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Bundesministerium für Bildung und Forschung

CKM gamma at LHCb

$B^+ \rightarrow DK^+$

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plan

- introduction
- B-Factory example
- LHCb
- expected sensitivity
- other channels

CKM quark mixing

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \approx \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

$\lambda \approx 0.23$

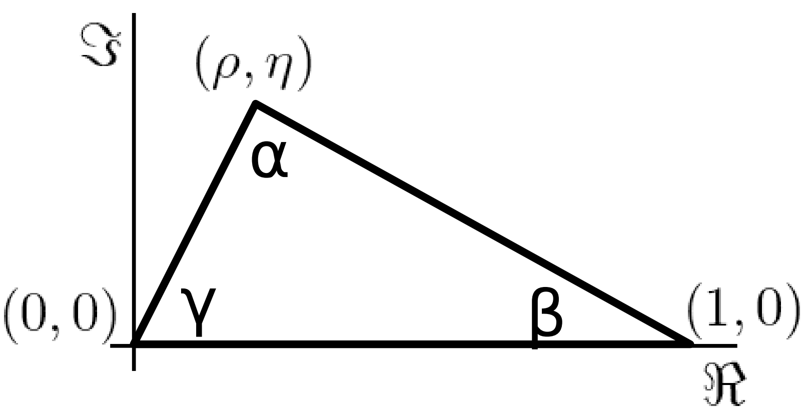
$A \approx 0.8$

$\rho \approx 0.2$

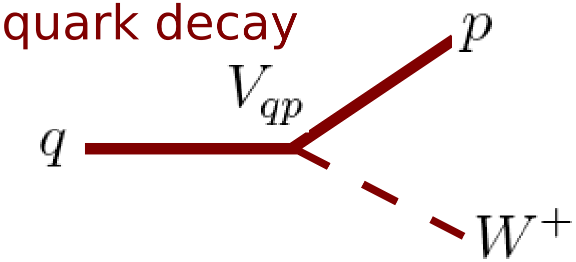
$\eta \approx 0.4$

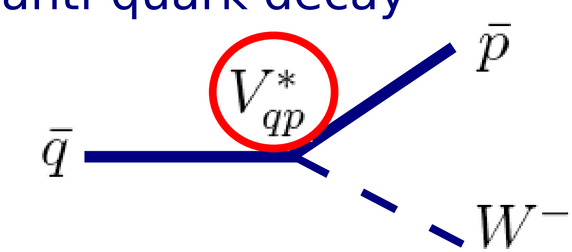
- flavor eigenstates are not mass eigenstates $\rightarrow$ relate them through a unitary matrix
- irreducible phase is the only source of CP violation in the Standard Model
- test the SM by over-constraining the unitarity triangle

$$V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$$

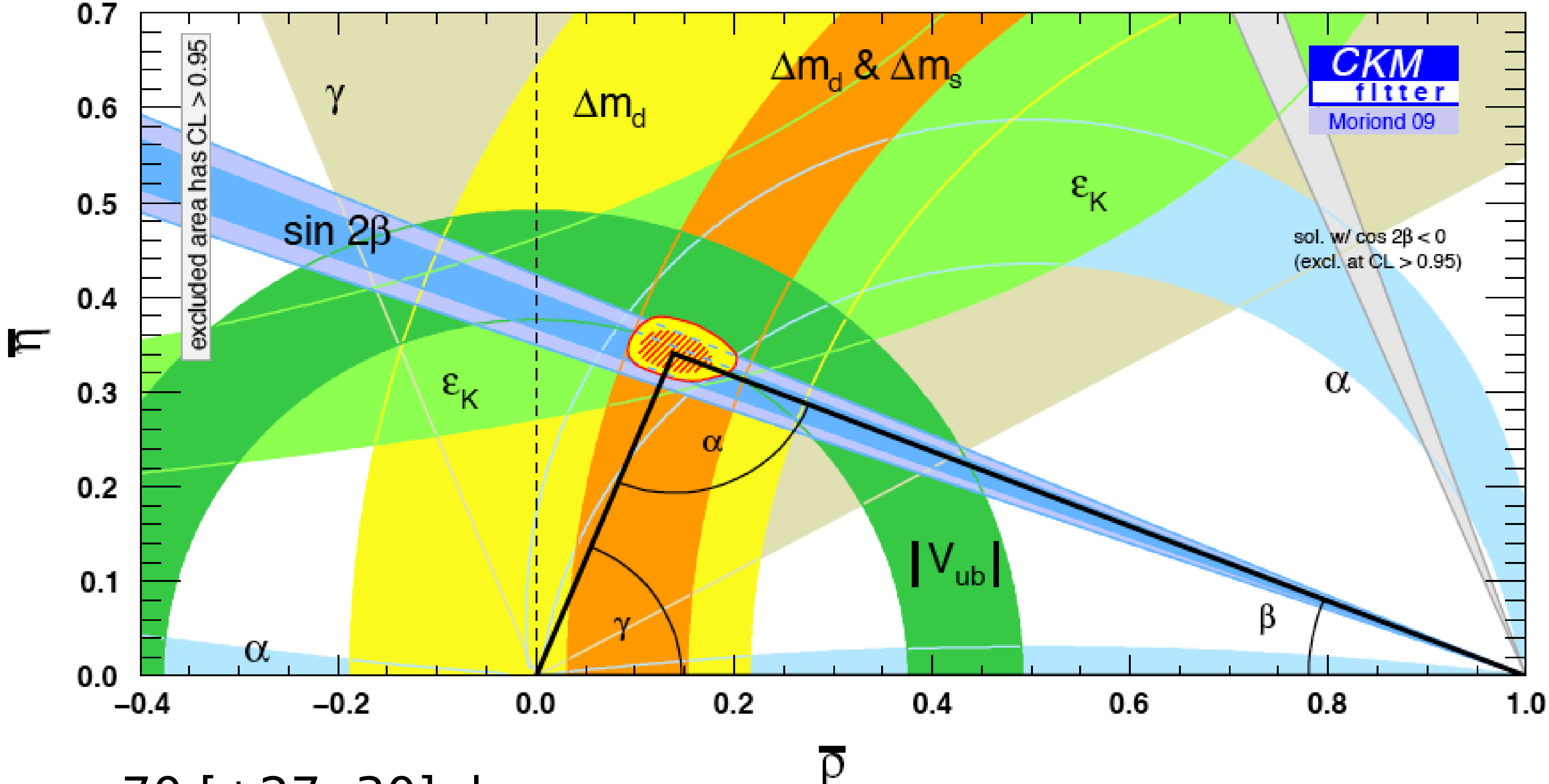


$$\gamma = \arg\left(-\frac{V_{ud}V_{ub}^*}{V_{cd}V_{cb}^*}\right)$$





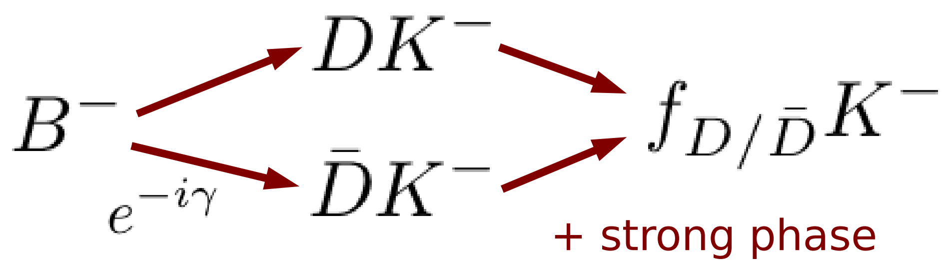
current situation



γ = 70 [+27 -30] degrees

$B \to DK$

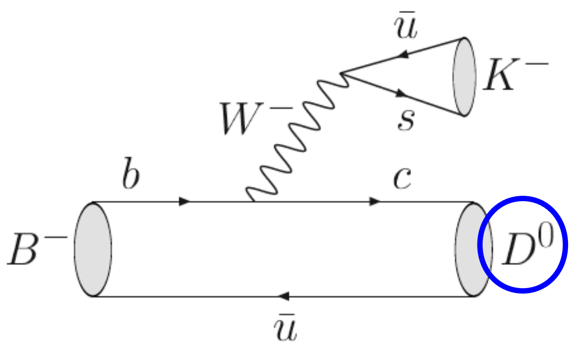
- Methods use final states accessible for both D^0 and $\bar{D}^0$. Tree dominated, no new physics.

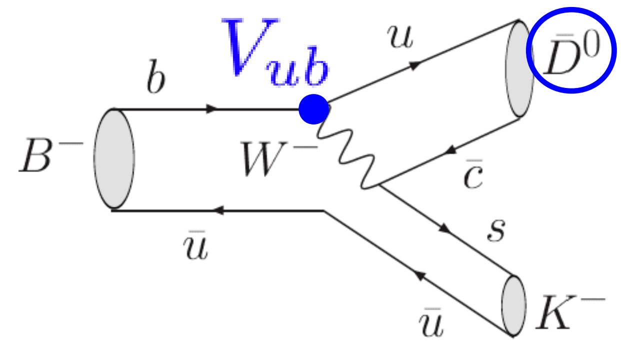


- Sensitivity on γ depends on amplitude ratio r. The uncertainty scales roughly like **1/r**.

$$r = \frac{|A(B \to \bar{D}^{(*)0}K)|}{|A(B \to D^{(*)0}K)|}$$

$$r \approx 0.1$$





- Several D final states can be used:
  - CP eigenstates (GLW)
  - Flavor eigenstates (ADS)
  - 3-body states (GGSZ Dalitz)

Gronau & London, PLB 253, 483 (1991)
Gronau & Wyler, PLB 265, 172 (1991)
Atwood, Dunietz, & Soni, PRL 78, 3257 (1997),
Atwood, Dunietz, & Soni, PRD 63, 036005 (2001)
Giri, Grossman, Soffer, & Zupan, PRD 68, 054018 (2003)
Bondar, PRD 70, 072003 (2004)

381 ·10⁶ BB pairs
PRD77,111102(R),2008

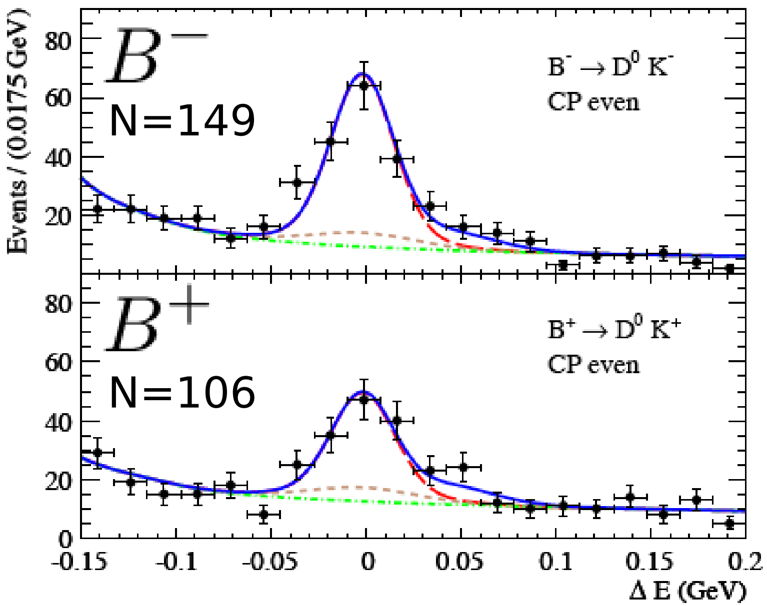
BaBar GLW

- CP- D final states: $K_S\pi^0$ $K_S\omega$ $K_S\Phi$
- CP+ D final states: $\pi^+\pi^-$ K^+K^-
- flavor D final state: $K^+\pi^-$

$$R_{CP\pm} = 1 + r^2 \pm 2r\cos\delta\cos\gamma$$
$$A_{CP\pm} = \pm 2r\sin\delta\sin\gamma / R_{CP\pm}$$

$$R_{CP\pm} = \frac{\Gamma(B^-\to D^0_{CP\pm}K^-) + \Gamma(B^+\to D^0_{CP\pm}K^+)}{[\Gamma(B^-\to D^0K^-) + \Gamma(B^+\to \overline{D}^0K^+)]/2}$$
$$A_{CP\pm} = \frac{\Gamma(B^-\to D^0_{CP\pm}K^-) - \Gamma(B^+\to D^0_{CP\pm}K^+)}{\Gamma(B^-\to D^0_{CP\pm}K^-) + \Gamma(B^+\to D^0_{CP\pm}K^+)}$$

D^0 mode	R_{CP}	A_{CP}
$CP+$	$1.06 \pm 0.10 \pm 0.05$	$0.27 \pm 0.09 \pm 0.04$
$CP-$	$1.03 \pm 0.10 \pm 0.05$	$-0.09 \pm 0.09 \pm 0.02$



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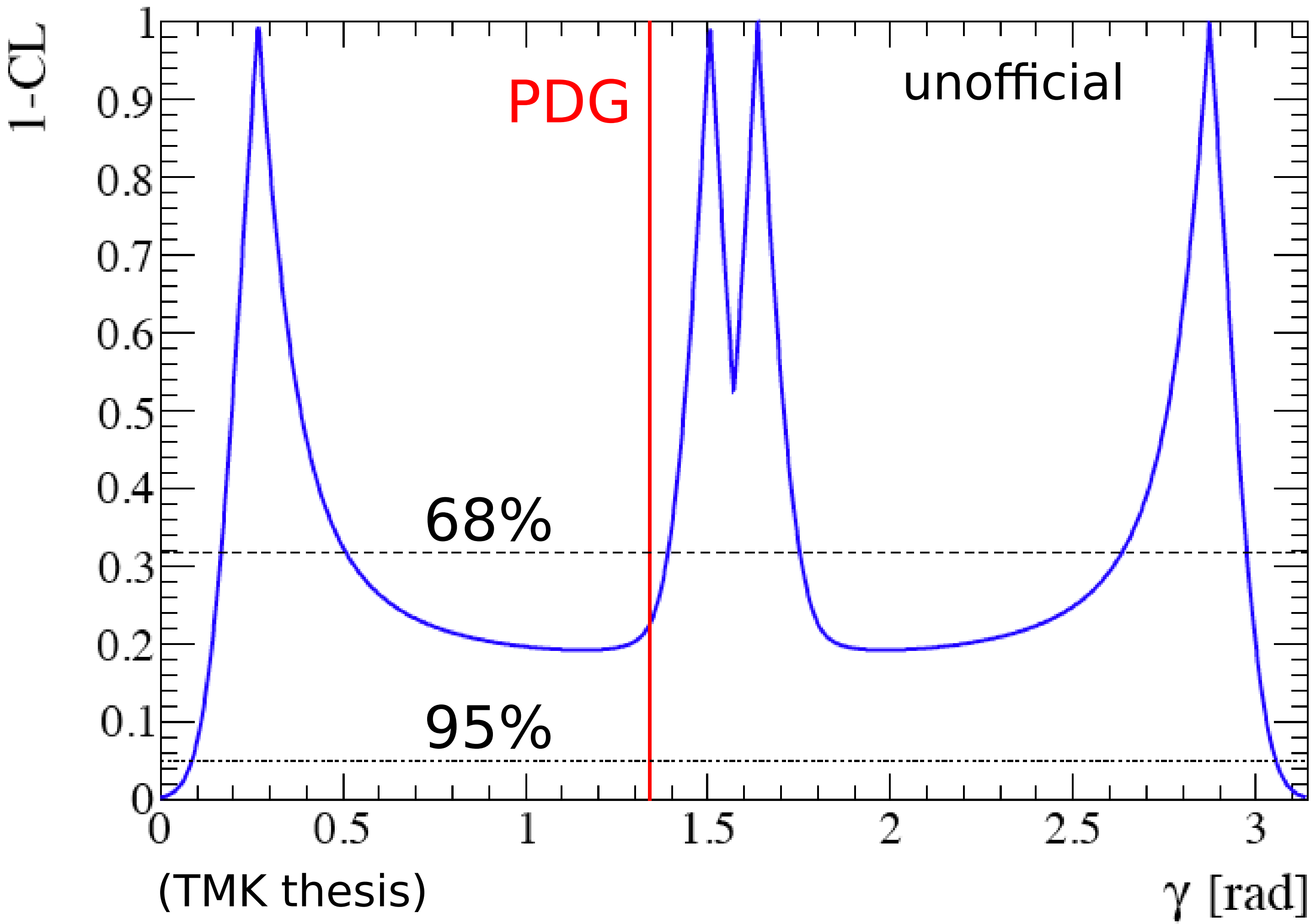
467 ·10⁶ BB pairs
unofficial

BaBar GLW



(TMK thesis)

BaBar
final dataset

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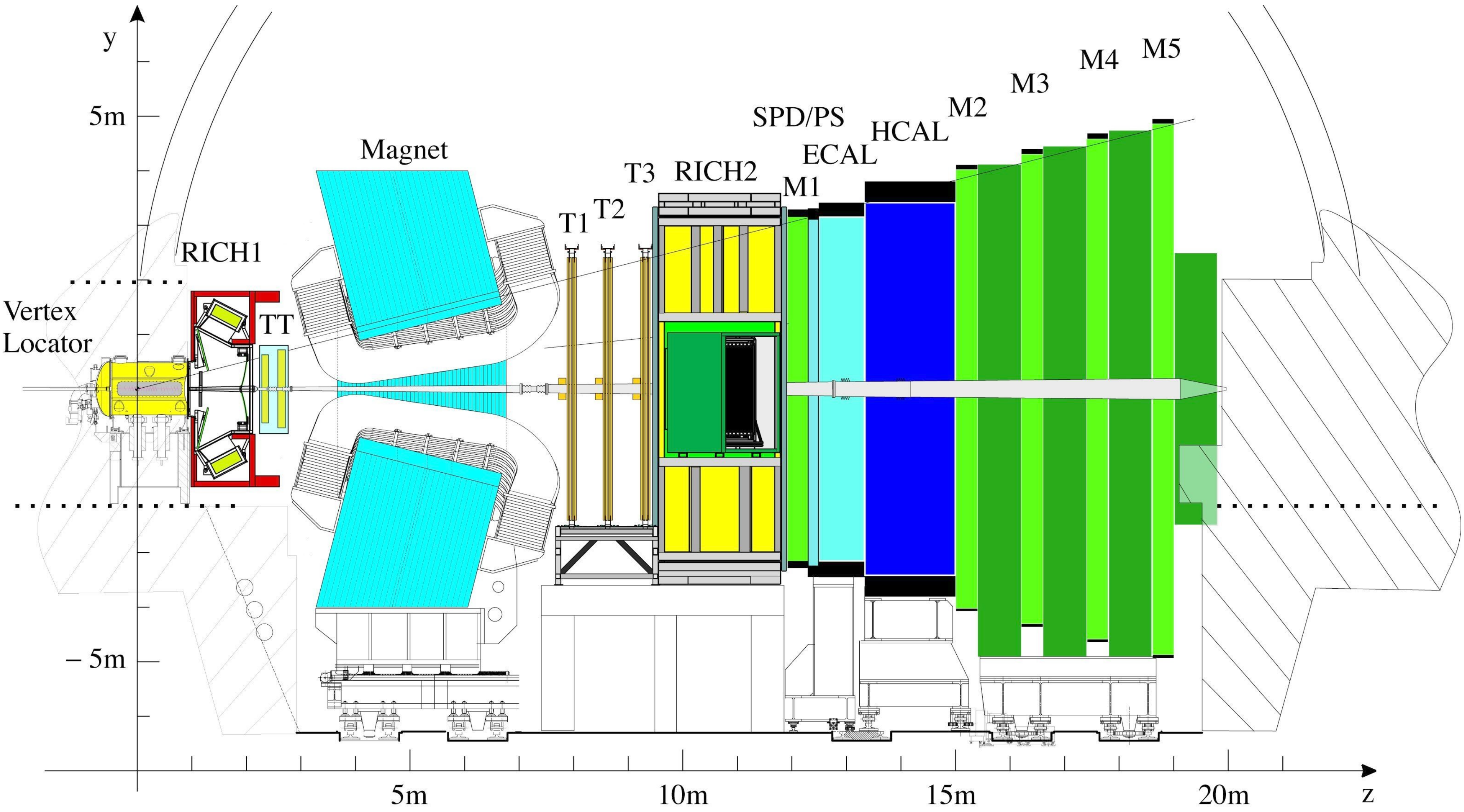
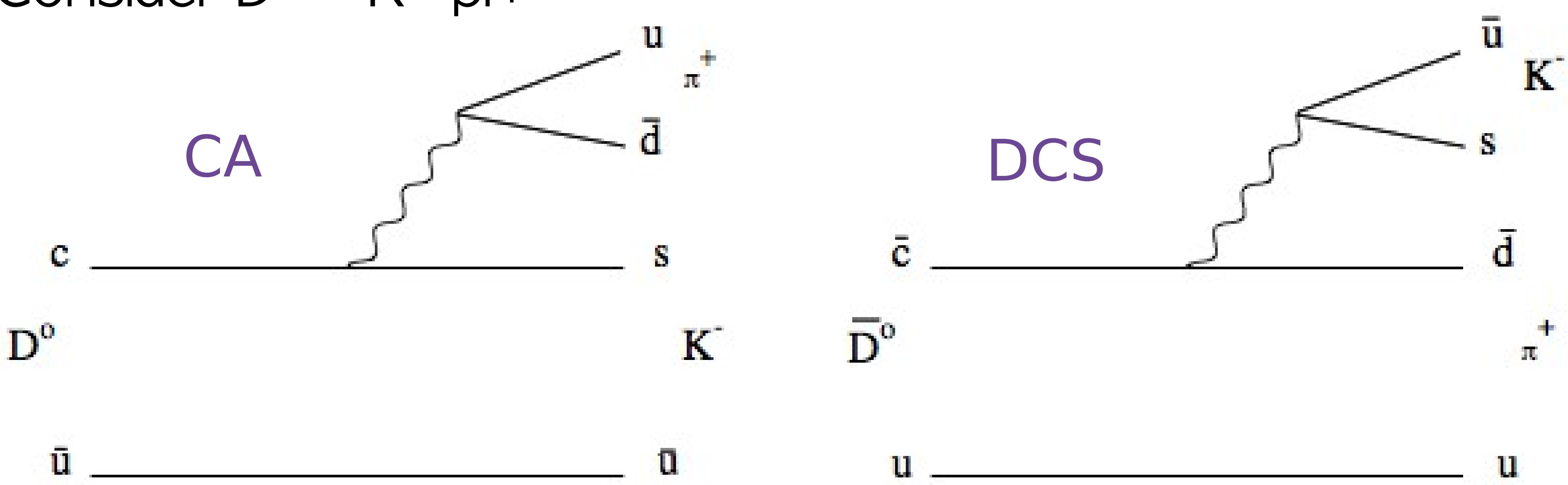
LHCb detector



GLW/ADS at LHCb

- At B-Factories, the "Dalitz analyses" are most successful: $B \rightarrow DK$, $D \rightarrow K_S$ pi+ pi-
- LHCb's strength are charged K's and pi's, therefore GLW/ADS channels are more promising
- Consider $D \rightarrow$ K- pi+



GLW/ADS at LHCb

- For the rates, it is:

allowed

0.06 from CLEO

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

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

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

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

- measuring relative rates gives three observables
- four unknowns: γ , r_B, and strong phases differences in B and D decay

GLW/ADS at LHCb

- Solution: add more channels!
- Each channel adds three observables, but at max two unknown phases (ratios again taken from external sources)
- So the measurement seems possible by adding

$$B^- \rightarrow (K^-\pi^+\pi^-\pi^+)_D K^-$$ „ADS channel"

$$B^- \rightarrow (K^-K^+)_D K^-$$ „GLW channel"

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expected yields in $2fb^{-1}$

Channel	Signal	Background
$B^\pm \to D(K^\pm\pi^\mp)K^\pm$	56k	35k
$B^+ \to D(K^-\pi^+)K^+$	680	780
$B^- \to D(K^+\pi^-)K^-$	400	780
$B^+ \to D(K^+K^- + \pi^+\pi^-)K^+$	3.3k	7.2k
$B^- \to D(K^+K^- + \pi^+\pi^-)K^-$	4.4k	7.2k
$B^\pm \to D(K^\pm\pi^\mp\pi^+\pi^-)K^\pm$	61k	40k
$B^+ \to D(K^-\pi^+\pi^+\pi^-)K^+$	470	1.2k
$B^- \to D(K^+\pi^-\pi^+\pi^-)K^-$	350	1.2k
$B^0 \to D(K^+\pi^-)K^{*0}$, $\bar{B}^0 \to D(K^-\pi^+)\bar{K}^{*0}$	3.4k	1.7k
$B^0 \to D(K^-\pi^+)K^{*0}$	350	850
$\bar{B}^0 \to D(K^+\pi^-)\bar{K}^{*0}$	230	850
$B^0 \to D(K^+K^- + \pi^+\pi^-)K^{*0}$	150	500
$\bar{B}^0 \to D(K^+K^- + \pi^+\pi^-)\bar{K}^{*0}$	550	500
$B^\pm \to D(K^0_S\pi^+\pi^-)K^\pm$	5k	4.7k
$B_s, \bar{B}_s \to D_s^\mp K^\pm$	6.2k	4.3k
$B^0, \bar{B}^0 \to D^\mp\pi^\pm$	1,300k	290k

x20 Babar

covered in this talk

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expected global sensitivity

δ_{B^0} (°)	0	45	90	135	180	
σ_γ for 0.5 fb^{-1} (°)	8.1	10.1	9.3	9.5	7.8	
σ_γ for 2 fb^{-1} (°)	4.1	5.1	4.8	5.1	3.9	~ 1y
σ_γ for 10 fb^{-1} (°)	2.0	2.7	2.4	2.6	1.9	~ 10y

contributing analyses (%):

Analysis	$\delta_{B^0} = 0°$	$\delta_{B^0} = 45°$	
$B^- \to D^0(hh)K^-$, $B^- \to D^0(K^\pm\pi^\mp\pi^+\pi^-)K^-$	25	38	GLW/ADS
$B^- \to D^0(K^0_S\pi^+\pi^-)K^-$	12	25	Dalitz
$B^0 \to D^0(hh)K^{*0}$	44	8	
$B_s \to D_s^\mp K^\pm$	16	24	
$B^0 \to D^\mp\pi^\pm$	3	5	

r_{B0} assumed to be 0.4

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conclusion

- LHCb has great potential to measure CKM gamma
- Many modes couldn't be covered
  (for instance the unique $B_s \rightarrow D_s K$ relying on beta_s from
  $B \rightarrow$ J/Psi Phi)
- A precision of **5 degrees** (stat) seems possible in 1y of nominal data taking.
- Will probably turn γ into a precision measurement!

Thanks to Guy Wilkinson et al.
for the relevant LHCb public notes.

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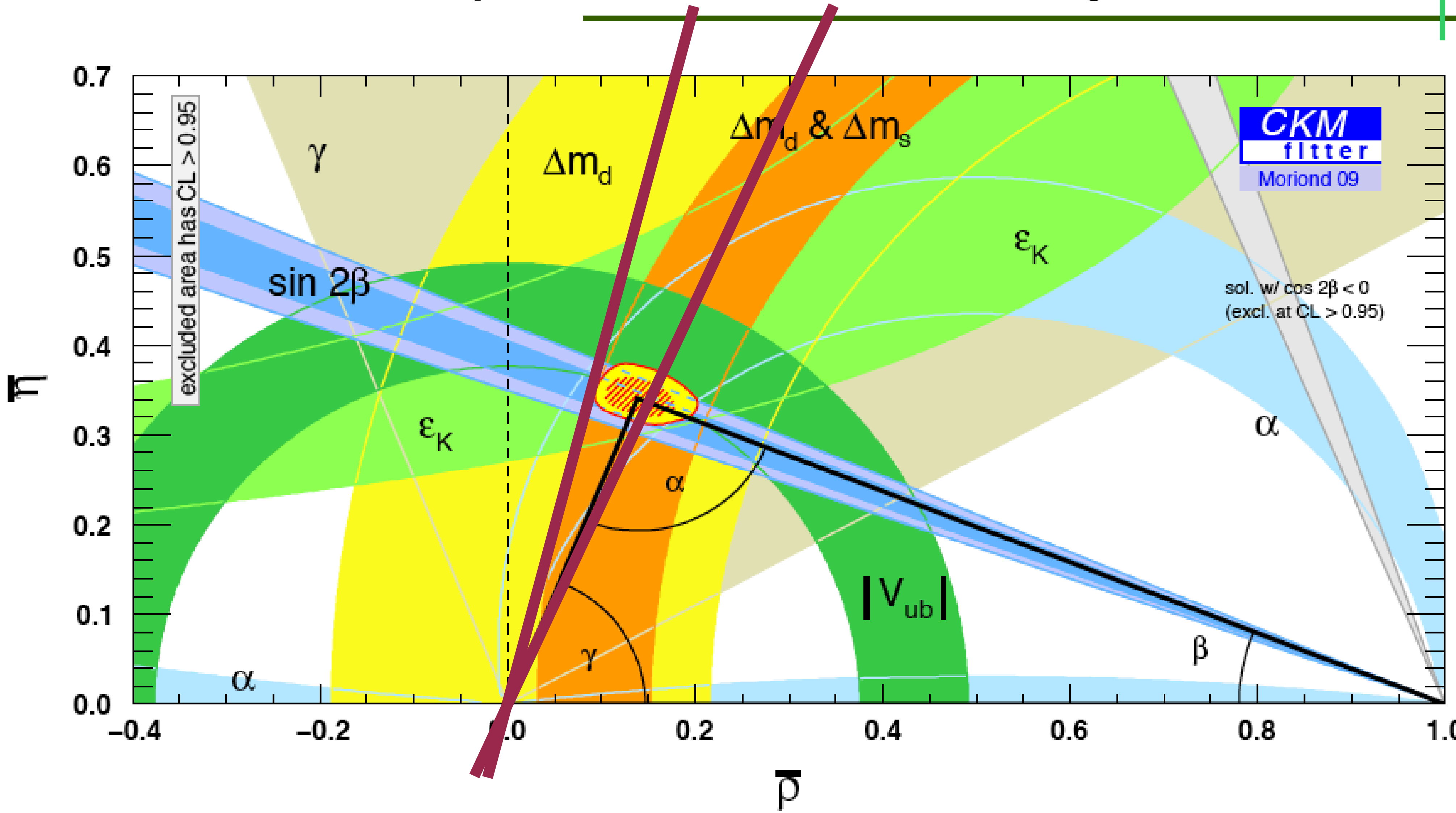
expected sensitivity



γ = 70 [+5 -5] degrees (1y nominal data)