

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

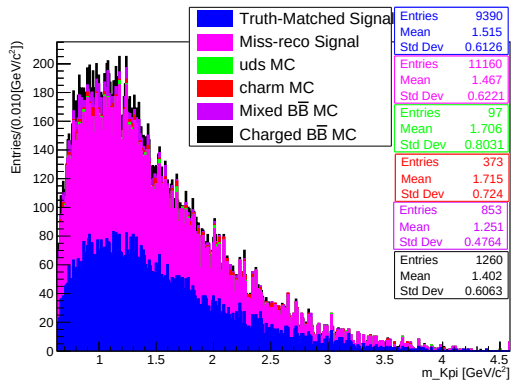
- Impact parameters: $|dr| < 1 \text{ cm}$ & $|dz| < 4 \text{ cm}$.
- Track momentum $p > 50 \text{ MeV}/c$.
- *electrons* : $e_{\text{ID}} > 0.6$, $\mu_{\text{ID}} < 0.98$,
 $\text{atcPIDBelle}(K, e) < 0.98$
- *muons* : $\mu_{\text{ID}} > 0.6$, $e_{\text{ID}} < 0.98$,
 $\text{atcPIDBelle}(K, \mu) <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

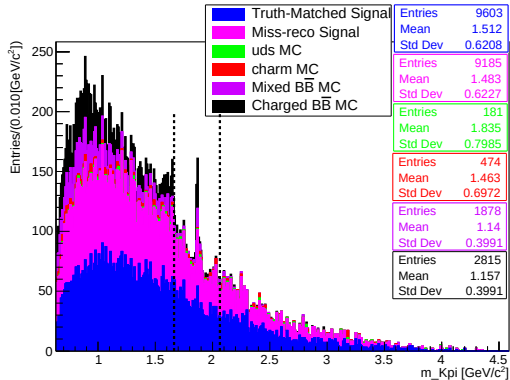
- goodBelleGamma: $E_{\gamma}^{\text{FE}} > 100 \text{ MeV}$,
 $E_{\gamma}^{\text{BR}} > 50 \text{ MeV}$, $E_{\gamma}^{\text{BE}} > 150 \text{ MeV}$.
- FakePhoton > 0.3 ,
BeamBackground > 0.3
- π^0 : $80 < M_{\gamma\gamma} < 180 \text{ MeV}/c^2$ &
 $\text{chiProb} > 0.001$
- ρ^+ : $570 < M_{\pi^+\pi^0}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

$\Upsilon(4S)$

- $|\sin \phi| < 1.0$

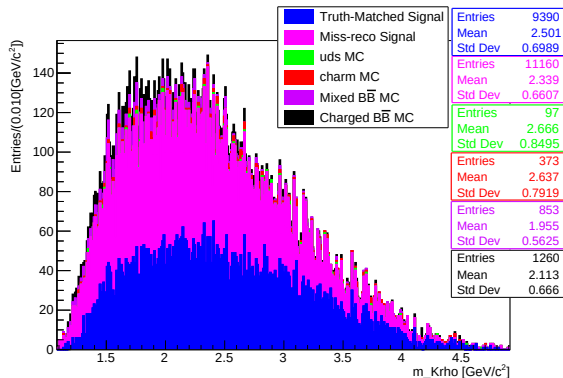


$$B^+ \rightarrow K^+ \tau^+ \ell^-$$

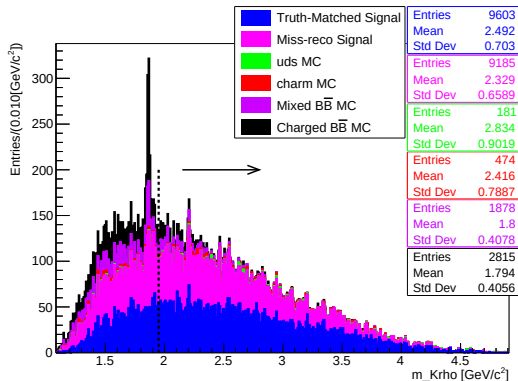


$$B^+ \rightarrow K^+ \tau^- \ell^+$$

- Invariant mass distribution of the $B^+ \rightarrow K^+ \tau^\pm [\pi^\pm \pi^0 \nu_\tau] \ell^\mp$ system.
- Select the $B^+ \rightarrow K^+ \tau^- \ell^+$ candidates for which $|m_{K^+ \ell^-} - m_{D^0}| > 200 \text{ MeV}/c^2$.

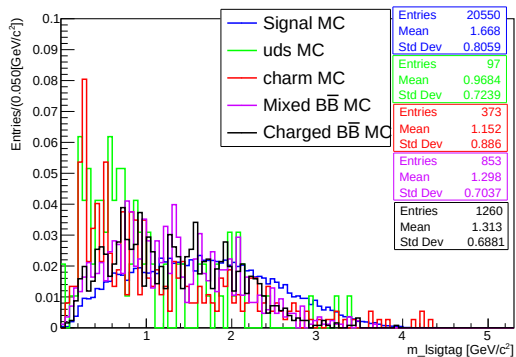


$$B^+ \rightarrow K^+ \tau^+ \ell^-$$

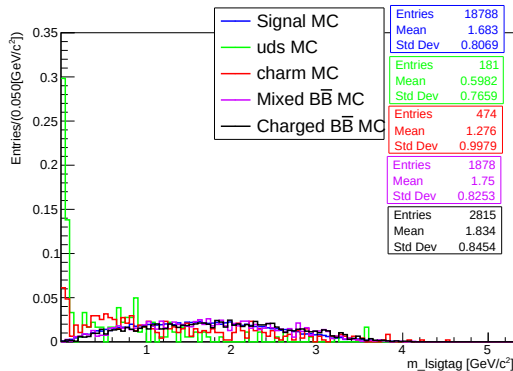


$$B^+ \rightarrow K^+ \tau^- \ell^+$$

- Cascades from $D^0 \rightarrow K^- \rho^+ (\mathcal{B} = 11.2\%)$ have significant contributions to the candidates from signal miss-reconstruction and $B\bar{B}$ background.
- Suggested cut: $M_{K\rho} > 1.95 \text{ GeV}/c^2$.

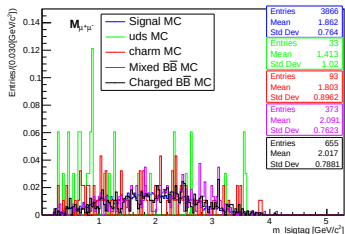
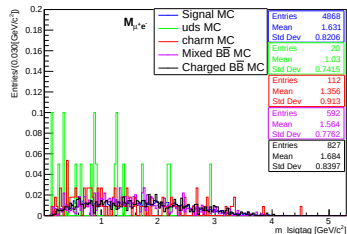
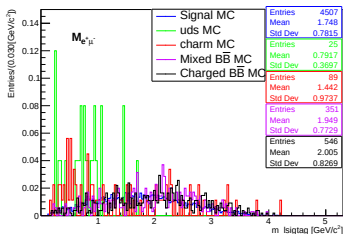
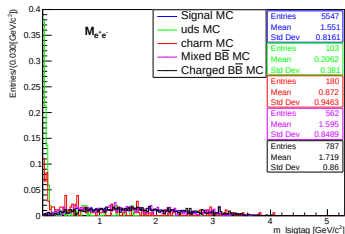


$$B^+ \rightarrow K^+ \tau^+ \ell^- \text{ \& \& } B^- \rightarrow D^0 \ell^-$$



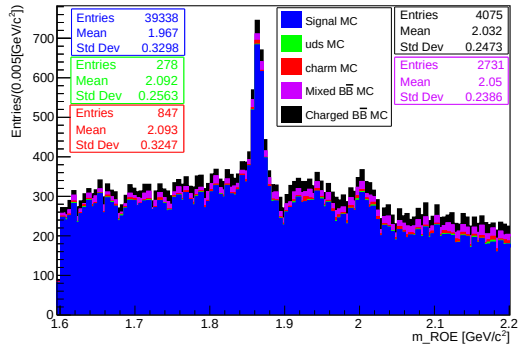
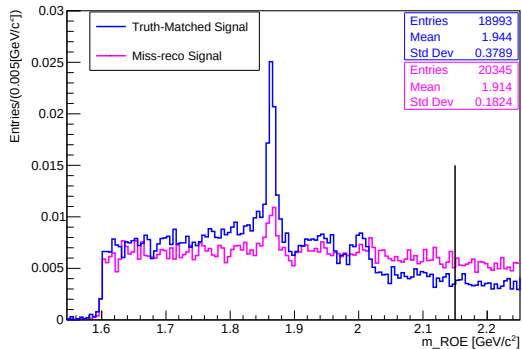
$$B^+ \rightarrow K^+ \tau^- \ell^+ \text{ \& \& } B^- \rightarrow D^0 \ell^-$$

$$M_{\text{sig} \ell \text{tag}}: B^+ \rightarrow K^+ \tau^- \ell^+ \text{ \& } B^- \rightarrow D^0 \ell^-$$



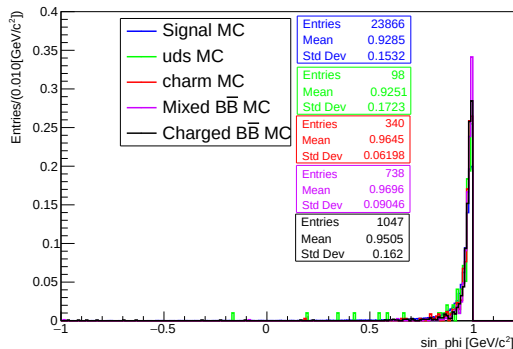
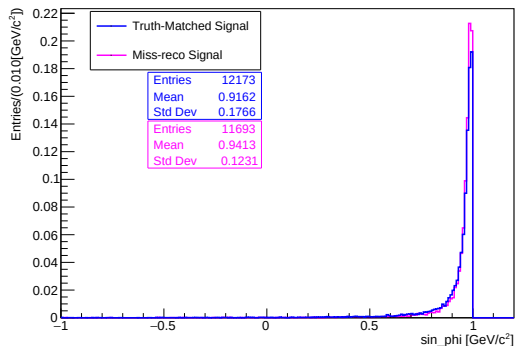
- Contributions from the e^+e^- combinations in the continuum events can be high suppressed by requiring the $m_{e^+_{\text{sig}} e^-_{\text{tag}}} > 20 \text{ MeV}/c^2$.

M_{ROE} (Inclusively D^0 mass)

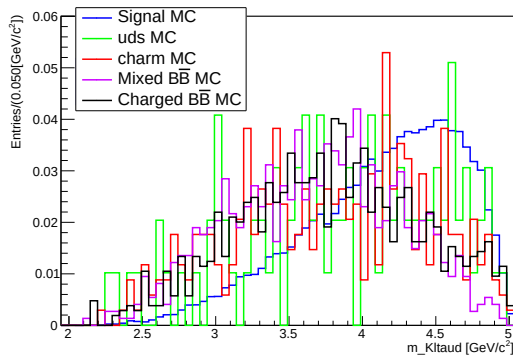
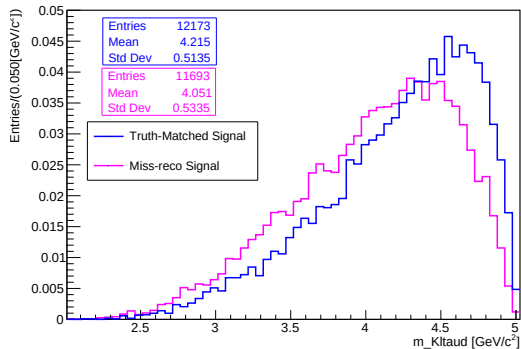


- Suggested cut: $m_{\text{ROE}} < 2.15$ GeV/c².

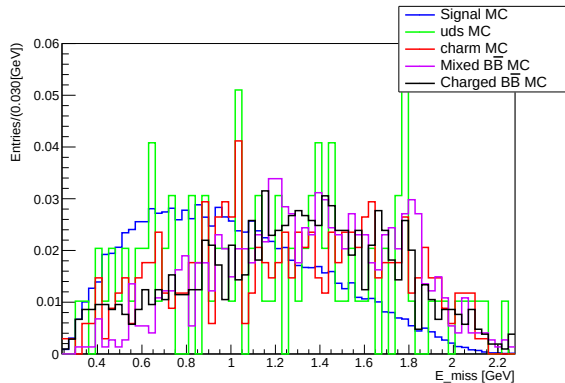
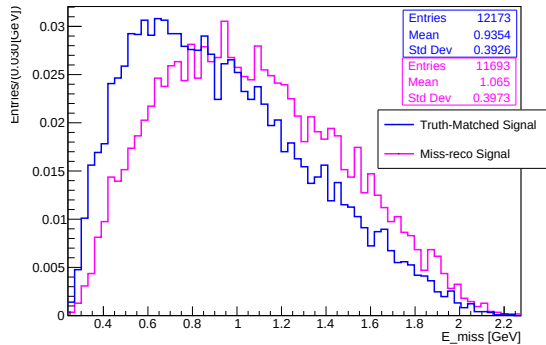
$\sin \phi$ with the suggested cuts



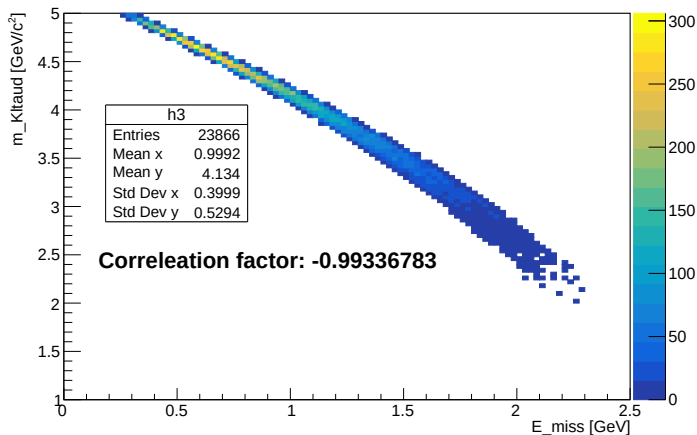
- $\epsilon = 0.6\%$, $\epsilon_{\text{true}} = 0.3\%$
- Background contributions: uds ~ 16 , charm ~ 57 , mixed- $B\bar{B}$ ~ 123 , and charged- $B\bar{B}$ ~ 175



- Invariant mass distribution of the $B^+ \rightarrow K^+ \tau^\pm [\rho^\pm \nu_\tau] \ell^\mp$ system.



E_{miss} vs $M_{K\ell\rho}$ correlation



- High correlation between the two observables: Better to look only at the missing energy.

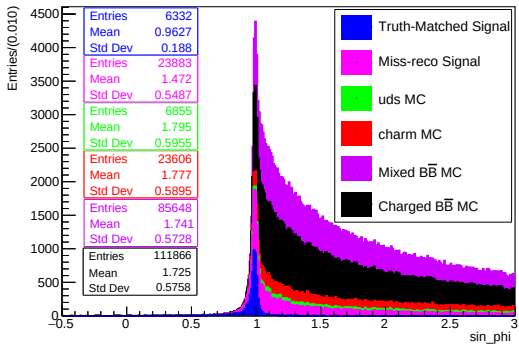
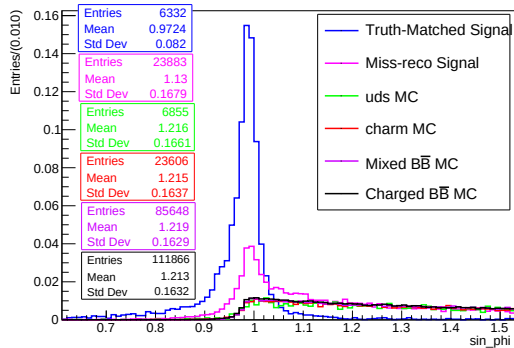
Back Up

Cut flow table

Condition	Signal MC ($\epsilon_{\text{rel}}\%$)	True Signals ($\epsilon_{\text{rel}}\%$)	uds (% loss)	charm (% loss)	mixed (% loss)	charged (% loss)
Pre-selection	327896(100)	9559(100)	83007(0)	352022(0)	1295617(0)	2005665(0)
eID < 0.98	318037(96.99)	9546(99.86)	80013(3.61)	338120(3.95)	1205877(6.93)	1865540(6.99)
mulID < 0.98	298018(93.71)	9504(99.56)	79229(0.98)	329890(2.43)	1149098(4.71)	1764922(5.39)
pionID > 0.4	231144(77.56)	9295(97.8)	64420(18.69)	252289(23.52)	912773(20.57)	1317819(25.33)
goodBelleGamma	231144(100)	9295(100)	64420(0)	252289(0)	912773(0)	1317819(0)
fakePhoton > 0.3	107873(46.67)	7930(85.31)	26134(59.43)	103701(58.9)	378863(58.49)	551014(58.19)
Beam-Background > 0.3	61476(56.99)	6893(86.92)	15156(42.01)	57208(44.83)	203070(46.4)	283738(48.51)
chiProb $M_{\pi^0} > 0.001$	30215(49.15)	6332(91.86)	6855(54.77)	23606(58.74)	85648(57.82)	111866(60.57)
$ \sin \phi < 1.2$	16996(56.25)	6174(97.5)	1391(79.71)	4991(78.86)	18769(78.09)	26039(76.72)
$\ell_{\text{ID}} < 0.6$	16642(97.92)	6069(98.3)	1348(3.09)	4865(2.52)	18298(2.51)	25315(2.78)
$ \sin \phi < 1.0$	8711(52.34)	4726(77.87)	245(81.82)	775(84.07)	2770(84.86)	4101(83.8)

- For the tighter lepton veto, percentage of the truth-matched signals varies from 36.32% $\rightarrow$ 36.47%.
- Tightening the $\sin \phi$ condition, percentage of the truth-matched signals varies from 36.47% $\rightarrow$ 54.25%.

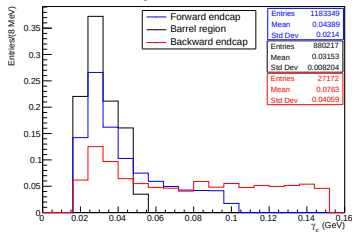
$\sin \phi$ distribution



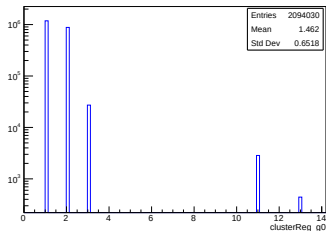
- $\Upsilon(4S)$ selection: $|\sin \phi| < 1.2$.

goodBelleGamma

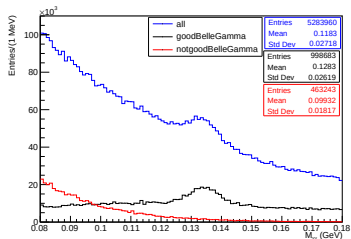
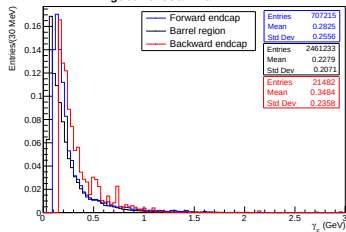
goodBelleGamma==0



clusterReg_g0 (tauDecay_decayModelID==1 && goodBelleGamma_g0==0)

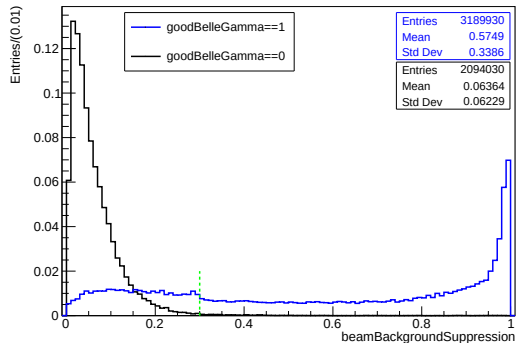
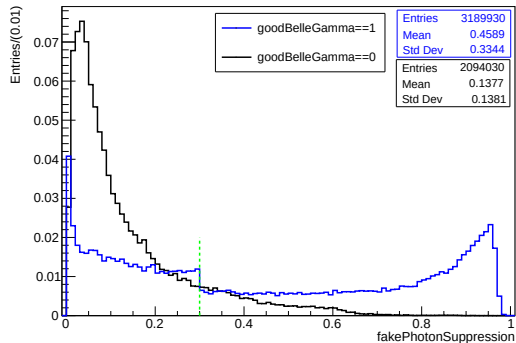


goodBelleGamma==1



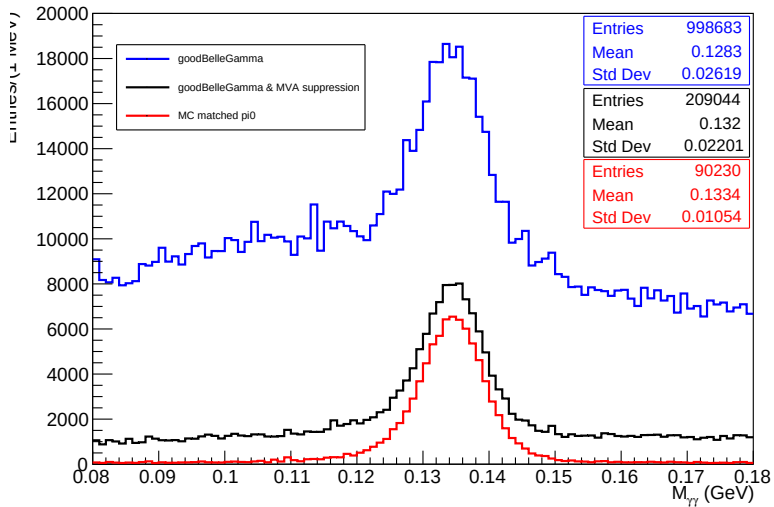
- $\text{goodBelleGamma} \in \text{clusterReg} = [1, 2, 3]$.
- Energy thresholds for these good photons:
 - [1] Forward endcap: > 100 MeV,
 - [2] Barrel region: > 50 MeV, and
 - [3] Backward endcap: > 150 MeV.

Fake photons and beam background suppression: MVA

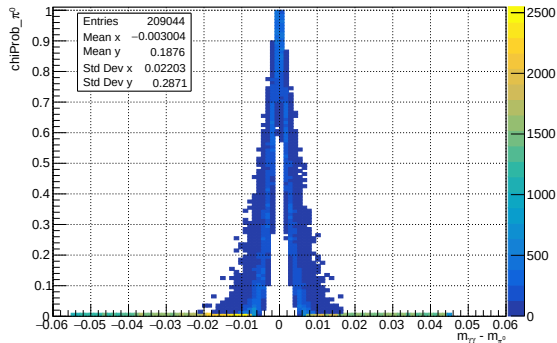
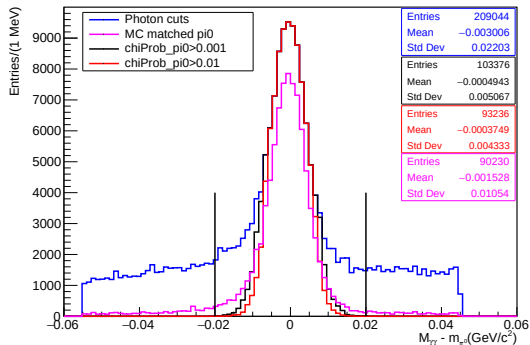


- Training variables: clusterE, clusterHighestE, clusterNhits, clusterTheta, clusterLAT, clusterE9E25, and minC2TDist.
- We select good Belle photons with MVA suppression to be greater than 0.3 for both the variables.

π^0 selection

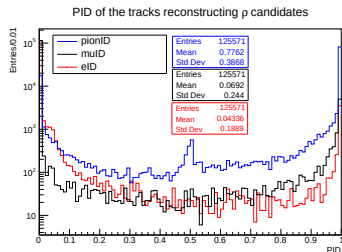
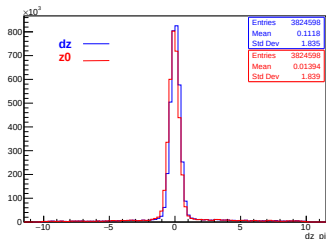
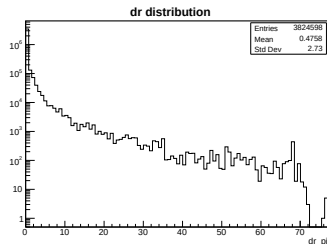


π^0 selection: Mass window or chiProb?



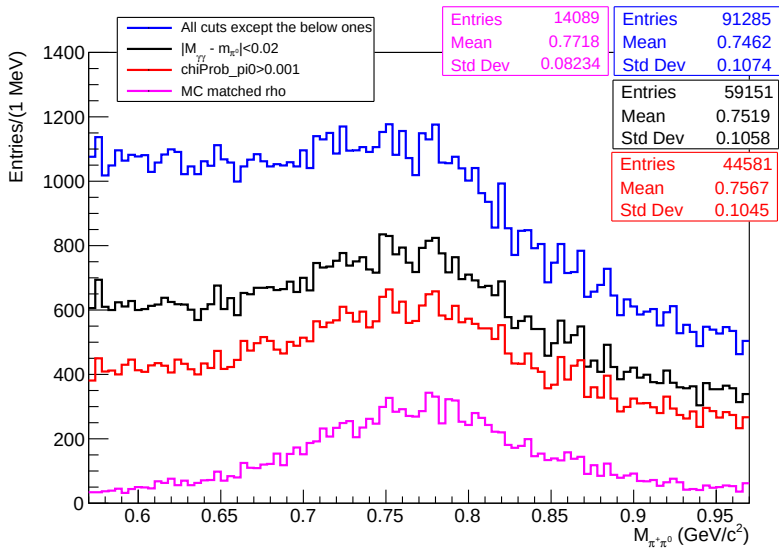
- Relative efficiency for the cut $|M_{\gamma\gamma} - m_{\pi^0}| < 20 \text{ MeV}/c^2$: 65.2%.
- For the $\text{chiProb} > 0.001$: 49.5%.

charged π selection



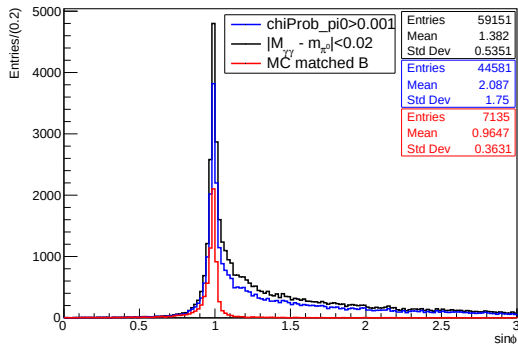
- Distances of the point of closest approach with respect to origin: $|dr| < 1$ cm and $|dz| < 4$ cm.
- PID conditions: $eID < 0.98$, $muID < 0.98$, and $pionID > 0.4$.

$M_{\pi^+\pi^0}$ distribution

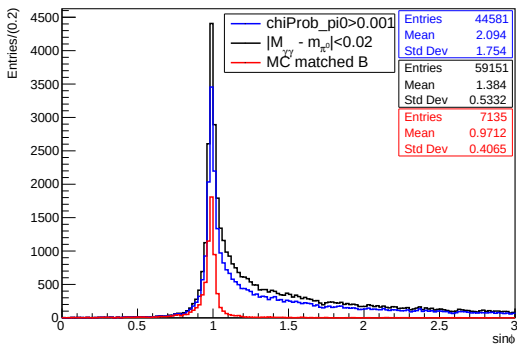


$\sin \phi$ distributions

m_p from pions

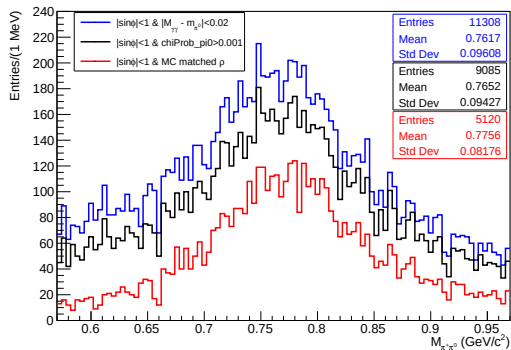
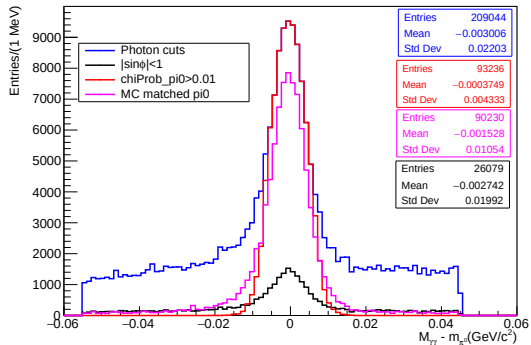


m_p from PDG

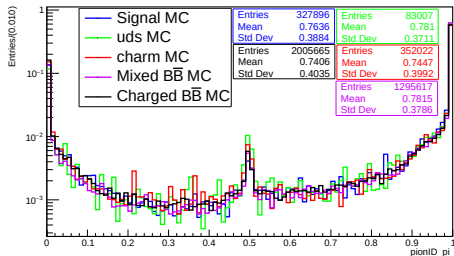
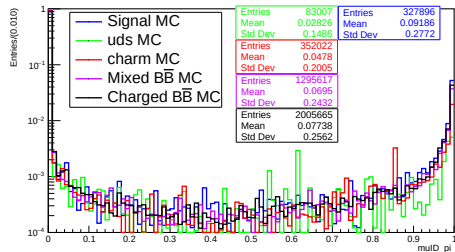
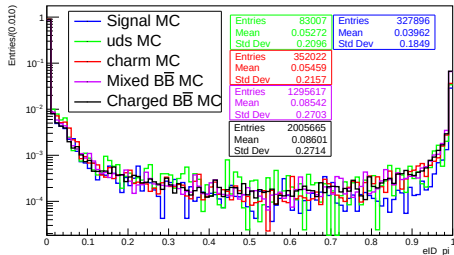


- Good candidates $\in |\sin \phi| < 1.0$

$M_{\gamma\gamma}$ and $M_{\pi^+\pi^0}$ distributions

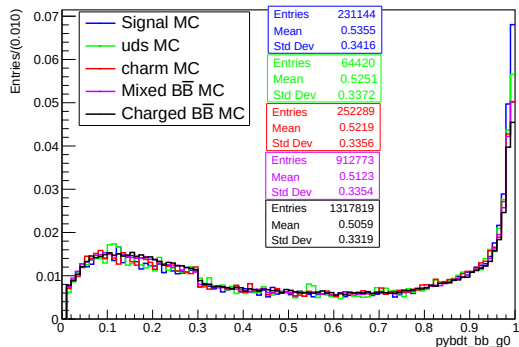
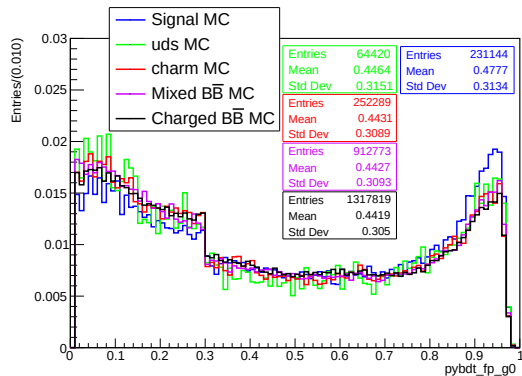


PID comparison: Charged pion selection



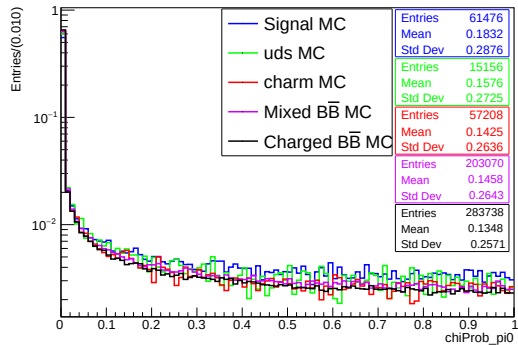
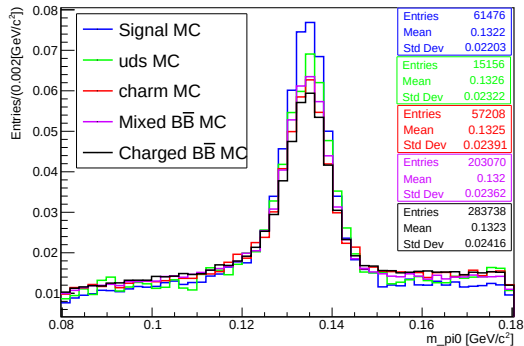
- $\text{pionID} > 0.4$
- Lepton veto: $\text{eID} < 0.6$ & $\text{muID} < 0.6$
- Correction: Earlier,
 $\text{eID} < 0.98$ & $\text{muID} < 0.98$

MVA based photon suppression



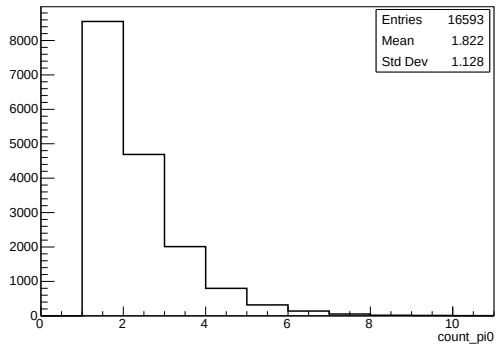
- No distinction between the photons from various components.
- Our conditions: fakePhotonSuppression > 0.3 and beamBackgroundSuppression > 0.3

π^0 invariant mass

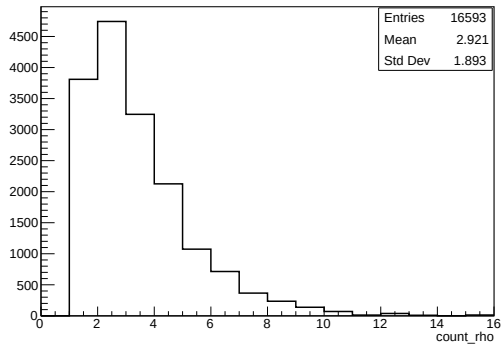


- π^0 Selection: $\text{chiProb} > 0.001$.

π^0 and ρ^+ multiplicity



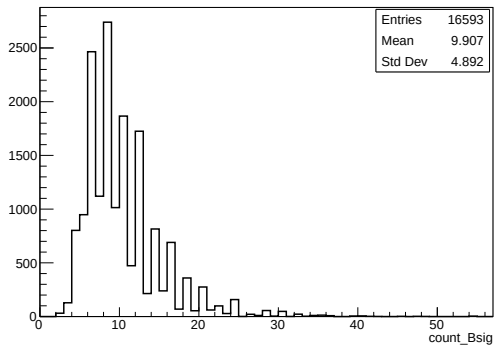
π^0



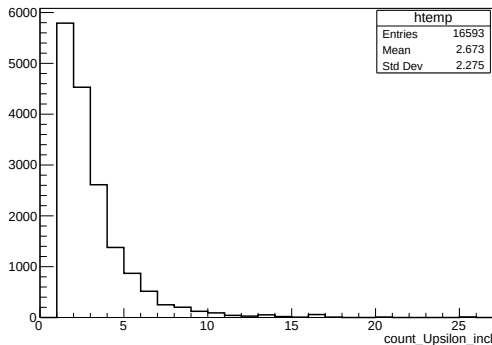
ρ^+

π^0 and ρ^+ multiplicity

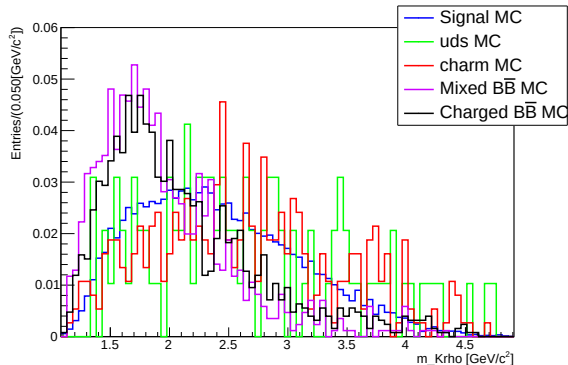
- List contains the numbers from $\tau \rightarrow \pi\nu_\tau$ mode as well.



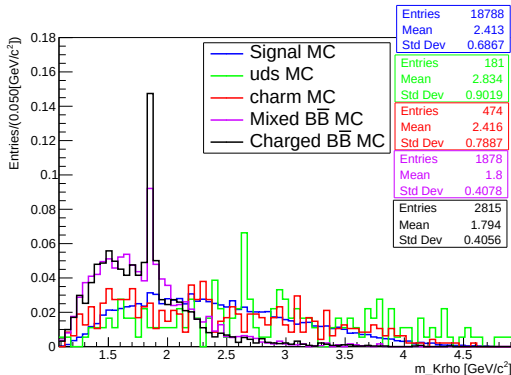
B_{sig}^+



$\Upsilon(4S)$ inclusive



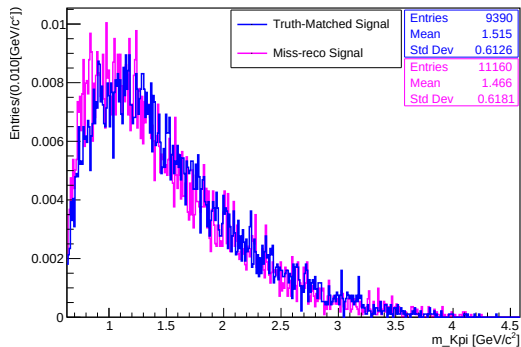
$$B^+ \rightarrow K^+ \tau^+ \ell^-$$



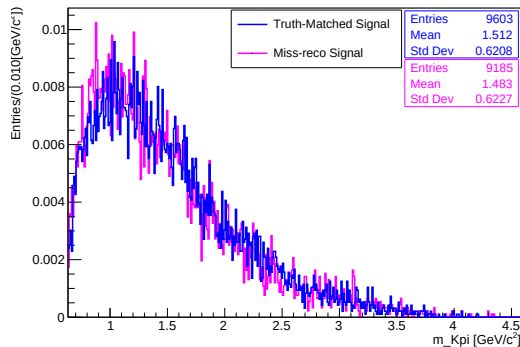
$$B^+ \rightarrow K^+ \tau^- \ell^+$$

- Cascades from $D^0 \rightarrow K^- \rho^+$ ($\mathcal{B} = 11.2\%$) have significant contributions to the candidates from signal miss-reconstruction and $B\bar{B}$ background.
- Suggested cut: $M_{K\rho} > 1.95 \text{ GeV}/c^2$.

$M_{K\pi}$: Signal MC



$$B^+ \rightarrow K^+ \tau^+ \ell^-$$



$$B^+ \rightarrow K^+ \tau^- \ell^+$$

- Invariant mass distribution of the $B^+ \rightarrow K^+ \tau^\pm [\pi^\pm \pi^0 \nu_\tau] \ell^\mp$ system.