B physics prospects at LHCb

XLIst Rencontres de Moriond
QCD and high energy hadronic interactions

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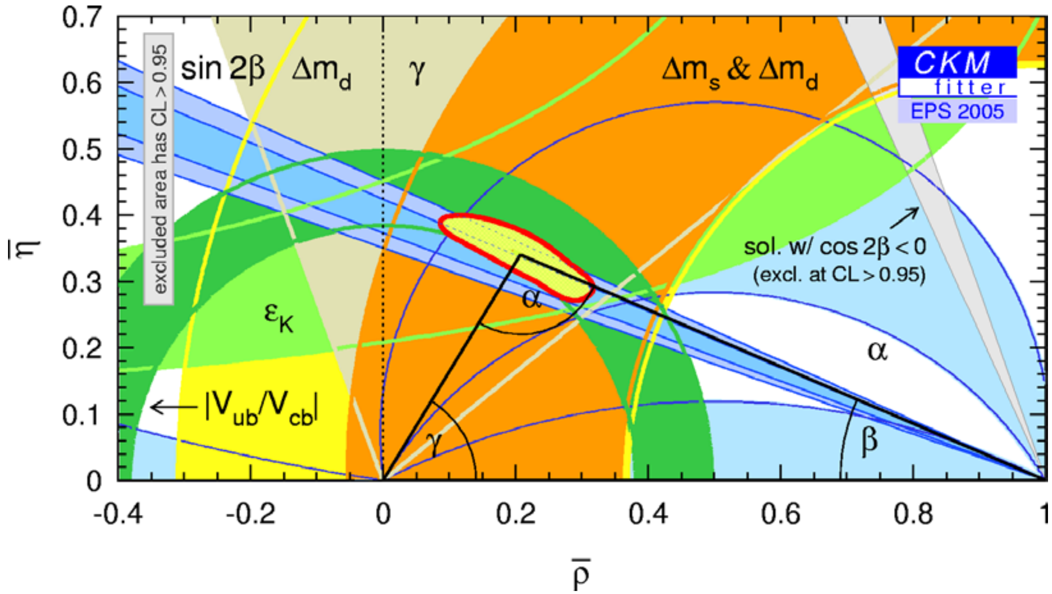
Tomáš Laštovička (CERN)

Overview

1. Introduction
   - status present, motivation
   - new physics searches
   - B physics at LHC
2. LHCb experiment
3. Physics performance
   - sin 2β measurement
   - measurements of Δm_s, ϕ_s and $\Delta\Gamma_s$
   - measurements of γ
4. Summary

CKM picture

- BABAR and BELLE
  - unitarity traingle well constrained within the standard model
  - room for improvements [measurement of γ]
- How accurate is the CKM picture?
- Is there any place for new physics still?

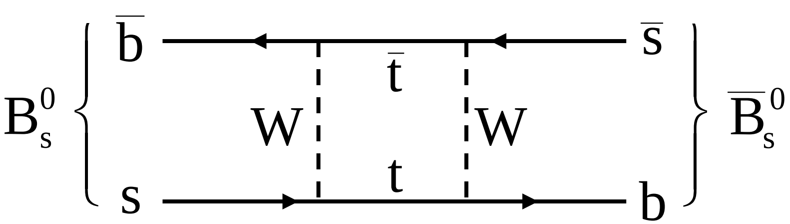


$$\bar{\varrho} = \varrho(1 - \frac{\lambda^2}{2}) \qquad \bar{\eta} = \eta(1 - \frac{\lambda^2}{2})$$

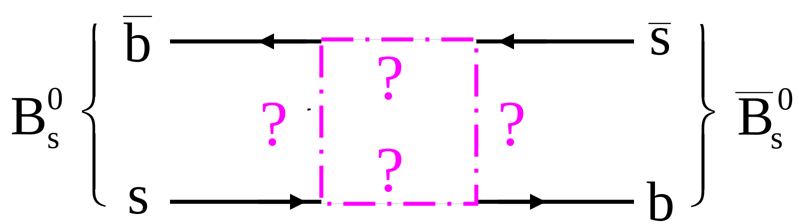
New Physics at LHCb

- Standard Model is a low energy effective approximation of more ultimate theory at a higher energy scale [expected to be in the TeV region – LHC accessible]
- New Physics can be discovered and studied
  - direct observation: new particles are produced and observed as real particles
  - indirect approach: new particles appear as virtual particles (e.g. in loops) and thus may lead to deviations of observables from Standard Model predictions.

For instance “Penguin diagrams” or “box diagrams”:



B_s–$\bar{B}_s$ oscillations



New physics? $\Delta m_s \neq \Delta m_s^{SM}$

Indirect approach

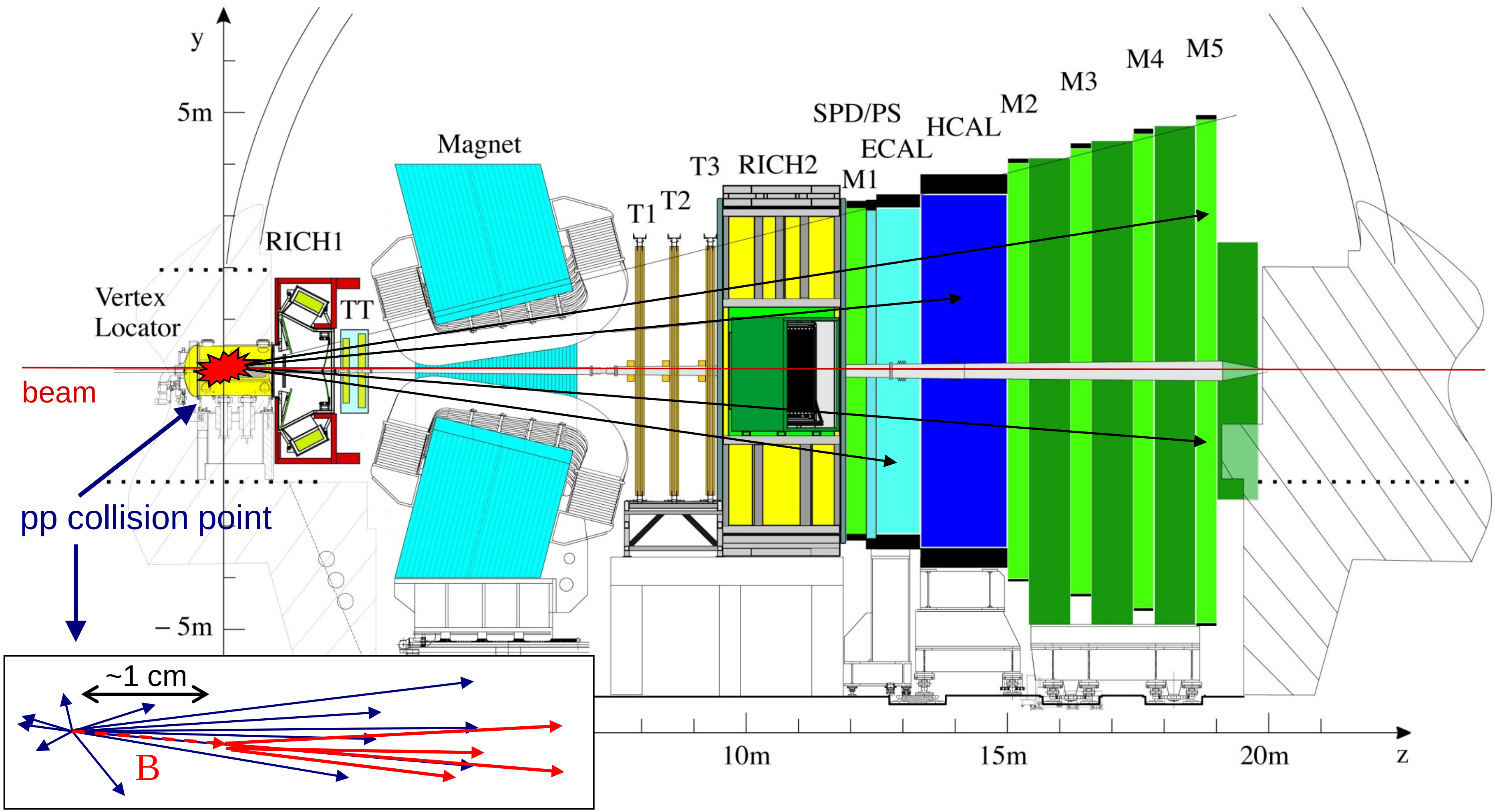
- Allows to access high energy scales sooner and thus to see possible new physics effects earlier
- Can in principle also access the phases of the new couplings:
  - NP at TeV scale needs to have a “flavour structure” to provide the suppression mechanism for already observed FCNC processes
  - once NP is discovered, it is important to measure this structure, including new phases
- Complementary to direct observations
  - may help to understand their nature and flavour structure

B physics: LHC vs B-factories

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

LHCb experiment

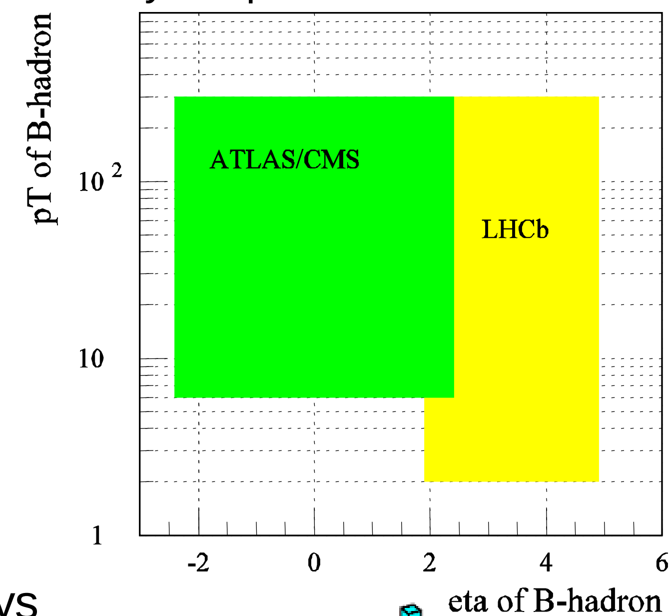
Vertex Locator: VELO [around interaction point]
TT, T1, T2, T3: Tracking stations
RICH1-2: Ring Imaging Cherenkov detectors
ECAL, HCAL: Calorimeters
M1–M5: Muon stations



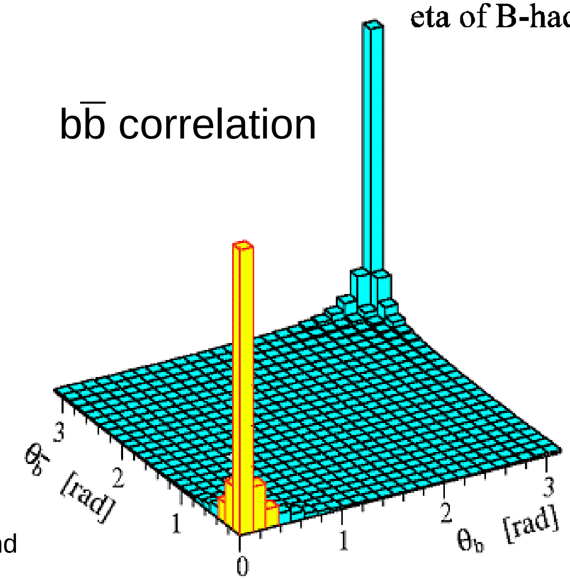
B acceptance

- LHCb
  - designed to maximize B acceptance
    [within cost and space constraints]
  - forward spectrometer, $1.9 < \eta < 4.9$
    - more b hadrons produced at low angles
    - single arm OK since bb pairs produced correlated in space
  - rely on relatively soft higt p_T triggers, efficient also for purely hadronic B decays
  - 1 year of running = ~2 fb^{-1}
    nominal luminosty: 2.10^{32} $cm^{-2}s^{-1}$

Pythia production cross section



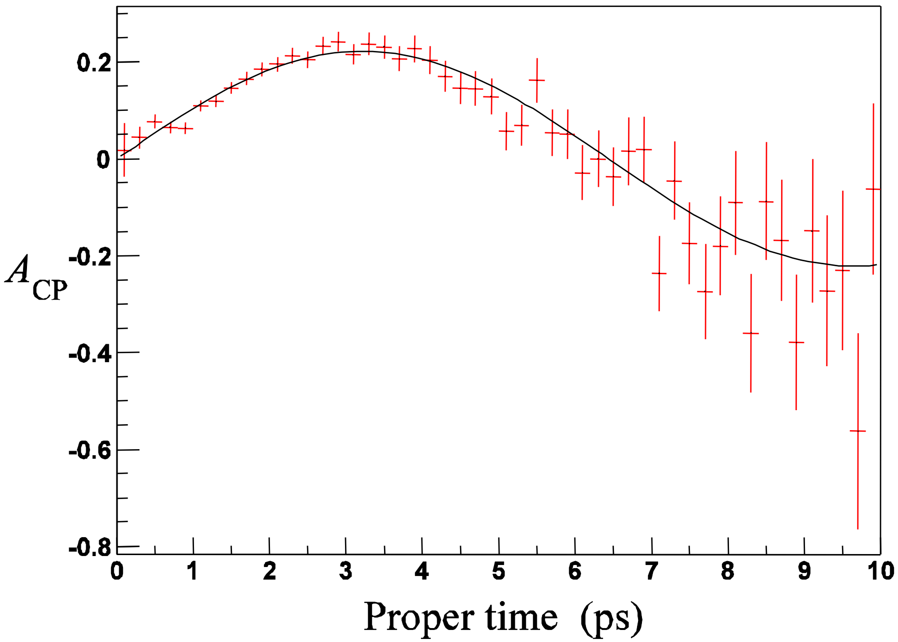
$b\bar{b}$ correlation



Measurement of sin 2β with $B^0 \to J/\psi K_S$

- One of the first CP measurements
  - golden mode, very well measured by b-factories
  - not the main physics goal at LHCb
  - will be an important check of CP analyses and of tagging performance
  - can search for direct CP violating term $\propto \cos \Delta m_d t$
- Expect 240k reconstructed $B^0 \to J/\psi K_S$ events/year
- Precision $\sigma_{stat}(\sin 2\beta) \sim 0.02$ in one year of data taking
  [currently $\sigma(\sin 2\beta) \sim 0.04$]

$A_{CP}(t)$ - background subtracted

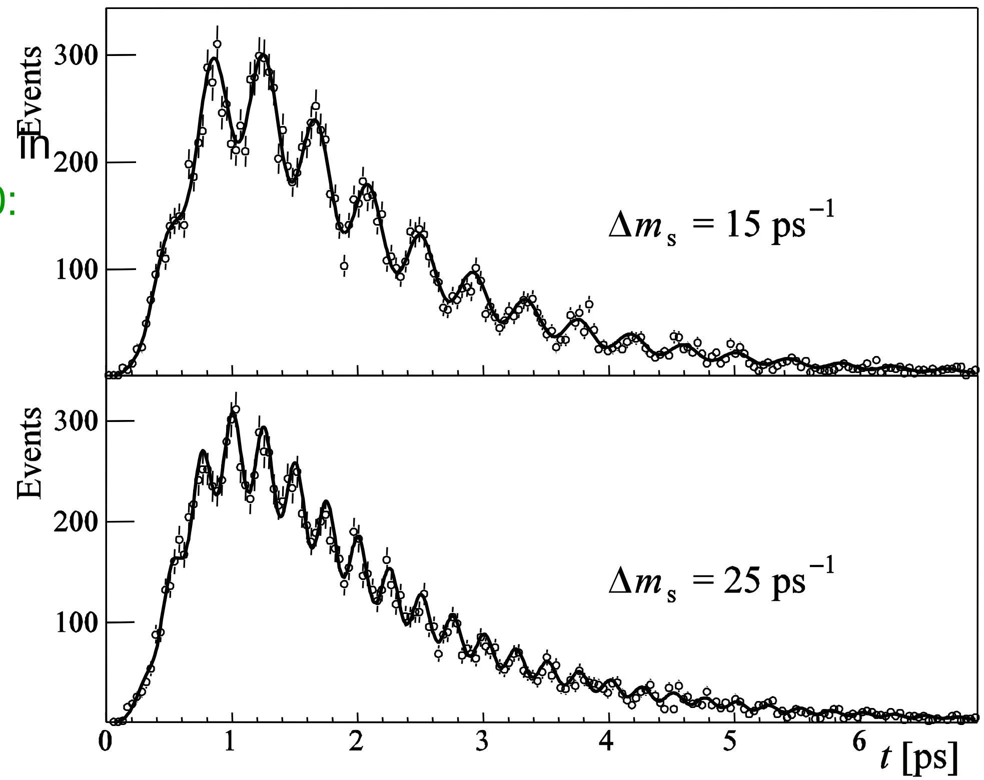


Measurement of Δm_s from B_s oscillations

- One of the first LHCb physics goals
  - important measurement
  - aiming for 5σ observation for Δm_s < 68 ps^{-1} [in one year]
  - LHCb could exclude full SM range
  - Once observed, precise value is obtained: $\sigma_{stat}(\Delta m_s) \sim 0.01$ ps^{-1} in one year of data taking [D0: $\sigma_{stat}(\Delta m_s) \sim 1$ ps^{-1}]
- Once oscillations are observed CP asymmetry measurements follow

$B_s \to D_s^- \pi^+$

Distribution of unmixed sample after 1 year (2 fb^{-1}), ~80k events

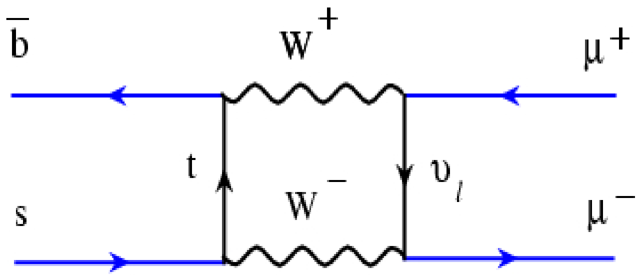


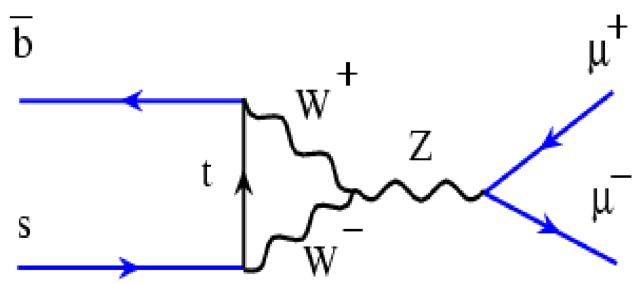
ϕ_s and $\Delta\Gamma_s$ from $B_s \to J/\psi\phi$, …

- $B_s \to J/\psi\,\phi$ is the B_s counterpart of the golden mode $B^0 \to J/\psi K_S$
  - CP asymmetry measures ϕ_s, the phase of B_s oscillation
  - ϕ_s is very small in SM: $\phi_s = -\arg(V_{ts}^2) = -2\lambda\eta^2 \sim -0.04$
  - sensitive probe for the new physics
  - final state contains CP-even and CP-odd contributions
  - fit for sin ϕ_s, $\Delta\Gamma_s$ and CP-odd fraction [needs external Δm_s]
- Sensitivity [assuming $\Delta m_s = 20\ ps^{-1}$]
  - 125k 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]
  - pure CP modes can also be added [e.g. $J/\psi\eta$ - 7k events/year]
    $\Rightarrow \sigma_{stat}(\sin\phi_s) \sim 0.013$ [first 5 years]

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

- Very rare decay
  - BR ~ 3.5×10^{-9} in SM, can be strongly enhanced in SUSY
  - sensitive to new physics
  - current limit from Tevatron (CDF+D0): 1.5×10^{-7} at 95% CL
- LHCb should have prospect for significant measurement, but difficult to get reliable estimate of expected background
  - aim for 2σ measurement in 2 years



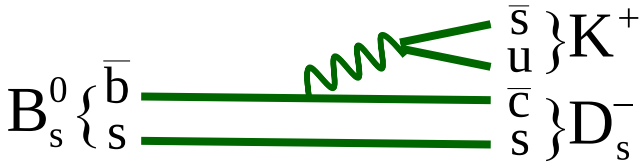


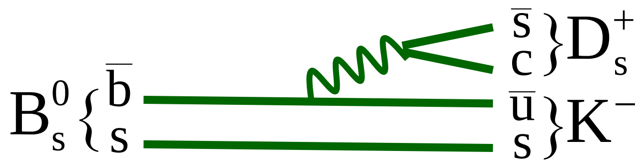
Measurements of γ

- from $B_s \to D_s K$
  - $\sigma(\gamma) \sim 14°$ in one year [$\Delta m_s = 20\ ps^{-1}$]
  - tree decay
- from $B^0 \to D^0 K^{*0}$
  - $\sigma(\gamma) \sim 8°$ in one year
  - both γ and strong phase Δ to be extracted
- from $B^{\pm} \to DK^{\pm}$
  - $\sigma(\gamma) \sim 5°$ precision in one year
  - tree decay
- from $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$
  - $\sigma(\gamma) \sim 5°$ precision in one year
  - sensitive to New Physics
  - nice yields: 26k $B^0 \to \pi^+\pi^-$ events/year
    37k $B_s \to K^+K^-$ events/year
- $B \to D^0K$ Dalitz ($D^0 \to K_s\pi\pi, K_sKK$) under investigation

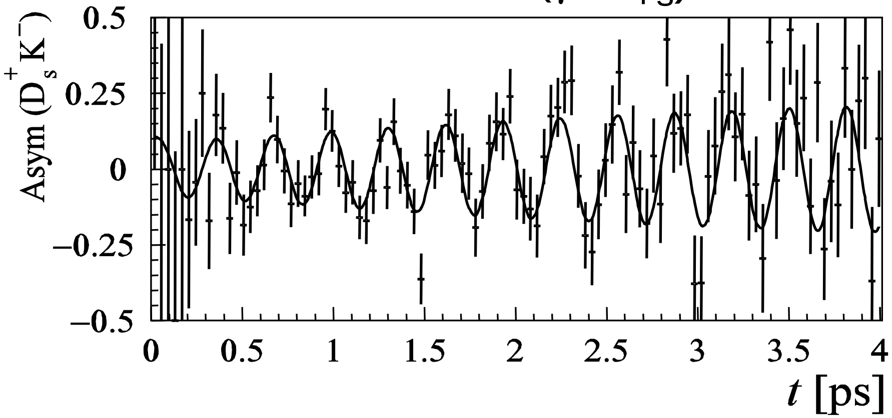
Measurements of γ from $B_s \to D_s K$

- from $B_s \to D_s^- K^+$ and $B_s \to D_s^+ K^-$
  - both tree decays, interference via B_s mixing
  - insensitive to new physics
  - measures $\gamma + \phi_s$ and thus γ
  - ϕ_s will be determined using $B_s \to J/\psi\phi$
  - very little theoretical uncertainty
- $\sigma(\gamma) \sim 14°$ in one year [$\Delta m_s = 20\ ps^{-1}$]

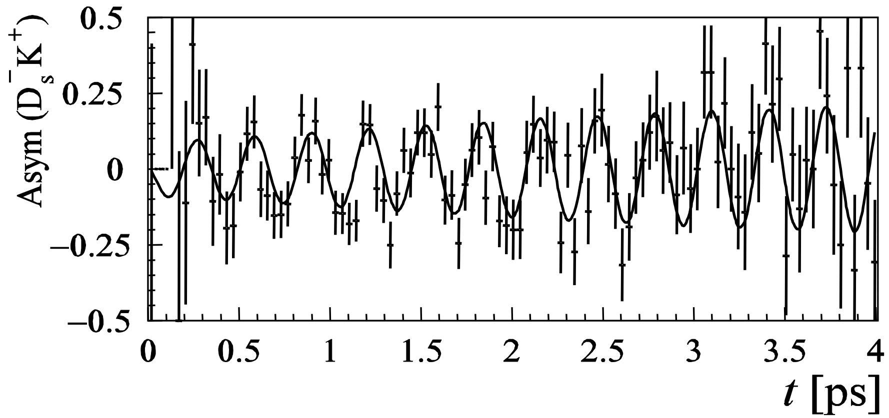




fit $\Delta + (\gamma + \phi_s)$

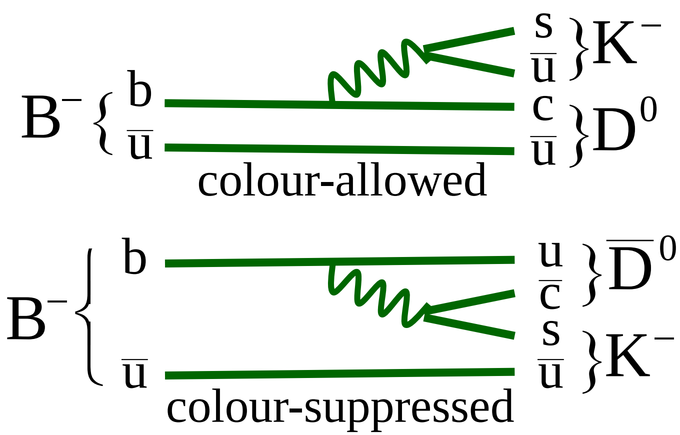


fit $\Delta - (\gamma + \phi_s)$



Measurements of γ from $B^{\pm} \to DK^{\pm}$

- New proposed clean measurement of γ for LHCb, based on ADS (Atwood, Dunietz, Soni) method
  - tree decays, not sensitive to new physics
  - measure the relative rates of $B^{-} \to DK^{-}$ and $B^{+} \to DK^{+}$ decays with neutral D's observed in final states
    [such as: $K^{-}\pi^{+}$ and $K^{+}\pi^{-}$, $K^{-}\pi^{+}\pi^{-}\pi^{+}$ and $K^{+}\pi^{-}\pi^{+}\pi^{-}$, $K^{+}K^{-}$]



- Candidate for LHCb's statistically most precise determination of γ
  - $\sigma(\gamma) \sim 5°$ precision in one year

Conclusion

- New physics at LHC will be searched for in loop B decays
  - There are few highly sensitive $b \rightarrow s$ observables:
    - B_s mixing magnitude and phase
    - Exclusive $B \rightarrow \mu\mu$, …
    - Large phase space can already be covered with the first LHC collisions
- LHCb will improve precision on CKM angles
  - Several γ measurements from tree decays only
    - $\sigma_{stat}(\gamma)$ few ° precision in ~5 years
  - May reveal inconsistencies with other measurements
- Looking forward to first collisions in 2007/2008
  - LHCb aiming for complete detector at end of 2006, ready to exploit nominal luminosity from day one

LHCb cavern – February 2006