Observation of the Ω_b^- and Measurements of the Properties of the Ξ_b^- and Ω_b^-

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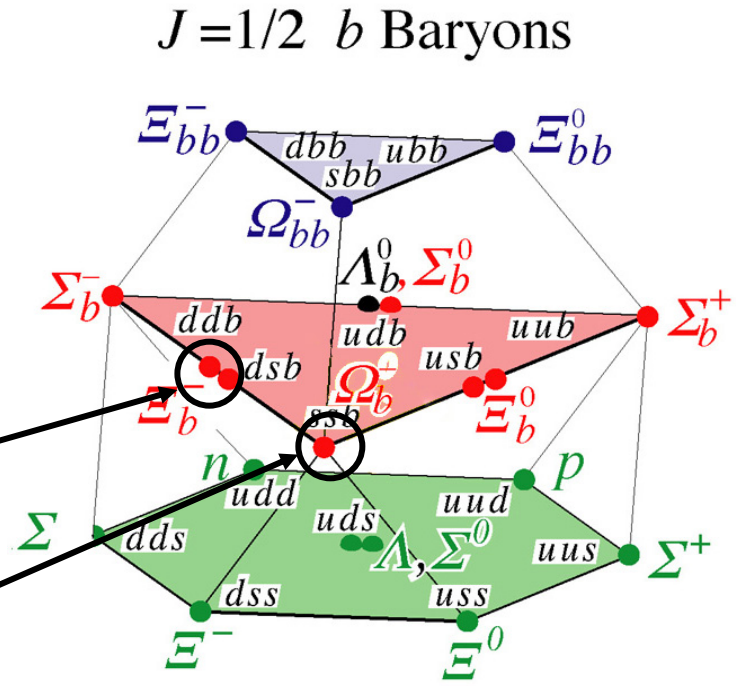
Baryon Ground States

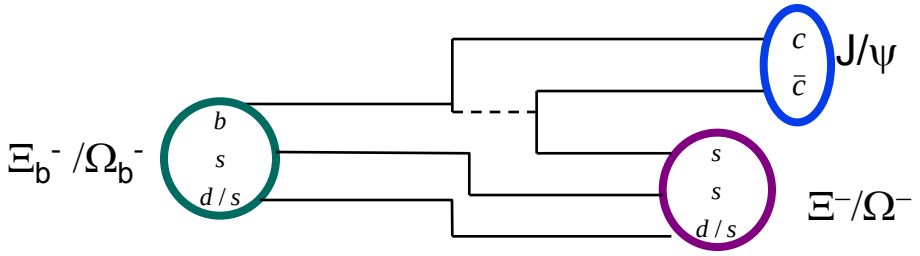
- This is a report on *b*-baryon property measurements
  - Fully reconstructed states
- This analysis measures properties of two of the most recently observed *b*-baryons
  - Ξ_b^-, observed in 2007
    - D0: 15, CDF: 18
  - Ω_b^-, observed by D0 in 2008
    - D0: 18



- This analysis is described in arXiv:0905.3123.

B Hadron Program

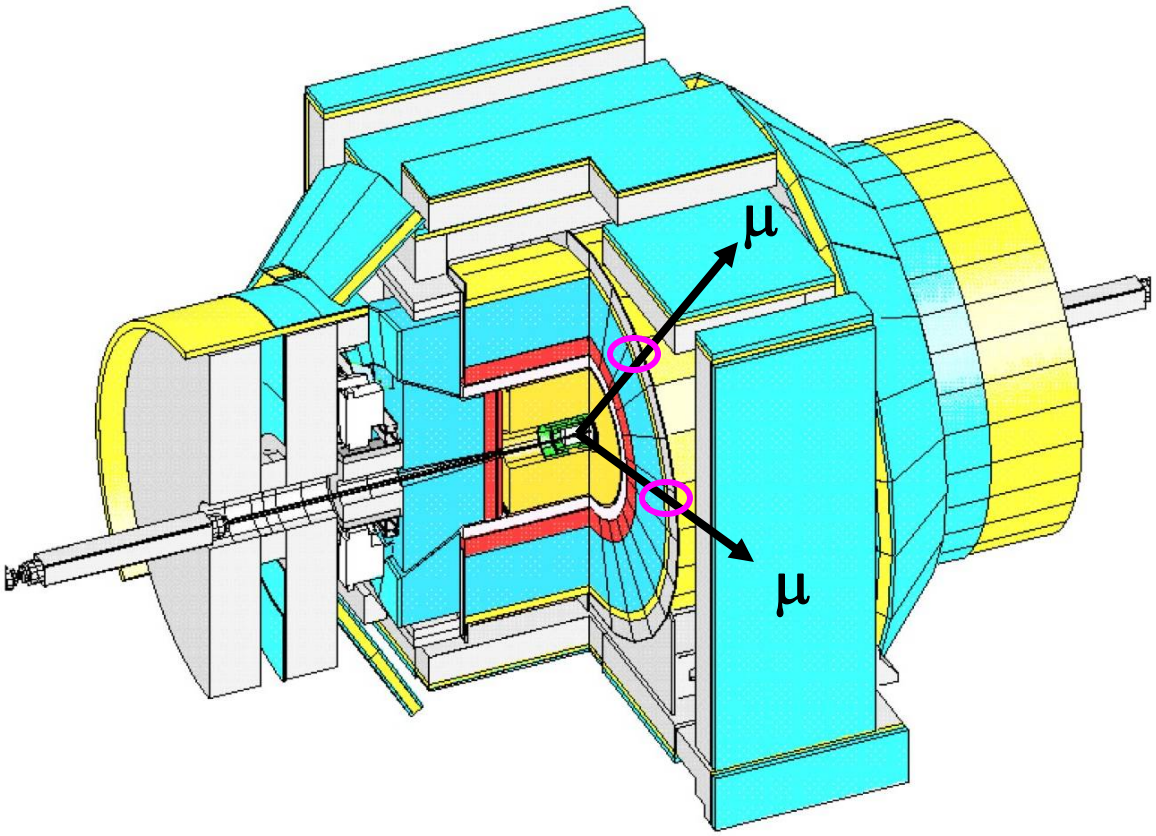
- The data set is from our di-muon trigger
  - $J/\psi \rightarrow \mu^+\mu^-$ in the final state
- We search for the Ξ_b^- and Ω_b^- through the processes
  - $\Xi_b^- \rightarrow J/\psi\, \Xi^-$, $J/\psi \rightarrow \mu^+\mu^-$, $\Xi^- \rightarrow \Lambda\pi^-$
  - $\Omega_b^- \rightarrow J/\psi\, \Omega^-$, $J/\psi \rightarrow \mu^+\mu^-$, $\Omega^- \rightarrow \Lambda K^-$
- This data set contains many *b*-meson candidates
- Therefore, the mesons and Λ_b are used as references
  - $B^0 \rightarrow J/\psi\, K^{*0}$, $J/\psi \rightarrow \mu^+\mu^-$, $K^{*0} \rightarrow K^+\pi^-$
  - $B^0 \rightarrow J/\psi\, K_s^0$, $J/\psi \rightarrow \mu^+\mu^-$, $K_S^0 \rightarrow \pi^+\pi^-$
  - $\Lambda_b \rightarrow J/\psi\, \Lambda$, $J/\psi \rightarrow \mu^+\mu^-$, $\Lambda \rightarrow p\pi^-$



- The baryon program is a natural extension of a larger *b*-meson program
- Similar selection and techniques are used for all species.

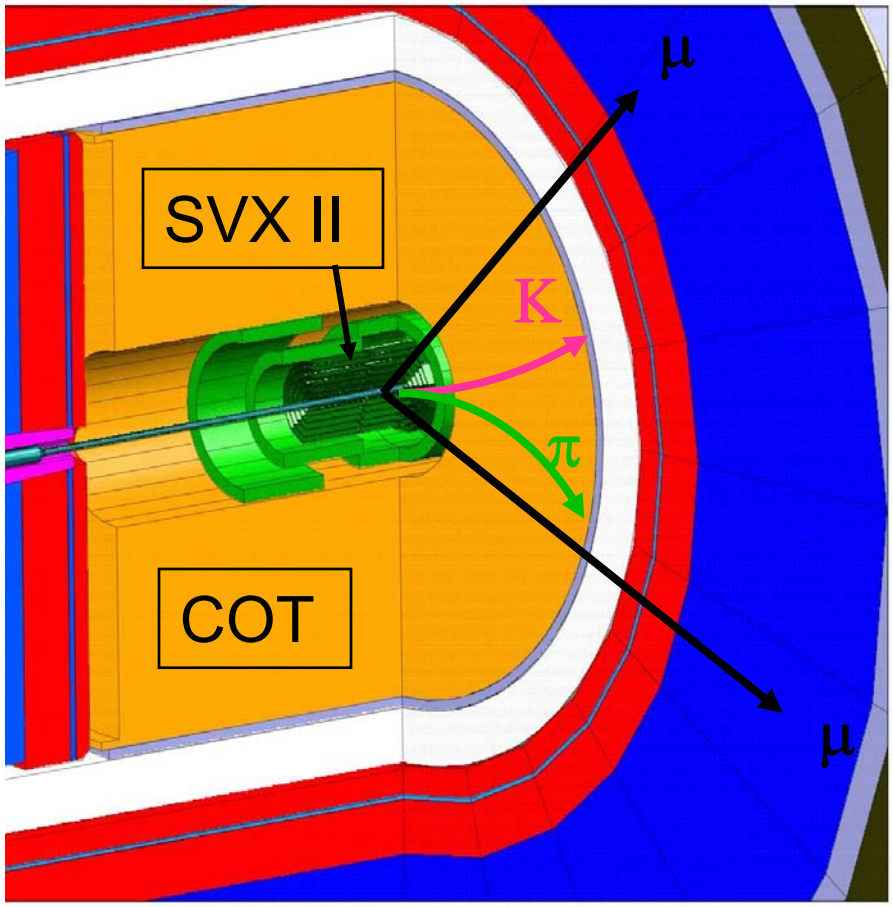
The CDF II Detector

- The data used in this analysis was collected with the CDF II Detector.
  - This analysis uses data from 4.2 fb^{-1}.
- The trigger requires
  - Tracks in muon chambers
  - Tracks in the central tracking chamber (COT) (p_T>1.5 GeV)
  - 2.7<M($\mu^+\mu^-$)<4.0 GeV/c^2
- Unbiased with respect to decay time for *b*-hadrons



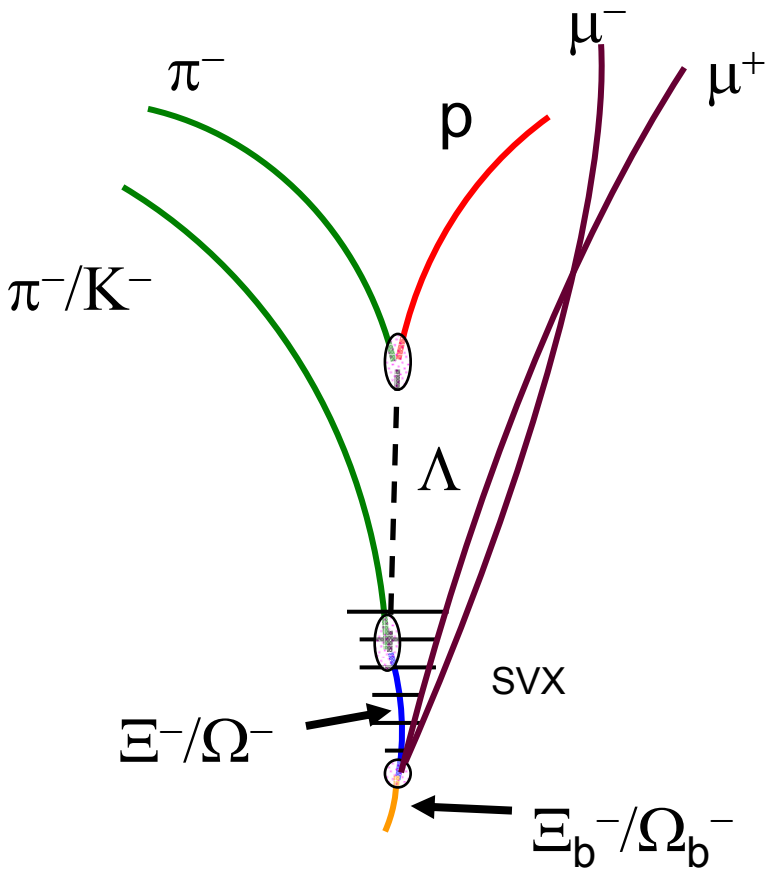
The CDF II Tracker

- Events that satisfy the trigger are fully analyzed.
- Track reconstruction identifies all tracks with p_T>0.4 GeV/c
- Three SVX II measurements are required for muon tracks.
  - Not used for p/K/π tracks



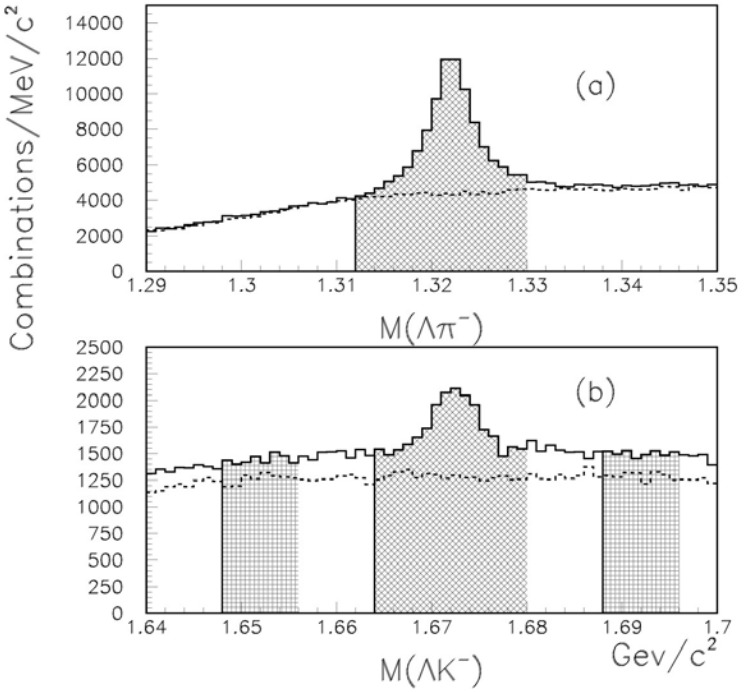
Ξ_b^-/Ω_b^- Reconstruction

- The Ξ_b^-/Ω_b^- reconstruction is complicated
  - 5 tracks, 3 vertices
- Same techniques used for the neutrals can be applied
- Constrained fit is imposed on the final state
  - Constrains topology
  - Constrains Λ, Ξ^-/Ω^-, and J/ψ masses
- The long life of the Ξ^- and Ω^- opens the possibility of using the silicon detector on the 6th track in the process.
  - Impact resolution improvement



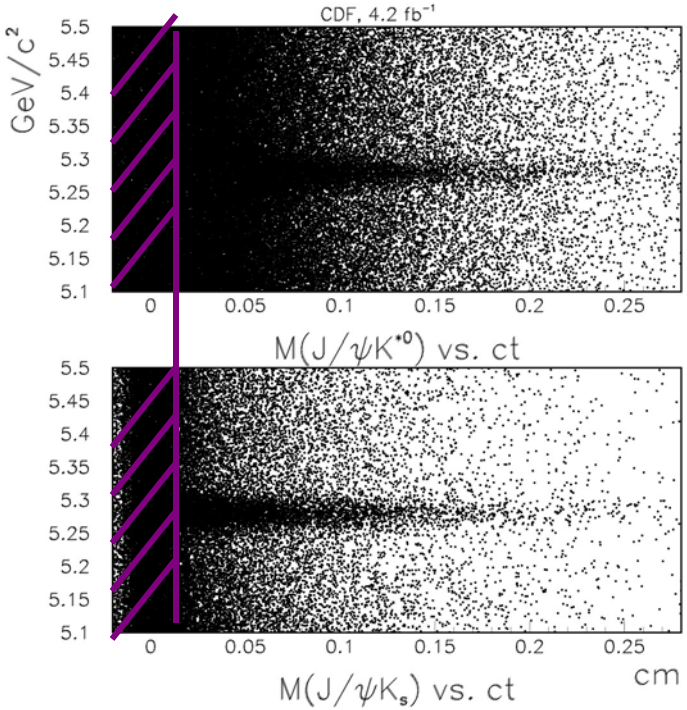
Inclusive Ξ^-/Ω^- Sample

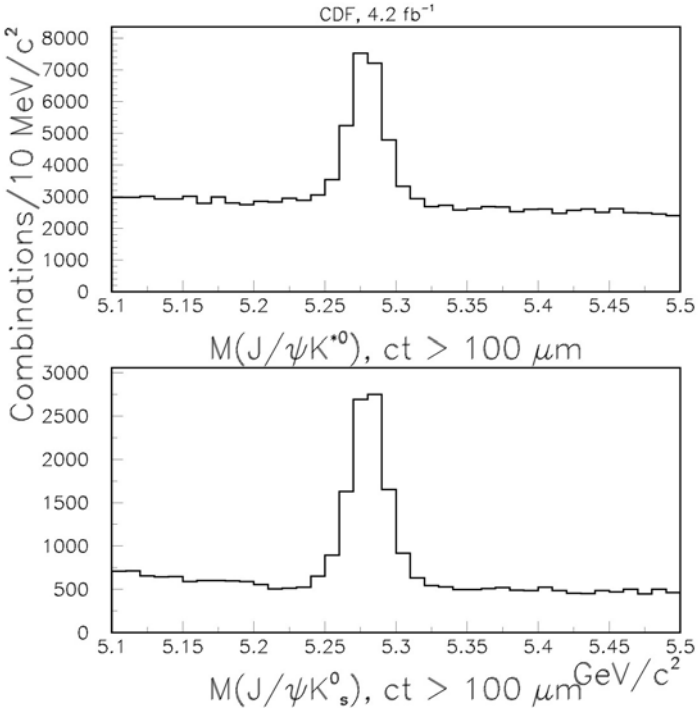
- The analysis is based data collected from 4.2 fb^{-1} of collisions.
- Yields in the full sample
  - J/ψ: 2.9×10^7
  - Λ: 3.6×10^6
  - Ξ^- : 41,000
  - Ω^-: 3,500



- Dashed histograms are $\Lambda\pi^+/K^+$
- Shaded are selection and sideband regions

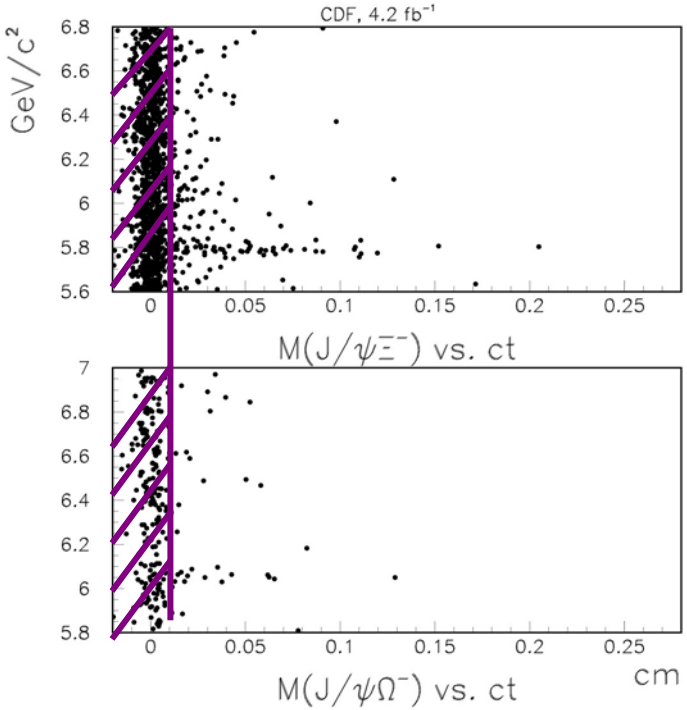
b-meson signals at CDF

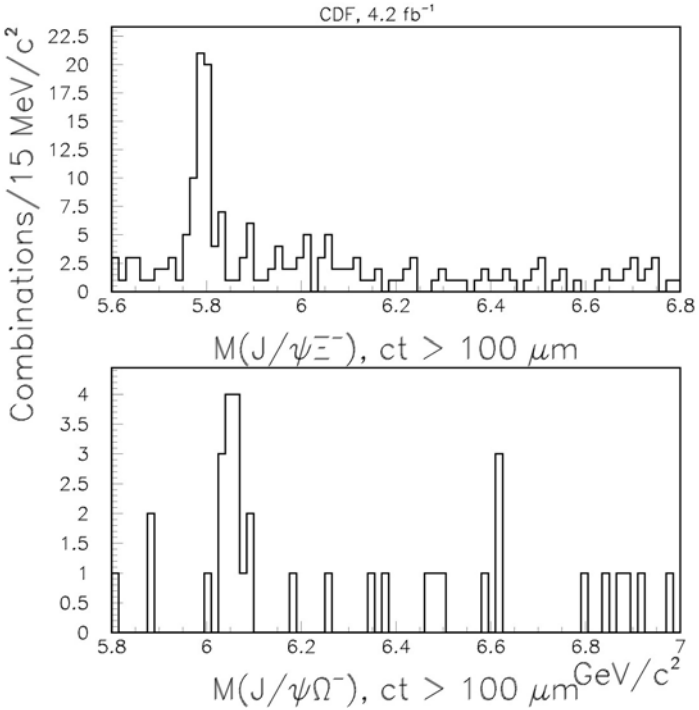




- Decay time selects B hadron signals from the prompt background
  - ct > 100 μm requirement removes most prompt background

b-baryon signals at CDF



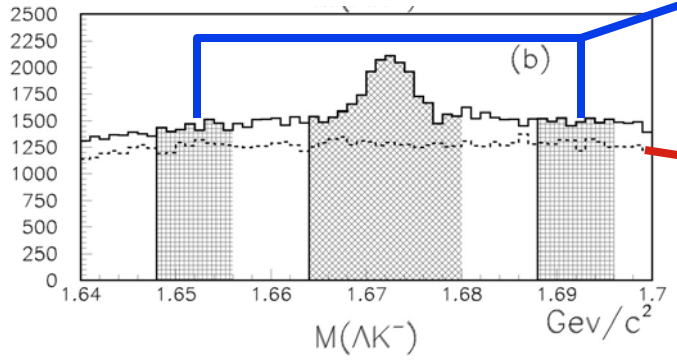


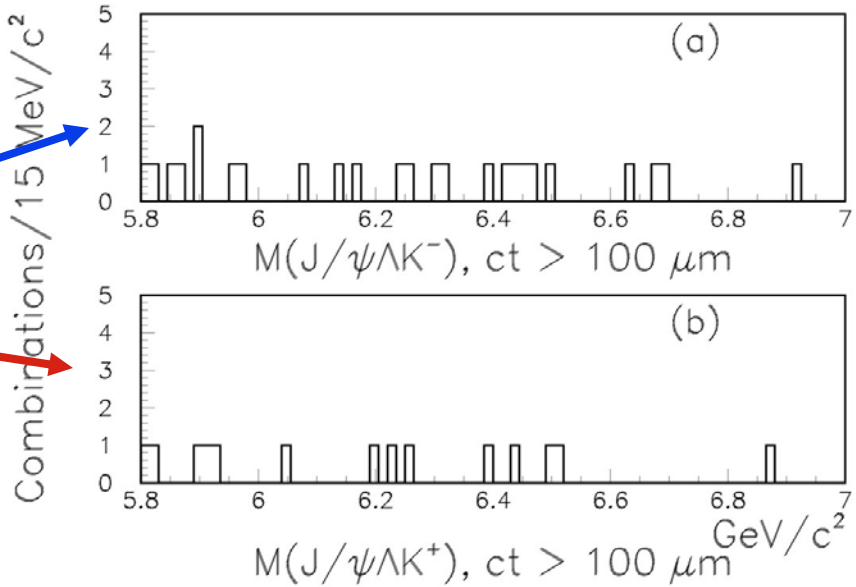
- J/ψ Ξ^- and J/ψ Ω^- samples
  - $p_T(B) > 6$ GeV/c
  - $p_T(\Xi^-/\Omega^-) > 2$ GeV/c
  - Good fit with J/ψ mass constraint

- Obvious Ξ_b^- signal when *ct* > 100 μm
- Cluster in the J/ψ Ω^- around 6.05 GeV/c^2 – test its significance

Where we expect nothing…

- For the same candidate selection, except for
  - The ΛK^- mass



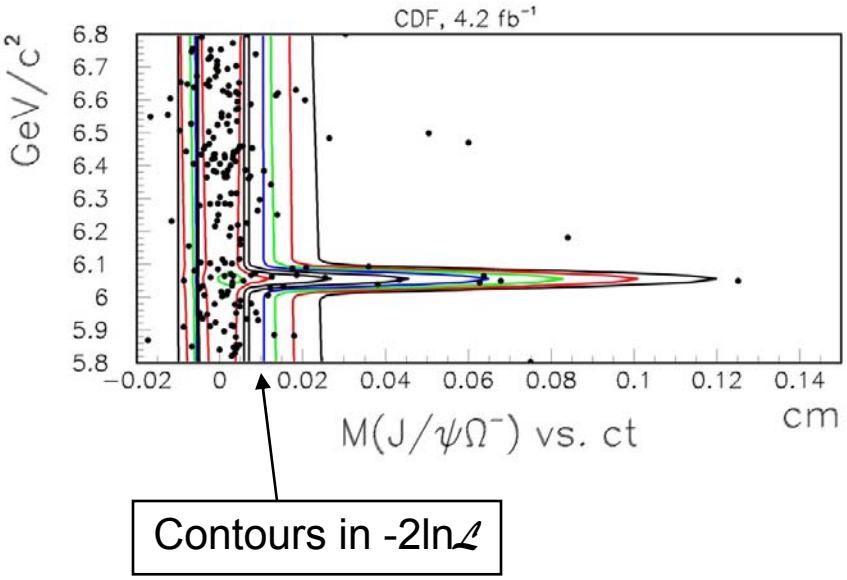


  - The "wrong sign" distribution

- Neither shows any features anywhere

Ω_b^- Significance – Mass/Decay Time Distribution Test

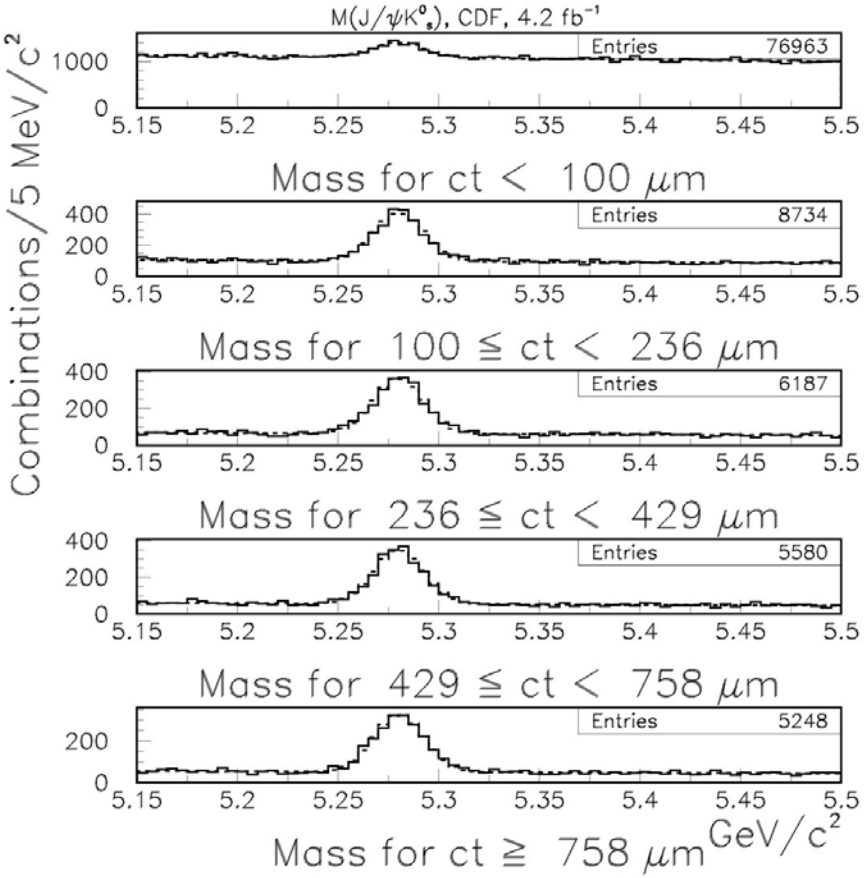
- Significance test - ratio of likelihoods of the mass-decay time distribution.
  - P.D.F in mass is Gaussian signal and a flat background.
  - P.D.F. in time is resolution smeared
    - Exponential(τ_0) for signal
    - Exponential(τ_b) for b-background
    - Delta function for prompt background
  - Fit freely, and with the null hypothesis
  - $\Delta 2\ln\mathcal{L} = 37.3$



- Interpreted as $P(\chi^2)$ with 3 d.o.f. (amp., mass, life) = 4.0×10^{-8}, => 5.5σ

Mass, Lifetime and Yield Measurements

- A binned lifetime fit makes us insensitive to the background lifetime
  - Demonstrated on the full $B^0 \rightarrow J/\psi K^0_s$ sample.
  - Bin boundaries are indicated.
    - ~20% area in each time range
  - Projections of the mass fits are overlaid on the data.
- Fit results -
  - Yield: 9424 ± 167
  - Mass: 5280.2 ± 0.2 MeV/c^2
    - PDG: 5279.53 ± 0.33 MeV/c^2
  - $c\tau_0$: 448 ± 7 μm
    - PDG: 459 ± 3 μm



Mass and Lifetime Results

	Mass (MeV)		Lifetime(μm)		
References	$B^0(K^{*0})$	5279.2 ± 0.2	453 ± 6		
	$B^0(K^0_S)$	5280.2 ± 0.2	448 ± 7		
	Λ_b	5620.3 ± 0.5	472 ± 17		
Results	Ξ_b	5790.9 ± 2.6	468	$^{+82}_{-74}$	
	Ω_b	6054.4 ± 6.8	340	$^{+160}_{-120}$	

- 2.0 MeV/c^2 shift in Ξ_b^- mass from 1.9 fb^{-1} measurement
  - PRL 99,052002(2007)
- Systematic uncertainty on mass – 0.8 (Ξ_b^-) and 0.9(Ω_b^-) MeV/c^2
- Systematic uncertainty on lifetime – 1.3% overall

Production Rate Measurements

- We have access to the product of cross section times branching fraction.
  - We will measure ratios, with respect to the Λ_b^0: $\frac{\sigma B(\Xi_b^- \to J/\psi \Xi^-)}{\sigma B(\Lambda_b \to J/\psi \Lambda)}$ $\frac{\sigma B(\Omega_b^- \to J/\psi \Omega^-)}{\sigma B(\Lambda_b \to J/\psi \Lambda)}$
    - Only other *b*-baryon with a large sample
- Our approach –
  - Obtain acceptance vs. p_T from simulation
  - Cross section of Ξ_b^- and Ω_b^- is p_T dependent
    - Assume it has the same dependence as Λ_b^0
  - Use measured Λ_b^0 production to integrate Ξ_b^- and Ω_b^- acceptance over p_T (6-20 GeV/c).
    - No Ξ_b^- or Ω_b^- candidates above 20 GeV/c

Rate Results

	Acceptance (6-20 GeV) * 10^{-3}	Yield
Λ_b^0	31 ± 2	1812 ± 61
Ξ_b^-	6.7 ± 0.2	66^{+14}_{-9}
Ω_b^-	9 ± 0.3	16^{+6}_{-4}

- Total systematic uncertainty of 7% for Ξ_b^-, 9% for Ω_b^-
- Yields, acceptances, and known branching fractions are combined to give

$$\frac{\sigma B(\Xi_b^- \to J/\psi \Xi^-)}{\sigma B(\Lambda_b^0 \to J/\psi \Lambda)} = 0.167^{+0.037}_{-0.025}(stat.) \pm 0.012(syst.)$$

$$\frac{\sigma B(\Omega_b^- \to J/\psi \Omega^-)}{\sigma B(\Lambda_b^0 \to J/\psi \Lambda)} = 0.045^{+0.017}_{-0.012}(stat.) \pm 0.004(syst.)$$

Conclusions

- CDF observes the process $\Omega_b^- \rightarrow J/\psi\ \Omega^-$
  - Simultaneous mass and decay time fit => 5.5σ significance.
- Properties of both Ξ_b^- and Ω_b^- have been measured:

	Mass (MeV/c^2)	τ_0(ps)	$\sigma B/\sigma B(\Lambda_b^0)$
Ξ_b^-	$5790.9 \pm 2.6 \pm 0.9$	$1.56\ ^{+0.27}_{-0.25} \pm 0.02$	$0.167\ ^{+0.037}_{-0.025} \pm 0.012$
Ω_b^-	$6054.4 \pm 6.8 \pm 0.9$	$1.13\ ^{+0.53}_{-0.40} \pm 0.02$	$0.045\ ^{+0.017}_{-0.012} \pm 0.004$

- Masses – new level of precision
- Lifetimes – first Ω_b^-,first fully reconstructed Ξ_b^-
- These strange *b*-baryons are simply additional members of a rich program of fully reconstructed *b*-hadrons obtained in the CDF J/ψ sample.