Local Polarimetry with Beam-Beam Counters at the SPD Experiment

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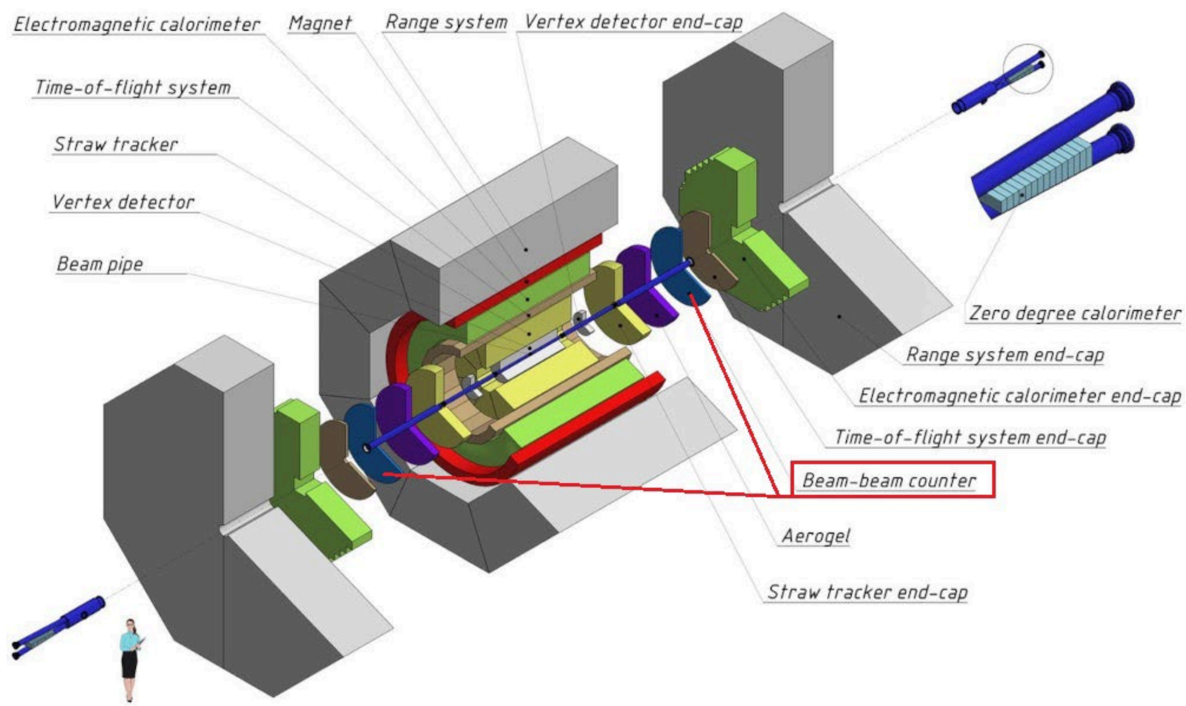
Beam-Beam Counters

The two Beam-Beam Counters (BBC) are components of the Spin Physics Detector (SPD) at the NICA collider. They will be installed in to end-caps parts of SPD and are designed to perform local polarimetry of the colliding polarized proton and deuteron beams and luminosity control in the beam interaction region. BBCs detect all the charged particles produced in the forward direction within their acceptance.

Here, the MC simulation of the BBC operation for proton-proton collisions is presented. The simulations are performed using the SpdRoot framework and the center-of-mass energy of 27 GeV. The results presented include the estimation of the magnetic field influence on the inclusive charged particle production asymmetries and on the BBC-loads. The selection of the *pp*-elastic scattering events in the BBC is also discussed.

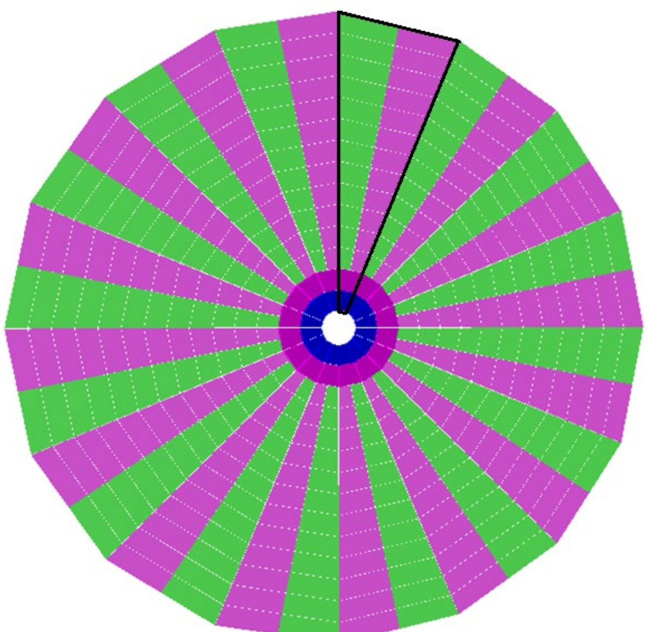


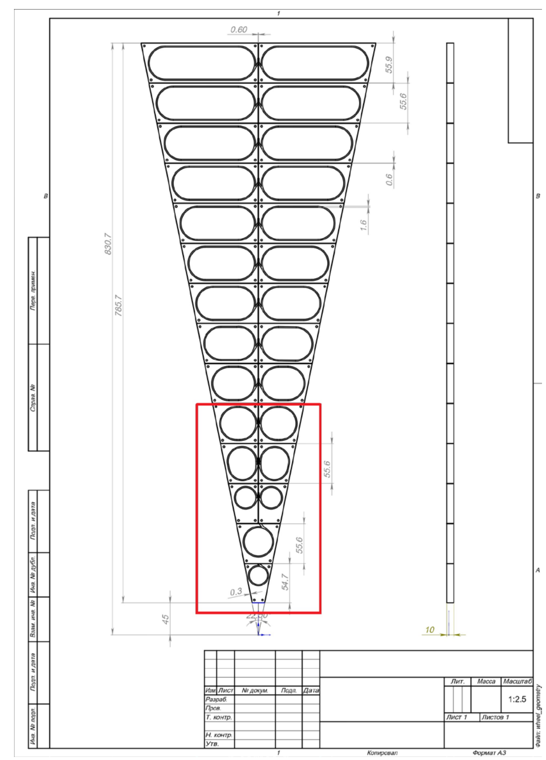
BBC design

In the new TDR design the BBC consist of ~ 416 scintillation tiles. It will be divided into 14 concentric layers with 16 azimuthal sectors each. The distance between tiles is 1 mm. The tile thickness is 10 mm. The diameter will be 1650 mm. The distance between each BBC and SPD center is 1716 mm. This configuration will be allowed to cover of the angle scattering range up to θ=25^{o}-30^{o}. The uncertainty of the interaction point is expected to be 300 mm. The wavelength shifting (WLS) fiber will be installed in each BBC tile. The tiles of the BBC viewed by the silicon photomultiplier (SiPMs).

The BBC prototype will be planned to use in the zero phase of the SPD – experiment.

TDR design 2023



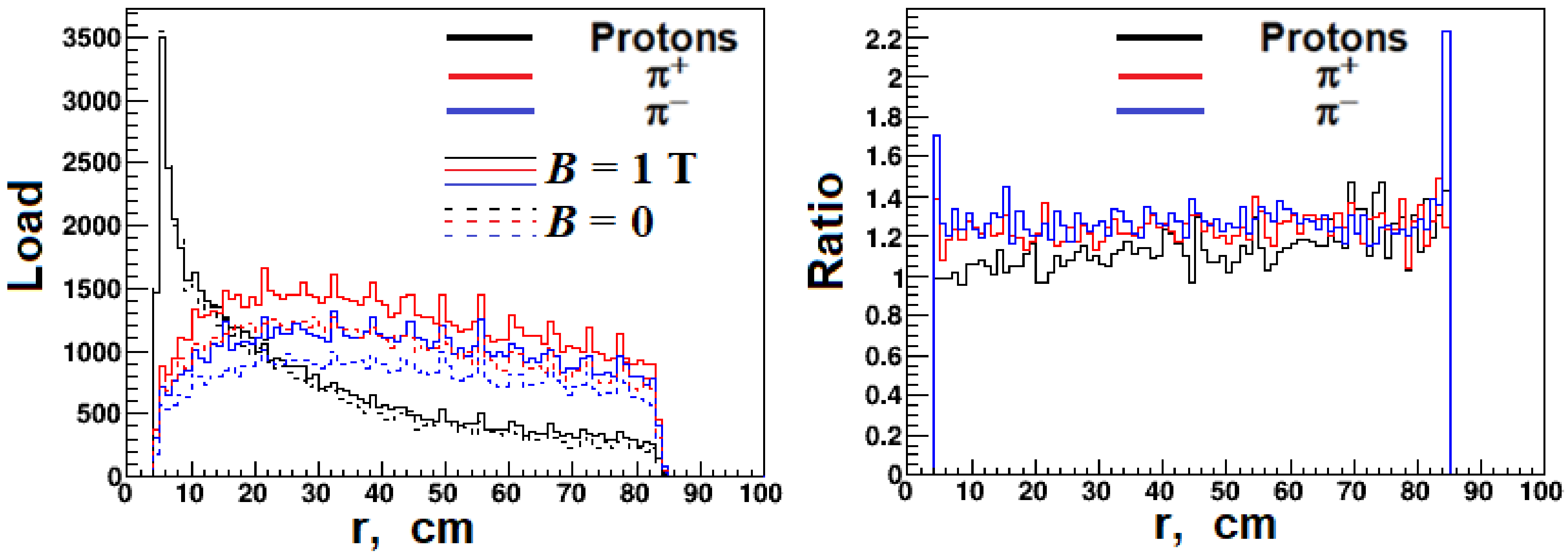


The simulation of the *pp*-scattering

Energy : $\sqrt{s}$ up to 27 GeV. Generator: Pythia8.

The estimation of the magnetic field influence on the BBC load.

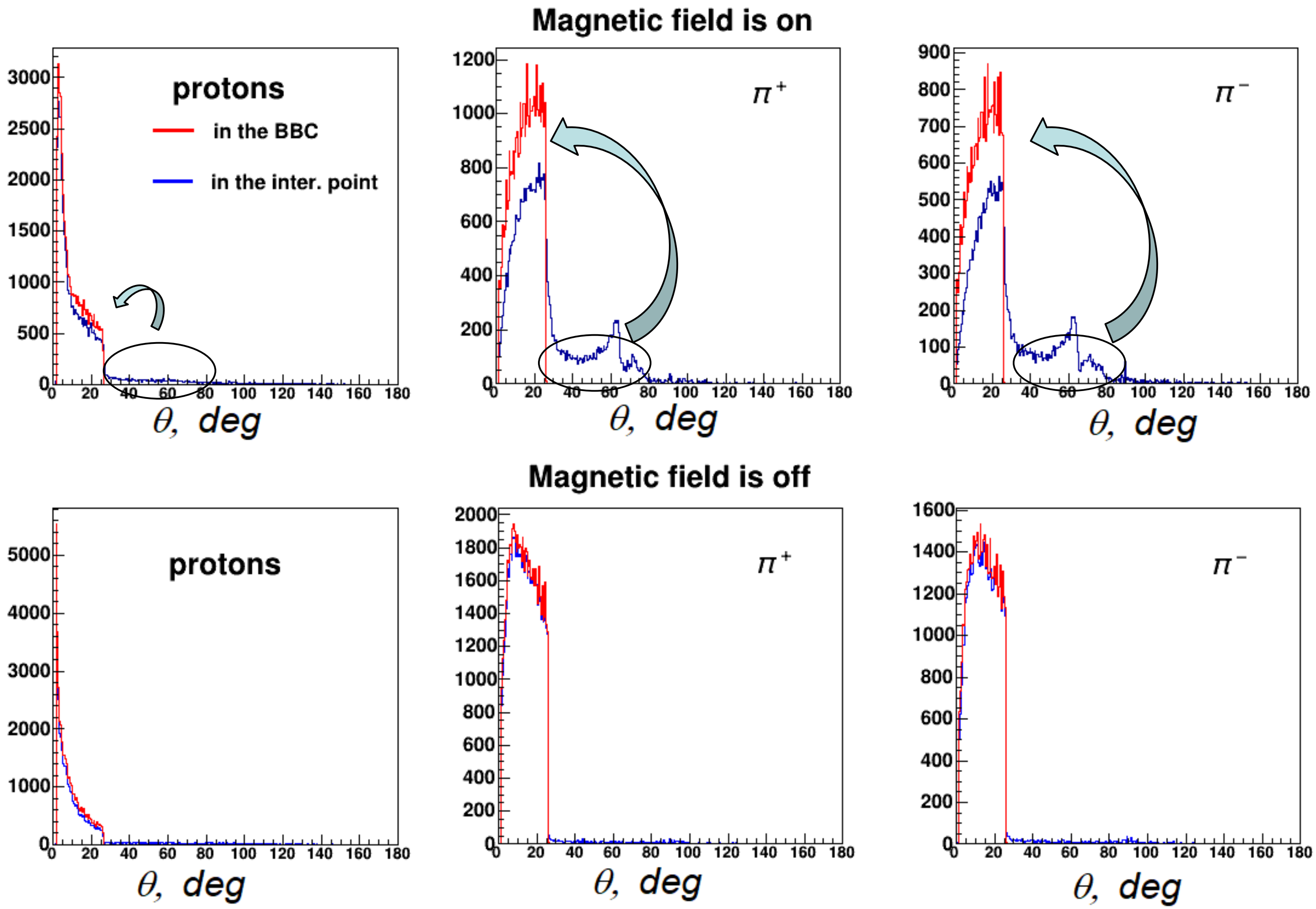
The radial dependence of the charged particles loads were obtained for one of BBC modules for cases when the magnetic field is turned on (solid line) and off (dashed line). One can see, the magnetic field presence increases the BBC load. This increase is observable for all radii for π^+ and π^-. For protons, the influence of the magnetic field is observed more prominently at large radii.



The estimation of the magnetic field influence on the BBC load.

Polar scattering angle θ – distribution

The comparison of the scattering angles in the points Z=0 and Z=1716 for each particle showed that BBC load increase is due to the capture of the particles in the magnetic field. The analysis of the time and momentum information for pions gives that the particles with the $\theta > 27^{o}$ have the momentum $p < 0.4$ GeV.

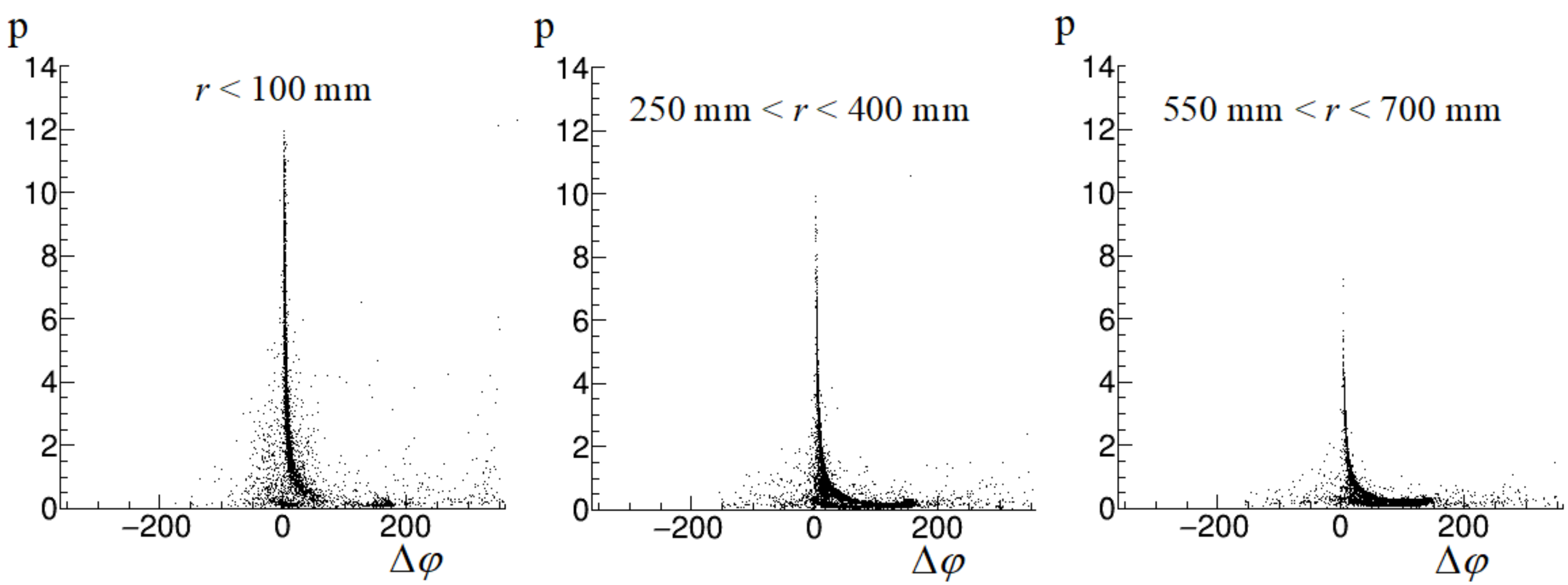


Track rotation in the magnetic field.

Phase shift $\Delta\varphi$ – distribution

The magnetic field changes particle trajectory. The rotation angle $\Delta\varphi$, depends on magnetic field as well as particle momentum and charge. The correlation of the $\Delta\varphi$ and p for each particle shows that the smear of the $\Delta\varphi$ – distribution increases with the increase of BBC radius r. For pions, large deviations ($\Delta\varphi > 50^{o}$) is corresponds to the momentum range $p < 0.4$ GeV/c. The particles with the small longitudinal momentum (and large transverse momentum $p\perp$) pass to the upper BBC layers.

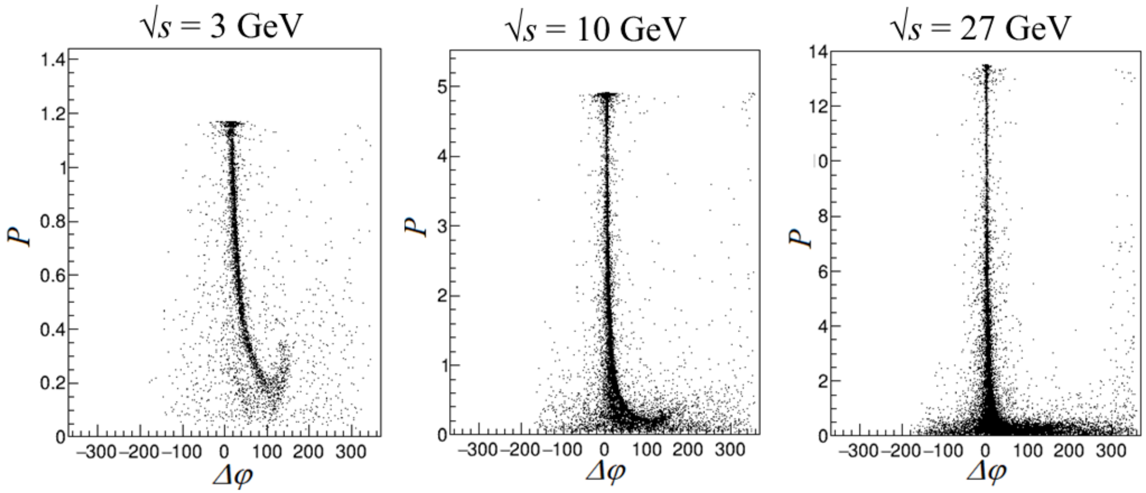
r – radius of BBC, $\Delta\varphi$ – rotation angle, p – particle momentum



Track rotation in the magnetic field.

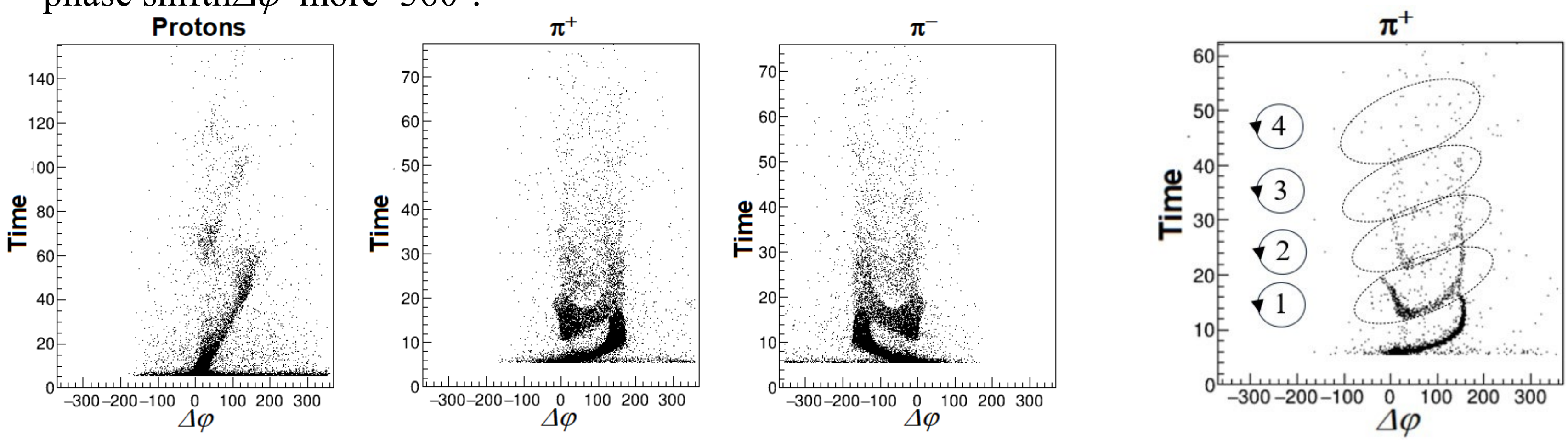
Energy dependence of the $\Delta\varphi : p$ - correlation

The simulation at 3, 10 and 27 GeV shows that the particles number with the $\Delta\varphi > 50^o$ is increased with the energy increasing. It is due to the increasing fraction of particles with large transverse momentum with increasing collision energy.



$\Delta\varphi$: *time* – correlation

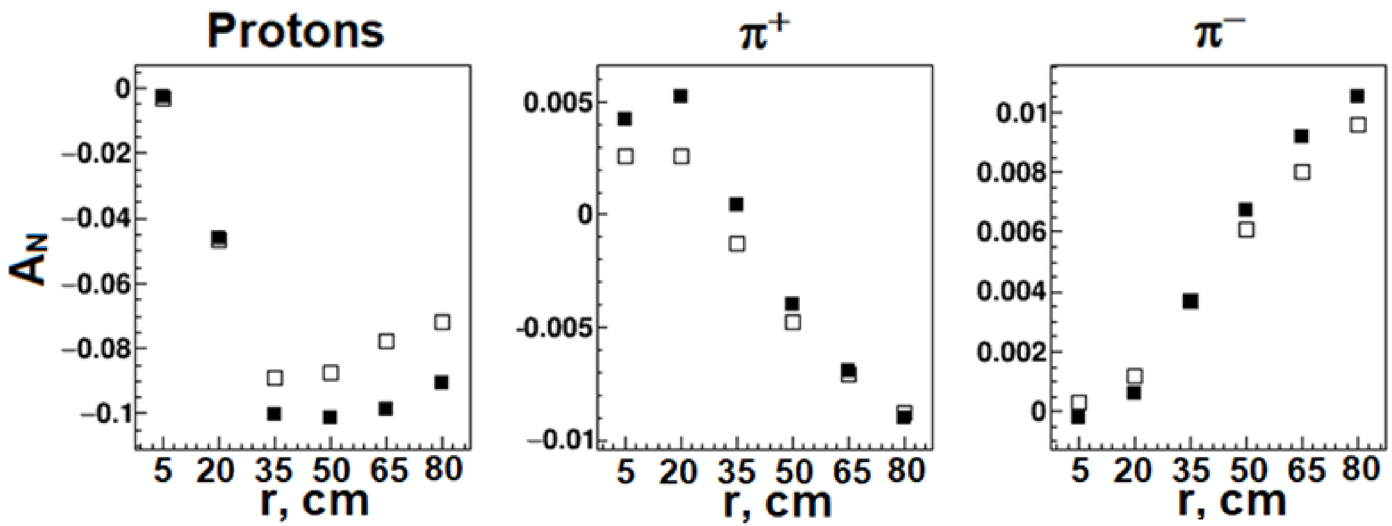
The correlation of the time t and phase shift $\Delta\varphi$ shows that we have the particles with the same phase and different momentum. One can see from the time information there are particles which have the phase shiftn$\Delta\varphi$ more 360^o.



The magnetic field influence on the inclusive charged particle production asymmetries.

The presence of the magnetic field leads to a change of the loads as the function of x_F and p_t up to 20% and 10%. The analyzing powers A_N have been calculated by the Abramov V. V. [1] for inclusive reaction within the framework of the phenomenological model for chromomagnetic polarization of quarks (CPQ).

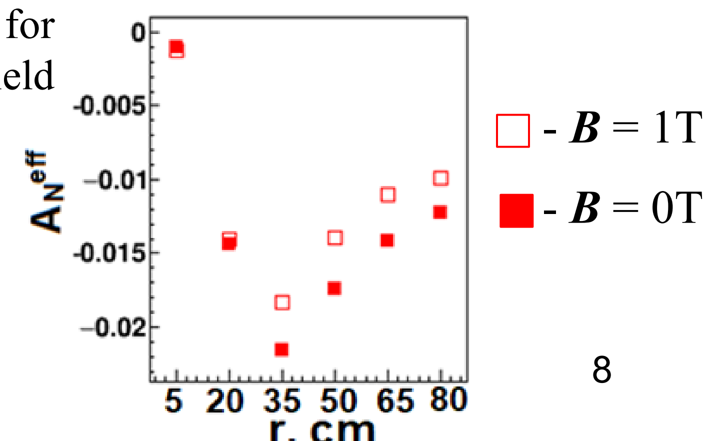
$\sqrt{s} = 27$ GeV. □ : $\boldsymbol{B} = 1$T, ■ : $\boldsymbol{B} = 0$.



Also the effective analyzing power A_N^{eff} have been calculated for two cases: $B = 0$ and $B = 1$T. The presence of the magnetic field leads to a change of the A_N^{eff} up to 22%.

$$A_N^{eff} = \frac{A_N^p N_p + A_N^{\pi^+} N_{\pi^+} + A_N^{\pi^-} N_{\pi^-}}{N_p + N_{\pi^+} + N_{\pi^-}}$$

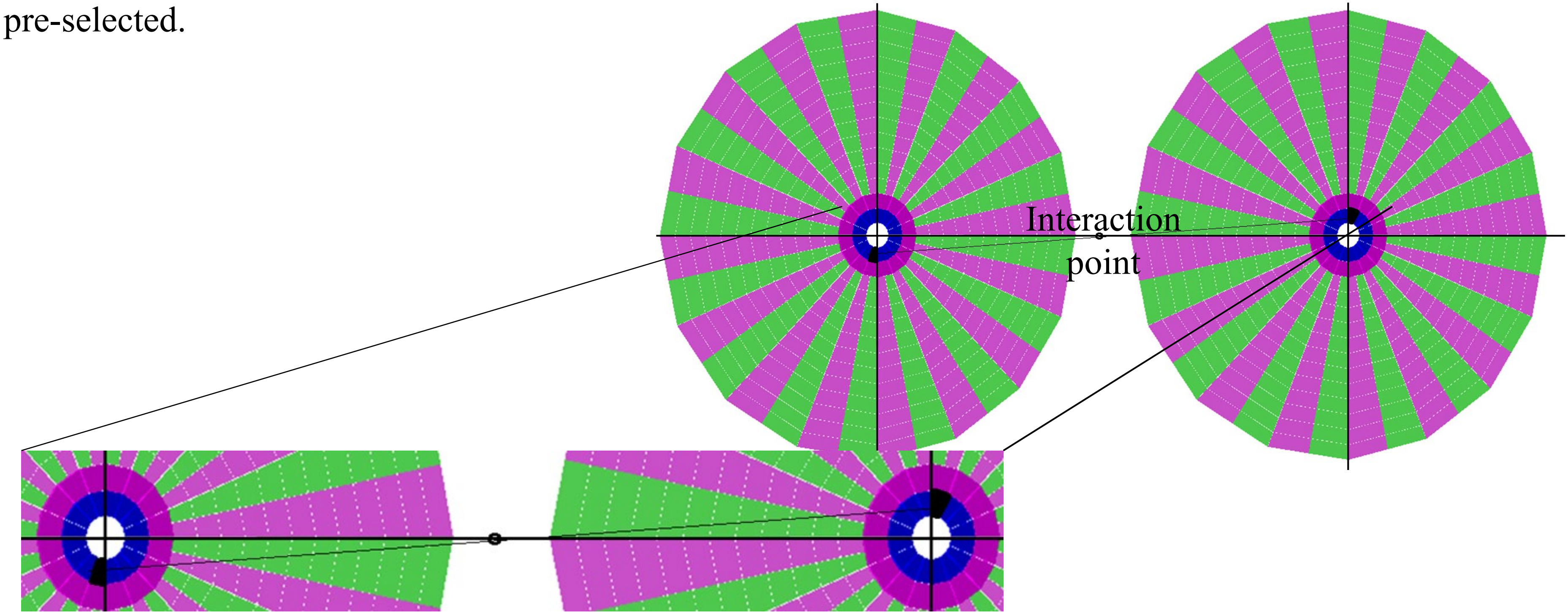
N_p, N_{π^+}, N_{π^-} – number of the protons, π^+, and π^- in each layer.



[1] Abramov V. V. JPS Conf.Proc. 37 (2022) 020901

PP – elastic scattering selection

Elastic scattering of protons can be used for polarimetry control of the colliding beams. Also elastically scattered protons have large momentum and therefore small rotation angle $\Delta\varphi$ in the magnetic field. Preliminary analysis shows [2] that the elastic scattering plays a significant role at all BBC layers at the energies $\sqrt{s}$ < 10 GeV. The comparison of the proton and pion analyzing powers A_N [2] show that the behavior of A^{eff}_N is dominated by the A^{proton}_N. Therefore, the selection of the elastic channel is of interest to estimate its contribution to the behavior of A^{eff}_N. The timing information for each hit in the kinematically corresponding tiles can be used for this purpose. Two corresponding tiles of the BBC first layers have been selected in the figure below as an example. The time distributions of the hits which are present simultaneously in the both BBCs have been obtain. In this way, elastic scattering events can be pre-selected.



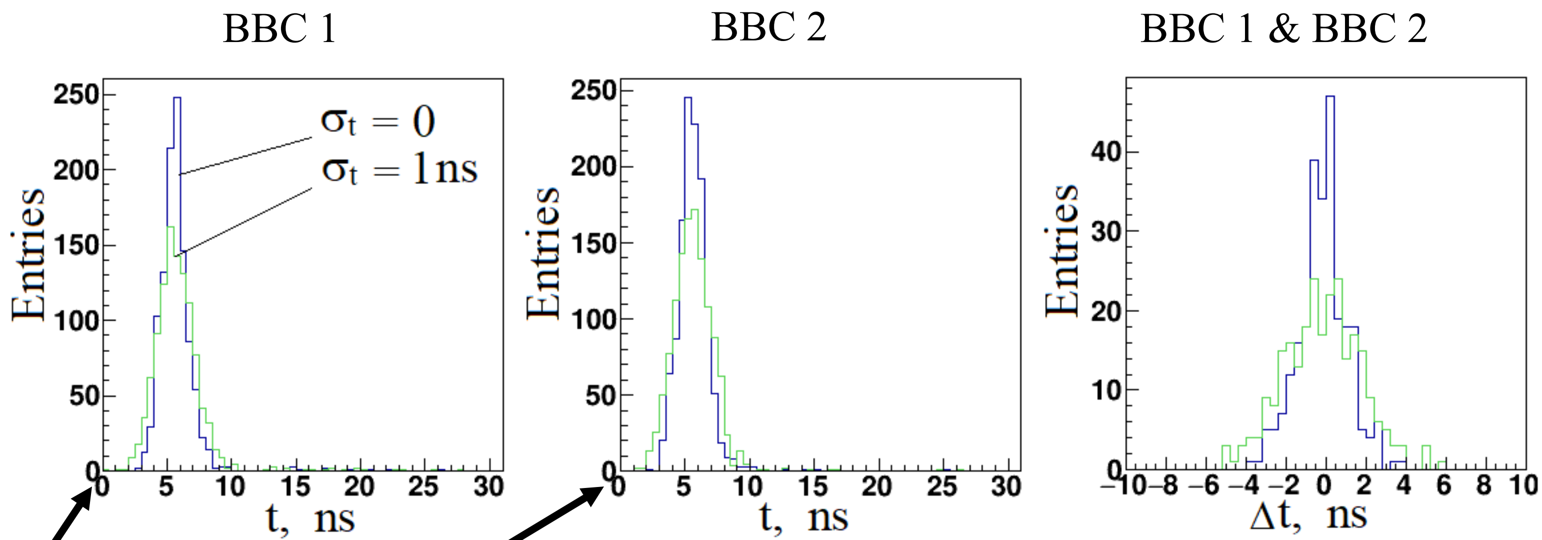
[2] Terekhin A.A. Phys. of Atomic Nuclei, V 87, № 2, p. 44 (2024)

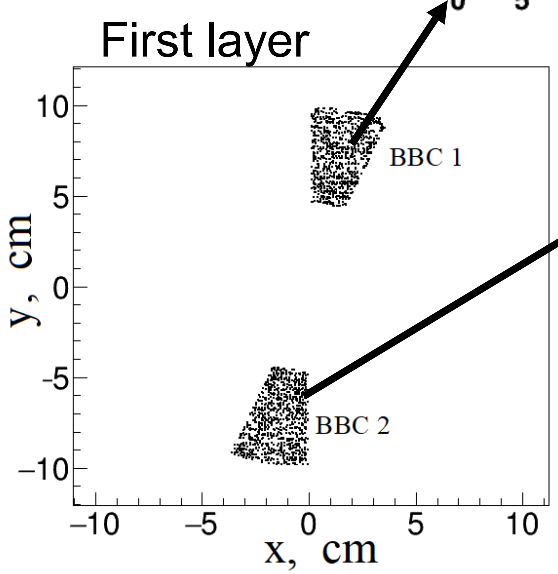
PP – elastic scattering selection

Time difference Δt

The timing distributions of hits have been obtained for each BBC. Also the time difference distribution for hits, which are registered in the both BBC simultaneously is showed.

$\sqrt{s} = 10$ GeV, $B = 0$, $\sigma_z = 300$mm





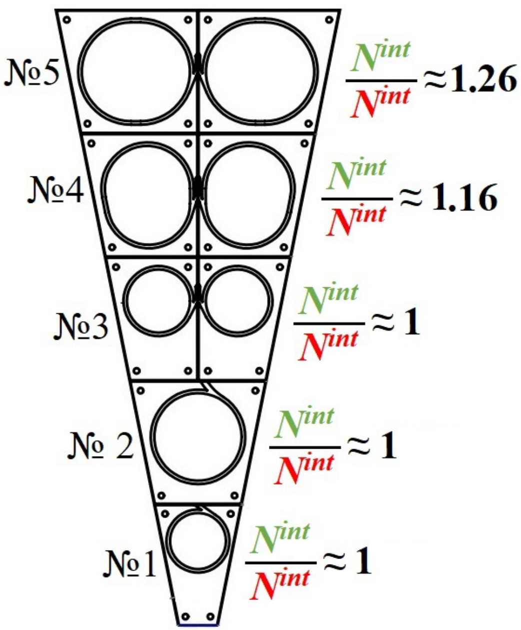
The total time resolution smeared the spectrum, but the main statistic part also is located in the domain ±4 ns.

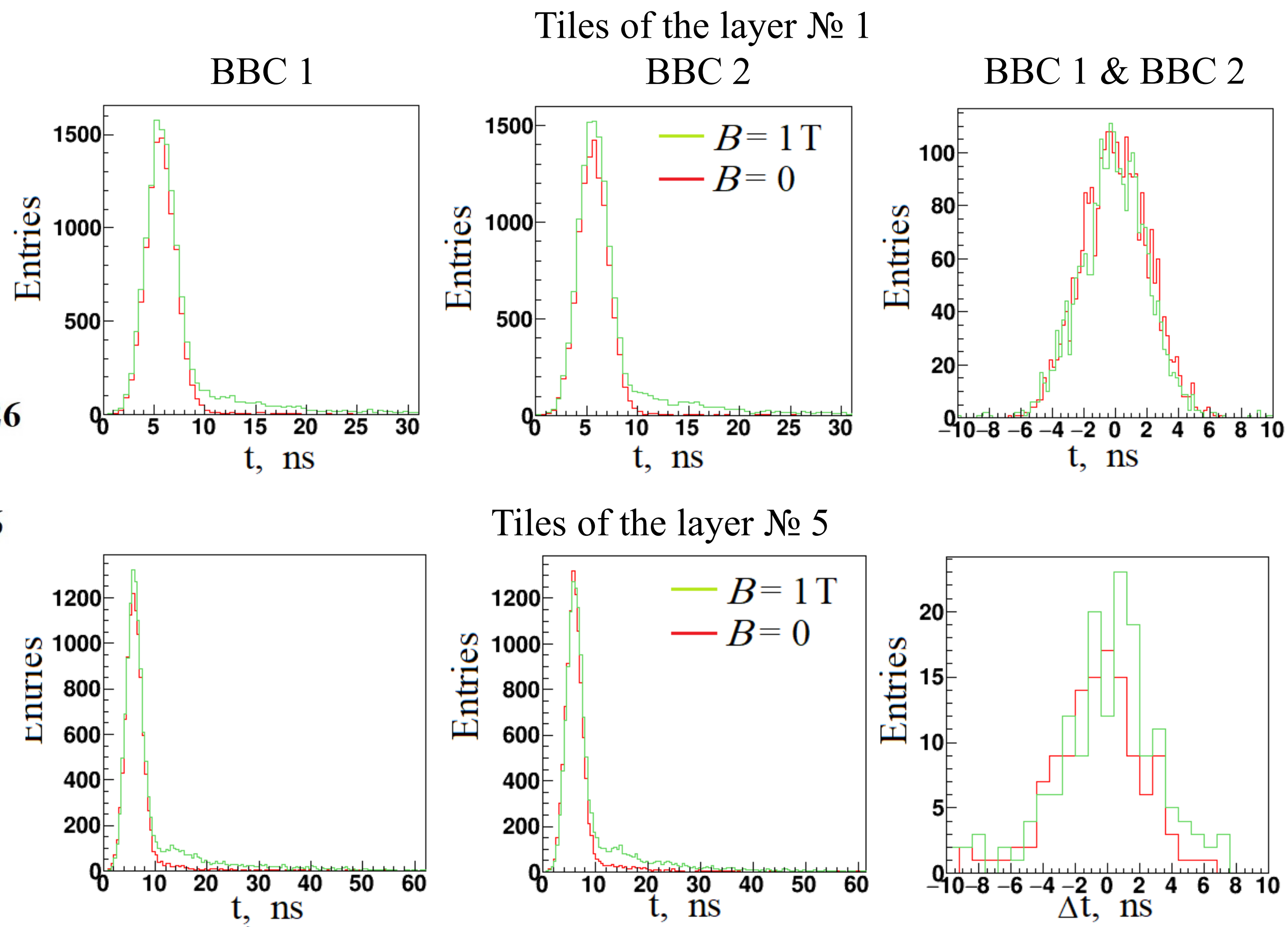
PP – elastic scattering selection

Comparison of the time – distribution at B = 0 and B = 1T

The timing distributions of hits for different BBC-layer have been obtained at B = 0 and B = 1T.

N^{int} (N^{int}) – total selected events in the i-layer, i = 1…5





! The magnetic field role to the elastic scattering events selection increases with the BBC-layers increasing.

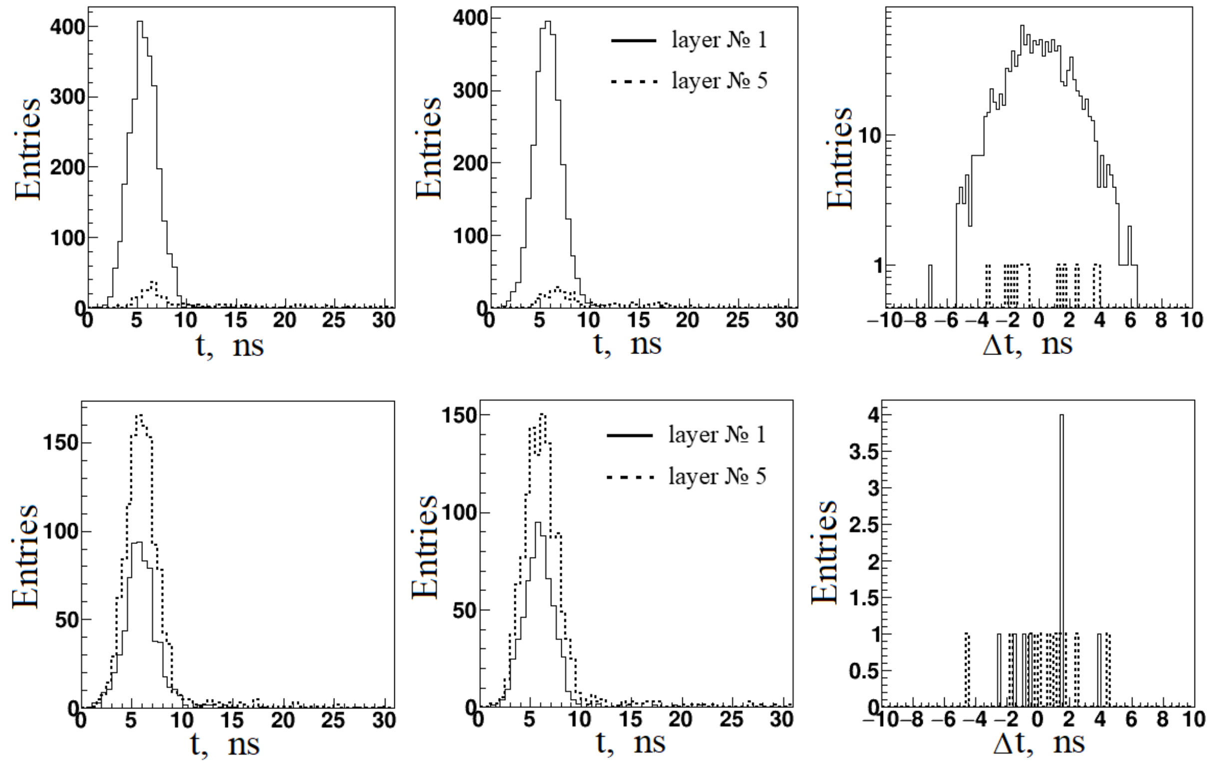
PP – elastic scattering selection

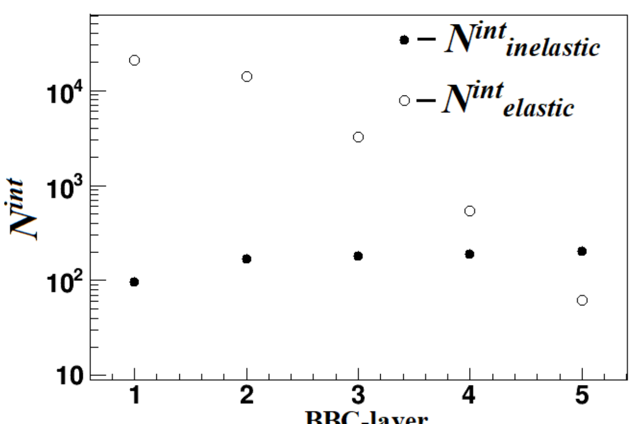
It due to the increasing of the background coincidences between BBC 1 and BBC 2. The simulation of the pp-elastic scattering only and pp-inelastic scattering only at 10 GeV have been performed to understand of the above obtained results.

BBC 1 | BBC 2 | BBC 1 & BBC 2

pp – elastic scattering

pp – inelastic scattering





N^{int} – total selected events in the *i*-layer, *i* = 1…5

Conclusion

- The influence of the magnetic field on the BBC load has been estimated. It presence increases the BBC load. This increase is observable for all radii for π^+ and π^-. For protons, the influence of the magnetic field is observed more prominently at large radii.
- The magnetic field gives the non zero phase $\Delta\varphi$ for each particles, which is dependent from particle momentum. However, the azimuthal φ – distributions are isotropic for the both cases when the B=0 and B=1T. The $\Delta\varphi > 50^o$ are corresponded to the small particle momentum (for pions $p < 0.4$ GeV).
-The analyzing powers A_N^{eff} for inclusive reaction have been calculated for case when the B=0 and B=1T. The presence of the magnetic field leads to a change of the A_N^{eff} up to 22%.
- There is start work to select of the elastic scattering events for future estimation its contribution to the behavior of A_N^{eff} and to polarimetry control of the collision beams.

Thank you for attention!