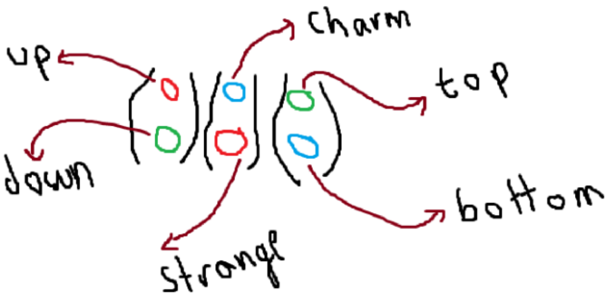
Radiative decays: The photon polarization in $b \to s \gamma$ penguin transitions from $B_s \to \phi\gamma$ at LHCb

Mostafa HOBALLAH

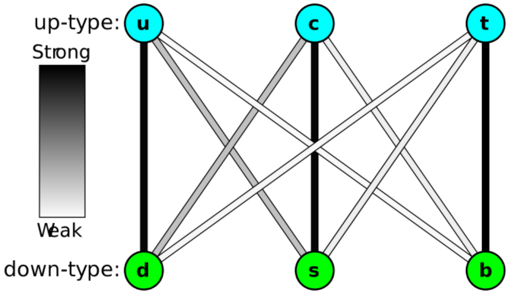
Introduction

- Quarks form 3 isospin doublets:

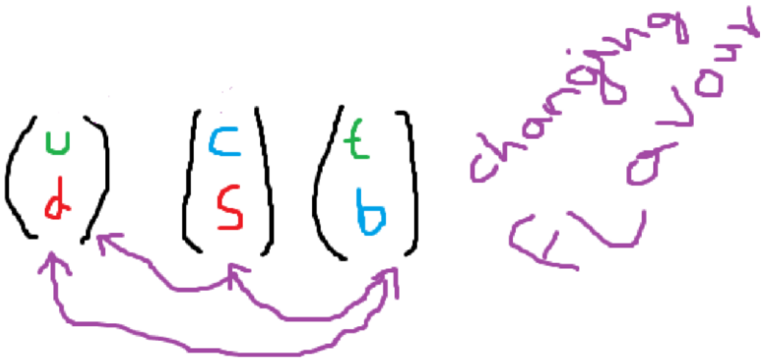


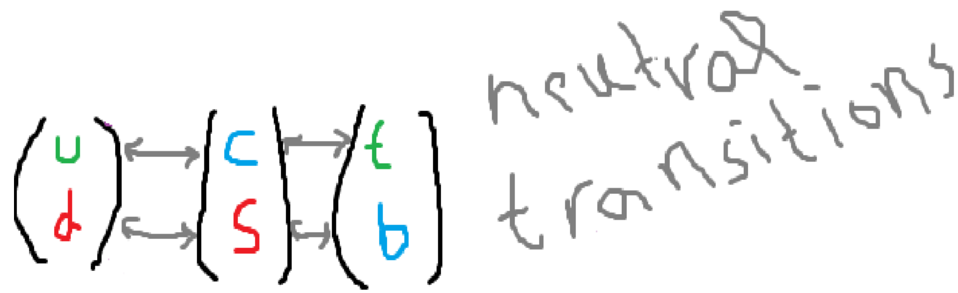
- The CKM matrix:
  - It gives us the strength of the tree level allowed transitions:
    - Only charged transitions are allowed

$$\begin{pmatrix} V_{ub} & V_{cb} & V_{tb} \\ V_{ud} & V_{cd} & V_{td} \\ V_{us} & V_{cs} & V_{ts} \end{pmatrix}$$

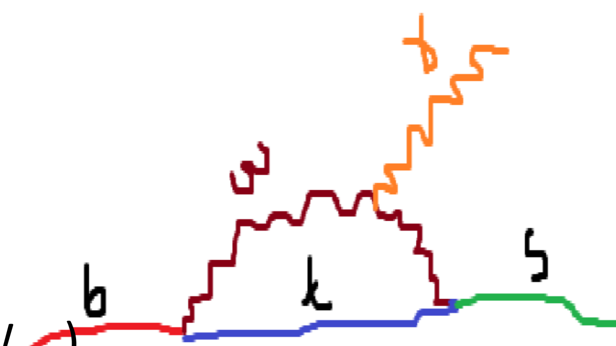


Flavour Changing Neutral Currents(FCNC)





- These currents are not allowed at tree level in the SM
- But we can loop:
- Quantum field theory loops:
  - possible new particles propagating
    - new physics (e.g charged Higgs instead of W …)

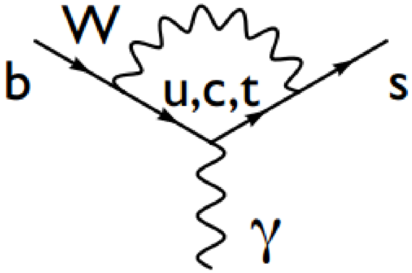


$b \rightarrow s\,\gamma$ FCNC

- A good probe of fundamental properties of SM as well as BSM

W boson couples to left handed quarks ⟷ The photon is left handedly polarized*

- $b \rightarrow s\,\gamma_L$ (left-handed polarization)
- $\bar{b} \rightarrow \bar{s}\,\gamma_R$ (right-handed polarization)



The ratio of right to left handed photons in the SM is of the order of 0.01

* *There is small fraction (ms/mb) of admixture*

How to measure the photon polarization?

- Time dependent decay rate study(B➔$f_{cp}\gamma$)

- B➔Kres(➔Kππ)γ up-down asymmetry
- B→K*ee angular analysis

Photon polarization: $B \to f_{cp}\gamma$ (1)

- In the decay rate, the photon polarization appears through two parameters S and $\mathcal{A}^{\Delta}$:

$$\Gamma_B(t) \propto |A|^2 e^{-\Gamma t}\left[\cosh(\Delta\Gamma t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma t/2) \pm C\cos(\Delta m t) \mp S\sin(\Delta m t)\right]$$

Defining:

$$\tan\psi = \frac{\overline{B} \to f^{CP}\gamma_R}{\overline{B} \to f^{CP}\gamma_L}$$

$$\mathcal{A}^{\Delta} = \sin(2\psi)\cos\phi \qquad S = \sin(2\psi)\sin\phi$$

Where ϕ is the B mixing phase

- Which channel?
- $B_s \to \varphi(K^+K^-)\gamma$
  - $\Delta\Gamma_s$ is not negligible → the dominant term is the sinh → $\mathcal{A}^{\Delta}$ can be measured
  - Doable at LHCb

Photon polarization: $B\to f_{cp}\gamma$ (2)

- Alternatively, we can measure an effective lifetime, fitting a single exponential.

$$\Gamma_{B_s}(t) \propto |A|^2 e^{-\Gamma_s t}\left[\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma_s t/2)\right] = |A|^2 e^{-\Gamma_{B_s\to\phi\gamma} t}$$

- The effective lifetime can be written in terms of $\mathcal{A}^{\Delta}$ as

$$\tau_f = \frac{\int_0^\infty t\langle\Gamma(B_s(t)\to f)\rangle dt}{\int_0^\infty \langle\Gamma(B_s(t)\to f)\rangle dt} = \frac{\tau_{B_s}}{1-y_s^2}\left[\frac{1+2\mathcal{A}^{\Delta}y_s + y_s^2}{1+\mathcal{A}^{\Delta}y_s}\right]$$

Where $y_s = \frac{\Delta\Gamma_s}{2\Gamma_s}$

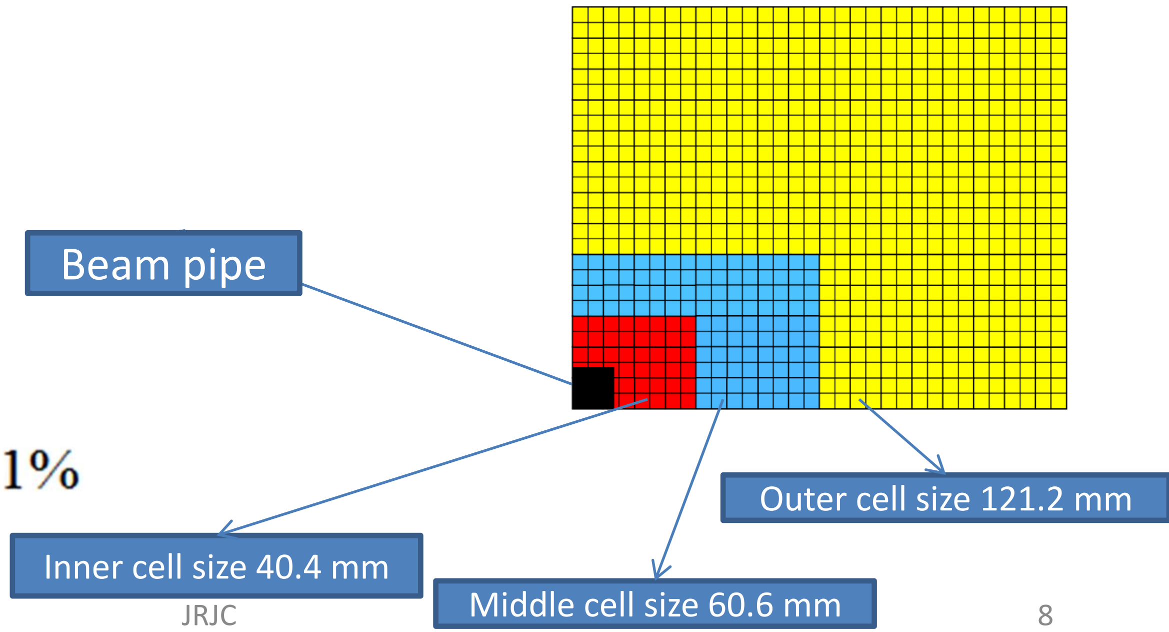
HFAG 2012 values are $\tau_{Bs} = 1/\Gamma_s = 1.503 \pm 0.010$ ps
$\Delta\Gamma_s = 0.091 \pm 0.011$ ps^{-1}

The LHCb calorimeter

- Photons are reconstructed as calorimeter clusters made of 3 x3 calorimeter cells.
- Transverse sizes of ECAL cells are 4x4 cm2 (inner), 6x6 cm2 (middle), 12x12 cm2 (outer).

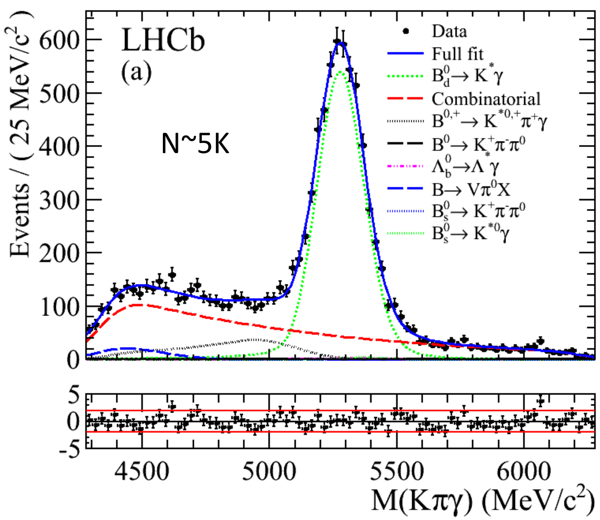
ECAL: $\sigma_E/E = 10\,\% / \sqrt{E} \oplus 1\%$

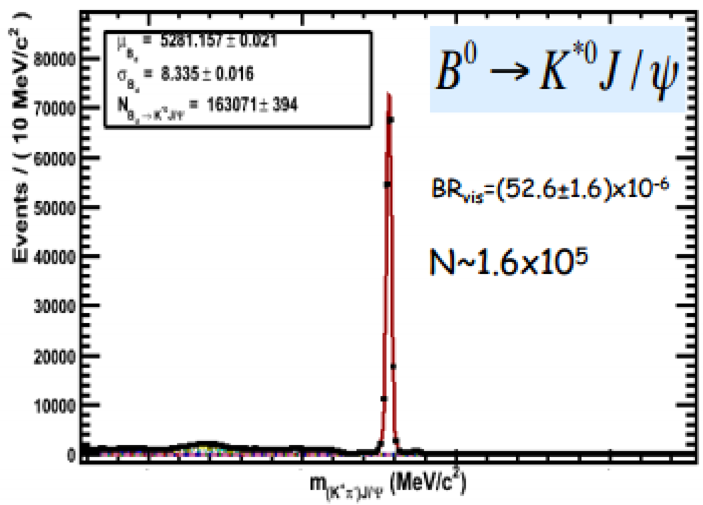
One quarter of the Ecal system



The LHCb calorimeter resolution

- Radiative Decays:
  - The invariant mass resolution is driven by the calorimeter resolution
  - σ_M (B→Vγ) ~ 90 MeV/c2
  - σ_M(B→J/ψV) ≤ 10 MeV/c2





Photon identification

The Photon identification (Motivations)

- The Electronic calorimeter records a lot of energy deposits
  - Very high background level
  - A separation mechanism of photons from other deposits in the calorimeter (neutral pions, electrons and non EM’s) is important

- We have almost 10 photons candidates per event (most of them from π^0)
- And almost 70 cluster per event in the calorimeter

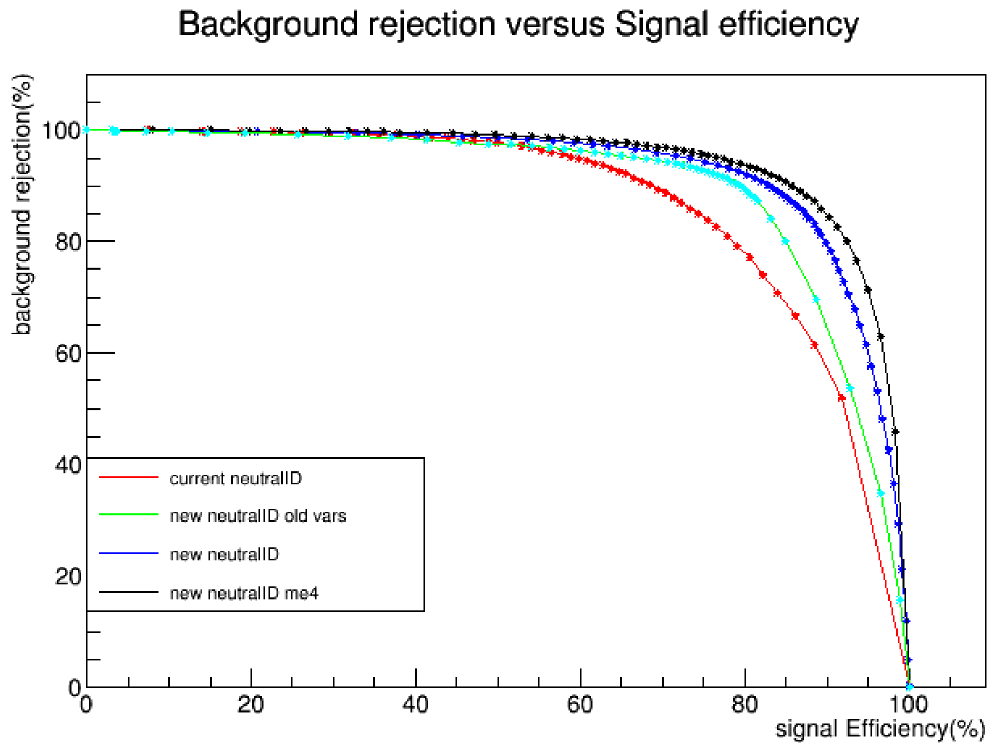
The PhotonID (γ/nonEM, electrons separation)

- We have worked on improving the current photon Identification tool at LHCb

- Use MLP (Multi Layer Perceptron) MVA approach
- Use discriminating variables to the training
  - Mainly variables related to photon cluster info
- Define the signal and background samples as:
  - Signal will be matched true photons
  - background sources will be considered separately:
    - e^- background
    - non EM

New versus current photon ID performance

- For the tool dedicated to non EM backgrounds, we validate its performance, compared to the current photon ID, on an independent sample



On average, there is a 15% improvement in the performance of rejecting non EM backgrounds

•Red is the currently implemented photon ID

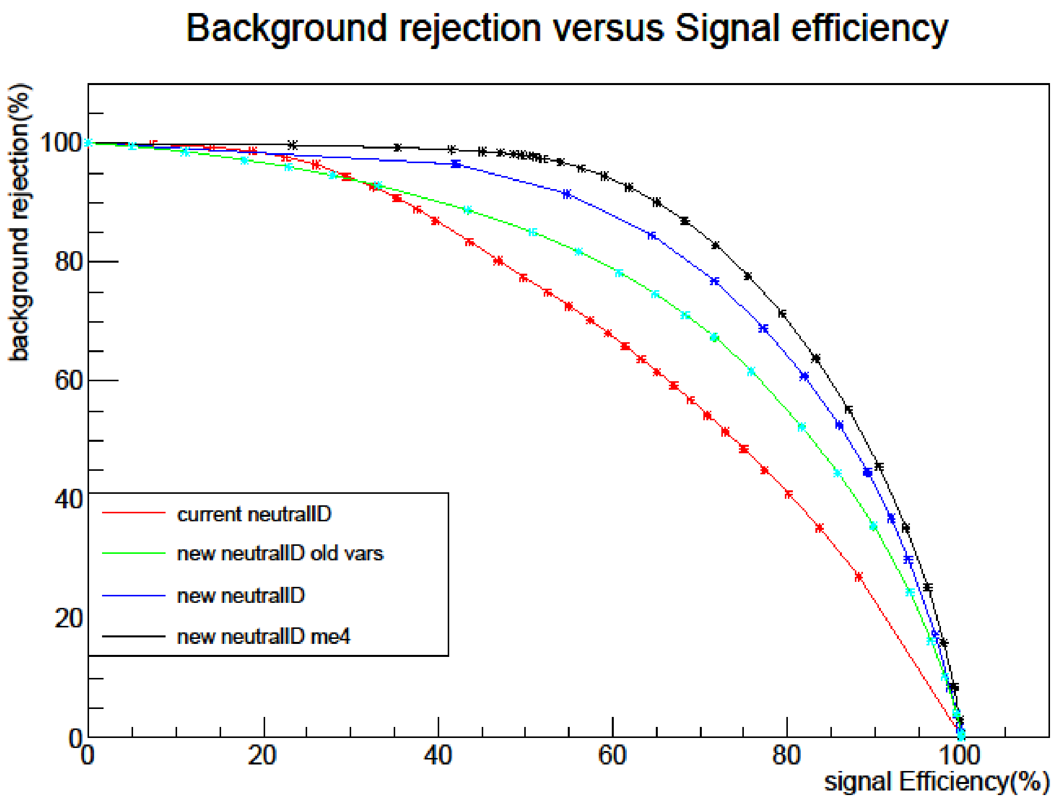
•Light blue is new tool based on the same variables

•Blue is the V0 of the latest developed version

•Black is the V1 with improvement

New versus current photon ID performance

- For the tool dedicated to reject electrons, we validate its performance, compared to the current photon ID, on an independent sample with electron background



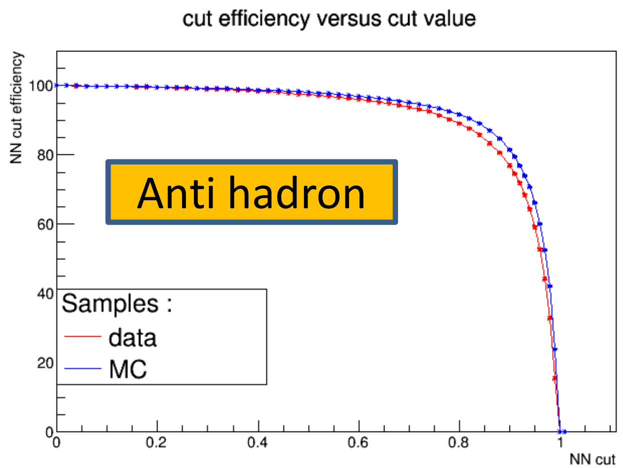
On average, there is a 15~20% improvement in the performance of rejecting electron background

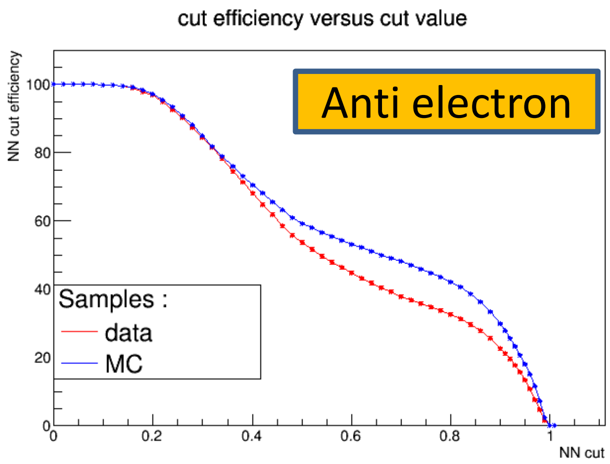
- Red is the currently implemented photon ID
- Light blue is new tool based on the same variables
- Blue is the V0 of the latest developed version
- Black is the V1 with improvement

Checking on data

- It is important to see how these descriminants behave on data :

•Check this on $B \to K^*\gamma$ data (background subtracted)
•Compute the efficiency of different cuts in the NN





•There is a 8% average discrepancy between MC and data
•Calibration tool is being developed
•This photonID tool will be implemented to the LHCb software at the next reprocessing of data

π^0/γ separation

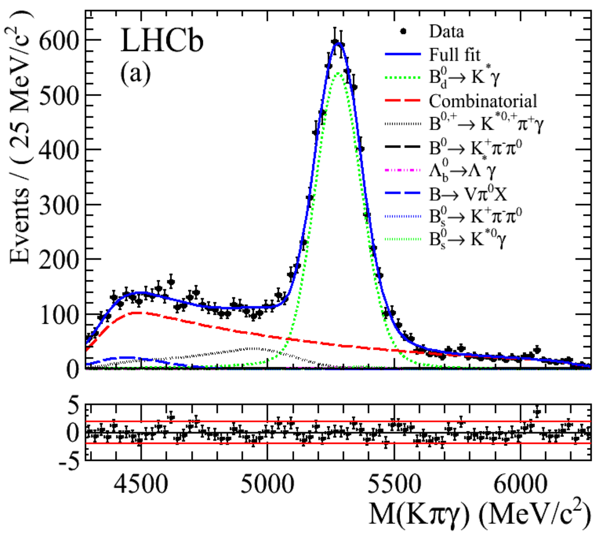
- Neutral pions that have a transverse momentum greater than 2 GeV/c start getting merged.
- A merged π^0 can easily be misidentified as a highly energetic photon inside the calorimeter and is ~50-60% of the *peaking* background in the radiative channels.

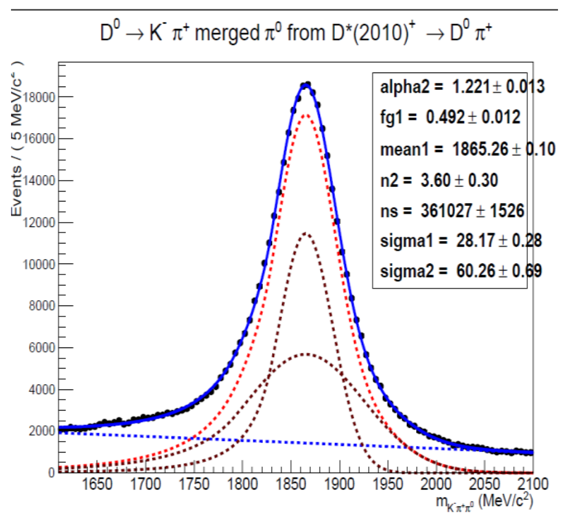
- A tool based on a MLP, good performance but potential data/MC discrepancies

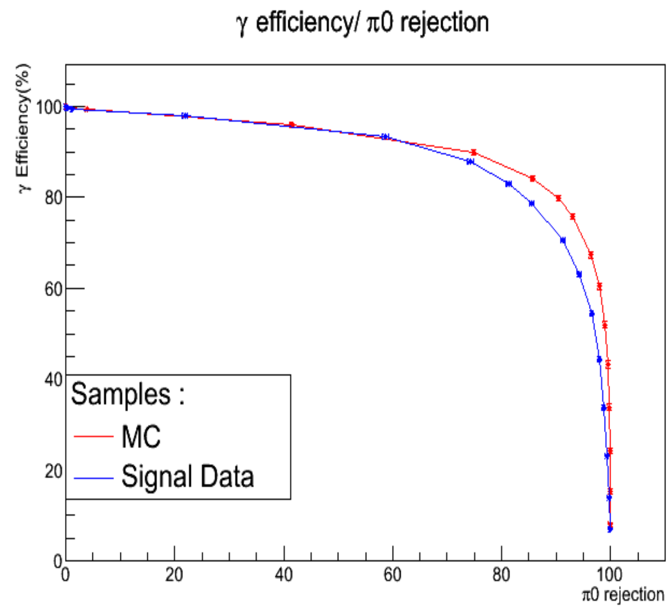
We provide a tool to reweight the MC performance of the γ/π^0 separation variable to reproduce data

π⁰/γ separation

The calibration data samples used are the reconstructed B→K*γ and D⁰→Kππ⁰ from D+→D⁰(Kππ⁰)π+



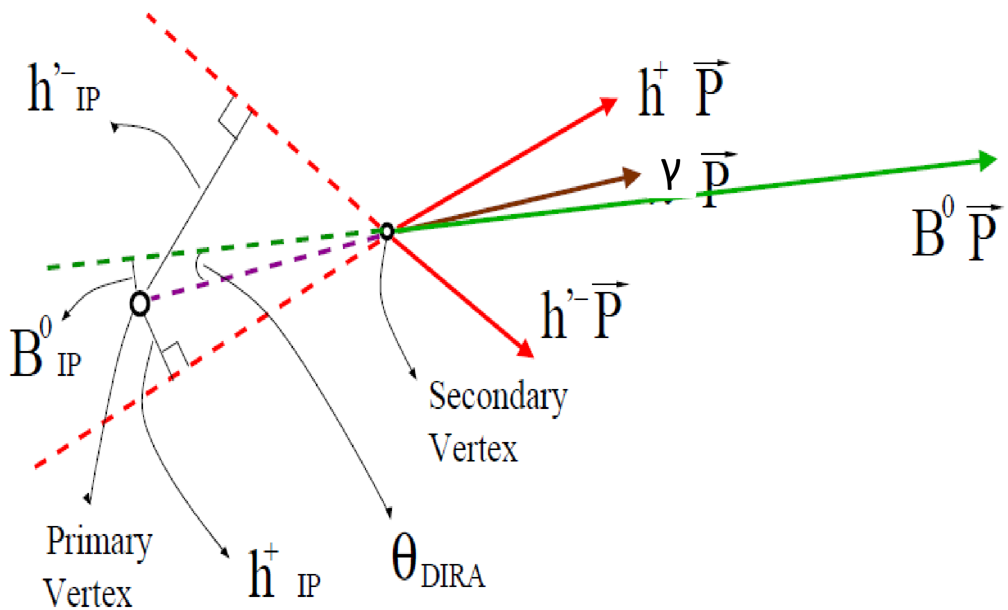




Physics analysis

Generic radiative decay's selection

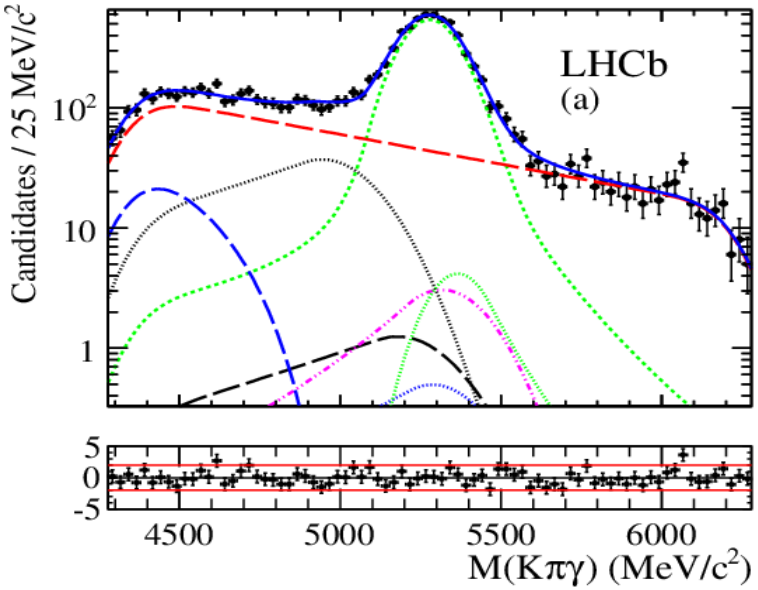
- 2 well-reconstructed tracks (low track χ^2/ndof);
- Tracks not coming from the primary vertex (large IP χ^2);
- Tracks forming a secondary vertex (low end vertex χ^2);
- $B^0_{d,s}$ coming from the primary vertex (low IP χ^2, low θ_{DIRA});
- A B meson decay: decay products with relatively high p_T (because of the high B mass), significant flight distance (high FDχ^2).

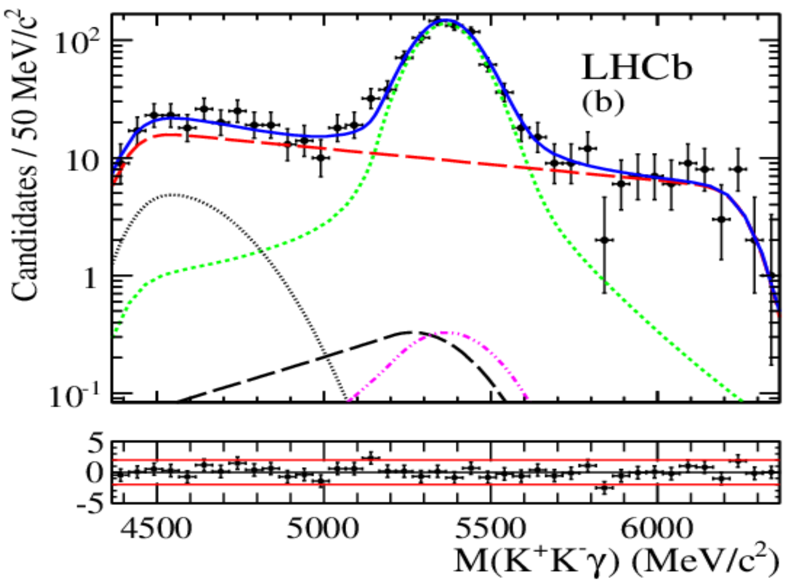


•The B vertex is reconstructed from the charged tracks only

Invariant mass fit

1.0 fb^{-1}of pp collisions of the LHCb data collected in 2011 at $\sqrt{S}$ = 7 TeV





- ~600 $B_s \to \phi\gamma$ events
- ~5K $B \to K^*\gamma$ events

Current world best measurement

$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B_s^0 \to \phi\gamma)} = 1.31 \pm 0.07(\text{stat}) \pm 0.04(\text{syst}) \pm 0.10(f_s/f_d).$$

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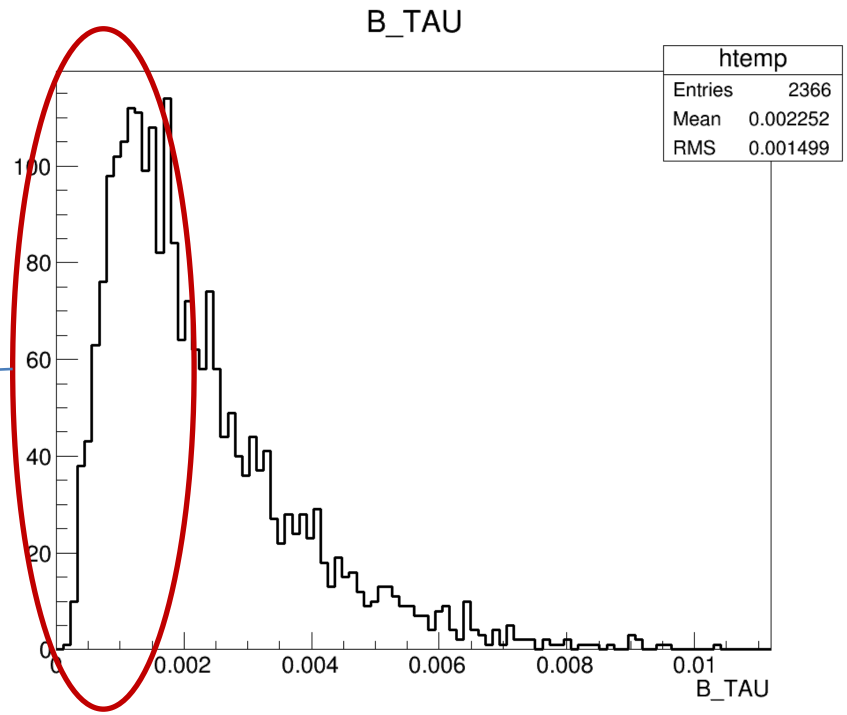
The proper time distribution

Selection acceptance effect



2011 and 2012 data 3/fb

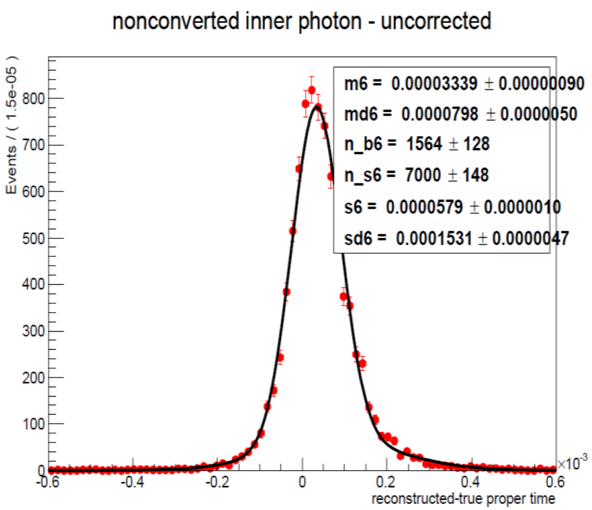
- To fit this we have to:
  - Evaluate accurately the acceptance
  - Determine the decay time resolution and its bias

The Decay time resolution bias

- There is a O(1%) energy bias on photon energy in both MC and data➔ O(0.5%) shift on the B mass
- Post calibration is applied to the mass in the radiative analysis
- Bias could also affect the propertime measurement

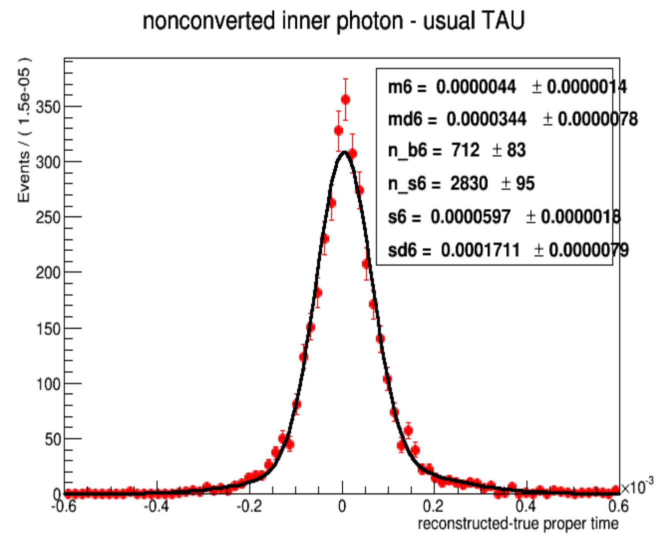
We model the resolution with an Apollonios function

$$\tau_{rec} - \tau_{true}$$



μ=(33.4±1)fs
σ =(58±1)fs

μ=(4.4±1.4)fs
σ =(59.7±1.8)fs



The bias continued…

- The bias has been quantified and reduced with the same correction as applied for the mass and momentum

- There is an order of 5 fs residual bias left which might not be related to photons

- Investigate their effect on the effective lifetime measurement

The proper time acceptance

- To evaluate it, we may use:
  - MC $B_s \rightarrow \phi\gamma$: we do not have same distribution as in data!
  - Data $B_d \rightarrow K^*\gamma$: not possible due to different vertex resolution
  - $B_s \rightarrow J/\psi\phi$ data omitting the J/ψ from the vertex (treating it as being a photon)- will explain in the next slides

Using the $Bs \to J/\psi\varphi$

- The main goal:
  - $B_s \to J/\psi\phi$ ➔ acceptance ➔ $B_s \to \phi\gamma$
- Why?
  - $B_s \to \phi\gamma$ ➔ 2K events in 3 /fb
  - $B_s \to J/\psi\phi$ ➔ factor 10 more statistics
    - Acurate evaluation of the acceptance
- To do first:
  - Validate the method

The roadmap

- First we have to work with the $B_d \to J/\psi\ K^*$ and $B_d \to K^*\gamma$
  - Acceptance $B_d \to J/\psi\ K^*$ = Acceptance $B_d \to K^*\gamma$

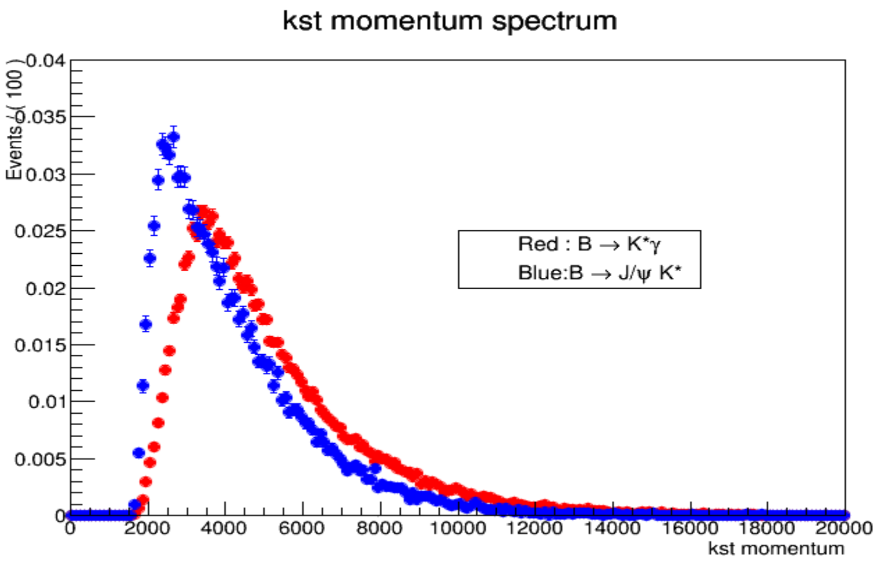
➔ The method works

  - Move to $B_s \to J/\psi\varphi$ and extract the acceptance for $B_s \to \varphi\gamma$

Selection

- Trigger and selection:
  - We should use that of K*γ (for J/ψ K*) with caution
    - Different cuts for J/ψ and γ

The momentum spectrum of the K*



Acceptance from MC (1/)

- The used fit:

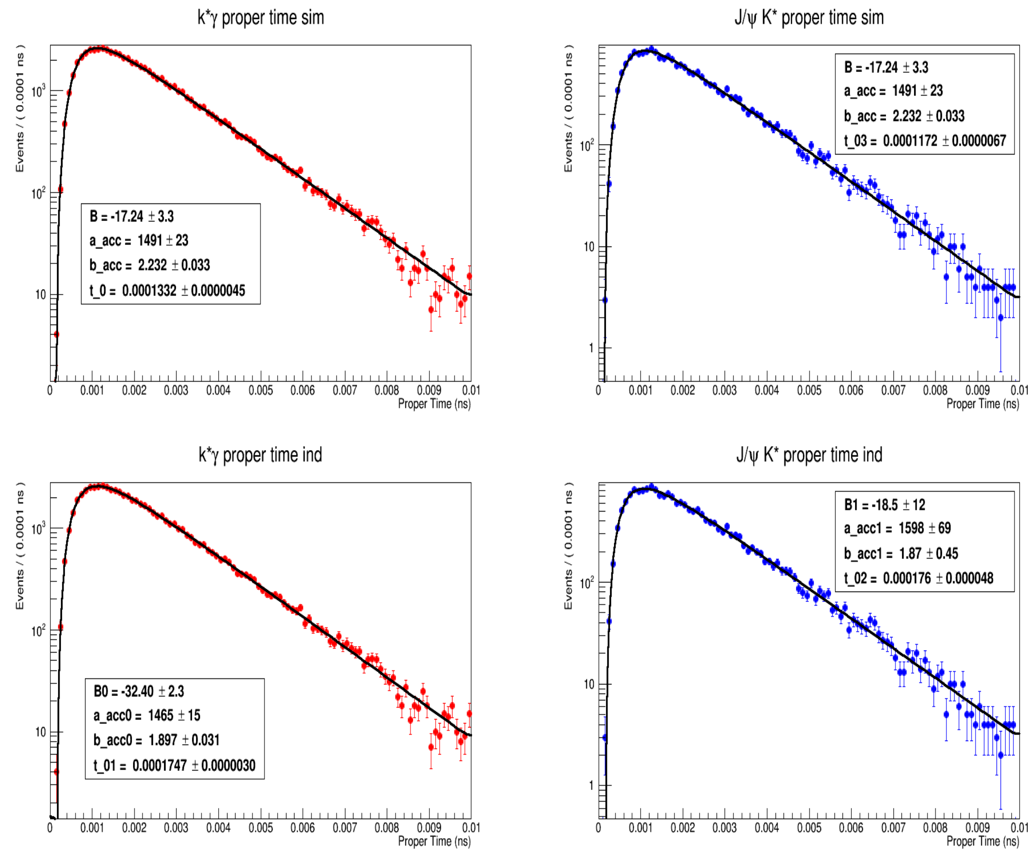
$$F(t) = \varepsilon(t) \times e^{\frac{-t}{\tau}} * A(t)$$

$$\varepsilon(t) = \exp\left[B \times t\right] \times \frac{(a \times t)^b}{1 + (a \times t)^b}$$

  - Where ε(t) is the acceptance function, A(t) is a resolution function
  - The lifetime τ is fixed in the fit to the PDG value

Acceptance from MC (2/)

- The Bd→K*γ and Bd→J/ψ K* acceptance



- Chi2=28 with 3 dof

Reweighting for the acceptance

- For now: acceptance $Bd \to K^*\gamma \neq Bd \to J/\psi\ K^*$
  - Maybe due to kinematical differences

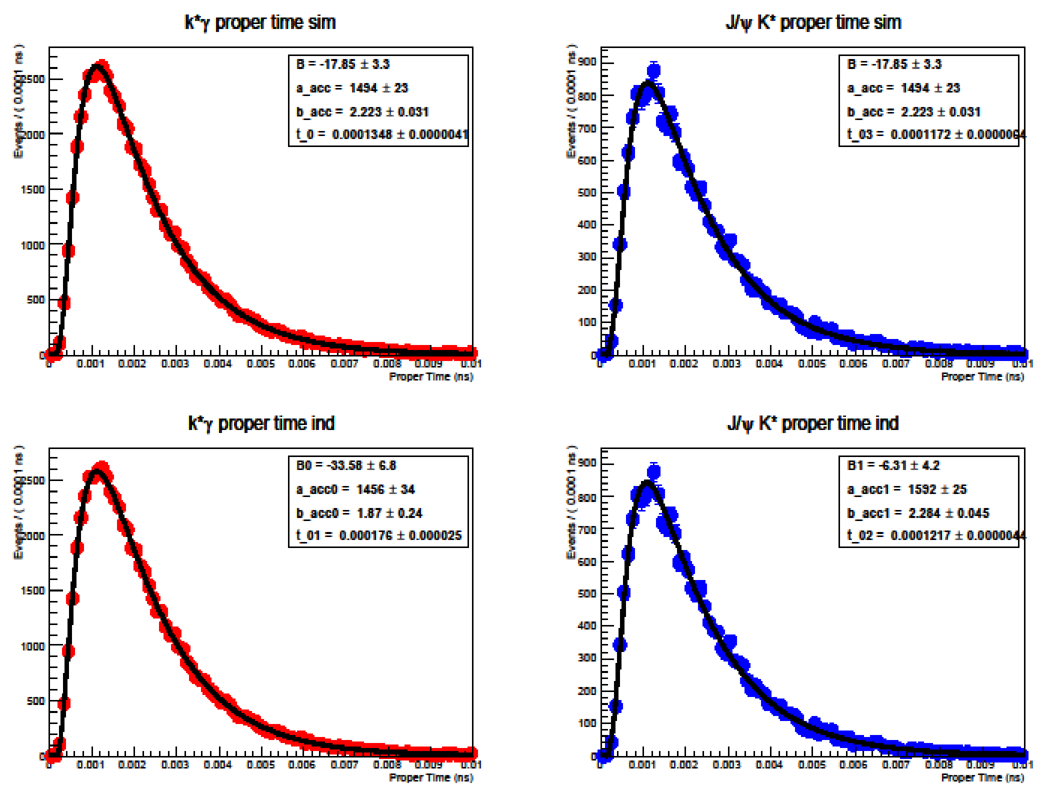
- Reweight the K* momentum distribution in $Bd \to J/\psi\ K^*$ with that in $Bd \to K^*\gamma$

- And other Variables:
  - The asymmetry between the momentum of the charged tracks
  - The opening angle

Acceptance from MC (3/)

- The Bd→K*γ and Bd→J/ψ K* acceptance
- Reweighted with the opening angle between the two tracks

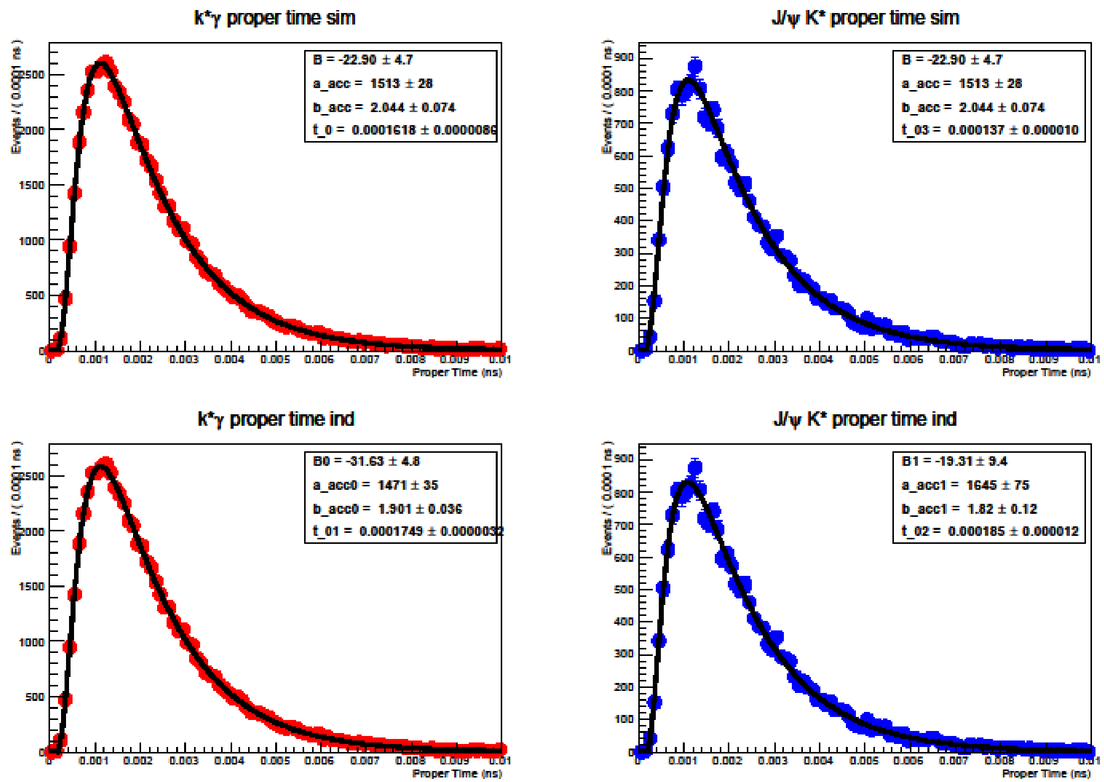
- Chi2=28.4 with 3 dof



Acceptance from MC (4/)

- The Bd→K*γ and Bd→J/ψ K* acceptance
- Reweighting with the K* transverse momentum

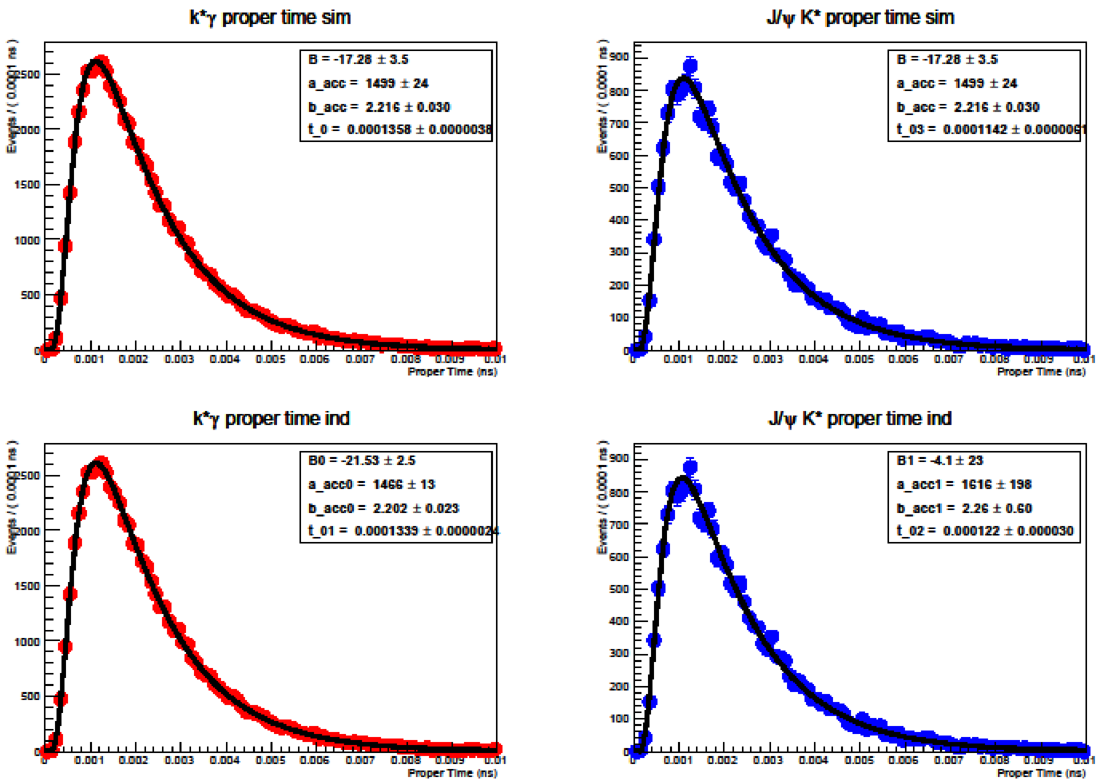
- Chi2=18.7 with 3 dof



Acceptance from MC (5/)

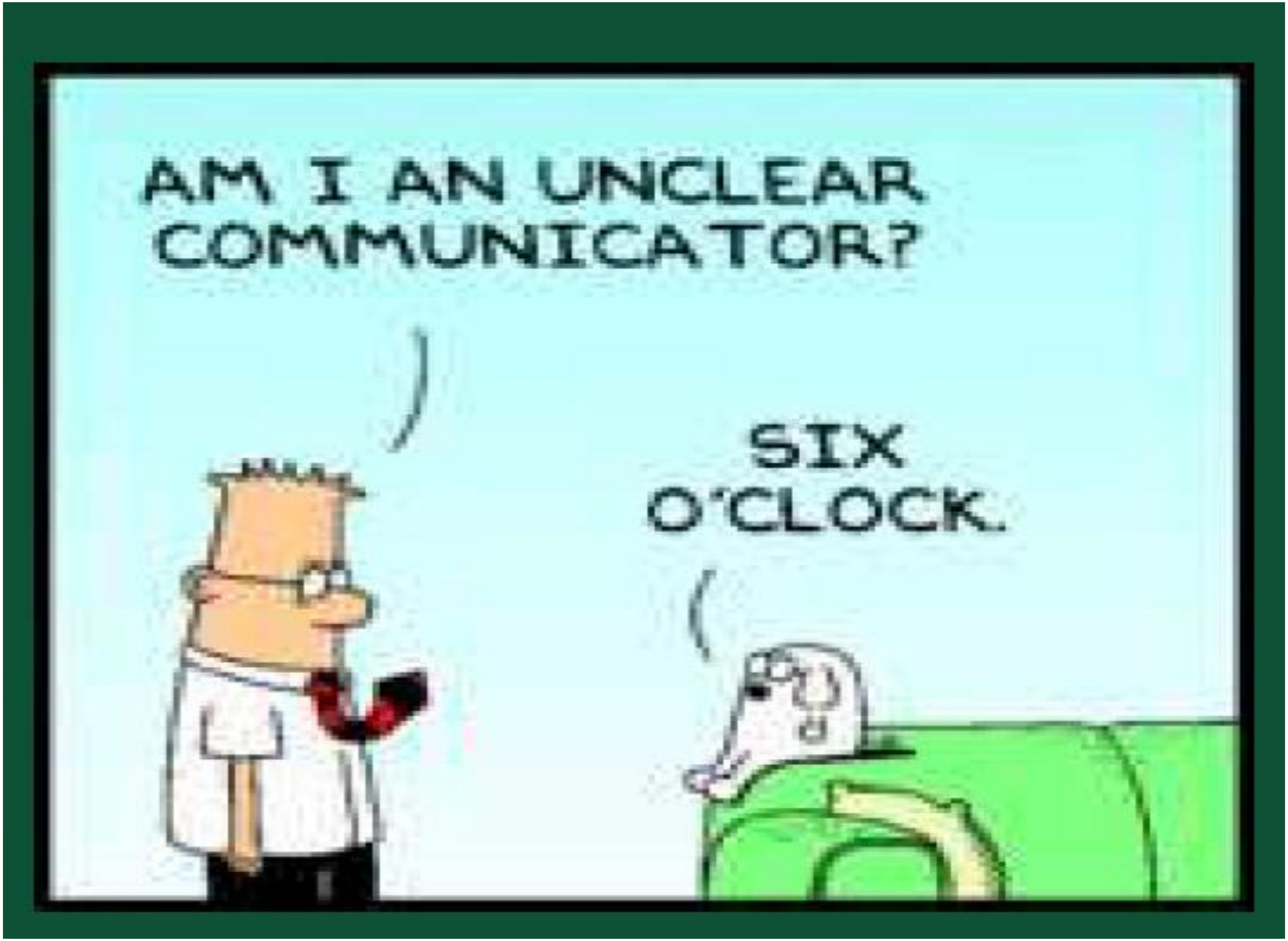
- The Bd→K*γ and Bd→J/ψ K* acceptance
- Reweighting with the P asymmetry

- Chi2=6.7 with 3 dof



Conclusions and perspectives

- The measurement of the photon polarization in $B_s \to \phi\gamma$ is the only key measurement at LHCb that has not been done yet
  - Very tough analysis that we aim to do
- In the quest to do this analysis we have:
  - Developed a new photon identification tool
  - Provide the calibration for the π^0/γ separation tool
- The physics analysis is ongoing and many proper time acceptance evaluation methods are under study
- This analysis is scheduled for the summer of 2014
  - Stay tuned!

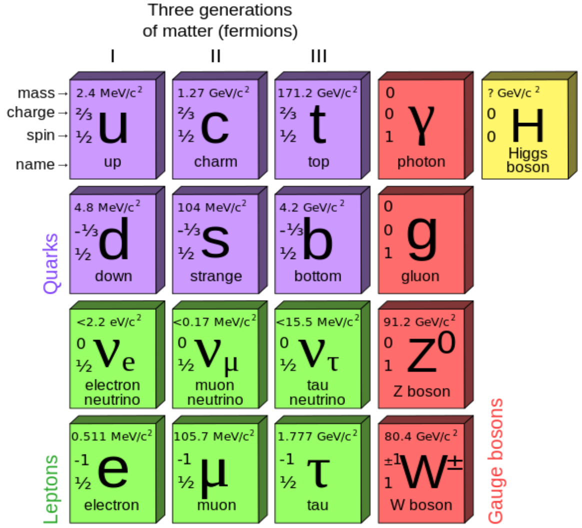

AM I AN UNCLEAR COMMUNICATOR?
SIX O'CLOCK.

Backups

Introduction

- The Standard Model of particle physics describes our understanding of the fundamental interactions

The elementary particles



Photon polarization: $B \to f_{cp}\gamma$ (1)

- In the decay rate, the photon polarization appears through two parameters S and $\mathcal{A}^{\Delta}$:

$$\Gamma_B(t) \propto |A|^2 e^{-\Gamma t}\left[\cosh(\Delta\Gamma t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma t/2) \pm C\cos(\Delta m t) \mp S\sin(\Delta m t)\right]$$

Defining:

$$\tan\psi = \frac{\overline{B} \to f^{CP}\gamma_R}{\overline{B} \to f^{CP}\gamma_L}$$

$$\mathcal{A}^{\Delta} = \sin(2\psi)\cos\phi \qquad S = \sin(2\psi)\sin\phi$$

Where ϕ is the B mixing phase

- Which channels?
- $B_d \to K^*(K_s\pi^0)\gamma$
  - $\Delta\Gamma \sim 0$ → the sinh term cancels and we have only acces to S
  - Done at Babar but not possible at LHCb S= $0.9 \pm 1.0 \pm 0.2$ (Babar, $1.1\,\text{GeV} < m_{K_S\pi^0} < 1.8\,\text{GeV}$)
- $B_s \to \phi(K+K-)\gamma$
  - $\Delta\Gamma_s$ is not negligible → the dominant term is the sinh → $\mathcal{A}^{\Delta}$ can be measured
  - Doable at LHCb

Photon polarization: $B \to f_{cp}\gamma$ (1)

- Assuming that the partial rates of B_s and B_s-bar are equal, the terms with C and S cancel in the addition of the two decay rates. Or considering C~0 and ϕ~0 in SM ($\Gamma_{Bs} = \Gamma_{\overline{Bs}}$, no flavour tagging required).

$$\Gamma_{B_s}(t) \propto |A|^2 e^{-\Gamma_s t}\left[\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma_s t/2)\right]$$

To fit $\mathcal{A}^{\Delta}$, we need as input Γ_s (= τ_s^{-1}) and $\Delta\Gamma_s$

- Alternatively, we can measure an effective lifetime, fitting a single exponential.

$$\Gamma_{B_s}(t) \propto |A|^2 e^{-\Gamma_s t}\left[\cosh(\Delta\Gamma_s t/2) - \mathcal{A}^{\Delta}\sinh(\Delta\Gamma_s t/2)\right] = |A|^2 e^{-\Gamma_{B_s \to \phi\gamma} t}$$

- The effective lifetime can be written in terms of $\mathcal{A}^{\Delta}$ as

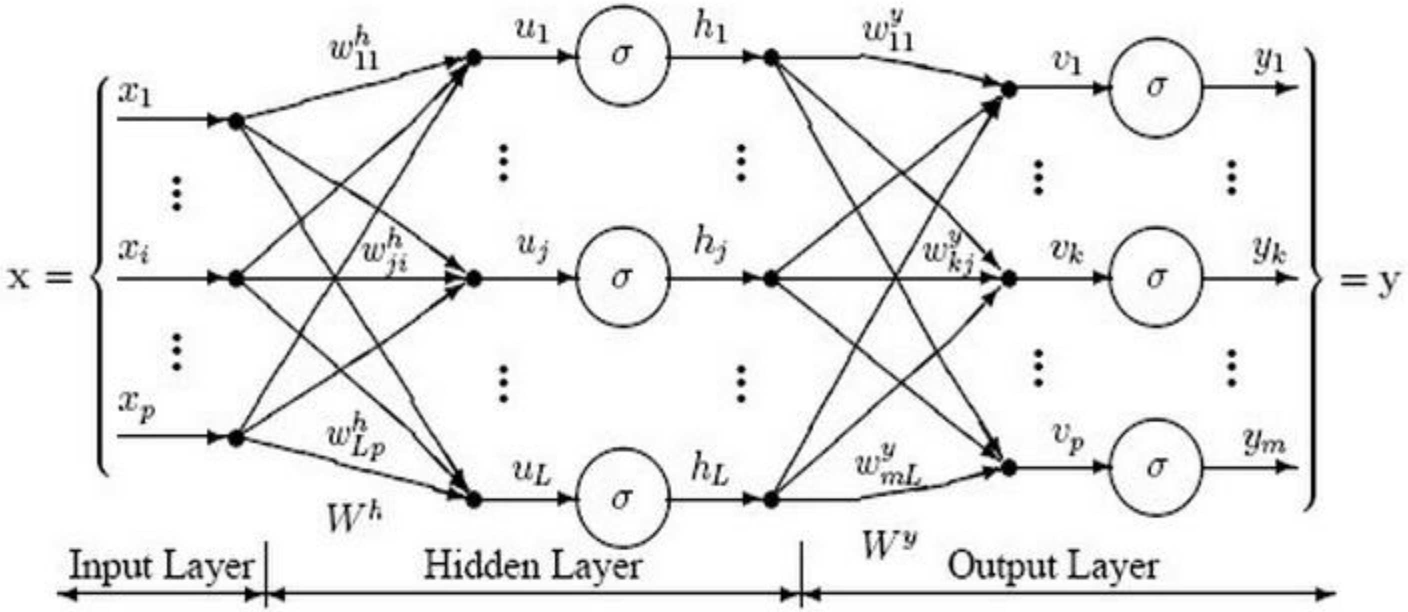
$$\tau_f = \frac{\int_0^{\infty} t\langle\Gamma(B_s(t)\to f)\rangle dt}{\int_0^{\infty}\langle\Gamma(B_s(t)\to f)\rangle dt} = \frac{\tau_{B_s}}{1-y_s^2}\left[\frac{1+2\mathcal{A}^{\Delta}y_s + y_s^2}{1+\mathcal{A}^{\Delta}y_s}\right]$$

Where $y_s = \frac{\Delta\Gamma_s}{2\Gamma_s}$

HFAG 2012 values are $\tau_{Bs} = 1/\Gamma_s = 1.503 \pm 0.010$ ps
$\Delta\Gamma_s = 0.091 \pm 0.011$ ps^{-1}

Neural Nets

- Should be in the backups!



Input variables(move to backups??)

- The variables used in the training are:
- From the current method variables:

2 dimensional Chi2 of the cluster	**Prs energy**

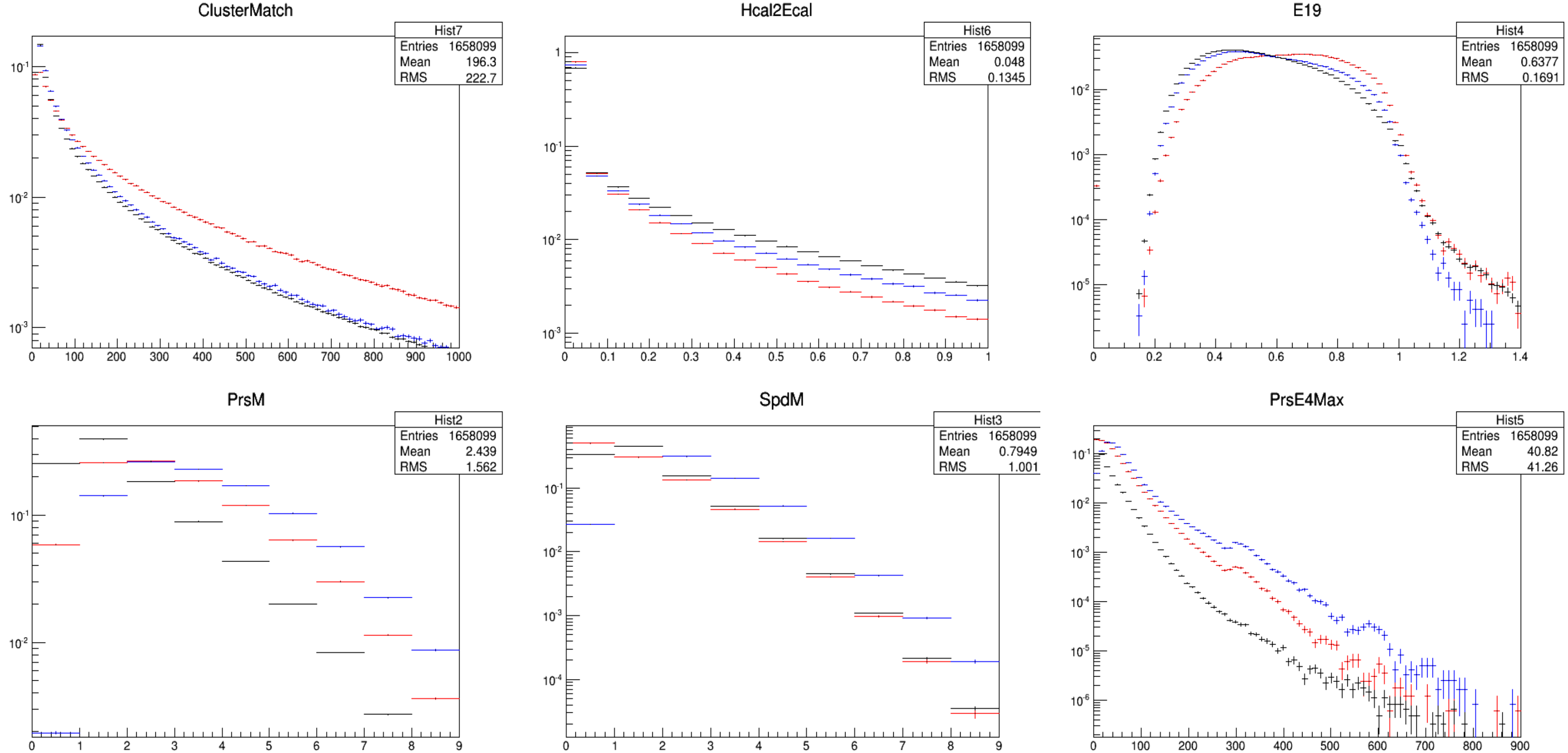
- New variables:

Cell energy/cluster energy (Ecal)	Prs multiplicity	Hcal/Ecal energy
Cluster spread	Cell energy/cluster energy (prs)	2X2 Prs cells with highest energy deposit

Spd multiplicity

Input variables (move to backups??)

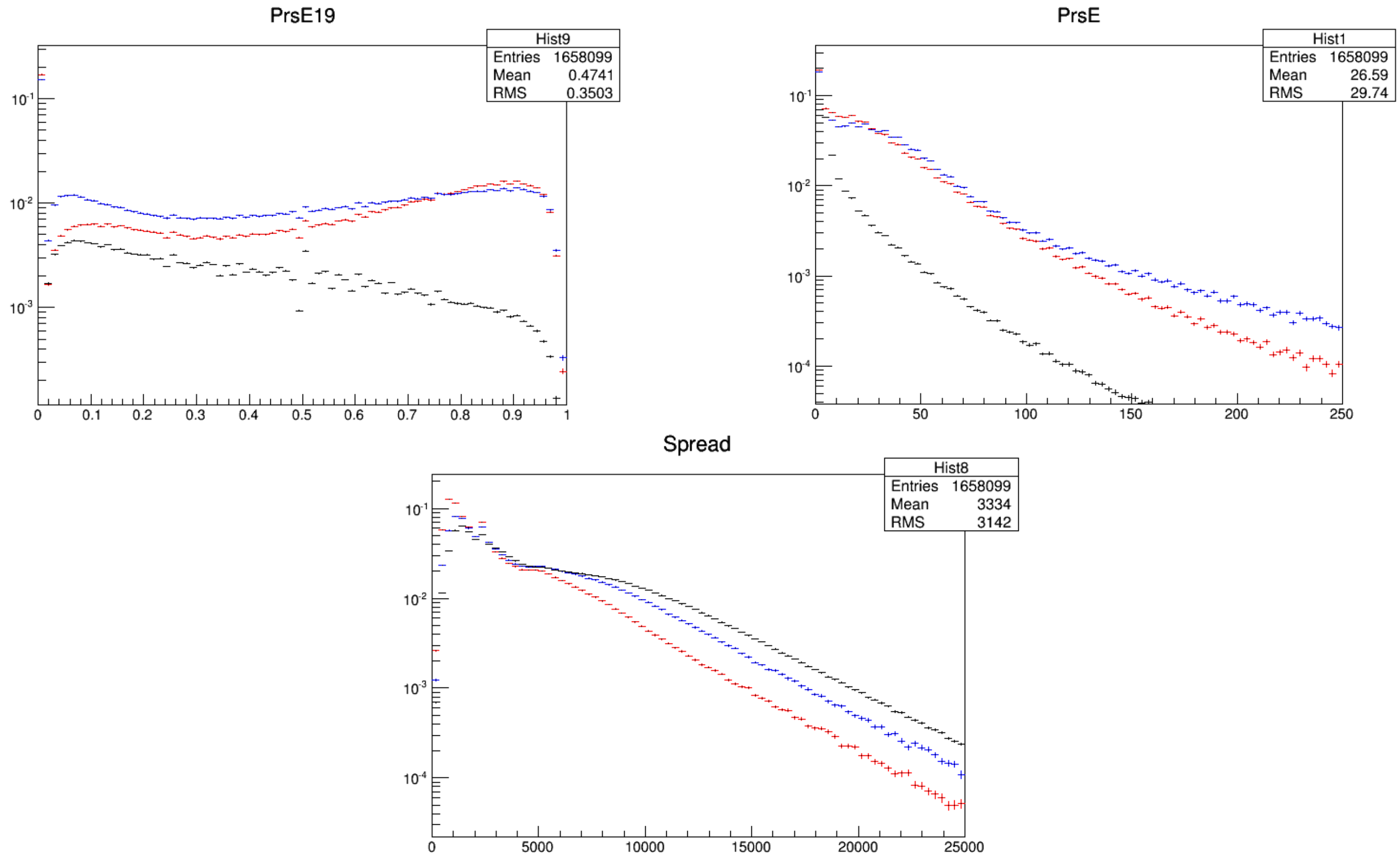
- The distribution of input variables



Red: photons | **Blue: electrons** | **Black: non EM**

Input variables (move to backups??)

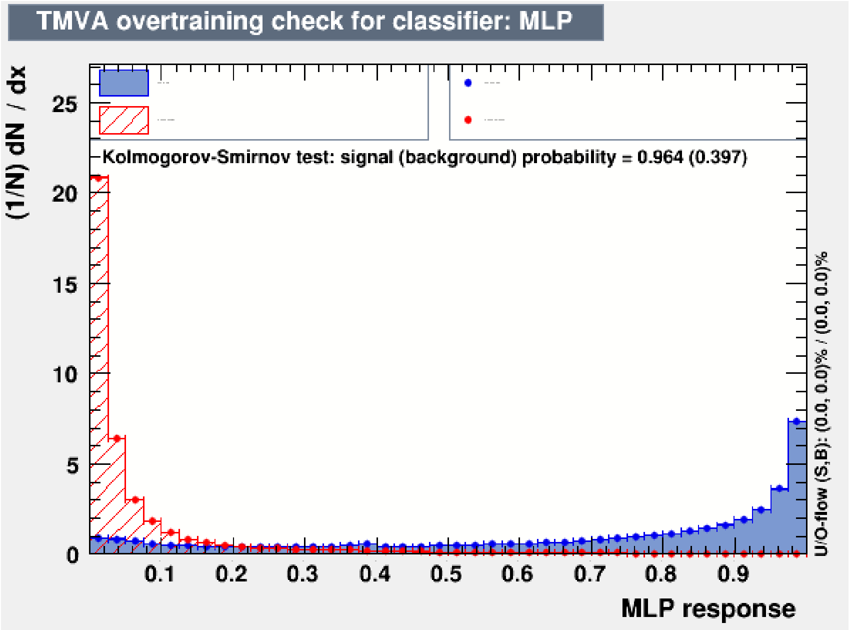
- The distribution of input variables

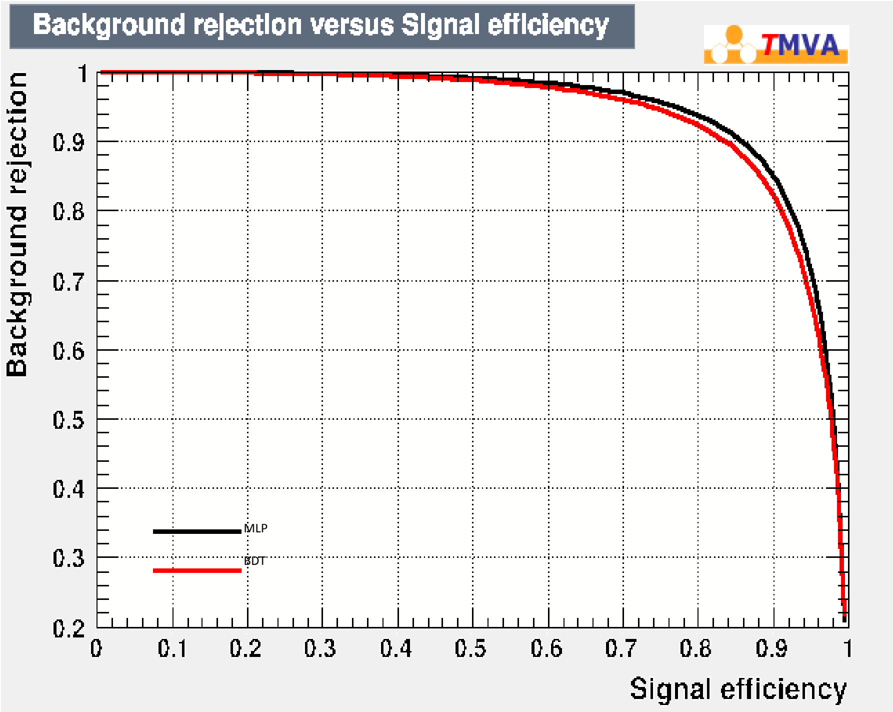


Red: photons | **Blue: electrons** | **Black: non EM**

Dedicated tool for non EM cluster rejection

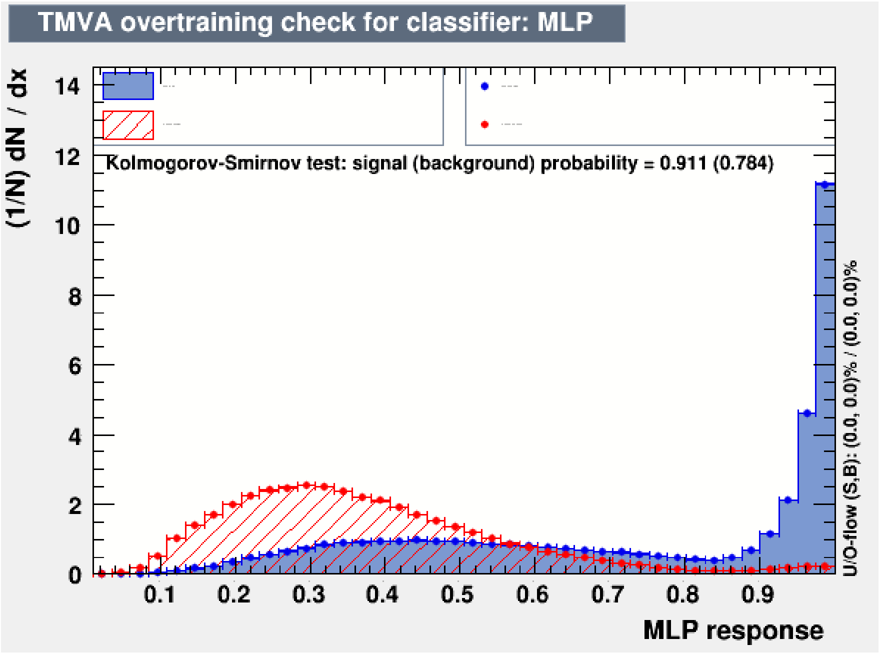
- Train on non EM background
- We use MC for training

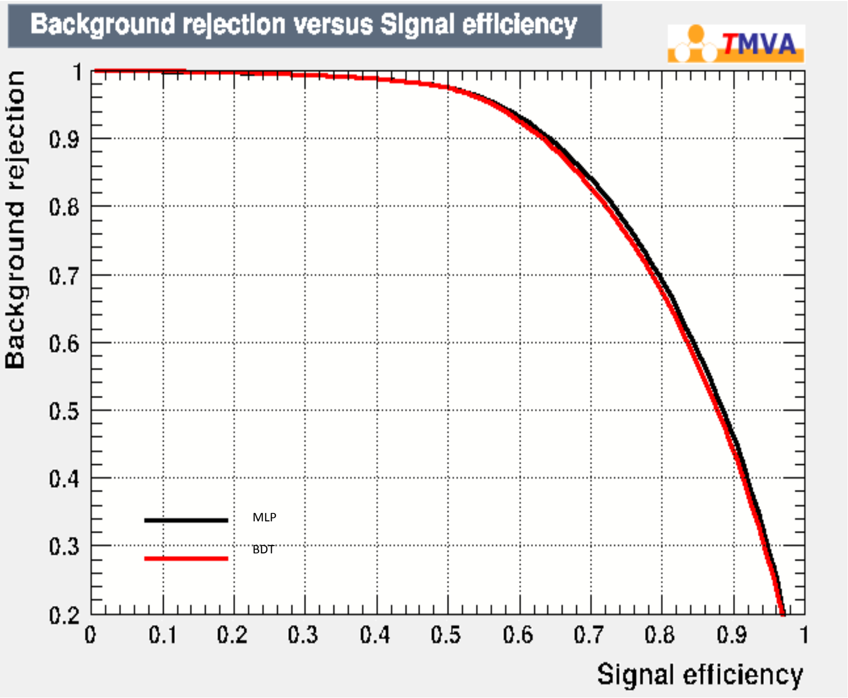




A dedicated tool for electron cluster rejection

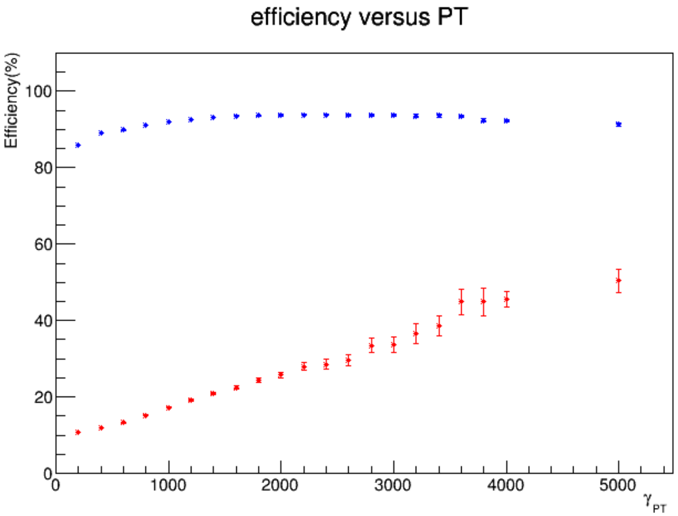
- Train on electron background
- MC is used for training





Efficiency versus PT (move to backups??)

- The efficiency versus photon PT for this tool non EM :

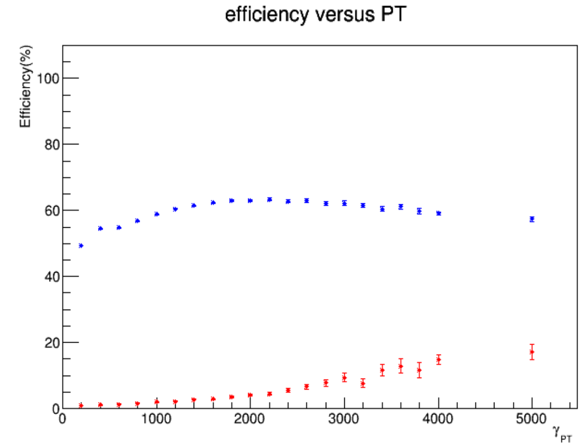


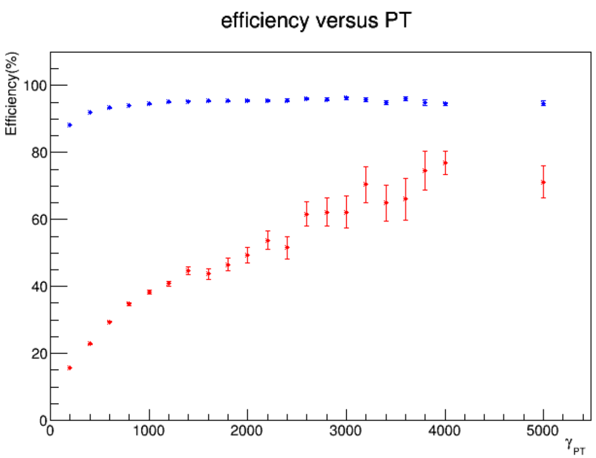
Cut is at 0.2 in the NN

Bins of 200 MeV turns to 1GeV after 4GeV and after 5GeV one bin

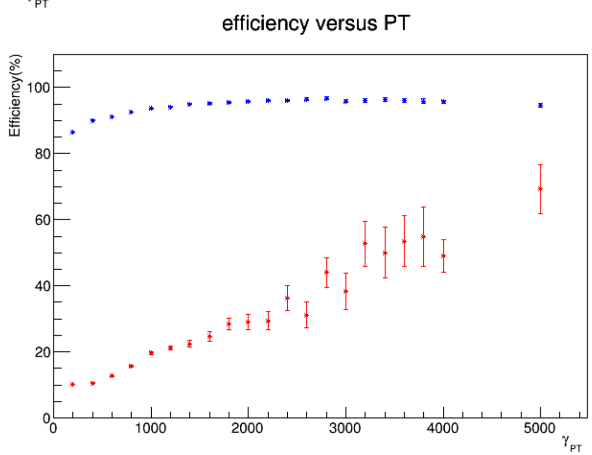
Blue:signal efficiency
Red: bkg efficiency

0.8

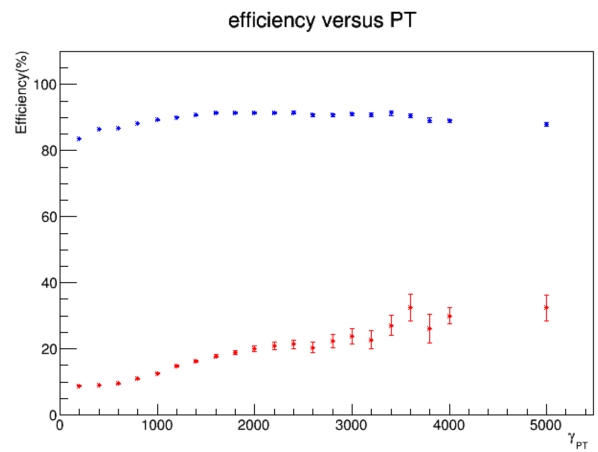




Inner



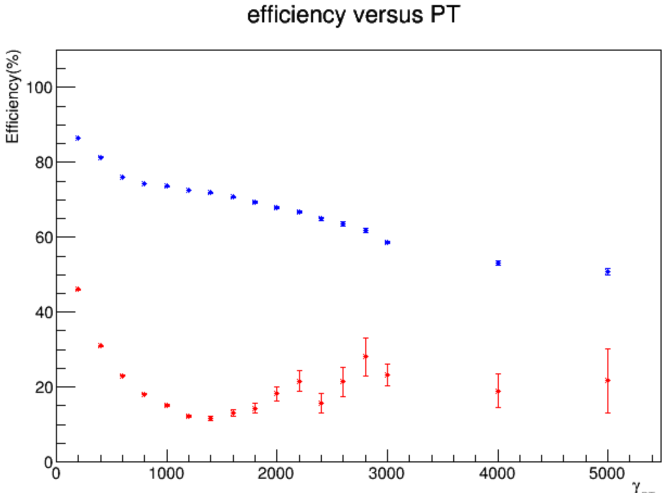
Middle



Outer

Efficiency versus PT (move to backups??)

- The efficiency versus gamma_PT for this tool (E tool) :

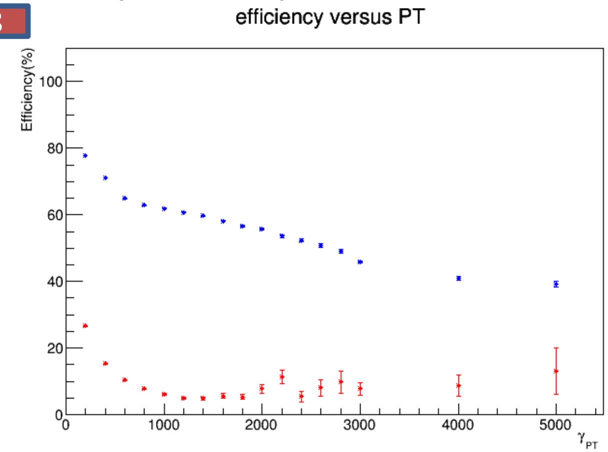


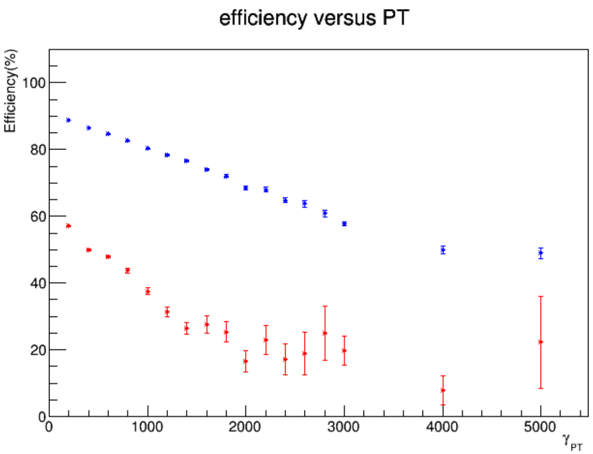
Cut is at 0.4 in the NN

Bins of 200 MeV turns to 1GeV after 3GeV and after 5GeV one bin

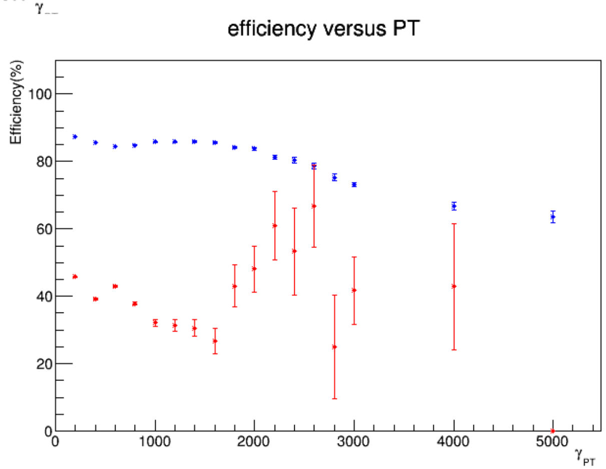
Blue:signal efficiency
Red: bkg efficiency

0.8

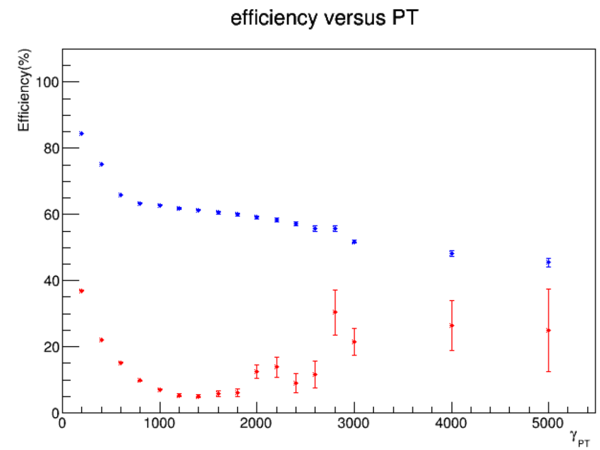




Inner

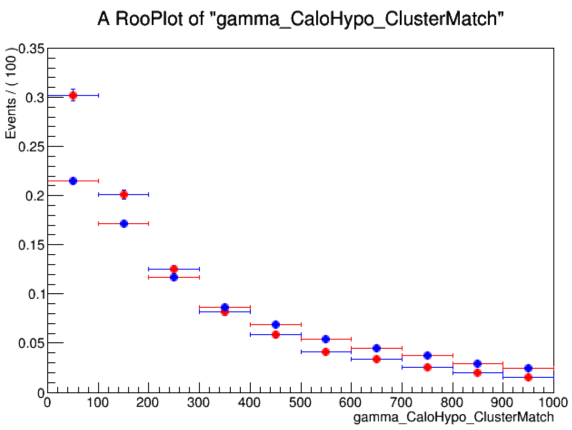


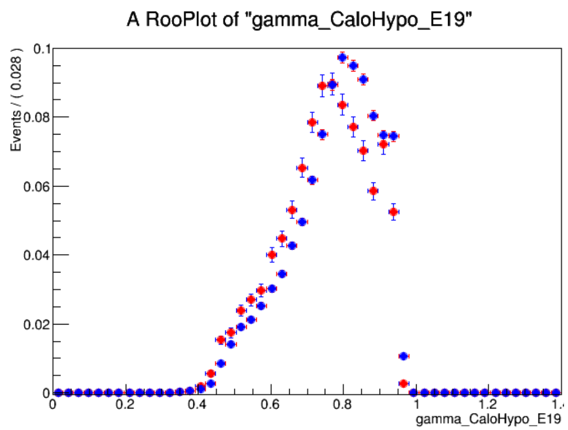
Middle

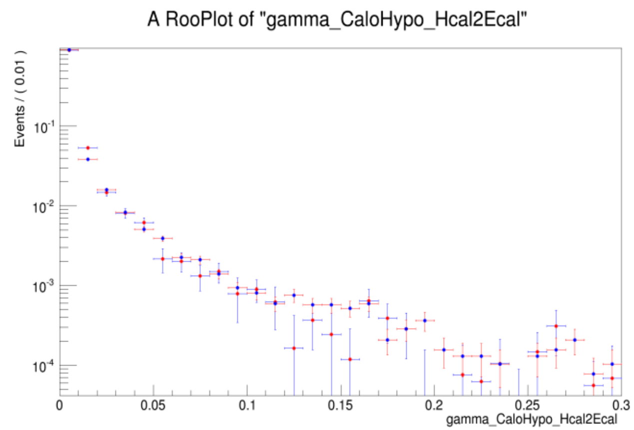


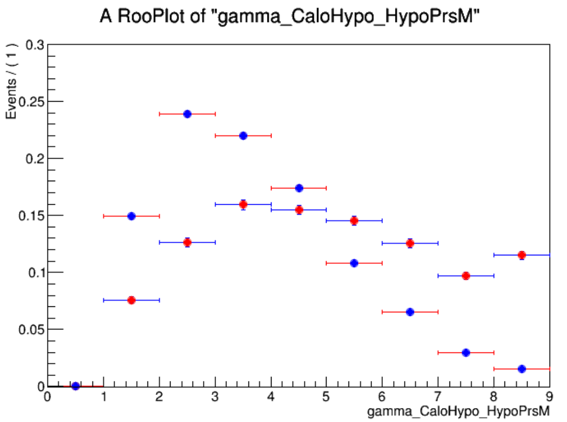
Outer

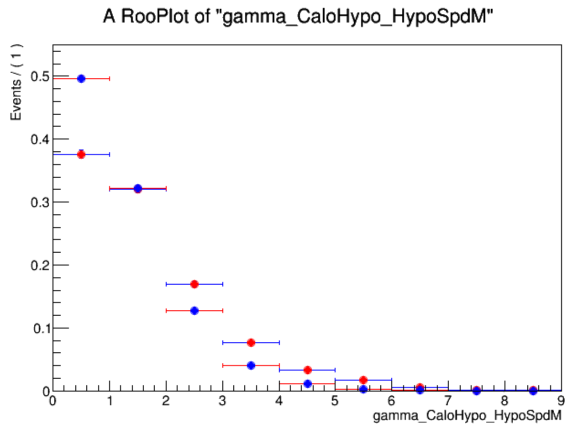
The input variables discrepancies

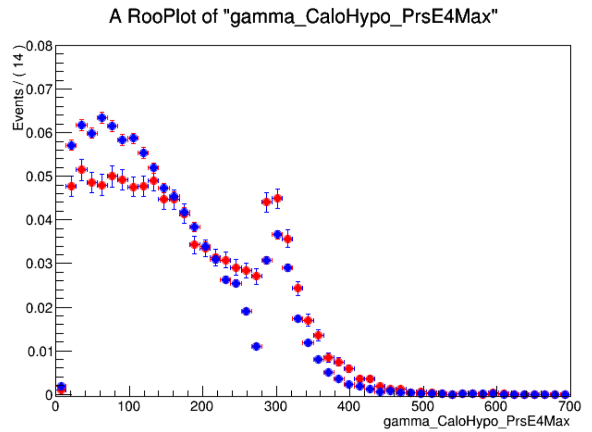










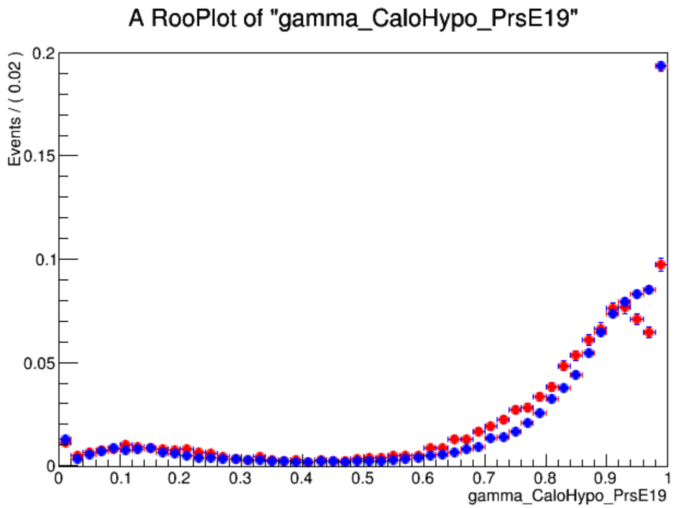


Blue dots: MC

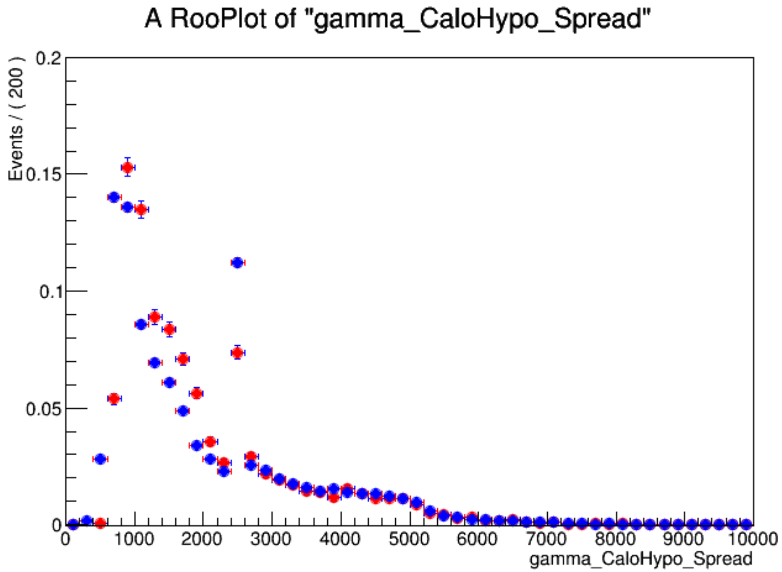
Red dots: sWeighted data

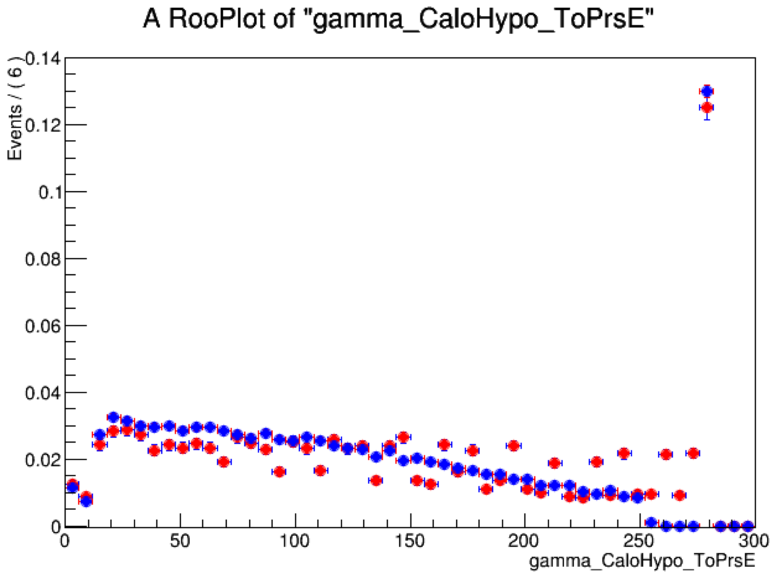
The input variables discrepancies

Blue dots: MC



Red dots: sWeighted data





π^0/γ separation

- The tool used now to do the separation is based on a TMVA analysis using the Multi Layer Perceptron (MLP)
- It makes use of the shape of the cluster, its squashiness the shape of the tails and other Prs and Ecal information

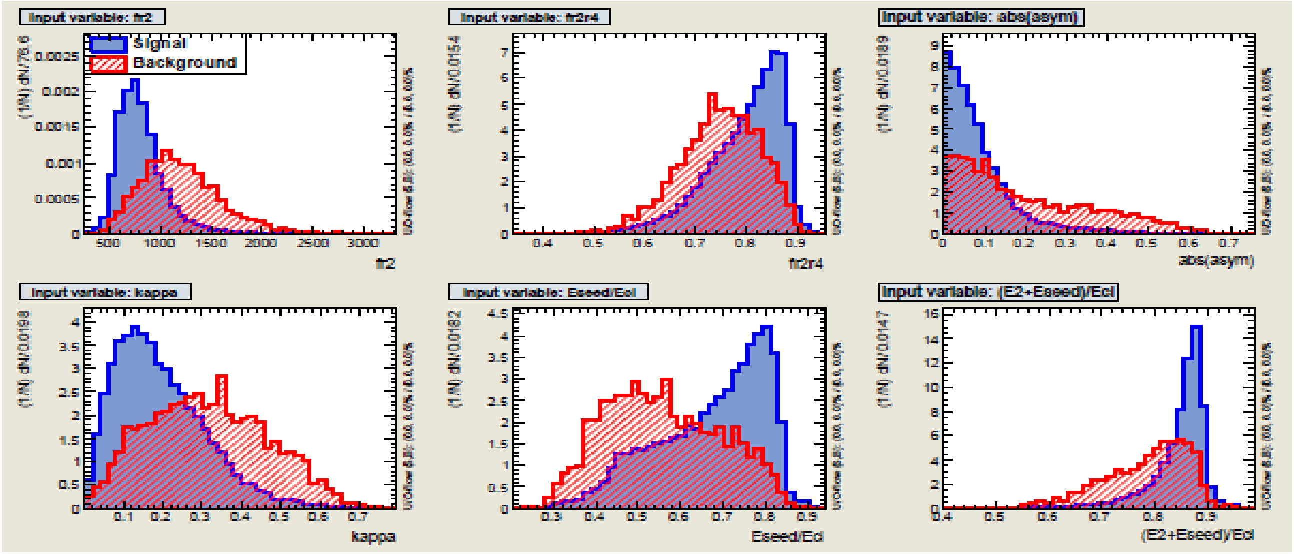
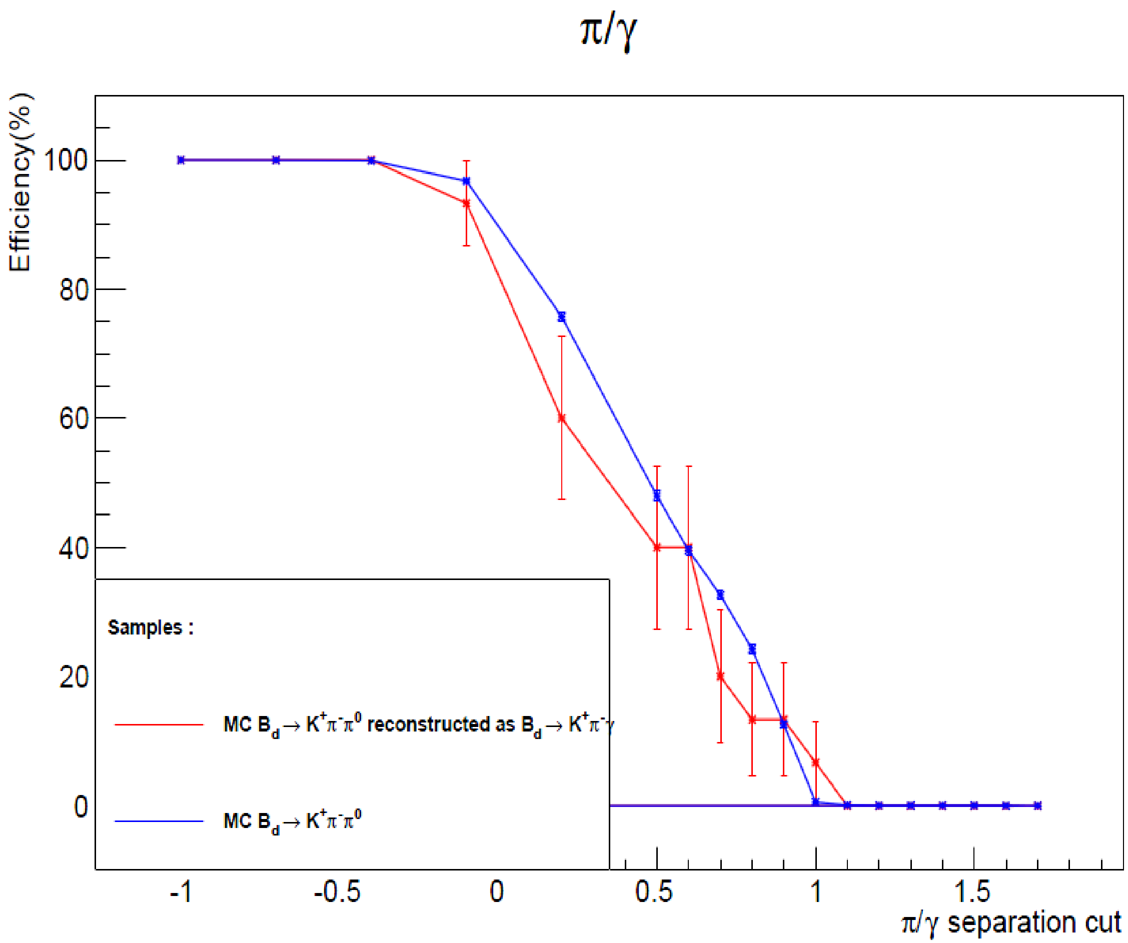


Figure 3 Distributions of ECAL cluster shape variables $r2$, $r2r4$, $|asym|$, κ, E_{seed}/E_{cl} and $(E_{seed}+E_{2nd})/E_{cl}$ for true MC photons (blue solid histogram) and true MC merged π^0 selected as photons (red dashed histogram) in the INNER region. Histograms are normalized to unity.

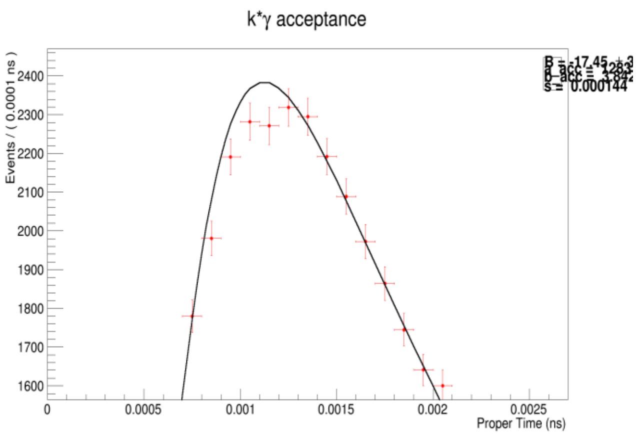
π^0/γ separation (backups?)

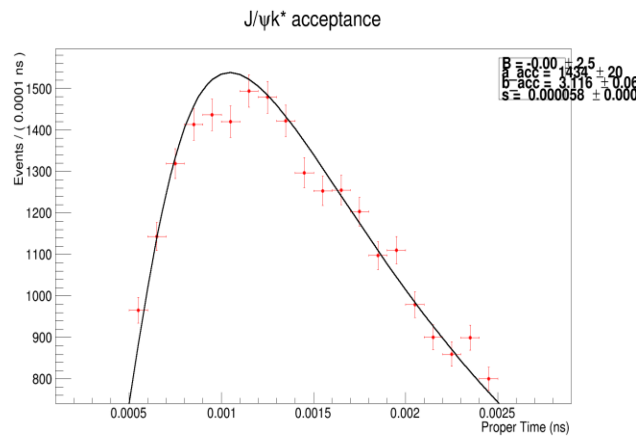
- Important issue : do the $\pi°$ reconstructed as γ (e.g. $K^*\pi°$ bkg in $K^*\gamma$ analysis) behave as merged $\pi°$ reconstructed as $\pi°$ (as in $D°\to K\pi\pi°$ calibration sample)…?!
- Yes!!
- Regardless of the very low statistics that the sample of $Bd\to K\pi\pi0$ reconstructed as $B0\to K^*\gamma$



Acceptance from MC (4/)

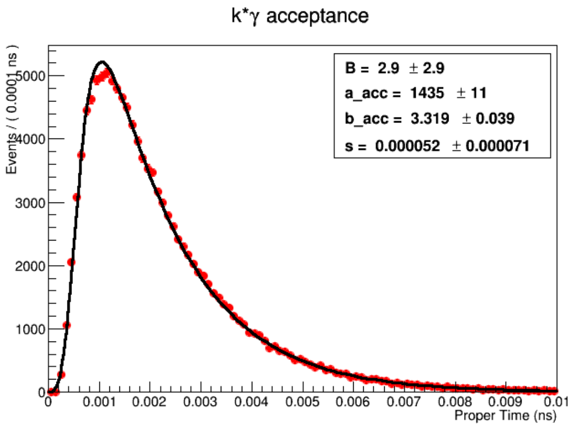
- A closer look at the acceptance:

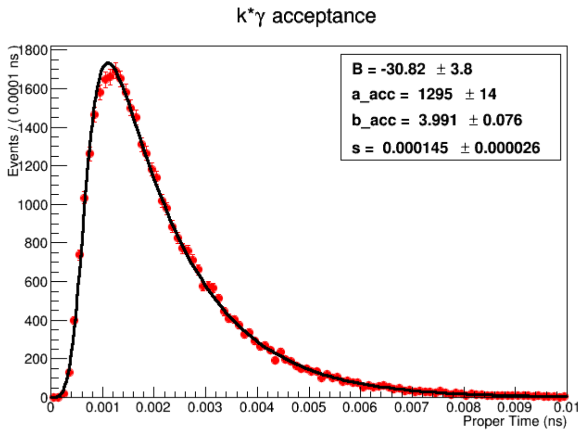




No trigger

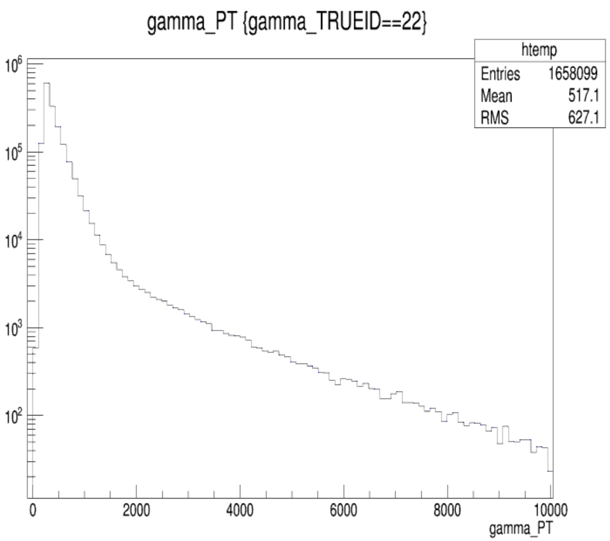
Strong IP cuts

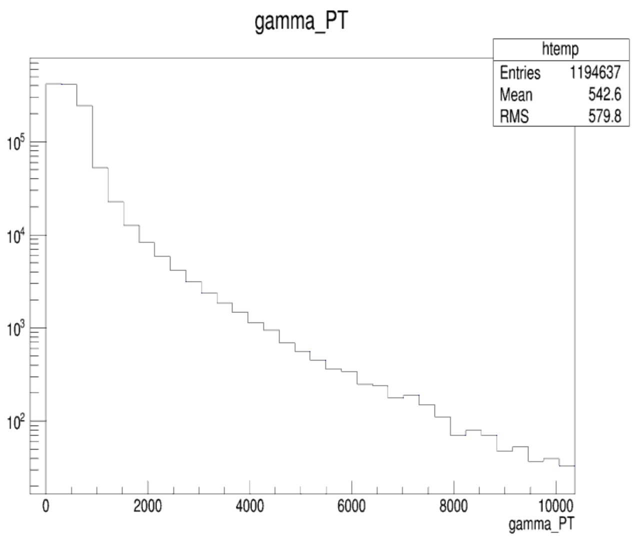


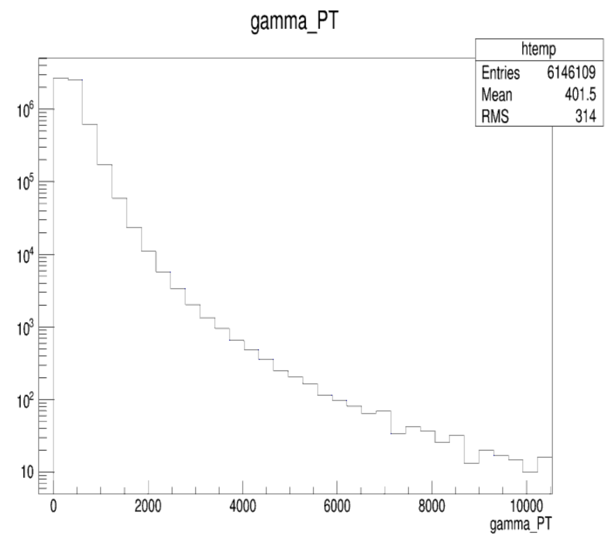


Transverse momentum distribution

- The PT distribution of photon candidates for each category
  - This is to verify that the training covers a large PT-range of photons







Photon signal

Electron background

Non EM background

Procedure

- What you will see in the next slides will go as follows:

1. Train on truth matched (TM) non electromagnetic background so as to have a dedicated γ/non-EM separation tool
2. Train and test on TM electron background so as to have a γ/e^- separation tool

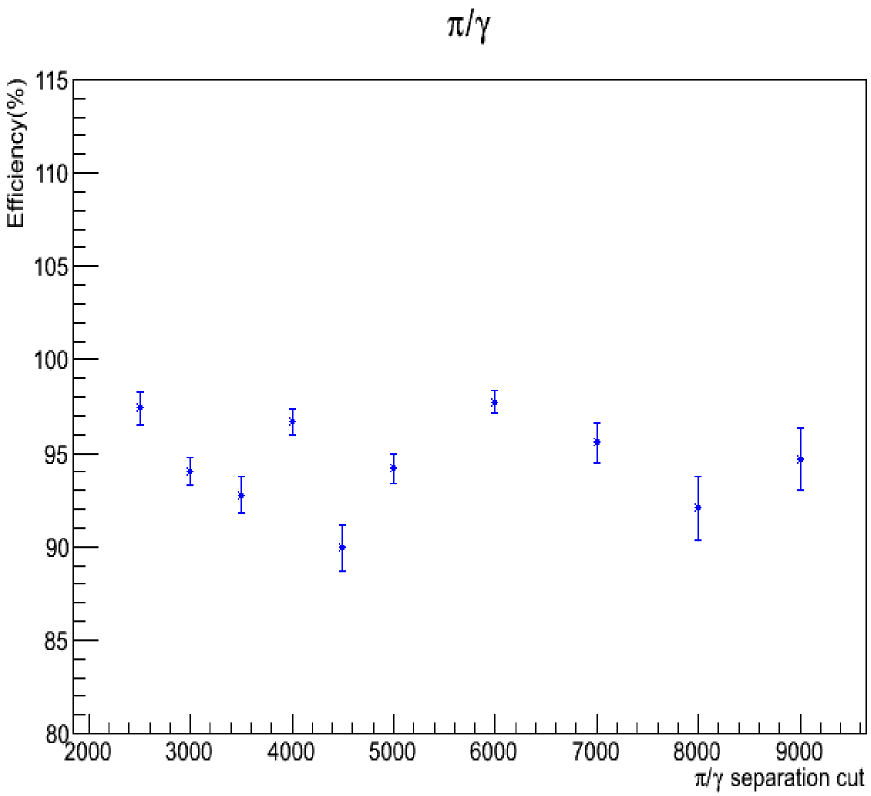
- Then the validation will proceed as follows:

1. Validate tool 1 on non EM background with a different sample
2. Validate tool 2 on electron background with a different sample

π^0/γ separation

γCL=0.25,$\gamma/\pi0$ separation cut = 0.875

This table is useful to reweight the MC in order it reproduce data efficiencies




```
std::pair<double,double> isPhotonDataeff(double pt){
if( pt >2500 && pt <3000 ) return std::make_pair(97.4171,0.840284 );
if( pt >3000 && pt <3500 ) return std::make_pair(94.0445,0.752683 );
if( pt >3500 && pt <4000 ) return std::make_pair(92.7767,0.943348 );
if( pt >4000 && pt <4500 ) return std::make_pair(96.6965,0.673714 );
if( pt >4500 && pt <5000 ) return std::make_pair(89.9366,1.20523 );
if( pt >5000 && pt <6000 ) return std::make_pair(94.1833,0.768753 );
if( pt >6000 && pt <7000 ) return std::make_pair(97.7492,0.60637 );
if( pt >7000 && pt <8000 ) return std::make_pair(95.5824,1.07693 );
if( pt >8000 && pt <9000 ) return std::make_pair(92.0903,1.71405 );
if( pt >9000 && pt <10000 ) return std::make_pair(94.6831,1.6655 );
if( pt >10000 && pt <11000 ) return std::make_pair(93.5642,2.10446 );
}
```

The bias correction

- Looking at how the proper time is fitted, naively one would proceed to correct for this shift through

$$L = \beta\gamma c\tau$$

$$c\tau = \frac{L}{\beta\gamma} = \frac{M}{P} L$$

- And get the approximately corrected proper time with

$$\tau_{corr} = \frac{P}{M} \bullet \frac{M_{corr}}{P_{corr}} \bullet \tau$$

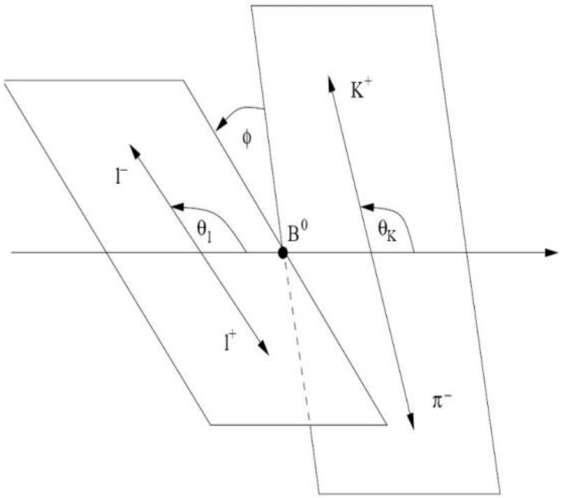
- We found out that if we correct with the ratio of momenta we do reduce the propertime bias (we do not know yet why!)

$$\tau_{corr} = \frac{P}{P_{corr}} \bullet \tau$$

$B \to K^*\gamma(ee)$

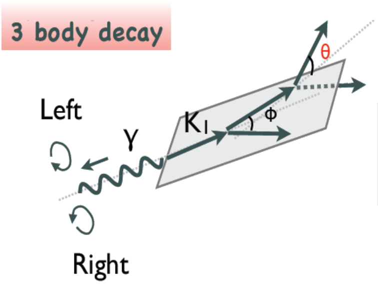
- The main goal is to perform an angular analysis to calculate the photon polarization (a virtual one)
- Now: with the 2011 statistics
  - Only BR measurement is done

    J. High Energy Phys. 05 (2013) 159, LHCB---PAPER---2013---005
- The analysis is ongoing



Up-Down Asymmetry of $B \to K_{res}\, \gamma \to (K\pi\pi)\gamma$

[LHCb-CONF-2013-009]

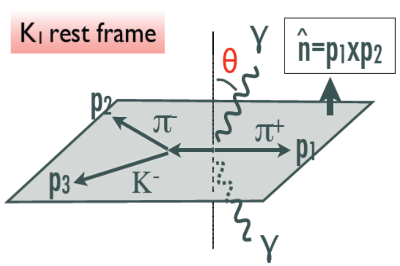


Circular polarization measurement of γ ⟺ Angular distribution of K_{res} decay

$A = -\,0.085 \pm 0.019(stat) \pm 0.003(syst)$

4.6 σ significance wrt to 0.

Up-Down Asymmetry : Count the number of events with photon above/below the K_{res} decay plane and subtract them.



$$\mathcal{A} = \frac{\int_0^1 \cos\theta \frac{d\Gamma}{d\cos\theta} - \int_{-1}^0 \cos\theta \frac{d\Gamma}{d\cos\theta}}{\int_{-1}^1 \cos\theta \frac{d\Gamma}{d\cos\theta}} = \frac{3}{4}\,\frac{\langle Im(\hat{n}\cdot(\vec{J}\times\vec{J}^*))\rangle}{\langle|\vec{J}|^2\rangle}\,\frac{|c_R|^2-|c_L|^2}{|c_R|^2+|c_L|^2}$$

- Λ: polarization parameter
- The average value of the triple product $\vec{p}_\gamma \cdot (\vec{p}_1 \times \vec{p}_2)$ has one sign for left handed photons and the opposite for right handed.

The branching fraction and the direct cp asymmetry

The ratio of branching fractions:

From unbinned fit to data | From PDG | From LHCb measurement (arXiv:hep-ex/1111.2357v1) | From simulation

$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B_s \to \phi\gamma)} = \frac{N_{sig}^{B^0 \to K^{*0}\gamma}}{N_{sig}^{B_s \to \phi\gamma}} \frac{\mathcal{B}(\phi \to K^+K^-)}{\mathcal{B}(K^* \to K^+\pi^-)} \frac{f_s}{f_d} \frac{\epsilon_{B_s \to \phi\gamma}}{\epsilon_{B^0 \to K^{*0}\gamma}}$$

$$\frac{\epsilon_{B_s \to \phi\gamma}}{\epsilon_{B^0 \to K^{*0}\gamma}} = r_{acc} \times r_{reco\&sel} \times r_{PID} \times r_{trigger}$$

We get the current world best measurement

$$\frac{\mathcal{B}(B^0 \to K^{*0}\gamma)}{\mathcal{B}(B_s^0 \to \phi\gamma)} = 1.31 \pm 0.07(\text{stat}) \pm 0.04(\text{syst}) \pm 0.10(f_s/f_d).$$

The CP Asymmetry :

$$\mathcal{A}_{CP}(B^0 \to K^{*0}\gamma) = \mathcal{A}^{\text{RAW}}(B^0 \to K^{*0}\gamma) - \mathcal{A}_{\text{D}}(K\pi) - \kappa\mathcal{A}_{\text{P}}(B^0)$$

Also the current world best measurement

$$\mathcal{A}_{CP}(B^0 \to K^{*0}\gamma) = 0.008 \pm 0.017(\text{stat}) \pm 0.009(\text{syst})$$

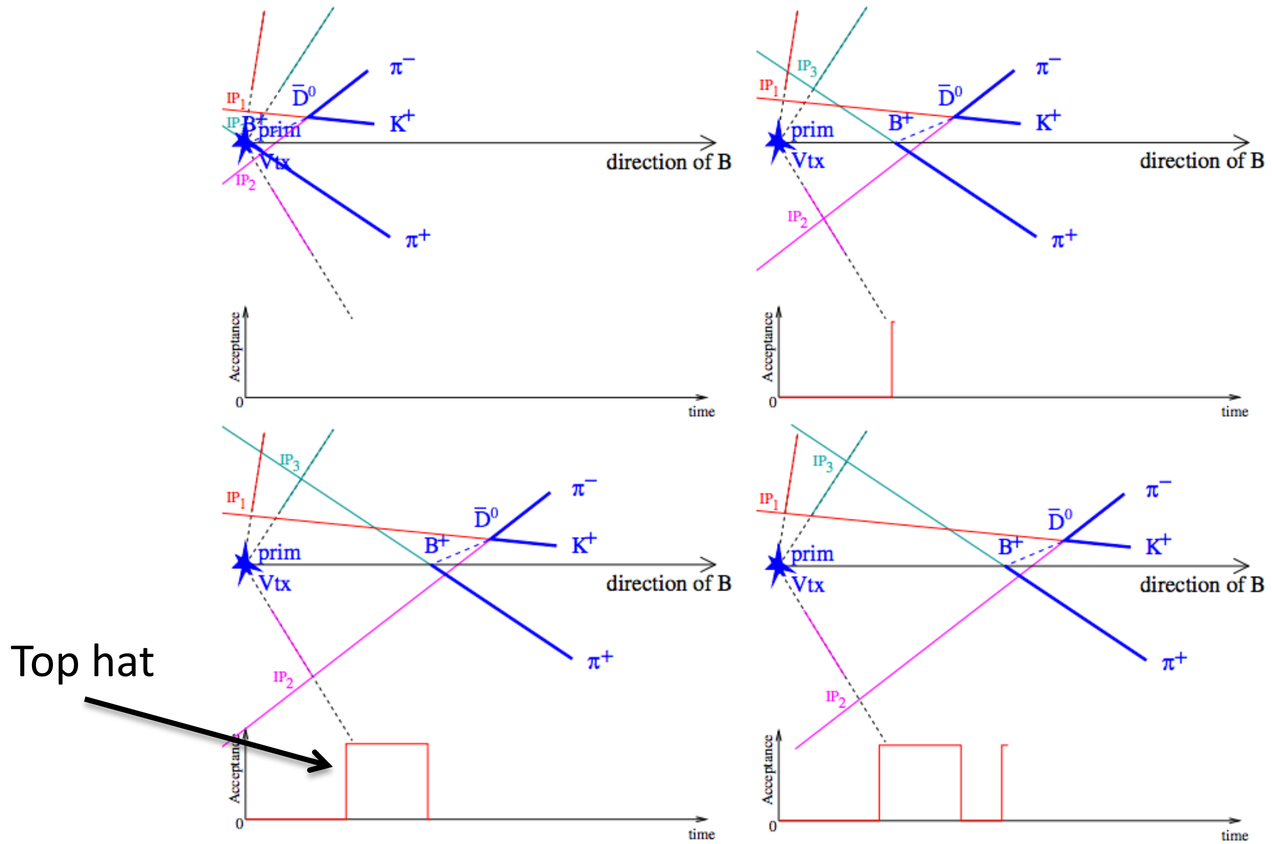
Nuclear Physics B, 867, 1-18 (2013)

The acceptance: swimming(1)

- Selection introduces biases/acceptance effects on the lifetime
- One of the tools to quantify them is swimming
- Basic idea
  - Re-run the trigger for every event moving the PV in the direction of the meson momentum
  - Find acceptance function $A(t)$
  - Calculate conditional probability of finding an event with lifetime t given the measured $A(t)$

The acceptance: swimming(2)

- Move the PV to calculate Acceptance



The acceptance: swimming(3)

- Calculate conditional probability (*n* top hats)

$$P(t,\mathrm{acc}) = \frac{\frac{1}{\tau}e^{\frac{-t}{\tau}}}{\sum_{i=1}^{n}\left(e^{\frac{-t_{min}}{\tau}} - e^{\frac{-t_{max}}{\tau}}\right)}P(\mathrm{acc}).$$

- With detector effects

$$P\left(t_m, \sigma_t, \mathrm{acc}\right) = \frac{\int_0^{+\infty} \frac{1}{\tau}e^{\frac{-t}{\tau}} \frac{1}{\sqrt{2\pi i \sigma_t}} e^{-\frac{(t-t_m)^2}{2\sigma_t^2}}\, dt}{\sum_{i=\mathrm{all\ intervals}} \int_{t_{\mathrm{min}\,i}}^{t_{\mathrm{max}\,i}} \int_0^{+\infty} \frac{1}{\tau}e^{\frac{-t}{\tau}} \frac{1}{\sqrt{2\pi}} e^{-\frac{(t-t_m)^2}{2\sigma_t^2}}\, dt\, dt_m}.$$

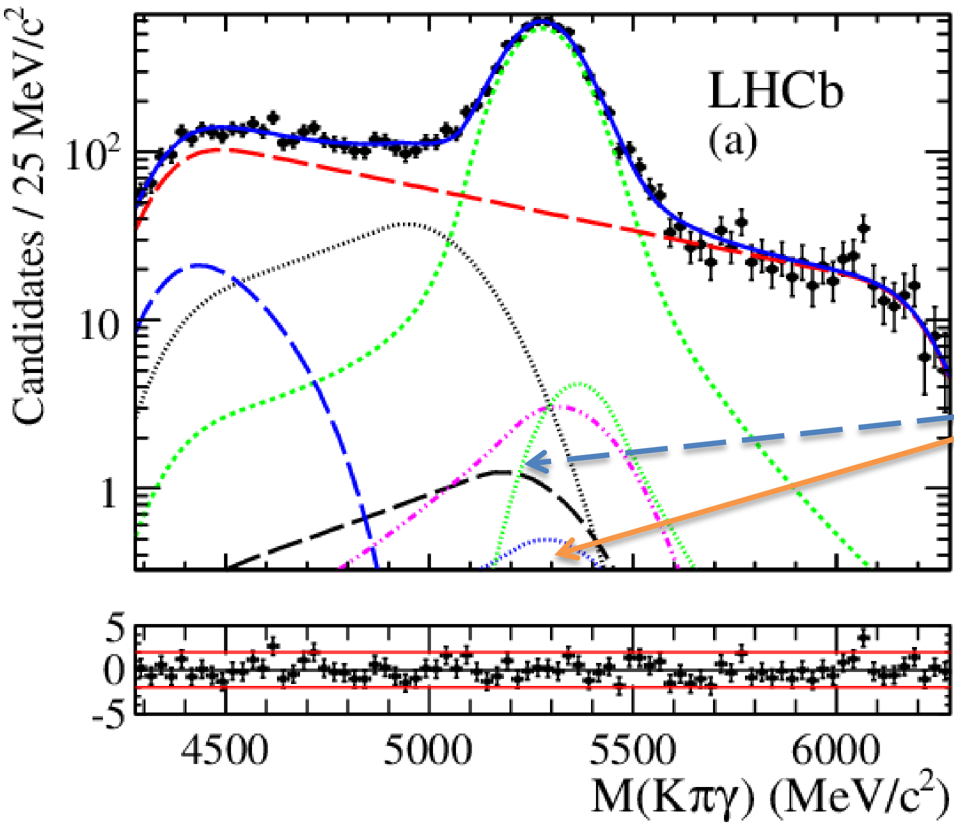
The acceptance: swimming(3)

- Swimming will be applied to the data collected by LHCb in 2011 and 2012. This requires a reprocessing of data
- The scripts and machinery are ready and will be applied soon
- With the statistics we have: not so accurate evaluation of the proper time acceptance is expected

π^0/γ separation (motivation)

Merged π^0 background is ~50-60% of the *peaking* background in the radiative channel

B→Vγ analysis Deschamps et al.



A plot of the B invariant mass in logarithmic scale showing the backgrounds

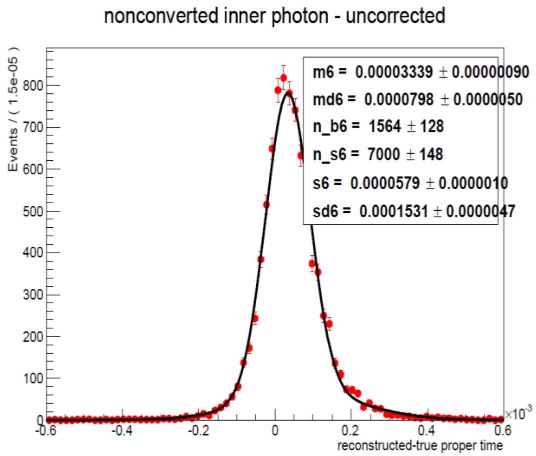
Bd(s)→$K\pi\pi^0$ contamination (π^0/γ separation cut applied)

π^0/γ separation is very important for very rare decays (e.g B→$\rho^0\gamma$)

The Decay time resolution bias

- There is a O(1%) energy bias on photon energy in both MC and data (we calibrate at low energies with π^0 and apply the calibration to all energy range)
- The photon energy bias leads to a O(0.5%) shift on the B mass (depending on the calorimeter region and photon type-converted or unconverted)
- Post calibration is applied to the mass in the radiative analysis
- Bias could also affect the propertime measurement

$$\tau_{rec} - \tau_{true}$$



μ=(33.4±1)fs
σ =(58±1)fs

We model the resolution with an Apollonios function