$B \to \omega K \gamma$ Analysis

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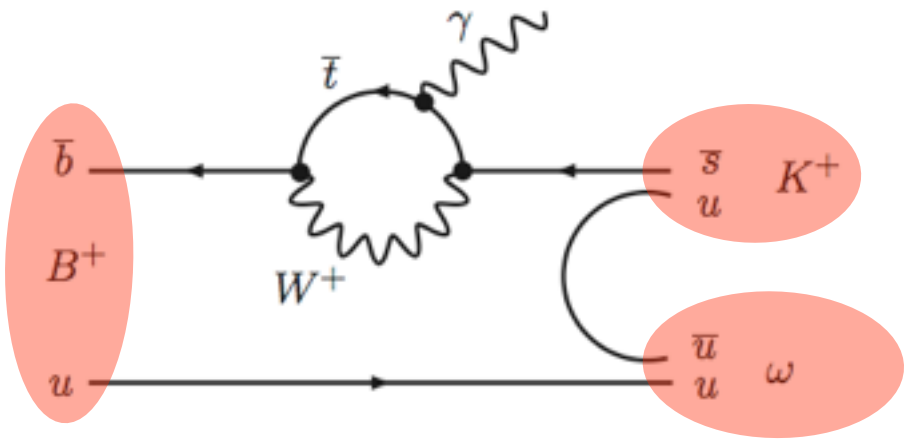
Motivation

- New radiative b→sγ penguin decay.



- Forbidden at tree-level in the SM, but allowed through loop (penguin) diagrams.
- Non-SM particles can contribute to the loop : excellent probe for physics beyond SM.
- Signal is not observed yet for this mode. This will be the first measurements in this channel.

Branching Fraction

- First measurement of branching fraction in charged and neutral mode.
- Assumed BF : using measured $B(\mathrm{B}\to\varphi\mathrm{K}\gamma)$ and the BF ratio of B decays of ωK and φK

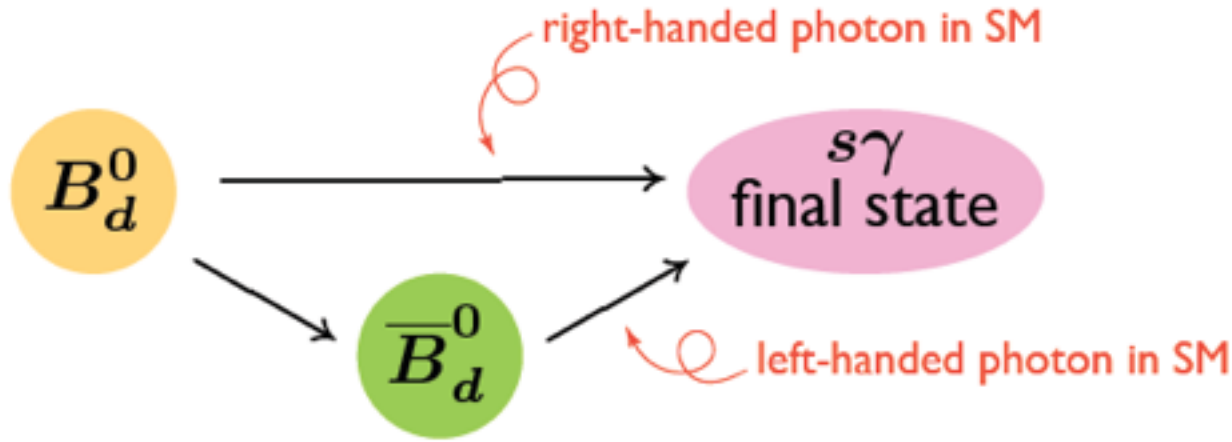
$$B(\mathrm{B}\to\omega\mathrm{K}\gamma) \simeq B(\mathrm{B}\to\varphi\mathrm{K}\gamma) \times [\, B(\mathrm{B}\to\omega\mathrm{K}) \,/\, B(\mathrm{B}\to\varphi\mathrm{K}) \,] \simeq 2.0 \times 10^{-6}$$

Branching Fraction

- Could even be four times larger due to hadronization of lighter quarks (uu, dd) to form the ω meson.
- Analogous to the mode with η meson (uu, dd, ss):$B(B^+ \to \eta K^+ \gamma)$ $= (7.9 \pm 0.9) \times 10^{-6}$
- Also room for new Physics.. (possible contribution from new resonances decaying to ωK)

Search for New Physics

D. Atwood, M.Gronau, A.Soni,
PRL 79, 185 (1997)



- In SM, radiative photon from b→sγ transition is flavor-specific.
- $B^0 \leftrightarrow \bar{B}^0$ interference can occur only through a helicity flip.
- The CP asymmetry in SM is suppressed by the quark mass ratio.

$$S \approx -2(m_s/m_b)\sin(2\phi_1) \sim 0.03$$

- A large CP asymmetry will be clear hint of new physics (e.g. LRSM model) : Sensitive to right handed currents rather than a new phase.
- With enough statistics in neutral mode, we can do a time-dependent measurement. (Vertexing from π^+, π- tracks; K_S vertexing is not required)

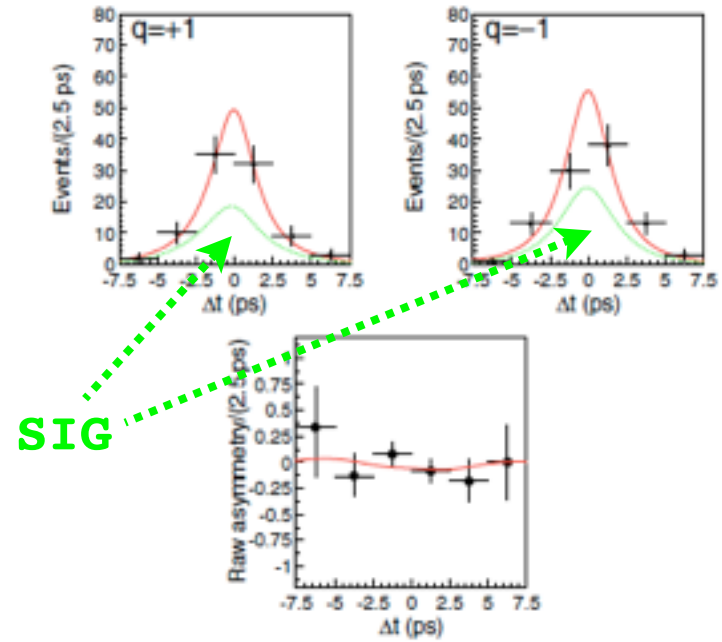
TCPV in b→sγ modes

$B^0 \to K_S \pi^0 \gamma$

PRD 74, 1111(R) (2006)
535 M $B\overline{B}$

Vertex is from Ks →$\pi^+\pi^-$ (K_S must decay inside silicon detector)

$$\mathcal{S}_{K_S\pi^0\gamma} = -0.10 \pm 0.31 \pm 0.07$$
$$\mathcal{A}_{K_S\pi^0\gamma} = -0.20 \pm 0.20 \pm 0.06$$

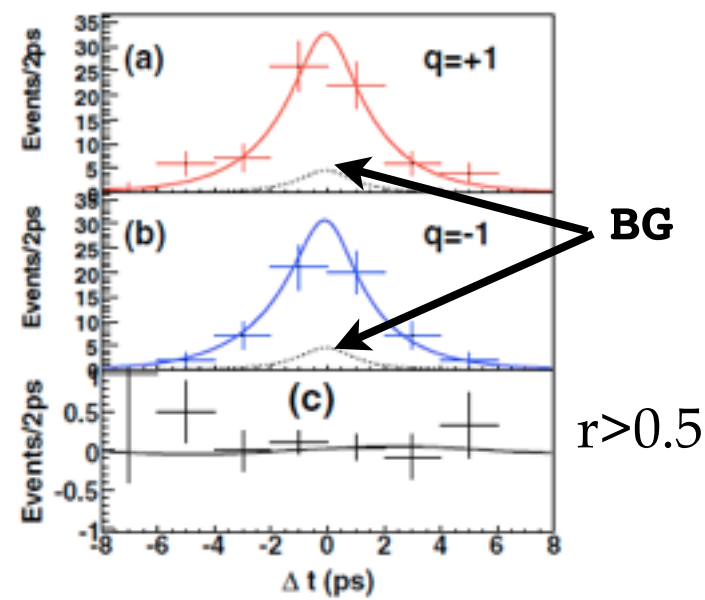


$B^0 \to K_S \rho^0 \gamma$

PRL 101, 251601 (2008)
657 M $B\overline{B}$

Vertex is from $\rho^0 \to \pi^+\pi^-$ (no K_S vertex is needed)

$$\mathcal{S}_{K_S\rho^0\gamma} = 0.11 \pm 0.33^{+0.05}_{-0.09}$$
$$\mathcal{A}_{K_S\rho^0\gamma} = 0.05 \pm 0.18 \pm 0.06$$



Consistent with the SM expectation

Decay Channels

$$B^+ \to \omega K^+ \gamma$$

$$\downarrow$$

$$\pi^+ \pi^- \pi^0$$

$$\mathrm{B}^0 \to \omega\, K_S^0\, \gamma$$

$$\downarrow \qquad \downarrow$$

$$\pi^+ \pi^- \pi^0 \qquad \pi^+ \pi^-$$

Analysis steps

- Signal MC Study, selection criteria, efficiency calculation.
- Background Study.
  - Continuum
  - b→c backgrounds
  - Rare
- Establish Fitting procedure.
- Toy MC test, GSIM ensemble test
- Signal PDF calibration
- ω mass sideband study, cross-check with data.
- Study with data.

Selection Criteria

1) $R_2<0.4$ is used in skimming

2) Impact parameter for kaons and pions : dr < 2 cm, dz < 5 cm

3) Kaon Likelihood : > 0.6 for kaons, < 0.4 for pions

1) π^0 : from Mdst_π^0 bank

2) 15 MeV mass cut around PDG mass

3) Mass constrained fit (default in π^0 bank)

4) $E_9/E_{25} > 0.9$ for each photon

5) $p^*(\pi^0) > 0.3$ GeV/c

6) ECL energy for photons : >50 MeV in barrel and >100 MeV in endcap

7) ω meson is reconstructed from π^+, π^-, π^0

$$0.12 < M_{\gamma\gamma} < 0.15 \text{ GeV}/c^2$$ ~2.5σ

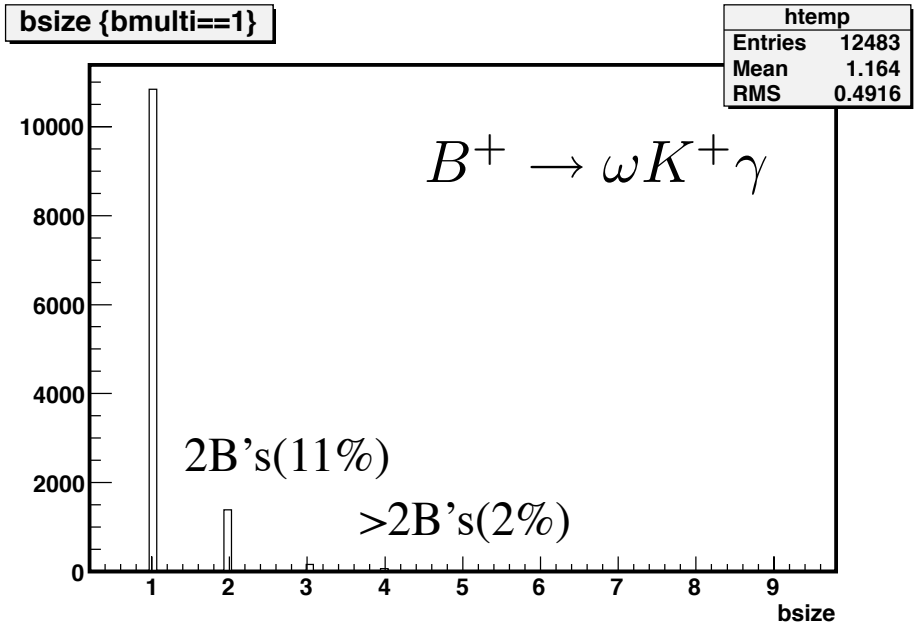
goodKs() selection

$$0.482 < M_{\pi^+\pi^-} < 0.514 \text{ GeV}/c^2$$

~5.7σ

Best Candidate Selection

$$-0.3 < \Delta E < 0.3\mathrm{GeV}$$
$$5.27 < M_{\mathrm{bc}} < 5.29\mathrm{GeV/c^2}$$
$$0.73 < M_{\pi^+\pi^-\pi^0} < 0.83\mathrm{GeV/c^2}$$



Best Candidate Selection:
M_{bc} close to nominal B mass (5.279 GeV)

Average multiplicity = Total B/Total Events = 1.2

%multiplicity = Events with >1B/Total Events = 13%

Self-cross-feed fraction is ~25%

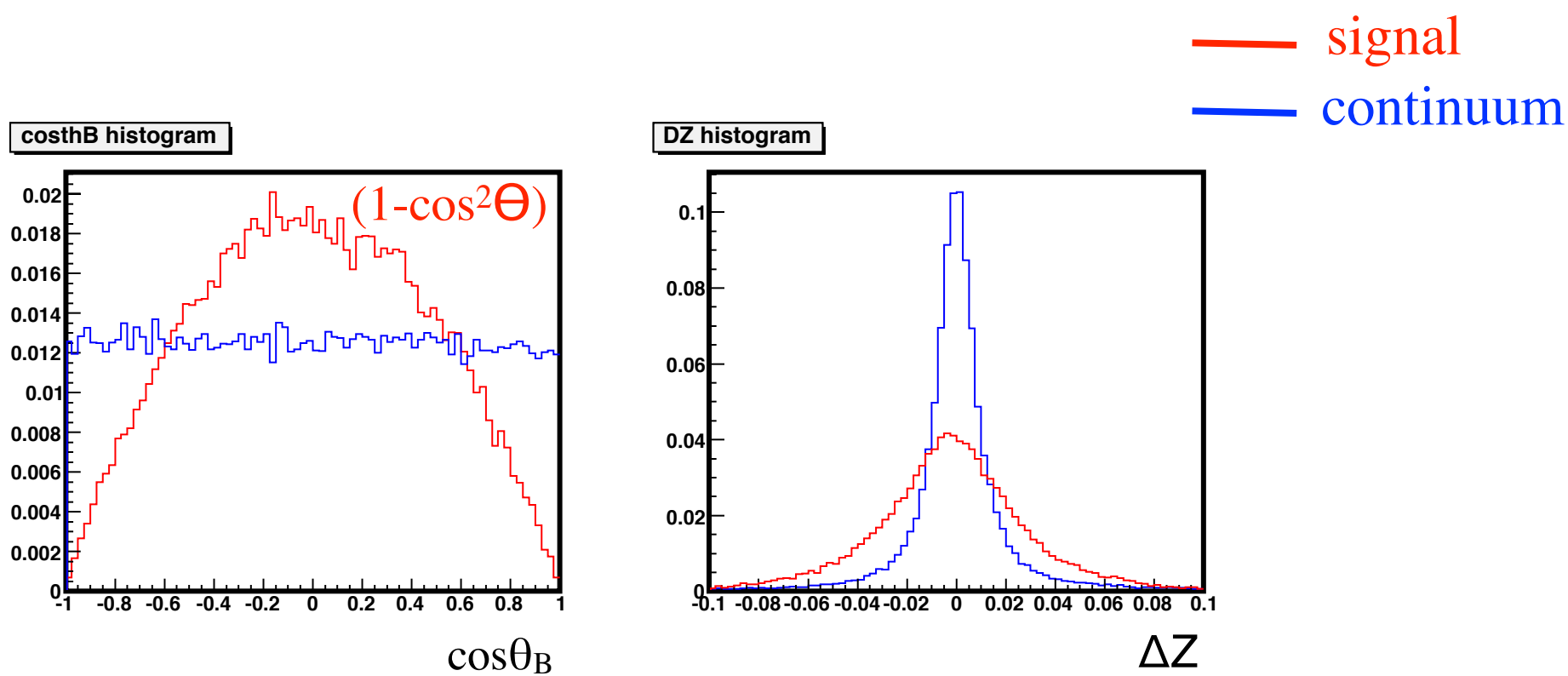
BCS is 60% efficient in picking the correct B candidate in case of multiple events (63% in case of 2B's)

ΔE and M(ω) will be used for signal extraction

Similar Numbers are also obtained in the Neutral mode

Continuum Backgrounds

- Continuum ($e^+e^- \to qq$) is the dominant contribution.
- Likelihood Ratio (LR) is calculated using KSFW, $\cos\theta_B$ and ΔZ distributions.
- Vertexing : π^+,π^-,K^+ tracks in charged mode and π^+,π^- in neutral mode.
- ΔZ information is used when both side vertex fits converge and $|\Delta Z|<0.1$cm.



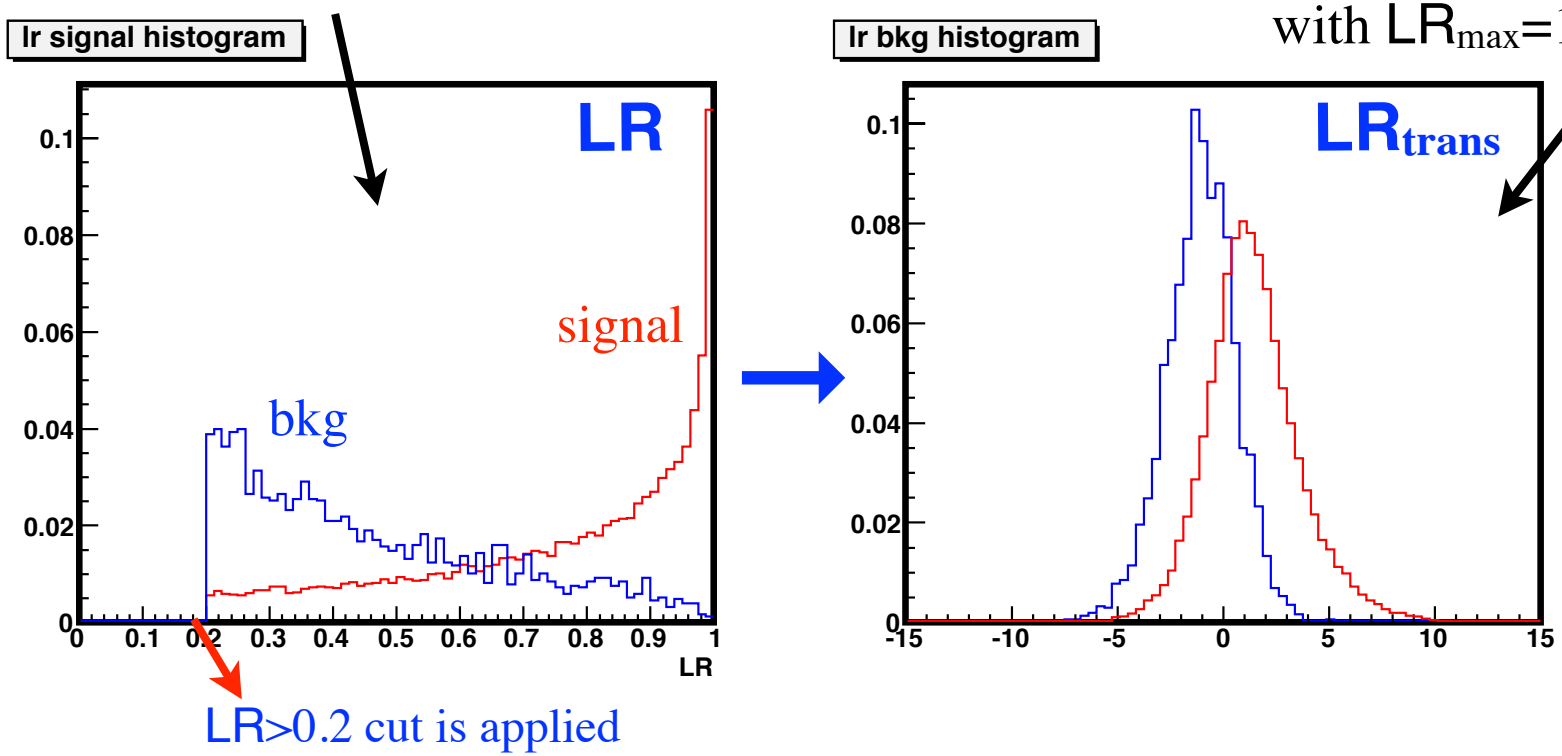
LR→LR$_{trans}$ distribution

- Normalized PDFs are used to obtain corresponding LR.
- A loose cut LR>0.2 is applied before the transformation.

$$\mathcal{LR}(KSFW, \cos\theta_B, \Delta Z) = \frac{\prod_i \mathcal{LR}(i)}{\prod_i \mathcal{LR}(i) + \prod_i (1 - \mathcal{LR}(i))}$$

$$LR_{trans} = \ln[(LR-LR_{min})/(LR_{max}-LR)]$$

with LR_{max}=1 and LR_{min}=0.2



We can model the LR$_{trans}$ distribution with analytical functions. Easier to assign systematics.

LR$_{trans}$ will be used in fitter

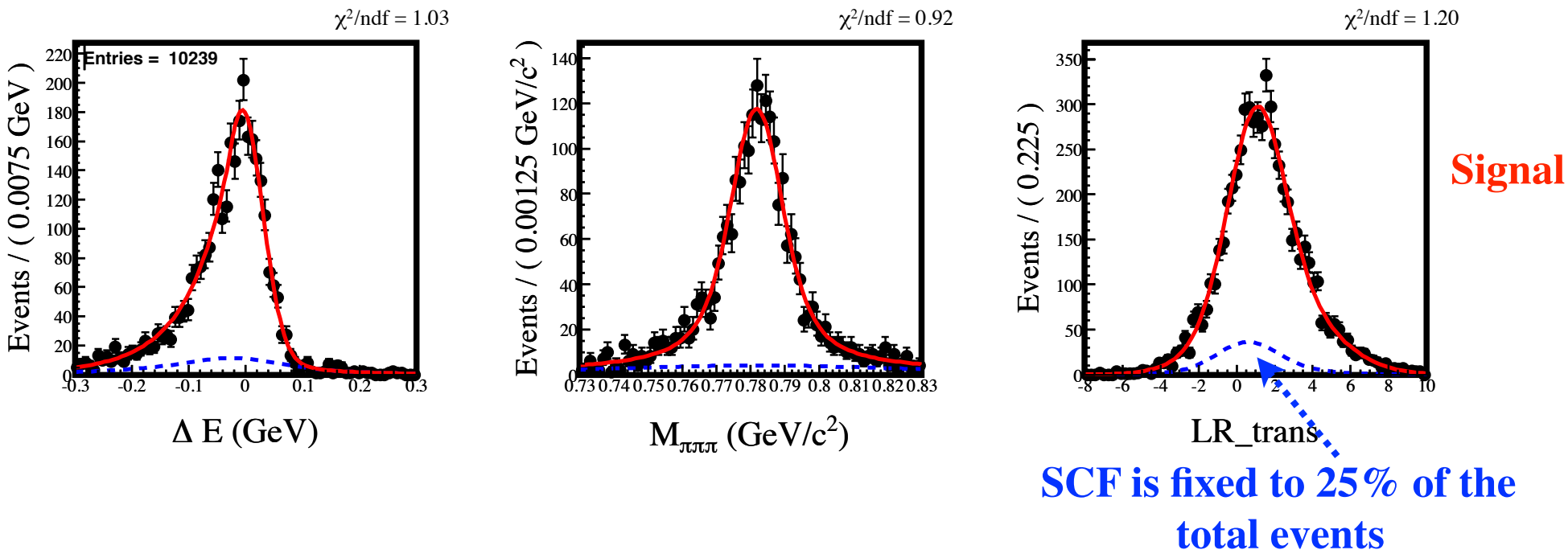
ΔE-$M(\omega)$-LR_{trans} 3D Fit [Signal MC]

$B^+ \to \omega K^+ \gamma$

Signal extraction from 3D fit using ΔE, $M(\omega)$ and LR_{trans} distribution.

Signal ➔ CB in ΔE × BW in $M(\omega)$ × double G in LR_{trans}

SCF ➔ (CB+G) in ΔE × BW in $M(\omega)$ × double G in LR_{trans} (fixed)



Efficiency [Signal MC]

Efficiency from 3D fit in signal MC :

$B^+ \to \omega K^+ \gamma$	$B^0 \to \omega K_S^0 \gamma$
7.23 ± 0.07	5.86 ± 0.06

SCF is included in the efficiency calculation

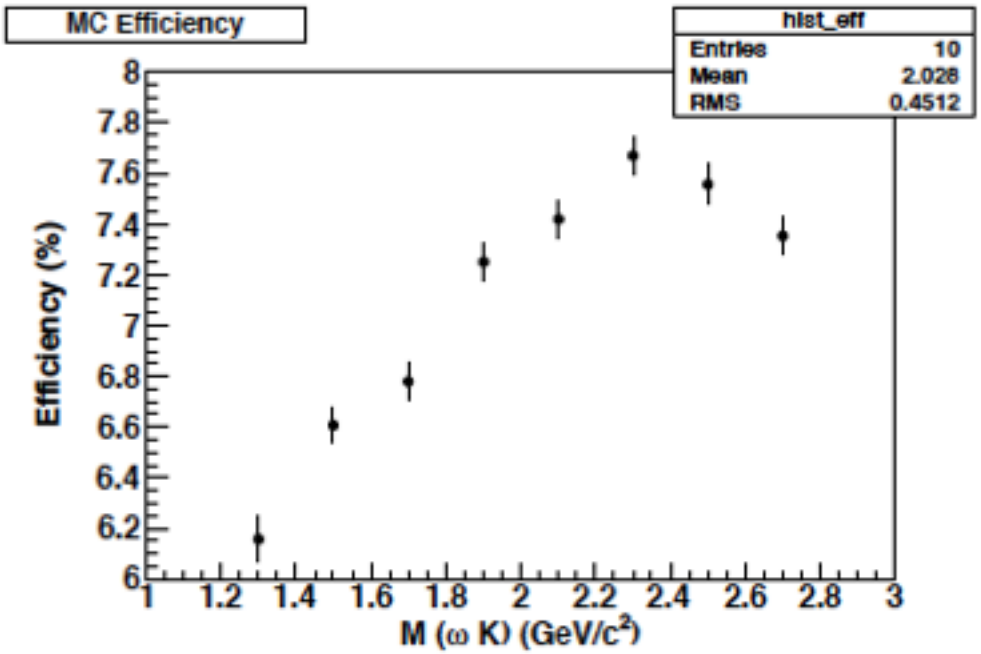
Expected yield : nearly 100 events for $B^+ \to \omega K^+ \gamma$ and 22 events for $B^0 \to \omega K_S \gamma$

(out of these 25% is SCF)

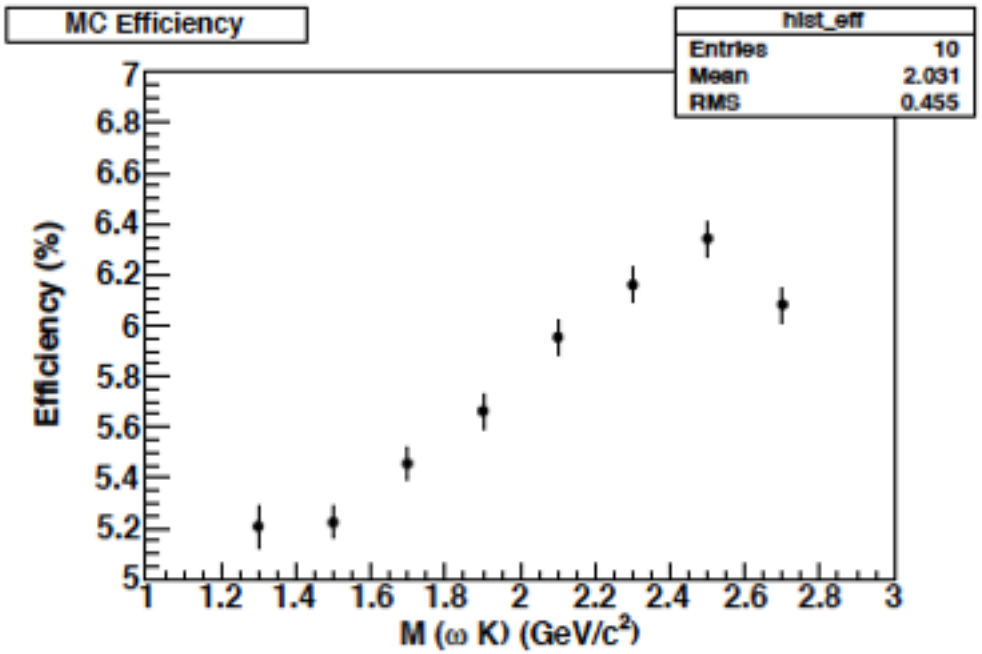
MC efficiency vrs. M(ωK) Mass [Signal MC]

- Efficiency is calculated in bins of M(ωK).
- The yield in each bin is raw events in fit region.
- Relative change of MC efficiency (~20%) across the full spectrum.

$B^+ \to \omega K^+ \gamma$



$B^0 \to \omega K_S \gamma$



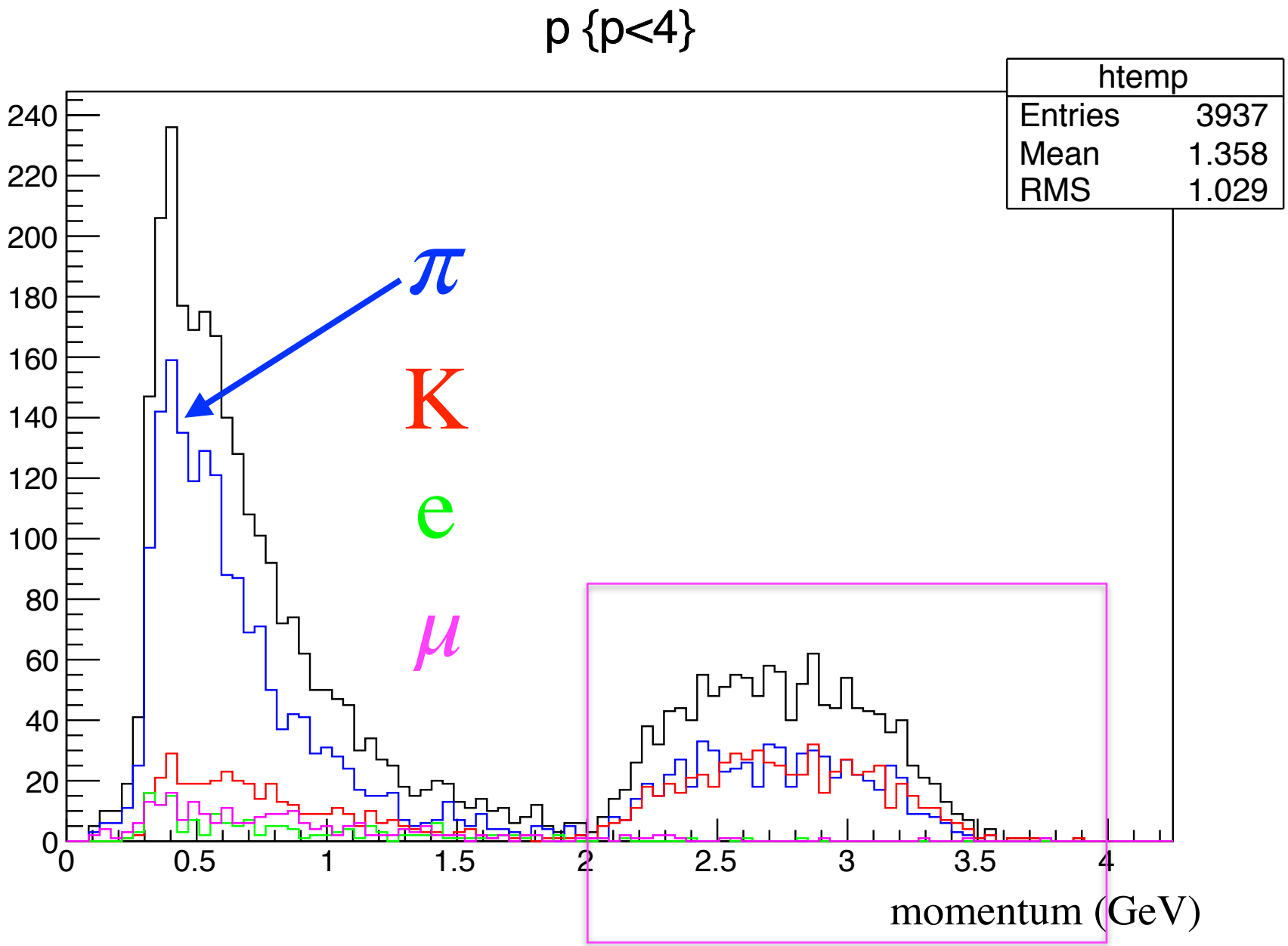
MC efficiency will be re-weighted according to measured M(ωK) in data.

Summary

- $B \rightarrow \omega K \gamma$ is a new radiative decay mode.
- Branching Fraction measurements under study.
- Neural mode is sensitive to right-handed currents.
- Estimated efficiency nearly 7.2% (charged) and 5.9% (neutral) mode.
- Expecting nearly 100 events for charged and 22 events for neutral mode.

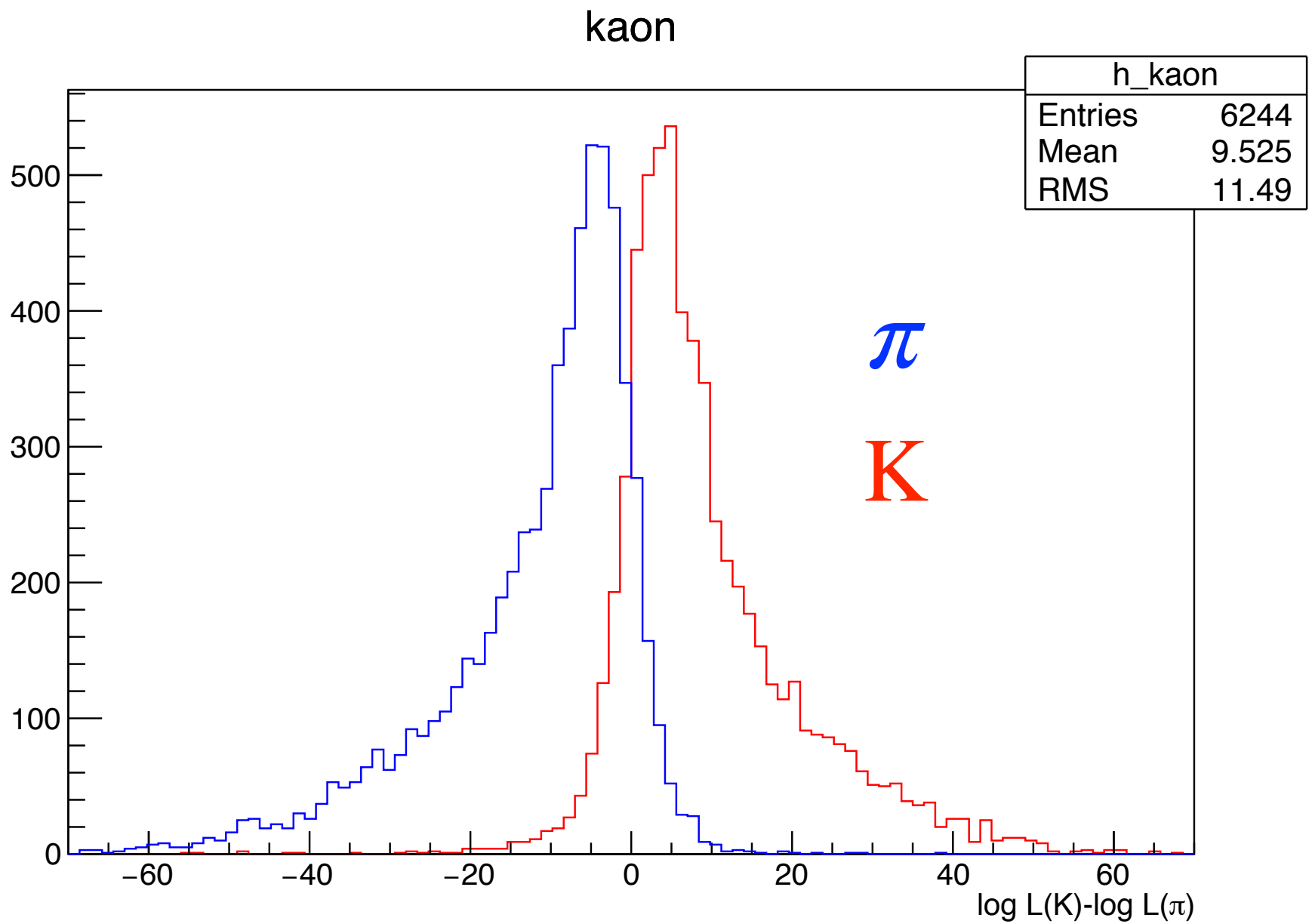
Particle Identification using TOP

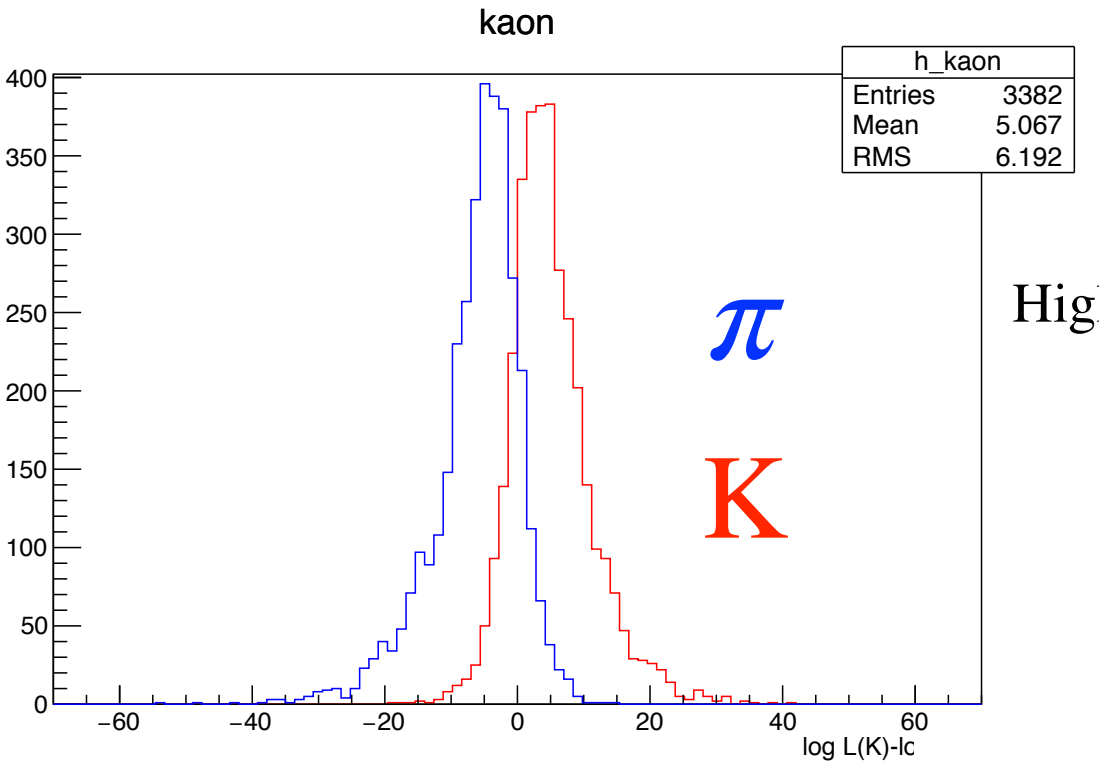
Momentum distribution ($B^0 \rightarrow K^+\pi^-$)



- Check the logL for kaon and pion hypothesis using TOP package.
- Plot logL(K)-logL(π).
- Plot separately for true pion and kaon particle.

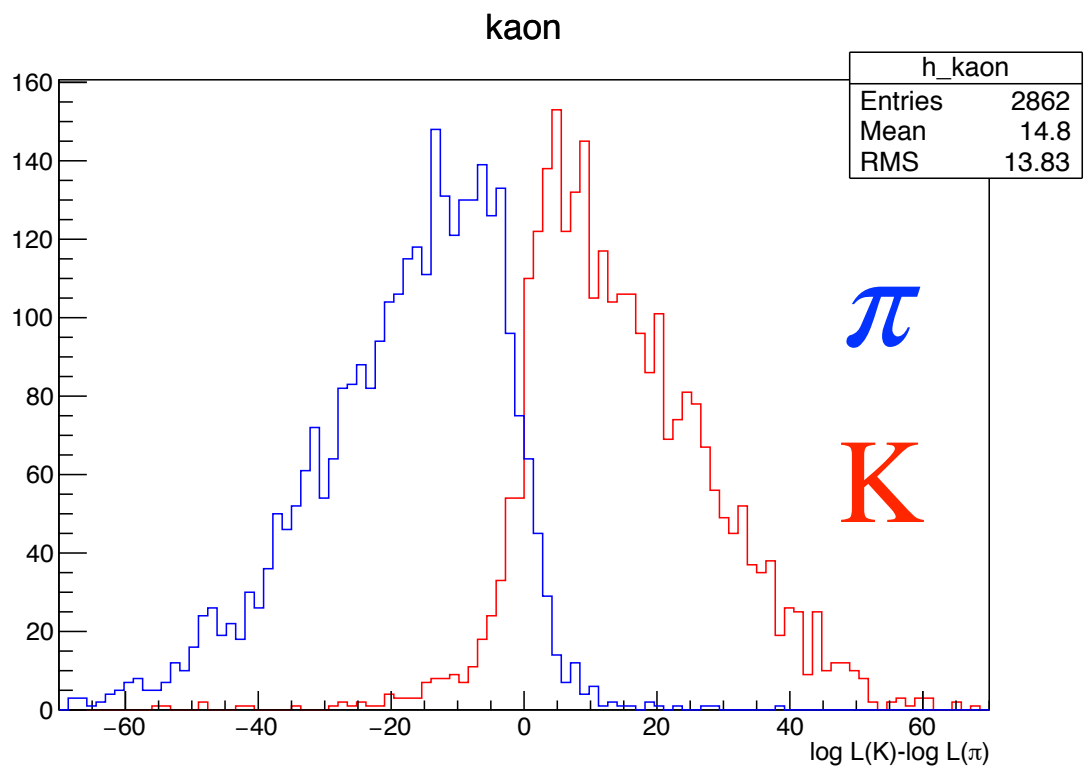
Momentum (2-4 GeV)





High Momentum region
(2.7-3.5 GeV)

Low Momentum region
(2.0-2.7 GeV)

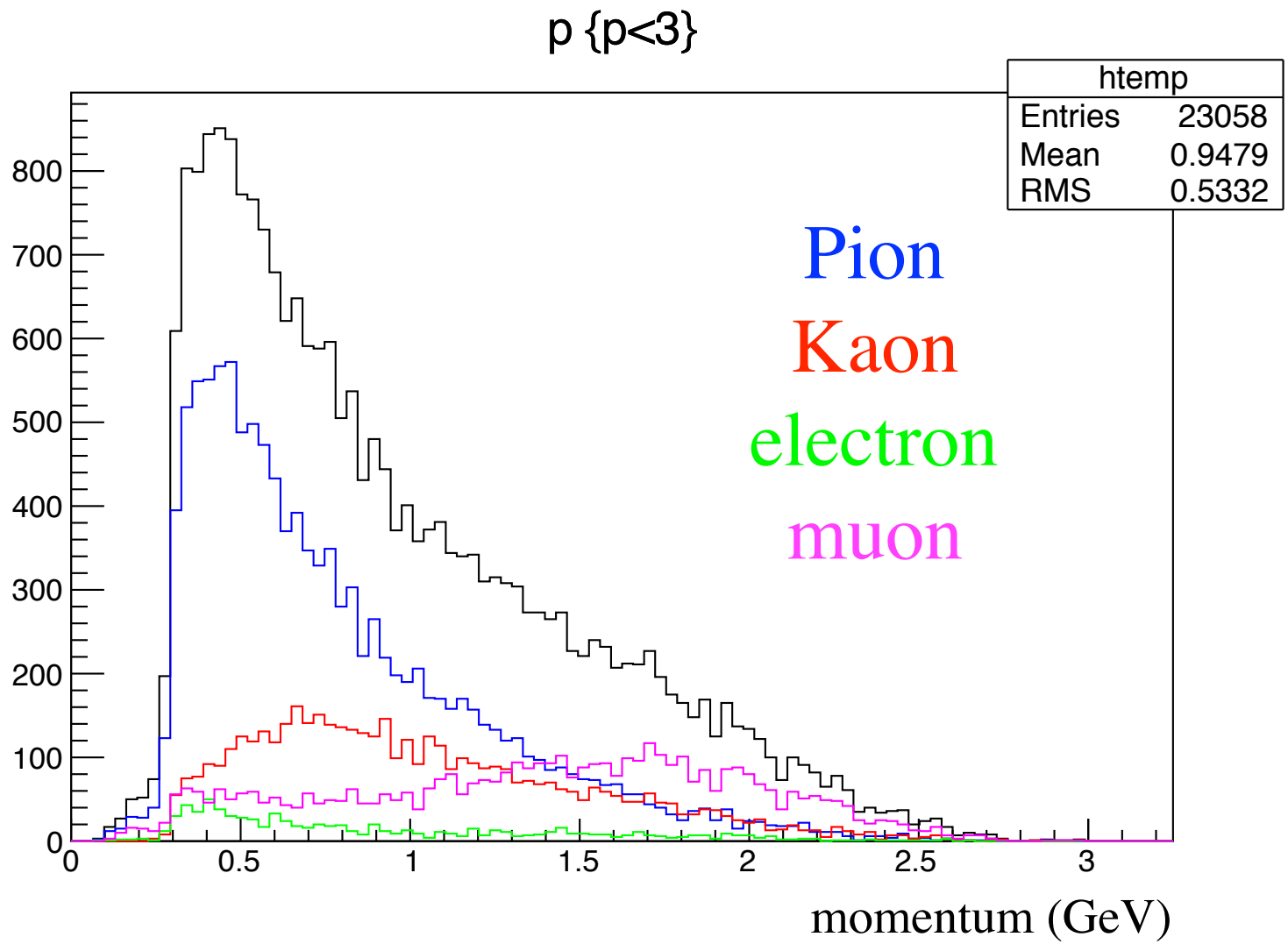


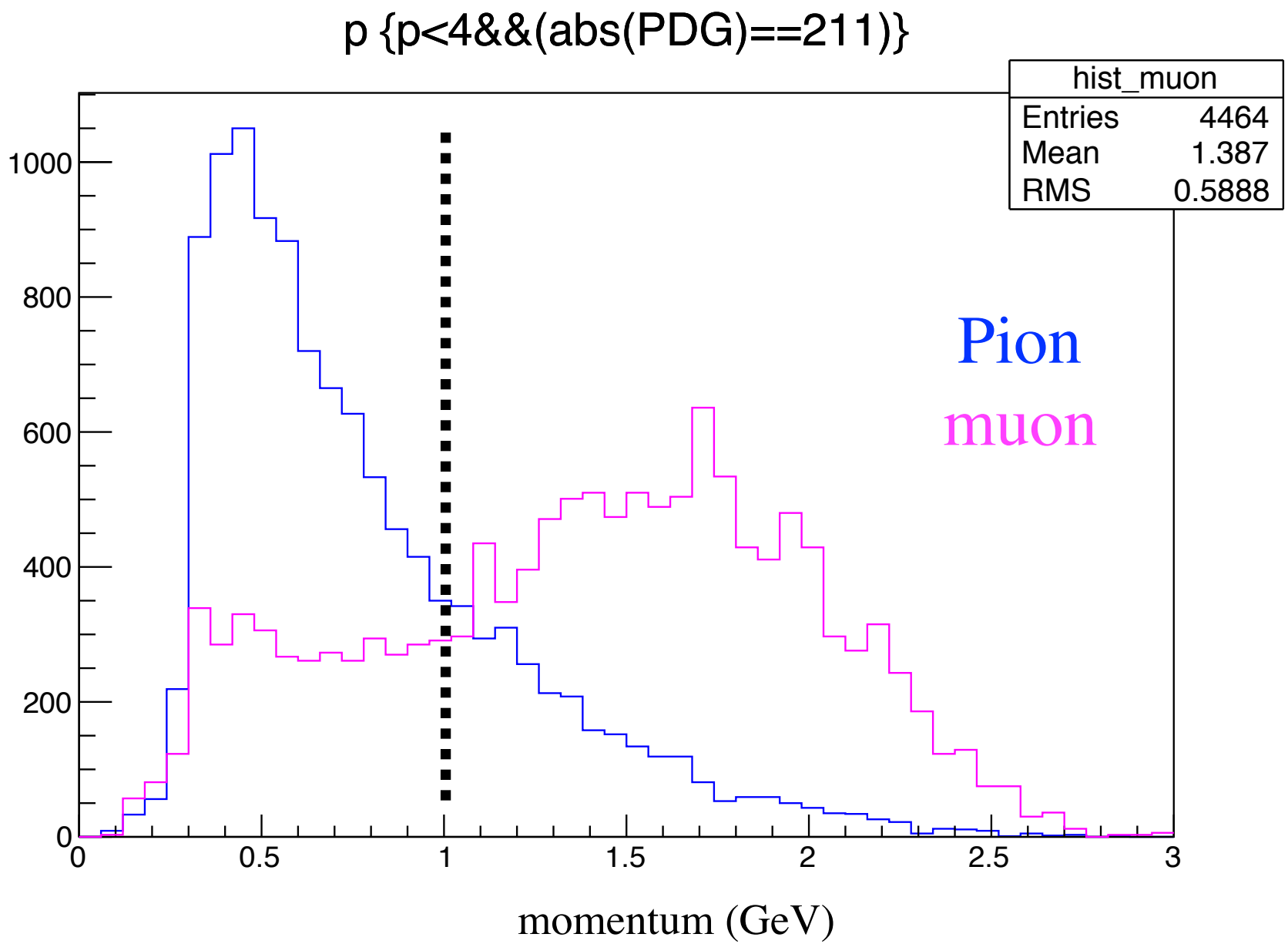
$B^0 \rightarrow D^{*-}\, l^+ \nu$

$B^0 \rightarrow D^{*-}\, \mu^+\, \nu_\mu$

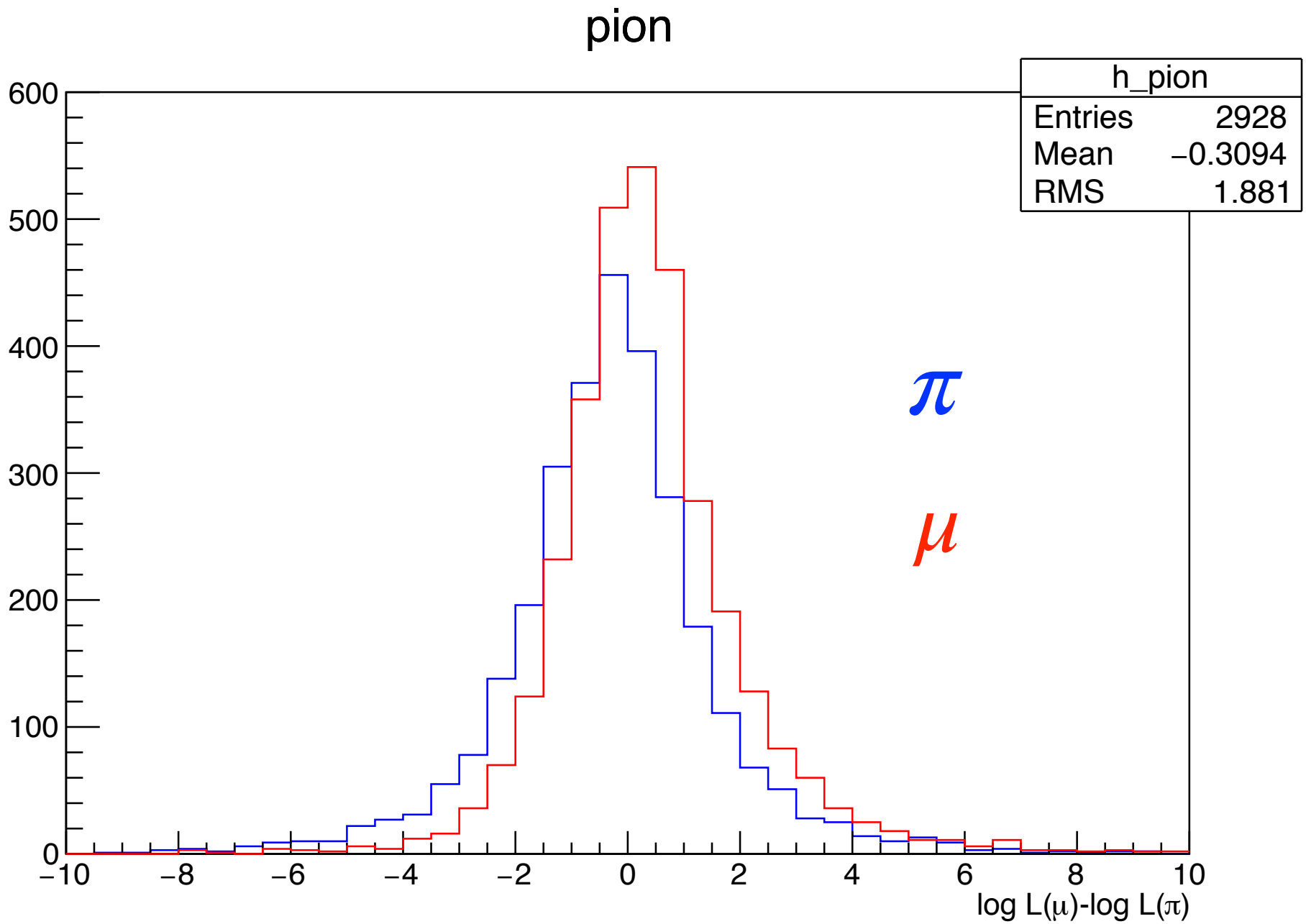
$D^{*+} \rightarrow D^0\, \pi^+$

$D^0 \rightarrow K^-\, \pi^+$

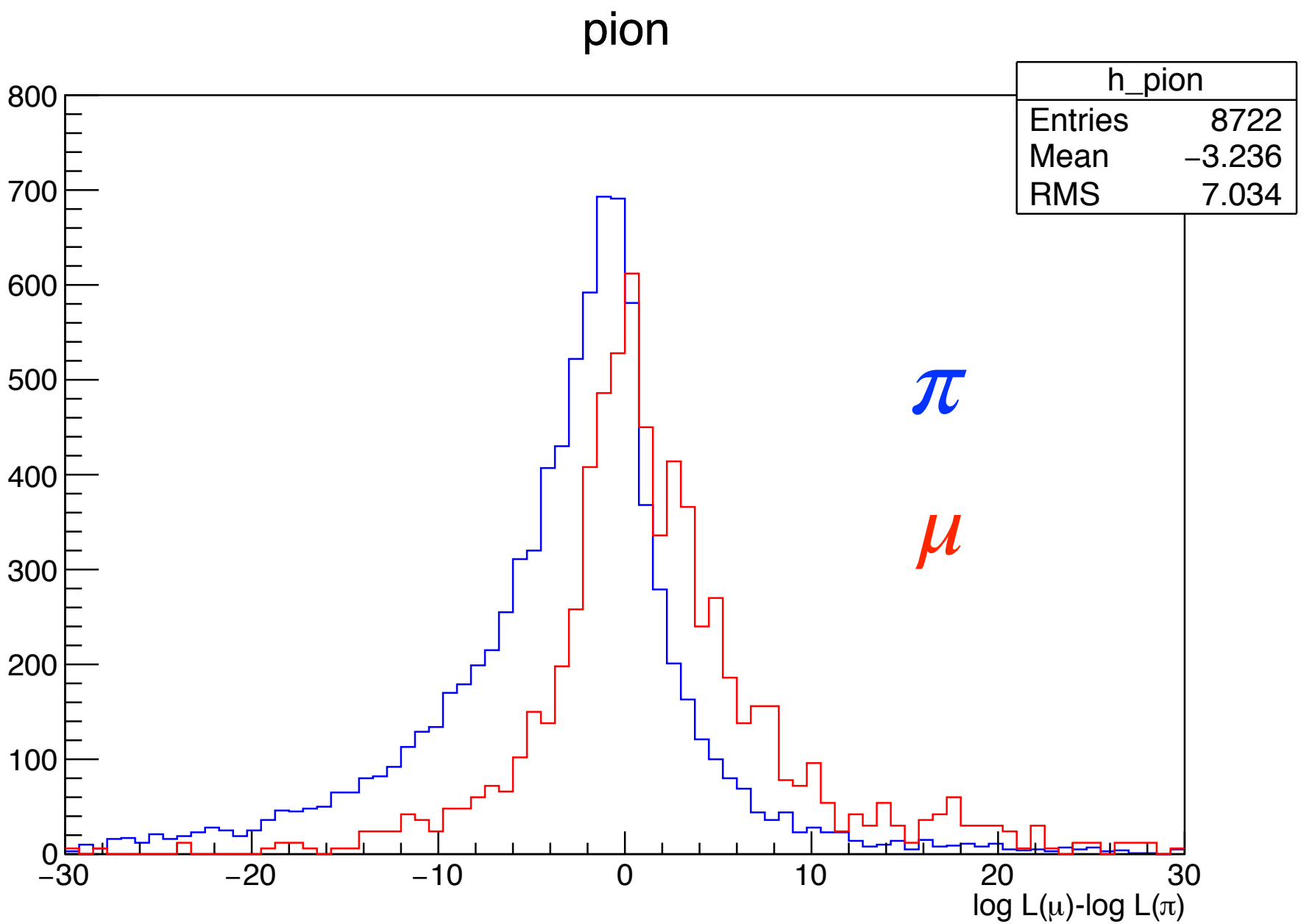



p {p<4&&(abs(PDG)==211)}
hist_muon
Entries 4464
Mean 1.387
RMS 0.5888
Pion
muon
1000
800
600
400
200
0
0
0.5
1
1.5
2
2.5
3
momentum (GeV)

likelihood (μ-π) (>1 GeV)



likelihood (μ-π) (<1 GeV)



PID Summary

- TOP PID performance is checked using high momentum kaons/pions from $B^0 \rightarrow K^+\pi^-$.
- Muons from $B^0 \rightarrow D^*l\nu$ are too low for KLM range.
- TOP shows some separation power for muons<1 GeV.

BACK UP