Study of the detection of Λ ($\bar{\Lambda}$)-hyperons in the SPD

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On behalf of the SPD Collaboration

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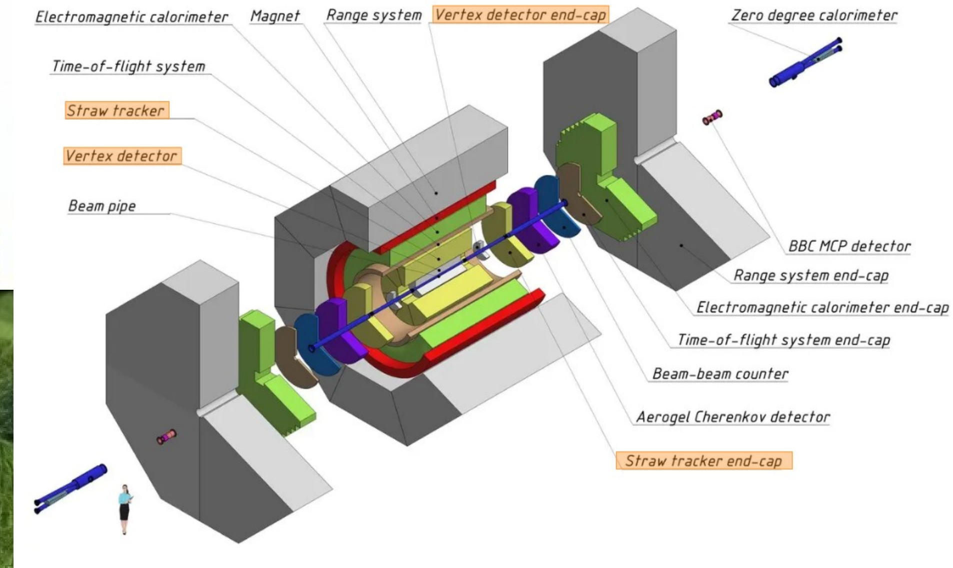
Polarized beams

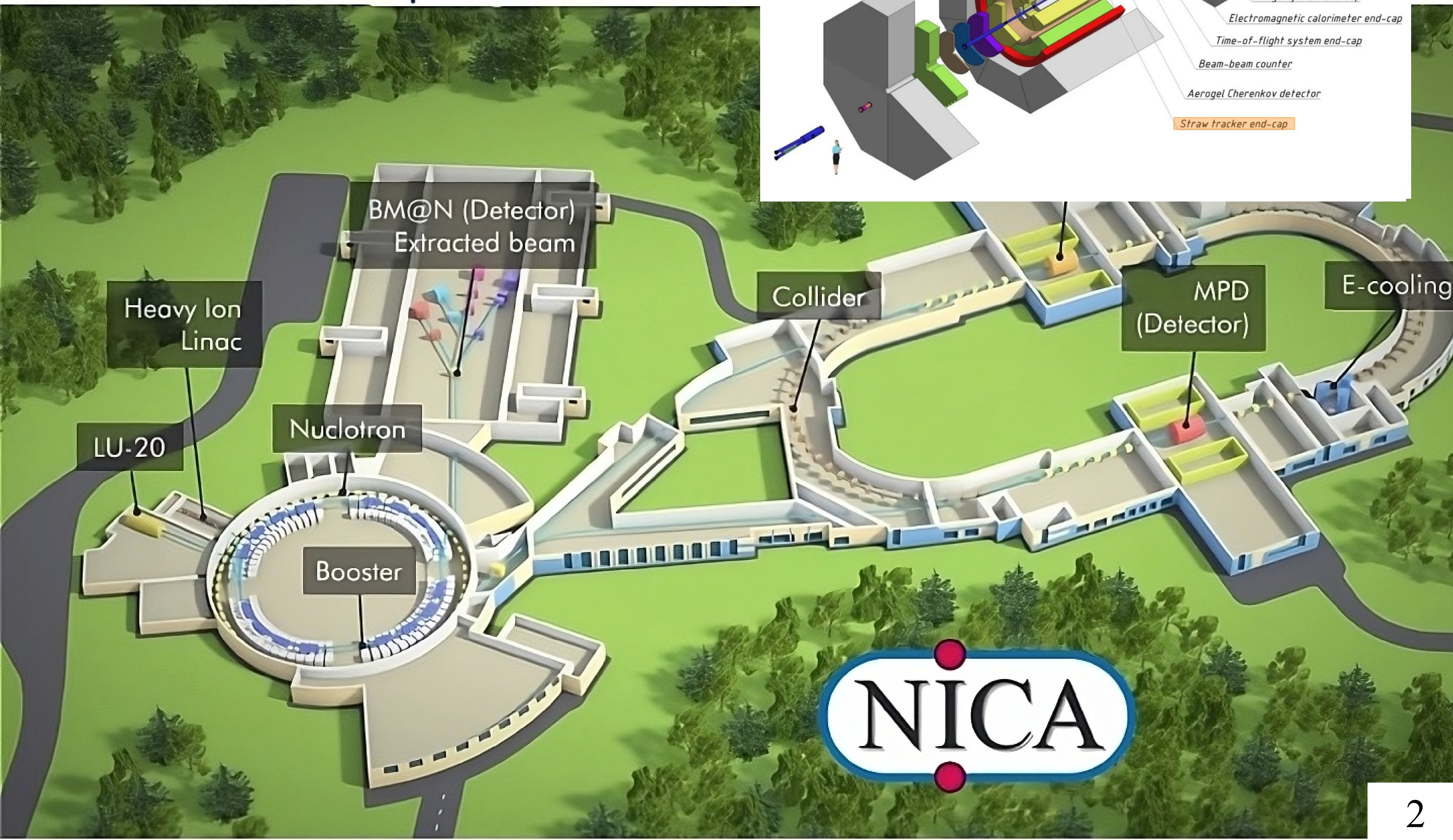
$p\uparrow p\uparrow$ at $\sqrt{s_{pp}} \leq 27$ GeV, $L_{av} \approx 10^{32}$ cm^{-2}s^{-1}

$d\uparrow d\uparrow$ at $\sqrt{s_{NN}} \leq 13.5$ GeV

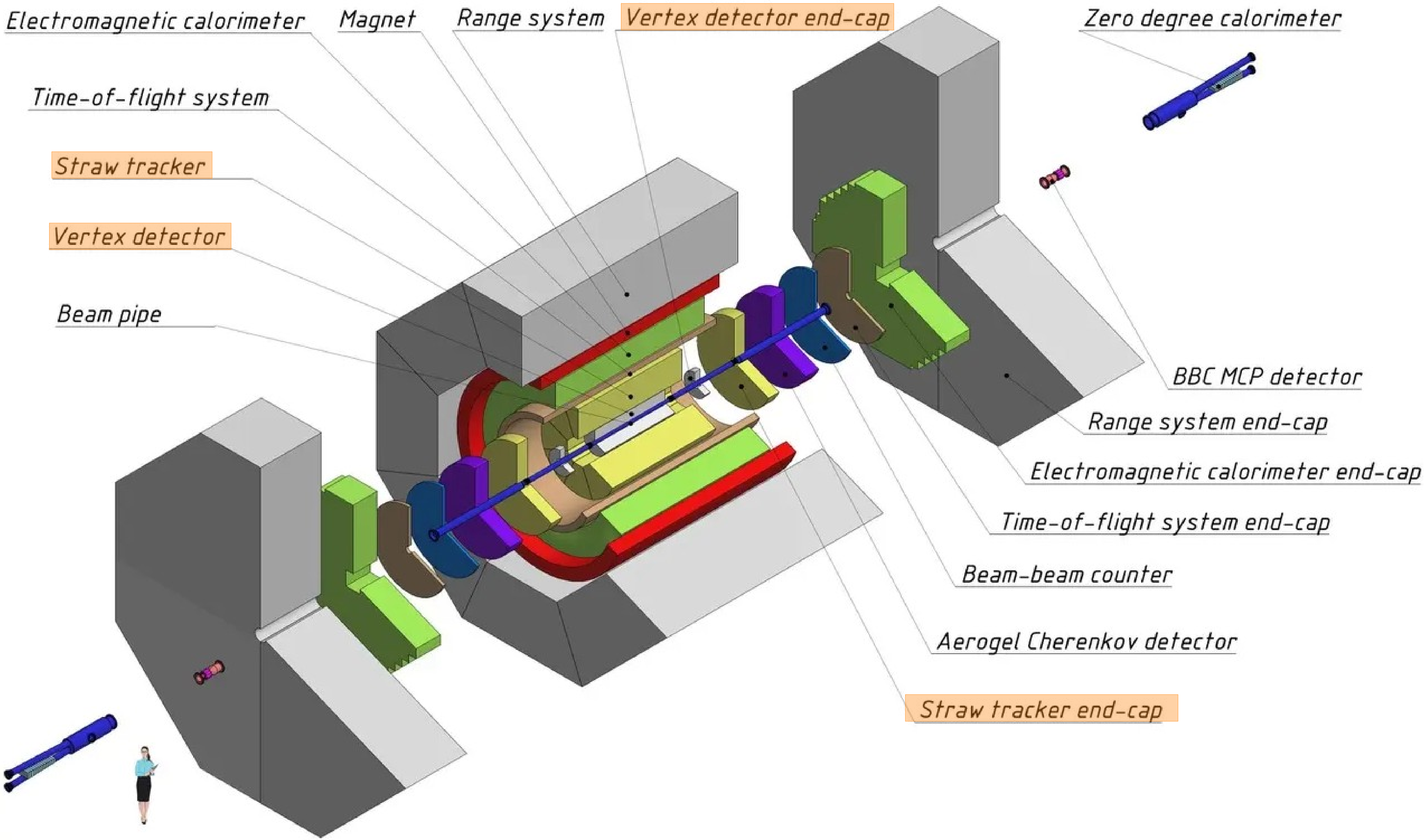
Operation: after **2028**

Spin Physics Detector (SPD)





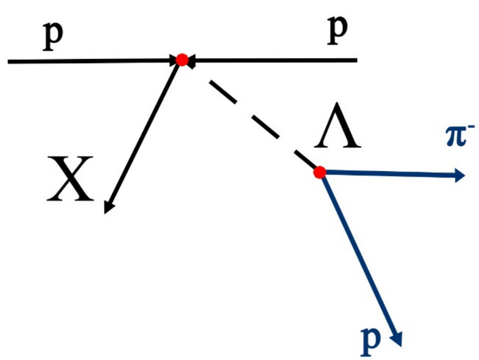
Spin Physics Detector

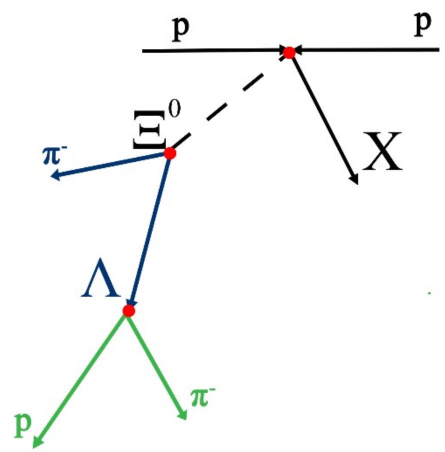


Λ-hyperon

The elementary particle Λ-hyperon is a hadron with strangeness S = -1, with quark composition uds, the lightest of the strange baryons.

It can be born either directly from hadron collisions or from the decay of heavier hyperons.





Mass 1115.693 ± 0.006 MeV, average life time $(2.632 \pm 0.02)*10^{-10}$ c.

The main modes of decay (π^-, p) and (π^0, n)

with probabilities (63.9 ± 0.5)% and (35.8 ± 0.5)%.

Λ-hyperon is a well-studied particle that can preserve the polarization of the original quarks in polarized collisions $p^\uparrow + p = X + \Lambda^\uparrow$. Particle also has spontaneous polarization $p + p = X + \Lambda^\uparrow$.

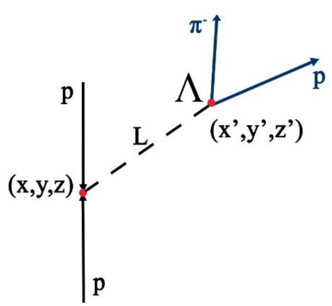
Simulation of events in the SPD

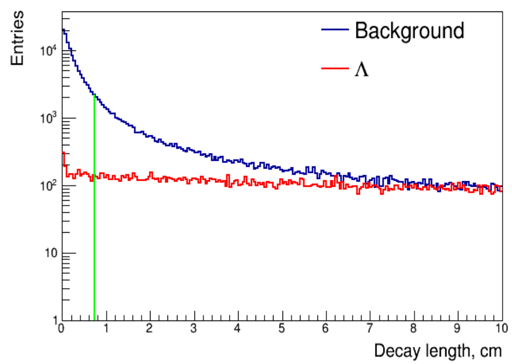
- PYTHIA8 used for generation of 4 mil. *pp* collisions with $\sqrt{s} = 27$ GeV;
- SpdRoot – program package that is used for simulation and analysis. Package has the geometry of SPD built in it and uses Geant4 toolkit to calculate particle interaction with the detector material;
- KFParticle – Kalman filter based package is designed to search and reconstruct short-lived particles by their decay products.

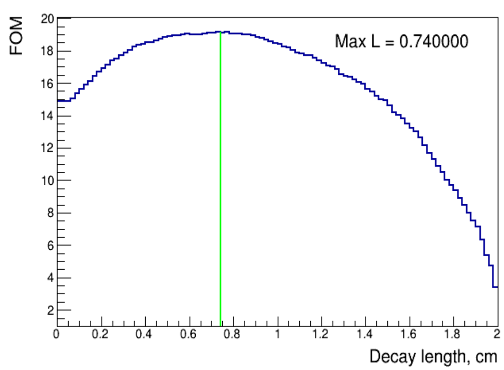
Analysis of optimal selection criteria

- Tracks with good approximation were selected (by χ^2/ndf value)

- Run length before decay, L

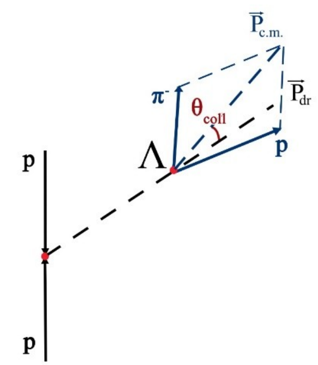


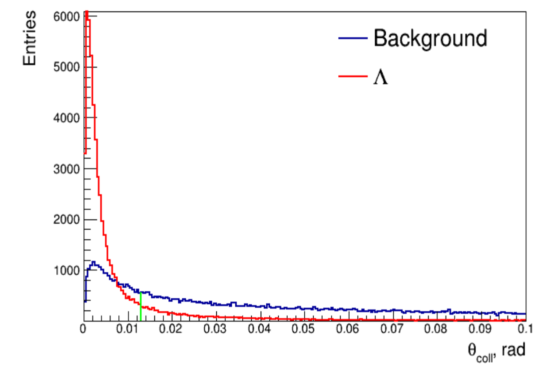


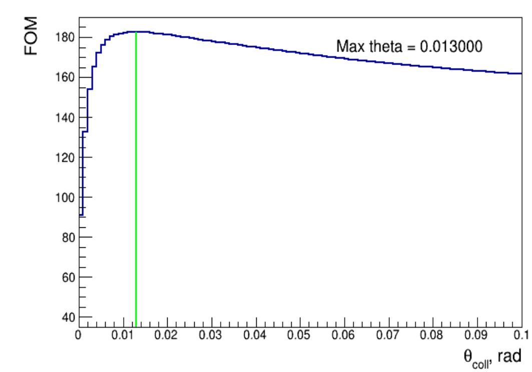


$$FOM = \frac{S}{\sqrt{(S+B)}}$$

- Colliniarity angle, θ_{coll}

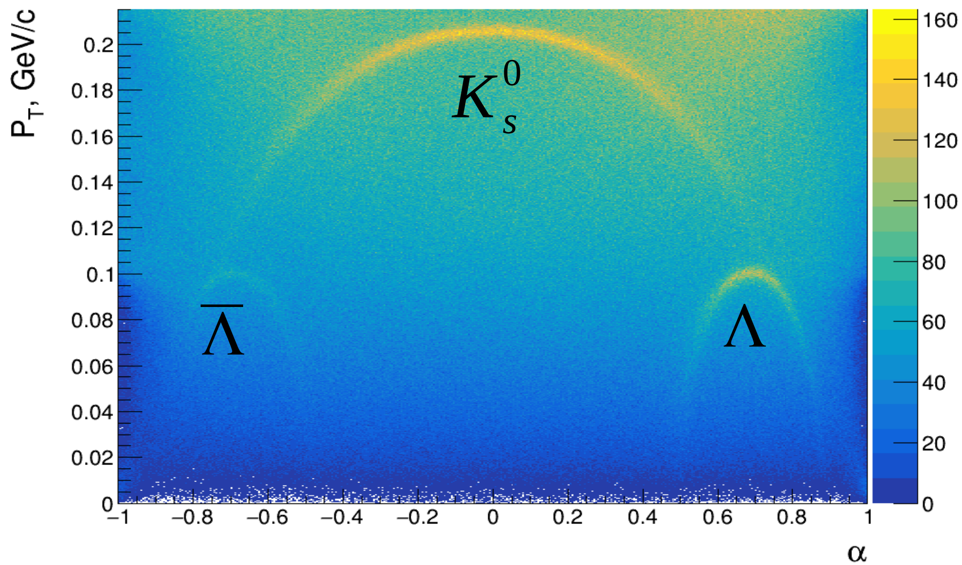


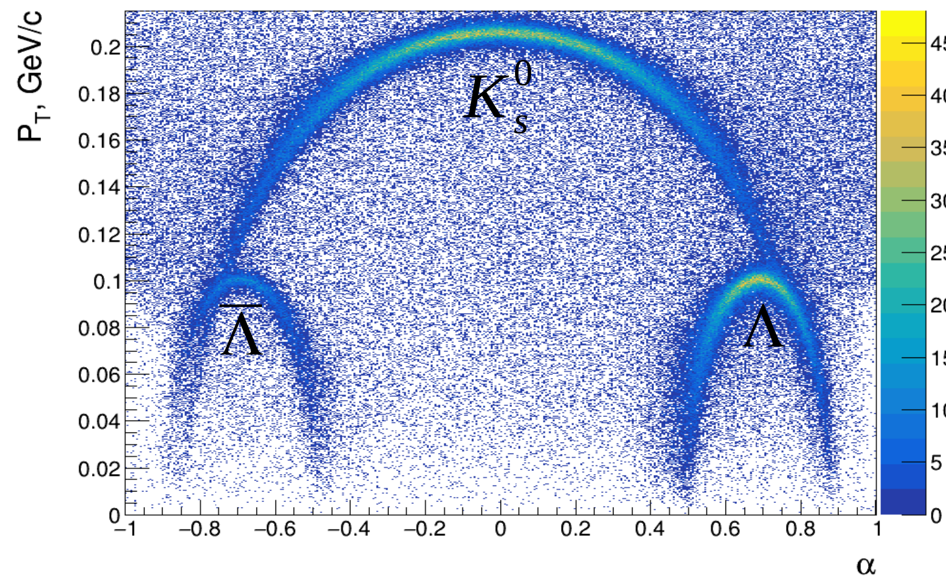


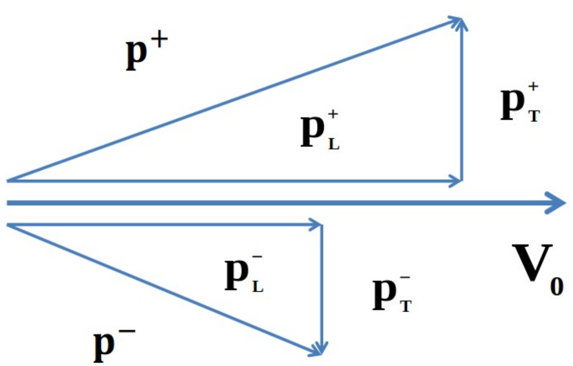


$$FOM = \frac{S}{\sqrt{(S+B)}}$$

Podolanski-Armenteros distribution



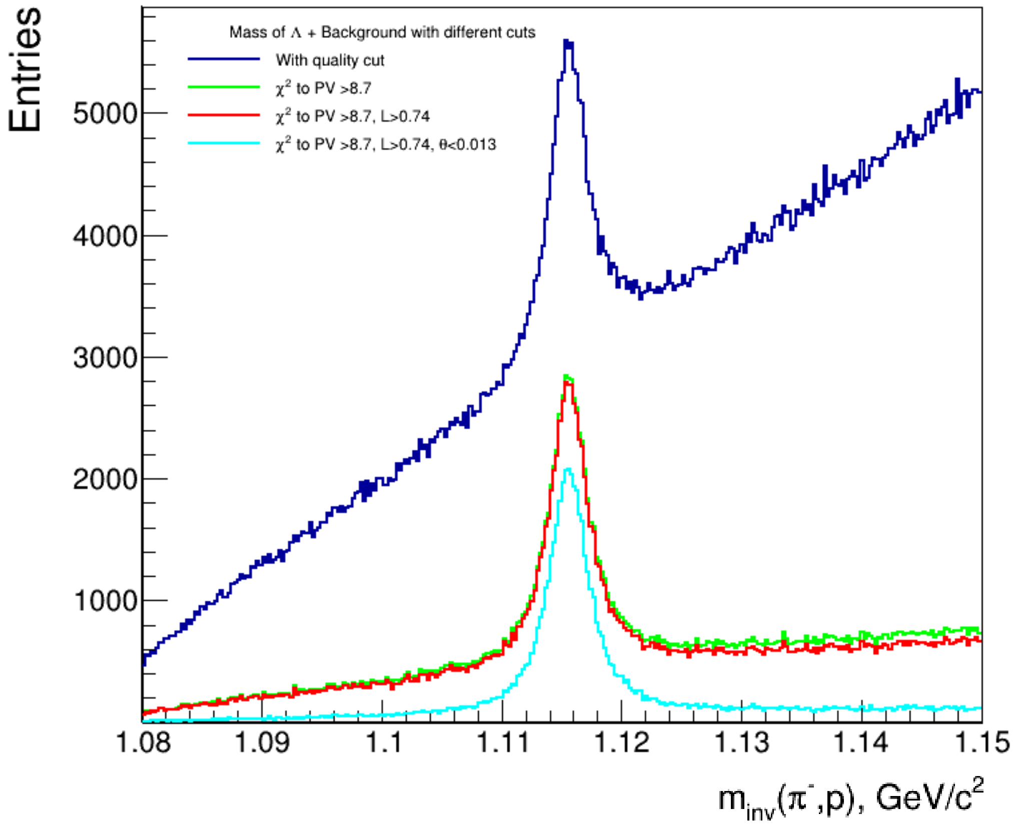




$$\alpha = \frac{p_L^+ - p_L^-}{p_L^+ + p_L^-}$$

p_L^+ and p_L^- are the longitudial momenta of the positive and negative decay particle respectively

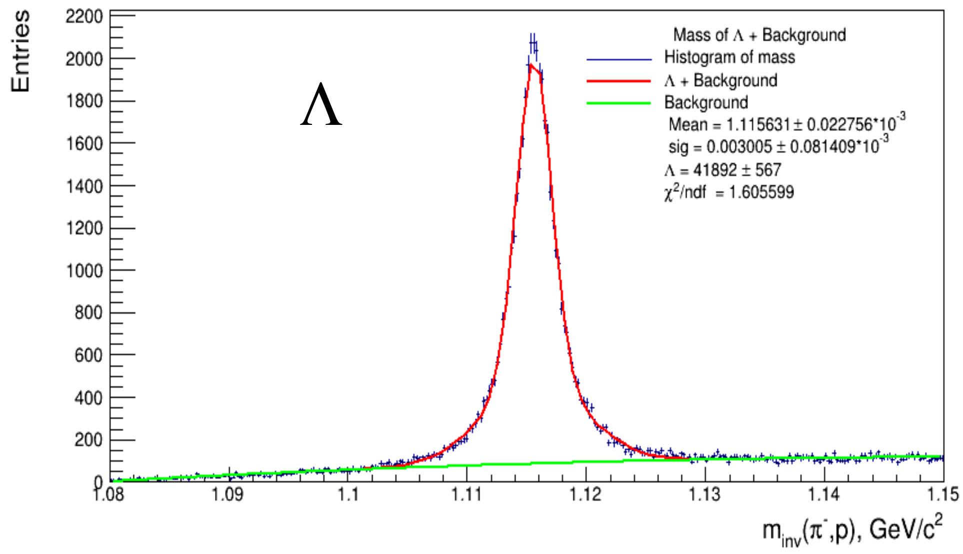
Invariant Mass of Λ ($\bar{\Lambda}$) with different cuts



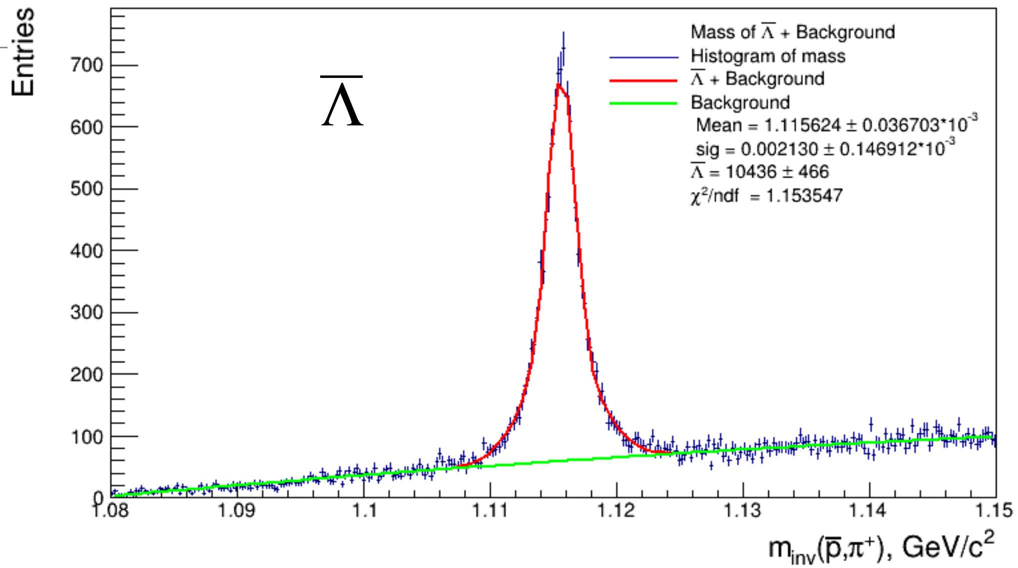
Cuts	Λ	Background	FOM
1	58898	224989	110
2	50768	37845	170
3	50538	34320	173
4	43216	5278	196

Cuts	$\bar{\Lambda}$	Background	FOM
1	14370	108381	41
2	12781	17480	73.4
3	12697	16031	74.9
4	10223	2527	90

Invariant mass of (π^-, p) and ($\bar{p}$, π^+)



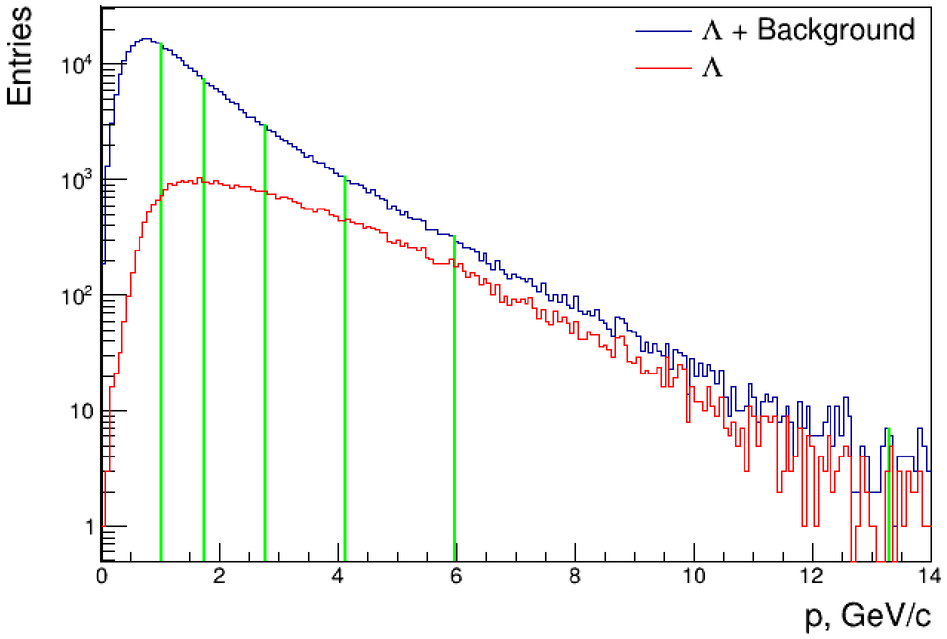
N = 41892 ± 567

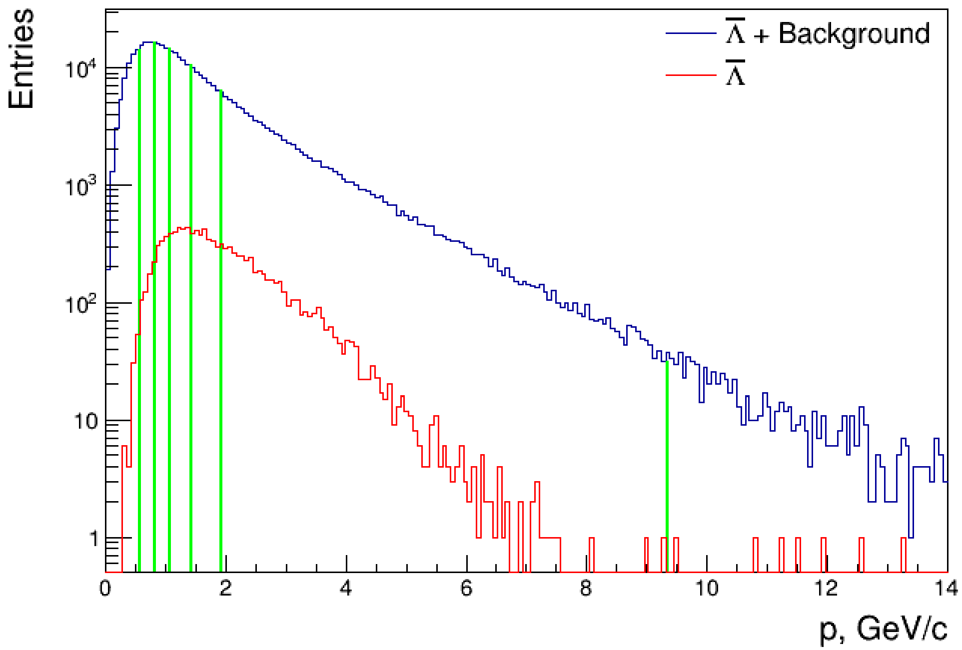


N = 10436 ± 466

For data approximation a combination of the following functions of double Gaussian (signal) and third order polynomial (background) were used

Binning for Λ ($\bar{\Lambda}$) by p

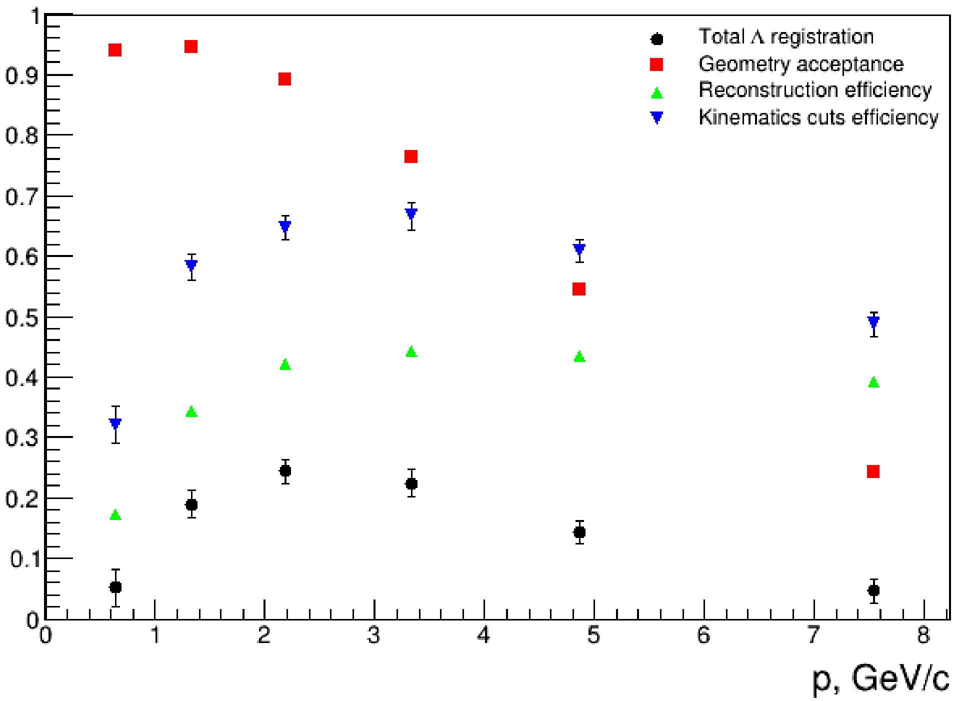




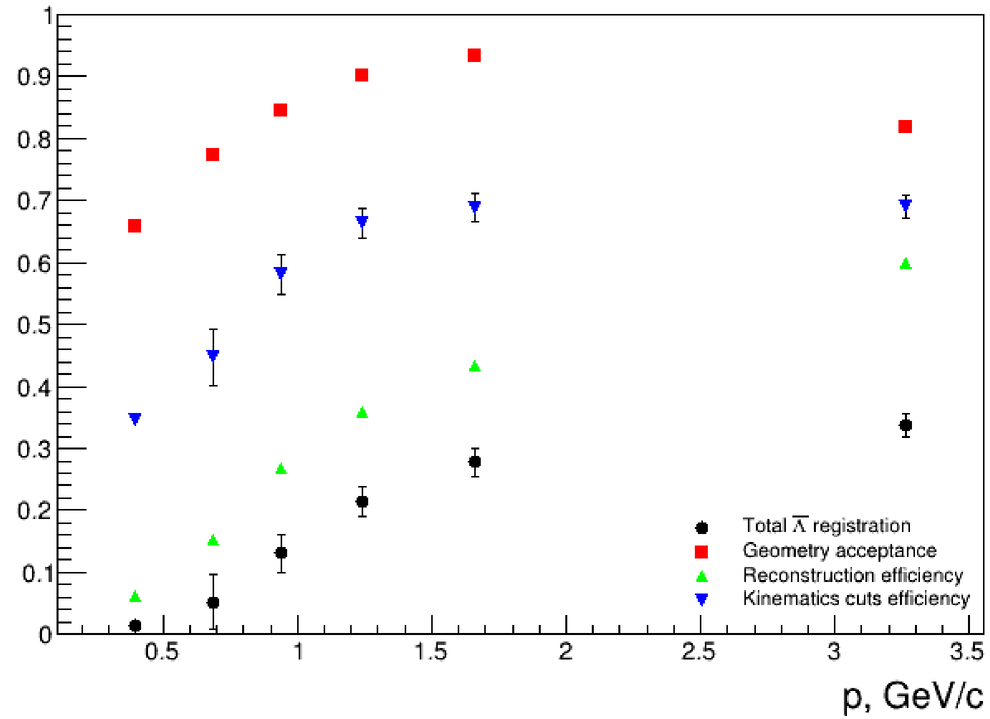
Binning was performed by using distribution of p for all generated Lambda.
Each bin has an approximately equal number of generated Lambda.

Reconstruction Efficiency as a function of p

Λ



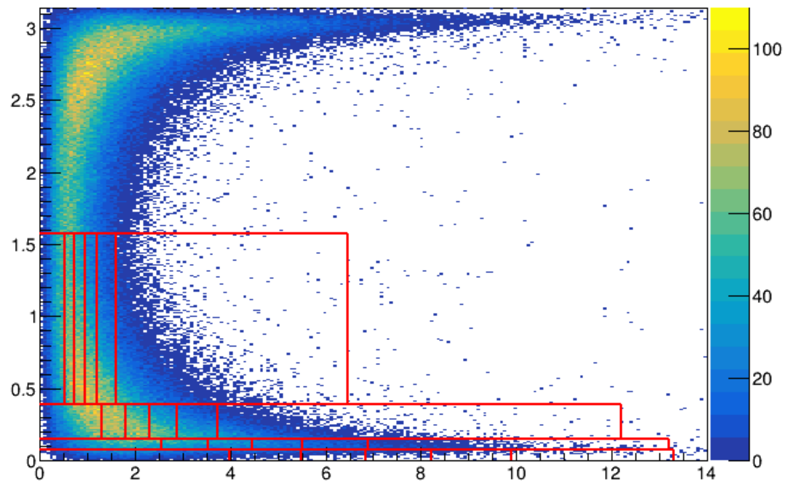
$\bar{\Lambda}$



$$C_{total} = \frac{N_{rec}}{N_{true}} = C_{Geo} * C_{Rec\,tr} * C_{Kin}$$

$$C_{Geo} = \frac{N_{3\,hits}}{N_{true}} \qquad C_{Rec\,tr} = \frac{N_{tr\,quality}}{N_{3\,hits}} \qquad C_{Kin} = \frac{N_{rec}}{N_{tr\,quality}}$$

Reconstruction Efficiency as a function of (p,θ) for the Λ-hyperon



$$C_{total} = \frac{N_{rec}}{N_{true}} = C_{Geo} * C_{Rec\,tr} * C_{Kin}$$

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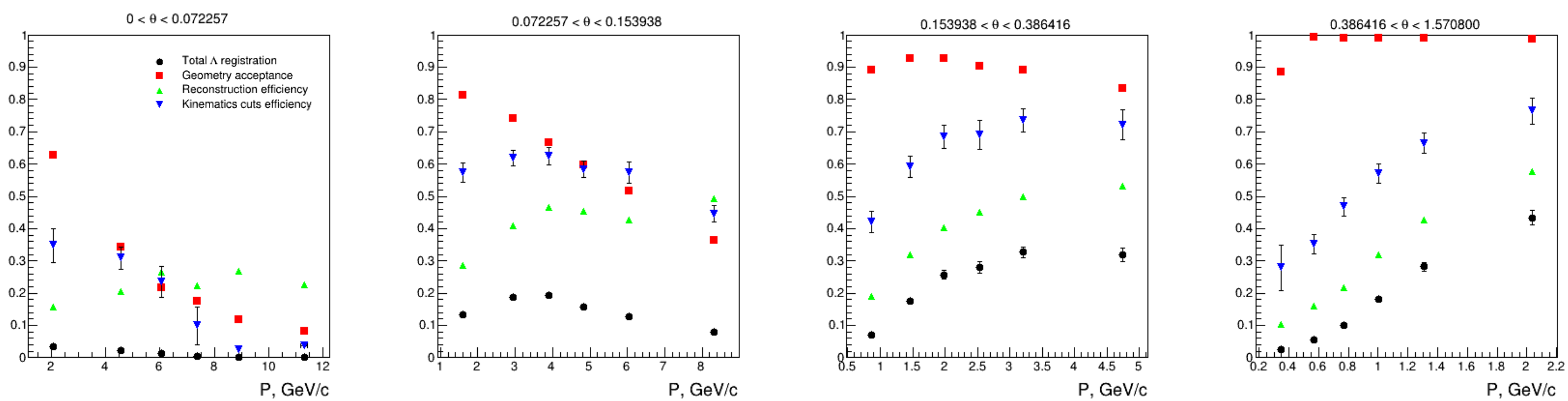

Conclusion

- Optimal selection criteria for lambda and anti-lambda hyperons are determined: decay length >0.74, collinearity angle < 0.013, χ^2 for track extrapolation to primary vertex > 8.7;
- Reconstruction efficiency of lambda and anti-lambda hyperons as a function of momentum is calculated: expected efficiency of lambda reconstruction ≈ 20% and efficiency of anti-lambda ≈ 25%;
- Reconstruction efficiency of lambda hyperon as a function of (p,θ) is calculated: expected efficiency of lambda reconstruction with high polar angle is up to 40%.

Thank you for your attention!