Performance and Physics with the channel $B_s \to J/\psi\ \phi$

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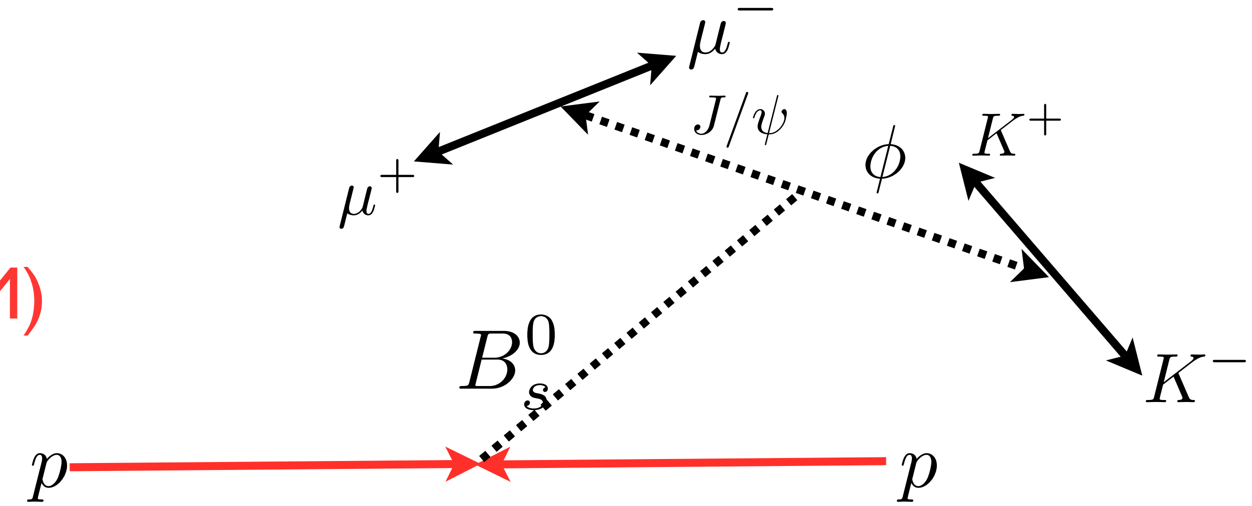
Motivation



- $B_s \rightarrow J/\psi\ \phi$ decay exhibits CP violation (CPV) sensitive to physics beyond SM (BSM)

To measure CPV, the 3 CP-eigenstates of $J/\psi\ \phi$ must be separated

$$CP+ = (A_{||} + A_{\perp})/2$$
$$CP- = (A_{||} - A_{\perp})/2$$
$$CP+ = A_0$$

This means the helicity amplitudes; $A_{||}$, $A_{\perp}$ and A_0 should be determined from angular analysis

→ very high statistics available only at LHC - in ATLAS 20 fb^{-1} = 100 000 events

- With early data > 150 pb^{-1} $B_s \rightarrow J/\psi\ \phi$ will serve for calibration, alignment tests (B mass and lifetime)

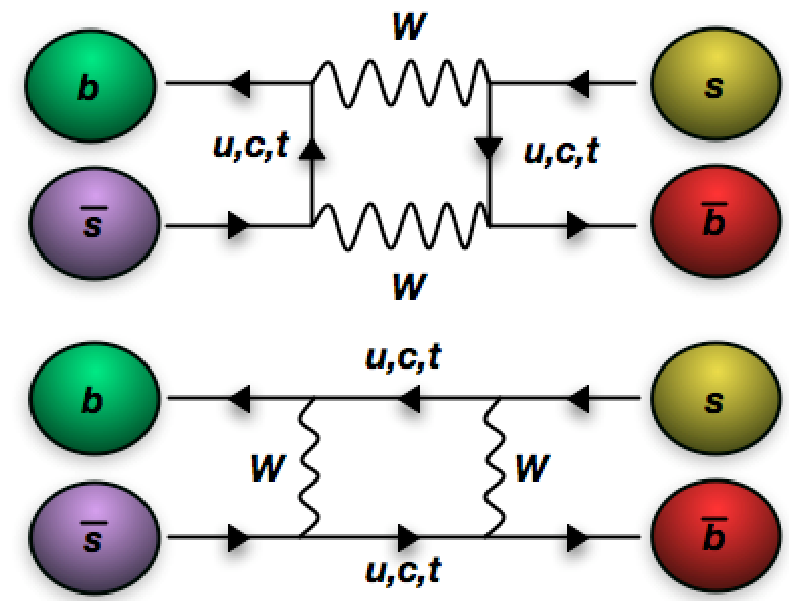
B_s-meson mixing

- Leads to two mass eigenstates: B_H, B_L with decay rates Γ_H, Γ_L

$$\Gamma_s = (\Gamma_H + \Gamma_L)/2$$
$$\Delta\Gamma = (\Gamma_H - \Gamma_L)/2$$

- CP violation can occur in interference between mixing and direct decay amplitudes with the weak phase difference Φ_s

Mixing in the SM



$$\phi_s \equiv 2\arg V_{ts}^{*} V_{tb} + \phi_{NEW}$$

Standard model — New physics

$$\Delta M = \Delta M_{SM} + \Delta M_{NEW}$$

	B_d	B_s
ΔM	0.507 ± 0.005	17.77 ± 0.01 ± 0.07
$\Delta\Gamma/\Gamma$	~0	0.12 ± 0.09
$\Phi_{d,s}$	0.738 ± 0.029	~0.04 (SM)

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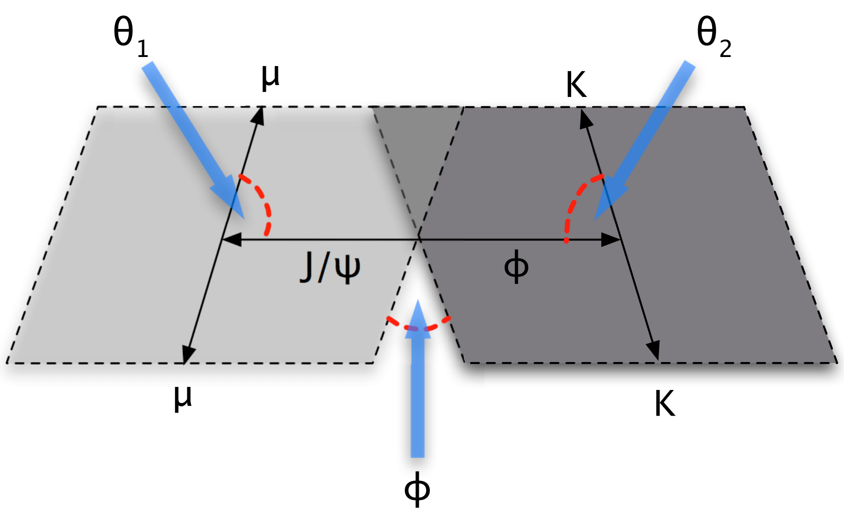
Measurable quantities

The process $B_s \rightarrow J/\psi\ \phi$ is described by 8 parameters

$$\Gamma_s, \Delta\Gamma, \phi_s, \Delta M_s, A_{||}, A_{\perp}, \delta_1, \delta_2$$

We measure the following variables; decay time of B_s, 3 decay angles and B_s tag



$$\left.\begin{array}{l} B_s^0 \\ \bar{B}_s^0 \end{array}\right\} \rightarrow J/\psi\,(\mu\mu)\,\phi\,(KK)$$

Both the B_s and $\bar{B}_s$ decay to the same final state so it will be necessary to tag the flavour of the B meson at production

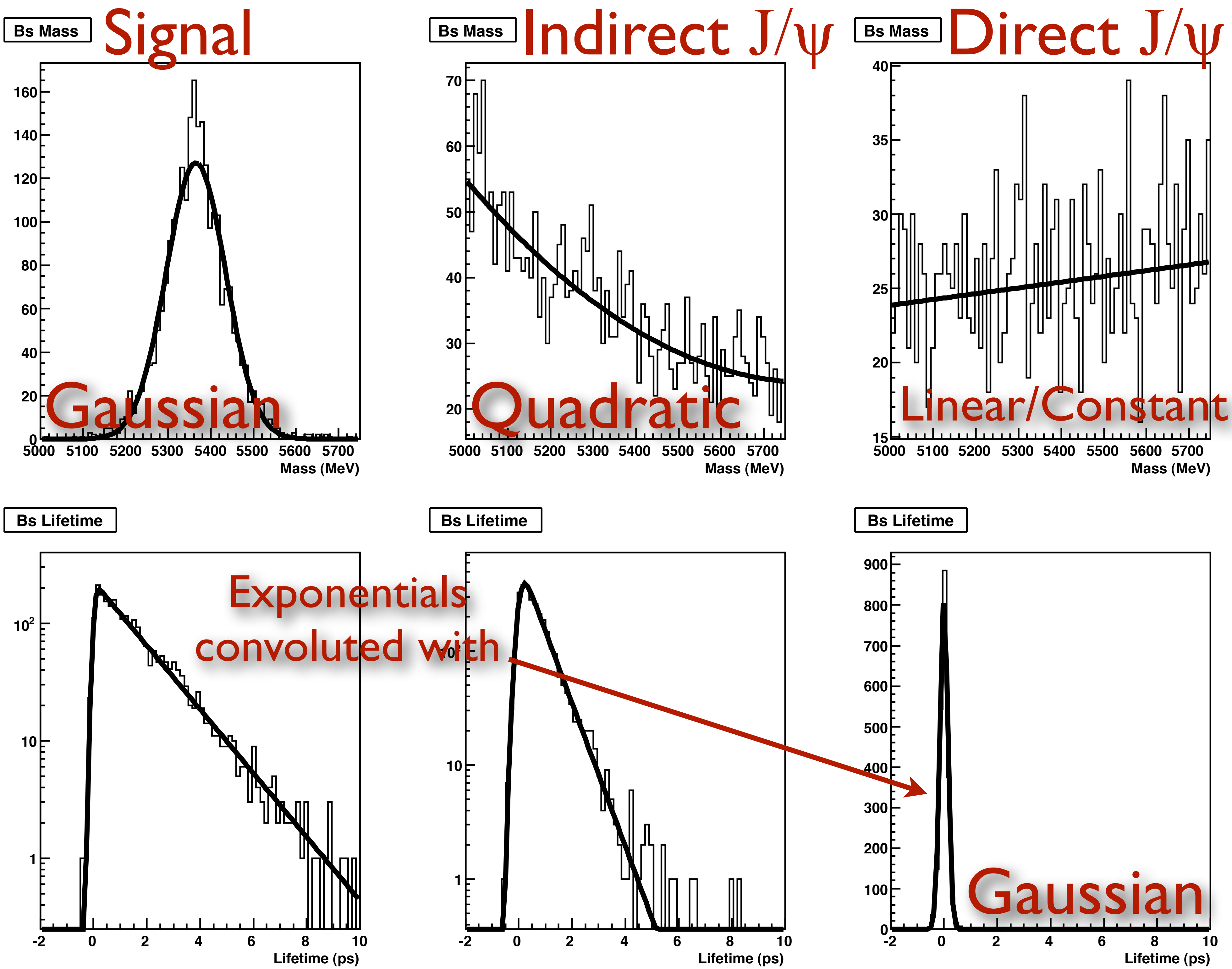
Physics with 10 to 200pb^{-1}

- The $B_d \rightarrow J/\psi\ K^{0*}$ decay will be the main source of background for the B_s decay so it will be important to understand it fully
- The $B_d \rightarrow J/\psi\ K^{0*}$ decay is topologically the same as $B_s \rightarrow J/\psi\ \phi$ and will occur 10 times more frequently
- With early data will focus on detector performance and alignment sensitive tests, such as measuring the lifetime and mass of the B_d and B_s meson
- At low luminosities we will not apply secondary vertex / decay time cut which will allow for the study of the vertex / decay time resolution

Simultaneous maximum likelihood fit

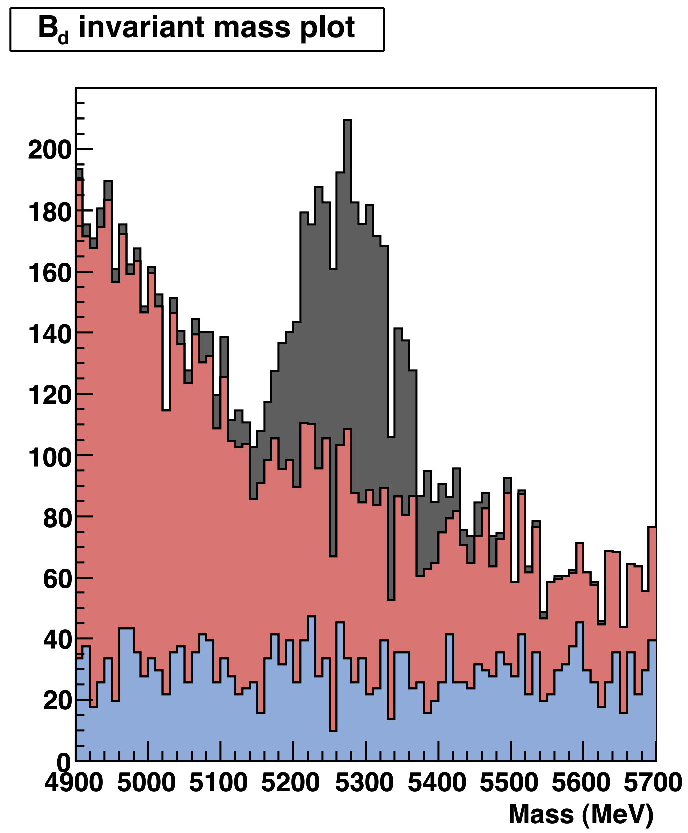
- Why is it needed?
  - High combinatoric background due to poor particle ID means that it is impossible to extract a lifetime measurement without using the mass.
  - A binned fit is not as accurate as a non-binned fit if some bins have very high statistics and others very low statistics such as with an exponential decay.
- How is it done?
  - A likelihood function needs to be constructed by looking at the various contributions expected from the signal and background.
  - The log of the likelihood function is maximized using the Minuit software package.

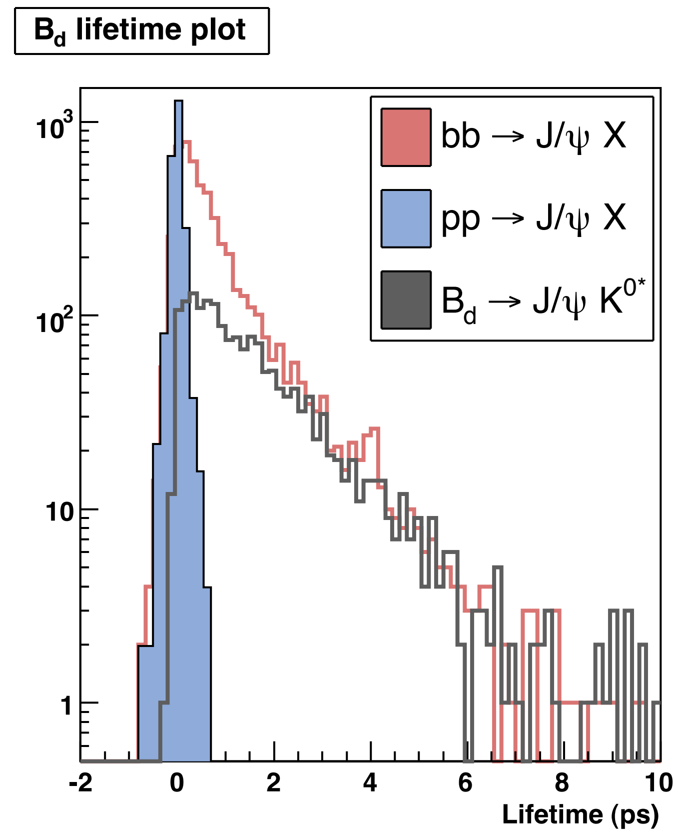
Constructing the likelihood function



Simultaneous fit to mass and decay time with 10pb^{-1}

- A non-binned maximum likelihood fit of 11 parameters was performed on simulated data
- Table shows results of 6 main parameters from fit to 10 pb^{-1} of $B_d \rightarrow J/\psi\ K^{0*}$ candidates
- Similar precision can be achieved for $B_s \rightarrow J/\psi\ \phi$ with 150 pb-1

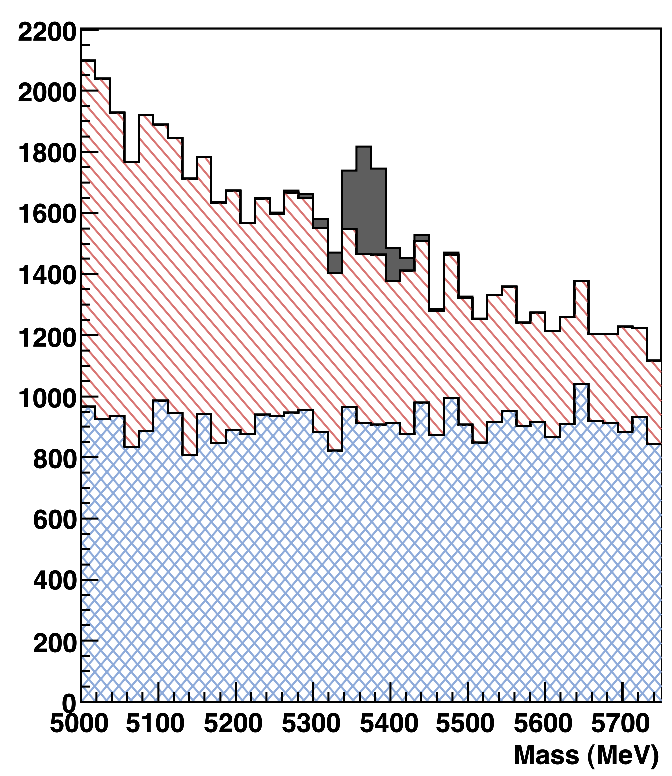


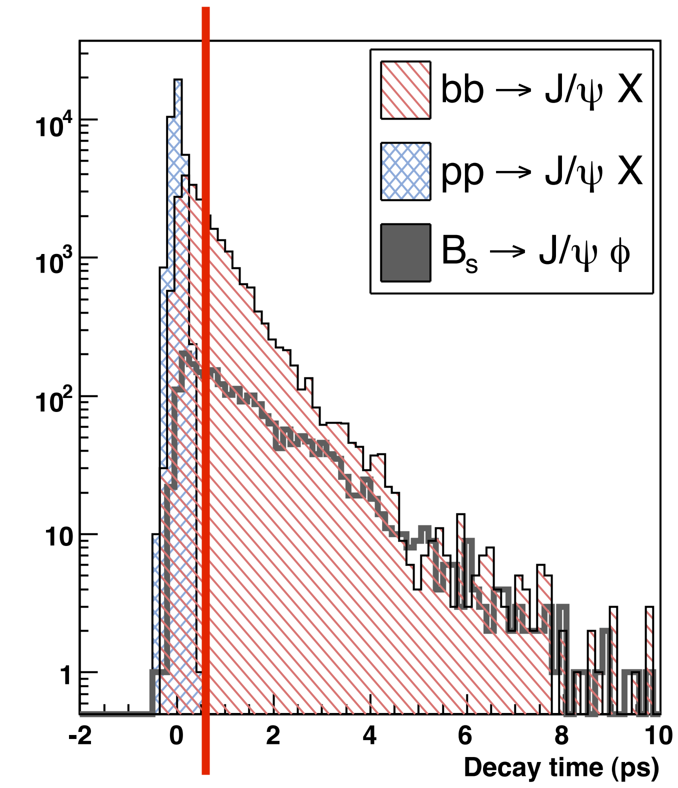


Parameter	Simulated value	Fit result with statitical error
$\Gamma,\ \mathrm{ps}^{-1}$	0.651	0.73 ± 0.07
$\mathrm{m(B)},\ \mathrm{GeV}$	5.279	5.284 ± 0.006
σ, ps	-	0.132 ± 0.004
$\sigma(m)$, GeV	-	0.054 ± 0.006
n_{sig}/N	0.16	0.155 ± 0.015
n_{bck1}/N	0.62	0.595 ± 0.017

Simultaneous fit to mass and decay time before and after 0.5 ps lifetime cut

- The plot shows the $B_s \to J/\psi\ \phi$ reconstruction with 150 pb-1
- The red line indicates the cut at 0.5 ps.
- The lifetime cut will be necessary to keep the event rate down at high luminosities.
- The lifetime cut effectively removes all the background from direct J/ψ production.
- The lifetime cut removes approximately 30% of the signal and indirect J/ψ background.
- Once the lifetime cut is in place the lifetime resolution of the detector will be fixed.





- As the statistics increases it will be possible to extract more physics parameters from the fit.
- With $1 fb^{-1}$ it will be possible to extract the 2 B_s lifetimes.
- With $20 fb^{-1}$ it will be possible to extract 5 of the 8 physics parameters describing the $B_s \to J/\psi\ \phi$ decay

$B_s \to J/\psi\ \phi$ analysis with 2 - 20 fb^{-1}

- Statistics corresponds to roughly 100 000 signal events
- A non-binned maximum likelihood fit was used to simultaneously determine the following parameters: $\Gamma_s, \Delta\Gamma, A_{||}, A_\perp, \phi_s$
  The remaining parameters were fixed

	Input	ATLAS with $20 fb^{-1}$	CDF with $1.7 fb^{-1}$
$A_\perp$	0.40	20%	Fixed from $B_d \to J/\psi K^{0*}$ fit
$A_{\|\|}$	0.57	10%	Fixed from $B_d \to J/\psi K^{0*}$ fit
$\Delta\Gamma$	0.08	20%	80%
Γ_s	0.65	2%	3%
ϕ_s	0.04	0.1	Fixed at 0

The values in the 3rd and 4th column are relative errors except Φ_s which is absolute error

The input values were taken from experiment results except for the Φ_s where the SM theoretical prediction was used

Conclusions and future work

- With early data $B_d \rightarrow J/\psi\ K^{0*}$ and $B_s \rightarrow J/\psi\ \phi$ can serve as a test of ATLAS detector performance by fitting mass and lifetime.
- In the $B_s \rightarrow J/\psi\ \phi$ decay it will be possible to measure Φ_s to an accuracy of 0.1 with 20 fb^{-1}. This precision allows us to test BSM contributions
- Aim to extend the fit to include backgrounds from more sources.