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Hawaii

The expected LHCb Physics Performance

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on behalf of the LHCb Collaboration

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Monte-Carlo

- Detailed simulation of the detector:
  - Event generation with PYTHIA 6.2 tuned to $\sqrt{s} = 14\,\mathrm{TeV}$;
  - Tracking of the particle though the detector with GEANT;
  - Simulation of the detector response including spillover and pile-up;
  - Simulation of the trigger decision.
- Object oriented software processes simulated events as real data:
  - Track finding;
  - Particle identification;
  - Selection of B-meson final states.
- Data samples end '03:
  - GEANT 3
  - 32×10^6 minimum bias;
  - 11×10^6 inclusive $b\bar{b}$ events
  - Many specific signal B decays: 50k to 200k per decay channel.
- Data samples end '04:
  - GEANT 4;
  - 110×10^6 minimum bias;
  - 61×10^6 inclusive $b\bar{b}$ events;
  - Many specific signal B decays.

All results quoted in this talk are based on 2003 samples

b hadrons production at LHC

- All b hadrons species are produced in proton-proton collisions at 14 TeV:

  B_d, B_s, B_c, $B^{\pm}$, Λ_b, ...:

27×10^3	B_d per second
7×10^3	B_s per second

  in the LHCb acceptance;

- B/S ~ 160.

- The huge statistics of B_s meson opens new approaches to study the CP symmetry in the beauty sector.

B_s system

- Mass and lifetime:

$$m_{B_s} = 5369.6 \pm 2.4\,\mathrm{MeV} \qquad \tau_s = 1.461 \pm 0.057\,\mathrm{ps}$$

- Most of observables are not yet measured:

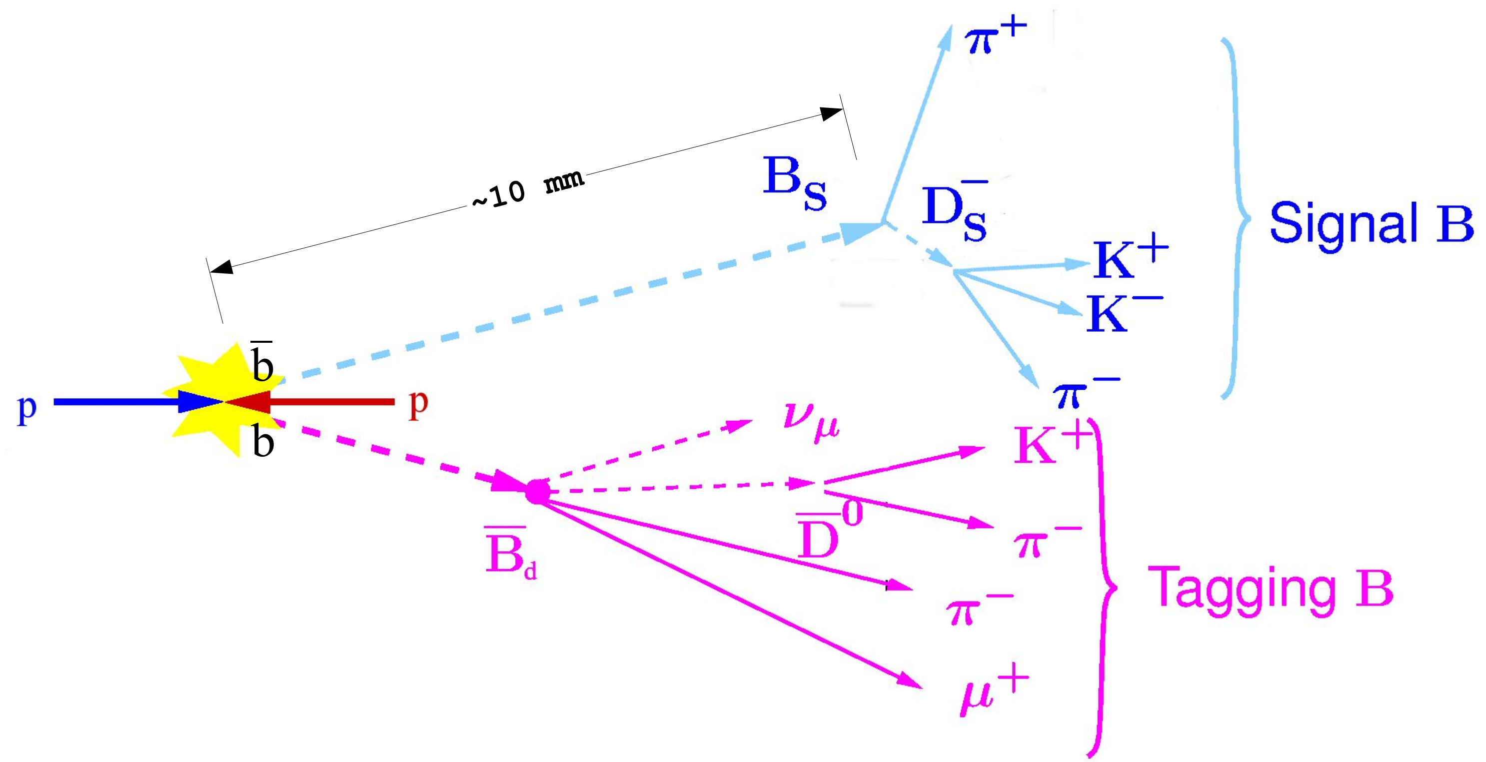
		SM Expectation
Oscillation frequency	Δm_s	~ $20\mathrm{ps}^{-1}$
Weak mixing phase	Φ_s	$-2\lambda^2\eta$ ~ -0.04
Relative decay width difference	$\Delta\Gamma_s/\Gamma_s$	~ 0.1

- Time dependent decay rate asymmetries:

$$A_f^{CP}(t) = \frac{R_{\bar{B}_s \to f}(t) - R_{B_s \to f}(t)}{R_{\bar{B}_s \to f}(t) + R_{B_s \to f}(t)} = \frac{A_f^{\mathrm{dir}} \cos(\Delta m_s t) + A_f^{\mathrm{mix}} \sin(\Delta m_s t)}{\cosh\left(\frac{\Delta\Gamma_s}{2} t\right) - A_f^{\Delta} \sinh\left(\frac{\Delta\Gamma_s}{2} t\right)}$$

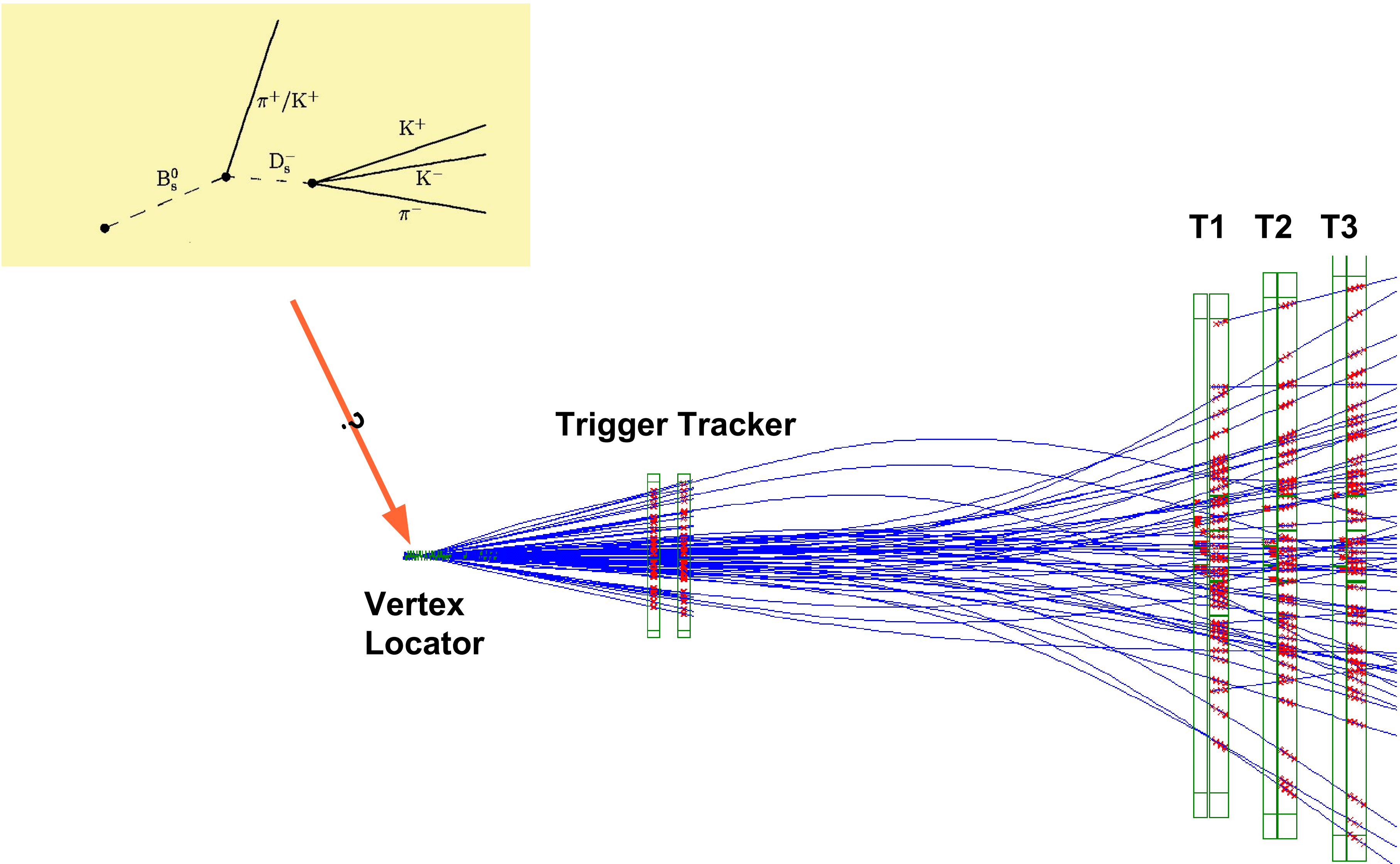
where: $\lambda_f = \frac{q}{p}\frac{\bar{A}_f}{A_f}$ $\quad A_f^{\mathrm{dir}} = -\frac{1-|\lambda_f|^2}{1+|\lambda_f|^2}$ $\quad A_f^{\mathrm{mix}} = \frac{2\,\mathrm{Im}(\lambda_f)}{1+|\lambda_f|^2}$ $\quad A_f^{\Delta} = \frac{2\,\mathrm{Re}(\lambda_f)}{1+|\lambda_f|^2}$

Time dependent asymmetry at LHCb



- The proper time of the signal B decay is measured via:
  - the position of the primary and secondary vertexes;
  - the momentum of the signal B state from its decay products.

Event selection: $B_s \rightarrow D_s^{\pm} K^{\mp} \rightarrow (K^+ K^- \pi^{\pm}) K^{\mp}$ (1)



Reconstructed event: ~72 tracks

Event selection: $B_s \to D_s^{\pm} K^{\mp} \to (K^+ K^- \pi^{\pm}) K^{\mp}$ (2)

1) Primary vertex.

2) D_s meson by using identified kaon and pion and a vertex constrained to the D_s mass.

3) B_s meson by combining a D_s with a kaon forming a vertex (no mass constraint).

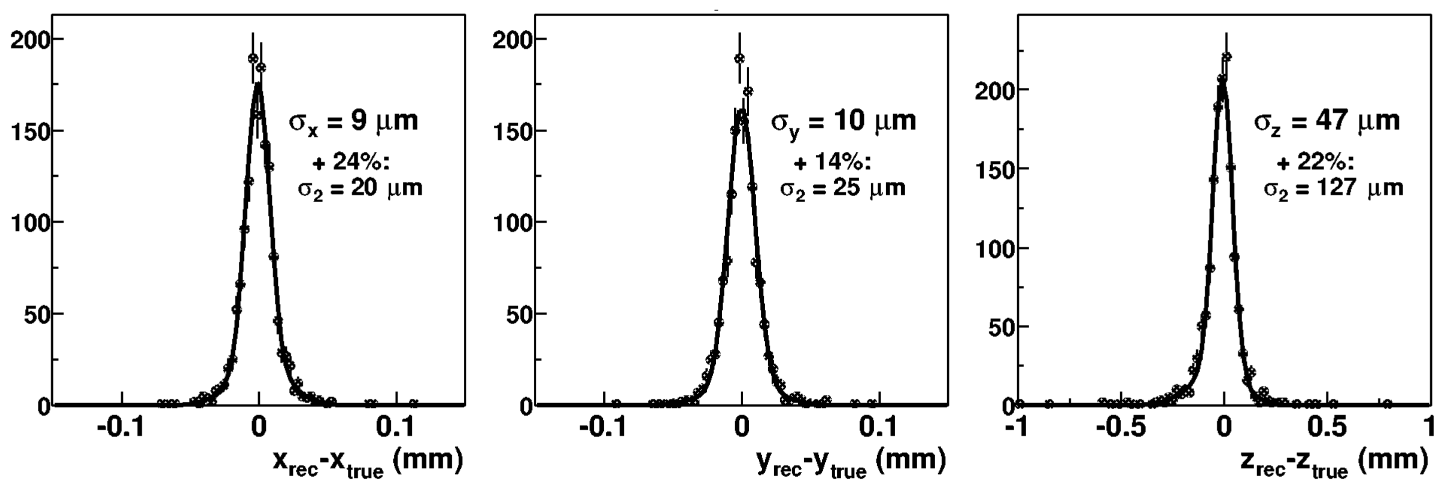
4) Select B_s with an impact parameter ~0 and an invariant mass in the window $m_{B_s} \pm 50\,\mathrm{MeV}/c^2$

Summary of the cuts.

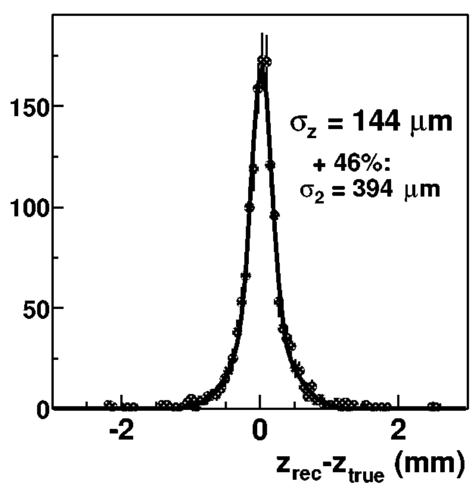
Selection requirements	$B_s^0 \to D_s^- h^+$
All products p	2 GeV/c
D_s product p_t	300 MeV/c
D_s product $\sum p_t$	2200 MeV/c
bachelor K/π p_t	700 MeV/c
pions: $\Delta\mathcal{L}_{\pi K}$	>-5
kaons: $\Delta\mathcal{L}_{K\pi}$	>-5
χ^2/NDF	< 4
Constrained D_s vertex χ^2	<10
D_s mass window	15 MeV/c^2
$S_{IP}(D_s$ prod)	>1
$S_{IP}(D_s)$	>2
$S_z(D_s, PV)$	>4.5
Unconstrained B_s vertex χ^2	<3
$S_{IP}(h)$m	>4
$S_{IP}(B_s)$	<3
$\cos(\theta)$	0.99997
$z_{B_s} - z_{D_s}$	>0 μm
B_s mass window (B-inclusive)	±50 (500) MeV/c^2
specific $B_s^0 \to D_s^{\pm} K^{\mp}$ selection criteria	
bachelor K: $\Delta\mathcal{L}_{K\pi}$	>2
bachelor K: $\Delta\mathcal{L}_{Ke}$	>2

Resolution: $B_s \rightarrow D_s^{\pm} K^{\mp} \rightarrow (K^+ K^- \pi^{\pm}) K^{\mp}$

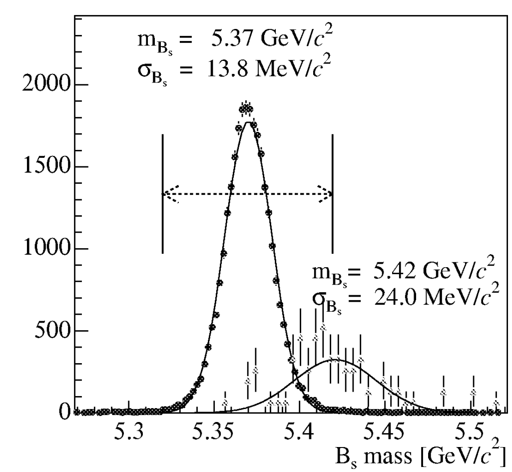
Primary vertex: 47μm



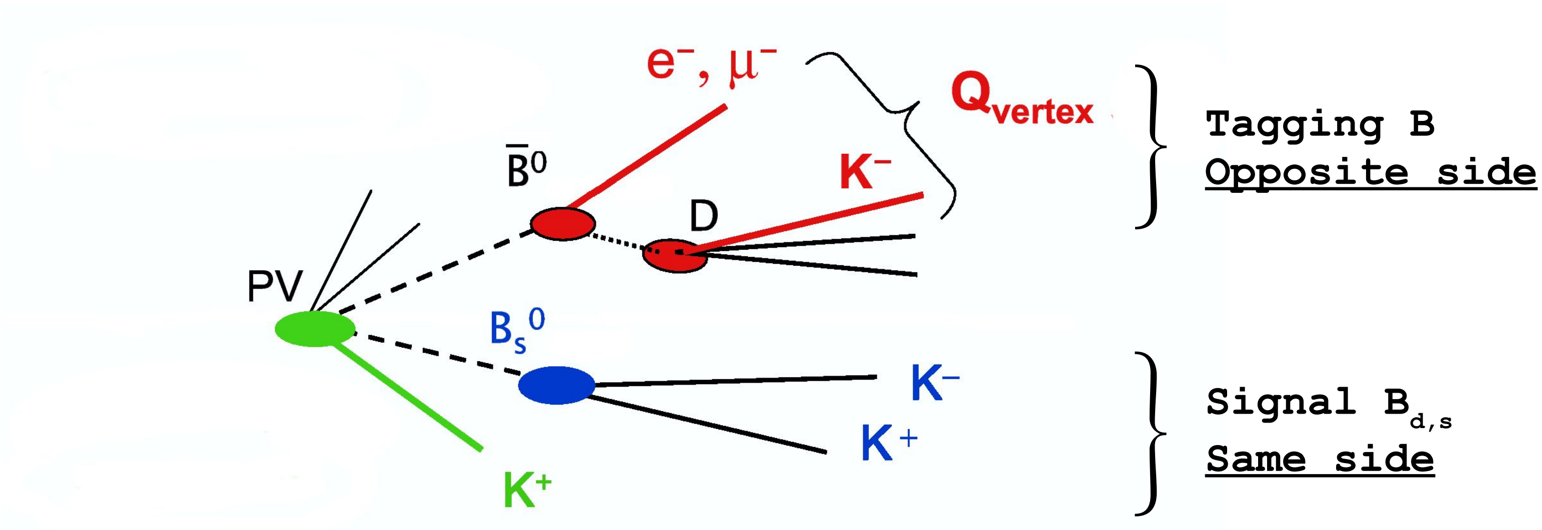
Bs vertex: 144μm



Bs mass: 14 MeV/c^2



Flavour Tagging



- Several algorithm to determine the flavour of the signal B meson at production:
  - Opposite side:
    - e, μ from semileptonic b decays;
    - $K^{\pm}$ from b decays chain;
    - Inclusive vertex charge.
  - Same side:
    - $K^{\pm}$ from fragmentation accompanying B_s meson.

Performance of Flavour Tagging

- After passing trigger and offline cuts

Channel	ε_{tag} (%)	w (%)	ε_{eff} (%)
$B^0 \to \pi^+\pi^-$	41.8±0.7	34.9±1.1	3.8±0.5
$B^0 \to K^+\pi^-$	43.2±1.4	33.3±2.1	4.8±1.0
$B^0 \to J/\psi\,(\mu\mu)K^0_S$	45.1±1.3	36.7±1.9	3.2±0.8
$B^0 \to J/\psi\,(\mu\mu)K^{*0}$	41.9±0.5	34.3±0.7	4.1±0.3
$B^0_s \to K^+K^-$	49.8±0.5	33.0±0.8	5.8±0.5
$B^0_s \to \pi^+K^-$	49.5±1.8	30.4±2.6	7.6±1.7
$B^0_s \to D^-_s\pi^+$	54.6±1.2	30.0±1.6	8.7±1.2
$B^0_s \to D^{\mp}_s K^{\pm}$	54.2±0.6	33.4±0.8	6.0±0.5
$B^0_s \to J/\psi\,(\mu\mu)\phi$	50.4±0.3	33.4±0.4	5.5±0.3

Breakdown for $B_{d,s} \to h^+h^-$

Tag	ε_{tag} (%)	w (%)	ε_{eff} (%)
μ	11.1±0.3	35.3±1.1	1.0±0.2
e	5.2±0.2	35.6±1.7	0.4±0.1
K_{opp}	16.6±0.3	31.2±0.9	2.4±0.2
Q_{vtx}	24.3±0.6	39.9±0.8	1.0±0.2
Combined (B^0)	40.9±0.4	34.6±0.7	3.9±0.3
K_{same}	17.5±0.4	32.8±1.2	2.1±0.3
Combined (B^0_s)	49.8±0.5	32.8±0.8	5.9±0.5

where:

$$\begin{cases} \varepsilon_{tag} = \dfrac{R+W}{R+W+U} \\ \omega = \dfrac{W}{R+W} \\ \varepsilon_{eff} = \varepsilon_{tag}(1-2\omega)^2 \end{cases}$$

- Effective tagging efficiencies vary between 3 and 9% depending on the final state.
- In real physics analysis, the wrong tag fraction will be measured using control channels with similar topology, e.g. $B_d \to J/\psi K^{*0}$ for $B_d \to J/\psi K_S$

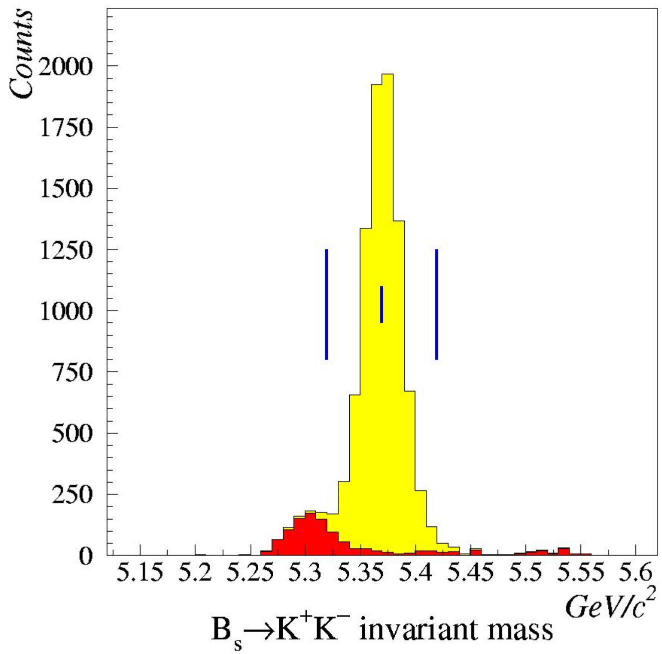
Estimation of Background

- Sources of background:
  - Exclusive B-decays mimicking the signal decay;
  - Combinatorial background in $b\bar{b}$ inclusive events.

- Difficult to estimate the combinatorial contribution since the available statistics of $b\bar{b}$ events is limited.

Method:

- Open the $B_{d,s}$ mass window $(\pm 500\,\mathrm{MeV}/c^2)$
- Scale down the obtained number to the tight mass window $(\pm 50\,\mathrm{MeV}/c^2)$ using linear extrapolation.



Event type	$B_s^0 \to K^+K^-$
$B^0 \to \pi^+\pi^-$	45
$B_s^0 \to K^+K^-$	36505
$B^0 \to K^+\pi^-$	904
$B_s^0 \to K^-\pi^+$	160
$\Lambda_b \to p\pi^-$	0
$\Lambda_b \to pK^-$	182

$$\begin{cases} B_{\mathrm{Exclusive}}/S & = 0.04 \\ B_{\mathrm{Comb.}}/S & < 0.51 \end{cases}$$

Evaluation of Sensitivity

- Sensitivities to CP violating observables are determined with a toy Monte-Carlo.

  Inputs come from the full simulation:
  - Number of signals/background events after trigger, off-line selection and tagging;
  - Wrong tag fraction;
  - Acceptances as a function of proper time;
  - Resolutions.

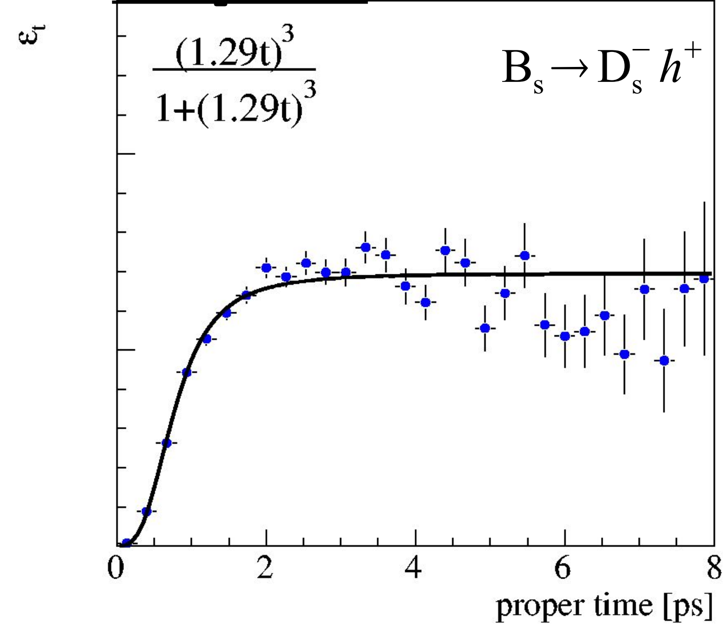
- Many sets of events are generated.

  For each of them, decay rates are fitted with an unbinned likelihood where

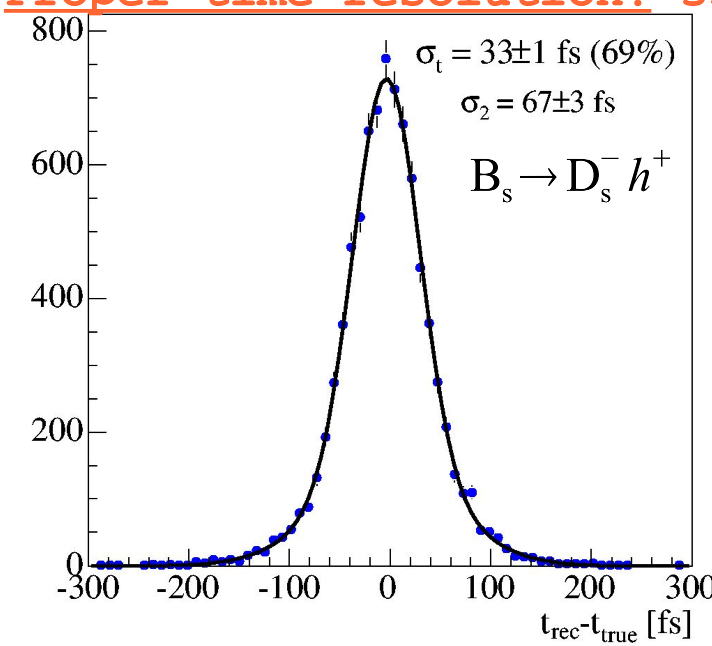
  $$\mathrm{Re}(\lambda_f), \mathrm{Im}(\lambda_f), \Delta m_{d,s}, \Delta\Gamma_{d,s}, \Gamma_{d,s}, \omega_f$$

  are free parameters. The fit also takes into account backgrounds and resolution.

Acceptance



Proper time resolution: 33fs



Branching Ratio

- Performances were evaluated through few benchmark channels.

	Visible Branching ratio
$B_d \to J/\psi\left(\mu^+\mu^-\right)K_S\left(\pi^+\pi^-\right)$	1.98×10^{-5}
$B_s \to D_s^-\left(K^+K^-\pi^-\right)\pi^+$	1.2×10^{-4}
$B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$	3.1×10^{-5}
$B_d \to \pi^+\pi^-$	4.8×10^{-6}
$B_s \to K^+K^-$	1.85×10^{-5}
$B_s \to D_s^\pm(K^\pm K^-\pi^+)K^\mp$	1.0×10^{-5}
$B_d \to \overline{D}^0(K^+\pi^-)K^{*0}(K^+\pi^-)$	1.2×10^{-6}
$B_d \to D_{CP}^0(K^+K^-)K^{*0}(K^+\pi^-)$	1.9×10^{-7}
$B_d \to \rho\pi$	2×10^{-5}

The phase β (Φ_1)...

The phase β in $B_d \to J/\psi(\mu^+\mu^-)K_S(\pi^+\pi^-)$

- Decay is dominated by a tree amplitude

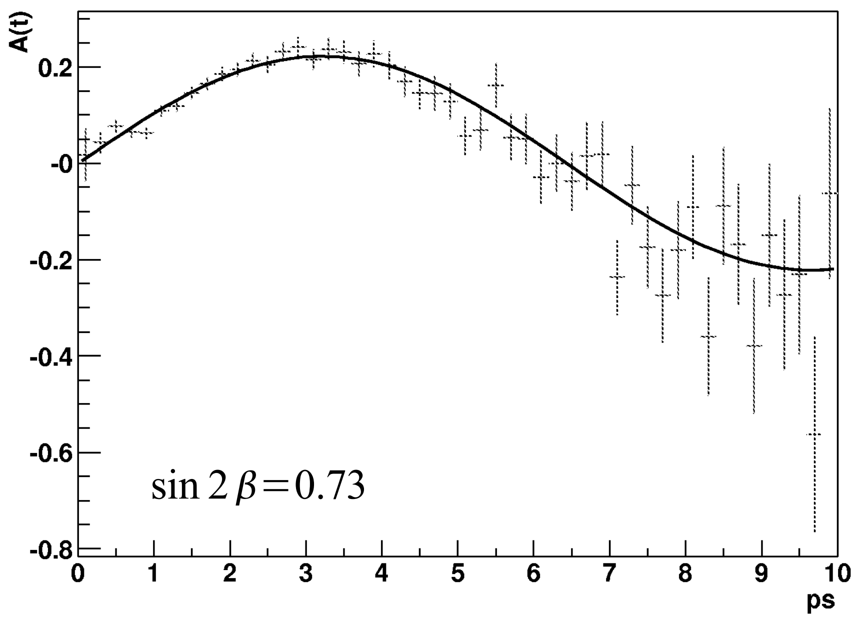
$$A_{CP}(t) = -(1-2\omega)\left\{\frac{(1-|\lambda|^2)}{(1+|\lambda|^2)}\cos(\Delta m t) - \frac{2\,\mathrm{Im}(\lambda)}{(1+|\lambda|^2)}\sin(\Delta m t)\right\}$$

where Im(λ) = sin2β

- The wrong tag fraction ω is determined with the self-tagging mode $B_d \to J/\psi K^{*0}$

- Sensitivity for 2 fb^{-1}:

N_{tagged}	91×10^3
B/S	0.69±0.11
$\sigma_{stat}(\sin2\beta)$	0.02



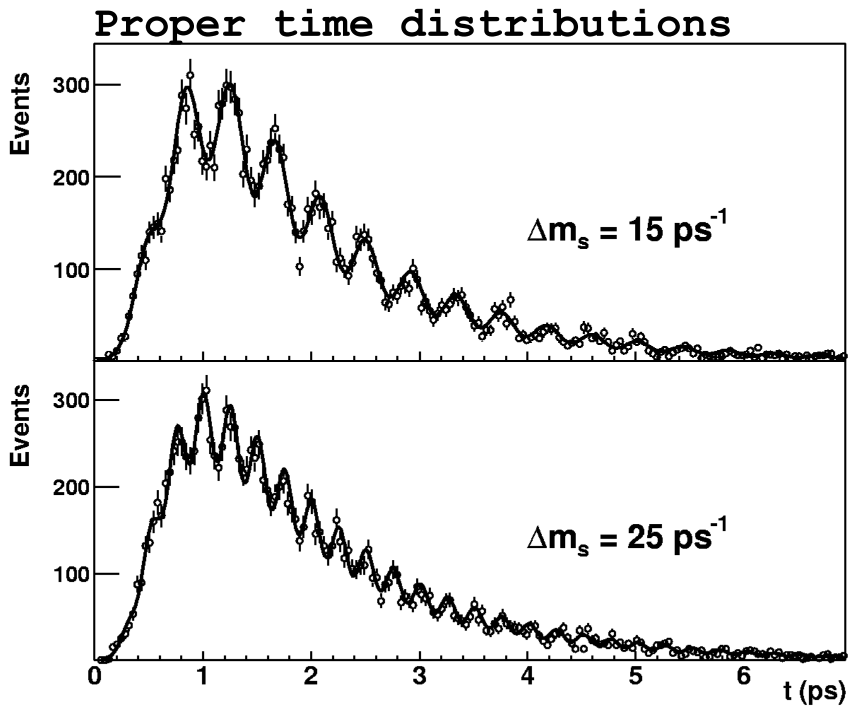
The B_s system...

- Δm_s in $B_s \to D_s^- \pi^+$
- $\Delta \Gamma_s$ and ϕ_s in $B_s \to J/\psi \phi$

Oscillation frequency Δm_s in $B_s \to D_s^-(K^+K^-\pi^-)\pi^+$

- Flavour-specific B decay:

$$A_{\Delta m_s}(t) = -(1-2\omega)\frac{\cos(\Delta m_s t)}{\cosh(\Delta \Gamma_s t)}$$



- Sensitivity for 2 fb^{-1}:

N_{tagged}	43×10^3
B/S	0.3±0.1
$\sigma_{stat}(\Delta m_s)$	0.011

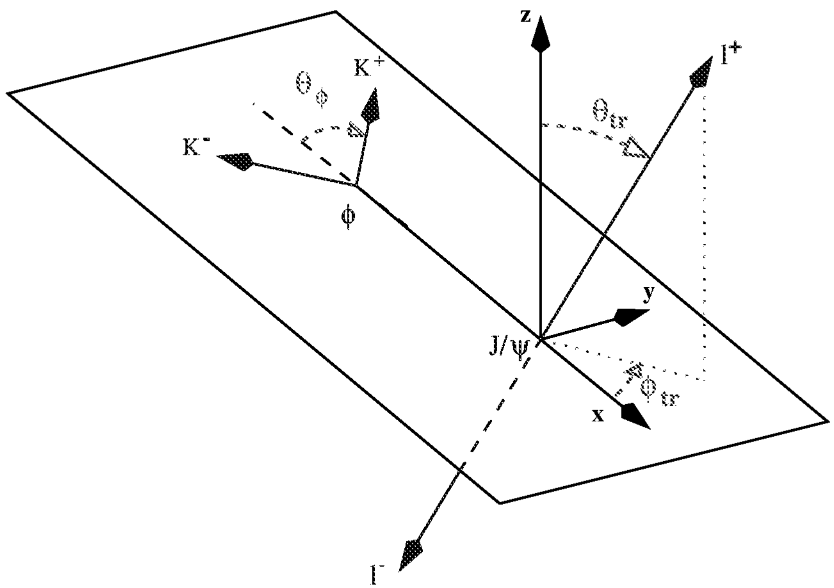
→ Highest Δm_s measurable = 68 ps^{-1} (statistical significance of at least 5σ)

Δm_s	15	20	25	30
$\sigma(\Delta m_s)$	0.009	0.011	0.013	0.016

The phase Φ_s and $\Delta\Gamma_s$ in $B_s \to J/\psi(\mu^+\mu^-)\phi(K^+K^-)$

- Counterpart of $B_d \to J/\psi K_S$
  Mixture of different CP eigenstates:

$$A_{CP}(t) = -(1-2\omega)\frac{1-R_t}{e^{\frac{-\Delta\Gamma_s}{2}t} + R_t e^{\frac{-\Delta\Gamma_s}{2}t}}\sin(\Delta m_s t)\phi_s$$



- Δm_s and the wrong tag fraction ω are determined in $B_s \to D_s\pi$ events.

- Sensitivity for 2 fb^{-1}:

N_{tagged}	50×10^3	
B/S	<0.3	(90% CL)
$\sigma_{stat}(\Phi_s)$	0.064	
$\sigma_{stat}(\Delta\Gamma_s/\Gamma_s)$	0.018	

Δm_s in ps^{-1}	15	20	25	30
$\sigma(\phi_s)$	0.057	0.064	0.075	0.088
$\sigma(\Delta\Gamma/\bar{\Gamma})$	0.018	0.018	0.018	0.018

$\Delta\Gamma/\Gamma$	0	0.1	0.2
$\sigma(\phi_s)$	0.059	0.064	0.070
$\sigma(\Delta\Gamma/\bar{\Gamma})$	0.015	0.018	0.019

ϕ_s	0	0.04	0.1	0.2
$\sigma(\phi_s)$	0.064	0.064	0.064	0.066
$\sigma(\Delta\Gamma/\bar{\Gamma})$	0.018	0.018	0.018	0.018

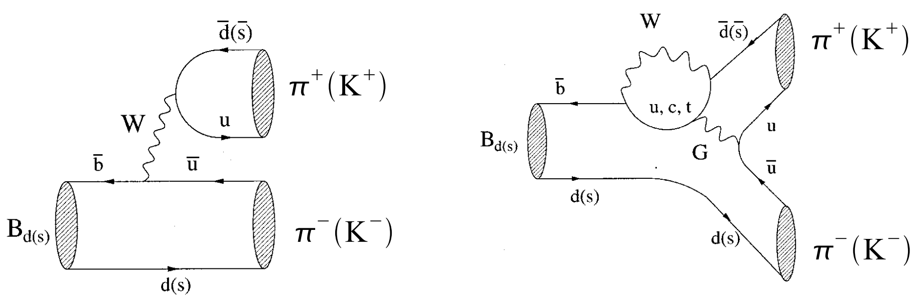
R_t	0.1	0.2	0.3
$\sigma(\phi_s)$	0.050	0.064	0.084
$\sigma(\Delta\Gamma/\bar{\Gamma})$	0.015	0.018	0.019

The phase γ (Φ_3)…

- $B_s \rightarrow K^+ K^-$ and $B_d \rightarrow \pi^+ \pi^-$
- $B_s \rightarrow D_s^{\pm} K^{\mp}$
- $B_d \rightarrow \overline{D}^0 K^{*0}, D^0 K^{*0}$
- …

The phase γ in $B_s \to K^+K^-$ and $B_d \to \pi^+\pi^-$ (1)

- Tree and penguins amplitudes:



- By exchanging all $d(\bar{d})$ in $s(\bar{s})$ the $B_d \to \pi^+\pi^-$ becomes $B_s \to K^+K^-$

$$\begin{cases} A^{dir}_{\pi\pi} = f^{dir}(d, \vartheta, \gamma) \\ A^{mix}_{\pi\pi} = f^{mix}(d, \vartheta, \gamma, \beta) \end{cases} \qquad \begin{cases} A^{dir}_{KK} = f^{dir}(d', \vartheta', \gamma) \\ A^{mix}_{KK} = f^{mix}(d', \vartheta', \gamma, \phi_s) \end{cases}$$

$$d\, e^{i\vartheta} = \left.\frac{penguins}{tree}\right|_{B_d \to \pi\pi} \qquad d'\, e^{i\vartheta'} = \left.\frac{penguins}{tree}\right|_{B_d \to KK}$$

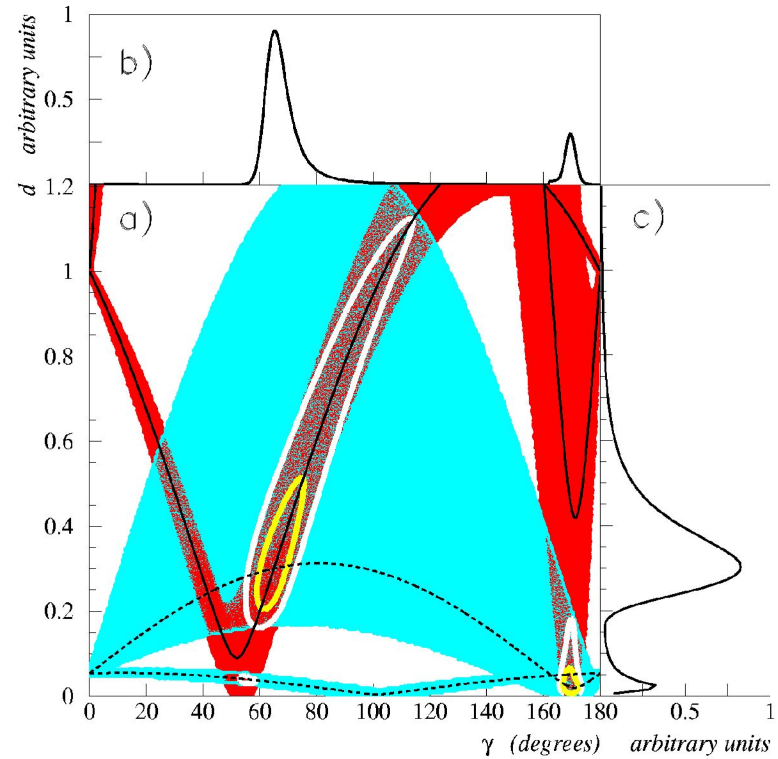
- SU(3) symmetry $d = d'$ and $\vartheta = \vartheta'$
  if β and ϕ_s are known, four observables to determine d, ϑ and γ

R. Fleischer, Phy. Lett. B 459 (1999) 306

The phase γ in $B_s \to K^+K^-$ and $B_d \to \pi^+\pi^-$ (2)

- The wrong tag fraction ω_d (ω_s) are determined $B_d \to K^+\pi^-$ ($B_s \to \pi^+K^-$)
- The phase β (Φ_s) comes from $B_d \to J/\psi K_S$ ($B_s \to J/\psi\,\phi$) decays.
- Sensitivity for 2 fb^{-1}:

$N_{tagged}(\pi\pi)$	11×10^3	
B/S	<0.7	(90% CL)
$N_{tagged}(KK)$	18×10^3	
B/S	0.3±0.1	
$\sigma_{stat}(\gamma)$	4.9°	



$\Delta\Gamma_s/\Gamma_s$	0	(0.1)	0.2
$\sigma(\gamma)$	5.2^o	4.9^o	4.5^o

Δm_s $[ps^{-1}]$	15	(20)	25	30
$\sigma(\gamma)$	4.0^o	4.9^o	5.9^o	8.5^o

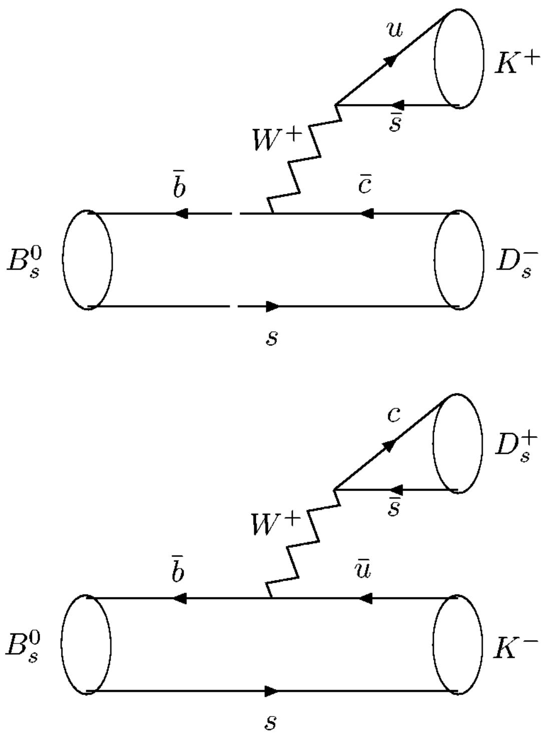
d	0.1	0.2	(0.3)	0.4
$\sigma(\gamma)$	1.8^o	2.7^o	4.9^o	9.0^o

ϑ	120^o	140^o	(160^o)	180^o	200^o
$\sigma(\gamma)$	3.8^o	3.8^o	4.9^o	6.7^o	5.2^o

γ	55^o	(65^o)	75^o	85^o	95^o	105^o
$\sigma(\gamma)$	5.8^o	4.9^o	4.3^o	4.7^o	4.7^o	4.7^o

ϕ_s [rad]	0	(-0.04)	-0.1	-0.2
$\sigma(\gamma)$	4.9^o	4.9^o	4.9^o	5.4^o

The phase γ in $B_s \to D_s^{\pm}(K^+K^-\pi^{\pm})K^{\mp}$



- Two trees diagrams contribute to the decay.
- From four decays rate:

$$\begin{cases} \gamma+\phi_s=\frac{1}{2}\{arg(\lambda)-arg(\bar{\lambda})\} \\ \Delta_{T_1/T_2}=\frac{1}{2}\{arg(\lambda)+arg(\bar{\lambda})\} \end{cases}$$

- Δm_s and the wrong tag fraction ω come from the $B_s \to D_s \pi$ decay.
- Sensitivity for 2 fb^{-1}:

N_{tagged}	2.9×10^3	
B/S	<1	(90% CL)
$\sigma_{stat}(\gamma+\Phi_s)$	14.2°	

Δm_s	15	20	25	30
$\sigma(\gamma+\phi_s)$	12.1	14.2	16.2	18.3

$\Delta\Gamma_s/\Gamma_s$	0	0.1	0.2
$\sigma(\gamma+\phi_s)$	14.7	14.2	12.9

$\gamma+\phi_s$	55	65	75	85	95	105
$\sigma(\gamma+\phi_s)$	14.5	14.2	15.0	15.0	15.1	15.2

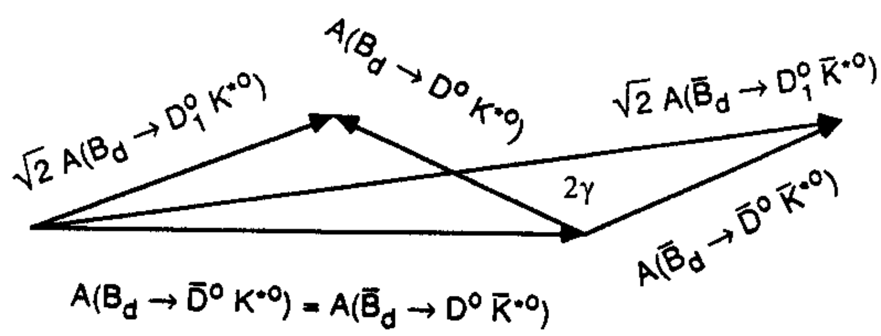
$\Delta_{T1/T2}$	−20	−10	0	+10	+20
$\sigma(\gamma+\phi_s)$	13.9	14.1	14.2	14.5	14.6

The phase γ in $B_d \to \overline{D}^0 K^{*0}, D^0 K^{*0}$

- Method from Gronau-Wyler adapted to $D^0 K^{*0}$ by Dunietz.

- Measurement of six decay rates:

$B_d \to$	$D^0(K^- \pi^+)$	$K^{*0}(K^+ \pi^-)$
$B_d \to$	$\overline{D}^0(K^+ \pi^-)$	$K^{*0}(K^+ \pi^-)$
$B_d \to$	$D^0_{CP}(K^+ K^-)$	$K^{*0}(K^+ \pi^-)$
$\overline{B}_d \to$	$D^0(K^- \pi^+)$	$\overline{K}^{*0}(K^- \pi^+)$
$\overline{B}_d \to$	$\overline{D}^0(K^+ \pi^-)$	$\overline{K}^{*0}(K^- \pi^+)$
$\overline{B}_d \to$	$D^0_{CP}(K^+ K^-)$	$\overline{K}^{*0}(K^- \pi^+)$



- Sensitivity for 2 fb^{-1}:

	Yield	B/S
$B_d \to \overline{D}^0 K^{*0} + c.c.$	3.4×10^3	0.3
$B_d \to D^0 K^{*0} + c.c.$	0.49×10^3	1.8
$B_d \to D^0_{CP} K^{*0} + c.c.$	0.59×10^3	1.4
$\sigma_{stat}(\gamma)$	8.2°	

γ	55°	65°	75°	85°	95°	105°
$\sigma(\gamma)$	9.0°	8.2°	7.6°	7.1°	7.0°	7.0°
Fail	3%	0.5%	0%	0%	0%	0%

I. Dunietz, Phy. Lett. B 270 (1991) 75

The sum (β+γ)…

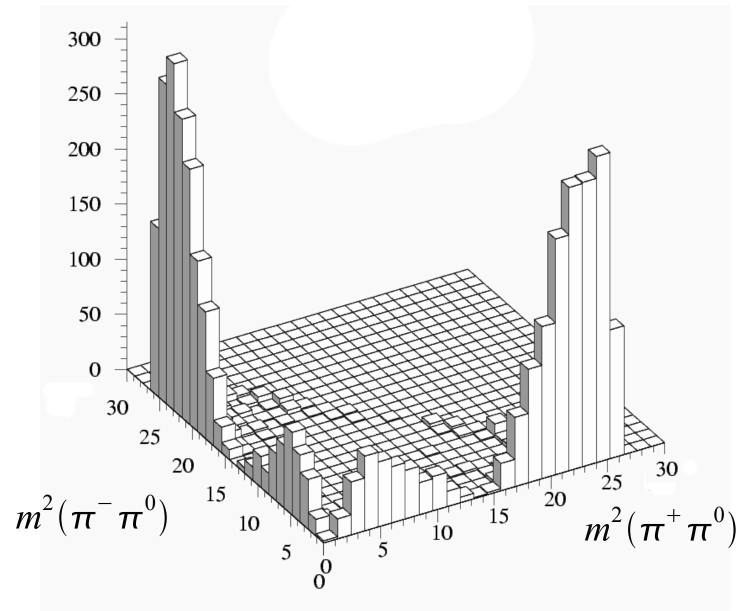
The sum (β+γ) in $B_d \to \rho\pi \to \pi^+\pi^-\pi^0$

- Analysis of time dependent, tagged, Dalitz plot distributions:

$$\begin{cases} B_d \to \omega\, M^{3\pi}_{B_d}(m^2(\pi^+\pi^0), m^2(\pi^-\pi^0), t, \vec{\alpha}) \\ \overline{B}_d \to \omega\, M^{3\pi}_{\overline{B}_d}(m^2(\pi^+\pi^0), m^2(\pi^-\pi^0), t, \vec{\alpha}) \end{cases}$$

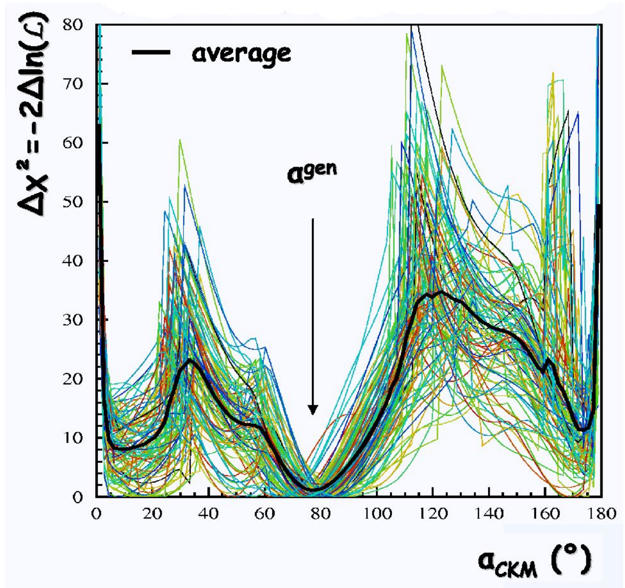
where

$$\vec{\alpha} = (\beta+\gamma, T^{-+}, \phi^{-+}, T^{00}, \phi^{00}, P^{-+}, \delta^{-+}, P^{+-}, \delta^{+-})$$



- Sensitivity for 2 fb^{-1}:

N_{evts}	14×10^3	
B/S	<3	(90% CL)
$\sigma_{stat}(\beta+\gamma)$	8°	



Penguin and box decays...

- Radiative penguin decays:

$$B_d \to K^{*0}\gamma$$
$$B_s \to \phi\gamma$$
$$B_d \to \omega\gamma$$

- Electroweak penguin decay:

$$B_d \to K^{*0}\mu^+\mu^-$$

- Gluonic penguin decays:

$$B_s \to \phi\phi$$
$$B_d \to \phi K_S$$

- Rare box diagram decay:

$$B_s \to \mu^+\mu^-$$

Events yield

- For 2 fb^{-1}, after trigger and offline selection:

Channel	B.R.	Yield	B/S (90% CL)
$B_d \to K^{*0}(K^+\pi^-)\gamma$	2.9×10^{-5}	3.5×10^4	<0.7
$B_s \to \phi(K^+K^-)\gamma$	2.1×10^{-5}	9.3×10^3	<2.4
$B_d \to \omega(\pi^+\pi^-\pi^0)\gamma$		40	<3.5
$B_d \to K^{*0}(K^+\pi^-)\mu^+\mu^-$	8×10^{-7}	4.4×10^3	<2.0
$B_d \to \phi(K^+K^-)K_S(\pi^+\pi^-)$	1.4×10^{-6}	0.8×10^3	<0.2
$B_s \to \phi(K^+K^-)\phi(K^+K^-)$	1.3×10^{-6}	1.2×10^3	<1.1
$B_s \to \mu^+\mu^-$	3.5×10^{-9}	17	<5.7

- Promising physics potential to study numerous loop-induced rare decays.
  Still room to adjust trigger in order to increase the rate for channels of topical interest

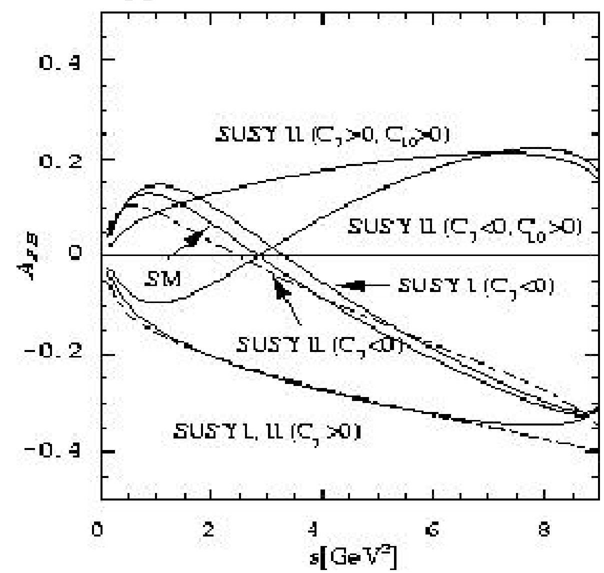
$B^0 \to K^{*0} \mu^+ \mu^-$

- Forward-backward asymmetry in the μμ rest frame $A_{FB}(s)$ is sensitive probe of new physics [Ali et al]

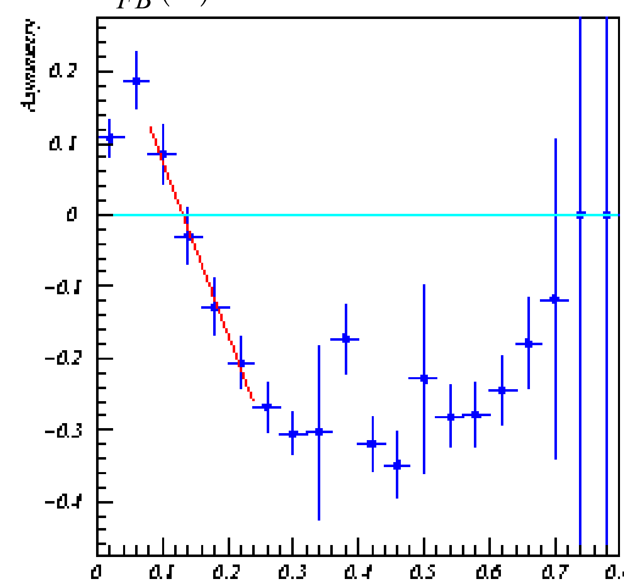
- Sensitivity for 2 fb^{-1}:

N_{evts}	4.4×10^3	
B/S	<2	(90% CL)
Zero point located	±0.04	

$A_{FB}(s)$



$A_{FB}(\hat{s})$



$\hat{s} = (m_{\mu\mu}/m_B)^2$

Systematics

- Some potential sources of systematic uncertainty:
  - $B/\overline{B}$ production asymmetry;
  - Charge dependent detection efficiencies;
  - Background asymmetries;
  - Trigger bias (eg for flavour tag, proper time acceptance)

- Some experimental handles available:
  - Control channels (eg $J/\psi K^*$ for $J/\psi K_S$)
  - Regular reversal of spectrometer B field
  - Simultaneous fit of signal and background (eg $D_s K/D_s \pi$)
  - Analysis of tagging performance in separate categories (eg triggered on B signal/triggered on other tracks)

- High trigger rate provided unbiased samples to study systematics using data.

Conclusions

- The installation of LHCb is progressing well. We will be ready in 2007.
- Expected performance will improve:
  - more decays channels: e.g. $B_d \to \rho\rho$.
  - better trigger and tagging algorithms;
  - new methods: e.g. γ in $B_s \to D_s K$ and $B_d \to D^{(*)}\pi$
- Many complementary ways to reveal physics beyond the standard model and to pin down its nature:
  - Δm_s
  - $A^{CP}_{B_s \to J/\psi\,\phi}(t)$
  - $BR(B_s \to \mu^+\mu^-)$
  - γ in $B_s \to D_s K$ versus $B_s \to K^+K^- + B_d \to \pi^+\pi^-$
  - ϕ_s in $B_s \to J/\psi\,\phi$ versus $B_s \to \phi\phi$
  - ...