Possibilities of Measuring $\eta_C \to p\bar{p}$ at SPD

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PYTHIA Details

- $m_{\eta_C} = 2.984$ GeV$/c^2$, BR $(\eta_C \to p\bar{p})$: 1.45×10^{-3}
- PYTHIA does not hadronize η_c. *J/Ψ used instead for study*
- 1 Million signal and 10 Billions MB events were produced
- Signal events normalized to 600K (expected events : SPD CDR) for one year of data at design luminosity
- Normalized to 39800 B MinBias events (39.8 mb cross-section at $\sqrt{s} = 27$ GeV, 1 fb^{-1} integrated luminosity)
- Momentum resolution used : $\frac{\delta p}{p} = 0.02 + 0.002p$
- This an update with some cross-checks and higher statistics background study

Invariant Mass Distributions

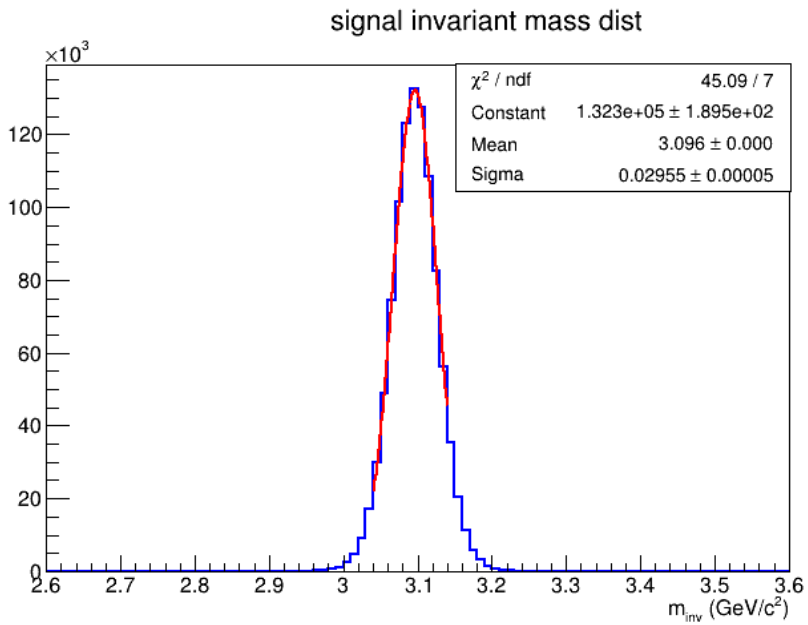


Figure 1: Overall invariant mass distribution of signal

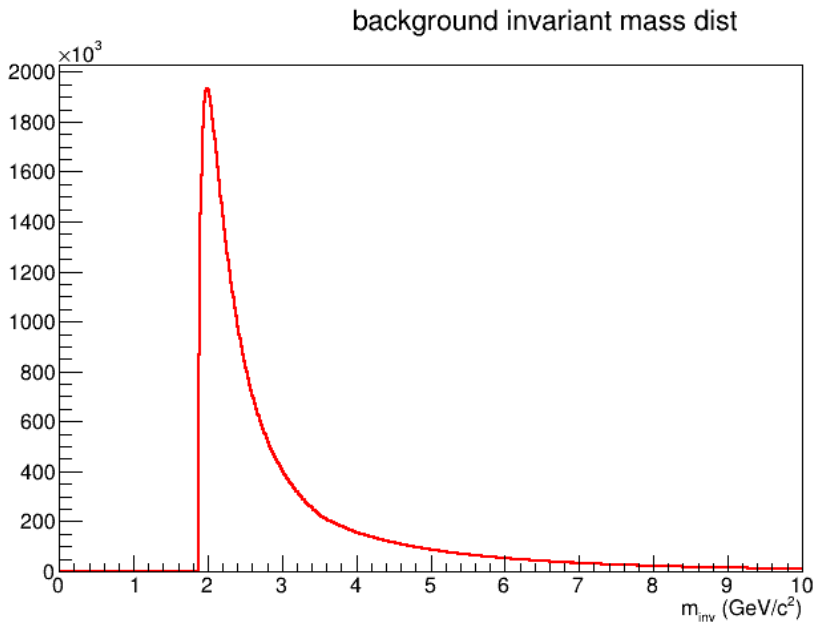


Figure 2: Overall invariant mass distribution of background

Three Differentiating Criteria

- Transverse momentum of daughter particles : plays the most prominent role in reducing background as distributions from signal are wider while the ones from random background are steeper and narrower
- Polar angles of daughter candidates : signal distributions are mostly flat whereas background distributions are heavily peaked at very forward and backward directions
- Opening angles between daughter candidates : signal tend to have acute angles whereas background have obtuse angles

Illustrating the Largest Difference

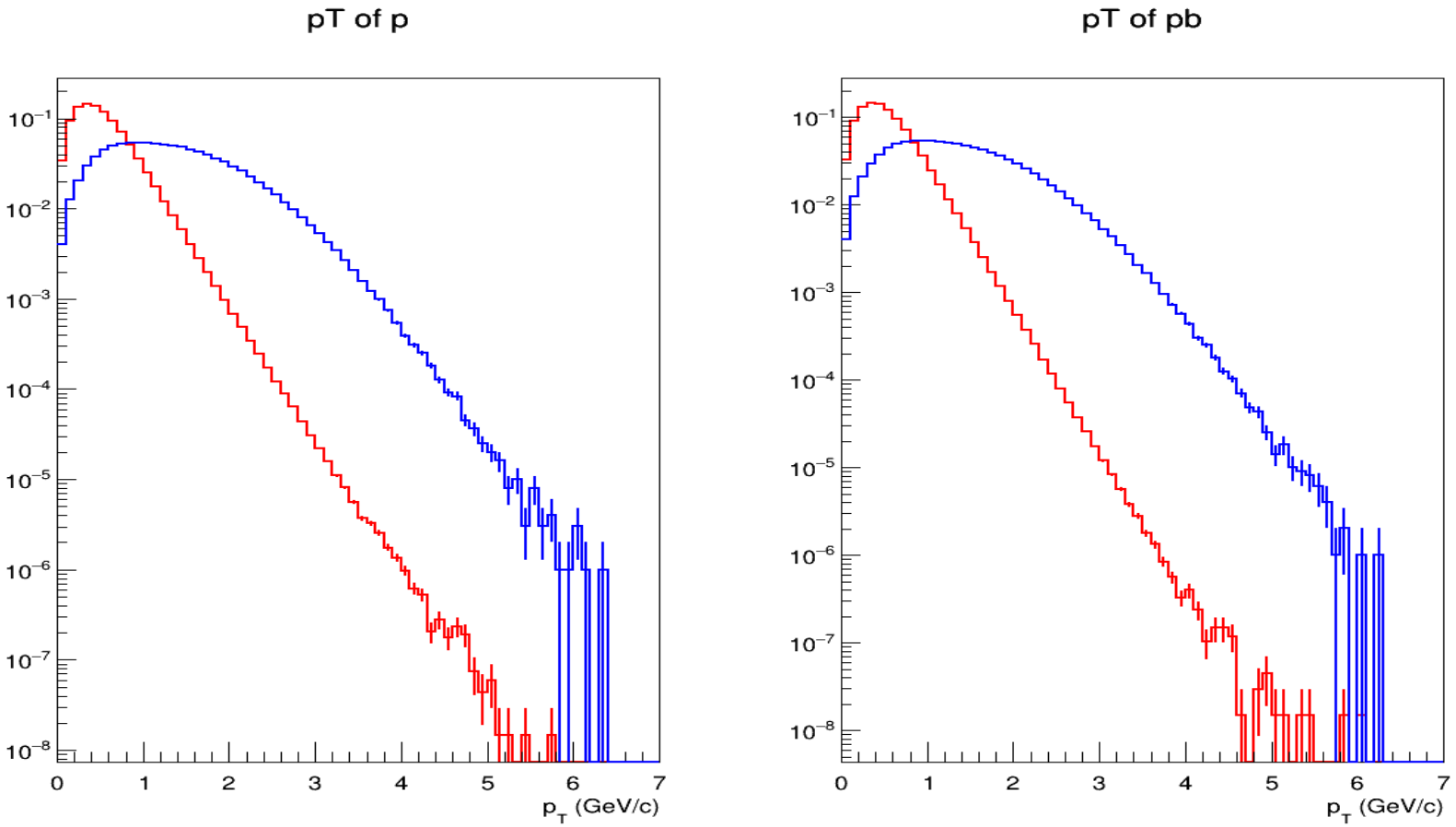


Figure 3: Transverse momentum of p (left) and $\bar{p}$ (right) : signal, background

Cuts For Sig/Bkg Study

- To clear multiple/other decays, events with single anti-protons are considered only
- Different daughter candidate p_T cuts used with fixed polar and opening angle cuts
- set 1 : $p_T > 0.2$ GeV, $-3. < y < 3.$, $45^0 < \theta_{p,\bar{p}} < 135^0$, $cos(\alpha) > 0.$
- set 2 : $p_T > 0.5$ GeV, $-3. < y < 3.$, $45^0 < \theta_{p,\bar{p}} < 135^0$, $cos(\alpha) > 0.$
- set 3 : $p_T > 1.0$ GeV, $-3. < y < 3.$, $45^0 < \theta_{p,\bar{p}} < 135^0$, $cos(\alpha) > 0.$
- set 4 : $p_T > 2.0$ GeV, $-3. < y < 3.$, $45^0 < \theta_{p,\bar{p}} < 135^0$, $cos(\alpha) > 0.$

Signal and Background : One Year of Data

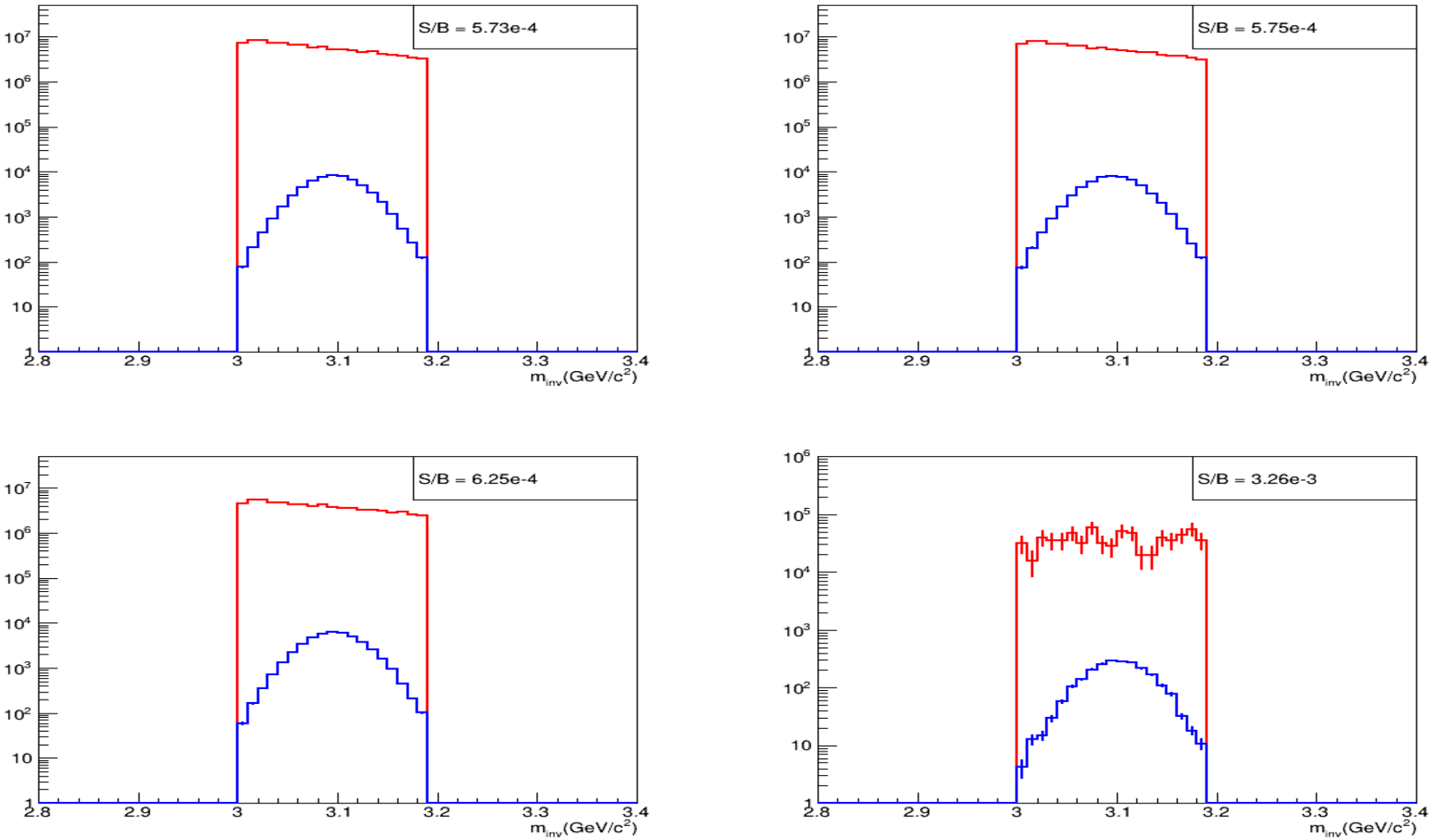


Figure 4: Invariant mass (within 3σ window of signal peak) for four different cut sets : signal, background

Crosscheck with Nikita Trubnov's Study

Nikita used different combinations of the following cuts :

- invariant particle p_T
- invariant particle polar angle $cos(\theta)$
- opening angle of daughter candidates $cos(\alpha_o)$
- relative momentum asymmetry between daughter candidates $\alpha = \frac{P_p - P_{\bar{p}}}{P_p + P_{\bar{p}}}$

Cross-checked cut sets :

1. $p_T > 2$ GeV, $\alpha < 0.6$: sig/bkg $= 1.14 * 10^{-4}$
2. $p_T > 3$ GeV, $\alpha < 0.6$: sig/bkg $= 2.76 * 10^{-4}$

Crosscheck with Previous Study

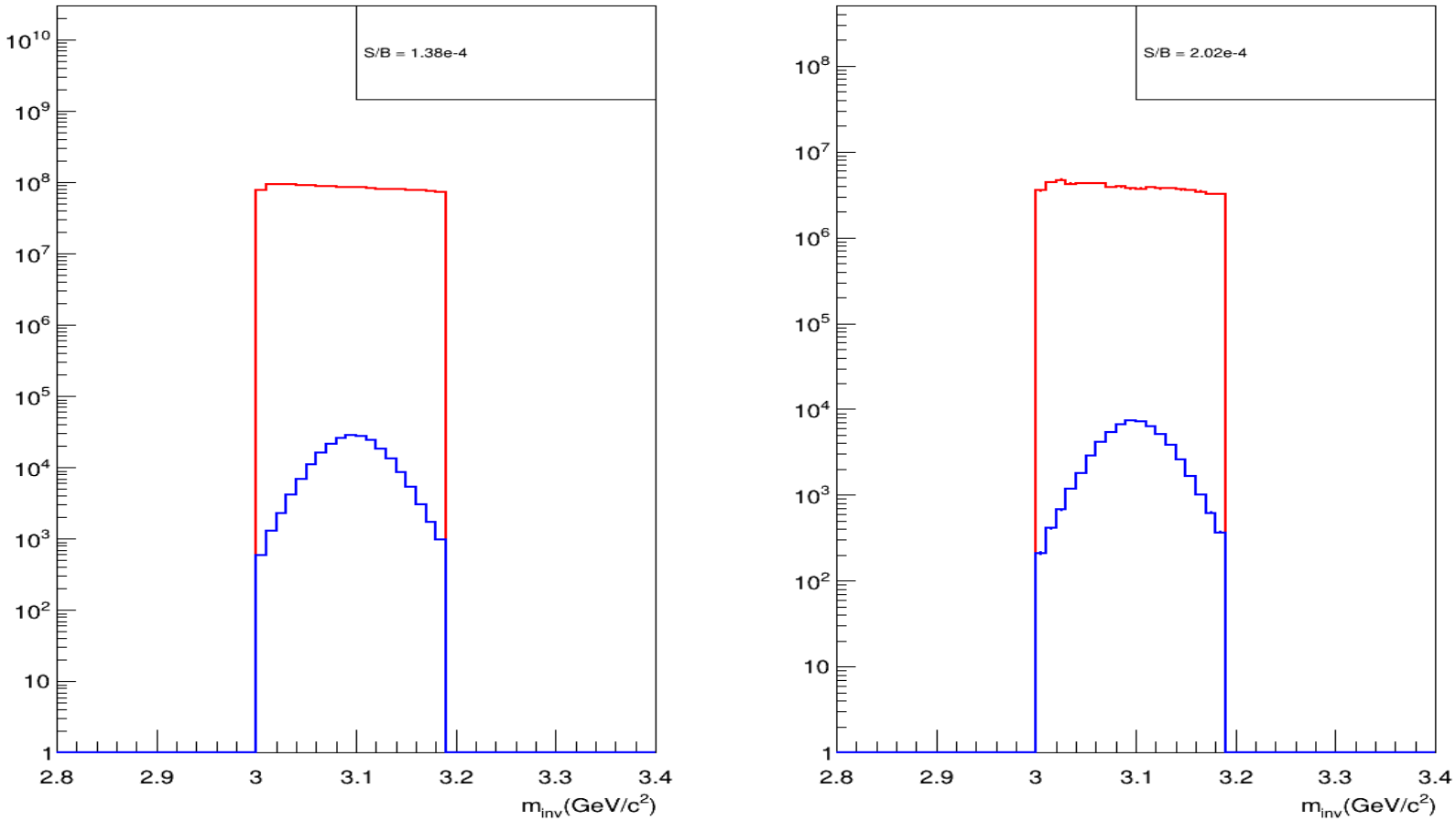


Figure 5: Invariant mass (within 3σ window of signal peak) for Nikita's cut sets : signal, background. Similar S/B ratios

Signal and Background : One Year of Data

	p_T^{min}	Signal	Background	Sig/Bkg	Stat. Sig.
	(GeV/c)	(S)	(B)	S/B	$(S/\sqrt{B})$
cut 1	0.2	61224	1.07×10^8	5.73×10^{-4}	5.92
cut 2	0.5	59301	1.03×10^8	5.75×10^{-4}	5.84
cut 3	1.0	46008	7.36×10^7	6.25×10^{-4}	5.36
cut 4	2.0	2311	7.08×10^5	3.26×10^{-3}	2.75

Table 1: For one year of $\eta_c \rightarrow p\bar{p}$ data at design luminosity : signal and background counts, ratios and statistical significances

Signal η_C Transverse Momentum Distributions

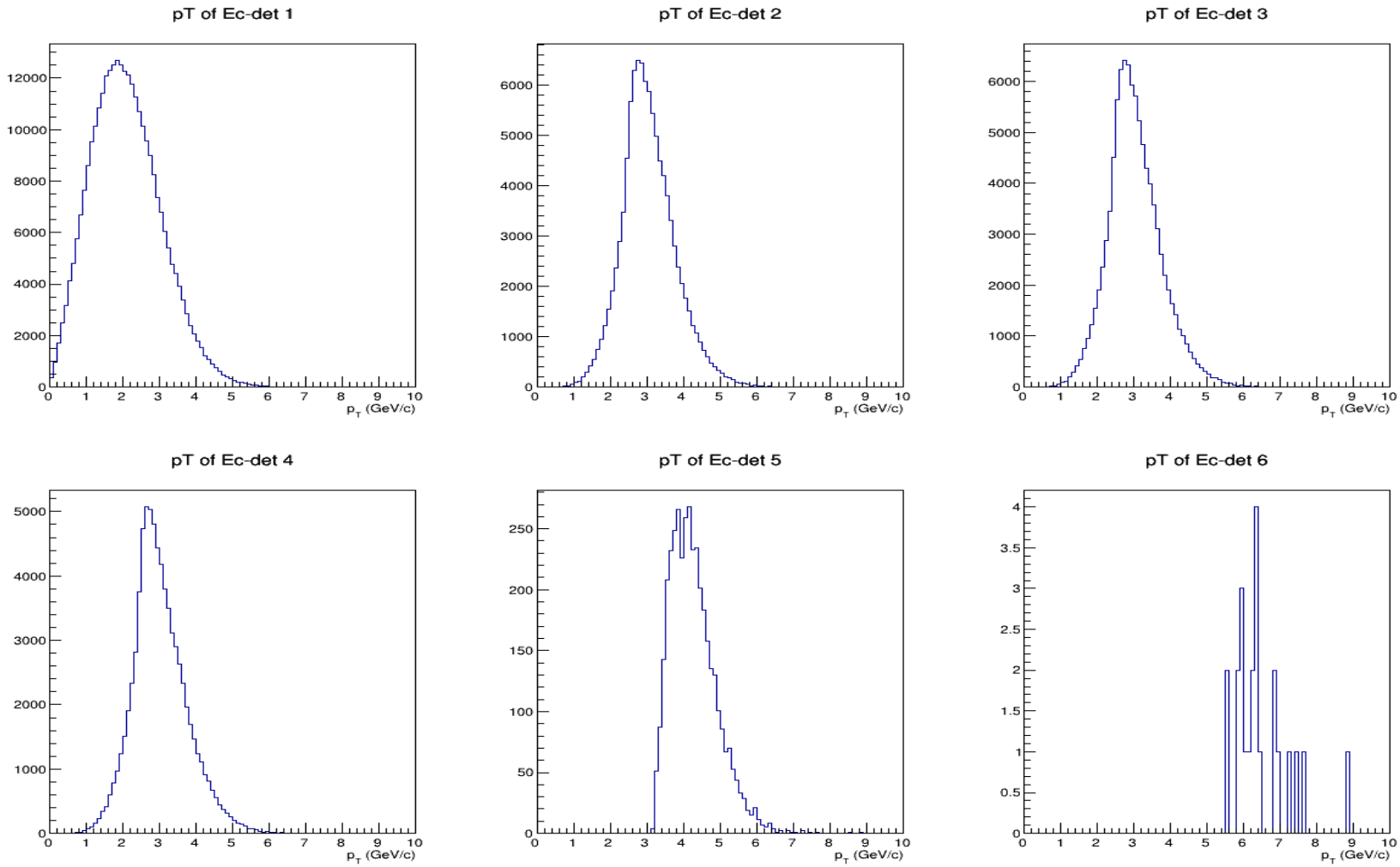


Figure 6: Transverse momentum distributions. Last plot ($p_T > 3$ GeV) added to illustrate impact of further daughter p_T cut on sigal counts

Outlook

- Daughter candidate p_T provides major tool to suppress background, best S/B $\sim 3 * 10^{-3}$
- Beyond $p_T = 2$ GeV/c, drastically reduces signal too, making measurement untenable
- Expect to detect a few thousand η_C candidates (depending on cuts) in a year's data at design luminosity
- Particle identification capability will affect the measurements ($p, \bar{p}$ candidates)
- High p_T η_C candidates could in fact be better for interpretation (firmly in the perturbative QCD regime)
- Cross-section measurements (combined different channels, multiple years of data) seems posisble at this stage
- Shall write an internal analysis note on the study

Thank You

Backup

Polar Angle : Protons

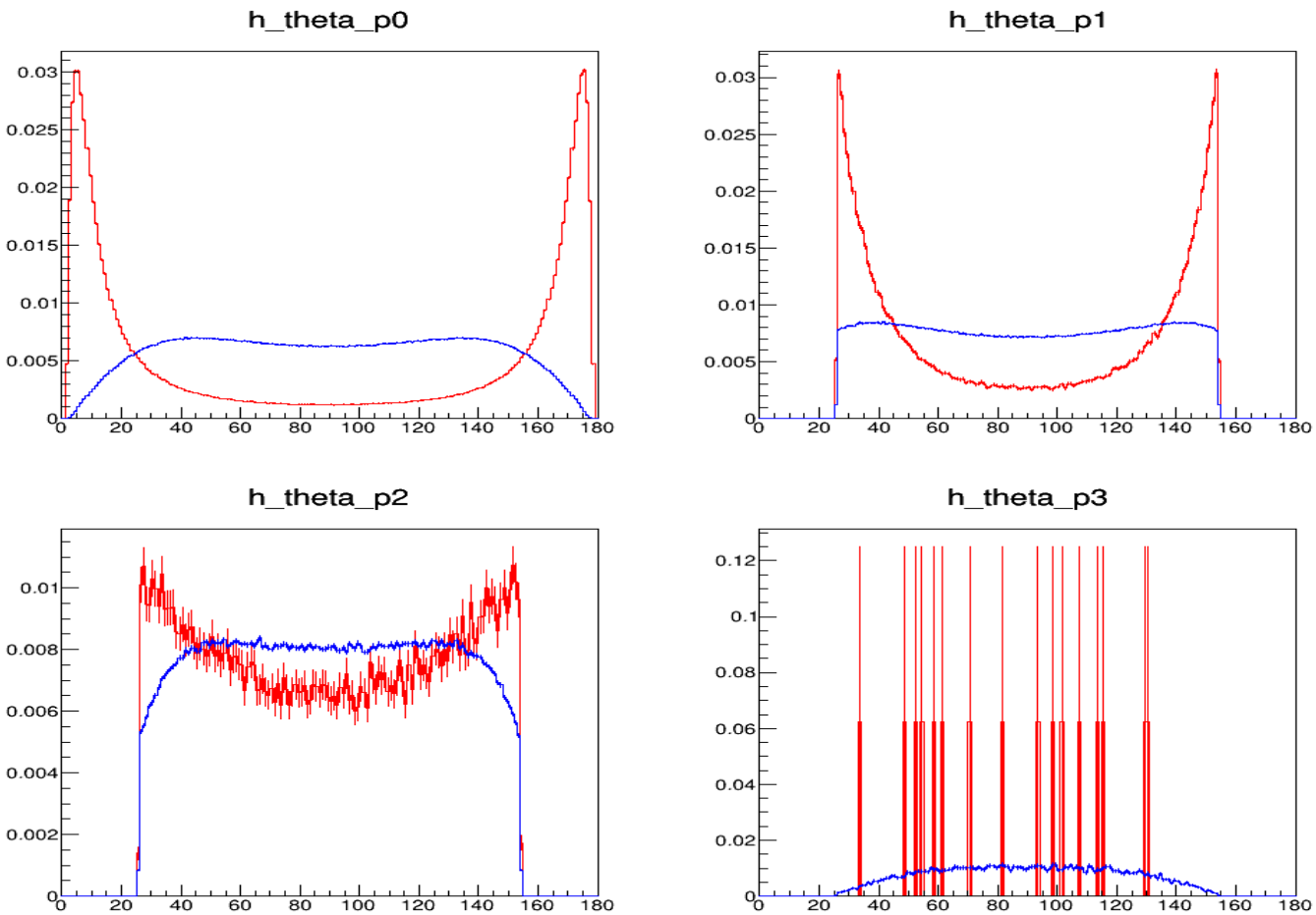
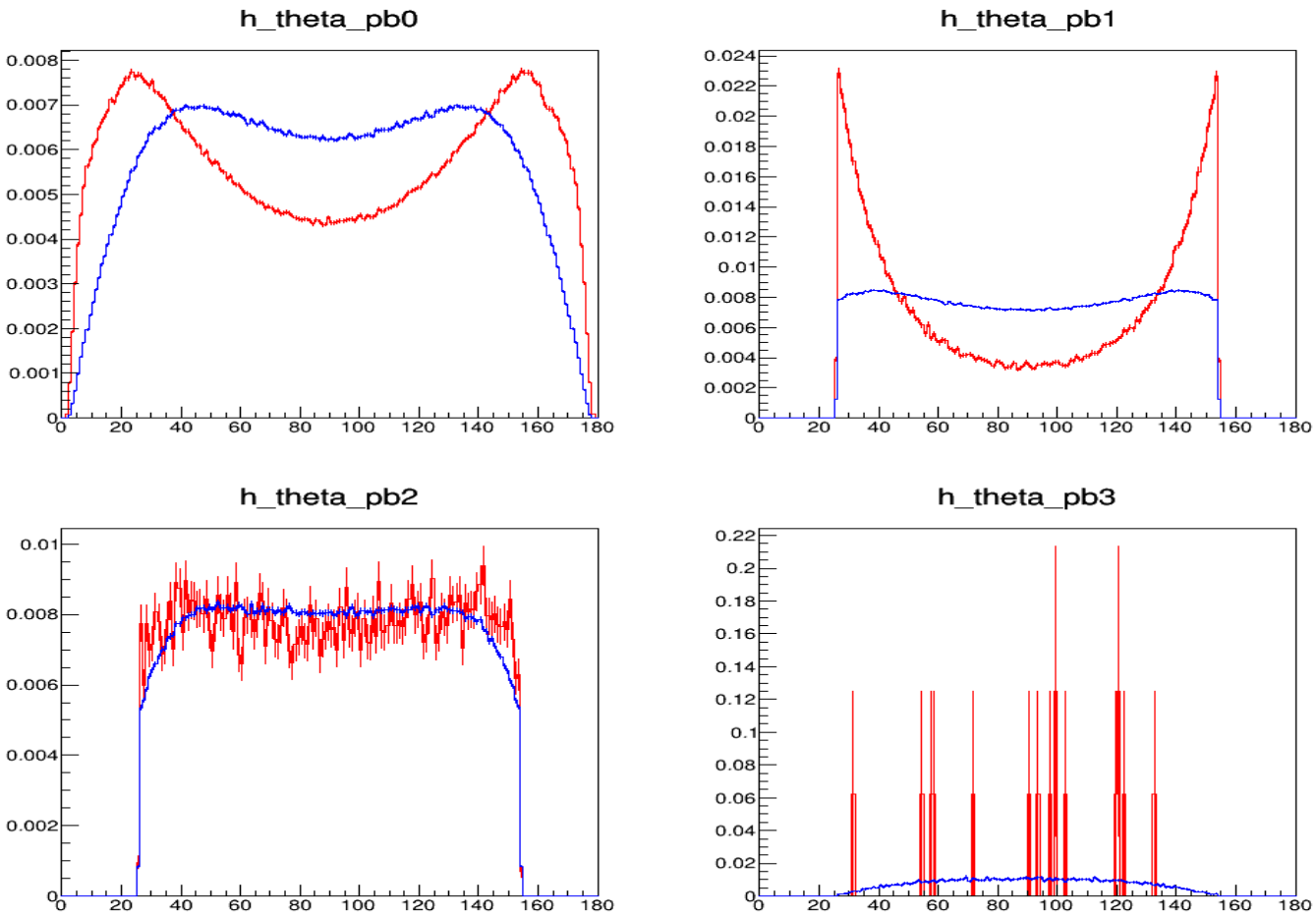


Figure 7: Polar angle (θ) of p in degrees: signal, background

- Mostly fwd and bkwd protons
- Cuts down as we require higher p_T
- More bkg protons as we move from mid-rapidity
- Decision : require $45^0 \leq \theta \leq 135^0$ to cut on background and keep most of signal

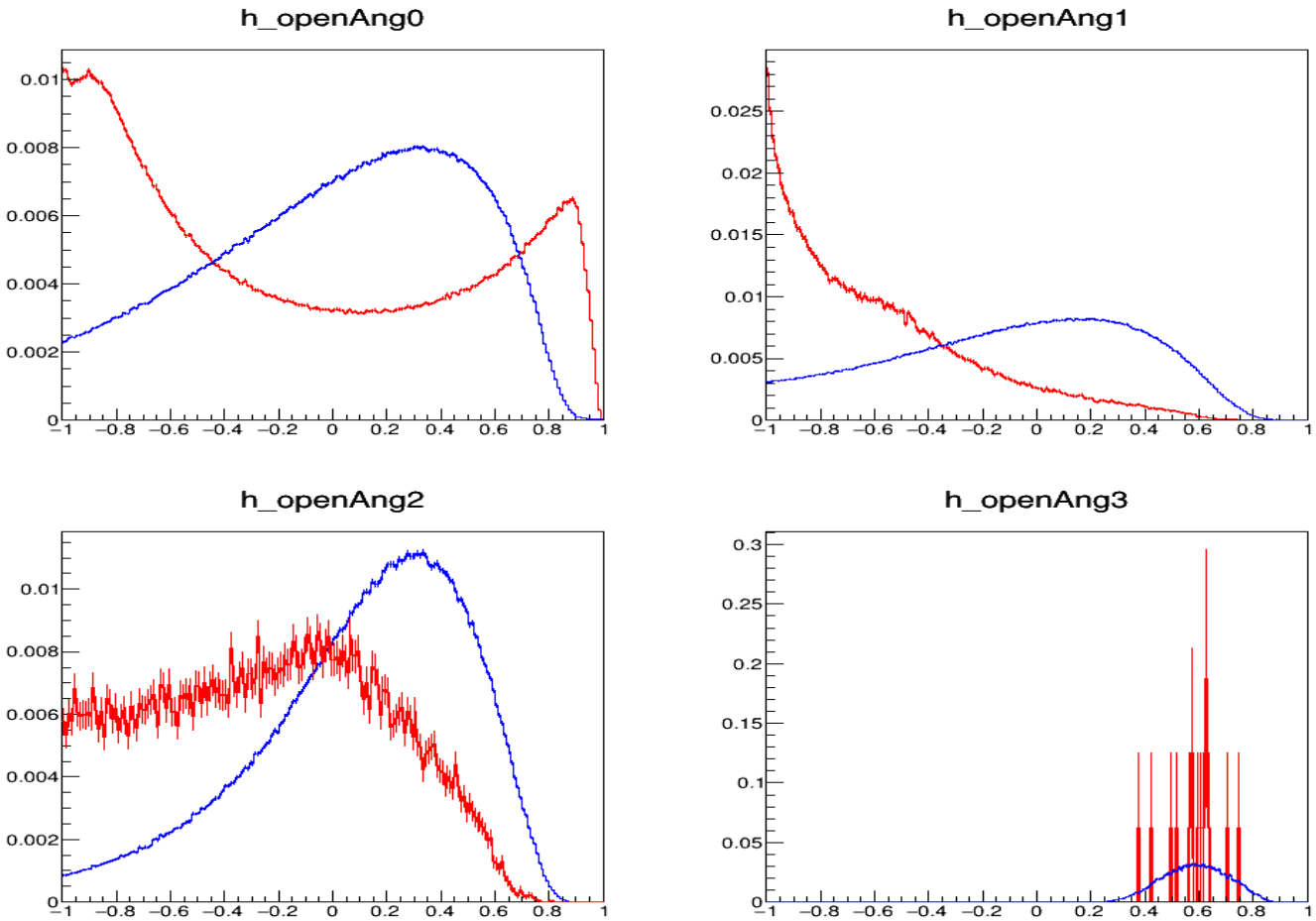
Polar Angle : Antirotons



- Similar pattern as for protons
- Similar cut introduced

Figure 8: Polar angle (θ) of $\bar{p}$ in degrees : signal, background

Opening Angle



- Many back to back combinations to start with
- Clear pattern for large angles for bkg
- Decision : require $cos(\alpha) > 0$.

Figure 9: Cosine of opening angle : signal, background

Invariant p_T

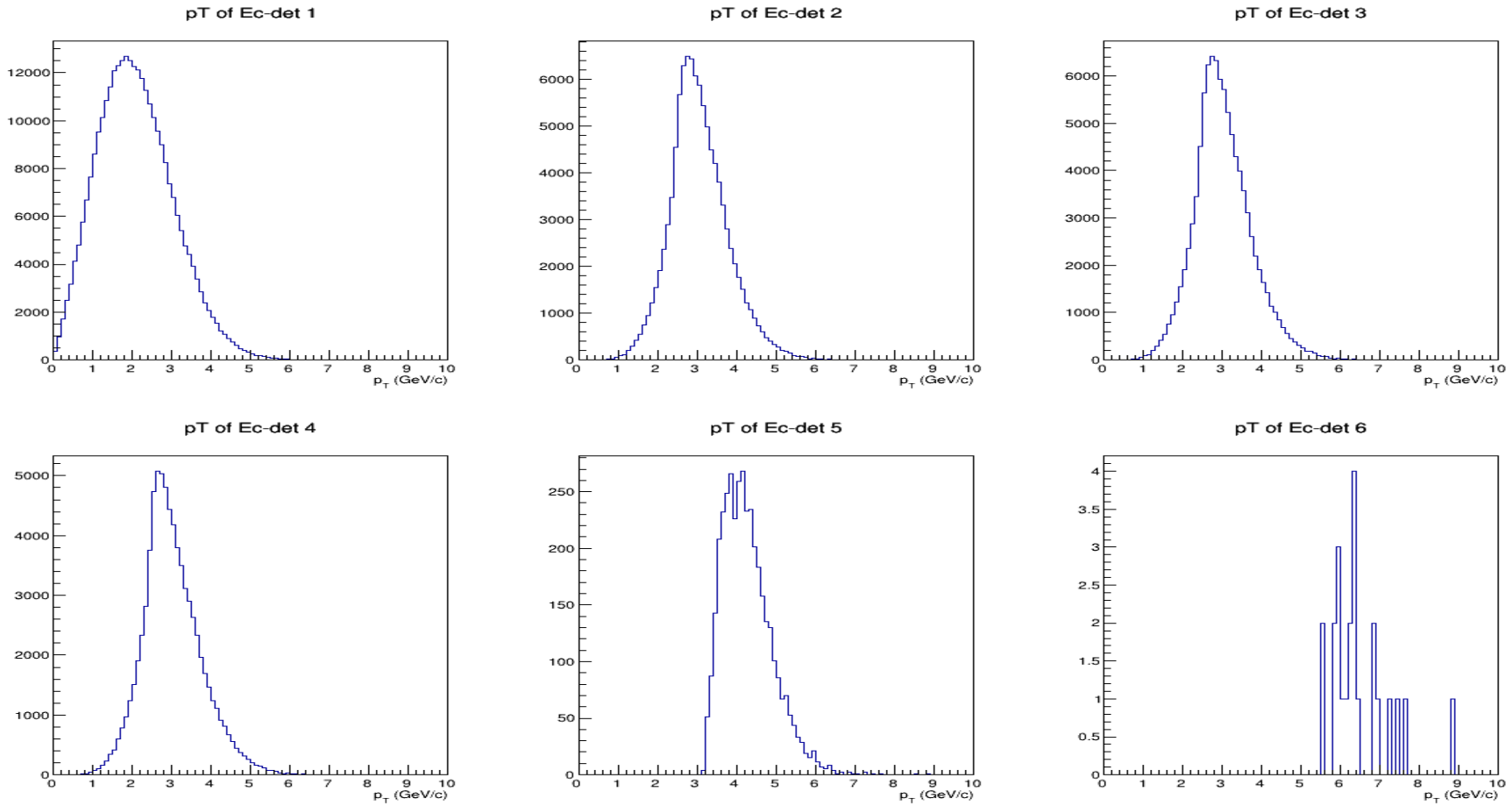


Figure 10: Invariant transverse momentum of signal particle

Invariant x_F

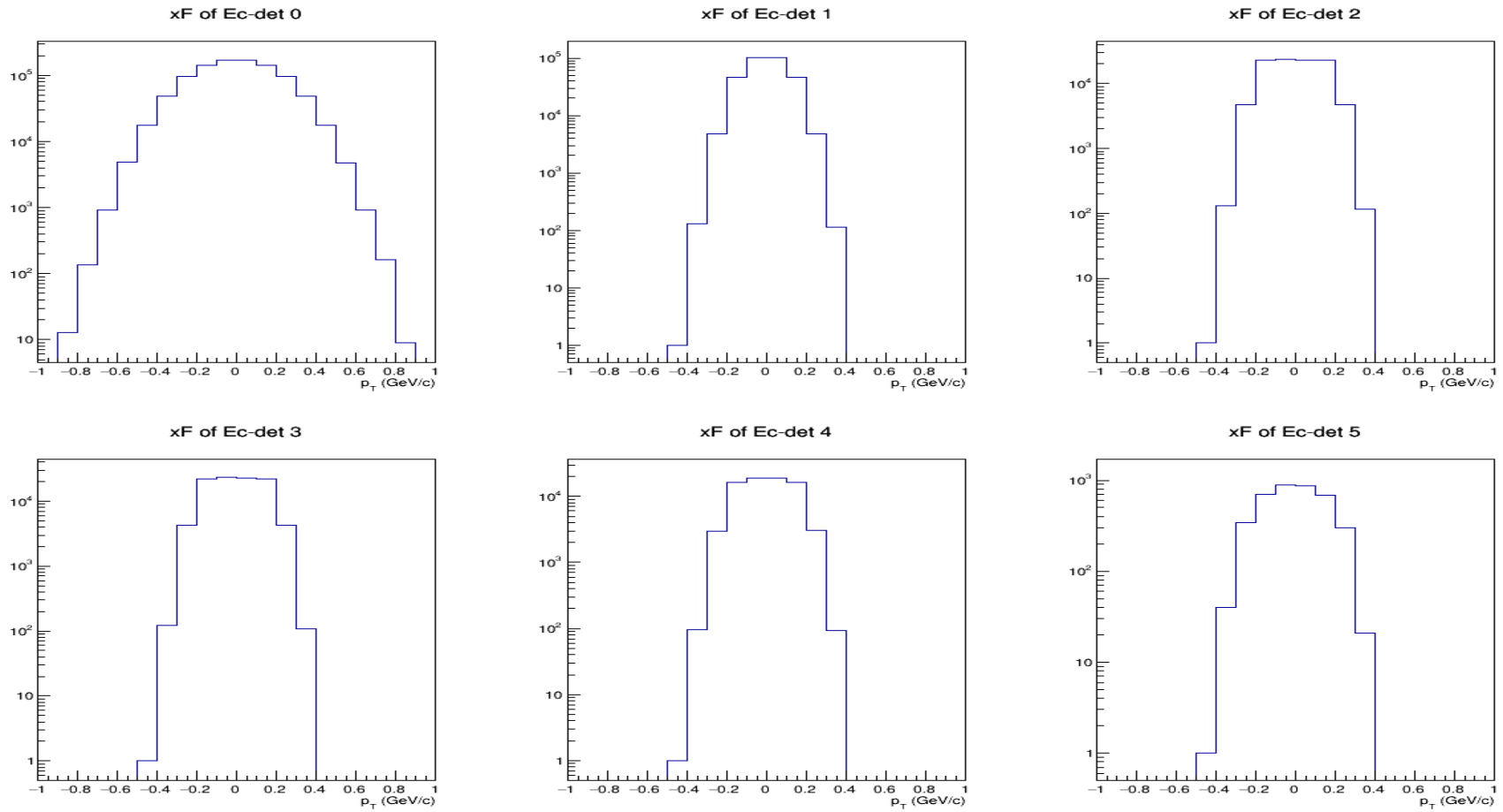


Figure 11: Feynman x of signal particle