b-baryon searches at the CMS experiment

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PhD students seminar
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Outline

- ★ Introduction - why *b*-baryons?
- ★ Search of Λ_b and charged Σ_b at CMS
  - what is known
  - event selection
  - results with 2011 data
- ★ Summary, ongoing and plans

Heavy baryons

★ **From the quark model (with *u,d,s,c,b* quarks):**

- 75 (ground state) baryons expected

★ **"Heavy" baryons: contain *c*(charm) or *b*(beauty) quark**

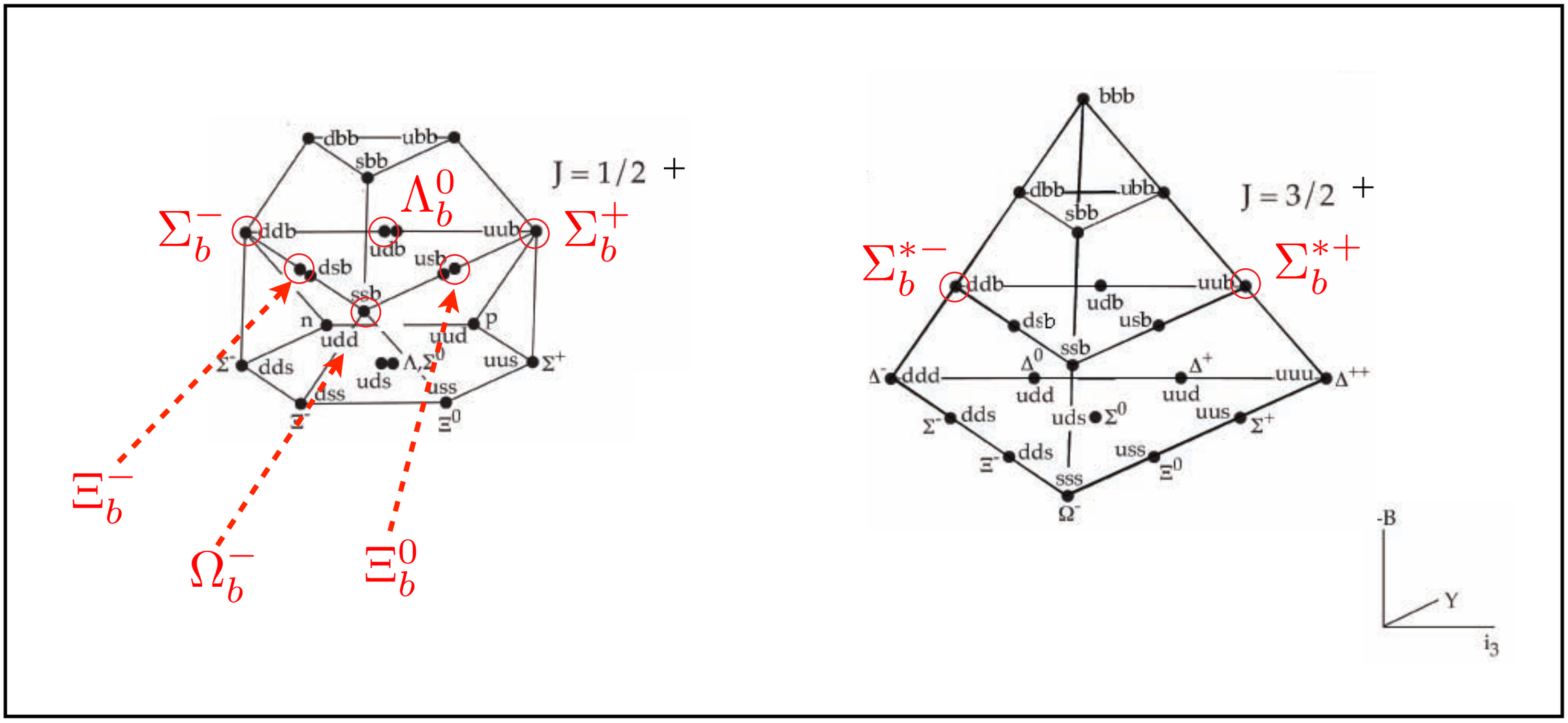
- 56 heavy baryons expected
- Observed baryons with *c* quark: 15
- **Observed baryons with a *b* quark: 8**

★ **Why *b*-baryons at CMS?**

- $b \rightarrow c$ => decays to J/ψ(μμ) => suitable to trigger on
- decays to (long-lived) hyperons => secondary (displaced) vertices

SU(4) with four quarks: *u,d,s,b*

- Only 8 baryons with *b*-quarks have been observed:



- Evidence often rests on a small number of events
- Most of the predicted ground states are still to be discovered

In this talk

I) $\Lambda_b(udb)$

$\Lambda_b \to J/\psi\Lambda$

$\Lambda \to p\pi$

$J/\psi \to \mu\mu$

II) $\Sigma_b^{(*)+}(uub),\ \Sigma_b^{(*)-}(ddb)$

$\Sigma_b^{(*)\pm} \to \Lambda_b\pi^{\pm}$

Processed data:

p-p collisions, $\sqrt{s}$ = 7 TeV

L ≈ 2 fb^{-1}

What is known about charged Σ_b

Four charged states observed so far:

$$\Sigma_b^{(*)+}\ (\mathrm{uub}) \rightarrow \Lambda_b^0 \pi^+$$
$$\Sigma_b^{(*)-}\ (\mathrm{ddb}) \rightarrow \Lambda_b^0 \pi^-$$

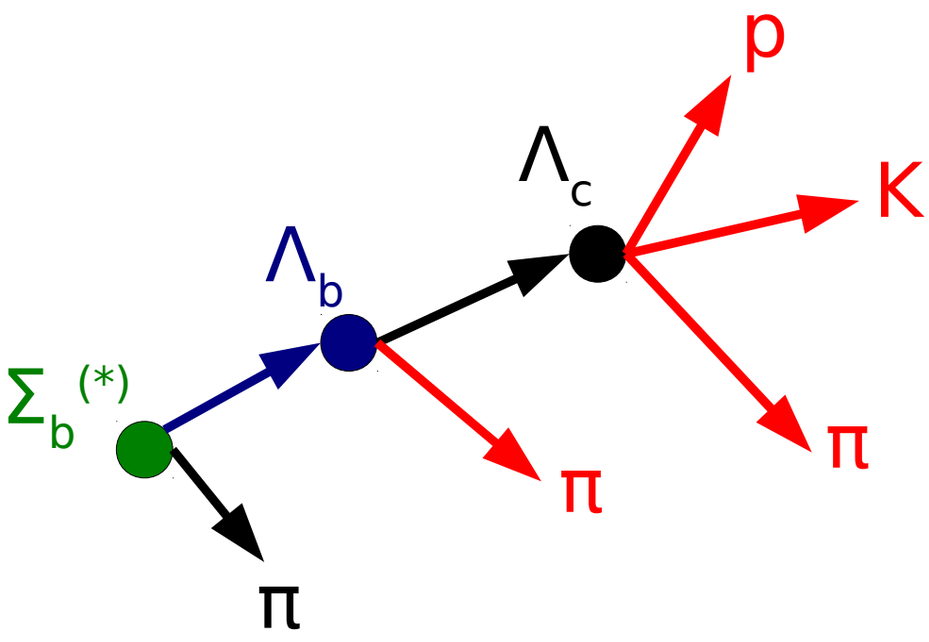
Theoretical expectations:

Σ_b property	Expected value ($\mathrm{MeV/c^2}$)
$m(\Sigma_b) - m(\Lambda_b^0)$	180 - 210
$m(\Sigma_b^*) - m(\Sigma_b)$	10 - 40
$m(\Sigma_b^-) - m(\Sigma_b^+)$	5 - 7
$\Gamma(\Sigma_b), \Gamma(\Sigma_b^*)$	$\sim$8, $\sim$15

What is known about charged Σ_b

- Σ_b states first observed by CDF (2006)
- Latest result: CDF, **L ≈ 6.0/fb (2010)**

  ~ 16,300 $\Lambda_b \to \Lambda_c^+ \pi^-$ candidates



CDF measures:

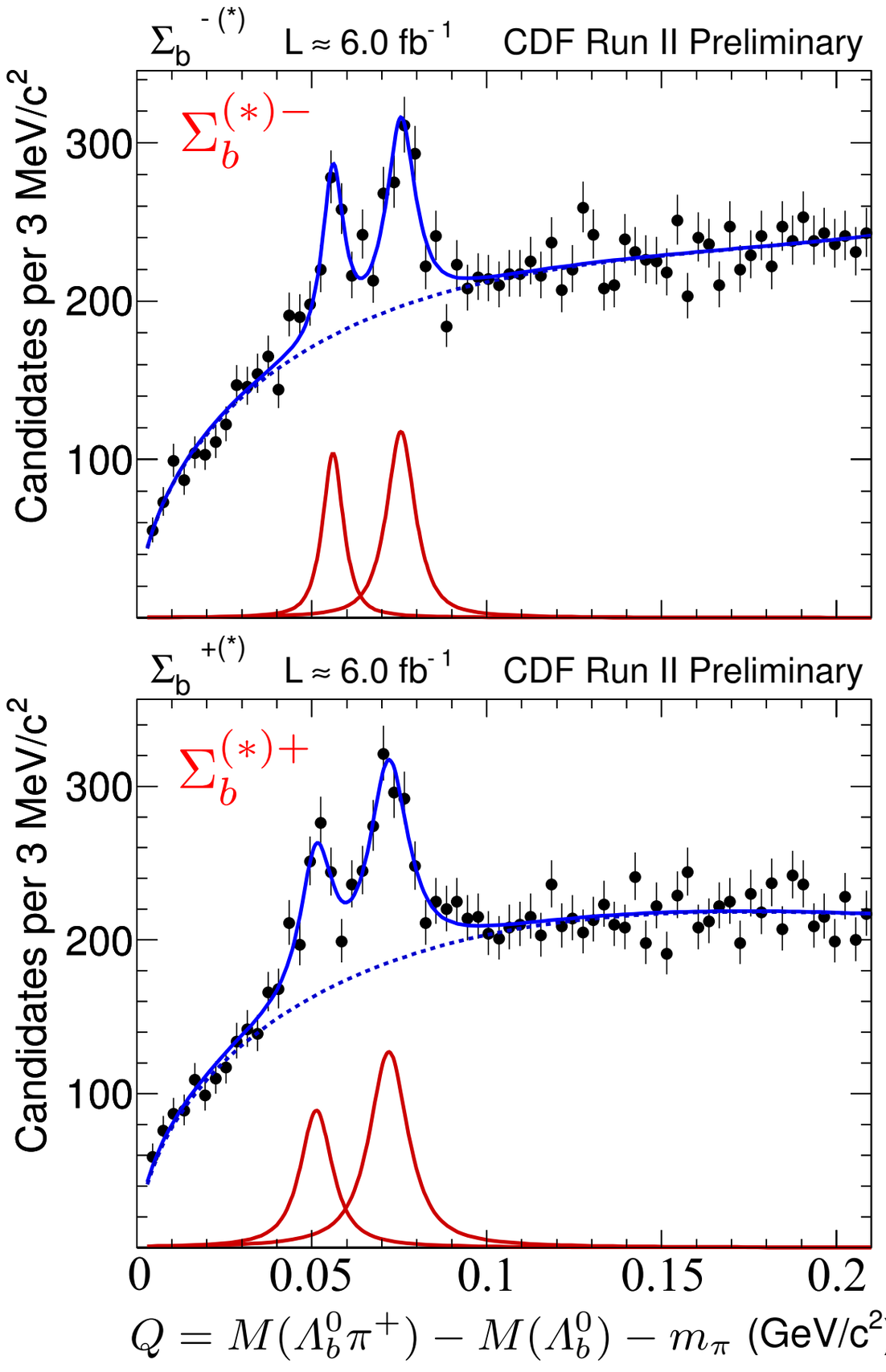
$m(\Sigma_b^+) \approx 5811.2\ \mathrm{MeV/c^2}$

$m(\Sigma_b^-) \approx 5815.5\ \mathrm{MeV/c^2}$

$m(\Sigma_b^{*+}) \approx 5832.0\ \mathrm{MeV/c^2}$

$m(\Sigma_b^{*-}) \approx 5835.0\ \mathrm{MeV/c^2}$

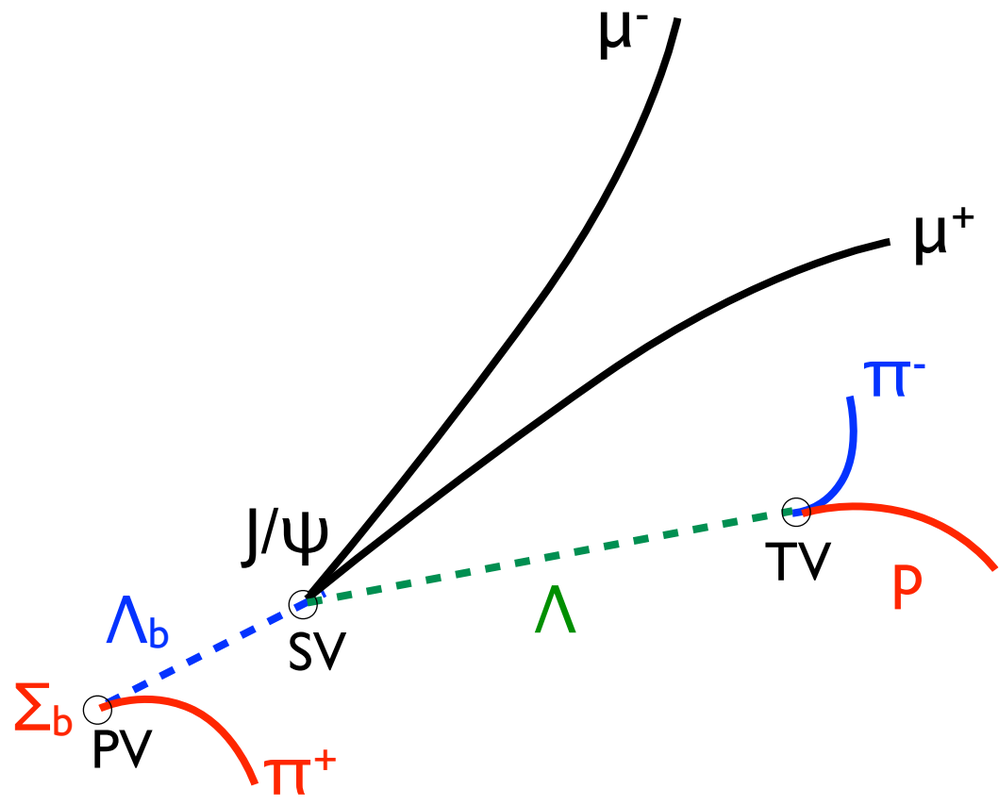
In agreement with theory



Σ_b search at CMS

Search for the decays:

$$\Sigma_b^{(*)\pm} \to \Lambda_b \pi^{\pm}$$
$$\Lambda_b \to J/\psi \Lambda$$
$$\Lambda \to p\pi$$
$$J/\psi \to \mu\mu$$



Note the different Λ_b decay channel w.r.t. CDF

Remarks:

- Σ_b decays strongly
  => decay takes place at the primary vertex
- pion from Σ_b is soft
  => need to distinguish among tens of other (higher energy) pions

First, start with Λ_b ...

$\Lambda_b \rightarrow J/\psi\Lambda$

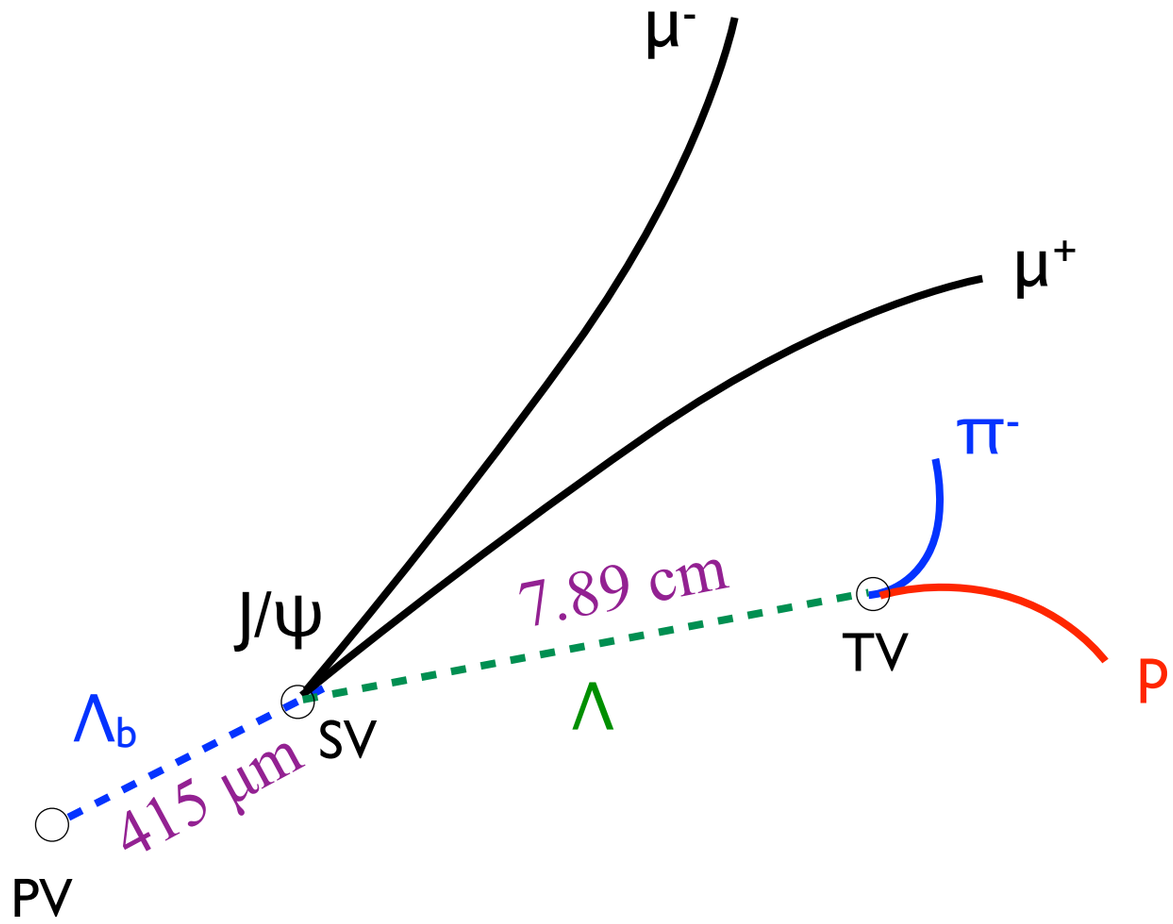
Why this decay channel?

- two muons to trigger on
- two displaced vertices

From PDG:

$M_{PDG}(\Lambda_b) = 5620.2(1.6)\ \mathrm{MeV/c^2}$

$c\tau(\Lambda_b) = 415\mu\mathrm{m}$



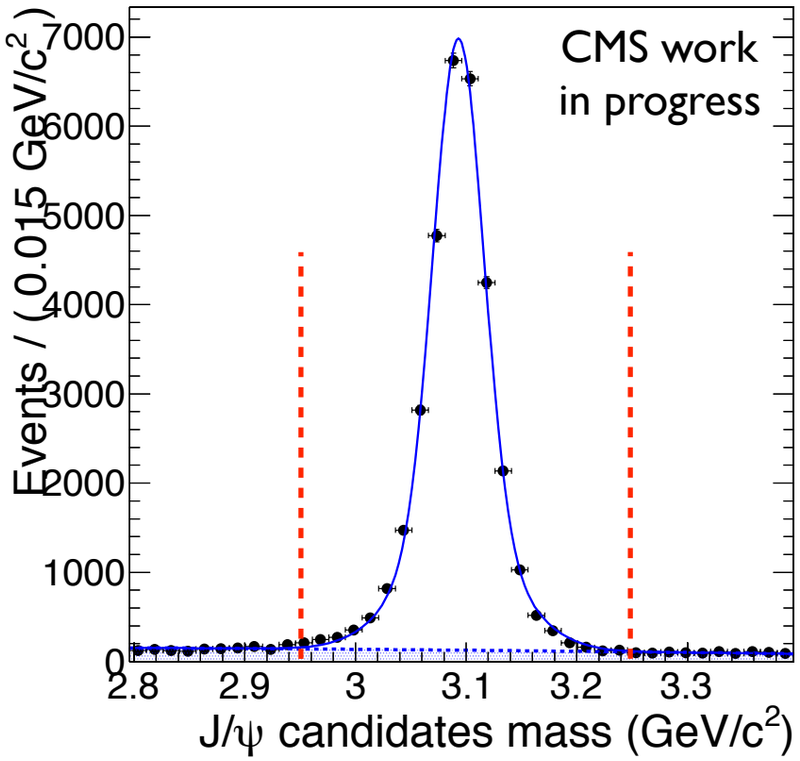
What do I want to measure with Λ_b?

- Σ_b cross-section relative to Λ_b
- Λ_b polarization
  - test for heavy quark factorization and PQCD models
  - how do heavy quarks hadronize?
  - is polarization preserved?

J/ψ and Λ selection

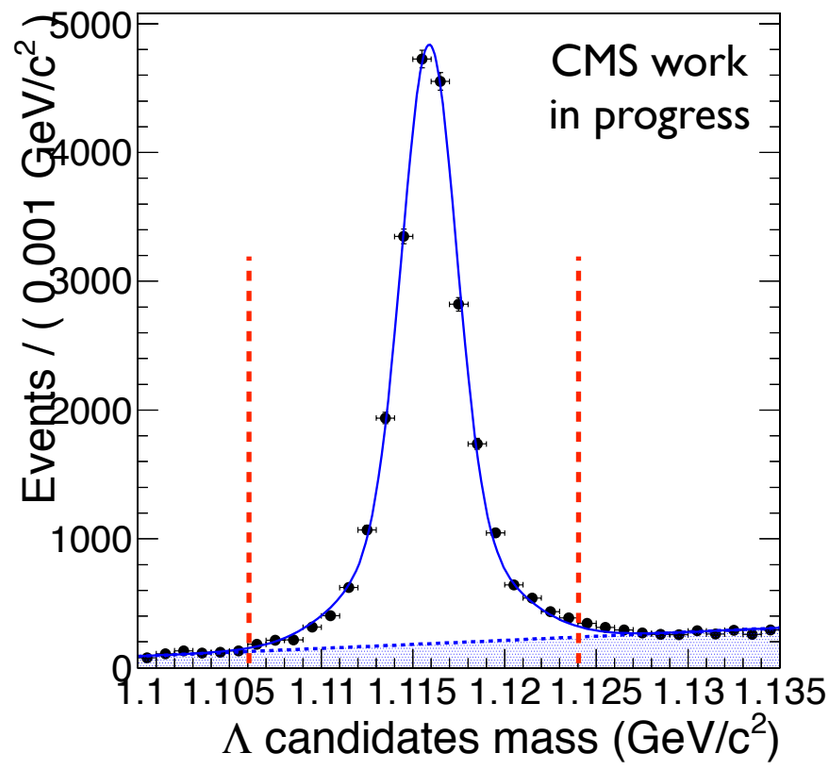
1) **J/ψ selection:**

- $p_T(\mu+,\mu-) > 3.5$ GeV/c
- $p_T(J/\psi) > 7$ GeV/c
- vertex probability (J/ψ) > 10% (Kalman fit)
- J/ψ mass: $m_{PDG} \pm 150$ MeV/c^2



2) **Λ selection:**

- $p_T(p) > 1$ GeV/c
- $p_T(\pi) > 0.3$ GeV/c
- $p_T(\Lambda) > 1.3$ GeV/c
- $c\tau_{xy}(\Lambda) > 0.5$ cm
- pointing angle w.r.t. J/ψ vertex, $\cos\theta(\Lambda) > 0.99$
- vertex probability (Λ) > 2% (Kalman fit)
- Λ mass: $m_{PDG} \pm 9$ MeV/c^2

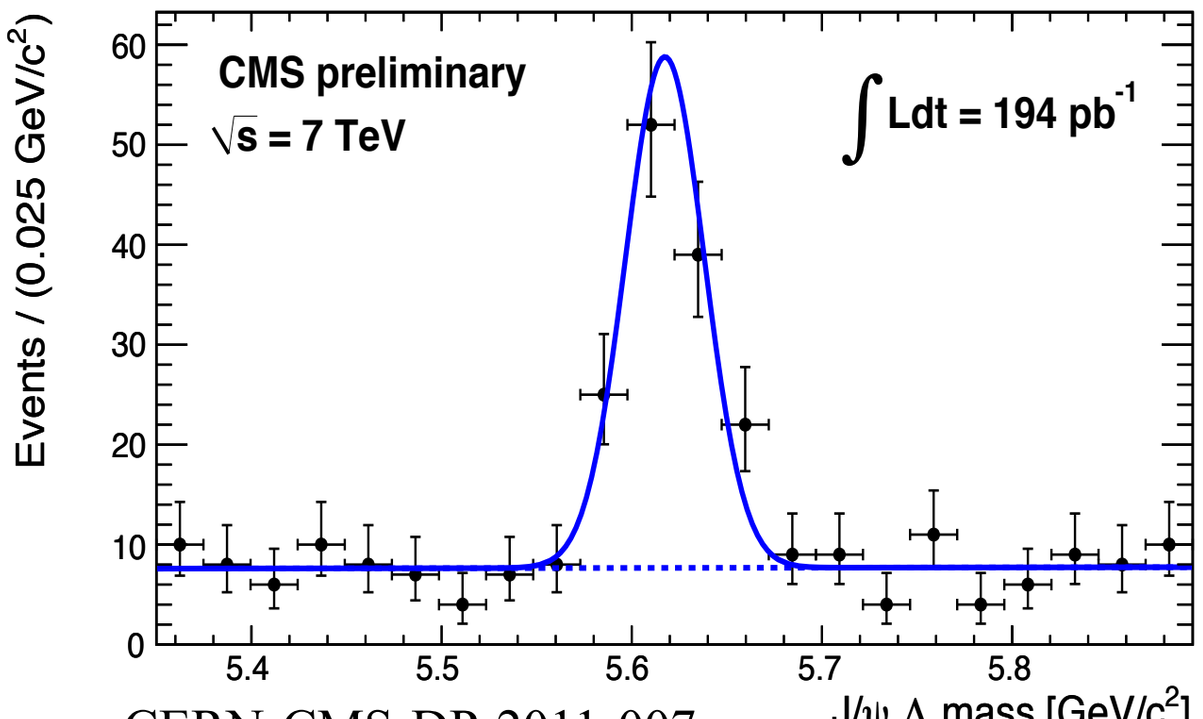


Λ_b selection

3) **Λ_b selection:**

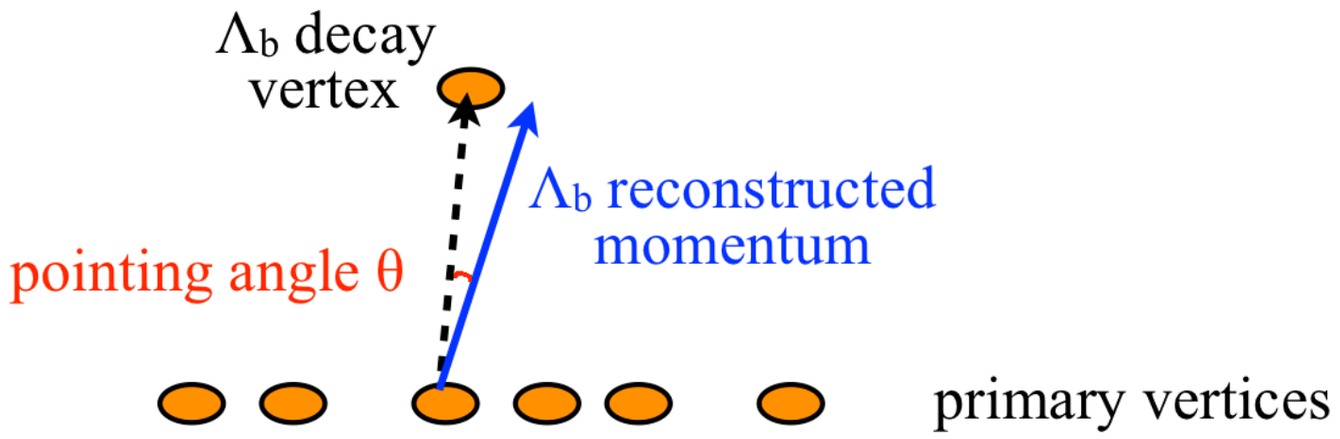
- $p_T(\Lambda_b) > 8.5$ GeV/c
- $c\tau_{xy}(\Lambda_b) > 30$ μm
- pointing angle w.r.t. PV $\cos\theta(\Lambda_b) > 0.9$
- vertex probability (Λ_b) > 1%
  (kinematic fit with J/ψ mass constrain)

example distribution of reconstructed Λ_b signal:



Primary vertex selection

- ~ 6 pile-up events (=> primary vertices) on average per event
- PV chosen from best (smallest) Λ_b pointing angle



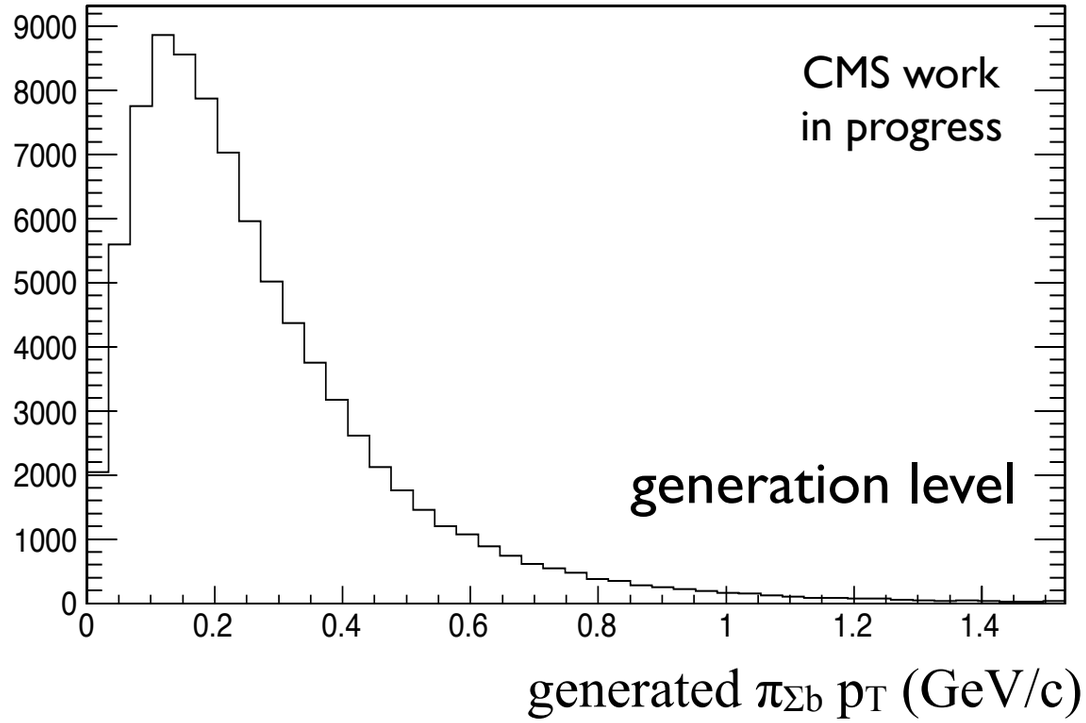
Σ_b selection

Challenges:

- soft (low energy) pion coming from PV
- huge combinatorial background

Many requirements to assure that:

- selected pion is from same PV as Λ_b



4) **Σ_b and soft $\pi_{\Sigma b}$ selection:**

- Λ_b mass: $m_{PDG} \pm 45$ MeV/c^2
- $p_T(\pi_{\Sigma b}) > 0.3$ GeV/c
- ($\pi_{\Sigma b}$, Λ_b) distance of closest approach < 0.2 cm
- $\pi_{\Sigma b}$ impact parameters in 3D < 0.3 cm
- $\pi_{\Sigma b}$ impact parameters in 3D significance < 3
- Δ(point of cl.appr.($\pi_{\Sigma b}$, Λ_b), PV) < 1 cm
- $\Delta R(\pi_{\Sigma b}, \Lambda_b)$ in (η,φ) <1

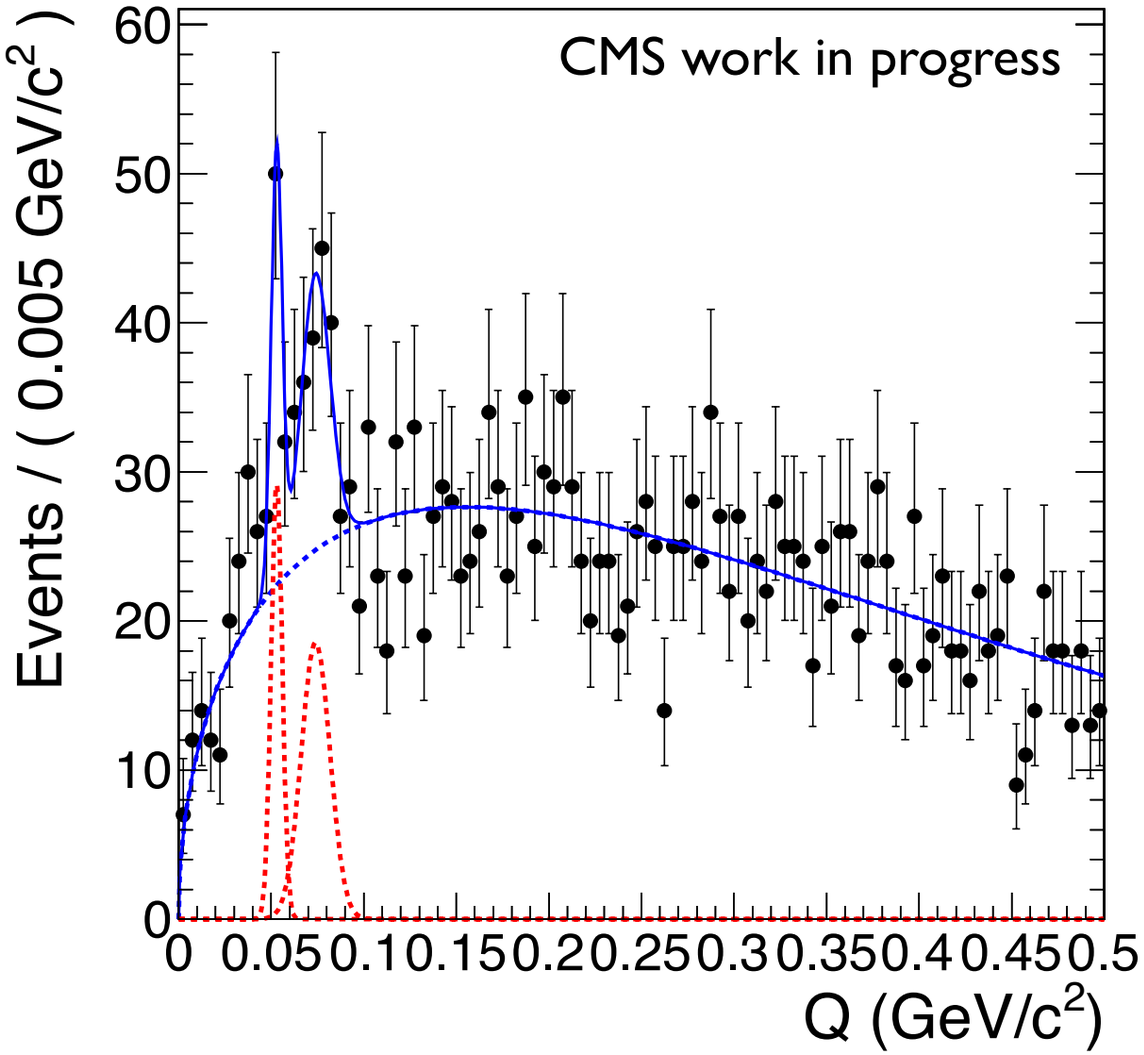
} assure $\pi_{\Sigma b}$ compatibility with PV and Λ_b

- # valid pixel hits ($\pi_{\Sigma b}$) ≥ 2
- # valid hits ($\pi_{\Sigma b}$) ≥ 5
- χ^2/NDF ($\pi_{\Sigma b}$) < 2

} track quality requirements

- $p_T(\Sigma_b) > 8.5$ GeV/c

Preliminary results: $\Sigma_b^{(*)+}$



$$Q = M(\Lambda_b^0\pi) - M(\Lambda_b^0) - M_{PDG}(\pi)$$

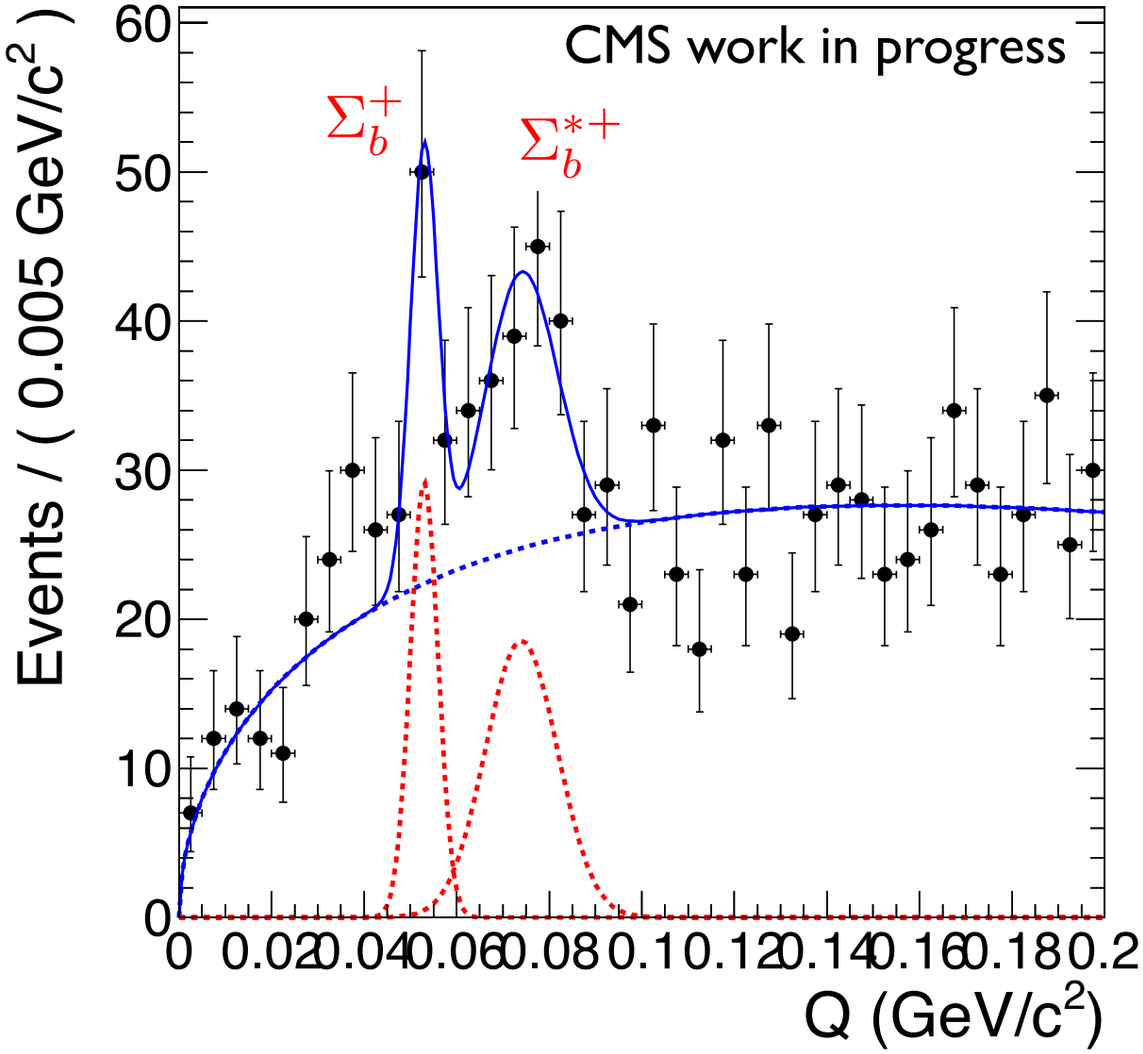
blue - fit on background excluding the signal region

red - fit of two Gaussians in the signal region Q ∈ (0.03,0.1) GeV/c^2

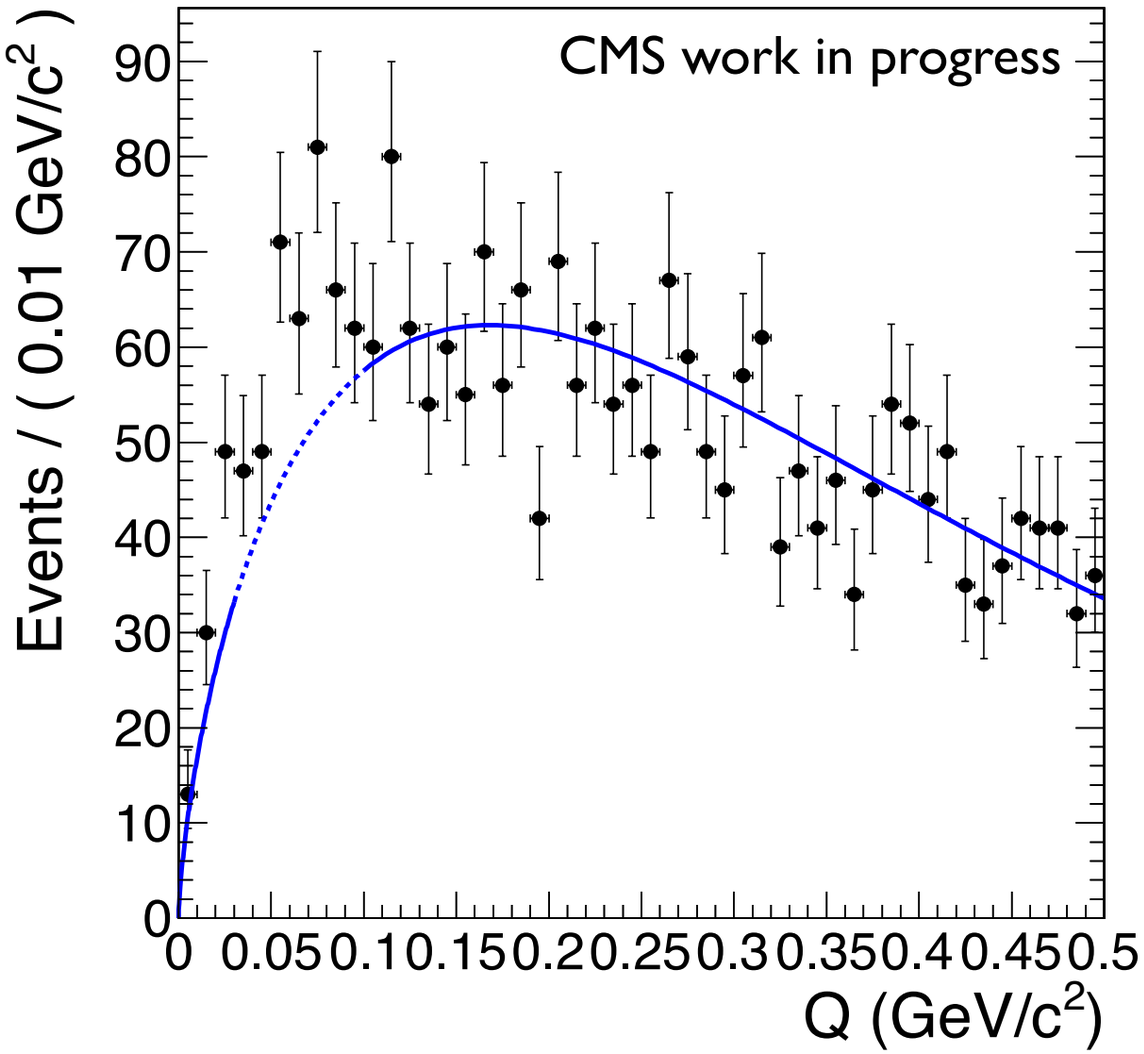
Expected signal region **Q ∈ (0.03, 0.1)** GeV/c^2

- Significant excess of events in signal region
- Clear hints of two states

$\Sigma_b^+ : S/\sqrt{B} \approx 5$ $\Sigma_b^{*+} : S/\sqrt{B} \approx 5$



Preliminary results: $\Sigma_b^{(*)-}$



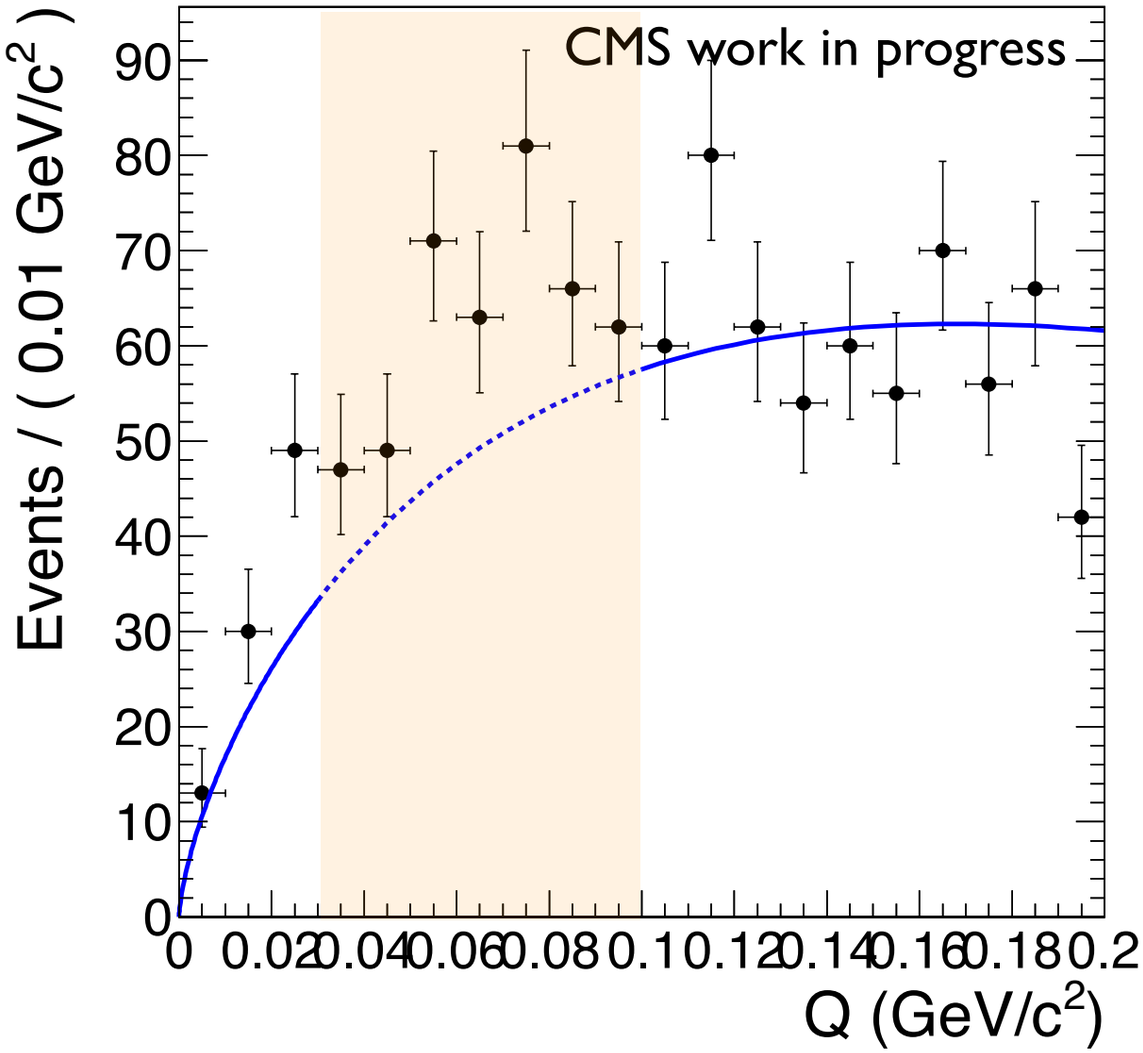
$$Q = M(\Lambda_b^0\pi) - M(\Lambda_b^0) - M_{PDG}(\pi)$$

blue - fit on background excluding the signal region

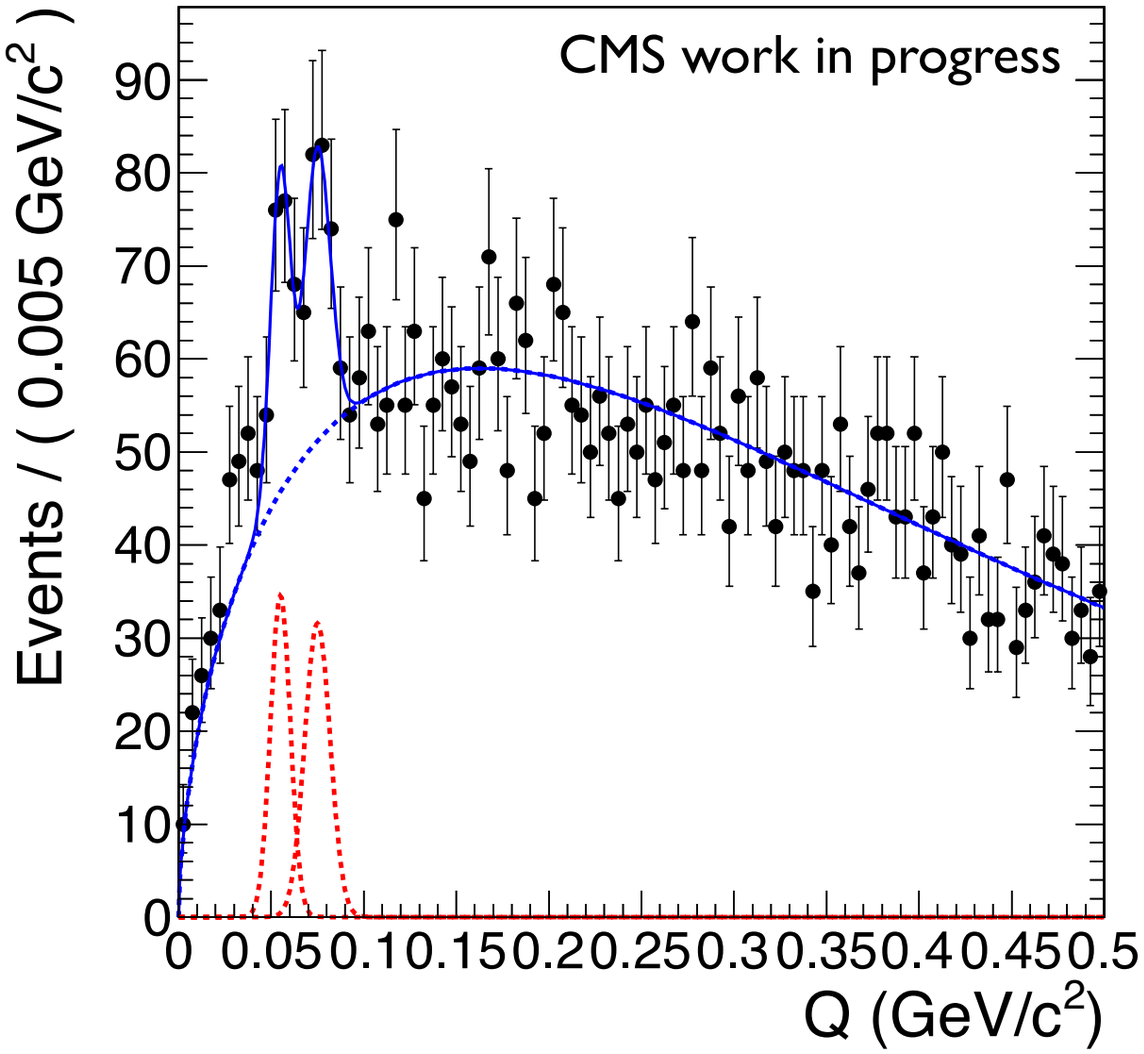
shaded area - signal region

Expected signal region **Q ∈ (0.03, 0.1)** GeV/c^2

- More statistics needed



Preliminary results: + and - together



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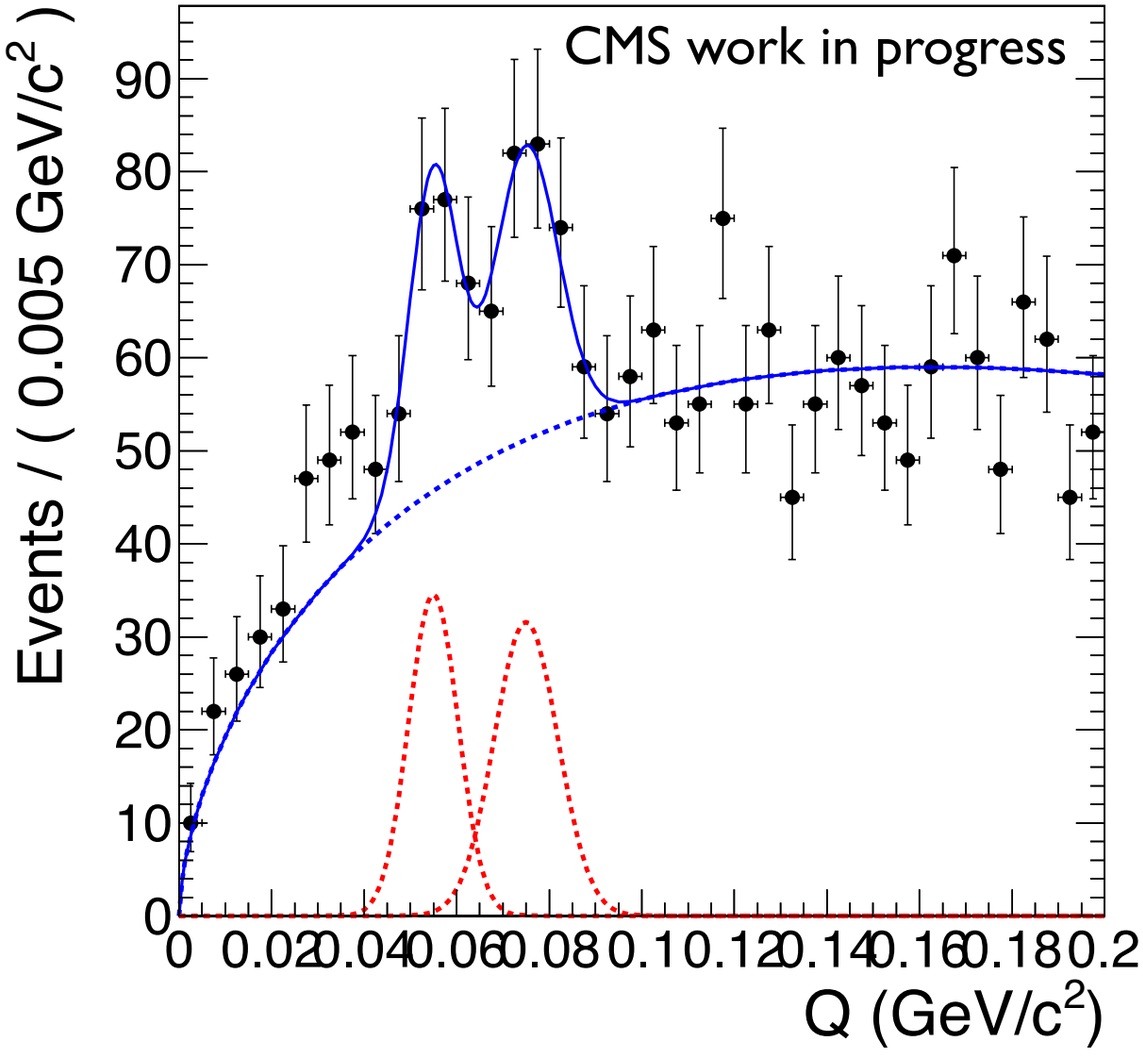

Summary, ongoing and plans

★ So far observed:

- clean signal of Λ_b
- hints of charged Σ_b states

★ Ongoing and plans:

- angular analysis of Λ_b, polarization studies
- measurement Σ_b cross-section relative to Λ_b

Thank you for your attention!