Update on $\Delta\Gamma_{B_s}$ Prospects for RunII

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$\Delta\Gamma_{B_s}$

- What is it, and why is it significant?
- How could we attempt to measure it at RunII?
- How well do we expect to do?
- What issues need to be addressed?

$\Delta\Gamma_{B_s}$: A brief reminder

- The width difference in the Bs system.
- The weak interaction eigenstates, $\left|B_s, L\right\rangle, \left|B_s, H\right\rangle$ are what decay.

$$\left.\begin{aligned}\left|B_s, L\right\rangle &= p\left|B_s\right\rangle + q\left|\overline{B_s}\right\rangle \\ \left|B_s, H\right\rangle &= p\left|B_s\right\rangle - q\left|\overline{B_s}\right\rangle\end{aligned}\right\}\left|B_s\right\rangle, \left|\overline{B_s}\right\rangle \text{ strong interaction eigenstates}$$

- $\Delta\Gamma_{B_s} = \Gamma_H - \Gamma_L$

Why is ΔΓs significant?

- SM prediction: $x_s = C \frac{\Delta\Gamma_{B_s}}{\overline{\Gamma}_{B_s}}$ $\left(\text{where } x_s = \frac{\Delta m_{B_s}}{\overline{\Gamma}_{B_s}} \text{ and } \overline{\Gamma}_{B_s} = \frac{1}{2}(\Gamma_H + \Gamma_L) \right)$
- Uncertainty in C dominated by uncertainty in: the ratio of “bag constants”.
- Favoured method of predicting C is lattice gauge theory.
- Beyond SM, above relation may well not hold.
- CDF expects to measure x_s over SM range.
- So what would be the significance of a measurement of $\Delta\Gamma_{B_s}$?

Some Possible Scenarios (simplifying!):

CDF x_s Measures in SM range	$\Delta\Gamma_{B_s}$ too small to measure	Depending on Lattice errors…could be new physics
	$\Delta\Gamma_{B_s}$ measured	Test SM prediction
x_s too big to measure	$\Delta\Gamma_{B_s}$ too small to measure	Likely to be new physics
	$\Delta\Gamma_{B_s}$ measured	Depending on measurement and lattice errors..could still be new physics

How could we measure $\Delta\Gamma_{B_s}$ at RunII?

- One possible tactic: Two Sample Method.
- Pick a sample where can isolate one CP eigenstate and measure Γ_{CP}
  - eg using $B_s \to J/\Psi\phi$
  - (58 ± 12) seen in RunI, since easy to trigger on with J/Ψ
- Use with a sample where 50:50 mixture of CP: eg using $B_s \to D_s\,\pi$ and measure $\Gamma_{CP\,50:50}$

$$\Delta\Gamma = 2\left(\Gamma_{CP\ Even} - \Gamma_{CP-50:50}\right)$$

Isolating a CP component:

- Some samples expected to be pure CP…so no problem.
- But some (eg $B_s \to J/\Psi\phi$) are not. (ie P   VV)
- Use angular distributions in "Transversity" Basis to separate CP states.
- Run I measurement for CP Odd component in

$$B_s \to J/\Psi\phi \ : \quad \frac{\Gamma_\perp}{\Gamma_{B_s}} = 0.229 \pm 0.188\,(stat) \pm 0.038\,(syst)$$

RunII Projection from RunI Results

- RunI input:
  - $58 \pm 12 \quad B_s \to J/\Psi\phi$ events, from which:
  - $\tau_{B_s} = 1.34\ \text{ps}\ (+0.23 - 0.19)\ stat\ (\pm 0.05)\ syst$
  - $\frac{\Gamma_\perp}{\Gamma_{B_s}} = 0.229 \pm 0.188(stat) \pm 0.038(syst)$

Mode	Event Yield	σ_τ Projection
$D_s\pi / D_s\pi\pi\pi$	$15300 \to 23400$	0.015ps
$J/\psi\ \phi$	6000	0.021ps

Project $\sigma_{\frac{\Delta\Gamma_S}{\Gamma_S}} = 0.065$

(assuming the central value of Run I measurement for , $\Gamma_\perp$ the CP odd fraction.)

Using B_s J/ψ φ

- Expected yield ≈ 6000 events leading to $\sigma(\tau) \approx 0.021 ps$
- Separate CP states using Transversity basis.
- 2 possible methods to separate the distributions:
  - Moments analysis to project out eigenstates separately.
  - Multi-variable Likelihood fit for both simultaneously
- 2 Toy Monte Carlo Studies have been done.
- Detector acceptance correction to Transversity Distribution.
- All of the above only valid in context of SM prediction of no CPV in this mode.

Toy MC study of likelihood method

- Toy MC based on signal and background distributions for $B_s \to J/\Psi\phi$ observed in RunI. (58 ± 12 projected to 6000 events.)
- Multi-Variable Likelihood analysis used to simultaneously
- fit $\tau_{CP\ \mathrm{Even}}, \tau_{CP\ \mathrm{Odd}}$ where $\bar{\tau}_{B_s}$ constrained to world average.
- CP Odd content assumed to be 25%

$$\mathrm{RunI:}\quad \frac{\Gamma_\perp}{\overline{\Gamma}_{B_s}} = 0.229 \pm 0.188(stat) \pm 0.038(syst)$$

Input $\frac{\Delta\Gamma_{B_s}}{\overline{\Gamma}_{B_s}}$	$\frac{\Delta\Gamma_s}{\overline{\Gamma}}$ Significance
0.085	1.35
0.1	1.79
0.125	2.53
0.15	2.69

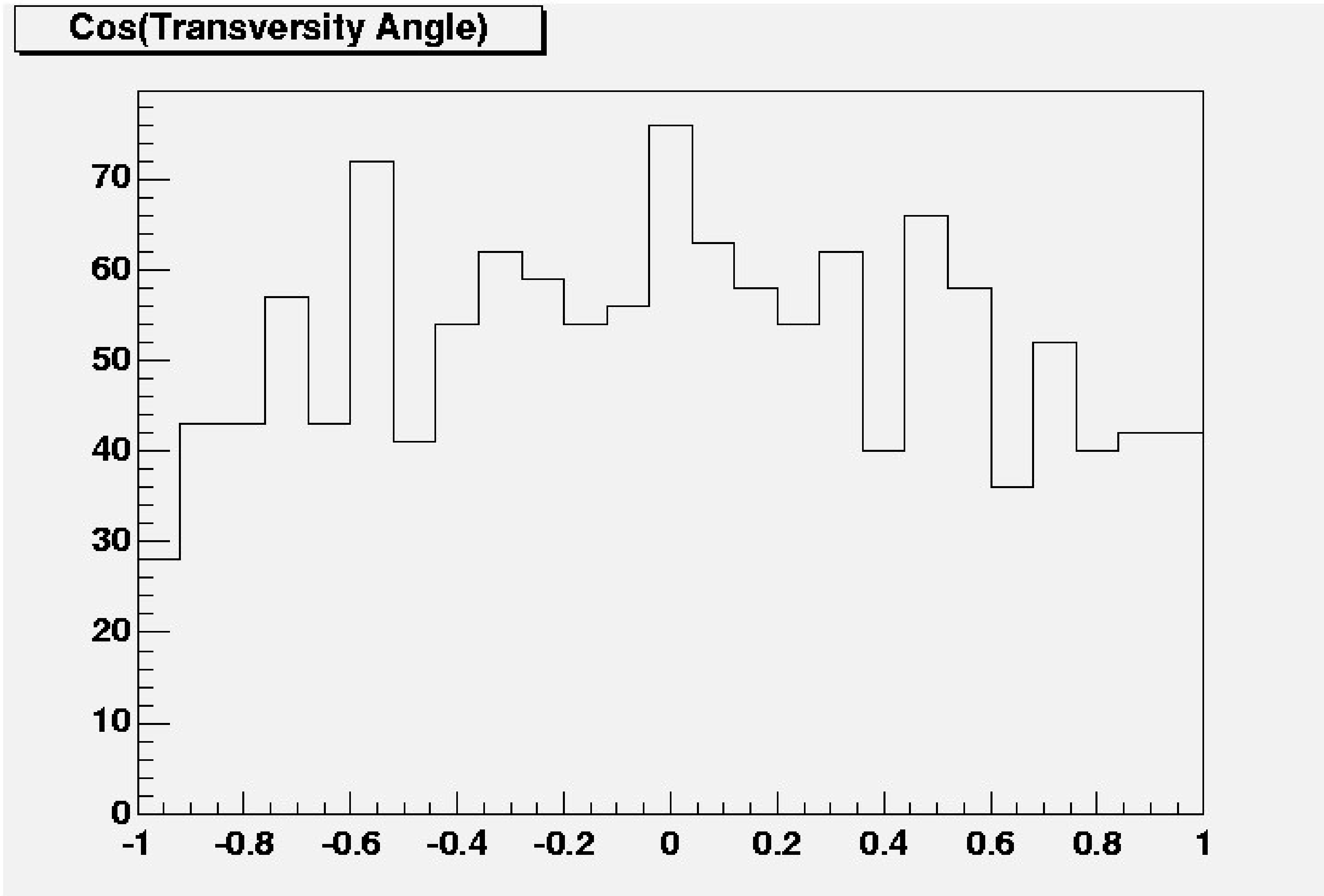
Toy MC study of Moments Analysis

- Same projection to 6000 $B_s \to J/\Psi\phi$ events.
- 25% CP-odd component assumed.
- Input $\frac{\Delta\Gamma_{B_s}}{\overline{\Gamma}_{B_s}} = 0.15$
- Measure $\frac{\Delta\Gamma_{B_s}}{\overline{\Gamma}_{B_s}}$ using CP even and odd components as measured in this one sample.

Results

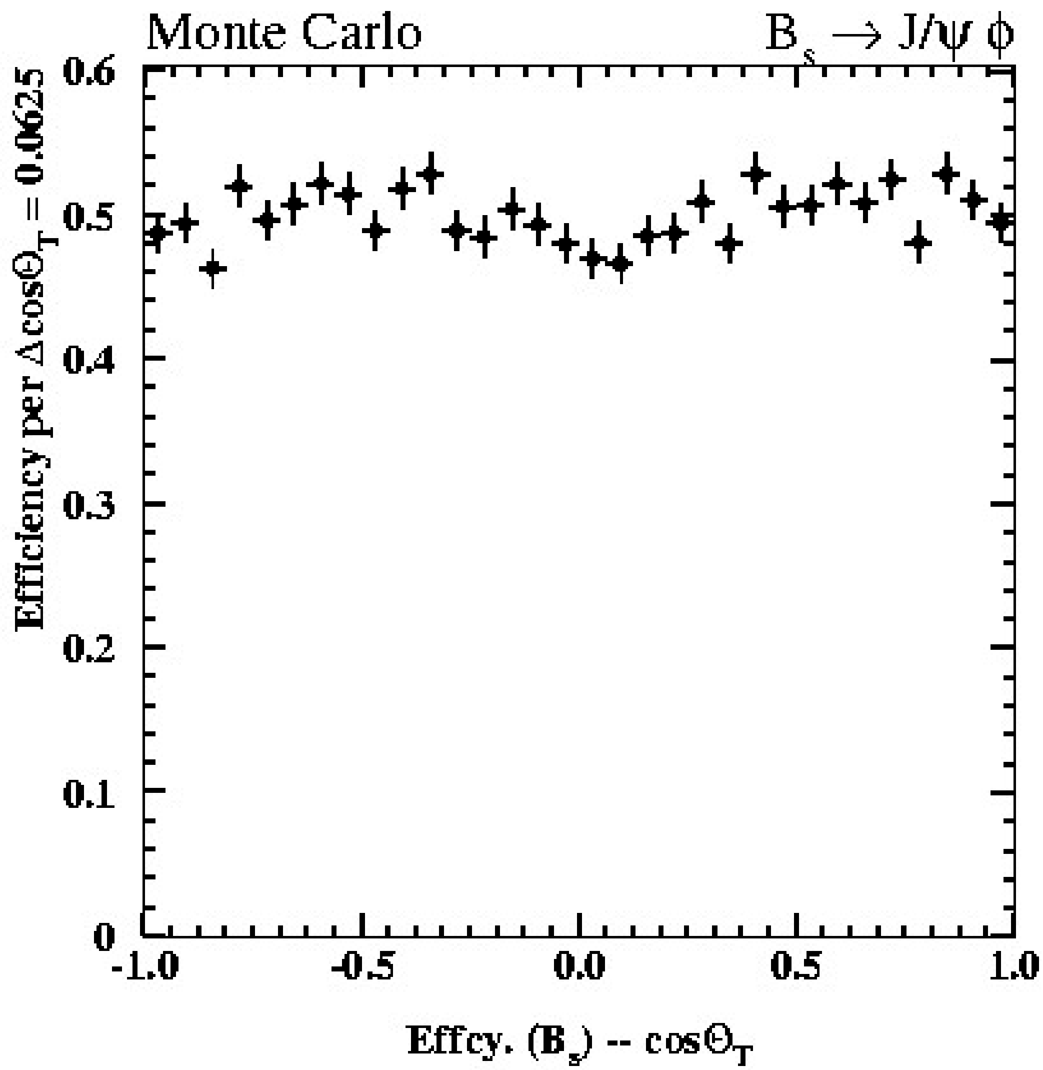
$c\tau$ cut (μm)	Detector sculpting	Background present	$\sigma_{\frac{\Delta\Gamma_s}{\Gamma_s}}$
100	✓	✓	0.091
100		✓	0.089
0		✓	0.11
100			0.053

- Need to work hard at improving S/B
- Need to develop a strategy to combine with other lifetime measurements

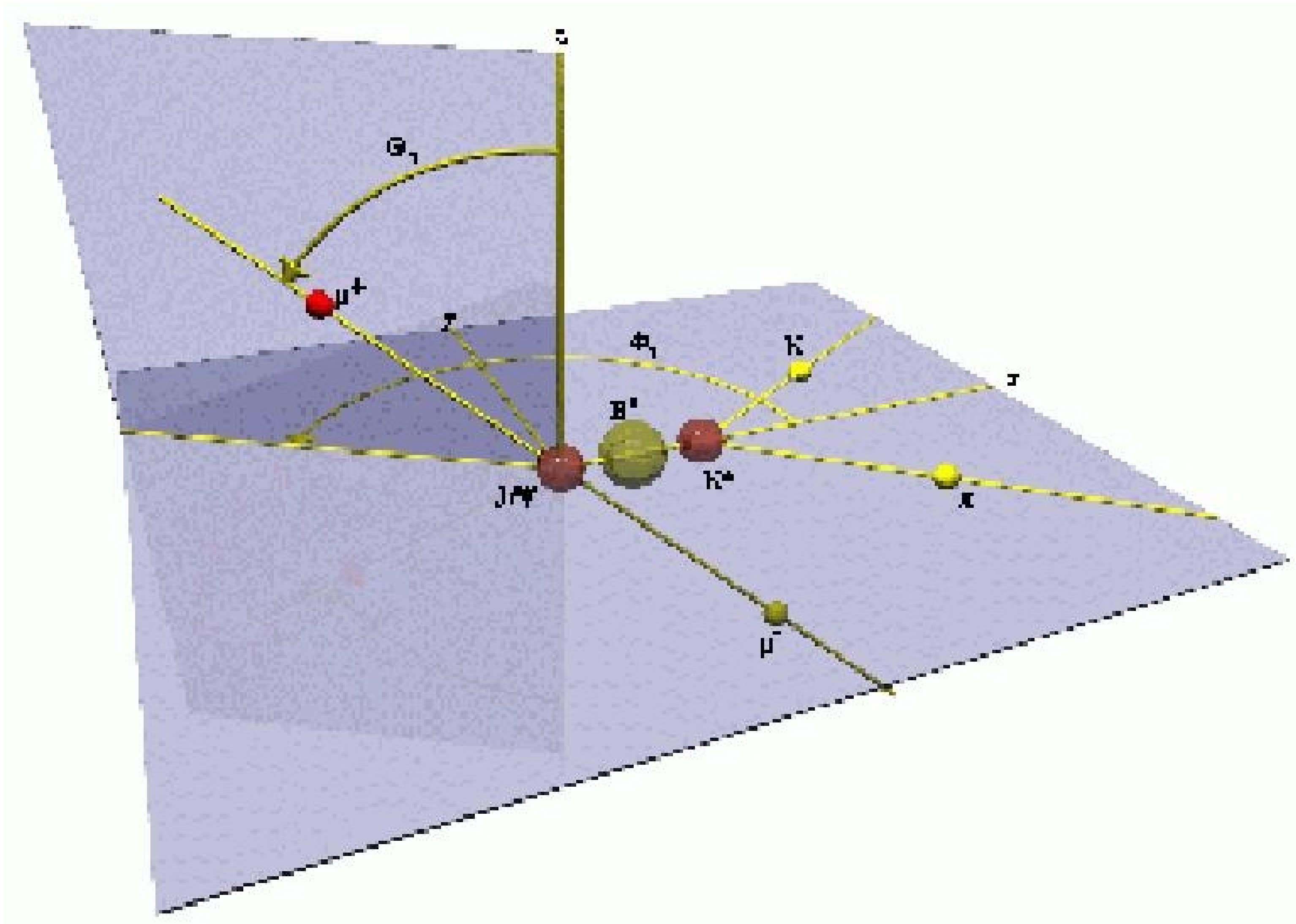


Simulation plot of Transversity to demonstrate the detector acceptance (flat).

Note: These are $B_s \to J/\Psi\phi$ events, generated using PYTHIA, put through GEANT, and reconstructed in the runII framework using the Universal finders.



RunI detector acceptance for Transversity angle (flat)(Taken from S.Pappas' Thesis on Polarization of Vector-Vector Decays of B-mesons.)


z
Θ_1
μ^+
y
Φ_1
K
x
B^0
K^*
J/ψ
π
μ^-

Other issues:

- Mixed CP modes:
  - $B_s \to D_s\pi, D_s\pi\pi\pi$
    - Comes in on hadronic trigger which might influence the CP content.
- other CP modes:
  - $B_s \to K^+K^-$
    - Overlap issues, see F.Würthwein's talk in WKG1
  - $B_s \to D_s^+ D_s^-$
    - Small sample using $\phi\pi$ mode, so seek to use others.
  - $B_s \to D_s^{*+} D_s^{*-}$
    - Larger sample, but angular separation needed, and final state photon smears out kinematics.
  - $B_s \to J/\psi\, K^0{}_s, B_s \to \pi^+\pi^-, B_s \to \overline{D}^0 K^0$
    - Very small expected sample sizes.

Conclusion

- Run II prediction based on Run I results:

  $58 \pm 12 \quad B_s \to J/\Psi\phi$

  $\frac{\Gamma_\perp}{\Gamma_{B_s}} = 0.229 \pm 0.188(stat) \pm 0.038(syst)$

  lead to: $\boxed{\text{Project } \sigma_{\frac{\Delta\Gamma_s}{\Gamma_s}} = 0.065}$

- Have studied several ways to do the analysis
- Investigating more samples which could prove useful
- In the process of detailed MC work

Comparison of MC's

- For $\frac{\Delta\Gamma_{B_s}}{\overline{\Gamma}_{B_s}} = 0.15$
  - likelihood MC: $\sigma_{\frac{\Delta\Gamma_s}{\Gamma_s}} = 0.056$
  - Moments MC:

$c\tau$ cut (μm)	Detector sculpting	Background present	$\sigma_{\frac{\Delta\Gamma_s}{\Gamma_s}}$
100	✔	✔	0.091
100		✔	0.089
0		✔	0.11
100			0.053

  - To compare RunII projection with Moments MC, consider the effect of $\sigma_{\tau_{CP\,\mathrm{Even}}}$ on $\sigma_{\frac{\Delta\Gamma_s}{\Gamma_s}}$:
    - RunII Projection: 0.056
    - Moments MC: 0.09