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The $B^+ \rightarrow K\tau\mu$ analysis

Introduction

In the verge of repeated evidence for LFU also LFV gains importance as it can be linked to LFU in several models. Especially involving lepto-quarks.

$$\mathcal{B}(B \rightarrow K \mu^\pm e^\mp) \sim 3 \cdot 10^{-8} \left(\frac{1 - R_K}{0.23} \right)^2, \quad \mathcal{B}(B \rightarrow K(e^\pm, \mu^\pm) \tau^\mp) \sim 2 \cdot 10^{-8} \left(\frac{1 - R_K}{0.23} \right)^2$$

[arXiv: 1609.08895v2]

Or in terms of $K\mu\mu$ decays:

$$\mathcal{B}(B^+ \rightarrow K^+ \mu^\pm e^\mp) \cong 2\rho_{NP}^2 \left| \frac{U_{L31}^\ell}{U_{L32}^\ell} \right|^2 \mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-)$$

$$\mathcal{B}(B^+ \rightarrow K^+ \mu^\pm \tau^\mp) \cong 2\rho_{NP}^2 \left| \frac{U_{L33}^\ell}{U_{L32}^\ell} \right|^2 \mathcal{B}(B^+ \rightarrow K^+ \mu^+ \mu^-).$$

arXiv:1204.2852

$$\rho_{NP} = \frac{\beta_{NP}}{\beta_{SM} + \beta_{NP}} = -0.159^{+0.069}_{-0.070}.$$

Considering RK result.

Mostly unknown mixing parameters

Interesting presentation: <http://v17flavour.in2p3.fr/FridayAfternoon/Guadagnoli.pdf>

Why τ channels?

It is interesting to study τ channels to have a complete picture:

- Hints of LFU effects in muons suggest a hierarchical dynamics

$$|U_{L31}^{d,\ell}|^2 \ll |U_{L32}^{d,\ell}|^2 \ll (U_{L33}^{d,\ell})^2 \cong 1.$$

- Due to unitarity if LFV is there but $e\mu$ is small then $\tau\mu$ should be big
- If anything is observed can be used in combination with $e\mu$ channels
- Even though efficiency is lower for τ the $\tau\mu$ channels can be still triggered on the muon and on top the BR are typically higher.



The **TAU** is a short-lived (3×10^{-13} second), heavier version of the muon and electron. It has the same negative charge, but is 3,478 times more massive than the electron.

Experimental status

- A limit already exists from BaBar

$$\mathcal{B}(B^+ \rightarrow K^+ \mu^\pm \tau^\mp) < 4.8 \times 10^{-5} \quad \text{arXiv:1204.2852}$$

- Corresponding to the constraint

$$|U_{L33}^\ell / U_{L32}^\ell| \lesssim 85 \quad (\text{vs } |U_{L31}^\ell / U_{L32}^\ell| \lesssim 3.7 \text{ for the } e\mu \text{ case})$$

arXiv:1411.0565

- In LHCb a lot of activity lately:
 - ✓ $B^0 \rightarrow e\mu$ just published an update
 - ✓ $B^+ \rightarrow K e\mu$ in very advanced state
 - ✓ $B^0 \rightarrow K^{*0} \tau\mu$ in progress
 - ✓ $B \rightarrow \tau\mu$ in progress
 - ✓ Along with all the LFU activity

$B^+ \rightarrow K\tau\mu$ is a nice complement to all this good work.

$B^+ \rightarrow K\tau\mu$: strategy

- Reconstruct using $\tau \rightarrow 3\pi\nu$
- Use all datasets 2011 \rightarrow 2016 and possibly 2017
- Trigger on the muon
- Using **B2XTauMu_3pi_looseLine** and the corresponding WS line
 - Also checked Bu2NLL_mtLine and LFVB2KTauMuLine but lower efficiency or/and less RelInfo
- Apply MVA and PID after stripping
- Use tools developed for $K^{*0}\tau\mu$ (and help developing)
 - Mass correction techniques
 - τ MVA trained to separate from D decays.

Good chance to test generality of the tool
- Use CLs for limits, publish and get glory



Stripping cuts

- Input from StdTightDetachedTau3pi

- π : $p_T > 250 \text{ MeV}$ & $p > 2 \text{ GeV}$ & $\chi^2_{\text{IP}} > 16.0$
& $\chi^2_{\text{trk}} < 4$ & $\text{GhostProb} < 0.4$ & $\text{ProbNNpi} > 0.55$
- $0.5 < M < 2 \text{ GeV}$
- $p_T > 1 \text{ GeV}$ & $p > 5.0 \text{ GeV}$
- $\text{DIRA} > 0.99$ & $\chi^2_{\text{vtx}} < 16$ & $\chi^2_{\text{FD}} > 16$
- $0.1 < \Delta\phi < 7.0 \text{ mm}$ & $\Delta z > 5.0 \text{ mm}$ & $\max(\text{DOCA}) < 0.2 \text{ mm}$

- K and μ

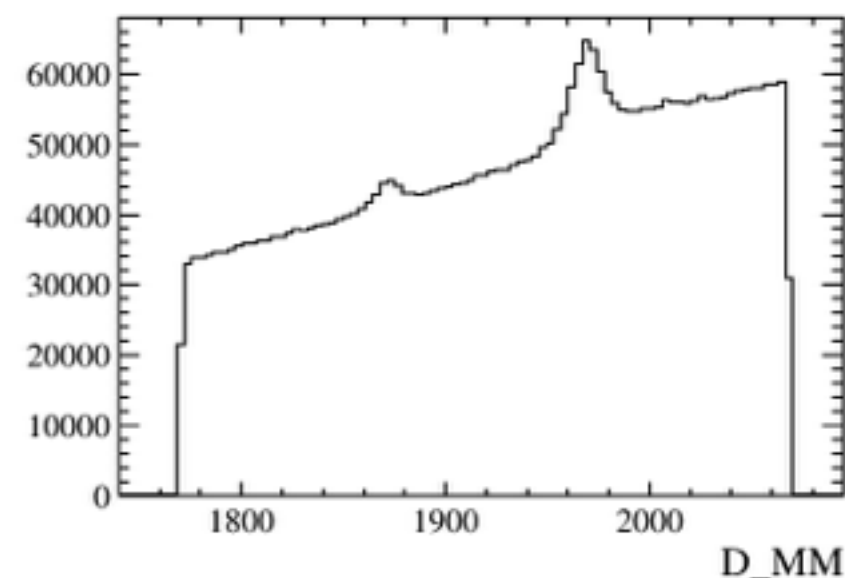
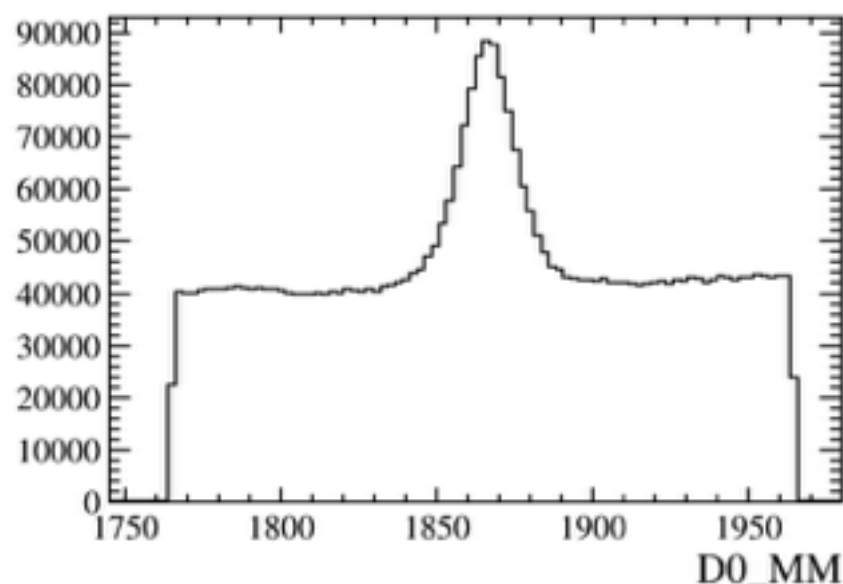
- K : $p > 3.0 \text{ GeV}$ & $p_T > 0.8 \text{ GeV}$ & $\text{DLLK} > 5$ & $\chi^2_{\text{IP}} > 36.0$
- μ : $\chi^2_{\text{IP}} > 36.0$

- B Large mass window 3000 - 7000 MeV

$$\chi^2_{\text{vtx}} < 4.0 \text{ \& } p_T > 3 \text{ GeV \& } \text{DIRA} > 0.999 \text{ \& } \chi^2_{\text{FD}} > 400.0$$

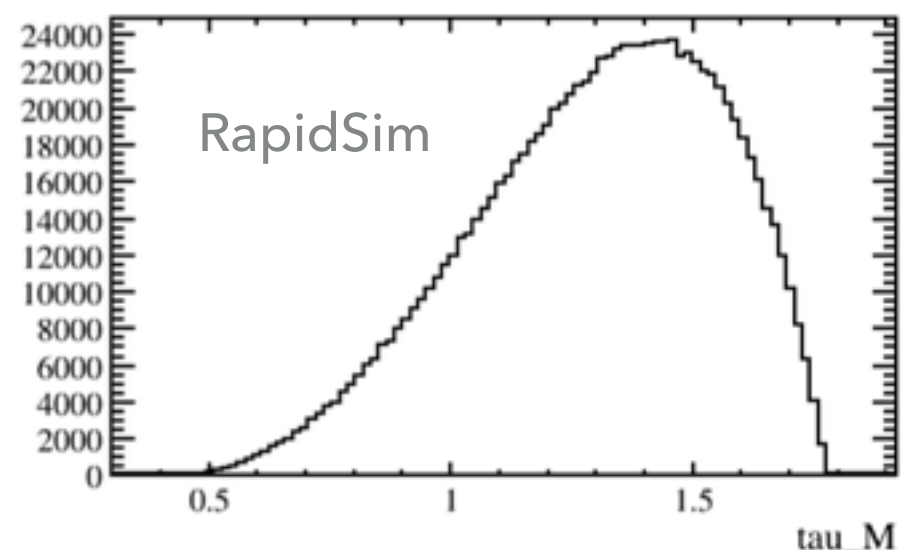
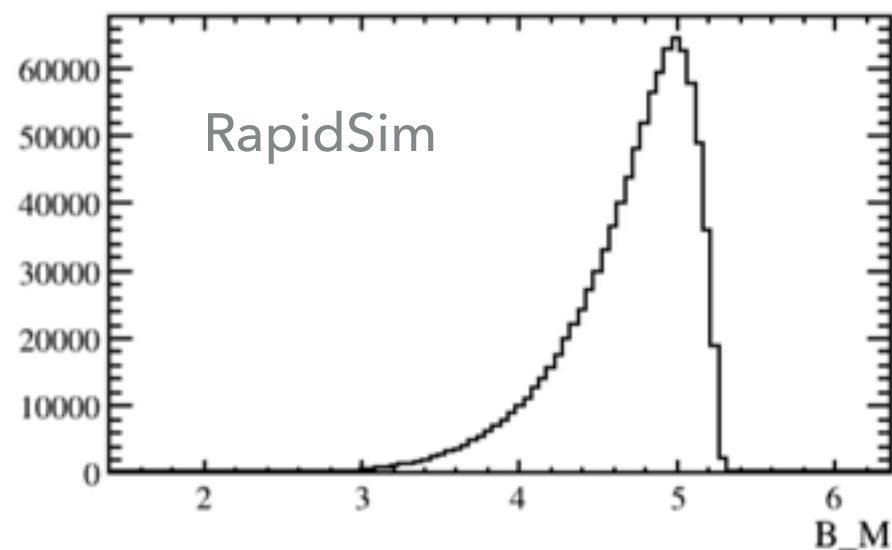
Normalisation

- Normalisation channel $B^+ \rightarrow (D^0 \rightarrow K\pi)(D_s \rightarrow KK\pi)$
 - ✓ Similar to what used for $B \rightarrow K^* \tau \mu$
 - ✓ The candidates can be found in the B2D0DBeauty2CharmLine
 - ✓ Will exploit the restripping to add RelInto and move B2XTauMu to the same stream.
- We could also use an abundant semileptonic decay e.g. $B \rightarrow (D^0 \rightarrow K\pi) \tau \nu$
 - More similar topology and final state particles but... neutrinos...



Status

- We have a repository LHCb-RD/vrd-B2KTauMu
 - Will use it also to share and develop τ tools (e.g. Tau MVA)
 - As well as other tools: pyutils (new!) and possibly easyanalysis (used by RK*)
- Tuples for all years are already on EOS
- RapidSim sample for signal to study cuts before requesting proper MC
- We now need proper MC...



MC request

Requested by Francesco,
no answer yet.

- Non filtered DST
- Correct tauola models: tune 5 for $\tau \rightarrow 3\pi\nu$ and tune 8 for $\tau \rightarrow 3\pi\pi^0\nu$
 - ➔ π^0 not reco but we have it in our signal so we need to evaluate efficiency.

$$B(\tau \rightarrow \pi^- \pi^+ \pi^- \nu) = (9.31 \pm 0.05) \%$$

$$B(\tau \rightarrow \pi^- \pi^+ \pi^- \pi^0 \nu) = (4.62 \pm 0.05) \%$$

- GenCuts to improve retention CPUtime < 1 min

```
# 'inAcc = in_range( 0.005, GTHETA, 0.400)',  
# 'goodMuon = ( GP > 2500 * MeV ) & inAcc',  
# 'goodKaon = ( GPT > 650 * MeV ) & inAcc',  
# 'goodPion = ( GPT > 220 * MeV ) & inAcc',  
# 'goodB = ( GPT > 2500 * MeV ) '
```

- DecFiles already released:

```
- Bu_Ktaumu,3pi=DecProdCut,TightCut,tauolababar,phsp.dec 12112000  
- Bu_Ktaumu,3pipi0=DecProdCut,TightCut,tauola8,phsp.dec 12112001
```

- For each DecFile, we would like to request:

➔ 500K + 1M + 300K + 1M for 2011/12/15/16 (= 2.8 M x 2)

Conclusions

- $B^+ \rightarrow K\tau\mu$ is an interesting complement to the ongoing LFU and LFV effort at LHCb
- Stripped data available and strategy will follow $K^*\tau\mu$
 - ◆ It will be one more excuse to develop common tool for τ
(as well as more generic common tools)
- Active work on the analysis started recently and one or more student should join in the next few months.
- Thanks for the attention, stay tuned and above everything

