Experimental study of the Pentaquarks

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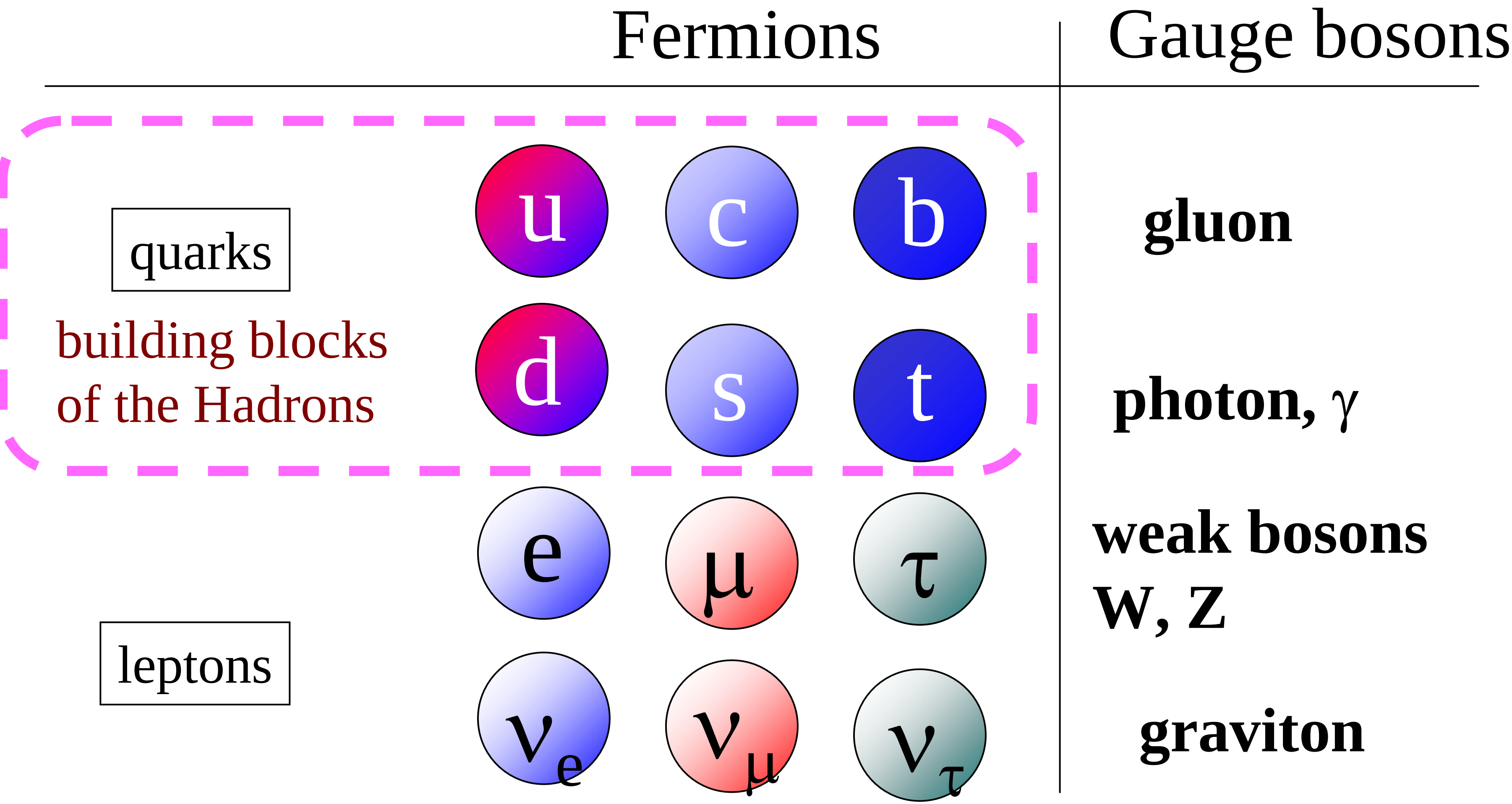
Outline

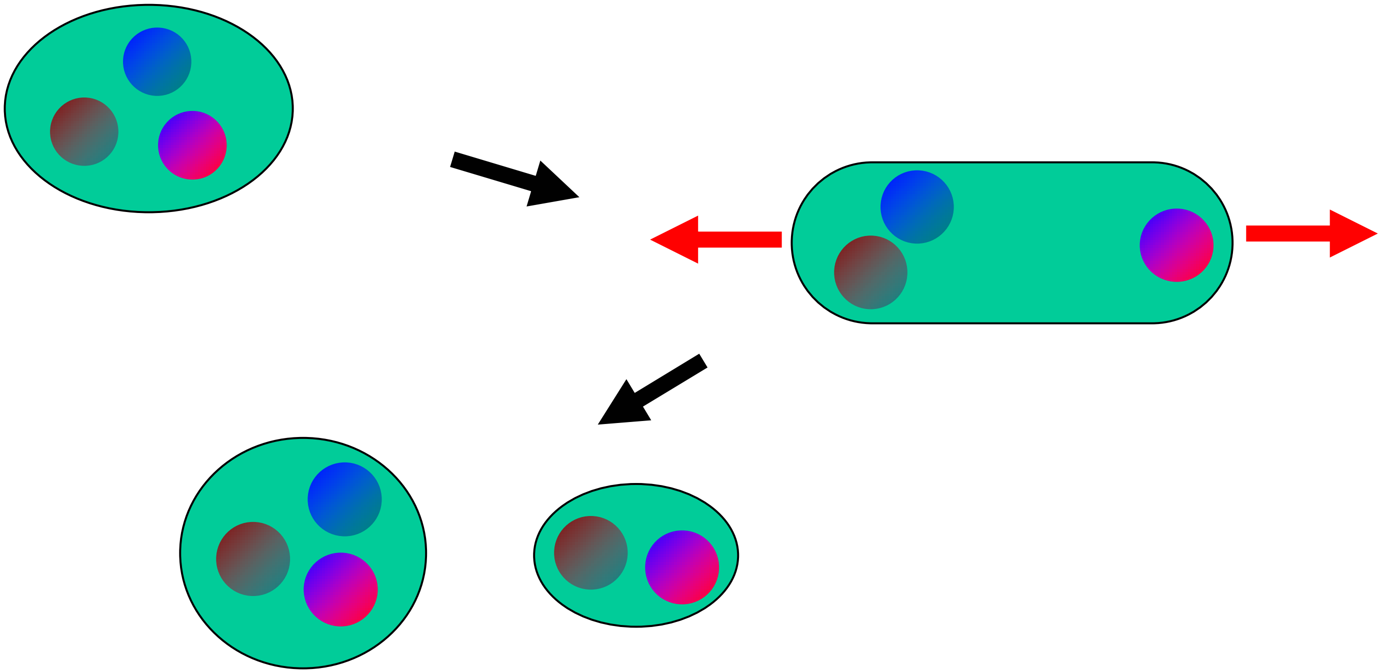
- Introduction
- Prediction of Anti-decuplet and Θ^+
- First evidence from LEPS/SPring-8
- Confirmation by other labs
- Null results from high energy experiments
- Summary and Outlook

Elementary particle of the Standard Model



Quark confinement

No free quark was observed! ∽ confined in a hadron



What are penta-quarks?

- Minimum quark content is 5 quarks.
- "Exotic" penta-quarks are those where the antiquark has a different flavor than the other 4 quarks $\left(qqqq\overline{Q}\right)$
- Quantum numbers cannot be defined by 3 quarks alone.

Example: $uudd\bar{s}$

Baryon number = 1/3 + 1/3 + 1/3 + 1/3 – 1/3 = 1

Strangeness = 0 + 0 + 0 + 0 + 1 = 1

e.g. $uudd\bar{c}$, $uuss\bar{d}$

c.f. Λ(1405): $uuds\bar{u}$ or uds

Review of the Baryons

- **"If I could remember the names of all those particles, I would have become a biologist!"**
  - **Enrico Fermi**

Tabular Form

Mass	Charge	Strange	Spin	Parity
0.938	0,+	0	½	+
1.115	0	-1	½	+
1.193	-,0,+	-1	½	+
1.232	-,0,+,++	0	3/2	+
1.320	-,0	-2	½	+
1.385	-,0,+	-1	3/2	+
1.405	0	-1	½	-
1.440	0,+	0	½	+
1.530	-,0	-2	3/2	+

A Simple Quark Model

- Ref: Sakharov and Zeldovich (1967).
- Linear mass term + hyperfine interaction
  - $M = \Sigma\, m_i + C_0\, \Sigma_{ij}\, (\sigma_i \,.\, \sigma_j) \,/\, (m_i \,.\, m_j)$
  - m_i is the effective (constituent) mass
  - (vector) σ_i is the quark spin operator
  - C_0 is the strength parameter

Sakharov-Zeldovich model

only 4 parameters: m_{ud}, m_s, μ_{ud}, μ_s

Meson	Exp.	Model	Baryon	Exp.	Model
π	139	133	N	939	928
ρ	770	753	Δ	1232	1238
K	494	490	Σ	1193	1195
K*	892	890	Λ	1115	1108
ω	782	780	Ξ	1318	1340
ϕ	1019	1020	Σ*	1385	1375
η	547	-----	Ξ*	1530	1520
η’	958	-----	Ω	1673	1675

Constituent Quarks

- Extension of this approach also gives good agreement with magnetic moments
- Parameter values sounds reasonable:
  - $m_u = m_d \sim$ 300-330 MeV, $m_s \sim$ 470-510 MeV
  - Hyperfine interaction is not huge.
  - Slightly better results with modern calc.

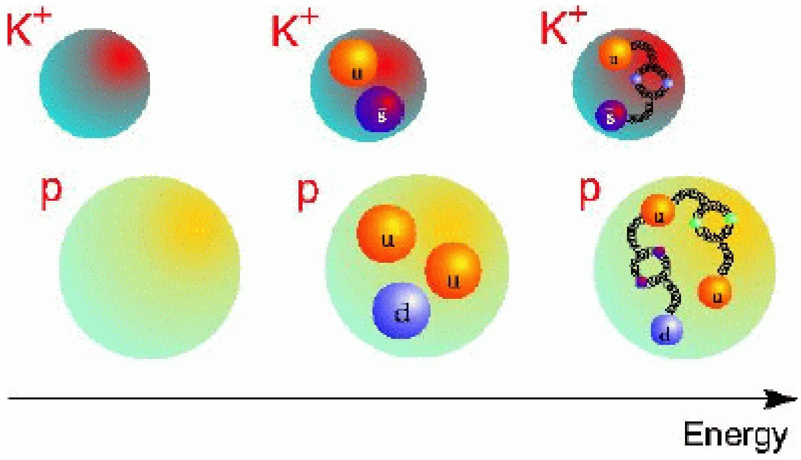
(see Perkins, section 5.10)

How simple is baryon structure?

- Bare quarks have a small mass
  - only ~2% of the proton's mass is from bare quarks!
  - most of the mass is generated dynamically.
- Quarks account for <30% of proton spin
  - so-called "spin crisis"
  - contributions from gluons, orbital L
- The proton has a "pion cloud"
  - from precise electron scattering (Q^2~1)
  - 3-quark core surrounded by q-q pairs
- The proton is a complex many-body system!

Degrees of Freedom

What is the relevant basis to describe the data?



- very large πN sigma term found from low-energy π scattering: constituent quarks give 4 times less:

$$\sigma = \frac{m_u + m_d}{2} < N|\bar{u}u + \bar{d}d|N > = 67 \pm 6\,\mathrm{MeV},$$

$$\text{From quarks :} \quad \frac{4\,\mathrm{MeV} + 7\,\mathrm{MeV}}{2} \times 3 = 17.5\,\mathrm{MeV}.$$

On the one hand σ-term is too big, but on the other one, it is too small as it explains only 7% (or 2%) of the N mass. Where does 93% of the N mass come from?

D. Diakonov, Talk at Pentaquak04

Baryon masses

- Mainly 3 quark baryons:

  M ~ 3Mq + (strangeness)

- 5-quark baryons, naively:

  M ~ 5Mq + (strangeness)

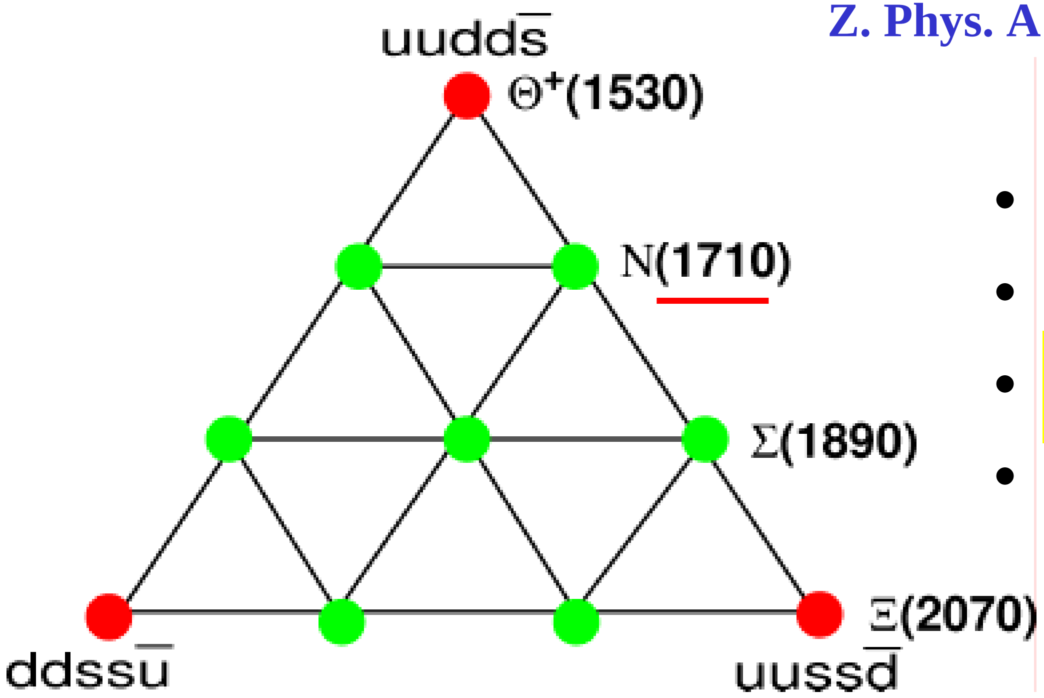
  1700~1900 MeV for Θ^+

- 5-quark baryons, in chiral quark soliton:

  M ~ 3Mq + 1/(baryon size) + (strangeness)

Prediction of the Θ^+ Baryon

D. Diakonov, V. Petrov, and M. Polyakov, Z. Phys. A 359 (1997) 305.

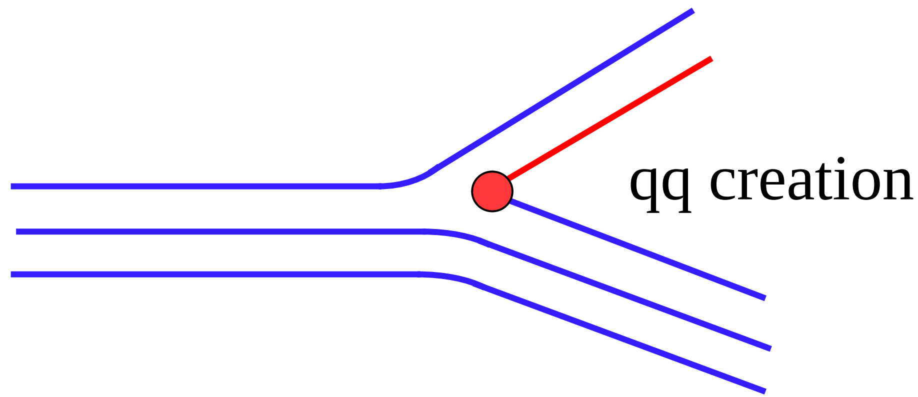


- **Exotic: S=+1**
- **Low mass: 1530 MeV**
- **Narrow width: ~ 15 MeV**
- **J^p=1/2$^+$**

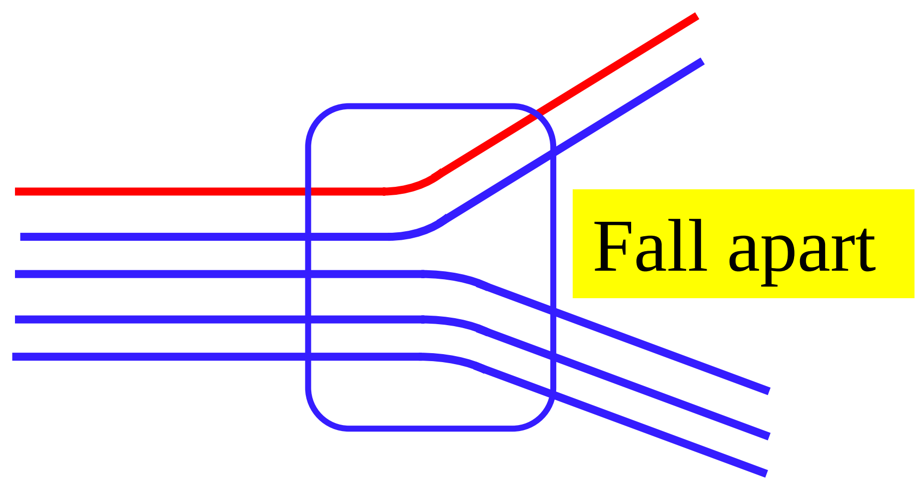
M = [1890-180*Y] MeV

Decay in the quark model

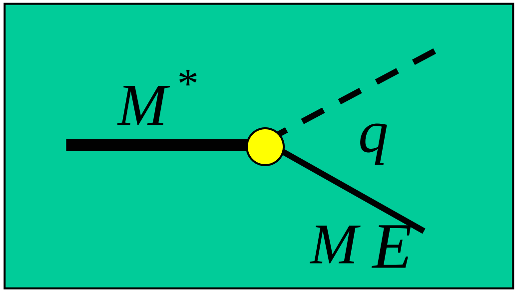
Ordinary baryons



For pentaquark



Decay of baryons



1/2+ P-wave coupling

$$L = g_{KN\Theta} \bar{N} \gamma_5 \Theta K \quad \rightarrow \quad \Gamma^+ = \frac{g_{KN\Theta}{}^2}{2\pi} \frac{Mq^3}{E(E+M)M^*}$$

For M^* = 1540 MeV, g = 13, then **Γ = 180 MeV**

If g = 4, then **Γ = 20 MeV**

cf: Roper N(1440) Γ ~ 200 MeV => g ~ 8

1/2- S-wave coupling

$$L = g_{KN\Theta} \bar{N} \Theta K \quad \rightarrow \quad \Gamma^- = \Gamma^+ \frac{(E+M)^2}{q^2}$$

~ 50 !

Γ= 9 GeV
1 GeV

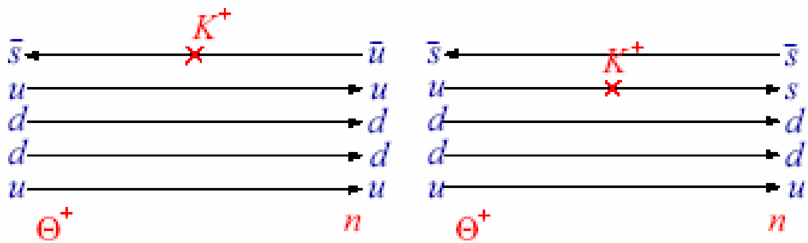
Why Θ+ is so narrow?

$\Theta^+ \to nK^+$ decay

$$\Gamma_\Theta = \frac{3\, g_{\mathrm{KN}\Theta}^2}{2\pi [m_N + m_\Theta]^2} \frac{m_N}{m_\Theta} \frac{1}{5} |\mathrm{p}|^3$$

$$g_{\mathrm{KN}\Theta} \approx \frac{g_A^{\Theta \to \mathrm{NK}} (m_N + m_\Theta)}{2\, F_K} \qquad \text{similar to} \quad g_{\pi \mathrm{NN}} = \frac{g_A\, m_N}{F_\pi}$$

$$g_A^{\Theta^+ \to nK^+} = \frac{< n^{(5)} | J_{05}^{K^+} | \Theta^+ > + \ldots}{\sqrt{\mathcal{N}_n^{(3)} + \mathcal{N}_n^{(5)} + \ldots}\, \sqrt{\mathcal{N}_\Theta^{(5)} + \ldots}}, \qquad \frac{\mathcal{N}_n^{(5)}}{\mathcal{N}_n^{(3)}} \ll 1$$



Θ decay is suppressed to the extent the 5-quark component of the neutron is less than its 3-quark component. Additional suppression comes from the peculiar flavor structure of the neutron's 5-quark component where the $\bar{Q}$ is in the flavor-singlet combination with one of the four Q.

A preliminary crude estimate gives $\Gamma_\Theta = 0.7\,\mathrm{MeV}$ without fitting any parameters!

D. Diakonov, Talk at Pentaquak04

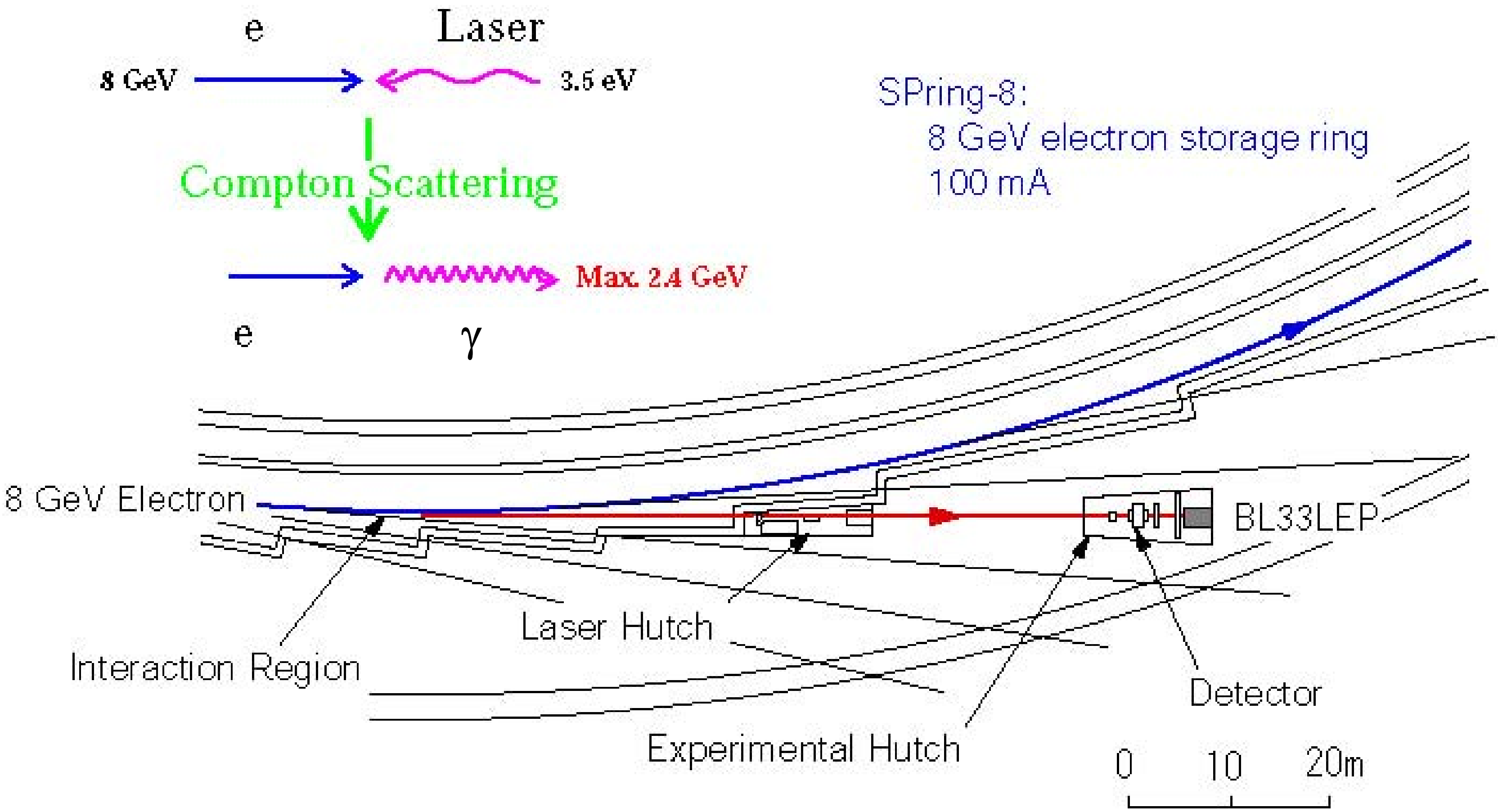
First evidence from LEPS

Super Photon ring-8 GeV SPring-8

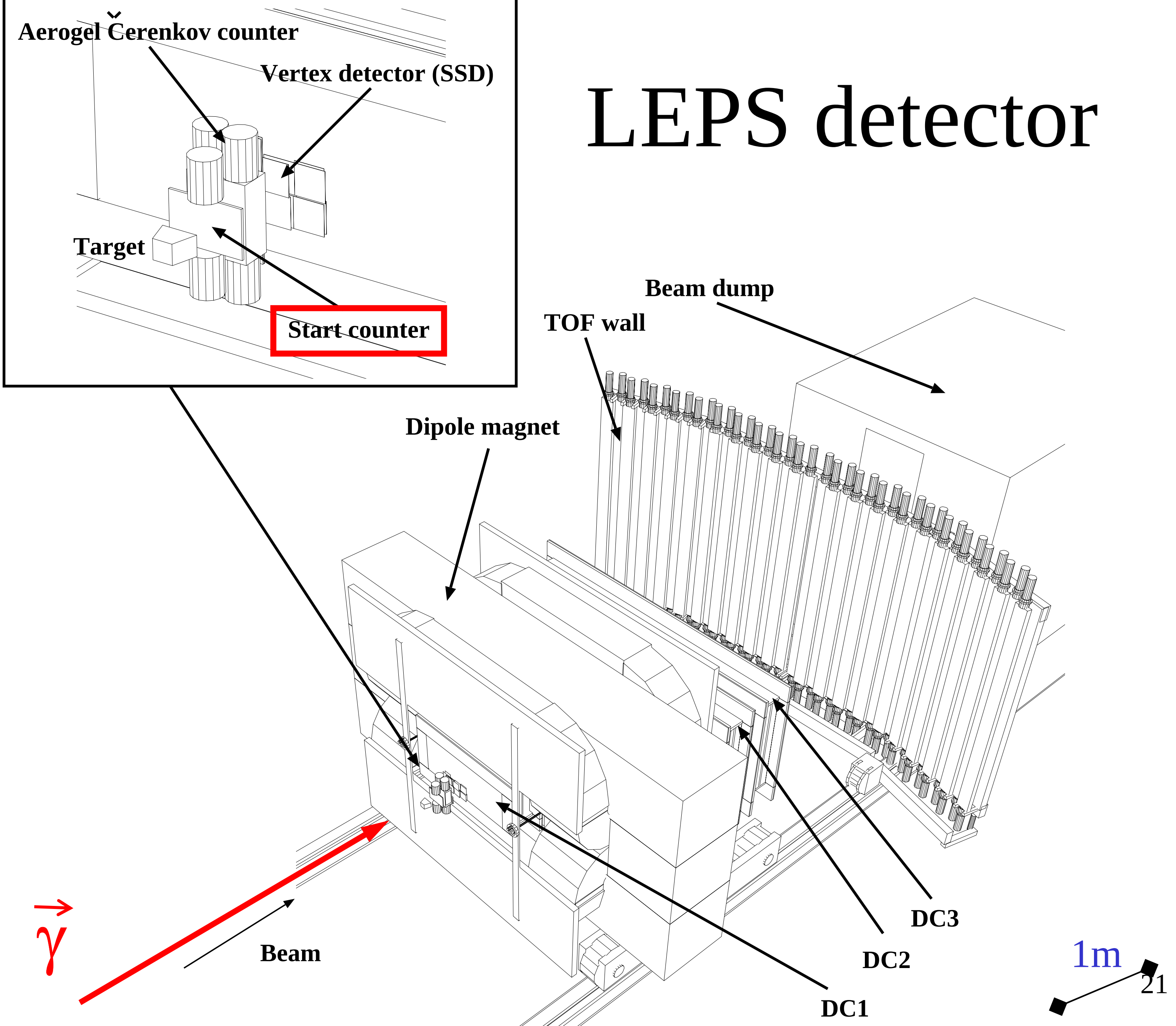
- Third-generation synchrotron radiation facility
- Circumference: 1436 m
- 8 GeV
- 100 mA
- 62 beamlines

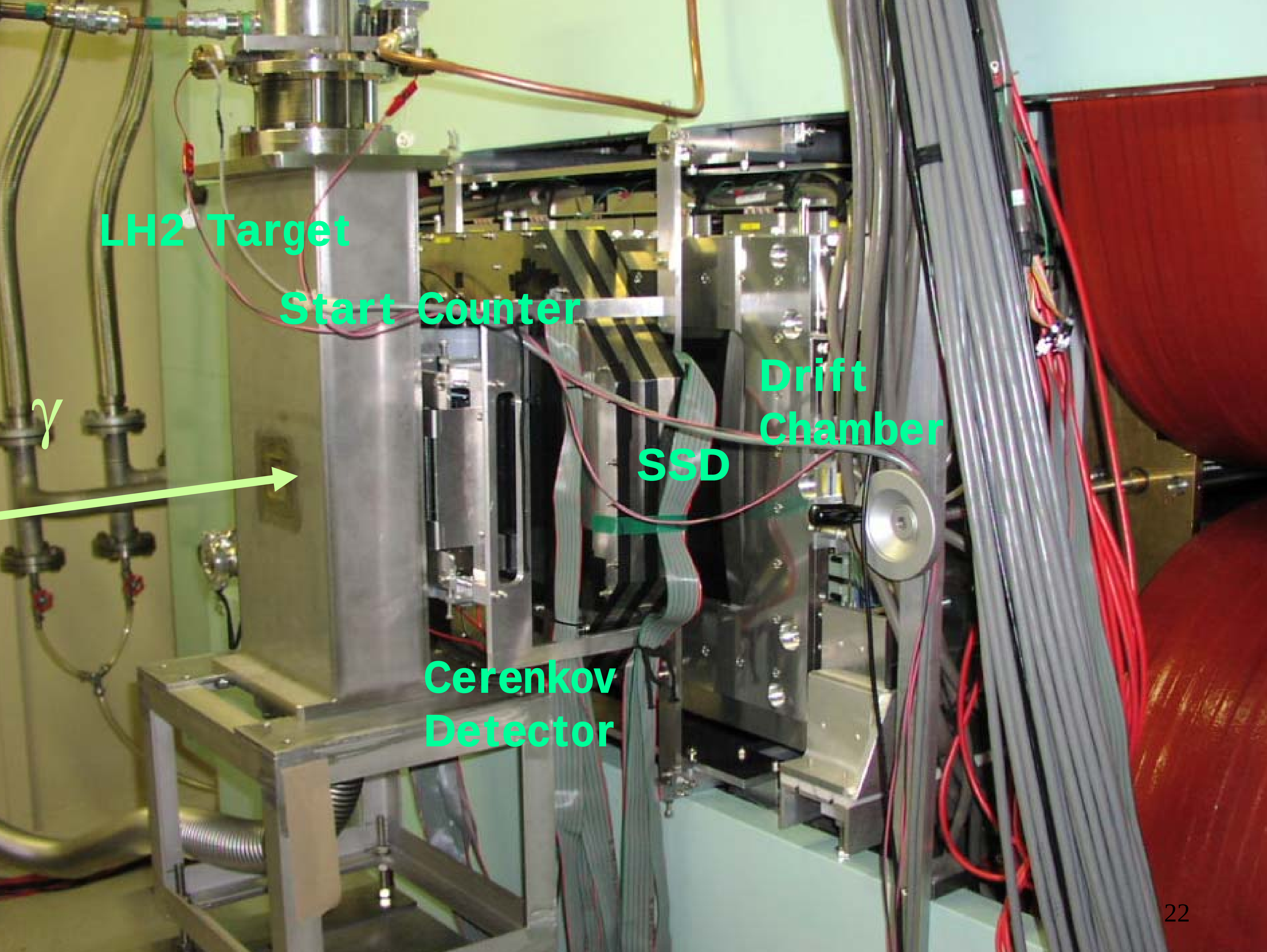
Laser Electron Photon facility at SPring-8

in operation since 2000



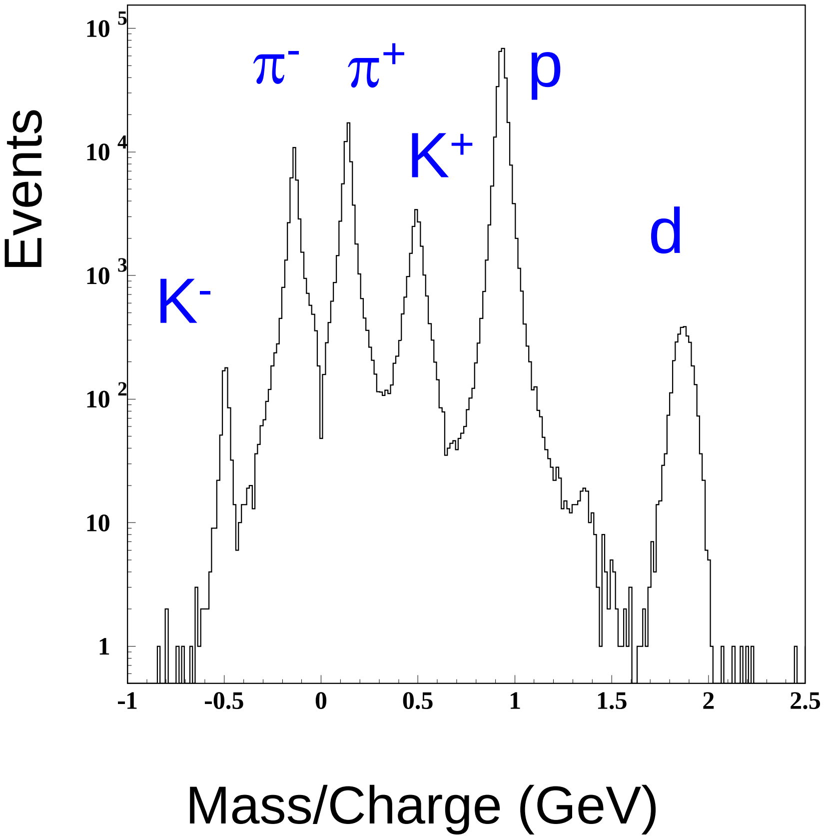
LEPS detector



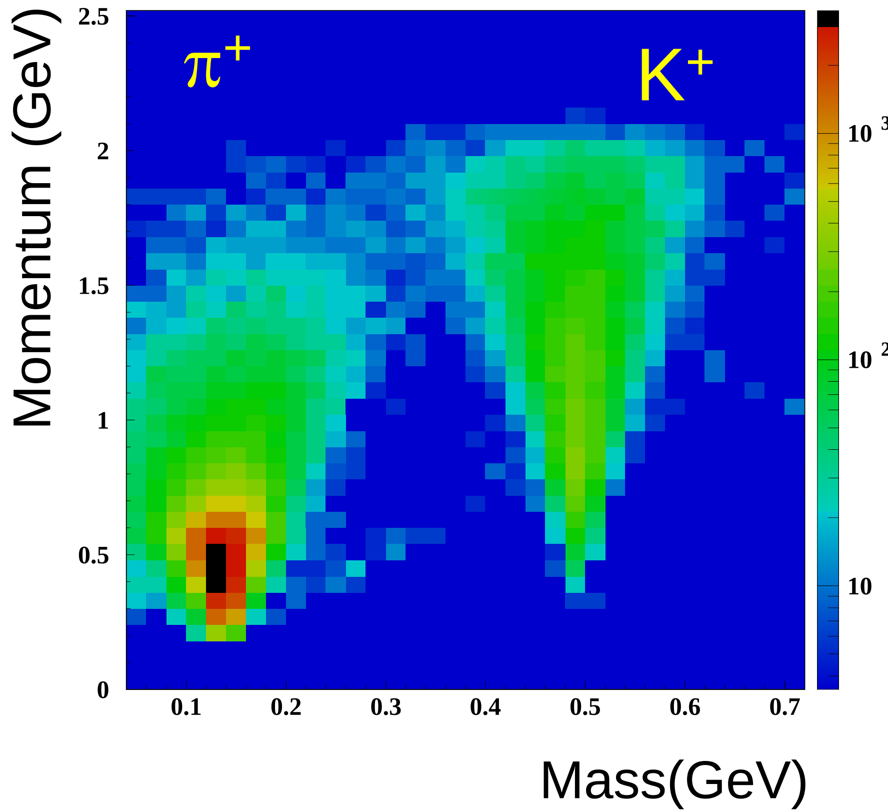

LH2 Target
Start Counter
γ
Drift
Chamber
SSD
Cerenkov
Detector

Charged particle identification

Reconstructed mass

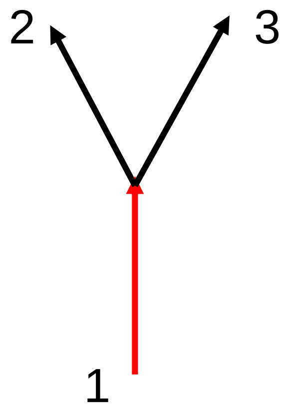


K/π separation (positive charge)



σ(mass) = 30 MeV(typ.) for 1 GeV/c Kaon

Mass of short lived particle

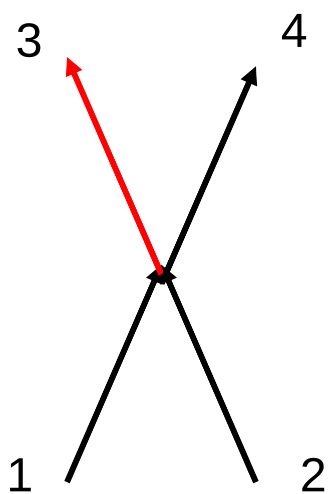


$$E_1 = E_2 + E_3$$

$$p_1 = p_2 + p_3$$

$$m_1^2 = E_1^2 - p_1^2$$

Invariant mass



$$E_3 = E_1 + E_2 - E_4$$

$$p_3 = p_1 + p_2 - p_4$$

$$m_3^2 = E_3^2 - p_3^2$$

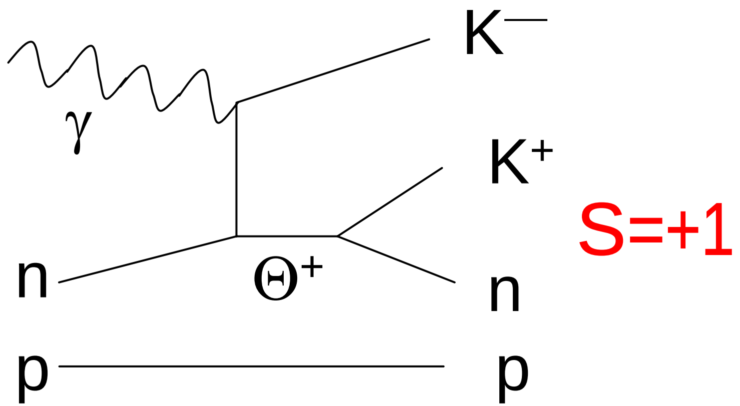
Missing mass

Reaction diagrams

$$\gamma n\,(p) \rightarrow \Theta^{+} K^{-}\,(p)$$

$$\Theta^{+} \rightarrow K^{+} n$$

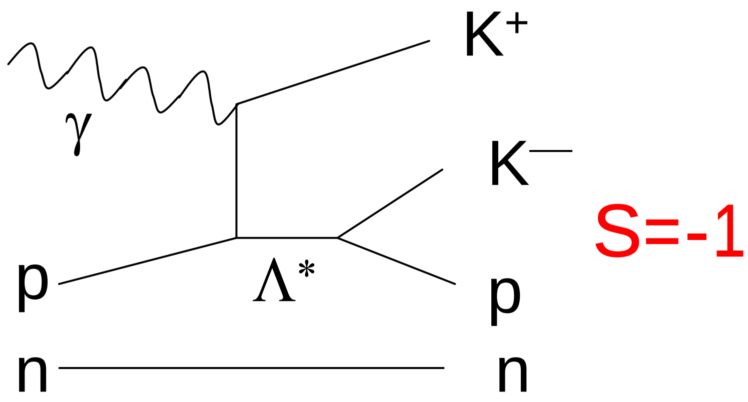
"Exotic"



$$\gamma p\,(n) \rightarrow \Lambda^{*}(1520) K^{+}\,(n)$$

$$\Lambda^{*}(1520) \rightarrow K^{-} p$$

"Standard" baryon



$\gamma N \rightarrow \phi(1020)\, N \rightarrow K^{+} K^{-} N$ Meson resonance

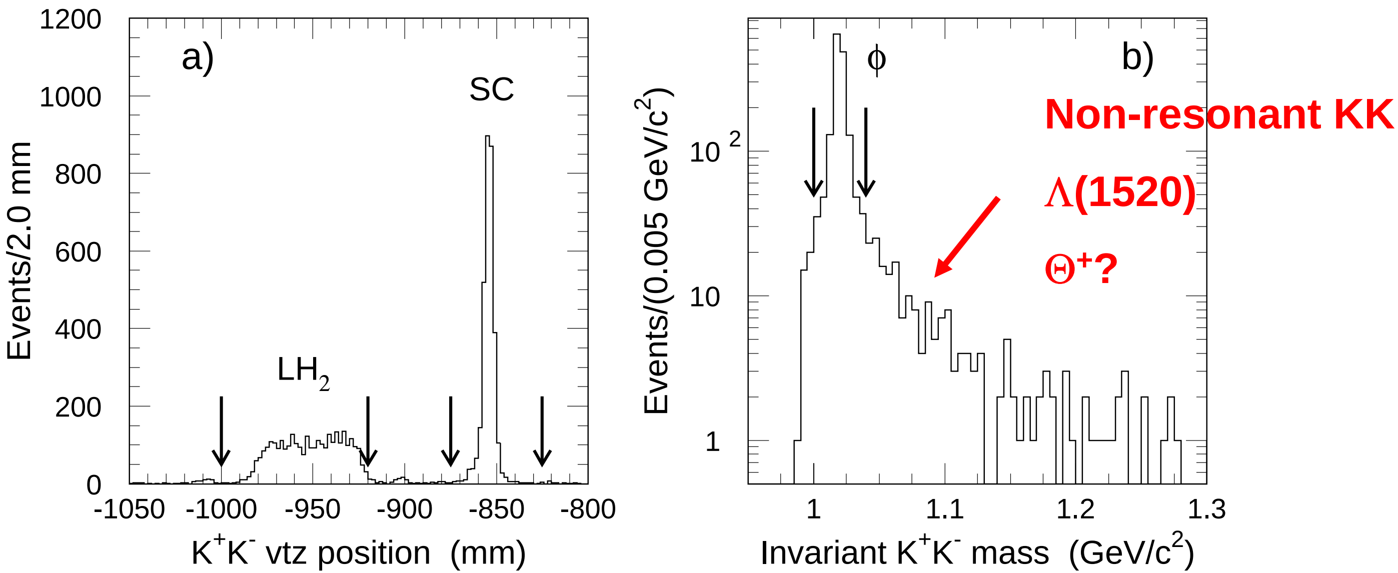
Identification of Θ^+

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

- K^- missing mass gives Θ^+ mass
- K^+K^- missing mass gives n

Problems:

- "background"
  - $\phi \rightarrow K^+K^-$ (produced from n & p)
- Fermi motion distorts a missing mass spectrum.

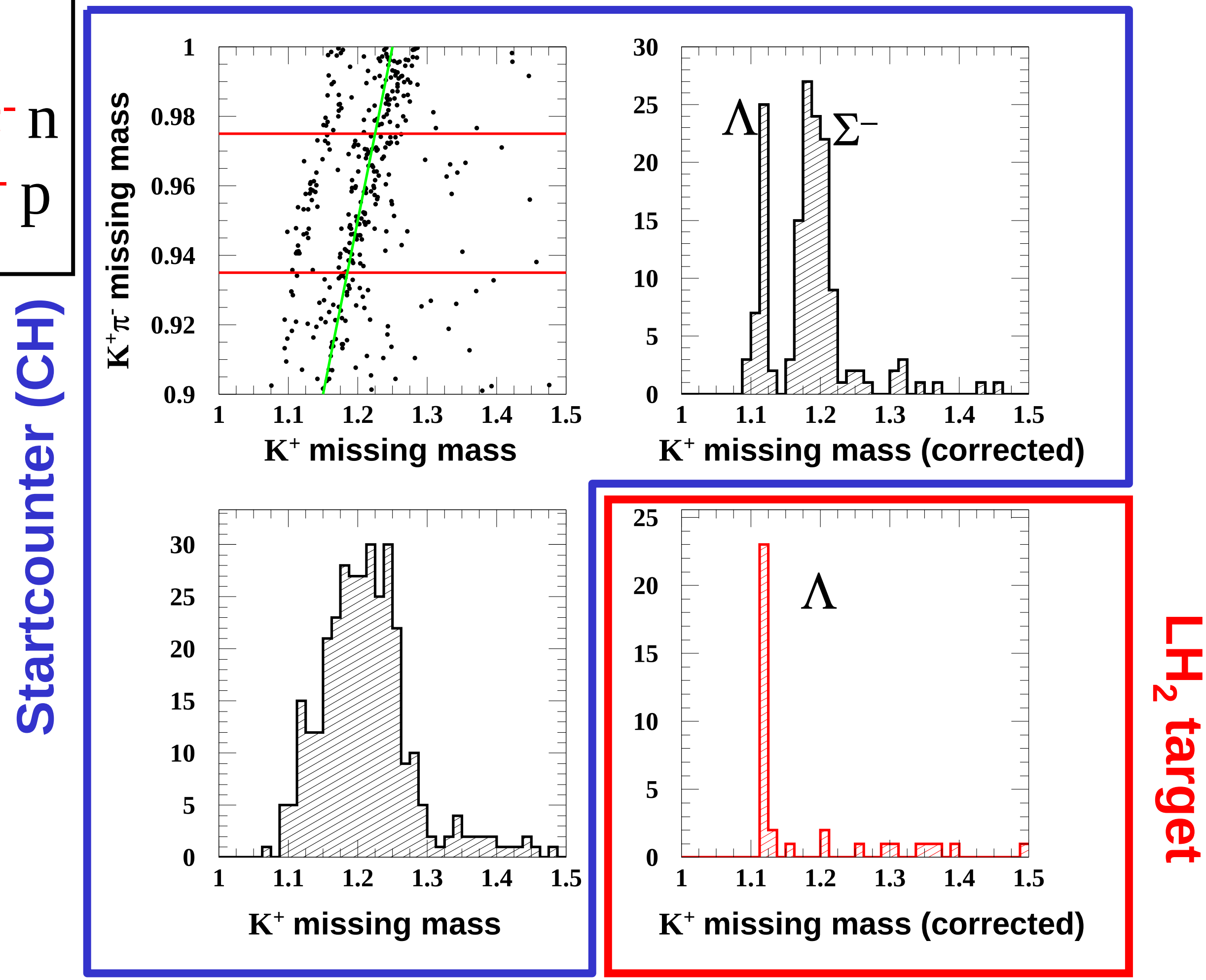


Fermi motion correction

Test-case:

$\gamma\, n \rightarrow K^{+}\Sigma^{-} \rightarrow K^{+}\pi^{-}n$

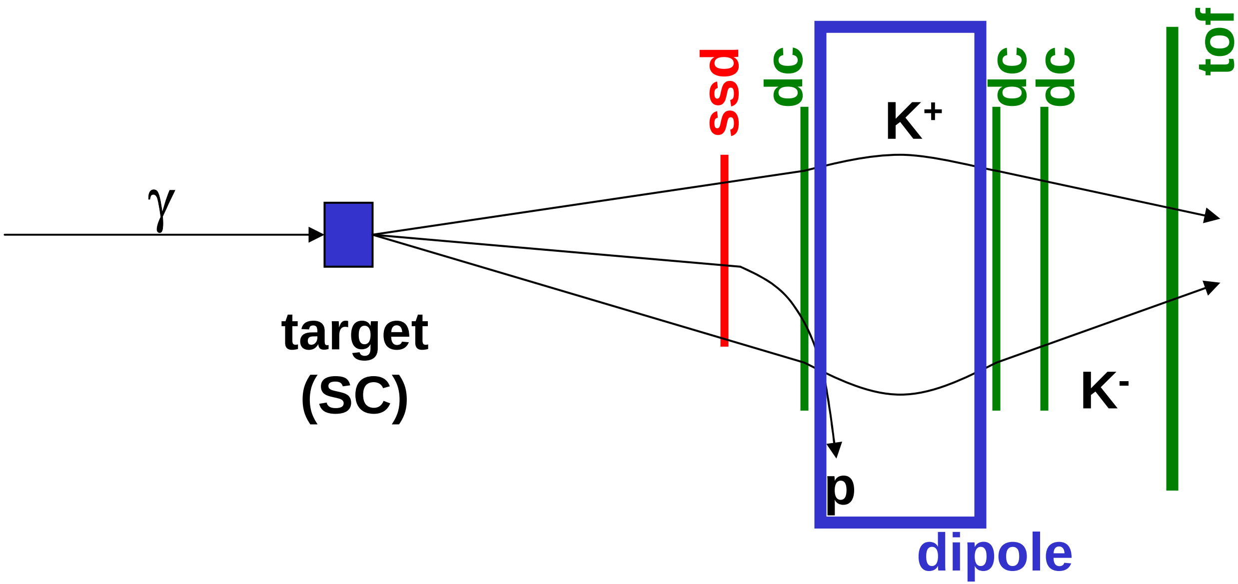
$\gamma\, p \rightarrow K^{+}\Lambda \rightarrow K^{+}\pi^{-}p$



Correction: $MM_{\gamma K+}\,(\text{corrected}) = MM_{\gamma K+} - MM_{\gamma K+\pi-} + M_n$

Proton-recoil cut

- $\gamma n \rightarrow K^+K^-n$ no recoil proton (proton is a spectator)
- $\gamma p \rightarrow K^+K^-p$ slow recoil proton is present
- proton is too slow to be seen in full detector, but might be seen in SSD vertex detector.



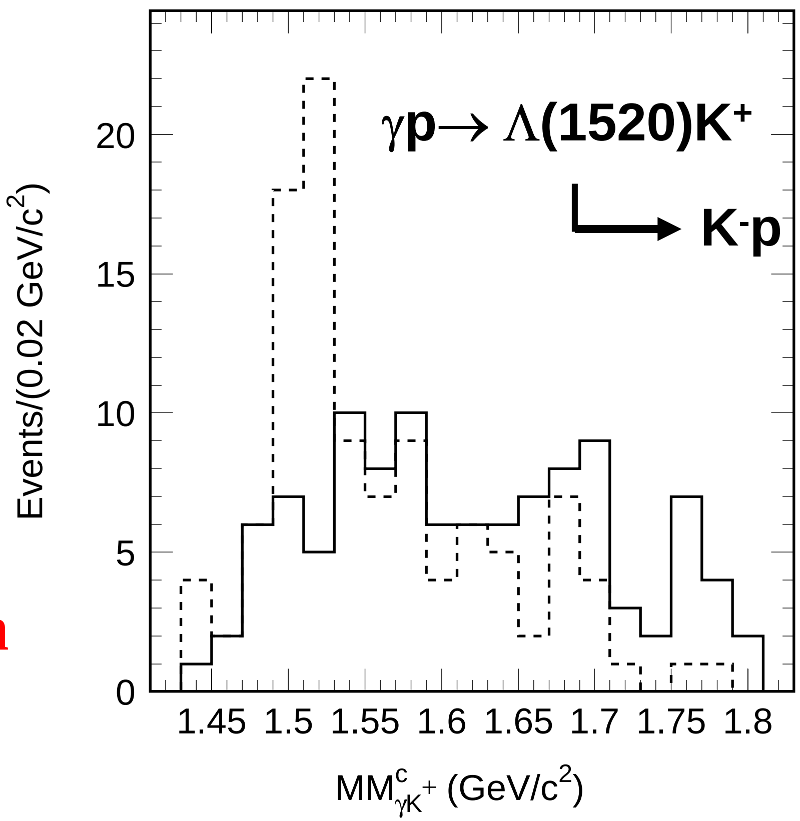
Remove all events for which proton is detected in SSD, or for which predicted proton track does not hit SSD.

Fermi motion corrected K^+ missing mass

$\gamma\, p(n) \rightarrow K^+ K^- p(n)$

$MM^c_{\gamma K+} = MM_{\gamma K+} - MM_{\gamma K+K-} + M_n$

- select KK events from start counter,
- look for a proton in the vertex counter.
  - proton is absent (solid line)
  - proton is present (dashed line)

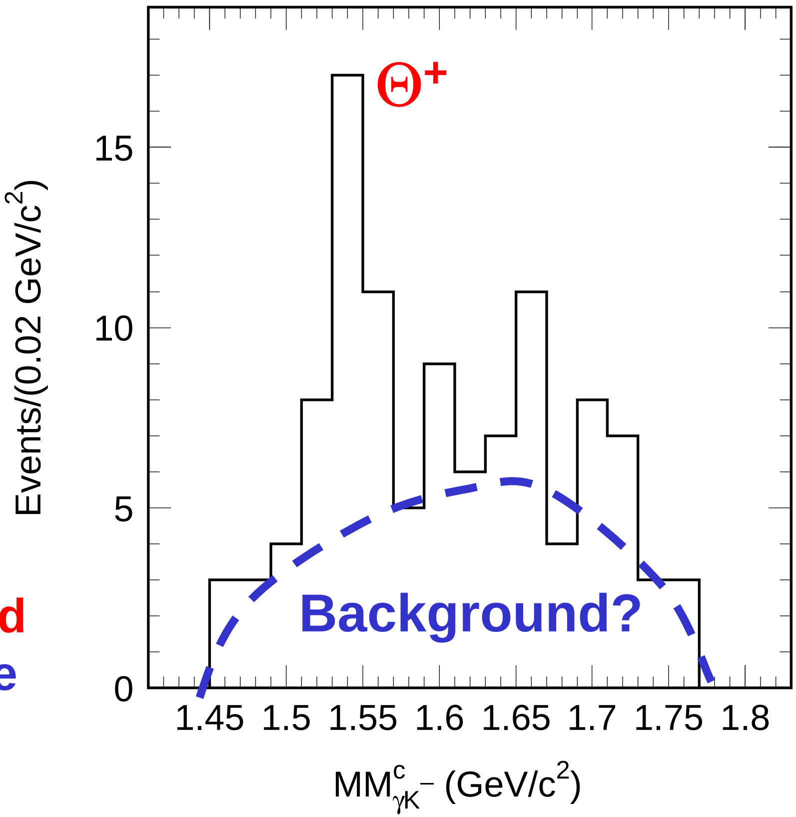


No Λ(1520) peak in events with a spectator proton.

n(γ,K$^-$) missing mass

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

- **select KK events from SC**
- **apply KK invariant mass cut (ϕ)**
- **apply KK missing mass cut ($0.9 < MM_{kk} < 0.98$)**
- **apply proton recoil cut**
- **construct K$^-$ missing mass plot**



Background shape can be determined from events from LH_2 target using the same cuts except for:

- **Proton-recoil cut is removed**
- **Λ(1520) events are removed (only from p)**

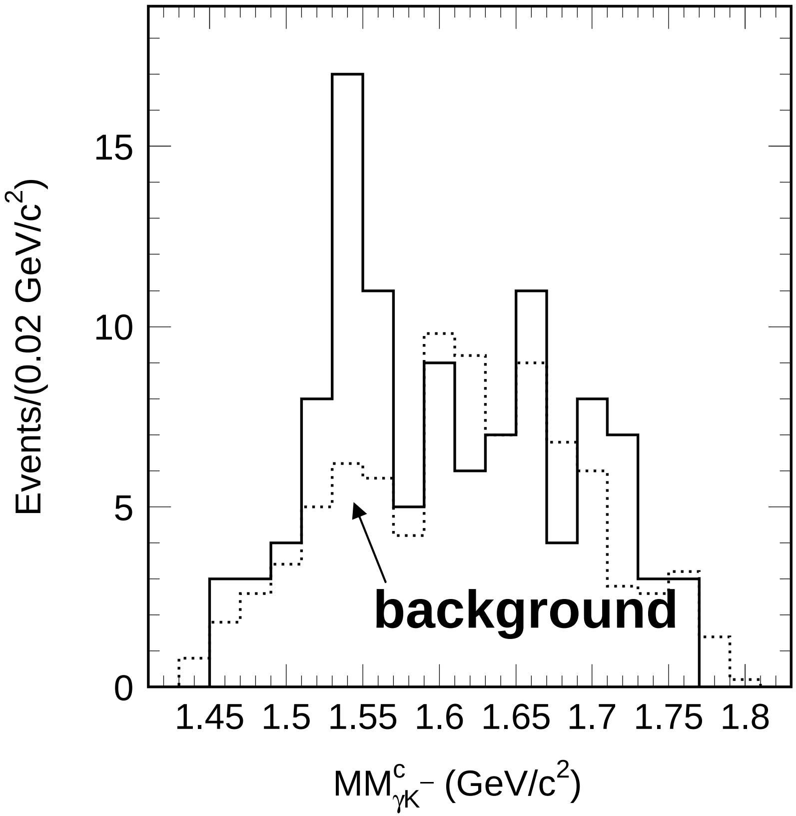
Θ^+ identification

M = 1.54±0.01 MeV
Γ < 25 MeV
Gaussian significance 4.6σ

Background level is estimated by a fit in a mass region above 1.59 GeV.

Assumption:

- **Background is from non-resonant K^+K^- production off the neutron/nucleus**
- **… is nearly identical to non-resonant K^+K^- production off the proton**



Phys.Rev.Lett. 91 (2003) 012002

hep-ex/0301020

Confirmations from other labs

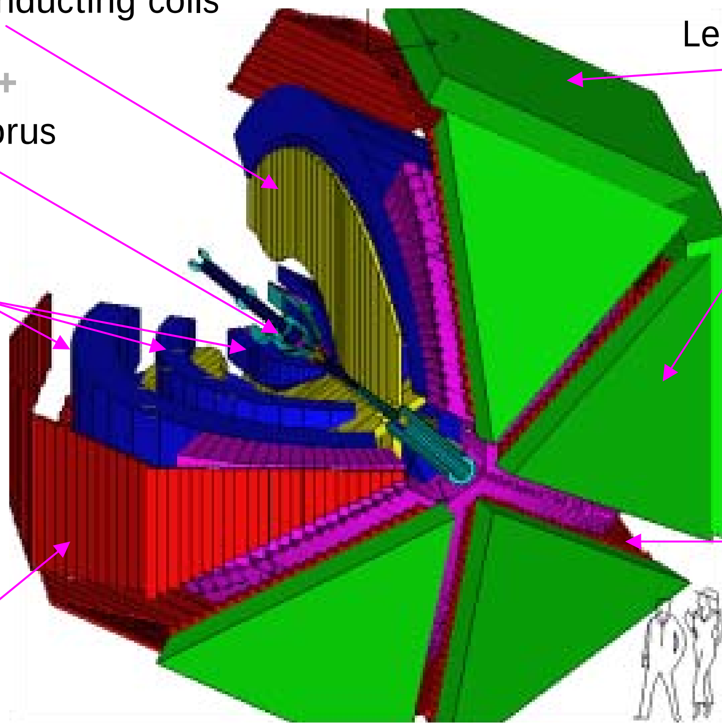
CEBAF Large Acceptance Spectrometer

Torus magnet
6 superconducting coils

Electromagnetic calorimeters
Lead/scintillator, 1296 photomultiplie

Liquid D_2 (H_2)target +
γ start counter; e minitorus

Drift chambers
argon/CO_2 gas, 35,000 cells



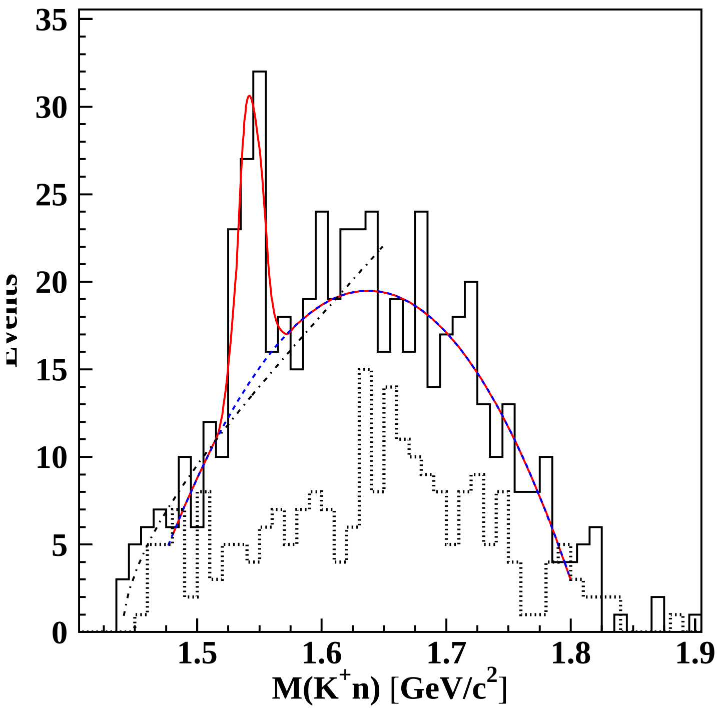
Gas Cherenkov counter
e/π separation, 256 PMTs

Time-of-flight counters
plastic scintillators, 684 photomultipliers

CLAS/JLAB Exclusive process

hep-ex/0307018

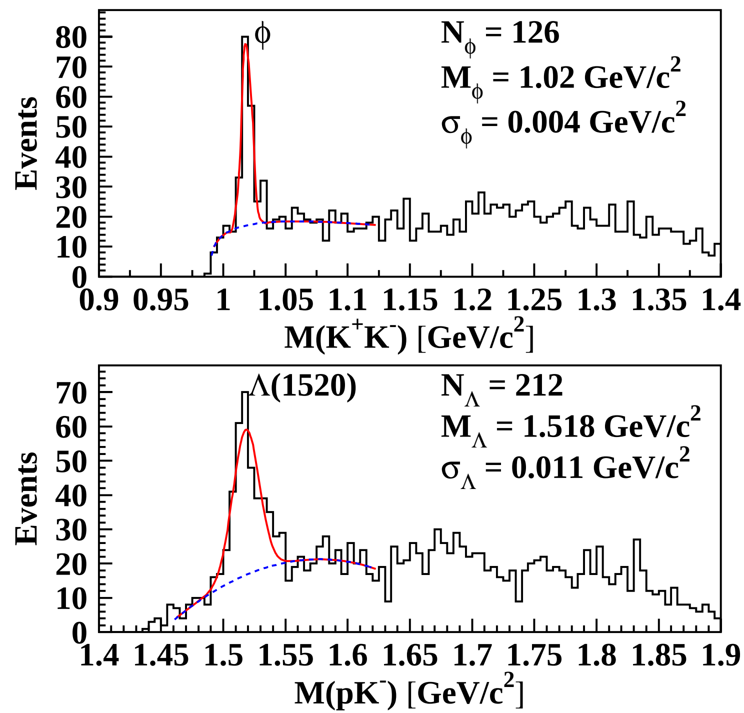
$\gamma\, d \rightarrow p\, K^{+} K^{-} n$



M = 1542±5 MeV

Γ < 21 MeV

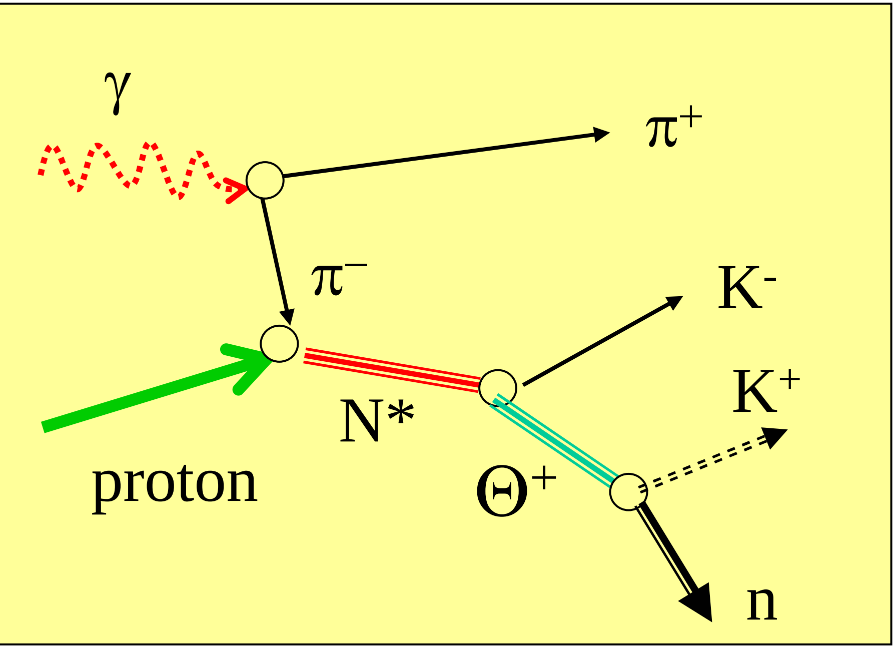
- **Detect $K^{+} K^{-}$ p**
- **Reconstruct neutron via missing mass.**
- **Remove ϕ and $\Lambda(1520)$.**



CLAS/JLAB on protons

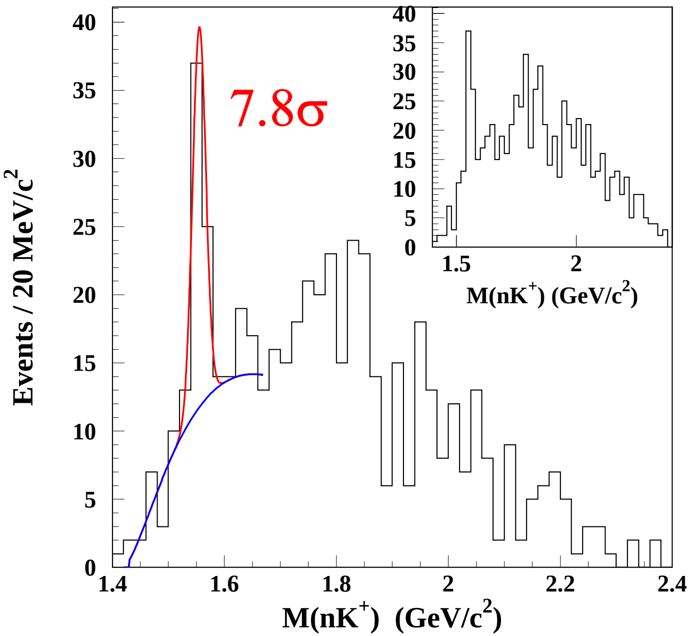
CLAS Collaboration
PRL 92, 032001-1 (2004).

$\gamma\, \mathbf{p} \rightarrow \pi^+ K^+ K^- (\mathbf{n})$

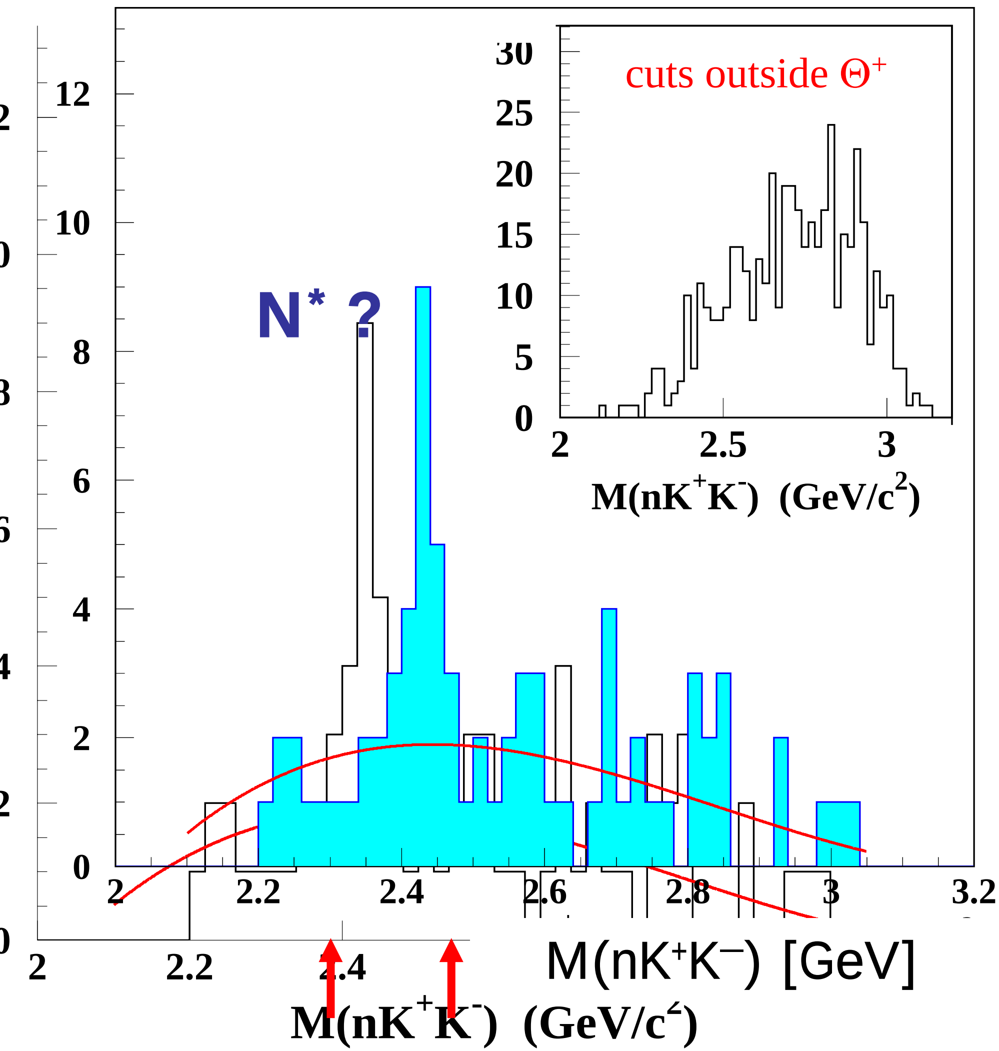


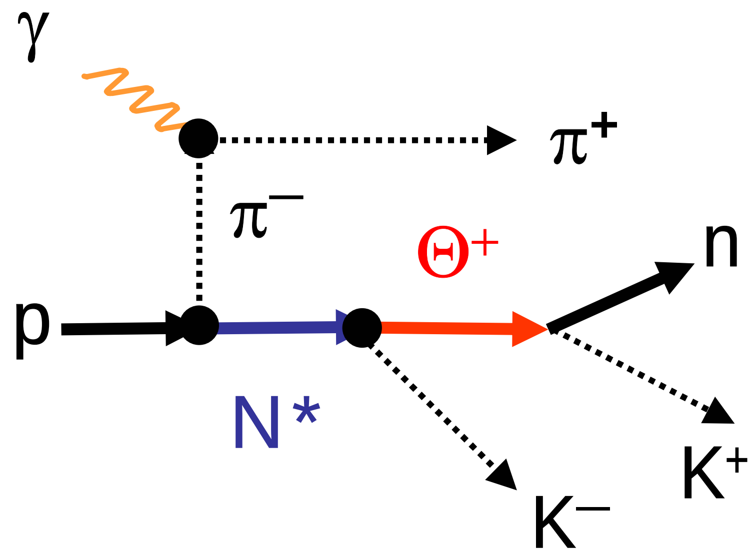
$M = 1555 \pm 1 \pm 10$ **MeV**
$\Gamma < 26$ **MeV**

- **Detect $K^+ K^- \pi^+$**
- **Reconstruct neutron from missing 4-momentum.**
- **Require cos $\theta\pi > 0.8$ & cos $\theta_K < 0.6$**



N* production mechanism?



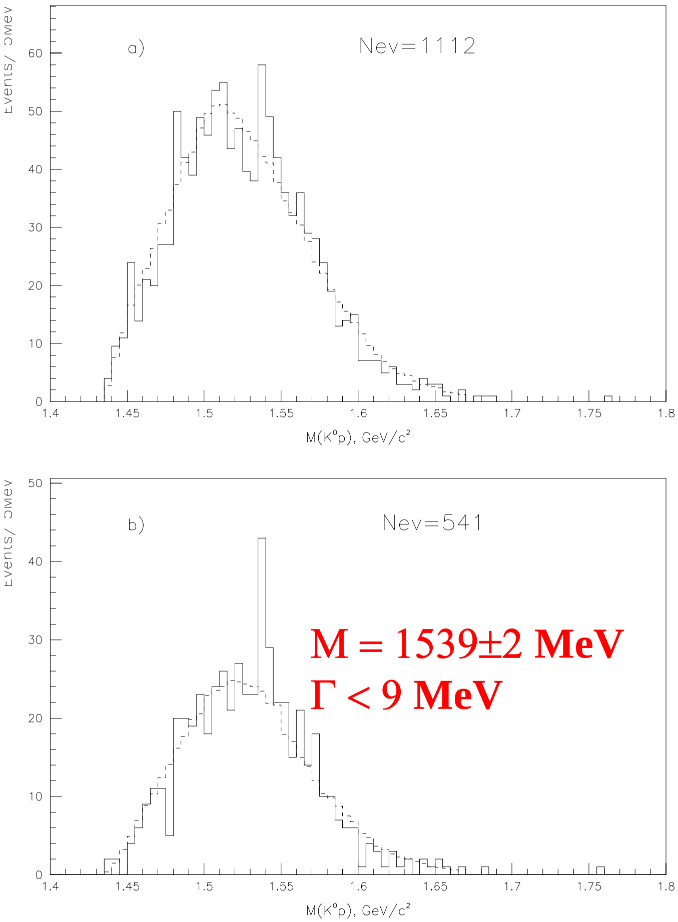


- **What do π^-p scattering data say?**
- π^-p cross section data in PDG have a gap in the mass range 2.3–2.43 GeV.

DIANA/ITEP Result

$K^+ Xe \rightarrow K^0 p X$

$(K^+ n \rightarrow K^0 p)$



hep-ex/0304040

- **P_{K+} < 530 MeV/c**
- **Require θ_K<100deg. & θ_p<100 deg.**
- **Remove cos ϕ_{pK} <0 ← back-to-back**

$K^+ n \rightarrow \Theta^+ \quad \longleftrightarrow \quad \Theta^+ \rightarrow K^+ n$

$\Gamma = 0.9 \pm 0.3$ **MeV**

Cahn and Trilling hep-ph/0311245

consistent with KN phase shift analysis by Arndt et. al.

Phys. Rev. C68, 042201(R)

Resonances Formalism

- The resonant Breit Wigner expression for $1\ 2 \rightarrow R \rightarrow 3\ 4$.

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

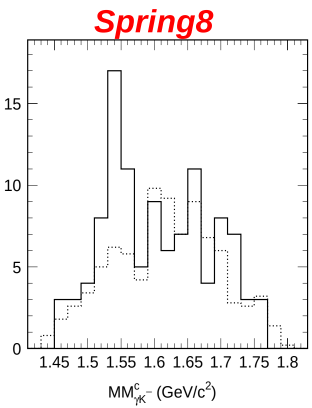
  $\times \{\Gamma^2/((E-M)^2 + \Gamma^2/4)\}$

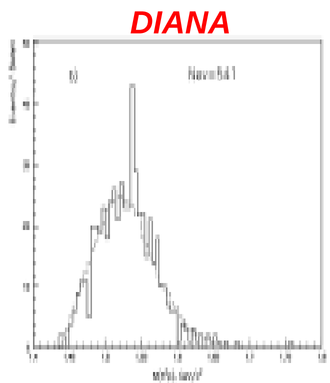
- Assume: The spin of the Θ^+ is 1/2.
  - $J=1/2$, $S1=0$, $S2=1/2$
  - For $K^+ n \rightarrow \Theta^+ \rightarrow K^0 p$, $B_{in}=B_{out}=1/2$.

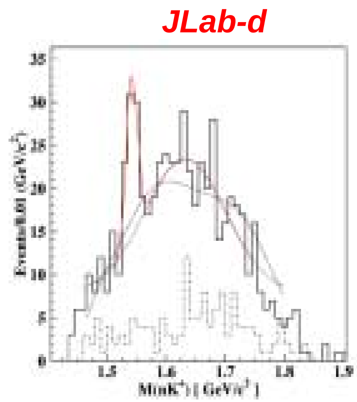
  $\sigma_{BW}(E) = (4\pi/k^2) \{\Gamma^2/((E-M)^2 + \Gamma^2/4)\}$

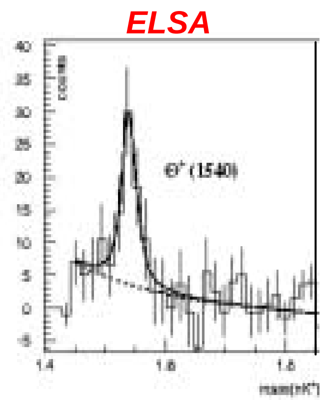
  At $E=M$, $\sigma_{BW}(M) = 16.8$ mb.

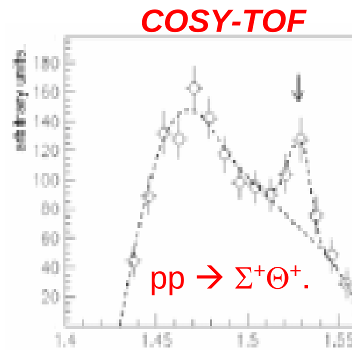
Evidence for Penta-Quark States

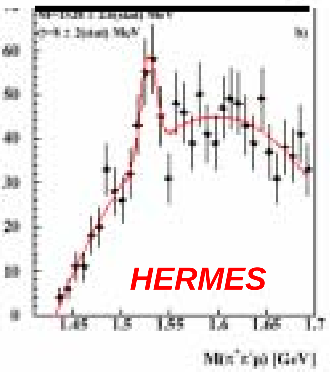


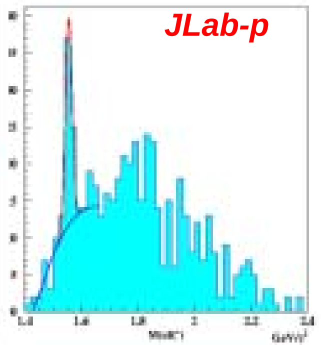


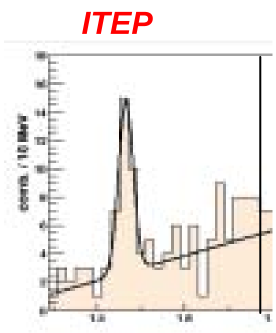


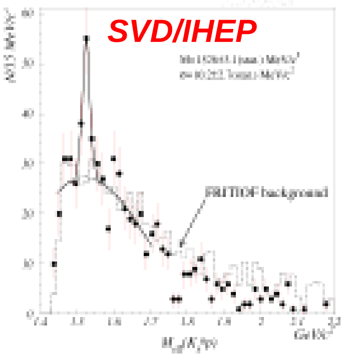




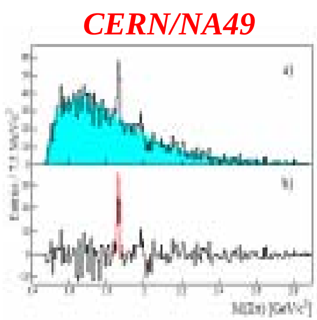


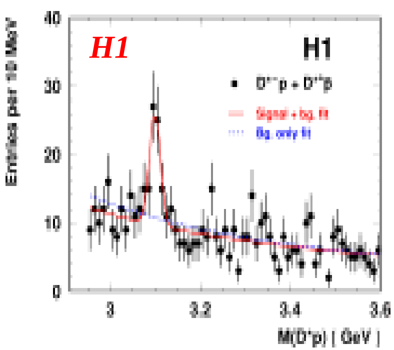


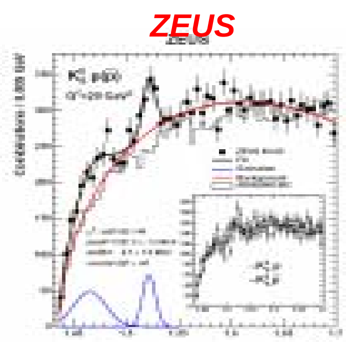


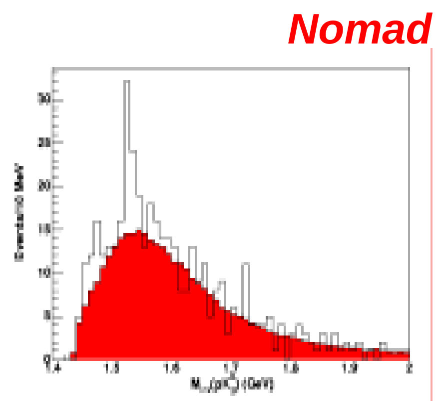


This is a lot of evidence









Θ^+: Summary of Expt.

Where	Reaction	Mass	Width	σ's*
LEPS	$\gamma C \to K^+K^- X$	1540 +- 10	< 25	4.6
DIANA	$K^+Xe \to K^0p X$	1539 +- 2	< 9	4.4
CLAS	$\gamma d \to K^+K^-p(n)$	1542 +- 5	< 21	5.2
SAPHIR	$\gamma p \to K^+K^0(n)$	1540 +- 6	< 25	4.8
ITEP	$\nu A \to K^0p X$	1533 +- 5	< 20	6.7
CLAS	$\gamma p \to \pi^+K^-K^+(n)$	1555 +- 10	< 26	7.8
HERMES	$e^+d \to K^0p X$	1528 +- 3	13 +- 9	~5
ZEUS	$e^+p \to e'K^0p X$	1522 +- 3	8 +- 4	~5
COSY	$pp \to K^0p\Sigma^+$	1530 +- 5	< 18	4-6

*Gaussian statistical significance: estimated background fluctuation

Mass

- M = 1.54 GeV: SPring-8, ITEP, CLAS-d
  - These were the first 3 publications
- M = 1.555 GeV: CLAS-p
  - This one has over 7 σ significance!
- M = 1.53 GeV: HERMES, ZEUS, COSY
  - These are the most recent ones…
- Can all of these be the same resonance?
  - We need to find better ways to estimate the experimental uncertainties.

Width

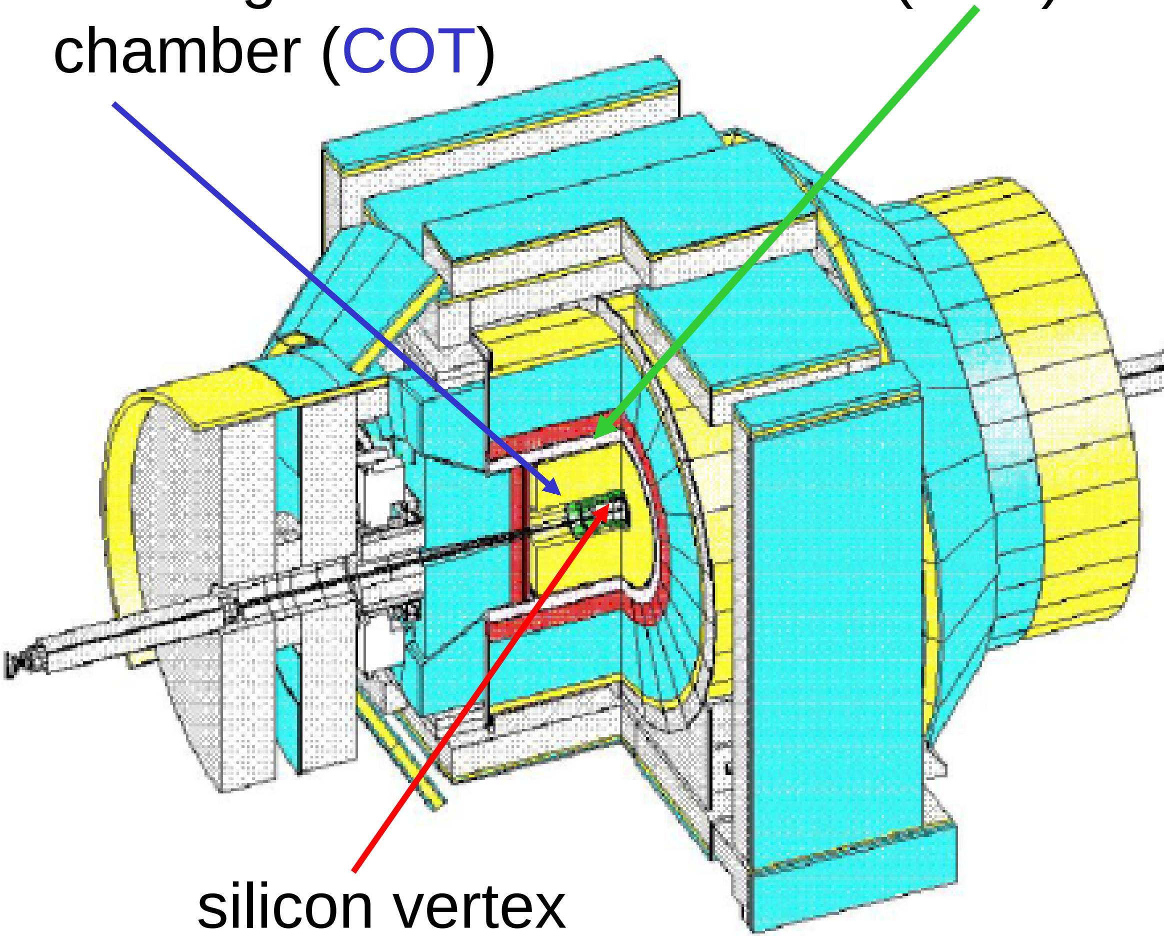
- Again, there is inconsistency:
  - Most measurements are only upper limits.
  - DIANA has $\Gamma < 9$ MeV.
  - HERMES: Γ = 13 +- 9 stat. (+- 3 sys.) MeV
  - ZEUS: Γ = 8 +- 4 stat. (+- 5 sys.) MeV
  - Arndt *et al.* and Cahn *et al.* analysis of KN phase shifts suggests that $\Gamma < 1$ MeV !!
- The small width is the hardest feature for theorists to understand…

Null results

Pentaquark Searches with CDF Detector

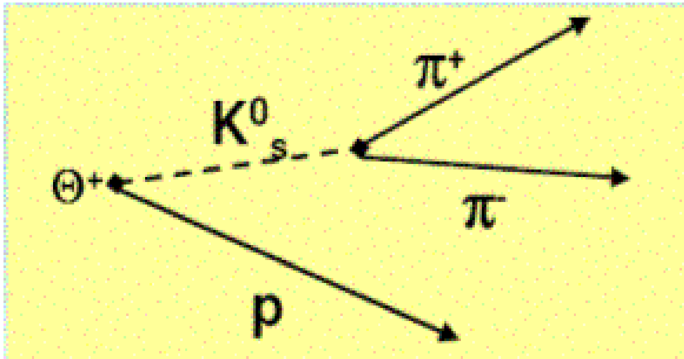
Search Modes:

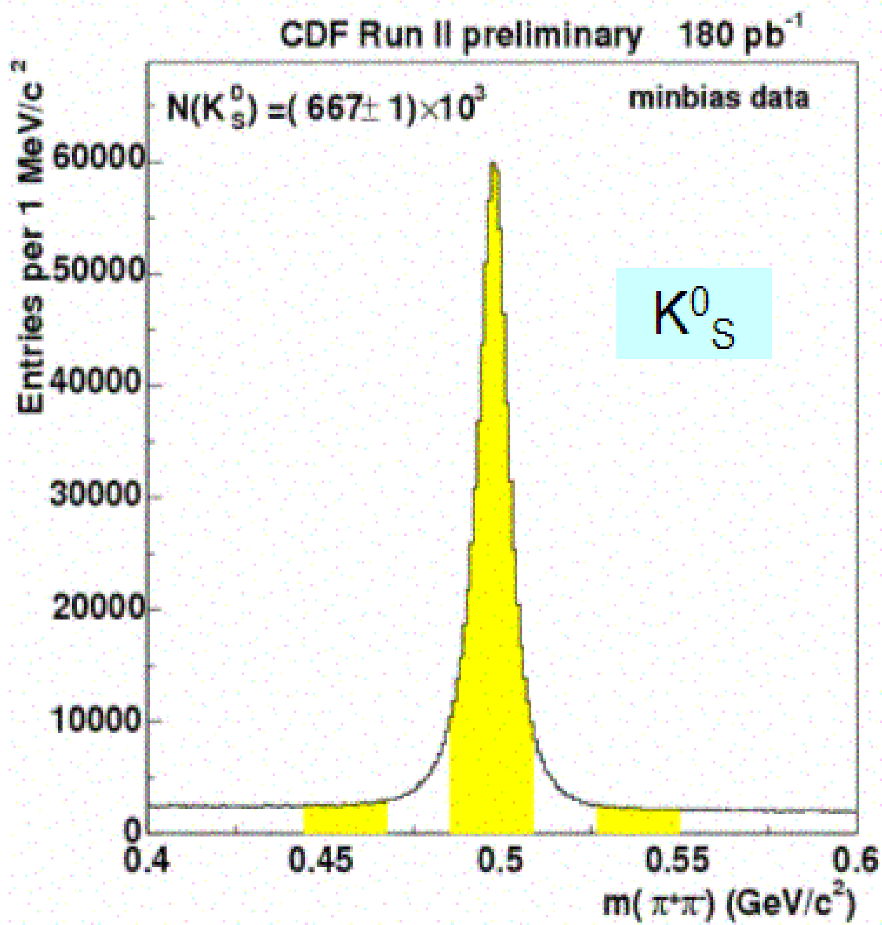
- Θc^0
  - ↳ D^{*+}p(bar)
    - ↳ $D^0\pi^+$
      - ↳ $K^-\pi^+$
- $\Theta^+ \to Ks^0 p$
  - ↳ $\pi^+ \pi^-$
- Ξ^{--}
  - ↳ $\Xi^- \pi^-$
    - ↳ $\Lambda \pi^-$
      - ↳ $\pi^- p$



Θ^+ Search: Strategy & Samples

$p\,K^0_S \rightarrow p\,\pi^+\,\pi^-$



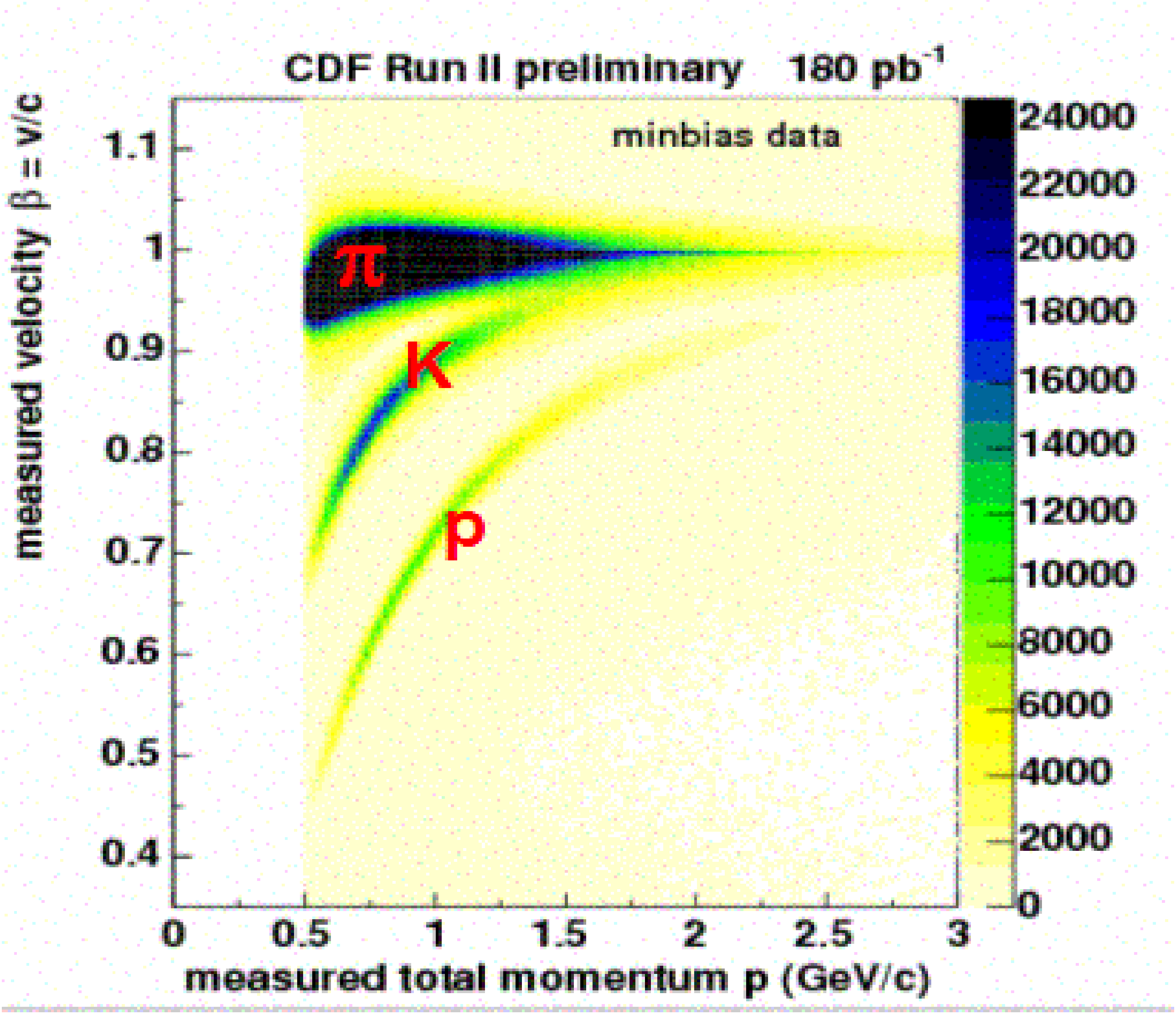


Two energy ranges:

- ***minbias***! 23£10^6 events
- ***jet20***! 16£10^6 events

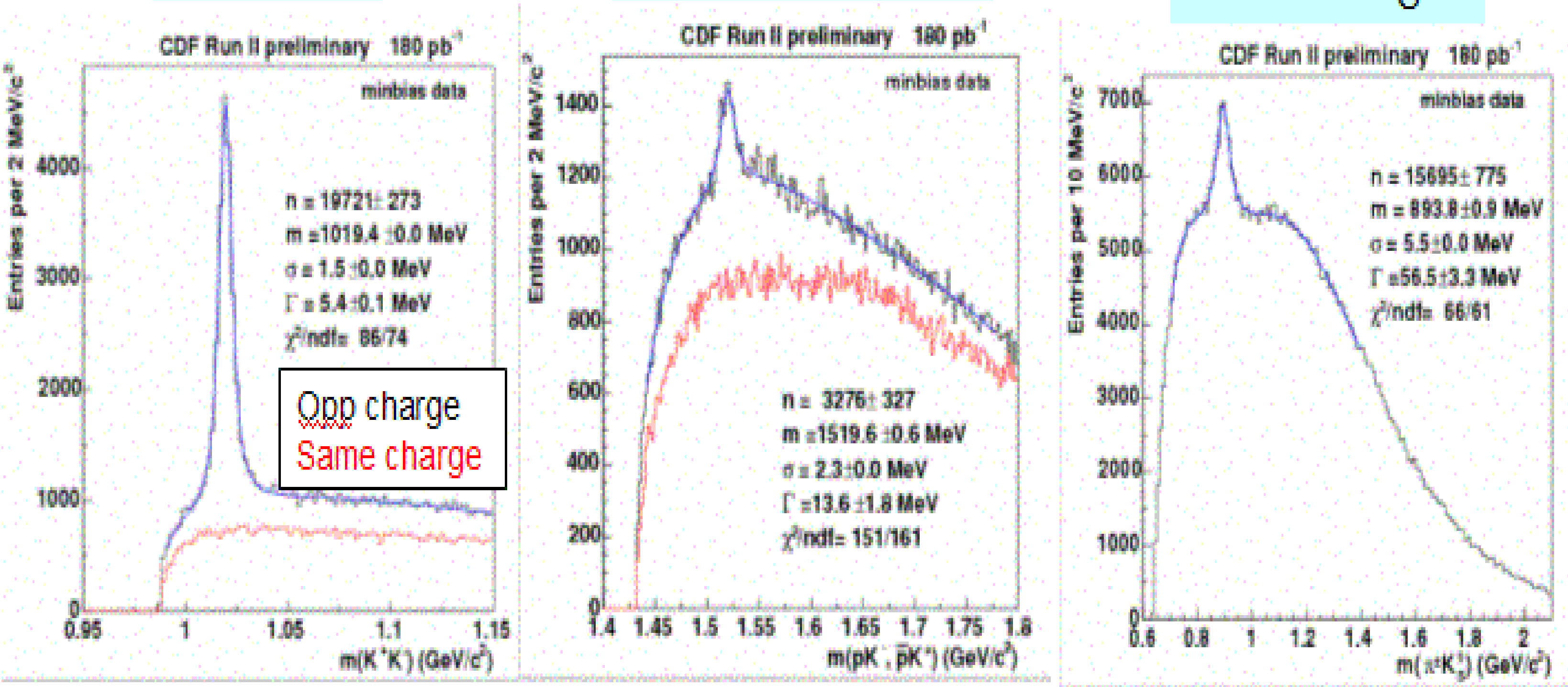
to remove $\Lambda \rightarrow p\pi^-$: m($\pi$p) and m(p$\pi$)¸ 1.13 GeV

Θ^+ Search: Proton ID with TOF



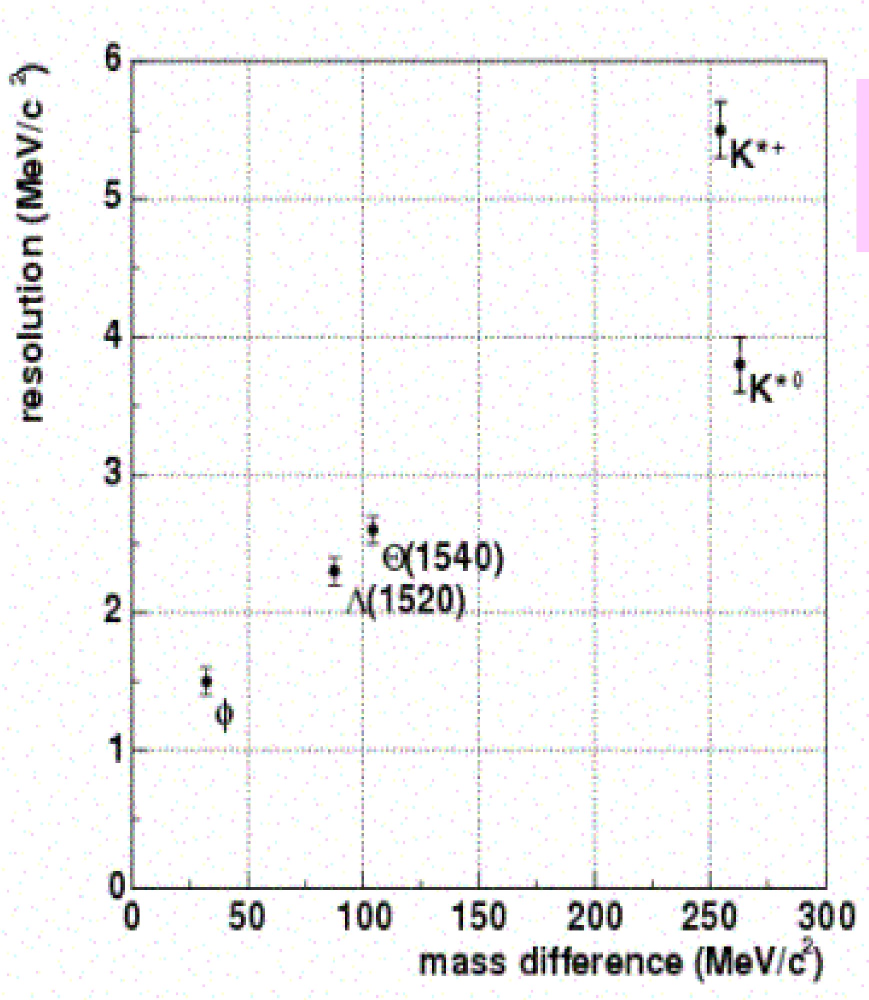
Θ^+ Search: Known Resonances

$\phi \rightarrow K^+K^-$ | $\Lambda(1520) \rightarrow pK^-$ | $K^{*+} \rightarrow K^0_S\pi^+$



Acceptance limited by TOF cuts: (determined with MC)

Θ^+ Search: Mass Resolutions

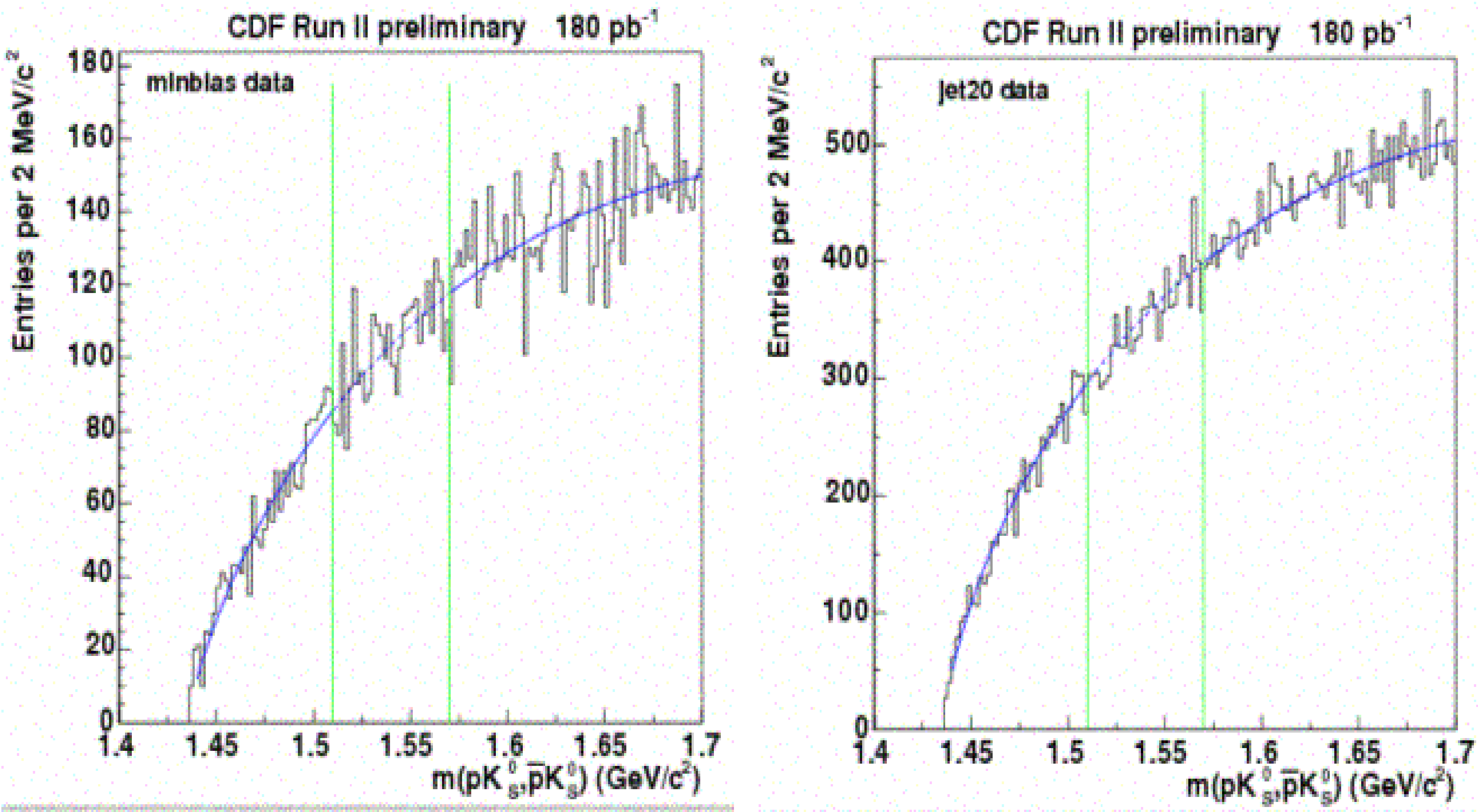


$\sigma(\Theta^+)<3$MeV,

compare with 15MeV expected width

MC resolution validated with K^0_S

Θ^+ Search: pK^0_S Mass Spectrum

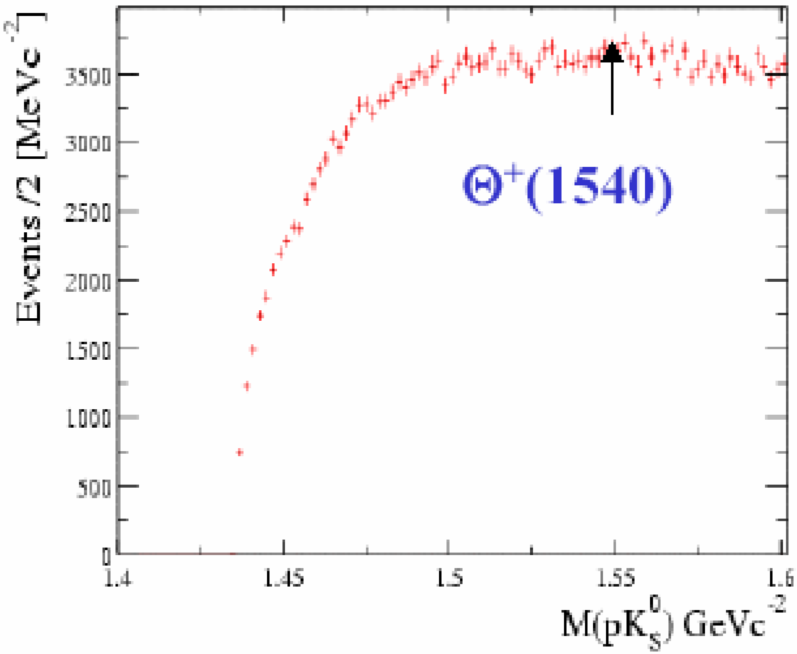


No evidence of narrow resonance

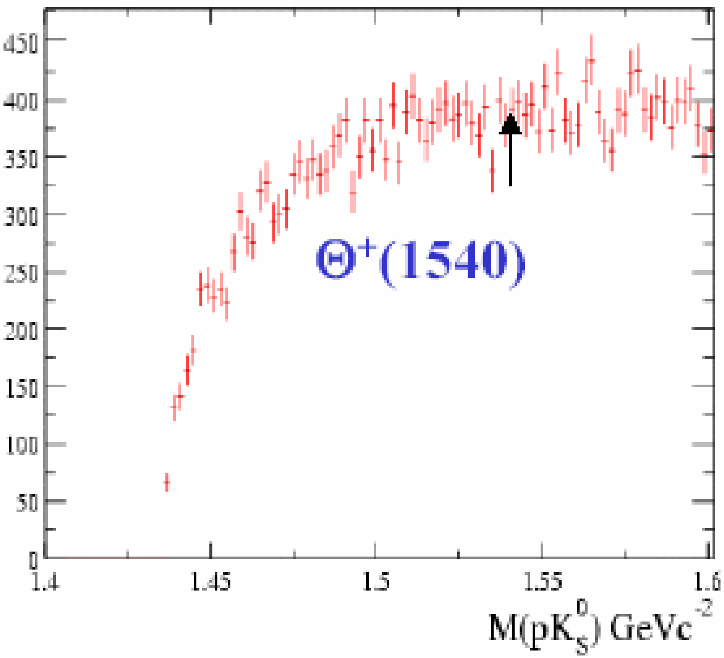
$\Theta^+(p\,K_s)(1540)$ Invariant Mass

No signal observed in any p* region (SFL > 0.0 cm)

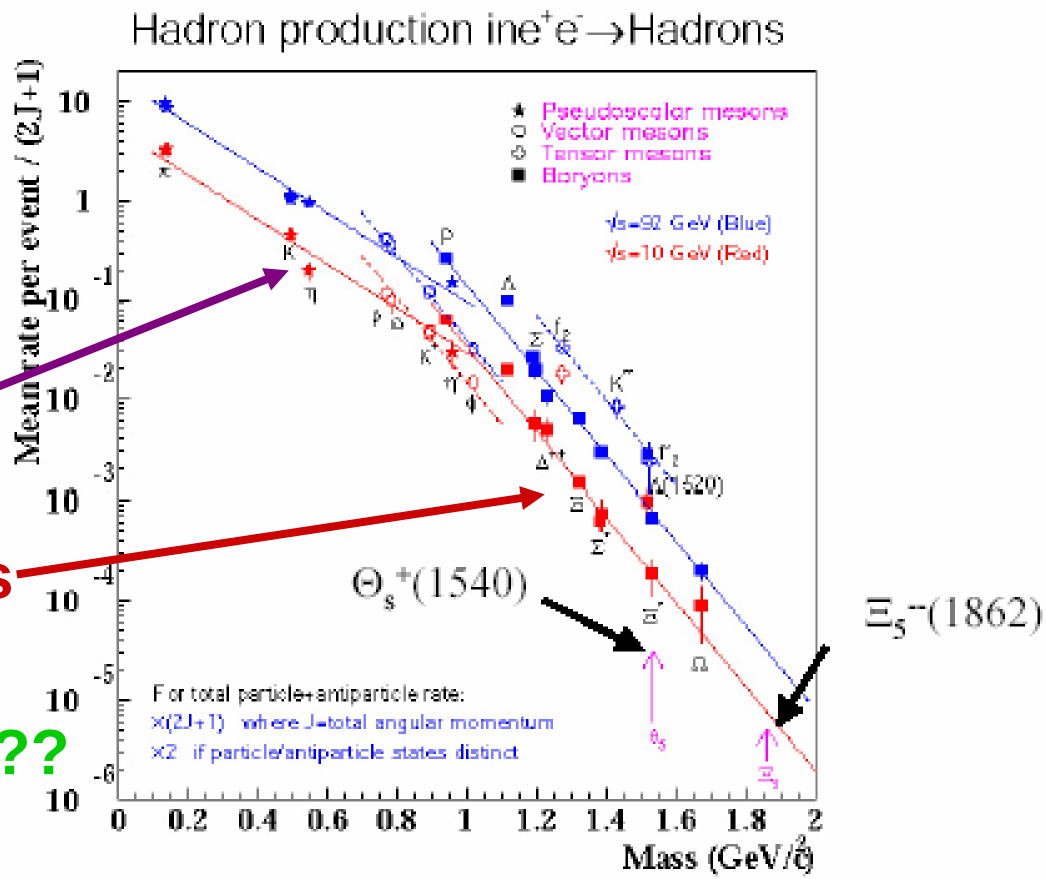
0.0 < p* < 0.5 GeV/c



3.5 < p* < 4.0 GeV/c



Hadron Rate in $e^+e^- \rightarrow$ Hadron



Slope for mesons

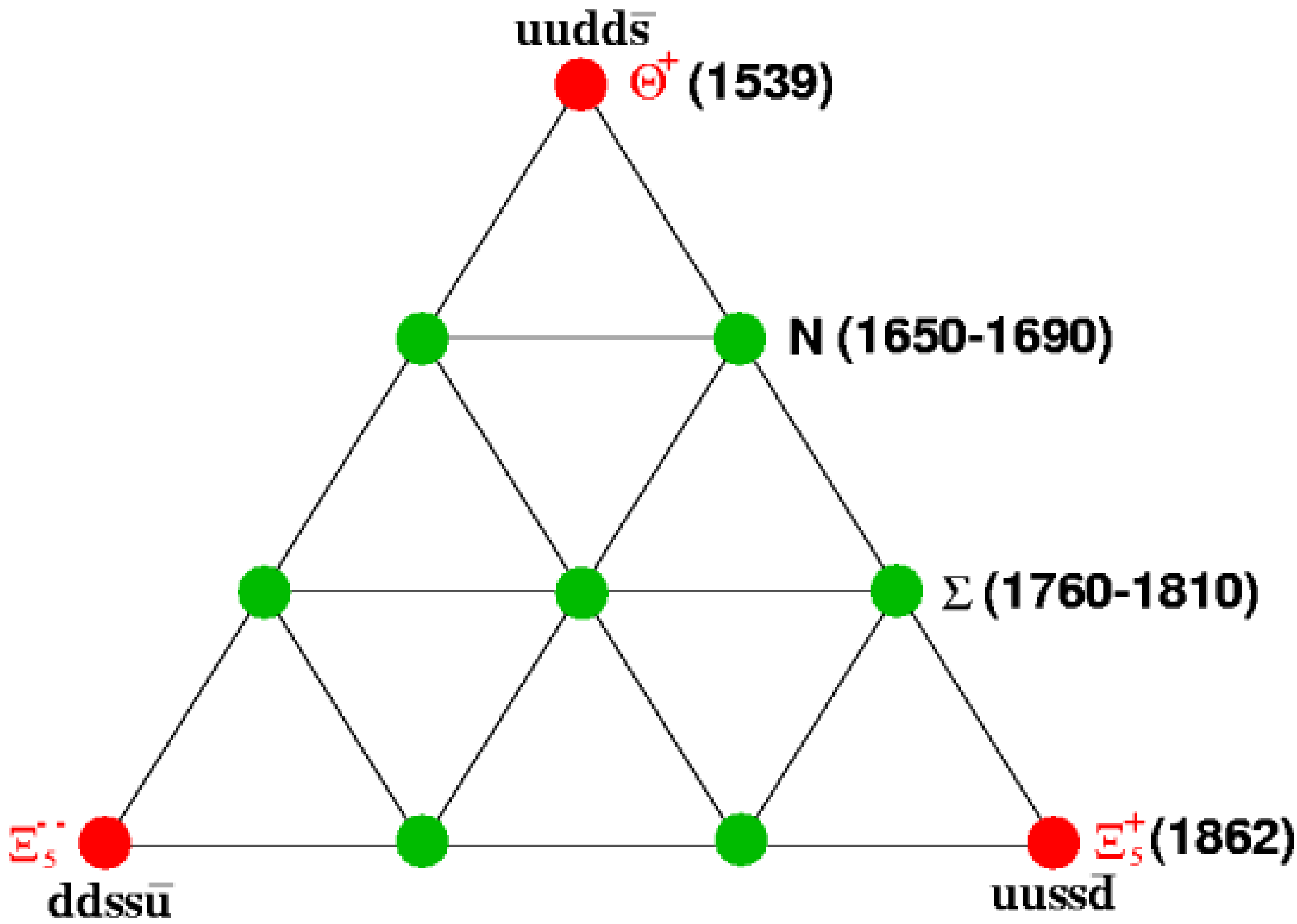
Slope for baryons

Slope for pentaquarks??

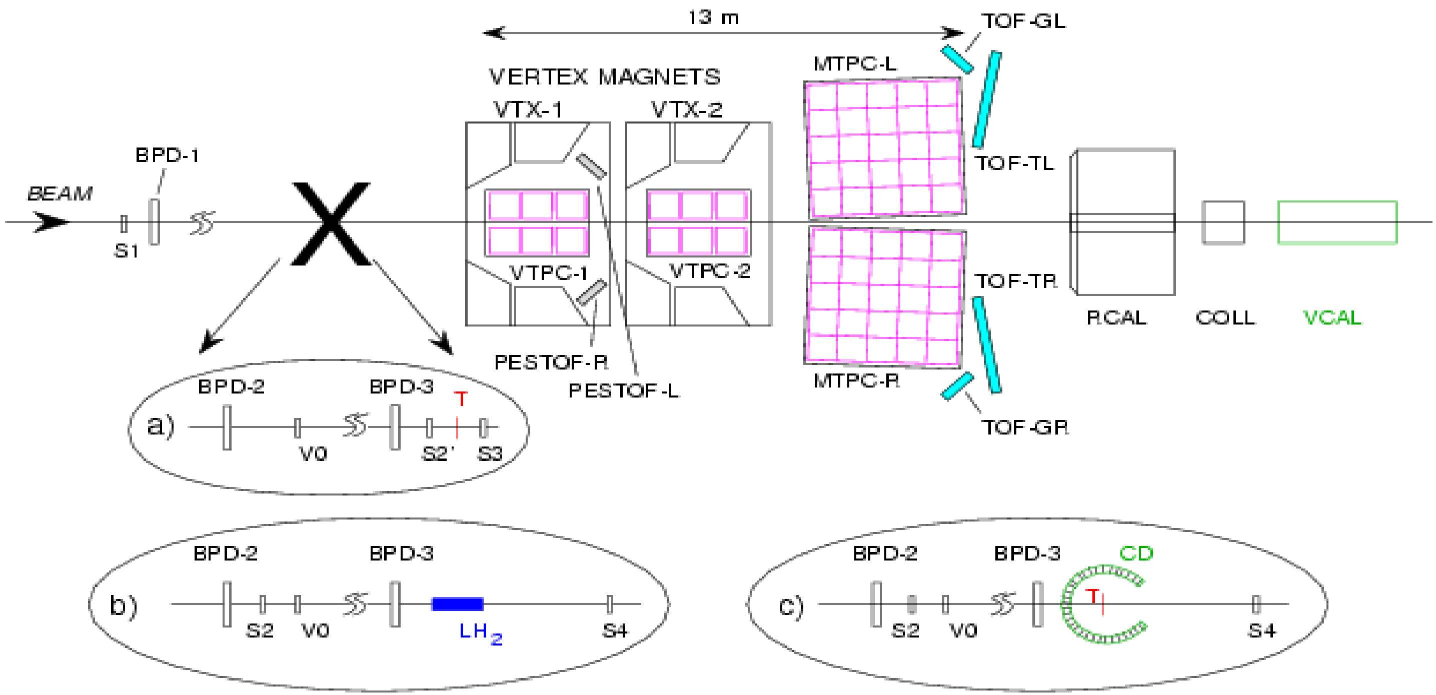
Assuming the Pentaquark production is the same as baryon production we expect the total production of Θ_s^+, Ξ_5^{--} per event continuum to be $\Theta_s^+ = 7 \times 10^{-4}$, $\Xi_5^{--} = 3. \times 10^{-5}$

Other Pentaquarks

The Revised Anti-decuplet



NA49 Experiment



$dp/p^2 = 7 \times (0.3)\ 10^{-4}\ (GeV/c)^{-1}$

VTPC-1 (VTPC-2+MTPC)

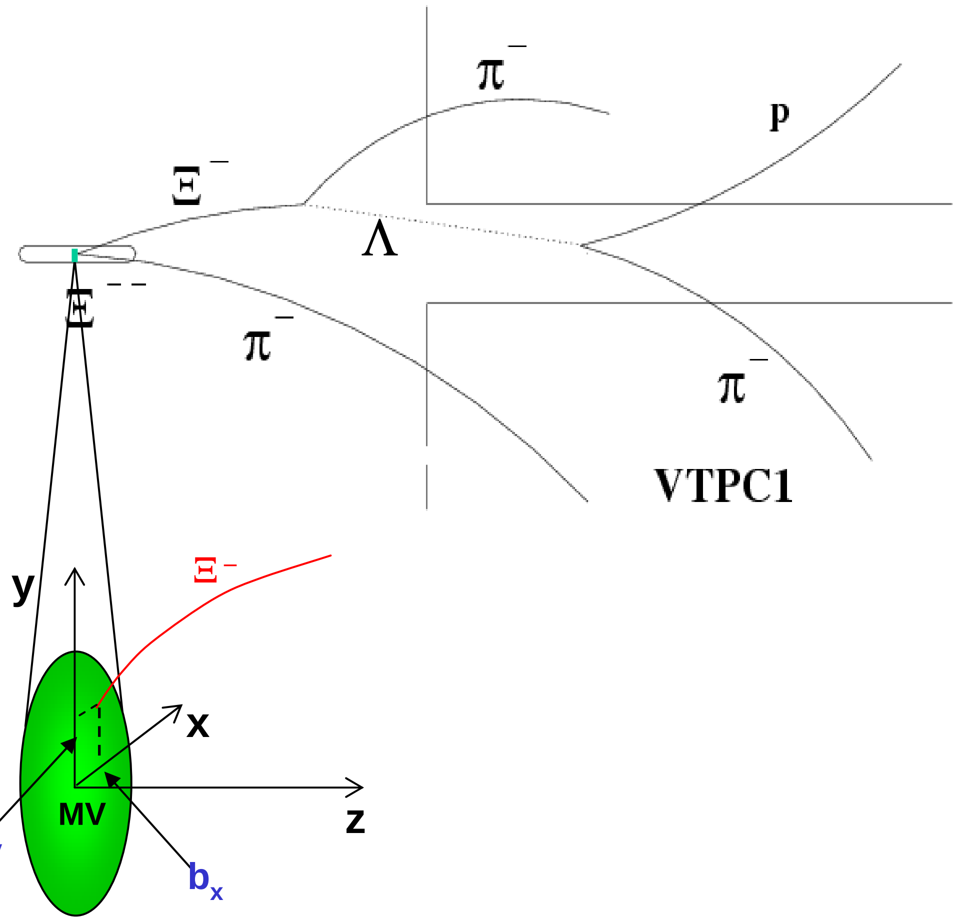
dE/dx resolution: 3-6 %

(σ_{Trig}= 28.1 mb)

Ξ_5 search

$$\Xi^{--}_{3/2} \longrightarrow \Xi^- \pi^- (\bar{\Xi}^{++}_{3/2} \longrightarrow \bar{\Xi}^+ \pi^+)$$

$$\Xi^{0}_{3/2} \longrightarrow \Xi^- \pi^+ (\bar{\Xi}^{0}_{3/2} \longrightarrow \bar{\Xi}^+ \pi^-)$$



Ξ^- selection:

Distance to Bethe- Bloch curve:

$|d_{bb}| < 3\,\sigma$

$|M(p\pi^-) - M(\Lambda)| < 0.015$ GeV

$Z_{\Xi^-} - Z_{main\_vtx} > 12$ cm

Ξ^- position at main vertex (b_x, b_y):

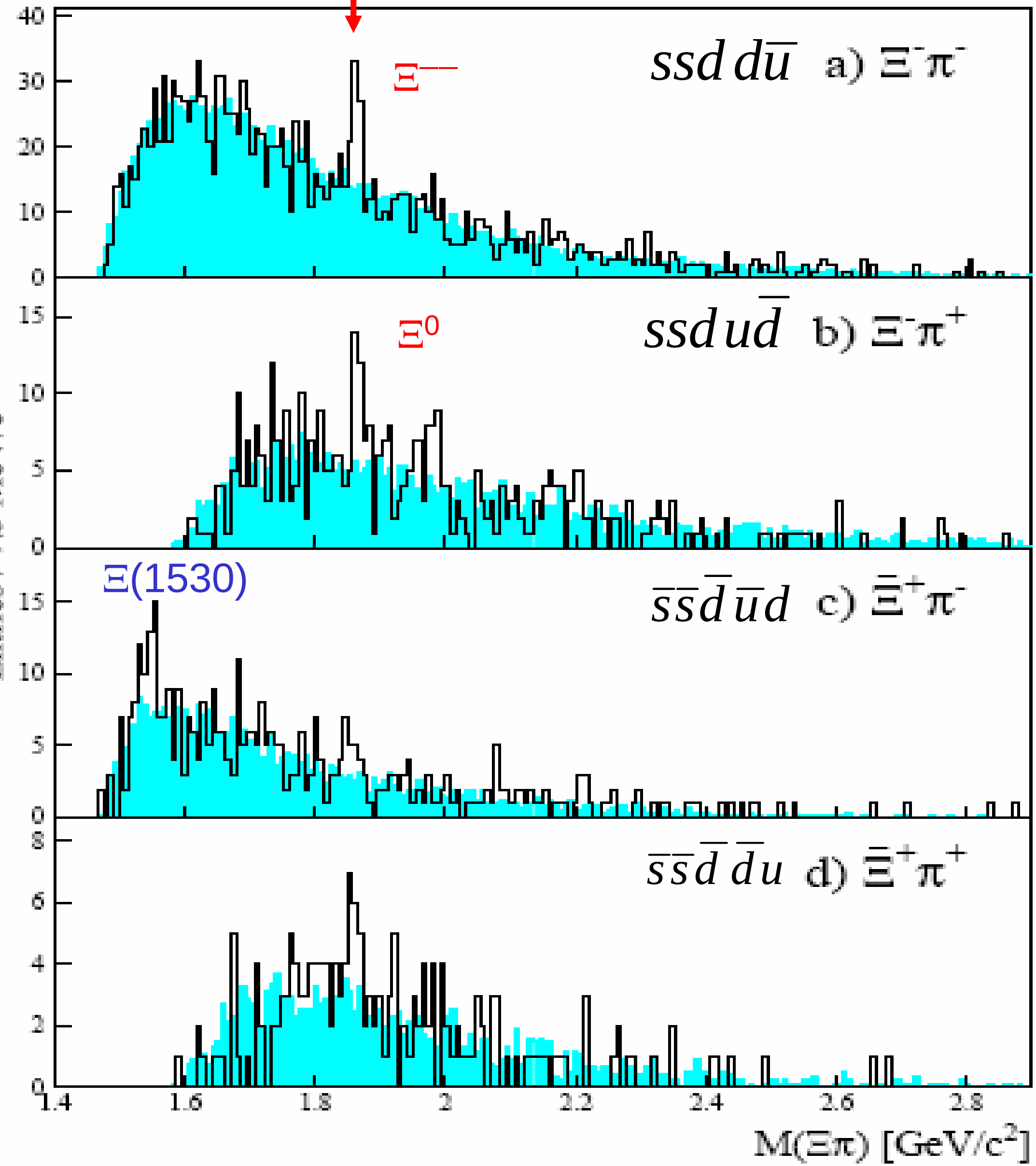
$|b_x| < 2$ cm

$|b_y| < 1$ cm

π (from Ξ^- decay) position at main vertex

$|b_y| > 0.5$ cm

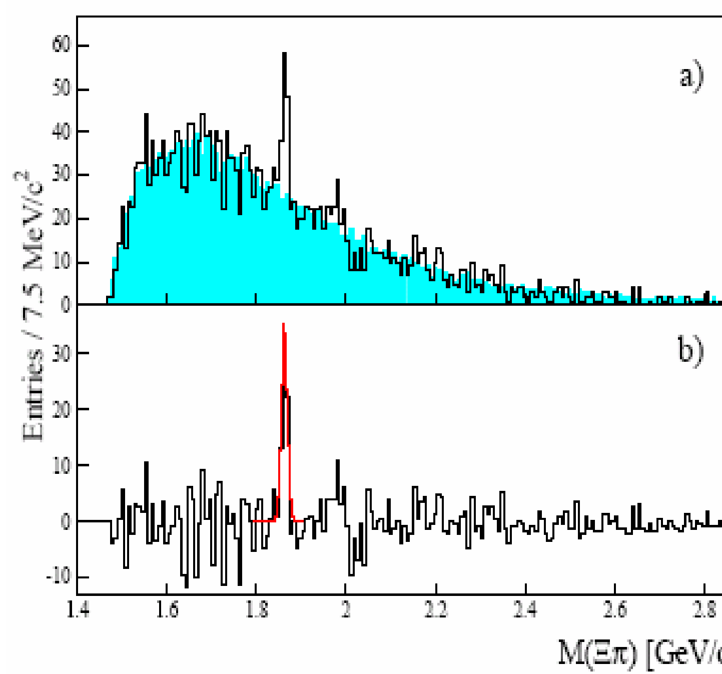
Observation of Exotic Ξ^{--}



M=1.862± 0.002 GeV

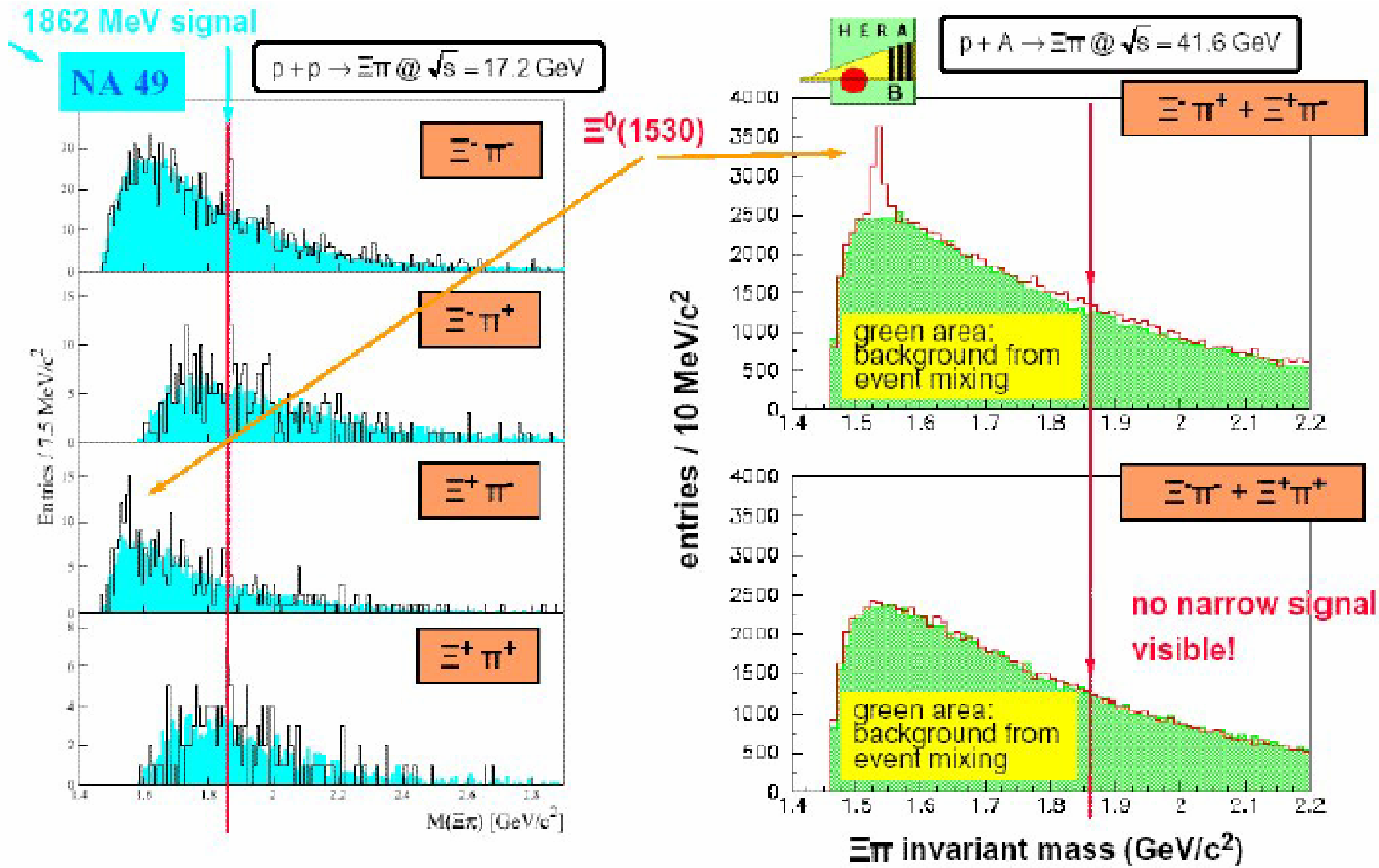
Γ<0.018 GeV

Combined spectra



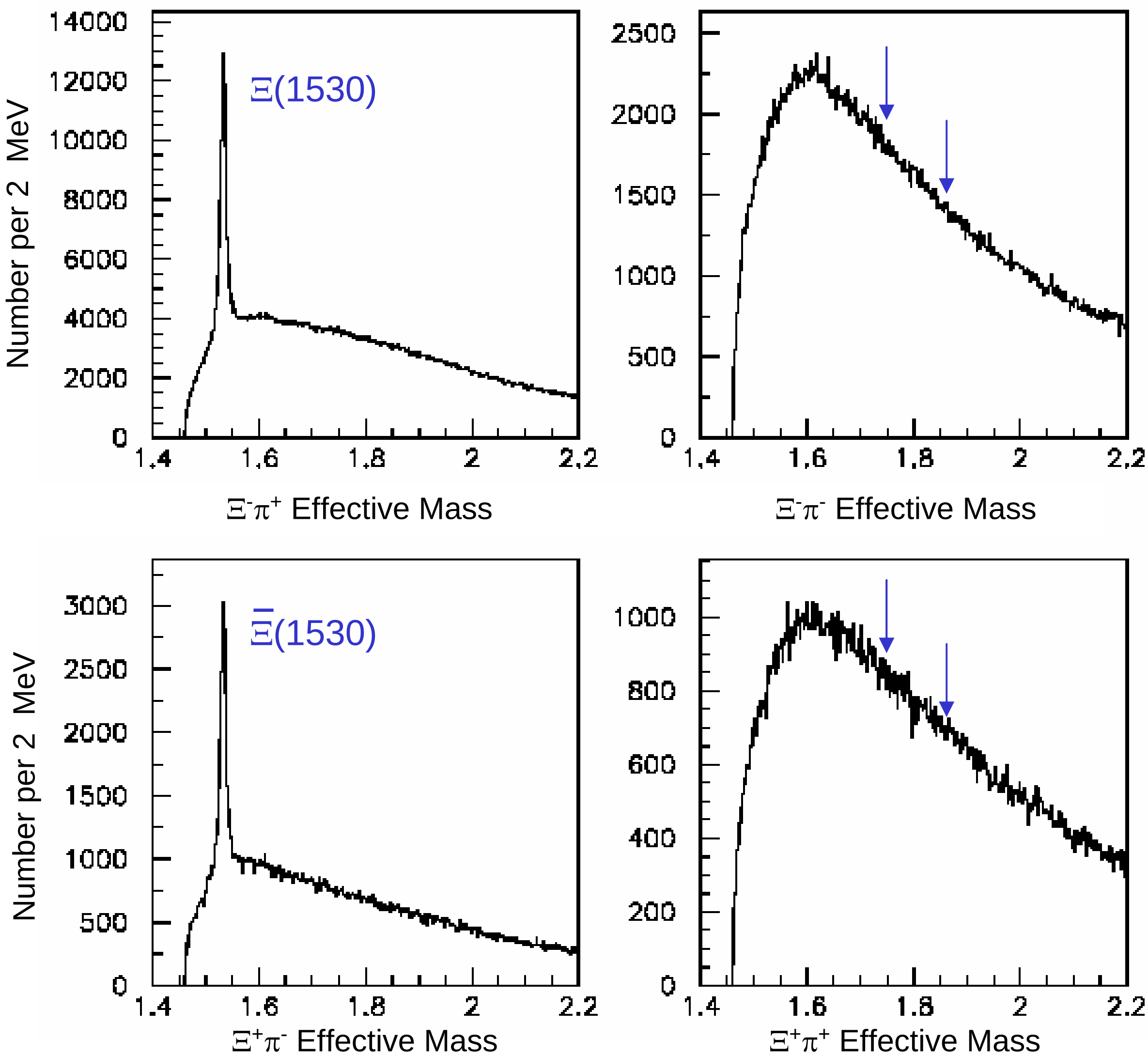
CERN SPS hep-ex/0310014

Negative result: HERA-B



Also not seen by CDF, BaBar and E690.

$\Xi^{\pm}\pi^{\pm}$ Effective Mass Spectra



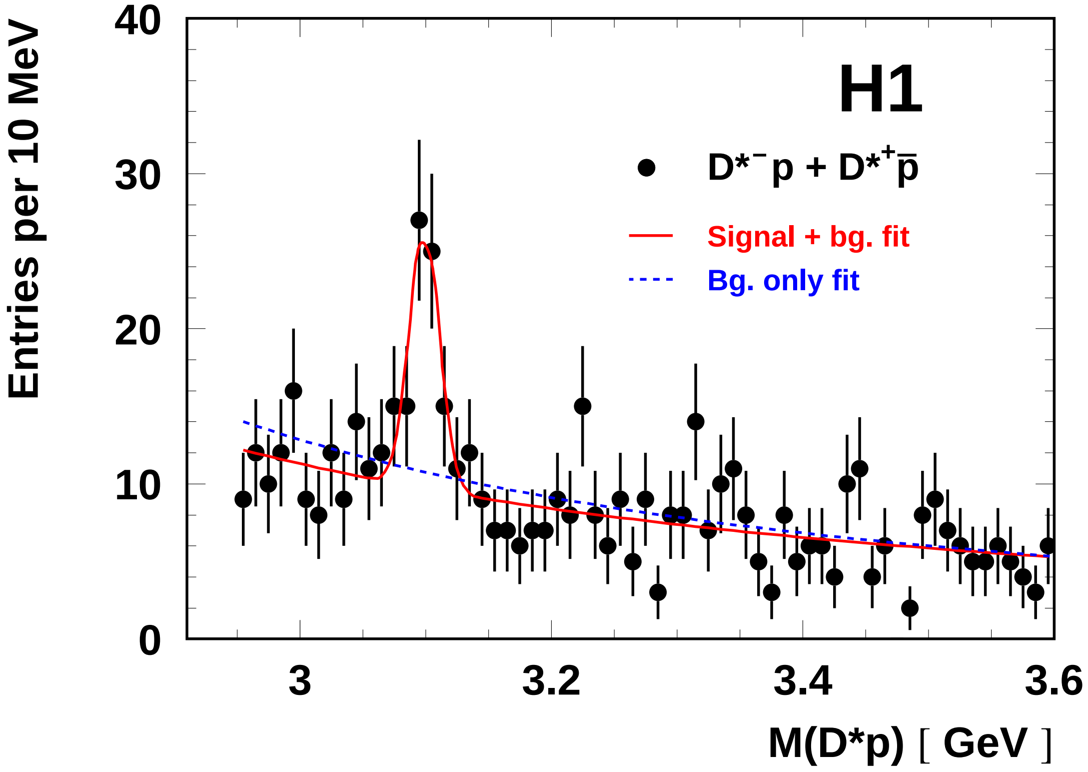
Arrows at
1750 MeV &
1860 MeV

Monte Carlo mass
resolution (σ) for $\Xi\pi$:
3.3 MeV at 1750 MeV;
4.5 MeV at 1862 MeV.

Anti-charmed pentaquark from H1

hep-ph/0403017

e-p collision at sqrt(s) ~ 300 GeV



M = 3099±3±5**MeV**
σ = 12±3 **MeV**

630 MeV above DN threshold.

Chiral Doublet?
hep-ph/0403184

Ξ_5 null results

Experiment	Θ_s^+	Ξ_5	Θ_c^+
CDF			
E690			
BaBar			
ZEUS			
ALEPH			
WA89			
HERA-B			
NA-49			

Questions to be answered

- **To be or not to be?**
- **What is the true mass?**
- **How narrow is the width?**
- **What is the Spin and Parity? How to measure?**
- **Is there $J^+=3/2^+$ partner? Still narrow?**
- **Other members of the anti-decuplet?**

Can the peak seen in the previous LEPS data be seen in the new data again?

LEPS New LD2 and LH2 runs

- Data taken from Oct. 2002 to Jun. 2003.
- ~$2 \cdot 10^{12}$ photons on a 15cm-long LD2 target.
- Less Fermi motion effect.
- LH2 data were taken in the same period with ~ $1.4 \cdot 10^{12}$ photons on the target.

# of photons: LH2:LD2 ≈ 2:3

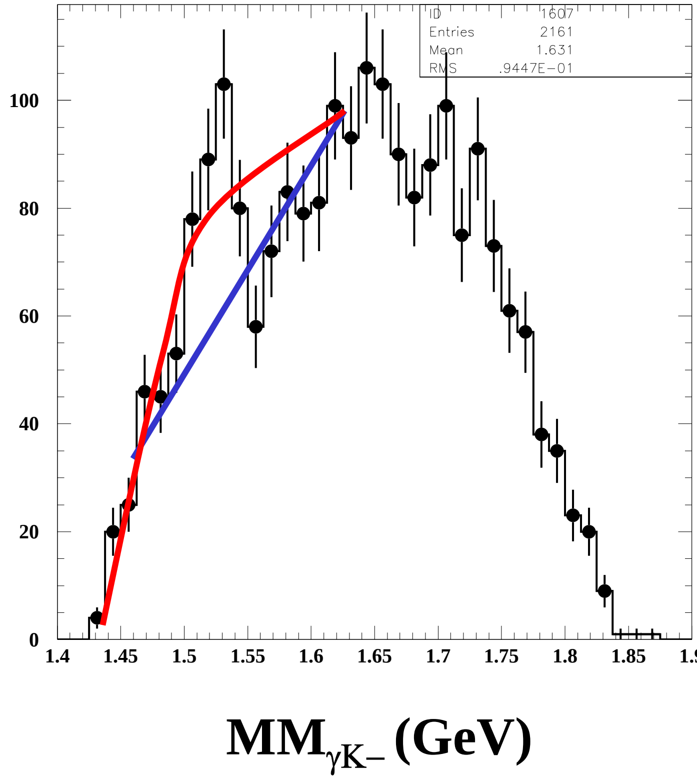
we expect

# of events from protons: LH2:LD2≈ 2:3

# of events: LH2:LD2≈ 1:3

Summary of LD2 data analysis

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

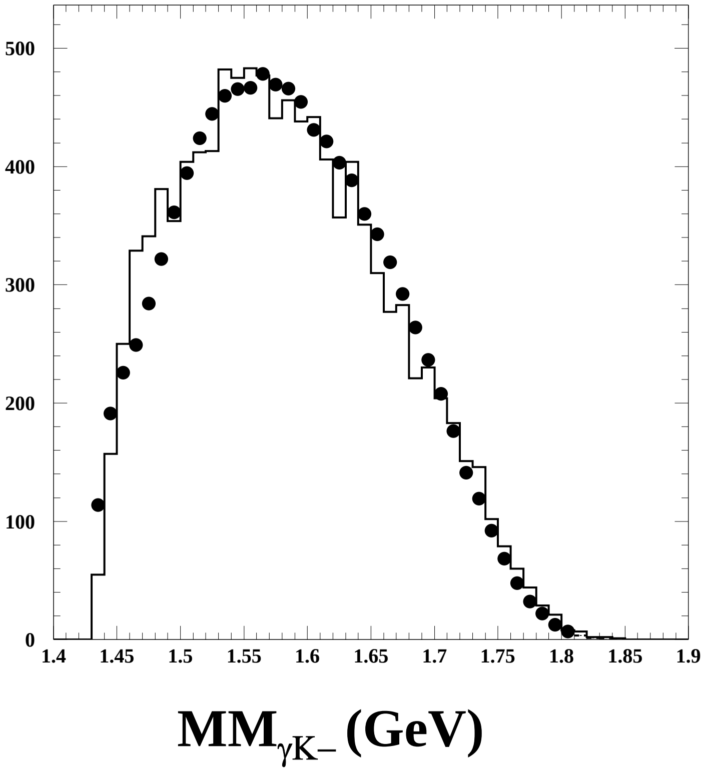


Reliable background estimation is essential to confirm the existence of the peak.

Statistics of LH2 data is small.

→ increase statistics by mixed event technique

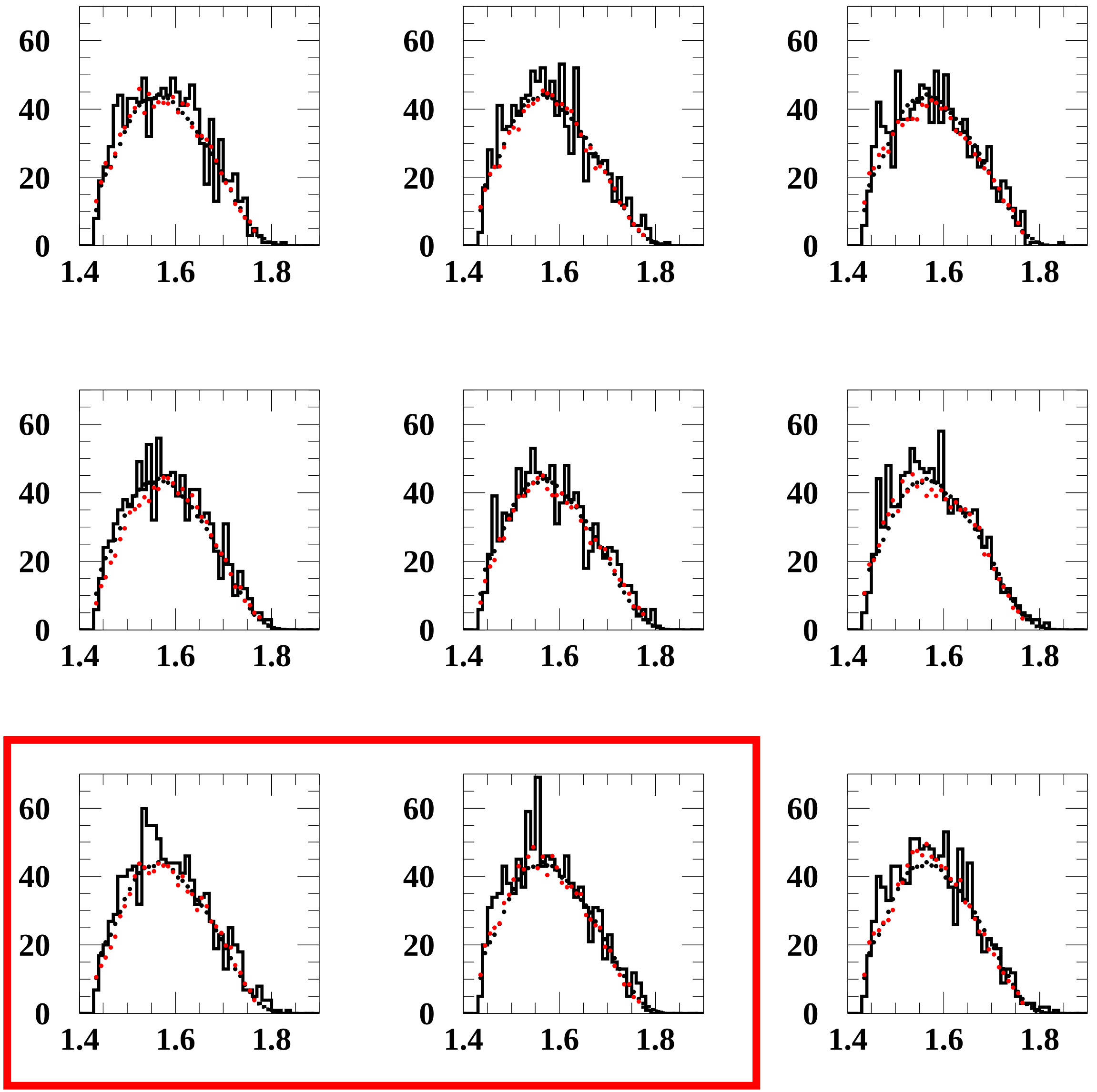
Mixed event analysis with KKN phase space MC data



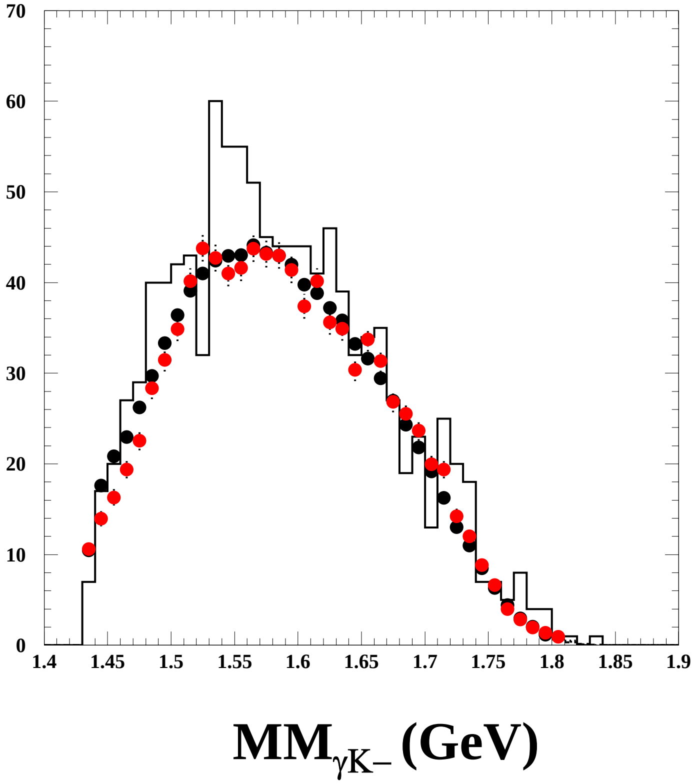
- Mix K^+, K^-, γ from different events.
- Apply the same selection cuts again on the mixed events.
- Check if the shape of the original distribution is reproduced by the mixed events.

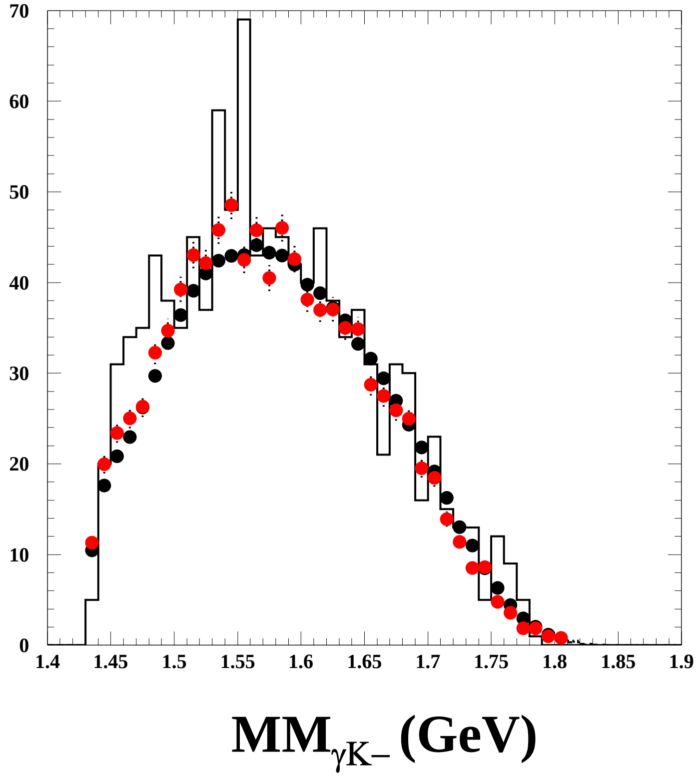
Mixed event analysis seems to work fine for the exclusive reaction!

Can we remove fluctuations?



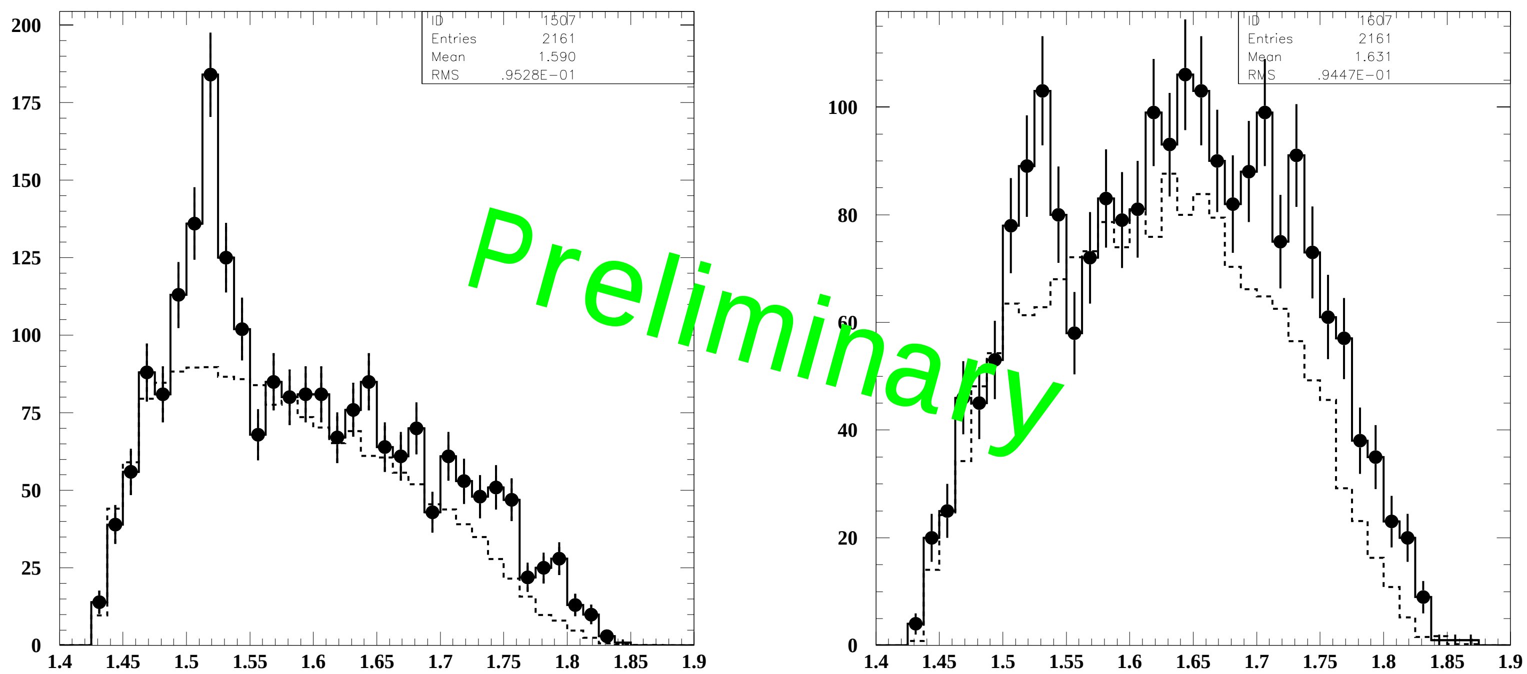
Can we remove fluctuations?





Mixed event analysis

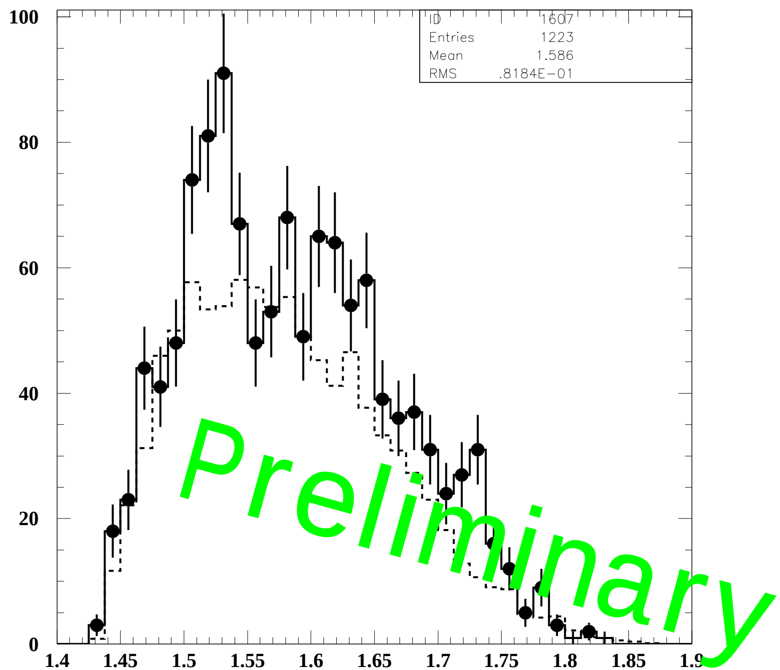
- LH2 mixed events are obtained by removing L(1520) contributions.
- The mixed event spectra are compared with the LD2 missing mass spectra.



$MM_{\gamma K+}$ (GeV)

$MM_{\gamma K-}$ (GeV)

After removing Λ(1520)



$MM_{\gamma K-}$ (GeV)

- Background level around 1.53 GeV in 4 bins is ~220 events **IF** we take the mixed event BG method.
- The excess above the BG level is ~90 events.
- The peak position, width, significance strongly depends on the BG shape.
- The mixed event BG method may not work if the major BG is due to narrow resonances in K^-p or K^+K^- channels.
- We need further BG study and it is in progress.

Summary

- Evidence for an S=+1 baryon around 1.54 GeV with a narrow width has been observed by several experimental groups.
- There are some inconsistencies in the measured masses and widths.
- No signal has been observed in high energy experiments with high statistics and good mass resolution.
- The Θ^+ does not exist or its production in high energy reactions must be highly suppressed.

Outlook

- LEPS new exp. re-observed the peak.
  - Unlikely to be due to statistical fluctuations.
  - Further checks are in progress.
- New dedicated experiments with high statistics are on-going, scheduled, or planned at several labs (Jlab, KEK, BNL, e.t.c.).
- The issue will be settled in near future.