Λ_c^+ observation possibility at SPD NICA experiment

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Motivation

An open charm production in proton-proton collisions at medium and low energy allows to study in detail heavy quark hadronization processes, as well as to better understand the proton structure.

Events simulation

Signal

- ~ 12000 events have been generated within the Pythia8 framework using the hard subprocesses $gg \to c\bar{c}$ and $q\bar{q} \to c\bar{c}$
- The events with Λ_c^+ has been selected
- All Λ_c^+ baryons have been enforced to decay to $p^+K^-\pi^+$ combination
- $\Lambda_c^+ \to (\Delta^{++} \to p^+\pi^+)K^-$ has been temporary used instead of complete decay model due to the technical reasons

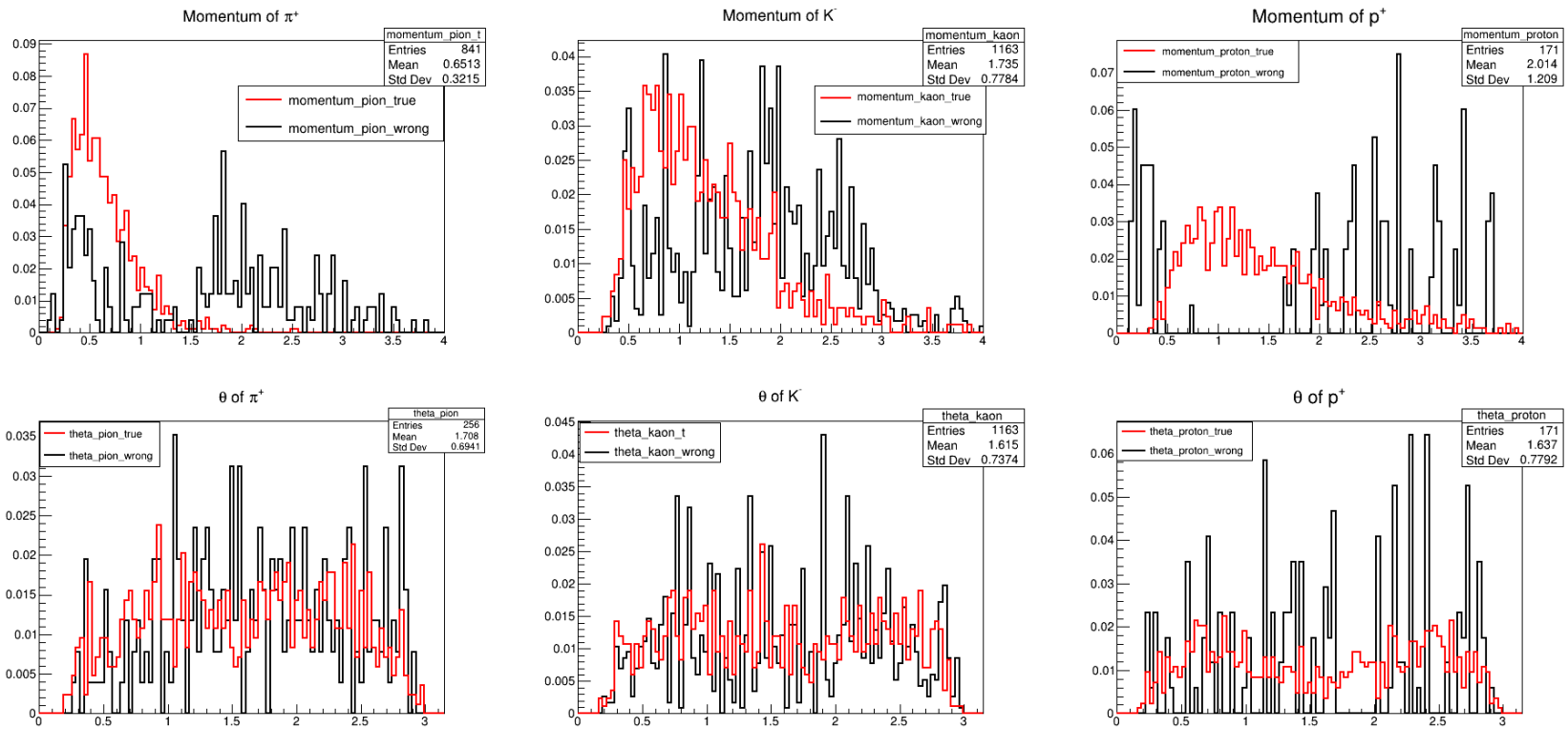
Background

~ 25000 softQCD(MB) events have been simulated within Pythia8 as a background.

Detector simulation

SPDROOT

Kinematical distributions: correct v.s. mistake TOF system output in Λ_c^+ events

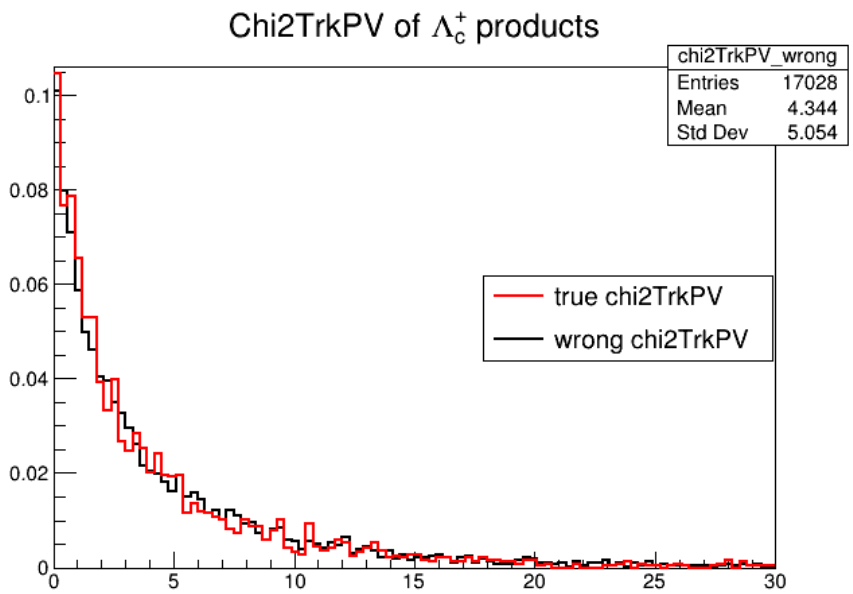


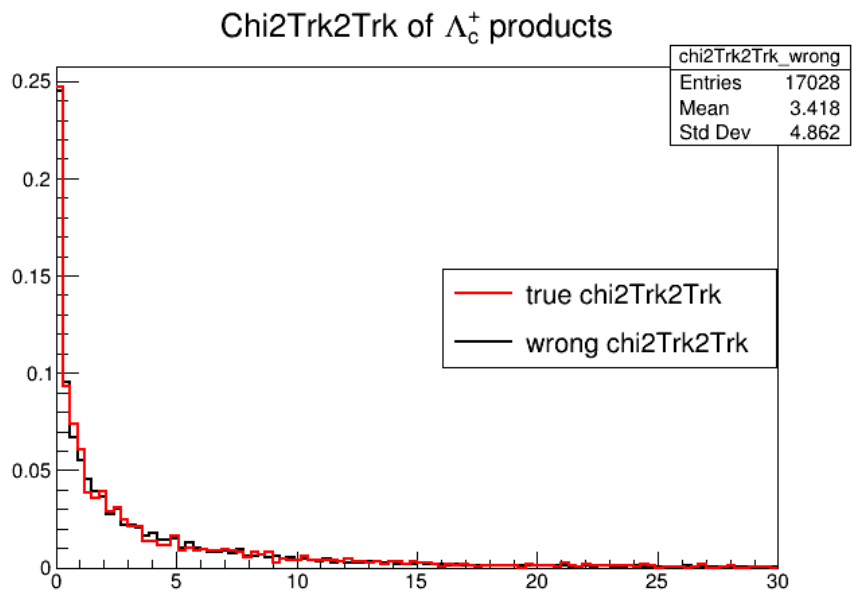
Cuts suggested to reduce combinatorial background due to wrong PID (TOF):

- $0.1 < P_{pion} < 1.5$ GeV;
- $P_{kaon} < 2$ GeV;
- $0.3 < P_{proton} < 2$ GeV;

(more statistics are needed for a more accurate analysis)

χ^2 distribution





χ^2 of SV p^+, K^-, π^+ tracks deviation from PV as well as χ^2 deviation between tracks of SV candidate does not give an effective cut on TOF mistake, despite it still might be effective in MB cut.

Secondary vertex selection

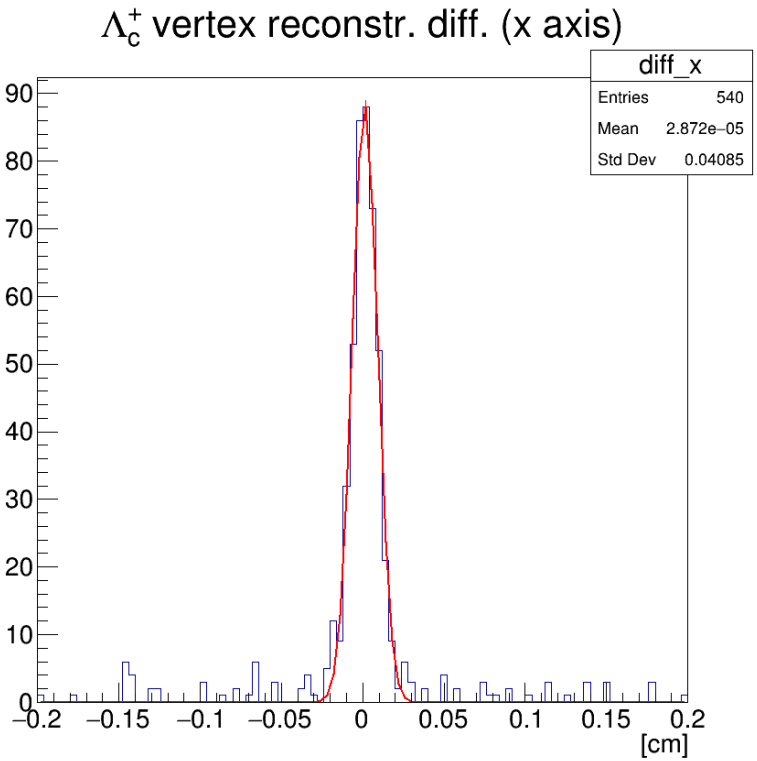
Tracks selection:

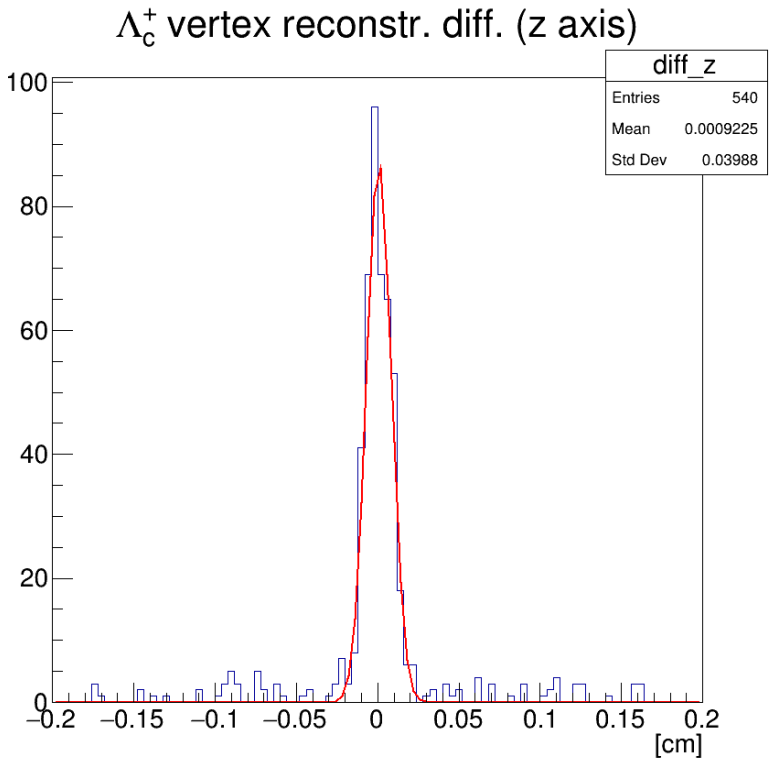
- GetNHitsIts > 3;
- GetIsFitted -> ok;
- GetIsGood -> ok;
- track identification implements by TOF system (divide all particles into pions, kaons and protons);
- pion, kaon and proton are at the same combination;
- $\chi^2_{tr2tr} < 10$;
- $\chi^2_{PV} > 1$ (temporarily).

Also the minimum Λ_c^+ candidate decay length cut has been added:

- $L > 0.008$ cm.

Decay length cut motivation (I)

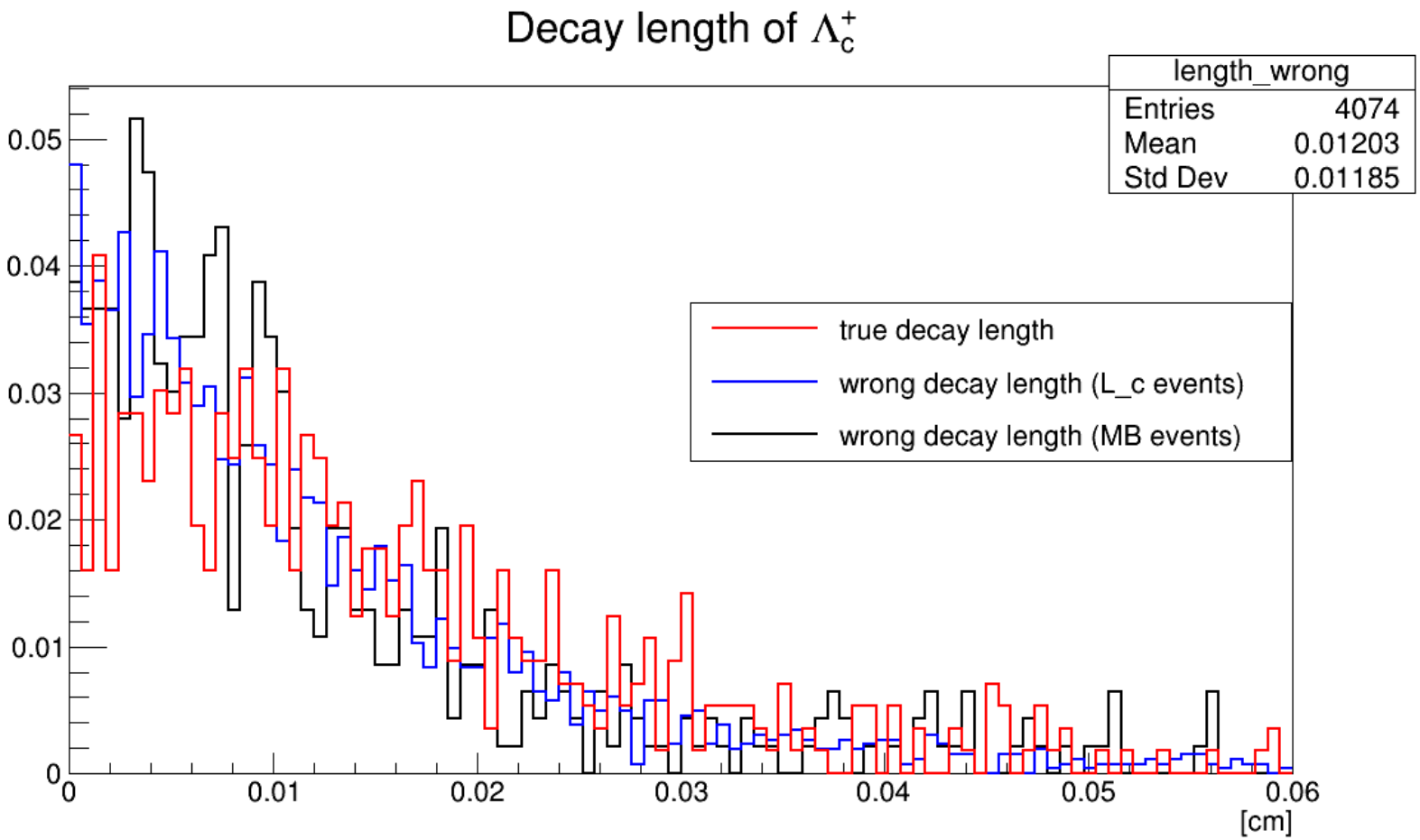




Gauss fit of the deviation of SV position(rec) and daughter particles starting track points:

- $\sigma_x = (7.8076 \pm 0.3172)^{-3}$cm;
- $\sigma_z = (7.6264 \pm 0.2849)^{-3}$cm.

Decay length cut motivation (II)



With decay length cut L $>$ 0.008 cm the ratio of reduced background exceeds the same for signal.

Data scaling

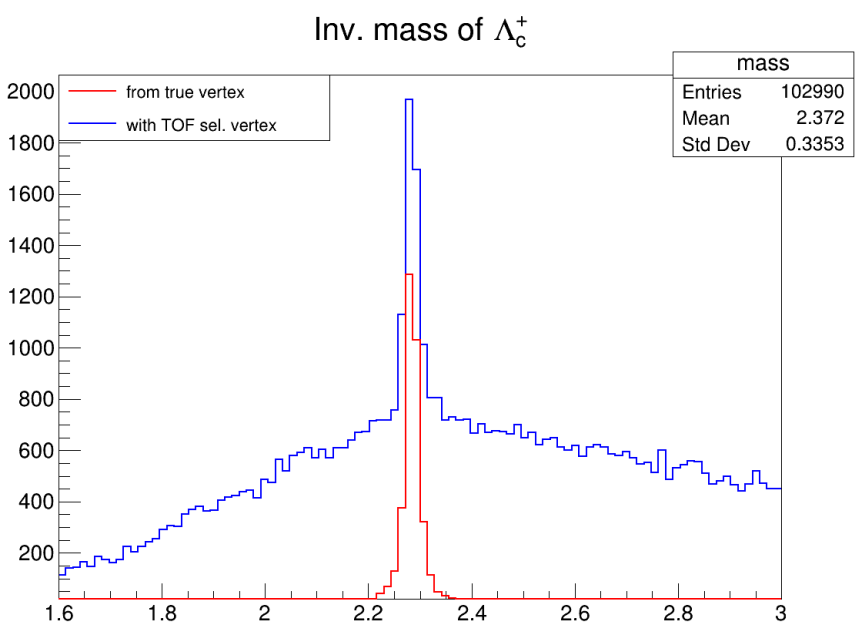
Parameters for the total inv. mass spectrum calculation:

- $\sigma_{\Lambda_c^+} \sim 3.44\ \mu b$ (experimental open charm cross section (20 μb) times ratio of Λ_c^+ Pythia production $\sim$ 0.172);
- $\sigma_{MB} \sim 40 mb$;
- $L \sim 10^{32} cm^{-2} c^{-1}$;
- $\tau \sim 10^7 c$;
- decay braching ~ 0.0626;

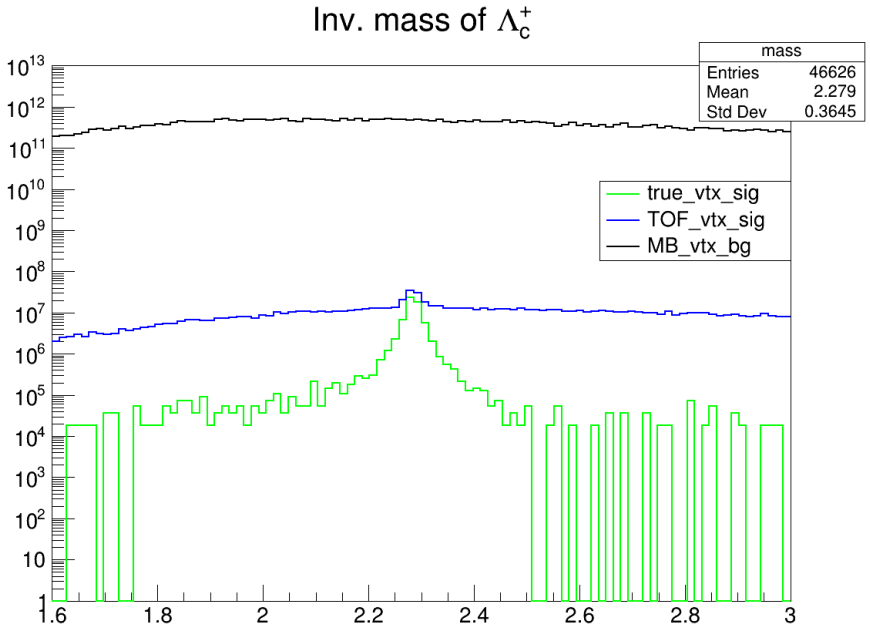
Total numbers

- Events with Λ_c^+ (fixed decay) expects $\sim 22 \cdot 10^7$;
- Events of minimum bias expects $\sim 40 \cdot 10^{12}$.

Cut on PIDs (TOF)

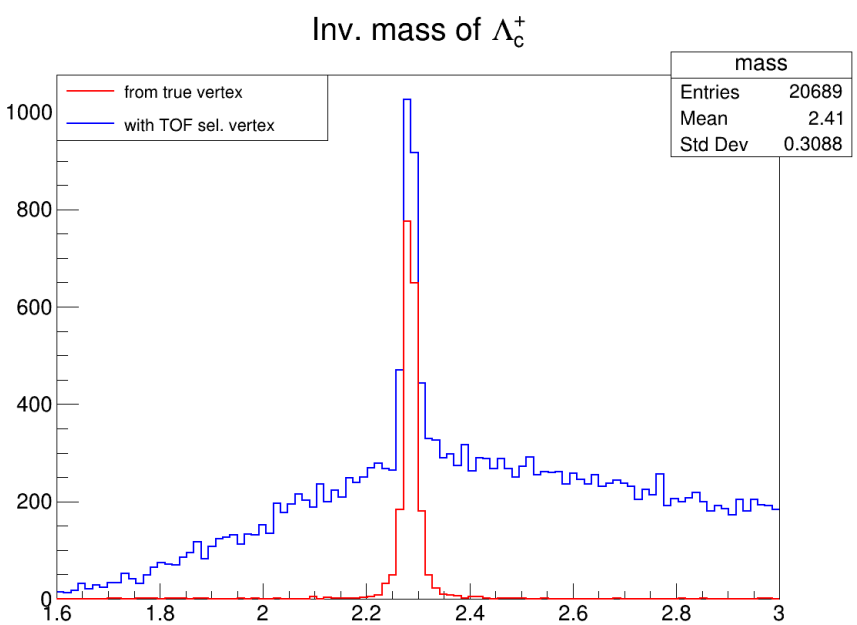


GetIsFitted & TOF -> ok cuts

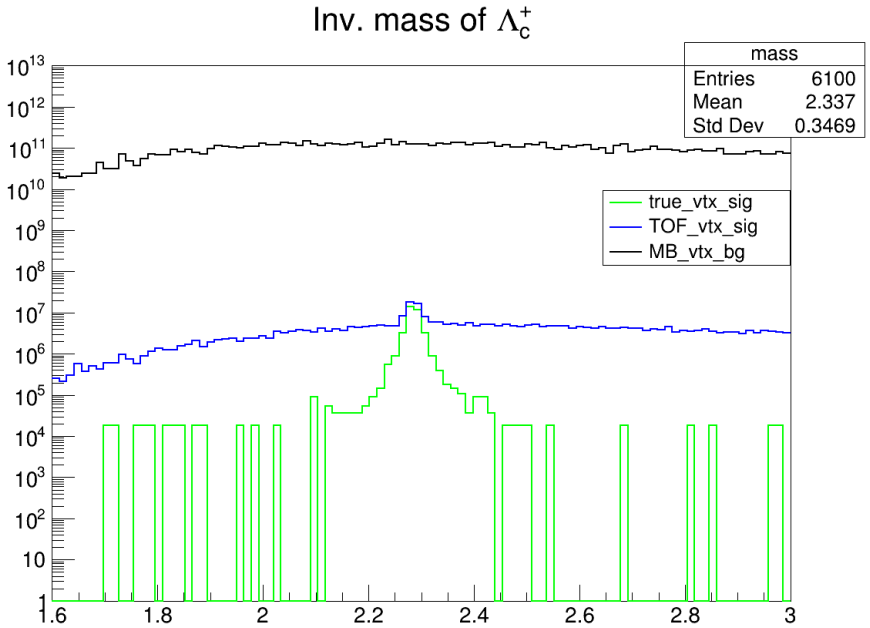


Scaled invariant mass spectrum

Cut on GetNHitsIts

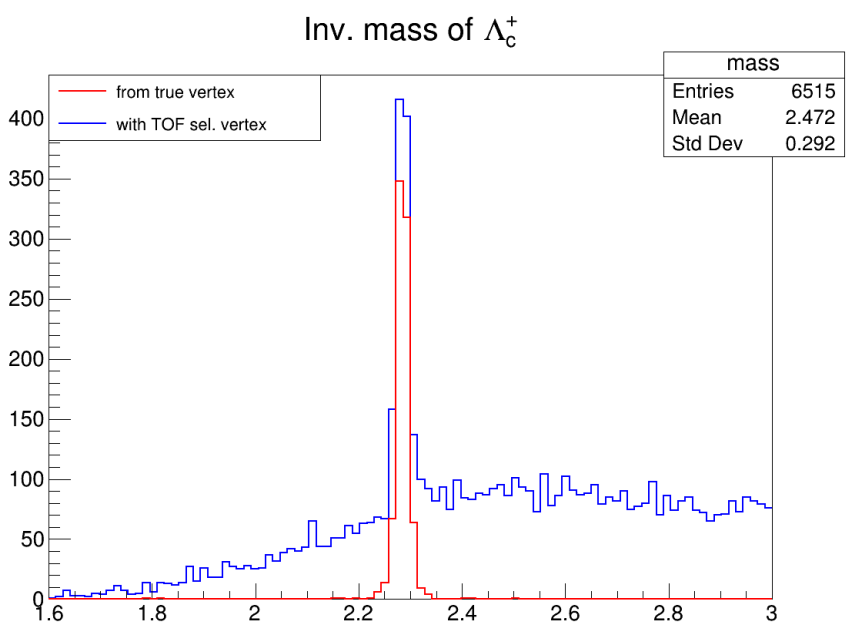


Add GetNHitsIts $>$ 3 cut

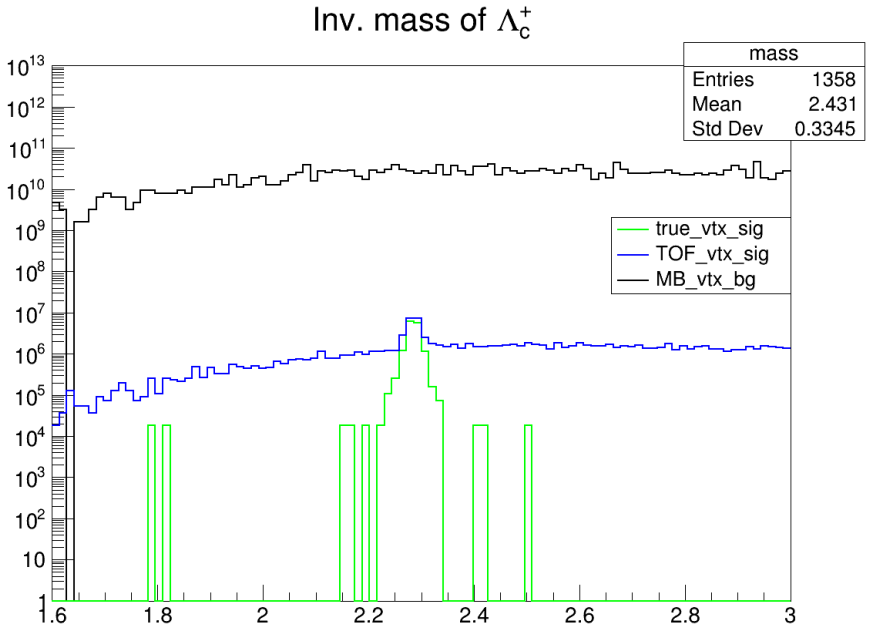


Scaled invariant mass spectrum

Cut on GetIsGood

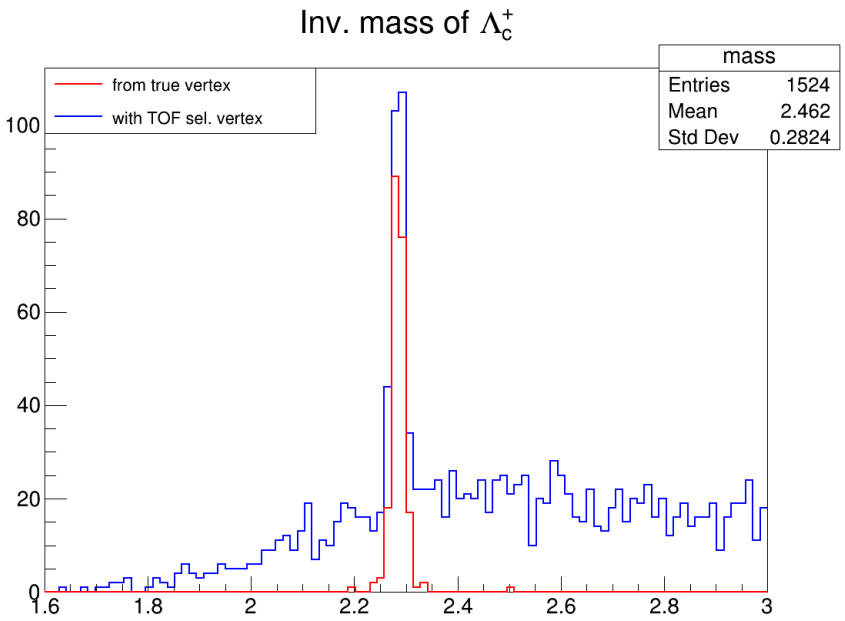


Add GetIsGood -> ok cut

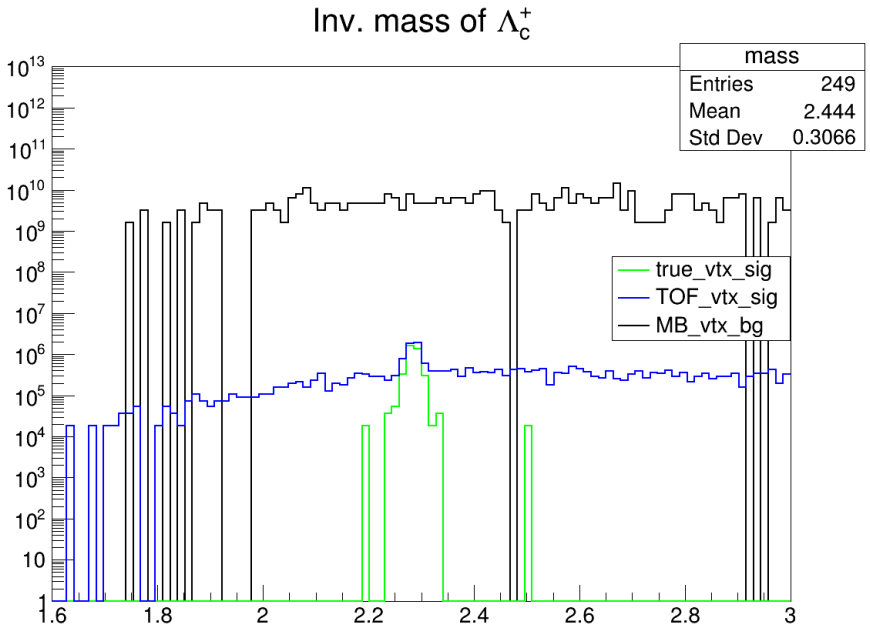


Scaled invariant mass spectrum

Cuts on χ^2_{PV} & χ^2_{tr2tr}

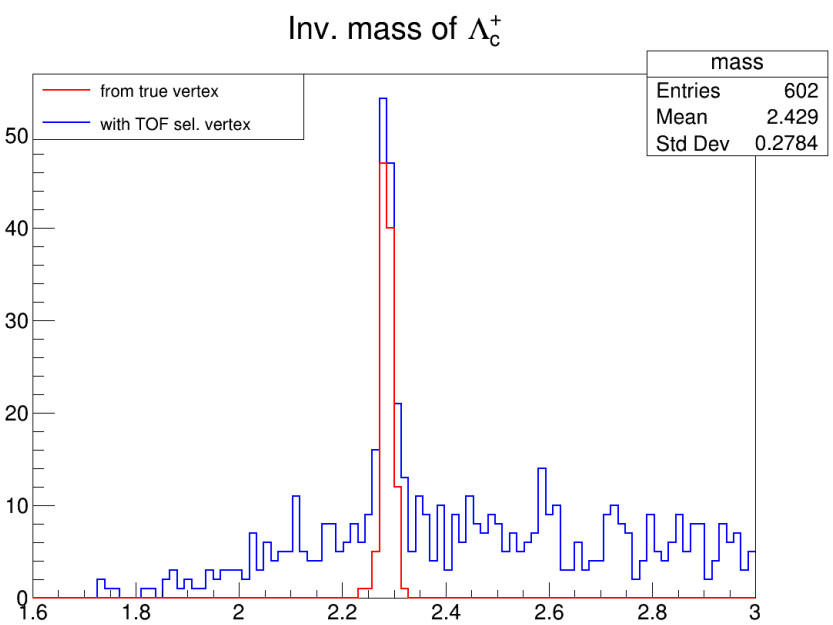


Add $\chi^2_{PV} > 1$ & $\chi^2_{tr2tr} < 10$ cuts

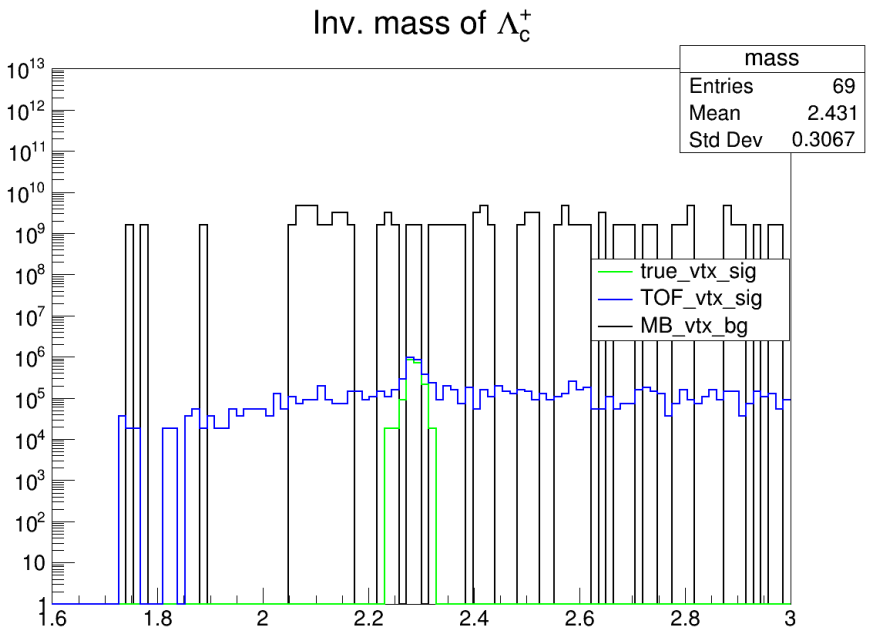


Scaled invariant mass spectrum

Cut on Λ_c decay length

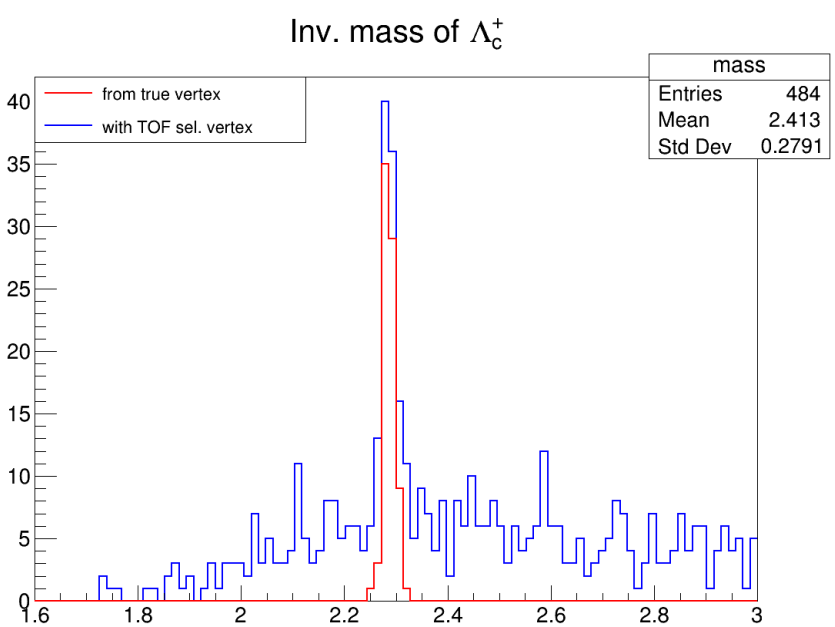


Add length $>$ 0.008 cm cut

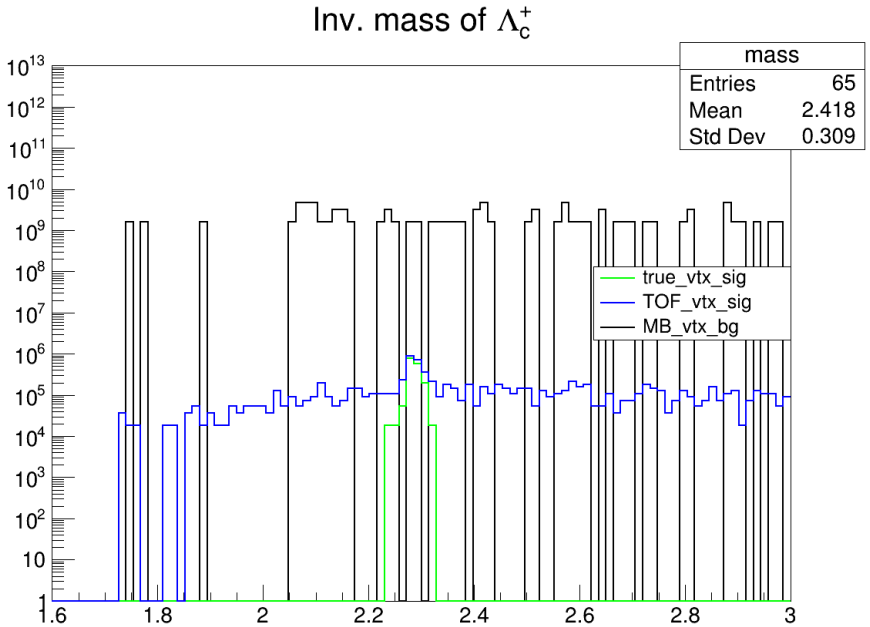


Scaled invariant mass spectrum

Cuts on particle momenta



Add momentum cuts



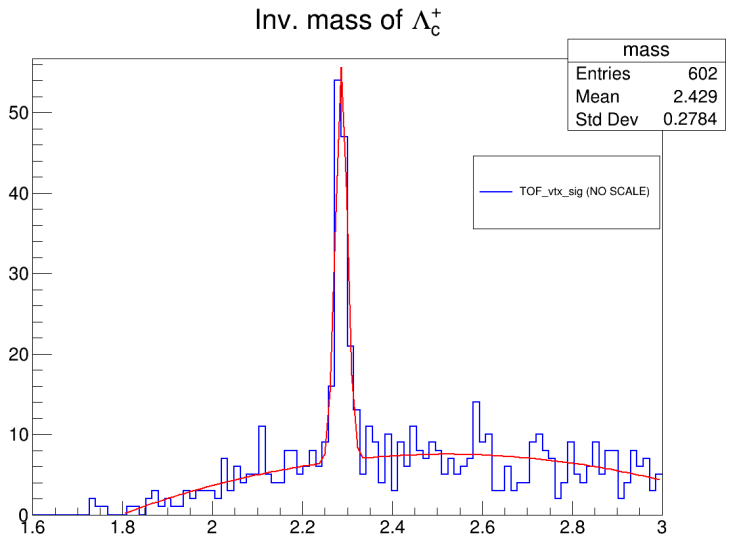
Scaled invariant mass spectrum

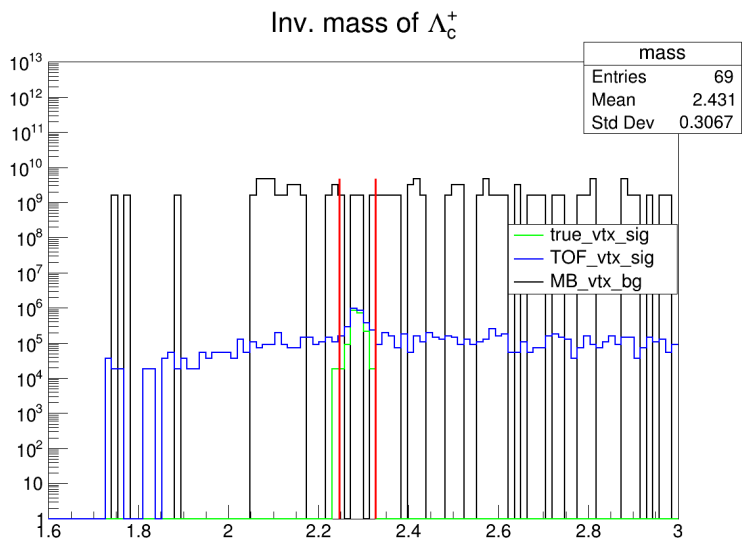
All applied cuts

Cut name	$\frac{\Lambda_c^+ vertices}{\text{Sel. vertices } (\Lambda_c^+ events)}$	$\frac{\Lambda_c^+ vertices}{\text{Sel. vertices (MB events)}}, 10^{-5}$
GetIsFitted & TOF	0.0369	0.0936
Mass window	0.0681	0.1735
GetNHitsIts	0.0982	0.3817
GetIsGood	0.1288	0.7079
χ^2_{PV} & χ^2_{tr2tr}	0.1378	0.9664
L_{min}	0.1777	1.7769
$P_{products}$	0.1669	1.6218

Decay products momentum cuts is not effective because previous cuts reduced essential part of background in the cut area. As the result the last cut just reduce signal ratio.

Inv. mass fit





Fit function:

- Gauss + Pol2;

Fit result:

- $m_{\Lambda_c} = 2.2867 \pm 0.0016$ GeV;
- $\sigma = 0.0133 \pm 0.0016$ GeV;

Number of events in 3σ from mean Gauss value:

- $N_{sig} = 2.87067 \cdot 10^6$;
- $N_{bg} = 6.36848 \cdot 10^9$;

Signal significance:

- $\frac{N_{sig}}{\sqrt{N_{bg}}} \sim 40$;

$$\frac{N_{sig}^{cuts}}{N_{sig}} \sim 0.03 \quad \frac{N_{bg}^{cuts}}{N_{bg}} \sim 0.0015$$

Conclusions

Current result with signal significance ~ 40 provides the opportunity to observe $\Lambda_c^+ \to p^+ K^- \pi^+$ decay at SPD experiment on $\sqrt{S} = 27$ GeV collision energy.

To do

- to implement the more adequate model of $\Lambda_c^+ \to p^+ K^- \pi^+$ decay
- to improve signal selection
- to study peaking background $D^+ \to K^- \pi^+ \pi^+$
- to simulate more statistics

Many thanks to Igor Denisenko for help and fruitful discussion.

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Thank you for your attention!