Bottom and Charm Masses and Lifetimes

at the Tevatron

LaThiule, March 3, 2004

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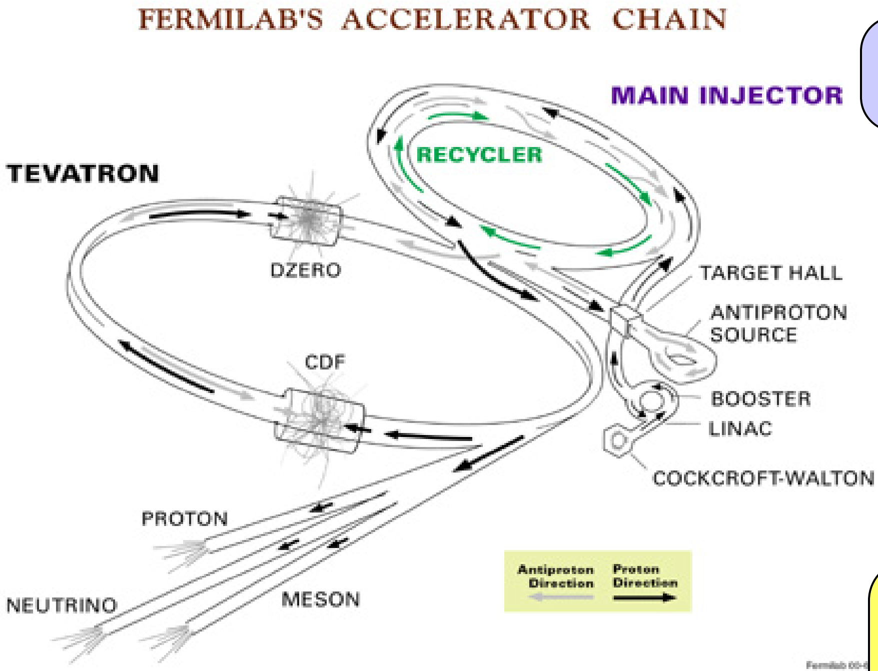
Talk Outline

- Tevatron Status
- CDF and D0 detectors
- The Masses
- The Lifetimes
- The Pentaquark Search (Ξ)



1995-2000 : substantial ($350m) upgrade

- main injector
- anti-proton recycler
- new synchrotron
- upgraded pbar source

2004

- Tevatron has achieved the initial goal of 5 times the Run-I luminosity (though a bit later than originally hoped).

- Expect a Core dataset of 2fb^{-1} by the end of 2005.

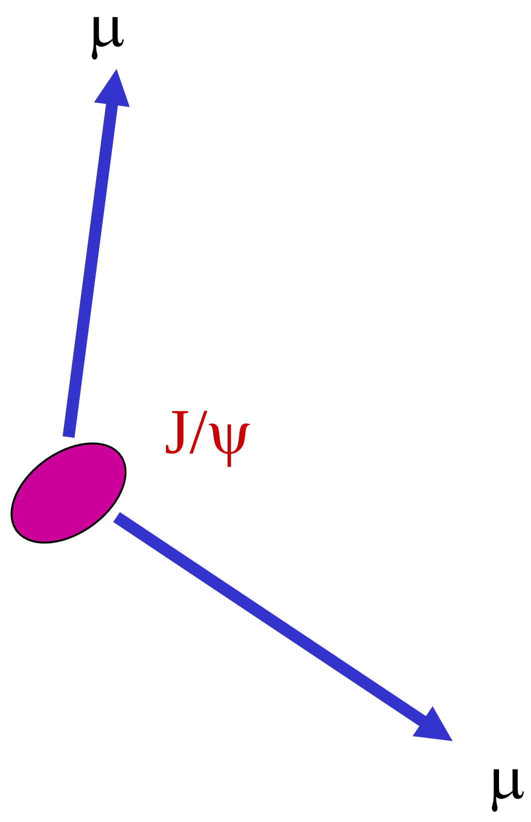
- Larger dataset (8 fb^{-1}), which was considered difficult to achieve is now looking possible. Certainly the minimum final integrated Luminosity of 4 fb^{-1} should be achievable.

Post-2000

- **Peak Luminosity of 6.8x10^{31}cm^{-2}s^{-1} have been achieved, 6x10^{31}cm^{-2}s^{-1} is common.**

$\mu\mu$ Trigger (J/ψ for this talk)

- Two muons of at least
  1.5-2.0 GeV/c - CDF
  1.5-3.0 GeV/c – D0 (dep. on prescale factor)
- CDF $\mu^{\pm}$ central ($|\eta|<1.1$)
  D0 $\mu^{\pm}$ $|\eta|<3.0$
- Good match between muon chamber and track.
- Silicon used to distinguish prompt from B production.

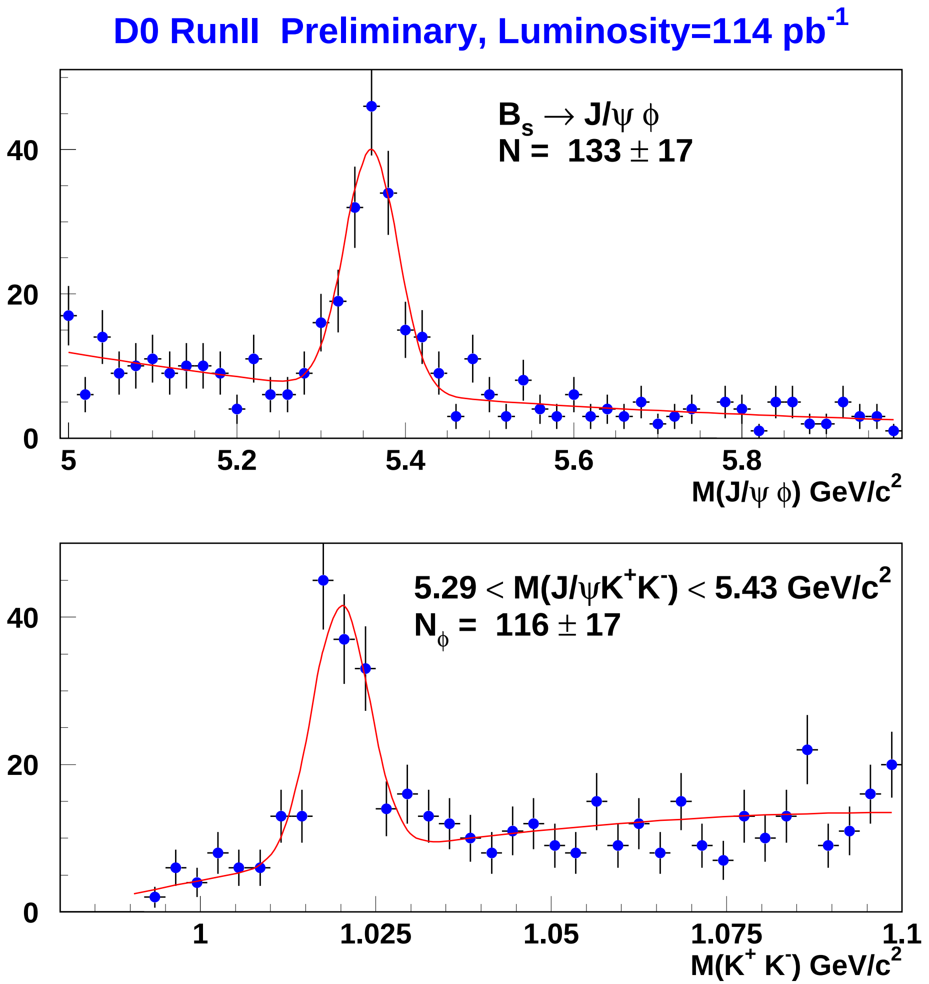


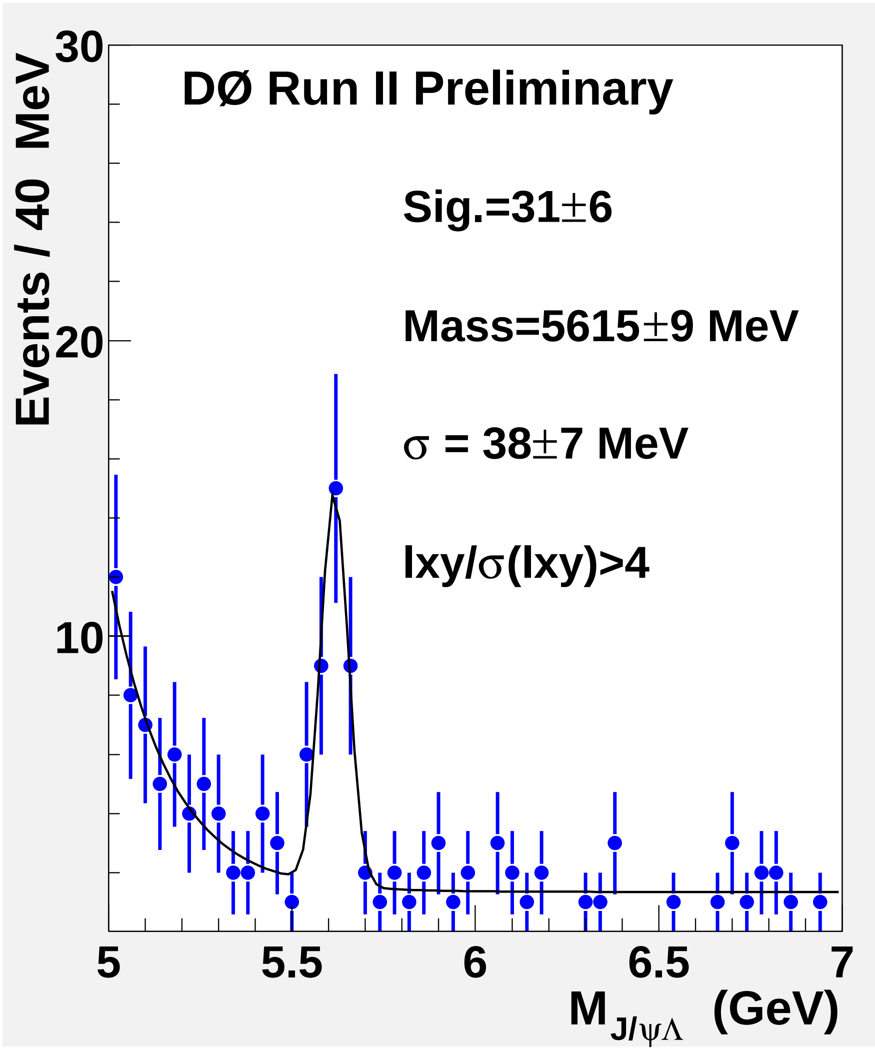
Mass Measurement Details

DO

- J/ψ is used extensively
  - Sets the absolute energy scale
    - Mass is set to World Average
  - Corrections for Energy loss in detector
  - Corrections for alignment (still on-going)
  - Corrections for rad. tail from muon bremstralung.
- Compare Upsilon(1S) mass to PDG value
- **Mass difference is consistent!**
- Then measure the masses B hadron states.

B Hadron Masses





- Finding Unique Decays of B Hadrons.

B** Mass Measurement

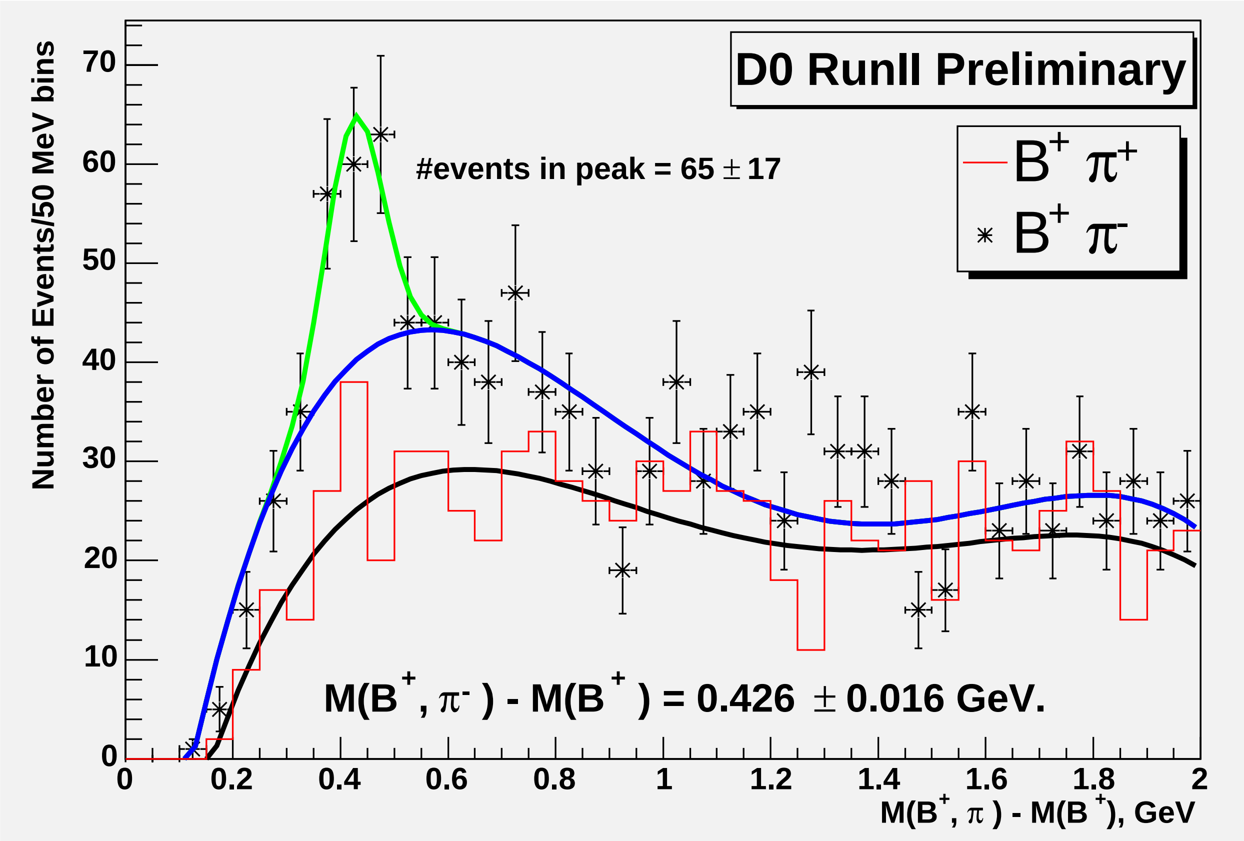
D0

B_d** is seen
M(B**) = 5.71+/-0.016 GeV/c^2

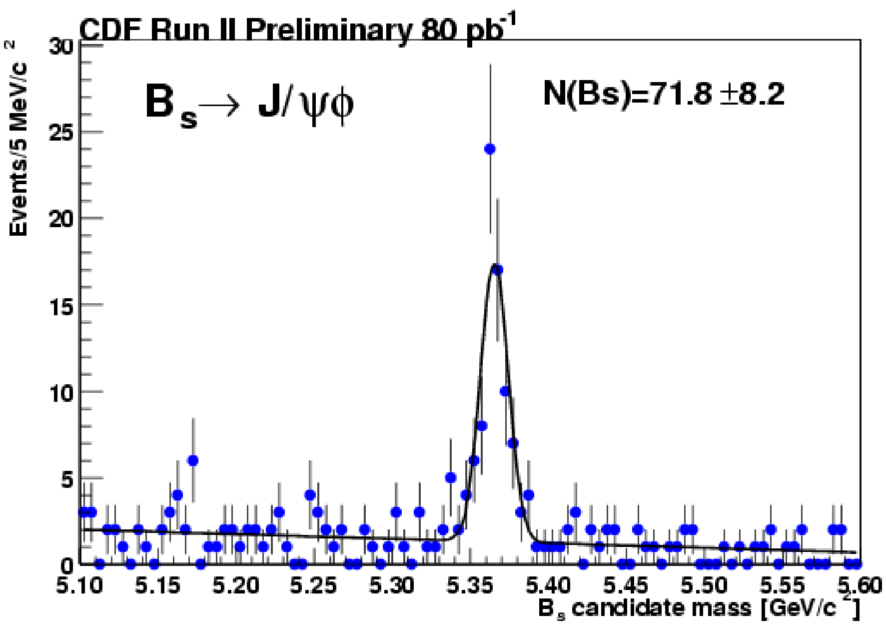
~115 pb^{-1}

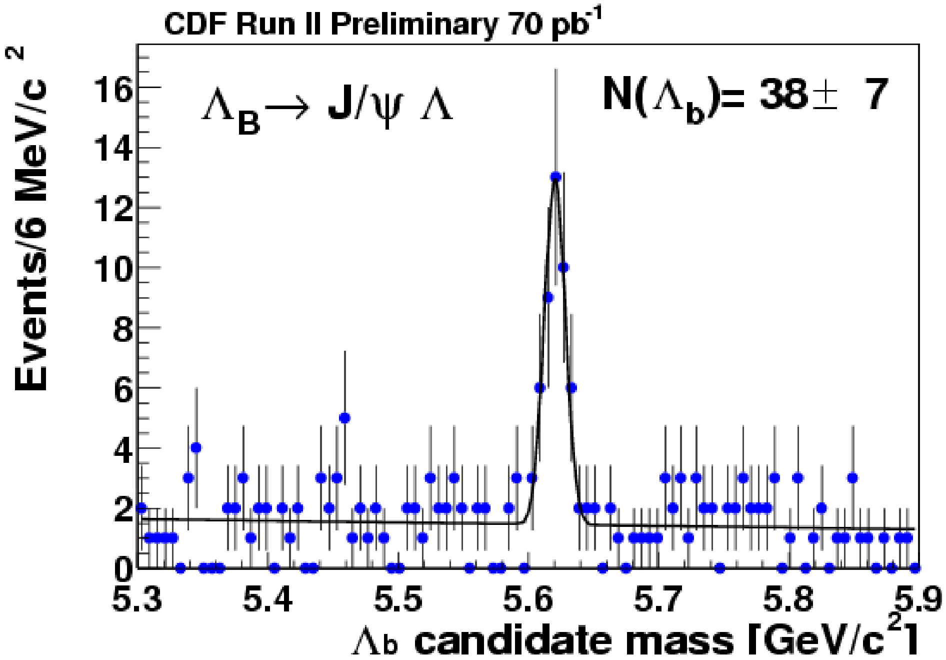
Significant signal in RS vs. WS.

No signal seen yet in B_u**.



B Hadron Masses





- Competitive measurements for B_d and B^+:

M(B_d) = 5280.30±0.92±0.96 MeV and M(B^+) = 5279.32±0.68±0.94 MeV

- World's best measurements for B_s and Λ_B:

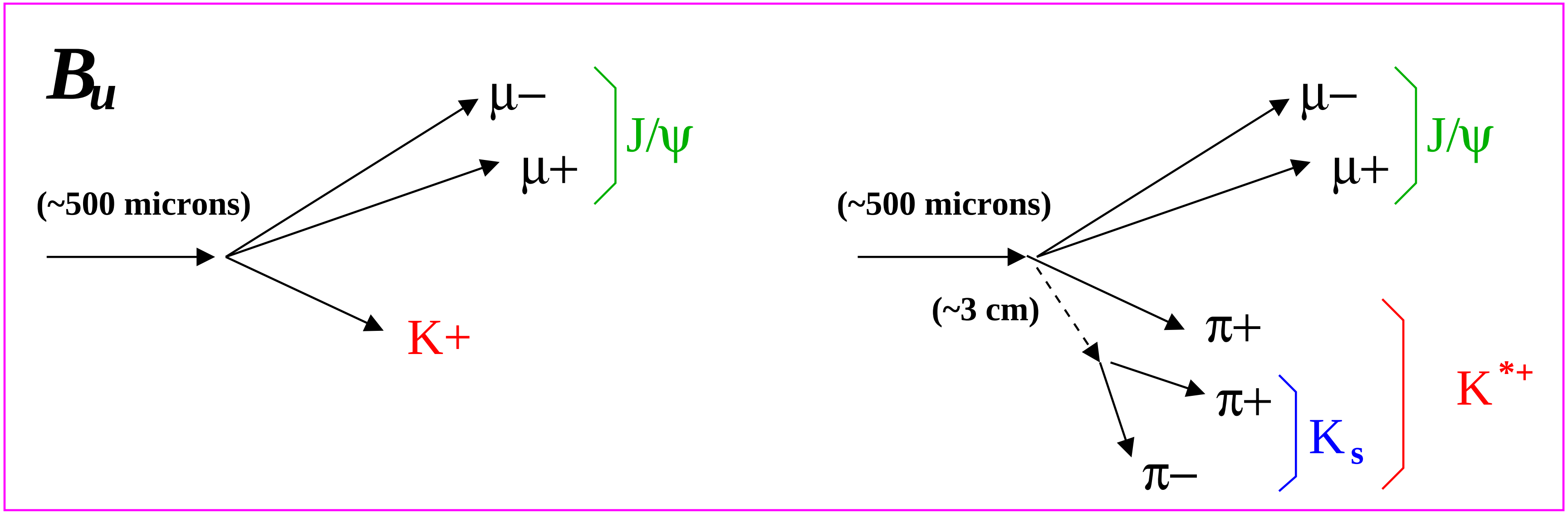
M(B_s) = 5365.50±1.29±0.94 MeV and M(Λ_B) = 5620.4±1.6±1.2 MeV

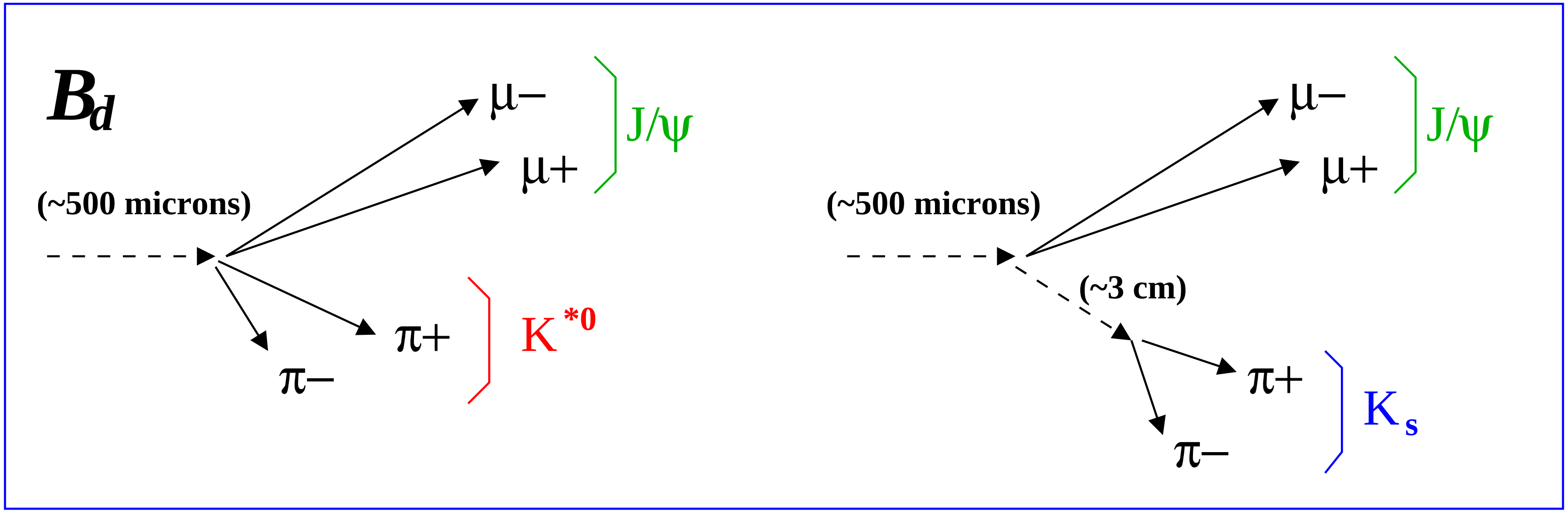
Lifetime Measurement Details

D0

- Exclusive decays: Two main procedures used
- **Procedure A:**
  - Plot the Mass
  - Fit the close sidebands to a parameterization of the 'short lived' and 'long lived' background. Fix the parameterization and relative background size.
  - Fit the lifetime to a convoluted exp-Gaussian distribution.
- **Procedure B:**
  - Fit the mass and lifetime simultaneously using a multivariate likelihood fit.
  - Include sufficient sidebands in fit to provide a good background sample
  - Likelihood functions will have many terms representing signal and background lifetime and mass distributions.

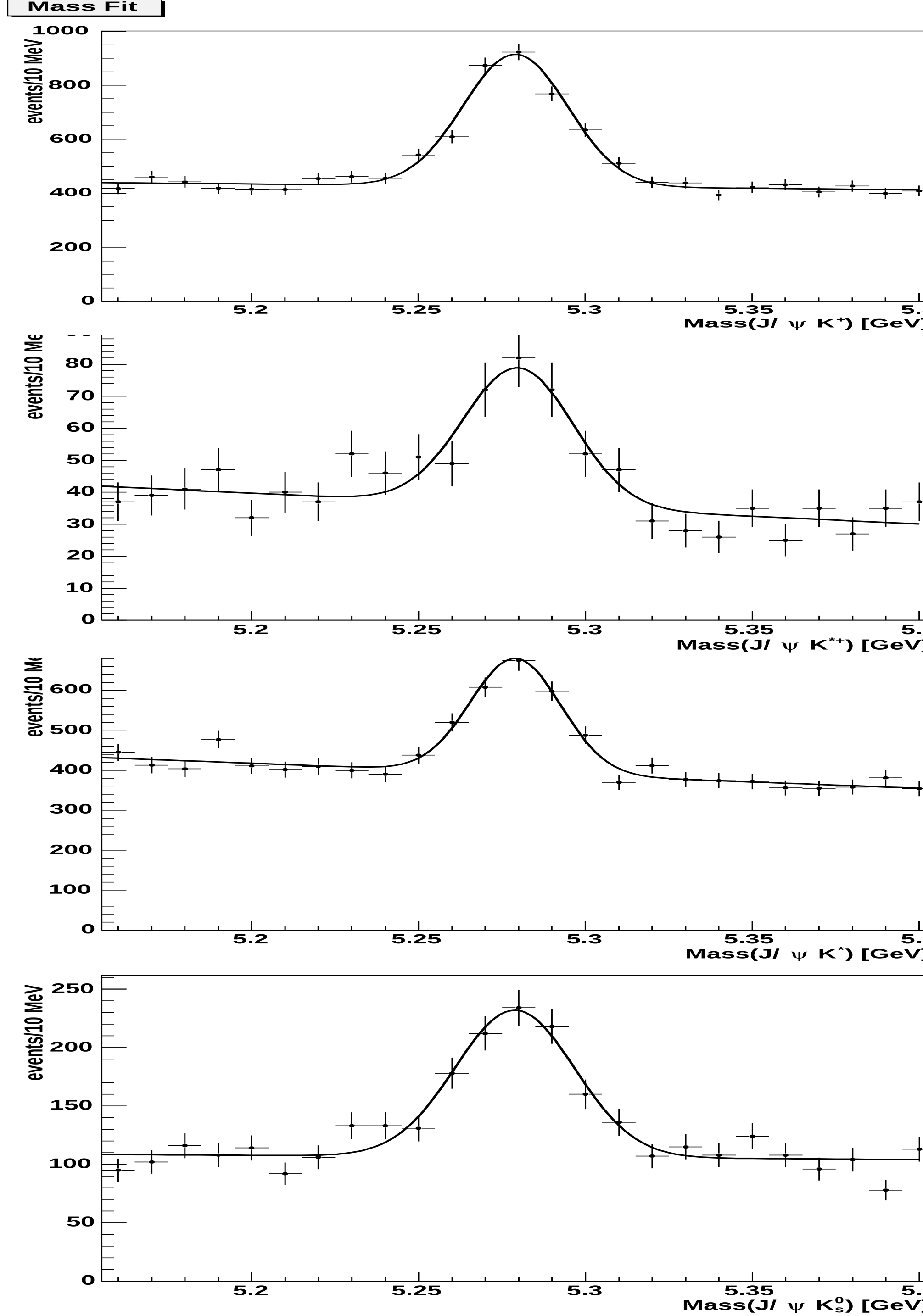
$B^{\pm}/B^0$ Lifetime Ratio





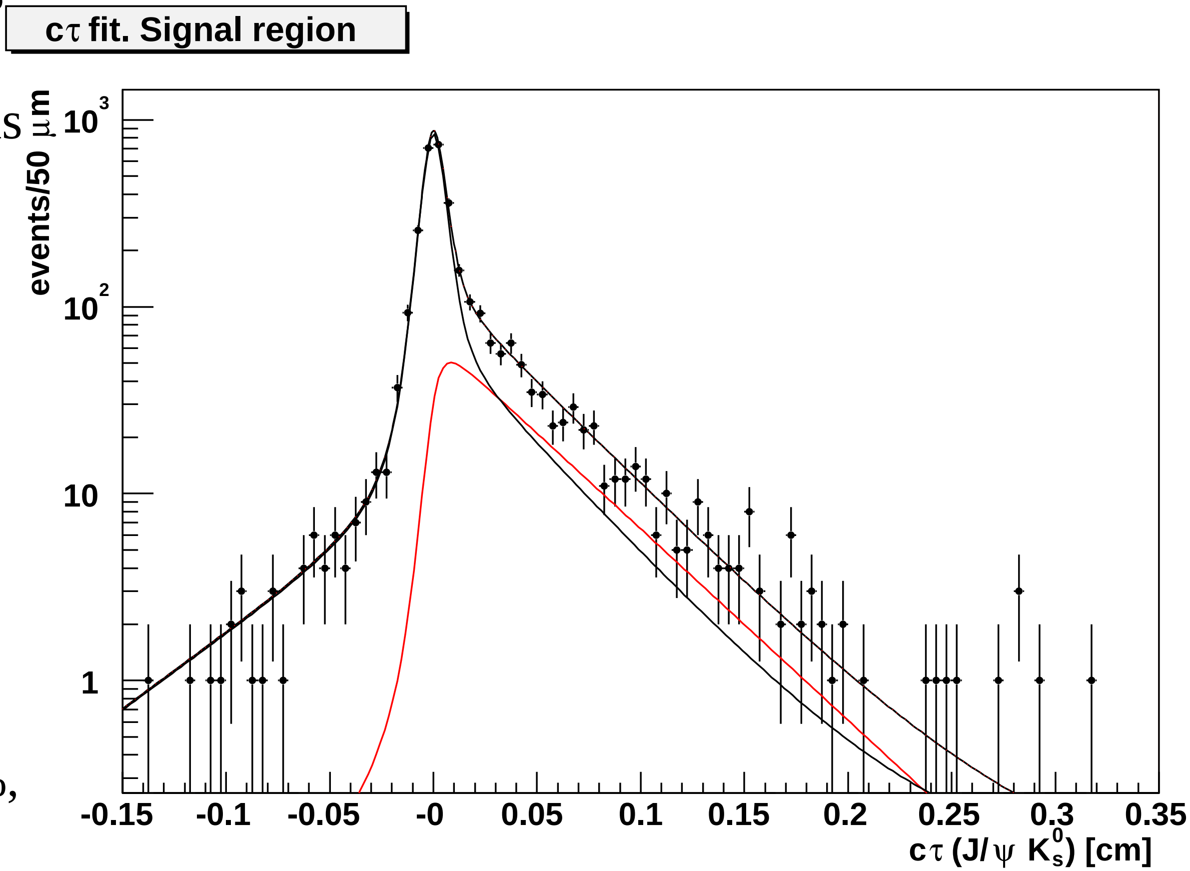
B$^{\pm}$/B^{0} Lifetime

- Procedure A
  - Reminder: The separated 'signal' and 'background' fits using the mass as the identifier.
- Used as Check and for systematic studies



$B^{\pm}/B^0$ Lifetime Ratio

- Procedure B
  - Using the J/ψ and the B vertex were tested against pull distributions in Monte Carlo.
    - J/ψ vertex is better estimator.
    - Better for combining several results
  - Goodness of fit determined by running Toy Monte Carlo experiments
    - CL's are 3.4%, 35.2%, 25.6%, and 26.3% in the 4 cases.



Proc. B is used for final Measurement

$B^{\pm}/B^0$ Lifetime Ratio

Systematic Uncertainties

	$J/\psi\ K^+$	$J/\psi\ K^{*+}$	$J/\psi\ K^*$	$J/\psi\ K_S$
Res. function	5 μm			
Alignment	2 μm			
Bg. Model	1 μm	17 μm	7 μm	9 μm
Total	5 μm	18 μm	9 μm	10 μm

	B^+	B^0	τ_+/τ_0
Res. Function	5 μm		0.0014
Alignment	2 μm		0.0
Bg. Model	2 μm	6 μm	0.014
Total	6 μm	8 μm	0.014

$B^{\pm}/B^0$ Lifetime Ratio

Signal and Sideband fit (method I)

- Results are combined as weighted averages with correlations between mass, $c\tau$, and resolution scale factor included.
- Results: CDF Run-II Preliminary

B^+: $c\tau = 499 \pm 12(\text{stat}) \pm 6\ (\text{sys})\ \mu m$

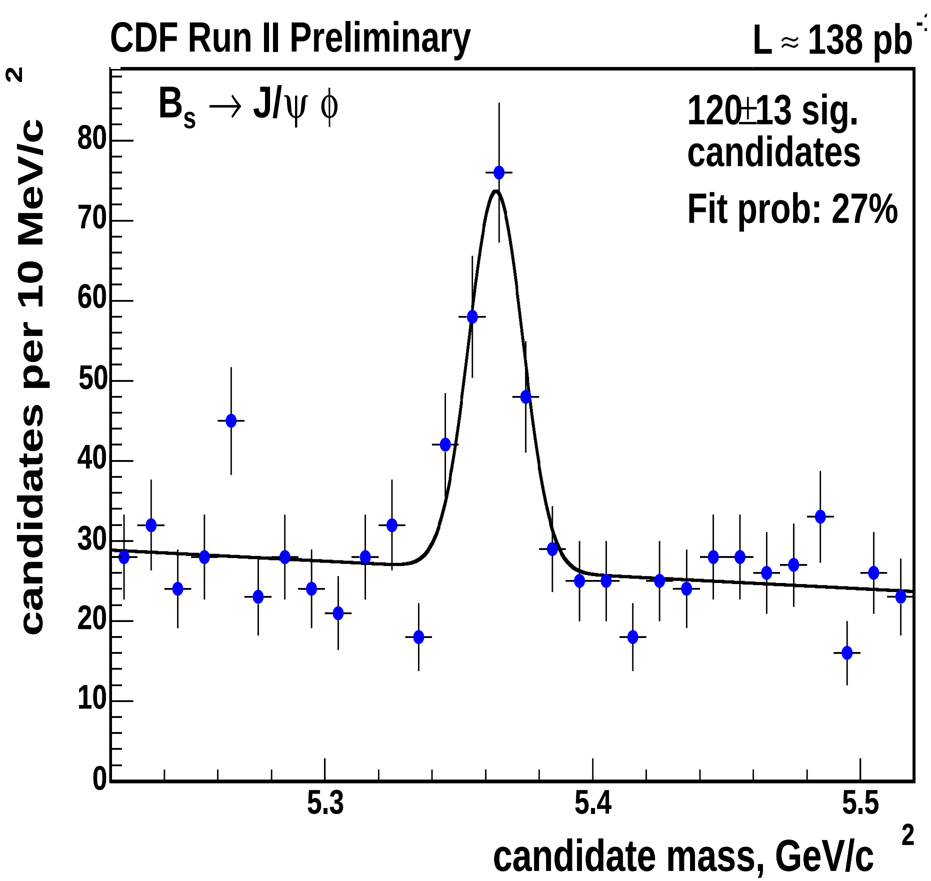
B^0: $c\tau = 446 \pm 15(\text{stat}) \pm 8(\text{sys})\ \mu m$

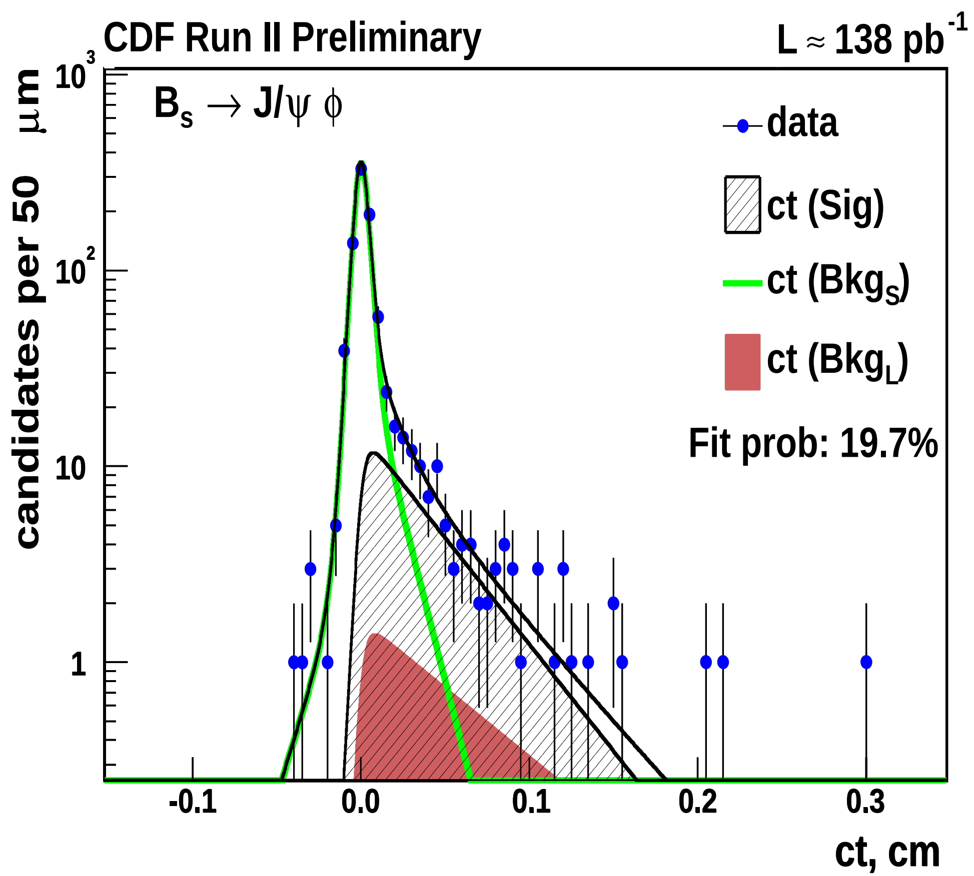
$\tau_+/\tau_0 = 1.119 \pm 0.046(\text{stat}) \pm 0.014(\text{sys})$

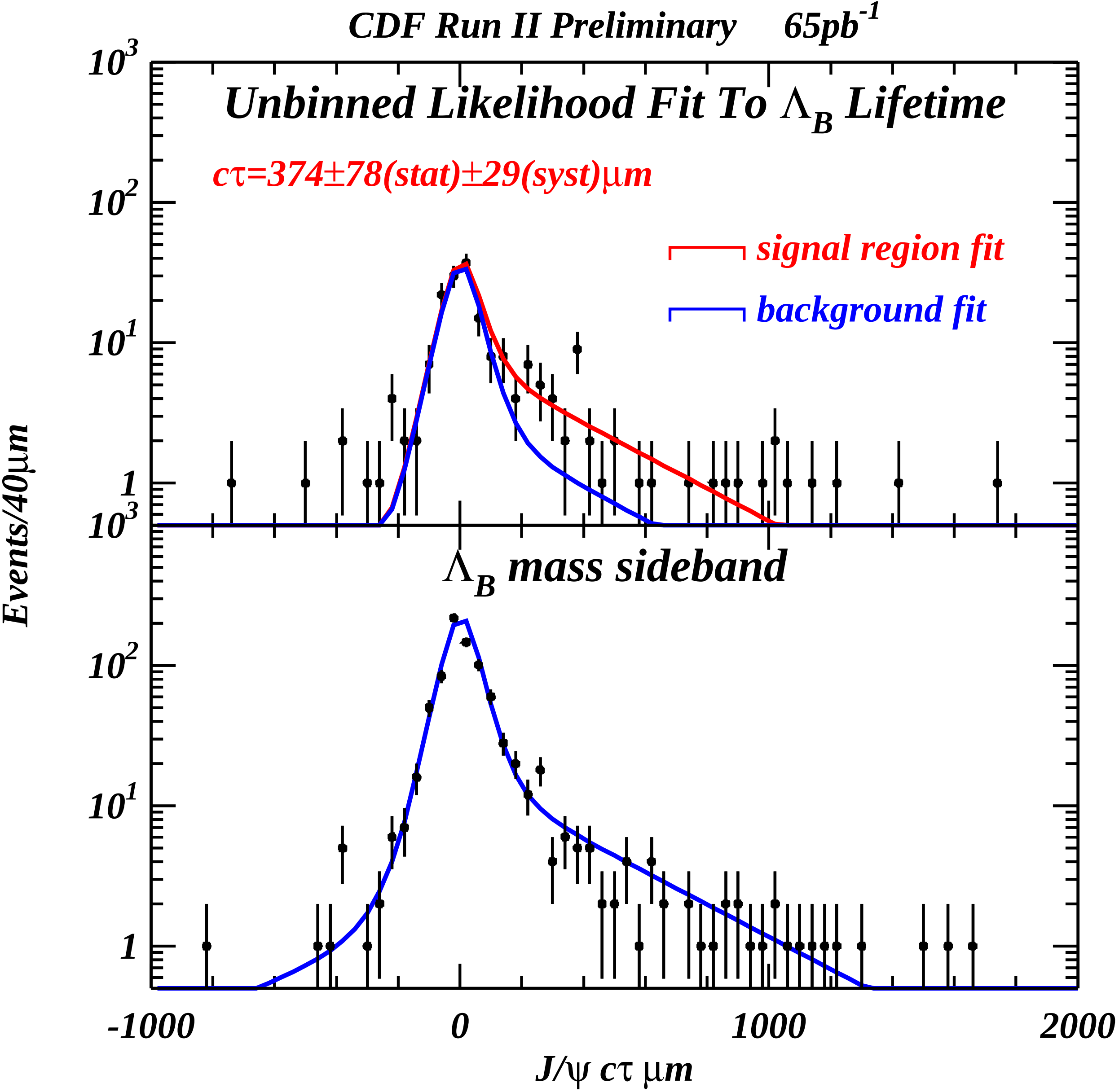
Bs: $\tau = 1.330 + 0.148(stat) - 0.129(stat) \pm 0.02\ (syst)$ ps

Also uses a similar multivariate fitting technique in the mass and the lifetime.

$B_S \rightarrow J/\psi\ \phi$





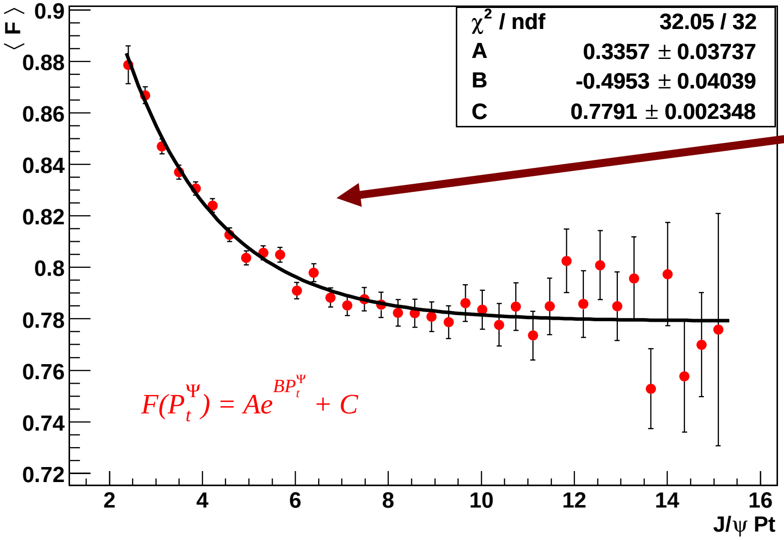


Λ_B->J/ψ Λ Lifetime: Separate fits to sig. and sideband.

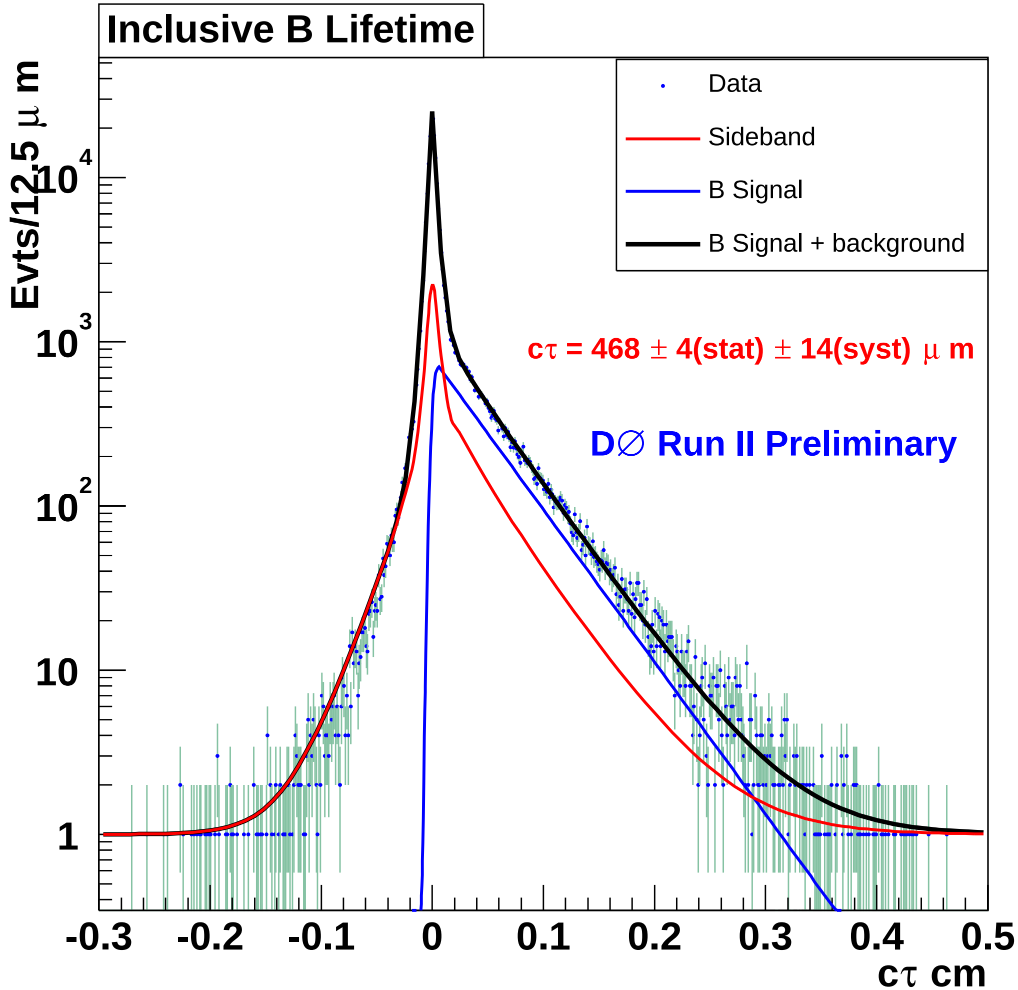
B^0->J/ψ K_S acts as a contol sample due to very similar decay geometry.

Largest systematic is from an asymmetric track reconstruction in the COT ~26μm.

Work is in progress to add more data and use better track reconstruction.



Inclusive B->J/ψ X
Need to correct for the missing Momentum - use Monte Carlo



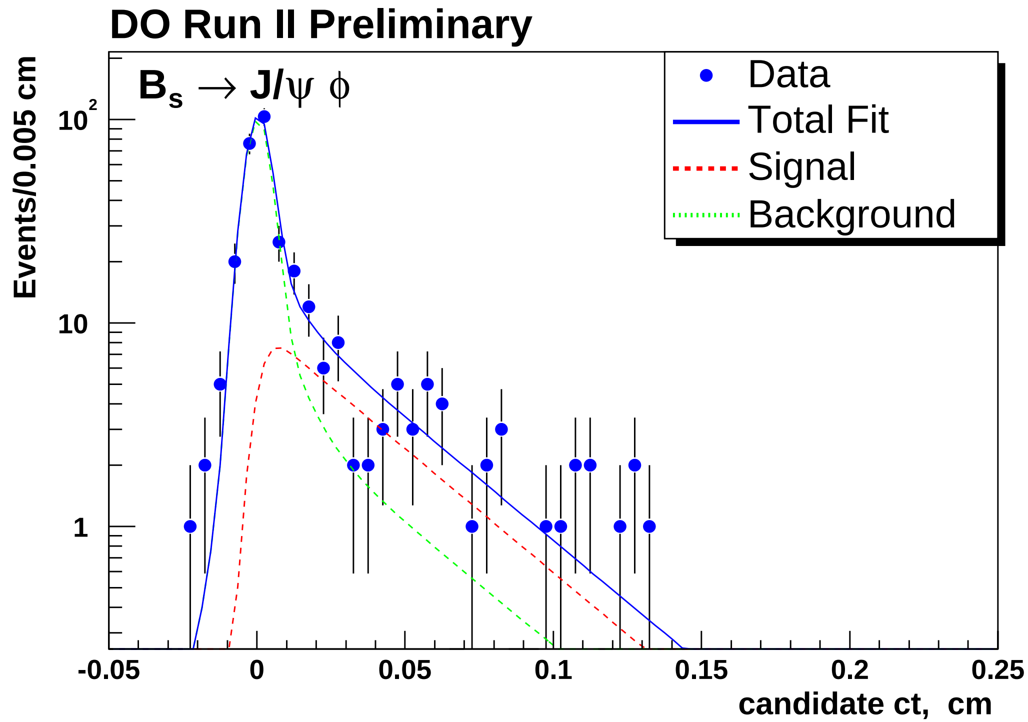
~18% of the J/y sample are from B decays.

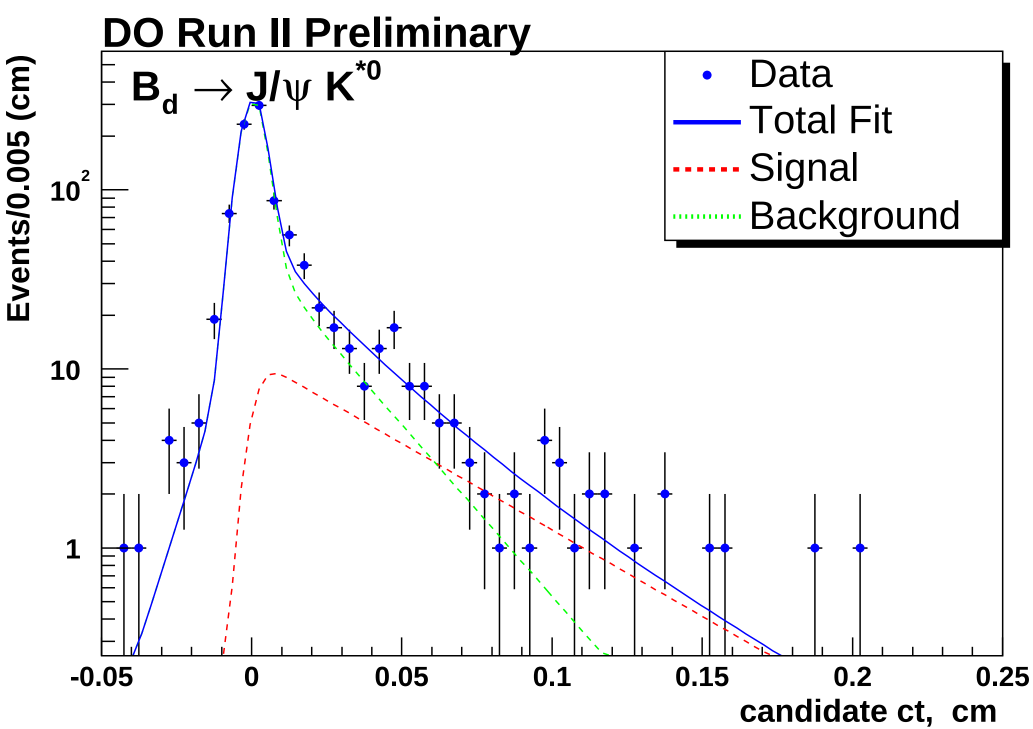
Similar percentage seen at CDF

Procedure B:

Simultaneous fit to the mass and lifetime.

$$\int Ldt \cong 115\ pb^{-1}$$





$$\tau_{Bs} = 1.19^{+0.19}_{-0.16}(stat) \pm 0.14(sys)$$

$$\tau_{Bd} = 1.51^{+0.19}_{-0.17}(stat) \pm 0.20(sys)$$

$$\tau_{Bu} = 1.63 \pm 0.083(stat) \pm 0.096(sys)$$

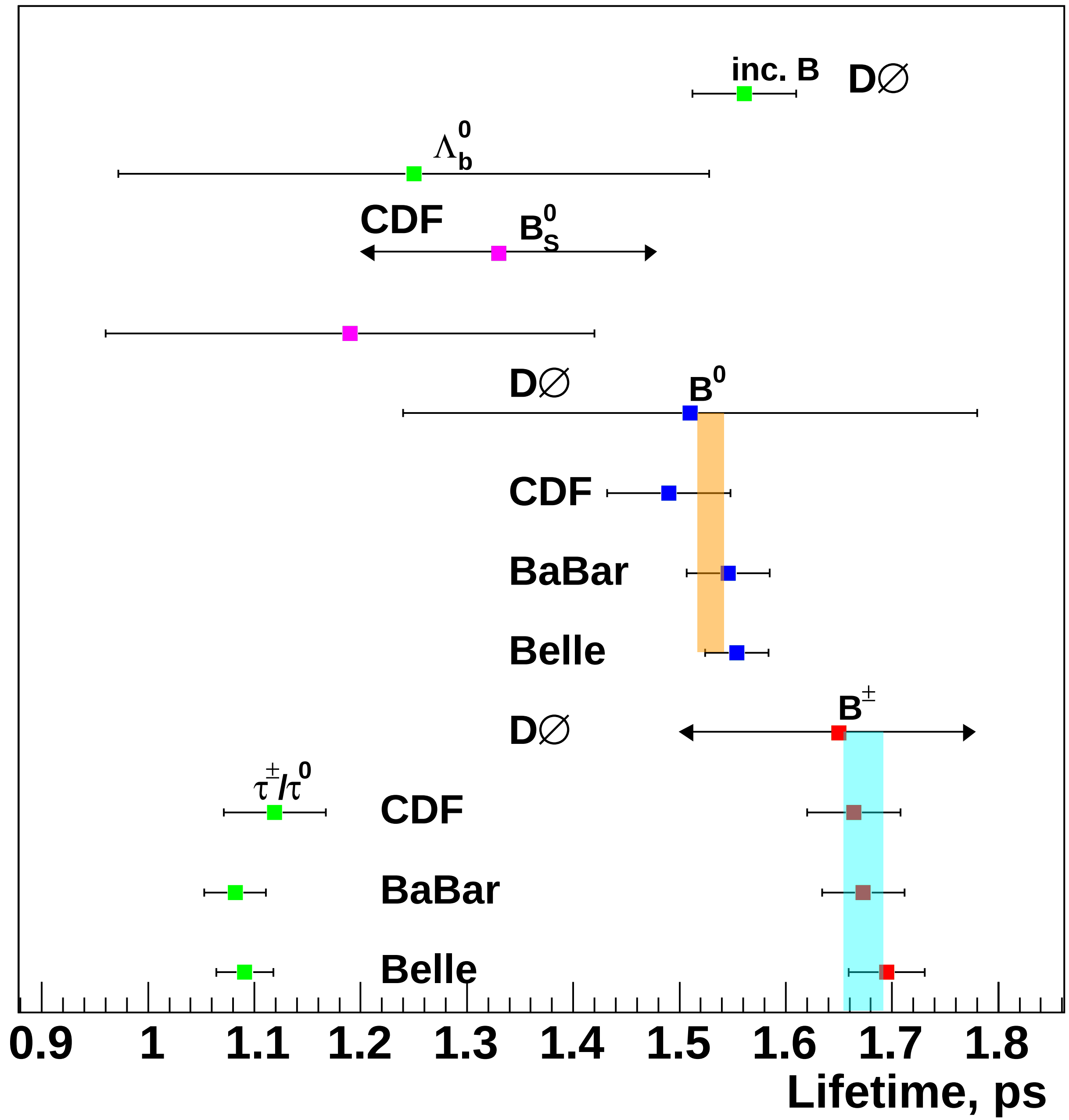
$\tau(\Lambda_b)$ is in progress.

B Hadron Lifetime and Ratio Summary

DO

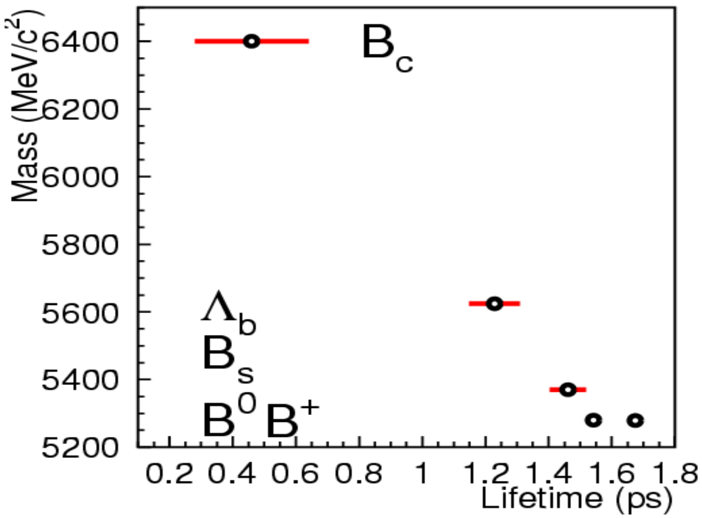
Average B^+ mass
PDG 2004

Average B^0 mass
PDG 2004



B Hadron Lifetimes:

Expectations and Existing Data



- **In the naive quark spectator model, the decay is a three body decay common to all *b* hadrons.**
- **(NLO) QCD predicted deviations in ≈ agreement with data**

	Heavy Quark Expansion	Experiment (PDG 2004)
• $\tau(B^+)/\tau(B_d)$	= 1.06± 0.02	1.086± 0.017
• $\tau(B_s)/\tau(B_d)$	= 1.00± 0.01	0.951 ± 0.038
• $\Delta\Gamma_s / \Gamma_s$	≈ 0.1	<0.54 (CL=95%)
• $\tau(\Lambda_b)/\tau(B_d)$	= 0.90 ± 0.05	0.800 ± 0.066

The goal is to measure the ratios accurately.

A Different test of the SM

- The SM predicts a relationship between mixing and the difference in decay time between CP even and CP odd states.

$$\left(\frac{\Delta\Gamma}{\Delta M}\right)_{Bs} = \frac{\pi}{2}\frac{m_b^2}{m_W^2}\left|\frac{V_{cb}V_{cs}}{V_{ts}V_{tb}}\right|^2 \times ratio\,of\;QCD\,bag\;parameters$$

Ref: hep-ph/9808385

$$\left(\frac{\Delta\Gamma}{\Delta M}\right)_{Bs} = \left(2.63^{+0.67}_{-1.36}\left(\mu_1 - dep.\right) \pm ?\right) \bullet 10^{-3}$$

μ_1 is the renormalization scale factor.

$\Delta\Gamma/\Gamma$ is also predicted for the B_S and B^0
CDF and D0 expect to measure it!

$$\frac{\Delta\Gamma_S}{\Gamma_S} \Rightarrow 2\% \quad @\ 4\text{fb}^{-1}$$

Pentaquark Search

NA49 also claimed observations of the pentaquark cascade (Ξ) states. (hep-ex/0310014)

CDF New Search:

Search conducted in:

Hadronic Two Track & Jet20 triggers

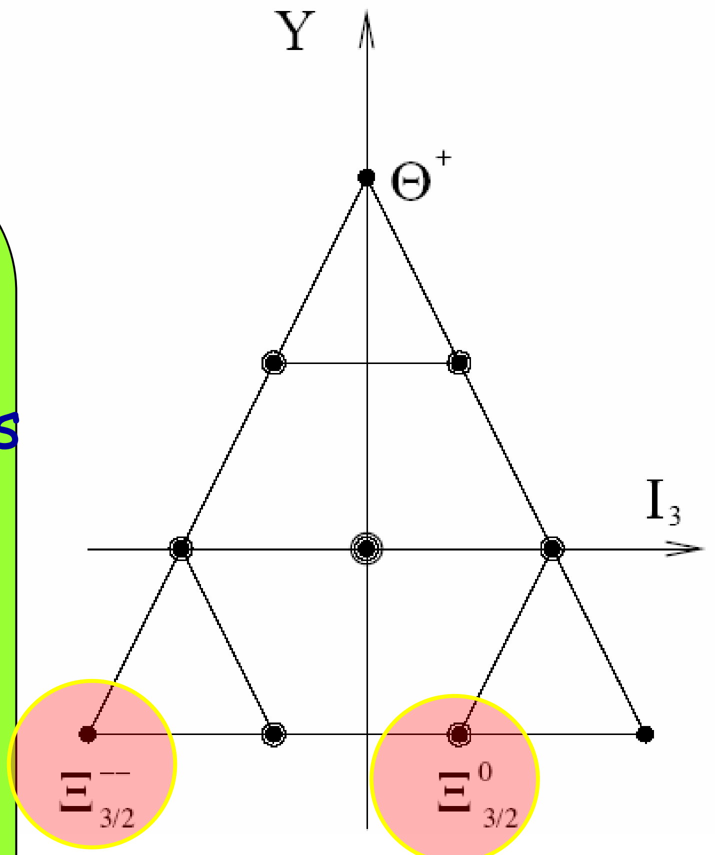
Trig. tracks not explicitly required

Decay Chains for Search:

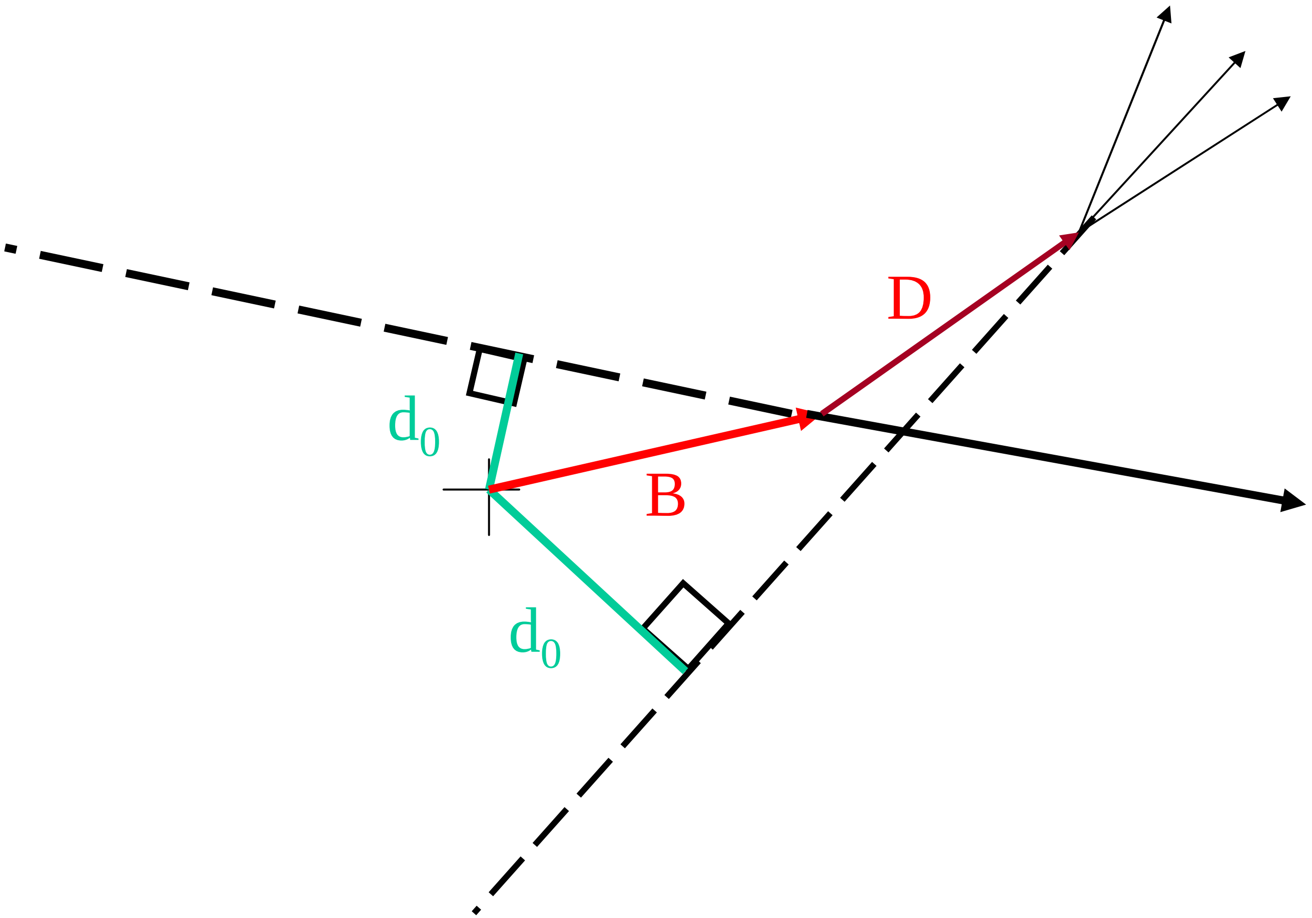
$\Xi^{--} \rightarrow \Xi^- \pi^-$ and $\Xi^0 \rightarrow \Xi^- \pi^+$

$\Xi^- \rightarrow \Lambda \pi^-$ with $\Lambda \rightarrow p\pi$

Ξ^- leaves hits in the silicon detector.



CDF
Impact parameter Trigger

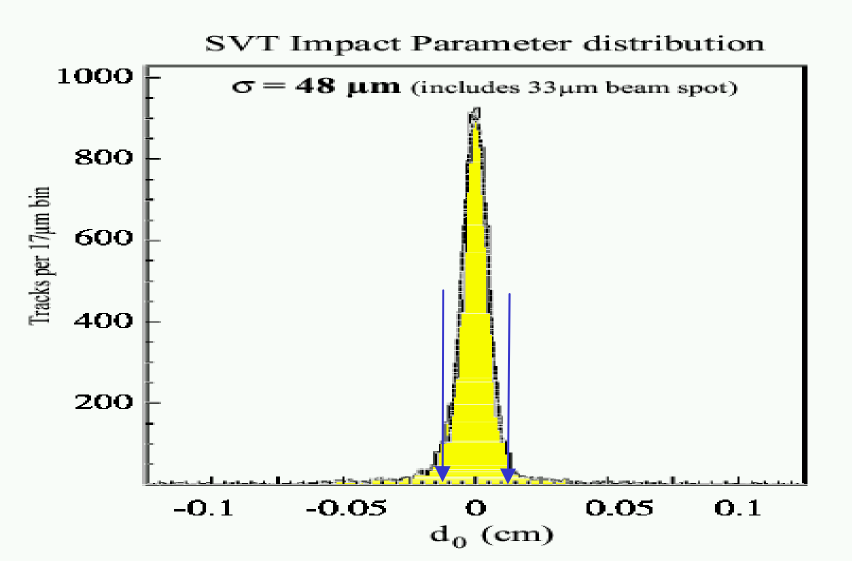


If we have B mesons, we get tracks with high impact parameter.

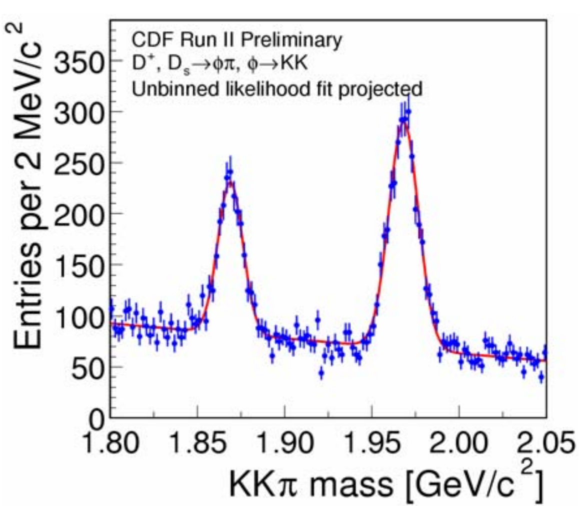
Data Samples: B and Charm Using the high Impact Parameter (IP) (Hadronic) trigger

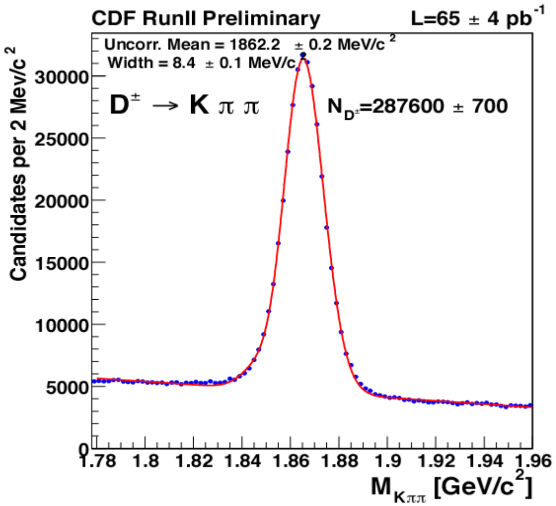
Select events by requiring :
- -2 tracks with IP>100 μm
- Opposite charge
- track P_T > 2GeV/c
- sum 2-track P_T > 5.5 GeV/c

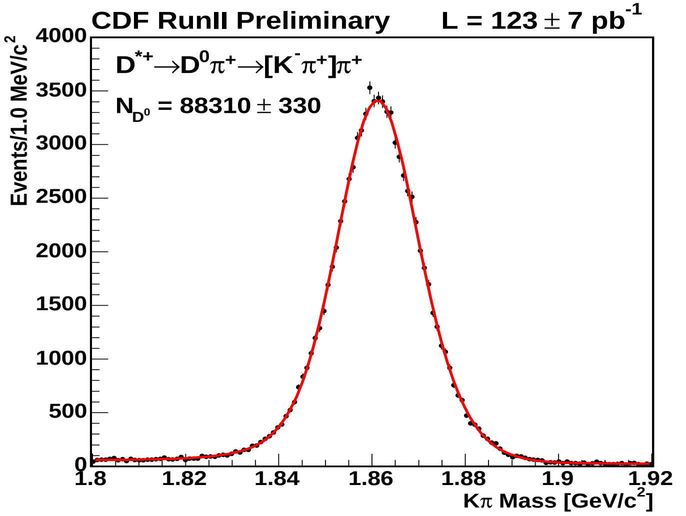
35μm ⊕ 33μm
resol ⊕ beam
⇒ σ = 48μm



0.5M Charm decays at CDF → 10-20% come from B: Great Potential for B and Charm Physics, opens at least as many avenues as J/ψ trigger





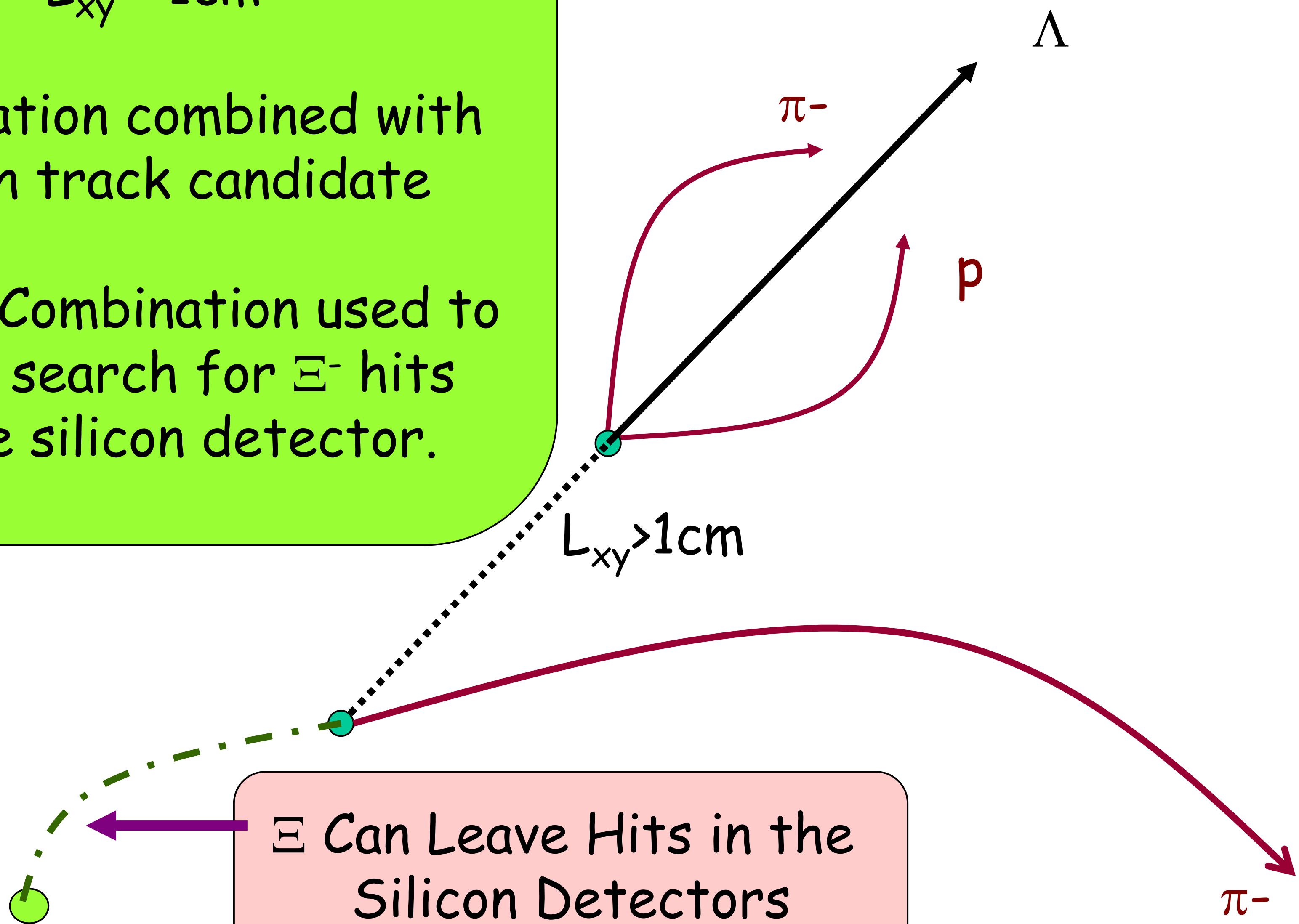


Finding Ξ^-

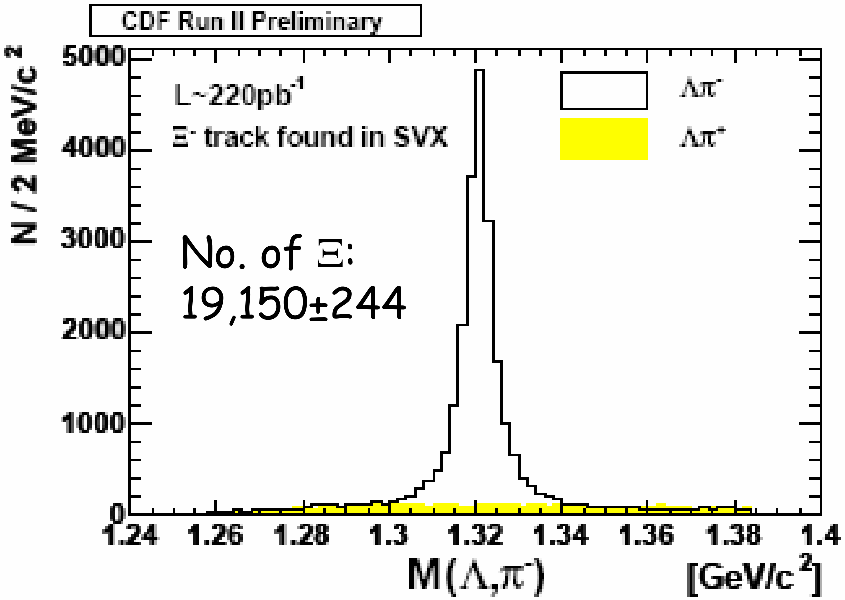
All opposite sign tracks
within 5MeV/c^2 of Λ mass
L_{xy} > 1cm

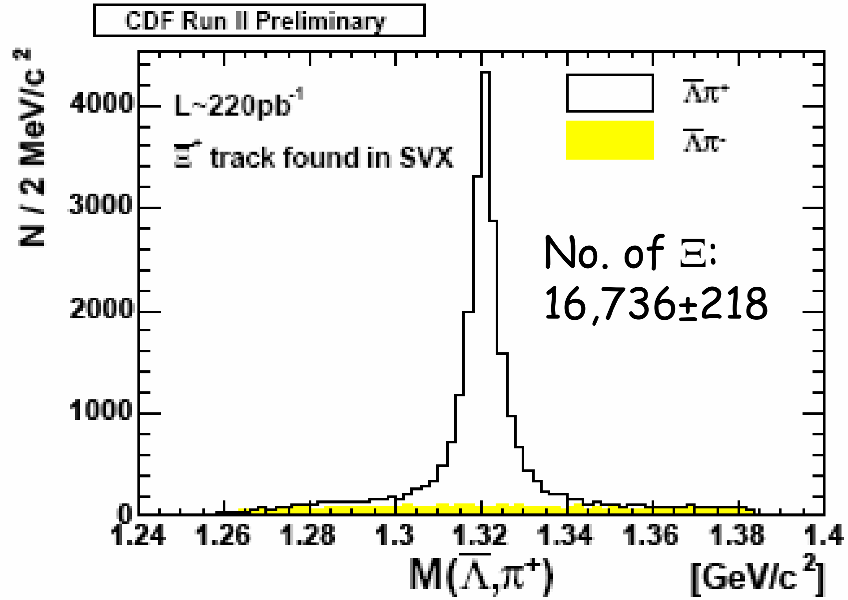
Combination combined with
a pion track candidate

3-track Combination used to
seed a search for Ξ^- hits
in the silicon detector.



Ξ Can Leave Hits in the
Silicon Detectors

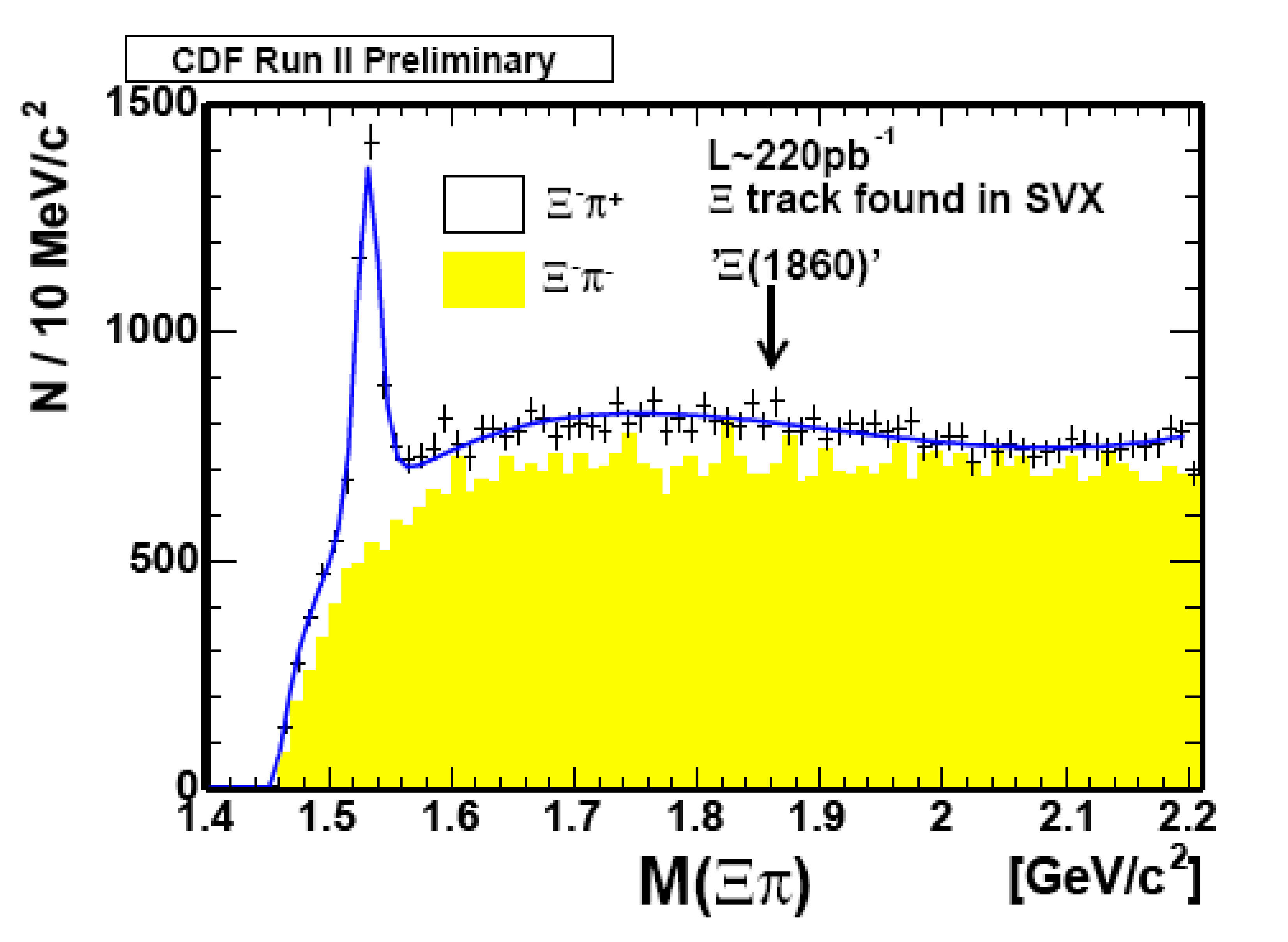




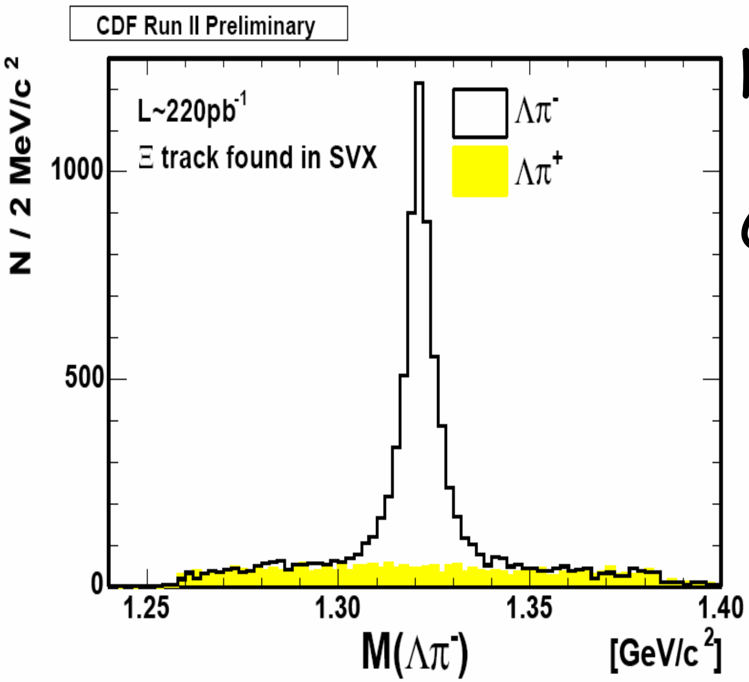
Combine the Ξ- (and charge conjugate) candidates with another pion to look for the Ξ(1860) Pentaquark state. We also expect to see the standard Ξ(1530).

Yield of Ξ(1860) relative to Ξ(1530) yield could be used to calibrate yields for CDF unless there is severe penalty in production mechanism for Ξ(1860) in *p-pbar* collisions at 2 TeV vs low energy (18 GeV) *pp* collisions of CERN SPS.

Pentaquark Search – TTT Data

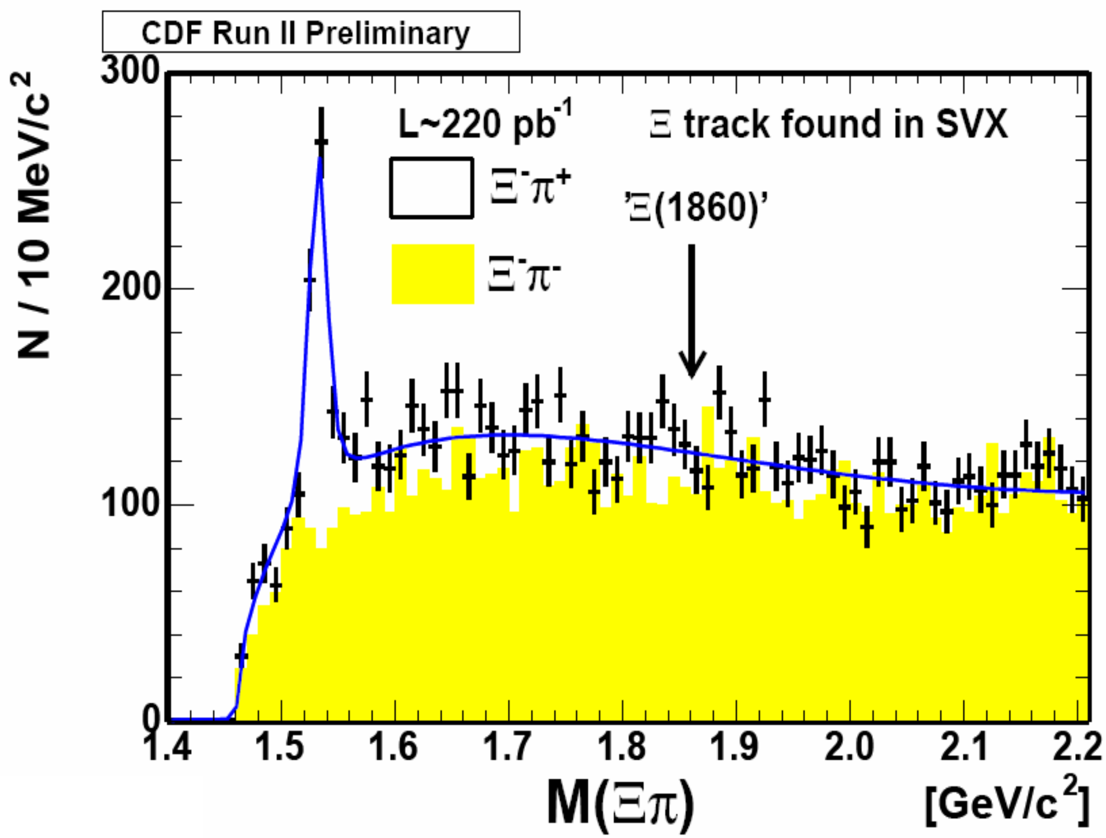


Pentaquark Search – Jet20 Data



No equivalent signal found.

CDF cannot confirm NA49 observation



More Jet 20 data

Also looking for Θ but search is not complete.

Pentaquark Production Limits

- Yields quoted relative to the production of the Ξ(1530) which is seen in both data sets.

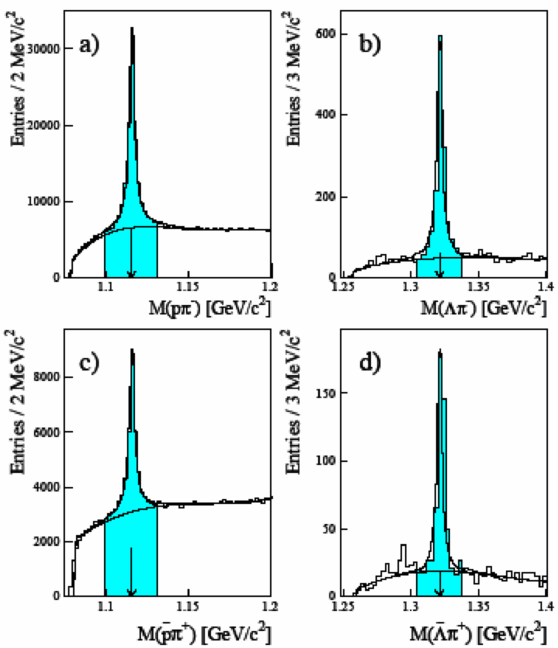
Channel	@ 90% CL	@ 95% CL
Two Track Trigger Sample – 220pb^{-1}		
$\Xi^- \pi^+/\Xi(1530)$	0.06	0.07
$\Xi^- \pi^-/ \Xi(1530)$	0.03	0.04
Combined Sample	0.07	0.08
Jet 20 Trigger Sample – 220pb^{-1}		
$\Xi^- \pi^+/ \Xi(1530)$	0.06	0.08
$\Xi^- \pi^-/ \Xi(1530)$	0.07	0.09
Combined Sample	0.09	0.11

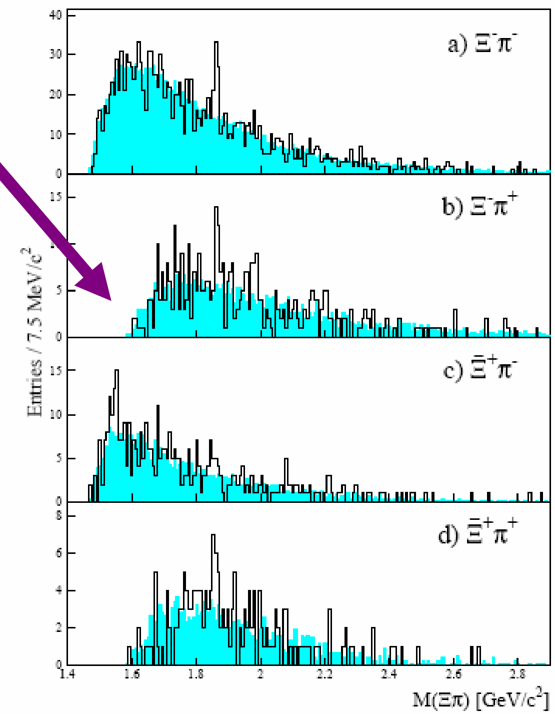
Conclusions

Back-up Slides

NA49 Digest

3.0 GeV/c cut on π+ momentum removes Ξ^0(1530) state due to phase space.





NA49 Digest

$$N(\Xi^-) = 1,640$$

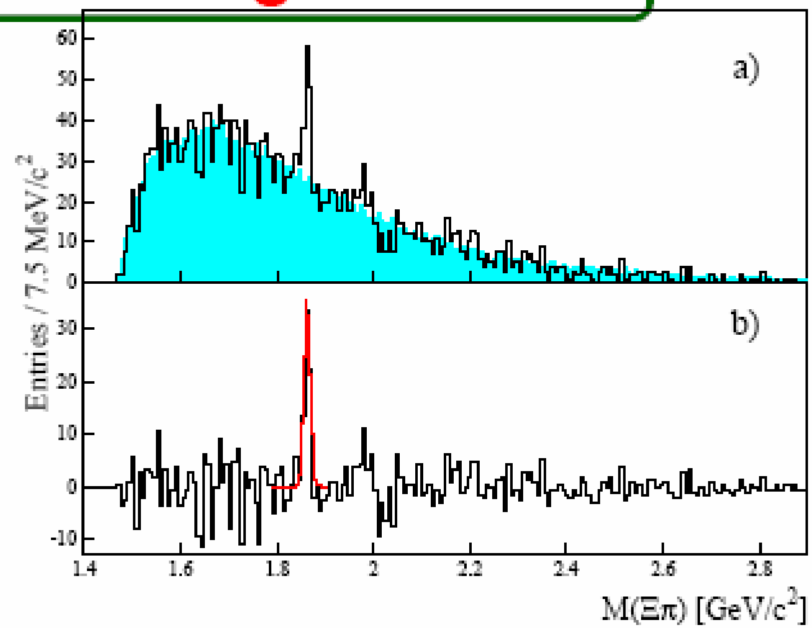
$$N(\bar{\Xi}^+) = 551$$

$$N(\Xi(1530)^0) \sim 150$$

$$N(\Xi(1860)) = 67.5$$

$$N(\Xi(1860)^{--}) = 36$$

$$N(\Xi(1860)^0) = 31.5$$



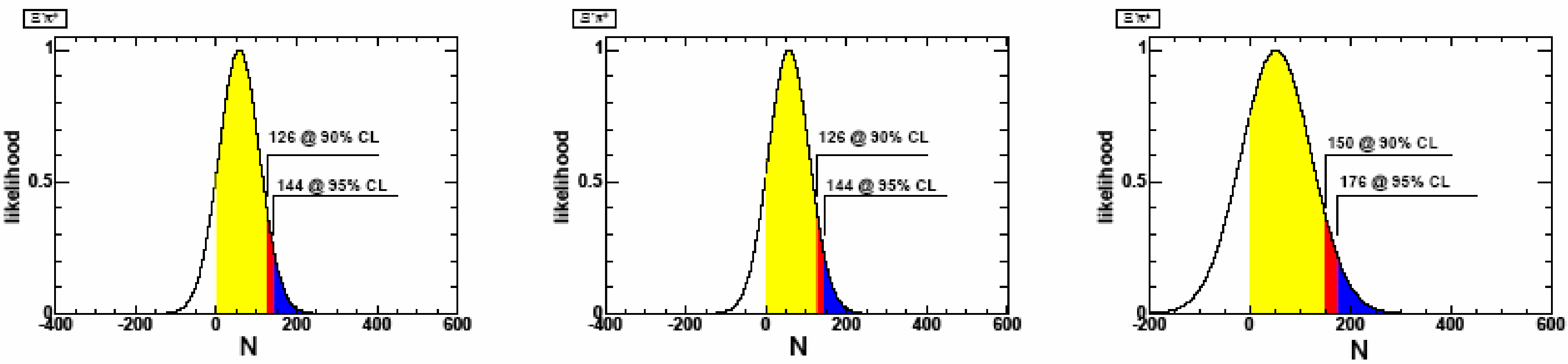
$$r^0_{NA49} = \frac{\#\Xi(1860)}{\#\Xi(1530)} = \frac{\sigma(pp \to \Xi(1860)) \cdot Br(\Xi(1860) \to \Xi^-\pi^+) \cdot a(\Xi(1860))}{\sigma(pp \to \Xi(1530)) \cdot a(\Xi(1530))} \sim 0.21, \quad (1)$$

$$r^{--}_{NA49} = \frac{\#\Xi(1860)}{\#\Xi(1530)} = \frac{\sigma(pp \to \Xi(1860)) \cdot Br(\Xi(1860) \to \Xi^-\pi^-) \cdot a(\Xi(1860))}{\sigma(pp \to \Xi(1530)) \cdot a(\Xi(1530))} \sim 0.24, \quad (2)$$

$$r_{NA49} = \frac{\#\Xi(1860)}{\#\Xi(1530)} = \frac{\sigma(pp \to \Xi(1860)) \cdot Br(\Xi(1860) \to \Xi^-\pi^\pm) \cdot a(\Xi(1860))}{\sigma(pp \to \Xi(1530)) \cdot a(\Xi(1530))} \sim 0.45 \quad (3)$$

$$\frac{\sigma(pp \to \Xi(1530)) \cdot a(\Xi(1530))}{\sigma(pp \to \Xi) \cdot a(\Xi)} \sim 0.068 \quad (4)$$

Limit Determination

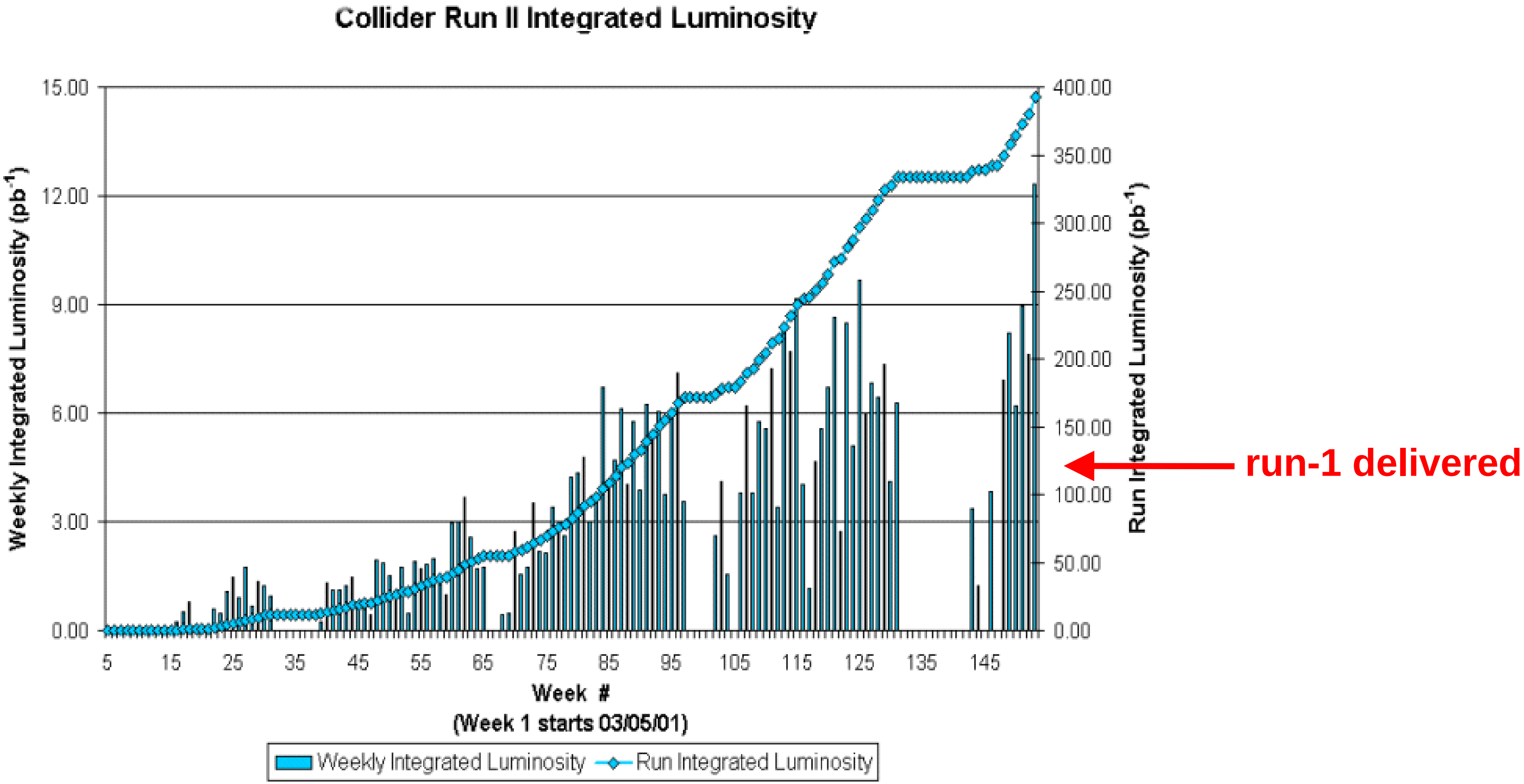


Fit to Gaussian + background, float only the background.

Find Likelihood for N Ξ(1860)'s where N is varied from -1000 to +1000 and plot that Likelihood (see above). 90% and 95% CL's are then taken from this plot.
If you don't like this:
talk to Louis Lyons, Chairman of the CDF Statistics

Pentaquark search

- Bound state of 5 quarks $(qqqq\bar{q})$
- Several possible states are predicted and some have claims to being found
  - LEPS at Spring-8 (Japan), Phys. Rev. Lett., 92, 012002 (2003).
  - ITEP DIANA Collaboration, hep-ex/0304040.
  - CLAS Collaboration at JLAB, hep-ex/0307018.
  - These report on the state. $(dsds\bar{u})$

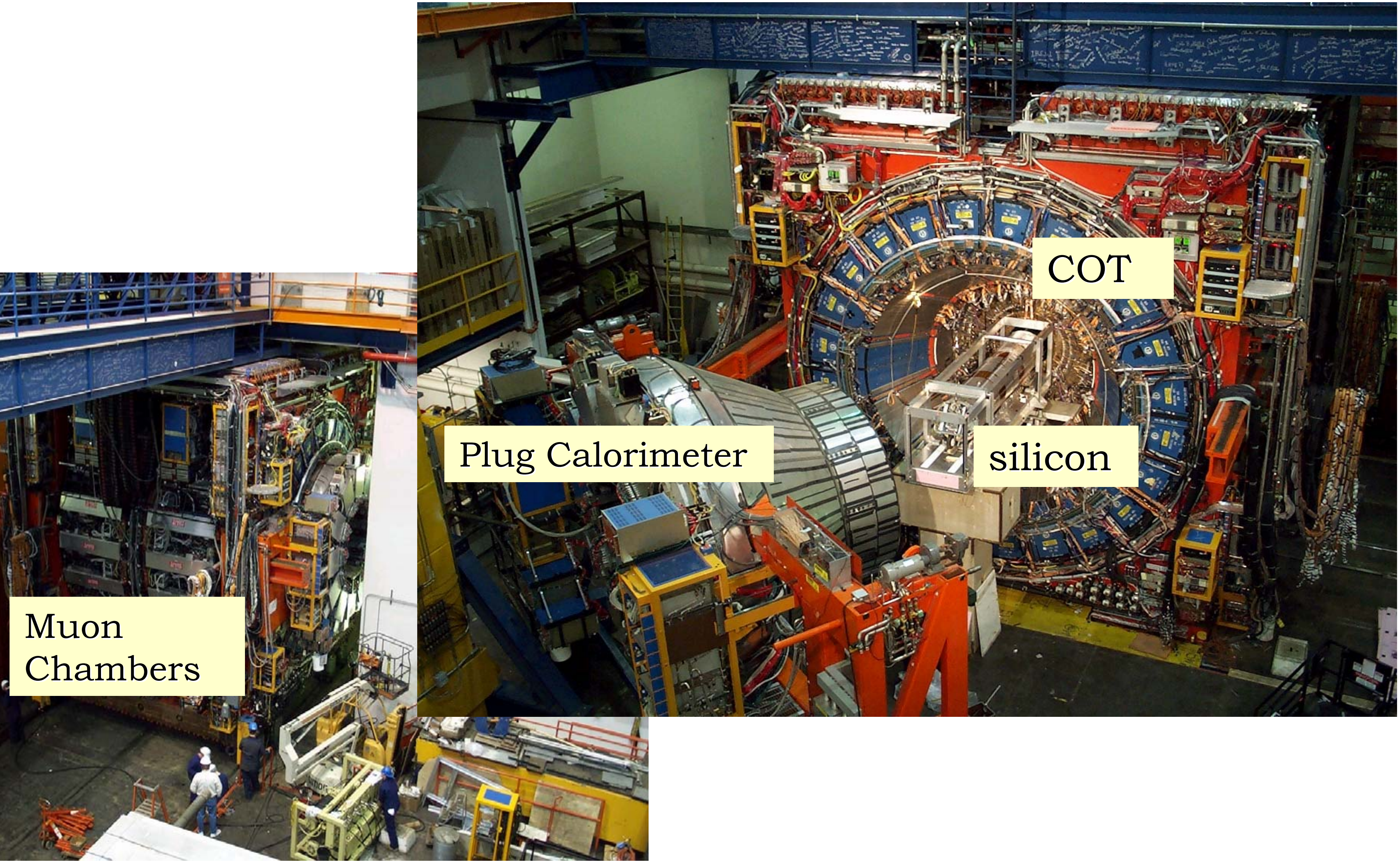


- to ensure success of run-2 the below expectation Tevatron performance has been the main focus at FNAL/DOE in the past 14 months.

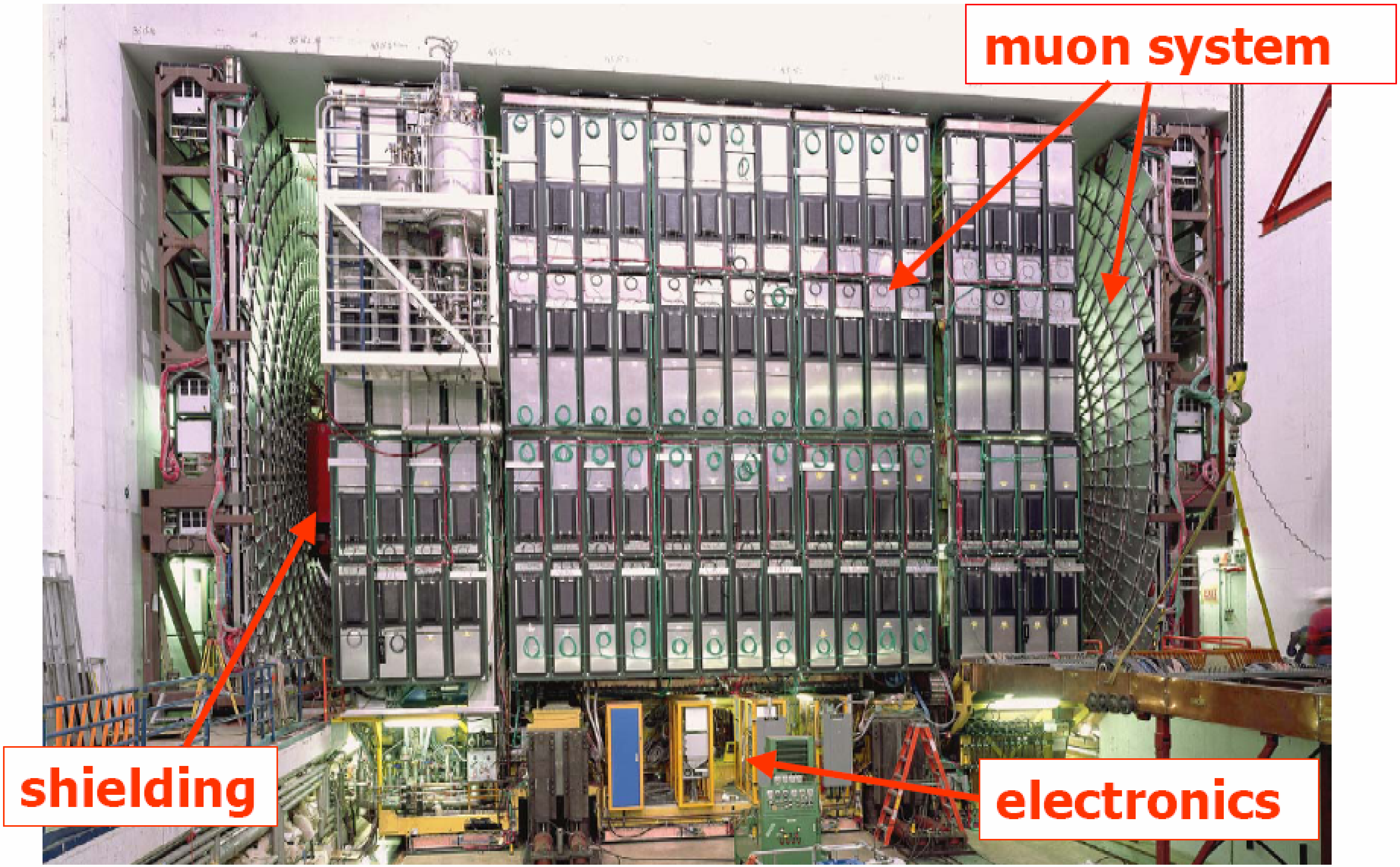
- We are seeing the positive impact of this attention! The Tevatron is certainly running up to the standard required to meet the baseline of $4fb^{-1}$ by 2008.

- This means we can begin to hope and plan for beyond baseline luminosities.

The CDF-II Detector



The D0 Detector



The CDF & D0 Detectors in Run-II

New: Time of Flight (TOF): some hadron ID

New: Silicon (SVT) online Si tracker: Select high IP tracks from b and c @ trigger level (First time at a hadron collider !)

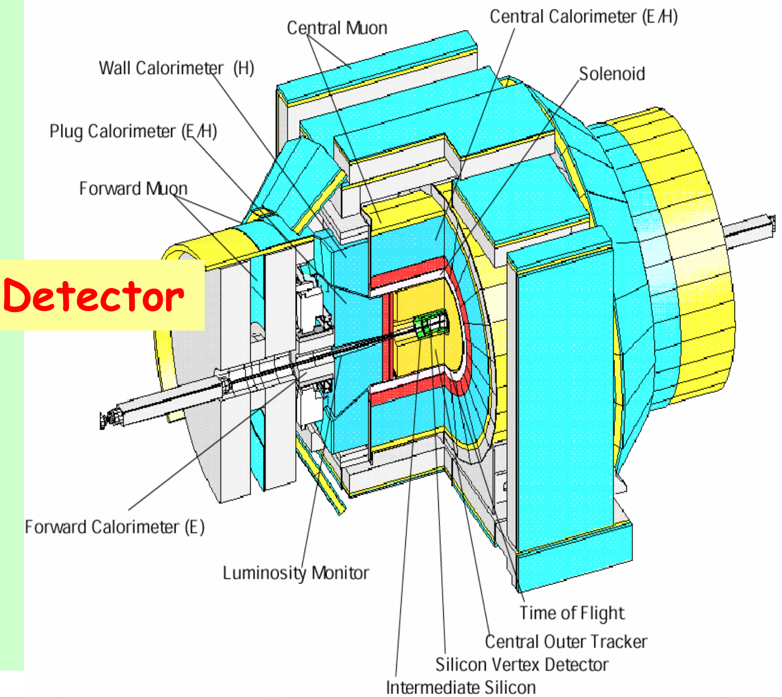
Improvements over Run-I

-Silicon Detector : 3-D tracking, 5 layers: B vertex, track IP resolution,

-Faster Drift Chamber : Momentum measurement

-Greater muon coverage : Select b, c → μ

CDF Detector



New : 2T Super conducting Magnet

New: Silicon tracker (vertex, track IP resolution)

New: Fiber tracker : Momentum

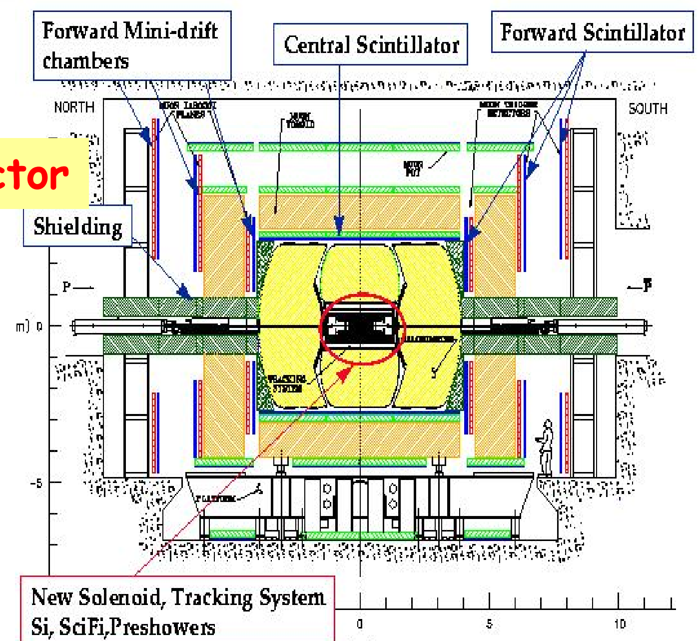
New: Si Track Trigger (displaced vertices) (Coming soon)

Improvements over Run-I

-Calorimetry and faster readout

-Upgraded muon system.

D0 Detector

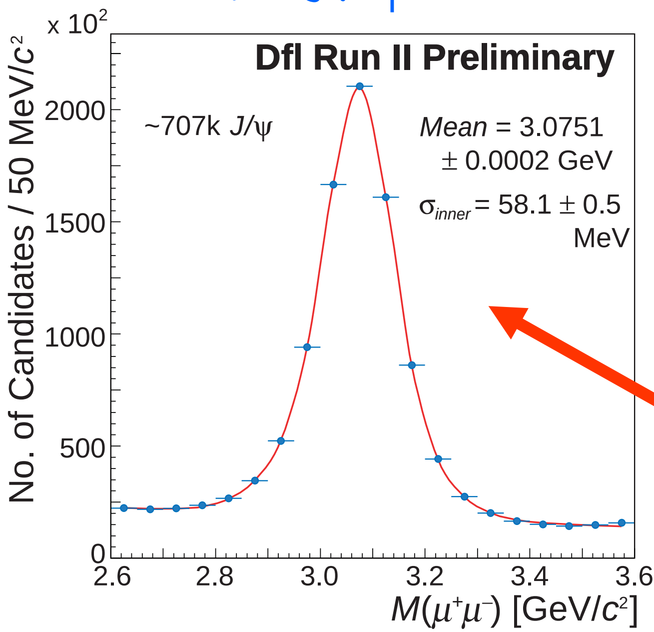


D0 has a magnetic field, and is able to pursue a competitive B-physics program as well !

Detector Performance

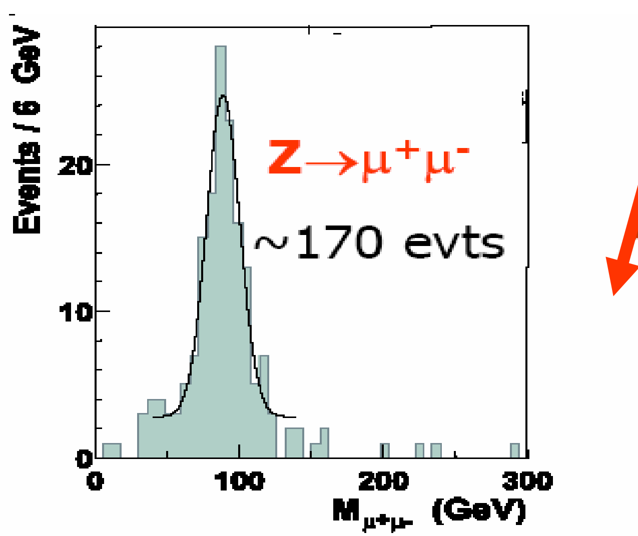
D0

The J/ψ



Combining Tracking with other systems

Muon system



Calorimeter