CKM angle measurements at LHCb

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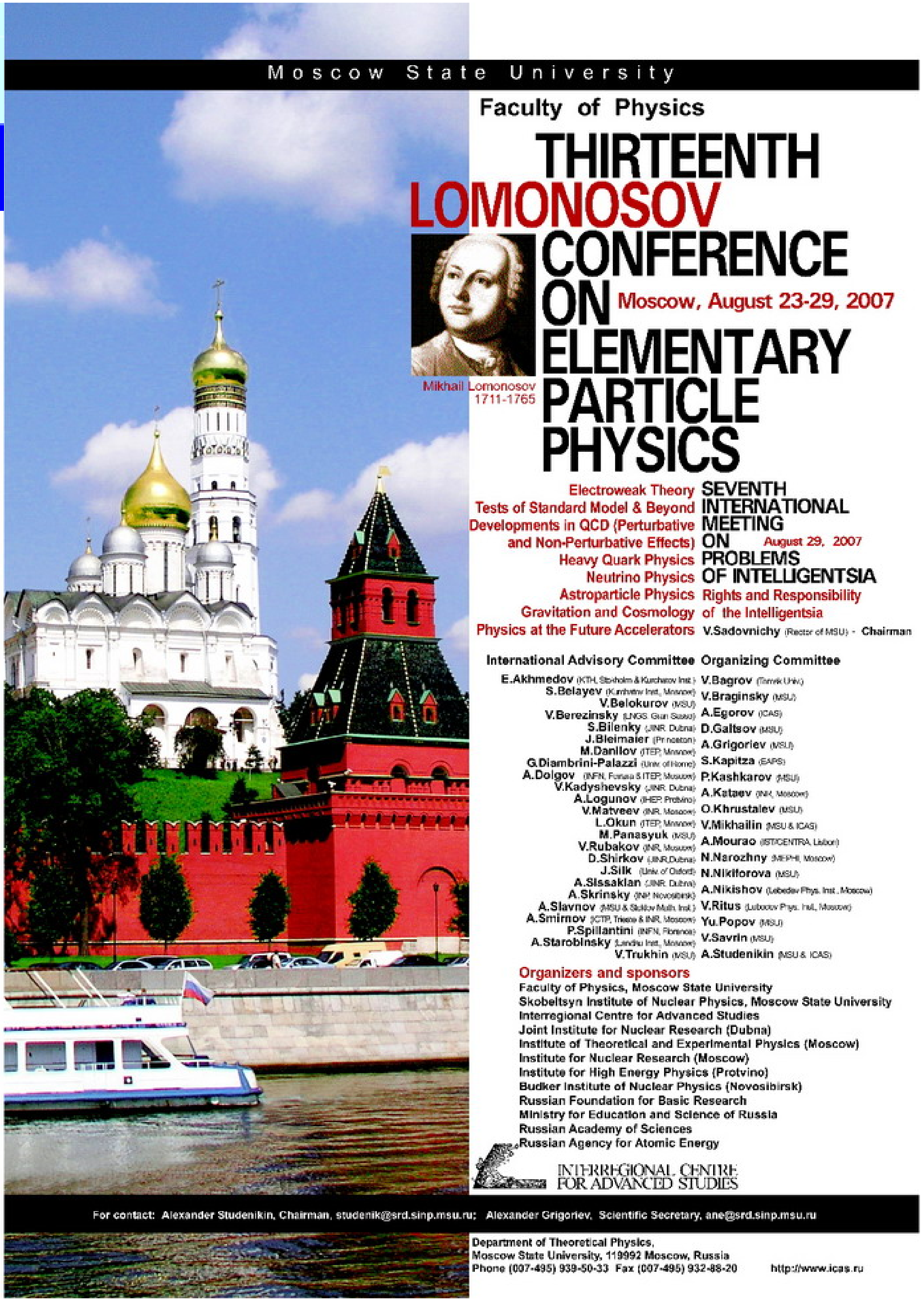
on behalf of the LHCb collaboration

13th Lomonosov Conference on Elementary Particle Physics

Moscow, August 23-29, 2007



Moscow State University
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THIRTEENTH LOMONOSOV CONFERENCE ON ELEMENTARY PARTICLE PHYSICS

Moscow, August 23-29, 2007

Mikhail Lomonosov
1711-1765

Electroweak Theory
Tests of Standard Model & Beyond
Developments in QCD (Perturbative and Non-Perturbative Effects)
Heavy Quark Physics
Neutrino Physics
Astroparticle Physics
Gravitation and Cosmology
Physics at the Future Accelerators

SEVENTH INTERNATIONAL MEETING ON PROBLEMS OF INTELLIGENTSIA

August 29, 2007

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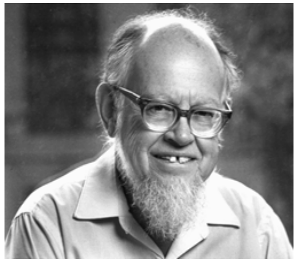
matrix in



parametrization…

γ

$$V_{CKM} = \begin{pmatrix} 1-\lambda^2/2-\lambda^4/8 & \lambda & A\underline{\lambda}^3(\rho - i\eta) \\ -\lambda + A^2\underline{\lambda}^5(1/2-\rho-i\eta) & 1-\lambda^2/2-\lambda^4(1+4A^2)/8 & A\lambda^2 \\ A\underline{\lambda}^3(1-\rho-i\eta)+A\underline{\lambda}^5(\rho+i\eta)/2 & -A\lambda^2+A\underline{\lambda}^4(1/2-\rho-i\eta) & 1-A^2\lambda^4/2 \end{pmatrix} + O(\lambda^6)$$

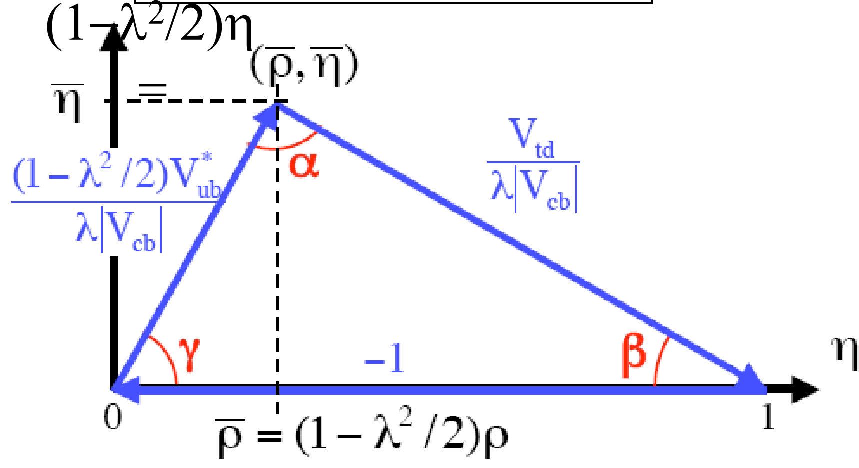
β χ

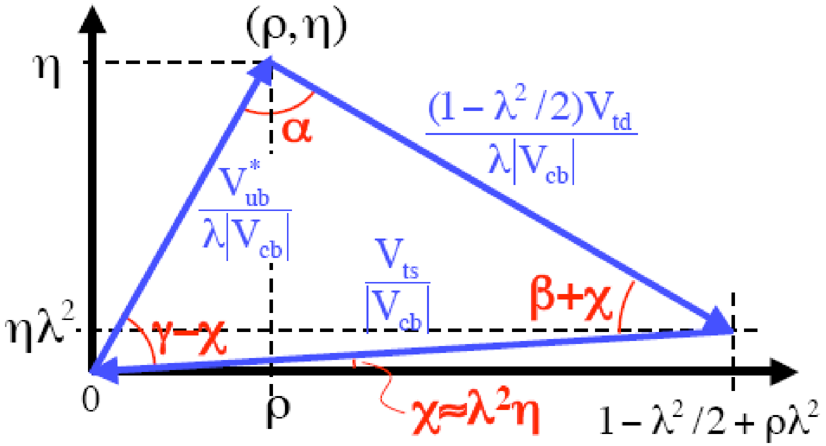
… and Unitarity triangles

$B_d\overline{B}_d$ mixing phase $\varphi_d^{SM} = \ 2\ \beta$
$B_s\overline{B}_s$ mixing phase $\varphi_s^{SM} = -2\ \chi = -2\ \lambda^2\eta \approx -0.037$

- ☐ Two of the 6 triangles useful for B physics. Divided by $|V^*_{cb}\ V_{cd}|$.

$\boxed{V_{ud}V^*_{ub} + V_{cd}V^*_{cb} + V_{td}V^*_{tb} = 0}$ ← keep terms up to $O(\lambda^5)$ → $\boxed{V_{tb}V^*_{ub} + V_{ts}V^*_{us} + V_{td}V^*_{ud} = 0}$



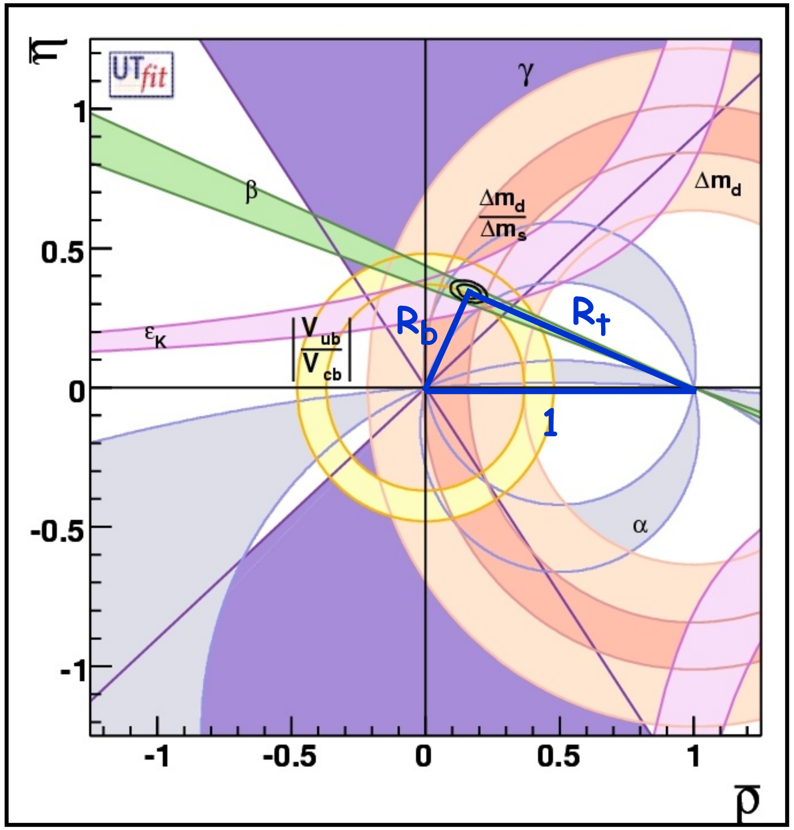


ρ ~ 0.2
η ~ 0.4
λ ~ 0.23
A ~ 0.8

$\boxed{\arg(V_{ub}) = -\gamma, \quad \arg(V_{td}) = -\beta, \quad \arg(V_{ts}) = \chi + \pi}$

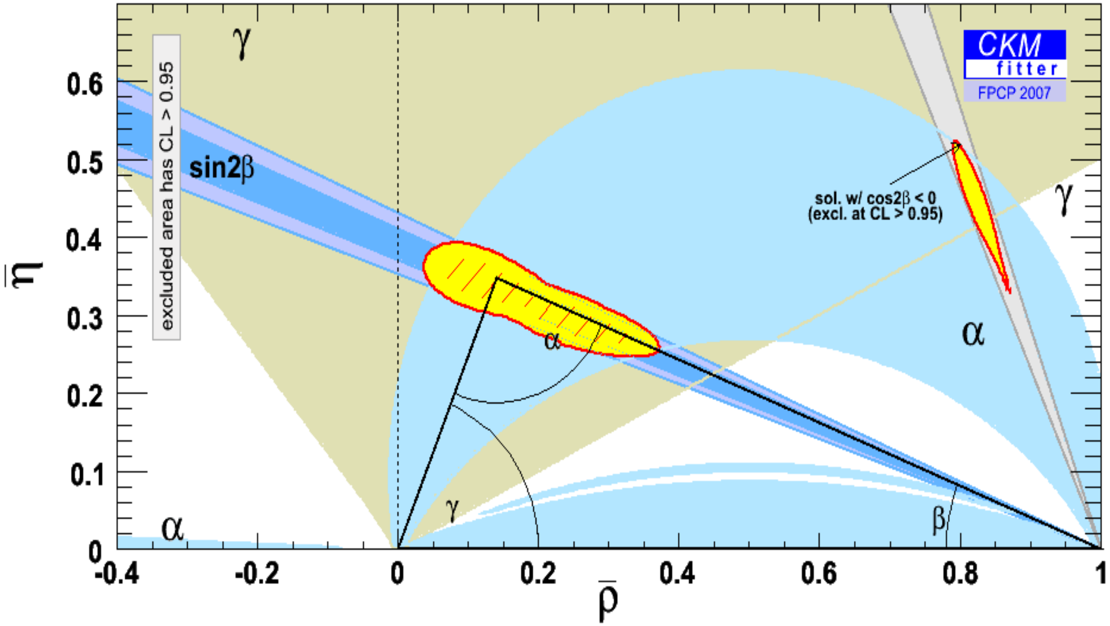
Current status of CKM parameters

- ☐ Impressive improvement due to results from B-factories and Tevatron
- ☐ The so far measurements are entirely consistent with the SM predictions



Accuracy of angles is limited by experiment:

α ~ ± 6°
β ~ ± 1°
γ ~ ± 20°
χ not yet measured



- ☐ Improve precision of angles to f
- ☐ Search for New Physics by comparing tree-mediated processes (γ, Rb) to those involving loop diagrams (γ, β, Rt)

-> complementary to direct searches !

LHCb - experiment to study $\cancel{CP}$ and rare phenomena in B meson decays

→ General LHCb talk

-> Bernhard Spaan

Main LHCb features

- Large rates, ~10^{12} b-hadrons / year with all b-species produced:
  B_u (~40%), B_d (~40%), B_s (~10%), B_c (~0.1%), Λ_b (~10%), … , Excited states, …
- Well separated B decay vertices => "easy" Bs oscillations
- Excellent vertexing and particle identification capabilities
- Dedicated B-physics trigger

Important LHCb contributions:

- precision CKM measurements, in particular **angle γ and Bs mixing phase φs**
- search for NP with rare decays

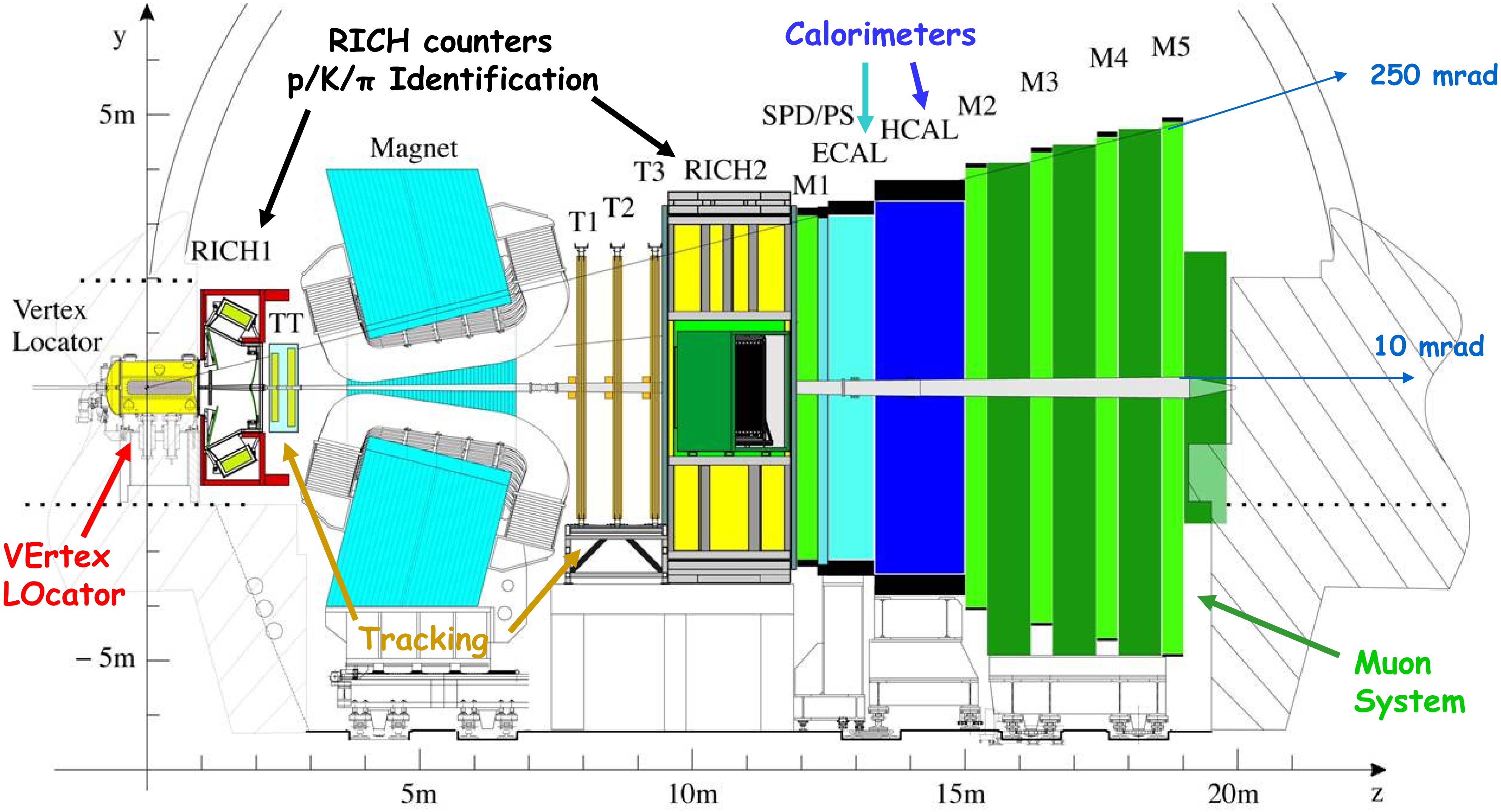
→ Rare decays at LHCb

-> Victor Egorychev

Data collection plan

- 2008 : $\int Ldt = 0.5\ fb^{-1}$
- ~2013 : $\int Ldt \sim 10\ fb^{-1}$ (~5 nominal years)

LHCb detector – single-arm forward spectrometer 10 - 250/300 mrad



Vertex reconstruction:
VELO

Kinematics:
Magnet
Tracker
Calorimeters

PID:
RICHs
Calorimeters
Muon Chambers

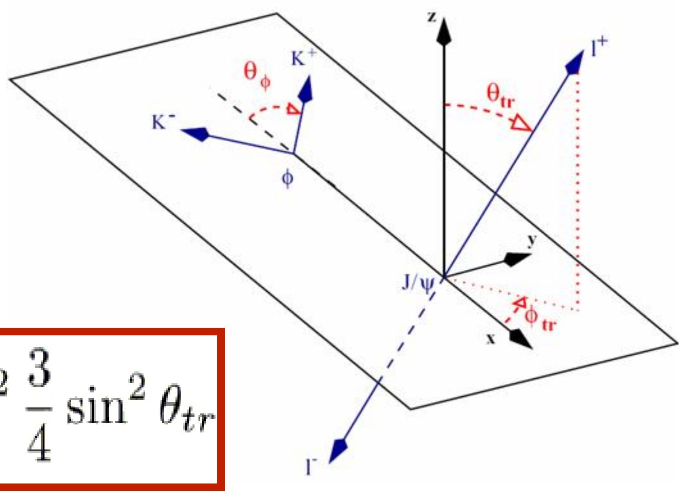
Trigger:
Muon Chambers
Calorimeters
Tracker

φ_s from B_s -> J/Ψ Φ

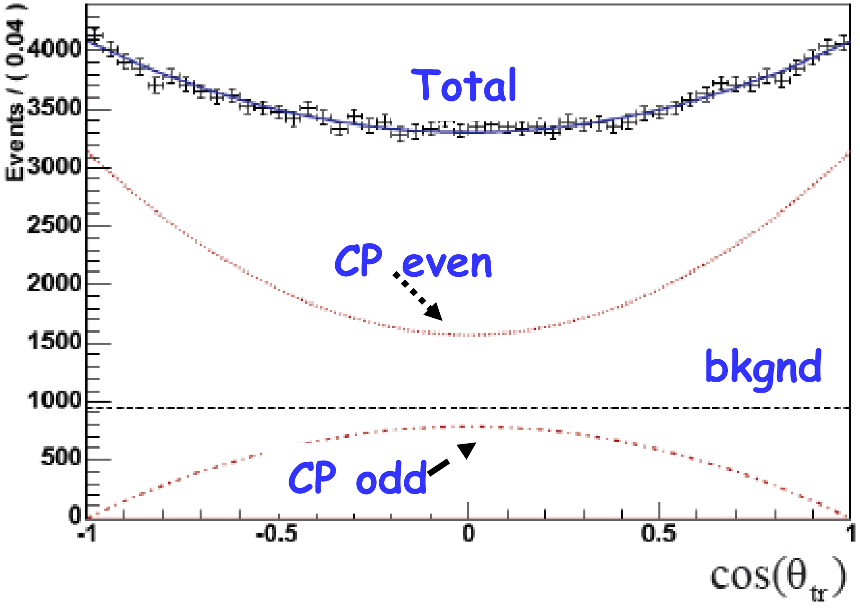
J/Ψ -> ll

Φ -> KK

- Mixture of CP=+1 for L=0,2
  and CP=-1 for L=1 => partial waves
- Measures $\varphi_s^{SM} = -2\chi = -0.037$ is small
- Simultaneous measurement of $\Delta\Gamma_s$



$$\boxed{\frac{d\Gamma(t)}{d(\cos(\theta_{tr}))} \propto \left[|A_0(t)|^2 + |A_{\|}(t)|^2\right] \frac{3}{8}(1+\cos^2\theta_{tr}) + |A_\perp(t)|^2 \frac{3}{4}\sin^2\theta_{tr}}$$



Simultaneous fit to **Time** and **Angular** Distributions

$$A_{CP}(t) = \frac{\Gamma[\overline{B}_s(t) \to f] - \Gamma[B_s(t) \to f]}{\Gamma[\overline{B}_s(t) \to f] + \Gamma[B_s(t) \to f]}$$

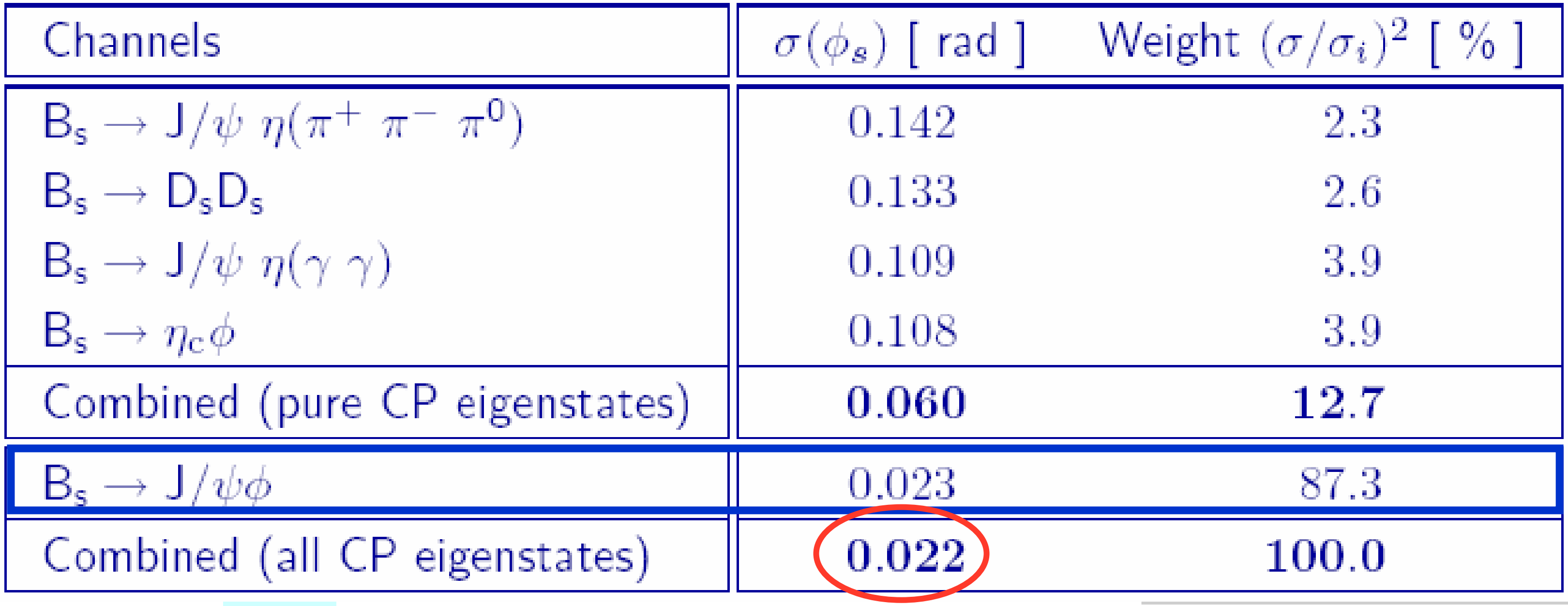
$$A_{CP}(t) = \frac{\eta_f sin\phi_s sin(\Delta m_s)t}{cosh(\Delta\Gamma_s t/2) - \eta_f cos\phi_s sinh(\Delta\Gamma_s t/2)}$$

1 LHCb year (2 fb^{-1}), **BR=$3\cdot10^{-5}$** :

131k events, $\sigma(\varphi_s)$= 0.023

φ_s: adding pure CP eigenstates

Channels used	Yield (2 fb^{-1})	B/S	$\langle\delta_\tau\rangle$ (fs)	σ_{mass} (MeV/c^2)
$B_s \to J/\psi(\mu^-\mu^+)\phi(K^+K^-)$	**131k**	0.12	36	14
$B_s \to \eta_c(h^-h^+h^-h^+)\phi(K^+K^-)$	3k	0.6	30	12
$B_s \to J/\psi(\mu^-\mu^+)\ \eta(\gamma\gamma)$	8.5k	2.0	37	34
$B_s \to J/\psi(\mu^-\mu^+)\ \eta(\pi^+\pi^-\pi^0(\gamma\gamma))$	3.0k	3.0	34	20
$B_s \to J/\psi\ (\mu^-\mu^+)\ \eta'(\pi^+\pi^-\eta\ (\gamma\gamma))$	2.2k	2.0	32	19
$B_s \to D_s(K^+K^-\pi^-)\ D_s(K^+K^-\pi^+)$	4.0k	0.3	56	6

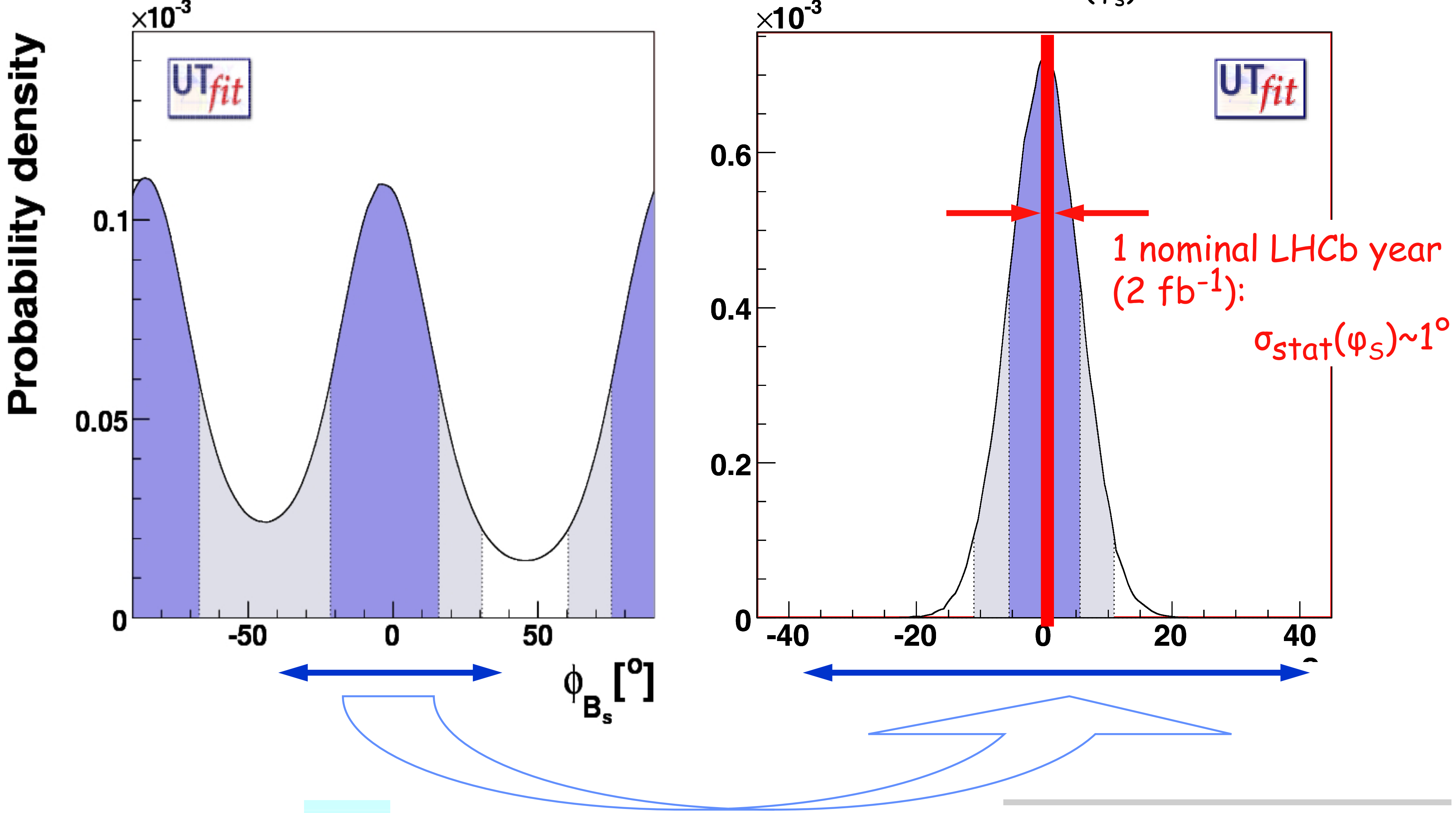


Channels	$\sigma(\phi_s)$ [rad]	Weight $(\sigma/\sigma_i)^2$ [%]
$B_s \to J/\psi\ \eta(\pi^+\ \pi^-\ \pi^0)$	0.142	2.3
$B_s \to D_sD_s$	0.133	2.6
$B_s \to J/\psi\ \eta(\gamma\ \gamma)$	0.109	3.9
$B_s \to \eta_c\phi$	0.108	3.9
Combined (pure CP eigenstates)	**0.060**	**12.7**
$B_s \to J/\psi\phi$	0.023	87.3
Combined (all CP eigenstates)	**0.022**	**100.0**

Example: impact of φ_s from B_s -> J/Ψ Φ

Present knowledge on φ_s

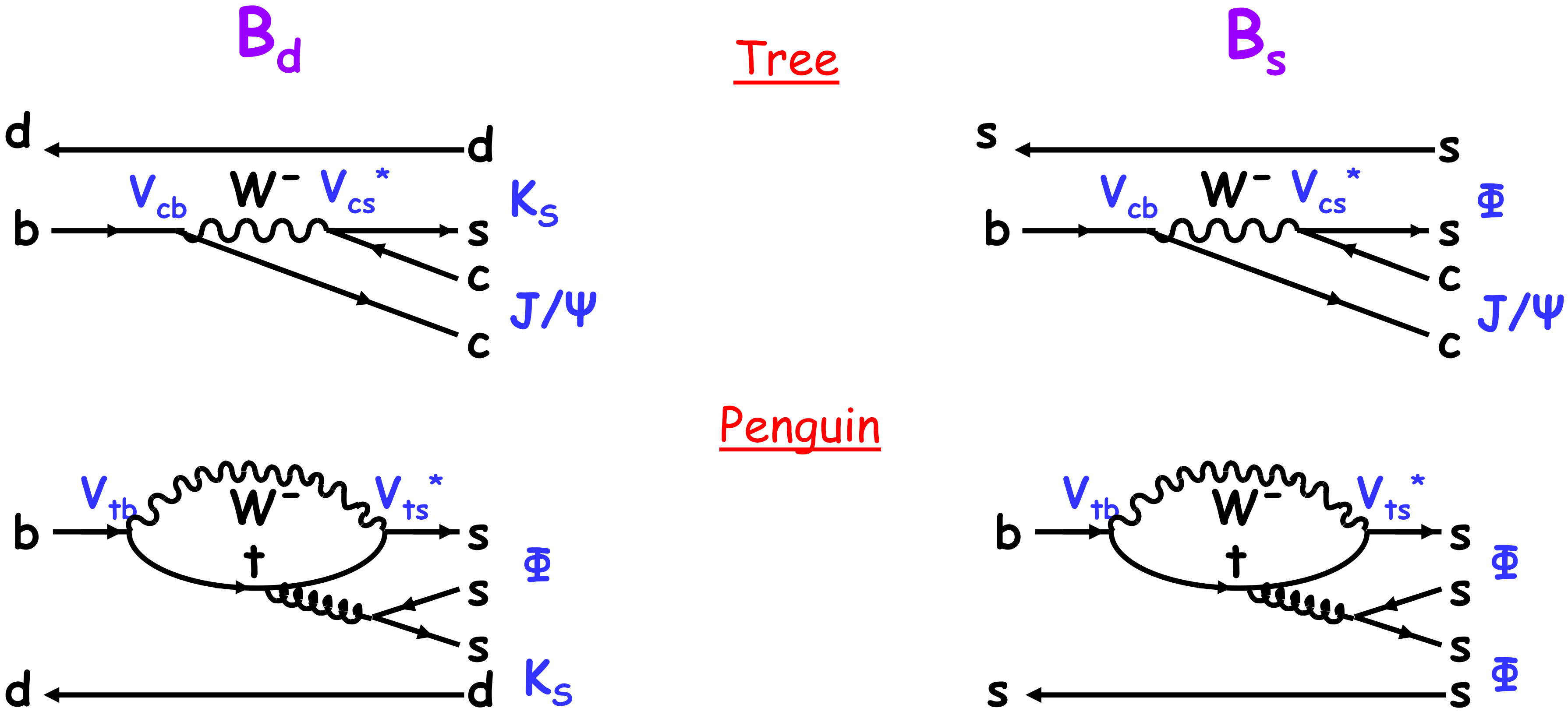
Expected precision at the end of Tevatron $\sigma(\varphi_s)$~6°



1 nominal LHCb year ($2\ fb^{-1}$):

$\sigma_{stat}(\varphi_s)$~1°

Example: New Physics through Tree-Penguin comparison



Beginning 2007:

β(tree)-β(penguin) = **$\delta\beta$(NP)**

Currently: **$\delta\beta$(NP) ~ 8° (2.6σ)**

χ(tree)-χ(penguin) = **$\delta\chi$(NP)**

In SM: $\delta\chi$(NP) = $\delta\beta$(NP)

LHCb sensitivity on $\delta\chi$(NP) ~3° (1 nominal year, 2fb^{-1})

Example: constraining NP with φ_s and Δm_s measurement

- The measurement can be interpreted via a parameterization of NP effects:

$$\boxed{M_{12} = (1 + h_s\, e^{2i\sigma_s})\, M^{SM}_{12}}$$

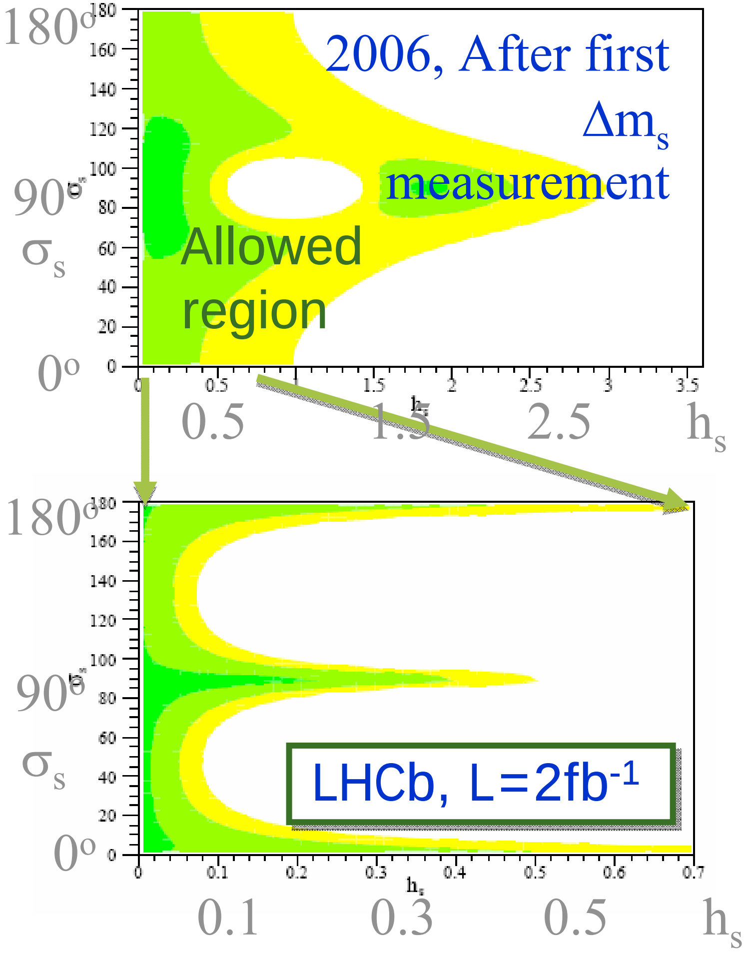
M^{SM}_{12}= dispersive part of the B_s mixing amplitude in the SM

- Then Δm_s and φ_s can be used to constrain NP in the oscillation:

$$\Delta m_s = \Delta m_s^{SM} \left|1 + h_s \exp(2i)\sigma_s\right|$$

$$\Phi_s = \Phi_s^{SM} + \arg\left(1 + h_s \exp\left(2i\sigma_s\right)\right)$$

From Z. Ligeti et al hep-ph/0604112
Allowed regions CL > 0.90, 0.32, 0.05



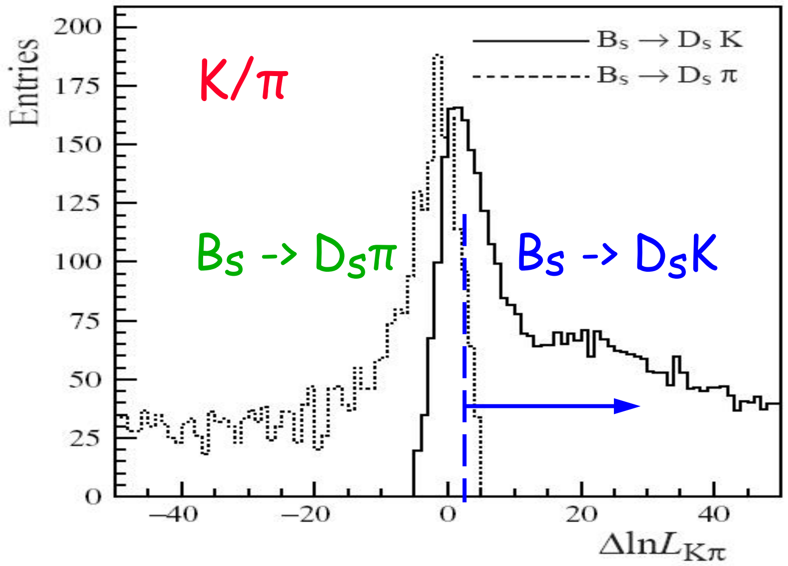
2006, After first Δm_s measurement

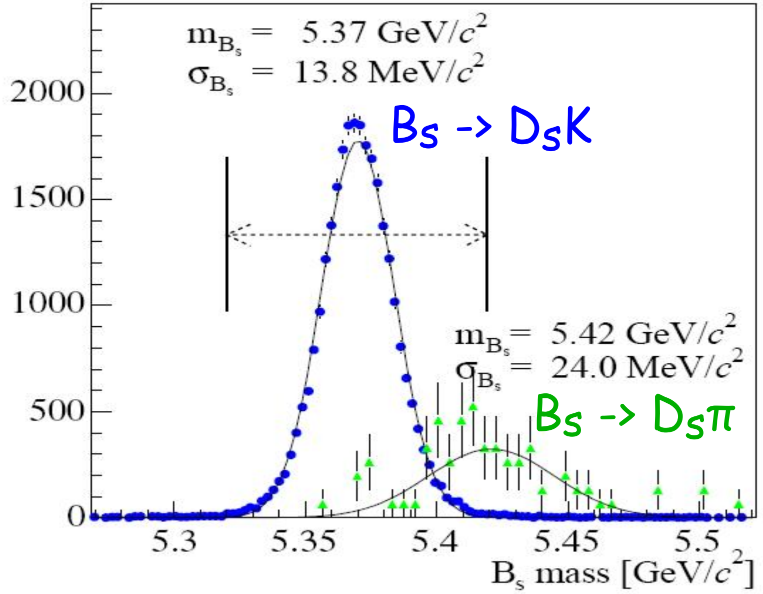
Allowed region

LHCb, L=2fb^{-1}

TREE

γ measurement: B_s -> D_sK D_s -> $KK\pi$

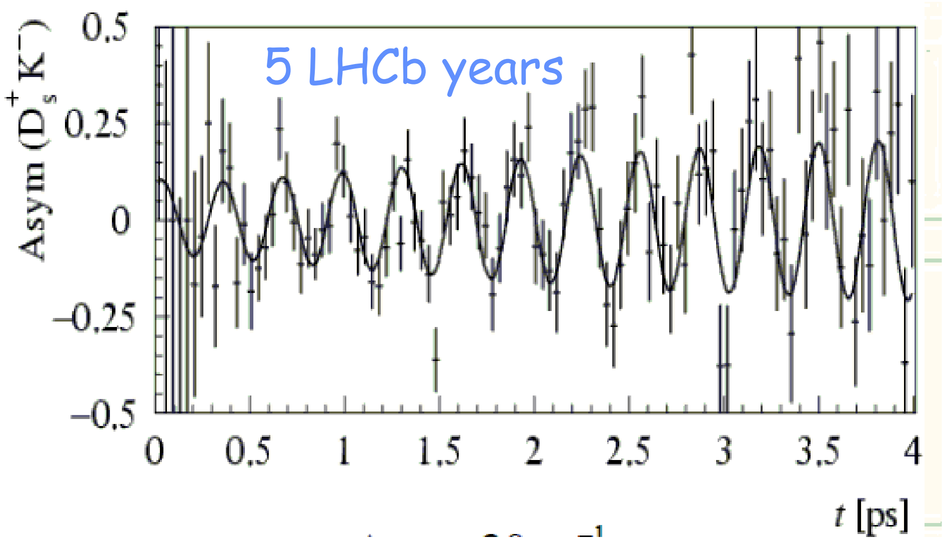




B_s -> $D_s\pi$ **residual contamination ~10%**

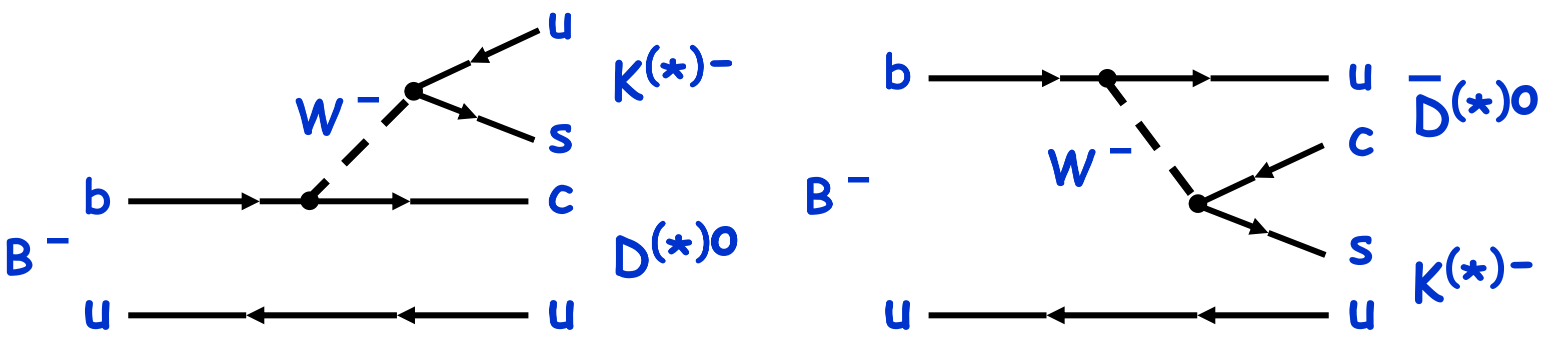
- B_s -> $D_s^-K^+$ and B_s -> $D_s^+K^-$ (b->u), both ~λ^3 tree diagrams, interference via mixing
- Phase $D_s^+K^-$: Δ - (γ + φs)
- Phase $D_s^-K^+$: Δ + (γ + φs)
- Fit 4 tagged time-dependent rates
- Measure simultaneously Δ and γ + φs

- Annual yield: 6.2k events, S/B > 1.4 @90% CL
- σ(γ + φs) ~ 10° with 2fb^{-1} (1 LHCb year)



γ from $B^{\pm} \to DK^{\pm}$

Interference between the two diagrams if same final state



Weak phase diff.:
γ
Magnitude ratio:
r_B~0.08
Strong phase diff.:
δ_B

$A(B^- \to \bar{D}^0 K^-) / A(B^- \to D^0 K^-) = r_B \, e^{i(\delta_B - \gamma)}$ Parameters: γ, (r_B, δ_B) per B mode

1) Use a CP mode for the D^0

Parameters: r_B, γ , δ_B , (r_D = 1, δ_D=0)

GLW (Gronau, London, Wyler)
CP+ and CP- modes

$(K^+K^-, \pi^+\pi^-)$ ← → $(K_S\pi^0, \phi K_S, \eta K_S, \rho K_S, \omega K_S)$

2) Use CAD ($K^- \pi^+$) for the V_{ub} decay and DCSD ($K^- \pi^+$) for the V_{cb} decay

Parameters: r_B, γ , δ_B, r_D~0.06, δ_D

ADS
(Atwood, Dunietz, Soni)

$D^0 \to K^-\pi^+$
$D^0 \to K^-\pi^+\pi^0$
$D^0 \to K^-\pi^+\pi^-\pi^+$

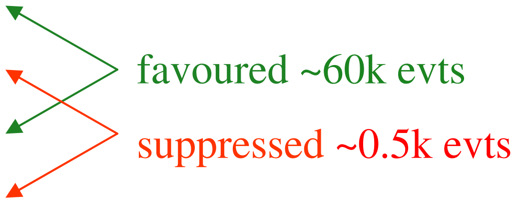
3) Use Dalitz plot analysis of 3-body D^0 decay, e.g. $D^0 \to K_S\pi\pi$

GGSZ (Giri, Grossman, Soffer, Zupan)

γ from B± -> DK±

- ☐ ADS: 4 time-integrated decay rates, 5 unknowns

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


favoured ~60k evts

suppressed ~0.5k evts

Parameters: γ $\quad \underbrace{r_B,\ \delta_B\ \boxed{\delta_D^{K\pi},\ \delta_D^{K3\pi}},\ \ldots}_{\text{mode dependent}} \longrightarrow$ may come from CLEO-C and (later) BESIII

- ☐ GLW: 2 time-integrated decay rates, +1 unknown

$$\Gamma(B^- \to D_{CP}\, K^-) \;\propto\; 1 + r_B{}^2 + 2 r_B \cos(\delta_B + \gamma)$$
$$\Gamma(B^+ \to D_{CP}\, K^+) \;\propto\; 1 + r_B{}^2 + 2 r_B \cos(\delta_B - \gamma)$$

⇒ **common ADS +GLW fit solves for all unknowns, including γ**

Precision: $\sigma(\gamma)$ ~ 5°- 13° in 1 nominal year, 2 fb^{-1}

depending on $\delta_D^{K\pi}$ ($-25° < \delta_D^{K\pi} < 25°$) and on $\delta_D^{K3\pi}$ ($-180° < \delta_D^{K3\pi} < 180°$)

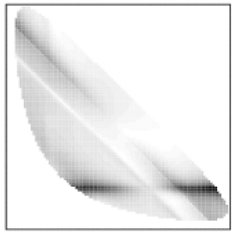
γ from Dalitz plot analysis of 3-body decay $D^0 \to K_S\pi\pi$

Interference due to the overlap of large resonances from V_{cb} and V_{ub} transitions

Dalitz distribution density: $d\sigma(m^2_{K_S\pi^+}, m^2_{K_S\pi^-}) \propto |\mathbf{A}|^2\, dm^2_{K_S\pi^+}\, dm^2_{K_S\pi^-}$

$|\mathbf{A}(m^2_{K_s\pi^+}, m^2_{K_s\pi^-})|^2 = \Bigg|$

$+\, re^{i\delta\pm i\phi_3}$



$\Bigg|^2$

- Assume no significant CP violation in D decays
- Measure magnitudes (r_D) from D->flavour tags
- Measure phases (δ_D) from D->CP tags
- D decay model: 'exclusive' point-by-point in PS or 'inclusive' (integrating)

$f(m^2_\pm, m^2_\mp)$ is determined from $D^{*-} \to D^0\pi^-$, $D^0 \to K_s\pi^+\pi^-$ decay
⇒ model uncertainty of the result

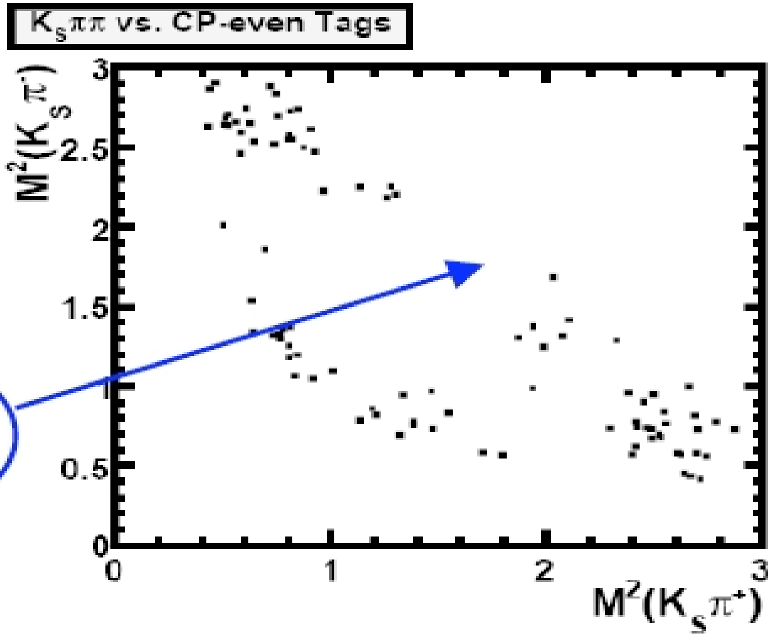
Or measure phase difference directly (model-independent) using the CP-tagged D^0 sample e.g. from $\psi'' \to D^0\bar{D}^0$, where tag-side D^0 decays into CP-eigenstate

=> CLEO-c, BESIII

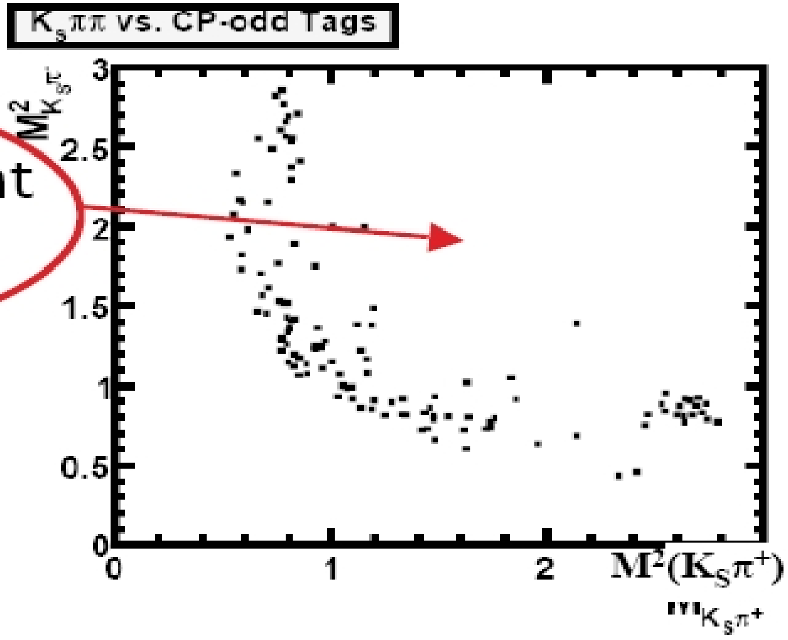
γ from Dalitz plot analysis of 3-body decay $D^0 \to K_S\pi\pi$

from R.Briere @ LP07

CP Tags give information on phase between D and $\overline{D}$ amplitudes



$K_S\,\rho^0$ resonance enhanced in CP-odd Dalitz plot



CP-odd $K_S\,\rho^0$ resonance absent in CP-even Dalitz plot

CLEO-C '07

γ from Dalitz plot analysis of 3-body decay $D^0 \to K_S\pi\pi$

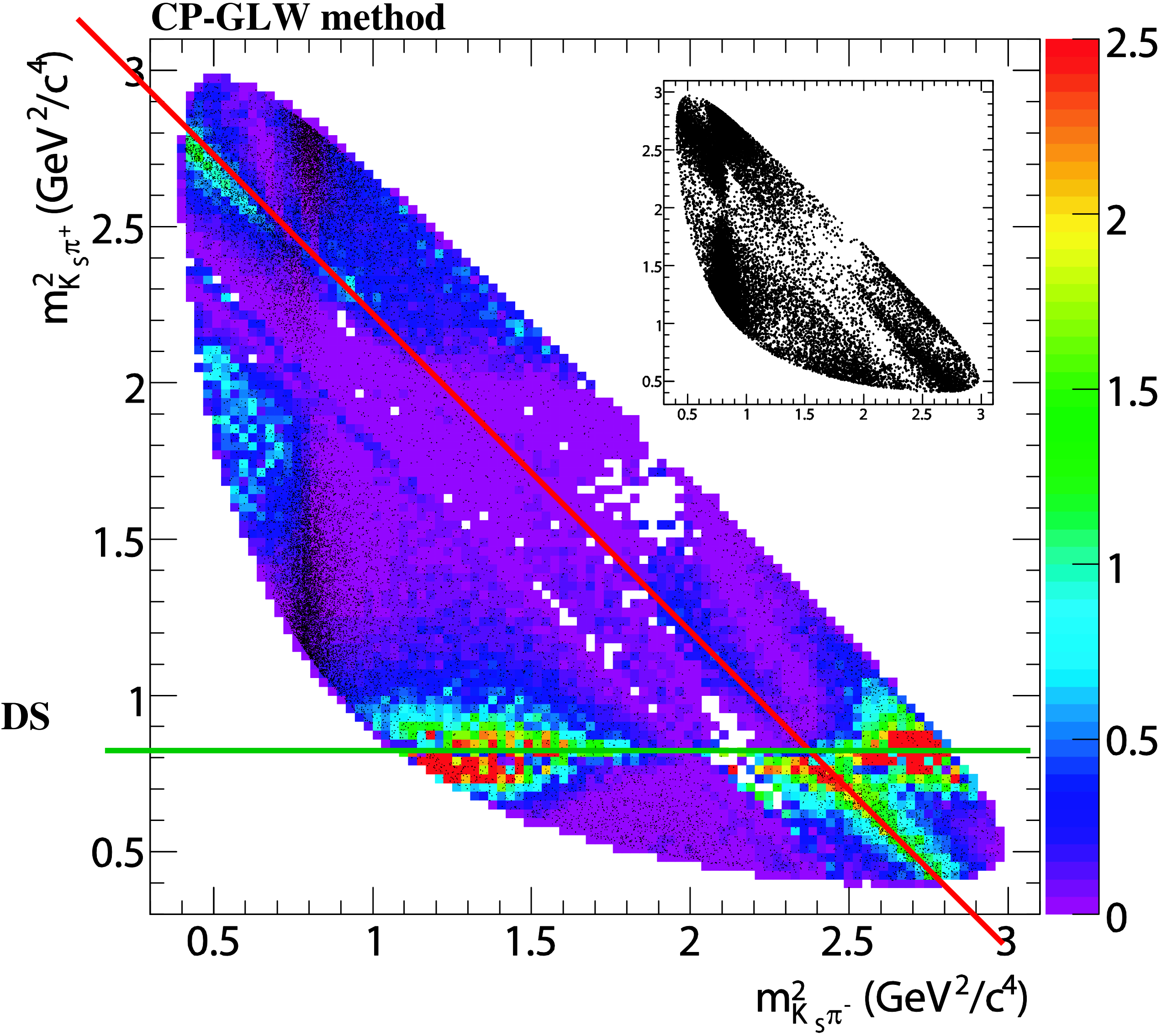
With known

$$f(m^2_\pm, m^2_\mp)$$

fit simulatniously

for r_B, δ_B, γ

$K_s\,\rho(\pi^+\pi^-)$
CP-GLW method



$K^{*+}(892)(K_s\,\pi^+)\,\pi^-$ ADS method

Event yield: 5k per 1 LHCb year

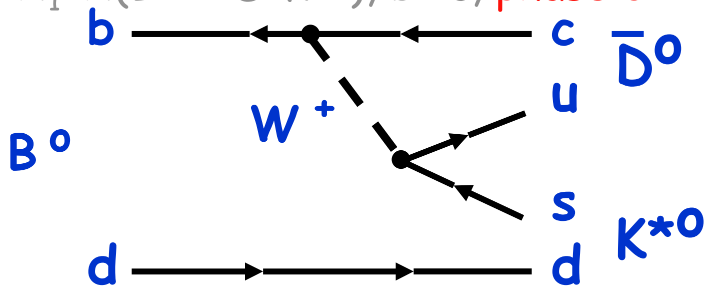
S/B > 1.0 @ 90% CL

Sensitivity with 2 fb^{-1}: $\sigma(\gamma) \sim 7^o$-12^o

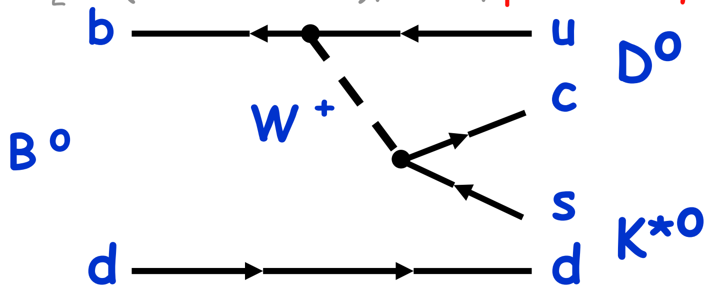
for r_B=1, depending on background conditions

γ from $B^0 \to DK^{*0}$

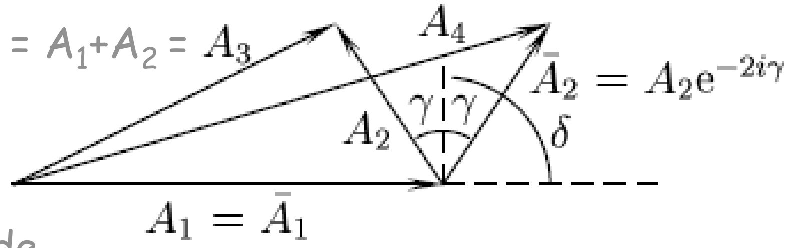
$A_1 = A(B^0 \to \bar{D}^0 K^{*0})$, b->c, phase 0



$A_2 = A(B^0 \to D^0 K^{*0})$, b->u, phase $\delta+\gamma$



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



- ❑ Self-tagging mode
- ❑ ADS: 4 time-integrated decay rates, 5 unknowns

$$\Gamma(B^0 \to (K^+\pi^-)_D K^{*0}) \propto 1 + (r_B r_D)^2 + 2 r_B r_D \cos(\delta_B + \delta_D + \gamma),$$
$$\Gamma(B^0 \to (K^-\pi^+)_D K^{*0}) \propto {r_B}^2 + {r_D}^2 + 2 r_B r_D \cos(\delta_B - \delta_D + \gamma),$$
$$\Gamma(\overline{B}^0 \to (K^-\pi^+)_D \overline{K}^{*0}) \propto 1 + (r_B r_D)^2 + 2 r_B r_D \cos(\delta_B + \delta_D - \gamma),$$
$$\Gamma(\overline{B}^0 \to (K^+\pi^-)_D \overline{K}^{*0}) \propto {r_B}^2 + {r_D}^2 + 2 r_B r_D \cos(\delta_B - \delta_D - \gamma),$$

- ❑ GLW: 2 time-integrated decay rates, +1 unknown

$$\Gamma(B^0 \to D_{CP} K^{*0}) \propto 1 + {r_B}^2 + 2 r_B \cos(\delta_B + \gamma)$$
$$\Gamma(\overline{B}^0 \to D_{CP} \overline{K}^{*0}) \propto 1 + {r_B}^2 + 2 r_B \cos(\delta_B - \gamma)$$

- ❑ Magnitude ratios

$$r_B \equiv \frac{A_2}{A_1} = \frac{|A(B^0 \to D^0 K^{*0})|}{|A(B^0 \to \overline{D}^0 K^{*0})|} \sim 0.4\ (?)$$

$$r_D \equiv \frac{|A(D^0 \to K^+\pi^-)|}{|A(\overline{D}^0 \to K^+\pi^-)|} \sim 0.06$$

Event yields

Decay mode (+cc)	2 fb^{-1} yield	S/B_{bb}
$B^0 \to (K^+\pi^-)_D K^{*0}$	3.4 k	>3.3
$B^0 \to (K^-\pi^+)_D K^{*0}$	0.5 k	>0.6
$B^0 \to (K^+K^-, \pi^+\pi^-)_D K^{*0}$	0.6 k	>0.7

Sensitivity with 2 fb^{-1}: $\sigma(\gamma) \sim 7°\text{-}10°$ (depending on δ_D)

Sensitivity to γ from B -> DK decays

DD MIXING BOX

B mode	D mode	Method	$\sigma(\gamma)$, 2 fb^{-1}
$B^+ \rightarrow DK^+$	$K\pi + KK/\pi\pi + K3\pi$	ADS+GLW	4°–13°
$B^+ \rightarrow D^*K^+$	$K\pi$	ADS+GLW	Under study
$B^+ \rightarrow DK^+$	$K_S\pi\pi$	GGSZ	7°-12°
$B^+ \rightarrow DK^+$	$KK\pi\pi$	4-body "Dalitz"	18°
$B^+ \rightarrow DK^+$	$K\pi\pi\pi$	4-body "Dalitz"	Under study
$B^0 \rightarrow DK^{*0}$	$K\pi + KK + \pi\pi$	ADS+GLW	7°–10°
$B^0 \rightarrow DK^{*0}$	$K_S\pi\pi$	GGSZ	Under study
$B_s \rightarrow D_sK$	$KK\pi$	tagged+untagged, A(t)	10°

All channels combined (educated guess): $\sigma(\gamma)$ ~4° with 2 fb^{-1}

$\sigma(\gamma)$ ~2° with 10 fb^{-1}

γ measurement: B_d -> $\pi\pi$, B_s -> KK

PENGUIN LOOP

- Measures γ
- Time-dependent asymmetries for B_d->$\pi\pi$ and B_s->KK:

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

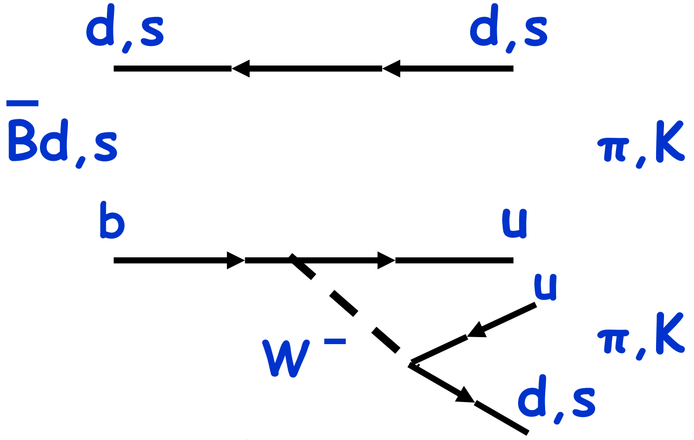
- Parameters: γ, $\varphi_d(\varphi_s)$, $P/T = d\, e^{\,i\theta}$
- Take $\varphi_d(\varphi_s)$ from other measurements
- U-spin symmetry assumption [Fleischer]:

  $d_{\pi\pi} = d_{KK}$ and $\theta_{\pi\pi} = \theta_{KK}$

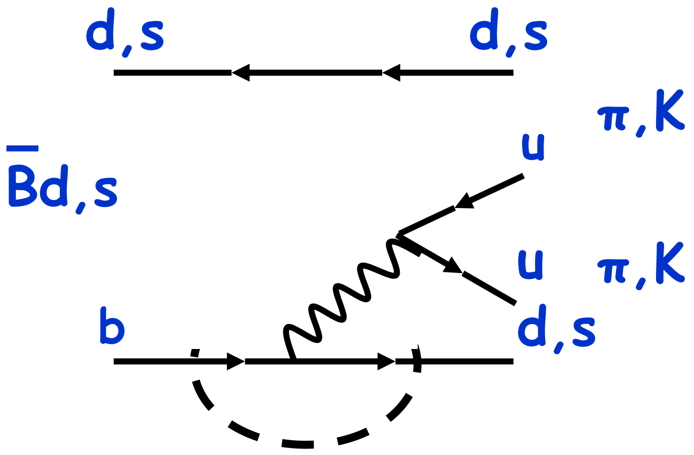
  => 4 measurements, 3 unknown

  => Solve for γ

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



tree



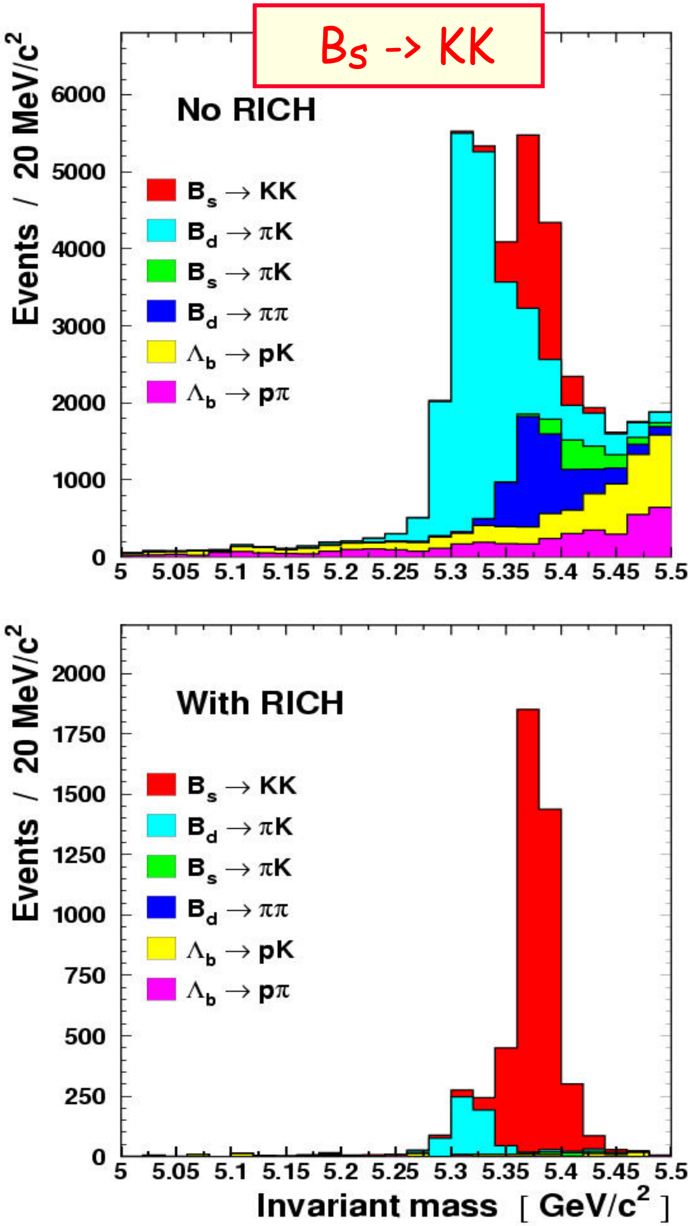
penguin

- B_d -> $\pi\pi$ 25k events/year, S/B ~2
- B_s -> KK 37k events/year, S/B > 7

If perfect U-spin symmetry in 1 LHCb year (2 fb^{-1}): $\sigma_{stat}(\gamma)$ ~4°

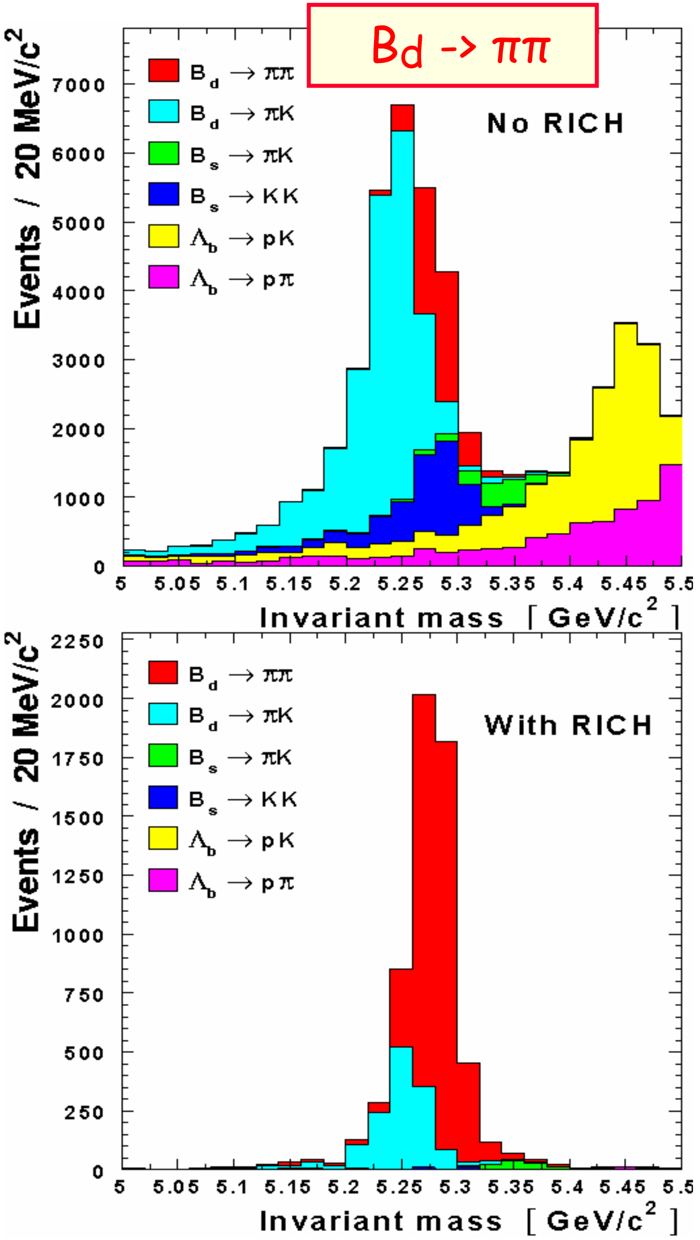
Particle ID: $B_d \to \pi\pi$, $B_s \to KK$

$B_s \to KK$



K/π !!!

$B_d \to \pi\pi$



Summary: LHCb is fit to precisely measure the CKM angles

B_d mixing phase $\varphi_d = 2\beta$

Validation channel for LHCb, but also search for direct CPV term ~ $\cos \Delta m_d t$

σ_{stat} (sin 2β) ~0.02, σ_{stat} (β) ~ 0.6° in one LHCb year ($2\ fb^{-1}$)

- B_s mixing phase $\varphi_s = -2\chi$

  LHCb will be the first experiment to reach sensitivity of φ_s (SM) ~ -0.04

  σ_{stat} (φ_s) ~ 0.02 in one LHCb year ($2\ fb^{-1}$)

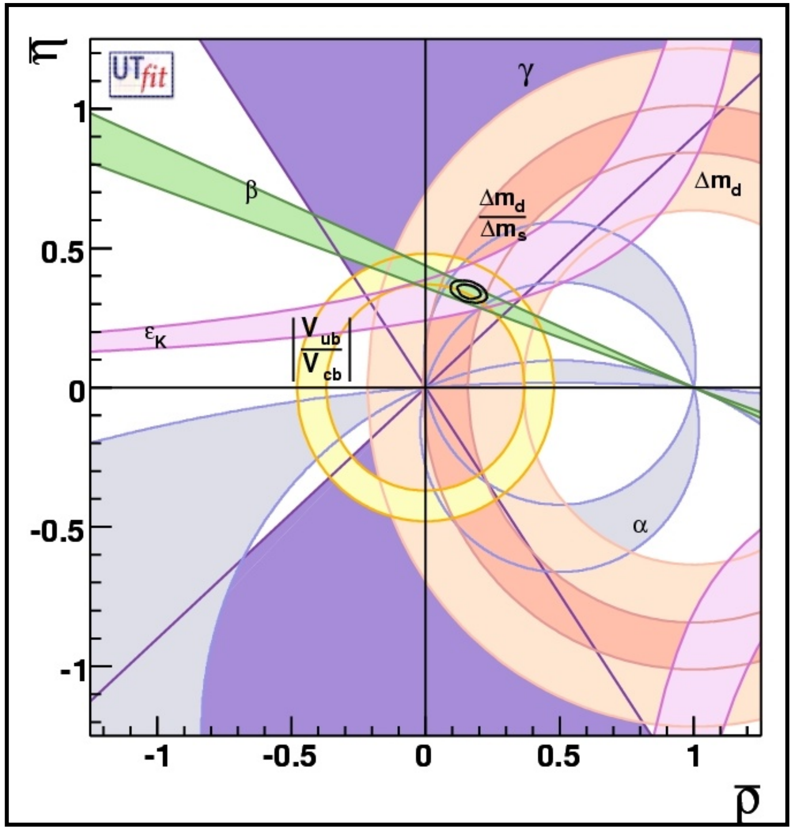
- LHCb will precisely measure angle γ via

  -> Pure tree processes : ~ 10°
  -> Potential NP in D^0 loops: σ_{stat} (γ) ~ 4° in one LHCb year ($2\ fb^{-1}$)
  -> Awaited NP in penguin loops: ~ 4° *perfect U-spin symmetry limit*

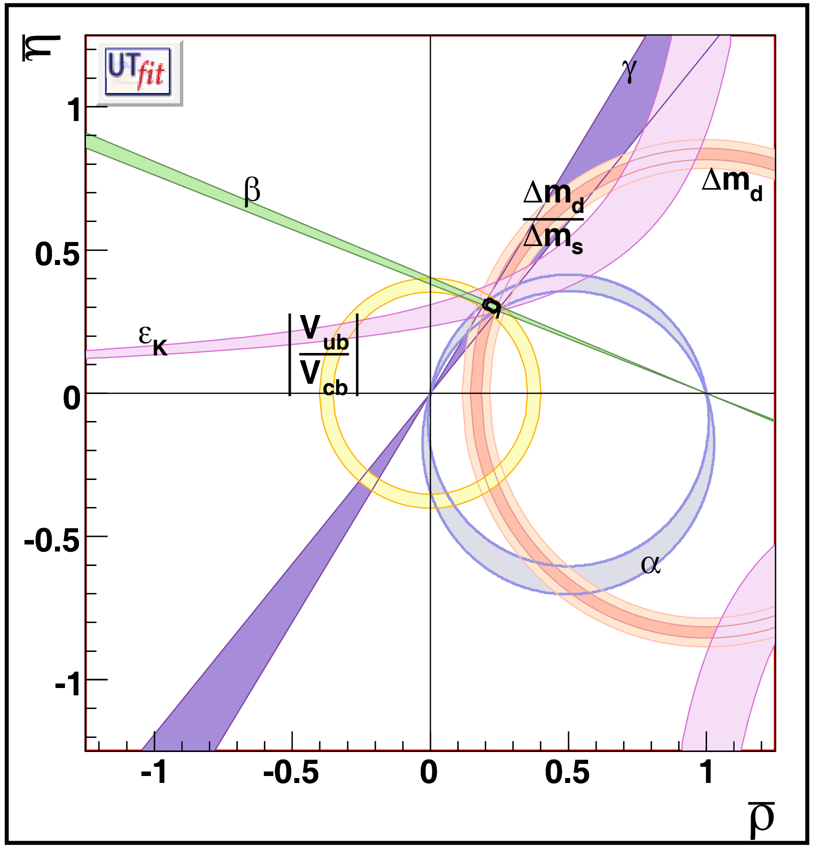
LHCb will measure angle α via B->ρπ Dalitz plot analysis and measuring asymmetry in $B \to \rho^0\rho^0$ σ_{stat} (α) ~ 6° in one LHCb year ($2\ fb^{-1}$)

Summary: UT evolution

now



LHCb after 5 years/10fb^{-1}



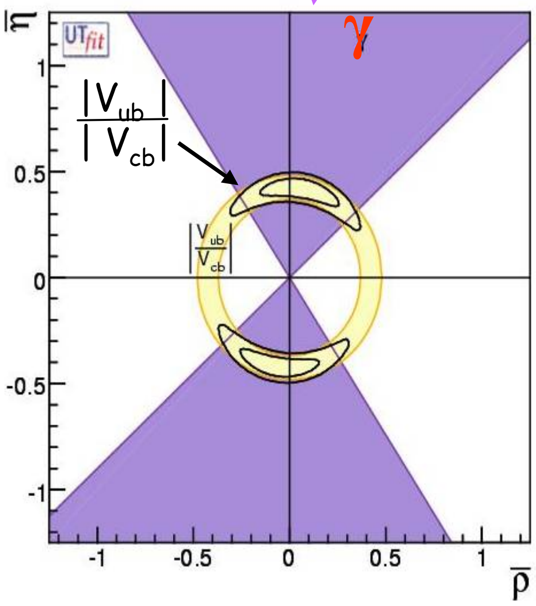
$\sigma(\beta) \sim 0.3^\circ$; $\sigma(\gamma) \sim 2^\circ$; $\sigma(\alpha) \sim 3^\circ$
(incl. Lattice QCD improvements, $\sigma(\xi)/\xi=1.5\%$)

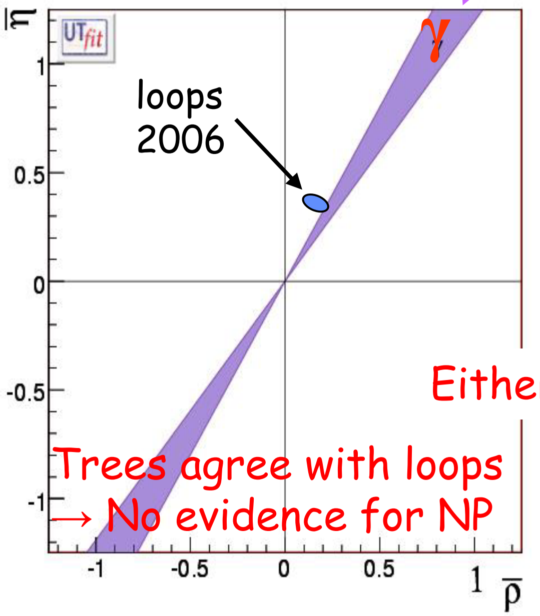
Summary: LHCb is fit to probe NP in loops

Will γ measured with tree processes be compatible with loop measurements ?

At present large uncertainties on γ from tree processes only (no NP contribution)

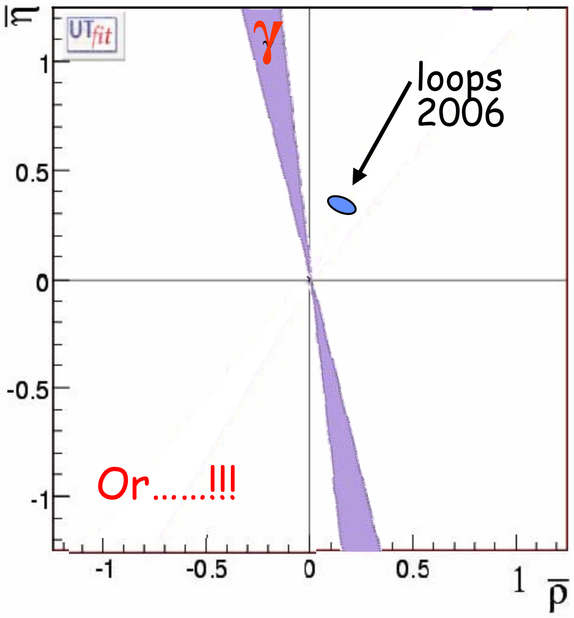
LHCb will provide tighter constraint on γ from B→DK (tree process only, no NP contribution) after 5years/10fb^{-1}





Either:

Trees agree with loops
→ No evidence for NP

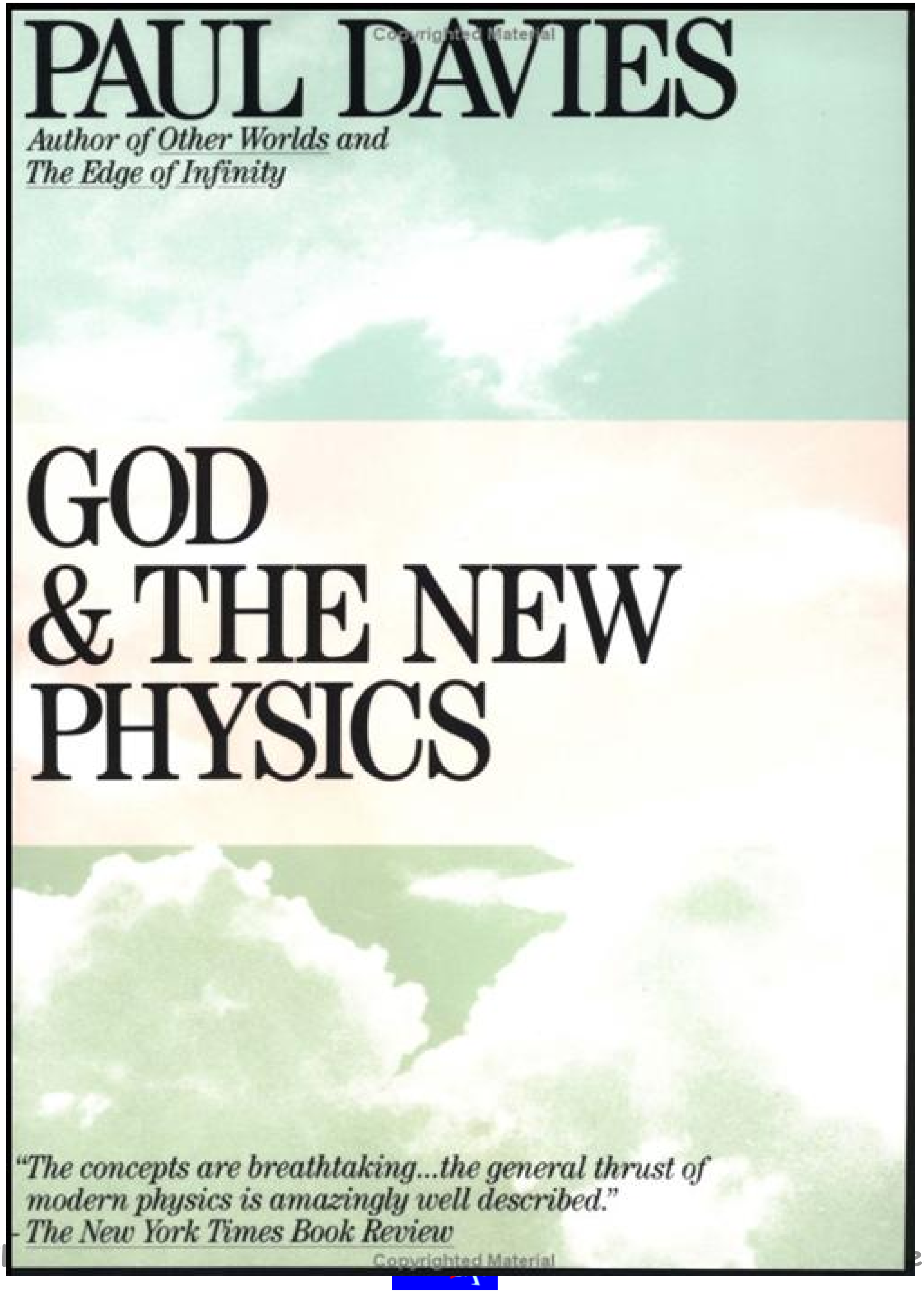


Or…….!!!

Other tools:

χ: if >> 1^{o} => NP in box diagram

$\delta\alpha$, $\delta\beta$, $\delta\chi$: if non-zero => NP in penguin loops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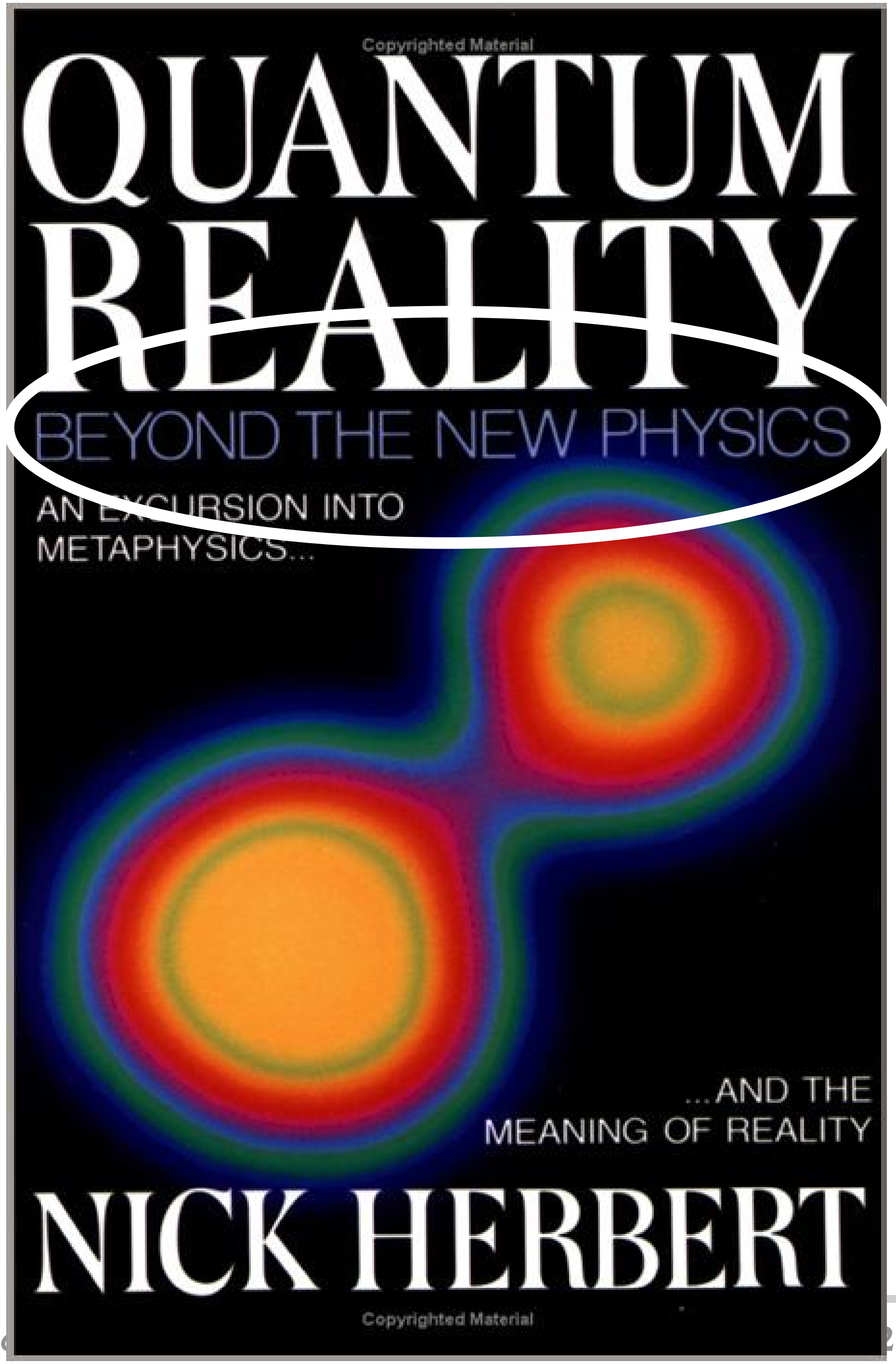
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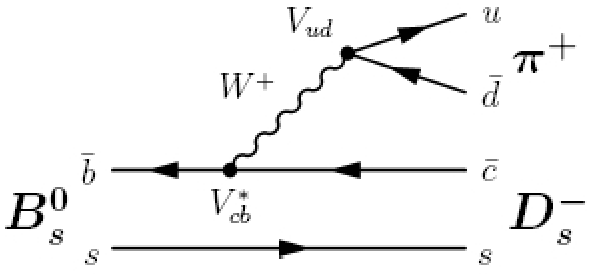
V_{ud}
u
π^+
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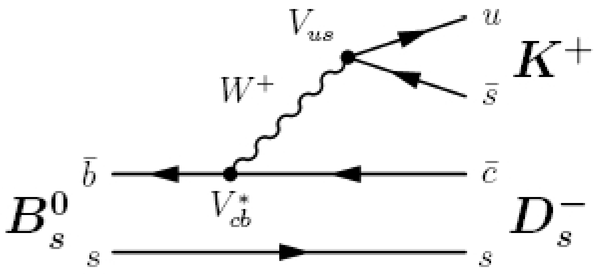
$\bar{b}$
$\bar{c}$
B_s^0
V_{cb}^*
D_s^-
s
s


V_{us}
u
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W^+
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$\bar{c}$
B_s^0
V_{cb}^*
D_s^-
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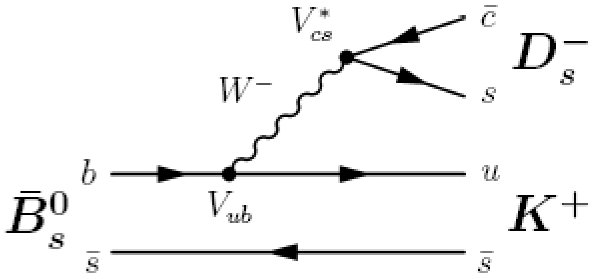
s


V_{cs}^*
$\bar{c}$
D_s^-
W^-
s
b
u
$\bar{B}_s^0$
V_{ub}
K^+
$\bar{s}$
$\bar{s}$

Measurement of angle β with “golden”-mode B -> J/Ψ Ks

- Validation channel starting from 0.5 fb^{-1}
- Search for direct CP violating term ~ cos Δ $m_d t$

- Expect 230k reconstructed B -> J/Ψ Ks events/year, S/B ~ 1

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

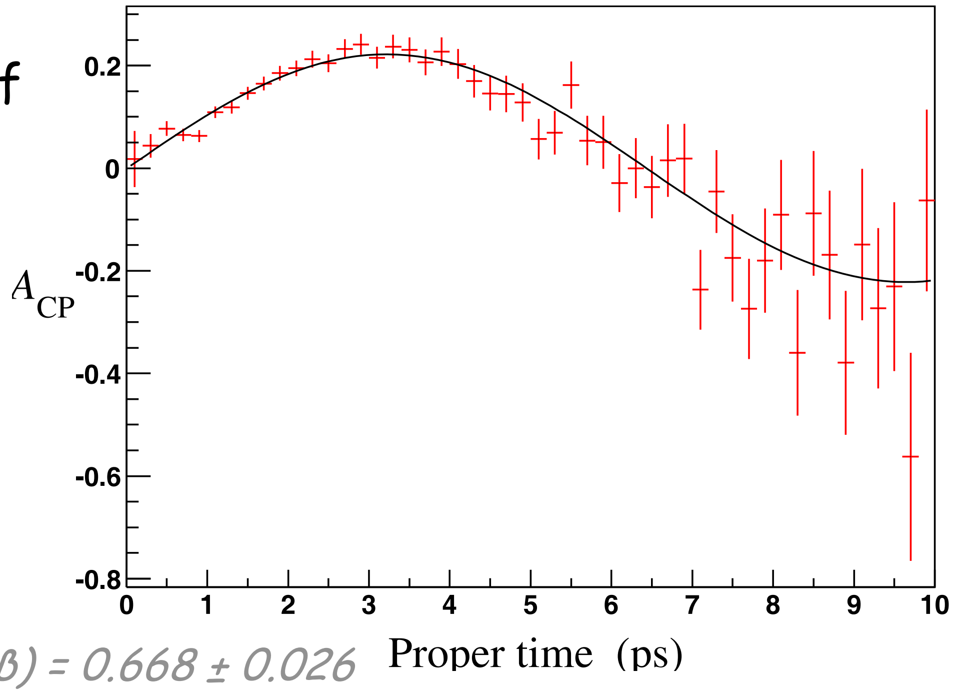
=0 in SM

=sin $2\beta_{eff}$

- Precision σ_{stat} (sin 2β) ~0.02,

  σ_{stat} (β) ~ 0.6°

  in one LHCb year (2 fb^{-1})



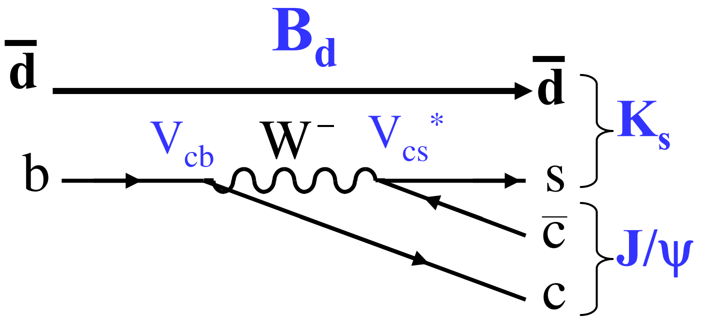
$A_{CP}(t)$ (background subtracted)

For reference:

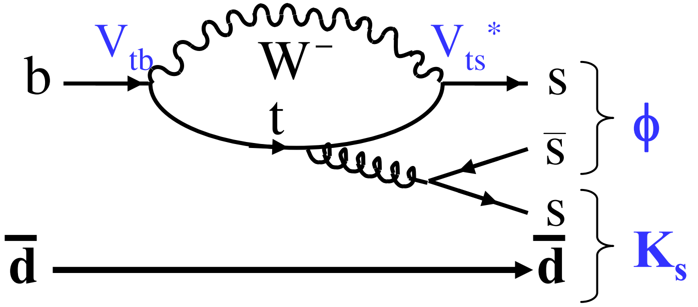
- *Current measurement (B-factories) : sin(2β) = 0.668 ± 0.026*
- *Expected uncertainty at the end of BABAR+BELLE data taking: ~ 0.018*

New Physics through Tree-Penguin comparison

Tree



Penguin



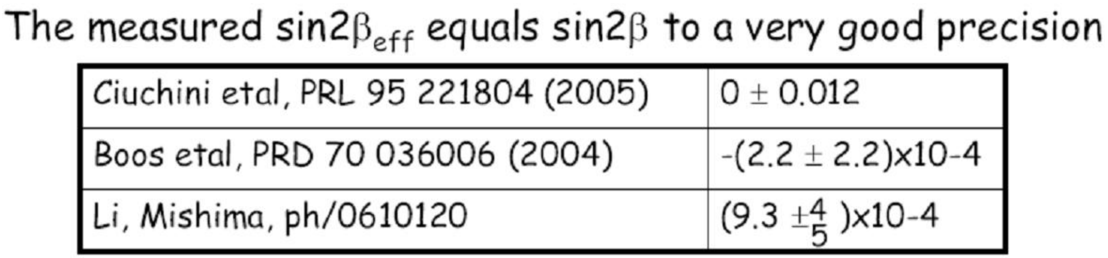
$\beta(\text{tree})-\beta(\text{penguin}) = \delta\beta(\text{NP})$

Possible evidence for NP:

Currently: $\delta\beta(\text{NP}) = 8^o$ (2.6σ)

$\beta_{eff} = \beta + \Delta\beta$

A very good tree indeed… (C.Cheng)



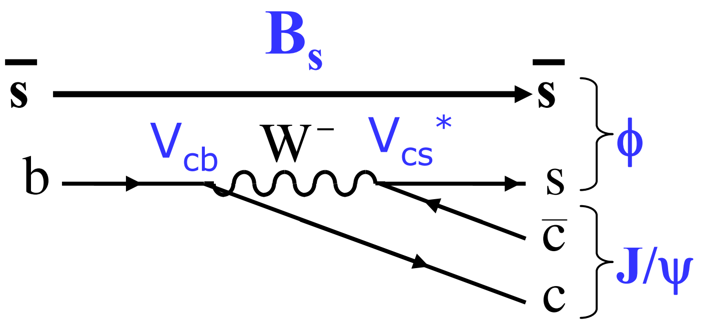
The measured $\sin 2\beta_{eff}$ equals $\sin 2\beta$ to a very good precision

Ciuchini etal, PRL 95 221804 (2005)	0 ± 0.012
Boos etal, PRD 70 036006 (2004)	$-(2.2 \pm 2.2)$x10-4
Li, Mishima, ph/0610120	$(9.3 \pm^{4}_{5})$x10-4

Scaling of 1 year sensitivity from $J/\psi K_s$ to ϕK_s:

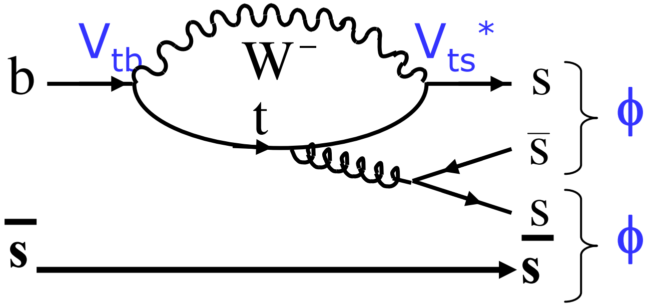
$\sigma(\sin 2\beta_{eff})$~0.4, Yield:0.8k, B/S<2.4.

New Physics through Tree-Penguin comparison



Tree

χ(tree)-χ(penguin) = $\delta\chi$(NP)



Penguin

Same s-penguin diagram as for $\delta\beta$

In SM: $\delta\chi(NP) = \delta\beta(NP)$

If $\delta\beta$ effect persists, we can expect a difference in $\delta\chi$

LHCb sensitivity on $\varphi_s(NP)= 6^\circ$ (2° for $10fb^{-1}$)

comparable to present value $\delta\beta \sim 8^0$

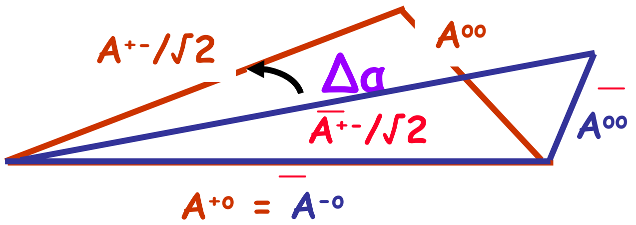
α from B -> ρρ mode

- Measuring the time dependent asymmetry of B -> $\rho^+\rho^-$ provides

$\alpha_{eff} = \alpha + \Delta\alpha$

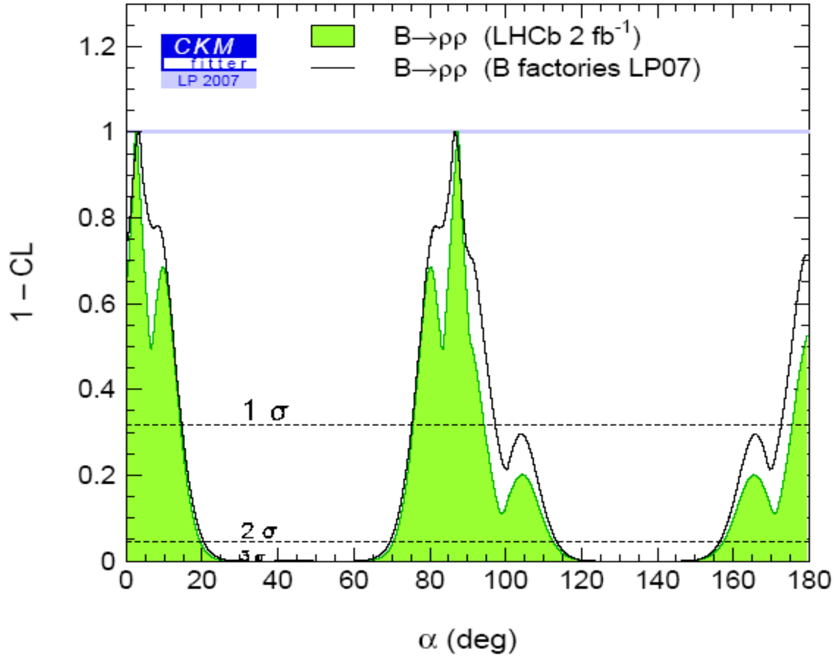
$$A_{\rho\rho}^{+-}(t) = S_{\rho\rho}^{+-}\sin(\Delta m_d t) - C_{\rho\rho}^{+-}\cos(\Delta m_d t)$$

with $S_{\rho\rho}^{+-} = \sqrt{1-C_{\rho\rho}^{+-2}}\,\sin(2\alpha_{eff})$



- LHCb contributes to measuring

A^{00} (t) asymmetry of the B -> $\rho^0\rho^0$ mode



- Yields at 2 fb^{-1}:

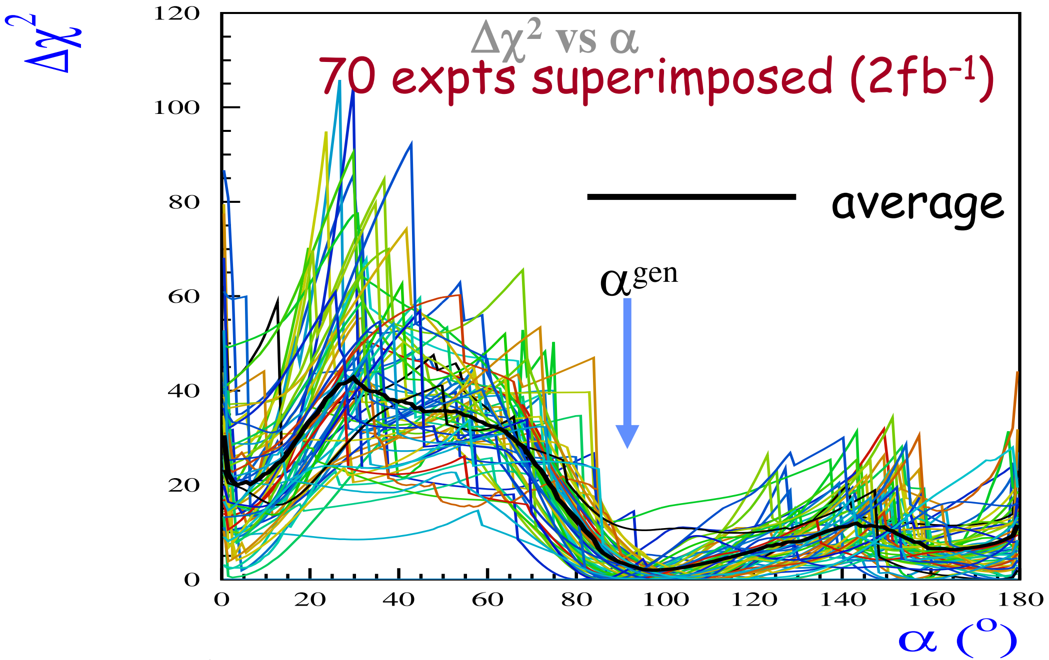
B -> $\rho^+\rho^-$: 2k (B/S<5, 90%CL)

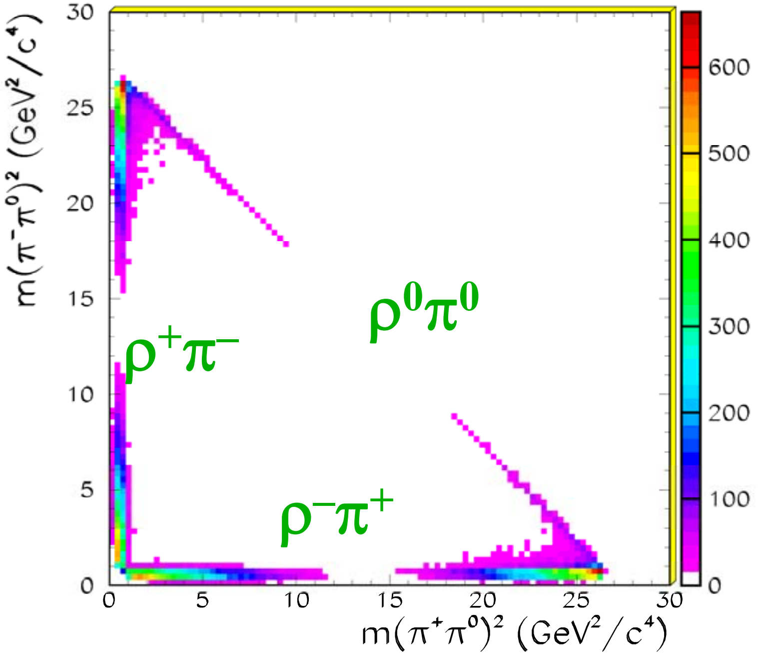
$B^\pm$ -> $\rho^\pm\rho^0$: 9k (B/S ~ 1)

B -> $\rho^0\rho^0$: ~0.5k,
assuming a BR=0.5 10^{-6}
(Babar: $B^{00} = (0.54^{+0.36}_{-0.32} \pm 0.19)10^{-6}$)

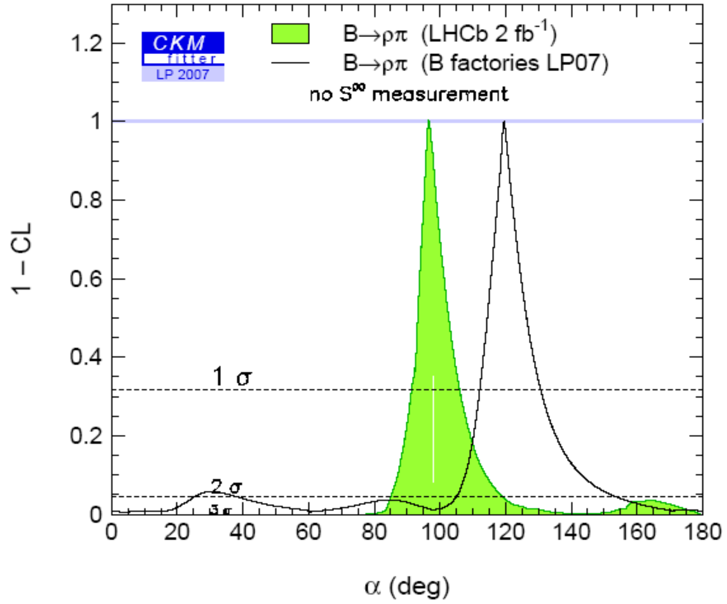
α from B^0 -> $\pi\pi\pi^0$

- Challenging analysis in the LHC environment :
  - π^0 reconstruction $\varepsilon(\pi^0)$=53 % for $B^0 \to \pi^+\pi^-\pi^0$.
  - Time dependent Dalitz plot analysis.



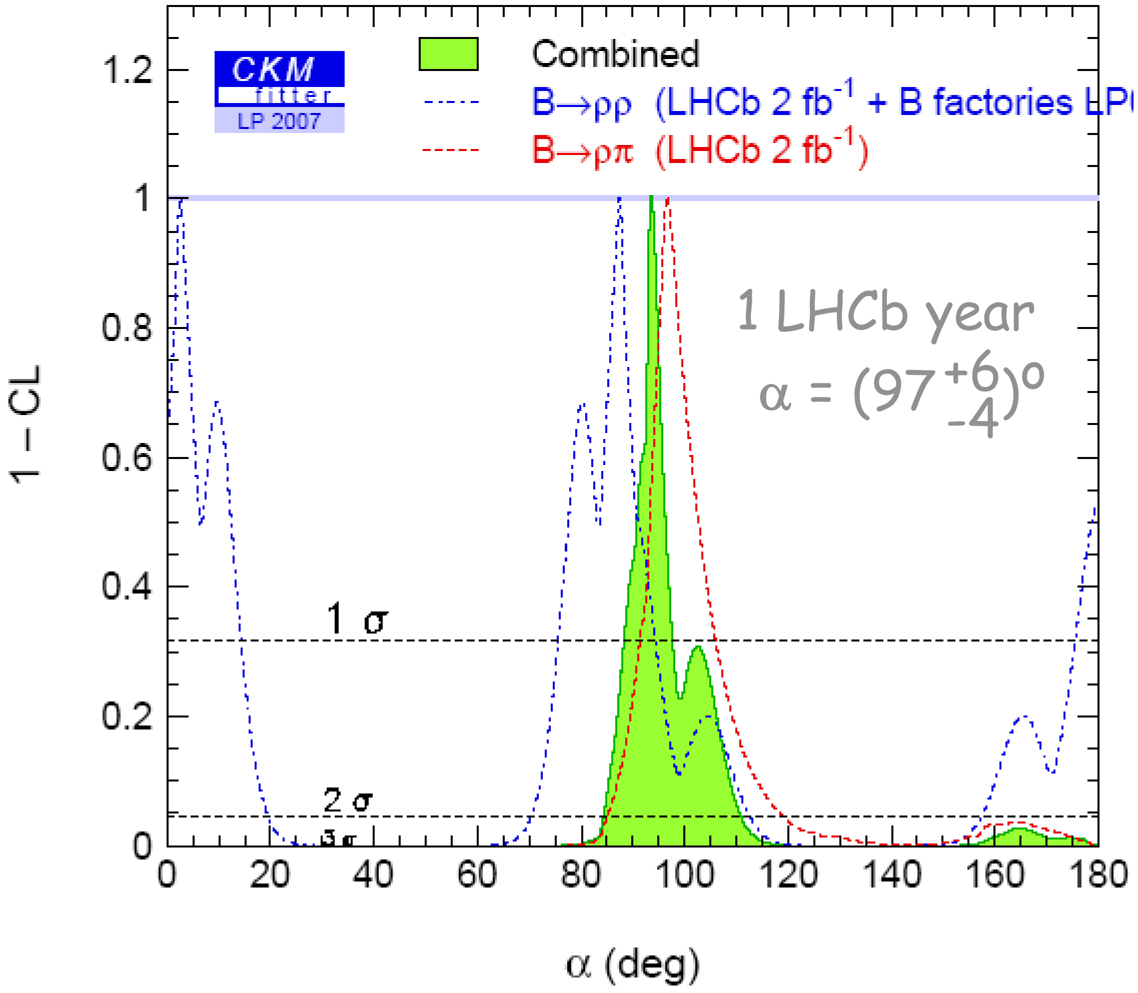


- 2fb^{-1}: 14k signal events B/S<0.8 @ 90%CL.
  (time resolution: 50 fs, tagging power: 6%)
- Use B/S=1 for sensitivity studies
- Probability 15% of mirror solution (< 1% with 10 fb^{-1})



$\sigma_{stat}(\alpha)$ < 10° in 90% of the cases (2 fb^{-1})

α from B^o -> ρρ, ρπ combined



1 LHCb year

$\alpha = (97^{+6}_{-4})^o$