B→Kμτ Background Study

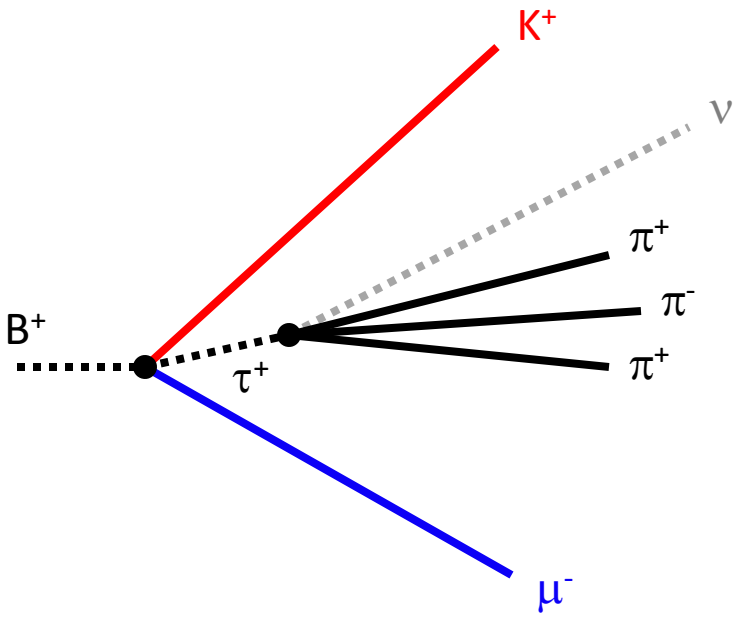
João Coelho and Guy Wormser

08 February 2018

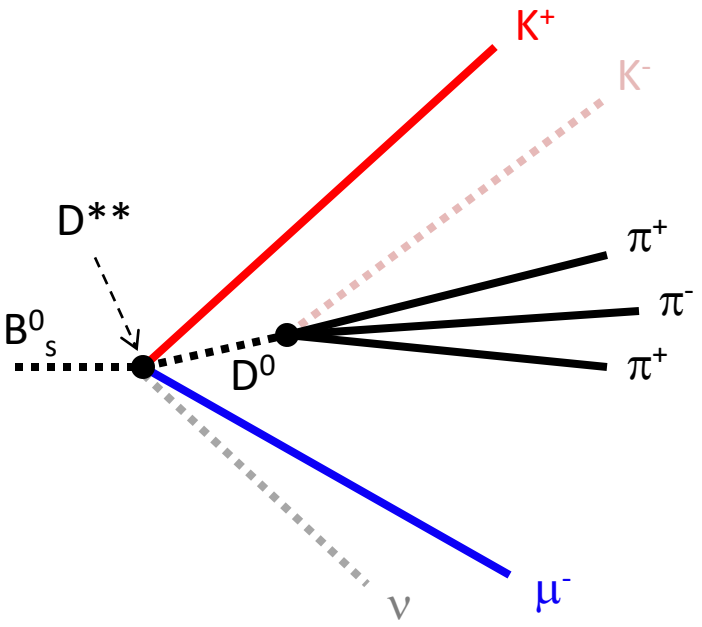
Signal Topology

- Two vertices displaced from the primary pp vertex
- Kμ from B decay + 3π from τ decay
- Potential backgrounds from D decays
- **Main tool: Cut above D meson masses**

Signal



Background



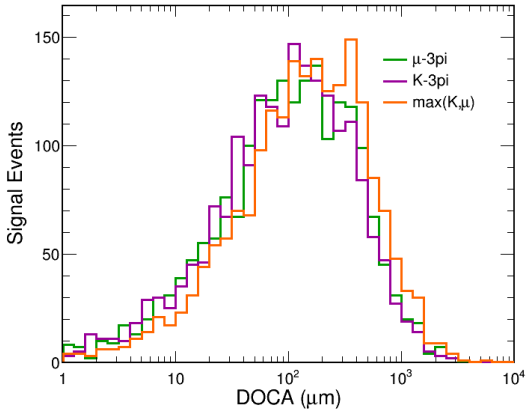
Gauss Generation

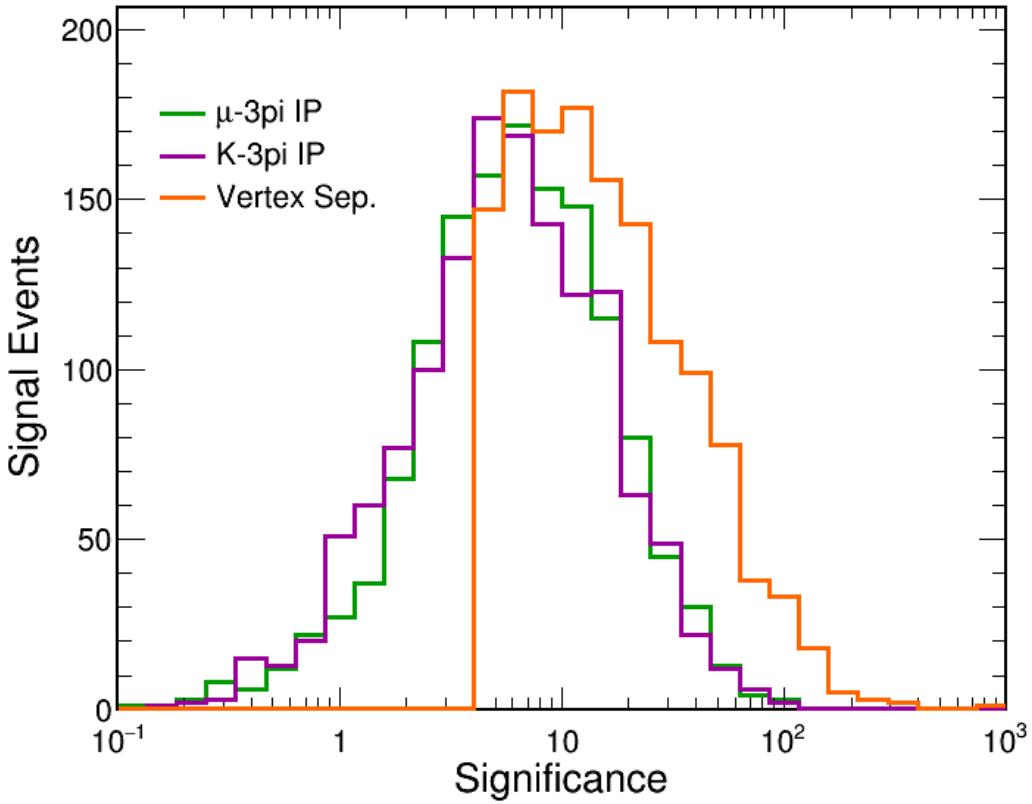
- Generated small signal tuple
  - **2000 events from Decfile 12715000**
  - Only generated $K^+ \mu^+ \tau^-$ charge combination
- Generated **large samples of background** events using ParticleGun*
  - B energies flat from 0 to 300 GeV
  - 5M events from each B type and charge combination:
    - B^+, B^0, B_s, B_c, Λ_b
    - $K^- \mu^+ (3\pi)^+$, $K^+ \mu^- (3\pi)^+$, $K^+ \mu^+ (3\pi)^-$
  - K^- combination probably can't happen in signal
  - **Total of 75M events**
  - Working on generating factor of 20 more background to reach BR(10^{-7}) sensitivity
  - Already processed 115M more events (B, B_s, B_c and Λ_b)

*See backup slide for more details

Initial Signal Studies

- Looked at some topological information
- Mostly interested in quantifying 3π detachment
- May **lose 40%** of signal with **3π vertex separation**
- An **extra 20% may be lost from IP** for μ-3π and K-3π





Initial Mass Studies

- Assuming topology can be well defined and selected look at invariant masses

- Select background with following MC truth cuts:
  - **Kμ share the same vertex**
  - **3π share the same vertex**
  - **3π vertex is downstream of Kμ vertex**

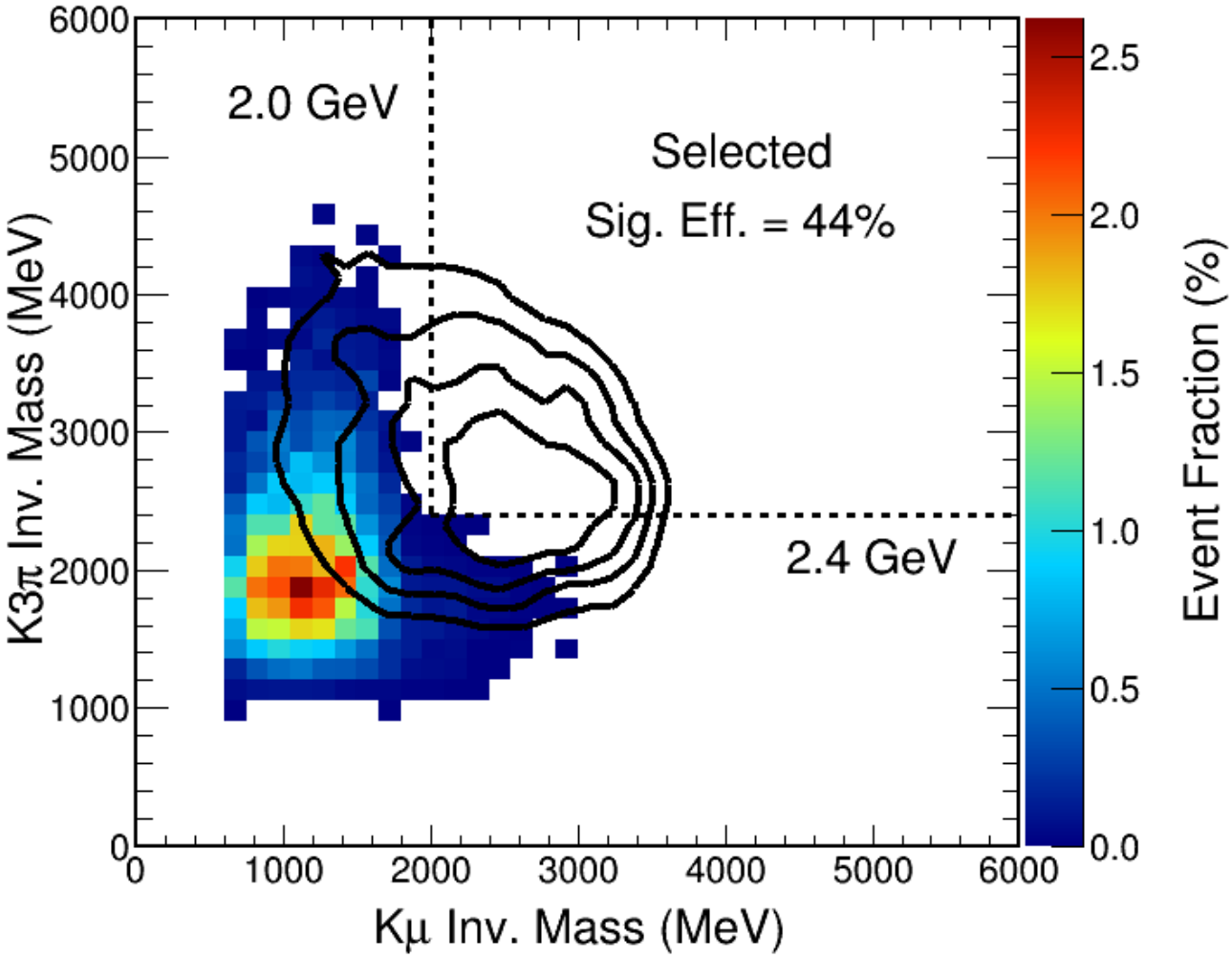
- For now, only considering **perfect PID** (no decay in flight, no π/K mis-ID, etc)

- Most important invariant masses: **K+μ and K+3π**

$K^+ \mu^- (3\pi)^+$

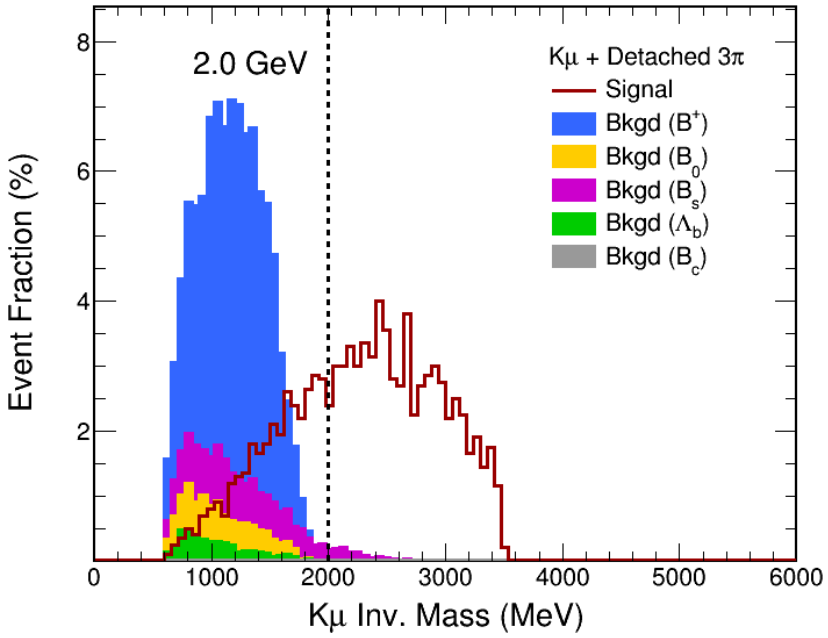
$K^+ \mu^- (3\pi)^+$ Combination

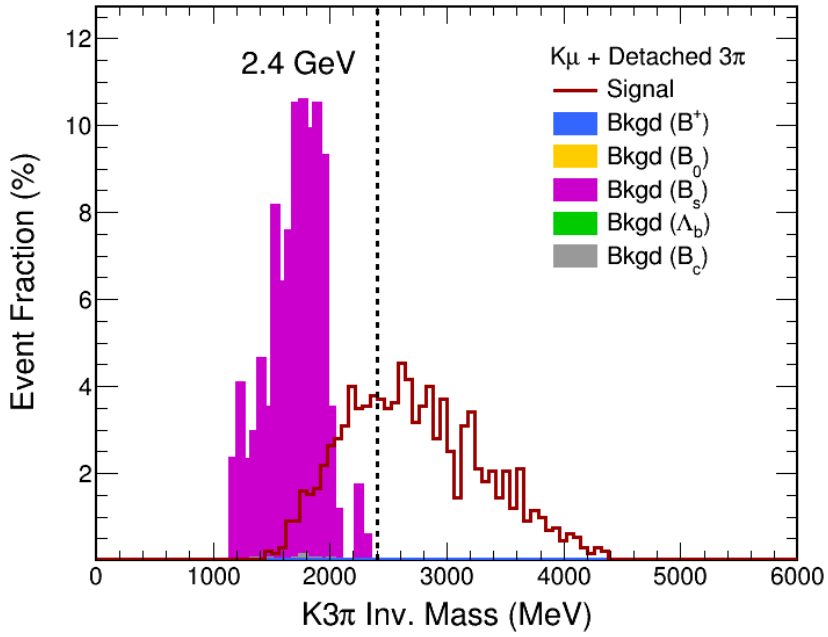
- Largest background component
- Can be removed by M(Kμ)>2 GeV and M(K3π) > 2.4 GeV



$K^+ \mu^- (3\pi)^+$ Combination

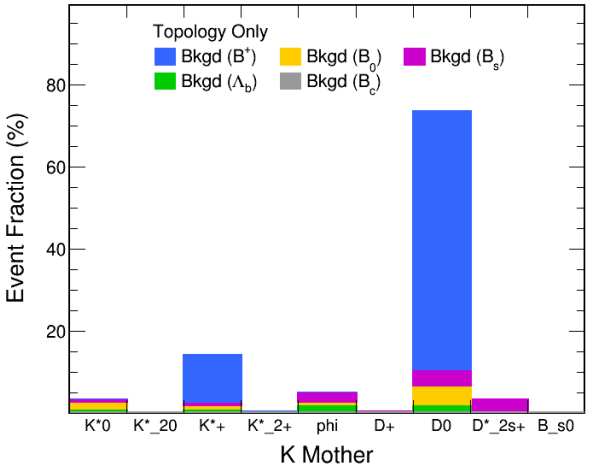
- Largest background component
- Can be removed by M(Kμ)>2 GeV and M(K3π) > 2.4 GeV
- Most important cut is M(Kμ) to remove most D decays
- All remaining bkgd from $B^0_s \rightarrow D^*_{s2}(2573)\ \mu\ \nu \rightarrow D^0\ K\ \mu\ \nu$
- M(K3π) cut can remove this last component

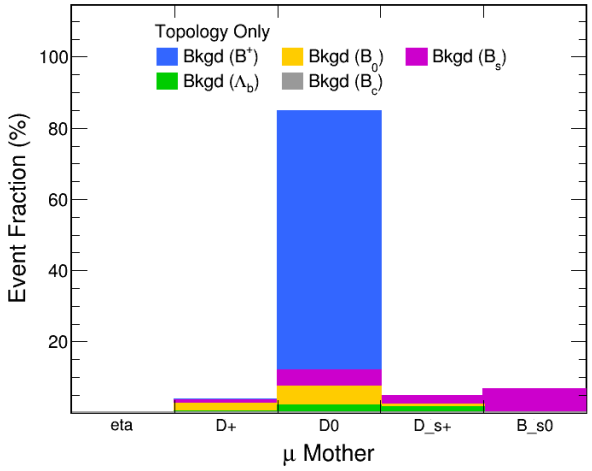


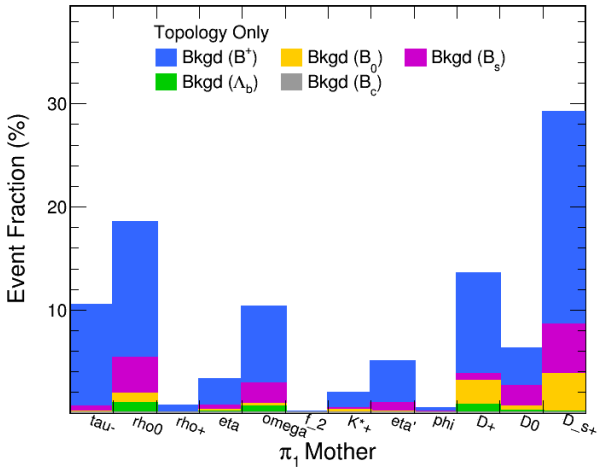


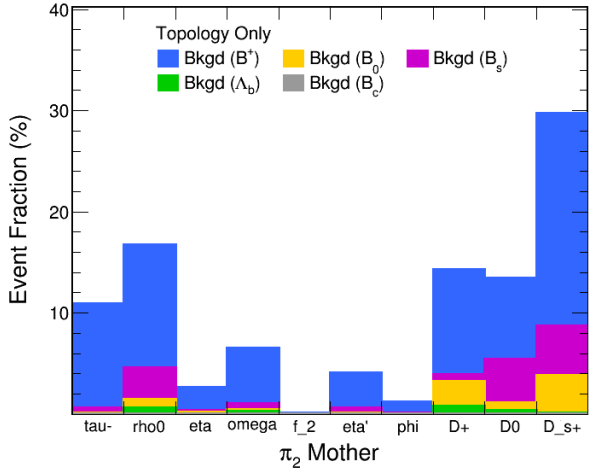
$K^+ \mu^- (3\pi)^+$ Combination

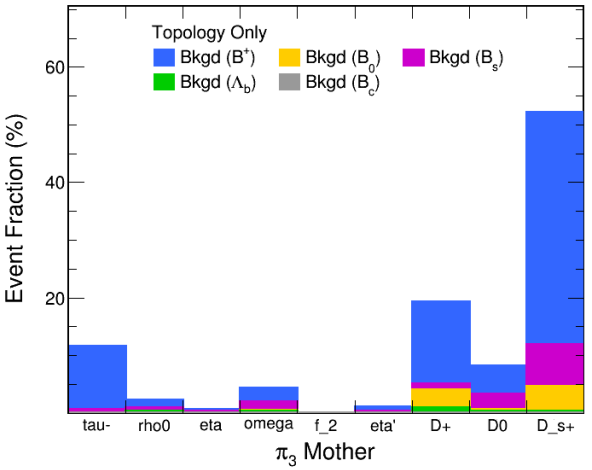
- Before mass cuts, most background from $B \rightarrow D^0 + X$, where the D^0 decays semileptonically





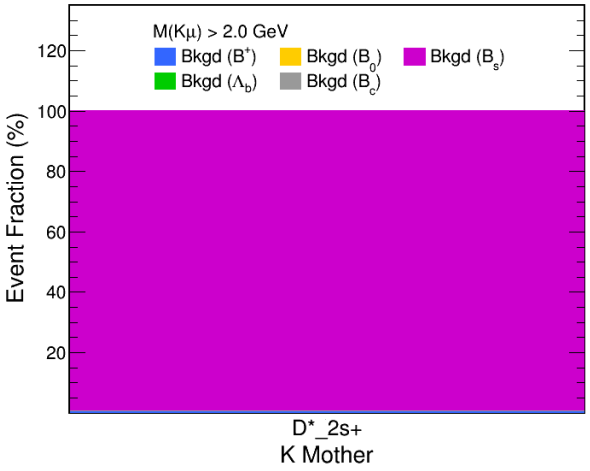


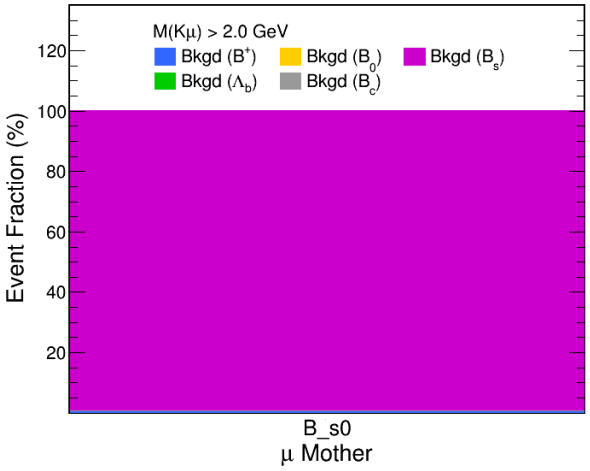


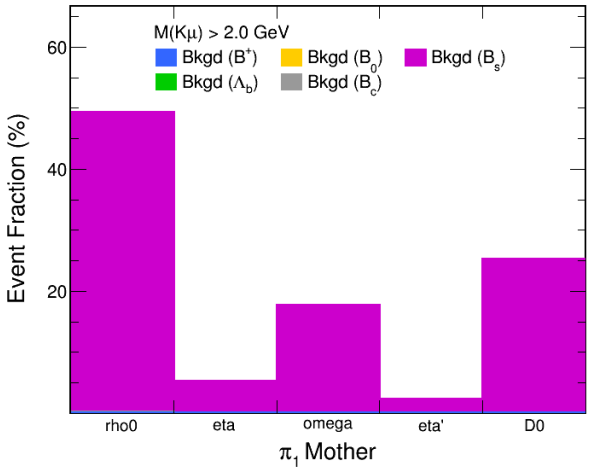


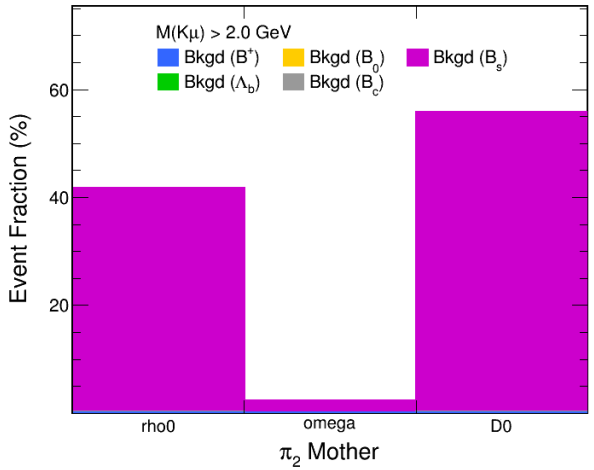
$K^+ \mu^- (3\pi)^+$ Combination

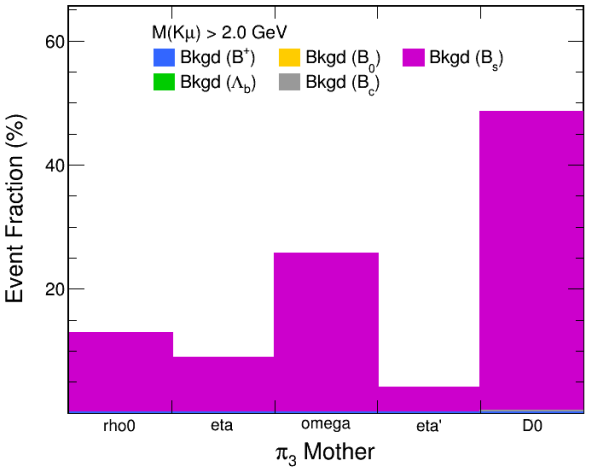
- Applying M(Kμ) cut leaves only $B^0_s \rightarrow D^*_{s2}(2573) + \mu\, \nu$





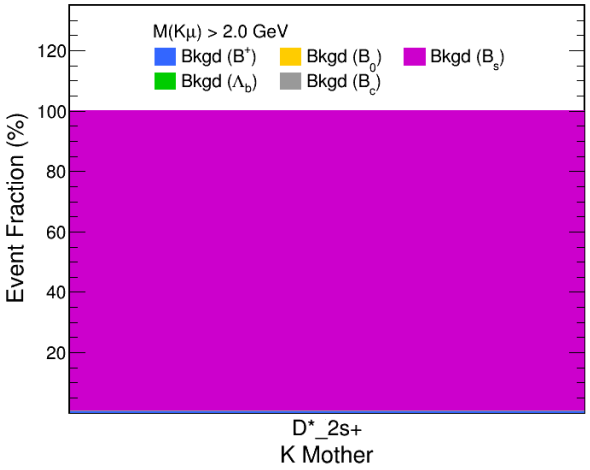


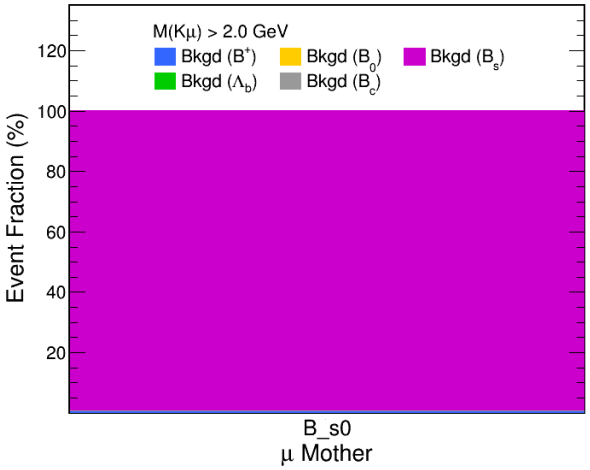


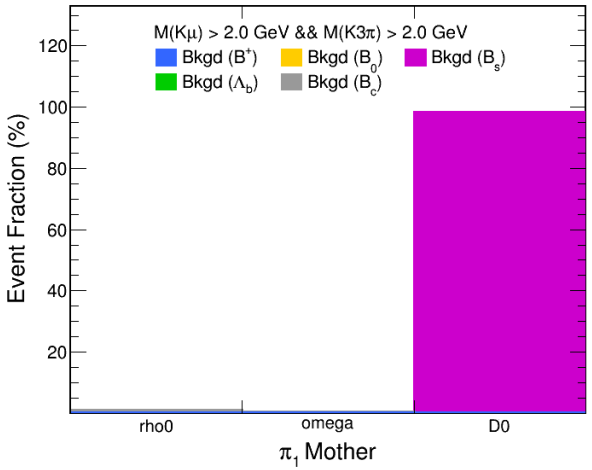


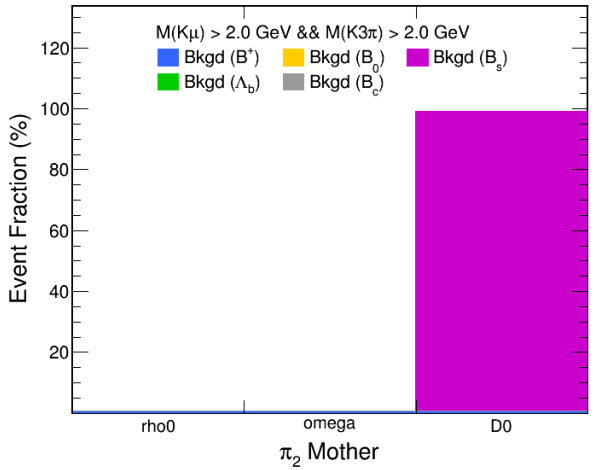
$K^+ \mu^- (3\pi)^+$ Combination

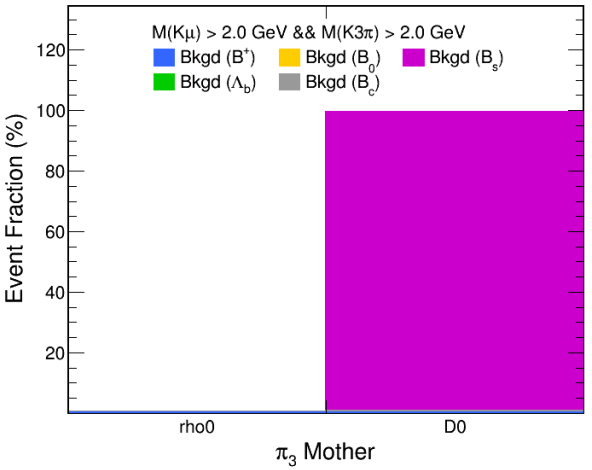
- Applying M(Kμ) cut leaves only $B^0_s \rightarrow D^*_{s2}(2573) + \mu\, \nu$
- A loose M(K3π) > 2 GeV cut leaves mostly 3π from D0 decays







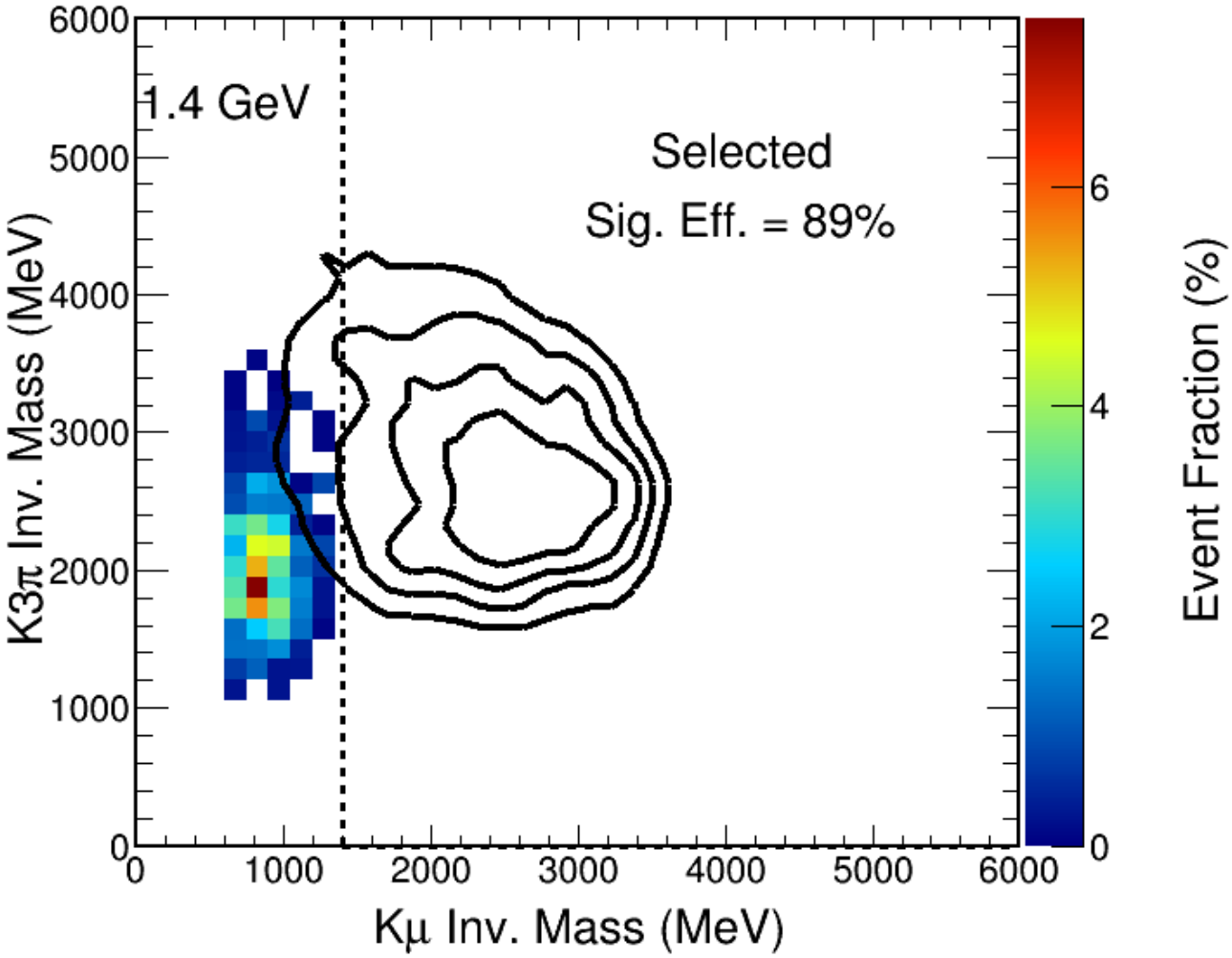




$K^+ \mu^+ (3\pi)^-$

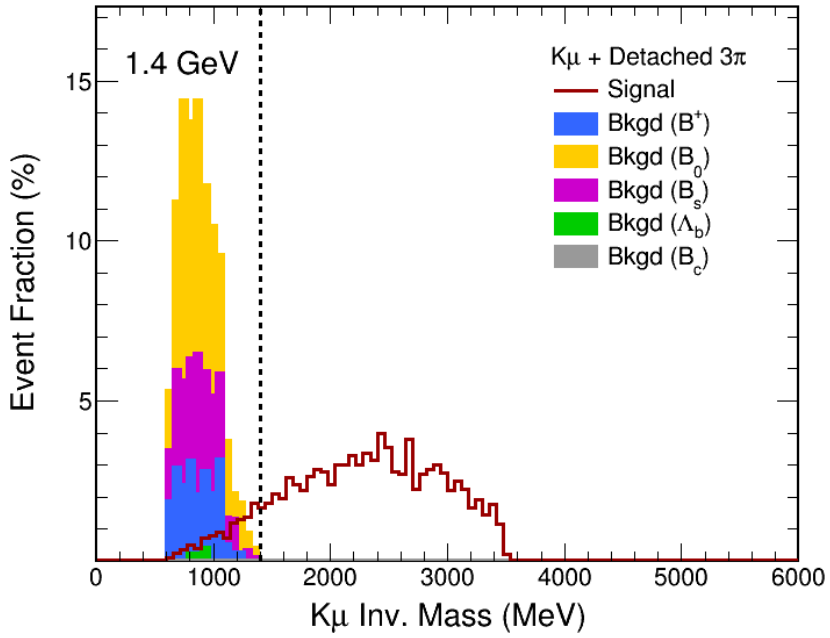
$K^+ \mu^+ (3\pi)^-$ Combination

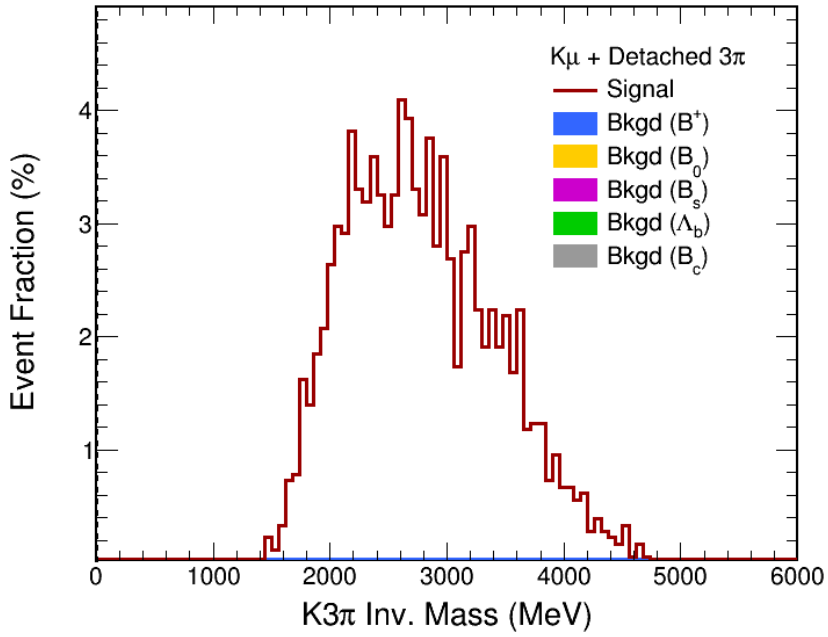
- Interesting mode as Kμ have same charge
- Can be removed by low M(Kμ) > 1.4 GeV alone



$K^+ \mu^+ (3\pi)^-$ Combination

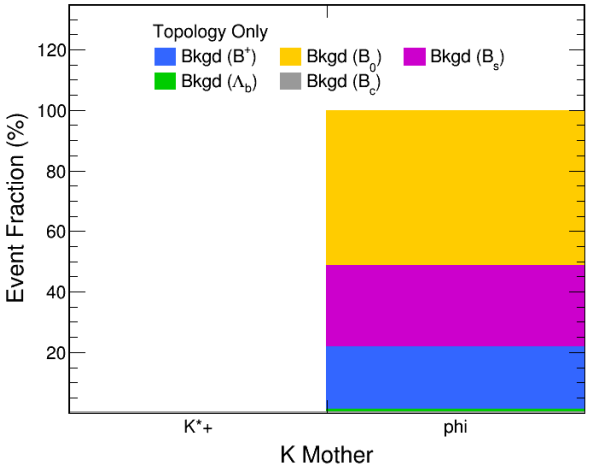
- Interesting mode as Kμ have same charge
- Can be removed by low M(Kμ) > 1.4 GeV alone
- Dominated by B^0 and B^0_s decays
- M(K3π) cut is not needed
- Large signal efficiency (89%)

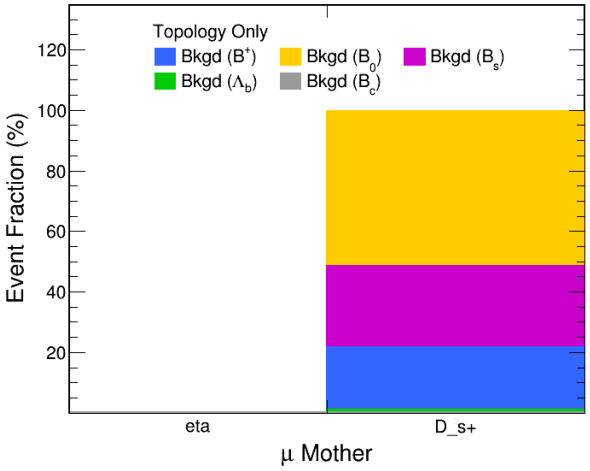


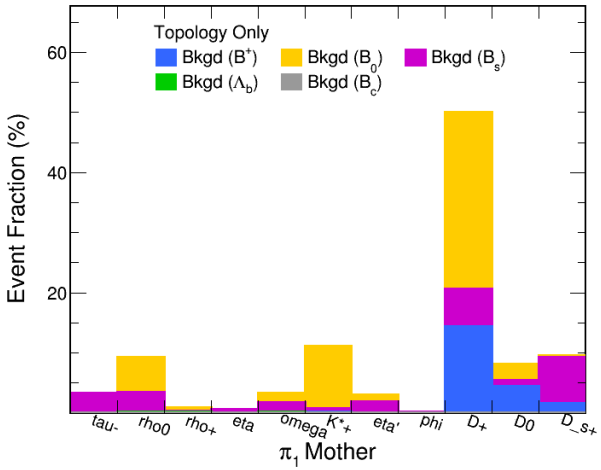


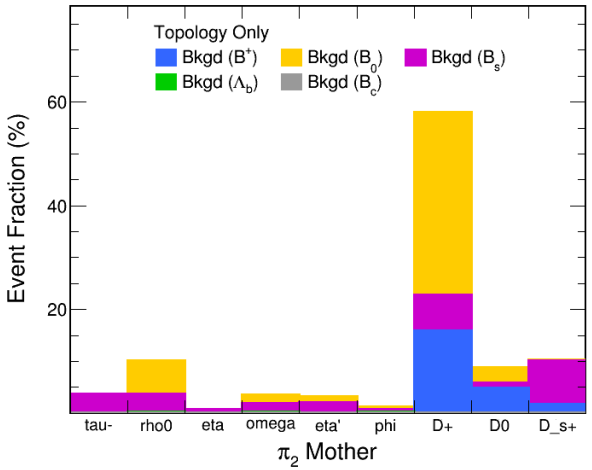
$K^+ \mu^+ (3\pi)^-$ Combination

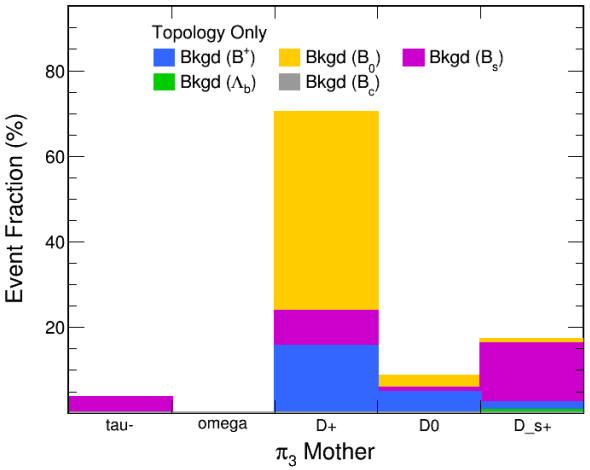
- Before the M(Kμ) cut, most background from $B \rightarrow D_s D$, where $D_s \rightarrow \phi \mu \nu$ and $\phi \rightarrow K^+K^-$, while the D decays to 3π







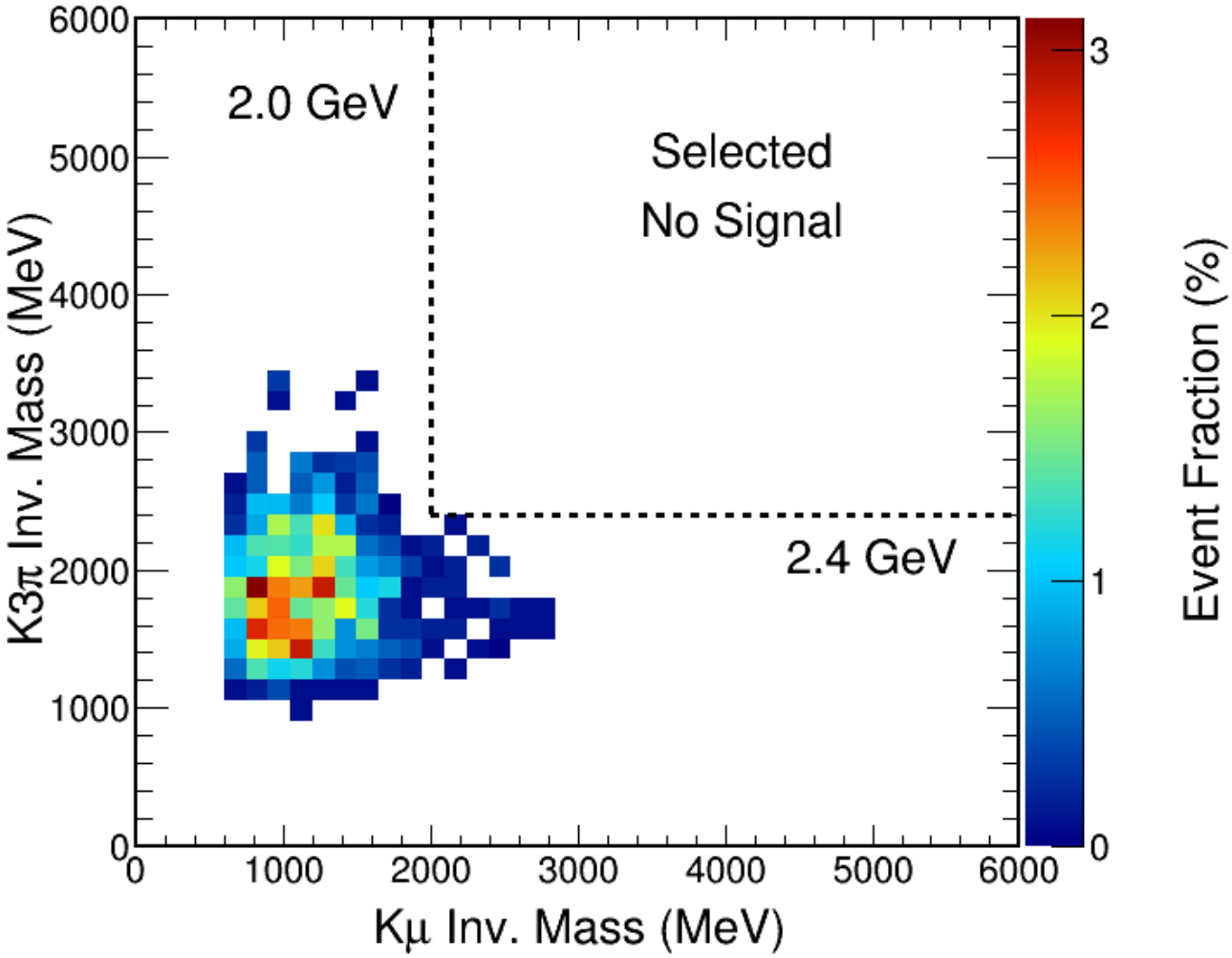




$K^- \mu^+ (3\pi)^+$

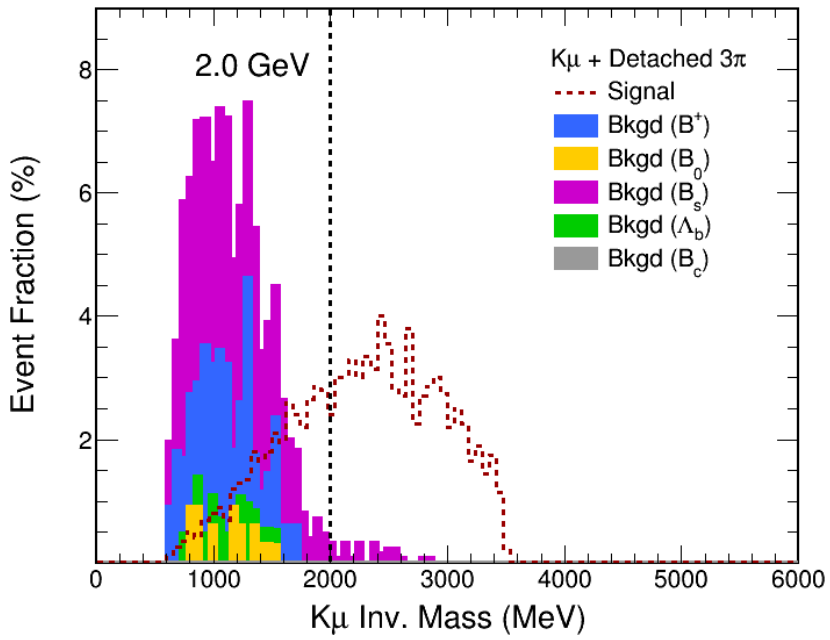
$K^- \mu^+ (3\pi)^+$ Combination

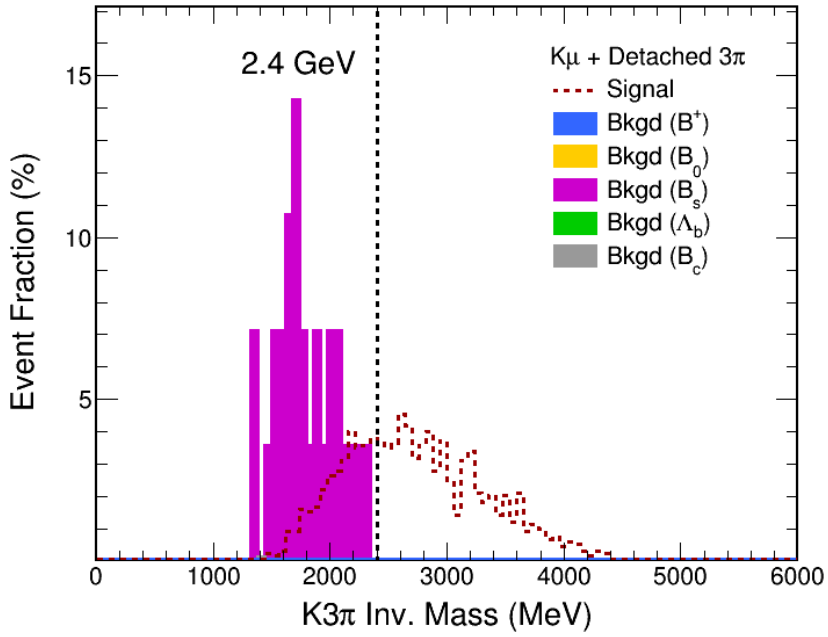
- No expected signal since μ and τ have same sign
- Can be removed by M(Kμ)>2 GeV and M(K3π) > 2.4 GeV



$K^- \mu^+ (3\pi)^+$ Combination

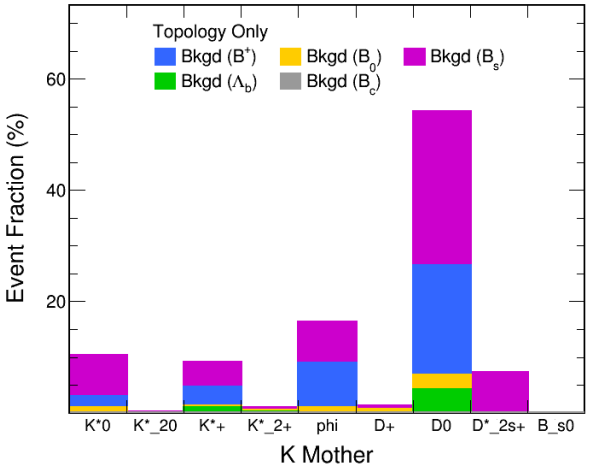
- No expected signal since μ and τ have same sign
- Can be removed by M(Kμ)>2 GeV and M(K3π) > 2.4 GeV
- Background similar to $K^+ \mu^- (3\pi)+$ but dominated by B^0_s
- Most important cut is M(Kμ) to remove most D decays
- All remaining bkgd from $B^0_s \rightarrow D^*_{s2}(2573)\ \mu\ \nu \rightarrow D^0\ K\ \mu\ \nu$

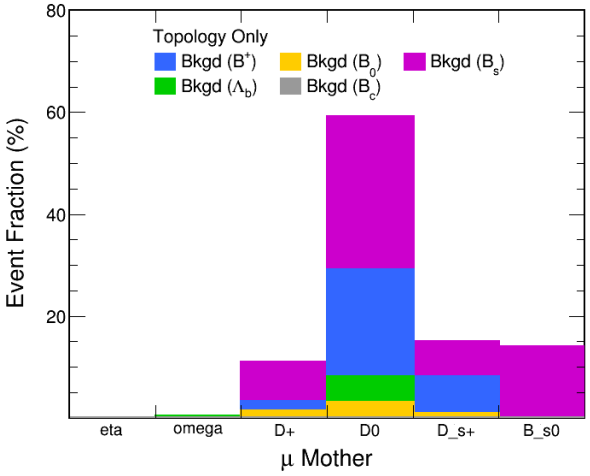


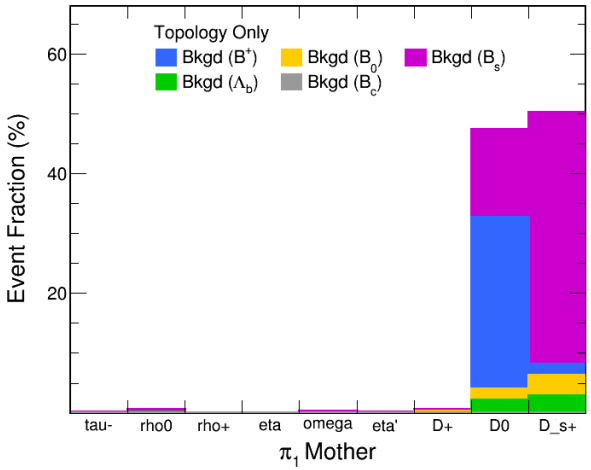


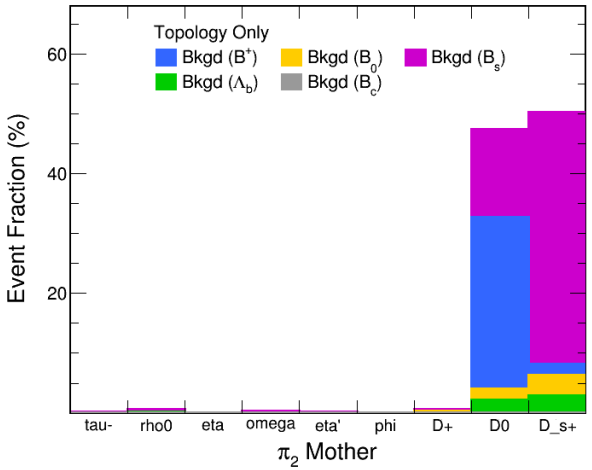
$K^- \mu^+ (3\pi)^+$ Combination

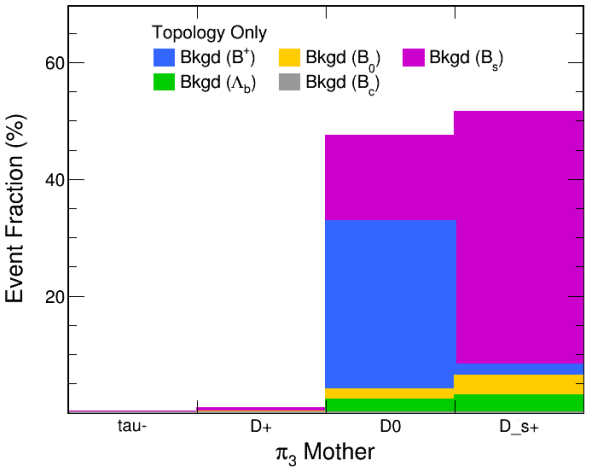
- Before mass cuts, most background from $B \rightarrow D^0 + X$, where the D^0 decays semileptonically, 3π come from a D_s or D^0





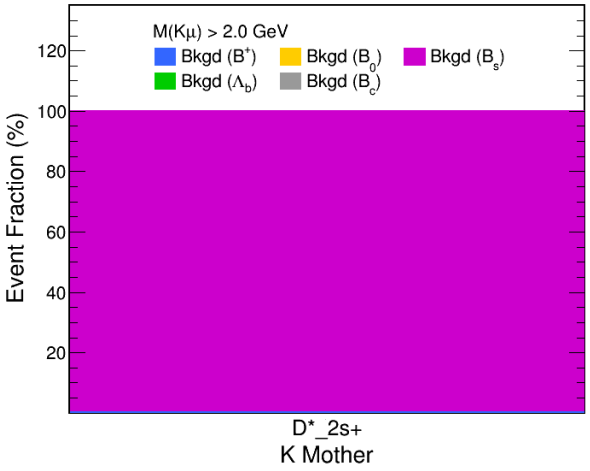


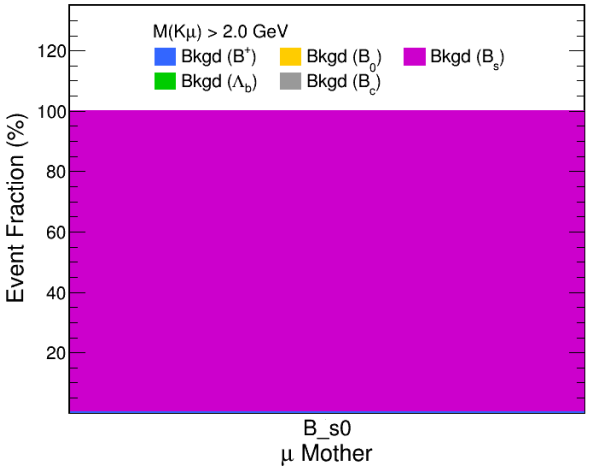


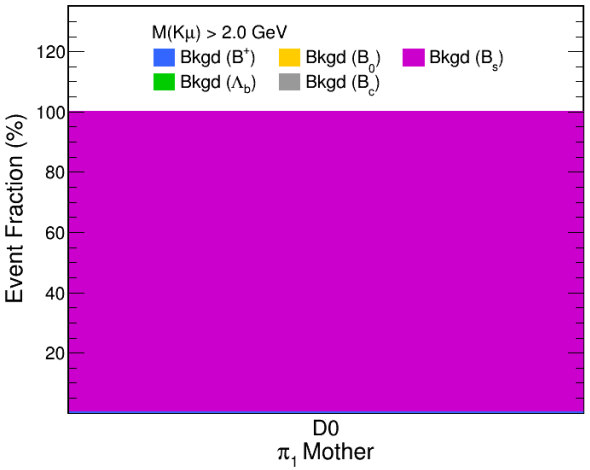


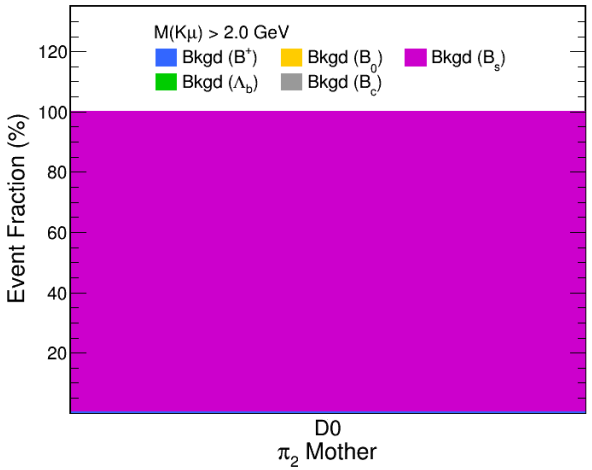
$K^- \mu^+ (3\pi)^+$ Combination

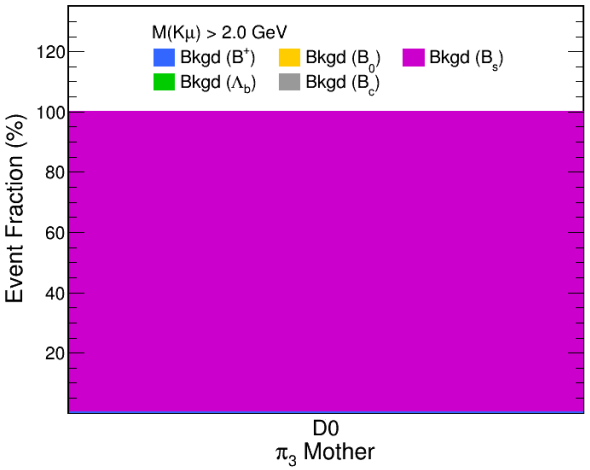
- Applying M(Kμ) cut leaves only $B^0_s \rightarrow D^*_{s2}(2573) + \mu\, \nu$
- 3π always come from the D^0 in this case











Final Comments

- Other sources of background will still need to be investigated

- Guy has identified one event in 5M where **$B \rightarrow (\omega,\eta,\phi)\ K\ D$**, with the light mesons decaying in two muons
- This may be dangerous if the $K\mu$ mass reaches above 2 GeV

- Some B_c decay modes were not present in the decay files that we used. The **B_c study needs to be revisited**

- More rare decays may show up with more statistics
- Need to **finish production of order 10^8 B events**

- Backgrounds tend to have extra particles
- Need full MC to study rejection power from this and mis-ID

Summary

- Generated some signal and background tuples
- Studied vertex and IP from truth for signal
- Looked at invariant mass cuts for different charge combinations
- A **reasonable signal efficiency** can be obtained with
  - **M(Kμ) > 2 GeV**
  - **M(K3π) > 2.4 GeV**
- For the **$K^+ \mu^+ \tau^-$ channel**, background is easier to remove
  - **M(Kμ) > 1.4 GeV is sufficient**
- Need to produce **MC for B^0_s -> $D^*_{s2}(2753)$ μ ν**, which is the main source of background found so far

Backup Slides

Gauss Generation Method

- ParticleGun using excited B* states and forcing decay into B + γ
  - B energies flat from 0 to 300 GeV
  - Inclusive decays of B hadrons
    - B^+, B^0, B_s, B_c, Λ_b
  - Can generate 50 events / second (~200k events/hour)
  - Produce tuples from xgen files with specific decay modes:
    - $K^- \mu^+ (3\pi)^+$, $K^+ \mu^- (3\pi)^+$, $K^+ \mu^+ (3\pi)^-$
  - Root tuple generation with DaVinci takes about the same time as producing the original xgen files
  - KNOWN BUG: If two identical particles are requested, the same particle may be written twice in the tuple. Needs to be removed manually
  - Happy to exchange experiences with anyone interested