Hyperon Spectroscopy at J-PARC

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NP08 Workshop Mar 5-7, 2008, Mito

$\Lambda(1405)$

$\Sigma(1480)$

Ξ Resonances

Exotics

The Nature of Λ(1405)

Λ(1405) S_{01} $\quad I(J^P) = 0(\frac{1}{2}^-)$

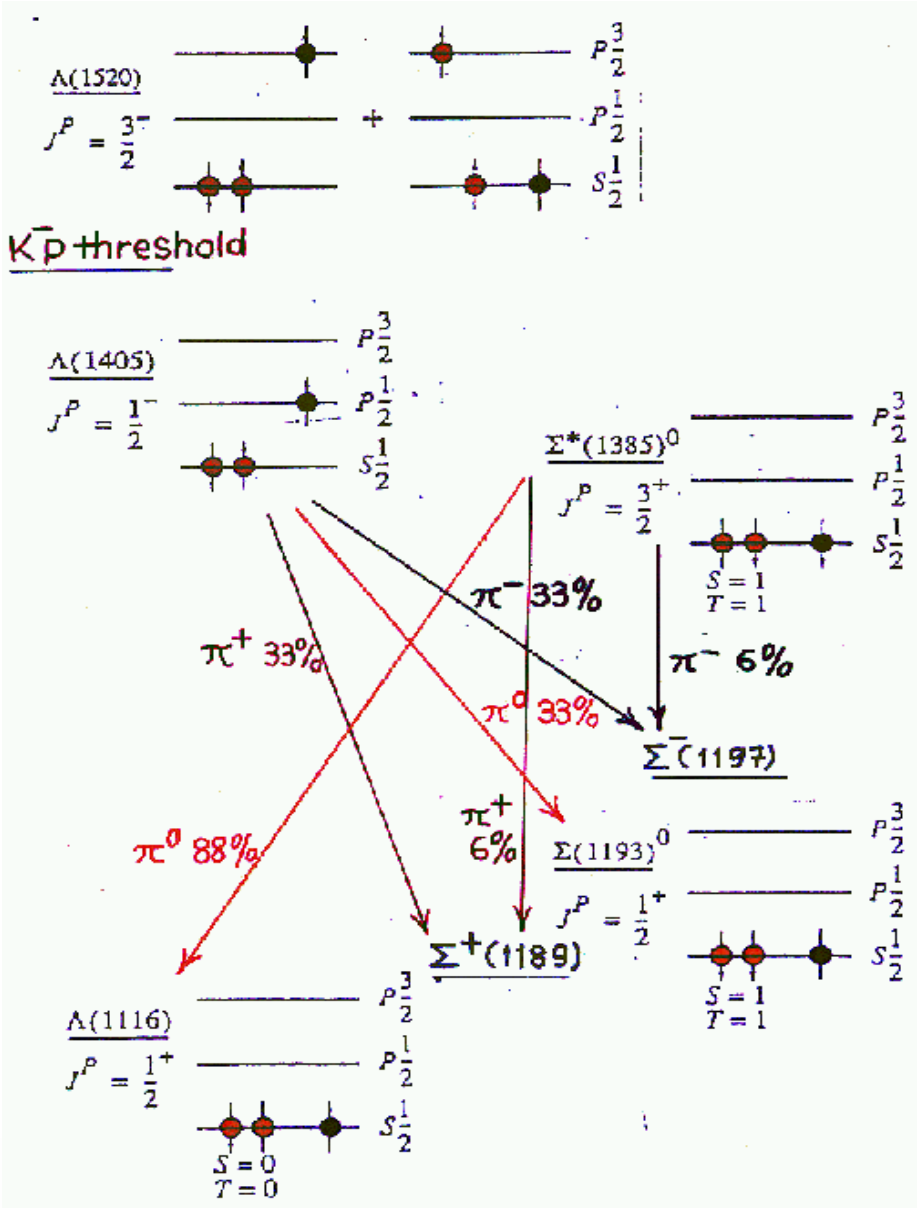
Mass $m = 1406 \pm 4$ MeV
Full width $\Gamma = 50.0 \pm 2.0$ MeV
Below $\overline{K}N$ threshold

Λ(1405) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Sigma\pi$	100 %	152

Σ(1385) P_{13} $\quad I(J^P) = 1(\frac{3}{2}^+)$

$\Sigma(1385)^+$ mass $m = 1382.8 \pm 0.4$ MeV (S = 2.0)
$\Sigma(1385)^0$ mass $m = 1383.7 \pm 1.0$ MeV (S = 1.4)
$\Sigma(1385)^-$ mass $m = 1387.2 \pm 0.5$ MeV (S = 2.2)
$\Sigma(1385)^+$ full width $\Gamma = 35.8 \pm 0.8$ MeV
$\Sigma(1385)^0$ full width $\Gamma = 36 \pm 5$ MeV
$\Sigma(1385)^-$ full width $\Gamma = 39.4 \pm 2.1$ MeV (S = 1.7)
Below $\overline{K}N$ threshold

Σ(1385) DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$\Lambda\pi$	88±2 %	208
$\Sigma\pi$	12±2 %	127

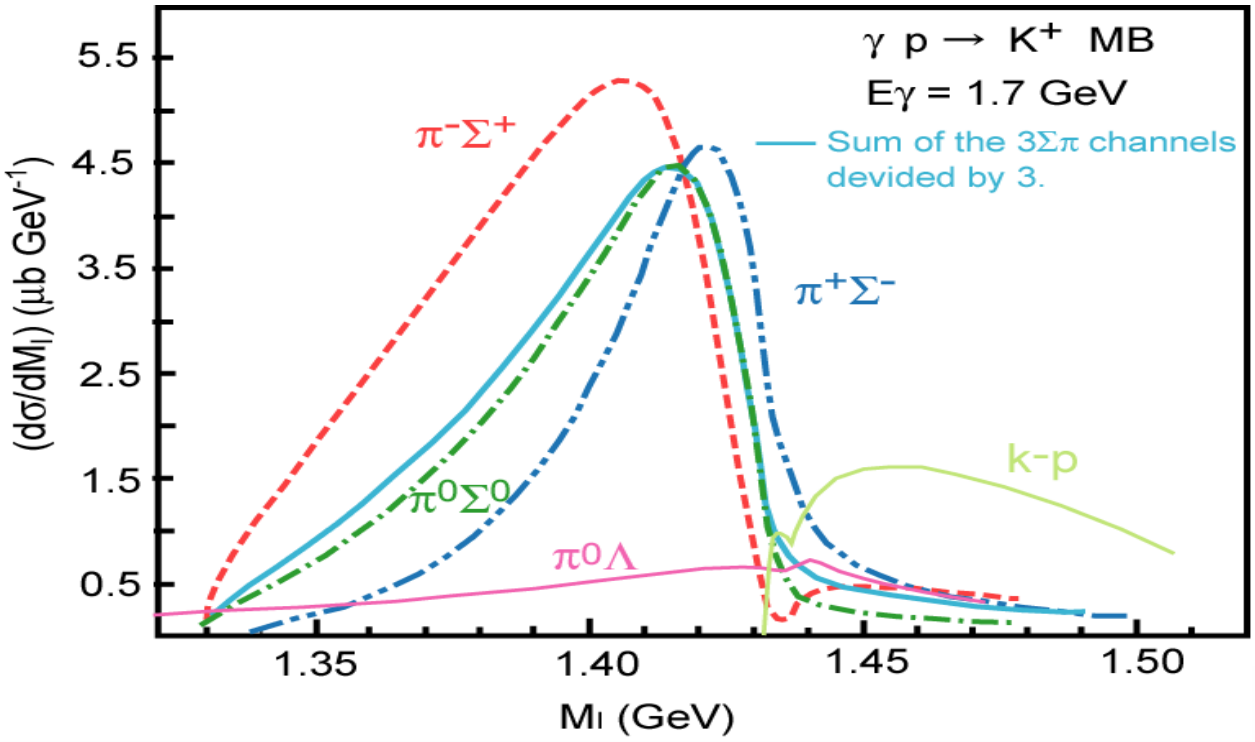


$\pi^0\Lambda$ $\pi^0\Sigma^0$ $\pi^-\Sigma^+$ $\pi^+\Sigma^-$ K^-p $\bar{K}^0p$ $\eta\Lambda$ $\pi^0\Sigma^0$ $K^0\Xi^0$ $K^-\Xi^+$

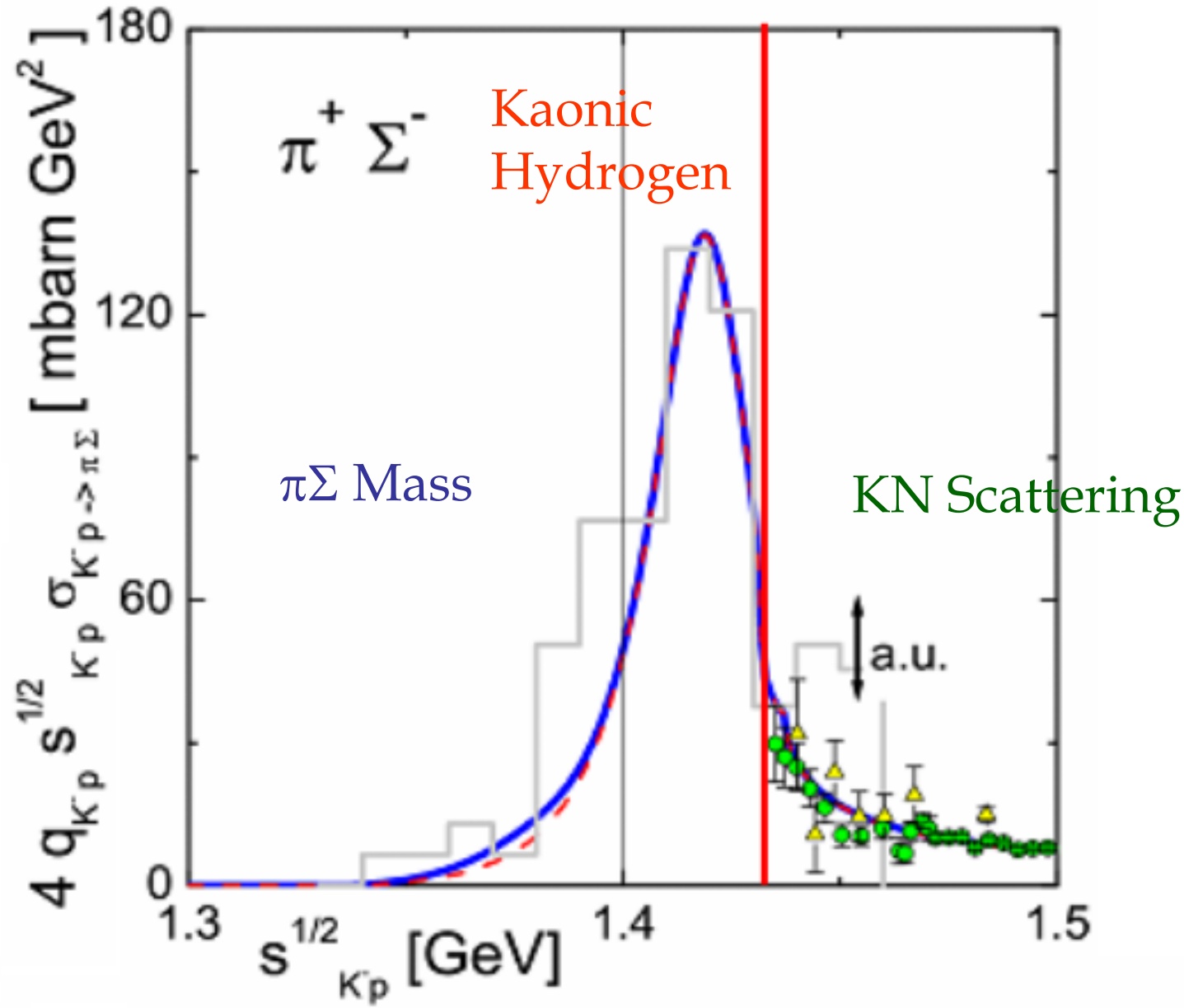
$$\frac{1}{2}|T^{(1)}|^2 + \frac{1}{3}|T^{(0)}|^2 + \frac{2}{\sqrt{6}}Re(T^{(0)}T^{(1)*}); \quad \pi^+\Sigma^-$$

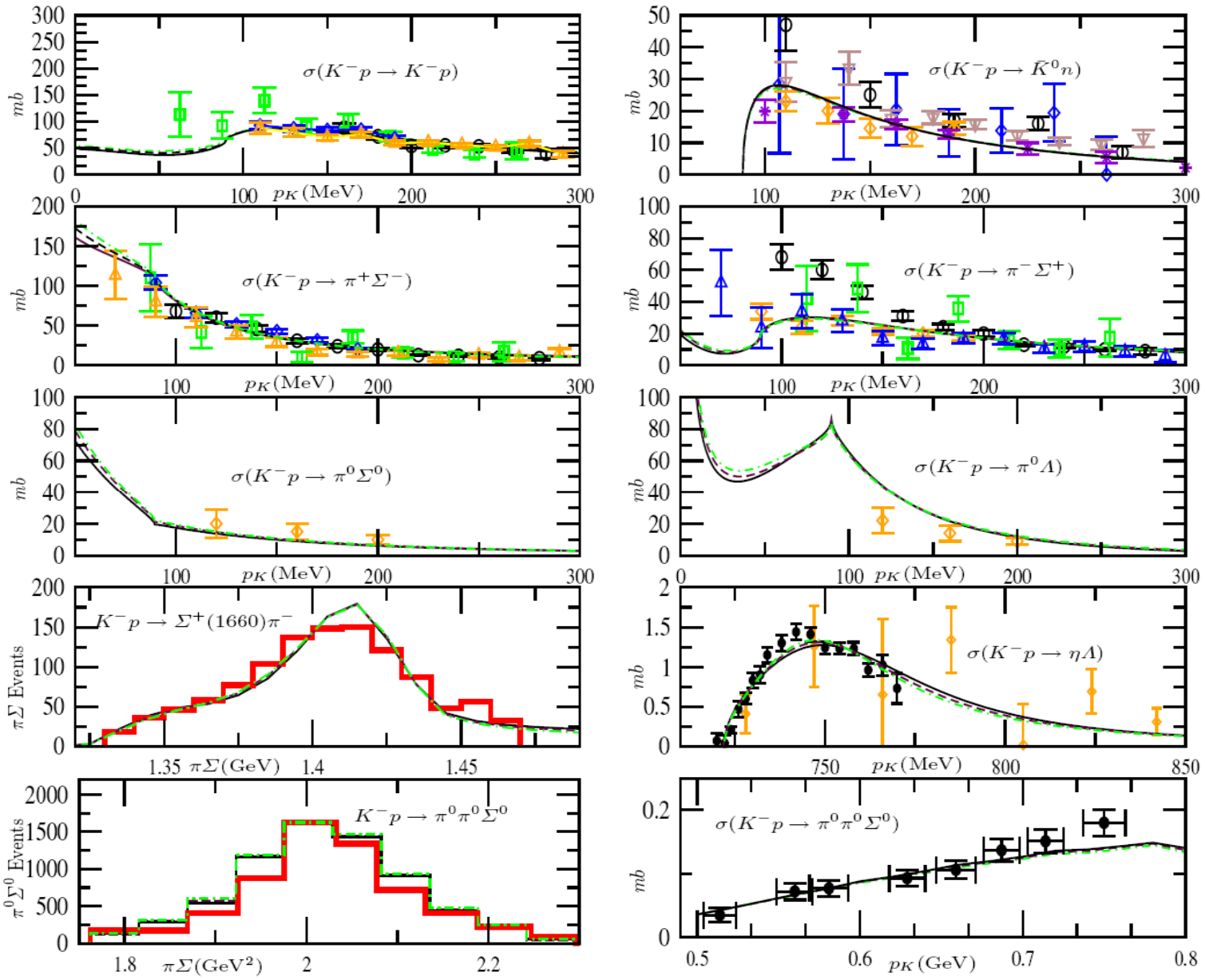
$$\frac{1}{2}|T^{(1)}|^2 + \frac{1}{3}|T^{(0)}|^2 - \frac{2}{\sqrt{6}}Re(T^{(0)}T^{(1)*}); \quad \pi^-\Sigma^+$$

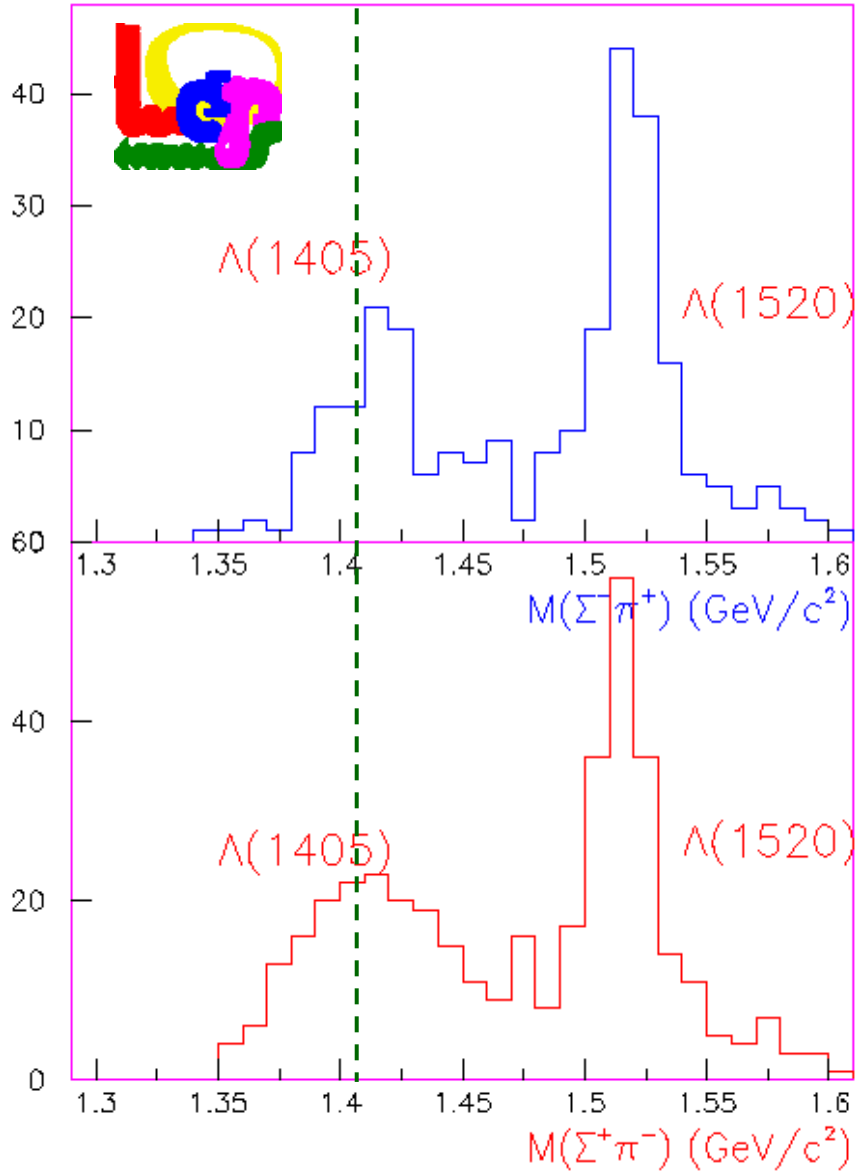
$$\frac{1}{3}|T^{(0)}|^2; \quad \pi^0\Sigma^0$$

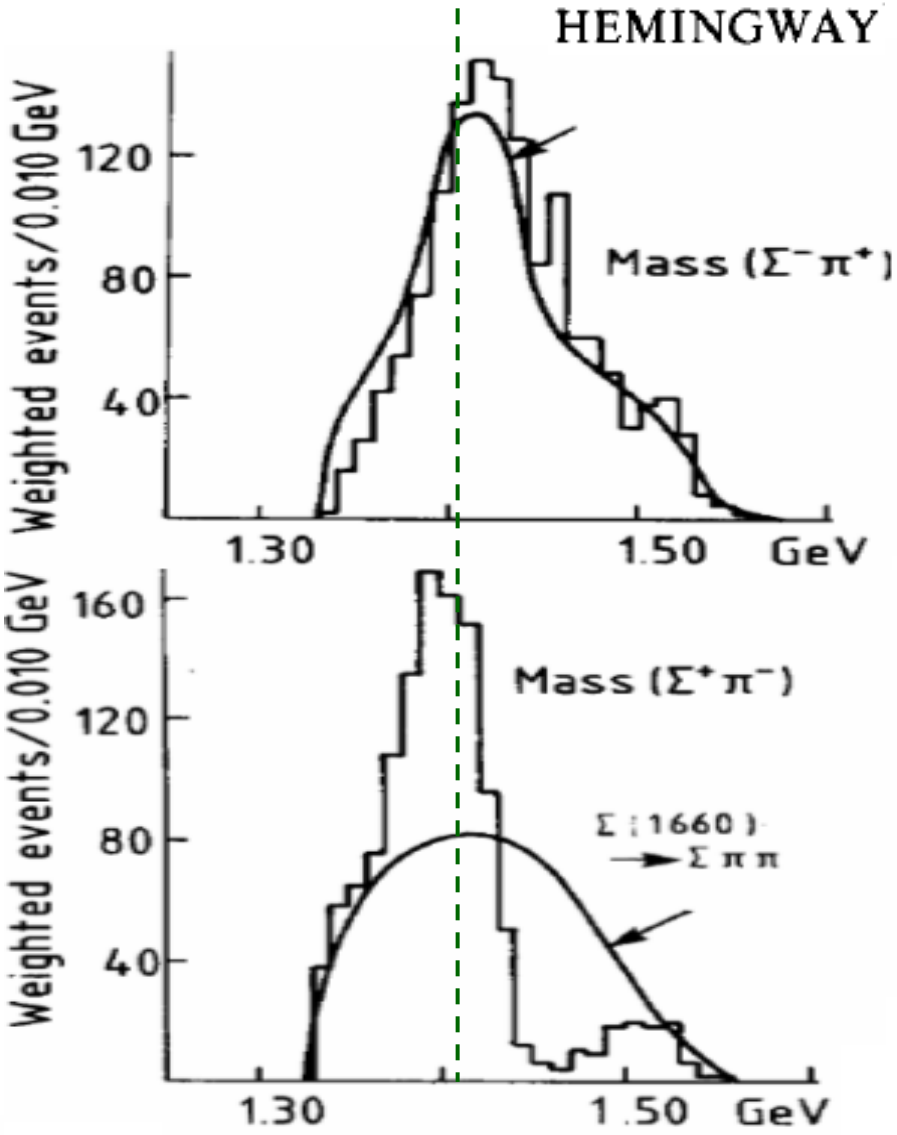


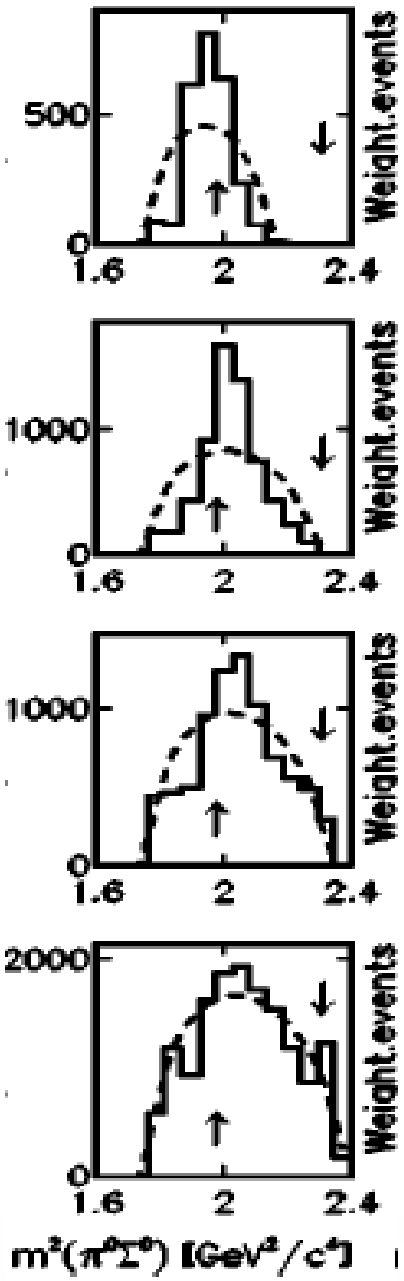
E. Oset et al.,
PLB455 55(1999)


$\pi^+ \Sigma^-$
Kaonic Hydrogen
πΣ Mass
KN Scattering
a.u.
$4\, q_{K^-p}\, s^{1/2}_{K^-p}\, \sigma_{K^-p \to \pi\Sigma}$ [mbarn GeV^2]
$s^{1/2}_{K^-p}$ [GeV]
180
120
60
0
1.3
1.4
1.5


$\sigma(K^-p \to K^-p)$
$\sigma(K^-p \to \bar{K}^0 n)$
$\sigma(K^-p \to \pi^+\Sigma^-)$
$\sigma(K^-p \to \pi^-\Sigma^+)$
$\sigma(K^-p \to \pi^0\Sigma^0)$
$\sigma(K^-p \to \pi^0\Lambda)$
$K^-p \to \Sigma^+(1660)\pi^-$
$\sigma(K^-p \to \eta\Lambda)$
$K^-p \to \pi^0\pi^0\Sigma^0$
$\sigma(K^-p \to \pi^0\pi^0\Sigma^0)$
mb
p_K(MeV)
$\pi\Sigma$ Events
$\pi\Sigma$(GeV)
$\pi^0\Sigma^0$ Events
$\pi\Sigma$(GeV^2)
p_K(GeV)


Λ(1405)
Λ(1520)
M(Σ⁻π⁺) (GeV/c²)
Λ(1405)
Λ(1520)
M(Σ⁺π⁻) (GeV/c²)


HEMINGWAY
Weighted events/0.010 GeV
Mass (Σ⁻π⁺)
1.30
1.50
GeV
Weighted events/0.010 GeV
Mass (Σ⁺π⁻)
Σ(1660)
→ Σππ
1.30
1.50
GeV



$K^- p \rightarrow \pi^0\pi^0\Sigma^0$

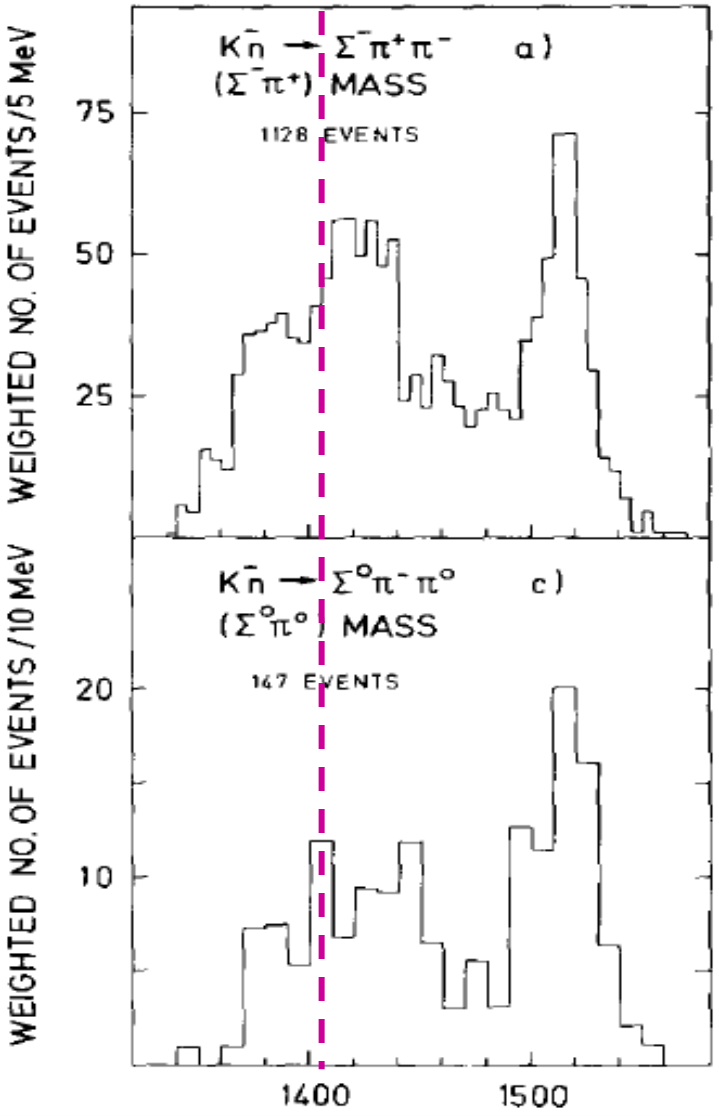
Crystal Ball collaboration

S. Prakhov et al.,

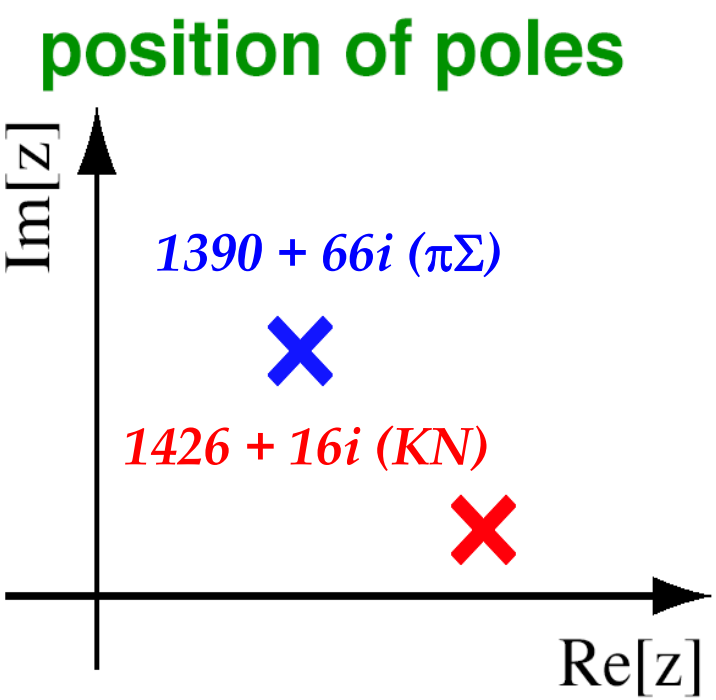
PRC 70(2004) 034605

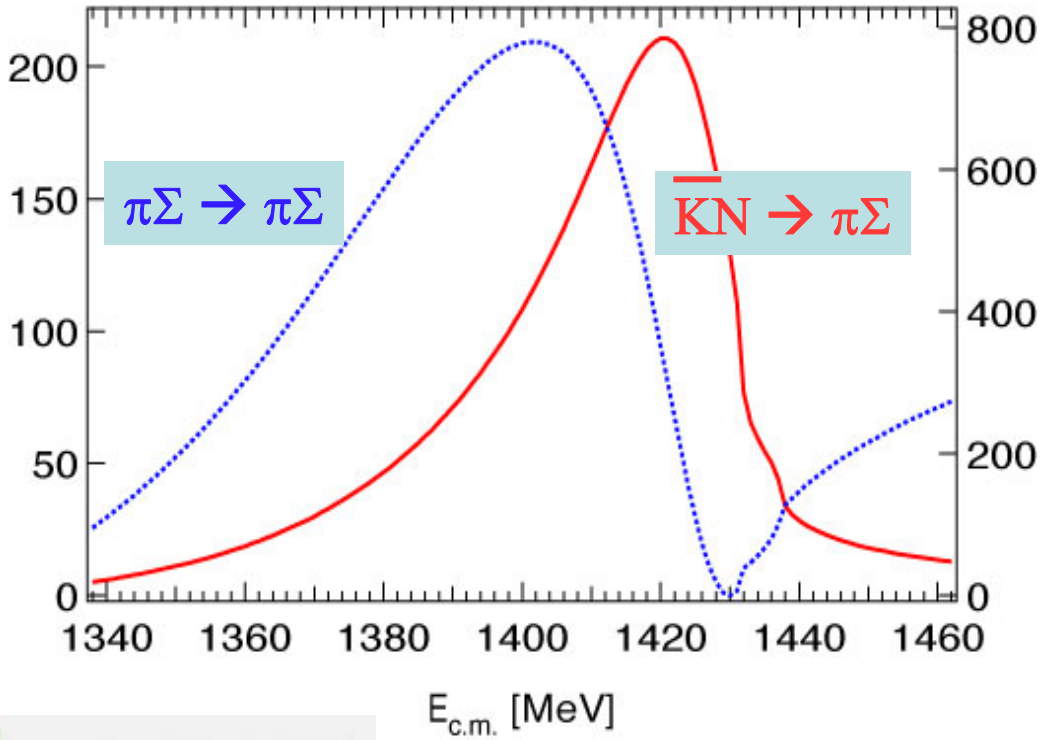
K⁻n INTERACTIONS

V. HEPP Nuclear Physics B115 (1976) 82



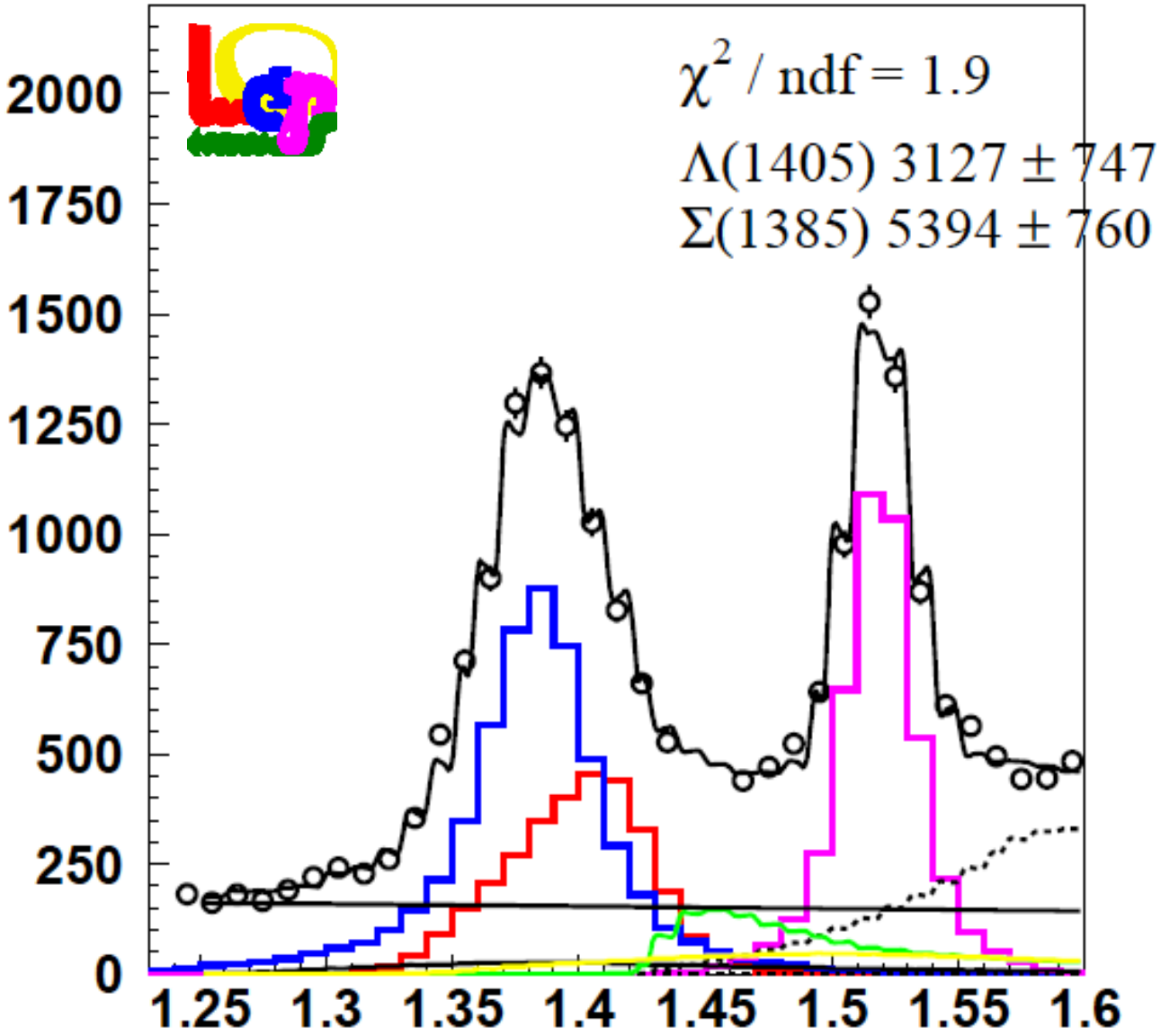
$\bar{K}N$ or $\pi\Sigma$ quasi-bound state





V.K. Magas, A. Ramos and E.O., Phys. Rev. Lett. 2005
Chiral dynamics of the meson baryon interaction for $S = -1, I = 0$ leads to two poles in the vicinity of the $\Lambda(1405)$

Jido-Oller-Oset-Ramos-Meissner, Nucl.Phys.A725, 181 (2003)


χ^2 / ndf = 1.9
Λ(1405) 3127 ± 747
Σ(1385) 5394 ± 760
2000
1750
1500
1250
1000
750
500
250
0
1.25
1.3
1.35
1.4
1.45
1.5
1.55
1.6

Σ(1385) DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Confidence level
Γ_1	$\Lambda\pi$	(87.0±1.5) %	
Γ_2	$\Sigma\pi$	(11.7±1.5) %	
Γ_3	$\Lambda\gamma$	(1.3±0.4) %	

Σ(1385) BRANCHING RATIOS

$\Gamma(\Sigma\pi)/\Gamma(\Lambda\pi)$ Γ_2/Γ_1

VALUE	DOCUMENT ID		TECN	CHG	COMMENT
0.135±0.011 OUR AVERAGE					
0.20 ±0.06	DIONISI	78B	HBC	±	$K^- p \to Y^* K\overline{K}$
0.16 ±0.03	BERTHON	74	HBC	+	$K^- p$ 1.26–1.84 GeV/c
0.11 ±0.02	BERTHON	74	HBC	−	$K^- p$ 1.26–1.84 GeV/c
0.21 ±0.05	BORENSTEIN	74	HBC	+	$K^- p \to \Lambda\pi^+\pi^-$, $\Sigma^0\pi^+\pi^-$
0.18 ±0.04	MAST	73	MPWA	±	$K^- p \to \Lambda\pi^+\pi^-$, $\Sigma^0\pi^+\pi^-$
0.10 ±0.05	THOMAS	73	HBC	−	$\pi^- p \to \Lambda K\pi$, $\Sigma K\pi$
0.16 ±0.07	AGUILAR-...	72B	HBC	+	$K^- p$ 3.9, 4.6 GeV/c
0.13 ±0.04	COLLEY	71B	DBC	−0	$K^- N$ 1.5 GeV/c
0.13 ±0.04	PAN	69	HBC	+	$\pi^+ p \to \Lambda K\pi$, $\Sigma K\pi$
0.08 ±0.06	LONDON	66	HBC	+	$K^- p$ 2.24 GeV/c
0.163±0.041	ARMENTEROS	65B	HBC	±	$K^- p$ 0.95–1.20 GeV/c
0.09 ±0.04	HUWE	64	HBC	±	$K^- p$ 1.2–1.7 GeV

"Right" and "Wrong" experiments

Harry J. LIPKIN

hep-ph/0701032

$$\frac{BR[\Sigma(1385) \to \Sigma\pi]}{BR[\Sigma(1385) \to \Lambda\pi]} = (4 \pm 4)\%$$

This led to a wrong selection rule forbidding $\Sigma^* \to \Sigma\pi$ and requiring the Σ^* to be in an exotic 27 - dimensional representation of SU(3).

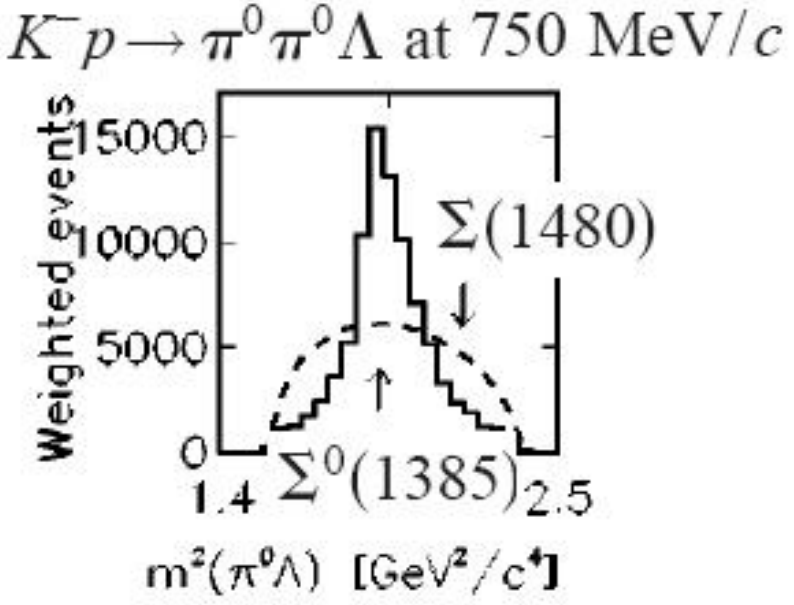
$$\frac{BR[\Sigma(27) \to \Sigma\pi]}{BR[\Sigma(27) \to \Lambda\pi]} = 0; \quad \frac{BR[\Sigma(10) \to \Sigma\pi]}{BR[\Sigma(10) \to \Lambda\pi]} = 15\%$$

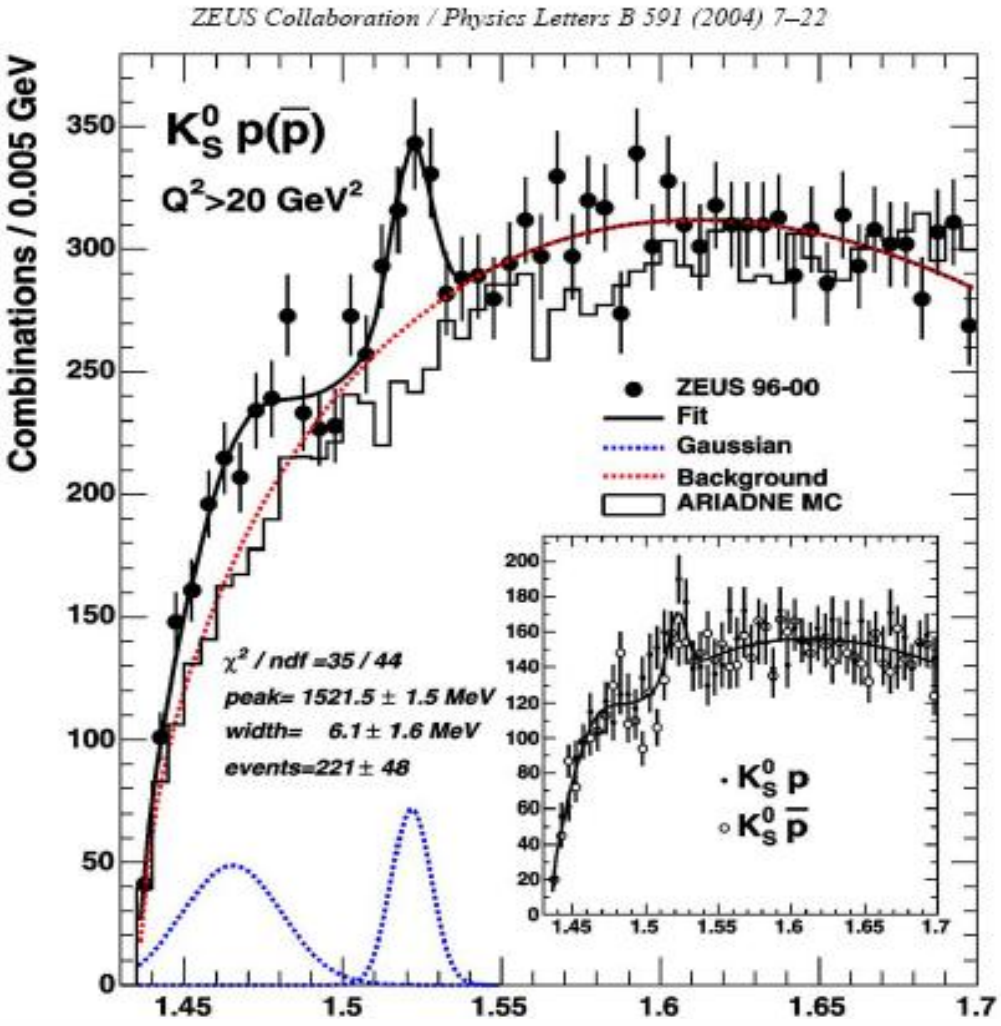
$$\frac{BR[\Sigma(1385) \to \Sigma\pi]}{BR[\Sigma(1385) \to \Lambda\pi]} = (13 \pm 2)\%$$

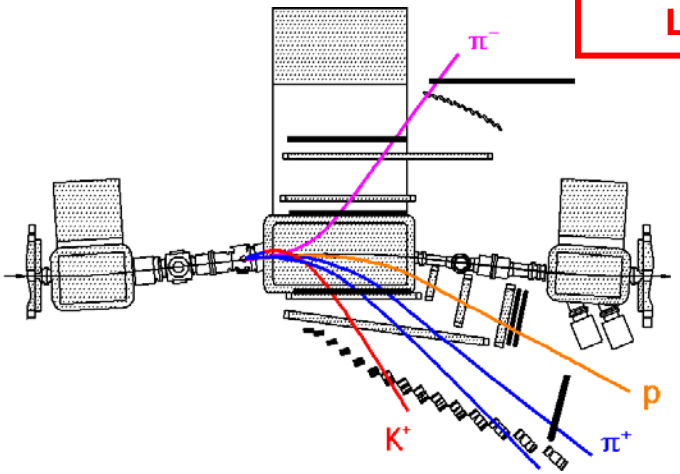
$\Sigma(1480)$ Bumps

$I(J^P) = 1(?^?)$ Status: *

ZEUS: *an indication in the K^0p invariant mass*
Crystal Ball: *not observed in $K^-p \to \pi^0\pi^0\Lambda$*

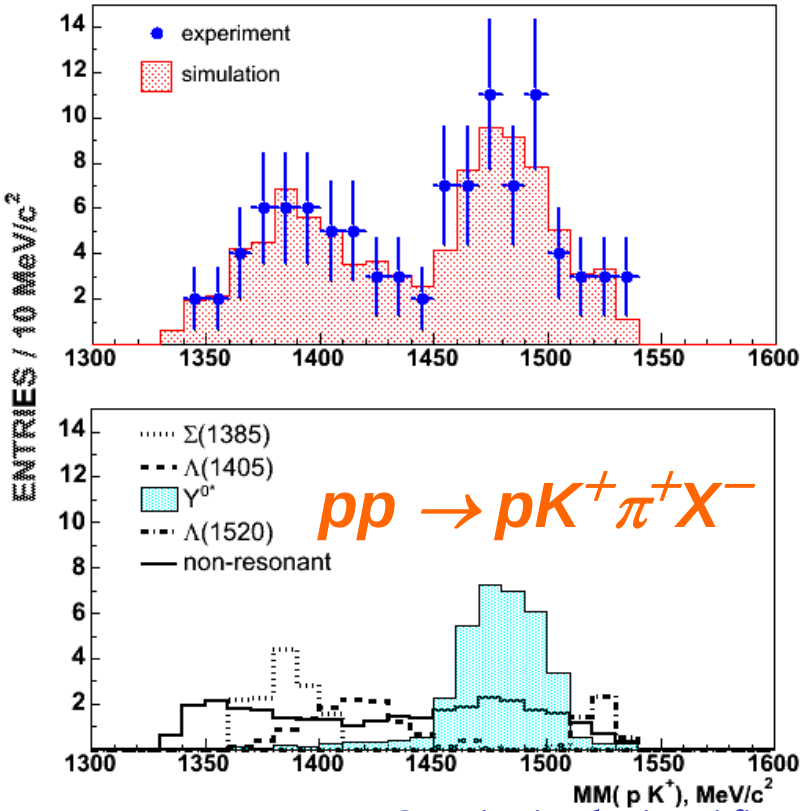


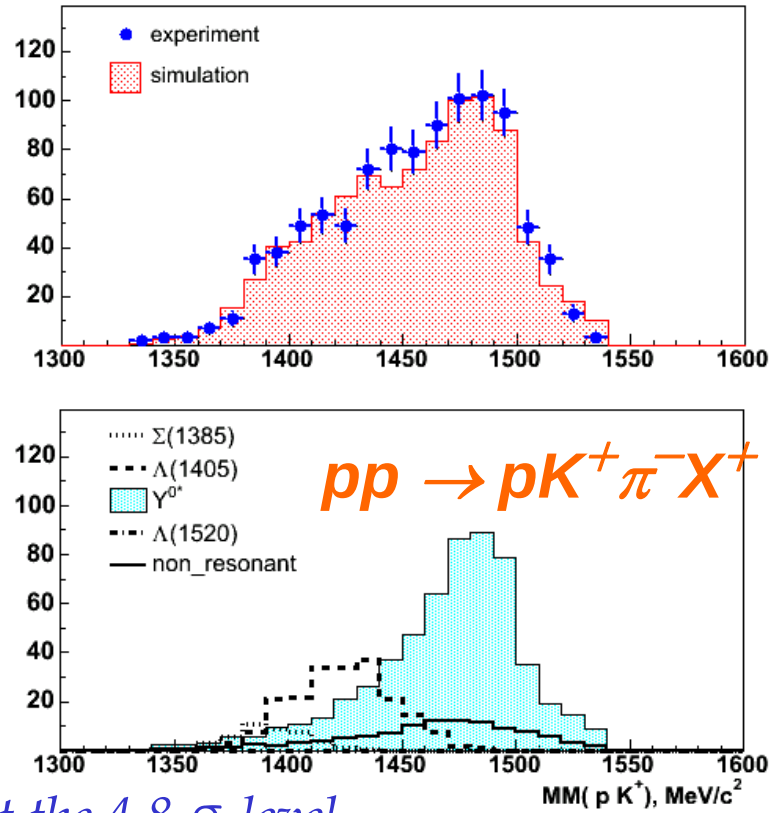




ANKE @ COSY *@ 3.65 GeV/c*

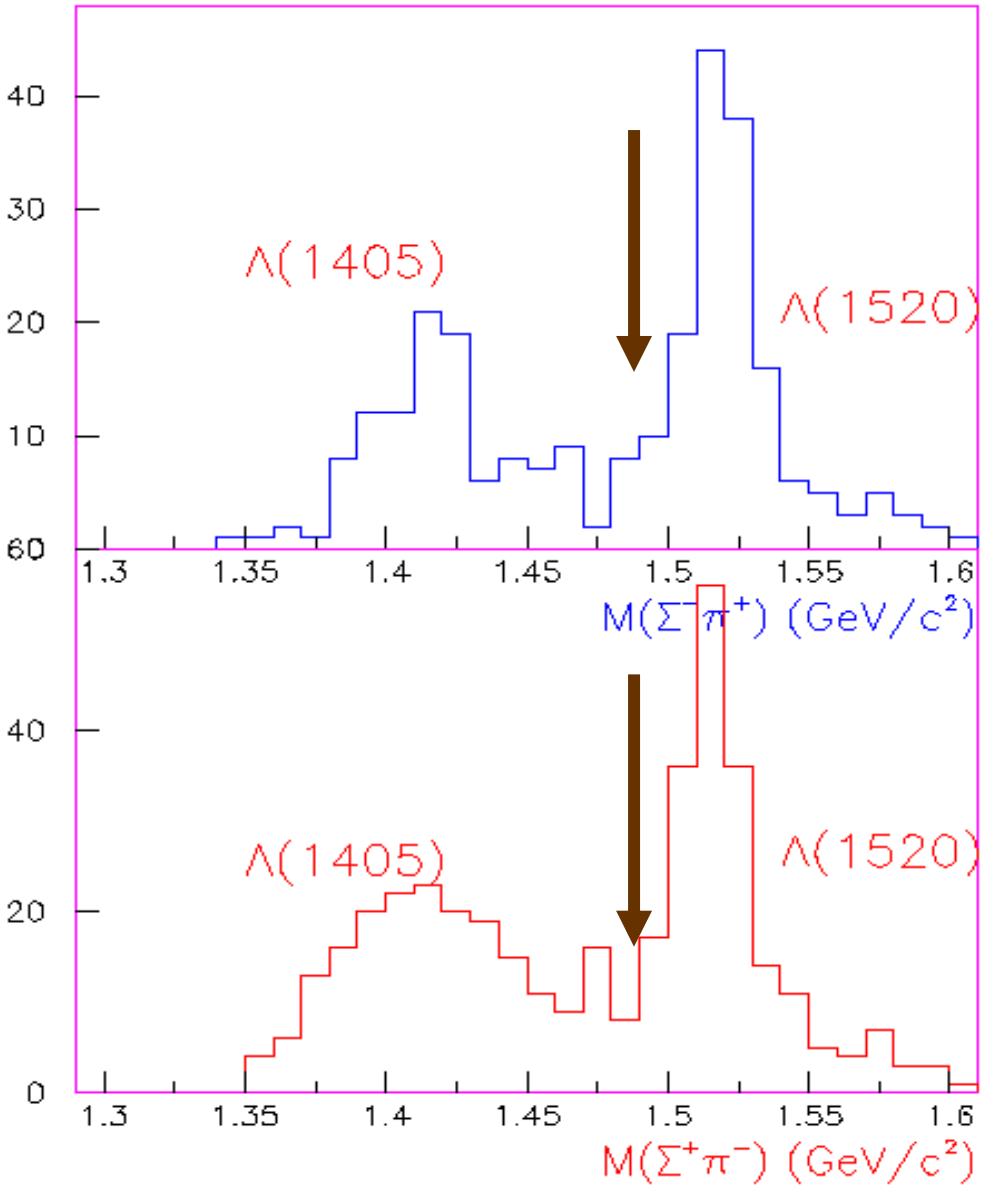
Y^{0*}: M=1480 MeV/c², Γ=60 MeV/c²

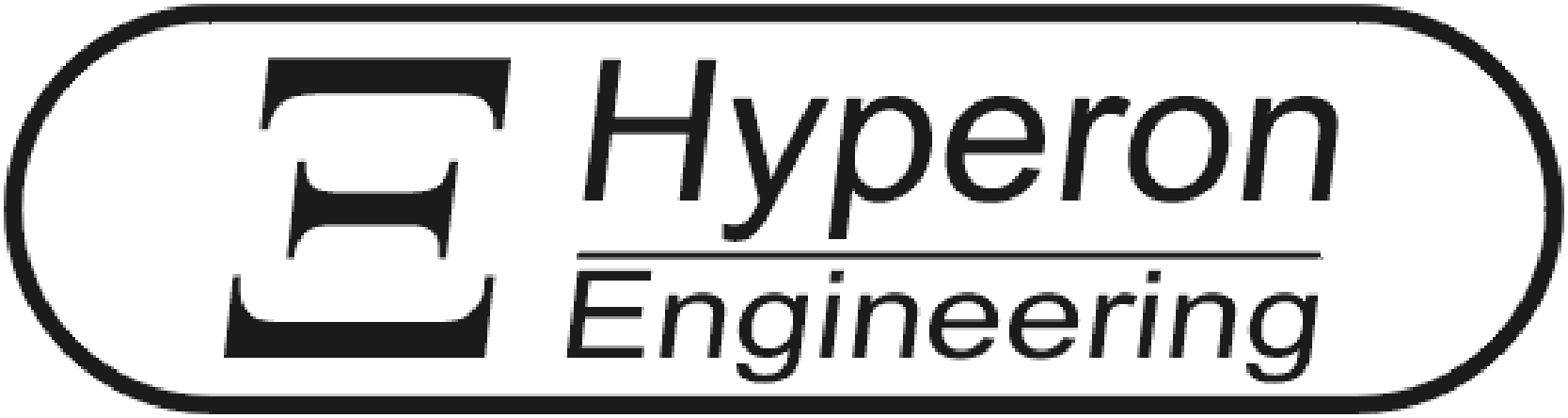




- *Statistical significance at the 4.8 σ level*

$p(\gamma, K^+\pi)$


40
30
20
10
60
Λ(1405)
Λ(1520)
1.3
1.35
1.4
1.45
1.5
1.55
1.6
M(Σ⁻π⁺) (GeV/c²)
40
20
0
Λ(1405)
Λ(1520)
1.3
1.35
1.4
1.45
1.5
1.55
1.6
M(Σ⁺π⁻) (GeV/c²)



http://hyperon.net/

Hyperon Resonances

➔ 6 GeV/*c* K beam for 2.5 GeV/c^2 Y* Production

Resonance	Δ^*	Λ^*	Σ^*	Ξ^*	Ω^*
Expected #	7	21	21	21	7
Observed #	10	14	10	6	2

Ξ^-

$\Xi(1530)$ P_{13}

$\Xi(1690)$

$\Xi(1820)$ D_{13}

$\Xi(1950)$

$\Xi(2030)$

TABLE I: The status of the Ξ resonances.

Particle	$L_{2I,2L}$	Status	$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Others
Ξ(1318)	P_{11}	****					weakly
Ξ(1530)	P_{13}	****	****				
Ξ(1620)		*	*				
Ξ(1690)		***		***	**		
Ξ(1820)	D_{13}	***	**	***	**	**	
Ξ(1950)		***	**	**		*	
Ξ(2030)		***		**	***		
Ξ(2120)		*					
Ξ(2250)		**					3-body
Ξ(2370)		**					3-body
Ξ(2500)		*		*	*		3-body

Compiled Ξ* Data

H. G. Fischer and S. Wenig, Eur. Phys. J. C **37**, 133 (2004).

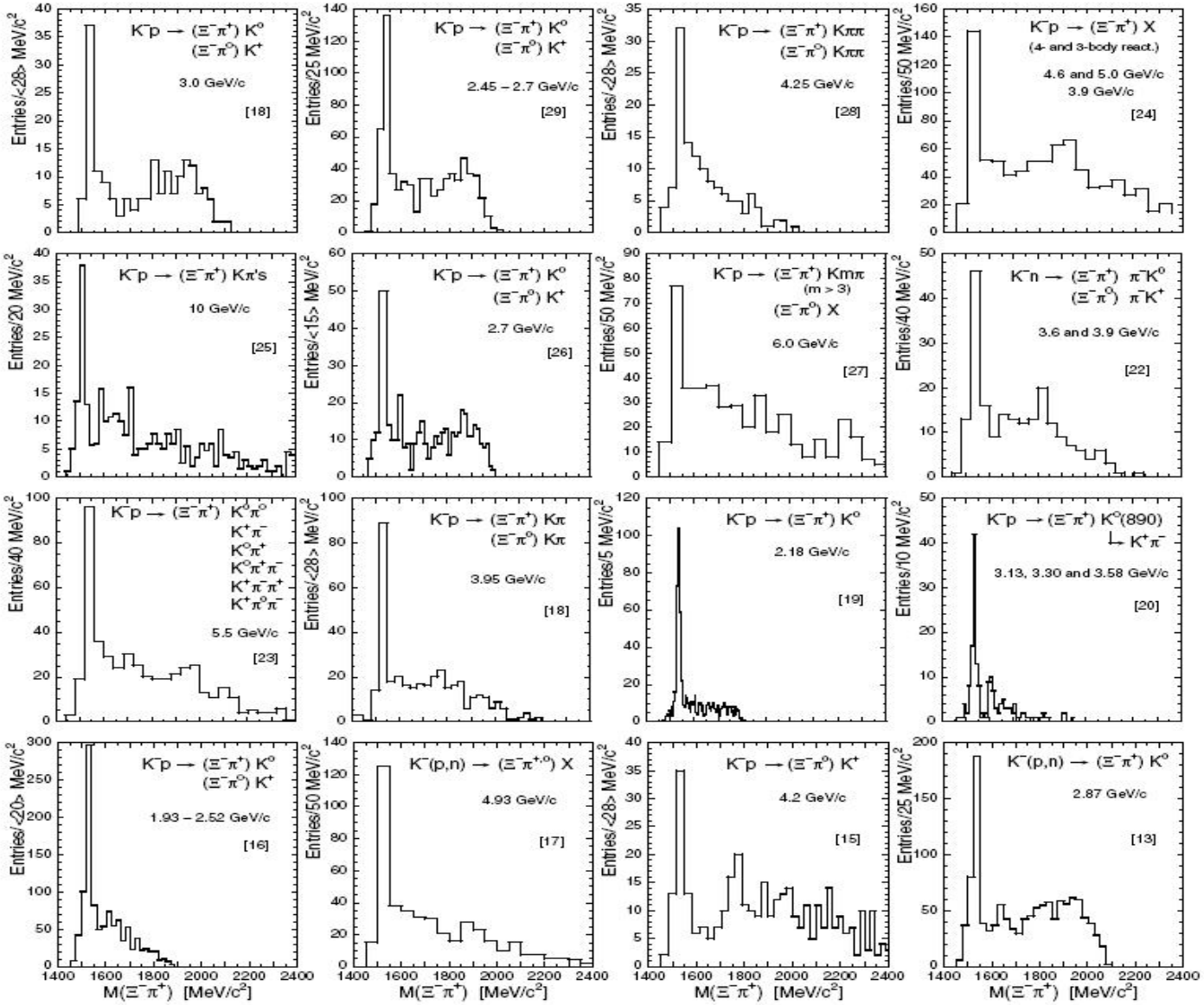
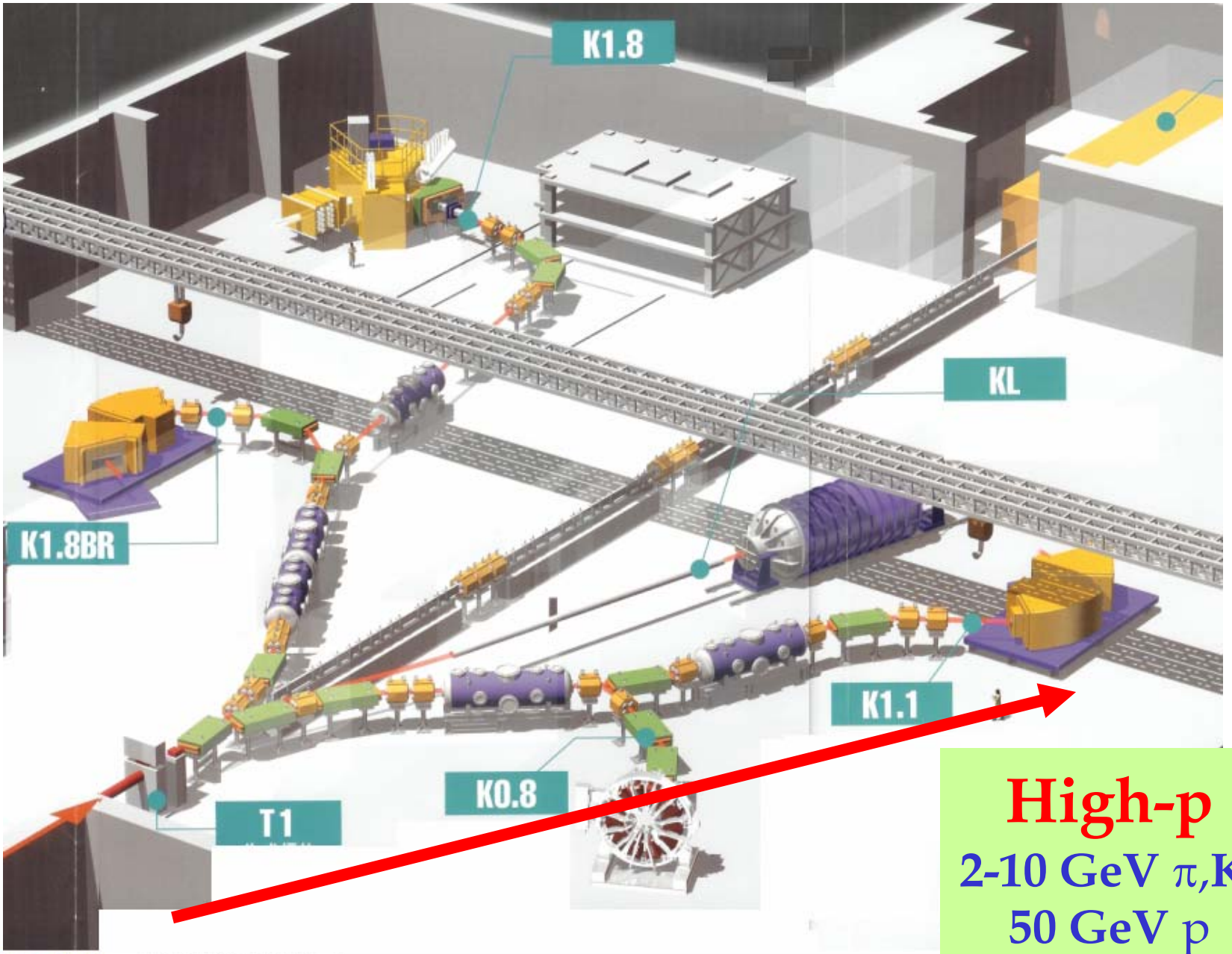
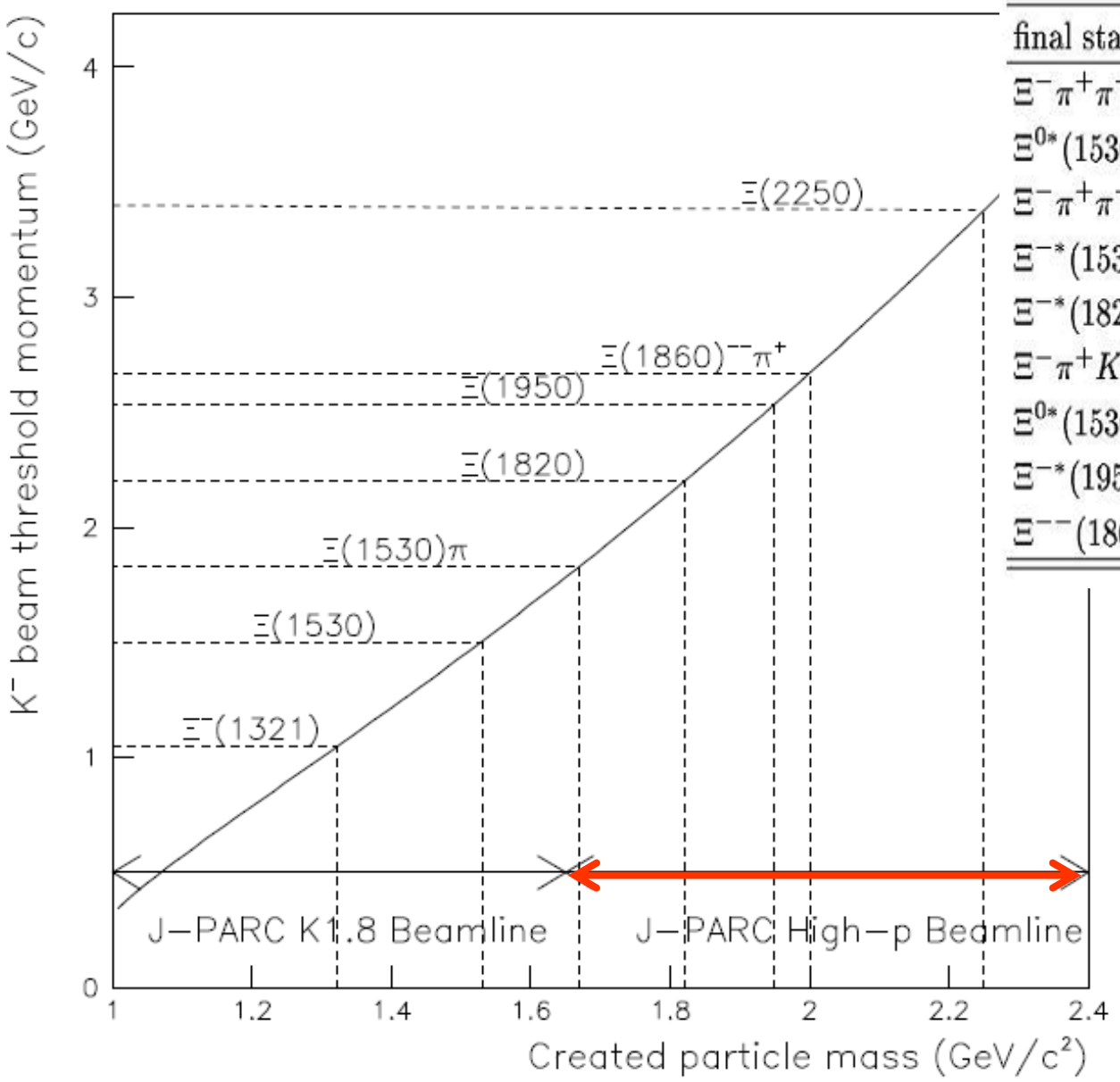


Fig. 1. Compilation of data on $\Xi^-\pi^{+0}$-spectroscopy



High-p
2-10 GeV π,K,
50 GeV p



final state	p_{th}(GeV)	$\sigma(\mu b)$
$\Xi^-\pi^+\pi^-K^+$	1.666	13^a, 26^b, 3^e
$\Xi^{0*}(1530)\pi^-K^+$	1.834	11.6^b, 9^e
$\Xi^-\pi^+\pi^-\pi^0K^+$	1.989	25.4^d
$\Xi^{-*}(1530)\pi^+\pi^-K^+$	2.184	
$\Xi^{-*}(1820)K^+$	2.206	4^a, 2.5^b
$\Xi^-\pi^+K^{0*}(892)$	2.309	10.5^b, 4^d
$\Xi^{0*}(1530)K^{0*}(892)$	2.494	7^c, 6.5^e
$\Xi^{-*}(1950)K^+$	2.536	0.8^b
$\Xi^{--}(1860)\pi^+K^+$	2.668	

The production yield for each Ξ^* resonance in the (K^-, K^+) reaction at 3 GeV/c can be written as

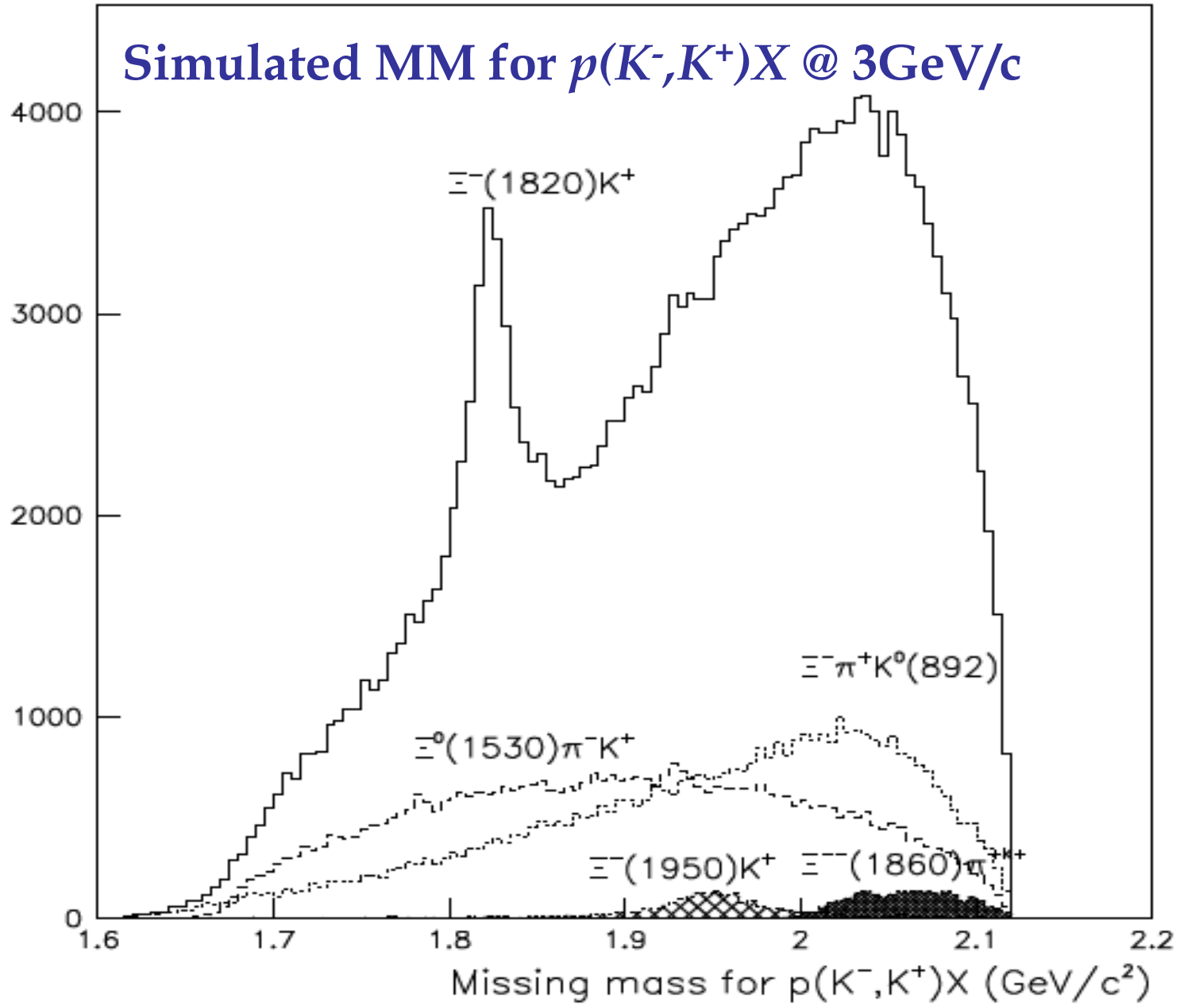
$$Y = F_{K^-} n_p \int_{\Delta\Omega} \frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} \mathrm{d}\Omega \cdot \epsilon_{K^+} \cdot \epsilon_{\mathrm{rec}},$$

10^{14} primary protons $\sim$ 1 % of primary protons

10 μb $\Delta\Omega/4\pi \cdot \epsilon_{K^+} \sim 0.2$

K^- beam flux of 6×10^4/s, the yield will be 8×10^{-2}/s or 6.6×10^3/d. The event yields in all figures correspond to a 3-day experiment. A more conservative estimate from unexpected factors can be cancelled out by increasing the run time.

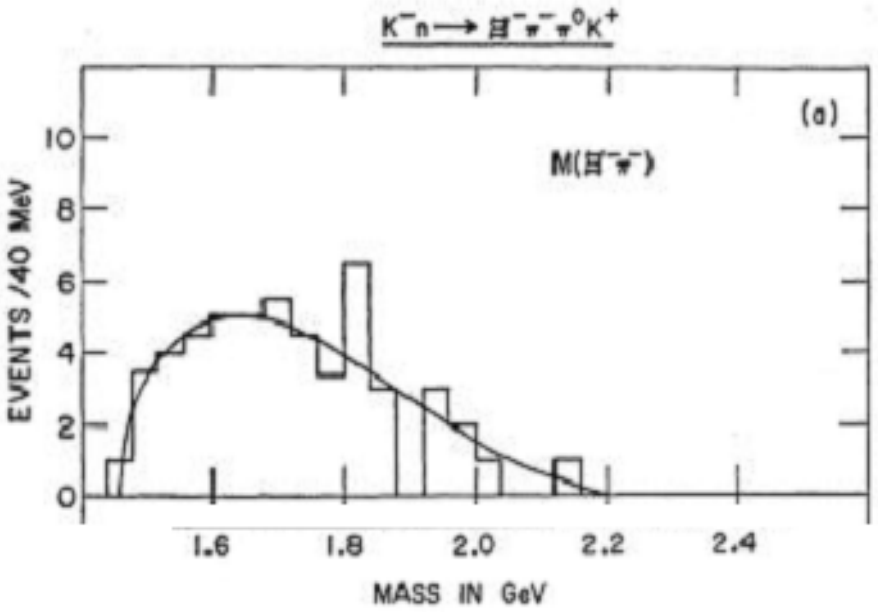
Simulated MM for $p(K^-,K^+)X$ @ 3GeV/c

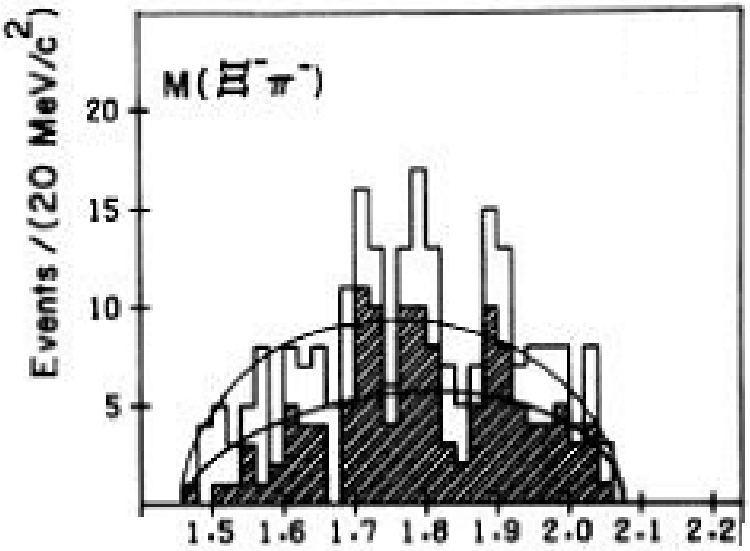


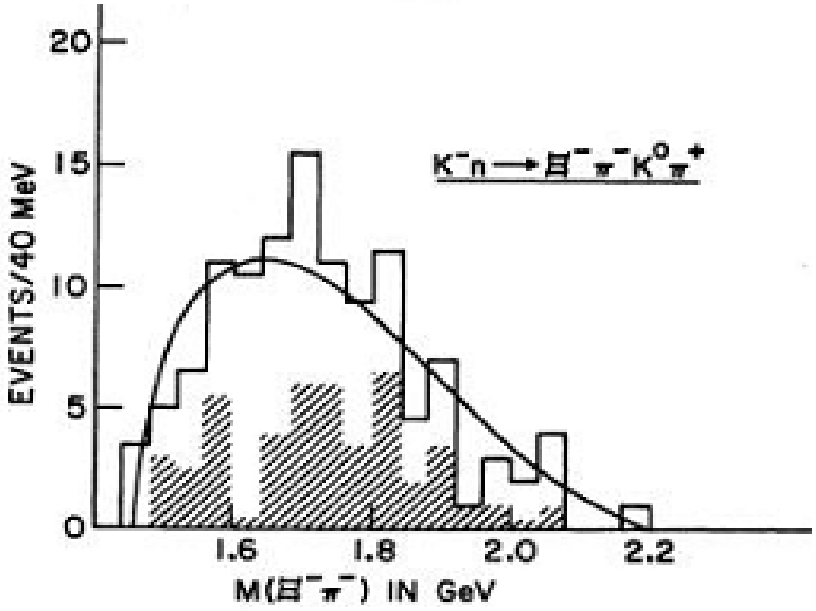
Φ(1860)

Old $\Xi^-\pi^-$ Data

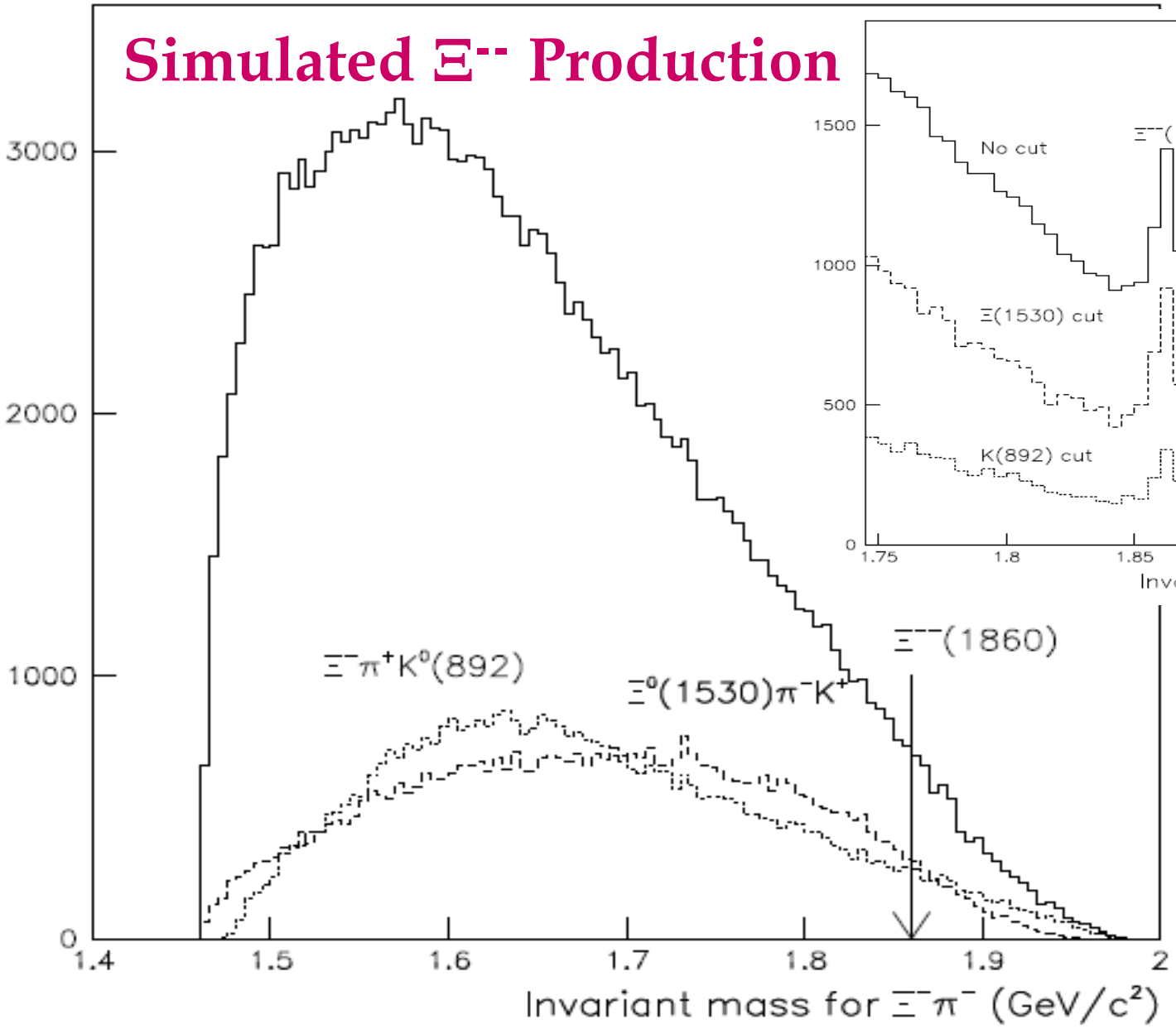
E. Briefel *et al.*, Phys. Rev. D **16**, 2706 (1977).
J. Badier *et al.*, Nucl. Phys. B **37**, 429 (1978).
J. Badier *et al.*, Phys. Lett. **16**, 171 (1965).
D. J. Crennel *et al.*, Phys. Rev. D **1**, 847 (1969).







Simulated Ξ^{--} Production



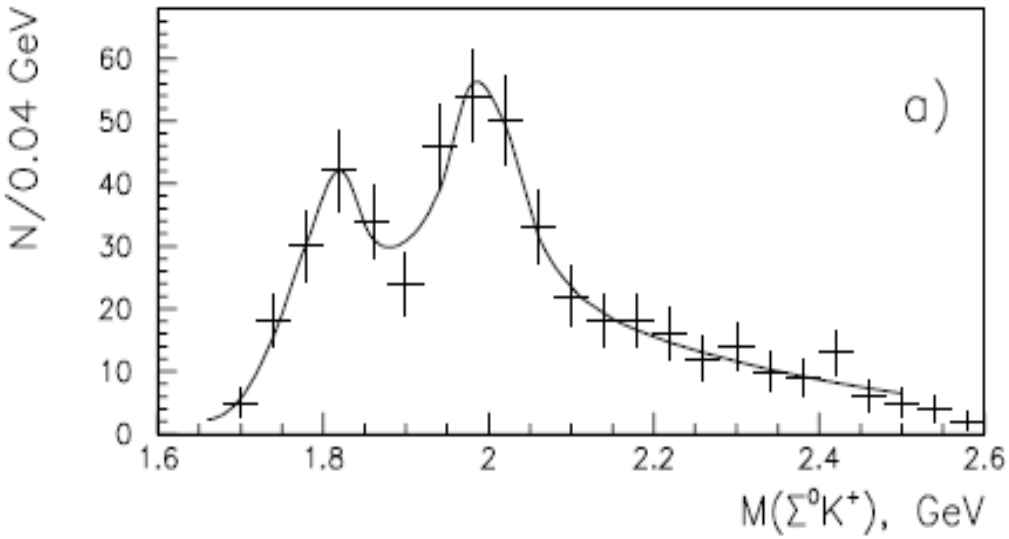
X(2000)

- pN → X(2000)N

  → $\Sigma^0 K^+ N$ @ 70 GeV

- **uudss̄ pentaquark?**

  SPHINX @ ITEP



Σ(3170) Bumps

$I(J^P) = 1(?^?)$ Status: *

- K-p → Σ(3170)π- → ΣKK̄ππ π- @ 6.5, 8.25 GeV
- **uusss̄ pentaquark? CERN and Argone BC**

Hyperon Ultra Clincher

Prices: ~~$3,699.99~~
Special Price: $3,249.99

Campagnolo Neutron

Prices: ~~$849.99~~
Special Price: $749.99