# Physics impact of the PID

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and new detector concept
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# Introduction

- In order to reconstruct heavy flavor decays, charged particle ID information is crucial
- Ideally, with accurate track momentum and particle energy measurements, mass of the particle can be determined by

$$M = \mathrm{sqrt}(E^2 - p^2)$$

  … therefore, PID can be determined

- In reality, E and p cannot be measured accurately, therefore PID information from TPC / Drift chamber / Cherenkov detector etc. are important
- This study shows how the PID information impact the physics performance

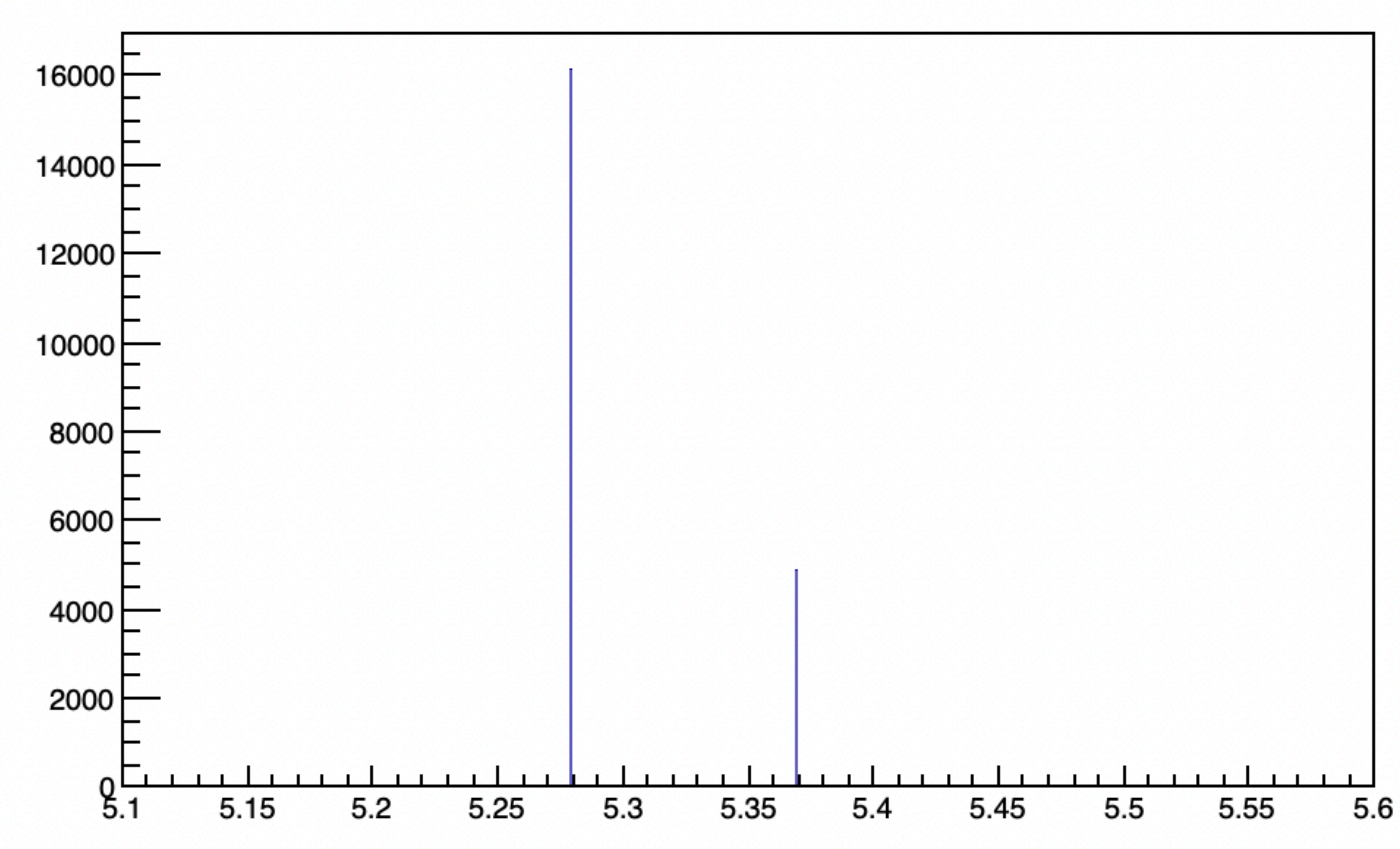
# Impact of K pi PID information studied with $B_{(s)}^0$ -> hh

# Studies with $B_{(s)}$->hh channel

- Studied with centralized CEPC simulation production
- Decay channels: $B_{(s)}$->hh, h=K or pi (with radiative decay allowed)
- Reconstructed signals (charged conjugated events are considered)
  - Within the mass window [5.1, 5.6] GeV/$c^2$: B->hh: 17132, $B_s$->hh: 5340
- Assumptions:
  - Backgrounds eliminated completely, no other particles

# Scenario 1: Ideal case

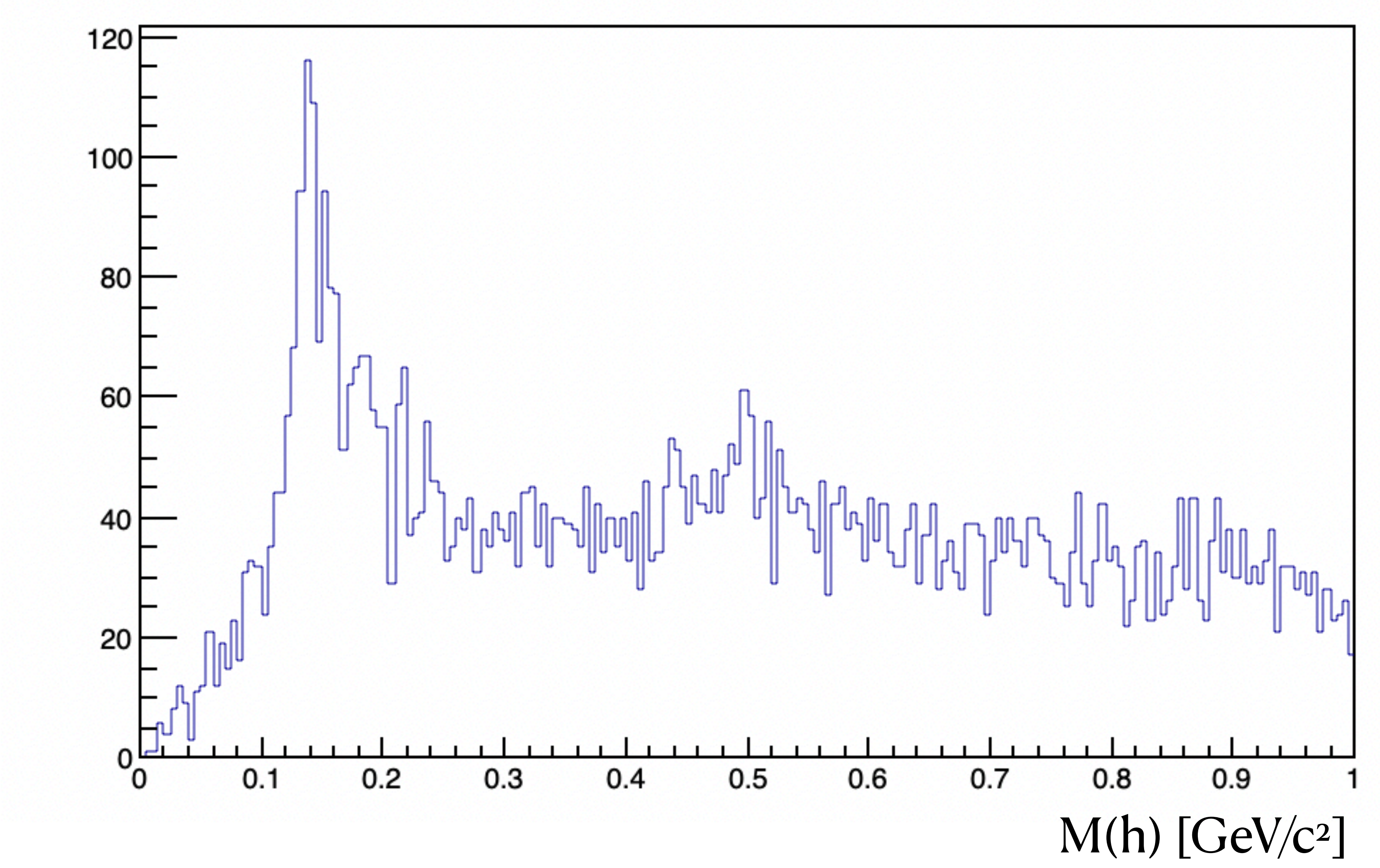
- … or the "MC truth":
- B and $B_{(s)}$ mass distributions: two delta functions

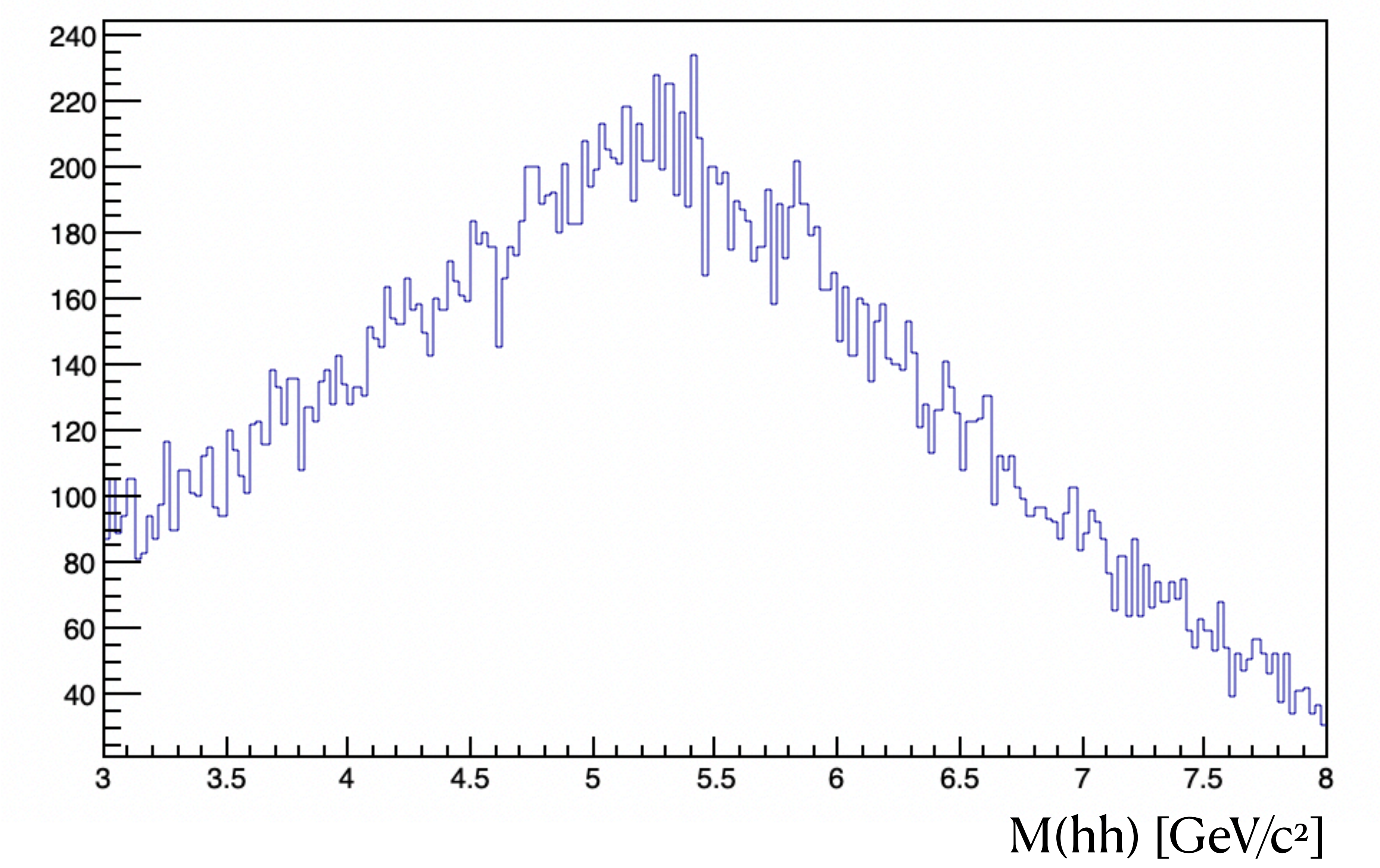


M(hh) [GeV/c²]

# Scenario 2: Real world without PID

- Assumptions:
  Momentum measurements resolution ~0.2%, and the resolution is isotropic
  Energy measurements resolution ~1%
  No PID information provided
- K / pi separation is extremely difficult, separation of B / $B_s$ is impossible

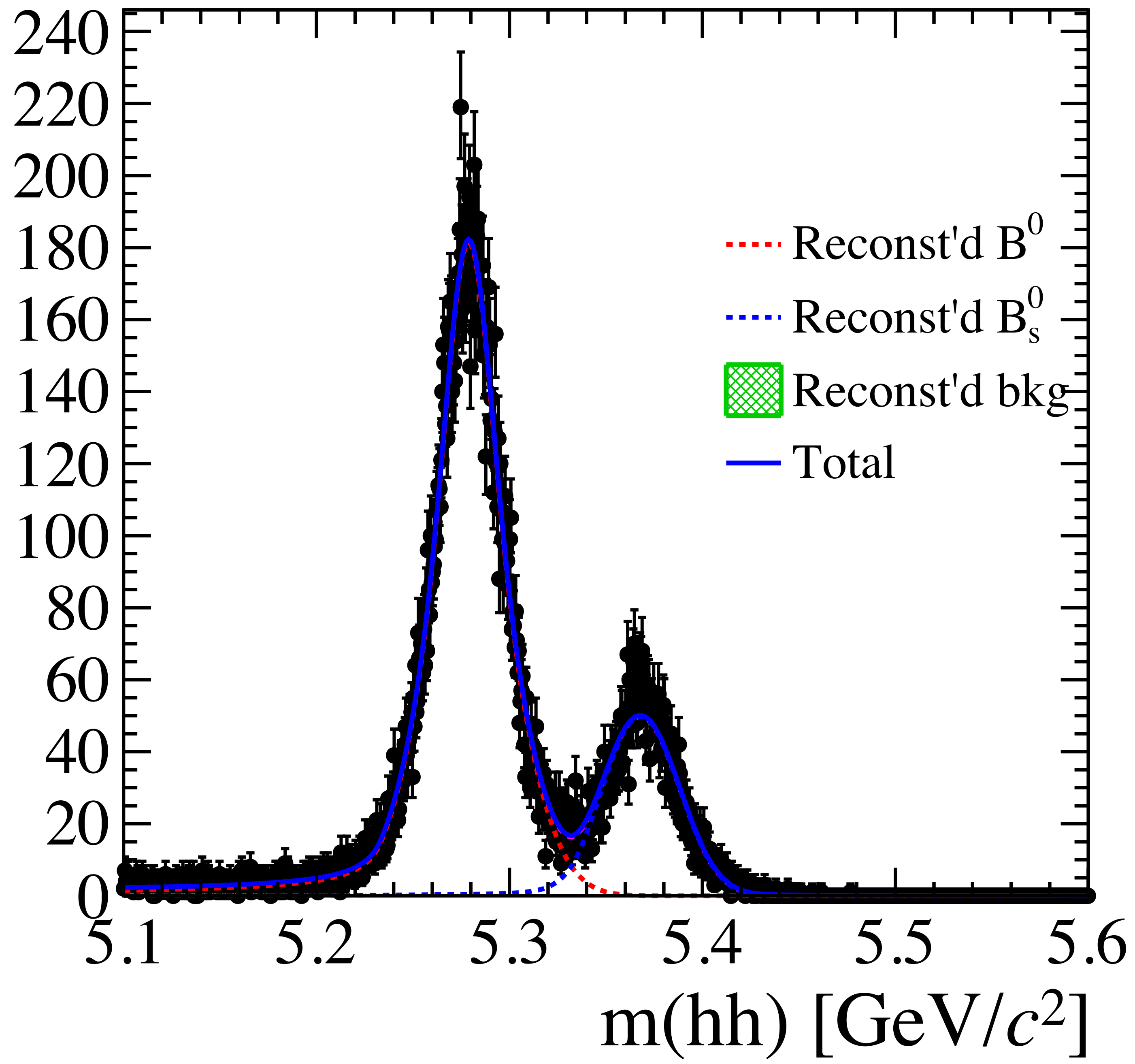


# Scenario 3: with perfect PID

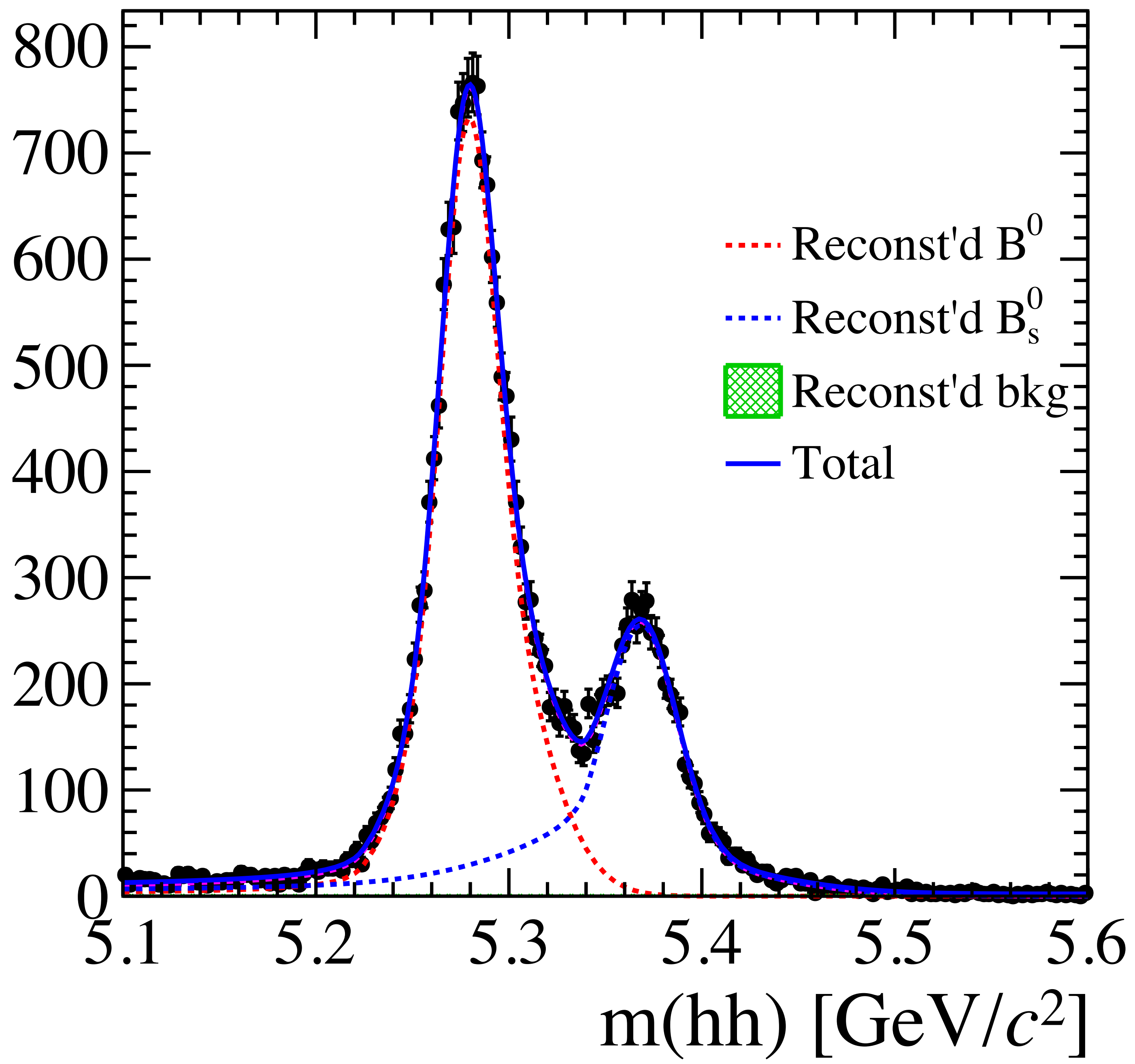
- K / pi mass constrained to their PDG mass
- Clear separation of B / $B_s$
- Fit functions: CB+Gauss for both B and $B_s$
- Yields from the fits:
  - B: 17099 +/- 151
  - $B_s$: 4975 +/- 70

- Reminder, MCTruth:
  B->hh: 17132,  $B_s$->hh: 5340
- Very close!



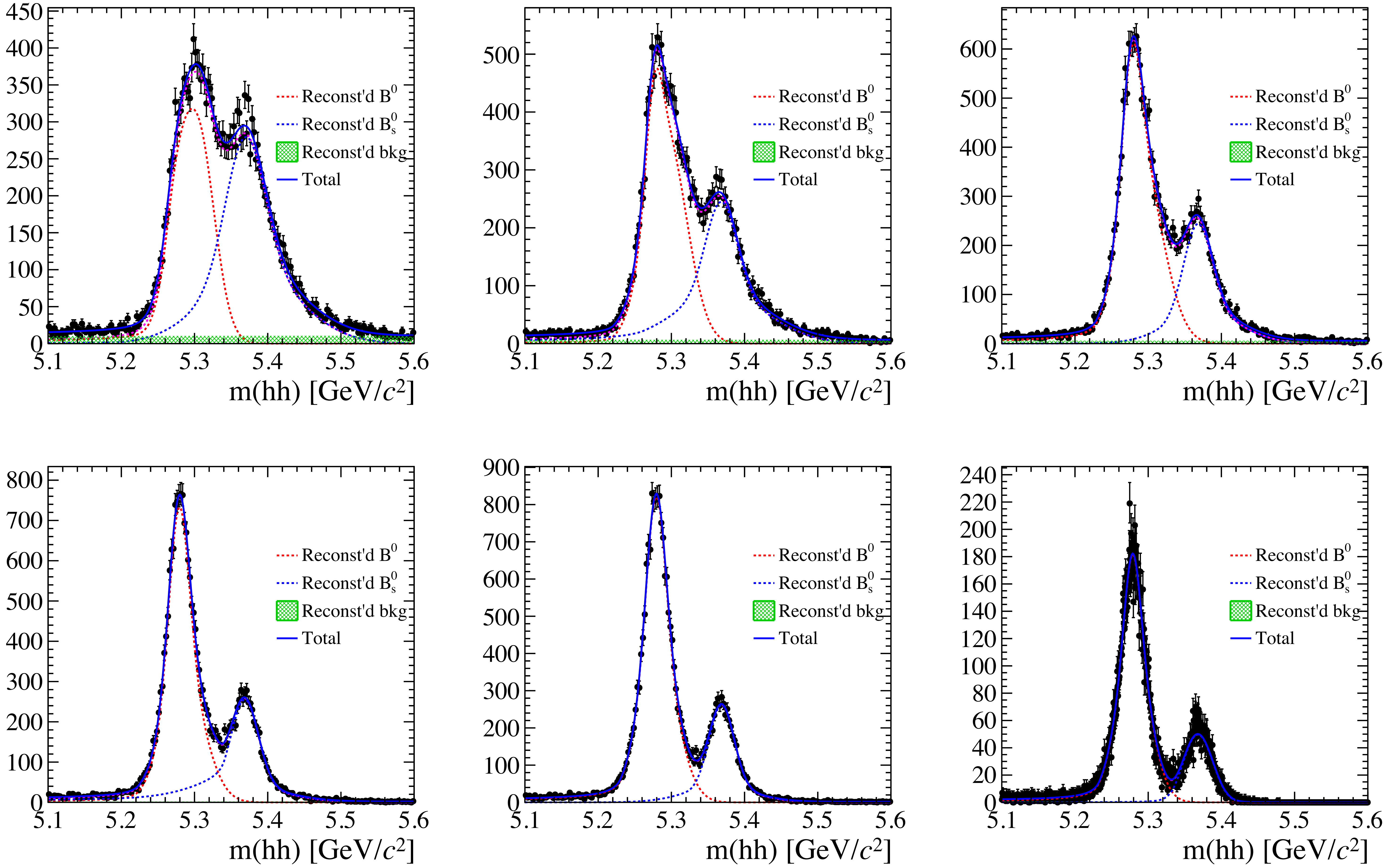
# Scenario 4: with imperfect PID

- In reality, it is difficult to have 100% PID efficiency
- Assumption:
  - PID efficiency uniformly distributed vs. momentum
- Example: 90% PID efficiency
- Looks OK, still can separate B / $B_s$
- But how good it is?



# Indicators vs. PID efficiency

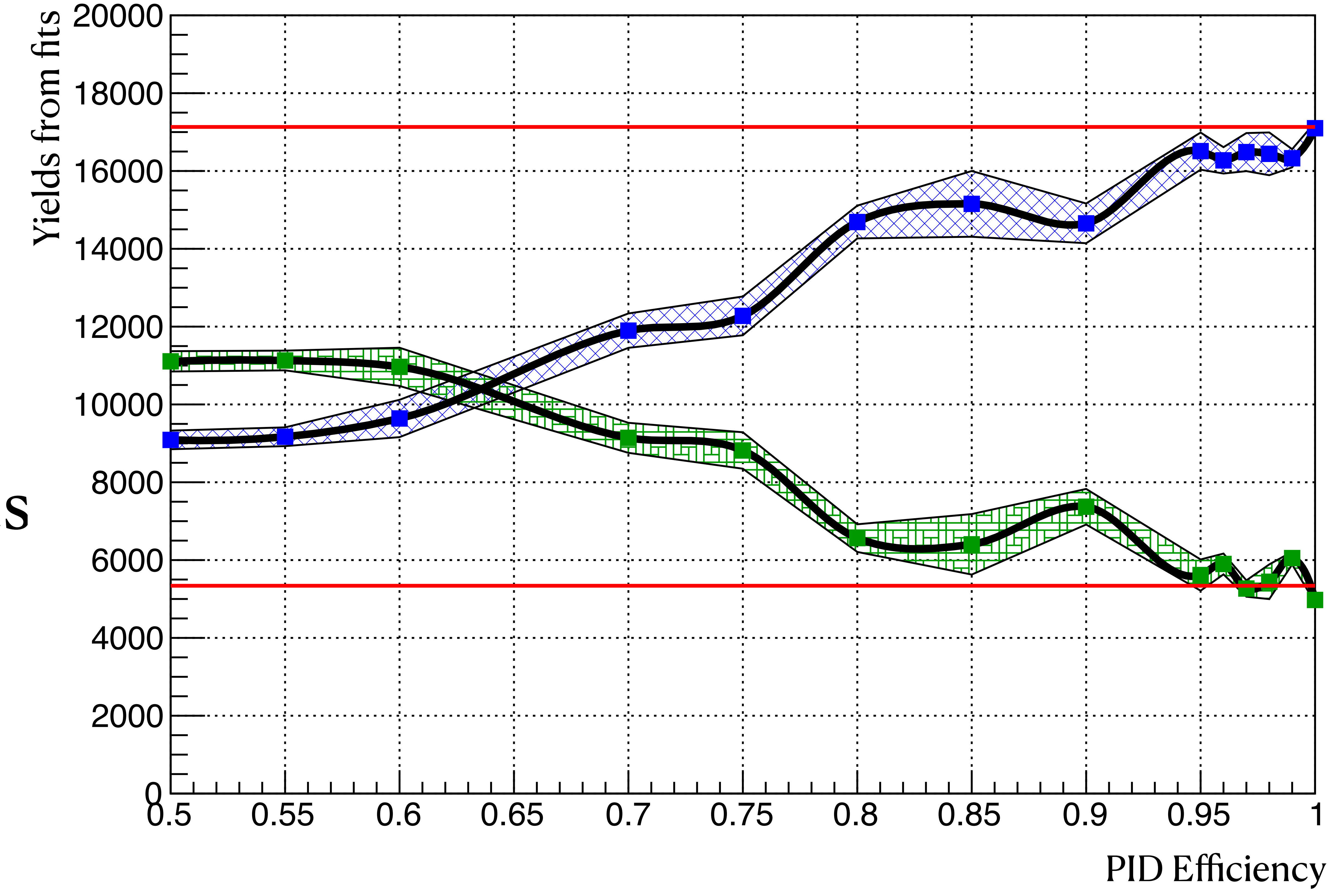
- Scan of the hh invariant mass vs. PID efficiency
- Examples shown here:
  PID efficiency 50%, 70%, 80%
  90%, 95%, 100%
- Indicators:
  - Mean values of the mass peaks form the fits
- Can make plots of Indicators vs. PID efficiency



# Yields vs. PID efficiency

- Red horizontal lines:
  Expected yield for B (upper line) and $B_s$ (lower line) "MCTruth"
- Blue points: B yields from fits
- Green points: $B_s$ yields from fits
- Shaded areas: uncertainties from fits

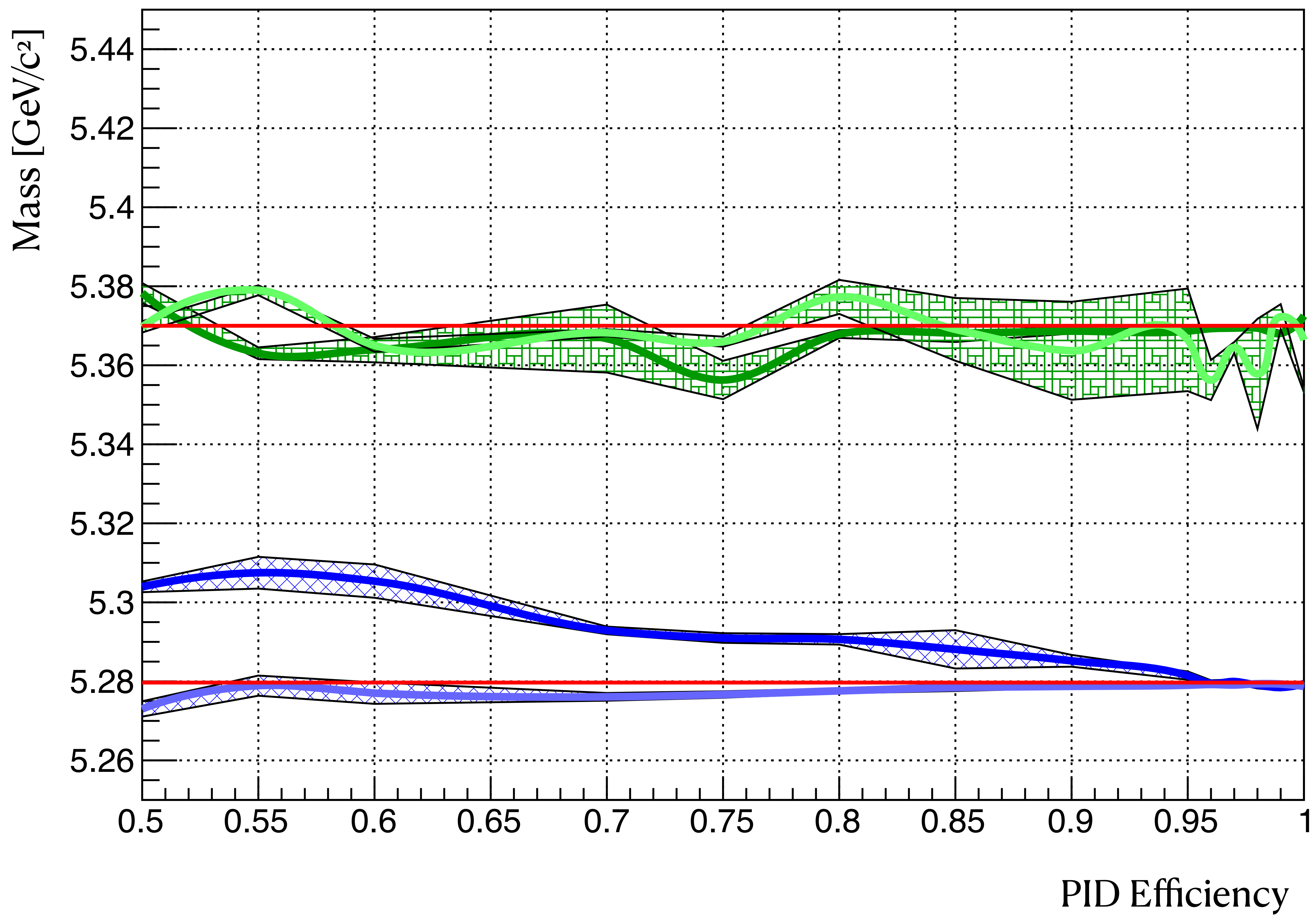
- Yields close to MCTruth yields with PID efficiency > ~95%



# Mass vs. PID efficiency

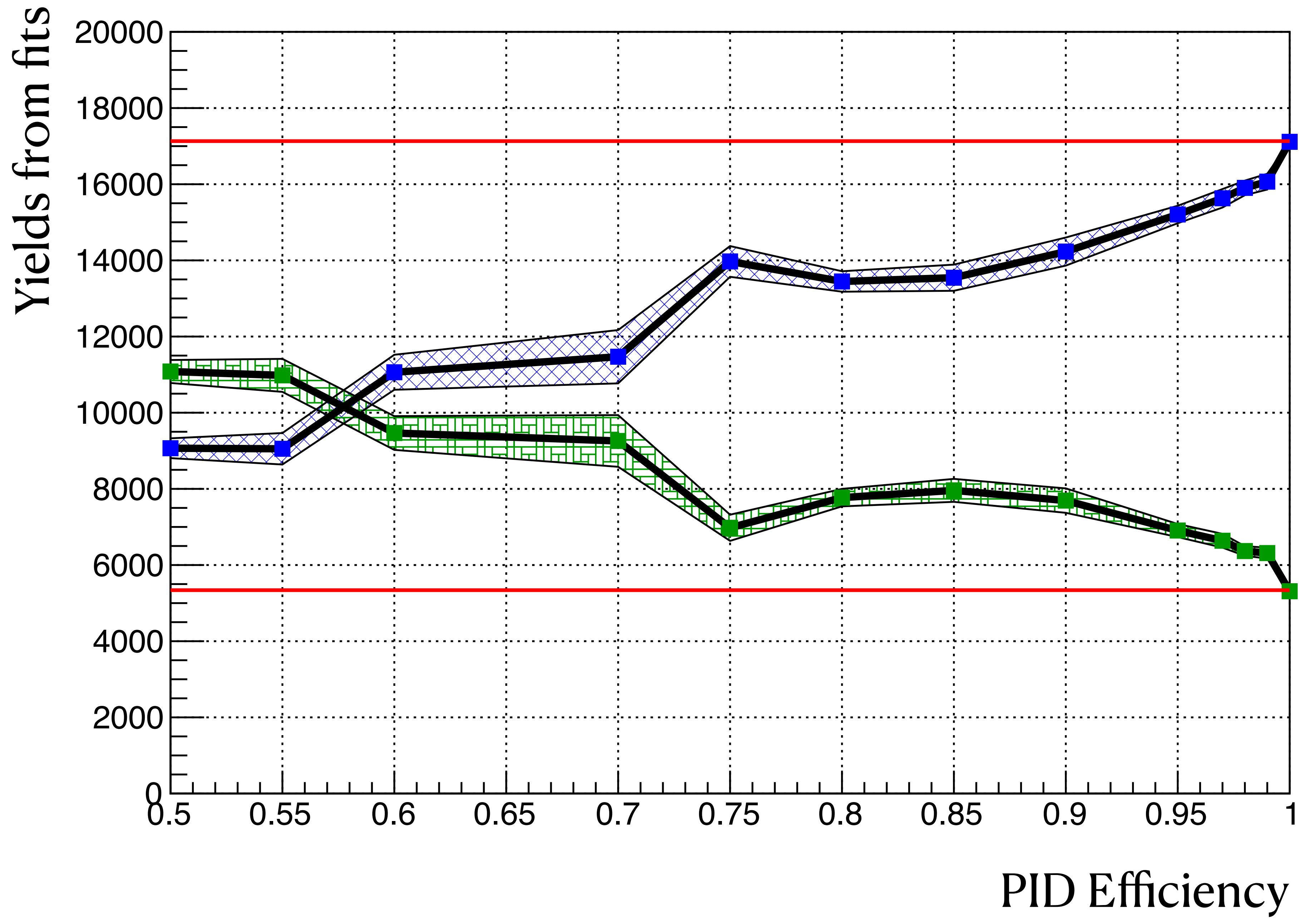
- Red horizontal lines:
  PDG mass for B (lower line)
  and $B_s$ (upper line)
- Blue lines: B, Green lines: $B_s$
- Dark blue/dark green lines: Mean values of CB function
- Light blue/light green lines: Mean values of Gaussian function
- Shaded areas: uncertainties from fits

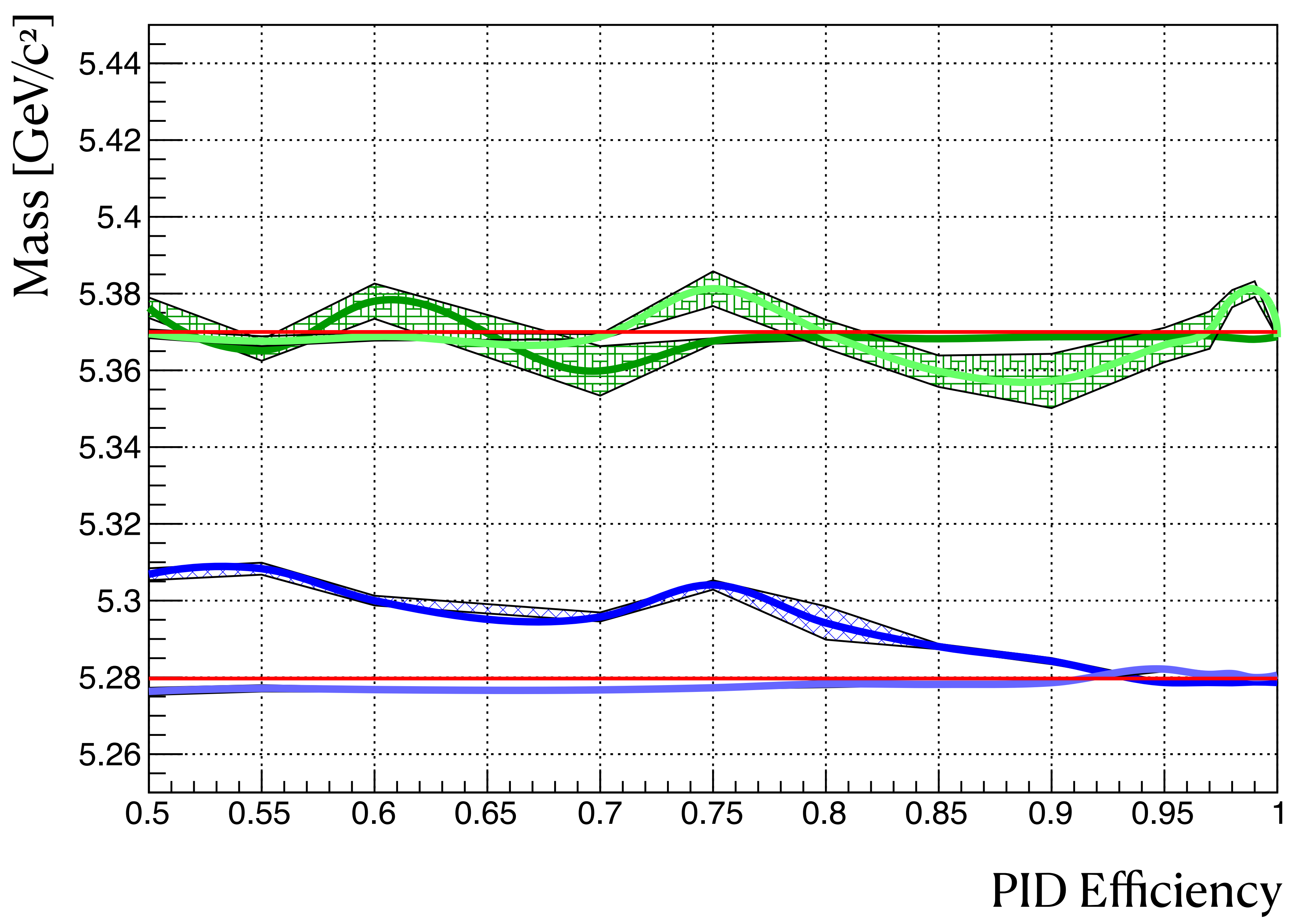
- Fitted B mass close to PDG with PID efficiency > ~95%



# Alternative momenta resolutions

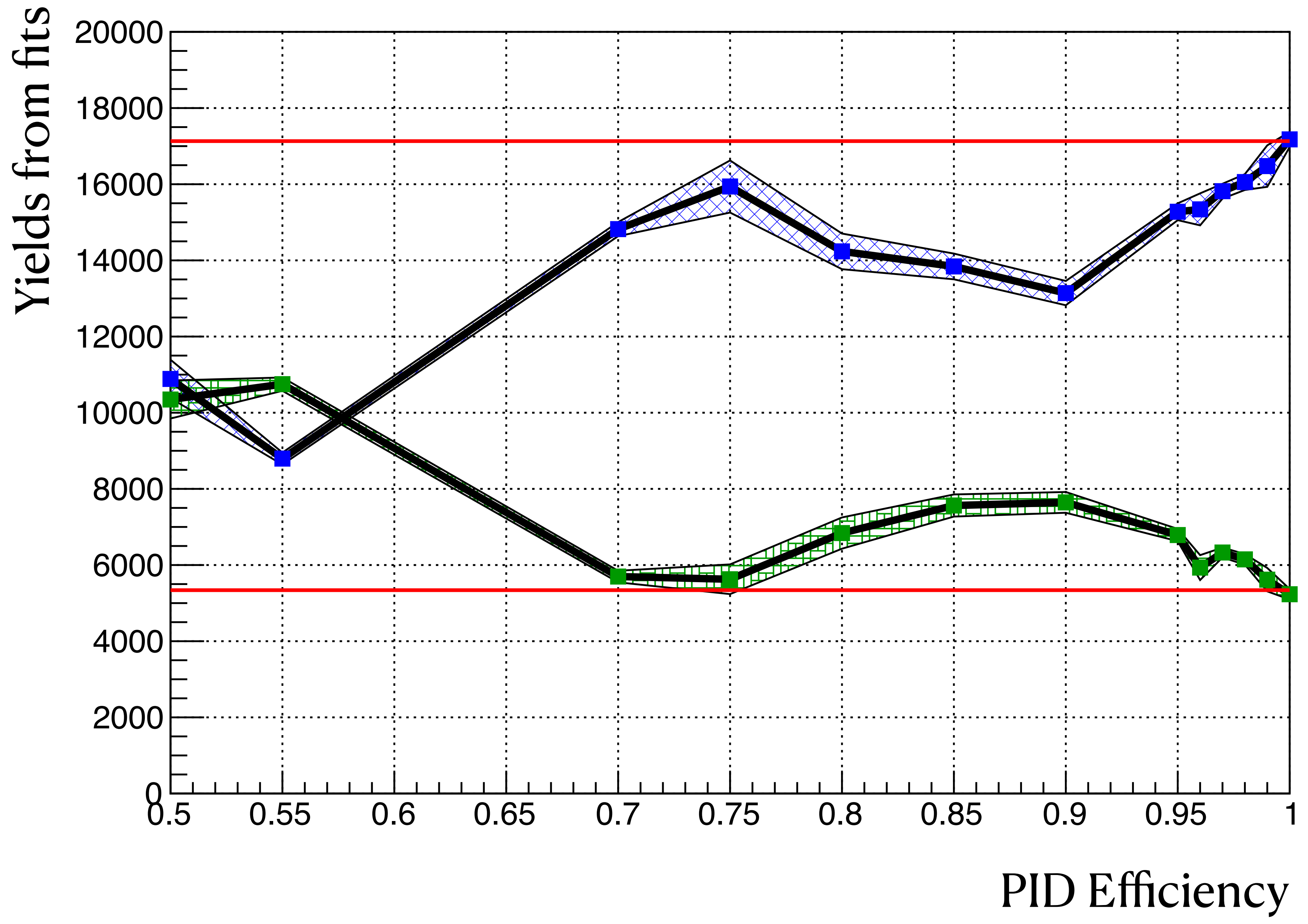
- Same procedures are done with samples at 0.15% and 0.1% momenta measurement resolution
- Momentum resolution 0.15%: Mass ok with > ~92% PID efficiency

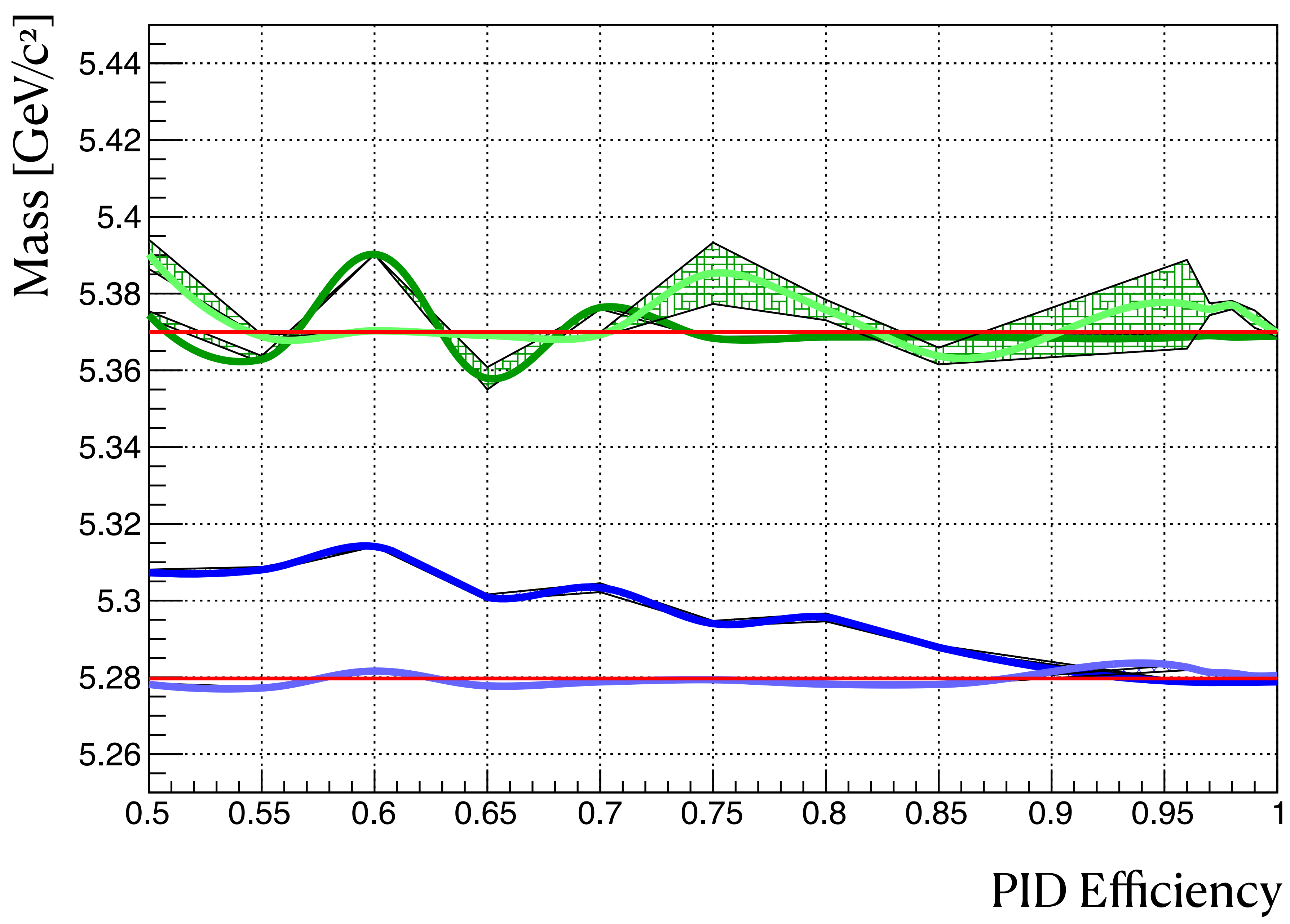


# Alternative momenta resolutions

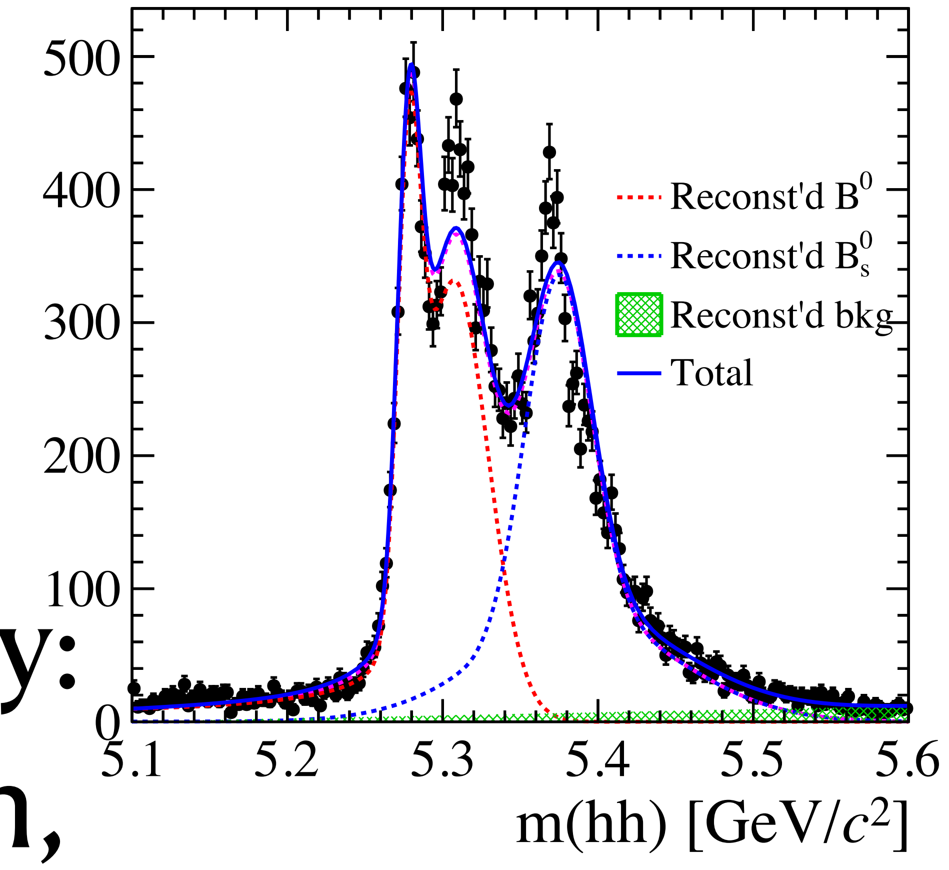
- Momentum resolution 0.1%: Mass ok with > ~90% PID efficiency
- It seems that with better momenta resolution, we can tolerate lower PID efficiency
  - Still need further studies to check!

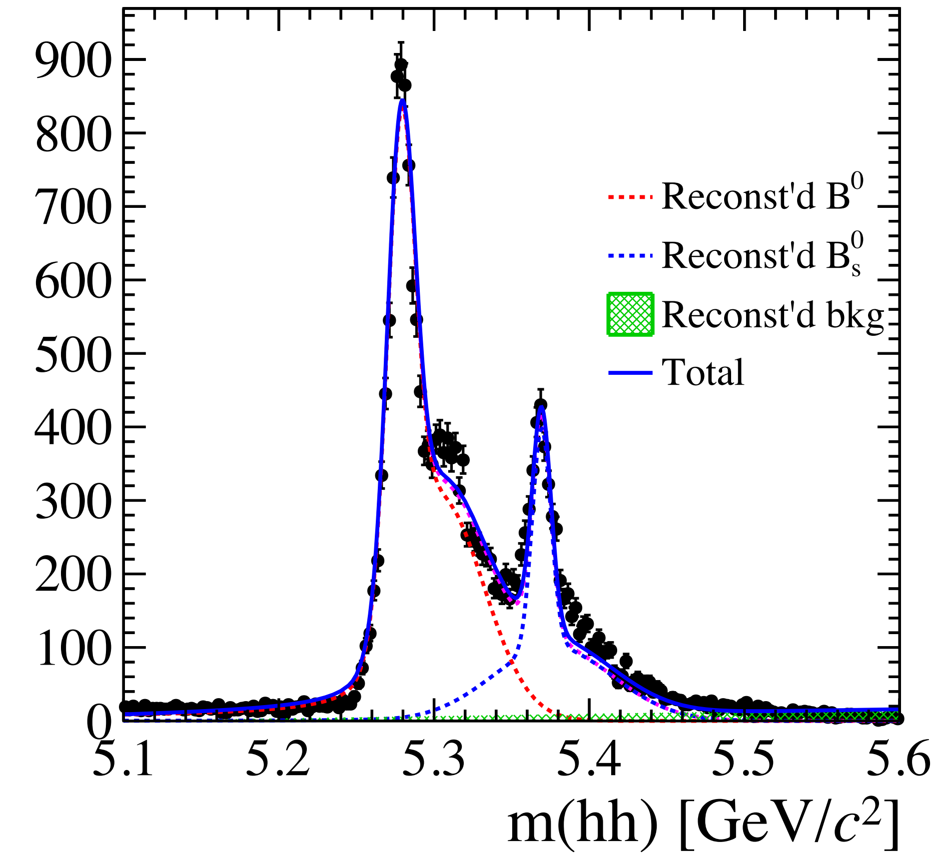


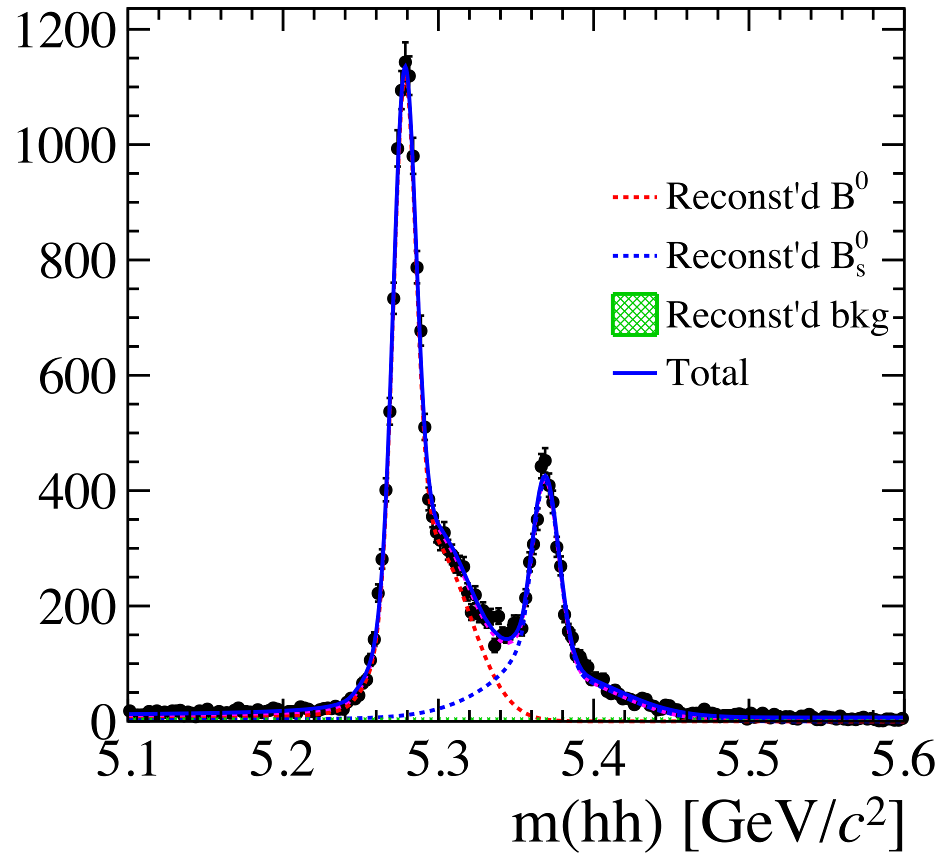



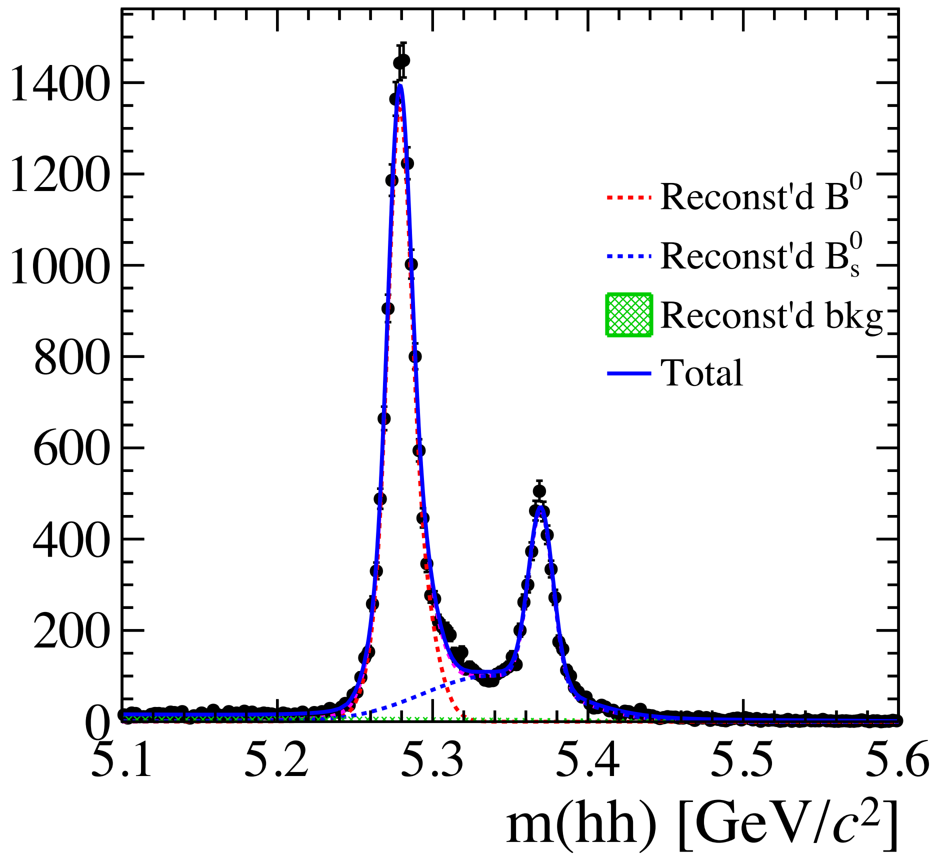
# Indicators vs. PID efficiency

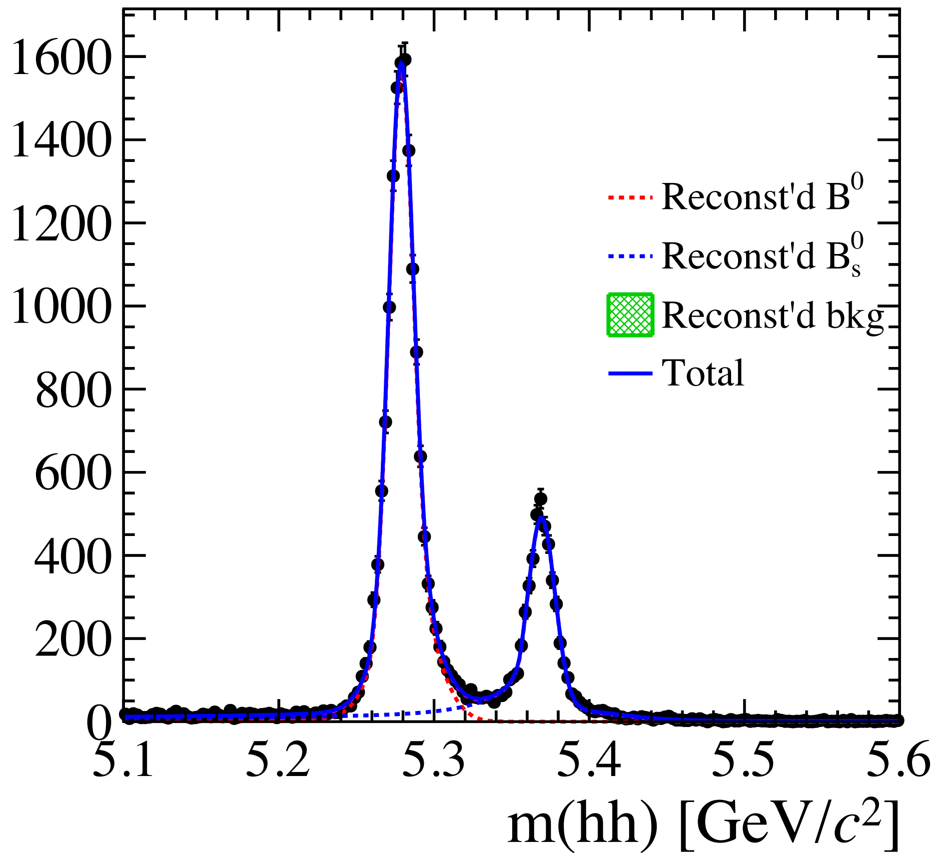
- Momentum resolution 0.1%: Fits to the M(hh) under different PID efficiency
- Examples shown here:
  PID efficiency 50%, 70%, 80%
  90%, 95%, 100%
- Third peak in low PID efficiency:
  One pion misidentified as Kaon, and with better momentum resolution, we can distinguish them

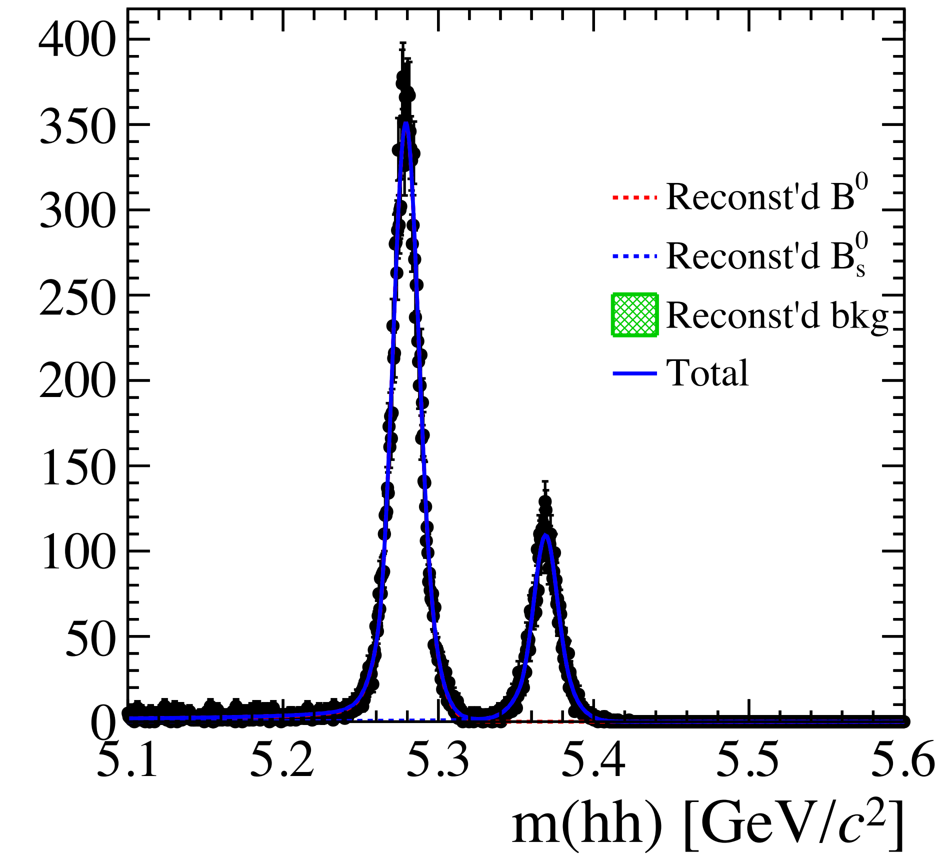


# Plan for the next steps

- PID efficiency as function of momentum
- Anisotropic momentum measurements resolution
- Backgrounds
- Proton PID
- Study with other possible indicators
- Collaborate with Tracking & PID detector experts for the detector designs

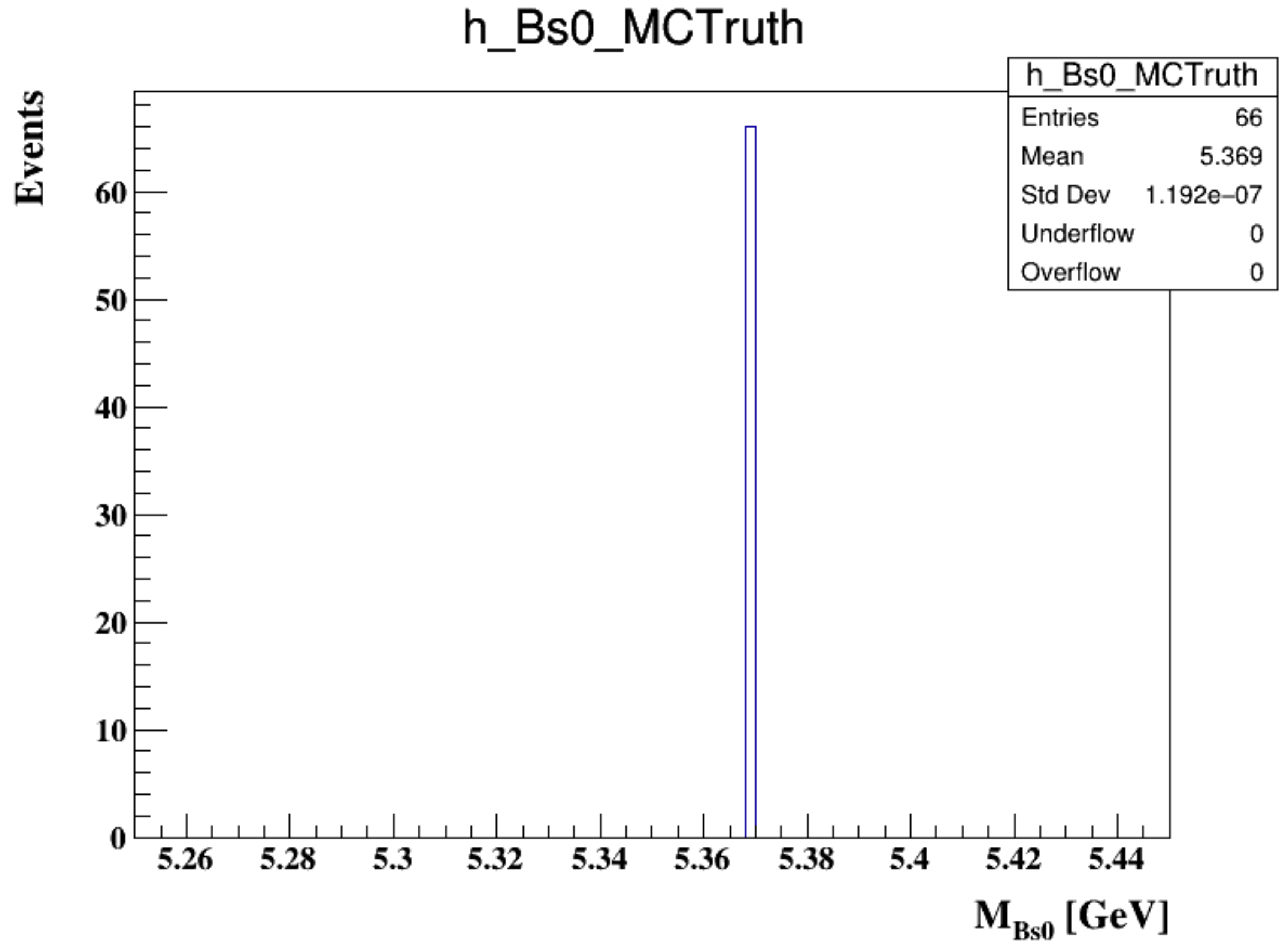
# Impact of K pi PID information studied with $B_s$ -> ($D_s$->KKpi) pi

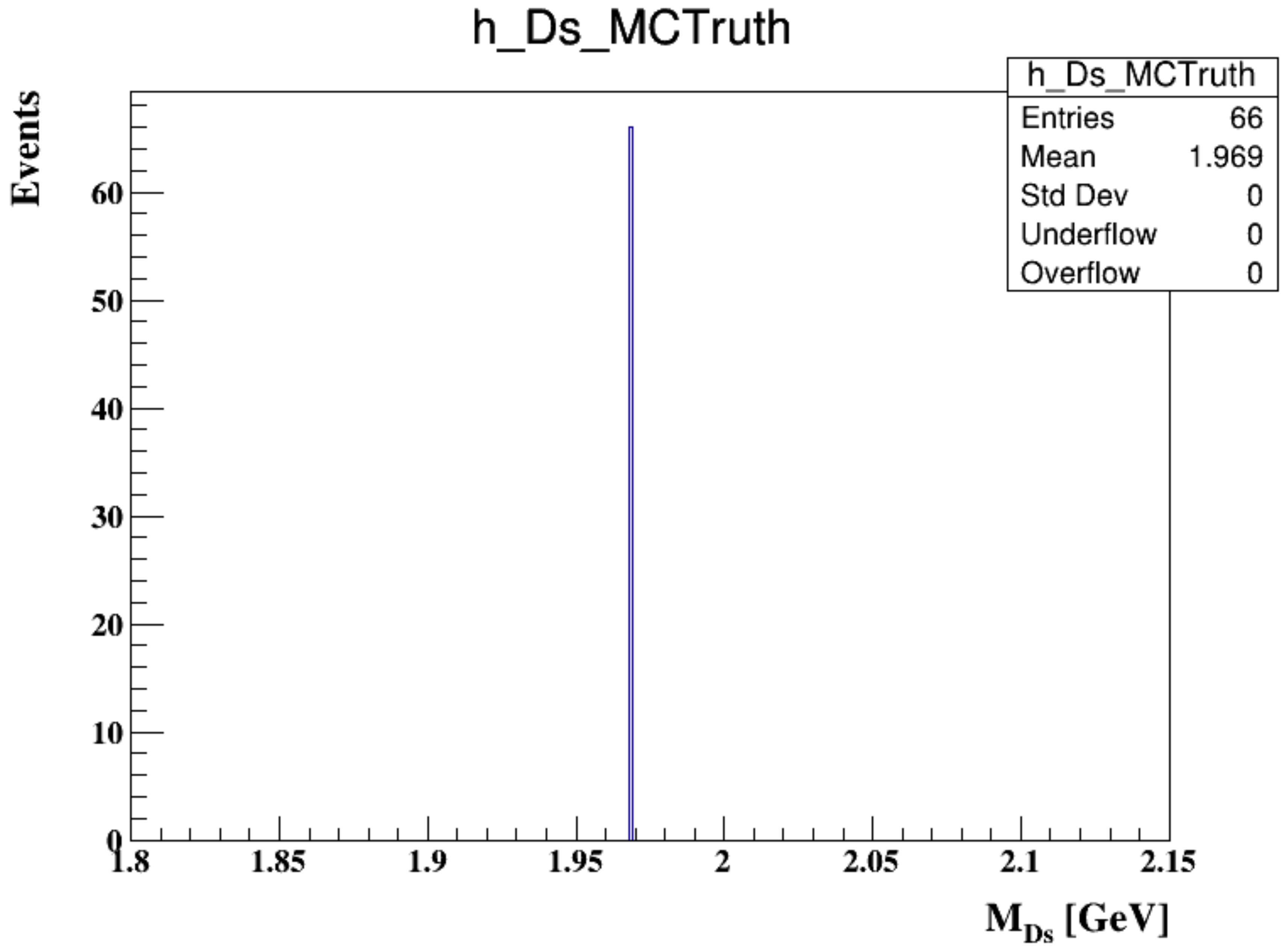
# Studies with $B_s$ -> ($D_s$->KKpi) pi

- Studied with centralized CEPC simulation production
- Reconstructed $B_s$ -> ($D_s$->KKpi) pi events: 66

# Mass($B_s^0$/$D_s$) from MC Truth info.

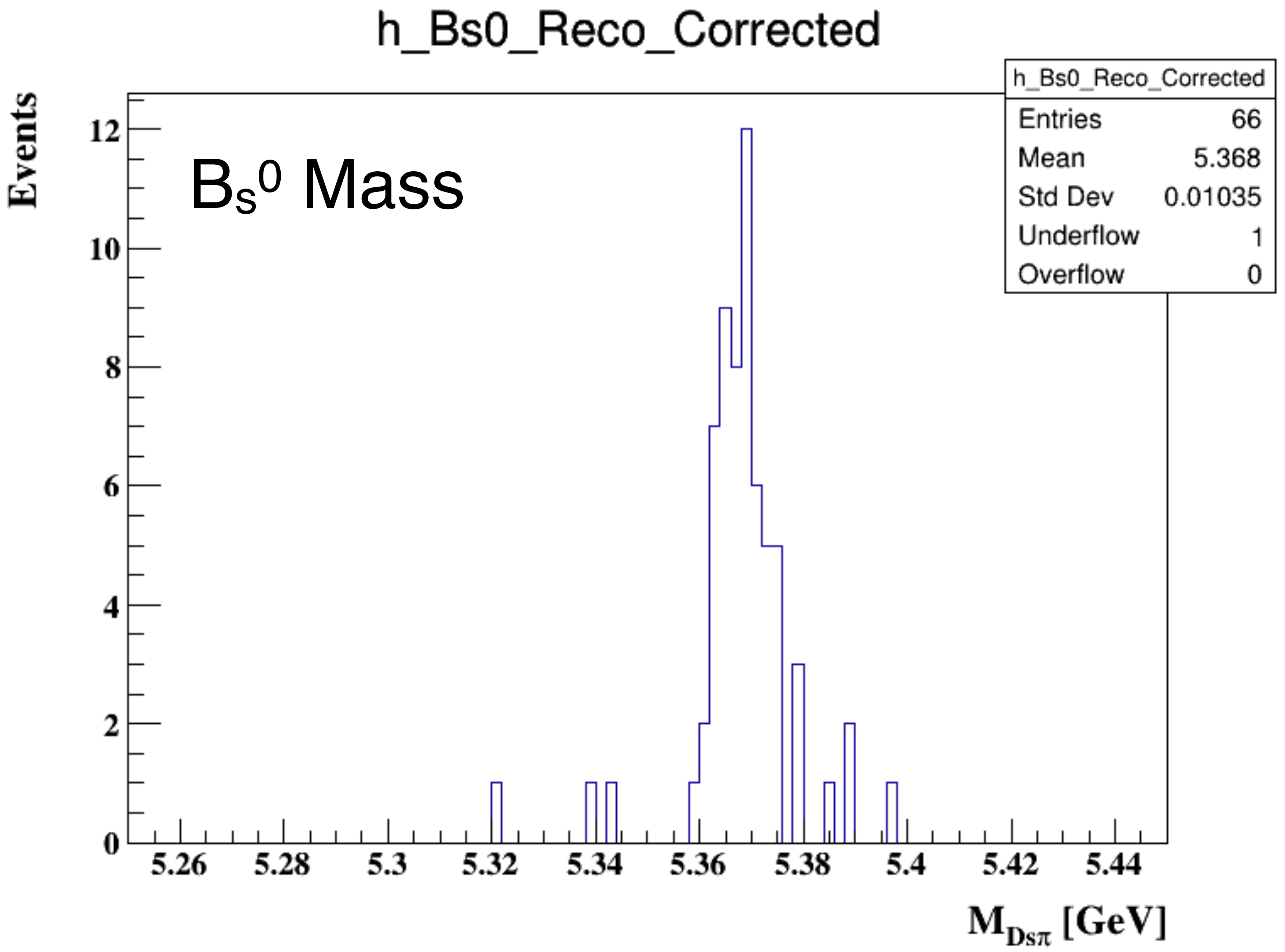
- Events are tagged/selected from MC truth by finding corresponding decay topology. (i.e. find Bso, $B_s^o$ ->$D_s$ pi, $D_s$ ->K K pi)

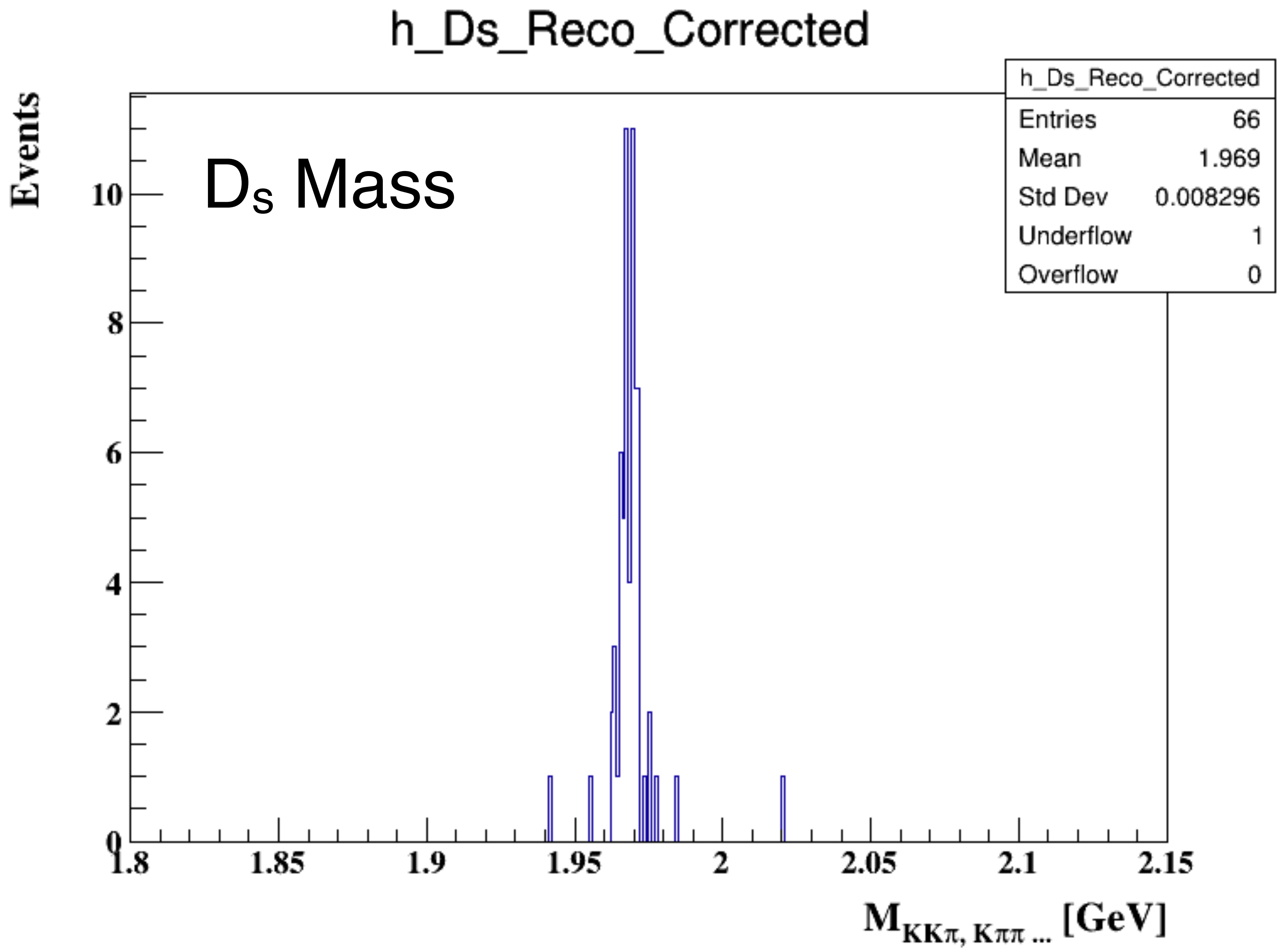


# Reconstructed mass

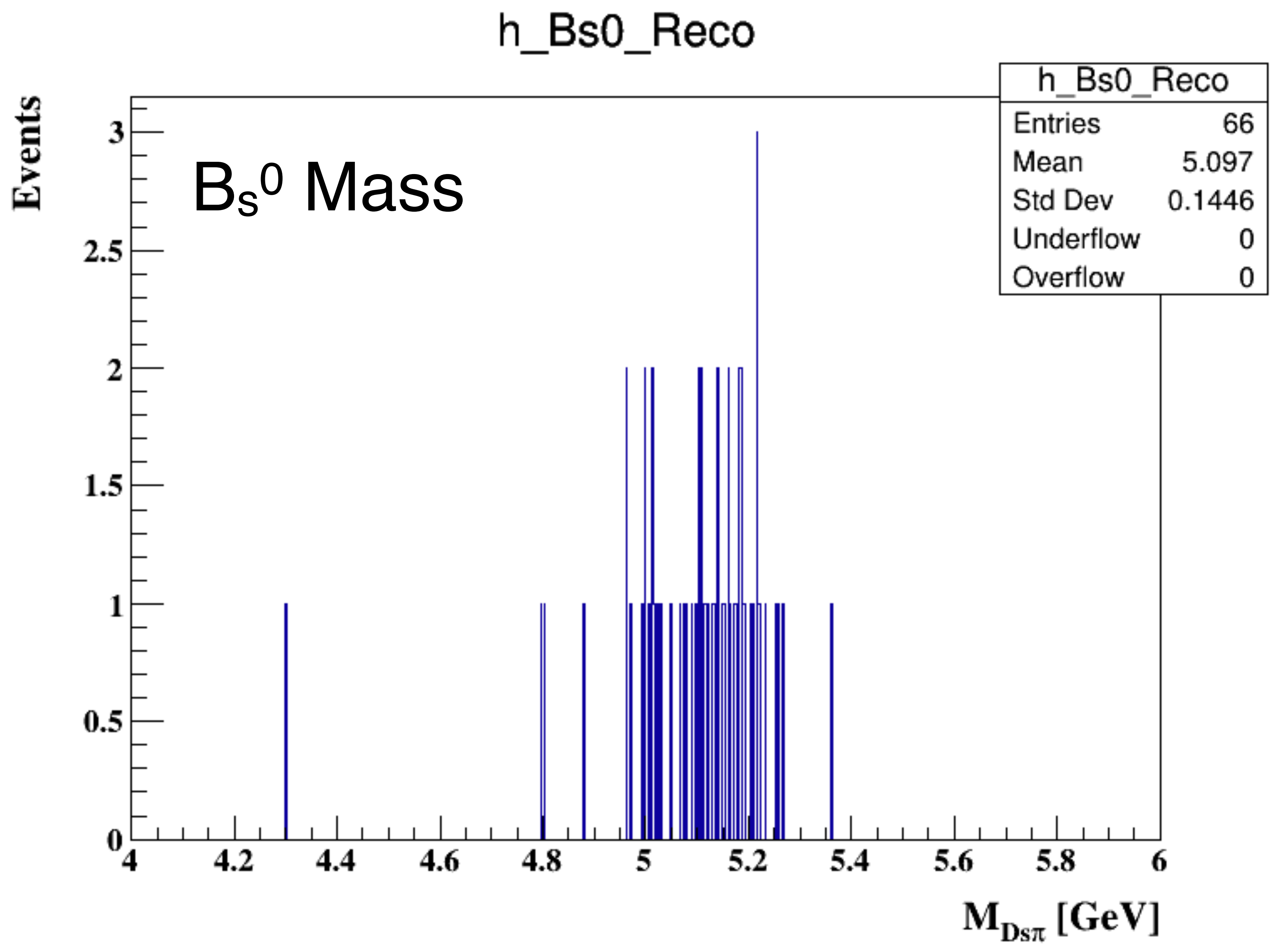
- Perfect PID scenario
- Reconstructed events with CEPC_v4 detector effects, K pi are constrained to their PDG mass according to MCTruth info

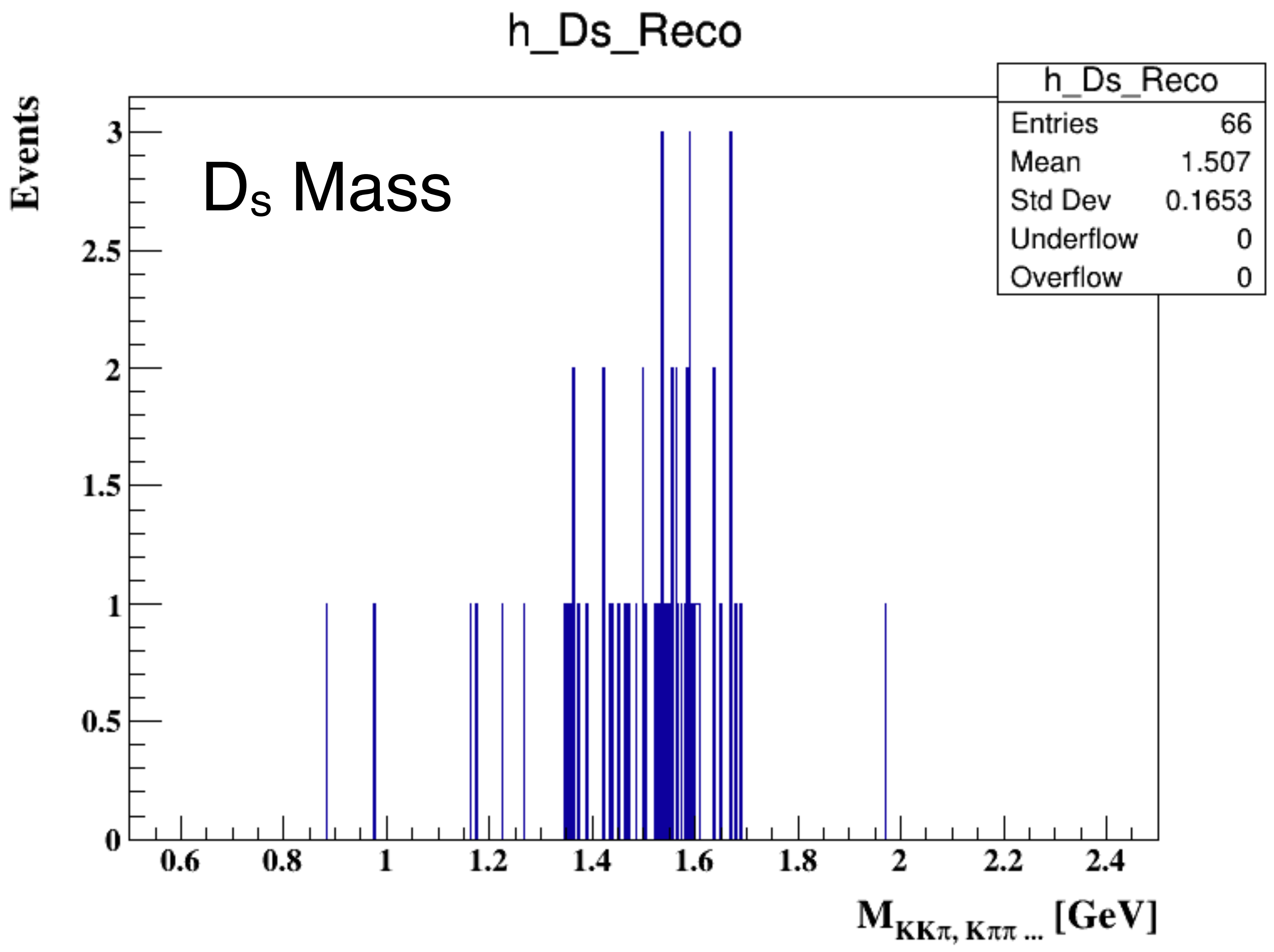


# Reconstructed mass

- Reconstructed events with CEPC_v4 detector effects, No additional PID correction according to MCTruth
- We could identify non-zero mis ID rate



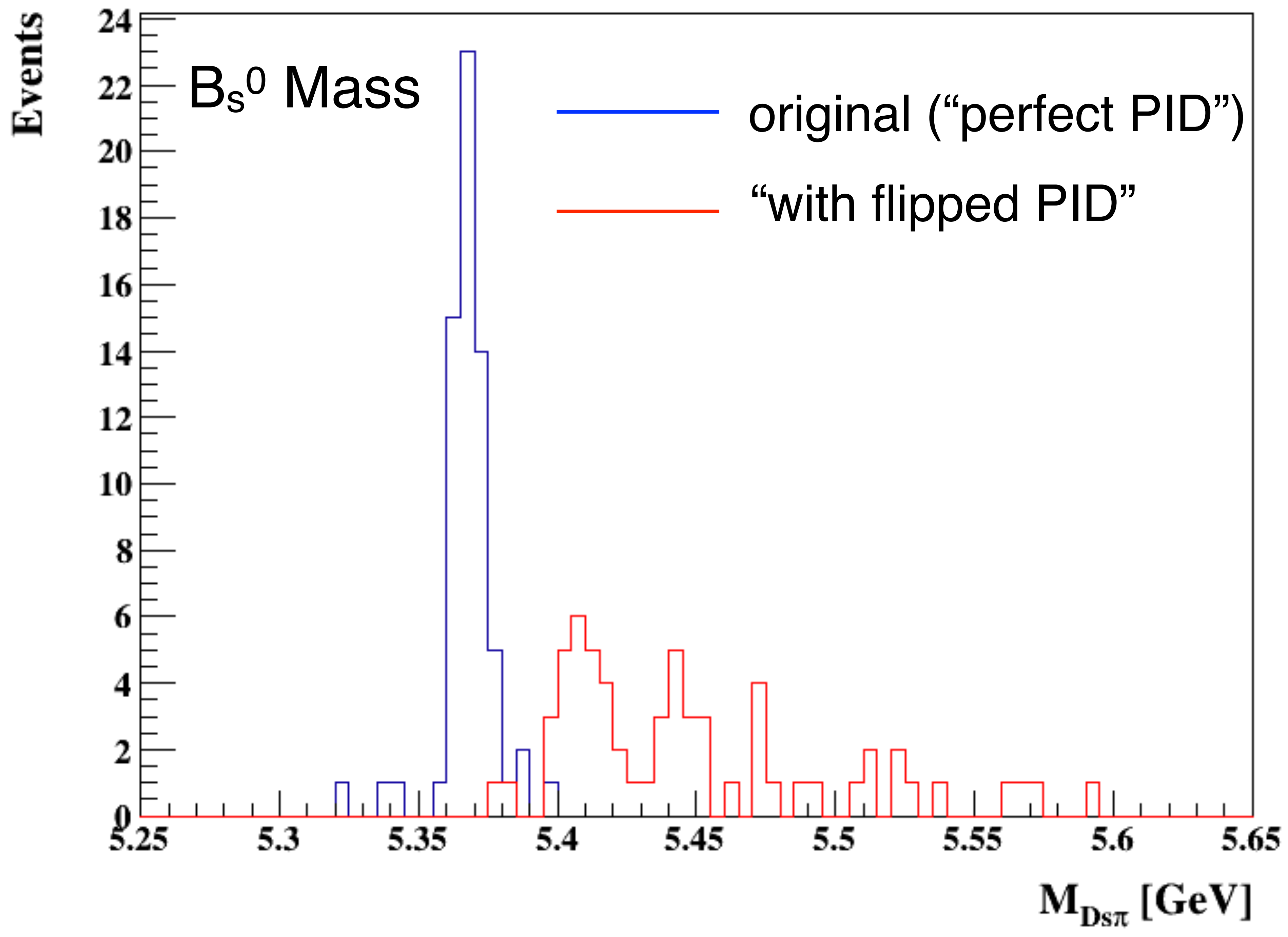



# Reconstructed Mass distribution with wrong PID

- Intentionally change one of MCTruth pions to kaon ID
  - i.e. $B_s^o$->($D_s$ ->K K pi ) pi

    ↓ or ↓

    K K




- Peak shifted rightwards
- Reconstructed events in much wider mass range

# Conclusions

- PID information is crucial for the reconstruction of heavy flavor decays
- The impact of PID information to the physics performance is studied with simulation samples
- A strategy of testing PID requirements is established
- Will collaborate with detector experts for further studies