Status of pentaquarks

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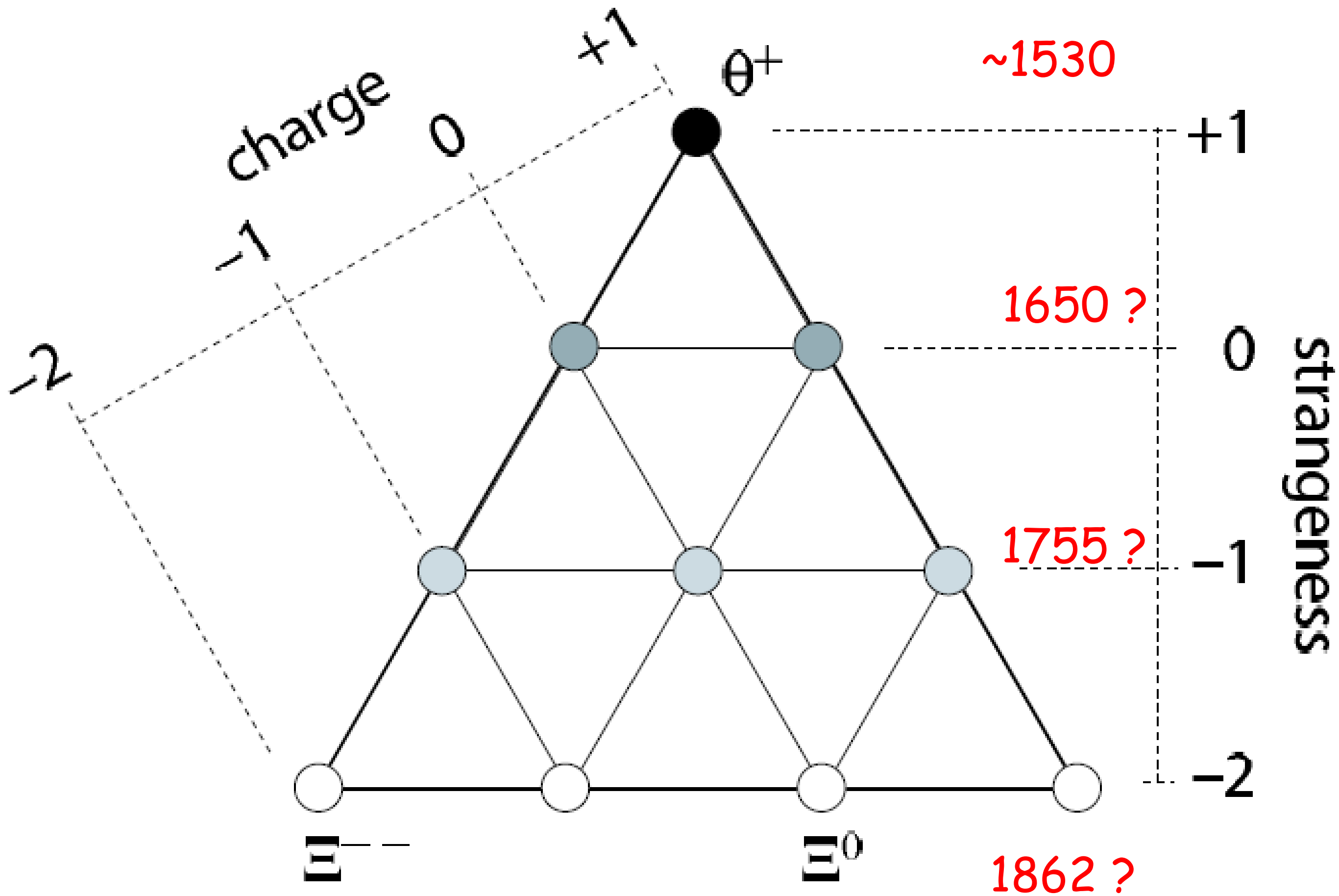
Uniwersytet Jagiellonski

Θ^+: uudd$\bar{s}$



Theoretical predictions

Biedenharn, Dothan (1984):

$\Delta_{10-8} \sim 600$ MeV Skyrme model

MP (1987):

$M_\Theta = 1535$ MeV Skyrme model
in model independent approach,
second order

Diakonov, Petrov, Polyakov (1997):

χQM - model independent approach,
$1/N_c$ corrections $\rightarrow M_\Theta = 1530$ MeV
small width < 15 MeV !

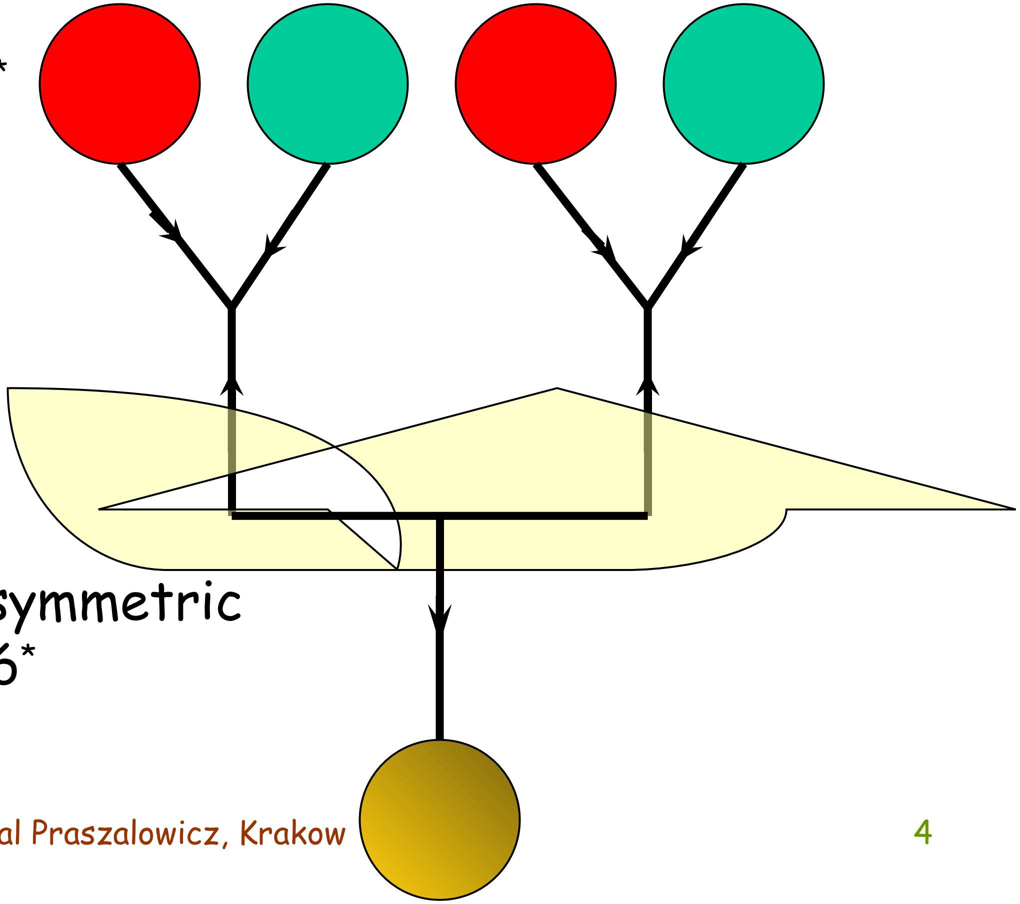
In Chiral Soliton Models quark-antiquark pairs are added as chiral excitations of low mass (pion is massless!) rather than as two constituent *(i.e.* heavy) quarks. Parity +, spin 1/2

Theoretical situation

1. Quark models: require diquark (Jaffe Wilczek), or even triquark correlations (Karliner, Lipkin):

spin 0, flavor 3*

10 and 8

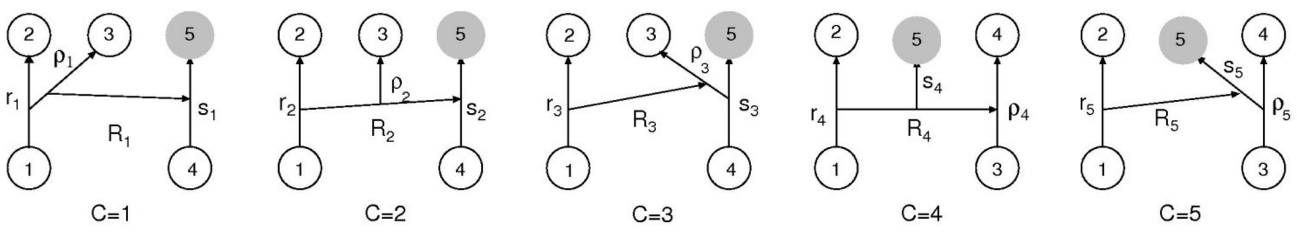


p – wave symmetric
in flavor 6*

Theoretical situation

1. Quark models: require diquark (Jaffe Wilczek), or even triquark correlations (Karliner, Lipkin).

2. „Serious" quark model calculations seem to give negativer results



Theoretical situation

1. Quark models: require diquark (Jaffe Wilczek),
   or even triquark correlations (Karliner, Lipkin).

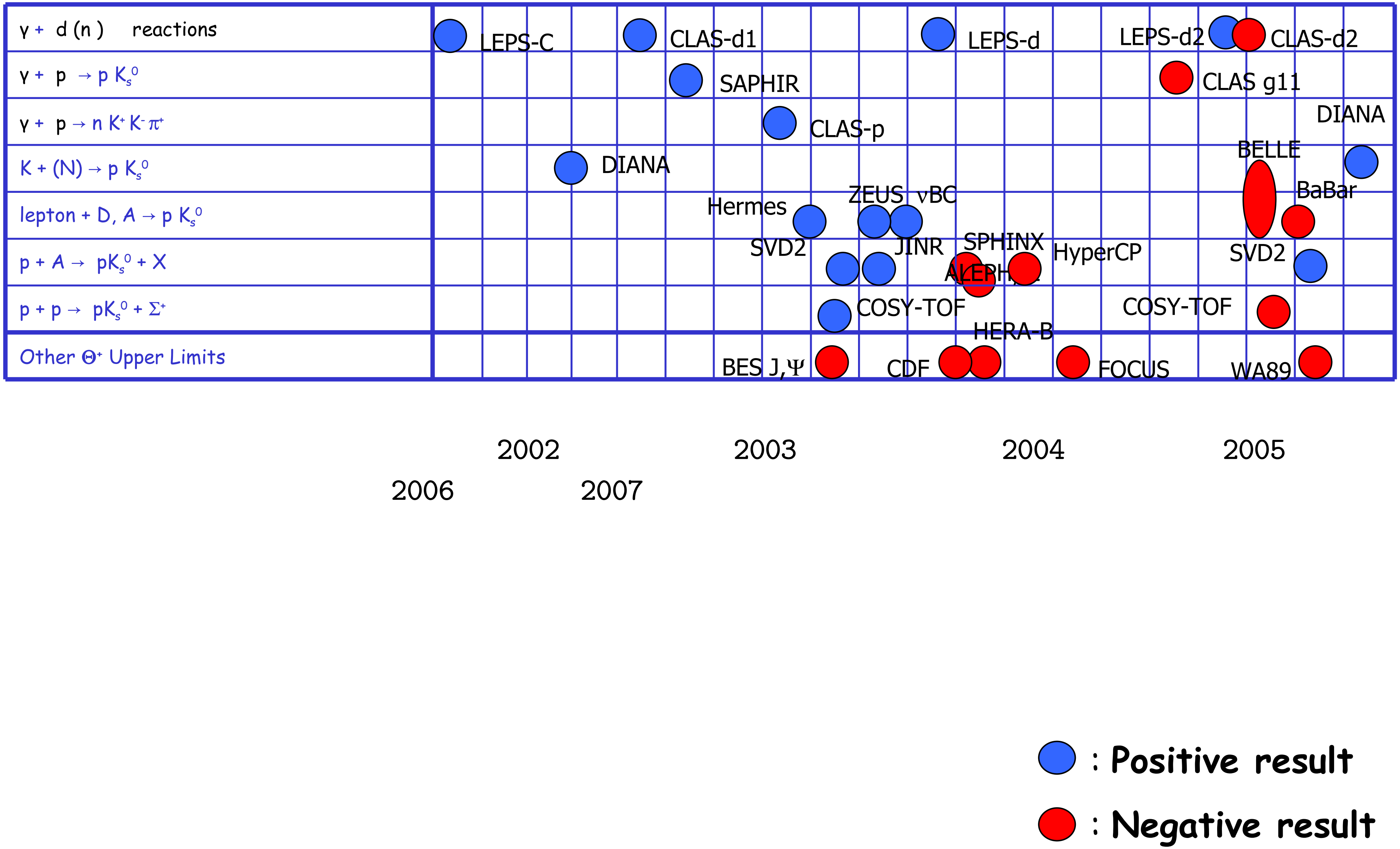
2. „Serious" quark model calculations seem to give
   negativer results

3. Lattice: mixed results, even spin 3/2 possible

4. Sum rules: mixed results

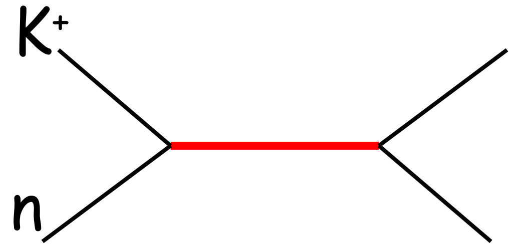
Experimental situation

Time dependent experimental status of Θ^+



Ideal experiment

Formation cross section



Breit-Wigner cross-section (GM + MP)

1/2

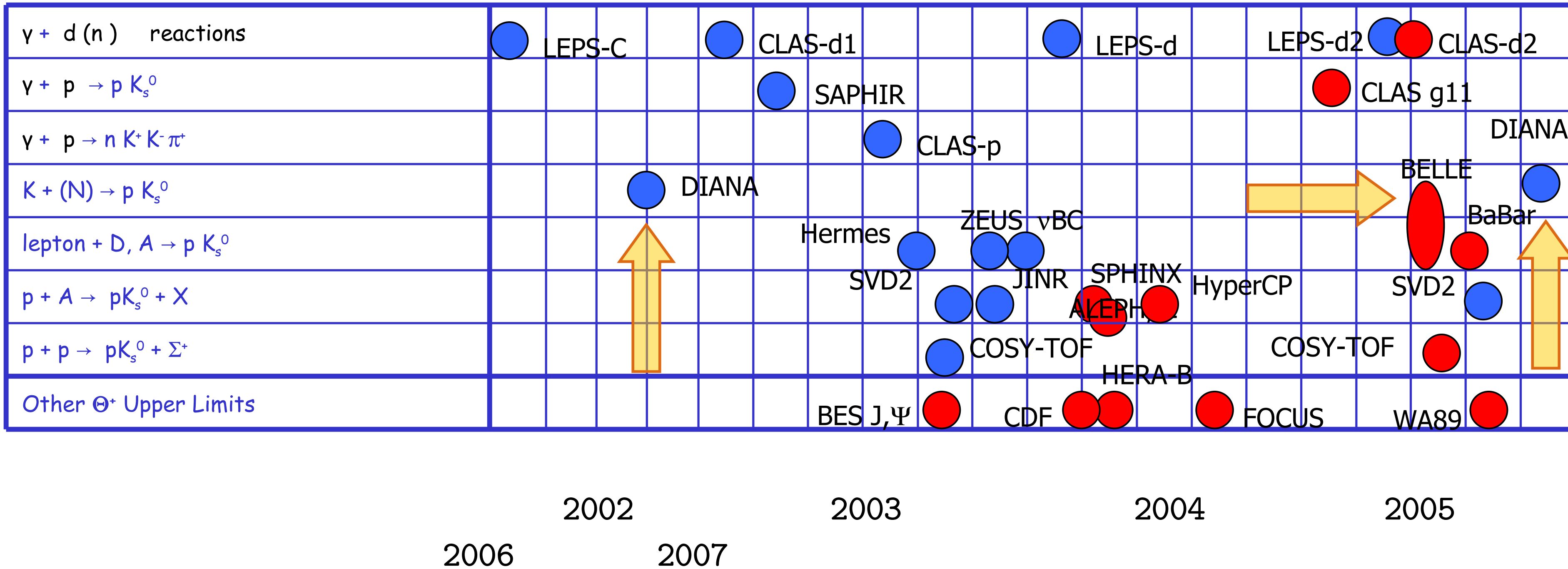
$$\sigma_{BW}(E) = \frac{2J+1}{(2S_1+1)(2S_2+1)}\frac{\pi}{k^2}B_{in}B_{out}\frac{\Gamma^2}{(E-M)^2+\Gamma^2/4}$$

0 1/2 1/2 1/2

$$\sigma_{BW}(M) = \frac{\pi}{k^2} \sim 16.8 \text{ [mb]}$$

$$\sigma_{BW}^{tot} = \frac{\pi}{4k^2}2\pi\Gamma \sim 26.4 \times \frac{\Gamma}{1 \text{ MeV}} \text{ [mb} \times \text{MeV]}$$

Time dependent experimental status of Θ^+



: **Positive result**

: **Negative result**

Phys.Atom.Nucl.70:35-43,2007.

Further evidence for formation of a narrow baryon resonance with positive strangeness in K^+ collisions with Xe nuclei

DIANA Collaboration

V.V. Barmin[a], A.E. Asratyan[a], V.S. Borisov[a], C. Curceanu[b], G.V. Davidenko[a], A.G. Dolgolenko[a,*], C. Guaraldo[b], M.A. Kubantsev[a,c], I.F. Larin[a], V.A. Matveev[a], V.A. Shebanov[a], N.N. Shishov[a], L.I. Sokolov[a], and G.K. Tumanov[a]

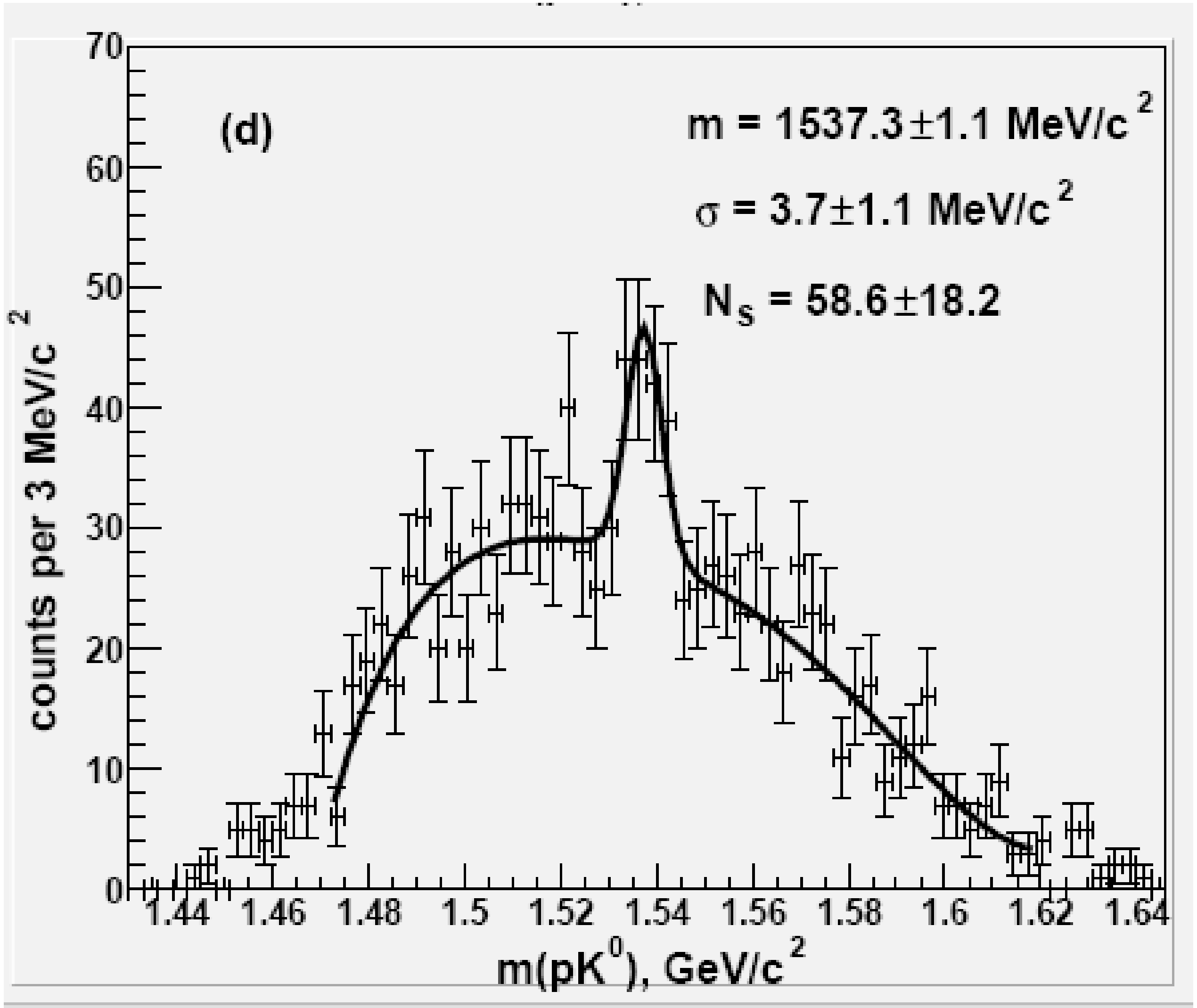
[a] *Institute of Theoretical and Experimental Physics, Moscow 117259, Russia*

[b] *Laboratori Nazionali di Frascati dell' INFN, C.P. 13-I-00044 Frascati, Italy*

[c] *Department of Physics and Astronomy, Northwestern University, Evanston, IL60208, USA*

May 23, 2006

$$K^+ n(\mathrm{Xe}) \rightarrow K^0 p$$



Γ = 0.36 MeV
significance
4.3 to 7.3 sigma

BELLE: secondary kaon beam from D decays interacting with silicon in vertex detecor :

$$\Gamma < 0.64 \text{ MeV}$$

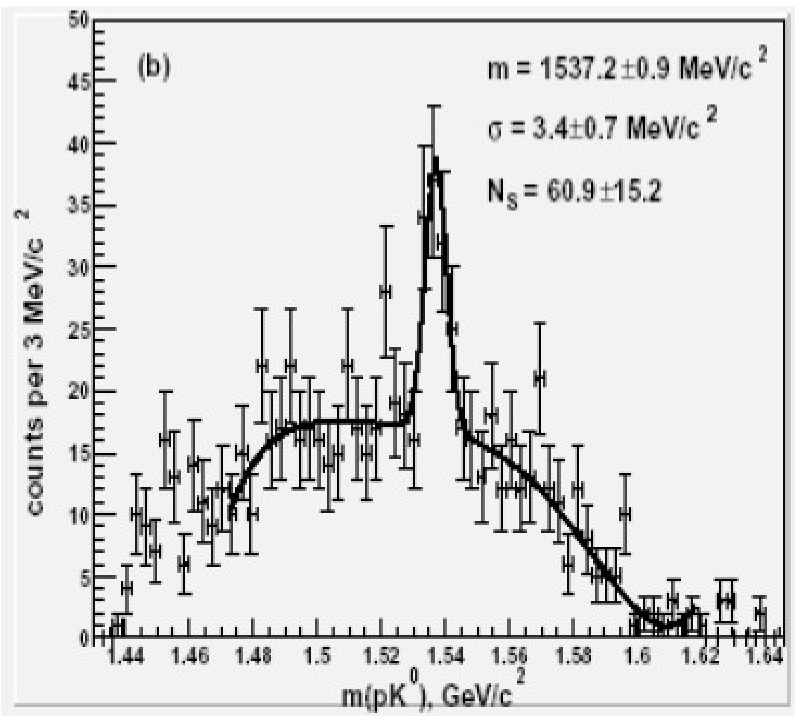
R. Mizuk, Europhysics 2005, Lisbon. July 2005

K^+n Scattering Experiments

DIANA

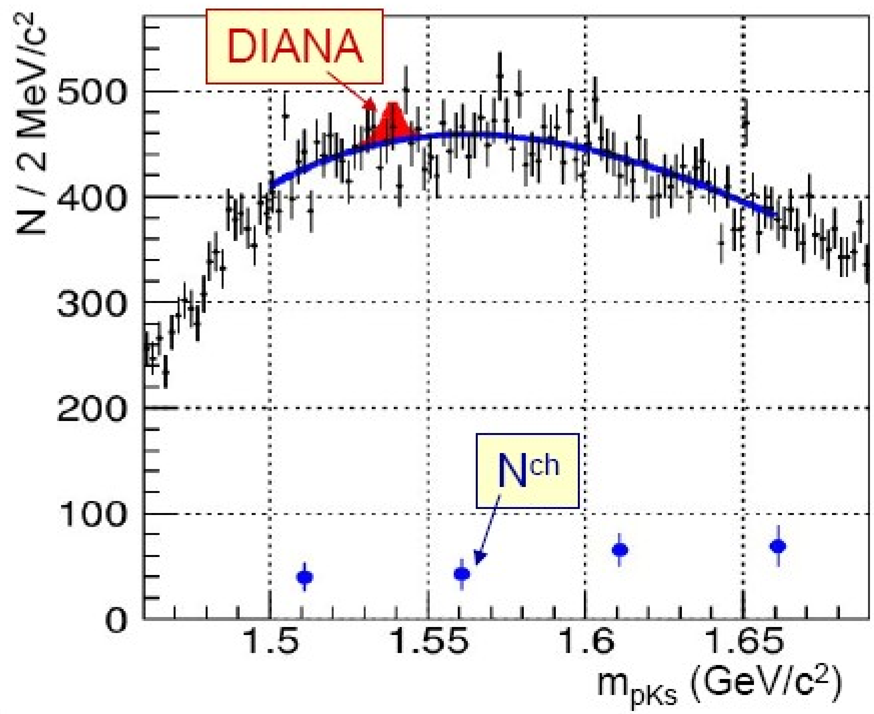
Old bubble chamber experiment

$K^+Xe \rightarrow K_S^0pX$



Belle

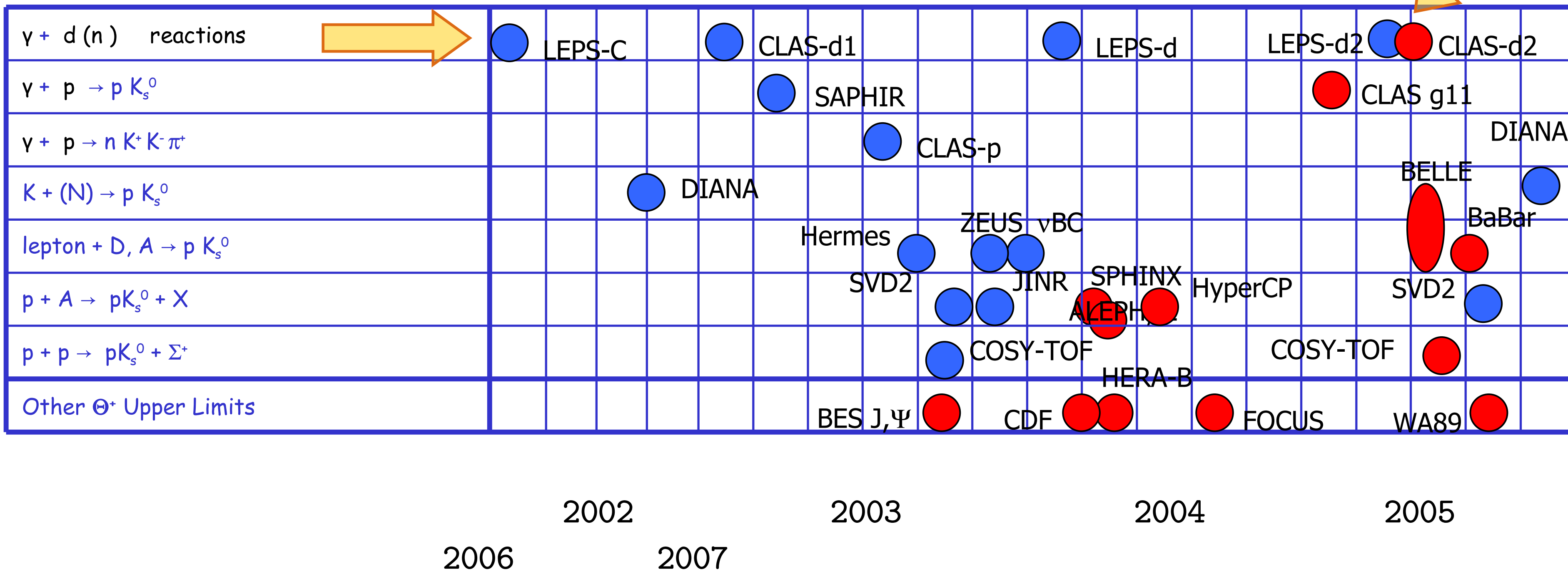
K^+ is 'reconstructed' from the reaction $D^{*-} \rightarrow D^0\pi^- \rightarrow (K^+\pi^-)\pi^-$



Need a modern experiment with high intensity K^+ beam at J-PARC

Possible resolution by K^+ nucleus formation experiment at J-Parc (if submitted and accepted)

Time dependent experimental status of Θ^+



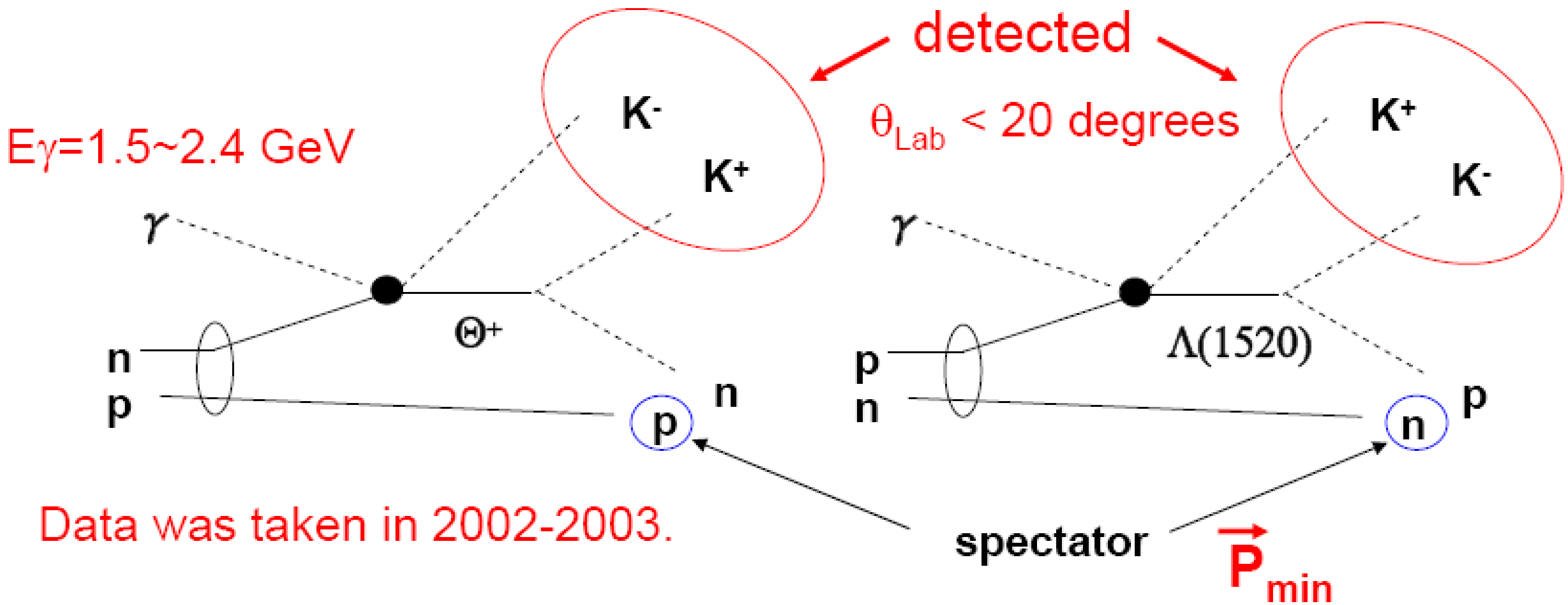
positive result from LEPS (Japan) remains

: **Positive result**

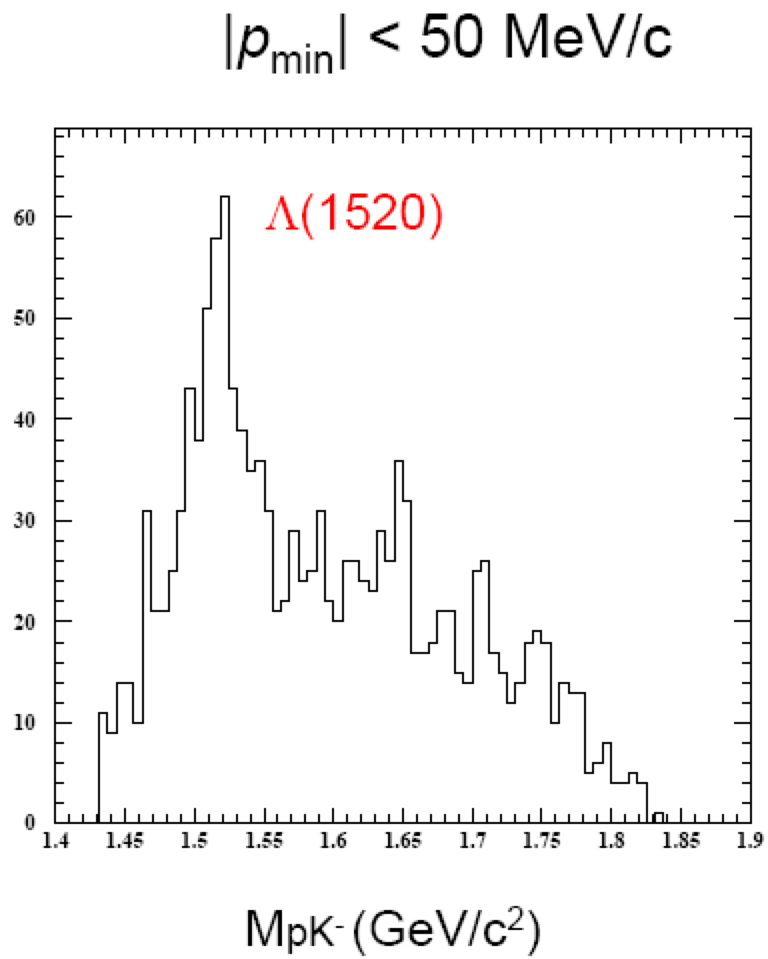
: **Negative result**

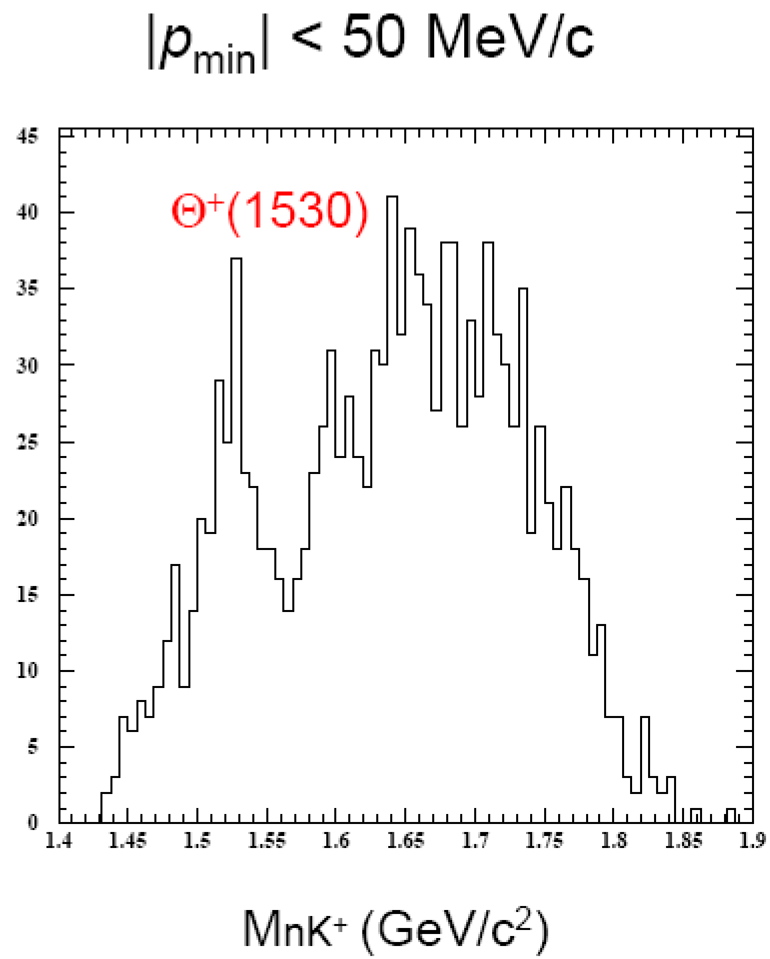
T. Nakano (Osaka)

Θ^+ search at LEPS/SPring-8



Data was taken in 2002-2003.





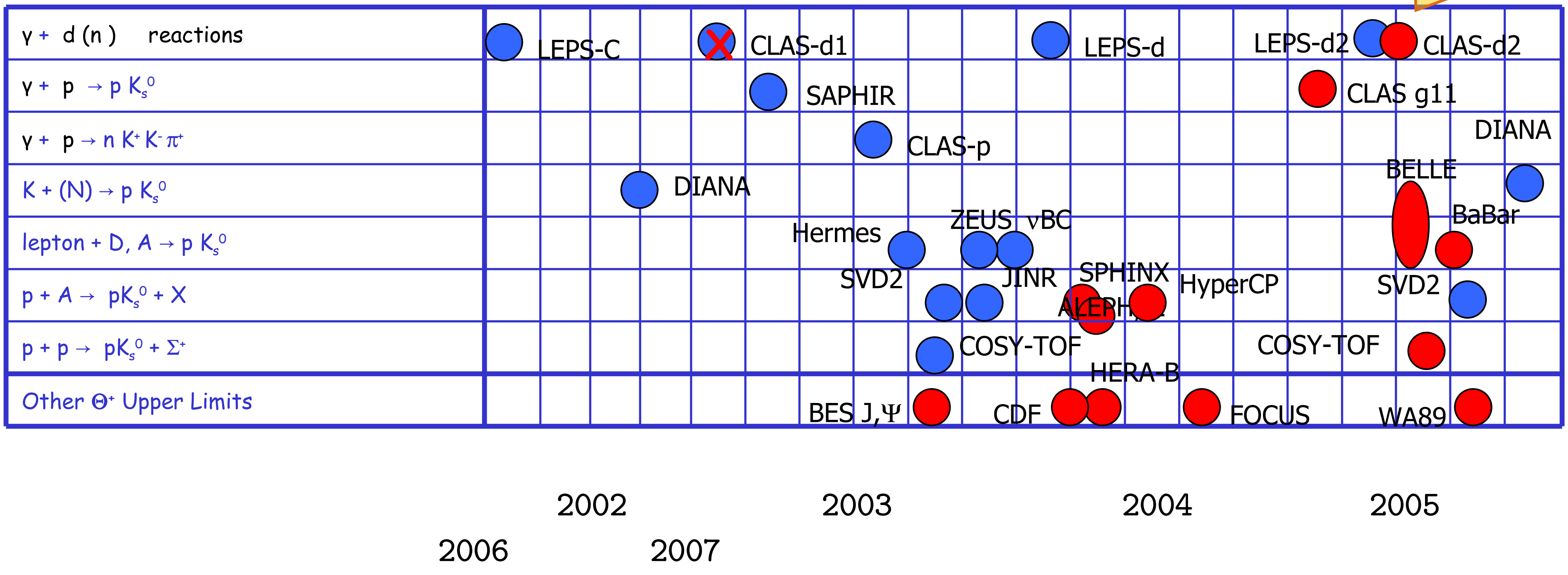
- Significance is estimated by dividing the Gaussian peak height by its uncertainty. Estimated significance is ~5.

Don't miss on Monday

arXiv:0812.1035v1 [nucl-ex] 4 Dec 2008

by the LEPS group!

Time dependent experimental status of Θ^+



negative results from CLAS high statistics d run
contradicts previous CLAS analysis
and contradicts LEPS

: Positive result

: Negative result

The reaction is the same: $\gamma n \rightarrow K^-\Theta^+$

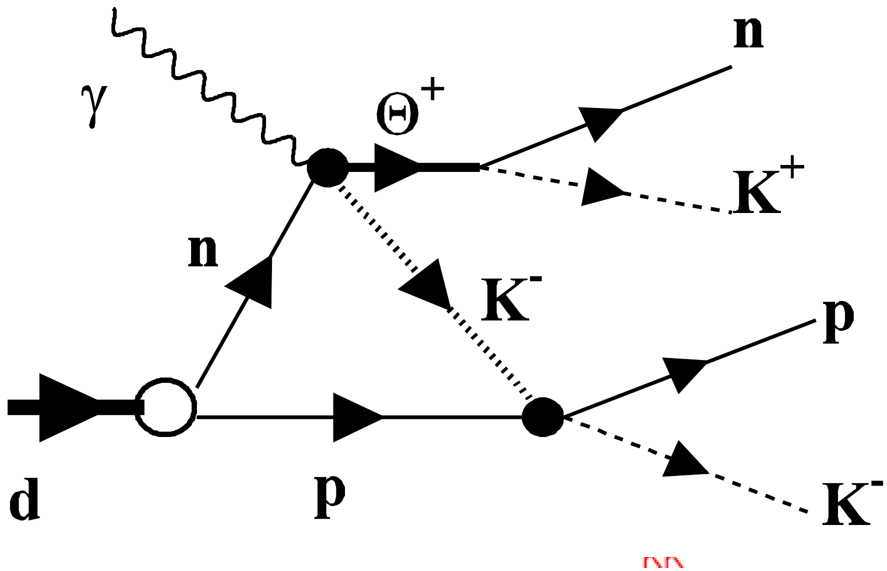
LEPS		CLAS
Good forward angle coverage	⟷	Poor forward angle coverage
Poor wide angle coverage	⟷	Good wide angle coverage
Low energy	⟷	Medium energy
Symmetric acceptance for K^+ and K^-	⟷	Asymmetric acceptance
$M_{KK} \gtrsim 1.04$ GeV/c^2	⟷	$M_{KK} > 1.07$ GeV/c^2
Select quasi-free process	⟷	Require re-scattering or large Fermi momentum of a spectator

LEPS: $\theta_{LAB} < 20$ degree $|t| < 0.6$ GeV^2

CLAS: $\theta_{LAB} > 20$ degree

Θ^+ might be a soft object.

The reaction is the same: $\gamma n \rightarrow K^- \Theta^+$



CLAS

Good forward … ngle coverage

Poor wide ang … gle coverage

Low energy … y

Symmetric acc … ceptance

$M_{KK} \gtrsim 1.04$ GeV … V/c^2

Select quasi-free process ⟷ Require re-scattering or large Fermi momentum of a spectator

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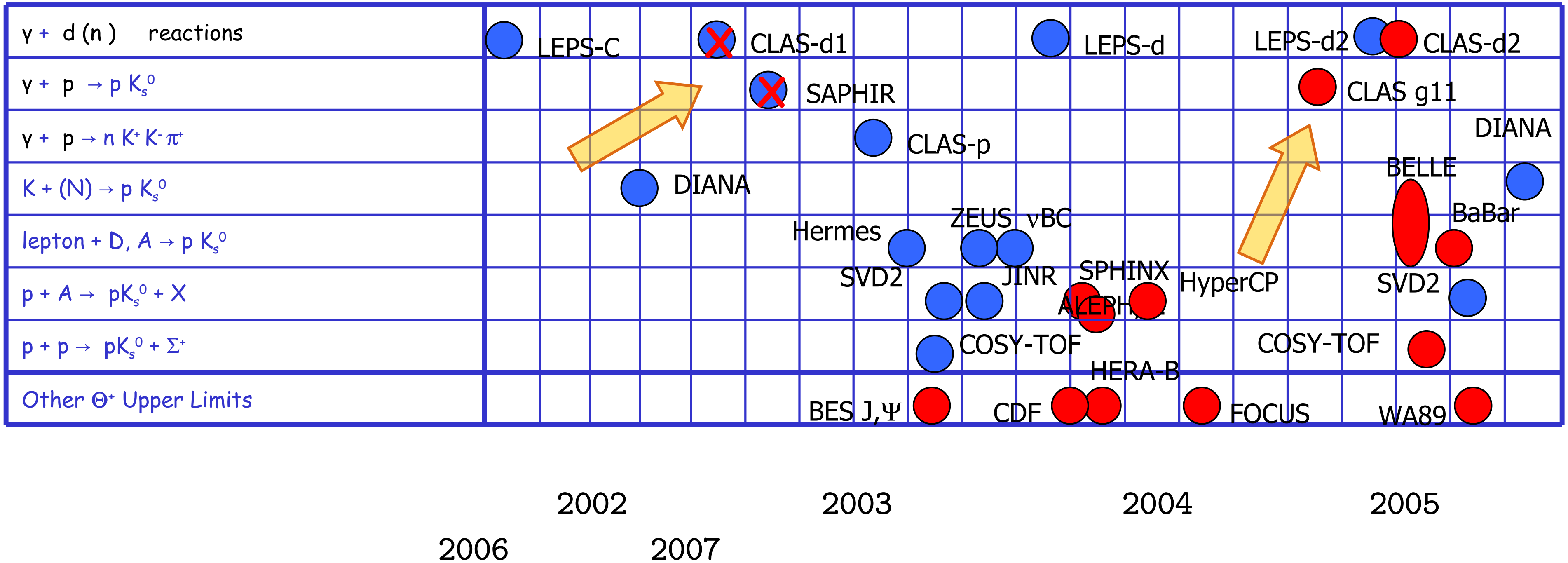
Time dependent experimental status of Θ+



negative results from CLAS high statistics run contradiced previous experiments

: **Positive result**

: **Negative result**

Comparison with SAPHIR proton results

Observed Yields

SAPHIR

$N(\Theta^+)/N(\Lambda^*) \sim 10\%$

CLAS

$N(\Theta^+)/N(\Lambda^*) < 0.2\%$ (95%CL)

Cross Sections

SAPHIR

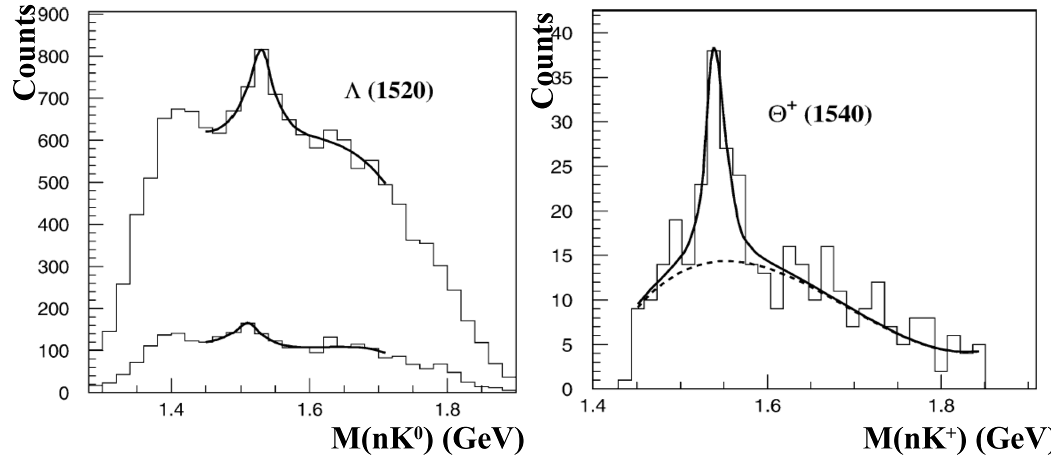
$\sigma \sim 300$ nb

reanalysis 50 nb (unpublished)

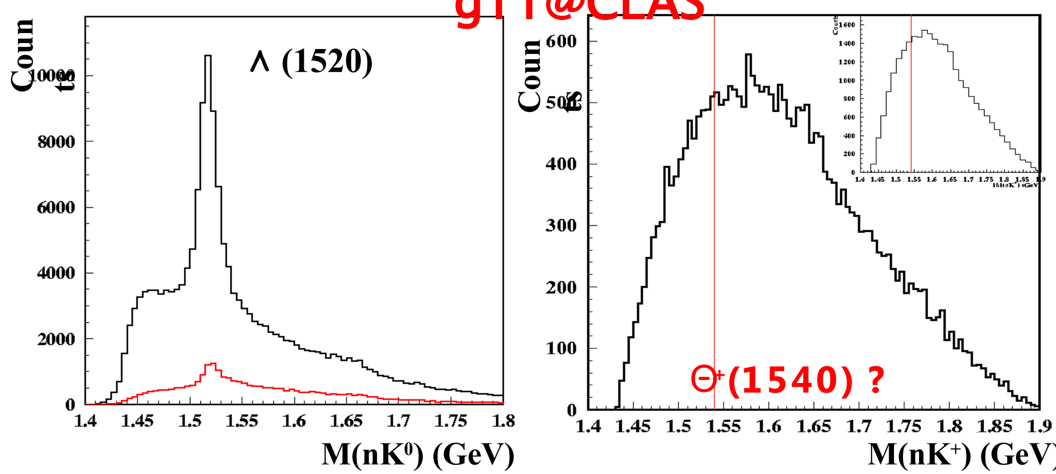
CLAS

$\sigma < 2$ nb

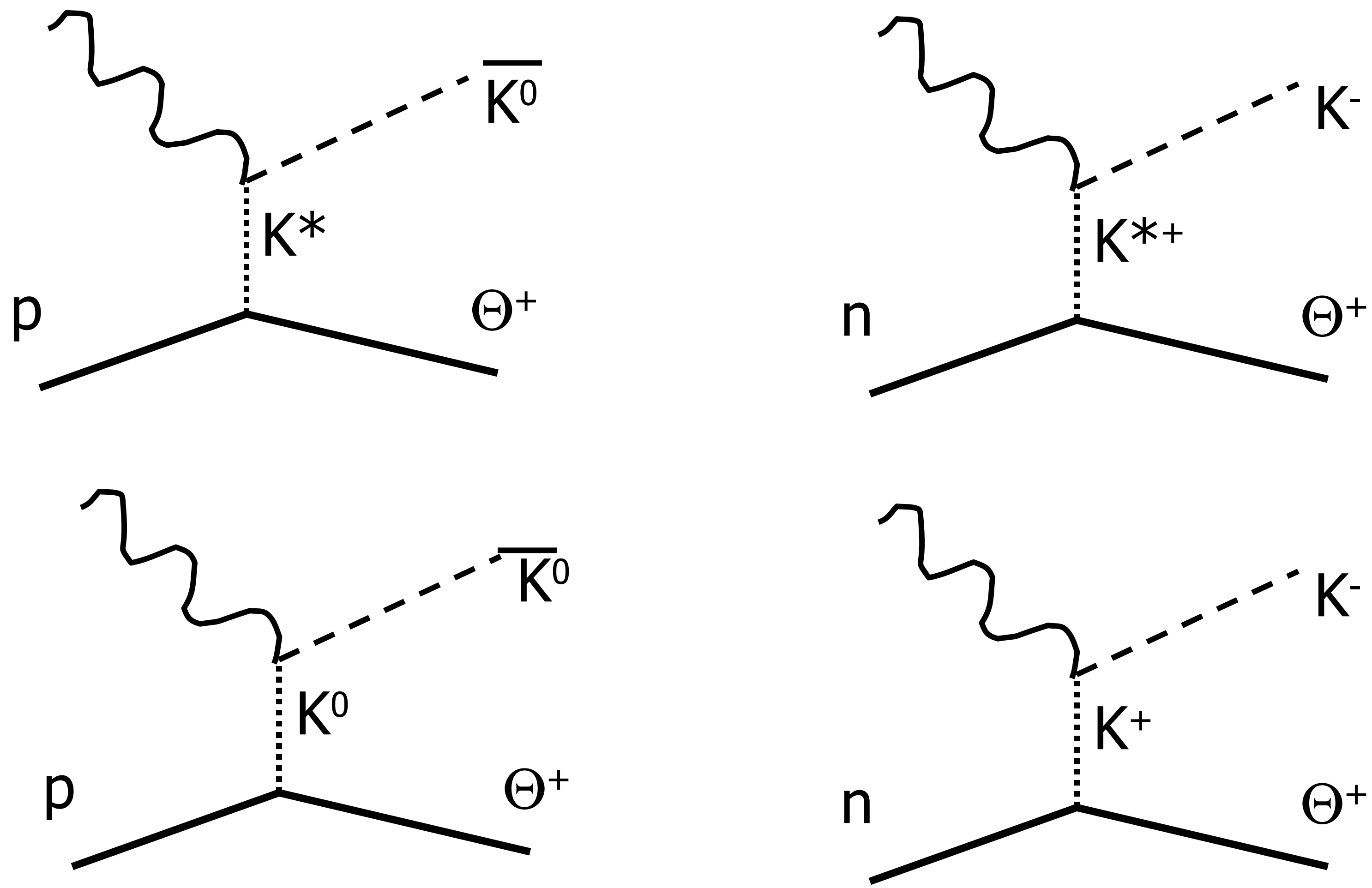
SAPHIR



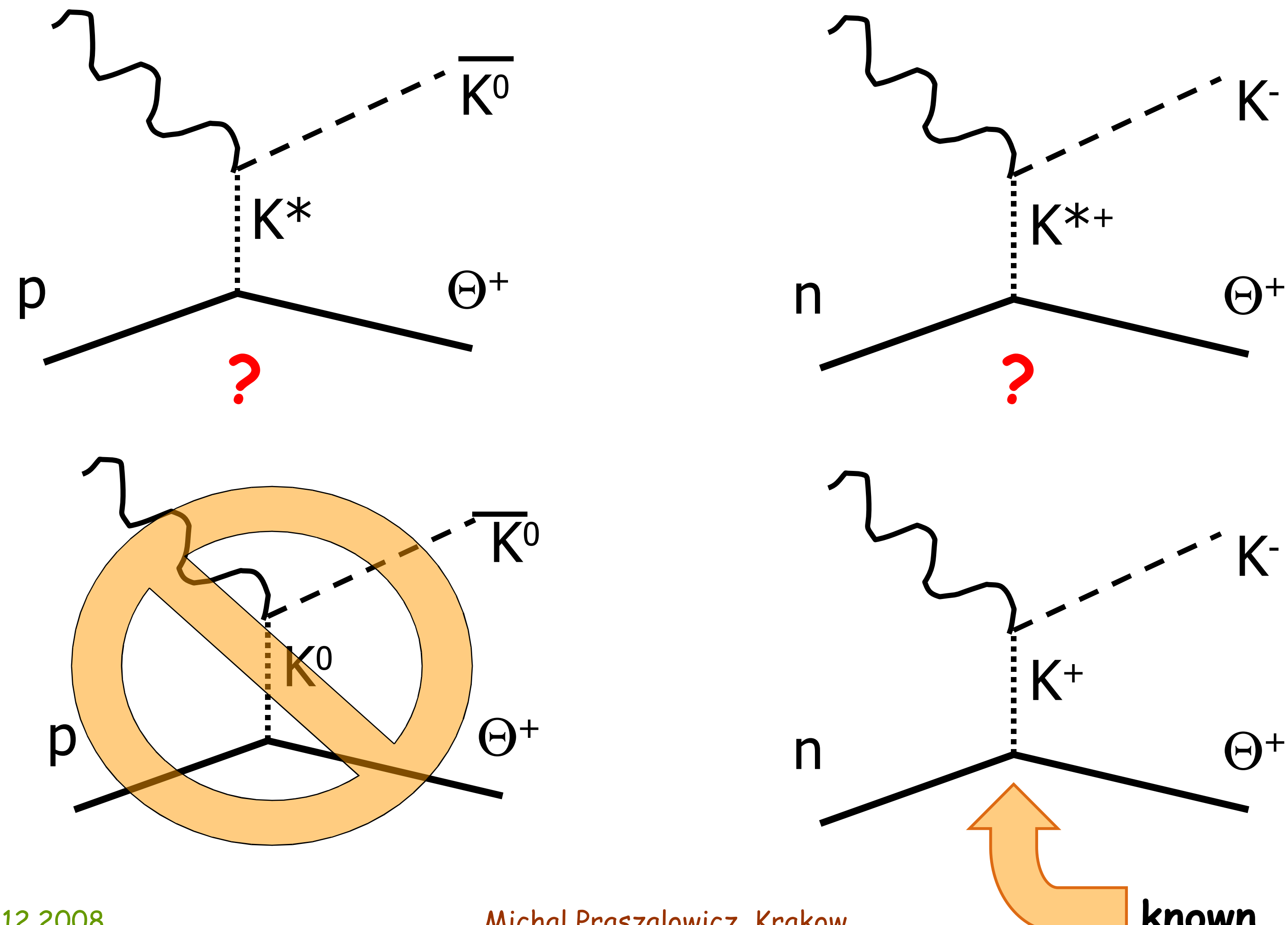
g11@CLAS



t-channel production of Θ^+



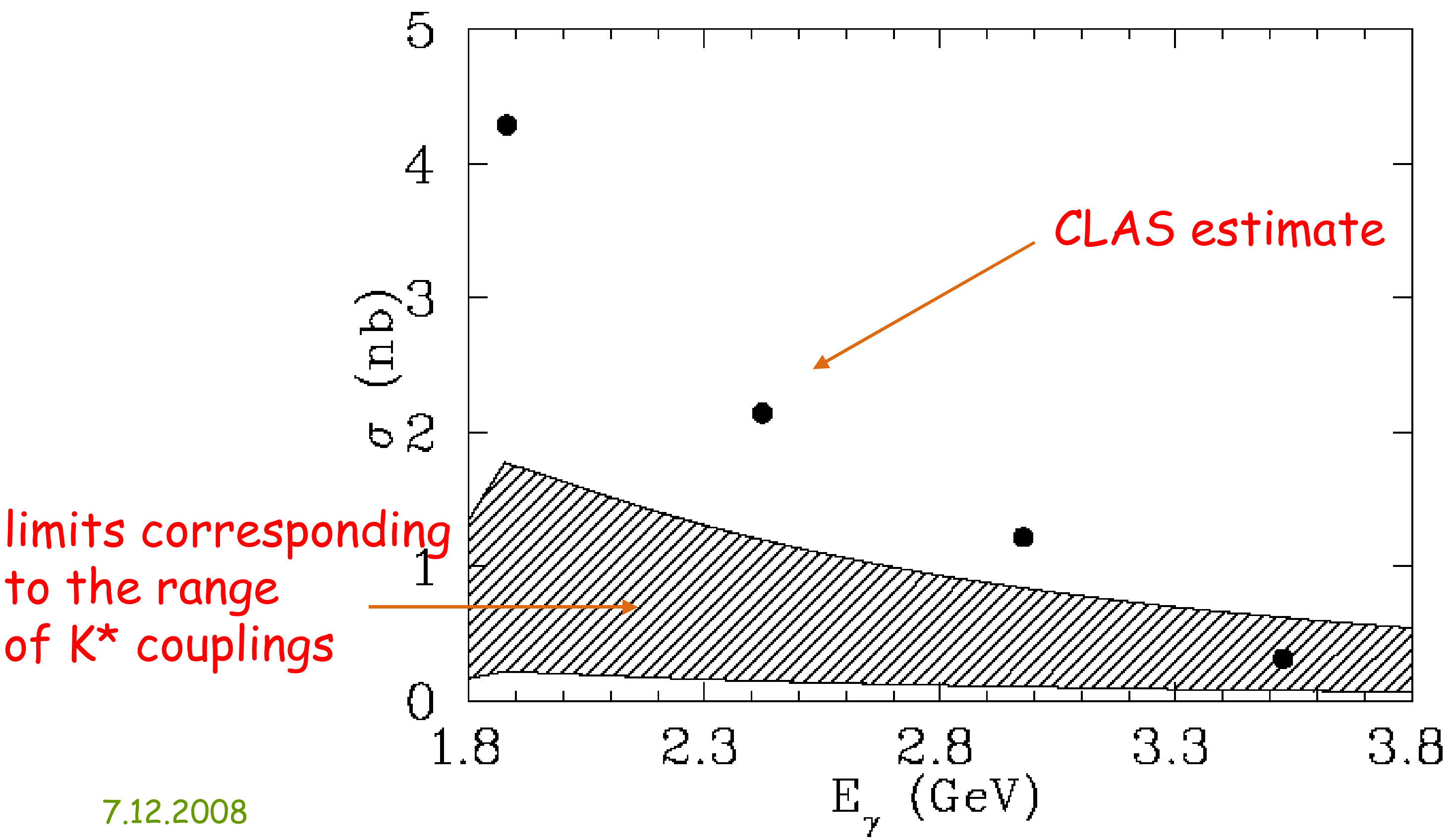
t-channel production of Θ^+



K^*-couplings for the antidecuplet excitation

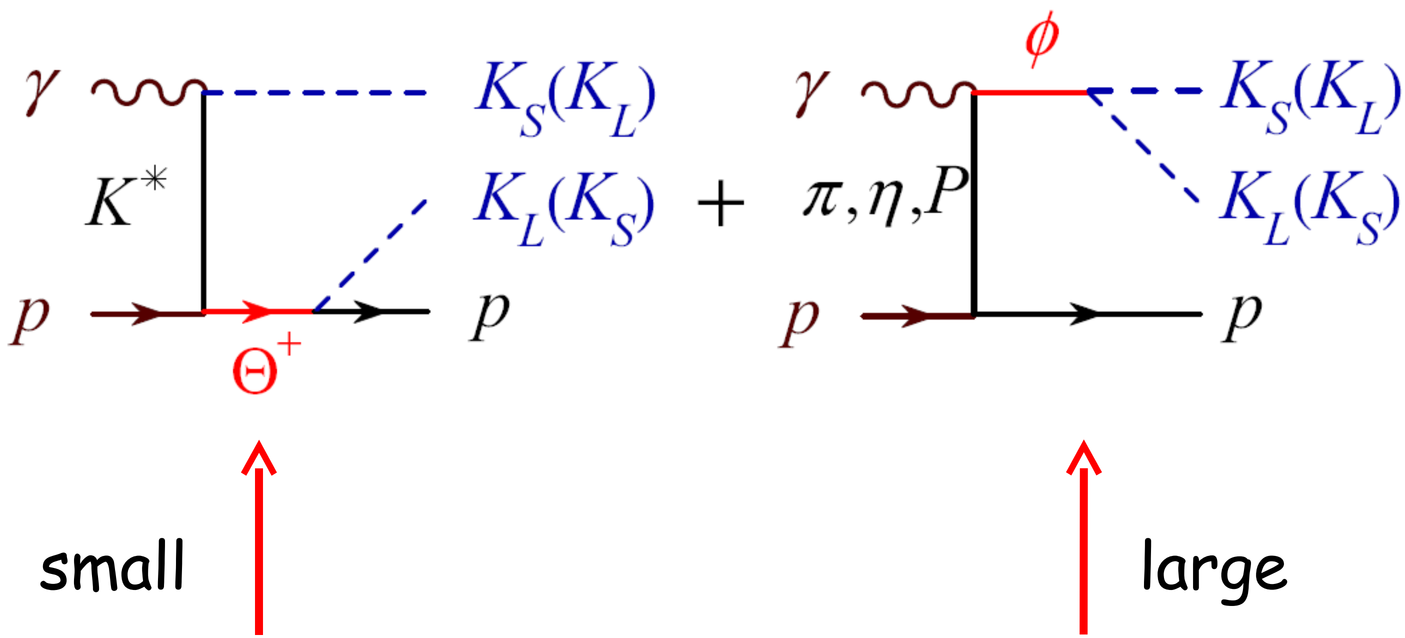
Ya. Azimov[1], V. Kuznetsov[2,3], M. V. Polyakov[1,4], I. Strakovsky[5]

arXiv:hep-ph/0611238 v2 26 Nov 2006



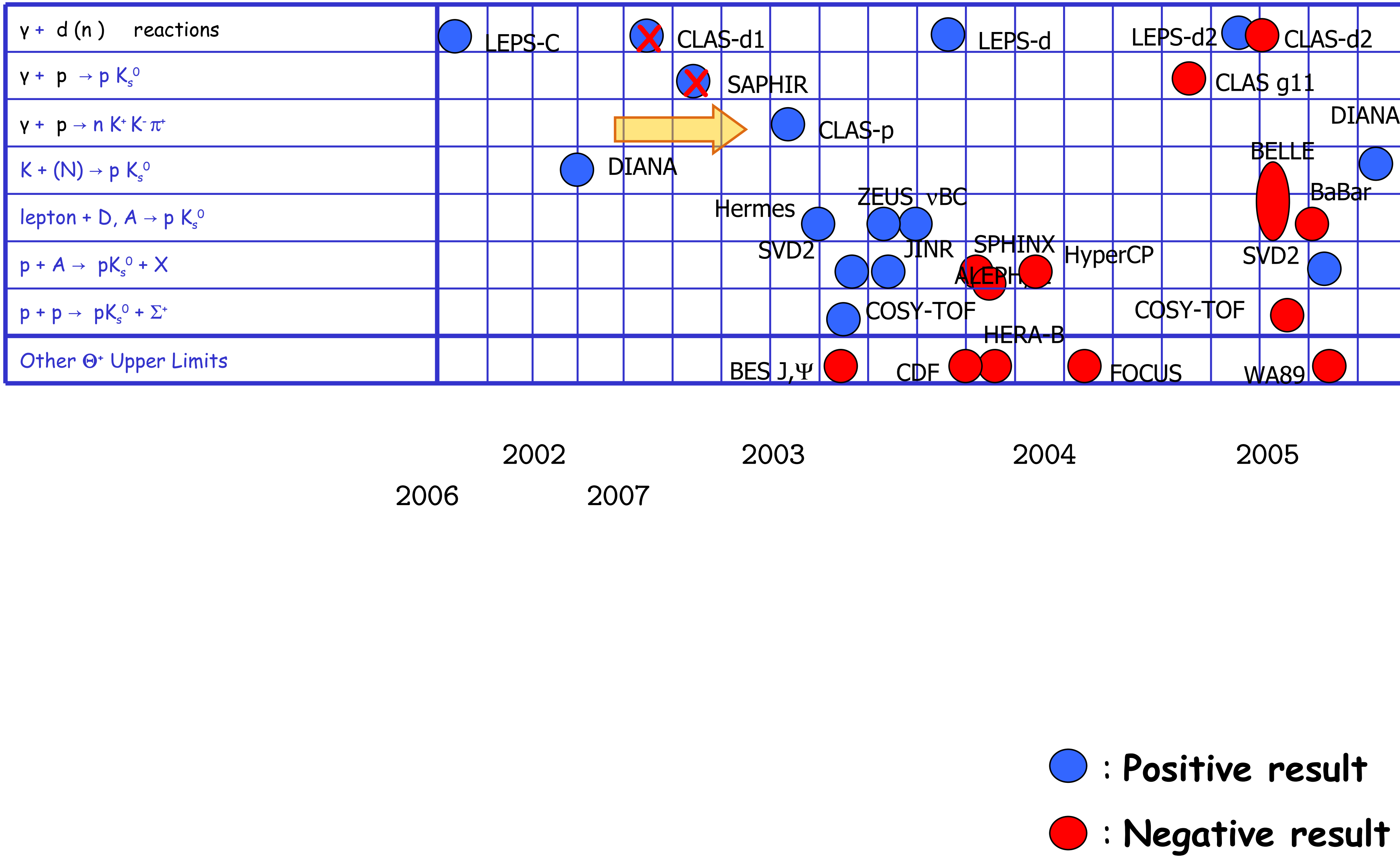
Interference effects

Moskov Amarian[a], Dmitri Diakonov[b,c], and Maxim V. Polyakov[b,c]

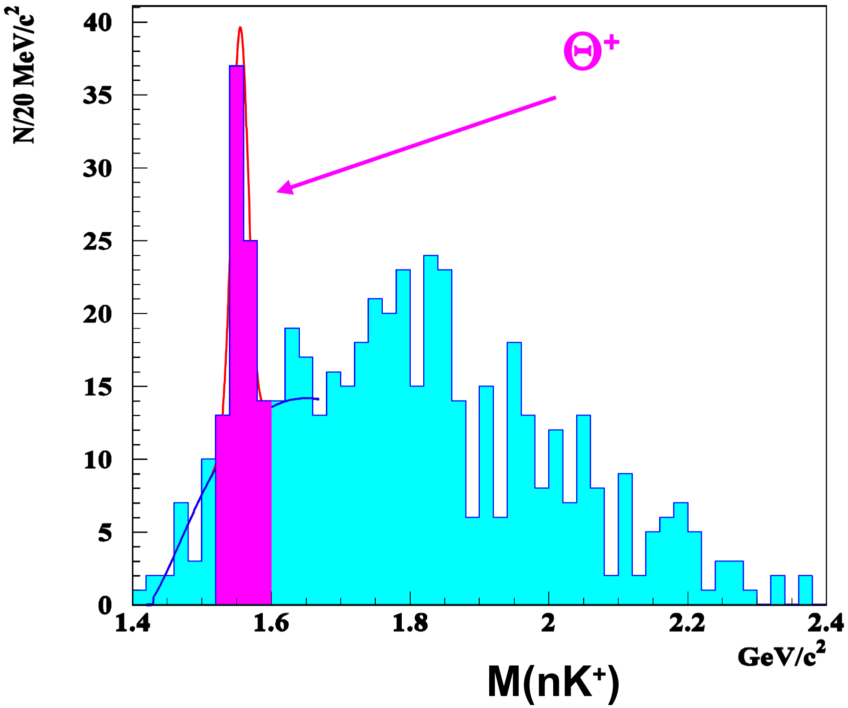


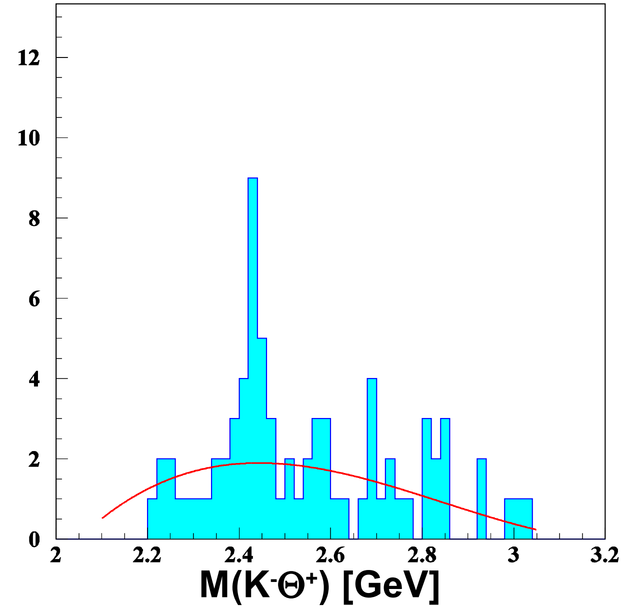
Interference gives higher statistics,
allows for better K identification

Time dependent experimental status of Θ^+



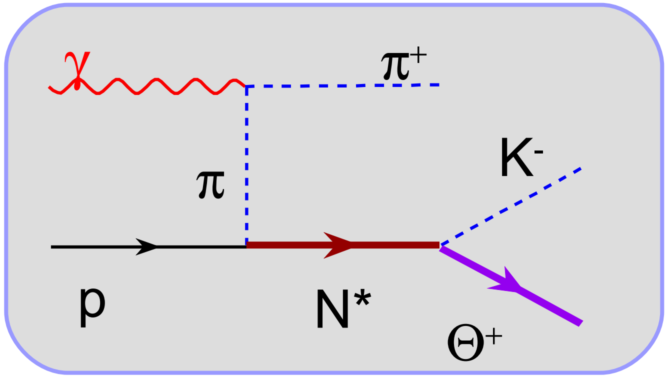
CLAS $\gamma p \to \pi^+ K^- K^+ (n) \to \pi^+ K^- \Theta^+$





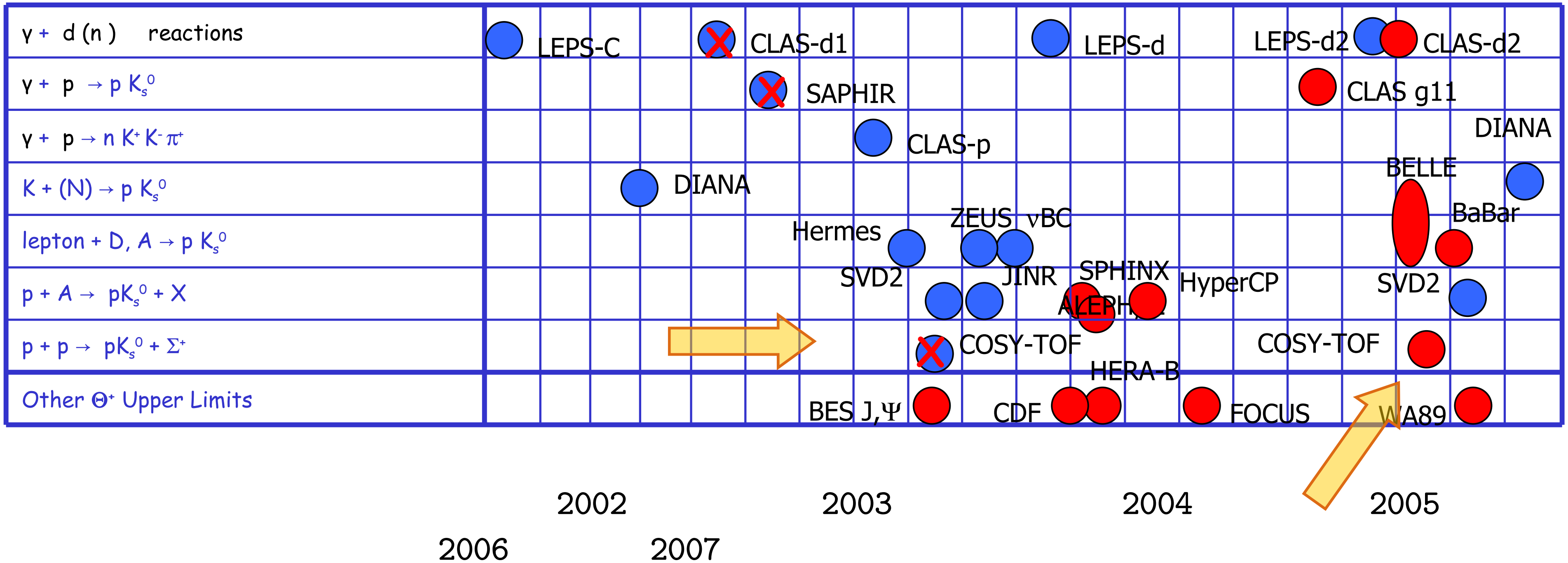
$E_\gamma = 4.8 - 5.6$ GeV

$\cos(\theta^*_\pi) > 0.8$



Will be run with order of magnitude more statistics in 2007.

Time dependent experimental status of Θ^+



COSY-TOF has not confirmed its first, positive result

: **Positive result**

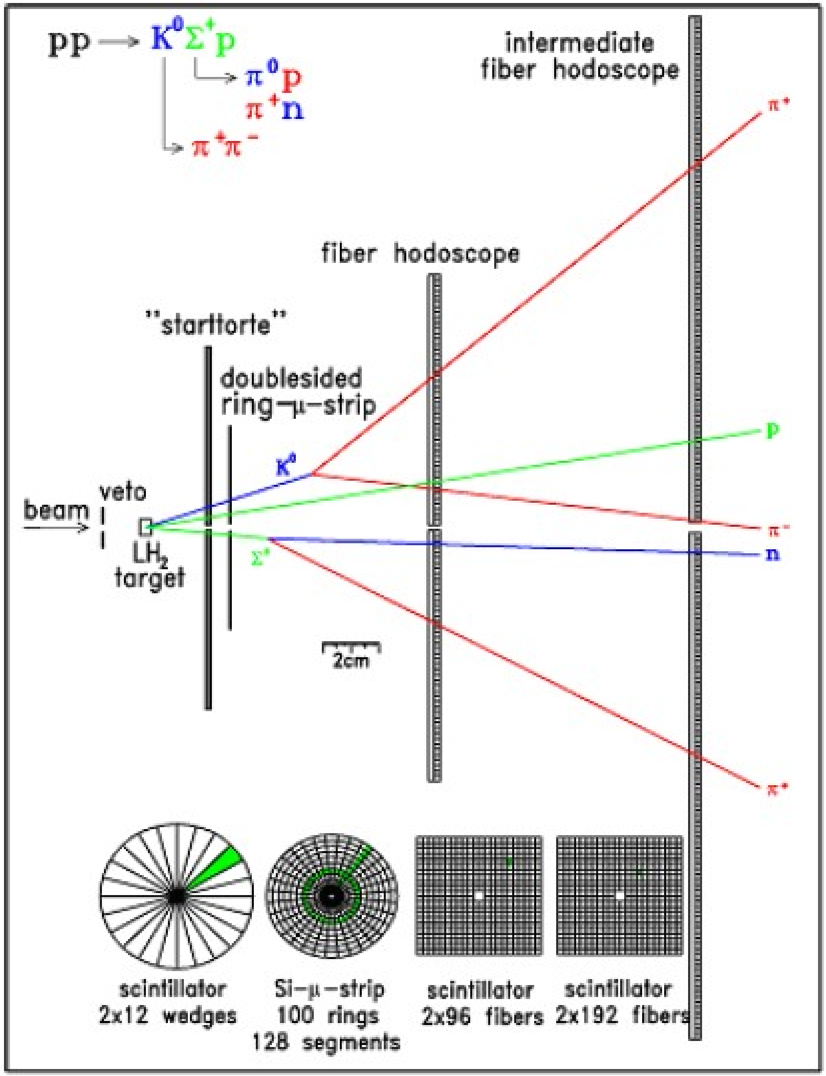
: **Negative result**

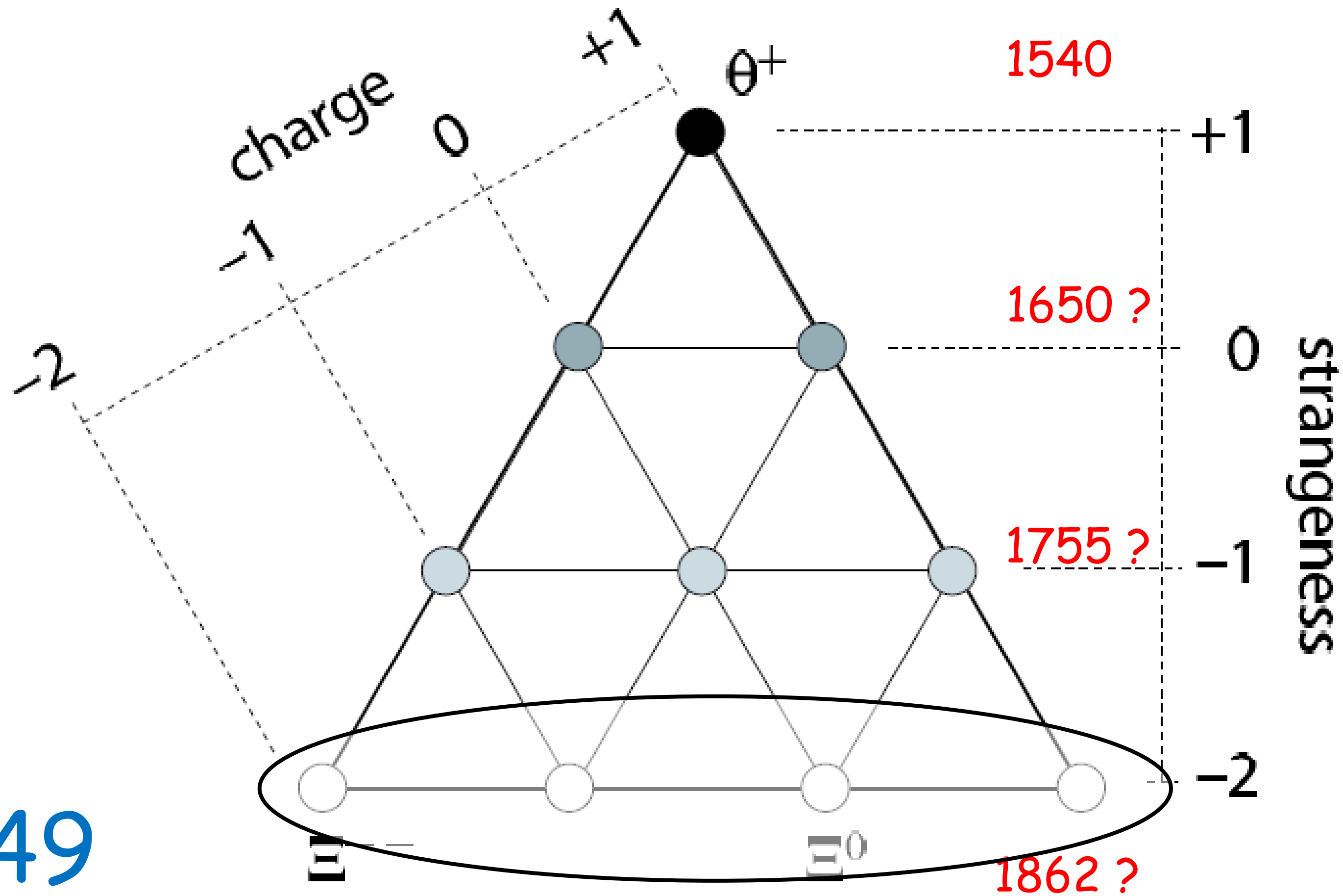
COSY: $pp \to \Sigma^+ K^0 p$

~3GeV/c protons
2004: positive signal
at σ = 0.4 μB
2007: no signal
at σ < 0.15 μB

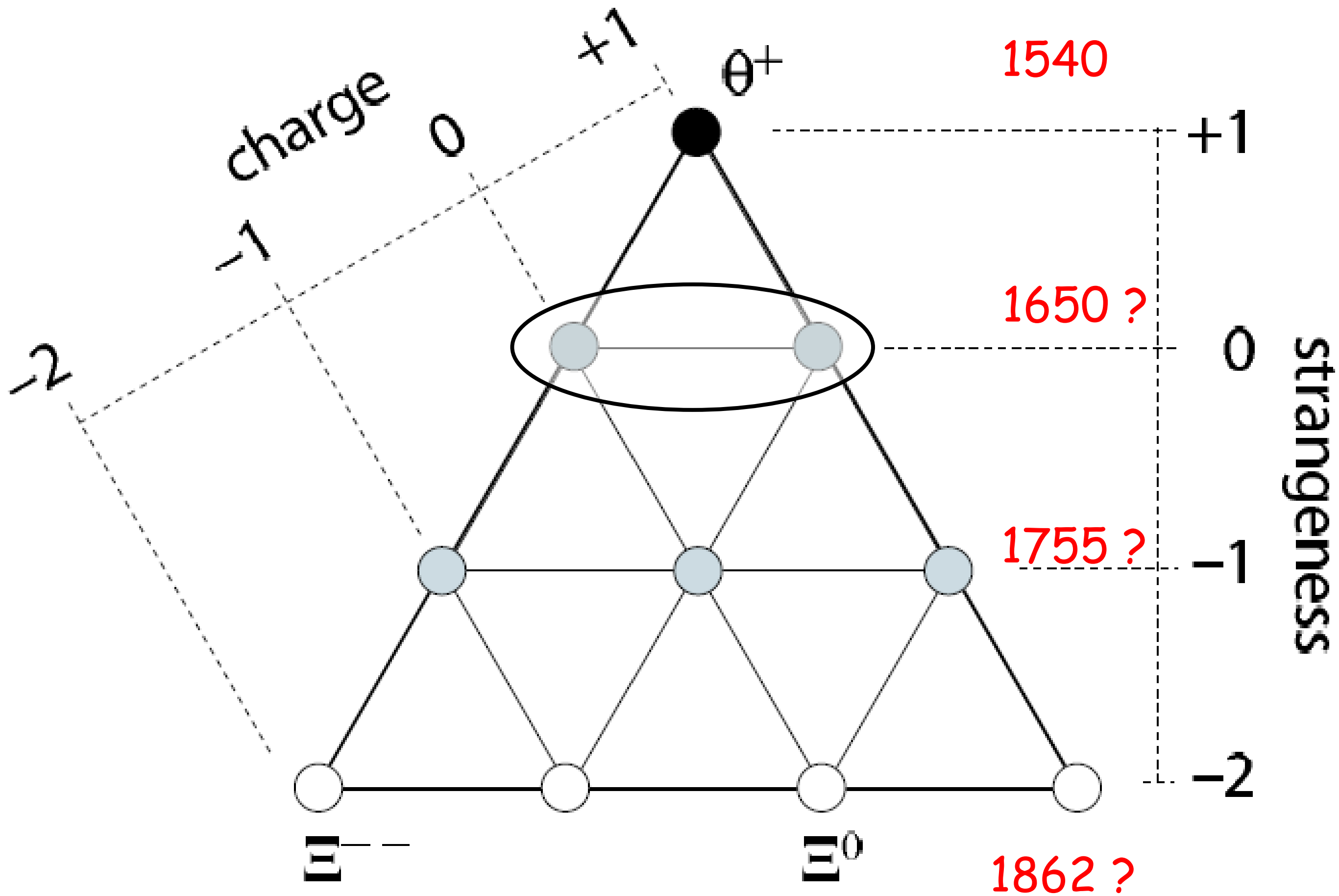
1999: Polyakov, Sibirtsev
Tsushima, Cassing, Goeke
σ ~ 100 nB for Γ = 5 MeV

SVD with 20 Gev/c
pA →Kp+X remains positive





NA 49

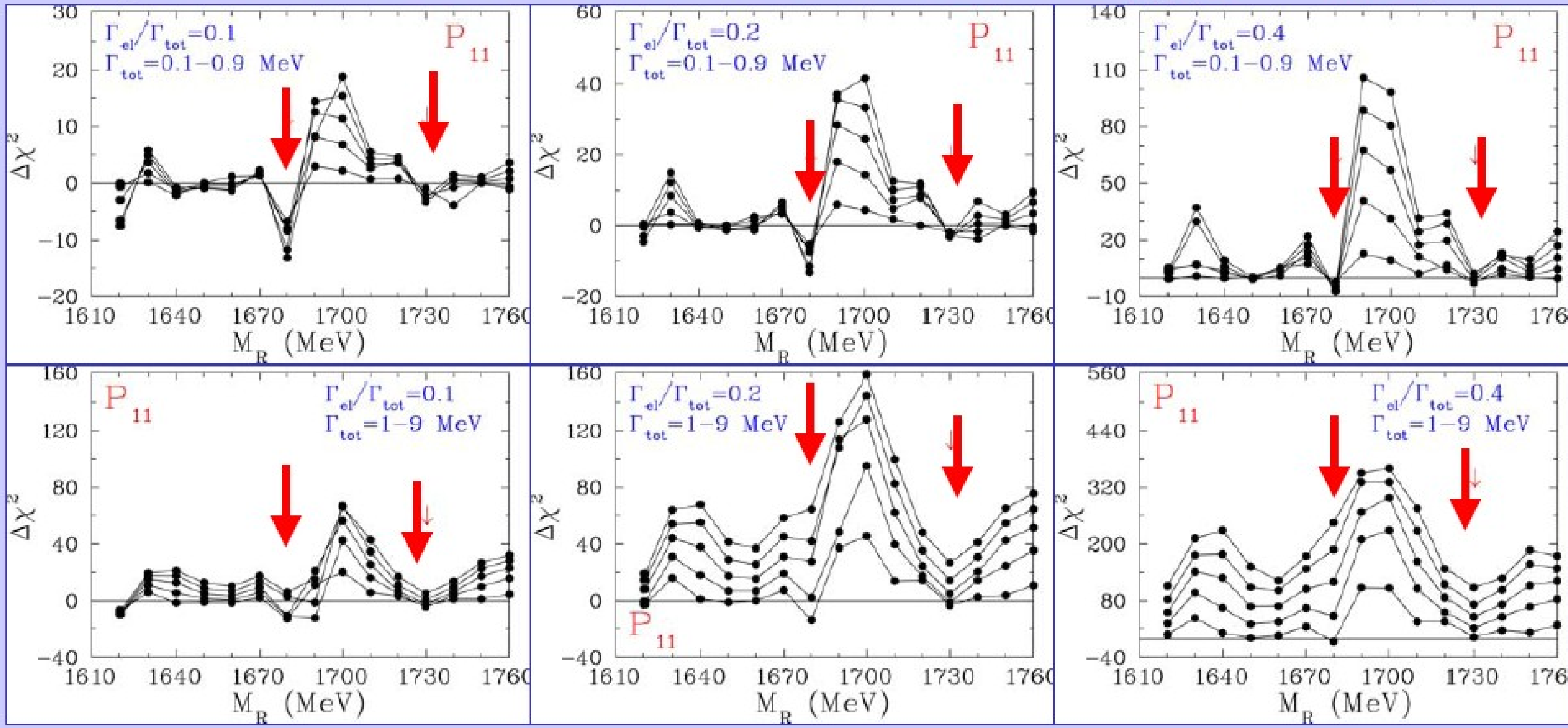


charge
-2
-1
0
+1
Θ^+
1540
+1
1650 ?
0
strangeness
1755 ?
-1
-2
Ξ^{--}
Ξ^0
1862 ?

Narrow Resonances in PWA

[R. Arndt, Ya. Azimov, M. Polyakov, IS, R. Workman, Phys Rev C **69**, 035208(2004)]

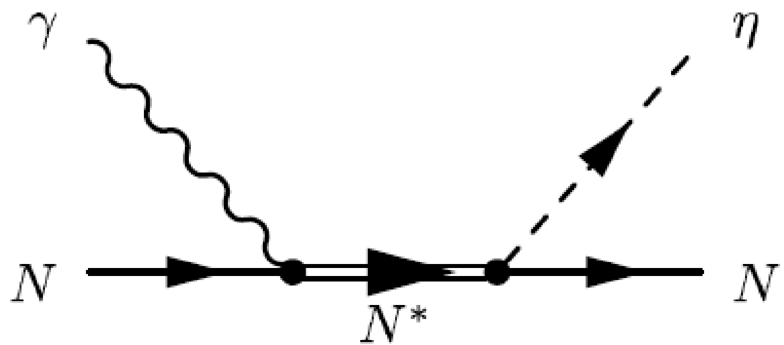
- $\Delta\chi^2$ due to insertion of a resonance into P_{11} ($J^P = 1/2^+$)

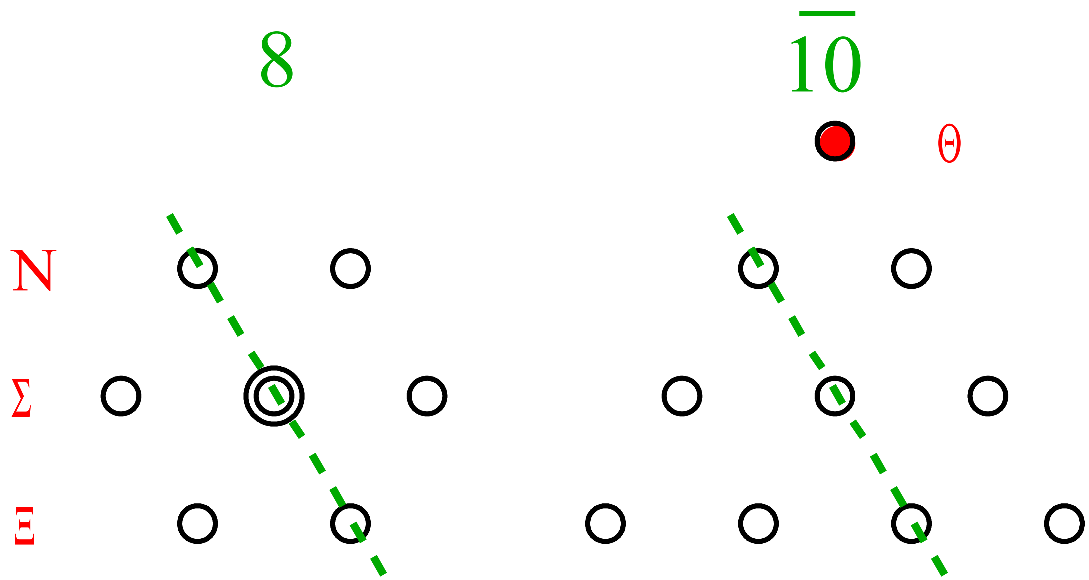


- At $|M_R - W| \gg \Gamma_R$, Res contributes ~ $\Gamma_{el}/(M_R - W)$
- Two candidates: M_R = 1680 MeV 1730 MeV

Γ_{el} < 0.5 MeV < 0.3 MeV

eta photoproduction on nucleon





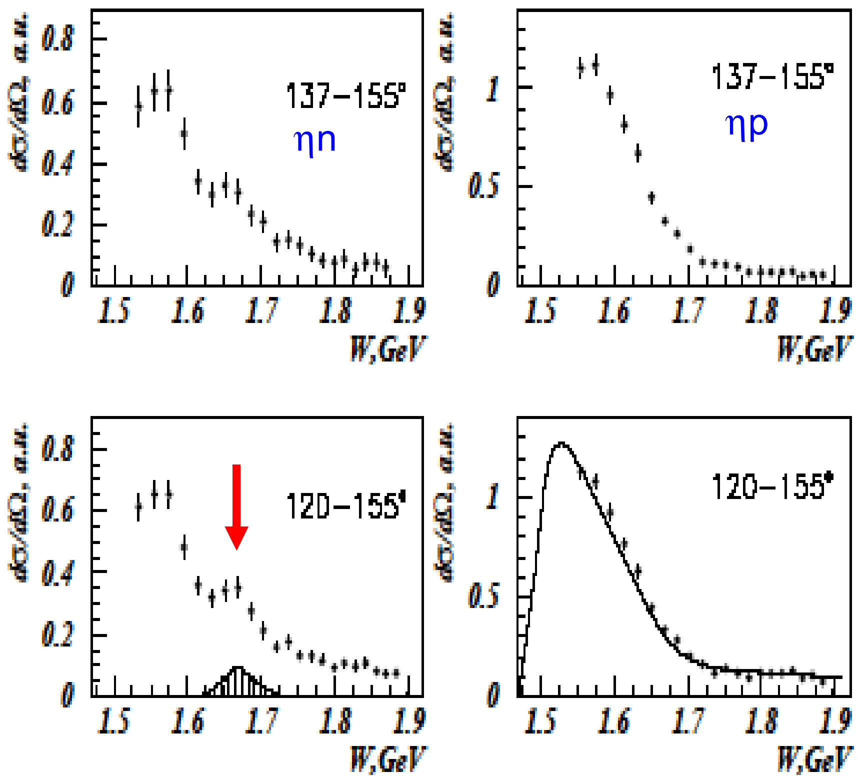
We are asking: Is there a narrow resonance in nucleon excitation?

GRAAL:

ηn measurement: quasi-free kinematics

ηn measurement in D(γ,ηn)p

Kunznetsov et al. preprint (05)



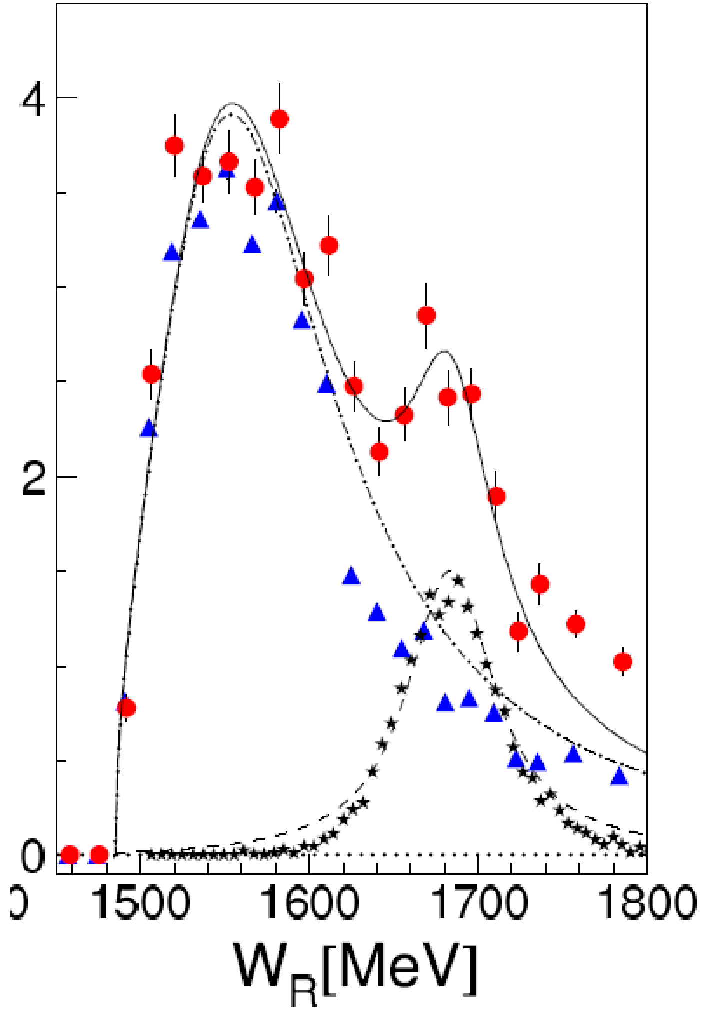


Fig. 2. $M(\eta n)$ spectrum from CBELSA/TAPS [12] (filled circle) in comparison with $M(\eta p)$ spectrum (filled triangles) Stars show the simulated signal of a narrow state.

Summary

- Theory is waiting for final experimental answer
- Θ is not seen in the most of high energy experiments; production rate $\Theta/\Lambda(1520)$ is less than 1%
- No positive results from from dedicated experiments: CLAS γp, γd; COSY-TOF pp (KEK-PS)
- Positive result from DIANA (SVD) remains: $\Gamma < 1$ MeV
- LEPS confirms signals in γd, possible inconsistency with CLAS
- NA49 repeated their analysis: $\Xi_{3/2}(1860)$
- Signals of narrow N(1685) resonance consistent with antidecuplet interpretation $\Gamma < 25$ MeV

If Θ exists, it is not like an ordinary baryon

Backup slides

EXPERIMENTAL REVIEW ON PENTAQUARKS

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B.Cheremushkinskaya 25
117218 Moscow
Russia

arXiv:0704.3531v2 [hep-ex] 24 Jul 2007

Table 1: *Experiments with evidence for the* Θ^+ *baryon.*

Reference	Group	Reaction	Mass (MeV)	Width (MeV)
4)	LEPS(1)	$\gamma C \to K^+K^-X$	1540 ± 10	< 25
5)	DIANA	$K^+Xe \to K^0pX$	1539 ± 2	< 9
24)	CLAS(d)	$\gamma d \to K^+K^-p(n)$	1542 ± 5	< 21
25)	SAPHIR	$\gamma d \to K^+\overline{K^0}(n)$	1540 ± 6	< 25
26)	νBC	$\nu A \to K^0_s pX$	1533 ± 5	< 20
27)	CLAS	$\gamma p \to \pi^+K^+K^-(n)$	1555 ± 10	< 26
28)	HERMES	$e^+d \to K^0_S pX$	1526 ± 3	13 ± 9
29)	ZEUS	$e^+p \to K^0_S pX$	1522 ± 3	8 ± 4
~~30)~~	~~COSY-TOF~~	~~$pp \to K^0 p\Sigma^+$~~	~~1530 ± 5~~	~~< 18~~
31)	SVD	$pA \to K^0_S pX$	1526 ± 5	< 24
32)	LEPS(2)	$\gamma d \to K^+K^-X$	~ 1530	
33)	$\nu BC2$	$\nu A \to K^0_s pX$	1532 ± 2	< 12
34)	NOMAD	$\nu A \to K^0_s pX$	1529 ± 3	< 9
35)	JINR	$p(C_3H_8) \to K^0_s pX$	1545 ± 12	16 ± 4
36)	JINR(2)	$CC \to K^0_s pX$	1532 ± 6	< 26
37)	LPI	$np \to npK^+K^-$	1541 ± 5	< 11

Table 2: *Experiments with non-observation of the Θ^+ baryon.*

Reference	Group	Reaction	Limit
42)	BES	$e^+e^- \to J/\Psi \to \bar{\Theta}\Theta$	$< 1.1 \times 10^{-5}$ B.R.
43)	BaBar	$e^+e^- \to \Upsilon(4S) \to pK^0X$	$< 1.0 \times 10^{-4}$ B.R.
44)	Belle	$e^+e^- \to B^0\bar{B}^0 \to p\bar{p}K^0X$	$< 2.3 \times 10^{-7}$ B.R.
46)	HERA-B	$pA \to K^0_S pX$	$< 0.02 \times \Lambda^*$
47)	SPHINX	$pC \to \Theta^+X$	$< 0.1 \times \Lambda^*$
48)	HyperCP	$\pi, K, pCu \to K^0_S pX$	$< 0.3\%$ K^0p
49)	CDF	$p\bar{p} \to K^0_S pX$	$< 0.03 \times \Lambda^*$
50)	FOCUS	$\gamma BeO \to K^0_S pX$	$< 0.02 \times \Sigma^*$
51)	Belle	$\pi, K, pA \to K^0_s pX$	$< 0.02 \times \Lambda^*$
52)	PHENIX	$Au + Au \to K^-\bar{n}X$	(not given)
45)	ALEPH	$e^+e^- \to K^0_s pX$	$< 0.07 \times \Lambda^*$
53)	COMPASS	$\mu^+A \to K^0_s pX$	–
54)	DELPHI	$e^+e^- \to K^0_s pX$	$< 0.5 \times \Lambda^*$
55)	E690	$pp \to K^0_s pX$	$< 0.005 \times \Lambda^*$
56)	LASS	$K^+p \to K^+n\pi^+$	–
54)	L3	$\gamma\gamma \to K^0_s pX$	$< 0.1 \times \Lambda$

New results from LEPS
Summary of LD2 data analysis

T. Hotta, Acta Phys. Pol. B36, 2173

- K^+K^- from LD2 target
- $MM_d(\gamma,K^+K^-)>1.89$ GeV
- $0.89< MM(\gamma,K^+K^-)<0.99$ GeV
- ϕ exclusion cut at R=0.2
- Fermi motion correction

Reliable background estimation is essential to confirm the existence of the peak.