

Updates on the $B^\pm \rightarrow K^\pm \tau^\pm \ell^\mp$

Inclusion of $\tau \rightarrow \rho \nu_\tau$ mode

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Selection criteria

Charged tracks

- Impact parameters: $|dr| < 1 \text{ cm}$ & $|dz| < 4 \text{ cm}$.
- Track momentum $p > 50 \text{ MeV}/c$.
- *electrons* : $e_{\text{ID}} > 0.6, \mu_{\text{ID}} < 0.98$,
 $\text{atcPIDBelle}(K, e) < 0.98$
- *muons* : $\mu_{\text{ID}} > 0.6, e_{\text{ID}} < 0.98$,
 $\text{atcPIDBelle}(K, \mu) < 0.98$
- *pions* : $\mu_{\text{ID}} < 0.6, e_{\text{ID}} < 0.6$,
 $\text{atcPIDBelle}(\pi, K) > 0.4$
- *Kaons* : $\mu_{\text{ID}} < 0.98, e_{\text{ID}} < 0.98$,
 $\text{atcPIDBelle}(K, \pi) > 0.6$

ECL Clusters, π^0 , & ρ^+

- goodBelleGamma: $E_{\gamma}^{\text{FE}} > 100 \text{ MeV}$, $E_{\gamma}^{\text{BR}} > 50 \text{ MeV}$, $E_{\gamma}^{\text{BE}} > 150 \text{ MeV}$.
- FakePhoton > 0.3 , BeamBackground > 0.3
- π^0 : $80 < M_{\gamma\gamma} < 180 \text{ MeV}/c^2$ & $\text{chiProb} > 0.001$
- ρ^+ : $570 < M_{\pi^+\pi^0} < 970 \text{ MeV}/c^2$.

$B^\pm$ signal and ROE side

- $m_{D^{0(*)} \text{ inclusive}} < 2.15 \text{ GeV}/c^2$, $|M_{\gamma\gamma} - m_{\pi^0}| < 20 \text{ MeV}/c^2$, & $|\sin \phi| < 1.0$.

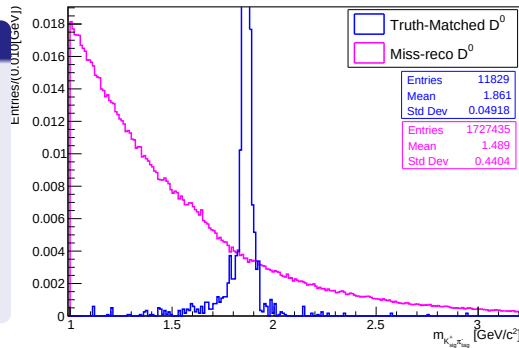
Veto conditions

- $|m_{K^+\pi^-} - m_{D^0}| > 200 \text{ MeV}/c^2$ for the $B^+ \rightarrow K^+\tau^-[\pi^-\pi^0\nu_\tau]\ell^+$ system.
- $m_{K^+\rho^-} > 1.95 \text{ GeV}/c^2$ for the $B^+ \rightarrow K^+\tau^-[\rho^-\nu_\tau]\ell^+$ system.
- $m_{e_{\text{sig}}^\pm e_{\text{tag}}^\mp} > 100 \text{ MeV}/c^2$.

D^0 veto: $K^-_{\text{signal side}} \& \pi^+_{\text{ROE side}}$

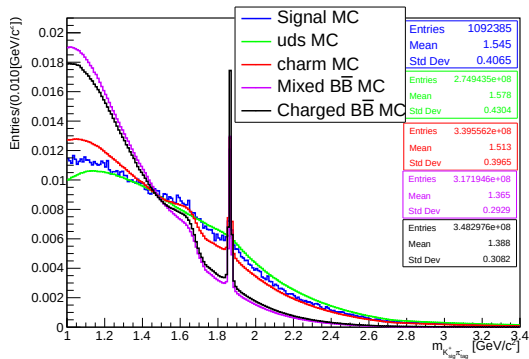
Procedure

- Select K^+ from the decay chain $B^+ \rightarrow K^+ \tau^\pm \ell^\mp$.
- Select good π^- from the charged particles in ROE.
- Combine to reconstruct the decay $\bar{D}^0 \rightarrow K^+ \pi^-$.

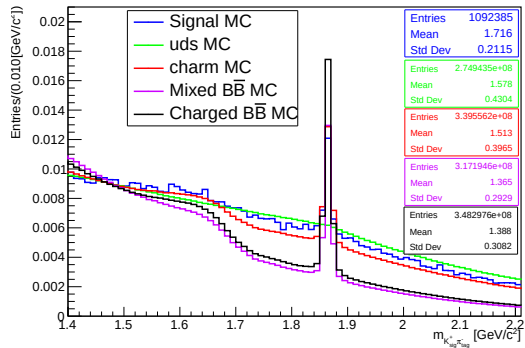


- **Important note:** Here, a D^0 list is selected for each B^+ candidate.
- **Next:** I will select the best $K\pi$ combination with invariant mass closest to D^0 nominal mass.

D^0 InvM: Signal and Background distributions



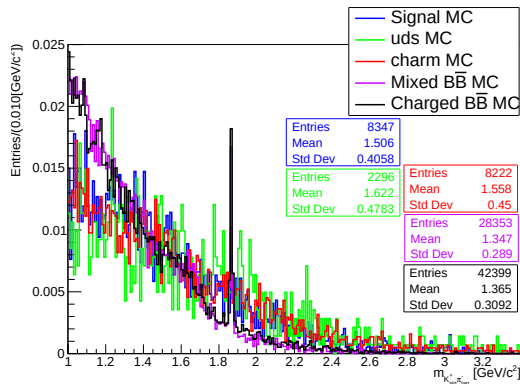
Wide range



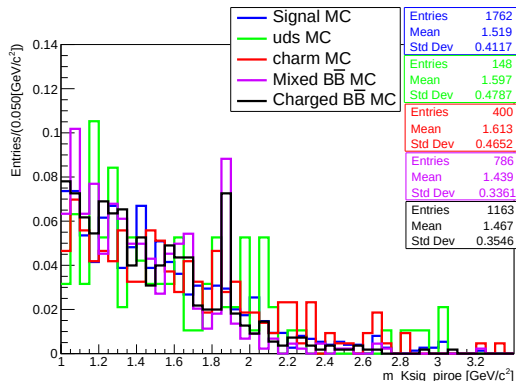
Zoomed in

- **Next:** Assign this information to the $\Upsilon(4S)$ tree and require $|\sin \phi| < 1$.

D^0 InvM: $|\sin \phi| < 1$



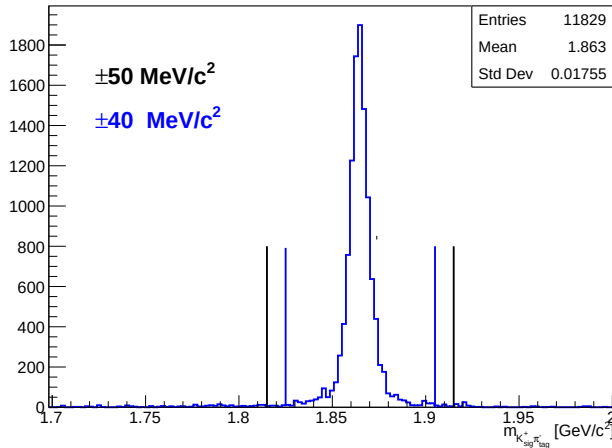
$|\sin \phi| < 1$



Other vetos

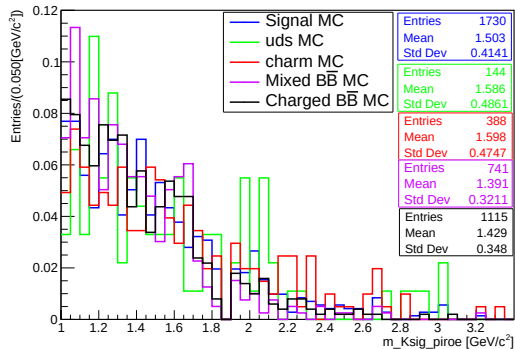
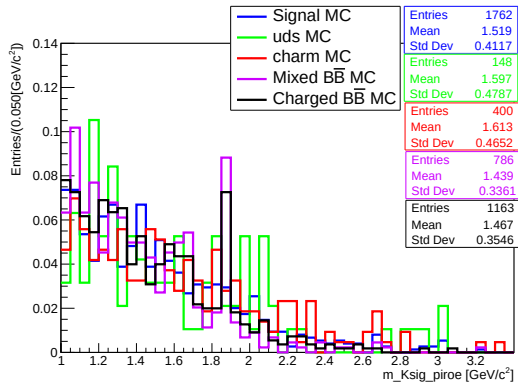
- **Next:** Compute a window to veto the peaking candidates.

D^0 InvM: Veto



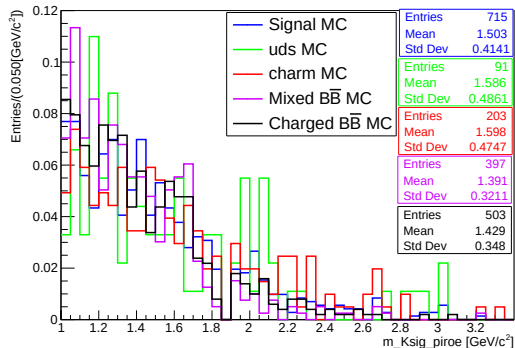
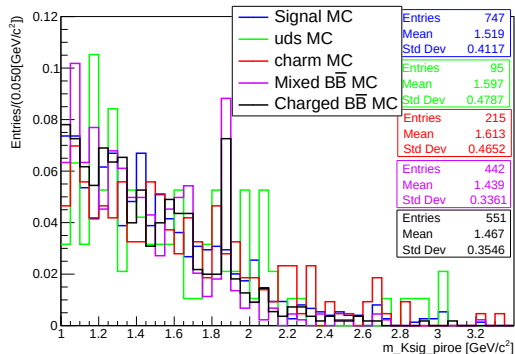
- Veto: $|m_{K^+_{\text{sig}}\pi^-_{\text{tag}}} - 1.865| > 0.04 \text{ GeV}/c^2$.

Impact: Including NAN

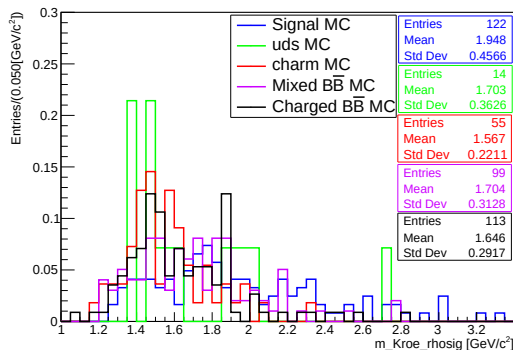
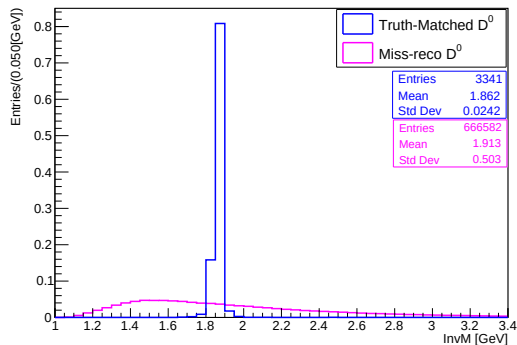


- % signal loss: 1.8%, True signals: 2.0% and Miss-reconstructed signals: 1.4%
- uds: 4.3%, Charm: 3.0%, mixed- $B\bar{B}$: 5.7%, & charged- $B\bar{B}$: 4.1%

Impact: Excluding NAN

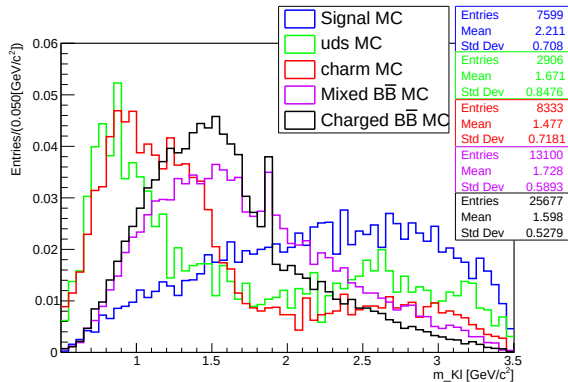


- Percentage of the candidates in which a combination is found:
 - Signal: 42.4%, uds: 64.2%, charm: 53.8%, charged- $B\bar{B}$: 56.2%, and mixed- $B\bar{B}$: 47.4%
- % signal loss: 4.3%, True signals: 5.3% and Miss-reconstructed signals: 2.7%
- uds: 4.3%, Charm: 5.6%, mixed- $B\bar{B}$: 10.2%, & charged- $B\bar{B}$: 8.7%



- **Left:** Possible combinations to each B candidate in the Signal sample
- **Right:** Best combination based on $|\Delta M|$ and after requiring all the selections
- Percentage of the candidates in which a combination is found:
 - Signal: 6.9%, uds: 9.6%, charm: 13.6%, charged- $B\bar{B}$: 13.6%, and mixed- $B\bar{B}$: 9.8%

- Input MC samples: $B \rightarrow K^+ \tau^\pm \ell^\mp$
- 4 million (one million each)
- Background: 6 streams for each type
- Channels: $B \rightarrow K^+ \tau^+ \ell^-$ (OS)
- Junaid's requirement: $M_{K\ell} > 1.91$
- Isn't it too tight?



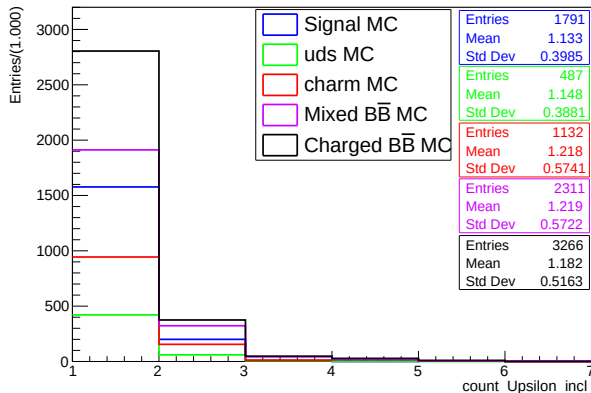
- % losses in these two channels: Signal = 36.2%, uds = 63.4, charm = 77.5, mixed- $B\bar{B}$ = 68.0%, and charged- $B\bar{B}$ = 78.8%
- We should also check this combination for the tag side lepton as well and vice-versa.

Next to do

- Make the following veto combinations:

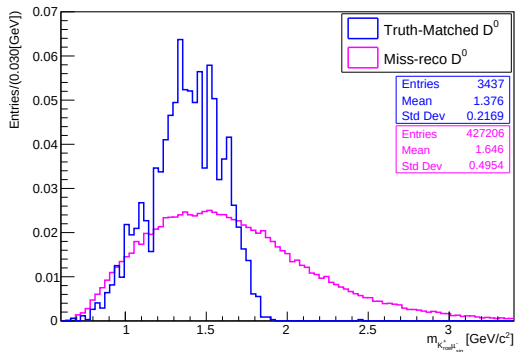
- $\bar{D}^0 \rightarrow K_{\text{sig}}^+ \pi_{\text{roe}}^- \pi_{\text{roe}}^0$
- $\bar{D}^0 \rightarrow K_{\text{sig}}^+ \ell_{\text{roe}}^- \nu_{\text{missing}}$ & a vice-versa
- $\bar{D}^0 \rightarrow K_{\text{roe}}^+ \pi_{\text{sig}}^-$

Multiplicity



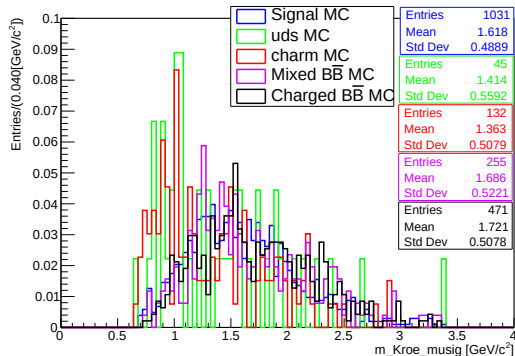
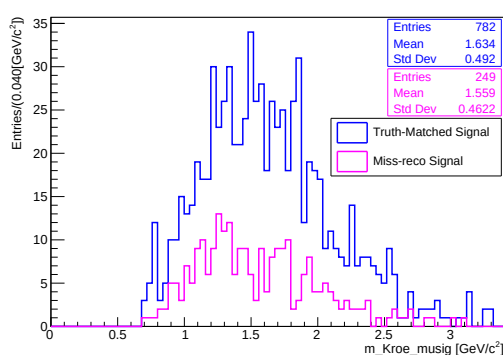
- The multiplicity is close to one after applying all the selection criteria up to vetoing the signal side particles.

- No major conditions on the B^+ signal list.



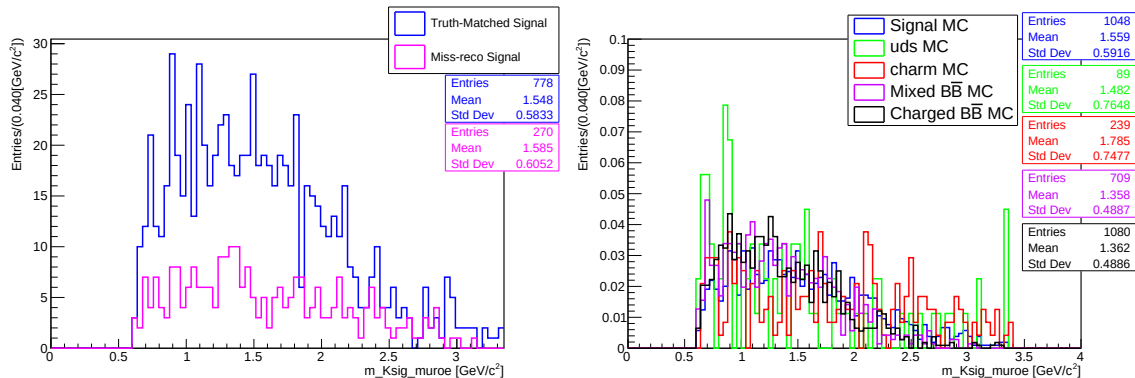
- One candidate $D^0 \rightarrow K_{\text{roe}}^- \mu_{\text{sig}}^+ \nu_{\text{missing}}$ for each B^+ candidate.
 - Selected based on the least value of $|\Delta M|$.
 - Probably, should have based on the vertex fit!
- All the good candidates have an invariant mass less than $1.9 \text{ GeV}/c^2$.

- Here, truth-matched candidates are actual $B^+ \rightarrow K^+ \tau^- \mu^+$ signals.



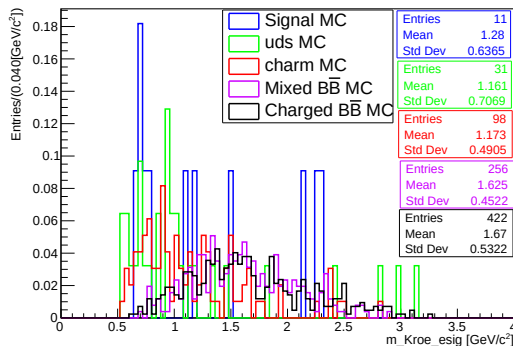
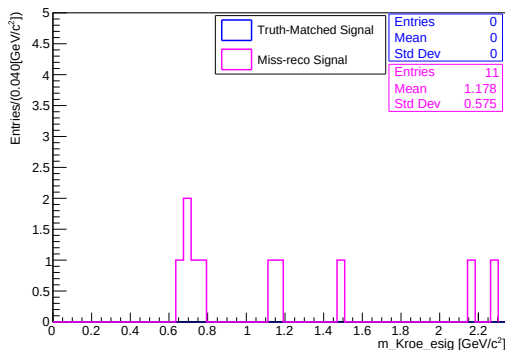
- Percentage loss for the given candidates: True signals = 74.6%, Miss-reco = 77.9%, uds = 82%, charm = 84.1%, charged = 69.8%, and mixed = 66.7%.
- Overall loss: Signals = 46.2% (true-reco = 50.0% & miss-reco = 37.7%), uds = 8.1%, charm = 10.8%, charged = 10.4%, and mixed = 8.5%.

- Here, truth-matched candidates are actual $B^+ \rightarrow K^+ \tau^- \mu^+$ signals.

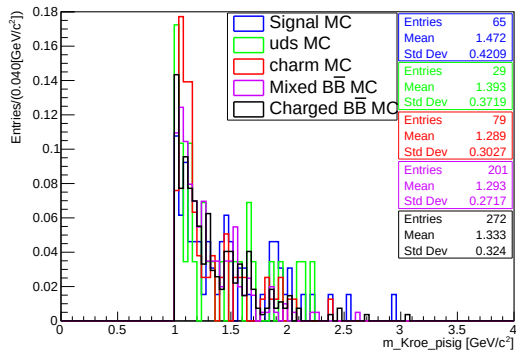
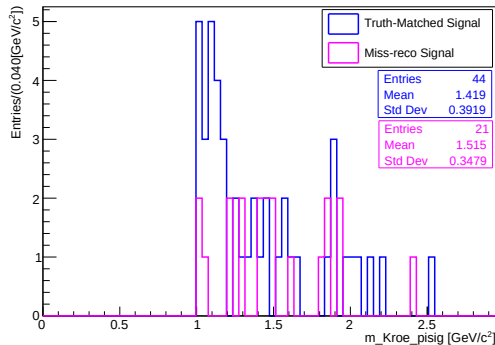


- Overall % loss corresponding to apply vetos for both $K\mu$ combinations: Signals = 57.3% (True signals = 61.8%, Miss-reco = 47.1%), uds = 18.5%, charm = 21.2%, charged = 33.3%, mixed = 31.0%

- Here, truth-matched candidates are actual $B^+ \rightarrow K^+ \tau^- e^+$ signals.

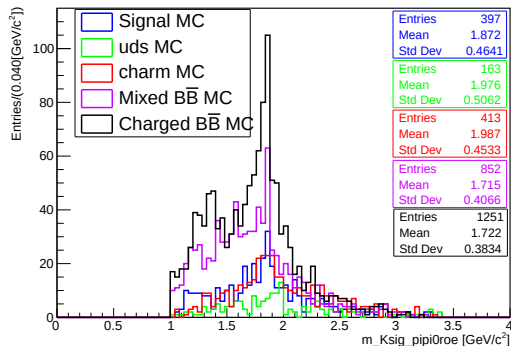
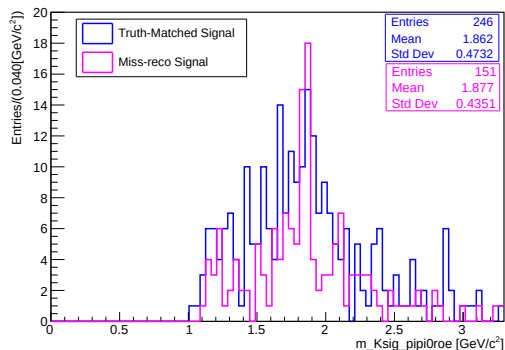


- Expecting the same for this channel.



- **Veto:** $|m_{K_{\text{roe}}^+ \pi_{\text{sig}}^-} - 1.865| > 0.04 \text{ GeV}/c^2$.
- % loss of the $K\pi$ combination: True signals = 9.1% (4 cand.), Miss-reco = 9.4 (2 cand.)%, uds = 3.4%, charm = 3.8%, charged = 2.9%, mixed = 3.0%

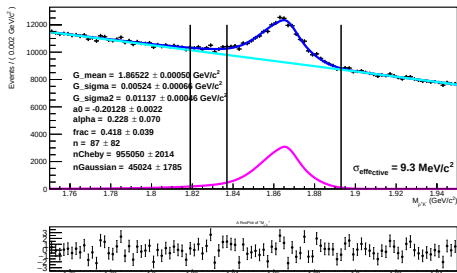
$$M_{K_{\text{sig}}^+ \pi_{\text{roe}}^- \pi_{\text{roe}}^0}$$



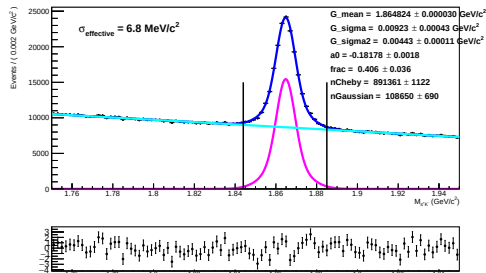
- **Veto:** $-0.100 < (m_{K_{\text{sig}}^+ \pi_{\text{roe}}^- \pi_{\text{roe}}^0} - 1.865) < 0.05 \text{ GeV}/c^2$.
- % loss for which a combination is found: True signals = 17.9% (44 cand.), Miss-reco = 25.8 (49 cand.)%, uds = 14.1%, charm = 20.8%, charged = 22.9%, mixed = 18.9%
- Overall % loss due to this veto: Signal = 4.9%, uds = 5.1%, charm = 8.7%, charged = 7.7%, and mixed = 9.5%.

M_{D^0} distributions: Real Data

$$\sigma_{\text{effective}} = \sqrt{f_1 \sigma_1^2 + (1 - f_1) \sigma_2^2}$$



$$1.819 < M_{K\rho} < 1.893 \text{ MeV}/c^2$$



$$1.844 < M_{K\pi} < 1.885 \text{ MeV}/c^2$$

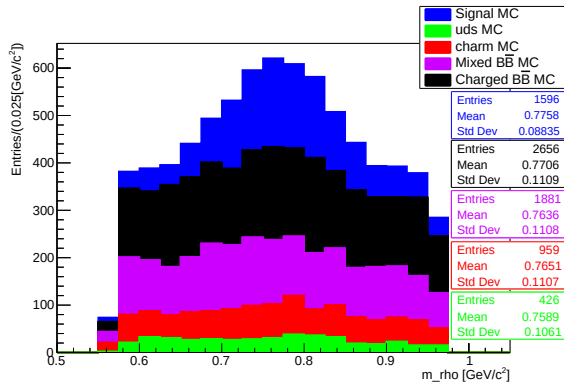
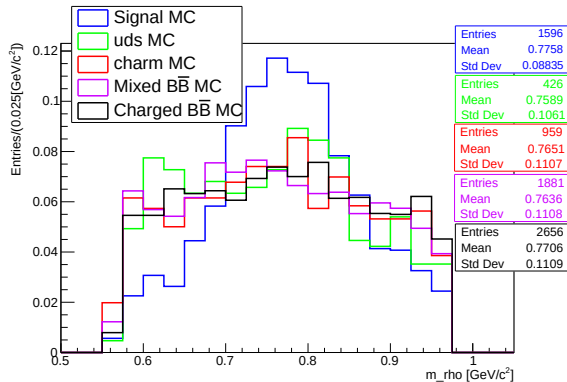
Comparison

Condition	Signal MC ($\epsilon_{\text{rel}}\%$)	True Signals ($\epsilon_{\text{rel}}\%$)	uds (% loss)	charm (% loss)	mixed (% loss)	charged (% loss)
Pre-selection	1791(100)	1205(100)	487(0)	1132(0)	2311(0)	3266(0)
BCS	1681(93.86)	1167(96.85)	453(6.98)	1030(9.01)	2095(9.35)	3018(7.59)
$m_{K\pi}$	1644(97.8)	1139(97.6)	438(3.31)	996(3.3)	1996(4.73)	2874(4.77)
$m_{K\rho}$	1544(93.92)	1081(94.91)	409(6.62)	896(10.04)	1786(10.52)	2494(13.22)

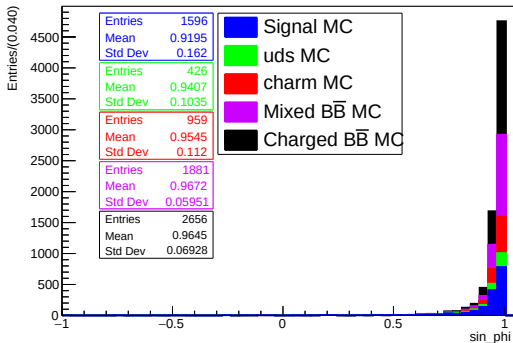
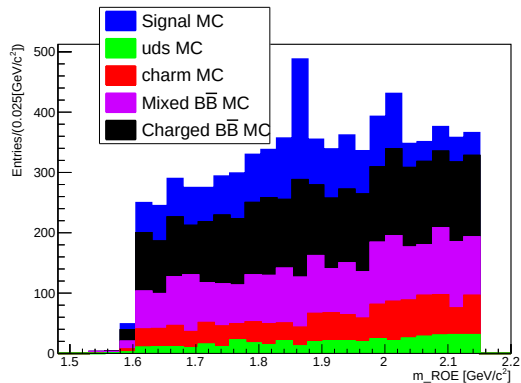
Cut flow table based on the real data

Condition	Signal MC ($\epsilon_{\text{rel}}\%$)	True Signals ($\epsilon_{\text{rel}}\%$)	uds (% loss)	charm (% loss)	mixed (% loss)	charged (% loss)
Pre-selection	1791(100)	1205(100)	487(0)	1132(0)	2311(0)	3266(0)
BCS	1681(93.86)	1167(96.85)	453(6.98)	1030(9.01)	2095(9.35)	3018(7.59)
$m_{K\pi}$	1660(98.75)	1153(98.8)	444(1.99)	1011(1.84)	2009(4.11)	2907(3.68)
$m_{K\rho}$	1596(96.14)	1122(97.31)	426(4.05)	959(5.14)	1881(6.37)	2656(8.63)

M_ρ distribution



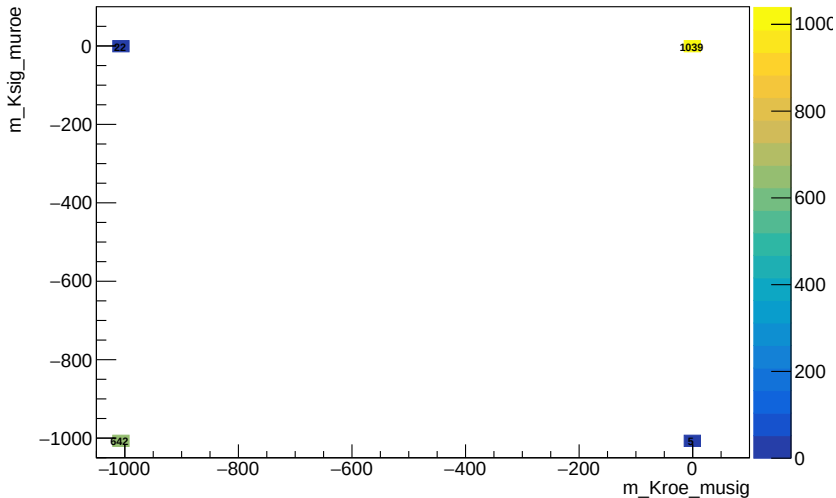
M_{ROE} and $\sin \phi$ distributions



- Signal selection efficiency: 0.15%
- Expected backgrounds as are in the distributions.

All the candidates after BCS

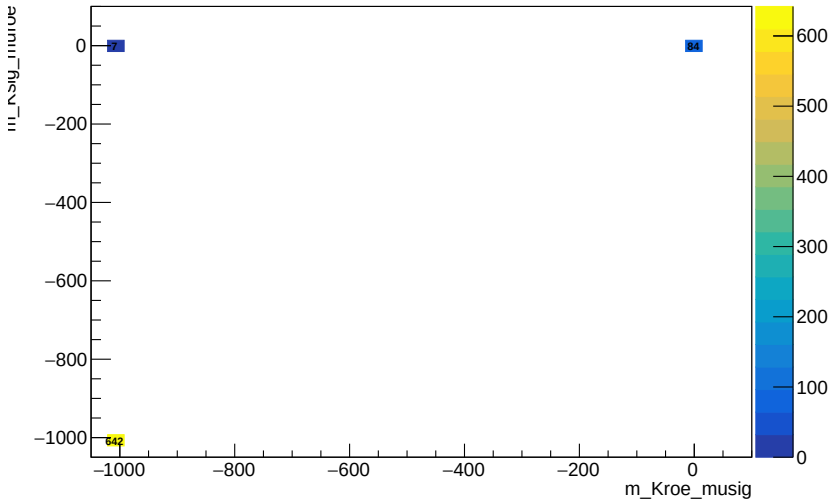
m_Ksig_muroe:m_Kroe_musig {Yincl_rank==1}



- Both not found: 642 times
- Only $K_{sig}\mu_{roe}$: 22 times
- Only $K_{roe}\mu_{sig}$: 5 times
- Both are found: 1039 times
- Total = 1708 candidates

Candidates passing the $K\mu$ veto

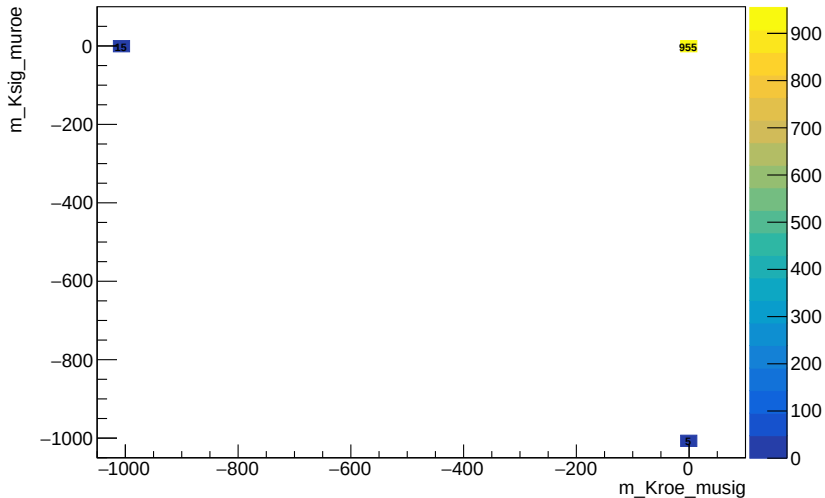
`m_Ksig_muroe:m_Kroe_musig {Yincl_rank==1 && ((m_Kroe_musig==999 || m_Kroe_musig>1.91) && (m_Ksig_muroe==999 || m_Ksig_muroe>1.91))}`



- Both not found: 642 times
- Only $K_{sig}\mu_{roe}$: 7 times
- Only $K_{roe}\mu_{sig}$: 0 times
- Both are found: 84 times
- Total = 733 candidates
- Relative $\epsilon = 42.9\%$

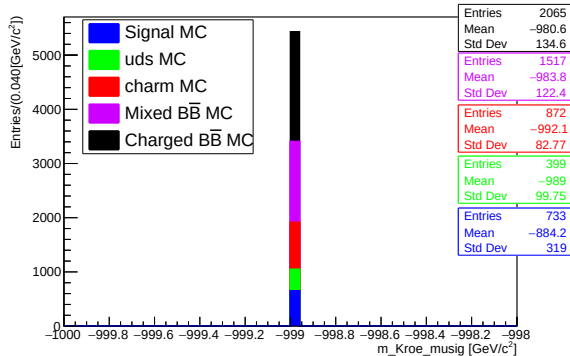
Candidates rejected by the $K\mu$ veto

m_Ksig_muroe:m_Kroe_musig (Yincl_rank==1 && ((m_Kroe_musig>0 && m_Kroe_musig<1.91) || (m_Ksig_muroe>0 && m_Ksig_muroe<1.91)))

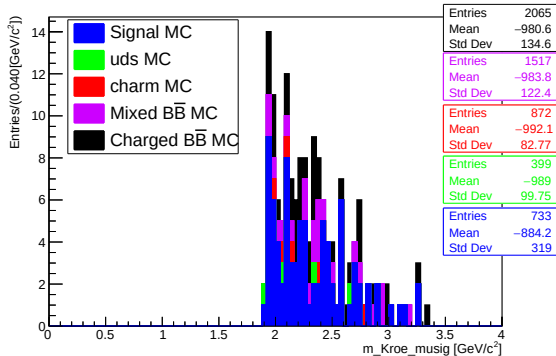


- Both not found: 0 times
- Only $K_{sig}\mu_{roe}$: 15 times
- Only $K_{roe}\mu_{sig}$: 5 times
- Both are found: 955 times
- Total = 975 candidates
- Relative loss = 57.1%

$M_{K_{\text{roe}}^+ \mu_{\text{sig}}^-}$ for the Accepted candidates

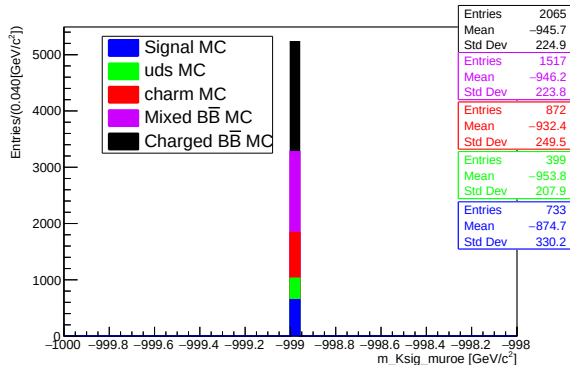


Combination not found

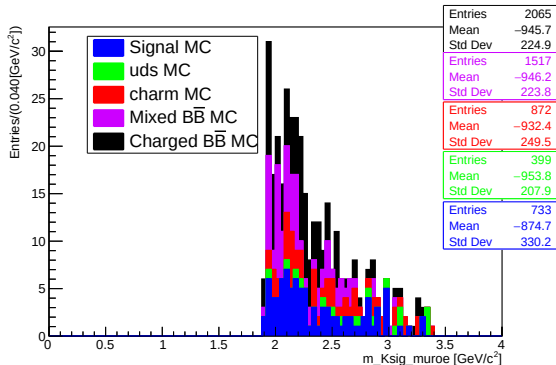


Combination found but not rejected

$M_{K_{\text{sig}}^+ \mu_{\text{ro}}^-}$ for the Accepted candidates

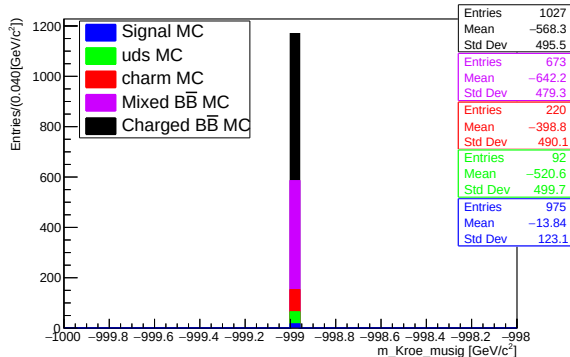


Combination not found

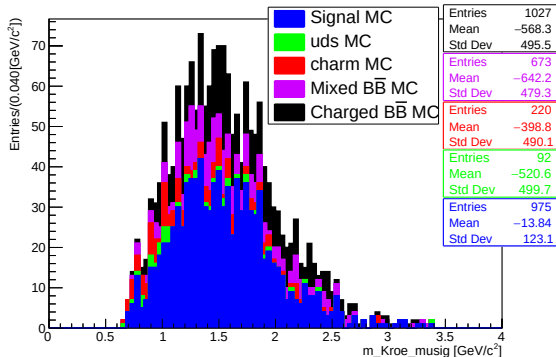


Combination found but not rejected

$M_{K_{\text{roe}}^+ \mu_{\text{sig}}^-}$ for the Rejected candidates

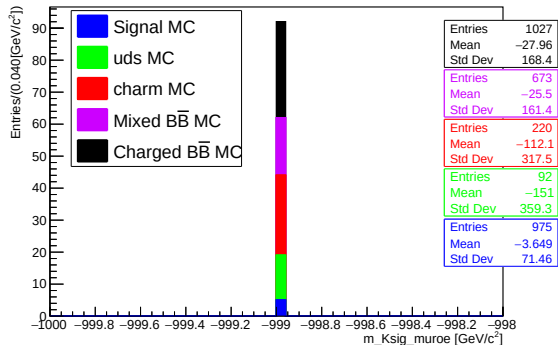


Combination not found

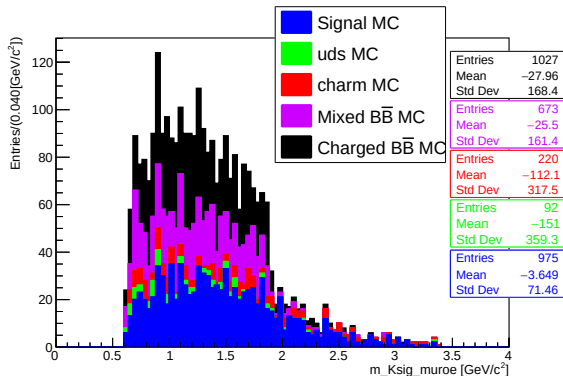


Combination found and rejected

$M_{K_{\text{sig}}^+ \mu_{\text{roe}}^-}$ for the Rejected candidates

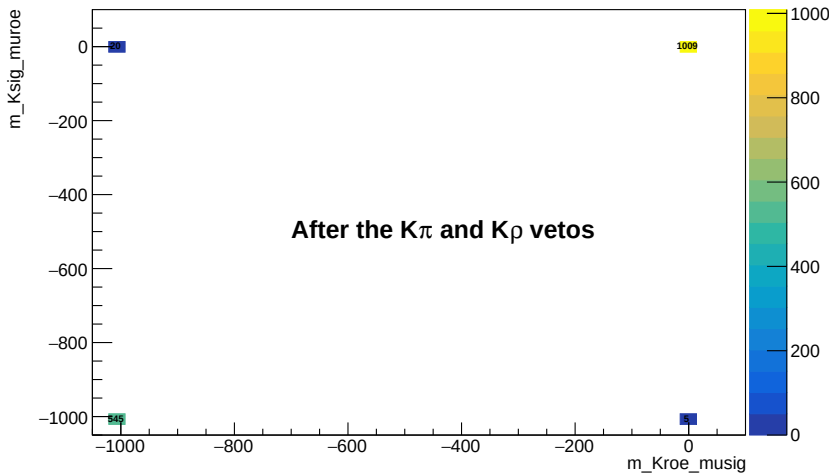


Combination not found



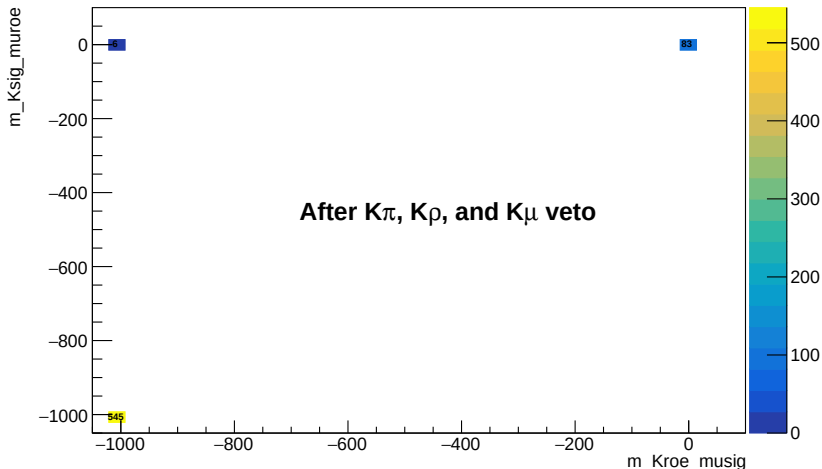
Combination found and rejected

All the candidates after BCS, $K\pi$, and $K\rho$ conditions



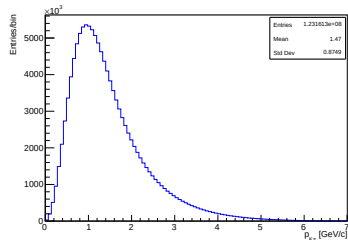
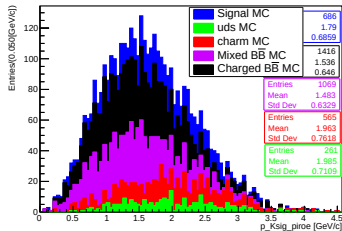
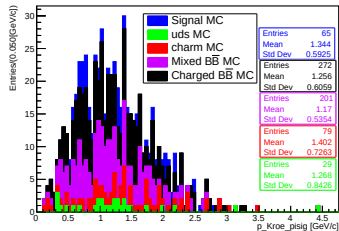
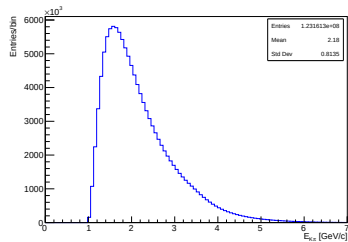
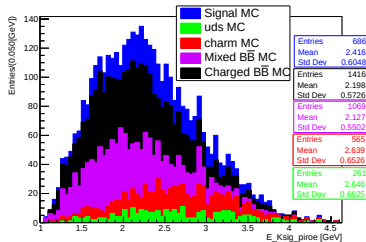
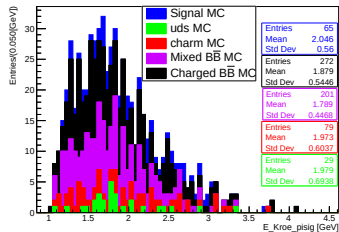
- Both not found: 545 times
- Only $K_{sig}\mu_{roe}$: 20 times
- Only $K_{roe}\mu_{sig}$: 5 times
- Both are found: 1009 times
- Total = 1579 candidates

All the candidates after BCS, $K\pi$, $K\rho$, and $K\mu$ conditions



- Both not found: 545 times
- Only $K_{\text{sig}}\mu_{\text{roe}}$: 6 times
- Only $K_{\text{roe}}\mu_{\text{sig}}$: 0 times
- Both are found: 83 times
- Total = 634 candidates
- Relative ϵ : 40.1%

$E_{K\pi}$ & $p_{K\pi}$ distributions: MC vs data



Back Up

Summary

Condition	Signal MC ($\epsilon_{\text{rel}}\%$)	True Signals ($\epsilon_{\text{rel}}\%$)	uds (% loss)	charm (% loss)	mixed (% loss)	charged (% loss)
Pre-selection	1791(100)	1205(100)	487(0)	1132(0)	2311(0)	3266(0)
BCS	1681(93.86)	1167(96.85)	453(6.98)	1030(9.01)	2095(9.35)	3018(7.59)
$m_{K\pi}$	1644(97.8)	1139(97.6)	438(3.31)	996(3.3)	1996(4.73)	2874(4.77)
$m_{K\rho}$	1544(93.92)	1081(94.91)	409(6.62)	896(10.04)	1786(10.52)	2494(13.22)
$m_{K\mu}$	613(39.7)	383(35.43)	332(18.83)	709(20.87)	1208(32.36)	1596(36.01)
m_{Ke}	609(99.35)	383(100)	320(3.61)	663(6.49)	1163(3.73)	1551(2.82)

Cut flow table based on the real data

Condition	Signal MC ($\epsilon_{\text{rel}}\%$)	True Signals ($\epsilon_{\text{rel}}\%$)	uds (% loss)	charm (% loss)	mixed (% loss)	charged (% loss)
Pre-selection	1791(100)	1205(100)	487(0)	1132(0)	2311(0)	3266(0)
BCS	1681(93.86)	1167(96.85)	453(6.98)	1030(9.01)	2095(9.35)	3018(7.59)
$m_{K\pi}$	1660(98.75)	1153(98.8)	444(1.99)	1011(1.84)	2009(4.11)	2907(3.68)
$m_{K\rho}$	1596(96.14)	1122(97.31)	426(4.05)	959(5.14)	1881(6.37)	2656(8.63)
$m_{K\mu}$	652(40.85)	412(36.72)	348(18.31)	762(20.54)	1281(31.9)	1729(34.9)
m_{Ke}	648(99.39)	412(100)	335(3.74)	715(6.17)	1235(3.59)	1683(2.66)