Results and Prospects in Rare and Semi-leptonic decays

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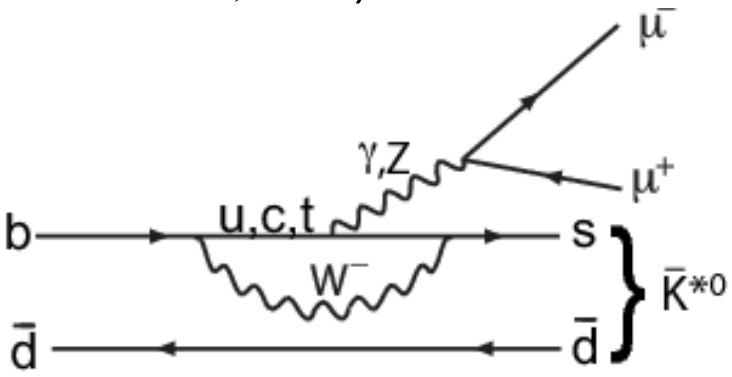
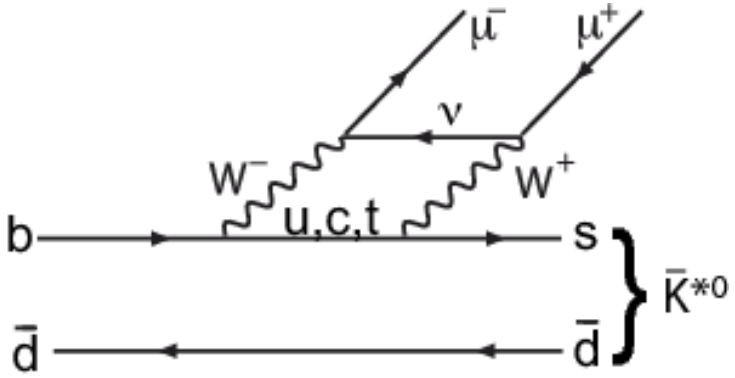
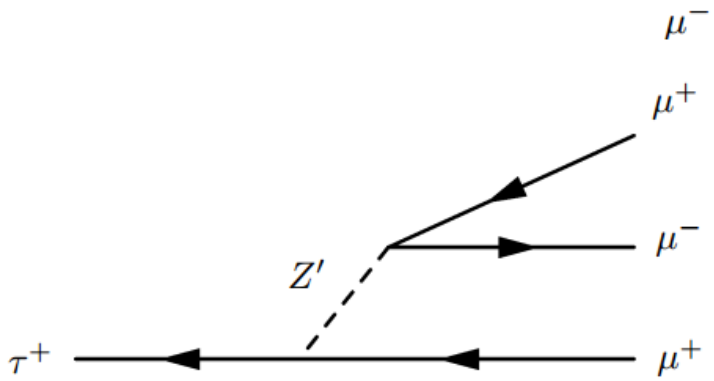
Zurich LHCb meeting, Churwalden
September 1-2, 2015

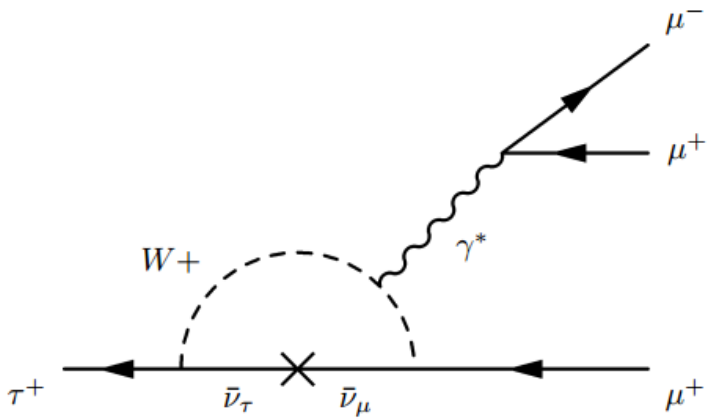
Rare decays in a nutshell

Rare decays are decays that are suppressed in the SM (forbidden on tree level, etc.)









- Allow for indirect probe of NP effects.

Rare decays theory in a nutshell

Typically one describes those decays in Heavy Quark Effective Field Theory(EFT) framework, where we sacrifice the beauty of substructure of the decays. The point like interaction is described by a Hamiltonian:

$$\mathcal{H} \sim \mathcal{M}_{CKM} \sum_i \mathcal{C}_i \mathcal{O}_i$$

Each decay contains only a couple of operators ($\mathcal{O}$) that contribute in the decay. NP searches are done by measuring the Willson coefficients: $\mathcal{C}_i = \mathcal{C}_i^{SM} + \mathcal{C}_i^{NP}$.
Measurement $\mathcal{C}_i \Rightarrow$ constrains on NP models

Run1 results from UZH

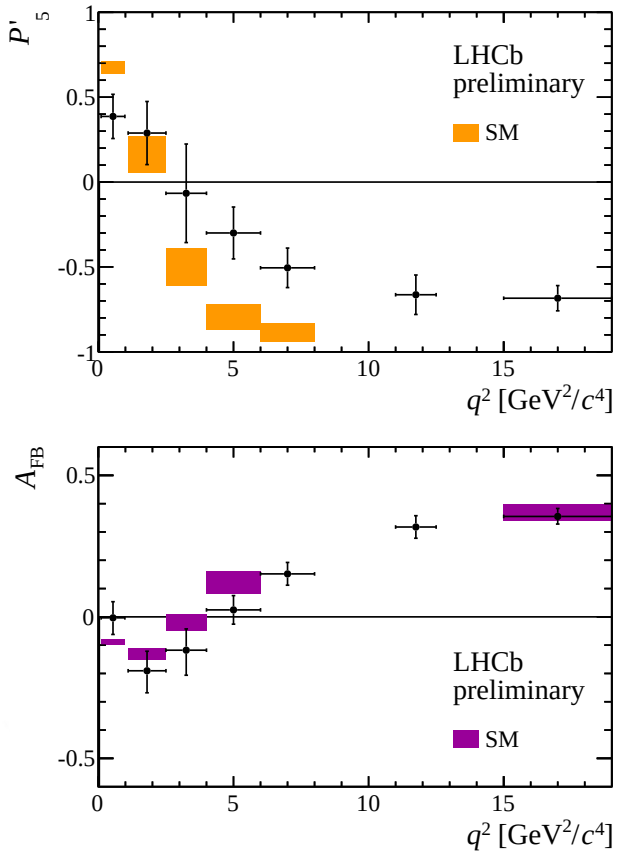
$\Rightarrow$ Zurich group was super active in Rare decays! just to give you a hint:

$\rightrightarrows$ Angular analysis of $B^0 \to K^* \mu^- \mu^+$
$\rightrightarrows$ Inflaton search in $B^\pm \to K^\pm \chi(\mu\mu)$
$\rightrightarrows$ Moments analysis of $B^0 \to K^*(14X0)\mu^- \mu^+$
$\rightrightarrows$ Lepton flavour violation search for $\tau \to \mu\mu\mu$.
$\rightrightarrows$ Kaggle competition for LHCb.
$\rightrightarrows$ The "holy grail" of LHCb $B_s^0 \to \mu^- \mu^+$.

Angular analysis of $B^0 \to K^*\mu^-\mu^+$

N.Serra, M.Chrzaszcz, E.Bowen, B.Storaci, M.Tresh

- Huge impact of the group!
- We were involved there from the start: pre-selection, BDT, etc.
- One of the three methods (MoM) is fully and exclusivelly ours.
- Separate paper about the method published: Phys. Rev. D 91, 114012 (2015)
- Paper is in the final stage of the review.



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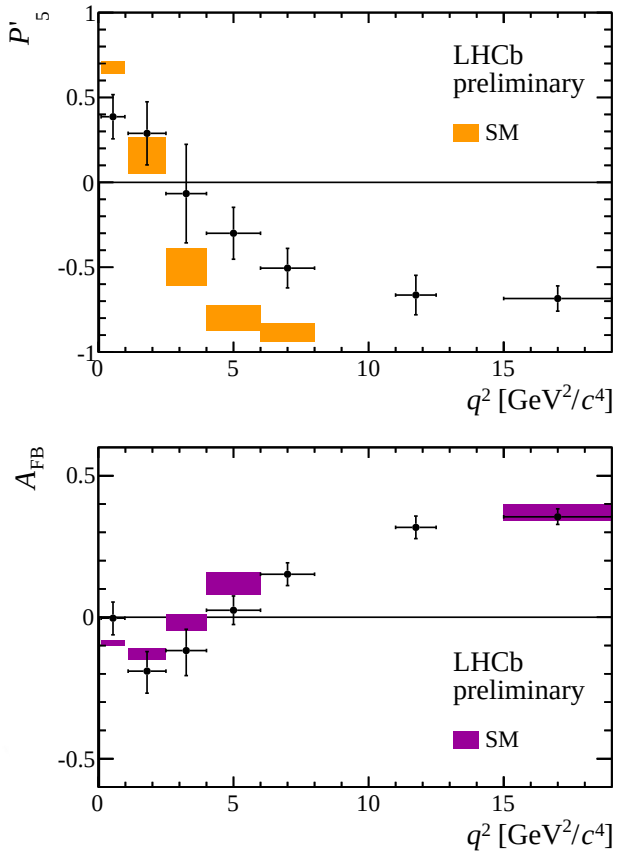
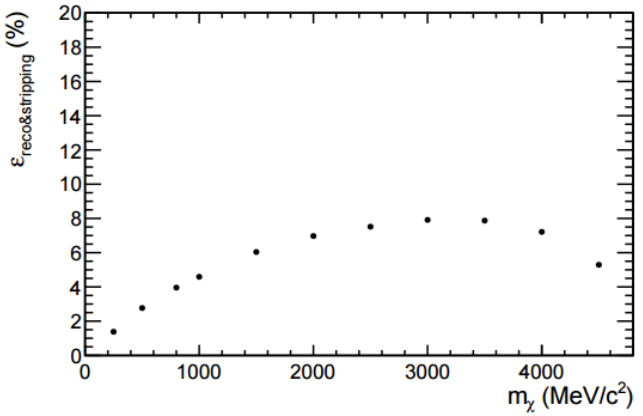


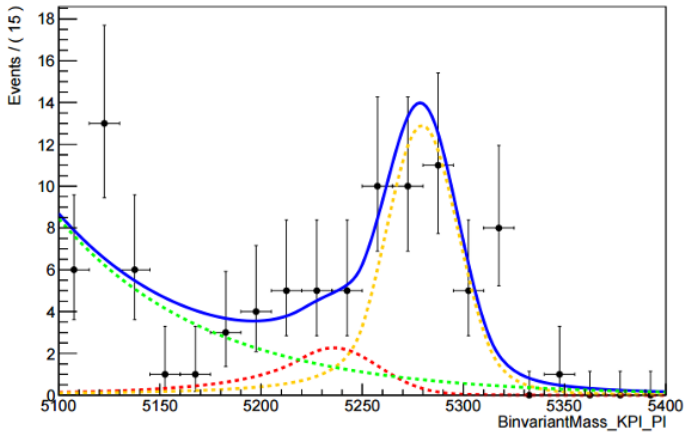
$\Rightarrow$ "Take a moment and discover New Physics"

Inflaton analysis: $B^+ \to K^+\chi(\mu\mu)$

A.Mauri, N.Serra, M.Chrzaszcz

- Analysis completely done by UZH!
- All the strategy is defined.
- Backgrounds understood.
- Soon ready for WG review.
- Main part of Andrea PhD.

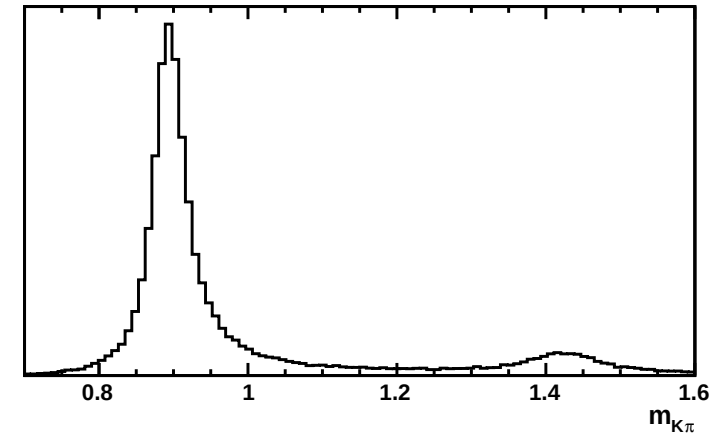


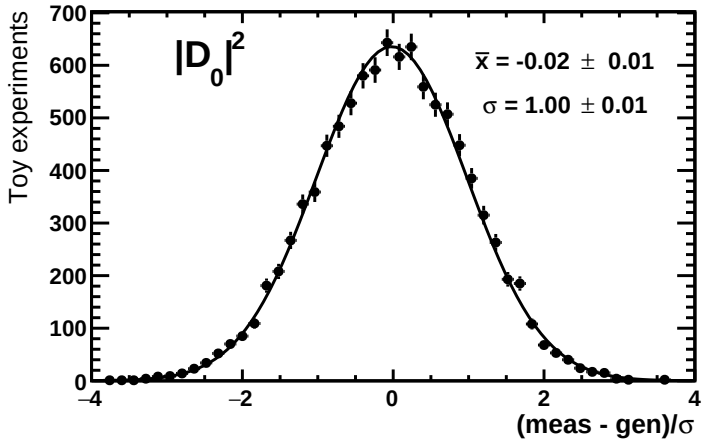


Moments analysis of $B^0 \to K^*(14X0)\mu^-\mu^+$

E.Bowen, N.Serra, B.Dey

- Analysis progressing well.
- Espen finished acceptance.
- Cross-checked with normal $B \to K^*\mu^-\mu^+$.
- Observables never measured before!
- Soon in WG review.





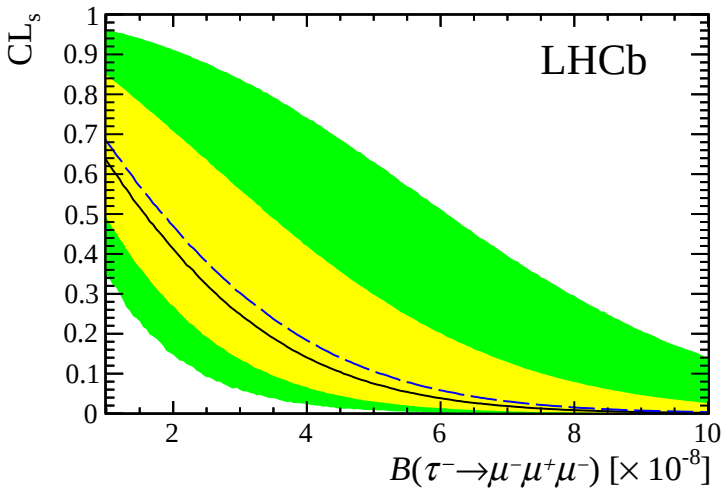
Lepton flavour violation search for $\tau \to \mu\mu\mu$.

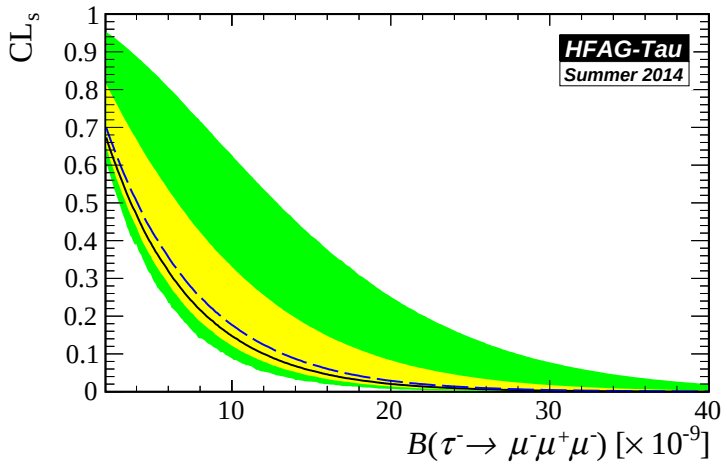
M.Chrzaszcz, N.Serra

- Analysis published in February.
- In parallel HFAG report was prepared.
- We got the best limit: $\mathcal{B}(\tau \to 3\mu) < 1.2 \times 10^{-8}$

Some stats:

- Till now HFAG report has 73 citations!
- All τ section citations are on $\tau \to 3\mu$!

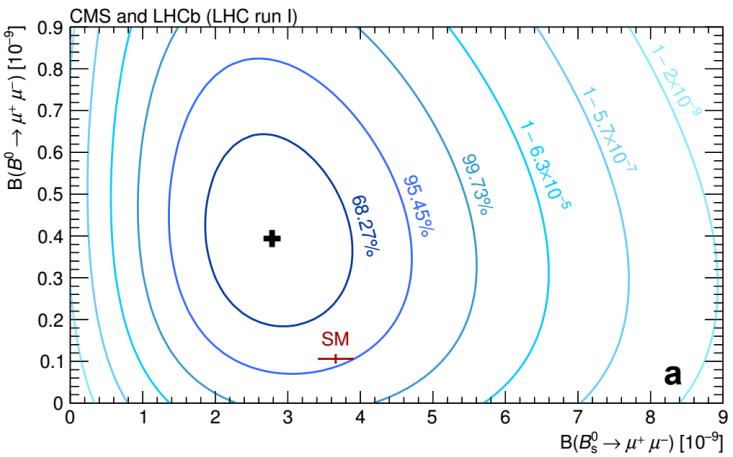


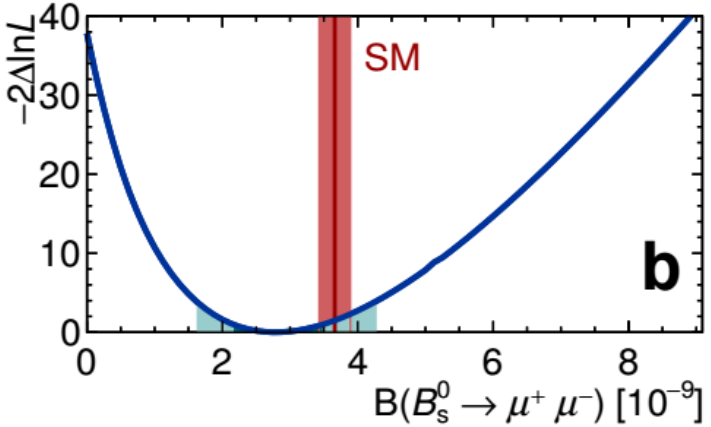


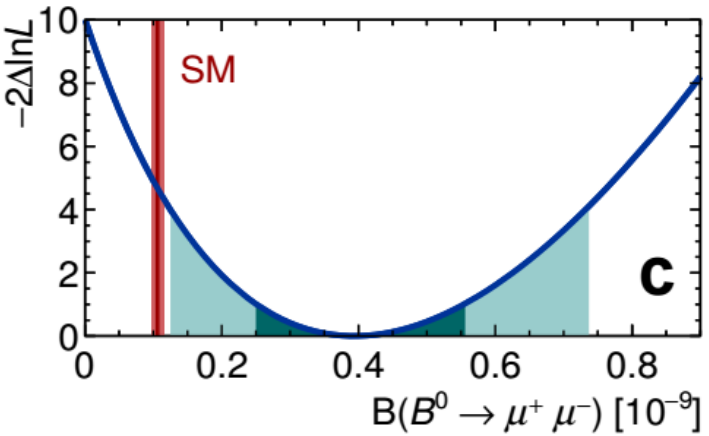
The "holy grail" of LHCb $B_s^0 \to \mu^- \mu^+$

C.Elsasser

- Christian main job was the calibration of the BDT.
- Analysis was latter combined with the CMS one.





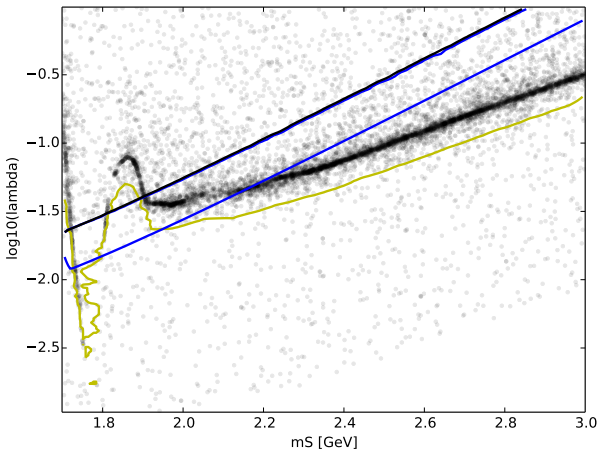


GAMBIT

N.Serra, M.Chrzaszcz

The Global And Modular BSM Inference Tool (GAMBIT):

- We were responsible for all Flavour likelihoods.
- Work are on the rest strait line towards producing results.
- First models that will be scanned:
  - Scalar singlet
  - MSSM25.
- Hope to soon become a paper factory.

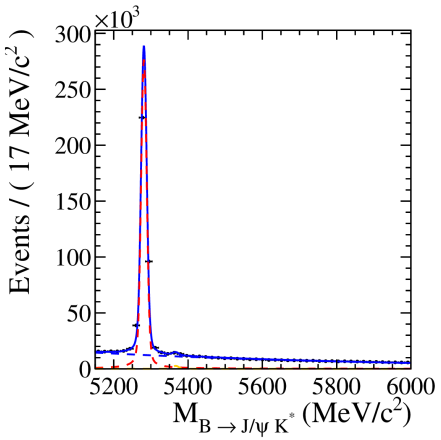


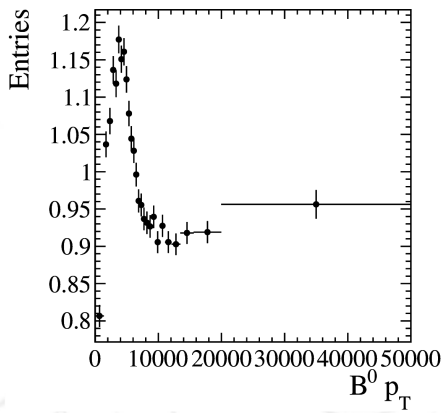
Angular analysis of $B^0 \to K^*[\mu^-\mu^+, e^-e^+]$

F.Lionetto, N.Serra, R.Silva Coutinho

$\Rightarrow$ LFV measurements using $B^0 \to K^* e^- e^+ (R_{K^*})$ are under way, [1] so it seems a good idea to study their angular observables.

- Analysis at an initial stage.
- Plan is to perform the MoM for sensitive observables
  - $1.1 < q^2 < 6.0\,\text{GeV}^2/c^4$
  - $q^2 > 15\text{GeV}^2/c^4$
- Studying smearing tool to reproduce Bremsstrahlung effects in muons.





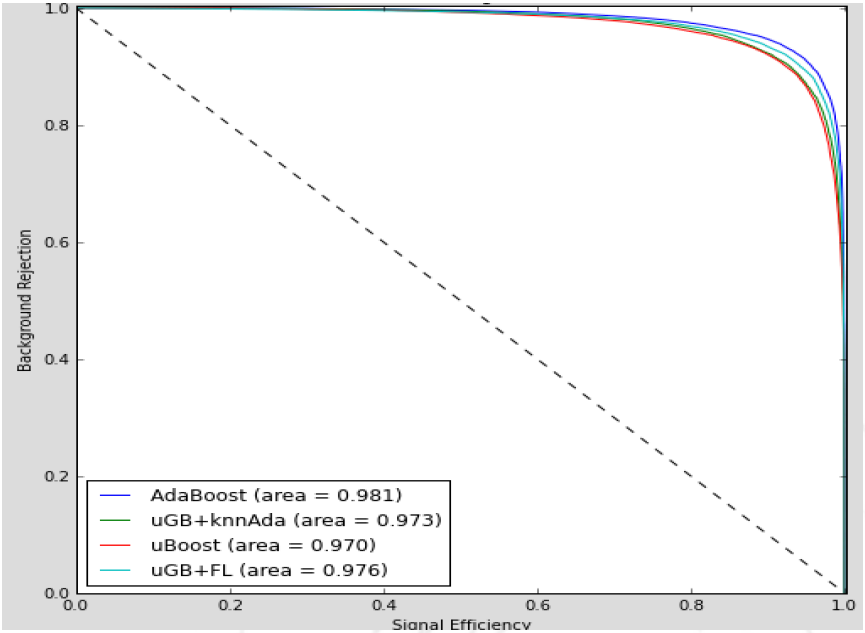
[1] Similarly LU tests for R_ϕ are also being performed.

Moments analysis of $B^0 \to K^*(14X0)[\mu^-\mu^+, e^-e^+]$

N.Serra, R.Silva Coutinho

$\Rightarrow$ Similar methodology used in the (S, P, D)-wave analysis performed by Espen, but extended to electrons.

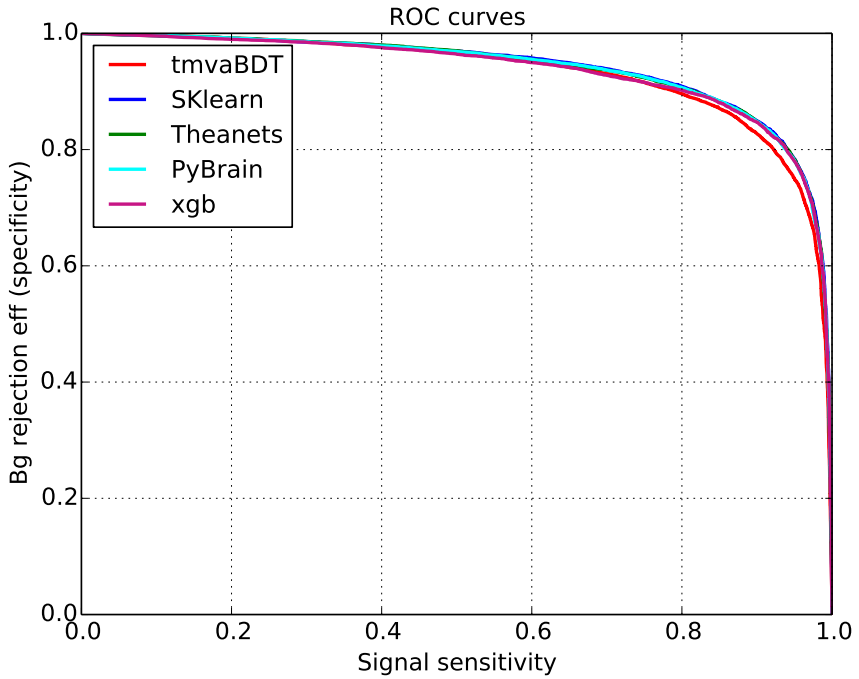
- Several tools used are shared with Federica's analysis.
- Revised selection (wrt the R_{K^*} analysis) optimised for the phase-space.
- Currently working on simulated studies to verify the sensitivity (and even feasibility) of the analysis.



Lepton flavour violation in $B \to K\ell\ell'$ decays

M.Chrzaszcz

- Several groups concentrate their affords in $B^0 \to K\tau\mu$.
- However, $B \to Ke^-\mu^+$ decays might be a better candidate.
  - Factor of 10 lost because of the hierarchical structure of NP, but you can this back because of τ branching fraction.
  - ... and still you do not have the neutrinos to worry about.
- Currently working on the MVA optimisation.



Prospects for the future

Run2 data

$\Rightarrow$ We should be prepared for Run2 data, however:

- Run1 is still not fully exploited!
- Analysis are still ongoing.
- Run2 data will be usable when we collect (~ 2) times the statistics of Run1.
- Finally Run1 data is understood, Run2 is an unexplored land.

$\Rightarrow$ To sum up: For another year or two we will still use the Run1 data for most of the NP searches.

Plans for the future?

$\Rightarrow$ So let's list the hints of NP we have:

- The famous P_5' anomaly ($3.7\ \sigma$).
- The R_k anomaly ($2.7\ \sigma$).
- The $R(D^*)$ anomaly ($2.1\ \sigma$)[2].

$\Rightarrow$ For fun let's assume that these anomalies are not just statistics fluctuation but nature showing its true face.

- All hints point out that there is clear indication that NP clearly violates lepton universality.
- There is also a clear hierarchical structure.
- So what to do with that?

[2] This anomaly was also observed by Babar and Belle with $2.7\ \sigma$ and 2.0σ significance.

Lets pin down NP now!

$\Rightarrow$ Some ideas what we can do:

- If the NP occurs in the R_k, it might also occur in the angular observables! $\Rightarrow$ Lets measure difference in observables like $P_5'^{\,\mu} - P_5'^{\,e}$.
- In the τ sector the NP is competing with a SM tree decay! We could measure: $R(\Lambda_c^*)$[3].
- If there exists LU breaking, one cloud also see LFV like: $B \to K\ell\ell'$, like: $B^+ \to K^+\mu e$.
- Now playing the devils advocate: Maybe we are remodelling the $B^0 \to K^*\mu\mu$? One could measure the partial and higher moments in this channel as well in $B \to Kee$, Collaboration with Roman Zwicky and Greg Cowan [4].
- Measure the angular observables of $B^+ \to K_1^{*+}ee$, $B^+ \to K^+ee$ and $\Lambda_b^0 \to \Lambda^*ee$ decays.

[3] Please remember that protons kill a lot of background. The main criticism on $R(D^*)$ analysis is the background modelling

[4] My personal opinion, we should keep as much of MoM in UZH as possible.

Lets pin down NP in Run2 data

$\Rightarrow$ Some ideas what we could do with the full Run2 data:

- Since decays involving τ's are more sensitive, we could start thinking in modes such as $B \to K(K^*)\tau\tau$.
  - Undergraduate student [Alex Daetwyler] is currently studying the sensitivity for $B^0 \to K^*\tau\tau$ decays with Run 1 and 2 data.
- We should definitely update $\tau \to 3\mu$.
- Some more Semi-leptonic measurements!

Summary

1. Future analysis will be more challenging!
2. Run1 data analysis program is still rich in NP searches.
3. Many analysis are in the pipe line.
4. We should maximize the coverage of the mentioned topics.

Backup