B Baryons at D-Zero

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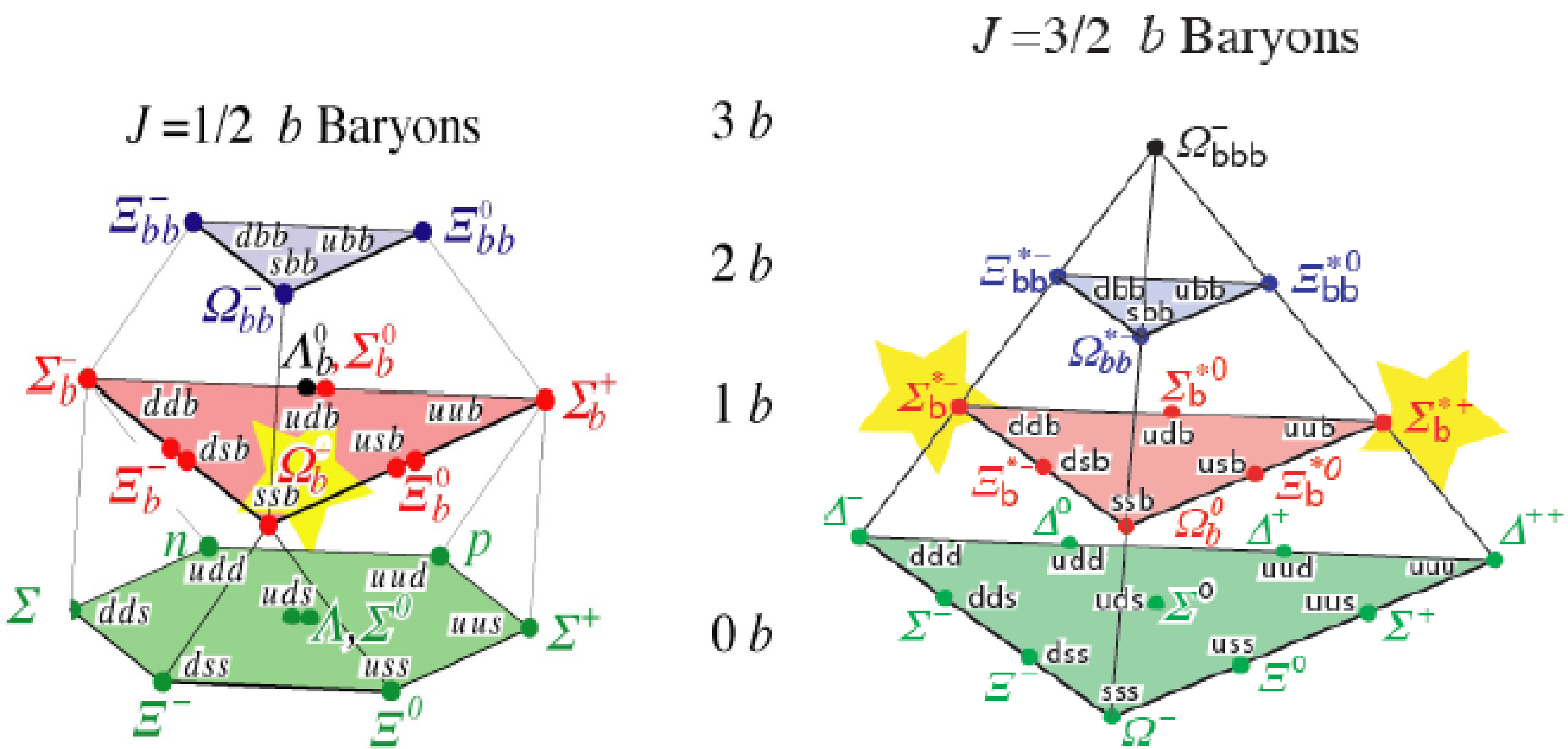
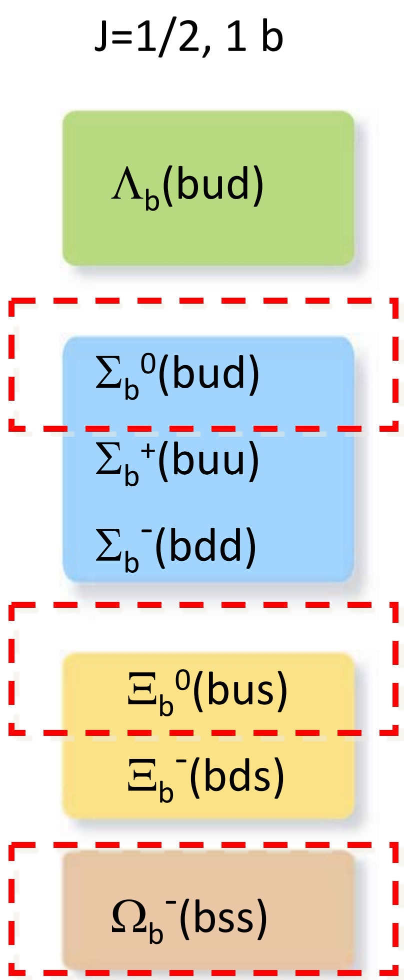
A total of 15 b baryons are predicted
(counting quark content only)

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



(Now observed!
Subject of this talk...)

Not yet observed

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

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

UA1: PL B273, 540 (1991)

However, four were discovered over the last two years:

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

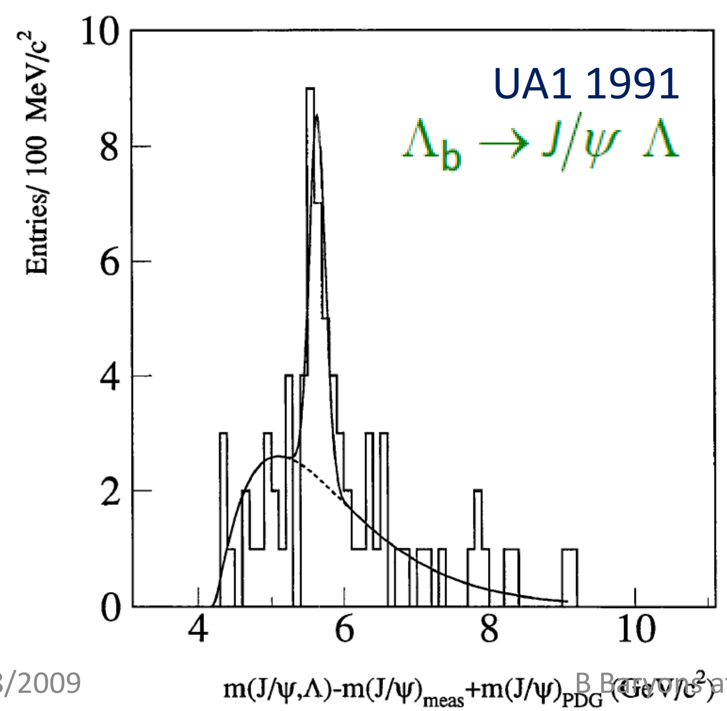
CDF: PRL 99, 202001 (2007)

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)

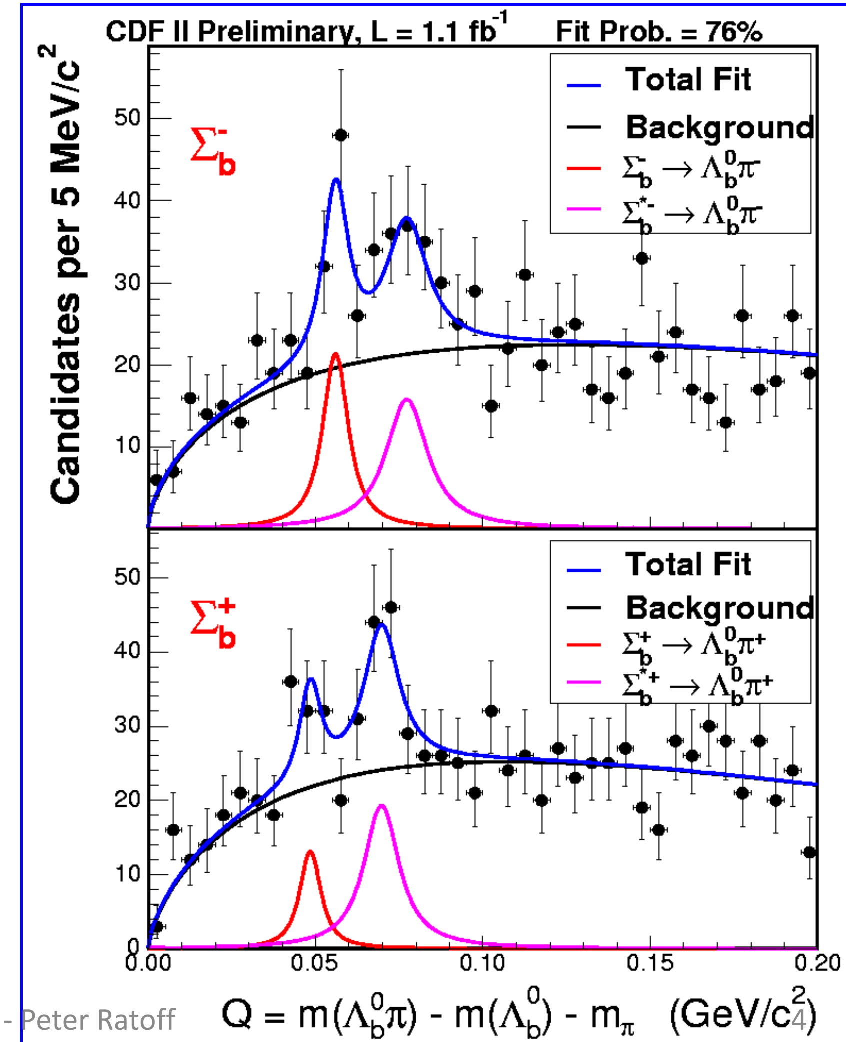
Ω_b^- (ssb): $\Omega_b^- \rightarrow J/\psi\ \Omega^- \rightarrow J/\psi\ \left(\Lambda K^-\right)$

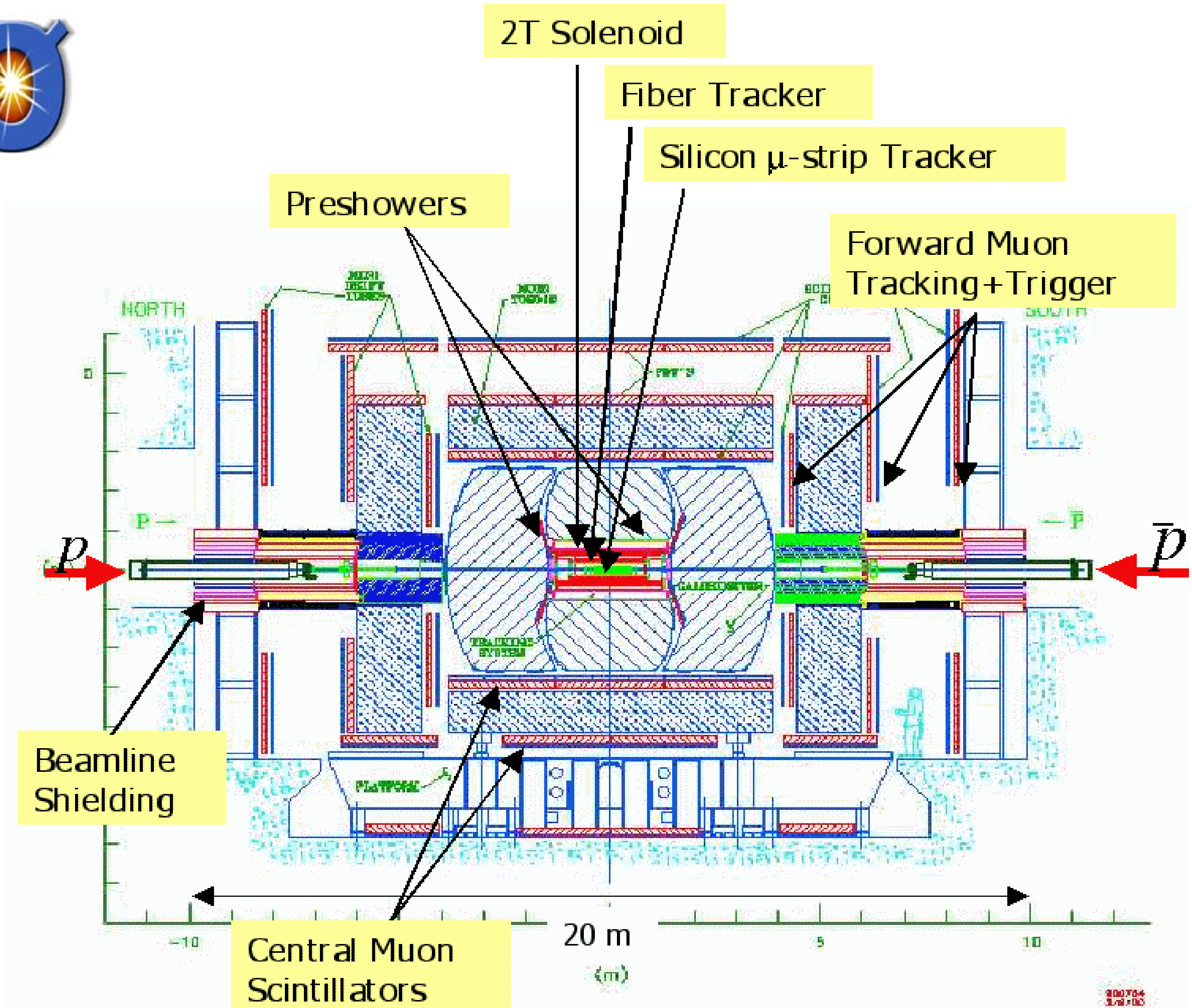
DØ: arXiv: 0808.4142 (2008)



CDF 2006

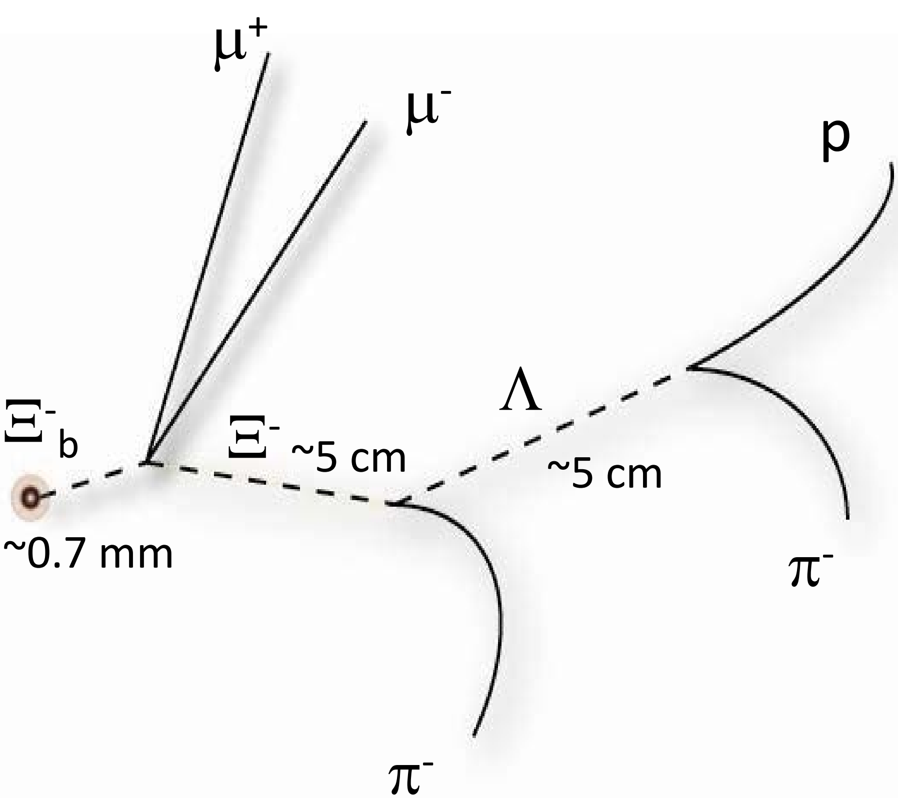
$\Sigma_b^\pm \rightarrow \Lambda_b \pi^\pm \rightarrow \left(\Lambda_c^+ \pi^-\right)\pi^\pm$

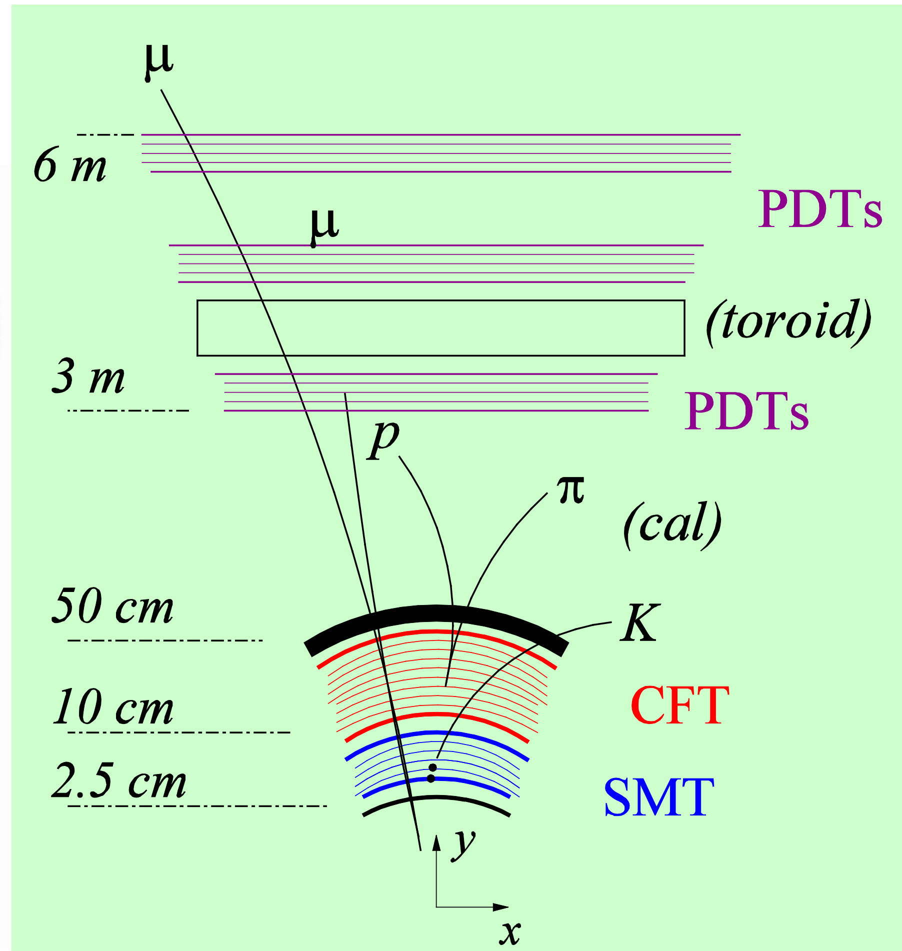



2T Solenoid
Fiber Tracker
Silicon μ-strip Tracker
Preshowers
Forward Muon
Tracking+Trigger
NORTH
p
$\bar{p}$
Beamline
Shielding
Central Muon
Scintillators
20 m
-10
5
10
(m)

How did we look for the Ξ^-_b?

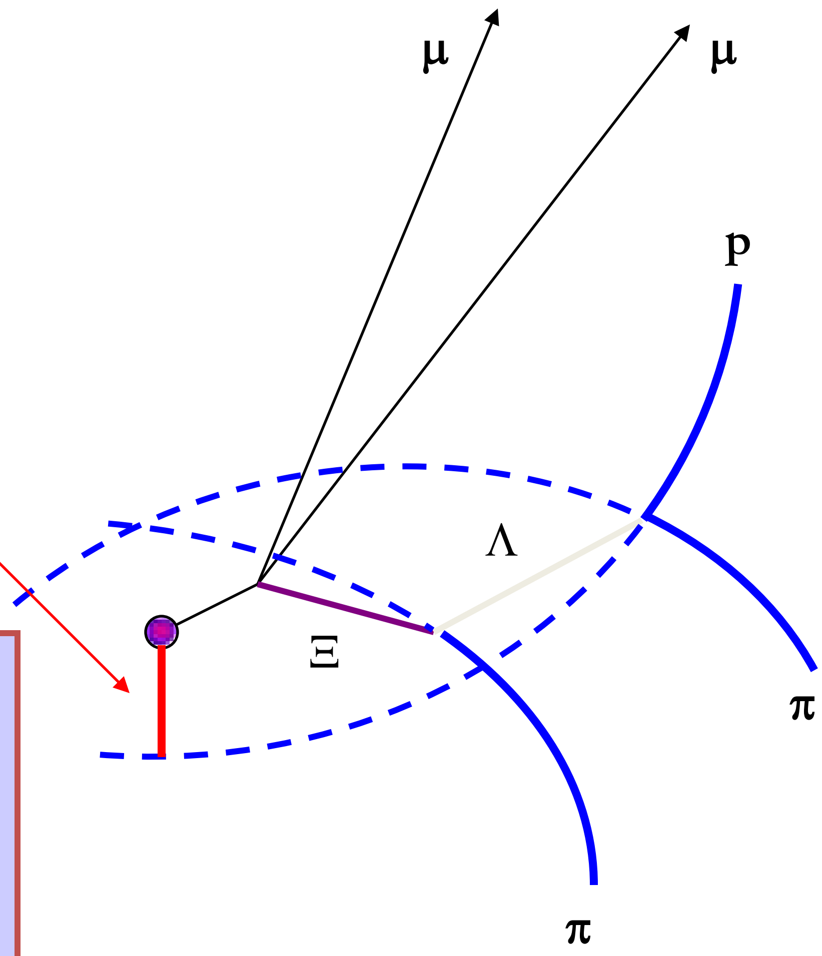
$\Xi^-_b \rightarrow J/\psi + \Xi^-$





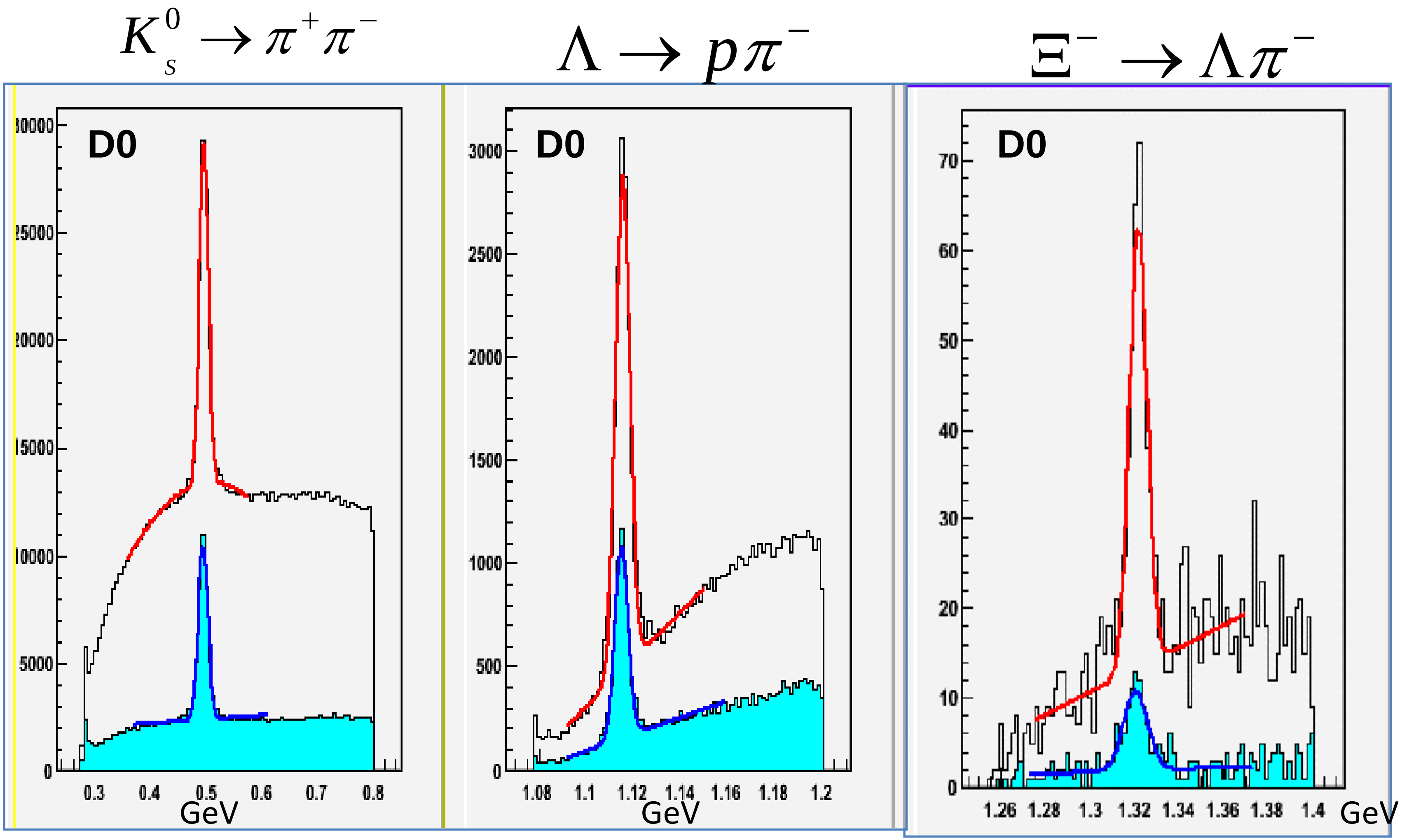
Data reprocessing

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



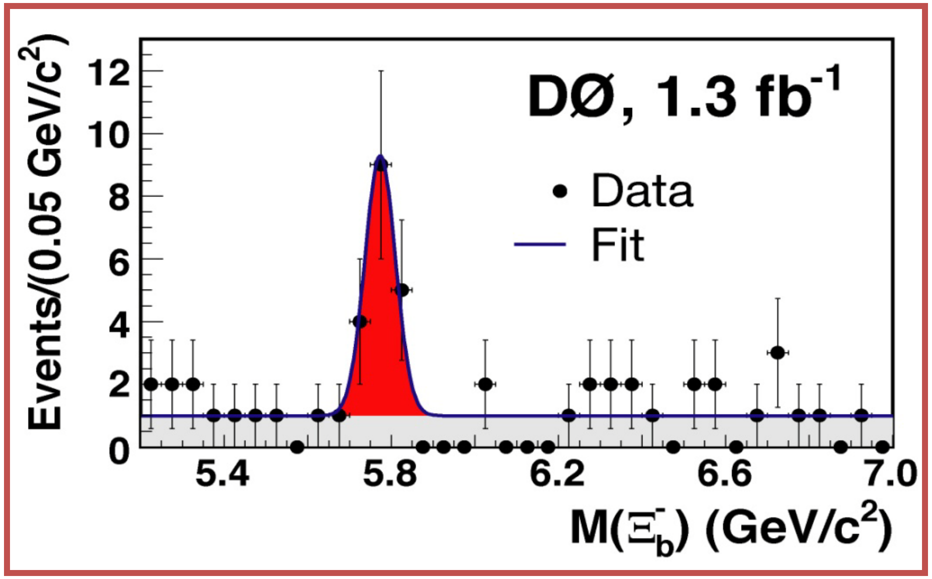
But for particles like the Ξ_b^-, this requirement could result in missing the π and proton tracks from the Λ and Ξ^- decays

Increase of reconstruction efficiency



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

Ξ^-_b observation



Number of events: 15.2 ± 4.4

Mass: 5.774 ± 0.011(stat) GeV

Width: 0.037 ± 0.008 GeV

We also measured:

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

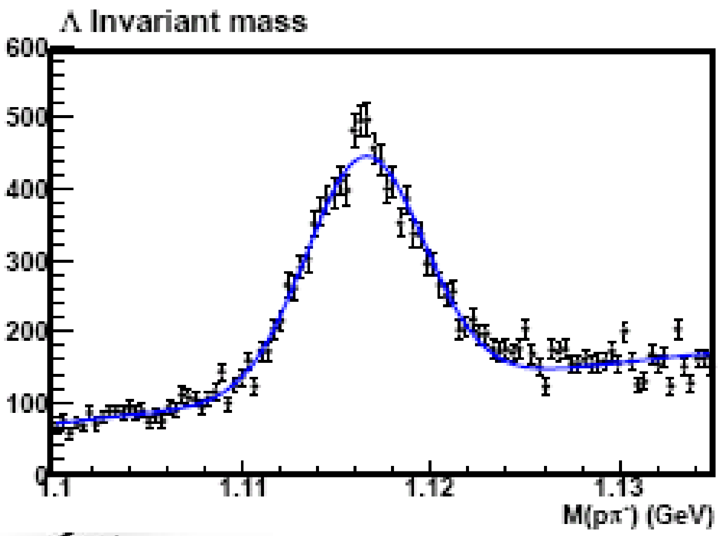
$$R = 0.28 \pm 0.09\,(\mathrm{stat})\,^{+0.09}_{-0.08}\,(\mathrm{syst})$$

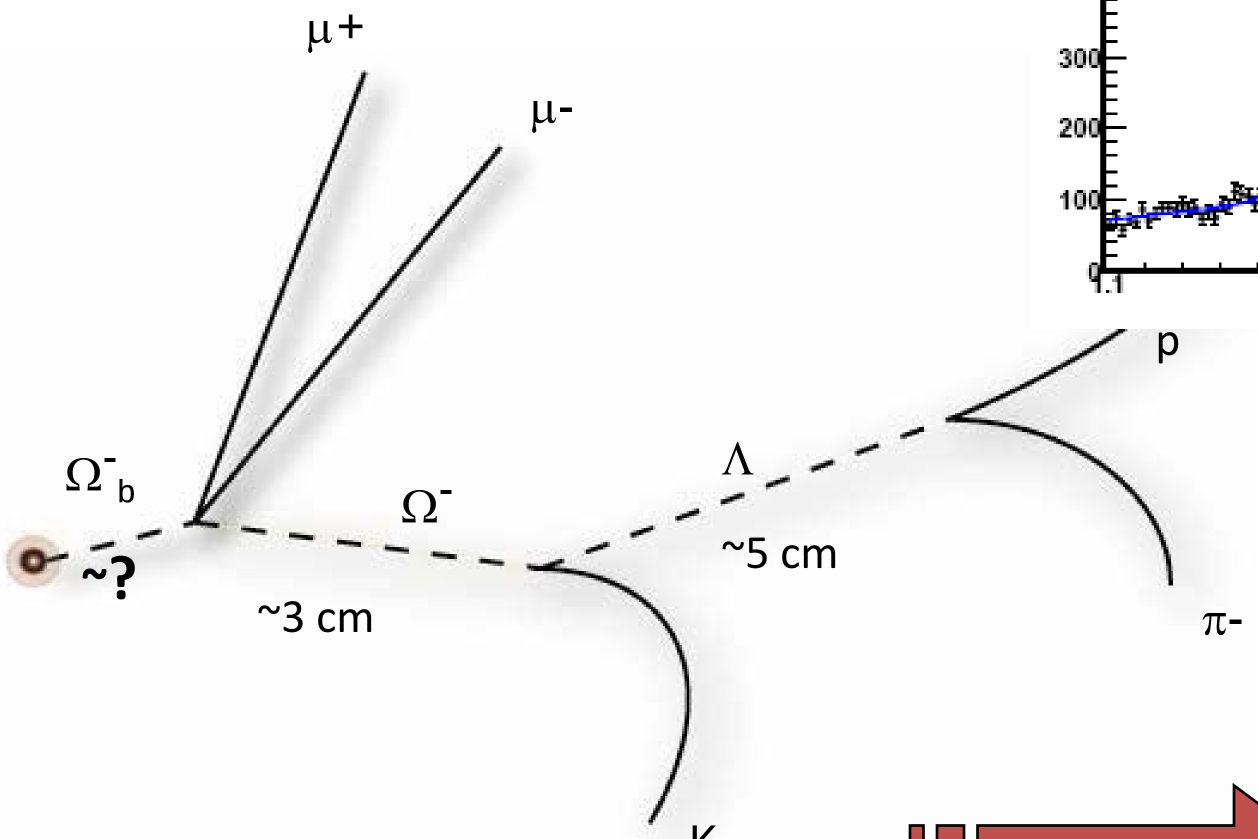
Signal Significance:

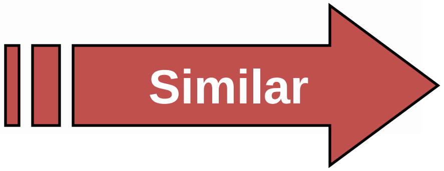
$$\sqrt{-2\Delta \ln L} = \sqrt{-2\ln\left(\frac{L_B}{L_{S+B}}\right)} = 5.5\sigma$$

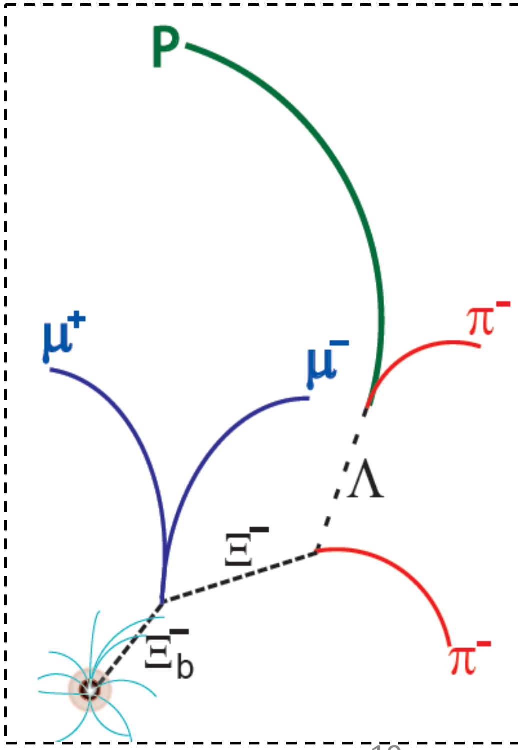
PRL 99, 052001 (2007)

How do we look for $\Omega^-_b(bss)$?

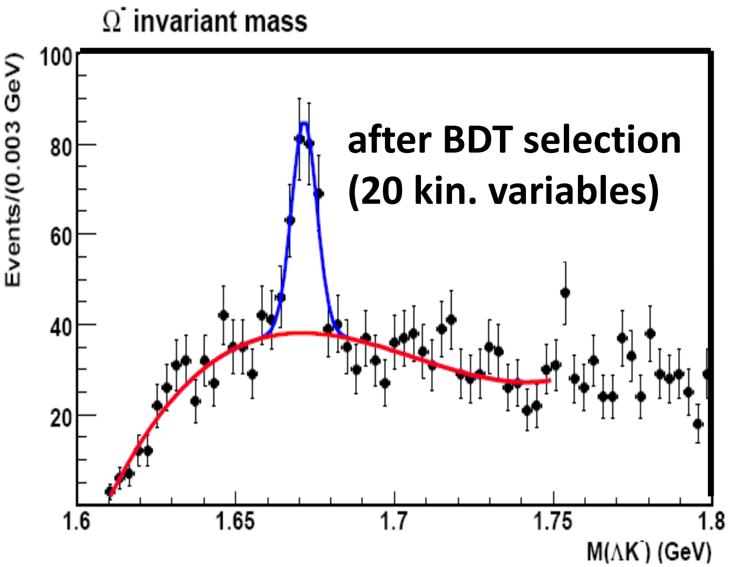


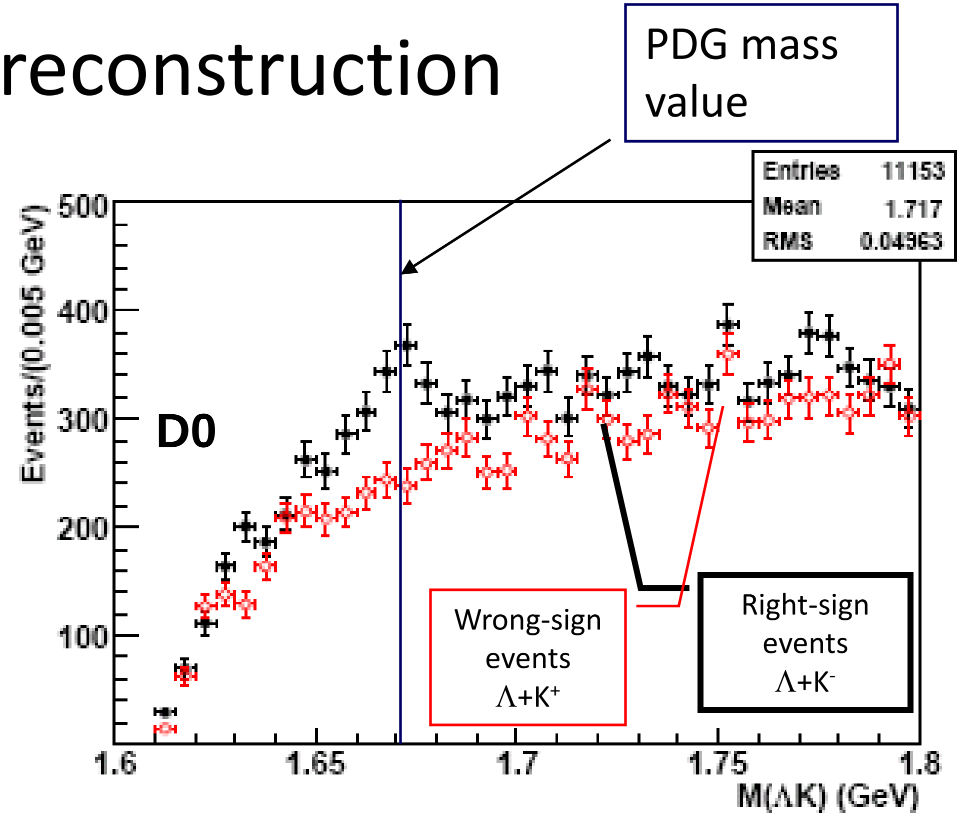


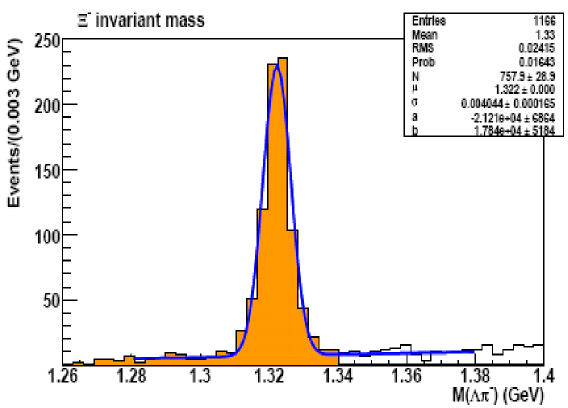


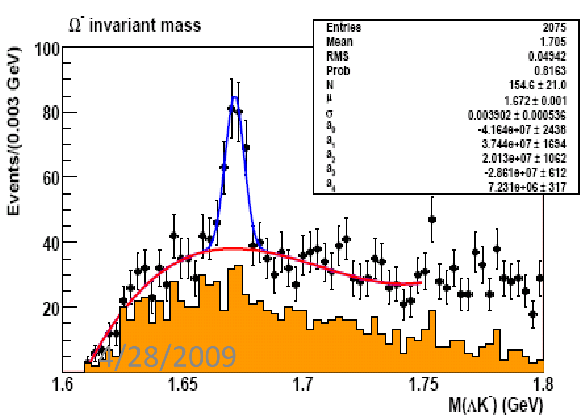


Ω reconstruction

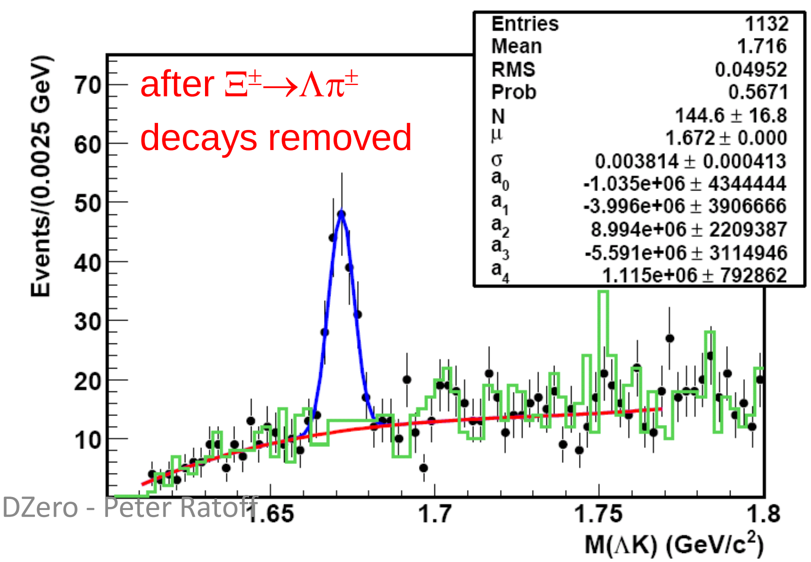








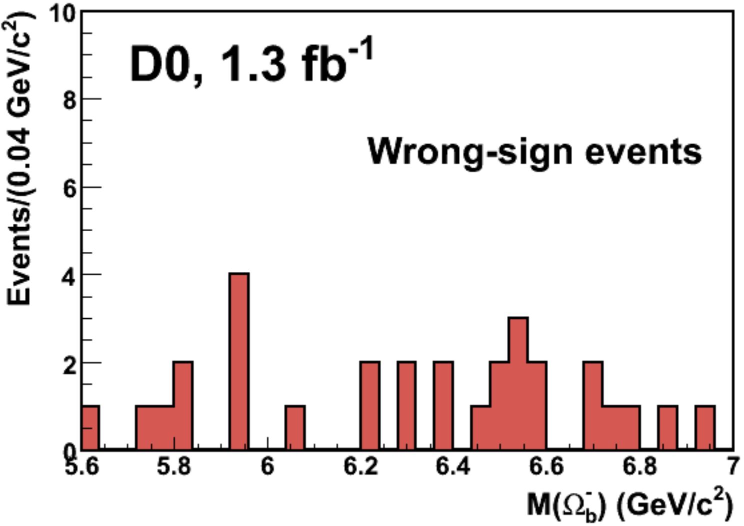
$M(\Lambda\pi)>1.34$



Systematic Checks

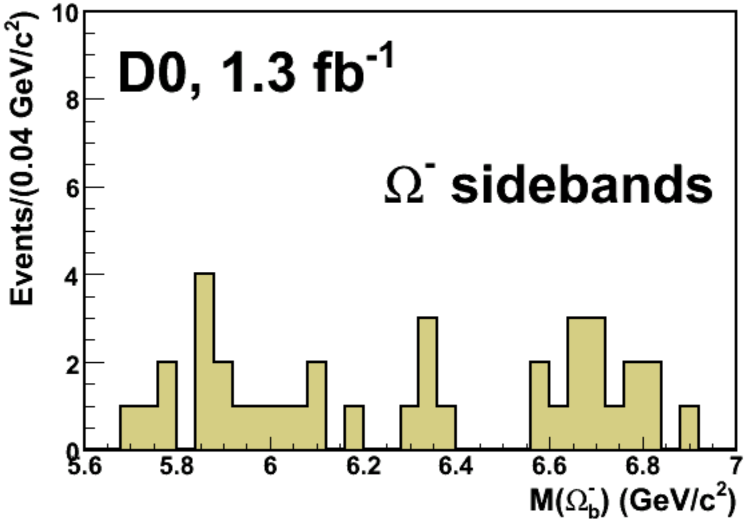
Mass window for the search: 5.6 - 7 GeV

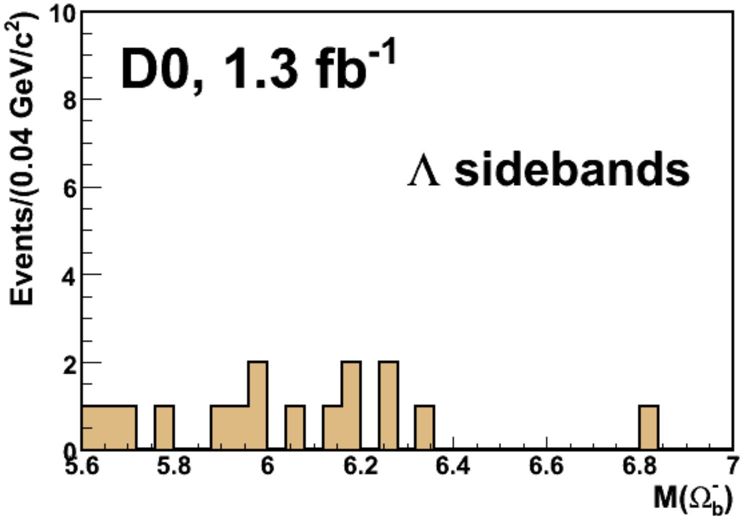
$$M = M_{J/\psi\Omega} - M_{J/\psi} - M_{\Omega} + M_{J/\psi}^{PDG} + M_{\Omega}^{PDG}$$



Optimization cuts

- σ_λ<0.03 cm
- J/ψ and Ω in the same hemisphere
- p_T(J/ψ+Ω) >6 GeV





We check also high statistics MC samples

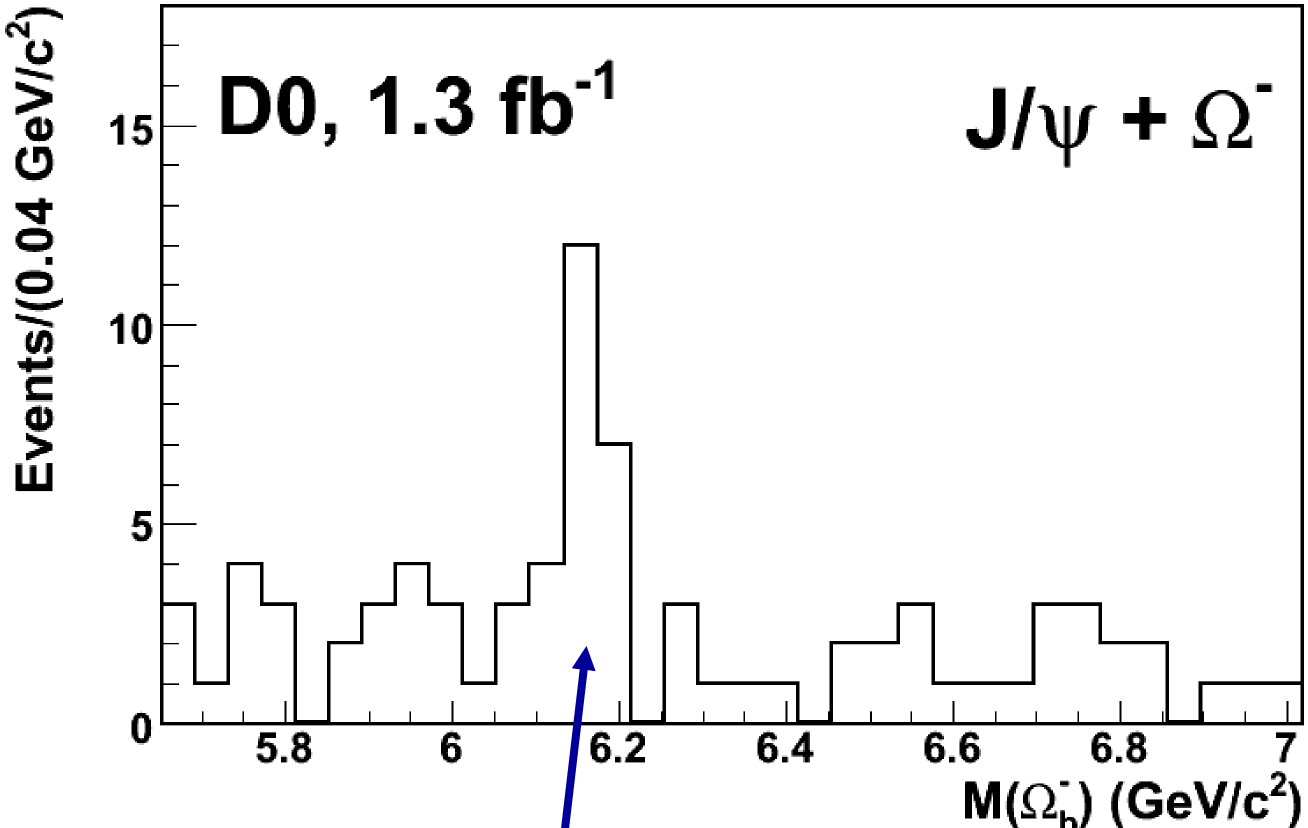
$$\Lambda_b \rightarrow J/\psi\Lambda \rightarrow (\mu^+\mu^-)(p\pi^-)$$

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

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

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

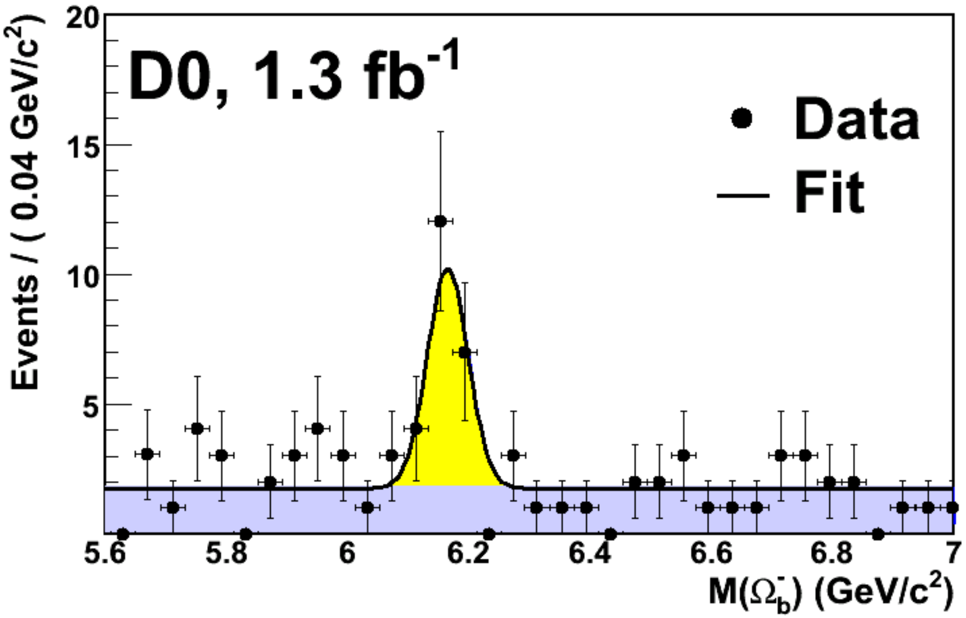
Looking at right-sign combinations



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 ± 0.010(stat) ± 0.013 (syst) GeV

Width of the Gaussian fixed (MC): 0.034 GeV

- Varying Gausssian width
- Momentum scale
- Event selection

Ω^-_b production rate

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

$$\frac{\varepsilon(\Omega_b^-)}{\varepsilon(\Xi_b^-)}=1.5\pm0.2\,(\mathrm{stat})$$

$$\frac{f(b\to\Omega_b^-)Br(\Omega_b^-\to J/\psi\,\Omega^-)}{f(b\to\Xi_b^-)Br(\Xi_b^-\to J/\psi\,\Xi^-)}=0.80\pm0.32(stat)^{+0.14}_{-0.22}(syst)$$

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

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

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

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

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

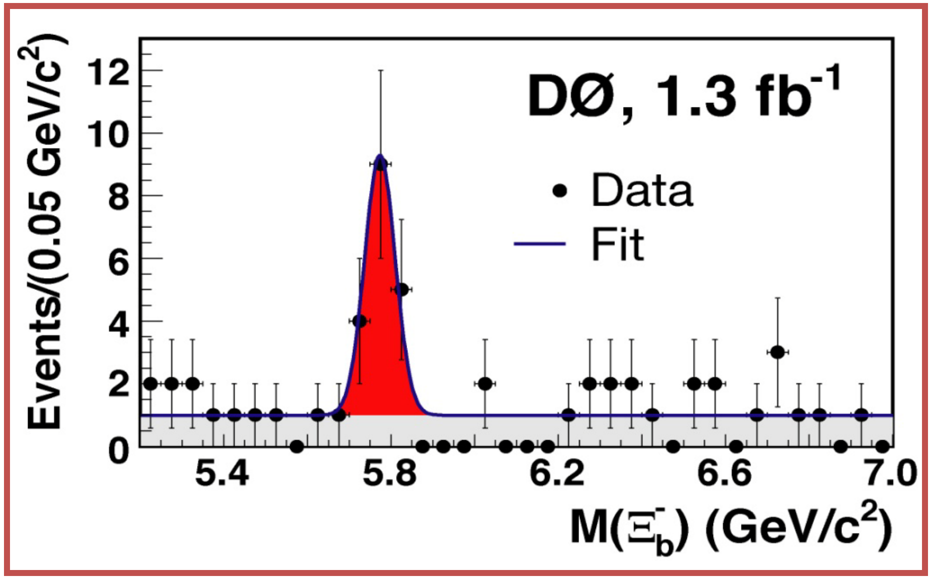
$0.83<\tau(\Omega_b^-)<1.67$ ps

theory

$$\frac{f(b\to\Omega_b^-)}{f(b\to\Xi_b^-)}\approx0.07-0.14$$

Summary

Ξ^-_b



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Significance = 5.5σ

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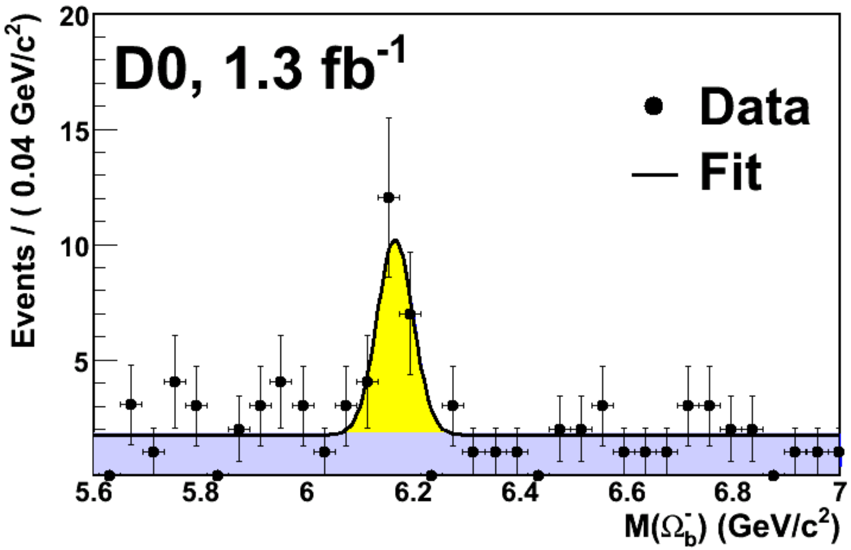
Ω^-_b



Number of signal events: 17.8 ± 4.9 (stat) ± 0.8(syst)

Mass: 6.165 ± 0.010(stat) ± 0.013(syst) GeV

Significance= 5.4σ

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

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

Consistent with expectations

Backup slides

Ξ_b Reconstruction procedure

Reconstruction procedure:

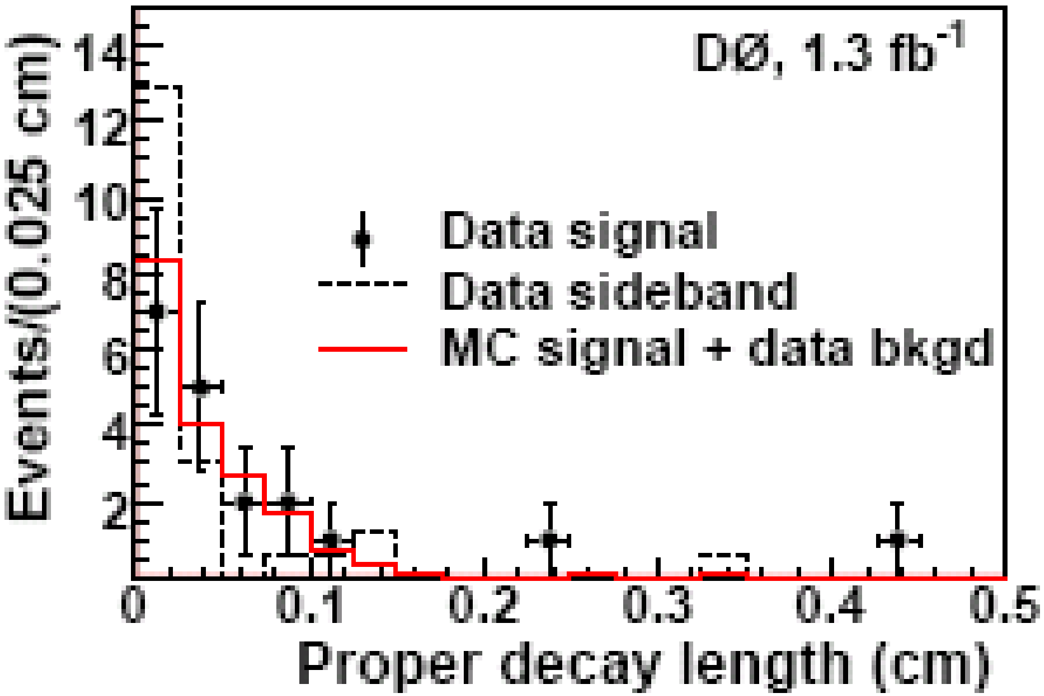
- Reconstruct $J/\psi \to \mu^+\mu^-$
- Reconstruct $\Lambda \to p\pi$
- Reconstruct $\Xi \to \Lambda + \pi$
- Combine $J/\psi + \Xi$
- Improve mass resolution by using an event-by-event mass difference correction
- **The optimization:**
  1. **$\Lambda_b \to J/\psi\Lambda$ decays in data**
  2. **$J/\psi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

Final Ξ_b selection cuts:

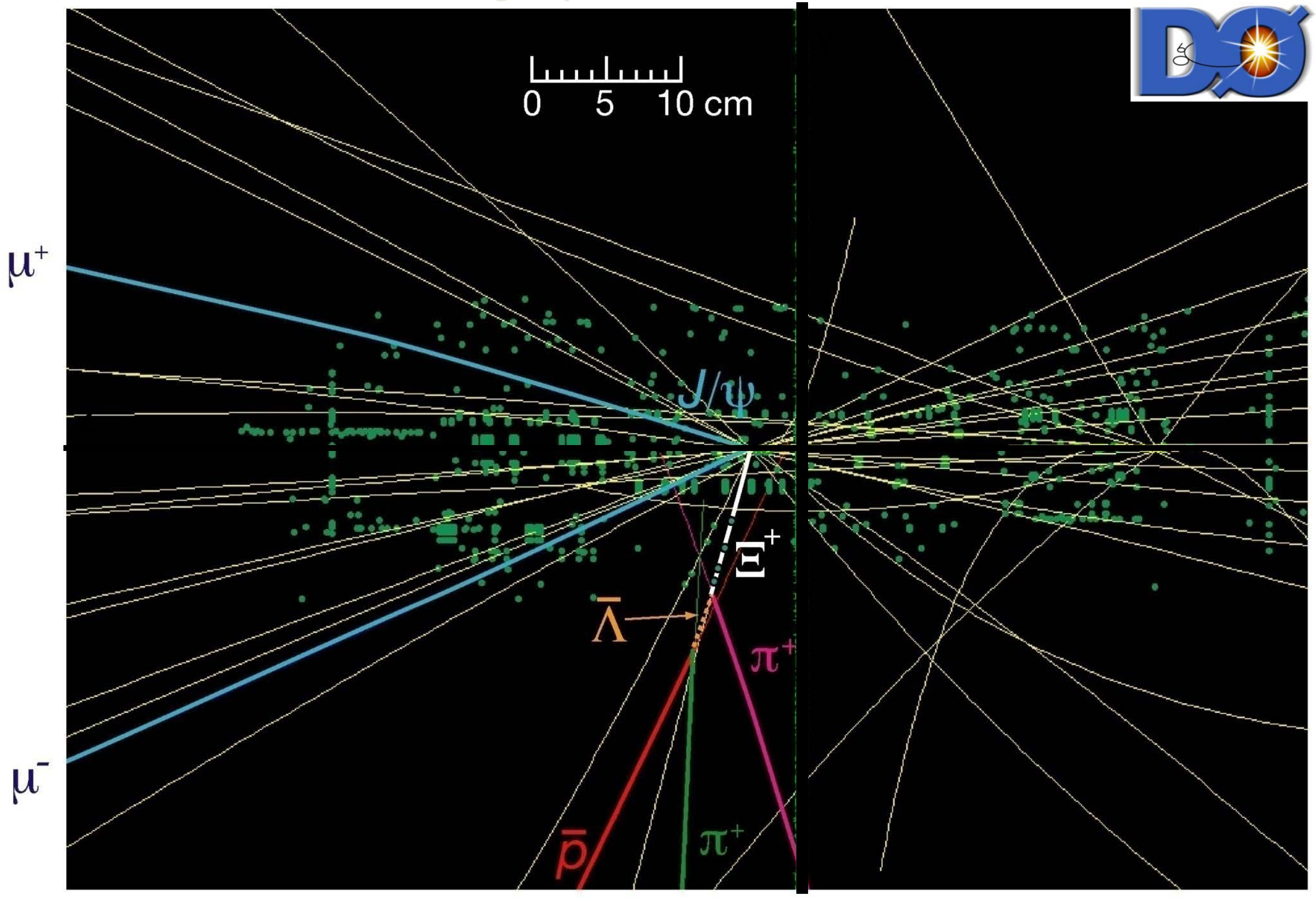
- $\Lambda \to p\pi$ decays:
  - $p_T(p) > 0.7$ GeV
  - $p_T(\pi) > 0.3$ GeV
- $\Xi^- \to \Lambda\pi$ decays:
  - $p_T(\pi) > 0.2$ GeV
  - Transverse decay length>0.5 cm
  - Collinearity>0.99
- Ξ^-_b particle:
  - Lifetime significance>2.
    (Lifetime divided by its error)

Consistency checks

- Ξ^-_b Decay length distribution



Event scan of event in the signal peak

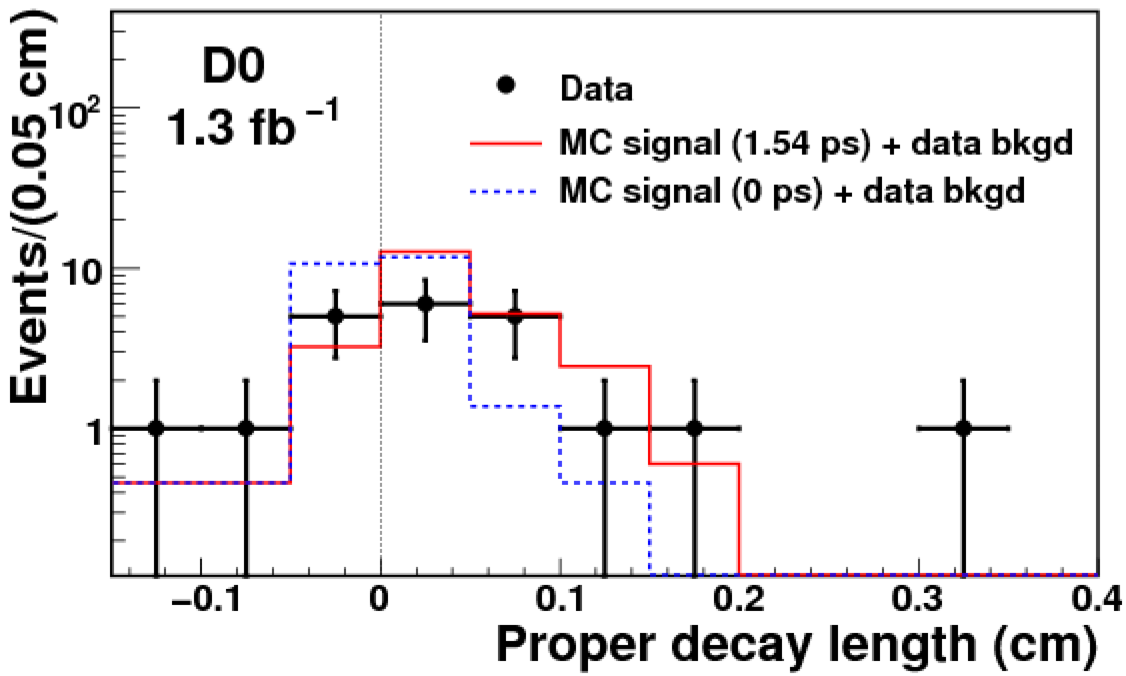


Run 179200, Event 55278820, $M(\Xi_b)$ = 5.788 GeV

Ω^-_b Analysis strategy

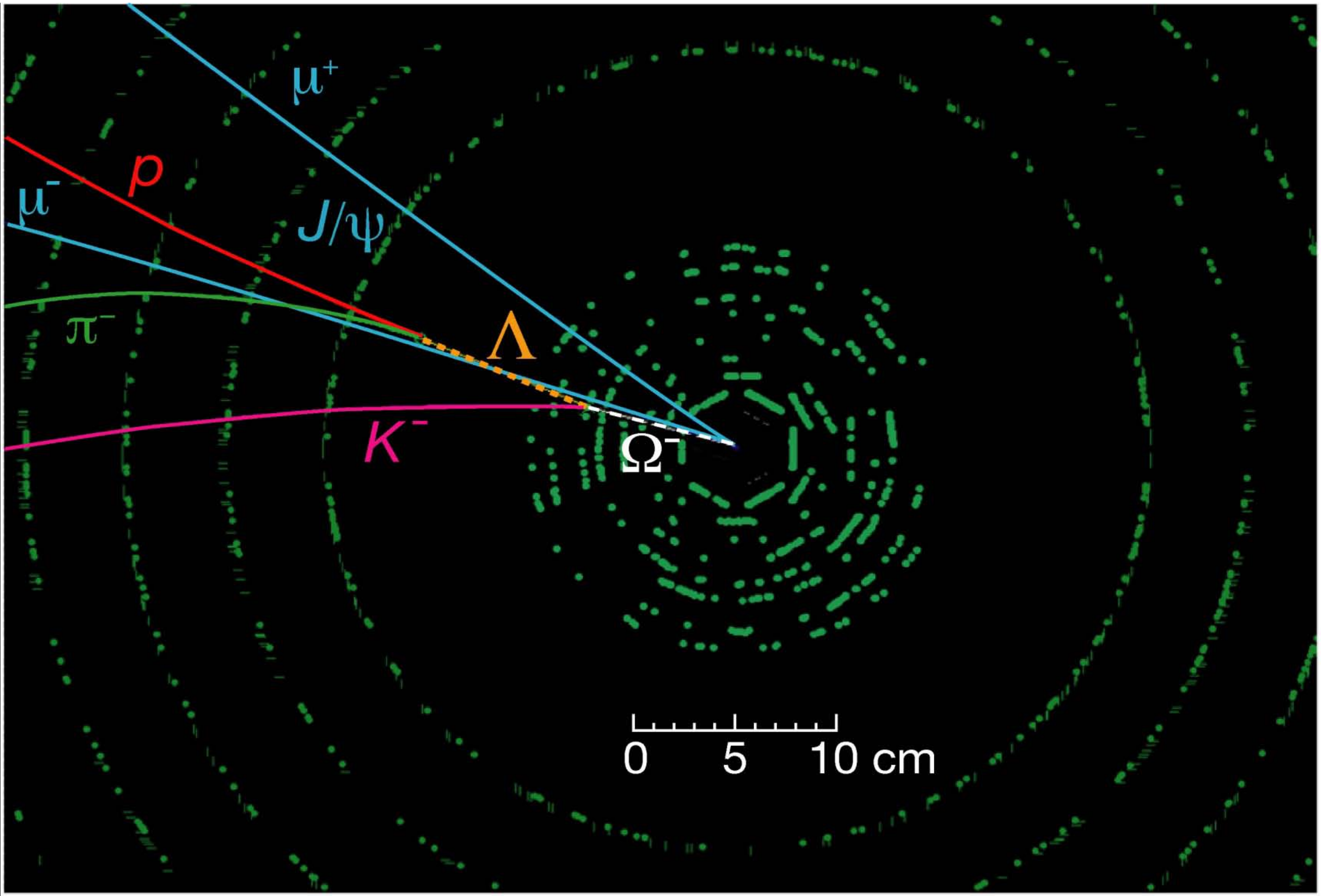
Select J/ψ candidates	Events are reprocessed to increase reconstruction efficiency of long-lived particles.
Select $\Lambda \rightarrow p\pi$	Yield is optimized by using proper decay length significance cuts.
Reconstruction of $\Omega \rightarrow \Lambda + K$	Optimize yield by using multivariate techniques
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 GeV