Steps towards $B \to K\pi\pi\gamma$ through $B^0 \to K^+\pi^-\gamma$ mode using monte-carlo data

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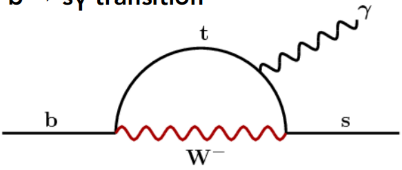
Outline

1. Motivation for the $B \to K\pi\pi\gamma$ analysis;
2. Training with $B^0 \to K^+\pi^-\gamma$ analysis;
3. Conclusions

Photon polarisation in radiative B-hadron decays

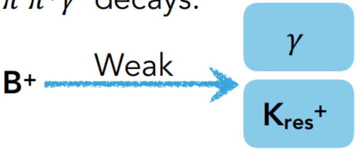
- The $b \to s\gamma$ transition occurs through a penguin loop;
- Radiative b-hadron decays are sensitive to NP but need observables that are independent from form factors, for example **photon polarisation parameter**

Penguin diagram for the
b → sγ transition

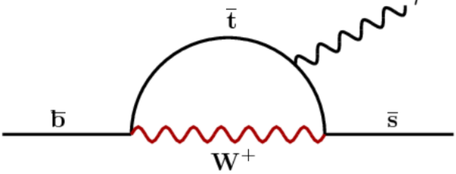


Why are $B \to K\pi\pi\gamma$ decays sensitive to the photon polarisation?

$B^+ \to K^+\pi^-\pi^+\gamma$ decays:



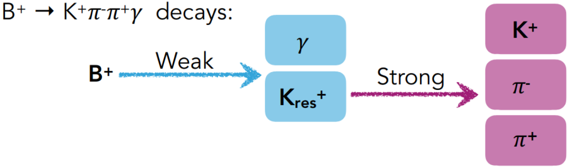
Penguin diagram for the $\bar{b} \to \bar{s}\gamma$ transition

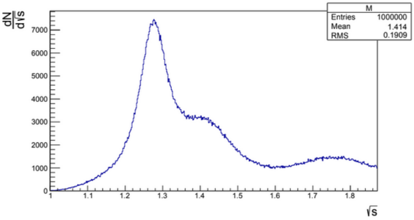


In the SM, the photon is mostly right-handed

In case of new physics, a significant fraction of left-handed photons could be produced

Why are $B \to K\pi\pi\gamma$ decays sensitive to the photon polarisation?



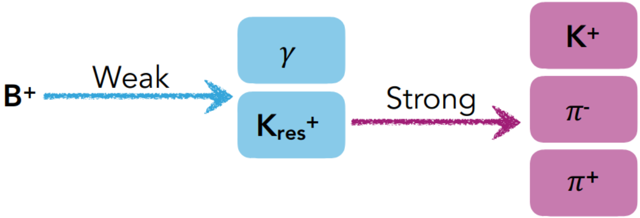


$M(K\pi\pi)$

Many kaonic resonances involved:

- Interferences give access to the photon polarisation parameter;
- Complexity of analysis

Decay rate as function of photon polarisation parameter



Differential decay rate for $B^+ \to K^+\pi^-\pi^+\gamma$ decays:

$$\frac{d\Gamma(B^+ \to K^+\pi^-\pi^+\gamma)}{ds} = |\sum_i c^i_{\mathrm{R}} B^i(s) A^i_{\mathrm{R}}|^2 + |\sum_i c^i_{\mathrm{L}} B^i(s) A^i_{\mathrm{L}}|^2$$

Weak decay amplitude for $B^+ \to K_{res}{}^+{}_R\, \gamma_R$

Propagator for the $K_{res}{}^+$

Strong decay amplitude for $K_{res}{}^+{}_R \to K^+\pi^-\pi^+$

$B^0 \to K^+\pi^-\gamma$ decay as control mode

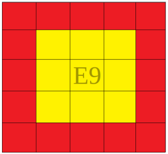
Monte-Carlo data

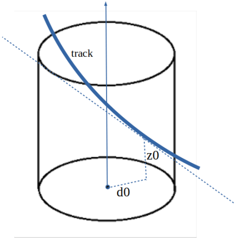
Initial data consists of:

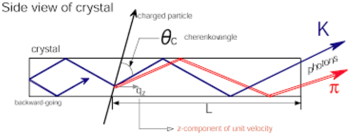
- Training sample consisting of equal amount of:
  1. Signal $B^0 \to K^+\pi^-\gamma$ events;
  2. Background part of generic monte-carlo: $B^+B^-, B^0\bar{B}^0, q\bar{q}, \tau^+\tau^-$
- Validation sample: generic monte-carlo consisting of 100 fb^{-1}

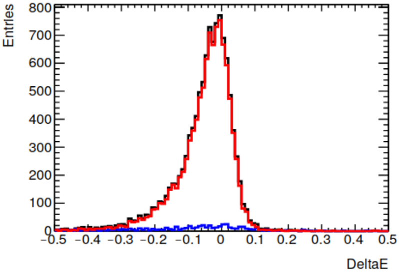
According to estimations 100 fb^{-1} of generic data contains:
$N_{sig} = 2 \cdot \sigma_{\Upsilon(4S)} \cdot L \cdot Br_{B^0\bar{B}^0} \cdot Br_{B^0 \to K^{*0}(K^+\pi^-)\gamma} = 3093$
of $B^0 \to K^{0*}\gamma$ events.

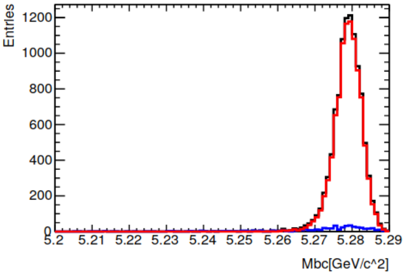
Preselection cuts





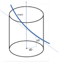
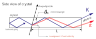
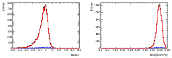






Preselection cuts

Table: Preselection cuts

γ: $clusterE9E25 > 0.95$; $1.8 < E_{\gamma CM} < 3.4\ GeV$	
$p(\chi^2) > 0.001$; $PID > 0.1$; $\lvert d_0 \rvert < 0.5$; $\lvert z0 \rvert < 5$; $p > 0.1\ GeV$;	 
$5.29 > M_{bc} > 5.2\ GeV$ and $-0.2 < \Delta E < 0.1$	
$0.817 < M_{K\pi} < 0.967$ $pdf_{\pi^0} \geq 0$ and $pdf_{\eta} \geq 0$; best candidate selection;	

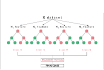
Preselection cuts: Result

After applying above mentioned cuts there are:

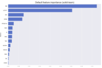
- 988 $B^0 \to K^{0*}\gamma$ events, which corresponds to $\epsilon = 31.9\%$ of signal efficiency;
- 57873 of background events, which corresponds to 99.99 % of background reduction;

Removing non-discriminating variables

while $(\max_f(DATA.correlation) < threshold)$:

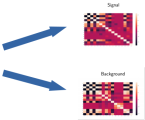


+DATA=



1

DATA



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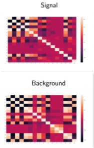
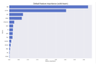


F1,F2

F1,F2+



3

4

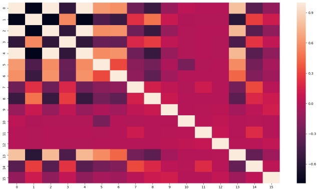
DATA.FEATURES -=

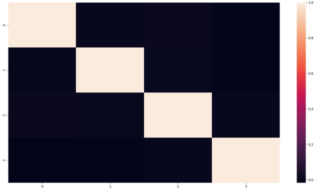
5

Correlation matrices reduction

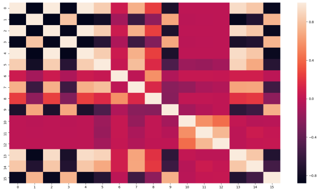
Results of reduction of discriminating variables number from 16 to 5, with decresing correlation to 55 % and decreasing accuracy on nearly 1 %.

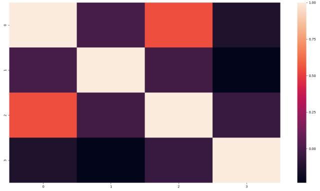
Signal





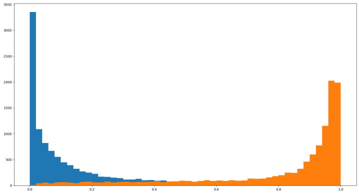
Background



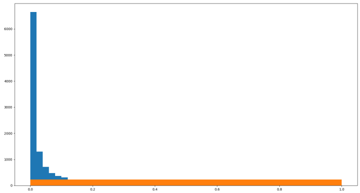


Neural net output

$\mu(y) = \int_0^y y' dy' / \int_0^1 y' dy'$, where y' — coming form distribution, which need to be flatted.



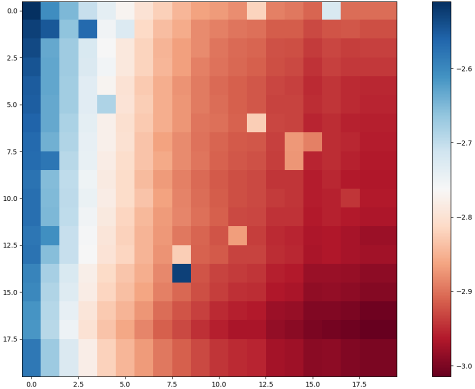
NN output



μ-transform of output

Cutting on $\mu NN > 0.5$ allows to keep 50 % of signal events (495 events) while suppressing 98.77 % of background events.

Optimizing cuts on π^0, η probabilities

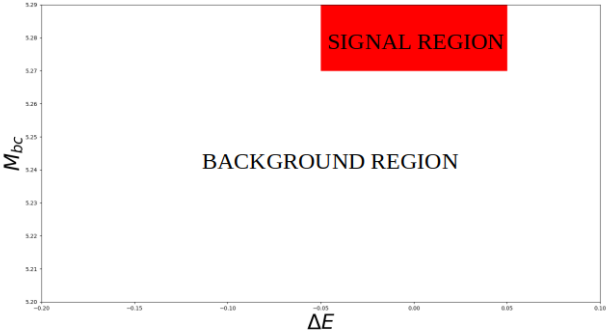


$$\sigma_{sig}/N_{sig} = f(P_{\pi^0}, P_\eta)$$

$P_{\pi^0}^{min} = 0.95$; $P_\eta^{min} = 1$. SIgnal efficiency 96.6 %, background suppression 43 %.

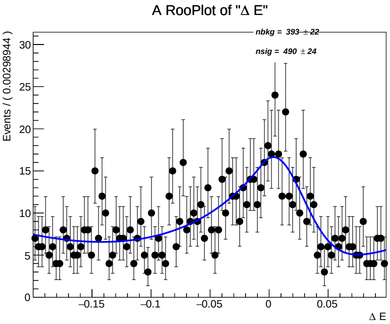
Efficiencies summary table

	preselection	NN cut	π^0, η probs.	total	N_{evt}
S	31.9 %	50 %	96.6 %	15.4 %	478
B	0.01 %	1.23 %	57 %	$7 \cdot 10^{-5}$ %	405

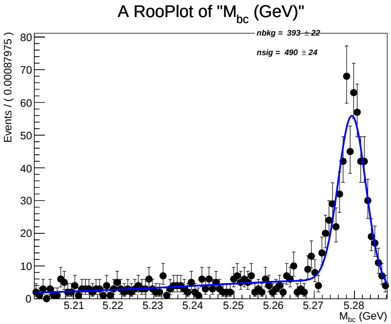


Extended likelihood fit

- Two dimensional data corresponds to M_{bc} and ΔE;
- Model parameters come within the following models: gaussian argus and crystal ball, first order polynomial;. N_{sig} and N_{bgr} are from Poisson distribution;

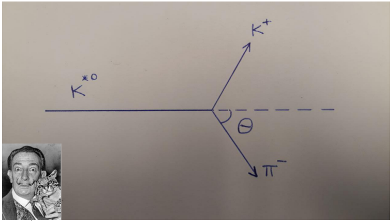


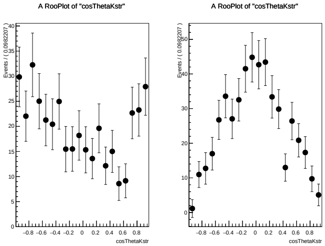
$\Delta E : (2.94 \cdot 10^{-3}; 2.61 \cdot 10^{-2})$



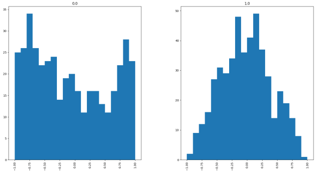
$M_{bc} : (5.2794; 3.4 \cdot 10^{-3})$

$_sPlot$: $\cos\theta_{\pi^-;K^{*0}}$



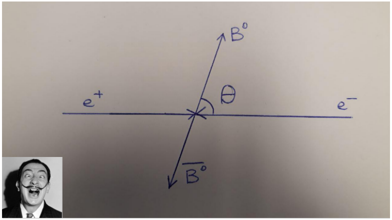


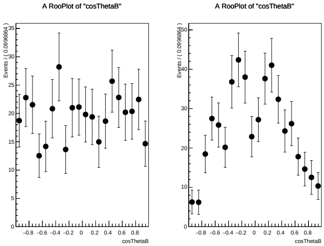
Reconstructed



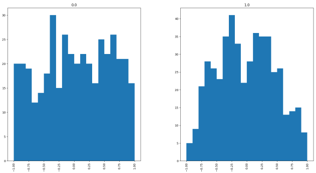
Truth

${}_s$*Plot*: $\cos\theta_{B;e^+e^-}$



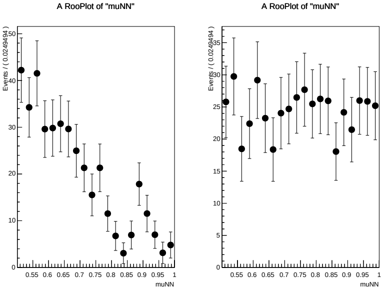


Reconstructed

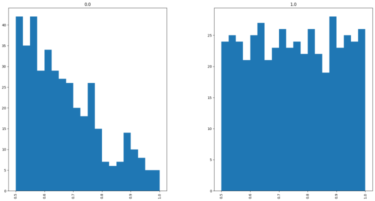


Truth

$_{s}Plot$: μNN



Reconstructed



Truth

Conclusions

In the current work

- Given motivation of studying $B \to K\pi\pi\gamma$ channel;
- Training steps for $B^0 \to K^+\pi^-\gamma$ channel was made;
- Preselection cuts are applied;
- Optimization technique has been implemented;
- Efficiencies estimation has been done;
- Full likelihood fit and $_s\mathit{Plot}$ of monte-carlo data is performed.