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# Status report of E27 Pilot run analyses

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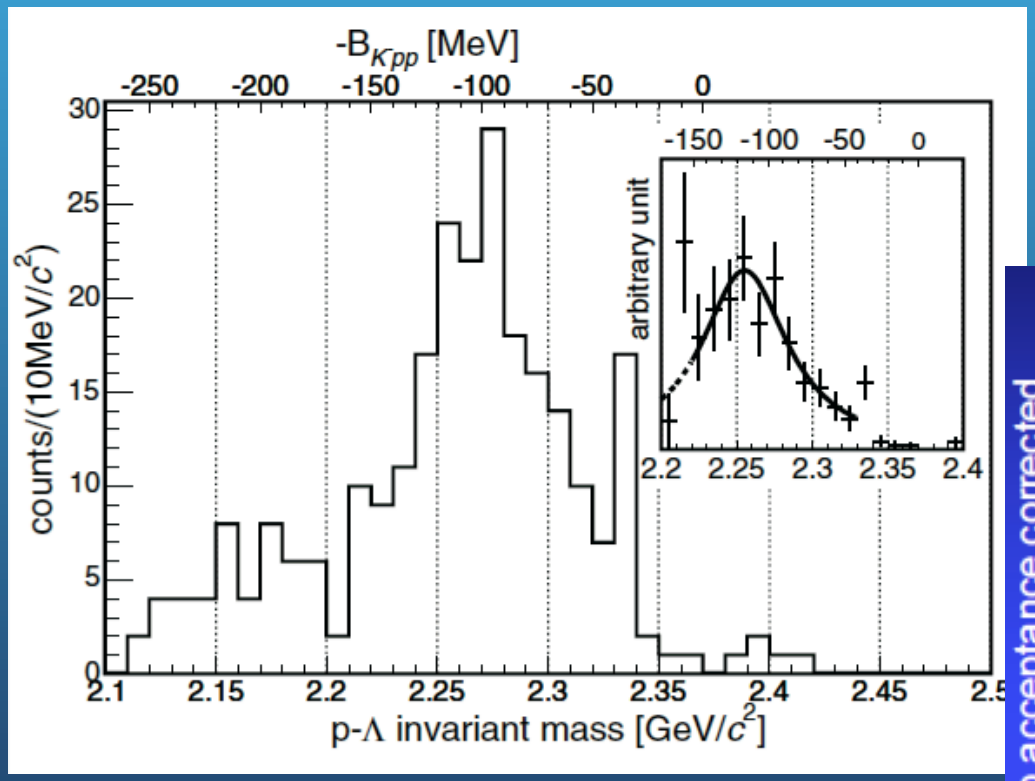
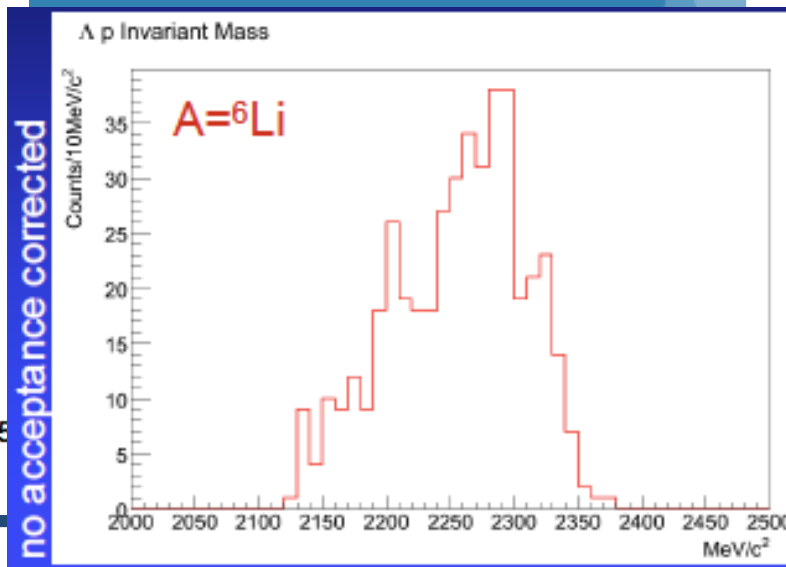
# $K^-pp$: experiments

- FINUDA; First evidence of $K^-pp$
  - Back-to-back Λ-p pairs in Stopped $K^-$ absorption on $^{6,7}Li+^{12}C$



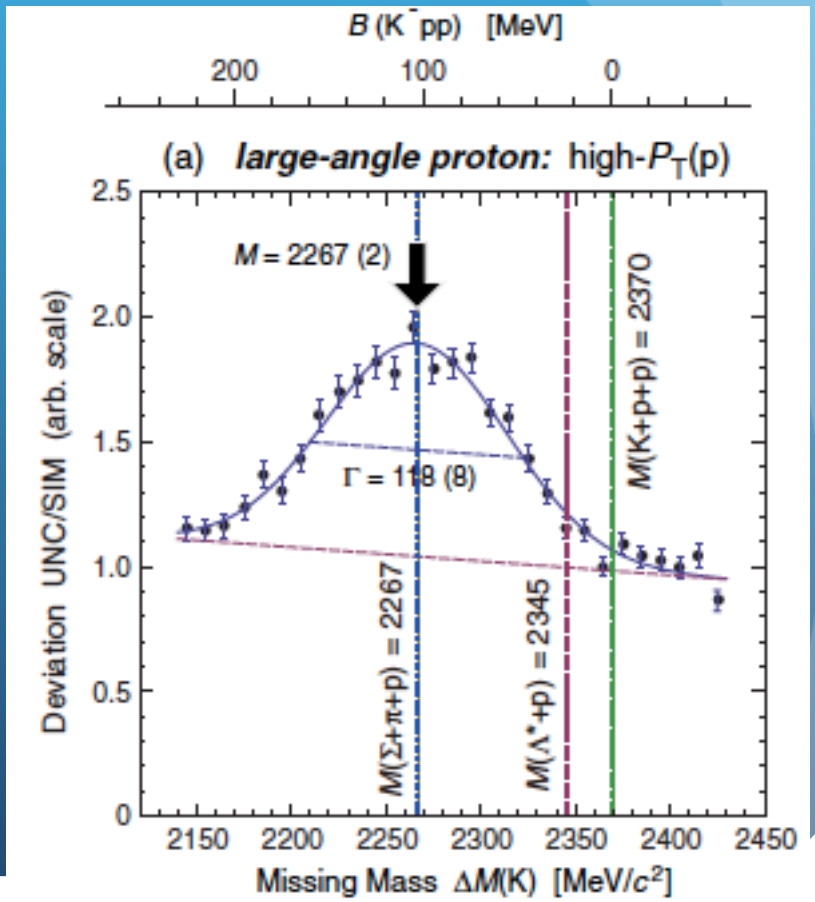

B=115+6/-5 MeV
Γ=67+14/-11 MeV

M. Agnello *et al.*,
PRL 94 (2005) 212303.



- DISTO
  - $pp \rightarrow K^{+}+X$ @ Tp=2.85 GeV
  - $X \rightarrow \Lambda p$
    - $M_x$=2267±3±5 MeV
      $\Gamma_x$=118±8±10 MeV

T. Yamazaki et al., PRL 104(2010) 132502.



# $K^-pp$: theoretical status

| Methods | Binding Energy (MeV) | Width (MeV) |
|---|---|---|
| Shevchenko, Gal, Mares<br>Faddeev | 50 - 70 | ~100 |
| Ikeda and Sato<br>Faddeev | 60 - 95 | 45 - 80 |
| Yamazaki and Akaishi<br>Variational (ATMS) | 48 | 61 |
| Dote, Hyodo, Weise<br>Variational (AMD) | 20±3 | 40 - 70 |

- *$K^-pp$ should exist as a bound state*.
  - Deep or Shallow ??
  - Width could be 40 – 100 MeV
- Λ(1405)-p bound state ? (Arai, Oka, and Yasui)

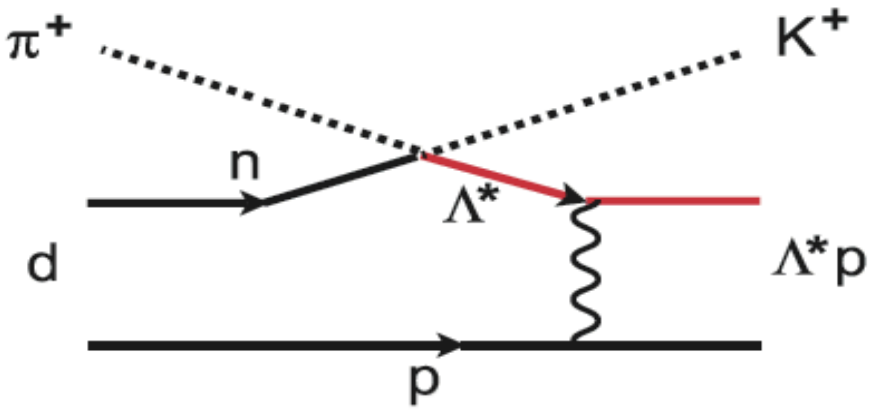
# $d(\pi^+,K^+)$ reaction

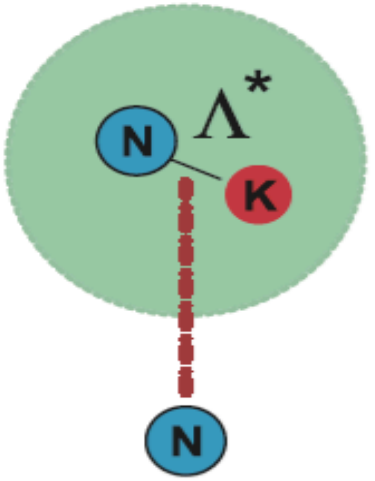
Yamazaki & Akaishi, Phys. Rev. C76 (2007) 045201.

$\pi^+$ + "n" --> "$\Lambda^*$" + $K^+$

"$\Lambda^*$" + "p" --> bound $K^-pp$ ***minor***

--> quasi-free $\Lambda^*$ ***dominant***

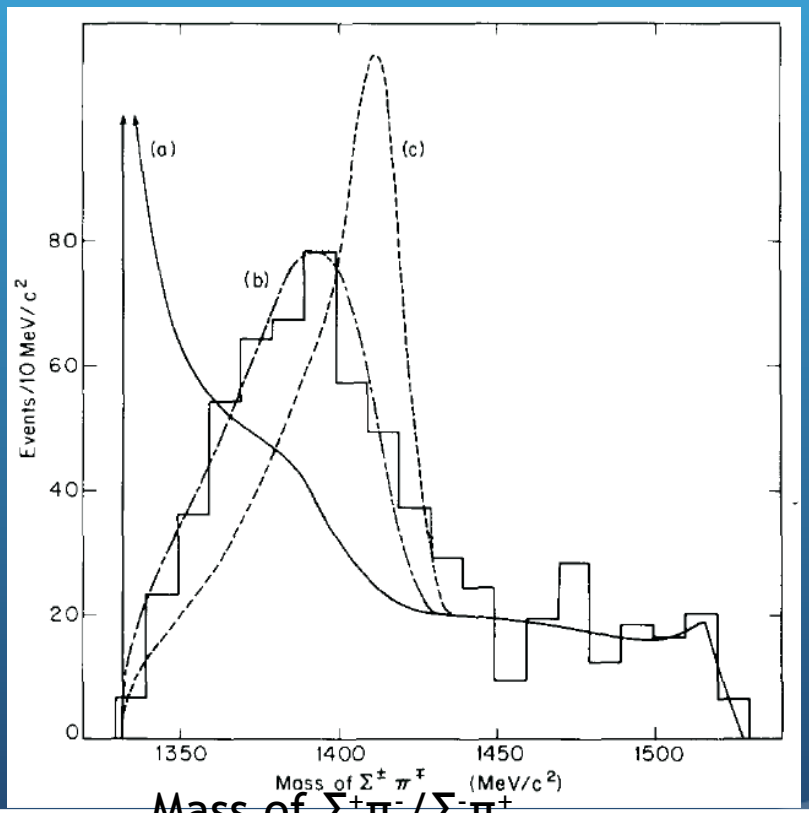


# Elementary process: $\pi^- p \rightarrow K^0 \Lambda(1405)$ at 1.59 GeV/c

- Production of Λ(1405); about 400 events clearly identified in theΣπ modes.

D.W. Thomas et al., Nucl. Phys. B 253 (1973) 15.

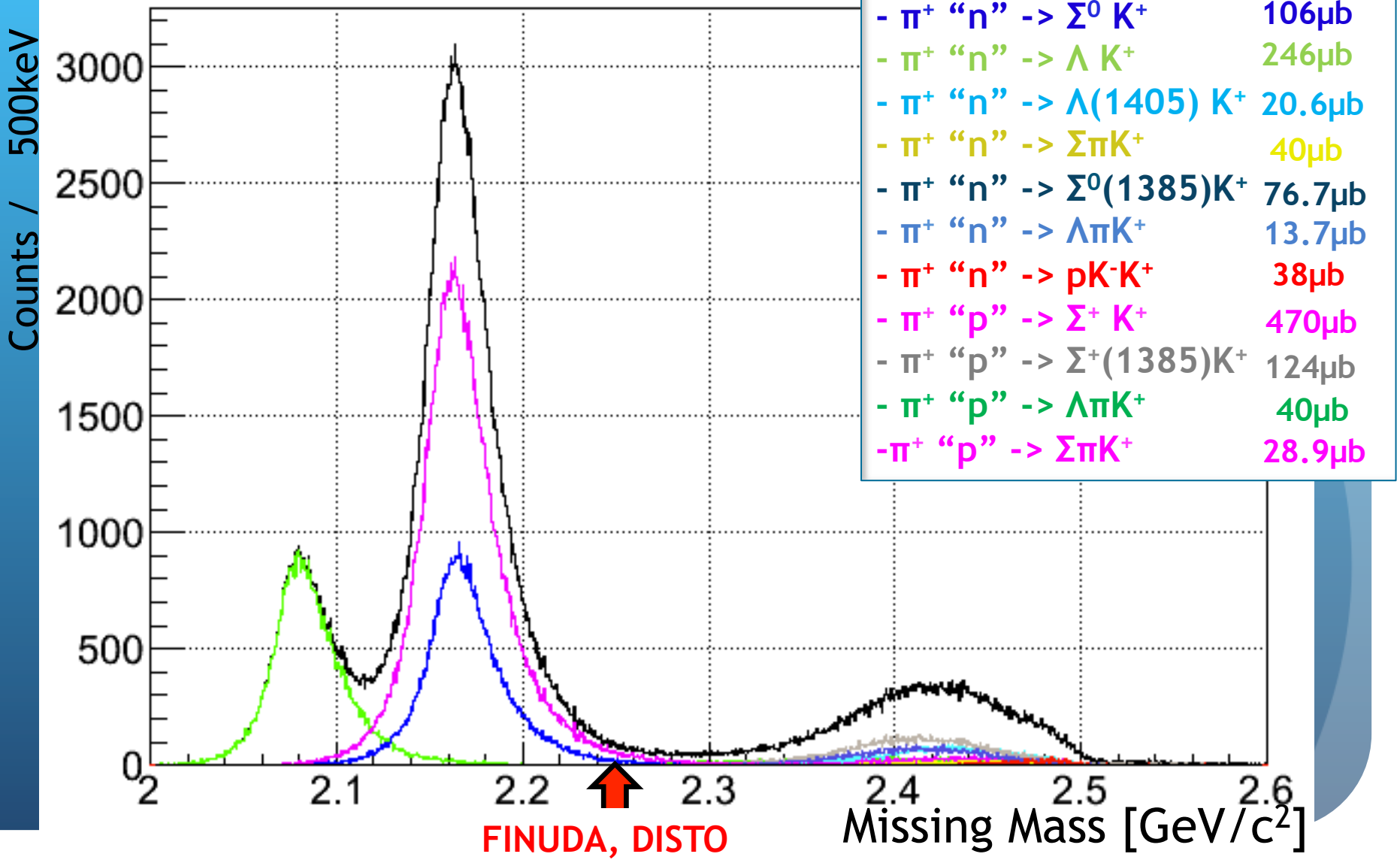



Mass of $\Sigma^+\pi^-/\Sigma^-\pi^+$

46% Λ(1405)
43% KπΣ
11% Σ(1385), Λ(1520)

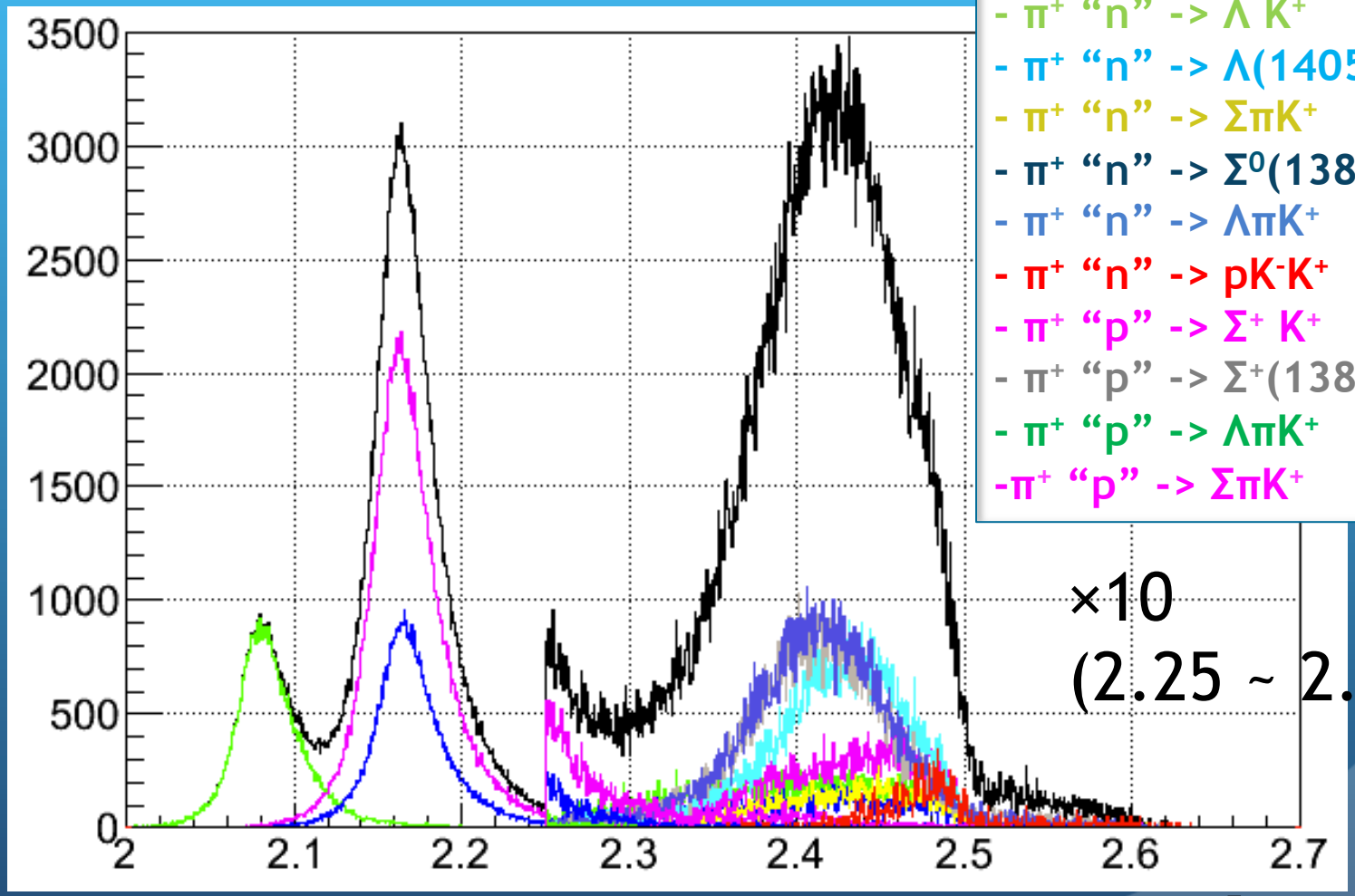
# Expected Inclusive spectrum

## Background of d（π⁺,K⁺）X @1.7GeV/c



# Expected Inclusive spectrum

**Background of d（$\pi^+$,$K^+$）X @1.7GeV/c**



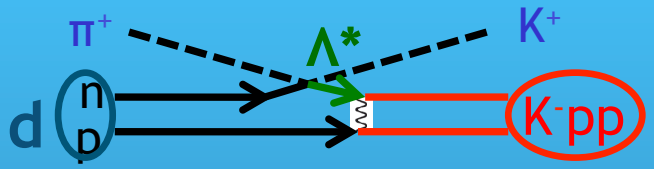

- $\pi^+$ “n” -> $\Sigma^0$ $K^+$ 106μb
- $\pi^+$ “n” -> $\Lambda$ $K^+$ 246μb
- $\pi^+$ “n” -> $\Lambda(1405)$ $K^+$ 20.6μb
- $\pi^+$ “n” -> $\Sigma\pi K^+$ 40μb
- $\pi^+$ “n” -> $\Sigma^0(1385)K^+$ 76.7μb
- $\pi^+$ “n” -> $\Lambda\pi K^+$ 13.7μb
- $\pi^+$ “n” -> $pK^-K^+$ 38μb
- $\pi^+$ “p” -> $\Sigma^+$ $K^+$ 470μb
- $\pi^+$ “p” -> $\Sigma^+(1385)K^+$ 124μb
- $\pi^+$ “p” -> $\Lambda\pi K^+$ 40μb
- $\pi^+$ “p” -> $\Sigma\pi K^+$ 28.9μb

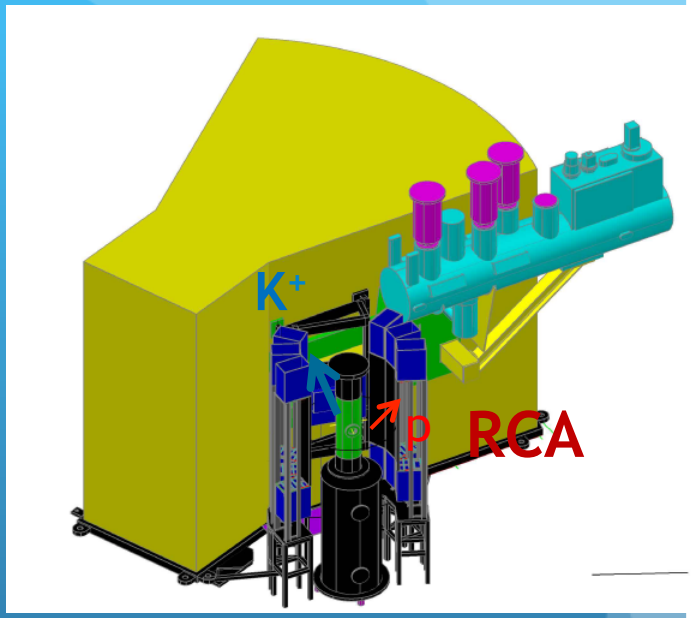
×10

(2.25 ~ 2.7GeV/$c^2$)

# E27: Search for "K⁻pp" bound state in the d(π⁺,K⁺)X reaction

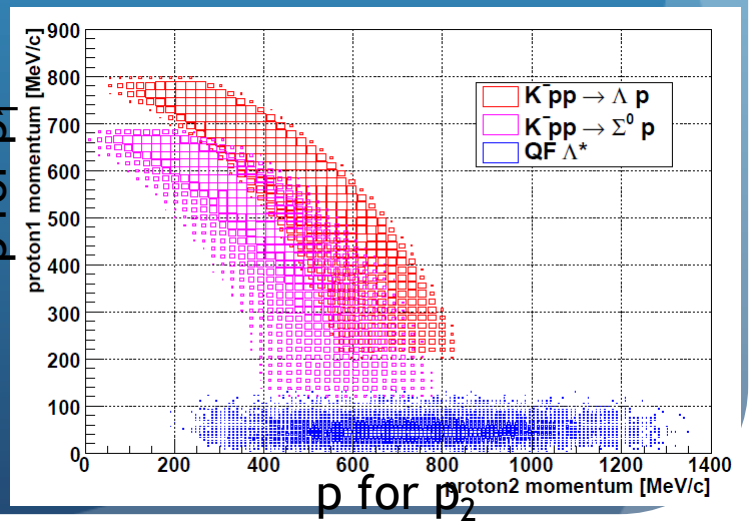
- "K⁻pp" is produced through Λ* doorway in the d(π⁺,K⁺) reaction




- Semi-exclusive measurement by Range Counter Array (RCA) in order to suppress quasi-free B.G.
  - $K^-pp \rightarrow \Lambda\, p_1,\ \Lambda \rightarrow p_2\, \pi^-$
  - $K^-pp \rightarrow \Sigma^0\, p_1,\ \Sigma^0 \rightarrow (\Lambda\gamma) \rightarrow p_2\, \pi^-\, \gamma$
  - $\pi^+d \rightarrow \Lambda^*\, K^+\, p_{1s},\ \Lambda^* \rightarrow \Sigma\, \pi,\ \Sigma^+ \rightarrow p_2\, \pi^0$
- Original Proposal: 5M/spill beam
  - $6\times10^4$ Λ* /day

  Assuming 1% trapping probability
  - 600 bound states/day ( inclusive )
  - ~300 events/40 days (exclusive) with $\varepsilon_{RCA}$ ~14% for two protons



# E27: The first step Goal

3M $\pi^+$/spill

- Inclusive d($\pi^+$,$K^+$)X spectrum @2.2 < Mx <2.5GeV/$c^2$.
  - The first measurement of this reaction and this missing mass region.
    →To evaluate the maximum value of the cross section, and to understand the background shapes.
  - p($\pi^+$,$K^+$)X for 1 day

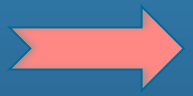
    →contribution of “p” in “d”

- Check the feasibility of coincidence measurement
  - One proton tag/Two proton tag

# Beam Requested for June Run

- Beam Commissioning (28h)
- Range Counter Calib.(4h,p)、Trigger study (4h)
- $\Sigma^+$ Calib. (8h,p)、Empty run (4h)

2 days 2 days

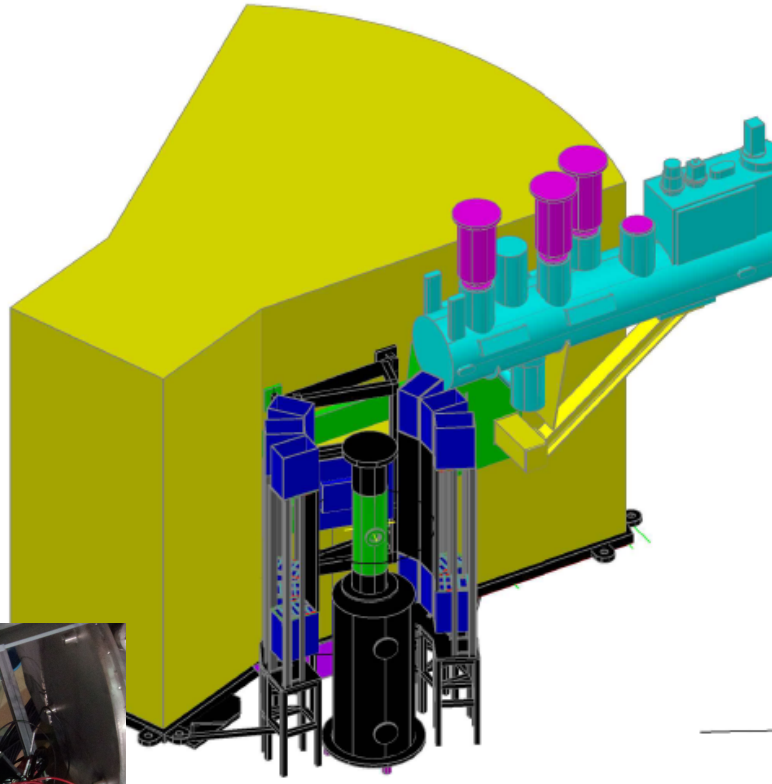
- $p(\pi^+,K^+)$ 0.5 days 0.6 days
- $d(\pi^+,K^+)$  10 days 7.6 days

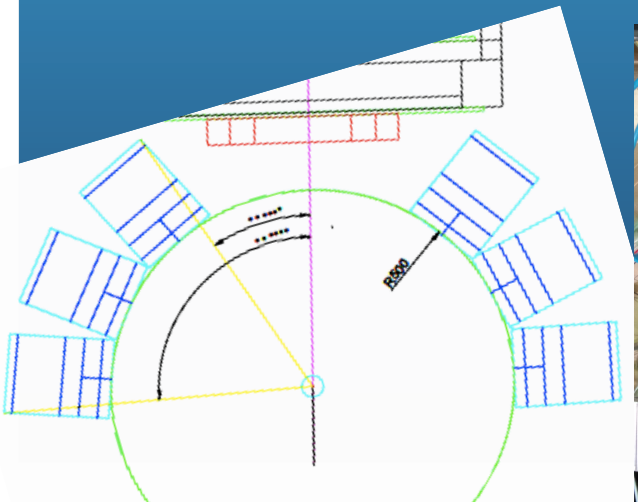
Preliminary Analysis Results are presented.

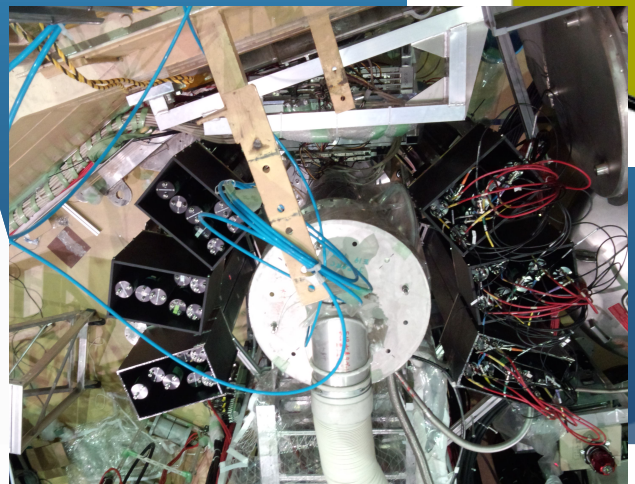
# Range Counter System for E27

- 5 layers (1+2+2+5+2cm)

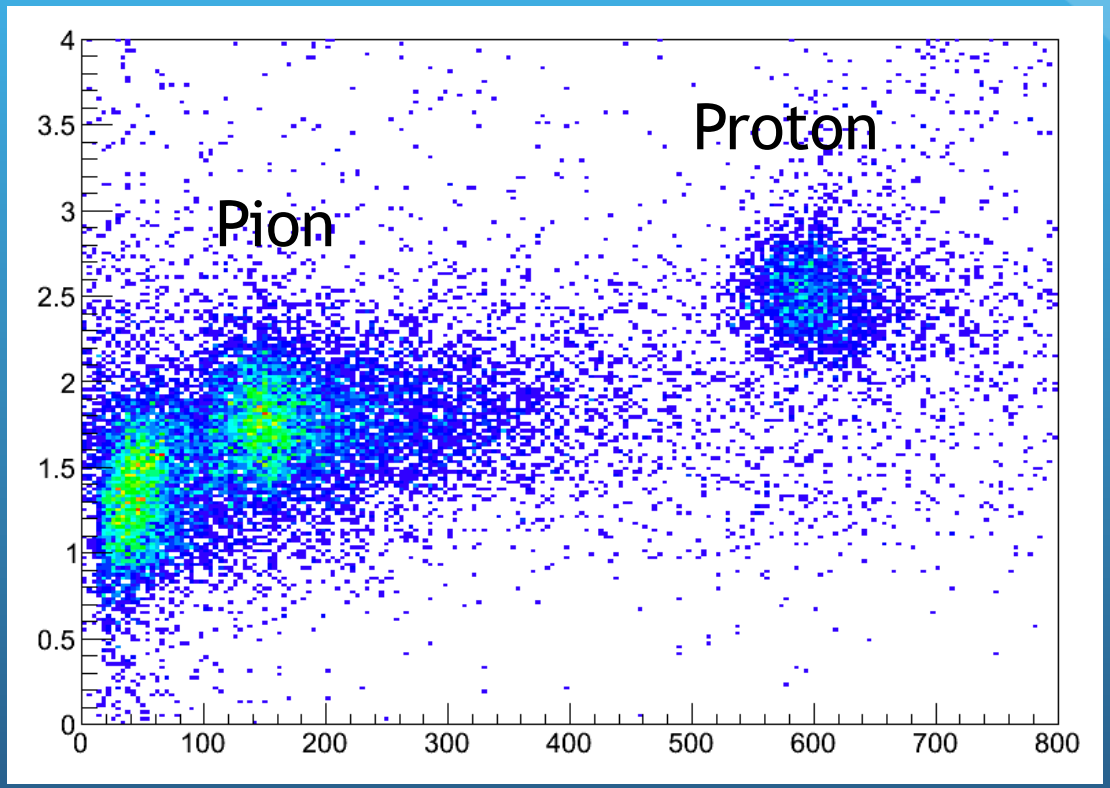
  of plastic scinti.
- 39 – 122 degrees (L+R)
- 50 cm TOF





# Particle Identification in Range Counter

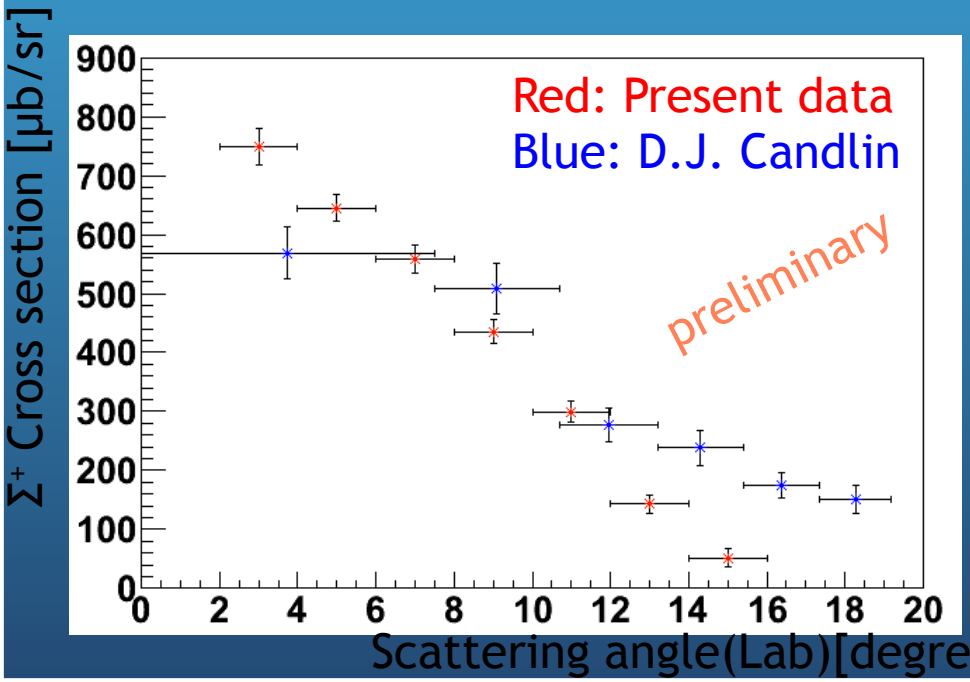


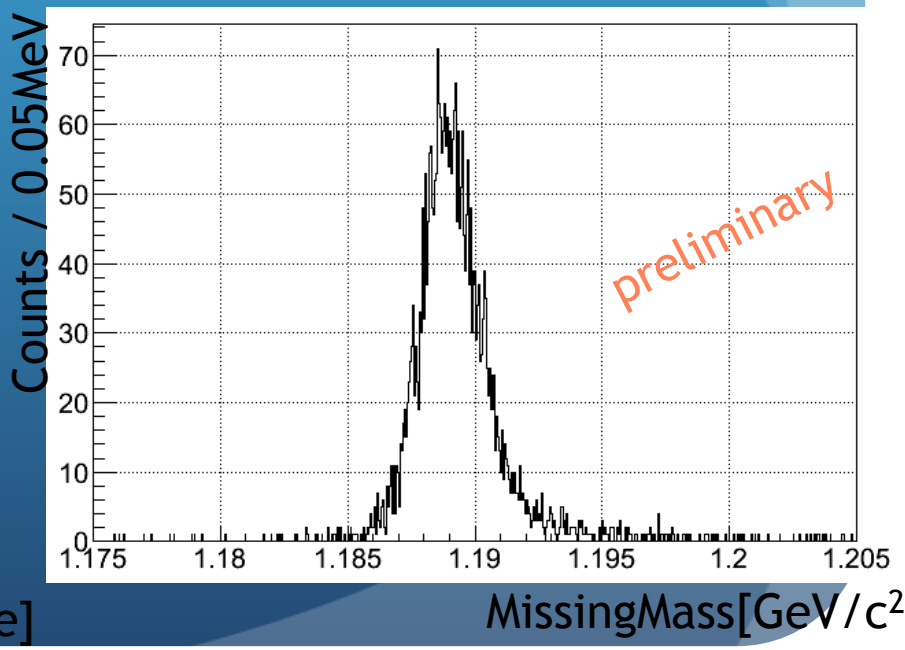
# Spectrometer performance

- $p(\pi^+,K^+)\Sigma^+$ @1.58 GeV/c [$LH_2$Target]

~ Energy Calibration & Cross section normalization ~

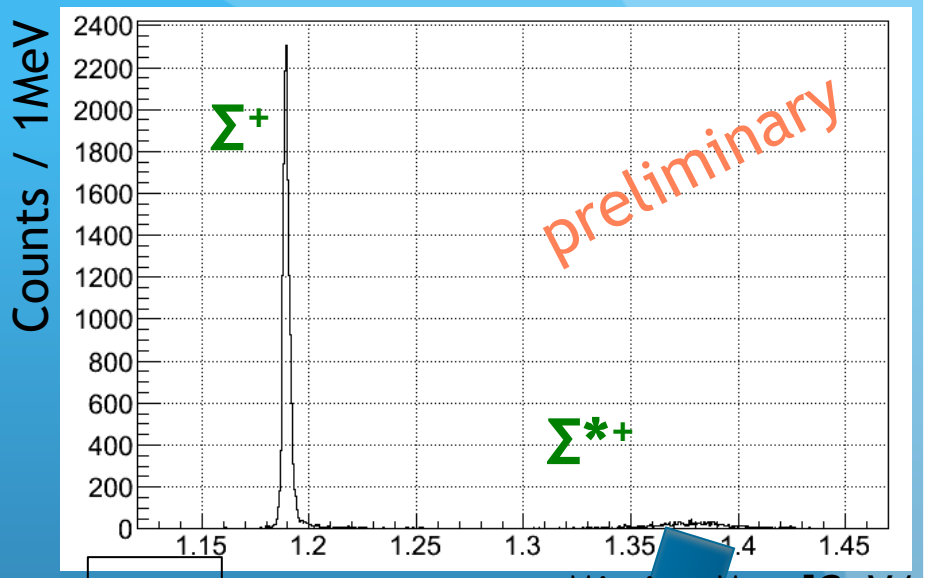
- Resolution ; ΔM ~ 2.41MeV(FWHM)
- Mean ; 1188.98 ± 0.03 MeV (PDG = 1189.37MeV)



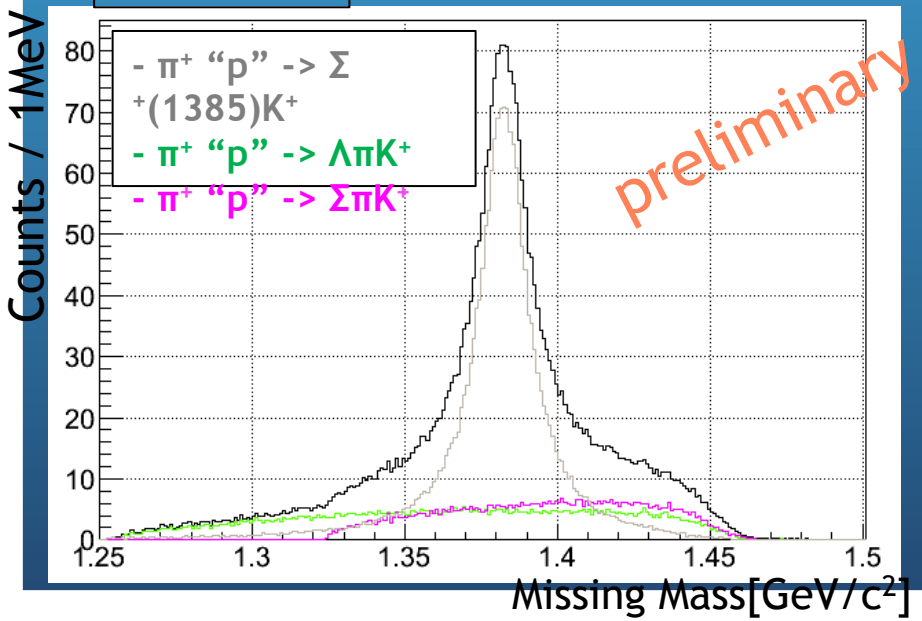



# p(π⁺,K⁺)1.7GeV/c

- $\Sigma^+$ production
  - $\Delta M$ = 3.2MeV(FWHM)
  - Mass = 1188.92MeV
- $\Sigma^+(1385)$ production
- $Y\pi$ production




**Simulation**

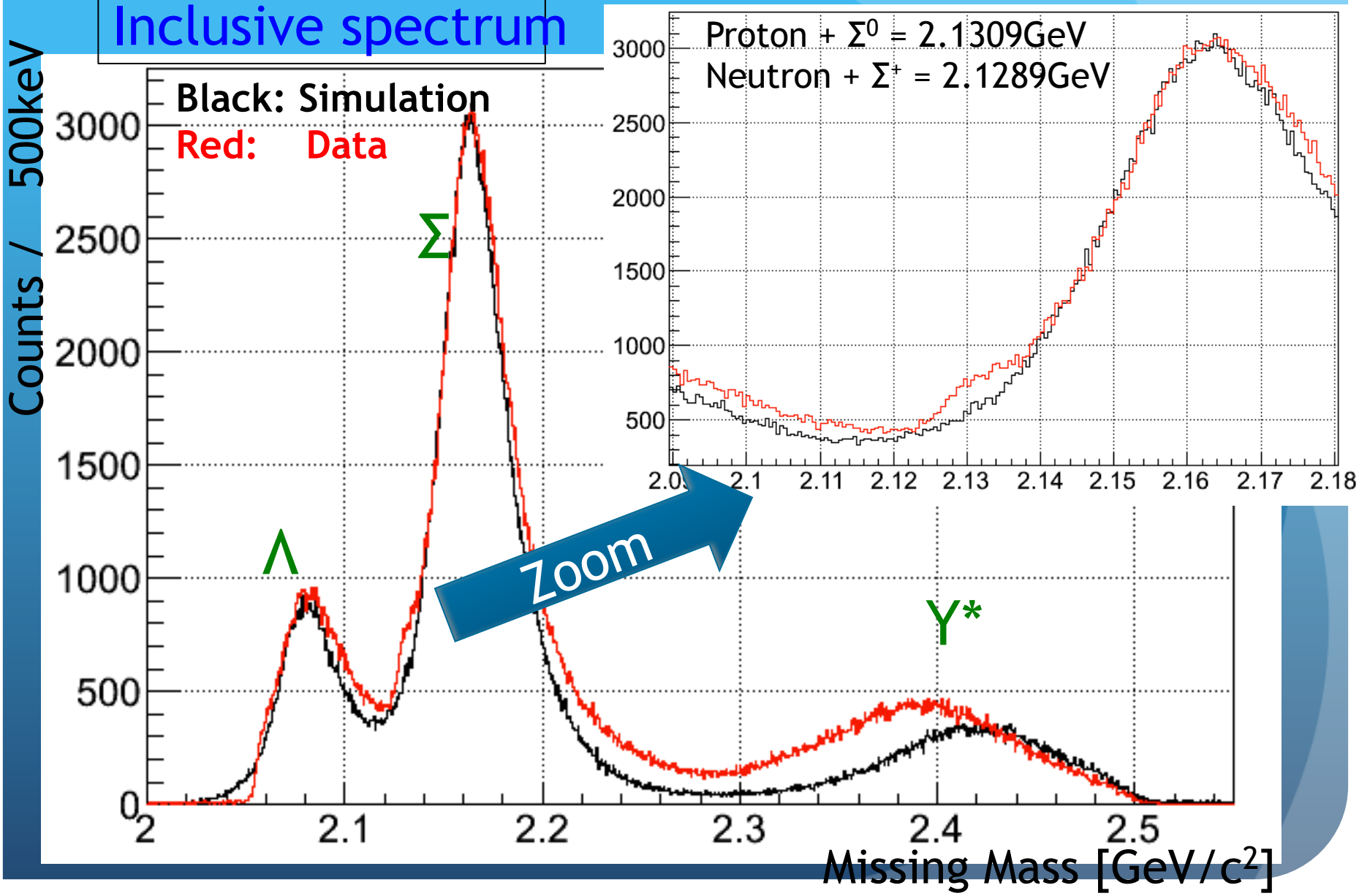



**Data**

Zoom

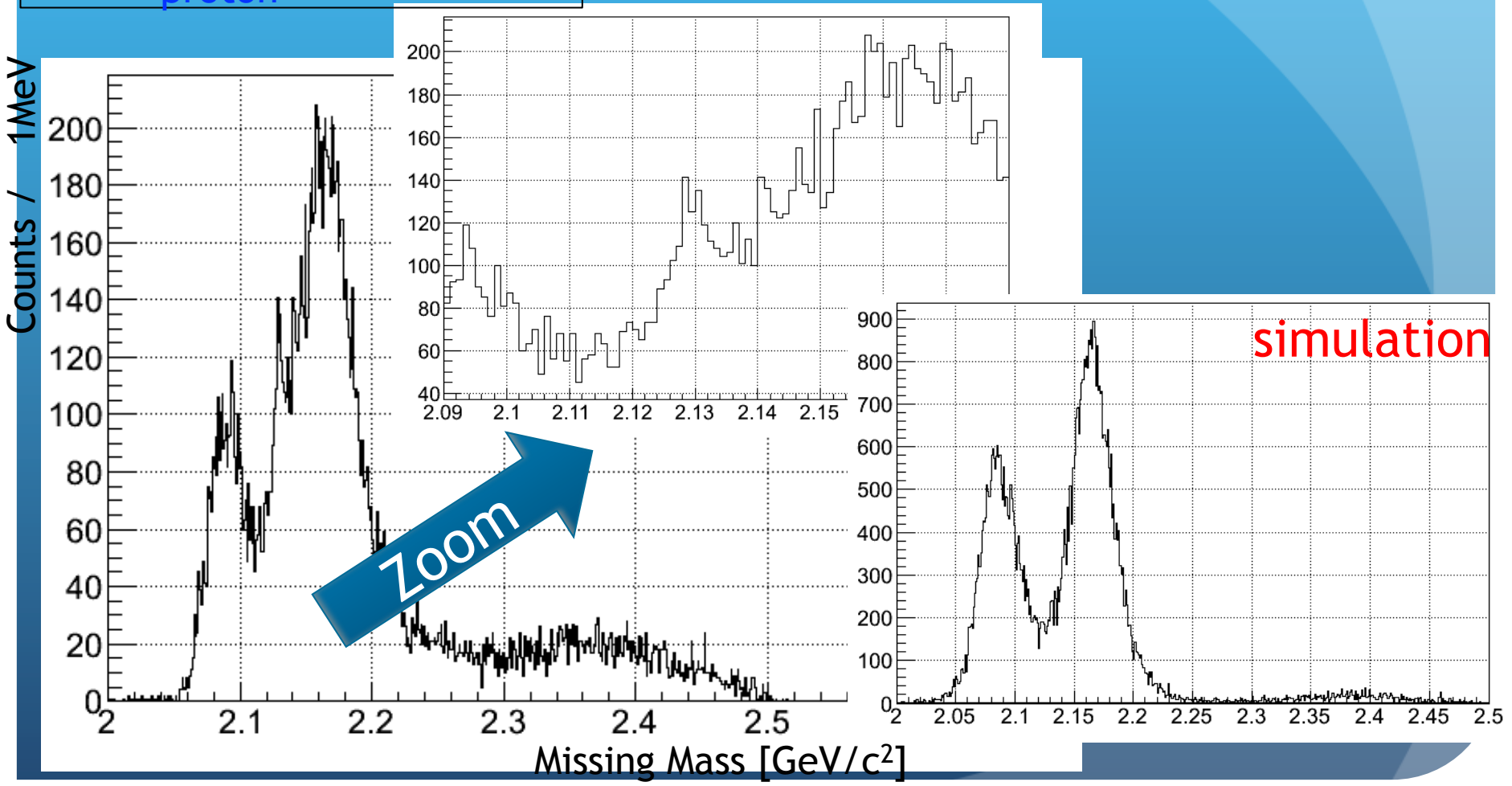
# $d(\pi^+, K^+)1.7GeV/c$

## Inclusive spectrum



# d(π⁺, K⁺)1.7GeV/c
# - 1-proton tagged spectrum -

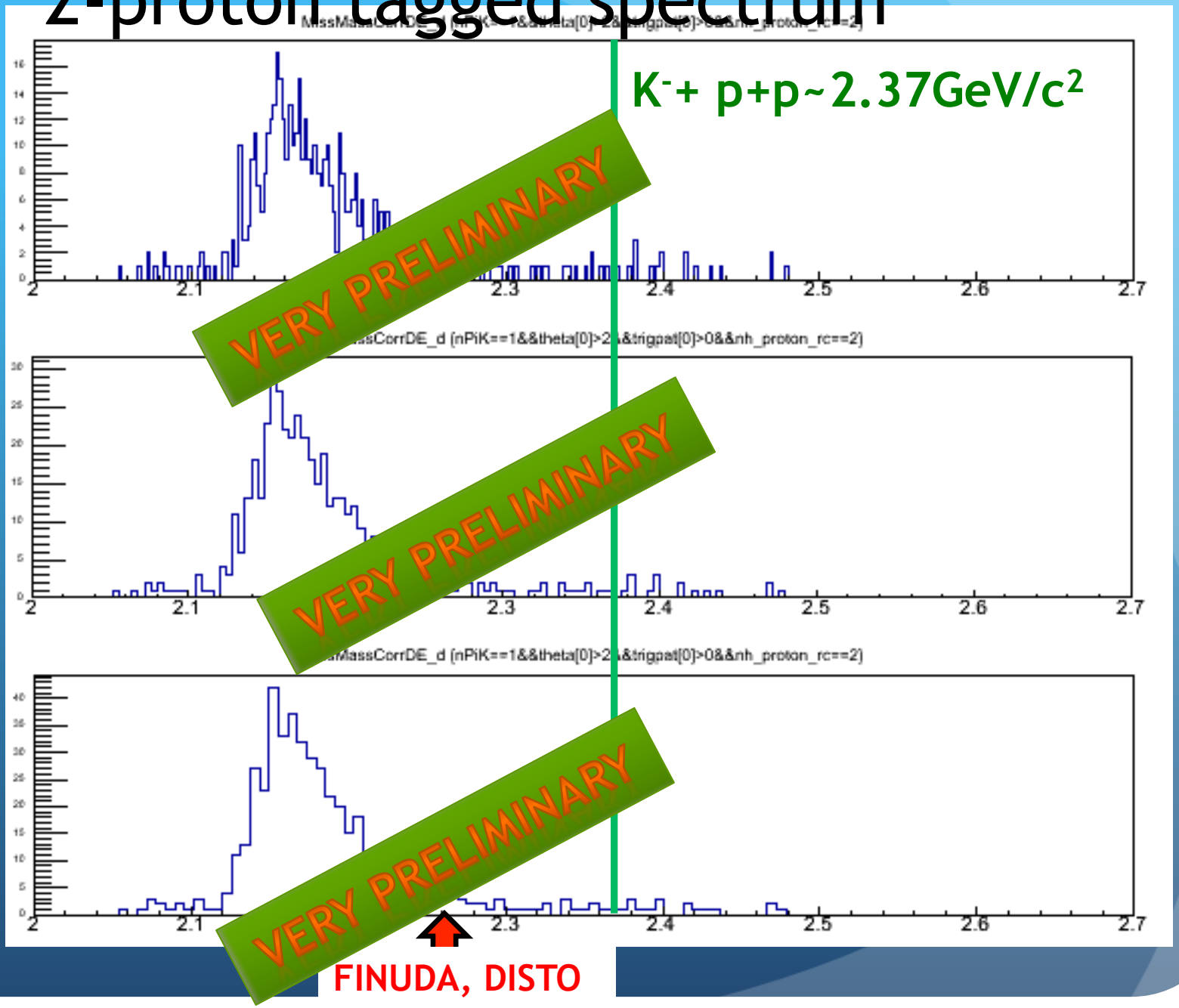
$Mom_{proton}$ > 0.3GeV/c



# $d(\pi^+, K^+)1.7GeV/c$
# - 1-proton tagged spectrum -

Y* Region
Left ; 1bin = 1MeV,  Right; 1bin =  2MeV

# 2-proton tagged spectrum



- In the original proposal:
  - 5 M $\pi^+$/spill, 40 days → 300 events with two-proton tagged
- In the Pilot run:
  - 3 M $\pi^+$/spill, 7.6 days → ~40 events (expected)
  - ~20 events observed !!
- Assumptions:
  - $\Lambda^*$ sticking probability: 1%
  - K-pp non-mesonic decay branch: 20%

# Summary

- E27 Pilot run; successful data taking
  - $d(\pi^+,K^+)$ @ 1.7 GeV/c
  - $p(\pi^+,K^+)$ @ 1.7 GeV/c
  - $p(\pi^+,K^+)\Sigma^+$ @ 1.58 GeV/c for calibration

- Inclusive spectra are roughly understandable except in the region of $2.2 < M.M. < 2.4$ GeV/$c^2$
  - Need detail study.
- Coincidence Analysis:
  - Enhancements in both one-proton and two-proton tagged spectra in the signal region.
  - Need further studies on tagging efficiencies

# Conference Presentations on E27

- The 20th Few-Body Conference in Fukuoka, Japan: 20-25 August
  - An invited talk, one oral presentation

- The 11th HYP Conference in Barcelona, Spain; 1-5 October
  - An invited talk, two posters