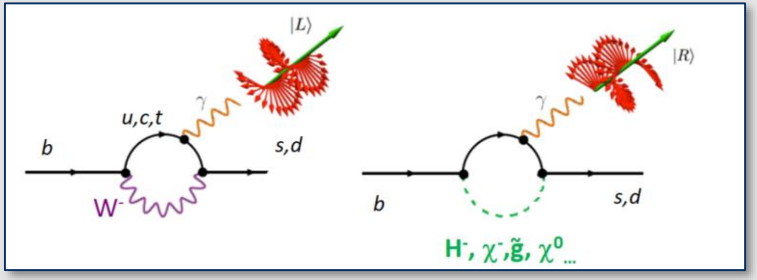
RADIATIVE B DECAYS INTO ORBITALLY EXCITED MESONS AT LHCB

Boris Quintana

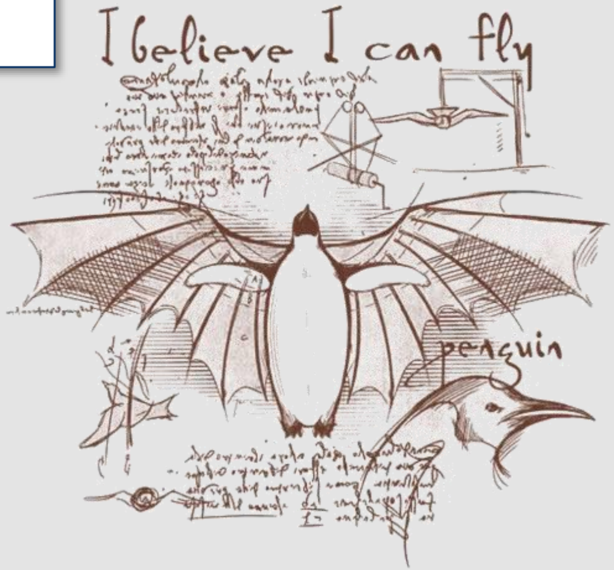
LPC Clermont-Ferrand

RADIATIVE DECAYS

Photons in $b \to s\gamma$ (FCNC process) are predominantly left-handed in the SM, since the W boson couples to left-handed quarks. New particles could enhance the right-handed contribution.



First observation at CLEO (1993) in $B_d \to K^* \gamma$



Physical observables :

Branching Ratios : $BR(B_d \to K^* \gamma) = \frac{N(B_d \to K^* \gamma)}{N(B_d)}$

CP Asymetries : $A_{CP} = \frac{N(B_d \to K^* \gamma) - N(\bar{B}_d \to \bar{K}^* \gamma)}{N(B_d \to K^* \gamma) + N(\bar{B}_d \to \bar{K}^* \gamma)}$

Photon polarisation : angular analysis / Time dependent analysis

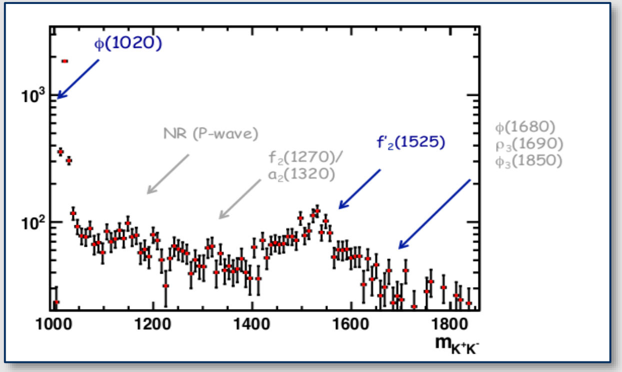
CKM Matrix elements : $|V_{td}|$, $|V_{ts}|$

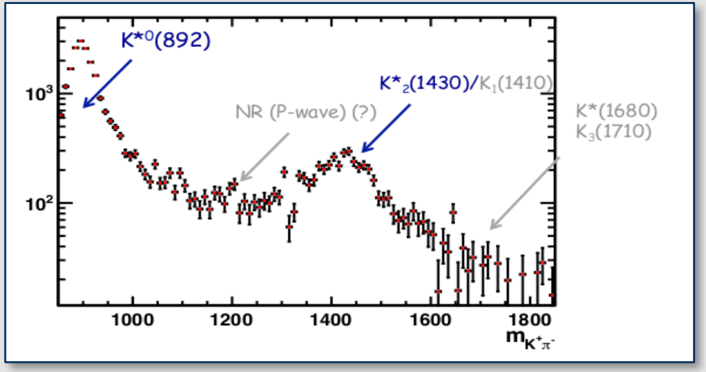
MOTIVATIONS

A simultaneous analysis of $B^0 \to K\pi\gamma$, $B_s \to KK\gamma$ (and $\Lambda_b \to pK\gamma$) :

- Aim to improve $K^*\gamma$ / $\Phi\gamma$ models with better understanding of NR and high-mass contamination
- Improve inclusive $BR(B \to X_s \gamma)$ in terms of sum over exclusives

h^+h^- spectrum :

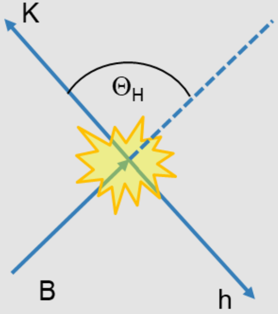




Already observed decay modes :

- $B^0 \to (K^{*0} \to K^+ \pi^-)\gamma$: $B_{vis} = 28.9 \pm 1.0 \times 10^{-6}$: Cleo, Babar, Belle, LHCb
- $B^0 \to (K^{*2} \to K^+ \pi^-)\gamma$: $B_{vis} = 4.1 \pm 0.8 \times 10^{-6}$: Babar (5.8σ), Belle(3σ),Cleo
- $B_s \to (\varphi \to K^+ K^-)\gamma$: $B_{vis} = 18 \pm 2 \times 10^{-6}$: Belle, LHCb

Helicity angle



Some limits on other modes :

- $B^0 \to (K^* (1410) \to K^+ \pi^-)\gamma$: $B_{vis} < 9 \times 10^{-6}$: Belle
- $B^0 \to (K^+ \pi^-)$ NR γ $B_{vis} < 2.6 \times 10^{-6}$: Belle ($m_{K\pi}$ in [1.25 , 1.60] GeV/c^2)

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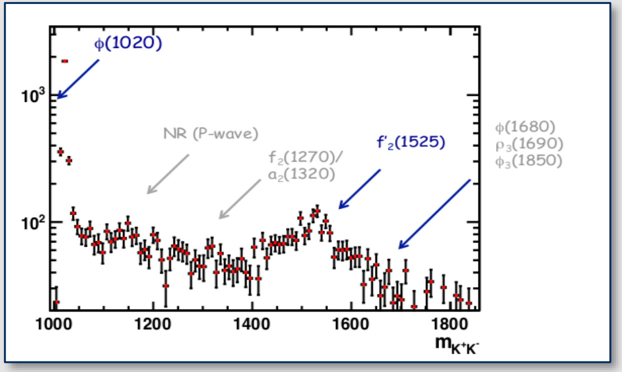
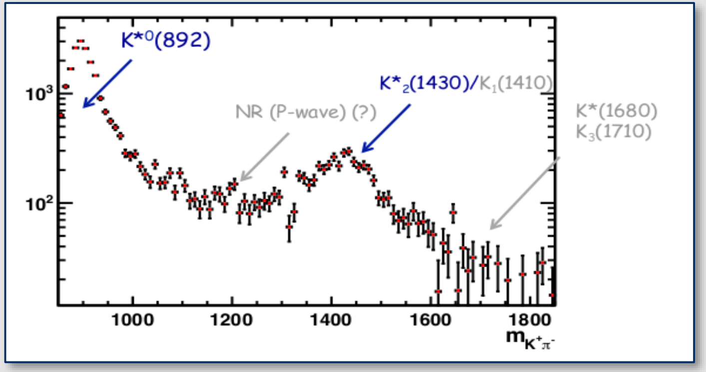
<u>h^+h^- spectrum :</u>





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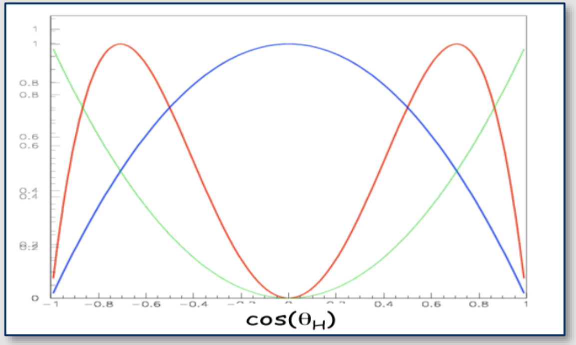

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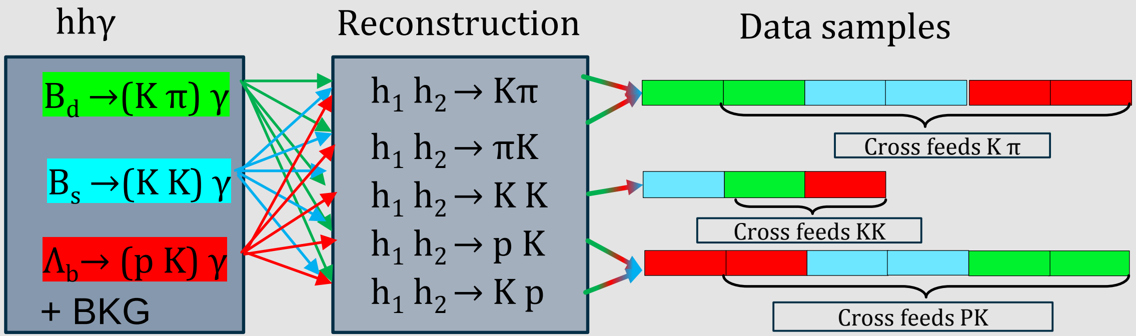
ANALYSIS SCHEME

$K\pi\gamma$, $KK\gamma$ and $pK\gamma$ final states can contribute to each other if one or two tracks are mis-identified (crossfeed) :
→ Simultaneous analysis !

We gather every (2tracks+1 high_PT photon) event and reconstruct them as $K\pi\gamma$, $KK\gamma$ and $pK\gamma$ by applying hadron masses to the tracks :



We also apply an additional set of cuts to reduce background from merged π^0 and to veto the charm decays :

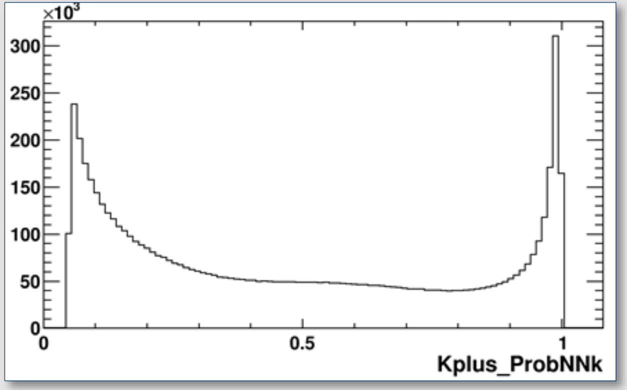
- $m(h\gamma_{\to\pi 0}) > 2000$ MeV/c^2
- IsPhoton $(\gamma/\pi^0) > 0{,}6$

PID SELECTION

To identify the tracks and build exclusive $K\pi\gamma$, $KK\gamma$ and $pK\gamma$ samples :

Classify $h^+ h^- \gamma$ candidates according to largest h_ProbNNx_i ($x_i = \pi, K, p$)

- h_ProbNNx_i > ProbNNx_j (h)   for all $x_j \neq x_i$

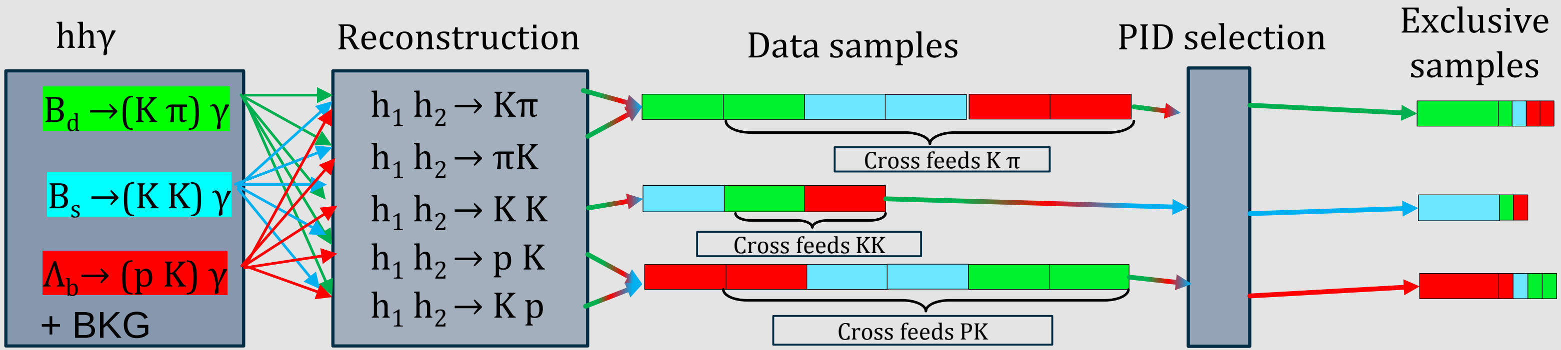


To optimise the selection in terms of signal significance :

- h1_ProbNNx_i > cut1
- h2_ProbNNx_2 > cut2

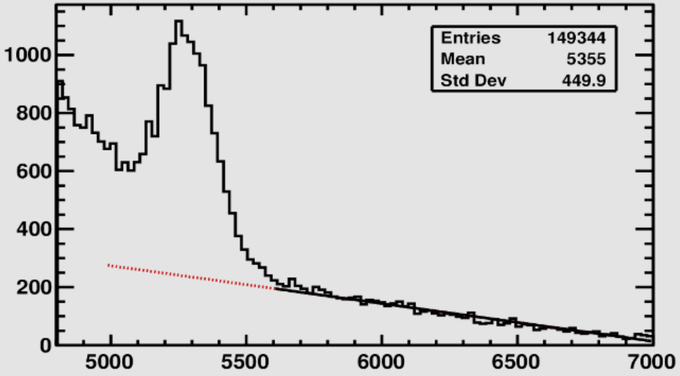
$$\text{FoM(cut1,cut2)} = \frac{S}{\sqrt{S+B}}$$

efficiencies and mis-ID rate using MC + calibration data



COMBINATORIAL BACKGROUND

After the PID selection a large amount of combinatorial background remains :



Use of Multivariate Analysis classifier trained using :

- Signal Monte Carlo simulations : $B^0 \rightarrow K^*(892)\gamma$, $B^0 \rightarrow K^{*2}(1430)\gamma$, $B^0 \rightarrow K^1(1410)\gamma$,
  $B_s \rightarrow \phi\gamma$, $B_s \rightarrow f'2\,(1525)\,\gamma$
  $\Lambda_b \rightarrow \Lambda^*(1520/1670/1820/1830)\,\gamma$
- Events in the Right Handed Side Band

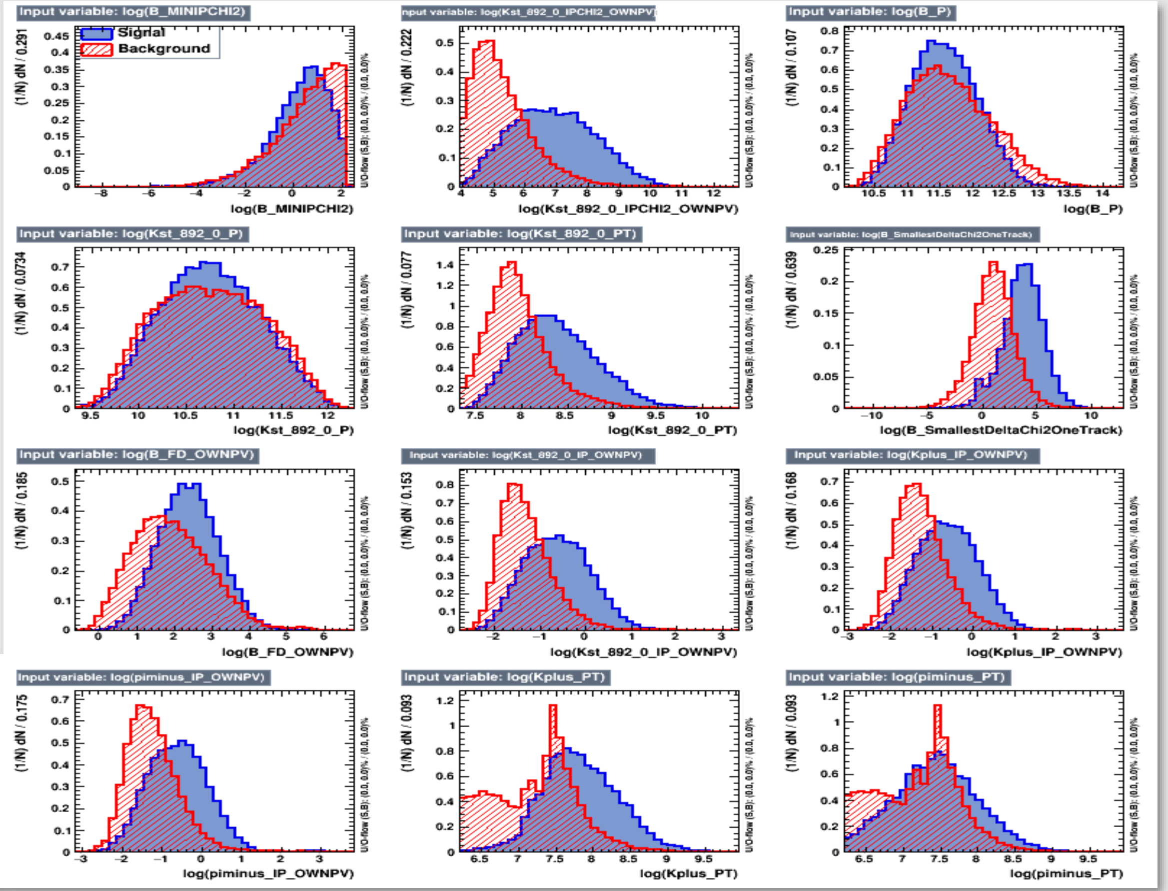
BDT VARIABLES

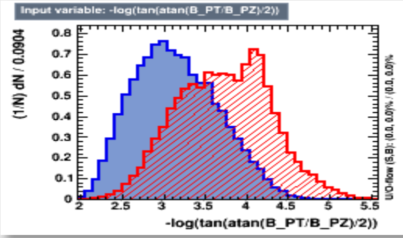
Final set :

- B min χ_{IP}^{2}
- B pseudorapidity
- B momentum
- B Flight Distance
- B vertex isolation (Smallest $\Delta\chi^{2}$)

- χ_{IP}^{2} of the (hh) resonance
- IP of the resonance
- Momentum of the resonance

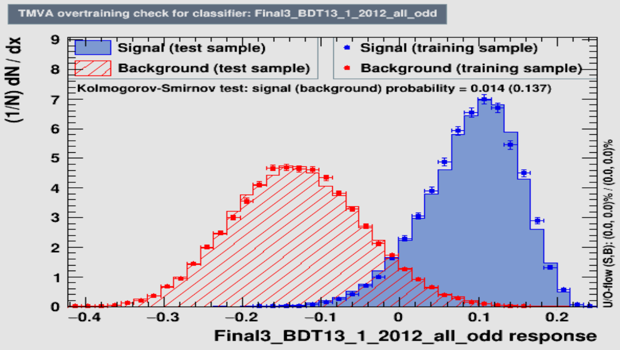
- IP of the tracks
- Transverse momenta of the tracks



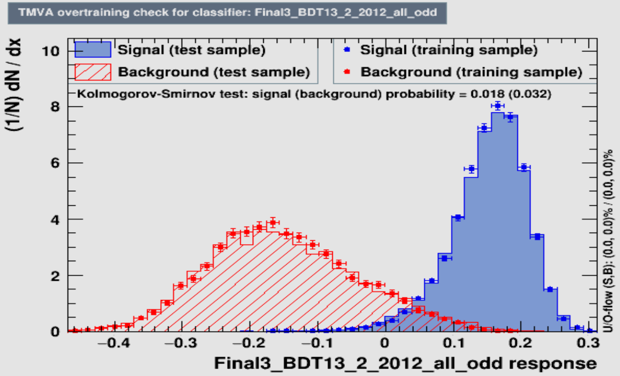


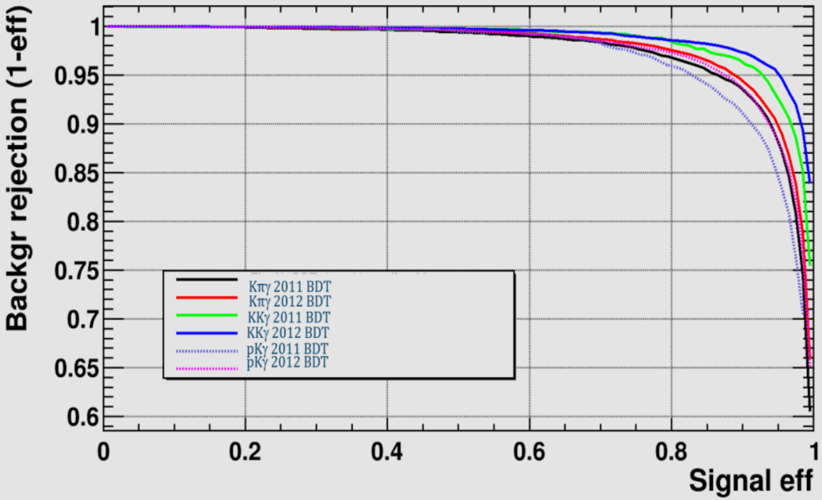
BDT PERFORMANCES

$K\pi\gamma$



$KK\gamma$





The best BDT are the ones trained on K^{*2}/K^{1} and f'2

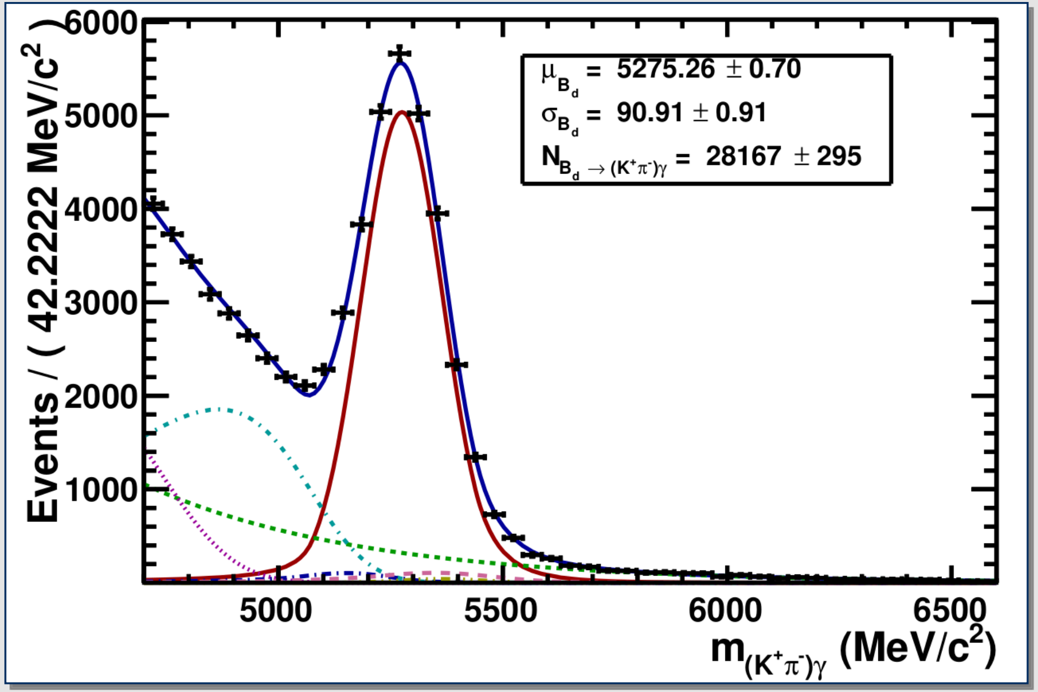
The cut to the BDT output is chosen to optimise the signal significance.

SIMULTANEOUS FIT

2012 massfit (preliminary) :

External constraints : $(m_B - m_{Bs})$ & $(m_B - m_{\Lambda b})$

Model description :



Total yields expected Run I + Run II : ~230k

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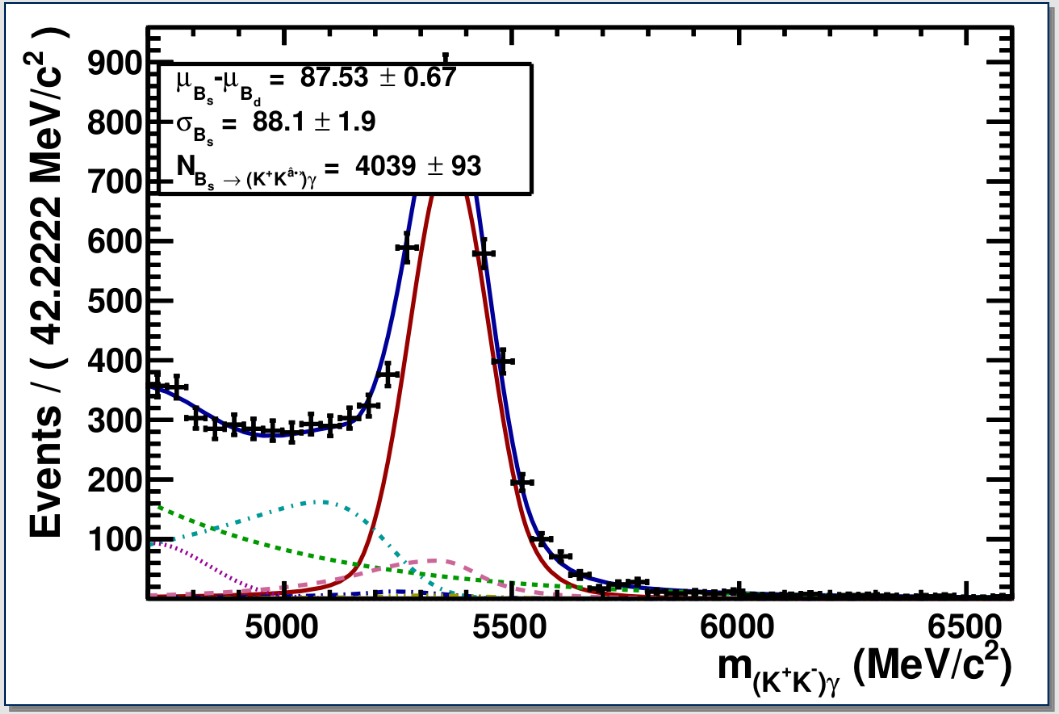

Total yields expected Run I + Run II : ~35k

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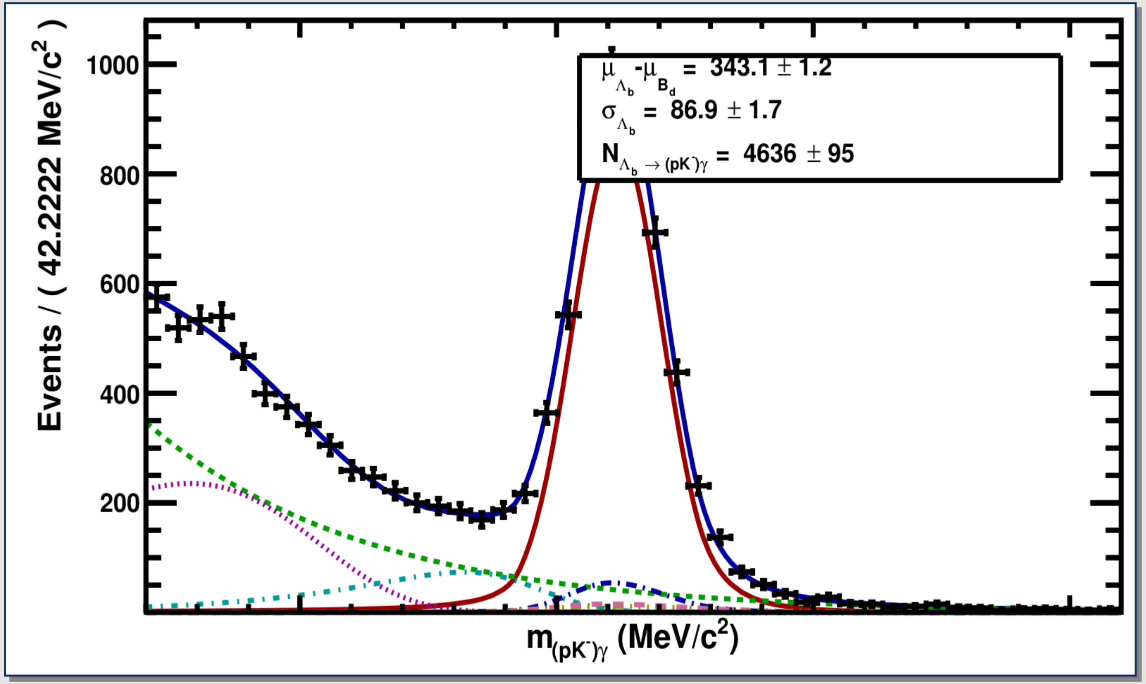
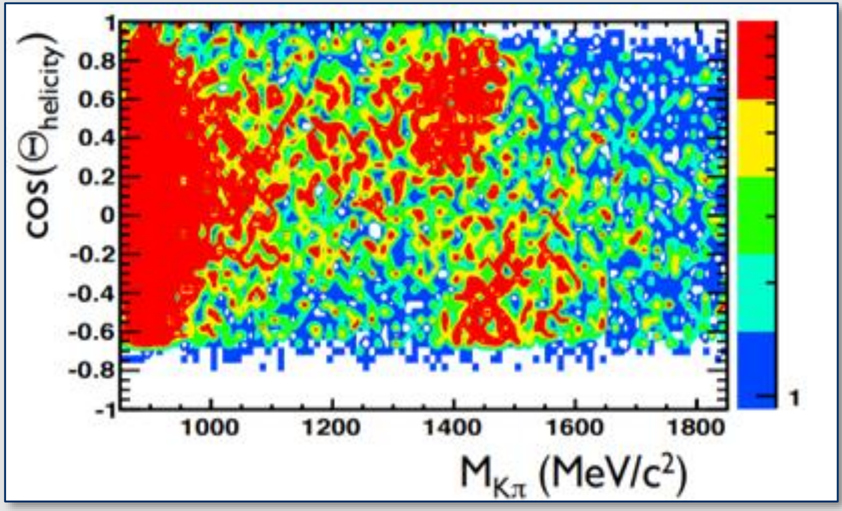
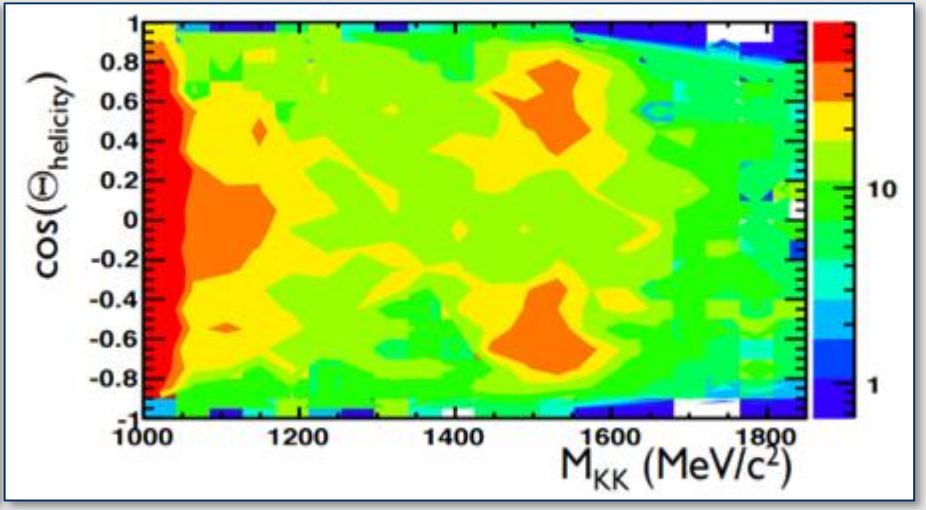


Total yields expected Run I + Run II : ~40k

PROSPECTS

Preliminary look to the data run1+run2 (2.7 + 1.0 fb^{-1}) :





- Clear D-wave contribution in the $K^*_2(K\pi)$ and $f'_2(KK)$ region
- Expecting a first observation of $B_s \to f'_2(1525)\,\gamma$ and $B^0 \to K_1(1410)\,\gamma$

- Fit 2D plane sWeighted ?
- 3D Fit $m(hh\gamma) \times m(hh) \times \cos(\Theta_h)$?

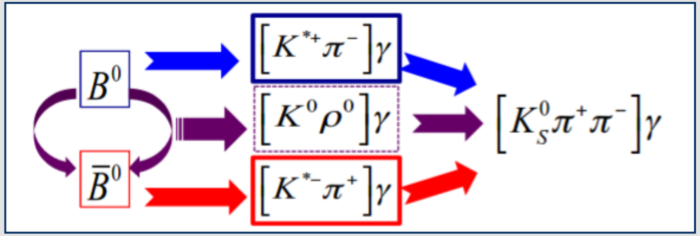
BONUS : $B \to K_S HHG$

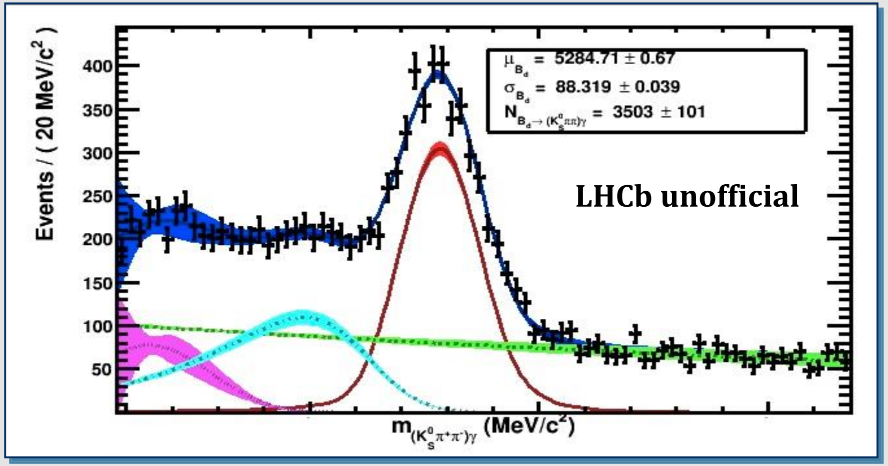
Started to select $(Khh)^0\gamma$ in the same fashion :

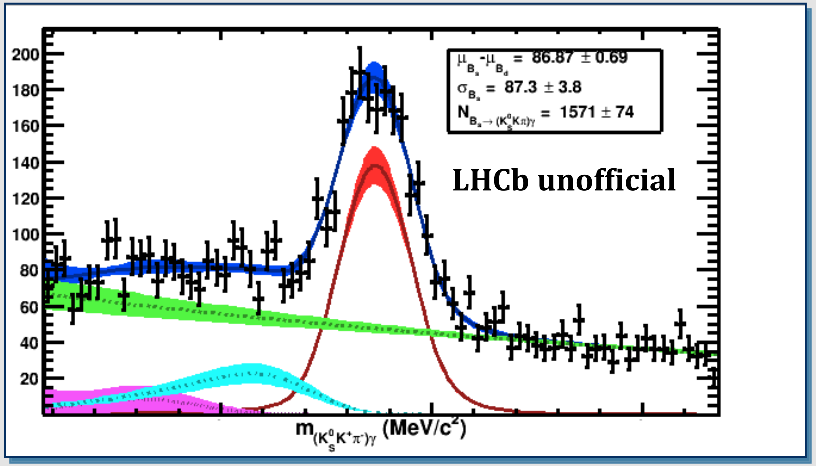
Amplitude analysis …

CPV … Photon Polarisation …

After a tight selection on Run I + Run II :








THANK YOU !

CONCLUSION AND PROSPECTS

-We achieved the selection of a high amount of radiative decay events (Run I + Run II)

-We'll be eventually able to measure new modes' BR

-$B_s \to f'_2(1525)\ \gamma$ would be the second $b \to s\gamma$ in B_s decays

- Need to develop the 2D fit to extract BR

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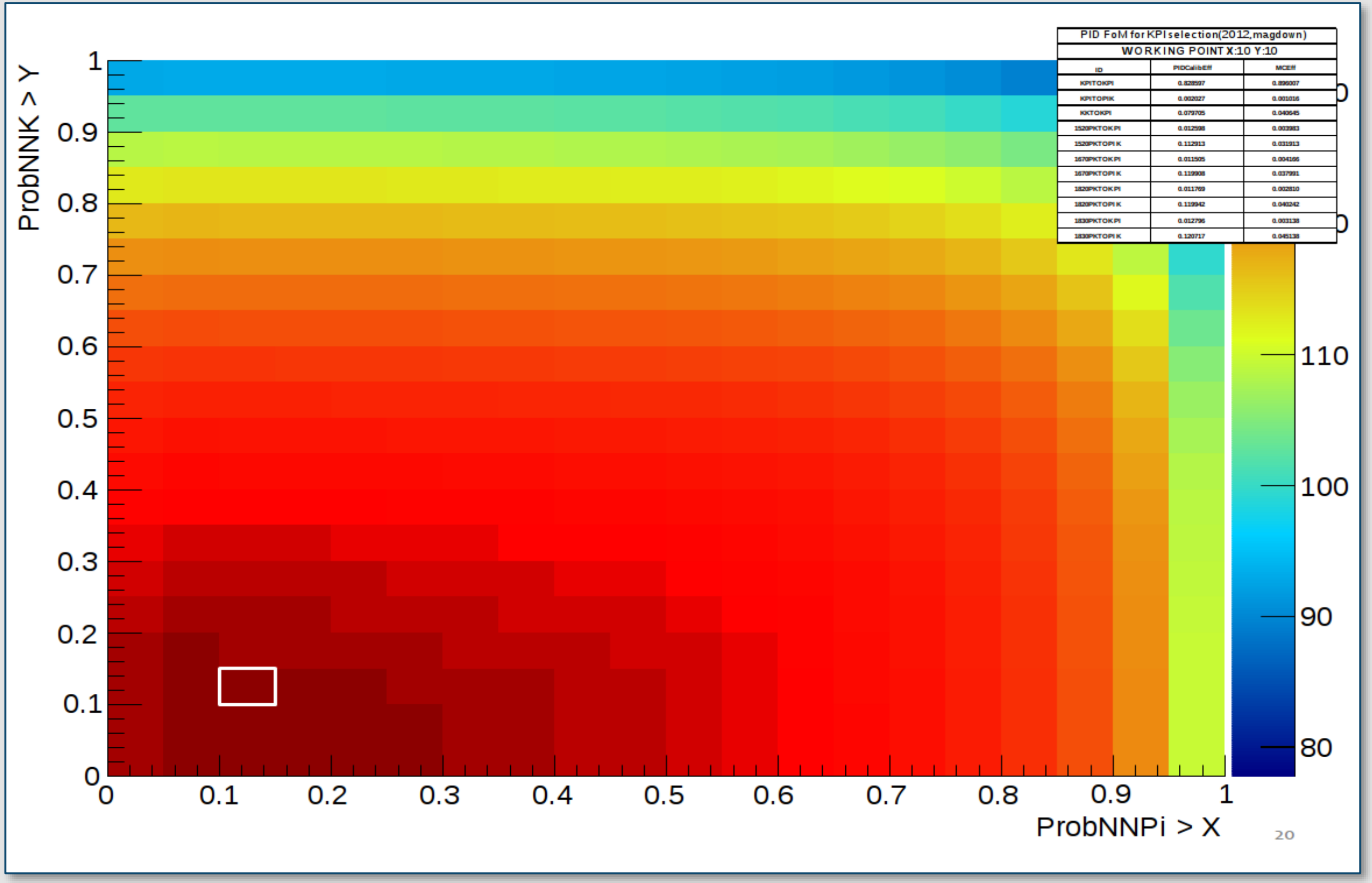
- Need to develop the 2D fit to extract BR

- Start writing the thesis …

BACK UP AND STUFF…

PID FOM FOR KPI SELECTION



PID FoM for KPI selection(2012,magdown)		
WORKING POINT X:10 Y:10		
ID	PIDCalibEff	MCEff
KPITOKPI	0.828597	0.896007
KPITOPIK	0.002027	0.001016
KKTOKPI	0.079705	0.040645
1520PKTOKPI	0.012598	0.003983
1520PKTOPIK	0.112913	0.031913
1670PKTOKPI	0.011505	0.004166
1670PKTOPIK	0.119908	0.037991
1820PKTOKPI	0.011769	0.002810
1820PKTOPIK	0.119942	0.040242
1830PKTOKPI	0.012796	0.003138
1830PKTOPIK	0.120717	0.045138

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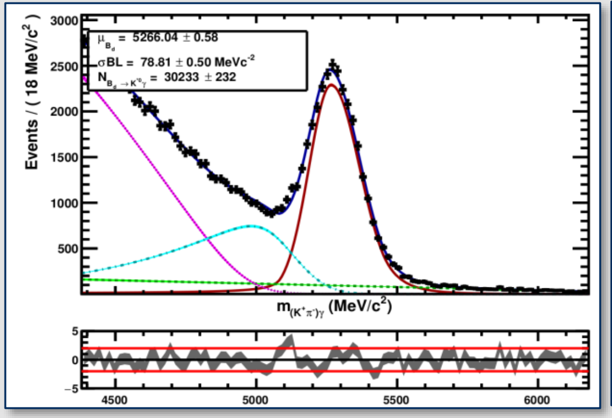
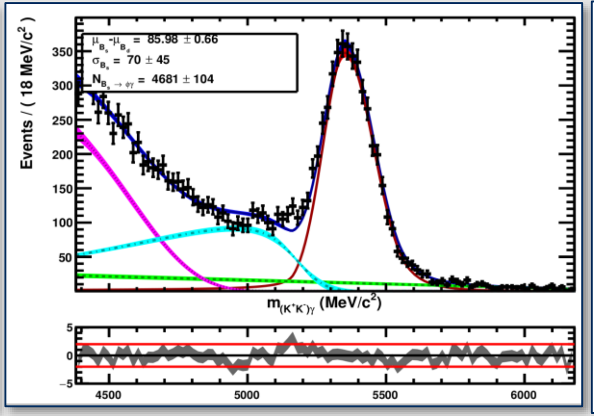
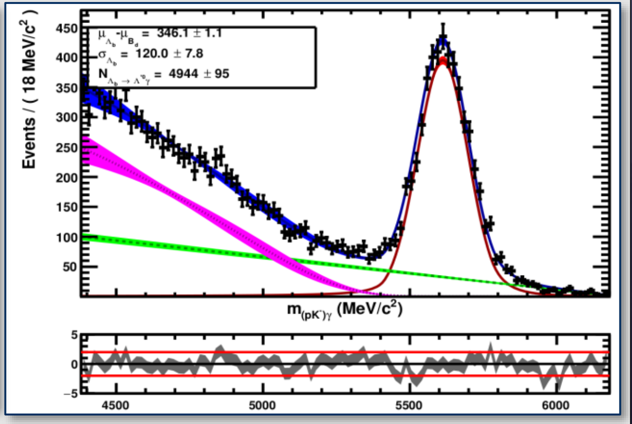






Total yields expected Run I + Run II :

$K\pi\gamma$: ~380k

KK γ : ~40k

PK γ : ~45k

PID FOM FOR KPI SELECTION

Mis-ID contaminations/rate/efficiencies ?

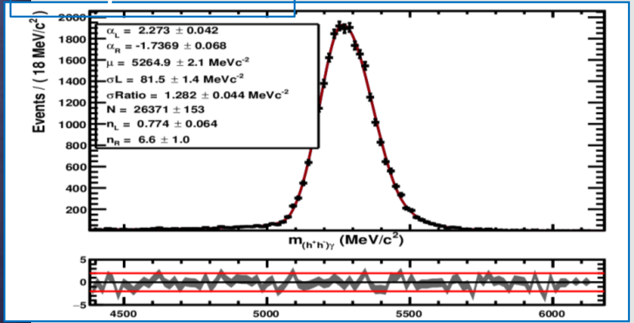
FITTING THE HHγ MASS

- <u>Signal :</u>
  - Asymetric bifurcated CB (μ, σ_{Left}, N ; $\frac{\sigma_{Left}}{\sigma_{Right}}$, α_{Left}, n_{Left}, α_{Right}, n_{Right})

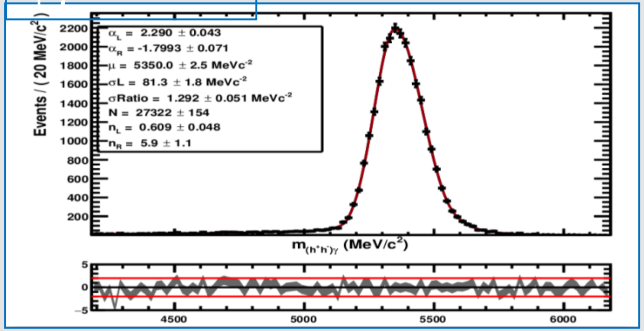
Free parameters

Fixed on MC

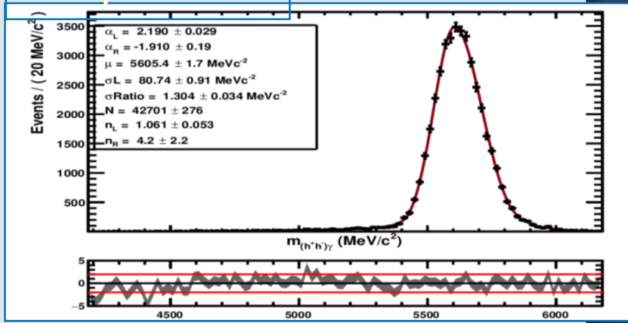
K* γ MC Fit



$\varphi\gamma$ MC Fit



Λ* γ MC Fit



- <u>Combinatorial BKG</u>: Exponential (shape and N free)
- <u>Inclusive partially reconstruced :</u> B -> hh π^0/γ + X (X > 2)
  - Argus (free, $\mu = m_B - 2\,m_\pi$) convoluted with Asym. Gaussian(μ=0, $\sigma = \sigma_{sig}$) (CB convo ?!)

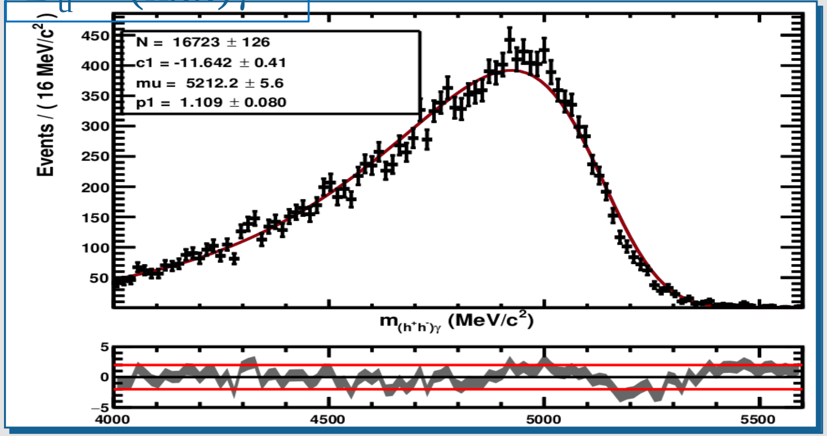
PARTIALLY RECONSTRUCTED

Partially reconstructed : B -> $(hh\pi)_{res}\ \gamma$

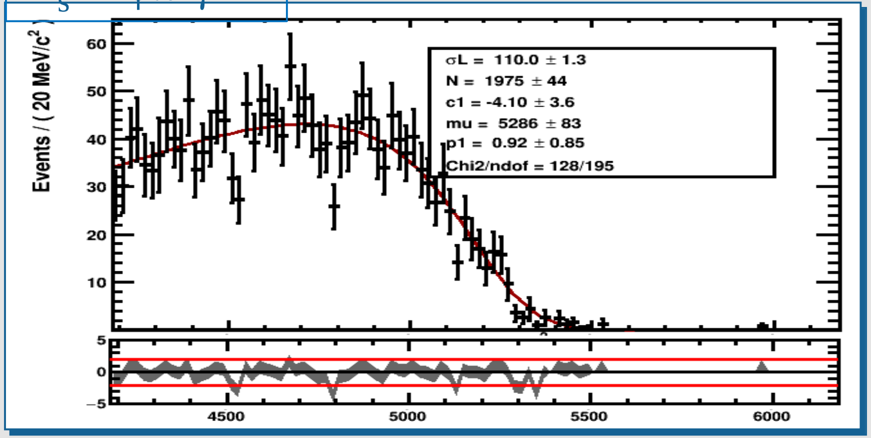
Shape : Argus ($\mu = m_B - m_\pi$, fixed on MC, free yield) convoluted with an

Asymetric Gaussian(μ=0, $\sigma = \sigma_{sig}$)

B_u-> $(k\pi\pi)\gamma$



B_s-> $\varphi\pi^0\gamma$

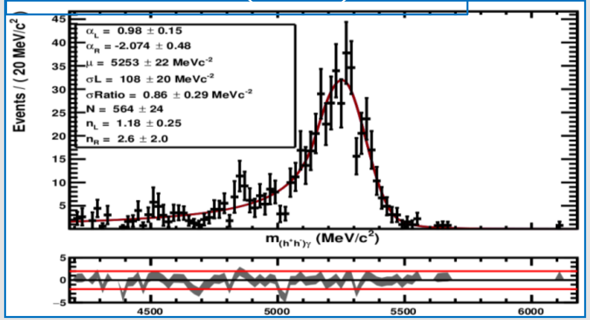


- For every shape we perform an extended maximum likelihood unbinned fit.
- The MC used is reweighted to propagate the overall PID efficiencies, and the BDT selection is applied.

Π^0/Γ MIS-ID CONTRIBUTIONS

- Shape : Asym bifurcated CB, shape and normalization fixed.

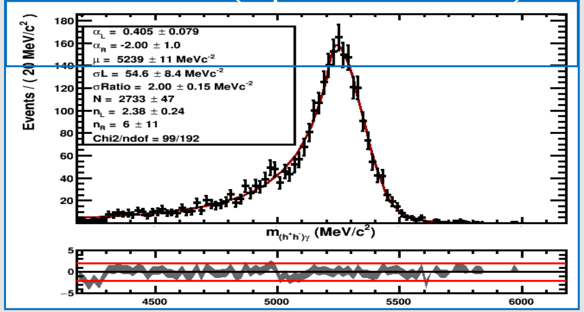
Bd->Kπ π^0 (2012)



BR = 3,78 e-5

Contamination : C = 2,6%

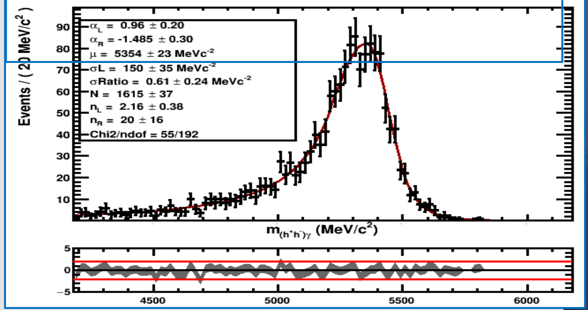
Bd->KK π^0 (sq_Dalitz_2012)



BR = 0,22 e-5

Contamination : C = 2,5%

Bs->KK π^0 (sq_Dalitz_2012)



BR = $\frac{BR(Bd \to K\pi\, \pi 0)}{BR(Bd->K*\gamma)} * BR(Bs \to \ \varphi\, \gamma)$

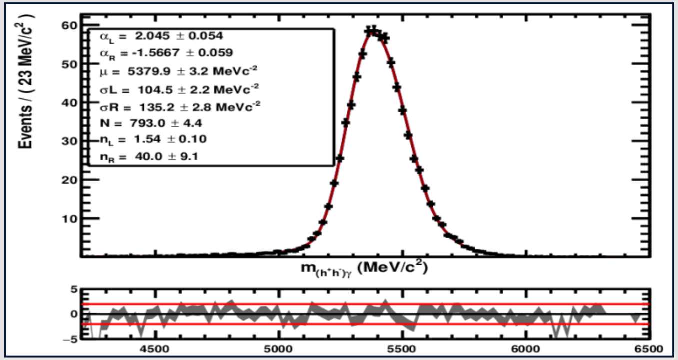
Contamination : C = 1,2%

- Note : the contamination are lower in 2011, seems to be due to the BDT

- TO DO : request better MC with new DecFile

CHARGED MIS-ID

- Shape : Asym bifurcated CB, shape and normalization fixed.
- Example : $K\pi\gamma$ -> $KK\gamma$ (2011)

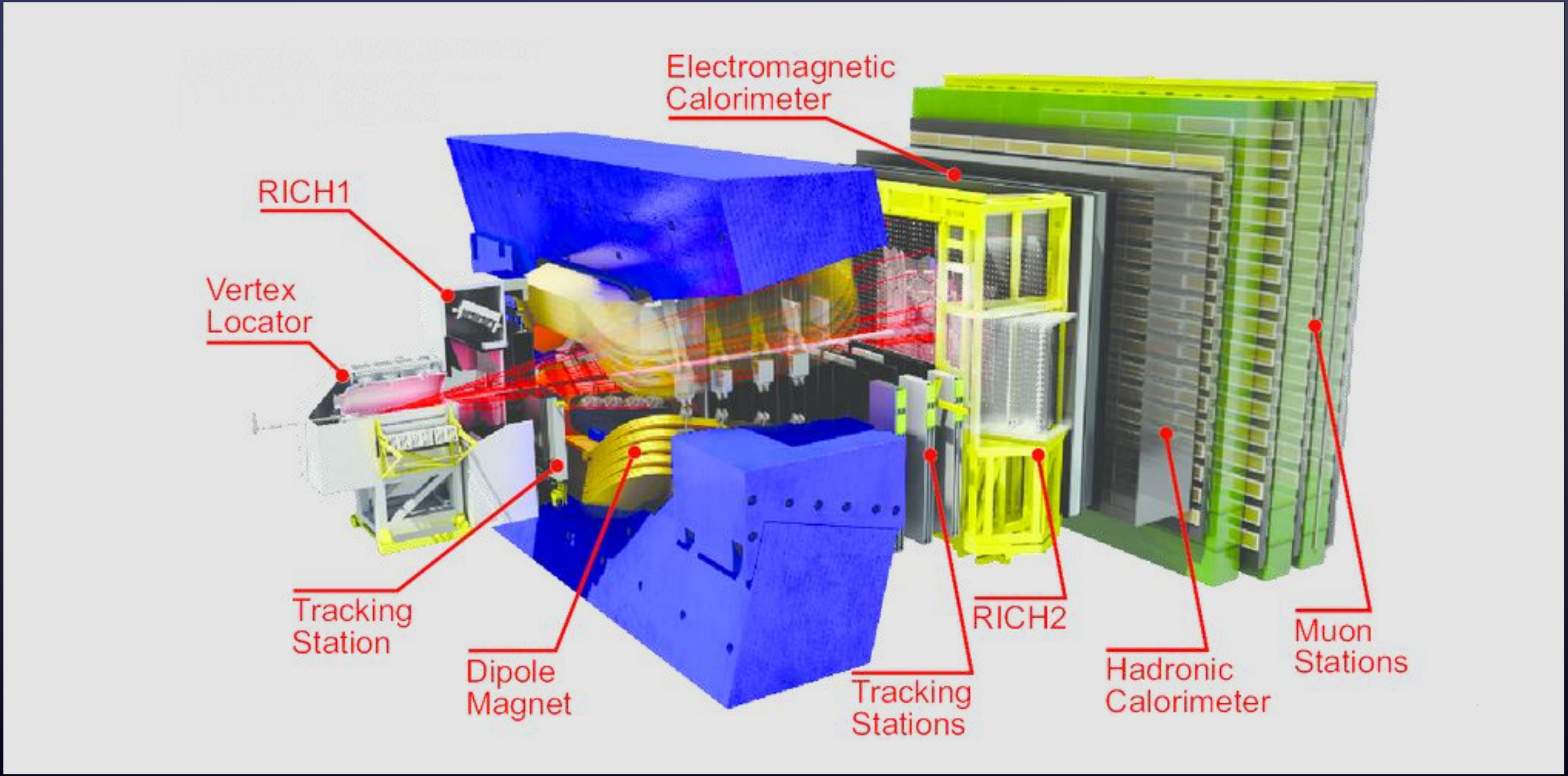


Contribution	Contamination	
KK -> KPI	2,4 %	2,6 %
PK -> PIK	9 %	14,2 %
PK -> KPI	0,89 %	1,2 %
KPI -> PIK	0,22 %	0,25 %
KPI -> KK	2,1 %	3,2 %
PK -> KK	5,8 %	7,4 %
KPI -> KP	13 %	9 %
KPI -> PK	1 %	0,8 %
KK -> PK	1,5 %	1,2 %

Note : normalisation wrt simult. fit :

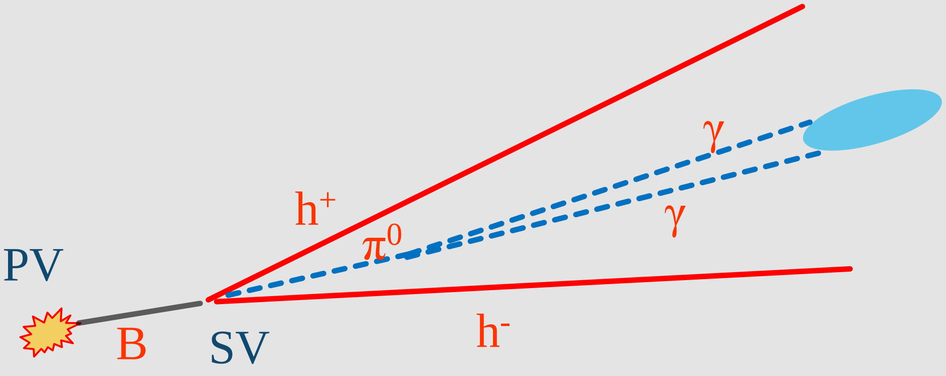
$$\frac{N(K\pi\gamma \rightarrow KK\gamma)}{N(K\pi\gamma)} \neq \text{Contamination}$$

LHCB DETECTOR

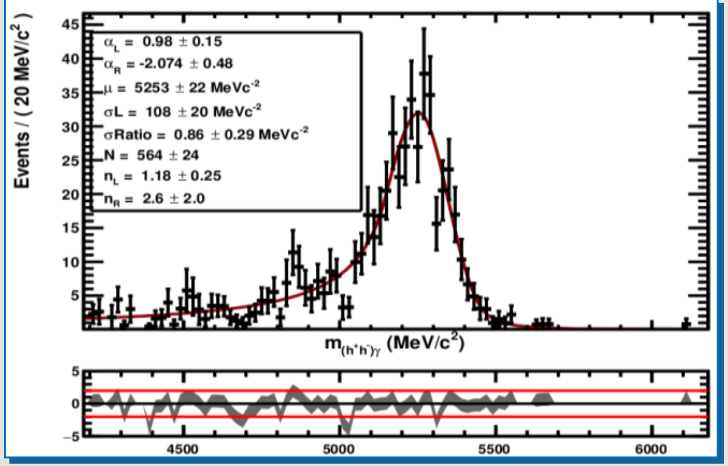


$\gamma \rightarrow \pi^0$ Mis-identification :

Peaks at the signal mass !



$B_d \rightarrow K\pi\pi^0$	BR = 3,78 e-5



IsPhoton > 0,6 : ~80% background rejection

Contamination : 2-5%

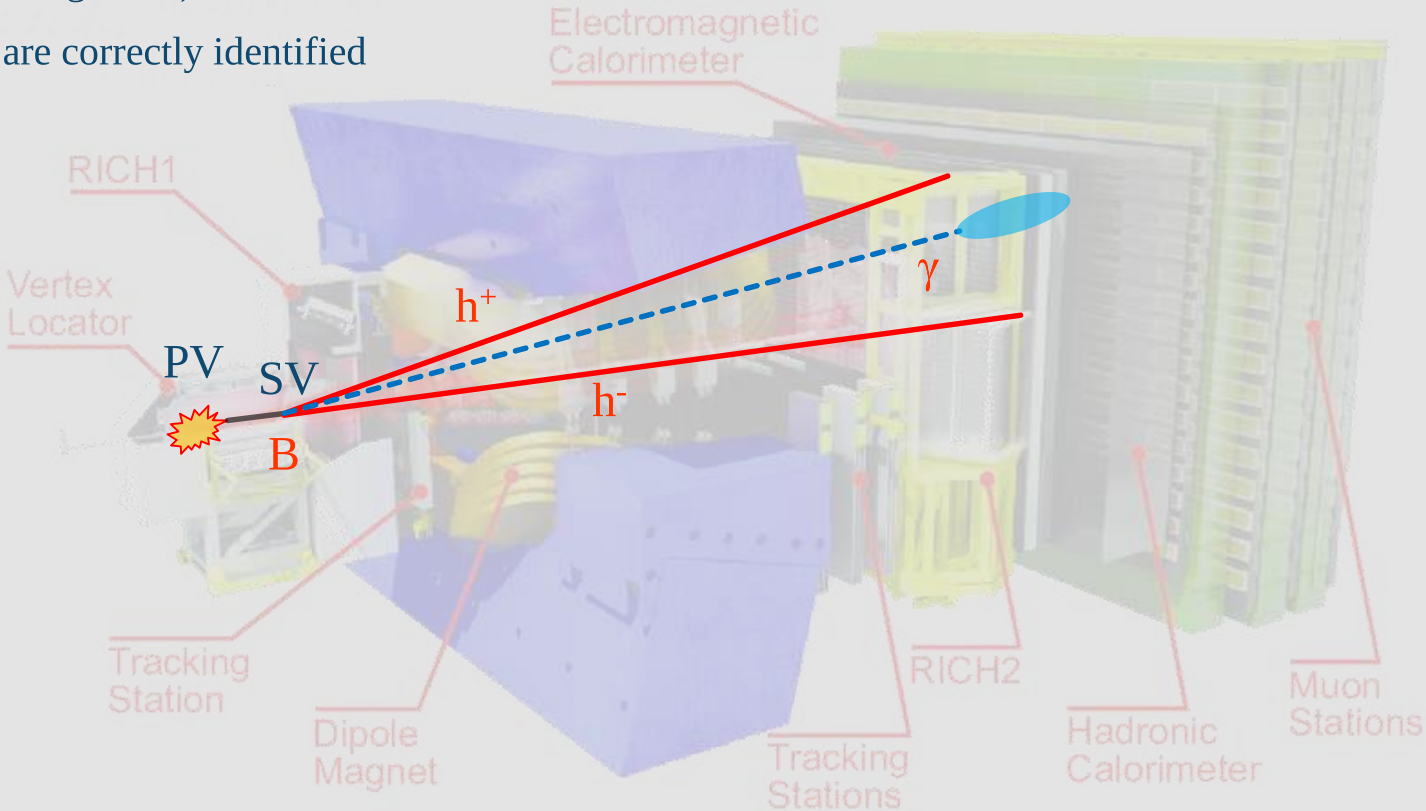
SIGNAL AND BACKGROUNDS

Signal (and Physical background) :

- final states particles are correctly identified

$B_d \to K^*\gamma$

$B_s \to K^*\gamma$



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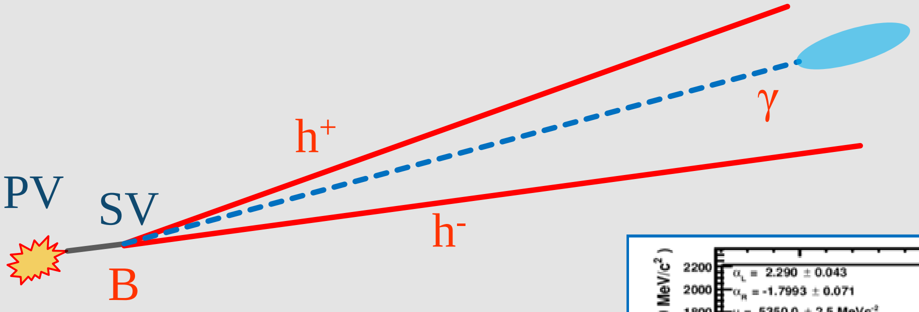
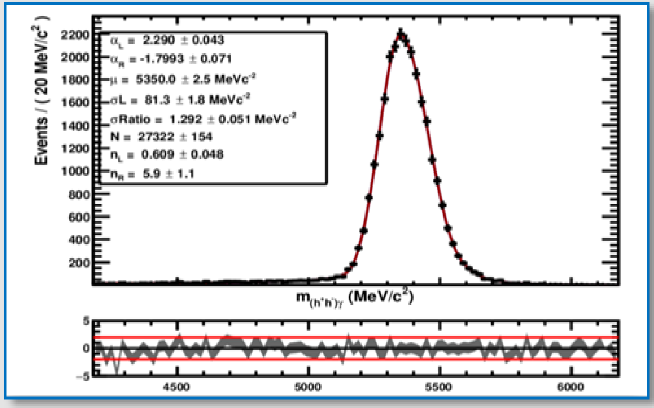
$B_d \rightarrow K^*\gamma$

$B_s \rightarrow K^*\gamma$



Expected yields and shape of the two contributions are extracted from Monte Carlo simulation :

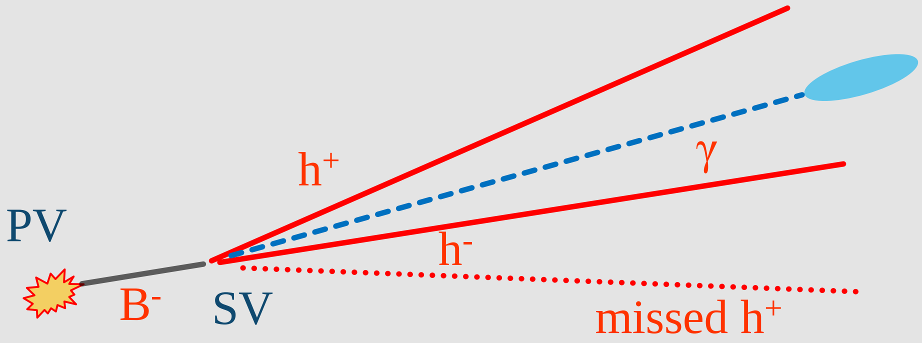


Contamination : 0,8 %

BACKGROUNDS

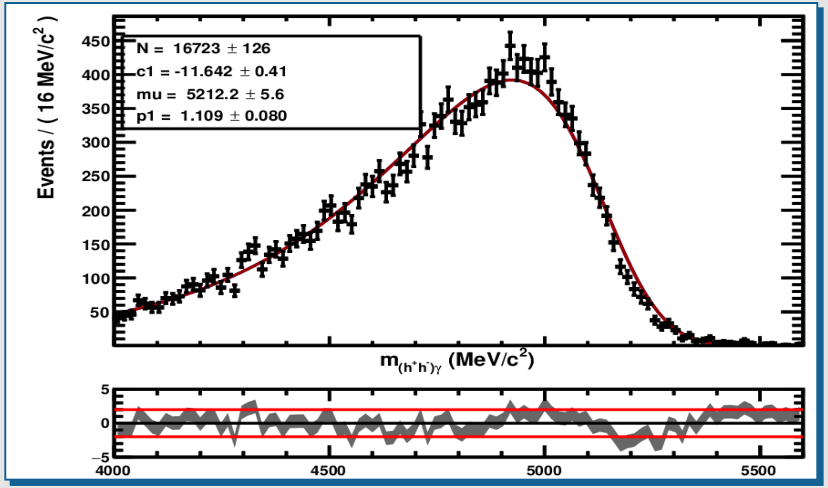
Partially reconstructed :

Ex : $B^+ \rightarrow K^{1+} \gamma \rightarrow K^+ \pi^- \pi^+ \gamma$



Expected yields and shape are extracted from

Monte Carlo simulation :

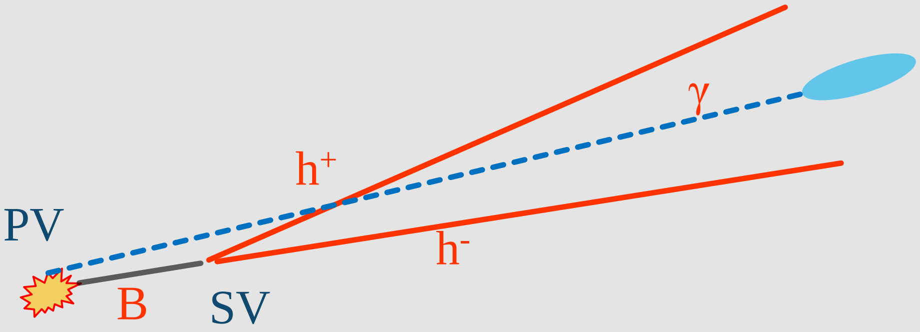


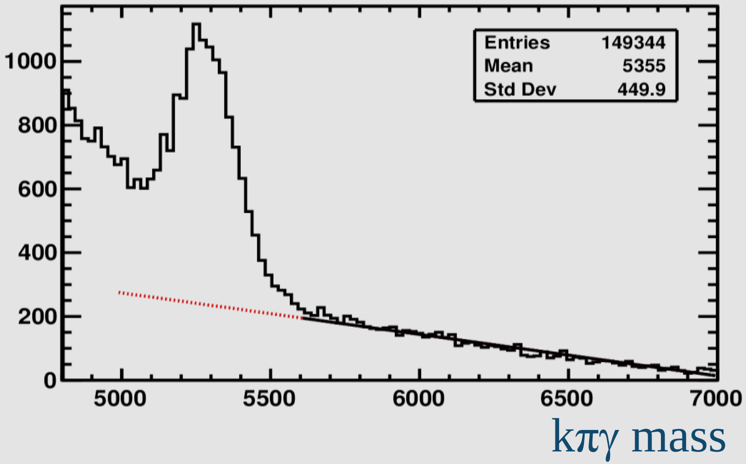
Contamination : ~1%

BACKGROUNDS

Combinatorial background :

Final state particles don't all come from the (same) B decay

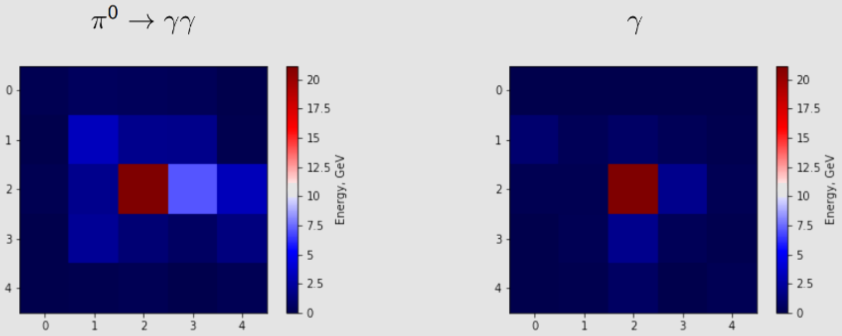


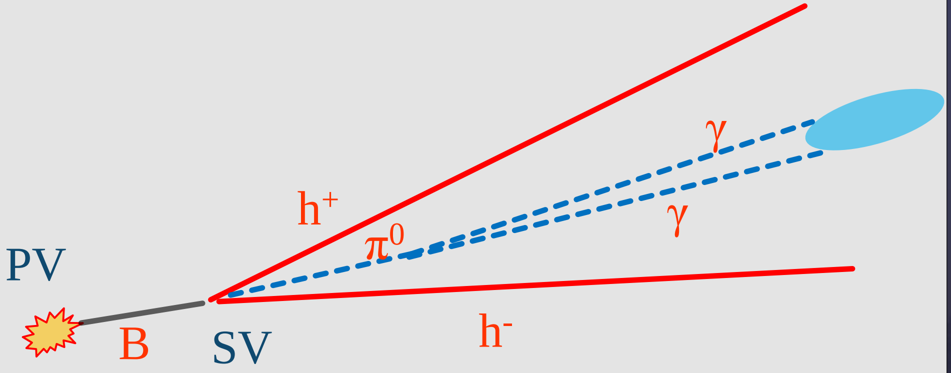


BACKGROUNDS

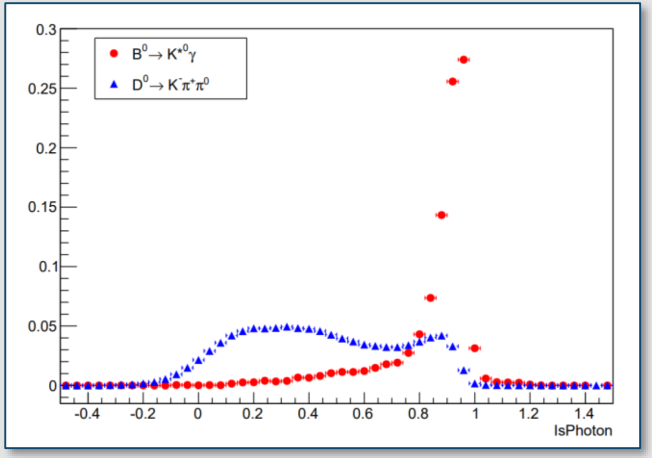
γ/π^0 Mis-identification :

$\pi^0 \to \gamma\gamma$ looks like a single γ in the ECAL :





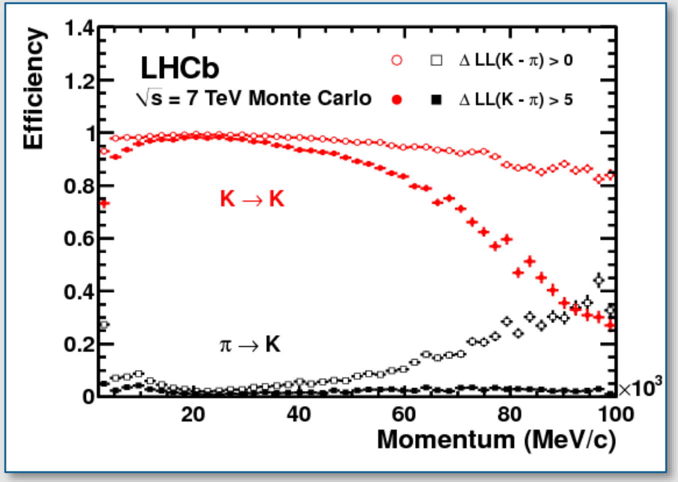
We use a Neural Network trained to distinguish between the two :

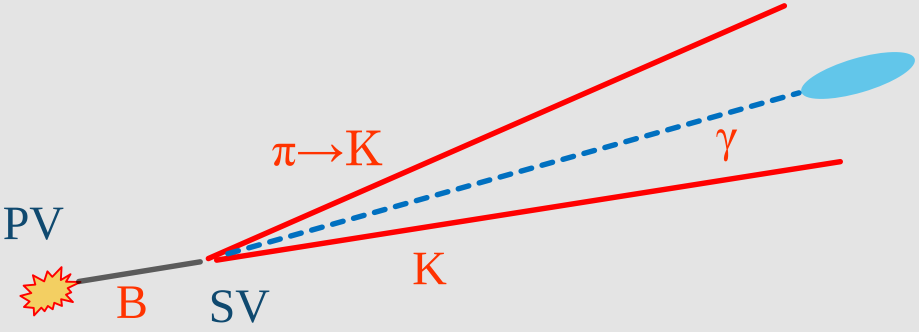


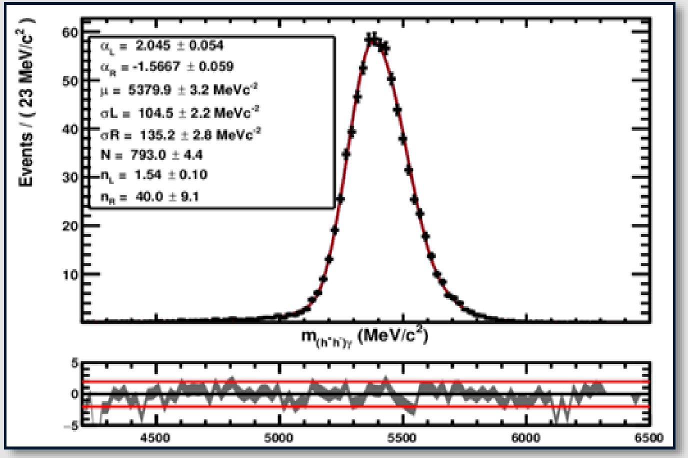
BACKGROUNDS

Charged tracks Mis-identification :

Peaks under the signal !







Contamination :

- 0,01 % for double mis-id
- From 1 to 10% for simple Mis-ID

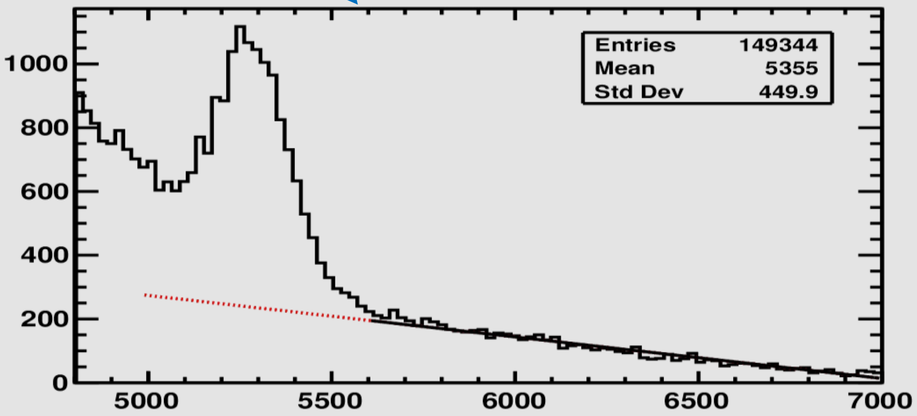
OPTIMAL CUT

$$\text{FoM} = \frac{S}{\sqrt{S+B}}$$

With $S = L * 2 * \sigma(bb) * f_{b\rightarrow(B^0/B_s/\Lambda b)} * BR(B\rightarrow hh\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{PID} * \varepsilon_{BDT\_sig}$

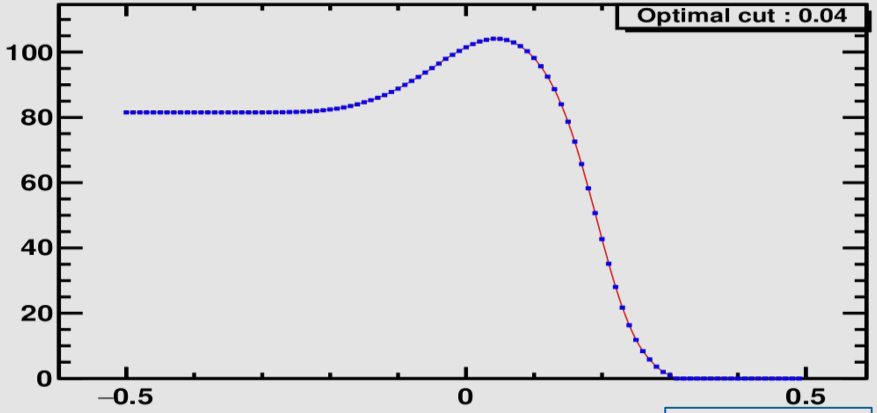
$$B = \underbrace{N^{3\sigma}_{bkg}}_{\text{From linear fit of combinatorial}} * \varepsilon_{BDT\_bkg}$$

From linear fit of combinatorial



kπγ mass

FoM



BDT cut

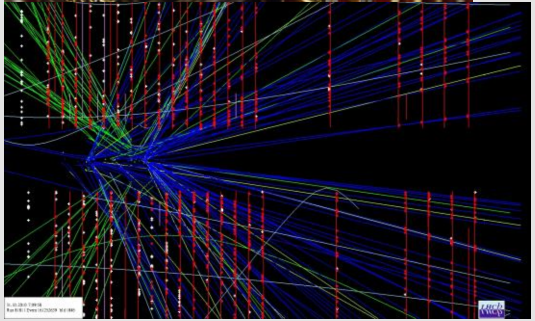
BDT EFFICIENCIES

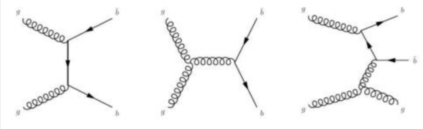
Training Sample	BDTCut	Efficiency (K^*/ϕ)	Efficiency ($K1+K^*2/f'2$)	BKG rejec.
$K^*\gamma$_2011	> 0,04	94,2 %	??	88,8 %
$K^*\gamma$_2012	> 0	91,3 %	79,6 %	93,3 %
$(K^*+K^*2+K1)\gamma$_2012	>0,01	89,6 %	88,3 %	93,8 %
$(K^*2+K1)\gamma$_2012	>-0,01	88,5 %	88,7 %	93,8 %
$\phi\gamma$_2011	> 0,13	93,4 %	??	93,7 %
$\phi\gamma$_2012	> 0,07	92 %	43,6 %	96,5 %
$(\phi + f'2)\,\gamma$_2012	> 0,07	89 %	76,3 %	96 %
$f'2\,\gamma$_2012	> 0,05	85 %	81,3 %	95,8 %
$(pK)\gamma$_2011	> 0,1	83,3 %	x	94,5 %
$(pK)\gamma$_2012	> 0,07	79,2 %	x	97,6 %

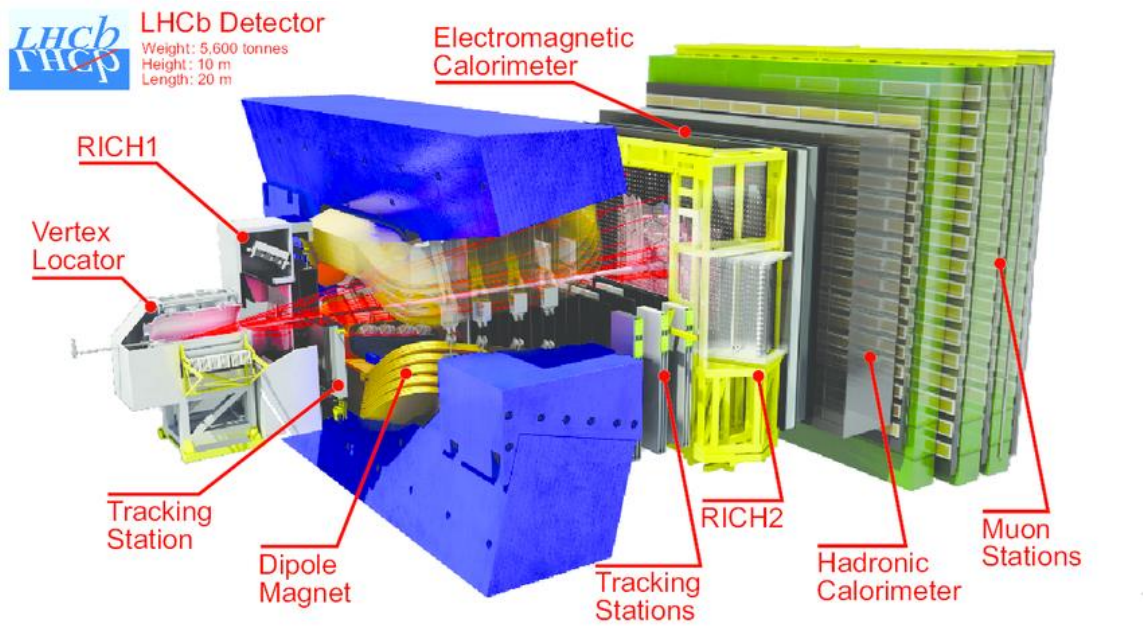
LHCB

The Vertex Locator :

Bunch crossing rate : 40M/s pp collision per crossing : ~2,57





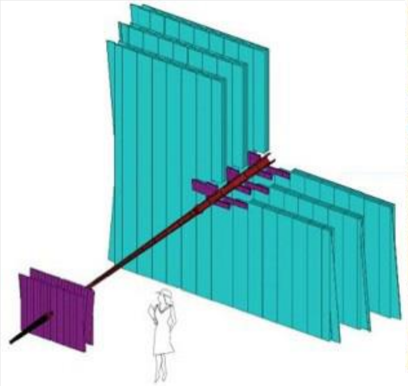


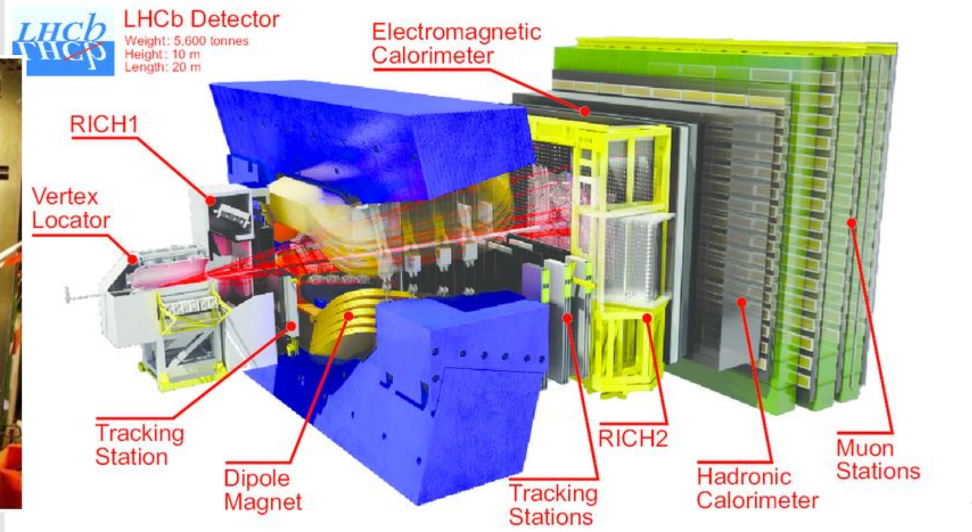
LHCB

The Tracking system

Magnetic field : 3,6Tm

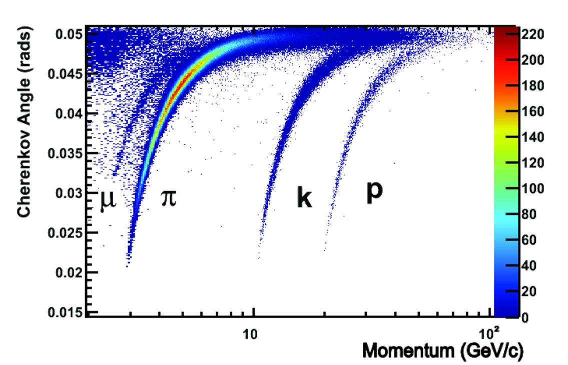
-> measure momenta : $R = \frac{\boldsymbol{mv}}{\boldsymbol{q}B}$



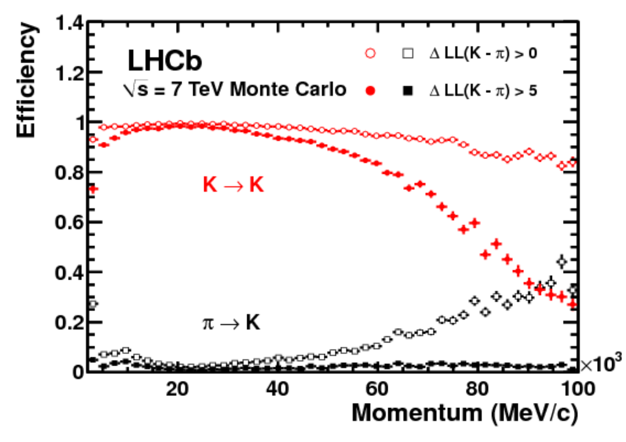


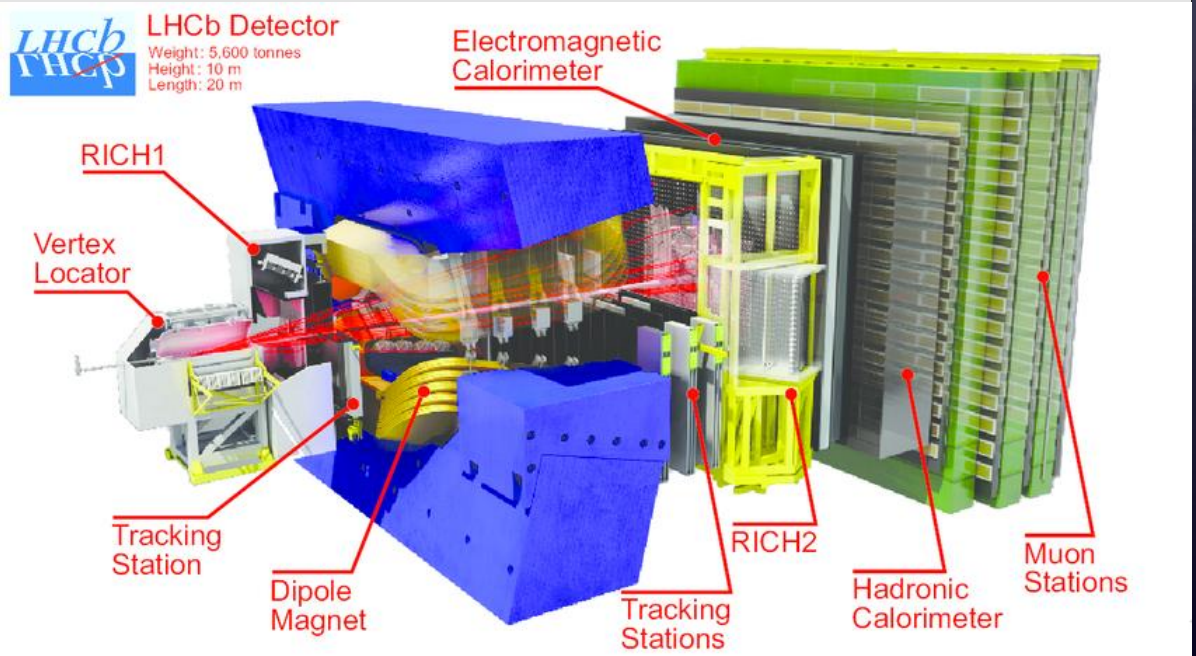
LHCB

RICH detectors



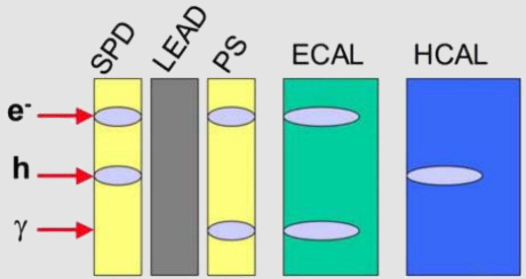
$$\cos\theta = \frac{1}{\beta n}$$



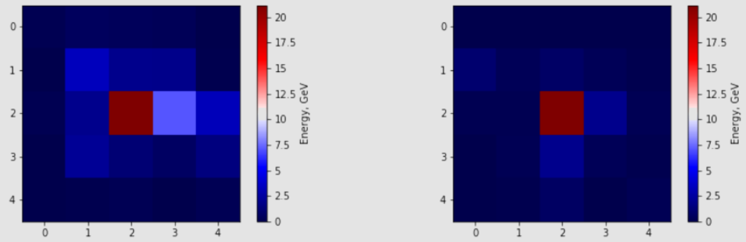


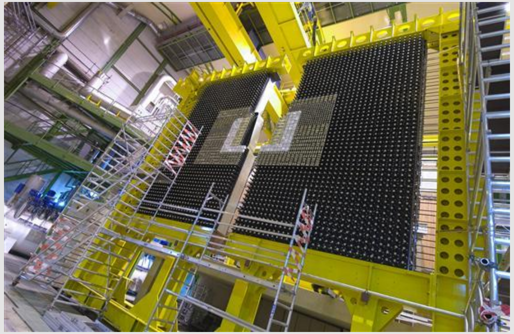
Calorimeters :

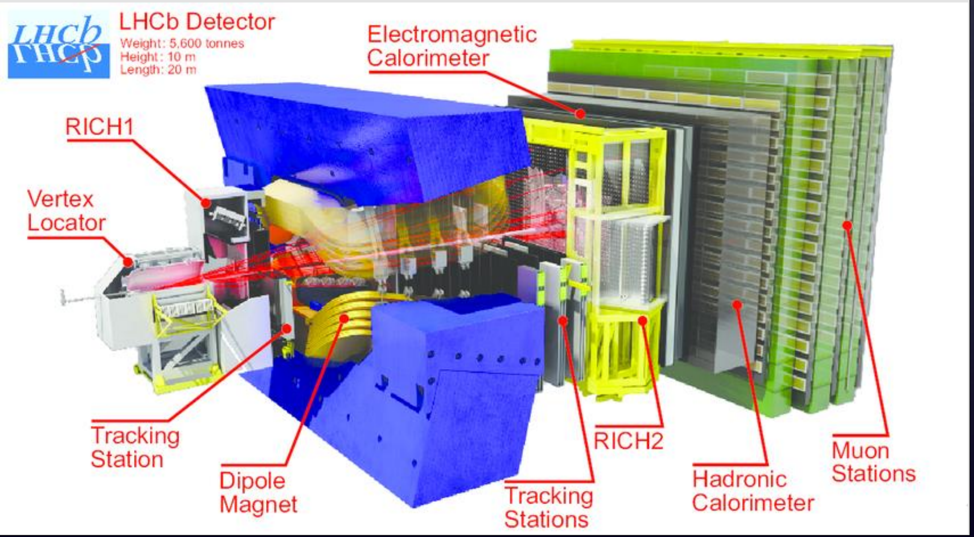
Resolution on B mass in radiatives : 80-100MeV



$\pi^0 \to \gamma\gamma$ γ



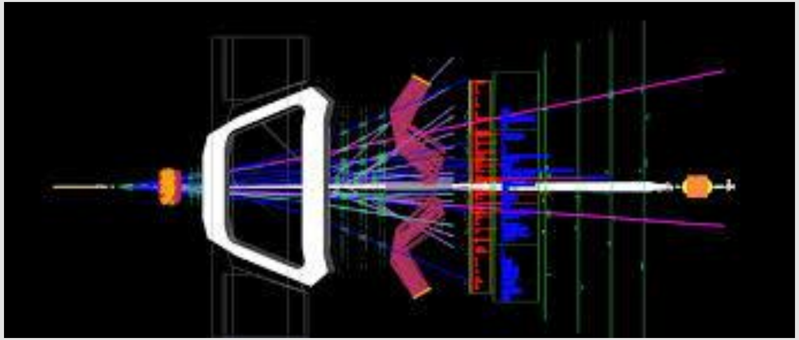


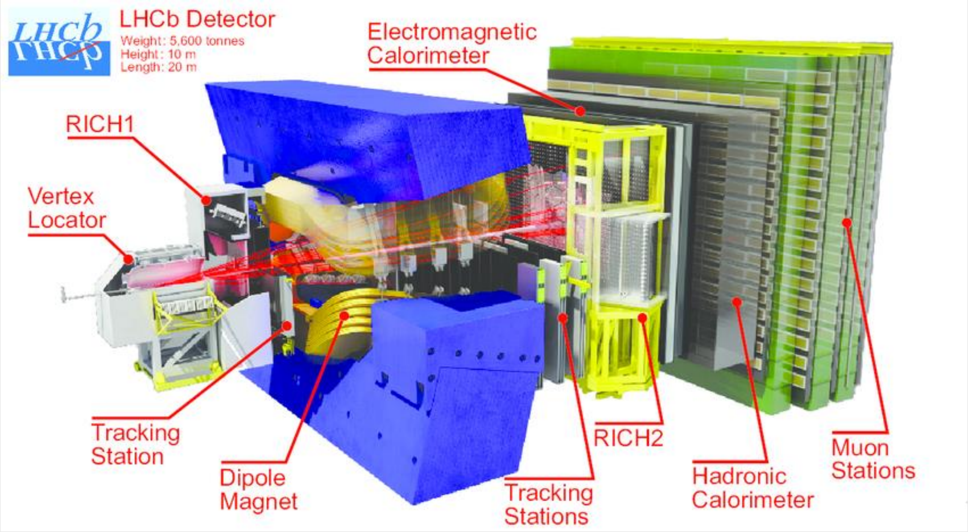


LHCB

Muon trackers :

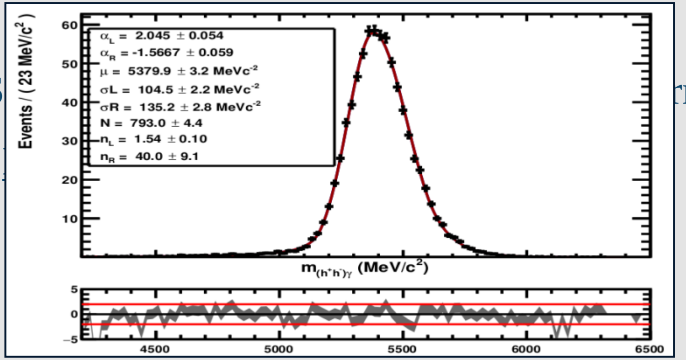
B-> mumu/ B-> K*mumu





CHARGED MIS-ID

- S … rmalization fixe
-



Note : normalisation wrt simult. fit :

$$\frac{N(K\pi\gamma \to KK\gamma)}{N(K\pi\gamma)} \neq \text{Contamination}$$

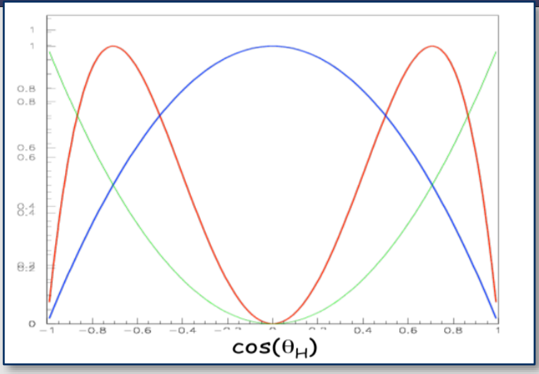
Contribution	Contamination	
KK -> KPI	2,4 %	2,6 %
PK -> PIK	9 %	14,2 %
PK -> KPI	0,89 %	1,2 %
KPI -> PIK	0,22 %	0,25 %
KPI -> KK	2,1 %	3,2 %
PK -> KK	5,8 %	7,4 %
KPI -> KP	13 %	9 %
KPI -> PK	1 %	0,8 %
KK -> PK	14,5 %	14,2 %

REWEIGHTING MC ?? (FOR LATER)

- MC
- Reweighting
- Efficiency studies ?
- Contamination computation ?

2D MASS FIT

Make use of the helicity angle



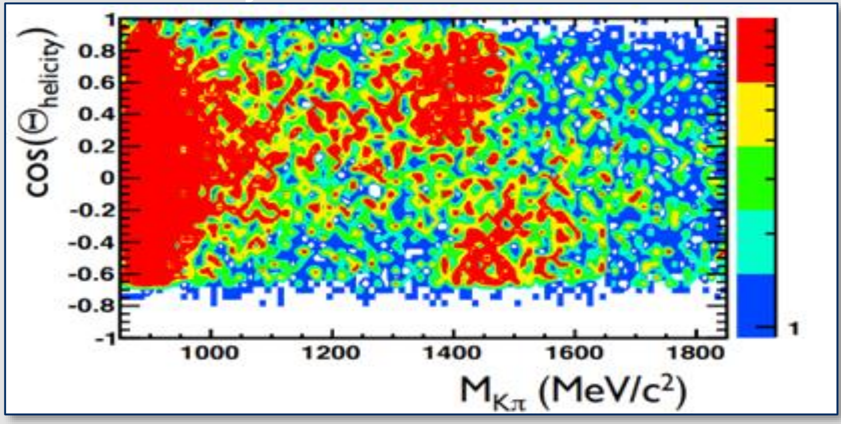
$\cos^2(\theta_H)$ for S- waves : π^0 backgrounds

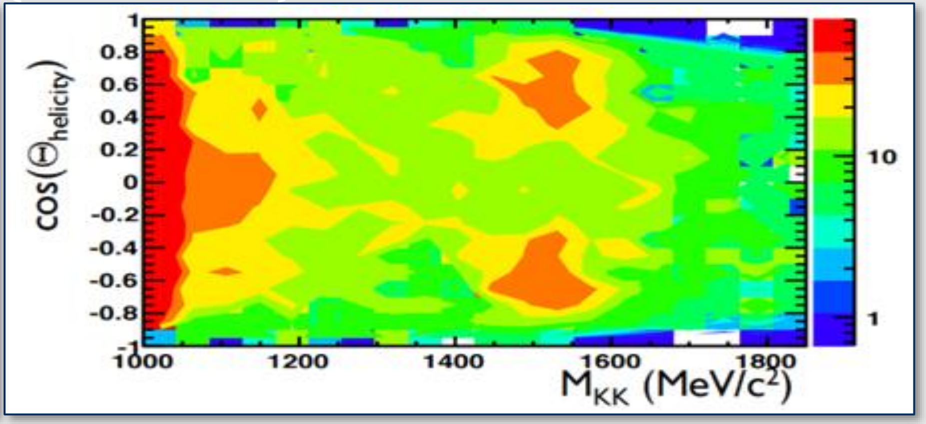
$\sin^2(\theta_H)$ for P-waves : $K^*(892)\gamma$, $K1(1410)\ \gamma$, $\varphi(1020)\ \gamma$

$\cos^2(\theta_H).\sin^2(\theta_H)$ for D-waves : $K^*\ 2\ (1430)\ \gamma$, $f'\ 2\ (1525)$

-> release the anti S-waves cut

Preliminary look to the data run1+run2 (2.7 + 1.0 fb^{-1}) :





- Clear D-wave contribution in the $K^*_2(K\pi)$ and $f'_2(KK)$ region
- Expecting a first observation of $B_s \to f'_2(1525)\ \gamma$ and $B^0 \to K_1(1410)\ \gamma$

PRESELECTION

- Standard Vγ selection with :
- - a release of the h^+h^- mass window (below the charm threshold)
- - no cut on the helicity
- - $m(h\ \gamma_{\rightarrow\pi^0}) > 2000$ MeV/c²

- List of cuts :

h_MINIPCHI2 > 16
max(h1_PT,h2_PT) > 1200
min(h1_PT,h2_PT) > 500
h_P > 500
h_P < 100000
h1_eta > 1.5
h1_eta1 < 5.0
res_ENDVERTEX_CHI2 < 9
h_TRACK_CHI2NDOF < 3
h_TRACK_GhostProb < 0.4
B_DiraAngle < 0.06

B_PT>2000
B_IPCHI2_OWNPV<9.0
gamma_CL > 0.2
gamma_PP_IsPhoton>0.6
gamma_PT > 3000

B_M01 < 1850 (<3000 for pKγ)

PID SELECTION

- In order to reduce the cross feeds and build exclusive samples the following cut is used :
- $\mathrm{probNNh_i\ (h) > xh_i\ \&\ probNNh_i\ (h) > probNNh_j\ (h)}$ for all $h_j \neq h_i$ $(h_i = \pi, K, p)$
- Optimisation : Scan (xh_1, xh_2) cut values
- The corresponding efficiency of each (h_1h_2) to be reconstructed as (kpi), (kk), (pk) etc… is extracted from calibration samples using nTracks-reweighted MC samples and the PIDCalib tool.
- MC used (Sim8 2011 / 2012):
- B_d -> $K^*(892)\ \gamma$
- B_s -> $\phi(1020)\ \gamma$
- Λ_b-> $\Lambda^*(1520/1670/1820/1830)\ \gamma$

1 sample / possible reconstruction (including misID kpi->kk, etc…) is build using truthmatching

- \- preselection and truthmatching applied on MC
- PIDCalib settings :
- \- Custom 3D binning in {nTracks(5), PT(8), ETA(8)} based on MC distributions
- \- V2 ProbNN variables

PID FOM

- The FoM computed for each (x_{h1}, x_{h2}) cut values is : FoM = $\frac{S}{\sqrt{S+B}}$
- With :

• $S = L * 2* \sigma(bb) * f_{b\to(B0/Bs/\Lambda B)} * BR(B\to hh\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{PID}(x_{h1}, x_{h2})$

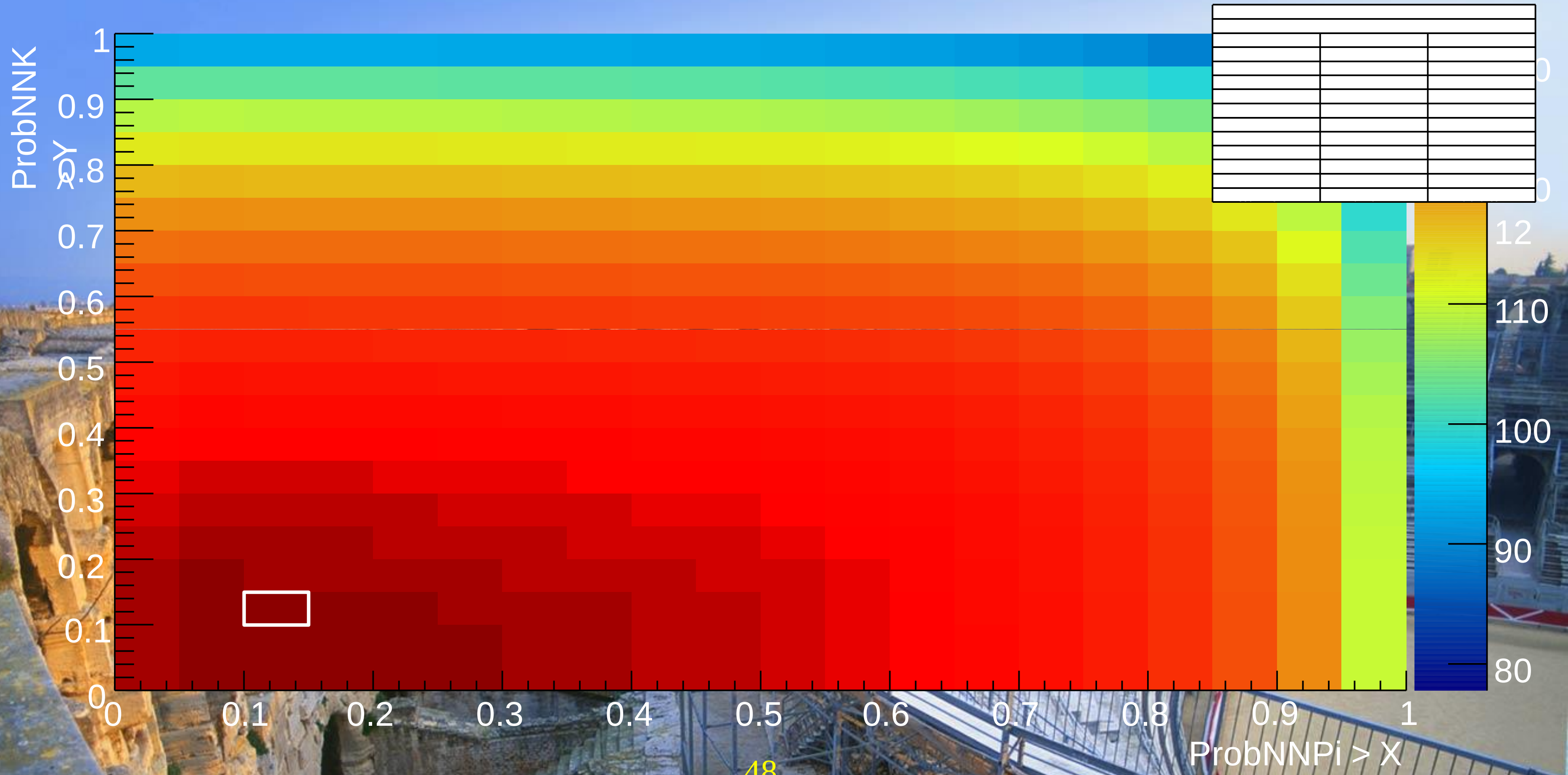
- assuming $BR_{vis}(B\to K\pi\gamma) = BR(B\to K^*(892)\gamma) / \boxed{0{,}65}$
- $BR_{vis}(B\to KK\gamma) = BR(B\to phi\ \gamma) / \boxed{0,\ 30}$
- $BR_{vis}(B\to pK\gamma) = 3.39\ 10^{-5}$ (from Vicente's thesis)
- ε_{PID} is taken as the mean of the PIDCalib eff in the reference sample

From preliminary fit

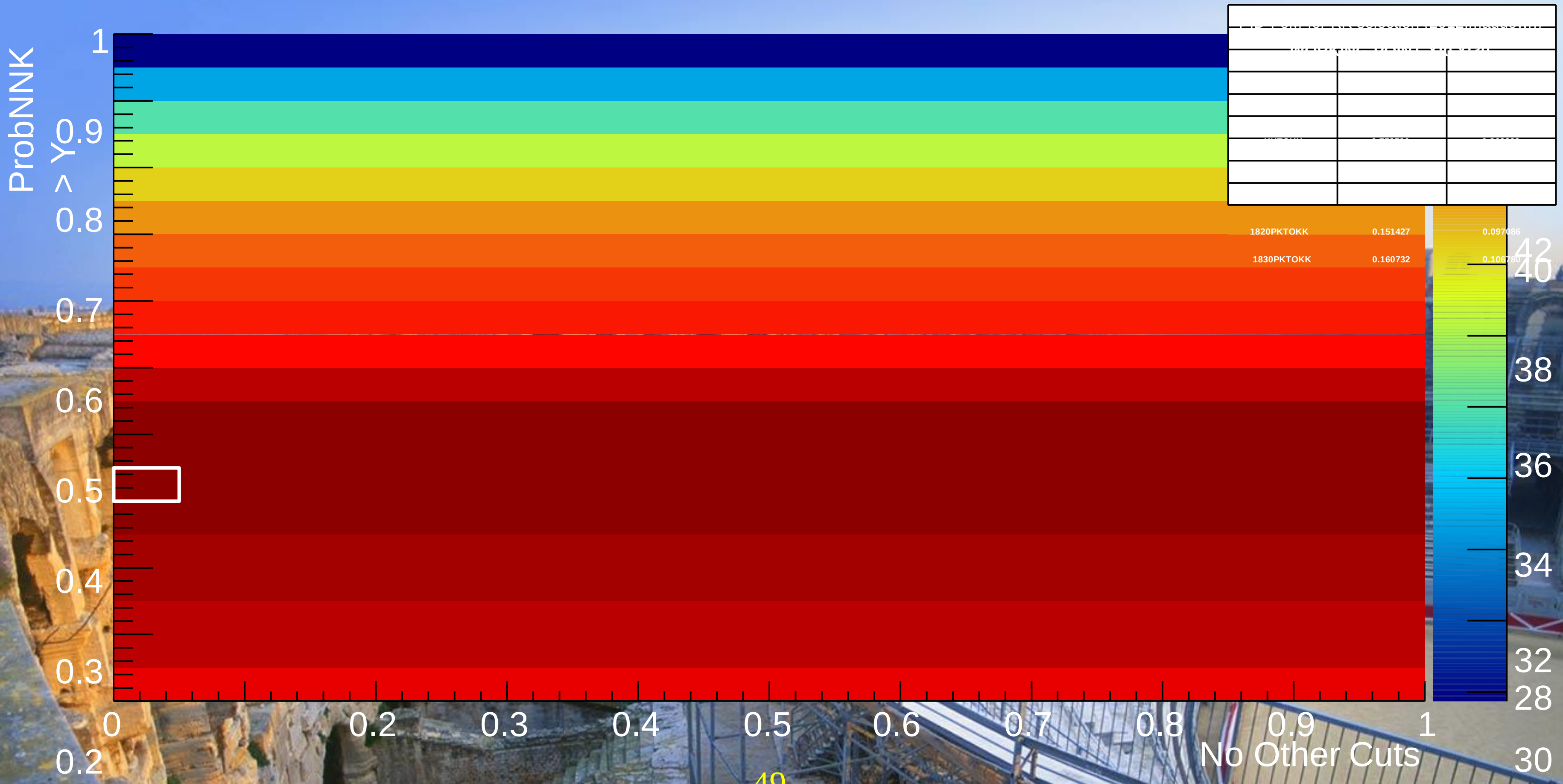
• $B = \sum^{cross\ feeds} L * 2* \sigma(bb) * fb_{\to(B0/Bs/\Lambda B)} * BR(B\to[hh]_{trueID}\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{misID}(x_{h1}, x_{h2})$

- This FoM has been drawn for a scan performed by steps of 0,05 in ProbNN
- and for each final state/year/magnet polarity

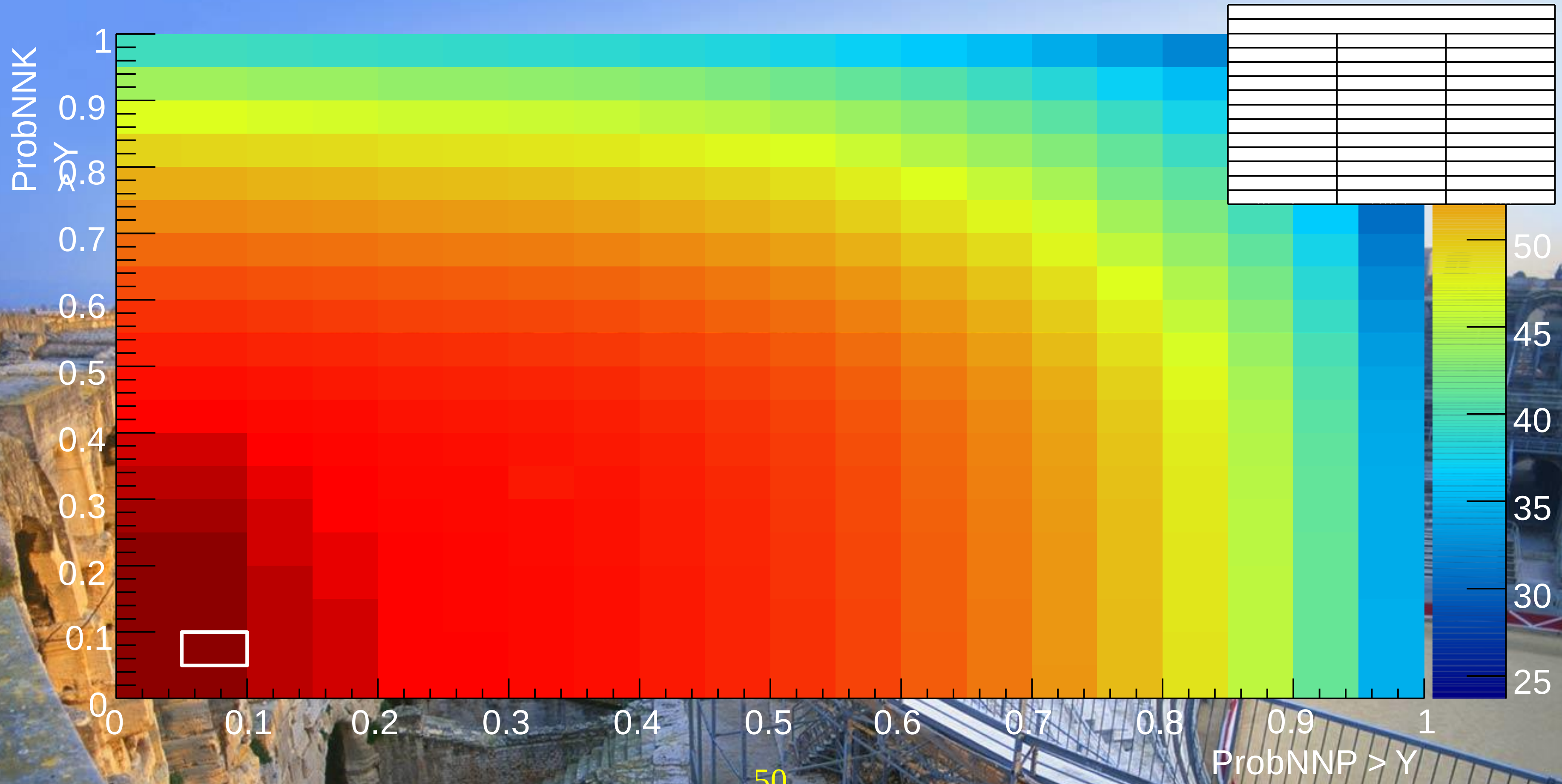
PID FOM FOR KPI SELECTION (2012,MAGDOWN)



PID FOM FOR KK SELECTION (2012,MAGDOWN)



PID FOM FOR PK SELECTION (2012,MAGDOWN)



FINAL WORKING POINTS

- The Fol

Final State	Cut h1	Cut h2	Eff for the signal
$K\pi\gamma$	ProbNNK > 0,1	ProbNNpi > 0,1	83 %
$KK\gamma$	ProbNNK > 0,3	ProbNNK > 0,3	73%
$pK\gamma$	ProbNNp > 0,05	ProbNNK > 0,05	60%

- Errors to be computed…

MULTIVARIATE ANALYSIS

- The next step is to train a Multivariate selection to reduce combinatorial contamination
- Signal samples:
- MC used for $K\pi\,\gamma$:
  - $B^0 \to (K^*(892) \to K\,\pi\,)\gamma$ (2011/12)
  - $B^0 \to (K^*_2(1430) \to K\,\pi\,)\gamma$ (2012)
  - $B^0 \to (K_1(1410) \to K\,\pi\,)\gamma$ (2012)

We train 3 MVA :
One with only K* for 2011 and 2012
One with a mix of all the resonances for 2012
One with K^*_2 / K_1 for 2012

- MC used for $KK\,\gamma$:
  - $B_s \to (\phi \to K\,K\,)\gamma$ (2011 / 2012)
  - $B_s \to (f'_2\,(1525) \to K\,K\,)\gamma$ (2011)

We train 3 MVA :
One with only $\phi(1020)$ for 2011 and2012
One with a mix of the two resonances
One with only f'_2

- MC used for $KK\,\gamma$:
  - $\Lambda_b \to (\Lambda^*(1520) \to p\,K\,)\gamma$
  - $\Lambda_b \to (\Lambda^*(1670) \to p\,K\,)\gamma$
  - $\Lambda_b \to (\Lambda^*(1820) \to p\,K\,)\gamma$
  - $\Lambda_b \to (\Lambda^*(1830) \to p\,K\,)\gamma$

We train one MVA for each year

- All the MC samples are reweighted on nTracks & PIDCalib_eff

MULTIVARIATE ANALYSIS

BK

S

Sample	MC Signal	SB	SB (no PID cut)
$K\pi\gamma$_2011	107544	6540	15999
$K\pi\gamma$_2012	29340	30970	75291
$KK\gamma$_2011	84080	460	3421
$KK\gamma$_2012	30208	1815	163309
$pK\gamma$_2011	40249	384	7707
$pK\gamma$_2012	45344	1988	40429

Low stats for training…

- Since the number of events in the Side Band is quite low for KK γ and pK γ samples after the PID cut, we choose to train on a SB without this cut.
- We first tested this for $K\pi\gamma$, by comparing two MVA trained on each of the SB

MVA BUILDING

- Different algorithms and settings have been tested (on $K\pi\gamma$):

- Best algorithm : BDT (AdaBoost)
- Best Settings : - Ntrees=800
- - MaxDepth=3
- - minNodSize=2,5%
- - nCuts=200
- - AdaBoost β=1

- Samples have been splitted in 2 according to (evtNumber%2=0), each subsample being tested on the other one.
- Starting from a set of 40 variables, the minimum set has been chosen removing variables one by one according to their rank during the training.
- We end up with 13 variables. Removing any one more seems to worsen significantly the performances (ROC AUC).

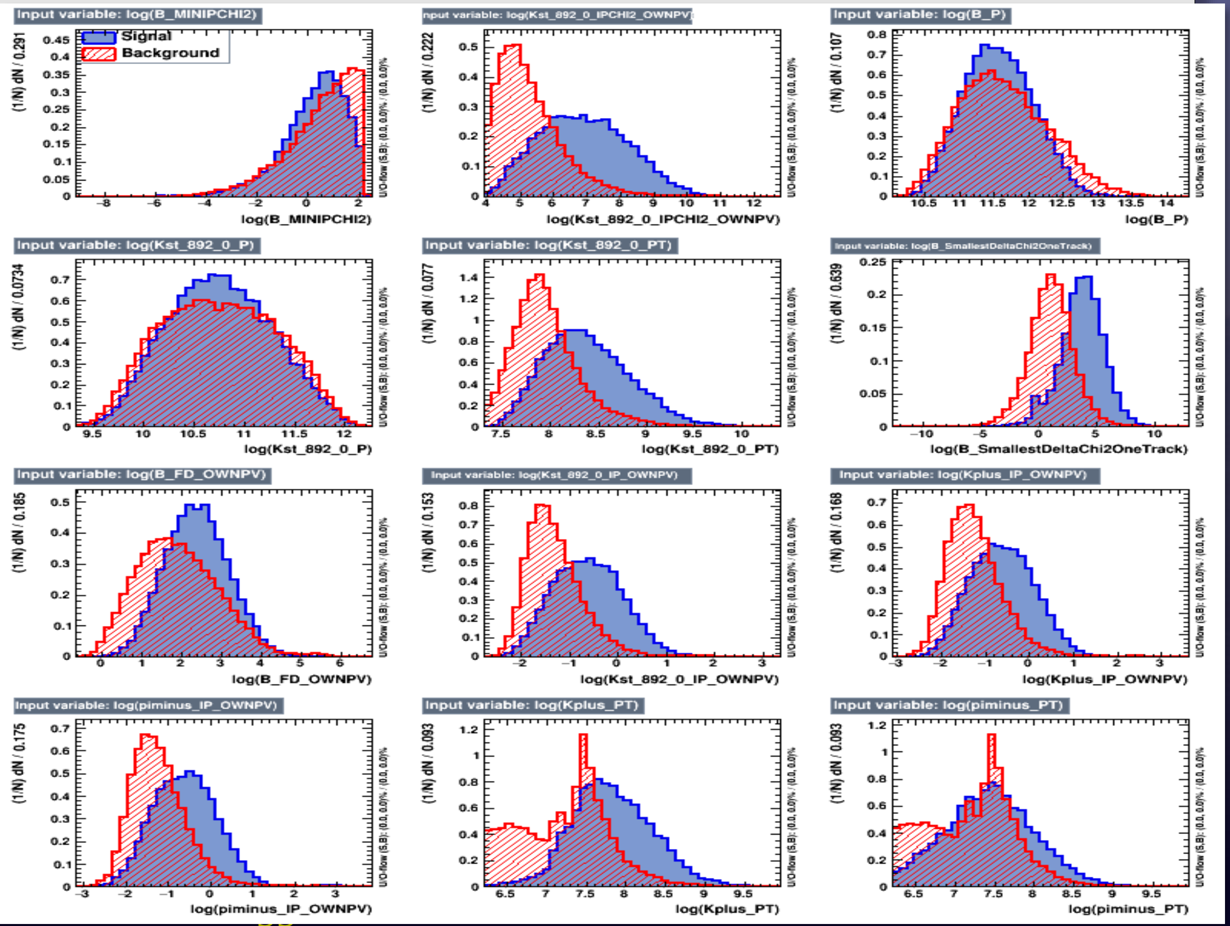
BDT VARIABLES

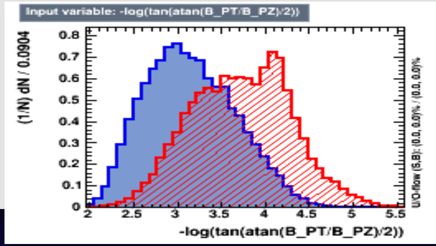
Final set :

- B min χ_{IP}^2
- B pseudorapidity
- B momentum
- B Flight Distance
- B vertex isolation (Smallest $\Delta\chi^2$)

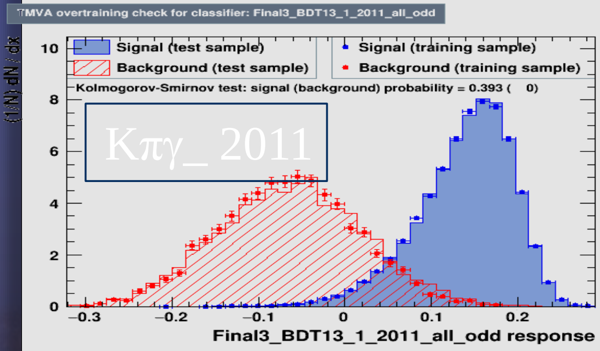
- χ_{IP}^2 of the (hh) resonance
- IP of the resonance
- Momentum of the resonance

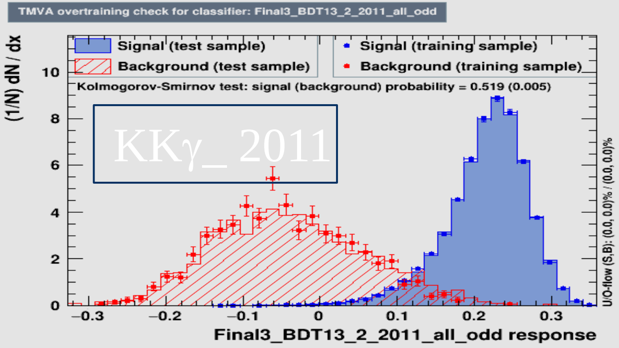
- IP of the tracks
- Transverse momenta of the tracks

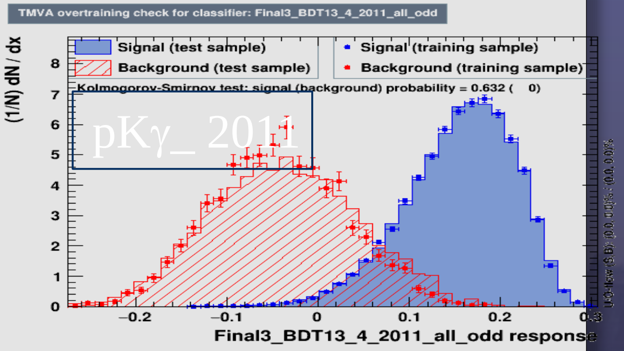




OVERTRAINING TESTS

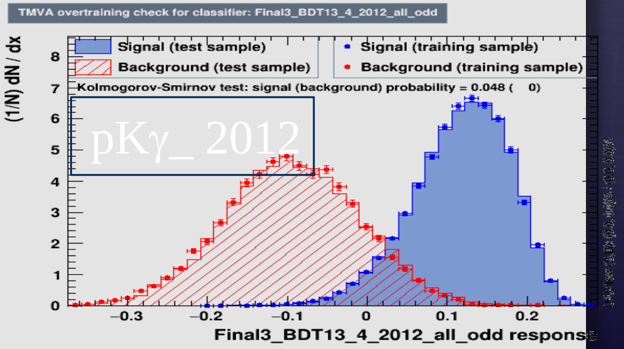






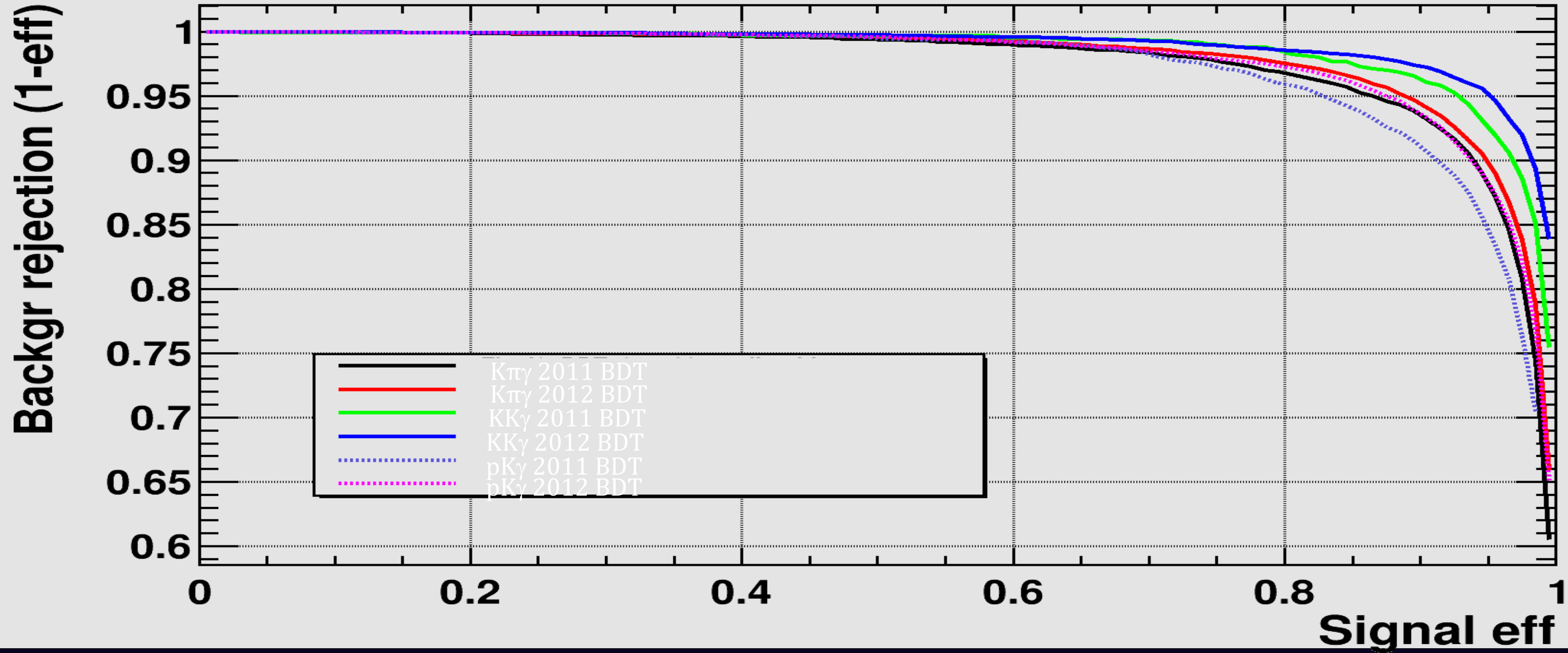
Kπγ_ 2012

KKγ_ 2012



BDT PERFORMANCES

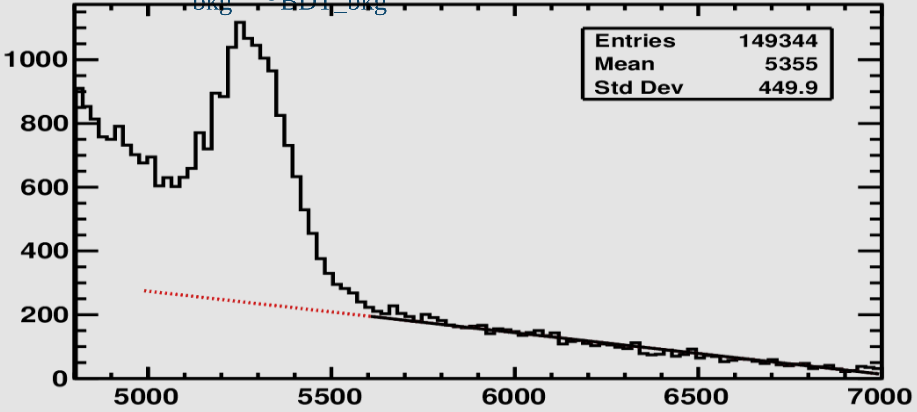
The variable set and settings optimised on $K\pi\gamma$ are used to train BDT on the two other modes :



OPTIMAL CUT

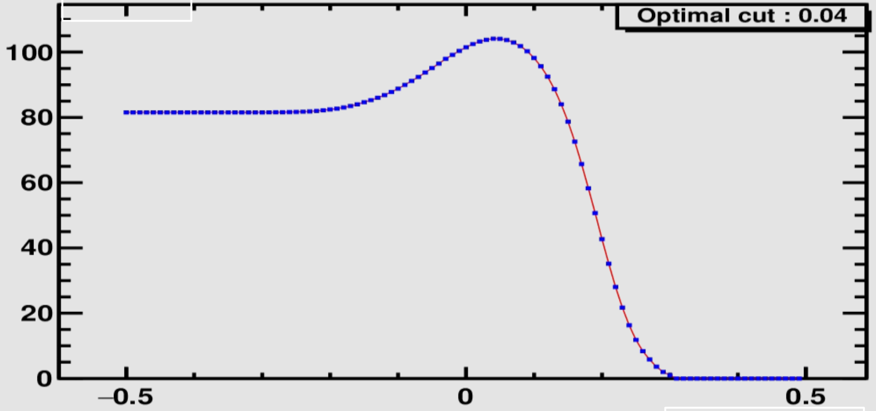
- FoM = $\frac{S}{\sqrt{S+B}}$
- With $S = L * 2 * \sigma(bb) * f_{b \to (B^0/B_s/Ab)} * BR(B \to hh\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{PID} * \varepsilon_{BDT\_sig}$
- $B = N^{3\sigma}_{bkg} * \varepsilon_{BDT\_bkg}$

From linear fit of combinatorial



kπγ mass

FoM



BDT cut

PID FOM

The FoM computed for each (x_{h1}, x_{h2}) cut values is : FoM = $\frac{S}{\sqrt{S+B}}$

With :

$$S = L * 2 * \sigma(bb) * f_{b\to(B_0/B_s/\Lambda_b)} * BR(B\to hh\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{PID}(x_{h1}, x_{h2})$$

$$B = \sum^{cross\ feeds} L * 2 * \sigma(bb) * fb_{\to(B_0/Bs/\Lambda b)} * BR(B\to[hh]_{trueID}\gamma) * \varepsilon_{MC} * \varepsilon_{presel} * \varepsilon_{misID}(x_{h1}, x_{h2})$$

This FoM has been drawn for a scan performed by steps of 0,05 in ProbNN.

The $\varepsilon_{PID}(x_{h1}, x_{h2})$ is taken from calibration data.

BDT EFFICIENCIES

Training Sample	BDTCut	Efficiency (K*/ ϕ)	Efficiency (K1+K*2/ f'2)	BKG rejec. (SB in test samples)	BKG rejec. (on SB after PID cut)
			Kπγ		
K*γ_2011	> 0,04	94,2 %	??	88,8 %	89,2 %
K*γ_2012	> 0	91,3 %	79,6 %	93,3 %	94 %
(K*+K*2+K1)γ_2012	>0,01	89,6 %	88,3 %	93,8 %	95,6%
(K*2+K1)γ_2012	>-0,01	88,5 %	88,7 %	93,8 %	95,6 %
			KKγ		
ϕγ_2011	> 0,13	93,4 %	??	93,7 %	93,1 %
ϕγ_2012	> 0,07	92 %	43,6 %	96,5 %	95,6 %
(ϕ + f'2) γ_2012	> 0,07	89 %	76,3 %	96 %	95,6 %
f'2 γ_2012	> 0,05	85 %	81,3 %	95,8 %	95,6 %
			PKγ		
(pK)γ_2011	> 0,1	83,3 %	x	94,5 %	92,3 %
(pK)γ_2012	> 0,07	79,2 %	x	97,6 %	94,8 %

We see that :

- BDT trained with only K* / ϕ MC samples gives a bad efficiency for the modes we are willing to see (43 % for $f'_2\gamma$, 79% for $K_1/K^*_2\,\gamma$)

- Training on a SB with no cuts on PID gives a good background rejection on SB after PID cut

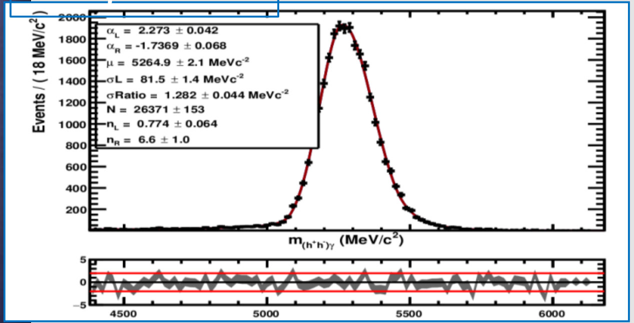
FITTING THE HHγ MASS

- Signal :
  - Asymetric bifurcated CB (μ, σ_{Left}, N ; $\frac{\sigma_{Left}}{\sigma_{Right}}$, α_{Left} , n_{Left} , α_{Right} , n_{Right})

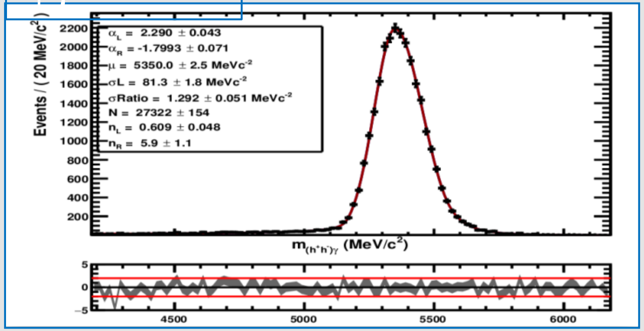
Free parameters

Fixed on MC

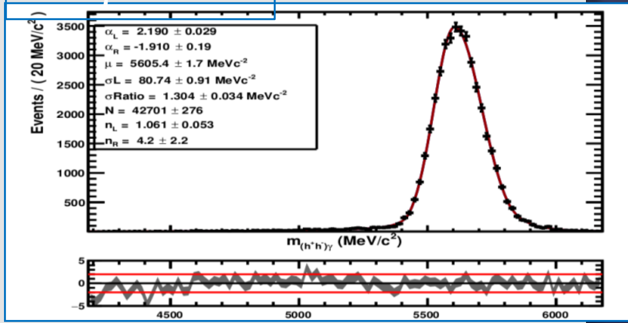
K* γ MC Fit



φγ MC Fit



Λ* γ MC Fit



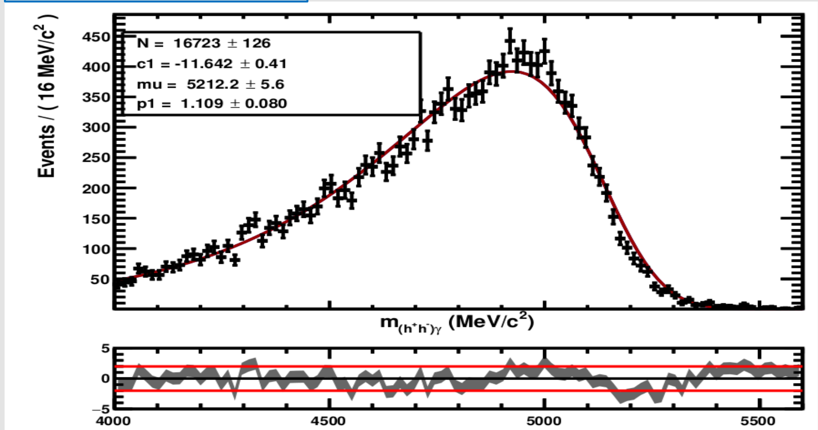
- Combinatorial BKG: Exponential (shape and N free)
- Inclusive partially reconstruced : B -> hh π^0/γ + X (X > 2)
  - Argus (free, $\mu = m_B - 2\, m_\pi$) convoluted with Asym. Gaussian(μ=0, $\sigma = \sigma_{sig}$) (CB convo ?!)

PARTIALLY RECONSTRUCTED

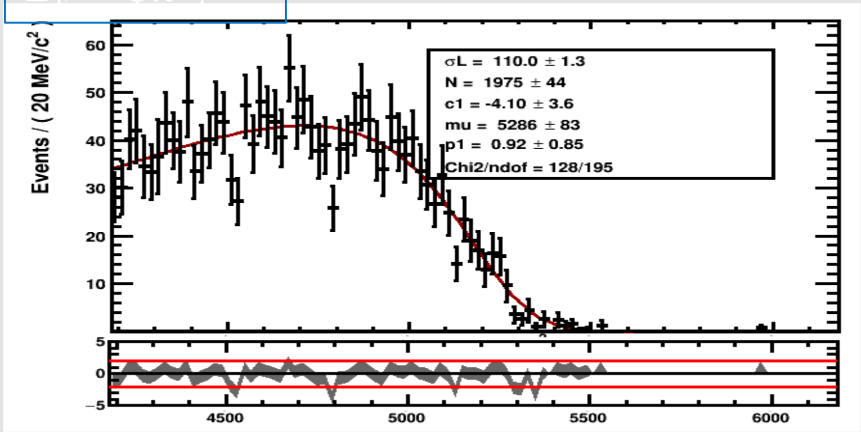
Partially reconstruced : B -> $(hh\pi)_{res}$ γ

- Shape : Argus ($\mu = m_B - m_\pi$, fixed on MC, free yield) convoluted with an
- Asymetric Gaussian(μ=0, $\sigma = \sigma_{sig}$)

B_u-> $(k\pi\pi)\gamma$



B_s-> $\varphi\pi^0\gamma$

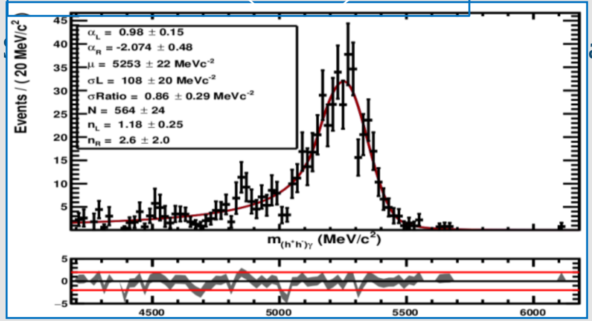


- For every shape we perform an extended maximum likelihood unbinned fit.
- The MC used is reweighted to propagate the overall PID efficiencies, and the BDT selection is applied.

TO DO : study hhη(-> γ γ), would be Argus, shape and yields fixed

Π^0/Γ MIS-ID CONTRIBUTIONS

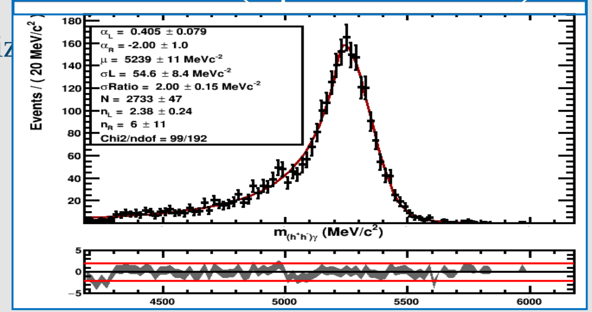
Bd->Kπ π^0 (2012)



BR = 3,78 e-5

Contamination : C = 2,6%

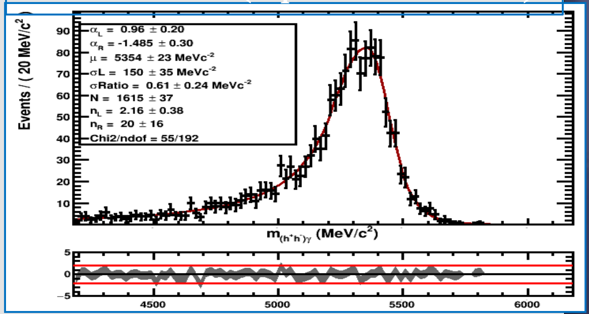
Bd->KK π^0 (sq_Dalitz_2012)



BR = 0,22 e-5

Contamination : C = 2,5%

Bs->KK π^0 (sq_Dalitz_2012)



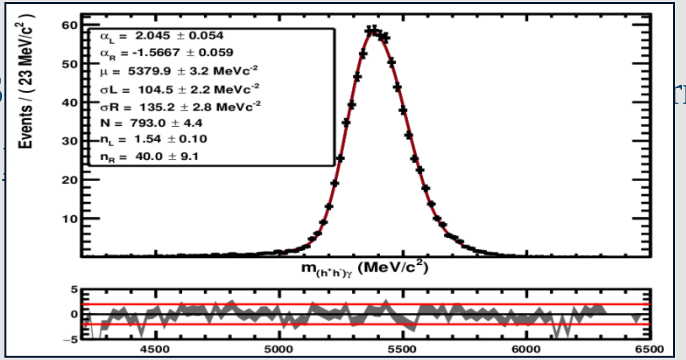
BR = $\frac{BR(Bd \to K\pi\,\pi 0)}{BR(Bd -> K*\gamma)} * BR(Bs \to \varphi\,\gamma)$

Contamination : C = 1,2%

- Note : the contamination are lower in 2011, seems to be due to the BDT
- TO DO : request better MC with new DecFile

CHARGED MIS-ID

- S rmalization fixe

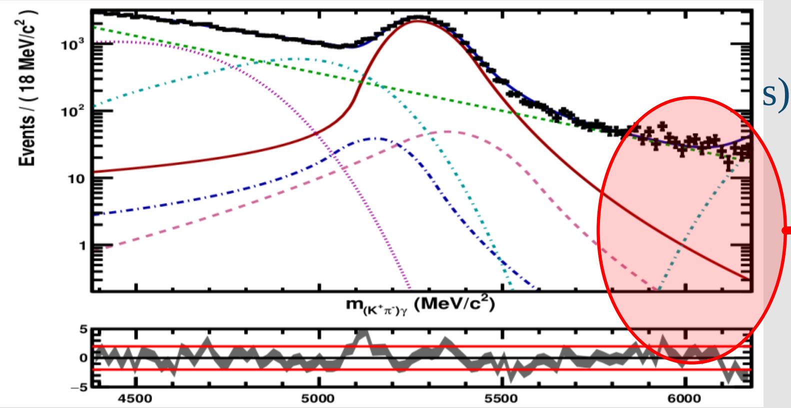


Note : normalisation wrt simult. fit :

$$\frac{N(K\pi\gamma \rightarrow KK\gamma)}{N(K\pi\gamma)} \neq \text{Contamination}$$

Contribution	Contamination	
KK -> KPI	2,4 %	2,6 %
PK -> PIK	9 %	14,2 %
PK -> KPI	0,89 %	1,2 %
KPI -> PIK	0,22 %	0,25 %
KPI -> KK	2,1 %	3,2 %
PK -> KK	5,8 %	7,4 %
KPI -> KP	13 %	9 %
KPI -> PK	1 %	0,8 %
KK -> PK	14,5 %	14,2 %

SIMULTANEOUS FIT

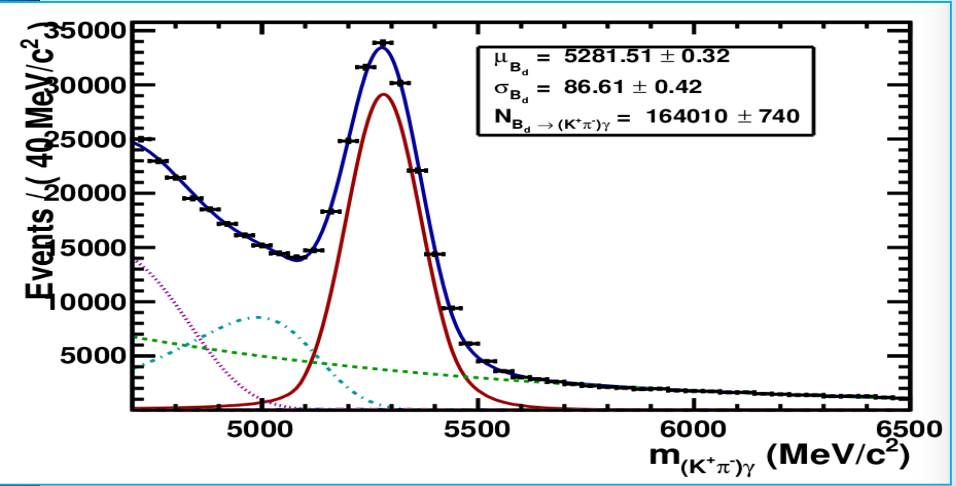


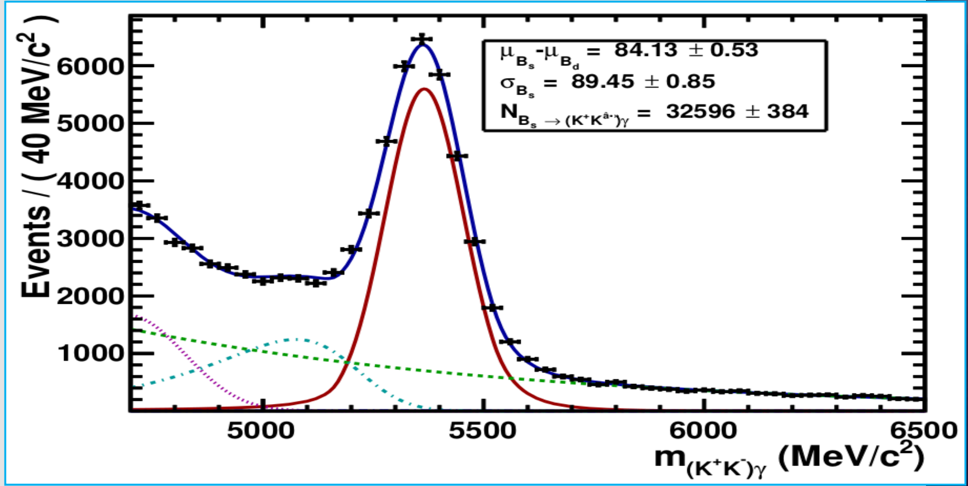
s) :

WORK IN PROGRESS !

RUN 2 ANALYSIS

- All the requested 2015/6 MC samples for kpi and kk are (almost) here.
- PID Calib efficiency tables have been generated.
- BDT for Run 2 with new isolation variables will be soon developped
- Run 2 approximated yields :





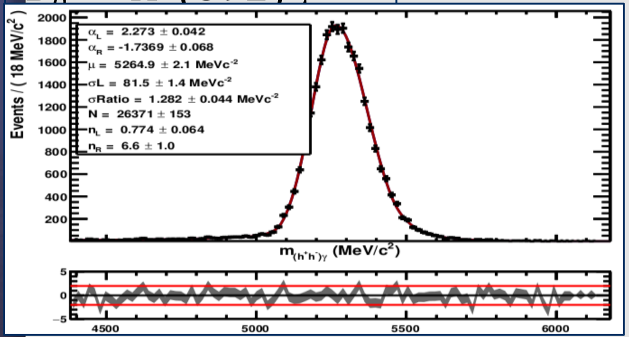
- Work is starting to apply a similar analysis procedure for $K_s hh\gamma$ run1+run2..

BACK UP

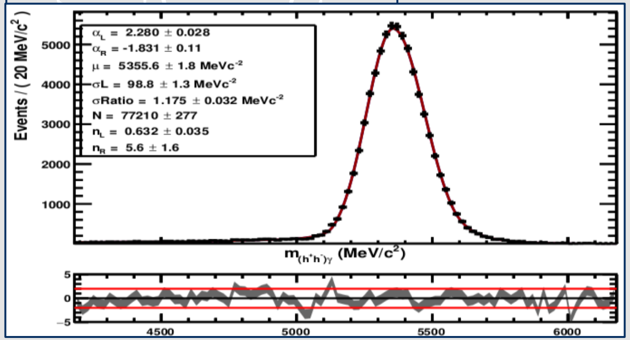
SIGNAL AND BKG SHAPES

- For every shape we perform an extended maximum likelihood unbinned fit.
- The MC used is reweighted to propagate the overall PID efficiencies, and the BDT selection is applied.

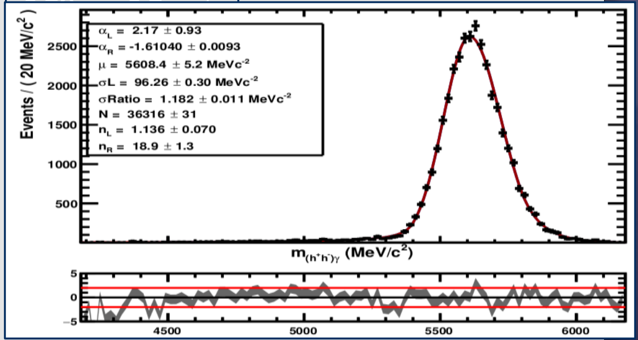
B_d -> K*(892) γ



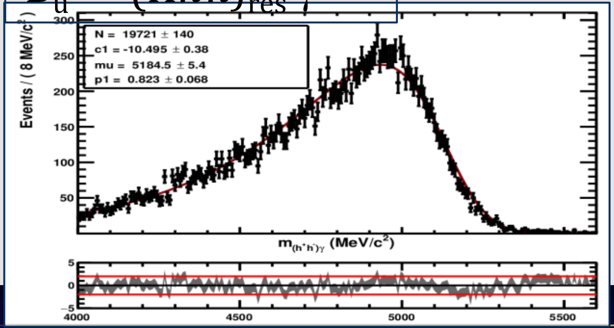
B_s -> ϕ(1020) γ



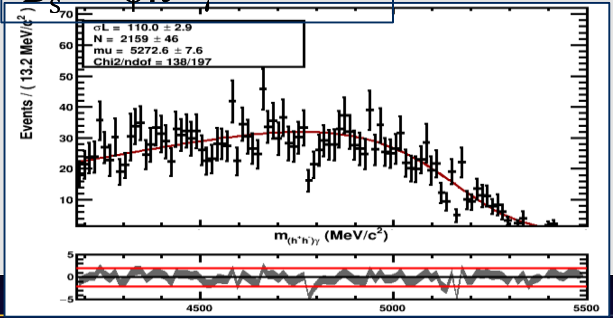
Λ_b -> Λ^* γ



B_u -> $(K\pi\pi)_{res}$ γ



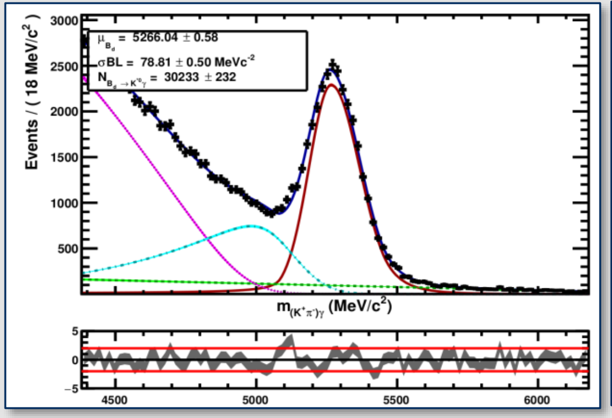
B_s -> $\phi\pi^0$ γ

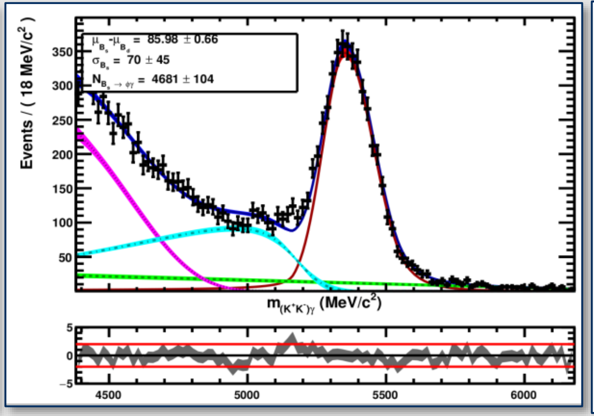


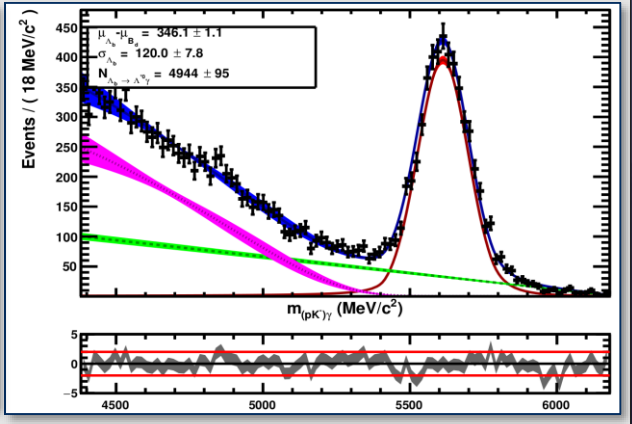
SIMULTANEOUS FIT

2012 massfit

External constraints : $(m_B - m_{Bs})$ & $(m_B - m_{\Lambda b})$







CONCLUSIONS AND PERSPECTIVES

- Run 1 selection OK, few crosschecks left for the PID and MVA studies
- Run 1 Yields according to prelimary fit :

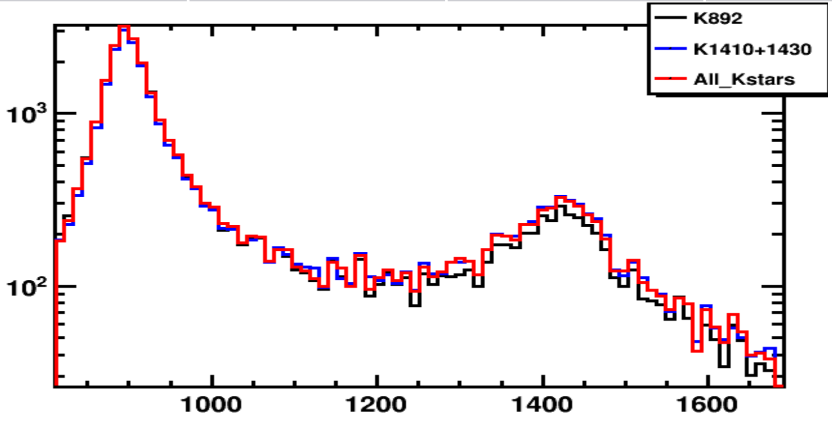
- $B^0 \to (K^* \to K\,\pi\,)\gamma$: ~ 38500
- $B_s \to (\phi \to K\,K\,)\gamma$: ~6000
- Λ_b-> $\Lambda^*\,\gamma$: ~6300

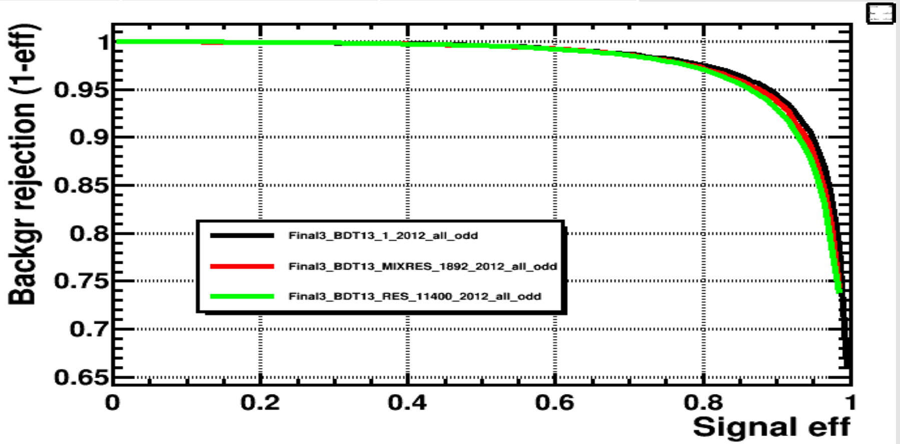
- Next steps:

- Selection run2: MC production ongoing
- Still need to train BDT for 2011 with f'2 / K_{res} MC
- Background studies : ongoing

BDT ON K1(1410)/K2(1430)

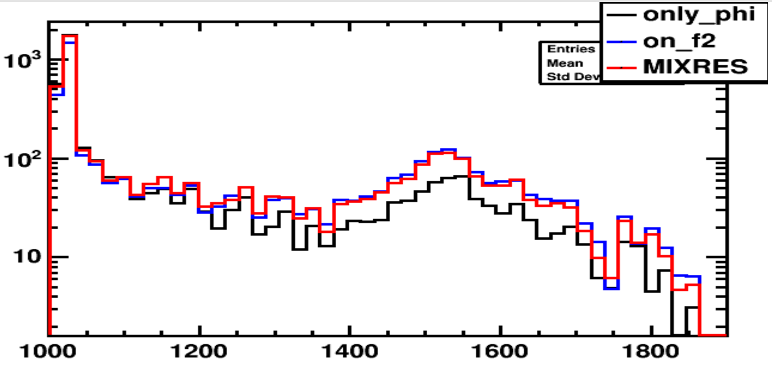
BDT training MC	cut	Sig Eff	k1 eff	Rej_SB	Rej_Filtered SB
K2 + k1	>-0,01	~88,5 %	~88,7 %	~93,8 %	~95,6 %
K*+k2+k1	>0,01	~89,6 %	~88,3 %	~93,8 %	Same #evt
Only K*	> 0	~91 %	~79,6 %	~93,3%	Same #evt

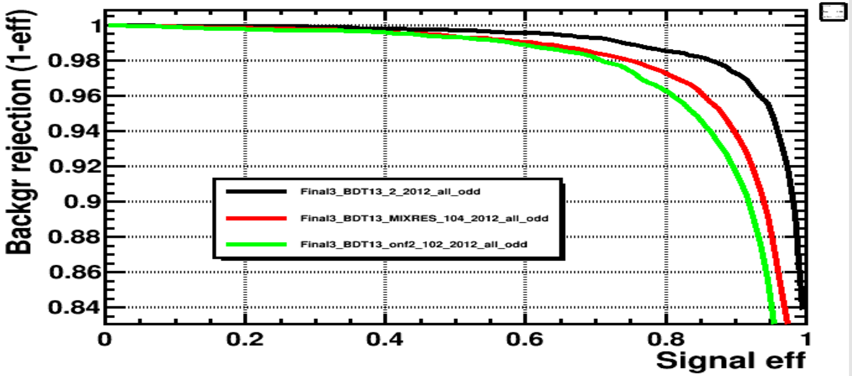




BDT ON F`2(1525)

BDT training MC	cut	FoM	Sig Eff	F`2 eff	Rej_SB	Rej_FilteredSB
Only f`2	>0,05	50	~81,3 %	~81,3 %	~95,8 %	~95,6 %
Mix f`2/phi	>0,07	53,3	~84 %	~76,3 %	~96 %	~95,6 %
Only phi	>0,07	58,6	~92 %	~43,6 %	~96	~95,6 %





In the end we choose to use the BDT trained on Mix f'2/phi

BDT EFFICIENCY

Sample	BDTCut	Signal efficiency	Background rejec. (Test Samples)	Background rejec. (filtered SB)
Kπγ_2011	BDToutput > 0,04	94,2 %	88,8 %	89,2 %
KKγ_2011	BDToutput > 0,13	93,4 %	93,7 %	93,1 %
pKγ_2011	BDToutput > 0,1	83,3 %	94,5 %	92,3 %
Kπγ_2012	BDToutput > 0	91,3 %	93,3 %	94 %
KKγ_2012	BDToutput > 0,07	92 %	96,5 %	95,6 %
pKγ_2012	BDToutput > 0,07	79,2 %	97,6 %	94,8 %

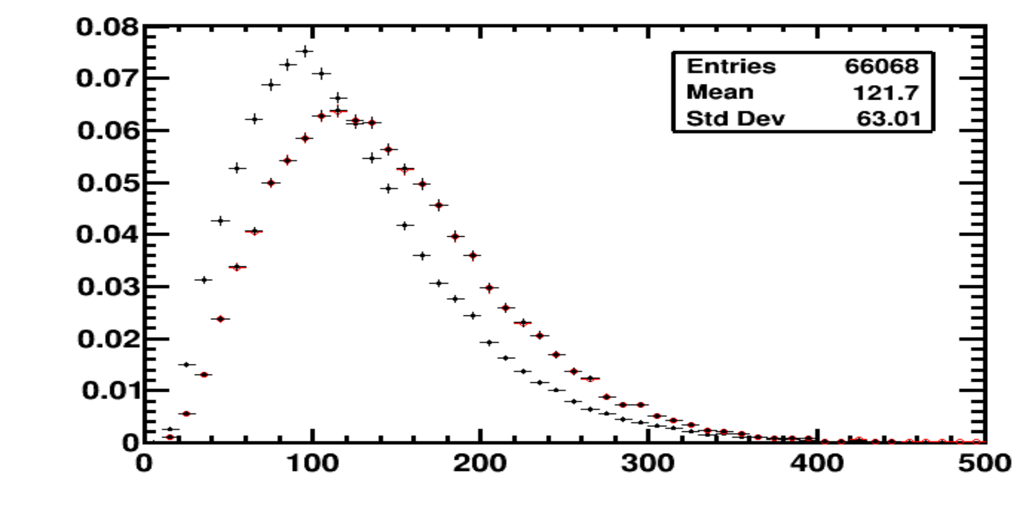
Bad efficiencies on Bs->K*2/K1 γ, Bs->f`2γ :

- efficiency of the BDT trained with Bs->ϕ γ MC on Bs->f`2γ MC : ~44% !
- equivalent for Bd -> k1 γ : ~80%

-> Train other BDTs with Mix of resonant states, and also only on f'2 / K1

NTRACKS REWEIGHTING

- Weights computed comparing BKG substracted Data (preliminar fit) and MC
- distributions :
- - Example for k*gam

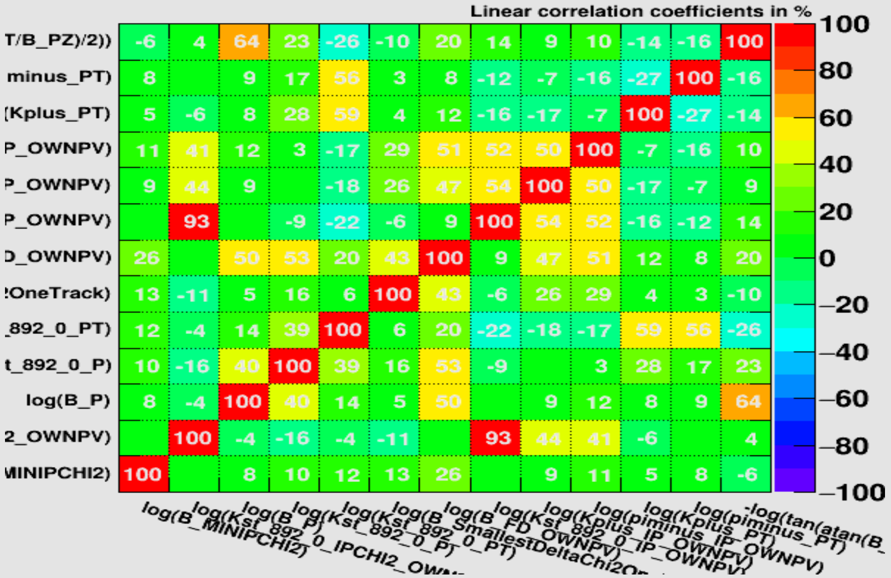


- - P & Eta well reproduced in MC, and not impacted by nTracks reweighting

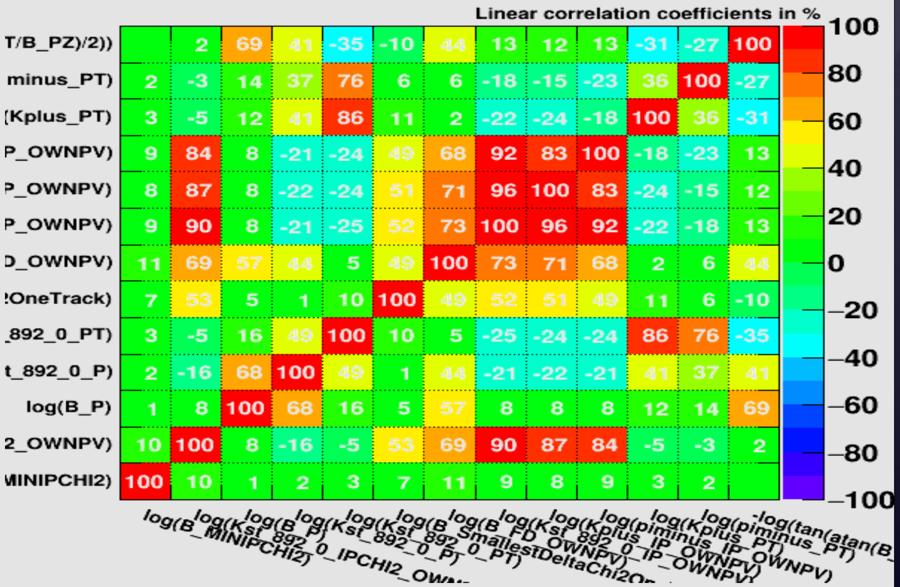
LINEAR CORRELATIONS

Some variables are highly correlated, yet seem necessary to keep good performances…
According to TMVA, BDT works fine with correlated variables…

Correlation Matrix (background)



Correlation Matrix (signal)

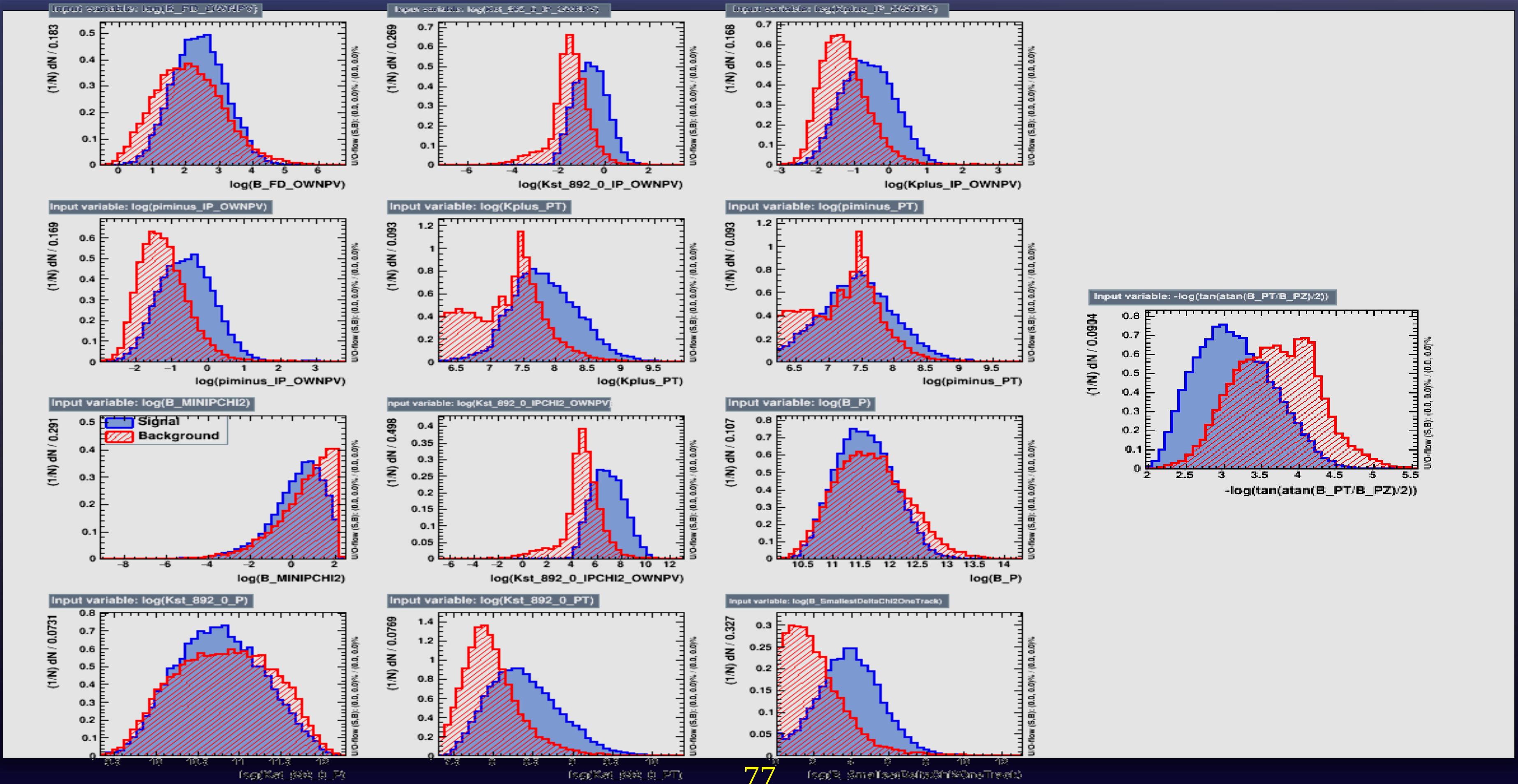


STRIPPING & PRESEL CUTS

Common cuts	Kπγ	KKγ	pKγ

h_MINIPCHI2 > 16
max(h1_PT,h2_PT) > 1200
min(h1_PT,h2_PT) > 500
h_P > 500
h_P < 100000
h1_eta > 1.5
h1_eta1+" < 5.0
res_ENDVERTEX_CHI2 < 9
h_TRACK_CHI2NDOF < 3
h_TRACK_GhostProb < 0.4
B_DiraAngle < 0.06
B_PT>2000
B_IPCHI2_OWNPV<9.0
gamma_CL > 0.2
gamma_PP_IsPhoton>0.6
gamma_PT > 3000
	B_M01 < 1850
	// D0(Kpi)
	B_M02_Subst2_gamma2pi0 >2000 //D+(K+pi0) (& K*+)
	B_M12_Subst2_gamma2pi0 >2000
	// D-(pi-pi0) (& rho-)
		B_M01 < 1850
		// D0(KK)
		B_M02_Subst2_gamma2pi0 >2000
		//D+(K+pi0) (& K*+)
		B_M12_Subst2_gamma2pi0 >2000
		// D-(K-pi0) (& K*-)
			B_M01 < 3000

BDT VARIABLES



ANALYSIS SCHEME (2)

3. **PID studies :**

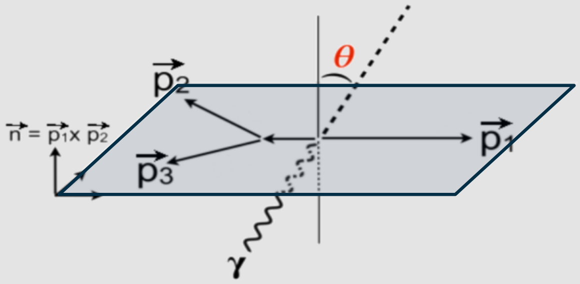
4. **Develop MVA selection**
5. **Fit B masses**
6. **Fit (hh) mass VS helicity**

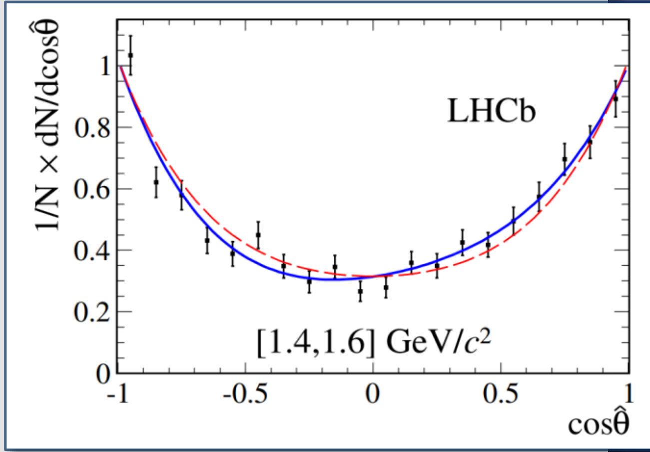
▶

PHOTON POLARIZATION (KSHHG)

On peut mesurer la distribution angulaire d'émission du photon par rapport au plan hadronique de l'état final :

$$\frac{d\Gamma}{ds\, ds_{13}\, ds_{23}\, d\cos\theta} \propto \sum_{i=0,2,4} a_i(s, s_{13}, s_{23}) \cos^i\theta + \lambda_\gamma \sum_{j=1,3} a_j(s, s_{13}, s_{23}) \cos^j\theta$$





(PHOTON POLARIZATION)

Une analyse basée sur la dépendance temporelle de la largeur de désintégration :

$$\Gamma_{B(\bar{B})^0_{(s)} \to \Phi^{CP}\gamma}(t) = |A|^2 e^{-\Gamma_{(s)} t} \left(\cosh(\Delta\Gamma_{(s)} t/2) + \mathcal{A}_\Delta \sinh(\Delta\Gamma_{(s)} t/2) \right.$$
$$\left. \pm \mathcal{C}_{CP} \cos(\Delta m_{(s)} t) \mp \mathcal{S}_{CP} sin(\Delta m_{(s)} t) \right)$$

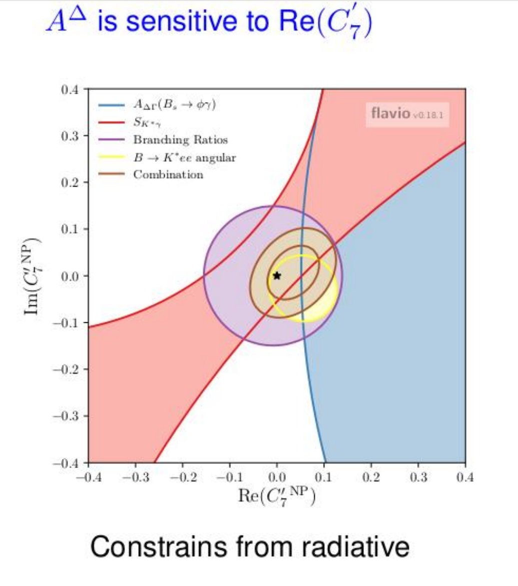
$$tan\Psi = \left| \frac{\mathcal{A}_R}{\mathcal{A}_L} \right|$$

Avec :

$$\mathcal{S}_{CP} \sim sin2\Psi sin\phi_{(s)}$$
$$\mathcal{A}_\Delta \sim sin2\Psi \cos\phi_{(s)}$$

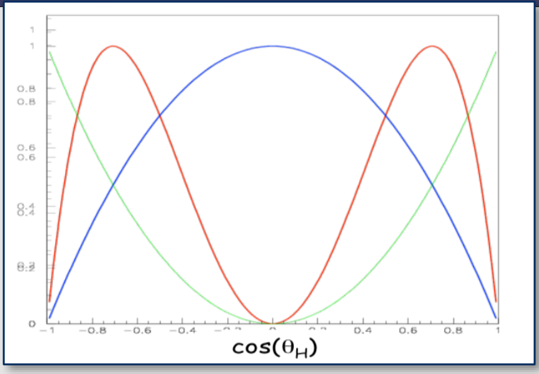
, $\Phi_{(s)}$ la phase de violation de CP, et

+ plot Carla workshop kshhg ?



(2D MASS FIT)

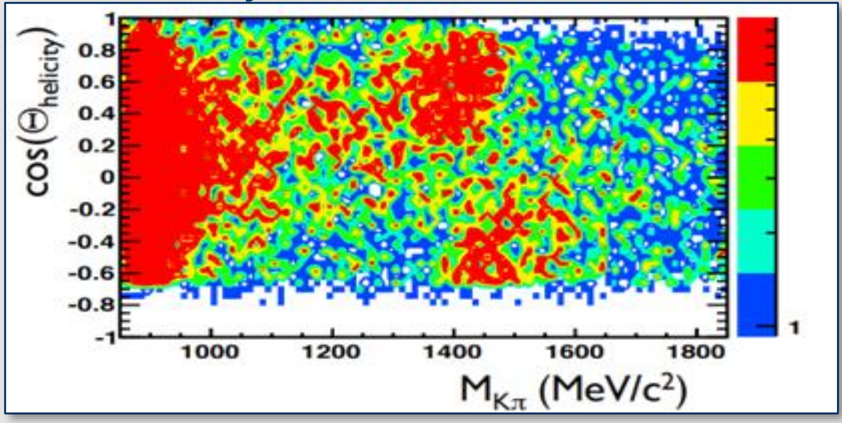
Make use of the helicity angle

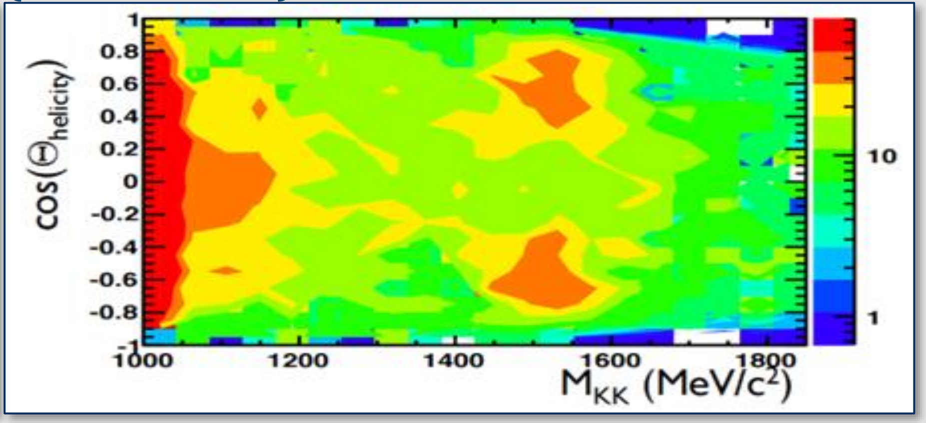


$Cos^2(\Theta_H)$ for S- waves : π^0 backgrounds
$Sin^2(\Theta_H)$ for P-waves : K*(892)γ , K1(1410) γ , φ(1020) γ
$Cos^2(\Theta_H).sin^2(\Theta_H)$ for D-waves : K* 2 (1430) γ , f' 2 (1525)

-> release the anti S-waves cut

Preliminary look to the data run1+run2 (2.7 + 1.0 fb^{-1}) :





- Clear D-wave contribution in the $K^*_2(K\pi)$ and $f'_2(KK)$ region
- Expecting a first observation of $B_s \to f'_2(1525)\gamma$ and $B^0 \to K_1(1410)\gamma$

TRIGGER SYSTEM

Bunch crossing too high for the detector to record

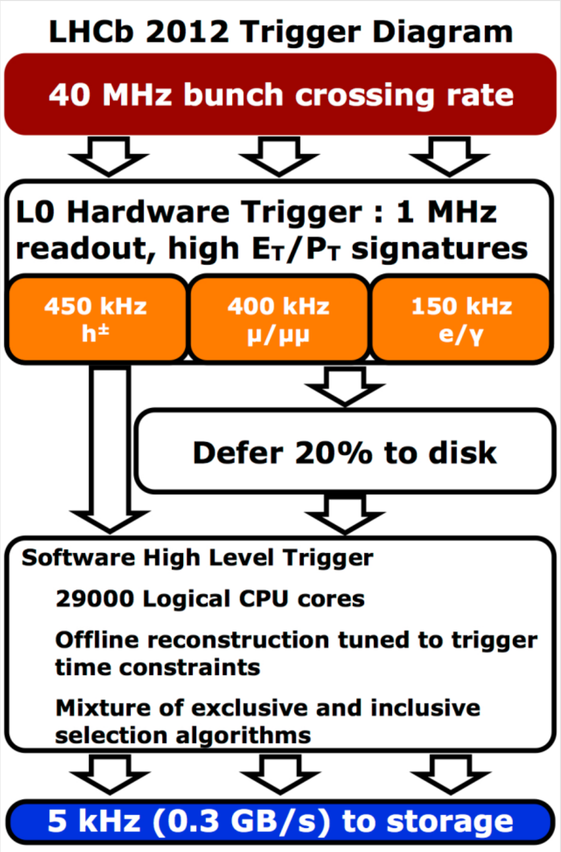
All -> Trigger selection implemented in the hardware

based on fast informations

(details(deposits))exemple tck ?

Aftert reconstruction of event :

Further selection at HLT before storage



ANALYSIS SCHEME

1. **Use data from inclusive line hh gamma :**

Trigger :

L0 : L0 photon	||	L0 electron	(TOS)
HLT1 : Hlt1trackAllL0	||	Hlt1trackPhoton	(TOS)
HLT 2 : Hlt2RadiativeTopoTrack	||	Hlt2RadiativeTopoPhoton	(TOS)

Stripping :

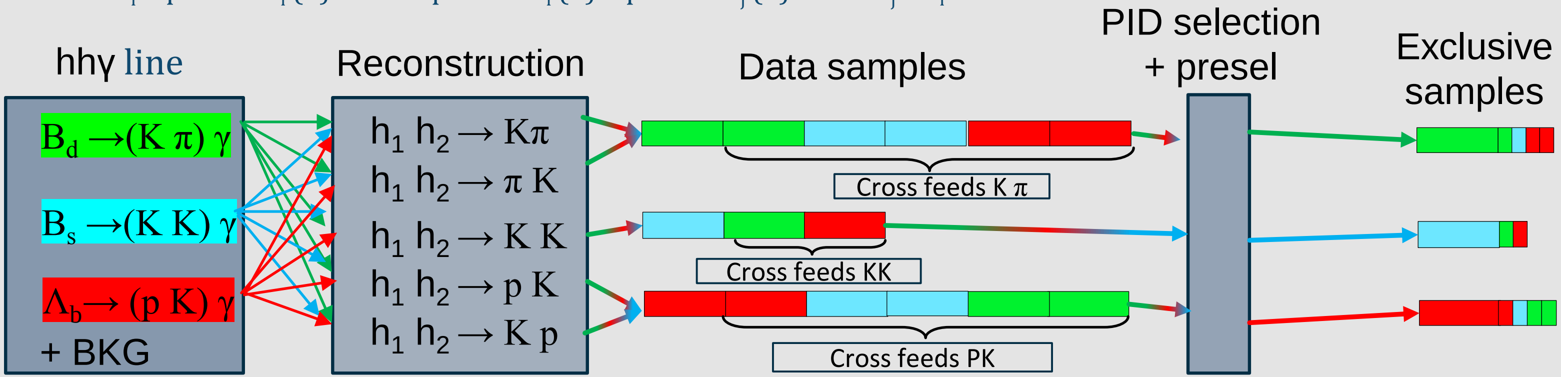
Inclusive hhγ (2pi_Line)

Reconstruct the 2h gamma categories :

Kπ & KK & pK hypothesis reconstructed by applying PID-substitution to stripped candidates

Classify $h^+ h^- \gamma$ candidates according to largest h-ProbNNx_i ($x_i = \pi,K,p$)

i.e. h== x_i if probNNx_i (h) > 0.1 & probNNx_i (h) > probNNx_j (h) for all $x_j \neq x_i$



BDT SELECTION

- Principles (slides master2 ?)
- Combi bkg selection
- Training
- Testing
- FoM
- Efficiency