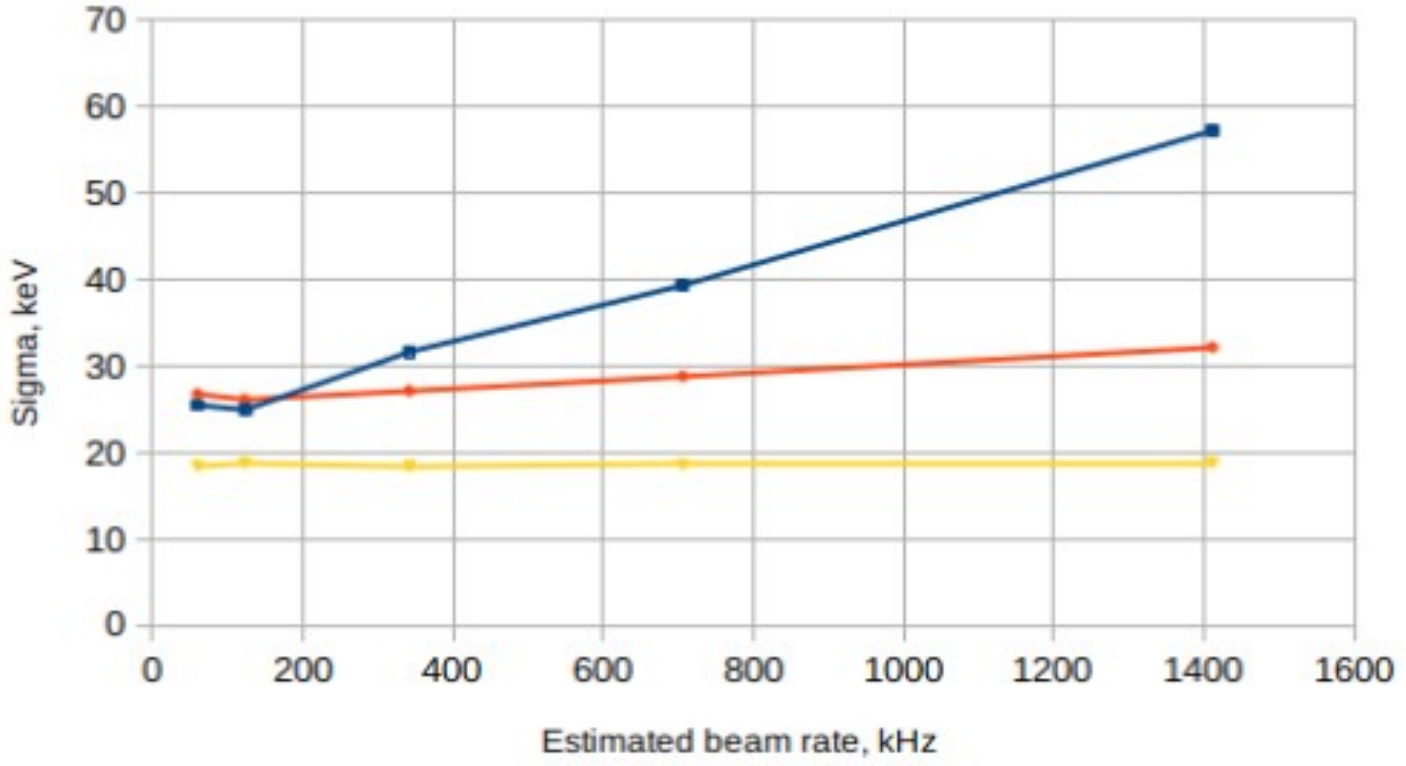


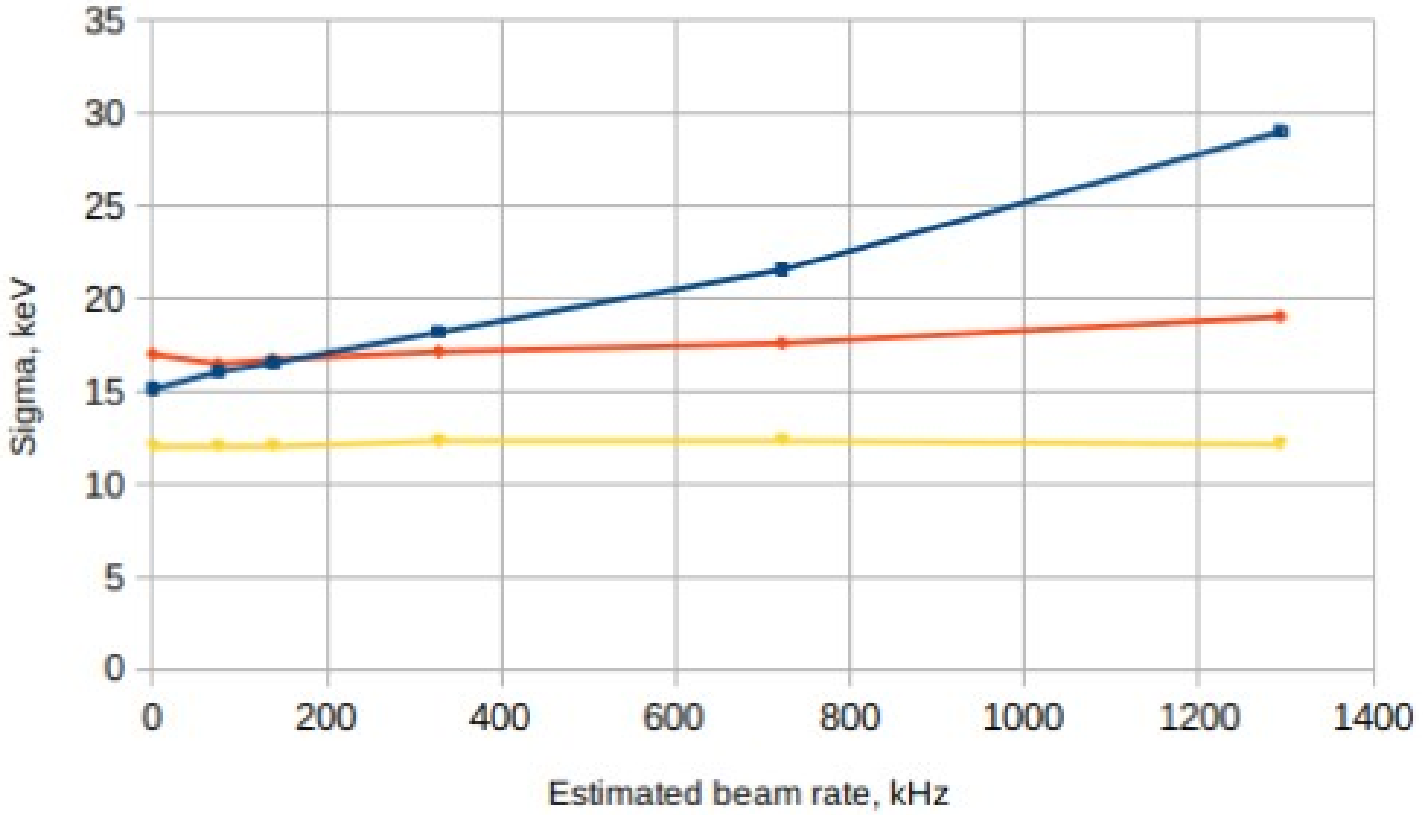
Fig.1. TPC anode structure.

The TPC anode plane consists of eight rings around a 1 cm in diameter central pad. The width of each ring, except the outer ring, is 40.0 mm with 0.1 mm gap between the rings. The width of the outer ring is 24 mm. The anode rings are fabricated with 50 μm precision in the radii of the rings. As an example, the radius of the border between Ring 7 and Ring 8 is $\rho_{7/8} = 285.75 \pm 0.05$ mm. The rings 5-8 can be subdivided in two sectors to reduce capacitance.

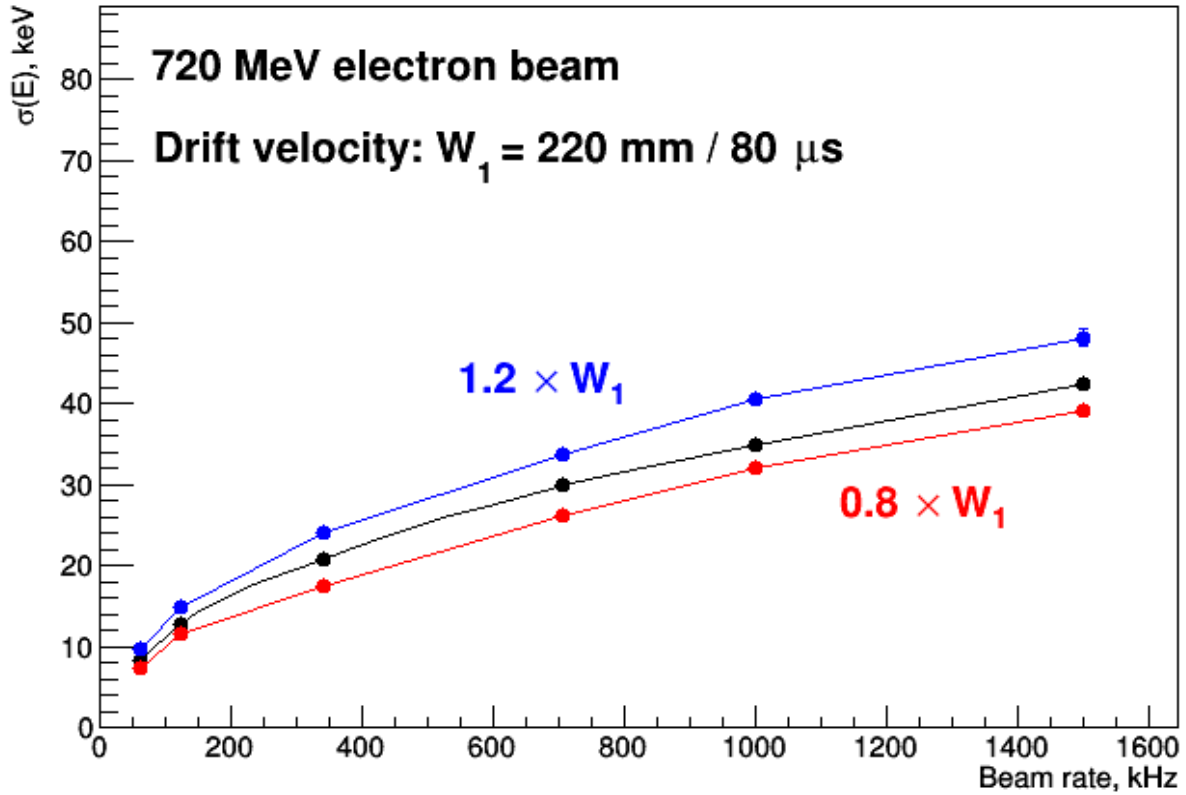
All the anode pads have independent readout channels with 20 keV (sigma) energy resolution, the preamps being outside the TPC volume.



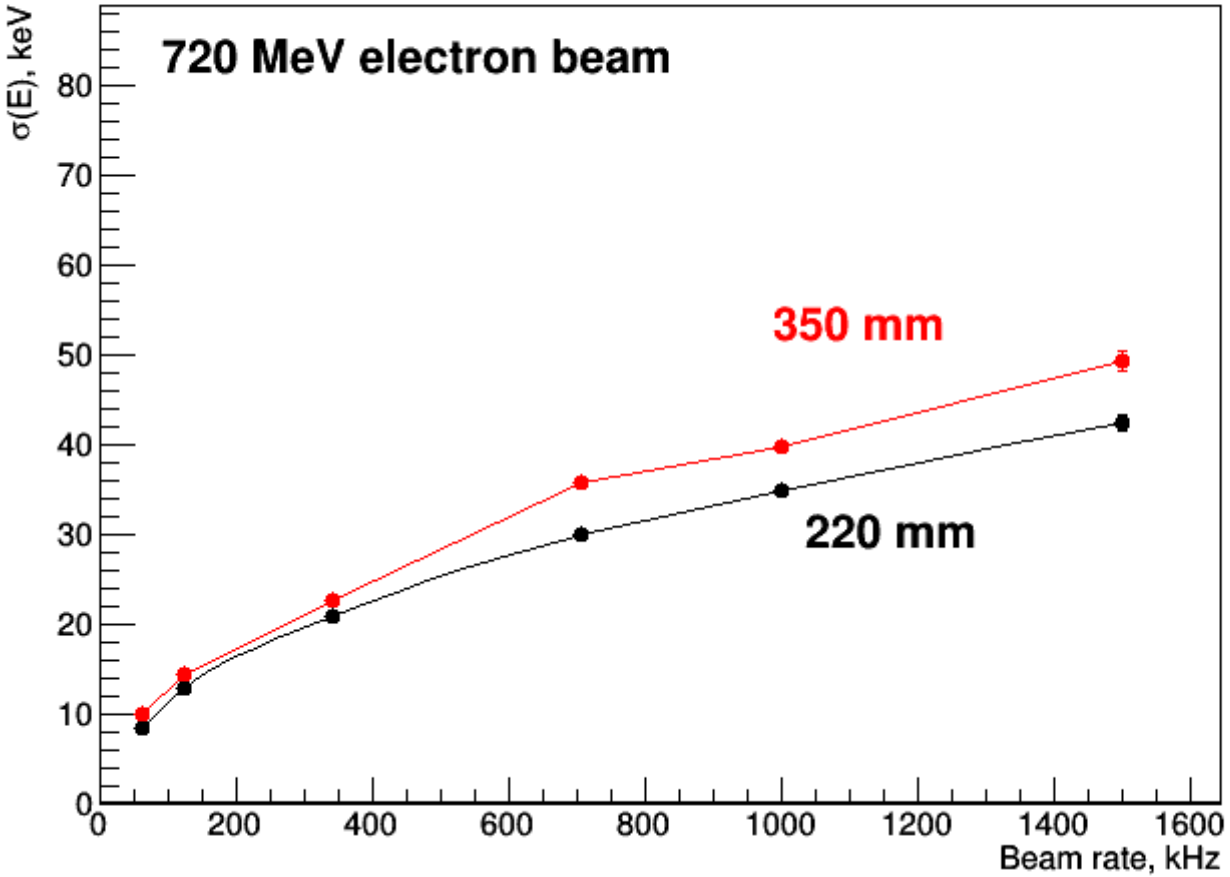
Beam ionization noise in function on the beam rate for the He + 4%N2 gas mixture at the pressure 10 bar . The measurements were done at different pads
(blue – *central pad #65, red*-nearest ring #66*, yellow-next segmented pad #33).*



Beam ionization noise in function on the beam rate for the He + 4%N2 gas mixture at the pressure 5 bar . The measurements were done at different pads
(blue – *central pad #65, red*-nearest ring #66*, yellow-next segmented pad #33).*



Beam ionization noise in function on the beam rate calculated for various drift velocities. He + 4%N2 gas mixture (10 bar), drift gap 220 mm.



Beam ionization noise in function on the beam rate calculated for drift gaps 220 mm and 350 mm. He + 4%N2 gas mixture (10bar). Drift velocity 2.75 mm/µs.

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