Simulation of the pp-scattering in BBC in the magnetic field

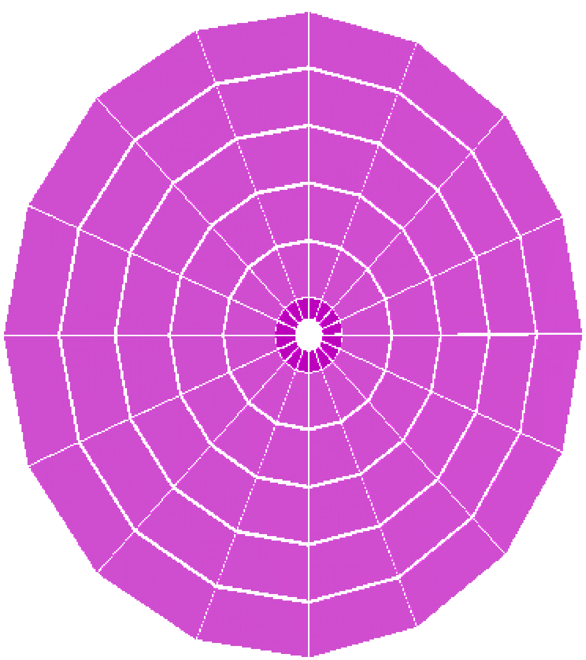
A.A Terekhin et al.
Joint Institute for Nuclear Research, Dubna, Russia

SPD Collaboration Meeting
20 – 24 May 2024

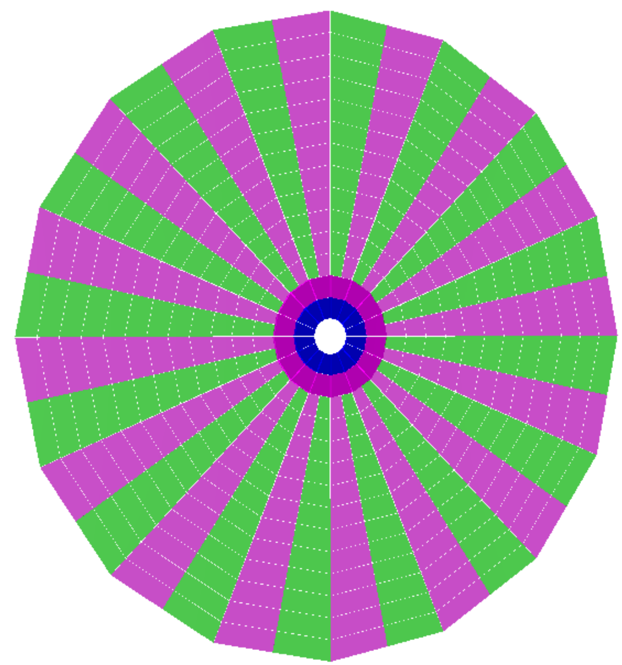
BBC - detector

The SPD will include the two BBC. 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 equal 1 mm. The tile thickness is equal 10 mm. The diameter will be equal about 1650 mm. The distance between each detector and SPD center is equal Z = 1716 mm. Such configuration will be allowed to cover of the angle scattering range up to θ=25°-30°. The uncertainty of location of the point interaction is expected to be ΔZ ~ ±300 mm. The uncertainty of location of the interaction point is expected to be ΔZ ~ ±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).

TDR design 2022



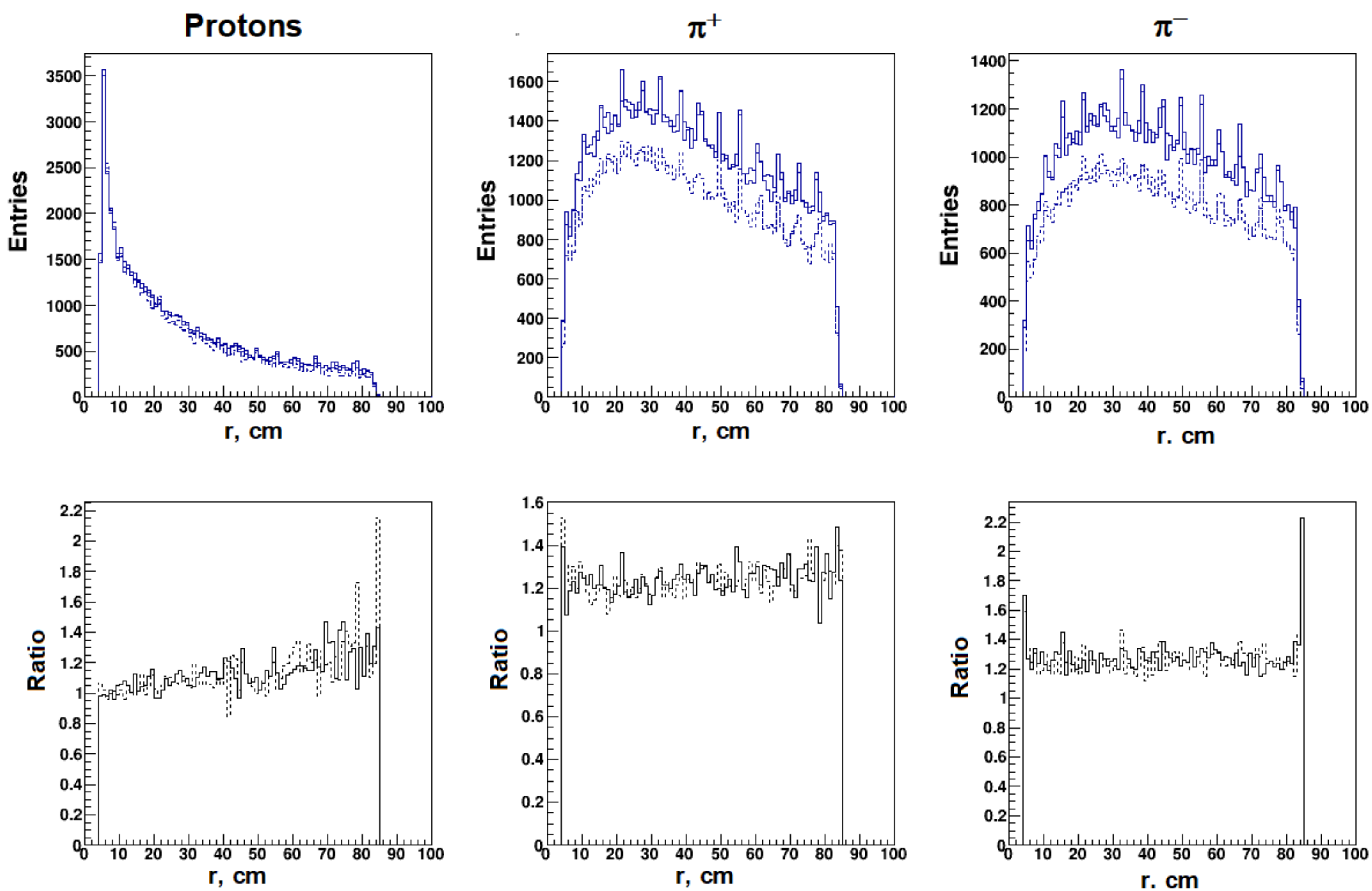
TDR design 2023



The simulation of the *pp*-scattering

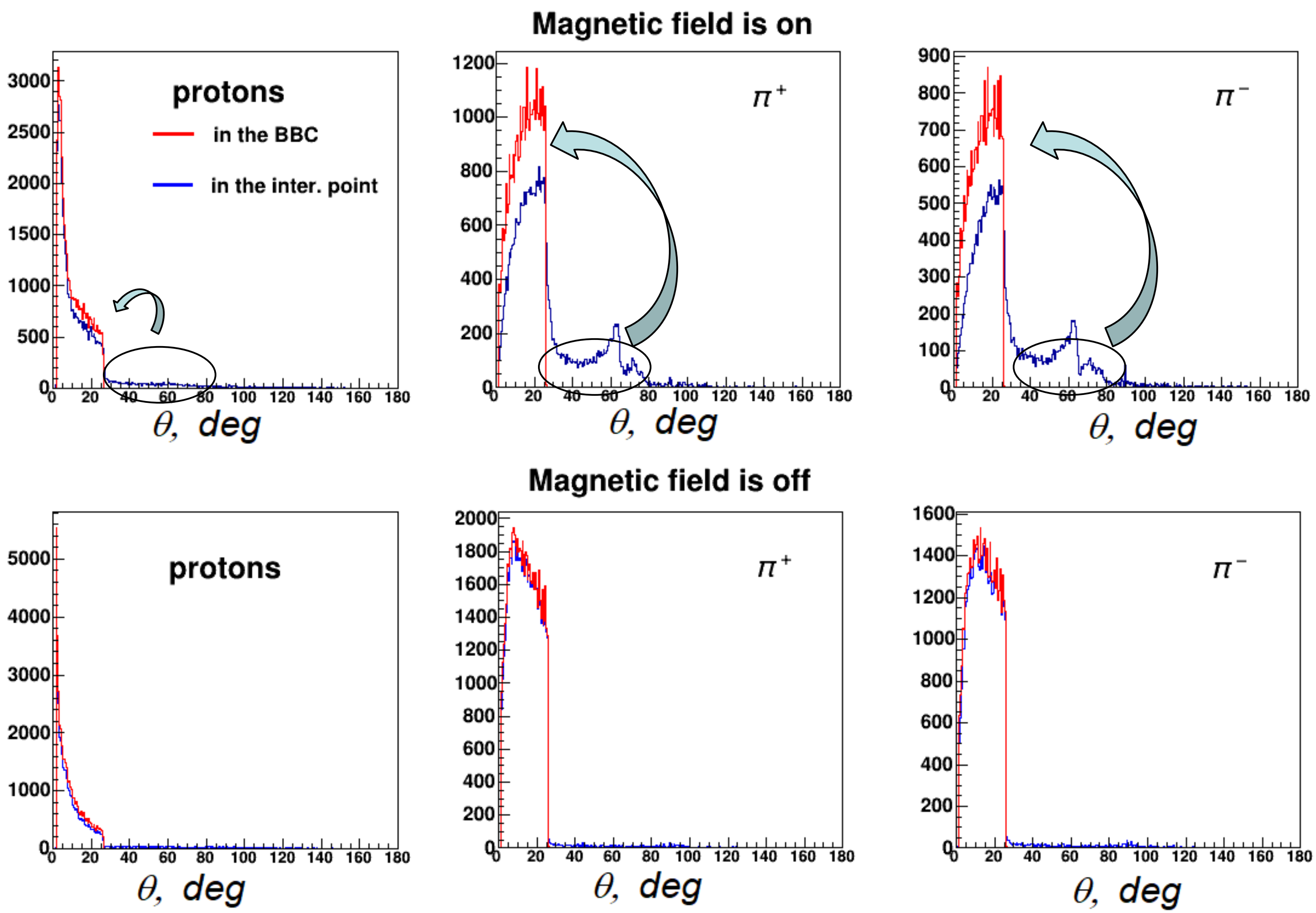
Energy : $\sqrt{s}$ = 27 GeV. Generator: Pythia8. BBC + Pipe

The radial dependences were obtained for both 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 is especially observed for π^+ , and π^- . For protons the influence of the magnetic field is observed in the range of the big radiuses.



Polar scattering angle θ – distribution

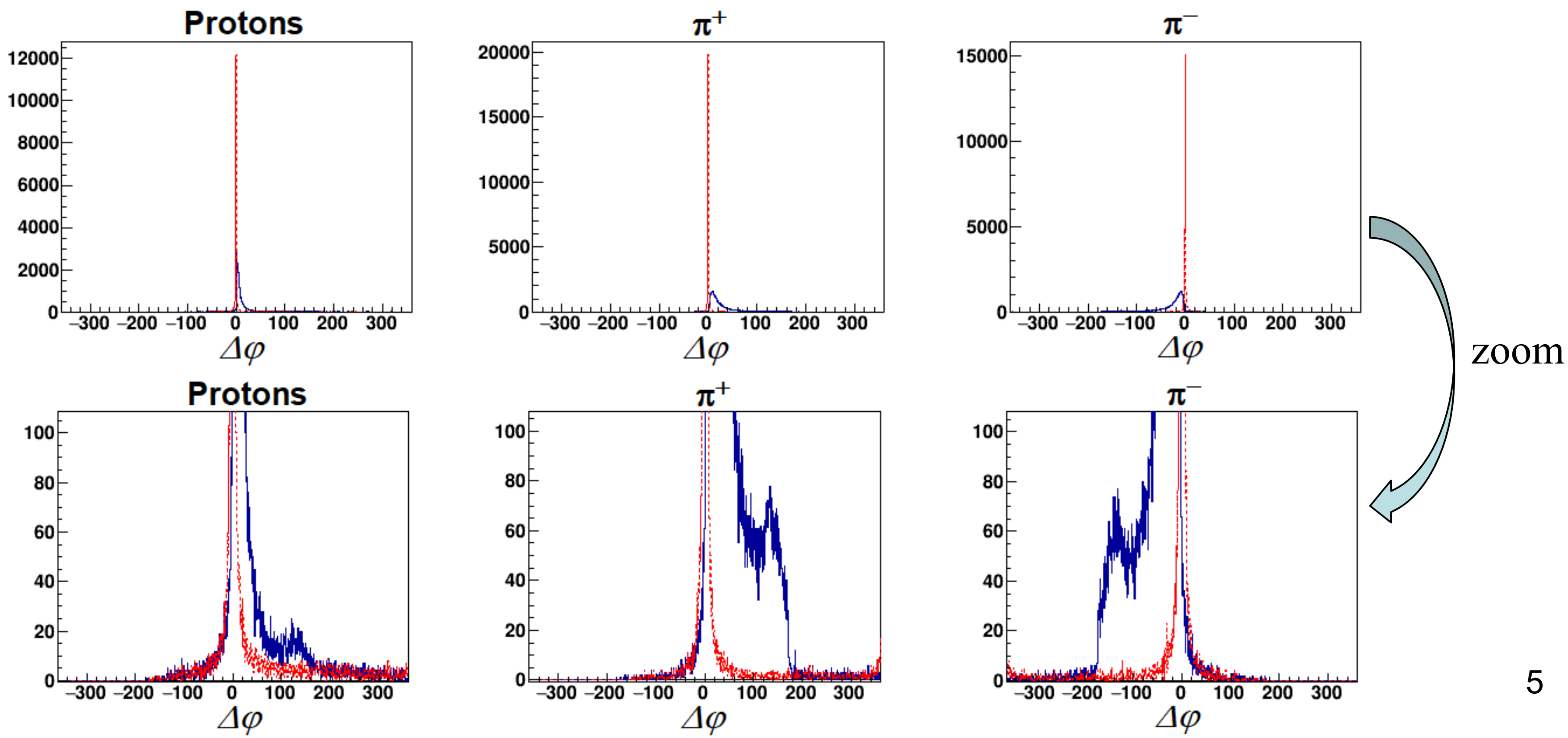
The comparison of the scattering angles in the points Z=0 and Z=1716 for each particle showed that BBC load increase is due to the capture of the particles in the magnetic field. The analysis of the time and momentum information for pions gives that the particles with the $\theta > 27^{o}$ have the momentum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



Phase $\Delta\varphi$ – distribution

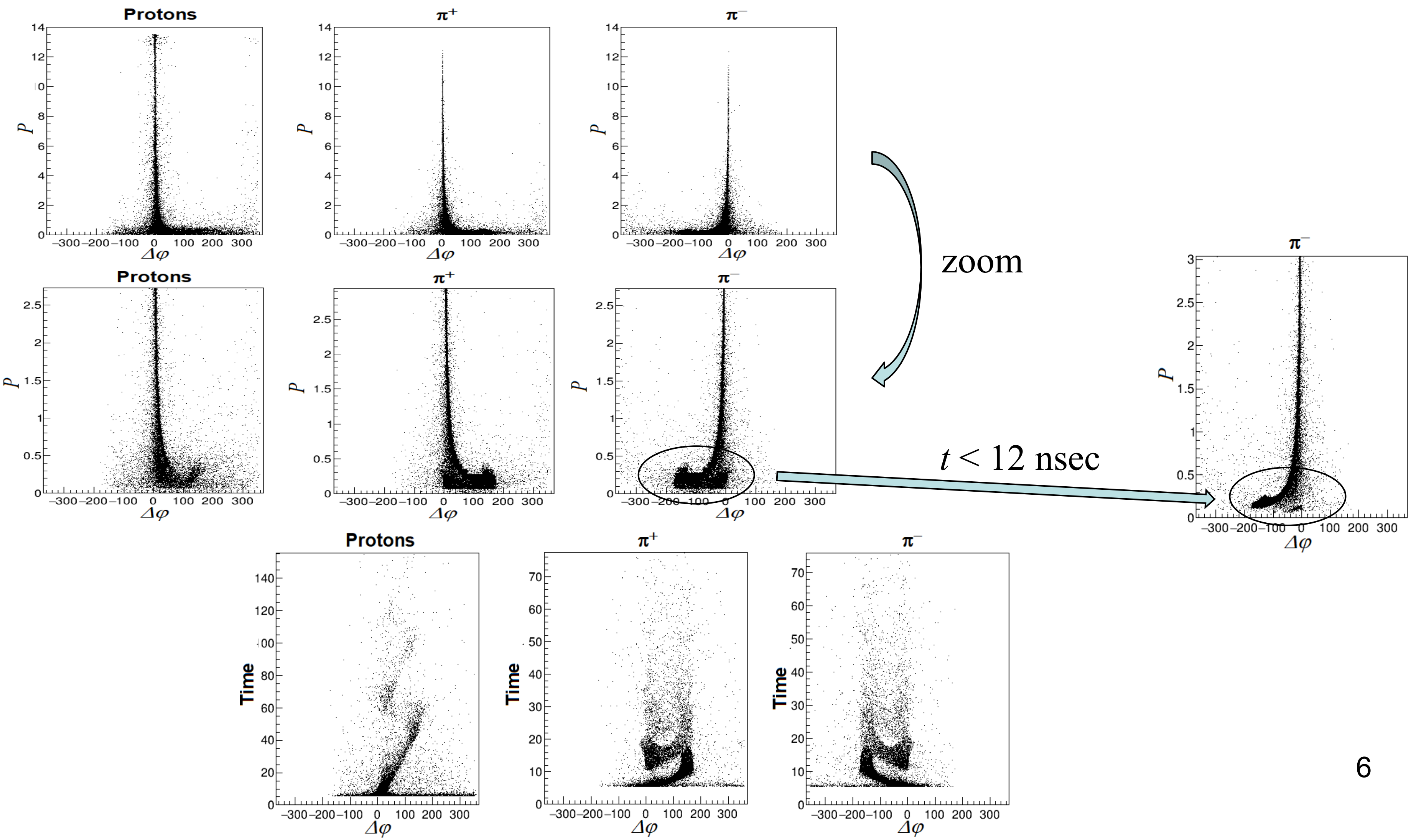
The magnetic field gives the non zero phase $\Delta\varphi$ for each particles, which is dependent from particle momentum. However, the azimuthal φ – distributions are isotropic for the both cases when the B=0 and B=1T. The $\Delta\varphi > 50^o$ are corresponded to the momentum p < 0.4 GeV (for pions).

$\Delta\varphi$ - distribution. $\Delta\varphi = \varphi - \varphi_0$. Red: B=0, Blue: B = 1T.

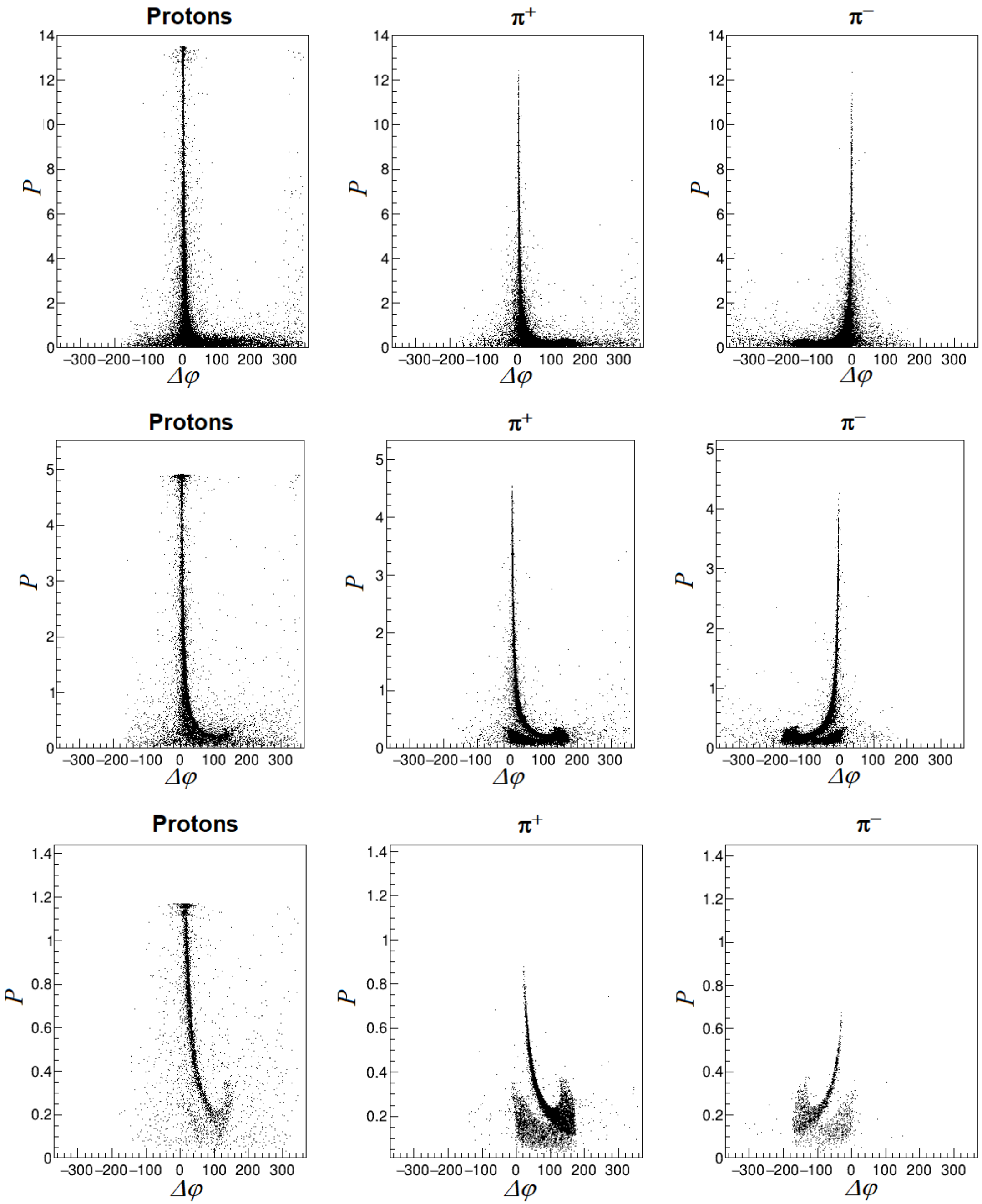


$\Delta\varphi : P-$ and $\Delta\varphi : t-$ correlation.

The correlation of the momentum p and phase $\Delta\varphi$ 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 $\Delta\varphi$ more 360^{o}. The using of the time cut allows to decrease of the very slow particles number.



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



The smear of the $\Delta\varphi$ is increased with the energy increasing. In due to the increase of the particles number with the big transverse momentum.

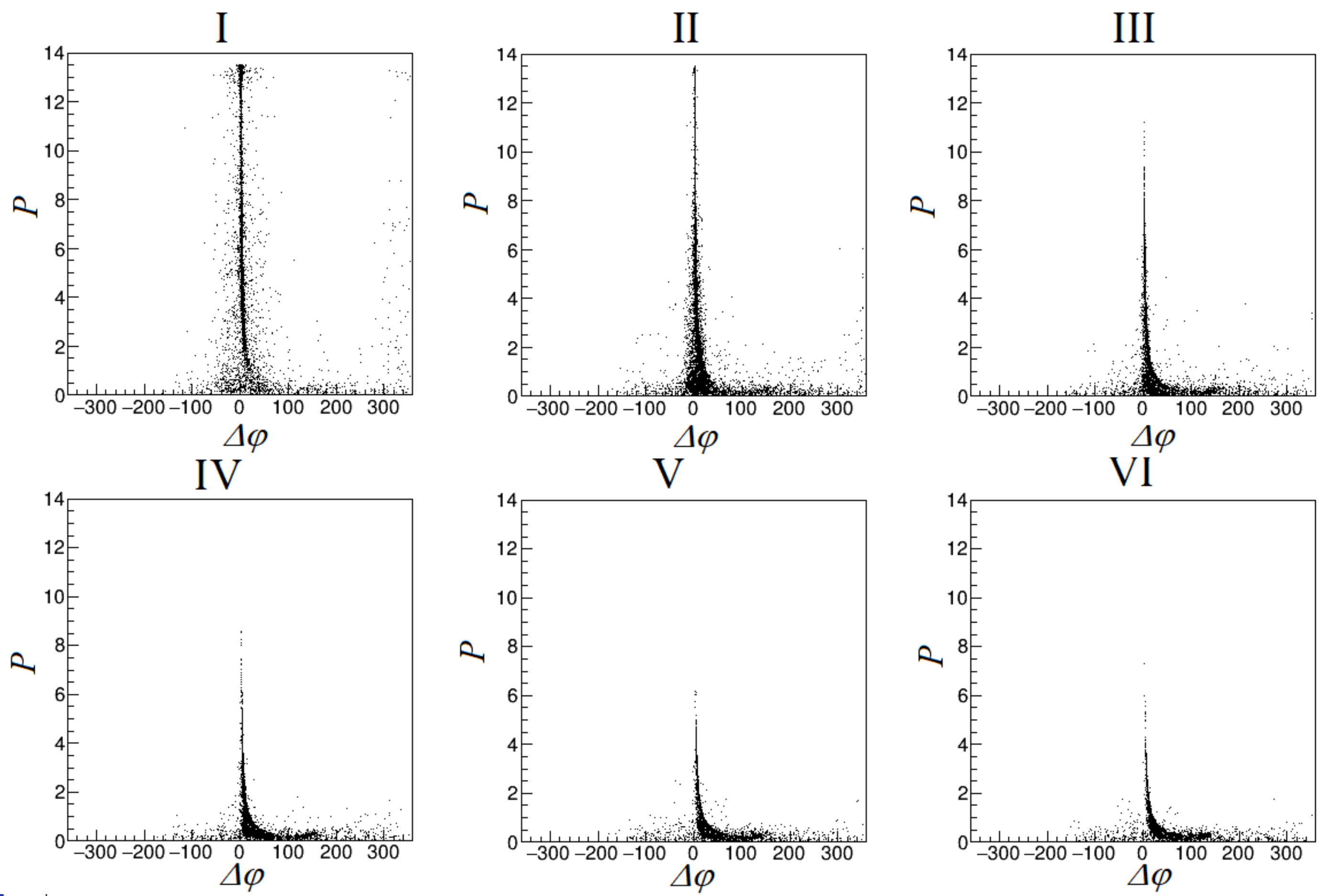
$\sqrt{s} = 27$ GeV

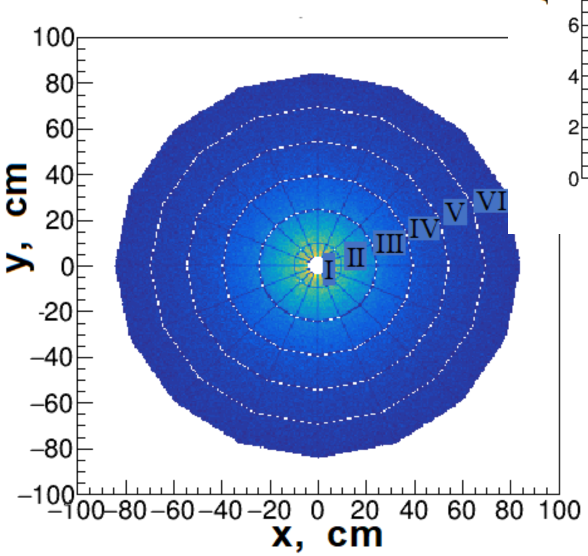
$\sqrt{s} = 10$ GeV

$\sqrt{s} = 3$ GeV

$\Delta\varphi : p$ – correlation in dependence of the BBC layer

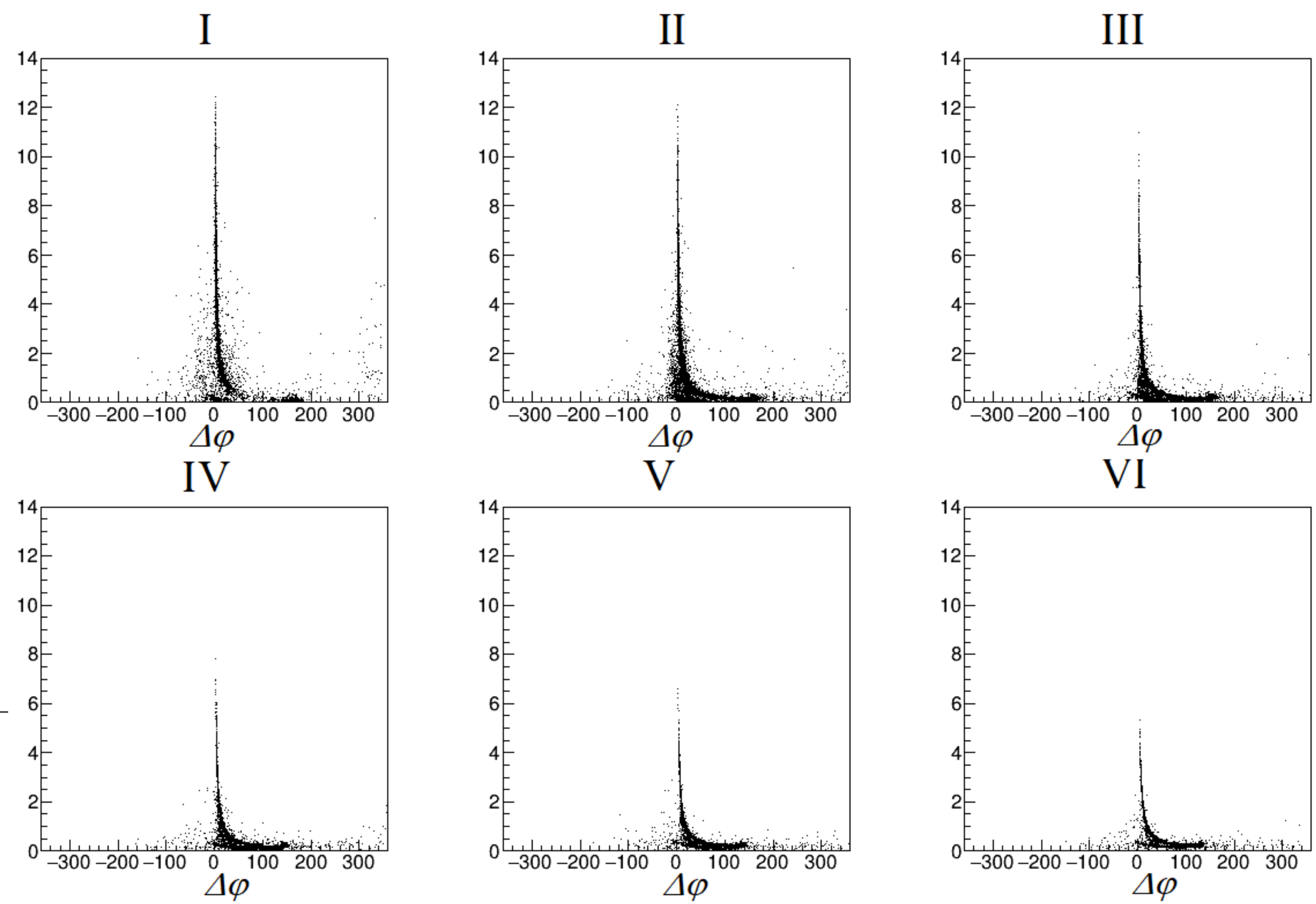
For protons

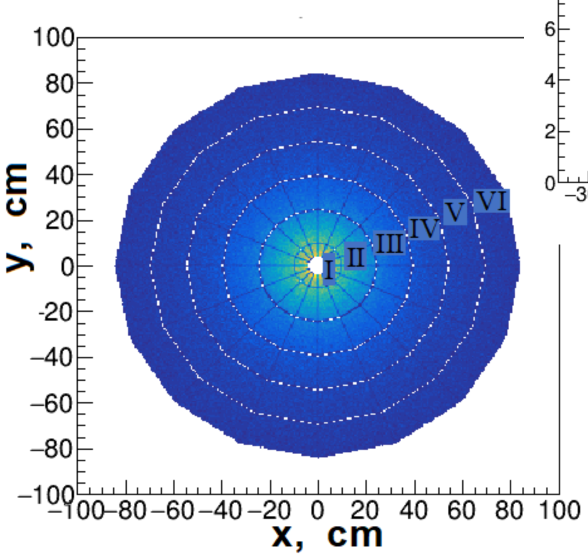




$\Delta\varphi : p$ – correlation in dependence of the BBC layer

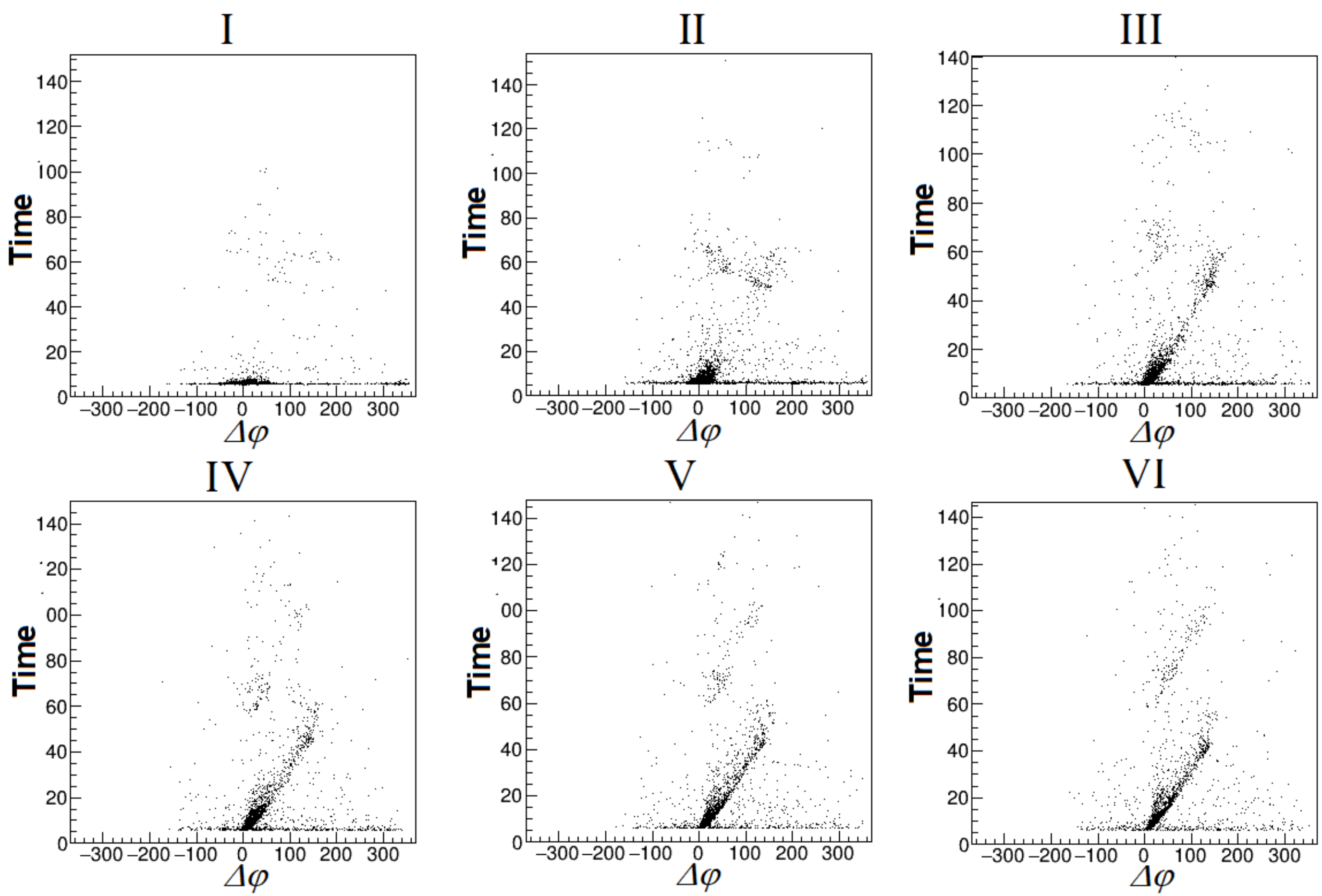
For π^+

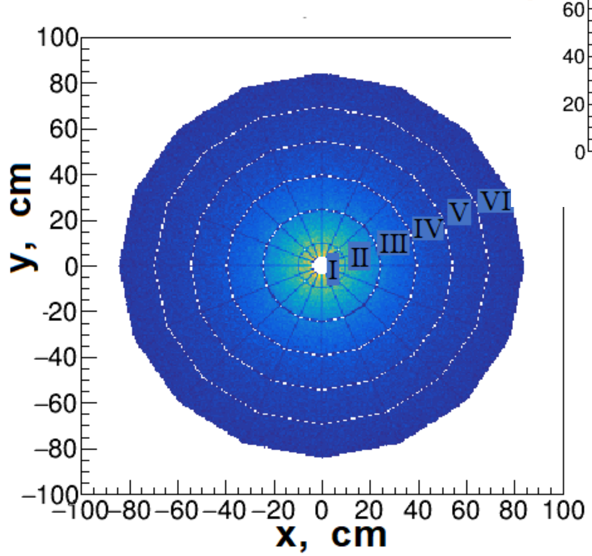




Δφ : *time* – correlation in dependence of the BBC layer

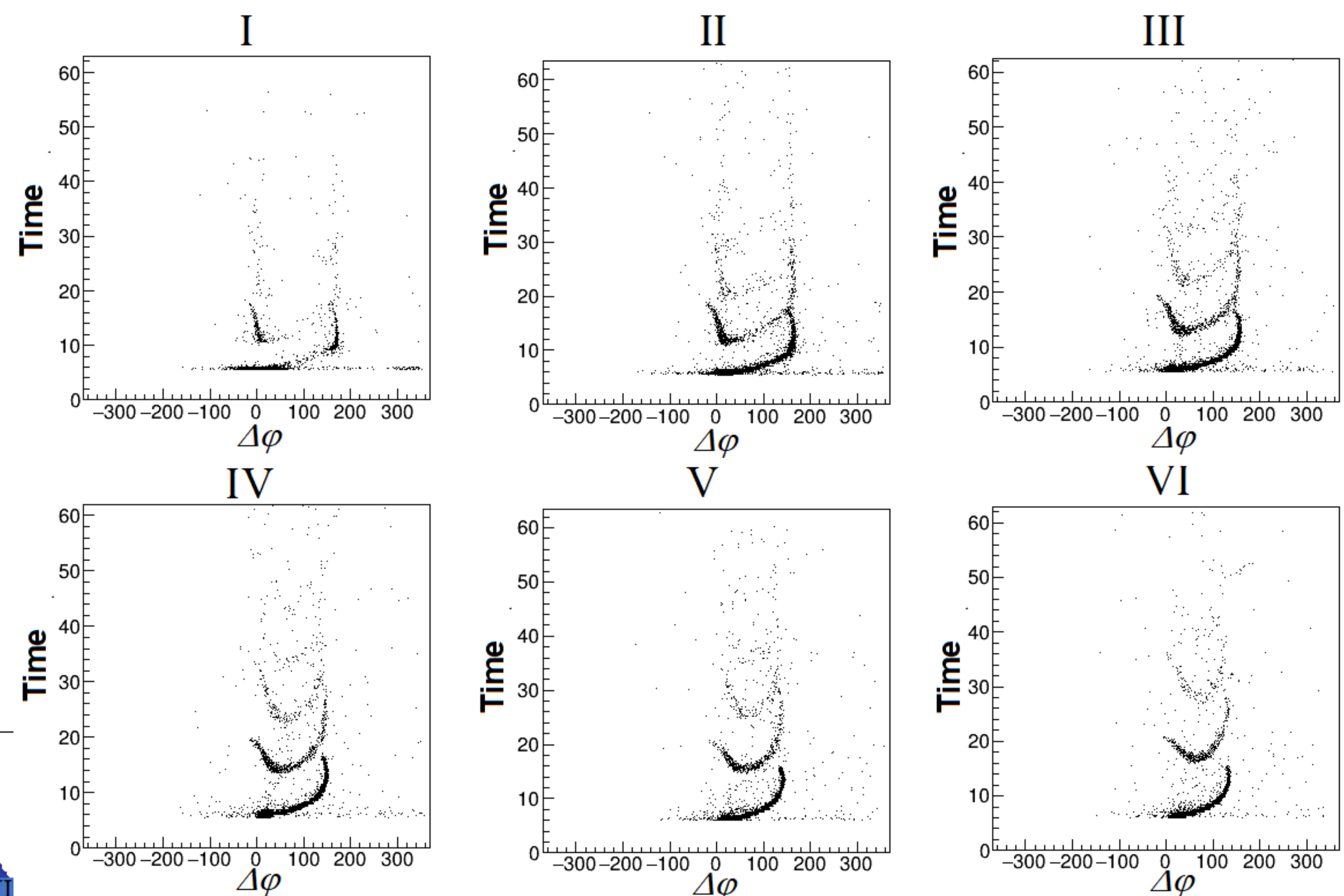
For protons

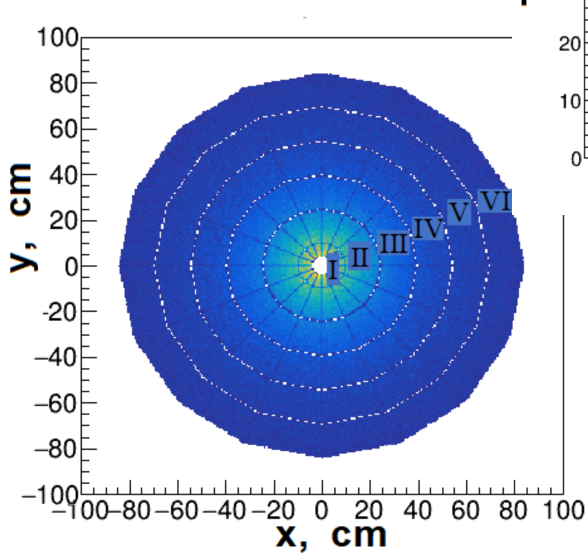




$\Delta\varphi$: *time* – correlation in dependence of the BBC layer

For π^+

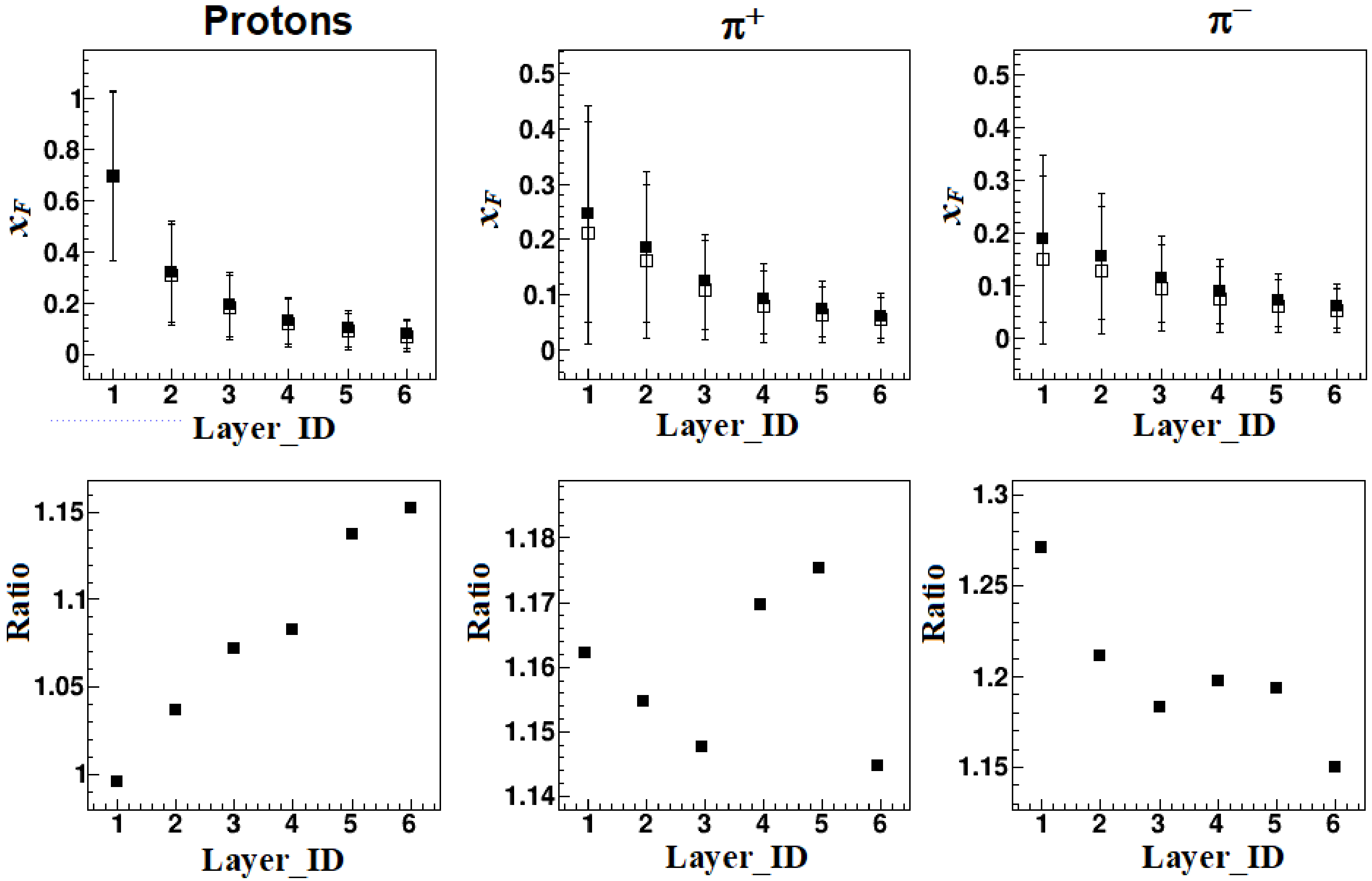




The pions with the p < 0.4 GeV make one or more rotations.

x_F as a function from the BBC layer

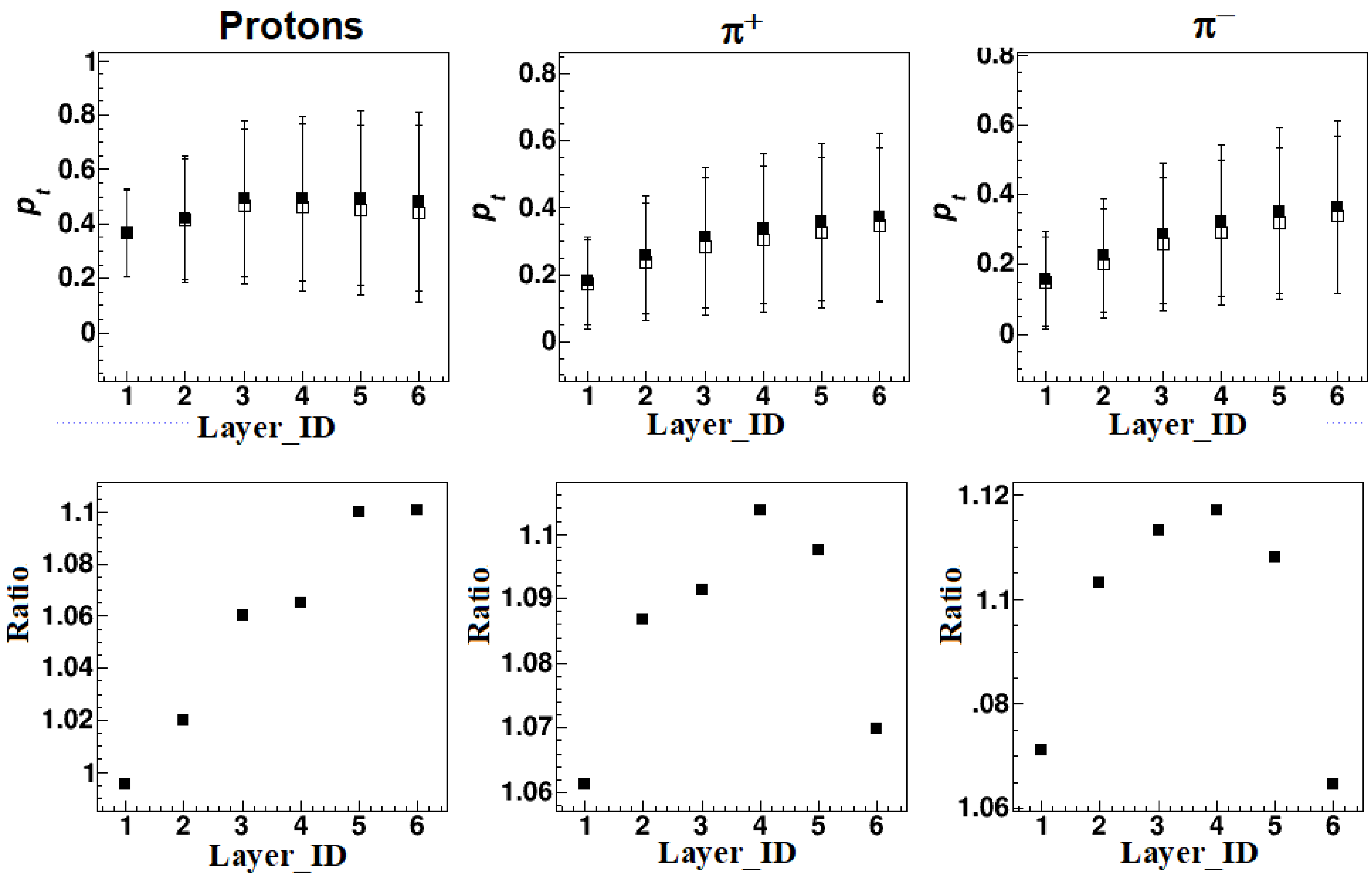
$\sqrt{s}$ = 27 GeV. Open symbols: $\boldsymbol{B}$ = 1T, Solid symbols: $\boldsymbol{B}$ = 0. Ratio = x_F (B=0) / x_F (B=1T)



The presence of the magnetic field leads to a change of the x_F up to 20%.

p_t as a function from the BBC layer

$\sqrt{s}$ = 27 GeV. Open symbols: $\boldsymbol{B}$ = 1T, Solid symbols: $\boldsymbol{B}$ = 0. Ratio = p_t (B=0) / p_t (B=1T)

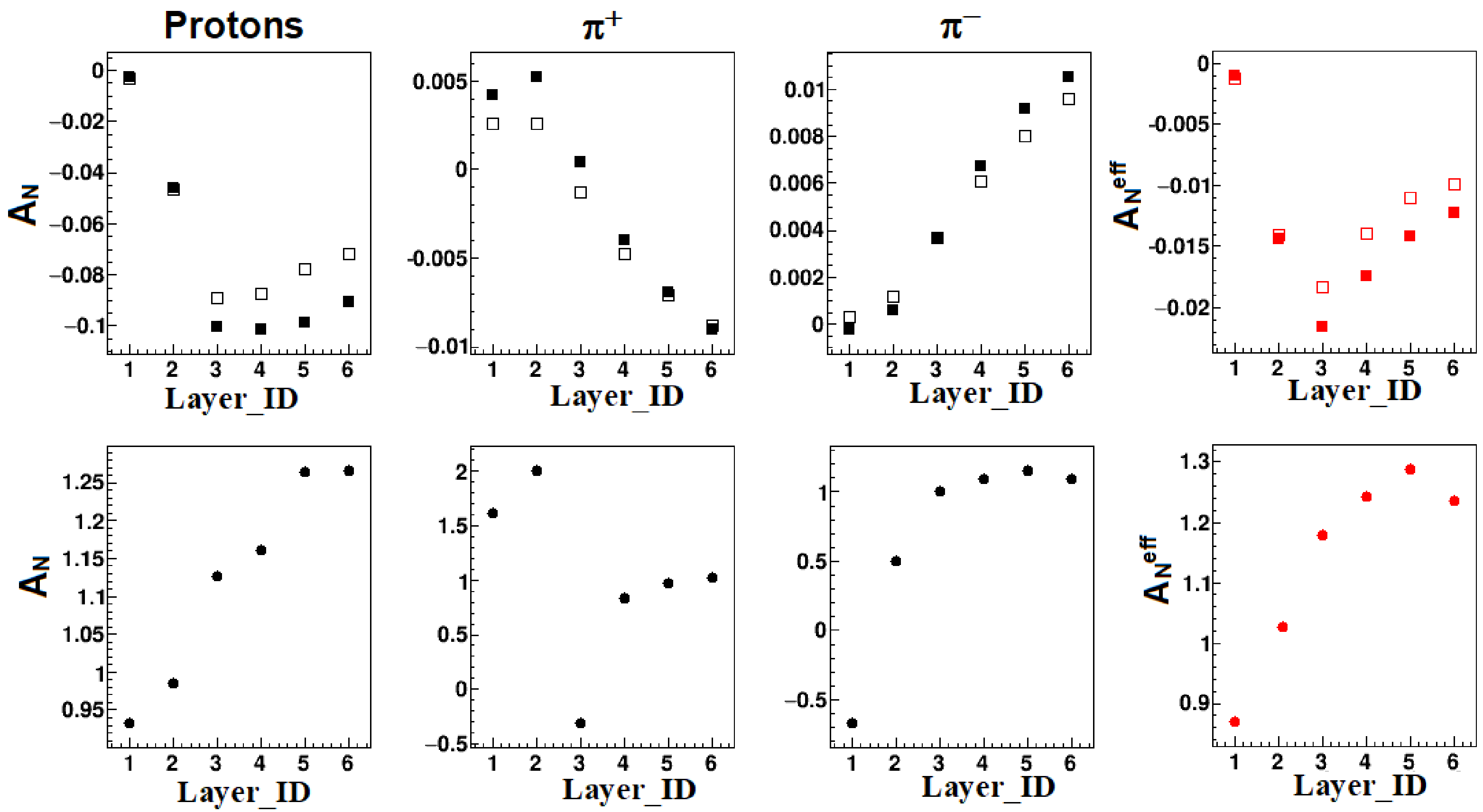


The presence of the magnetic field leads to a change of the p_t up to 10%.

A_N as a function from the BBC layer

$\sqrt{s} = 27$ GeV. Open symbols: $\boldsymbol{B} = 1$T, Solid symbols: $\boldsymbol{B} = 0$.

The analyzing powers A_N have been calculated by the Abramov V. V. for inclusive reaction within the framework of the phenomenological model for chromomagnetic polarization of quarks (CPQ).



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

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

The presence of the magnetic field leads to a change of the A_N^{eff} up to 22%.

Toy simulation model

- So, apart from affecting BBC load, the magnetic field is rotating tracks. The rotation angle, when particles reaches BBC depends, on its momentum and charge. So the "visible" asymmetry in BBC can be different from the true one. We don't have generators at hand, so weighting method can be used.

- For clear results a significant number of events is required. A toy MC of 500M MB events generated with Pythia8 for collisions energies $\sqrt{s} = 27$ is studied (this study can be easily repeated once production data are available).

- Analytical track parameterization is extrapolated to Z_{BBC} (1T magnetic field is assumed). Only tracks in the BBC acceptance region are considered

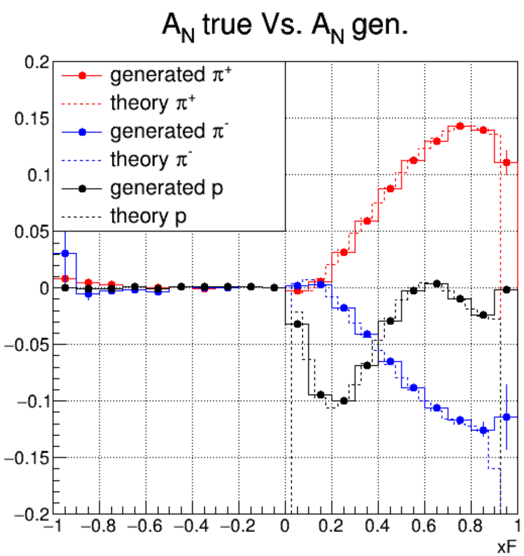
- Individual track weighting: $w = 1 + A_N(x_F, p_T)*\cos(\phi)$, charged pion and proton tracks are weighted (taking into account only slightly affects the results).

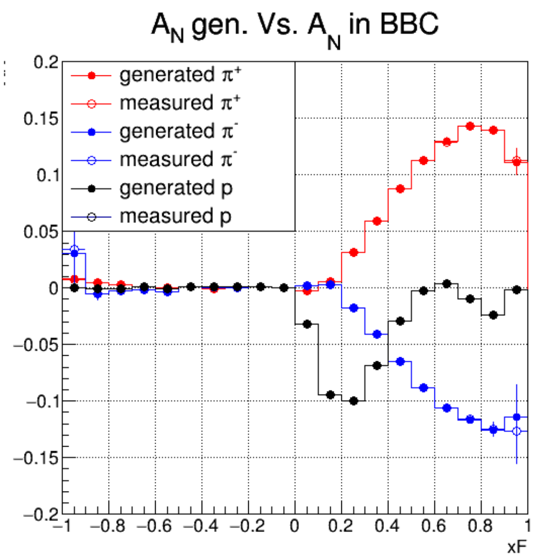
- The CPQ model predictions for $A_N(x_F, p_T)$ kindly provided by V. Abramov for 27 GeV are used (dependence on both variables is crucial).

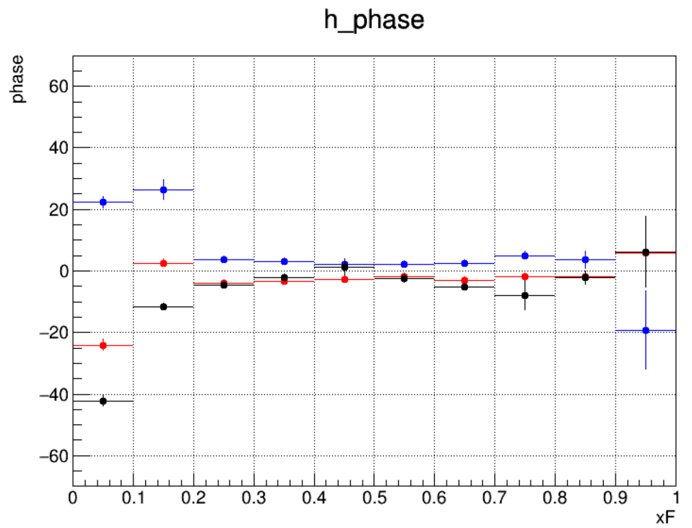
- More details can be found in the talk by I. Denisenko at SPD Physics & MC Meeting 17.04.24

Weighting results (x_F-dependence)

- The left figure shows a comparison of the model to weighted data (π^+, π^- p).
- The middle plot shows comparison of A_N value at generation stage to visible asymmetry at BBC. No notable differences are seen.
- The figure on the right shows phase shift. A notable phase shift is seen (up to 40 degrees) which depends on the particle type.



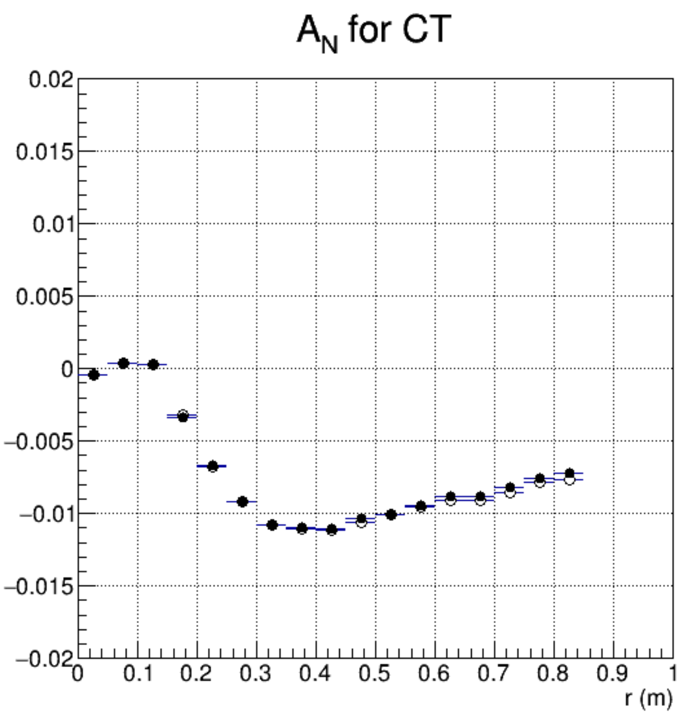




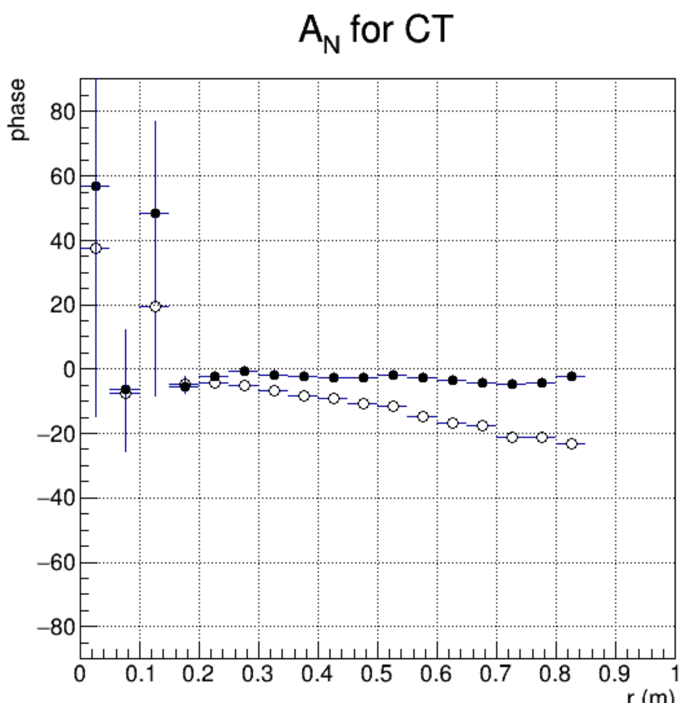
Weighting results (x_F-dependence)

The slide shows the r-dependence of the total asymmetry (bins do not corresponds to BBC tile geometry).

- Left plot shows value without magnetic field (solid markers) and with the case of field. There a strong dependence on r, which strongly depends on the weighting model and asymmetries at low x_F-bins. The A_N only slightly affected by field.
- The right plot shows dependence of the phase shift, which can be up to 20 degrees.



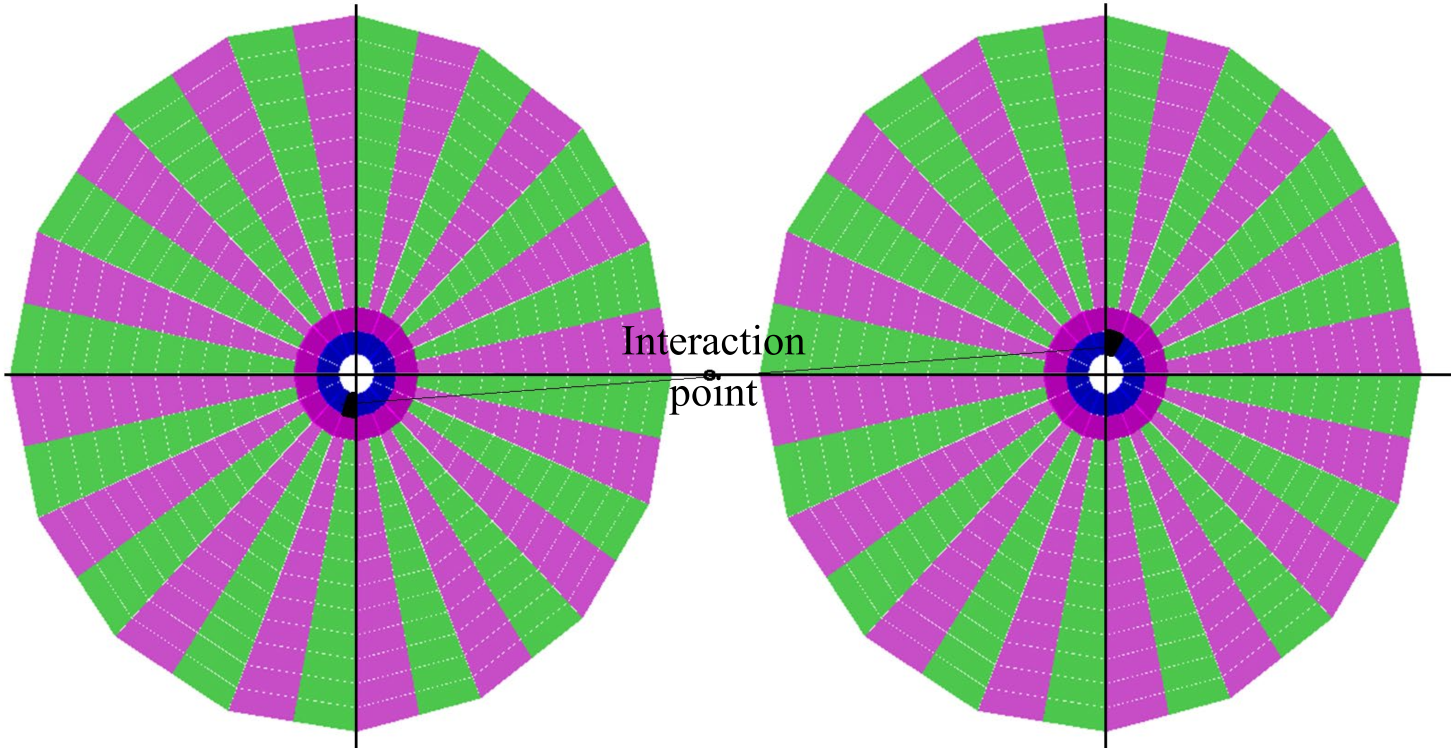
No mgnetic field A_N (solid markers) Vs. “observed” (open markers)



No magnetic field A_N phase (solid markers) Vs. “observed” (open markers)

PP – elastic scattering selection

The comparison of the proton and pion analyzing powers A_N shows, that the main account in the behavior of A^{eff}_N gives 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. It may to do by using the time information for each hit in the kinematically corresponding tiles. The two corresponding tile of the BBC first layers have been selected for example. The times of all hits in each BBC for each events were written. After this the time difference of the hits, which are present simultaneously in the both BBC was performed.



PP – elastic scattering selection

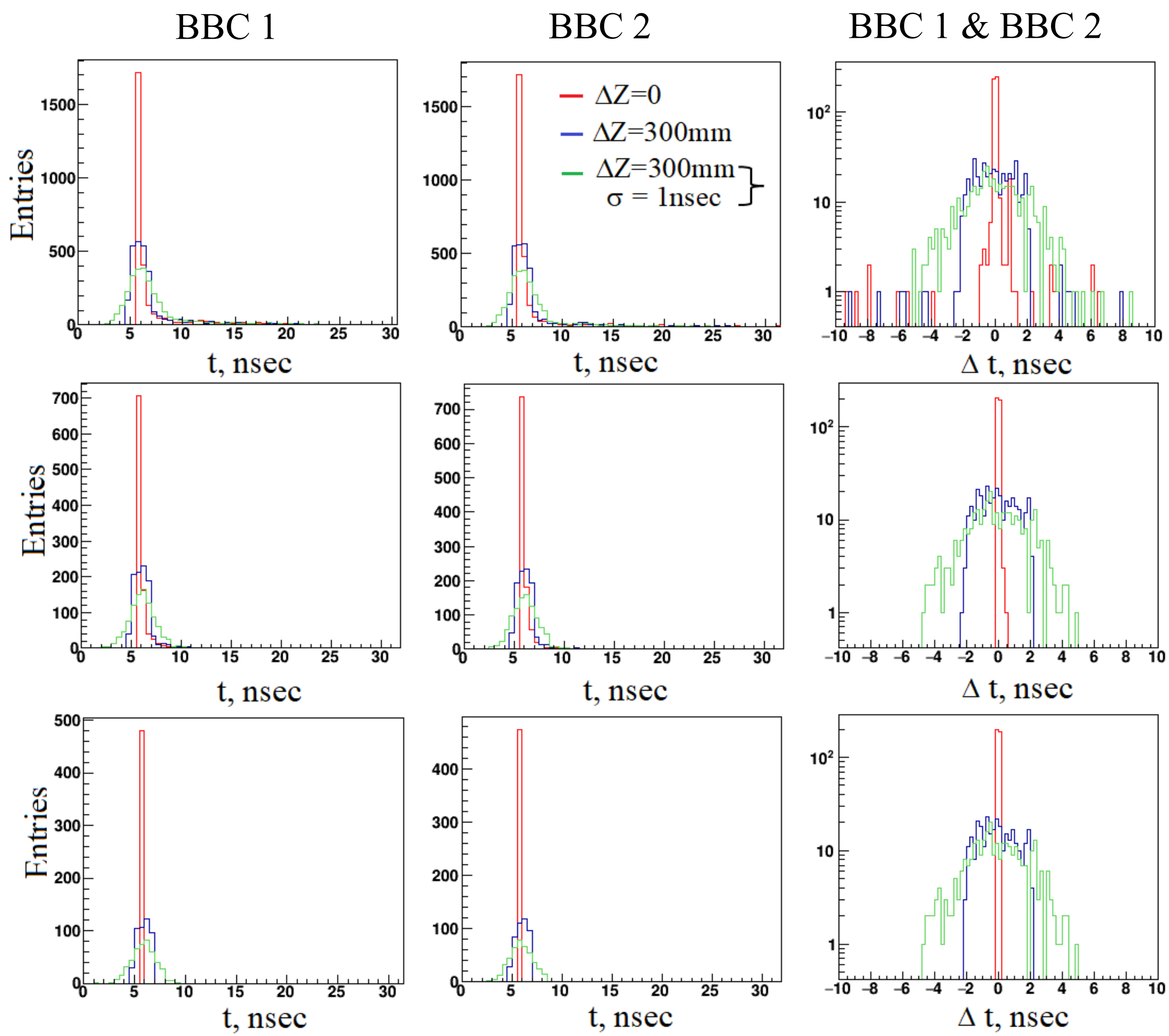
The use of the additional criteria on the particles type and momentum value allows to background decrease and to select of the elastic protons.

Protons and background particles

Protons only

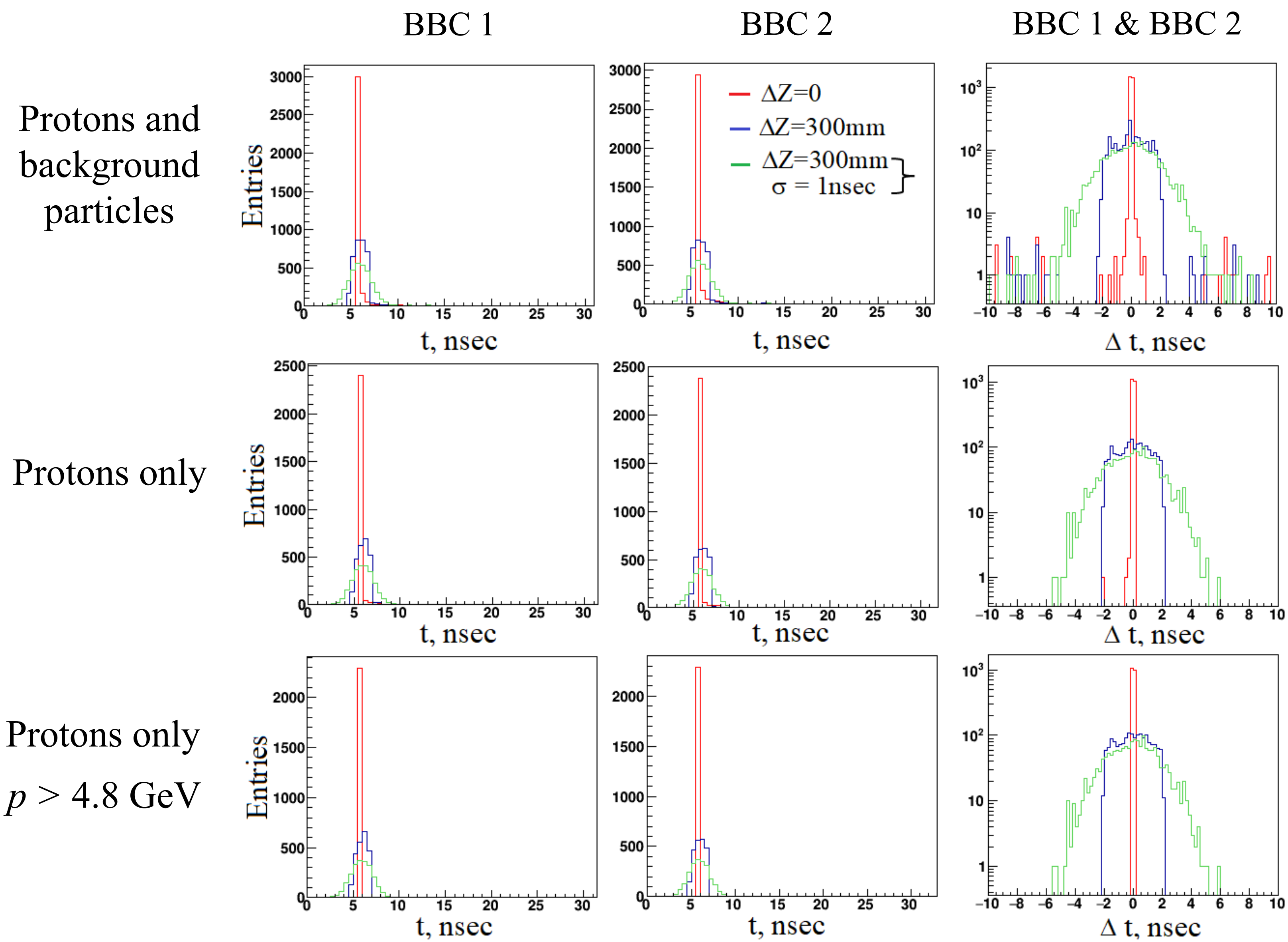
Protons only

$p > 4.8$ GeV



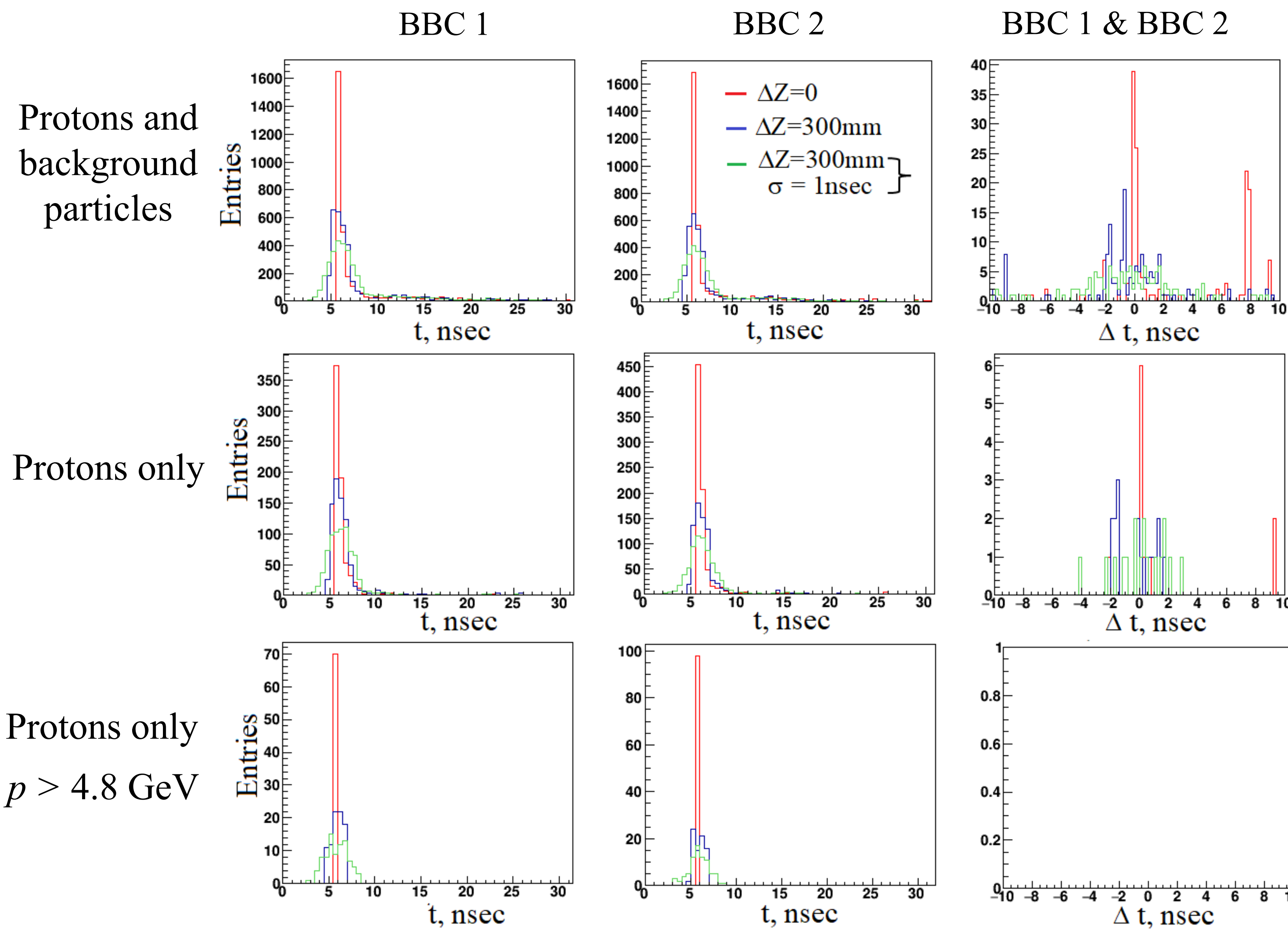
PP – elastic scattering selection

Also the simulation only of the pp-elastic scattering at 10 GeV have been performed to compare with the tease results.



PP – elastic scattering selection

Also the simulation of the pp-scattering at 10 GeV have been performed with out the pp-elastic scattering channel.



Conclusion

- The influence of the magnetic field on the BBC load has been estimated. It presence increases the BBC load. This is especially observed for π^+, and π^-. For protons the influence of the magnetic field is observed in the range of the big radiuses. BBC load increase is due to the capture of the particles for which the $\theta > 27^o$ and $p < 0.4$ GeV by the magnetic field.
- 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 momentum $p < 0.4$ GeV (for pions).
- The time information can be used to cut the very slow particles (for which the phase $\Delta\varphi > 360^o$).
- 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%.
- Toy MC analysis for BBC in magnetic field have been performed. Track-wise weighting seem to be preferable.
- 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!