TRACK-FINDING EFFICIENCY USING PARTIALLY RECONSTRUCTED D*$\longrightarrow$D0[K$\pi\pi\pi$]π DECAYS

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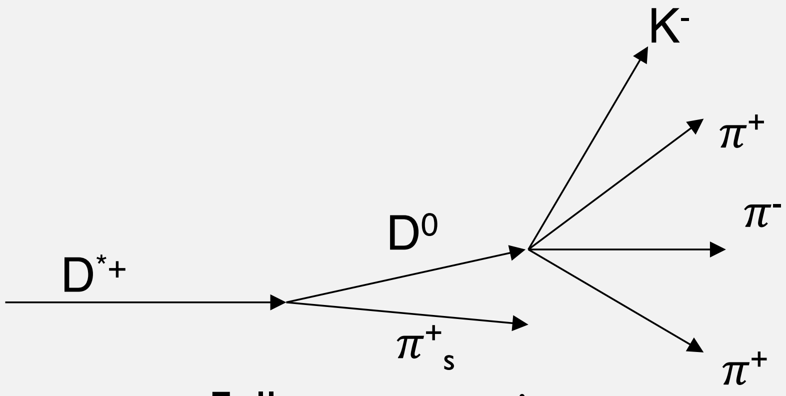
OUTLINE

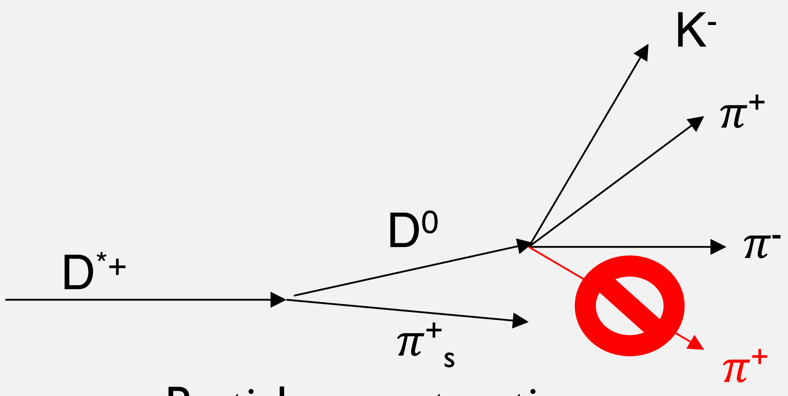
- April 2018 first physics data at Υ(4S) with only a slice of SVD.
- We started to explore whether we can assess Belle II track-finding efficiency using CDC data only.
- Today: initial findings from MC study based on partially reconstructed $D^* \longrightarrow D0[K\pi\pi\pi]\pi$ decays. (Byproduct: might get us an early-data assessment of performance for benchmark charm physics channels)

METHOD

- Use $D^{*+} \rightarrow D^0(\rightarrow 4 \text{ charged tracks})\pi_s^+$ decay. Sufficient kinematic constraints to reconstruct this decay even if one of the D^0 tracks is missed: $M(D^{*\pm})$ 2010.26 ± 0.07 MeV $M(D^0)$ = 1864.84 ± 0.07 MeV $M(\pi^\pm)$ = 139.57018 ± 0.00035 MeV Q < 20 MeV.
- BF(D*⟶D0[K$\pi\pi\pi$]π) = 5.4% . Phase 2 signal yield ≈ 10^6 events



Full reconstruction



Partial reconstruction

$$\epsilon(track) = \frac{N_{full}(D^* \rightarrow D^0(\longrightarrow K\pi\pi\pi)\pi_s)}{N_{part}(D^{*+} \rightarrow D^0(K\pi\pi[\pi])\pi_s^+)}$$

Similar to LHCb arXiv:1205.0897v2

STRATEGY

- Simulated signal-only events to get acquainted with the signal mass shapes and estimate the broadening due to partial reconstruction
- Apply a simple cut-based optimization on simulated phase-III events to identify a viable selection
- Explore the possibility to adapt the strategy to phase II data
- Apply the findings on real data

- Signal only. 5000 MC events
  - $e^+e^- \longrightarrow$ ccbar $\longrightarrow [D^* \longrightarrow D^0(\longrightarrow K\pi\pi\pi)\pi_s]$+anything

  - $e^+e^- \longrightarrow$ anything generic MC7 samples
    - $e^+e^- \longrightarrow$ BBbar mixed
    - $e^+e^- \longrightarrow$ uubar
    - $e^+e^- \longrightarrow$ ddbar
    - $e^+e^- \longrightarrow$ ssbar
    - $e^+e^- \longrightarrow$ ccbar
    - $e^+e^- \longrightarrow \tau^+\tau^-$

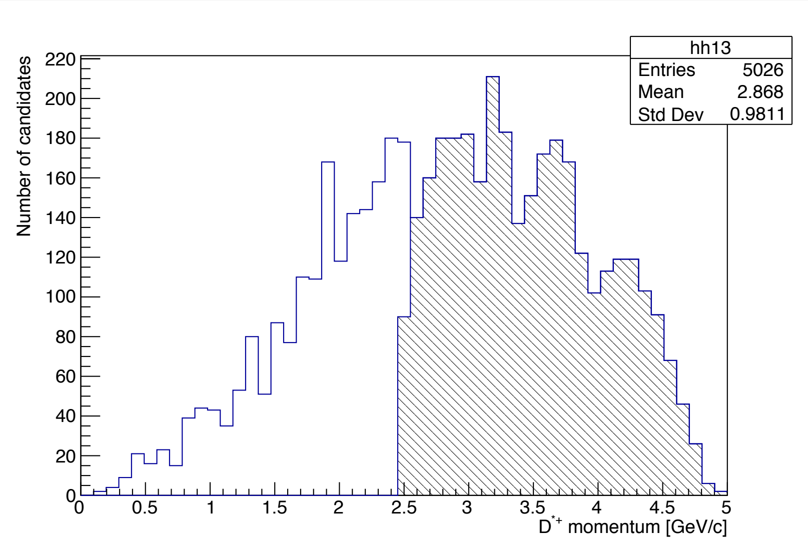
	Phase II	**Phase III**
Signal only	✗	✓
$e^+e^- \longrightarrow$ anything	✓	✓

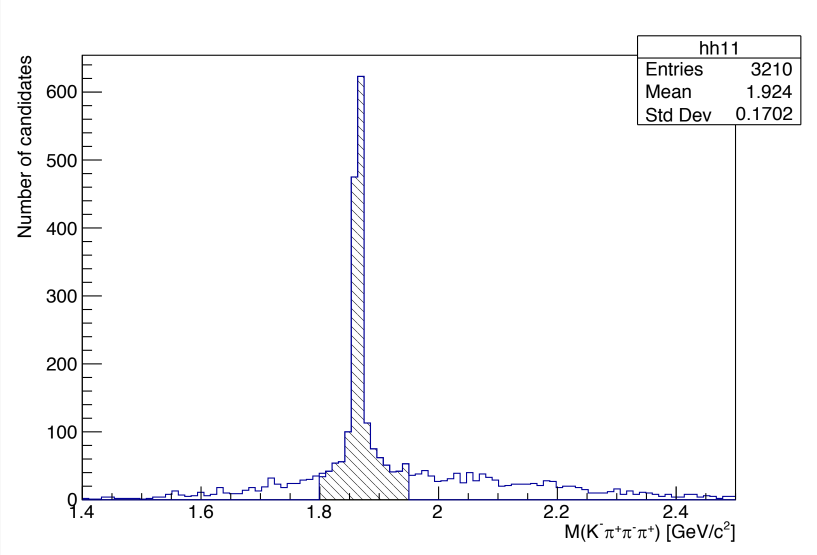
SIGNAL SHAPES

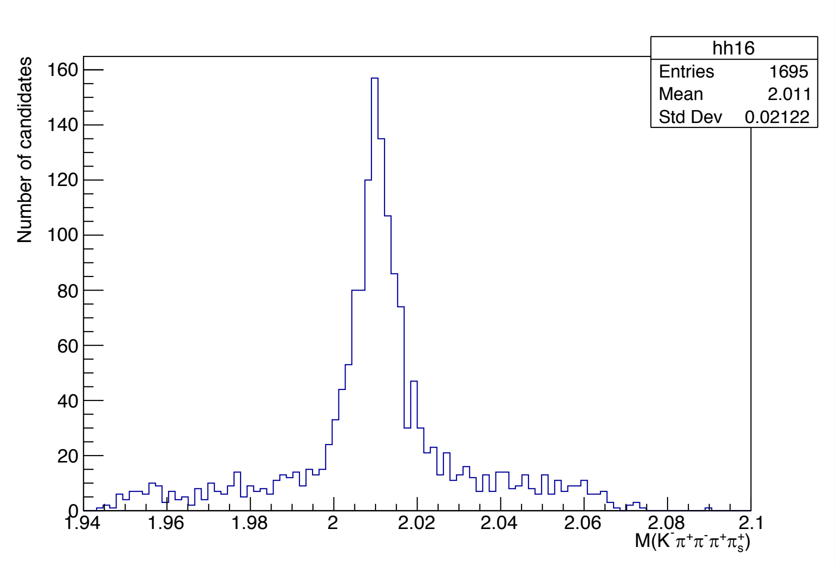
FULL RECONSTRUCTION
SIMPLE INITIAL BASELINE CUTS

Get acquainted with tools and physics of fully reconstructed signal

- Truth-matching
- $p(D^*)_{CMS} > 2.5$ GeV
- $Q = M(K^-\pi^+\pi^-\pi^+\pi_s^+) - M(K^-\pi^+\pi^-\pi^+) - M(\pi_s) < 100$ MeV
- $1.8 < M(K^-\pi^+\pi^-\pi^+) < 1.92$ GeV

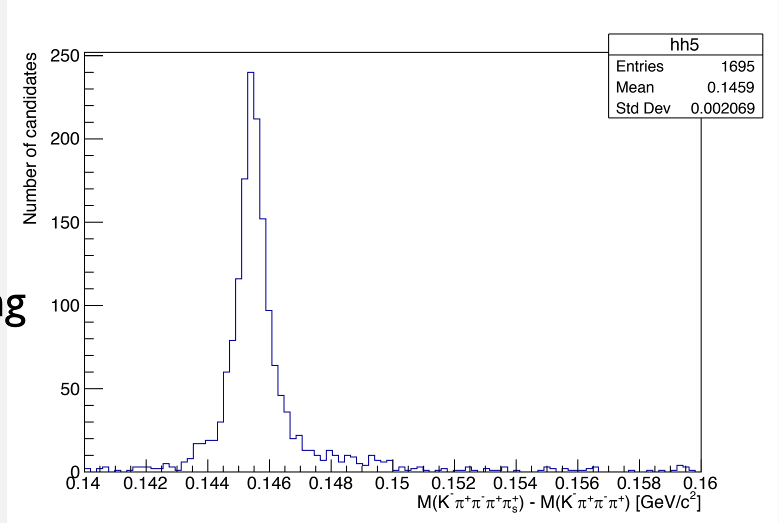


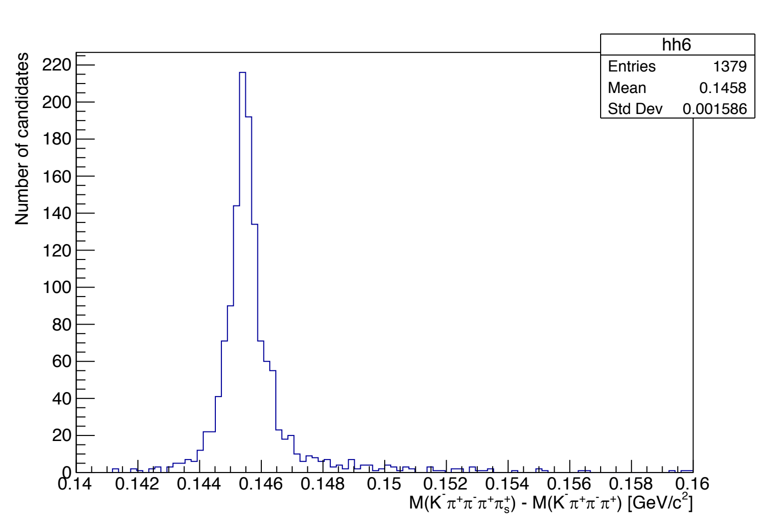




FULL RECONSTRUCTION
D^{*+}-D^0 MASS DIFFERENCE

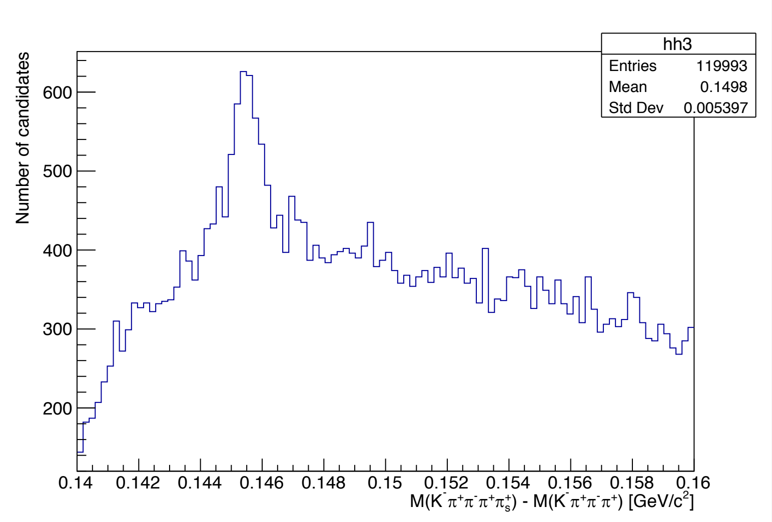
Without vertex fit
With truth-matching

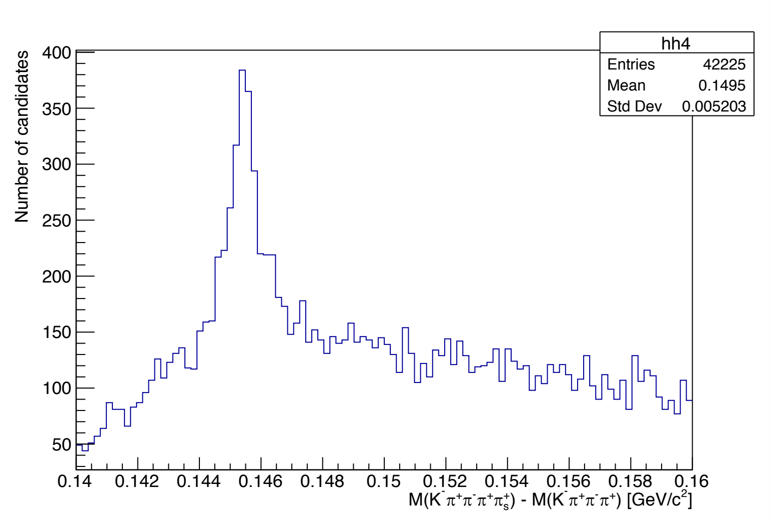




With vertex fit
With truth-matching

Without vertex fit
Without truth-matching



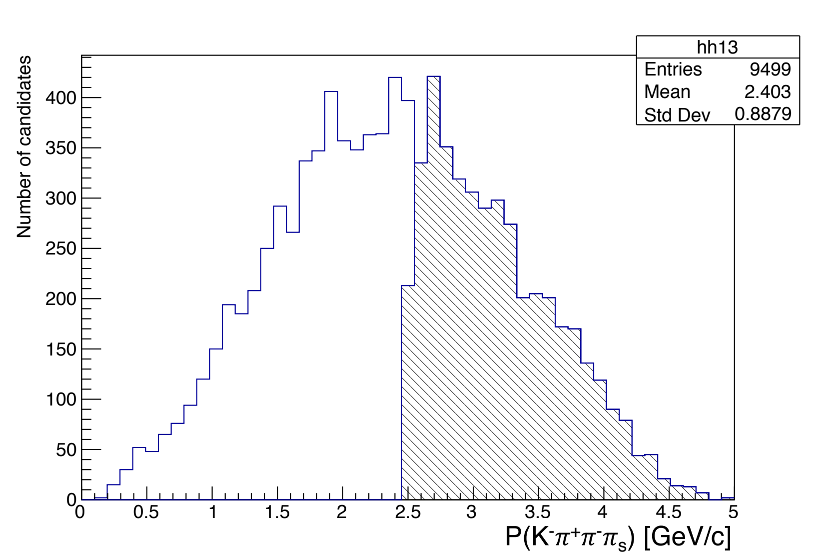


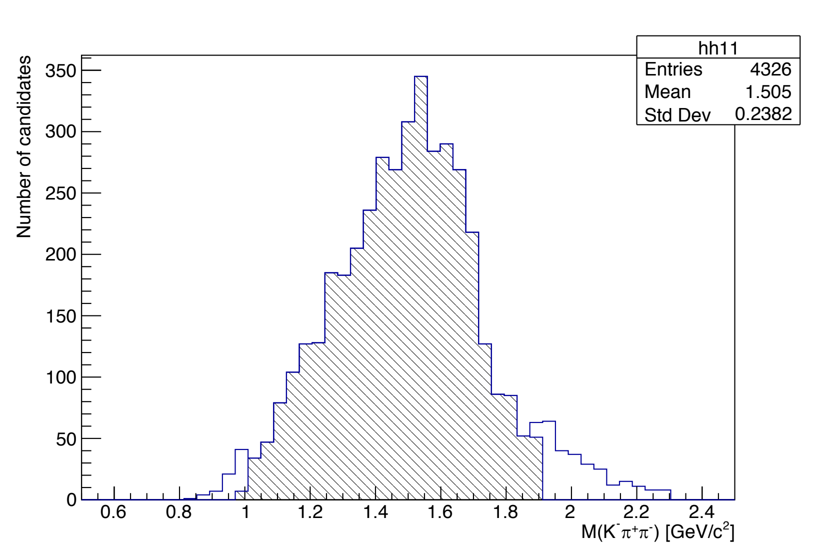
With vertex fit
Without truth-matching

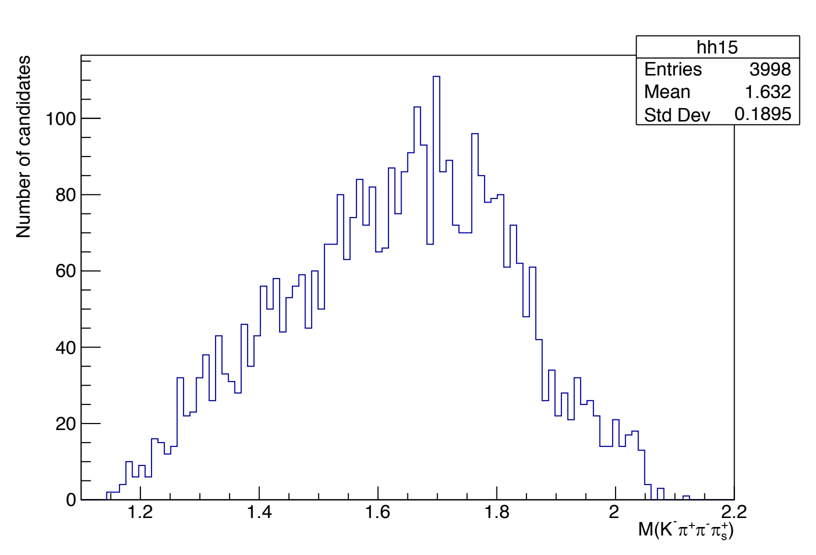
Lack of vertex reconstruction does not spoil the mass resolution

PARTIAL RECONSTRUCTION
π^+ IS MISSED
APPLIED CUTS

- Truth-matching
- $p(K^-\pi^+\pi^-\pi_s)_{CMS} > 2.5$ GeV
- $Q = M(K^-\pi^+\pi[\pi]^-\pi_s^+) - M(K^-\pi^+\pi^-[\pi]^-) - M(\pi_s) < 100$ MeV
- $1.0 < M(K^-\pi^+\pi^-) < 1.9$ GeV



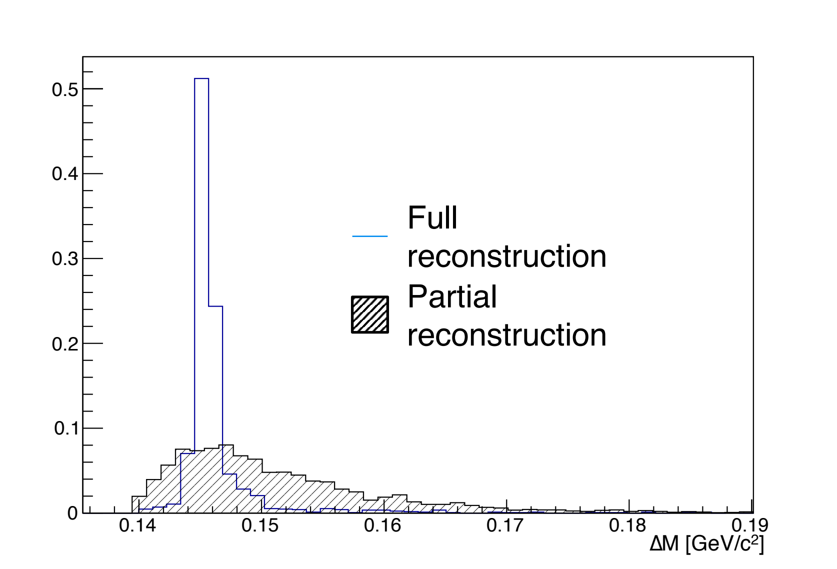




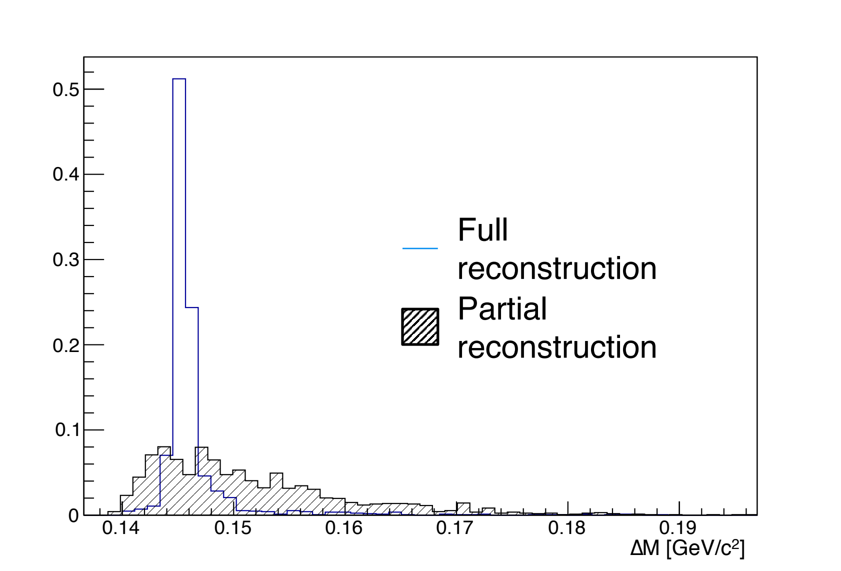
PARTIAL RECONSTRUCTION
D^{*+}-D^0 MASS DIFFERENCE

With truth-matching

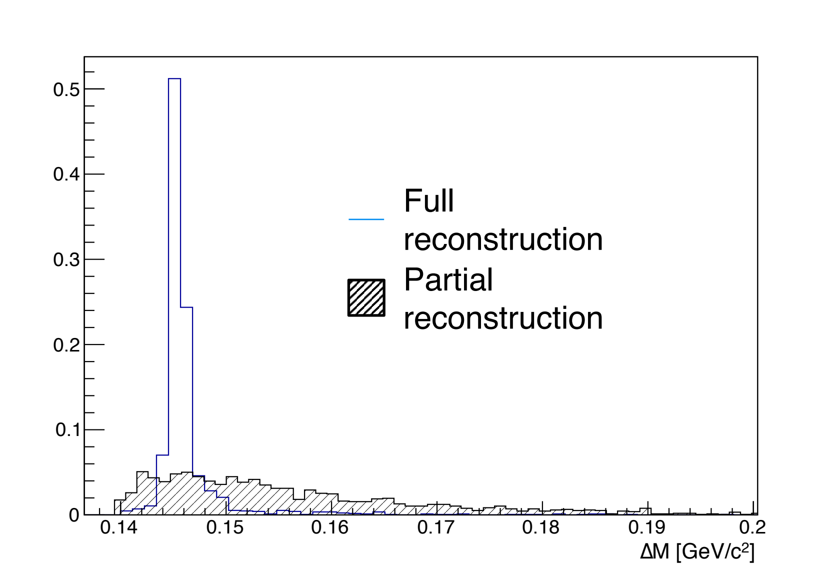
π^+ is missed



π^- is missed



K^- is missed



Partial reconstruction broadens the signal peak by factors 4-5

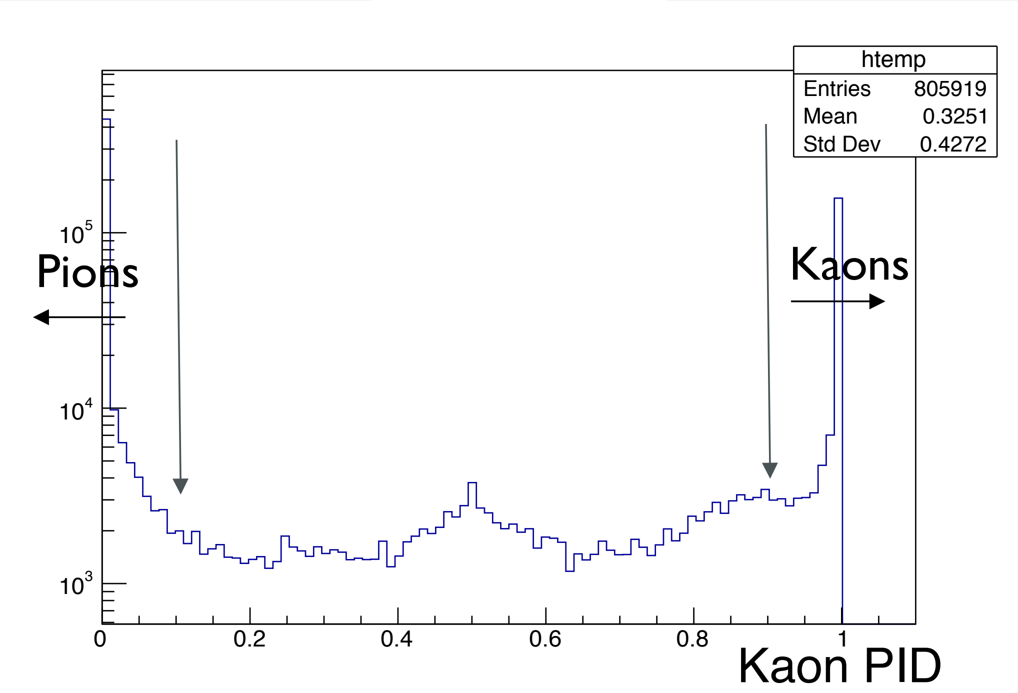
GENERIC MC
PHASE3 GEOMETRY ONLY
$e^+e^- \rightarrow anything$

CUTS OPTIMIZATION
PRE-CUTS

Approximate the composition of a e+e- —> anything sample by merging the dominant components according to the cross sections of Table 19 of BTIP draft. Neglect beam-backgrounds

Table 19: Total production cross section from various physics processes from collisions at $\sqrt{s} = 10.58$ GeV. $W_{\ell\ell}$ is the minimum invariant secondary fermion pair mass.

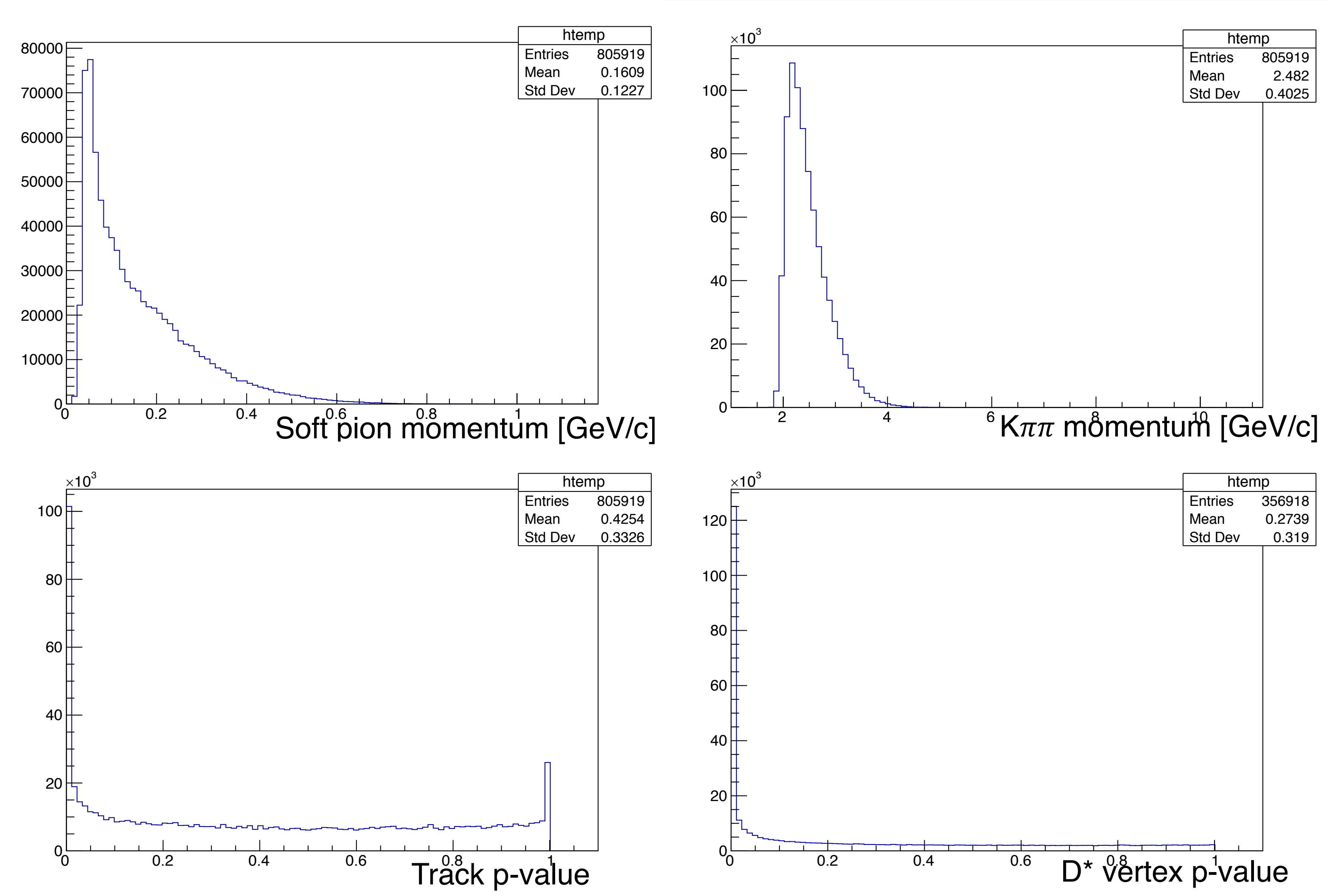
Physics process	Cross section [nb]	Selection Criteria	Reference
$\Upsilon(4S)$	1.110 ± 0.008	-	[16]
$u\bar{u}(\gamma)$	1.61	-	KKMC
$d\bar{d}(\gamma)$	0.40	-	KKMC
$s\bar{s}(\gamma)$	0.38	-	KKMC
$c\bar{c}(\gamma)$	1.30	-	KKMC
$e^+e^-(\gamma)$	300 ± 3 (MC stat.)	$10° < \theta^*_e < 170°$, $E^*_e > 0.15$ GeV	BABAYAGA.NLO
$e^+e^-(\gamma)$	74.4	$p_e > 0.5$ GeV/c and e in ECL	-
$\gamma\gamma(\gamma)$	4.99 ± 0.05 (MC stat.)	$10° < \theta^*_\gamma < 170°$, $E^*_\gamma > 0.15$ GeV	BABAYAGA.NLO
$\gamma\gamma(\gamma)$	3.30	$E_\gamma > 0.5$ GeV in ECL	-
$\mu^+\mu^-(\gamma)$	1.148	-	KKMC
$\mu^+\mu^-(\gamma)$	0.831	$p_\mu > 0.5$ GeV/c in CDC	-
$\mu^+\mu^-\gamma(\gamma)$	0.242	$p_\mu > 0.5$ GeV in CDC, ≥ 1 γ ($E_\gamma > 0.5$ GeV) in ECL	-
$\tau^+\tau^-(\gamma)$	0.919	-	KKMC
$\nu\bar{\nu}(\gamma)$	0.25×10^{-3}	-	KKMC
$e^+e^-e^+e^-$	39.7 ± 0.1 (MC stat.)	$W_{\ell\ell} > 0.5$ GeV/c^2	AAFH
$e^+e^-\mu^+\mu^-$	18.9 ± 0.1 (MC stat.)	$W_{\ell\ell} > 0.5$ GeV/c^2	AAFH



PID(K) > 0.9 for kaons
PID(K) < 0.1 for pions

CUTS OPTIMIZATION
'OPTIMIZATION VARIABLES'

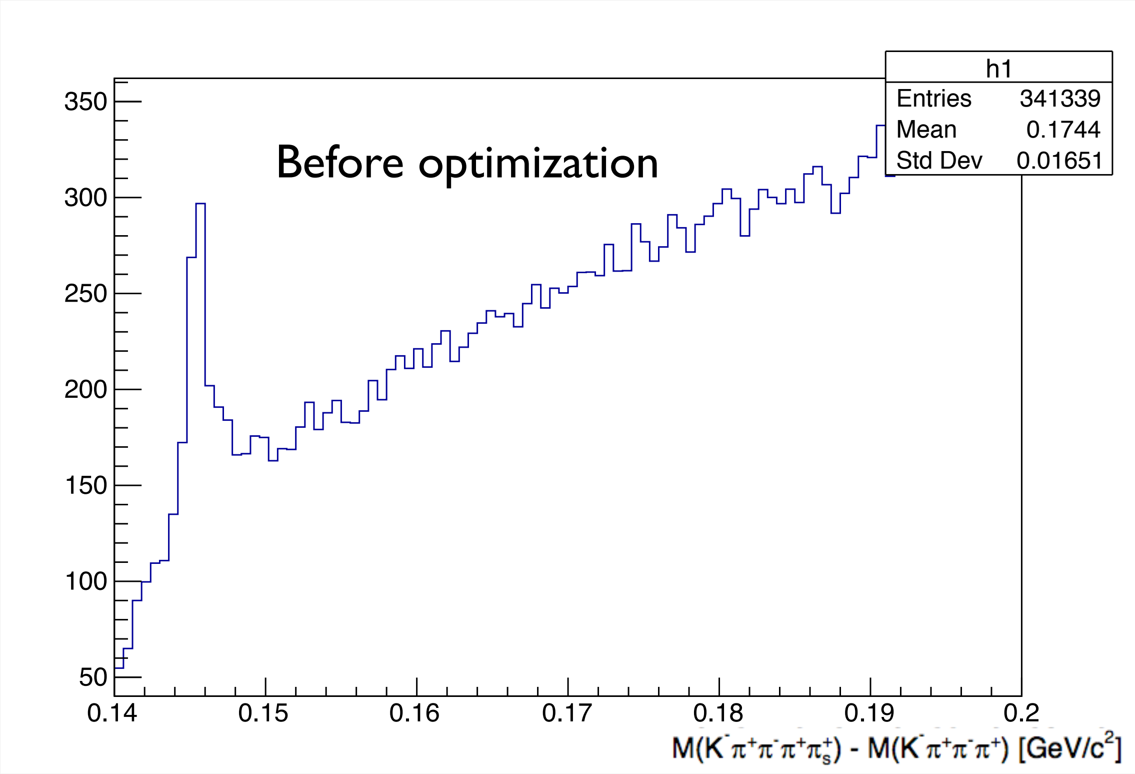
1. Tracks' p-value
2. Scalar sum of the D^0 three daughter momenta. Skip unreconstructed track.
3. Momentum of soft pion
4. D* vertex p-value

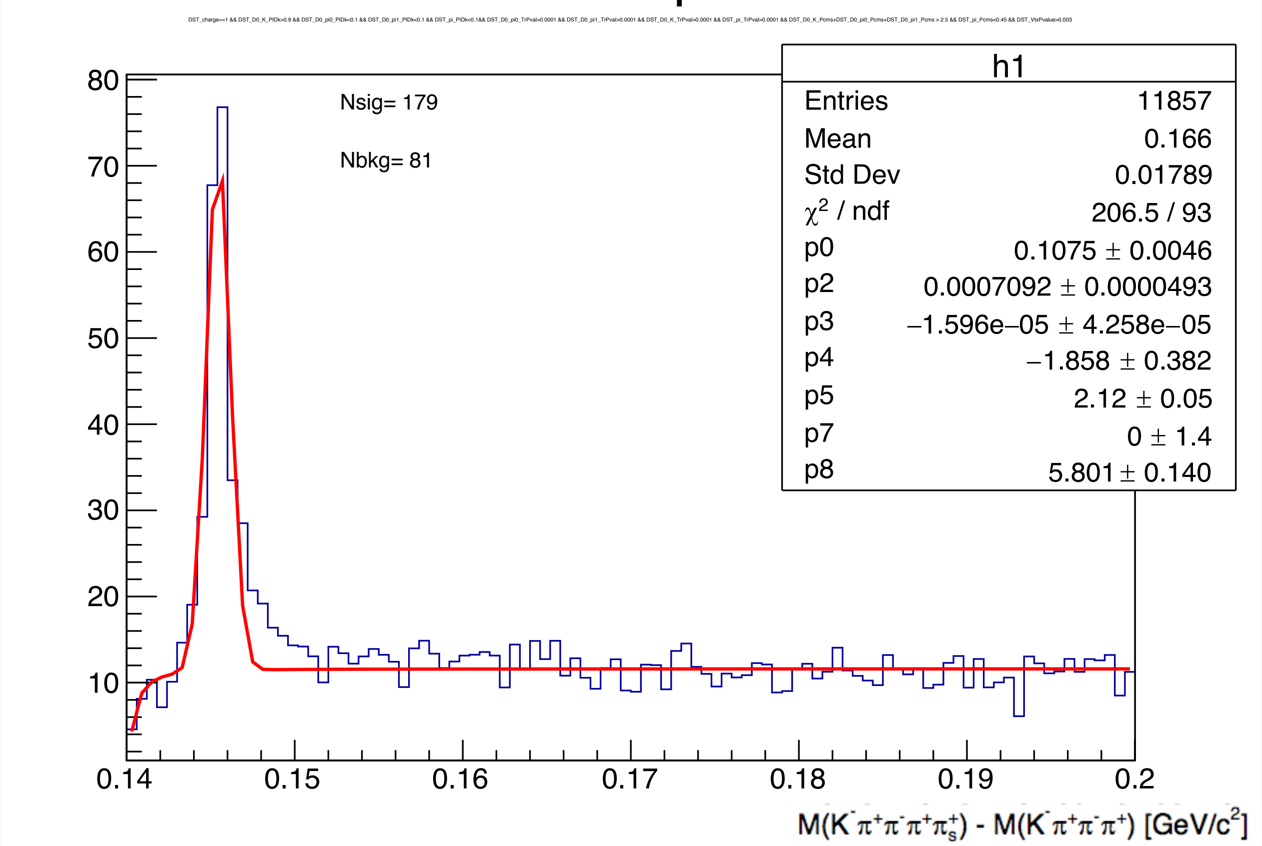


CUTS OPTIMIZATION

Optimize $\frac{S}{\sqrt{S+B}}$ on the fully reconstructed D*-D^0 mass difference.

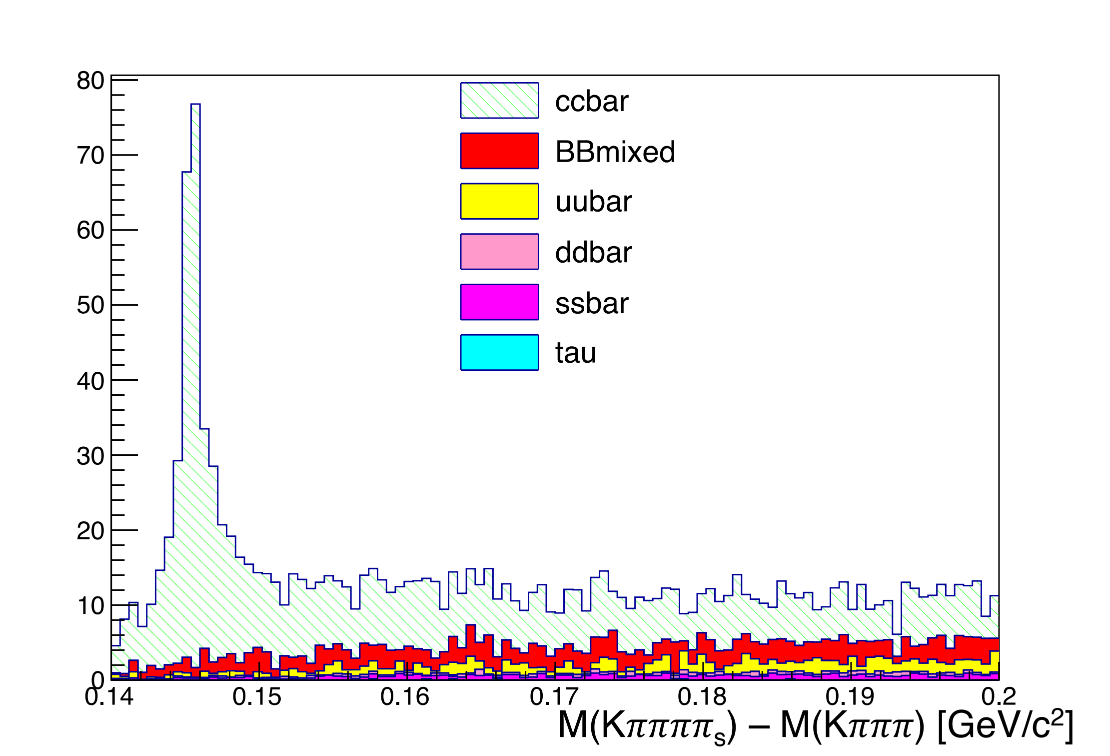
Tracks' p-value > 0.0001
P(Kpipi) > 2.5 GeV
P(soft pion) <0.45 GeV
D* vertex p-value > 0.003



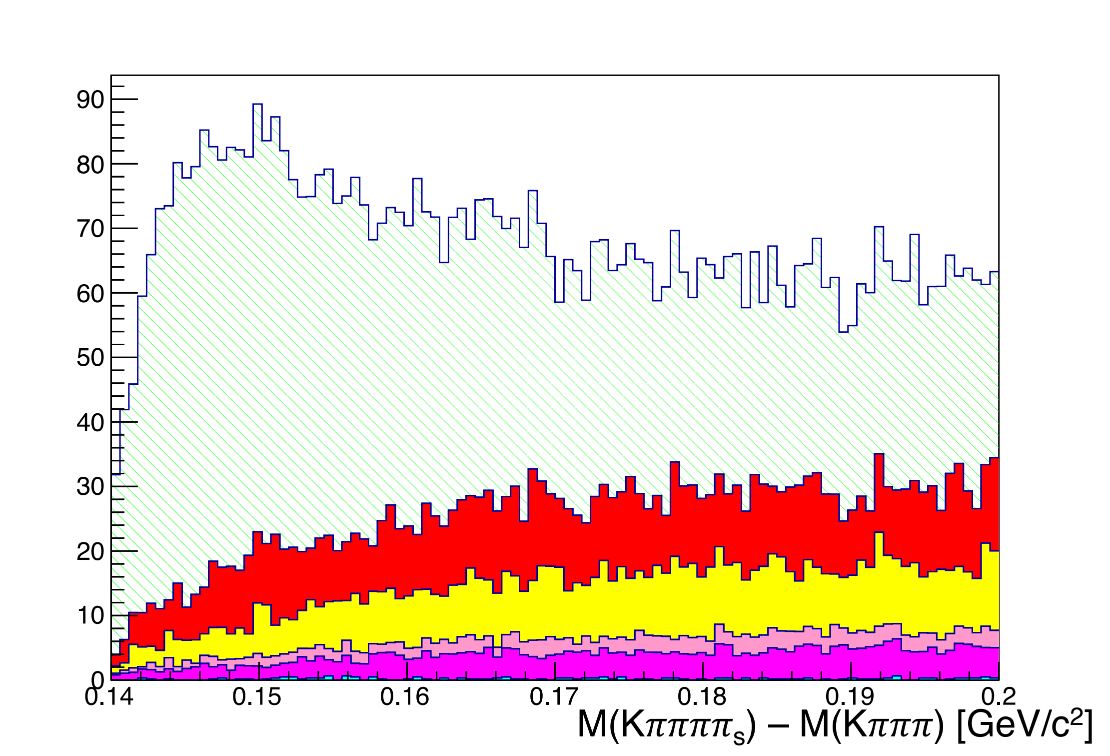


D*-D0 MASS DIFFERENCE

Full reconstruction



π^+ is missing



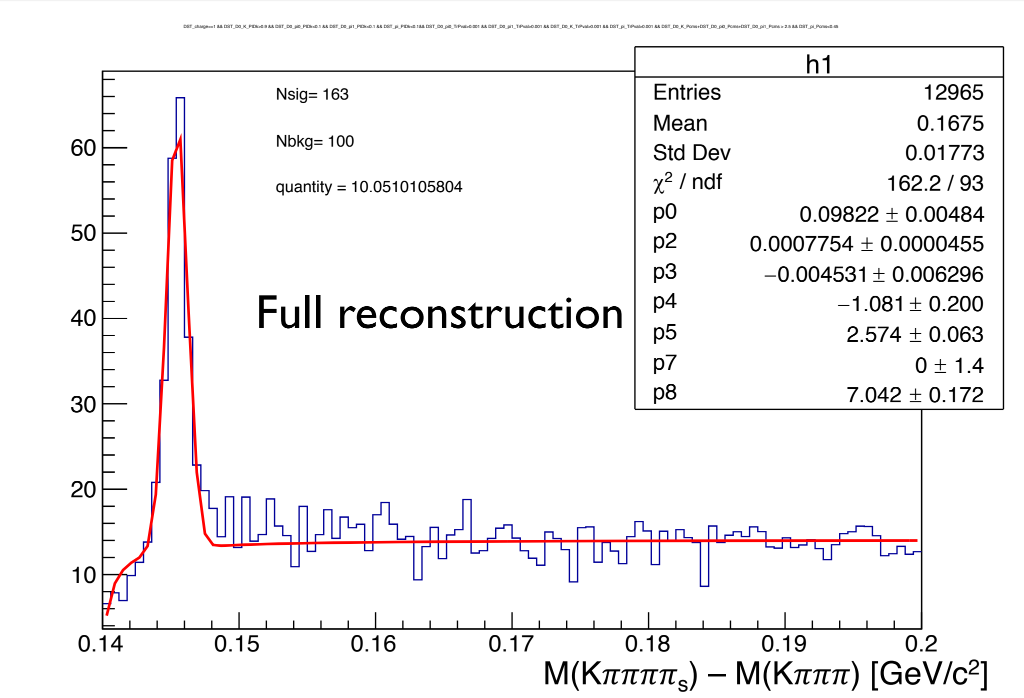
Mass difference for partially reconstructed candidates.

- Dedicated optimization ongoing -

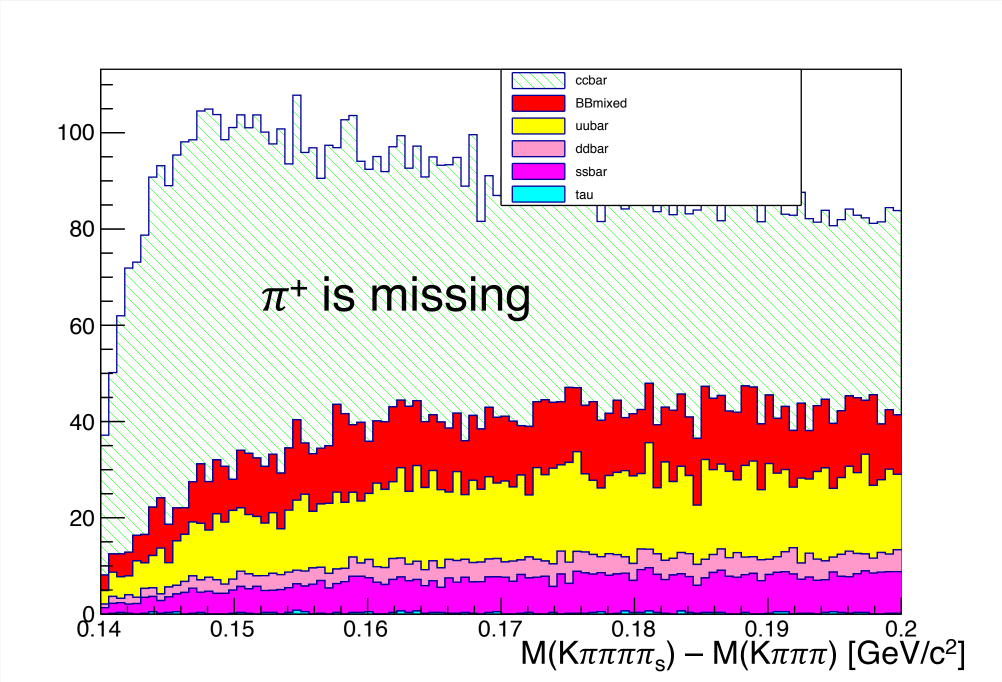
GENERIC MC
PHASE2 GEOMETRY ONLY
$e^+e^- \rightarrow anything$

CUTS OPTIMIZATION

- Repeat same procedure using phase II MC. Didn't use any vertex information.

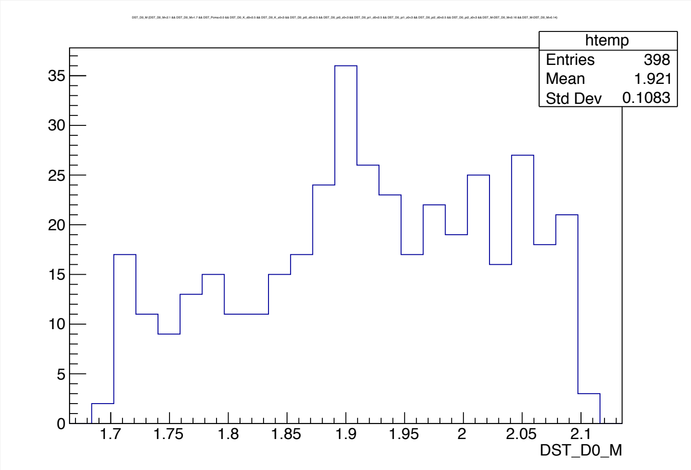


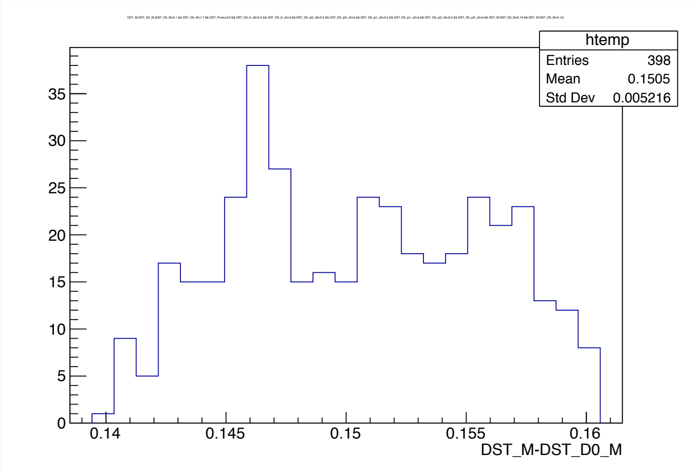
Track
p-value >0.001
P(Kππ) > 2.5 GeV
P(soft π) <0.45 GeV



No major difference with respect to phase 3.

TEASER





Cuts:

- $1.7 < M(D^0) < 2.1$ GeV
- $P(D^*) > 3.0$ GeV
- $z0(K, \pi)_{D0} < 3$ cm
- $d0(K, \pi)_{D0} < 0.5$ cm
- $0.14 < M(D^*) - M(D^0) < 0.16$ GeV

The runs used for the plots are 112-1355

Don't get too excited – masses are off. Probably background

SUMMARY

- Exploring data-driven track-finding efficiency using $D^* \longrightarrow D^0(\longrightarrow K\pi\pi\pi)\pi_s$ decays
- Currently studying a viable optimization for partially reconstructed D* signal
- If we sort this out might be applicable in phase 2 already