

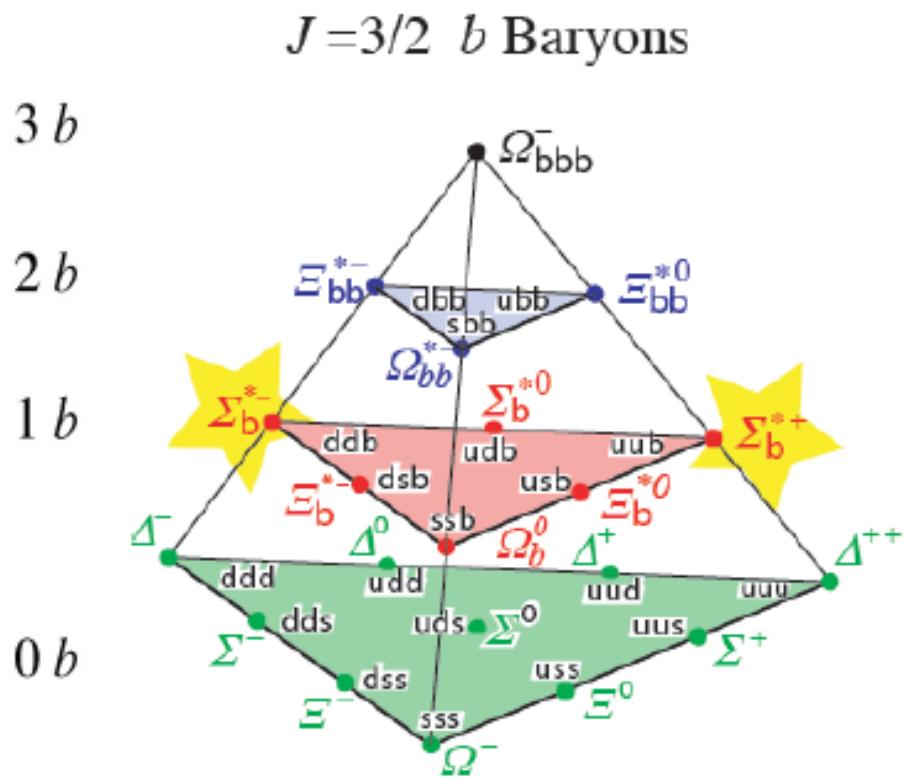
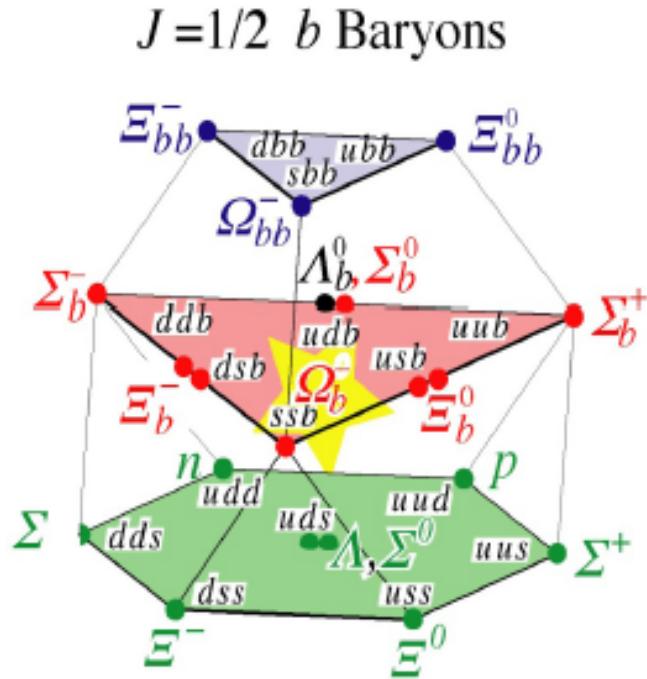
B Baryons at D-Zero

Peter Ratoff

Lancaster University

A total of 15 b baryons are predicted
(counting quark content only)

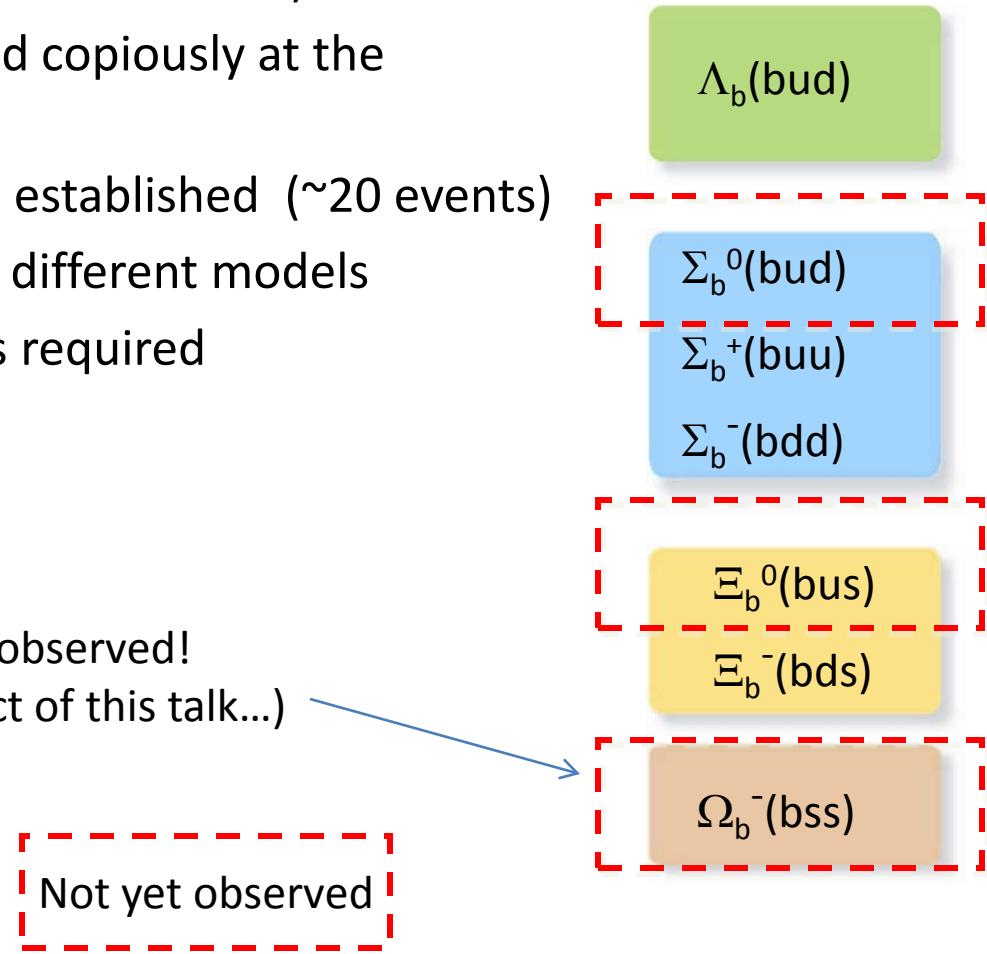
charmless b baryon (10 in total) multiplet



B baryons at the Tevatron

- Unique to Tevatron (not produced in B factories)
- B baryons expected to be produced copiously at the Tevatron
- At start of Run2: only Λ_b had been established (~20 events)
- Interesting mass predictions using different models
- However, very challenging analysis required

J=1/2, 1 b



Until recently, only one b baryon has been directly observed.

Λ_b (udb): $\Lambda_b \rightarrow J/\psi \Lambda$

UA1: PL B273, 540 (1991)

CDF 2006

However, four were discovered over the last two years:

Σ_b^+ (uub) / Σ_b^- (ddb): $\Sigma_b^\pm \rightarrow \Lambda_b \pi^\pm \rightarrow (\Lambda_c^+ \pi^-) \pi^\pm$

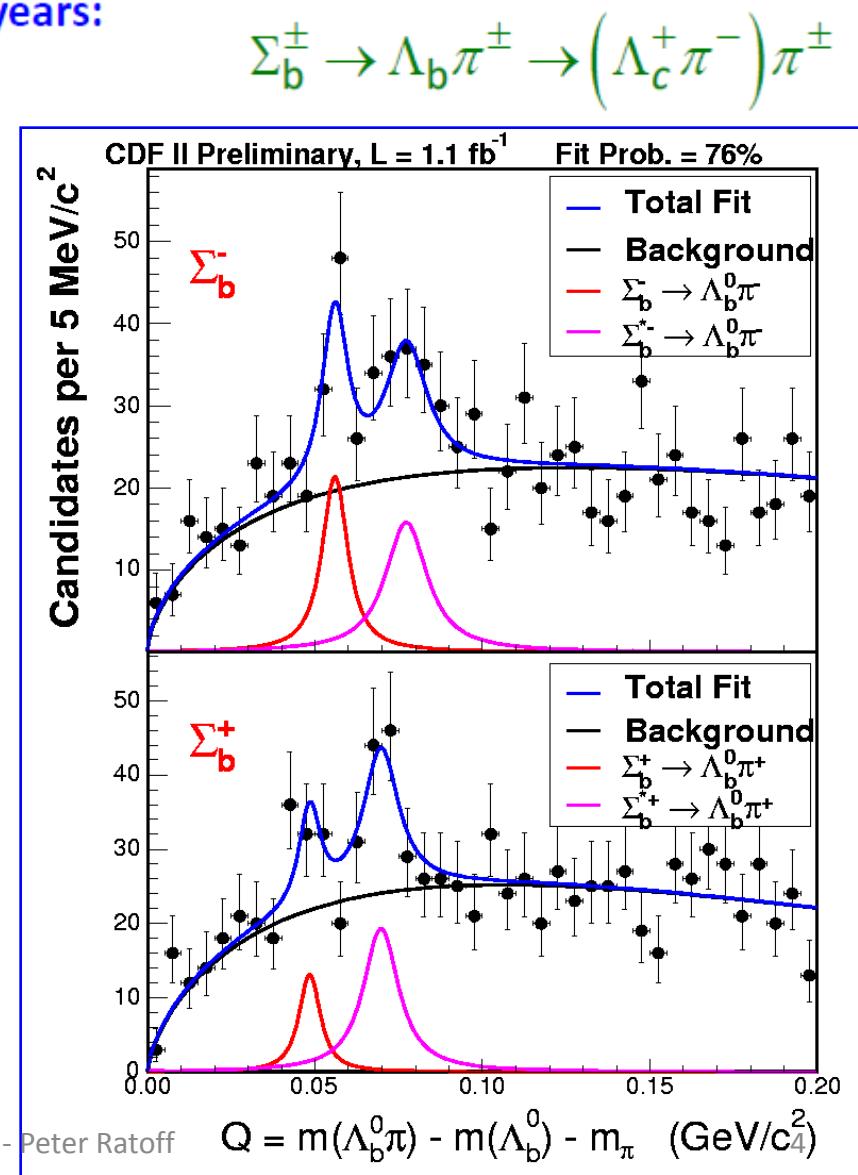
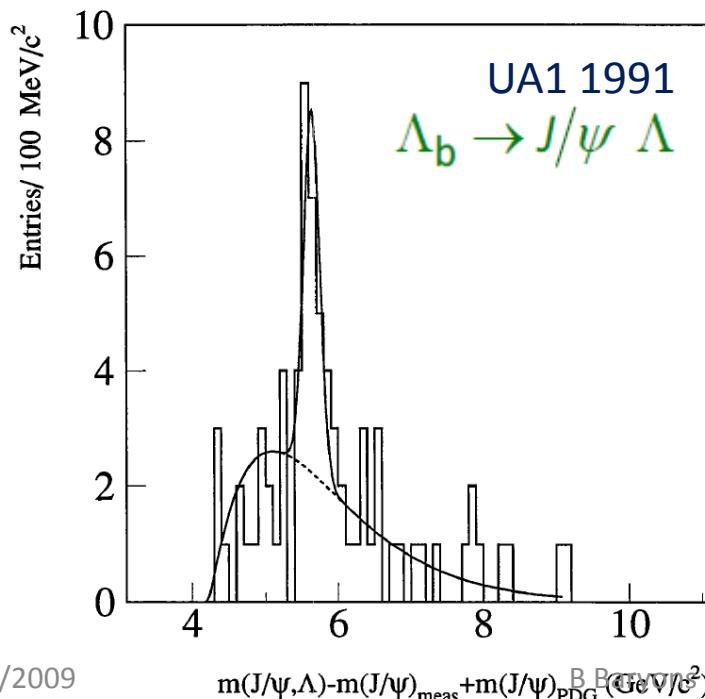
CDF: PRL 99, 202001 (2007)

★ Ξ_b^- (dsb): $\Xi_b^- \rightarrow J/\psi \Xi^-$ (DØ, CDF); $\Xi_b^- \rightarrow \Xi_c^0 \pi^-$ (CDF)

DØ: PRL 99, 052001 (2007); CDF: PRL 99, 052002 (2007)

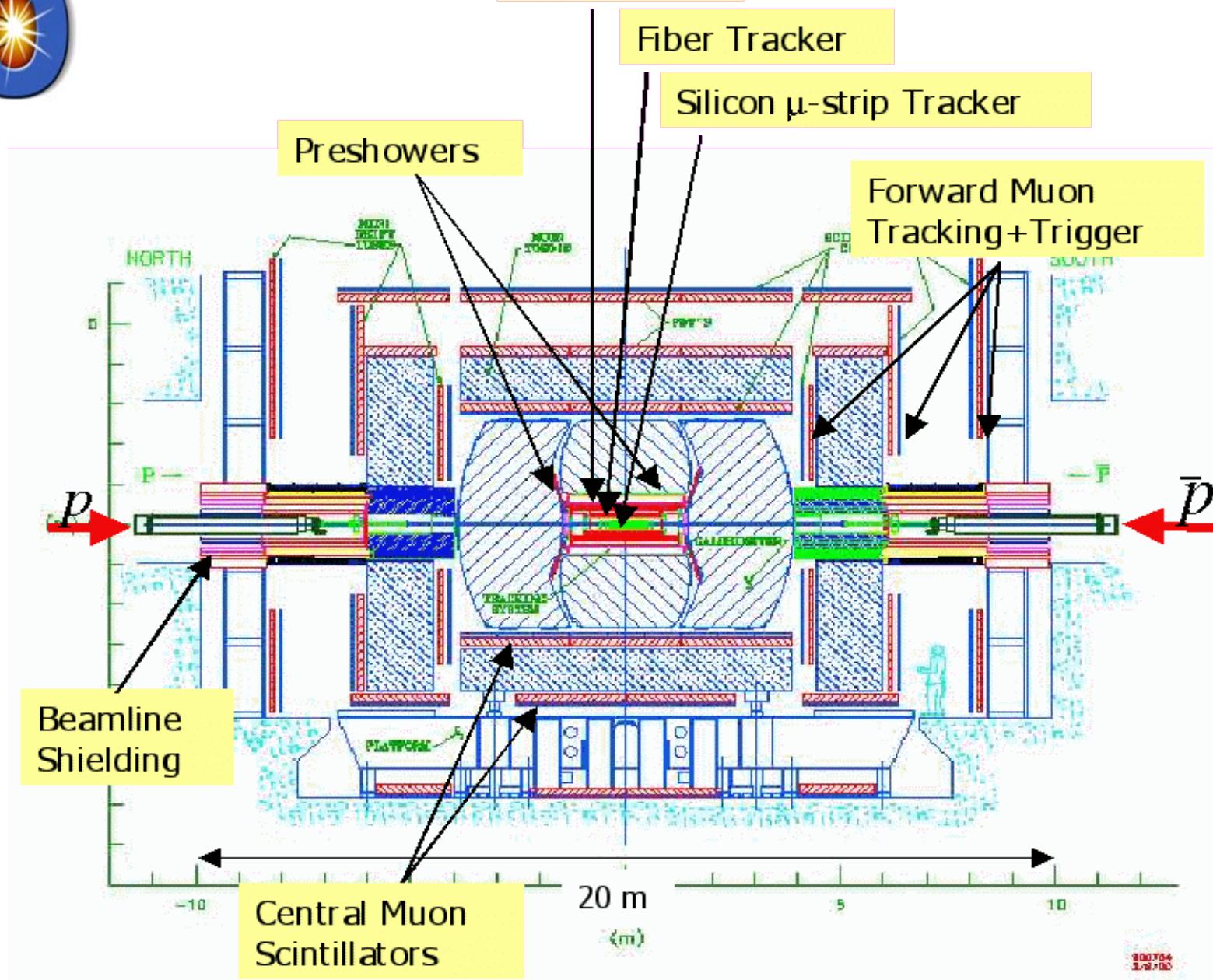
★ Ω_b^- (ssb): $\Omega_b^- \rightarrow J/\psi \Omega^- \rightarrow J/\psi (\Lambda K^-)$

DØ: arXiv: 0808.4142 (2008)



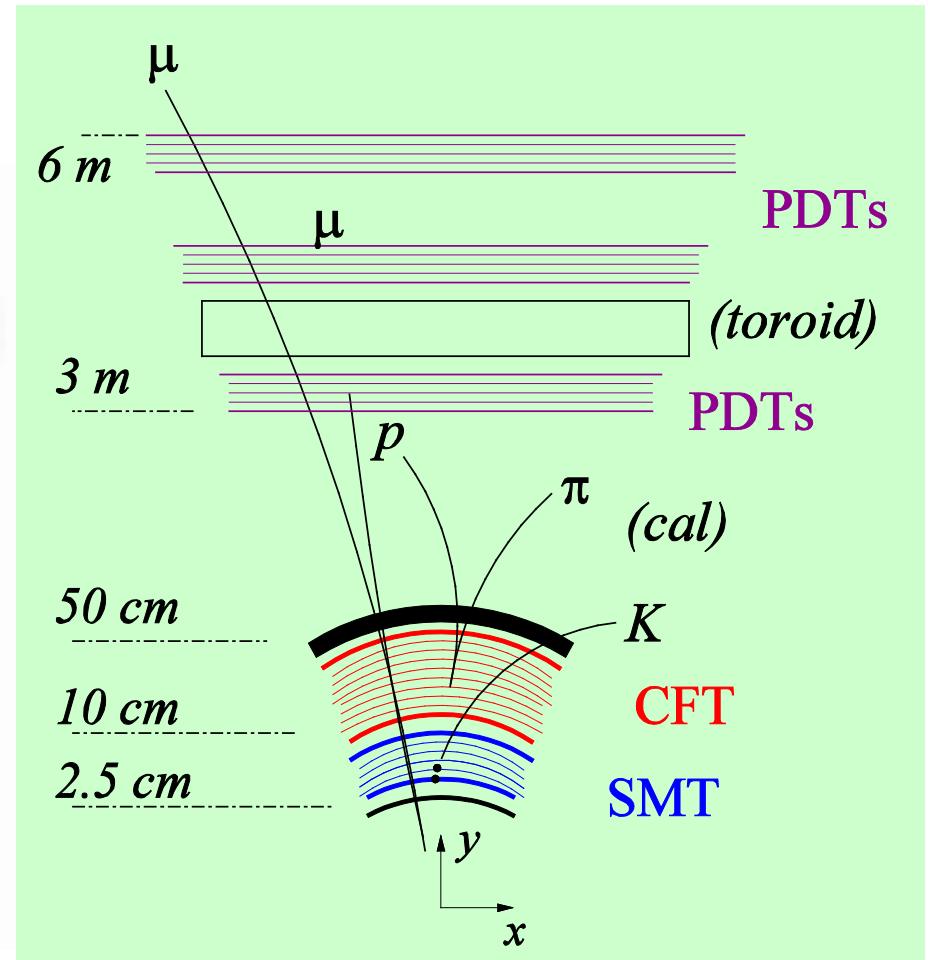
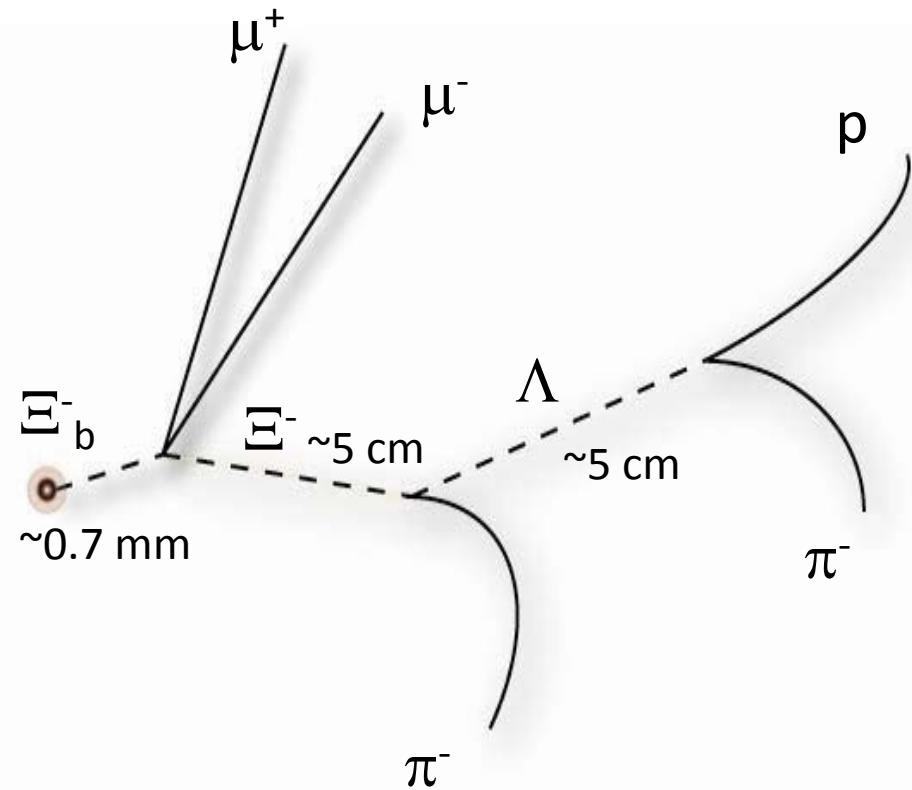


2T Solenoid



How did we look for the Ξ_b^- ?

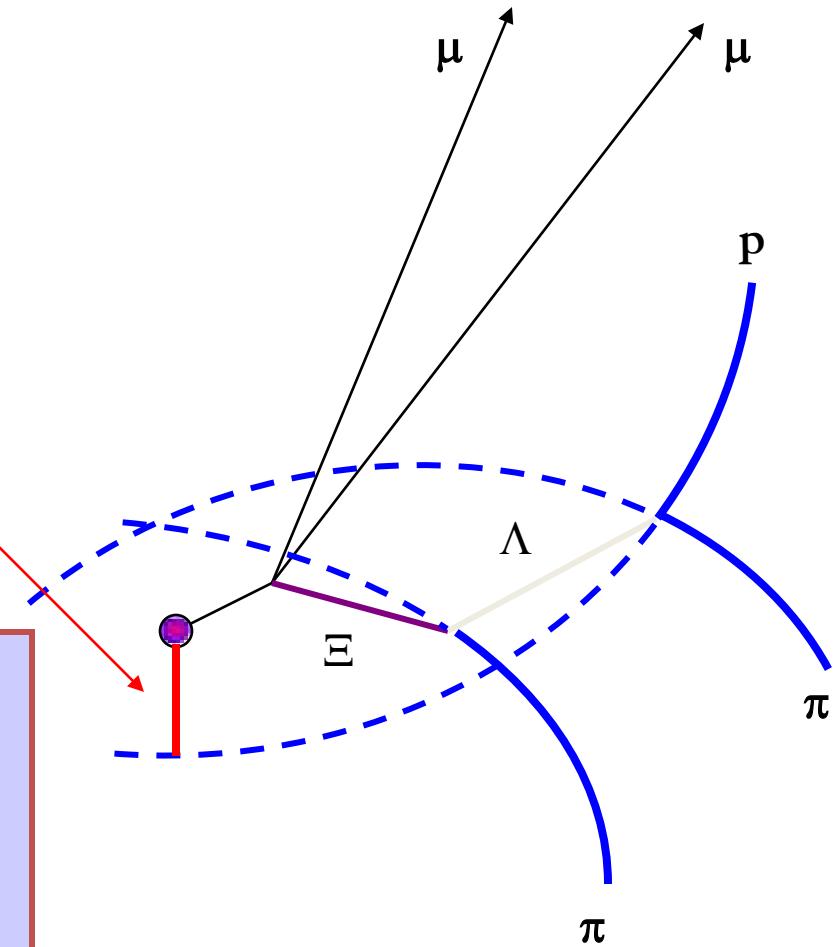
$$\Xi_b^- \rightarrow J/\psi + \Xi^-$$



Data reprocessing

When tracks are reconstructed, a maximum impact parameter is required to increase the reconstruction speed and lower the rate of fake tracks.

But for particles like the Ξ_b^- , this requirement could result in missing the π and proton tracks from the Λ and Ξ^- decays

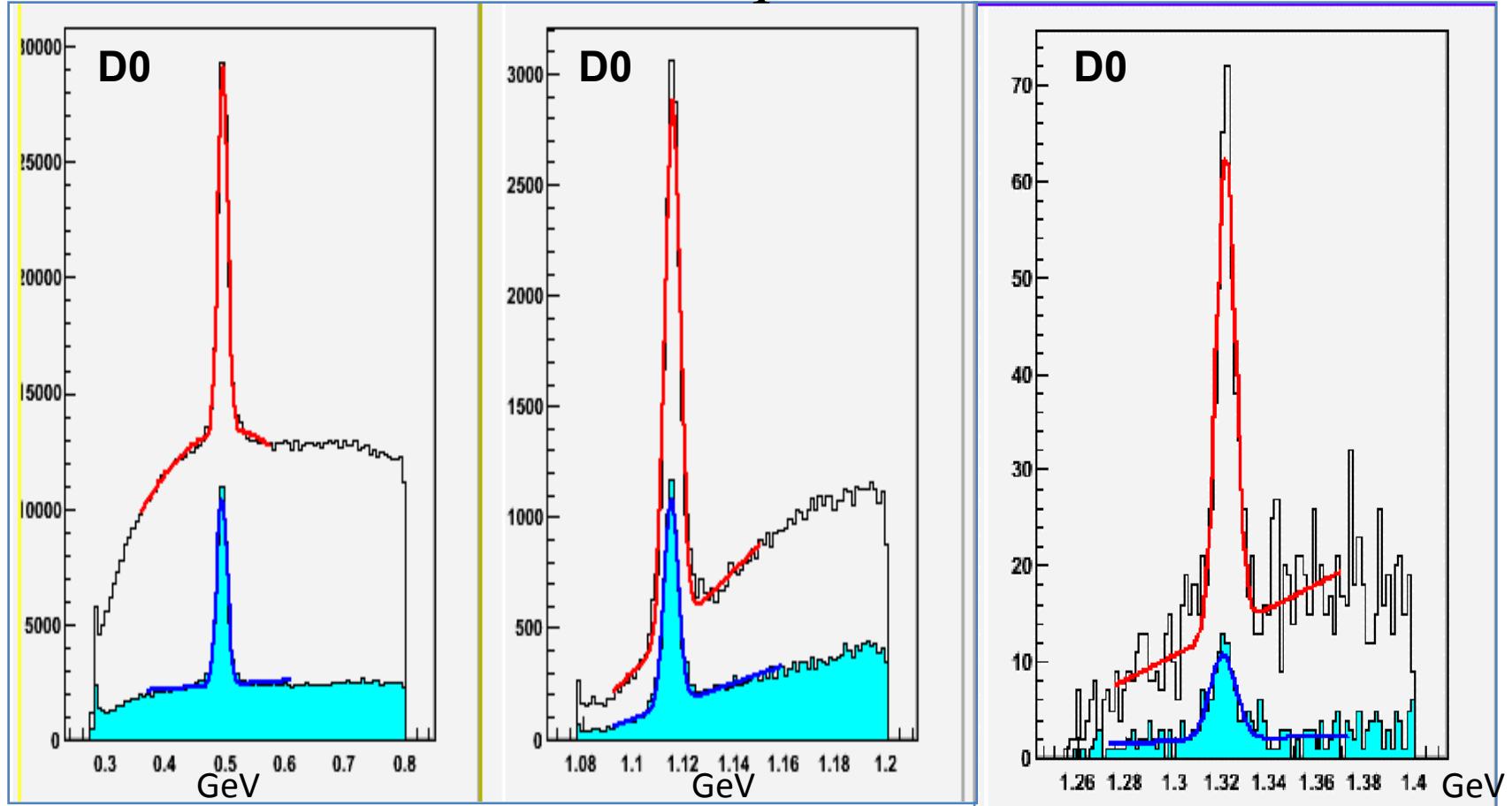


Increase of reconstruction efficiency

$$K_s^0 \rightarrow \pi^+ \pi^-$$

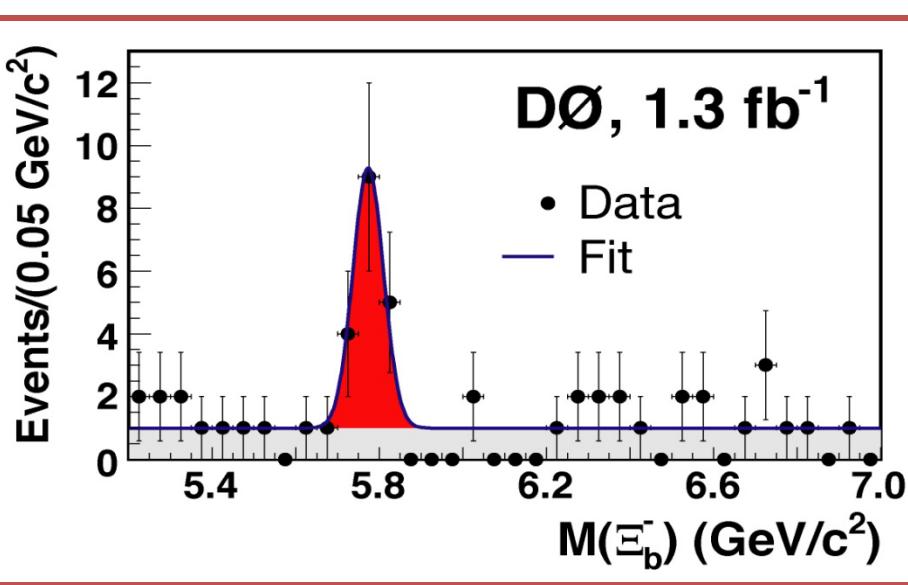
$$\Lambda \rightarrow p \pi^-$$

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



Opening up the IP cut: (Before) (After)

Ξ_b^- observation



Number of events: 15.2 ± 4.4
 Mass: $5.774 \pm 0.011(\text{stat}) \text{ GeV}$
 Width: $0.037 \pm 0.008 \text{ GeV}$

We also measured:

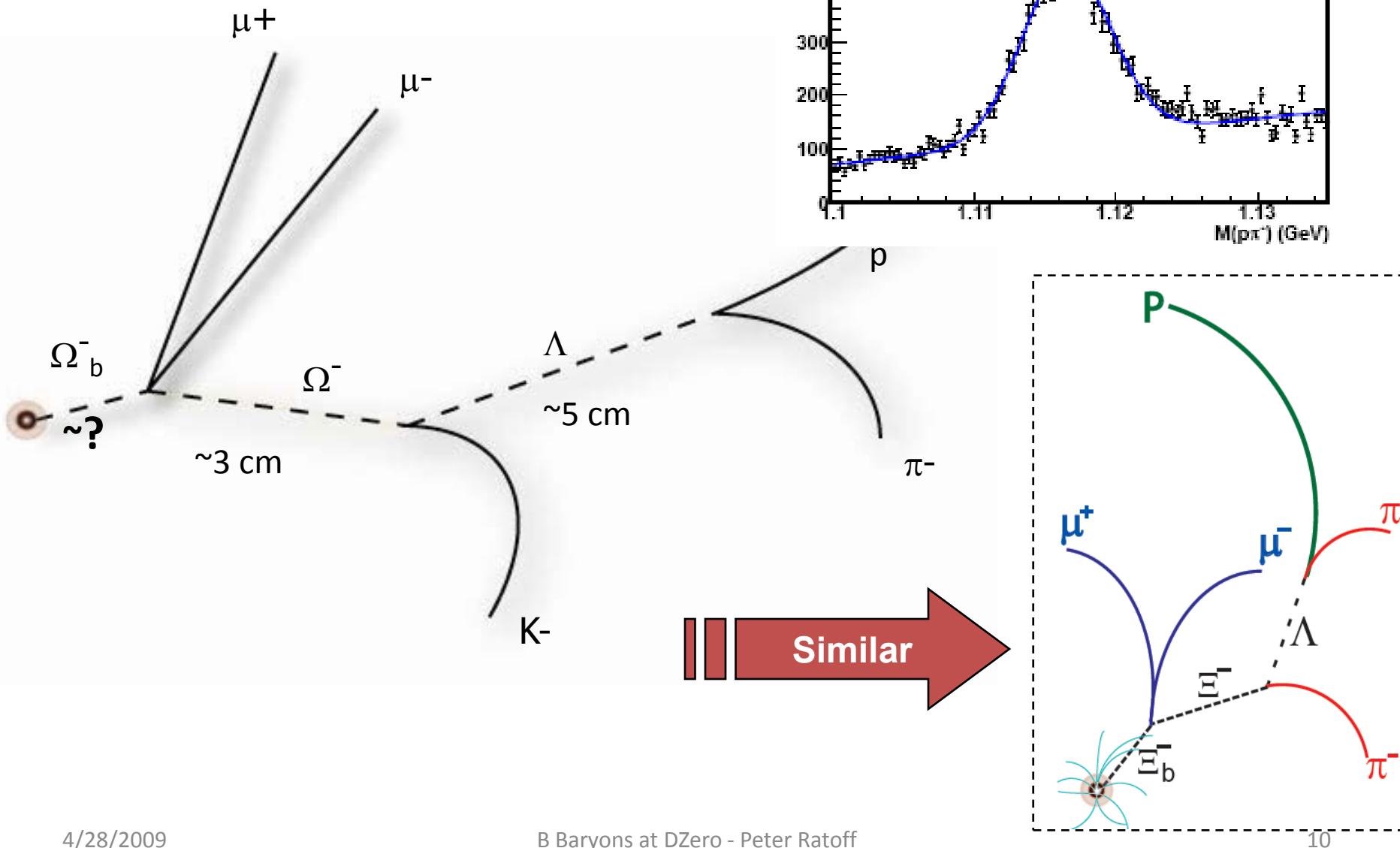
$$R = \frac{\sigma(\Xi_b^-) BR(\Xi_b^- \rightarrow J/\psi \Xi^-)}{\sigma(\Lambda_b) BR(\Lambda_b \rightarrow J/\psi \Lambda)}$$

$$R = 0.28 \pm 0.09 \text{ (stat)} {}^{+0.09}_{-0.08} \text{ (syst)}$$

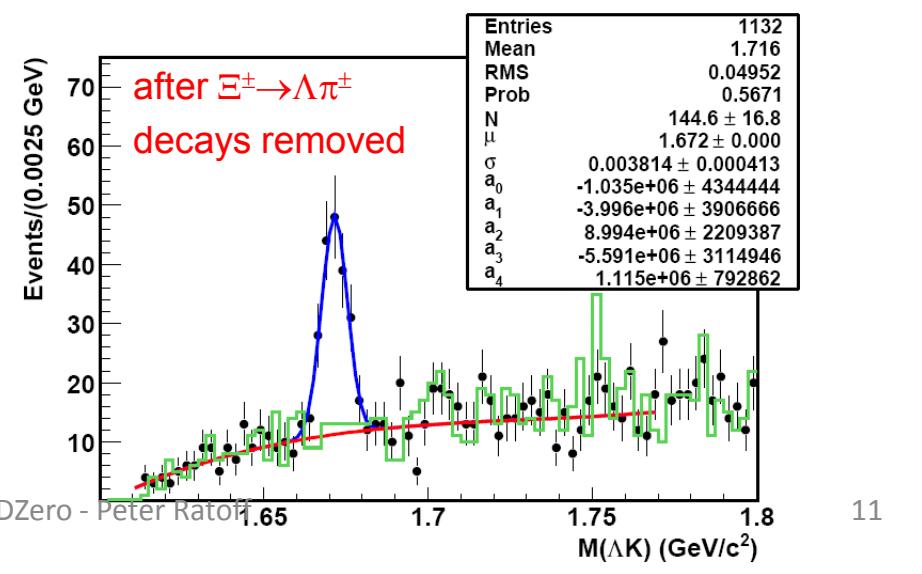
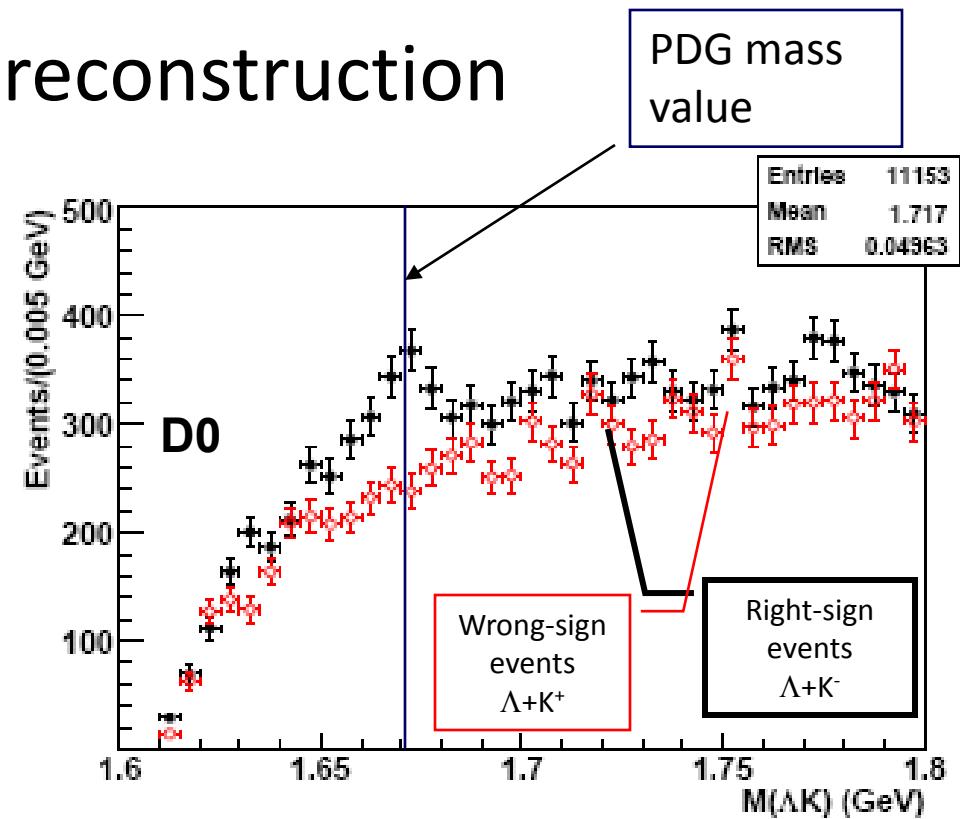
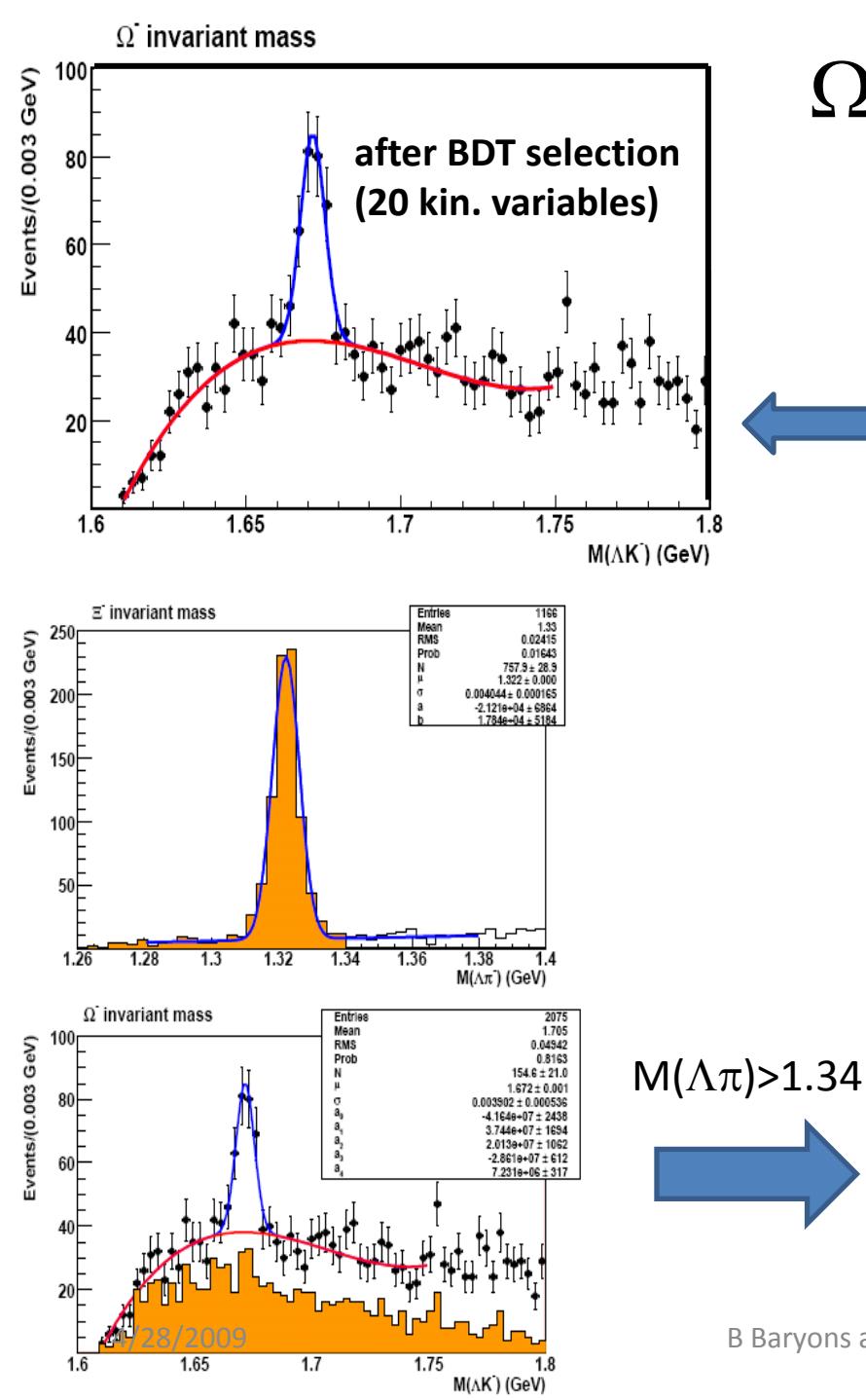
Signal Significance:

$$\sqrt{-2\Delta \ln L} = \sqrt{-2 \ln \left(\frac{L_B}{L_{S+B}} \right)} = 5.5\sigma$$

How do we look for Ω_b^- (bss)?



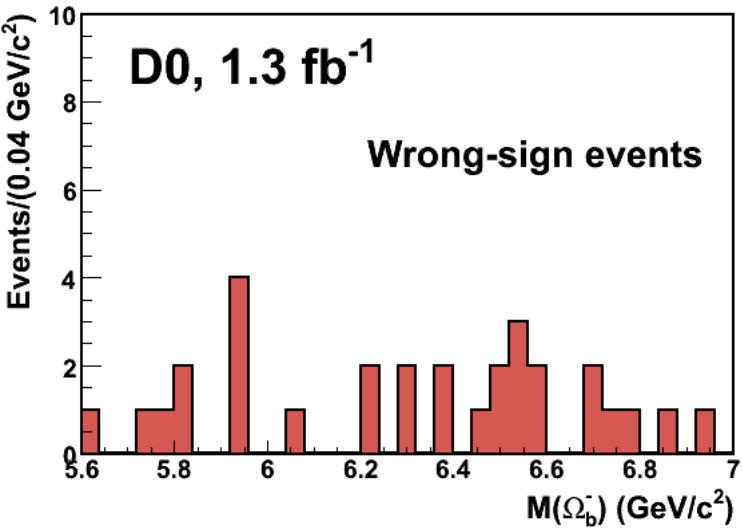
Ω reconstruction



Systematic Checks

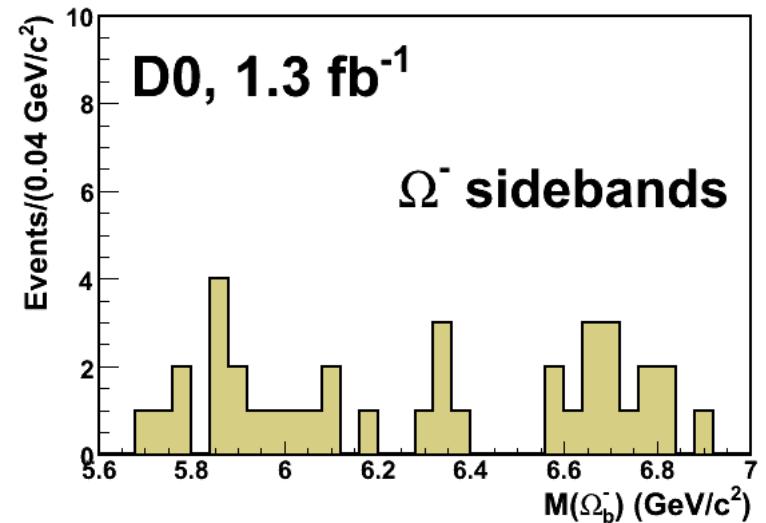
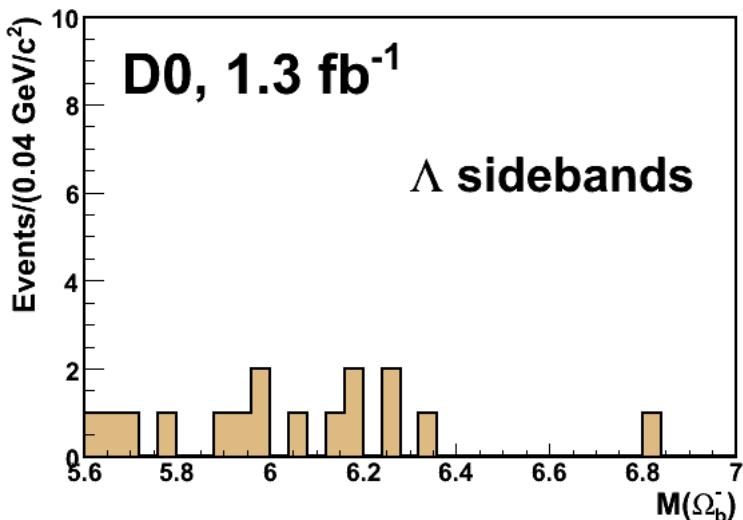
Mass window for the search: 5.6 - 7 GeV

$$M = M_{J/\psi\Omega} - M_{J/\psi} - M_{\Omega} + M_{J/\psi}^{PDG} + M_{\Omega}^{PDG}$$



Optimization cuts

- $\sigma_\lambda < 0.03$ cm
- J/ψ and Ω in the same hemisphere
- $p_T(J/\psi + \Omega) > 6$ GeV



We check also high statistics MC samples

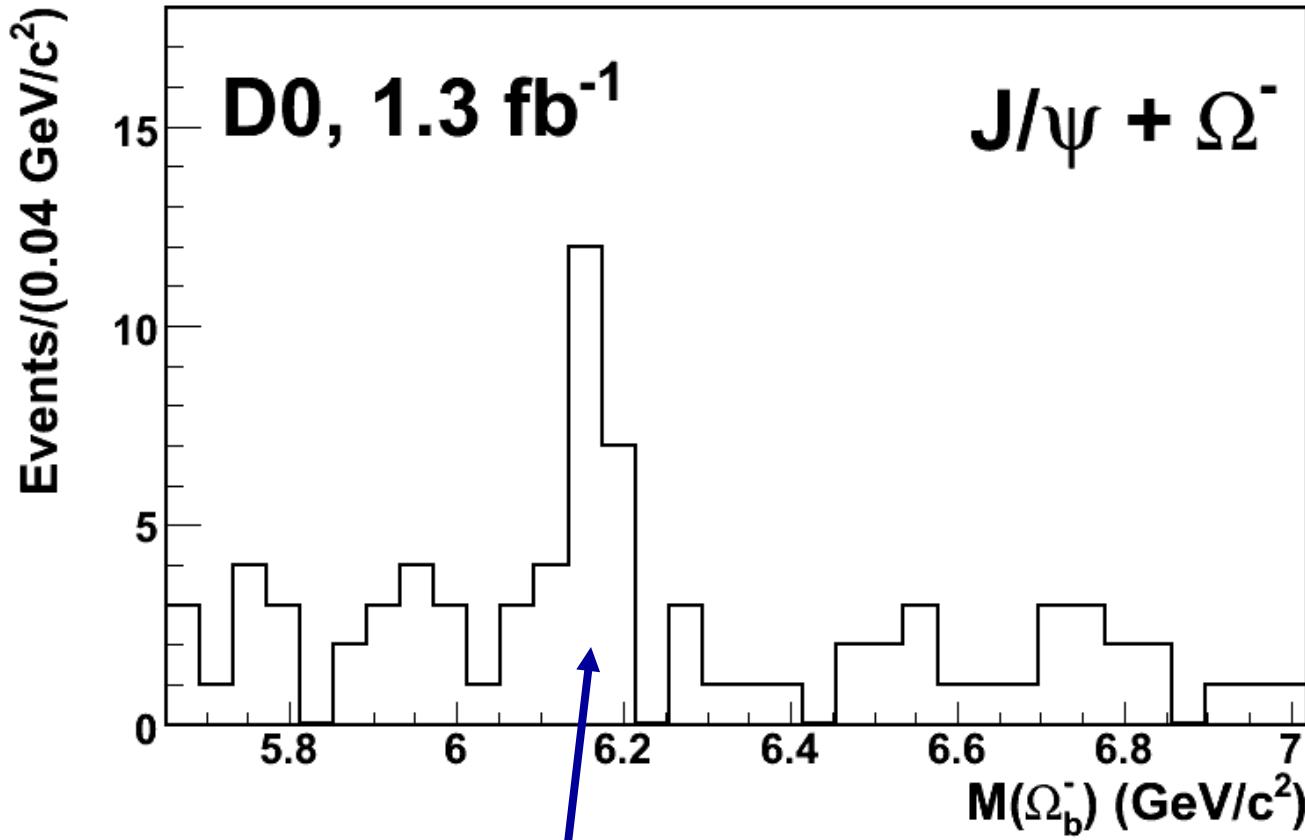
$$\Lambda_b \rightarrow J/\psi \Lambda \rightarrow (\mu^+ \mu^-)(p\pi^-)$$

$$B^- \rightarrow J/\psi K^{*-} \rightarrow (\mu^+ \mu^-)(K_S^0 \pi^-) \rightarrow (\mu^+ \mu^-)((\pi^+ \pi^-)\pi^-)$$

$$\Xi_b^- \rightarrow J/\psi \Xi^- \rightarrow (\mu^+ \mu^-)(\Lambda \pi^-) \rightarrow (\mu^+ \mu^-)((p\pi^-)\pi^-)$$

No excess is observed in any control sample after selection criteria is applied to them

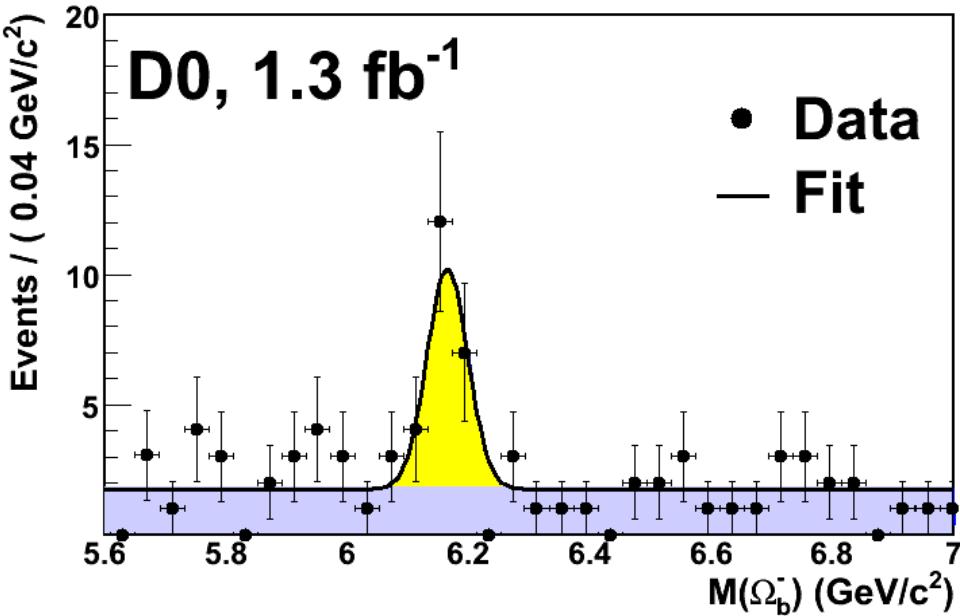
Looking at right-sign combinations



Clear excess of events near 6.2 GeV

Ω_b^- mass measurement

PRL 101, 232002 (2008)



Fit:

- Unbinned extended log-likelihood fit
- Gaussian signal, flat background
- Number of background/signal events are floating parameters

Two likelihood fits are performed:

1. Signal + background hypothesis (L_{S+B})
2. Only background hypothesis (L_B)

We evaluate the significance:

$$\sqrt{-2\Delta \ln L} = \sqrt{-2 \ln \left(\frac{L_B}{L_{S+B}} \right)}$$

Significance of the observed signal: 5.4σ

Number of signal events: 17.8 ± 4.9

Mean of the Gaussian: $6.165 \pm 0.010(\text{stat}) \pm 0.013 (\text{syst}) \text{ GeV}$

Width of the Gaussian fixed (MC): 0.034 GeV

- Varying Gaussian width
- Momentum scale
- Event selection

Ω^-_b production rate

$$\frac{f(b \rightarrow \Omega_b^-) Br(\Omega_b^- \rightarrow J/\psi \Omega^-)}{f(b \rightarrow \Xi_b^-) Br(\Xi_b^- \rightarrow J/\psi \Xi^-)} = \frac{\varepsilon(\Xi_b^-)}{\varepsilon(\Omega_b^-)} \frac{N(\Omega_b^-)}{N(\Xi_b^-)}$$

$$\frac{\varepsilon(\Omega_b^-)}{\varepsilon(\Xi_b^-)} = 1.5 \pm 0.2 \text{ (stat)}$$

$$\frac{f(b \rightarrow \Omega_b^-) Br(\Omega_b^- \rightarrow J/\psi \Omega^-)}{f(b \rightarrow \Xi_b^-) Br(\Xi_b^- \rightarrow J/\psi \Xi^-)} = 0.80 \pm 0.32 \text{ (stat)}^{+0.14}_{-0.22} \text{ (syst)}$$

The systematic uncertainty includes contributions from the signal yields as well as selection efficiencies

From Phys. Rev. D 56, 2799 (1997):

$$\frac{\Gamma(\Omega_b^- \rightarrow J/\psi \Omega^-)}{\Gamma(\Xi_b^- \rightarrow J/\psi \Xi^-)} = 9.8$$

$$\frac{f(b \rightarrow \Omega_b^-)}{f(b \rightarrow \Xi_b^-)} = \begin{cases} 0.126 & (\tau(\Omega_b^-) = 0.83 \text{ ps}) \\ 0.062 & (\tau(\Omega_b^-) = 1.67 \text{ ps}) \end{cases}$$

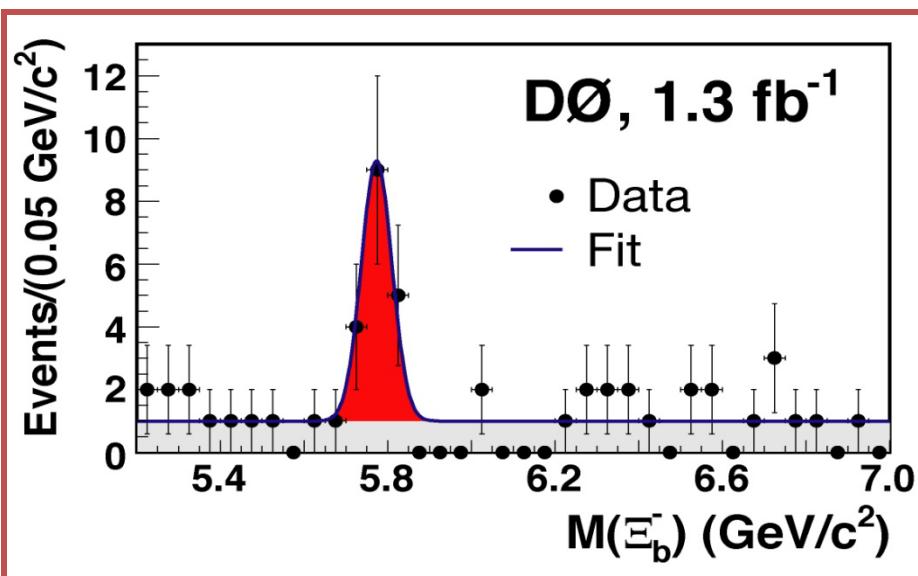
$$\tau(\Xi_b^-) = 1.42^{+0.28}_{-0.24} \text{ ps}$$

$0.83 < \tau(\Omega_b^-) < 1.67 \text{ ps}$
theory

$$\frac{f(b \rightarrow \Omega_b^-)}{f(b \rightarrow \Xi_b^-)} \approx 0.07 - 0.14$$

Ξ_b^-

Summary

 Ω_b^- 

Number of events: 15.2 ± 4.4

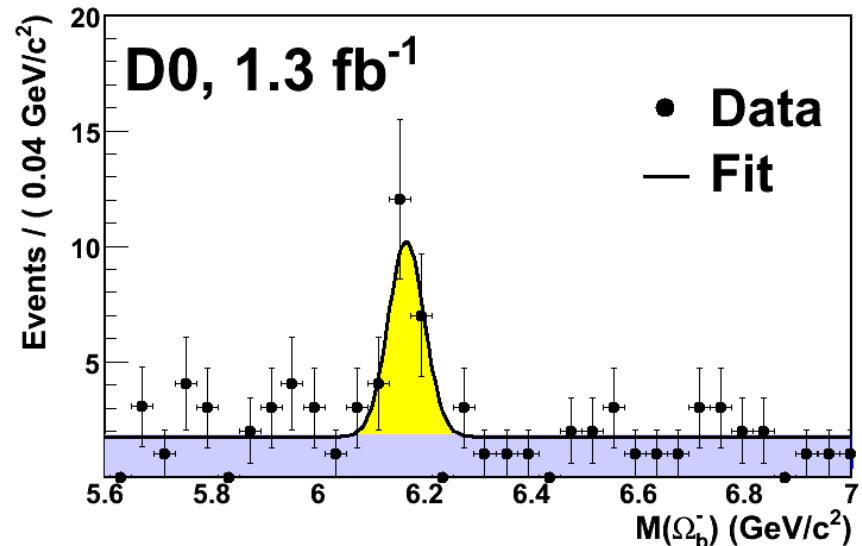
Mass: $5.774 \pm 0.011(\text{stat})$ GeV

Width: 0.037 ± 0.008 GeV

Significance = 5.5σ

$$R = \frac{\sigma(\Xi_b^-) BR(\Xi_b^- \rightarrow J/\psi \Xi^-)}{\sigma(\Lambda_b) BR(\Lambda_b \rightarrow J/\psi \Lambda)}$$

$$R = 0.28 \pm 0.09 \text{ (stat)} {}^{+0.09}_{-0.08} \text{ (syst)}$$



Number of signal events: $17.8 \pm 4.9 \text{ (stat)} \pm 0.8 \text{ (syst)}$

Mass: $6.165 \pm 0.010(\text{stat}) \pm 0.013(\text{syst})$ GeV

Significance= 5.4σ

$$\frac{f(b \rightarrow \Omega_b^-) Br(\Omega_b^- \rightarrow J/\psi \Omega^-)}{f(b \rightarrow \Xi_b^-) Br(\Xi_b^- \rightarrow J/\psi \Xi^-)} = 0.80 \pm 0.32(\text{stat}) {}^{+0.14}_{-0.22}(\text{syst})$$

$$\frac{f(b \rightarrow \Omega_b^-)}{f(b \rightarrow \Xi_b^-)} \approx 0.07 - 0.14$$

Consistent with expectations

Backup slides

Ξ_b Reconstruction procedure

Reconstruction procedure:

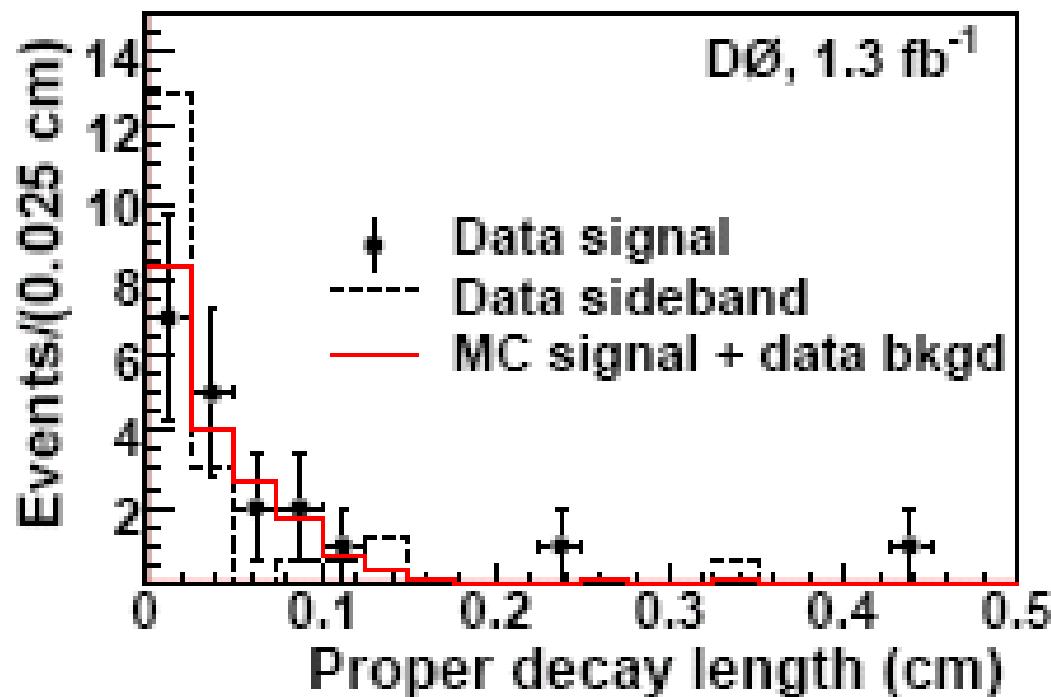
- Reconstruct $J/\psi \rightarrow \mu^+ \mu^-$
- Reconstruct $\Lambda \rightarrow p\pi$
- Reconstruct $\Xi \rightarrow \Lambda + \pi$
- Combine $J/\psi + \Xi$
- Improve mass resolution by using an event-by-event mass difference correction
- **The optimization:**
 1. $\Lambda_b \rightarrow J/\psi \Lambda$ decays in data
 2. $J/\psi + \Xi$ (fake from $\Lambda(p\pi^-)\pi^+$)
 3. Monte Carlo simulation of $\Xi_b^- \rightarrow J/\psi + \Xi^-$

Final Ξ_b selection cuts:

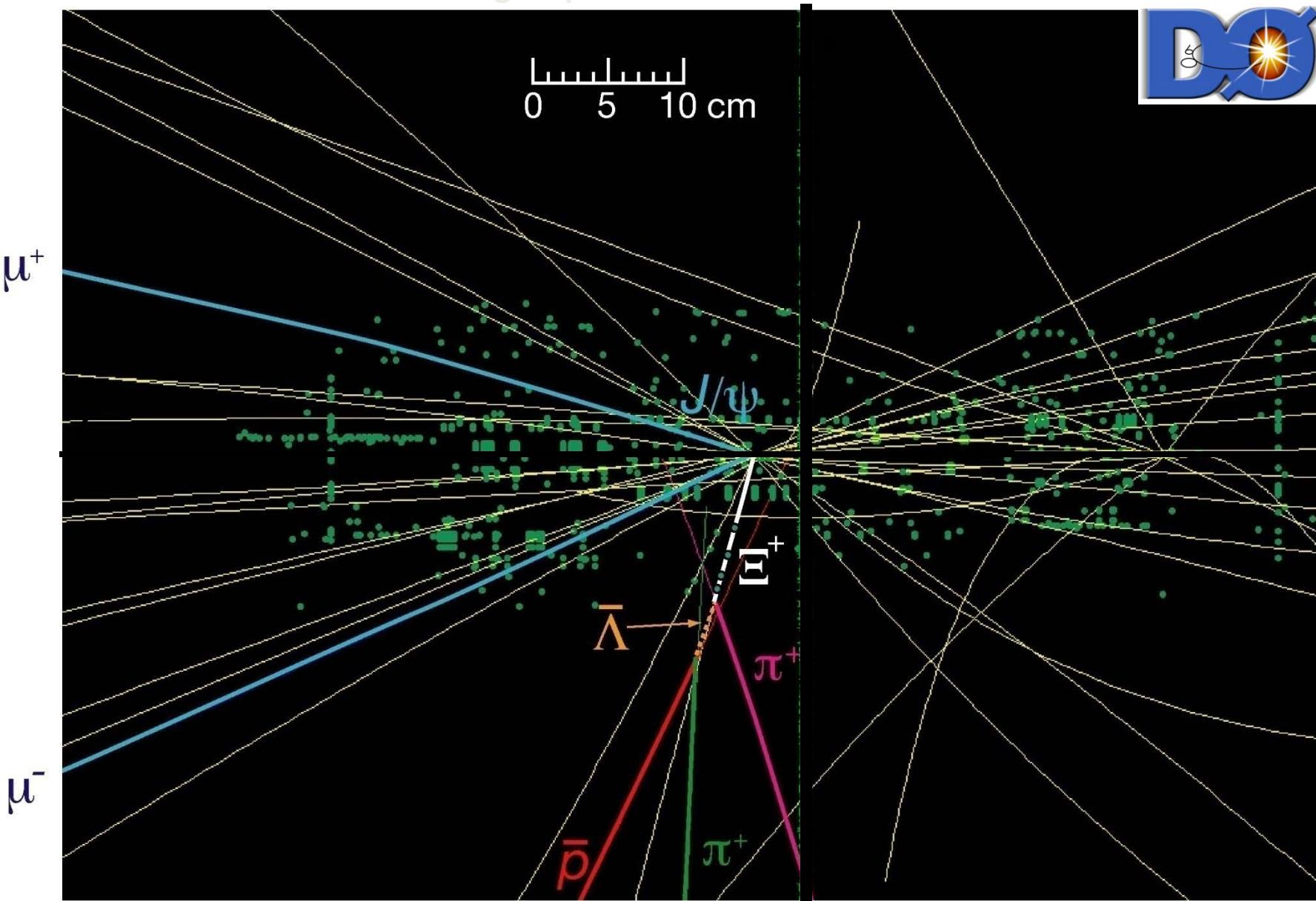
- $\Lambda \rightarrow p\pi$ decays:
 - $p_T(p) > 0.7$ GeV
 - $p_T(\pi) > 0.3$ GeV
- $\Xi^- \rightarrow \Lambda \pi$ decays:
 - $p_T(\pi) > 0.2$ GeV
 - Transverse decay length > 0.5 cm
 - Collinearity > 0.99
- Ξ_b^- particle:
 - Lifetime significance > 2 .
(Lifetime divided by its error)

Consistency checks

- Ξ_b^- Decay length distribution



Event scan of event in the signal peak



Run 179200, Event 55278820, $M(\Xi_b) = 5.788 \text{ GeV}$

4/28/2009

B Baryons at DZero - Peter Ratoff



Ω^-_b Analysis strategy

→ Select J/ψ candidates

Events are reprocessed to increase reconstruction efficiency of long-lived particles.

→ Select $\Lambda \rightarrow p\pi$

Yield is optimized by using proper decay length significance cuts.

→ Reconstruction of $\Omega \rightarrow \Lambda + K$

Optimize yield by using multivariate techniques

→ Combine $J/\psi + (\Lambda K^+)$

Keep blinded $J/\psi + \Omega$ combinations and optimize on $J/\psi + (\Lambda K^+)$

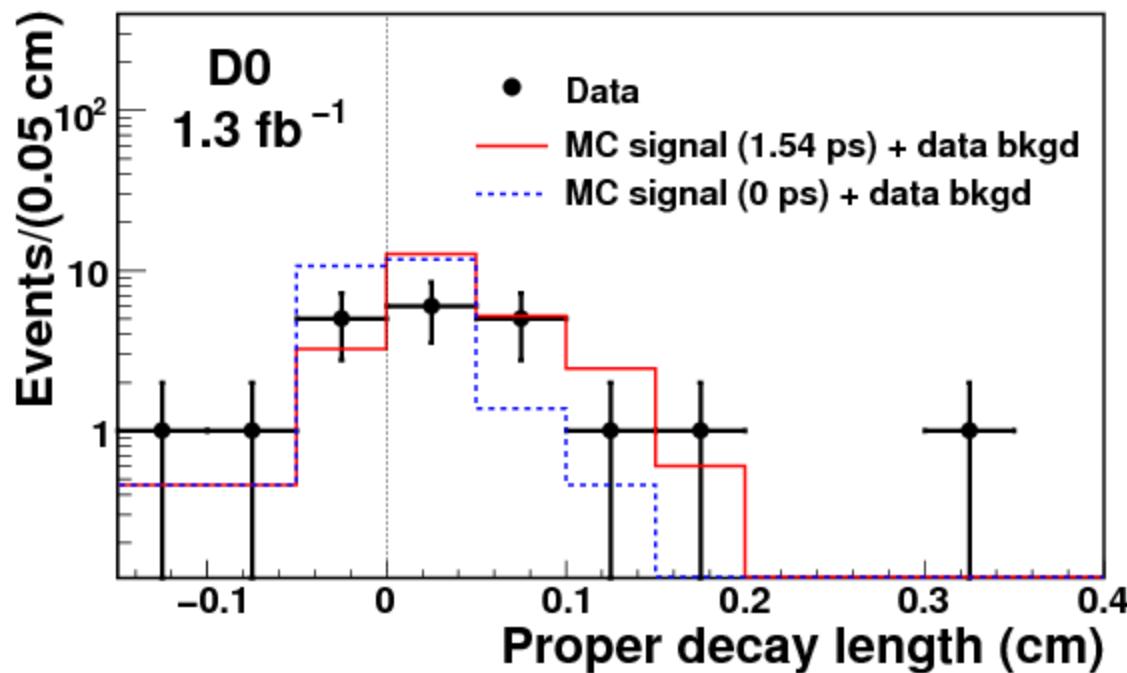
→ Event per event mass correction

Improve mass resolution from 80 MeV to 34 MeV

→ Fix selection criteria and then apply them to $J/\psi + \Omega$

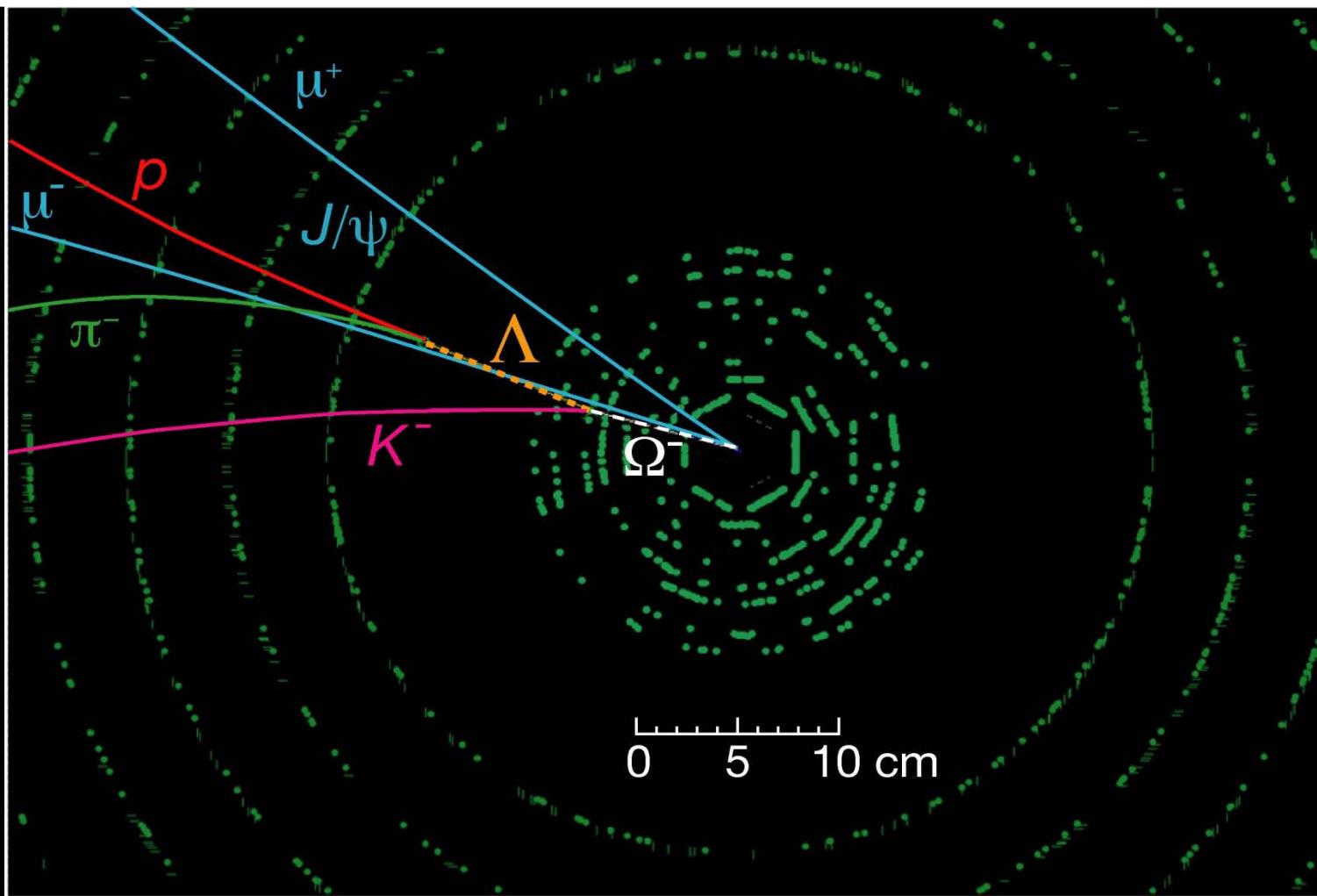
Perform as many test as possible in different background samples

Consistency check: lifetime



We compare to a MC sample with a lifetime of 1.54 ps (~460 microns).

One example: Event display



Run 203929, Event 22881065, $M(\Omega_b) = 6.158 \text{ GeV}$