

Physics Perspectives for Future K -Long Facility at JLab

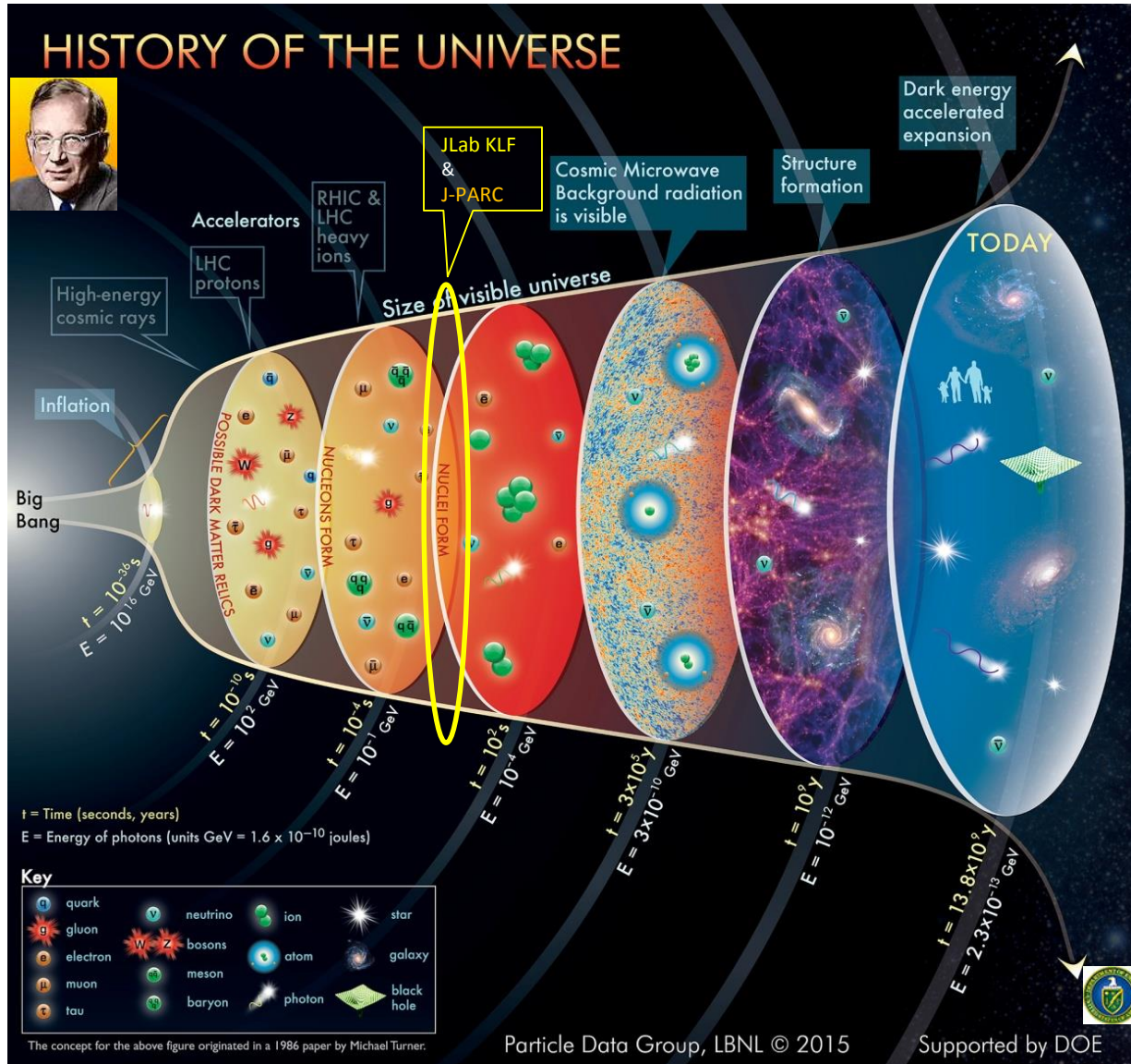
Igor Strakovsky^{}
The George Washington University
(for GlueX Collaboration)*



- Thermodynamics at freeze-out
- Spectroscopy of hyperons
- PWA for strange sector
- $K_L p$ database
- Opportunity with K_L beam
- Expected $K_L p$ data
- Summary



History of the Universe

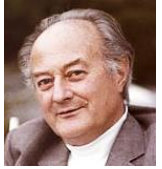


- The omission of any “missing hyperon states” in **Standard Model** will negatively impact our understanding of QCD **freeze-out** in heavy-ion & hadron collisions, hadron spectroscopy, & thermodynamics of **early Universe**.
- For that reason, advancing our understanding of formation of **baryons** from quarks & gluons requires new experiments to search for any **missing** hyperon states or resonances.



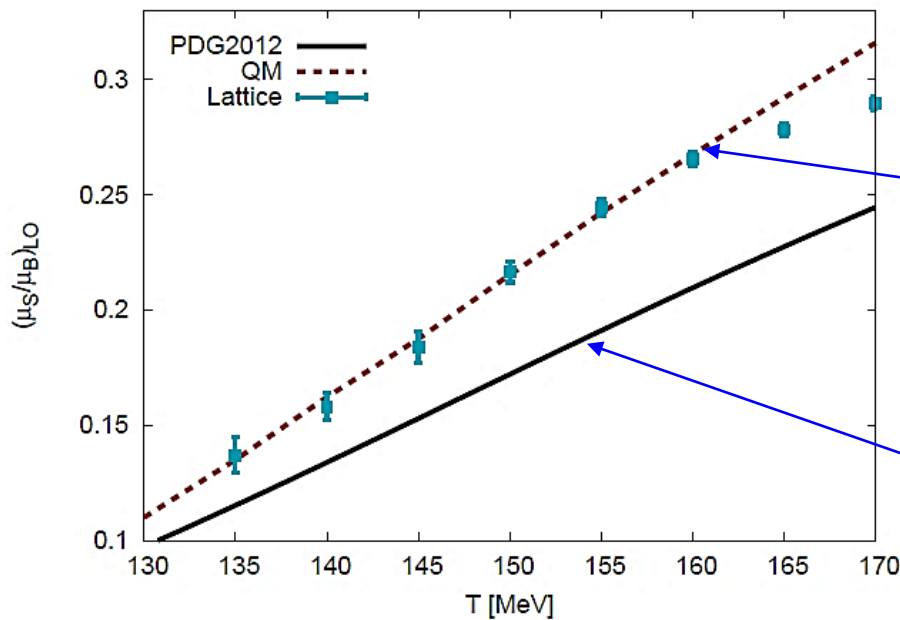
Thermodynamics at Freeze-Out

- Recent studies that compare **LQCD** calculations of thermodynamic, statistical **Hadron Resonance Gas** models, & ratios between measured yields of different hadron species in heavy ion collisions provide indirect evidence for presence of **“missing”** resonances in all of these contexts.



Chemical Potential

$$\left(\frac{\mu_S}{\mu_B}\right)_{LO} = -\frac{\chi_{11}^{BS}}{\chi_2^S} - \frac{\chi_{11}^{QS}}{\chi_2^S} \frac{\mu_Q}{\mu_B}$$



• + **“Missing” Hyperons (QM calculations).**

• Contribution from **observed Resonances.**



Courtesy of Claudia Ratti, YSTAR2016



11/8/2017

FDSA2017, Mexico City, November 2017

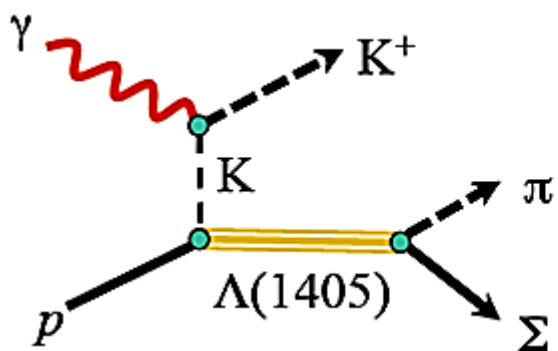
Igor Strakovsky 3



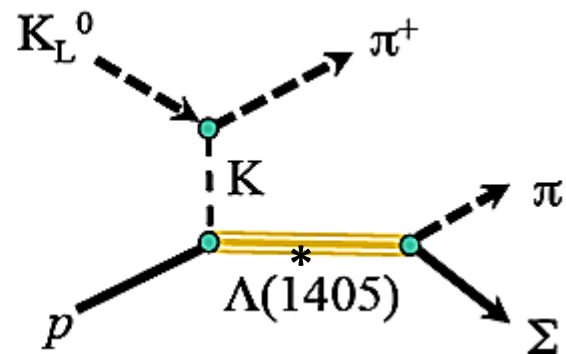
Sample of Hunting for Bumps

γK^+ Outlook at GlueX for $\Lambda(1405)$ Line- Shape Measurement

- That is doable while **PWA** technology is much more promising.



- Measurement may be feasible



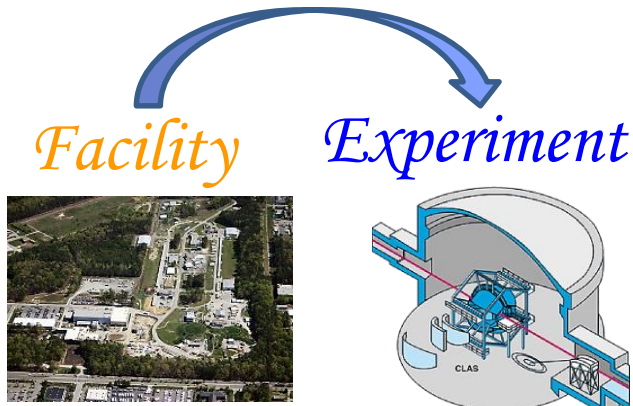
- $K_L^0 p \rightarrow \Lambda(1405) \pi^+ \rightarrow \Sigma^{+0} \pi^{-0+} \pi^+$



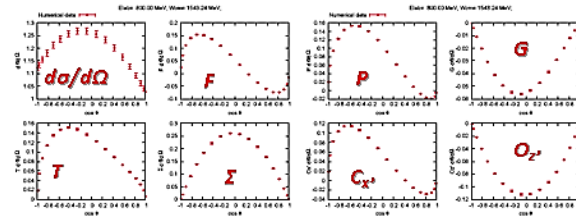
Courtesy of Reinhard Schumacher, KL2016



Road Map to Baryon Spectroscopy

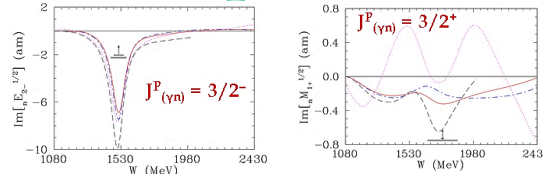


Data

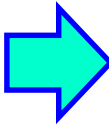
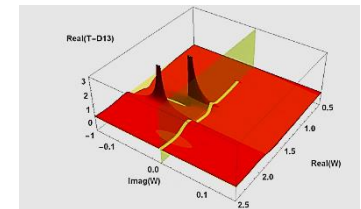


PWA

Amplitudes



Resonances



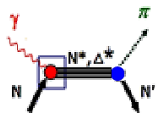
Crarim: C. Patrignani et al. (Particle Data Group), Chin. Phys. C, 40, 100001 (2016) and 2017 update.

$\Delta(1232) \ 3/2^+$ $I(P^0) = \frac{3}{2}(\frac{3}{2}^+)$ Status: ****

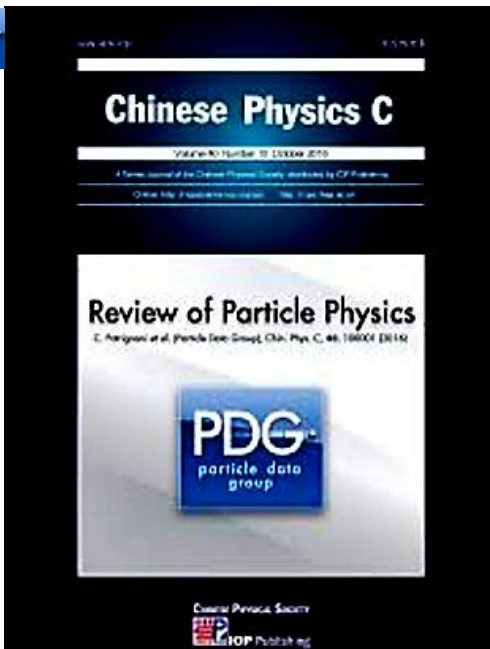
Older and obsolete values are listed and referenced in the 2014 edition, Chinese Physics C38 070001 (2014).

$\Delta(1232)$ POLE POSITIONS

REAL PART, MIXED CHARGES	DOCUMENT ID	YEAR	COMMENT
1232	10111	1970	OUR ESTIMATE
1231	±1	±1	SWARC 14 LJP ±N - ±N
1231	±1.0	±1.0	ANDERSONICH 12a EPWA Measurement
1231	±1.1	±1.1	AFND7 06 EPWA ±N - ±N, ±N
1230	±1.0	±1.0	HUGILLER 93 ARCD ±N - ±N
1210	±1	±1	CUTKOSKY 88 BWVA ±N - ±N



Baryon Sector at PDG16



GW Contribution C. Patrignani et al, Chin Phys C 40, 090001 (2016)

p	$1/2^+$ ****	$\Delta(1232)$	$3/2^+$ ****	Σ^+	$1/2^+$ ****	Ξ^0	$1/2^+$ ****	Λ_c^+	$1/2^+$ ****
n	$1/2^+$ ****	$\Delta(1600)$	$3/2^+$ ***	Σ^0	$1/2^+$ ****	Ξ^-	$1/2^+$ ****	$\Lambda_c(2595)^+$	$1/2^-$ ***
$N(1440)$	$1/2^+$ ****	$\Delta(1620)$	$1/2^-$ ****	Σ^-	$1/2^+$ ****	$\Xi(1530)^0$	$3/2^+$ ****	$\Lambda_c(2625)^+$	$3/2^-$ ***
$N(1520)$	$3/2^-$ ****	$\Delta(1700)$	$3/2^-$ ****	$\Sigma(1305)$	$3/2^+$ ****	$\Xi(1620)^0$	*	$\Lambda_c(2765)^+$	*
$N(1535)$	$1/2^-$ ****	$\Delta(1750)$	$1/2^+$ *	$\Sigma(1400)$	*	$\Xi(1690)^0$	***	$\Lambda_c(2890)^+$	$5/2^+$ ***
$N(1650)$	$1/2^-$ ****	$\Delta(1900)$	$1/2^-$ **	$\Sigma(1560)$	**	$\Xi(1820)^0$	***	$\Lambda_c(2940)^+$	*
$N(1675)$	$5/2^-$ ****	$\Delta(1905)$	$5/2^+$ ****	$\Sigma(1580)$	$3/2^-$ *	$\Xi(1950)^0$	***	$\Sigma_c(2455)$	$1/2^+$ ****
$N(1690)$	$5/2^+$ ****	$\Delta(1910)$	$1/2^+$ ****	$\Sigma(1620)$	$1/2^-$ **	$\Xi(2030)^0$	$\geq 3/2^+$ ***	$\Sigma_c(2520)$	$3/2^+$ ****
$N(1695)$	*	$\Delta(1920)$	$3/2^-$ **	$\Sigma(1660)$	$1/2^+$ ***	$\Xi(2250)^0$	**	$\Sigma_c(2800)$	***
$N(1700)$	$3/2^-$ ***	$\Delta(1930)$	$5/2^-$ **	$\Sigma(1670)$	$3/2^-$ ****	$\Xi(2250)^+$	**	Ξ_c^+	$1/2^+$ ***
$N(1710)$	$1/2^+$ ***	$\Delta(1940)$	$3/2^-$ **	$\Sigma(1690)$	**	$\Xi(2370)^0$	**	Ξ_c^0	$1/2^+$ ***
$N(1720)$	$3/2^+$ ***	$\Delta(1950)$	$7/2^+$ **	$\Sigma(1750)$	$1/2^-$ **	$\Xi(2500)^0$	**	Ξ_c^-	$1/2^+$ ***
$N(1830)$	$5/2^+$ **	$\Delta(2000)$	$5/2^+$ **	$\Sigma(1770)$	$1/2^+$ **	$\Xi(2500)^+$	**	Ξ_c^0	$1/2^+$ ***
$N(1850)$	$3/2^-$ **	$\Delta(2100)$	$1/2^-$ **	$\Sigma(1775)$	$1/2^-$ ****	Ω_c^+	$3/2^+$ *	$\Xi_c(2645)$	$3/2^+$ ***
$N(1880)$	$1/2^+$ **	$\Delta(2200)$	$7/2^-$ **	$\Sigma(1840)$	$3/2^+$ *	$\Omega_c(2700)^-$	*	$\Xi_c(2790)$	$1/2^-$ ***
$N(1915)$	$2/2^+$ **	$\Delta(2300)$	$9/2^+$ **	$\Sigma(1880)$	$1/2^+$ **	$\Omega_c(2800)^-$	*	$\Xi_c(2815)$	$3/2^-$ ***
$N(2000)$	$5/2^+$ **	$\Delta(2350)$	$5/2^-$ *	$\Sigma(1915)$	$5/2^+$ ****	$\Omega_c(2700)^-$	*	$\Xi_c(2930)$	*
$N(2090)$	$7/2^-$ **	$\Delta(2390)$	$7/2^+$ *	$\Sigma(2000)$	$1/2^-$ *			$\Xi_c(2980)$	***
$N(2000)$	$5/2^+$ **	$\Delta(2400)$	$9/2^-$ **	$\Sigma(2000)$	$1/2^-$ *			$\Xi_c(3055)$	**
$N(2040)$	$3/2^+$ **	$\Delta(2420)$	$11/2^+$ ****	$\Sigma(2030)$	$7/2^+$ ****			$\Xi_c(3080)$	***
$N(2060)$	$5/2^-$ **	$\Delta(2750)$	$13/2^-$ **	$\Sigma(2070)$	$5/2^+$ **			$\Xi_c(3123)$	*
$N(2100)$	$1/2^+$ *	$\Delta(2950)$	$15/2^+$ **	$\Sigma(2080)$	$3/2^+$ **			$\Omega_c(2770)^0$	$3/2^+$ ***
$N(2120)$	$3/2^-$ **			$\Sigma(2100)$	$7/2^-$ *			Ω_c^+	$1/2^+$ ***
$N(2190)$	$7/2^-$ ****	Λ	$1/2^+$ ****	$\Sigma(2250)$	***			$\Omega_c(2770)^0$	$3/2^+$ ***
$N(2220)$	$9/2^+$ ****	$\Lambda(1405)$	$1/2^-$ ****	$\Sigma(2455)$	**			Ξ_c^+	*
$N(2250)$	$9/2^+$ ****	$\Lambda(1520)$	$3/2^-$ ****	$\Sigma(2620)$	**			Ξ_c^0	*
$N(2600)$	$11/2^-$ ***	$\Lambda(1600)$	$1/2^+$ ***	$\Sigma(3000)$	*			Λ_b^0	$1/2^+$ ***
$N(2780)$	$13/2^+$ **	$\Lambda(1670)$	$1/2^-$ ****	$\Sigma(3170)$	*			Σ_b^+	$1/2^+$ ***
		$\Lambda(1690)$	$3/2^-$ ****					Σ_b^0	$1/2^+$ ***
		$\Lambda(1800)$	$1/2^-$ **					Σ_b^-	$3/2^+$ ***
		$\Lambda(1810)$	$1/2^-$ **					Ξ_b^0	$1/2^+$ ***
		$\Lambda(1820)$	$5/2^+$ **					Ξ_b^-	$1/2^+$ ***
		$\Lambda(1830)$	$3/2^-$ **					Ω_b^-	$1/2^+$ ***
		$\Lambda(1890)$	$3/2^+$ **						
		$\Lambda(2000)$							
		$\Lambda(2010)$	$7/2^+$ **						
		$\Lambda(2100)$	$7/2^-$ ****						
		$\Lambda(2110)$	$5/2^+$ ***						
		$\Lambda(2325)$	$3/2^-$ *						
		$\Lambda(2350)$	$9/2^+$ **						
		$\Lambda(2585)$	**						

• First hyperon was discovered in 1947.

• Pole position in complex energy plane for hyperons has been made only recently, in 2010.

- PDG16 has 109 Baryon Resonances (58 of them are 4* & 3*).
- In case of SU(6) x O(3), 434 states would be present if all revealed multiplets were fleshed out (three 70 & four 56).



GLUEX collaboration
11/8/2017

Y. Qung et al, Phys Lett B 694, 123 (2010)

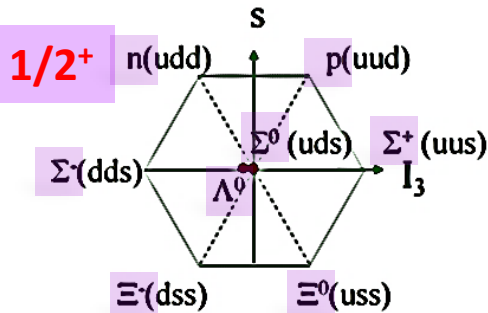
FDSA2017, Mexico City, November 2017

Igor Strakovsky 6

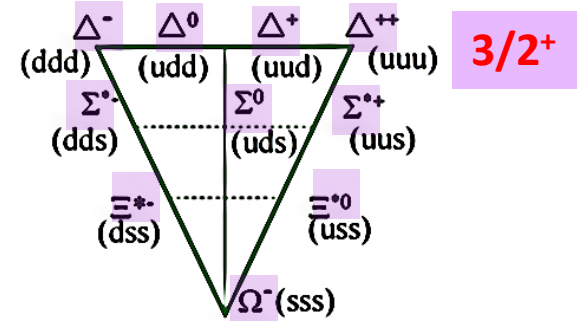



Baryon Resonances

- Three light quarks can be arranged in 6 baryonic families, N^* , Δ^* , Λ^* , Σ^* , Ξ^* , & Ω^* .
- Number of members in family that can exist is not arbitrary.
- If $SU(3)_F$ symmetry of QCD is controlling, then:



Octet: N^* , Λ^* , Σ^* , Ξ^*
Decuplet: Δ^* , Σ^* , Ξ^* , & Ω^*



- Number of experimentally identified resonances of each baryon family in  Summary Tables is 16 N^* , 10 Δ^* , 14 Λ^* , 10 Σ^* , 6 Ξ^* , & 2 Ω^* .
- Constituent Quark models, for instance, predict existence of no less than 64 N^* , 22 Δ^* states with mass < 3 GeV.

- Seriousness of “missing-states” problem is obvious from these numbers.



• To complete $SU(3)_F$ multiplets, one needs no less than 17 Λ^* , 43 Σ^* , 42 Ξ^* , & 24 Ω^* .

B.M.K. Nefkens, πN Newsletter, 14, 150 (1997)



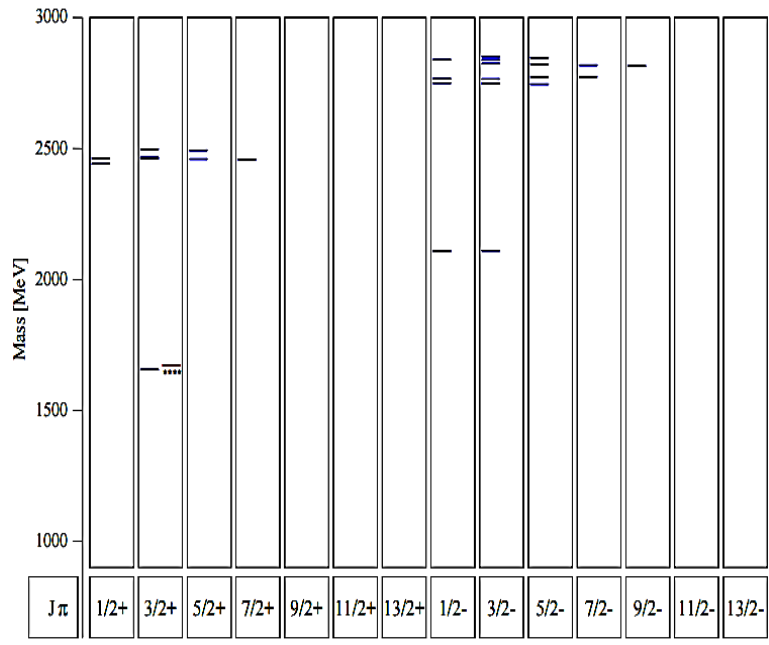
Very Strange Resonances & Problem of “Missing” States



R. Koniuk & N. Isgur, Phys Rev Lett **44**, 845 (1980)

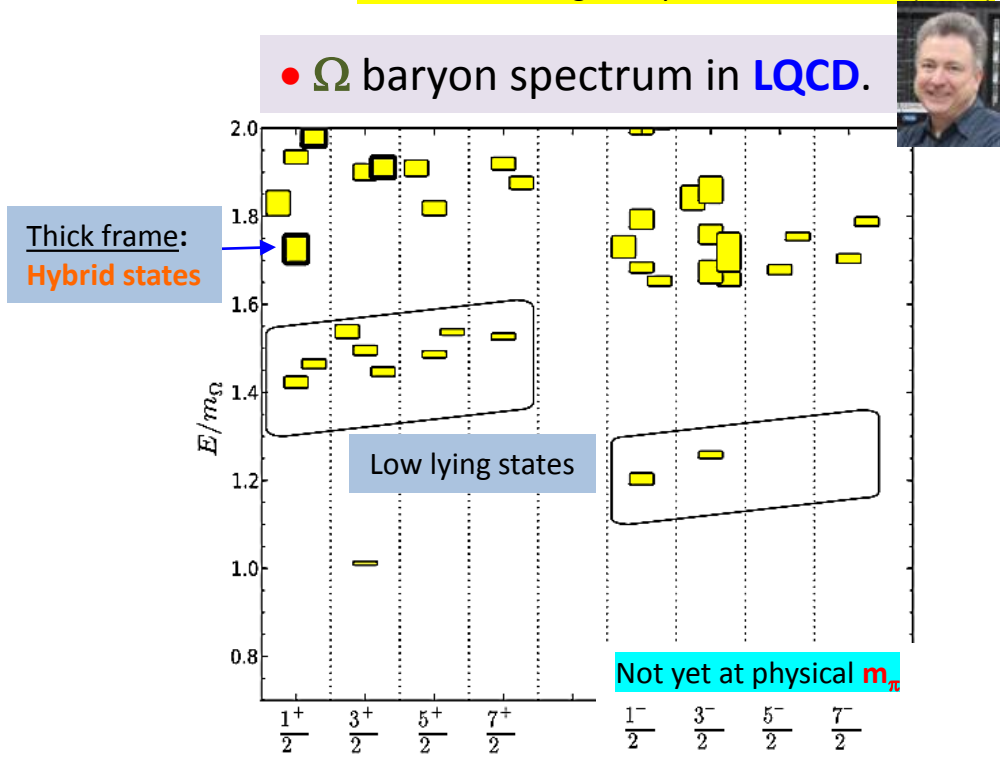
- Experimental **knowledge** of hadron spectrum is **incomplete**: more excited states are **expected** to exist.

• Ω baryon spectrum in QM.



U. Löring *et al* Eur Phys J A **10**, 447 (2001)

• Ω baryon spectrum in LQCD.

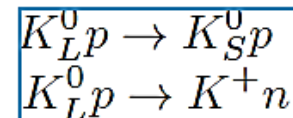


R.G. Edwards *et al* Phys Rev D **87**, 054506 (2013)

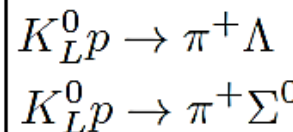


What Can Be Learned with K_L^0 Beam ?

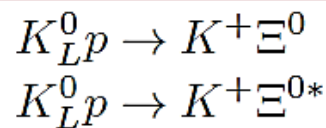
Elastic and charge-exchange



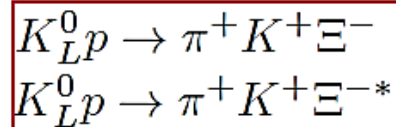
Two-body with $S=-1$



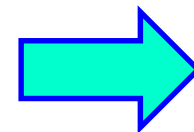
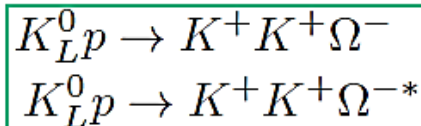
Two-body with $S=-2$



Three-body with $S=-2$



Three-body with $S=-3$



Why We Have to Measure Double-Strange Cascades in JLab

- **Heavy quark symmetry (Isgur–Wise symmetry)** suggests that multiplet splittings in **strange, charm, & bottom hyperons** should scale as approximately inverses of corresponding **quark masses**:

$$1/m_s : 1/m_c : 1/m_b$$



N. Isgur & M.B. Wise, Phys Rev Lett **66** 1130 (1991)

- If they don't, that scaling failure implies that structures of corresponding states are **anomalous**, & very **different** from one another.
- So far only **hyperon** resonance multiplet, where this scaling can be "tested" & seen is lowest **negative parity** multiplet:

$$\Lambda(1405)1/2^- - \Lambda(1520)3/2^-, \quad \Lambda_c(2595)1/2^- - \Lambda_c(2625)3/2^-, \quad \Lambda_b(5912)1/2^- - \Lambda_b(5920)3/2^-$$

- It works **approximately (30%)** well for those Λ -splittings. It would work **even better** for Ξ, Ξ_c, Ξ_b splittings, & should be **very good** for $\Omega, \Omega_c, \Omega_b$ splittings.

Particle	J^P	Overall status	Status as seen in —				
			$\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	$1/2^+$	****					Decays weakly
$\Xi(1530)$	$3/2^+$	****	****				
$\Xi(1620)$		*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	$3/2^-$	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		
$\Xi(2120)$		*		*			
$\Xi(2250)$		**					3-body decays
$\Xi(2370)$		**					3-body decays
$\Xi(2500)$		*		*			3-body decays

• **Jefferson Lab** can do **double cascade** spectrum.

As **LHCb** is doing **double charm cascade** spectrum.

$$\Xi_c(2790)1/2^- - \Xi_c(2815)3/2^-$$

R. Aaij *et al*, Phys Rev Lett **119**, 112001 (2017)



Courtesy of Dan-Olof Riska, 2017



11/8/2017

FDSA2017, Mexico City, November 2017

Igor Strakovsky 10





- **Differential cross section** & **polarization** for $K_L p$ scattering are given by

$$\frac{d\sigma}{d\Omega} = \lambda^2 (|f|^2 + |g|^2)$$
$$P \frac{d\sigma}{d\Omega} = 2\lambda^2 \text{Im}(fg^*)$$

$\lambda = \hbar/k$, & \mathbf{k} is momentum of incoming kaon in CM.

$f(\mathbf{W}, \theta)$ & $g(\mathbf{W}, \theta)$ are **nonspin-flip** & **spin-flip** amplitudes at \mathbf{W} & θ .

Partial-Wave Expansion

- In terms of partial waves, $f(\mathbf{W}, \theta)$ & $g(\mathbf{W}, \theta)$ can be expanded as

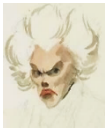
$$f(W, \theta) = \sum_{l=0}^{\infty} [(l+1)T_{l+} + lT_{l-}] P_l(\cos \theta)$$

$$g(W, \theta) = \sum_{l=1}^{\infty} [T_{l+} - T_{l-}] P_l^1(\cos \theta)$$

l is initial orbital angular momentum.

$P_l(\cos \theta)$ is Legendre polynomial.

$P_l^1(\cos \theta)$ is associated Legendre function.



Total angular momentum for T_{l+} is $J=l+1/2$, while that for T_{l-} is $J=l-1/2$.

Isospin Amplitudes

- Ignoring small **CP**-violating terms ($\sim 10^{-3}$), we can write

$$K_L^0 = \frac{1}{\sqrt{2}}(K^0 - \bar{K}^0)$$
$$K_S^0 = \frac{1}{\sqrt{2}}(K^0 + \bar{K}^0)$$

We have both $I = 0$ & $I = 1$ amplitudes for **KN** & $\bar{\text{KN}}$ scattering.

Amplitudes $T_{I\pm}$ can be expanded in isospin amplitudes as

$$T_{I\pm} = C_0 T_{I\pm}^0 + C_1 T_{I\pm}^1$$

$T_{I\pm}^l$ are partial-wave amplitudes

with isospin I & total angular momentum $J = I \pm 1/2$

C^l are appropriate **Clebsch–Gordan** coefficients.



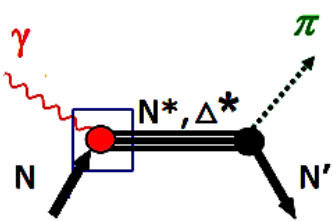


Photo-Decay Amplitudes in BW & Pole Forms

- Pole is main signature of resonance !

$$A_h^{BW} = C \sqrt{\frac{q_r}{k_r} \frac{\pi(2J+1)M_r \Gamma_r^2}{m_N \Gamma_{\pi,r}}} \tilde{A}_\alpha^h$$

Evaluated at Res Energy

$$A_h^{pole} = C \sqrt{\frac{q_p}{k_p} \frac{2\pi(2J+1)W_p}{m_N \text{Res}_{\pi/N}}} \text{Res } A_\alpha^h$$

Evaluated at Pole

TABLE I. Breit-Wigner and pole values for selected nucleon resonances. Masses, widths, and residues are given in units of MeV, the helicity 1/2 and 3/2 photo-decay amplitudes in units of $10^{-3}(\text{GeV})^{-1/2}$. Errors on the phases are generally 2–5 degrees. For isospin 1/2 resonances the values of the proton target are given.

Resonance	Breit-Wigner values				Pole values			
	(Mass, width)	$\Gamma_\pi/2$	$A_{1/2}$	$A_{3/2}$	(Re W_p , $-2 \text{Im } W_p$)	R_π	$A_{1/2}$	$A_{3/2}$
$\Delta(1232) 3/2^+$	(1233, 119)	60	-141 ± 3	-258 ± 5	(1211, 99)	52 $[-47^\circ]$	$-136 \pm 5 [-18^\circ]$	$-255 \pm 5 [-6^\circ]$
$N(1440) 1/2^+$	(1485, 284)	112	-60 ± 2		(1359, 162)	38 $[-98^\circ]$	$-66 \pm 5 [-38^\circ]$	
$N(1520) 3/2^-$	(1515, 104)	33	-19 ± 2	$+153 \pm 3$	(1515, 113)	38 $[-5^\circ]$	$-24 \pm 3 [-7^\circ]$	$+157 \pm 6 [+10^\circ]$
$N(1535) 1/2^-$	(1547, 188)	34	$+92 \pm 5$		(1502, 95)	16 $[-16^\circ]$	$+77 \pm 5 [+4^\circ]$	
$N(1650) 1/2^-$	(1635, 115)	58	$+35 \pm 5$		(1648, 80)	14 $[-69^\circ]$	$+35 \pm 3 [-16^\circ]$	





R.L. Workman *et al*, Phys Rev C **87**, 068201 (2013)

A. Svarc *et al*, Phys Rev C **89**, 065208 (2014)



KN & $\bar{K}N$ Final States

$$\begin{aligned}
 T(K_{LP}^0 \rightarrow K_{SP}^0) &= \frac{1}{2} \left(\frac{1}{2} T^1(KN \rightarrow KN) + \frac{1}{2} T^0(KN \rightarrow KN) \right) \\
 &\quad - \frac{1}{2} T^1(\bar{K}N \rightarrow \bar{K}N) \\
 T(K_{LP}^0 \rightarrow K_{LP}^0) &= \frac{1}{2} \left(\frac{1}{2} T^1(KN \rightarrow KN) + \frac{1}{2} T^0(KN \rightarrow KN) \right) \\
 &\quad + \frac{1}{2} T^1(\bar{K}N \rightarrow \bar{K}N) \\
 T(K_{LP}^0 \rightarrow K^+n) &= \frac{1}{\sqrt{2}} \left(\frac{1}{2} T^1(KN \rightarrow KN) - \frac{1}{2} T^0(KN \rightarrow KN) \right) \\
 &\quad - \frac{1}{2} T^1(\bar{K}N \rightarrow \bar{K}N)
 \end{aligned}$$

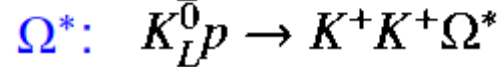
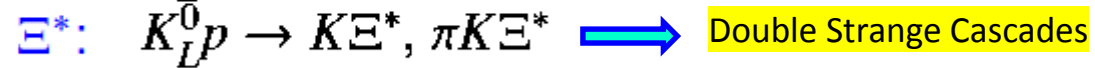
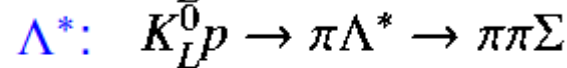
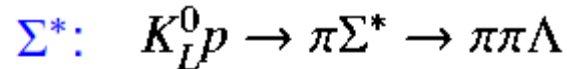
- New  data with  hadronic program via K^- induced measurements (complimentary program) will greatly constrain **PWAs** & reduce model-dependent uncertainties in extraction of strange resonance properties.

$$\begin{aligned}
 T(K^-p \rightarrow K^-p) &= \frac{1}{2} T^1(\bar{K}N \rightarrow \bar{K}N) + \frac{1}{2} T^0(\bar{K}N \rightarrow \bar{K}N) \\
 T(K^-p \rightarrow \bar{K}^0n) &= \frac{1}{2} T^1(\bar{K}N \rightarrow \bar{K}N) - \frac{1}{2} T^0(\bar{K}N \rightarrow \bar{K}N) \\
 T(K^+p \rightarrow K^+p) &= T^1(KN \rightarrow KN) \\
 T(K^+n \rightarrow K^+n) &= \frac{1}{2} T^1(KN \rightarrow KN) + \frac{1}{2} T^0(KN \rightarrow KN)
 \end{aligned}$$



How to Search for “Missing” Hyperons

- **New data** for inelastic $K_L p$ scattering would significantly improve our knowledge of Σ^* , Λ^* , & Ξ^* resonances.
- Very few **polarization** data are available for any $K_L p$ reactions but are needed to help **remove ambiguities** in **PWAs**.
- To search for “missing” hyperons, we need measurements of production reactions:



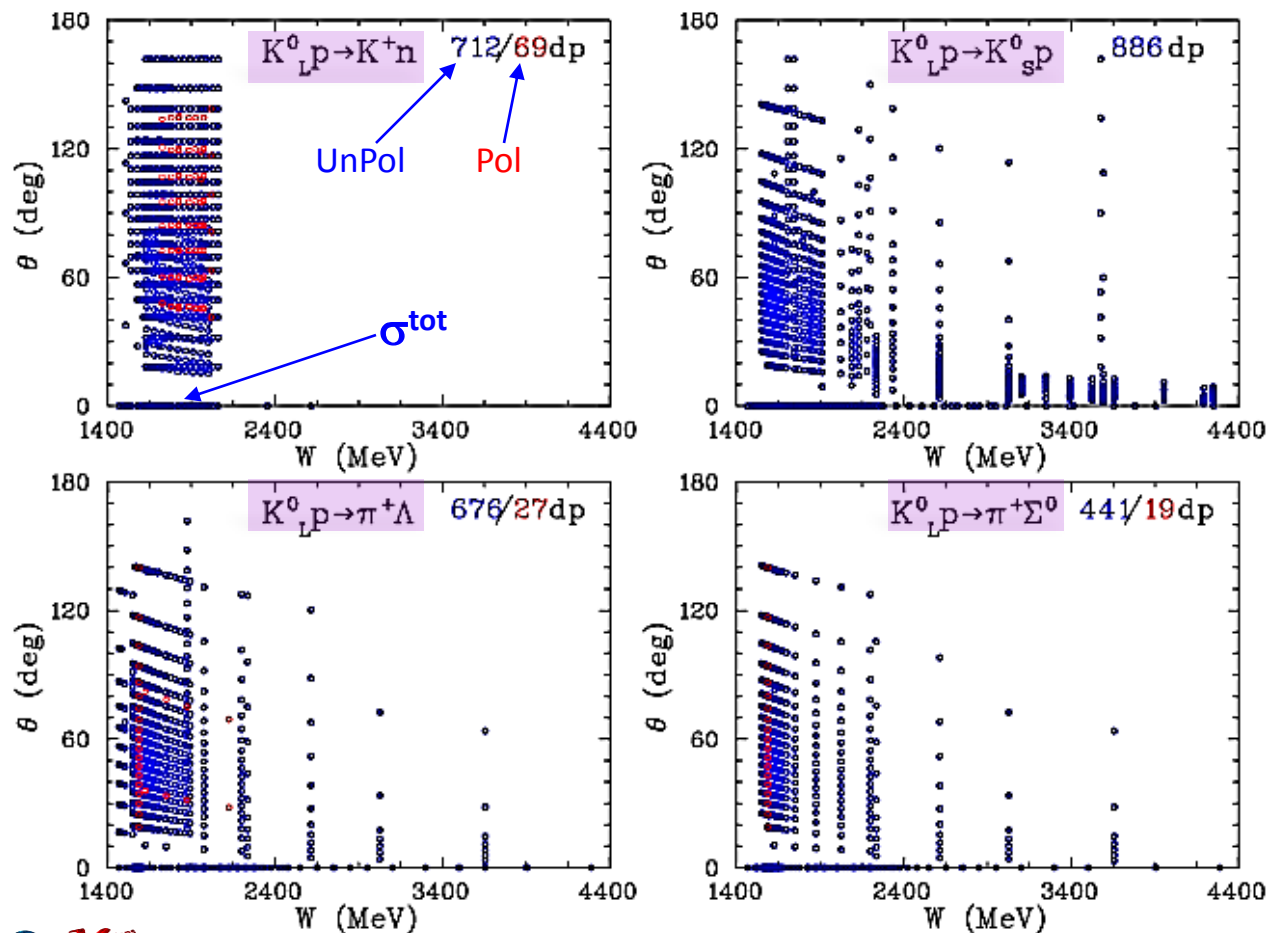
- If such measurements can be performed with good **energy** & **angular** coverage with good **statistics**.
- Then it is very likely that measurements with K_L beam would find several “**missing**” hyperons.

W = 1.45 – 5.05 GeV

SAID: <http://gwdac.phys.gwu.edu/>



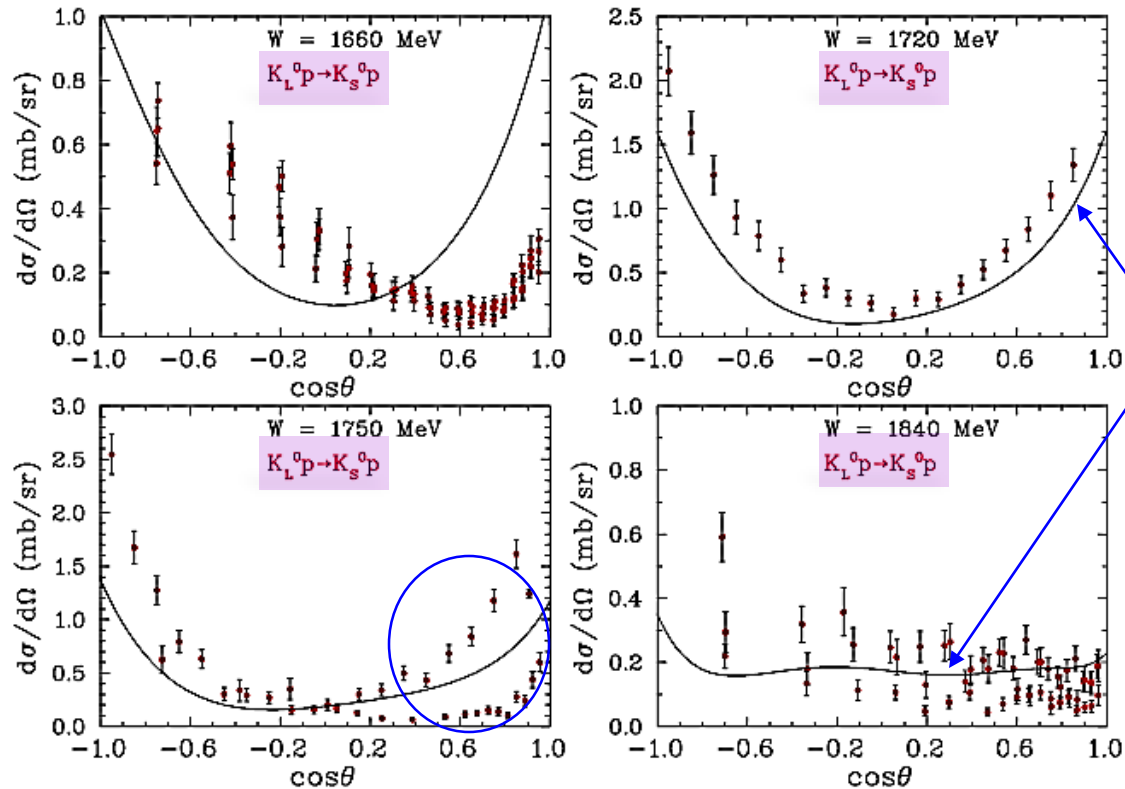
- Limited number of K_L induced measurements (1961 – 1982)
 2426 $d\sigma/d\Omega$, 348 σ^{tot} , & 115 P observables do not allow today to **feel comfortable** with **Hyperon Spectroscopy** results.



- Limited number of K_L observables in **hyperon spectroscopy** at present poorly constrain theoretical analyses.
- Overall systematics** of previous experiments varies between **15% & 35%**. **Energy binning** is much broader than hyperon widths.
- There were no measurements using **polarized target**. It means that there are no **double polarized** observables which are critical for **complete experiment** program.
- We are not aware of any data on **neutron** target.



Data for $K_L p \rightarrow K_S p$



• No $d\sigma/d\Omega$ data are available for $K_L p \rightarrow K_L p$ below $W = 3$ GeV.

• PWA (KSU&GW) predictions at lower & higher energies have poorer agreement for $S \neq 0$ data than for $S = 0$ data.



R.L. Workman *et al* Phys. At. Nucl. **69**, 90 (2006)
 R.L. Workman *et al* Phys. Rev. C **70**, 028201 (2004)



H. Zhang *et al* Phys Rev C **88**, 035204 (2013)
 H. Zhang *et al* Phys Rev C **88**, 035205 (2013)



GLUEX relations
 partment

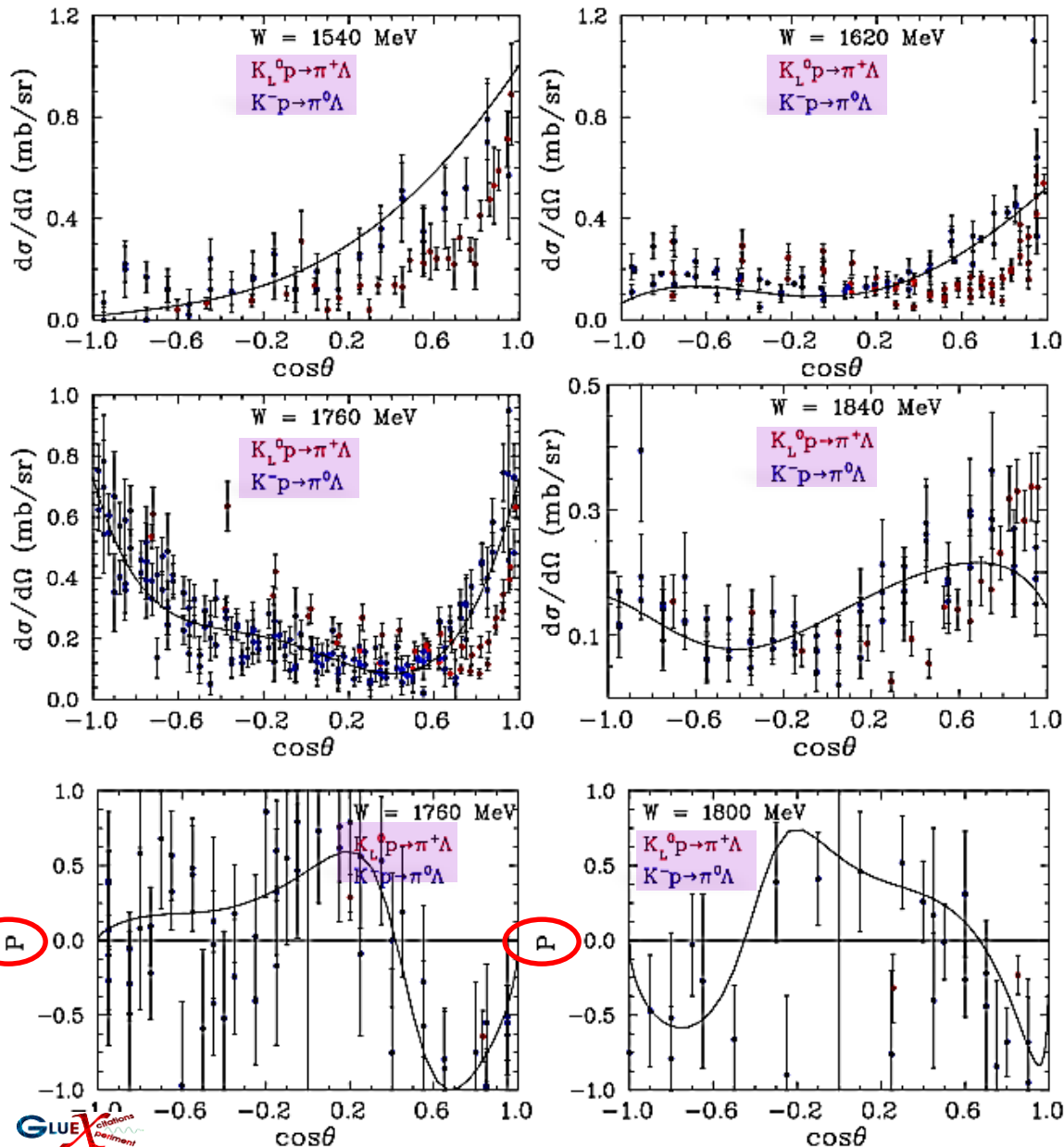
11/8/2017

FDSA2017, Mexico City, November 2017

Igor Strakovsky 18



Data for $K_L p \rightarrow \pi^+ \Lambda$ & $K^- p \rightarrow \pi^0 \Lambda$

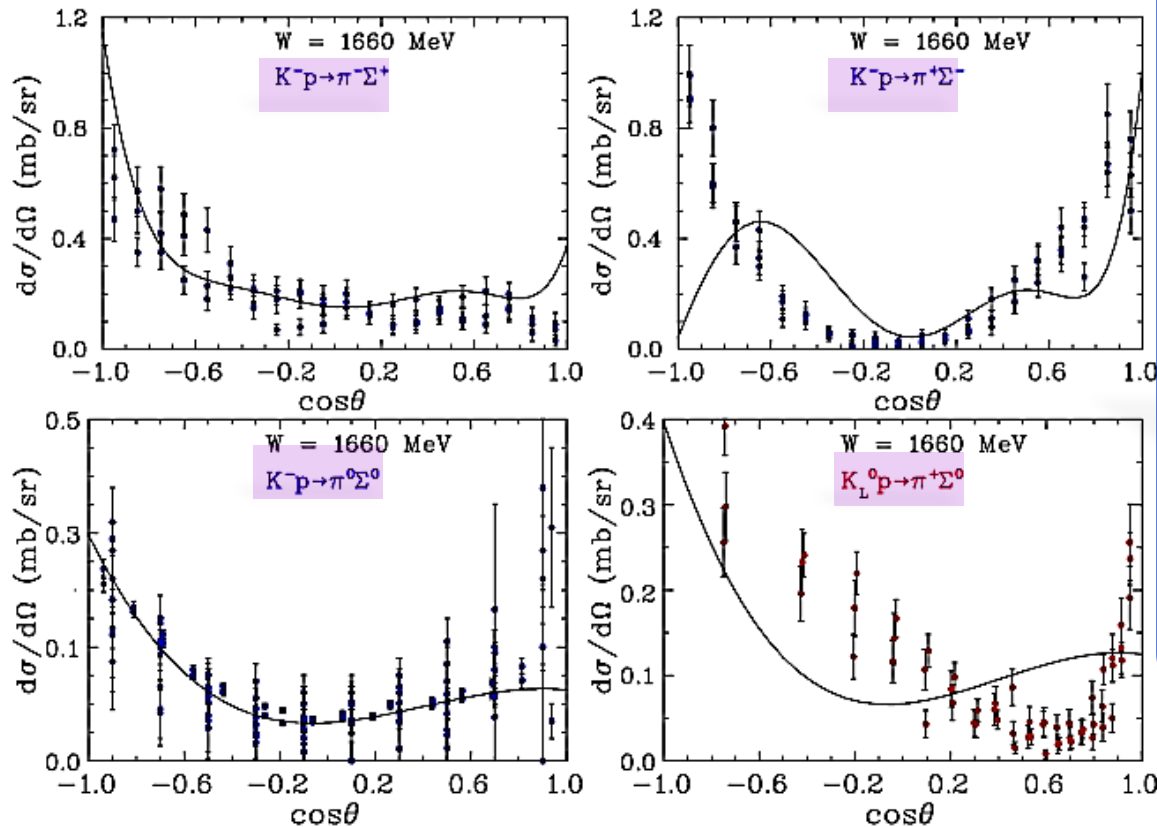


• $K^- p \rightarrow \pi^0 \Lambda$ & $K_L p \rightarrow \pi^+ \Lambda$ amplitudes imply that their observables measured at same energy should be identical except for small differences due to isospin-violating mass differences in hadrons.

• Polarized measurements are **tolerable** for **any PWA** solutions.




Data for $K_L p \rightarrow \pi^+ \Sigma^0$ & $K^- p \rightarrow \pi \Sigma$



- Reactions $K_L p \rightarrow \pi^+ \Sigma^0$ & $K_L p \rightarrow \pi^0 \Sigma^+$ are Isospin selective (only $I = 1$ amplitudes are involved) & $K^- p \rightarrow \pi^0 \Sigma^0$ isospin selective for $I = 0$ whereas reactions $K^- p \rightarrow \pi^- \Sigma^+$ & $K^- p \rightarrow \pi^+ \Sigma^-$ involve both $I = 0$ & $I = 1$ amplitudes.

- New measurements with K_L -beam would lead to better understanding of Σ^* states & help constrain amplitudes for $K^- p \rightarrow \pi \Sigma$ reactions.

- Quality of $K_L p$ data is comparable to that for $K^- p$ data. It would be advantageous to combine $K_L p$ data in new coupled-channel PWA with available $K^- p$ measurements.

-  lists only **two** results on
BR to $K\Sigma$ $\Lambda(2100)7/2^-$ (BR < 3%)
 $\Sigma(2030)7/2^+$ (BR < 2%).



A bit of History

PHYSICAL REVIEW

VOLUME 138, NUMBER 5B

7 JUNE 1965

First paper on subject

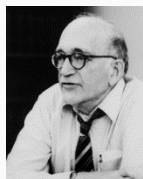
Photoproduction of Neutral K Mesons*

S. D. DRELL AND M. JACOB†

Stanford Linear Accelerator Center, Stanford University, Stanford, California

(Received 6 January 1965)

CP-violation (1964)
Hot topic!

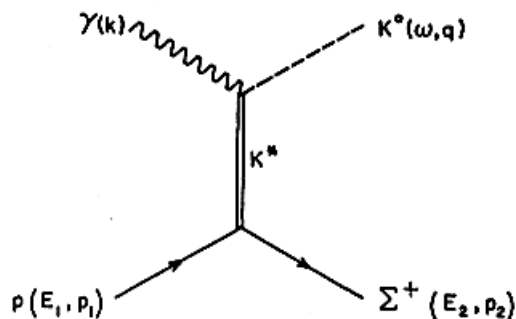


Photoproduction of a neutral K -meson beam at high energies from hydrogen is computed in terms of a K^* vector-meson exchange mechanism corrected for final-state interactions. The results are very encouraging for the intensity of high-energy K_2 beams at high-energy electron accelerators. A typical magnitude is $20 \mu\text{b/sr}$ for a lower limit of the K^0 photoproduction differential cross section, at a laboratory peak angle of 2° , for 15-BeV incident photons.



FIG. 1. K^* exchange in photoproduction.

[Not dominant]



Our motivation in carrying out this calculation is to emphasize the strong suggestion that an intense “healthy” K_2 beam will emerge from high-energy electron accelerators (SLAC in particular) and will be available for detailed experimental studies.

50 $\mu\text{b/sr}$

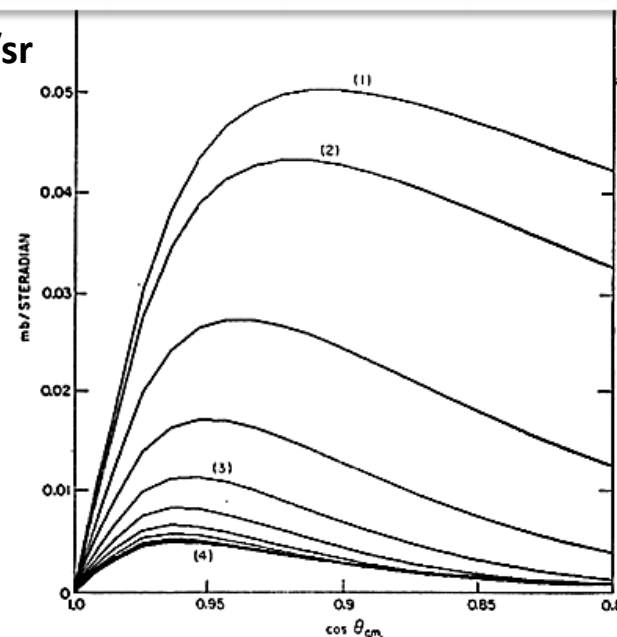


FIG. 3. Center-of-mass differential cross section at 10 BeV. Curve (1) gives the Born approximation. Curve (2) is obtained after subtraction of the $j=1/2$ partial wave. Curves (3) and (4) are respectively obtained after the $j=1/2, 3/2, 5/2, 7/2$, and all partial waves have been corrected for absorption in final state. The results shown as directly obtained from and drawn by the computer.



GLUEX relations
partner

11/8/2017

Courtesy of Mike Albrow, KL2016

FDSA2017, Mexico City, November 2017



A bit of History

The possibility that useful K_L beam could be made at electron synchrotron by photoproduction was being considered, & 1965 prediction for SLAC by Drell & Jacob was optimistic.



8.B.5 Nuclear Physics B23 (1970) 509-524. North-Holland Publishing Company
8.B.6

PHOTOPRODUCTION OF K^0 MESONS FROM PROTONS AND FROM COMPLEX NUCLEI

M. G. ALBROW[†], D. ASTON, D. P. BARBER, L. BIRD^{††},
R. J. ELLISON, C. HALLIWELL, A. E. HARCKHAM^{†††},
F. K. LOEBINGER, P. G. MURPHY, J. WALTERS^{††} and A. J. WYNROE
*Schuster Laboratories, The University of Manchester,
Manchester M13 9PL*

R. F. TEMPLEMAN
*Daresbury Nuclear Physics Laboratory, Daresbury,
Near Warrington, Lancs.*

Received 16 July 1970

"We were at Manchester Univ. close to Daresbury 5 GeV e-synchrotron."

CP-violation

VOLUME 22, NUMBER 18

PHYSICAL REVIEW LETTERS

5 May 1969

PRODUCTION OF K_2^0 MESONS AND NEUTRONS BY 10- AND 16-GeV ELECTRONS ON BERYLLIUM*

A. D. Brody, W. B. Johnson, D. W. G. S. Leith, G. Loew, J. S. Loos, G. Luste, R. Miller, K. Moriyasu, B. C. Shen, W. M. Smart, and R. Yamartino
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 13 March 1969)



SLAC NATIONAL ACCELERATOR LABORATORY

Systematics of particle anti-particle processes through intrinsic property of K-longs.



GLUEX collations experiment

11/8/2017

FDSA2017, Mexico City, November 2017

Igor Strakovsky 22



Proposal for JLab PAC46

PR12-17-001

Strange Hadron Spectroscopy with a Secondary K_L Beam at GlueX








S. Adhikari¹², H. Al Ghoul¹², A. Ali¹⁷, M. J. Amarian^{45,51}, E. G. Anassontzis²,
A. V. Anisovich^{20,14}, A. Austregesilo¹², M. Baalouch⁴⁰, F. Barbosa²², A. Barnes⁹,
M. Bashkany^{15,1}, T. D. Beattie⁴⁴, R. Bellwied²², V. V. Berdnikov²⁷, T. Black⁴¹, W. Boeglin¹²,
W. J. Briscoe¹², T. Britton²², W. K. Brooks⁴⁶, B. E. Cannon¹², E. Chudakov²², P. L. Cole²²,
V. Crede¹², M. M. Dalton²², A. Deur²², P. Degtyarenko²², S. Dobbs⁴², G. Dodge⁴⁰,
A. G. Dolgolenko²⁹, M. Döring^{15,22}, M. Dugger¹, R. Dzhygadilo¹⁷, R. Edwards²², H. Egayan²²,
S. Eidelman^{4,21}, A. Ernst¹², A. Eskandarian¹⁵, P. Eugenio¹², C. Fanelli²², S. Fegan²⁶,
A. M. Foda⁴⁴, J. Frye²⁴, S. Furletov²², L. Gan⁴², A. Gasparian²⁹, G. Gavalian¹²,
V. Gauzshtein^{47,48}, N. Gevorgyan²⁰, D. I. Glazier⁴⁵, K. Goetzen¹⁷, J. Goity^{22,21},
V. S. Goryachev²⁹, L. Guo¹², H. Habermann¹², M. Hadzimehmedovic⁴², H. Hakobyan⁴⁶,
A. Hamdi¹⁷, S. Han²³, J. Hardin¹², A. Hayrapetyan¹⁹, T. Horn⁷, G. M. Huber⁴⁴, C. E. Hyde⁴⁰,
D. G. Ireland¹⁶, M. M. Ito²², B. C. Jackson¹⁸, N. S. Jarvis⁶, R. T. Jones⁹, V. Kakoyan²⁰,
G. Kalicy⁷, M. Kamel¹², C. D. Keith²², C. W. Kim¹², F. J. Klein¹², C. Kourkouvelis²,
S. Kulshov⁴⁶, I. Kuznetsov^{47,48}, A. B. Laptev²², I. Larin²⁹, D. Lawrence²², M. Levillain²⁹,
W. I. Levine⁶, K. Livingston¹⁶, G. J. Lolos⁴⁴, V. E. Lyubovitskij^{47,48,22,46}, D. Mack²², M. Mai¹²,
D. M. Manley²⁷, U.-G. Meißner^{22,24}, H. Marukyan²⁰, V. Mathieu²⁴, P. T. Matlone²²,
M. Matveev¹⁴, V. Matveev²⁹, M. McCaughan²², M. McCracken⁶, W. McGinley⁶, J. McIntyre⁹,
C. A. Meyer⁶, R. Miskimen²⁴, R. E. Mitchell²⁴, F. Mokaya⁹, V. Mokzev²², K. Nakayama¹⁸,
E. Nerling¹⁷, Y. Oh²⁸, H. Osmanovic⁴⁹, A. I. Ostrovidov¹², R. Omerovic⁴⁹, Z. Papandreou⁴⁴,
K. Park²², E. Pasyuk²², M. Pasyuk²², P. Pauli¹⁶, R. Pedroni²⁹, M. R. Pennington¹⁶, L. Pentchev²²,
K. J. Peters¹⁷, W. Phelps¹², E. Pooser²², B. Prati⁹, J. W. Price⁵, N. Qin²³, J. Reinhold¹²,
D. Richards²², D.-O. Riska¹¹, B. G. Ritchie¹, J. Ritman^{2,26,1}, L. Robison⁴², D. Romanov²⁷,
H.-Y. Ryu⁴², C. Salgado²⁹, E. Santopinto²², A. V. Sarantsev^{20,14}, R. A. Schumacher⁶,
C. Schwarz¹⁷, J. Schwienting¹⁷, A. Semenov⁴⁴, I. Semenov⁴⁴, K. K. Seth¹², M. R. Shepherd²⁴,
E. S. Smith²², D. I. Sober¹, D. Sokhan¹⁶, A. Somov²², S. Somov²⁷, O. Soto⁴⁶, N. Sparks¹,
J. Stahov⁴⁹, M. J. Stalbc⁶, J. R. Stevens^{22,1}, I. I. Strakovsky^{15,1}, A. Subedi²⁴, A. Švarc⁴⁵,
A. Szczepaniak^{24,22}, V. Tarasov²⁹, S. Taylor²², A. Teymurazyan⁴⁴, A. Tomaradze⁴², A. Tsaris¹²,
G. Vasiladakis², D. Watts¹⁰, D. Werthmüller⁴⁶, N. Wickramaarachchi⁴⁰, T. Whittlatch²²,
M. Williams²⁵, B. Wojtsekhowski²², R. L. Workman¹², T. Xiao⁴², Y. Yang²⁵, N. Zachariou¹⁰,
J. Zanting²⁴, Z. Zhang²², B. Zou⁸, J. Zhang²², X. Zhou²², B. Zhitnitsky²²

• 177 people from
54 institutes
are co-authors.

Hyperon &
Strange Meson
Spectroscopy

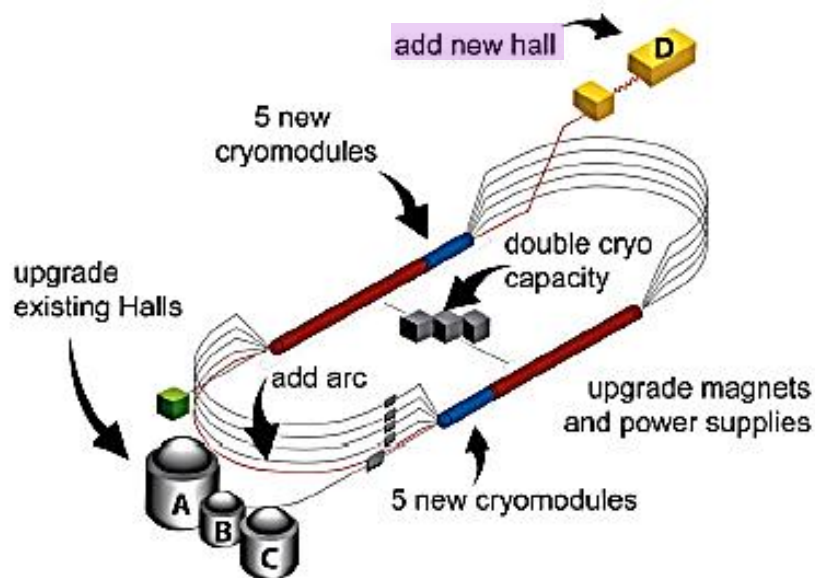
• We plan to resubmit full Proposal for JLab PAC46 in 2018.

Aims of Jlab KLF Project

- **KLF** project has to **establish** secondary K_L beam line at  with **flux** of **three order of magnitude** higher than  had, for scattering experiments on both **proton & neutron** (**first time !**) targets in order to determine **differential cross sections & self-polarization** of strange **hyperons** with  detector to enable precise **PWA** in order to determine all **resonances** up to **3 GeV** in spectra of Λ^* , Σ^* , Ξ^* , & Ω^* .
- In addition, we intend to do **strange meson spectroscopy** by studies of the π -**K** interaction to locate the **pole** positions in $l = 1/2$ & $3/2$ channels.
- **KLF** has link to **ion-ion high energy** facilities as  &  & will allow understand formation of our world in **several microseconds** after **Big Bang**.



CEBAF Upgrade to 12 GeV

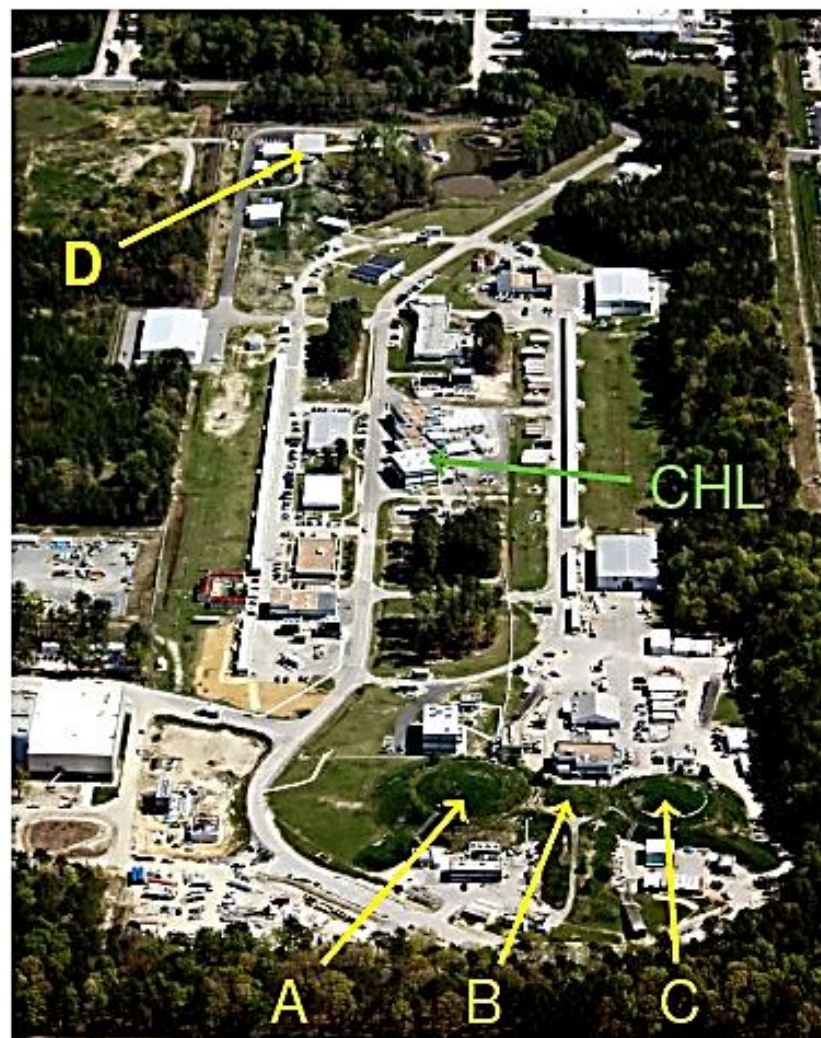


Upgrade Goals

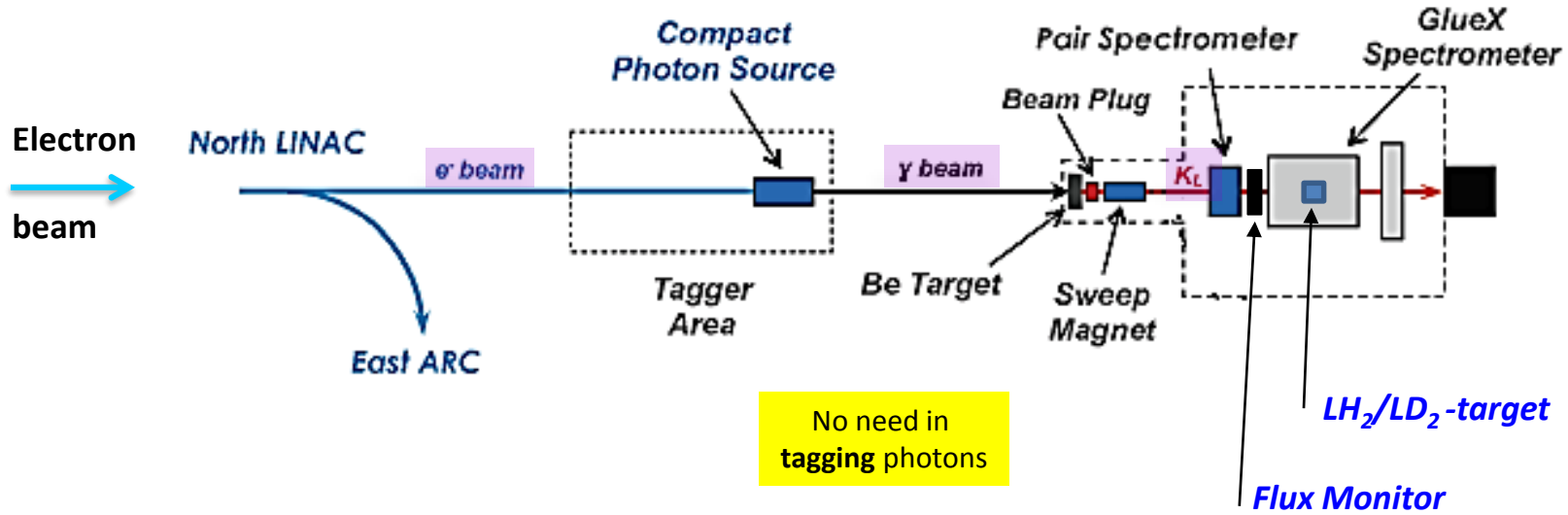
- Accelerator: 6 GeV \Rightarrow 12 GeV
- Halls A,B,C: $e^- < 11$ GeV, $< 100 \mu\text{A}$
- Hall D: $e^- 12$ GeV $\Rightarrow \gamma$ -beam

Upgrade Status

- Reached 12 GeV in Dec 2015
- Halls A,D: finished
- Halls B,C: about a year to go



Hall D Beam Line Set up for K -longs



$I_e = 5 \mu A$
 W-radiator = 0.1 R.L.
 Be-target = 1.7 R.L.

- **Electrons** are hitting **W**-radiator at **CPS**.
- **Photons** are hitting **Be**-target at **cave**.
- **K_L s** are hitting the **LH_2/LD_2** target within **GLueX** setting.

Hall D / GlueX

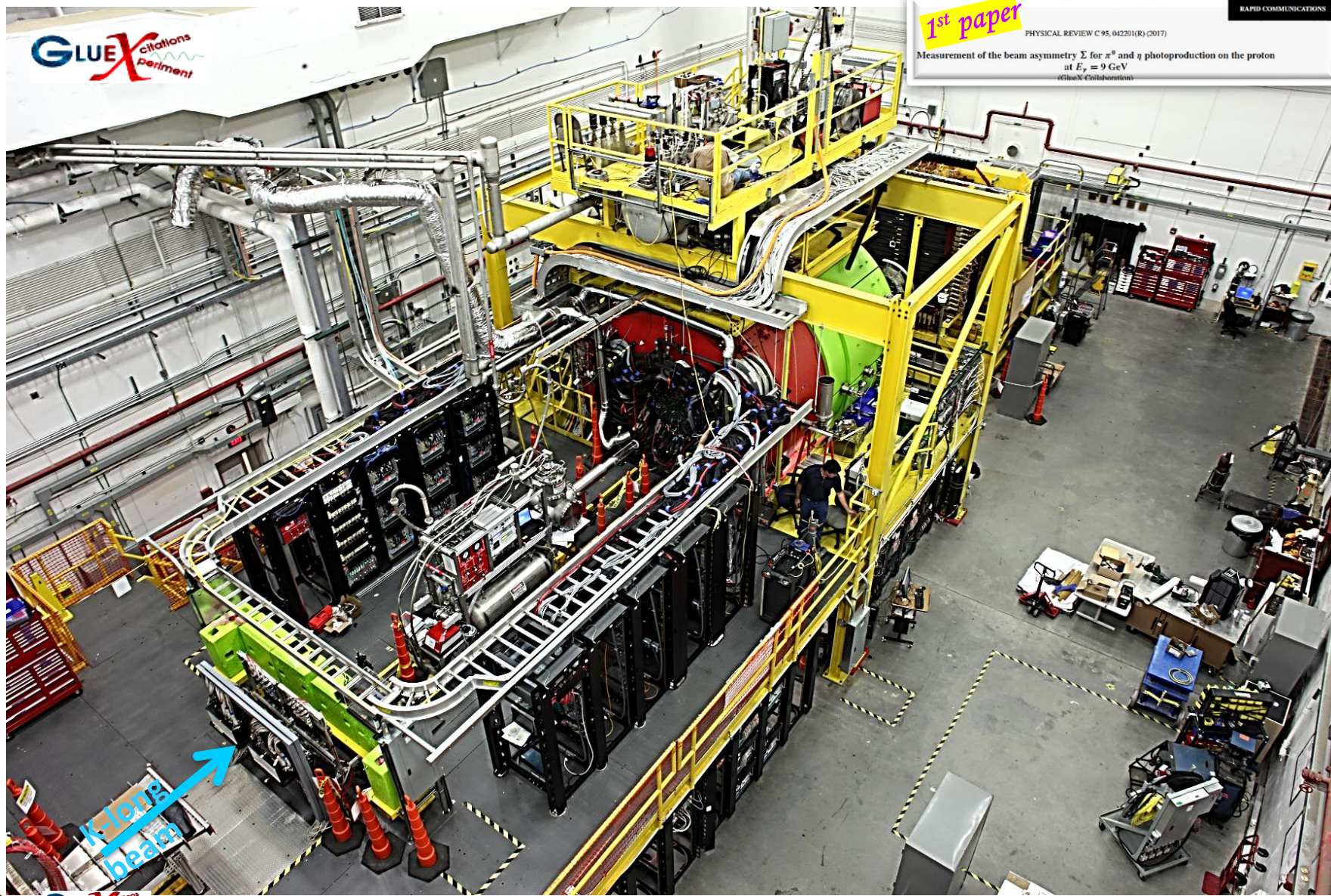
GLUEX citations
experiment

1st paper

RAPID COMMUNICATIONS

PHYSICAL REVIEW C 95, 042201(R) (2017)

Measurement of the beam asymmetry Σ for π^0 and η photoproduction on the proton
at $E_\gamma = 9$ GeV
(GlueX Collaboration)



X-ray beam



GLUEX citations
experiment
11/8/2017

FDSA2017, Mexico City, November 2017

Igor Strakovsky 27



K-long & Neutron Rate on GlueX LH_2/LD_2 -target



MC @ 12 GeV



Data @ 16 GeV

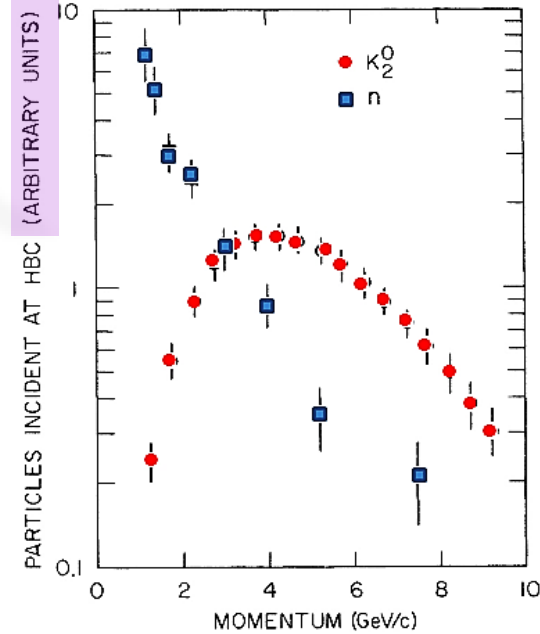
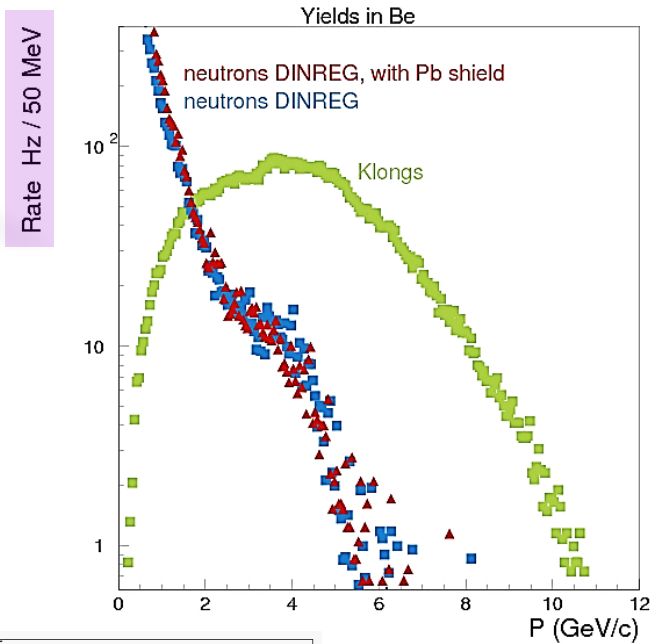
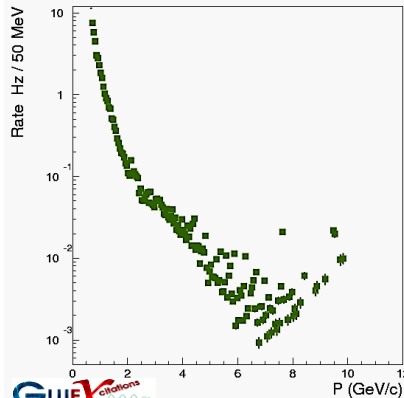


FIG. 2. Comparison of the neutron and K_2^0 fluxes at the hydrogen bubble chamber for 2° production with 16-GeV electrons. A.D. Brody *et al* Phys Rev Lett **22**, 966 (1969)



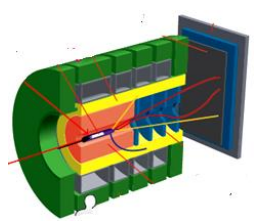
Flux ratio n/K_L

• Delivered with **64 ns** bunch spacing avoids overlap in range of $p = 0.35 - 10.0$ GeV/c.

• With proton beam, ratio $n/K_L = 10^3 - 10^4$.



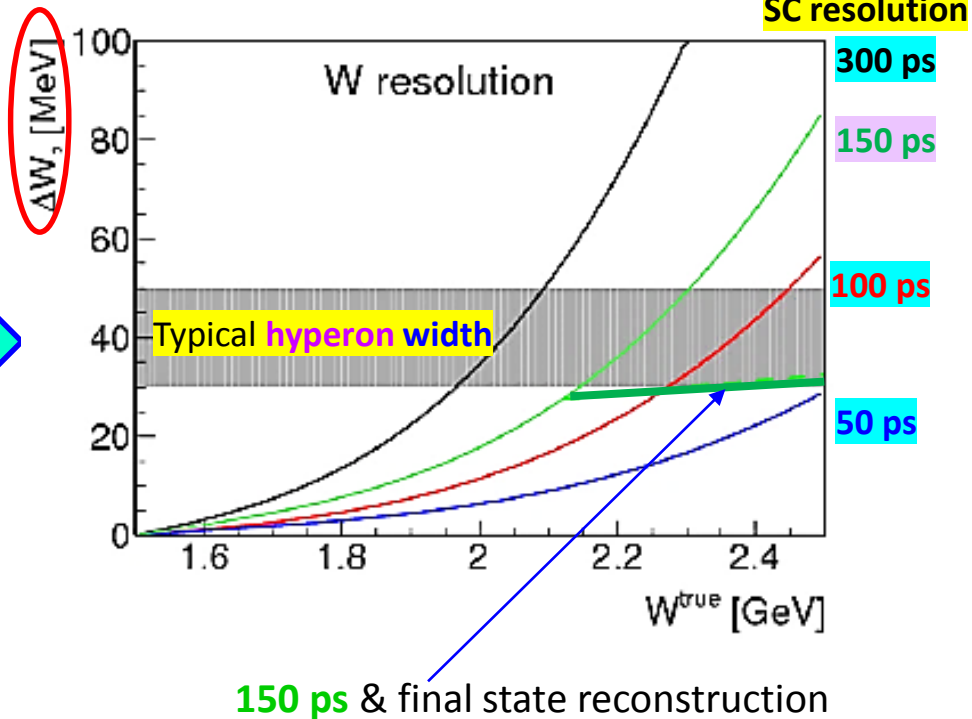
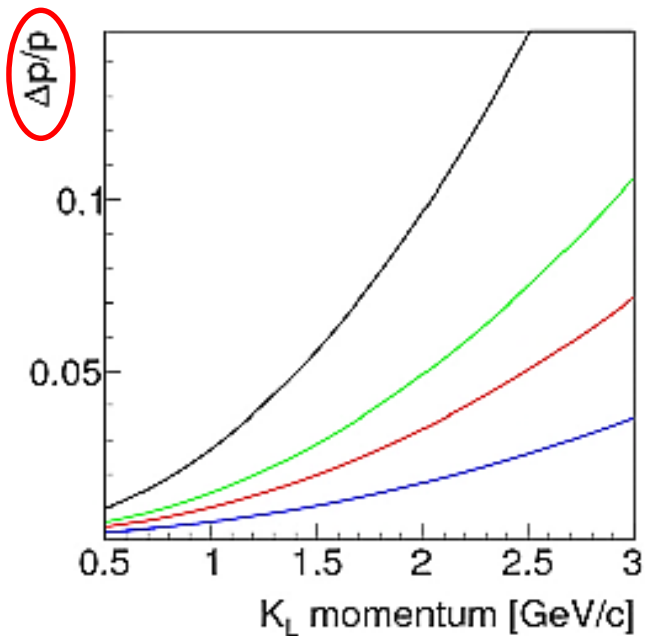
Expected Energy-Resolution

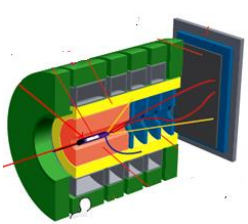


- Mean lifetime of K^- is **12.38 ns** ($c\tau = 3.7$ m) whereas mean lifetime of K_L is **51.16 ns** ($c\tau = 15.3$ m).

Thus, it is possible to perform measurements of $K_L p$ scattering at **lower energies** than $K^- p$ scattering due to high beam flux.

- Momentum measured with **TOF** between **SC** (surrounded LH_2/LD_2) & **RF** from **CEBAF**.





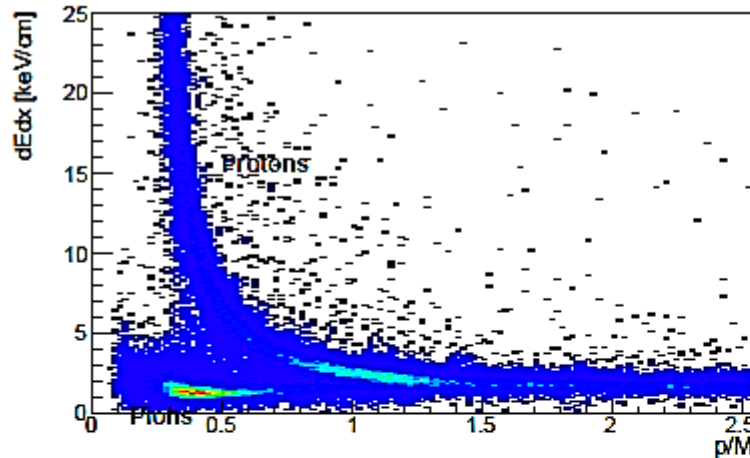
Expected Particle Identification



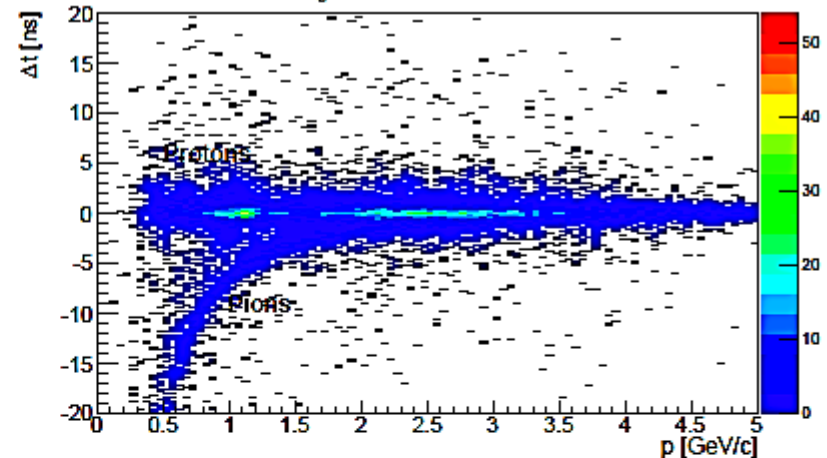
- dE/dx for pK_s .

- Time difference at primary "vertex" for proton hypothesis for pK_s using TOF.

dEdx vs p/M for proton candidates

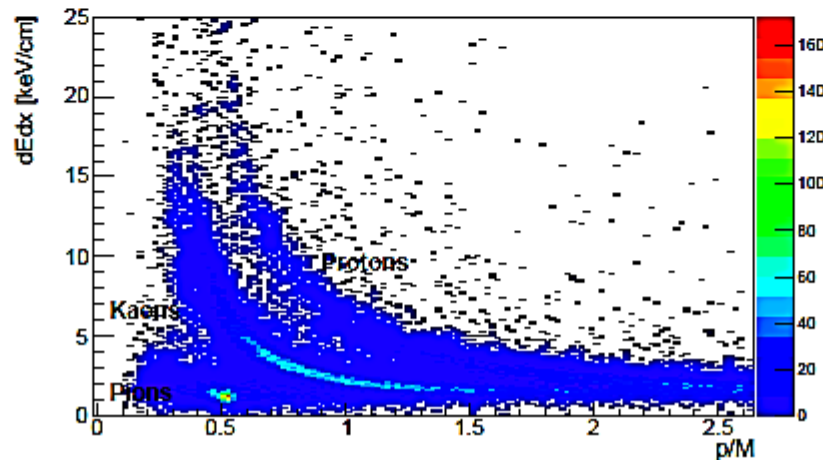


$t_{\text{tof}} - t_{\text{flight}} - t_{\text{vertex}}$ vs p for proton



dE/dx vs. p/M for K^+ candidates

- dE/dx for $K^+ \pi^0$.

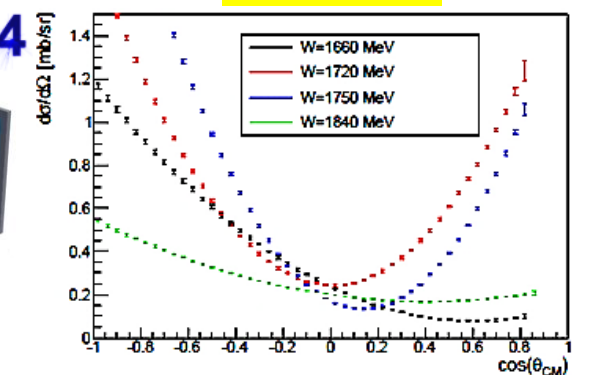
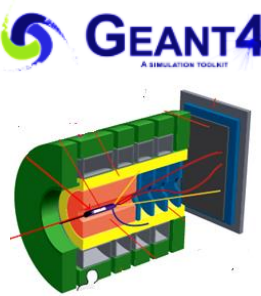


Expected Cross Sections vs Bubble Chamber Data

• **GlueX** measurements will span $\cos\theta$ from -0.95 to 0.95 in CM above $W = 1490$ MeV.

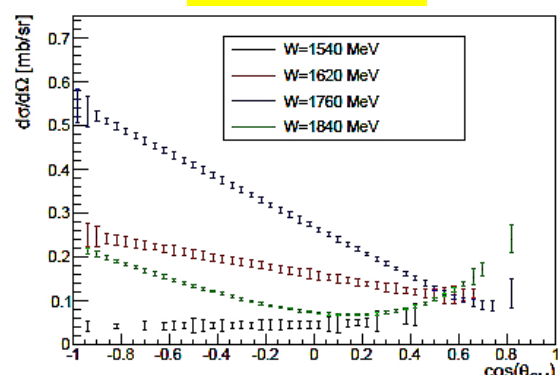
- K_L rate is $10^4 K_L/s = 2500 \times$ **SLAC** NATIONAL ACCELERATOR LABORATORY
- Uncertainties (statistics only) correspond to **100** days of running time for:

$K_L p \rightarrow K_S p$

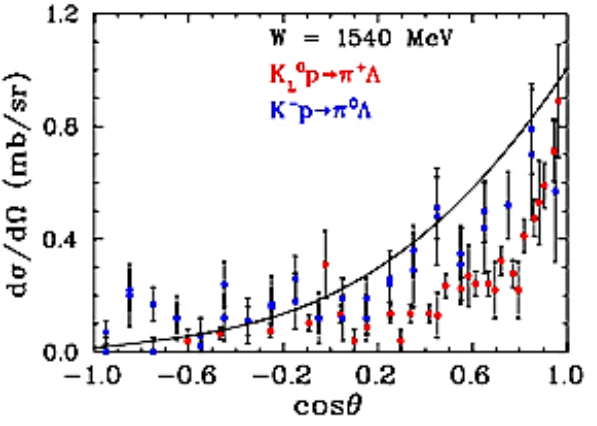
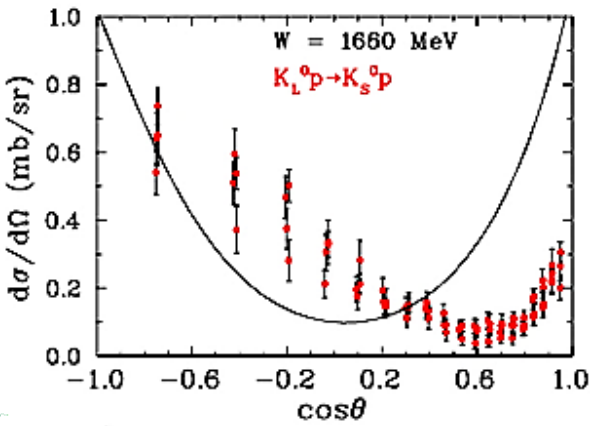


Expected
GlueX Data

$K_L p \rightarrow \pi^+ \Lambda$



BC Data



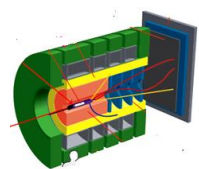
GLUEX collaboration
partner

11/8/2017

FDSA2017, Mexico City, November 2017

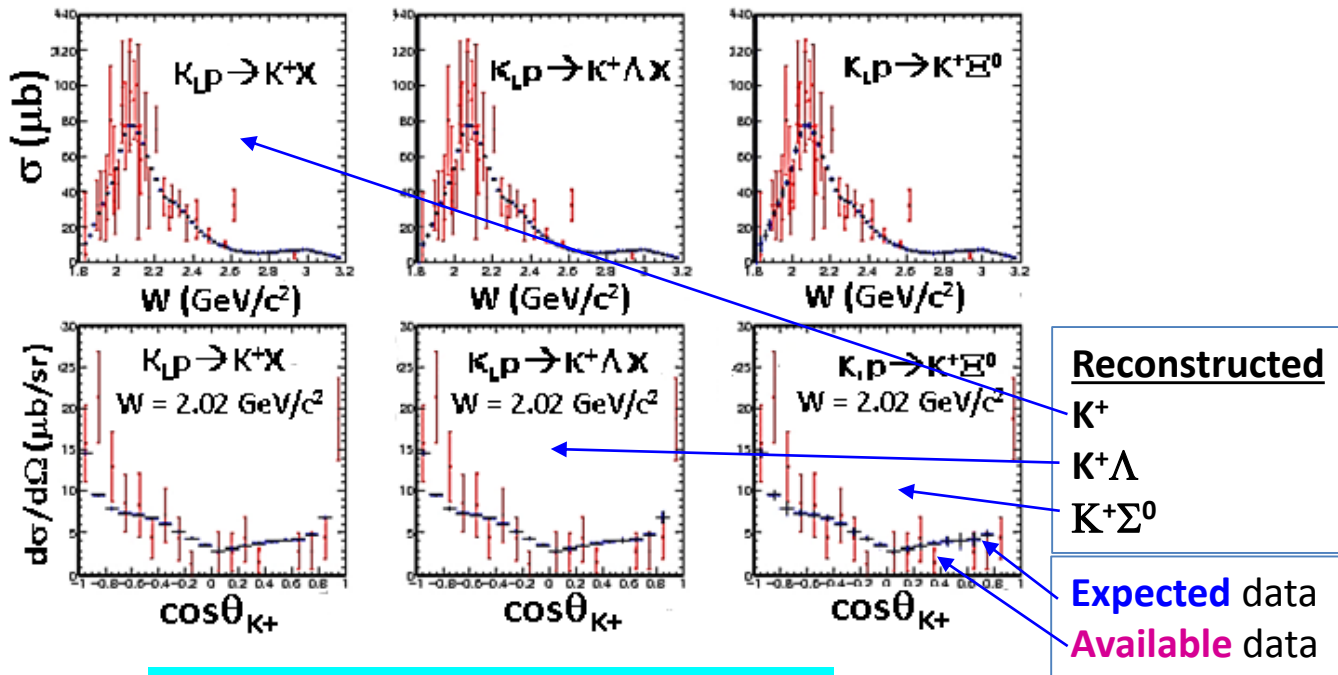
Igor Strakovsky 31



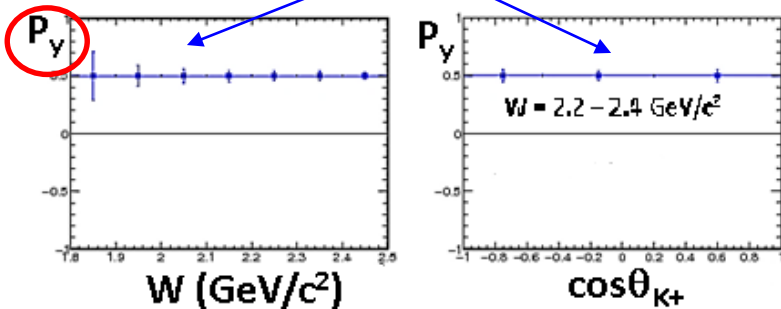


$K_L p \rightarrow K^+ \Sigma^0$ for *Double Strange Hyperons*

- Total & diff Xsec for different **topologies**



- Recoil Polarization for **one-fold differential** and **two-fold differential**



D.A. Sharov, V.L. Korotkikh, D.E. Lanskoj, Eur. Phys. J. A **47**, 109 (2011)





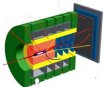


(measured, reconstructed)



PAC45 Report:

The beam time request is dominated by the hyperon polarimetry measurements. A simulated example of a partial wave analysis, and how it would feed into the proposed spectroscopy measurements, will be needed in a future proposal.

-  &  groups will evaluate impact of new **KLF** measurements to compare available data **w/o**  quasi-data generated using  & knowing  detector properties.



Pion-Kaon Interaction

- Detailed study of $K\pi$ system is very important to extract so-called $K\pi$ vector & scalar form factors to be compared with $\tau \rightarrow K\pi\nu_\tau$ decay & can be used to constrain V_{us} Cabibbo-Kobayashi-Maskawa (CKM) matrix element as well as to be used in testing CP violation from Dalitz plot analysis of open charm D meson decays & in charmless decays of B mesons into $K\pi\pi$ final states.



$K_0^*(800)$ MASS				$K_1^*(800)$ WIDTH				PDG particle data group		
VALUE (MeV)		EVTS	Err	VALUE (MeV)		EVTS	DOCUMENT ID	TECN	COMMENT	
682 ±29	OUR AVERAGE			547 ± 24	OUR AVERAGE				Error includes scale factor of 1.1.	
826 ±49	+49 -34	1338	1	449 ±156	+144 -81	1338	18 ABLIKIM	11B BES2	$J/\psi \rightarrow K_S^0 K_S^0 \pi^+ \pi^-$	
849 ±77	+18 -14	1421	2,3	512 ± 80	+ 92 - 44	1421	19,20 ABLIKIM	10E BES2	$J/\psi \rightarrow K^\pm K_S^0 \pi^\mp \pi^0$	
841 ±30	+81 -73	25k	4,5	618 ± 90	+ 96 -144	25k	19,21 ABLIKIM	06C BES2	$J/\psi \rightarrow \bar{K}^*(892)^0 K^+ \pi^-$	
658 ±13			6	557 ± 24			22 DESCOTES-G..06	RVUE	$\pi K \rightarrow \pi K$	
797 ±19	±43	15k	7,8	410 ± 43	± 87	15k	23,24 AITALA	02 E791	$D^+ \rightarrow K^- \pi^+ \pi^+$	

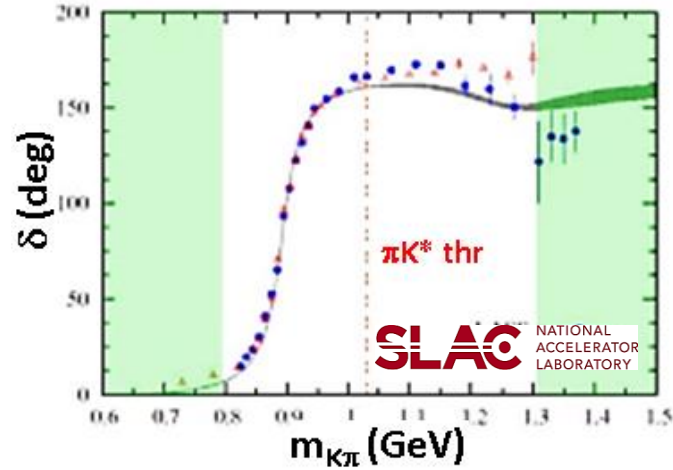
$K^*(892)$



- Results coming from **Roy–Steiner** & data at higher energy not in agreement with low energy experimental data **need** improvement !

S. Descotes-Genon & B. Moussallam, Eur Phys J C **48**, 553 (2006)

- $I = 1/2$ $K\pi$ scattering P-wave phase-shift

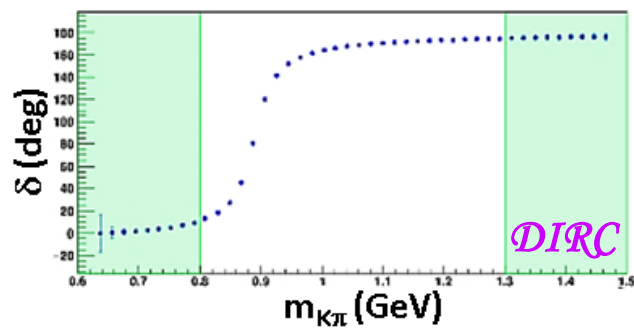


Fit to τ -decay from BELLE:

D.R. Boito, R. Escribano, M. Jamin, JHEP **1009**, 031 (2010)

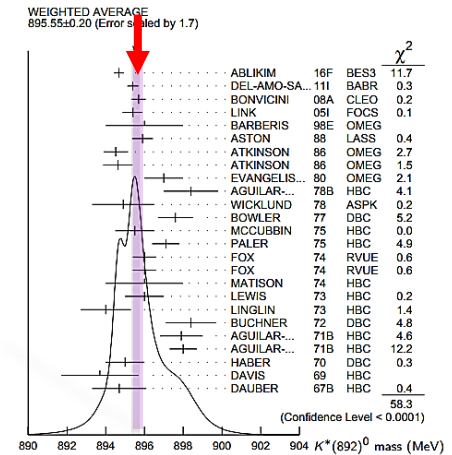
LASS @ SLAC: D. Aston *et al.* Nucl Phys B **296**, 493 (1988)

SLAC: P. Estabrooks *et al.* Nucl Phys B **133**, 490 (1978)



- **100** days of running period. **Statistical errors** are increased by factor of **10** for better visibility.

- It is coming from  now.



GLUEX relations
partner

11/8/2017

FDSA2017, Mexico City, November 2017

Igor Strakovsky 35





*Pion-Kaon Interaction [PKI2018]
 Workshop at JLab
 February 14th through 16th, 2018*

The π -K scattering enables direct investigations of scalar and vector K^* states, including the not yet established S-wave $\kappa(800)$ state. These studies are also needed to get precise values of vector and scalar form factors: to independently extract CKM matrix element V_{us} and to test the Standard Model unitarity relation in the first row of CKM matrix, to study CP violation from the Dalitz plot analysis of open charm D meson decays and in a charmless decays of B mesons in $K\pi\pi$ final states. Significant progress is made lately in Lattice QCD, in the phenomenology and in the Chiral Perturbation Theory to describe different aspects of π -K scattering. The main source of experimental data is based on experiments performed in SLAC almost five decades ago at 1970-80s. The recently proposed KL Facility incorporating the GlueX spectrometer at JLab will be able to improve the π -K scattering database by about three orders of magnitude in statistics. The workshop will discuss the necessity for and the impact of the future high statistics data obtained at JLab on π -K scattering.

Organizers:
 Moskov Amaryan
 Ulf-G. Meissner
 Curtis Meyer
 James Ritman
 Igor Strakovsky


<https://www.jlab.org/conferences/pki2018/>



11/8/2017



- Our goal is

- To **establish KL Facility** at  Jefferson Lab
Thomas Jefferson National Accelerator Facility
- To do **measurements** which bring new physics.

- Here we reviewed what can be learned by studying $K_L p$ & $K_L n$ scattering leading to **two-body** final states (**1st stage**).

At later stages, we plan to do $K_L N$ on aka **FROST** with hydrogen & deuterium.



- **JLab K-long Facility** would advance **Hyperon Spectroscopy** & study of **strangeness** in nuclear & hadronic physics.

It may extract very many missing strange states.

To complete $SU(3)_F$ multiplets, one needs no less than **17 Λ^* , 43 Σ^* , 42 Ξ^* , & 24 Ω^* .**

- **Discovering** of “**missing**” **hyperon states** would assist in advance our understanding of formation of **baryons** from **quarks** & **gluons** microseconds after **Big Bang**.

- **Full Proposal** is coming for **PAC46** in **2018**, **WELCOME** to **JOIN US**.

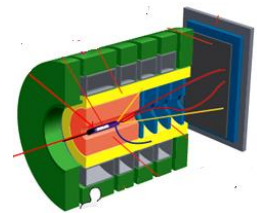


Wer's nicht glaubt, bezahlt einen Taler.



Backup Slides

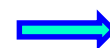




- Expected statistics for differential cross sections of different reactions with LH_2 & below $W = 3$ GeV for **100 days** of beam time.

For $d\sigma/d\Omega$

Reaction	Statistics (events)
$K_{LP} \rightarrow K_{Sp}$	8M
$K_{LP} \rightarrow \pi^+ \Lambda$	24M
$K_{LP} \rightarrow K^+ \Xi^0$	4M
$K_{LP} \rightarrow K^+ n$	200M
$K_{LP} \rightarrow K^- \pi^+ p$	2M



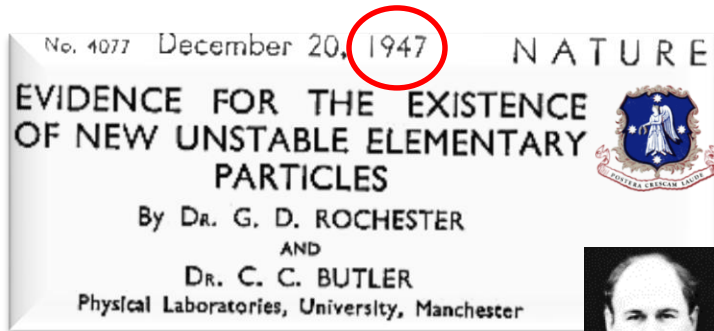
For **P**, statistics is **0.4M**

- There are no data on "neutron" targets &, for this reason, it is hard to make realistic estimate of statistics for K_n reactions.

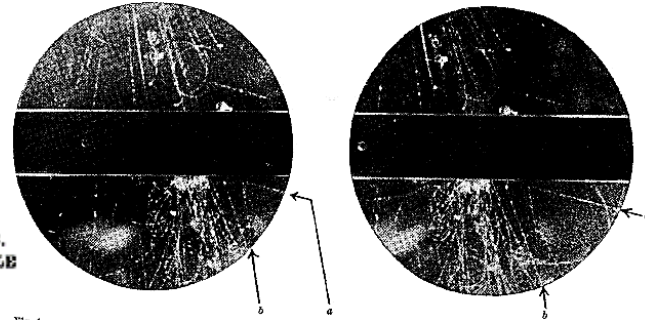
If we assume similar statistics as on proton target, full program will be completed after running **100 days with LH_2** & **100 days with LD_2** targets.

A bit of Strange History

- **First** hyperon, $\Lambda(1116)1/2^+$, was discovered during study of cosmic-ray interactions.
- It led to discovery of **strange quark**.



STEREOSCOPIC PHOTOGRAPHS SHOWING AN UNUSUAL FORK (a b) IN THE GAS. THE DIRECTION OF THE MAGNETIC FIELD IS SUCH THAT A POSITIVE PARTICLE COMING DOWNWARDS IS DEVIATED IN AN ANTICLOCKWISE DIRECTION



- **Pole** position in complex energy plane for **hyperons** has begun to be studied only recently, first of all for $\Lambda(1520)3/2^-$.

Phys Lett B 694, 123 (2010)

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Contents lists available at ScienceDirect

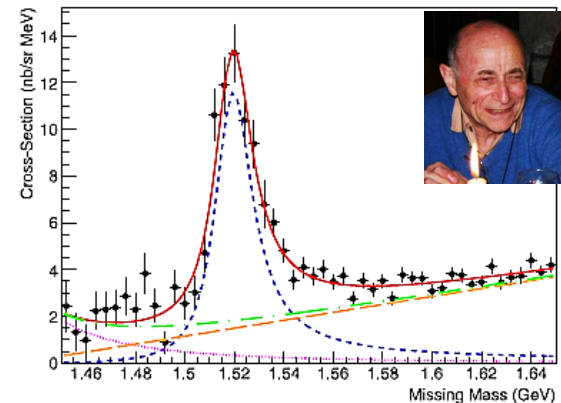
ELSEVIER

Physics Letters B

www.elsevier.com/locate/physletb

Properties of the $\Lambda(1520)$ resonance from high-precision electroproduction data

Y. Qiang^{a,b}, Ya.I. Azimov^c, I.I. Strakovsky^{d,*}, W.J. Briscoe^d, H. Gao^a, D.W. Higinbotham^b, V.V. Nelyubin^c



Quasi-Data: *What to Expect When you're Expecting*

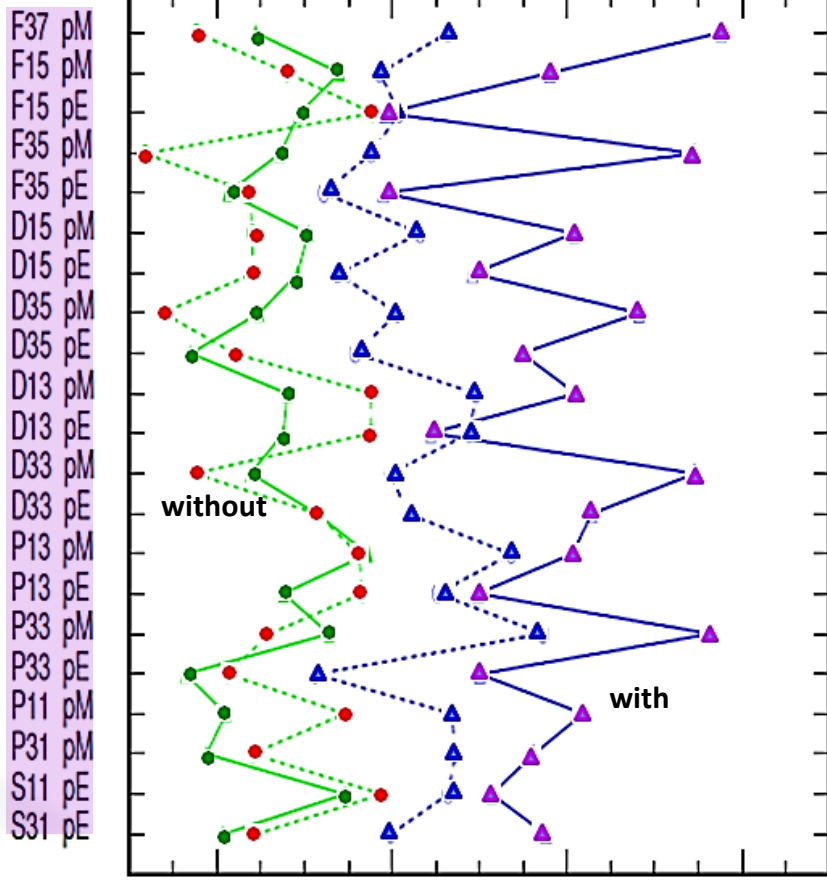


- Prove motivation of **JLab** Proposal **E-03-105**
Pion PhotoProduction from Polarized Target for **FROST** Project.



Transverse Polarization [H, P, T, F] **Longitudinal Polarization** [G, E]

$$R = u(A_{MC}) / u(A_{world})$$



Average ratio of uncertainties of amplitudes w/o expected **FROST** data.

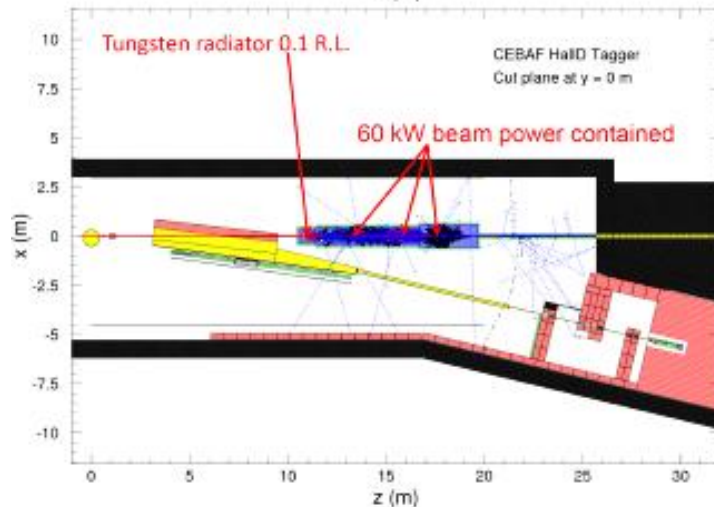
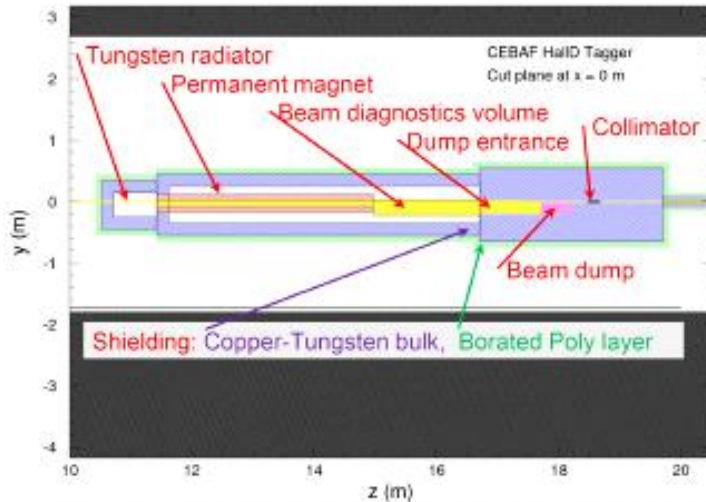
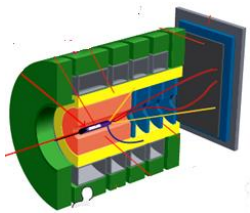
- The data generated by this work will fill # of **gaps** in existing database of single & double meson photoproduction.

- Greatest effect naturally requires measurement of all possible quantities as accomplished by **FROST**.

π^+n E: S. Strauch *et al*, Phys Lett B **750**, 53 (2015)
 ηp E: I. Senderovich *et al*, Phys Lett B **755**, 64 (2016)
 ωp E: Z. Akbar *et al*, arXiv:1708.02608 [nucl-ex]
 More results are coming...



Compact Photon Source



PAC45 Report:

The CPS design is progressing but details on the KL target and shielding for the detector need to be fleshed out.

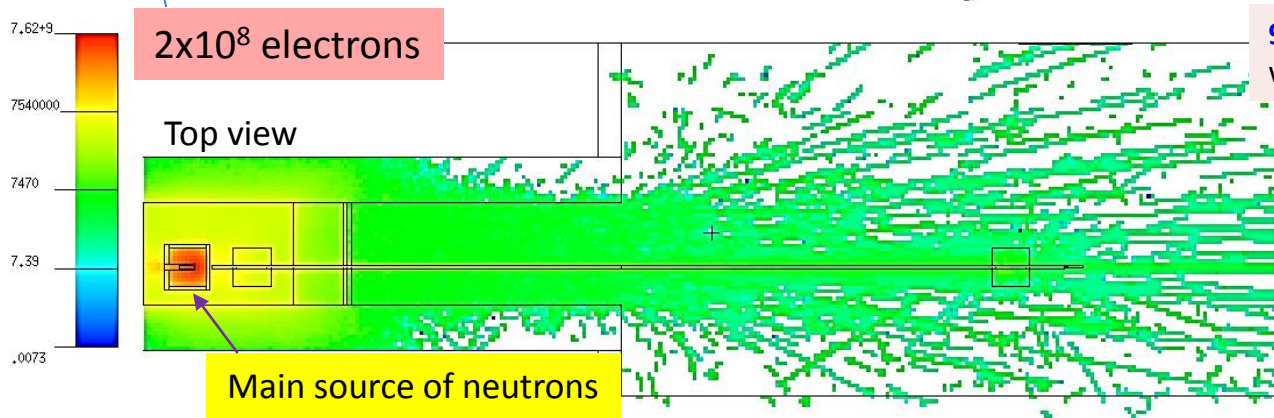
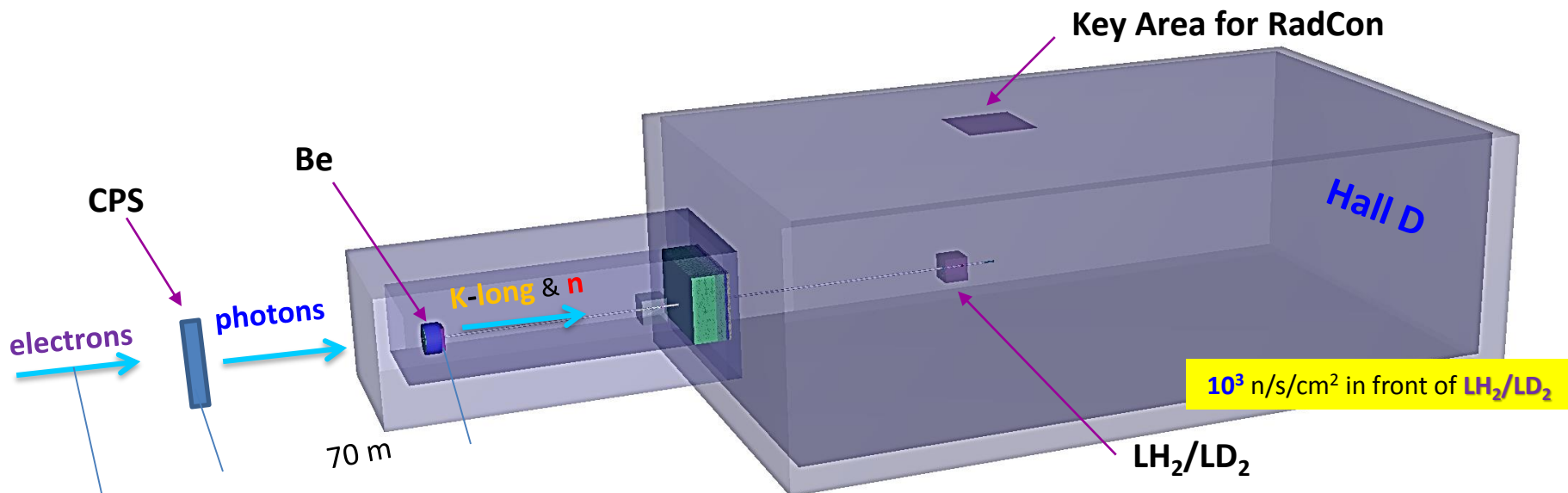


JLab CPS group is still working to make general design which will work for both Halls D & C.

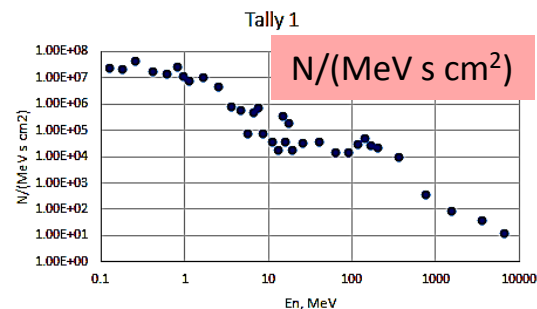


Expected Neutron Background

- Most important & unpleasant background for K_L comes from **neutrons**.

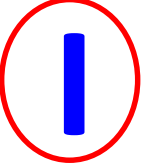


99% of neutrons associated with $T < 90$ MeV while 0.6% of them are for $T > 125$ MeV.



For **neutron** calculations, we use **MCNP6** transport code.





Speakers: Amaryan

Manley

Filippi

Myhrer

Degtyarenko

Nakayama

Ohnishi

Goity

Mai

Ziegler

Noumi

Chudakov

Albrow

Richards

Ramos

Zou

Schumacher

Oset

Montgomery

Kamano

Santopinto

Szczepaniak

Mathieu

Passemar

Taylor

Oh

Pennington

Keith

Kohl

Larin



60 people from 9 countries & 30 talks

PHYSICS WITH NEUTRAL KAON BEAM AT JLAB

KL2016

FEBRUARY 1-3, 2016
JEFFERSON LAB
NEWPORT NEWS, VIRGINIA

SCOPE

The Workshop is following LoI12-15-001 "Physics Opportunities with Secondary KL beam at JLab" and will be dedicated to the physics of hyperons produced by the kaon beam on unpolarized and polarized targets with GlueX set up in Hall D. The emphasis will be on the hyperon spectroscopy. Such studies could contribute to the existing scientific program on hadron spectroscopy at Jefferson Lab.

The Workshop will also aim at boosting the international collaboration, in particular between the US and EU research institutions and universities.

The Workshop would help to address the comments made by the PAC43, and to prepare the full proposal for the next PAC44.

ORGANIZING COMMITTEE

Moskov Amaryan, ODU, chair
Eugene Chudakov, JLab
Curtis Meyer, CMU
Michael Pennington, JLab
James Ritman, Ruhr-Uni-Bochum & IKP Jülich
Igor Strakovsky, GWU

WWW.JLAB.ORG/CONFERENCES/KL2016

THE GEORGE WASHINGTON UNIVERSITY | JÜLICH | OLD DOMINION UNIVERSITY | Jefferson Lab | FEA

Jefferson Lab
Thomas Jefferson National Accelerator Facility



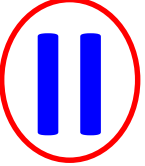
11/8/2017

<https://www.jlab.org/conferences/kl2016/>

FDSA2017, Mexico City, November 2017

Igor Strakovsky 45





Speakers: Mai

Chudakov

Garcilazo

Amaryan

Begun

Noronha-Hostler

Myhrer

Ohnishi

Ritman

Capstick

Noumi

Bellwied

Ratti

Tang

Doenigus Huovinen Tsuchikawa

YSTAR
Excited Hyperons in QCD
Thermodynamics at Freeze-Out **2016**

NOVEMBER 16 - 17, 2016
Jefferson Lab
Newport News, Virginia

ORGANIZING COMMITTEE
Moskov Amaryan - Chair, James Ritman, Ruhr U. Bochum & ICP Jülich
Eugene Chudakov, Igor Strakovsky, JLab, GWU
Krishna Rajagopal, MIT
Claudia Ratti, University of Houston

A workshop to discuss the influence of possible "missing" hyperon resonances (JLab KLF Project) on QCD thermodynamics, on freeze-out in heavy ion collisions and in the early universe, and in spectroscopy. Recent studies that compare lattice QCD calculations of thermodynamic calculations, statistical hadron resonance gas models, and ratios between measured yields of different hadron species in heavy ion collisions provide indirect evidence for the presence of "missing" resonances in all of these contexts. The aim of the workshop is to sharpen these comparisons, advance our understanding of the formation of baryons from quarks and gluons microseconds after the Big Bang and in today's experiments, and to connect these developments to experimental searches for direct, spectroscopic, evidence for these resonances. This Workshop is a successor to the recent KL2016 Workshop

WWW.JLAB.ORG/CONFERENCES/YSTAR2016/

THE GEORGE WASHINGTON UNIVERSITY, JÜLICH, OLD DOMINION UNIVERSITY, Jefferson Lab, RISA

Arriola

Xie

Edwards

Goity

Montgomery

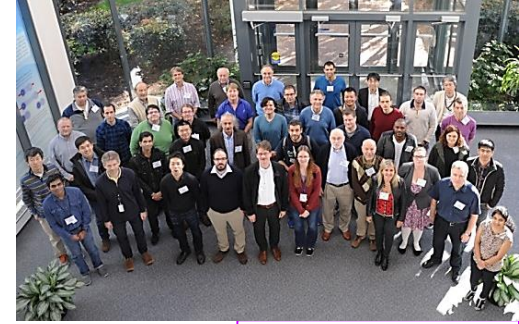
Manley

Crede

Alba

Guo

Stroth



71 people from 11 countries & 27 talks

Jefferson Lab Thomas Jefferson National Accelerator Facility



GLUEX collaborations

11/8/2017

<https://www.jlab.org/conferences/YSTAR2016/>

FDSA2017, Mexico City, November 2017

Igor Strakovsky 46





Goity

Perera

Speakers: Mai

Dominguez

Tadevosyan

Beminiwhatta

Wojtsekhowski

Degtyarenko

Niculescu

Liuti

HIPS 2017
New Opportunities with High-Intensity Photon Sources

February 6-7, 2017
Catholic University of America
Washington, DC U.S.A.

This workshop aims at producing an optimized photon source concept with potential increase of scientific output at Jefferson Lab, and at refining the science for hadron physics experiments benefitting from such a high-intensity photon source. The workshop is dedicated to bringing together the communities directly using such sources for photo-production experiments, or for conversion into K_L beams. The combination of high precision calorimetry and high intensity photon sources can provide greatly enhanced scientific benefit to (deep) exclusive processes like wide-angle and time-like Compton scattering. Potential prospects of such a high-intensity source with modern polarized targets will also be discussed. The availability of K_L beams would open new avenues for hadron spectroscopy, for example for the investigations of "missing" hyperon resonances, with potential impact on QCD thermodynamics and on freeze-out both in heavy ion collisions and the early universe.

Organizing Committee:
Tanja Horn - CIA
Cynthia Keppel - EAB
Carlos Munoz-Camacho - IPNO
Igor Strakovsky - CBK

JEK CIA
Jefferson Lab

Sirca

43 people from 4 countries & 19 talks

Keppel

Strakovsky

Hamilton

Keller

Kroll

Organizers:
Tanja Horn
Cynthia Keppel
Carlos Munoz-Camacho
Igor Strakovsky

Sargsian

Patsyuk

Zhang



11/8/2017

FDSA2017, Mexico City

<https://www.jlab.org/conferences/HIPS2017/>

Igor Strakovsky 47

