Study of $B^{\pm} \rightarrow D^0(K_s\pi^+\pi^-)K^{\pm}$ Dalitz decay and Sensitivity to γ in LHCb

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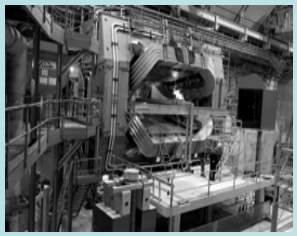
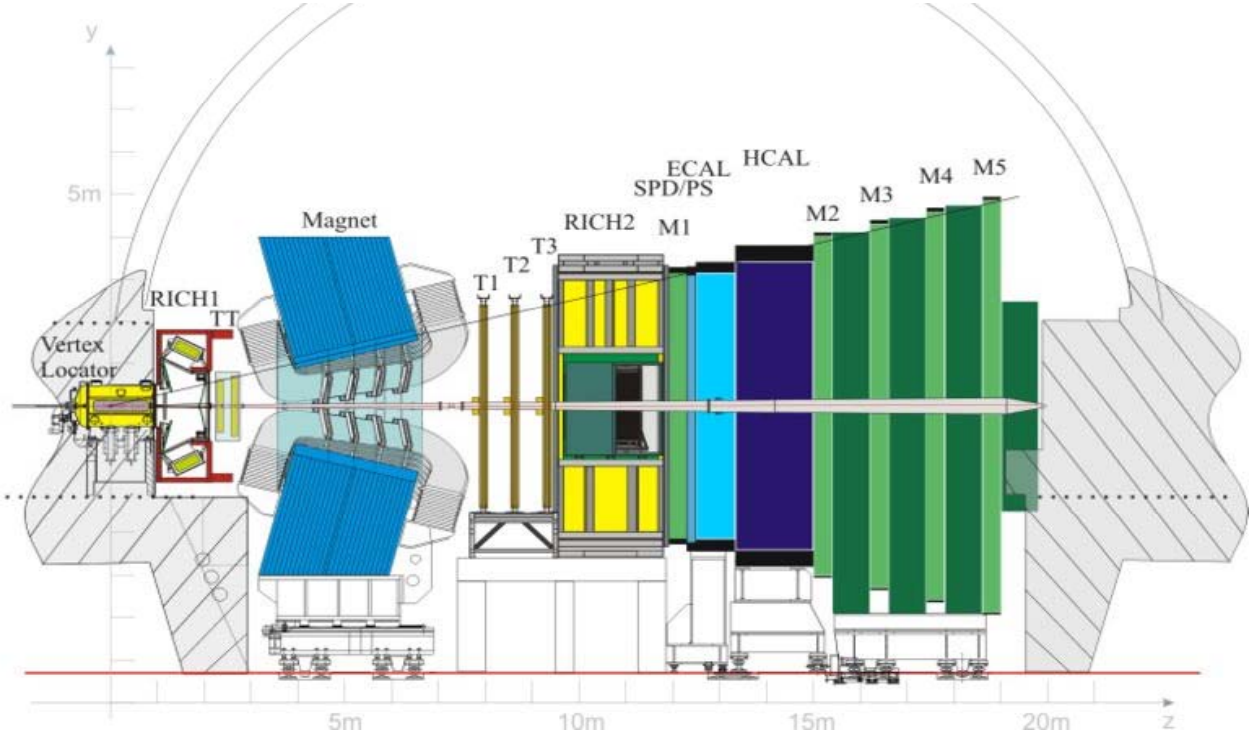
Details found in LHCb public note: LHCb-48-2007

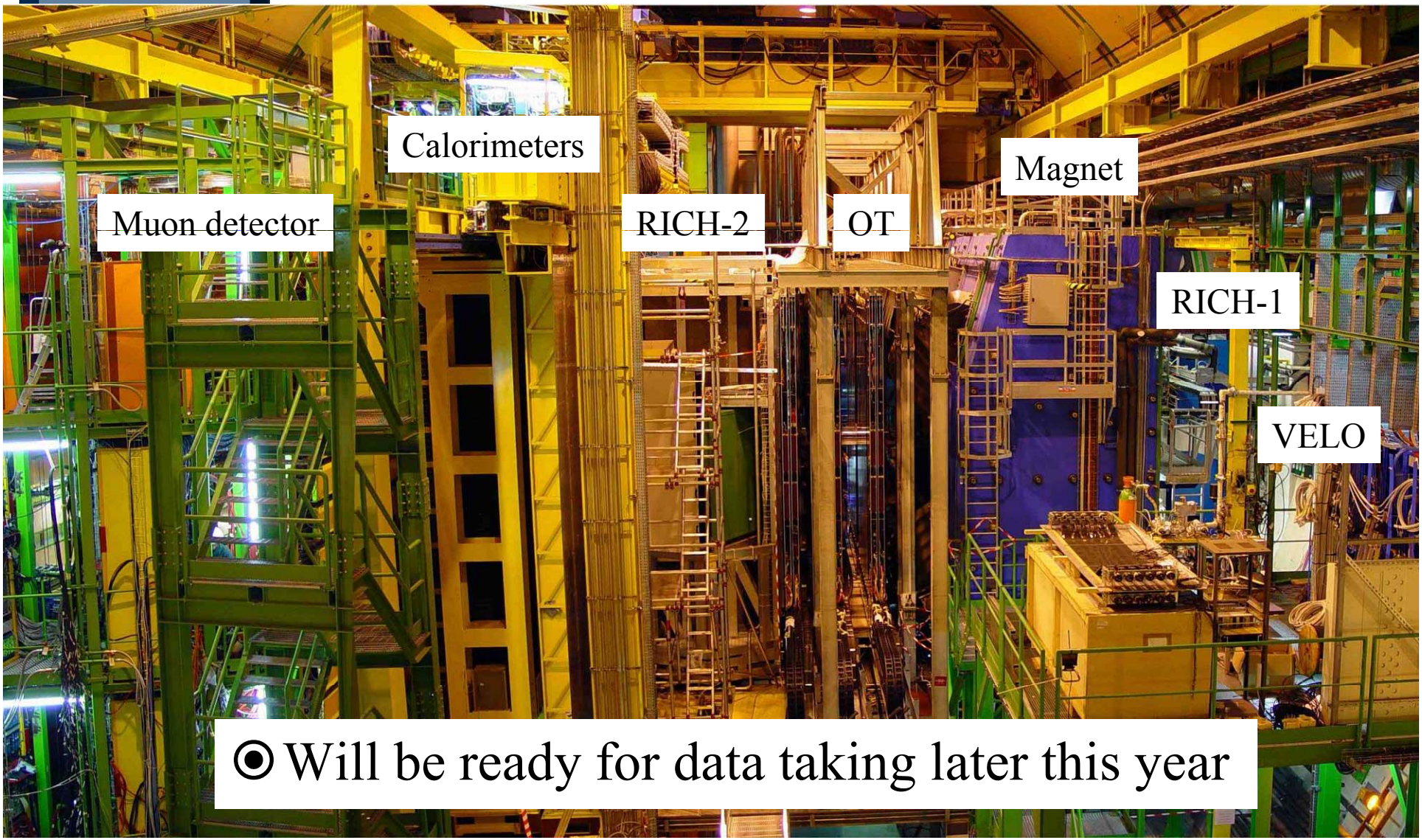


Introduction

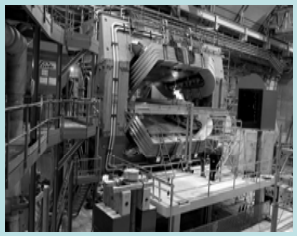


- LHCb is the dedicated **B physics** detector at the LHC
  - integrated **luminosity of 2fb^{-1} per year,** $\sigma_{b\bar{b}}$= 500μb
  - **10^{12} $b\bar{b}$** pairs per year.
- One of its main goals is to study CP violation

LHCb current status

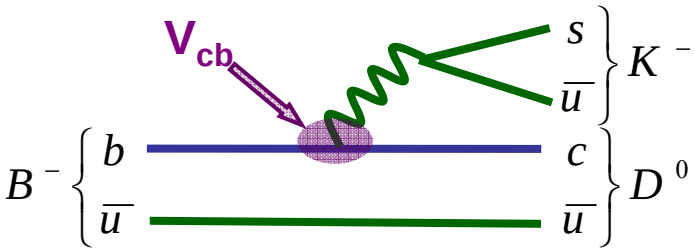


- Will be ready for data taking later this year

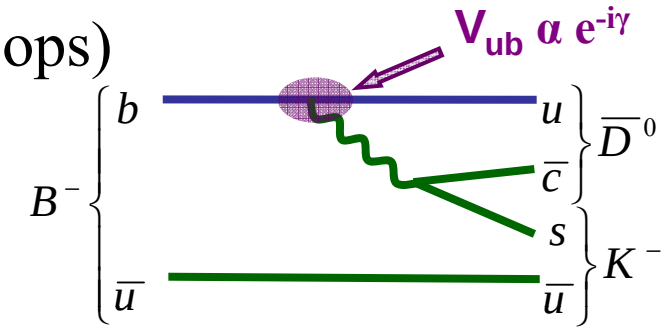


$B \rightarrow D^0/\bar{D}^0(K_s\pi^+\pi^-)K$

- Two interfering trees (no loops)



Colour **favoured**



Colour **suppressed**

- Same final decay mode of $D^0/\bar{D}^0 \rightarrow K_s\pi^+\pi^-$ produce interference effects

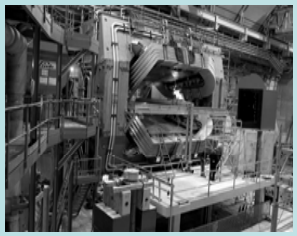
$$\frac{A(B^- \rightarrow \bar{D}^0 K^-)}{A(B^- \rightarrow D^0 K^-)} = r_B e^{i\delta} e^{-i\gamma}$$

γ the unitary triangle CP angle, from $b \rightarrow c$, $b \rightarrow u$ interference

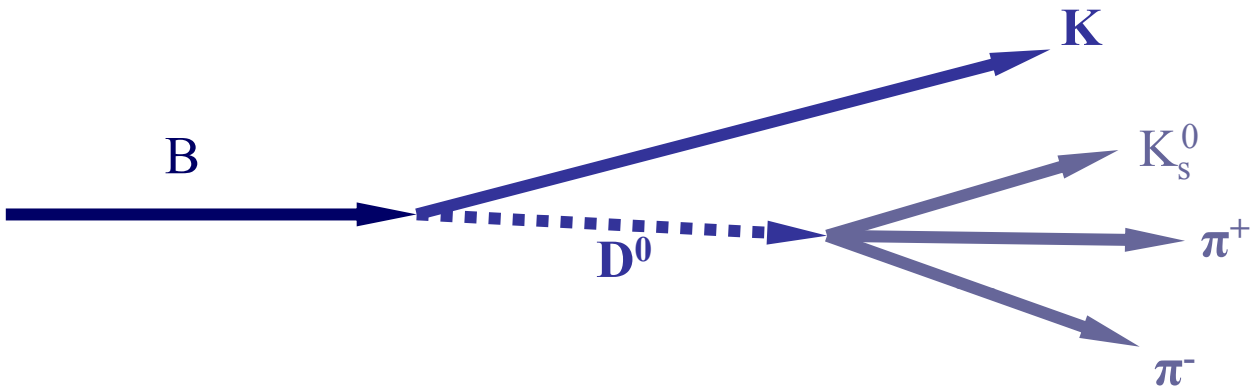
δ the CP conserving strong phase

$r_B = (V_{ub}V^*_{cs}/V_{cb}V^*_{us})f_c$

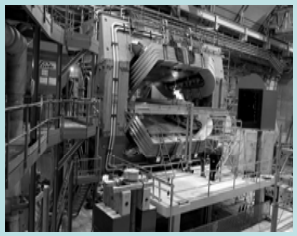
- All three parameters can be extracted by fitting the amplitudes in the Dalitz plane of the D^0 decay



Signal annual yield

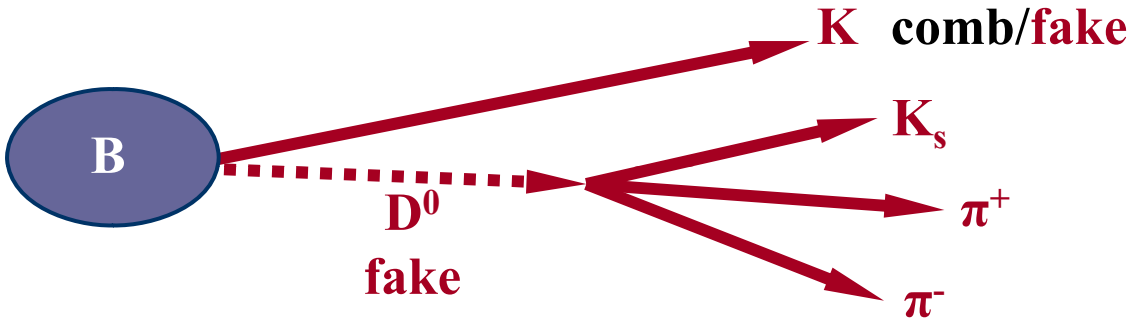


- Selection cuts (p_T, vertex χ^2, Δmass etc…) applied to
  - MC data at **$2fb^{-1}$**, sample size of **0.4M events**
  - Few min of data taking
- Maximises the $S/\sqrt{(B+S)}$ ratio
- No triggers applied, but expected $\varepsilon_{trigger} \sim 40\%$
- Selection efficiency: **(0.86 0.03) %**
- Purity: **95.1%**
- Estimated annual yield: **~10K events/yr**

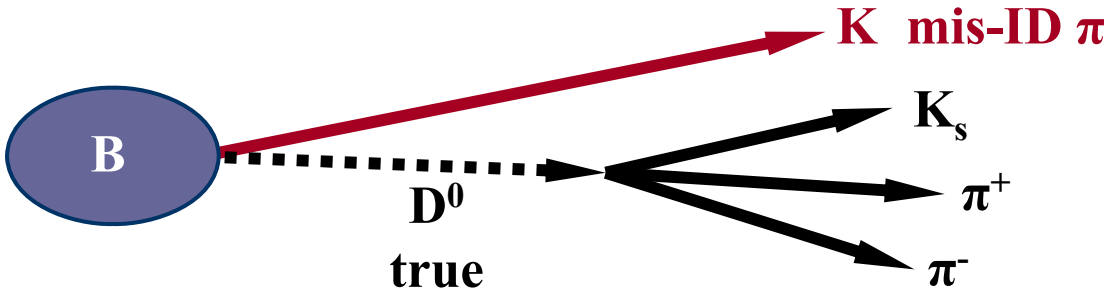


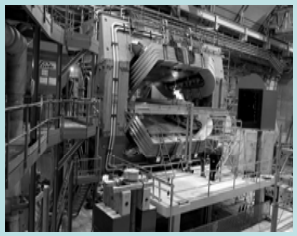
Four background types

1. Pure combinatoric



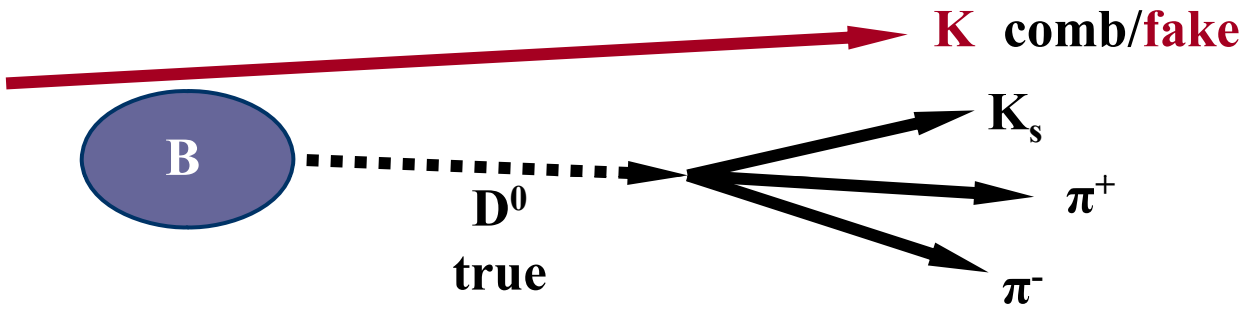
2. Dπ background



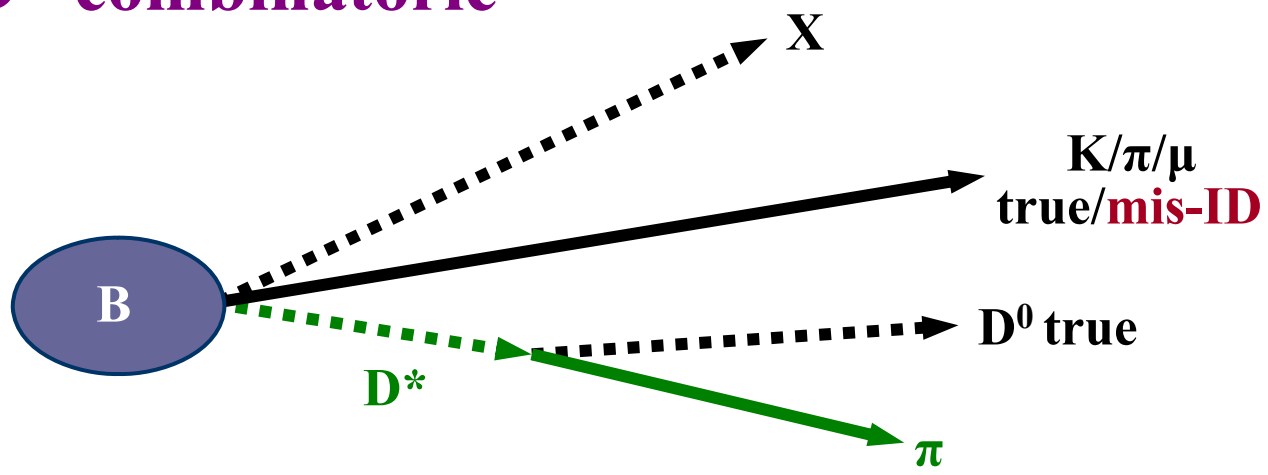


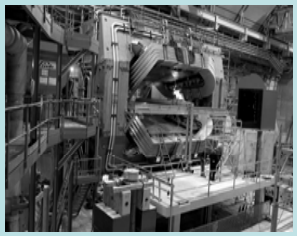
Four background types

3. DK combinatoric



4. D* combinatoric



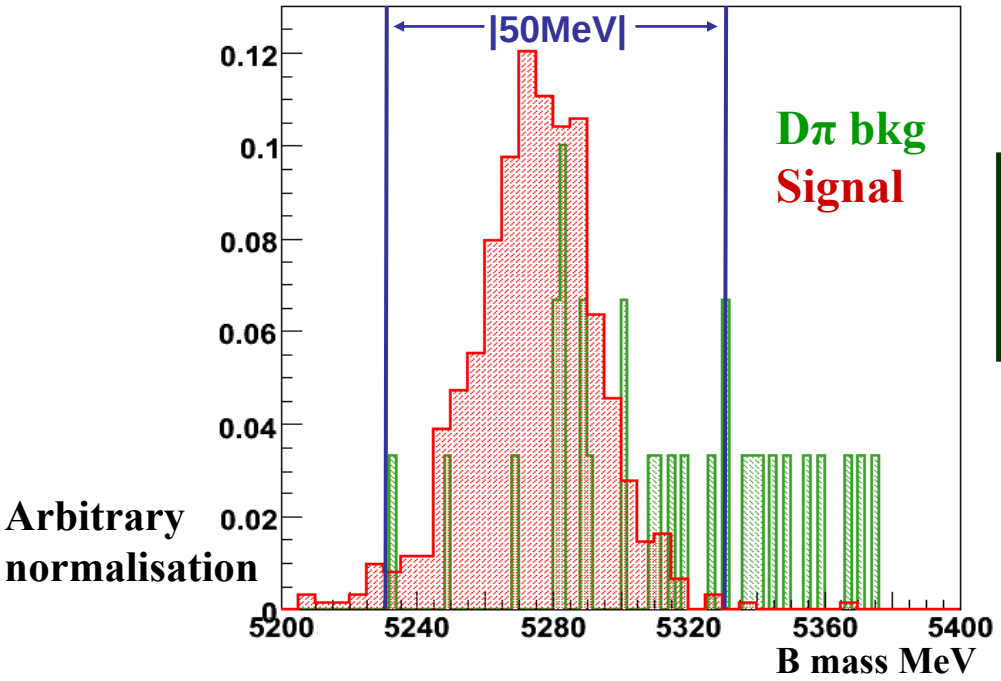


B/S ratios

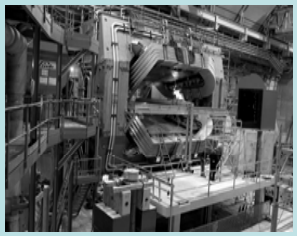
1. Pure combinatoric
   - $b\bar{b}$ gives us the most generic background type

$B_{b\bar{b}}/S < 0.7$ @ 90%C.L

2. Dπ background
   - Dedicated MC sample of **5K events**



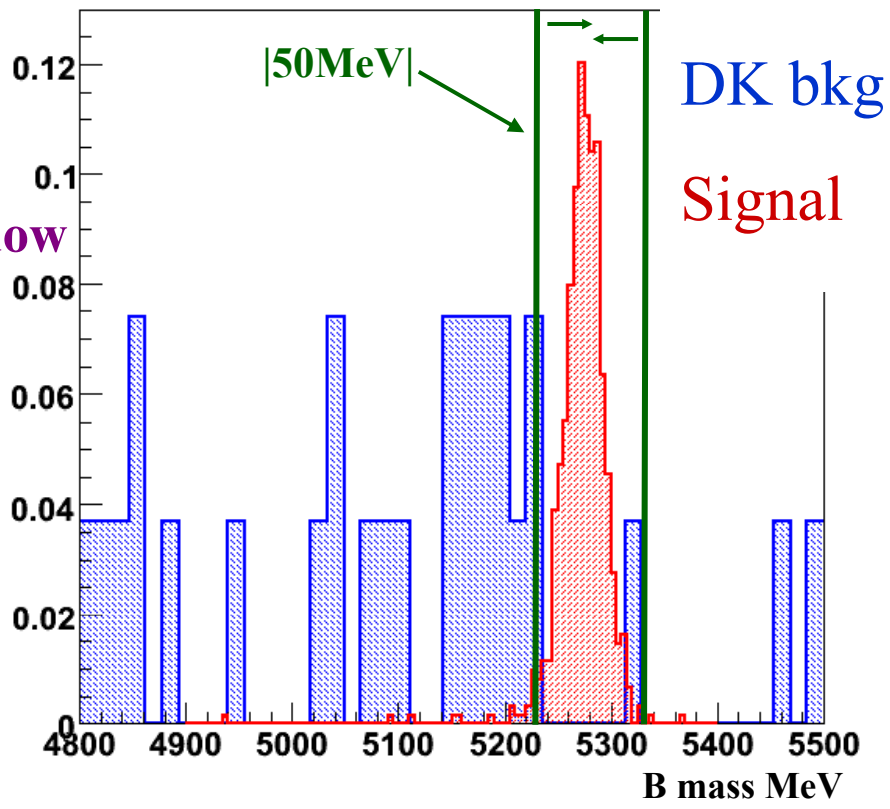
$B_{D\pi}/S$ = 0.24 0.06



B/S ratios

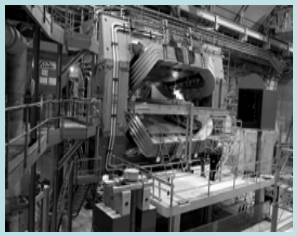
3. DK background

- Estimated from large sample of **B→D*(D⁰(HH)π)X**
  - We use the D* sample as a **source of true D⁰**
- Look at frequency of this being **paired with a random or fake K**
- Mother mass lands in the **B mass window**



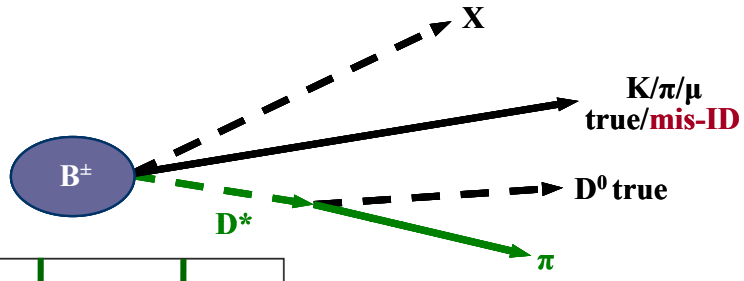
Arbitrary normalisation

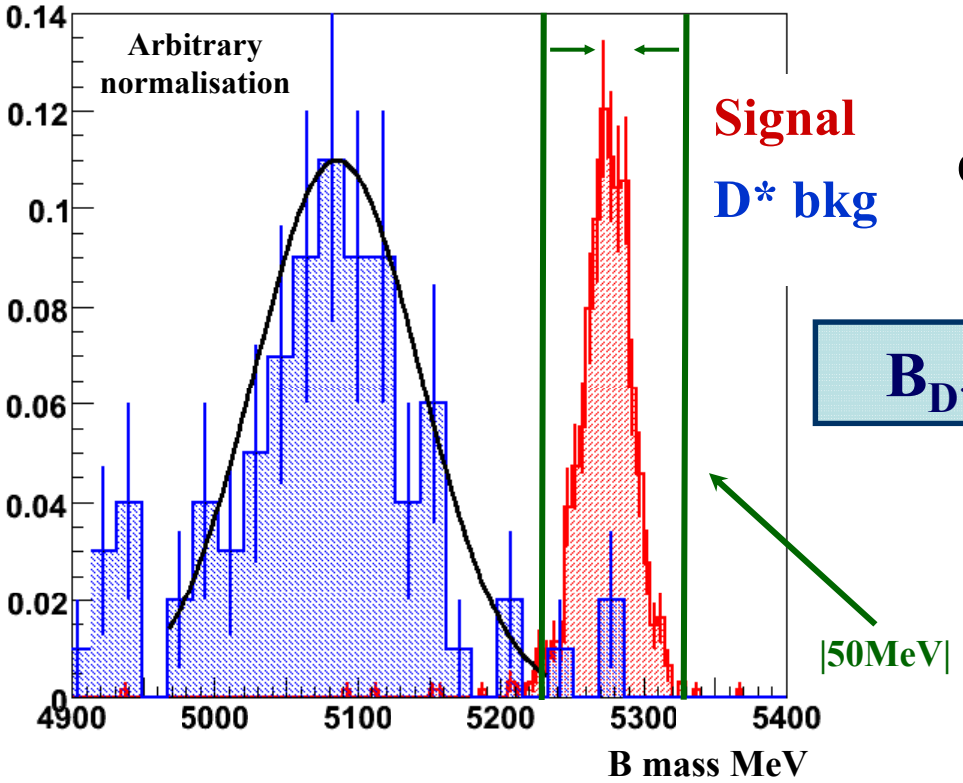
$B_{DK}/S = 0.22 \pm 0.01$



B/S ratios

4. From same D* sample also extract the D* background

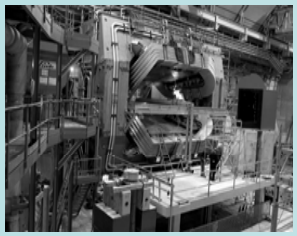




From fit and extrapolation

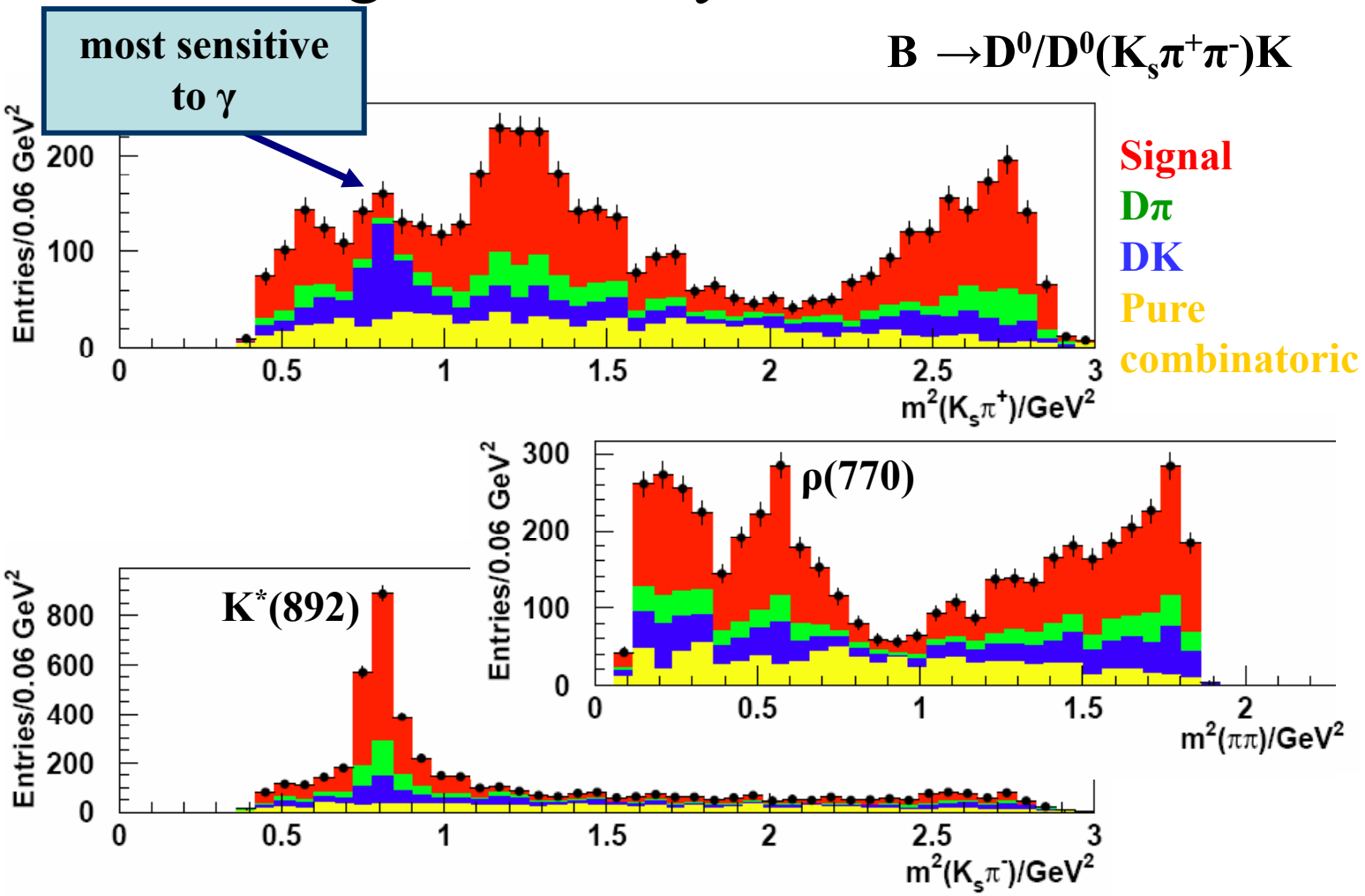
$B_{D^*}/S = 0.069\text{-}0.335$

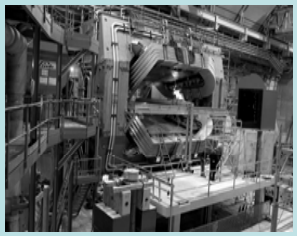
From direct calculation in tight mass window



Background on Dalitz plane

- D* background not yet included





Sensitivity

- γ most sensitive to DK background
  - set $B_{DK}/S = 0.7$, $B_{D\pi}/S = 0.24$
    - D* background yet to be added
- Two models (Belle + BaBar) used to fit the Dalitz plot
  - Both model dependent methods of extracting γ
    - S. Brisbane will show model independent method
  - Unbinned maximum likelyhood fit
    - 500 toy MC

Fit scenario	σ(γ)	$\sigma(r_B)$	σ(δ)
No background	6	0.01	6
$2fb^{-1}$ + bkg	12	0.02	11
$10fb^{-1}$ + bkg	5	0.009	5

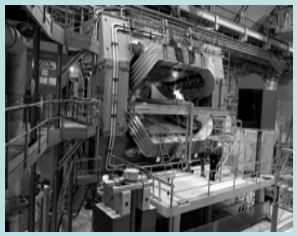
Input:

$\gamma=60$, $r_B=0.1$, $\delta=130^o$

Belle: $\gamma = (76^{+12}_{-13}$ (stat) 4(syst) 9(model))

BaBar: $\gamma = (76^{+23}_{-24}$ (syst+stat))

Moriond



Cartesian coordinates

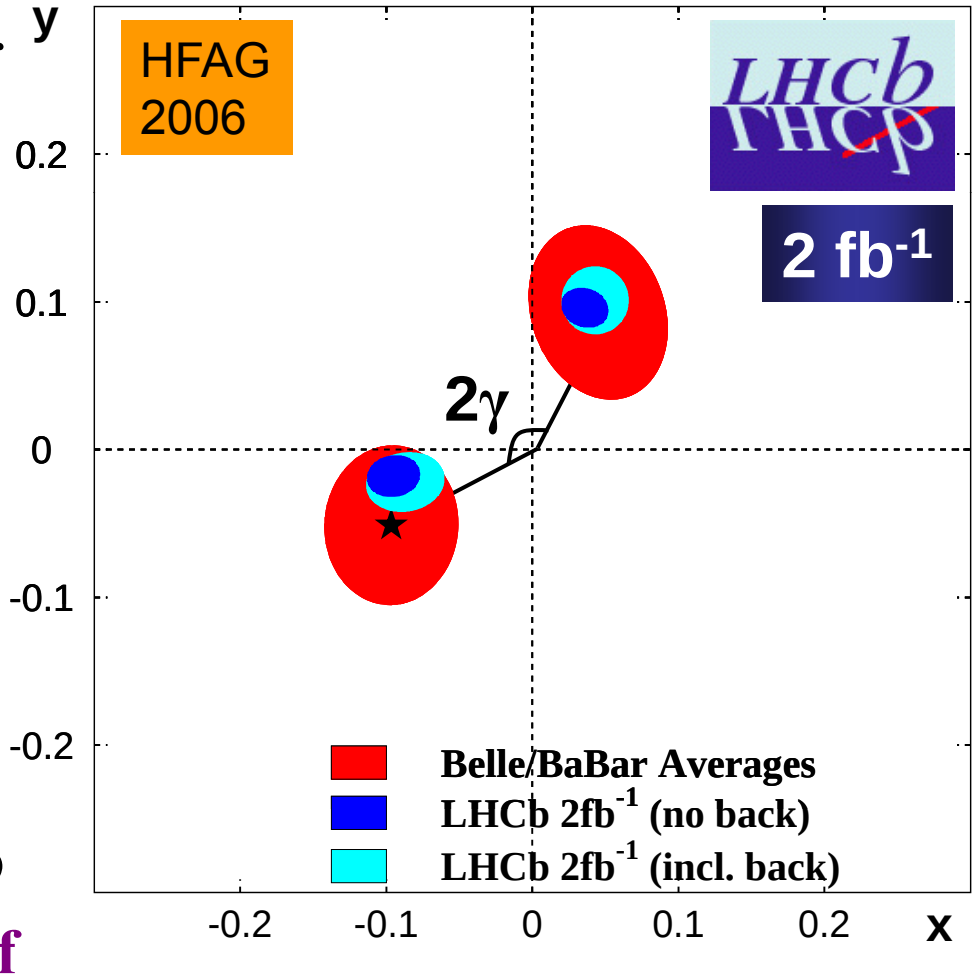
- Fit using **cartesian coordinates** (DK^+, $D\to K_S\pi^+\pi^-$ a la Belle/BaBar) for comparison
- **4 parameters**

$$x_\pm = r_{B\pm}\cos(\pm\gamma+\delta)$$
$$y_\pm = r_{B\pm}\sin(\pm\gamma+\delta)$$

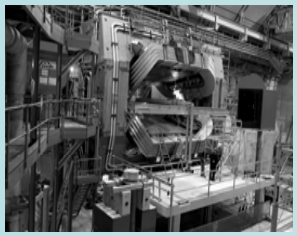
- Contours give:

$-2\Delta(\ln L) = \Delta\chi^2=1$

- corresponding to **60.7% CL for 2 dof**



Contours give $-2\Delta(\ln L) = \Delta\chi^2 = 1$, corresponding to 60.7% CL for 2 dof



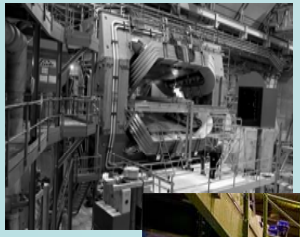
Summary

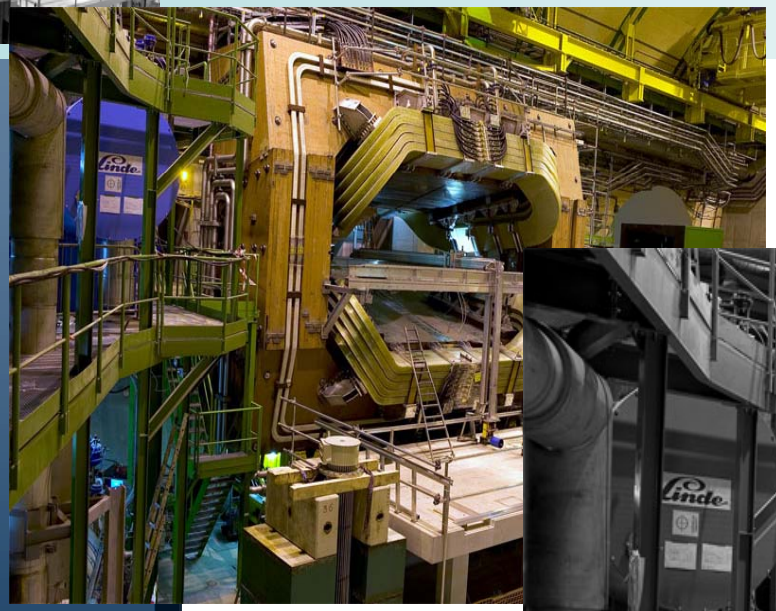
- Majority of LHCb detector is in place, and **will be ready for data taking**.
- Preperation to measure CKM angle **γ** from the decay:

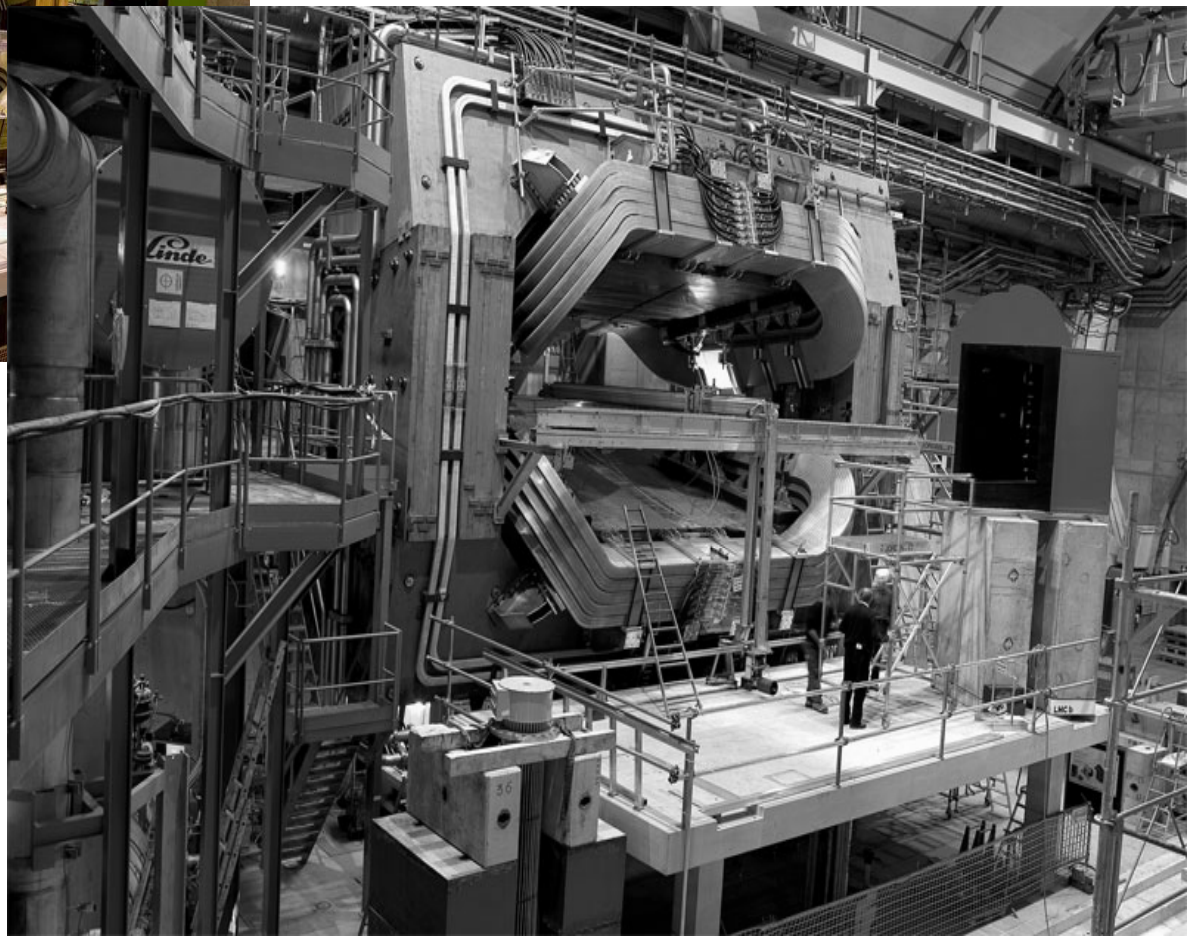
$$B \rightarrow D^0/\bar{D}^0(K_s\pi^+\pi^-)K$$

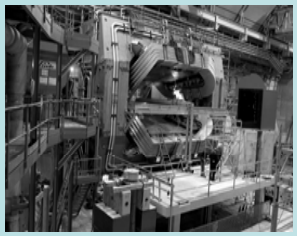
  at LHCb is well in advanced.
- LHCb is set to make **precise measurements of γ with the first data**.

Spare Slides



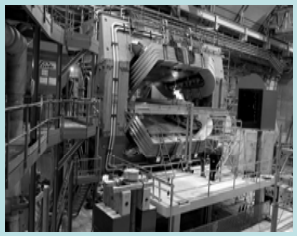






Signal tight selection cuts

Particle	DD Cut	LL Cut
D^0 daughters: K_s	Pt > 1.2 GeV	> 1.0 GeV
D^0 daughters: π	Pt > 0.4 GeV	
D^0 candidates	|mass-1864| < 40MeV	< 30 MeV
	Vertex χ^2 < 25	< 15
	Pt > 2.0 GeV	
	PV SIPS > 1.5	
	D^0 – K_s distance > 10mm	
	D^0-B SIPS < 2	
	$\cos\theta_D$ > 0.9998	
Bachelor K	Pt > 0.7 GeV	
	PV SIPS > 4	
	$\Delta LLK\pi > 2$, $\Delta LLKp > -2$	
B candidates	|mass-5279| < 50 MeV	< 35 MeV
	$\cos\theta_B$ > 0.9999	
	Vertex χ^2 < 6	
	Vertex < 5 additional tracks within 2σIP	
	Pt > 4.0 GeV	> 3.5 GeV
	PV SIPS < 4	



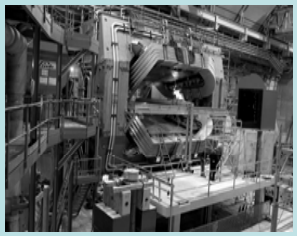
Selection cuts for D* sample

Particle	DD Cut	LL Cut
D^0 daughters: Ks	Pt > 1.2 GeV	> 1.0 GeV
D^0 daughters:π	Pt > 0.4 GeV	
D^0 candidates	|mass-1864| < 40MeV	< 30 MeV
	Vertex χ^2 < 25	< 15
	Pt > 2.0 GeV	
	PV SIPS > 1.5	
	D0 – Ks distance > 10mm	
	D0-B SIPS < 2	
	cosθD > 0.9998	
Bachelor K	Pt > 0.7 GeV	
	PV SIPS > 4	
	ΔLLKπ > 2, ΔLLKp > -2	
B candidates	|mass-5279| < 50 MeV	< 35 MeV
	cosθB > 0.9999	
	Vertex χ^2 < 6	
	Vertex < 5 additional tracks within 2σIP	
	Pt > 4.0 GeV	> 3.5 GeV
	PV SIPS < 4	

D* Channel	Cut	
$D^0 \rightarrow K\pi$	K: Pt > 0.6 GeV PV SIPS > 3.0 ΔLLπK > -5	π: Pt > 0.6 GeV PV SIPS > 3.0 ΔLLKπ > -2, ΔLLKp >-5
$D^0 \rightarrow KK$		
$D^0 \rightarrow \pi\pi$		

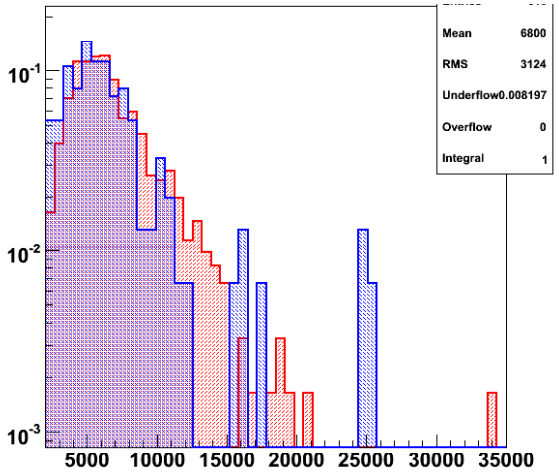
Signal	D*
|mass-1864| < 15MeV at 2σ	|mass-1864| < 20MeV at 2σ

- Change **D^0 daughter cuts** to ones from (LHCb/2006-066) on D* sample
- Keep the rest of cuts on D^0, K and B
  - Taking the **looser cut** between the DD and the LL
  - Take a **2σ cut on D^0 mass**
- Apply same cuts (apart from D^0 daughter cuts) to both Signal and D* samples
- Look at the tight B mass window and also, a **10x wider B mass window**
  - $B_{|mass-5279|} < 500$ MeV

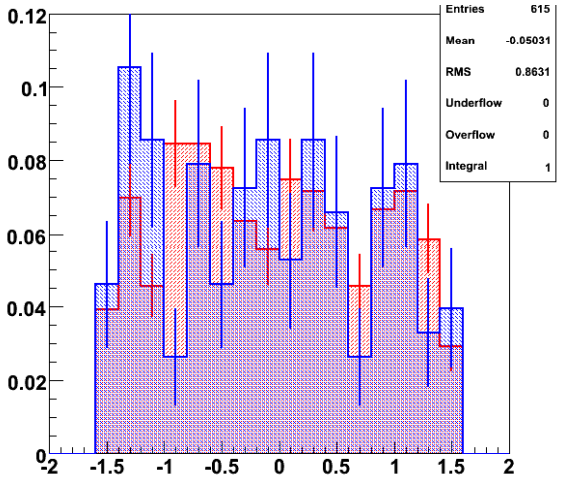


D^0 distribution from D*

Pt



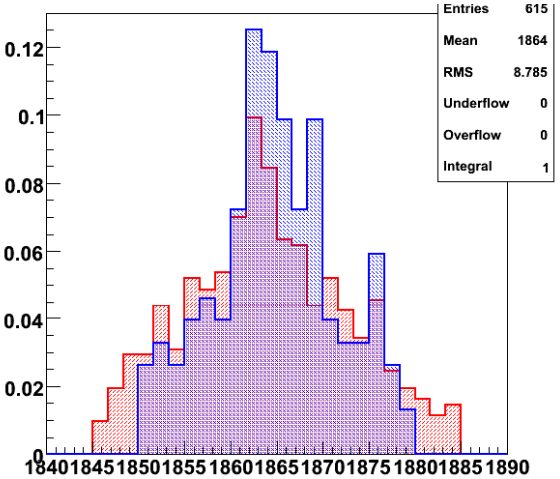
Angle distributions θ



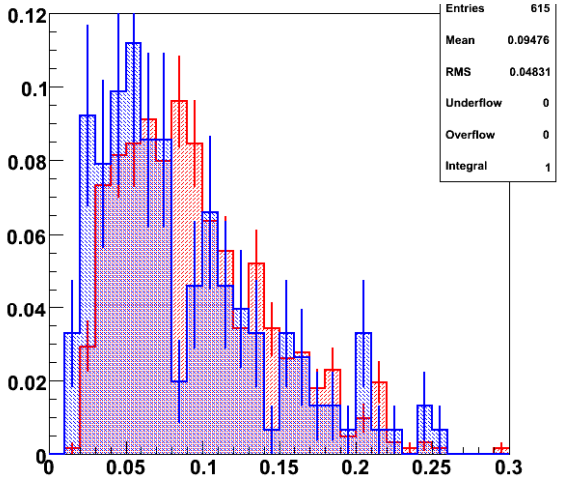
D* sample

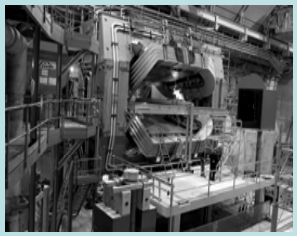
Signal sample

D^0 mass



Angle distributions φ





Belle/BaBar models

- Both isobar models with:

amplitude+phase extracted from $D^{*+}\to D^0\pi^+$ sample

# of resonances

$$f(m_+^2,m_-^2)=\sum_{j=1}^{N} a_j e^{i\alpha_j} A_j(m_+^2,m_-^2)+be^{i\beta}$$

Breit-Wigner + non-resonant

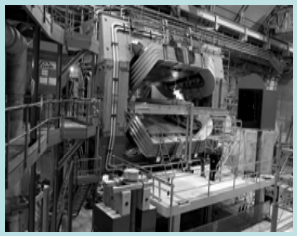
- Decay amplitudes:

$$A^- = f(m_-^2,m_+^2)+r_B e^{i(-\gamma+\delta)} f(m_+^2,m_-^2)$$

$$A^+ = f(m_+^2,m_-^2)+r_B e^{i(\gamma+\delta)} f(m_-^2,m_+^2)$$

- m = $K_s\pi$ invariant mass
- $f(m^2, m_m^2)$ Dalitz amplitudes

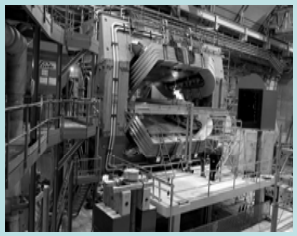
$$|A^-|^2 = |f(m_-^2,m_+^2)|^2 + r_B^2 |f(m_+^2,m_-^2)|^2 + 2r_B \Re(f(m_+^2,m_-^2) f^*(m_-^2,m_+^2) e^{i(-\gamma+\delta)})$$



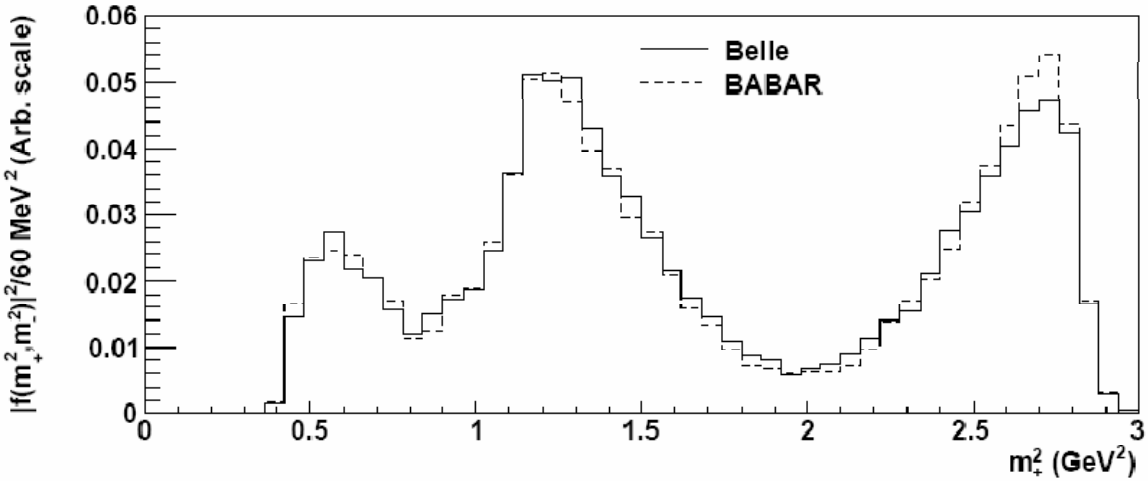
Belle/BaBar models

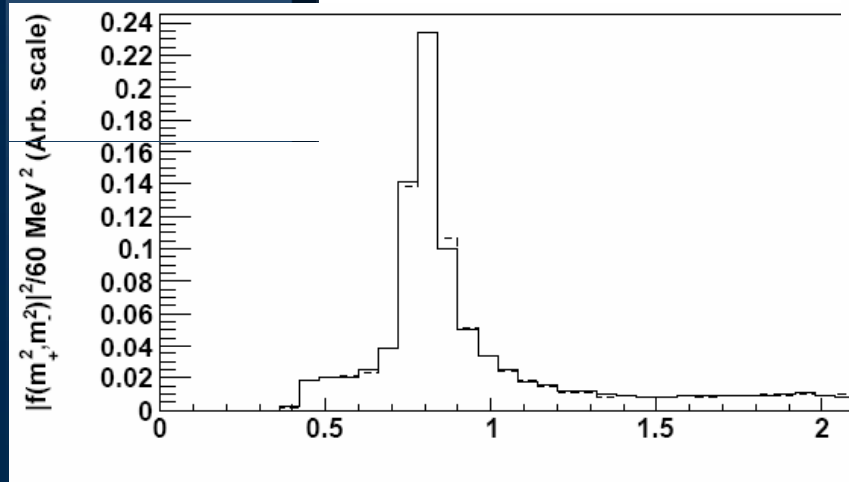
doubly-Cabbibo suppressed

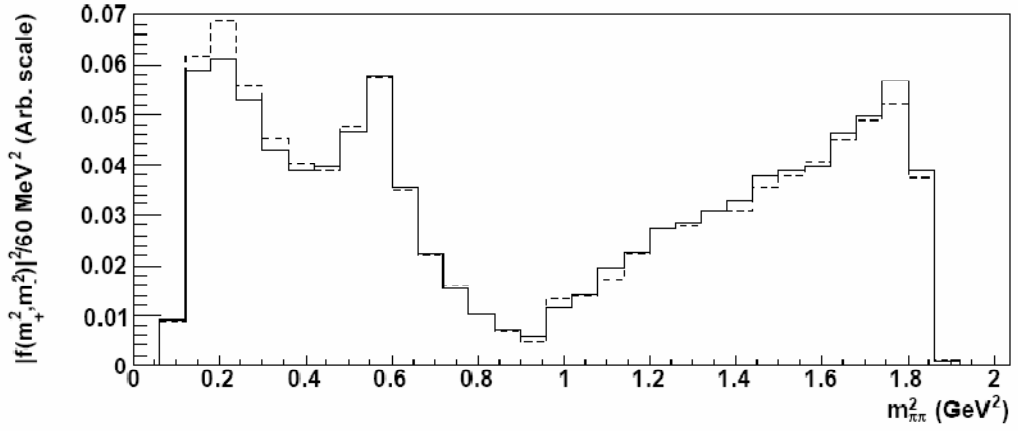
Resonance	BABAR			BELLE		
	a_r	ϕ_r (°)	F_r	a_r	ϕ_r (°)	F_r
$K^*(892)^-$	1.781	131.0	0.586	1.621	131.7	0.612
$K_0^*(1430)^-$	2.45	-8.3	0.083	2.15	-11.3	0.074
$K_2^*(1430)^-$	1.05	-54.3	0.027	1.11	-39.5	0.022
$K^*(1410)^-$	0.52	154	0.004	0.22	120	0.001
$K^*(1680)^-$	0.89	-139	0.003	2.34	110	0.004
$K^*(892)^+$	0.180	-44.1	0.006	0.154	-42.3	0.006
$K_0^*(1430)^+$	0.37	18	0.002	0.52	89	0.004
$K_2^*(1430)^+$	0.075	-104	0.000	0.23	-97	0.001
$K_2^*(1410)^+$	–	–	–	0.35	-107	0.001
$K_2^*(1680)^+$	–	–	–	1.3	87	0.001
$\rho(770)$	1 (fixed)	0 (fixed)	0.224	1 (fixed)	0 (fixed)	0.216
$\omega(782)$	0.0391	115.3	0.006	0.0310	113.4	0.004
$f_0(980)$	0.482	-141.8	0.061	0.394	-153	0.049
$f_0(1370)$	2.25	113.2	0.032	1.25	69	0.011
$f_2(1270)$	0.922	-21.3	0.030	1.32	-12	0.015
$\rho(1450)$	0.52	38	0.002	0.89	1	0.004
σ	1.36	-177.9	0.093	1.57	-146	0.098
σ'	0.340	153.0	0.013	0.23	-150	0.006
Non-res.	3.53	128.0	0.073	3.8	157	0.097

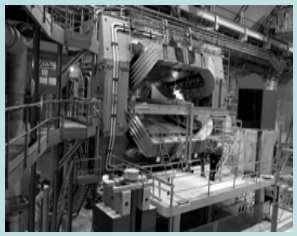


Belle/BaBar models

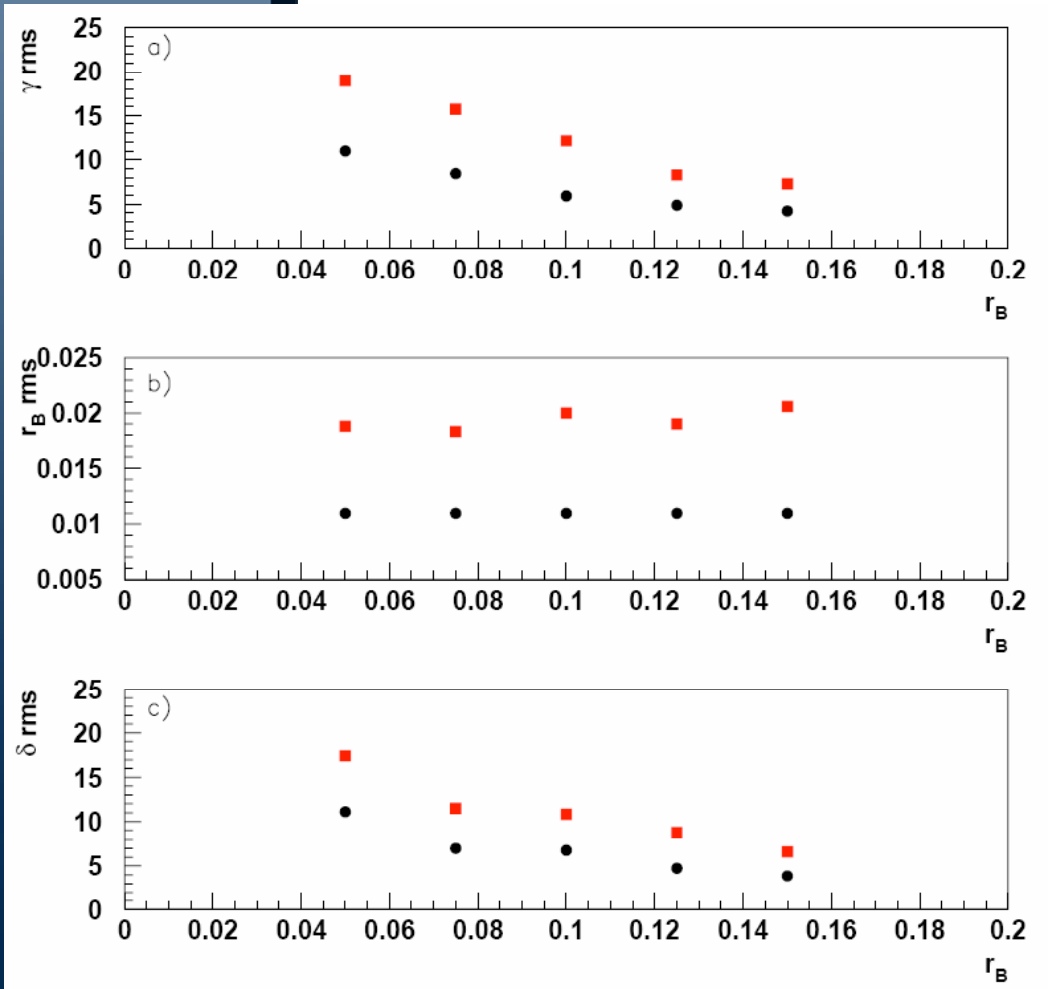








r.m.s fit error



- Fit error on γ, r_B, δ as a function of r_B
- "Worst case" scenario

Baseline fit ●

Fit with acceptance correction ■