Angle measurements and new physics

Jure Zupan
Josef Stefan Inst. & Univ. of Ljubljana & SISSA

A SIMPLE REMINDER

why are we interested in measuring angles (and other CKM parameters)?

THE GOALS

- the goals:
  - measure parameters of SM Lagrangian a.k.a. “Lagrangian of Nature”
  - find deviations = New Physics
- in light of imminent discoveries at LHC turn around
  - measure properties of new states i.e. the “real Lagrangian of Nature”

WHAT ARE WE MEASURING?

- for some time our knowledge about new states discovered at LHC will be limited
- important to know:
  - which observables sensitive to NP
    - measuring SM triangle or something else?
  - an unrelated, but equally important, question: hadronic uncertainties
    - how well can we do?

WHAT TYPE OF NEW PHYSICS?

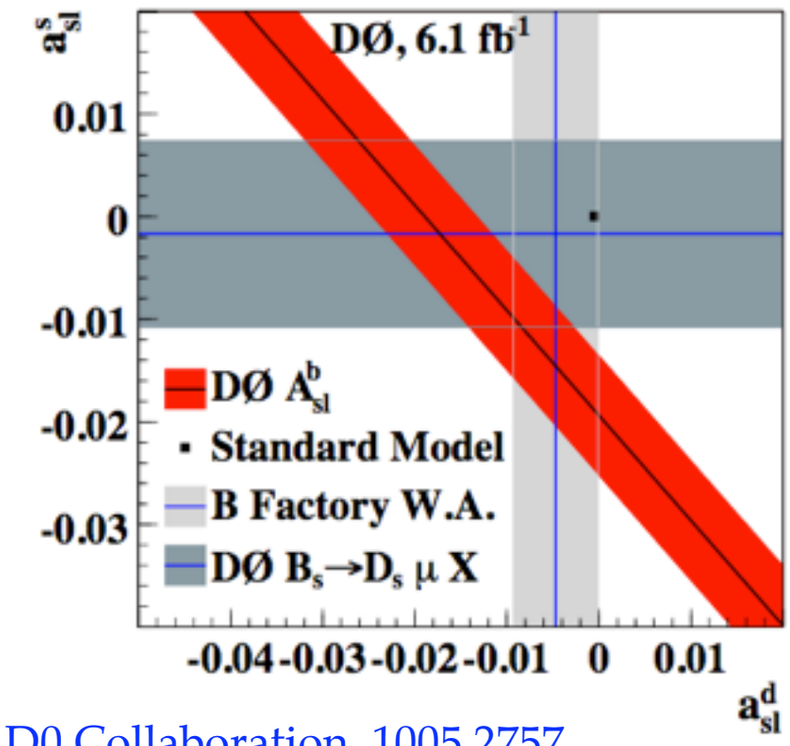
- as a template the new dimuon anomaly from D0

cf. talk by Brooijmans, next session; D0 Collaboration, 1005.2757

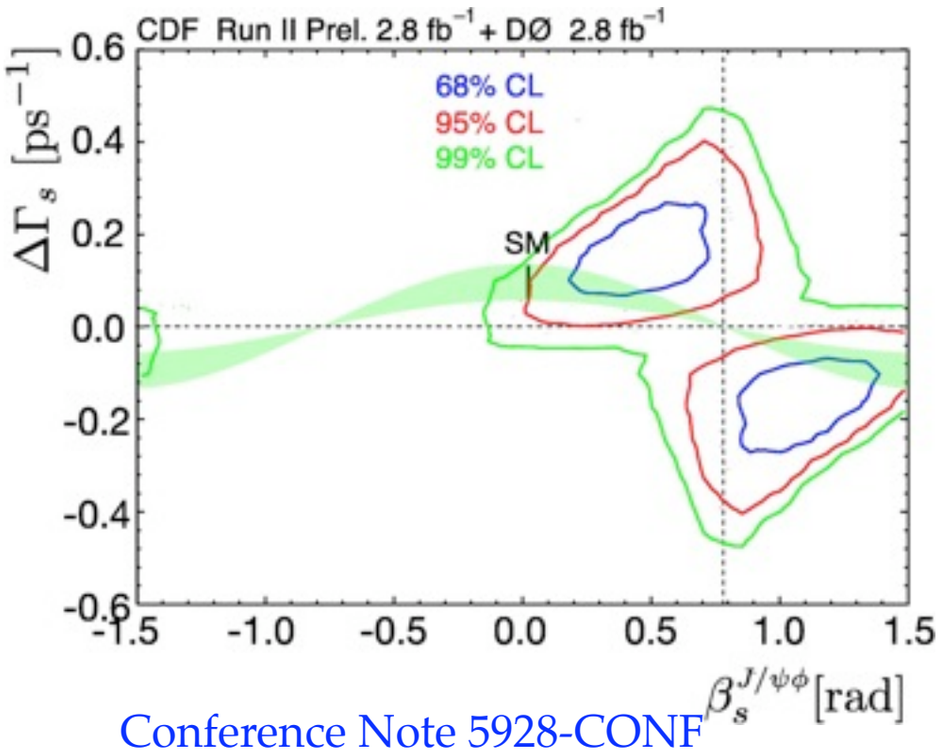
- phase in B_s mixing (possibly B_d) away from SM

cf. talks by Stone, Oakes, Chandra, next session;

- anything in $\Delta F=1$?



D0 Collaboration, 1005.2757



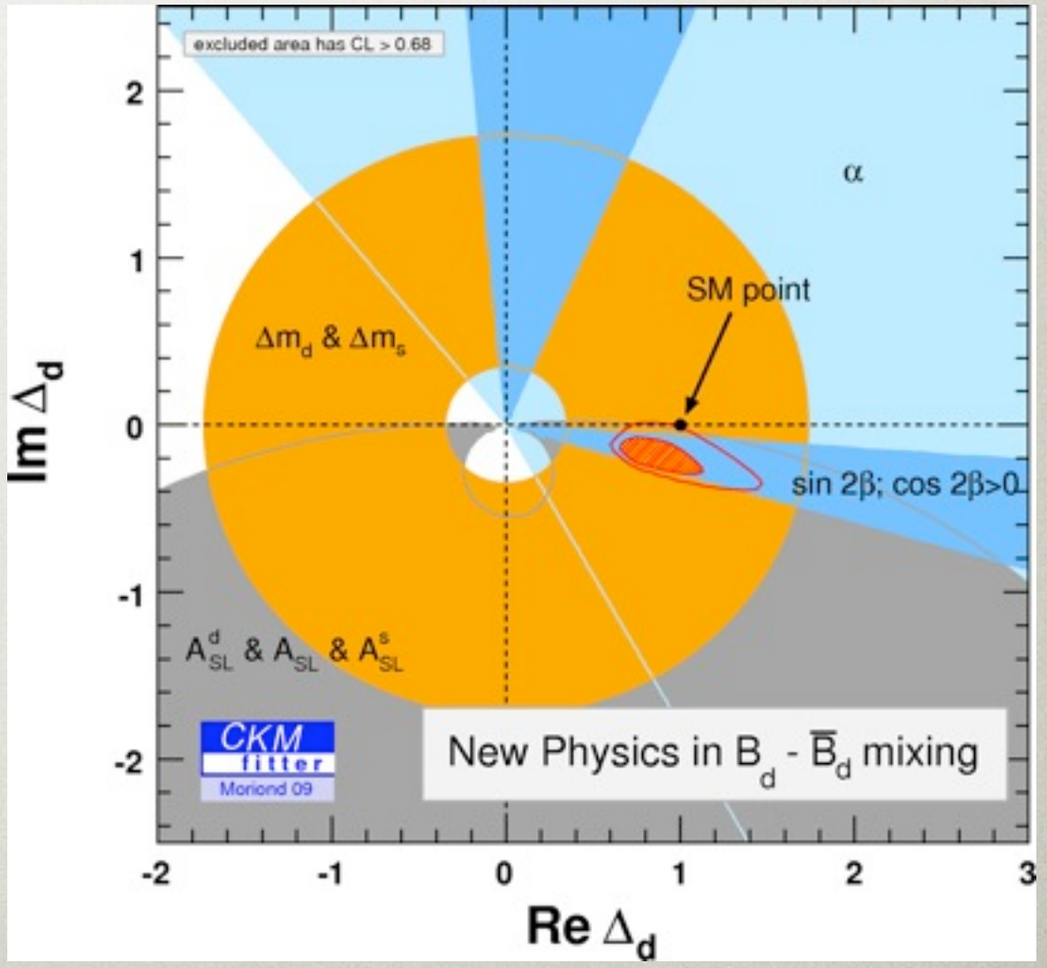
Conference Note 5928-CONF

ANGLES?

- How does this affect extraction of SM CKM parameters?
  - measurement of β cf. talk by Sumisawa, this session
  - measurement of α cf. talk by Dalseno, this session
  - measurement of γ cf. talks by Derkach, Thomas, this session
  - three body decays

MEASUREMENT OF β: NEW PHYSICS EFFECTS

- if NP in B_d mixing, β obviously affected
  - "measurement of β" is not measurement of CKM phase δ_{CKM}
- the NP shift in β is small though



HADR. UNCERTAINTIES IN MEASUREMENT OF β

- hadronic uncertainties cf. talk by Mannel at FPCP2009
  - $B_d \to J/\psi K_S$ tree dominated, how large is the penguin?
- comparison with $B_d \to J/\psi \pi^0$ gives shift of $\beta \to \beta\text{-}O(5\%)$ possible Faller, Fleischer, Jung, Mannel, 0809.0842; Chiuchini, Pierini, Silvestrini, hep-ph/0507290
  - SU(3) breaking? More precise measurements in $B_d \to J/\psi \pi^0$ needed
- perturbative and rescattering calculations give much smaller effects, below 0.1% Boos, Mannel, Reuter, hep-ph/0403085; Gronau, Rosner, 0812.4796

MEASUREMENT OF α: NP EFFECTS

- $B \to \pi\pi$, $\varrho\varrho$, $\varrho\pi$, $a_1\pi$, tree level dominated
- if NP only in $\Delta F=2$
  - $|q/p| = 1.0002 \pm 0.0028$ so only phase changes
  - $\gamma = 180^o - \alpha - \beta$ measures SM δ_{CKM}
- what if NP in $\Delta F=1$?
  - no effect if $\Delta I=1/2$ (penguin-like)
  - if $\Delta I=3/2$ (tree-like): does it avoid other constraints?
    - answer only within NP model

MEASUREMENT OF α: HADRONIC UNCERTAINTIES

- hadronic uncertainties: isospin breaking
  - calculable effects small, at degree level

Gronau, Zupan, 2005

MEASUREMENT OF γ: HADRONIC UNCERTAINTIES

- in SM very clean theoretically
  - standard candle type of measurement

MEASUREMENT OF γ: NEW PHYSICS EFFECTS

- NP in Delta F=2?
  - charged B→DK no effect
  - in B_d→DK, again only a change of β from SM value
    - if measured β used extracted γ is the SM one
- same for NP in B_s mixing, D mixing
  - use measured mixing parameters
  - careful about $\Delta\Gamma^s_{CP}$ vs. $\Delta\Gamma^s$
- NP in Delta F=1?: has to compete with tree level SM

THREE BODY DECAYS

Ciuchini, Pierini and Silvestrini, 2006; Gronau, Pirjol, JZ, 2006

- from B→Kππ Dalitz plot

$$\bar{\eta} = \tan \Phi_{3/2} \, [\bar{\rho} - 0.24 \pm 0.03]$$

- where in the absence of EWP $\Phi_{3/2}$ equals γ

$$\gamma = \Phi_{3/2} \equiv -\frac{1}{2}\arg\left(R_{3/2}\right) \ , \qquad R_{3/2} \equiv \frac{\bar{A}_{3/2}}{A_{3/2}}$$

$$3A_{3/2} = A(B^0 \to K^{*+}\pi^-) + \sqrt{2}A(B^0 \to K^{*0}\pi^0)$$

- NP in mixing ⇒ use measured β
- penguin domin., more sensitive to NP in ΔF=1
  - can we test for it?

INTERMEDIATE SUMMARY

- If NP in mixing ⇒ easy to accommodate to obtain δ_{CKM} of SM
- What about direct CPV NP contribs.?

TEST FOR $\Delta F=1$ NP CONTRIBUTIONS

- isospin sum rules
  - not necessarily directly related to angle measurements
  - but are very precise (just isospin)
- in $B\to K\pi$ known for some time now

Gronau, hep-ph/0508047

$$\Delta(K^+\pi^-)+\Delta(K^0\pi^+)-2\Delta(K^+\pi^0)-2\Delta(K^0\pi^0)\approx 0$$

$$-0.02\ (-0.01)<A_{CP}(K^+\pi^-)+A_{CP}(K^0\pi^+)-A_{CP}(K^+\pi^0)-A_{CP}(K^0\pi^0)\leq 0$$

- for three body decays also a sum rule
  - it uses SU(3) on tree ampl. only

Gronau, Pirjol, JZ, 1001.0702

$$\Delta(K\rho)-\Delta(K^*\pi)=2\Delta\left((K^*\pi)_{3/2}\right)$$

$$\Delta(f)\equiv\Delta^f_{+-}+\Delta^f_{0+}-2\Delta^f_{+0}-2\Delta^f_{00}$$

EXTRA NP IN DECAY AMPLITUDES?

- α extraction only affected if NP not ΔI=0
  - for B→ϱπ can use isospin pentagon as a check
- extraction of γ has a built in test for presence of extra NP in decay ampl.

$$A(B^- \to f_D K^-) \propto r_D e^{i\delta_D} + r_B e^{i\delta_B - \gamma} + r'_B e^{i\delta'_B - \gamma'}$$

$$A(B^+ \to f_D K^+) \propto r_D e^{i\delta_D} + r_B e^{i\delta_B + \gamma} + r'_B e^{i\delta'_B + \gamma'}$$

- thus for B^+ and B^- different r_B

$$r_{B^+} \to |r_B e^{i\delta_B + \gamma} + r'_B e^{i\delta'_B + \gamma'}|; \quad r_{B^-} \to |r_B e^{i\delta_B - \gamma} + r'_B e^{i\delta'_B - \gamma'}|$$

TEST OF DIRECT CP NP IN B→DK

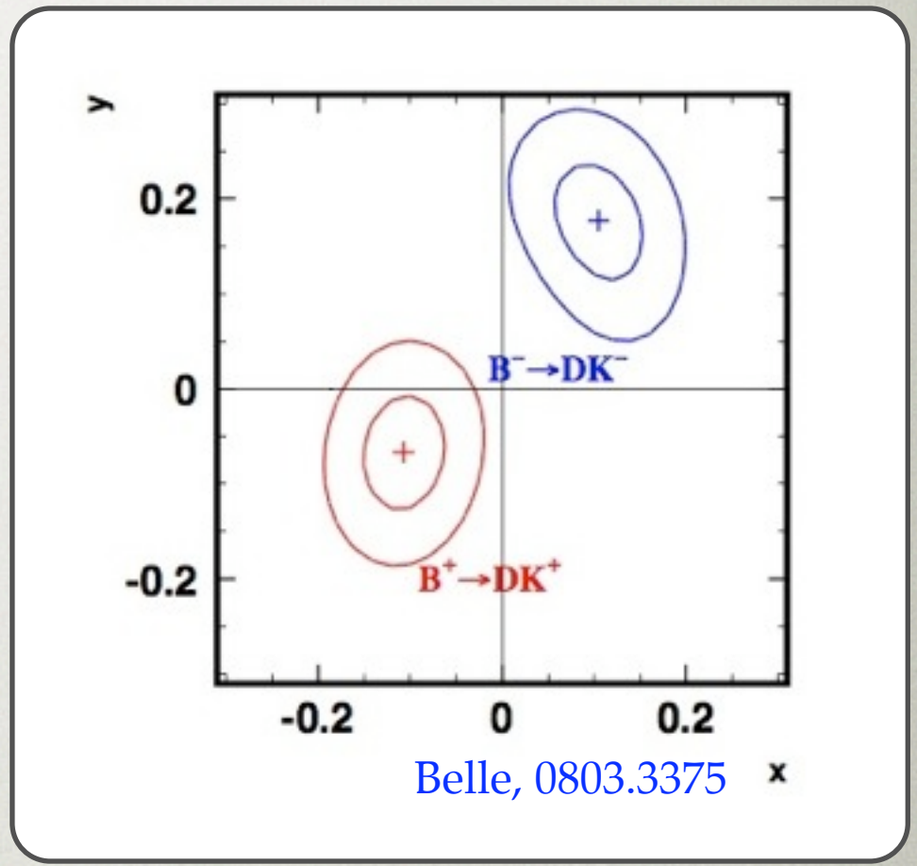
- there is NP in B→DK amplitude if

$$r_{B^-} \neq r_{B^+}$$

- Belle and Babar already measure this

$$x_\pm = r_B \cos(\gamma \pm \delta_B)$$
$$y_\pm = \pm r_B \sin(\gamma \pm \delta_B)$$

- even, if $x_+^2 + y_+^2 = x_-^2 + y_-^2$ still possible that γ is shifted



Belle, 0803.3375

- another test: γ from $B^\pm \to DK^\pm$, $B^\pm \to DK^{*\pm}$, $B^\pm \to D^*K^\pm$, $B^0 \to DK^0$,... all need to coincide!

ULTIMATE TEST

- Q: are we measuring SM γ?
- A: yes if all measurements (α, γ, different channels) give the same γ (δ_{CKM})

CONCLUSIONS

- NP in mixing can be easily included / accounted for when measuring angles
- NP in amplitudes can be tested for

BACKUP SLIDES