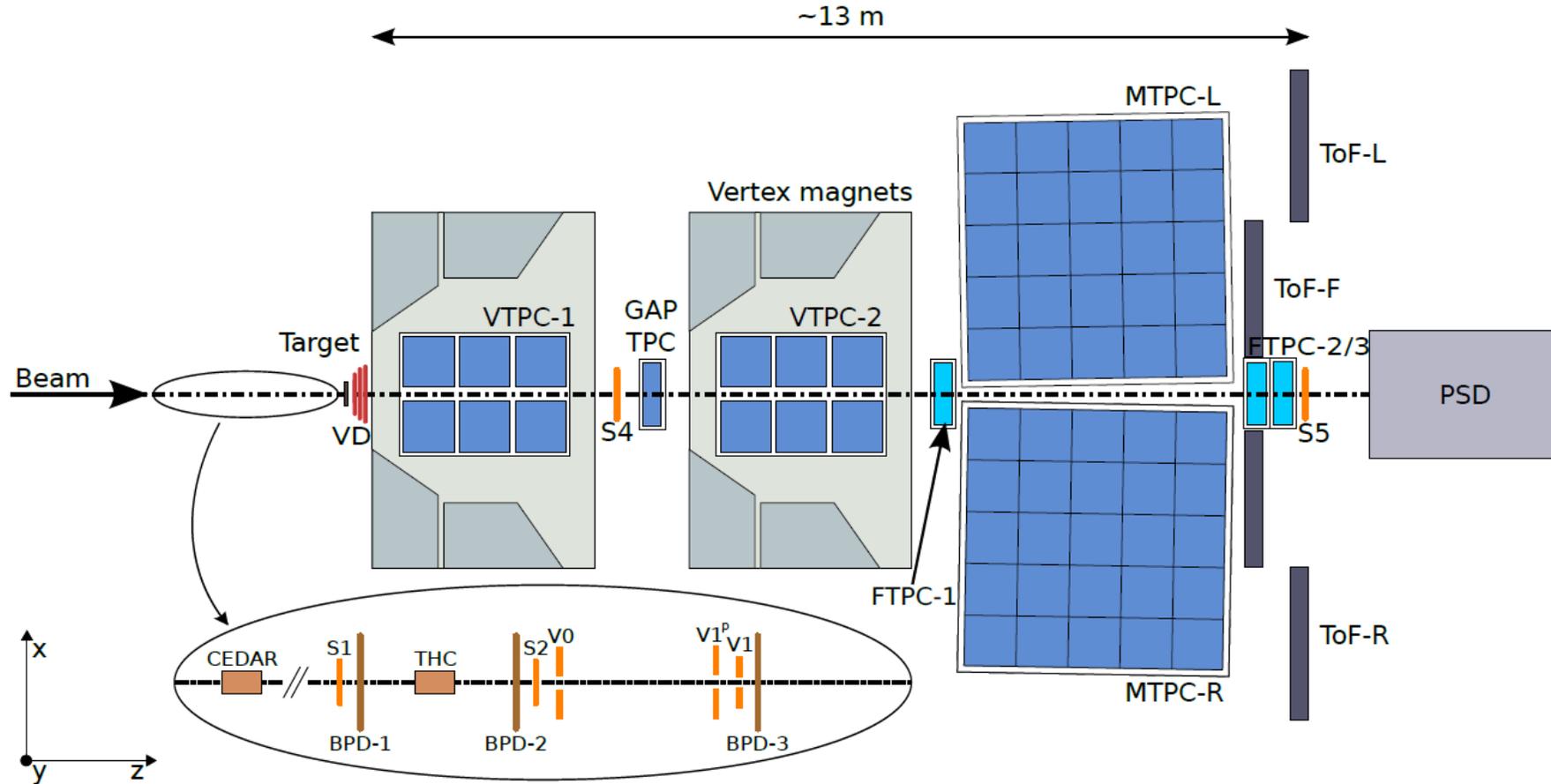




Multi-strange hadron
production in $p+p$ interactions
at $\sqrt{s_{NN}} = 17.3$ GeV

Szymon Puławski
for the NA61/SHINE

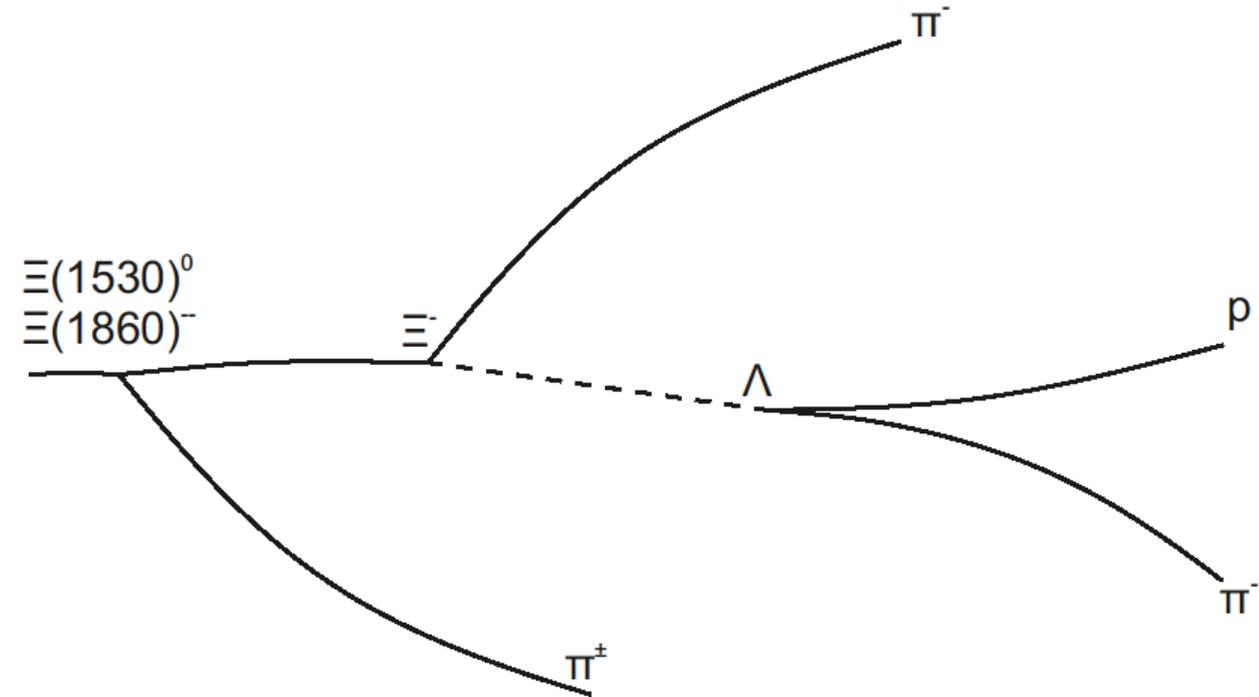
Fixed target experiment located at the CERN SPS accelerator



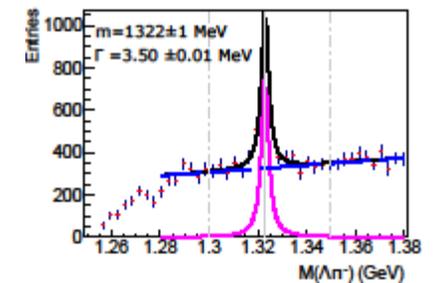
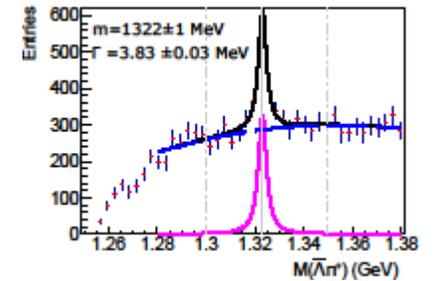
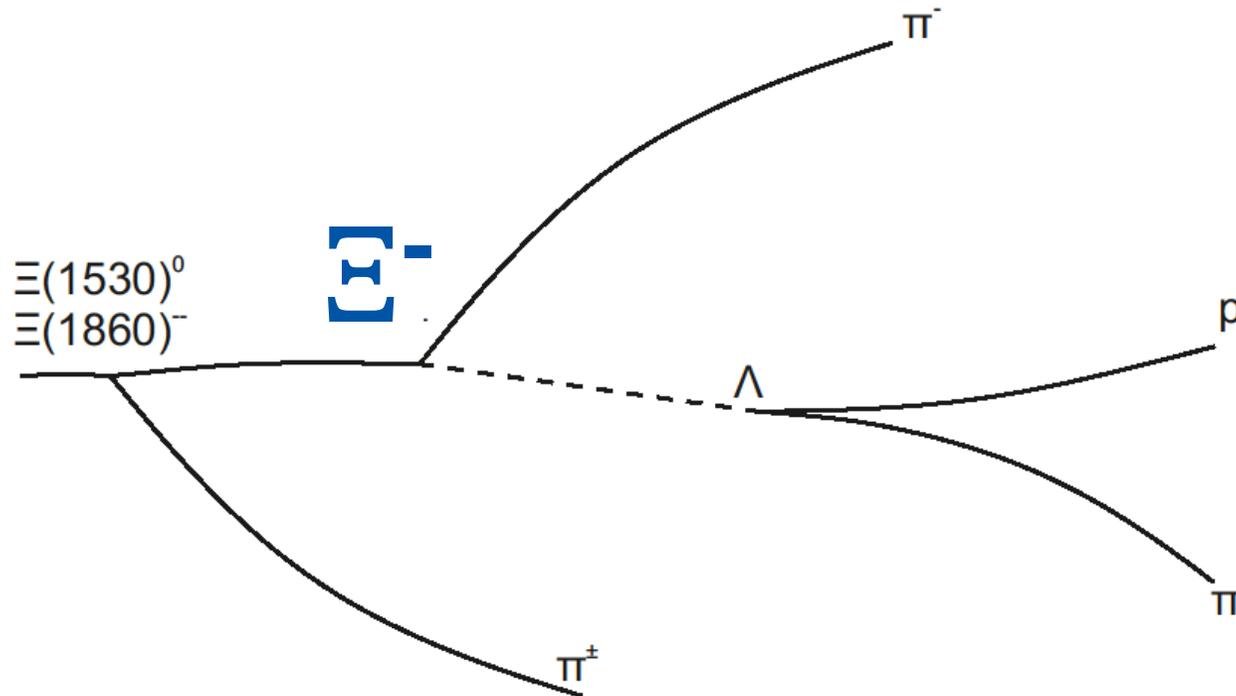
Large acceptance hadron spectrometer –
 coverage of the full forward hemisphere, down to $p_T = 0$

Multi-strange measurements

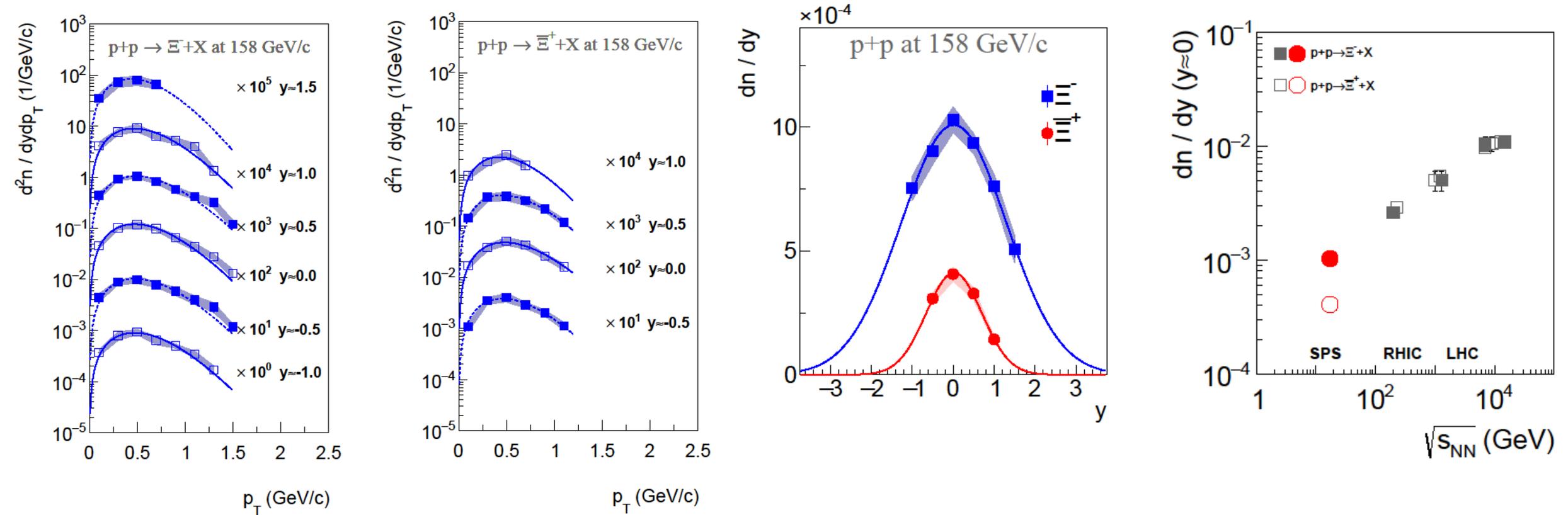
- ❑ **Final results** stand for **multi-strange hyperon production in inelastic $p+p$ interactions at 158 GeV/c** corresponding to $\sqrt{s_{NN}} = 17.3 \text{ GeV}$.
- ❑ Results are corrected for geometrical detector acceptance and reconstruction efficiency and secondary interactions and branching ratios to unmeasured channels.
- ❑ A total of **33 million** events were analyzed.
- ❑ Multi-strange hyperons are identified by their decay topologies.



Ξ production in $p+p$ at 158 GeV/c

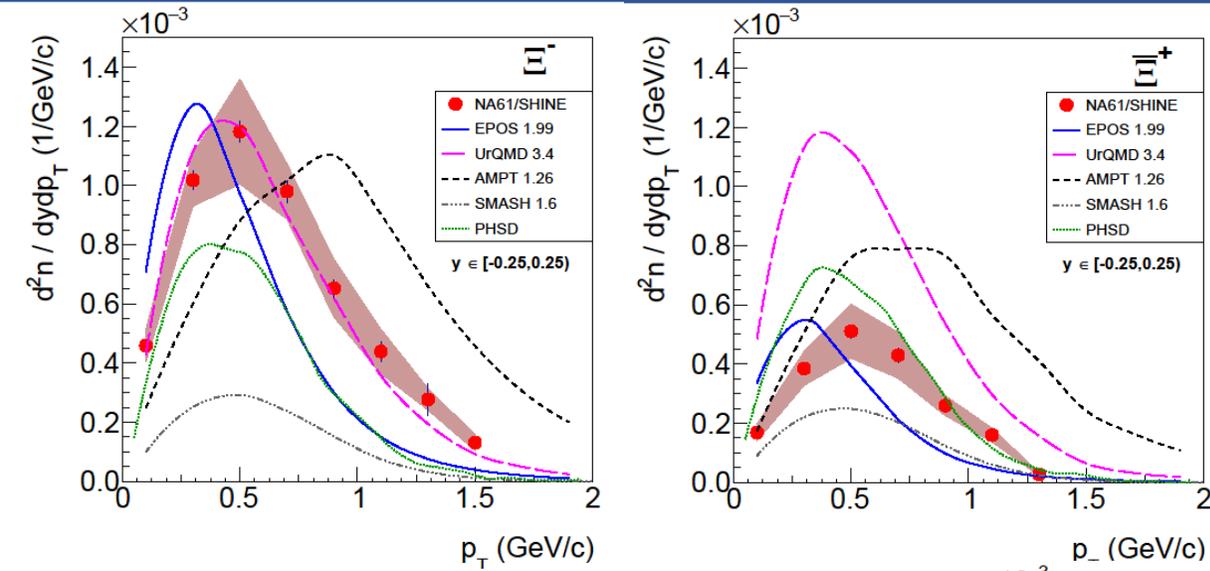


Ξ production in inelastic $p+p$ collisions at 158 GeV/c

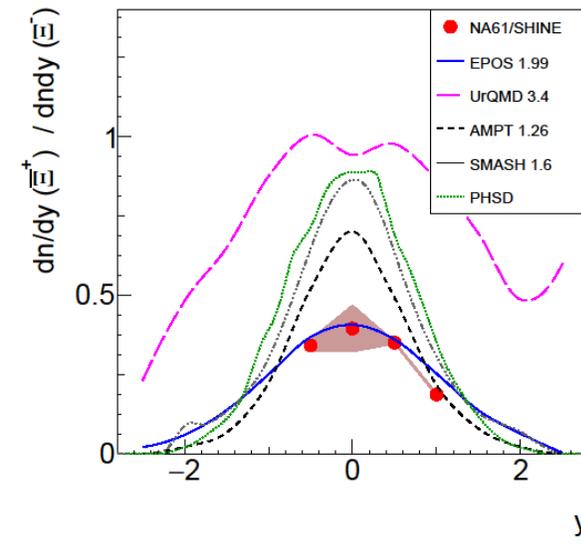
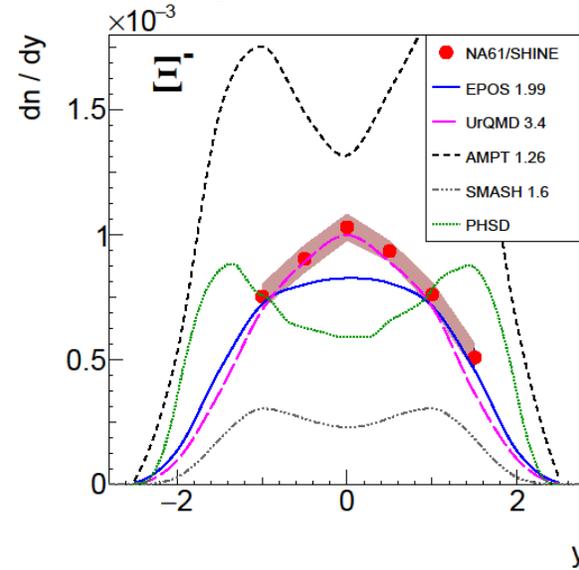
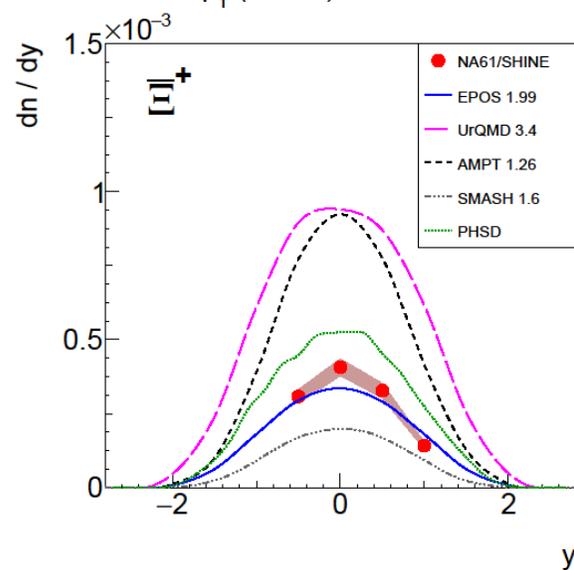


- The only results on Ξ^- and Ξ^+ production in $p+p$ at the SPS energy
- Strong suppression of Ξ^+ production: $\langle \Xi^+ \rangle / \langle \Xi^- \rangle = 0.24 \pm 0.01 \pm 0.05$

[Ξ] production in inelastic $p+p$ collisions – model comparison

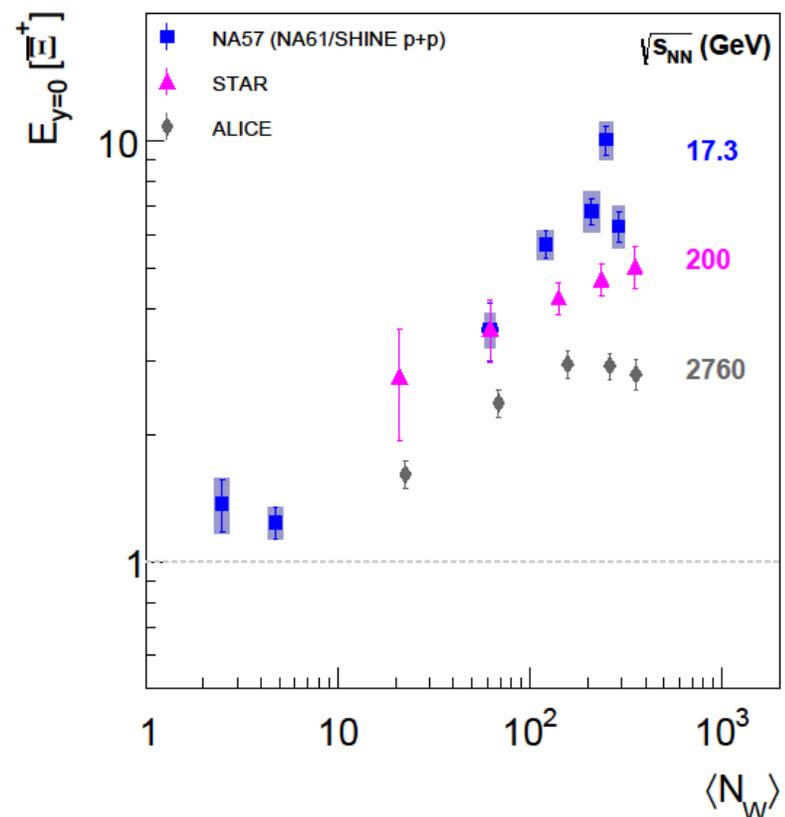
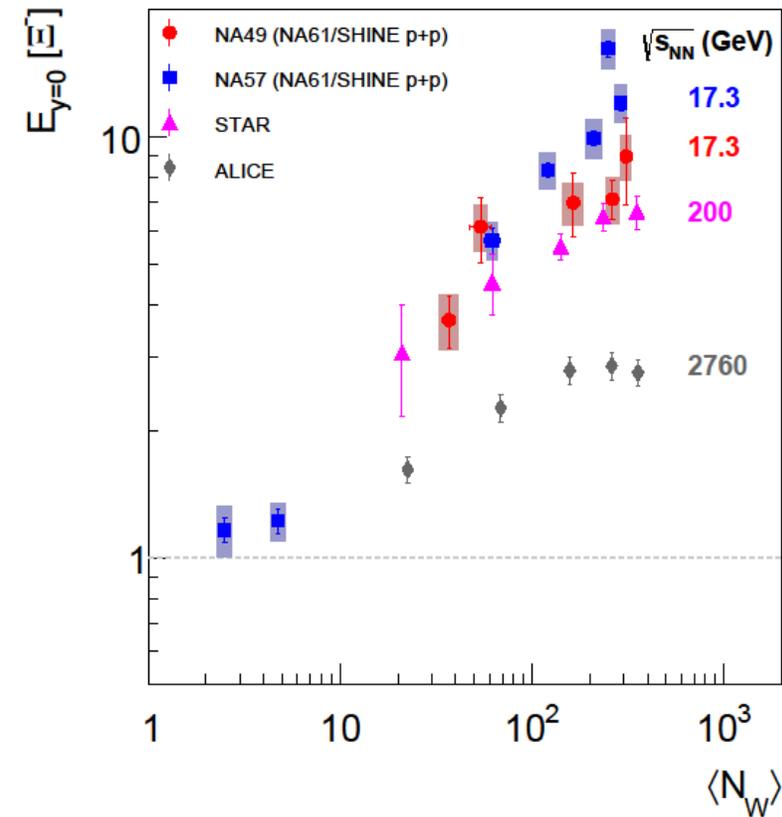


Transport models **fail** to describe the NA61/SHINE results on Ξ production in $p+p$ collisions



Strangeness enhancement factors - Ξ production

□ The enhancement recalculated based on the NA61/SHINE data



□ The strangeness enhancement factor:

$$E = \frac{2}{\langle N_W \rangle} \frac{dn/dy(A+A)}{dn/dy(p+p)}$$

Nucl. Phys. B111 (1976) 461

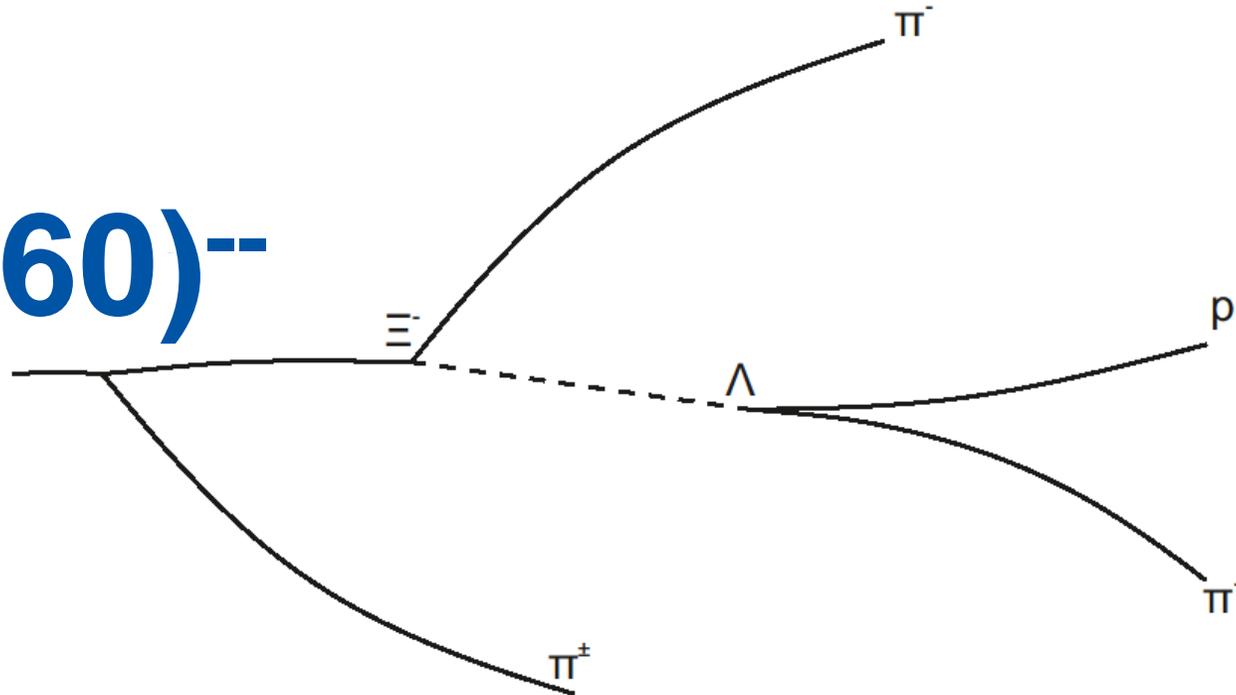
J. Phys. G 32 (2006) 427–442

□ The NA61/SHINE $p+p$ data is new baseline for Ξ production at 158 GeV/c



$\Xi(1860)^{-}$ search in $p+p$ at 158 GeV/c

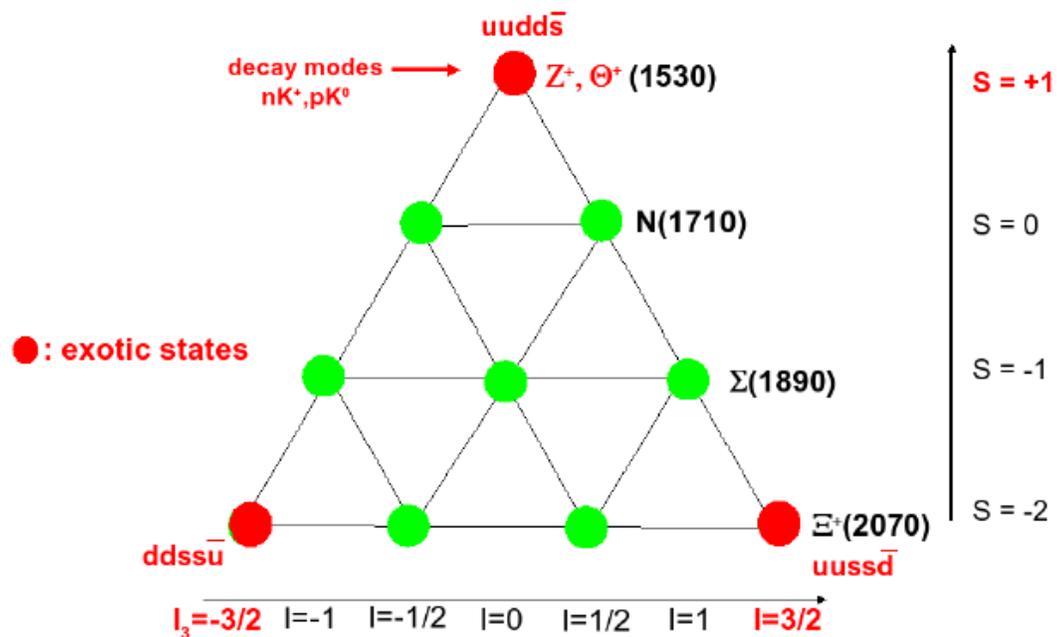
$\Xi(1860)^{-}$



$\Xi(1860)^-$ pentaquark search in NA61/SHINE - motivation

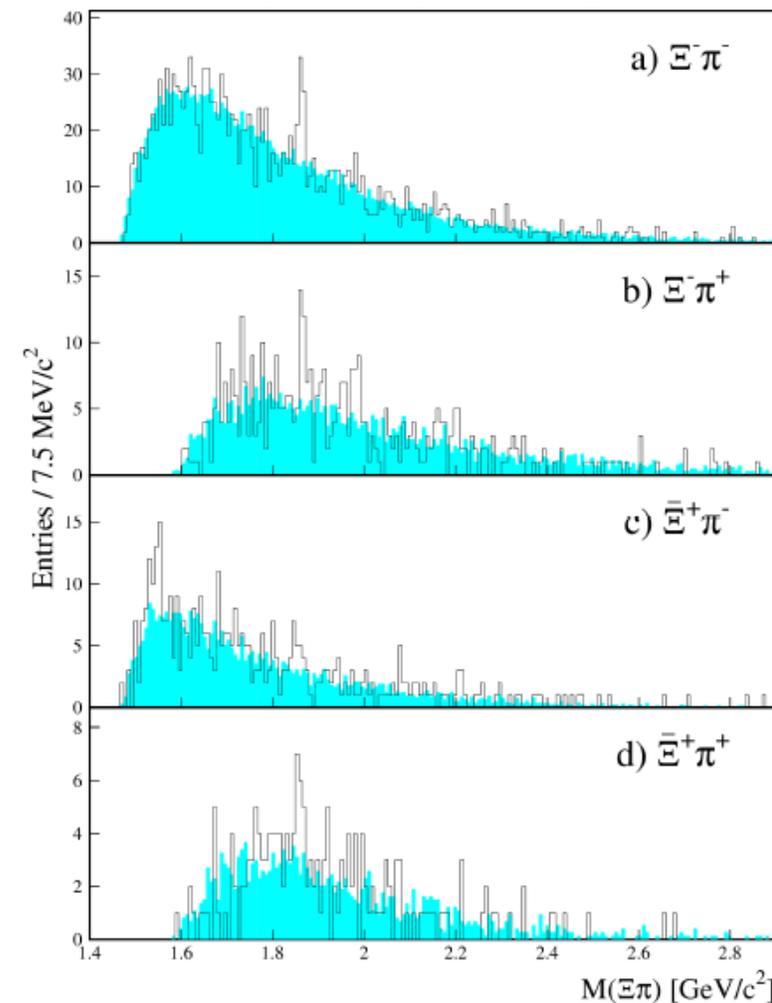
Anti-decuplet of baryons ($J^P=1/2^+$) predicted in chiral soliton model

Diakonov, Petrov, Polyakov, ZP A359, 305, 1997

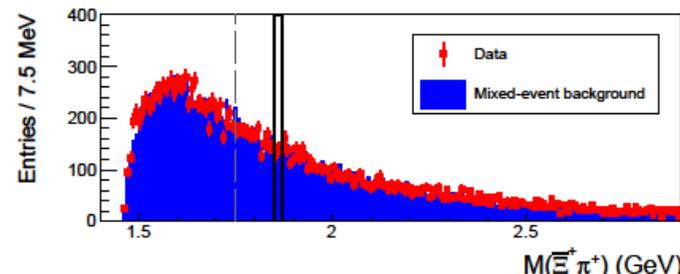
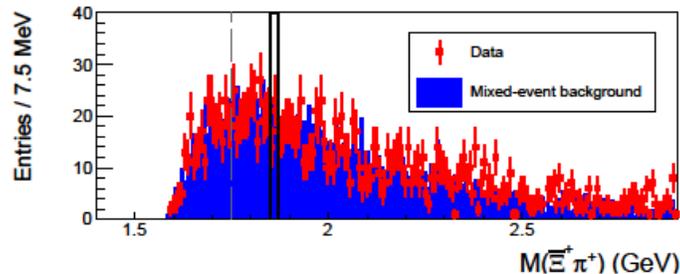
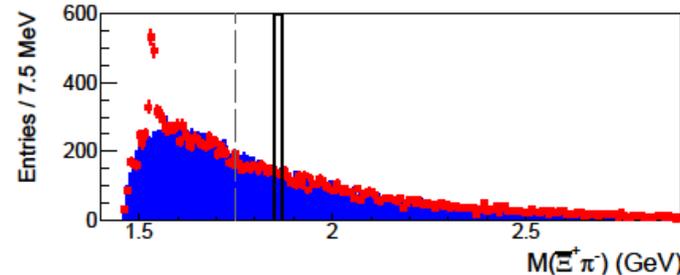
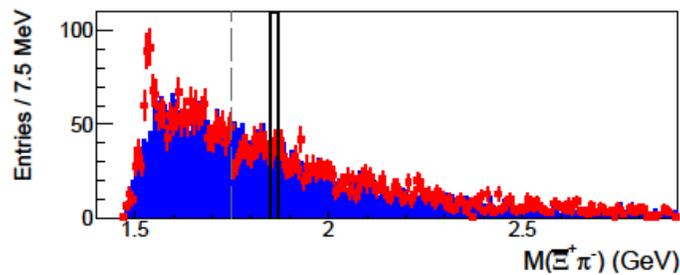
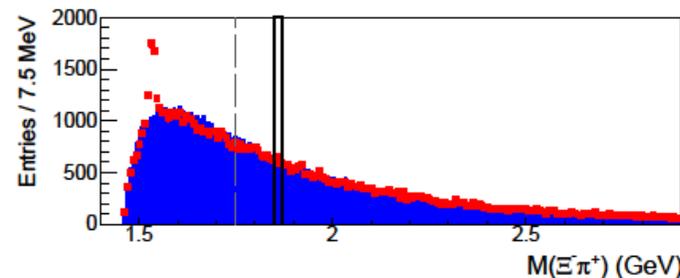
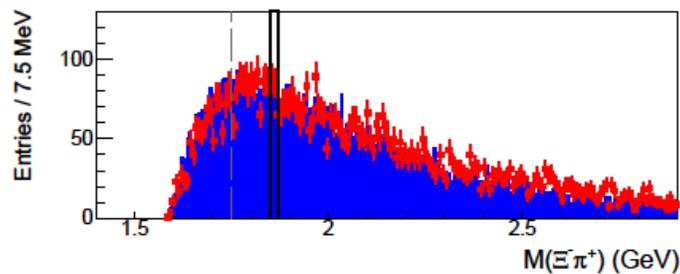
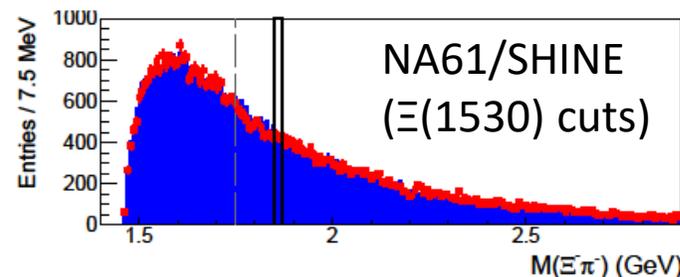
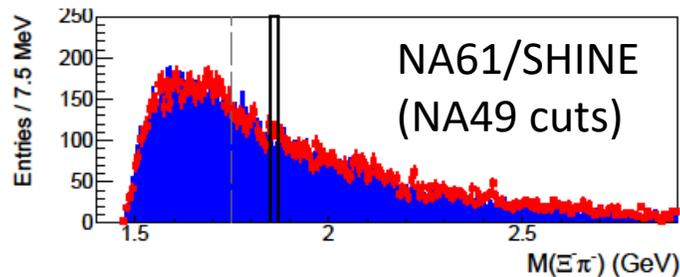


NA49 indication for $\Xi(1860)^-$ pentaquark

NA49, PRL 92, 042003, 2004



$\Xi(1860)^-$ pentaquarks search in NA61/SHINE



NA49: NA49, PRL 92, 042003, 2004

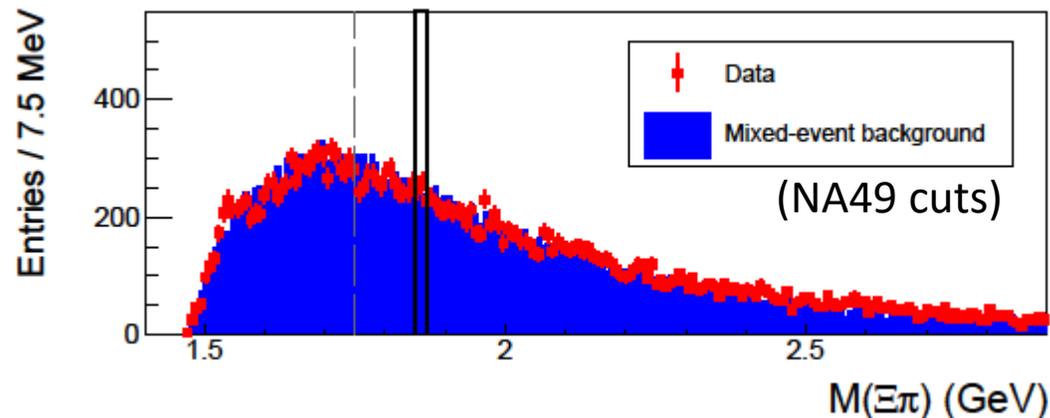
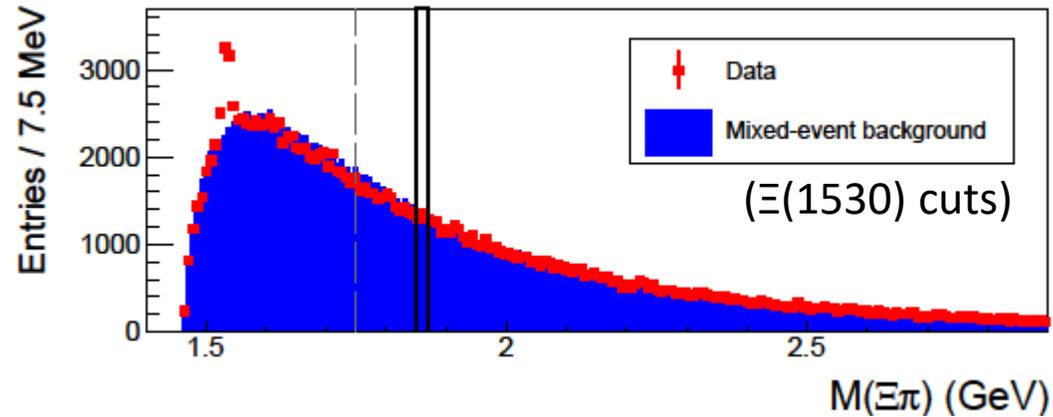
- 6.5M events
- resonance with mass of $1.862 \pm 0.002 \text{ GeV}/c^2$
- width below the detector resolution.
- the significance was estimated to be 4.0 sigma.

NA61/SHINE:

- 53M events (26M after cuts)
- Same analysis as NA49
- Additional analysis with cuts optimize for $\Xi(1530)$ search

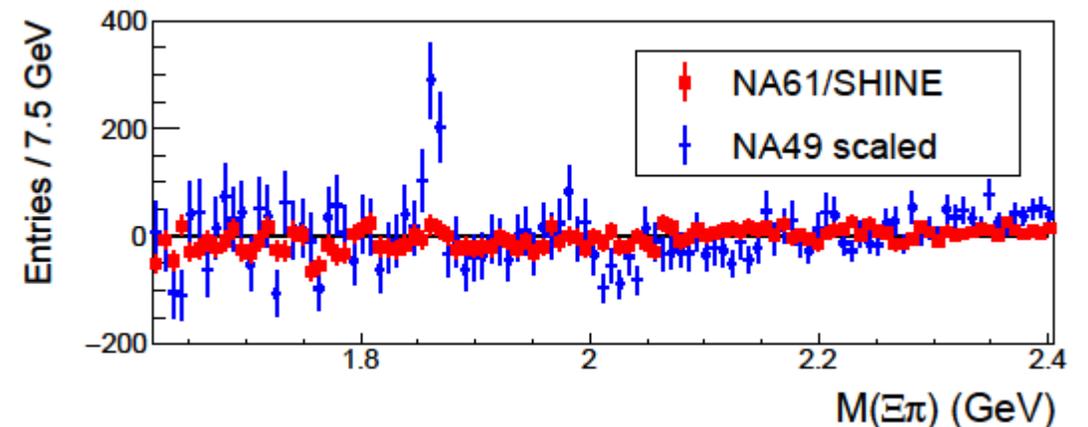
$\Xi(1860)^{-}$ pentaquarks search in NA61/SHINE

Summarized signal



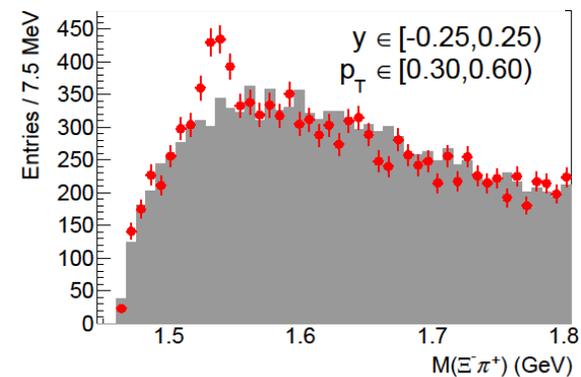
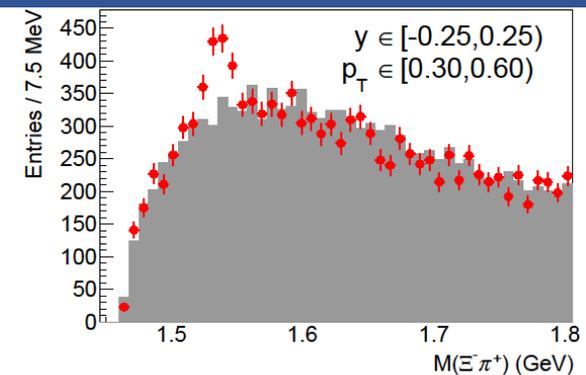
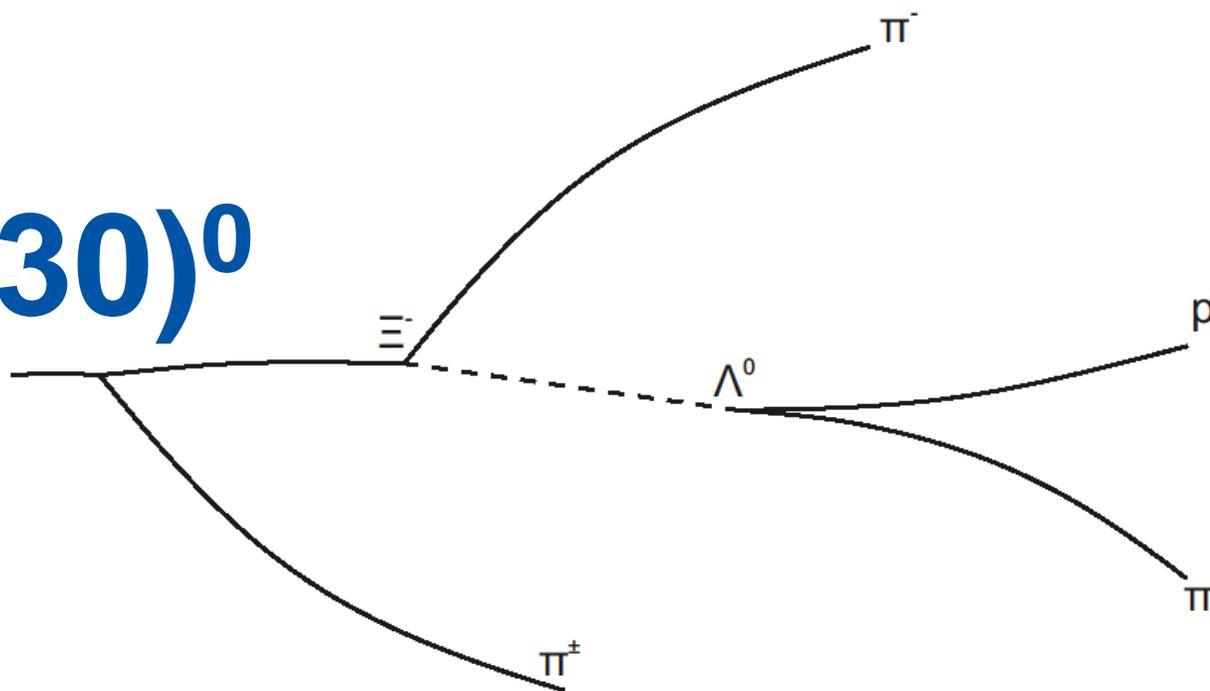
- No $\Xi(1860)^{-}$ pentaquark signal
- Observation by NA49 (PRL 92, 042003, 2004) not confirmed by NA61/SHINE with $10\times$ bigger statistics
- $\Xi(1530)$ well visible

Background subtracted summarized signal

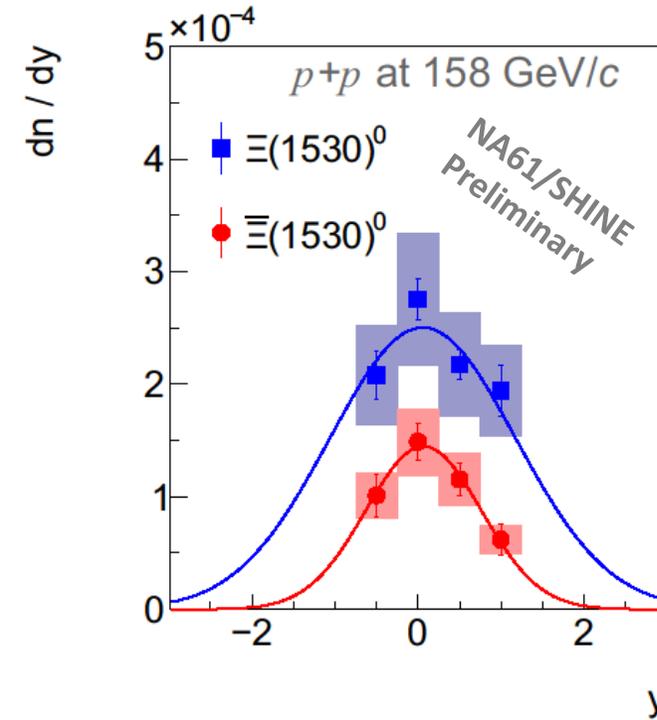
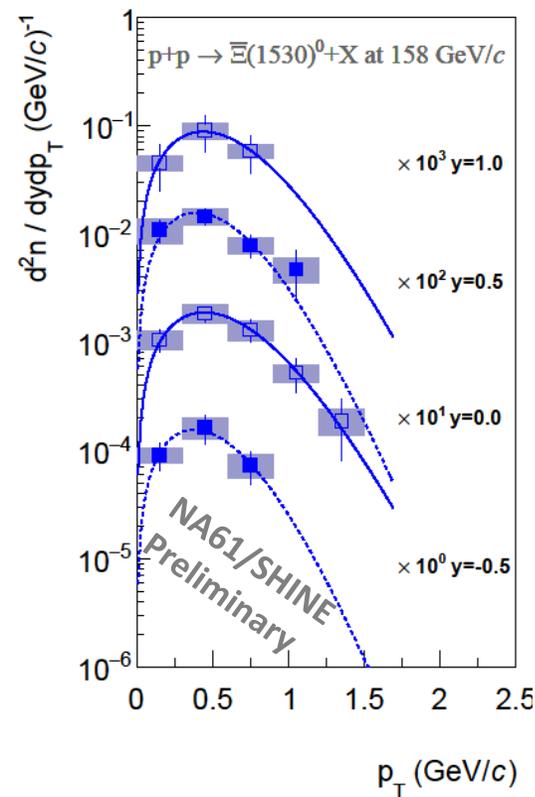
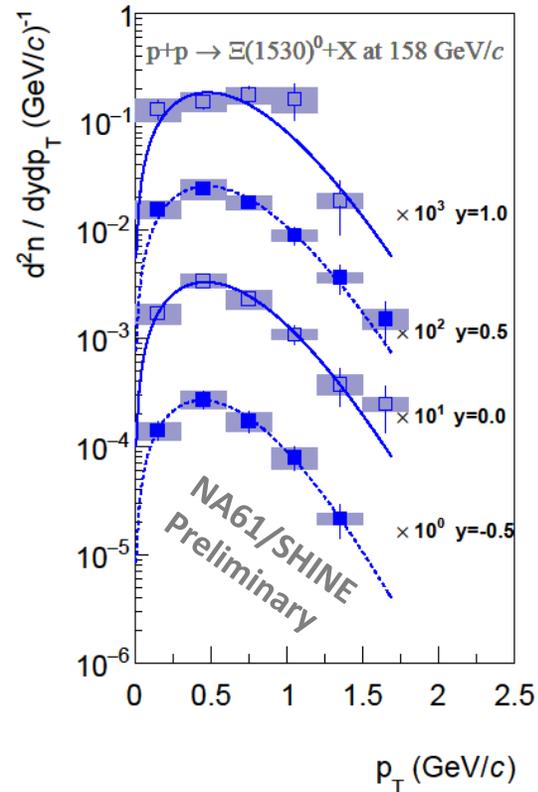


$\Xi(1530)^0$ production in $p+p$ at 158 GeV/c

$\Xi(1530)^0$

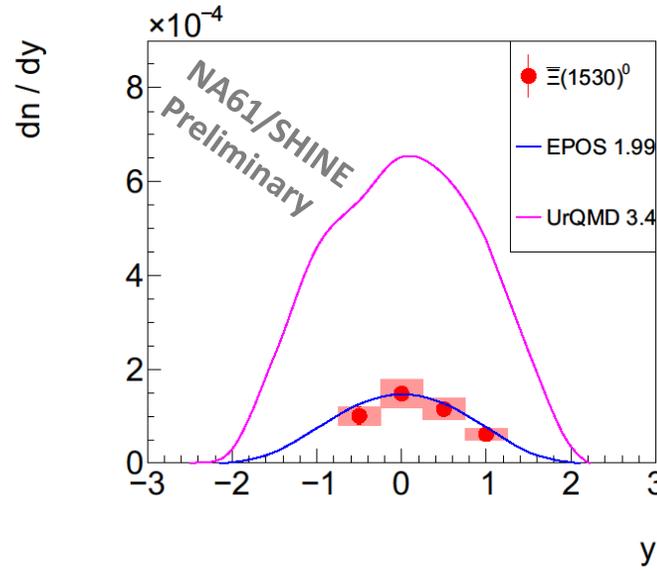
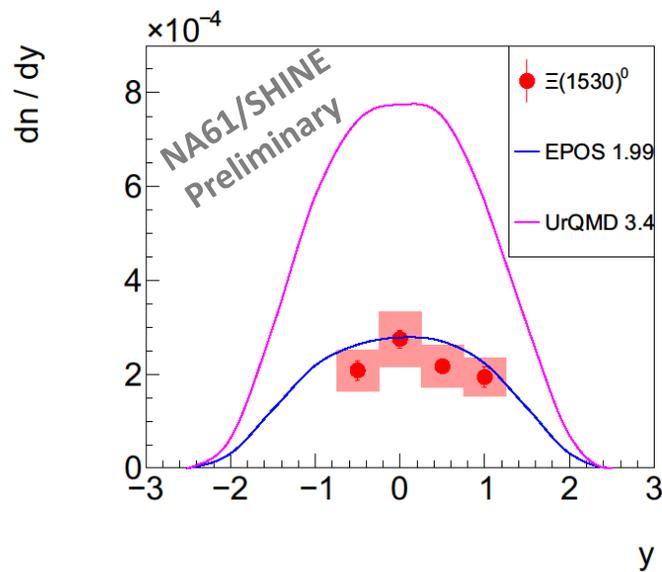
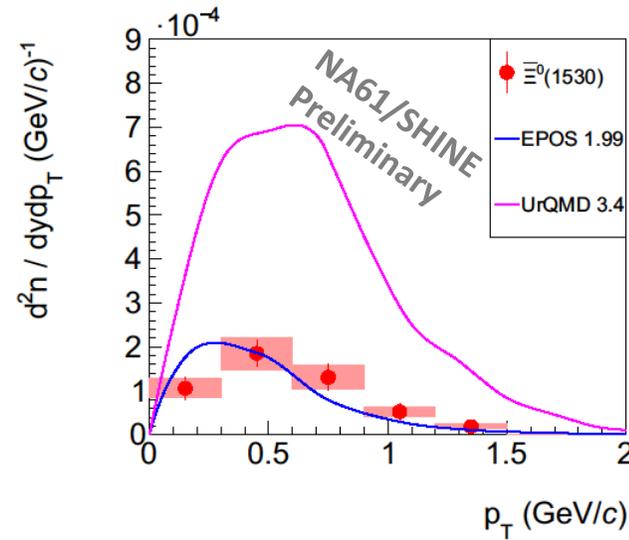
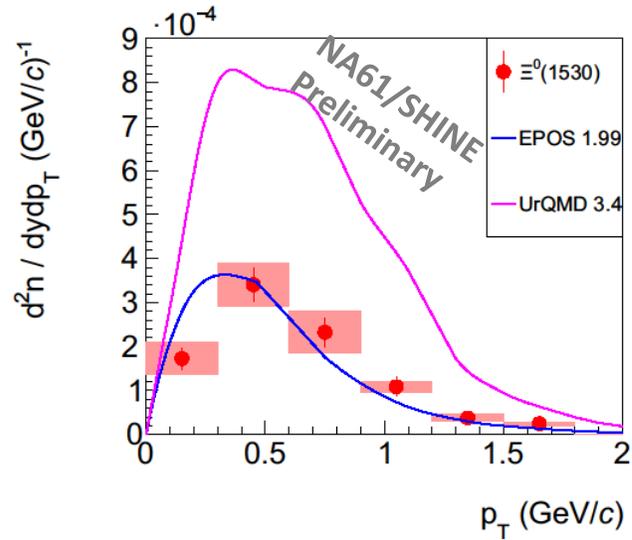


$\Xi(1530)^0$ production in inelastic $p+p$ collisions at 158 GeV/c



- The only results on $\Xi(1530)^0$ production in $p+p$ at the SPS energy
- The second result on $\Xi(1530)^0$ production in $p+p$ (ALICE at 7 TeV [Eur.Phys.J.C 75 \(2015\) 1](#))
- Suppression of $\Xi\bar{\Xi}(1530)^0$ production: $\langle \Xi\bar{\Xi}(1530)^0 \rangle / \langle \Xi(1530)^0 \rangle = 0.35 \pm 0.04 \pm 0.05$

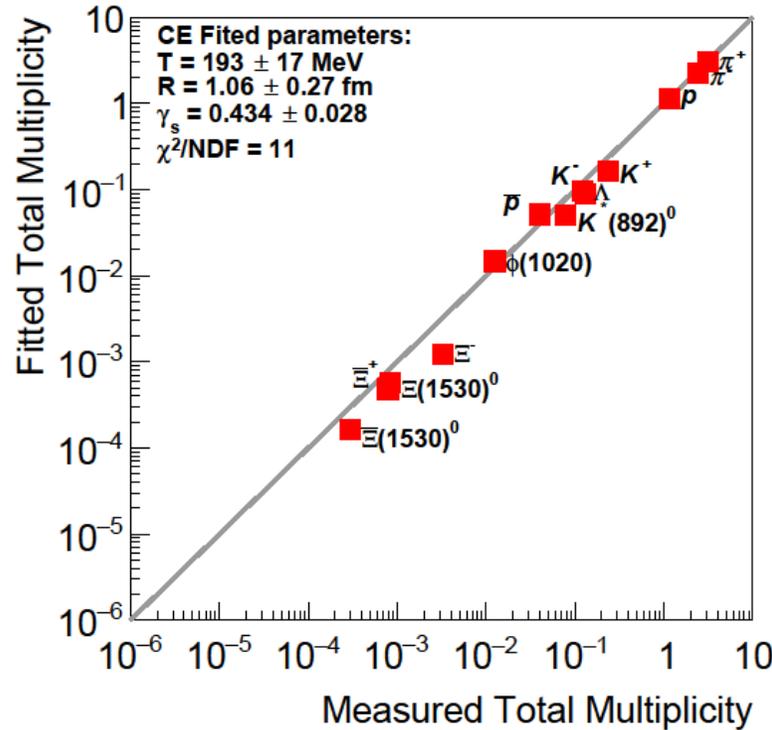
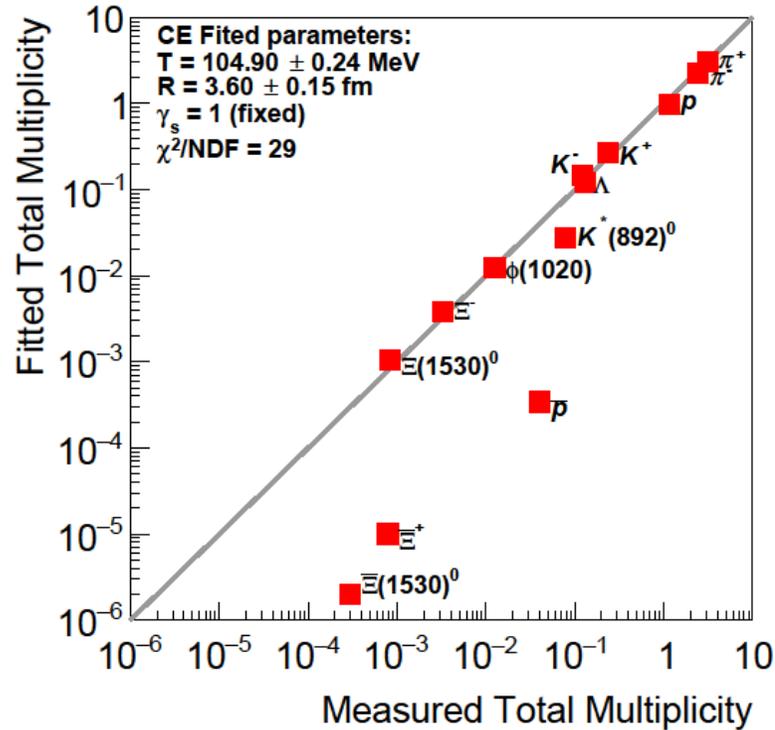
$\Xi(1530)^0$ production in inelastic $p+p$ collisions at 158 GeV/c



□ EPOS describes well transverse momentum and rapidity distributions of $\Xi(1530)^0$ and $\bar{\Xi}(1530)^0$

□ UrQMD significantly overestimates all spectra of $\Xi(1530)^0$ and $\bar{\Xi}(1530)^0$ hyperons

HRG model in the CE formulation and $p+p$ data



- Fit by different variants of the HRG model (THERMAL-FIST1.3 Comput.Phys.Commun.244(2019)295):
 - Canonical Ensemble with fixed $\gamma_s=1$
 - Canonical Ensemble with fitted strangeness saturation parameter γ_s

- Significant discrepancies of the fitted parameters
- The statistical model fails when fixed γ_s
- The fit with free γ_s finds $\gamma_s = 0.434 \pm 0.028$ and reproduces the measurements well - a suppression of strange particle production in $p+p$ collisions at CERN SPS energies

Summary

- ❑ **New and unique results on Ξ^- and $\bar{\Xi}^+$, $\Xi(1530)^0$ and $\bar{\Xi}(1530)^0$ production in $p+p$ interactions at 158 GeV/c**
- ❑ **Transport models do not describe the NA61/SHINE results on Ξ^- and $\bar{\Xi}^+$ production**
- ❑ **EPOS describes well transverse momentum and rapidity distributions of $\Xi(1530)^0$ and $\bar{\Xi}(1530)^0$. UrQMD significantly overestimates spectra of $\Xi(1530)^0$ and $\bar{\Xi}(1530)^0$ hyperons.**
- ❑ **No $\Xi^{--}(1860)$ pentaquark signal in $p+p$ at 158 GeV/c**
- ❑ **The Canonical Ensemble HRG fit with free γ_s finds $\gamma_s = 0.434 \pm 0.028$ and reproduces the measurements well**
- ❑ **Suppression of strange particle production in $p+p$ collisions at CERN SPS energies**



Thank you