Status of Λ_c^+ Reconstruction in the ePIC Experiment

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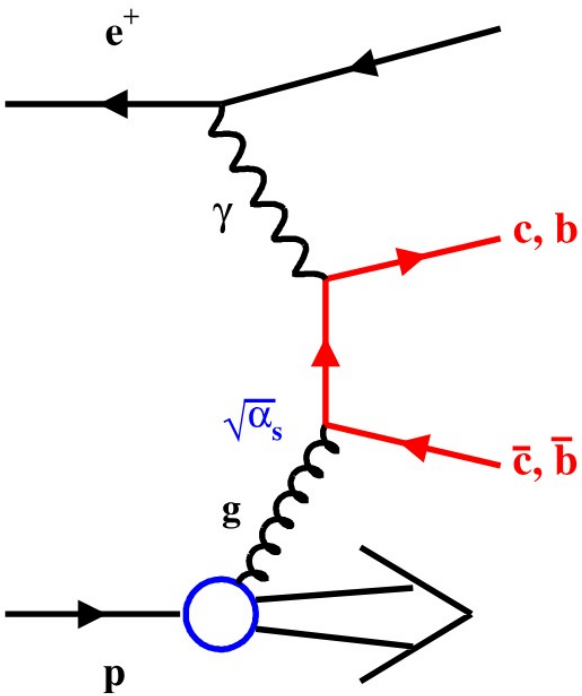
FAIR (Future Artificial Intelligence Research) Spoke 6 Project, funded by the NextGenerationEU program in Italy

Heavy-flavor Production

Photon-Gluon Fusion (PGF) is leading order [LO] mechanism

https://doi.org/10.1016/j.ppnp.2015.06.002



$$\gamma^* g \rightarrow c\bar{c} \text{ or } b\bar{b}$$

$$c \rightarrow D^0(c\bar{u}) \rightarrow K^- \pi^+$$

$$c \rightarrow \Lambda_c^+(udc) \rightarrow p K^- \pi^+$$

Particle	Mass (GeV/c²)	cτ (μm)
$D^{\pm}$	1.869	312
D^0	1.864	123
$B^{\pm}$	5.279	491
B^0	5.280	456
Λ_c^+	2.286	60

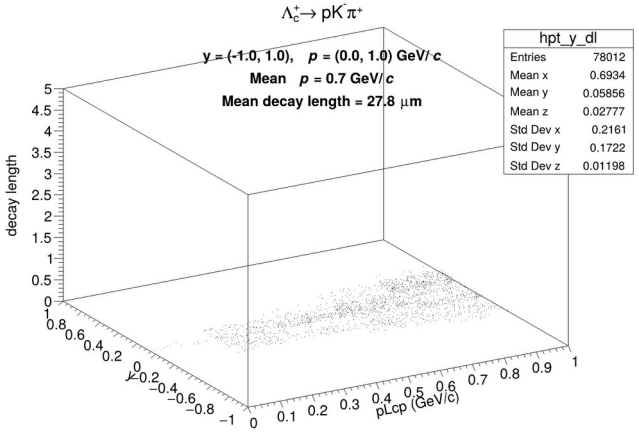
Study includes Λ_c^+ and Λ_c^- both

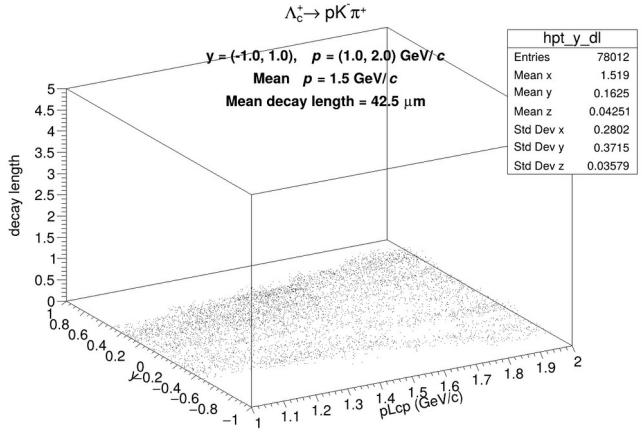
Virtual photon (γ*) from the electron interacts with a gluon from the proton, produces $c\bar{c}$ or $b\bar{b}$ pair

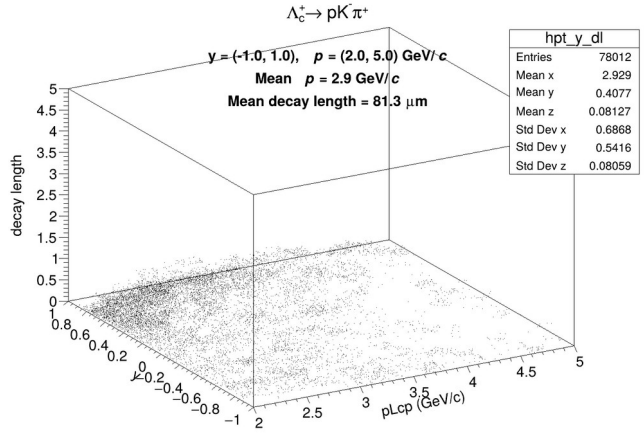
To understand charm-quark hadronization in ep collisions and it's modification in nuclear matter (eA)

Decay length at Simulation level (After GEANT4)

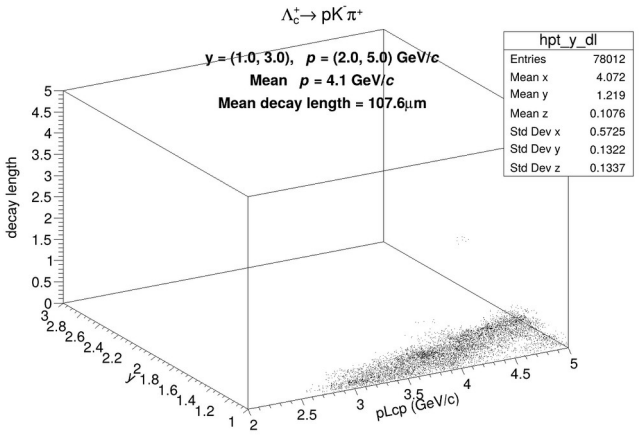
Mid rapidity

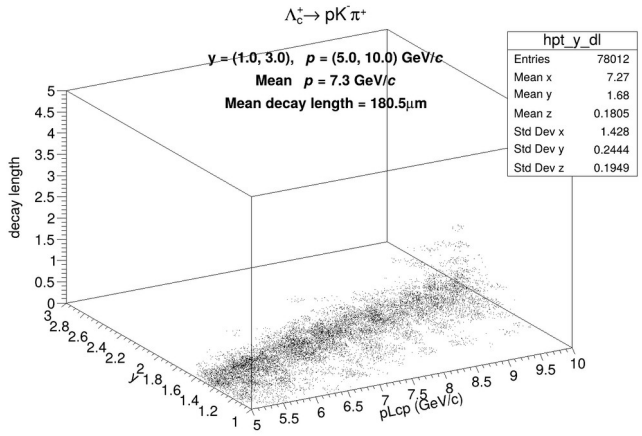






Forward rapidity





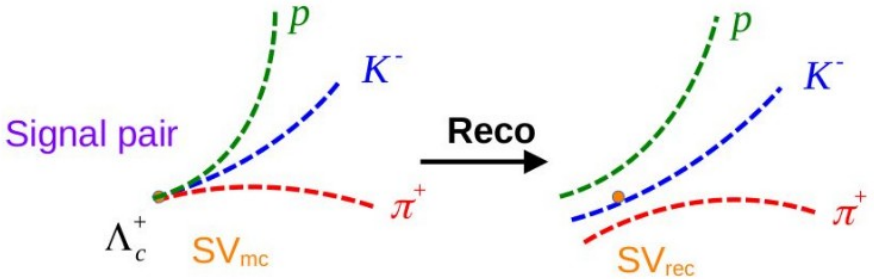
$$\Lambda_c^+ \to p K^- \pi^+$$

Expected mean decay length

$$\beta\gamma = \frac{p}{m_0 c}$$

$$\text{Decay length} = \beta c \gamma \tau = \frac{p}{m_0 c}(c\tau)$$

Secondary Vertex Resolution



[Tracking Issues (Slides)]

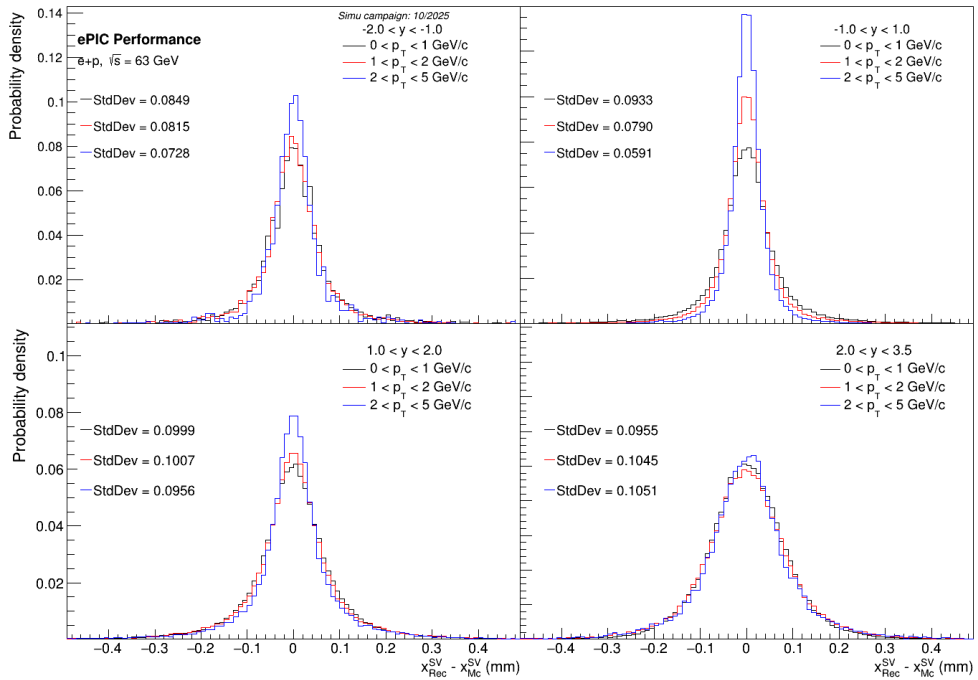
[Λc Reconstruction Code]

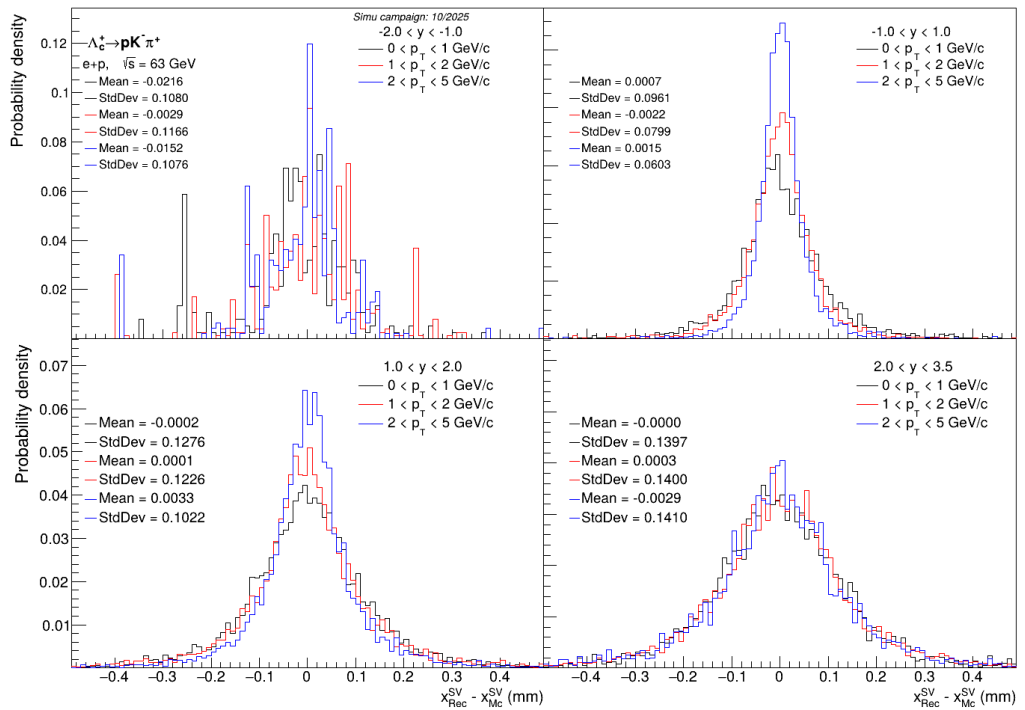
Chi-square minimization

$D^0 \rightarrow K^- \pi^+$

$(SV_{rec}^{x,y} - SV_{mc}^{x,y})$

$\Lambda_c^+ \rightarrow p K^- \pi^+$



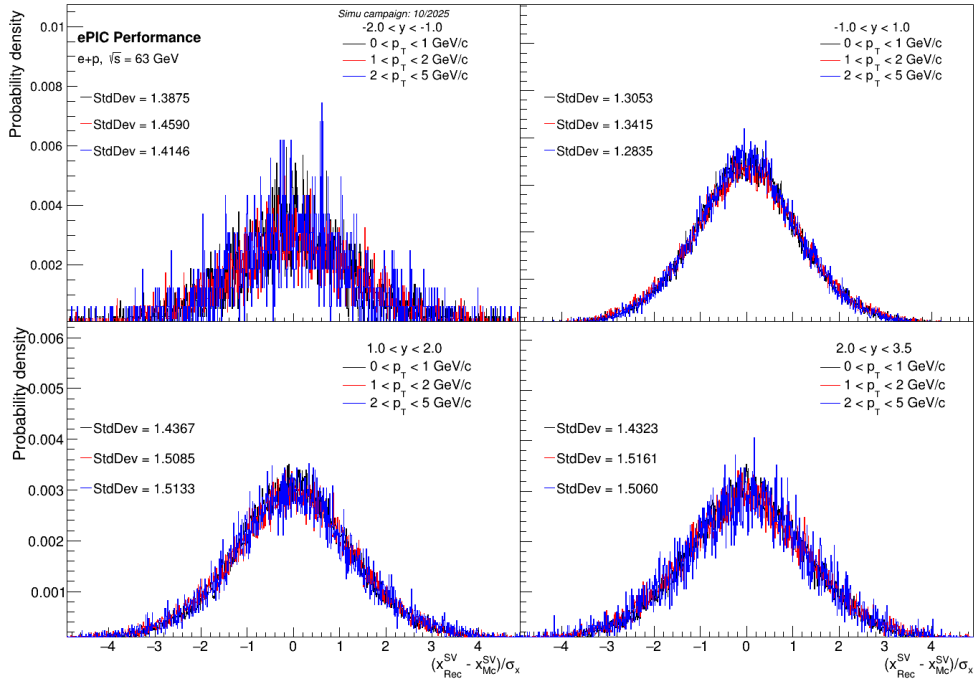


Secondary Vertex Resolution

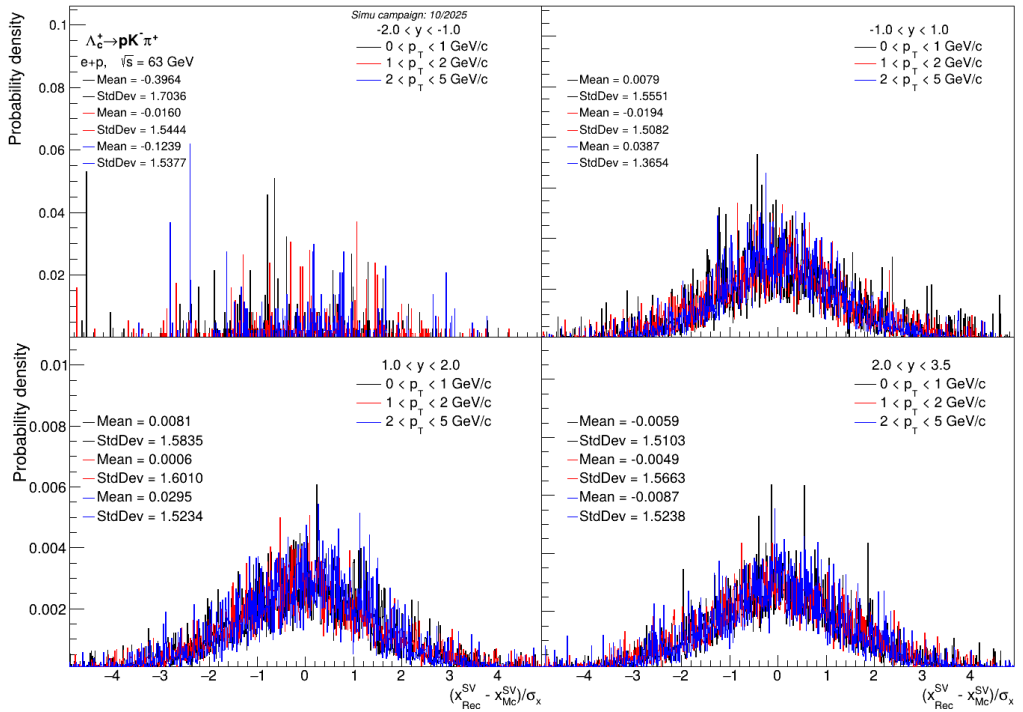
$$\text{Pulls} = \frac{SV^{x,y}_{rec} - SV^{x,y}_{mc}}{\sigma_{x,y}}$$

Chi-square minimization

$D^0 \rightarrow K^- \pi^+$



$\Lambda_c^+ \rightarrow p K^- \pi^+$



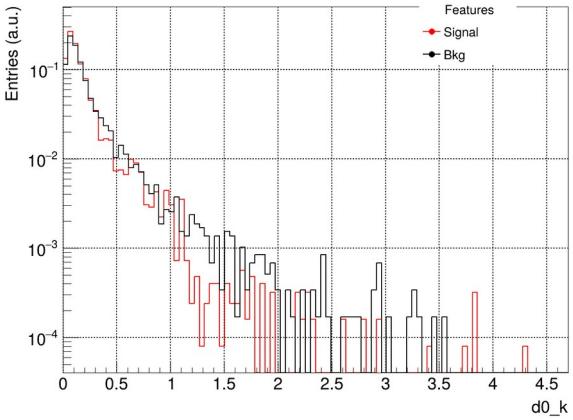
Minor degradation of pull distributions in October simulation campaigns

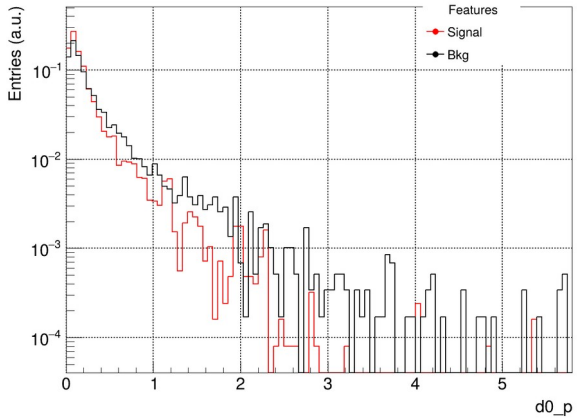
Topological features

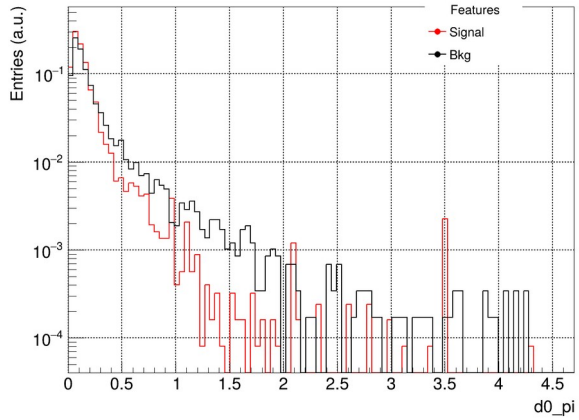
Signal pairs

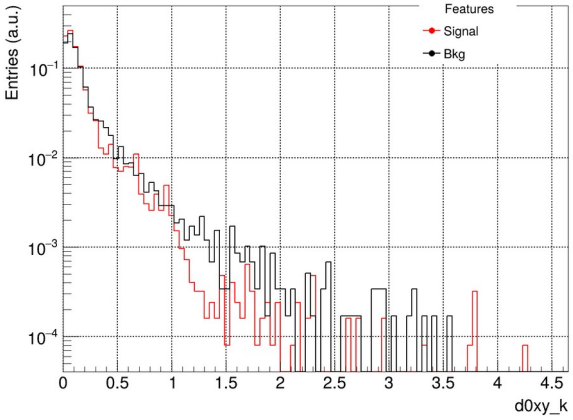
Bkg pairs

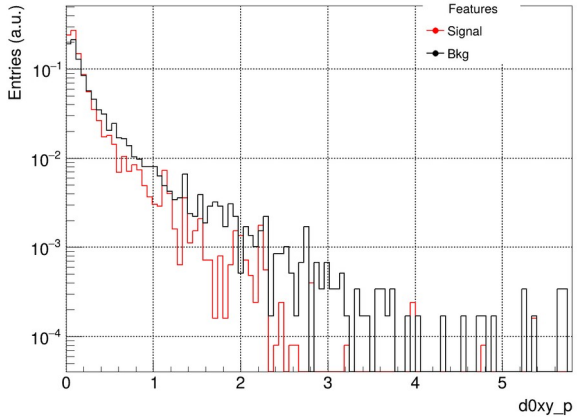
$y \in [-1,1], p_T \in [0,1] \mathrm{GeV}/c$

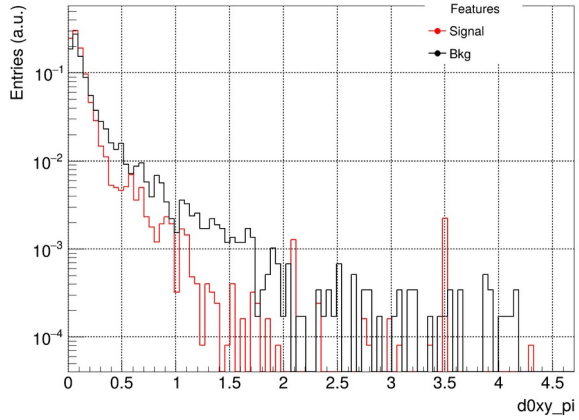










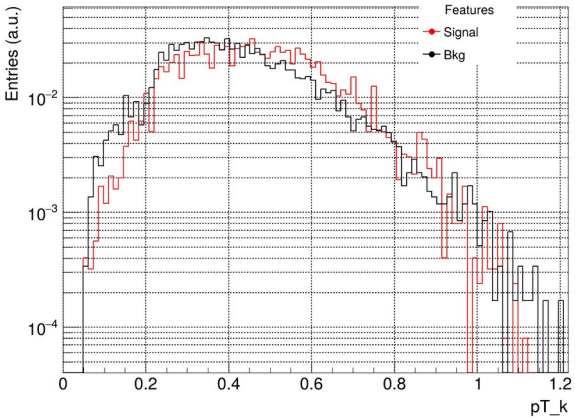


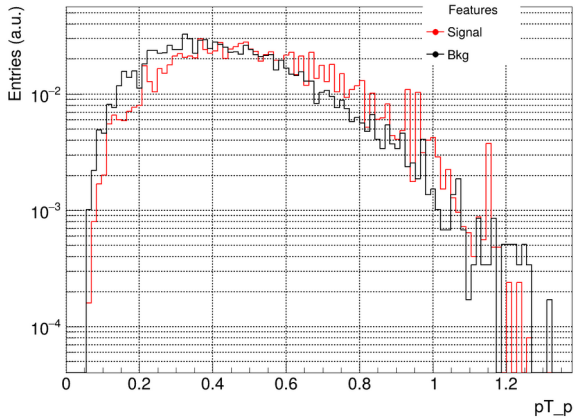
Topological features

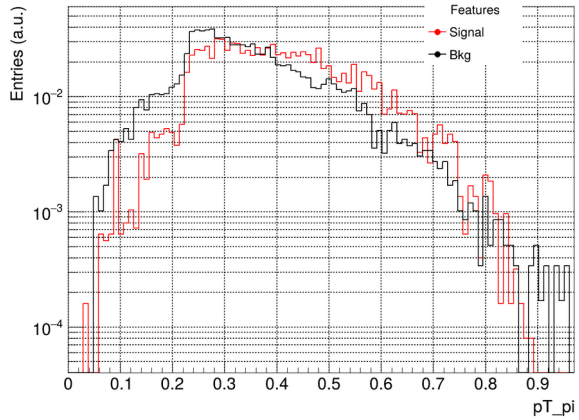
Signal pairs

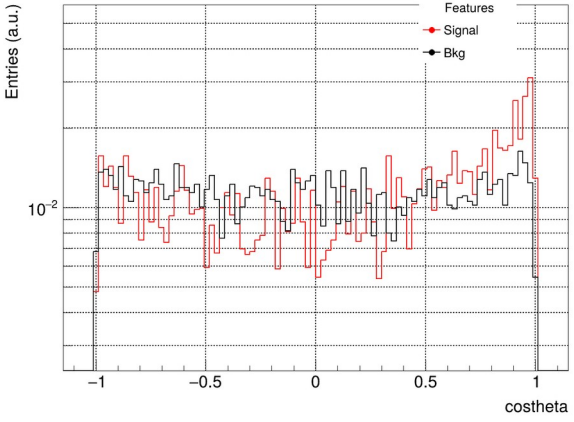
Bkg pairs

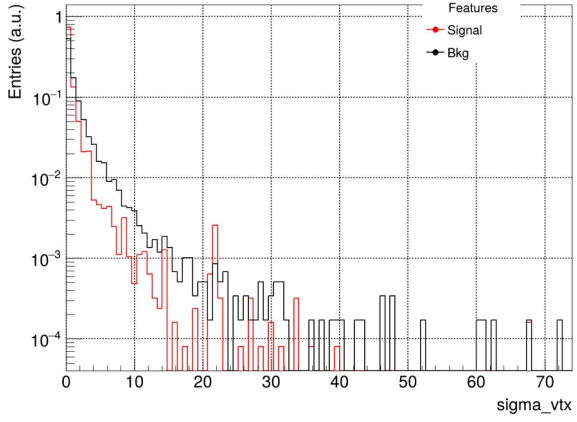
$y \in [-1,1], p_T \in [0,1]\,\mathrm{GeV}/c$

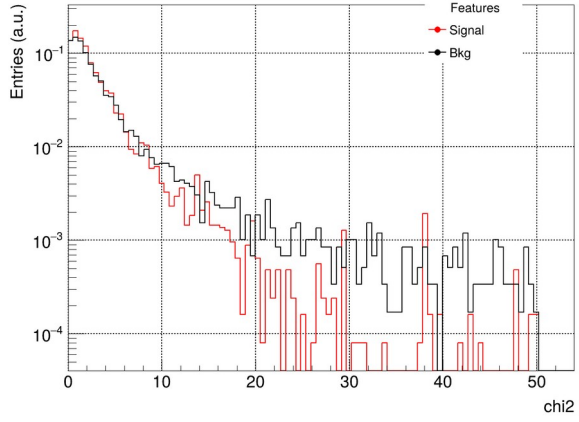










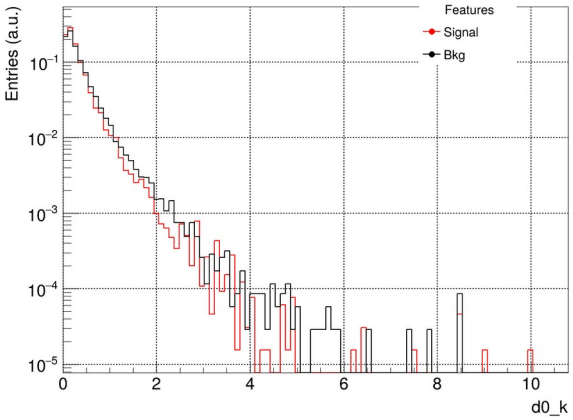


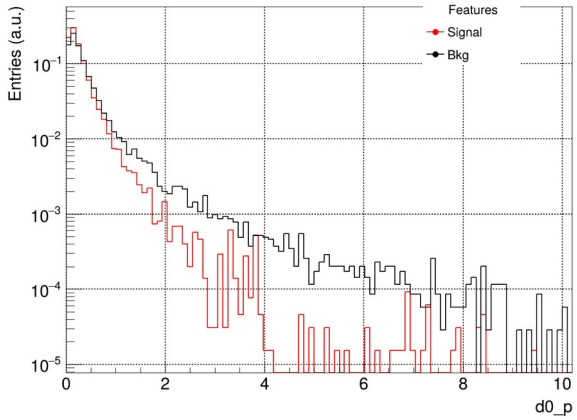
Topological features

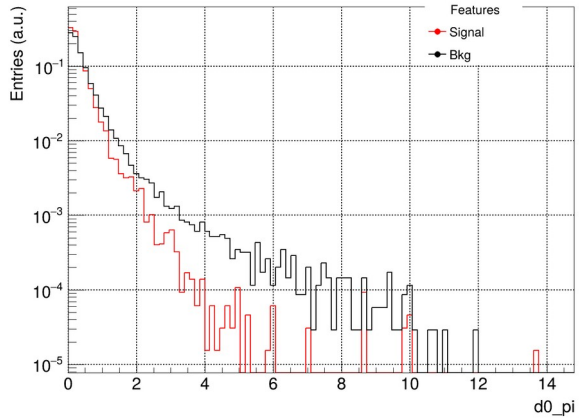
Signal pairs

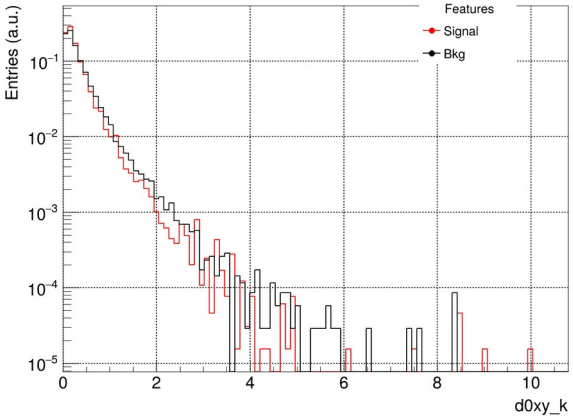
Bkg pairs

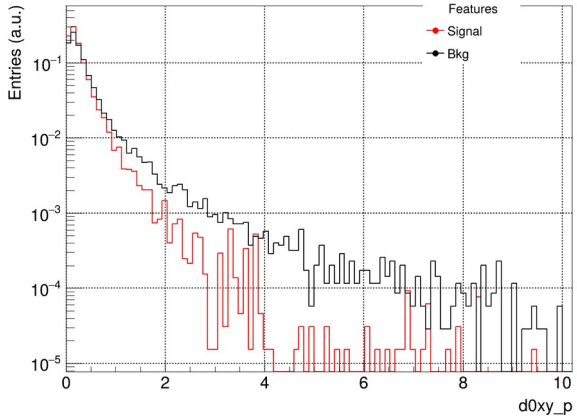
$y \in [1,3], p_T \in [0,1] \text{GeV}/c$

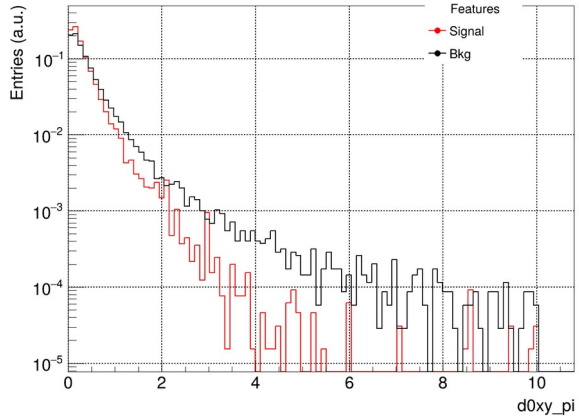












Topological features

Signal pairs

Bkg pairs

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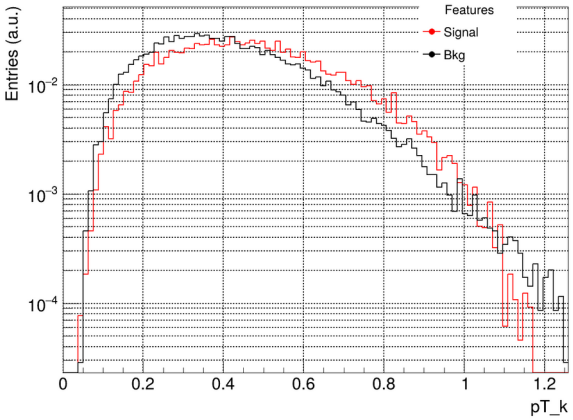
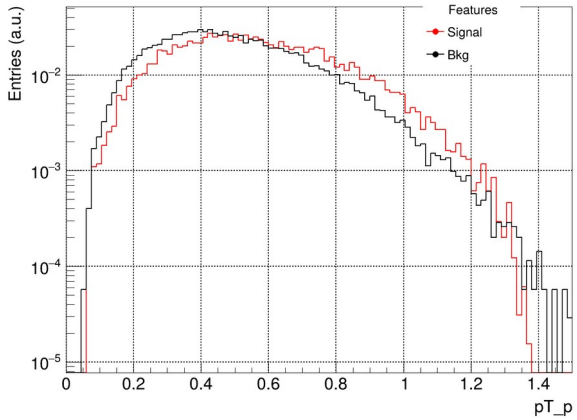
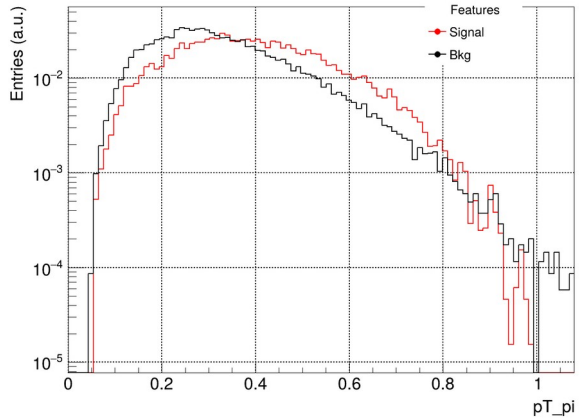
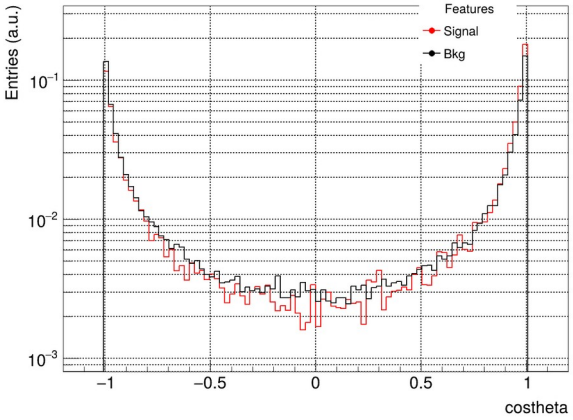
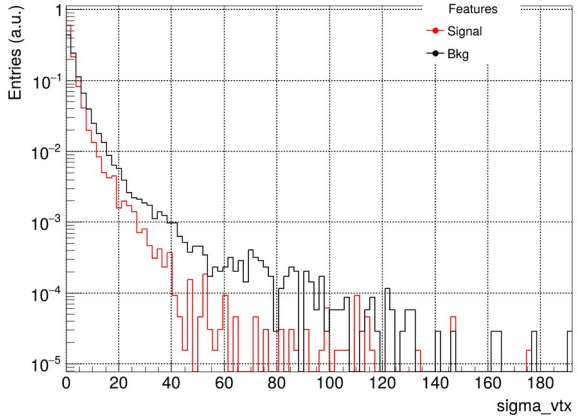
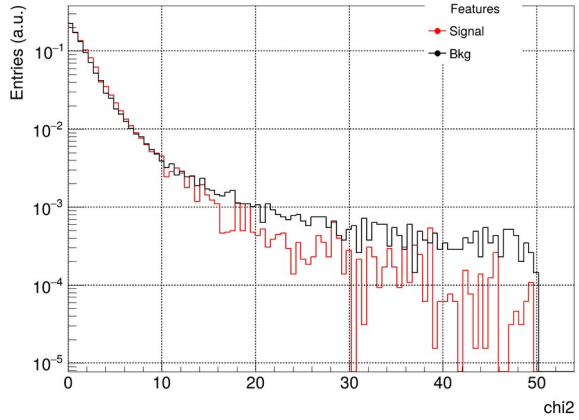












Event Statistics

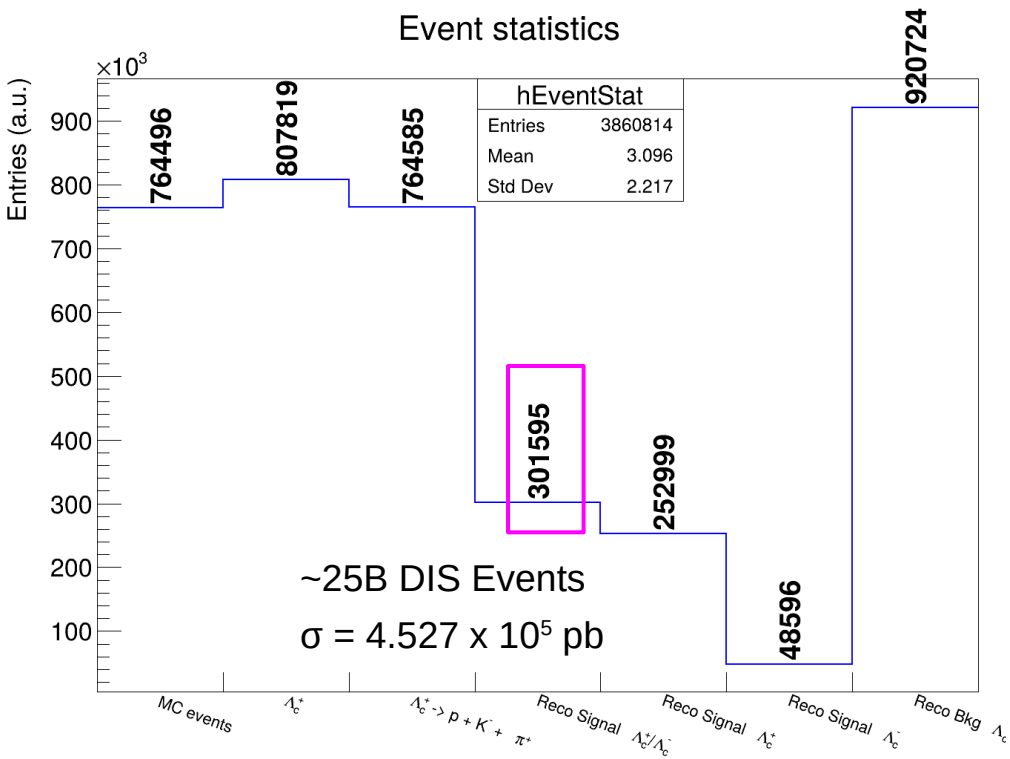
October 2025 Campaigns

Slide 14

$$L_{int} = \frac{250 \times 10^8}{4.527 \times 10^8 \text{ fb}} = 55.22421 \text{ fb}^{-1}$$

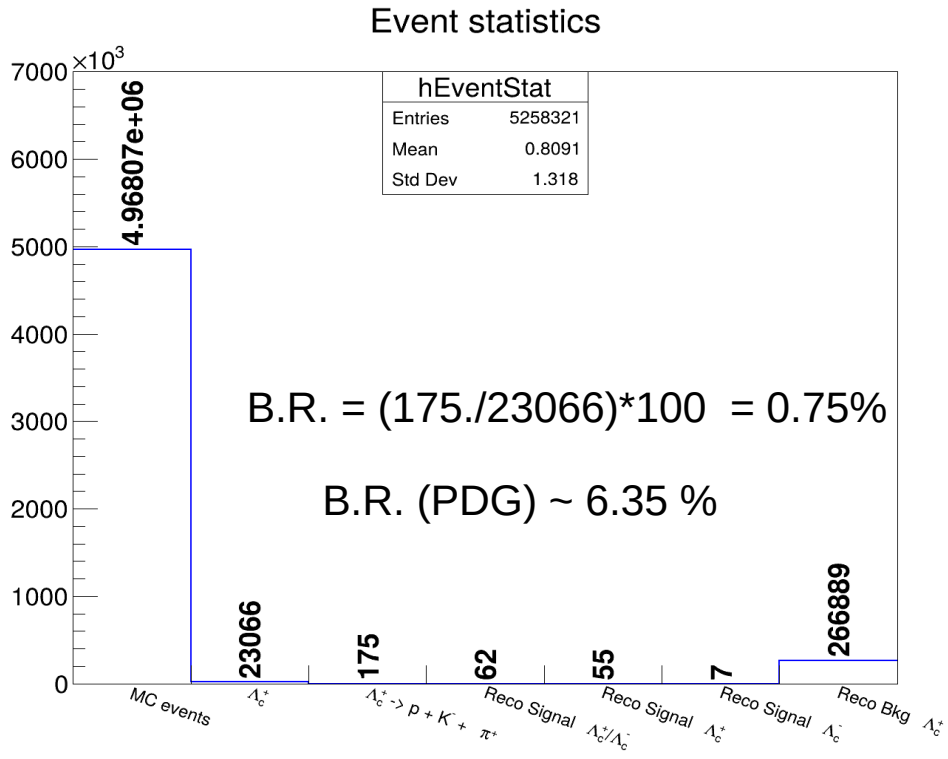
Truth PID

Λ_c^+ Sample



Reco efficiency = 301595/764585 = 0.395

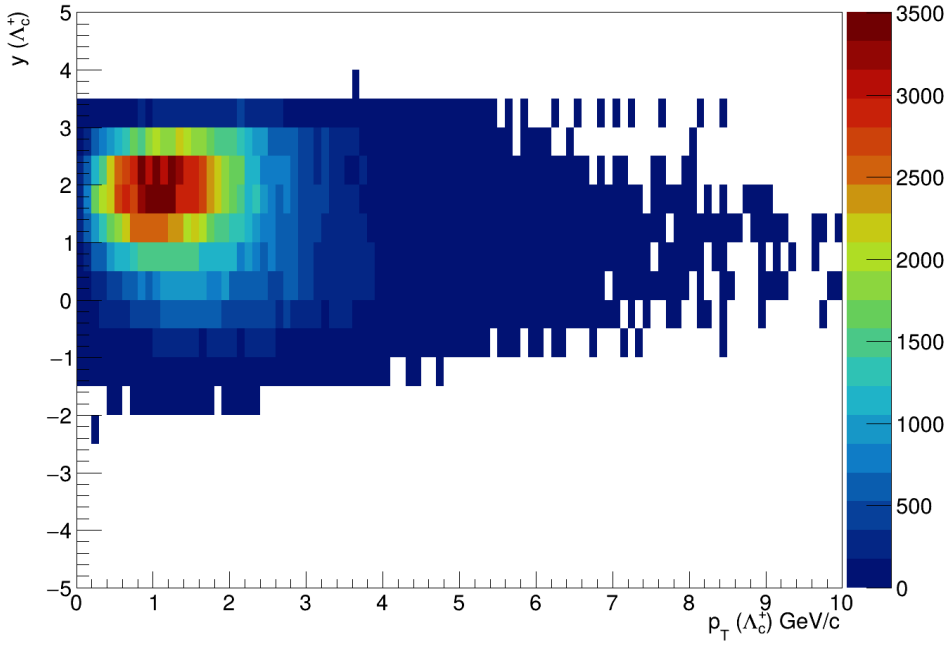
DIS Sample



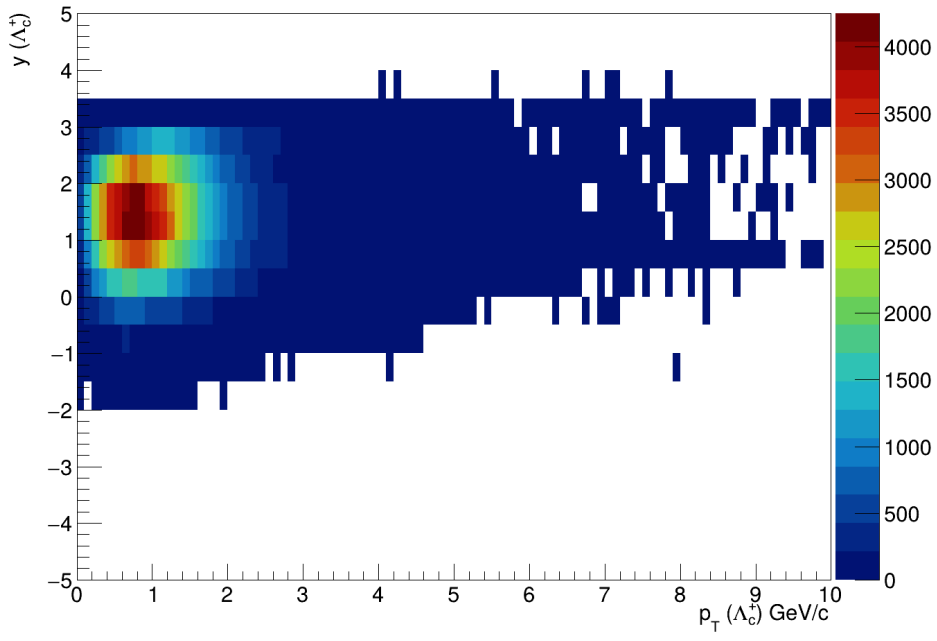
Reco efficiency = 62/175 = 0.354

Phase Space (Signal and Bkg Pairs)

Signal pairs (Λ_c Sample)



Bkg pairs (DIS Sample)



Truth/Real PID

// Invariant mass window

$m_{\Lambda c} > 1.8$ && $m_{\Lambda c} < 2.8$

// Track impact parameters

$d_{0xy\_p} > 0.02$ && $d_{0xy\_p} < 10.0$

$d_{0xy\_pi} > 0.02$ && $d_{0xy\_pi} < 10.0$

$d_{0xy\_k} > 0.02$ && $d_{0xy\_k} < 10.0$

// Vertex quality

$\sigma_{vtx} < 40.0$

chi2 < 40.0

// Track pT cuts

$p_{T\_k} > 0.20$

$p_{T\_p} > 0.20$

$p_{T\_pi} > 0.20$

Sampling Signal

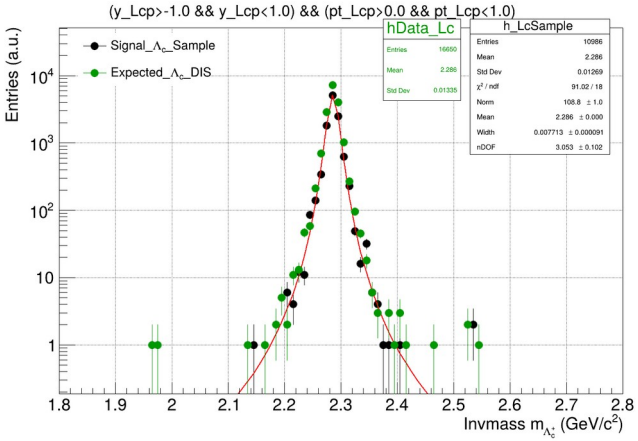
$10\,\mathrm{fb}^{-1} = 4.527\,\mathrm{B}$ Events

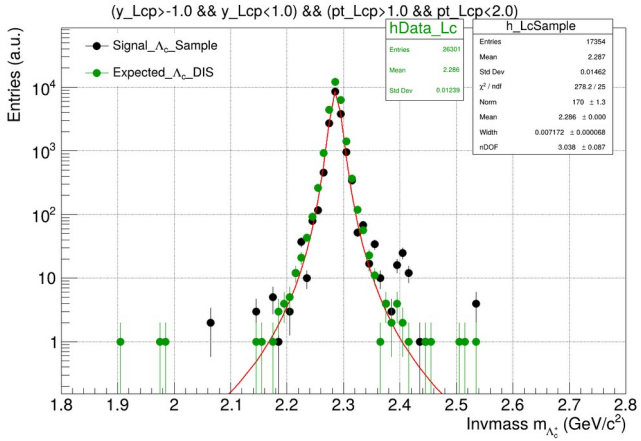
B.R. Scaling = 6.35/0.75

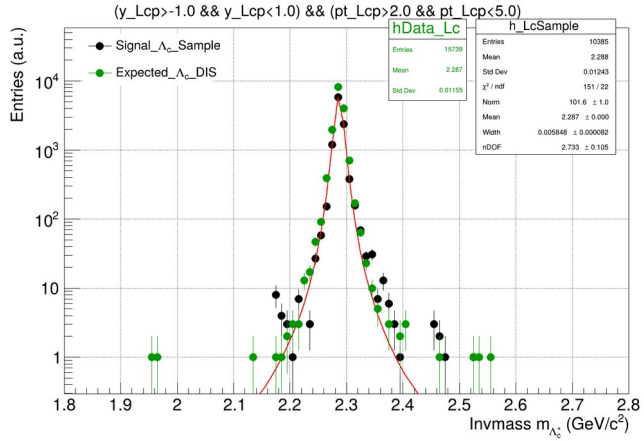
~25B Events

~(4.5B x B.R. Scaling) Events

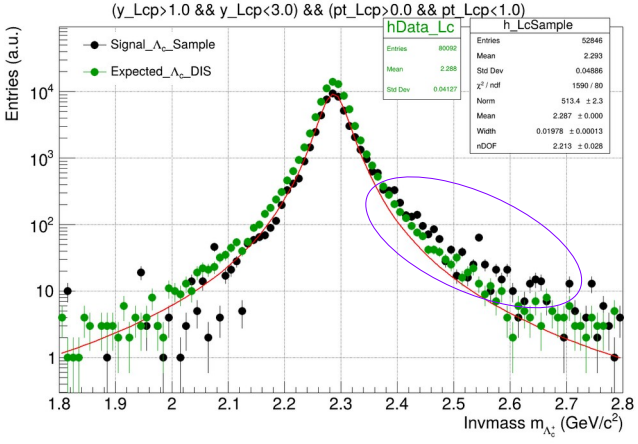
Mid rapidity

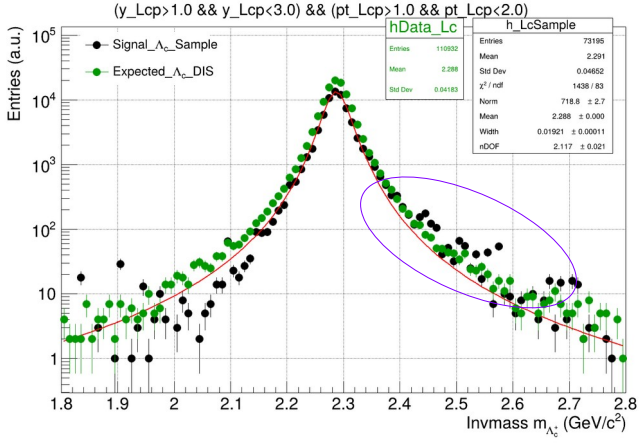


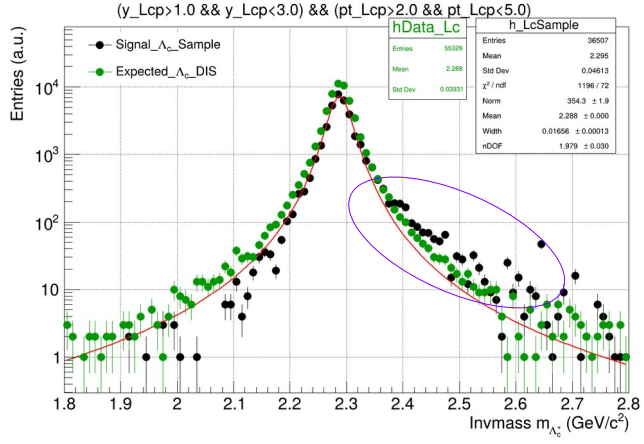




Forward rapidity







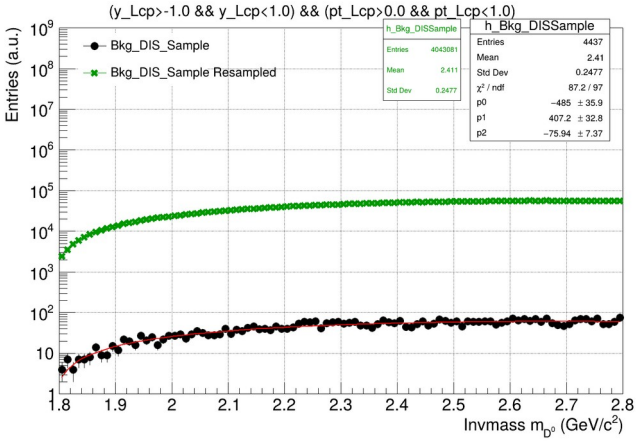
Sampling Background

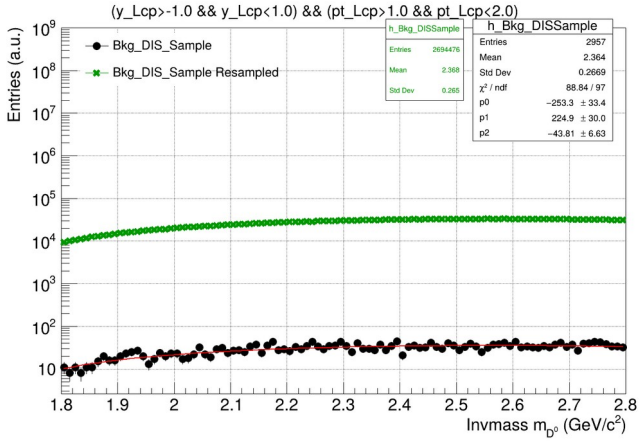
$10\,\mathrm{fb}^{-1} = 4.527\,\mathrm{B}$ Events

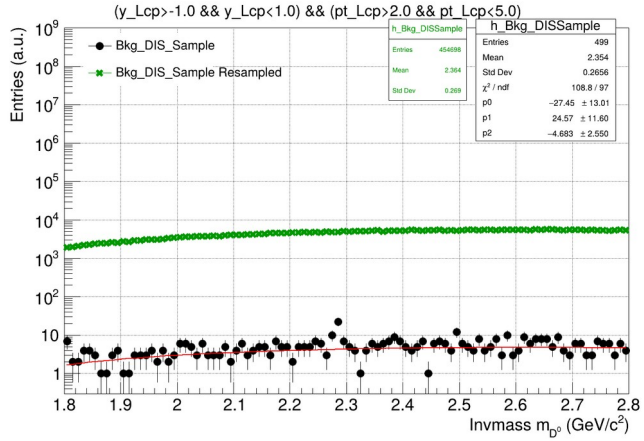
~5M Events

Mid rapidity

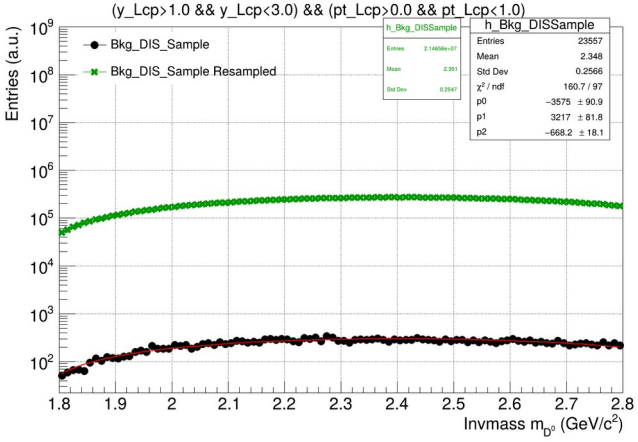
~4.5B Events

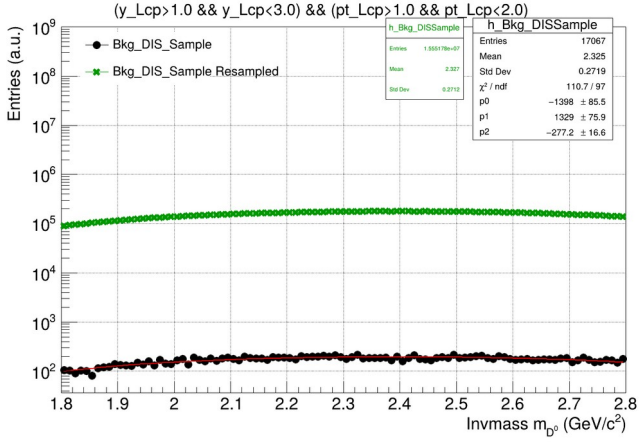


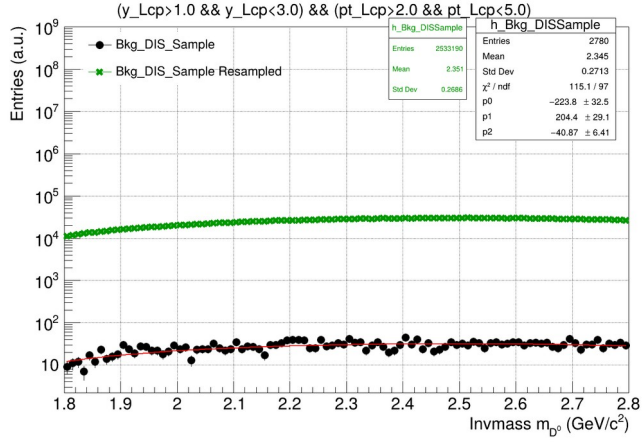




Forward rapidity



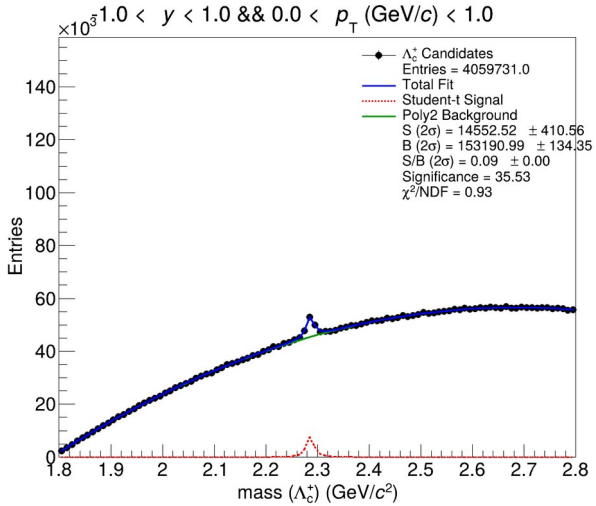


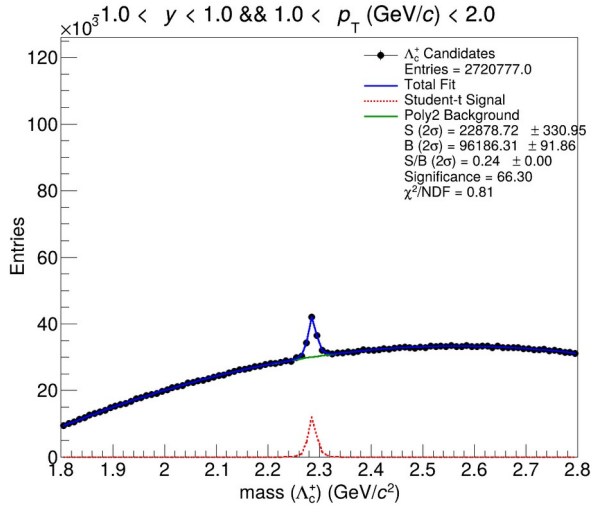


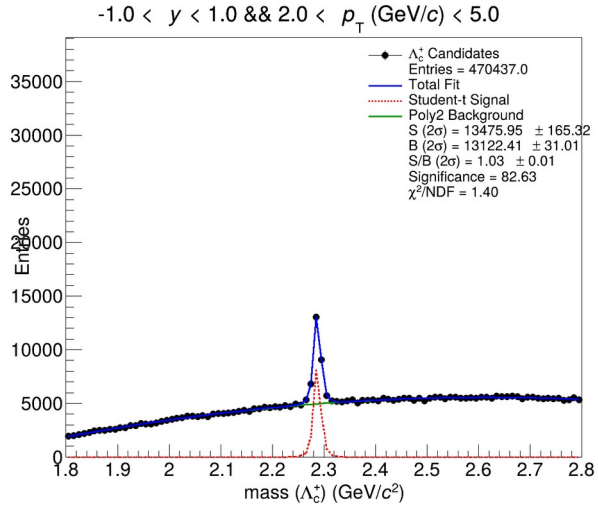
Invariant Mass Plots

Mid rapidity

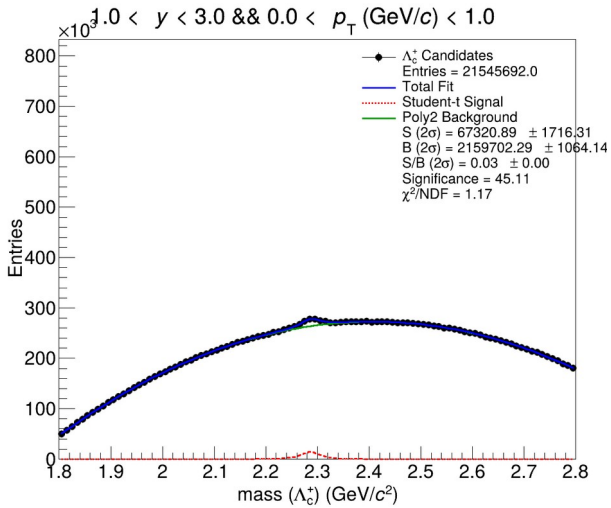
Truth PID

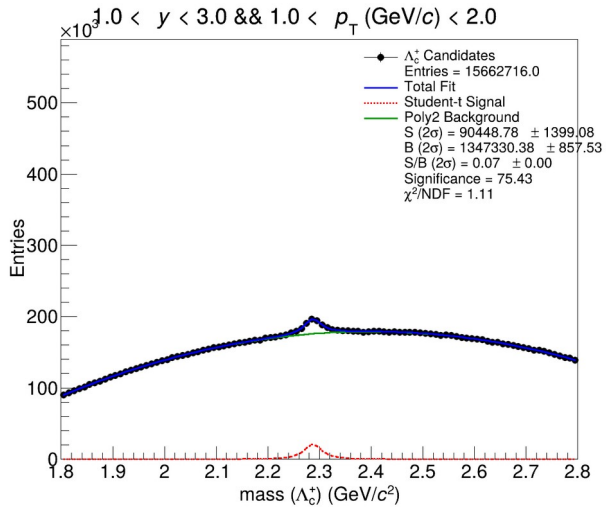


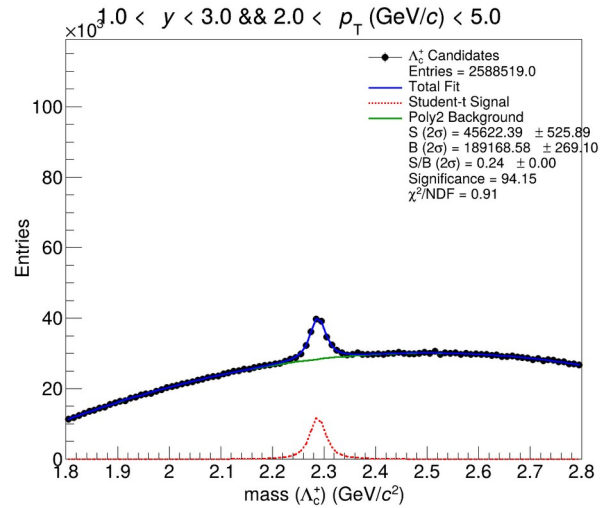




Forward rapidity







Event Statistics

October 2025 Campaigns

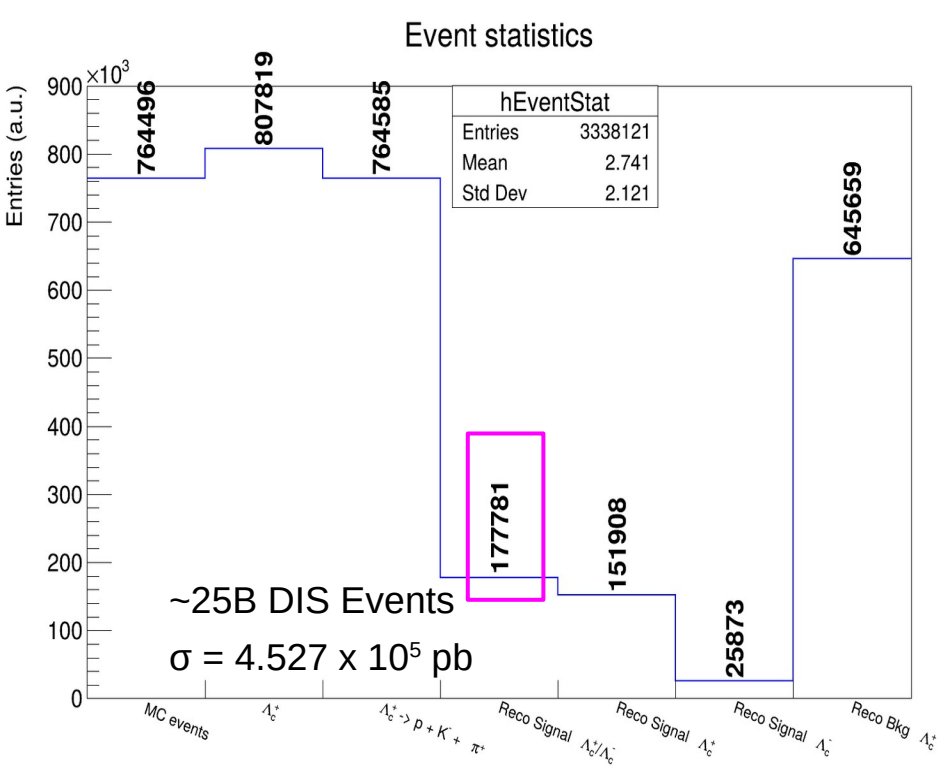
Slide 14

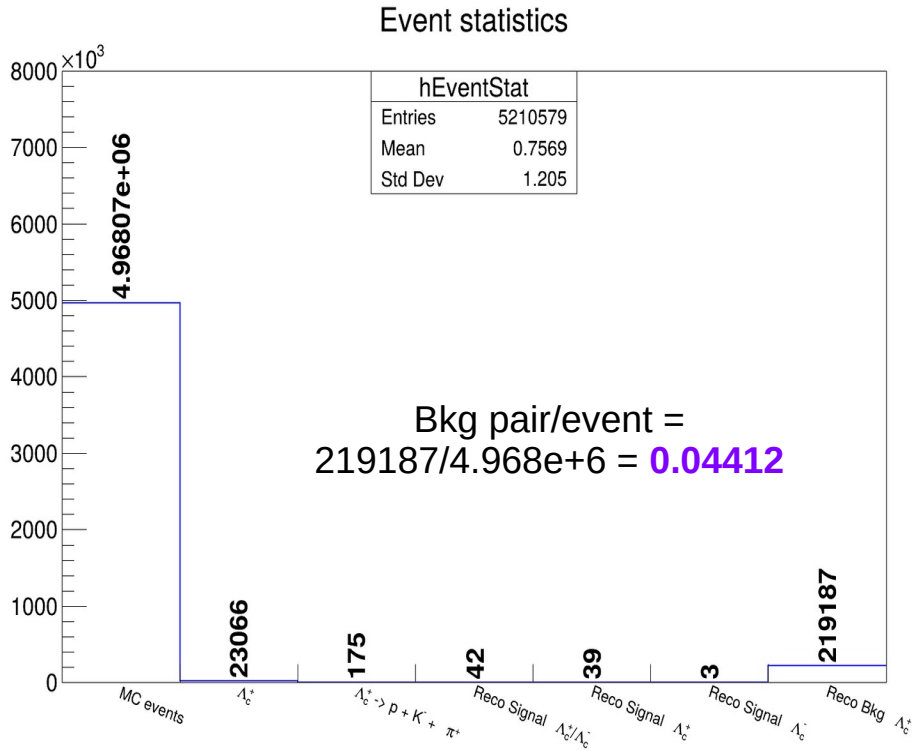
$$L_{int} = \frac{250 \times 10^8}{4.527 \times 10^8 \text{ fb}} = 55.22421 \text{ fb}^{-1}$$

Real PID

Λ_c^+ Sample

DIS Sample





Reco efficiency = 177781/764585 = 0.233

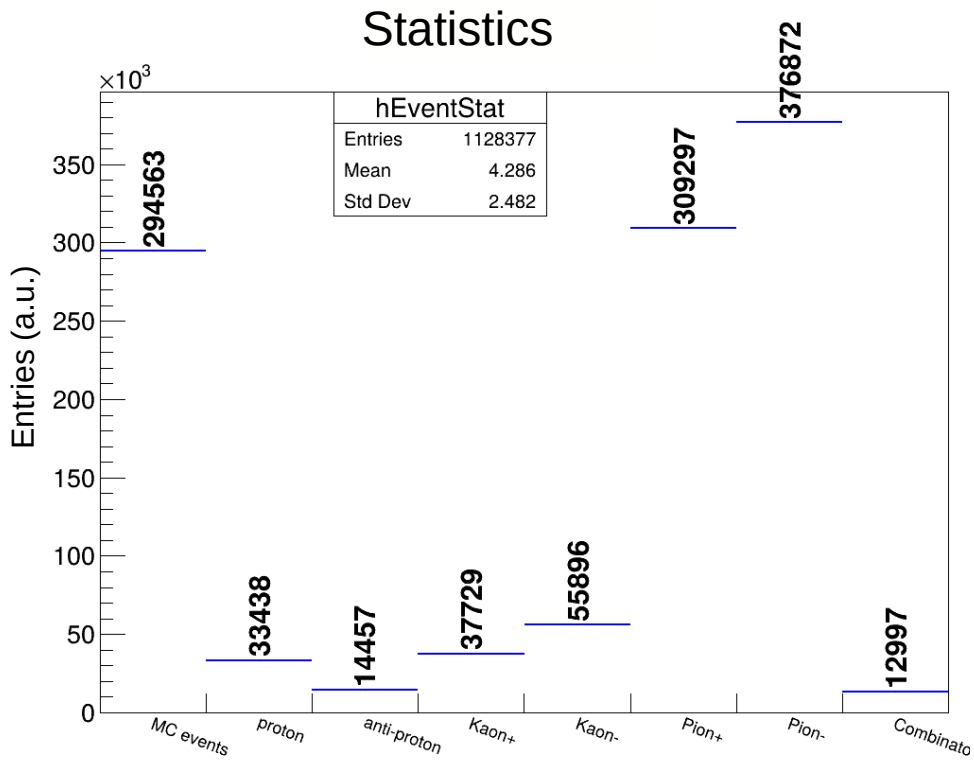
Reco efficiency = 41/175 = 0.24

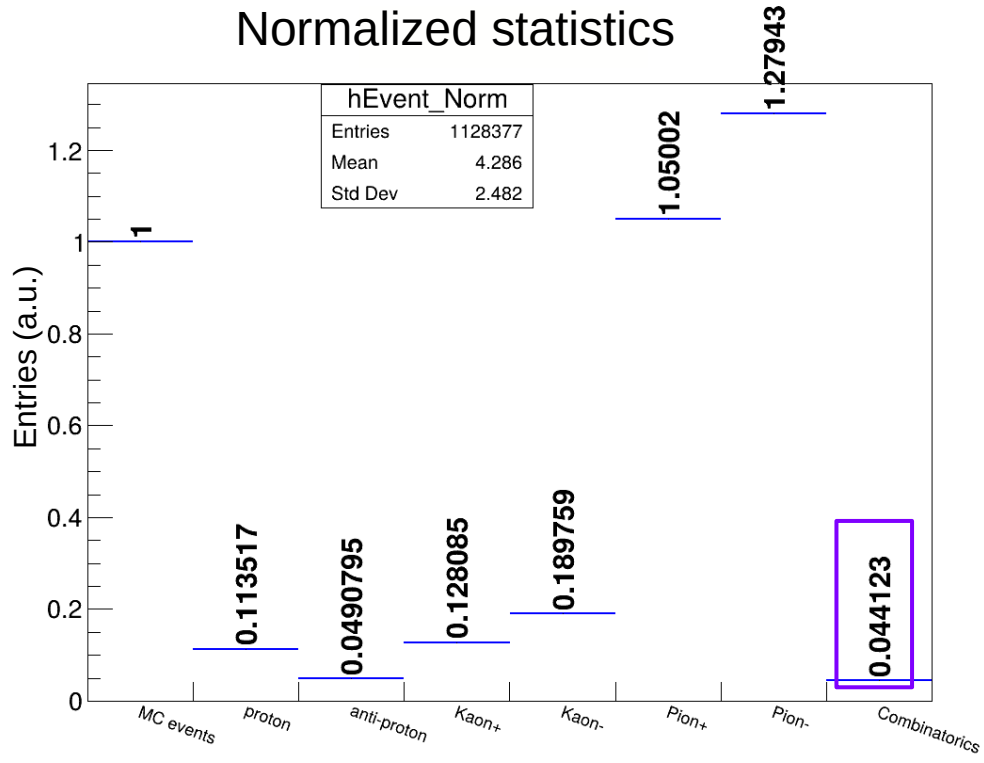
Event Statistics

Using Reco charge and particle identification

```
for (int i = 0; i < rcCharge.GetSize(); ++i) {

  if      (rcPdg[i] ==  2212) { hEventStat->Fill(1.5); nP++;    } // p
  else if (rcPdg[i] == -2212) { hEventStat->Fill(2.5); nPbar++; } // pbar
  else if (rcPdg[i] ==   321) { hEventStat->Fill(3.5); nKp++;   } // K+
  else if (rcPdg[i] ==  -321) { hEventStat->Fill(4.5); nKm++;   } // K-
  else if (rcPdg[i] ==   211) { hEventStat->Fill(5.5); nPip++;  } // pi+
  else if (rcPdg[i] ==  -211) { hEventStat->Fill(6.5); nPim++;  } // pi-
}
```

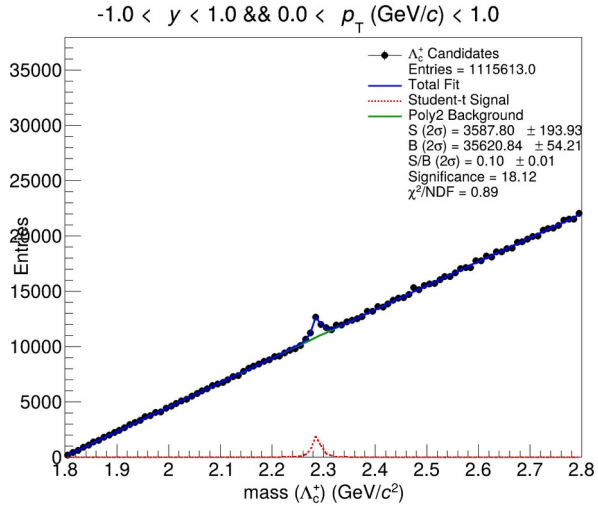


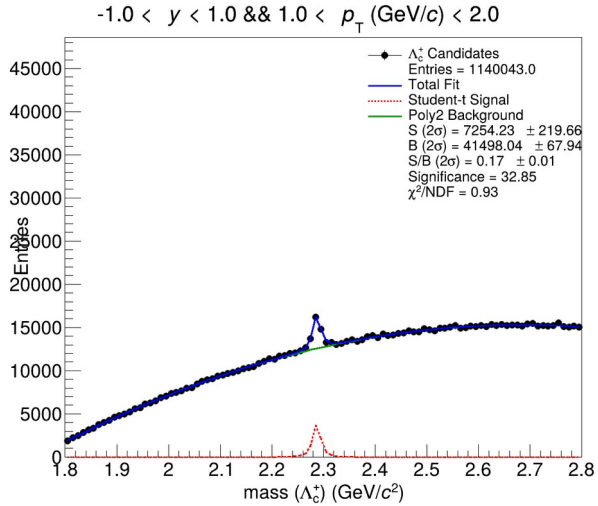


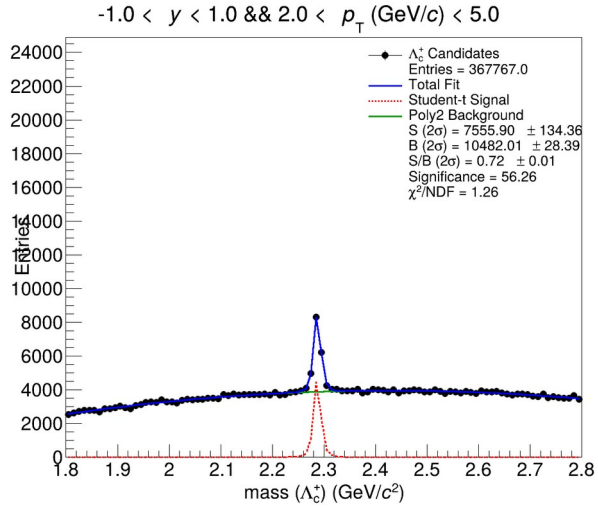
Invariant Mass Plots

Real PID for proton

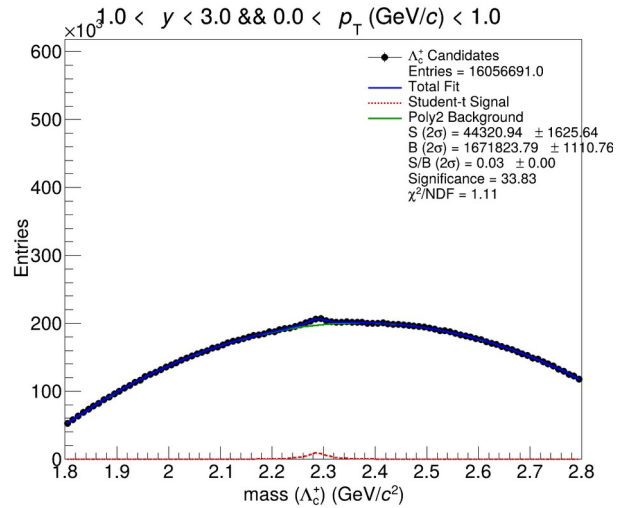
Mid rapidity

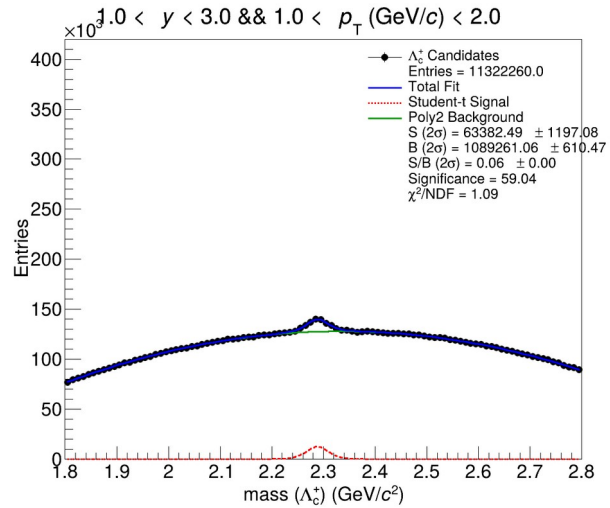


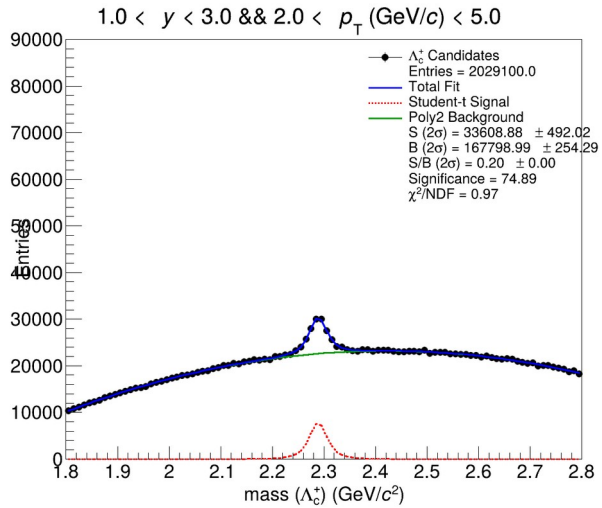




Forward rapidity



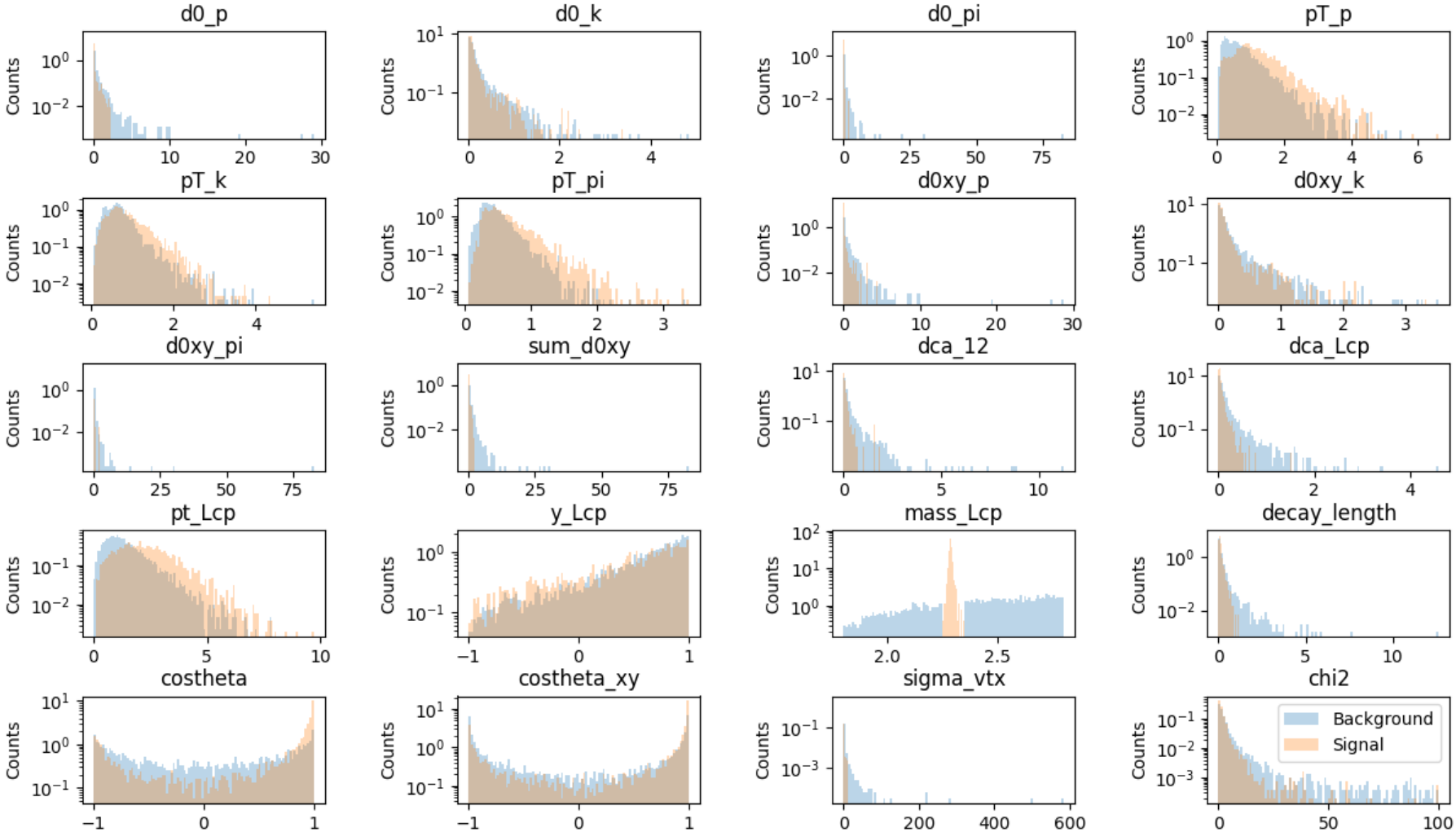




Machine Learning (ML) Approach

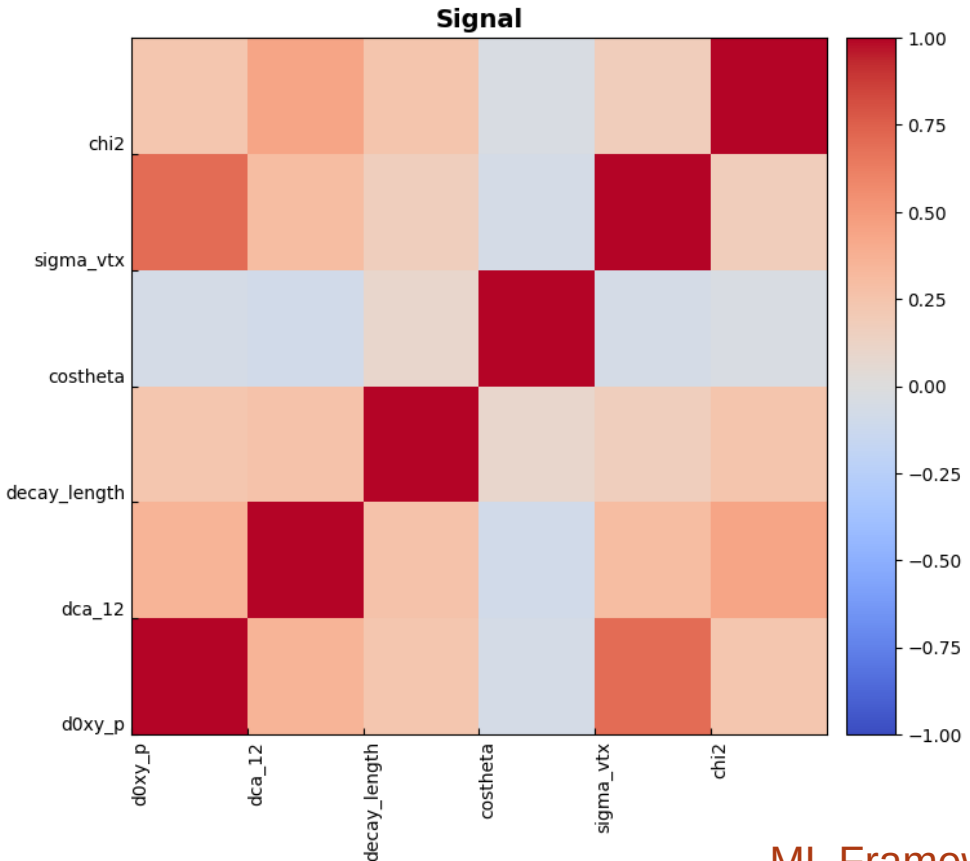
Preselections: ($m_{\Lambda c}$ > 1.8 && $m_{\Lambda c}$ < 2.8) && d_{0xy_p} < 100.0 && d_{0xy_pi} < 100.0 && d_{0xy_k} < 100.0 && chi2 < 100.0

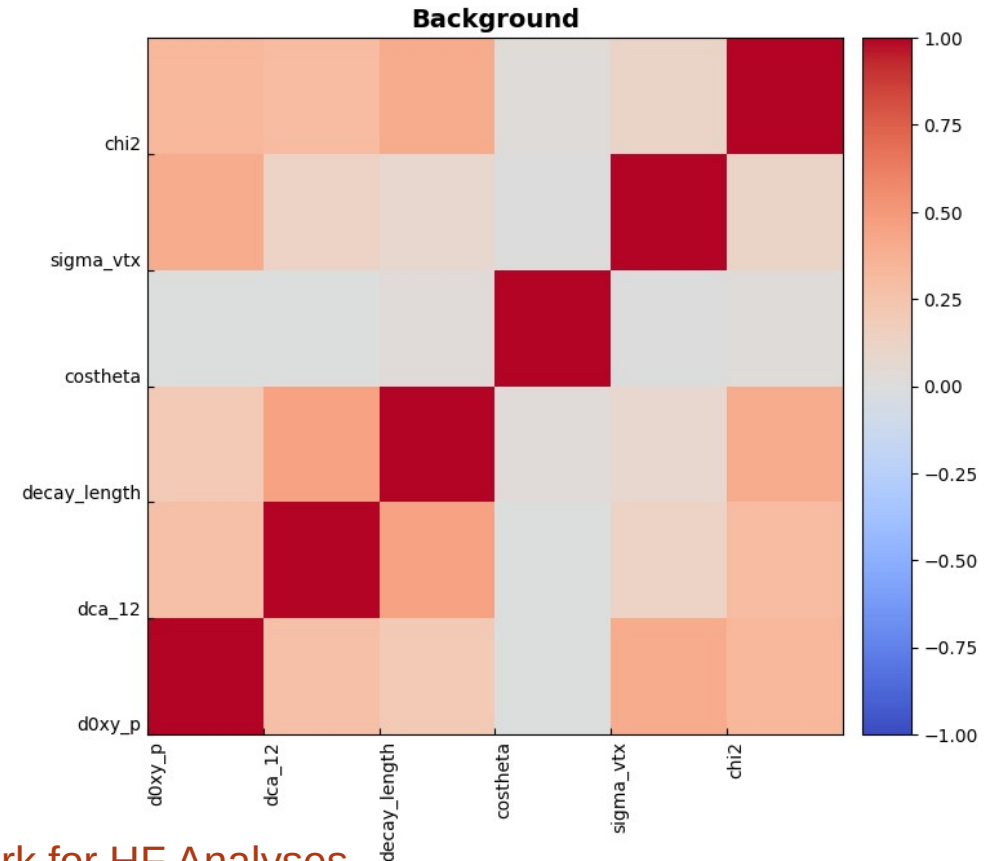
-1 < $y_{\Lambda c}$ < 1, 0 < p_T (Λ_c) < 10 GeV/c



Correlation Matrix

Features used in the training for the Machine learning (ML)
Signal candidates for ML: 5243 Background candidates for ML: 5243



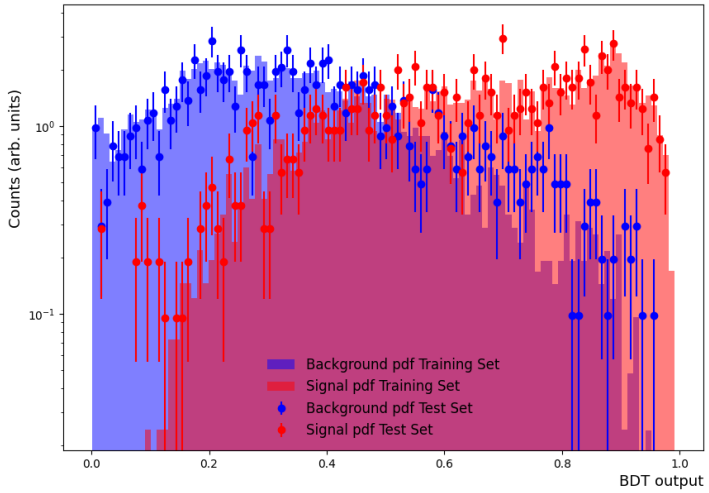


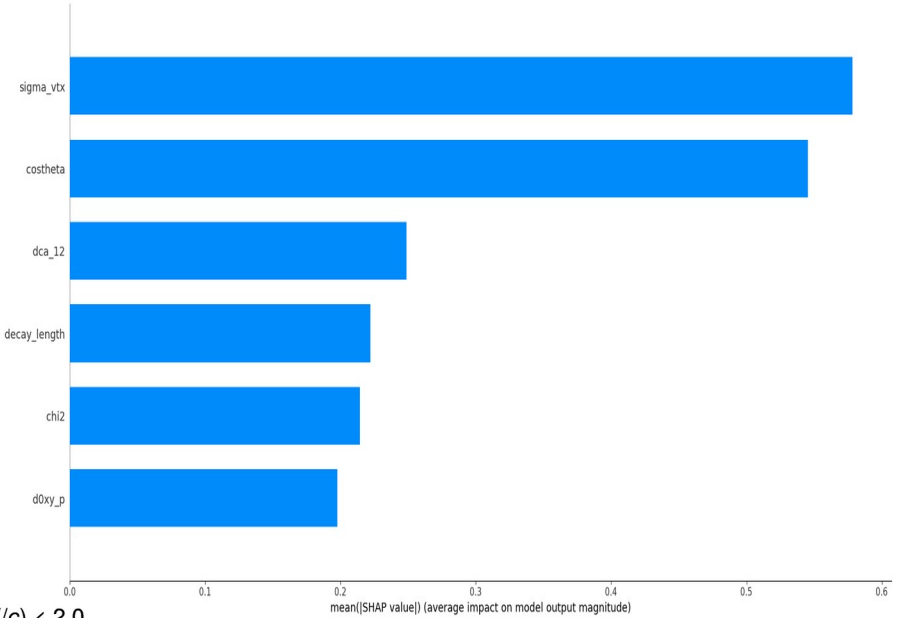
ML Framework for HF Analyses

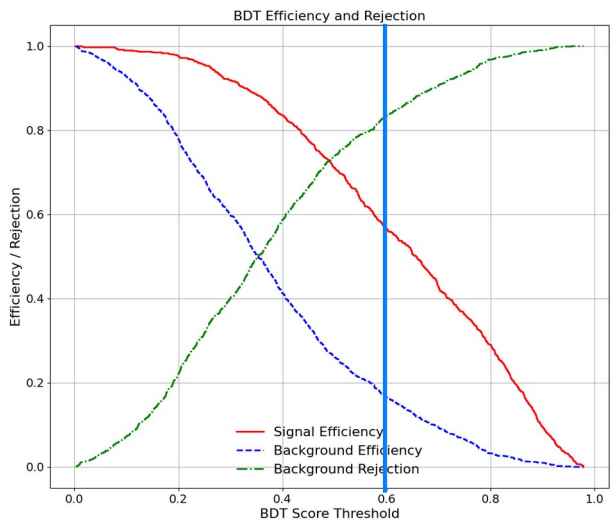
FAIR (Future Artificial Intelligence Research) Spoke 6 Project, funded by the NextGenerationEU program in Italy

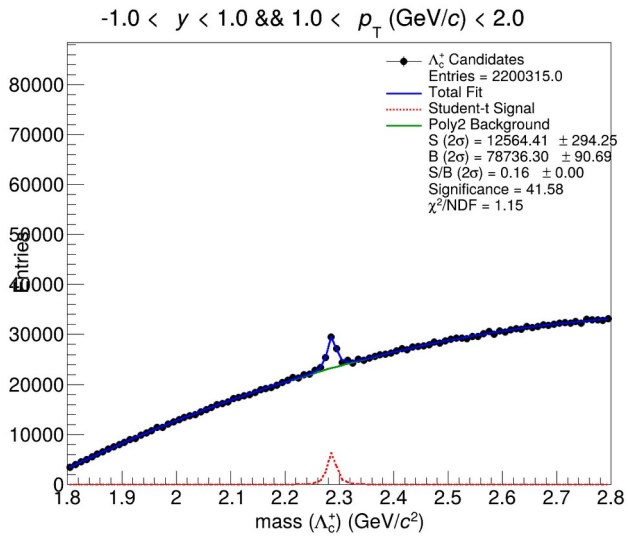
Machine Learning (ML) Training Results

$-1 < y_{\Lambda c} < 1$, $0 < p_T(\Lambda_c) < 10$ GeV/c









ϵ_{sig} ~0.57, ϵ_{bkg} ~0.17

$$\left(\frac{S}{B}\right)_{ML} = \left(\frac{S}{B}\right)_{presel} \times \left(\frac{\epsilon_{sig}}{\epsilon_{bkg}}\right) \sim 0.54$$

$$\text{Signif}_{ML} = \frac{S \times \epsilon_{sig}}{\sqrt{(S \times \epsilon_{sig} + B \times \epsilon_{bkg})}} \sim 50$$

Summary and Future Plan

- Presented the results on Λ_c^+ reconstruction with truth as welll as real PID
- There is a large combinatorial background at low momentum
- Structure also visible in the mass plots most probably related to higher excited charm hadrons
- Further optimize ML to improve the results in different rapidity and momentum bins

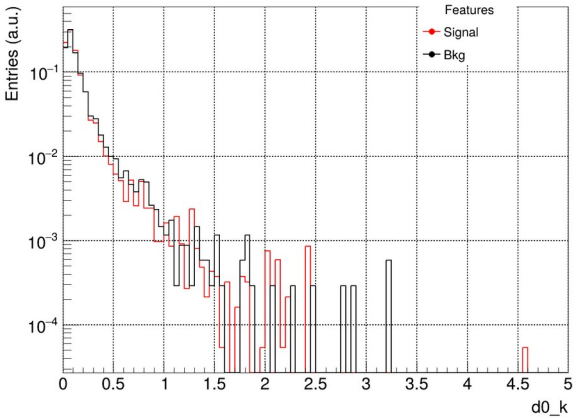
Thank you for your attention!

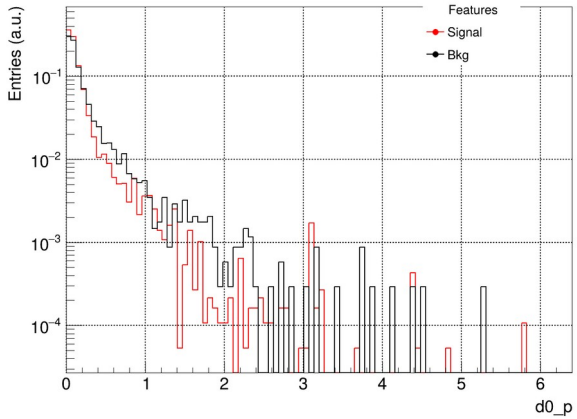
Topological features

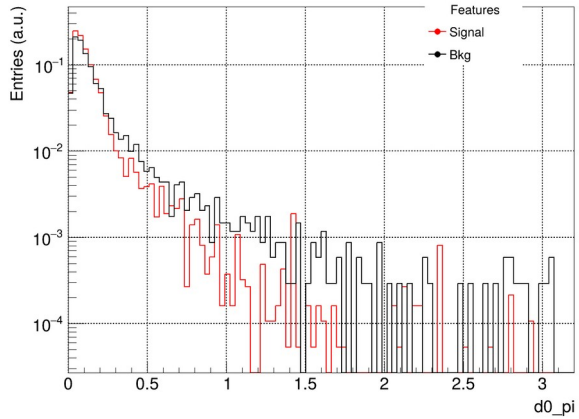
Signal pairs

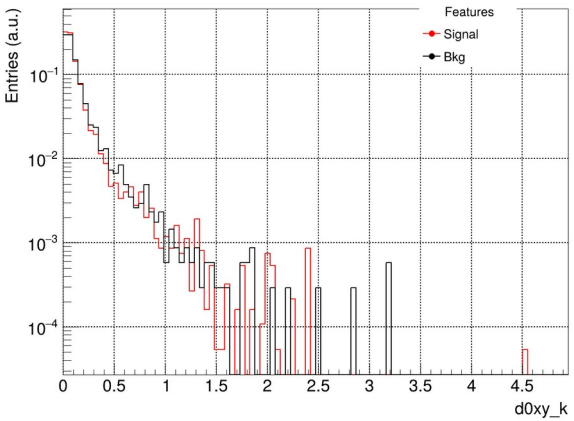
Bkg pairs

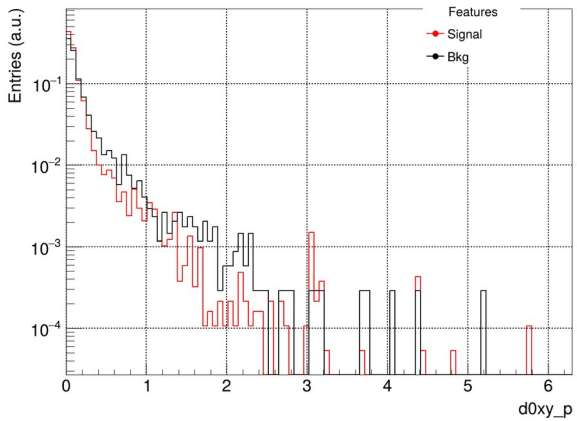
$y \in [-1,1], p_T \in [1,2]\,\mathrm{GeV}/c$

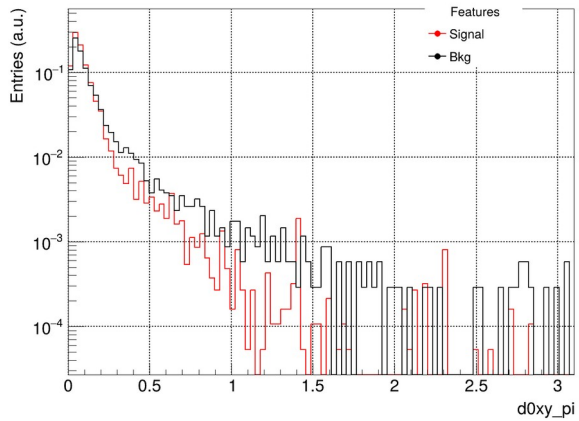










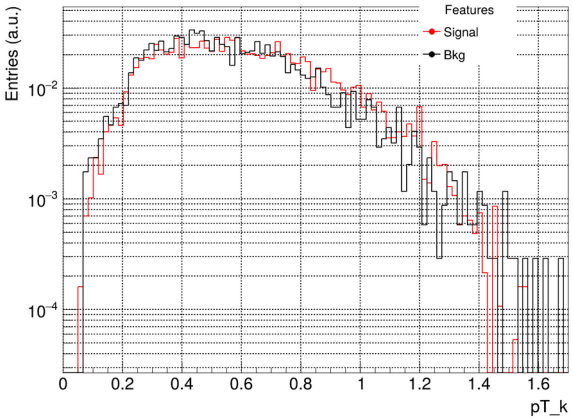


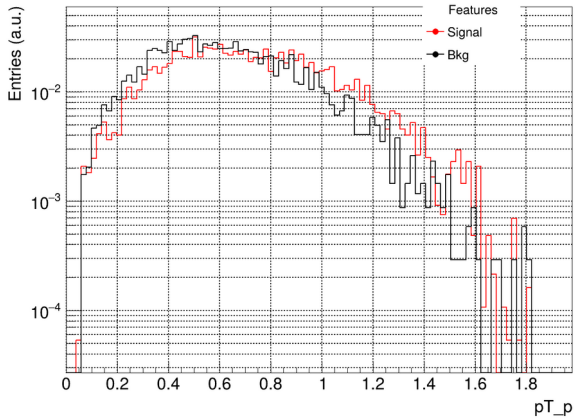
Topological features

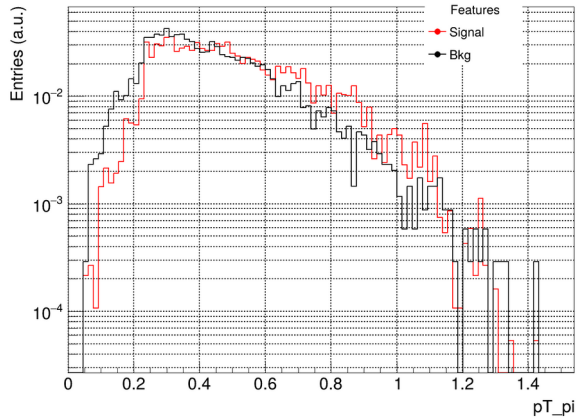
Signal pairs

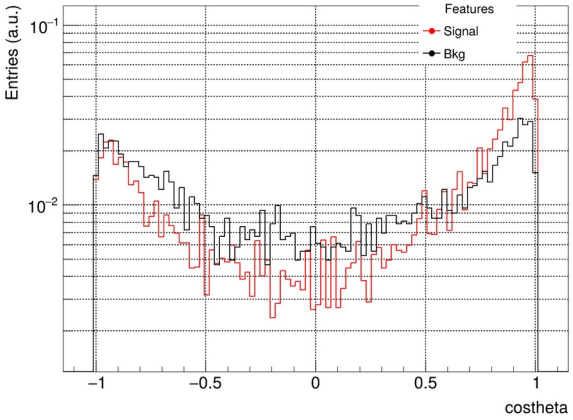
Bkg pairs

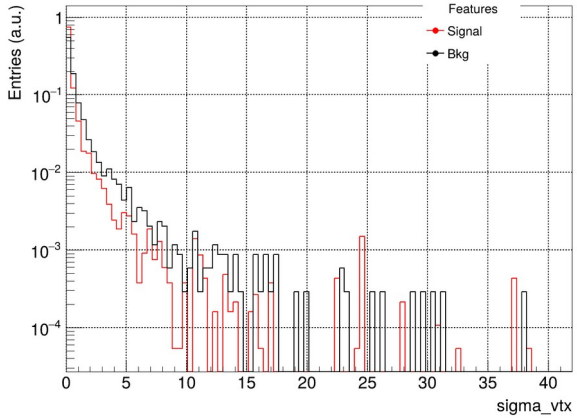
$y \in [-1,1], p_T \in [1,2]\,\mathrm{GeV}/c$

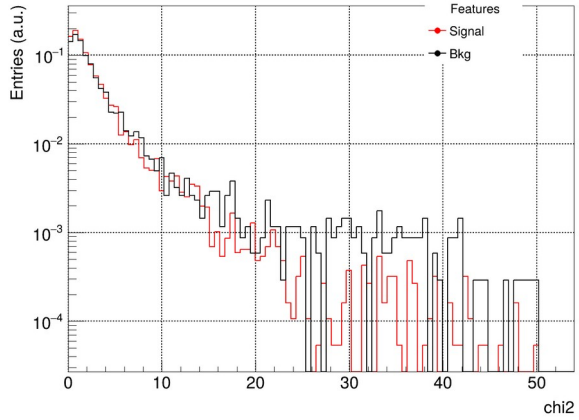










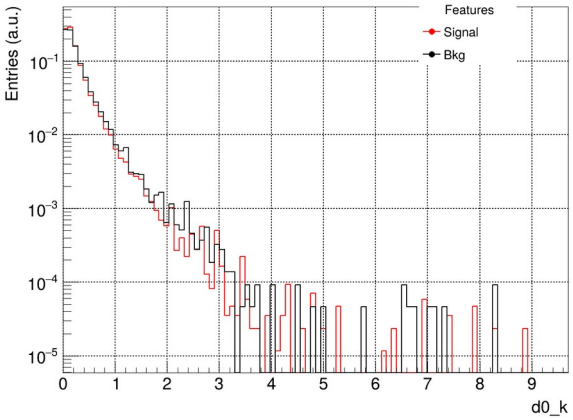


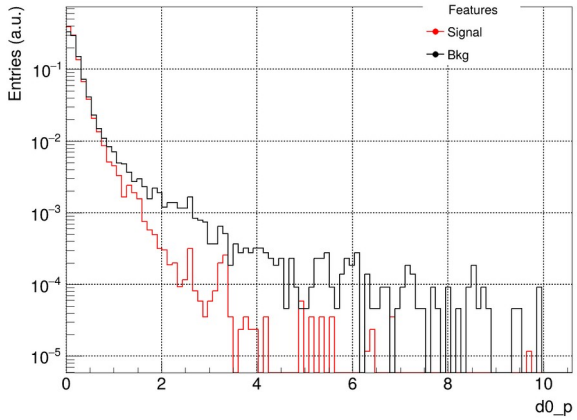
Topological features

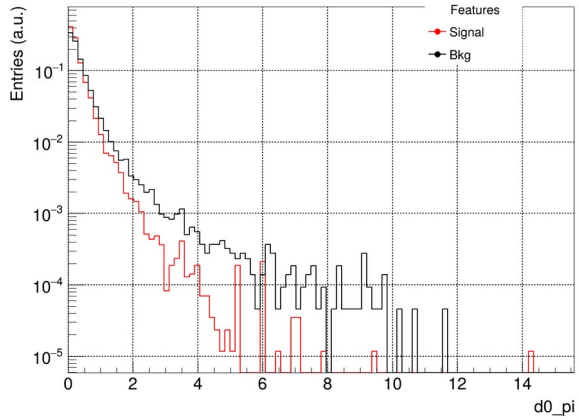
Signal pairs

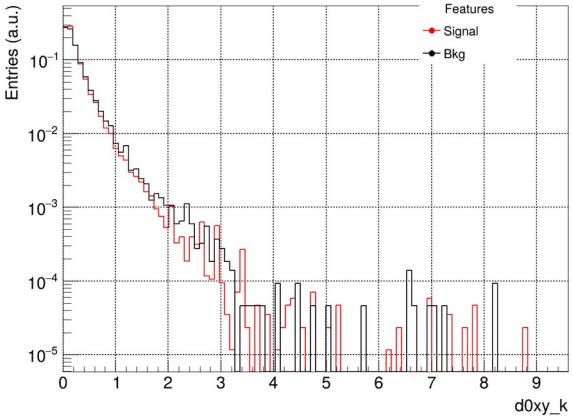
Bkg pairs

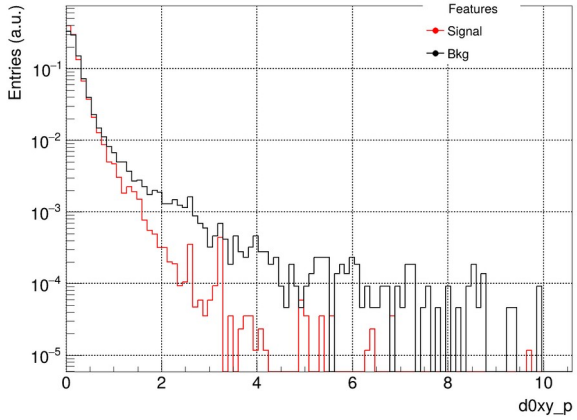
$y \in [1,3], p_T \in [1,2] \mathrm{GeV}/c$

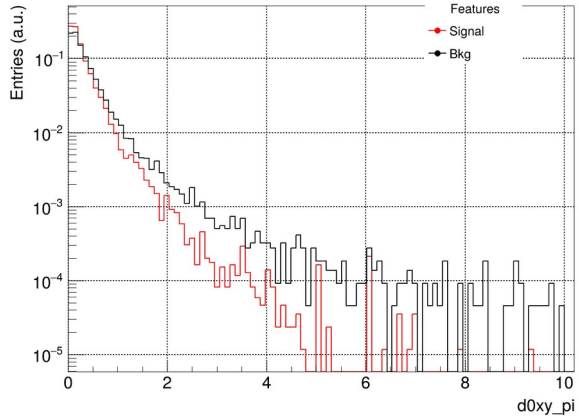










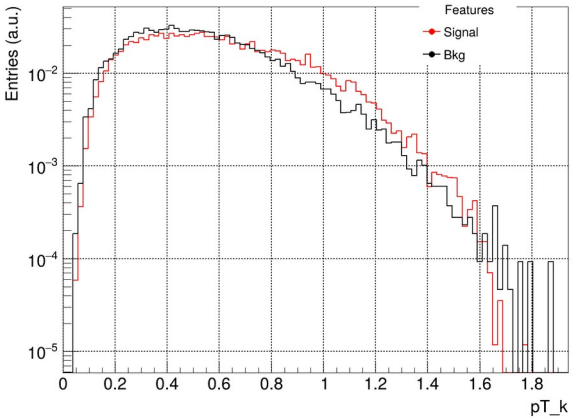


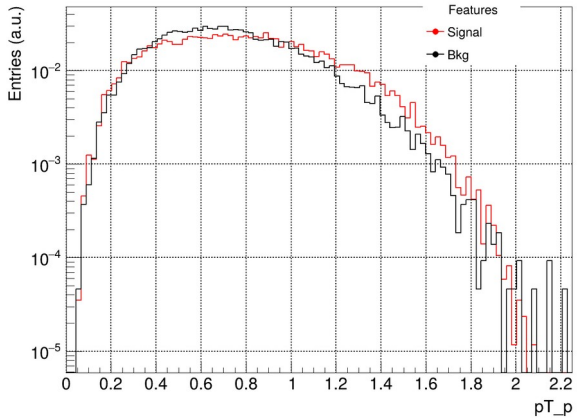
Topological features

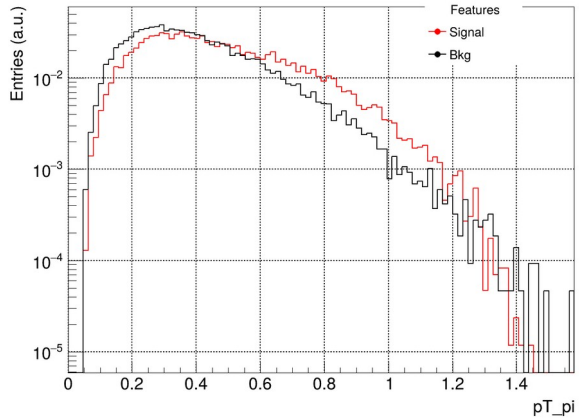
Signal pairs

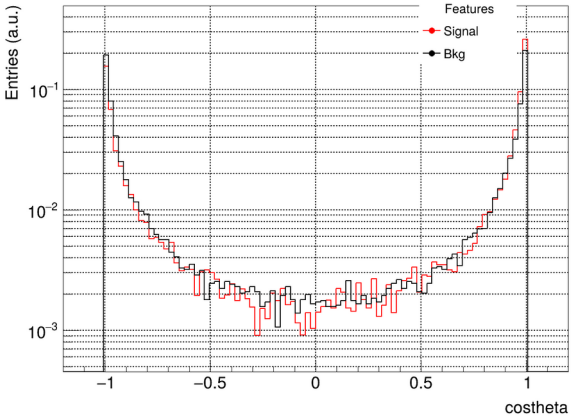
Bkg pairs

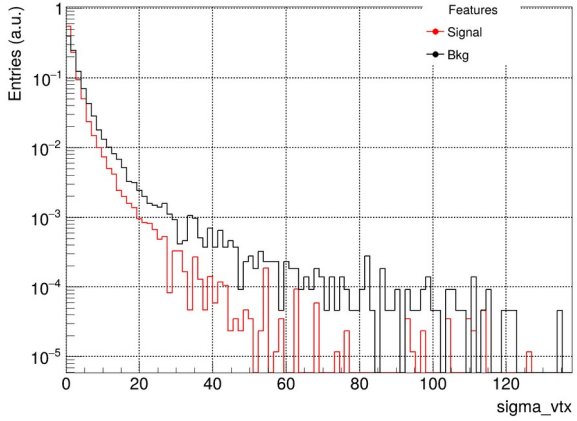
$y \in [1,3], p_T \in [1,2] \mathrm{GeV}/c$

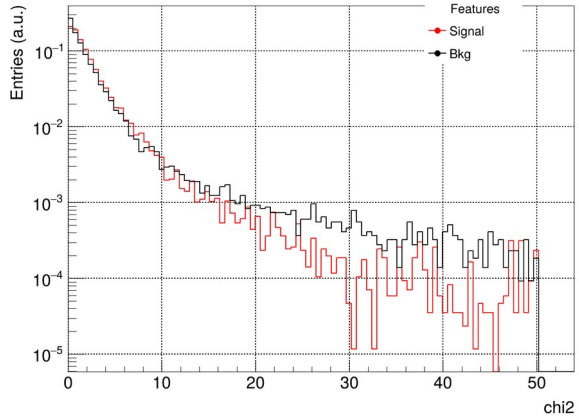




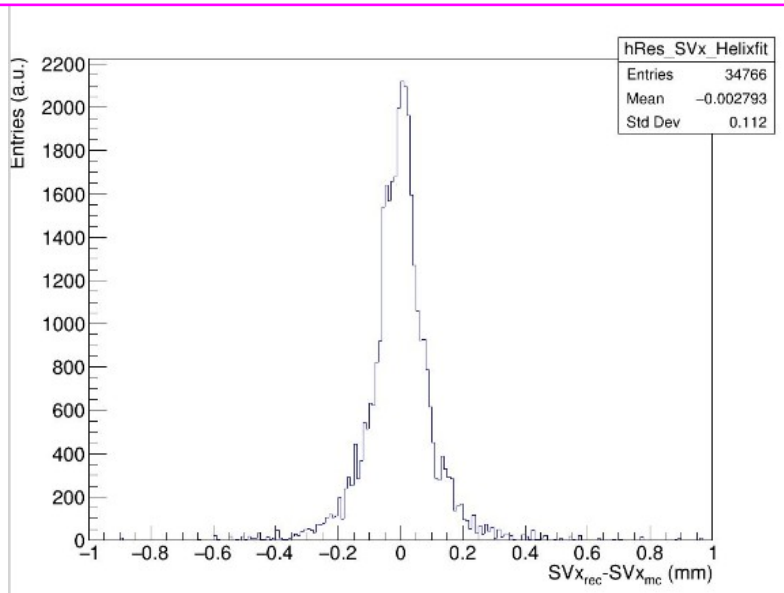


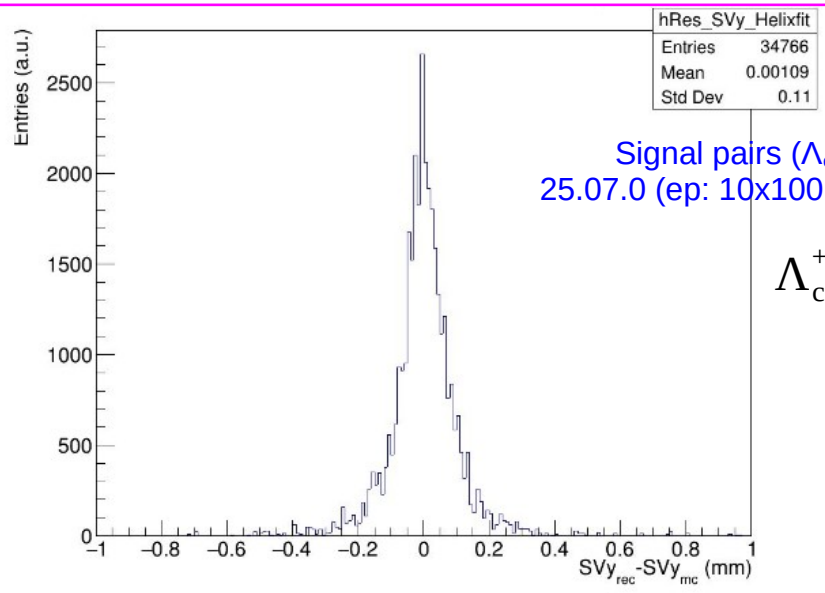






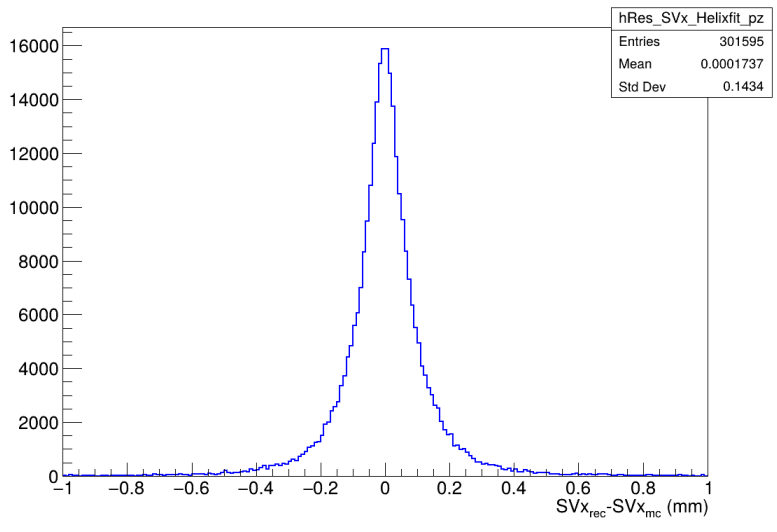
Secondary Vertex Resolution

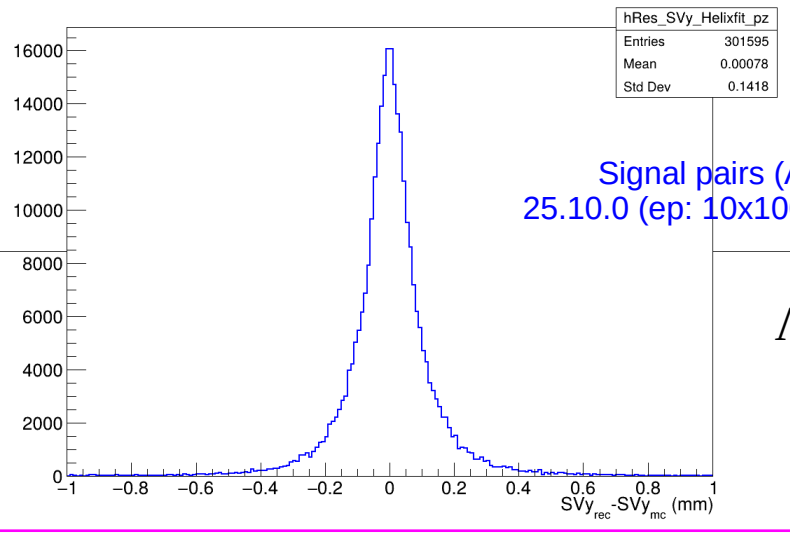




Signal pairs (Λ_c baryon)
25.07.0 (ep: 10x100, $Q^2 > 1$ GeV^2)

$\Lambda_c^+ \rightarrow p K^- \pi^+$





Signal pairs (Λ_c baryon)
25.10.0 (ep: 10x100, $Q^2 > 1$ GeV^2)

$\Lambda_c^+ \rightarrow p K^- \pi^+$