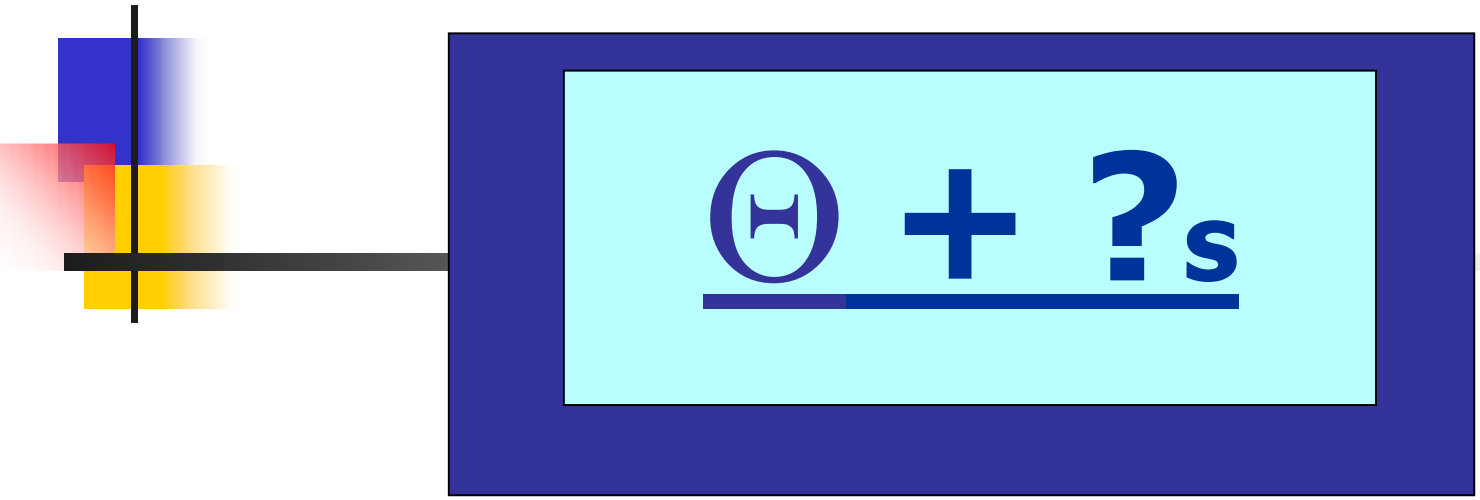
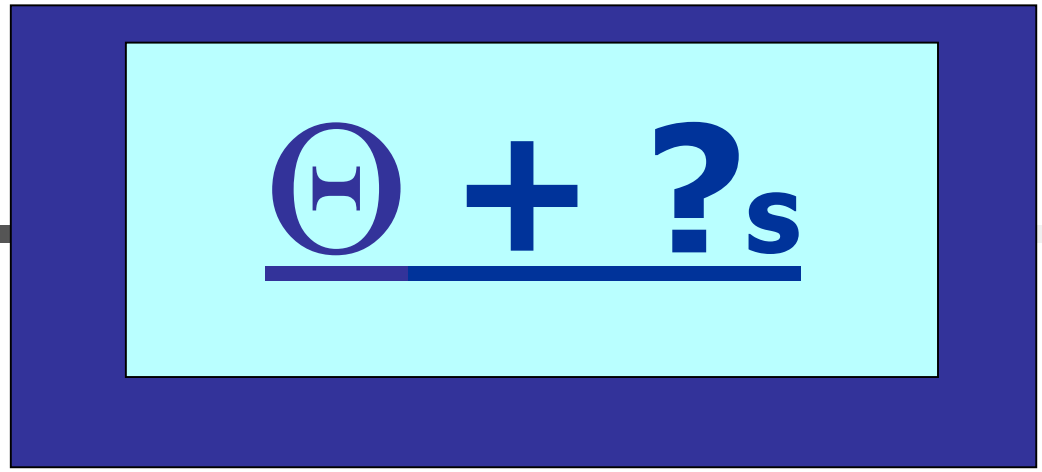


Thomas S. Bauer - NIKHEF



Some questions and critical remarks to the recently reported exotic states:

$$\Theta^{+} = \{ u\, u\, d\, d\, \bar{s} \} \text{ at } 1.540 \text{ GeV}$$

and

$$\Xi^{--} = \{ \bar{u}\, d\, d\, s\, s \} \text{ at } 1.862 \text{ GeV}.$$

discussion of some of the experiments;

consistency;

comparison with older data.

Present experimental status

- several experiments reporting positive results;
- all reported signals are not very strong;
- revisiting an intensively studied domain;

- several critical remarks published;
- questions on consistency with existing data;
- possibly other origins of observed effects.

it is time for a

systematic discussion

of the available data!

List of experiments:

γ	SPring-8 (Japan)	hep-ex/0301020	08 Jul. 2003
γ	CLAS (TJLab)	hep-ex/0307018	10 Dec. 2003
γ	SAPHIR (Bonn)	hep-ex/0307083	30 Sep. 2003
e-scatt.	Hermes (HERA)	hep-ex/0312044	22 Jan. 2004
	ν-data (BEBC and Fermilab)	hep-ex/0309042	25 Sep. 2003
$(K^+ + Xe)$	Diana (ITEP)	hep-ex/0304040	18 Sep. 2003
$(p + A)$	SVD-2 (Protvino)	hep-ex/0401024	22 Ja
$(p + p)$	2004		
	NA49 (CERN)	hep-ex/0310014	8 Oct. 2003
	and others.		

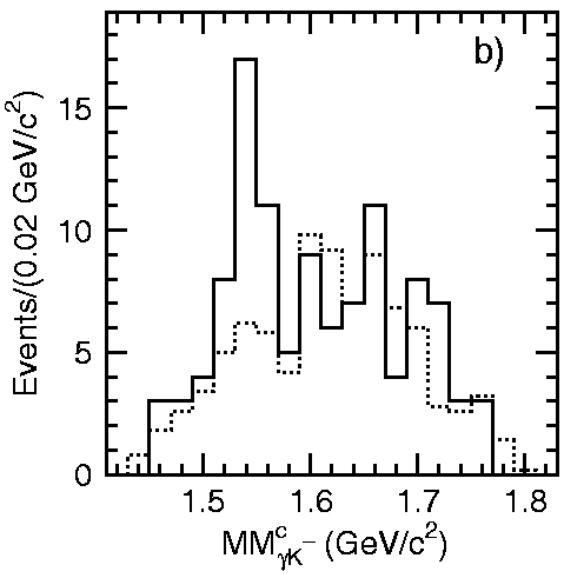
SPring-8 (LEPS) (γ + ^{12}C)

Some salient features:

- new experiment, optimized for ϕ-physics;
- uses real photons from Synchr. Radiation Source;
- E_γ < 2.4 GeV;
- **LH_2** target and **^{12}C** target - only **^{12}C** used;
- PID through ToF and magnetic field;
- recoiling protons via Si-strip detector;
- correction for Fermi-motion.

- new data on D-target.

SPring-8 (LEPS)



first evidence for Θ^+-state;

produced in :

$\gamma + n \rightarrow \Theta^+ + K^-$;

$\Theta^+ \rightarrow K^+ + n$;

used C-target;

19 events in peak.

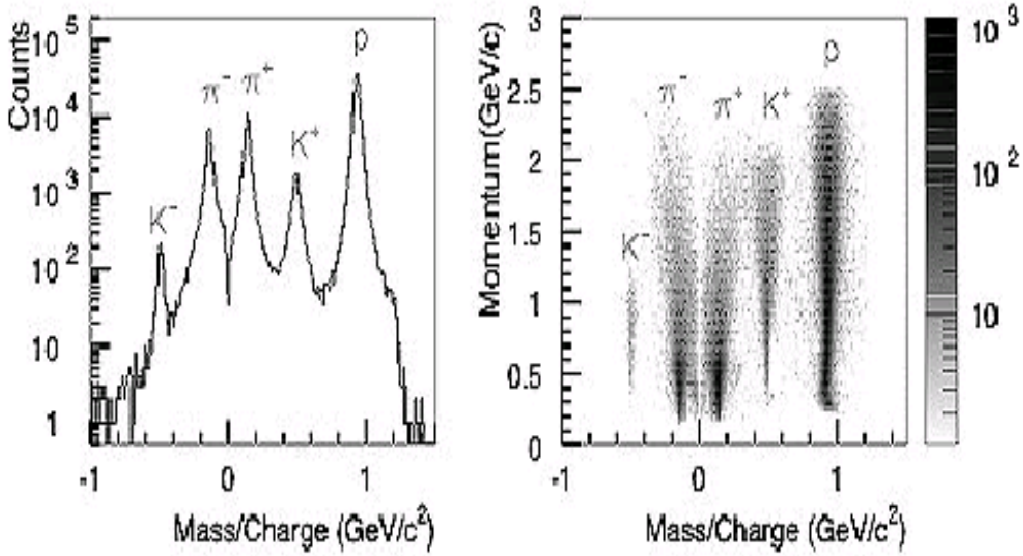
SPring-8 (LEPS)

Particle Identification:

magnetic field

+

Time of Flight



possible problem:

43 * 10^6 triggers

8000 events with K^+ K^-,

final signal = 19 events

need purity of **10^{-6} !!** **(including other cuts)**

SPring-8 (LEPS)

A closer look at Fermi motion:

- due to nuclear target;
- "correlated with Q-value";
- **crucial for final result!**

	$\Lambda \rightarrow n\pi^-$	$\Sigma \rightarrow n\pi^-$	$\Theta \rightarrow n\pi^+$
Q (MeV)	37	120	107
Γ(MeV)	<10	42	~20
p (cms)	104	193	244

However

- measured width of $\Theta^+ \rightarrow n\,K^+$ much smaller than width of Σ !! (20 MeV vs. 42 MeV)

by the way: shouldn't the width rather be correlated to momentum in cms ...? which would make things worse.

SPring-8 (LEPS)

- Identification of Θ^+ state relies heavily on absence of (fast) proton:

- the Si-strip detector is used as VETO --
- this relies crucially on (very) high efficiency.

  (no info on this found in the different SPRING-8 publications).

  (Questions: strip efficiency, coincidence between layers, etc.)

- The Veto condition is checked at ± 45 mm around the presumed impact of the proton.
- this requires knowledge of the complete kinematics – *which is not available!*

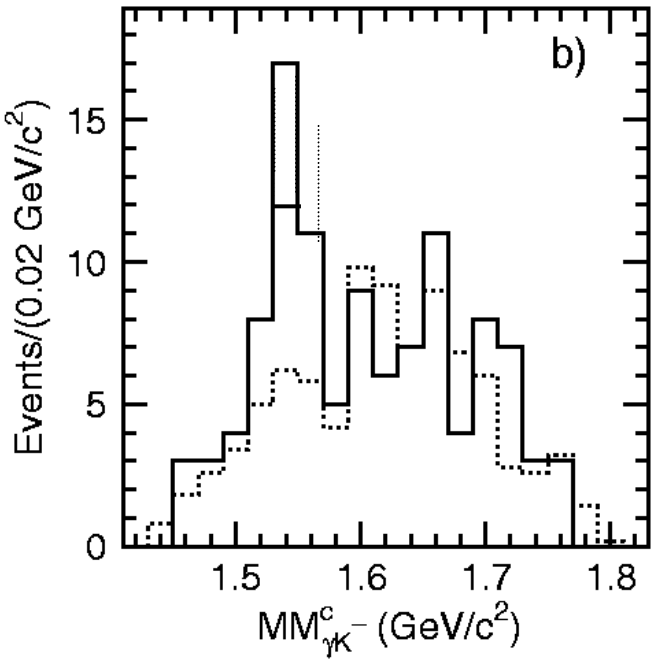
SPring-8 (LEPS)

- Information on production rates:
- though difficult to gauge acceptance and efficiency, SPring-8 finds:

  - total: $43 * 10^6$ events,
  - ϕ: ~1500
  - Λ_{1520} : ~ **35**
  - Θ^+: **19**

SPring-8 (LEPS)

Question:
“removing” 5 events destroys peak.



(from Nakano et al.)

Note: SPring-8/LEPS can (most likely) trigger on pions of K^0_s decay.

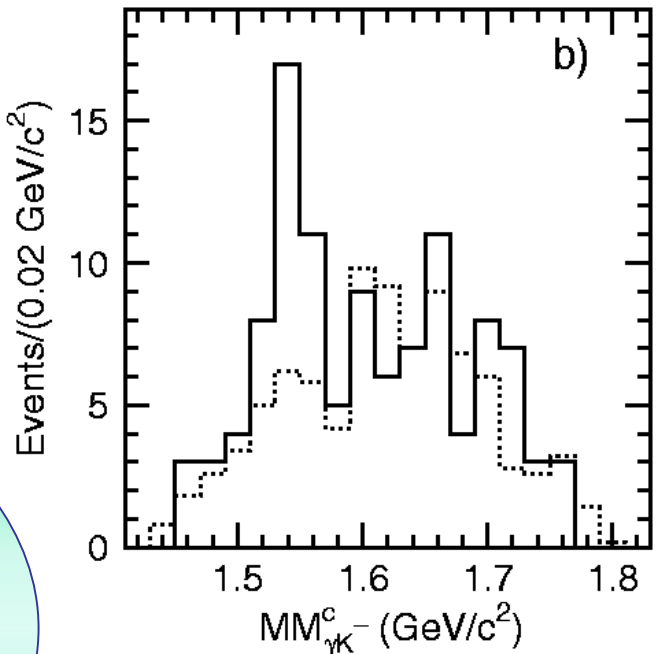
SPring-8 (LEPS)

Question:
"removing" 5 events destroys peak.
Thus: how can we gain trust in result ?

- **Answer:**

Use data on LH_2:

- **must be able to see $\Theta^+ \rightarrow p + K^0_s$;**
- **no problem with proton-veto ;**
- **no problem with Fermi-motion.**



(from Nakano et al.)

Note: SPring-8/LEPS can (most likely) trigger on pions of K^0_s decay.

CLAS (γ + ^{2}D, γ + ^{1}H)

Some salient features:

- Large acceptance experiment, several years of operation;
- domain: Baryon resonances;
- E_γ < 2.9 GeV and < 5 GeV , (respectively)
- **H_2** target and **^{2}D** target ;
- PID through ToF and magnetic field;
- Correction for Fermi-motion (when needed).

CLAS

- attempt:

  analyze D-target data, assuming $\gamma + n \rightarrow \Theta^+ + K^-$,

  Fermi correction treated as by SPring-8 collaboration:

- Problem:

  "No statistical significant result obtained!"

  and

  "CLAS ... unfavorable... for direct Θ^+ photoproduction detection"

  (Luminita Todor, Seminar@JLAB, Aug. 15, 2003)

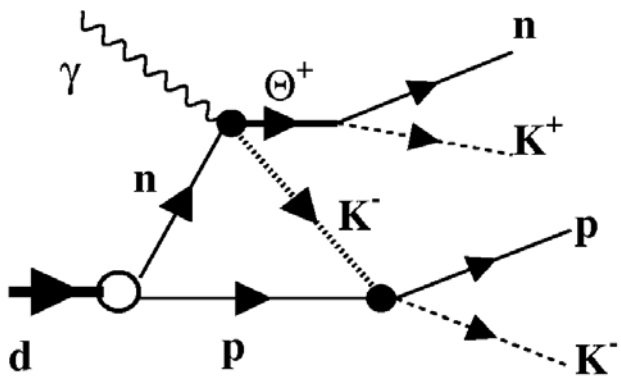
- --- how to proceed ???

CLAS

Goal: $n + \gamma \rightarrow \Theta^+ + K^-$;

Problem: no free neutron target ;

- **apply trick :**
  - **use n in D-target;**
  - **require double scattering process to eject proton;**



measurement kinematically complete

CLAS

- Prize for re-scattering:

  yield goes down.

  (claim CLAS: "~50 %")

- reported yields:

  ϕ: 124

  Λ_{1520} : 228

  Θ^{+}: 42

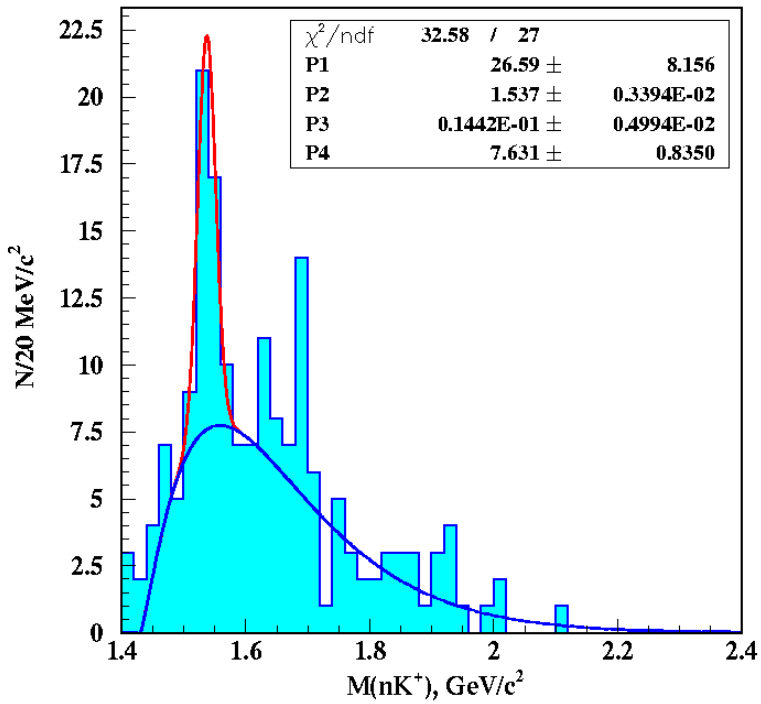
  Attention: difficult to compare:

  - acceptances not known, presumably not equal.
  - yield Θ / yield $\Lambda \approx 0.4$ – perhaps even larger

- Need Monte Carlo in order to detemine acceptance and cross section.

CLAS

- Production on H:
- $\gamma + p \rightarrow \Theta^+ + K^*$
  $\rightarrow \pi^+ + K^+ + K^- + n$
- find a total of 27 events...
- several cuts applied



SAPHIR (Elsa-Bonn) (γ + ^{1}H)

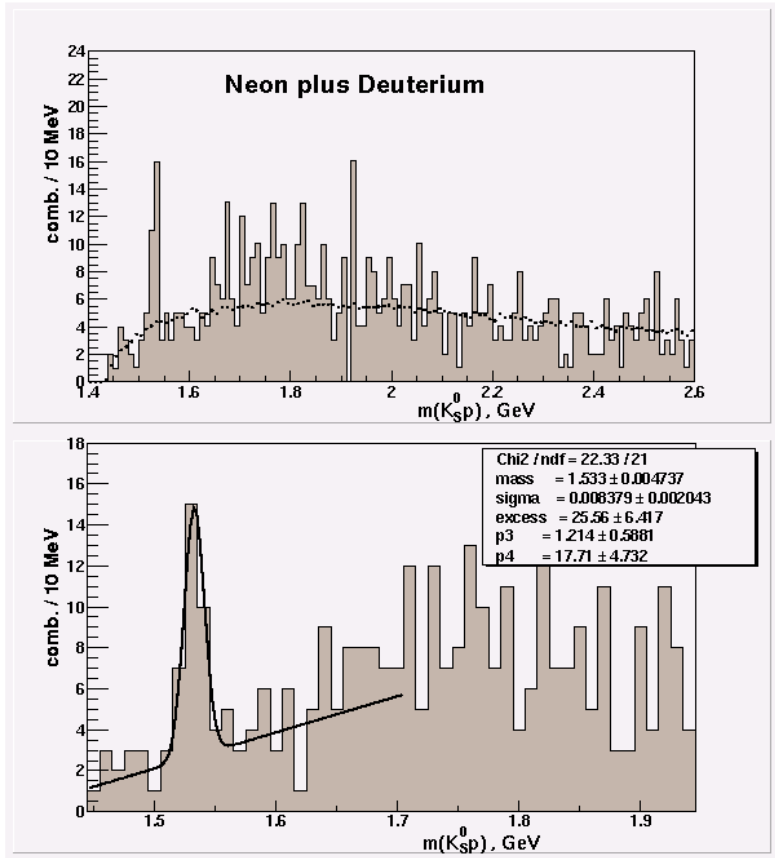
- 133 M events (taken ~5 years ago)
- trigger = 2 charged tracks

- signal: ~ 50 events
- corresponds to production
  cross section of $\sigma \sim 200$ nb.

- this is ≈ 20 % of Λ, Σ and Λ_{1520} cross sections
- rising with energy.
- but decreasing with time . . .

Neutrino's (reanalysis)

- reanalysis of BEBC and Fermilab database
  (Asratyan, Dolgolenko and Kubantsev)
- 120 000 ν_μ induced events used
- measured in BEBC and Fermilab 15' chamber
- signal: ~ 27 events over small background.
- largest significance claimed:
  $\sigma \approx 6.7$ (27 ± 8 events)



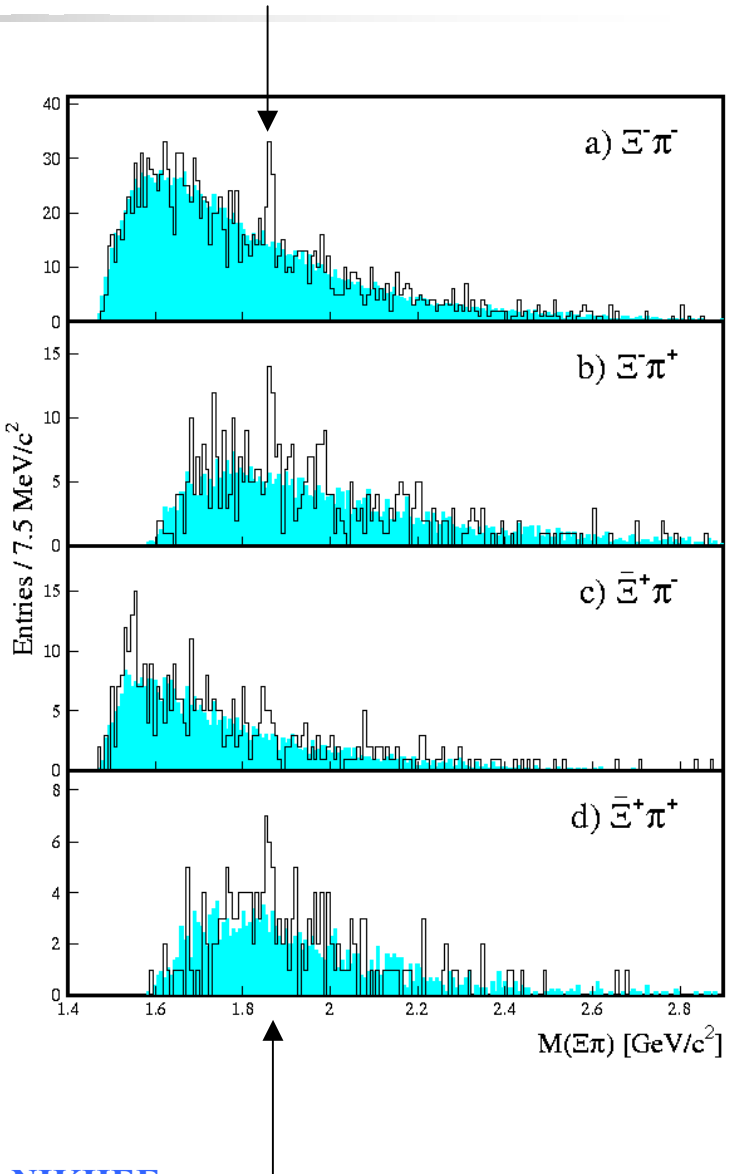
Ξ^{--} another member of the anti-decuplet...

$\Theta^{+} = \{ u\ u\ d\ \bar{d}\ s \}$ at 1.540 GeV

- $\Xi^{--} = \{ \bar{u}\ d\ d\ s\ s \}$.

NA49 (p-p, √ s = 17 GeV)

- p-p scattering at √ s = 17 GeV
- signals for Ξ^{--} :
  - combining Ξ^- and π^-
  - cross check with other charge combinations.
- can use Ξ^{0*}_{1530} as benchmark.



NA49

Remarks:

- Vertex resolution : $\sigma \sim 56\ \mu m$ (transv).*)
  - Vertex cut: ± 0.5 (x) and ± 1.5 (y) cm !!
- opening angle $\Theta_{lab} > 4.5\ ^{o}$
  - note: Θ_{lab} is not a physical parameter
- Ξ^{*0}_{1530} visible, but weaker than Ξ^{-} (1860)
  - (might be due to some cuts...)

***) taken from NA49 detector publication.**

NA49

- Criticism:

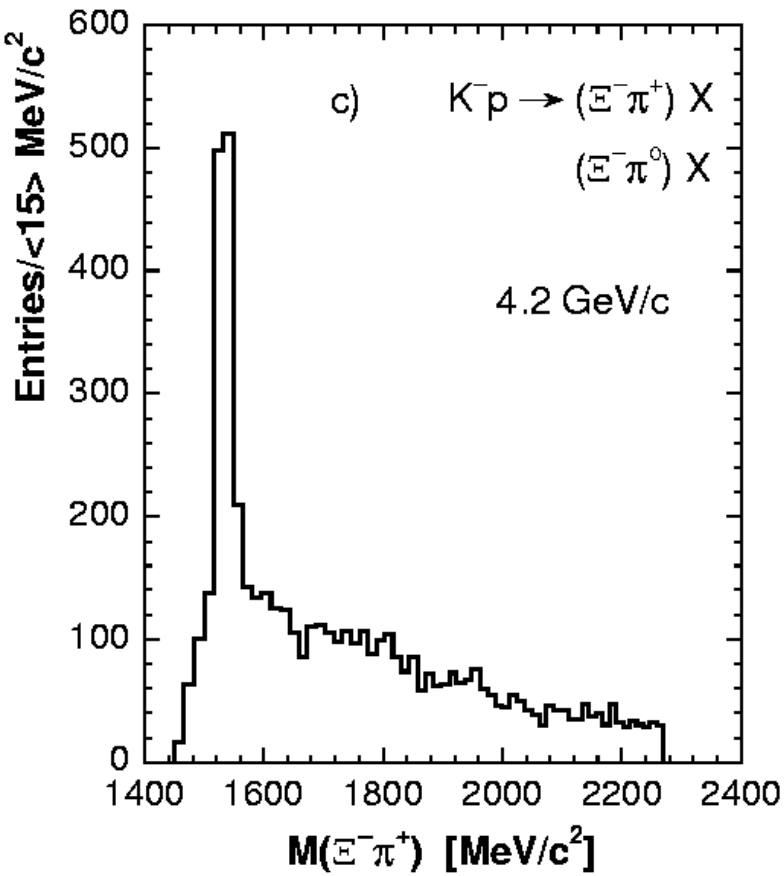
  (Thanks to H.G. Fischer and S. Wenig, CERN, hep-ex/0401014 – 12 Jan 2004)

- NA49 used 1640 Ξ^- and 551 Ξ^+ events
- NA49 sees a total of

  $\sim 150\ \Xi^{*0}_{1530}$

- S.N. Gangule et al. (NP. B128-408, (1977) report

  $\sim 800\ \Xi^{*0}_{1530}$

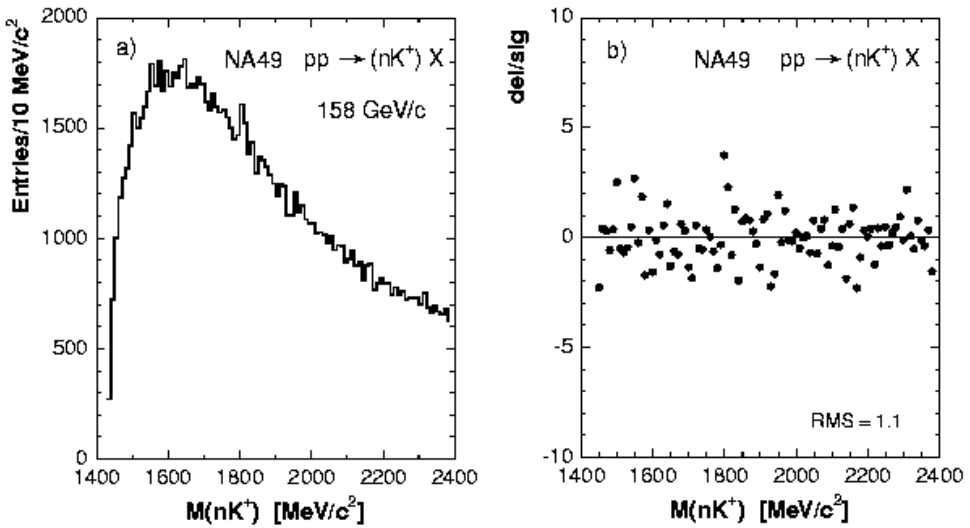


from S.N. Gangule et al. Nucl.Phys. B128, 408, (1977)

NA49 $\Theta^+ \rightarrow nK^+$

a) nK^+ inv. mass spectrum;

b) deviation from polynomial;



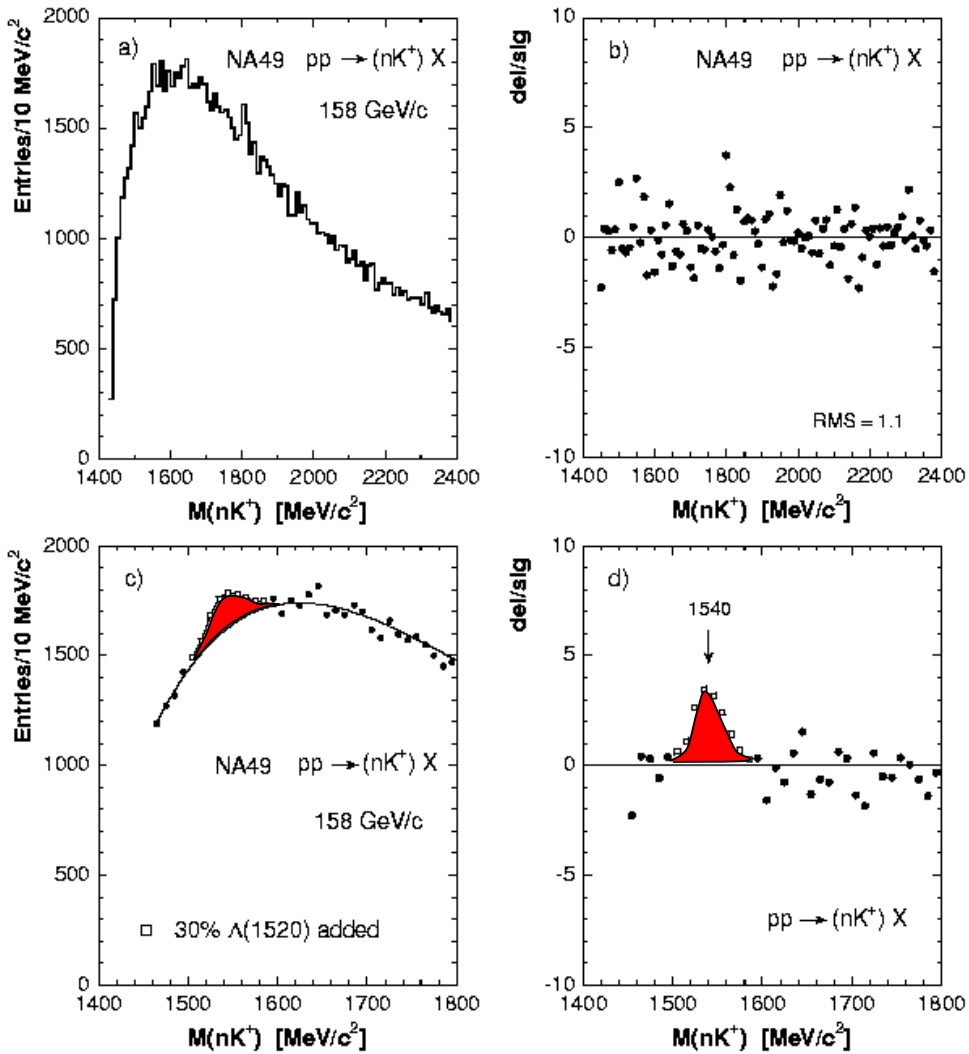
NA49 $\Theta^+ \rightarrow nK^+$

a) nK^+ inv. mass spectrum;

b) deviation from polynomial;

c) 30 % of Λ_{1520} added as a hypothetical Θ^+ ;

d) statistical significance of added signal.



note different E-scale!

other work

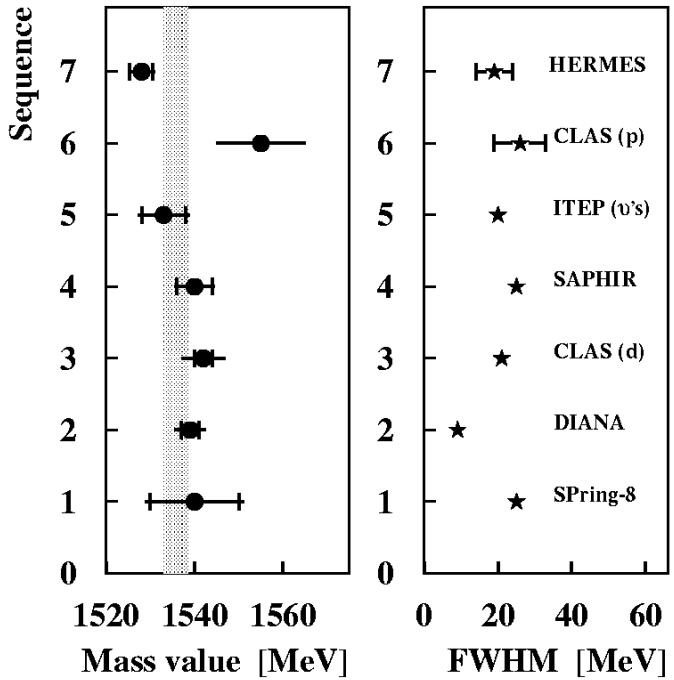
- R. A. Arndt, I.I. Strakovsky and R.L. Workman:
  (nucl-th/0311030, 10 Nov. 2003)
  - reexamine existing K^+p and K^+d database;
  - "how could such a state have been missed"?
  - "The lack of structure in database implies:
- " **a width of an MeV or less , assuming a state exists near 1540 MeV**."

Masses

The reported masses do not agree perfectly, but differences are at present not yet a real point of worry.

A comparison with other masses , especially Λ_{1520}, would be very helpful, but is not available from the publications.

Note: new result from Zeus!



from Hermes publication

Yields and σ (taken from publications)

	Θ^+	σ	φ	Λ(1520)
SPring-8	**19 ± 2.8**	**4.6**	≈ 1500	≈ 35
CLAS-d	**43 ± ?**	**5.8**	≈ 126	≈ 212
CLAS-p	**27 ± 8**	**4.8**	--	--
SAPHIR	**63 ± 13**	**4.8**	--	530 ± 90
Neutrino	**27 ± 8**	**6.7**	--	--
Diana	**27 ± ?**	**4.4**	--	--
Hermes	**≈ 70 ± 18**	**≈ 4**	?	? (≈ 400)
SVD-2	**~ 50 ± ?**	**≈ 5.6**		
			Ξ^{--}	σ
NA49	**no signal !**		**36 ± 6 ?**	**5.6**

Summary -- *start to conclude, at least*

- by now, >8 experiments claim positive signals;
- **all signals are weak:**
  - **<< 100 events;**
  - **σ between ~ 3 and 6** or 7 *(could be discussed)*

  BUT
- **yield close to Λ_{1520}** (except for SAPHIR)

  -- this is contradiction to above – many expts. in Lit. with good Λ_{1520} yields!
- claims not confirmed by earlier experiments
  - ***strange, since strangeness long and intensively studied ...***
  - ***and some of them have much higher statistics ...***
  - ***and partially in straight discrepancy.***

Some contradictions:

- Ξ^{--} in Na49 not confirmed;
- NA49 does not confirm Θ^{+} ;
- Width:
  - Zeus vs Diana; 25 MeV vs <9 MeV;
  - Arndt et al: <~ 1 MeV;
- $\sigma(\Lambda_{1520}) \sim 10\, \sigma(\Theta^{+})$;
  - But many expts with LARGE Λ_{1520} yield!
    - → *talk of Antonello Sbrizzi tomorrow*
- Cosy vs SAPHIR: 0.4 μb vs 0.2 μb;

On the other side:

- new data from Spring-8 on D look promising;
- new data expected soon from CLAS;
- many experiments (seem to) see small signals;
- … more which we don't know yet?

a way out ??

- Needed: *(dead or alive!)* predictions of
  - spin, width,
  - production cross sections:

    as function of :
    - probe (real or virtual photon, hadrons, ν, ...)
    - energy (2 GeV at SPring-8 ... 40 (320) GeV
    - ...
- good experimental info about production ratios wrt. known states
  - such as:
    - Λ_{1520}, , Ξ^-_{1530}, ...

finally

- What about the width???
- How can a state at this energy be so narrow??

finally

- What about the width???
- How can a state at this energy be so narrow??

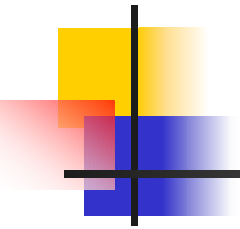
An experimentalist's prediction:

finally

- What about the width???
- How can a state at this energy be so narrow??

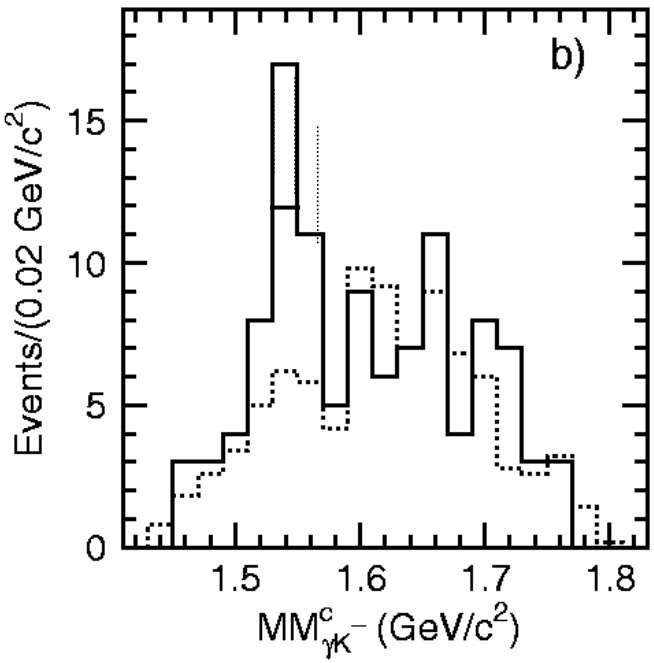
An experimentalist's prediction:

$$\Gamma \geq 10^{-22}\ \text{eV}$$



finally...

SPring-8 (LEPS)

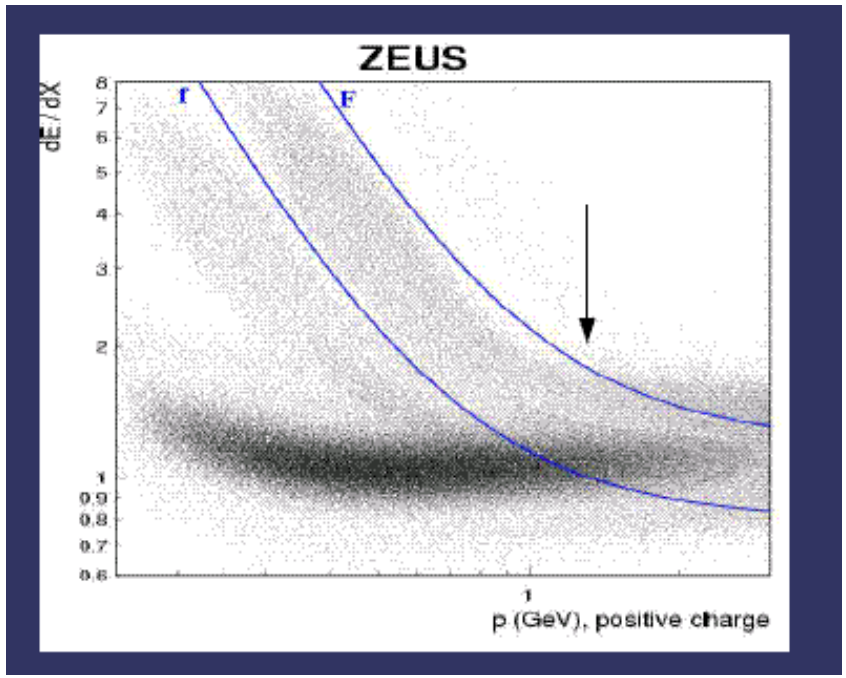


ZEUS (HERA)

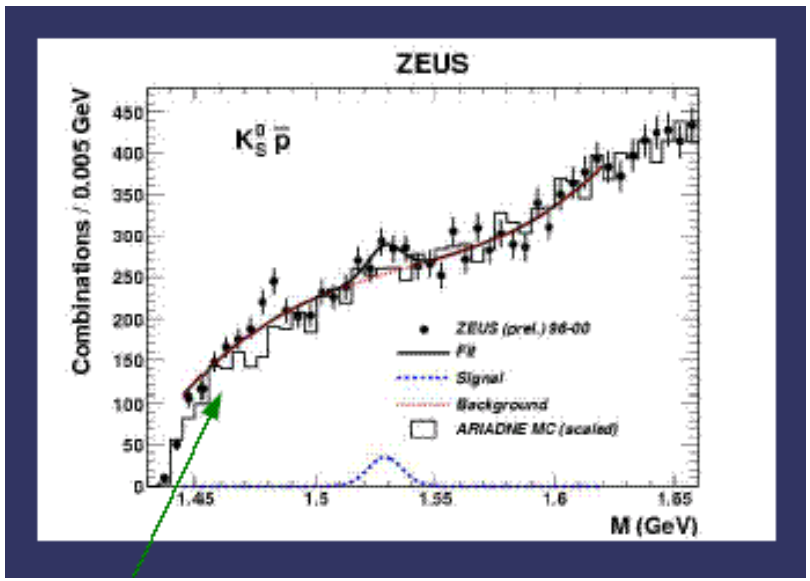
Highest energy of all experiments in list (320 GeV)
(but useful energy ≈ 10 GeV)

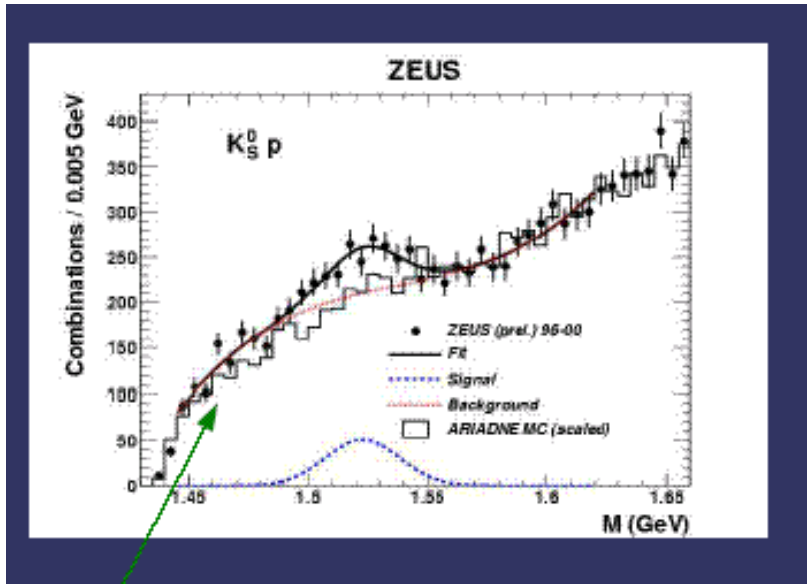
analysis p-K^0 channel

p-identification through dE/dx implying
p-momentum < 1.3 GeV (!)



ZEUS (HERA)





- **anti-p channel << p-channel;**
- **Sum of 2 channels < p-channel ...**