UTfit and CKMfitter: impact of LHCb measurements

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Implications of LHCb measurements and future prospects workshop
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Credits

The plots and numbers used in this talk were prepared by the following people:

UTfit

http://utfit.org/

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CKMfitter

http://ckmfitter.in2p3.fr/

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*Actual LHCb members

Statistical method

UTfit

Use the Bayesian statistics to extract the observables. Extract the credibility interval from the fit.

Gaussian PDFs are used to represent statistical and systematic uncertainties.

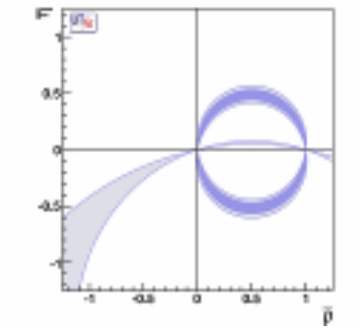
CKM fitter

Use Frequentist Hypothesis testing to build statistical significance (p-value) functions from which estimates and confidence intervals are obtained.

RFit scheme for the treatment of theoretical systematics. Theoretical systematics are considered as additional nuisance parameters .

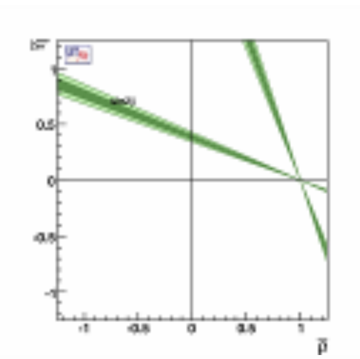
Constraints used (angles)

α



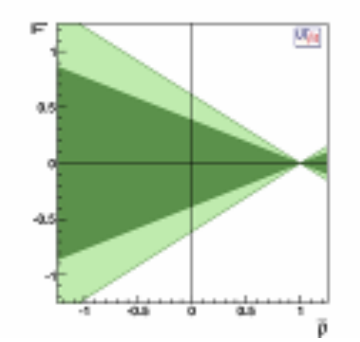
B→ππ, B→Kπ, B→KK

sin(2β)



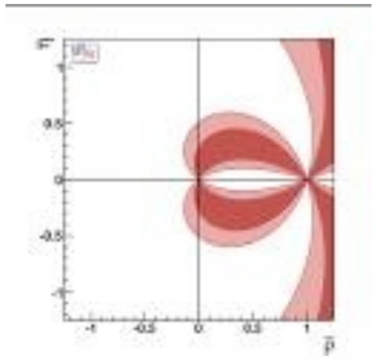
B→J/Ψπ, B→J/ΨK

cos(2β)



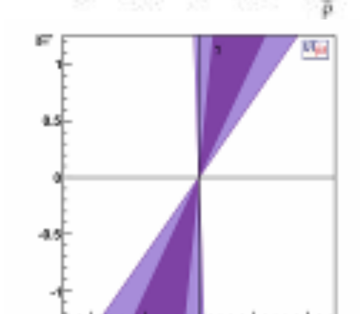
B→DK, B→Dπ

2β+γ

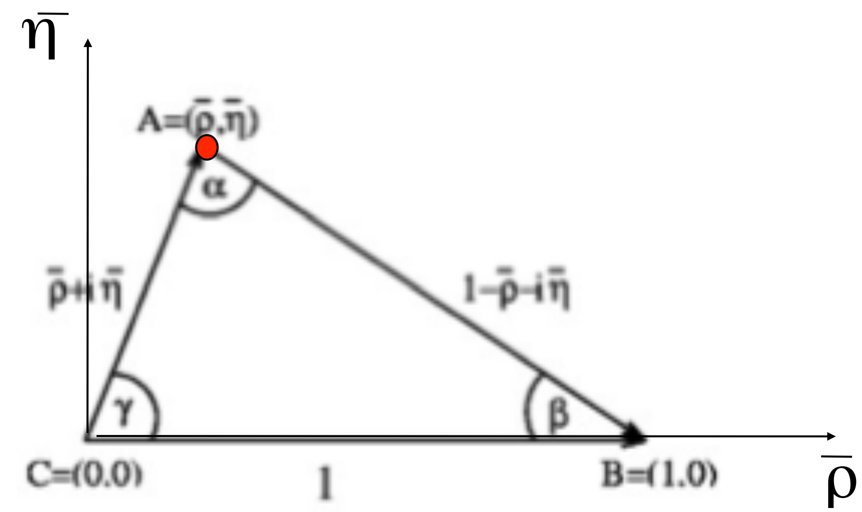


B→DK, B→Dπ

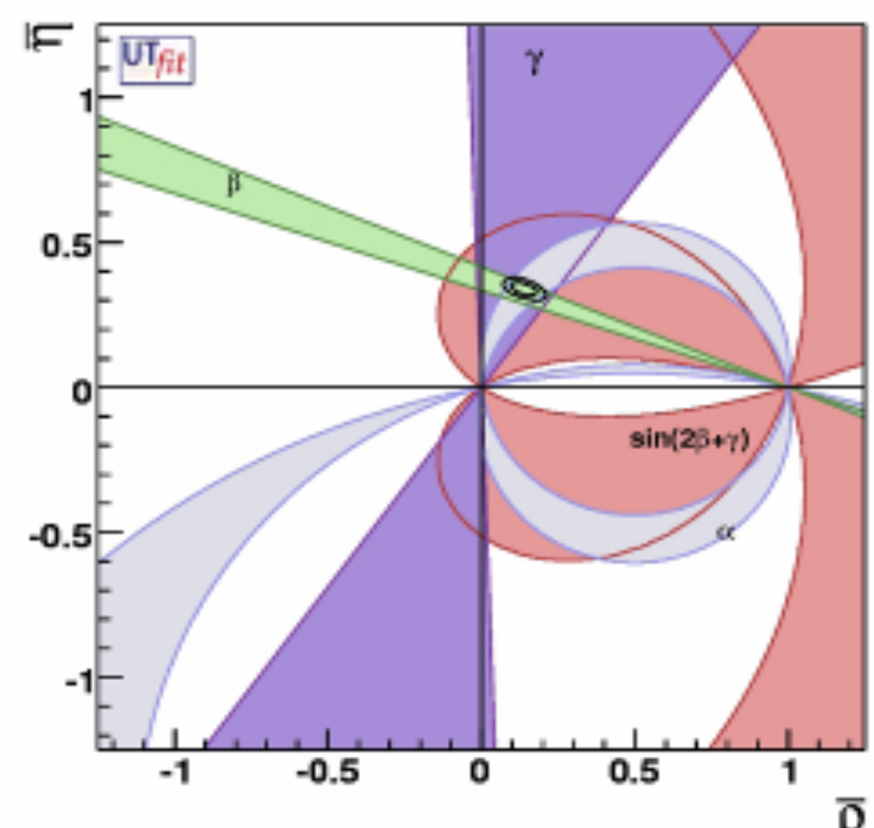
γ



B→DK*



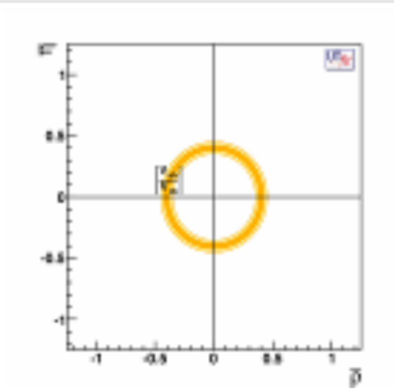
Information is already sufficient to constrain the apex:



*Include present LHCb results

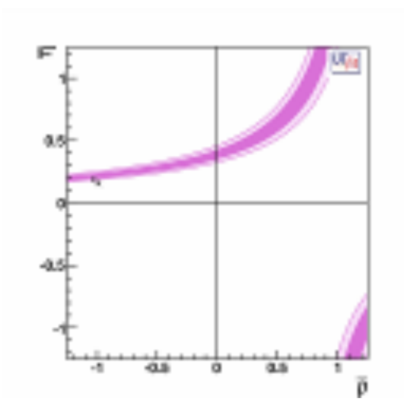
Constraints used (sides constraints)

$|V_{ub}/V_{cb}|$



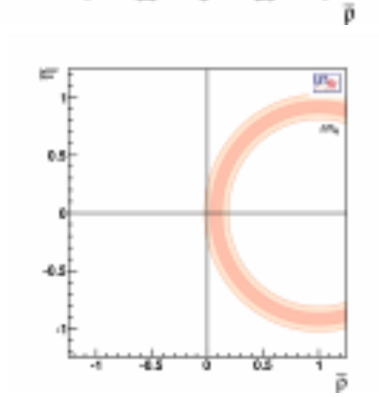
exclusive B→Dlν (B→π(ρ)lν) determination
inclusive b→c (b→u) determination

ε_K



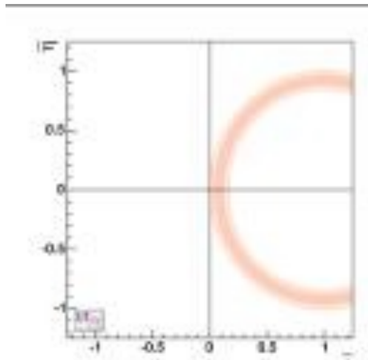
indirect *CP*
violation in K_L decays

Δm_d

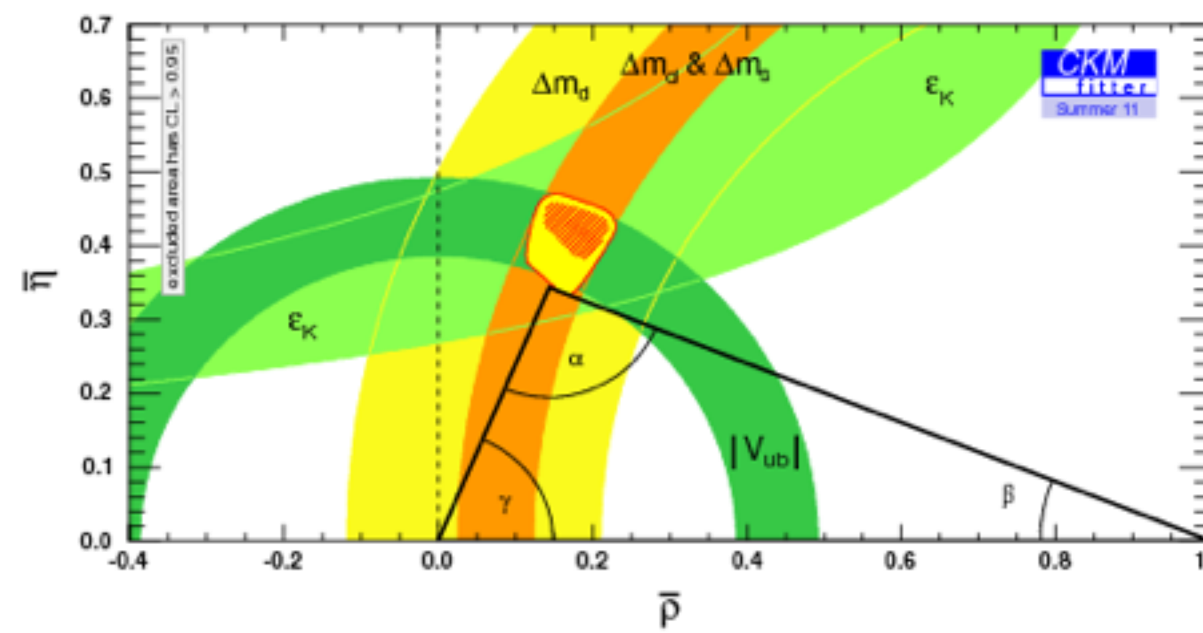


B_d mixing*

$\Delta m_d/\Delta m_s$



$B_{d,s}$ mixing*

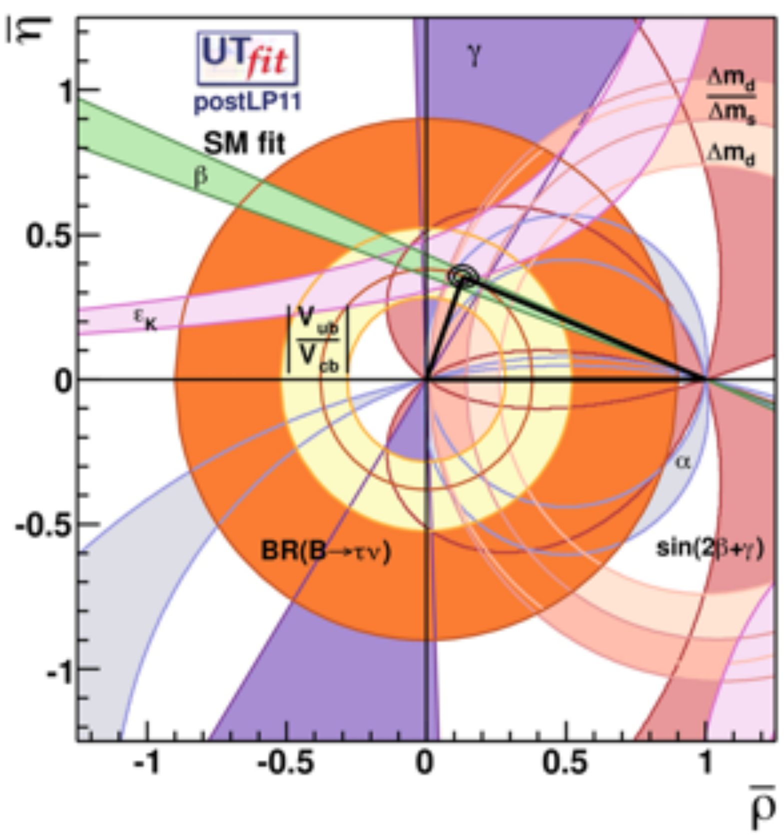


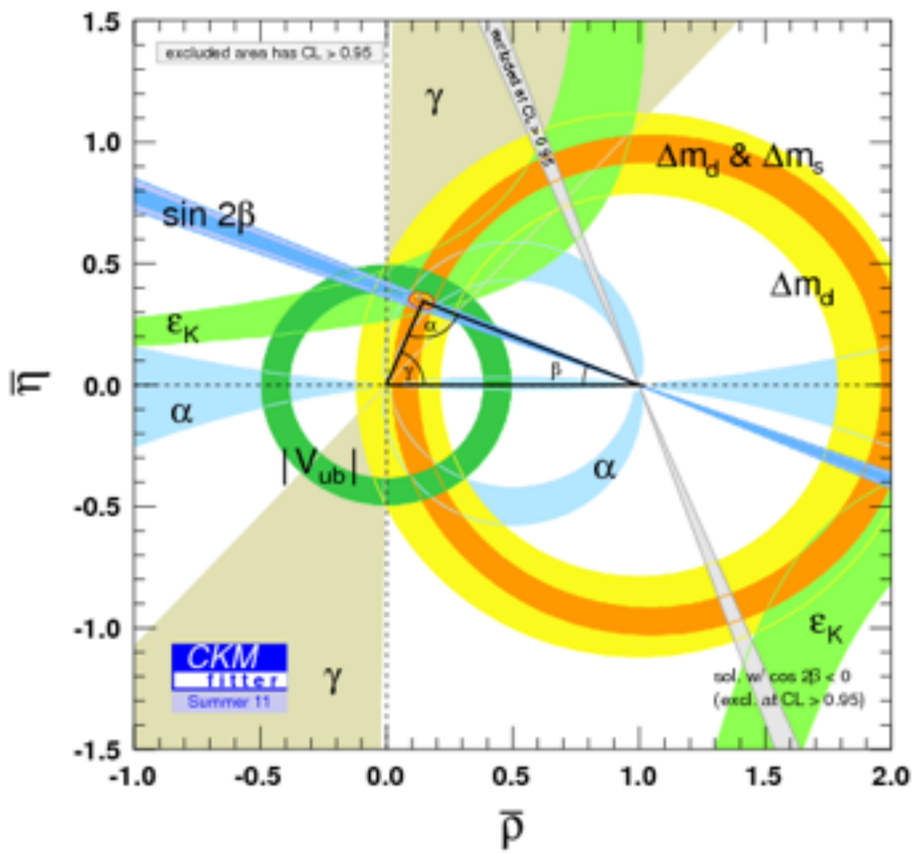
NB: apex constraint is coming from the full fit

*Include actual LHCb results

Main fit results

Combining all the constraints in one fit, groups get:





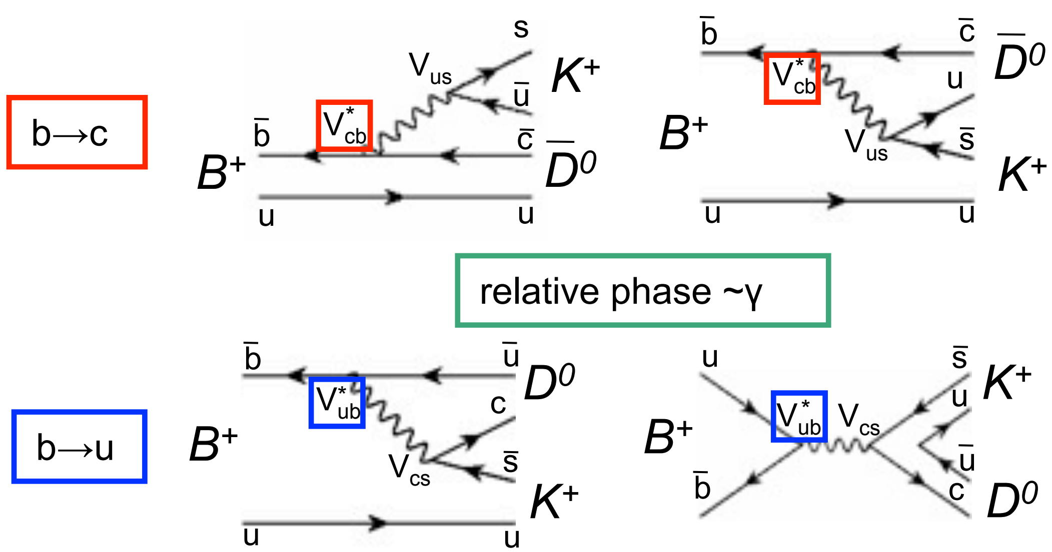
$\bar{\rho} = 0.131 \pm 0.022$
$\bar{\eta} = 0.354 \pm 0.015$

$\bar{\rho} = 0.144^{+0.023}_{-0.026}$
$\bar{\eta} = 0.343^{+0.015}_{-0.014}$

The central values are consistent within errors. SM stands very precise and there are no big tensions for a moment. Keep in mind $B \to \tau\nu$ and $\sin(2\beta)$ mutual tension of ~2-3σ.

Multiple analyses treatment

In several input measurements we need to combine different analyses types and different experiments. A good example of such a combination is CKM angle γ extraction.



Related variables (depend on the *B* meson decay channel):

$$r_B = \frac{|A_{b\to u}|}{|A_{b\to c}|} \begin{cases} r_B \sim 0.1 & \text{For charged } B \text{ mesons} \\ r_B \sim 0.3 & \text{For neutral } B \text{ mesons} \end{cases}$$

δ_B strong phase (*CP* conserving)

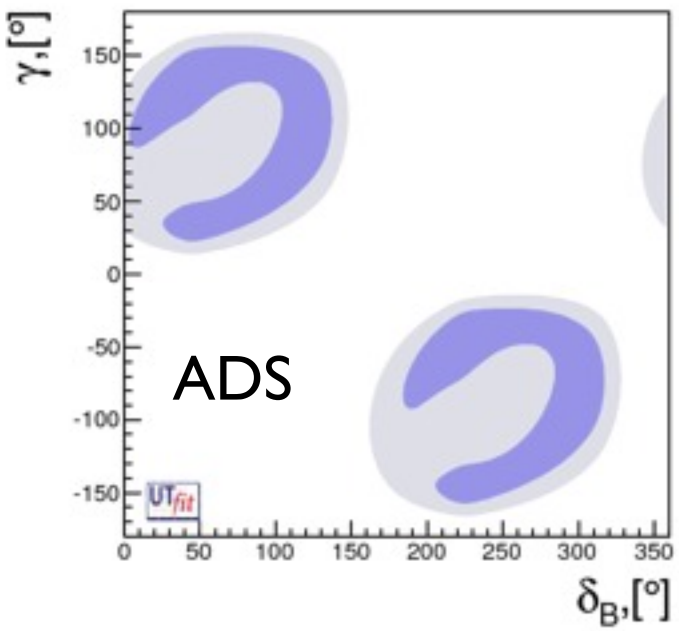
Experimentally not easy to measure.

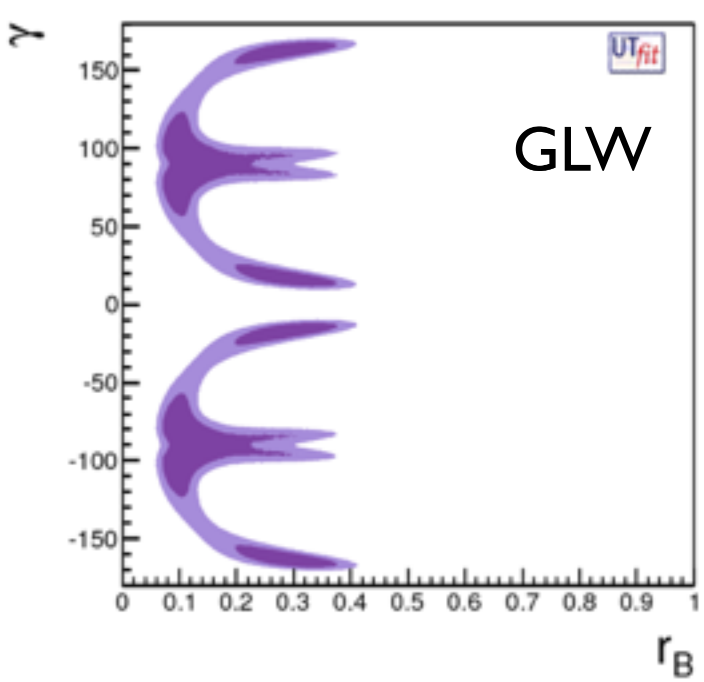
Three ways to extract the information:

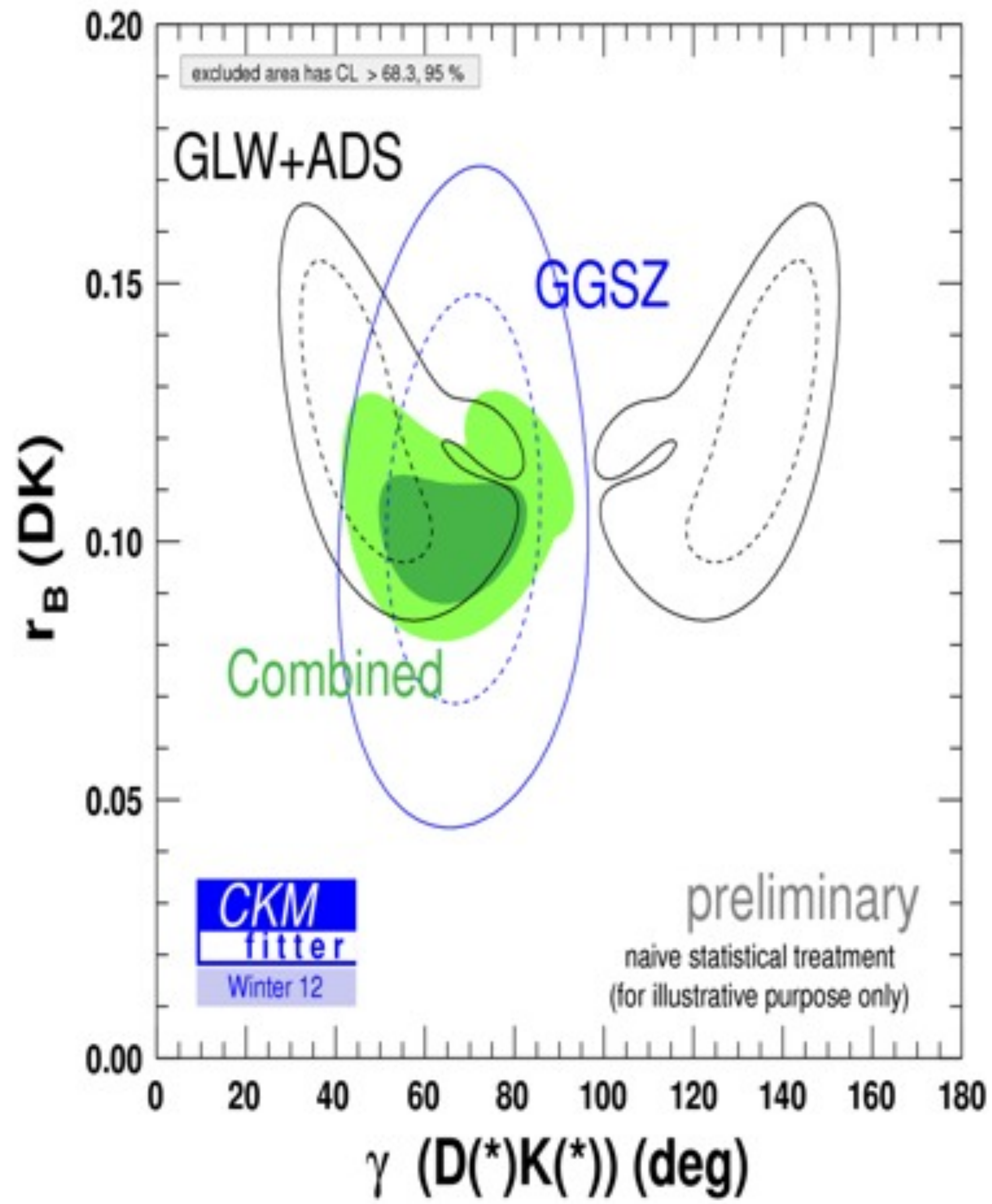
- •GLW (D→CP+ (KK, ππ)* or CP−($K_s\varphi$, $K_s\omega$) eigenstate)
- •ADS (D→Kπ, D→$K\pi\pi^0$, D→Kπππ)*
- •GGSZ (D→$K_s\pi\pi$, D→K_sKK)

*Include present LHCb results, the B^+→DK^+ channels precision is lead by LHCb.

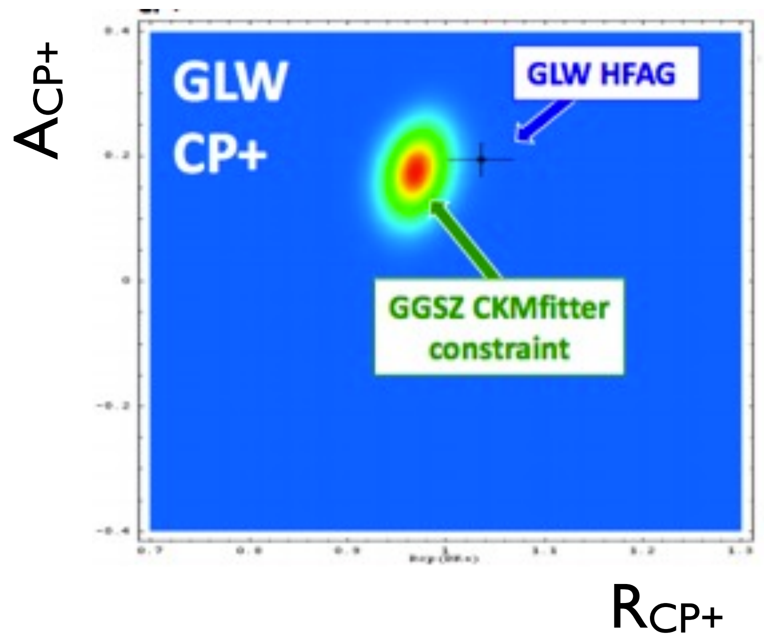
The combination is performed starting from the HFAG averages. The main problem is treatment of the nontrivial likelihoods for $\{\gamma, \delta_B, r_B\}$ observables.

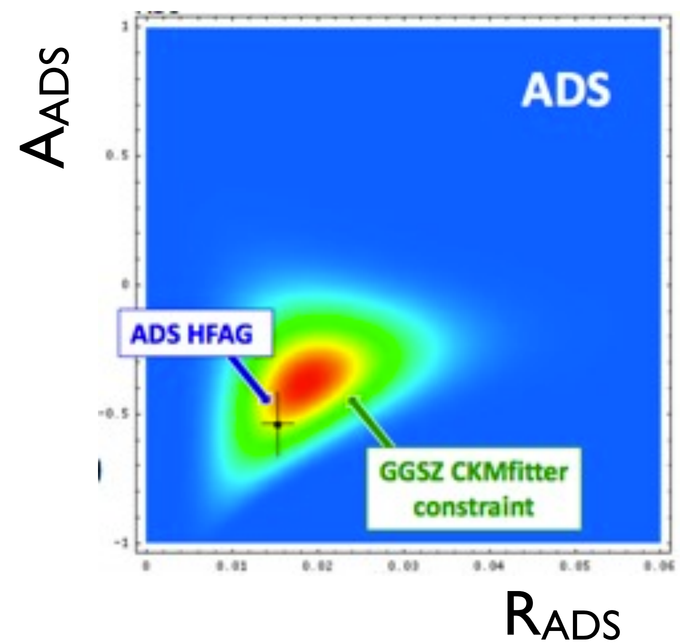


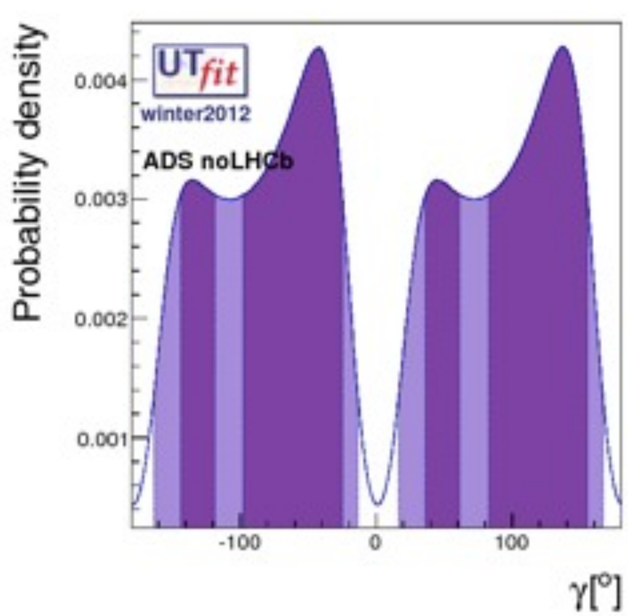




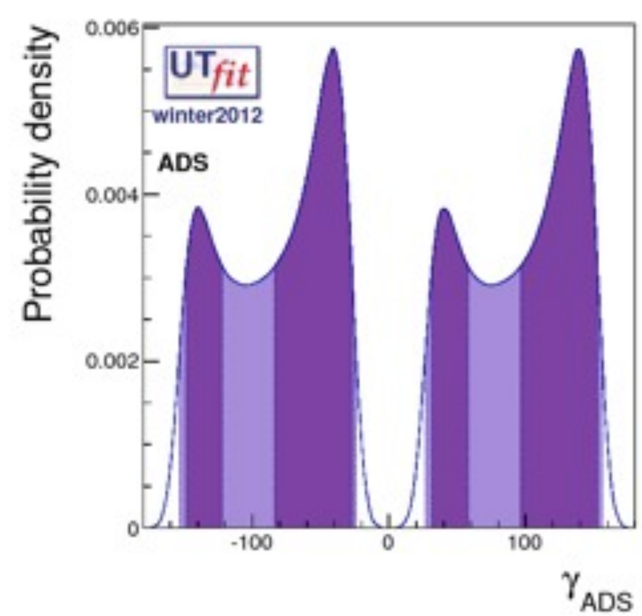
LHCb has already produced measurements, which have got leading precision for this type of analyses.







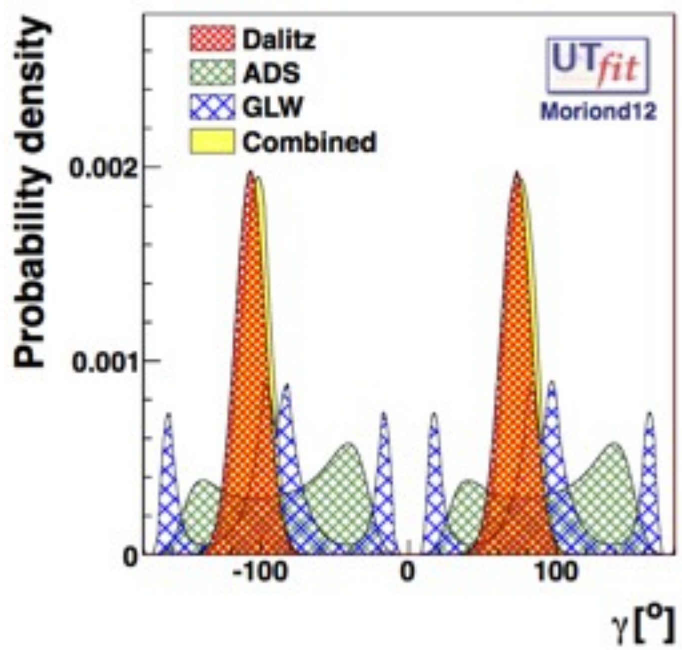
Nice example of LHCb entering the game



To resolve the ambiguities, one needs more decay channels to be analyzed.

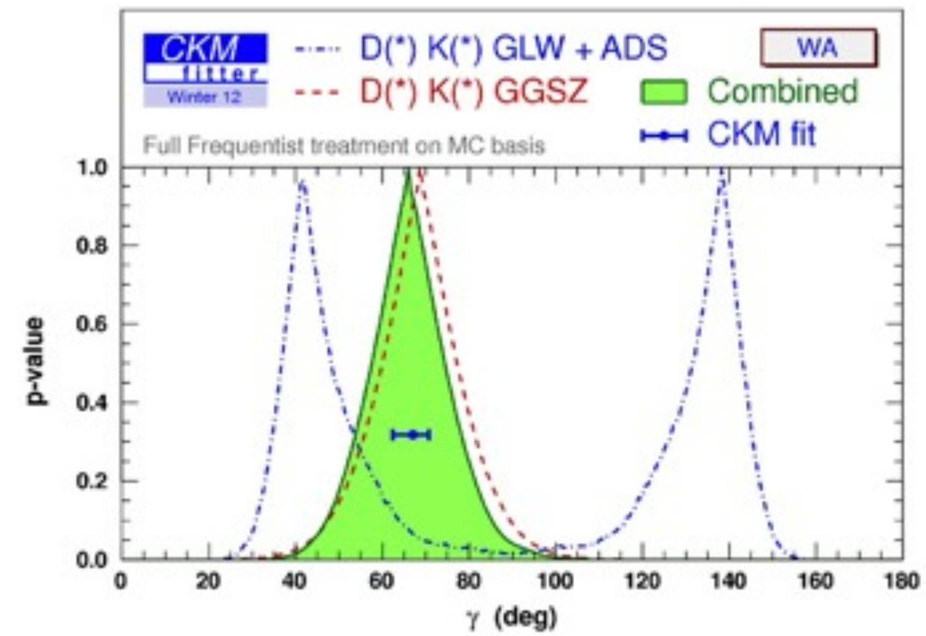
γ results

The SM prediction can be obtained removing γ from the full fit.



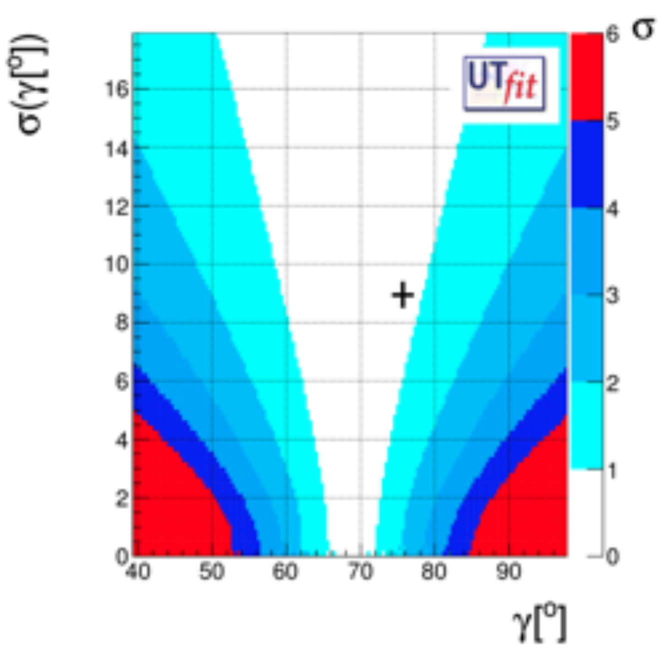
γ_{comb} = (75.5 ±10.5)°*

γ_{SM} =(68.5±3.2)°



γ_{comb} =(66±12)°*

γ_{SM} = $(67.1^{+4.6}_{-3.7})$°



With new LHCb results we are now able to have good γ reconstruction in the GLW analysis.

The issue of central values is now under discussion, however, both results show that there's no tension in this sector.

*Post Moriond 2012 results

Summary Table of the SM predictions and pulls

	UTfit			CKMfitter		
	Prediction	Measurement	Pull	Prediction	Measurement	Pull
α, °	(85.8±3.9)	(91.4±6.1)	+0.8	$(92.9^{+3.6}_{-5.1})$	$(89.0^{+4.4}_{-4.2})$	-0.6
$\sin(2\beta)$	(0.80±0.05)	(0.679±0.024)	-2.2	$(0.830^{+0.013}_{-0.033})$	(0.679±0.024)	-2.7
γ , °	(68.5±3.2)	(75.5±10.5)	+0.6	$(67.1^{+4.6}_{-3.7})$	(66±12)	~0
V_{ub}, 10^{-3}	(3.61±0.14)	(3.8±0.6)	+0.6	$(3.42^{+0.2}_{-0.1})$	(3.92±0.09±0.45)	+1
V_{cb}, 10^{-3}	(41.5±0.7)	(41.±1.)	-0.3	(40.69±0.99)	(40.89±0.38±0.59)	+0,2
ε_K, 10^{-3}	(1.92±0.18)	(2.229±0.010)	+1.7	$(1.86^{+0.67}_{-0.39})$	(2.229±0.010)	~0
Δm_s, ps^{-1}	(19.0±1.5)	(17.7±0.08)	-0.9	$(18.1^{+2.2}_{-2.1})$	(17.731±0.045)	-0.2
$B(B\to\tau\nu)$, 10^{-4}	(1.64±0.34)	(0.831±0.093)	-2.3	(1.68±0.31)	(0.832±0.084)	-2.8
β_s, rad*	(0.01876±0.0008)			$(0.01824^{+0.00080}_{-0.00075})$		

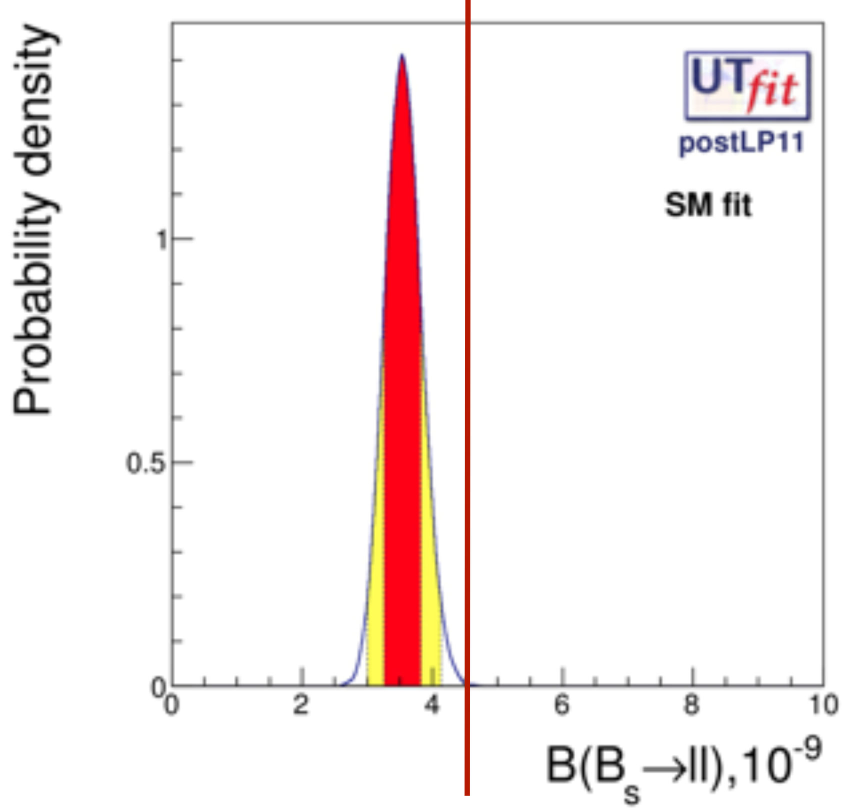
*To be compared to the most recent LHCb measurement: ϕ_s= -0.002 ± 0.083(stat.) ± 0.027(syst.)

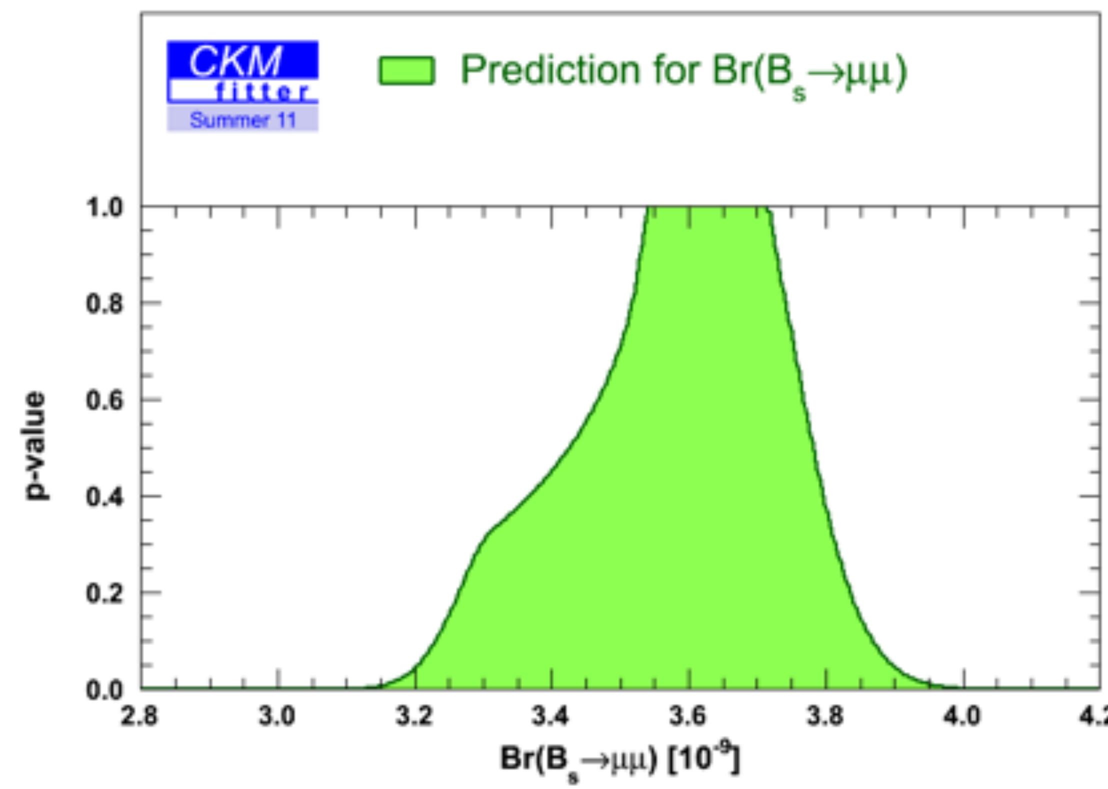
$\phi_s = -2\beta_s$

$B_s \rightarrow \mu\mu$

The global fit is also able to predict other values of interest for LHCb:

Current LHCb limit





$BR(B_s \rightarrow \mu\mu) = (3.54 \pm 0.28) \cdot 10^{-9}$

$BR(B_s \rightarrow \mu\mu) = (3.63^{+0.18}_{-0.32}) \cdot 10^{-9}$

Current LHCb limit, $BR(B_s \rightarrow \mu\mu) < 4.5 \cdot 10^{-9}$

The situation is getting more and more interesting.

Since the fit is over constrained, we can introduce new parameters added in order to parameterize generic NP ΔF=2 processes in all sectors

B_d and B_s mixing amplitudes (2+2 real parameters):

$$A_q e^{2i\phi_q} = C_{B_q} e^{2i\phi_{B_q}} A_q^{SM} e^{2i\phi_q^{SM}} = \left(1 + \frac{A_q^{NP}}{A_q^{SM}} e^{2i(\phi_q^{NP}-\phi_q^{SM})}\right) A_q^{SM} e^{2i\phi_q^{SM}}$$

In case of absence of NP effects, $C_i=1$, $\varphi_i=0$

Observables:

$$\Delta m_{q/K} = C_{B_q/\Delta m_K} (\Delta m_{q/K})^{SM} \qquad \varepsilon_K = C_\varepsilon \varepsilon_K^{SM}$$

$$A_{CP}^{B_d \to J/\psi K_s} = \sin 2(\beta + \phi_{B_d}) \qquad A_{CP}^{B_s \to J/\psi\phi} \sim \sin 2(-\beta_s + \phi_{B_s})$$

$$A_{SL}^q = \mathrm{Im}(\Gamma_{12}^q / A_q) \qquad \Delta\Gamma^q / \Delta m_q = \mathrm{Re}(\Gamma_{12}^q / A_q)$$

UTfit

SM:
$\bar\rho = 0.132 \pm 0.020$
$\bar\eta = 0.358 \pm 0.012$

NP:
$\bar\rho = 0.134 \pm 0.044$
$\bar\eta = 0.403 \pm 0.050$

CKM fitter

SM:
$\bar\rho = 0.144^{+0.023}_{-0.026}$
$\bar\eta = 0.343^{+0.015}_{-0.014}$

NP:
$\bar\rho = 0.159^{+0.036}_{-0.035}$
$\bar\eta = 0.438^{+0.019}_{-0.029}$

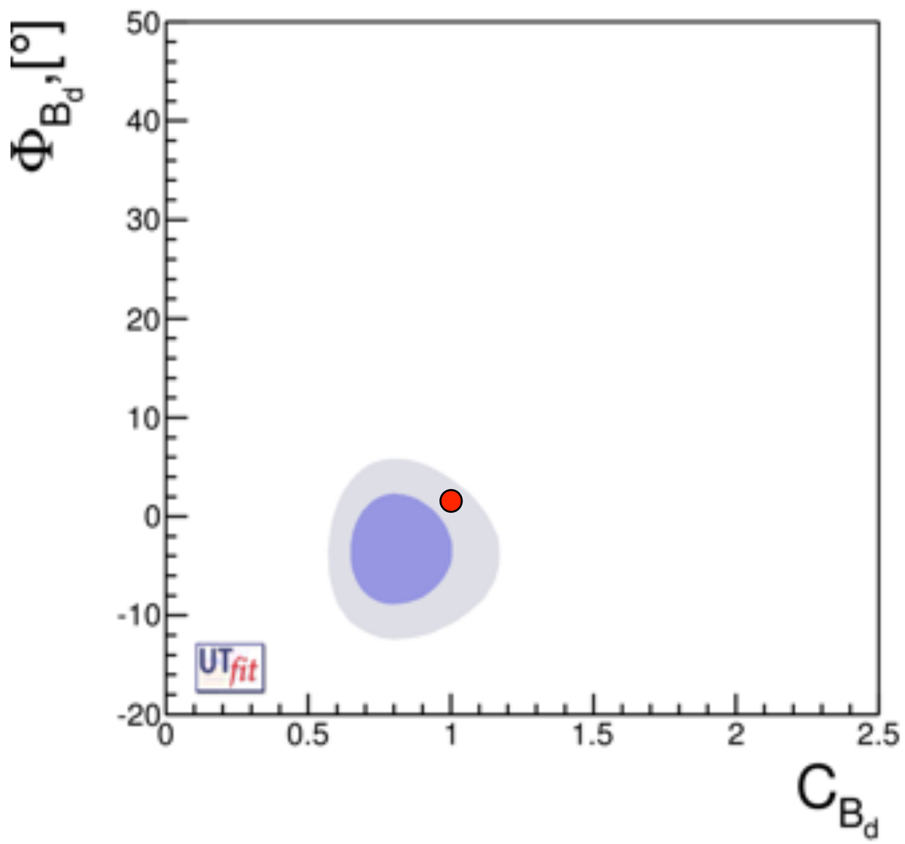
		ρ, η	C_d	φ_d	C_s	φ_s	$C_{\varepsilon K}$
Tree processes	γ (DK)	X					
	V_{ub}/V_{cb}	X					
1↔3 family	Δm_d	X	X				
	ACP (J/Ψ K)	X		X			
	ACP (Dπ(ρ),DKπ)	X		X			
	A_{SL}		X	X			
	α (ρρ,ρπ,ππ)	X		X			
	A_{CH}		X	X	X	X	
2↔3 family	τ(Bs), $\Delta\Gamma_s/\Gamma_s$				X	X	
	Δm_s				X		
	ASL(Bs)				X	X	
	ACP (J/Ψ φ)	~X				X	
1↔2 familiy	ε_K	X					X

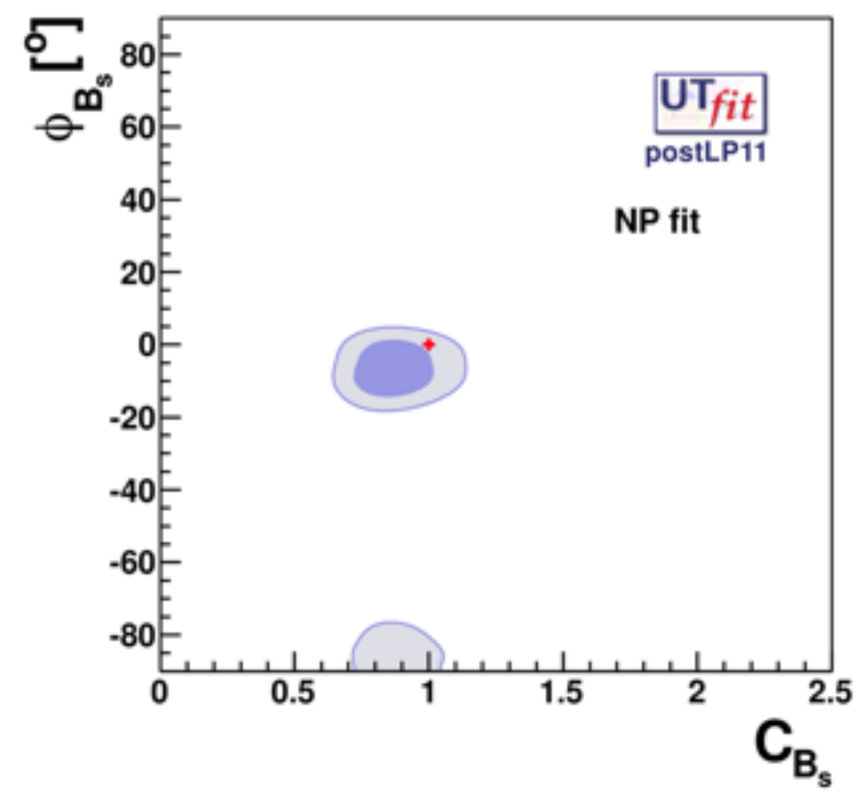
NP parameters fit result from UTFIT

Recent LHCb results on the B_s mixing phase have pinned down the possible new physics effects. Almost no tension is seen in the

C_{Bd}=0.81±0.12

φ_{Bd}=(-3.4±3.7)°





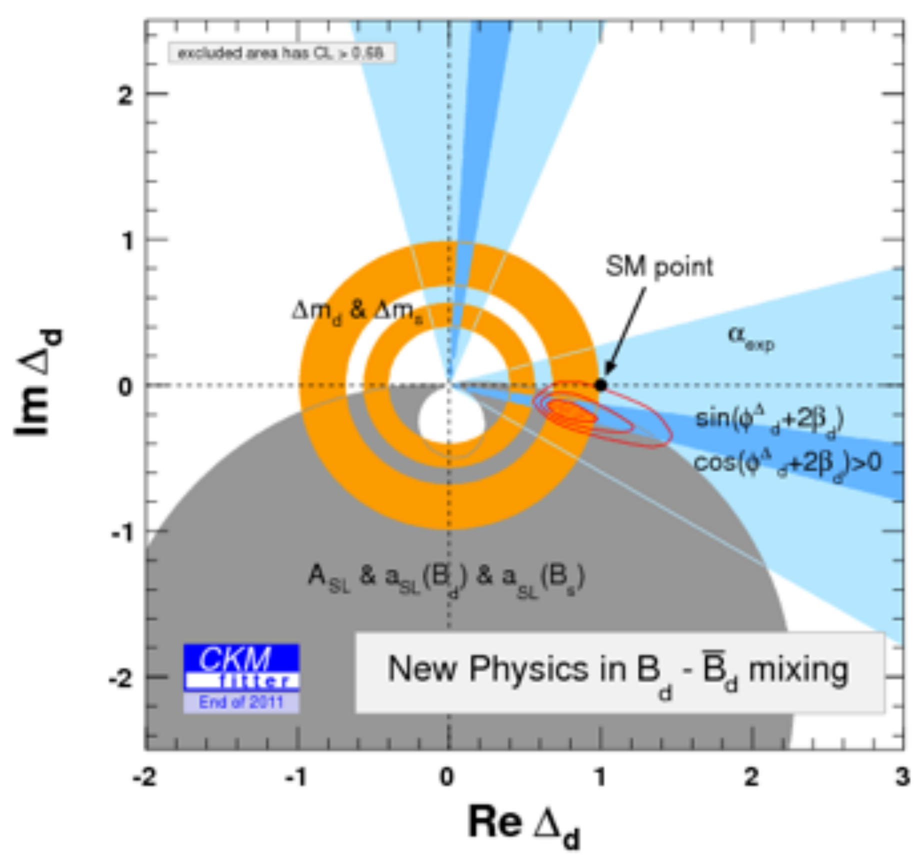
C_{Bs}=0.87±0.10

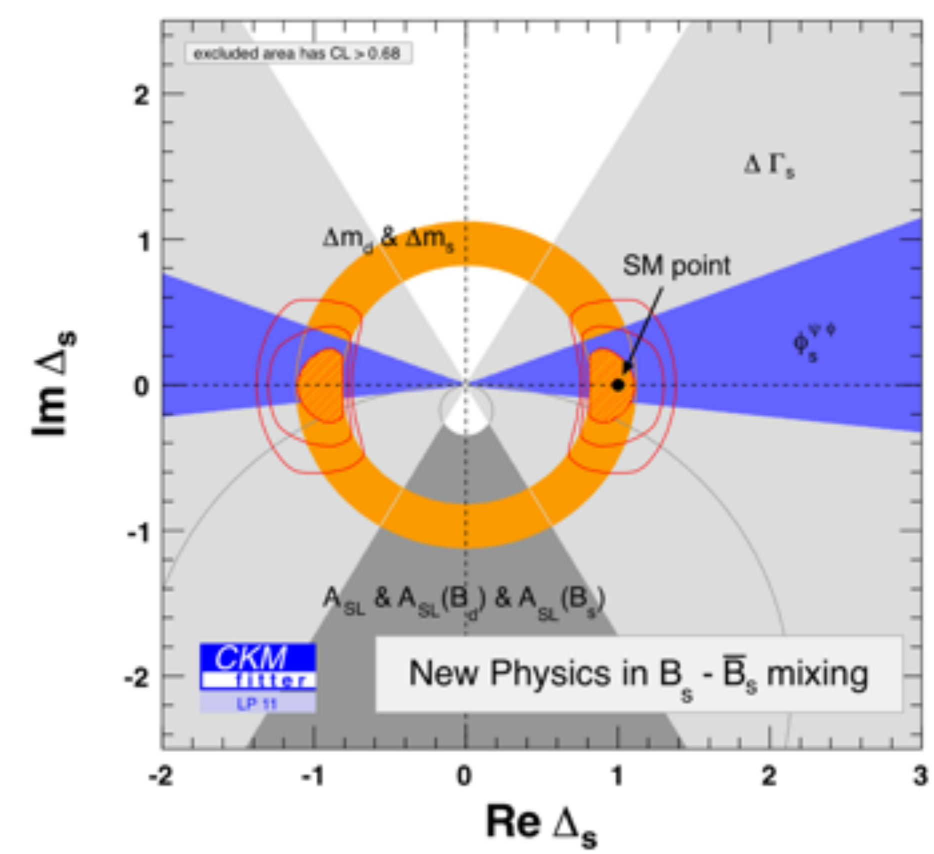
φ_{Bs}=(-6.9±5.6)°

M. Bona et al., JHEP 0803 (2008) 049

Analysis with close parameterization is also performed by the CKMfitter group

$$\frac{M_{12}^{q}}{M_{12}^{SM,q}} = \left(\mathrm{Re}[\Delta_q] + i\,\mathrm{Im}[\Delta_q]\right) = \left|\Delta_q\right| e^{2i\Phi_q^{NP}}$$





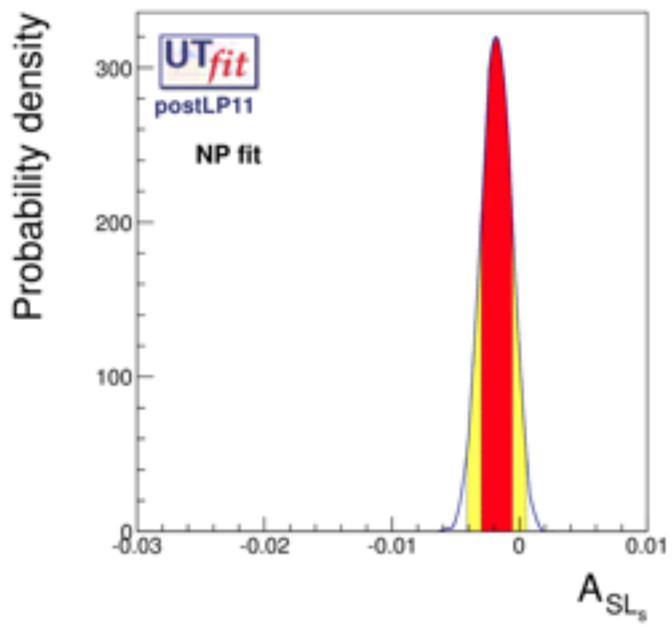
Re $\Delta_d = 0.757^{+0.132}_{-0.083}$, and Im $\Delta_d = -0.181^{+0.053}_{-0.045}$

Re $\Delta_s = -0.895^{+0.082}_{-0.120}$ or $0.895^{+0.020}_{-0.018}$, and Im $\Delta_s = -0.04^{+0.17}_{-0.17}$

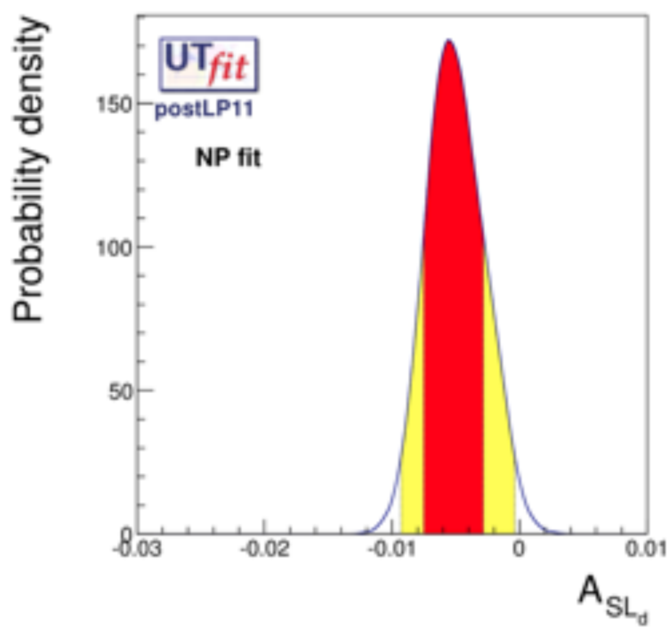
A. Lenz et al., Phys.Rev. D83 (2011) 036004

Out of the same fit we can get the information for A_{sl}

Including the A_{sl} results:

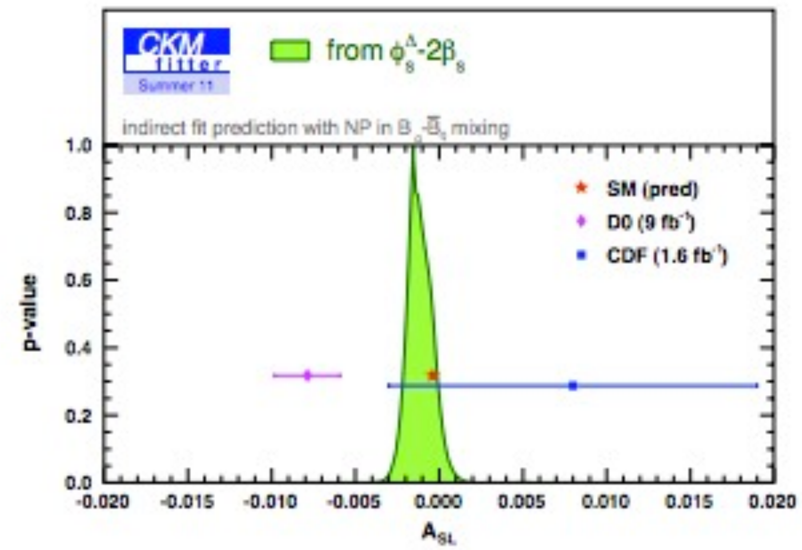


$$A^s_{\rm sl} = -0.0017 \pm 0.0012$$



$$A^d_{\rm sl} = -0.0051 \pm 0.0023$$

Not including the A_{sl} results:



$$A_{SL} = (-15.5^{+14.3}_{-5.9}) \cdot 10^{-4}$$

Conclusions

CKM matrix is the dominant source of flavour mixing and CP violation in *B* and *K* systems

$\sigma(\rho)\sim15\%$ $\sigma(\eta)\sim4\%$

General UTA provides precise determinations of CKM parameters and NP contributions to $\Delta F=2$ amplitudes.

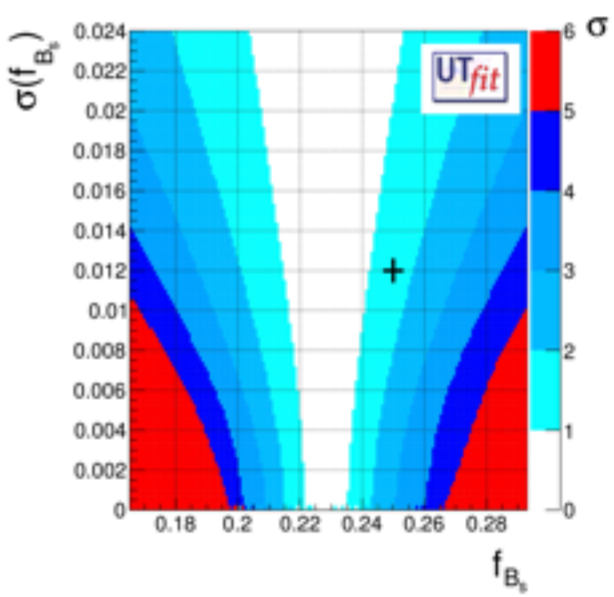
Model Independent fit shows some discrepancy in the B_d sector in the NP phase parameters.

LHCb results play more and more important role in the fits. Hope for a good 2012 run.

The predictions for $B_s \to \mu\mu$ shown in this talk are based on the lattice averages of last summer by Laiho, Lunghi and Van de Water in http://www.latticeaverages.org/ :

Reference	Article	N_f	Mean	Stat	Syst
MILC02	[29]	2	217	6	$^{+58}_{-31}$
JLQCD03	[33]	2	215	9	$^{+19}_{-15}$
ETMC09	[34]	2	243	6	15
HPQCD03	[30]	2+1	260	7	39
FNAL-MILC09	[35]	2+1	243	6	23
HPQCD09	[36]	2+1	231	5	30
Our average			231	3	15

f_{Bs}=250(10) MeV



f_{Bs}= 229(7) MeV

prediction f_{Bs} = 238.5 [+4.8 -12.7]