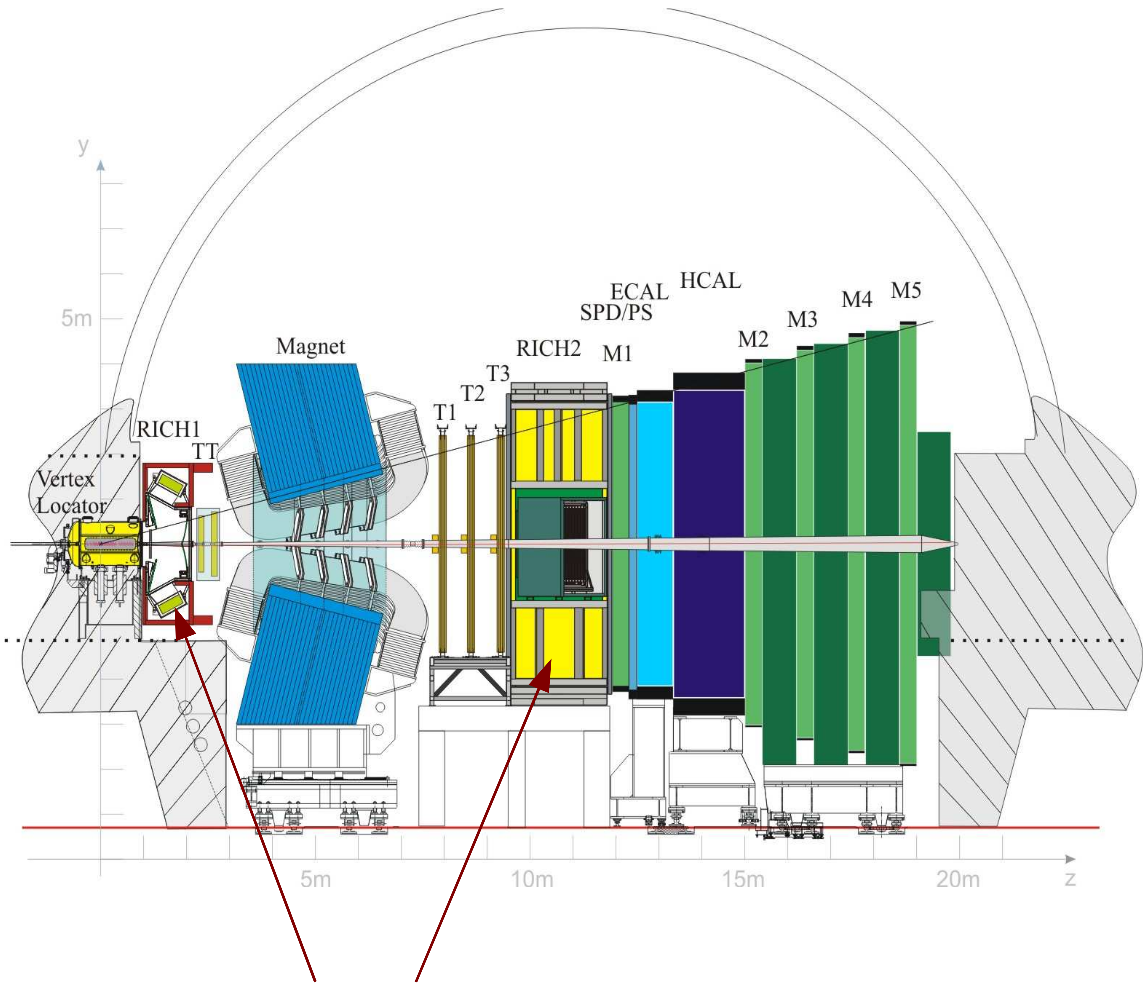
Reconstructing $B_s \rightarrow D_s^{-/+} K^{\pm}$ Decays with the LHCb experiment

James Lawrence
University of Edinburgh

Outline

- The LHCb Detector
- CP Violation
- Cut Optimisation
- Genetic Algorithms
- $B_s \rightarrow D_s K$ General Points
- $B_s \rightarrow D_s K$
- Conclusion

The LHCb Detector



The RICH Detectors

- Based at the LHC
- Online 2007
- Forward arm spectrometer
- p-p interactions – 40MHz

- ✓ Production of B_u, B_d, B_s, Λ_b...
- ✓ COM energy 14TeV
- ✓ Good X-section for bbar production – 10^5 events/sec
- ✓ Decay Length ~ 7mm

- ✗ Hadron environment
- ✗ Trigger Essential
- ✗ Excellent PID required

CP Violation and Bs Oscillation

Want to calculate rates for Bs decays to final state f

$$R_{B_s \to f} \quad \alpha \quad |<f|B_s>|^2 \quad ; \quad R_{\overline{B}_s \to f} \quad \alpha \quad |<f|\overline{B}_s>|^2$$

$$|<f|B_s>|^2 = \frac{|A_f|^2}{2} exp\{-\Gamma t\}\{I_+ + I_-\}$$

$$|<f|\overline{B}_s>|^2 = \frac{|A_f|^2}{2} |\frac{p}{q}|^2 exp\{-\Gamma t\}\{I_+ - I_-\}$$

Rates governed by oscillating terms in time

frequencies determined by

Δm_s - mass difference ~ 20ps^{-1}

$\Delta\Gamma$ - lifetime difference ~ 10%

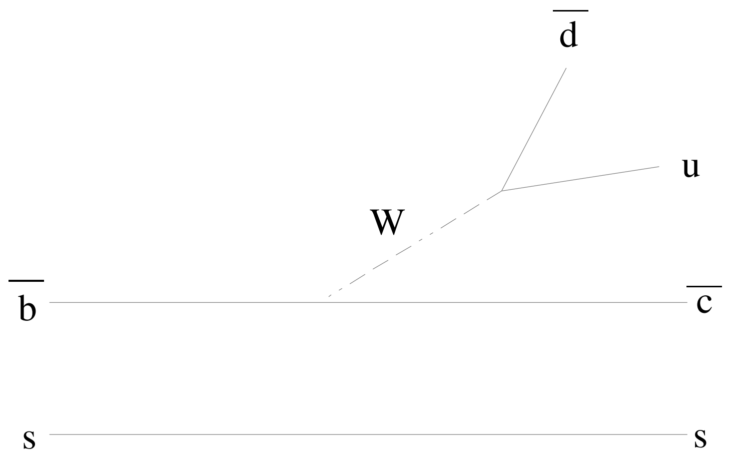
$$I_+ = (1 + |\lambda_f|^2) cosh(\frac{\Delta\Gamma}{2} t) + 2\Re\{\lambda_f\} sinh(\frac{\Delta\Gamma}{2} t)$$

$$I_- = (1 - |\lambda_f|^2) cos(\Delta m_s t) + 2\Im\{\lambda_f\} sin(\Delta m_s t)$$

$$\lambda_f = \frac{\overline{A}_f}{A_f}\frac{q}{p} \quad ; \quad \overline{\lambda}_f = \frac{A_f}{\overline{A}_f}\frac{p}{q}$$

$$\begin{pmatrix} A_f \\ \overline{A}_f \end{pmatrix} = <f| \begin{pmatrix} |B_s^0> \\ |\overline{B}_s^0> \end{pmatrix}_{(t=0)}$$

$B_s \rightarrow D_s^- \pi^+$



Only one diagram allowed: $\overline{A}_f = \lambda_f = 0$

$B_s \rightarrow D_s^- \pi^+$

Total Rate takes a simple form

$$R_{tot} = Cexp\{-\Gamma t\}cosh(\frac{\Delta\Gamma}{2}t)$$

→ Allows Measurement of Γ and $\Delta\Gamma$

Defining the flavour asymmetry vs time

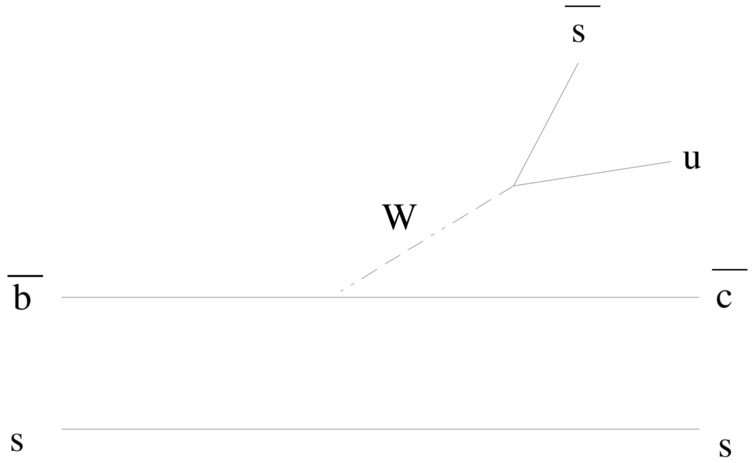
$$A_{CP}^{flav} = \frac{\Gamma_{\overline{B_s}\rightarrow f} - \Gamma_{B_s\rightarrow f}}{\Gamma_{\overline{B_s}\rightarrow f} + \Gamma_{B_s\rightarrow f}}$$

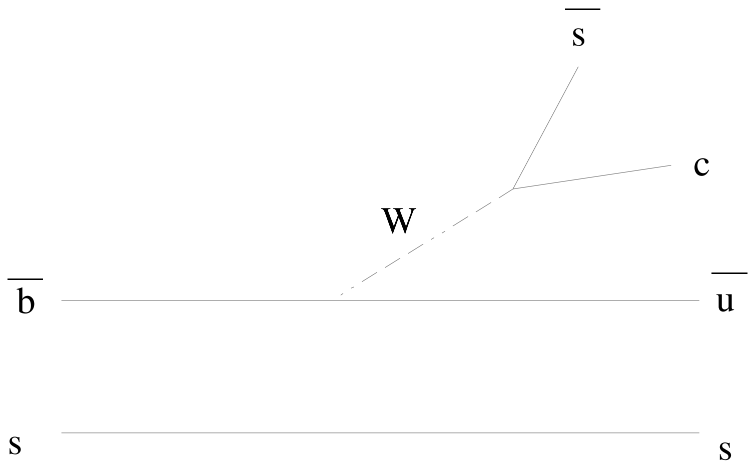
Greatly simplifies to

$$A_{CP}^{flav} = -D\frac{cos(\Delta m t)}{cosh(\frac{\Delta\Gamma}{2}t)}$$

→ Can now measure Δm_s

$B_s \rightarrow D_s^{-/+} K^{\pm}$





Both channels same order in λ $\quad A_f = \overline{A}_f$

We expect the following

$$\lambda_{(Ds^+K^-)} \propto \frac{V_{tb}^* V_{ts}}{V_{tb} V_{ts}^*} e^{i\Delta} \frac{V_{ub} V_{cs}^*}{V_{cb}^* V_{us}} \propto e^{-i\Delta} e^{-i(\gamma+\delta\gamma)}$$

$$\lambda_{(Ds^-K^+)} \propto \frac{V_{tb} V_{ts}^*}{V_{tb}^* V_{ts}} e^{i\Delta} \frac{V_{ub}^* V_{cs}}{V_{cb} V_{us}^*} \propto e^{-i\Delta} e^{i(\gamma+\delta\gamma)}$$

Which, when combined with other decays (eg $B_s \rightarrow J/\psi\phi$)

allows us to measure

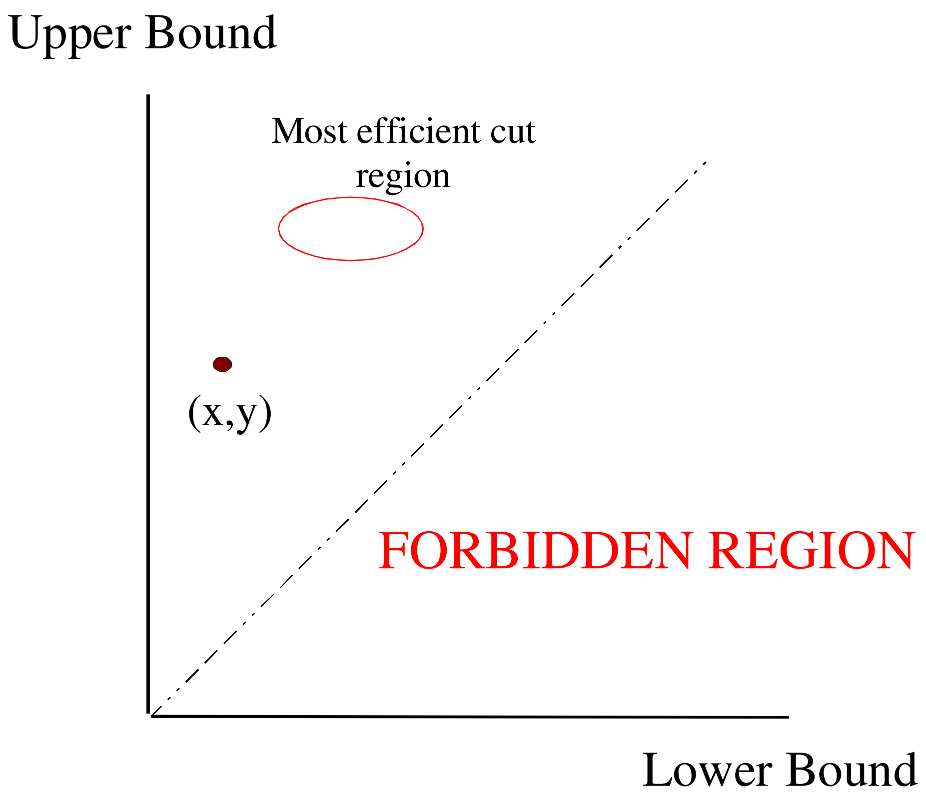
$$\gamma + \delta\gamma = \frac{1}{2}\left(arg\{\lambda_f\} - arg\{\overline{\lambda}_f\}\right)$$

$$\Delta = \frac{1}{2}\left(arg\{\lambda_f\} + arg\{\overline{\lambda}_f\}\right)$$

Expected sensitivity (1 year): ~14°

Cut Optimisation

Single Variable eg Momentum



· Point (x,y) represents a choice of upper and lower cut for a chosen variable

· Associated with this point is a "fitness", given by the standard definition

$$\frac{signal}{\sqrt{signal + background}}$$

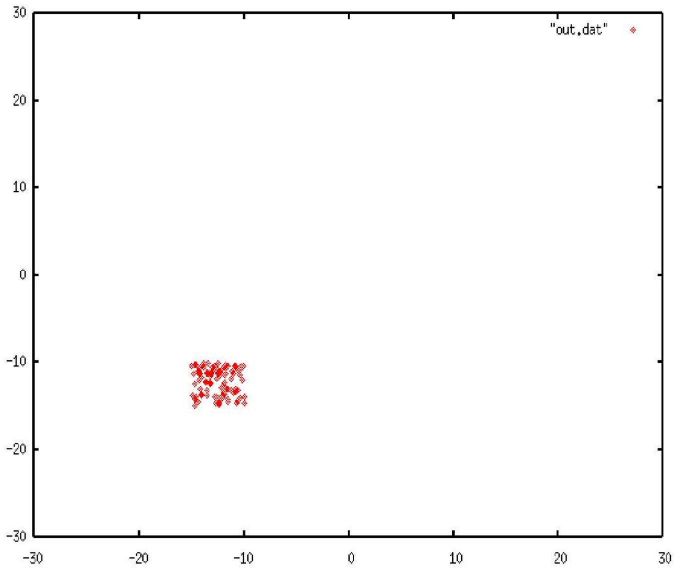
·Need a way of finding the optimum cut window

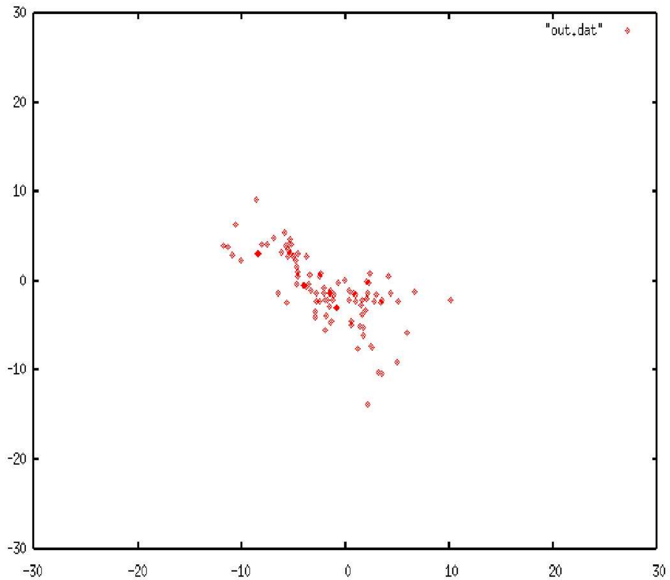
·Genetic Algorithm

·Can be used for all N variables simultaneously

·2N hyperspace takes into account correlations

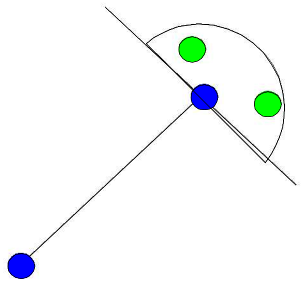
Genetic Algorithms





Methodology

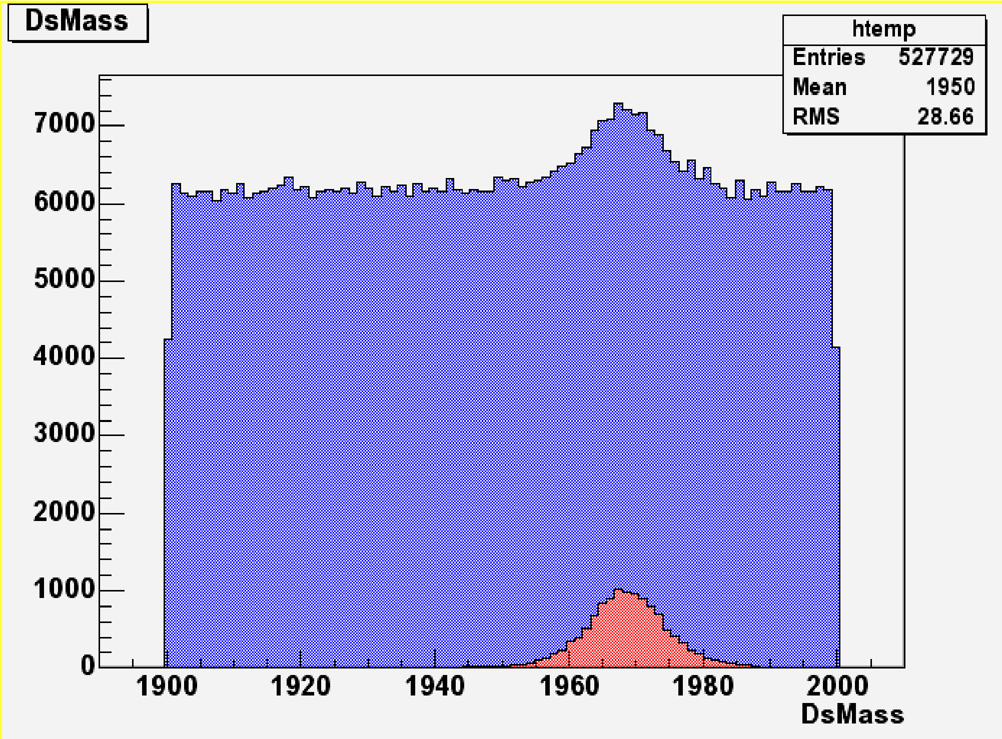
·Create a "population"
·Breed or Mutate



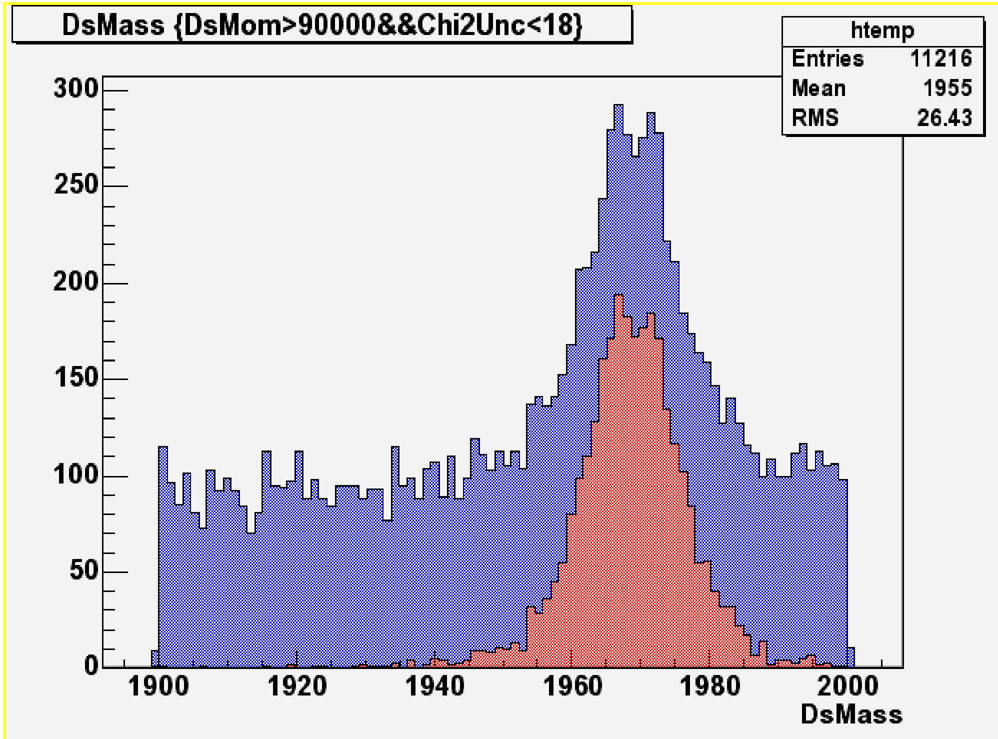
·Repeat 15 (or N) times
·Find best cut

$D_s^{\pm}$ Reconstruction

Before Optimisation



After Optimisation



Example: Ds Reconstruction
Population Size / Cut: 10
Number of Generations: 15
Number of Points sampled: 150
cf systematic scan of 50x50 points: 1250 points

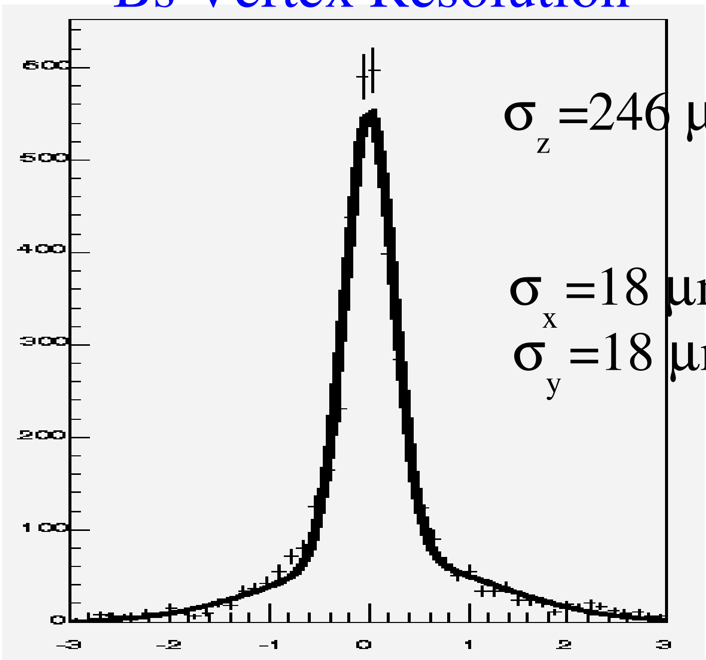
Final Cuts:

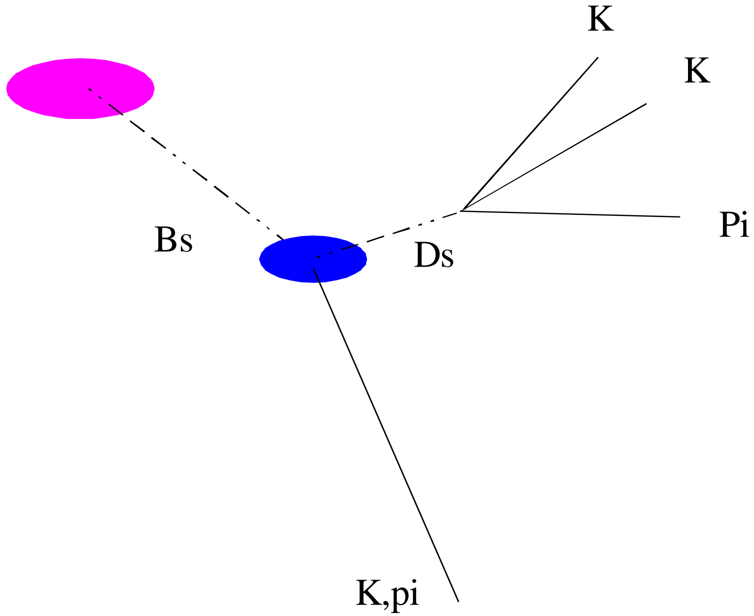
DsMom > 90GeV
Chi2 < 18

General Points

- Decay Topology is very similar
- Particle ID therefore very important
- One decay is the main background of the other
- DsPi has 15 time higher Branching Fraction than DsK

Bs Vertex Resolution





$B_s \rightarrow D_s^{-/+} K^{\pm}$

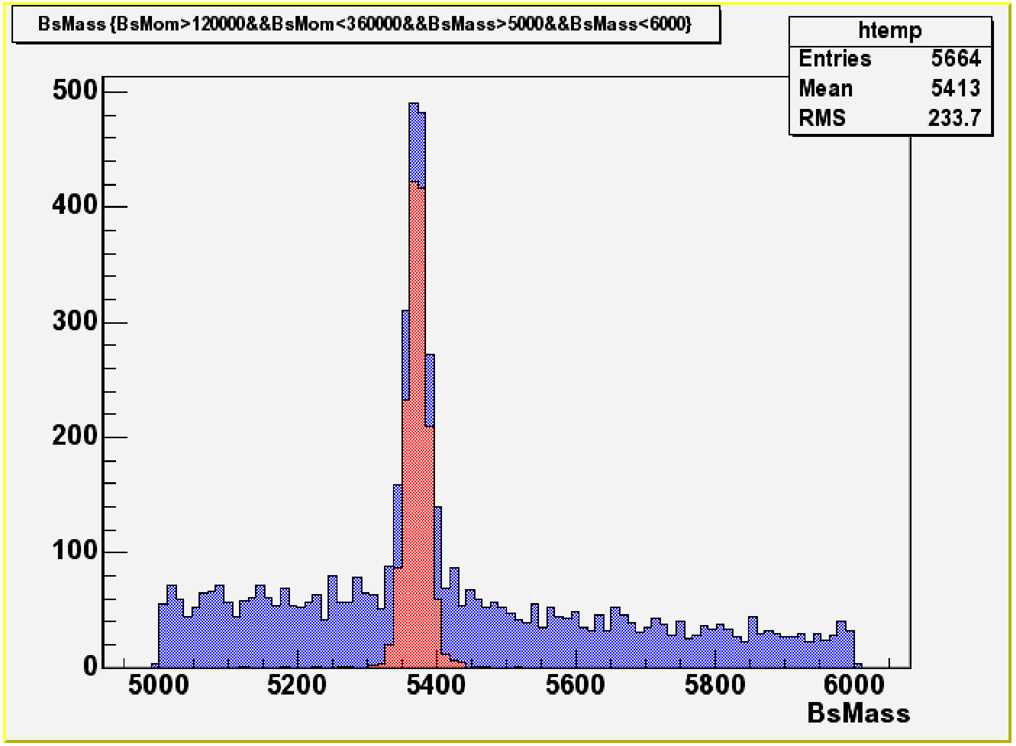
Cuts: D_s

Decay Dist < 600mm
Vertex Chi^2 < 18
Momentum > 90GeV

Cuts: B_s

2mm < Decay Dist < 20mm
Vertex Chi^2 < 100
120GeV < Momentum < 360GeV
IP(PV) < 3mm
σ(IP) < 5

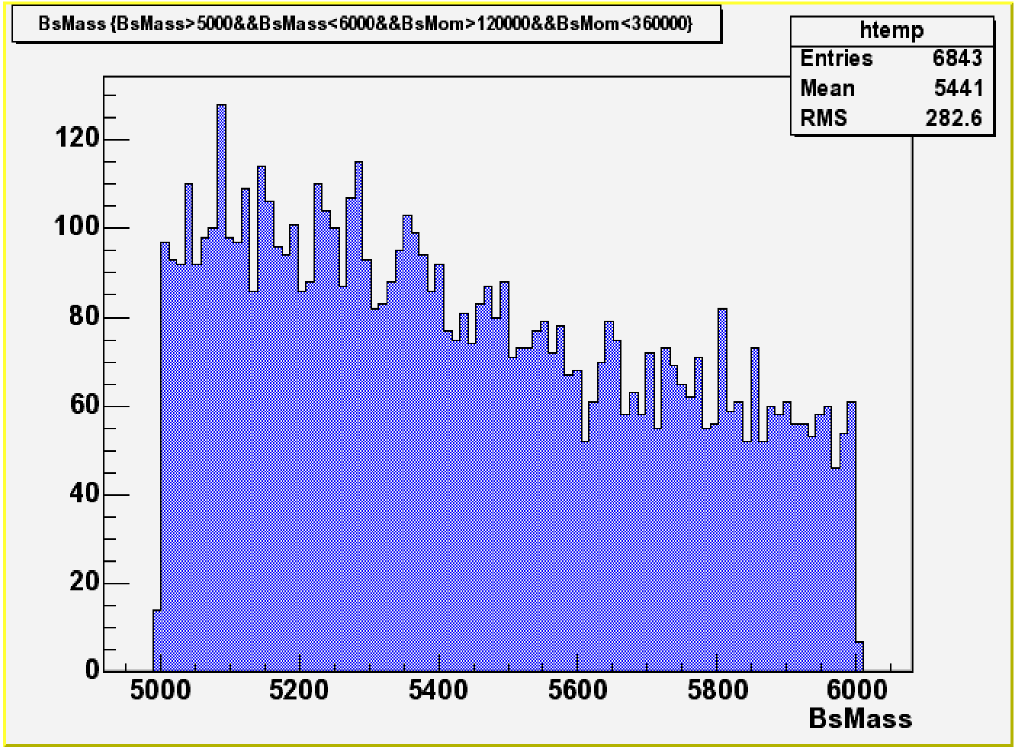
$B_s \rightarrow D_s^{-/+} K^{\pm}$



Number of events in this sample ~100k
Raw efficiency ~ 3%
However, only ~1200 events reconstructible
Efficiency ~ 24%

Compatible with early expectations
Doesn't take into account the Ds results – should allow for wider cuts
CAVEAT: Pre-bbar tuning!

$B_s \to D_s^{-/+} K^{\pm}$



Inclusive bbar 1M events
With Signal Cuts

Shows dangers of Genetic Algorithms

$$\frac{signal}{\sqrt{signal + background}}$$

Not an appropriate fitness function

Conclusion

·There is much potential in this channel to measure some valuable CP violation parameters

·LHCb is well suited for this task

·Work needs doing:

· Flavour Tagging

· Sensitivity Study

Back Up Slides

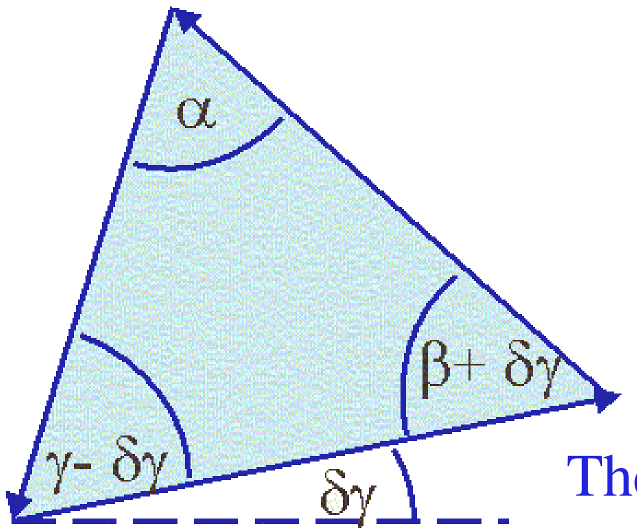
CP Violation and Bs Oscillation

A Unitarity Condition

$$V_{ts}V_{us}^* + V_{td}V_{ud}^* + V_{tb}V_{ub}^* = 0.$$

The CKM Matrix

$$V_{ckm} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$



The Unitarity Triangle