First observation of the Ξ_b^0 baryon

New result for this conference.

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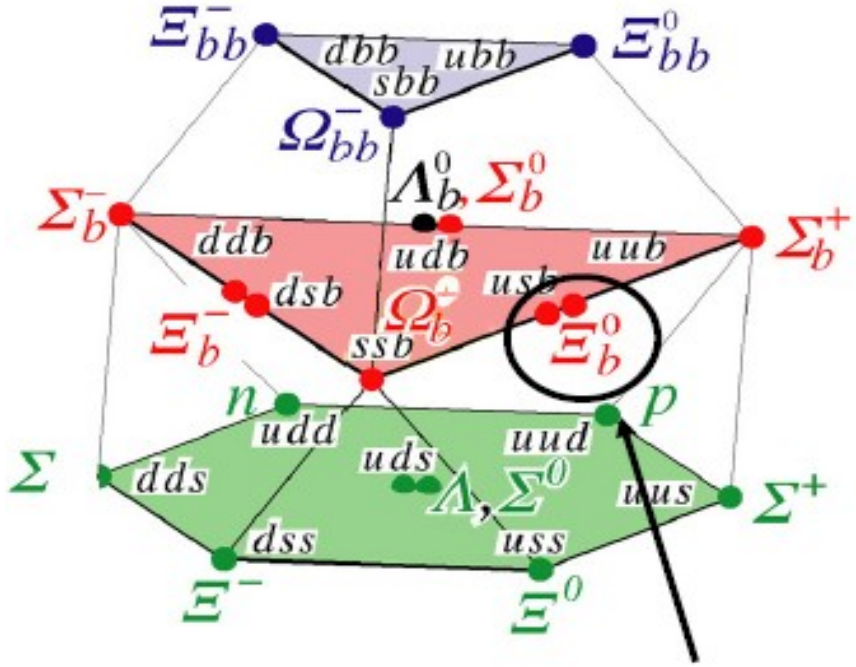
The b-baryon family

The family of j = ½ b-baryons is related to the s-baryons by replacing s by b.



so far not yet observed

So far within our reach are the "single-b" baryonic states. **Look for the missing Ξ_b^0.**

Important to keep checking quark model and measure masses of states to compare to theory:

E Jenkins, P.R. D77 (2008) 034012, R. Lewis and R.M. Woloshyn, P.R. D79 (2009) 014502,
D. Ebert et al., P.R. D72 (2005) 034026, M Karliner et al., Ann. Phys. (NY) 324 (2009) 2,
A Valcarce et al., Eur. Phys. J. A37 (2008) 217

Brief history of b-baryons

The b-baryons have required high energy and beam intensity for their observation:

Λ_b^0	$\|udb\rangle$	5620±1.6 MeV	1991	CERN, Tevatron
$\Sigma_b^{\pm}$	$\|uub\rangle$, $\|ddb\rangle$	5808±2.7, 5815±2.0 MeV	2007	Tevatron
Ξ_b^-	$\|dsb\rangle$	5791±3 MeV	2007	Tevatron
Ω_b^-	$\|ssb\rangle$	6054±7 MeV	2008/9	Tevatron

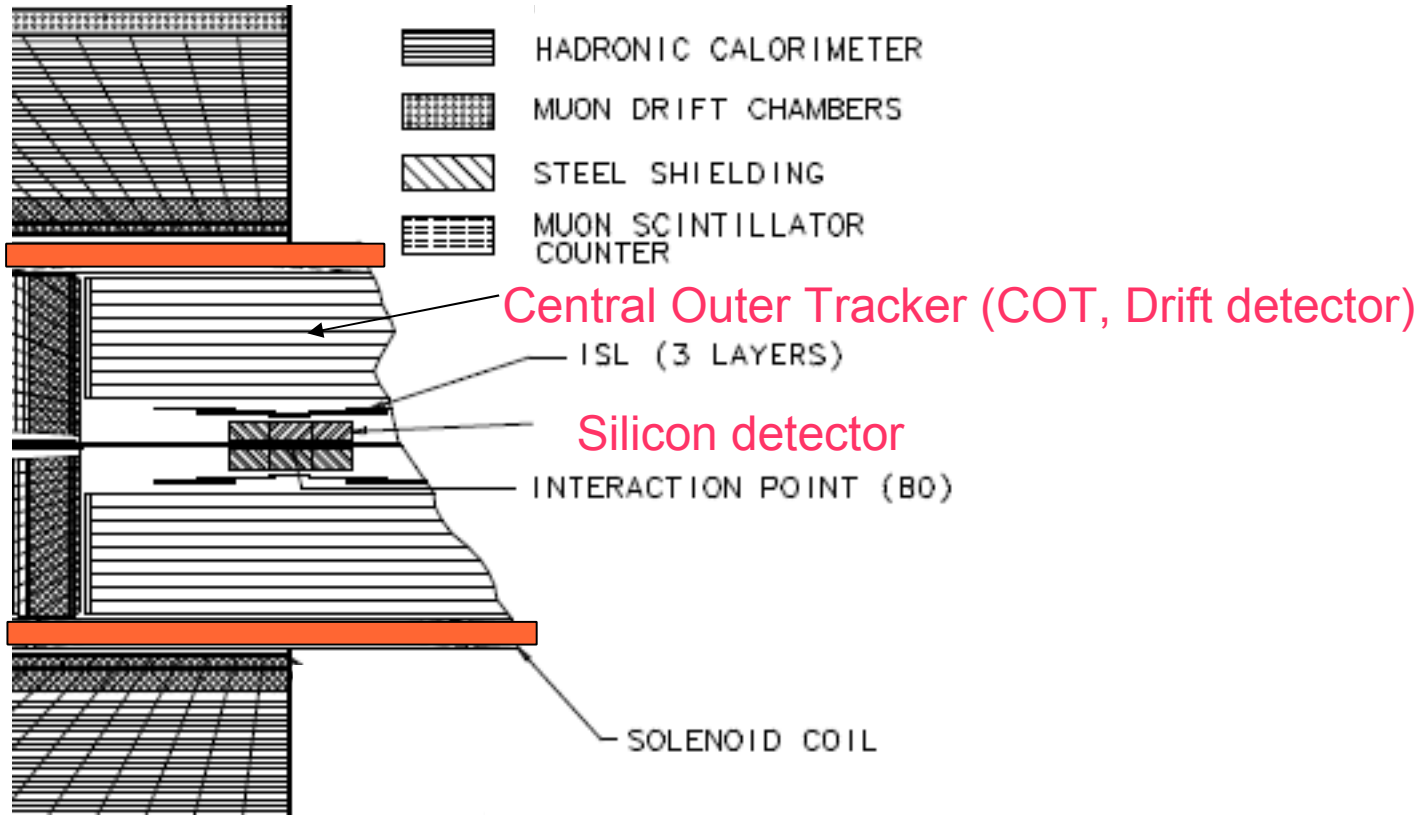
Ξ_b^0 $\|usb\rangle$?

These baryons have high branching ratios into semileptonic states but this means a neutrino is unobserved. Best to search in a rarer but completely reconstructible fully hadronic state.

N.b. "+ charge conjugate" is implied throughout these pages.

CDF detector

The main sections of the CDF detector used for this analysis:



A displaced track trigger, using silicon and COT information, was used to select events.

4.2 fb^{-1} of integrated luminosity used for this measurement.

Search methodology

One search possibility is to use decays into J/ψ.

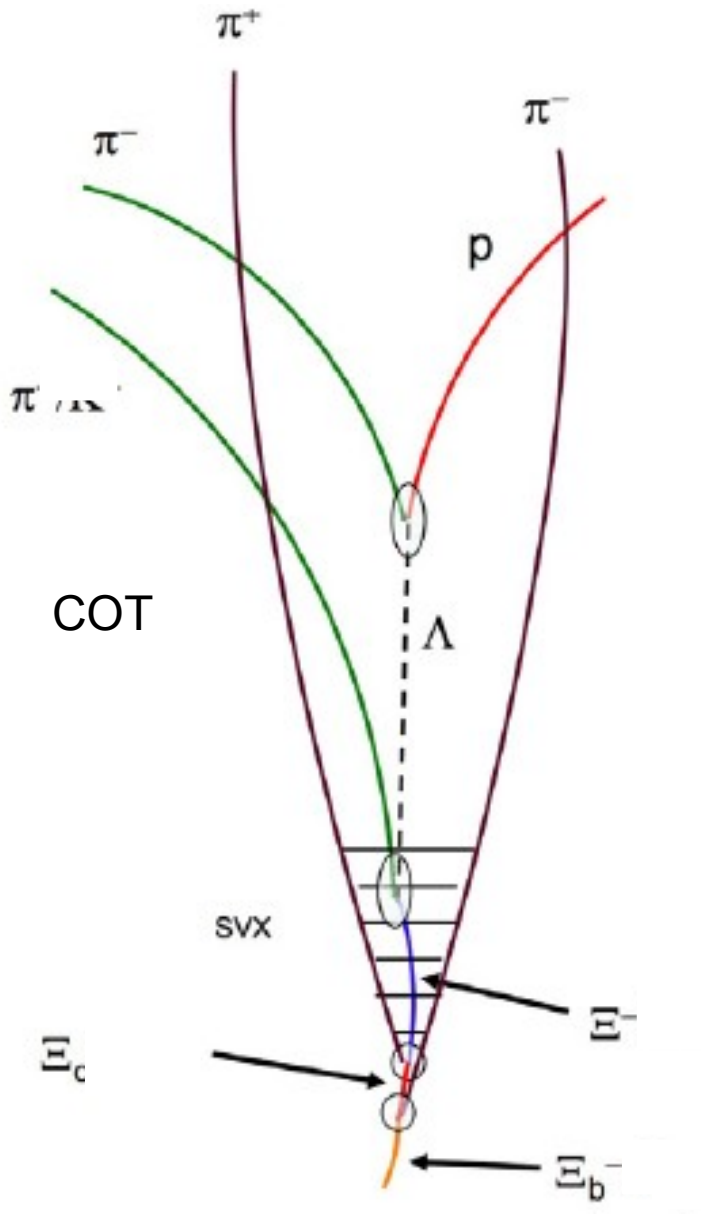
This won't work for the Ξ_b^0 (π^0 in the decay chain)

Instead, use decays into Ξ_c.

We look **simultaneously** for Ξ_b^0 and Ξ_b^-.
Combined search uses the established Ξ_b^- state as a check on the Ξ_b^0

$\Xi_b \rightarrow \Xi_c \pi^-$ with $\Xi_c \rightarrow \Xi^-\pi^+(\pi^+)$
and $\Xi^- \rightarrow \Lambda\pi^-$
and $\Lambda \rightarrow p\pi^-$

with $\Xi_c^0 \rightarrow \Xi^-\pi^+$ from the Ξ_b^-
and $\Xi_c^+ \rightarrow \Xi^-\pi^+\pi^+$ from the Ξ_b^0



Search methodology

$\Xi_b \rightarrow \Xi_c \pi^-$ with $\Xi_c \rightarrow \Xi^-\pi^+(\pi^+)$

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

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

Method:

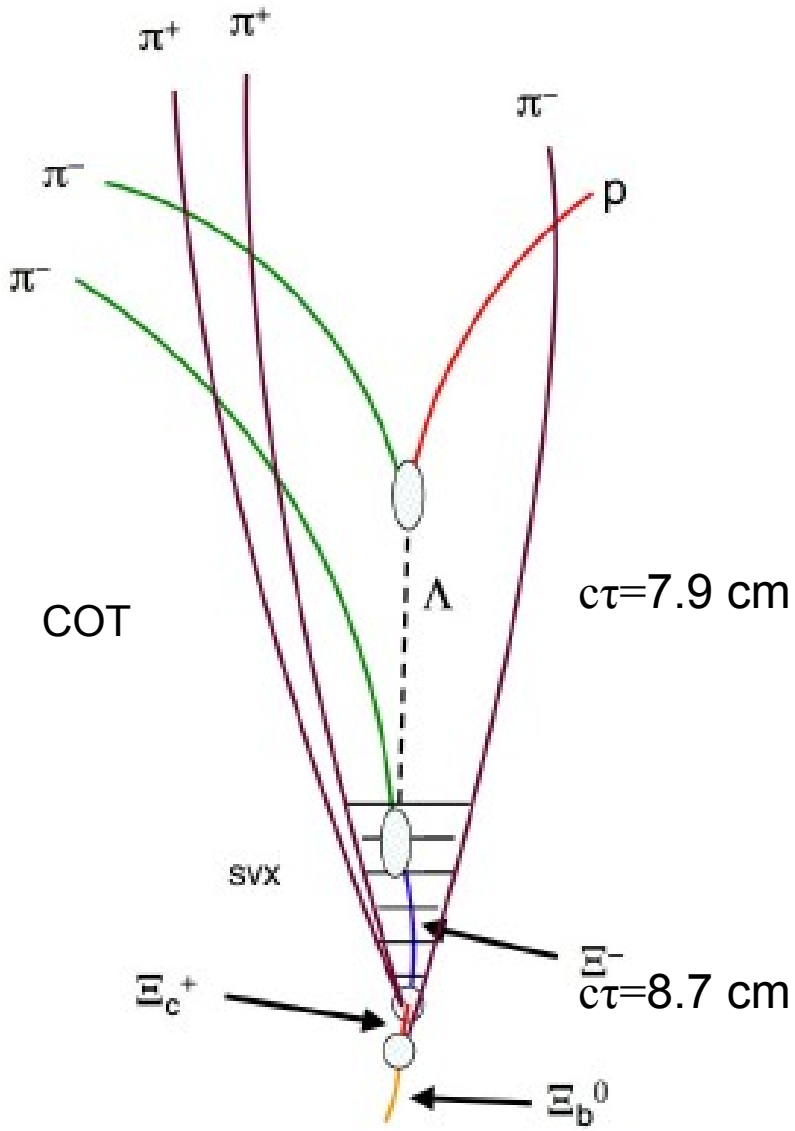
- reconstruct the Λ

- link it with a π^- to form a Ξ^-

  - put silicon hits on the Ξ^-

- link this with π^+ ($\pi^+\pi^+$) to form $\Xi_c^{\ 0}$ ($\Xi_c^{\ +}$)

- link this with a π^- to form a $\Xi_b^{\ -}$ ($\Xi_b^{\ 0}$)

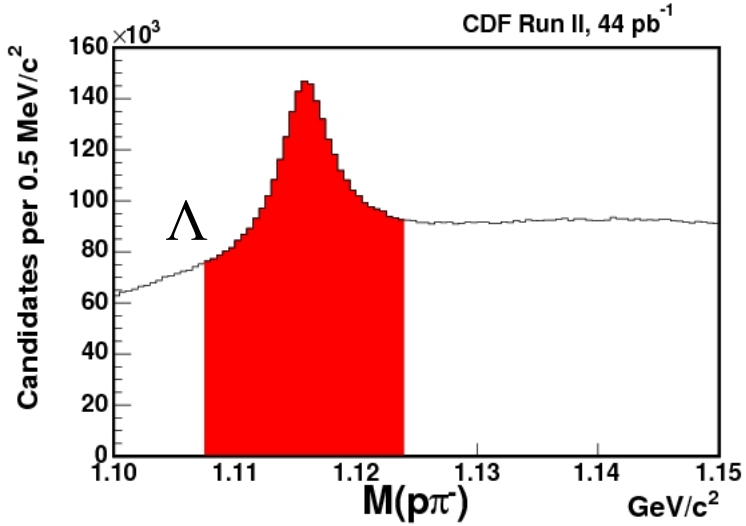


Technical procedure

At each stage, it is necessary to optimise signal, minimise backgrounds.
Checks were made against known signals.

Λ reconstruction:

use pairs of tracks with p_T > 0.4 GeV/c
in CDF COT
require good vertex
proton = higher momentum track
(PID not used)
total flight distance > 1 cm (in xy plane)
(removes badly measured vtx. tracks)



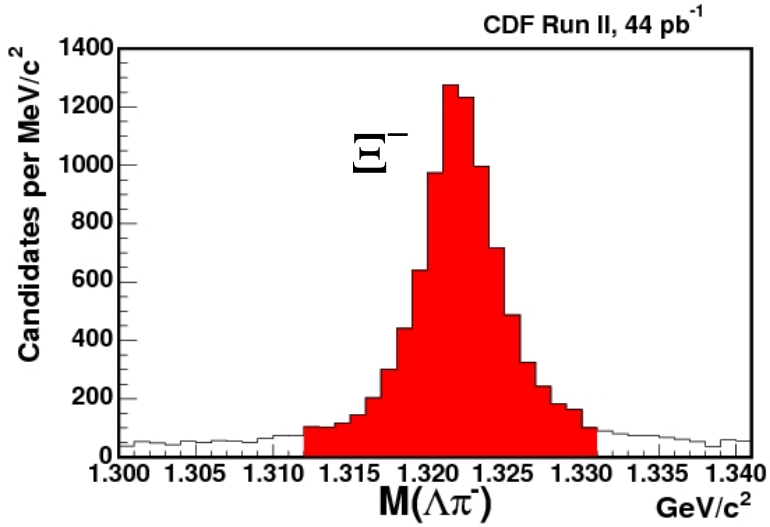
Ξ^- reconstruction:

combine Λ candidates with pion tracks,
in a fit constraining Λ mass and good $\Lambda\pi$ intersection.

Λ flight distance from Ξ^- decay vtx. > 1 cm.

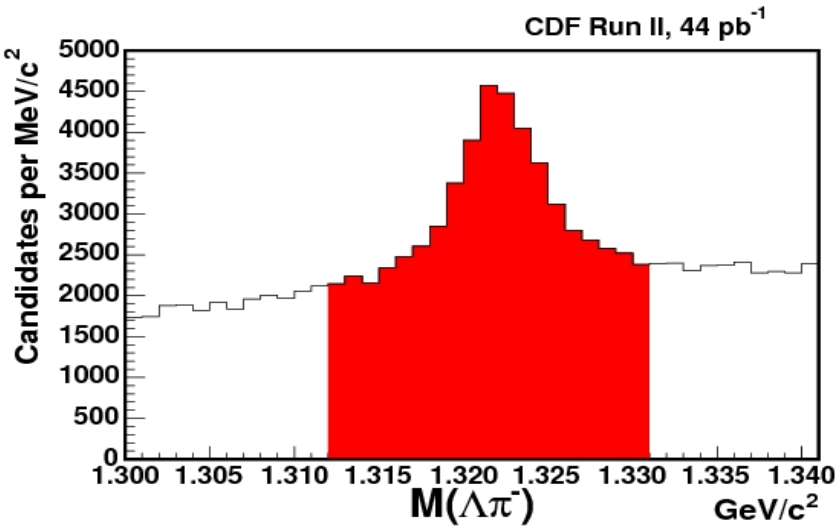
Ξ^- flight distance from primary vtx. > 1 cm.

Require Si detector hits on Ξ^-. Refit.

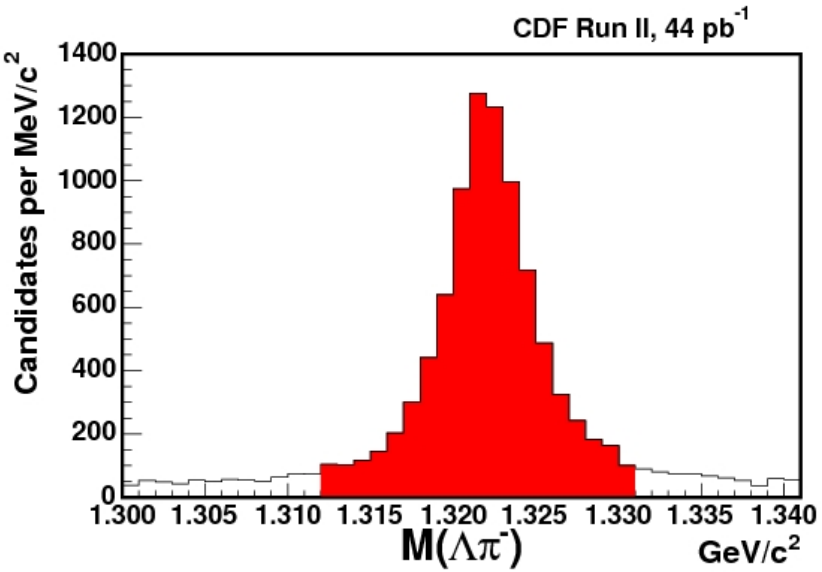


Silicon hits

Improvement in Ξ^- signal/background by including silicon detector hits on it.



Without



With Si hits

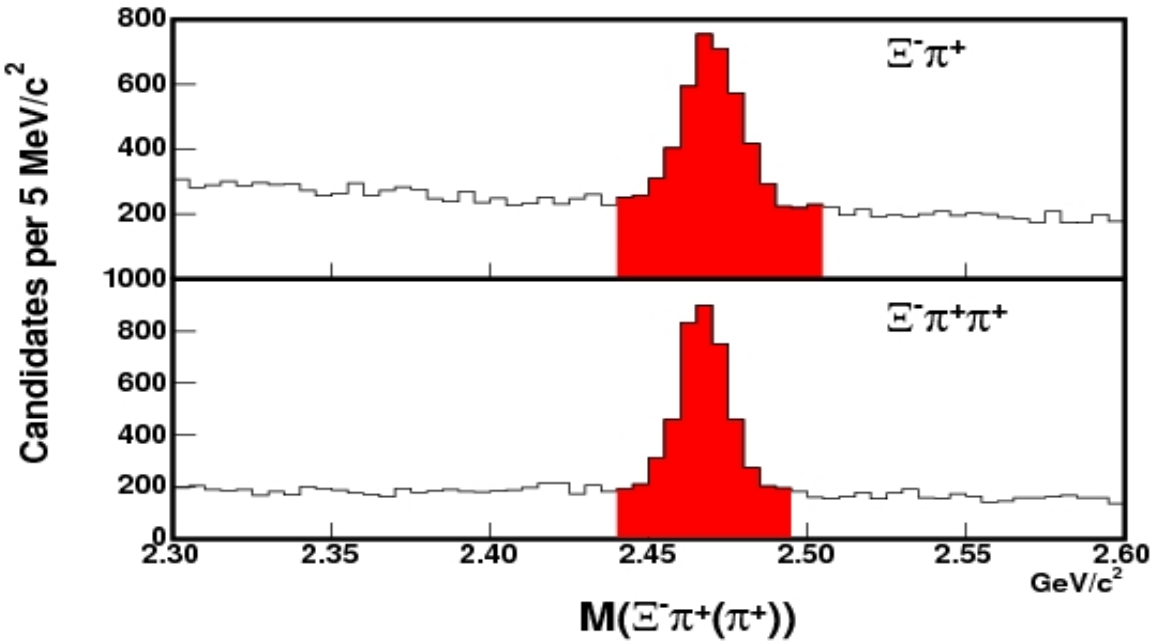
Ξ_c reconstruction:

Combine Ξ^- with one (two) π^+ tracks with
>2 silicon detector hits
p_T > 2 GeV/c
impact parameter $|d_0|$ > 100 μm

Extrapolate Ξ^- direction, fit to vertex with pion(s), applying mass constraints
The combination must have
p_T > 4 GeV/c
ct > 100 μm

Event yields: Ξ_c^0 2110±70

Ξ_c^+ 3048±67



Final Ξ_b combination

Combine the Ξ_c candidates with further π^- tracks in the event to form Ξ_b candidates.
These must satisfy selection criteria based on previous CDF studies:

p_T > 6 GeV/c (for good modelling of system in CDF)
a constrained vertex fit including all the known baryon masses, using the extrapolated Ξ_c direction
pointing towards primary vertex

$-2\sigma < t < 3\tau + 2\sigma$ for the decay time t of the Ξ_c candidate

(based on a study of $\Lambda_b \rightarrow \Lambda_c^+ \pi^-$ events)

(Nb. decay distances of Ξ_c^+ , Ξ_c^0 are 440 μm, 110μm .)

Note: the trigger particles are this π^- and one of the π^+ in the Ξ_c..
This enables the other selections to be applied without bias.

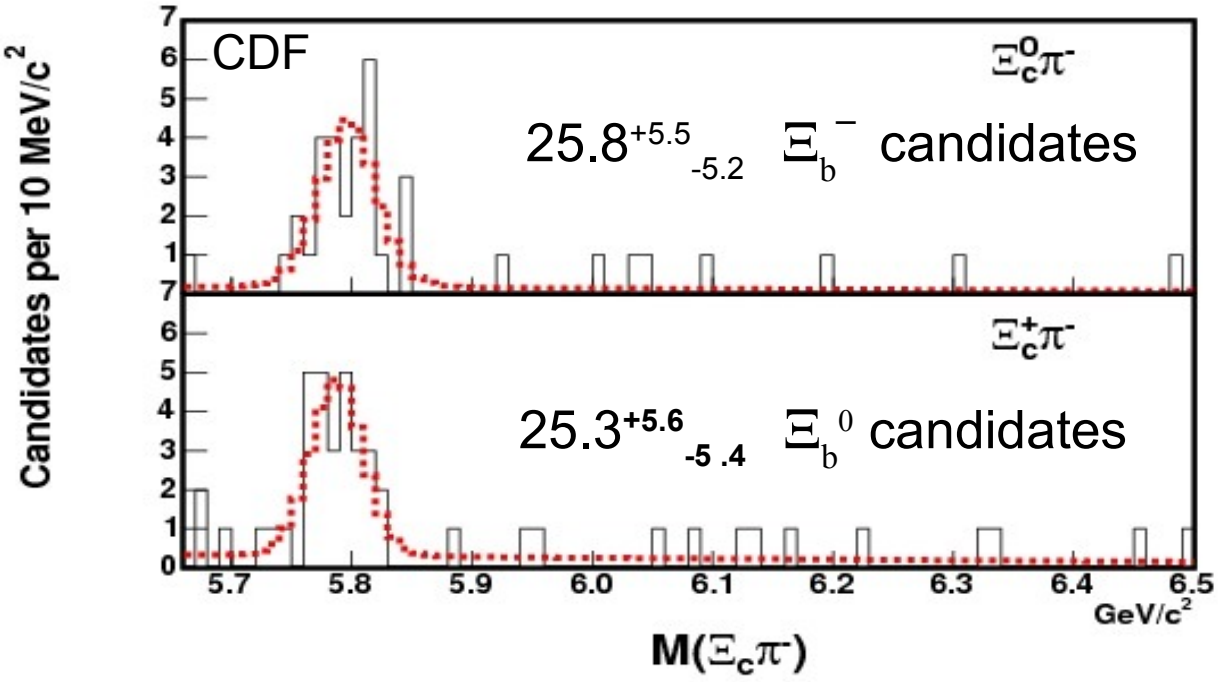
Mass fit of final combinations

Red histograms = results of unbinned likelihood fit to peak + bgd.

Ξ_b^- p = 3.9x10^{-12}

Ξ_b^0 p = 3.6x10^{-12}

Both peaks > 6.8σ equivalent statistical significance.



Systematics estimated by comparing other measured masses with standard values. Momentum scale and resolution were the biggest effects.

Fitted mass of Ξ_b^0 = 5787.8 ± 5.0 (stat) ± 1.3 (sys) MeV

in agreement with theoretical expectations

Fitted mass of Ξ_b^- = 5796.7 ± 5.1 (stat) ± 1.4 (sys) MeV

in agreement with earlier CDF Phys. Rev. D 80 072003 (2009)

Mass difference: m(Ξ_b^-) - m(Ξ_b^0) = 3.1± 5.6(stat) ± 1.3 (sys) MeV/c²

using the earlier CDF Ξ_b^- mass 5790.9±2.6±0.8 MeV/c²

Conclusions

Using 4.2 fb^{-1} of data in pp collisions at the Tevatron, CDF have observed

the Ξ_b^0 baryon,

the Ξ_b^- baryon in its $\Xi_c\pi^-$ decay mode.

Both are first measurements.

ArXiv 1107.4015

Mass of Ξ_b^0 = 5787.8 ± 5.0 (stat) ± 1.3 (sys) MeV

Breakdown of systematic uncertainties on Ξ_b mass measurement

	Ξ_b^-		Ξ_b^0	
$\Xi_c^{0,+}$ mass	0.34	-0.8	0.4	-0.6
Momentum Scale	0.5	-0.5	0.5	-0.5
Resolution Model	1.4	-1.4	1.4	-1.4
Total	1.5	-1.7	1.5	-1.6