



Radiative b-decays with ATLAS

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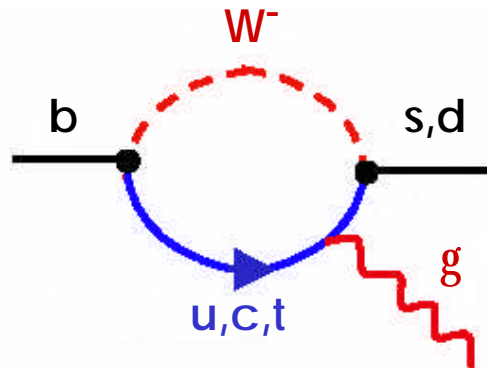
Radiative b-decays with ATLAS

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
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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)



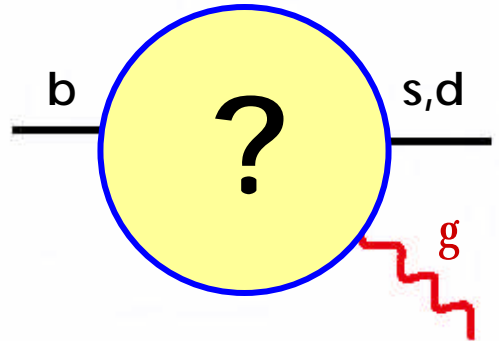
Physical observables (branching ratios, CP asymmetries) modified



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 ($B \rightarrow K^* g$, $B \rightarrow \rho g$, ...).
- Ⓜ 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_μ 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 :

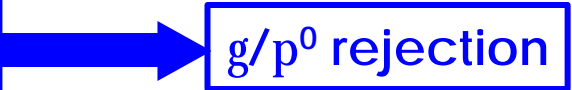
1 Cluster $E_t > 4 \text{ GeV}$

- 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 2nd maximum \wedge 6%
- 6 2nd maximum physical meaning \wedge 1.5%



g/p⁰ rejection

K*0 reconstruction

1 K+ selection :

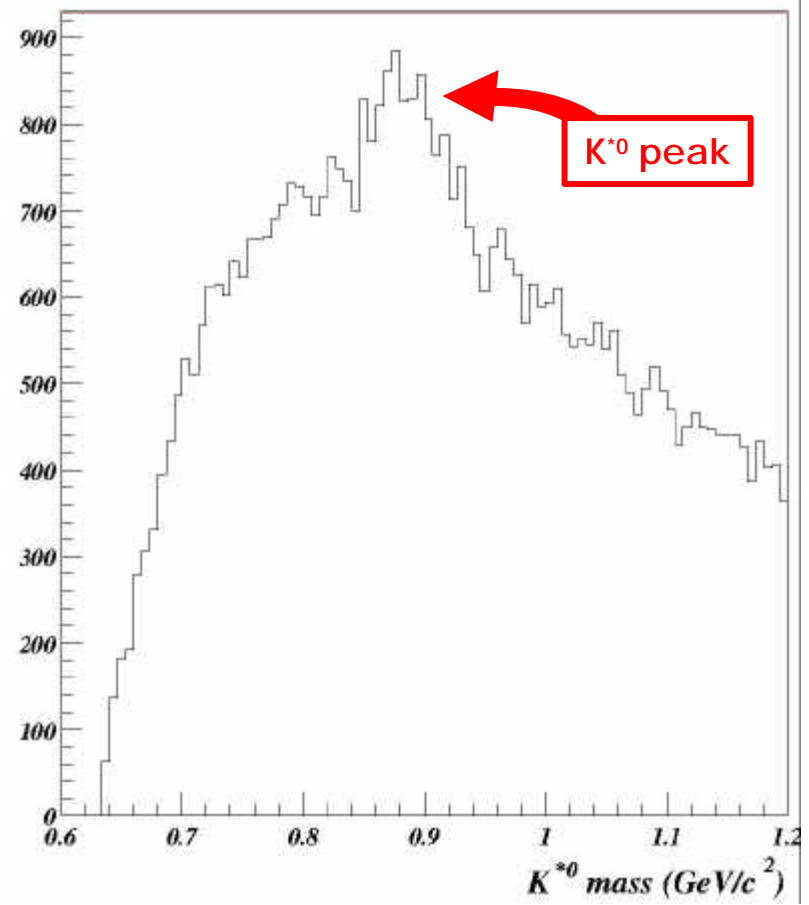
- Positive charge
- $|h| < 2.5$
- $P_t > 1.3 \text{ GeV}$

2 p- selection :

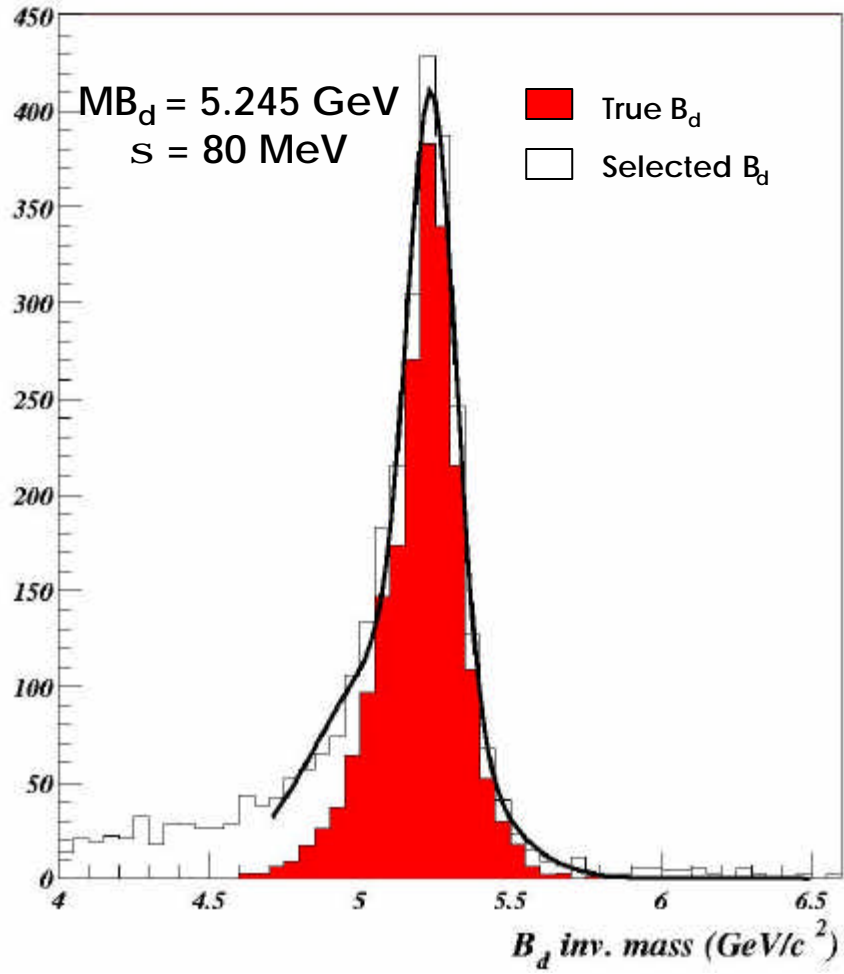
- Negative charge
- $|h| < 2.5$
- $P_t > 0.8 \text{ GeV}$

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 3σ mass window) :

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

- **Signal** purity (in 3σ 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(π^-) > 0

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

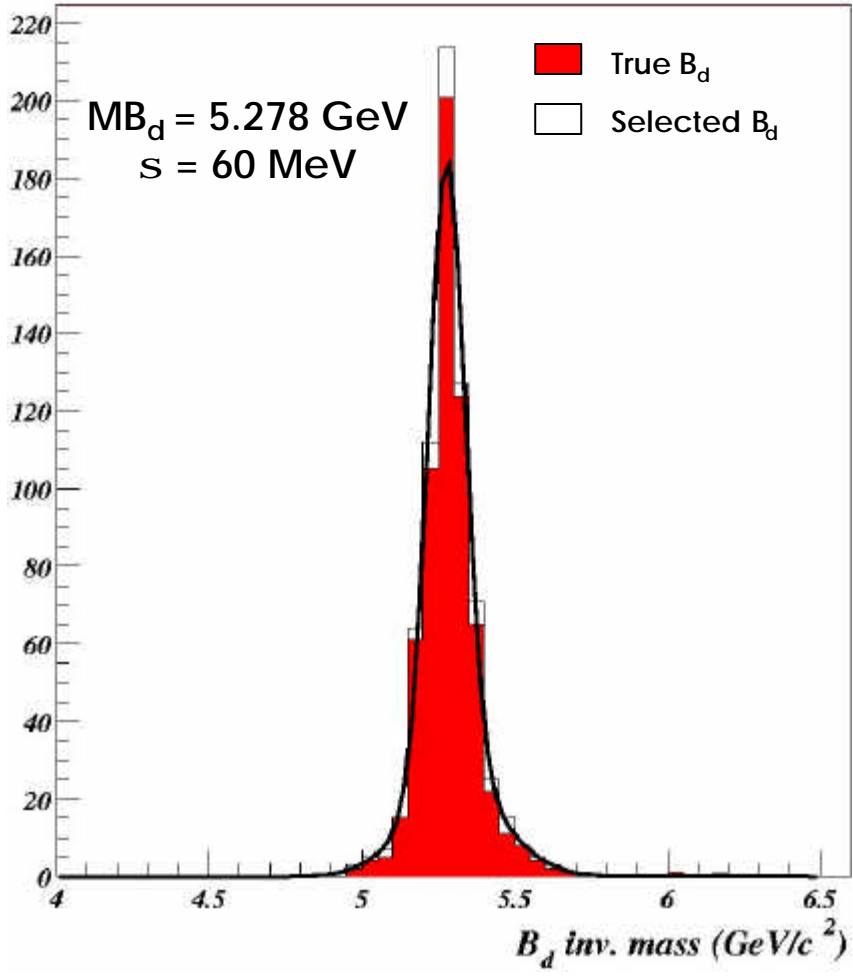
2 B_d candidate is selected if :

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

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

Minimal distance bet. γ trajectory & B_d decay vertex < 9cm

B_d final reconstruction
Signal only



• Reconstruction efficiency with all the cuts:

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

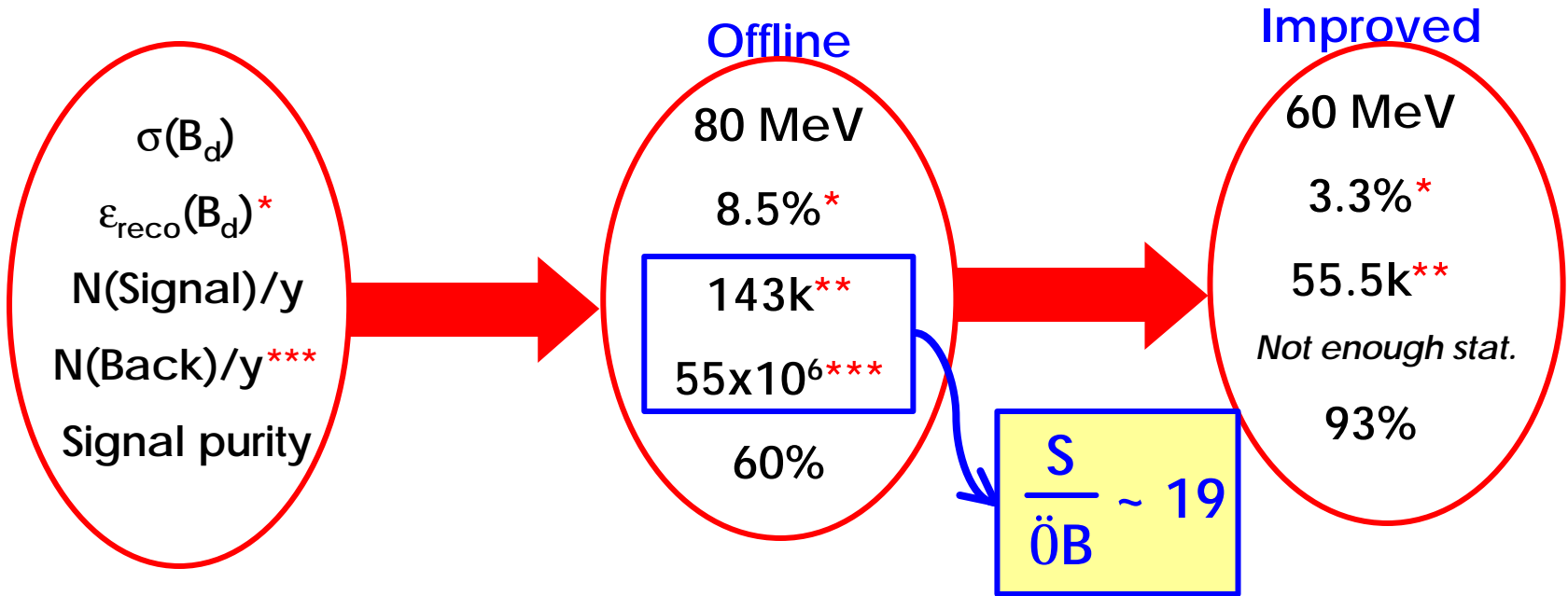
• Signal purity (in 4s mass window):

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

Preliminary result

Summary & conclusion

PRELIMINARY

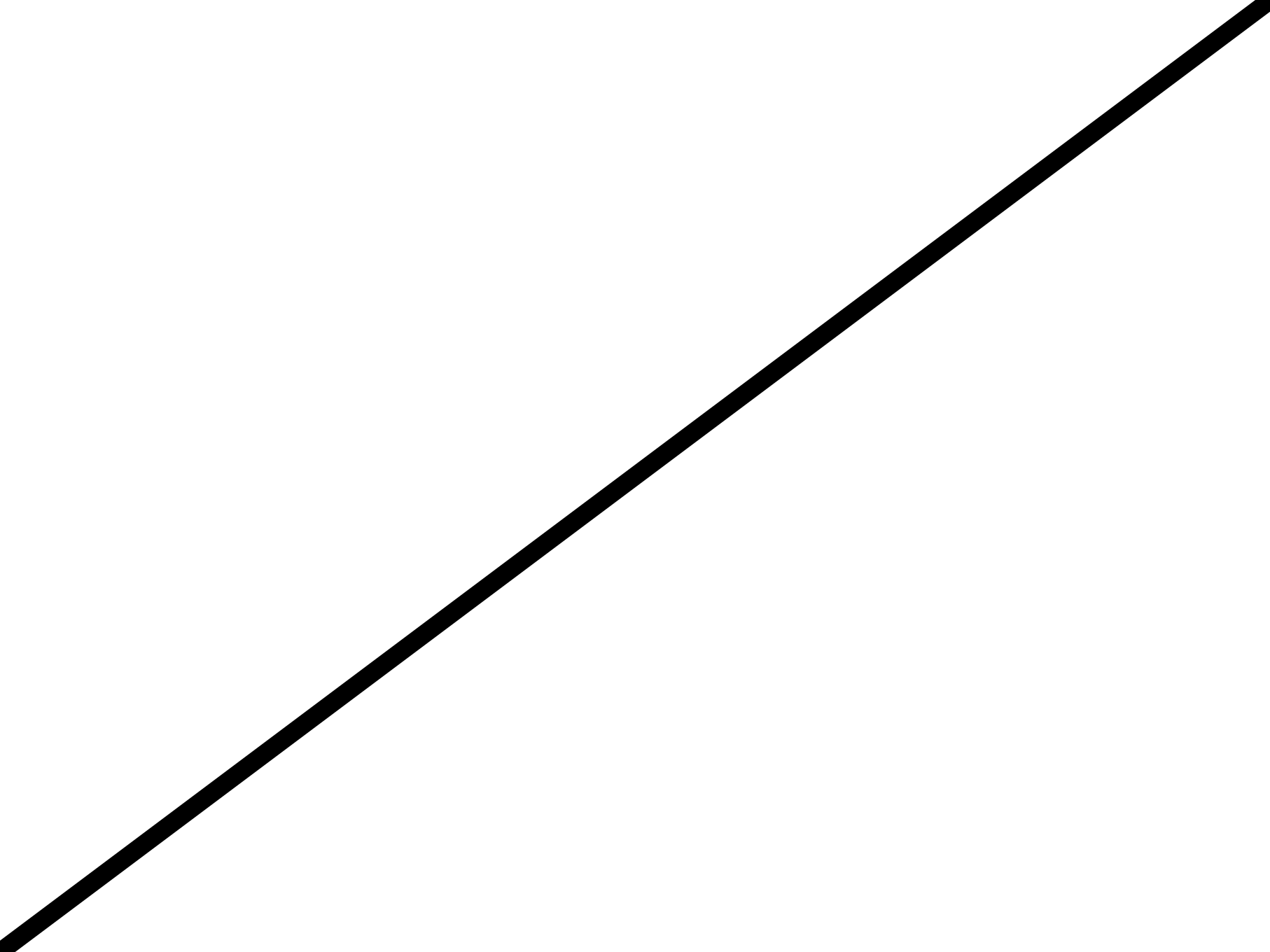


* The L1 $\mu 6$ efficiency is included.
 ** $L_{\text{inst}} = 2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
 *** Old results with release **2.4.1** and **weaker cuts**.

Perspective

Just preliminary results [®] 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 ...

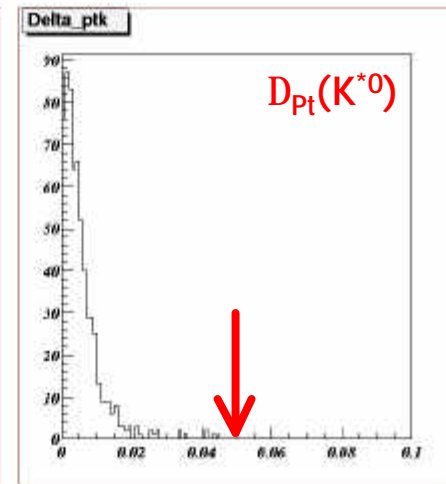
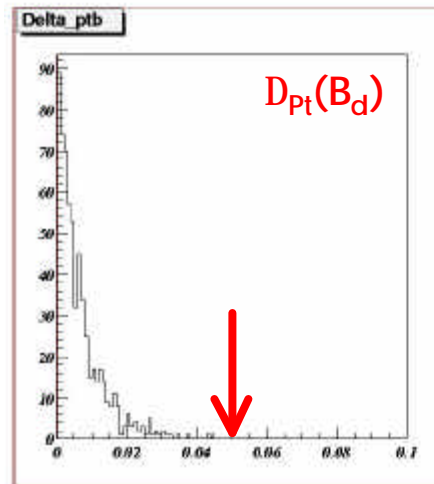


B_d authentication (TRUTH)

Is the reconstructed B_d
true or fake ?



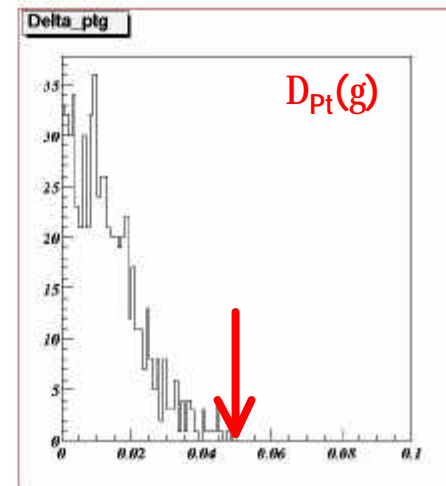
Calculated p_t's are compared
to real p_t's (Using **KINE**)



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

Reconstructed B_d is **true** if

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

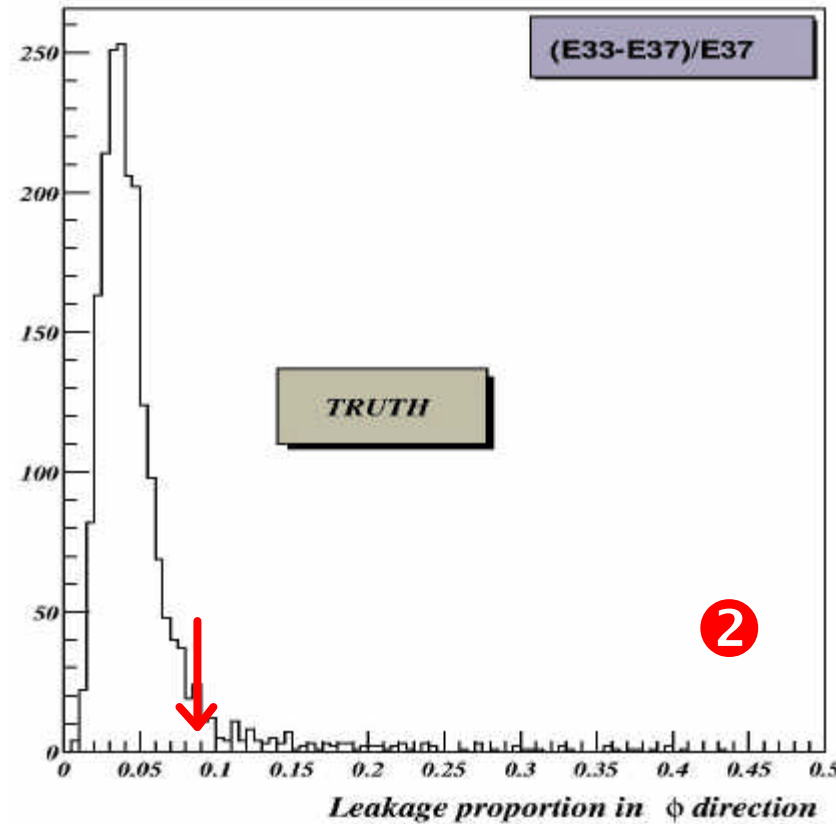
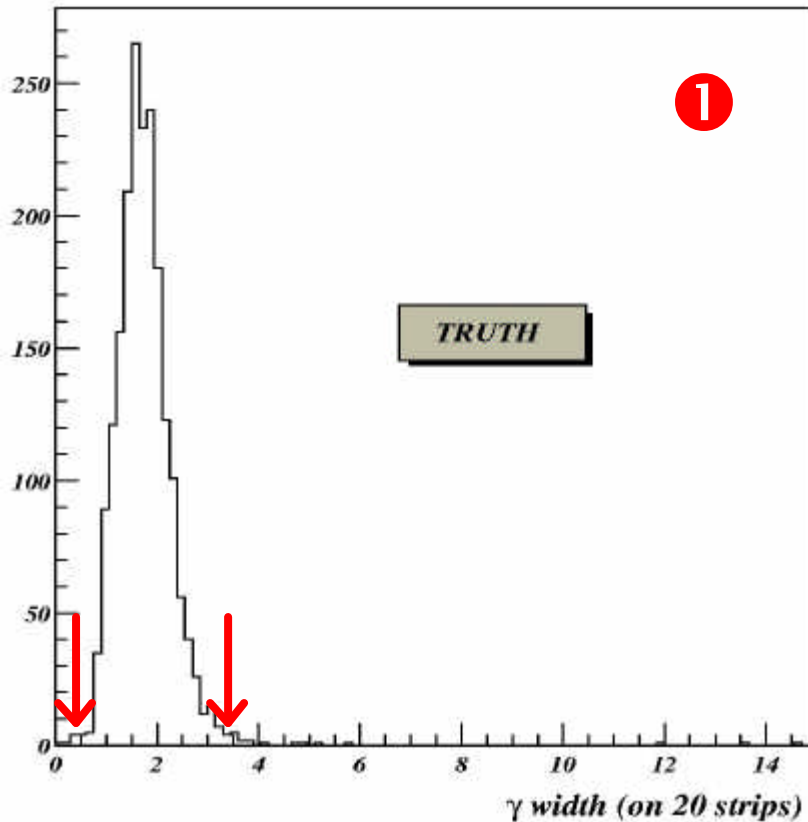


g selection

1. Shower shape

① Total cluster width (over 20 strips)

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

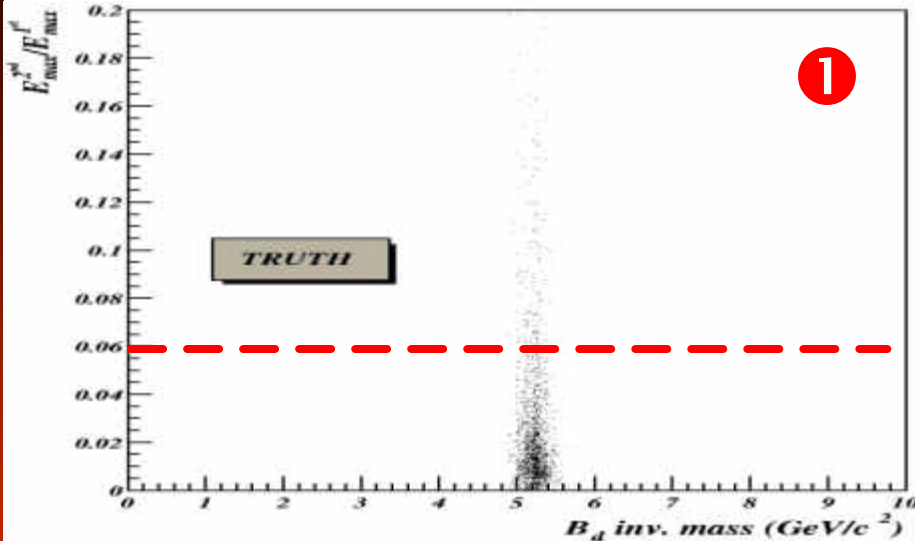


② Shower shape in f & h direction (ECAL 2nd sampling)

LVL2 cut: \times 9 %

g selection

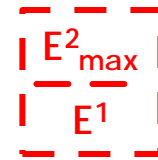
2. γ/π^0 rejection



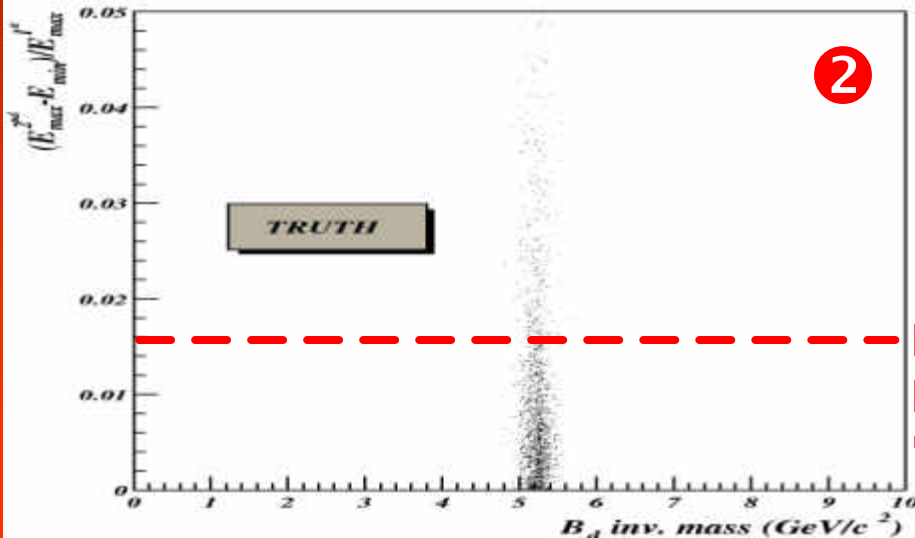
Search for a 2nd maximum in the strips:

- g: no 2nd max
- π^0 : 2nd max close to the 1st one

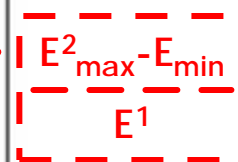
1 Transverse energy of the 2nd max on total transverse energy in the strips



LVL2 cut: $\leq 6\%$



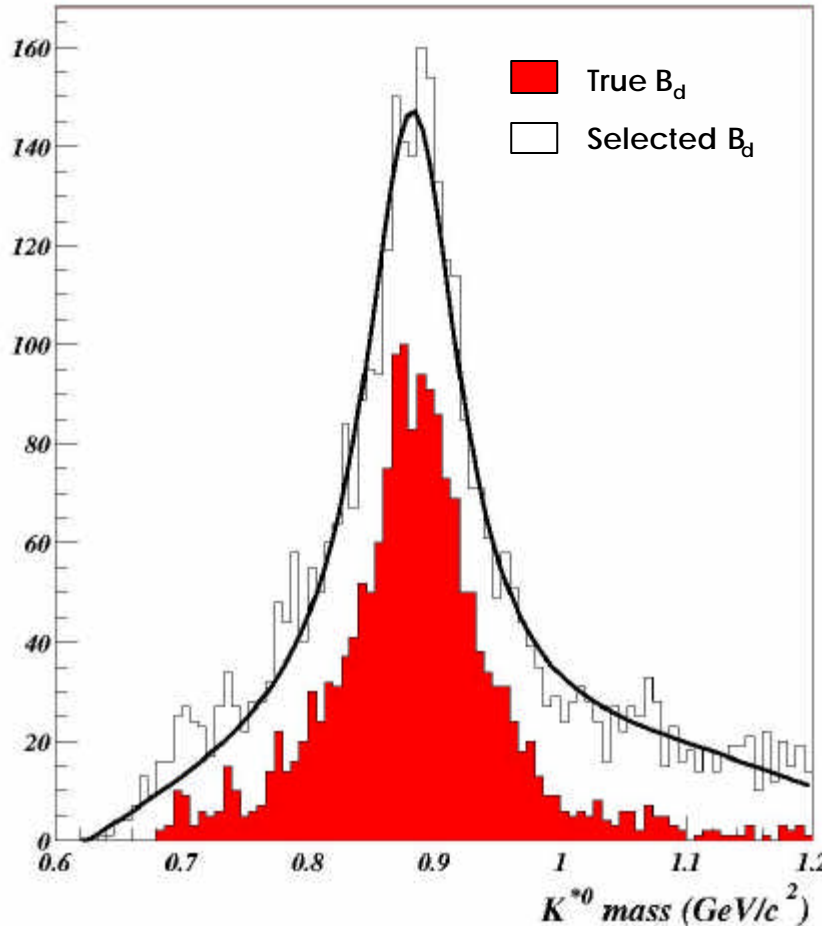
2 Physical meaning of the 2nd max (real max or 1st max artefact). Look at the minimum energy between the two max and compare it to 2nd max energy



LVL2 cut: $\leq 1.5\%$

K^{*0} reconstruction

Mass window determination



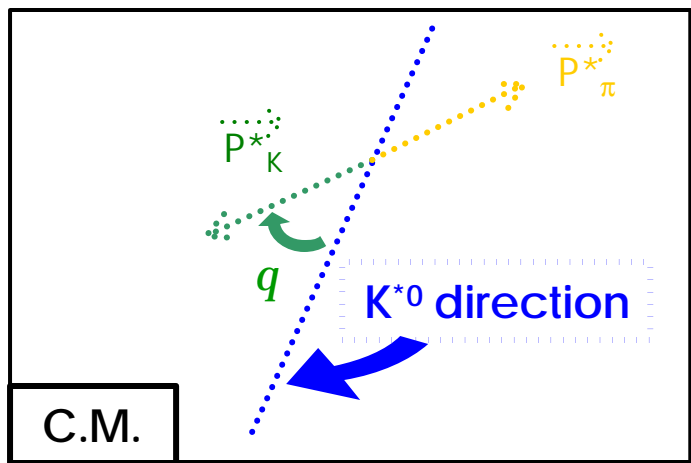
A **raw** K^{*0} reconstruction is performed (no cuts)

K^{*0} candidates giving a selected B_d are displayed

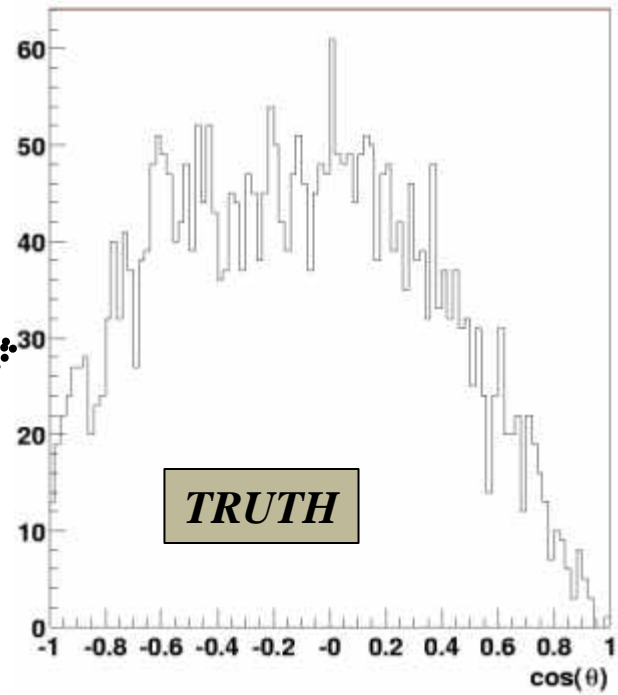
A **2 σ mass window** cut on $M_{K^{*0}}$ is sufficient for correct signal reconstruction

We then re-reconstruct the B_d using this mass cut

Refined cuts
K*0 angular distributions



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

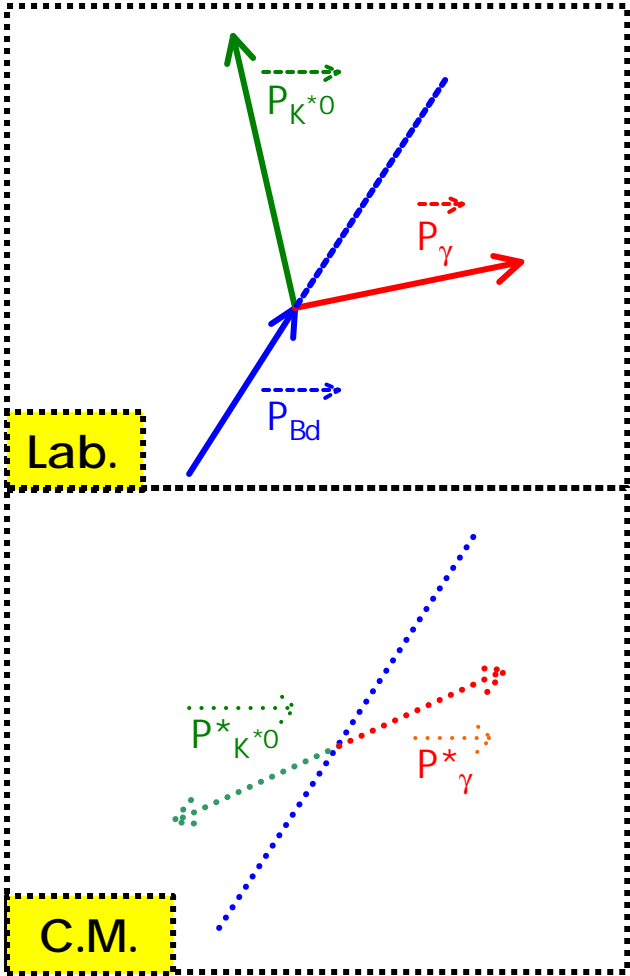


Flat distribution for combinatorial

Interesting cut

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

Refined cuts
Mass cuts (1/2)



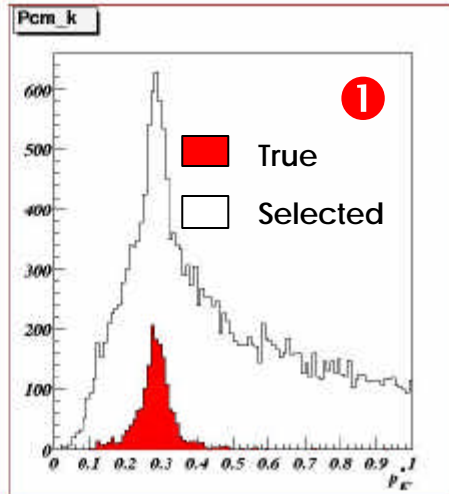
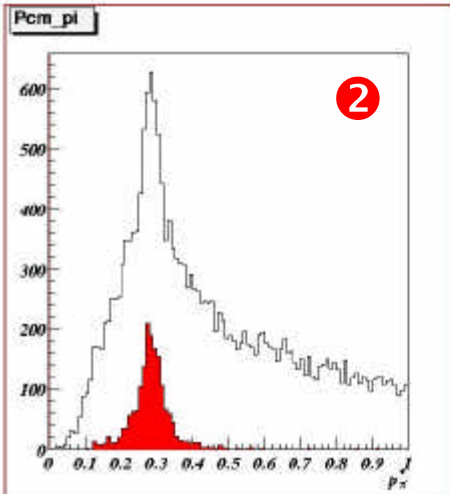
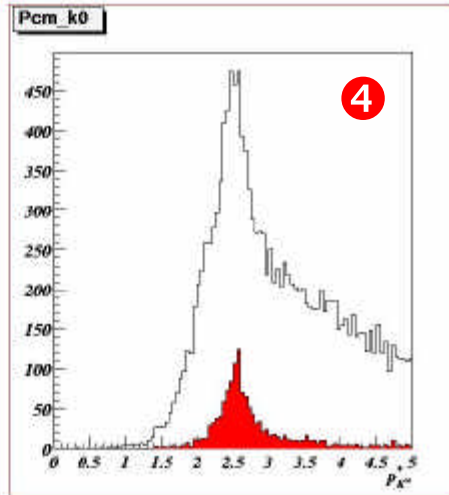
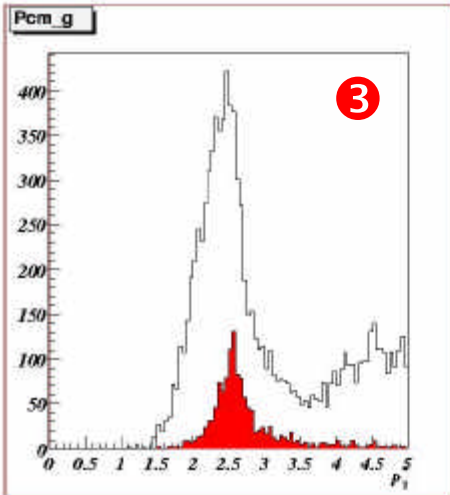
• In C.M.S. we have :

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

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

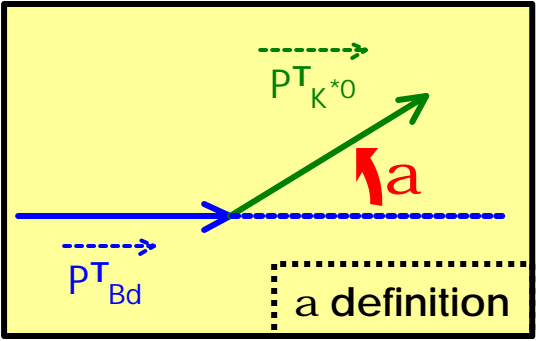
2 $0.2 \text{ GeV} < P_{p^-}^* < 0.35 \text{ GeV}$

• B_d is selected if:

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

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

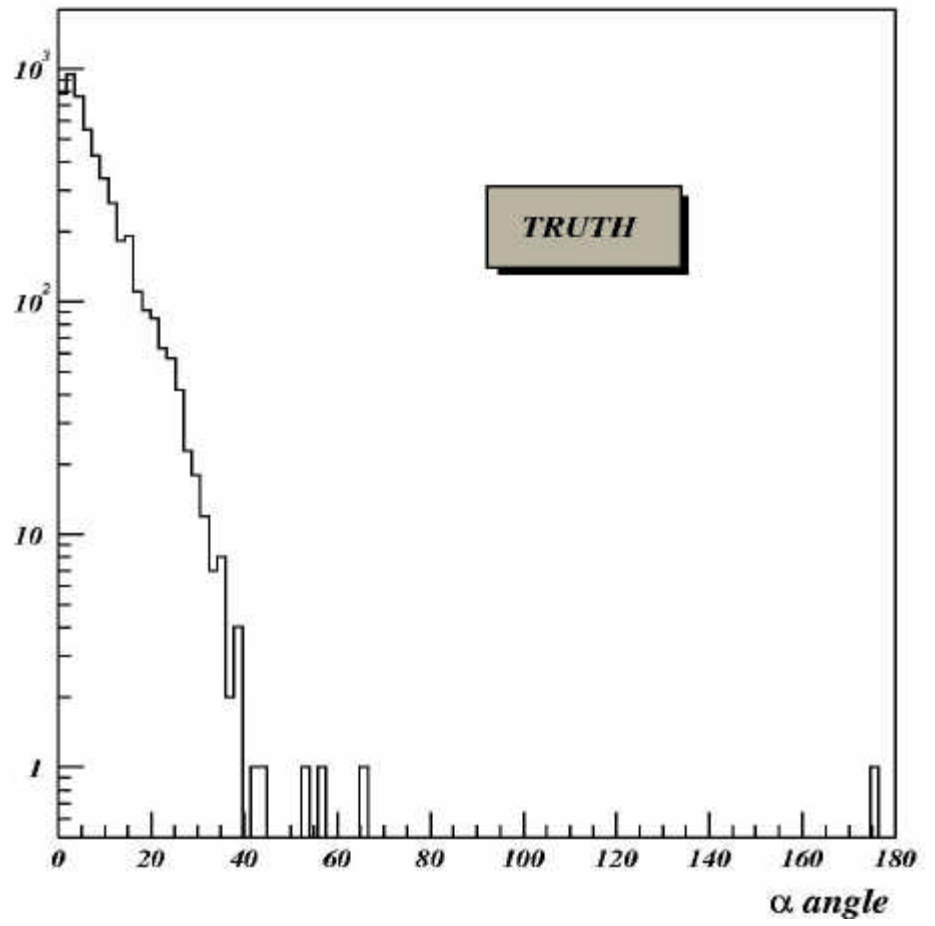
Refined cuts
 K^{*0} transverse direction



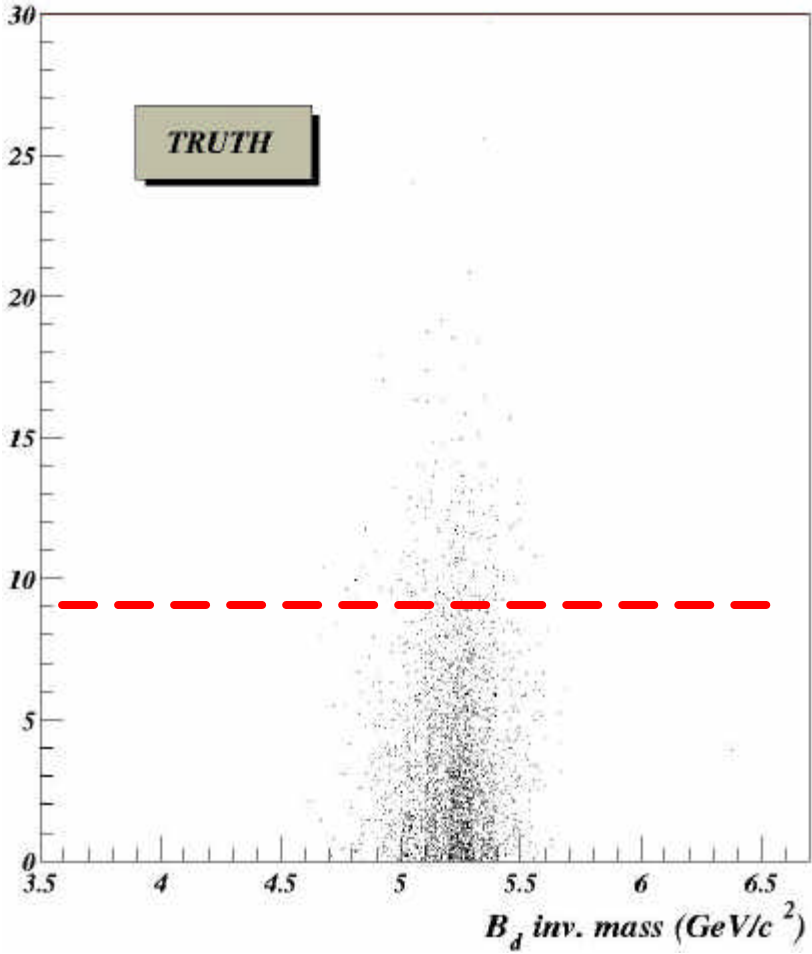
B_d boost

α small

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



Refined cuts
Minimal distance between B_d vertex and γ trajectory



- No information on γ in the ID
- ➔ Vertexing routine couldn't be used
- K^{*0} time of flight very short
- ➔ K^{*0} decay vertex = B_d decay vertex
- γ trajectory should contain this vertex
- Minimal distance between γ 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 $\overline{B}_d \text{ @ } \overline{K}^{*0} g$!

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

σ_{prod} should be confirmed

$$\sigma_{\text{prod}}(\text{signal}) = 0.15 \text{ mbarn} \quad \leftarrow \begin{array}{l} \text{(from Pythia)} \\ \text{ } \end{array}$$

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

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

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

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

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