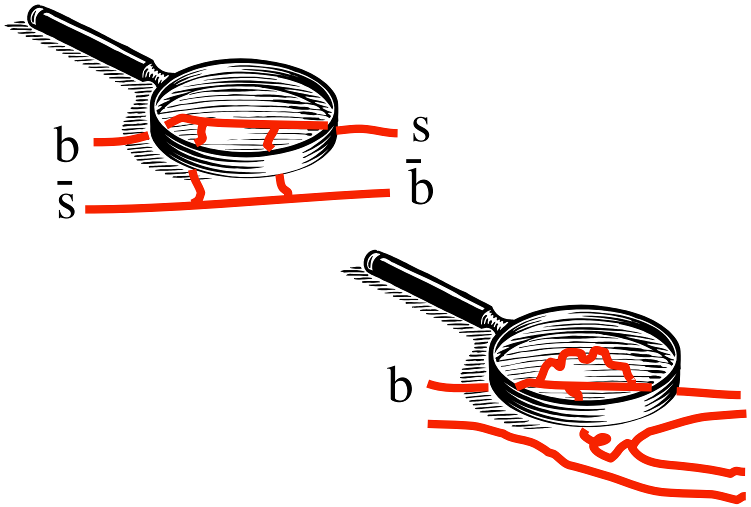
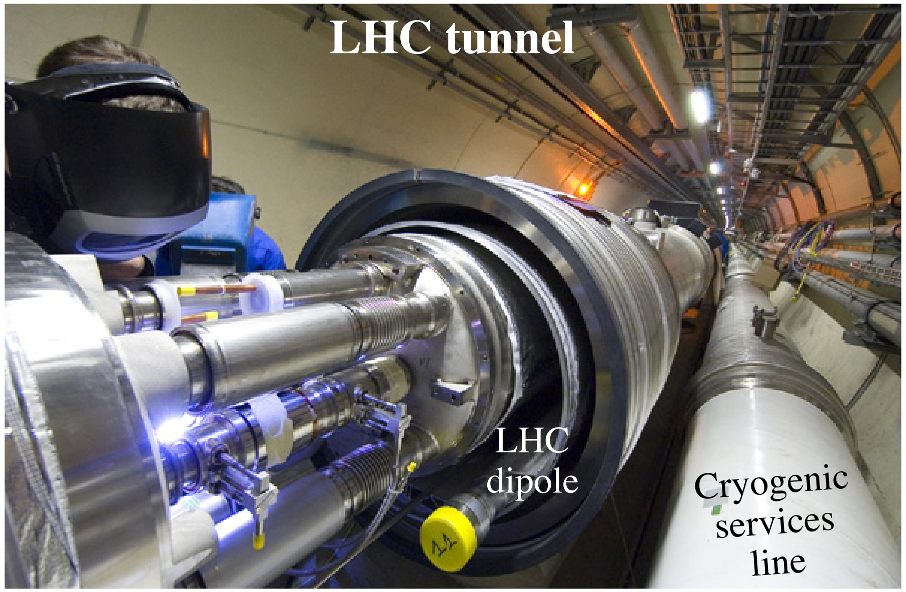
Workshop on "Flavour in the era of LHC"
First meeting, CERN, November 7–10, 2005

B physics prospects at the LHC





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  - Motivation, B physics strategy
- Experiments at LHC
  - Hadronic collider environment
  - Acceptance, luminosity, pileup
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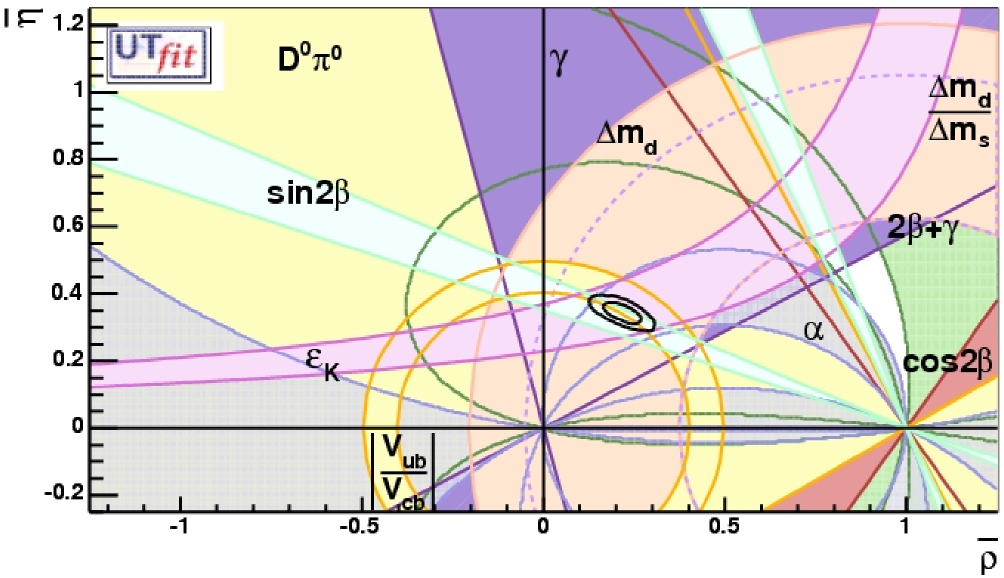
- Expected physics performance
  - Flavour tagging and sin2β
  - B_s mixing (Δm_s, $\Delta\Gamma_s$, ϕ_s)
  - Other $b \to s$ boxes and penguins
  - Measurements of γ
- Conclusion

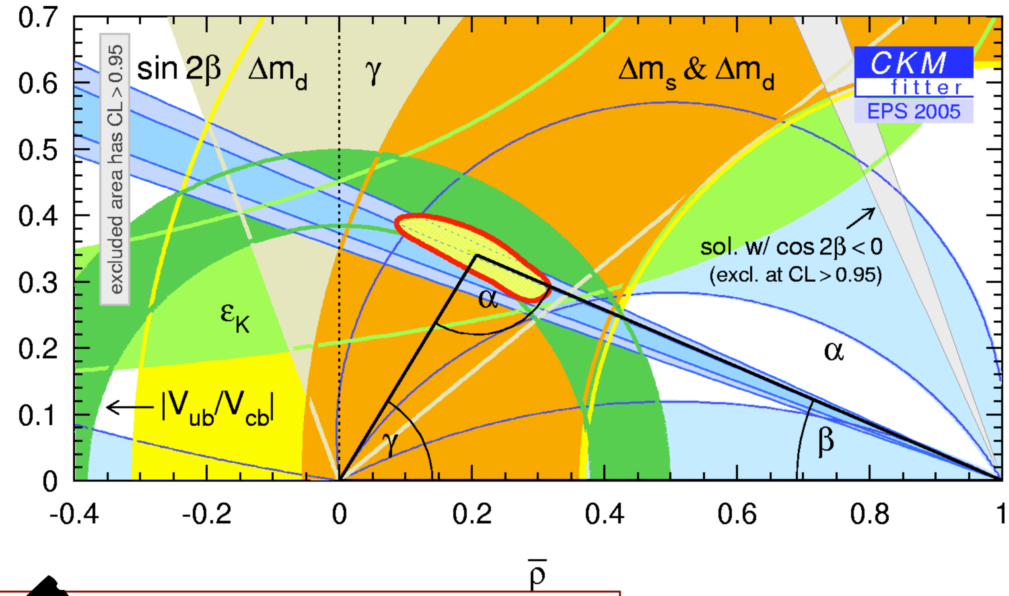
See also LHC experimental talks in the parallel sessions of WG2:

B_s mixing:	L. Fernandez (LHCb)
$B \to K^{(*)} l^+ l^-$:	P. Koppenburg (LHCb)
Rare $\mu\mu$ decays:	N. Nikitine (ATLAS)
$B_s \to \mu^+\mu^-$:	T. Speer (CMS)

Consistency of CKM picture

- B factories (BABAR & Belle) have done a superb job to constrain the unitarity triangle within the SM !





Does the SM give a cohere[illegible]scription of CP violation ?
If not what are the[illegible]rnatives to CKM ?

How accurate is the CKM picture ?
Are there “corrections” to it ?
Can new physics still hide somewhere ?

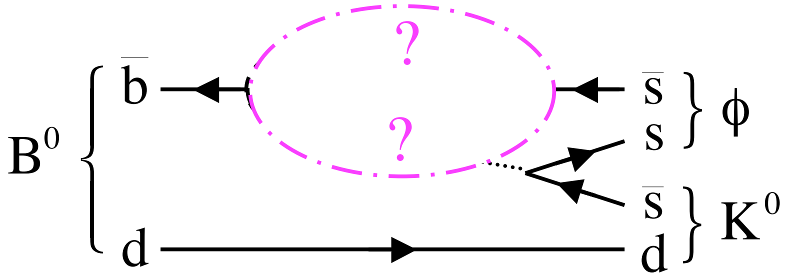
Motivation for continuing the game

- SM cannot be the ultimate theory
  - must be a low-energy effective theory of a more fundamental theory at a higher energy scale, expected to be in the TeV region (accessible at LHC !)
- How can New Physics (NP) be discovered and studied ?
  - NP models introduce new particles, dynamics and/or symmetries at the higher scale. These new particles could
    - be produced and observed as real particles at energy frontier machines (e.g LHC)
    - appear as virtual particles (e.g. in loop processes), leading to observable deviations from the pure SM expectations in flavour physics and CP violation

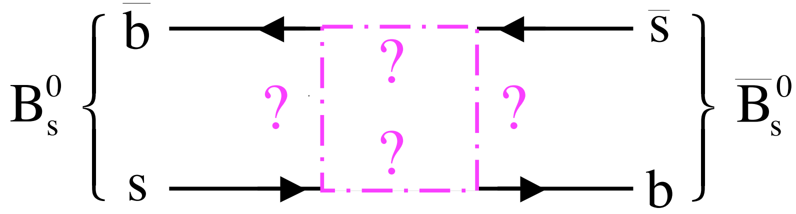
New Physics

$\Delta m_s \neq \Delta m_s^{SM} \propto |V_{ts}^2|$,

$\phi_s \neq \phi_s^{SM} = -\arg(V_{ts}^2) = -2\lambda\eta^2$



$B^0 \to \phi K^0$ decay: "Penguin" diagram



B_s–$\bar{B}_s$ oscillations: "Box" diagram

Strengths of indirect approach

- Can in principle access higher scales and therefore see effect earlier:
  - Third quark family inferred by Kobayashi and Maskawa (1973) to explain small CP violation measured in kaon mixing (1964), but only directly observed in 1977 (b) and1995 (t)
  - Neutral currents (ν+N$\rightarrow$ ν+N) discovered in 1973, but real Z discovered in 1983
- Can in principle also access the phases of the new couplings:
  - NP at TeV scale needs to have a "flavour structure" to provide the suppression mechanism for already observed FCNC processes → once NP is discovered, it is important to measure this structure, including new phases

Complementarity with the "direct" approach:

- If NP found in direct searches at LHC, B (as well as D, K) physics measurements will help understanding its nature and flavour structure

⇒ this workshop to explore such complementarity

Search strategies for NP

in quark flavor sector

- Measure FCNC transitions where NP may show up as a relatively large contribution, especially in $b \to s$ transitions which are poorly constrained by existing data:
  - B_s oscillations (Δm_s) and B_s mixing phase (ϕ_s)
  - $b \to s\gamma$, $b \to s l^+ l^-$, $B_{(s)} \to \mu\mu$
  - Also: rare K and D decays, D^0 mixing

Single measurements with NP discovery potential

- Improve measurement precision of CKM elements
  - Compare two measurements of the same quantity, one which is insensitive and another one which is sensitive to NP:
    - $\sin(2\beta)$ from $B^0 \to J/\psi K_S$ and $\sin(2\beta)$ from $B^0 \to \phi K_S$
    - γ from $B_{(s)} \to D_{(s)}K$ and γ from $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$
  - Measure all angles and sides in many different ways
    - any inconsistency will be a sign of new physics

Precision CKMology, including NP-free determinations of angle γ

Most promising channels

th. error $\lesssim 10\%$
(grey oval) = exp. error $\lesssim 10\%$
(white oval) = exp. error $\sim 30\%$

Table from G. Isidori

FLAVOUR COUPLING:

ELECTROWEAK STRUCTURE	$b \to s$ $(\sim\lambda^2)$	$b \to d$ $(\sim\lambda^3)$	$s \to d$ $(\sim\lambda^5)$
$\Delta F=2$ box	ΔM_{Bs} $A_{CP}(B_s \to \psi\phi)$	ΔM_{Bd} $A_{CP}(B_d \to \psi K)$	ΔM_K, ε_K
$\Delta F=1$ 4-quark box	$B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to \pi\pi$, $B_d \to \rho\pi$, ...	ε'/ε, $K \to 3\pi$, ...
gluon penguin	$B_d \to X_s \gamma$, $B_d \to \phi K$ $B_d \to K\pi$, ...	$B_d \to X_d \gamma$, $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
γ penguin	$B_d \to X_s l^+ l^-$, $B_d \to X_s \gamma$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to X_d \gamma$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, ...
Z^0 penguin	$B_d \to X_s l^+ l^-$, $B_s \to \mu\mu$ $B_d \to \phi K$, $B_d \to K\pi$, ...	$B_d \to X_d l^+ l^-$, $B_d \to \mu\mu$ $B_d \to \pi\pi$, ...	ε'/ε, $K_L \to \pi^0 l^+ l^-$, $K \to \pi\nu\nu$, $K \to \mu\mu$, ...
H^0 penguin	$B_s \to \mu\mu$	$B_d \to \mu\mu$	$K_{L,S} \to \mu\mu$

Still a lot of room for B physics contributions from LHC !

B physics at LHC: (dis)advantages

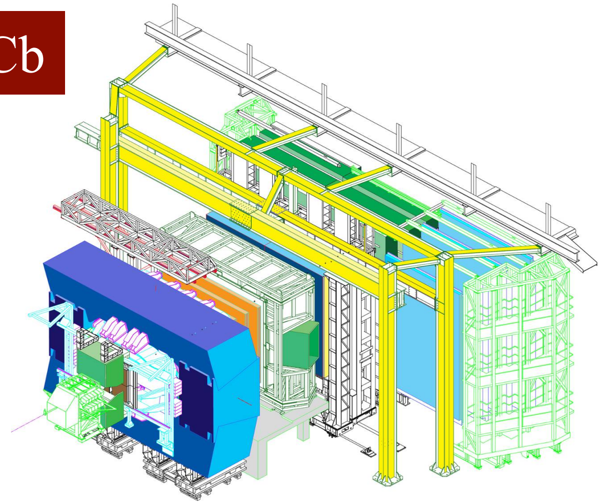
	$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\overline{B}$ PEPII, KEKB	**$pp \rightarrow b\overline{b}X$** ($\sqrt{s}$ = 14 TeV, Δt_{bunch}=25 ns) LHC (LHCb–ATLAS/CMS)	
Production σ_{bb}	1 nb	~500 μb	☺
Typical $b\overline{b}$ rate	10 Hz	100–1000 kHz	
$b\overline{b}$ purity	~1/4	$\sigma_{bb}/\sigma_{inel}$ = 0.6% Trigger is a major issue !	☹
Pileup	0	0.5–5	
b-hadron types	B^+B^- (50%) $B^0\overline{B}^0$ (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 $B^0\overline{B}^0$ pair mixing	Incoherent B^0 and B_s mixing (extra flavour-tagging dilution)	☹
Event structure	$B\overline{B}$ pair alone	Many particles not associated with the two b hadrons	

LHC experiments

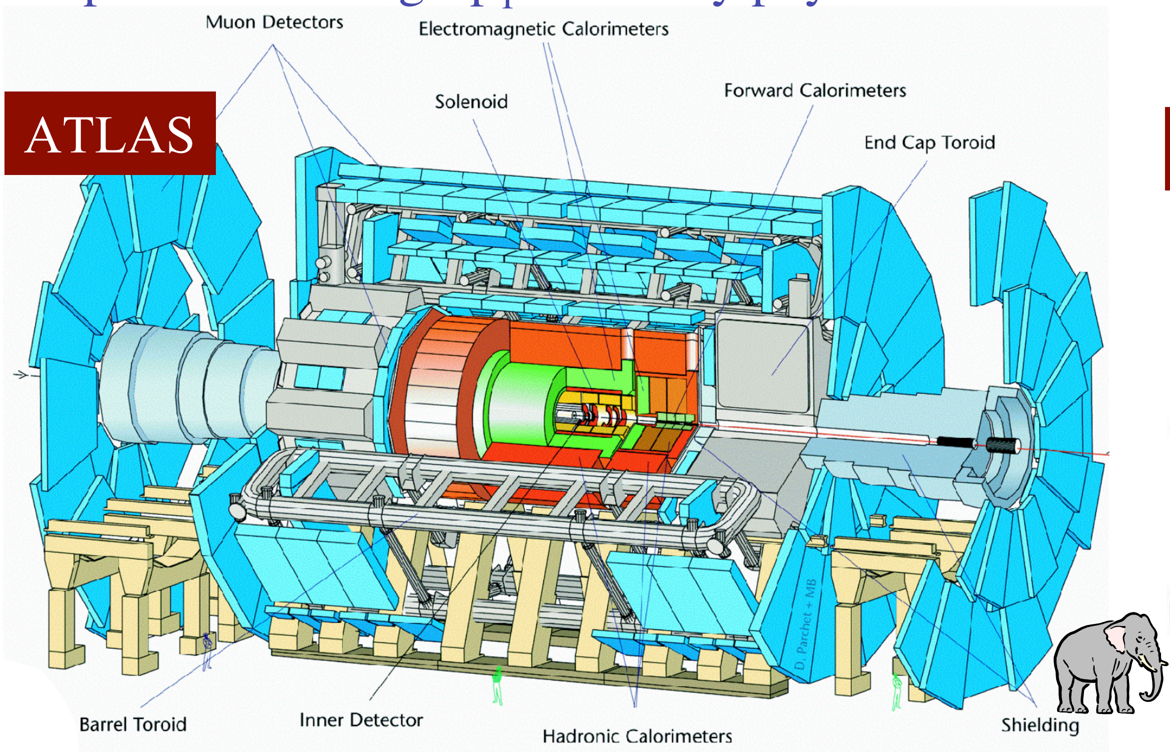
that will do B physics

- LHCb:
  - dedicated B physics experiment
  - (may be the only one running after the B factories, unless Super-B is approved)
- ATLAS/CMS:
  - general purpose experiments,
  - optimized for high-p_T discovery physics at 10^{34} $cm^{-2}s^{-1}$

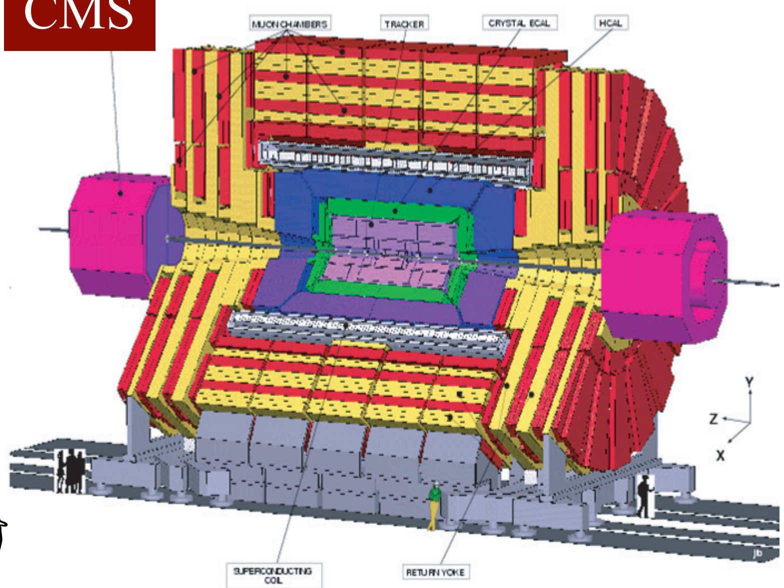
LHCb



ATLAS

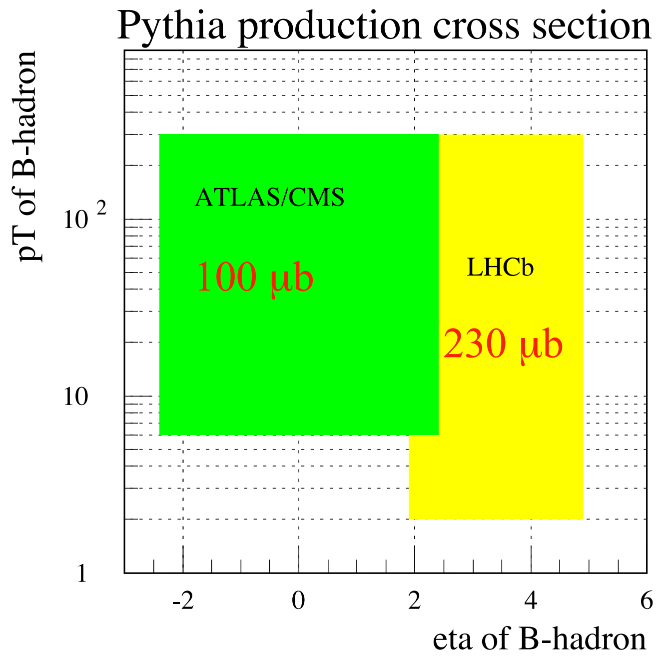


CMS

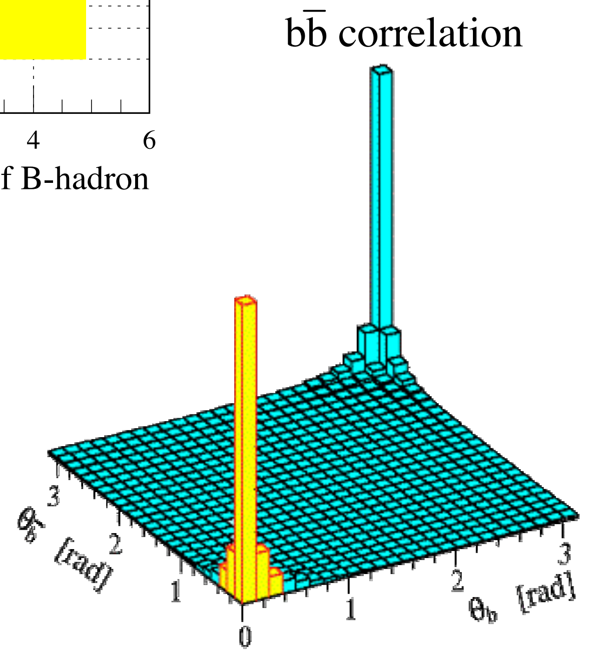


B acceptance

- **ATLAS/CMS:**
  - central detectors, |η|<2.5
  - will do B physics using high-p_T muon triggers, mostly with modes involving dimuon
    - purely hadronic modes triggered by tagging muon

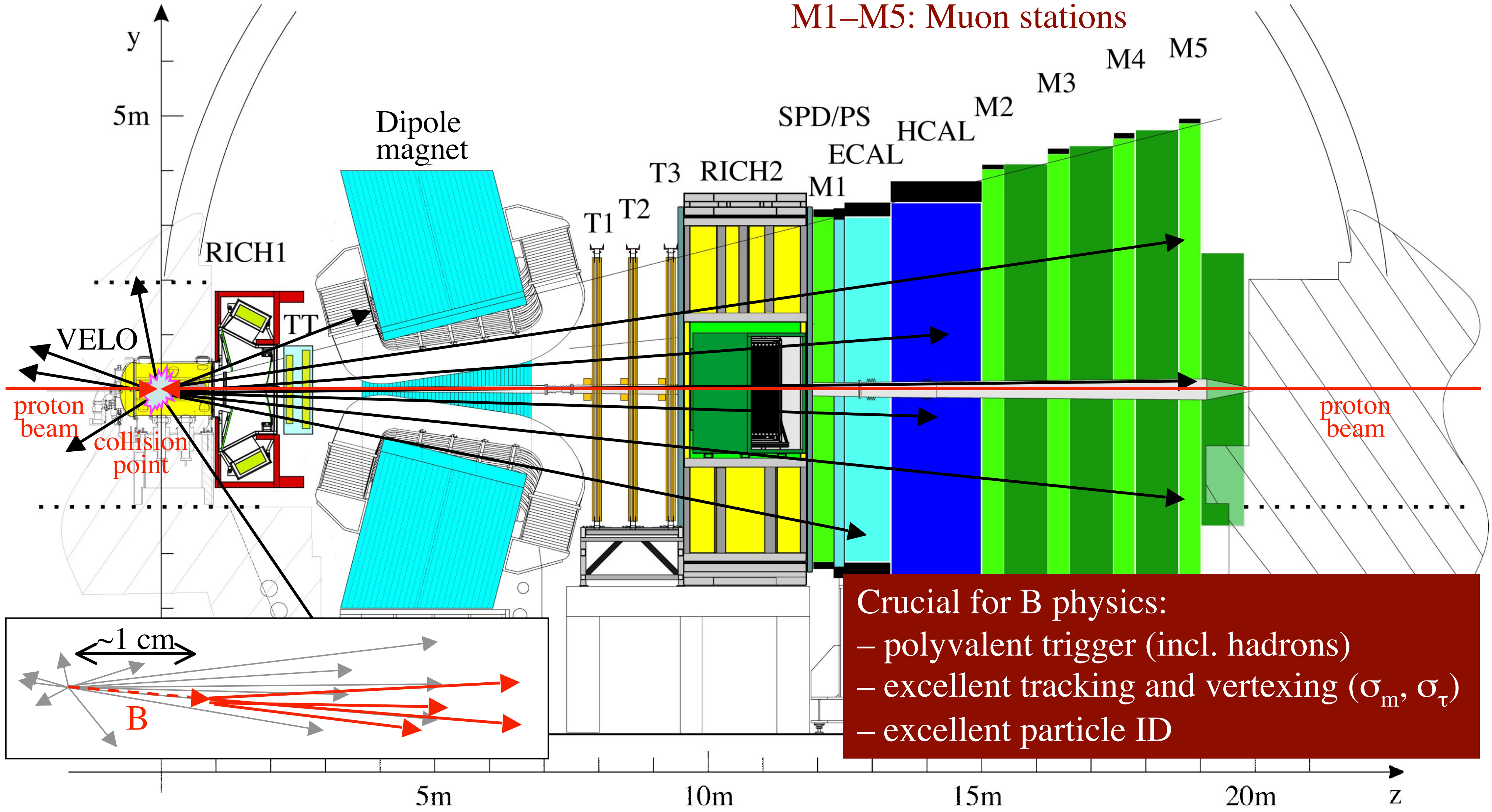


- **LHCb:**
  - designed to maximize B acceptance (within cost and space constraints)
  - forward spectrometer, 1.9 < η < 4.9
    - more b hadrons produced at low angles
    - single arm OK since $b\bar{b}$ pairs produced correlated in space
  - rely on much softer, lower p_T triggers, efficient also for purely hadronic B decays



LHCb spectrometer

VELO: Vertex Locator (around interaction point)
TT, T1, T2, T3: Tracking stations
RICH1-2: Ring Imaging Cherenkov detectors
ECAL, HCAL: Calorimeters
M1–M5: Muon stations



Crucial for B physics:
– polyvalent trigger (incl. hadrons)
– excellent tracking and vertexing (σ_m, σ_τ)
– excellent particle ID

Luminosity and pileup

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

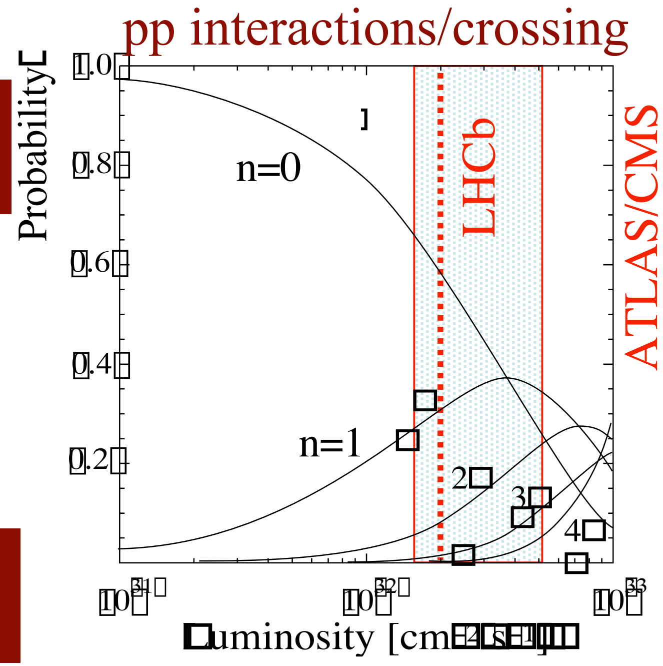
L = instantaneous luminosity
f = non-empty bunch crossing rate
σ_{inel} = 80 mb

- **ATLAS/CMS** (f = 32 MHz)
  - Want to run at highest luminosity available
  - Expect $L < 2 \times 10^{33}$ 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
30 fb^{-1} total at low L

- **LHCb** (f = 30 MHz)
  - L tuneable by defocusing the beams
  - Choose to run at $\langle L \rangle \sim 2\times10^{32}$ 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



(nominal year = 10^7 s)

ATLAS B 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 ($> 2\times10^{33}$ $cm^{-2}s^{-1}$):
    - 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
      - 2nd muon (with lower threshold) in muon RoI
      - Single e/γ or e^+e^- pair in EM RoI
      - Hadronic b decay products in Jet RoI

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 and B physics

- Trigger to cover widest range of discovery physics (Higgs, SUSY, …)
  - Level 1: 3.2μs buffer, → 100 kHz (nominal)
  - HLT (High-Level Trigger): 1s buffer, 40 ms processing, → 100 Hz
- B events:
  - Level 1:
    - single μ (p_T> 14 GeV/c) or di-μ (p_T> 3 GeV/c each)
  - 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 startup)	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)**

custom electronics boards

Hardware trigger
- 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)**

single PC farm of ~ 2000 CPUs

Software trigger
- 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 reconstr.: excl. and incl. streams

↓ **≤ 2 kHz (storage)**

Main changes since original design:

2003: track p_T at 1 MHz
2005: increased output rate
2005: full readout at 1 MHz

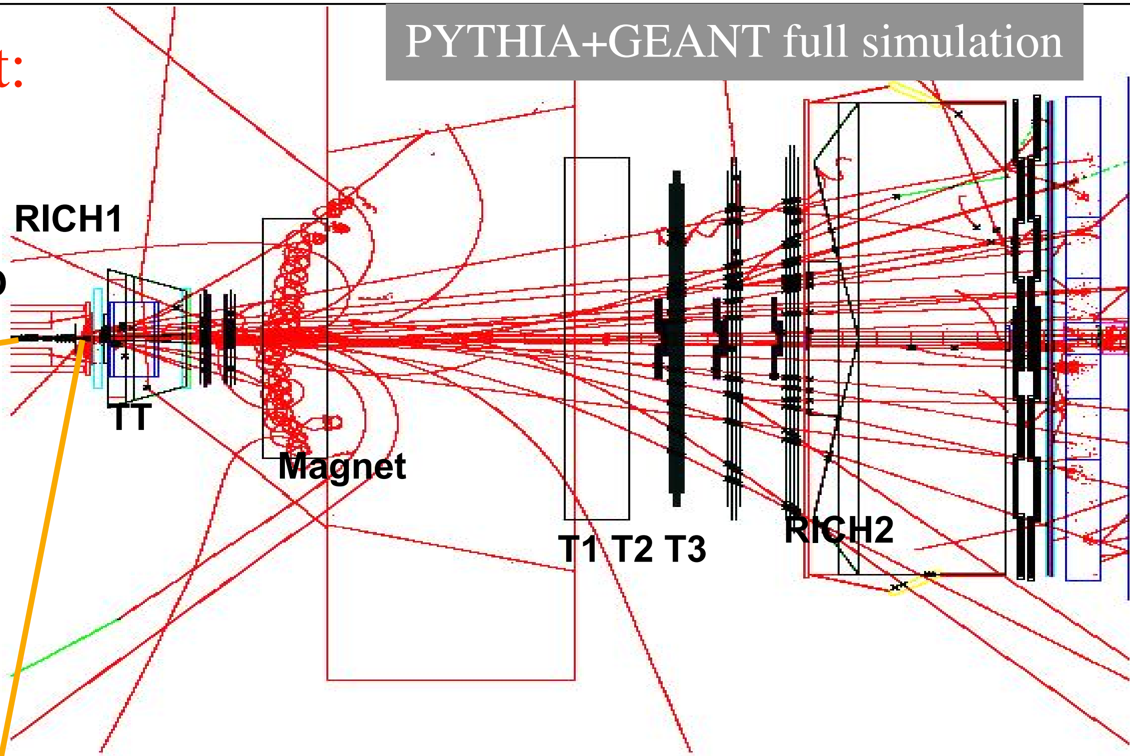
Trigger output rates and physics

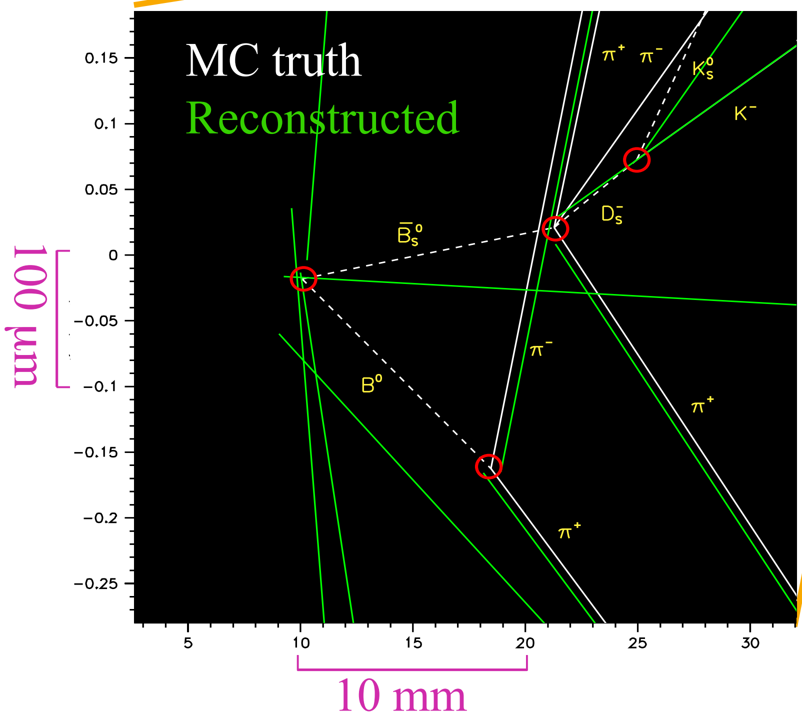
Output rate	Event type	Physics
200 Hz	Exclusive B candidates	B (core program)
600 Hz	High mass di-muons	J/ψ, $b \to J/\psi X$ (unbiased)
300 Hz	D* candidates	Charm
900 Hz	Inclusive b (e.g. $b \to \mu$)	B (data mining)

- Output rates:
  - Rough guess at present (split between streams still to be determined)
  - Large inclusive streams to be used to control calibration and systematics (trigger, tracking, PID, tagging)
- Charm physics possibilities (to be explored):
  - Could trigger on 500M signal $D^* \to D^0(h^+h^-)\pi$ per year
  - D^0 mixing (x and y_{CP}) and CP violation in $D^0 \to K^+K^-$
    - could reach SM levels or close
    - systematics ?

Expected LHCb tracking performance

- **High multiplicity environment:**
  - In a $b\bar{b}$ event, ~30 charged particles traverse the whole spectrometer





- **Full pattern recognition implemented:**
  - Track finding efficiency > 95% for long tracks from B decays (only 4% ghosts for $p_T > 0.5$ GeV/c)
  - $K_S \to \pi^+\pi^-$ reconstruction 75% efficient for decay in the VELO, lower otherwise

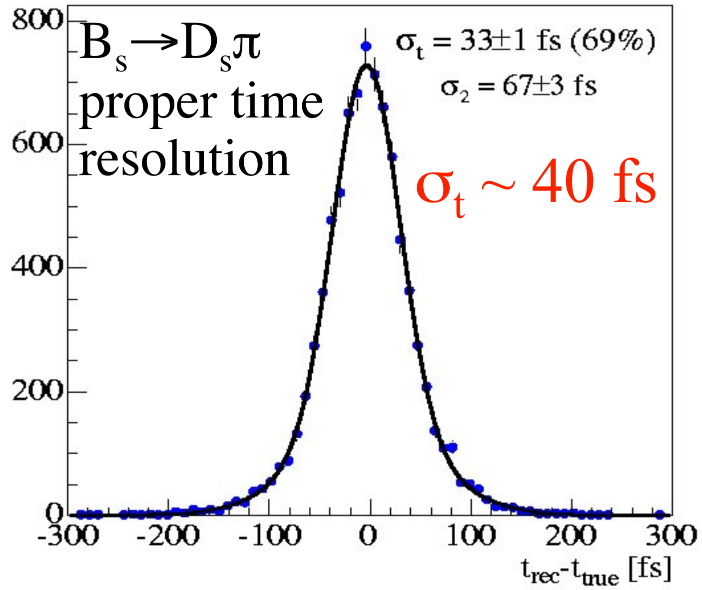
Expected tracking performance

- **Mass resolutions** in MeV/c^2

	ATLAS	CMS	LHCb	
$B_s \to \mu\mu$	80	46	18	
$B_s \to D_s \pi$	46	–	14	
$B_s \to J/\psi\, \phi$	38	32	16	without J/ψ mass constraint
$B_s \to J/\psi\, \phi$	17	13	8	with J/ψ mass constraint

- **Proper time resolution:**

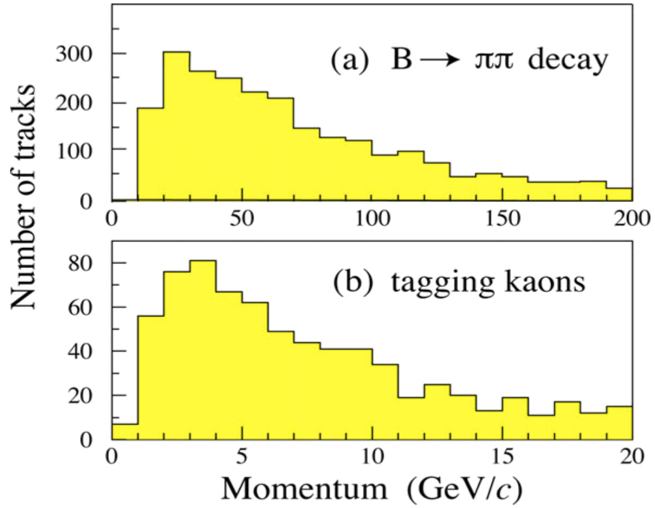
ATLAS: $\sigma_t \sim 100$ fs (was 70 fs)
CMS: $\sigma_t \sim 100$ fs
LHCb: $\sigma_t \sim 40$ fs →

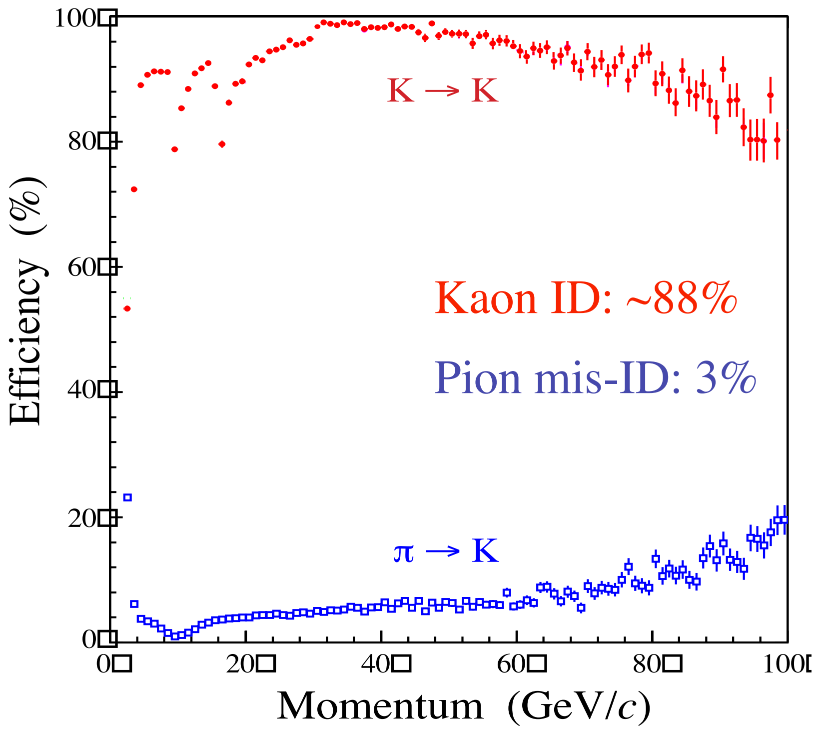


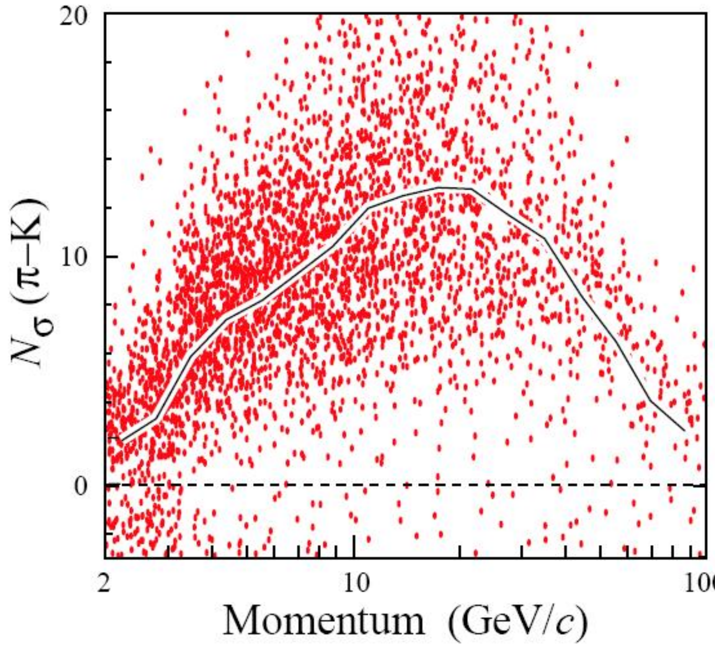
Good proper time resolution essential for time-dependent B_s measurements !

LHCb particle ID performance

- Fully simulated pattern recognition in two LHCb RICHes:
  - Reconstruct rings around tracks found in tracking
  - Good K-π separation achievable in 2–100 GeV/c range



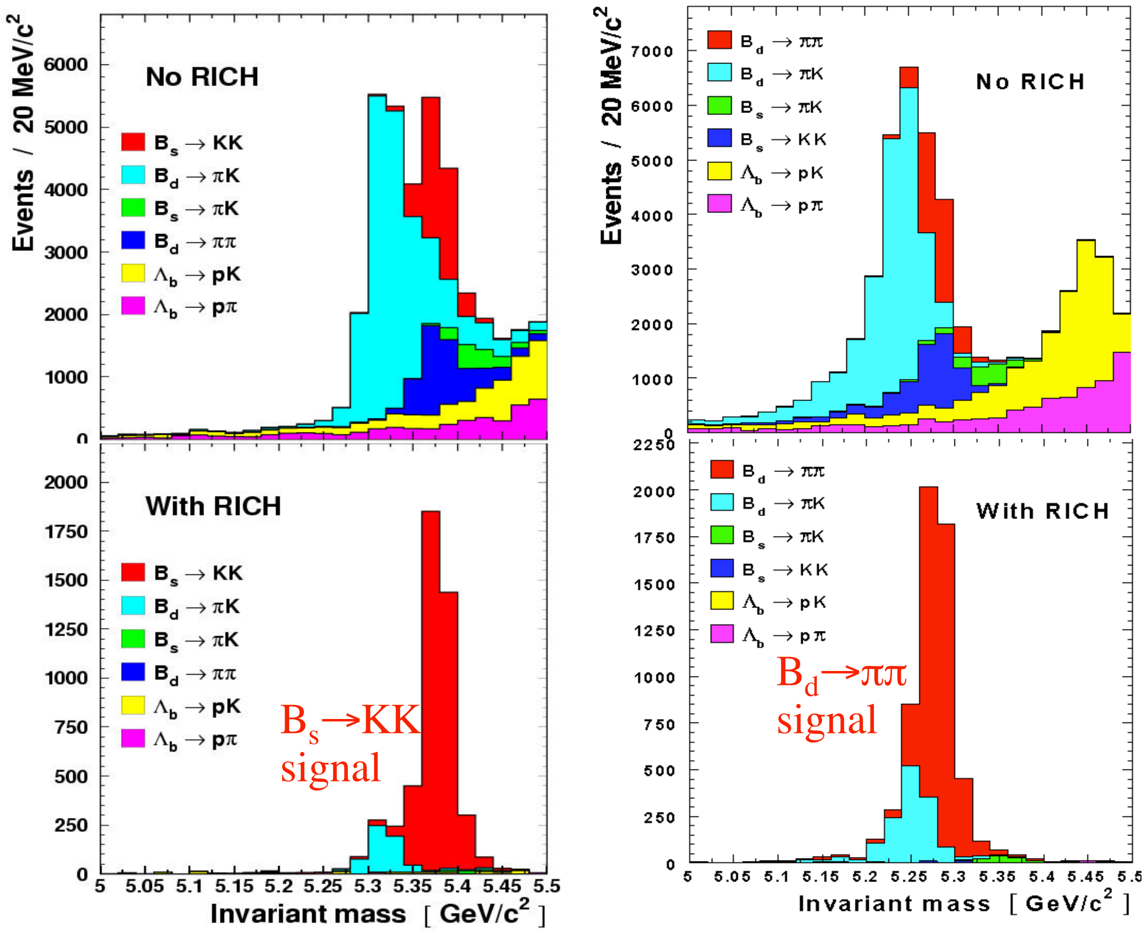


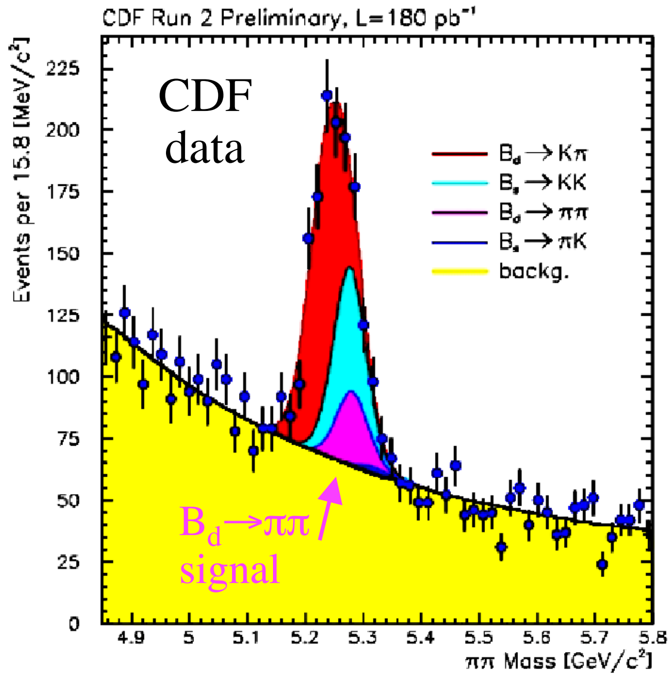


$B_{(s)} \rightarrow h^+h^-$ modes

- Clean separation of different $B_{(s)} \rightarrow hh$ modes: a unique feature of LHCb at hadron colliders

LHCb full simulation

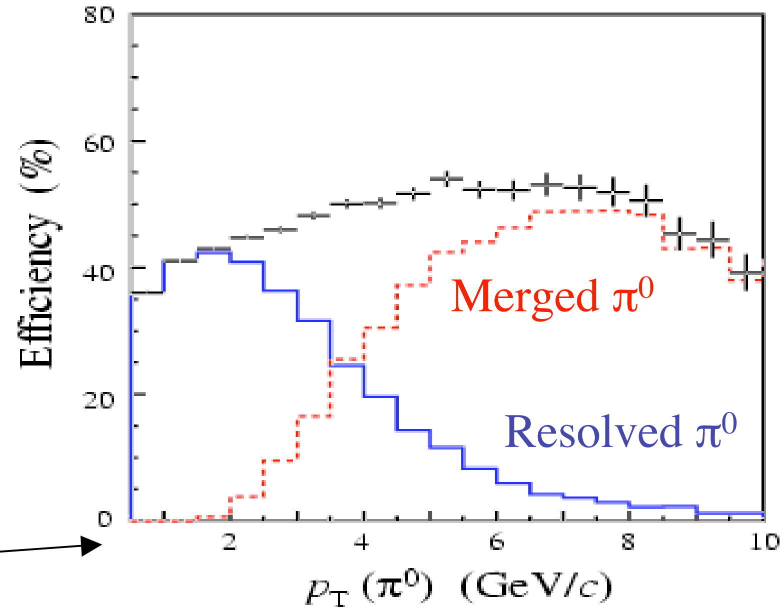


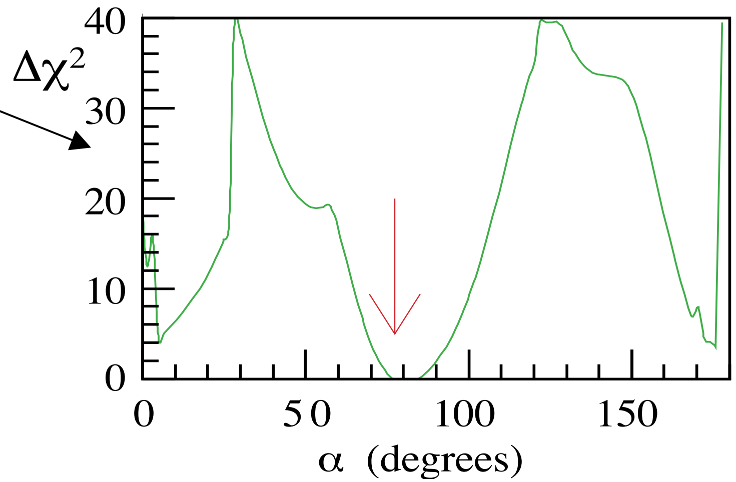


Neutral reconstruction at LHCb

- Neutral π reconstruction:
  - Use calorimeter clusters unassociated to charged tracks
  - Reconstruct π^0 as two separate (resolved) clusters or a single (merged) cluster
- Example:
  - Time-dependent Dalitz plot analysis of $B^0 \to \rho\pi \to \pi^+\pi^-\pi^0$ for extraction of α, amplitudes & strong phases (Snyder & Quinn)
    - Reasonable efficiency for π^0
    - 14k signal events/year, S/B ~ 1.3
    - 11-parameter fit studied with toy Monte Carlo (incl. resonant and non-resonant background)

  $\to \sigma_{stat}(\alpha) \sim 10°$ in one year

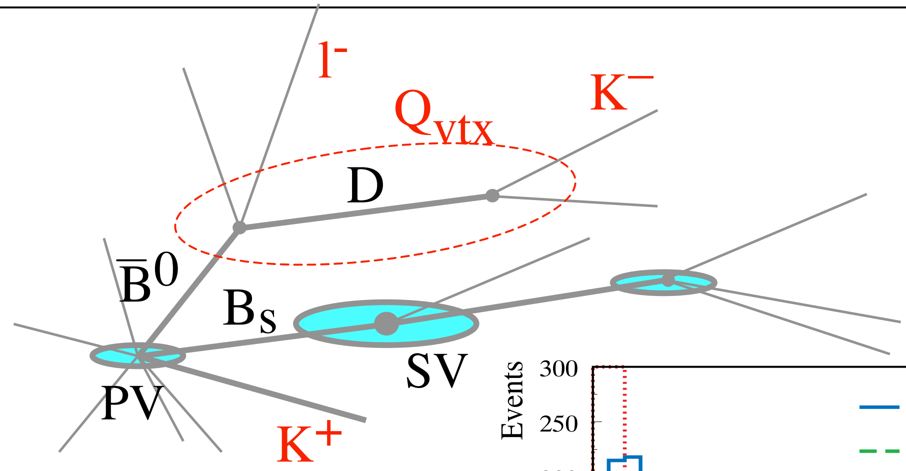




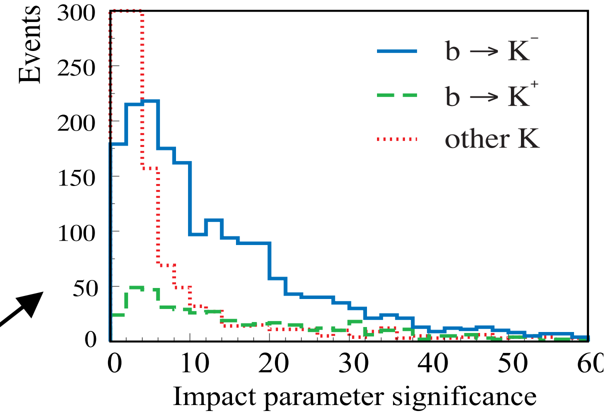
- Can also reconstruct modes with $\eta \to \gamma\gamma$
- Modes with multiple neutrals (π^0, η, K_S, …) will be challenging at LHCb

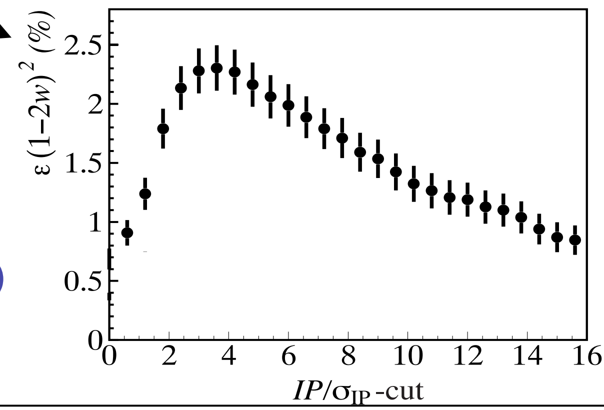
Flavour tagging

	$\varepsilon D^2 = \varepsilon(1-2w)^2$ 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)



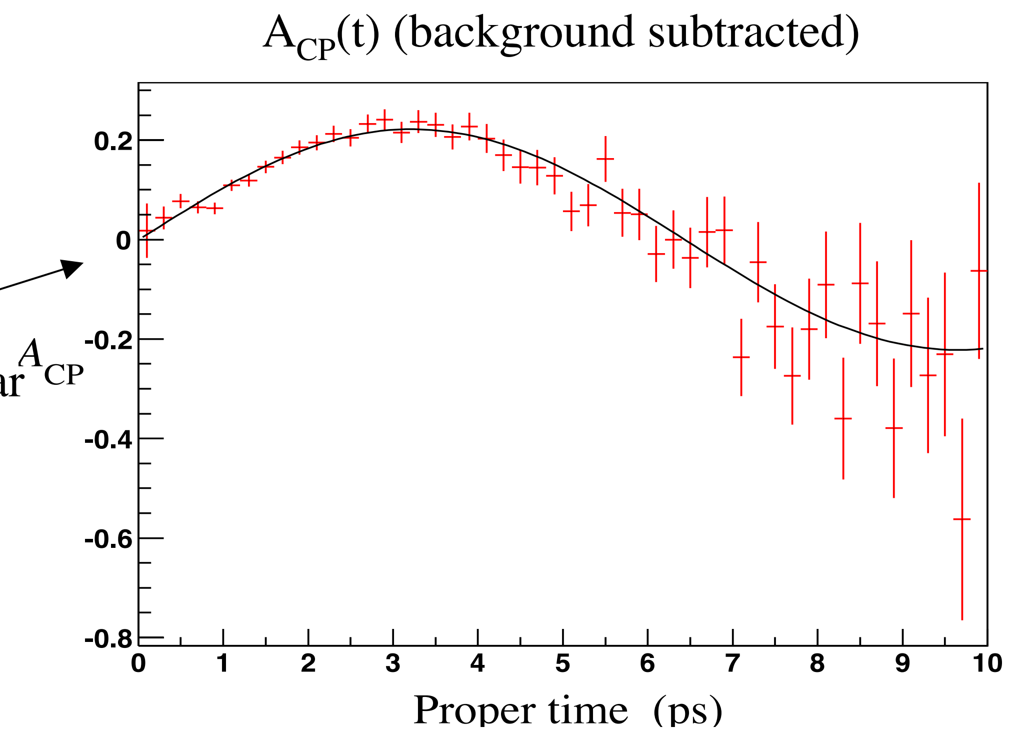
- LHCb:
  - Most powerful tag is opposite kaon (from b→c→s)
  - Combined **$\varepsilon D^2 \sim 6\%$ (B_s) or $\sim 4\%$ (B^0)**
  - Recent neural network approach leads to ~9% for B_s
- Compare with:
  - CDF/D0 achieved ~1.5% (expect ~3% for B_s in Run IIb)
  - B factories achieved ~ 30%





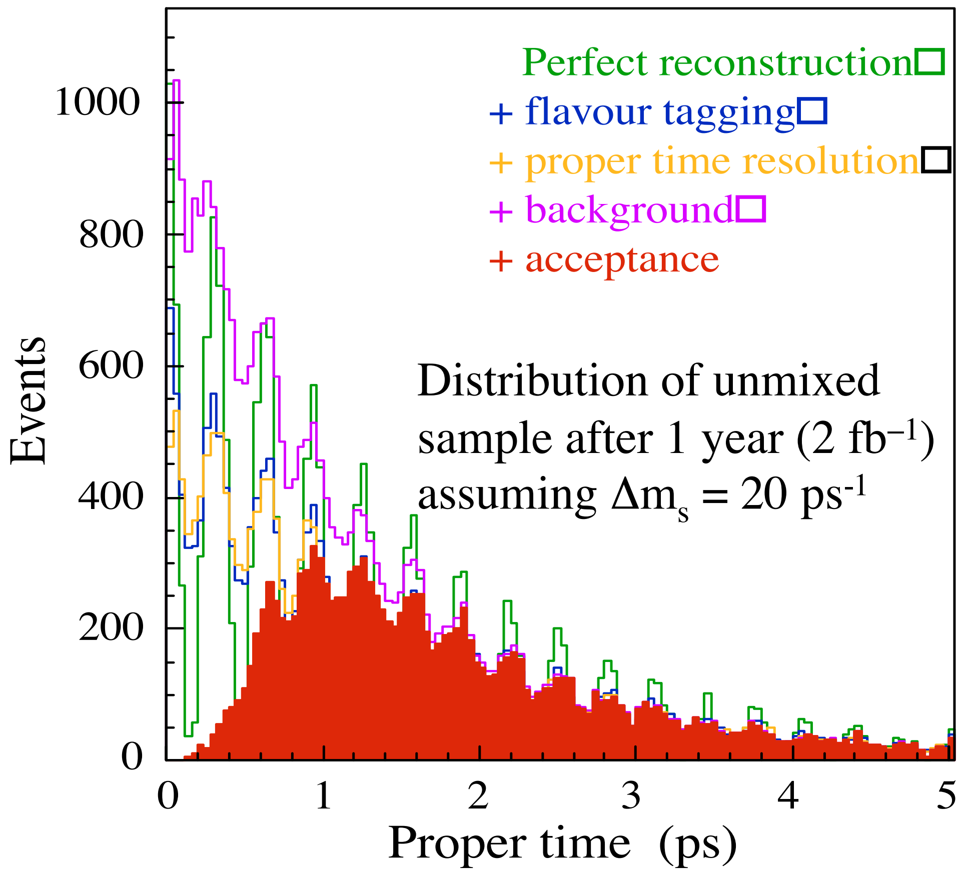
sin(2β) with $B^0 \to J/\psi\, K_S$

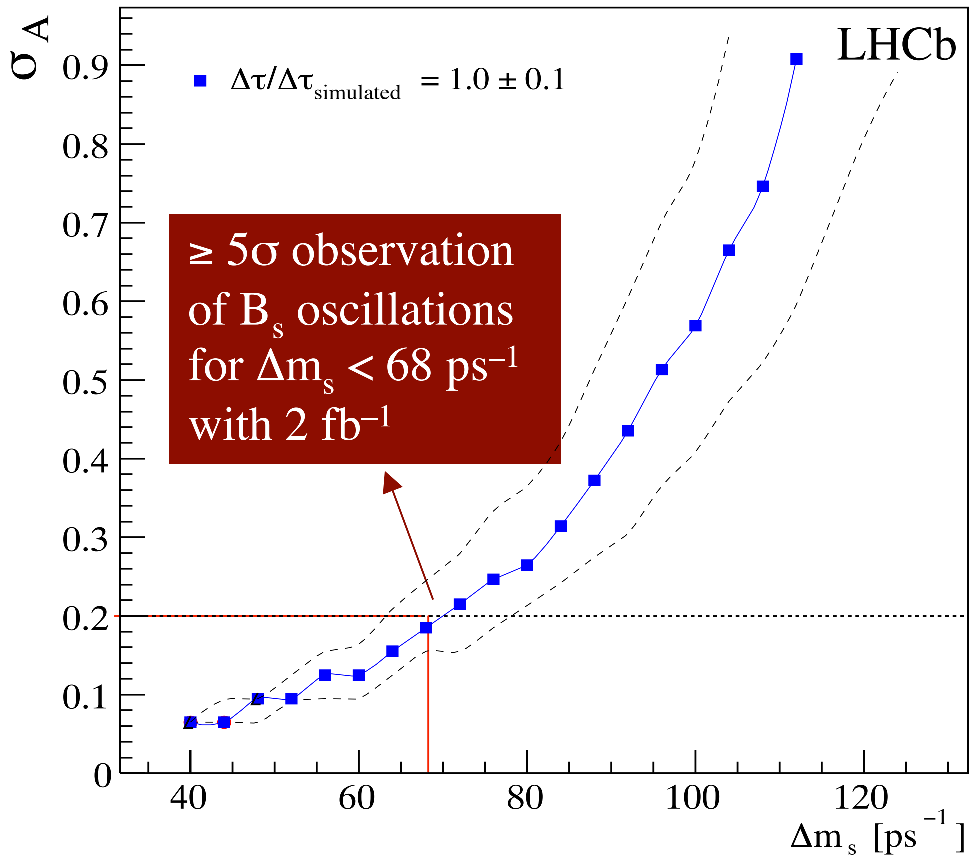
- Expected to be one of the first CP measurements:
  - Demonstrate tagging performance and ability for CP physics
  - Tagging systematics:
    - Extract tagging performance from control channels (e.g $B^+ \to J/\psi K^+$ and $B^0 \to J/\psi K^{*0}$ in this case)
    - Tagging performance depends on how event is triggered (e.g. on signal or on rest of the event)
  - Sensitivity:
    - LHCb expects ~240k signal events/year $\Rightarrow \sigma_{stat}(\sin(2\beta)) \sim 0.02$
    - Similar at ATLAS
  - Can also push further the search for direct CP violating term $\propto \cos(\Delta m_d t)$



B_s oscillations

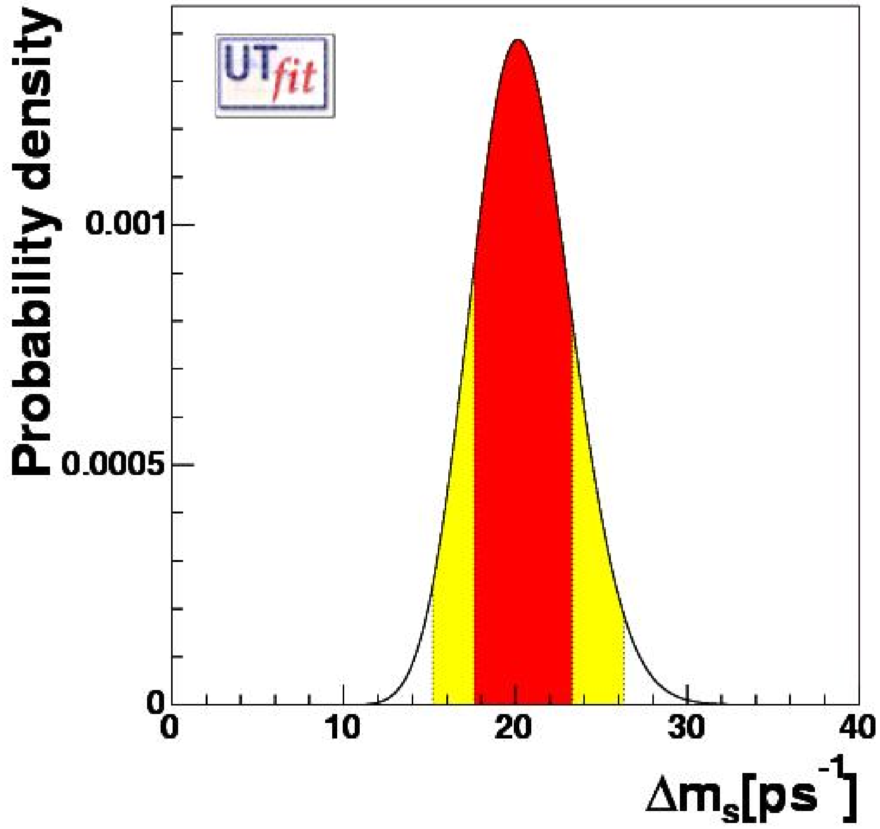
- Measurement of Δm_s is one of the first LHCb physics goals
  - Expect 80k $B_s \to D_s^-\pi^+$ events per year (2 fb^{-1}), average $\sigma_t \sim 40$ fs
  - S/B ~ 3 (derived from 10^7 fully simulated inclusive $b\bar{b}$ events)





B_s oscillations

- Current SM expectation of Δm_s (UTFit collab.):

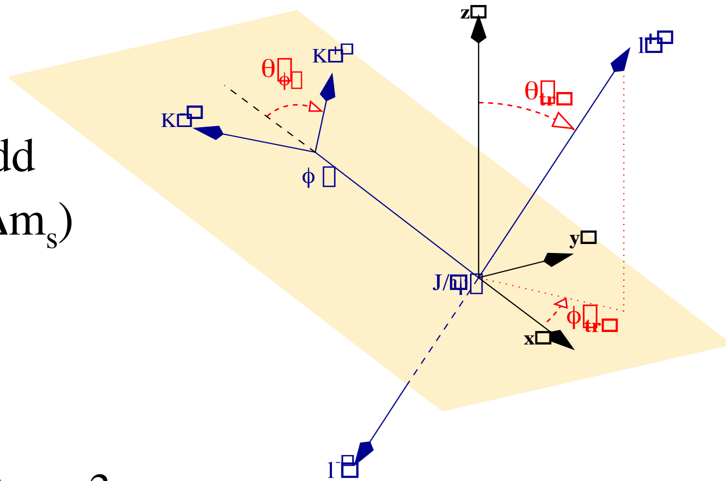


- LHC reach for 5σ observation:

ATLAS/CMS	**30 fb^{-1}**	**3 years**	→
LHCb	**0.25 fb^{-1}**	**1/8 year**	→

ϕ_s and $\Delta\Gamma_s$ from $B_s \to J/\psi\phi$, …

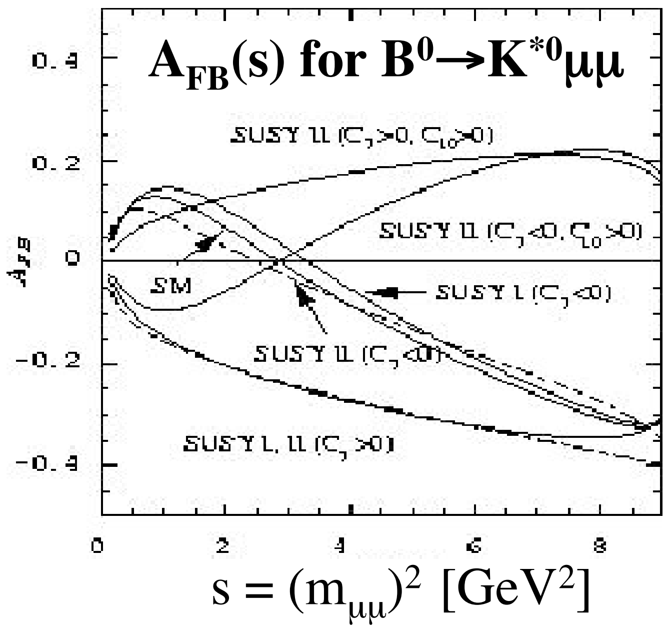
- $B_s \to J/\psi\phi$ is the B_s counterpart of $B^0 \to J/\psi K_S$:
  - B_s mixing phase ϕ_s is very small in SM: $\phi_s = -\arg(V_{ts}^2) = -2\lambda\eta^2 \sim -0.04$
    $\Rightarrow$ sensitive probe for new physics
  - $J/\psi\phi$ final state contains two vectors:
    - Angular analysis needed to separate CP-even and CP-odd
    - Fit for $\sin\phi_s$, $\Delta\Gamma_s$ and CP-odd fraction (needs external Δm_s)

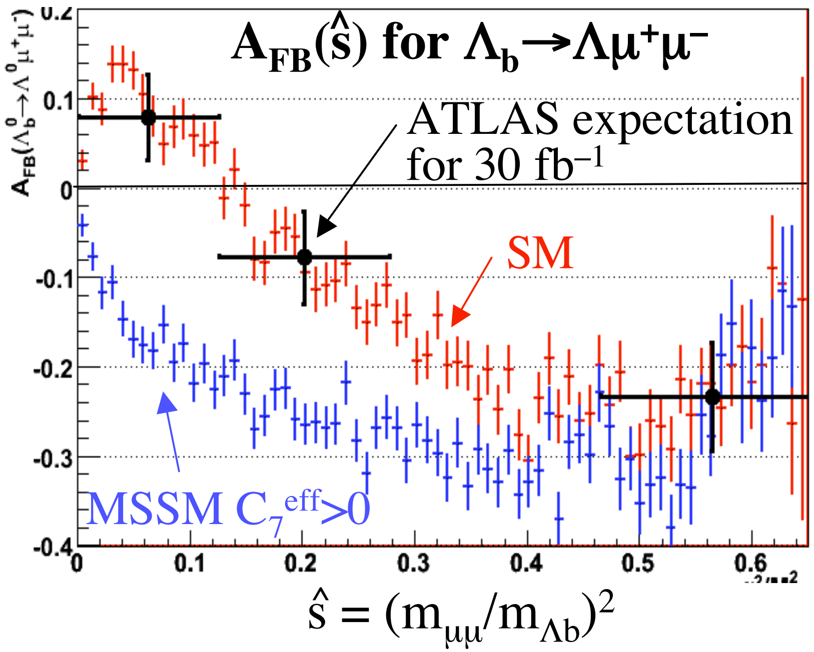


- Sensitivity (at $\Delta m_s = 20\ \text{ps}^{-1}$):
  - LHCb:
    - 125k $B_s \to J/\psi\phi$ signal events/year (before tagging), $S/B_{bb} > 3$
      $\Rightarrow \sigma_{stat}(\sin\phi_s) \sim 0.031$, $\sigma_{stat}(\Delta\Gamma_s/\Gamma_s) \sim 0.011$ (1 year, 2 fb^{-1})
    - can also add pure CP modes such as $J/\psi\eta$, $J/\psi\eta'$, $\eta_c\phi$ (small improvement)
      $\Rightarrow \sigma_{stat}(\sin\phi_s) \sim 0.013$ (first 5 years) $\to$ will eventually cover down to ~SM
  - ATLAS:
    - similar signal rate as LHCb, but $\sigma_{stat}(\sin\phi_s) \sim 0.14$ (1 year, 10 fb^{-1})
  - CMS:
    - > 50k events/year, sensitivity study in progress

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

- Suppressed decays, SM BR ~ 10^{-6}
- Forward-backward asymmetry $A_{FB}(s)$ in the $\mu\mu$ rest-frame is sensitive probe of New Physics:
  - Zero can be predicted at LO with no hadronic uncertainties, depends on Wilson coefficients





- LHCb:
  - 4400 $B^0 \to K^{*0}\mu^+\mu^-$ events/2fb^{-1}, S/B > 0.4
  - After 5 years: zero of $A_{FB}(s)$ located to ±0.53 GeV^2 → determine C_7^{eff}/C_9^{eff} with 13% error (SM)
- ATLAS:
  - 1000 $B^0 \to K^{*0}\mu^+\mu^-$ events/10fb^{-1}, S/B > 1
- Other exclusive $b \to s\mu\mu$ feasible (B_s, Λ_b)

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

- Very rare decay, sensitive to new physics:
  - BR ~ 3.5×10^{-9} in SM, can be strongly enhanced in SUSY
  - Current limit from Tevatron (CDF+D0): 1.5×10^{-7} at 95% CL
- LHC should have prospect for significant measurement, but difficult to get reliable estimate of expected background:
  - LHCb: Full simulation: 10M inclusive bb events + 10M b→μ, b→μ events (all rejected)
  - ATLAS: 80k bb→μμ events with generator cuts, efficiency assuming cut factorization
  - CMS: 10k b→μ, b→μ events with generator cuts, trigger simulated at generator level, efficiency assuming cut factorization

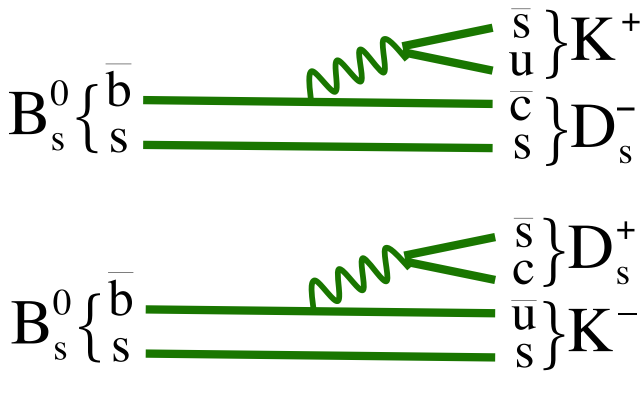
	1 year	$B_s \to \mu^+\mu^-$ signal (SM)	b→μ, b→μ background	Inclusive bb background	All backgrounds
LHCb	2 fb^{-1}	17	< 100	< 7500	
ATLAS	10 fb^{-1}	7	< 20		
CMS (1999)	10 fb^{-1}	7	< 1		

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

γ from $B_s \rightarrow D_s K$

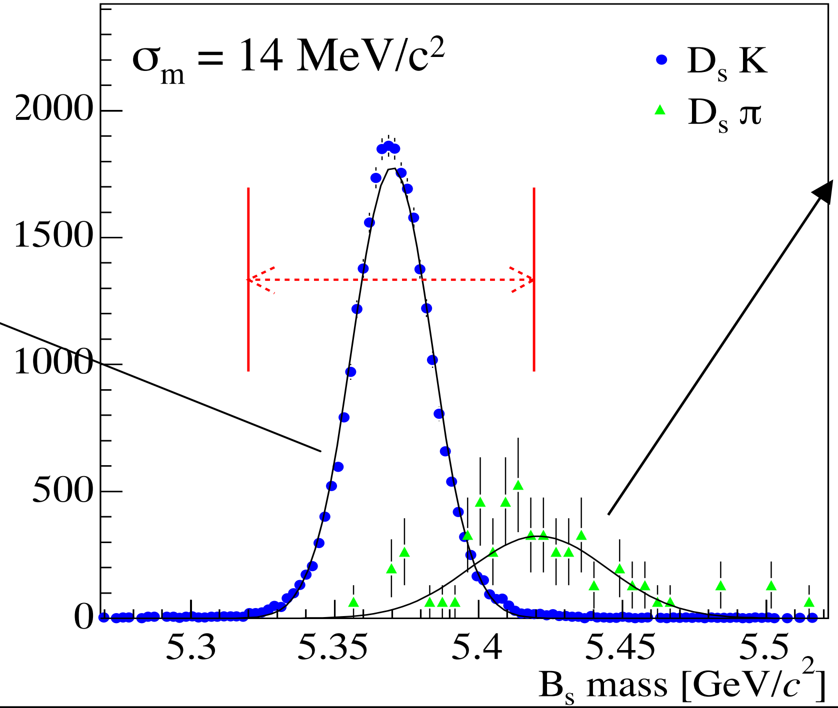
LHCb

- Two tree decays ($b \rightarrow c$ and $b \rightarrow u$), which interfere via B_s mixing:
  - can determine $\phi_s + \gamma$, hence γ in a very clean way
  - similar to $2\beta+\gamma$ extraction with $B^0 \rightarrow D^*\pi$, but with the advantage that the two decay amplitudes are similar ($\sim\lambda^3$) and that their ratio can be extracted from data



Expect 5400 signal events/year

$S/B_{bb} > 1$ at 90% CL (estimated from one MC bb events after cuts, not shown here)

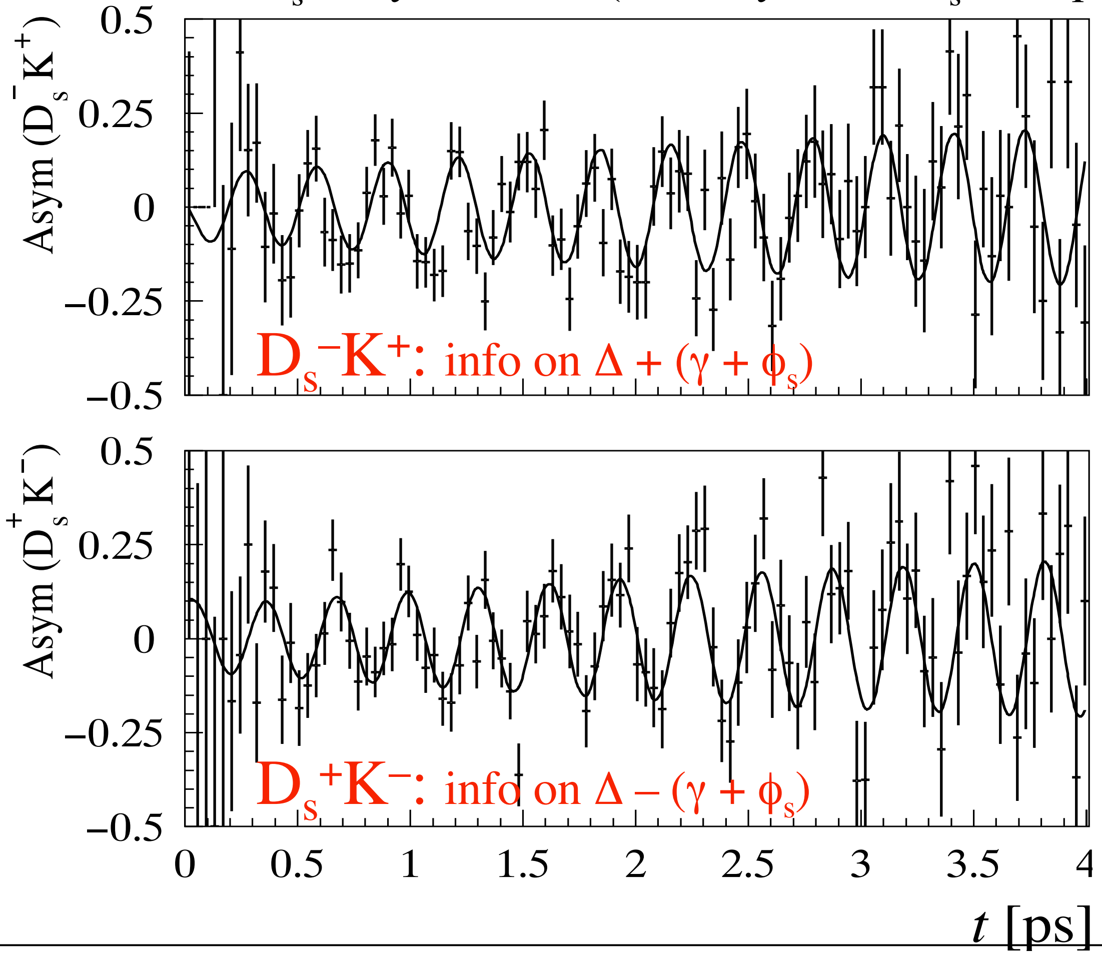


$B_s \rightarrow D_s^-\pi^+$ background (with ~ 12 × larger BR) suppressed using PID:
$\rightarrow$ residual contamination only ~ 10%

γ from $B_s \to D_s K$ LHCb

- Fit the 4 tagged time-dependent rates:
  - Extract $\phi_s + \gamma$, strong phase difference Δ, amplitude ratio
  - $B_s \to D_s\pi$ also used in the fit to constrain other parameters (mistag rate, Δm_s, $\Delta\Gamma_s$ …)

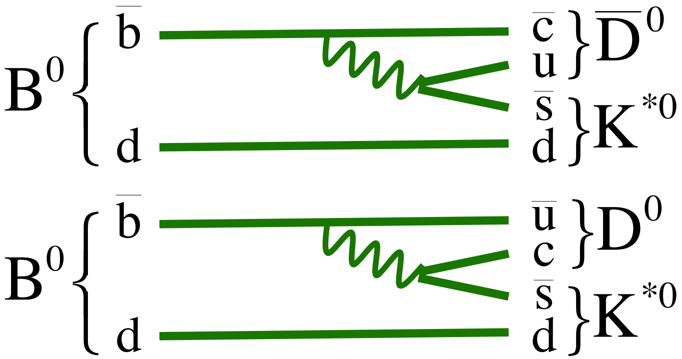
Both D_sK asymmetries (after 5 years, $\Delta m_s = 20\ ps^{-1}$)

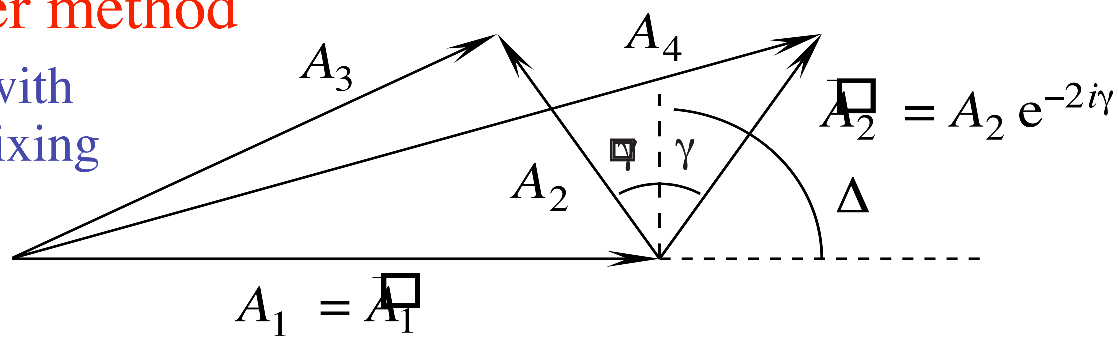


- $\sigma(\gamma) \sim 14°$ in one year (if $\Delta m_s = 20\ ps^{-1}$)
  - expected to be statistically limited
  - 8-fold ambiguity can be resolved (→ 2-fold) if $\Delta\Gamma_s$ large enough, or using $B^0 \to D\pi$ together with U-spin symmetry (Fleischer)

γ from $B^0 \to D^0 K^{*0}$ LHCb

- Dunietz variant of Gronau-Wyler method
  - Two colour-suppressed diagrams with $|A_2|/|A_1| \sim 0.4$ interfering via D^0 mixing





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

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

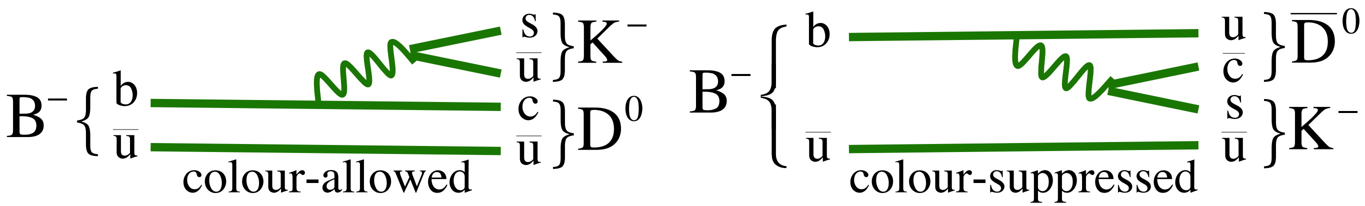
$A_3 = \sqrt{2}\, A(B^0 \to D_{CP} K^{*0}) = A_1 + A_2$, because $D_{CP} = (\bar{D}^0 + D^0)/\sqrt{2}$

- Measure 6 decay rates (self-tagged + time-integrated):
  - LHCb expectations for 2 fb^{-1} (γ=65°, Δ=0)

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

$\to \sigma(\gamma) \sim 8°$ in one year

γ from $B^{\pm} \rightarrow DK^{\pm}$ LHCb



Weak phase difference = γ
Magnitude ratio = $r_B \sim 0.15$

- New proposed clean measurement of γ for LHCb, based on ADS (Atwood, Dunietz, Soni) method:
  - Measure the relative rates of $B^- \rightarrow DK^-$ and $B^+ \rightarrow DK^+$ decays with neutral D's observed in final states such as:
    - $K^-\pi^+$ and $K^+\pi^-$, $K^-\pi^+\pi^-\pi^+$ and $K^+\pi^-\pi^+\pi^-$, K^+K^-
  - These depend on:
    - Relative magnitude, weak phase and strong phase between $B^- \rightarrow D^0K^-$ and $B^- \rightarrow \bar{D}^0K^-$
    - Relative magnitudes (known) and strong phases between $D^0 \rightarrow K^-\pi^+$ and $\bar{D}^0 \rightarrow K^-\pi^+$, and between $D^0 \rightarrow K^-\pi^+\pi^-\pi^+$ and $\bar{D}^0 \rightarrow K^-\pi^+\pi^-\pi^+$
  - Can solve for all unknowns, including the weak phase γ
- Candidate for LHCb's statistically most precise determination of γ
  - $\sigma(\gamma) \sim 5°$ in one year ? To be studied during this workshop …
    [also $B \rightarrow D^0K$, with $D^0 \rightarrow K_S\pi\pi$ Dalitz analysis]

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

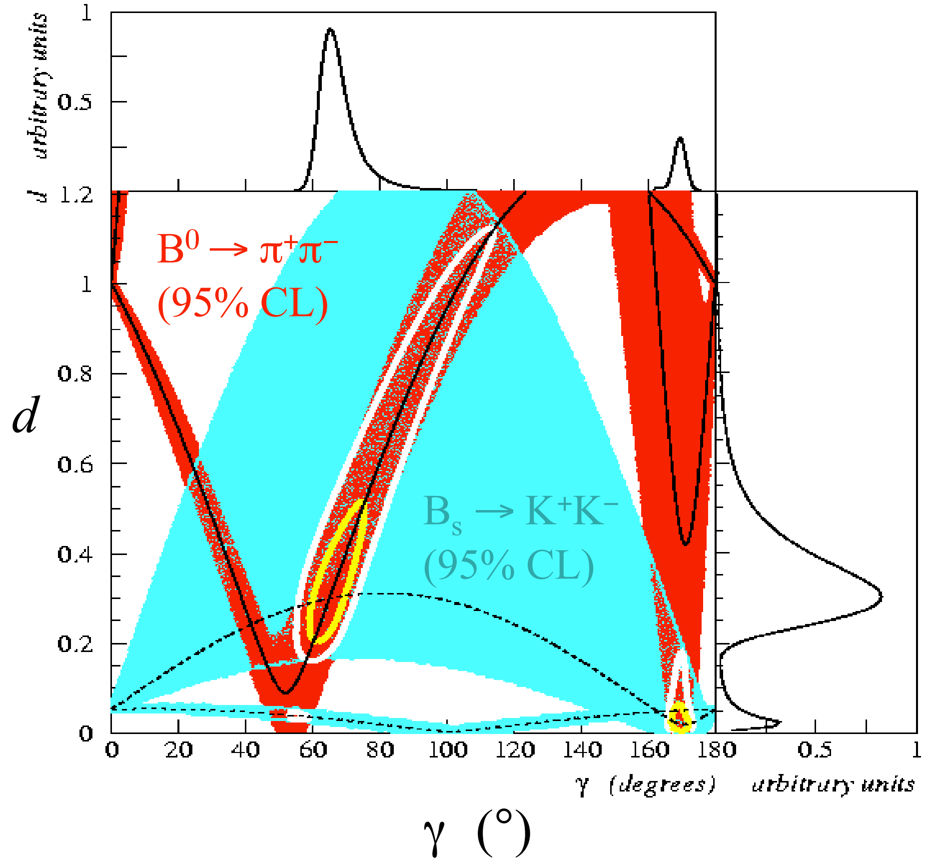
- For each mode, measure time-dependent CP asymmetry:

$$A_{CP}(t) = A_{dir}\cos(\Delta m t) + A_{mix}\sin(\Delta m t)$$

  - A_{dir} and A_{mix} depend on mixing phase, angle γ, and ratio of penguin to tree amplitudes $= d\,e^{i\theta}$
- Exploit U-spin symmetry (Fleischer):
  - Assume $d_{\pi\pi}=d_{KK}$ and $\theta_{\pi\pi}=\theta_{KK}$
  - 4 measurements and 3 unknowns (taking mixing phases from other modes) $\to$ can solve for γ
- LHCb expectations (one year):
  - 26k $B^0 \to \pi^+\pi^-$
  - 37k $B_s \to K^+K^-$

  $\to \sigma(\gamma) \sim 5°$

    - Uncertainty from U-spin assumption
    - Sensitive to new physics in penguins



Conclusion

- The hadronic flavour sector will surely contribute significantly to the overall LHC effort to find and study physics beyond the SM:
  - New physics will be chased at LHC in loop B decays
    - **A few superb (highly-sensitive) $b \to s$ observables are accessible: B_s mixing magnitude and phase, exclusive $b \to s\mu\mu$, $B \to \mu\mu$**
    - Large phase space can already be covered with the first 10^7 s of data
  - LHCb will improve precision on CKM angles
    - **Several γ measurements from tree decays only**: $\sigma_{stat}(\gamma)$ ~2.5° in 5 years
    - May reveal inconsistencies with other/indirect measurements after several years
  - Looking forward to end of LHC machine installation and first collisions in 2007
    - LHCb aiming for complete detector at end of 2006, ready to exploit nominal luminosity from day 1
    - CMS aiming for complete detector in early 2008, ATLAS/CMS will contribute in specific areas mostly during the startup years