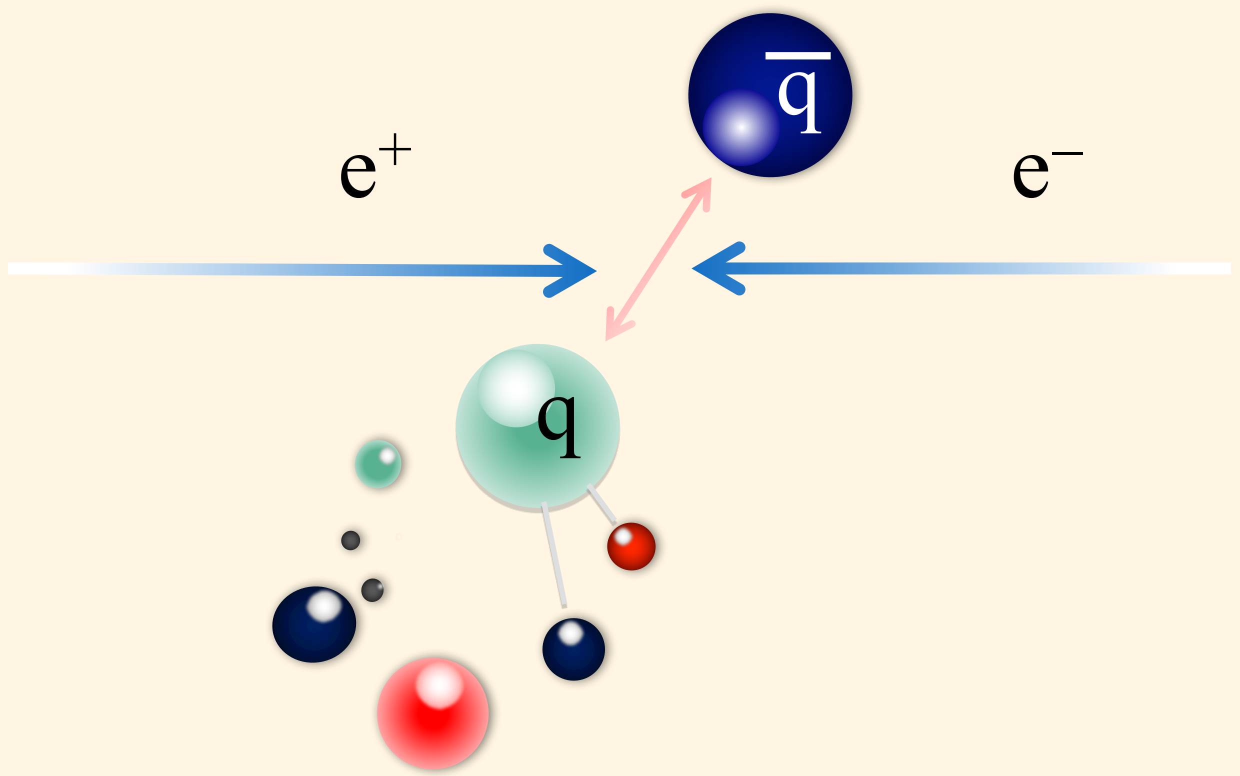
Production cross sections of hyperons and charmed baryons from e+e- annihilation near $\Upsilon(4S)$

arXiv:1706.06791 [hep-ex]

M. Niiyama (Kyoto U.)

Baryon production rates in e⁺e⁻ collision

- $e^+e^- \longrightarrow \gamma^* \longrightarrow q\bar{q} \longrightarrow$ Haronization
  - ex) $e^+e^- \longrightarrow \gamma^* \longrightarrow \Lambda +$ anything

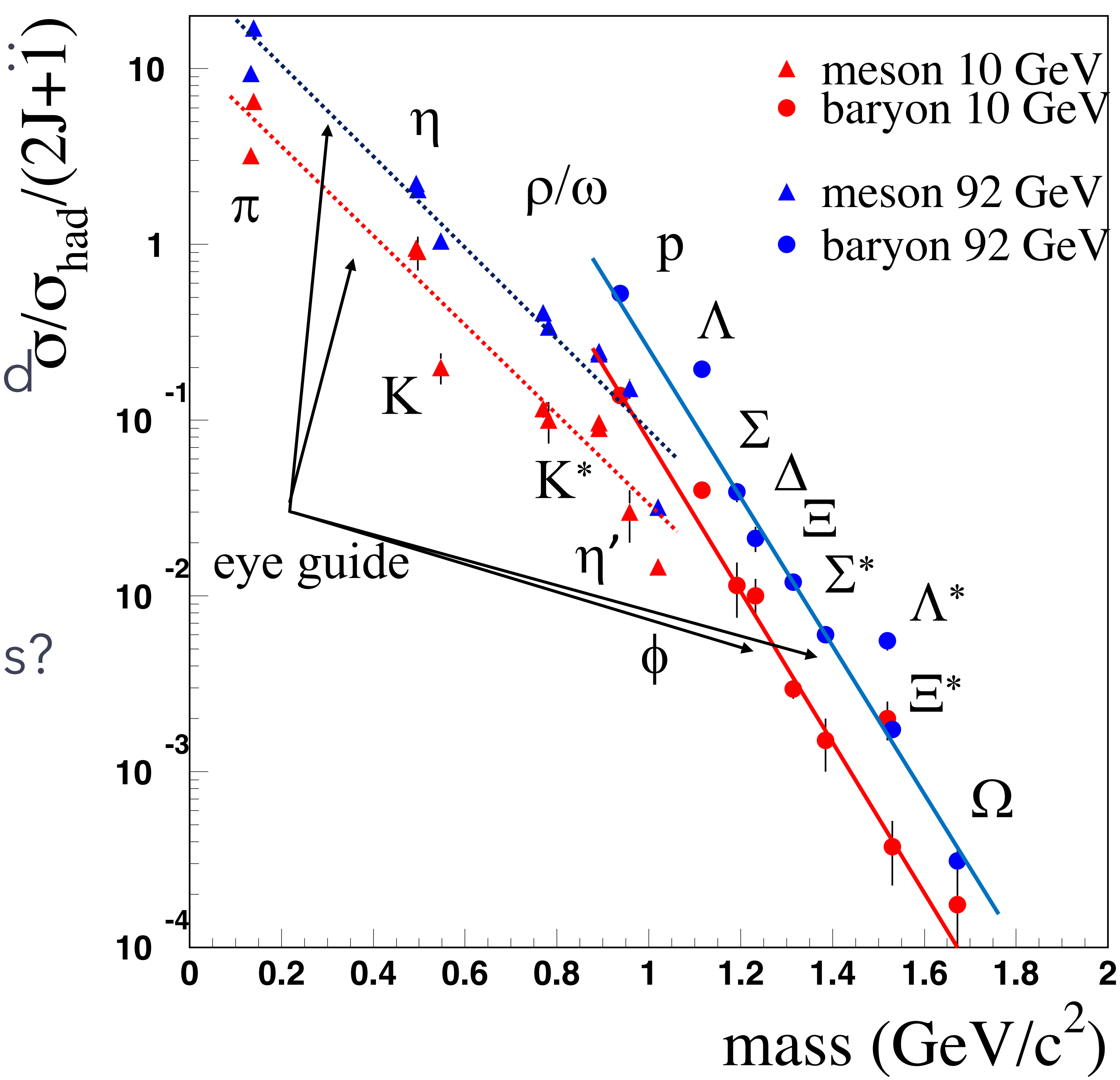


Hadron production rates in e^+e^- collision

- $e^+e^- \to \gamma^* \to qq \to$ Haronization
  - ex) $e^+e^- \to \gamma^* \to \Lambda$ + anything
- Scale on exponential function:

$$\frac{\sigma}{\sigma_{had}(2J+1)} \propto \exp(-\alpha m_{had})$$

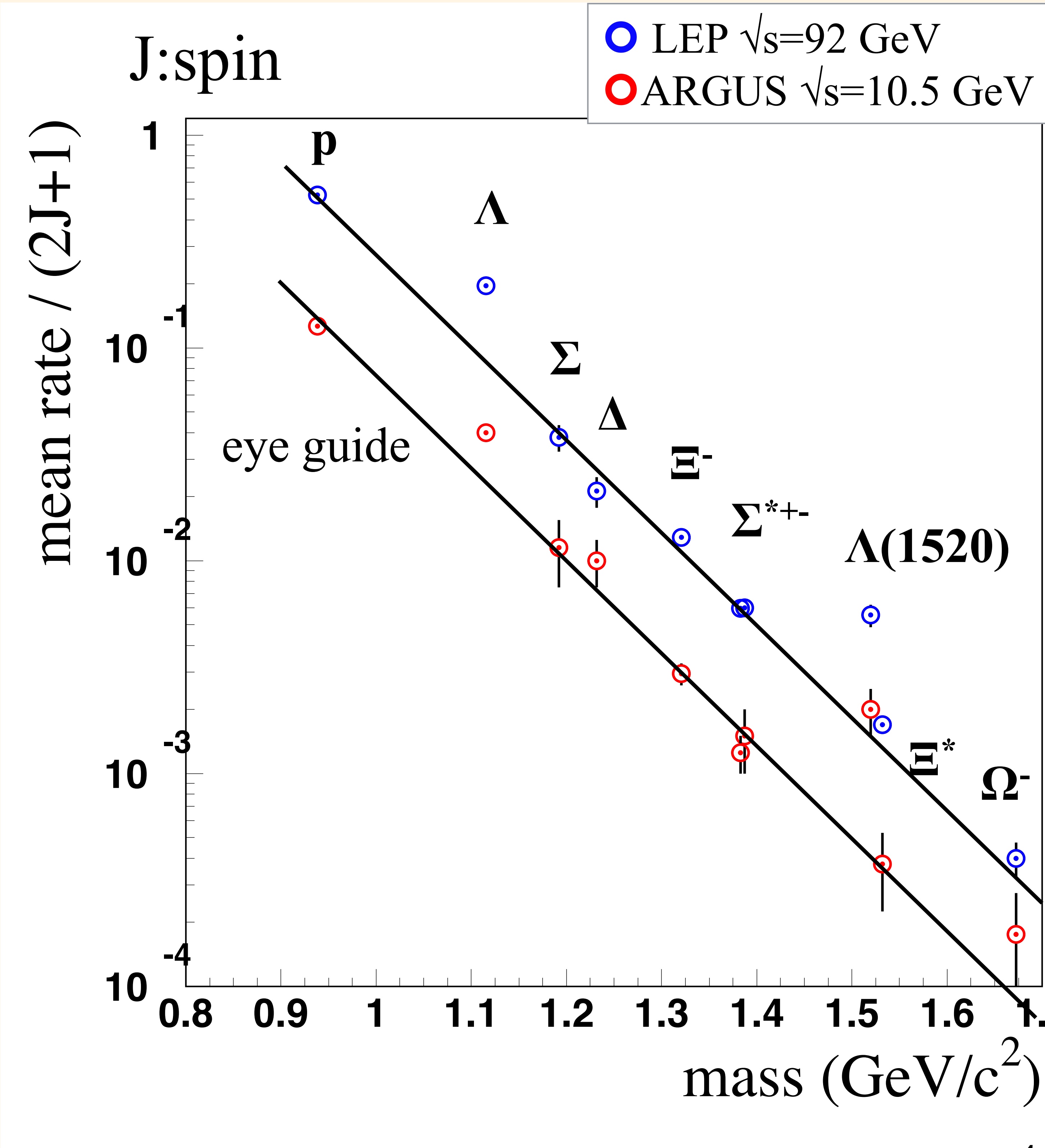
- Different slope for mesons and baryons
  - quark counting?
  - what about "exotic" hadrons?
    - $\Lambda(1405)$, $\Xi(1530)$



Baryon production rates in e⁺e⁻ collision

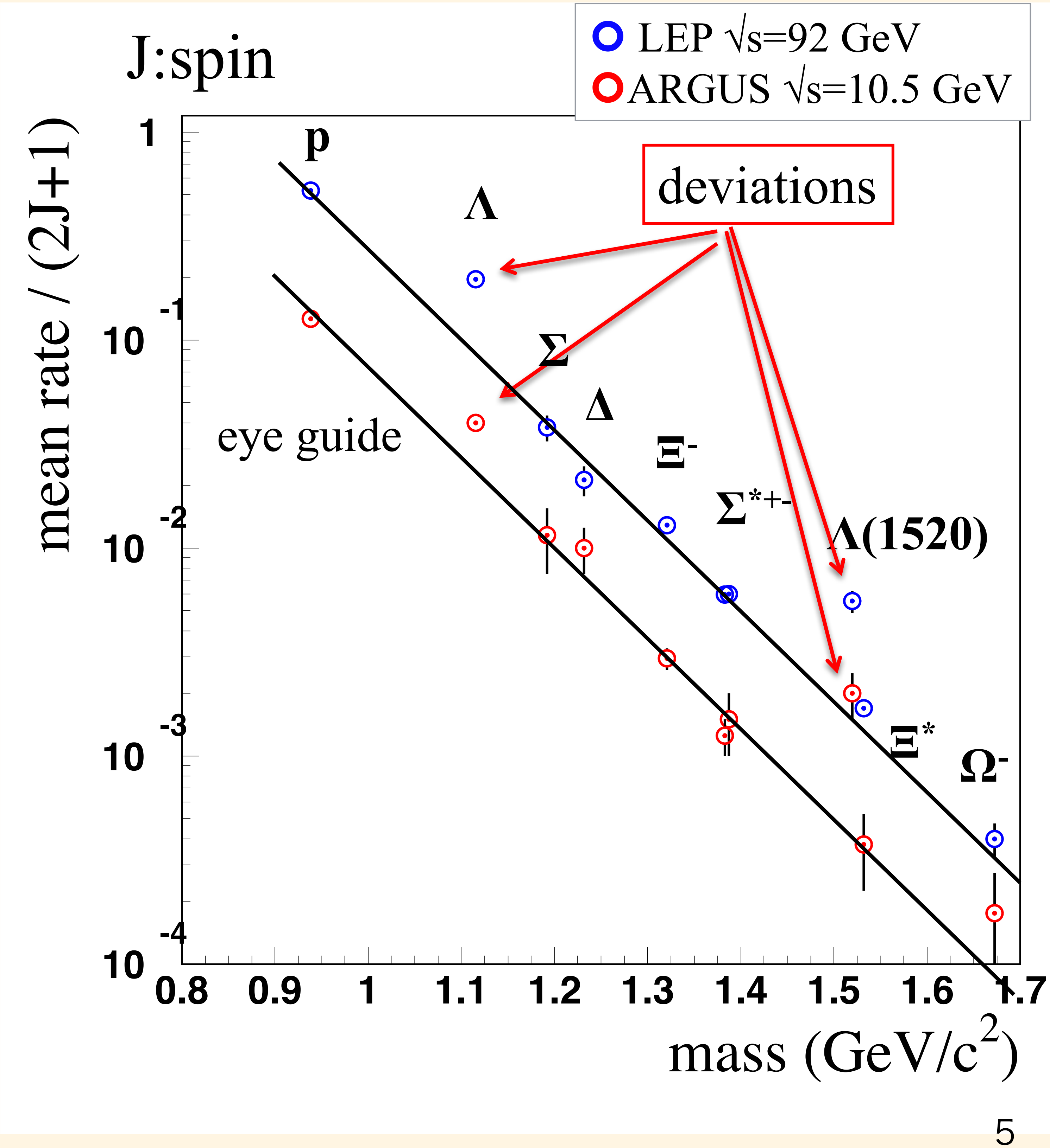
- Baryon production: color suppression to form color-singlet combination among random quark colors
- Diquark-antidiquark production model can explain relatively high production rate
- Relativistic-string model

B. Andersson, G. Gustafson, T. Sjostrand, Physica Scripta 32, 574, 1985

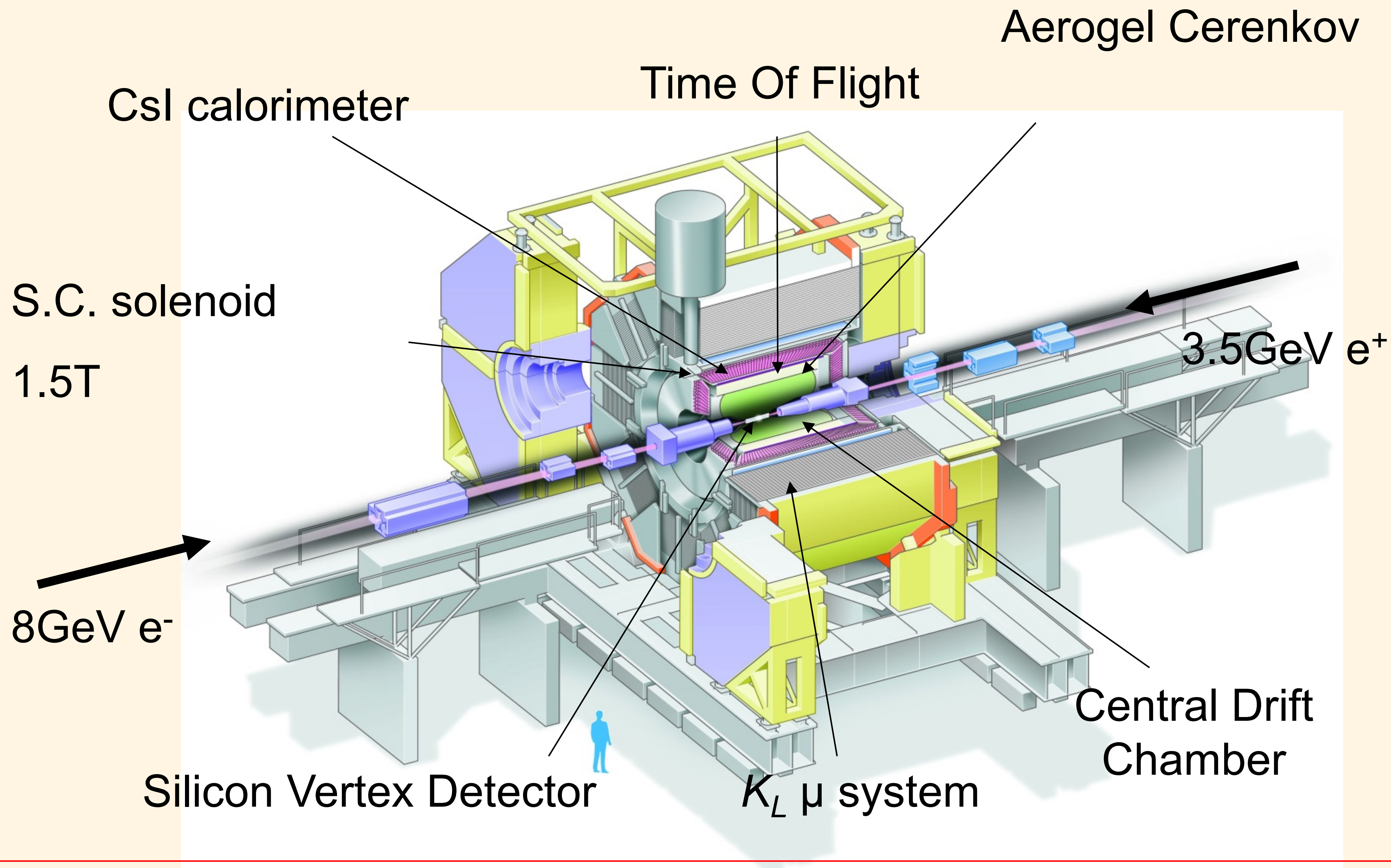


Baryon production rates in e^+e^- collision

- Higher rates for Λ and Λ(1520) in ARGUS and LEP.
- J=0, light (ud) diquark in Λ?
  - R.L. Jaffe, Phys.Rept.409,1 (2005)
  - A. Selem, F. Wilczek, hep-ph/0602128
- Issues
  - Feed down is subtracted?
  - Large error in ARGUS results
  - How about charmed baryons?
- Study at Belle!



Belle data



Integrated luminosity

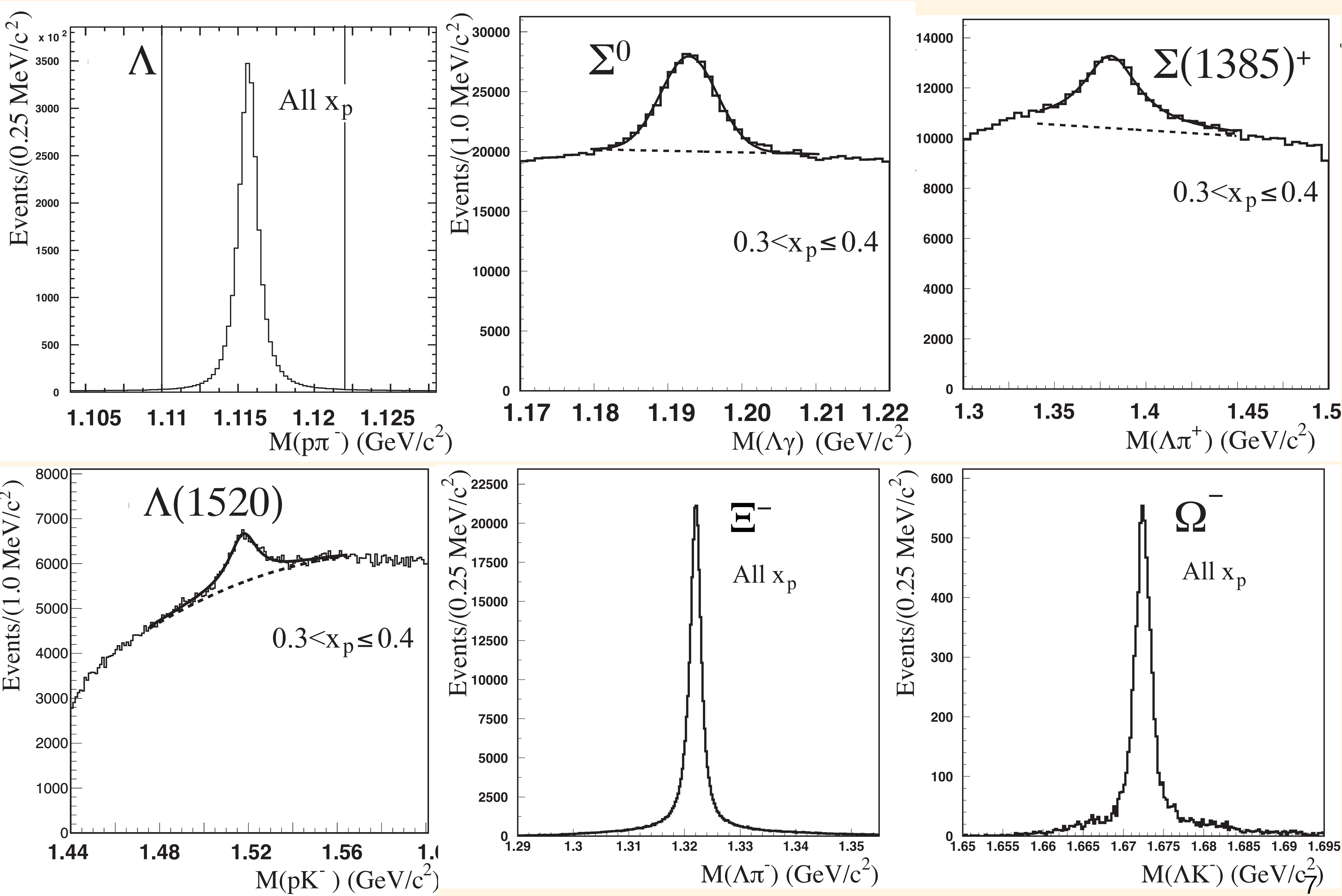
: 562. fb^{-1} @ on $\Upsilon(4S)$ resonance data for charmed baryons

($\sqrt{s}$ =10.58 GeV)

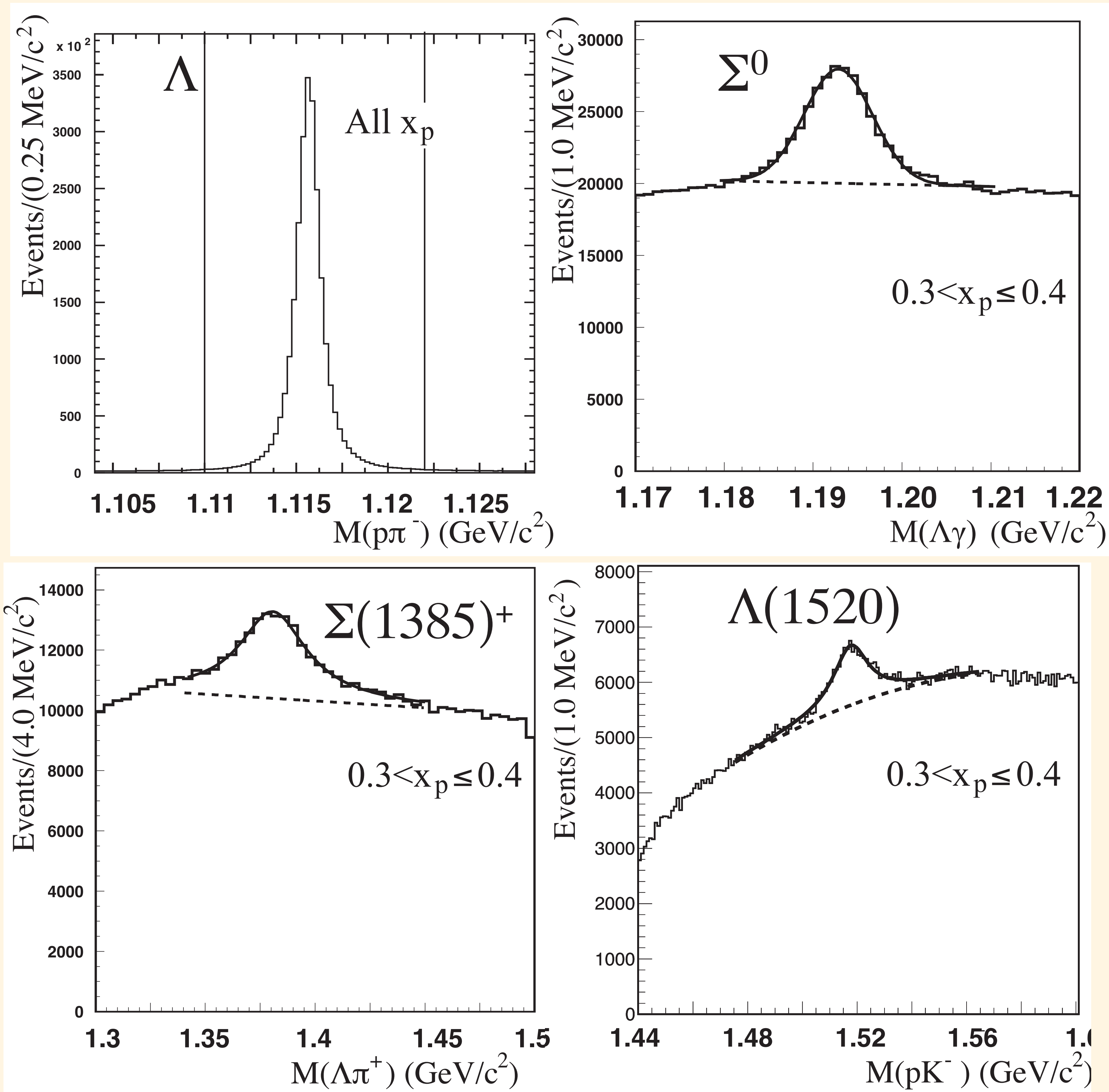
: 79.3 fb^{-1} @ continuum data for hyperons, charmed baryons

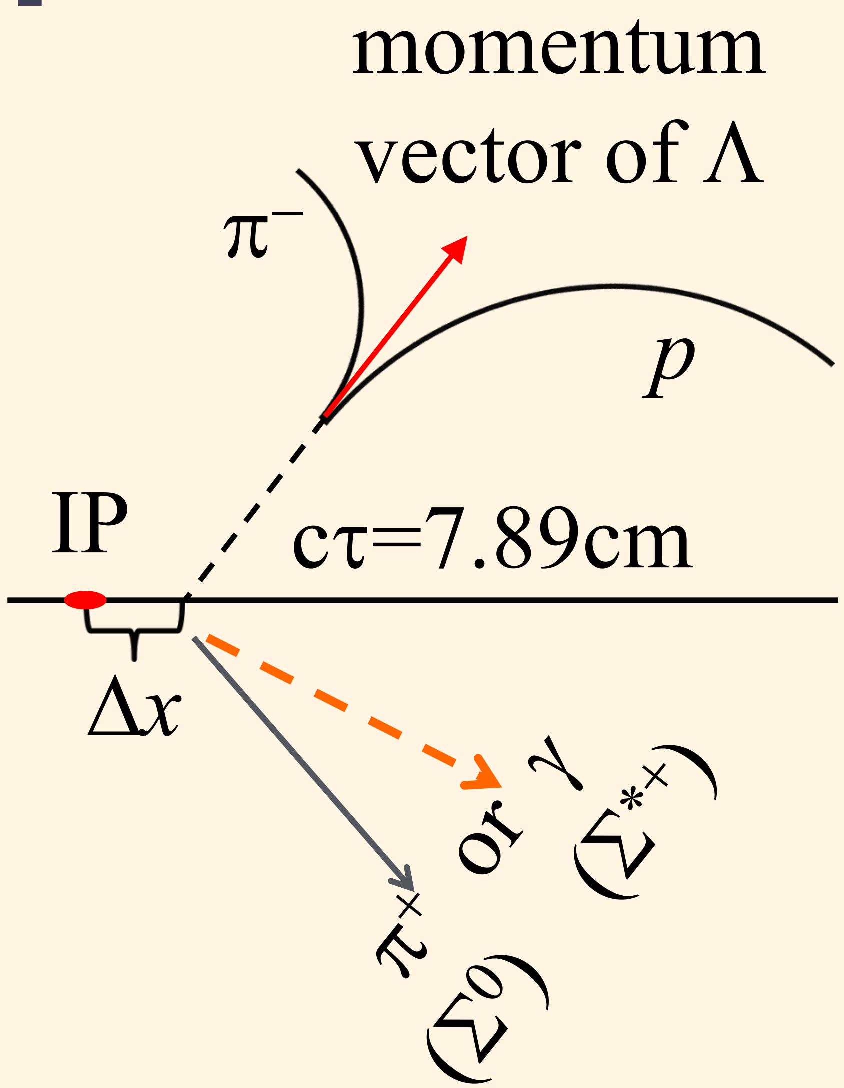
($\sqrt{s}$ =10.52 GeV)

Mass spectra for hyperons

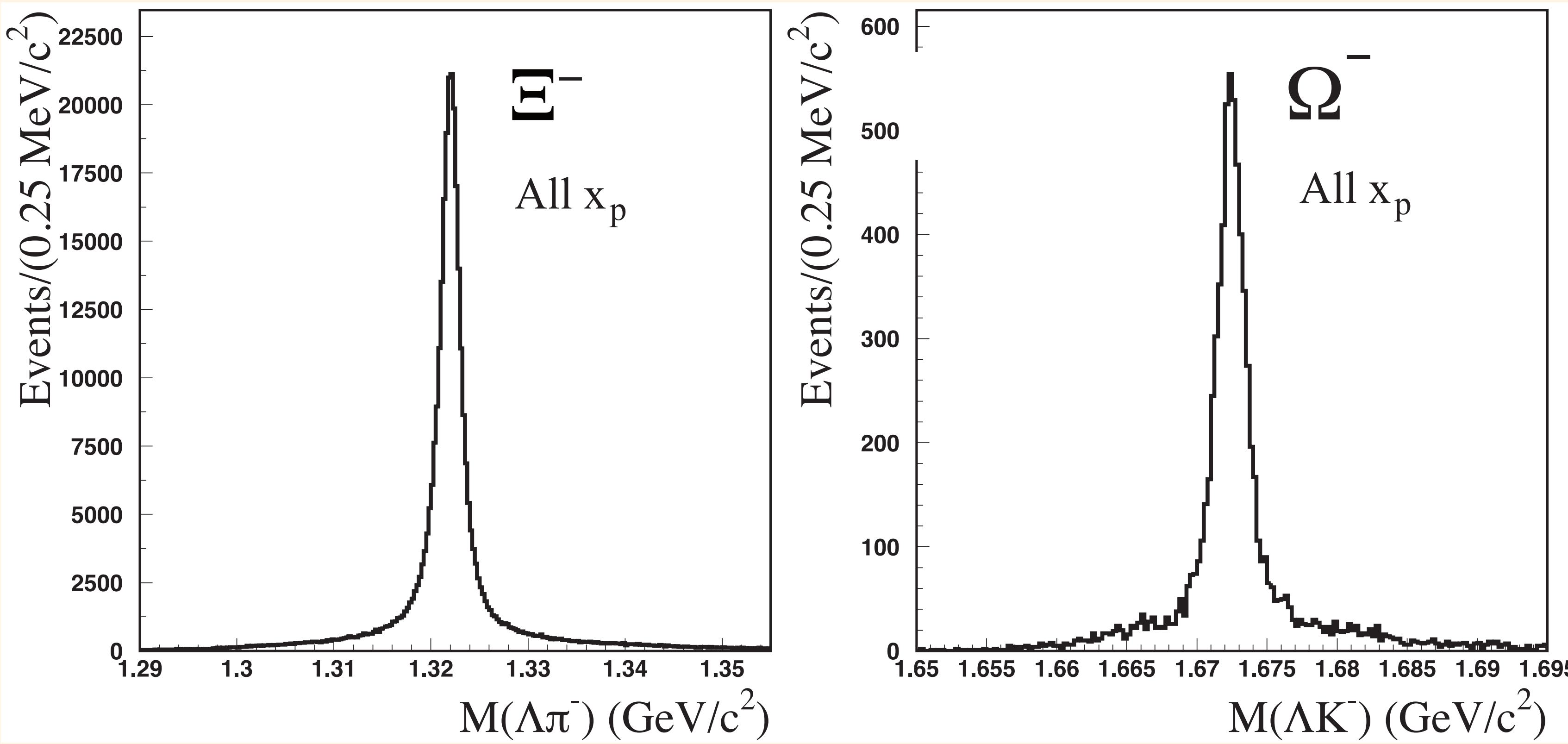


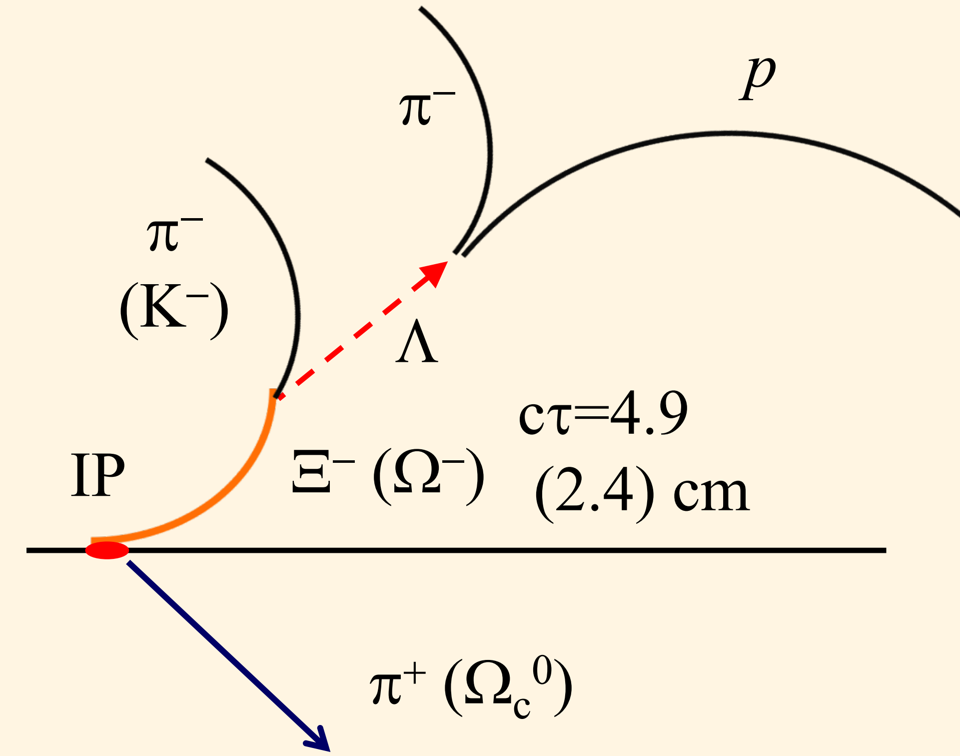
Reconstruction of S=-1 hyperons

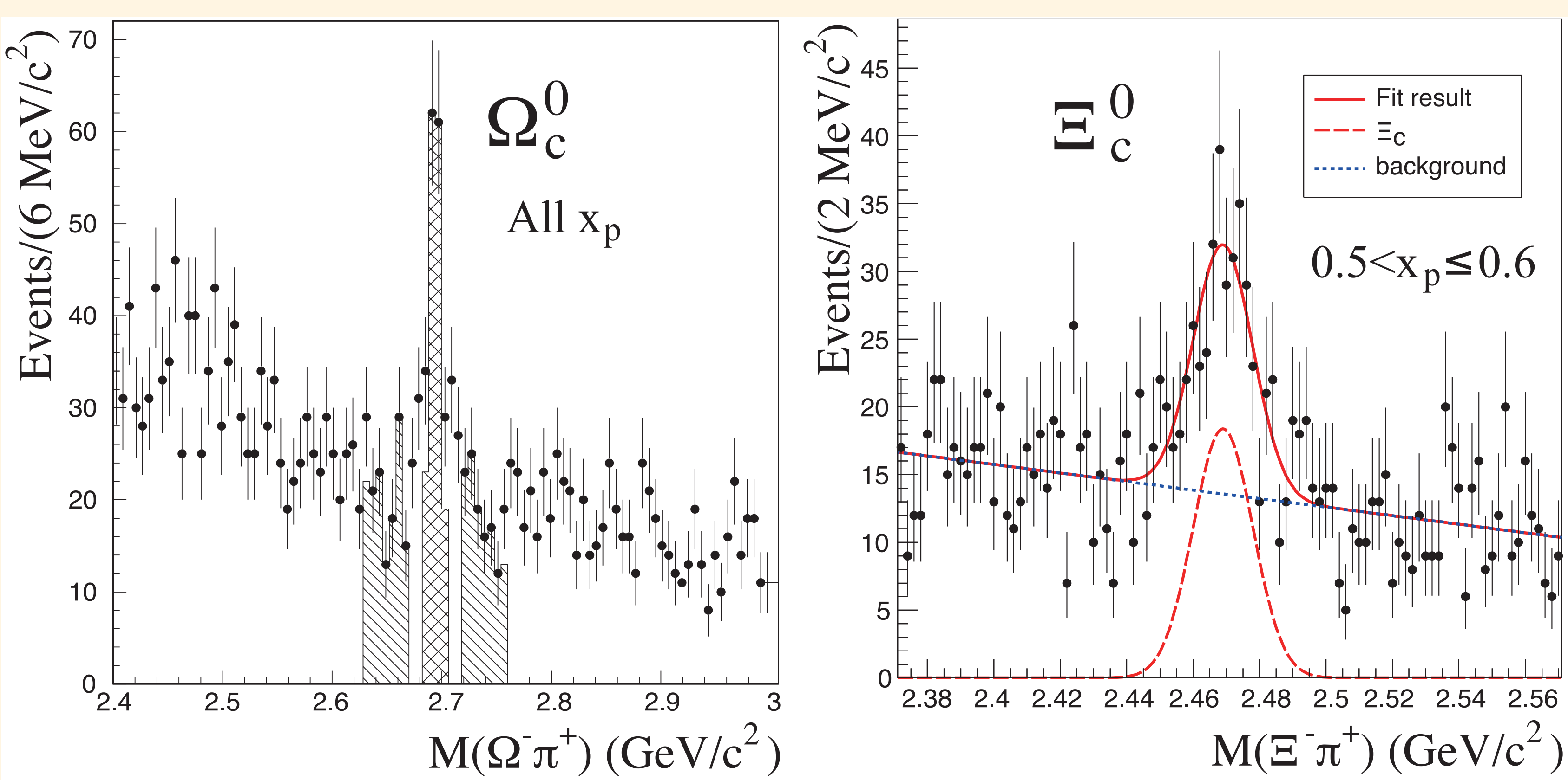


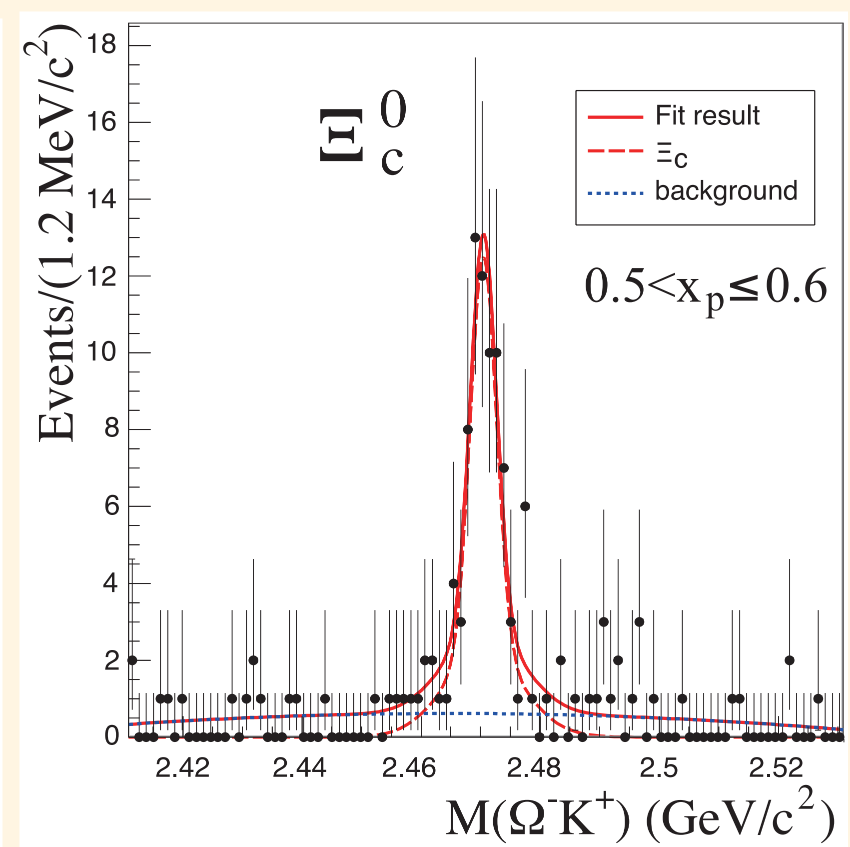


Reconstruction of Ξ^-, Ω^-, Ω_c, Ξ_c

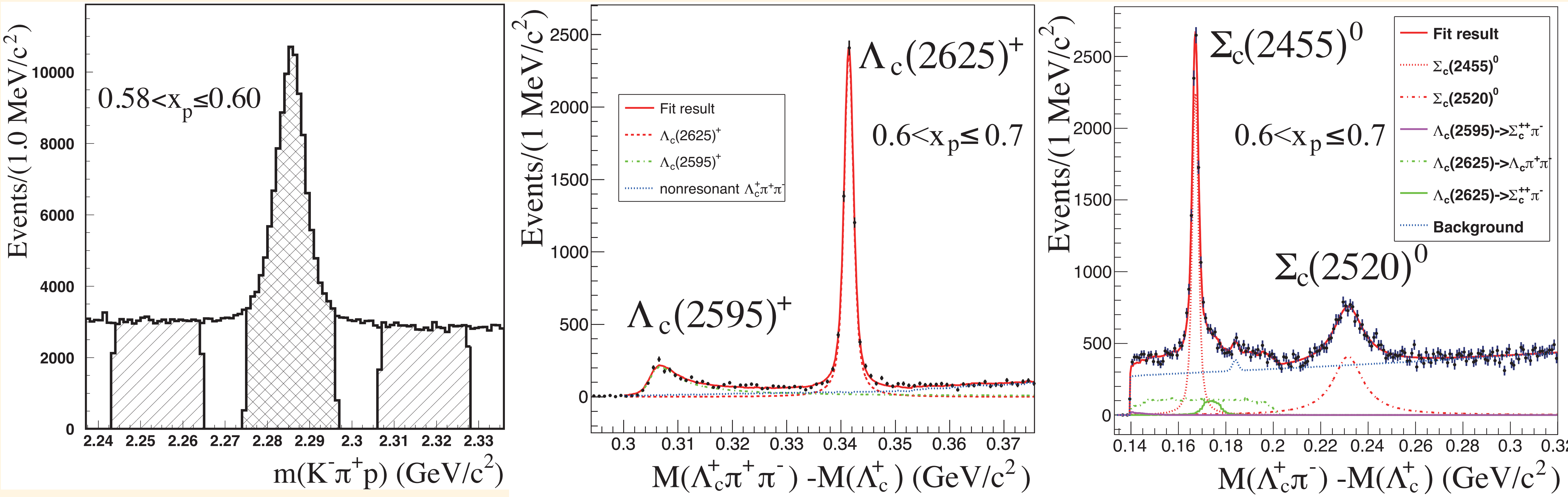






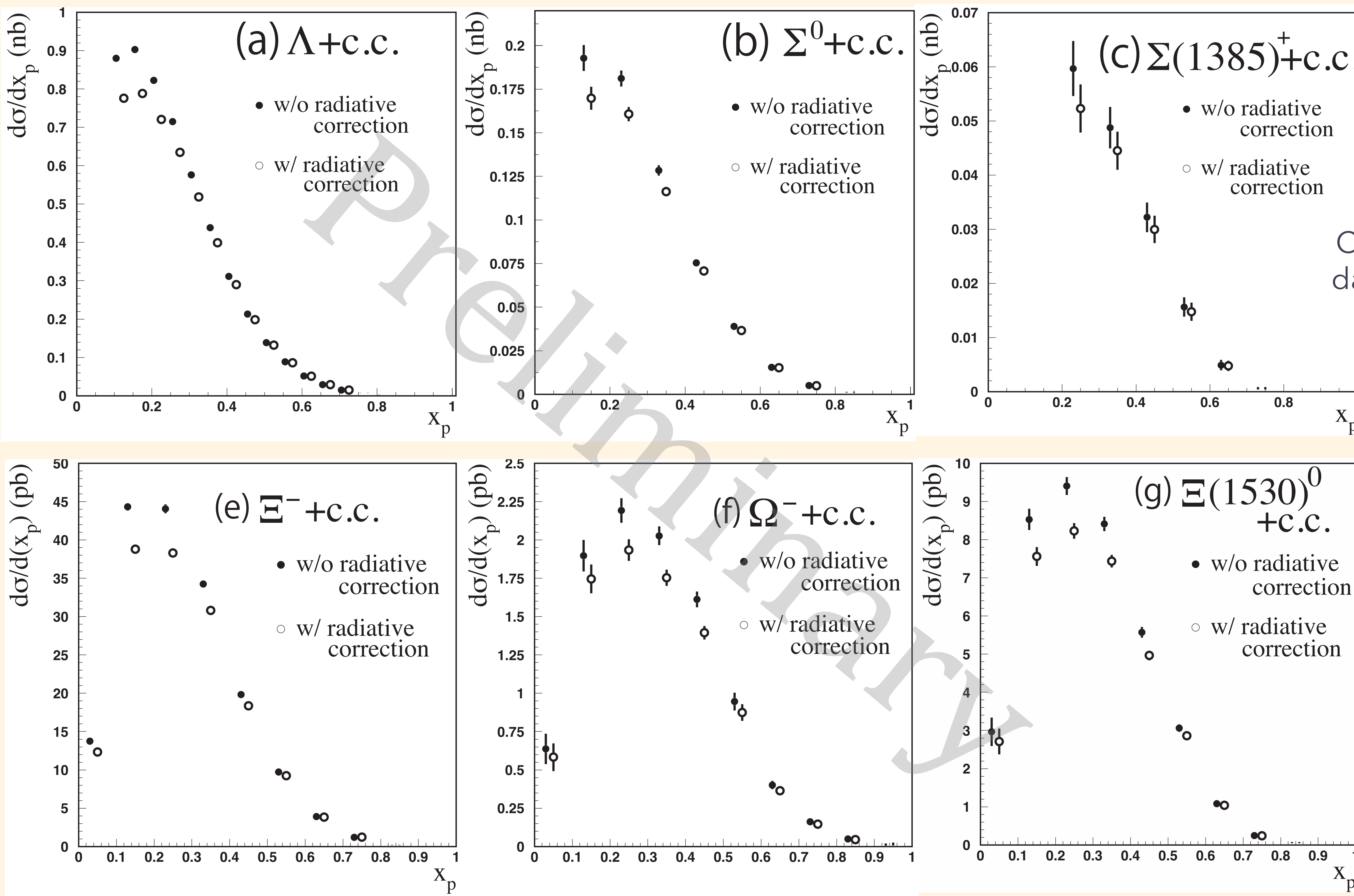


Mass spectra for charmed baryons



Inclusive differential cross sections, hyperons

“Inclusive” cross sections (including feed-down) are obtained as a function of hadron scaled momentum (x_p). $x_p = p/\sqrt{s/4 - M^2}$ (M, p : mass and CM momentum)



Continuum data

Error bar represent statistical fluctuation.

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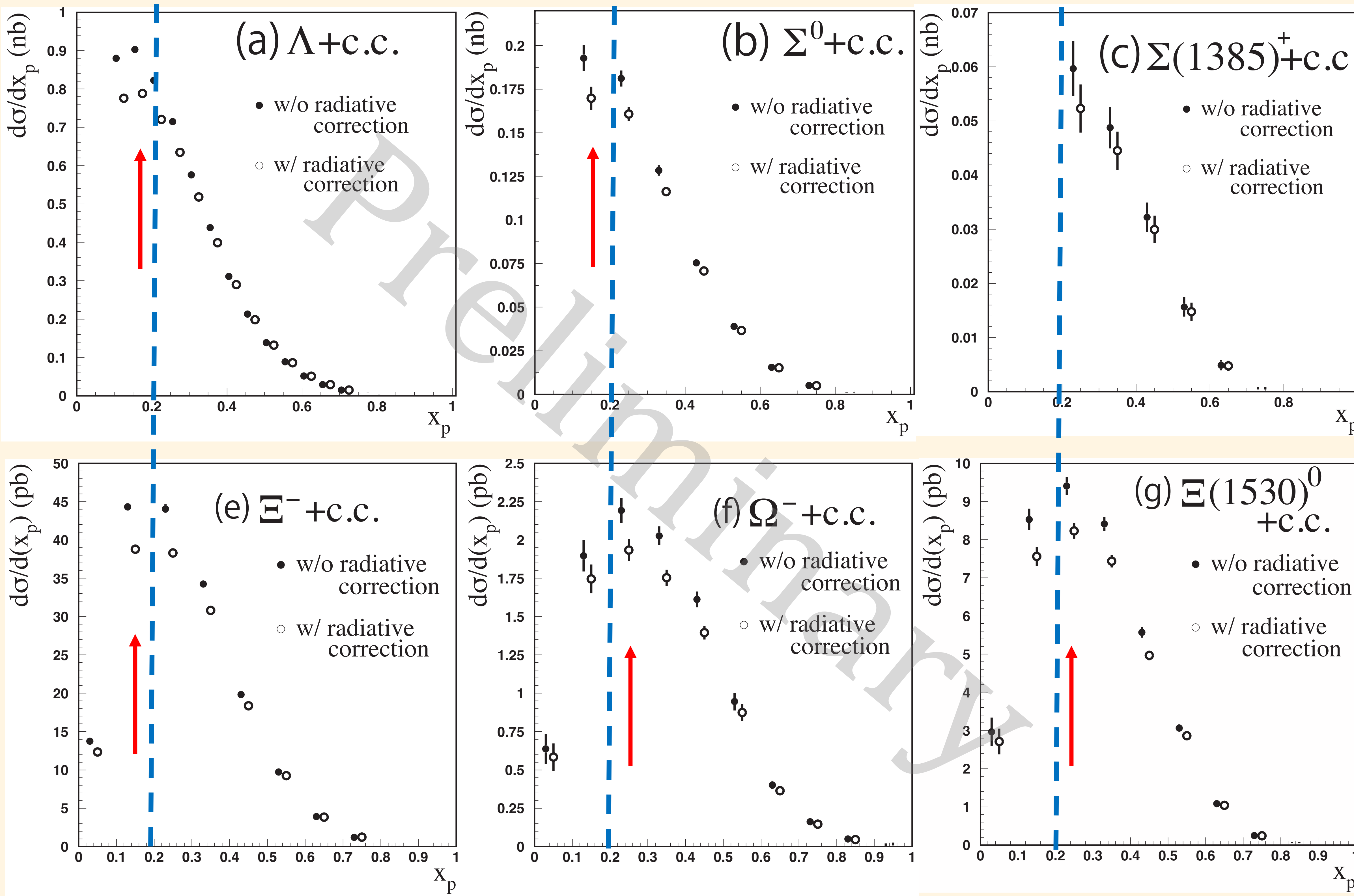

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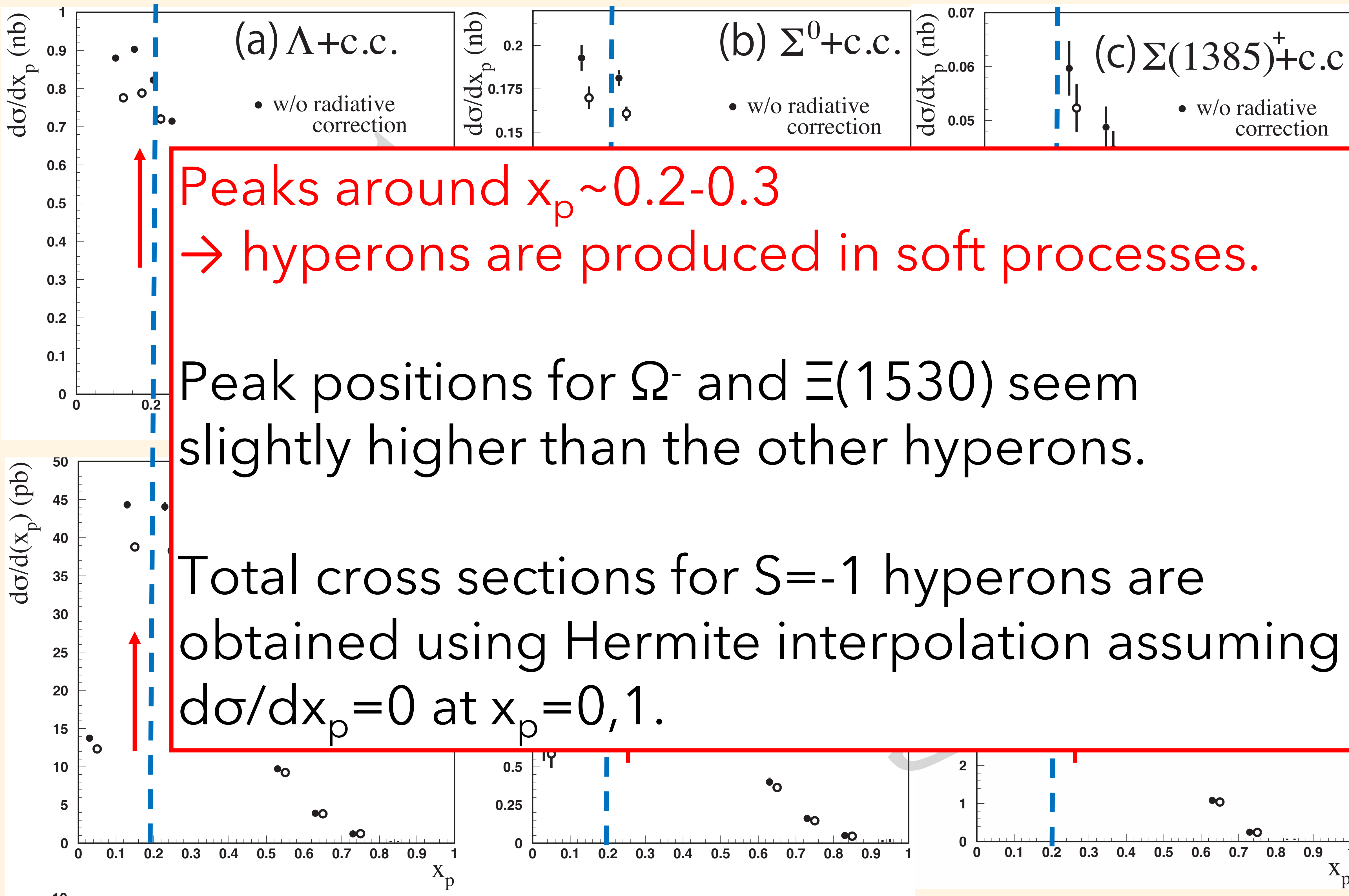


Peaks around x_p~0.2-0.3

→ hyperons are produced in soft processes.

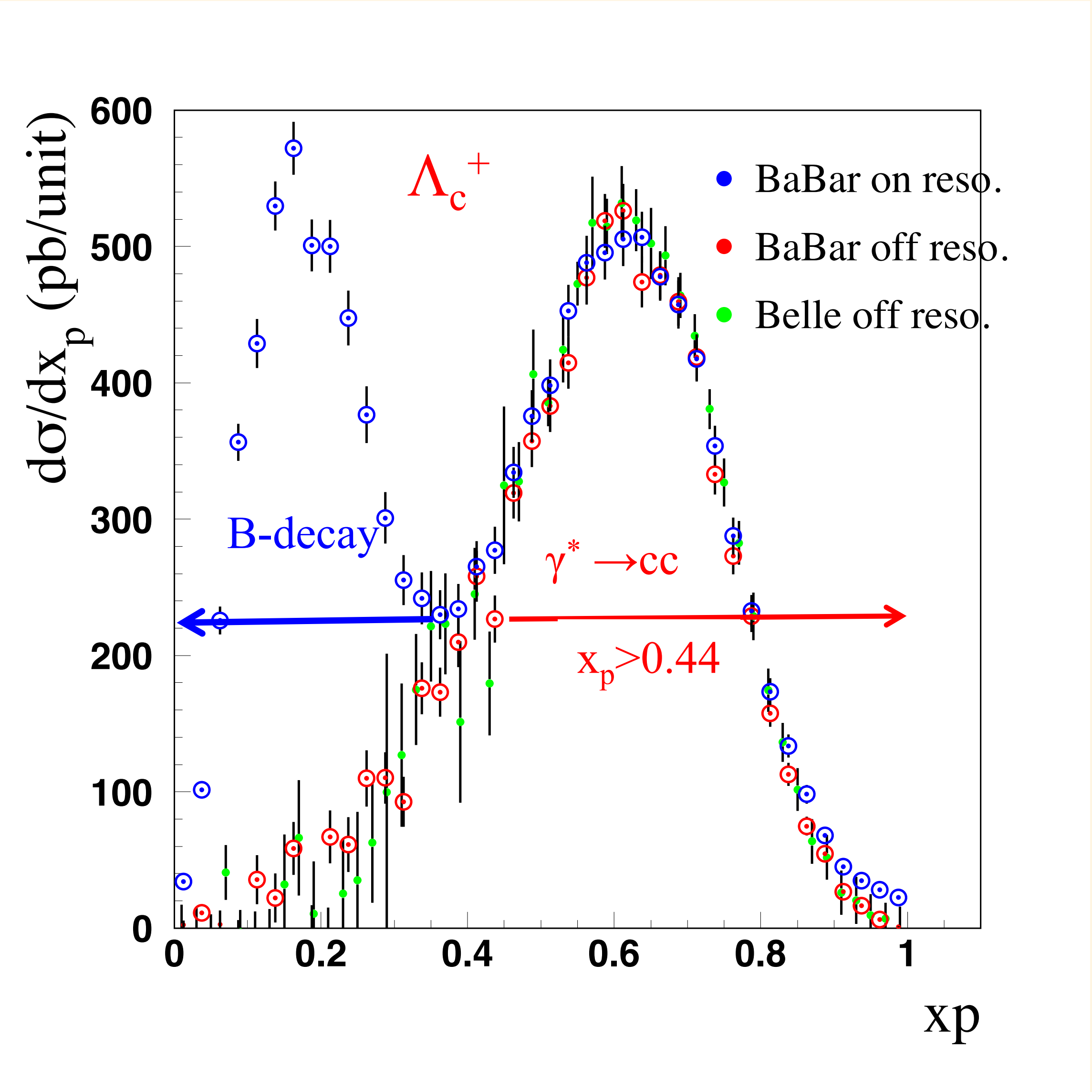
Peak positions for Ω^- and Ξ(1530) seem slightly higher than the other hyperons.

Total cross sections for S=-1 hyperons are obtained using Hermite interpolation assuming $d\sigma/dx_p=0$ at $x_p=0,1$.

Error bar represent statistical fluctuation.

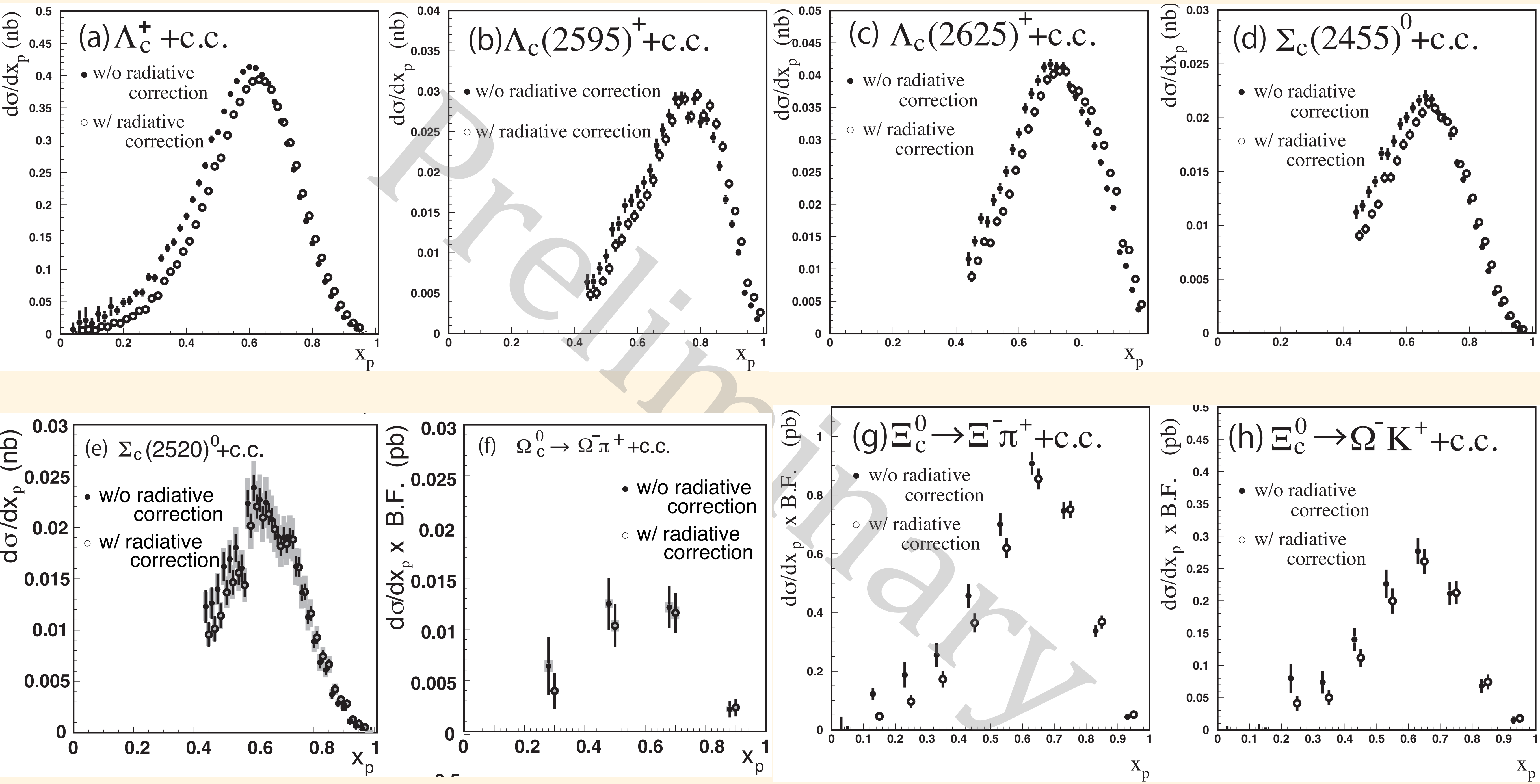
Inclusive differential cross sections, charmed baryons

- In order to increase statistics, both of on $\Upsilon(4S)$ and continuum data are used.
- B-meson decay contribution concentrate in low x_p, and is eliminated by selecting $x_p > 0.44$.



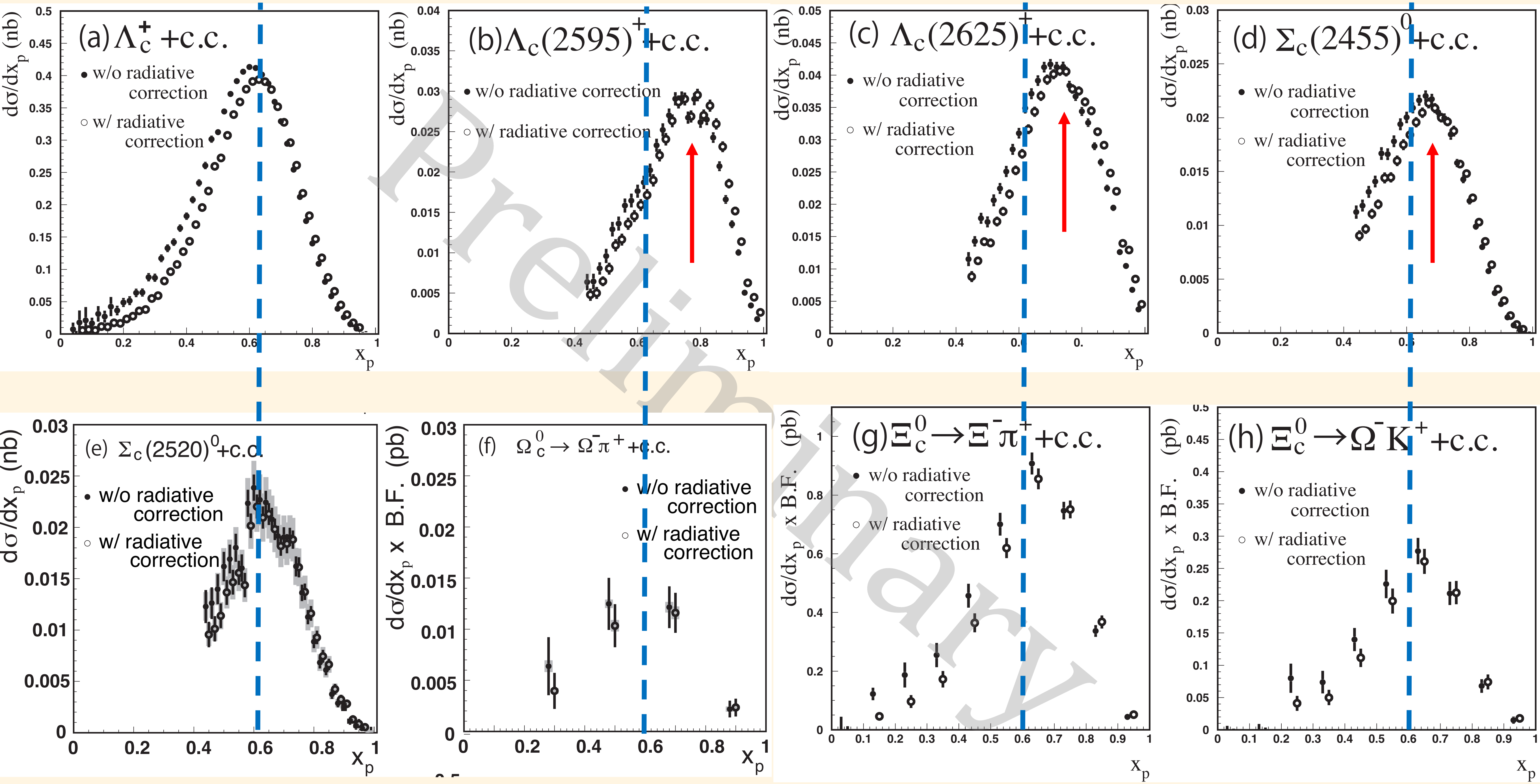
Inclusive differential cross sections, charmed baryons

Sum of on $\Upsilon(4S)$ and continuum

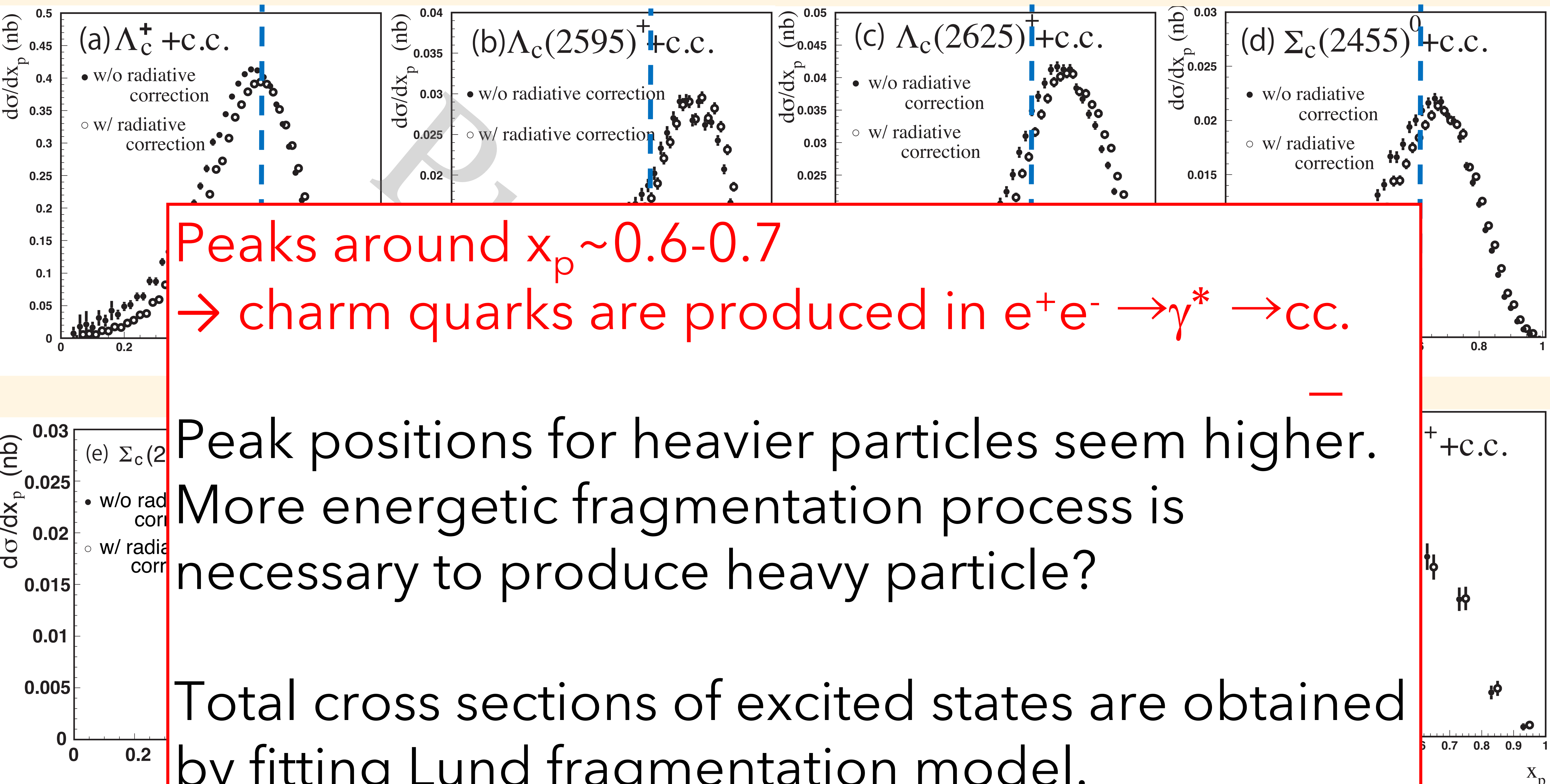


Absolute B.F. for Ω_c, Ξ_c is unknown.

Inclusive differential cross sections, charmed baryons



Inclusive differential cross sections, charmed baryons

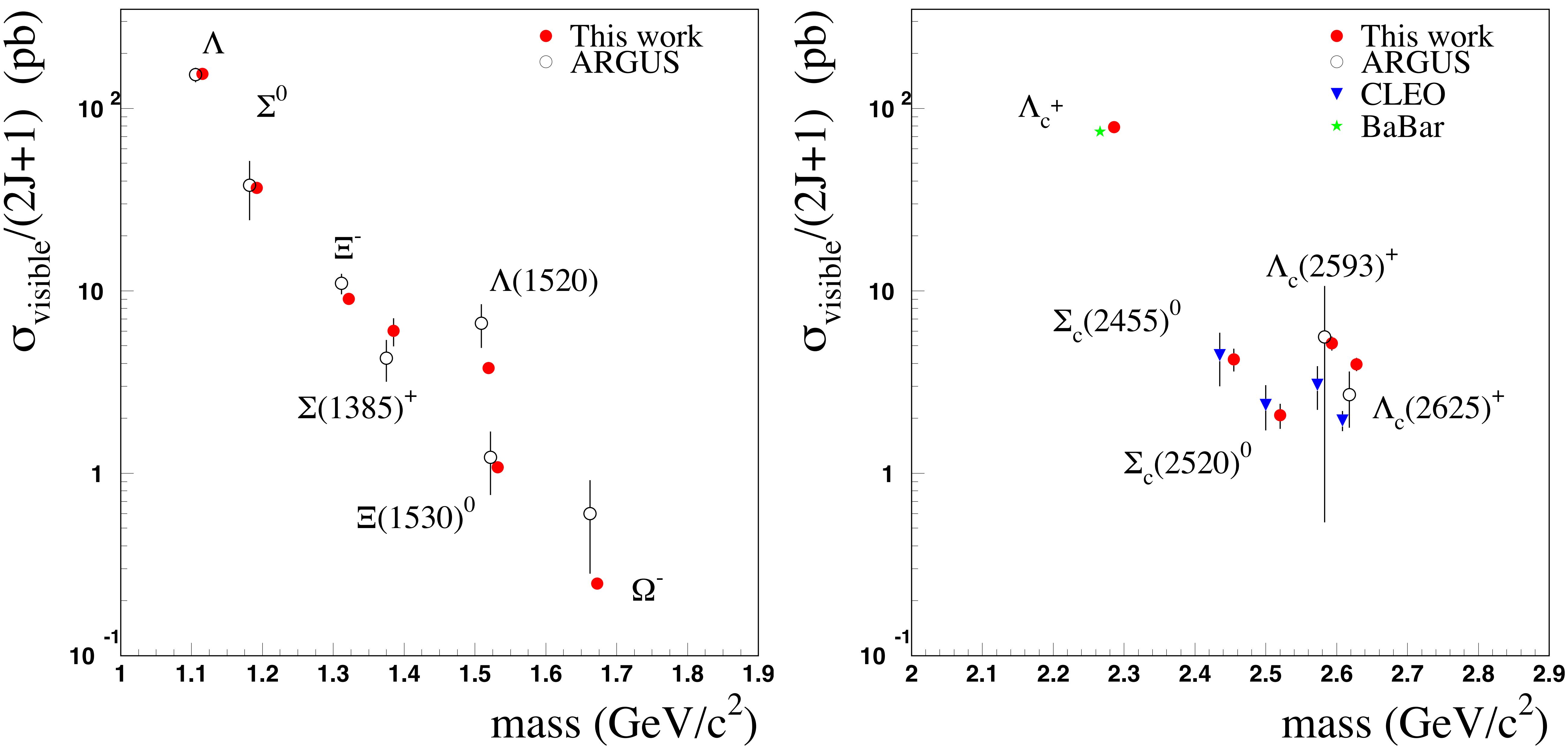


Peaks around x_p~0.6-0.7
→ charm quarks are produced in $e^+e^- \rightarrow \gamma^* \rightarrow c\bar{c}$.

Peak positions for heavier particles seem higher.
More energetic fragmentation process is necessary to produce heavy particle?

Total cross sections of excited states are obtained by fitting Lund fragmentation model.

Comparison of visible cross section with previous measurements



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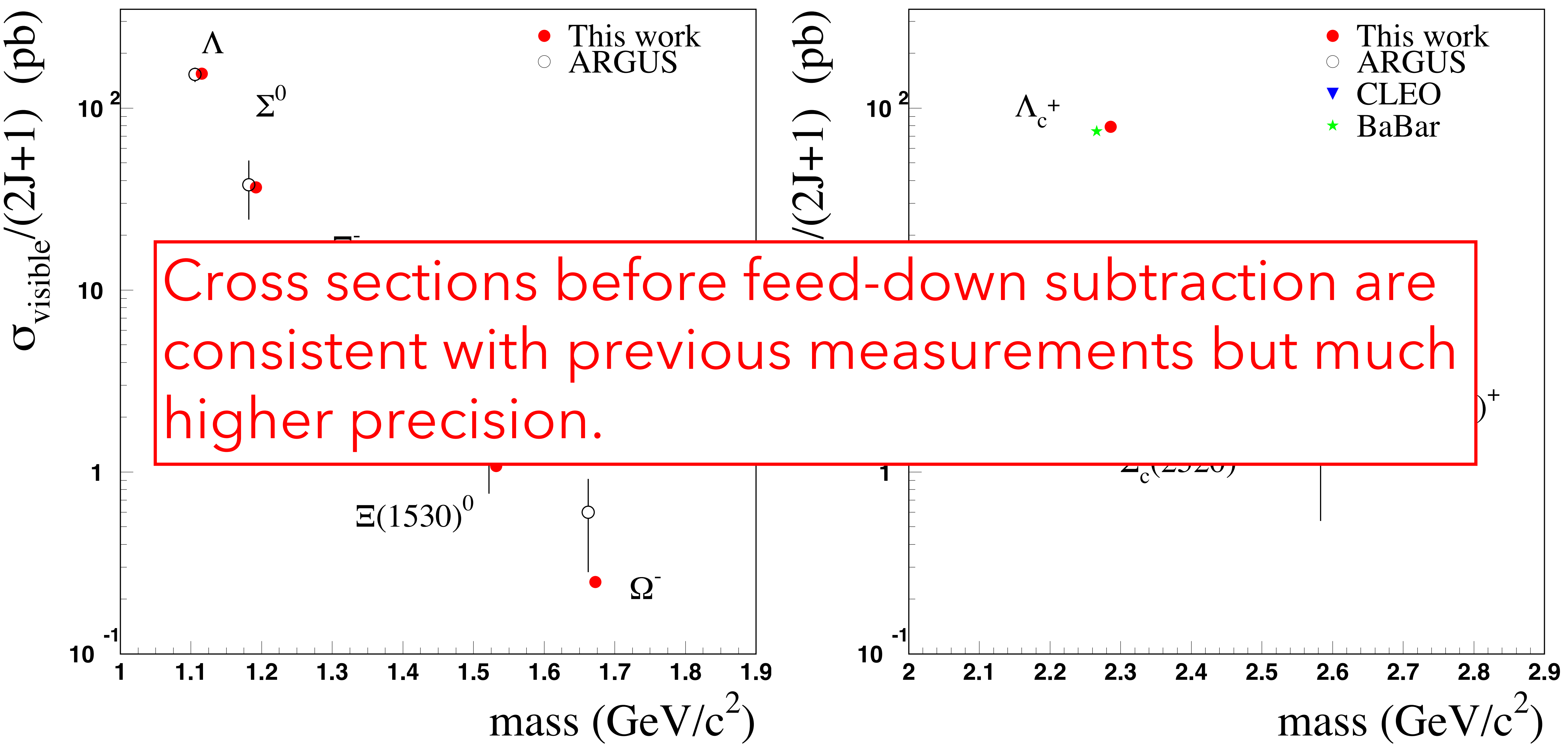
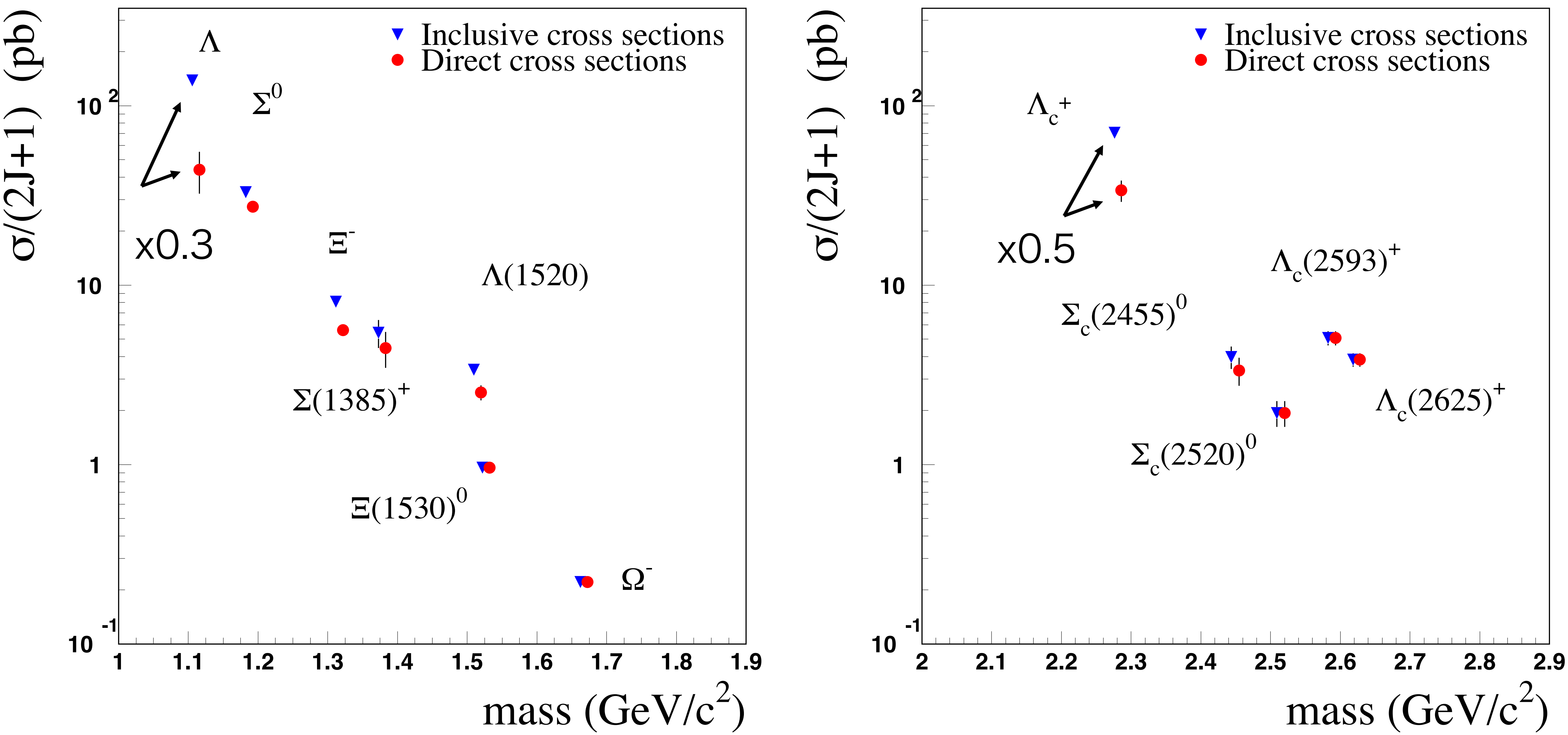
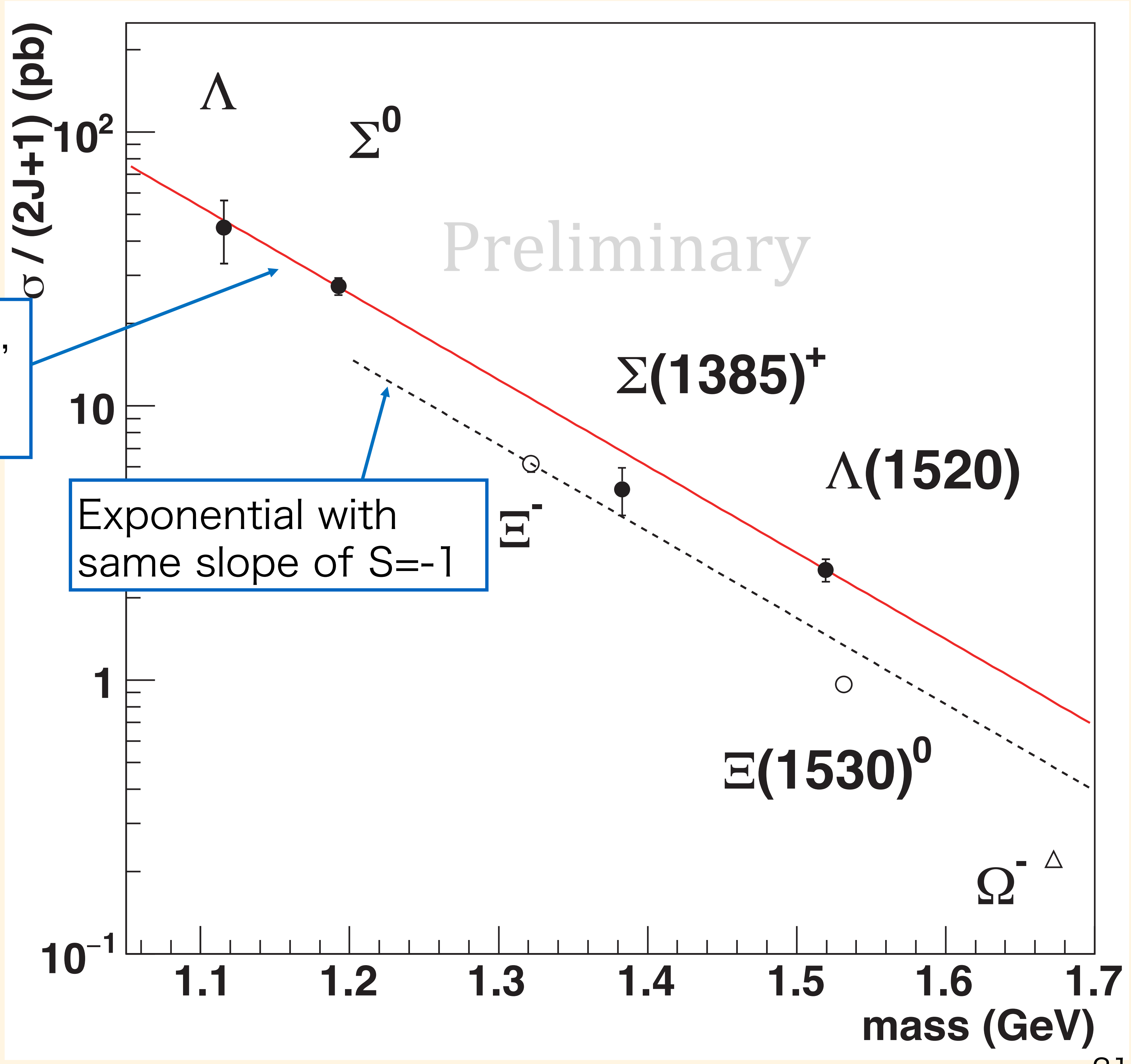


Cross sections before feed-down subtraction are consistent with previous measurements but much higher precision.

Feed-down subtracted (direct) cross section



Results for hyperons

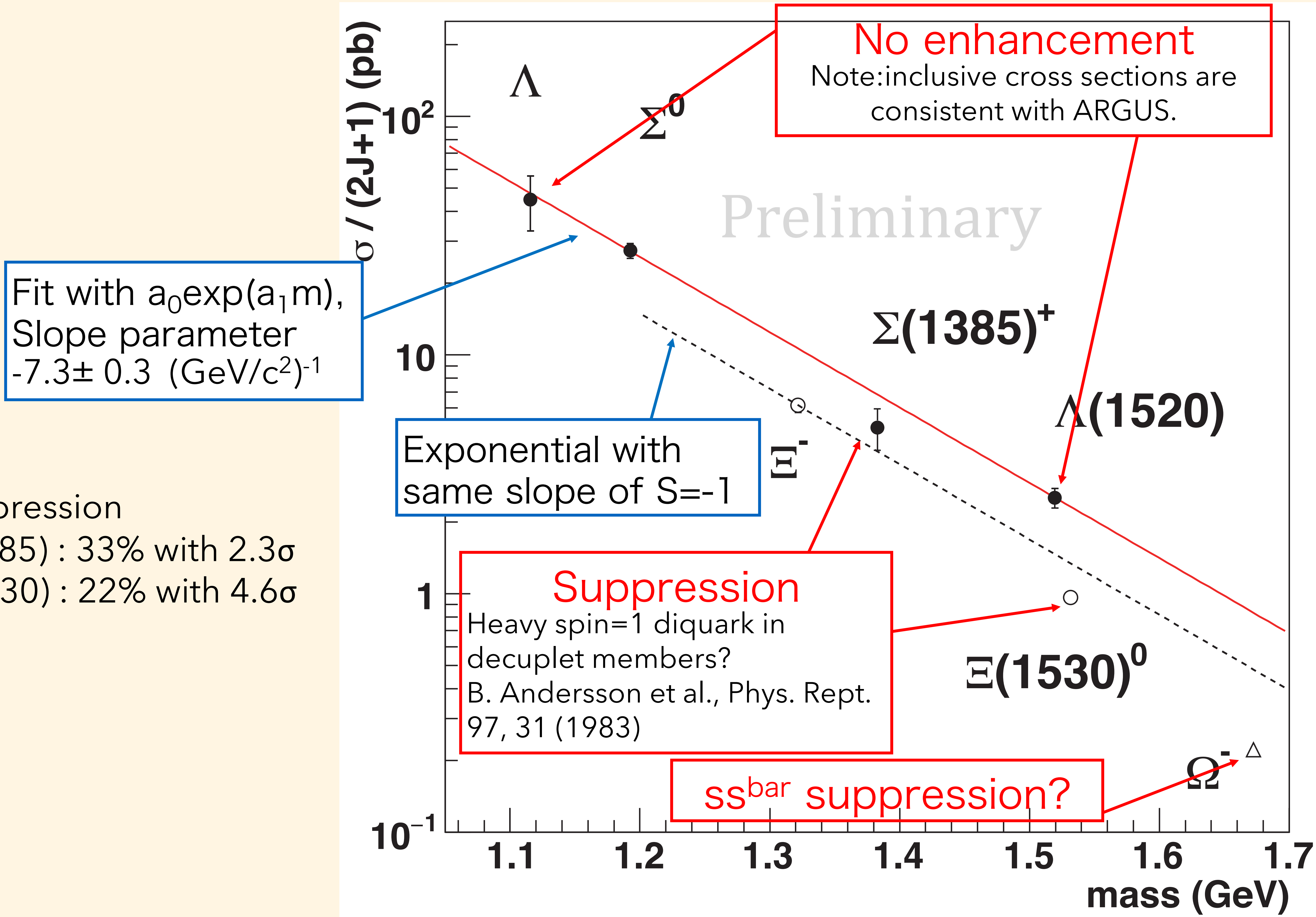


Fit with $a_0\exp(a_1 m)$,
Slope parameter
-7.3± 0.3 $(\mathrm{GeV}/c^2)^{-1}$

Exponential with
same slope of S=-1

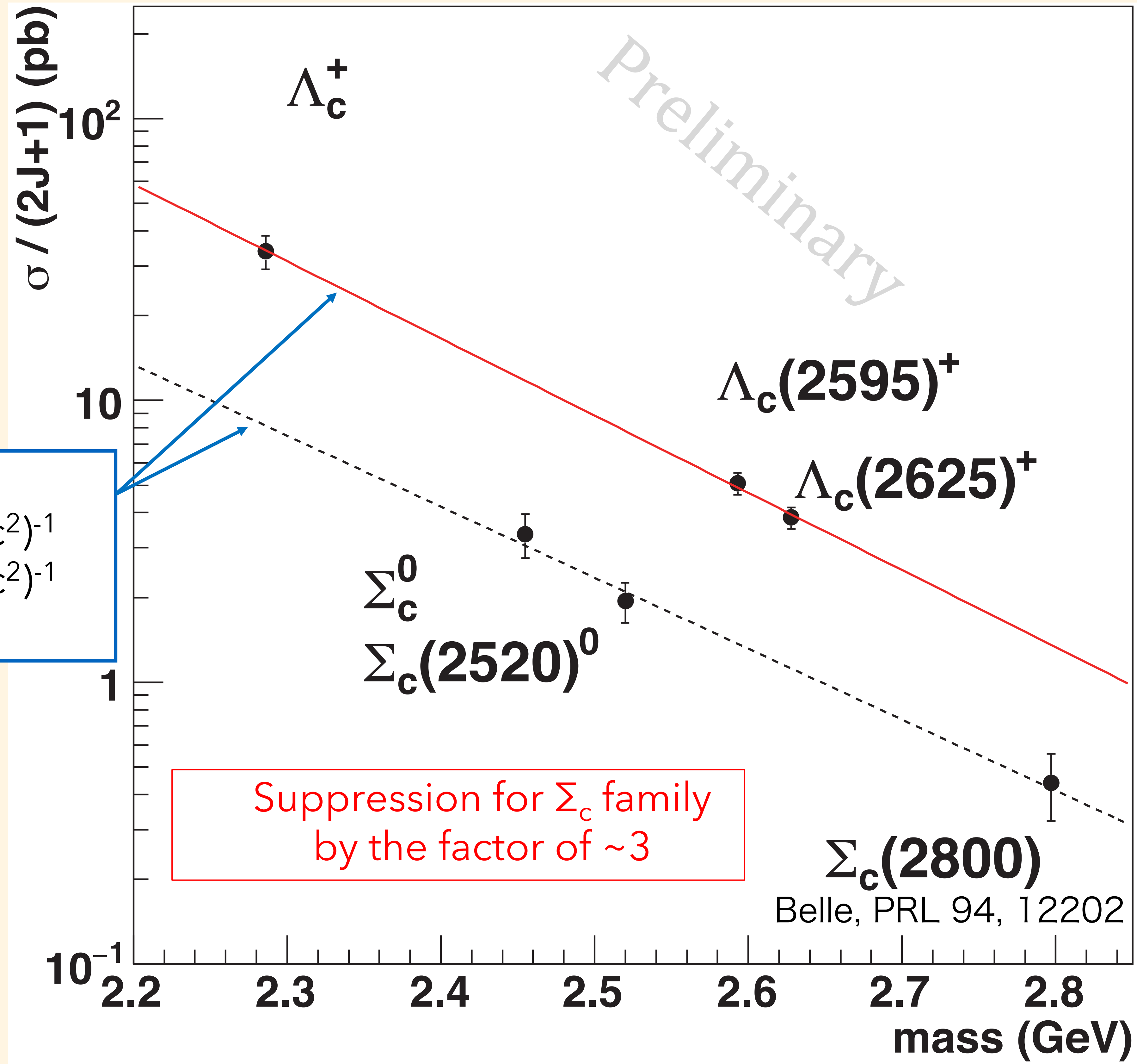
Results for hyperons

- Suppression
- Σ(1385) : 33% with 2.3σ
- Ξ(1530) : 22% with 4.6σ



Results of charmed baryons

Slope parameters
Λ_c : -6.3± 0.5 $(GeV/c^2)^{-1}$
Σ_c : -5.8± 1.0 $(GeV/c^2)^{-1}$
consistent



Discussion

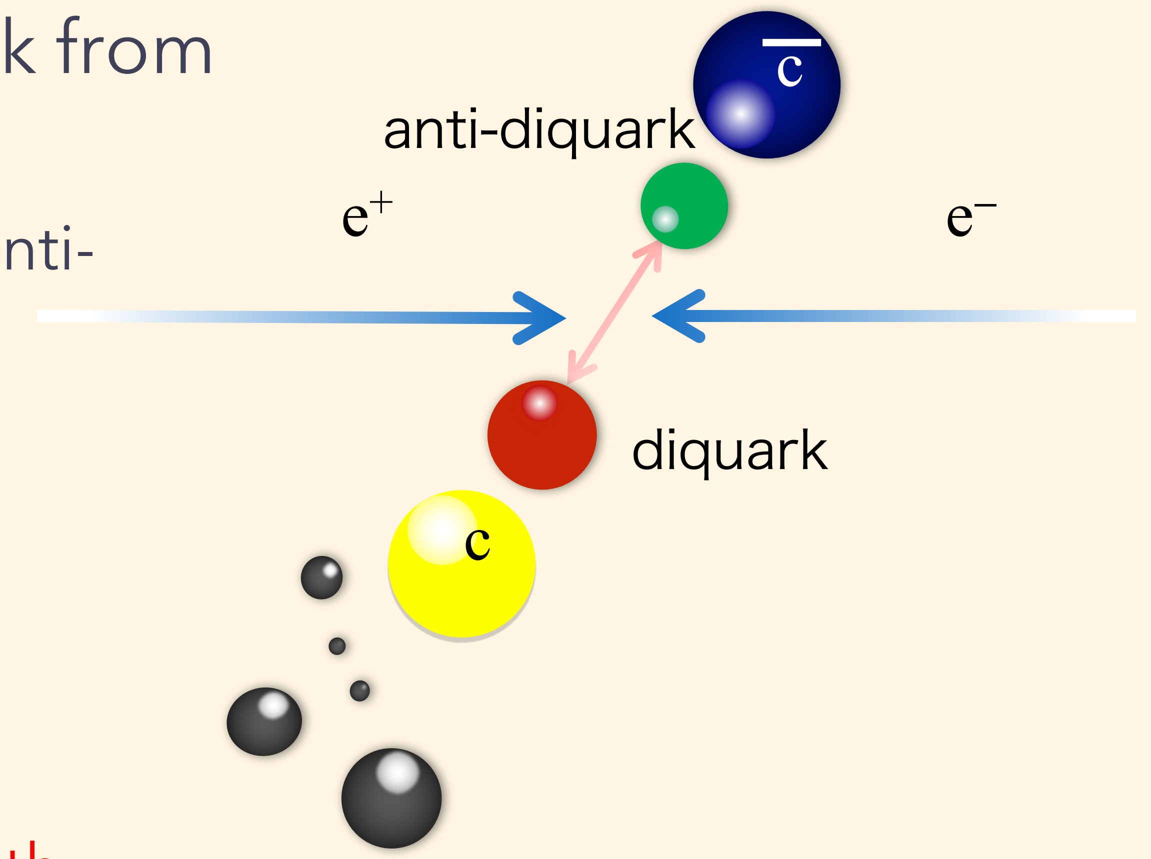
- Assuming that a c-quark picks up a diquark from vacuum,
  - Schwinger-like "tunnel effect" of diquark and anti-diquark

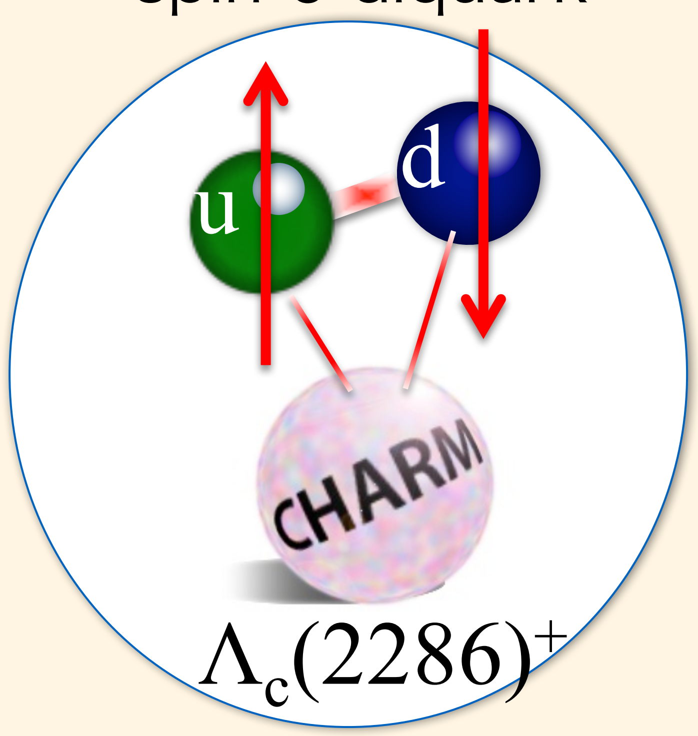
$$\sigma \propto \exp(-\pi\mu^2/\kappa)$$

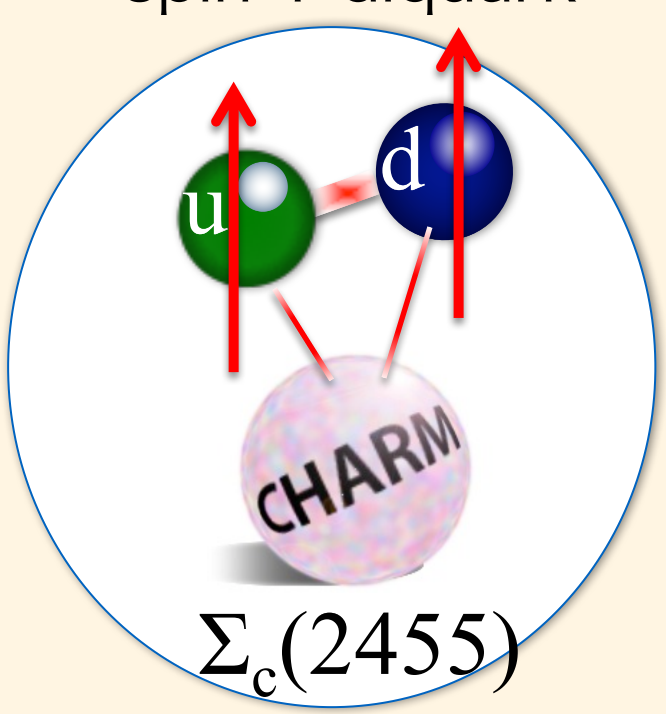
μ : diquark mass
κ : gluonic string tension

B. Andersson et al., Phys. Scripta. 32, 574 (1985)

  - Λ_c : spin-0 light diquark ("good" diquark),
  - Σ_c : spin-1 heavy diquark ("bad" diquark)
- Difference of production rates may be related with diquark structure in Λ_c and. Σ_c .







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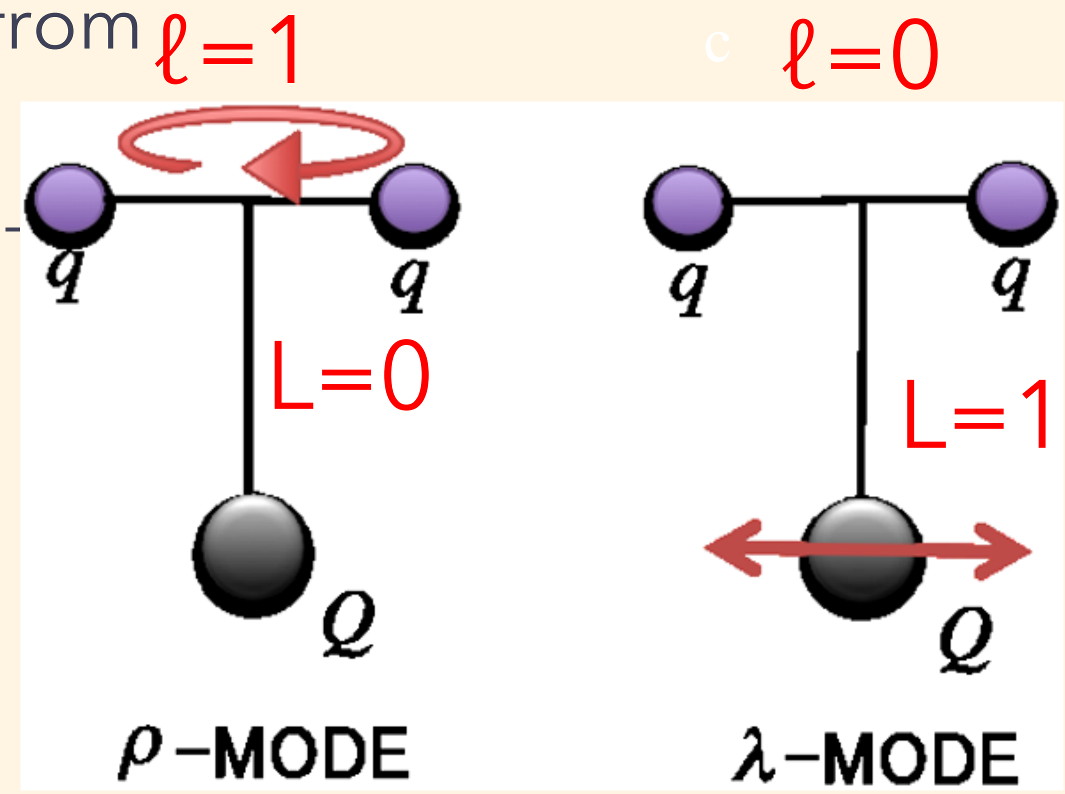
- Quark model prediction by

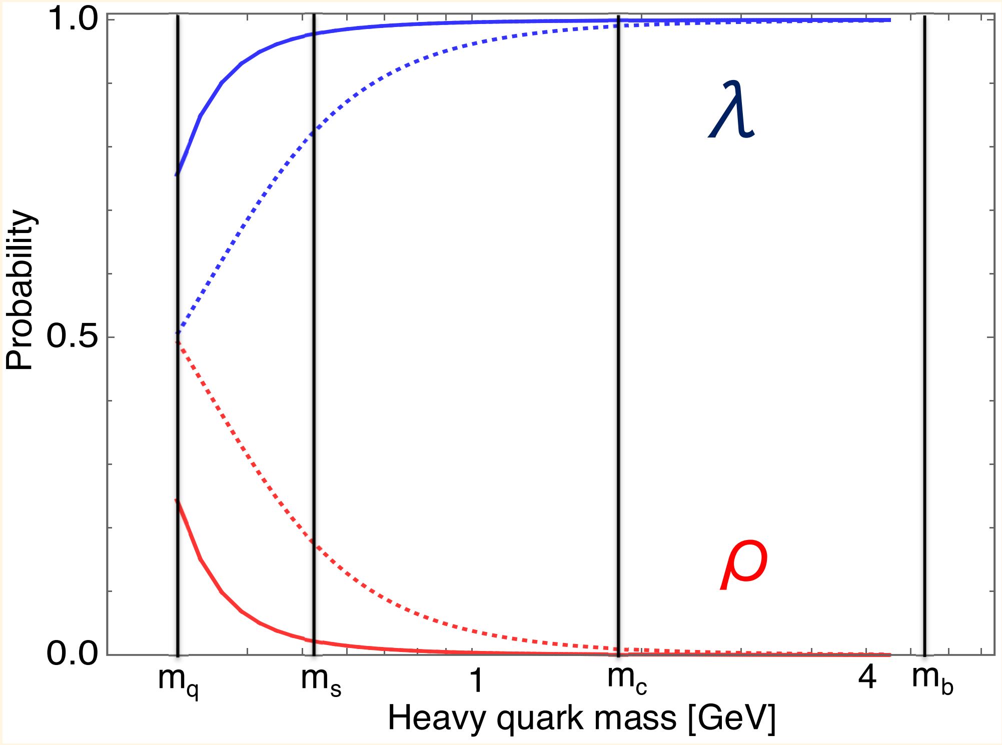
  T. Yoshida et al, PRD92, 114029 (2015)

  Λ_c(2593) (1/2-) and Λ_c(2625) (3/2-)

  are composed of $(qq)_{\ell=0}$ diquark with L=1

  excitation relative to charm quark.





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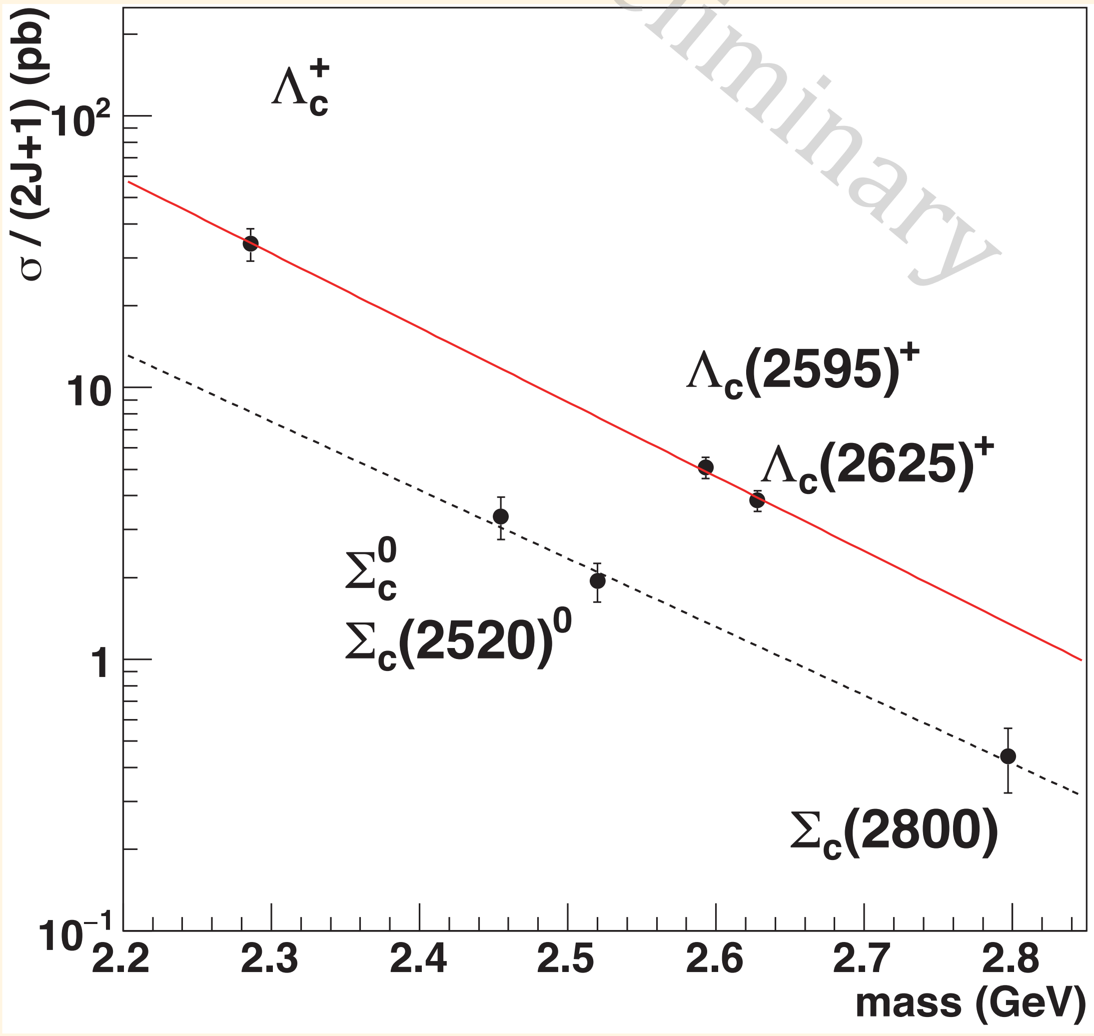
- $\sigma(\Sigma_c)/\sigma(\Lambda_c) = 0.27 \pm 0.07$
  - mass difference of spin-1 and 0 diquarks

$$m(ud_1)^2 - m(ud_0)^2 = (8.2 \pm 0.8) \times 10^4 \ (\mathrm{MeV}/c^2)^2$$

ref. $490^2 - 420^2 = 6.4 \times 10^4 \ (\mathrm{MeV}/c^2)^2$

B. Andersson et al., Phys. Rept. 97, 31 (1983)



- Slightly higher than reference but consistent with the spin-1/0 diquark mass difference!

Summary

- Production cross sections of hyperons and charmed baryons are measured near the $\Upsilon(4S)$ energy using Belle data.
- $d\sigma/dx_p$ distributions for hyperons
    - Slightly higher Peak positions for Ω- and $\Xi(1530)$
- $d\sigma/dx_p$ distributions for charmed baryons
    - Peak positions for heavier particles seem higher.
- "Inclusive" total cross sections for hyperons
    - Consistent with previous measurements with much higher precision
- Direct total cross sections
    - Clear exponential dependence on baryon masses
    - No enhancements for Λ, $\Lambda(1520)$
    - Suppression of decuplet hyperons and Σ_c family
    - Suggesting diquark structure in ground and low-lying Λ_c, Σ_c
- Next, exotic candidates, heavier Λ_c resonances …
    - Input of absolute B.F. for Ξ_c is helpful