# Pentaquarks in E949

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# What are penta-quarks?

- Minimum quark content is 4 quarks + 1 antiquark
- "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

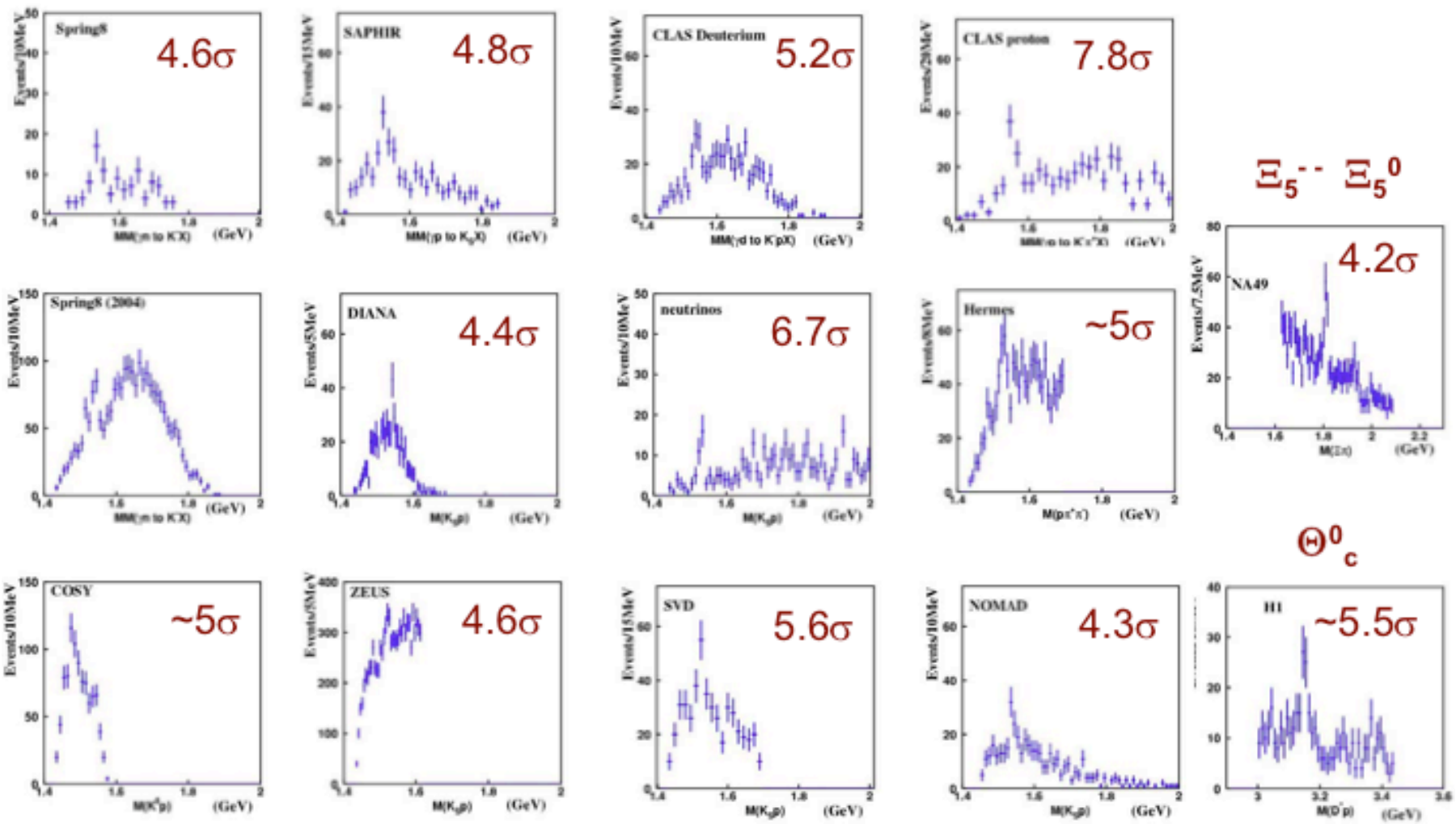
e.g. $uudd\bar{c}$, $uuss\bar{d}$

c.f. $\Lambda(1405)$: $uuds\bar{u}$ or uds

Unexpected feature: narrow width!

# Evidence for qqqq$\bar{Q}$ States

Reported Significance



# Evidence against $qqqq\bar{Q}$ States

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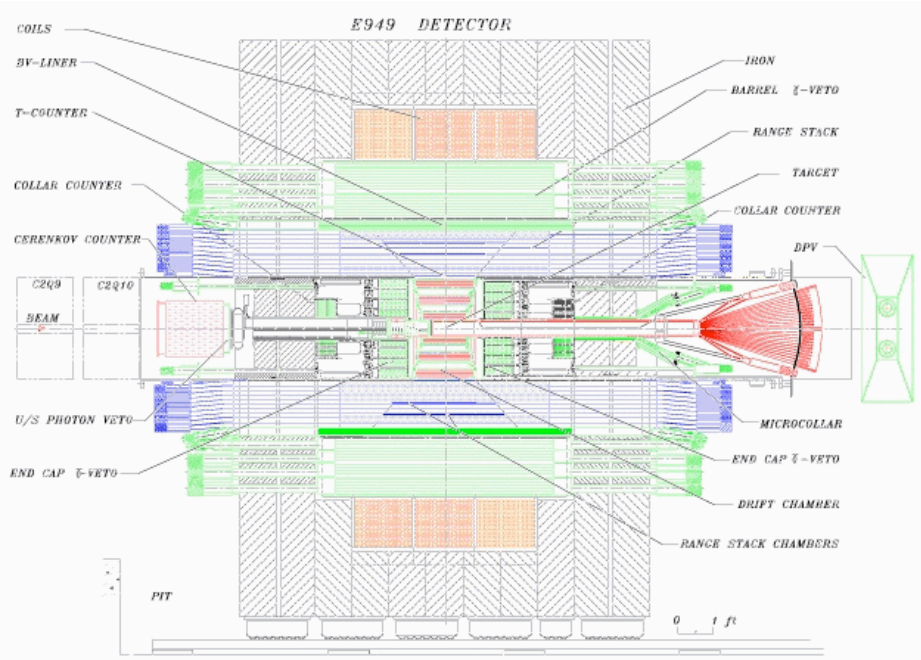
|---|---|---|---|---|---|
| **CDF** | $p\bar{p} \to PX$<br>hep-ex/0408025,0410024 | $\Theta^+$<br>$\Theta_c^0$<br>$\Xi_5$ | **ALEPH** | Hadronic Z decays<br>Submitted to **Phys. Lett. B** | $\Theta^+$<br>$\Theta_c^0$<br>$\Xi_5$ |
| **HyperCP** | $(\pi^+,K^+,p)Cu \to PX$<br>hep-ex/0410027 | $\Theta^+$ | **DELPHI** | Hadronic Z decays<br>hep-ex/0410080 | $\Theta^+$ |
| **SELEX** | $(\pi,p,\Sigma)p \to PX$<br>Quark Confinement 2004 | $\Theta^+$ | **L3** | $\gamma\gamma \to \Theta\Theta$<br>hep-ex/0410080 | $\Theta^+$ |
| **FOCUS** | $\gamma p \to PX$<br>DPF 2004 | $\Theta^+$<br>$\Theta_c^0$<br>$\Xi_5$ | **WA89** | $\Sigma^- N \to PX$<br>hep-ex/0410029 | $\Xi_5$ |
| **E690** | $pp \to PX$<br>QNP2004 - | $\Theta^+$<br>$\Xi_5$ | **ZEUS** | $ep \to PX$<br>hep-ex/0407026 | $\Theta_c^0$<br>$\Xi_5$ |
| **BES** | $e^+e^- \to J/\psi\ (\psi(2S)$<br>PRD 70 (2004) 012004 | $\Theta^+$ | **HERA-B** | $pA \to PX$<br>Accepted in PRL | $\Theta^+$<br>$\Xi_5$ |
| **BELLE** | $KN \to PX$<br>hep-ex/0411005 | $\Theta^+$<br>$\Theta_c^0$ | **SPHINX** | $pC(N) \to \theta K X$<br>hep-ex/0407026 | $\Theta^+$ |
| **BaBar** | $e^+e^- \to \Upsilon\ (4S)$<br>hep-ex/0408064 | $\Theta^+$<br>$\Xi_5$ | **PHENIX** | $AuAu \to PX$<br>nuc-ex/0404001 | $\Theta^+$ |
| **COMPASS** | | $\Theta^+$<br>$\Xi_5$ | **LASS** | $K^+p \to K^+ n \pi^+$<br>hep-ex/0412031 | $\Theta^+$ |

# Pentaquarks

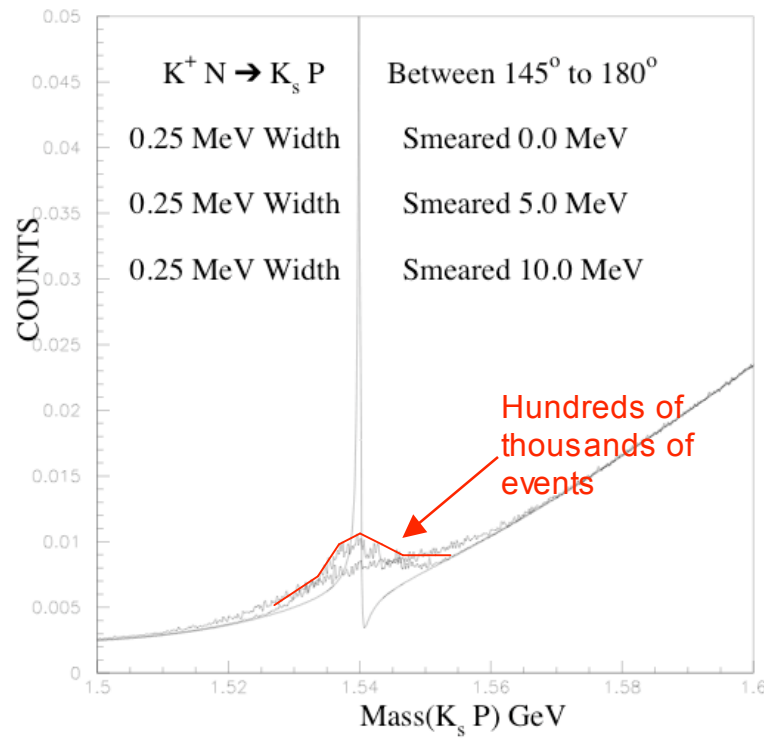
- Conflicting evidence!
  - Very difficult to resolve in production experiments - can always find an excuse!
- Need a "silver bullet" - formation experiment, large cross-section, no excuses!
- Search for $\Theta^+(1530)$ in formation experiment with high intensity kaon beam and large acceptance detector
  - $K^+n \rightarrow K^0p$, also can see $K^+p \rightarrow K^+p$
  - Excellent beamline (LESB3) and detector (E949) available
    - Would cost tens of millions of $ to duplicate!
  - Running with RHIC (particularly $p\uparrow$) very cheap
- Modest investment would make it possible

# LOI

- LOI submitted in Sept. 2004
- PAC encouraged the preparation of a full proposal
- Institutions:
  - Arizona State U., BNL, IHEP, INR-Moscow, KEK, Ohio, RCNP-Osaka, Juelich, New Mexico



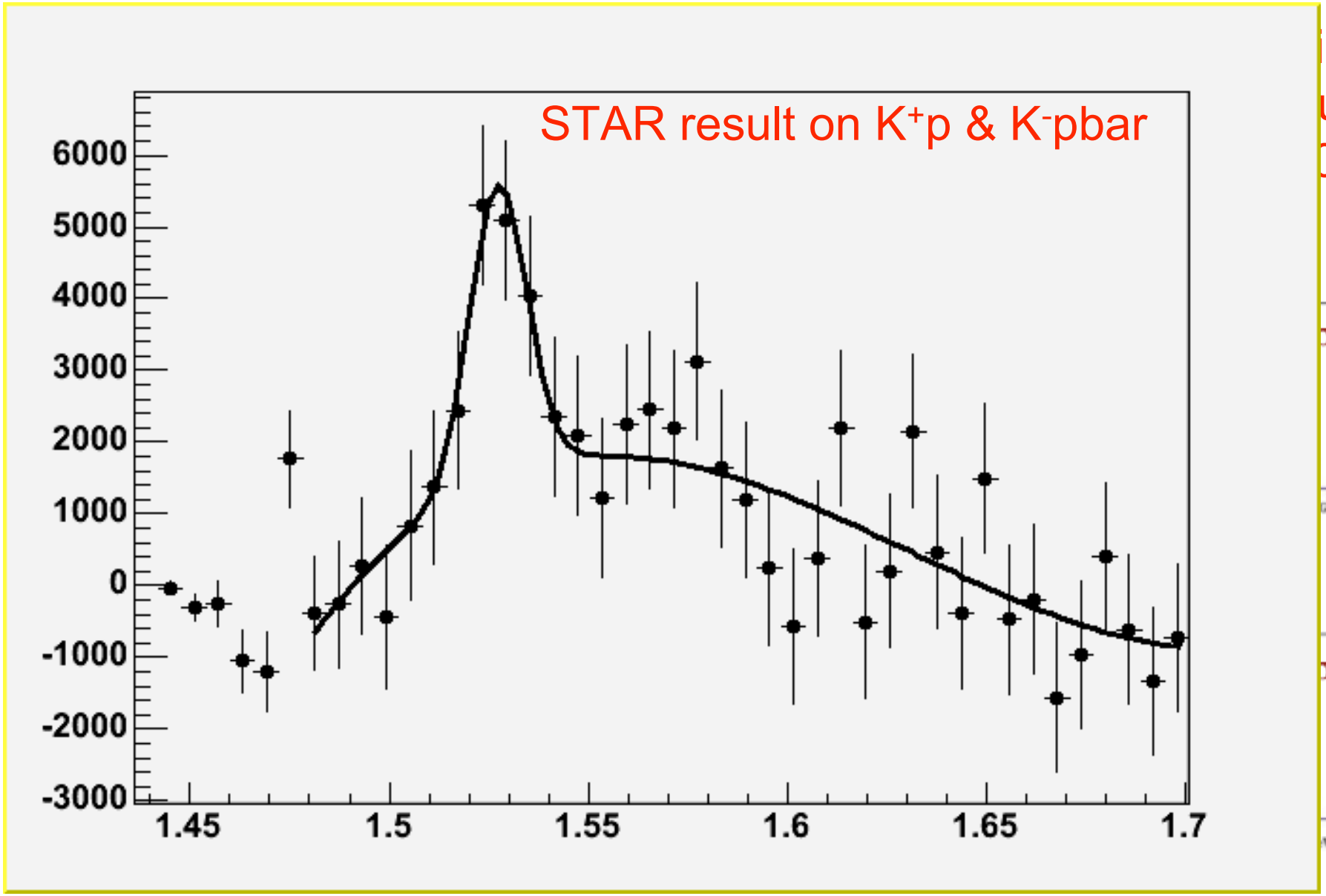

Elevation view of the E949 detector.



# LDRD

- Would keep detector alive - huge investment preserved
  - Mainly technical labor for minor modifications, care & feeding
  - Need regular cosmic ray tests
  - Some consumables (e.g. chamber gas, pmts)
- Modifications for pentaquark study
  - Hodoscopes
  - Bring safety systems up to spec.
- Success would initiate a new round of multiquark state studies at the AGS.

# Evidence for qqqq$\bar{Q}$ States

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