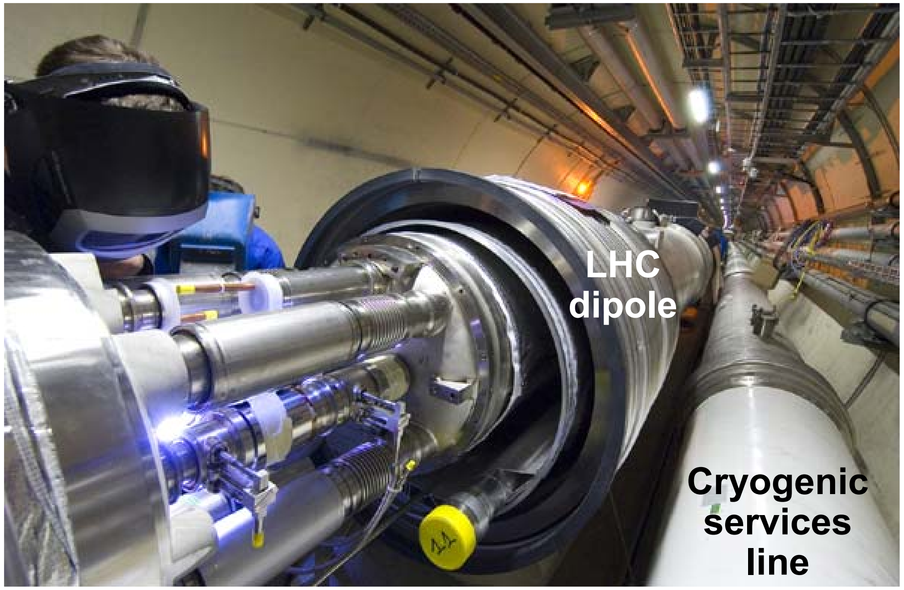
Flavor Physics and CP Violation at LHC



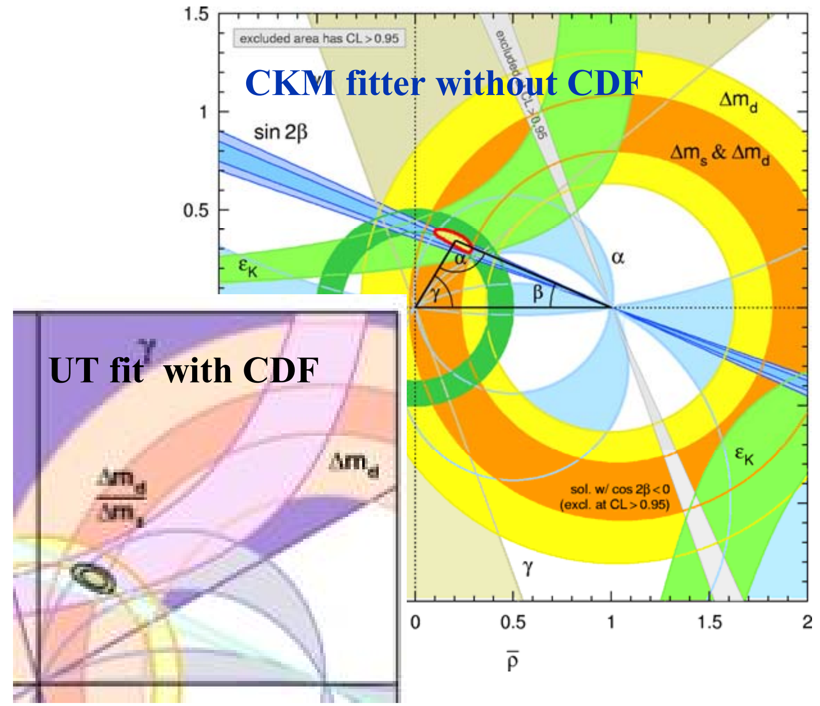
Vancouver, 9-12 April 2006

Andreas Schopper (CERN)

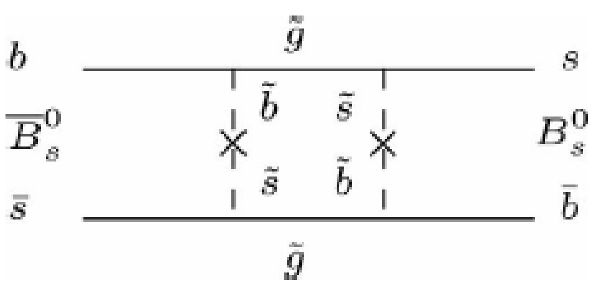
- Motivation
- Experimental sensitivity
- Expected physics performance
- Conclusion

Motivation

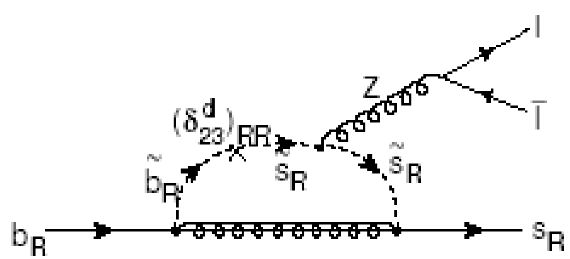
B-factories (BABAR&BELLE) are extremely successful in constraining the unitary triangle within the SM and Tevatron (D0&CDF) has demonstrated its B_s physics capability!



LHC will act as a **b**-factory with large b-quark production rate including B_s, allowing to improve the CKM consistency test and to look for deviations from the SM rare processes



New Physics models introduce new particles, dynamics and/or symmetries at a higher energy scale (expected in the TeV region) with virtual particles that appear e.g. in loop processes



B Physics measurements are complementary to direct searches and will allow to understand the nature and flavour structure of possible New Physics

Completing the program on B Physics…

- Precise measurement of B^0_s-$\overline{B}^0_s$ mixing: Δm_s, $\Delta\Gamma_s$ and phase ϕ_s.

  $B_s \to D_s\pi$, …
  $B_s \to J/\psi\phi$, $B_s \to J/\psi\eta^{(\prime)}$

- Search for effects of NP appearing in suppressed and rare exclusive and inclusive B decays

  $B_{(s)}{}^0 \to X\gamma$, $B^0 \to K^{*0}l^+l^-$, $b \to sl^+l^-$, $B_s \to \mu^+\mu^-$...

- Precise γ determinations including processes only at tree-level, in order to disentangle possible NP contributions

  $B_s \to D_sK$,
  $B^0 \to D^0K^{*0}$, $B^\pm \to DK^\pm$,
  $B^0 \to \pi\pi$ & $B_s \to KK$, …

- Other measurements of CP phases in different channels to over-constrain the Unitarity Triangles

  $B^0 \to \phi K_s$, $B_s \to \phi\phi$, ...
  $B^0 \to \rho\pi$, $B^0 \to \rho\rho$, …

B-factories vs. b-factory

	$e^+e^- \to \Upsilon(4S) \to B\bar{B}$ PEPII, KEKB	$pp \to b\bar{b}X$ ($\sqrt{s}$ = 14 TeV, Δt_{bunch}=25 ns) LHC (LHCb–ATLAS/CMS)	
Production σ_{bb}	1 nb	~500 μb	☺
Typical $b\bar{b}$ rate	10 Hz	100–1000 kHz	
$b\bar{b}$ purity	~1/4	$\sigma_{bb}/\sigma_{inel}$ = 0.6% Trigger is a major issue !	☹
Pileup	0	0.5–5	
b-hadron types	B^+B^- (50%) $B^0\bar{B}^0$ (50%)	B^+ (40%), B^0 (40%), B_s (10%) B_c (< 0.1%), b-baryons (10%)	☺
b-hadron boost	Small	Large (decay vertexes well separated)	
Production vertex	Not reconstructed	Reconstructed (many tracks)	
Neutral B mixing	Coherent $B^0\bar{B}^0$ pair mixing	Incoherent B^0 and B_s mixing (extra flavour-tagging dilution)	☹
Event structure	$B\bar{B}$ pair alone	Many particles not associated with the two b hadrons	

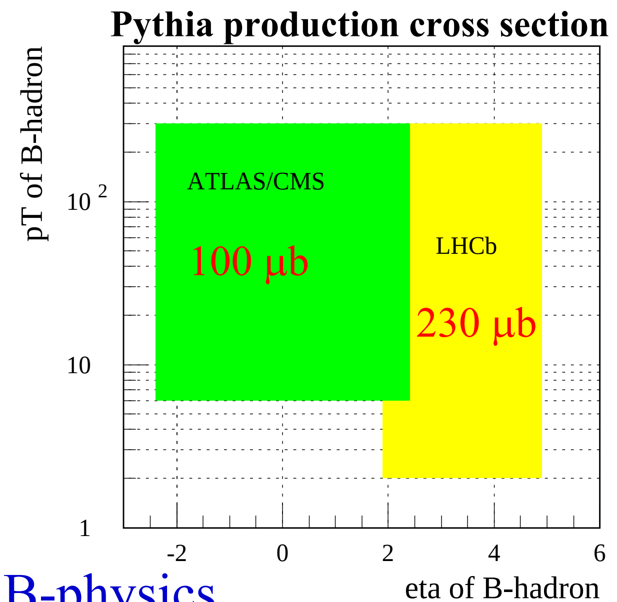
Experimental sensitivity

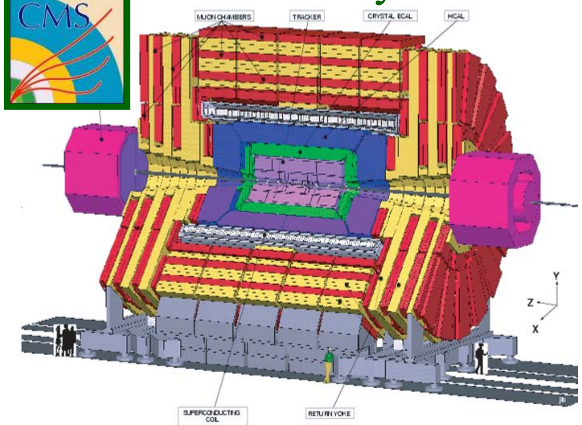
How to reach high sensitivities:

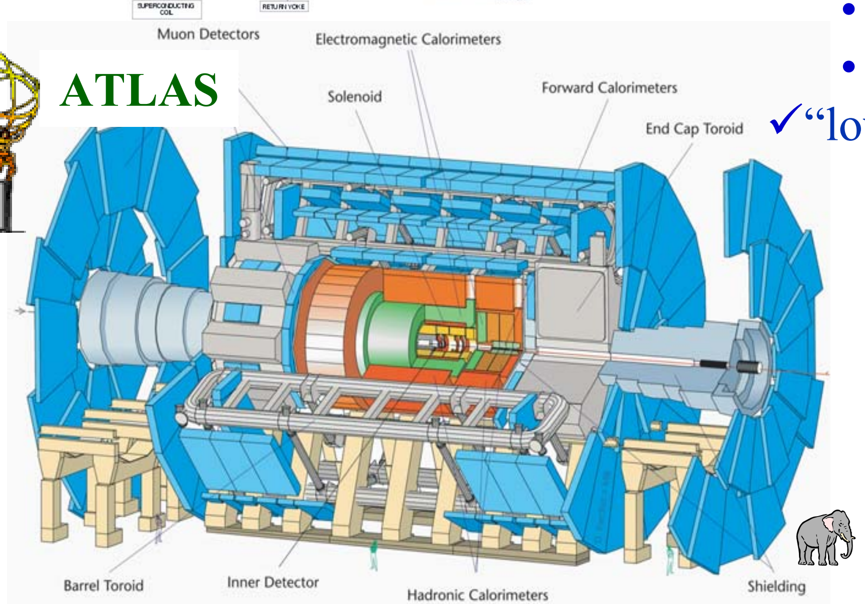
- *B* production rate and detector acceptance
- trigger (incl. fully hadronic decays)
- background reduction
  - ✓ Good mass resolution
  - ✓ Particle Identification
- Good decay time resolution for B_s
- flavour tagging

LHC Experiments (that will do B-physics)

- ATLAS and CMS: general purpose experiments
  - ✓ central detectors, $|\eta|<2.5$
  - ✓ B physics using high-p_T muon triggers, mostly with modes involving dimuon

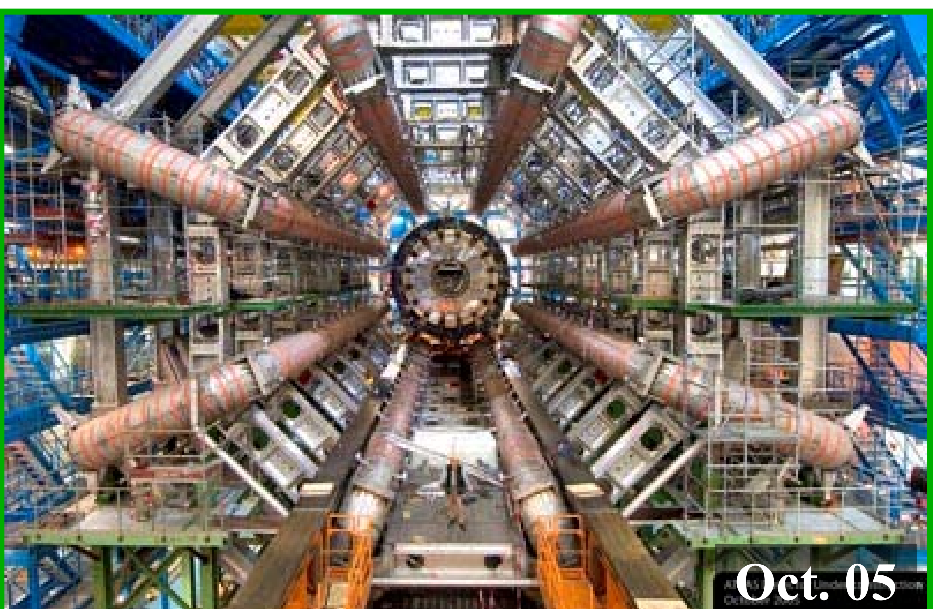






- LHCb: dedicated to B-physics
  - ✓ designed to maximize B acceptance
  - ✓ Forward, single arm spectrometer, $1.9 < \eta < 4.9$
    - more b hadrons produced at low angles
    - $b\bar{b}$ pairs produced correlated in space
  - ✓ "lower" p_T triggers, including purely hadronic modes

Status of detectors



Expect first collisions in summer 2007!

Luminosity and pileup

- **Pileup**
  - ✓ number of inelastic pp interactions in a bunch crossing is Poisson-distributed with mean $n = L\sigma_{inel}/f$

L = instantaneous luminosity
f = non-empty bunch crossing rate
σ_{inel} = 80 mb

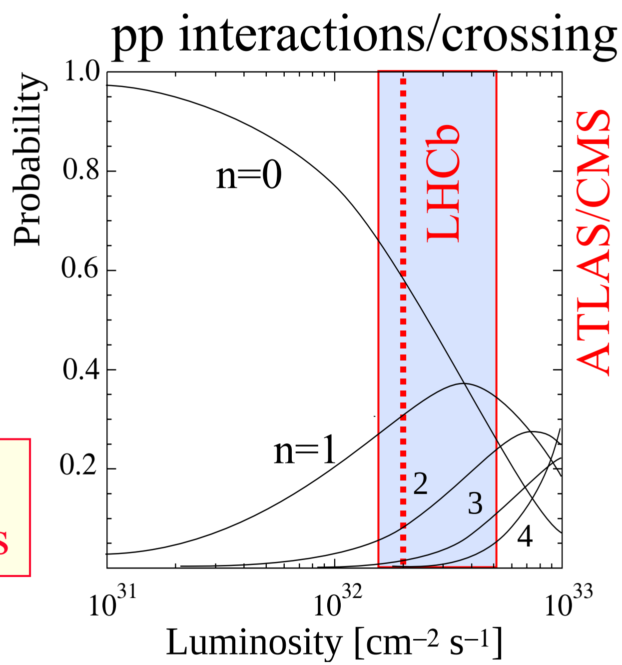
(nominal year = 10^7 s)

- **ATLAS/CMS** (f = 32 MHz)
  - ✓ want to run at highest luminosity available
  - ✓ expect $L<2\times10^{33}$ cm^{-2}s^{-1} (n < 5) for first 3 years
  - ✓ at $L=10^{34}$ cm^{-2}s^{-1} (n = 25), expect only $B\to\mu\mu$ still possible

10 fb^{-1} / year at low L
30 fb^{-1} total at low L

- **LHCb** (f = 30 MHz)
  - ✓ L tuneable by adjusting the beam focus
  - ✓ choose to run at $\langle L\rangle\sim2\times10^{32}$ cm^{-2}s^{-1} (max. 5×10^{32} cm^{-2}s^{-1})
    - clean environment (n = 0.5)
    - less radiation damage (LHCb 8mm from beam, ATLAS 5 cm, CMS 4 cm)
    - will be available from 1st physics run

2 fb^{-1} / year
10 fb^{-1} in first 5 years



ATLAS trigger

Full ATLAS trigger:

- LVL1: hardware, coarse detector granularity, 2 μs latency
- LVL2: full granularity, LVL1 confirmation + partial rec., 10 ms processing
- EF (event filter): full event access, “offline” algorithms 1 s processing

Strategy for B physics trigger:

- High luminosity (> 2×10^{33} $cm^{-2}s^{-1}$):
  - ✓ LVL1: dimuon, p_T > 6 GeV/c each
- Low luminosity (or end of) fills:
  - ✓ LVL1: add single muon, p_T > 6–8 GeV/c
  - ✓ LVL2: look for objects around muon
    - 2^{nd} muon (with lower threshold) in muon RoI
    - Single e/γ or e^+e^- pair in EM RoI
    - Hadronic b decay products in Jet RoI (e.g. $B_s \to D_s^-\pi^+$)

Trigger level	Total output rate	Output rate for B physics
LVL1	**75 kHz**	**10–15 kHz**
LVL2	**2 kHz**	**1–1.5 kHz**
EF	**200 Hz**	**10–15 Hz**

CMS trigger

Trigger to cover widest range of discovery physics (Higgs, SUSY, …)

- Level 1: (nominal) 3.2μs buffer, → 100 kHz
- HLT (High-Level Trigger): 1s buffer, 40 ms processing, → 100 Hz

Trigger on B events:

- Level 1: di-μ with p_T > 3 GeV/c each (or single μ with p_T > 14 GeV/c)
- HLT: Limited time budget
  → restrict B reconstruction to RoI around μ or use reduced number of hits/track ($D_s\pi$)

Trigger level	Total output rate (at start-up)	Output rate relevant for B physics
Level 1	**50 kHz**	**14 kHz (1μ)** **0.9 kHz (2μ)**
HLT	**100 Hz**	**~ 5 Hz of incl. b,c→μ+jet + O(1 Hz) for each excl. B mode**

LHCb trigger

↓ **10 MHz (visible bunch crossings)**

Hardware trigger

Custom electronics boards

- ✓ Fully synchronized (40 MHz), 4 μs fixed latency
- ✓ "High p_T" μ, μμ, e, γ and hadron + pileup info (e.g. $p_T(\mu) > 1.3$ GeV/c)

↓ **1 MHz (full detector readout)**

Software trigger

PC farm of ~2000 CPUs

- ✓ Full detector info available, only limit is CPU time
- ✓ 1st stage: ~1 ms → 40 kHz (could change)
  - Tracks with min. impact param. and p_T + (di)muon
- ✓ High-Level trigger: ~ 10 ms
  - Full event reconstruction: excl. and incl. streams

↓ **≤ 2 kHz (storage)**

Out put rate	Event type	Physics
200 Hz	Exclusive B candidates	B (core program)
600 Hz	High mass di-muons	J/ψ, b→J/ψX (unbiased)
300 Hz	D* candidates	Charm
900 Hz	Inclusive b (e.g. b→μ)	B (data mining)

- ➢ exact splitting between streams can be optimized according to physics requirements
- ➢ large inclusive streams to be used to control calibration and systematics (trigger, tracking, PID, tagging)

Tracking performance

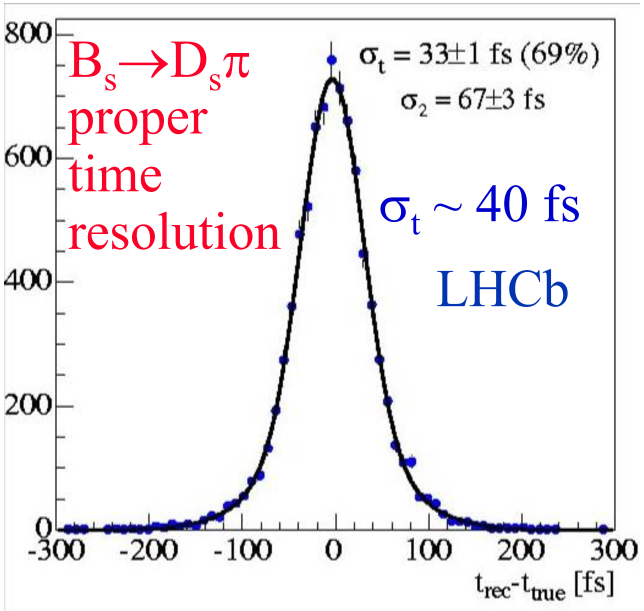
- Mass resolutions in MeV/c^2

	ATLAS	CMS	LHCb	
$B_s \to \mu\mu$	80	46	18	
$B_s \to D_s \pi$	43	–	14	
$B_s \to J/\psi \phi$	36	32	16	without J/ψ mass
$B_s \to J/\psi \phi$	16	13	8	with J/ψ mass constraint

- Proper time resolution

ATLAS: $\sigma_t \sim 95$ fs
CMS: $\sigma_t \sim 100$ fs
LHCb: $\sigma_t \sim 40$ fs →

Good proper time resolution essential for time-dependent B_s measurements !

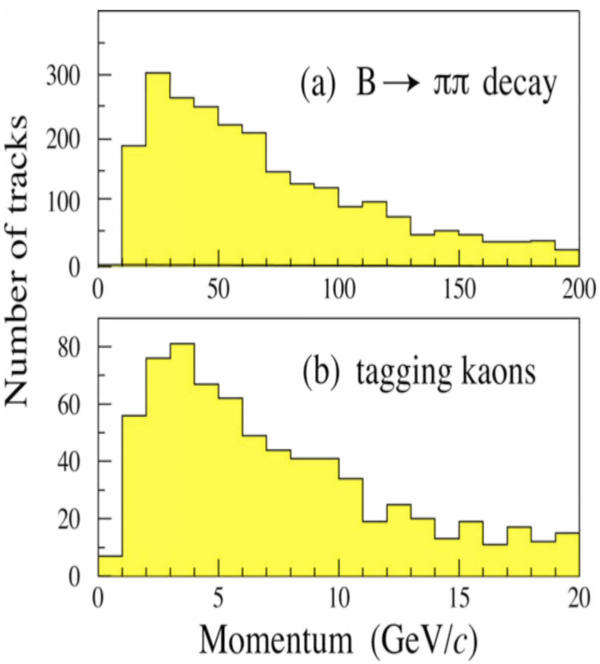


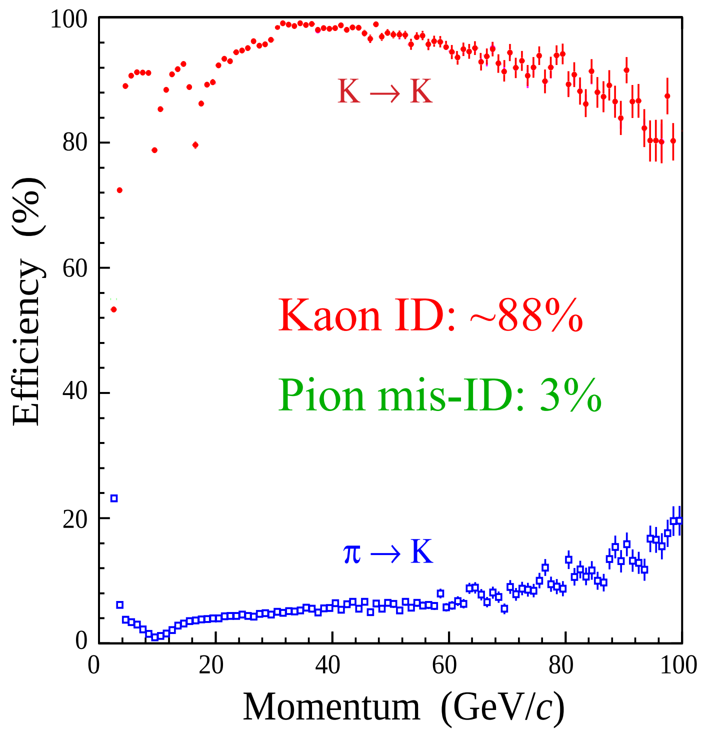
Particle ID performance of LHCb

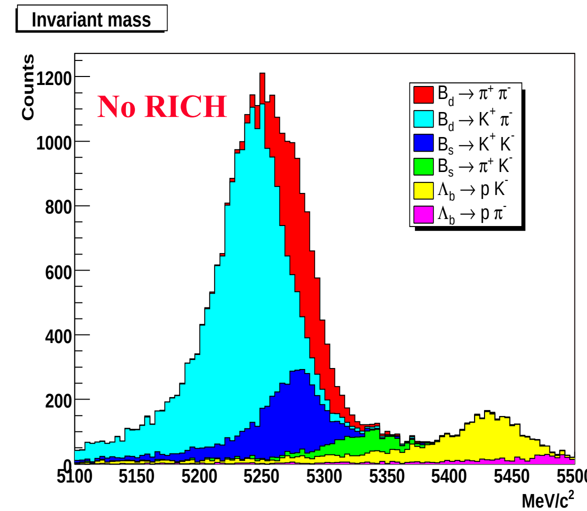
Requirements:

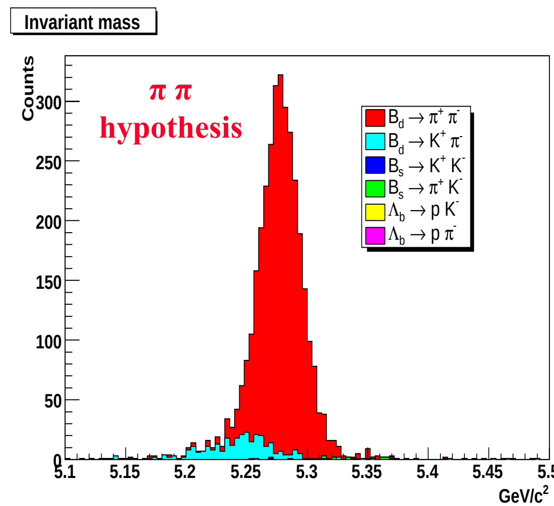
✓ Background suppression => high momentum hadrons in two-body B decays

✓ B flavor tagging (identify K from b→c→s) => low momentum hadrons







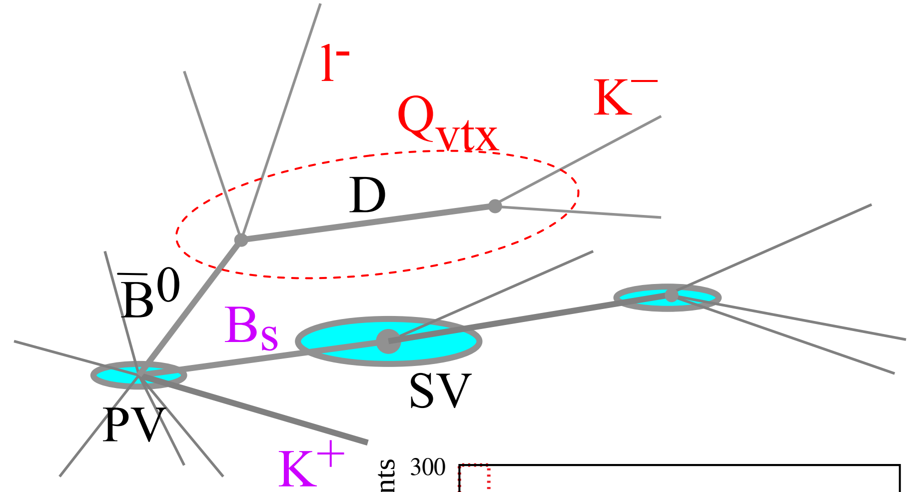


Fully simulated pattern recognition in two LHCb RICHes:

➢ Good K-π separation achievable in 2–100 GeV/c range

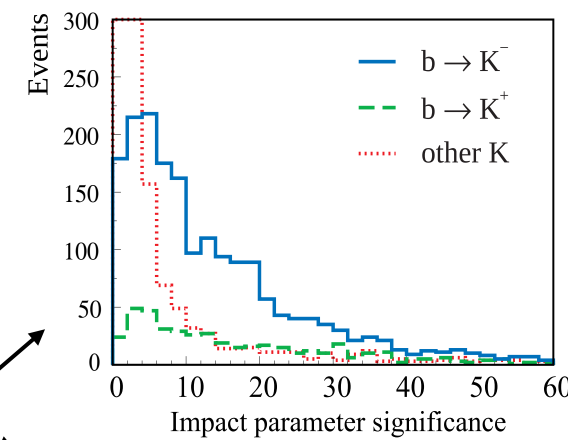
➢ Reconstruct rings around tracks found in tracking

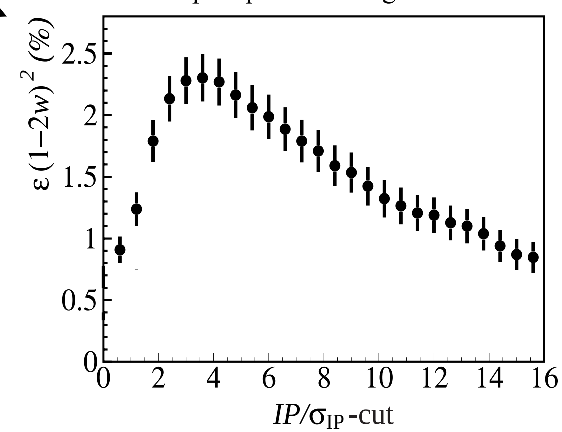
Flavour tagging



Tagging power	$\varepsilon D^2 = \varepsilon(1-2w)^2$ in %		
Tag	**LHCb**	**ATLAS**	**CMS (1999)**
Muon	**1.0**	**0.7**	**(0.6)**
Electron	**0.4**	**0.4**	**(0.5)**
Kaon	**2.4**	**–**	**–**
Jet/vertex	**1.0**	**1.8–2.1**	**(2.3)**
Same side	**2.1**	**2.1–2.4**	**(2.2)**

- LHCb:
  - ✓ Most powerful tag is opposite kaon (from b→c→s)
  - ✓ Combined $\varepsilon D^2 \sim 6\%$ (B_s) or $\sim 4\%$ (B^0)
  - ✓ Recent neural network approach leads to ~9% for B_s
- Compare with:
  - ✓ Tevatron: D0 ~2.5% , CDF ~1.5% OS and ~4% SS
  - ✓ B factories achieved ~ 30%





Expected Physics Performance

B-mixing:

- "control channel" $B^0 \rightarrow J/\psi\ K_S$
- Δm_s with $B_s^0 \rightarrow D_s\pi$
- ϕ_s and $\Delta\Gamma_s$ with $B^0_s \rightarrow J/\psi\phi\ (\eta)$

Suppressed and rare decays:

- Exclusive $b \rightarrow s\ \mu^+\mu^-$
- $B_s^0 \rightarrow \mu^+\mu^-$

Measurement of γ:

- from $B_s \rightarrow D_sK$
- from $B^0 \rightarrow D^0K^{*0}$
- from $B^\pm \rightarrow DK^\pm$
- from $B^0 \rightarrow \pi^+\pi^-$ and $B_s \rightarrow K^+K^-$

sin(2β) from $B^0 \to J/\psi\, K_S$

- "gold-plated" decay channel at B-factories for measuring the B_d- $\bar{B}_d$ mixing phase
- needed for extracting γ from $B \to \pi\pi$ and $B_s \to KK$, or from $B \to D^*\pi$
- in SM A_{CP}^{dir}~0, non-vanishing value $\mathcal{O}$(0.01) could be a signal of Physics Beyond SM

$$A_{CP}^{th}(t) = A_{CP}^{dir} \cdot \cos(\Delta m_d \cdot t) + A_{CP}^{mix} \cdot \sin(\Delta m_d \cdot t)$$

One of the first CP measurements at LHC:

- ✓ demonstrate CP analysis performance
- ✓ study tagging systematics

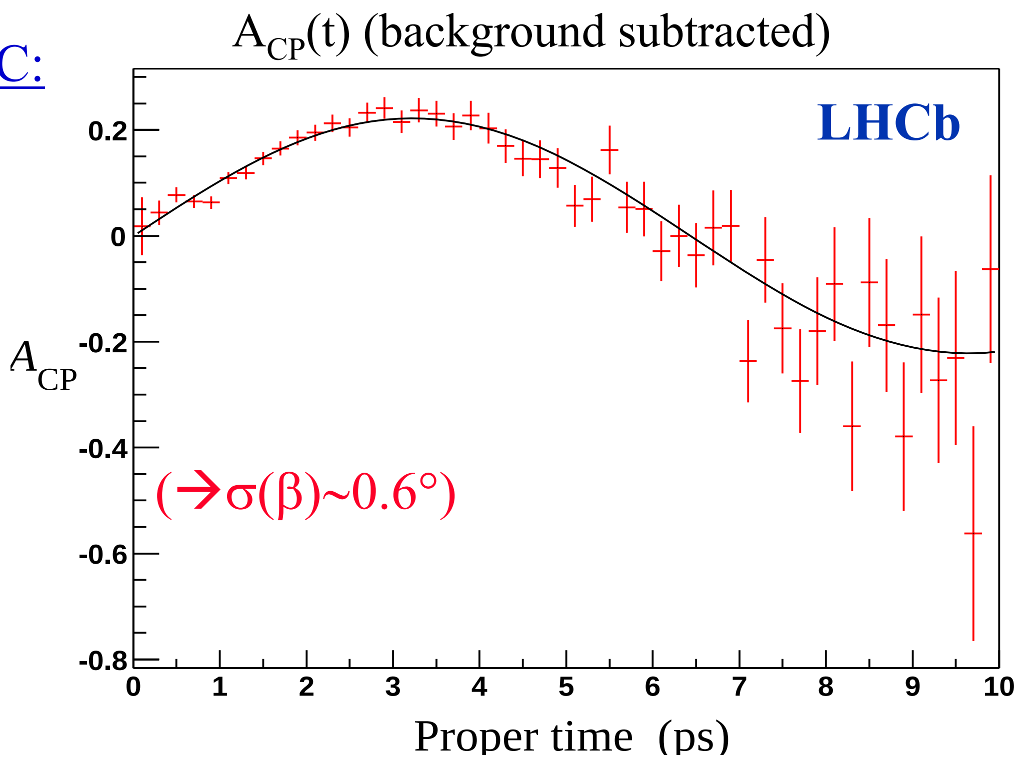
Expected sensitivity:

- ✓ LHCb: 240k signal events/year

  → σ_{stat}(sin(2β)) ~ 0.02 (1year, 2fb^{-1})

- ✓ ATLAS: similar sensitivity for (first 3years, 30fb^{-1})

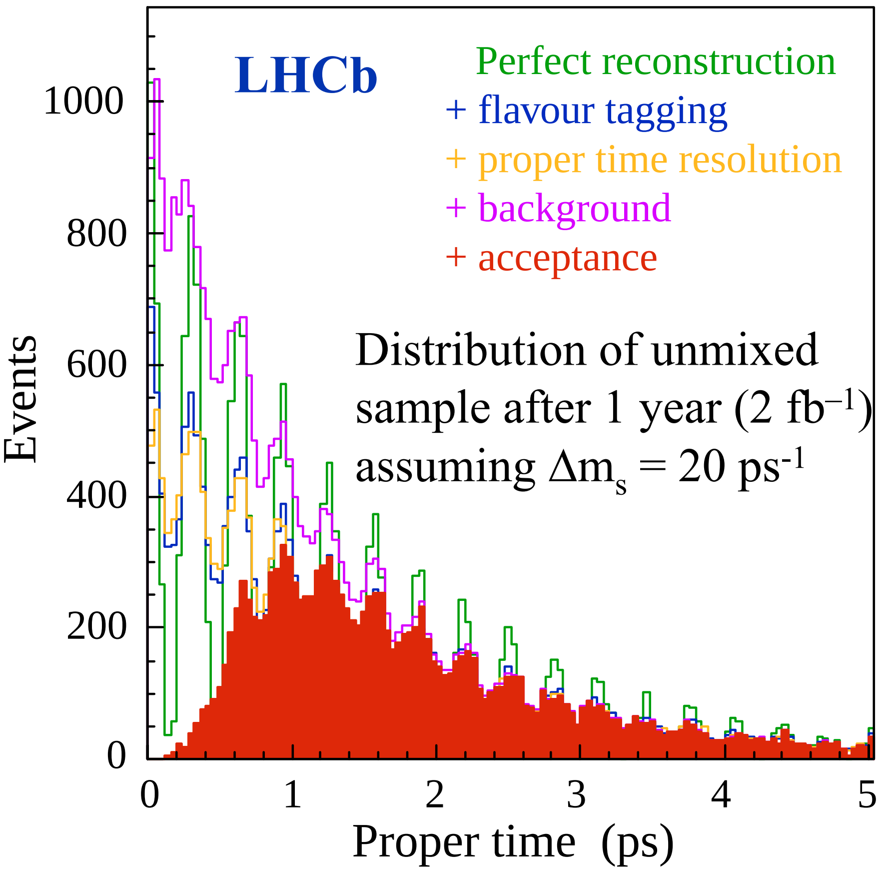
Search for direct CP violating term…

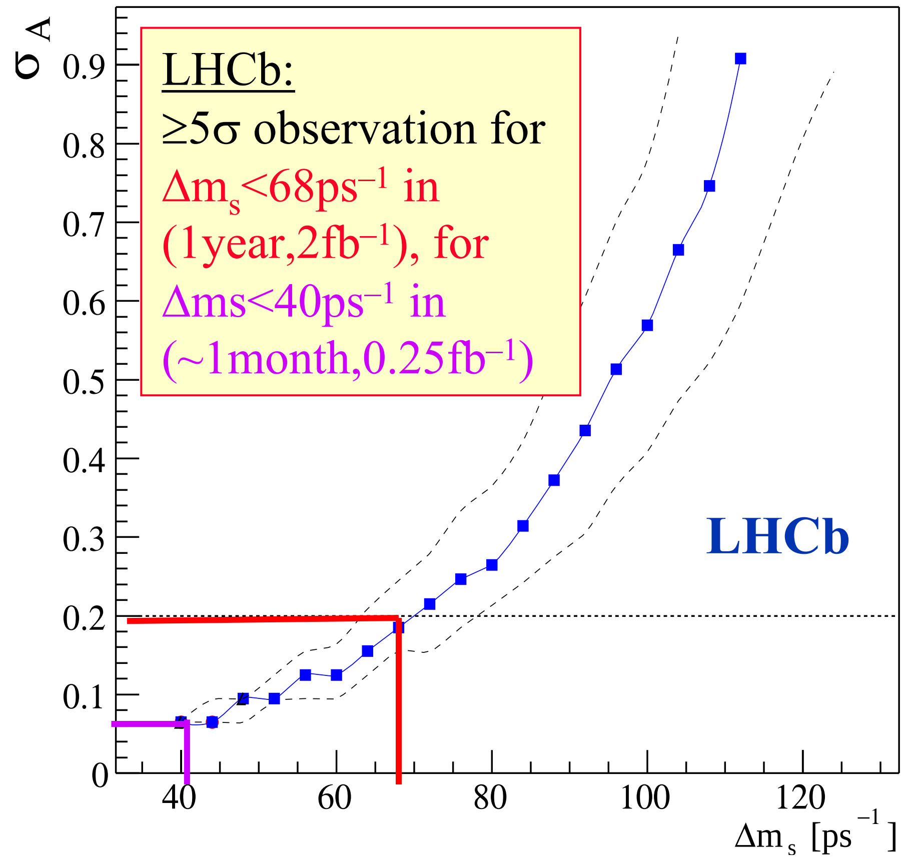


(→σ(β)~0.6°)

B_s oscillations

- Measurement of Δm_s is one of the first LHCb physics goals
  - ✓ Expect 80k $B_s \to D_s^- \pi^+$ events per (1year, $2fb^{-1}$), average $\sigma_t \sim 40$ fs
  - ✓ S/B ~ 3 (derived from 10^7 fully simulated inclusive $b\bar{b}$ ev.)





- <u>ATLAS/CMS</u>: 5σ observation for $\Delta m_s < 22\ ps^{-1}$ in (3years, $30fb^{-1}$)

ϕ_s and $\Delta\Gamma_s$ from $B_s \to J/\psi\phi$ (η,η'…)

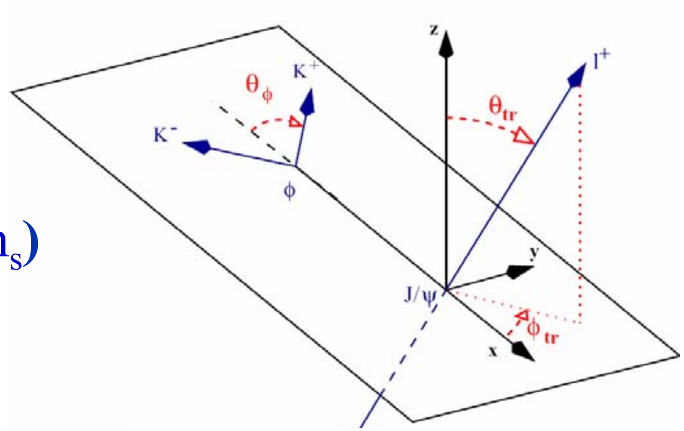
- SU(3) analogue of $B \to J/\psi K_s$, measuring the B_s- $\bar{B}_s$ mixing phase
- in SM $\phi_s = -\arg(V_{ts}^2) = -2\lambda\eta^2 \sim -0.04$ → increased sensitivity to New Physics
- large CP asymmetry would signal Physics Beyond SM
- also needed for extracting γ from $B_s \to D_s K$ or from $B \to \pi\pi$ and $B_s \to KK$

$J/\psi\phi$ is not a pure CP eigenstate:

✓ 2 CP even, 1 CP odd amplitudes contributing

✓ need to fit angular distributions of decay final states as function of proper time (needs external Δm_s)

✓ requires very good proper time resolution



Expected sensitivity: (at $\Delta m_s = 20\ ps^{-1}$)

✓ LHCb: 125k $Bs \to J/\psi\phi$ signal events/year

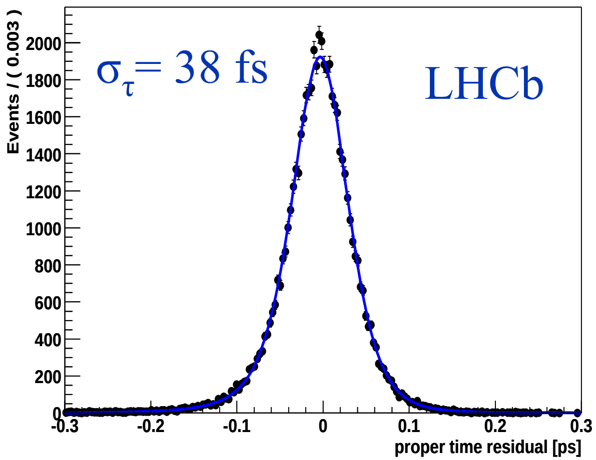
→ $\sigma_{stat}(\sin\phi_s)$~0.031, $\sigma_{stat}(\Delta\Gamma_s/\Gamma_s)$~ 0.011 /(1year, $2fb^{-1}$)

→ **$\sigma_{stat}(\sin\phi_s)$~0.013 after first 5 years,** adding pure CP modes like $J/\psi\eta$, $J/\psi\eta'$ (small improvement)

✓ ATLAS: similar event rate as LHCb but less sensitive

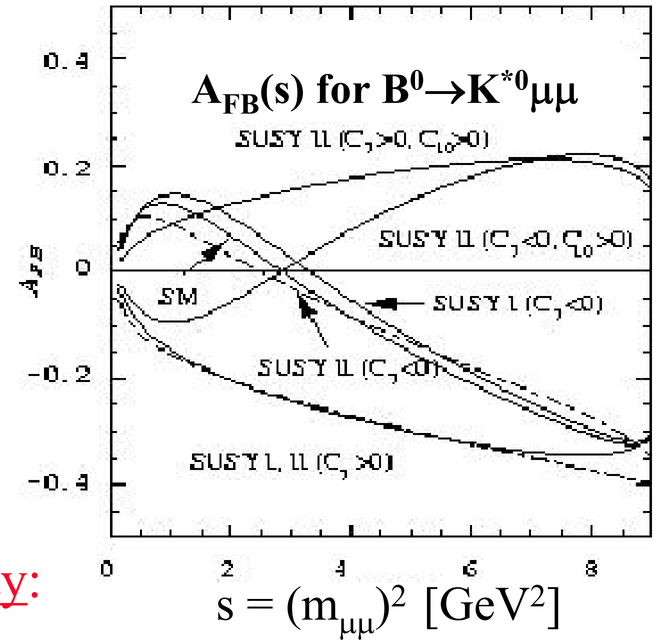
→ $\sigma_{stat}(\sin\phi_s)$~0.08 (1year, $10fb^{-1}$)

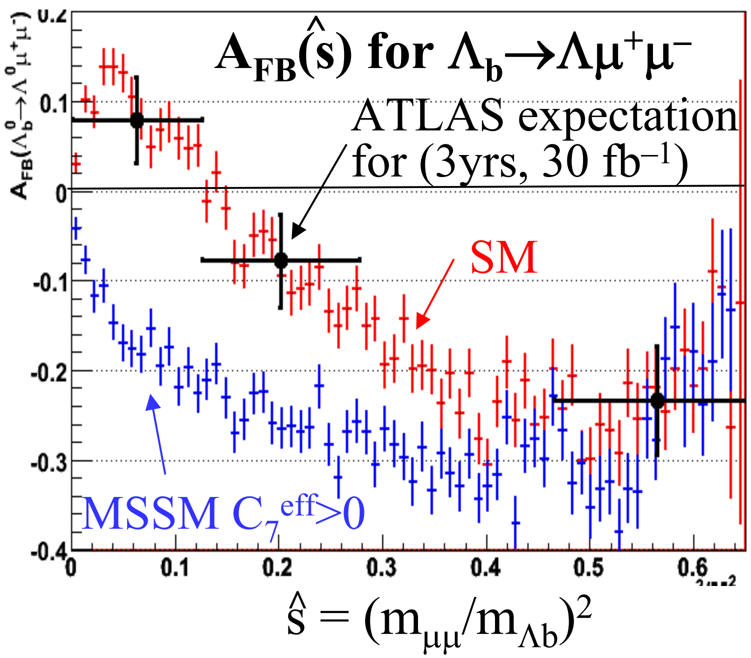
✓ CMS: > 50k events/year, sensitivity study ongoing



Exclusive $b \to s\,\mu^+\mu^-$

- Suppressed decays ($\Delta B=1$ FCNC), SM BR ~ 10^{-6}
- Forward-backward asymmetry $A_{FB}(s)$ in the $\mu\mu$ rest-frame is a sensitive probe of New Physics
  [A.Ali et al., Phys. Lett. B273,505 (1991)]
- Zero point can be predicted at LO with no hadronic uncertainties, known at 5% level in SM, sensitive to NP via non-standard values of Wilson coefficients





Expected sensitivity:

✓LHCb:

4400 $B^0 \to K^{*0}\mu^+\mu^-$ events/(yr,2fb^{-1}), S/B>0.4
$\to$ determine C_7^{eff}/C_9^{eff} with 13% error (SM)

✓ATLAS:

1000 $B^0 \to K^{*0}\mu^+\mu^-$ events/(yr,10fb^{-1}), S/B>1

✓Other exclusive $b \to s\mu\mu$ feasible (B_s, Λ_b)

$B_s \rightarrow \mu^+\mu^-$

- Very rare decay, sensitive to new physics
- BR ~ 3.5×10^{-9} in SM, can be strongly enhanced in SUSY
- Current limit from Tevatron:
  - ✓ D0: 2.3×10^{-7} at 95% CL
  - ✓ CDF: 1.0×10^{-7} at 95% CL

LHC has prospect for significant measurement

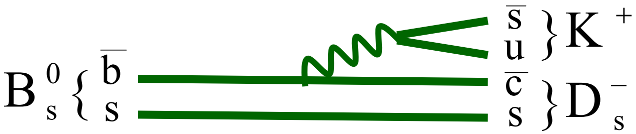
but difficult to get reliable estimate of expected background:

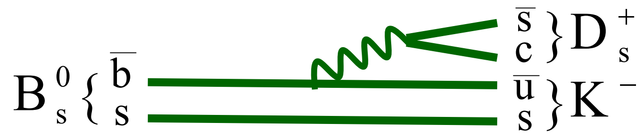
- ✓LHCb: Full simulation: 10M incl. bb events + 10M $b\rightarrow\mu$, $b\rightarrow\mu$ events (all rejected)
- ✓ATLAS: 80k $bb\rightarrow\mu\mu$ events with generator cuts, efficiency assuming cut factorization
- ✓CMS: 10k $b\rightarrow\mu$, $b\rightarrow\mu$ events with generator cuts, trigger simulated at generator level, efficiency assuming cut factorization

	1 year	$B_s \rightarrow \mu^+\mu^-$ signal (SM)	$b\rightarrow\mu$, $b\rightarrow\mu$ background	Inclusive bb background	Other backgrounds
LHCb	**2 fb^{-1}**	**30**	**< 100**	**< 7500**	
ATLAS	**10 fb^{-1}**	**7**	**< 20**		
CMS (1999)	**10 fb^{-1}**	**7**	**< 1**		

- New assessment of ATLAS/CMS reach at 10^{34} cm^{-2}s^{-1} in progress

γ from $B_s \to D_s K$





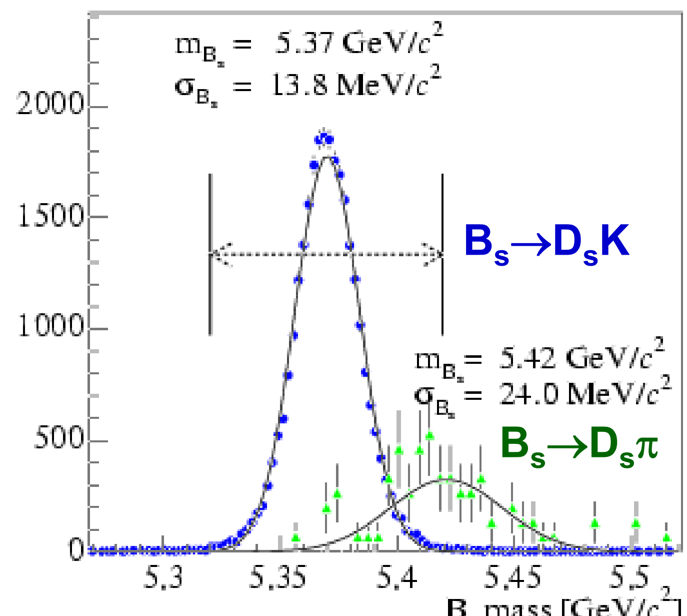
- 2 time dependent asymmetries from 4 decay rates: B_s ($\overline{B}_s$) $\to$ $D^-_s K^+$, $D^+_s K^-$
- 2 tree decays ($b\to c$ and $b\to u$) of same magnitude ($\sim\lambda^3$) interfere via B_s mixing
  - → insensitive to new physics
  - → large interference effects expected
- CP asymmetry measures ($\gamma+\phi_s$), with ϕ_s being determined using $B_s \to J/\psi\ \phi$
- needs suppression of $B_s\to D_s\pi$ background (BR~12 higher)

Important for selection:

- ✓ hadron trigger
- ✓ mass resolution
- ✓ proper-time resolution
- ✓ K/π separation

Expected LHCb signal rates and background:

- ✓ 5400 signal events in (1year, $2fb^{-1}$)
- ✓ residual contamination from $B_s\to D_s\pi$ ~ 10%
- ✓ S/B_{bb} > 1 at 90% CL (from one MC bb event)



γ from $B_s \to D_sK$

Fit the 4 tagged, time-dependent rates:

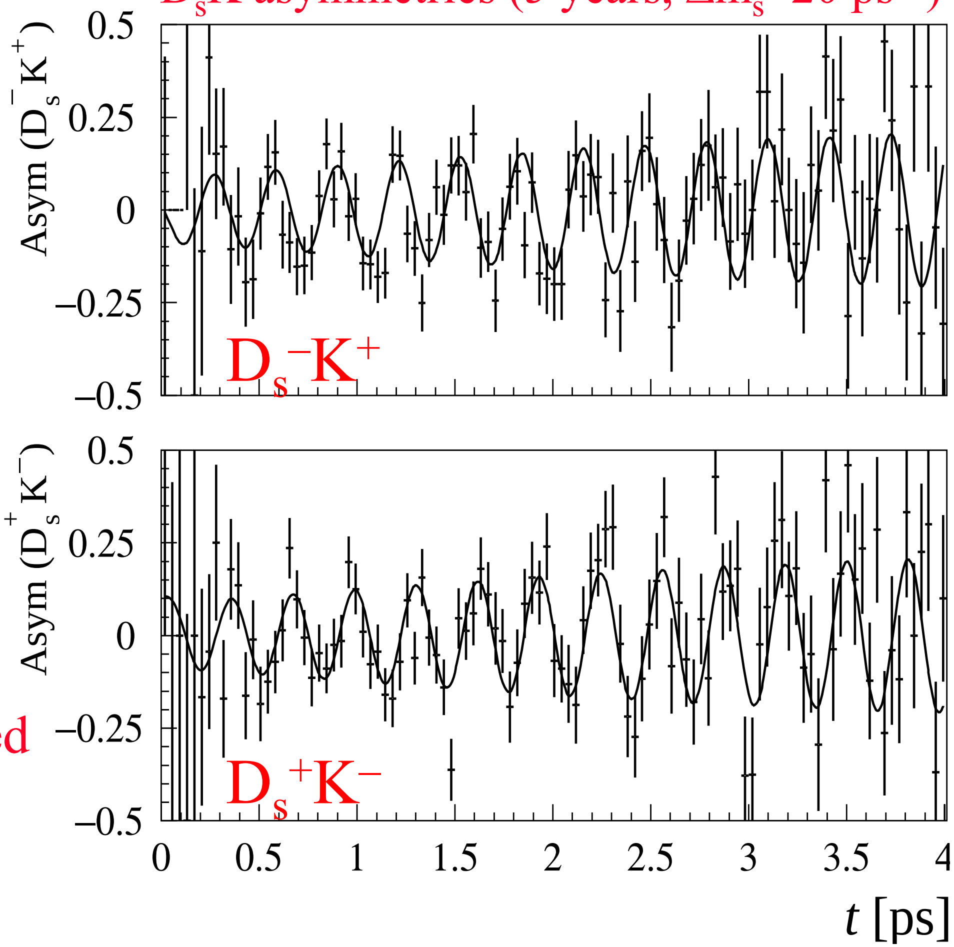
- ✓ phase of $D^-_s K^+ = \Delta + (\gamma + \phi_s)$
- ✓ phase of $D^+_s K^- = \Delta - (\gamma + \phi_s)$
  - → extract both Δ and $(\gamma + \phi_s)$

Expected LHCb sensitivity:

(at $\Delta m_s = 20ps^{-1}$, $-20° < \Delta < 20°$)

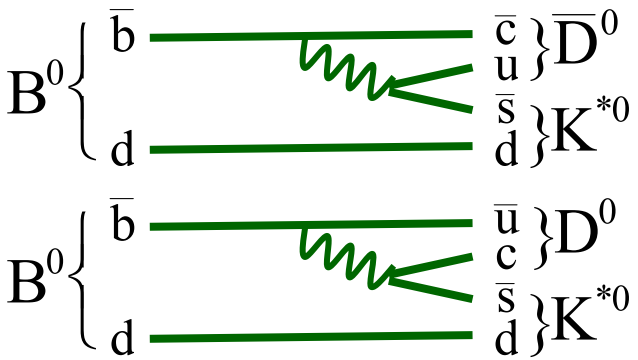
- ✓ $\sigma(\gamma) \sim 14°$ in (1year, $2fb^{-1}$)
  (expected to be statistically limited)
- ✓ Discrete ambiguities in γ can be resolved
  - if $\Delta\Gamma_s$ large enough, or
  - using $B^0 \to D\pi$ and U-spin symmetry

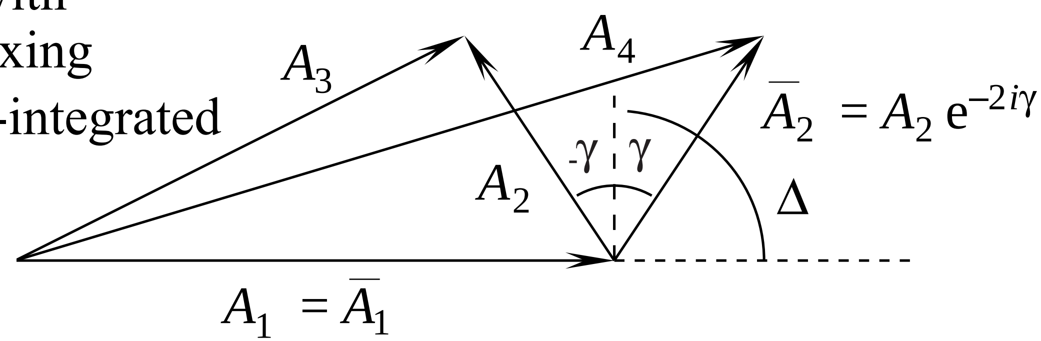
D_sK asymmetries (5 years, Δm_s=20 ps^{-1})



γ from $B^0 \to D^0 K^{*0}$

- Dunietz variant of Gronau-Wyler method *[Phys. Lett. B270, 75 (1991)]*
- Two colour-suppressed diagrams with $|A_2|/|A_1| \sim 0.4$ interfering via D^0 mixing
- 6 decay rates, self-tagged and time-integrated





$A_1 = A(B^0 \to \overline{D}{}^0 K^{*0})$: b→c transition, phase 0

$A_2 = A(B^0 \to D^0 K^{*0})$: b→u transition, phase $\Delta+\gamma$

$A_3 = \sqrt{2}\, A(B^0 \to D_{CP} K^{*0}) = A_1 + A_2$, because $D_{CP} = (\overline{D}{}^0 + D^0)/\sqrt{2}$

<u>Expected signal rates and background:</u> (1year, 2fb^{-1}), $\gamma=65°$, $\Delta=0$

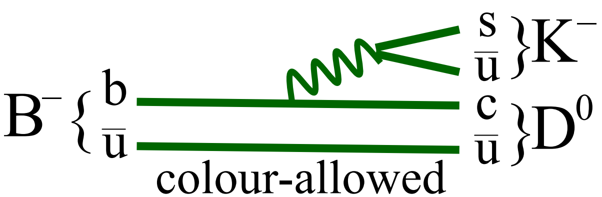
Mode (+ CP conjugates)	Yield	S/B_{bb} (90%CL)
$B^0 \to \overline{D}{}^0 (K^+\pi^-)\, K^{*0} (K^+\pi^-)$	3.4 k	> 2
$B^0 \to D^0 (K^-\pi^+)\, K^{*0} (K^+\pi^-)$	0.5 k	> 0.3
$B^0 \to D^0_{CP} (K^+K^-)\, K^{*0} (K^+\pi^-)$	0.6 k	> 0.3

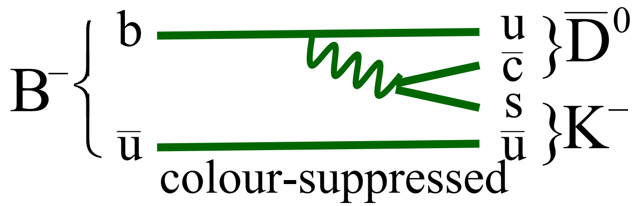
<u>Expected LHCb sensitivity:</u>

✓ $\sigma(\gamma) \sim 8°$ in (1year, 2fb^{-1}) for $55° < \gamma < 105°$, $-20° < \Delta < 20°$

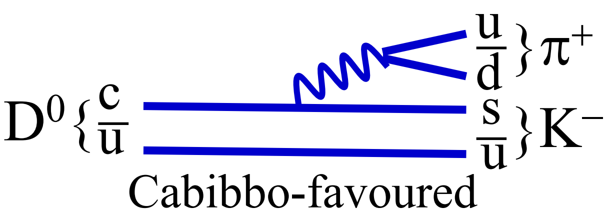
γ from $B^{\pm} \to DK^{\pm}$

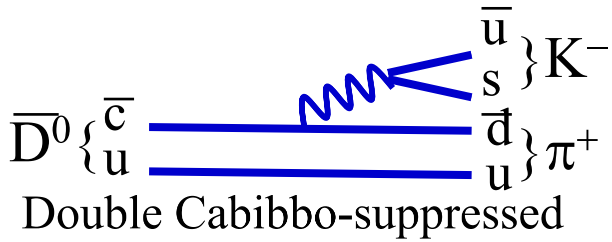
- based on Atwood-Dunietz-Soni method *[Phys. Rev. Lett. 78, 3257 (1997)]*
- measure relative rates of $B^- \to D(K\pi)\,K^-$ and $B^+ \to D(K\pi)\,K^+$
  - ✓ Two interfering tree B-diagrams, one colour-suppressed ($r_B \sim 0.15$)
  - ✓ Two interfering tree D-diagrams, one Double Cabibbo-suppressed ($r_D^{K\pi} \sim 0.06$)





Weak phase diff.: γ
Magnitude ratio: r_B
Strong phase diff.: δ_B





Magnitude ratio: $r_D^{K\pi}$
Strong phase diff.: $\delta_D^{K\pi}$

Measure *relative* B-decay rates:

$$\Gamma(B^- \to (K^-\pi^+)_D\,K^-) \;\propto\; 1 + (r_B\, r_D^{K\pi})^2 + 2\, r_B r_D^{K\pi} \cos\left(\delta_B - \delta_D^{K\pi} - \gamma\right), \quad (1)$$

$$\Gamma(B^- \to (K^+\pi^-)_D\,K^-) \;\propto\; r_B^2 + \left(r_D^{K\pi}\right)^2 + 2\, r_B r_D^{K\pi} \cos\left(\delta_B + \delta_D^{K\pi} - \gamma\right), \quad (2)$$

$$\Gamma(B^+ \to (K^+\pi^-)_D\,K^+) \;\propto\; 1 + (r_B\, r_D^{K\pi})^2 + 2\, r_B r_D^{K\pi} \cos\left(\delta_B - \delta_D^{K\pi} + \gamma\right), \quad (3)$$

$$\Gamma(B^+ \to (K^-\pi^+)_D\,K^+) \;\propto\; r_B^2 + \left(r_D^{K\pi}\right)^2 + 2\, r_B r_D^{K\pi} \cos\left(\delta_B + \delta_D^{K\pi} + \gamma\right), \quad (4)$$

- 3 observables, 5 parameters (γ, δ_B, $\delta_D^{K\pi}$, r_B, $r_D^{K\pi}$) , but $r_D^{K\pi} \sim 0.06$ known
- add more D-decays to constrain further…

γ from $B^\pm \to DK^\pm$

Add further D-decays:

- $D \to K\pi\pi\pi$ (Cabibbo favoured + DCS decay)
  - ✓ 4 new rates with 2 new parameters, one known: $\delta_D^{K3\pi}$; $r_D^{K3\pi} \sim 0.06$
- $D \to KK$ (CP eigenstate)
  - ✓ 2 new rates, no new unknown: $r_D^{KK} = 1$; $\delta_D^{KK} = 0$

➔ 7 relative rates and 5 unknowns: γ, r_B, δ_B, $\delta_D^{K\pi}$, $\delta_D^{K3\pi}$

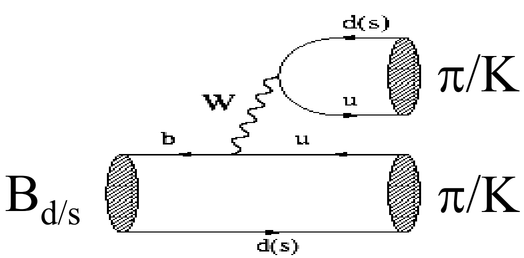
- ✓ Candidate for LHCb's statistically most precise determination of γ
- ✓ Estimated sensitivity: $\sigma(\gamma) \sim 5°$ in (1year, $2fb^{-1}$) ➔ Studies ongoing…

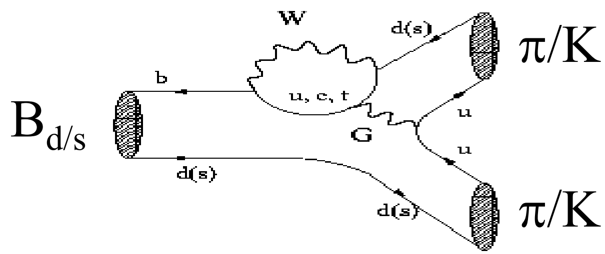
Further B-channel considered…

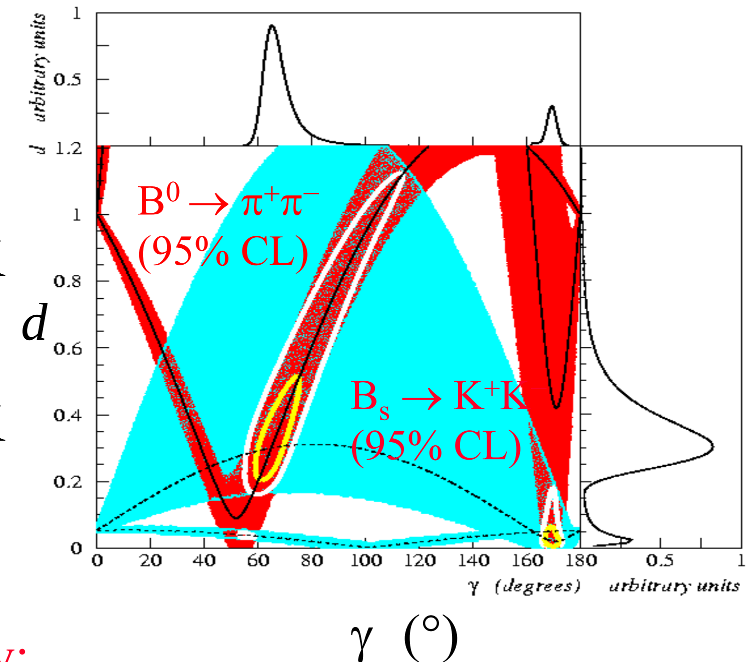
- $B^\pm \to D^*K^\pm$ with
  - $D^* \to D^0\pi^0$ ➔ D^* and D^0 have same CP
  - $D^* \to D^0\gamma$ ➔ D^* and D^0 have opposite CP

γ from $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$

- large penguin contributions in both decays → sensitive to New Physics
- measure time-dependent CP asymmetry for $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$
  - ✓ $A_{CP}(t) = A_{dir} \cos(\Delta m t) + A_{mix} \sin(\Delta m t)$
  - ✓ A_{dir} and A_{mix} depend on γ, mixing phases, and ratio of penguin to tree = $d\, e^{i\theta}$
- exploit "U-spin" symmetry (d↔s) *[R.Fleischer, Phys.Lett. B459, 306 (1999)]*
  - ✓ $d_{\pi\pi} = d_{KK}$ and $\theta_{\pi\pi} = \theta_{KK}$
  - ✓ 4 measurements and 3 unknowns, if mixing phases from $B^0 \to J/\psi K_S$ and $B_s \to J/\psi\phi$







Important for selection:

- ✓ hadron trigger
- ✓ K/π separation
- ✓ mass resolution
- ✓ proper-time resolution

Expected sensitivity:

- 26k $B^0 \to \pi^+\pi^-$, 37k $B_s \to K^+K^-$, 135k $B^0 \to K^+\pi^-$
- **$\sigma(\gamma) \sim 5°$ in (1year, 2fb^{-1})**

Conclusion

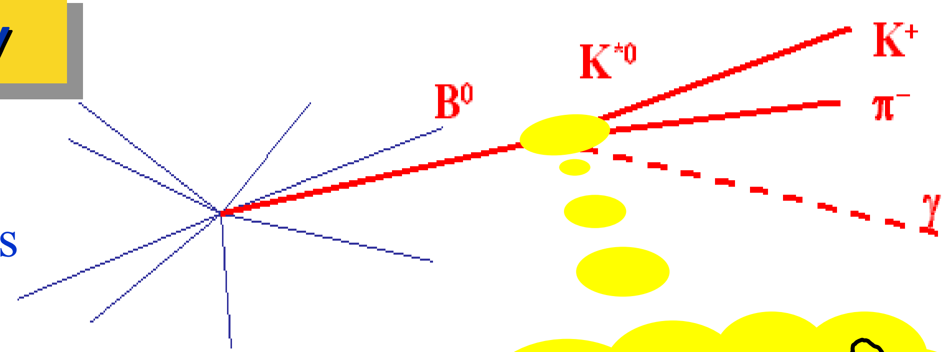
- Experiments at ***LHC*** will pursue an extensive program on B-physics
  - ✓ with high statistics
  - ✓ access to B_s decays
- ***LHCb*** can fully exploit the large B-meson yields at LHC from the start-up
  - ✓ with excellent mass and decay-time resolution, and particle ID
  - ✓ with a flexible and robust trigger dedicated to B-physics
  - ✓ measure e.g. Δm_s with 5σ in ~1month (for $\Delta m_s < 40\ ps^{-1}$)
- ***ATLAS*** and ***CMS*** will also contribute significantly
  - ✓ competitive for modes with muons and small BR

After 5 years:	**σ**	**SM expectation**	
$\phi_s(B_s \to \bar{c}c\bar{s}s)$	~0.013	~0.035	
$Br(B_s \to \mu^+\mu^-)$	$\sim 0.7\times10^{-9}$	$\sim 3.5\times10^{-9}$	
$\gamma\ (D_sK, DK)$	~1°	~60°	(tree only)
$\gamma\ (KK+\pi\pi)$	~2°	~60°	(tree + penguin)

➔ **Flavor Physics at LHC will contribute significantly to the search for NP via precise and complementary measurements of CKM angles and the study of loop decays**

Backup slides

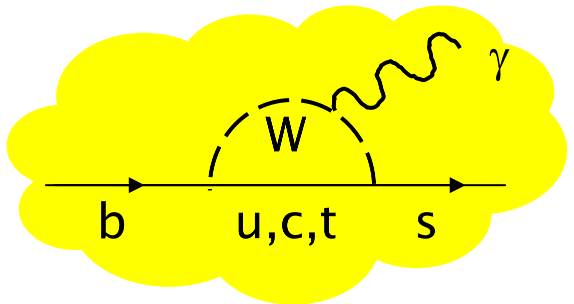
$B^0 \to K^{0*}\gamma$ and $B_s \to \phi\gamma$

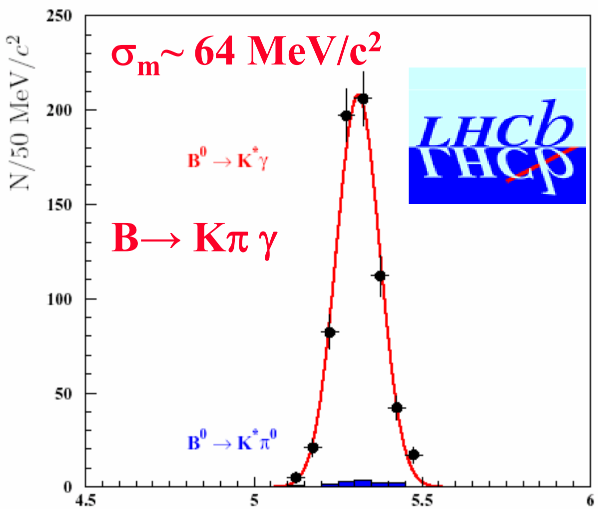


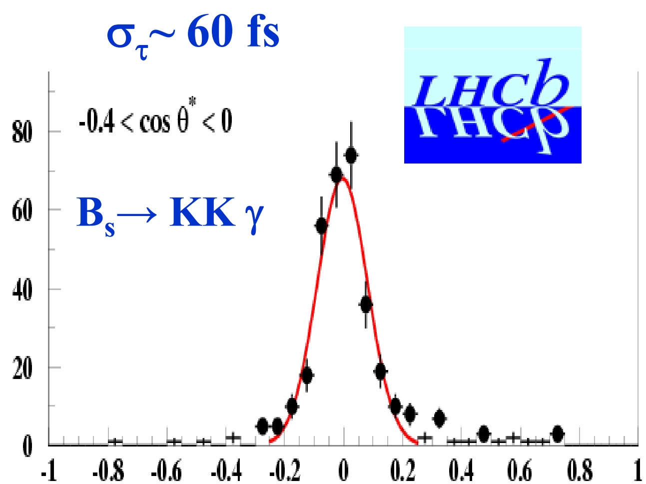
In SM:

- loop-suppressed $b \to s\gamma$ transitions
- BR($B^0 \to K^{*0}\gamma$) = $(4.3\pm0.4)\ 10^{-5}$
- expected direct CP violation <1% for $B^0 \to K^{*0}\gamma$
- expected CP violation in mixing ~0 for $B_s \to \phi\gamma$

→ sensitive to New Physics







Preliminary study:

- for $B \to K^{0*}\gamma$
  $\sigma(A_{CP}) < 0.01$
  for one year LHCb
- for $B_s \to \phi\gamma$ sensitivity study ongoing

In 1 year LHCb expects triggered and reconstructed:

35k events $B^0 \to K^{0*}(K^+\pi^-)\gamma$; S/B>1.4

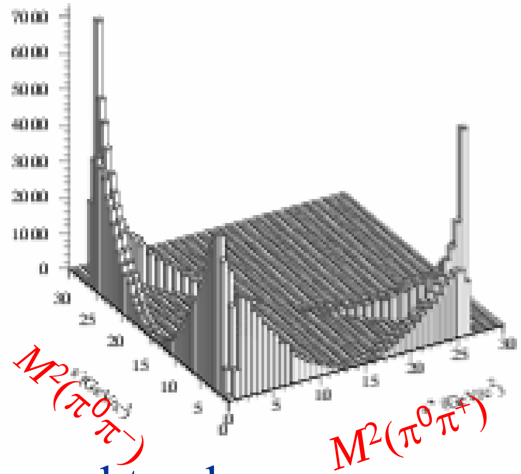
9.4k events $B_s \to \phi(K^+K^+)\gamma$; S/B>0.4

ATLAS expected signal events/year:

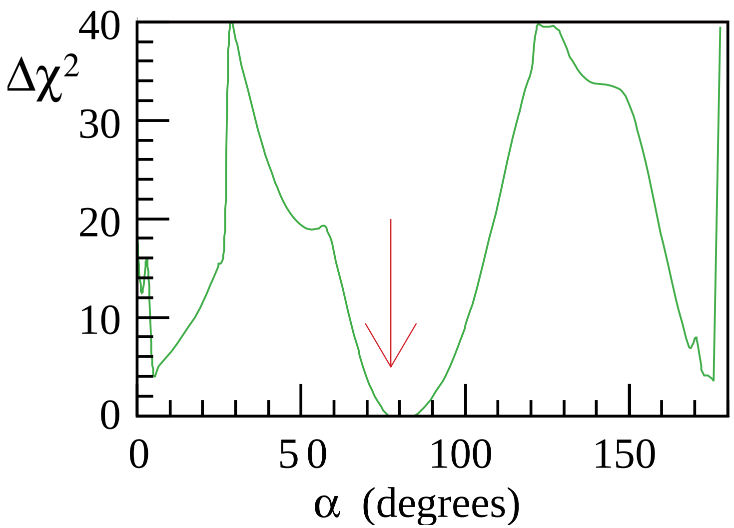
$B_d \to K^{*0}\gamma$: ~3.3k ev. ; $S/\sqrt{BG} > 5$

$B_s \to \phi\gamma$: ~1.1k ev. ;$S/\sqrt{BG} > 7$

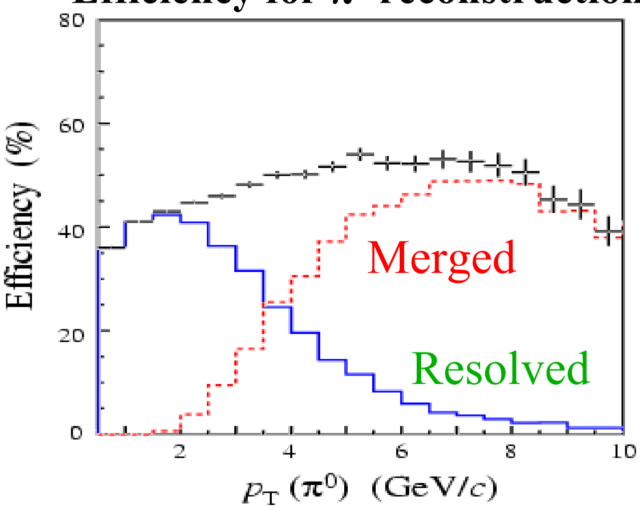
α from $B^0 \to \pi^+\pi^-\pi^0$



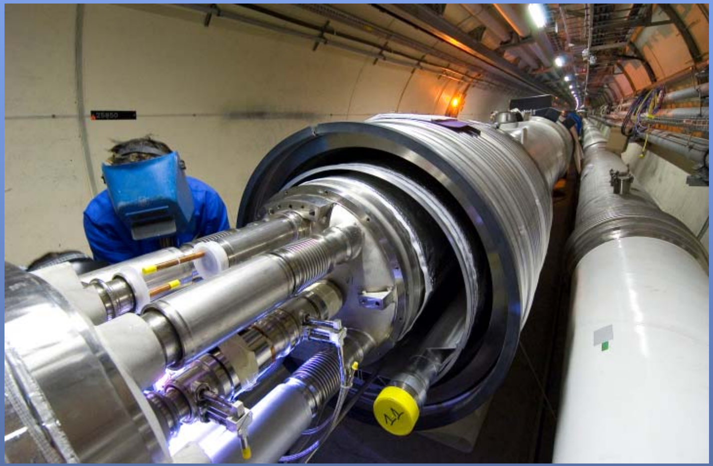
- Time-dependent Dalitz plot analysis of $B^0 \to \rho\pi \to \pi^+\pi^-\pi^0$ permits extraction of α along with amplitudes + strong phases [Snyder & Quinn]
- Neutral π^0 reconstruction with clusters unassociated to charged tracks
- Annual yield ~ 14k events, S/B ~ 1.3 (LHCb)
  Complicated 11-parameter fit, studied with toy MC
  Statistical precision of $\sigma(\alpha)$ ~ 10° achievable in one year
  Study of $B^0 \to \rho\rho$ has started, few $\times 10^2$ $\rho^0\rho^0$ /year (for BR = 10^{-6})



Efficiency for π^0 reconstruction



LHC underground



LHC status (March 2006)

- All key objectives have been reached for the end of 2005.
  - End of repair of QRL, reinstallation of sector 7-8 and cold test of sub-sectors A and B.
  - Cool-down of full sector 8-1.
  - Pressure test of sector 4-5.
  - Endurance test of two full octants of power converters.
- Magnet installation rate is now at 20 per week with more than 450 installed (25%). In the next month, we will ramp up to 25/week. Installation will finish end February 2007.