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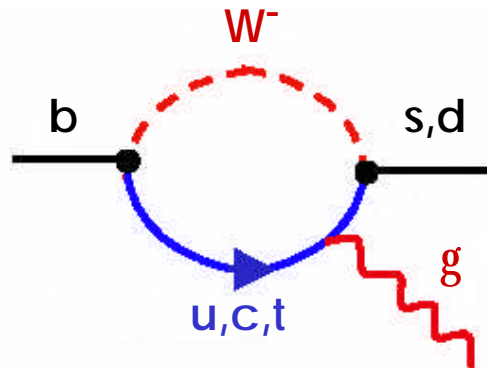
# Radiative b-decays with ATLAS

Preliminary analysis of  $B_d \rightarrow K^{*0} \gamma$

- ➊ Motivation
- ➋ Generation, simulation, reconstruction
- ➌ Analysis, results, and comments
- ➍ Conclusion & perspective

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*on behalf of*  
S. Viret, LPSC Grenoble

**Physical interest**  
1. A laboratory for QCD



- New **constraints on CKM matrix** parameters ( $V_{ts}$ ,  $V_{td}$ ) could be obtained:

$$\frac{\text{Br}(\mathbf{B} \rightarrow rg)}{\text{Br}(\mathbf{B} \rightarrow K^*g)} = \frac{|V_{td}|^2}{|V_{ts}|^2} \times \mathbf{R} \times \mathbf{\Phi}$$

Form factors ratio  
Phase space factor

- **Branching ratios measurements** will give useful constraints on QCD parameters (form factors,  $m_b, \dots$ ):

$$\text{Br}(\mathbf{B} \rightarrow K^*g) = (7.2 \pm 1.1) \times 10^{-5} \times \left(\frac{t_B}{1.6\text{ps}}\right) \times \left(\frac{m_b}{4.65}\right)^2 \times \left(\frac{x_{\perp}(K^*)}{0.35}\right)^2$$

B quark mass      Form factor

- **CP asymmetries** in  $\mathbf{B} \rightarrow rg$  decays, **isospin violation** in  $\mathbf{B} \rightarrow K^*g$  &  $\mathbf{B} \rightarrow rg$  decays.

Physical interest  
2. New Physics influences

New diagrams appearing  
(charged Higgs, chargino, squark contributions)



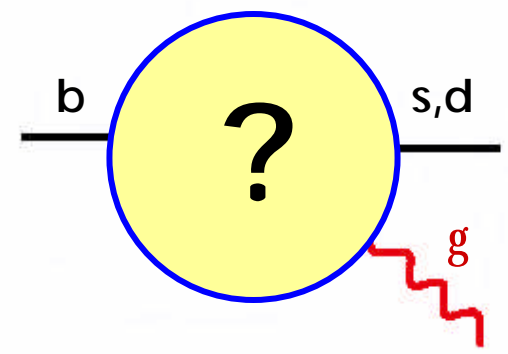
Physical observables (branching ratios, CP asymmetries) modified



Modifications largely model dependent



Useful constraints on new physics parameter space



## How to study $B \rightarrow Xg$ with ATLAS?

### 1 Inclusive measurements:

- Ⓜ Involve a very precise knowledge of the 'non-B' background (using, e.g., off-resonance data).
- Ⓜ Cannot be achieved (using classic methods) at LHC.

### 2 Semi-inclusive measurements:

- Ⓜ An hadronic system with a single kaon and few pions is searched, then B meson is reconstructed. This method leads with a good accuracy to the photon spectrum.
- Ⓜ Quite difficult without an efficient K/p identification.

### 3 Exclusive measurements:

- Ⓜ Direct reconstruction of principal decays ( $B \rightarrow K^* g, B \rightarrow \rho g, \dots$ ).
- Ⓜ Certainly the more accessible to ATLAS

## Event sample production

- **Generation: (Athena+PythiaBmodule+Model (for signal))**

- 5.0.0 release, (Pythia 6.2) : 30k  $B_d \otimes K^{*0} g_4$  events  
50k  $\bar{b}b \otimes m_6 X$  events

- **Simulation: (Atlsim)**

- 6.0.2 release, initial layout : 16.5k  $B_d \otimes K^{*0} g_4$  events  
50k  $\bar{b}b \otimes m_6 X$  events

- **Reconstruction: (Athena)**

- 6.0.3 release, initial layout : 16.5k  $B_d \otimes K^{*0} g_4$  events

*Background coming soon...*

Comparisons done with an old sample (2.4.1 reconstruction)

## Strategy of the analysis

- **Level 1: (Muon trigger)**

- **$m_\mu$  selection:** a 85% efficiency is assumed (*muon reconstruction coming soon...*)

- **Level 2:**

- **g selection in the calorimeter:**  $g/p^0$  isolation, shower shape,  $p_t$  cut

- **Offline cuts:**

- **$K^{*0}$  reconstruction in the ID:** Combination of pairs of "K+p-" tracks (*Vertex fit*), and  $K^{*0}$  invariant mass reconstruction. Cuts on tracks  $p_t$ , on impact parameter, Fit likelihood,...

- **$B_d$  invariant mass reconstruction:** Cut on  $p_t$ , and invariant mass.

- **Refined cuts:**

- Cuts on angular distributions,  $g/K^{*0}$  center of mass momentum,...

g selection

➔ g cluster candidate is selected if :

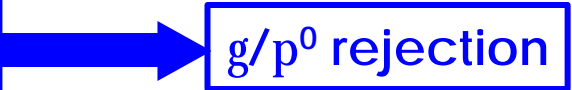
1 Cluster  $E_t > 4$  GeV

- 2 0.5 strips  $\wedge$  cluster width  $\wedge$  3.5 strips
- 3 Energy leakage in  $f$  direction  $\wedge$  9 %
- 4 Energy leakage in  $h$  direction  $\wedge$  9 %



Shower shape

- 5 Energy proportion of strips 2<sup>nd</sup> maximum  $\wedge$  6%
- 6 2<sup>nd</sup> maximum physical meaning  $\wedge$  1.5%



g/p<sup>0</sup> rejection



# K\*0 reconstruction

1 K+ selection :

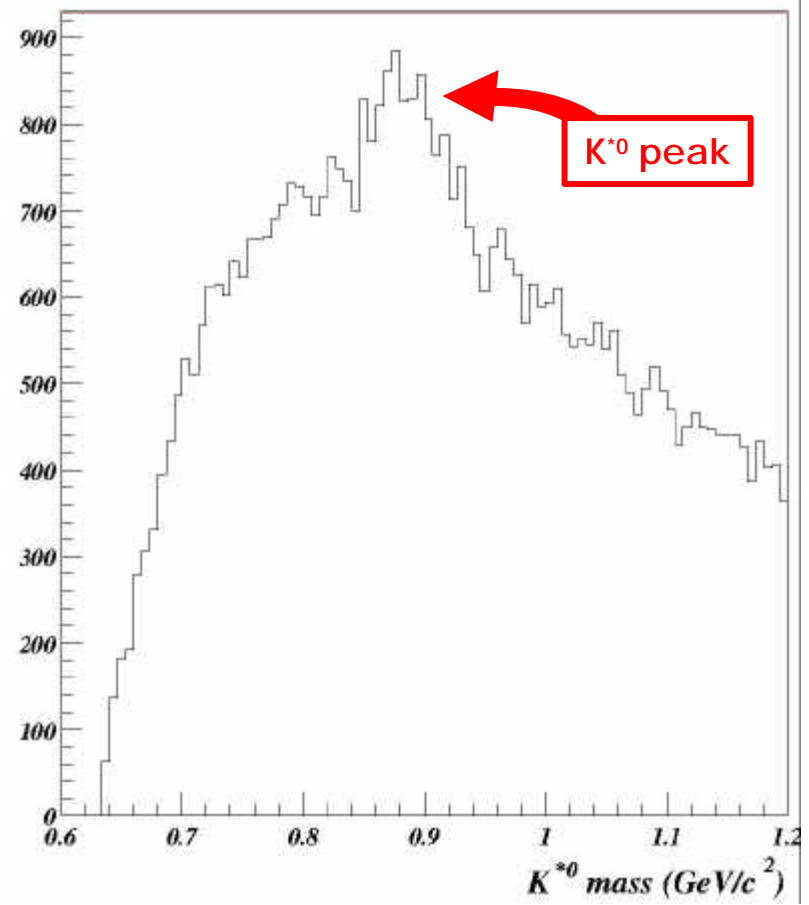
- Positive charge
- $|h| < 2.5$
- $P_t > 1.3 \text{ GeV}$

2 p- selection :

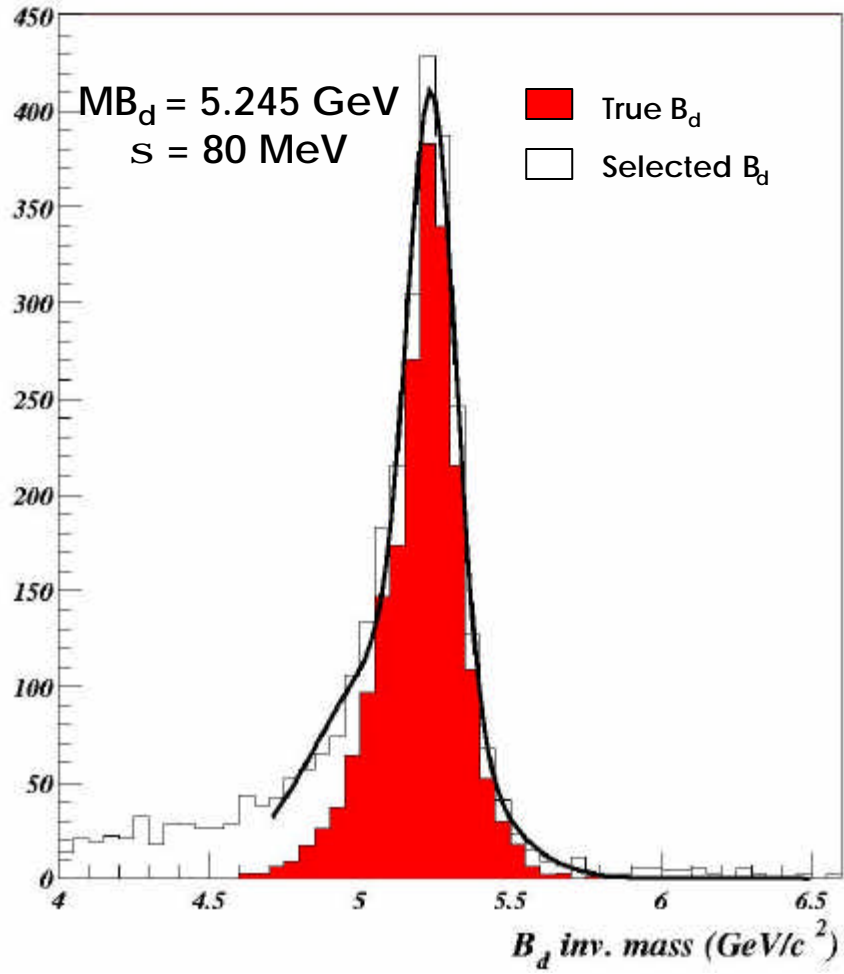
- Negative charge
- $|h| < 2.5$
- $P_t > 0.8 \text{ GeV}$

Vertexing of the 2 tracks.  
K\*0 selected if :  
 $c^2 < 6$  &  $L_{tr}(K^{*0}) > 250\text{mm}$

2s mass cut ( $s = 90 \text{ MeV}$ )



**$B_d$  final reconstruction**  
Signal only



- For each event,  $B_d$  candidate with best mass is selected.
- Reconstruction efficiency with off-cuts (in  $3\sigma$  mass window) :

$\epsilon(\text{True } B_d) = 10\%$

- **Signal** purity (in  $3\sigma$  mass window):

$$\frac{\text{True } B_d}{\text{Selected } B_d} = 60\%$$

Preliminary result

Refined offline cuts

1  $K^{*0}$  candidate is selected if :

$$\left. \begin{aligned} 0.2 \text{ GeV} < P_{K^+}^* < 0.35 \text{ GeV} \\ 0.2 \text{ GeV} < P_{\pi^-}^* < 0.35 \text{ GeV} \end{aligned} \right\} P^* = \text{center of mass momentum}$$

Impact( $K^+$ ) x Impact( $\pi^-$ ) > 0

Angle between  $K^{*0} p_t$  &  $B_d$  transverse length < 40°

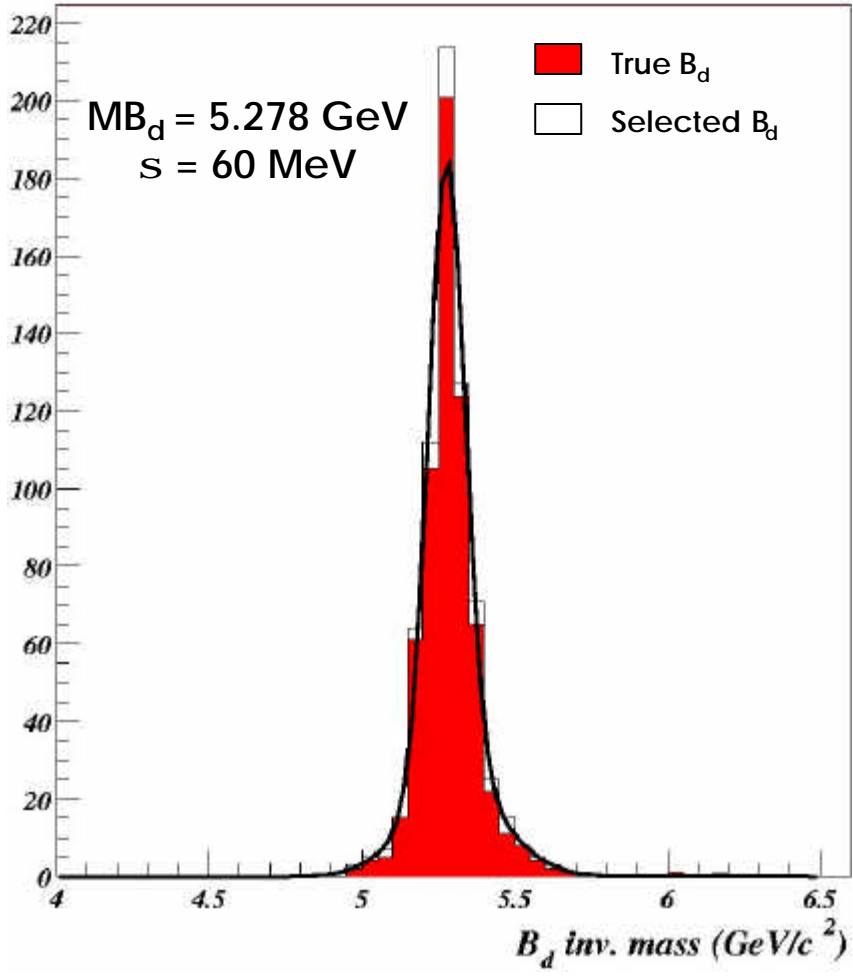
2  $B_d$  candidate is selected if :

$$1.8 \text{ GeV} < P_{\gamma}^* < 3.5 \text{ GeV}$$

$$1.8 \text{ GeV} < P_{K^{*0}}^* < 3.5 \text{ GeV}$$

Minimal distance bet.  $\gamma$  trajectory &  $B_d$  decay vertex < 9cm

**B<sub>d</sub> final reconstruction**  
Signal only



• Reconstruction efficiency with all the cuts:

$$\epsilon(\text{True } B_d) = 3.85\%$$

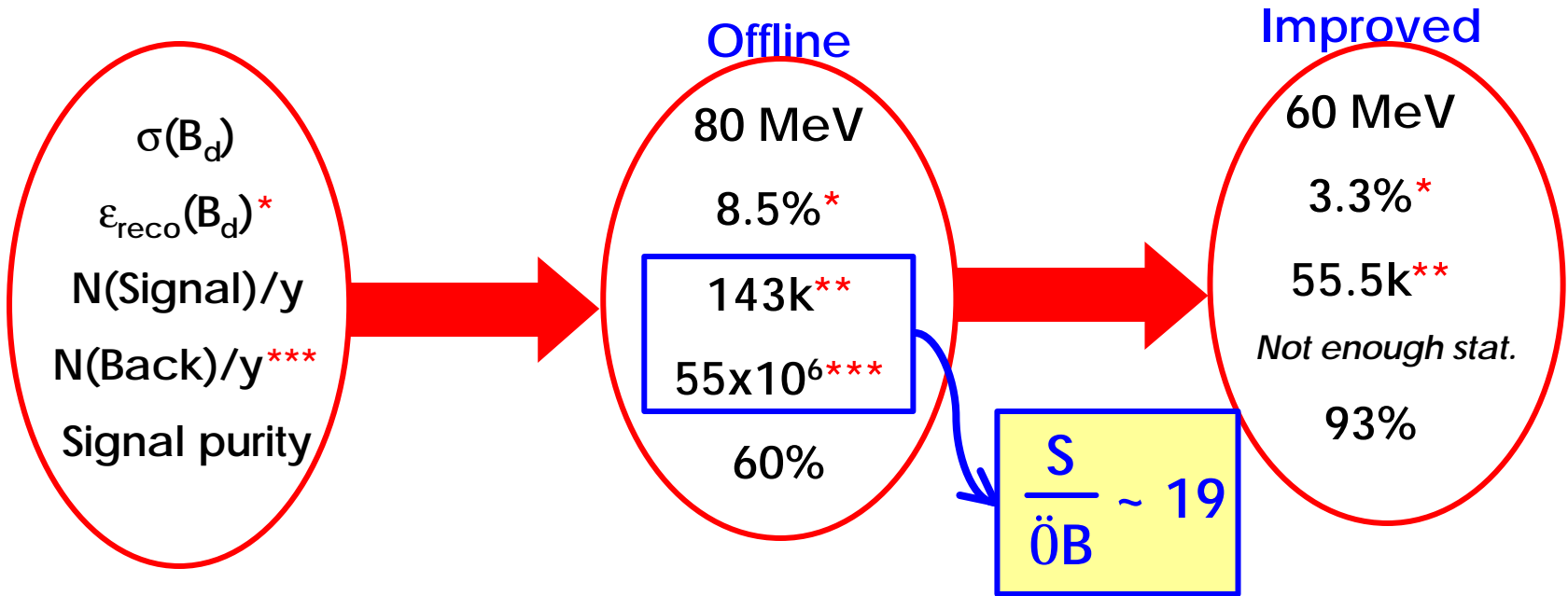
• Signal purity (in 4s mass window):

$$\frac{\text{True } B_d}{\text{Selected } B_d} = 93\%$$

Preliminary result

Summary & conclusion

PRELIMINARY

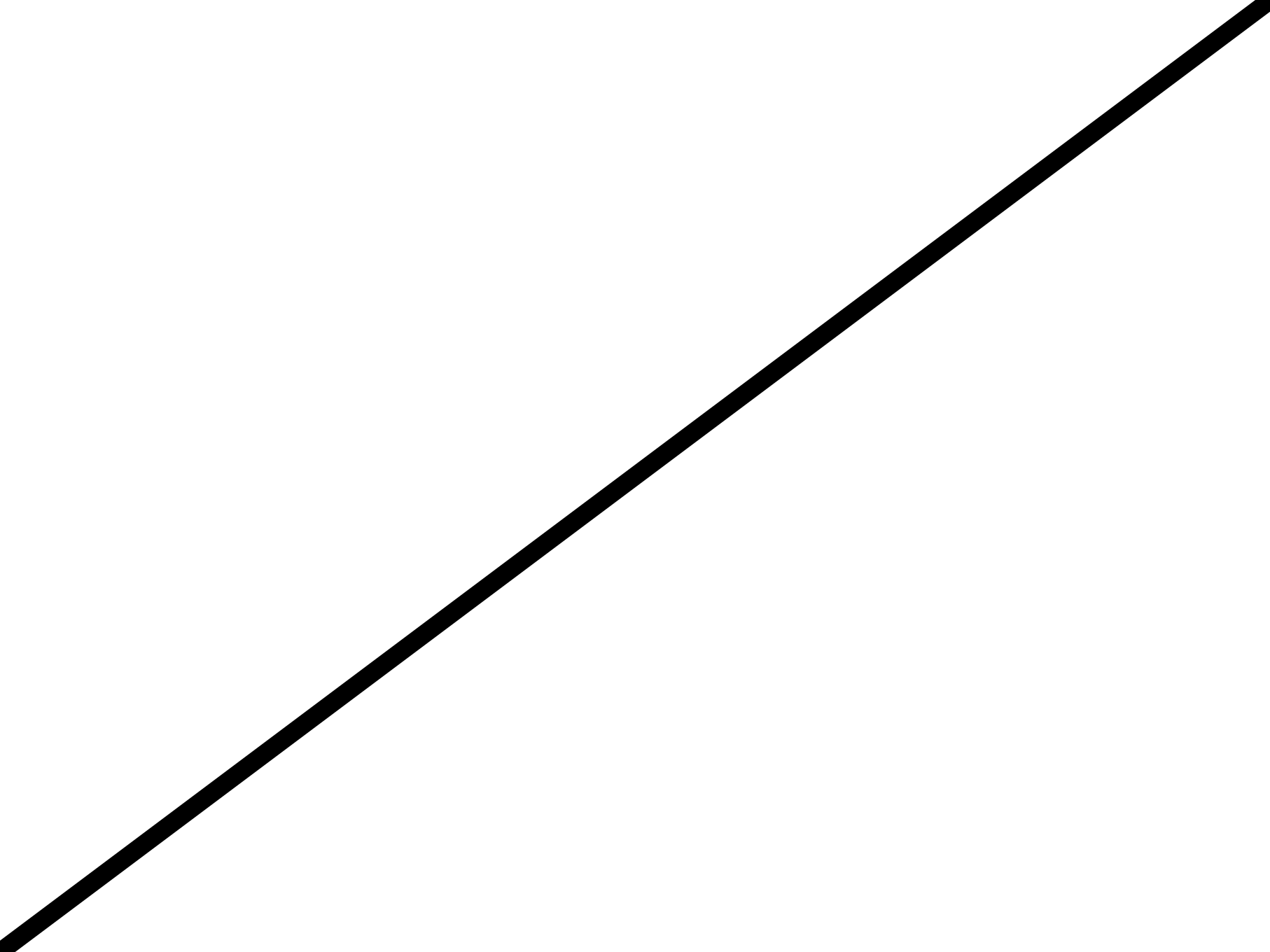


\* The L1  $\mu 6$  efficiency is included.  
 \*\*  $L_{\text{inst}} = 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$   
 \*\*\* Old results with release **2.4.1** and **weaker cuts**.

## Perspective

Just preliminary results <sup>®</sup> still lot of work to do:

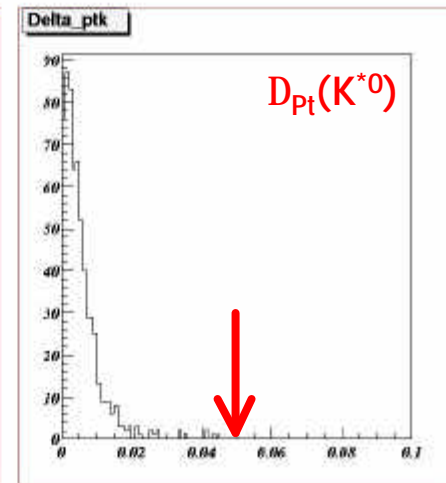
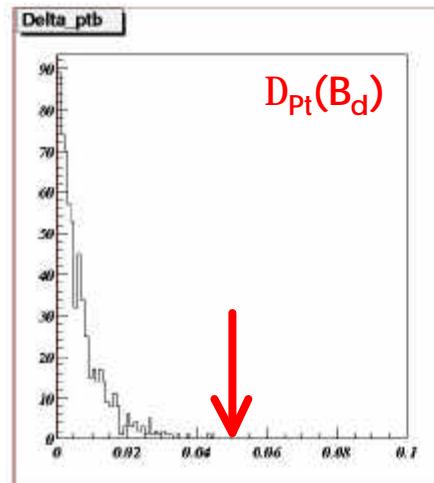
- 1 Process the physics background with initial layout
- 2 Perform cuts on  $K^{*0}$  angular distributions
- 3 Vertexing routine (*Athena patch for displaced vertex, real magnetic field,...*)
- 4 Look at  $B_d \rightarrow p\gamma$  decay (*CKM matrix constraints*)
- 5 Test the feasibility of a L1 calorimeter guided trigger ( $g?$ )
- 6 High-luminosity feasibility
- 7 ...



# $B_d$ authentication ( *TRUTH* )

Is the reconstructed  $B_d$  true or fake ?

Calculated  $p_t$ 's are compared to real  $p_t$ 's (Using **KINE**)



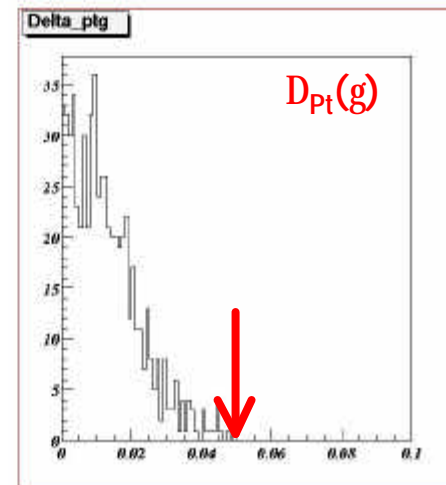
$$\Delta_{pt} = \frac{|p_t(\text{kine}) - p_t(\text{calculated})|}{p_t(\text{kine}) + p_t(\text{calculated})}$$

Reconstructed  $B_d$  is **true** if

$$D_{Pt}(B_d) < 5.0\%$$

$$D_{Pt}(K^{*0}) < 5.0\%$$

$$D_{Pt}(g) < 5.0\%$$



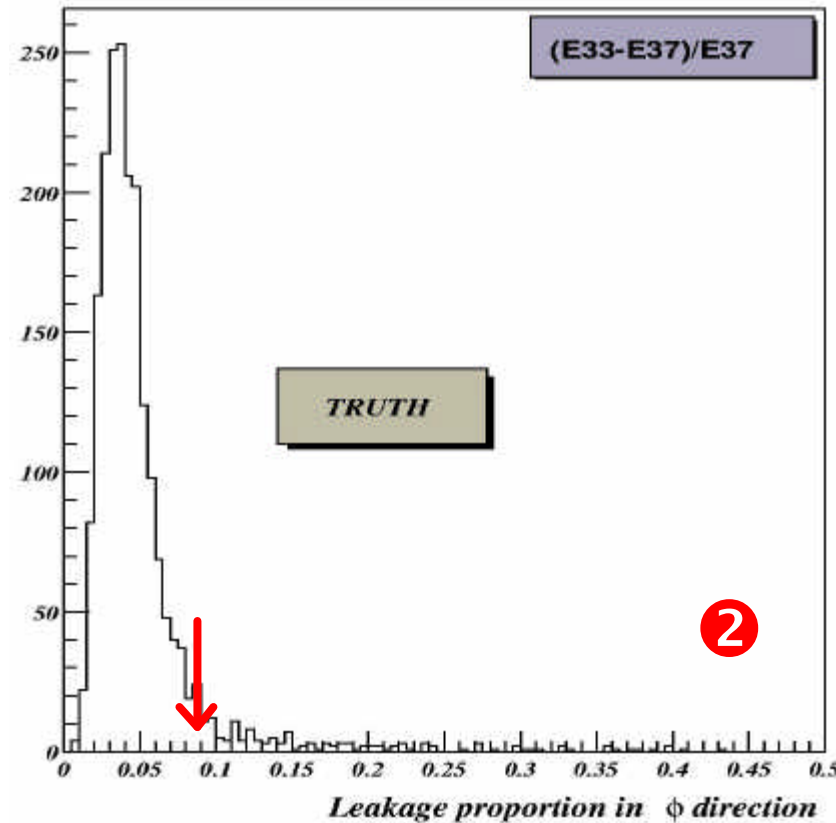
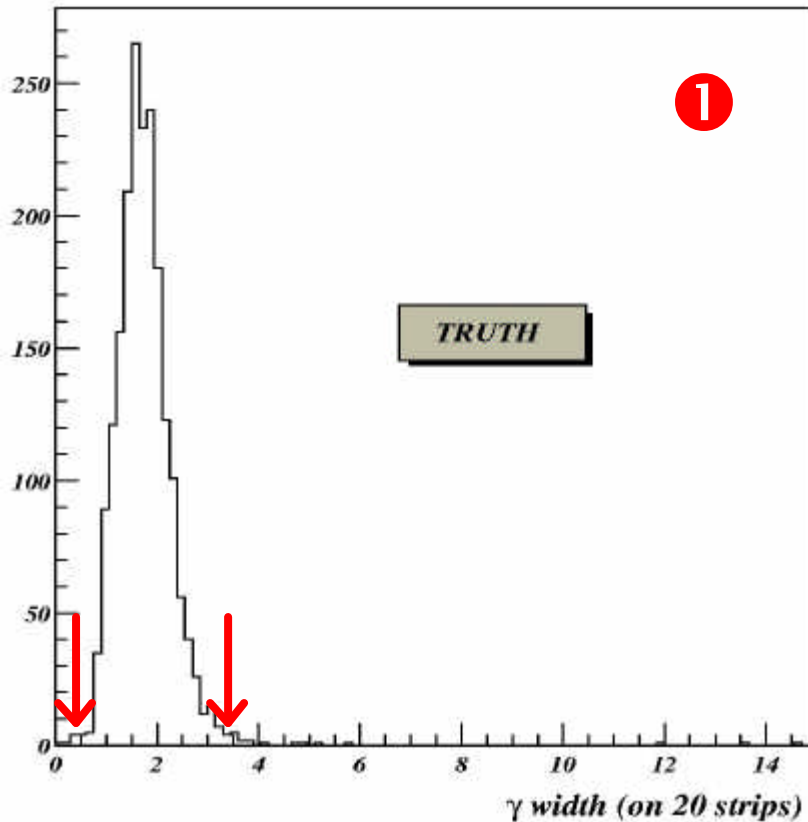


# g selection

## 1. Shower shape

① Total cluster width (over 20 strips)

LVL2 cut: 0.5 strips  $\times$  width  $\times$  3.5 strips

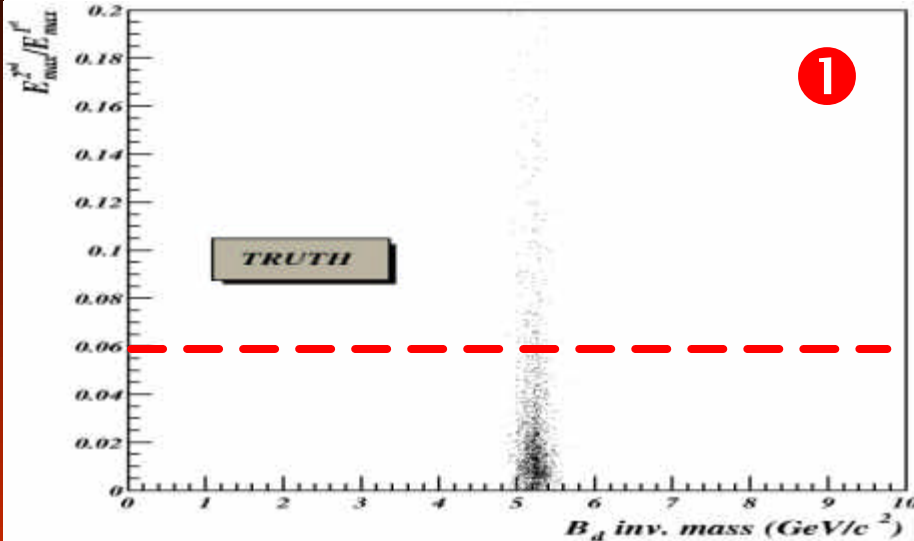


② Shower shape in  $f$  &  $h$  direction  
(ECAL 2<sup>nd</sup> sampling)

LVL2 cut:  $\times$  9 %

# g selection

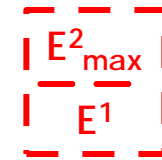
## 2. $\gamma/\pi^0$ rejection



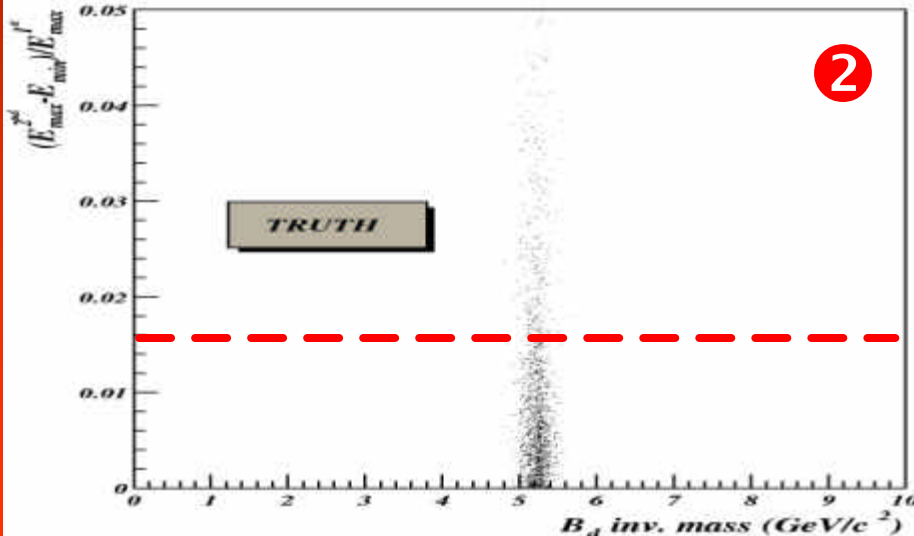
Search for a 2<sup>nd</sup> maximum in the strips:

- g: no 2<sup>nd</sup> max
- $\pi^0$ : 2<sup>nd</sup> max close to the 1<sup>st</sup> one

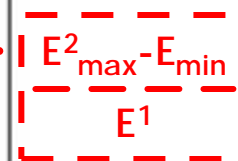
1 Transverse energy of the 2<sup>nd</sup> max on total transverse energy in the strips



LVL2 cut:  $\leq 6\%$



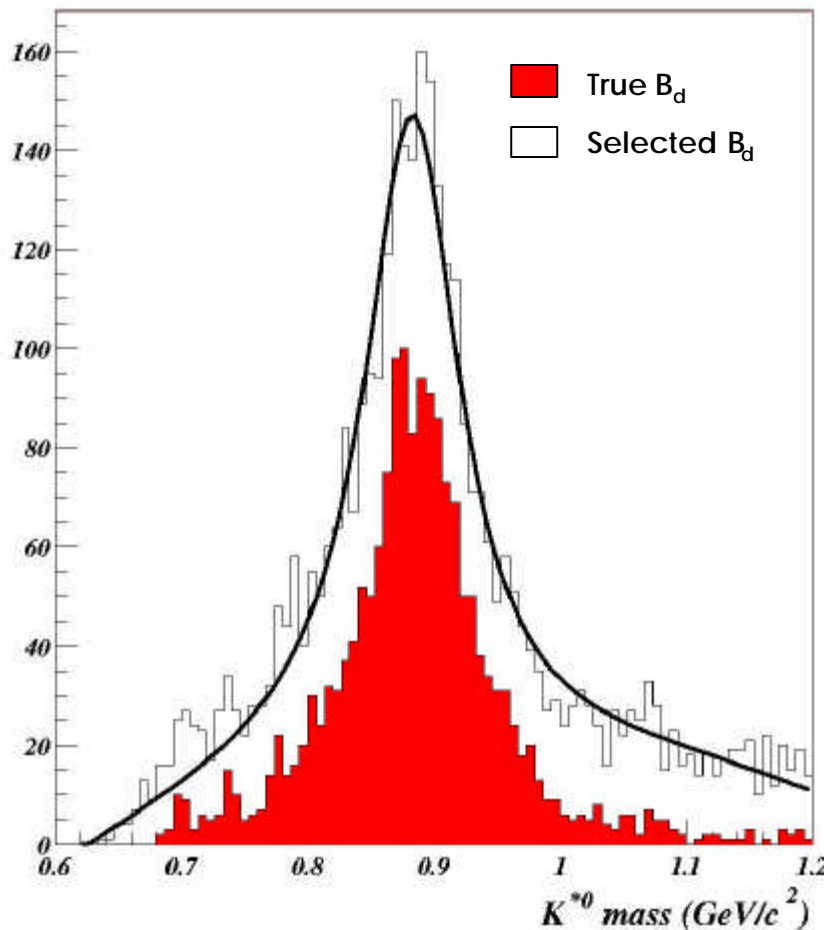
2 Physical meaning of the 2<sup>nd</sup> max (real max or 1<sup>st</sup> max artefact). Look at the minimum energy between the two max and compare it to 2<sup>nd</sup> max energy



LVL2 cut:  $\leq 1.5\%$

## K<sup>\*0</sup> reconstruction

*Mass window determination*



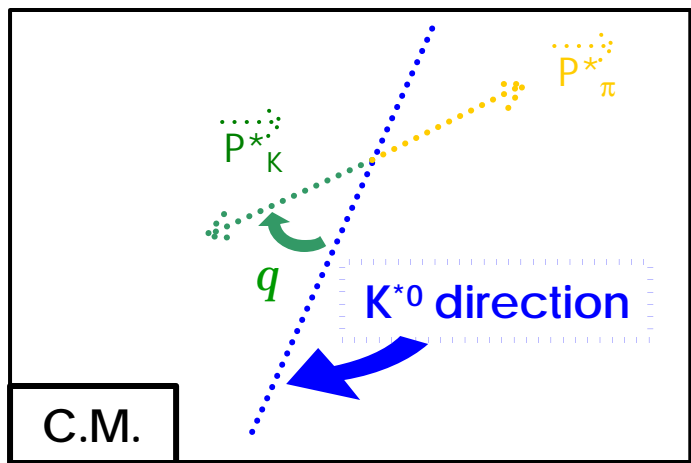
A **raw** K<sup>\*0</sup> reconstruction is performed (no cuts)

K<sup>\*0</sup> candidates giving a selected B<sub>d</sub> are displayed

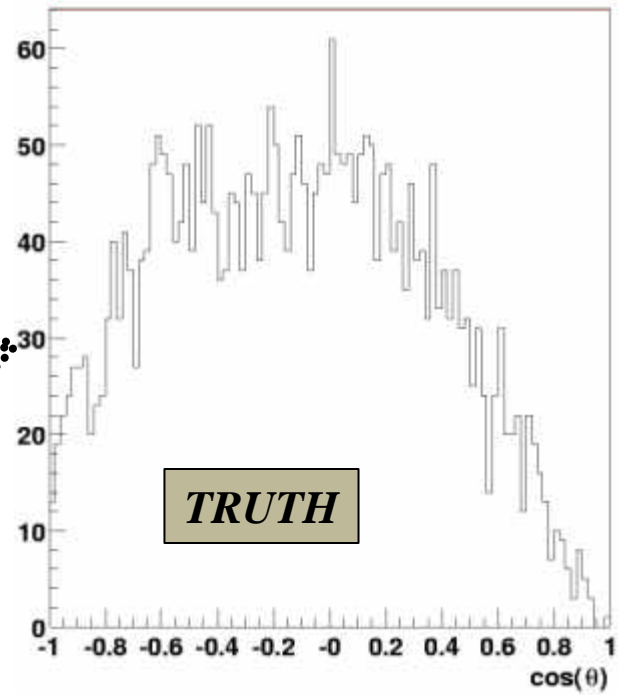
A **2σ mass window** cut on M<sub>K<sup>\*0</sup></sub> is sufficient for correct signal reconstruction

We then re-reconstruct the B<sub>d</sub> using this mass cut

Refined cuts  
K\*0 angular distributions



$$\frac{dG(K^{*0} @ K^+ p^-)}{d\cos(q)} \sim \sin^2(q)$$

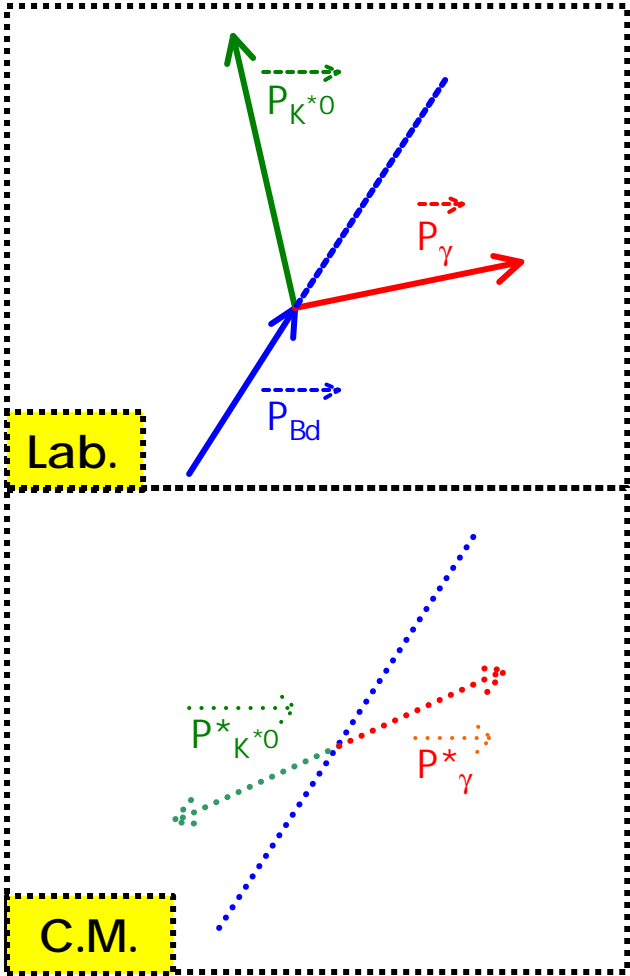


Flat distribution for combinatorial

Interesting cut

Still not used  
(Small asymmetry should be understood (vertexing ?))

Refined cuts  
Mass cuts (1/2)



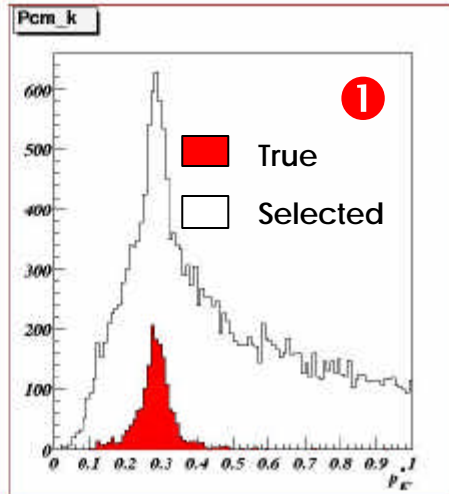
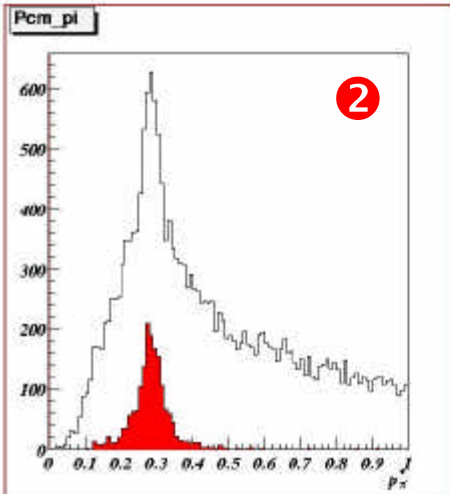
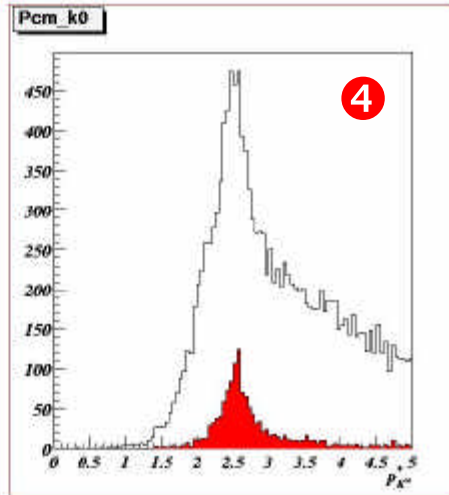
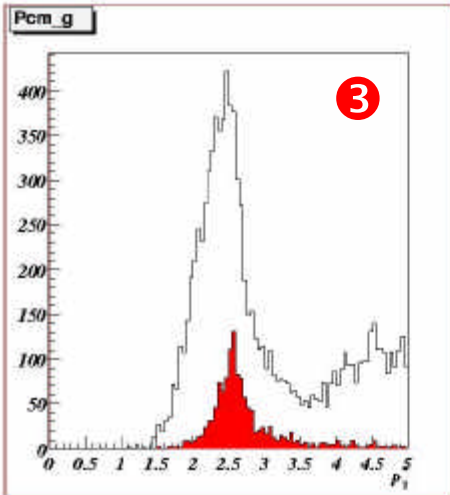
• In C.M.S. we have :

$$\left\{ \begin{array}{l} |P_{K^*0}^*| = |P_{\pi^0}^*| = 2.56 \text{ GeV} \\ |P_{K^+}^*| = |P_{p^-}^*| = 0.29 \text{ GeV} \end{array} \right.$$

Cuts on  $p^*$   $\longleftrightarrow$  Natural mass cuts

→ Use C.M.S. cuts instead of mass windows classic cuts

Refined cuts  
Mass cuts (2/2)



• C.M.S. momenta were calculated.

•  $K^0$  is selected if:

①  $0.2 \text{ GeV} < P_{K^+}^* < 0.35 \text{ GeV}$

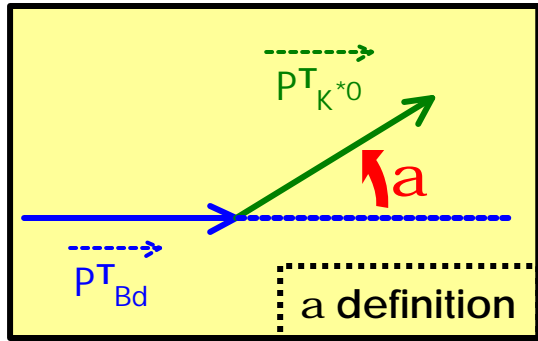
②  $0.2 \text{ GeV} < P_{p^-}^* < 0.35 \text{ GeV}$

•  $B_d$  is selected if:

③  $1.8 \text{ GeV} < P_{g}^* < 3.5 \text{ GeV}$

④  $1.8 \text{ GeV} < P_{K^{*0}}^* < 3.5 \text{ GeV}$

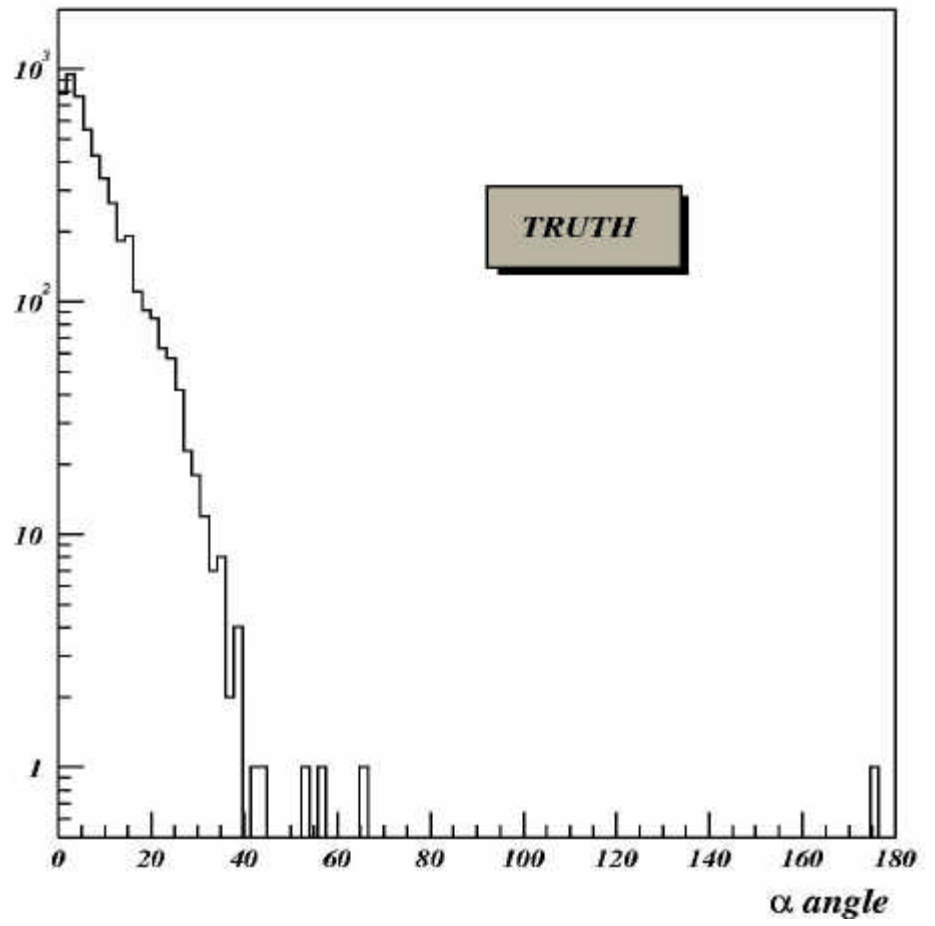
Refined cuts  
 $K^{*0}$  transverse direction



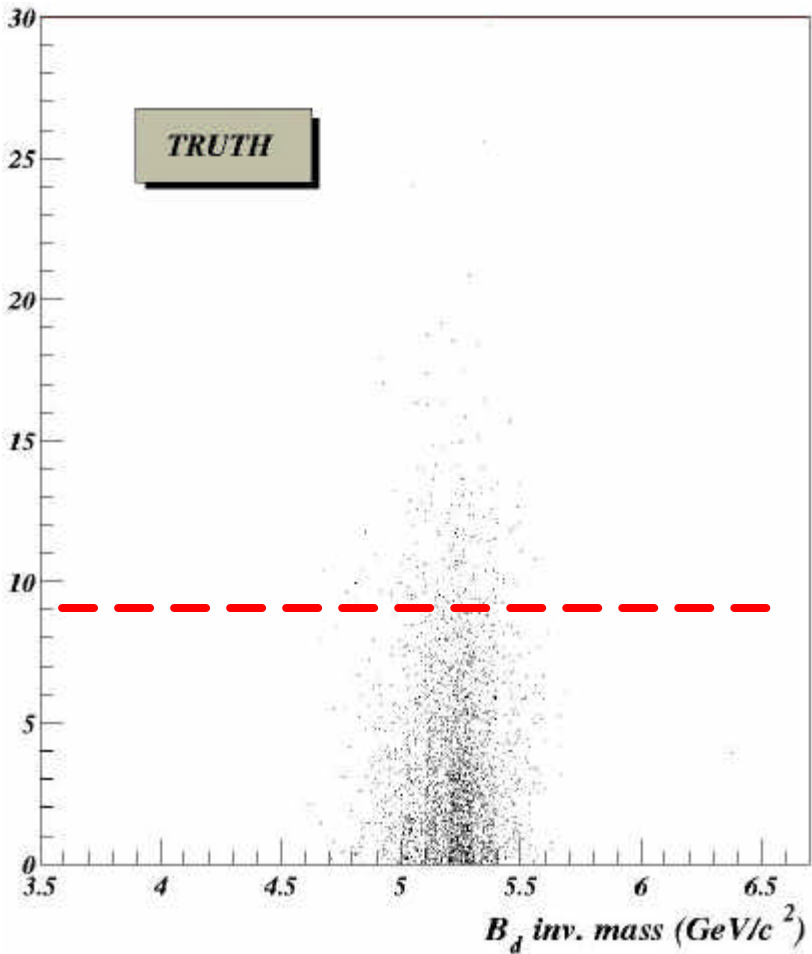
$B_d$  boost

$\alpha$  small

B candidate selected if  
 $\alpha < 40^\circ$



**Refined cuts**  
Minimal distance between  $B_d$  vertex and  $\gamma$  trajectory



- No information on  $\gamma$  in the ID
- ➔ Vertexing routine couldn't be used
- $K^{*0}$  time of flight very short
- ➔  $K^{*0}$  decay vertex =  $B_d$  decay vertex
- $\gamma$  trajectory should contain this vertex
- Minimal distance between  $\gamma$  trajectory & B-decay vertex is calculated ( $L_{min}$ ).
- $B_d$  candidate is selected if:

$L_{min} < 9 \text{ cm}$



## Event rates calculation

Don't forget  $\overline{B}_d \text{ @ } \overline{K}^{*0} g$  !

$$\begin{cases} N_s = 2 \times \sigma_{\text{prod}}(\text{signal}) \times \varepsilon_{\text{reconstruction}}(\text{signal}) \times \text{Br}(\overline{B}_d \text{ @ } \overline{K}^{*0} \text{ @ } Kp) \times L_{\text{inst}} \\ N_b = \sigma_{\text{prod}}(\text{background}) \times \varepsilon_{\text{reconstruction}}(\text{background}) \times L_{\text{inst}} \end{cases}$$

$\sigma_{\text{prod}}$  should be confirmed

$S_{\text{prod}}(\text{signal}) = 0.15 \text{ mbarn}$  ← (from Pythia)

$S_{\text{prod}}(\text{background}) = 2.89 \text{ mbarn}$  ←

$\text{Br}(\overline{B}_d \text{ @ } \overline{K}^{*0} \text{ @ } Kp) \gg 4.44 \times 10^{-5}$

$L_{\text{inst}} = 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

$N_s = 0.053 \text{ e}_{\text{reco}}(\text{signal})$

$N_b = 5800 \text{ e}_{\text{reco}}(\text{background})$