$B_s \to J/\psi\ \phi$ and Misalignment

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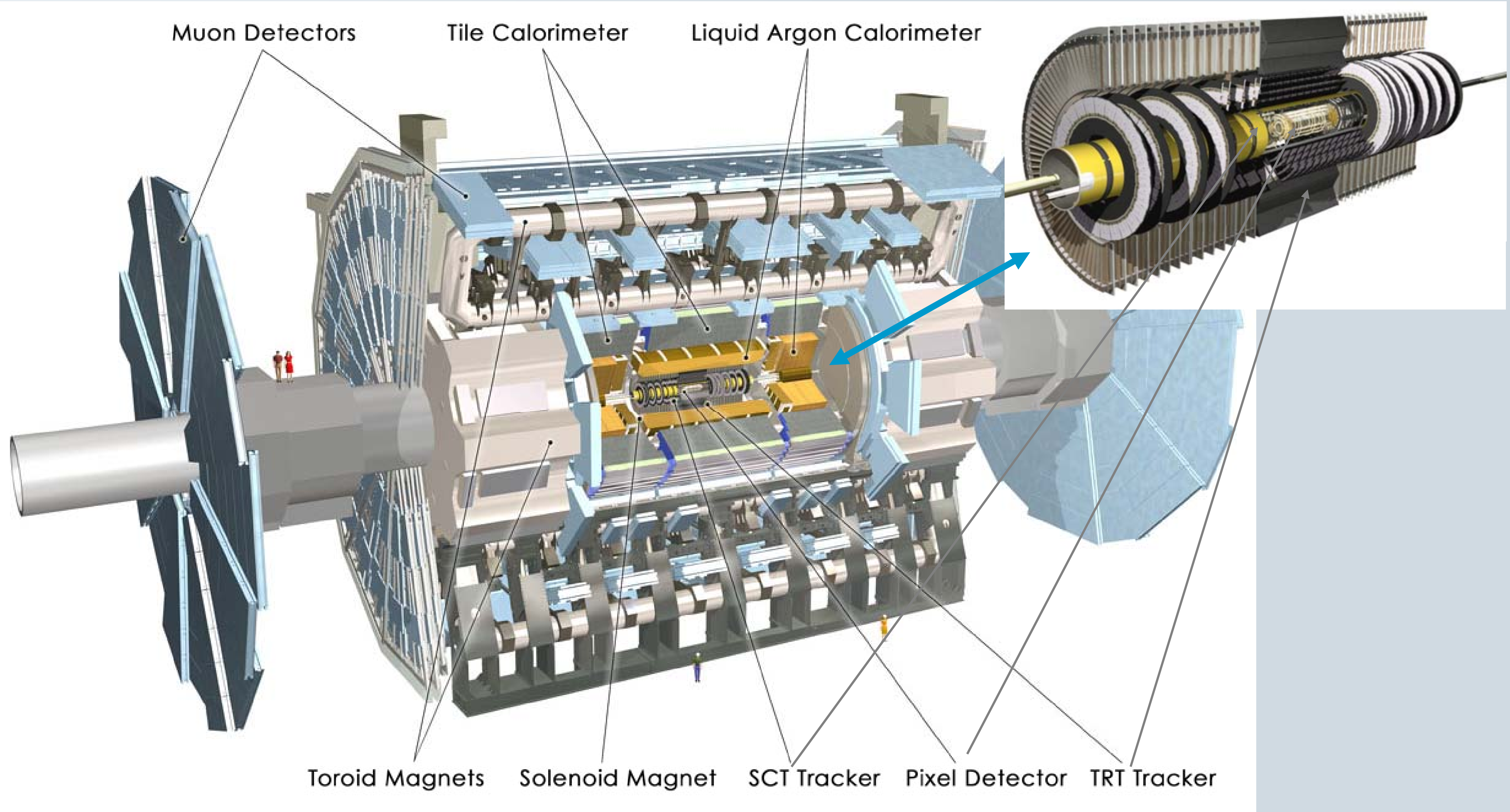
Introduction

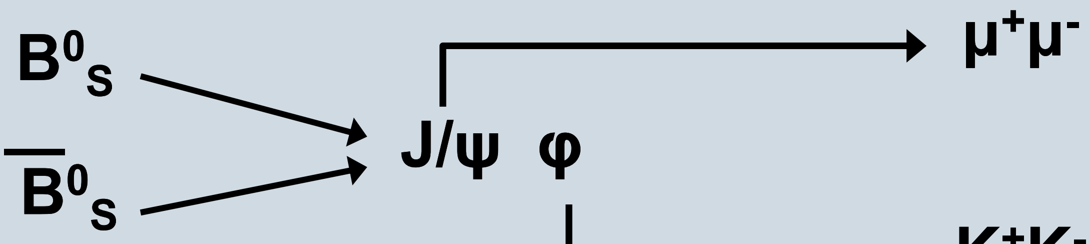
- The ATLAS Detector
- $B_s \rightarrow J/\psi\ \phi$ decay and parameterisation
- Lifetime Fitting
- Decay time resolution
- Misalignment in the Inner Detector
- Early Data and Systematic Errors

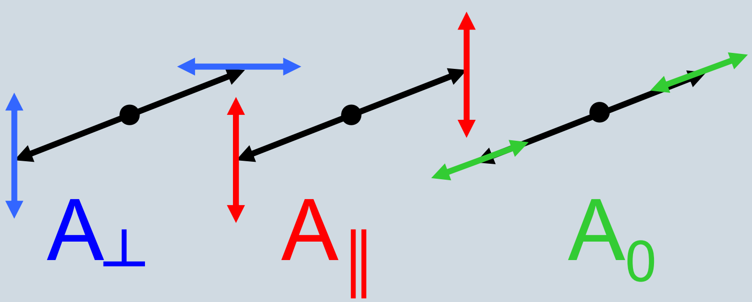
The ATLAS Detector



$B_s \to J/\psi\ \phi$

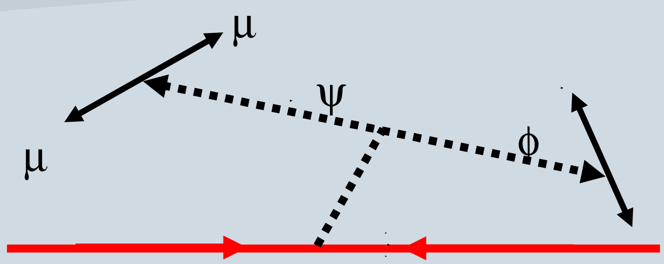
- B_s and $\overline{B}_s$ created as oscillating pairs with mass eigenstates B_H and B_L
- Oscillation frequency is not directly measurable in $B_s \to J/\psi\ \phi$ - look at other parameters
- Eigenstates decay to the same final state particles.





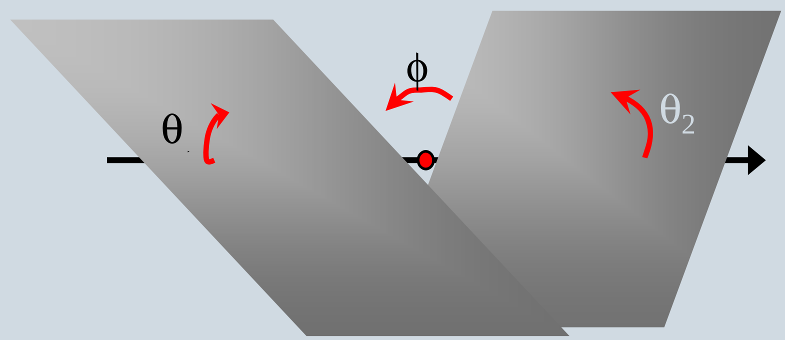
- Scalar particle decays to two vector particles:
- gives three possible final state helicity amplitudes

Angular Analysis



- To extract mixing parameters, must separate eigenstate amplitudes

- Analyse the angular distribution of decay products, and tag and proper time information



Decay Parametrisation

- 3 transversity amplitudes
  - 4 independent parameters - 2 magnitudes and 2 phases:
  - $|A_{\parallel}|$ $|A_{\perp}|$ δ_1 δ_2
- 3 mixing parameters and weak phase:
  - Γ_s $\Delta\Gamma_s$ ΔM_s ϕ_S
- Parameters are extracted via maximum likelihood fit
- Take into account 8 free parameters (in probability distribution), also wrongtag fraction & background

Lifetime Fitting

- The normalised maximum likelihood estimator is:

$$\mathcal{L} = \prod_{i=1}^{N} \frac{\left(\epsilon_1 W^+ (t', \Omega_i) + \epsilon_2 W^- (t', \Omega_i) + b e^{-\Gamma_0 t'}\right) \otimes \rho (t_i - t')}{\int_{t_{min}}^{\infty} \int_0^{2\pi} (\epsilon_1 W^+ (t', \Omega) + \epsilon_2 W^- (t', \Omega) + b e^{-\Gamma_0 t'}) \otimes \rho (t - t') \, d\Omega dt}$$

Probability distribution

1-(wrong tag)

Background

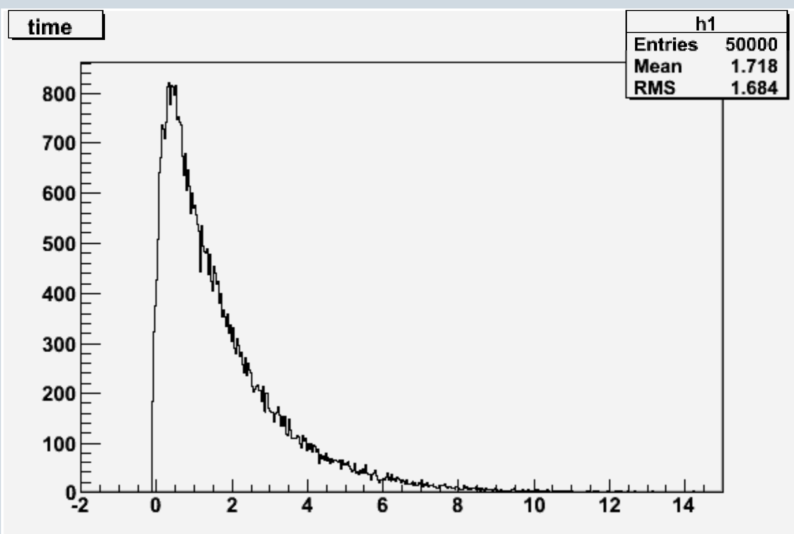
Decay time resolution

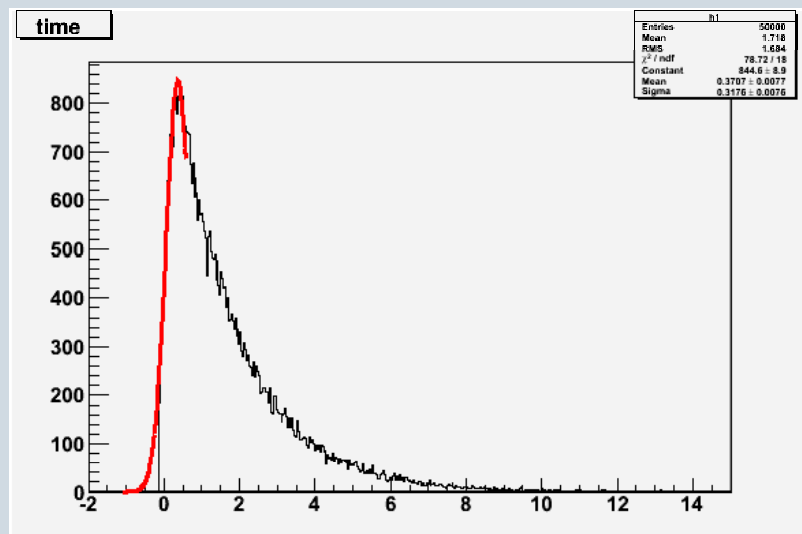
- Complicated PDF
- Fit to all 8 free parameters is difficult
- Fix 6 parameters and fit 2 lifetimes

k	$\Omega^{(k)}(t)$		$g(t)$
1	$\lvert A_0(t)\rvert^2$		$4\sin^2\theta_1 \cos^2\theta_2$
	$\frac{1}{2}\lvert A_0(0)\rvert^2$	$(1+\cos\phi_s)e^{-\Gamma_L^{(s)}t}+$ $(1-\cos\phi_s)e^{-\Gamma_H^{s}t}+$ $2e^{-\Gamma_s t}\sin(\Delta M_s t)\sin\phi_s$	
2	$\lvert A_\parallel(t)\rvert^2$		$(1+\cos^2\theta_1)\sin^2\theta_2 - \sin^2\theta_1\sin^2\theta_2\cos 2\chi$
	$\frac{1}{2}\lvert A_\parallel(0)\rvert^2$	$(1+\cos\phi_s)e^{-\Gamma_L^{(s)}t}+$ $(1-\cos\phi_s)e^{-\Gamma_H^{s}t}+$ $2e^{-\Gamma_s t}\sin(\Delta M_s t)\sin\phi_s$	
3	$\lvert A_\perp(t)\rvert^2$		$(1+\cos^2\theta_1)\sin^2\theta_2 + \sin^2\theta_1\sin^2\theta_2\cos 2\chi$
	$\frac{1}{2}\lvert A_\perp(0)\rvert^2$	$(1-\cos\phi_s)e^{-\Gamma_L^{(s)}t}+$ $(1+\cos\phi_s)e^{-\Gamma_H^{s}t}-$ $2e^{-\Gamma_s t}\sin(\Delta M_s t)\sin\phi_s$	
4	$\mathcal{R}\{A_0^*(t)A_\parallel(t)\}$		$2\sin^2\theta_1\sin^2\theta_2\sin 2\chi$
	$\frac{1}{2}\lvert A_0(0)\rvert\lvert A_\parallel(0)\rvert\cos(\delta_2-\delta 1)$	$(1+\cos\phi_s)e^{-\Gamma_L(t)}+$ $(1-\cos\phi_s)e^{-\Gamma_H^{(s)}t}+$ $2e^{-\Gamma_s t}\sin(\Delta M_s t)\cos\phi_s$	
5	$\mathcal{I}\{A_\parallel^*(t)A_\perp(t)\}$		$-\sqrt{2}\sin 2\theta_1\sin 2\theta_2\cos\chi$
	$\lvert A_\parallel(0)\rvert\lvert A_\perp(0)\rvert$	$e^{-\Gamma_s t}\{\sin\delta_1\cos(\Delta M_s t)-$ $\cos\delta_1\sin(\Delta M_s t)\cos\phi_s\}-$ $\frac{1}{2}\left(e^{-\Gamma_H^{(s)}t}-e^{-\Gamma_L^{(s)}t}\right)\cos\delta_1\sin\phi_s$	
6	$\mathcal{I}\{A_0^*(t)A_\perp(t)\}$		$\sqrt{2}\sin 2\theta_1\sin 2\theta_2\cos\chi$
	$\lvert A_0(0)\rvert\lvert A_\perp(0)\rvert$	$e^{-\Gamma_s t}\{\sin\delta_2\cos(\Delta M_s t)-$ $\cos\delta_2\sin(\Delta M_s t)\cos\phi_s\}-$ $\frac{1}{2}\left(e^{-\Gamma_H^{(s)}t}-e^{-\Gamma_L^{(s)}t}\right)\cos\delta_2\sin\phi_s$	

Decay time resolution

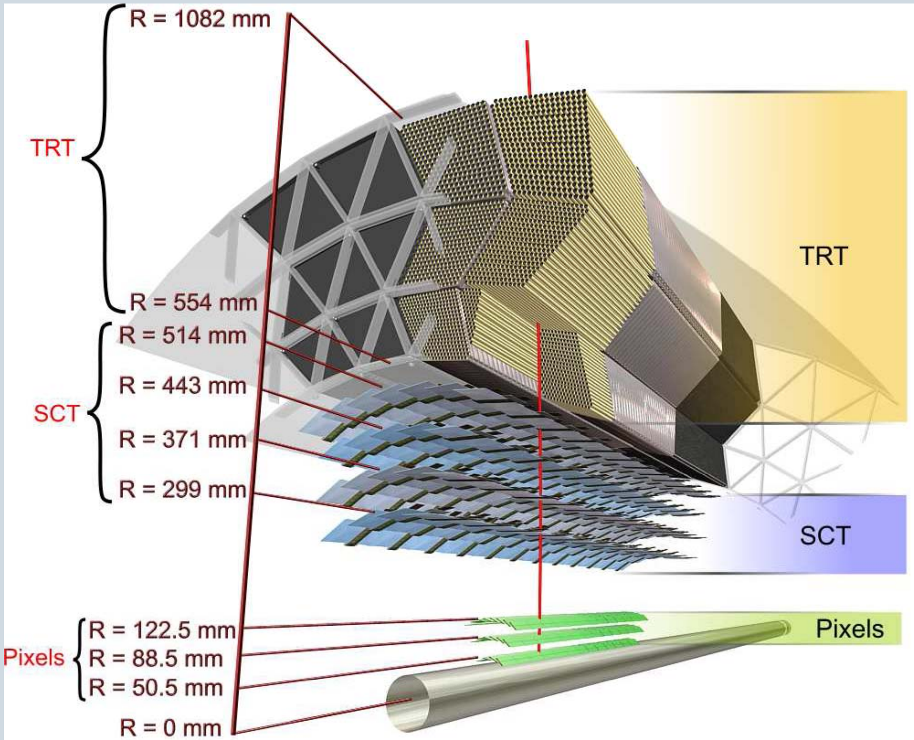
- Accuracy of lifetime measurement depends on finding secondary vertex where meson decays
- Granularity of detectors causes “smearing” in data
- Can extract this effect from data by performing fit to negative lifetime measurements





Misalignment in the Inner Detector

- Misalignment occurs where detector components are out of place in reconstruction
- Affects precision of secondary vertex measurement
- For early data misalignment in inner detector will not be well understood



- Reconstruction precision will improve with more data

How to account for systematic errors

- "Decay time resolution" term takes account of detector resolution effects
- Can we take account of other systematic effects in the same way?
- Maximum likelihood estimator takes single gaussian convolution

$$\mathcal{L} = \prod_{i=1}^{N} \frac{\left(\epsilon_1 W^+ (t', \Omega_i) + \epsilon_2 W^- (t', \Omega_i) + b e^{-\Gamma_0 t'}\right) \otimes \rho(t_i - t')}{\int_{t_{min}}^{\infty} \int_0^{2\pi} \left(\epsilon_1 W^+ (t', \Omega) + \epsilon_2 W^- (t', \Omega) + b e^{-\Gamma_0 t'}\right) \otimes \rho(t - t')\, d\Omega dt}$$

Probability distribution

1-(wrong tag)

Background

Systematic error effects

Fit to data

- Will reconstruct data with two misalignment sets
- Sets created by the Inner Detector Alignment Group as estimates of initial and final detector misalignments
- In accept-reject Monte Carlo studies, large convolution values sometimes caused fit to fail
- Extract convolution term from fit to misaligned data
- Current model uses single gaussian as convolution term – may try double gaussian

Future Work

- Over next few weeks will be running fit for data reconstructed for different detector misalignments
- Will determine whether this analysis method gives good results - particularly for early data