

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* : $\mu_{\text{ID}} < 0.98$, $e_{\text{ID}} < 0.98$, $\text{atcPIDBelle}(K, \pi) > 0.6$

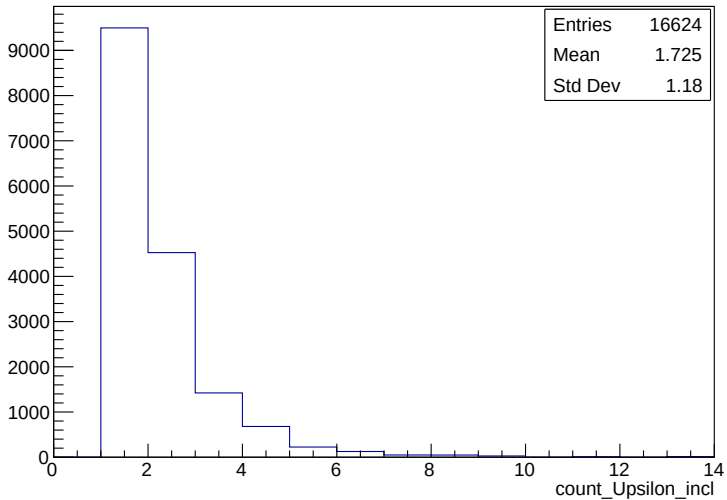
ECL Clusters, π^0 , & ρ^+

- 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^+ : $570 < M_{\pi^+\pi^0} < 970 \text{ MeV}/c^2$.

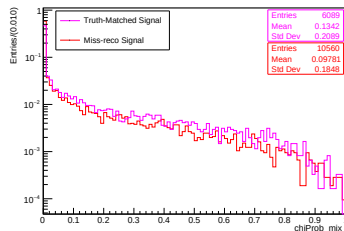
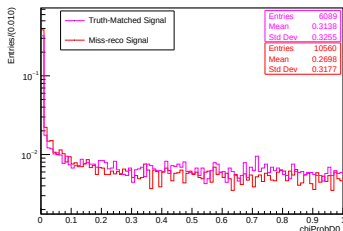
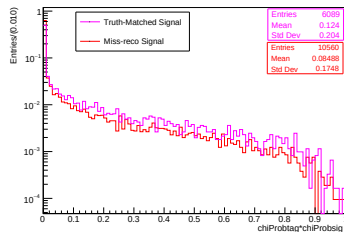
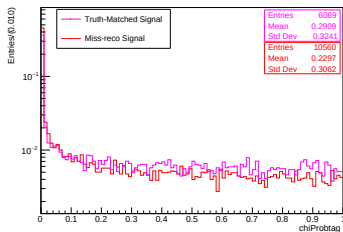
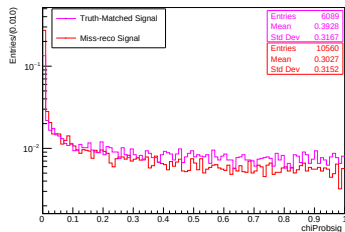
$\Upsilon(4S)$

- $\sin \phi < 1.2$

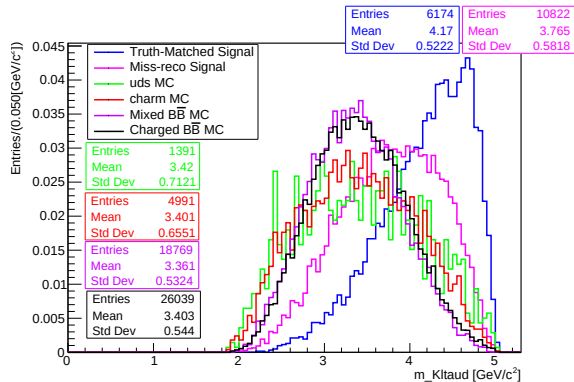
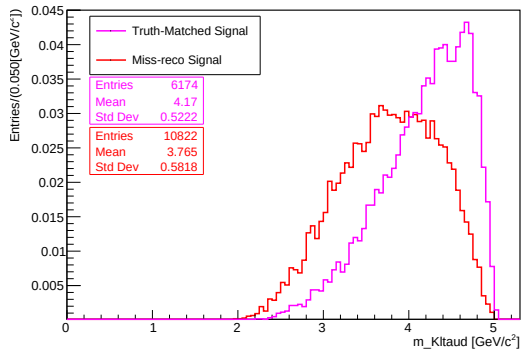
of $\Upsilon(4S)$ candidates



chiProb distributions

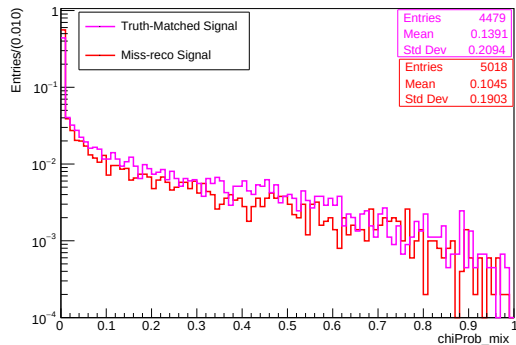


- Fitter: treeFit
- Constraint: IP

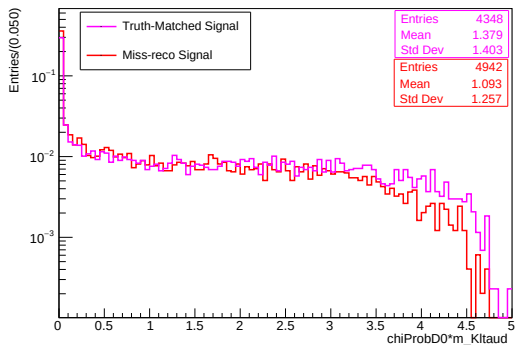


- Truth-matched signal distribution has relatively higher mean.

Single candidate events



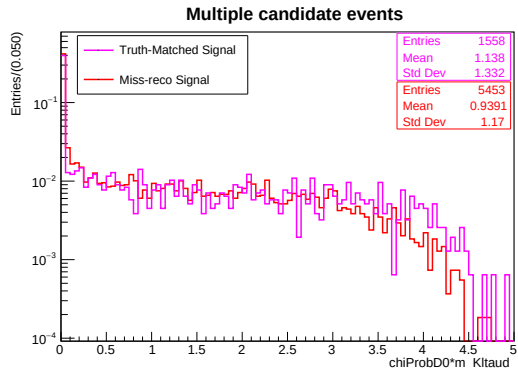
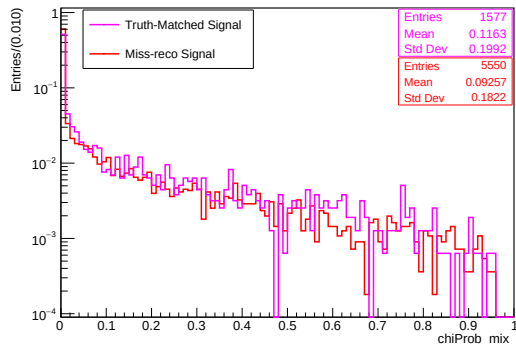
% of True candidates = 47.2



% of True candidates = 46.8

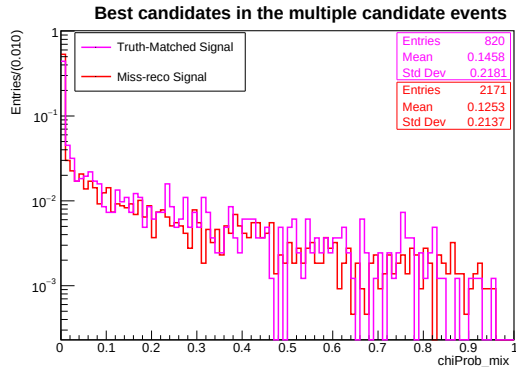
- No distinct selection criteria has been applied. (only an iteration with ranking based on the later variable)

Multiple candidate events

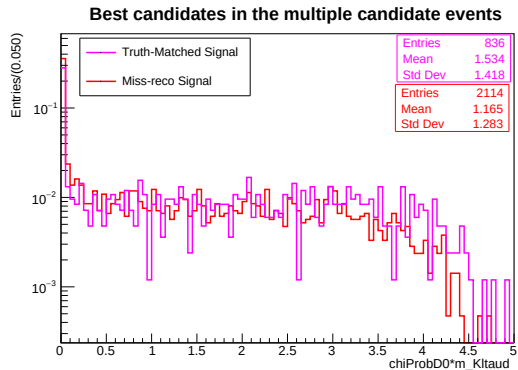


- Distributions from multiple candidate events.
- Around 24% of the selected events have multiple candidates.

Best candidate in the multiple candidate events

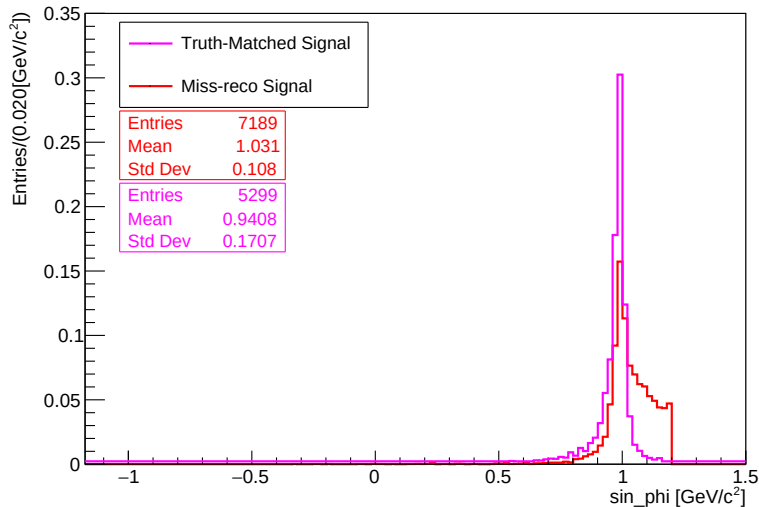


% of True candidates = 27.4%



% of True candidates = 28.3%

Best Candidates



- $\epsilon = 1.2\%$

- $\epsilon_{true} = 0.5\%$

Bkg stat. per stream
(BCS not applied)

- # uds < 225
- # charm < 811
- # mixed < 3050
- # charged < 4219.

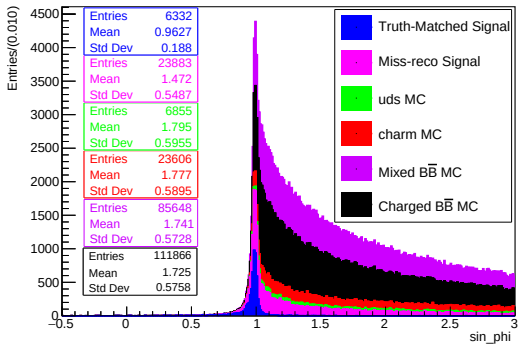
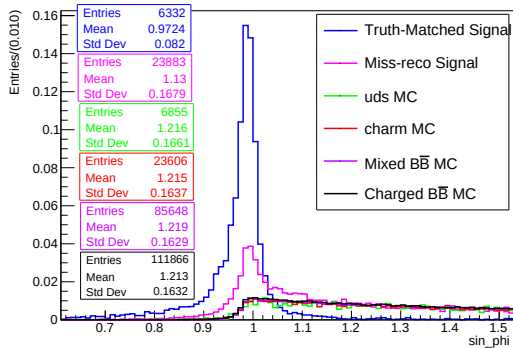
Back Up

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)
$\mu ID < 0.98$	298018(93.71)	9504(99.56)	79229(0.98)	329890(2.43)	1149098(4.71)	1764922(5.39)
$\pi ID > 0.4$	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)
$\chi\text{Prob } M_{\pi^0} > 0.001$	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)
$\ell_{ID} < 0.6$	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%.

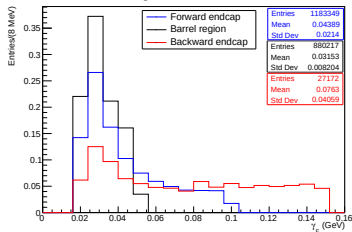
$\sin \phi$ distribution



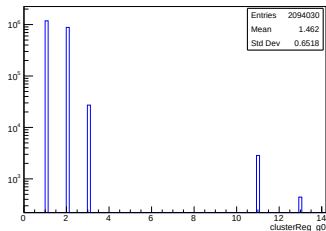
- $\Upsilon(4S)$ selection: $|\sin \phi| < 1.2$.

goodBelleGamma

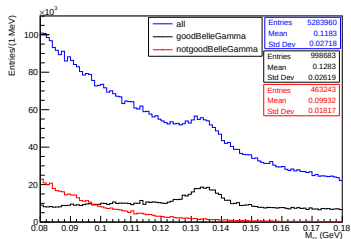
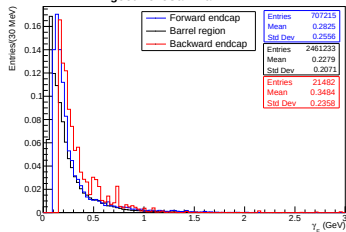
goodBelleGamma==0



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

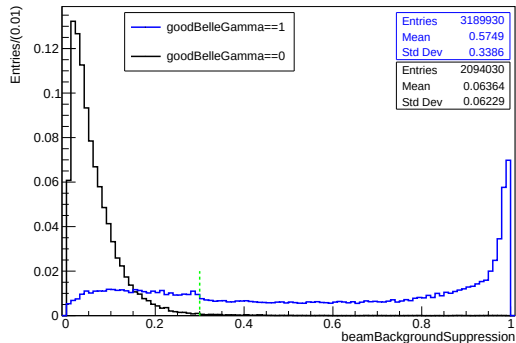
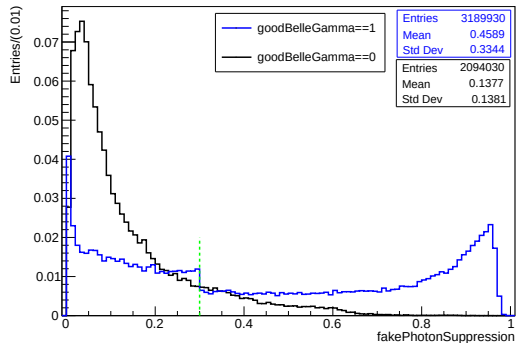


goodBelleGamma==1



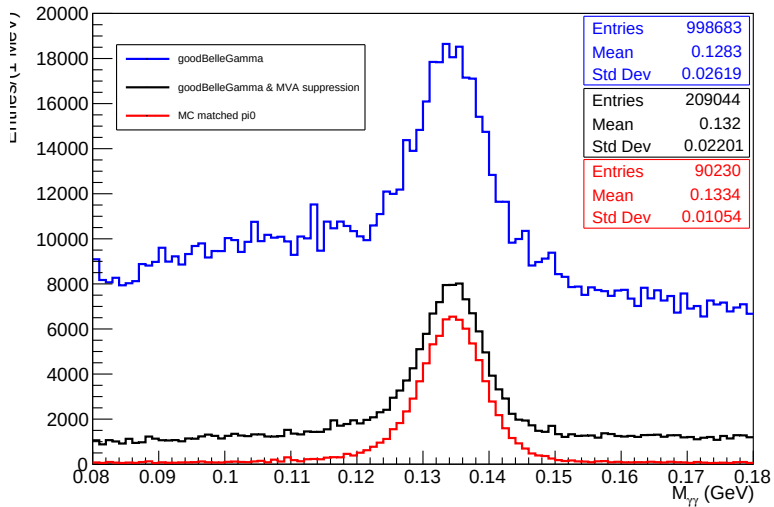
- $\text{goodBelleGamma} \in \text{clusterReg} = [1, 2, 3]$.
- Energy thresholds for these good photons:
 - [1] Forward endcap: > 100 MeV,
 - [2] Barrel region: > 50 MeV, and
 - [3] Backward endcap: > 150 MeV.

Fake photons and beam background suppression: MVA

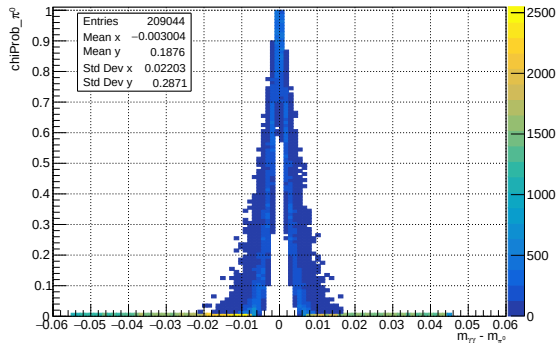
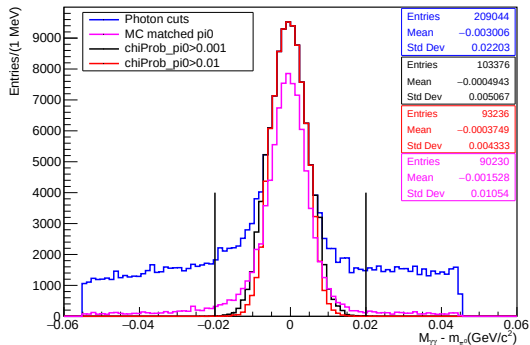


- Training variables: clusterE, clusterHighestE, clusterNhits, clusterTheta, clusterLAT, clusterE9E25, and minC2TDist.
- We select good Belle photons with MVA suppression to be greater than 0.3 for both the variables.

π^0 selection

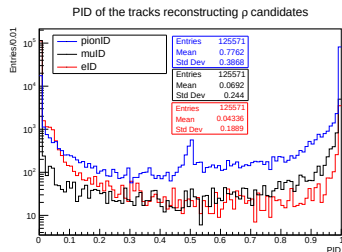
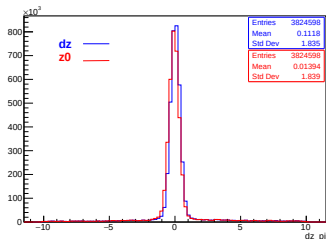
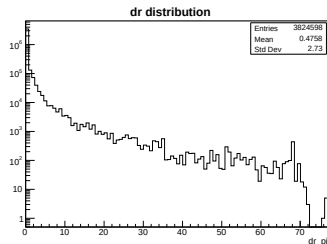


π^0 selection: Mass window or chiProb?



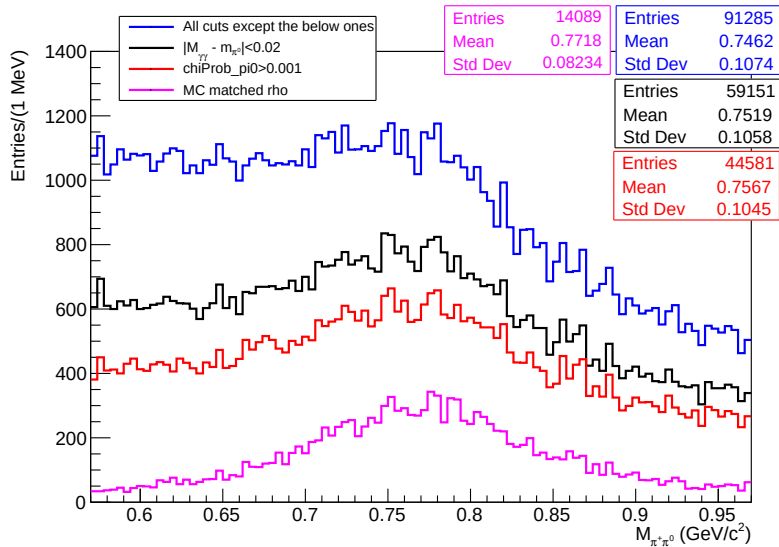
- Relative efficiency for the cut $|M_{\gamma\gamma} - m_{\pi^0}| < 20 \text{ MeV}/c^2$: 65.2%.
- For the $\text{chiProb} > 0.001$: 49.5%.

charged π selection



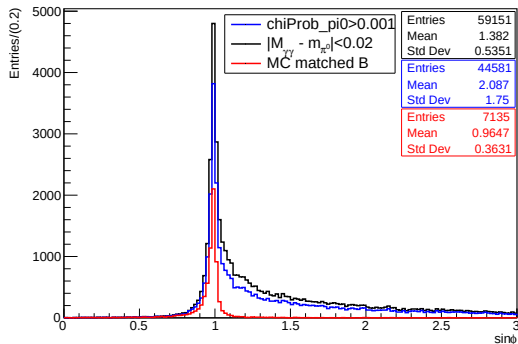
- Distances of the point of closest approach with respect to origin: $|dr| < 1$ cm and $|dz| < 4$ cm.
- PID conditions: $eID < 0.98$, $muID < 0.98$, and $pionID > 0.4$.

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

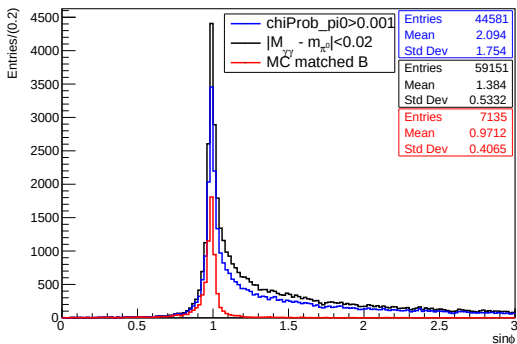


$\sin \phi$ distributions

m_p from pions

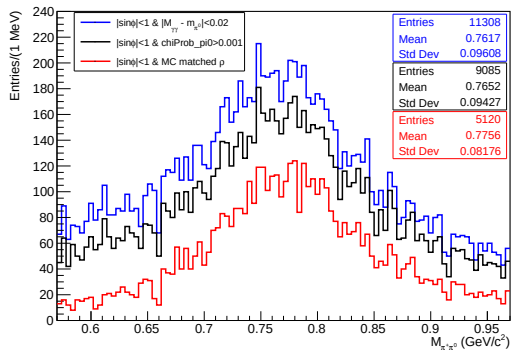
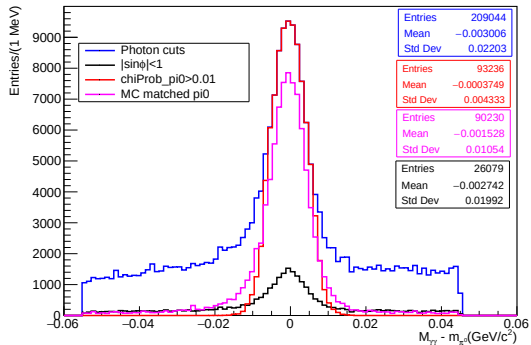


m_p from PDG

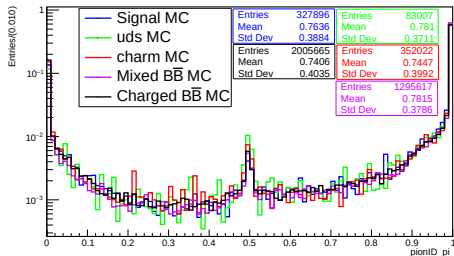
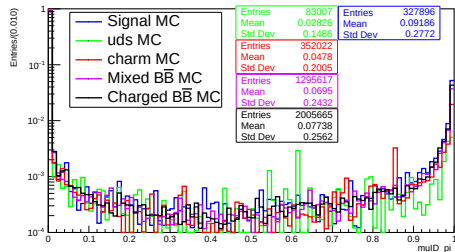
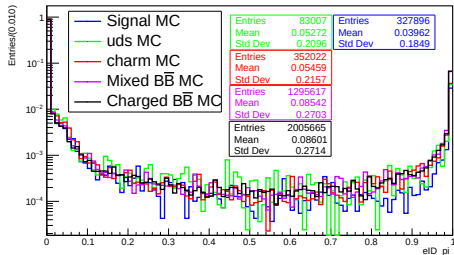


- Good candidates $\in |\sin \phi| < 1.0$

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

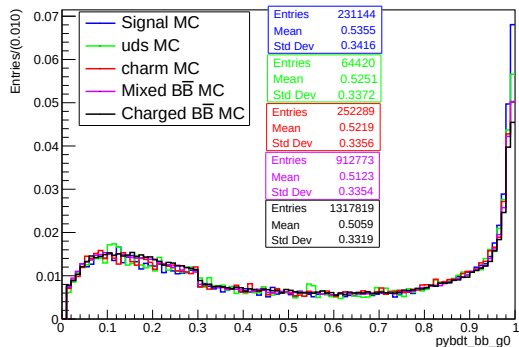
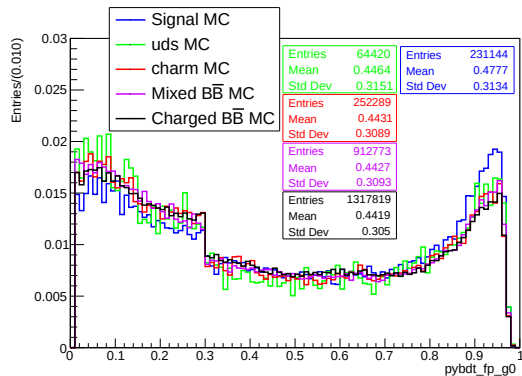


PID comparison: Charged pion selection



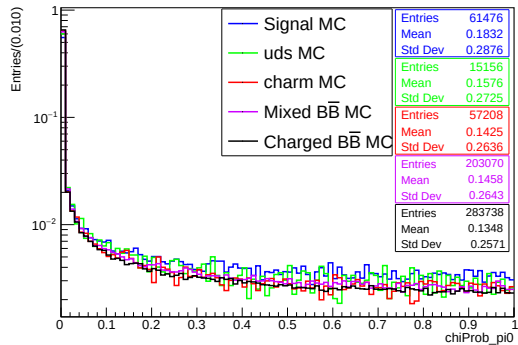
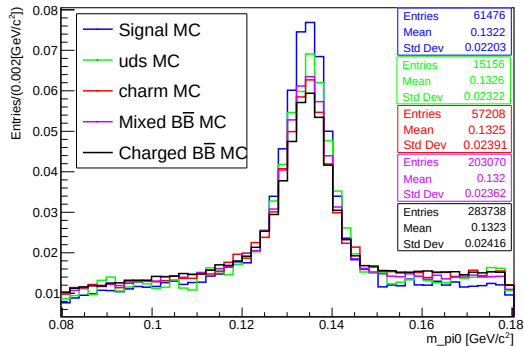
- $\text{pionID} > 0.4$
- Lepton veto: $\text{eID} < 0.6$ & $\text{muID} < 0.6$
- Correction: Earlier,
 $\text{eID} < 0.98$ & $\text{muID} < 0.98$

MVA based photon suppression



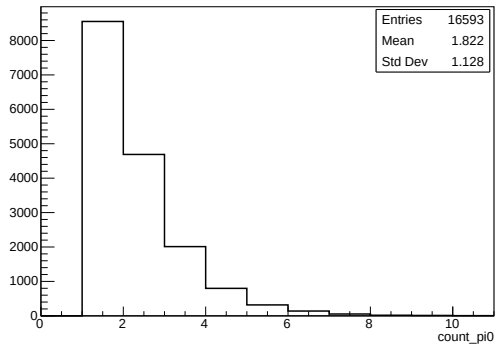
- No distinction between the photons from various components.
- Our conditions: fakePhotonSuppression > 0.3 and beamBackgroundSuppression > 0.3

π^0 invariant mass

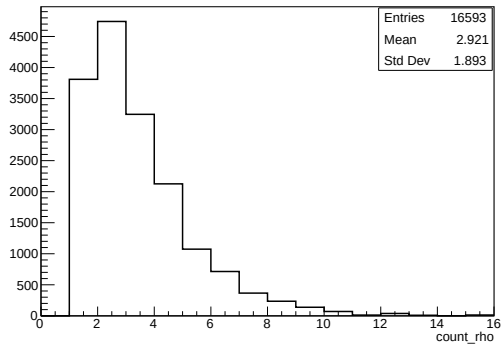


- π^0 Selection: $\text{chiProb} > 0.001$.

π^0 and ρ^+ multiplicity



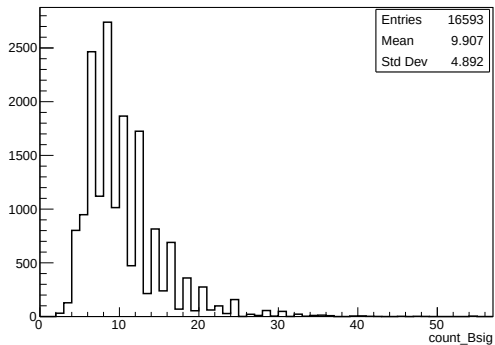
π^0



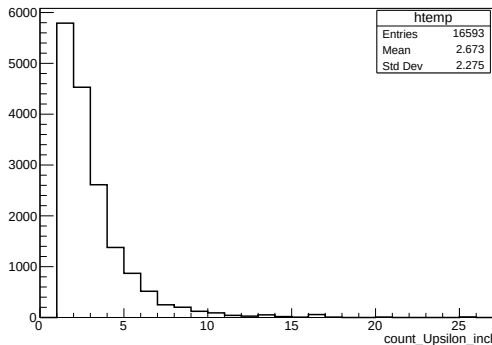
ρ^+

π^0 and ρ^+ multiplicity

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



B_{sig}^+



$\Upsilon(4S)$ inclusive