

Searches and Results for the $\Theta(1540)^+$ @ *BaBar*

Jonathon Coleman

For the



BABAR

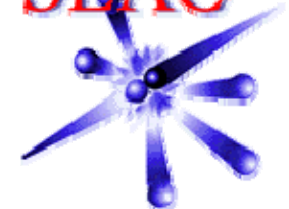
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collaboration



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SLAC



What are pentaquarks?

- Minimum quark content is 4 quarks and 1 antiquark. ($qqqq\bar{q}$)
- "Exotic" pentaquarks are those where the antiquark has a different flavor than that of each of the other 4 quarks
- Quantum numbers cannot be defined by 3 quarks alone.

Example: $uudd\bar{s}$ $\{\Theta(1540)^+ : \text{SPRING-8, etc....}\}$

$$\text{Baryon number} = 1/3 + 1/3 + 1/3 + 1/3 - 1/3 = 1$$

$$\text{Strangeness} = 0 + 0 + 0 + 0 + 1 = 1$$

$$\text{Also. } d\bar{u}dss \quad \{ \Xi(1860)^- : \text{NA49} \}$$

$$uudd\bar{c} \quad \{ \Theta_c(3100)^0 : \text{H1} \}$$

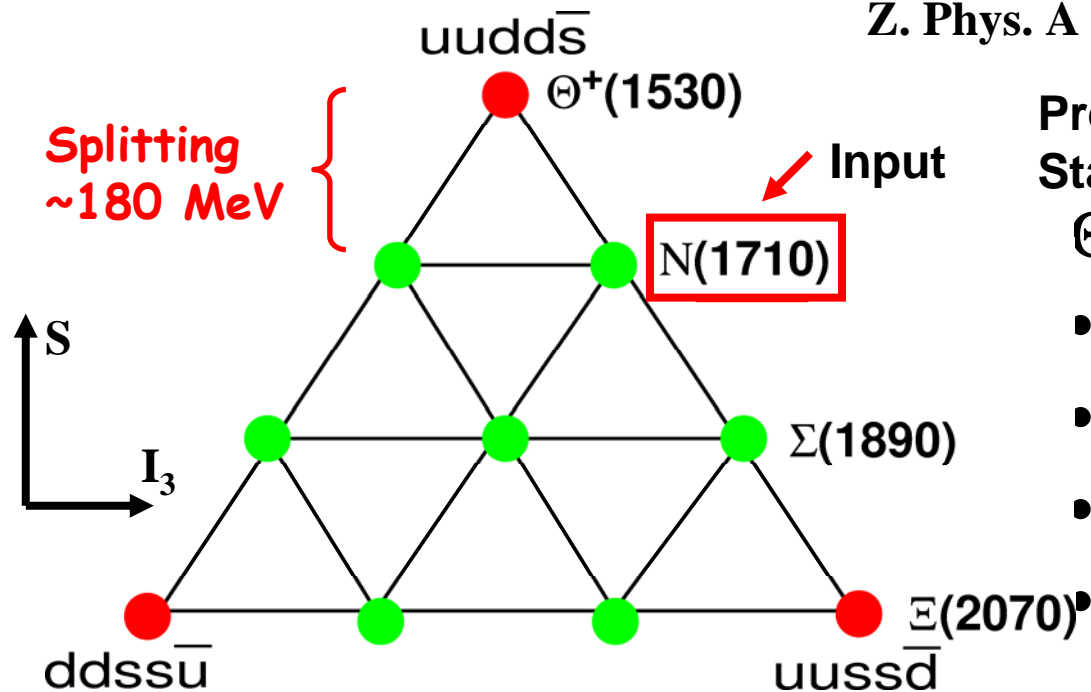
Brief History (Experimental)

- Since late 60's physicists have searched for $s = +1$ baryon resonance production in KN scattering experiments.
- Partial wave analyses of KN scattering in the later 80's and early 90's \Rightarrow two possible isoscalar resonances Z(1780) and Z(1865)
- Summary on $s = 1$ baryon resonance searches was dropped from PDG as of 1986:
- “The general prejudice against baryons not made of three quarks and the lack of any experimental activity in this area make it likely that it will be another 15 years before the issue is decided .”

i.e PDG's prediction: the pentquark issue cannot be settled
until $\geq 1986 + 15 = 2001$

Pentaquark Revival – The Θ^+ Prediction

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

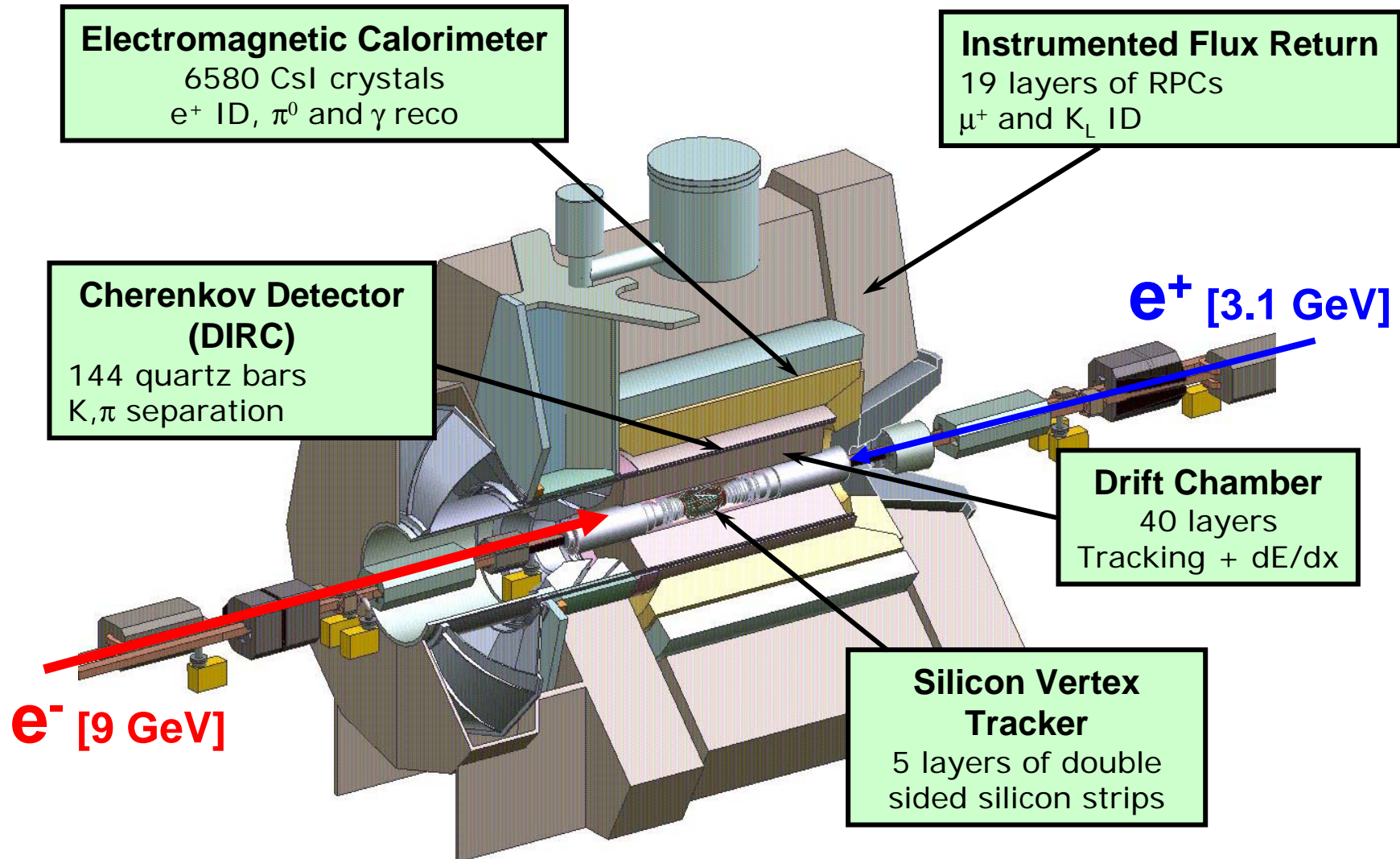


Predicted 10 structure for subset of States, taking $M_N=1710$,

Θ^+ predicted as:

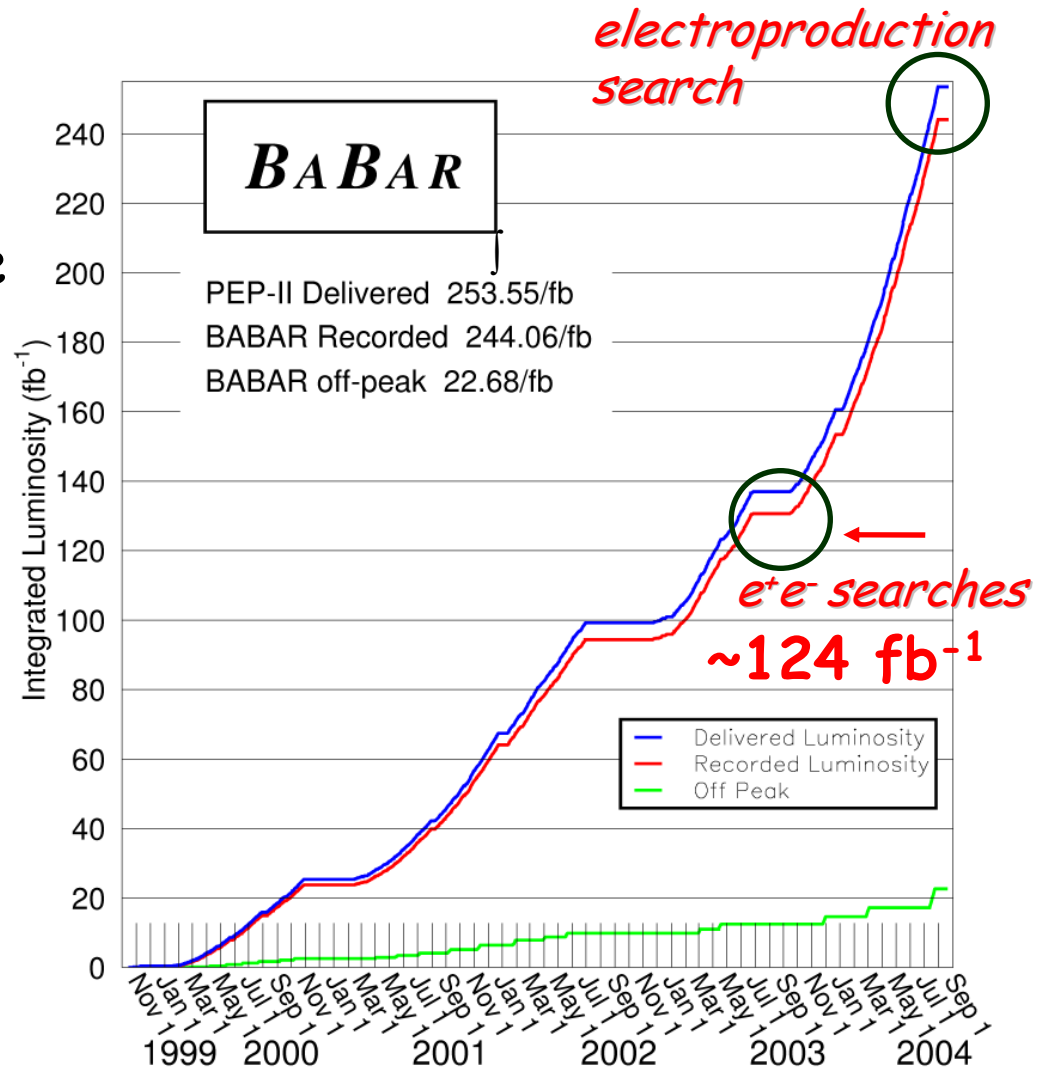
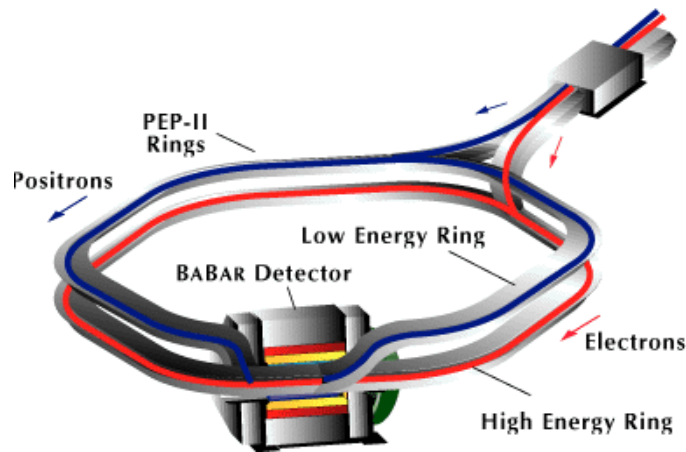
- Exotic: $S=+1$
 - Low mass: 1530 MeV
 - **Narrow width: ~ 15 MeV**
- $J^P=1/2^+$

The BaBar Experiment at PEP-II



Data Samples for these Analyses

- c.m. energy ~ 10.58 GeV
- On $\Upsilon(4S)$ resonance and ~ 40 MeV below resonance



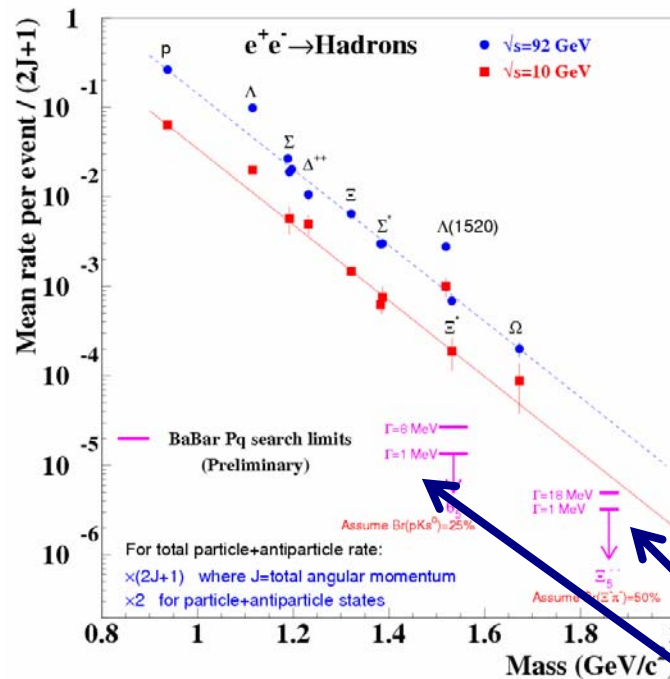
Inclusive Pentaquark Search in e^+e^- collisions

hep-ex/0502004

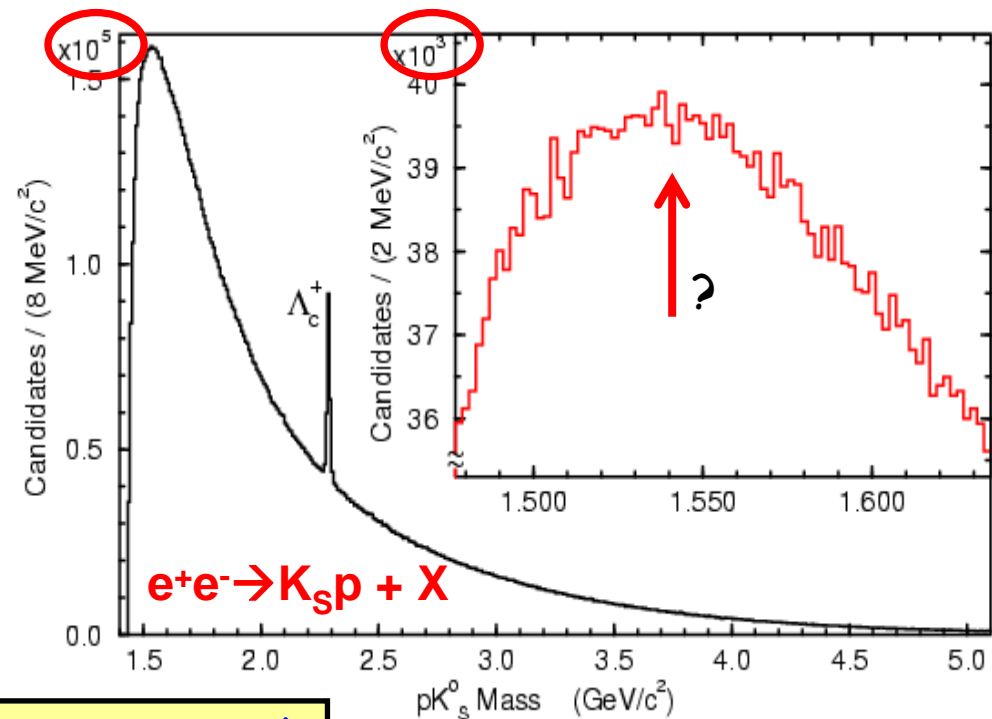
$\sim 124 \text{ fb}^{-1}$

Large signal for $\Lambda_c^+ \rightarrow pK_S$ (100K events); no signal at $\sim 1.54 \text{ GeV}/c^2$

Limits on Θ_5^+ and Ξ_5^{--} are smaller than expected for "normal" baryons



BaBar pentaquark production limits

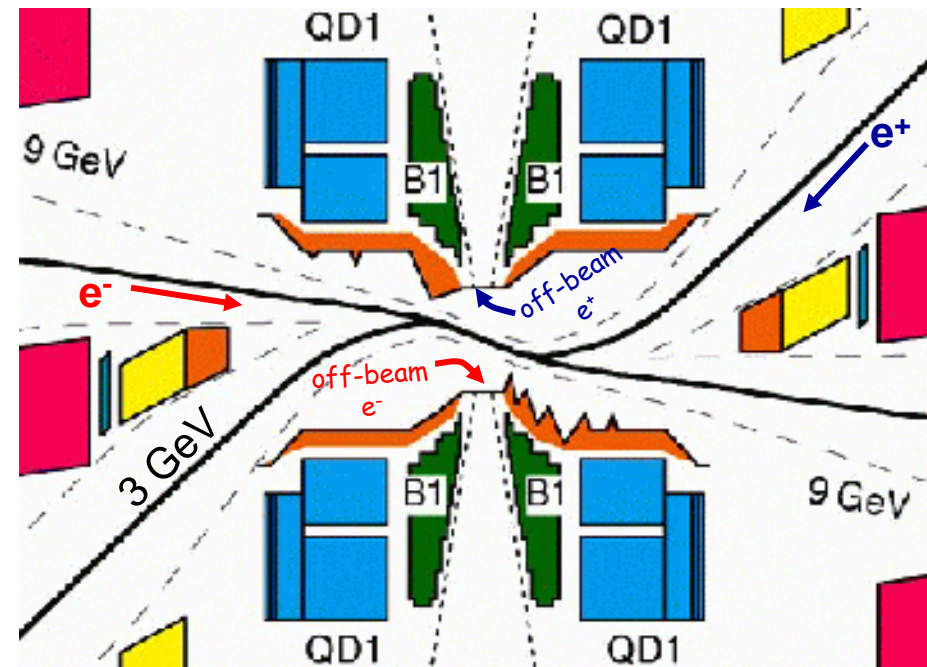


Also searched for other 10 members

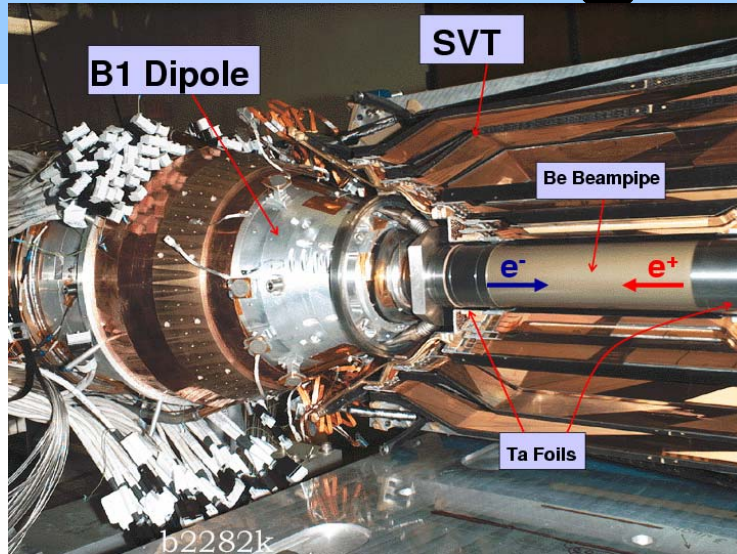
Search for $\Theta_5(1540)^+ \rightarrow K_S p$ **NEW** in electro- and hadro-production

- **Hadroproduction:** interactions in detector material of hadrons produced in e^+e^- annihilations

• **Electroproduction:** off-beam e^- and e^+ bent into Be beampipe in horizontal plane

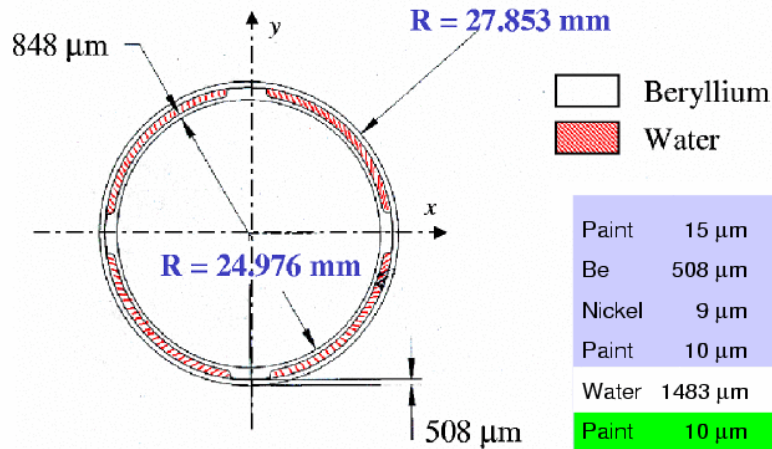
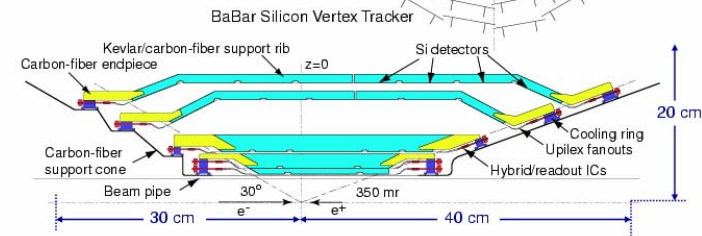
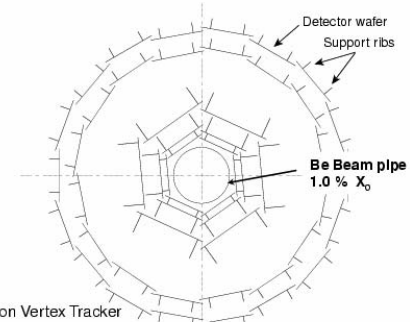


Target Material:



SVT

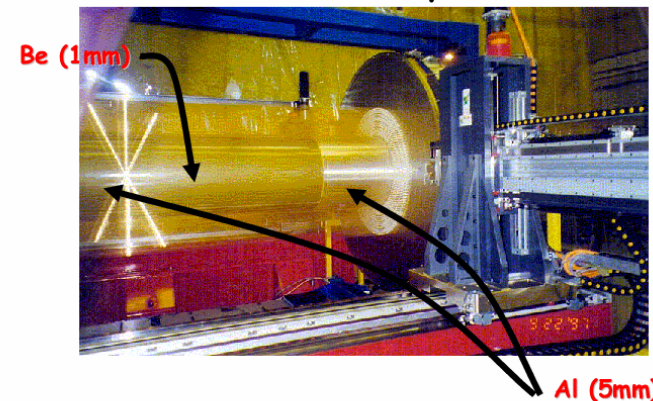
Layer	Radius
1	3.3 cm
2	4.0 cm
3	5.9 cm
4	9.1 to 12.7 cm
5	11.4 to 14.6 cm



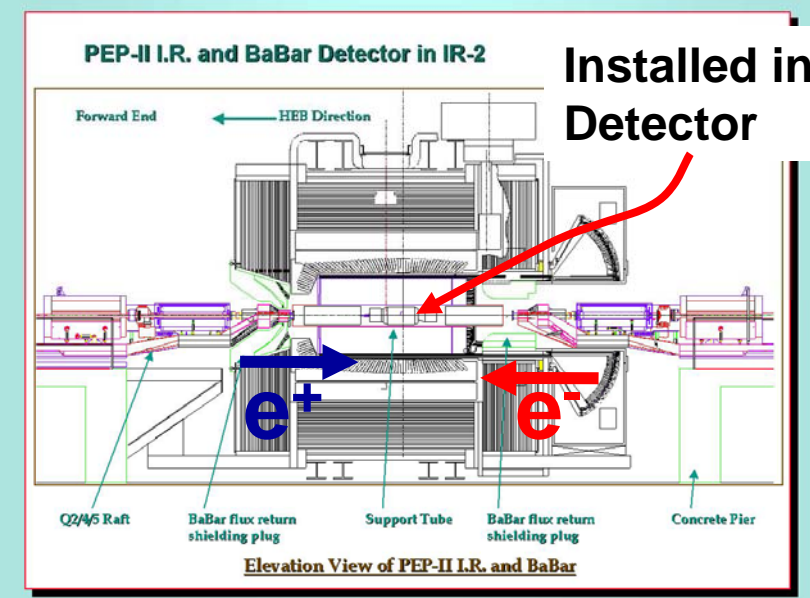
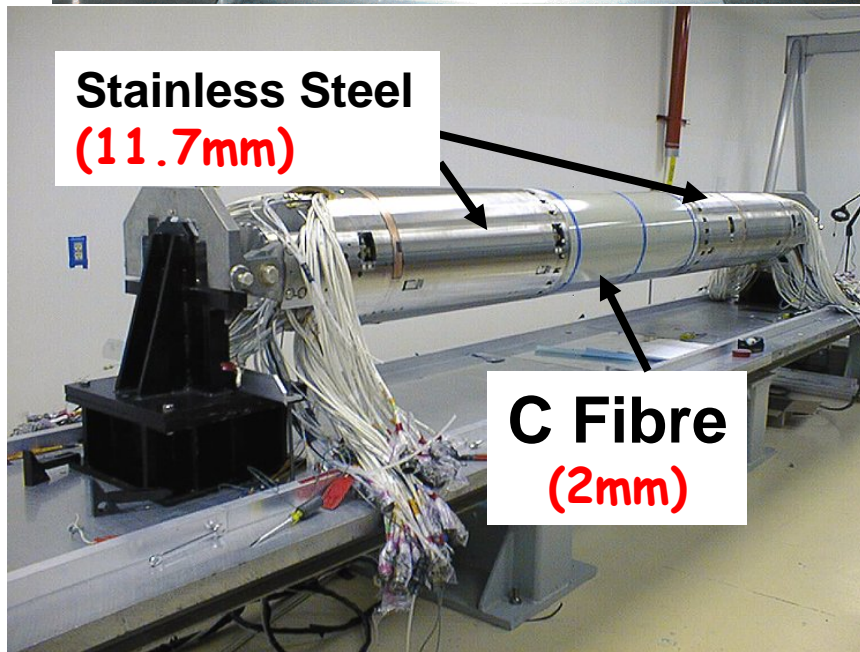
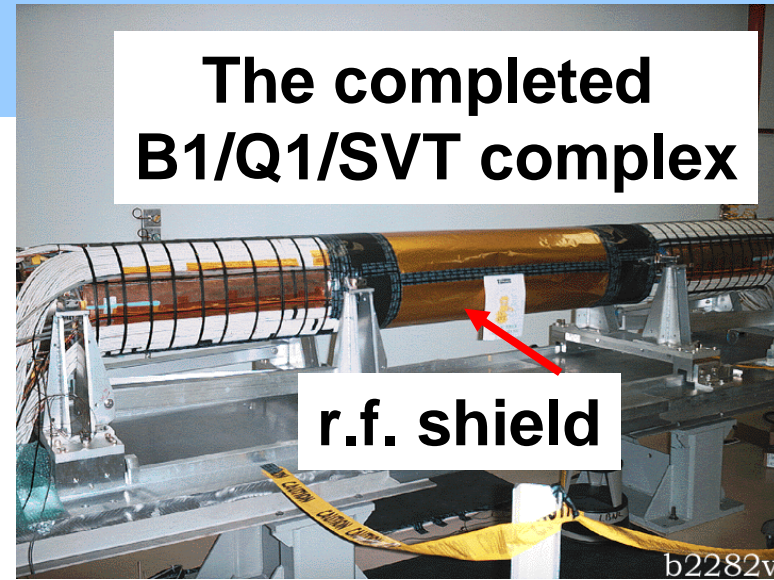
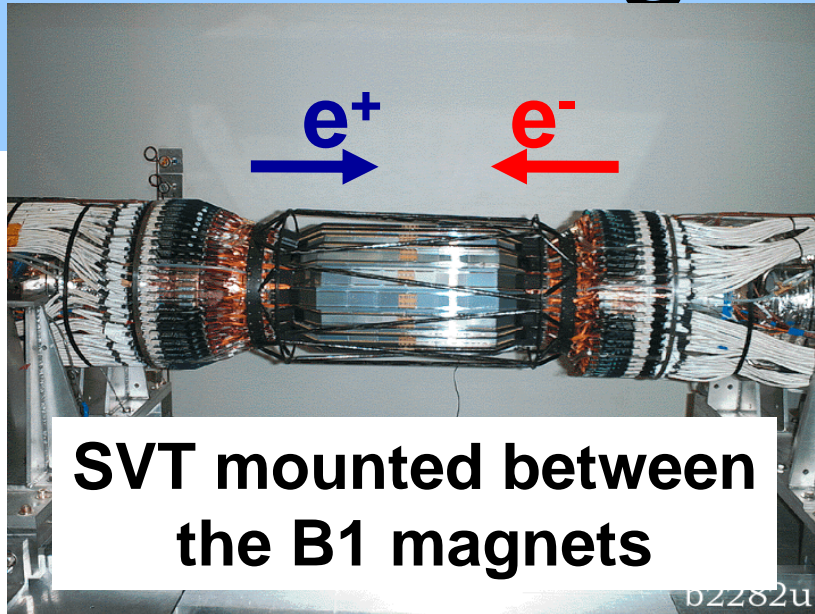
$-70 \text{ mm} < z < 20 \text{ mm}$

Material	Thickness	Region
Paint	15 μm	Water jacket
Be	508 μm	
Nickel	9 μm	
Paint	10 μm	
Water	1483 μm	beampipe
Paint	10 μm	
Nickel	9 μm	
Be	848 μm	
Gold	4 μm	

DCH Be Inner Cylinder

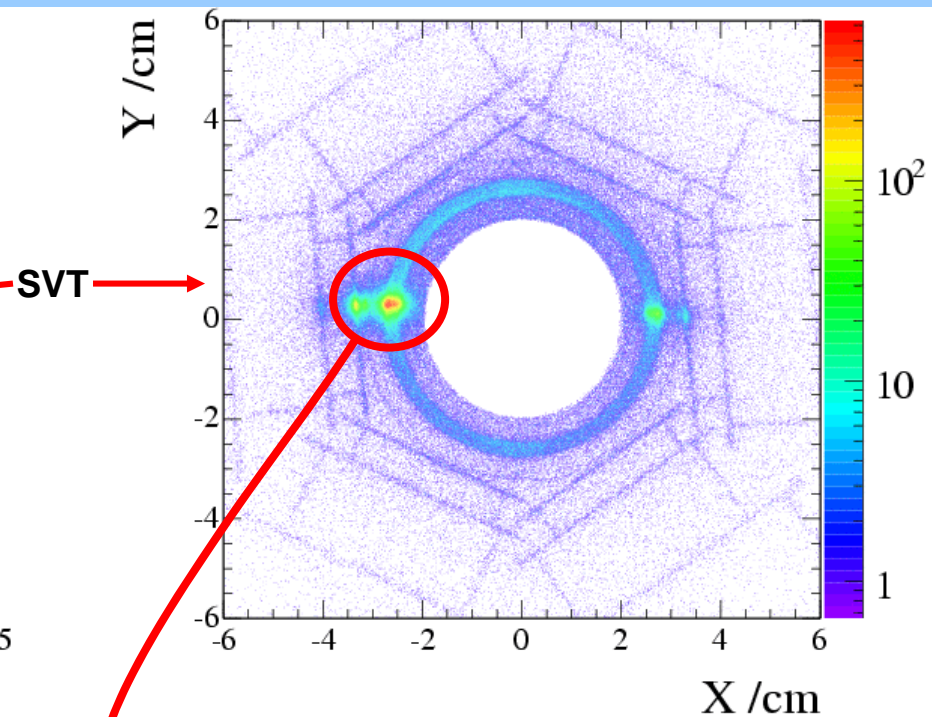
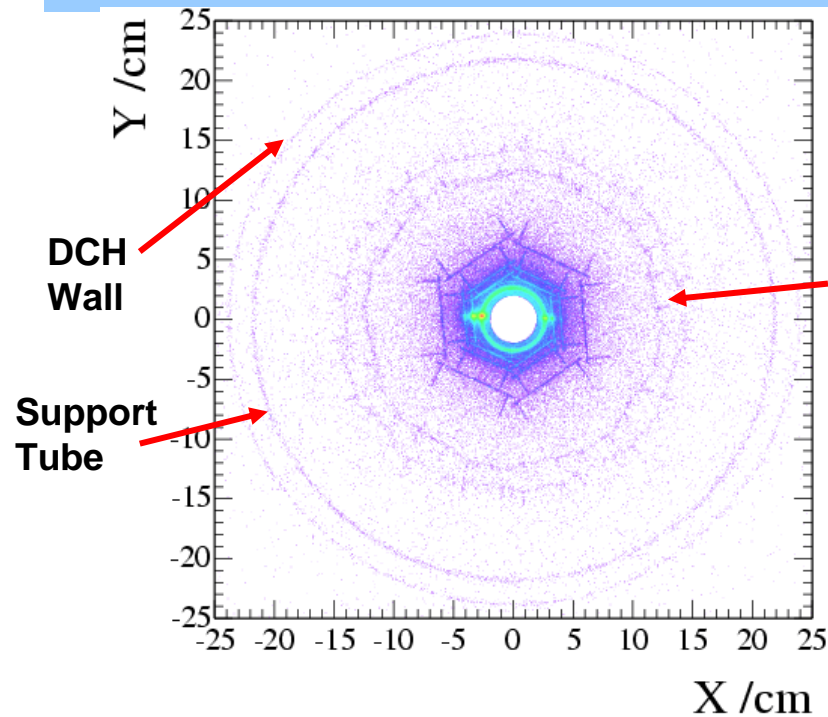


Target Material (ctd):

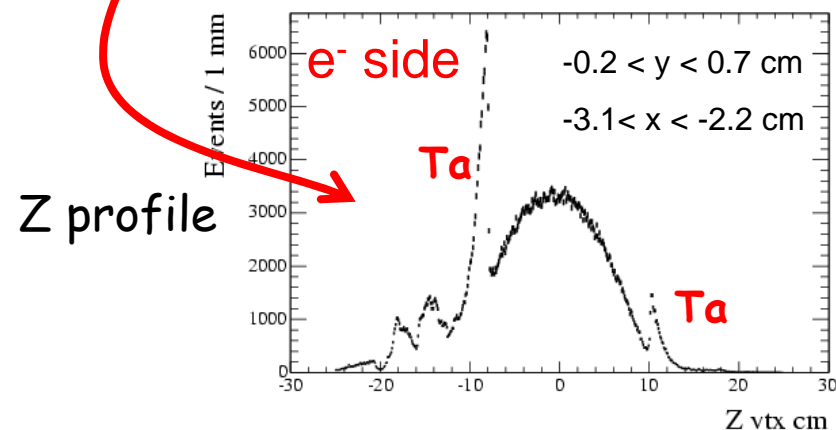


Detector Tomography with pK_S Vertices

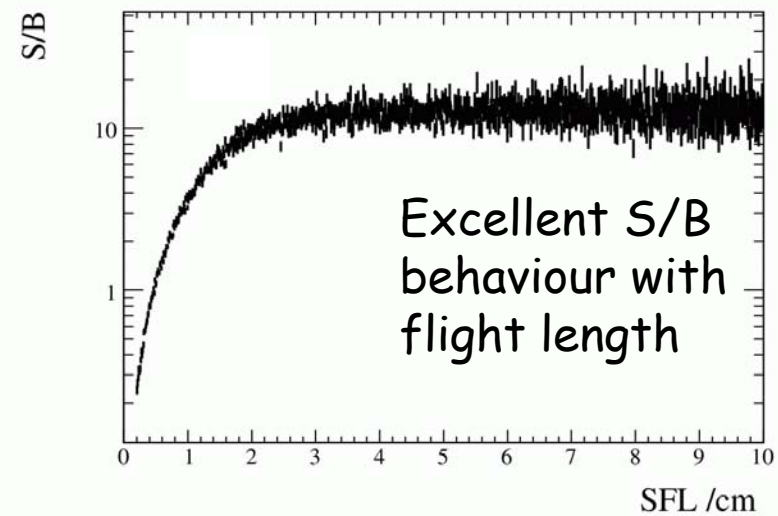
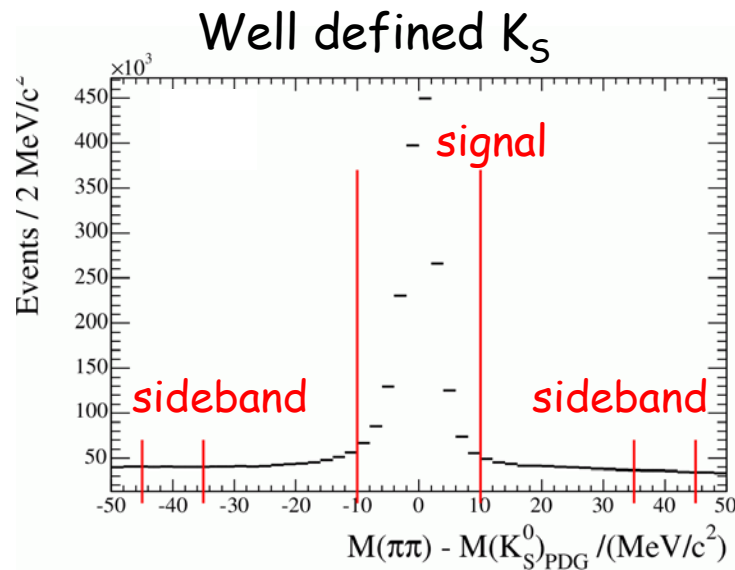
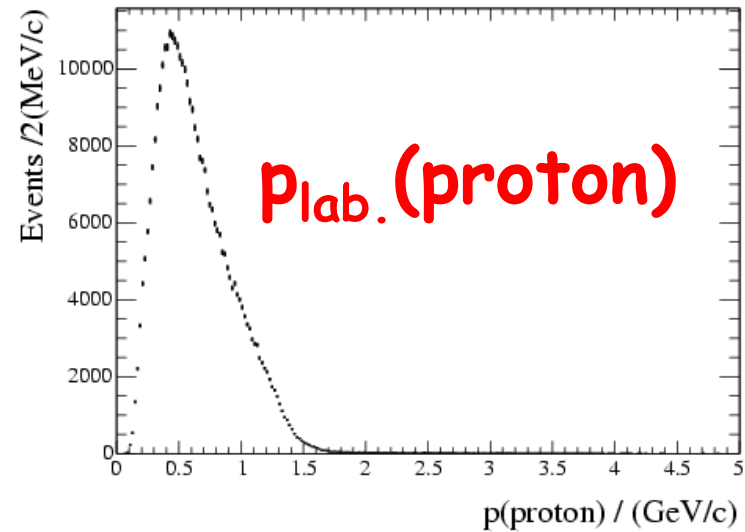
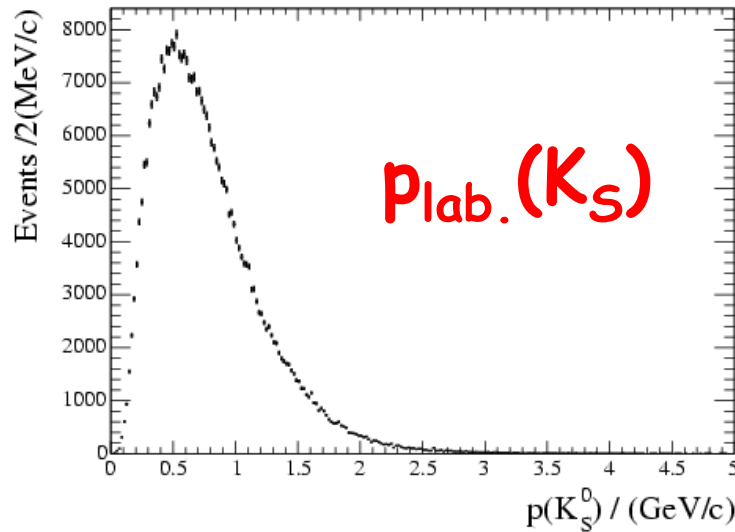
244 fb⁻¹



+ many other detailed features well reproduced

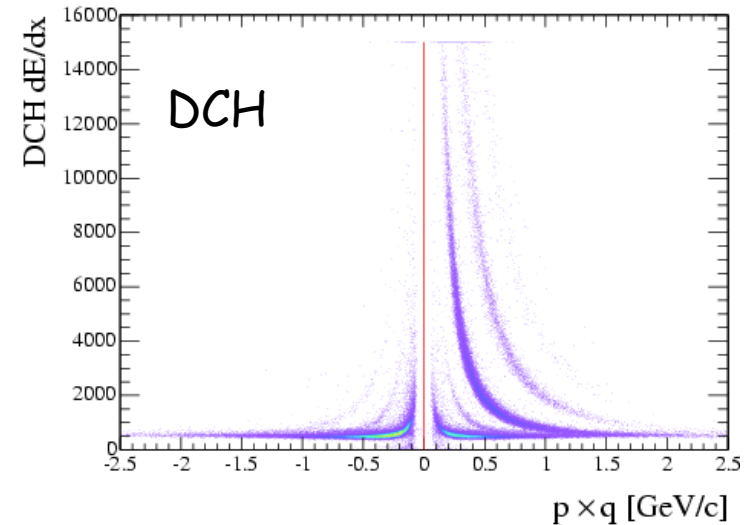
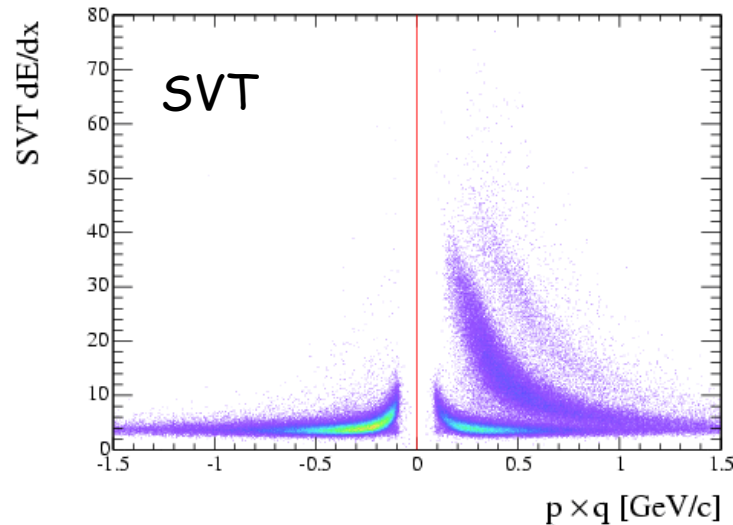
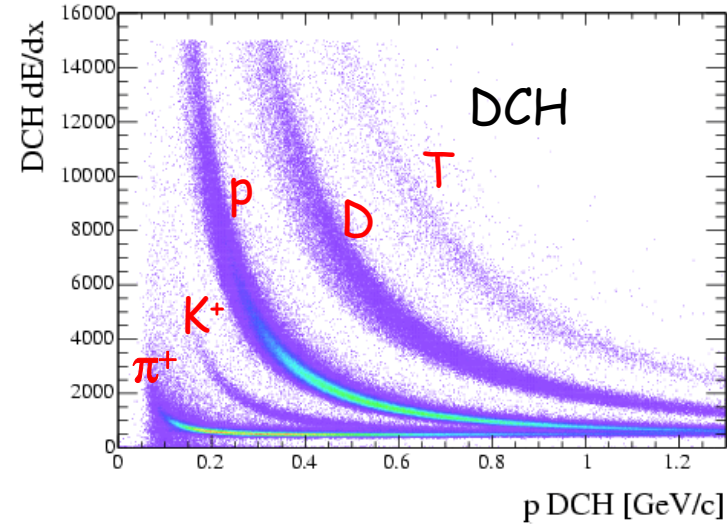
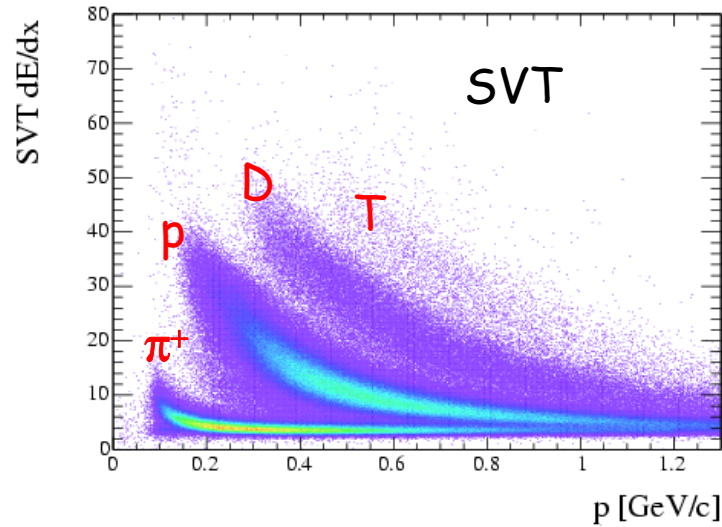


The selected (K_S , p) Candidates

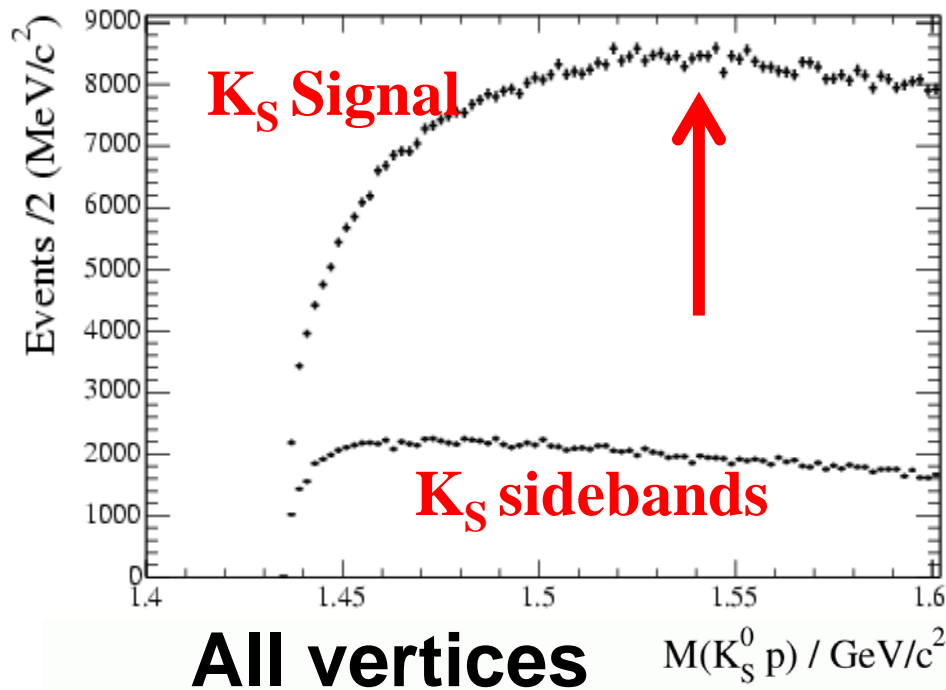


Event Selection:

- Candidate $K_S \pi^+ \pi^-$ and proton vertices selected using geometry + $|m(\pi\pi) - m(K_S^{\text{PDG}})| < 50 \text{ MeV}/c^2$

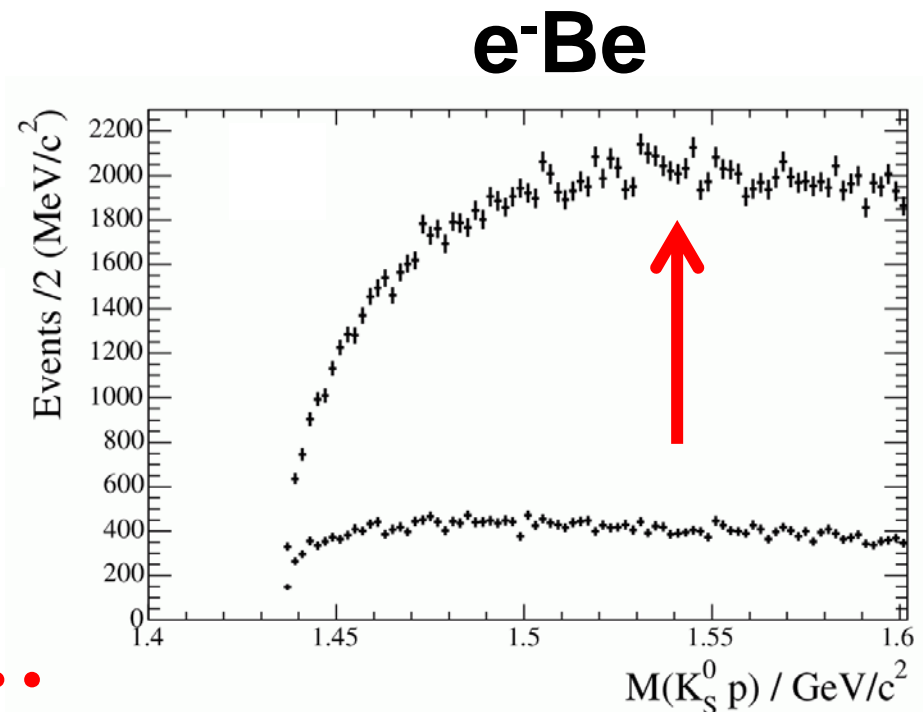


pK_S mass distributions in the $\Theta(1540)$ region



...so associate additional charged tracks...

- No signal observed...



Include Additional Vertex-Associated Charged Tracks

Require:

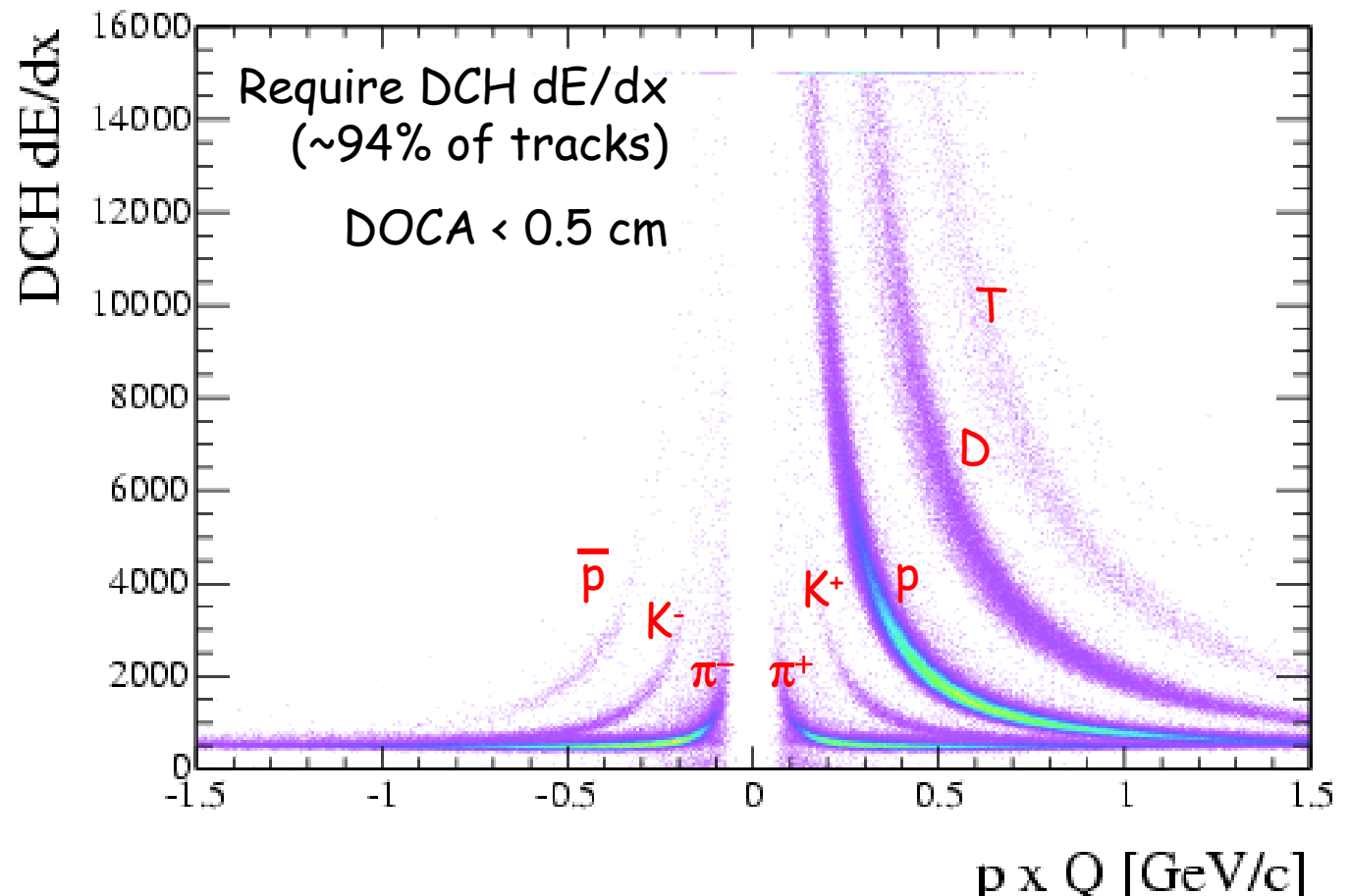
At least one associated track

Remove candidates with > 1 associated baryon

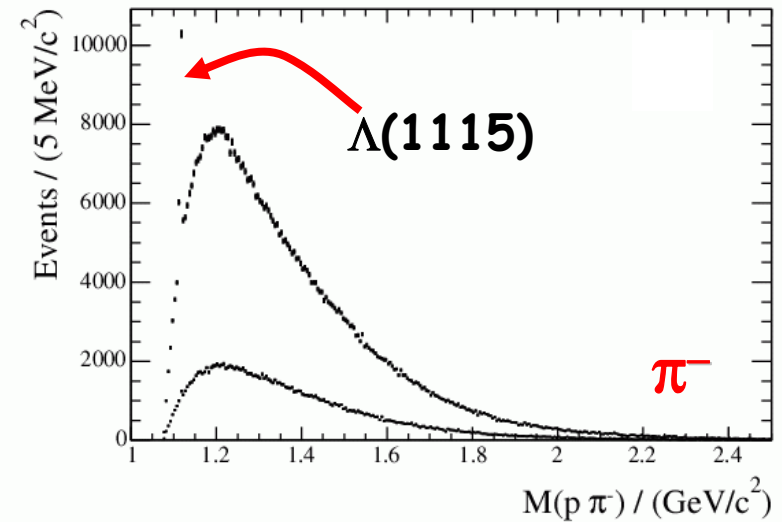
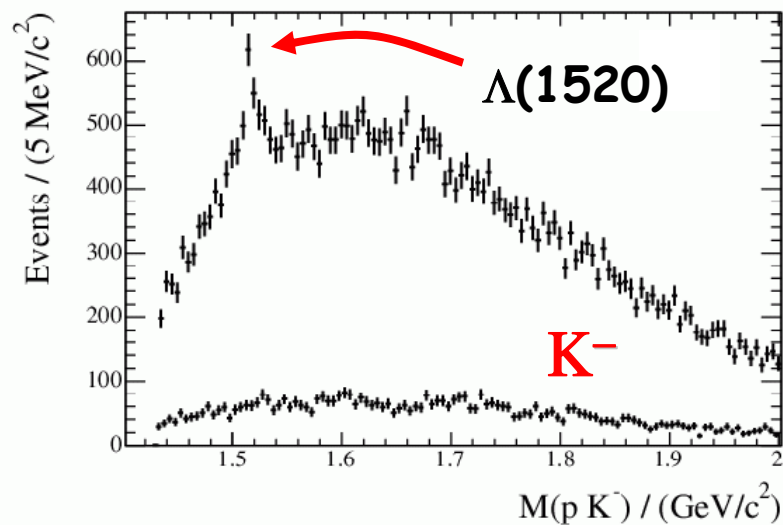
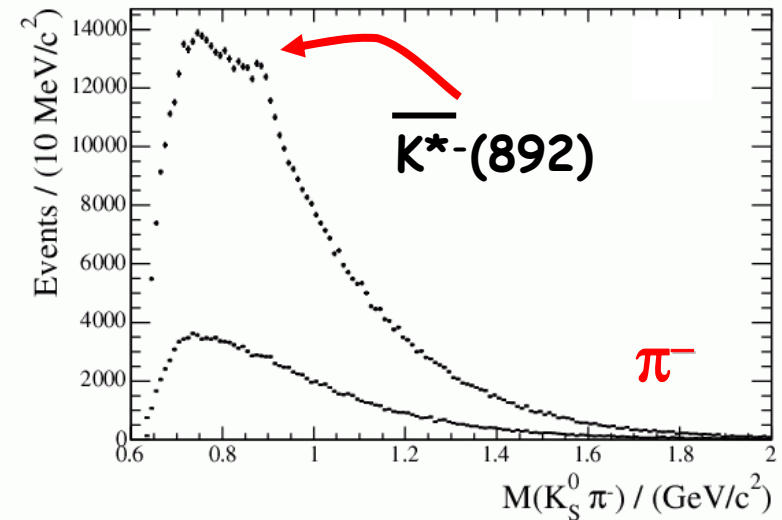
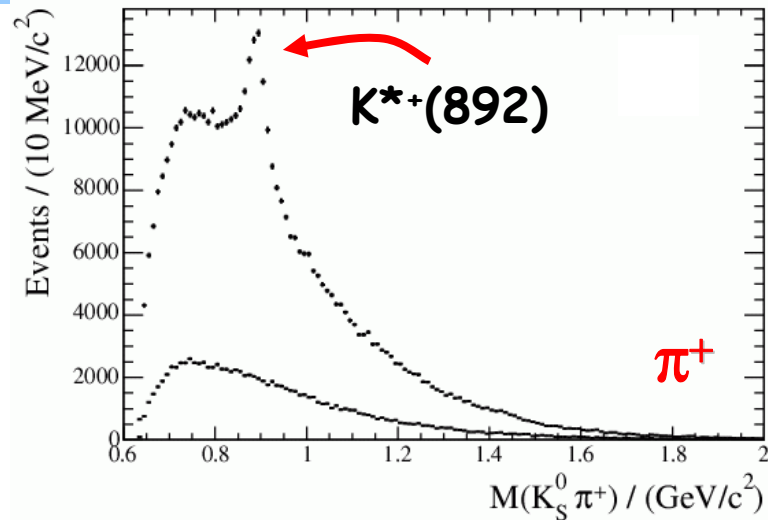
(\Rightarrow nuclear breakup, strong rescattering etc.)

Then:

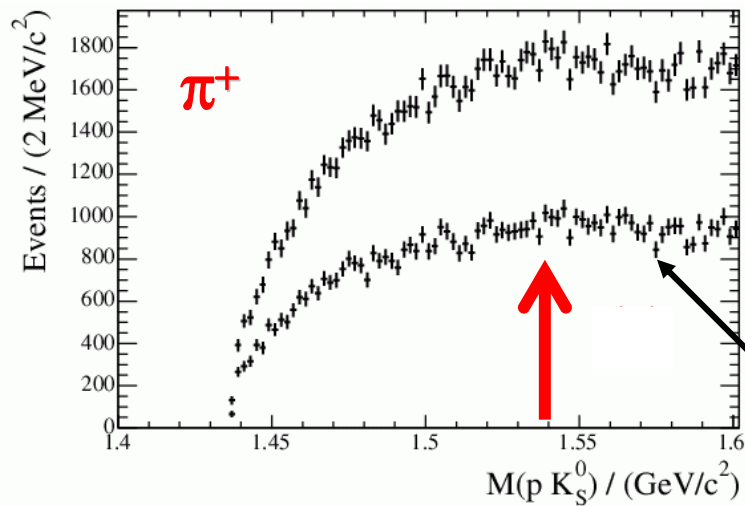
- associated π^+
- associated π^-
- associated K^+
- associated K^-



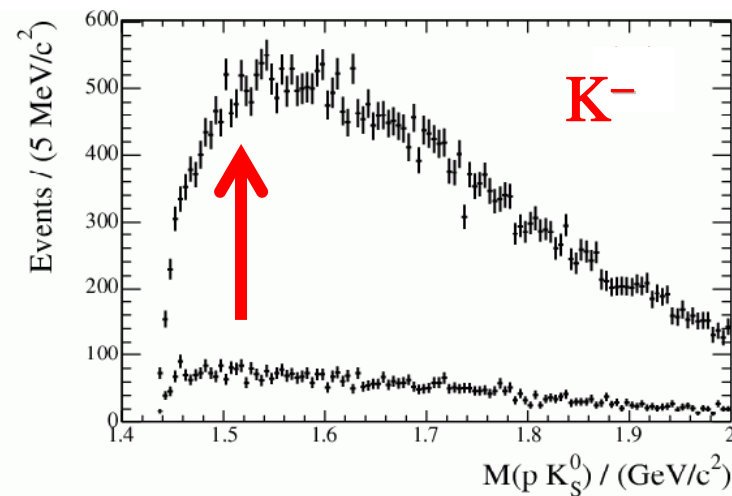
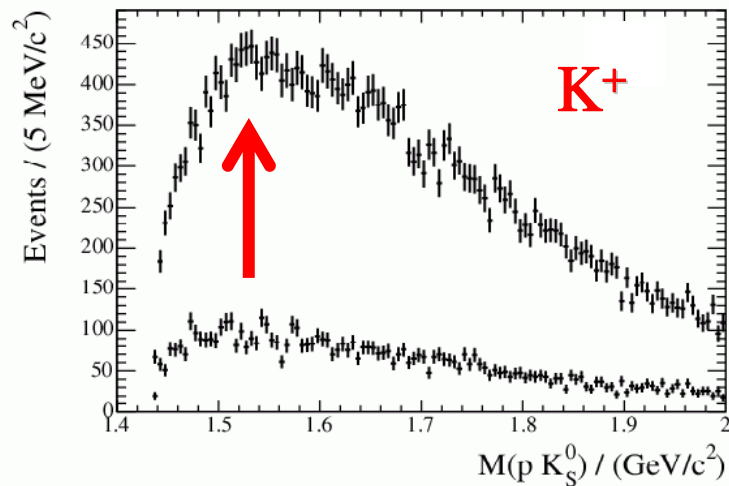
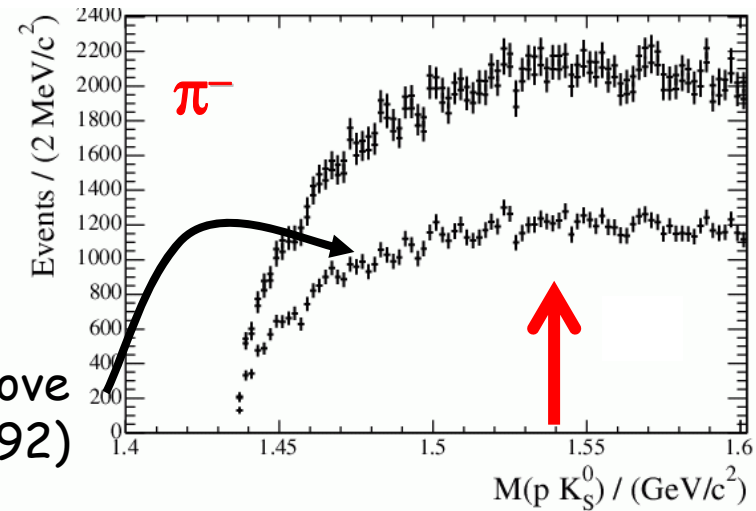
Combine p or K_S with identified π^\pm or K^\pm



... but no $\Theta_5(1540)^+$
{All Events; e-Be same with fewer events}

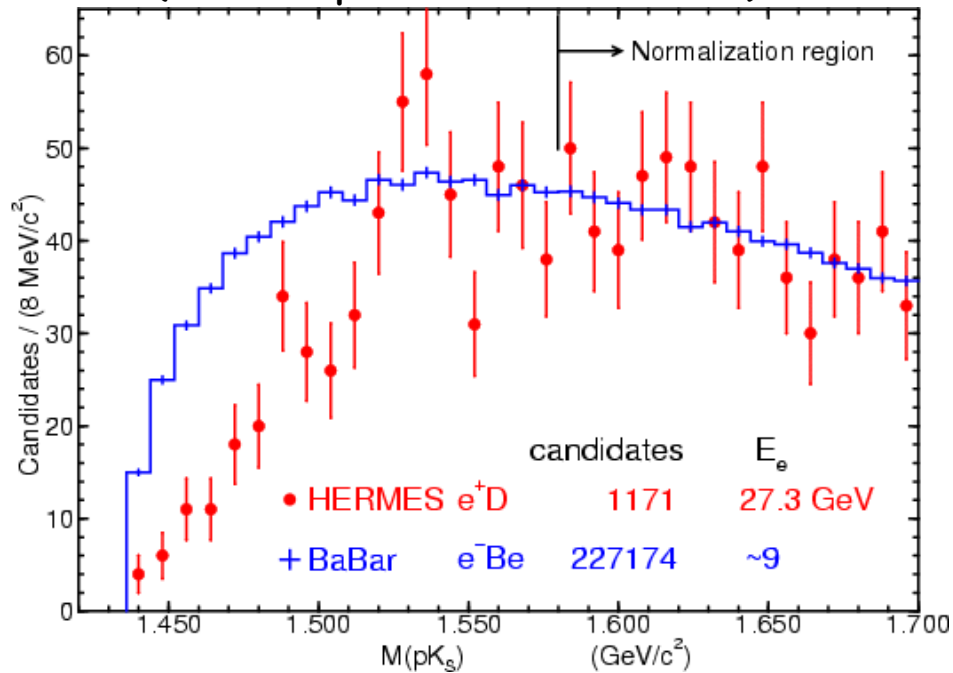


Remove
 $K^*(892)$

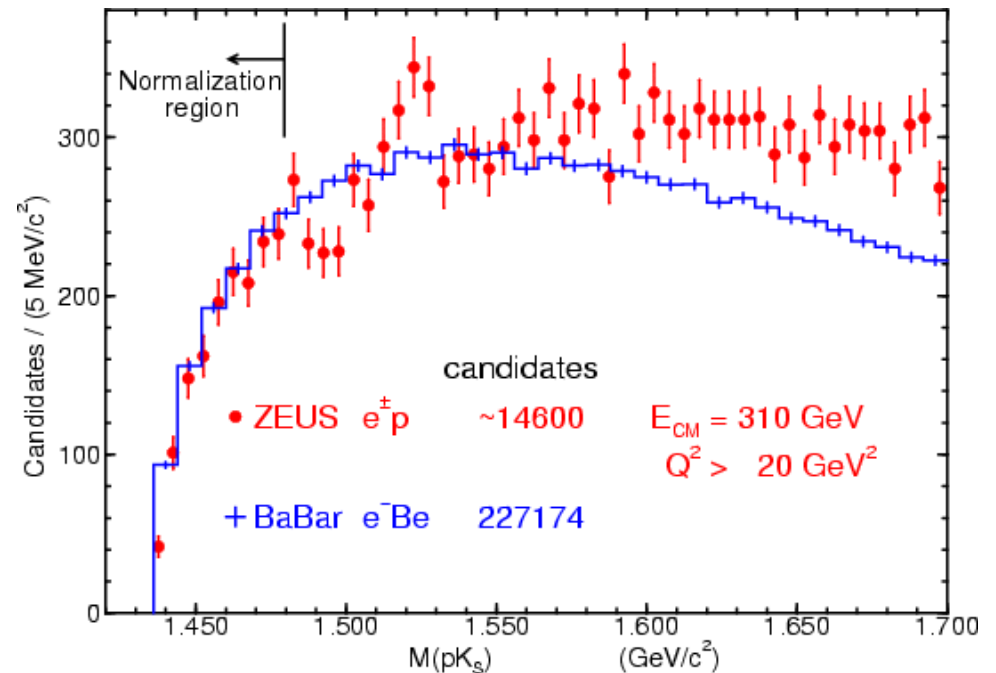


BaBar e^-Be Compared to $\Theta(1540)$ Electroproduction:

HERMES, possible acceptance loss at low mass (PID on proton $> 4.1 \text{ GeV}/c$)



ZEUS fit uses $\Sigma^*(1480)$ [PDG, 1 star]



SAPHIR: $\gamma p \rightarrow K^+ n \bar{K}^0$

compare: $e^-Be \rightarrow K_S p K^- X$ using $\Lambda(1520)$ signals

Implies $\sim 2\sigma$ effect in BaBar $m(K_S p)$

i.e. no obvious contradiction

Summary

- No evidence for non-charmed pentaquark production in e^+e^- interactions at BaBar; cross section UL's obtained
- $\Theta_5(1540)^+$ Searches in electro- and hadro- production
 - No signal found
 - e-Be compared to other electroproduction data
 - And to SAPHIR [via $\Lambda(1520)$]