Experimental precision of $\sin 2\beta$ ($\sin 2\phi_1$) measurements

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What limits the precision of sin2β measurements?

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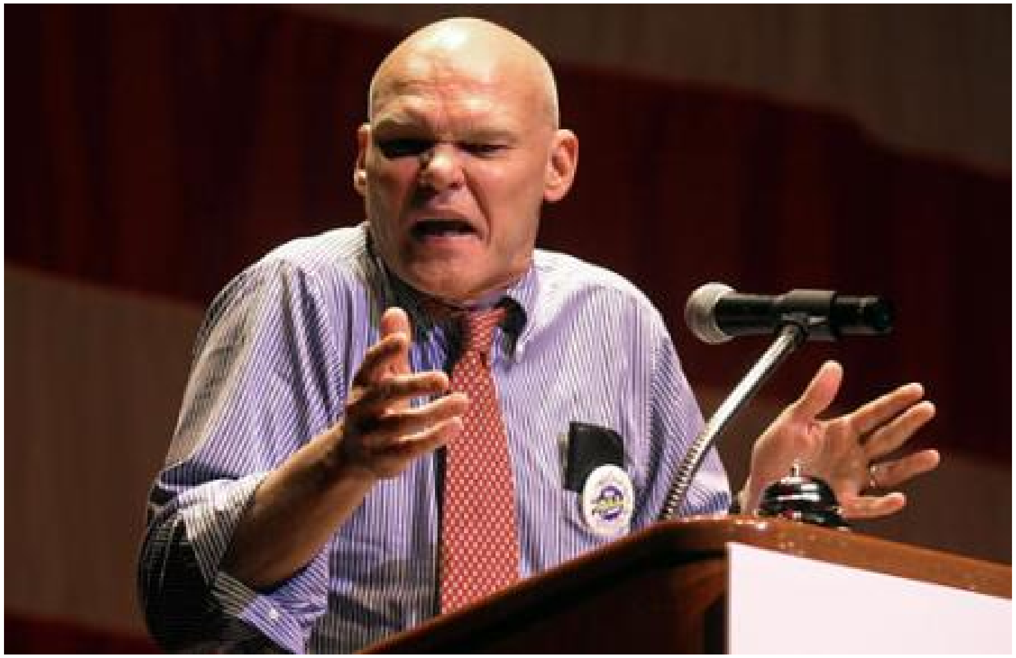

luminosity

"It's the ~~economy~~, stupid!" James Carville

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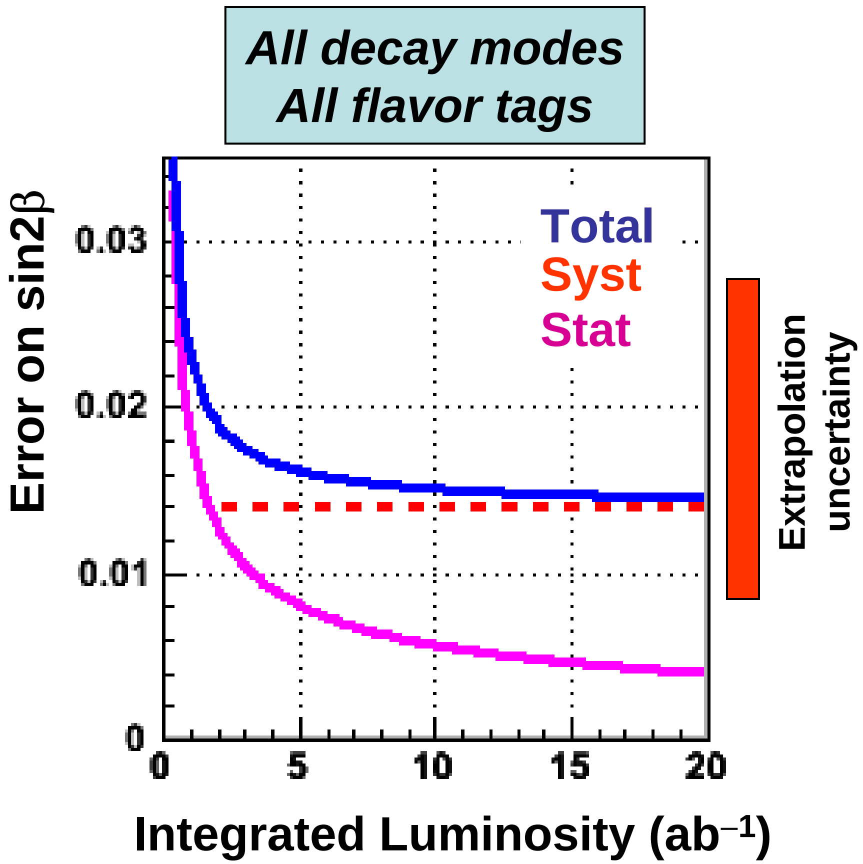
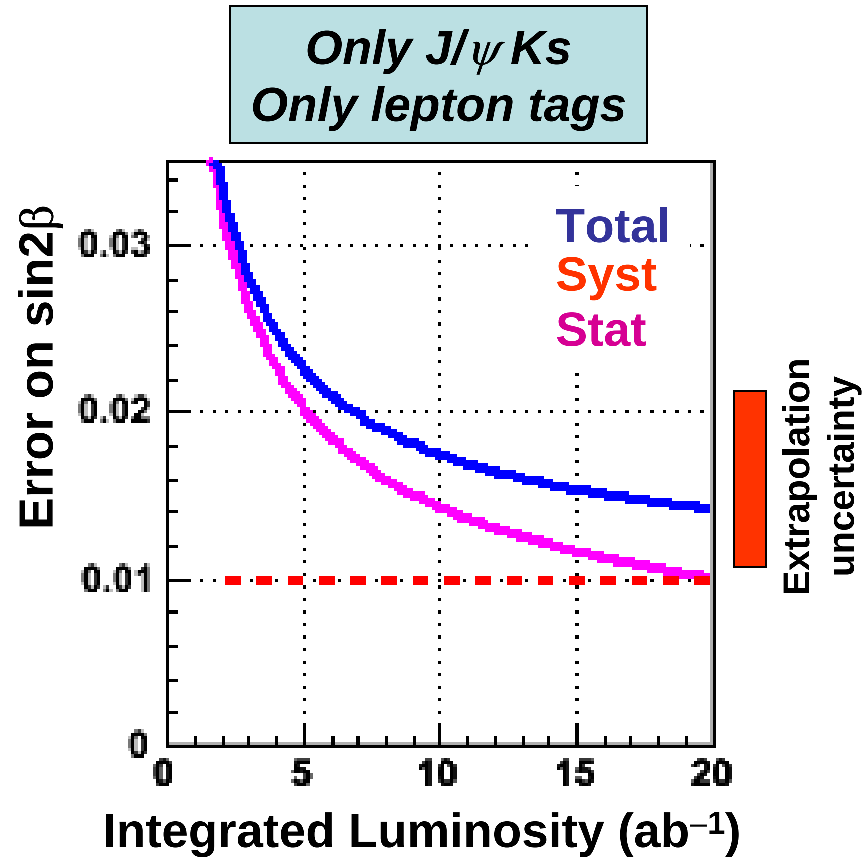
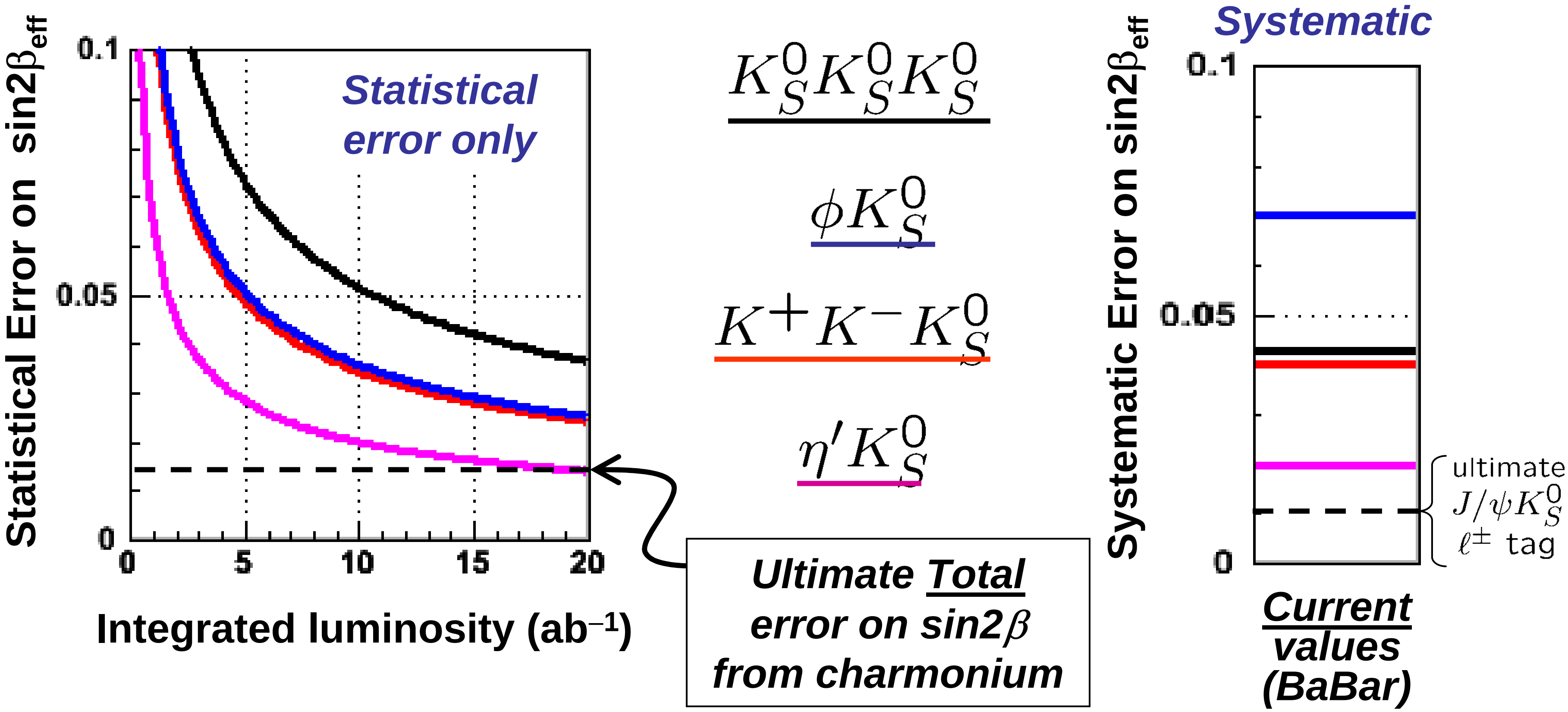
sin2β from charmonium modes





- **Extrapolation uncertainty**: asymptotic systematic error could by off by a factor of two either way (x0.5 or x2.0).

$\sin 2\beta_{eff}$ in $b \rightarrow s$ penguin modes



- Uncertainty on CP of $K^+K^-K_s$ included in statistical error.
- More difficult than charmonium to extrapolate systematic errors (next slide…)

Limiting issues (?) for b→s penguin modes

- $\eta' K^0_S$: Nothing special for this mode? Ultimate systematic error close to J/ψ K_s ?
- $K^0_S K^0_S K^0_S$: CP vertex measurement may suffer if machine backgrounds cause excessive occupancy in inner silicon? Efficiency will depend on design of detector…
- ϕK^0_S and $K^+ K^- K^0_S$: Dominant systematics are from uncertain CP content (S-wave contamination and average CP).
  - With *super-B statistics*, will do a time-dependent Dalitz analysis of the $K^+K^-K_s$ system (e.g. $\rho\pi$). Systematic errors could reach 0.02 level?

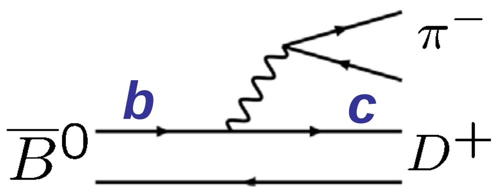
Systematics common to all measurements

- **Beamspot location** ($\delta S \sim 0.01$): Current techniques use constraint from (local) average beam position in Δt reconstruction.
  - *Essential* for $K_s K_s K_s$ (theoretically pristine(?) mode) and single-track tag vertex events.
  - Unclear if this will improve in B → super B. May even get worse…

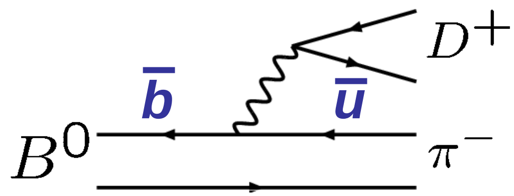
- **Silicon alignment and Δt resolution model** ($\delta S \sim 0.01$):
  - Unlikely to improve much over today's values
    - Randomness in tag vertex (long lived daughters) → model dependence.
  - Si alignment depends on detector (and beam?) stability.

Another common systematic – Tag-side interference

- From *b→c* vs *b→u* interference on the tag side.



$$\overline{A} \propto 1$$



$$A \propto r' \, e^{i(\gamma+\delta')}$$

$$r' \approx 0.02$$
$$\delta' \approx ?$$

- Small for sin2β (S) due to *fortunately small* coefficient (δS<<0.01).

$$S_{\text{fit}} \approx S_0 \left[1 - 2\,r' \cos\delta' \{\cos 2\beta \cos(2\beta+\gamma) + \mathcal{K} \sin 2\beta \sin(2\beta+\gamma)\}\right]$$
$$S_{\text{fit}} \approx S_0 \left[1 - 2\,r' \cos\delta' \times (\approx -0.01)\right]$$

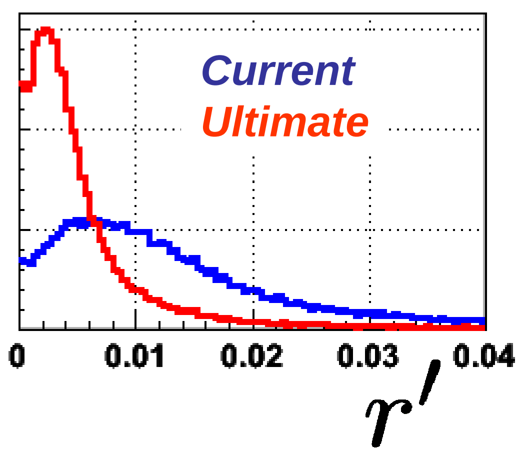
- *Not* so small for direct *CP* term (δA or δC~0.02 to 0.03).

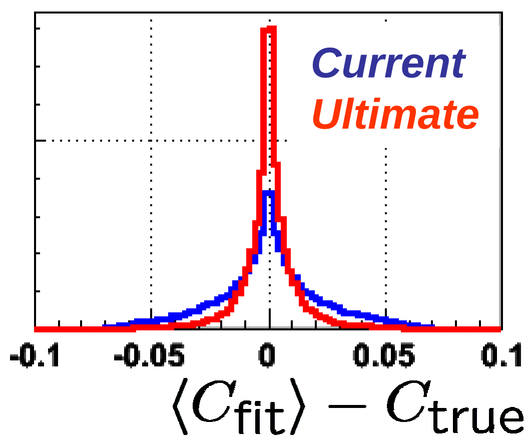
$$C_{\text{fit}} \approx 2\,r' \sin\gamma \sin\delta'$$
$$C_{\text{fit}} \approx 2\,r' \sin\delta' \times (\approx 0.87)$$

Constraining tag-side interference

- Constrain the tag-side parameters with *D*l* ν
  - CP violation can *only* come from tag-side effect.
  - *Belle* sin(2β+γ) analysis already uses *D*l*ν (PRL **93**, 031802 (2004))

- Example of what could be done using *D*l* ν constraint assuming measurements indicate r'=0.





Bayesian analysis:
- Flat prior in r' and δ'
- Gamma: $\sigma\gamma$ = 9º
- Gaussian population in *D*l*ν observables with
  - Current σ = 0.015
  - Ultimate σ = 0.005

- Improvement of at least x3. Will probably go below δC~0.01.

Summary

- **sin2β from charmonium** will reach around $\sigma(\sin 2\beta) \approx \underline{0.015}$
  - Luminosity is *not* the limiting factor. Make life simple and work with the best events: $J/\psi\ K_s$ and lepton tags.

- **Control / understanding of beam position** should be kept in mind
  - Some modes could manage without beam constraint, for others it's essential
  - We don't want this to get significantly worse than current standards (~0.01)

- **b→s penguin modes** likely *will* be limited by statistics
  - Current major systematics should scale with statistics
  - Will the *KsKsKs* mode suffer significantly in the new environment? Let's hope not.

- **Tag-side interference** is an issue for the direct CP coefficient
  - Systematic can be significantly reduced by using constraints from $D^*l\nu$.