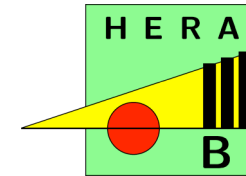


Search for Pentaquarks with HERA-B

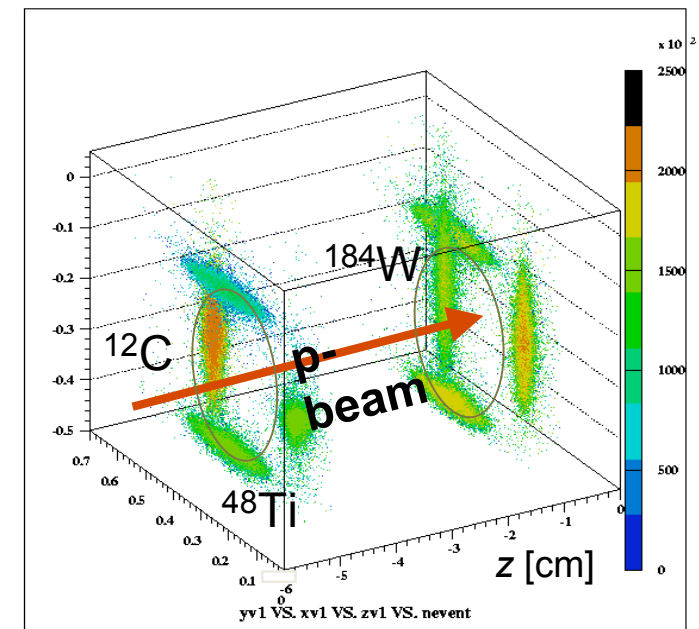
J. Spengler

MPI für Kernphysik Heidelberg

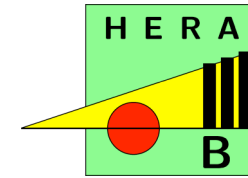
The Hera-B Detector



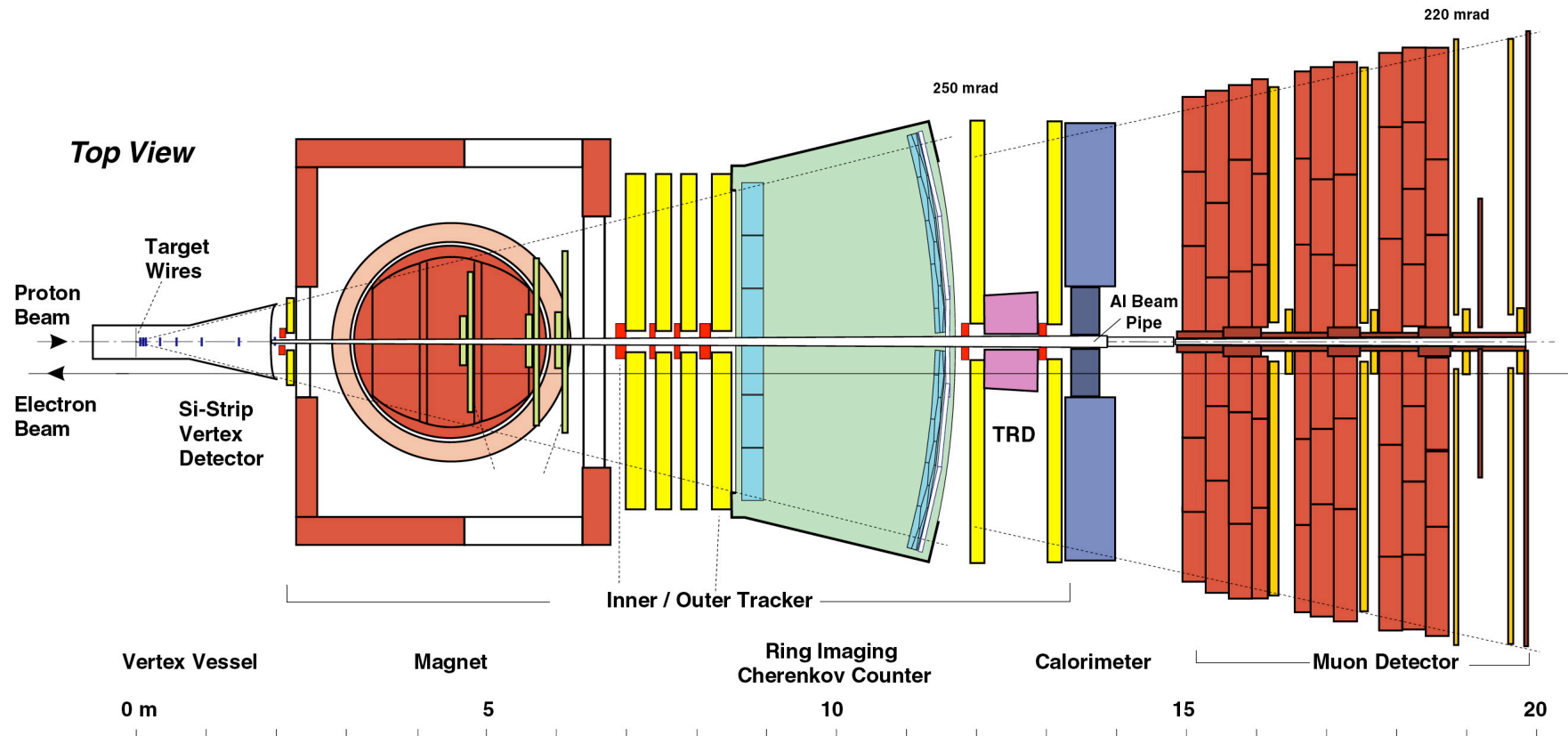
- Fixed target detector at e-p ring HERA, Desy
- High rate forward spectrometer ($< 40\text{MHz}$)
- Wire targets (different materials) in proton halo
- Proton beam at $920\text{ GeV}/c$ ($\sqrt{s} = 41.6\text{ GeV}$)
- High resolution vertexing
- Very good particle ID for (e, μ, π, K, p)
- Hardware track trigger for lepton pairs
- Multiple trigger level
- On-line event reconstruction



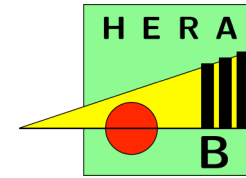
The Hera-B Detector



Angular coverage in bending plane:
15 - 220 mrad

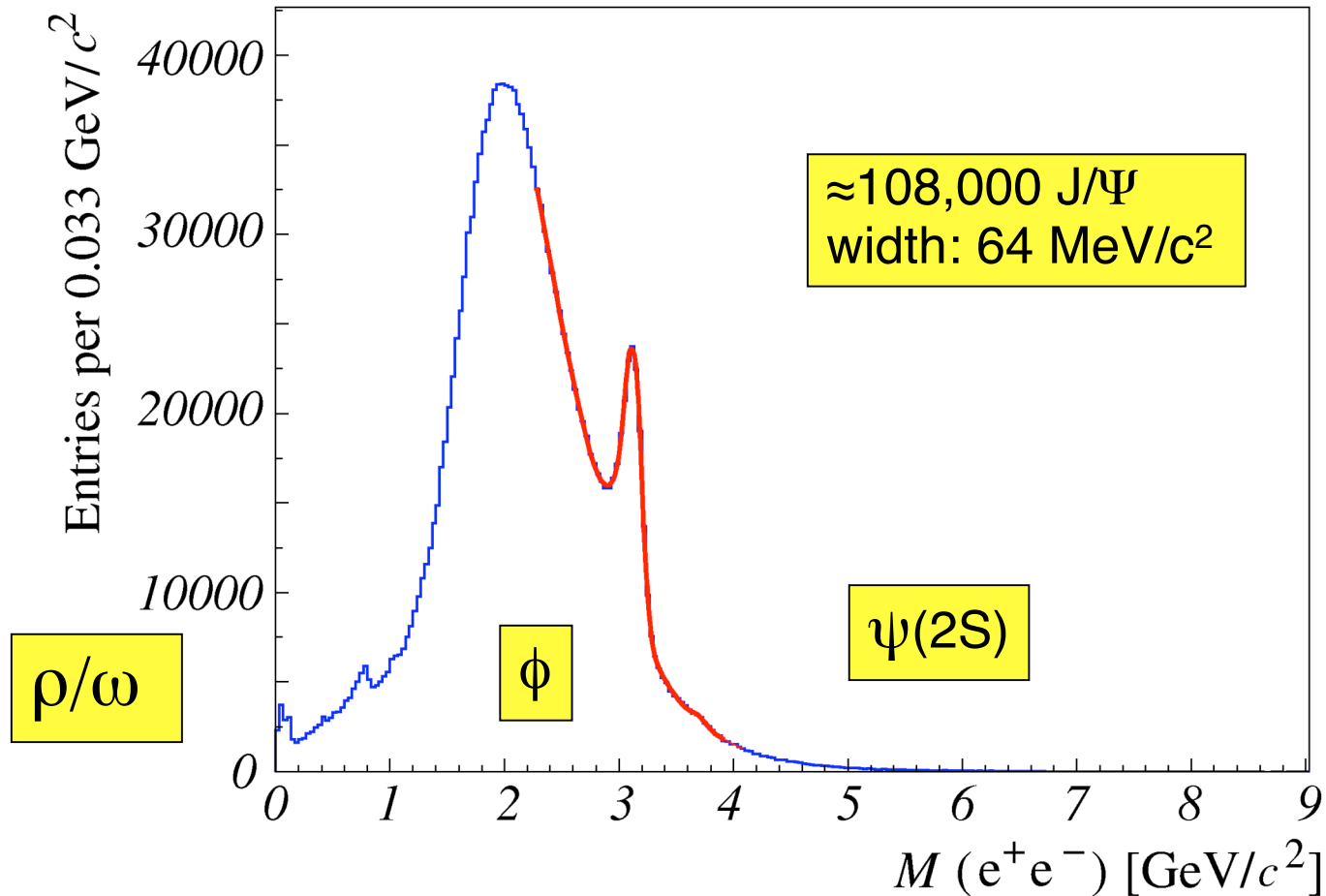
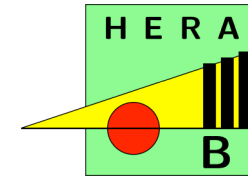


Data Sample



- $200 \cdot 10^6$ minimum bias events
achieved logging rates: 1000 Hz (1.7 TB/d)
- $150 \cdot 10^6$ dilepton (e^+e^- and $\mu^+\mu^-$)
triggered events with $\sim 300,000$ J/ψ
achieved J/ψ rates: 1200 - 1400 / hour
- $90 \cdot 10^6$ hard photon + Glueball trigger

e^+e^- Mass Spectrum



J/ψ

$\psi(2s)$

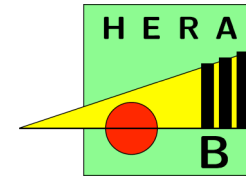
χ_c

Υ

$b \bar{b}$

Dilepton mass accessible from 0 - 11 GeV/c^2

Experimental situation

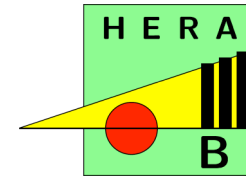


- According to a recent count*:
 - 12 reports of a narrow resonance (NR) in nK^+ or pK_s^0 near 1530 MeV/c² (Θ^+).
 - 8 reports this year of negative results on searches for Θ^+ .
 - H1 reports a NR decaying into D^*p (Θ_c^0) but Zeus, CDF, FOCUS report non-observation.
 - NA49 reports a NR decaying into $\Xi^-\pi^-$ (Ξ^{--}) but Zeus, CDF, E690, Babar report non-observation.

The existence of pentaquarks is not established.
If they exist, the production mechanism is unclear.

*J. Pochodzalla, hep-ex/0406077

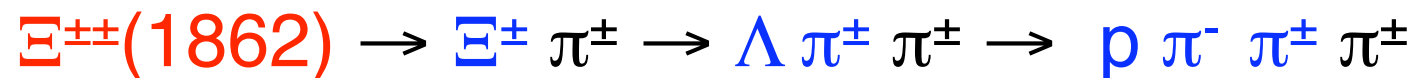
Search for Pentaquarks



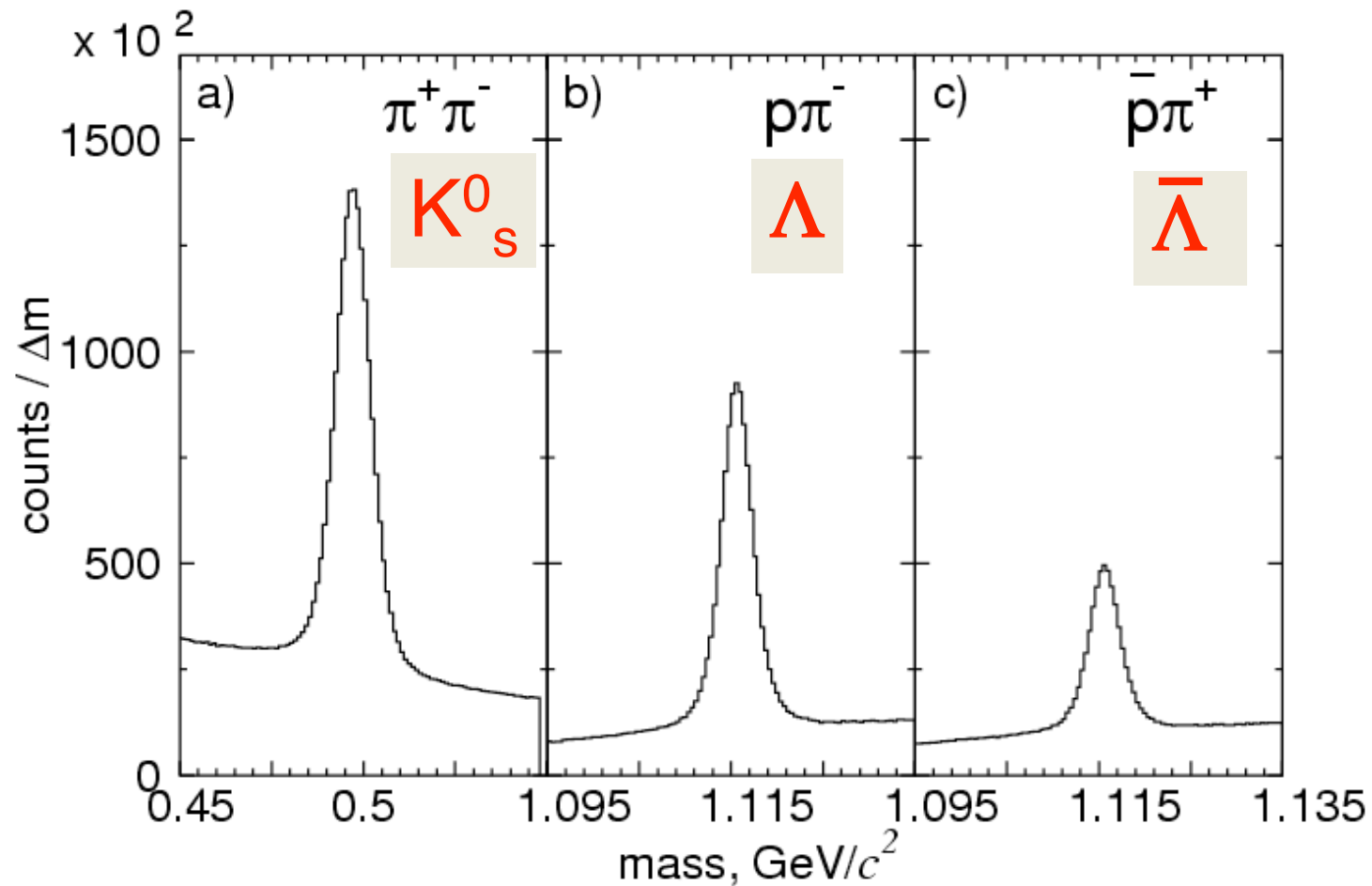
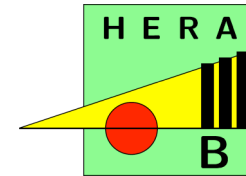
HERA-B has

- Large data sample of 200 million interactions
- Good mass resolution and particle ID
- Mid-rapidity in pA collisions at 920 GeV
- Different targets (A = C, Ti, W)

Final states explored:

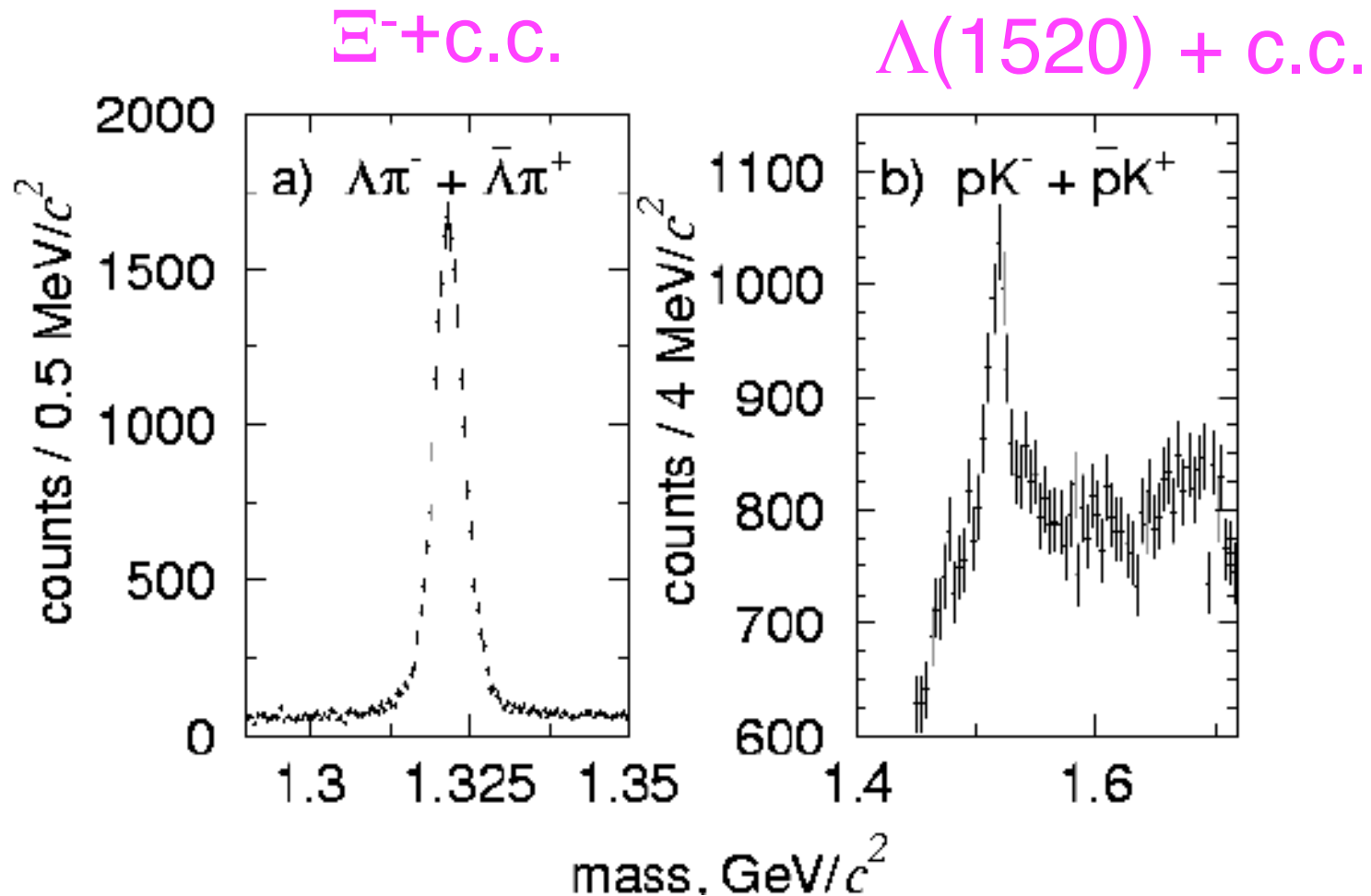
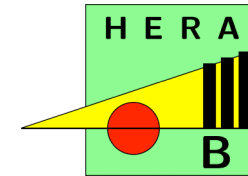


V^0 Selection



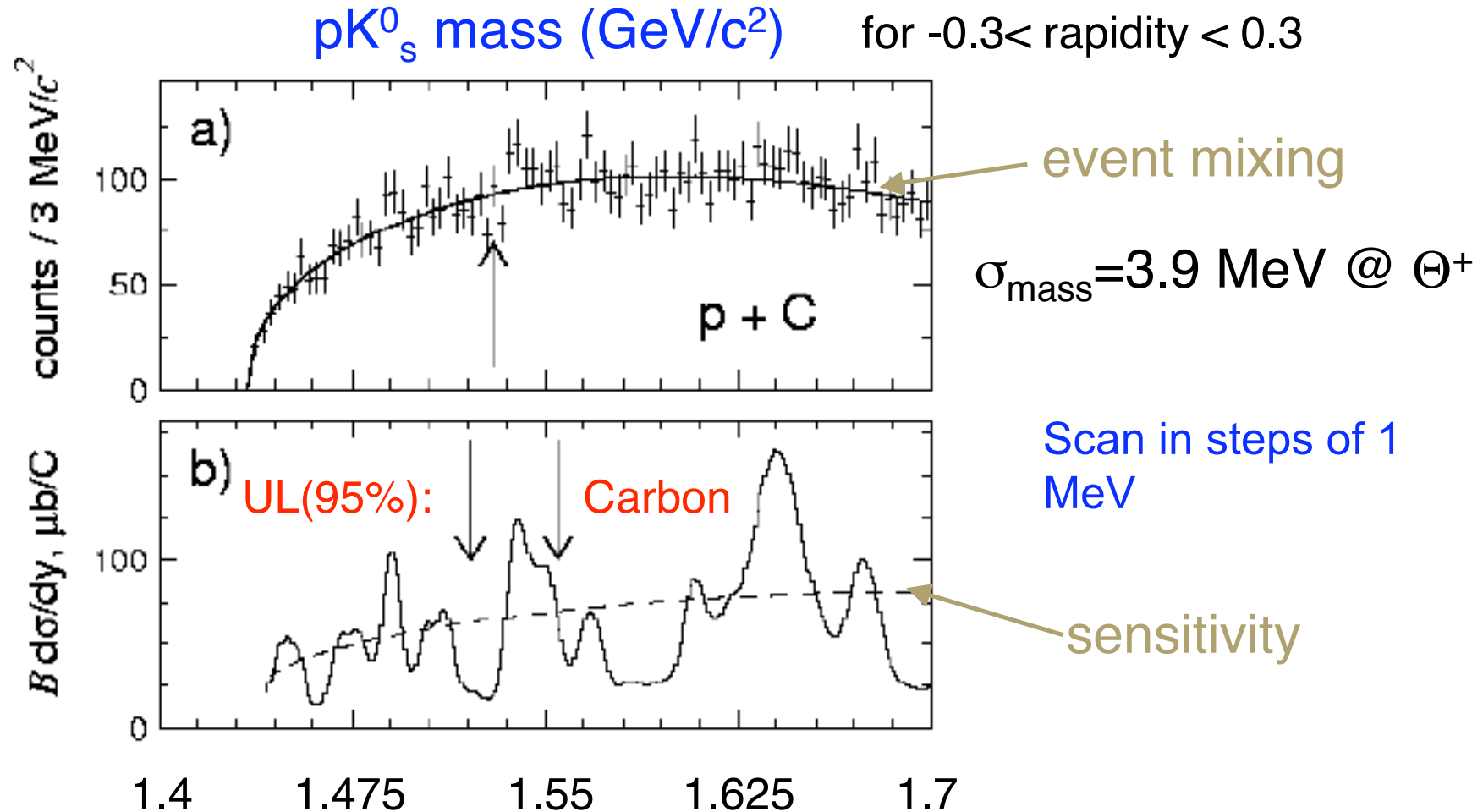
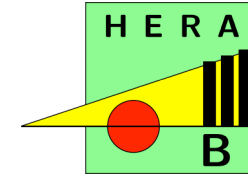
Soft vertex cuts only, K_s^0/Λ ambiguities are rejected

E^- and $\Lambda(1520)$ Signals



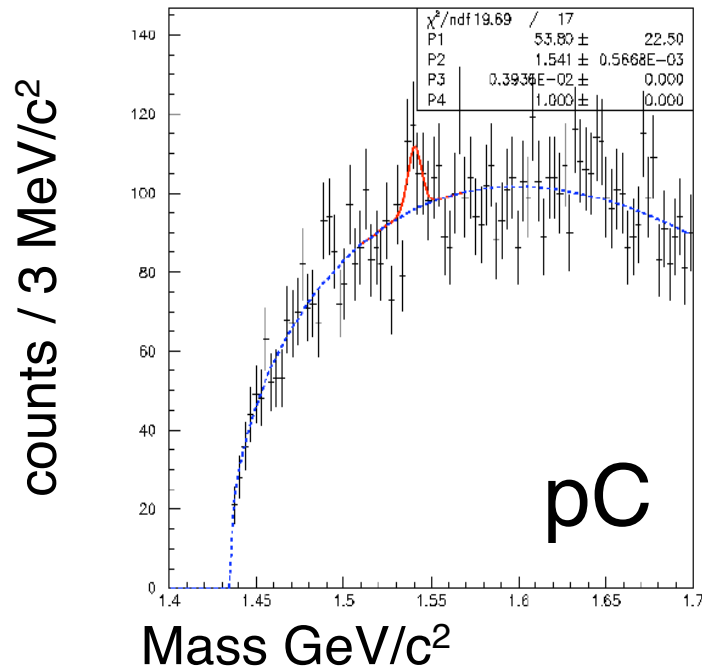
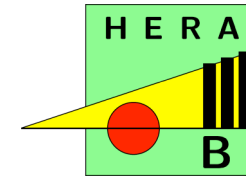
E^- recon: $|m_{p\pi} - m_{\Lambda}| < 3\sigma$, Cascade topology, $\Delta z > 2.5\text{cm}$

pK⁰_s Mass, Upper Limit



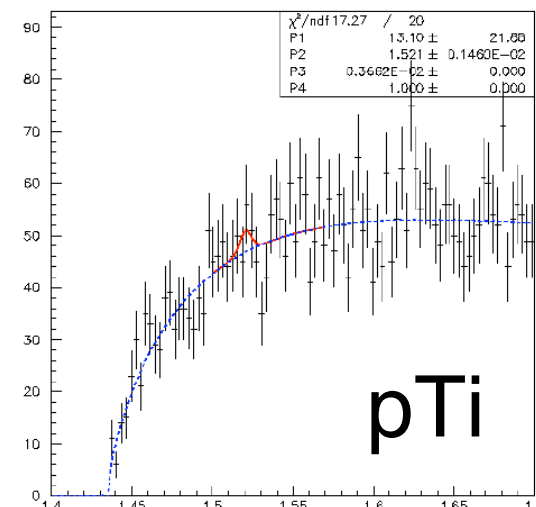
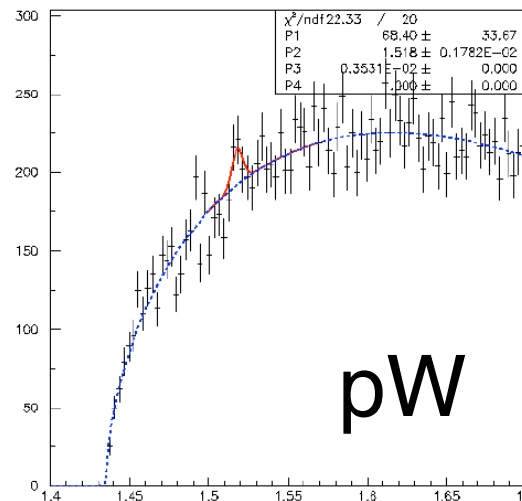
With $\sigma_N \propto A^{0.7}$, $UL(95\%) B \cdot d\sigma/dy|_{y=0} = 3 \mu\text{b/N} - 22 \mu\text{b/N}$

Excess at 1540 MeV/c²?

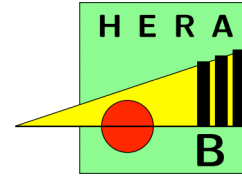


- Fit to Gaussian with $\sigma = \text{exp. resolution} + \text{fixed background}$ in region of highest U.L.
- Result: 54 ± 22 evts (2.4σ)
 $M = 1541 \pm 1$ MeV
- Consistent with a fluctuation

Nothing seen near 1540 MeV in pTi, pW samples.

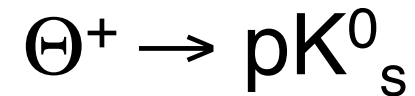
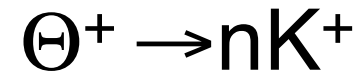
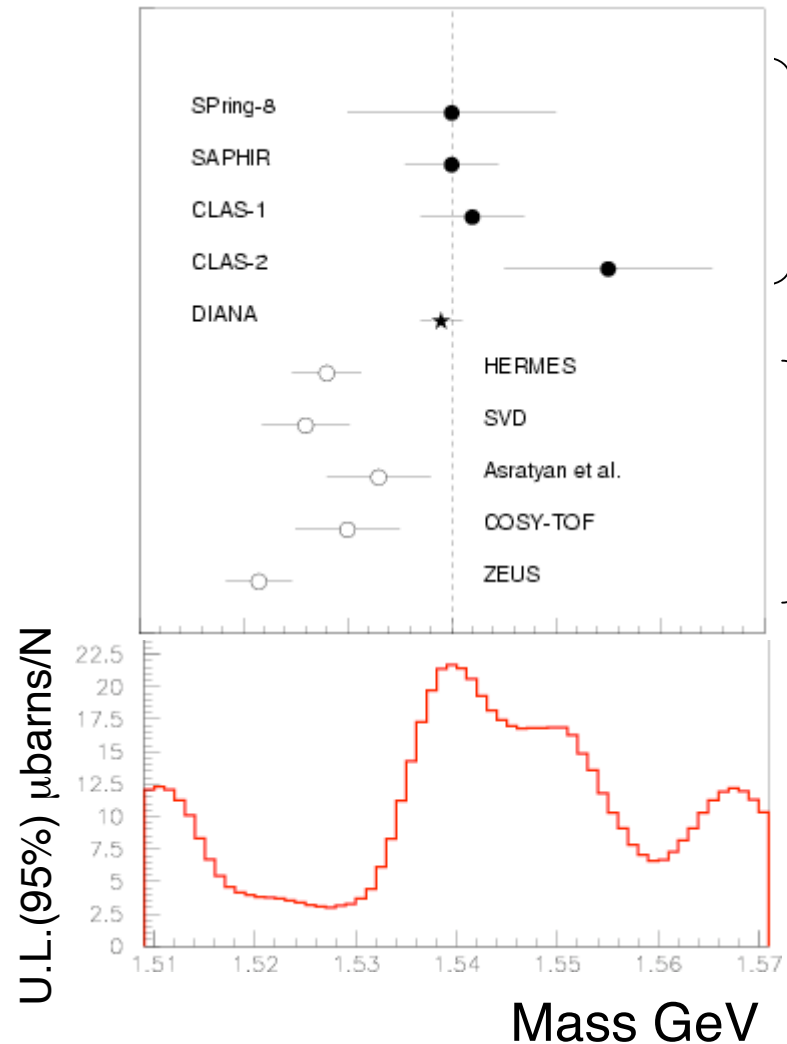


U.L. vs. Mass, Comparison



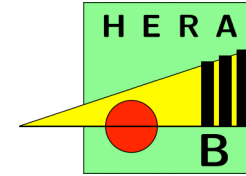
Quoted
mass
values

HERA-B
95% U.L.

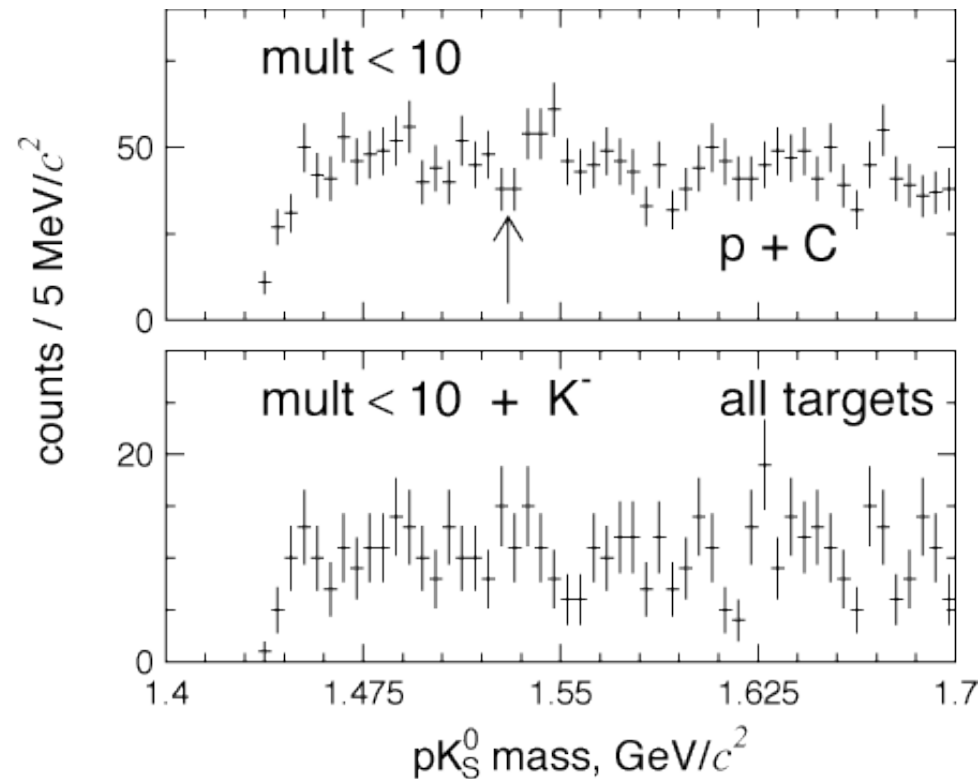


Q. Zhao & F. Close,
hep-ph/0404075

pK_s^0 Mass with add. cuts

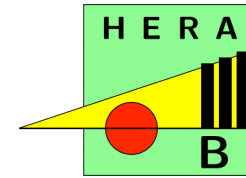


Charged multiplicity < 10



+ strange-
ness tag

Summary : $\Theta^+ \rightarrow p K_s^0$



pC (pAll): $B \cdot d\sigma/dy|_{y=0}$: 3.7 (4.8) $\mu\text{b}/\text{N}$ at 1530 MeV

pC (pAll): $B \cdot d\sigma/dy|_{y=0}$: 3 (4) $\mu\text{b}/\text{N}$ - 22 (16) $\mu\text{b}/\text{N}$

in range $1521 \text{ MeV} < m(pK_s^0) < 1555 \text{ MeV}$

See PRL 93 (2004) 212003 for more details

Upper limits on the relative yield at mid-rapidity (95% C.L.):

$\Theta^+ (1540) / \Lambda(1520) < 0.027$ at $m=1530 \text{ MeV}$

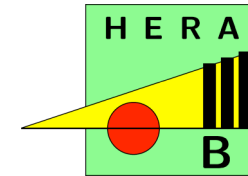
$\Theta^+ (1540) / \Lambda(1520) < 0.10$ at $m=1540 \text{ MeV}$

using $B(\Theta^+ \rightarrow p K_s^0) \equiv 0.25$

Result of Hermes: 27.6 GeV e^\pm on deuterium target (HERA)

$\Theta^+ (1540) / \Lambda(1520) = 1.6 - 3.5$ at $m=1528 \text{ MeV}$

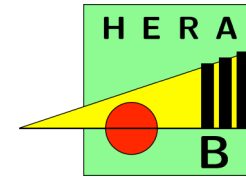
Summary: $\Theta^+ \rightarrow p K_s^0$



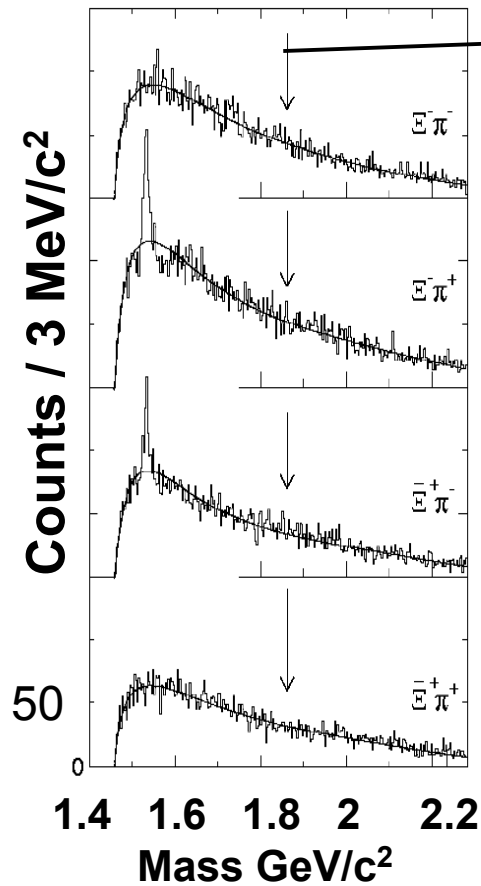
Reaction	\sqrt{s} GeV	Θ^+ / Λ (%)	$\Theta^+ / \Lambda(1520)$ (%)	Source
pA, $y \approx 0$	42	<0.92	<2.7	HERA-B (1530 MeV)
ed	28		160 - 350	HERMES
ep	320	5		ZEUS
pp, $y=0$	18	2.3		M. Bleicher et al.
pp	20/40	6.3/5.0		F.M. Liu et al.
pp	17	4.7	57	F. Becattini et al.
AA	20	3-10	50-200	J. Letessier et al.
AA	40	3-7	44-140	J. Letessier et al.

$$B(\Theta^+ \rightarrow p K_s^0) \equiv 0.25$$

$\Xi^\pm \pi^\pm$ Mass

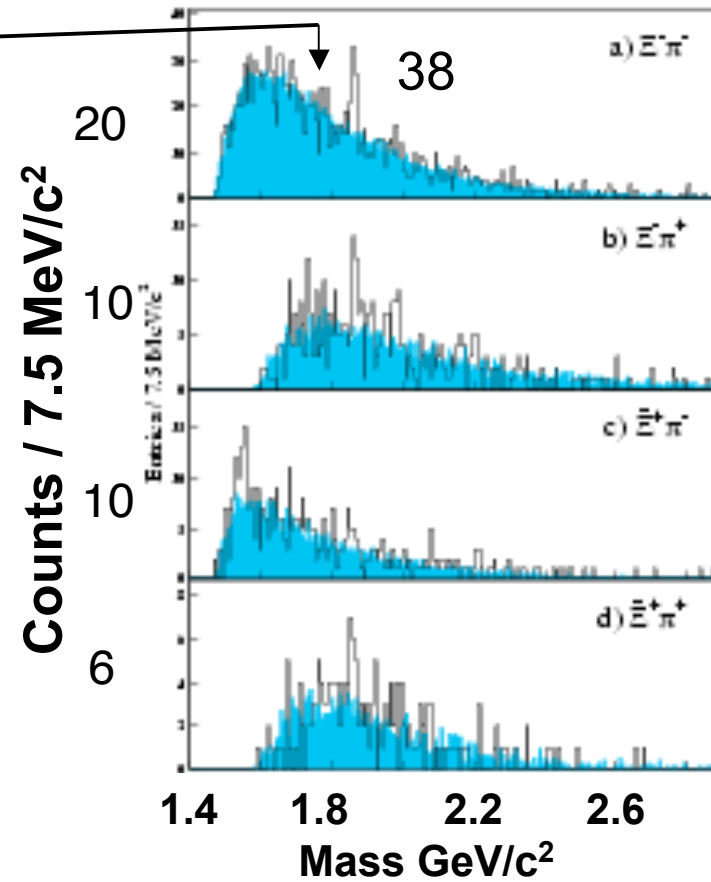


HERA-B pC



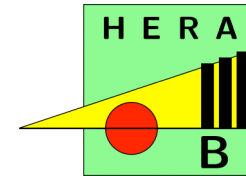
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-+
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NA49



C. Alt et al. PRL 92, 042003

Signal Statistics

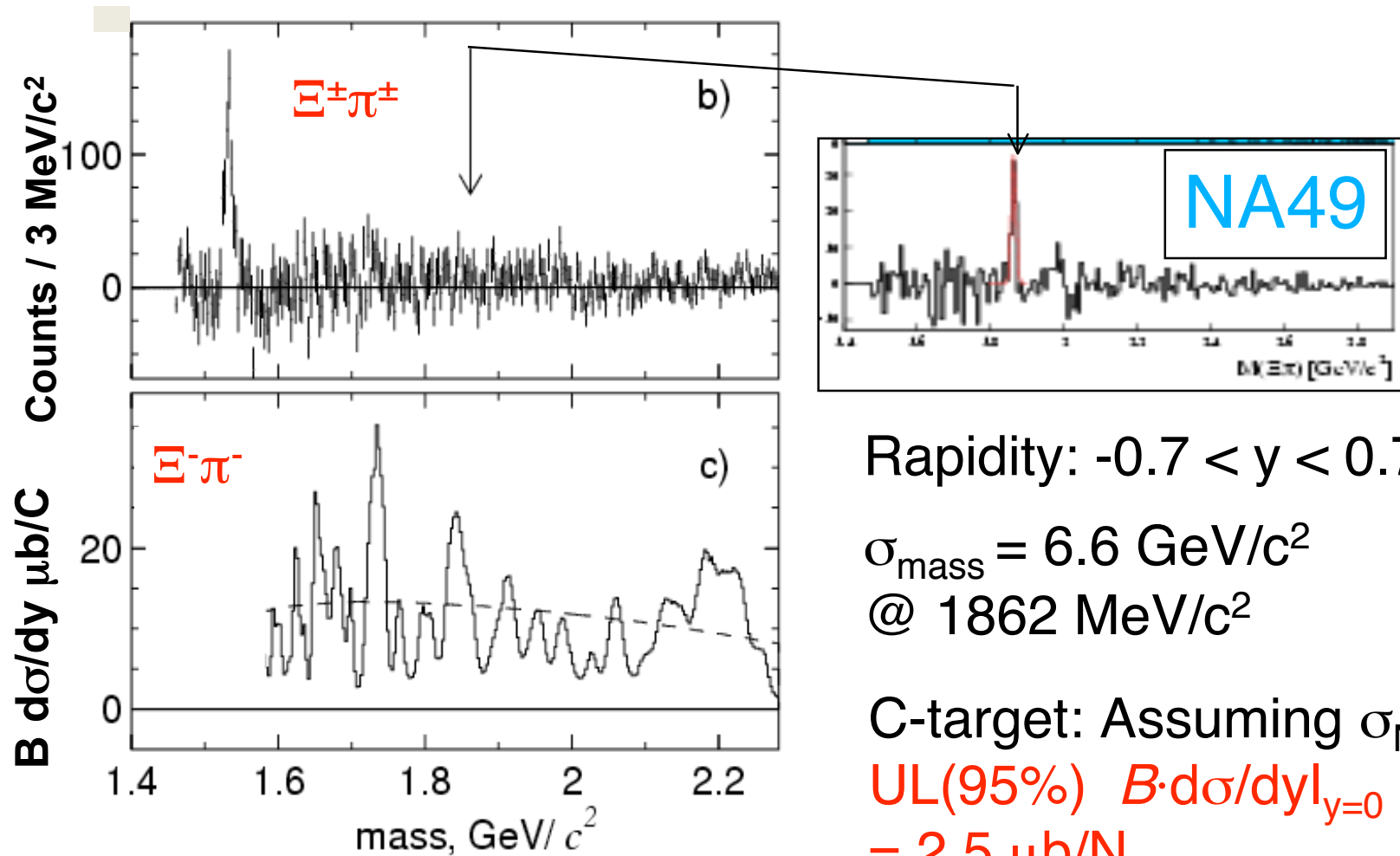
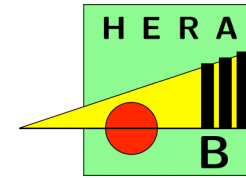


Signal	C Target	All targets	σ MeV/c ²	NA49
K_s^0	2.2M	4.9M	4.9	
Λ	440k / 210k	1.1M / 520k	1.6	
$\Lambda(1520)$	1.3k / 760	3.5k / 2.1k	2.3	
Ξ^-	4.7k / 3.4k	12k / 8.2k	2.6	1.6k / 550
$\Xi(1530)^0$	610 / 380	1.4k / 940	2.9	(150*)

Particle / anti-particle, σ : mass resolution

*H.G.Fischer, S.Wenig hep-ex0401014

$\Xi\pi$ Combined Plot, UL(95%)



Rapidity: $-0.7 < y < 0.7$

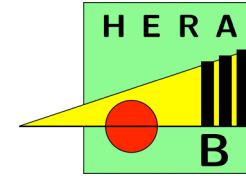
$\sigma_{\text{mass}} = 6.6 \text{ GeV}/c^2$
 @ $1862 \text{ MeV}/c^2$

C-target: Assuming $\sigma_N \propto A^{0.7}$

**UL(95%) $B \cdot d\sigma/dy|_{y=0}$
 = $2.5 \mu\text{b}/N$**

@ $m(\Xi\pi) = 1862 \text{ MeV}/c^2$

Summary: $\Xi^{\pm\pm}(1862) \rightarrow \Xi^{\pm} \pi^{\pm}$



a) Assuming $\sigma_N \propto A^{0.7}$, UL(95%) $B \cdot d\sigma/dy|_{y=0} =$

pC: 2.5 ($\Xi^-\pi^-$), 2.3 ($\Xi^-\pi^+$), 0.85 ($\Xi^+\pi^+$), 3.1 ($\Xi^+\pi^-$) $\mu\text{b}/\text{N}$

pAll: 2.7 ($\Xi^-\pi^-$), 3.2 ($\Xi^-\pi^+$), 0.94 ($\Xi^+\pi^+$), 3.1 ($\Xi^+\pi^-$) $\mu\text{b}/\text{N}$

b) Upper limits on the relative yield at mid-rapidity (95% C.L.)

$$B \cdot \Xi^-(1862) / \Xi^- < 0.03$$

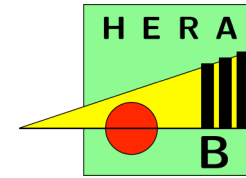
$$B \cdot \Xi^-(1862) / \Xi^0(1530) < 0.04$$

NA49 result (pp at $\sqrt{s} = 17$ GeV):

$$B \cdot \Xi^-(1862) / \Xi^0(1530) \approx 0.18$$

Using $N(\Xi^0)$ from hep-ex/0401014, Ξ^- / Ξ^0 eff ratio = HERA-B

Summary: $\Xi^{--}(1862) \rightarrow \Xi^- \pi^-$



Reaction	\sqrt{s} GeV	Ξ^{--} / Ξ^- (%)	$\Xi^{--} / \Xi(1530)^0$ (%)	Source
pA, $y \approx 0$	42	$<3/B$	$<4/B$	HERA-B
ep	320		$<29/B$ no accep. correction	ZEUS
$p\bar{p}$	1960		$<4/B$	CDF
pp	20/40	2.5/3.6		F.M. Liu et al.
AA	20	0.4 -- 1		J. Letessier et al.
AA	40	0.4 -- 1		J. Letessier et al.
pp	17		$\approx 18/B$	J. Kadija* (NA49)