LHCb physics performance

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physics
performance

On behalf of the LHCb collaboration
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- $\sigma(\sin 2\beta) \approx 0.03$ by BABAR, Belle, ...
- $|V_{td}/V_{ts}|$ from Δm_s by CDF, DØ
- $|V_{ub}/V_{cb}|$ from $b \rightarrow u$ by BABAR, Belle

} Dominated by theoretical errors

- $\sigma(\sin 2\beta) = 0.02$ from $B^0 \rightarrow J/\psi K_S^0$
- $\sigma(\gamma) \approx 7^\circ$ from $B^0 \rightarrow D^* \pi$ and $B_s \rightarrow D_s K$
- $\sigma(\alpha) < 5^\circ$ “ $(\beta + \gamma)$ ” from $B \rightarrow \rho \pi$, $B \rightarrow \pi \pi$
- $\sigma(\Delta m_s) = 0.01 \text{ ps}^{-1}$ (at 20 ps^{-1}) from $B_s \rightarrow D_s \pi$ (limited by QCD).

... or maybe ...

... maybe γ will provide a surprise ...

LHCb experiment

- LHC: High statistics
- High η
- Hadron trigger
- RICH: K/π separation
- VELO: Very good vertexing resolution
- Good Resolution:
 - ~ 12 MeV on B mass
 - ~ 40 fs on flight time

Sources of systematic errors are:

Charge-dependent detector efficiencies

- can mimic CP asymmetries
- can bias tagging efficiencies
- swap dipole polarity (warm magnet)
- use non-CP control samples

CP-asymmetric background

- study CP violation in B mass sidebands

$b, \bar{b}$ production asymmetries

- use control samples

Control samples:

	yield
$B \rightarrow J/\psi K^*$	600k
$B \rightarrow J/\psi K^\pm$	600k
$B_s \rightarrow D_s \pi$	86k

β from $B \rightarrow J/\psi K_S^0$

$$\mathcal{A}_{CP}(t) = \underbrace{\mathcal{A}_{dir}}_{=0?} \cos(\Delta m_d t) + \mathcal{A}_{mix} \sin(\Delta m_d t)$$

- $\sigma(\sin 2\beta) \approx 0.03$ in 2006
- Theoretically clean
- Needs high stats to fit $\mathcal{A}_{dir}$

$> 10^5$ events/year.

B mass resolution = 7 MeV

B time resolution = 36 fs

- $\sigma(\sin 2\beta) = 0.02$ (1 year)
- $\mathcal{A}_{dir}$ can be fitted.

Compare with $B \rightarrow \phi K_S^0$
Different β would reveal New Physics in penguins

- 4900 $B \rightarrow \pi\pi$ events/year at $S/B > 1$.
- RICH needed
- Hadron trigger

Decay affected
by penguins:

unknown but may
be large (0.2 ?).

- Use $B \rightarrow K\pi$ to estimate $|P/T|$
(33000/year) + More theoretical input
- $B \rightarrow K\pi$ and $B \rightarrow \pi\pi$ to extract γ .
Need charged B. To be studied.

Use $B \rightarrow \rho\pi$ to extract α

α from $B^0 \rightarrow \rho\pi$

	Yield
$B^0 \rightarrow \rho^+\pi^-$	1000
$B^0 \rightarrow \rho^-\pi^+$	200
$B^0 \rightarrow \rho^0\pi^0$	100

Preliminary!

NEW! All interference regions are visible!

- Fit α + 8 parameters
- B mass resolution: 42 MeV (35 when π^0 mass constrained)

- RICH
- Hadron trigger
- **NEW!**
 π^0 trigger

$2.5^\circ < \sigma(\alpha) < 5.0^\circ$
in one year

γ from $B^0 \rightarrow D^* \pi$

- Theoretically clean
- Small CP asymmetry
→ Large statistics needed
- Hadron trigger

	Yield	S/B	
$B \rightarrow D^* (\bar{D}(K\pi)\pi)\pi$	73k	5.6	NEW!
$B \rightarrow D^* (\bar{D}(\text{incl})\pi)\pi$	460k	4.4	NEW!
$B \rightarrow D^* (\bar{D}(\text{incl})\pi)a_1$	360k	4	

B Mass resolution:

13.6 MeV (excl), 220 MeV (incl)

Time resolution:

60 fs (excl) and 170 fs (incl)

- fit $\phi^{\text{mix}} + \gamma$ and strong phase Δ^{QCD}
- get γ using ϕ^{mix} from $B \rightarrow J/\psi K_S^0$

$\sigma(\phi^{\text{mix}} + \gamma)$ versus $\phi^{\text{mix}} + \gamma$.

$\sigma(\gamma) = \mathcal{O}(10^\circ)$ (one year)

$\gamma - 2\delta\gamma$ from $B_s \rightarrow D_s K$

- Theoretically clean
- Needs PID to remove $B_s \rightarrow D_s \pi$ background
- Hadron trigger
- Time: 43 fs, B Mass: 11 MeV

	yield
$B_s \rightarrow D_s^- (KK\pi) K^+$	2100
$B_s \rightarrow D_s^+ (KK\pi) K^-$	320

- get γ using $2\delta\gamma$ from $B_s \rightarrow J/\psi\phi$ (next slide)

$$\sigma(\gamma) = \mathcal{O}(10^0) \text{ (one year)}$$

depending on x_s , γ , strong phases.

$\delta\gamma$ from $B_s \rightarrow J/\psi\phi$

- 80k (32k tagged) events
- negligible background
- J/ψ mass resolution: 9 MeV
- B mass resolution: 12 MeV
- time resolution: 31 fs.
- Improved L1 trigger is expected to increase statistics (c.f. F. Teubert's talk)

Complicated: $\underbrace{B_s}_{J=0} \rightarrow \underbrace{J/\psi}_{J=1} \underbrace{\phi}_{J=1}$
 $L=0,1,2$

Better ? : $\underbrace{B_s}_{J=0} \rightarrow \underbrace{J/\psi}_{J=1} \underbrace{\eta}_{J=0}$
 $L=1$

$$\sigma(\delta\gamma) \approx 2^\circ \text{ (1 year)}$$

(depends on x_s).

$|V_{td}/V_{ts}|$ from Δm_s

- $\sim 34k$ reconstructed and tagged $B_s \rightarrow D_s \pi$ events/year.
- $S/B = 20$.
- Time resolution: 43 fs.
- Hadron trigger

$\sigma(\Delta m_s) = 0.01 \text{ ps}^{-1}$ at 20 ps^{-1} ,
 $> 5\sigma$ on Δm_s up to 48 ps^{-1}

$$\frac{\Delta m_d}{\Delta m_s} = \frac{m_{B^0}}{m_{B_s}} \xi^2 \frac{|V_{td}|^2}{|V_{ts}|^2}$$

$\rightarrow |V_{td}/V_{ts}|$ already limited by theoretical uncertainties after one year.

$|V_{td}/V_{ts}|$ from $B \rightarrow \mu\mu X_{\bar{s}}$ and $B \rightarrow \mu\mu X_{\bar{d}}$

NEW!

	yield	S/B
$(B^0, B^\pm) \rightarrow \mu\mu X_{\bar{s}}$	16000	~ 15
$(B^0, B^\pm) \rightarrow \mu\mu X_{\bar{d}}$	600	~ 1

$\rightarrow V_{td}, V_{ts}$ in box and penguins

$\sigma|V_{td}/V_{ts}|^2 = 11\%$ (one year).
 Theoretical uncertainty $\sim 1\%$.
 Better than uncertainty
 on $\Delta m_s/\Delta m_d$ after 5 years!

Summary

Channel	Hadron Trigger	RICH	Annual Yield	Physics Performance
β	$B \rightarrow J/\psi K_S^0$ $B \rightarrow \phi K_S^0$	✓	✓	100k	$\sigma(\sin 2\beta) = 0.02$ To be studied
γ	$B \rightarrow D^* \pi$ $B_s \rightarrow D_s K$	✓ ✓	✓ ✓	530k 2.4k	$\sigma(\gamma) = \mathcal{O}(10^\circ)$ $\sigma(\gamma) = \mathcal{O}(10^\circ)$
α	$B \rightarrow \pi\pi$ $B \rightarrow \rho\pi$	✓ ✓	✓	4.9k 1.3k	depends on theory $2.5^\circ < \sigma(\alpha) = 5.0^\circ$
$\delta\gamma$	$B_s \rightarrow J/\psi\phi$ $B \rightarrow J/\psi\eta$			2.4k	$\sigma(\delta\gamma) \approx 2^\circ$ To be studied
$ V_{td}/V_{ts} $	$B_s \rightarrow D_s \pi$ $B \rightarrow \mu\mu X_{s,d}$	✓	✓	34k 17k	$\sigma(\Delta m_s) \approx 0.01 \text{ ps}^{-1}$ $\sigma(V_{td}/V_{ts}) = 11^\circ$