Analysis of the $B^0 \rightarrow D^0 K^{*0}$ decays at LHCb

IOP HEPP Annual Meeting

Lancaster 31/3 → 2/4

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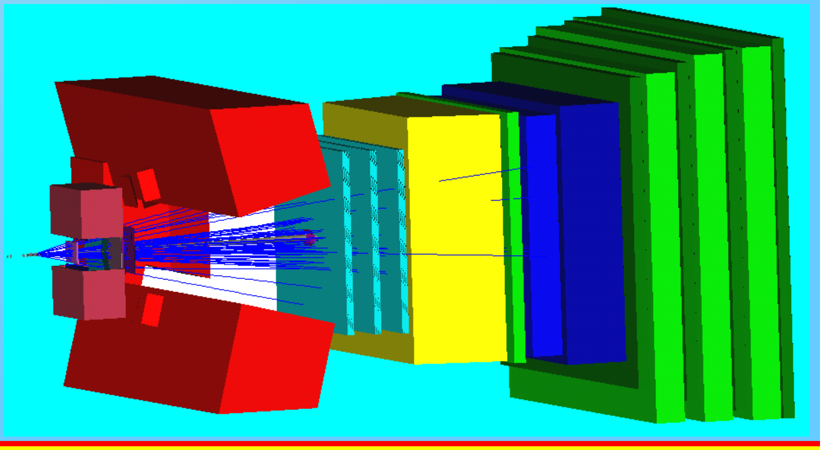
RAL

Outline:
- The LHCb detector
- $B^0 \rightarrow D^0 K^{0*}$ event selection
- $B^0 \rightarrow D^0 K^{0*}$ sensitivity studies
- Conclusion



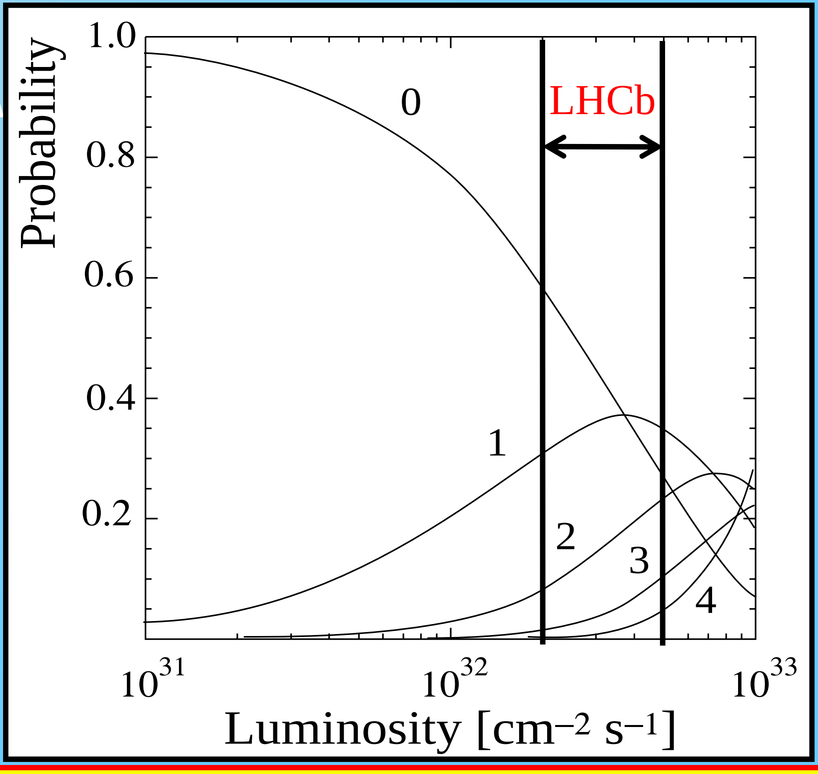
The Large Hadron Collider (LHC)

Start: 2008

LHC
p-p collisions with 14 TeV
Bunch crossing @ 40MHz (25 ns)

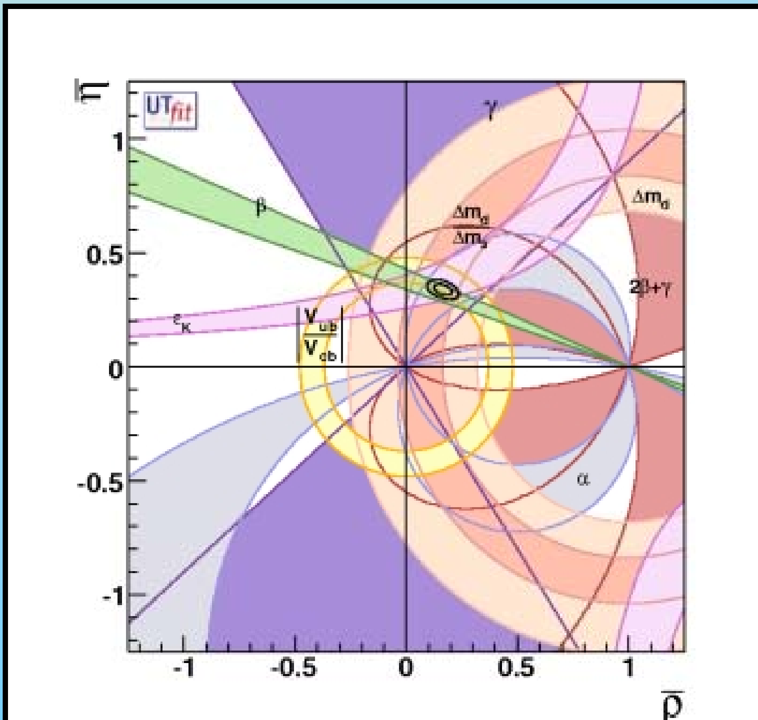
LHCb:
L ~ 2 .10^{32} $cm^{-2}s^{-1}$ (mostly single interactions)
~ 14 Million collisions per second
1 in 160 collisions is B physics

Inelastic pp collisions/crossing



Physics motivations

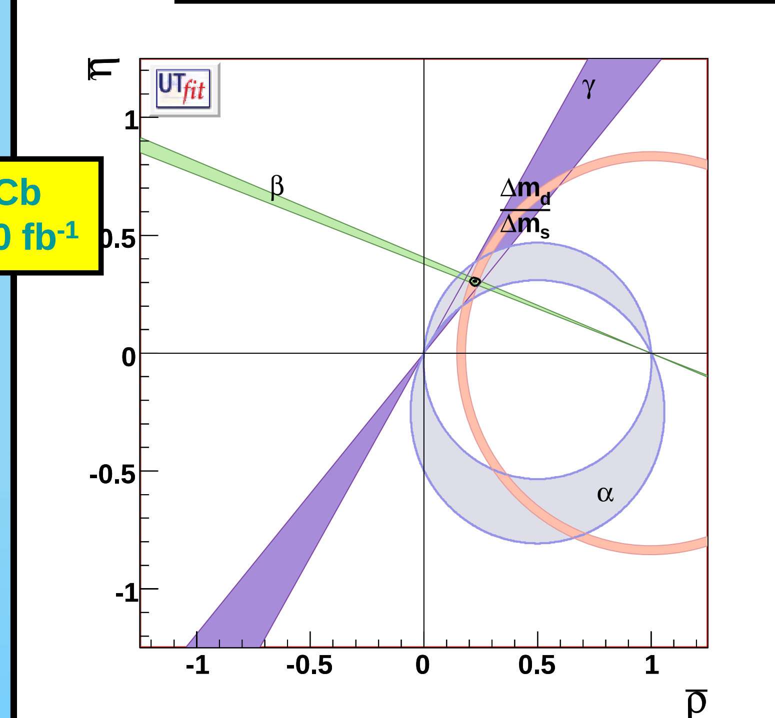
B-factories and the Tevatron Winter 2007



$$\sigma(\bar{\rho})/\bar{\rho} = 17\%$$
$$\sigma(\bar{\eta})/\bar{\eta} = 4.7\%$$

Unitarity Triangle prospects from LHCb only (2014)

LHCb
L=10 fb^{-1}

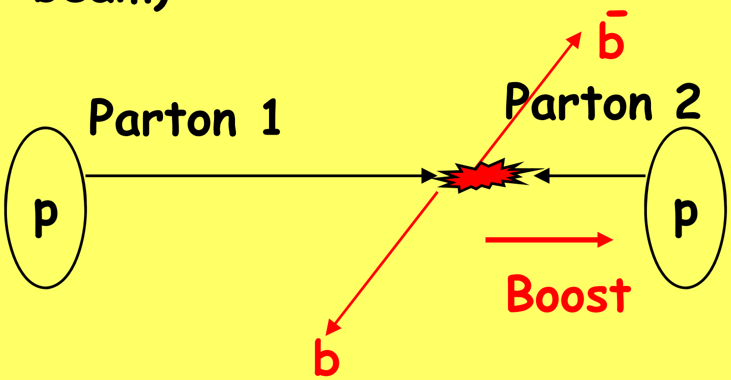


$$\sigma(\bar{\rho})/\bar{\rho} = 3.6\%$$
$$\sigma(\bar{\eta})/\bar{\eta} = 1.8\%$$

In this talk I'll concentrate on a clean mode for γ extraction: $B^0 \rightarrow D^0 K^{0*}$

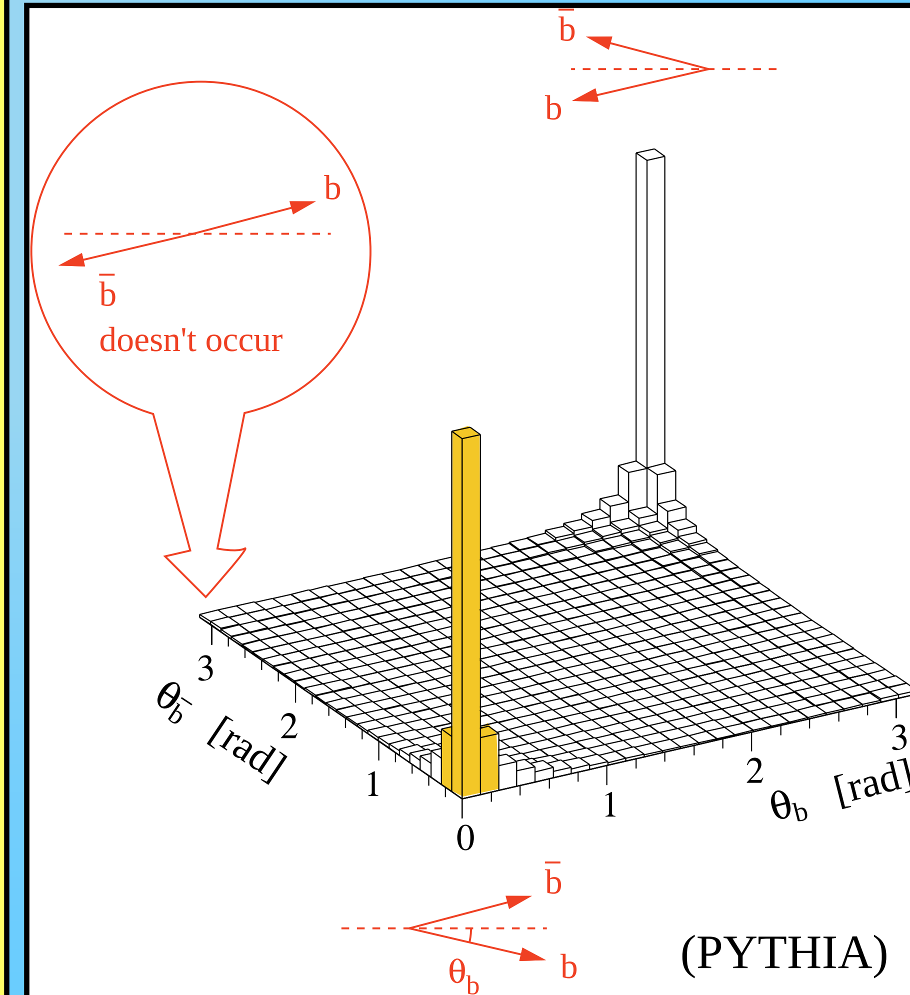
B production

- B hadrons are mostly produced in the forward direction (along the beam)

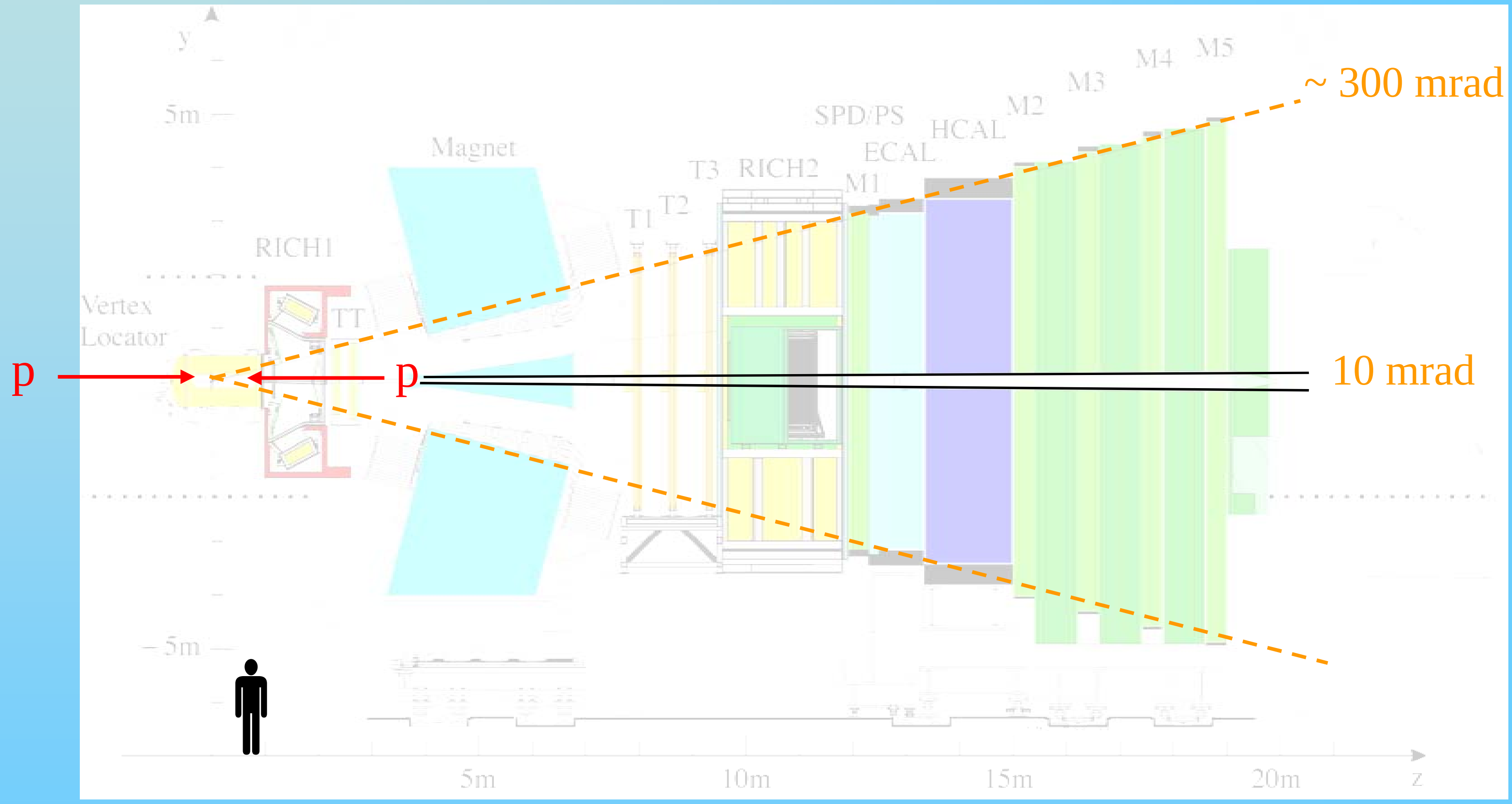


- Choose a forward spectrometer 10–300 mrad
- Both b and b̄ in the acceptance: important to tag the B flavour at production to study CP violation

b–b̄ correlation

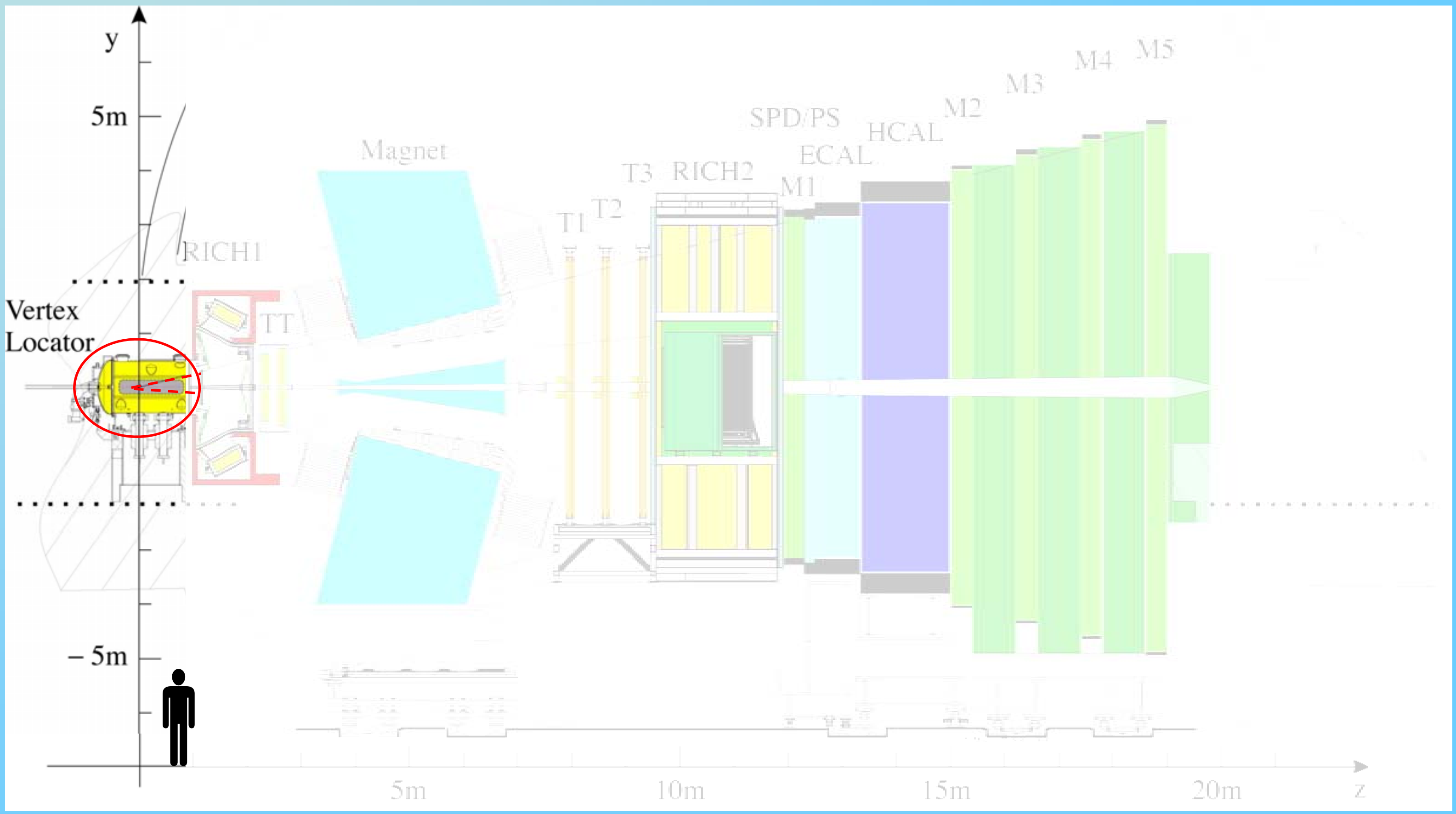


LHCb Detector



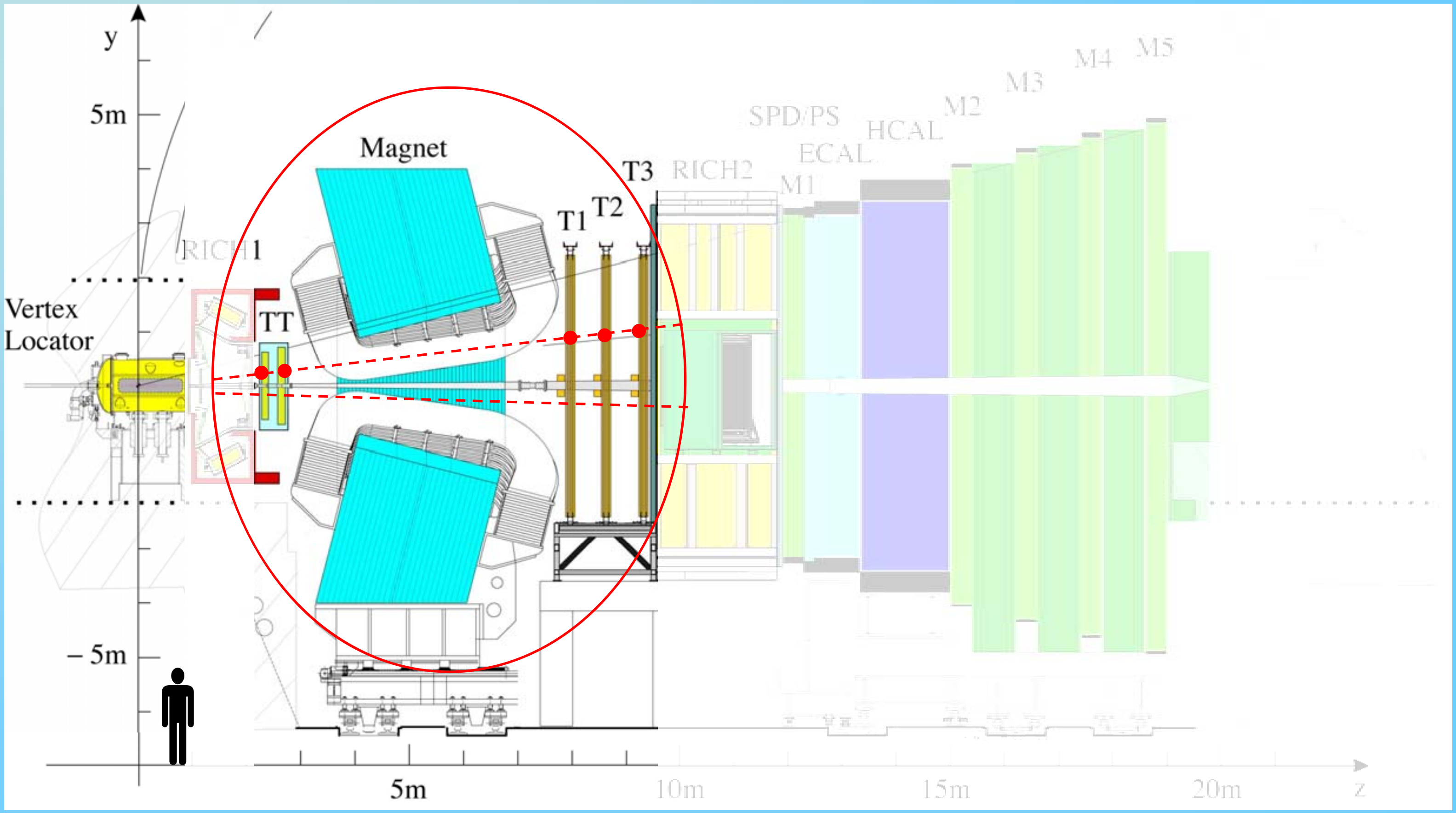
Forward spectrometer (running in pp collider mode)

LHCb Detector



Vertex locator around the interaction region

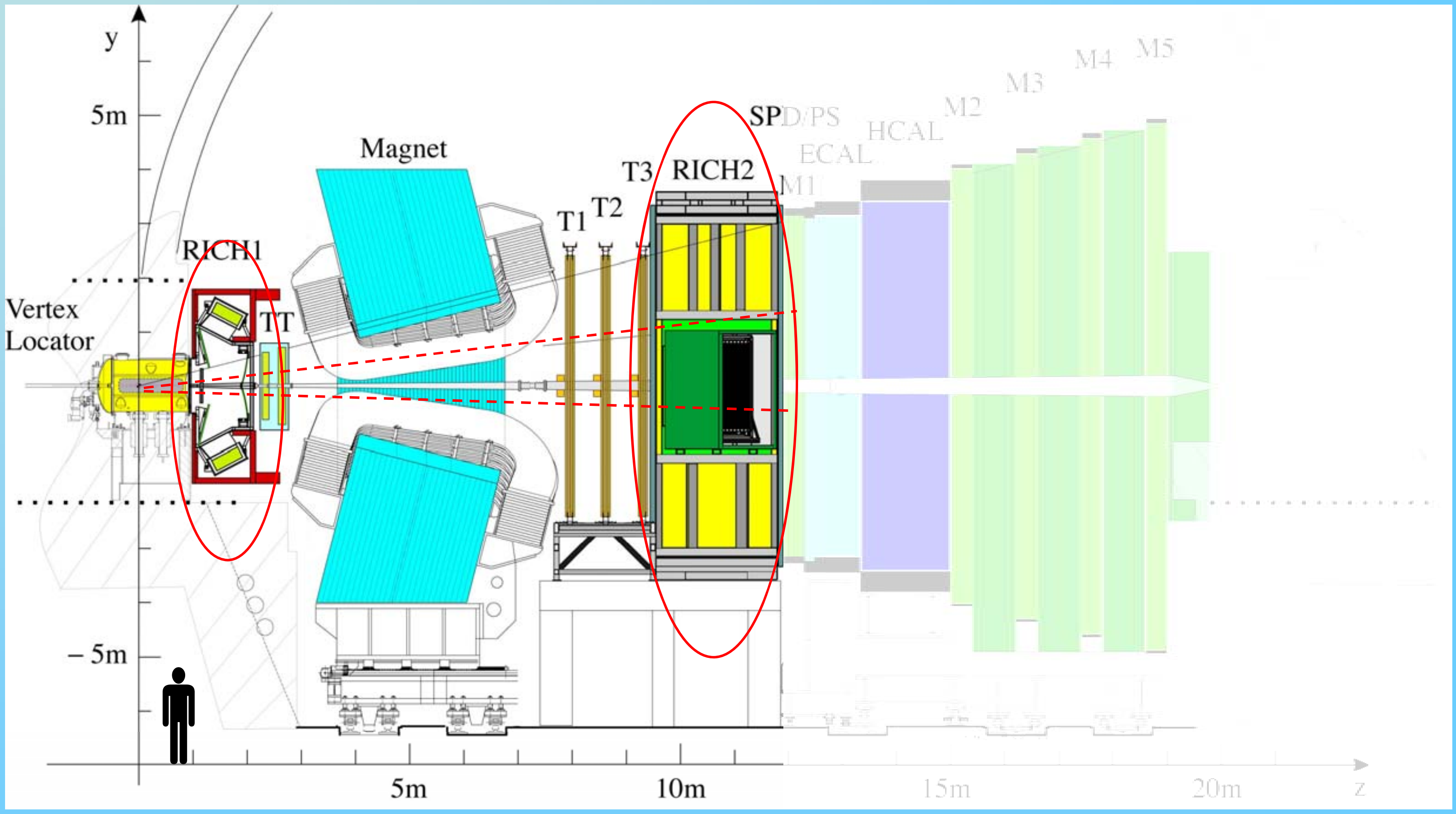
LHCb Detector



Tracking system and dipole magnet to measure angles and momenta $\Delta p/p \sim 0.4\ \%$

Magnetic field regularly reversed to reduce experimental systematics

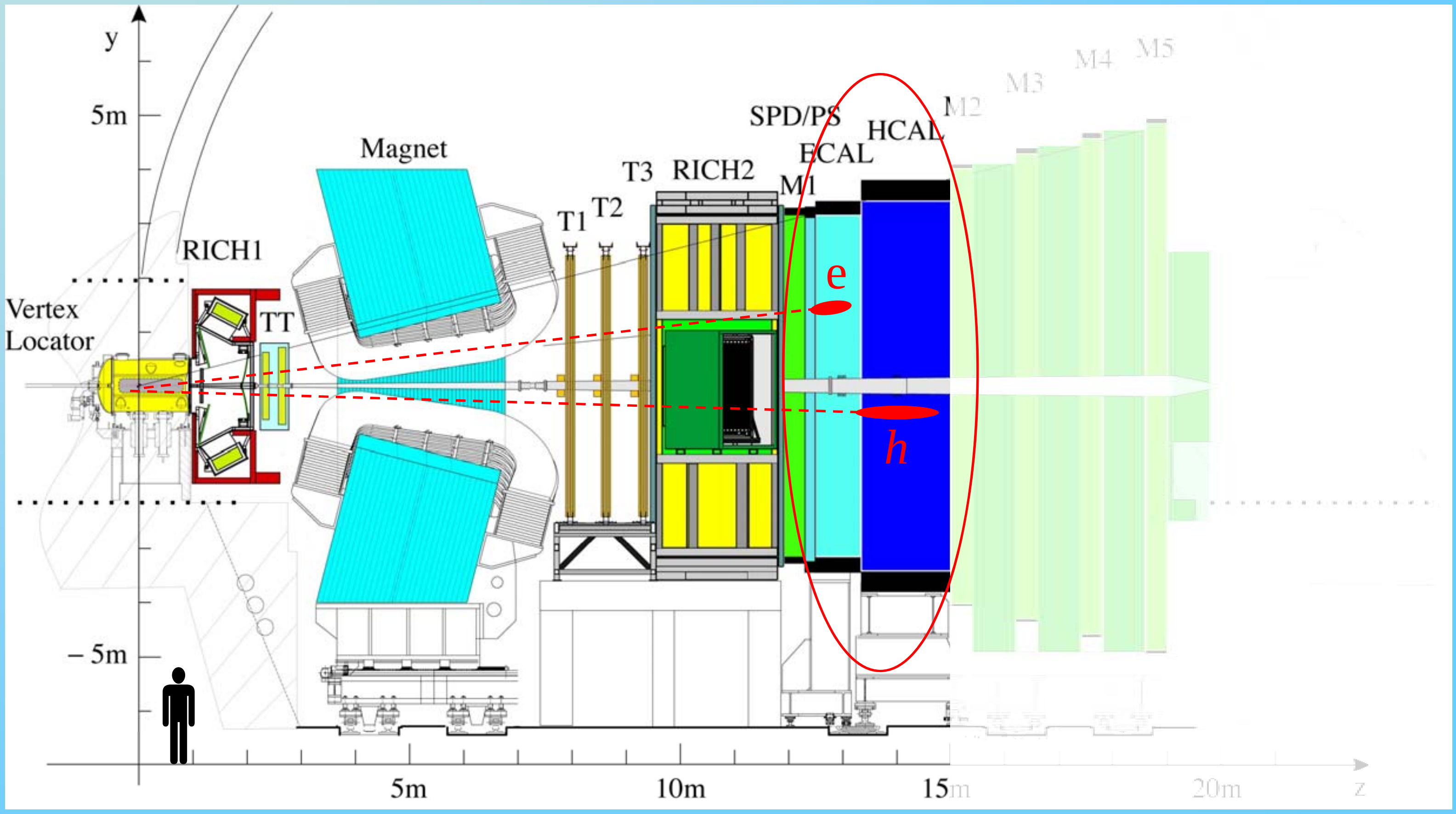
LHCb Detector



Two **RICH** detectors for charged hadron identification

Provide > **3σ π\K** separation for 3 < *p* < 100 GeV

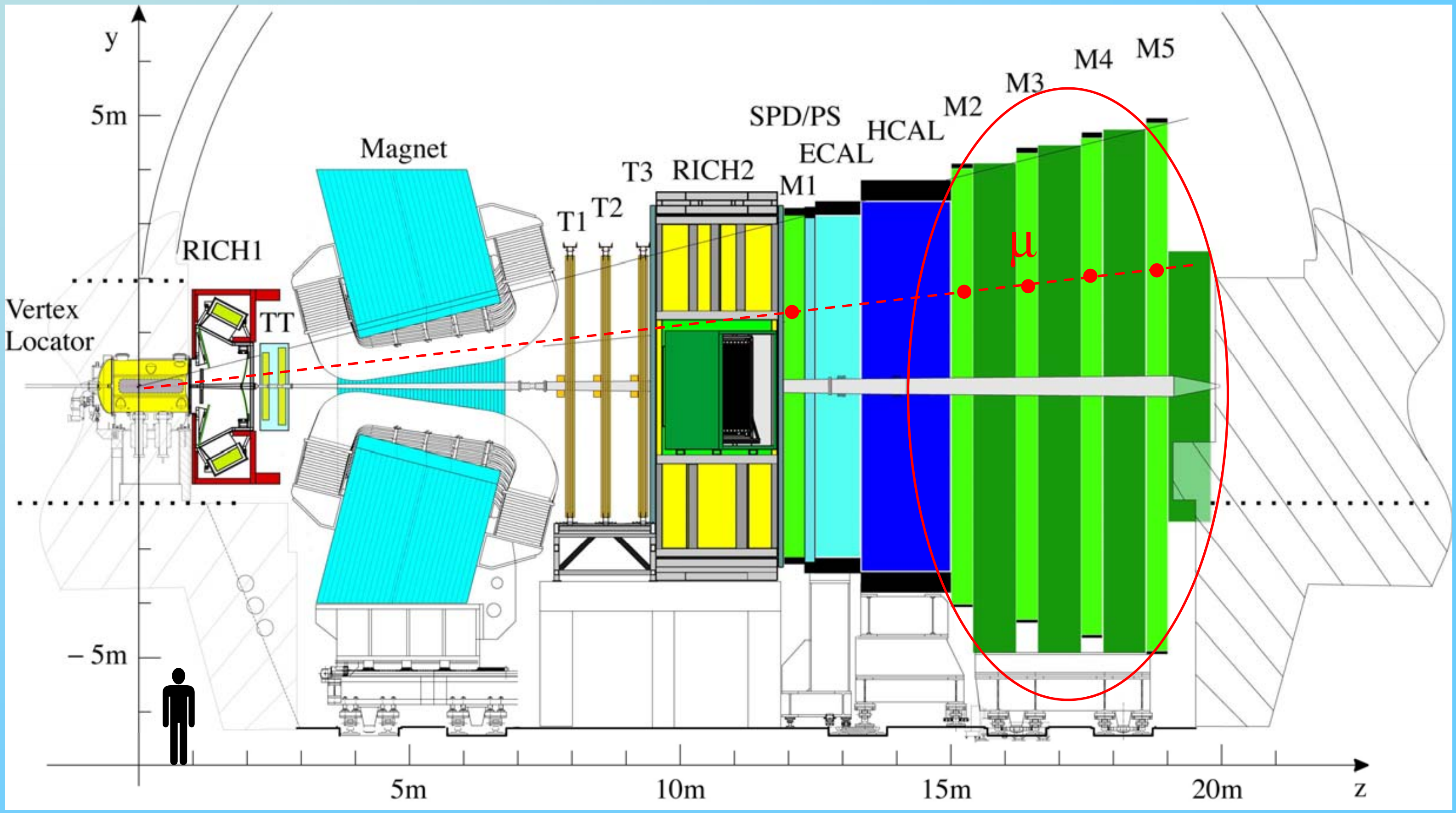
LHCb Detector



Calorimeter system to identify electrons, hadrons and neutrals

Important for the first level of the trigger

LHCb Detector



Muon system to identify muons, also used in first level of trigger

A bit of theory
Decays of interests

Decays of interests are $B^0 \rightarrow D^0 K^{*0}$ *with* $D^0 \rightarrow K^{\pm}\pi^{\pm}$ *and* $K^{*0} \rightarrow K^+\pi^-$

$B^0 \rightarrow \bar{D}^0 K^{*0}$ *with* $\bar{D}^0 \rightarrow K^{\pm}\pi^{\pm}$

analogously we have $\bar{B}^0 \rightarrow \underline{D}^0\, \bar{\underline{K}}^{*0}$ *with* $\bar{K}^{*0} \rightarrow K^-\pi^+$

and $\bar{B}^0 \rightarrow \bar{D}^0\, \bar{K}^{*0}$

Finally there are also the decays to CP eigenstates: $D^0 \rightarrow K^+K^-$ *or* $D^0 \rightarrow \pi^+\pi^-$

- *Extraction of* γ *through CP modes originally proposed by Gronau - London - Wyler:* Phys. Lett. B253, 483 (1991)
- *Possibility of using not only CP modes proposed by Atwood - Dunietz - Soni* Phys.Rev.Lett. 78 3257 (1997)

A bit of theory

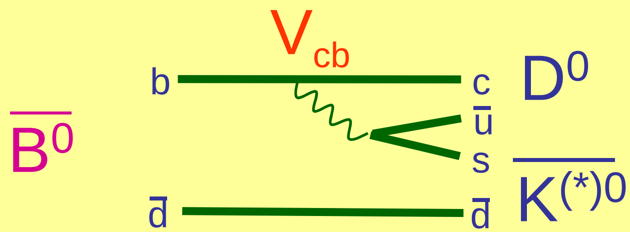
- *LHCb cannot easily measure CP odd states → GLW alone is not enough*
- *Combining GLW and ADS solves problem (using also non CP modes)*

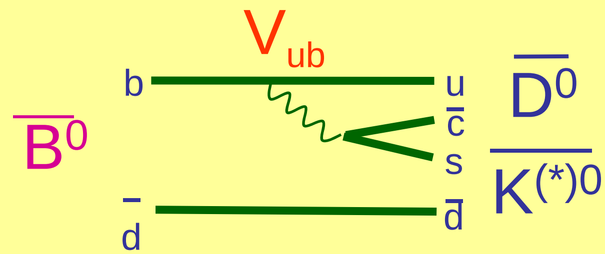
$$\begin{aligned}
\Gamma(B^0 \to (K^+\pi^-)_D K^{*0}) &= N_{K\pi}(1 + (r_B r_D)^2 + 2 r_B r_D \cos(\delta_B + \delta_D + \gamma)) \\
\Gamma(B^0 \to (K^-\pi^+)_D K^{*0}) &= N_{K\pi}(r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B - \delta_D + \gamma)) \\
\Gamma(\overline{B^0} \to (K^-\pi^+)_D \overline{K^{*0}}) &= N_{K\pi}(1 + (r_B r_D)^2 + 2 r_B r_D \cos(\delta_B + \delta_D - \gamma)) \\
\Gamma(\overline{B^0} \to (K^+\pi^-)_D \overline{K^{*0}}) &= N_{K\pi}(r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B - \delta_D - \gamma))
\end{aligned}$$

$$\begin{aligned}
\Gamma(B^0 \to D_{CP} K^{*0}) &= N_{CP}(1 + r_B^2 + 2 r_B \cos(\delta_B + \gamma)) \\
\Gamma(\overline{B^0} \to D_{CP} \overline{K^{*0}}) &= N_{CP}(1 + r_B^2 + 2 r_B \cos(\delta_B - \gamma))
\end{aligned}$$

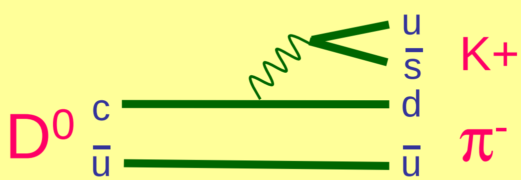
- *We have 6 equations and 5 unknowns: r_B, δ_B, δ_D, γ and $N_{K\pi}$*
- *N_{CP} is determined from $N_{K\pi}$ taking in account the different BR and efficiencies*
- *Method described in LHCb note 2005-066.*

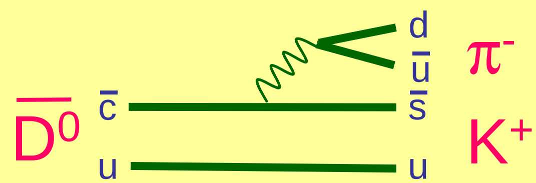
A bit of theory





•*Both diagrams colour-suppressed ⇒ similar magnitude and large interference*





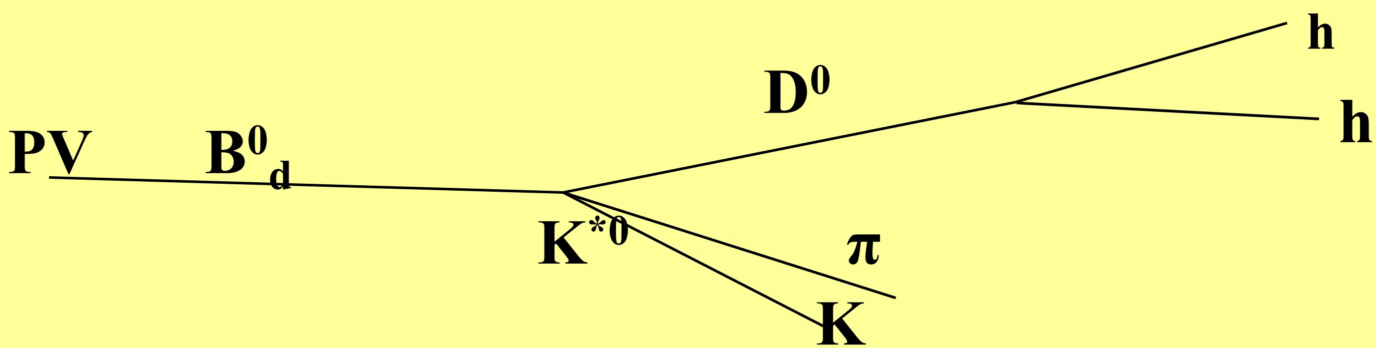
• *Decays of D^0, $\overline{D^0}$ to same final state gives access to interference*

$$r_B = \frac{|A(B^0 \longrightarrow D^0 K^{*0})|}{|A(B^0 \longrightarrow \overline{D}^0 K^{*0})|} \approx \frac{1}{\lambda}\frac{|V_{ub}|}{|V_{cb}|} \approx 0.4$$

• *Modes with $K^{*0} \to K^+\pi^-$ are self-tagging: sign of kaon charge distinguishes B^0 from $\overline{B}^0$*
$\overline{K}^{*0} \to K^-\pi^+$

• *Branching fractions involved all rather small*

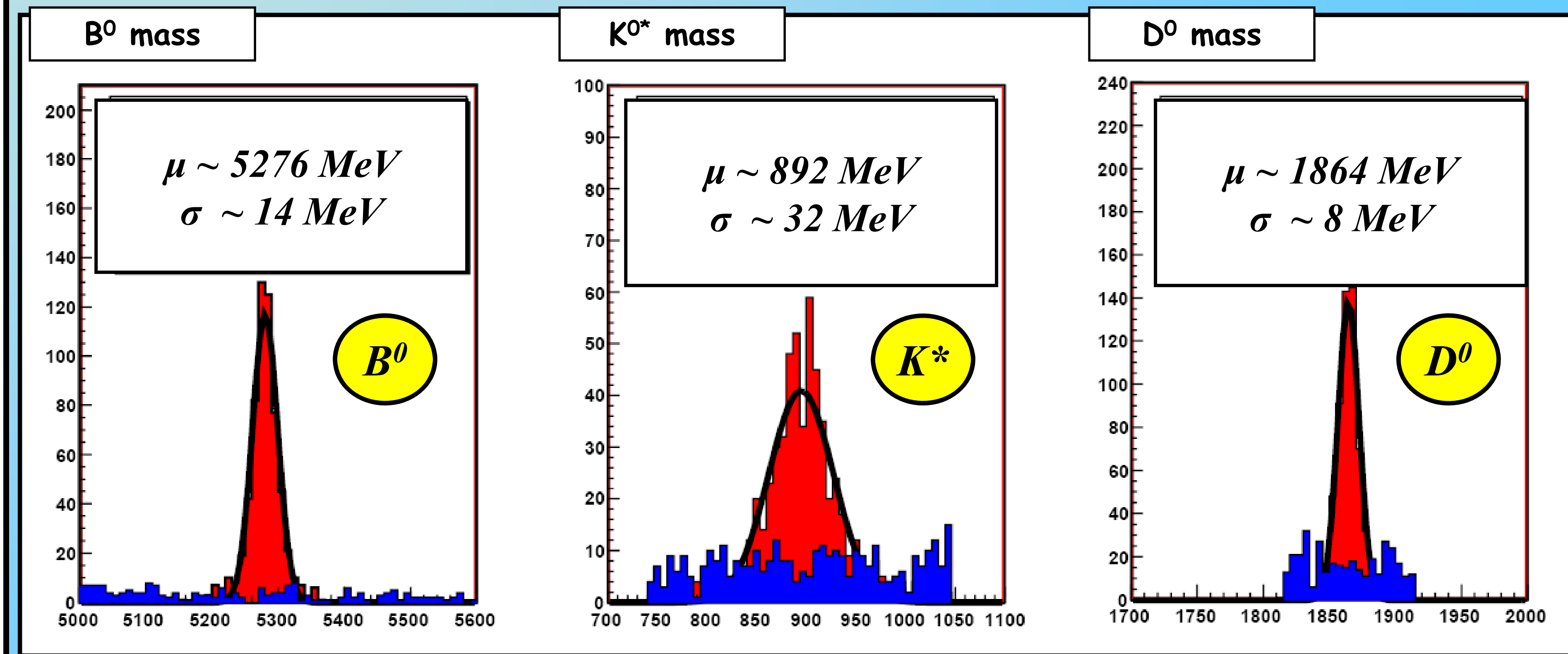
Decay topology and event selection



	$D^0 \to K^-\pi^+$	$D^0 \to K^+K^-$	$D^0 \to \pi^+\pi^-$
D^0 vertex maximum χ^2/ndof	20	12	20
K^{*0} vertex maximum χ^2/ndof	20	20	20
B^0 vertex maximum χ^2/ndof	20	20	20
Maximum IPS of D^0 wrt K^{*0} vertex	5	5	3
D^0 or K^{*0} minimum P_T	1000 MeV/c	1000 MeV/c	1000 MeV/c
D^0 or K^{*0} minimum IPS	2.0	2.0	2.0
Maximum B^0 IPS wrt PV	3.0	3.0	3.0
Maximum final state h P_T	300 MeV/c	300 MeV/c	300 MeV/c
B^0 momentum·flight vector	> 0.9990	> 0.9990	>0.9999
Minimum $\Sigma \log(h_{P_T})$	29.0	27.5	29.0
Minimum $\Sigma \log(h_{IPS})$	6.0	6.0	6.0
Minimum $\frac{D^0{}_{vtx}(z) - B^0{}_{vtx}(z)}{\sigma}$	0.0	0.0	0.6
Maximum K (from K^{*0}) momentum	90 GeV/c	-	-

Analysis described in LHCb public note: 2007-050

Mass resolution



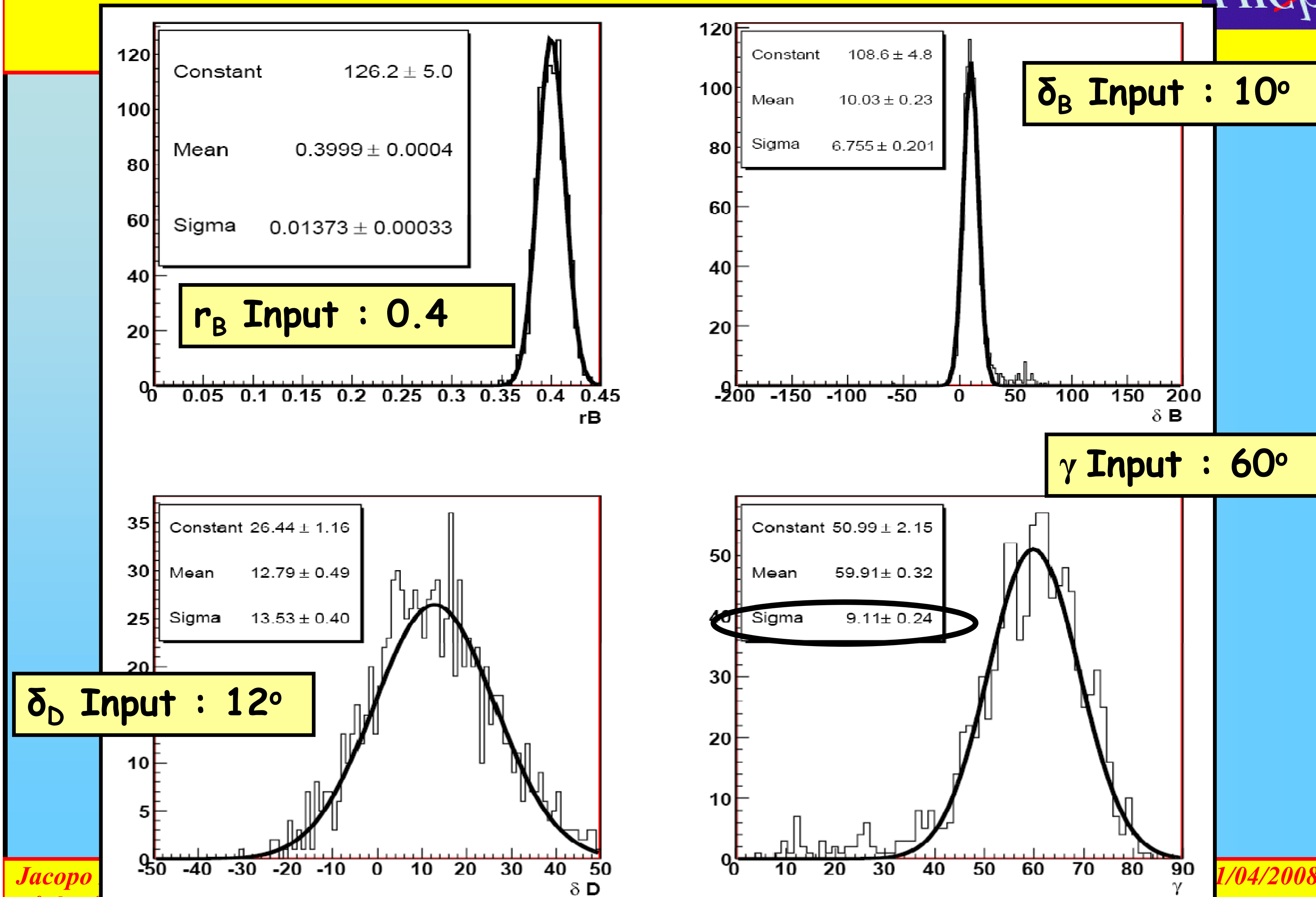
Monte Carlo Selection Results
(on 2/fb of data)

Channel	Annual yield	B/S
$B^0 \rightarrow \overline{D^0}(\rightarrow K^+\pi^-)K^{0*}$	3350	< 2.1
$B^0 \rightarrow D^0(\rightarrow K^+\pi^-)K^{0*}$	536	< 12.8
$B^0 \rightarrow D^0(\rightarrow K^+K^-)K^{0*}$	474	< 4.1
$B^0 \rightarrow D^0(\rightarrow \pi^+\pi^-)K^{0*}$	134	< 14

• Most of the background arises from π/K misidentifications, where we have a ρ^0 instead of a K^{*0}. Other background comes from D* resonances

•The limits are calculated, assuming Poisson statistics, after none of the original 34 M bbar passes the event selection.

TOY MC Results: 1000 experiments (2/fb each)



Scans

r_B Scan

r_B	$\sigma(\gamma)$	fitted γ
0.1	25°	62.7°
0.2	18°	58.0°
0.3	11.4°	59.4°
0.4	8.7°	59.8°
0.5	7.2°	59.8°
0.6	6.2°	59.9°

δ_D Scan

δ_D	$\sigma(\gamma)$	fitted γ
-30°	8.7°	59.5°
-18°	8.8°	59.7°
-12°	8.8°	59.7°
-5°	8.8°	59.8°
0°	8.7°	59.8°
5°	8.8°	59.7°
12°	8.7°	59.6°
18°	8.7°	59.7°
30°	8.5°	59.7°

δ_B Scan

δ_B	$\sigma(\gamma)$	fitted γ
-180°	6.4°	60.3°
-120°	–	-51.3°
-90°	–	-41.1°
-60°	–	-53.0°
-30°	9.6°	60.9°
-20°	8.9°	60.4°
-10°	8.7°	59.4°
0°	8.7°	59.4°
10°	8.8°	59.8°
20°	8.9°	60.6°
30°	9.9°	60.7°
60°	–	-63.0°
90°	–	-40.5°
120°	–	-52.7°
180°	6.4°	60.3°

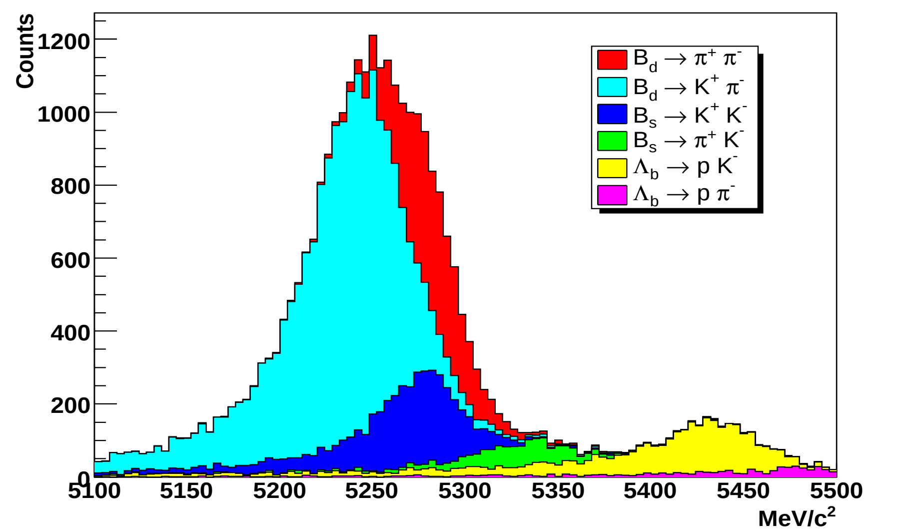
Summary

- *The $B^0 \rightarrow D^0 K^{0*}$ decays offer a "penguin free" way to extract the CKM angle γ*
- *An event selection has been studied on Monte Carlo data, which will allow LHCb to achieve a good S/B for all studied decay channels. It was found that low background levels are crucial in particular for B decays with $D^0 \rightarrow$ CP modes. Therefore a tighter event selection has been developed for these rarer decay modes.*
- *Using $B^0 \rightarrow D^0(\rightarrow hh)K^{0*}$ decays, γ can be determined with a statistical error better than 10 degrees with one year of data at nominal luminosity for $r_B > 0.3$.*

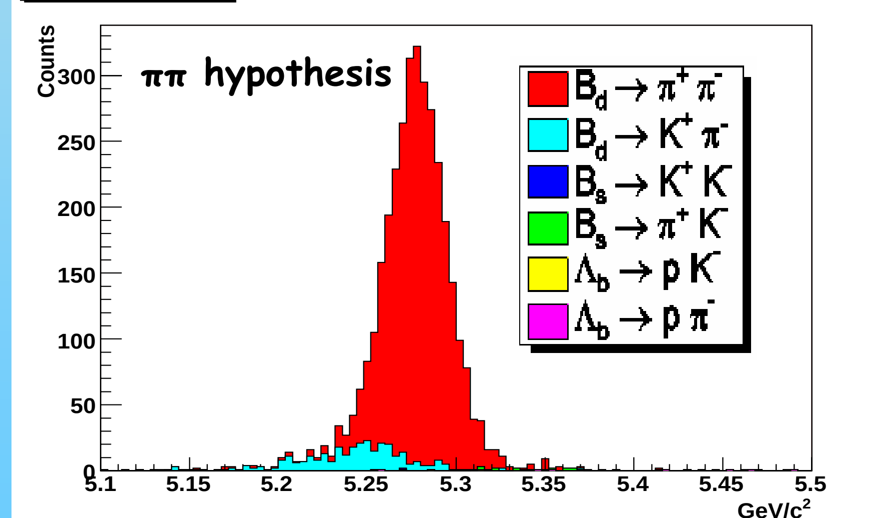
Back Up Slides

Particle identification through RICH system
$p/K/\pi$ separation

Invariant mass (no PID)

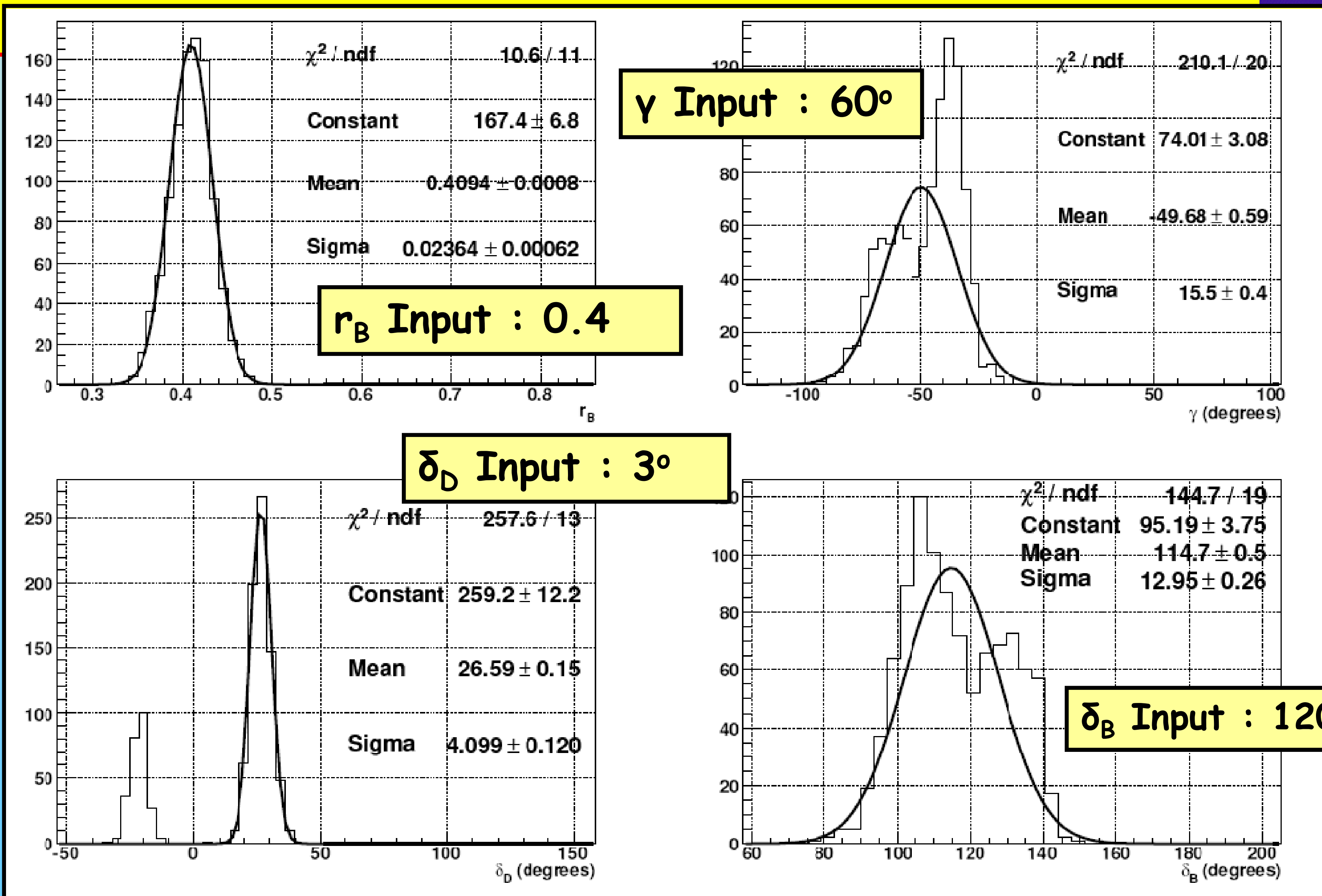


Invariant mass (with PID)



Clean samples through expected PID performance of RICH system

Results : a badly behaved case (2/fb)



Sensitivity studies

- ***A TOY for the extraction of γ in the $B^0 \to D^0 K^{*0}$ has been developed***
- ***In the TOY the following equations are parameterized***

$$\begin{aligned}
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\end{aligned}$$

- ***We have 6 equations and 5 unknowns: r_B, δ_B, δ_D, γ and $N_{K\pi}$***
- ***N_{CP} is determined from $N_{K\pi}$ taking in account the different BR and efficiencies***