Estimate of Sensitivity on $\Delta\Gamma_{B_s}$ in BTeV using the Lifetime Method

Harry Cheung, Fermilab - 25th February 2000

Measure sensitivity on $\Delta\Gamma_{B_s}$ by measuring the lifetime for CP specific and CP mixed modes:

$$\frac{\Delta\Gamma}{\Gamma} = \frac{\Gamma_+ - \Gamma_-}{\frac{1}{2}(\Gamma_+ + \Gamma_-)} = 2 \times \frac{\tau_- - \tau_+}{\tau_- + \tau_+} = 2 \times \frac{\tau_{mixed} - \tau_+}{\tau_+}$$

where $\tau_{mixed} = 2/(\Gamma_+ + \Gamma_-)$

For a given error on τ measuring the difference between the CP even and CP odd decays gives twice the sensitivity of using a CP mixed state.

Actual performance depends on statistics of each decay mode and the accuracy of any acceptance corrections.

Decays Considered

- **CP Even Modes (ignored any CP odd component for now)**

⇒ $B_s \to J/\psi\,\phi$ **BR = (9.3 ± 3.3) × 10**

$B_s \to D_s^+ D_s^-$ **BR < 0.218**

$B_s \to D^0$**(CP even)** K_s^0

- **CP Odd Modes**

$B_s \to J/\psi\,\eta$, $J/\psi\,\eta'$ **BR <0.0038**

- **CP Mixed Modes**

⇒ $B_s \to D_s^- \pi^+$ **BR < 0.13**

⇒ Decays looked at for this study so far

Monte Carlo Studies

- Use MCFAST Simulation
  - Geant MC available recently - will do comparison for May
  - Limited Reconstruction Code:
    - No pattern recognition problems simulated
    - Crude particle identification simulation
    - No electronic noise simulated
    - Beam related noise, cosmic rays, etc. not simulated
  - Some Geometry and code updates to come before May
  - Uses Pythia v6.129 for production and QQ v902 for decays
  - No B** production simulated
    - Will try to include for May

Monte Carlo Studies

❒ Limited Background Simulation

- ◆ Includes only certain specific background from total $B\bar{B}$
  - ❖ Modes included depend on signal studied
- ◆ Includes min.bias (uds) embedded in $B\bar{B}$ events
  - ❖ This study uses 2 interactions/crossing
    Number of min.bias events taken from a Poisson distribution with a mean of 2
- ◆ Still need to consider in detail:
  - ❖ Min. bias (uds) events
  - ❖ generic charm
  - ❖ generic charm embedded in $B\bar{B}$ events

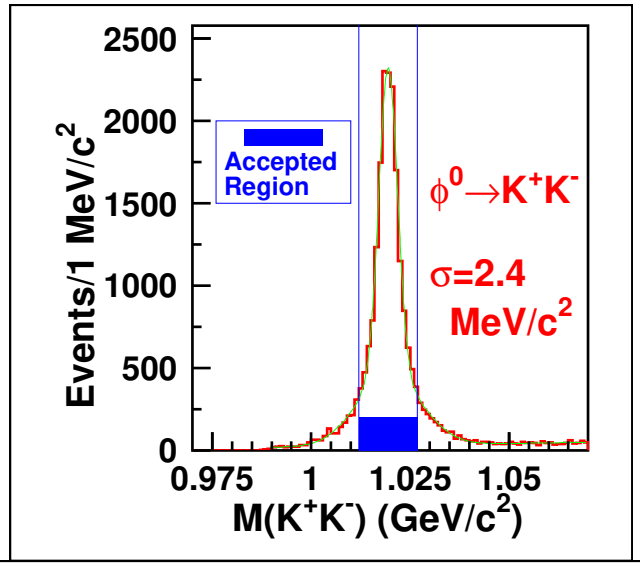
CP Even Mode $B_s^0 \rightarrow J/\psi\ \phi$

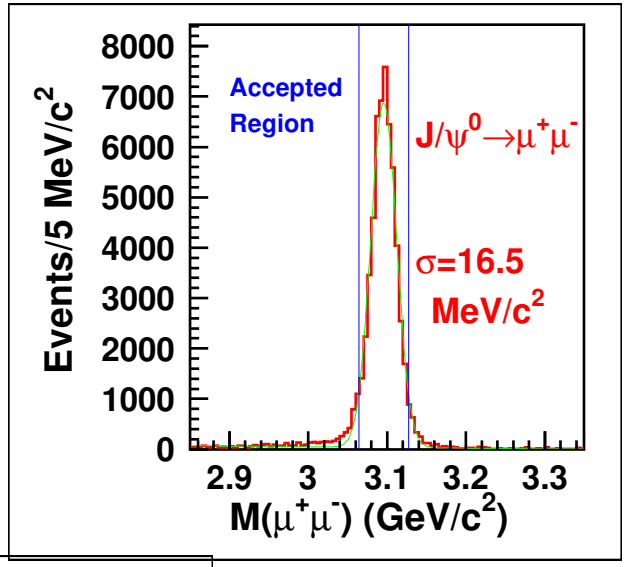
$J/\psi \rightarrow \mu^+\mu^-,\ \phi \rightarrow K^+K^-$

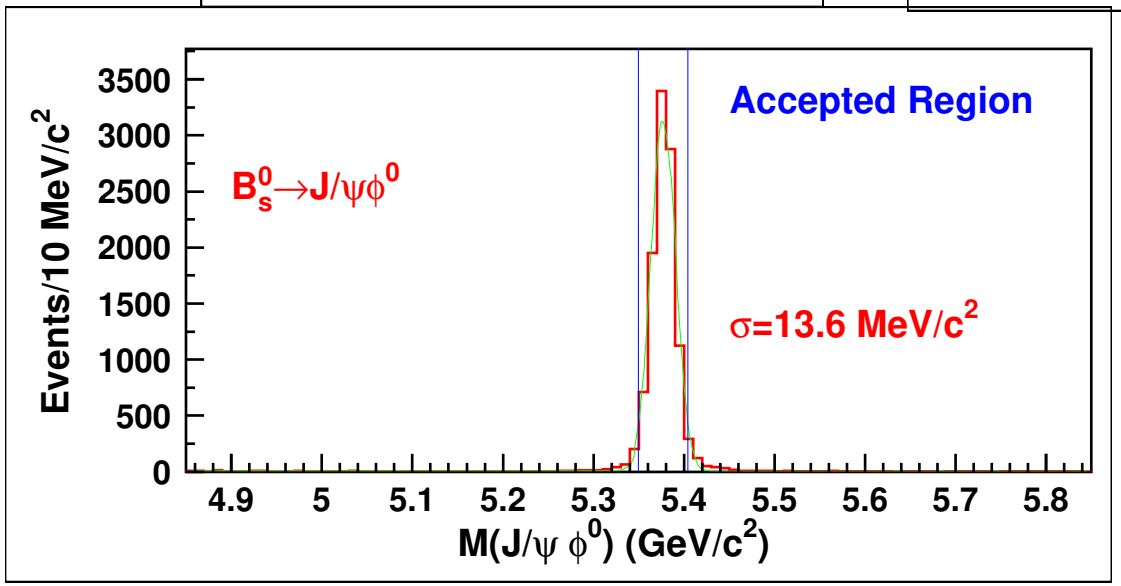
- Particle ID simulation for this study:
  - 100% Kaon ID and for tracks entering RICH detector and with valid momentum range (3-70 GeV/c)
  - 100% Muon ID and for tracks reaching muon detectors and with momentum > 1 GeV/c
  - Crude 2% Kaon misid. and 0.5% Muon misid.
- Initial Selection Criteria:
  - KK vertex confidence level > 1%
  - μμ vertex confidence level > 1%
  - KKμμ vertex confidence level > 1%

CP Even Mode $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$







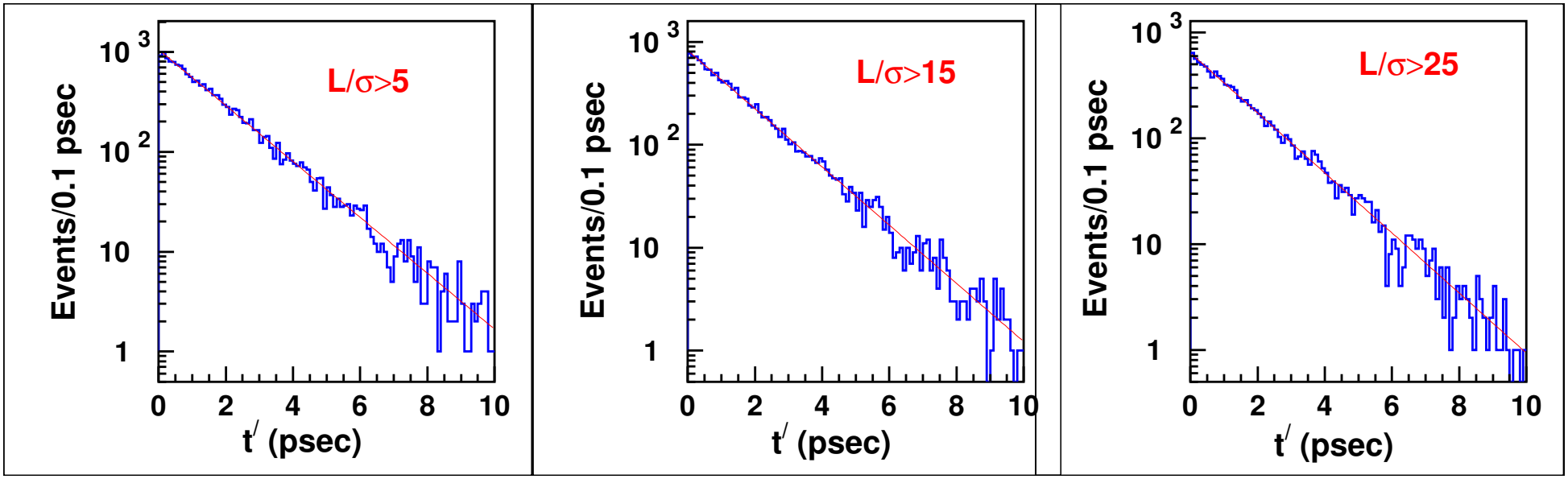
± 3σ Cut on φ

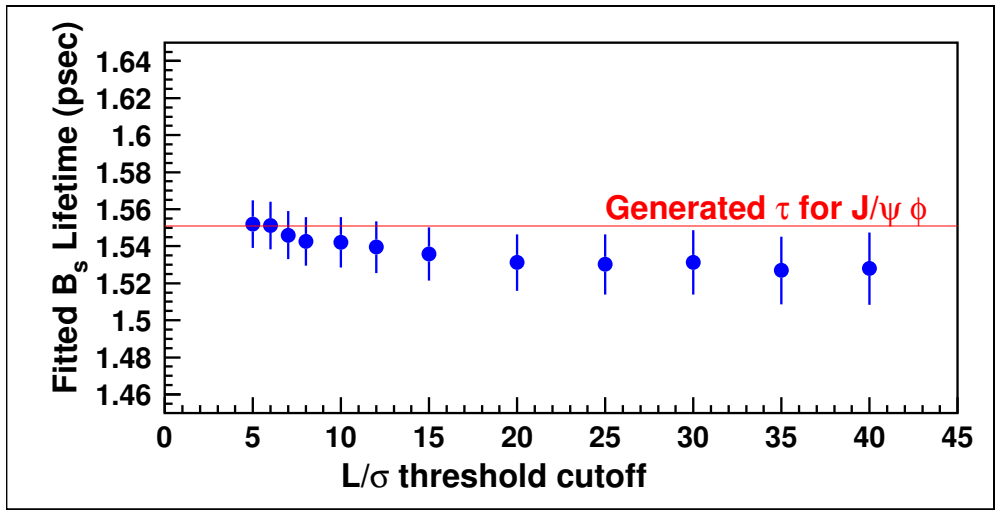
± 2σ Cut on J/ψ

± 2σ Cut on B_s
For Lifetime study

CP Even Mode $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$





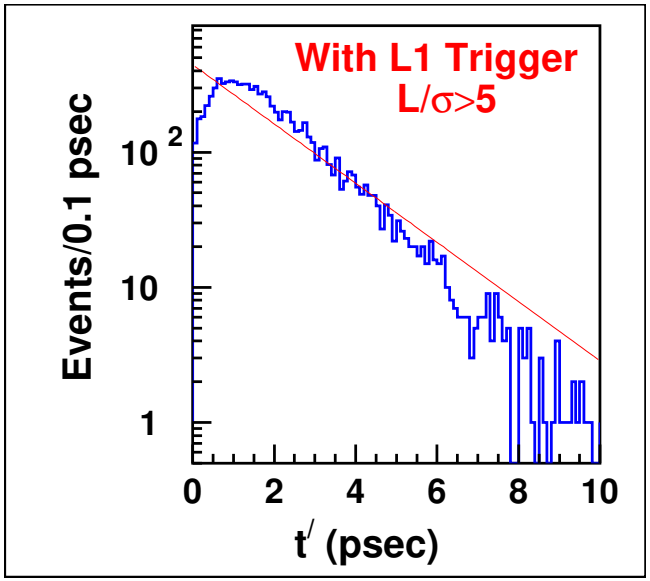
Reduced Proper Time:

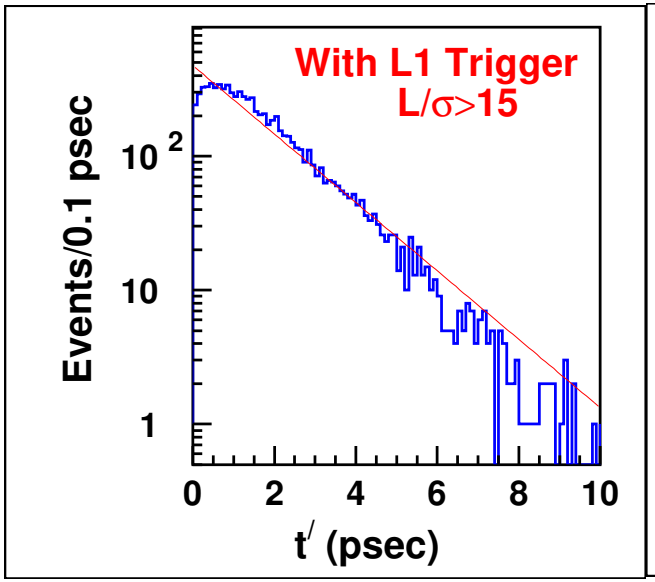
$$t' = t - N\sigma\left(\frac{m_B}{p_B c}\right)$$

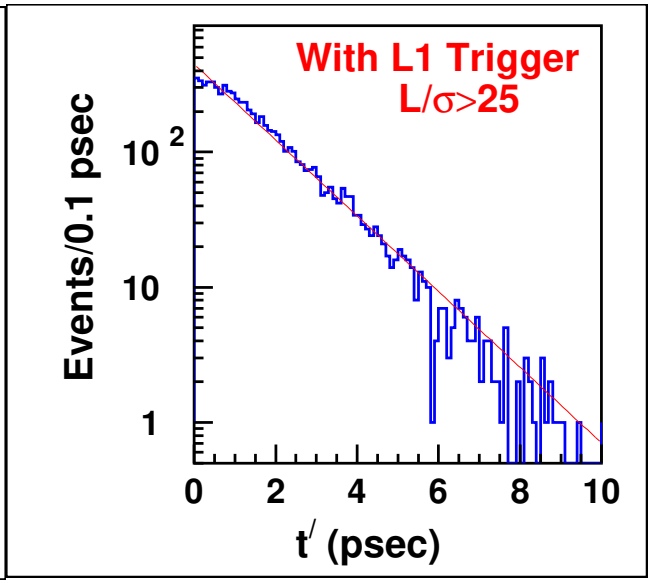
$$t = L\left(\frac{m_B}{p_B c}\right), \qquad L/\sigma > N$$

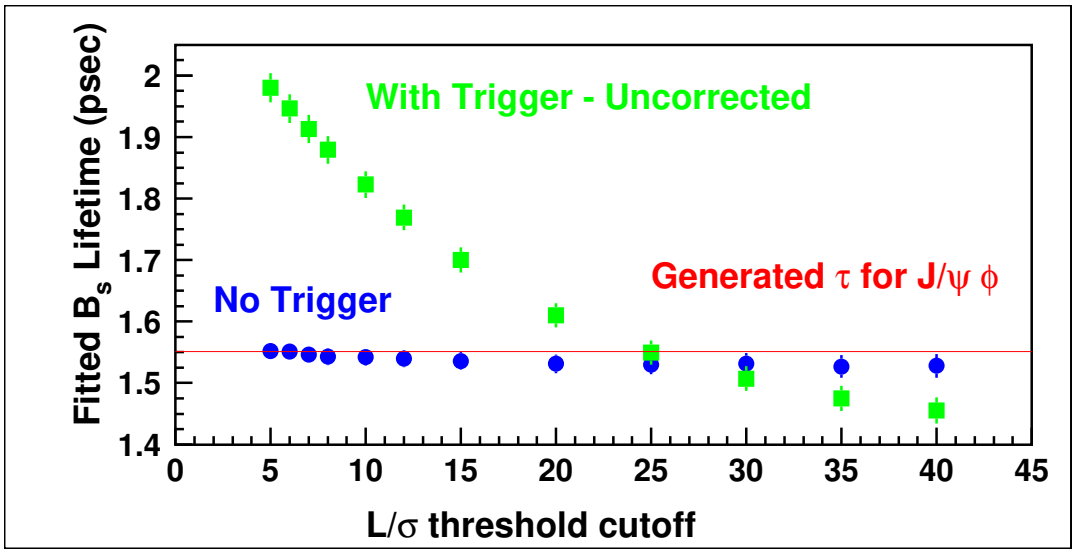
CP Even Mode $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$





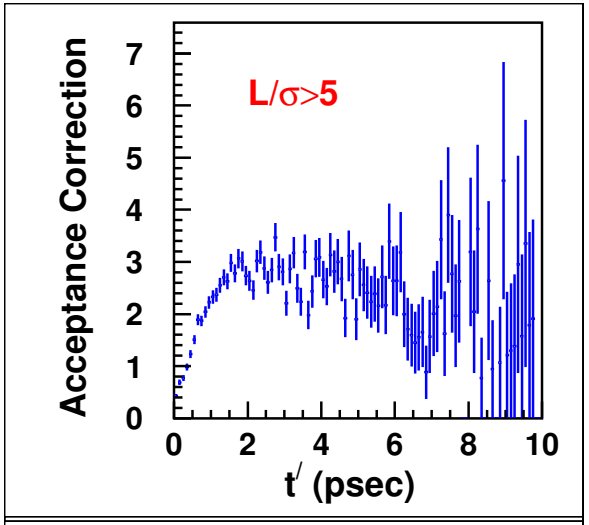


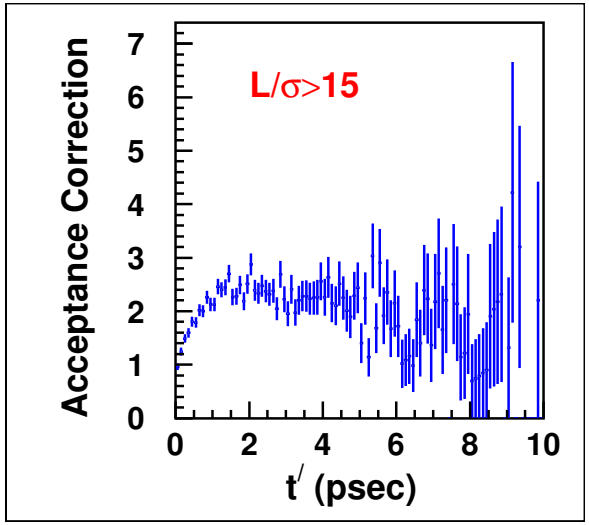


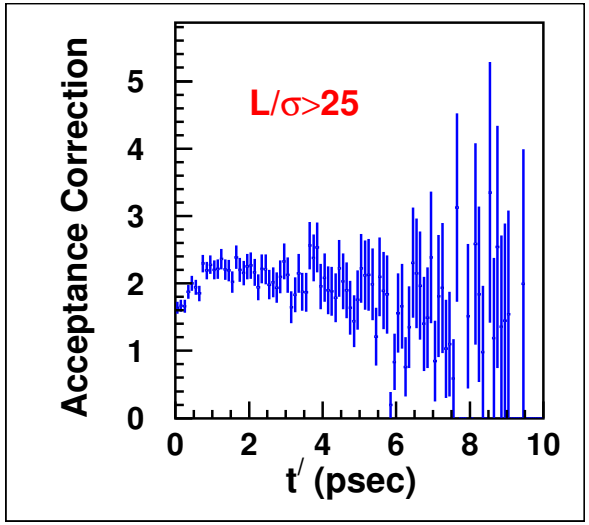
Large acceptance corrections at small L/σ cuts

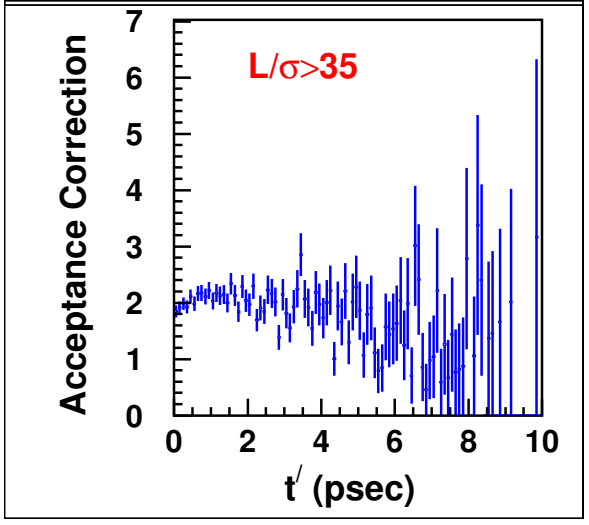
Acceptance Corrections

$B_s^0 \to J/\psi\ \phi$ $\quad J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$









$$\text{Acceptance Correction} = f(t') = \frac{N_{\text{accepted}}(t')}{exp(-t'/\tau_{gen})}$$

Large acceptance corrections at small L/σ cuts

Sensitivity for $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

Calculation of the sensitivity (total error) on $\tau(J/\psi\ \phi)$ depends on:

- Statistics of signal
- Systematic error on acceptance correction
- Effect of backgrounds (event selection)

  Have included embedded minbias (uds) events

  Assume largest background is from generic $B\bar{B}$ events containing a J/ψ and a ϕ once a large enough L/σ cut is used

  Need to consider other backgrounds later!

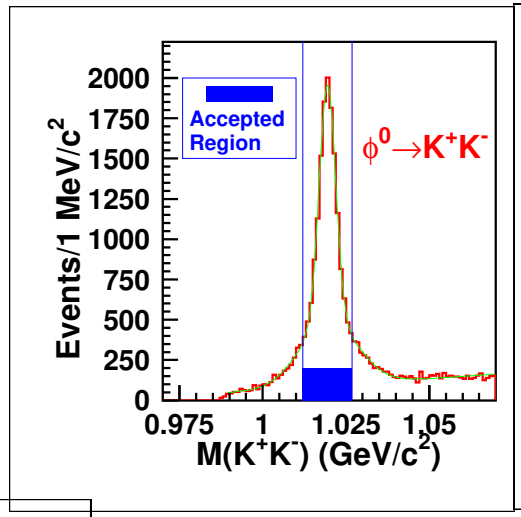
Backgrounds for $B_s^0 \to J/\psi\ \phi$

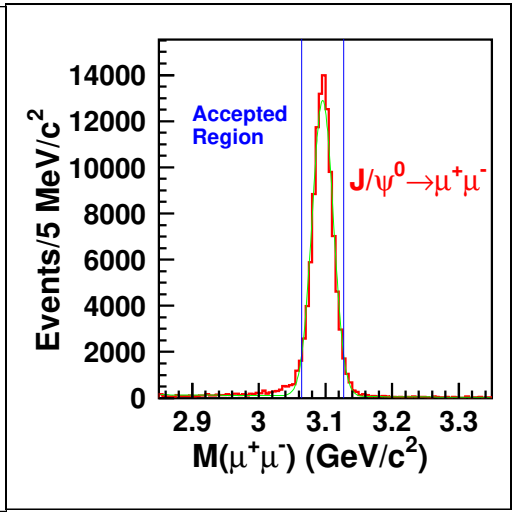
$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

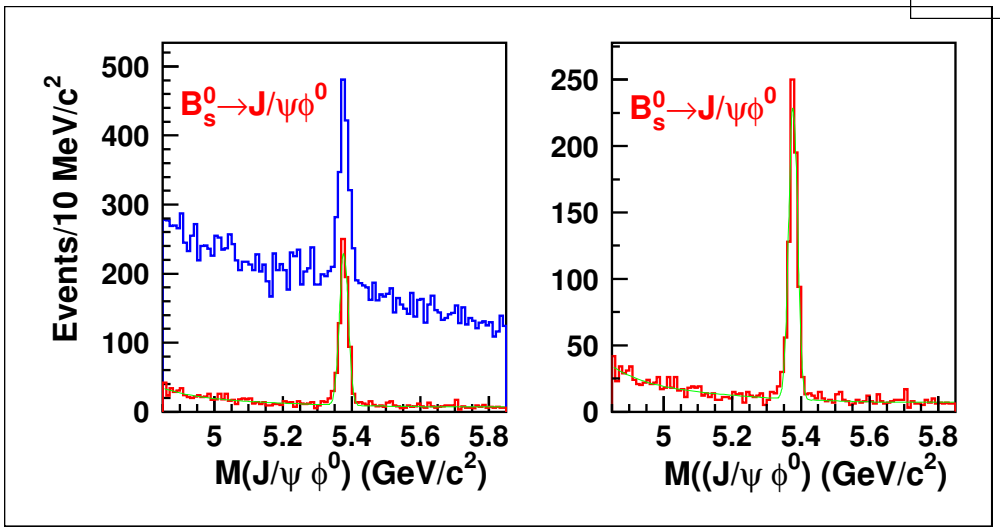
Only generated enough $B\bar{B} \to J/\psi+\phi+X$ background for 8K signal

No L/σ Cuts yet applied

J/ψ and ϕ mass plots have vertex confidence cuts





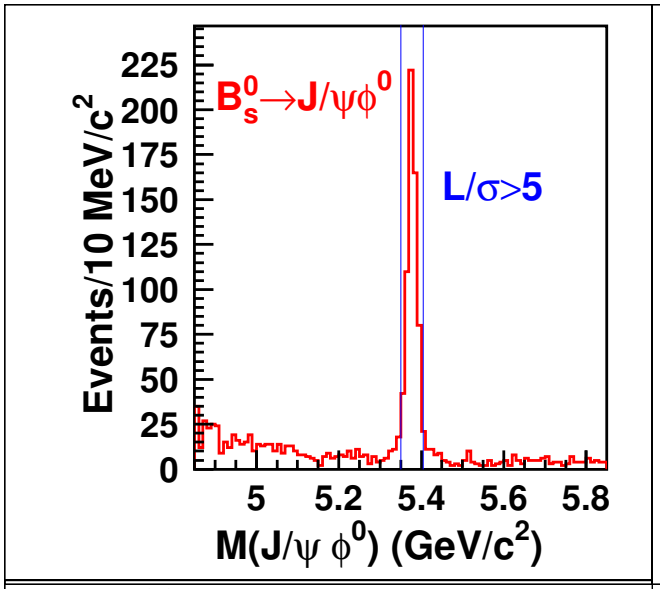


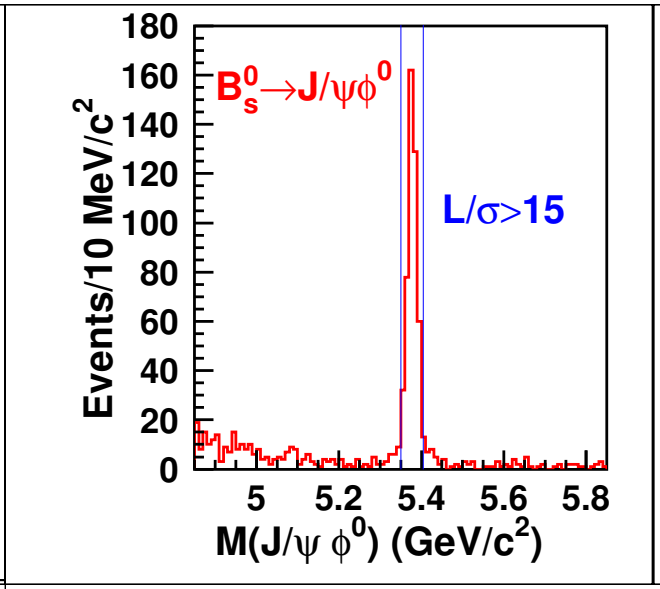
With vertex confidence cuts but no J/ψ and ϕ mass cuts for B_s

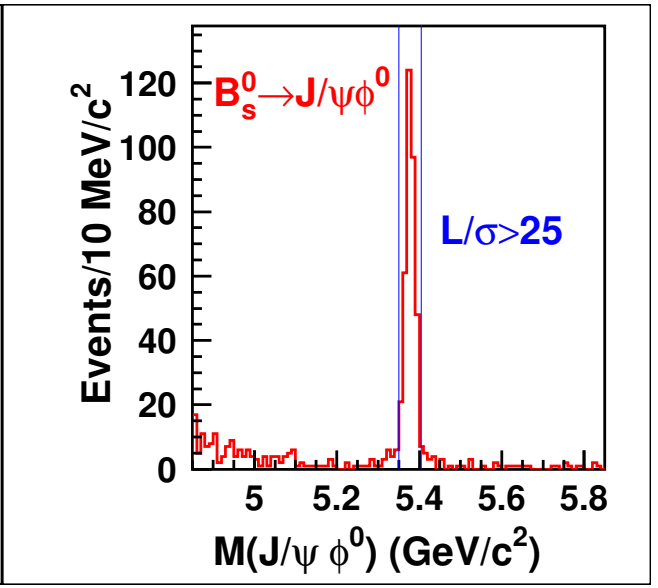
With mass cuts in red

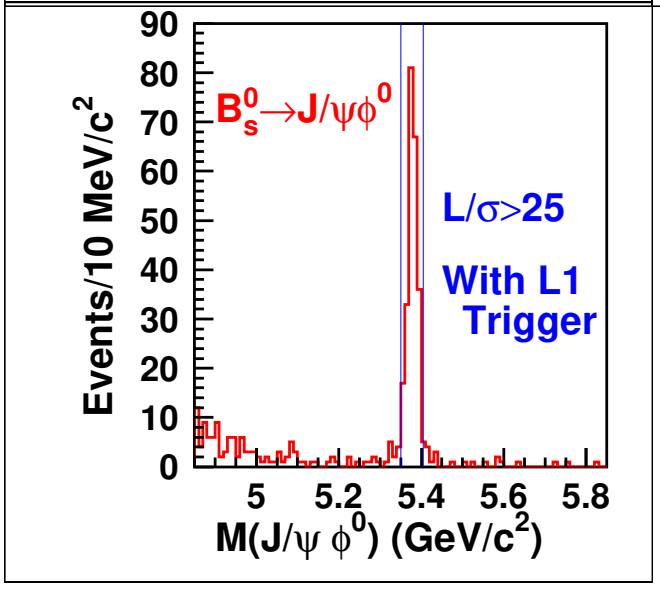
Backgrounds for $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$









L1 Trigger Efficiency for chosen cuts:

for signal

L/σ Cut	Efficiency
5	53.4 ± 0.4%
15	63.5 ± 0.4%
25	70.2 ± 0.4%

(Used 220,000 generated signal sample)

Error on τ for $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

Contributions to the lifetime error from:

- Signal statistics
- Acceptance correction systematics
- systematics due to backgrounds

- Total reconstruction efficiency (including L1 Trigger):

Used 220,000 generated signal sample

L/σ Cut	Efficiency
5	4.2%
15	3.8%
25	3.3%

(No estimate for true error on efficiency yet)

Error on τ for $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

- Estimation of signal size:

  Assume 100 μb for $\sigma(b\bar{b})$, so 2 $fb^{-1} \Rightarrow$ $2 \times 10^{11}\ b\bar{b}$

  Pythia gives 1 $B_s^0/\bar{B}_s^0$ for 17.2 $b\bar{b}$ $\Rightarrow 1.2 \times 10^{10}\ B_s$

  BR = 0.001 $\Rightarrow 1.2 \times 10^{7}\ B_s \to J/\psi\ \phi$

  BR for J/ψ and for φ $\Rightarrow 3.4 \times 10^{5}\ B_s \to J/\psi\ \phi$

  $J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

  Efficiency for $L/\sigma > 25$ Cut = 3.3% $\Rightarrow 1.1 \times 10^{4}\ B_s$ recon.

- Extrapolation to 2, 10 and 20 fb^{-1}:

  Used 220,000 generated signal sample

  Must extrapolate signal size by a factor of 1.6, 7.8 and 15.6

Error on τ for $B_s^0 \to J/\psi\ \phi$

$J/\psi \to \mu^+\mu^-,\ \phi \to K^+K^-$

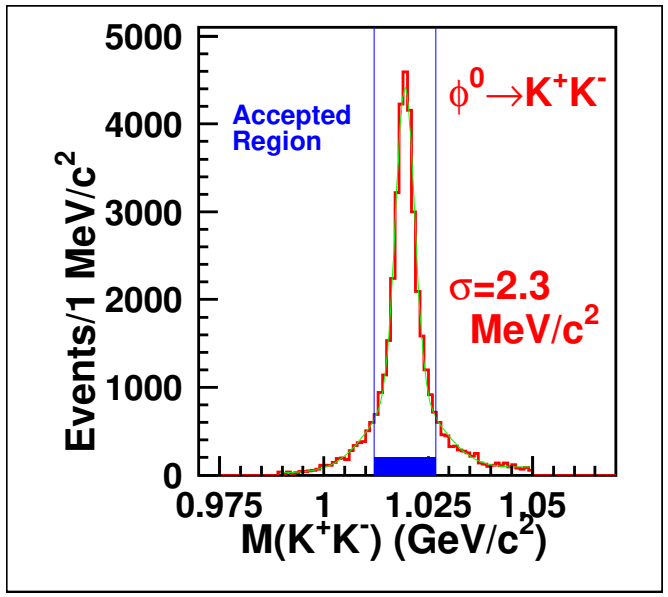
- Estimation of statistical error on the Lifetime:

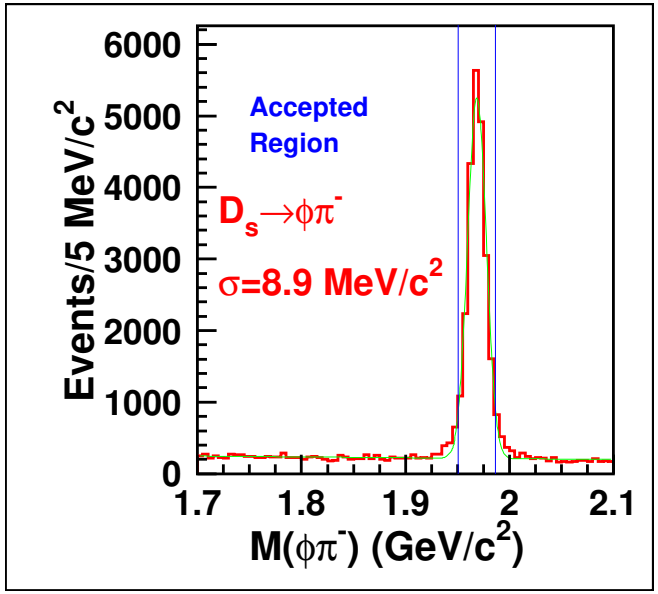
	stat.	total
statistical error on τ with 220,000 gen. signal	1.26 %	
statistical error on τ for 2 fb^{-1}	1.01%	1.43%
10 fb^{-1}	0.45%	0.64%
20 fb^{-1}	0.32%	0.45%

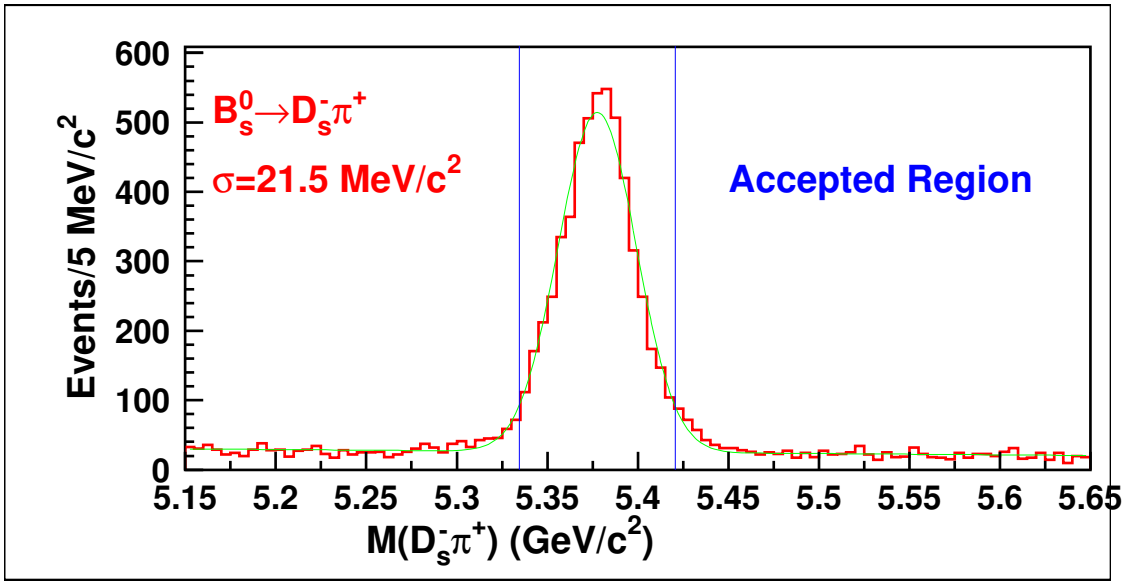
- Assume can keep systematics to the same order as statistical:

Total error = $\sqrt{2}$ × statistical error

CP Mixed Mode $B_s \rightarrow D_s^- \pi^+$







± 3σ Cut on φ

± 2σ Cut on D_s

± 2σ Cut on B_s
For Lifetime study

Error on τ for $B_s \rightarrow D_s^- \pi^+$

Contributions to the lifetime error from:

- Signal statistics
- Acceptance correction systematics
- systematics due to backgrounds

- Total reconstruction efficiency (including L1 Trigger):

Used 100,000 generated signal sample

L/σ Cut	Efficiency
5	5.09%
15	4.30%
25	3.36%

(No estimate for true error on efficiency yet)

Error on τ for $B_s \rightarrow D_s^- \pi^+$

- Estimation of signal size:

  Assume 100 μb for $\sigma(b\bar{b})$, so 2 $fb^{-1} \Rightarrow$ $2 \times 10^{11} b\bar{b}$

  Pythia gives 1 $B_s^0/\bar{B}_s^0$ for 17.2 $b\bar{b}$ $\Rightarrow 1.2 \times 10^{10}$ B_s

  Assume BR = 0. $\Rightarrow 1.2 \times 10^8 B_s \rightarrow D_s \phi$

  BR for D_s and for ϕ $\Rightarrow 2.1 \times 10^6 B_s \rightarrow D_s \phi$

  Efficiency for $L/\sigma > 25$ Cut = 3.36% $\Rightarrow 6.9 \times 10^4 B_s$ recon.

- Should have comparable signal size to CP even mode

  Assumes BR of 1%

Estimation of Error on $\Delta\Gamma/\Gamma$

- Error on $\Delta\Gamma/\Gamma$ for the two different methods:

CP even and mixed modes:

$$\sigma\left(\frac{\Delta\Gamma}{\Gamma}\right) = 2\frac{\tau_{mixed}}{\tau_+}\sqrt{\left(\frac{\sigma_{\tau_{mixed}}}{\tau_{mixed}}\right)^2 + \left(\frac{\sigma_{\tau_+}}{\tau_+}\right)^2}$$

$\Rightarrow$ 2.15 $\times\sqrt{(\ )}$ for $\Delta\Gamma/\Gamma$ = 0.15

CP even and CP odd modes:

$$\sigma\left(\frac{\Delta\Gamma}{\Gamma}\right) = 4\frac{\tau_+\tau_-}{(\tau_- + \tau_+)^2}\sqrt{\left(\frac{\sigma_{\tau_-}}{\tau_-}\right)^2 + \left(\frac{\sigma_{\tau_+}}{\tau_+}\right)^2}$$

$\Rightarrow$ 0.99 $\times\sqrt{(\ )}$ for $\Delta\Gamma/\Gamma$ = 0.15

- IF assume equal error on τ(mixed) and τ(odd) as on τ(even):

NOTE: From 1 Decay only

	Error on $\Delta\Gamma/\Gamma$	
	CP even/mixed	CP even/odd
2 fb^{-1}	4.3%	2.0%
10 fb^{-1}	1.9%	0.9%
20 fb^{-1}	1.4%	0.6%