Lifetimes

B_s->J/ψ ϕ Λ_B->J/ψ Λ_0

B_d->J/ψ K* B^0->J/ψ K_s

at DØ

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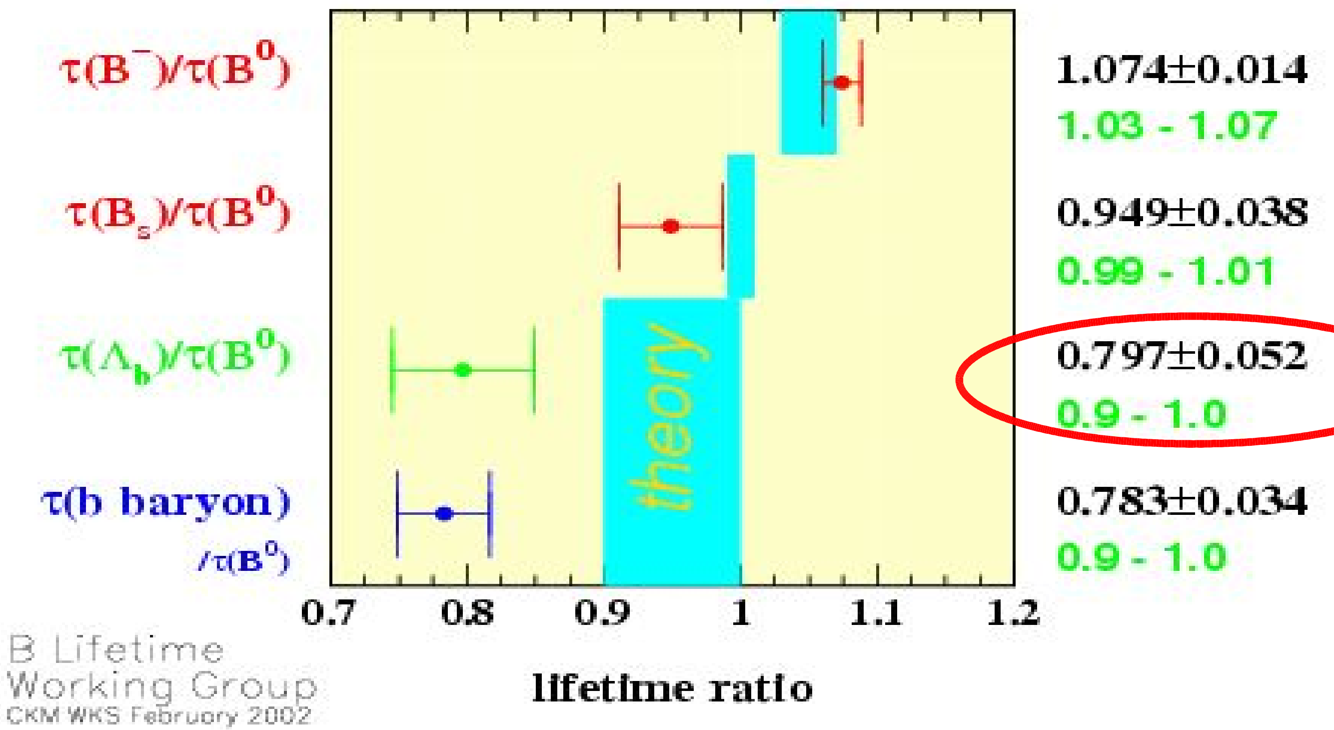
CINVESTAV-MEXICO

Outline

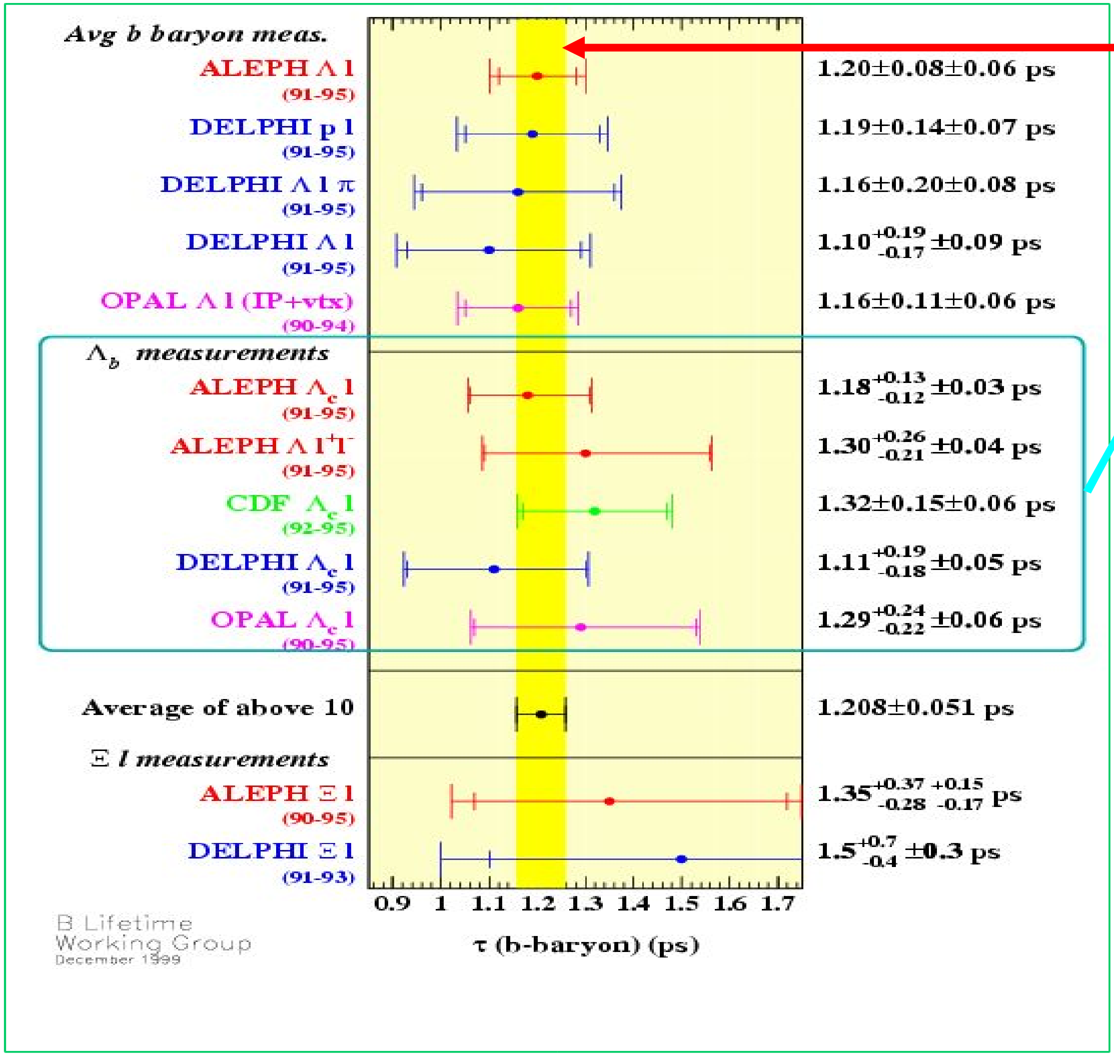
- Motivations
- Topology
- Data
- Cuts
- Fitting technique
- Systematics
- Crosschecks

Motivations:

b-baryon discrepancy:



Motivations: Current measurements:



Average b-baryon lifetime

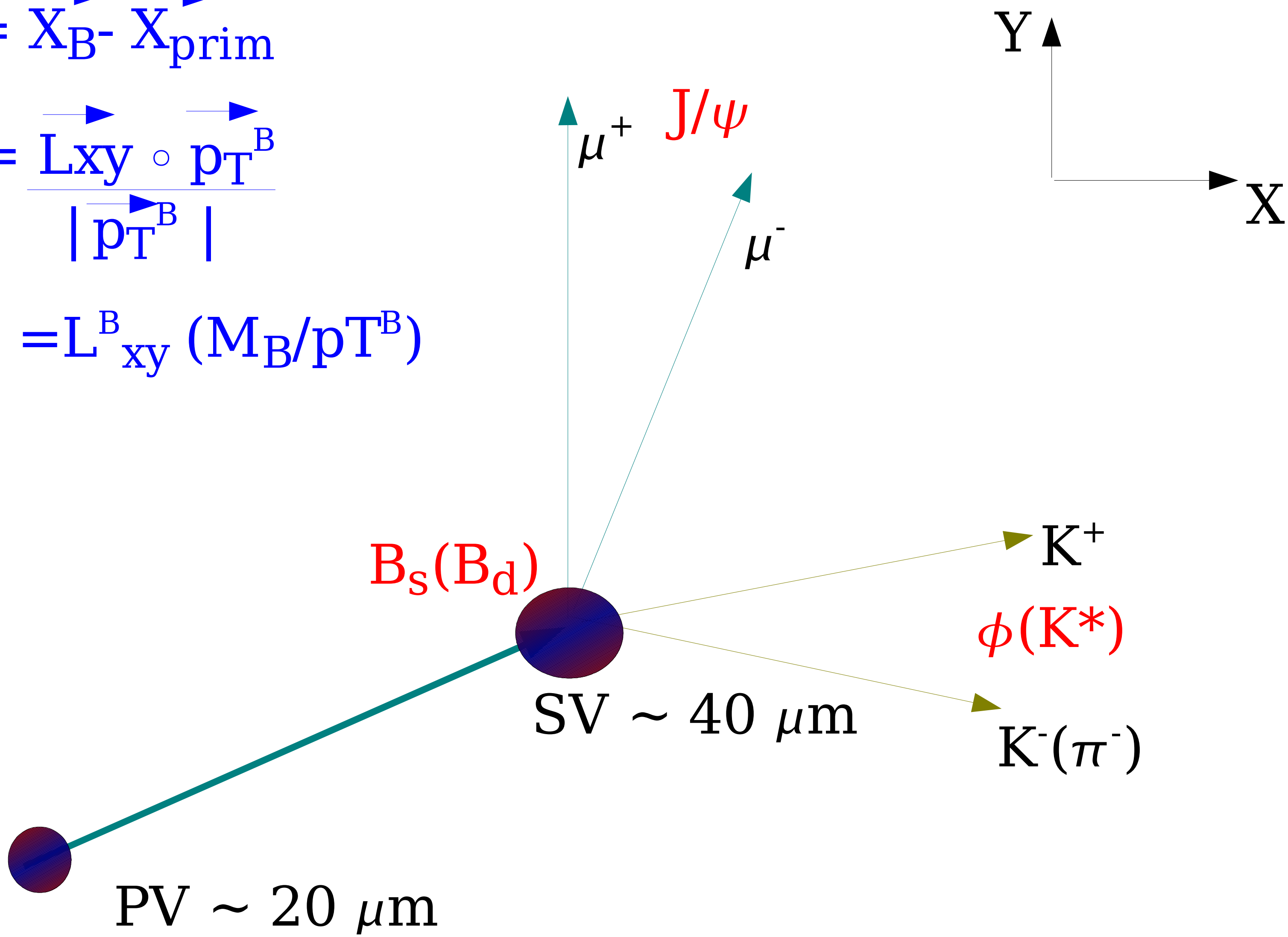
All measurements performed in semileptonic decays (No fully reconstructed)

4 track Vertex Topology

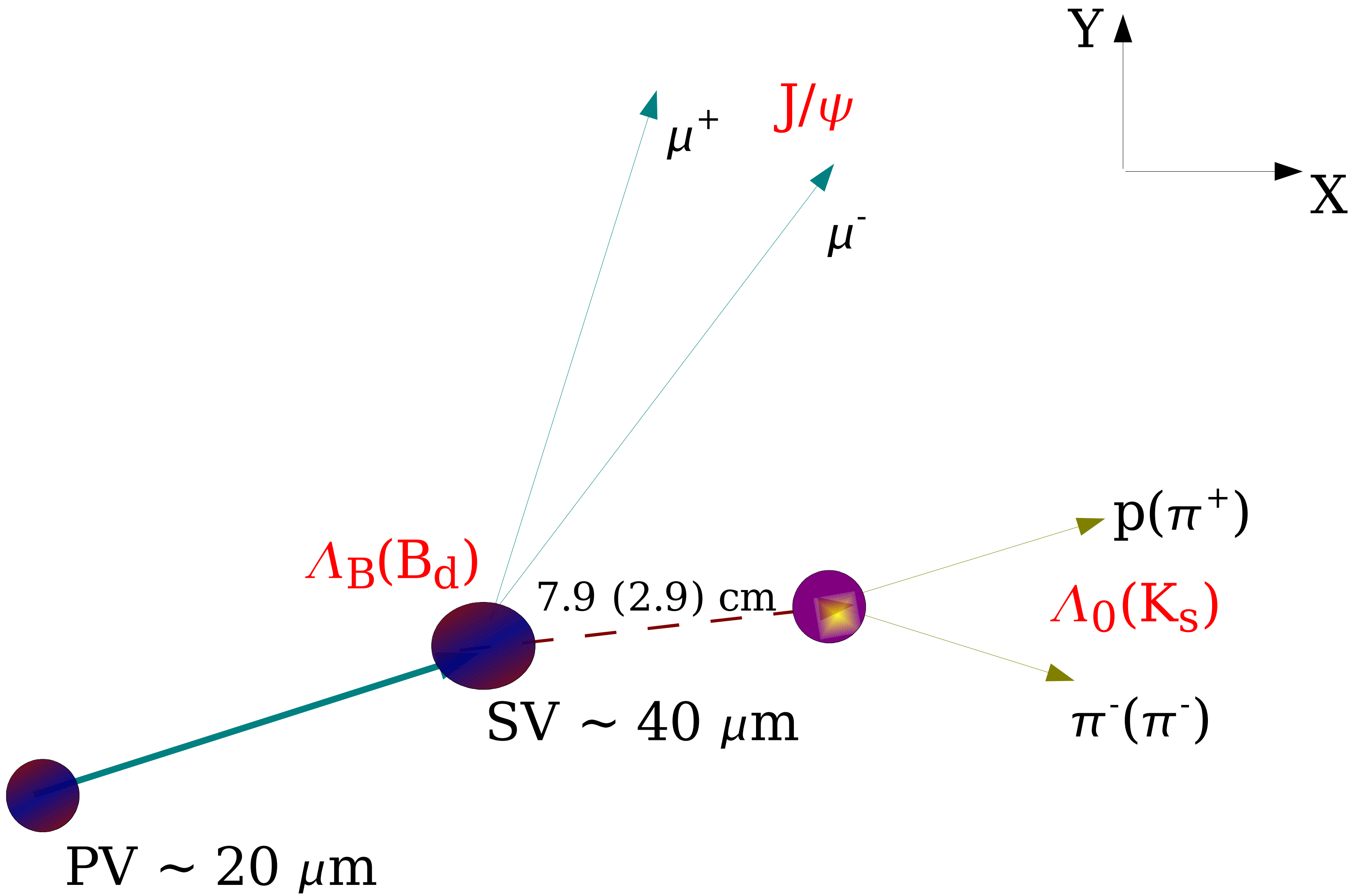
$$\vec{L}_{xy} = \vec{X}_B - \vec{X}_{prim}$$

$$L^B_{xy} = \frac{\vec{L}_{xy} \circ \vec{p}_T^{\,B}}{|\vec{p}_T^{\,B}|}$$

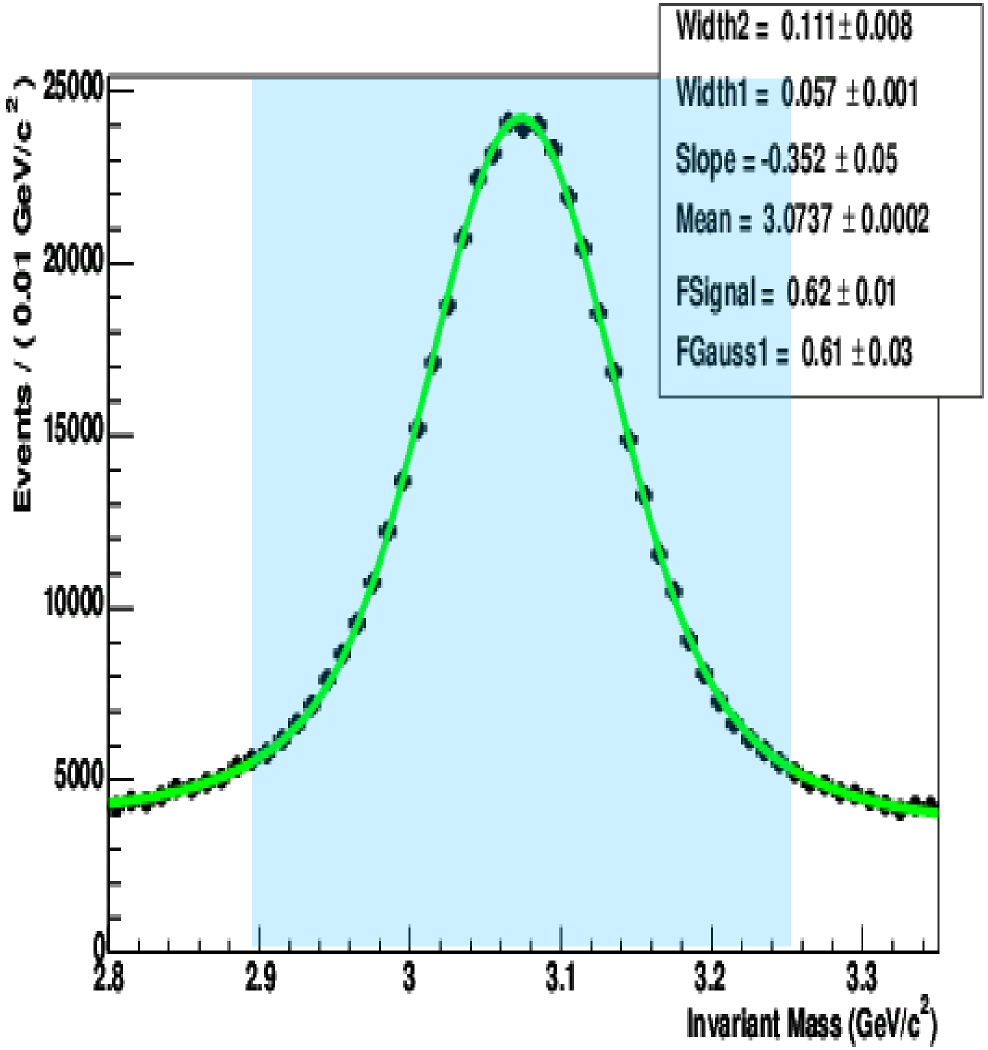
$$c\tau_B = \lambda_B = L^B_{xy}\,(M_B/pT^B)$$



3 track Vertex Topology



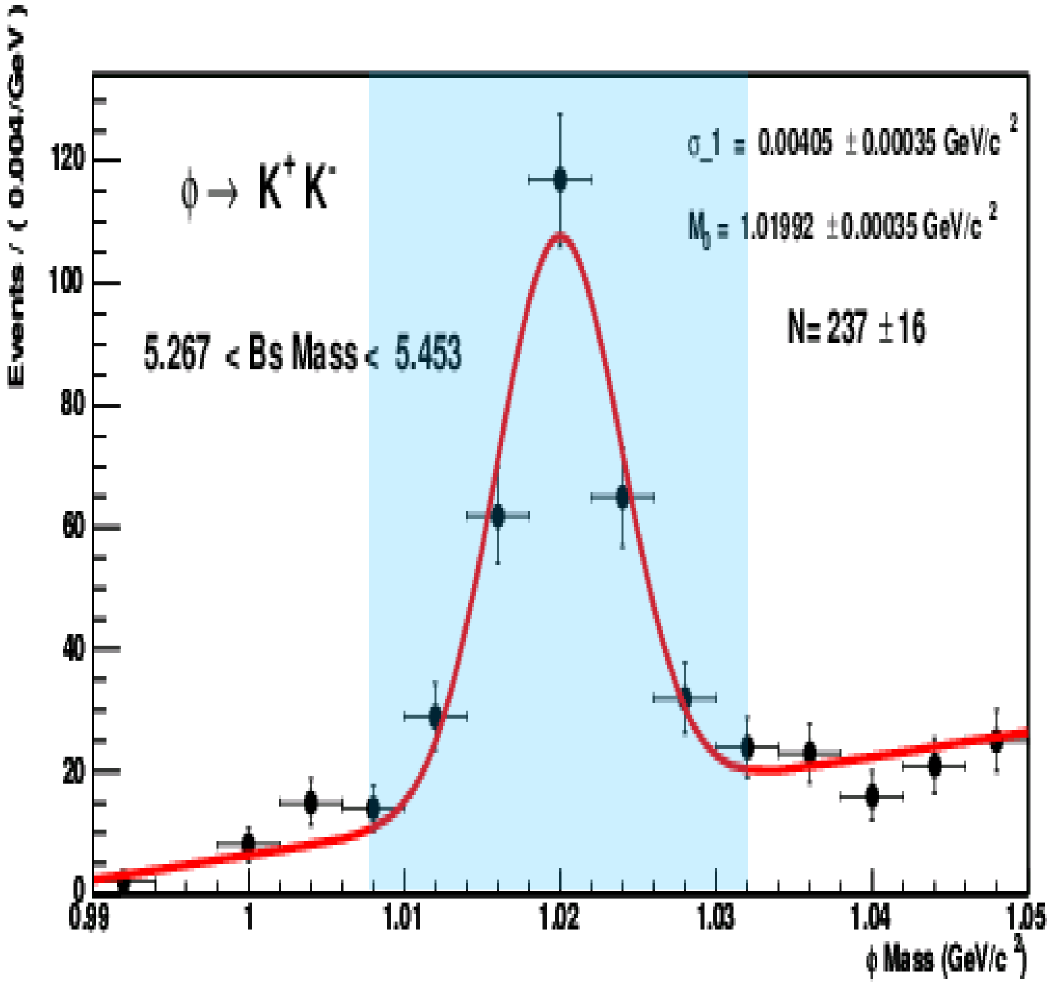
$J/\psi \rightarrow \mu^+\mu^-$



J/ψ cuts

- J/ψ mass [2.9,3.25] GeV
- Smt hits in muon >1
- Distance from PV to J/psi vertex <10 cm
- Al least one PV reconstructed
- Track measurements downstream (<1) to the vertex and misses upstream (<5)

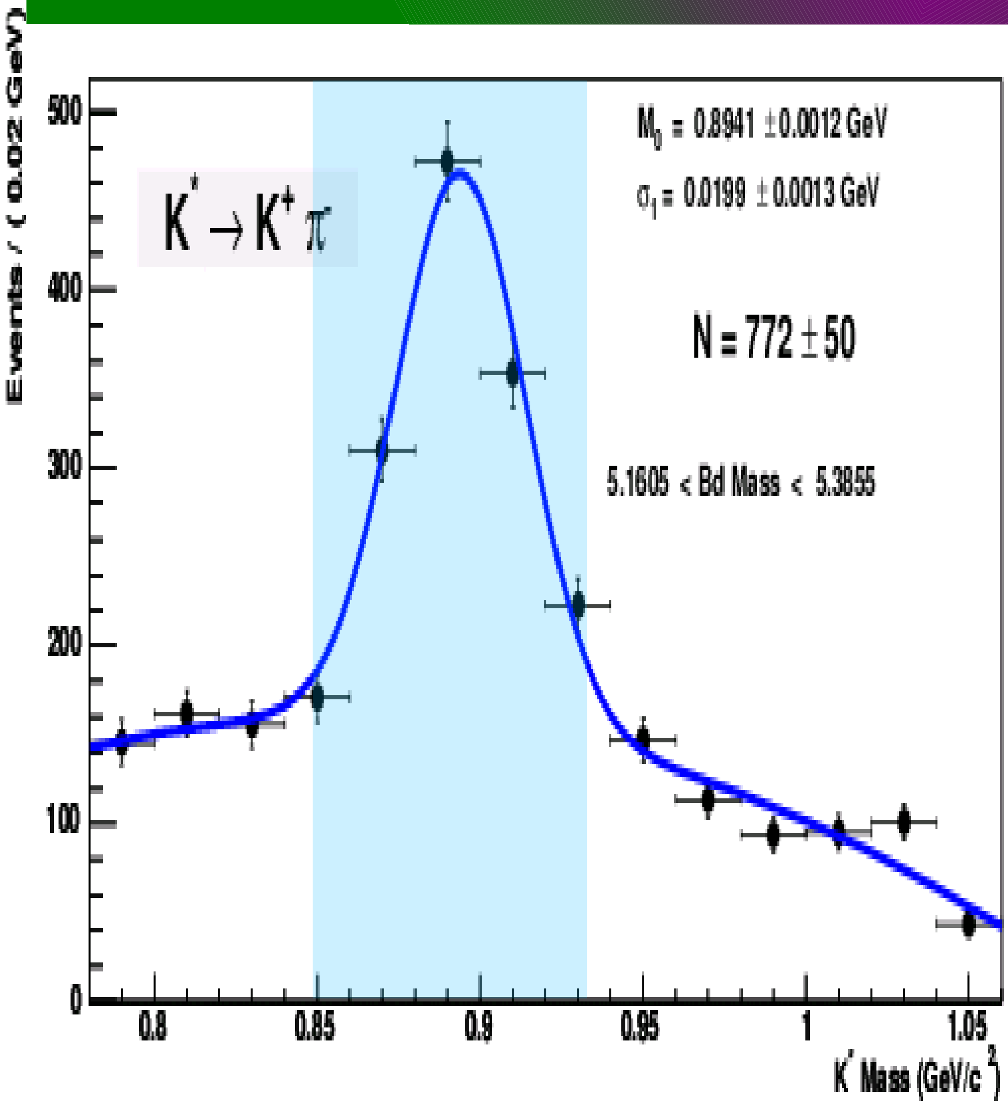
$\phi \rightarrow K^+K^-$



ϕ cuts

- Mass windows [1.008,1.032] GeV,
- 2 opposite charge tracks that make a vertex of 4 tracks with the Jpsi vertex
- SMT hits > 0 for each track

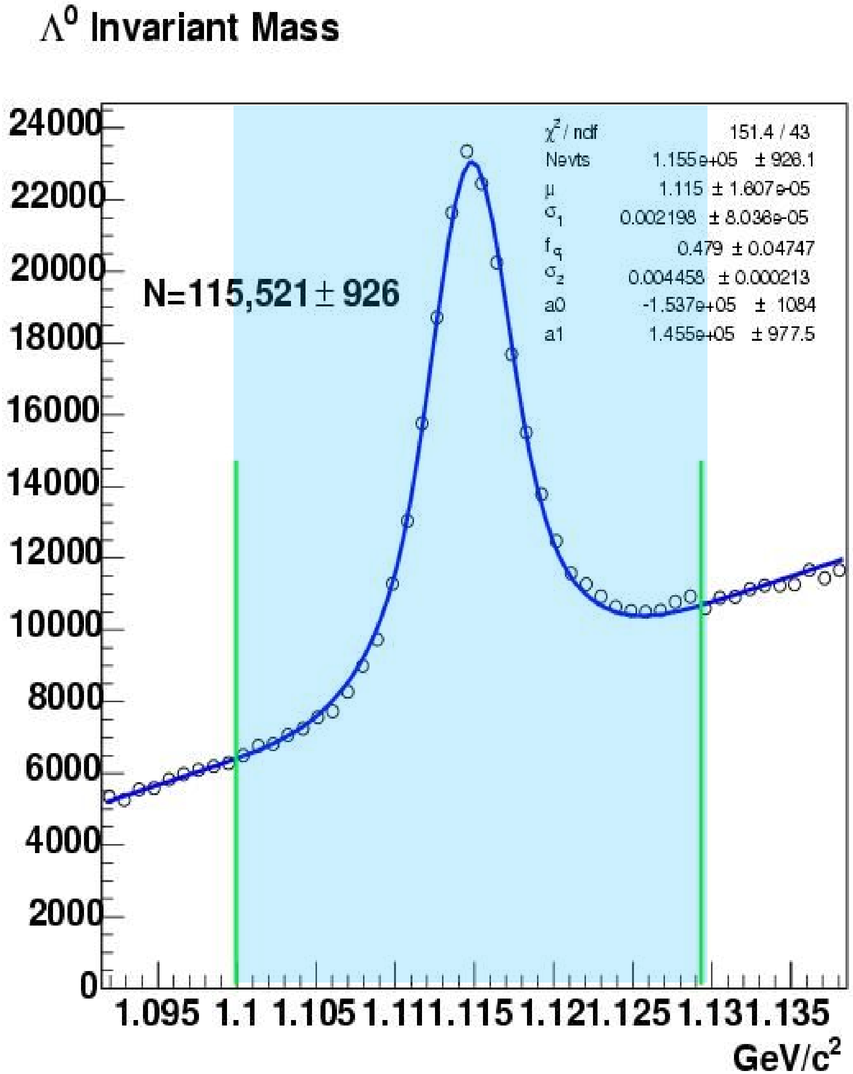
$K^* \to K^+ \pi^-$



K* cuts

- Mass windows (0.85,0.93) GeV
- 2 opposite charge tracks that make a vertex of 4 tracks with the Jpsi vertex
- SMT hits > 0 for each track

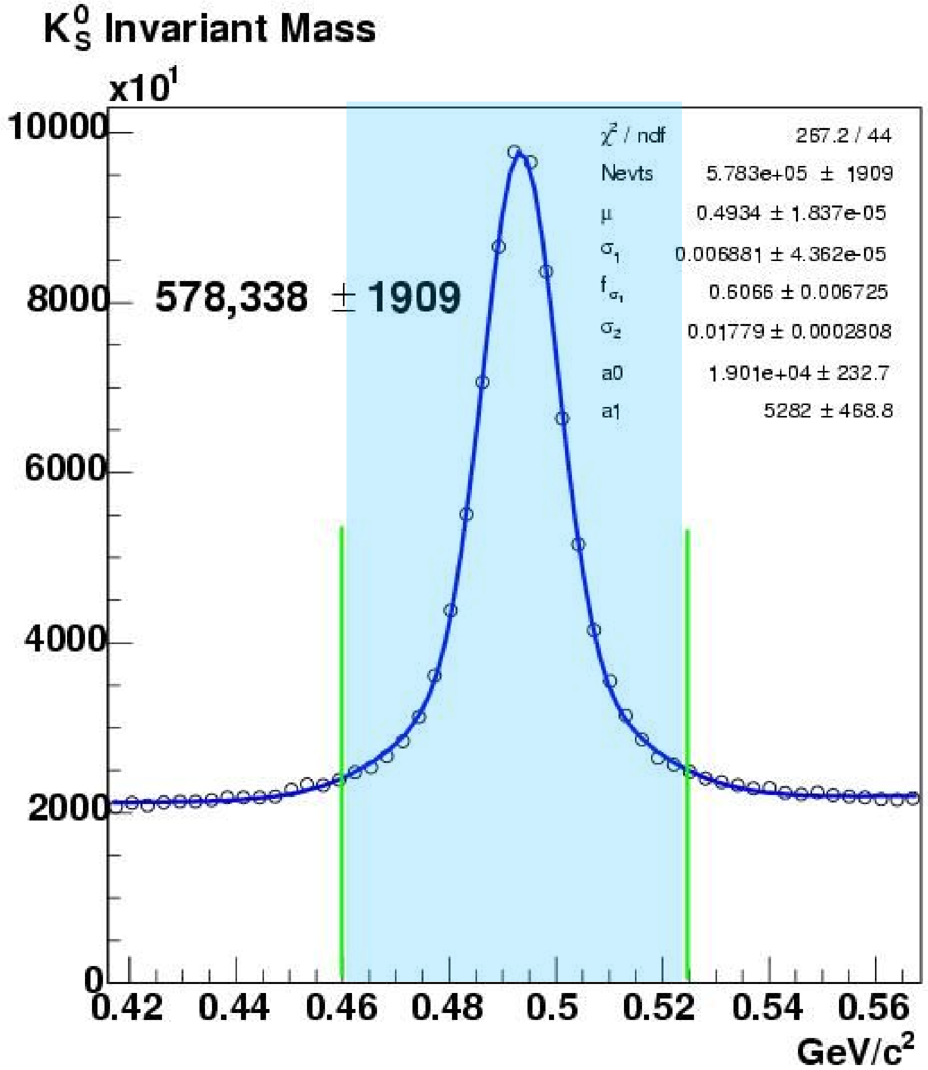
$\Lambda \rightarrow K^{+}\pi^{-}$



cuts

- Mass windows (0.85,0.93) GeV
- 2 opposite charge tracks that make a vertex of 4 tracks with the Jpsi vertex
- SMT hits > 0 for each track

$K_S \to \pi^- \pi^+$



K_S **cuts**

- Mass windows (0.85,0.93) GeV
- 2 opposite charge tracks that make a vertex of 4 tracks with the Jpsi vertex
- SMT hits > 0 for each track

PDF models:

- Mass Model:
  - S_M : Gaussian
  - B_M : First(Second)-order polynomial background
- Resolution Model
  - Gaussian using event-per-event lifetime error & “s” scale factor

$$Res(\lambda_j, \sigma_j) = \frac{1}{\sqrt{2\pi s \sigma_j}} e^{\lambda_j^2/2(s\sigma_j)^2}$$

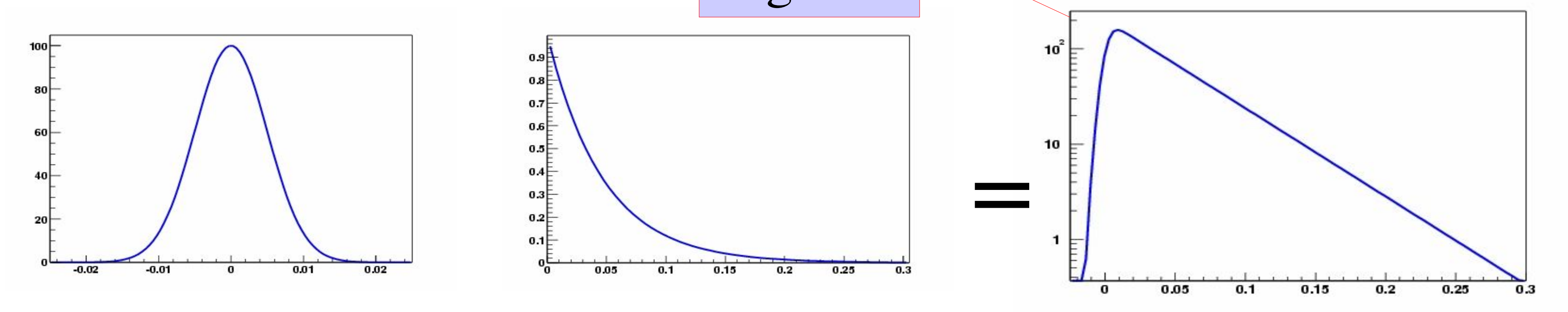
PDF models:

- Lifetime models
  - S_{LF} : Signal lifetime PDF
    - Convolution(Exponential decay, Resolution)
  - B_{LF} : Background lifetime PDF
    - Resolution + negative exp. decay + 2 positive exp. decays
- 2Dim PDF:

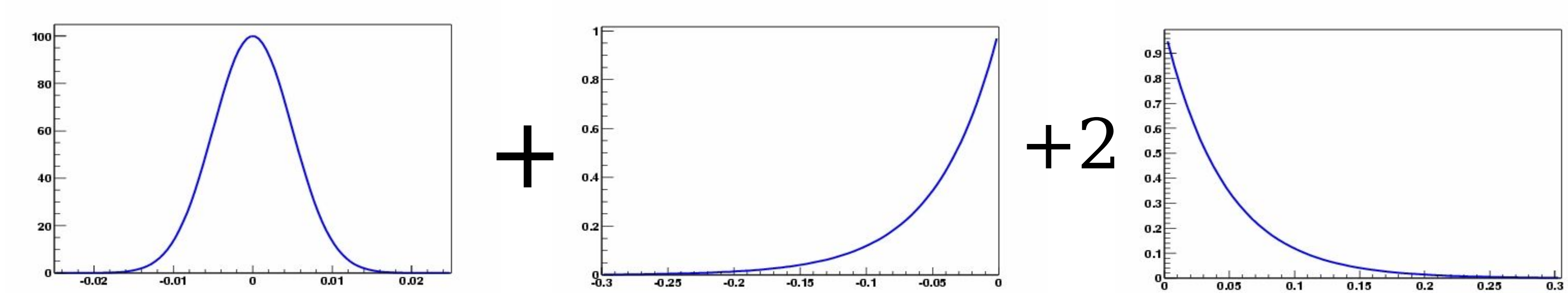
$$L = f_s S_M(M_j) S_{LF}(\lambda_j, \sigma_j) + (1 - f_s) B_M(M_j) B_{LF}(\lambda_j, \sigma_j)$$

Lifetime distribution models

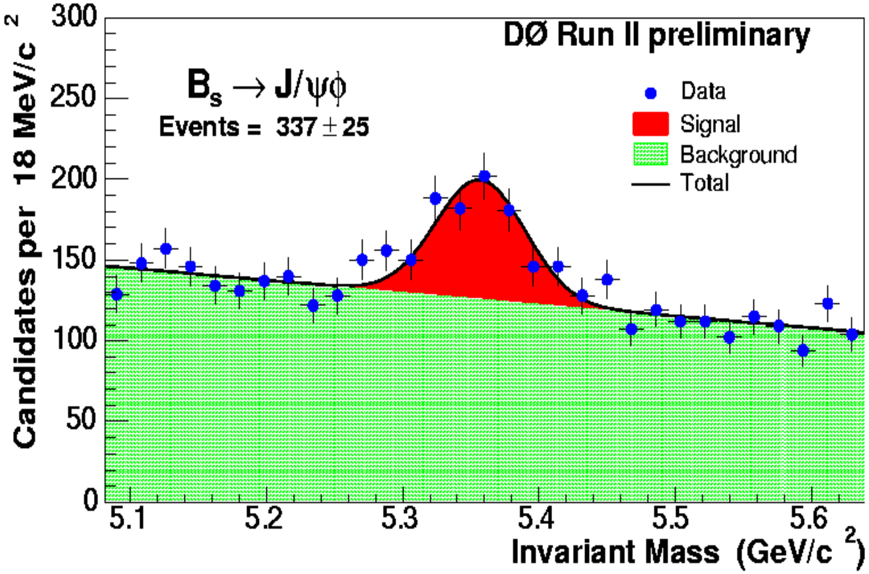
Log scale



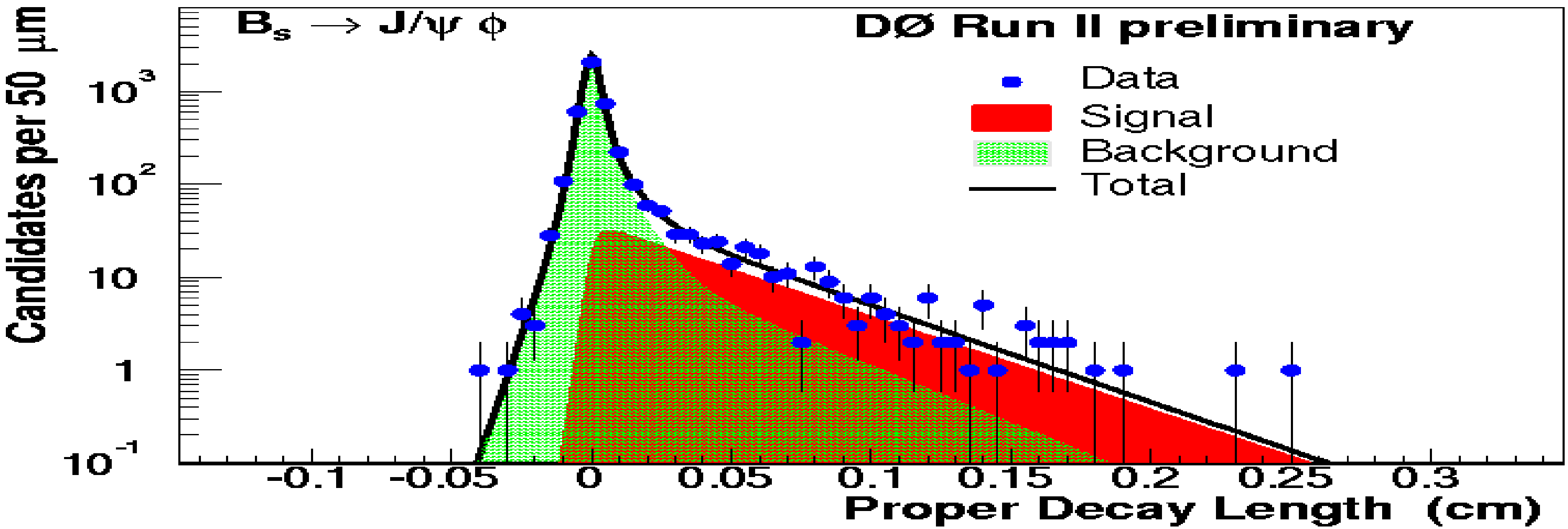
An exponential decay convoluted with a gaussian (Resolution) is used for the b hadron lifetime distribution

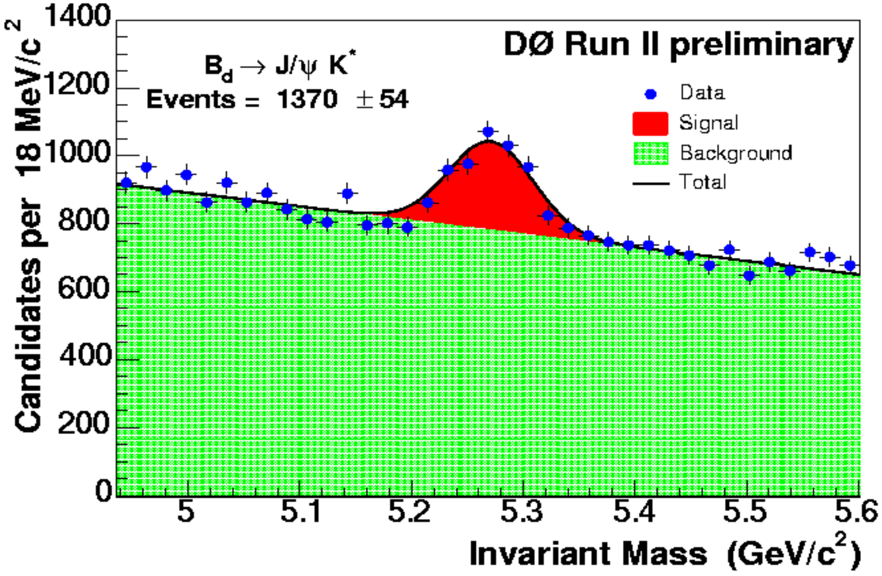


Background lifetime distribution modeled as a gaussian for zero lifetime + short exponential decays (positive and negative), and a long-lived exponential decay.

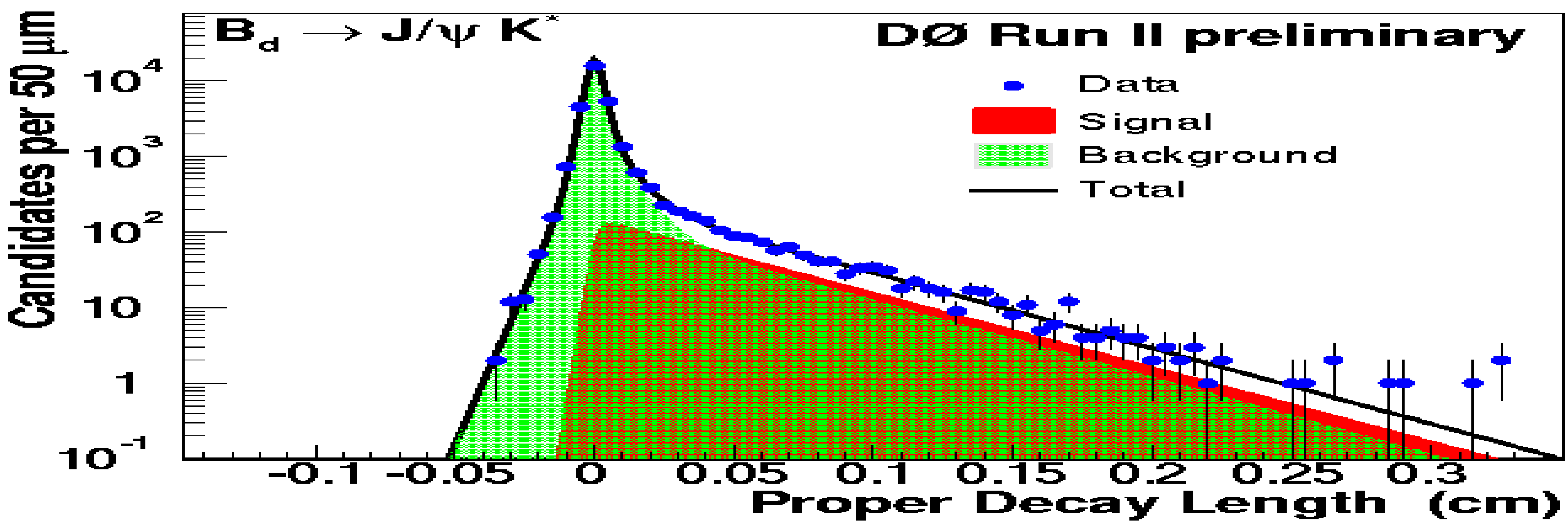


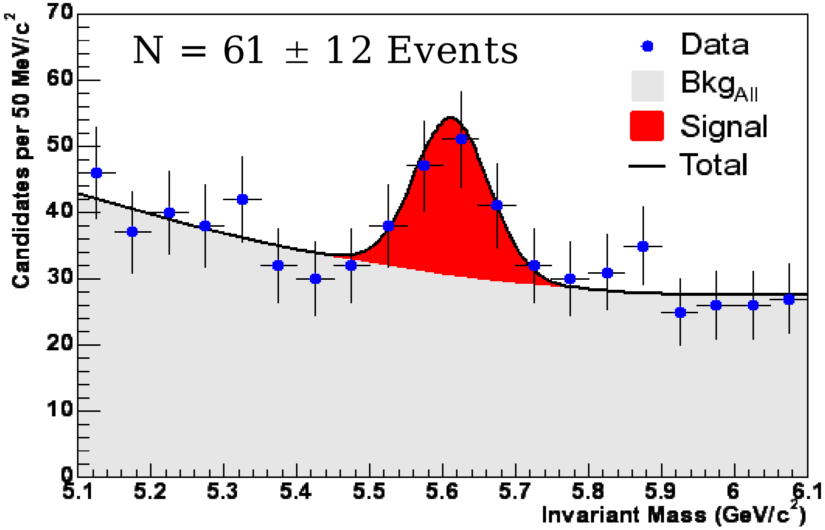
Parameter	Value	Error −	Error +	Units
σ_M	32.9	−2.3	2.5	MeV
M_0	5357.0	−2.5	2.5	MeV
$a1$	−1.641	−0.276	0.277	GeV^{-3}
f_+	0.165	−0.016	0.016	
f_{++}	0.034	−0.009	0.011	
f_-	0.085	−0.015	0.016	
λ^+	75.0	−7.6	7.5	μm
λ^{++}	358.1	−57.0	77.7	μm
λ^-	50.6	−4.4	5.4	μm
s	1.142	−0.027	0.028	
f_s	0.080	−0.006	0.006	
λ^B	432.9	−27.0	29.5	μm



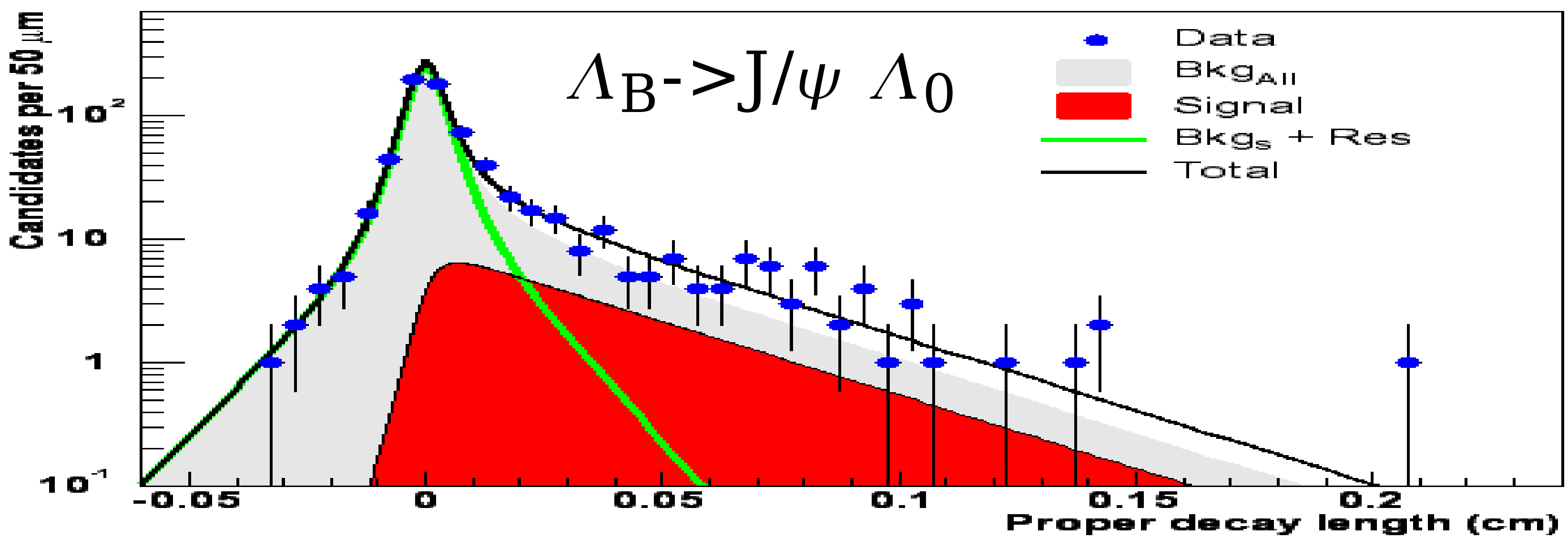


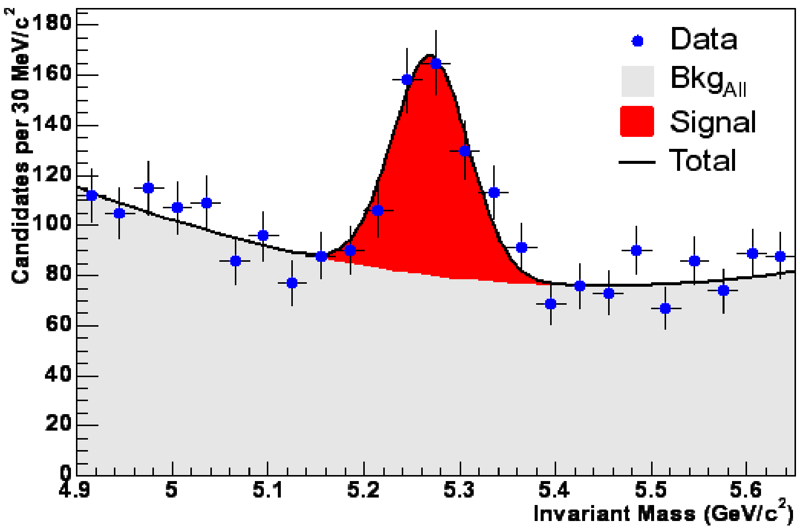
Parameter	Value	Error −	Error +	Units
σ_M	37.9	−1.3	1.4	MeV
M_0	5271.2	−1.5	1.5	MeV
$a1$	−1.274	−0.073	0.073	GeV^{-3}
f_+	0.142	−0.005	0.005	
f_{++}	0.039	−0.003	0.003	
f_-	0.067	−0.005	0.005	
λ^+	73.5	−3.1	3.3	μm
λ^{++}	426.0	−22.5	24.6	μm
λ^-	53.2	−2.0	2.1	μm
s	1.128	−0.009	0.009	
f_s	0.045	−0.002	0.002	
λ^B	441.7	−15.1	15.7	μm



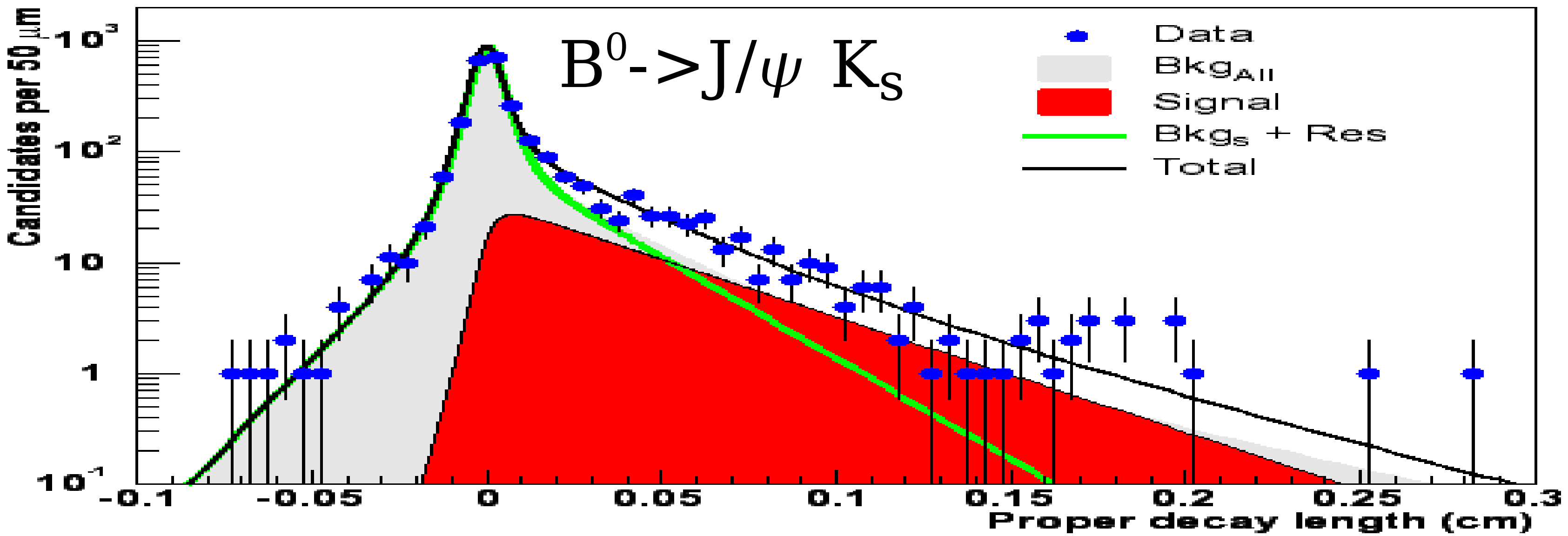


N signal (b)	61 ± 12 events
fraction (signal)	0.087 (+0.018,-0.017)
mass	**5.612 (+0.011,-0.011) GeV**
width	0.052 (+0.010,-0.008) GeV
A1	-13.760 (+12.900,-13.200)
A2	1.144 (+1.180,-1.150)
lifetime (b)	**366.0 (+65.2,-53.6) um**
lifetime(bkg short -)	112.5 (+37.3,-23.7) um
lifetime(bkg short +)	102.1 (+61.4,-34.3) um
lifetime(bkg long)	360.9 (+69.5,-51.0) um
fraction(bkg short)	0.097 (+0.056,-0.057)
fraction(bkg long)	0.193 (+0.049,-0.053)
fraction(Resolution)	0.635 (+0.051,-0.060)
correction factor	1.272 (+0.095,-0.096)





N signal (B0d)	291 ± 23 events
fraction (signal)	0.114 (+0.010,-0.009)
mass	**5.269 (+0.003,-0.003) GeV**
width	0.040 (+0.003,-0.003) GeV
A1	-37.903 (+11.700,-11.600)
A2	3.481 (+1.090,-1.100)
lifetime (B0d)	**418.7 (+32.0,-29.3) um**
lifetime(bkg short -)	135.5 (+19.3,-15.7) um
lifetime(bkg short +)	237.9 (+41.0,-67.5) um
lifetime(bkg long)	628.9 (+404.0,-186.0) um
fraction(bkg short)	0.192 (+0.030,-0.065)
fraction(bkg long)	0.041 (+0.071,-0.029)
fraction(Resolution)	0.702 (+0.022,-0.024)
correction factor	1.387 (+0.046,-0.045)

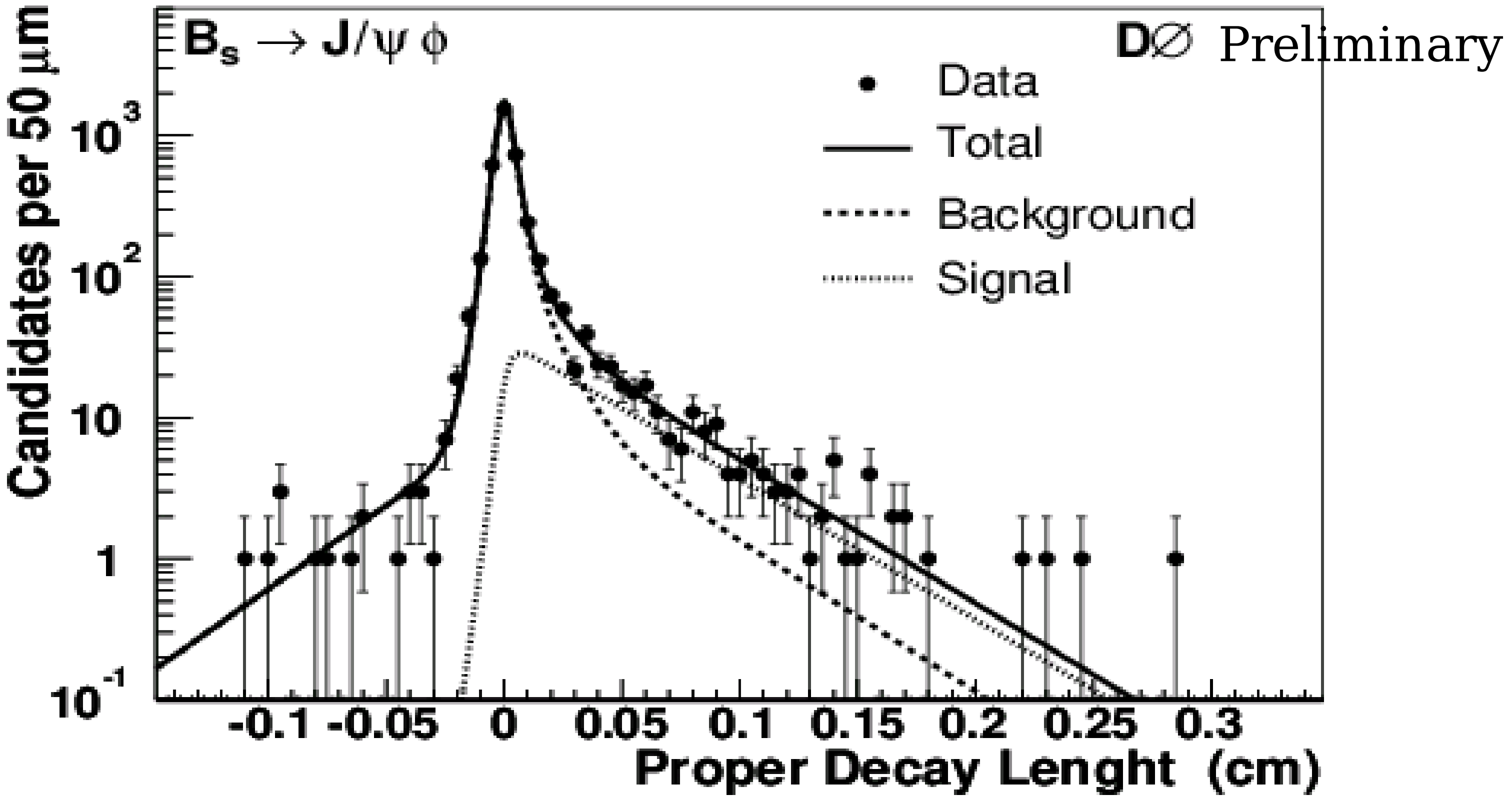


Systematics

J/psi Vertex	✓ Use J/ψ vertex instead of B vertex.
Alignment	✓ Run with a different geometry.
Fitting	✓ Use toy MC to test or Fit code.
Background	✓Use a quadratic polynomial in Mass ✓Convolute exponentials ✓Use two decays for long lifetime. ✓Cross feed contamination Bs⇔Bd
Resolution	✓ Use different Model for resolution

J/ψ Vertex

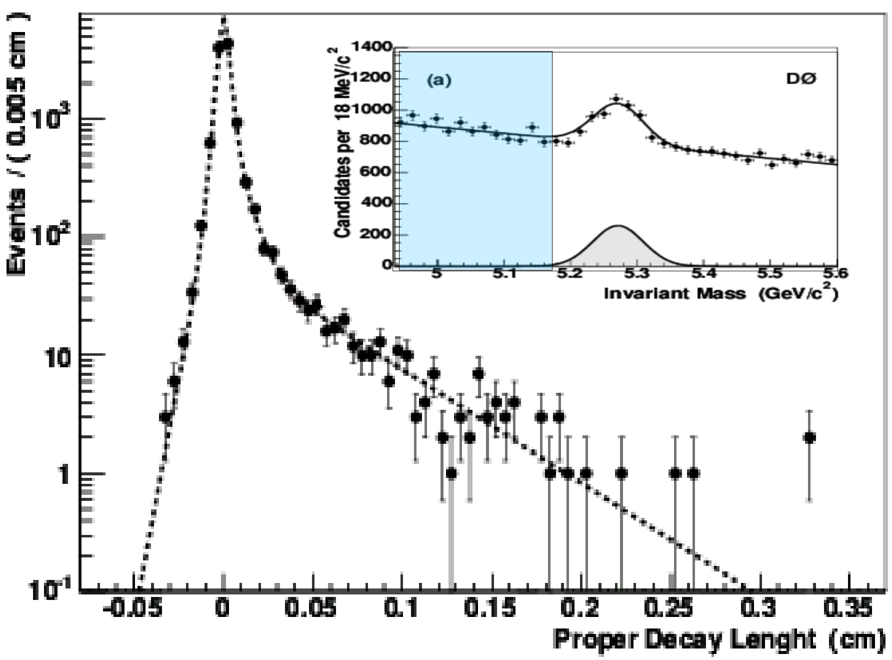
For ideal B candidates, B and J/ψ vertex should be equal. J/ψvertex may be inaccurate when two tracks are very close (collinear). We got a sytematic errors of 3 μm for Bs and 4 μm for Bd.

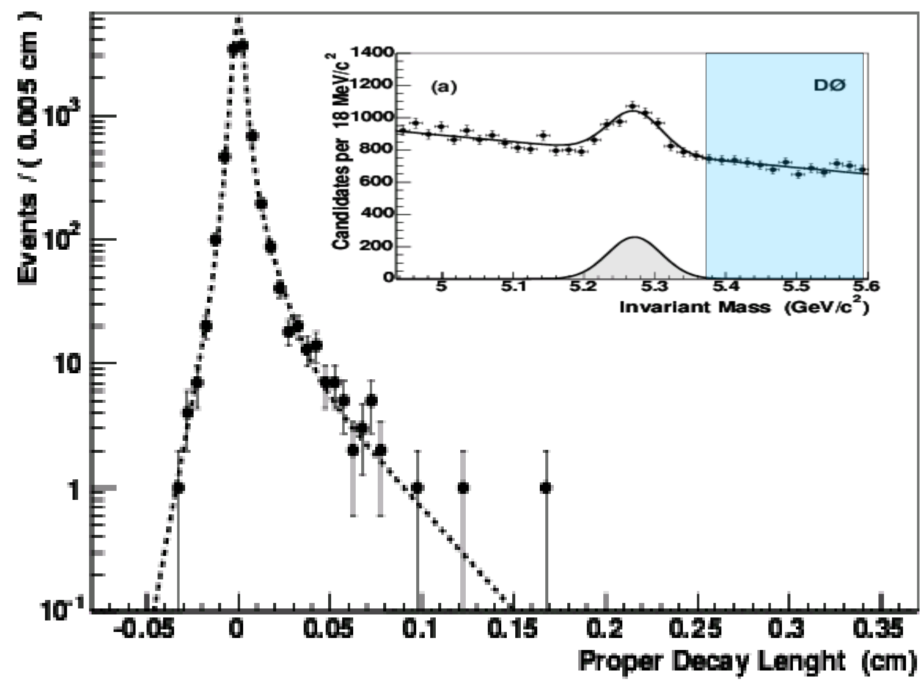


Background

We have that the $c\tau$ distributions from the "sideband". Hi and Low are not equal. Sytematic Error of 3 μm for Bs, Bd.

$$f_{++}\left(\frac{f_{LL}}{\lambda^{lo}}e^{-\lambda_j/\lambda^{lo}}+\frac{(1-f_{LL})}{\lambda^{hi}}e^{-\lambda_j/\lambda^{hi}}\right)$$

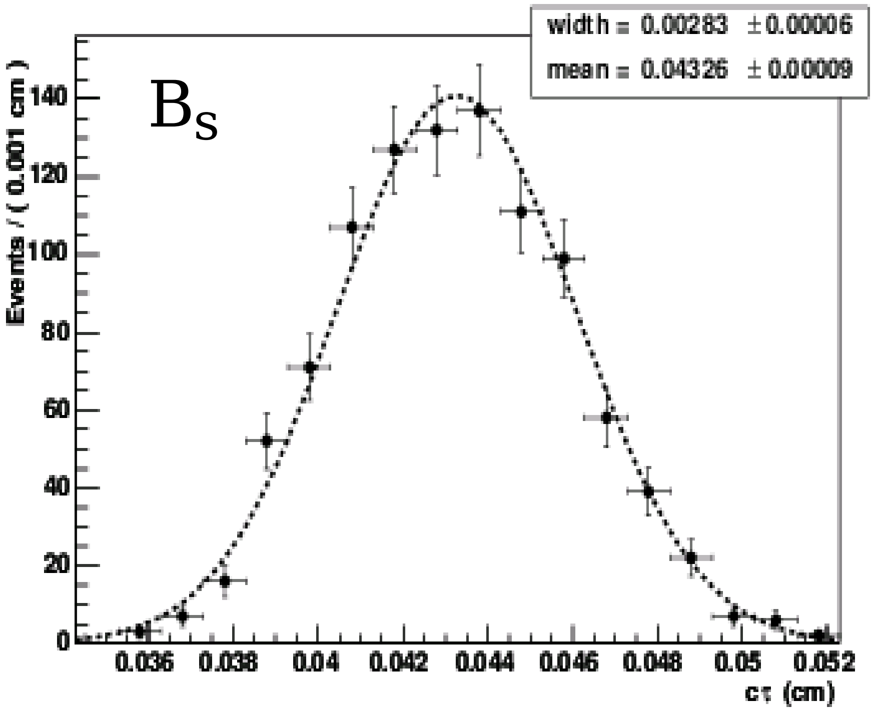




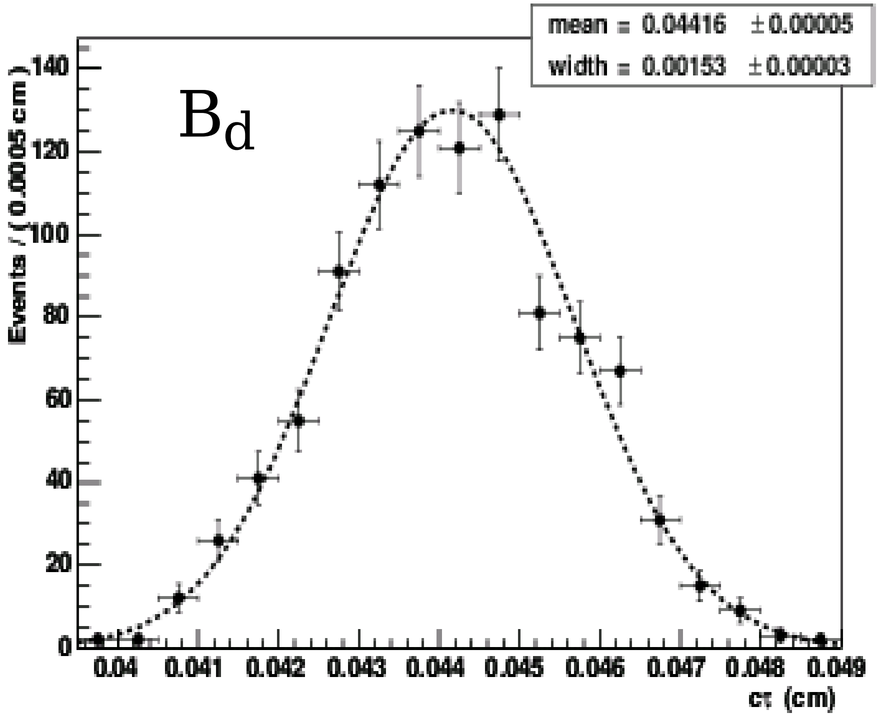
Fitted PDL Low(left) and High(right) mass regions for the B_d

Fitting Code

We generated a 1000 samples with the B_s PDF, and parameters. We fit using same code. This told us how well our fitting method is.



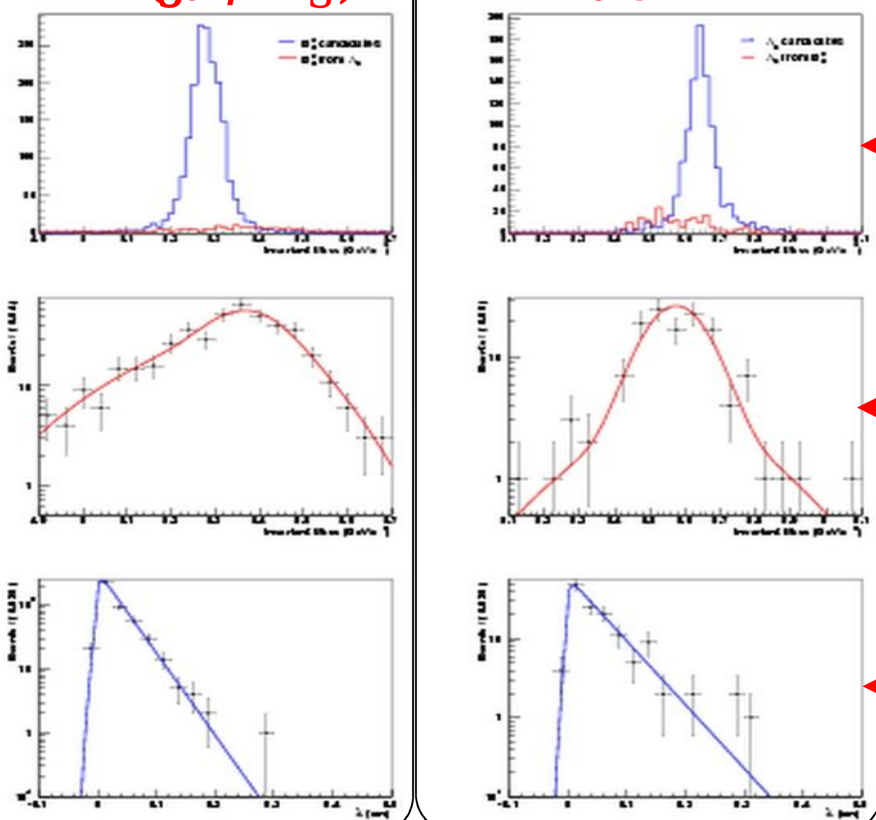
Difference = 0.3 ± 0.9 μm



Difference = 0.2 ± 0.5 μm

Cross-feed contamination (estimated from MC)

$B^0(J/\psi K_s)$ $\Lambda_b(J/\Psi\Lambda)$



Mass MC signal in blue, and cross feed contamination in red

Mass distribution for the cross feed contamination (log scale)

Lifetime distribution for cross feed events

Systematics summary

Source	$B_s \to J/\psi\phi$	$B_d \to J/\psi K^*$	τ_s/τ_d
Alignment	2	2	0.000
J/ψ vertex	3	4	0.002
Resolution model	3	3	0.000
Background model	4	5	0.002
Total	**6**	**7**	**0.003**

Source	B^0 (um)	Λ_b (um)
Alignment	5.4	5.4
Resolution Model	2.7	6.7
Long-lived component	0.1	1.5
Cross-feed contamination	0.8	8.8
Mass distribution model	6.2	2.5
Background lifetime distribution model	3.1	2.7
Fitting	0	0
Total	9.2	12.9

MC studies

Vertex studies (Pulls and resolutions)

- Our vertexes is working. Errors are meaningful.
- Find a possible bias

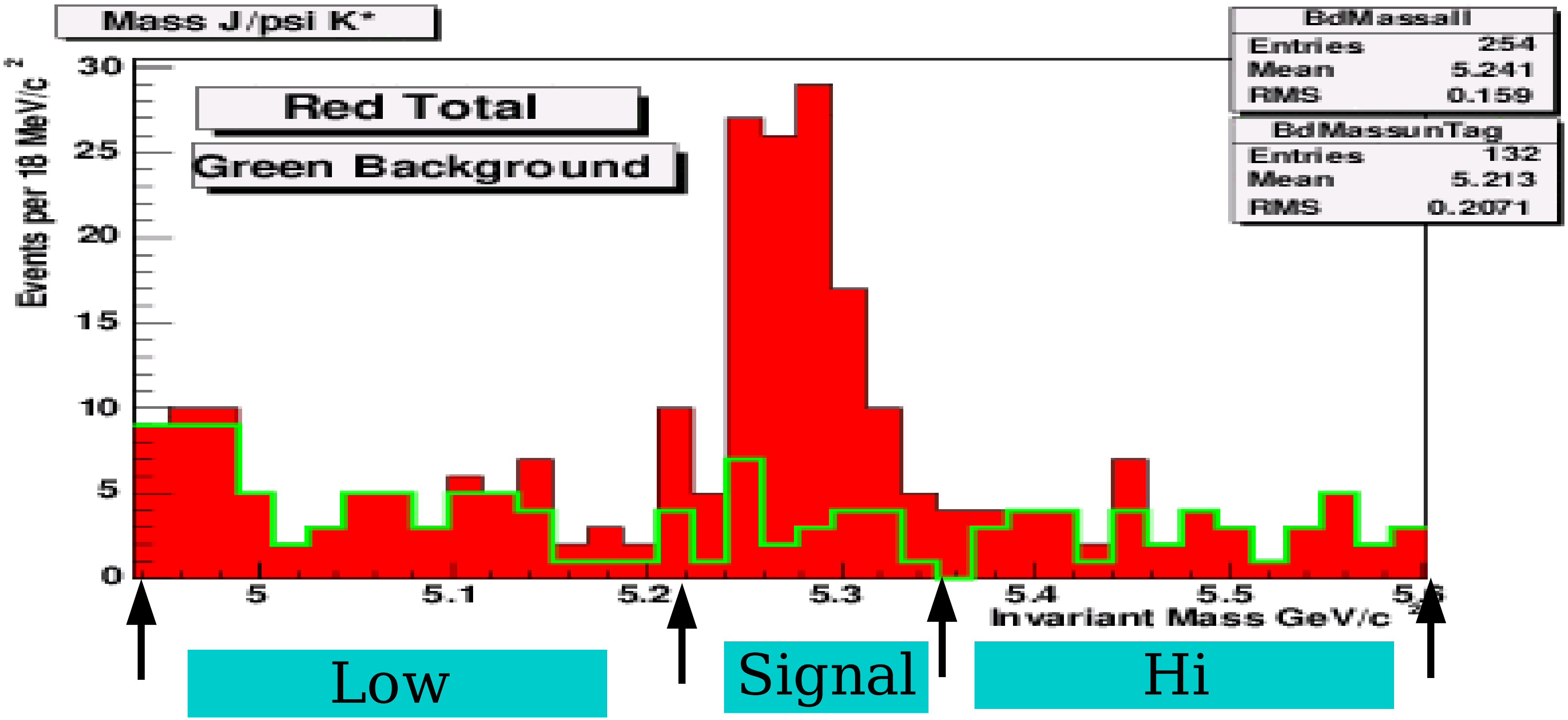
Fit in a Bs, Bd MC sample.

- Make the resolution studies
- Cross feed Bs Bd
- Estimate linearity of our Fit.

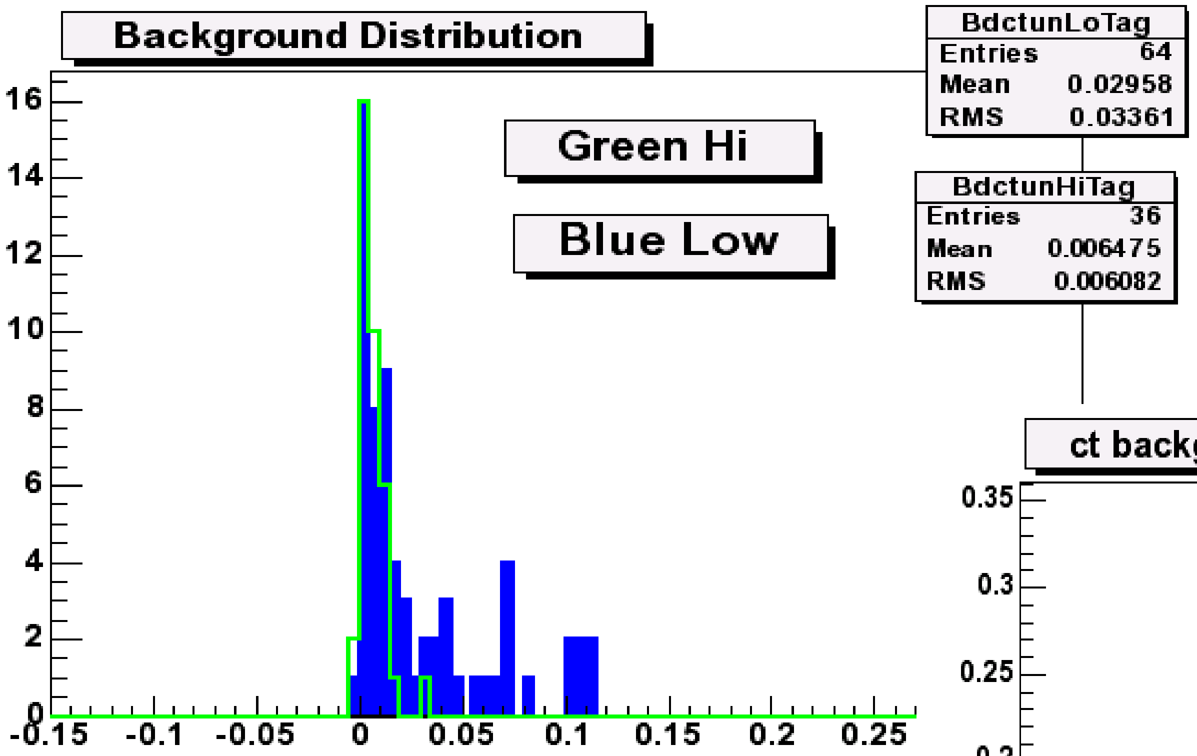
Fit in J/psi X Inclusive MC sample

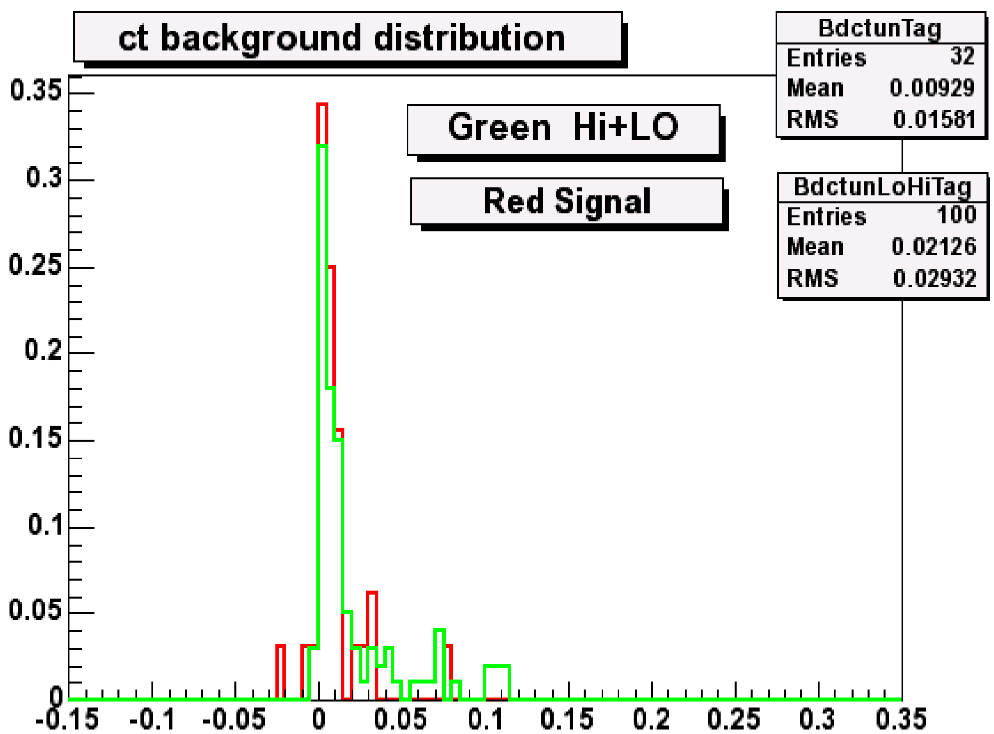
- Long Lifetime component, better understanding of the background.

Understanding Long Lifetime Background I



Understanding Long Lifetime Background II

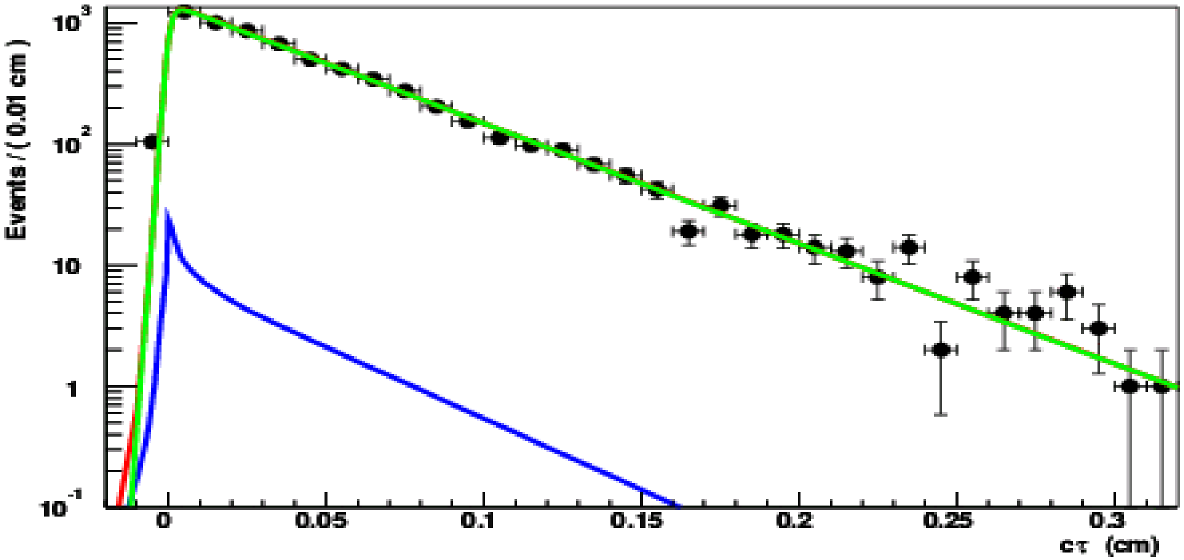




consistency studies

Full analysis test

We have tested our code in a full simulated MC sample . For the Bs the input was 439 μm . We got 437.3 +/- 5.4 μm , same behavior was observed for Bd .



Red All contributions, Green signal, blue combinatorial: mainly from misreconstruted.

consistency studies

Range of Mass selection

Fitting Region	$c\tau(B_s)$ (μm)	$c\tau(B_d)$ (μm)
$\pm 6\sigma$	433.2 ± 29.1	438.2 ± 15.4
$\pm 8\sigma$	432.5 ± 28.4	441.7 ± 15.2
$\pm 9\sigma$	433.9 ± 28.2	441.7 ± 15.4
$\pm 10\sigma$	432.9 ± 28.3	441.5 ± 15.4
$\pm 11\sigma$	430.4 ± 27.9	442.9 ± 15.6

Dependence of the Mass

All D0 mass peak are slightly shifted due to magnetic and material uncertainties, instead of use the PDG mass in the PDL definition (slide) we use the central value of our fit . We found a difference of 0.75 microns.

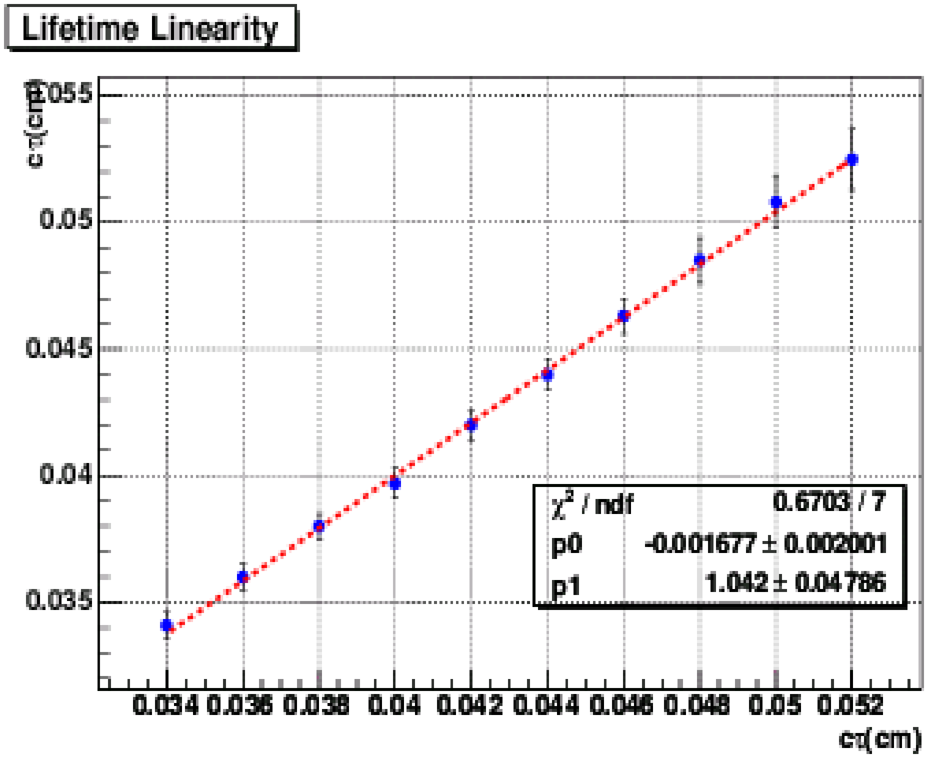
Different Cuts an split samples

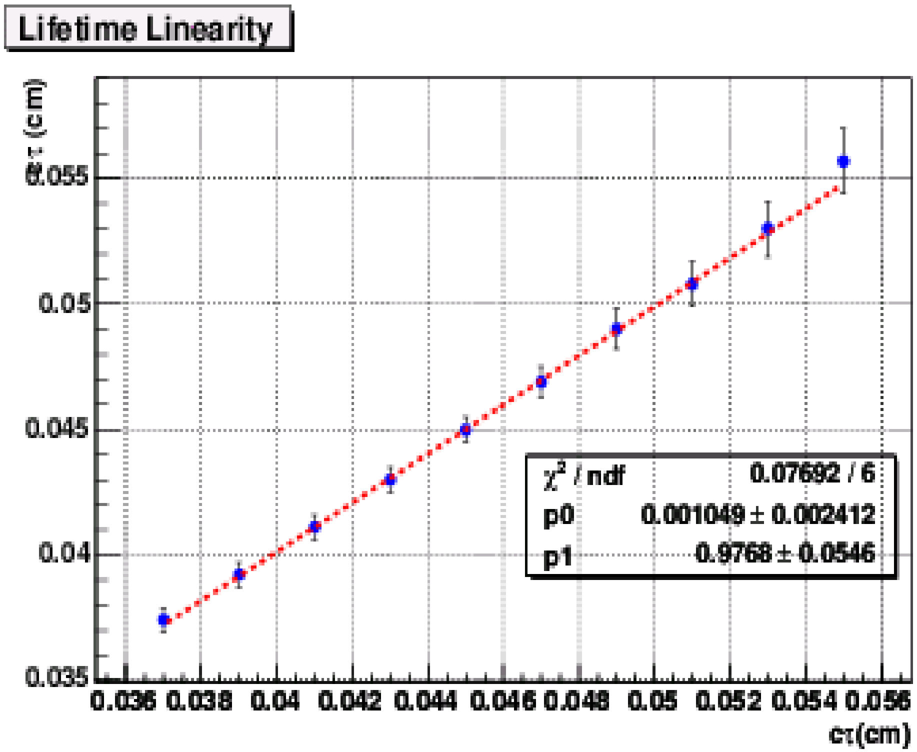
We have explored two additional set of cuts , 1) Maximum S/B (low statistics), 2)Maximum yield (large background). We also split the sample in several ways.

Check	$c\tau(B_s)$ μm	$c\tau(B_d)$ μm
cuts set1	427 ± 27	449 ± 15
cuts set2	435 ± 32	447 ± 18
run < 180956	436 ± 34	442 ± 18
run > 180956	428 ± 56	440 ± 29
$\phi(B_s) < \pi$	443 ± 38	445 ± 20
$\phi(B_s) > \pi$	423 ± 31	436 ± 24
$\eta(B_s) < 0.8$	462 ± 36	427 ± 21
$\eta(B_s) > 0.8$	405 ± 33	453 ± 22
random $< .5$	433 ± 32	432 ± 22
random $> .5$	432 ± 32	451 ± 22
sim. fit	434 ± 30	445 ± 16
fix sb fit	433 ± 29	445 ± 16

Linearity

In a Full simulated MC, we fit using various lifetimes inputs. Our results are consistents with linear.





Test of linearity of the lifetime fit, Left Bs MC, right Bd MC.

Sumary Results I

With approximately 220 pb-1 in DØ detector up to february2004. We reconstructed 337(1370) $B_s(B_d)$ candidates and we have measured the lifetime.

$$\tau(B_s) = 1.444\ ^{+0.098}_{-0.090}\ (\text{stat}) \pm 0.020\ (\text{syst})\ \text{ps.}$$

$$\tau(B_d) = 1.473\ ^{+0.052}_{-0.050}\ (\text{stat}) \pm 0.023\ (\text{syst})\ \text{ps.}$$

And the ratio

$$\tau(B_s)/\tau(B_d) = 0.980\ ^{+0.075}_{-0.070}\ (\text{stat}) \pm 0.003\ \text{syst}$$

D0 conference and analysis notes at:

http://www-d0.fnal.gov/cinvestav/d0_private/Analysis/Bs/Bs.html

Comparison

Experiment	B_s	B_d
World Average	1.461 ± 0.057	1.536 ± 0.014
This measurement	1.444 +0.098/-0.090 ±0.020	1.4713 +0.052/- 0.050± 0.023
CDF (RunII) prelim	1.369 ± 0.100 +0.08/-0.010	1.539 ± 0.051± 0.008
BaBar	--	1.523 +0.024/-0.023± 0.022
BELLE	--	1.554 ± 0.030± 0.019
CDF Run I	1.36 ± 0.09 +0.06/-0.05	1.497 ± 0.073± 0.032
DELPHI	1.42 +0.14/-0.13 ± 0.03	1.532 ± 0.041± 0.040
OPAL	1.50 +0.16/-0.15 ± 0.04	1.541 ± 0.028± 0.023
ALEPH	1.47 ± 0.14 ± 0.08	1.518 ± 0.053± 0.034

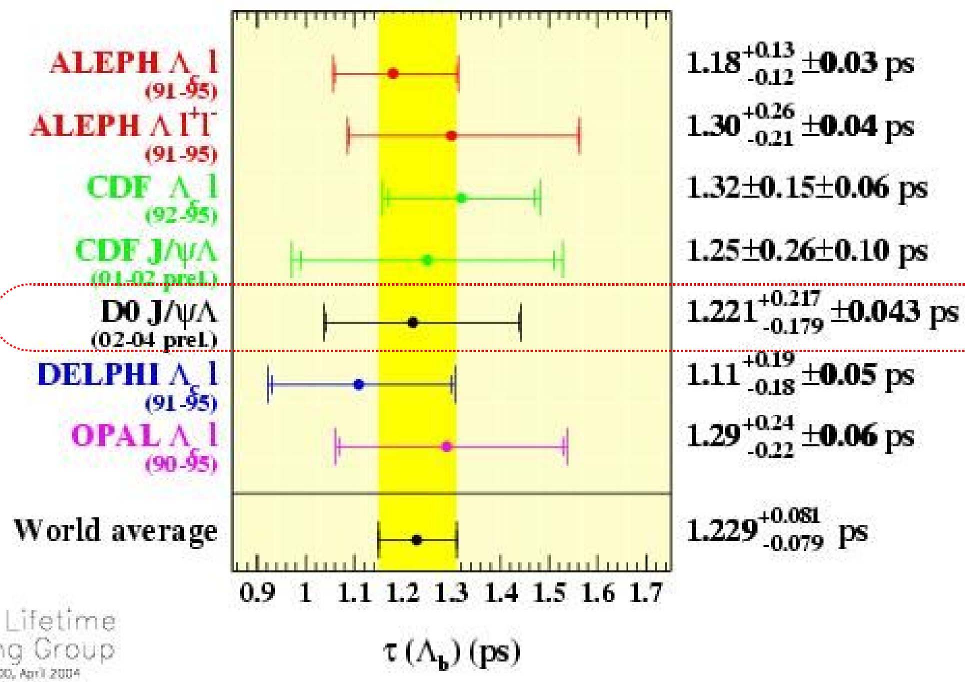
The current world best single measurement.

Summary results II :

$$\tau(\Lambda_b) = 1.221 \;{}^{+0.217}_{-0.179}\,(stat) \pm 0.043\,(syst)\;ps$$

$$\tau(B^0) = 1.397 \;{}^{+0.107}_{-0.098}\,(stat) \pm 0.031\,(syst)\;ps$$

$$\frac{\tau(\Lambda_b)}{\tau(B^0)} = 0.874 \;{}^{+0.169}_{-0.142}\,(stat) \pm 0.028\,(syst)$$



We are consistent with the world average

LEP B Lifetime Working Group
Privately Add D0, April 2004

CINVESTAV

In progress

- Add more available data.
- Bd, Bs Angular analysis, integrated in the time.
- Bs, Bd time dependent Transversity Analysis.
- Bs lifetime in the semileptonic channel.

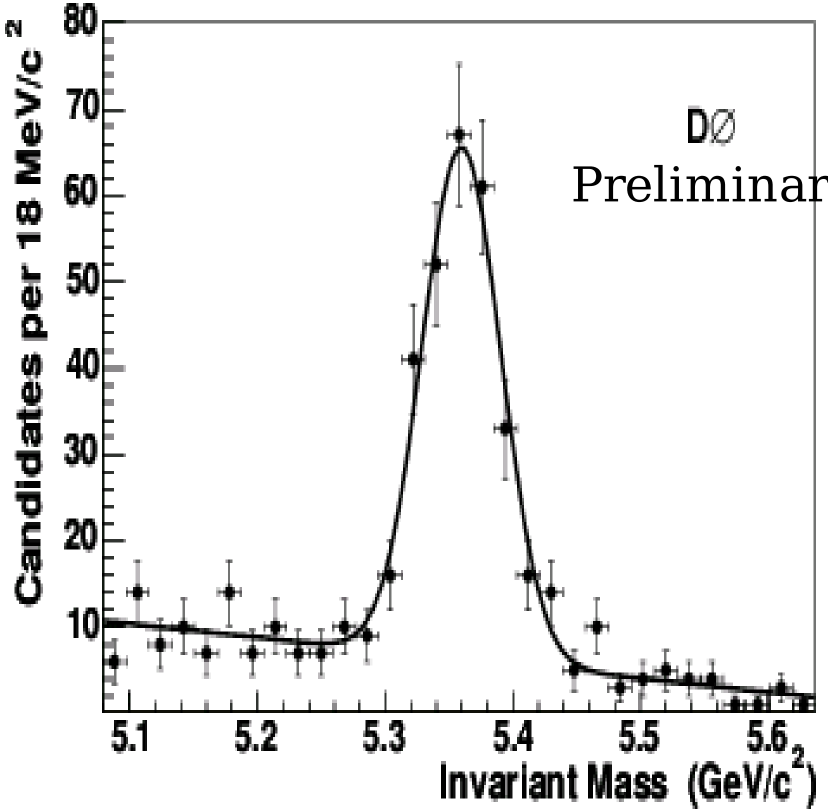
Backup slides

Data Samples

- Luminosity ~ 220 pb^{-1}
- Remove all bad data.

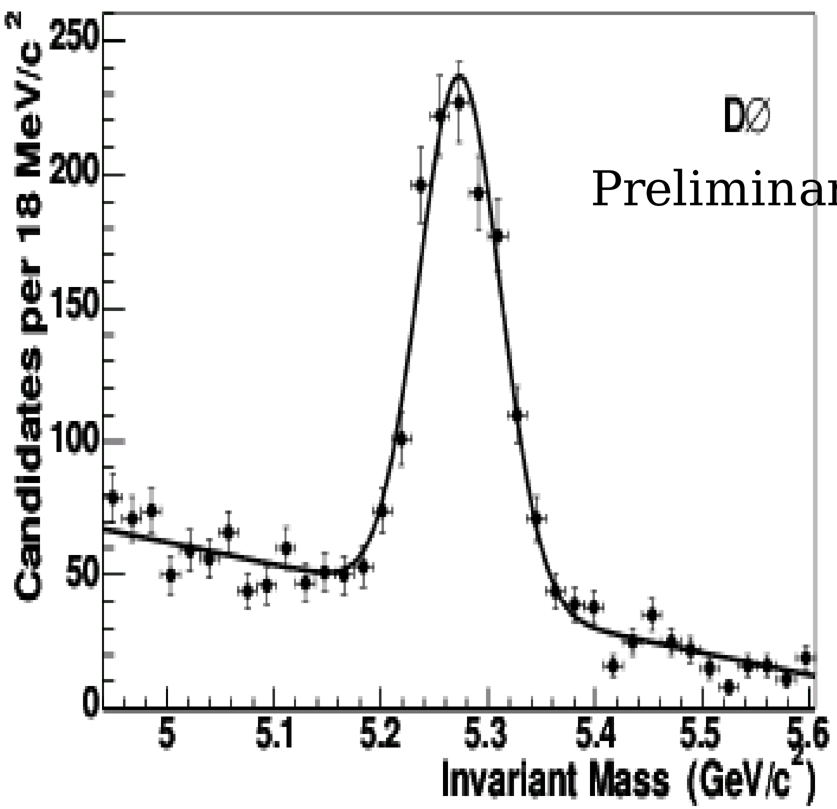
Mass Distributions with a $c\tau/\sigma(c\tau) > 5$

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



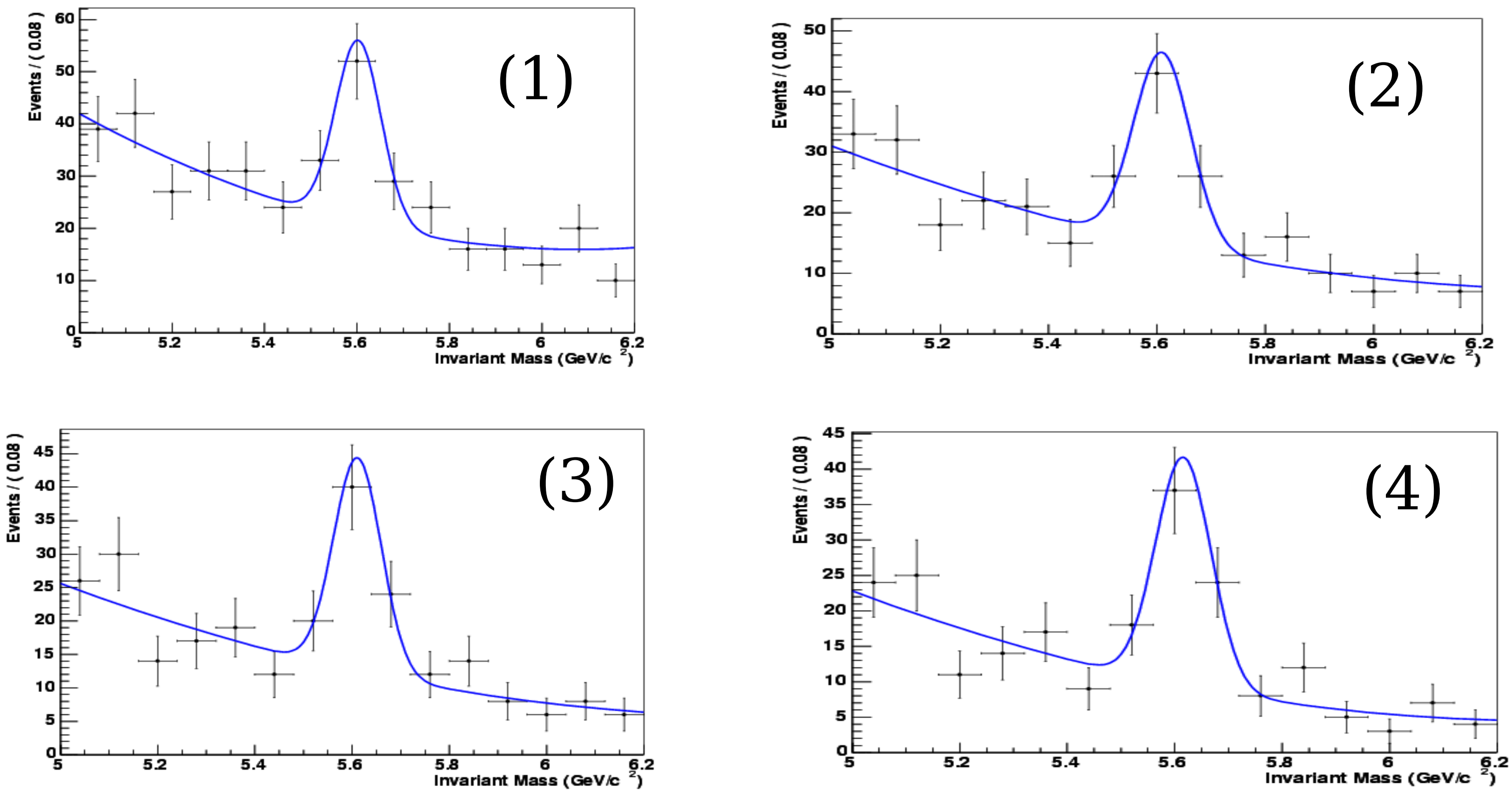
N = 259 ± 14

$B_d \to J/\psi\ K^*$



N = 1028 ± 36

Establishing the Λ_b signal



As cross check we applied the cut c / (ct)> : 1, 2, 3, and 4. (It can not be used for lifetime measurements)