Radiative decays in LHCb

Carla Marin Benito

Universitat de Barcelona

Taller de Altas Energias

Benasque 2013

Outlook

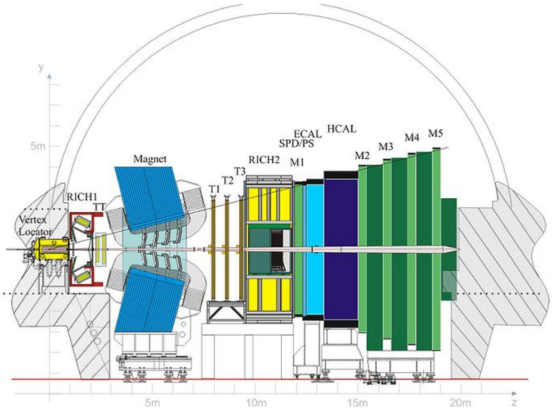
- Radiative B decays
- LHCb experiment and detectors
- $B_s \to \phi\gamma$ and $B \to \omega\gamma$ event selection in LHCb (Master Thesis)
  - Offline selection
  - Results
    - $B_s \to \phi(K^+K^-)\gamma$: 2012 trigger and stripping validation
    - $B \to \omega(\pi^+\pi^-\pi^0)\gamma$: 1st time in LHCb
- Multichannel fit of radiative decays (Radiative group)

Radiative B decays

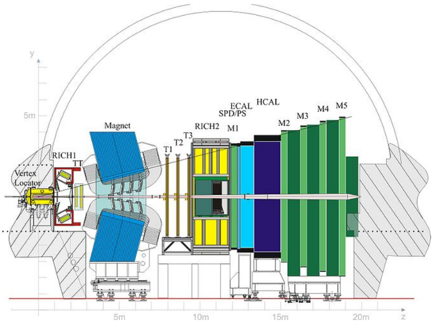
- $B \to X\gamma$
- **Flavour changing neutral currents (FCNC)**:
  - No tree-level contribution.
  - 1-loop contribution involves CKM elements.
  - 1-loop contribution sensitive to new physics.
- **Presence of photon**: clear experimental signature, but limitation from calorimeter resolution.
- **History**:
  - 1st radiative decay observed: $B \to K^*\gamma$ by CLEO, 1993.
  - World average measurements before LHC:
    - $BR(B \to K^*\gamma) = (4.33 \pm 0.15) \cdot 10^{-5}$ (Cleo2, Belle, BaBar)
    - $BR(B_s \to \phi\gamma) = \left(5.7^{+2.2}_{-1.9}\right) \cdot 10^{-5}$ (Belle)
    - $BR(B \to \rho\gamma) = (8.6 \pm 1.5) \cdot 10^{-7}$ (Belle, BaBar)
    - $BR(B \to \omega\gamma) = \left(4.4^{+1.8}_{-1.6}\right) \cdot 10^{-7}$ (Belle, BaBar)
    - $BR(\Lambda_b \to \Lambda^*\gamma)$ Not observed

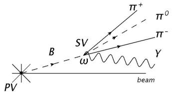
LHCb experiment and detector

- LHCb: one of the main experiments at LHC, CERN, Geneva. Dedicated to b and c physics.
- LHCb detector: single-arm spectrometer (15-300 mrad horizontal, 15-250 mrad vertical)



LHCb experiment and detector





- **Tracking system**: VeLo, TT, magnet, T1-T3.
  - Localize interaction vertex and reconstruct tracks.
  - High momentum precision.
- **Particle identification**: RICH, ECAL, HCAL, M1-M5.
  - Distinguish different particle types.
  - Optimized to separate pions from kaons.
- **Trigger system**: custom electronics (quickest detectors).
  - Select interesting events.

Data preselection: trigger and stripping

Bunch crossing: 40 MHz, but

- only $\frac{1}{200}$ $b\bar{b}$ pairs
- radiative $BR < 10^{-3}$
- limited computing resources

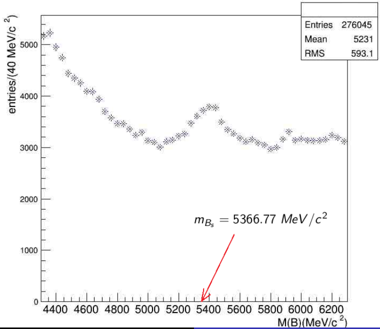
$\rightarrow$ reduce and select data.

- Trigger system: decides which events are recorded.
  - L0: synchronous. Calorimeters and muon detectors.
  - HLT: asynchronous. All detectors.
    - HLT1: partial reconstruction for further reduction.
    - HLT2: full event reconstruction $\rightarrow$ global event cuts.
- Stripping: selects and classifies events from different decays $\rightarrow$ data already classified for offline analysis.

$B_s \to \phi\gamma$: first look with 2012 data

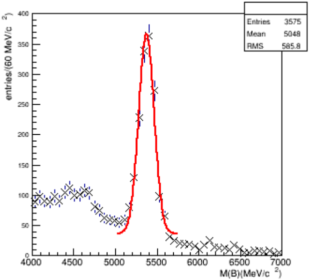
- Already studied with 2011 data.
- **Purpose**: validate 2012 trigger and stripping configuration $\to$ update offline selection.
- **Method**: comparing signal and background properties $\to$ linear cuts.
- **Data**: 1.75 fb^{-1} from 2012 LHCb data at 8 TeV,

Data directly from the stripping:



$B_s \to \phi\gamma$: signal fit

After applying linear cuts:



Fit:

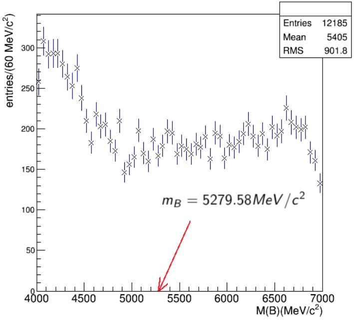
$$f(x) = p_0 + p_1 \cdot \exp\left(-0.5\left(\frac{x-p_2}{p_3}\right)^2\right)$$

- From fit: $N_{fit} = 1200 \pm 70$
- From MC: $N_{expected} = 1500 \pm 300$
- In 2011: $N = 691 \pm 36$ (with $1.1\ fb^{-1}$)

Compatible results

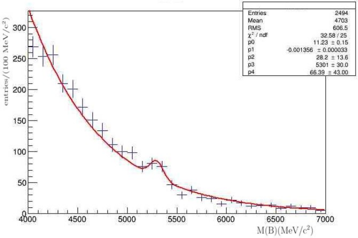
- 1st time with dedicated stripping line.
- $BR(B \to \omega\gamma) = \left(4.4^{+1.8}_{-1.6}\right) \cdot 10^{-7}$ Like a needle in a haystack!
- **Systematic method**: optimize cuts maximizing $\frac{S}{\sqrt{S+B}}$.
- Data: 2 fb^{-1} from 2012 LHCb data at 8 TeV.

Data directly from the stripping:



$B \to \omega\gamma$: Signal fit

After applying all cuts:



Fit:

$$p_0 \exp(p_1 x) + p_2 \exp\left(-0.5\left(\frac{p_3 - x}{p_4}\right)^2\right)$$

- From fit: $N_{fit} = 50 \pm 40$
- From MC: $N_{expected} = 47 \pm 15$

Compatible but with large uncertainty!

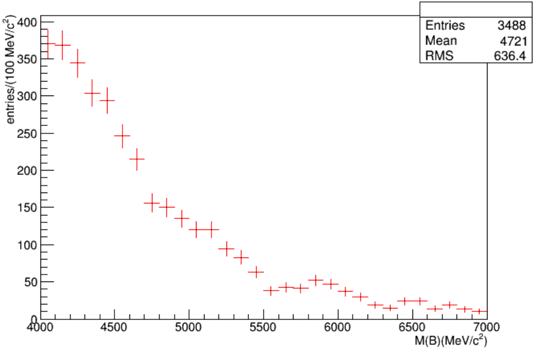
Comparing to fitting a single exponential: better fit when including the Gaussian $\rightarrow$ **Small signal accumulation in the m_B region**

$B \to \omega\gamma$: Neural net approach

To improve selection: **neural net**

- Trained with same samples as before
- Variables cut before used as input

Applying output cut giving maximum significance:



No hint of signal but compatible with previous result

Multichannel fit: b-hadron $\to$ V meson + γ

Purpose: fit simultaneously the radiative decays:

- $B^0 \to K^*\gamma$
- $B_s^0 \to \phi\gamma$
- $B^0 \to \rho\gamma$
- $\Lambda_b \to \Lambda^*\gamma$

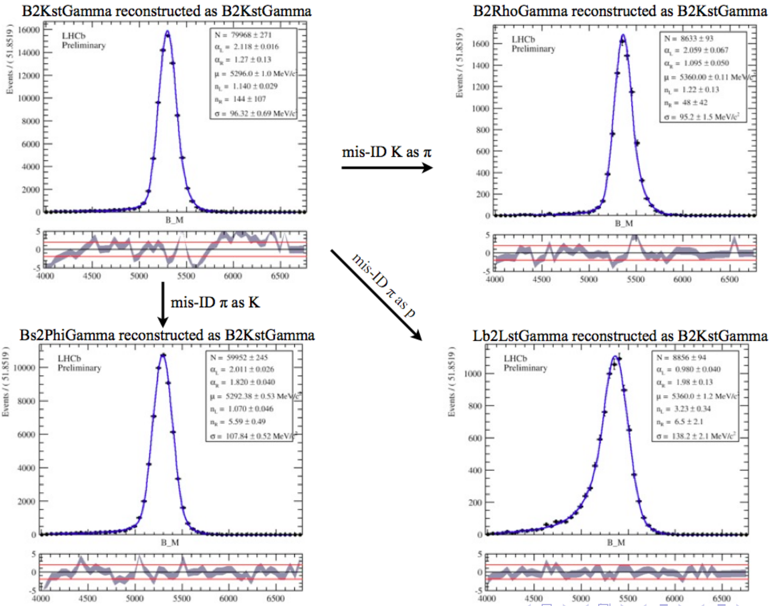
Interest in:

- CP asymmetry
- Discovery (Λ_b channel not seen yet)
- Branching ratios (with $K^*\gamma$ as control channel)

Steps:

- Generate MC for signals and all backgrounds In process
- Define a common selection In process
- Compute contaminations Trouble with PID efficiency
- Build a simultaneous fitter Almost done

Multichannel fit: Example (LHCb unnoficial)



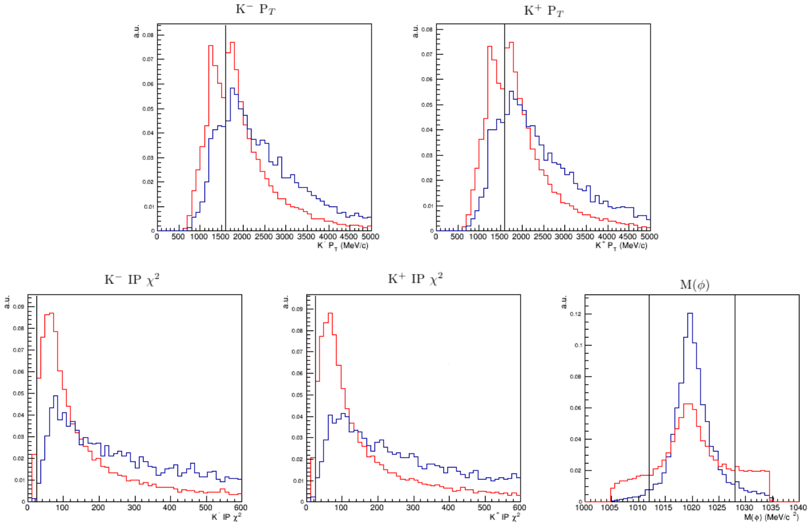
Summary

- Master thesis with the LHCb group in Universitat de Barcelona
  - Event selection for $B_s \to \phi\gamma$ and $B \to \omega\gamma$ with 2012 data.
- Starting PhD with the radiative decays group of LHCb
  - Participating in the multichannel fit to the main radiative decays.
  - Future: study of γ polarization with radiative B decays.

Thank you for your attention!

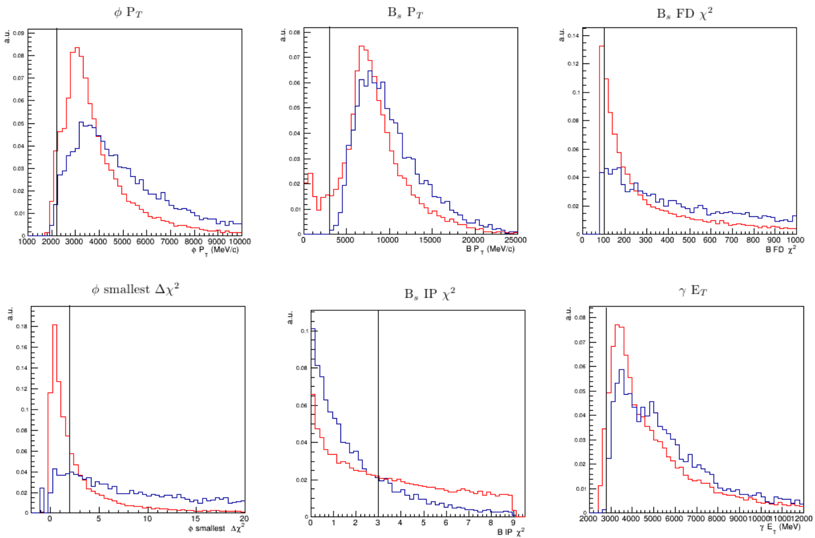
BACK-UP

$B_s \to \phi\gamma$ linear cuts graphics



Signal/Background

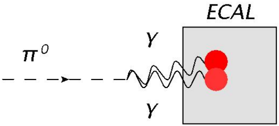
$B_s \to \phi\gamma$ linear cuts graphics



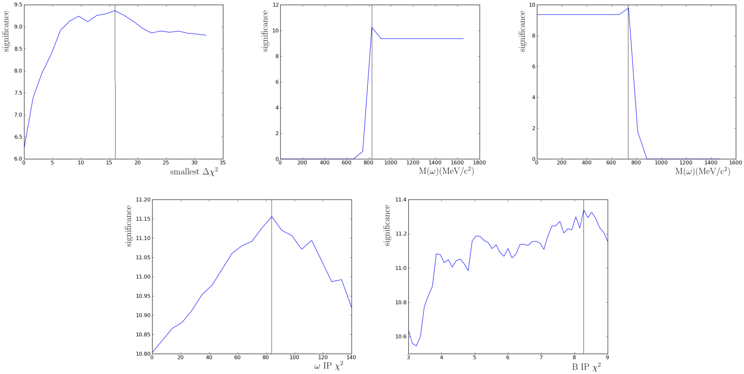
$B_s \to \phi\gamma$ offline selection summary

		Stripping	Offline
Track IP χ^2		> 16	> 25
Track P_T	(MeV/c)	> 500	> 1600
V meson P_T	(MeV/c)	-	> 2200
V meson ΔM_{PDG}	(MeV/c^2)	< 15	< 8
V meson smallest $\Delta\,\chi^2$		-	> 2
Photon E_T	(MeV)	> 2500	> 2800
B candidate IP χ^2		< 9	< 3
B candidate FD χ^2		> 64	> 100
π^0/γ separation		-	> 0.5

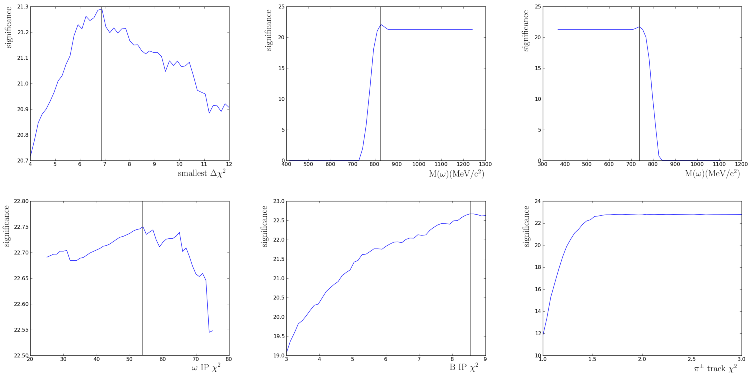
Peculiarity: merged and resolved π^0 events have different properties $\rightarrow$ separate analysis.



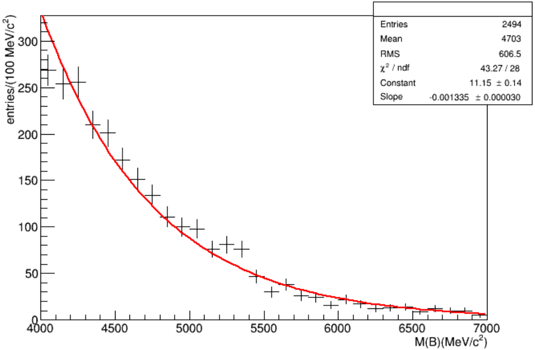
For merged π^0 events:



For resolved π^0 events:



$B \to \omega\gamma$: fitting single exponential



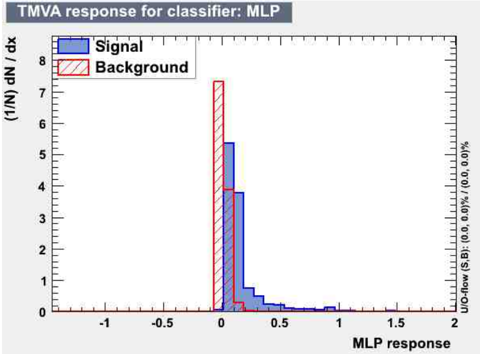
	Expo + gaussian	Only expo
χ^2/ndf	32.58/25	43.27/28

$B \to \omega\gamma$: Neural nets approach

Purpose: improve the offline selection.

Method: multivariate technique $\to$ Neural net.

- Multilayer feed-forward net with 1 hidden layer.
- Same signal and background samples.
- Input variables: ones used in linear cuts.



Comparison between linear and neural net selections:

- Cut on net output $\to$ same background rejection.

	Neural network out > 0.13	Linear cuts
Background rejection	0.989	0.989
Signal efficiency	0.343	0.221
Significance	10.55	7.37

Much improvement: $\sim 50\%$ more efficiency and $\sim 40\%$ more significance!