Particle Identification in LHCb

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On behalf of LHCb collaboration

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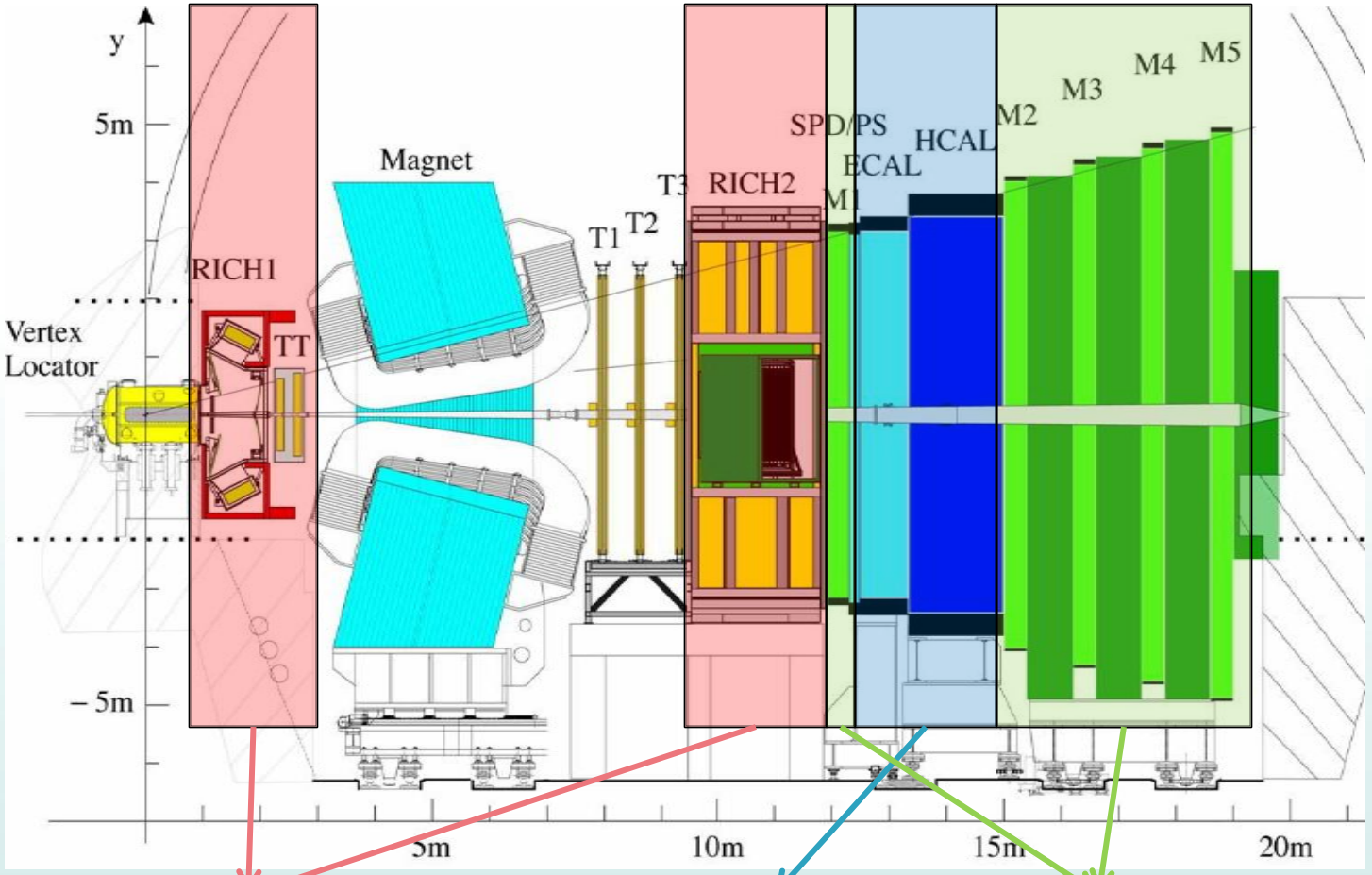
LHCb PID sub-systems

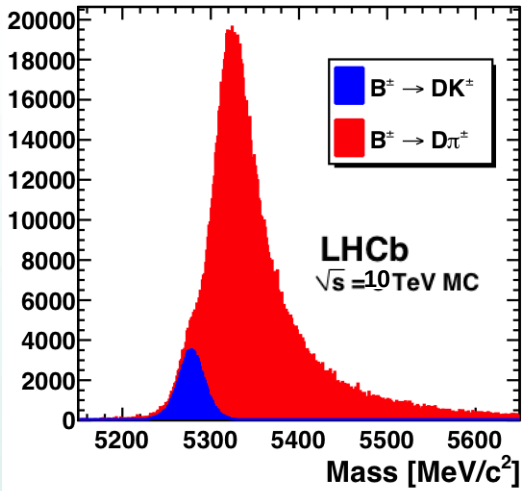


1. RICH

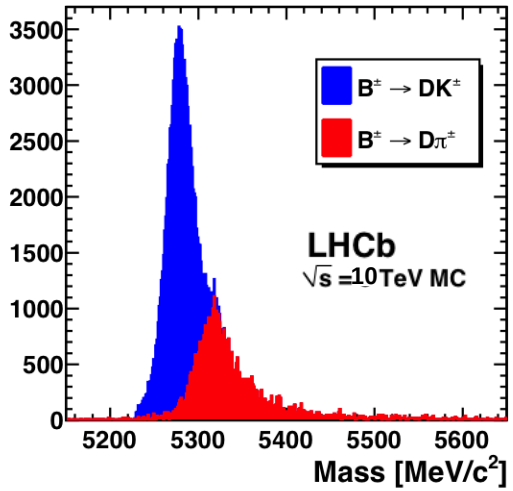
1. RICH

- *K*, π separation is crucial to many LHCb analyses.

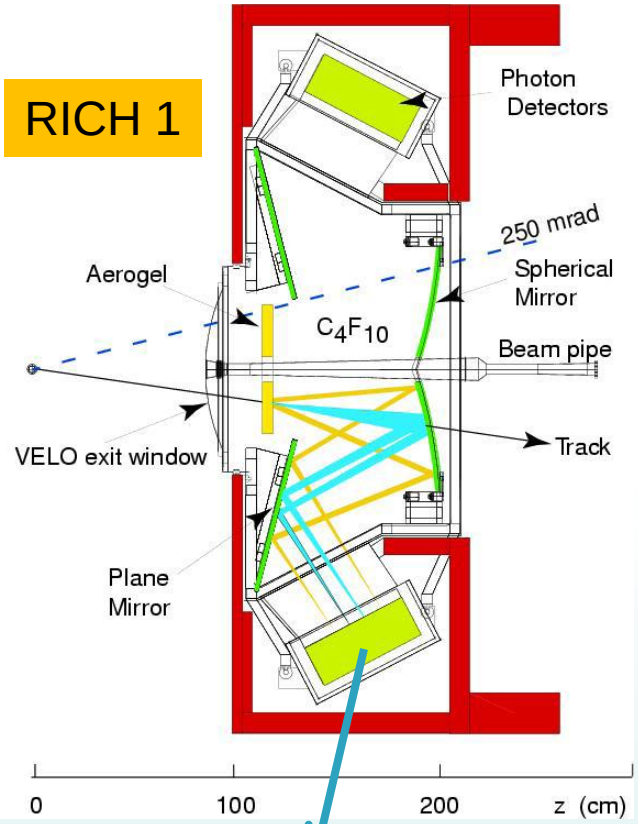
without RICH



with RICH



RICH 1

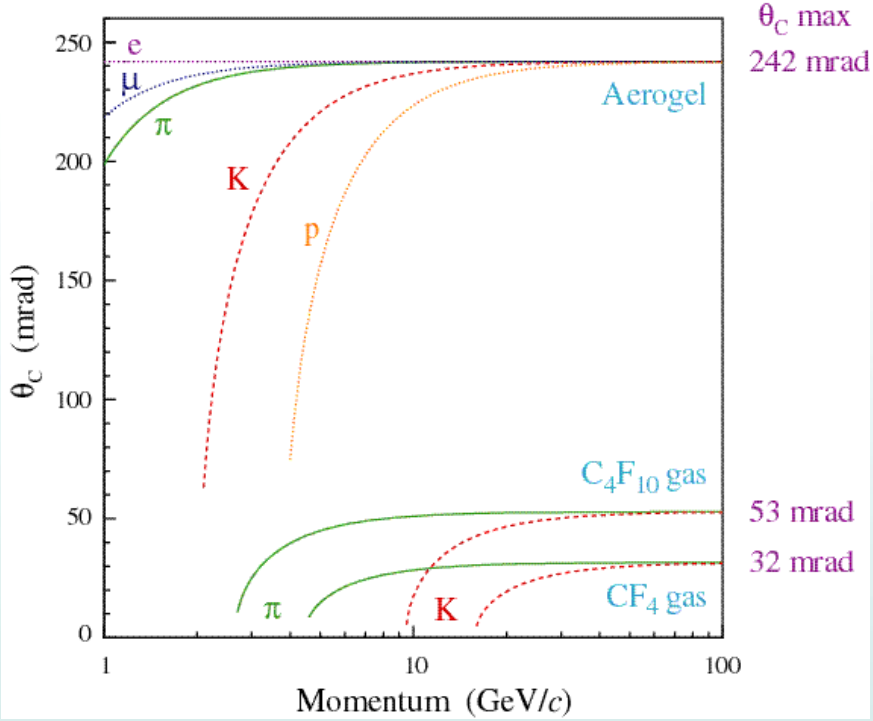


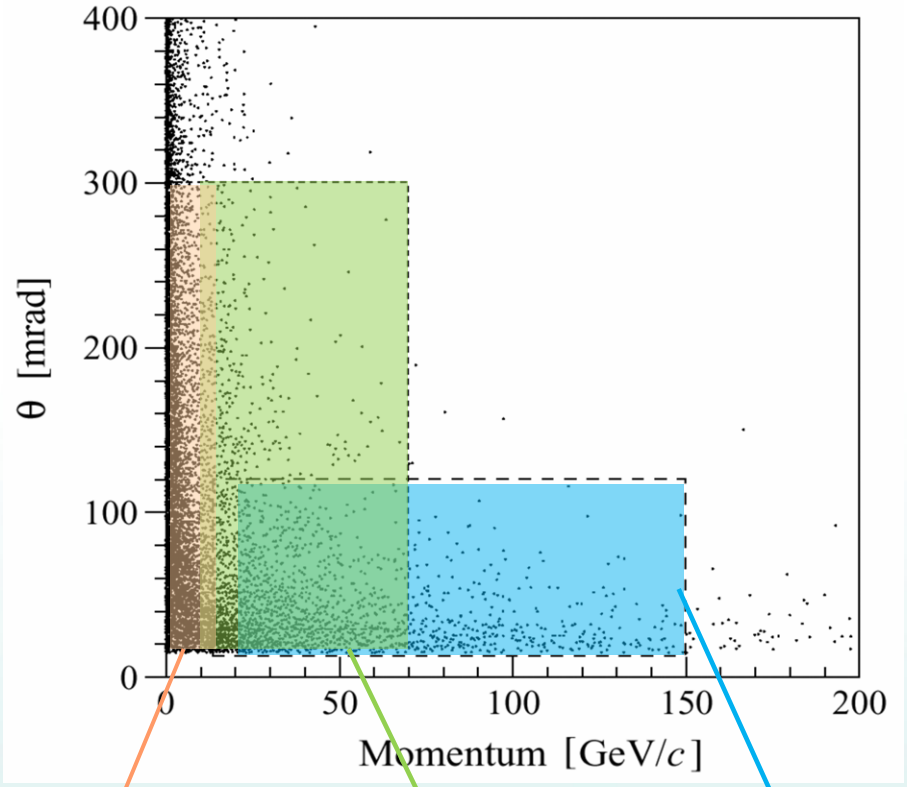
Hybrid Photo Diodes (HPDs)

196 (RICH1) + 288 (RICH2)

1. RICH – Radiators

- 3 radiators
- 1–100 GeV coverage





Silica Aerogel
n=1.03
1-10 GeV/c

C_4F_{10} gas
n=1.0014
Up to ~70 GeV/c

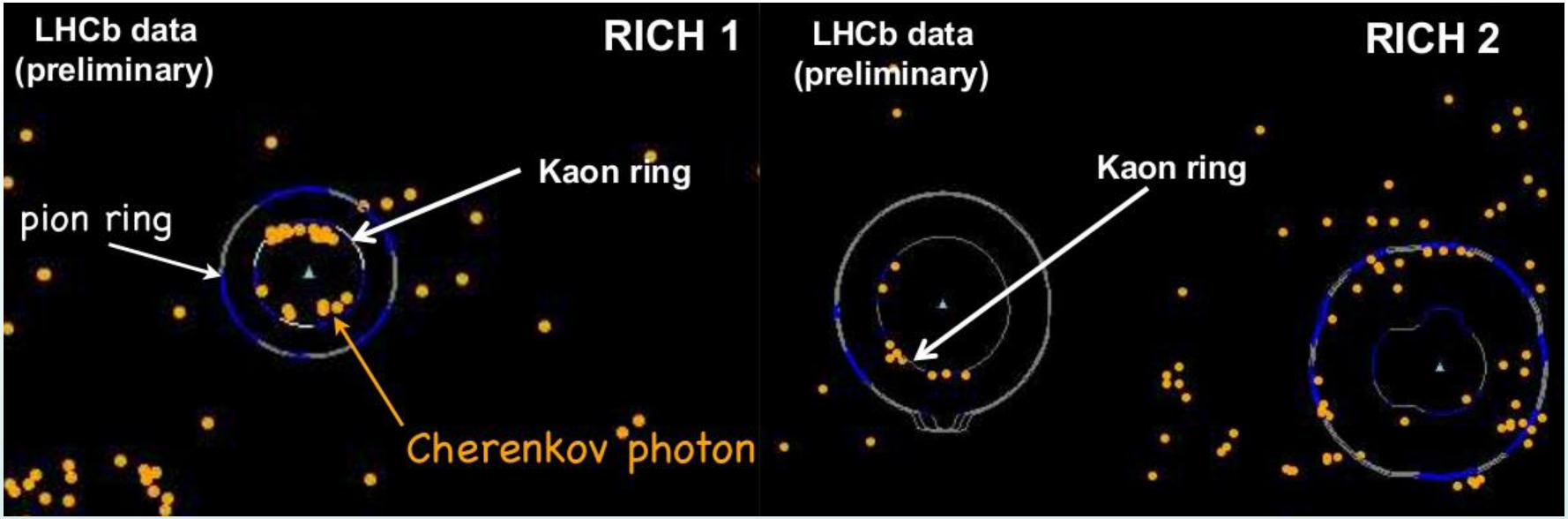
CF_4 gas
n=1.0005
Up to ~100 GeV/c

RICH1

RICH2

1. RICH – Cherenkov Rings

- RICH aligned with tracking system;
- Clear K and π rings seen:



1. RICH – PID Algorithms

- Take all photons from all tracks, in all radiators and maximise the Likelihood function:

$$\mathcal{L} = \mathcal{L}\left(n_{pixel}, \sum_{track} a_{pixel,track}, b_{pixel}\right)$$

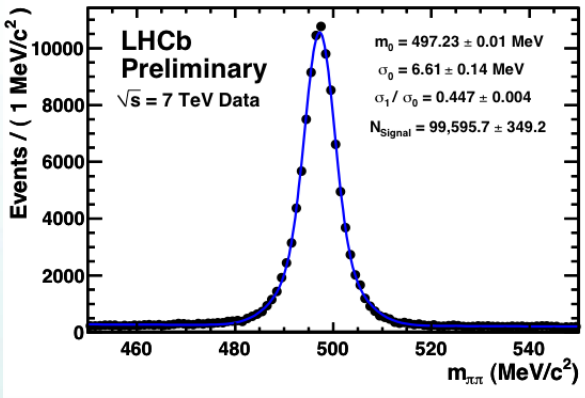
- Take all PIDs to be π (or seed with a previous iteration) and estimate background parameter b_{pixel} per HPD;
- Calculate likelihood of a given pixel distribution;
- Iterate until converge:
  - Change PID hypothesis, one track at a time
  - Recalculate likelihood for a given hypothesis
  - Assign new PID that maximises the likelihood
- With signal photons "identified", update background estimate and iterate

ΔlogL per track and hypothesis ⇨ PID.

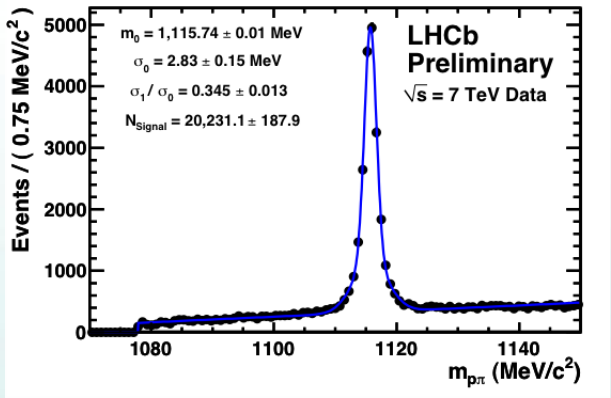
1. RICH – Calibration

- To maintain the integrity of the LHCb physics performance, it is essential to monitor the PID efficiency and mis-ID rates.

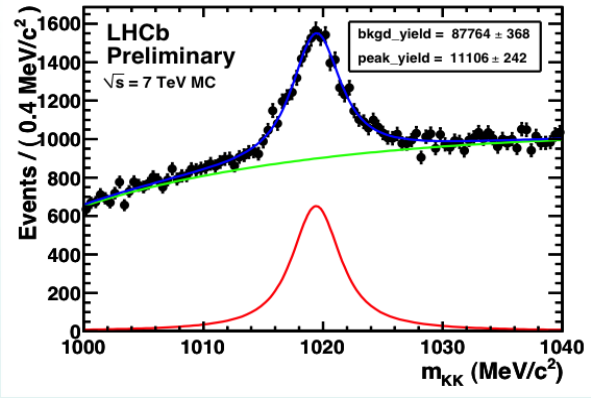
$K^0_S \to \pi^-\pi^+$



$\Lambda^0 \to p\pi^-$



$\phi(1020) \to K^+K^-$

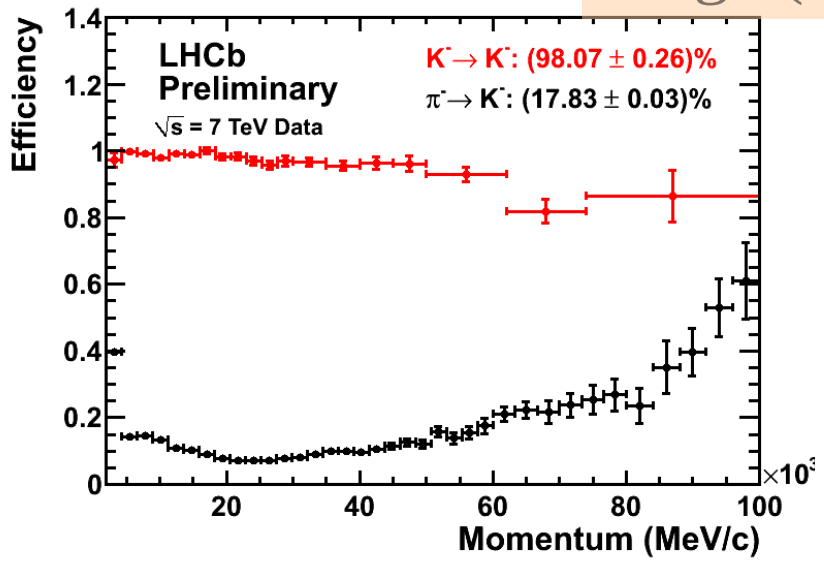


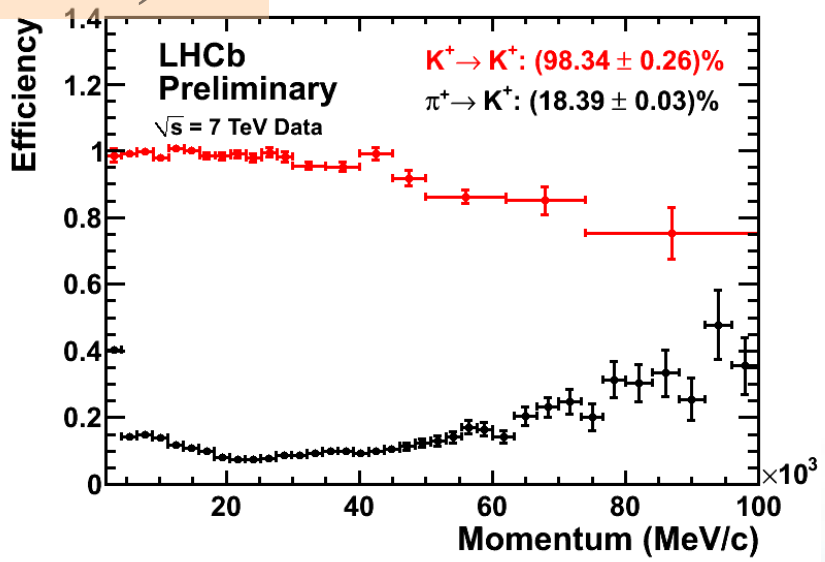
(tag and probe)

$D^{*+} \to D^0(K^-\pi^+)\pi^+$
$D_s^+ \to \phi(K^+K^-)\pi^+$

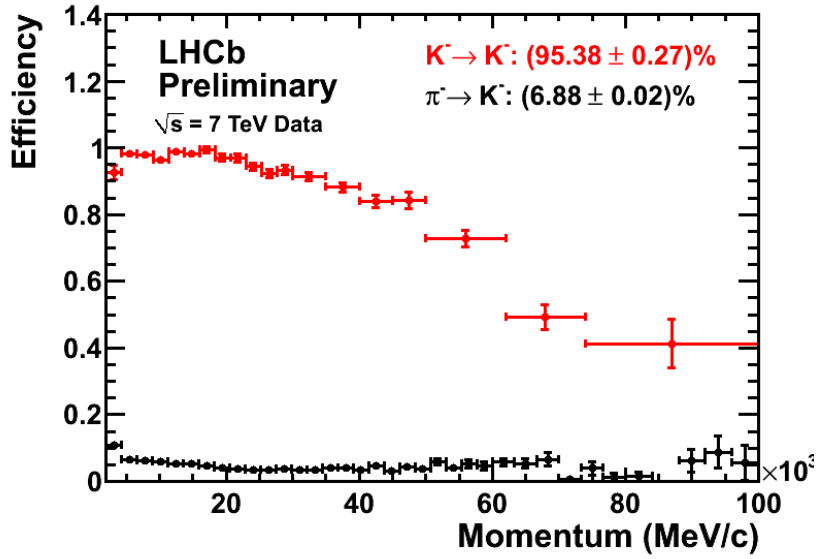
Will become main channels for kaon performance monitoring at nominal luminosities.

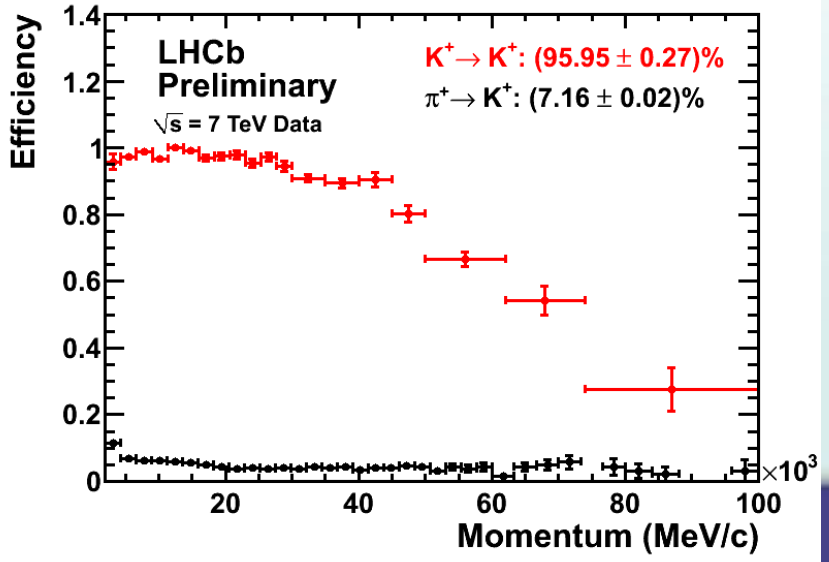
$\Delta \log L(K-\pi) > 0$



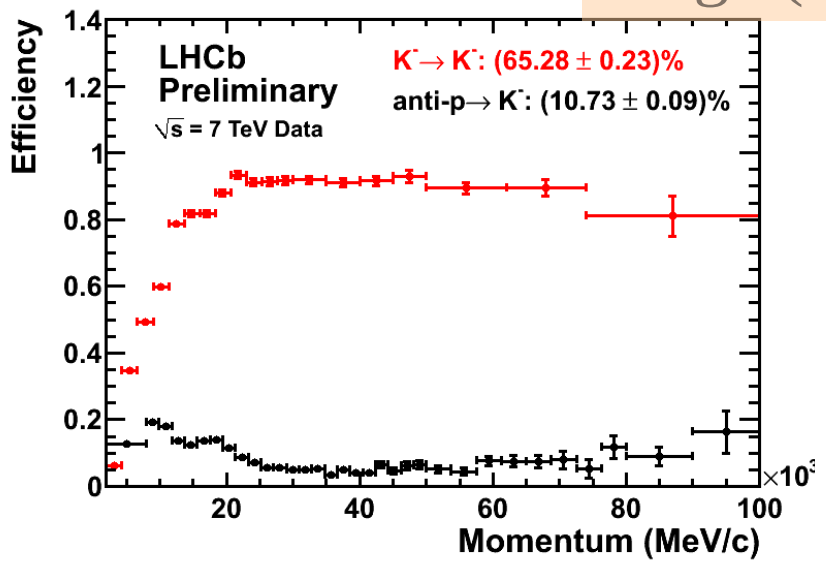


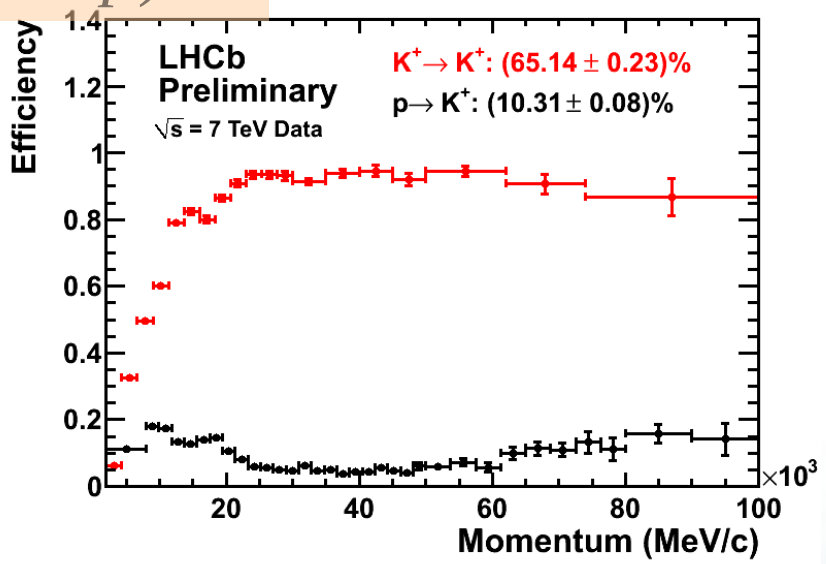
$\Delta \log L(K-\pi) > 5$



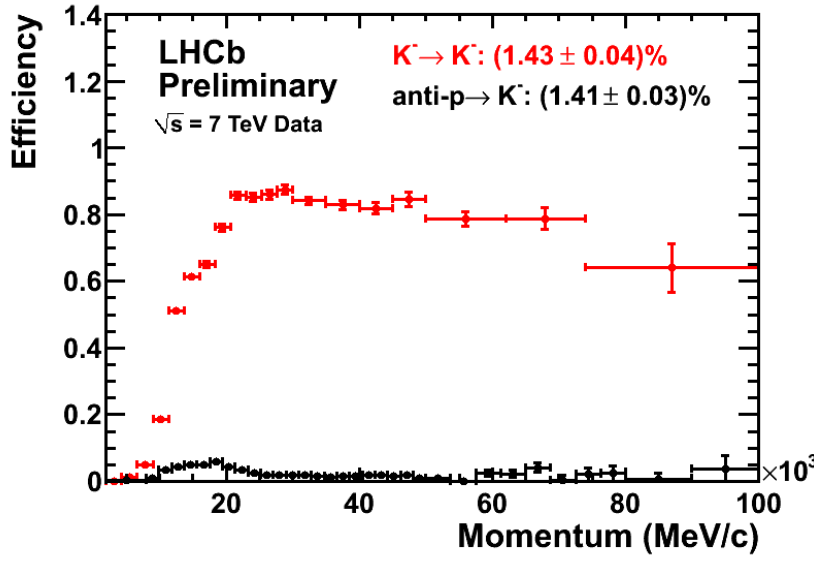


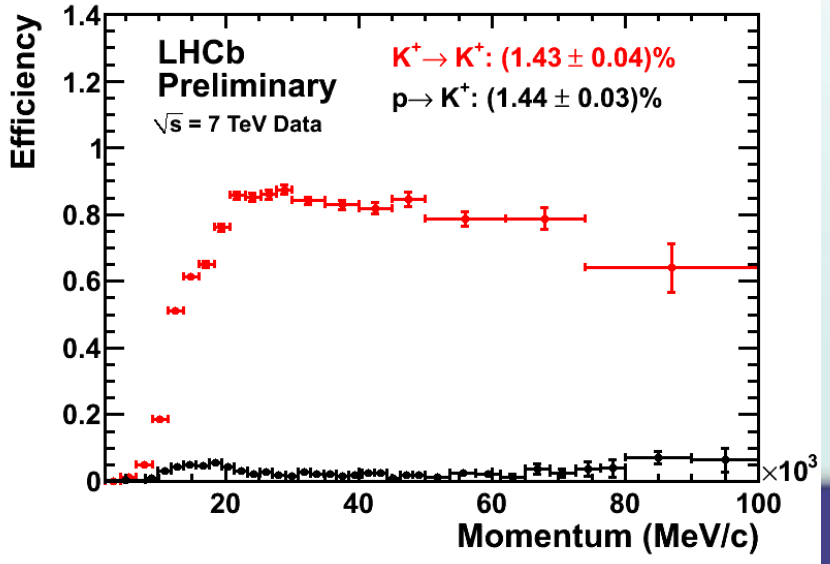
$\Delta \log L(K-p) > 0$



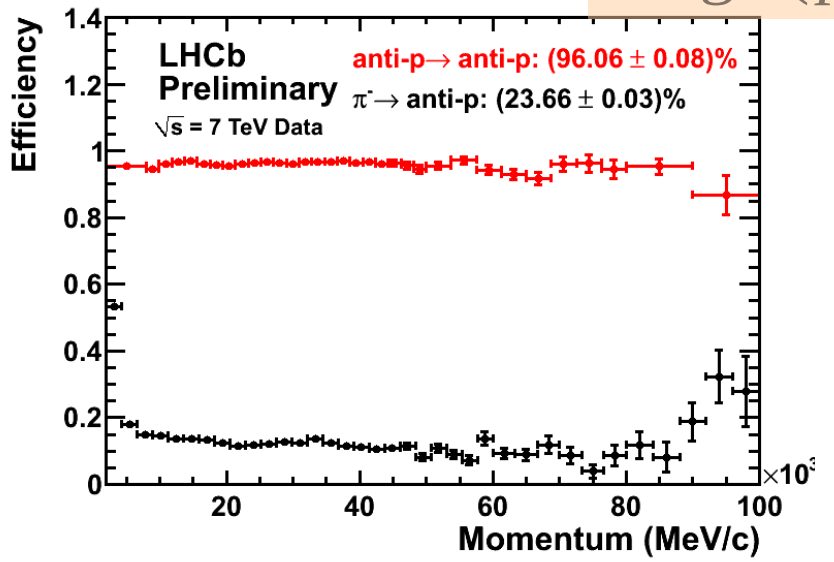


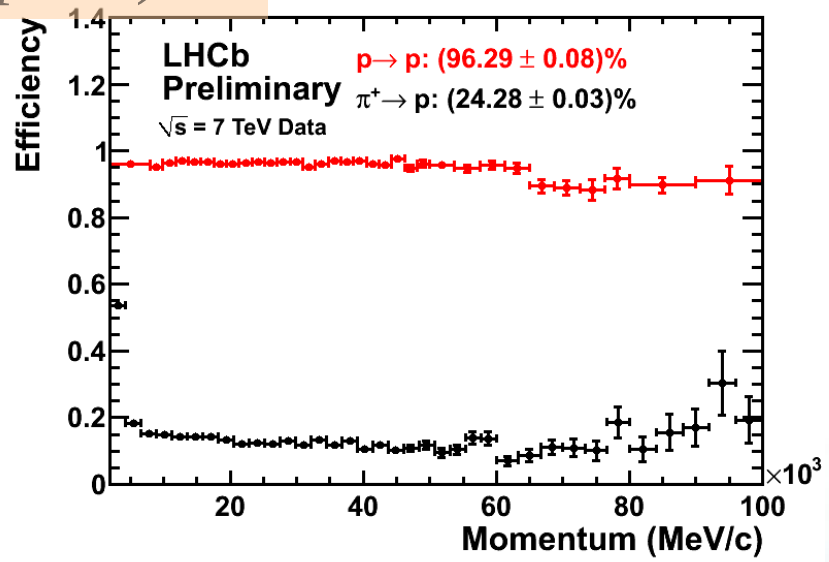
$\Delta \log L(K-p) > 5$



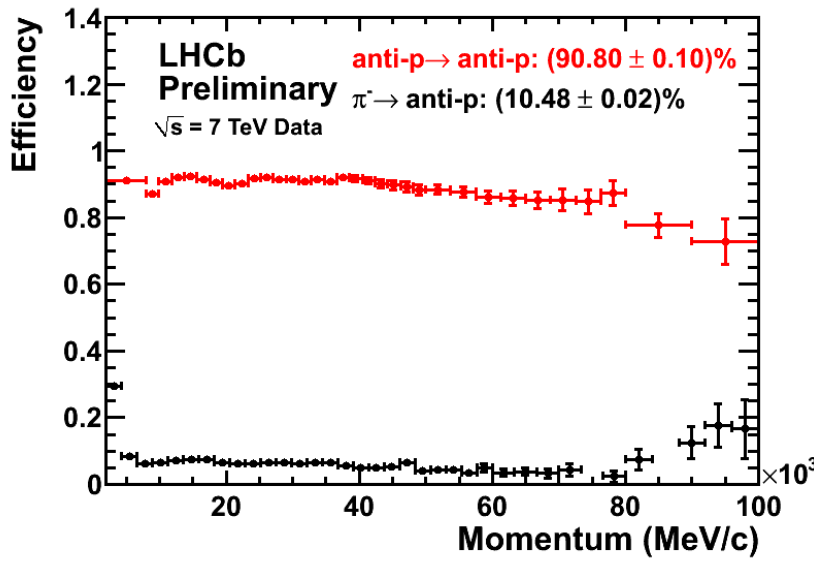


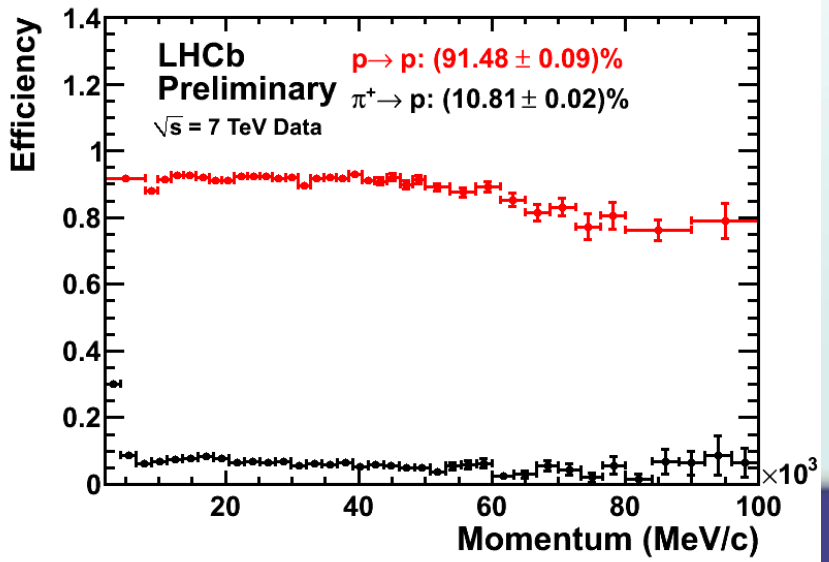
$\Delta \log L(p-\pi) > 0$





$\Delta \log L(p-\pi) > 5$

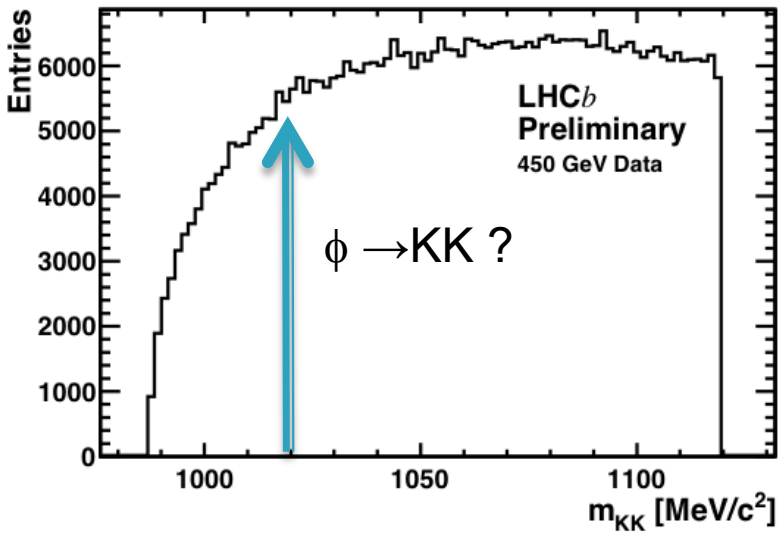




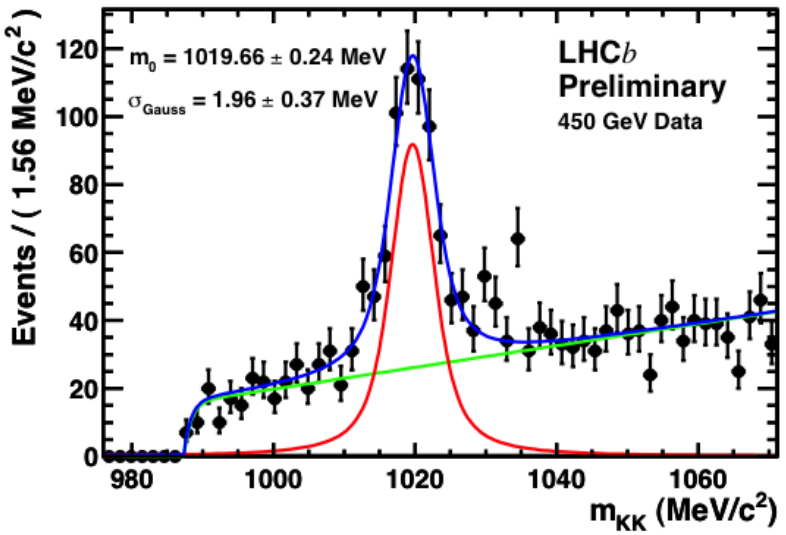
1. RICH – PID in Data

- Applying RICH PID to data:

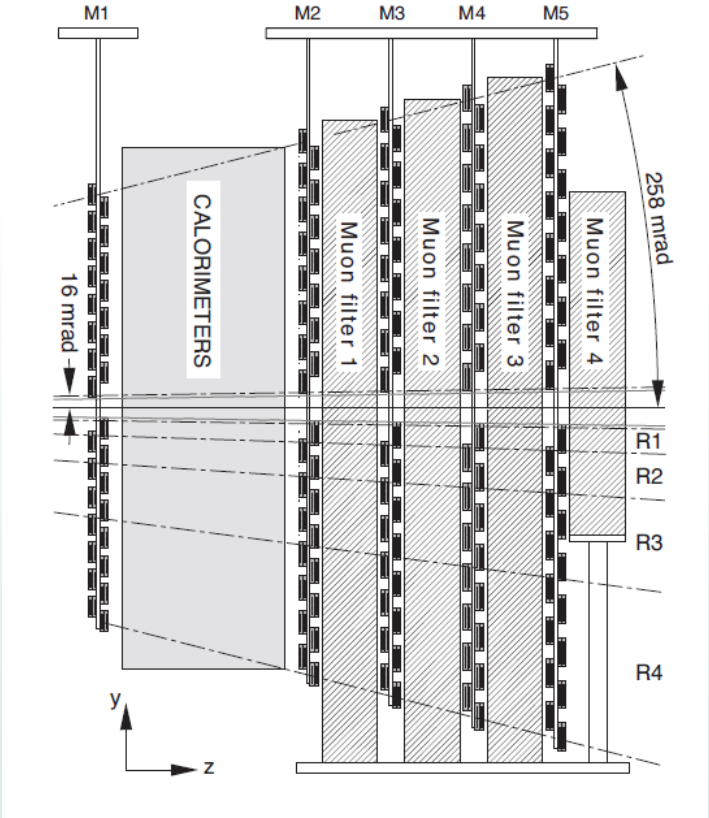
without RICH



with RICH



2. Muon Systems



2. Muon Systems

Several key measurements of LHCb rely on μ–ID:
e.g. $B_s \rightarrow \mu^+\mu^-$ and $B_d \rightarrow K^{*0}\mu^+\mu^-$

- Muon systems provides μ–ID to very high purity;
- 5 tracking stations, each subdivided in 4 regions with different granularities;
- Equipped with Multi Wire Proportional Chambers (MWPCs) and Gas Electron Multipliers (GEMs).
- Total thickness of LHCb hadron absorber (muon shield): ~ 23λ

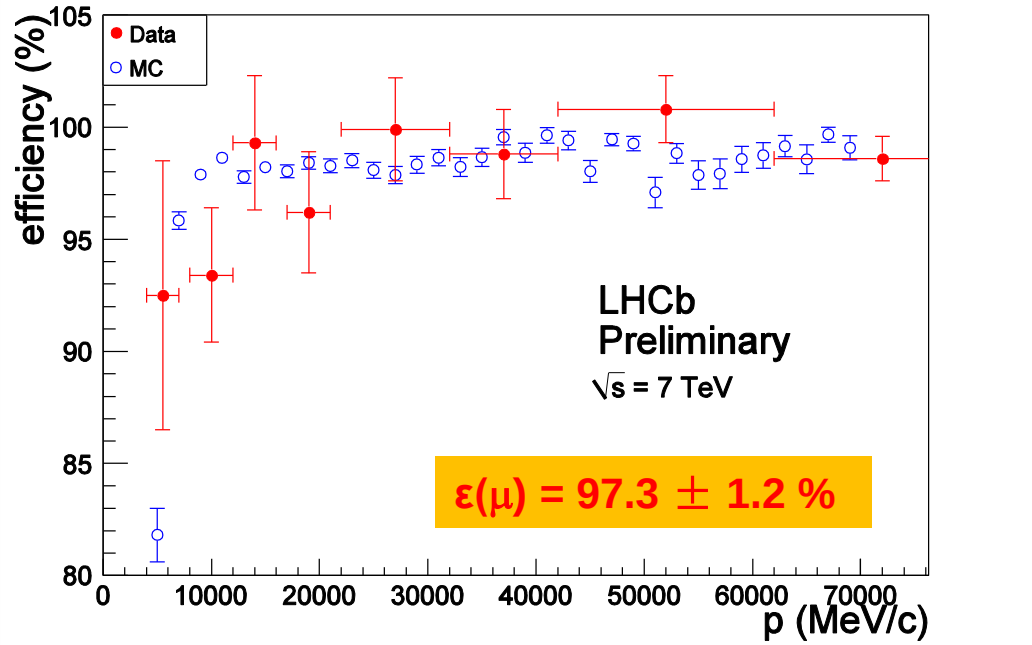
2. Muon Systems

Muon identification:

- Extrapolate tracks and find hits in a Field of Interest;
- Find muon candidates requiring hits in different stations depending on momentum;
- Calculate a probability using the position of the hits in different stations.

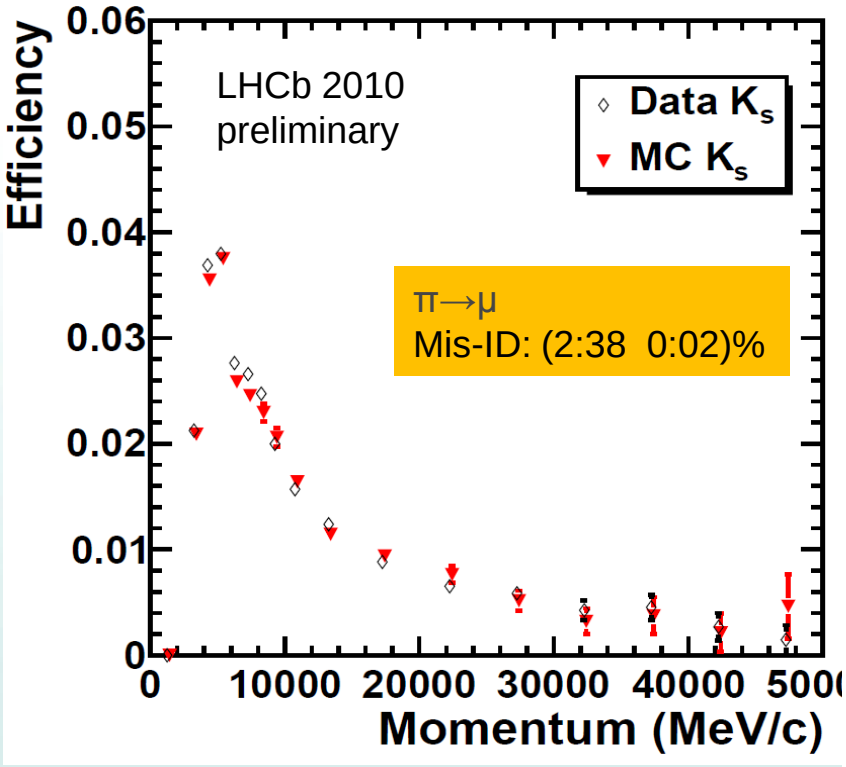
2. Muon Systems

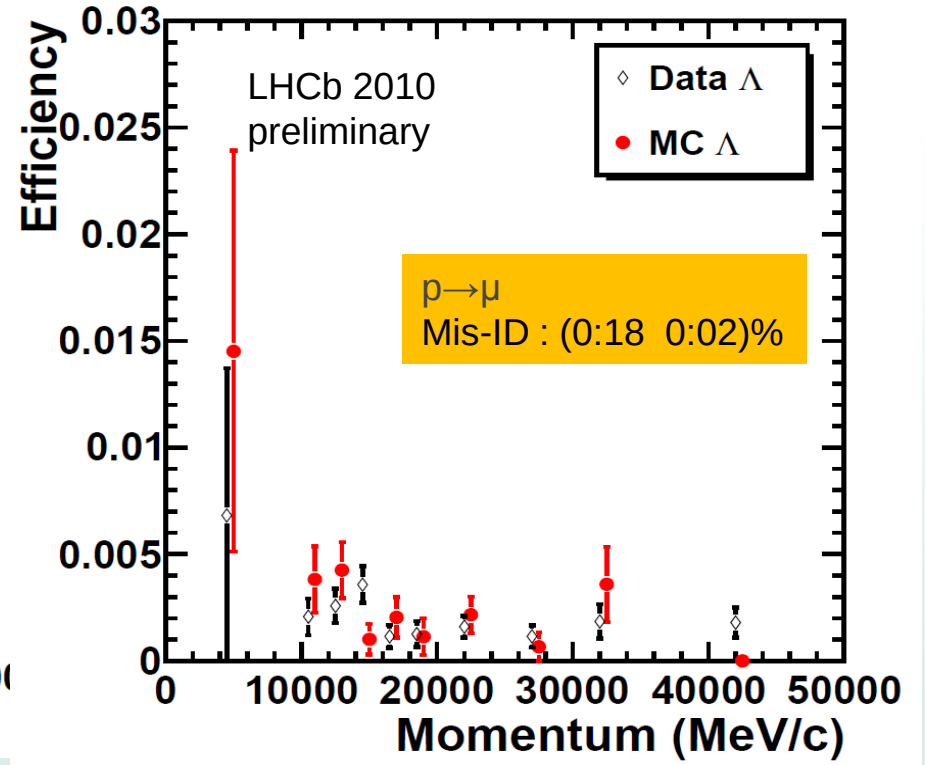
- Calibration: $J/\Psi \rightarrow \mu^+\mu^-$ (tag & probe):
  - Identify one muon with the muon system (Tag) and the other muon by MIPs in the calorimeters (Probe);
  - Use the probe muon to estimate μ–ID efficiency.



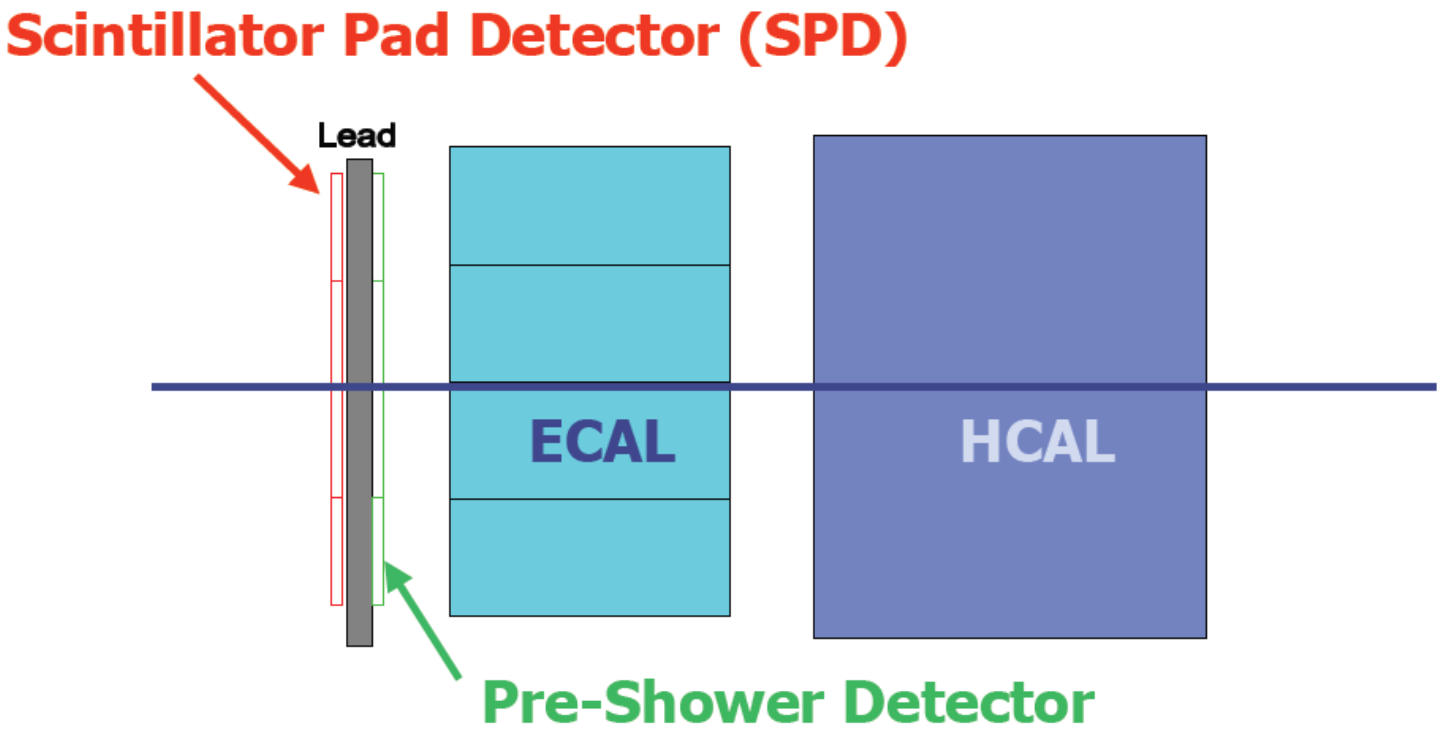
2. Muon Systems

- Also use K_S and Λ to test mis-ID rates:



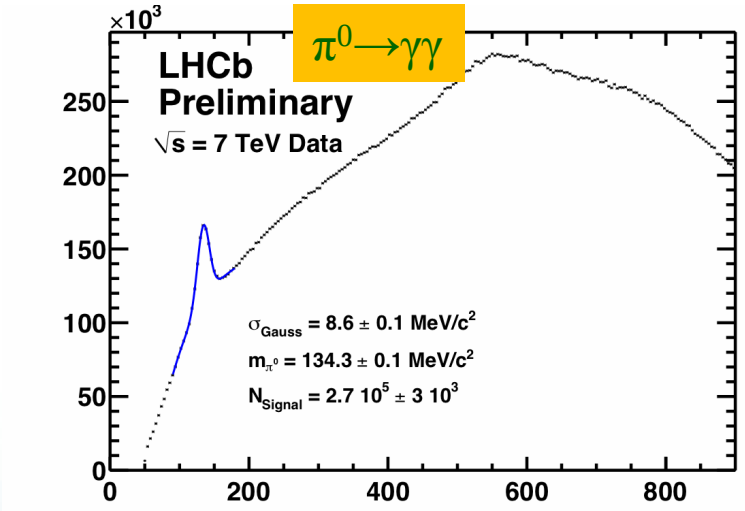


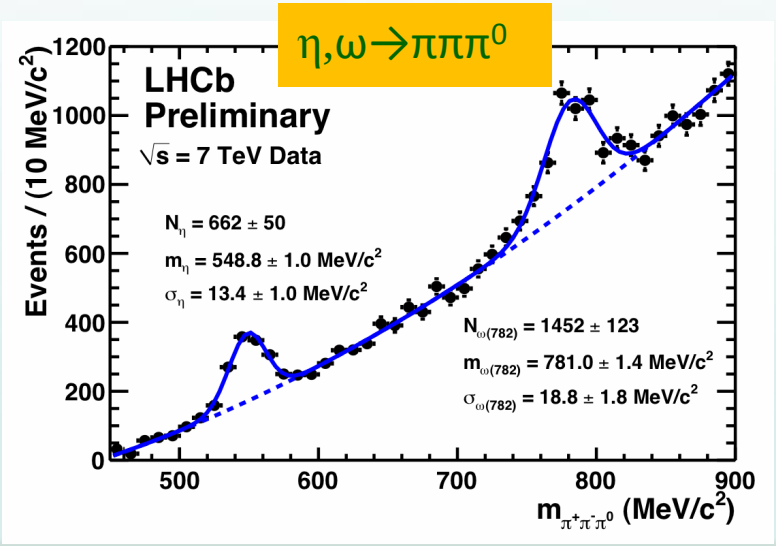
3. Calorimeters



3. Calorimeters

- They provide identification of *e*, *γ* and hadrons as well as the measurement of their energies and positions.
- Electron e/p: mean ~ 99.7%, sigma ~10.76%.
- Important for neutral particle identification.





Summary

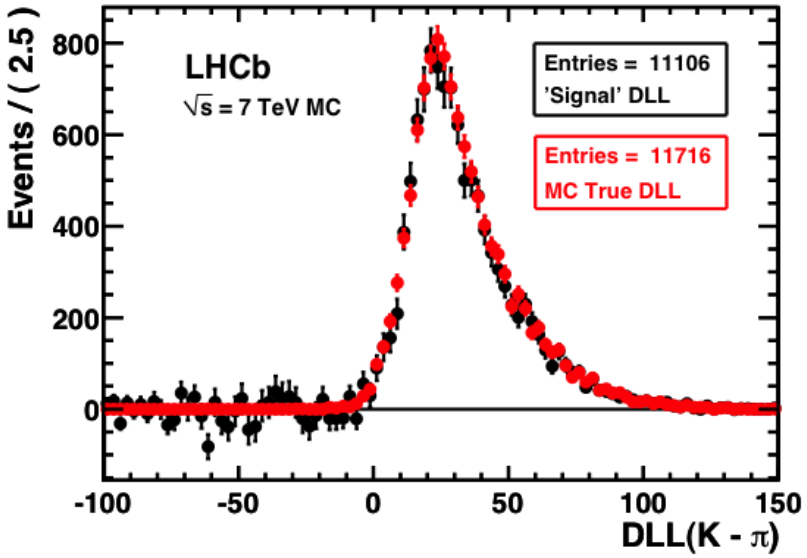
- Progress being made on all fronts on calibrating the PID sub-systems;
- Expect further improvements with better tracking alignments;
- More channels can be utilised for calibration at nominal luminosity.

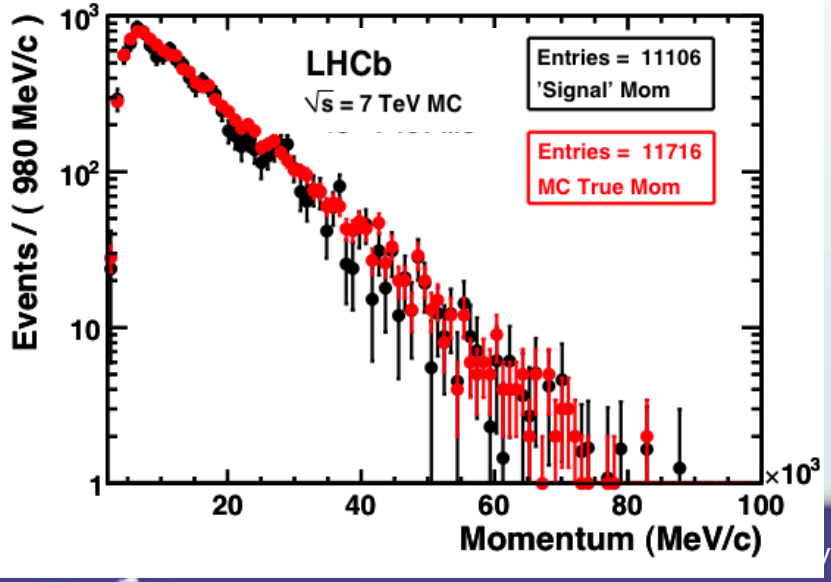
Backup slides

sPlots and sWeights

- The functional form describing the signal and background contributions of ϕ invariant-mass distributions are known but not those in ΔlogL, p etc.
- However, since ΔlogL and p of a daughter track are uncorrelated to the mother invariant-mass, one can utilise **"sWeights"**:
  - Following a fit to the invariant-mass distribution, can assign a weight (sWeight) to each candidate defining its probability to be signal or background
  - Can then use these weights to "unfold" the background and signal contributions to the daughter track DlogL distributions
  - The "unfolded" distributions are then referred to as "sPlots"

sPlots and sWeights





- Test method on Monte Carlo
  - Top, unfolded ΔlogL distribution
  - Bottom, unfolded momentum distribution
  - Excellent agreement to **MC true**
  - Method therefore applied to data
  - Used for both:
    - Kaons from ϕ
    - protons from Λ

DLL Distributions

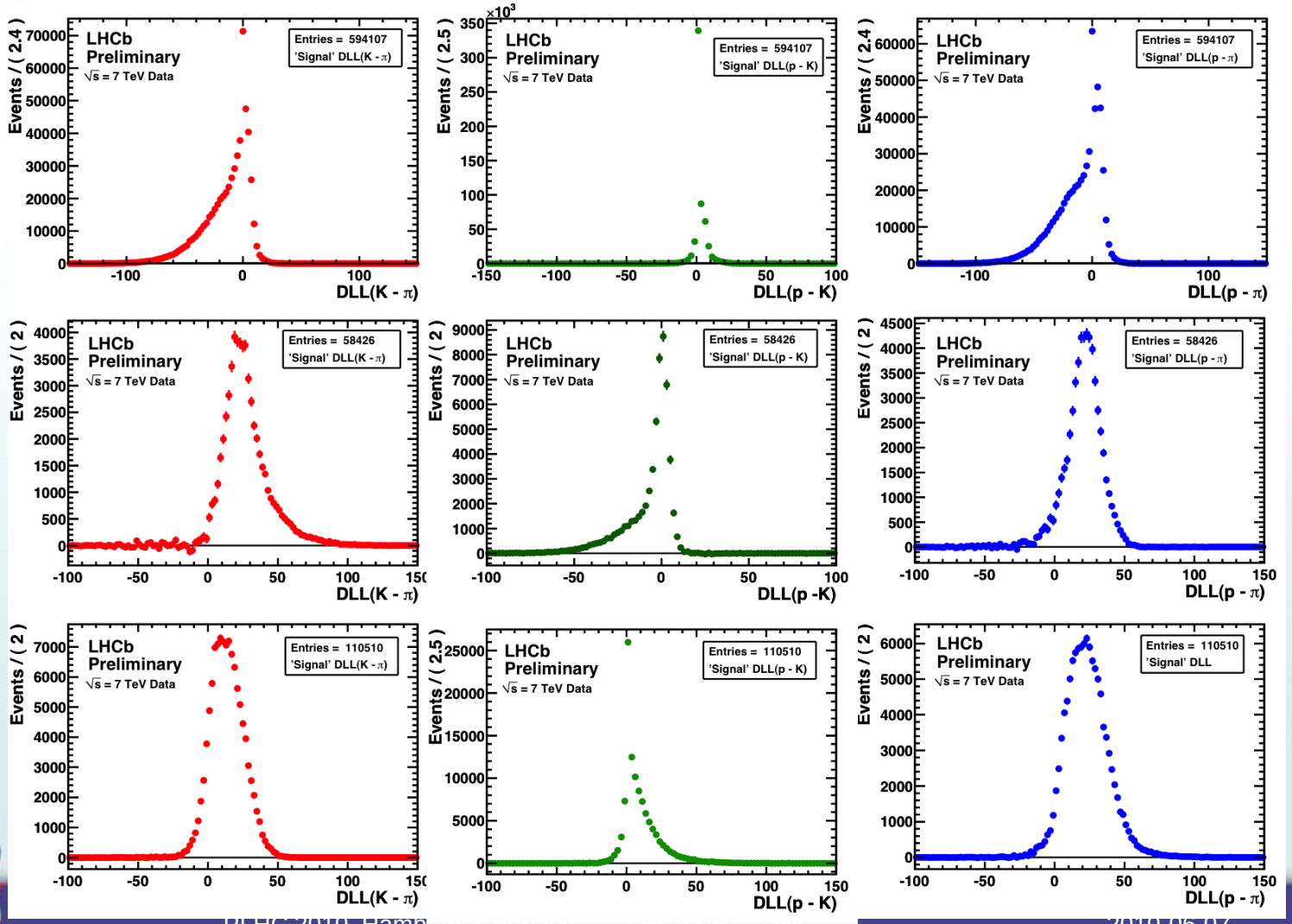
LHCb Preliminary
$\sqrt{s}$ = 7 TeV Data

$\Delta\log\mathcal{L}(K-\pi)$ $\Delta\log\mathcal{L}(p-K)$ $\Delta\log\mathcal{L}(p-\pi)$

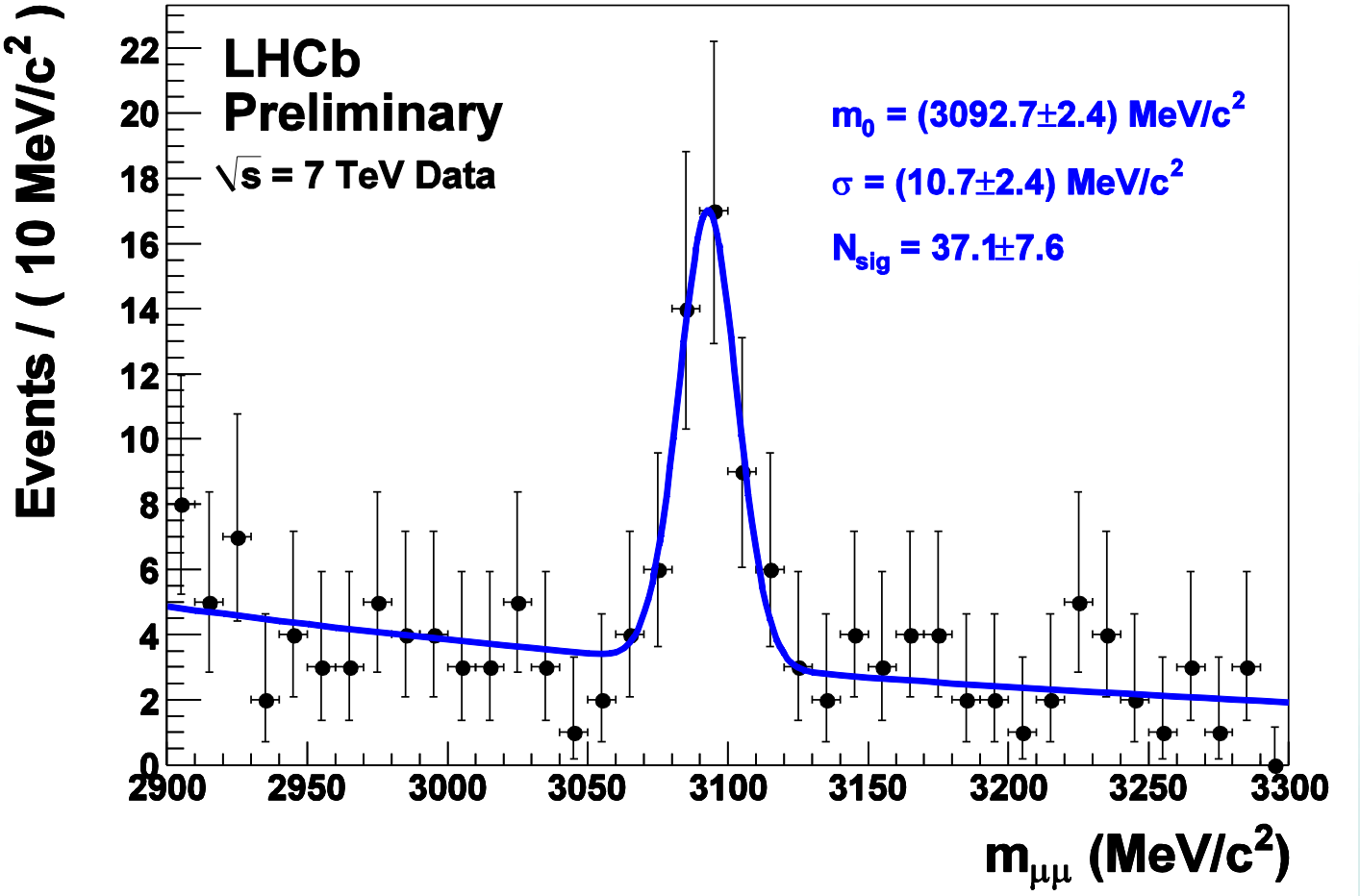
π

K

p



J/ψ Fit


LHCb
Preliminary
√s = 7 TeV Data
m0 = (3092.7±2.4) MeV/c2
σ = (10.7±2.4) MeV/c2
Nsig = 37.1±7.6
Events / (10 MeV/c2)
mμμ (MeV/c2)
0
2
4
6
8
10
12
14
16
18
20
22
2900
2950
3000
3050
3100
3150
3200
3250
3300