Λ_b Lifetime Measurement at DØ

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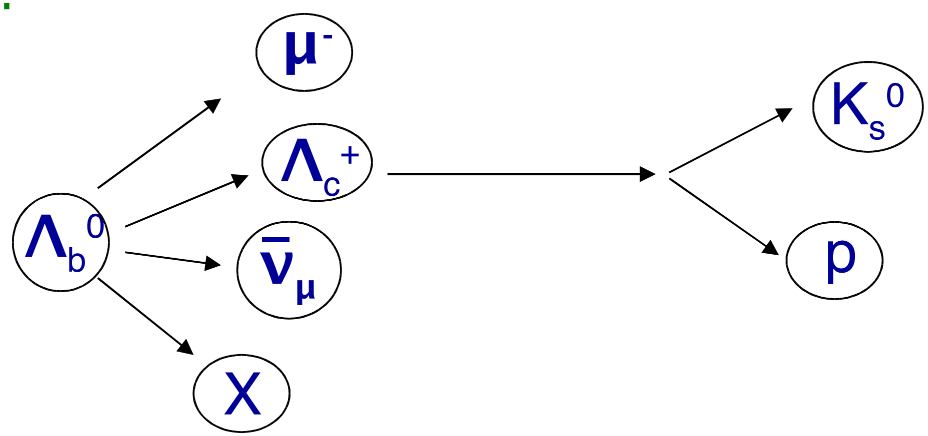
12 April 2006
IOP HEP Conference

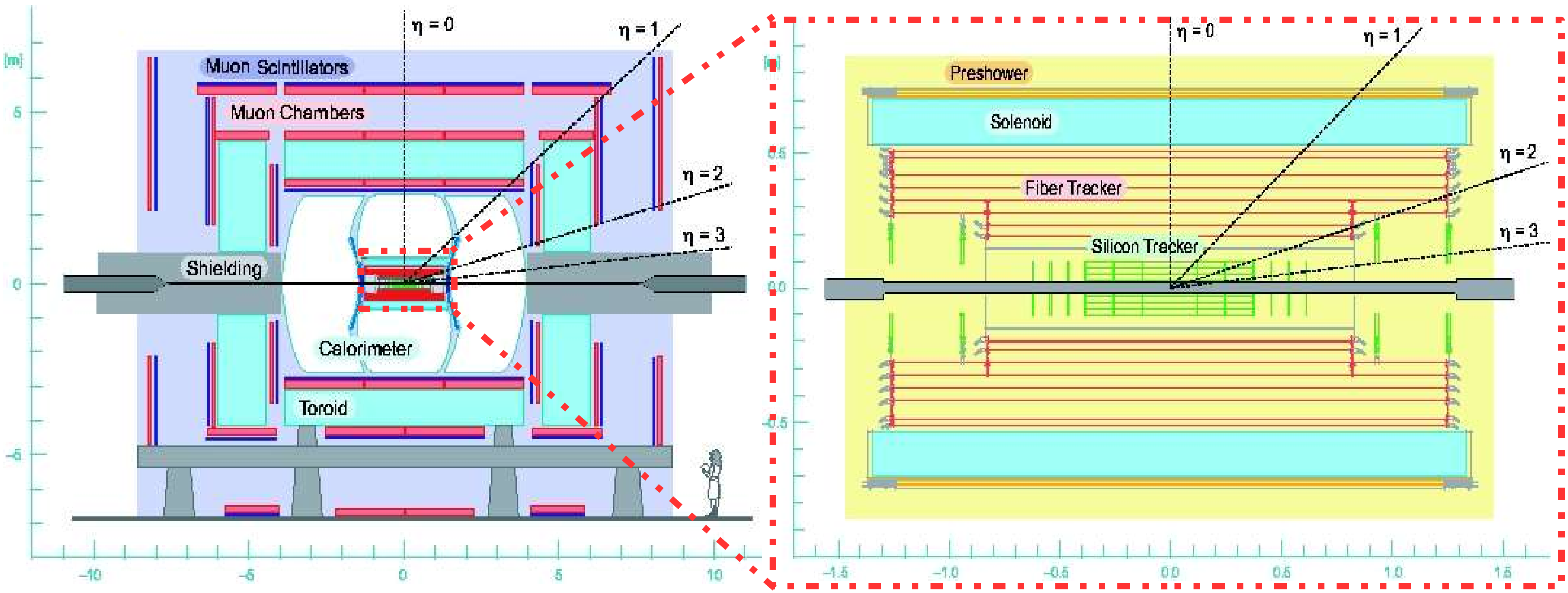
Introduction

- Pattern of lifetime differences between B hadrons predicted by Heavy Quark Expansion theory
- All B hadrons, including, B^+, B_d, B_s mesons and Λ_b baryons produced at the Tevatron – $\sqrt{s}$ =1.96TeV gives large boost which is good for lifetime studies
- Aim to select:



- High branching fractions compared to fully reconstructible decay but high background

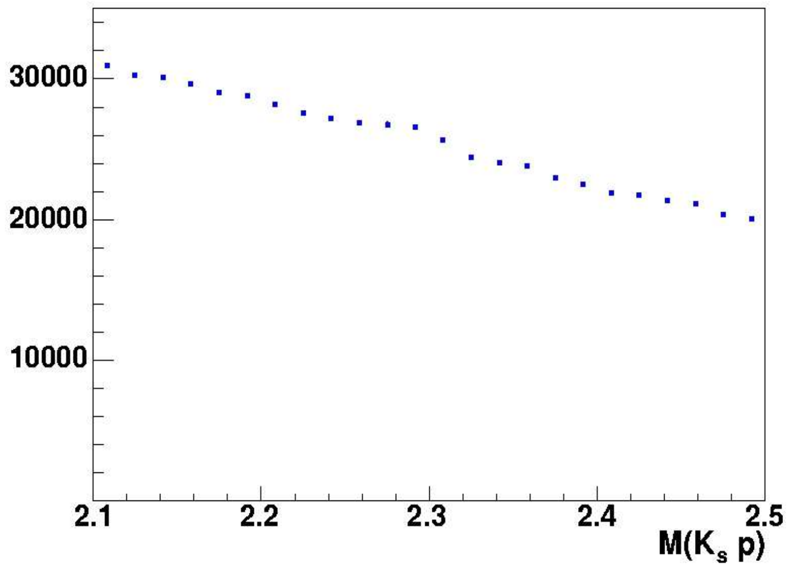
DØ Detector



- Tracking – Silicon microstrips and scintillating fibers in 2T magnetic field
- Muon system – drift tubes and scintillation trigger counters, good coverage out to η=2

Event Selection

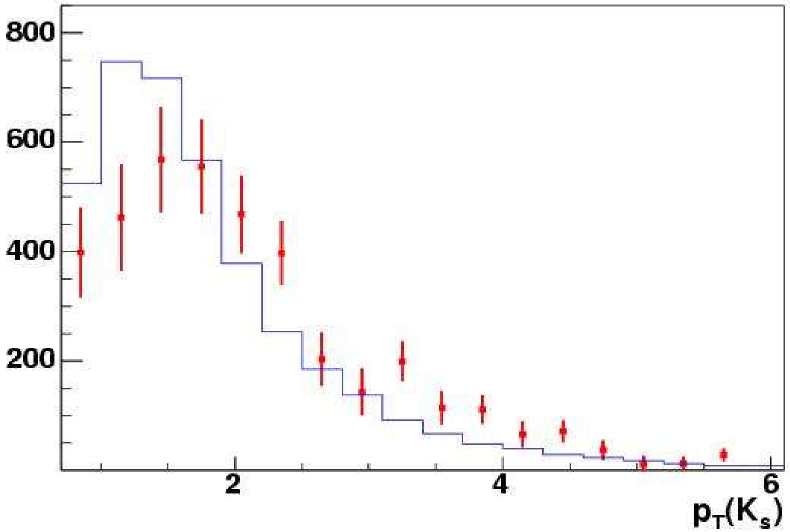
- $K_S \rightarrow \pi^+\pi^-$ decay, select a decay to two oppositely charged tracks with invariant mass within a window
- No particle ID so proton candidate is any other track which we can vertex with K_S
- Vertex Λ_c candidate with a muon with $p_T > 2.0$ GeV
- Much background to remove, but no lifetime biasing cuts allowed:
  - p_T of all decay products
  - χ^2 of Λ_b and Λ_c vertices
  - Decay length of Λ_c
  - Isolation of Λ_b



- No significant signal

Combined Likelihoods

- Therefore use a combined likelihood selection to improve signal significance:
  - Take a number of discriminating variables, x_i – eg $p_T(K_S)$
  - Estimate distribution of each for signal and background events
  - Parametrize ratios of probabilities y_i, to estimate the relative signal/background probability for a value of x_i
  - combine them to obtain a measure of how background like or signal like an event is based on several variables

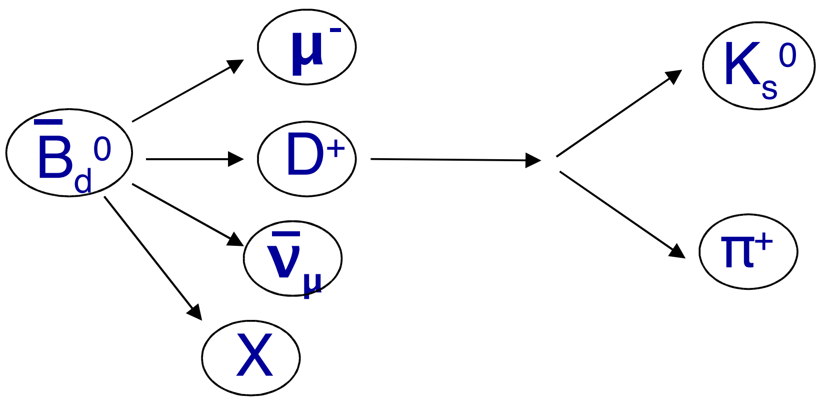


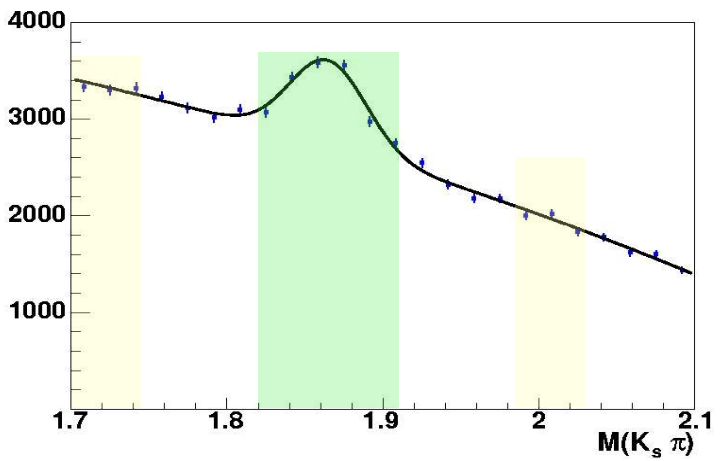
$$y_i = \frac{f_i^b(x_i)}{f_i^s(x_i)}$$

$$y = \prod_{i=1}^{n} y_i$$

Combined Likelihood Selection

- How to estimate distributions of the variables for signal?
- Using the same selections we also select the decay:

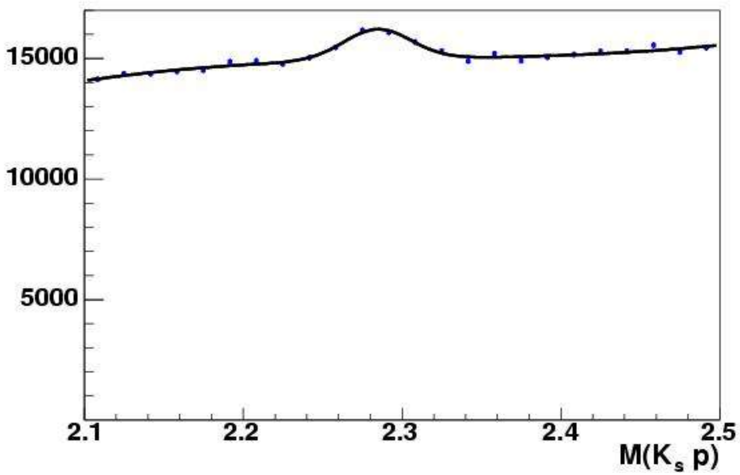




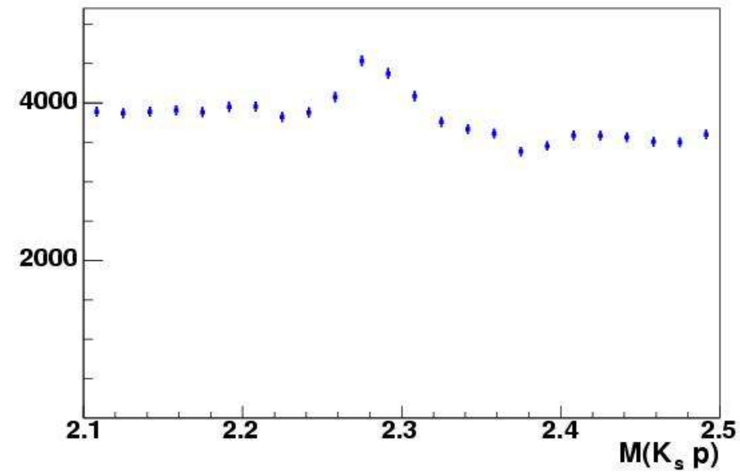
  - These events have similar kinematics to the signal
  - Use these to create PDFs for the signal and background for each variable
  - Define a signal region and two half width sidebands
  - PDF(signal) = PDF(signal band) – PDF(sidebands)

Final Selection

- Variables parametrized are:
  - isolation of B /Λ_b
  - $p_T(K_s^0)$
  - $p_T(\pi/\mathbf{p})$
  - $M(\boldsymbol{\mu}+D/\Lambda_c)$
  - $pT(D/\Lambda_c)$
- Select an optimal cut and we reduce background for the Λ_b decay to ~50%
- 4044 +/-339 signal events from ~1 fb^{-1}

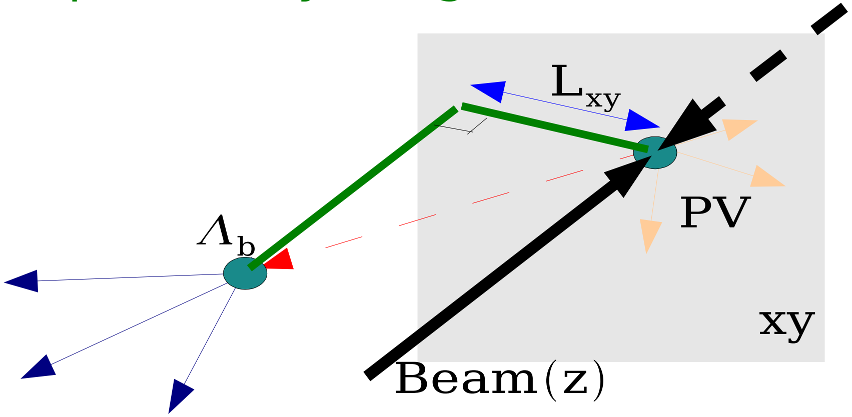


Visible Proper Decay length >0.02cm:



Lifetime Measurment

- Measure the transverse decay length L_{xy} and calculate the Visible Proper Decay Length λ:

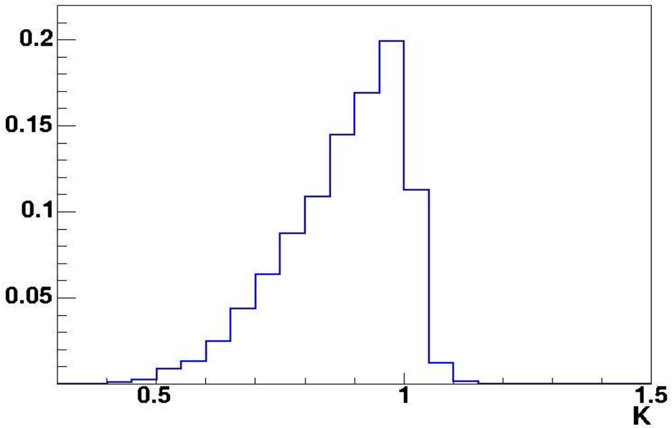


$$\lambda = L_{xy} \frac{M}{p_T(\Lambda_c \mu)} = \frac{c\tau(\Lambda_b)}{K}$$

- We don't fully reconstruct the Λ_b so we have to include the K factor:

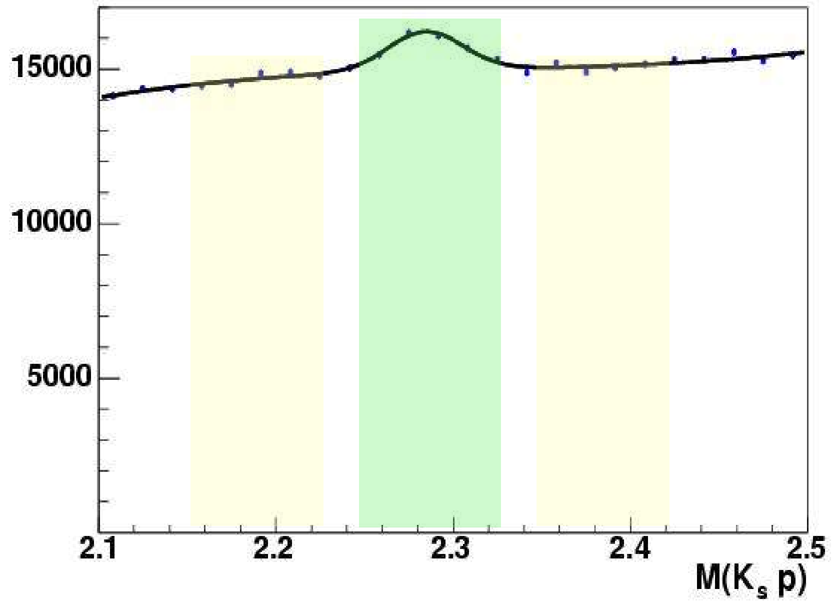
$$K = \frac{p_T(\Lambda_c \mu)}{p_T(\Lambda_b)}$$

- Distribution of K factors from signal Monte Carlo:



Lifetime Fitting

- Select a region containing the signal and 2 sidebands
- The background in the sidebands is assumed to model the background under the signal peak



- Define a lifetime PDF for the background, and a PDF for the signal then fit both samples simultaneously
- Use an unbinned maximum likelihood fit and extract the mean Λ_b lifetime and the other fitted parameters

Lifetime Likelihood

- The fit maximises the following likelihood:

$$L = C_{sig} \prod_{i=1}^{N_s} \left[f_s F_{sig}(\lambda, \sigma_\lambda) + (1 - f_s) F_{BG}(\lambda, \sigma_\lambda) \right] \prod_{j=1}^{N_B} F_{BG}(\lambda, \sigma_\lambda)$$

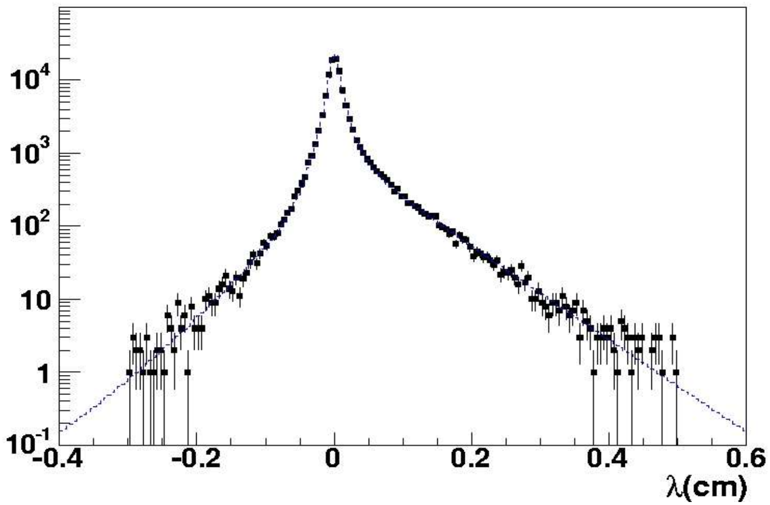
Signal sample Sidebands

- f_s is the fraction of signal in the signal sample – a free parameter estimated from the mass fit
- F_{sig} is our signal lifetime distribution
- F_{bg} is the background lifetime distribution
- C_{sig} is the PDF for the signal fraction f_s – a gaussian

Lifetime PDFs

- The PDF for the background lifetime is a Gaussian resolution + 4 exponentials

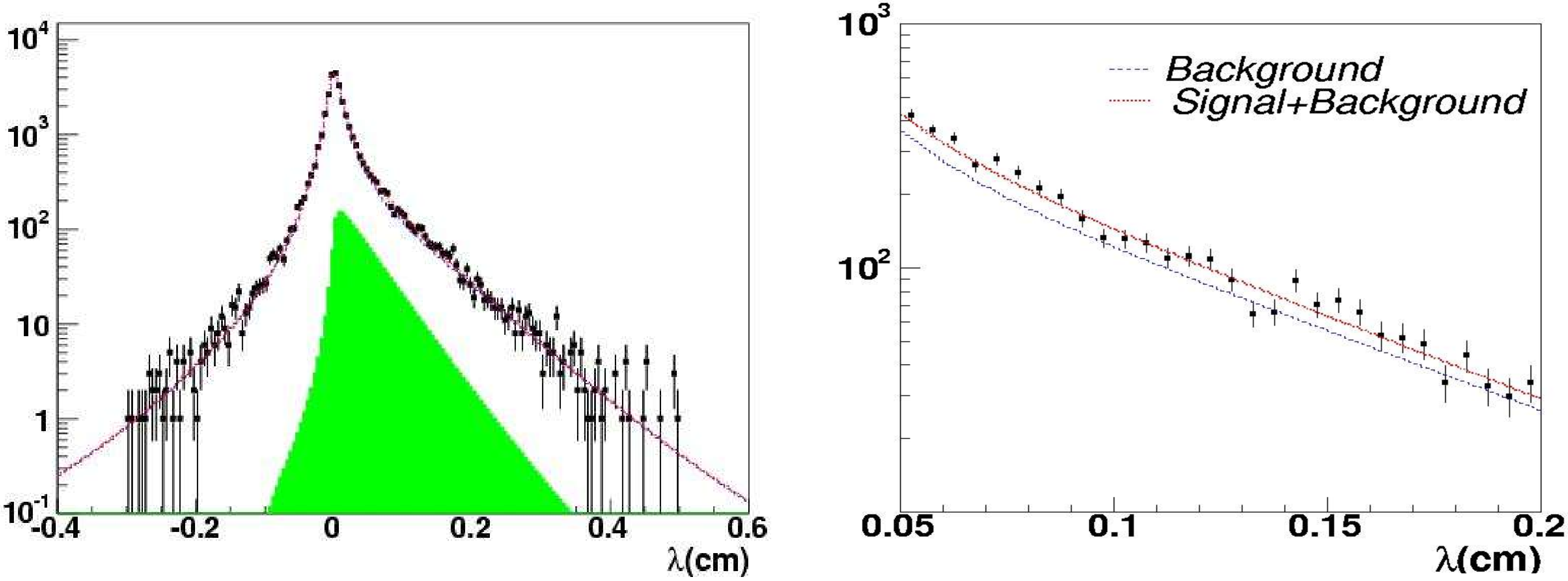
- Signal lifetime PDF is exponential decay convoluted with a Gaussian resolution function and integrated over K factors



$$S_L(\lambda_j,\sigma_j,s)=(1-f_{c\bar{c}})\int d(K)H(K)\left[\frac{K}{c\tau(\Lambda_b)}e^{-K\lambda_j/c\tau(\Lambda_b)}\otimes R_1(\lambda_j,\sigma_j,s)\right]+f_{c\bar{c}}G(\lambda_j)$$

- The last term is for the background of Λ_c produced at primary vertex and vertexed with a muon
  - Modelled with a gaussian

Lifetime Fit



- Fitting procedure still has to be finalised
- Expect to have a very competitive statistical precision
- Background modelling expected to be the largest systematic error

Summary

- Successfully reduced large background and obtained a significant signal
- Our Λ_b sample is much larger than any previous measurement
- Expect a high statistical precision lifetime measurement
- Working on finalising the lifetime fitting procedure
- Systematics to study, eg:
  - Background lifetime modelling
  - Detector alignment
  - Charm background
  - K factor distribution