TORCH physics case

M. Kreps for TORCH collaboration

Physics Department

- Initial look to possible gains
- Plans for physics studies

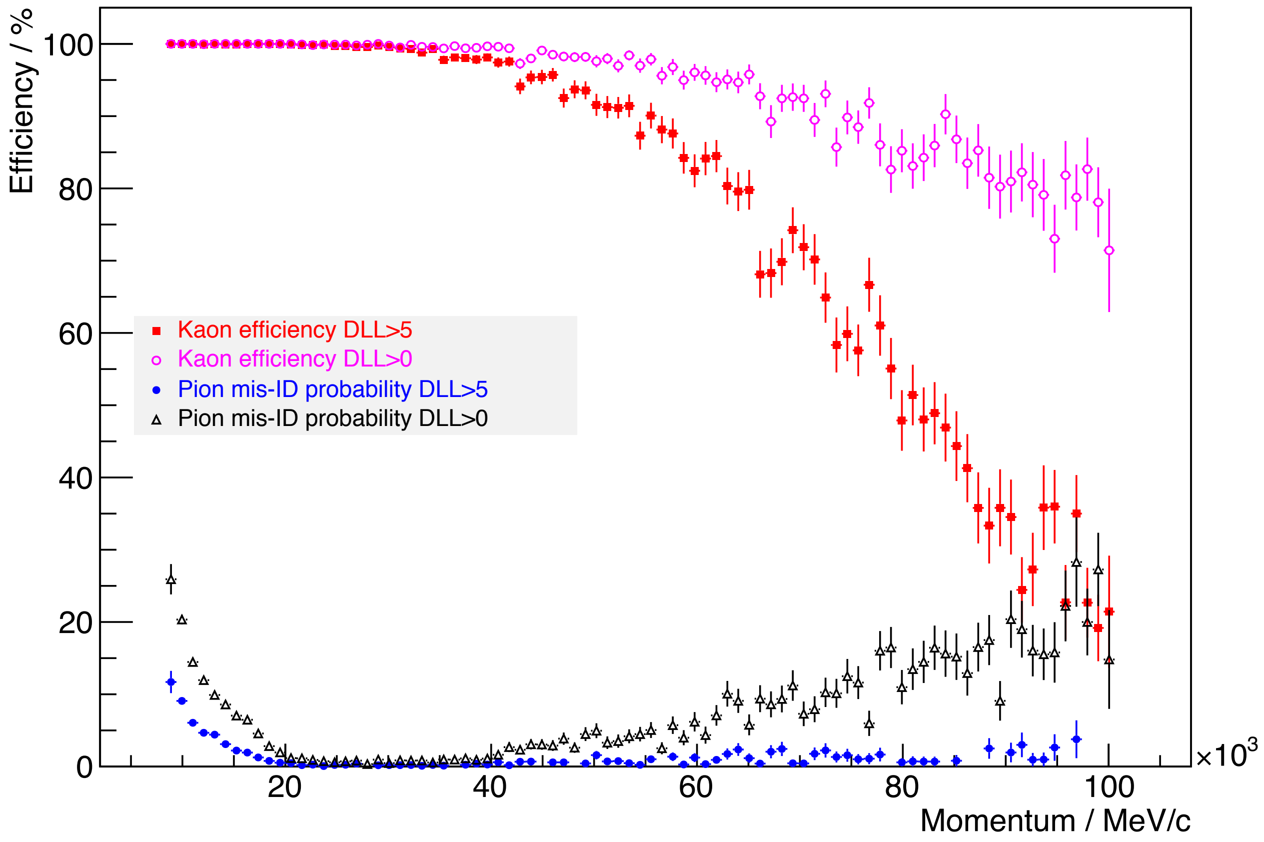
What physics to look at?

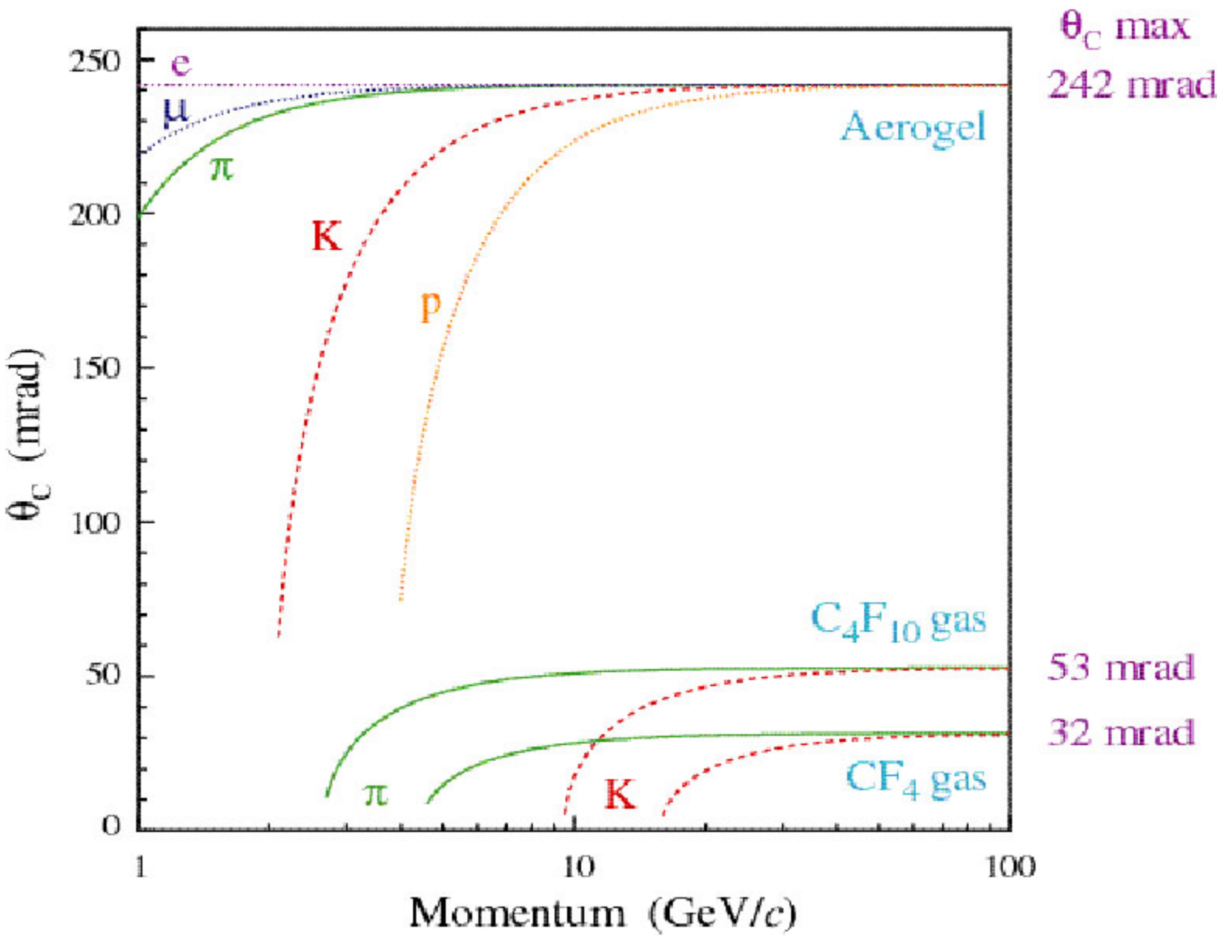
- TORCH could be used for various purposes
- At this moment treat TORCH as PID detector which will help π, K, p separation
- Choose few decays which will
  - Evaluate performance gain for both kaons and protons
  - Try to map LHCb physics across several WG
- What I'm going to show is more starting point than anything sophisticated
- Some of the gains showed might need other changes/improvements to benefit from TORCH

Where TORCH helps?

- Our capability to separate kaons from protons limited at low momentum
- As we go with momentum below 10 GeV mis-ID rate rises
- While we have some capability for PID below 10 GeV, for simplicity here I look what fraction of signal has hadron below

LHCb-TDR-014





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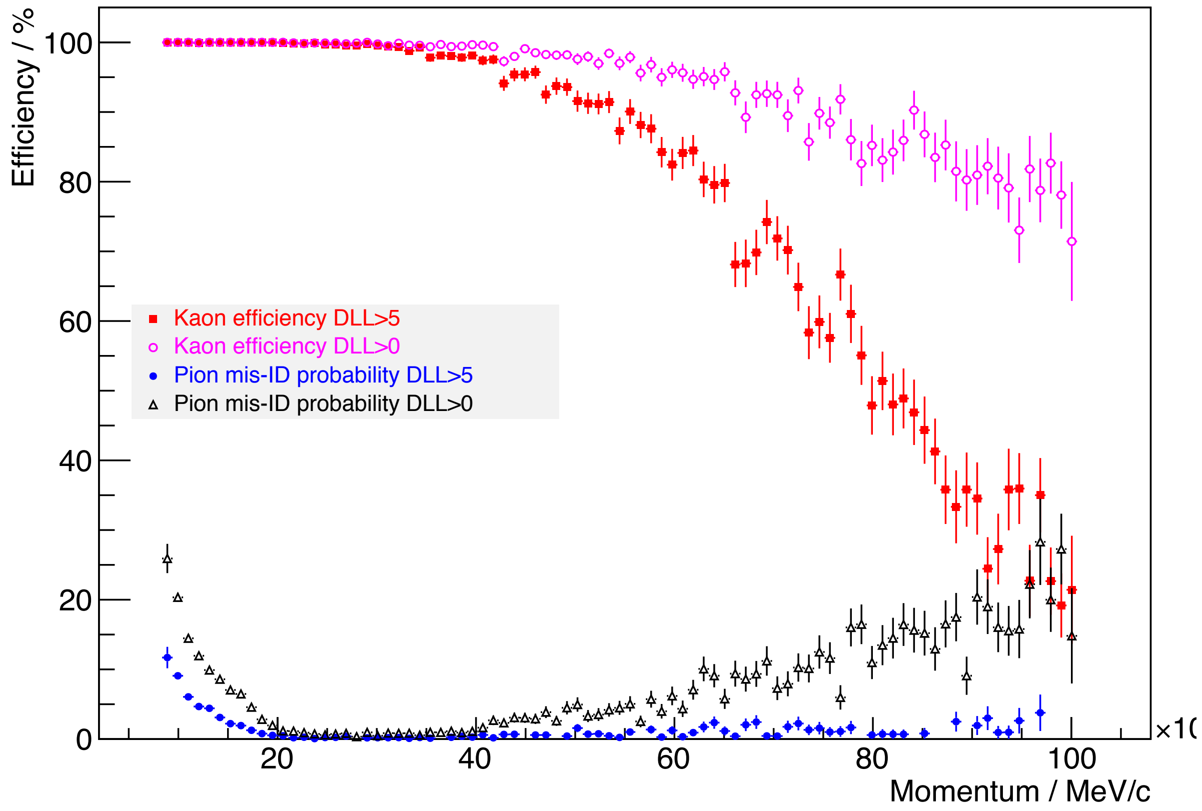
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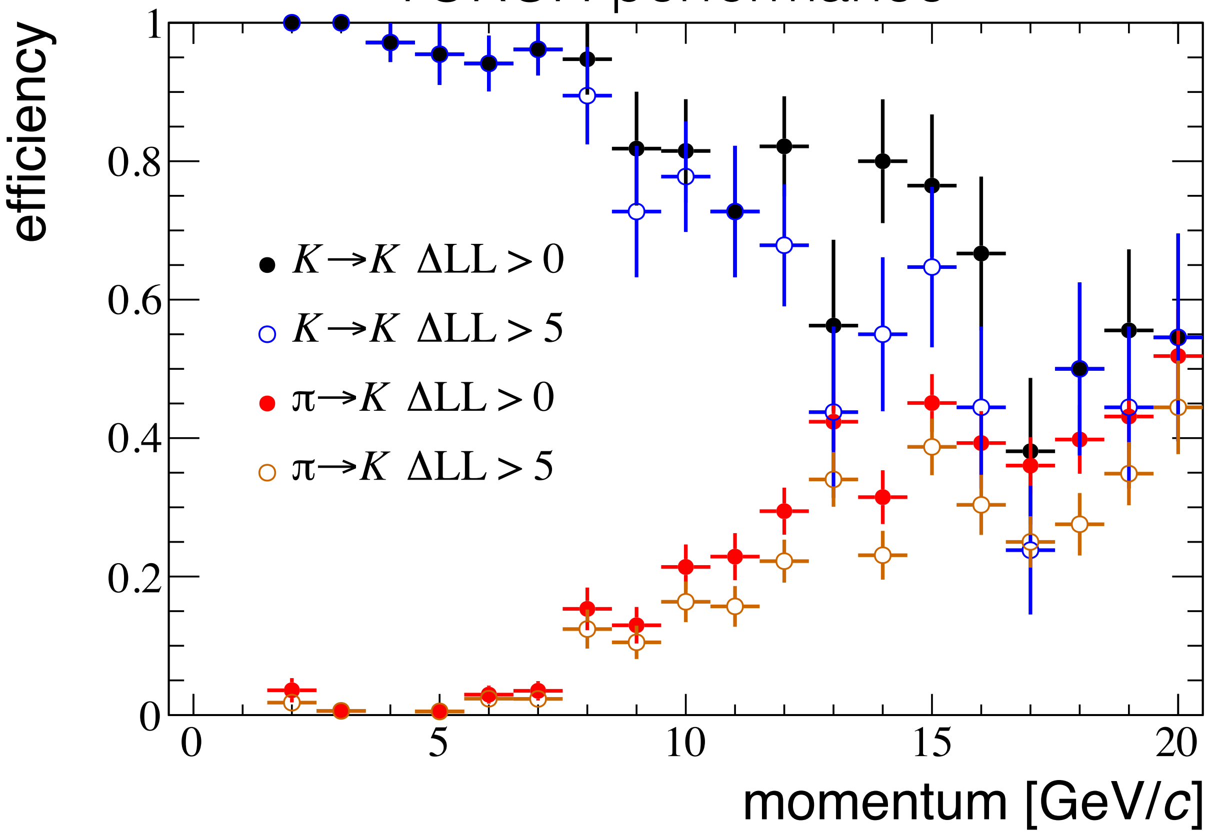
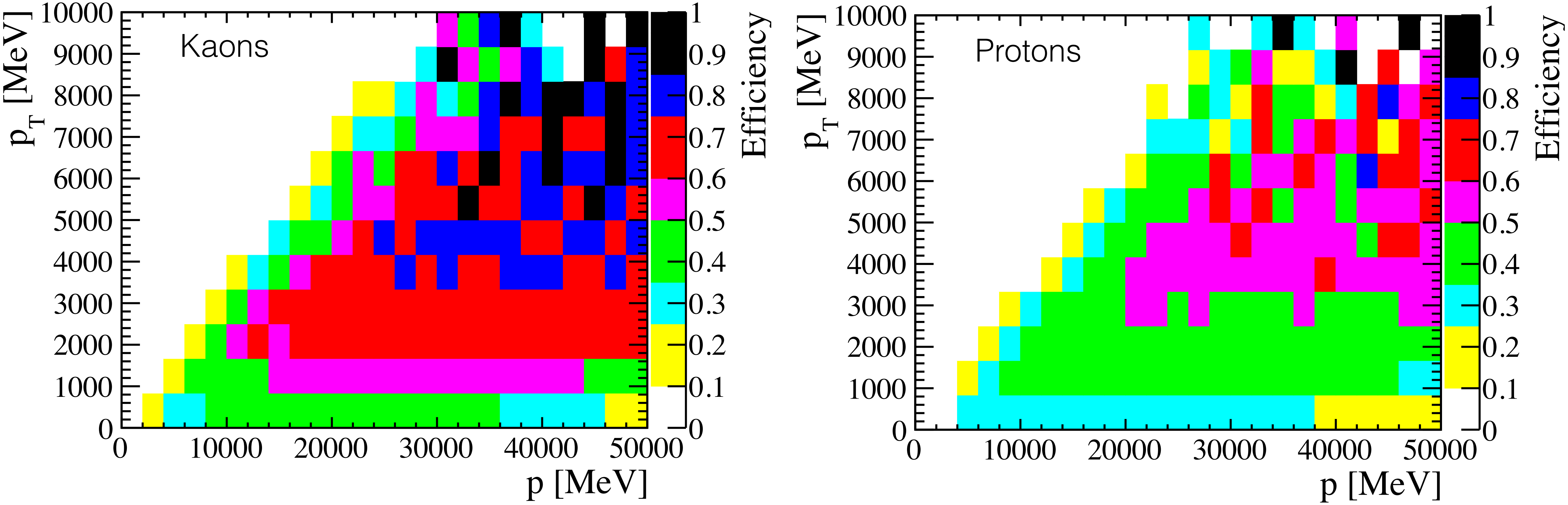

TORCH performance

What is done

- Take generator level samples of signals (pythia8 @ 14 TeV)
- Use latest minimum bias simulation with latest upgrade detector to evaluate which tracks we can reconstructed
- Do very simple estimate of potential gains by counting "reconstructed" candidates with hadron with $p < 10/12$ GeV
    - Probably bit optimistic as it assumes no hadrons with lower momentum are used
- At this moment looking only to the signal, no background
- Eventually will need to make sure that phase-space region where TORCH helps is
    - reconstructed in tracking
    - used in analysis

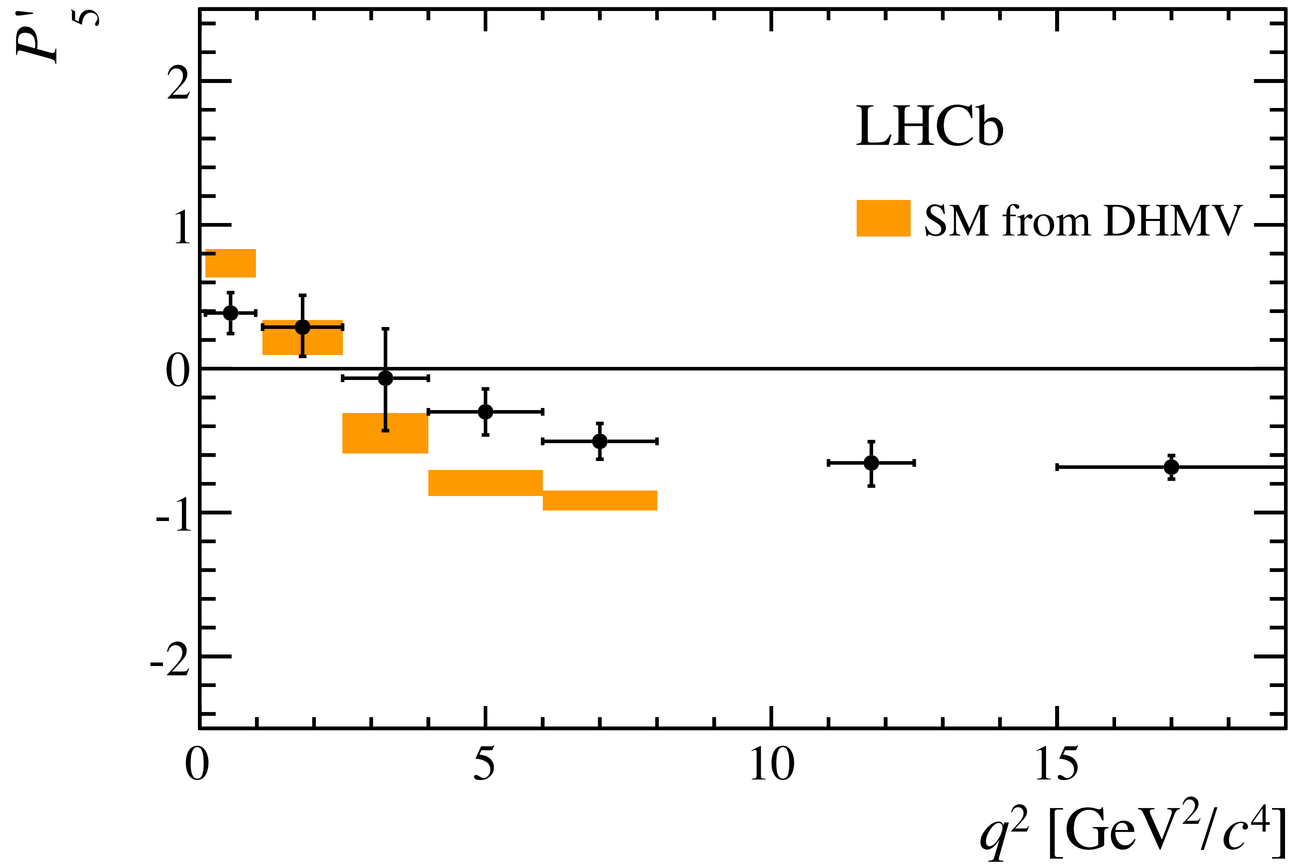
Which tracks can be reconstructed in LHCb?

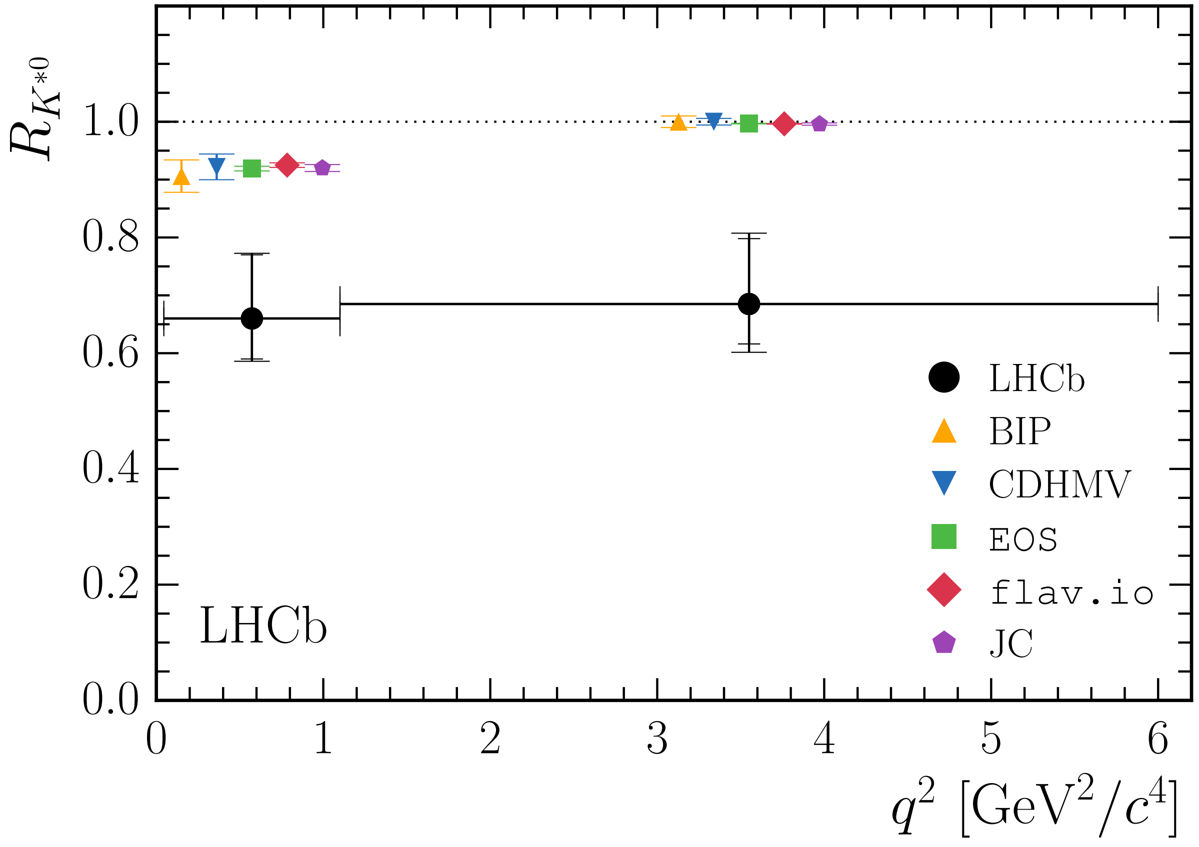
- PID helps only if we have tracks reconstructed
- Look to minimum bias upgrade simulation to create efficiency map
- In study we use generator level signal decays folded with reconstruction chance
  - Do not consider particles we cannot reconstruct as long tracks



Electroweak penguins

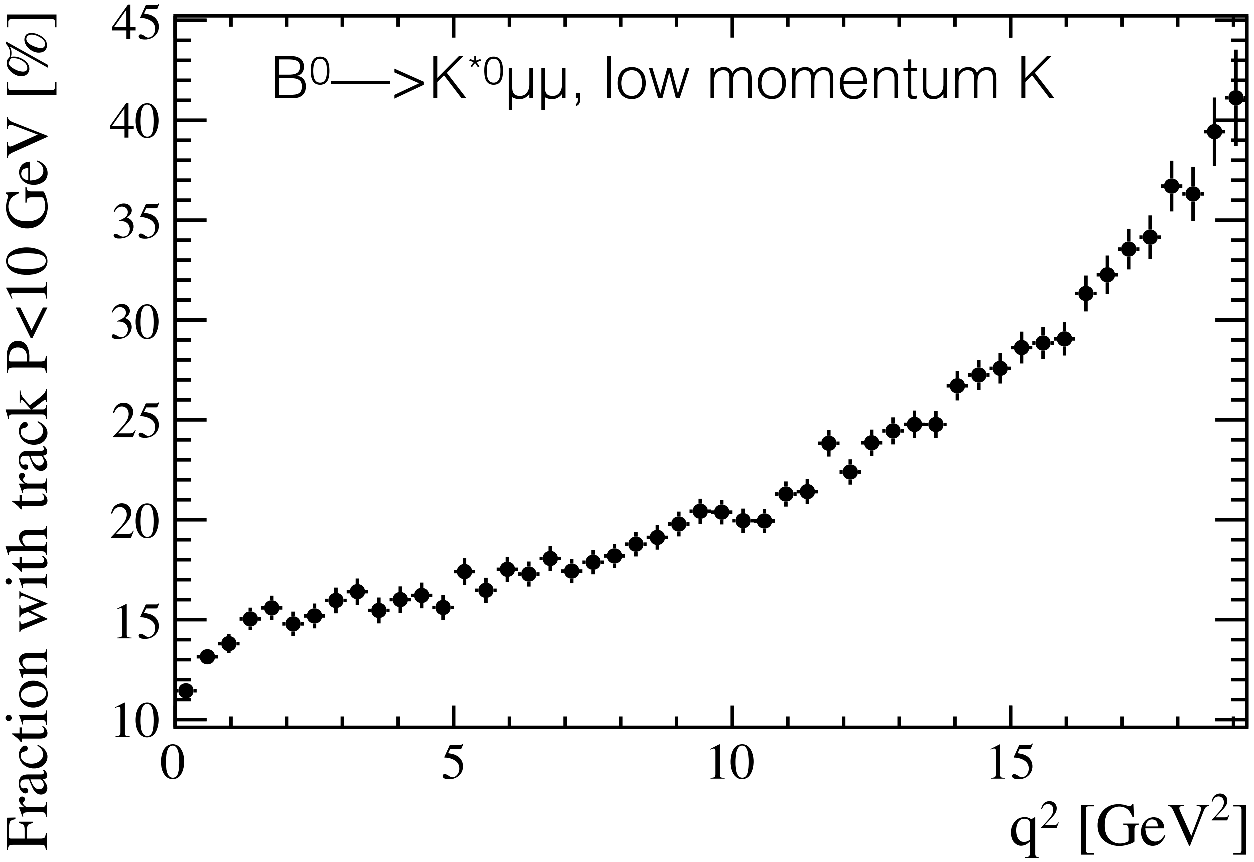
- Interesting tensions with run 1 data
- Several measurements could be tested
  - Angular analysis
  - Lepton universality tests
- Check which of these has larger fraction of low momentum tracks to find one which will benefit significantly

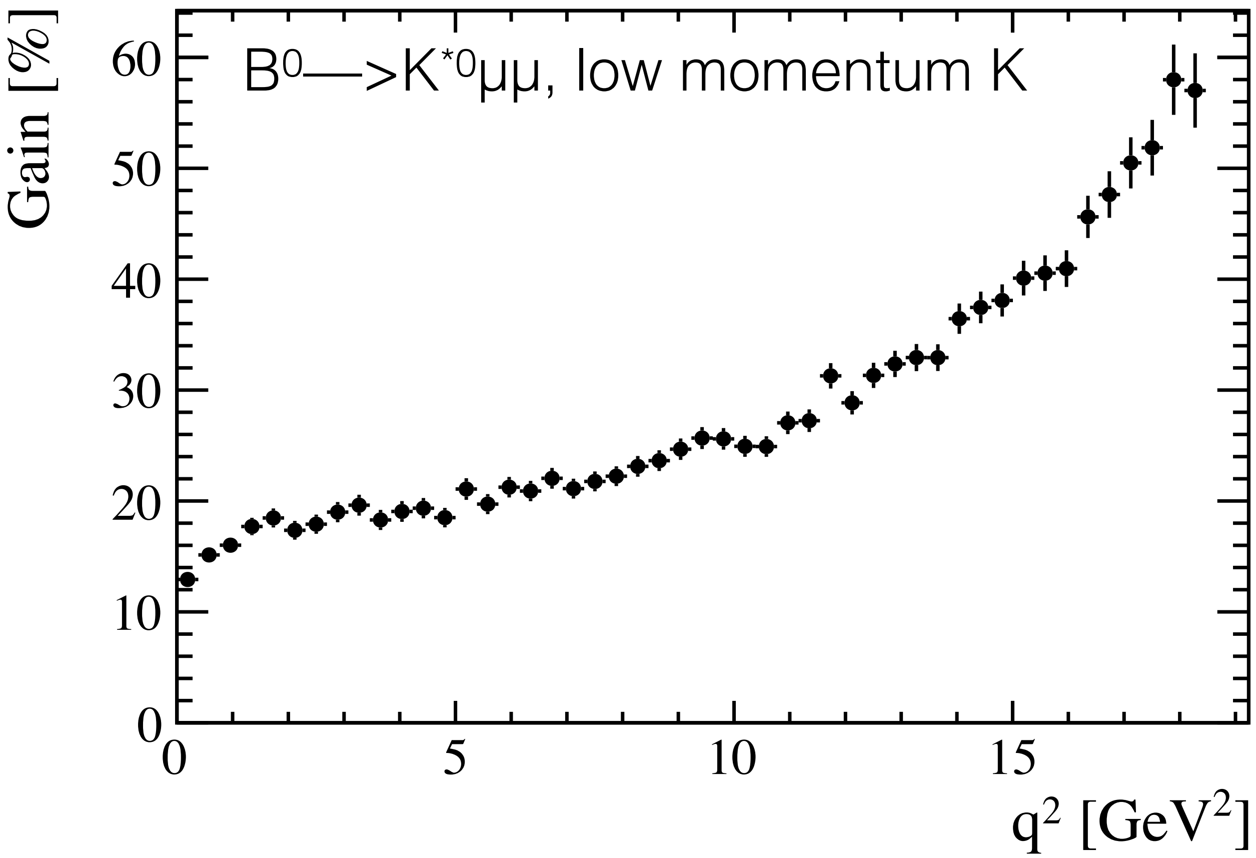




Electroweak penguins

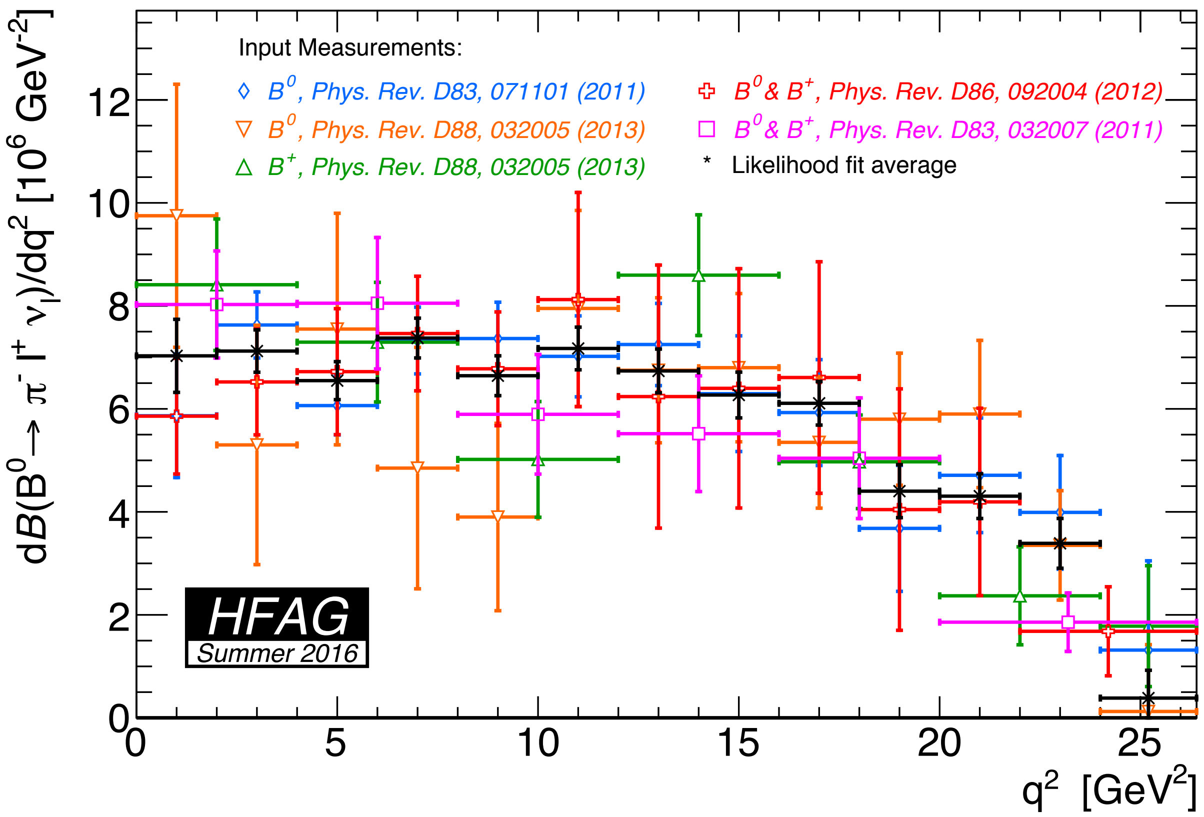
- Reasonably large amount of signal has low momentum kaon
- Effect will depend on q^2 but we should benefit over whole q2 range
- Need to look carefully how angular efficiency and mis-ID rate will go
- There seems to potential for gain

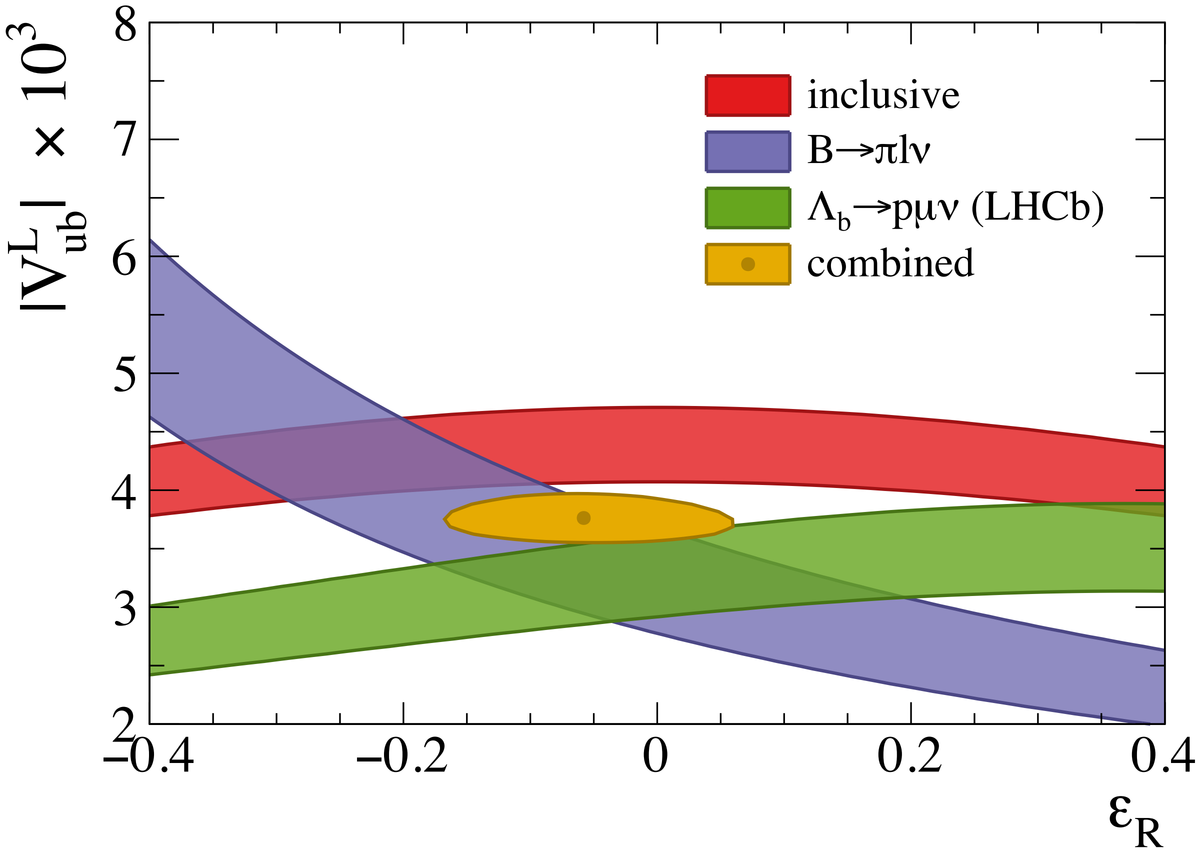




$B_s \rightarrow K\mu\nu$ and $\Lambda_b \rightarrow p\mu\nu$

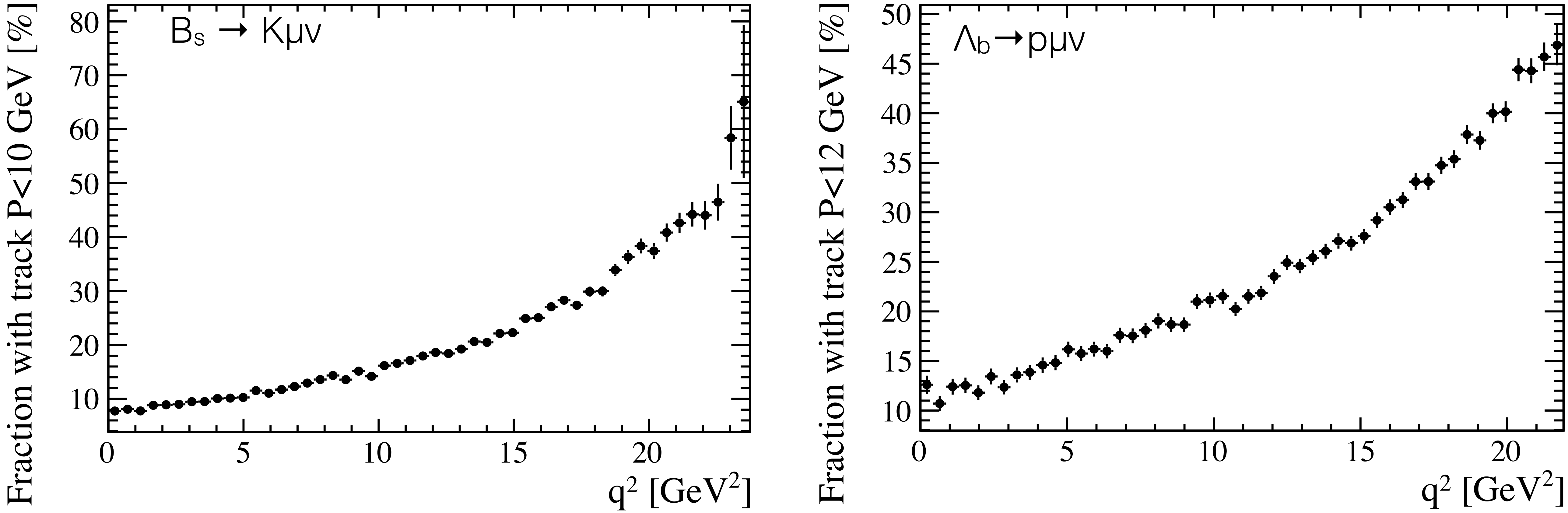
- Decay to measure $|V_{ub}|$
- Most precise determinations in high q^2 region where LQCD performs its calculations
- There was measurement with Λ_b but not yet with B_s (ongoing)
- In Λ_b proton momentum > 15 GeV because of PID performance
- Possible improvements in both cases with better PID at low momenta





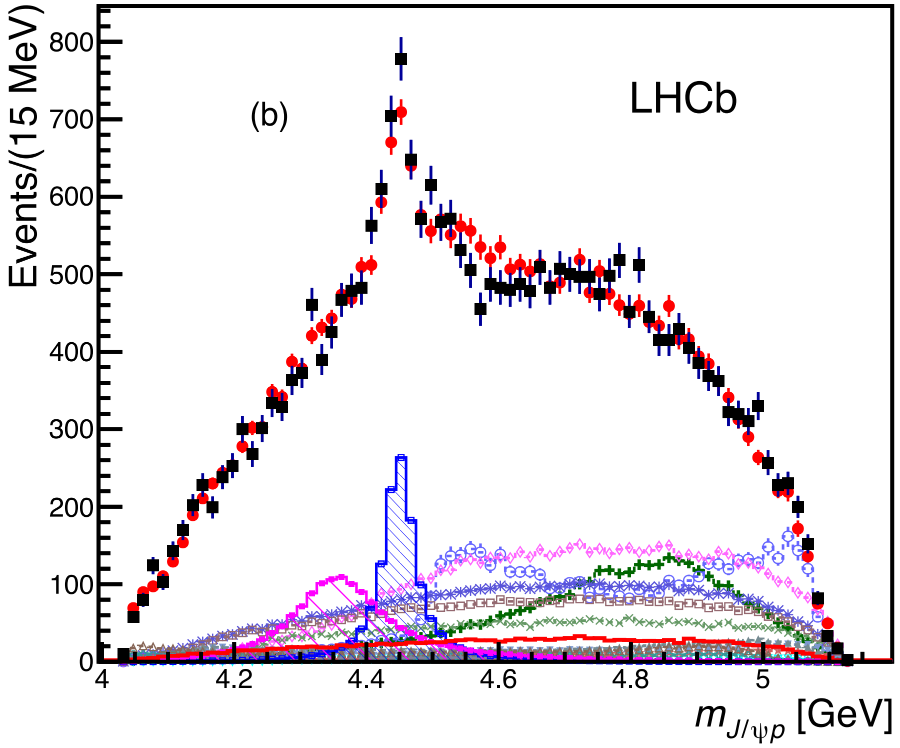
$B_s \rightarrow K\mu\nu$ and $\Lambda_b \rightarrow p\mu\nu$

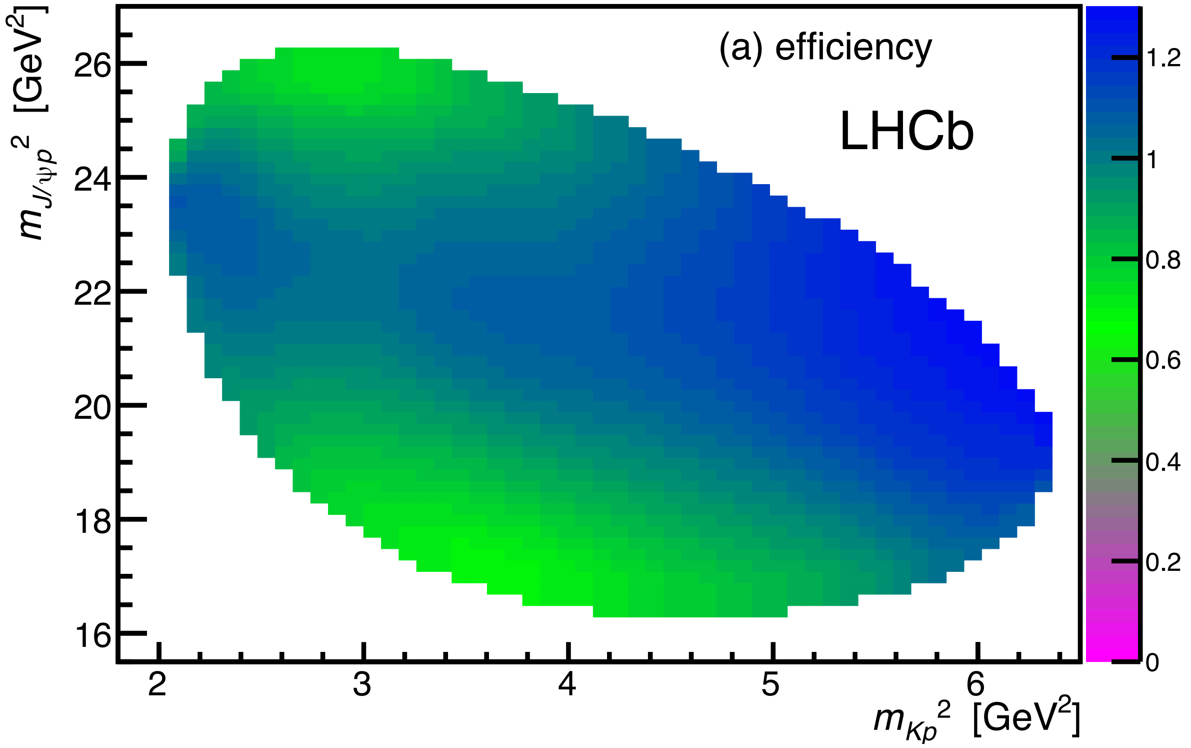
- Check how many kaons/protons we have with p<10/12 GeV
- For protons should probably go bit higher
- At high q^2 possible impact is quite large
- Need to fold in PID (both RICH and TORCH) and also what happens to muon



Pentaquarks

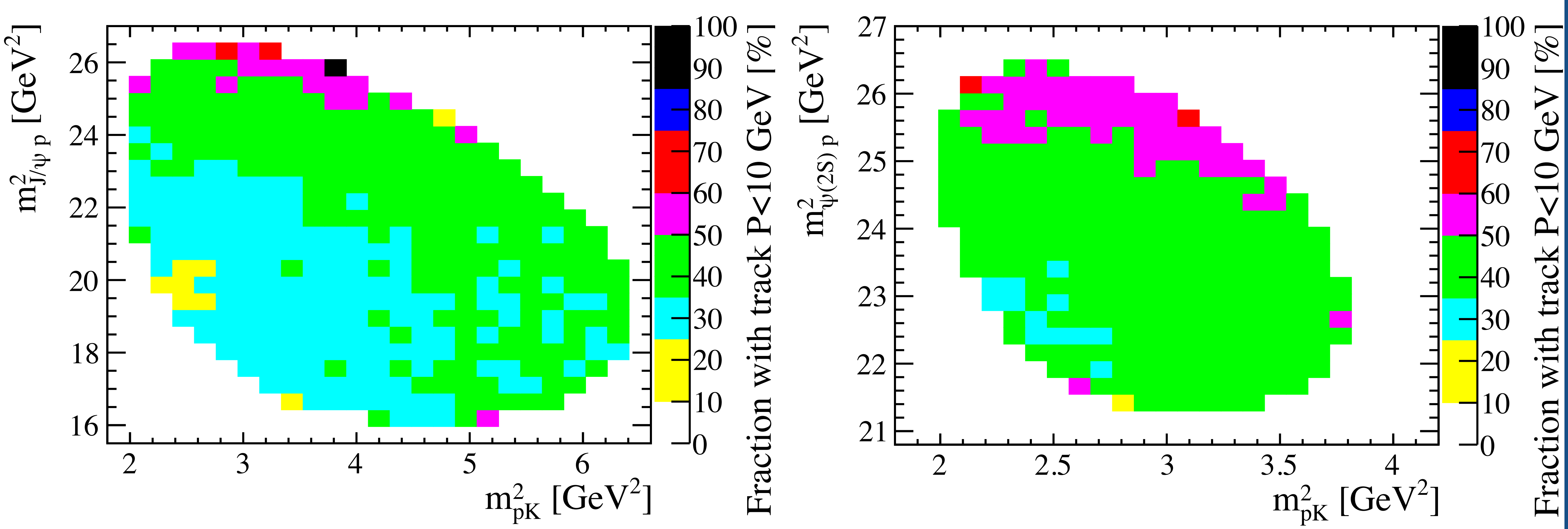
- Pentaquarks generated considerable interest
- Efficiency varies across phase-space
- Decreasing this variation can significantly improve result
- Full amplitude fit is probably beyond this study, but model independent version of this analysis is reasonably simple
- Search for prompt production in J/ψp important to build full understanding of the states





Pentaquarks

- Potentially large fraction of decays have K or p with momentum below 10 GeV
- Proton-kaon separation also important for correctly assigning tracks
- With better low moment PID, increase in efficiency, decrease swaps and possibly more uniform efficiency across Dalitz plot



Other physics to look at

- Flavour tagging strongly depends on PID (dominantly kaon)
- Possible options to evaluate its performance
  - B_s→KK: interesting for studies of CKM phase parameter in loop decay
  - B_s→D_sK: Used to determine CKM angle γ
- B_s→KK has simpler time dependence, but B_s→D_sK can potentially benefit more
- Needs some thinking how to do this, might need to wait for TORCH in Gauss
- Weak decay of D_{sJ}→p pbar π
  - Having two protons from D_{sJ} leads to many low momentum protons
  - PID will be main handle to suppress background

Summary

- Initial look to which channels are useful for building more detailed physics case for TORCH
- What I have showed is start rather than end product
- Next step:
  - Properly fold in PID efficiencies to the study (possibly should be quick)
  - Start to look for backgrounds and replicate measurements in toy studies
- Full simulation within LHCb
  - Did started on incorporating TORCH into Gauss (hopefully geometry can be done within next two weeks)
  - Start to prepare code to simulate TORCH in Gauss