Physics Perspectives for Future K-Long Facility

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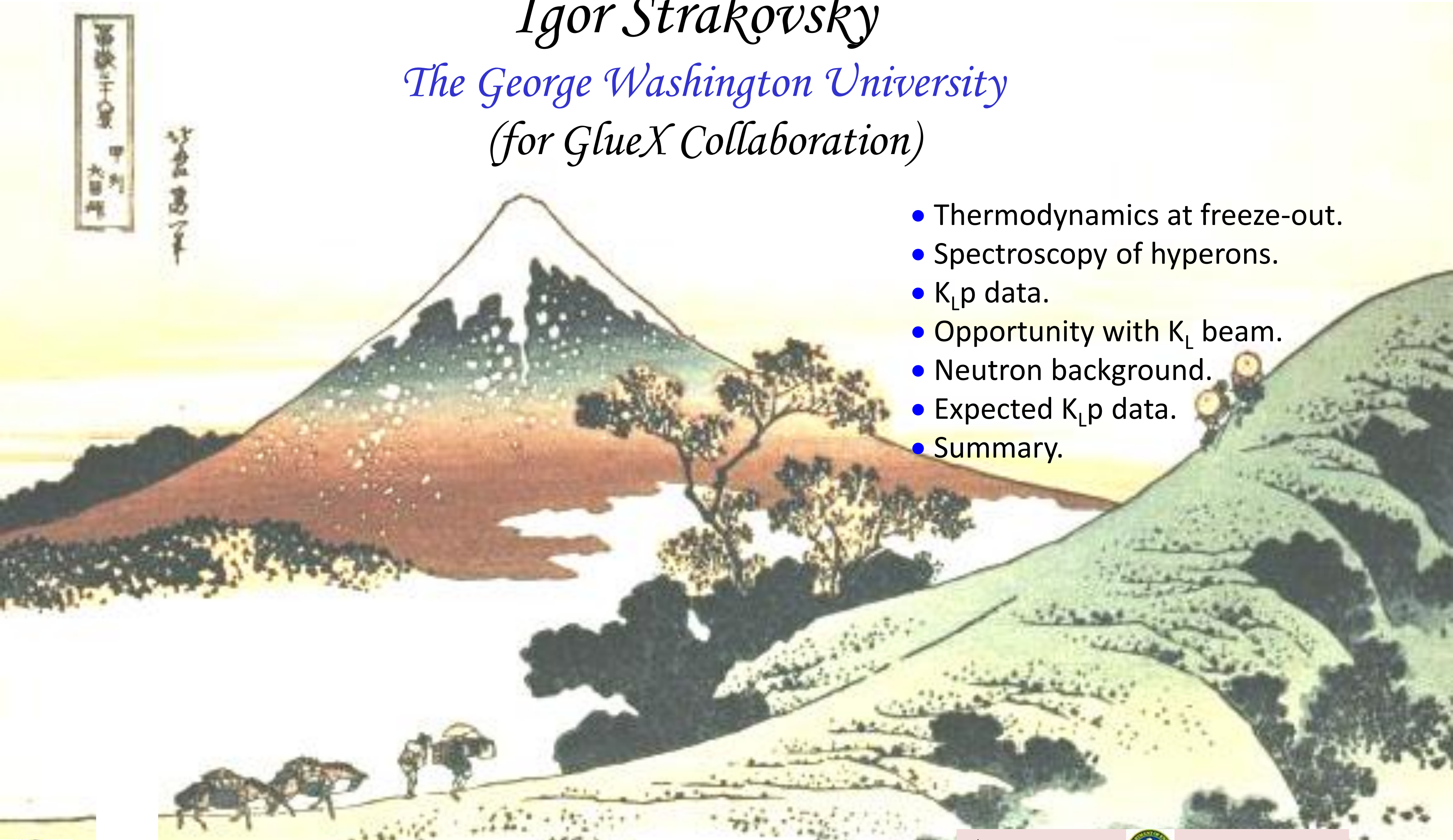
The George Washington University

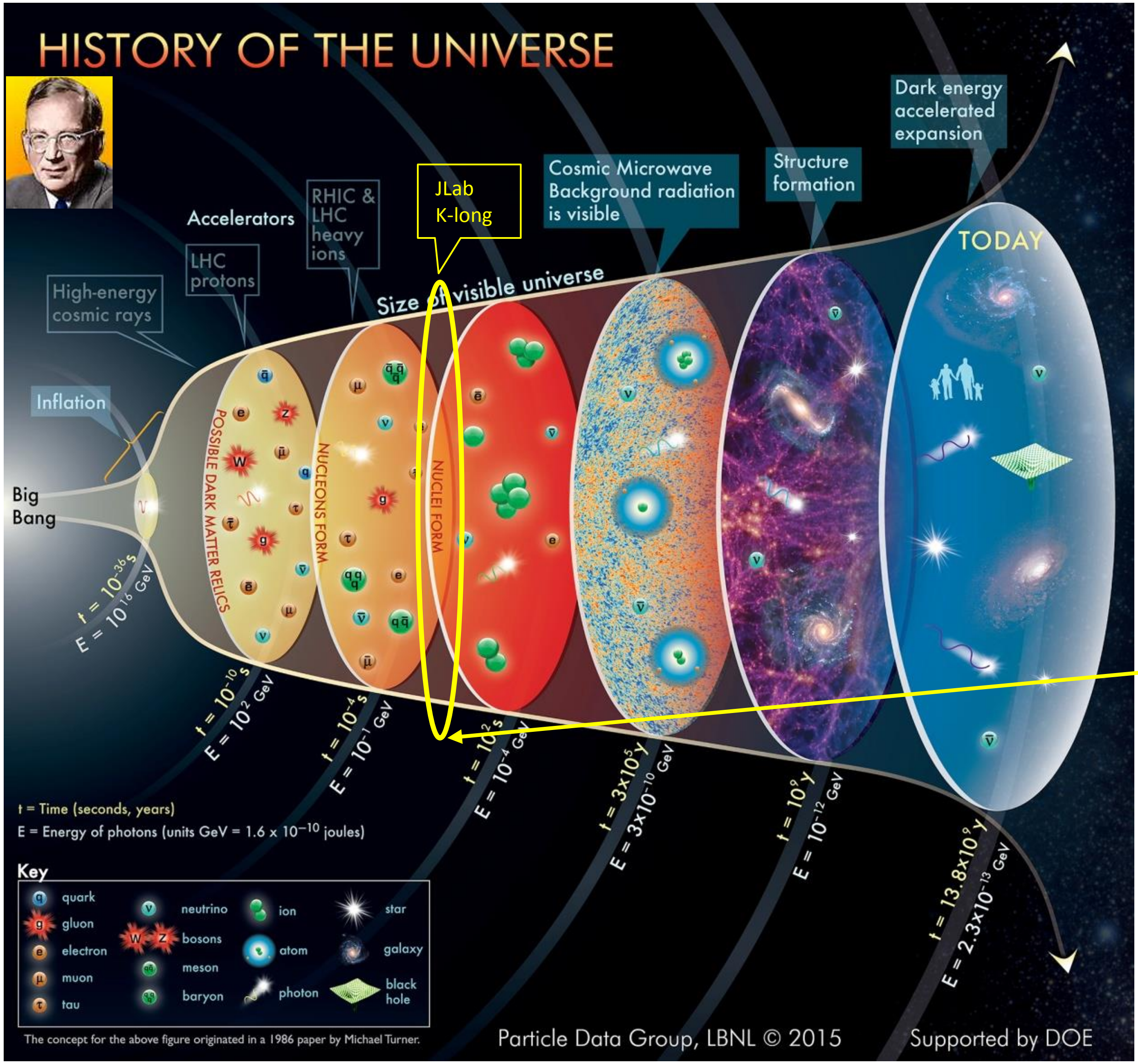
(for GlueX Collaboration)



- Thermodynamics at freeze-out.
- Spectroscopy of hyperons.
- $K_L p$ data.
- Opportunity with K_L beam.
- Neutron background.
- Expected $K_L p$ data.
- Summary.

[*] Supported by DE-SC0016583

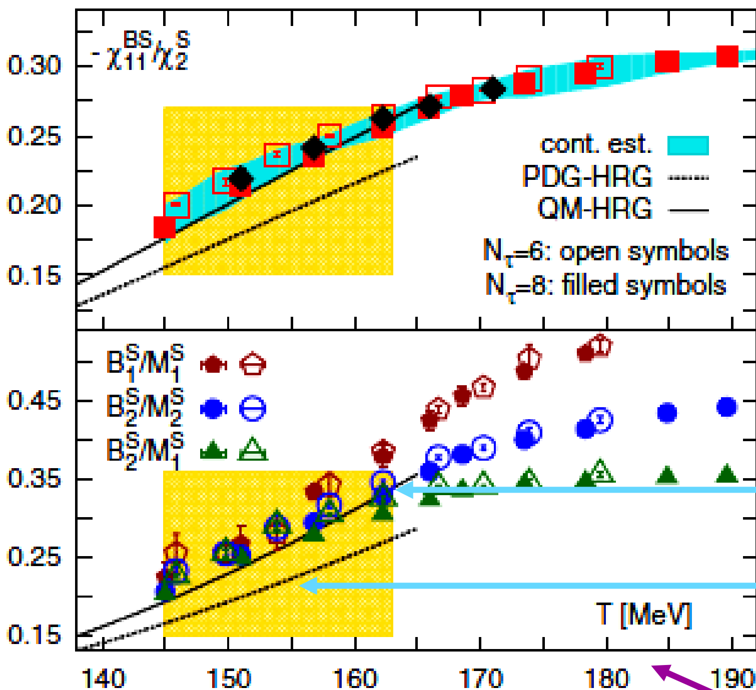
History of the Universe



- There is Influence of possible "**missing**" hyperons on QCD thermodynamics, on **freeze-out** in heavy ion & hadon collisions & in **early Universe**, & in spectroscopy.
- Advance our understanding of **formation** of **baryons** from **quarks** & **gluons** **microseconds** after **Big Bang** & in today's experiments, & connection these developments to experimental searches for direct, spectroscopic, evidence for these "**missing**" 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 the presence of "missing" resonances in all of these contexts.



A. Bazavov *et al* Phys Rev Lett **113**, 072001 (2014)

- Partial **pressure** of strange **mesons**

$$M_1^S = \chi_2^S - \chi_{22}^{BS},$$

$$M_2^S = \frac{1}{12}(\chi_4^S + 11\chi_2^S) + \frac{1}{2}(\chi_{11}^{BS} + \chi_{13}^{BS}),$$

- Partial **pressure** of strange **baryons**

$$B_1^S = -\frac{1}{6}(11\chi_{11}^{BS} + 6\chi_{22}^{BS} + \chi_{13}^{BS}),$$

$$B_2^S = \frac{1}{12}(\chi_4^S - \chi_2^S) - \frac{1}{3}(4\chi_{11}^{BS} - \chi_{13}^{BS}).$$

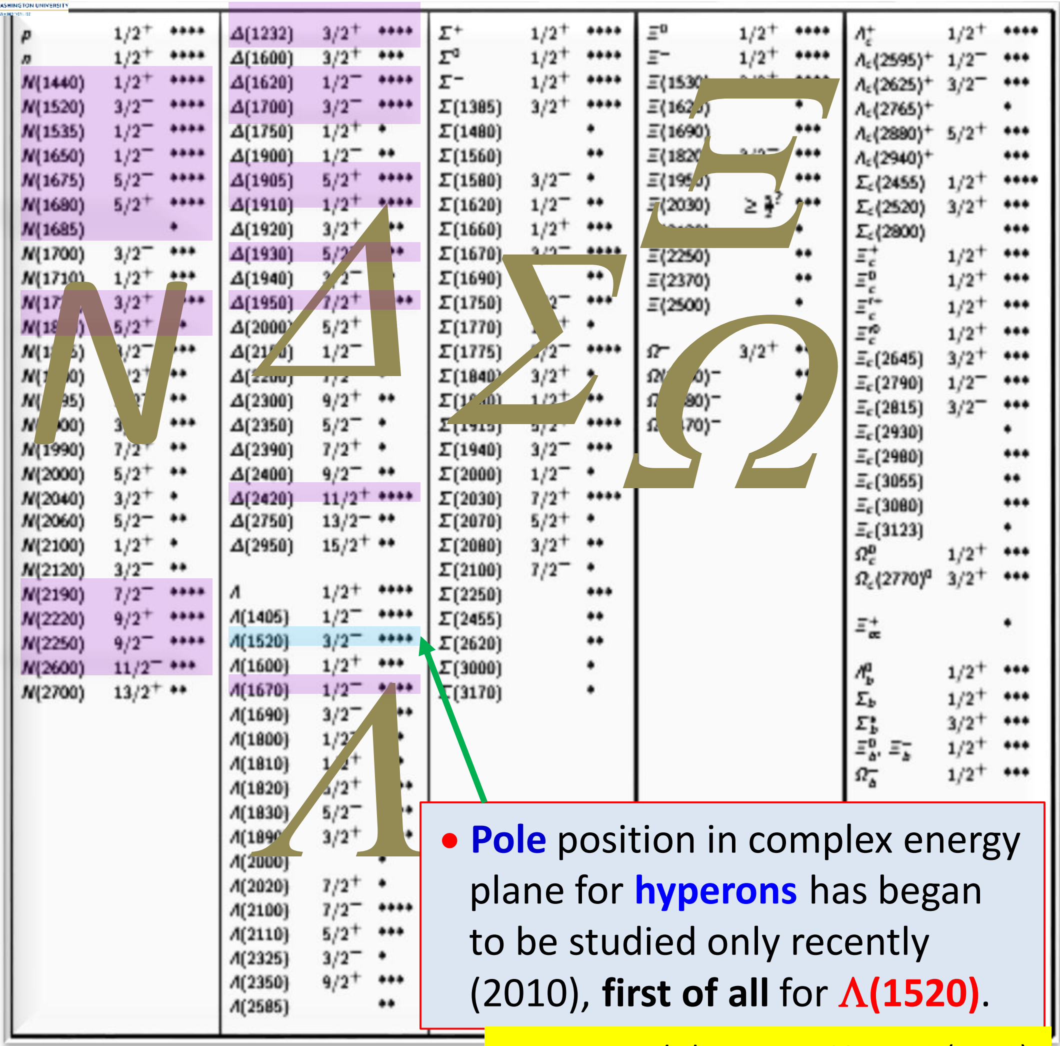
- + "**Missing**" **Resonances** (**QM** calculations).
- Contribution from **observed Resonances.** PDG

- Three independent **ratios** start to coincide in crossover region giving identical results only below **chiral crossover temperature** at physical values of quark masses **T_c = 154 ± 9** MeV.

Baryon Sector at PDG16

GW Contribution

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



p	$1/2^+$	****
n	$1/2^+$	****
N(1440)	$1/2^+$	****
N(1520)	$3/2^-$	****
N(1535)	$1/2^-$	****
N(1650)	$1/2^-$	****
N(1675)	$5/2^-$	****
N(1680)	$5/2^+$	****
N(1685)		*
N(1700)	$3/2^-$	***
N(1710)	$1/2^+$	***
N(17[illegible])	$3/2^+$	[illegible]
N(18[illegible])	$5/2^+$	[illegible]
N(1[illegible]5)	[illegible]$/2^-$	***
N(1[illegible]0)	[illegible]$/2^+$	**
N([illegible]95)	[illegible]	**
N([illegible]00)	3[illegible]	***
N(1990)	$7/2^+$	**
N(2000)	$5/2^+$	**
N(2040)	$3/2^+$	*
N(2060)	$5/2^-$	**
N(2100)	$1/2^+$	*
N(2120)	$3/2^-$	**
N(2190)	$7/2^-$	****
N(2220)	$9/2^+$	****
N(2250)	$9/2^-$	****
N(2600)	$11/2^-$	***
N(2700)	$13/2^+$	**

Δ(1232)	$3/2^+$	****
Δ(1600)	$3/2^+$	***
Δ(1620)	$1/2^-$	****
Δ(1700)	$3/2^-$	****
Δ(1750)	$1/2^+$	*
Δ(1900)	$1/2^-$	**
Δ(1905)	$5/2^+$	****
Δ(1910)	$1/2^+$	****
Δ(1920)	$3/2^+$	[illegible]
Δ(1930)	$5/2$[illegible]	[illegible]
Δ(1940)	[illegible]$/2^-$	[illegible]
Δ(1950)	$7/2^+$	[illegible]
Δ(2000)	$5/2^+$	[illegible]
Δ(21[illegible])	$1/2^-$	[illegible]
Δ(2[illegible])	[illegible]	[illegible]
Δ(2300)	$9/2^+$	**
Δ(2350)	$5/2^-$	*
Δ(2390)	$7/2^+$	*
Δ(2400)	$9/2^-$	**
Δ(2420)	$11/2^+$	****
Δ(2750)	$13/2^-$	**
Δ(2950)	$15/2^+$	**
Λ	$1/2^+$	****
Λ(1405)	$1/2^-$	****
Λ(1520)	$3/2^-$	****
Λ(1600)	$1/2^+$	***
Λ(1670)	$1/2^-$	[illegible]
Λ(1690)	$3/2^-$	[illegible]
Λ(1800)	$1/2$[illegible]	[illegible]
Λ(1810)	1[illegible]2^+	[illegible]
Λ(1820)	[illegible]$/2^+$	[illegible]
Λ(1830)	$5/2^-$	[illegible]
Λ(189[illegible])	$3/2^+$	[illegible]
Λ(2000)		*
Λ(2020)	$7/2^+$	*
Λ(2100)	$7/2^-$	****
Λ(2110)	$5/2^+$	***
Λ(2325)	$3/2^-$	*
Λ(2350)	$9/2^+$	***
Λ(2585)		**

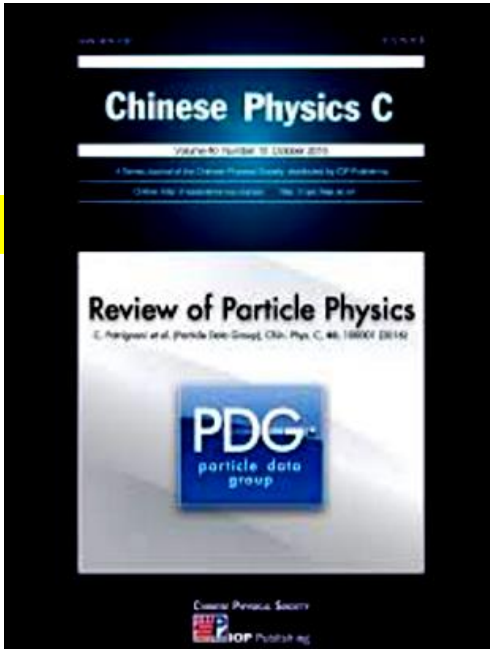
Σ^+	$1/2^+$	****
Σ^0	$1/2^+$	****
Σ^-	$1/2^+$	****
Σ(1385)	$3/2^+$	****
Σ(1480)		*
Σ(1560)		**
Σ(1580)	$3/2^-$	*
Σ(1620)	$1/2^-$	**
Σ(1660)	$1/2^+$	***
Σ(1670)	[illegible]	****
Σ(1690)	[illegible]	**
Σ(1750)	[illegible]2^-	***
Σ(1770)	[illegible]$^+$	*
Σ(1775)	[illegible]$/2^-$	****
Σ(1840)	$3/2^+$	*
Σ(1[illegible])	$1/2^+$	**
Σ([illegible])	[illegible]	****
Σ(1940)	$3/2^-$	***
Σ(2000)	$1/2^-$	*
Σ(2030)	$7/2^+$	****
Σ(2070)	$5/2^+$	*
Σ(2080)	$3/2^+$	**
Σ(2100)	$7/2^-$	*
Σ(2250)		***
Σ(2455)		**
Σ(2620)		**
Σ(3000)		*
Σ(3170)		*

Ξ^0	$1/2^+$	****
Ξ^-	$1/2^+$	****
Ξ(153[illegible])	[illegible]	[illegible]
Ξ(162[illegible])		*
Ξ(1690)		***
Ξ(182[illegible])	[illegible]	***
Ξ(195[illegible])		***
Ξ(2030)	≥ [illegible]	***
[illegible]		*
Ξ(2250)		**
Ξ(2370)		**
Ξ(2500)		*
Ω^-	$3/2^+$	[illegible]
Ω([illegible])$^-$		[illegible]
Ω([illegible]80)$^-$		[illegible]
Ω([illegible]70)$^-$		

Λ_c^+	$1/2^+$	****
$\Lambda_c(2595)^+$	$1/2^-$	***
$\Lambda_c(2625)^+$	$3/2^-$	***
$\Lambda_c(2765)^+$		*
$\Lambda_c(2880)^+$	$5/2^+$	***
$\Lambda_c(2940)^+$		***
$\Sigma_c(2455)$	$1/2^+$	****
$\Sigma_c(2520)$	$3/2^+$	***
$\Sigma_c(2800)$		***
Ξ_c^+	$1/2^+$	***
Ξ_c^0	$1/2^+$	***
$\Xi_c^{\prime +}$	$1/2^+$	***
$\Xi_c^{\prime 0}$	$1/2^+$	***
$\Xi_c(2645)$	$3/2^+$	***
$\Xi_c(2790)$	$1/2^-$	***
$\Xi_c(2815)$	$3/2^-$	***
$\Xi_c(2930)$		*
$\Xi_c(2980)$		***
$\Xi_c(3055)$		**
$\Xi_c(3080)$		***
$\Xi_c(3123)$		*
Ω_c^0	$1/2^+$	***
$\Omega_c(2770)^0$	$3/2^+$	***
Ξ_{cc}^+		*
Λ_b^0	$1/2^+$	***
Σ_b	$1/2^+$	***
Σ_b^*	$3/2^+$	***
Ξ_b^0, Ξ_b^-	$1/2^+$	***
Ω_b^-	$1/2^+$	***

- **Pole** position in complex energy plane for **hyperons** has began to be studied only recently (2010), **first of all** for **Λ(1520)**.

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



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

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 PDG 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***.

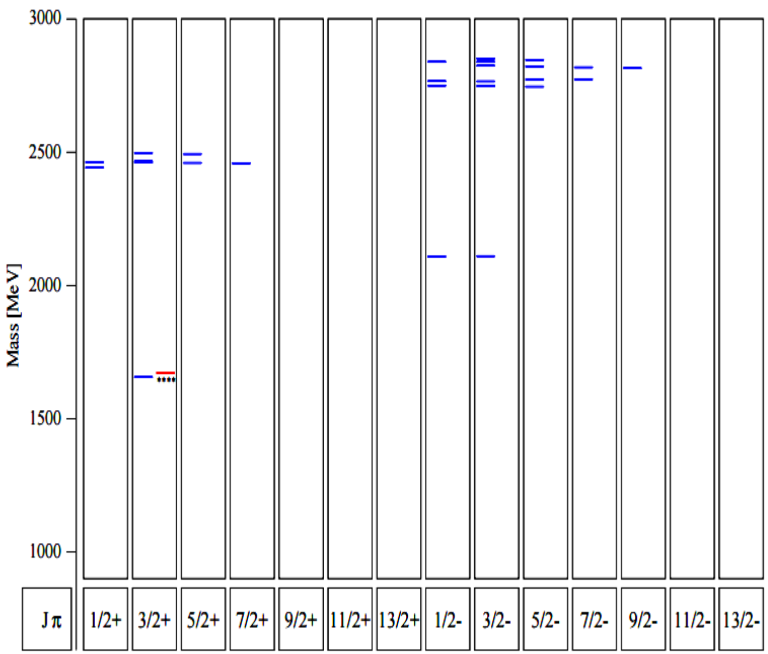
B.M.K. Nefkens, πN Newsletter, **14**, 150 (1997)

Very Strange Resonances & Problem of "Missing" States

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

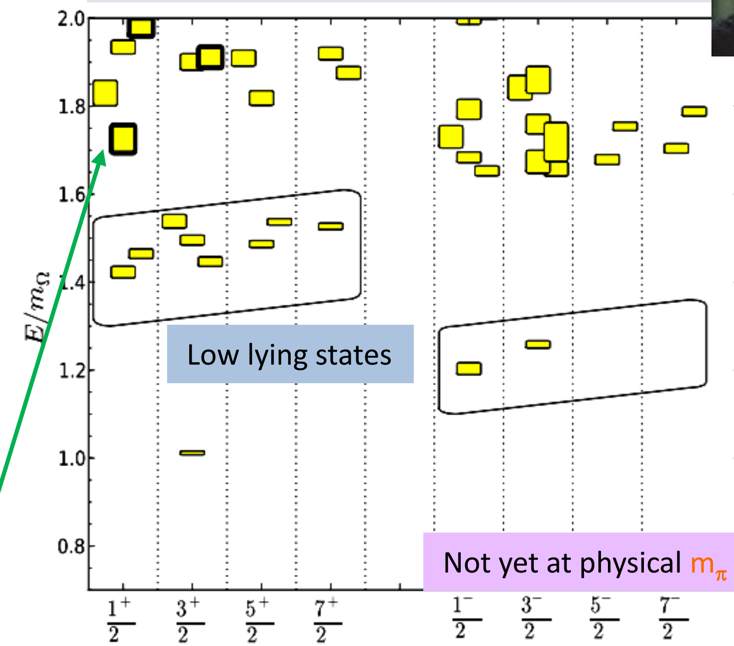

R. Koniuk and N. Isgur, Phys Rev Lett **44**, 845 (1980)

- Ω baryon spectrum in **QM**.



U. Lőring *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)

Thick frame: **Hybrid states**

How to Search for Missing Hyperons

- New data for inelastic $K_L^0 p$ scattering would significantly improve our knowledge of Σ^* Resonances
- Very few polarization data are available for any $K_L^0 p$ reactions but are needed to help remove ambiguities in PWAs
- To search for missing hyperon resonances, we need measurements of production reactions:

$$\Sigma^*: \quad K_L^0 p \to \pi\Sigma^* \to \pi\pi\Lambda$$
$$\Lambda^*: \quad K_L^0 p \to \pi\Lambda^* \to \pi\pi\Sigma$$
$$\Xi^*: \quad K_L^0 p \to K\Xi^*, \pi K\Xi^*$$
$$\Omega^*: \quad K_L^0 p \to K^+K^+\Omega^*$$

- If such measurements can be performed with good energy & angle coverage & good statistics, then it is very likely that measurements with K_L^0 beams would find several missing hyperon resonances.

Courtesy of Mark Manley, YSTAR2016

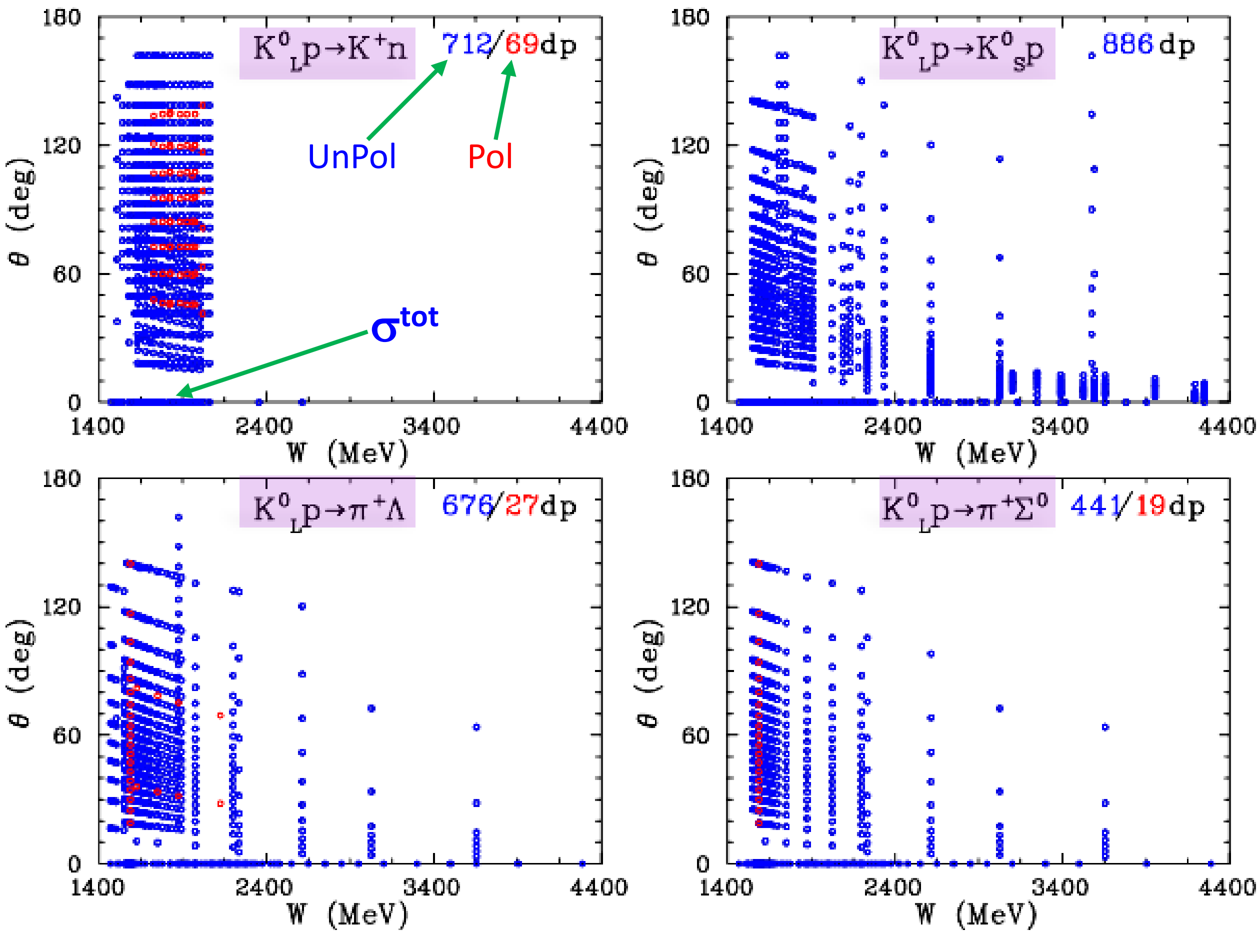
World K–long Data – Ground for Hyperon Phenomenology

— Data Analysis Center —
Institute for Nuclear Studies
THE GEORGE WASHINGTON UNIVERSITY
WASHINGTON, DC

W = 1.45 – 5.05 GeV

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

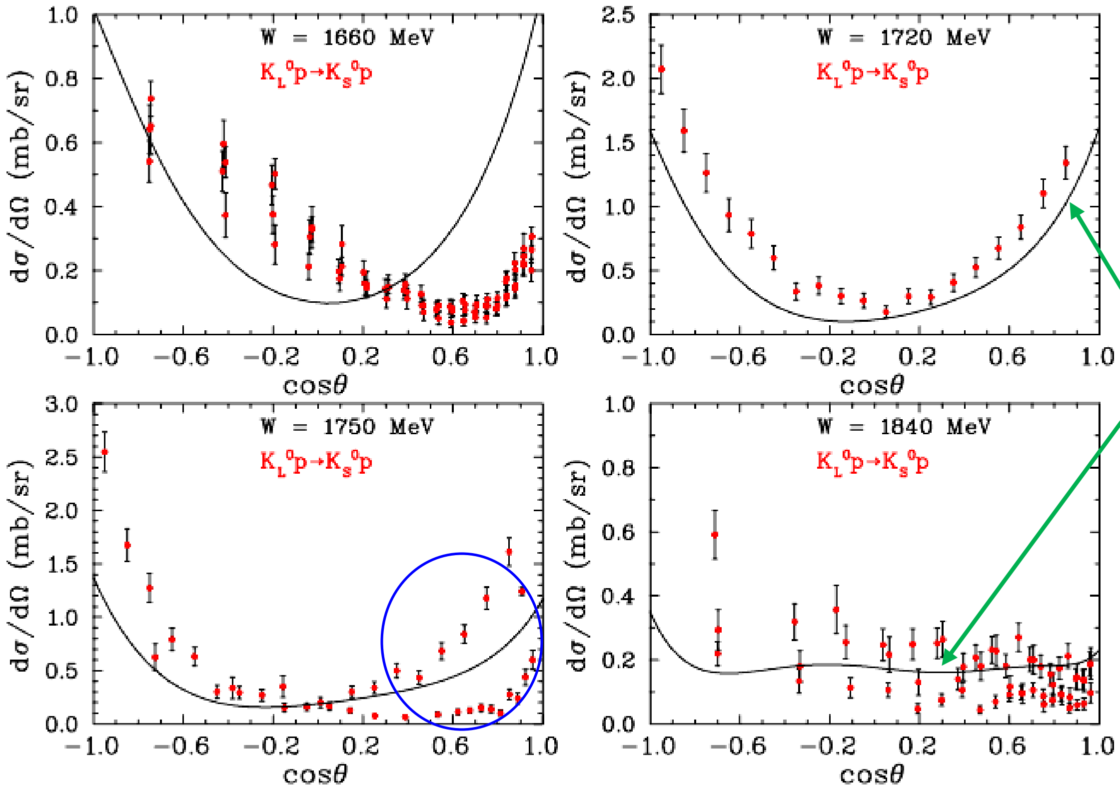
- Limited number of K_L induced measurements (**1961 – 1982**) **2426 dσ/dΩ, 348 σ^{tot}, & 115 P** observables do not allow today to **feel comfortable** with **Hyperon Spectroscopy** results.



- Most of **data** were obtained from **old** low statistics **measurements** with hydrogen **Bubble Chambers**.
- **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 $K_L p \rightarrow K_S p$

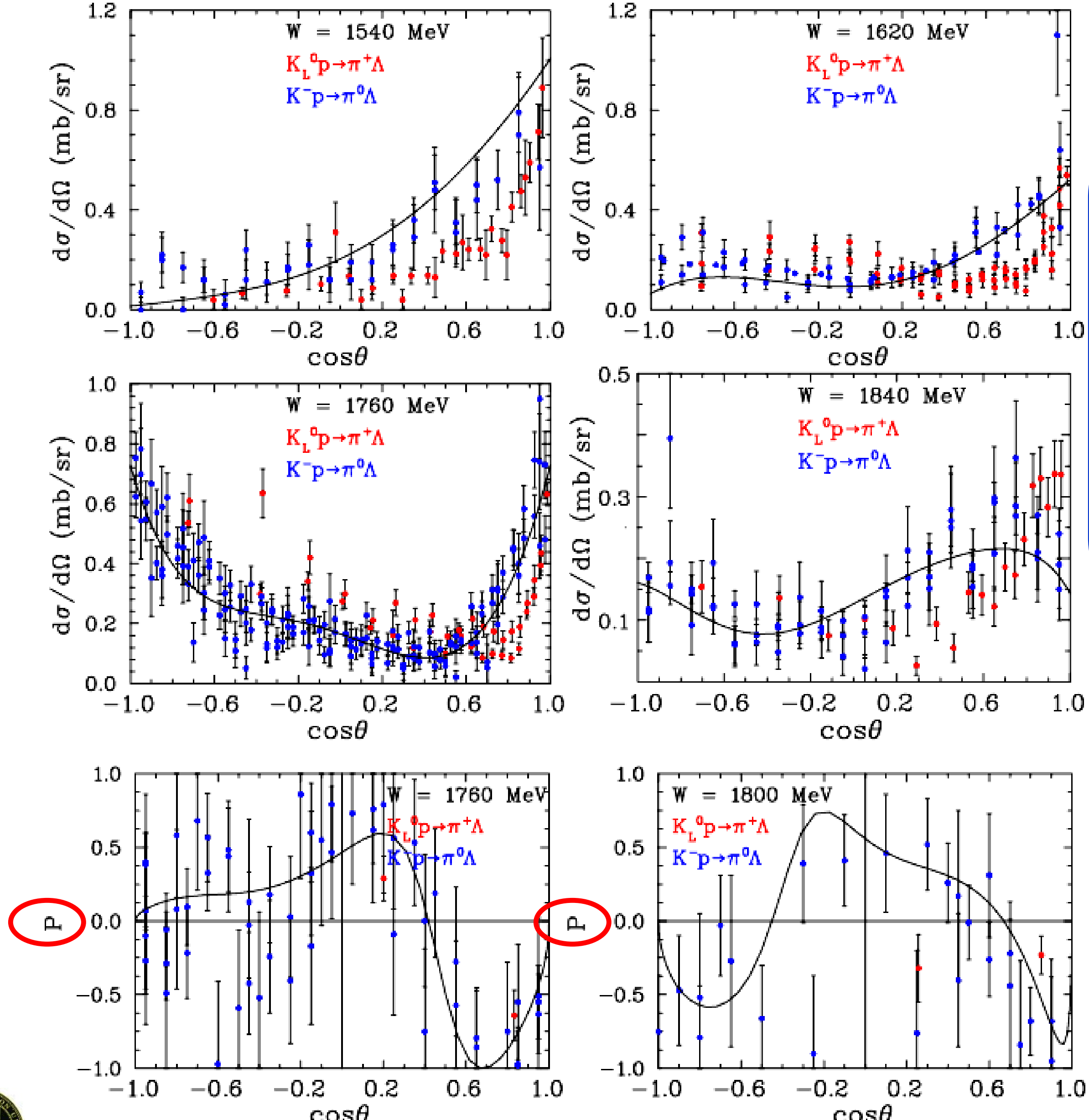
- No **dσ/dΩ** data are available for **$K_L p \rightarrow K_L p$** below W = **3** GeV.



- **PWA** (**KSU**&**GW**) predictions at lower & higher energies tend to agree worse with data than in non-strange case.

Courtesy of Mark Manley, KL2016

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

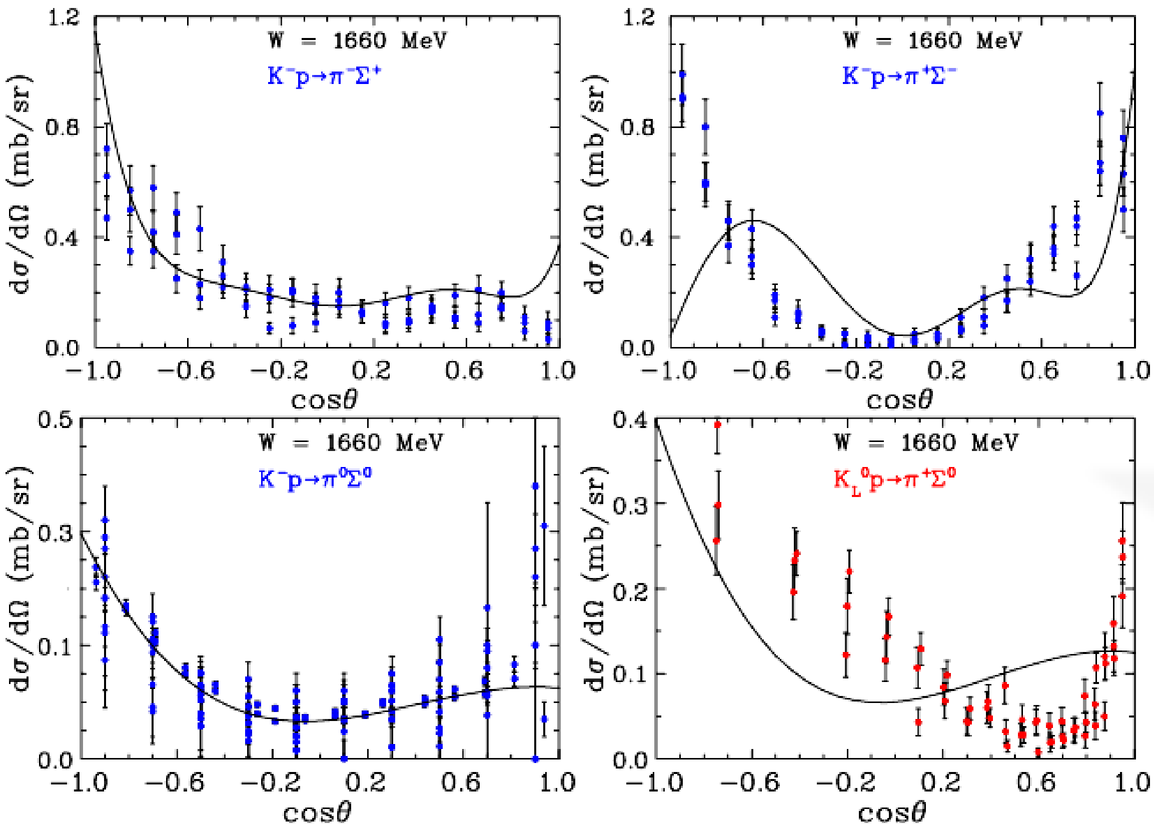


- $K^-p \rightarrow \pi^0\Lambda$ & $K_Lp \rightarrow \pi^+\Lambda$ amplitudes imply that their observables measured at same energy should be identical except for small differences due to isospin-violating mass differences in hadrons.

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

Courtesy of Mark Manley, KL2016

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



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

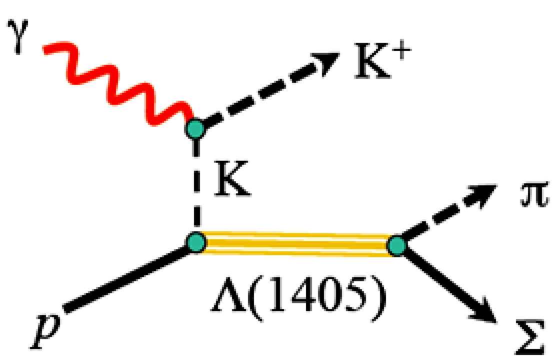
- Quality of **$K_L p$** data is comparable to that for **$K^- p$** data. It would be advantageous to combine **$K_L p$** data in a new coupled-channel **PWA** with available **$K^- p$** measurements.

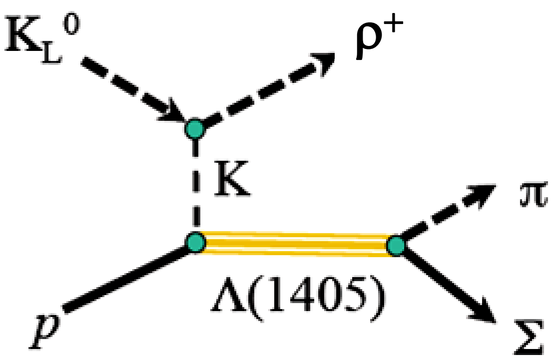
- PDG lists only **two** results on **BR** to **KΣ** **Λ(2100)7/2⁻** (BR < **3%**) **Σ(2030)7/2⁺** (BR < **2%**).

Courtesy of Mark Manley, KL2016

Sample of Hunting for Bumps

Outlook at GlueX for Λ(1405) Line-Shape Measurement





- Measurement may be feasible

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

Courtesy of Reinhard Schumacher, KL2016

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 μb/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.

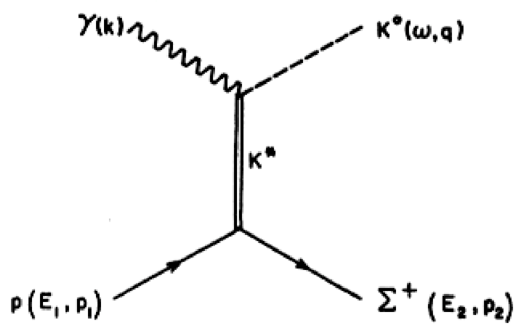


Fig. 1. K^* exchange in photoproduction.

[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.

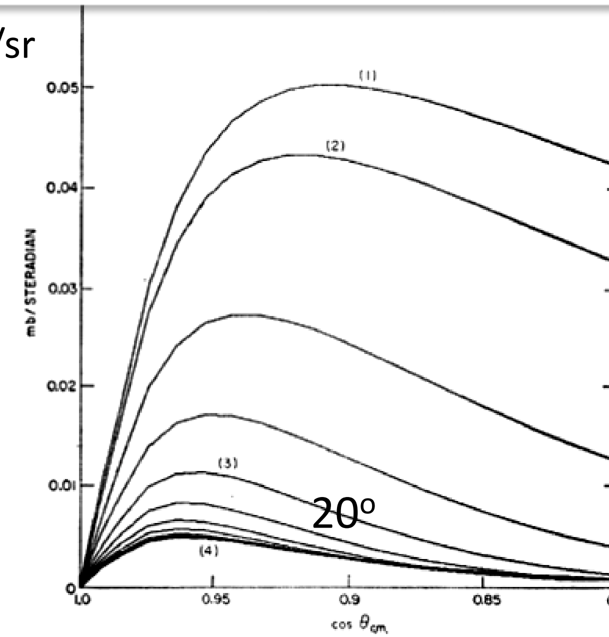


Fig. 3. Center-of-mass differential cross section at 10 BeV. Curve (1) gives the Born approximation. Curve (2) is obtained after subtraction of the $j=\frac{1}{2}$ partial wave. Curves (3) and (4) are respectively obtained after the $j=\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, and all par[...] have been corrected for absorption in final state. The r[...] shown as directly obtained from and drawn by the com[...]

Courtesy of Mike Albrow, KL2016

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

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

Sci-Tech DARESBURY

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

CP-violation

PHYSICAL REVIEW D VOLUME 7, NUMBER 3 1 FEBRUARY 1973

Production of K_L^0 Mesons and Neutrons from Electrons on Beryllium Above 10 GeV*

G. W. Brandenburg, A. D. Brody, W. B. Johnson, D. W. G. S. Leith, J. S. Loos,† G. J. Luste,‡ J. A. J. Matthews, K. Moriyasu,§ B. C. Shen,‖ W. M. Smart,** F. C. Winkelmann, and R. J. Yamartino
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305

(Received 14 August 1972)

SLAC NATIONAL ACCELERATOR LABORATORY

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

JLab LoI12-15-001

A Letter of Intent to Jefferson Lab PAC-43.

Physics Opportunities with a Secondary K_L^0 Beam at JLab.

Moskov J. Amaryan (spokesperson),[1,*] Yakov I. Azimov,[2] William J. Briscoe,[3] Eugene Chudakov,[4] Pavel Degtyarenko,[4] Gail Dodge,[1] Michael Döring,[3] Helmut Haberzettl,[3] Charles E. Hyde,[1] Benjamin C. Jackson,[5] Christopher D. Keith,[4] Ilya Larin,[1] Dave J. Mack,[4] D. Mark Manley,[6] Kanzo Nakayama,[5] Yongseok Oh,[7] Emilie Passemar,[8] Diane Schott,[3] Alexander Somov,[4] Igor Strakovsky,[3] and Ronald Workman[3]

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[4] *Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606*
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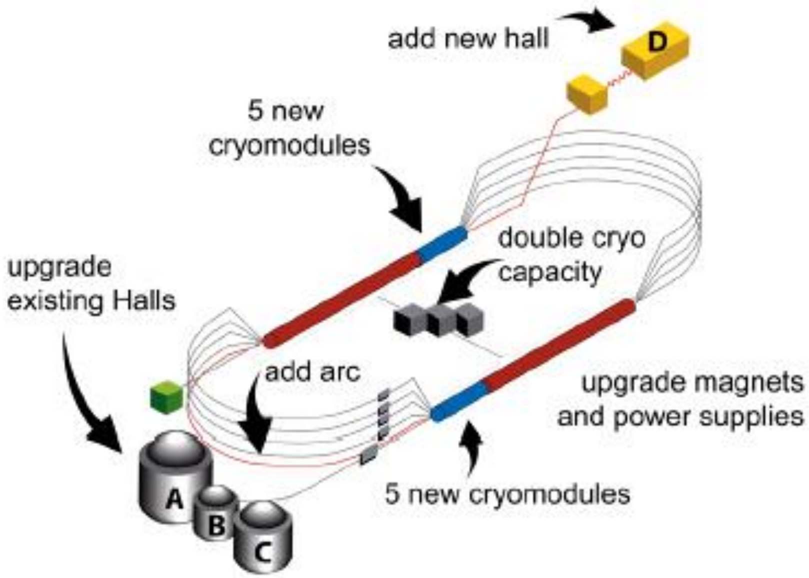
[6] *Kent State University, Kent, OH 44242*
[7] *Kyungpook National University, Daegu 702-701, Korea*
[8] *Indiana University, Bloomington, IN 47405*

(Dated: May 14, 2015)

Hyperon Spectroscopy

- We plan to submit a full **Proposal** for **JLab PAC45** in **2017**.

CEBAF Upgrade to 12 GeV

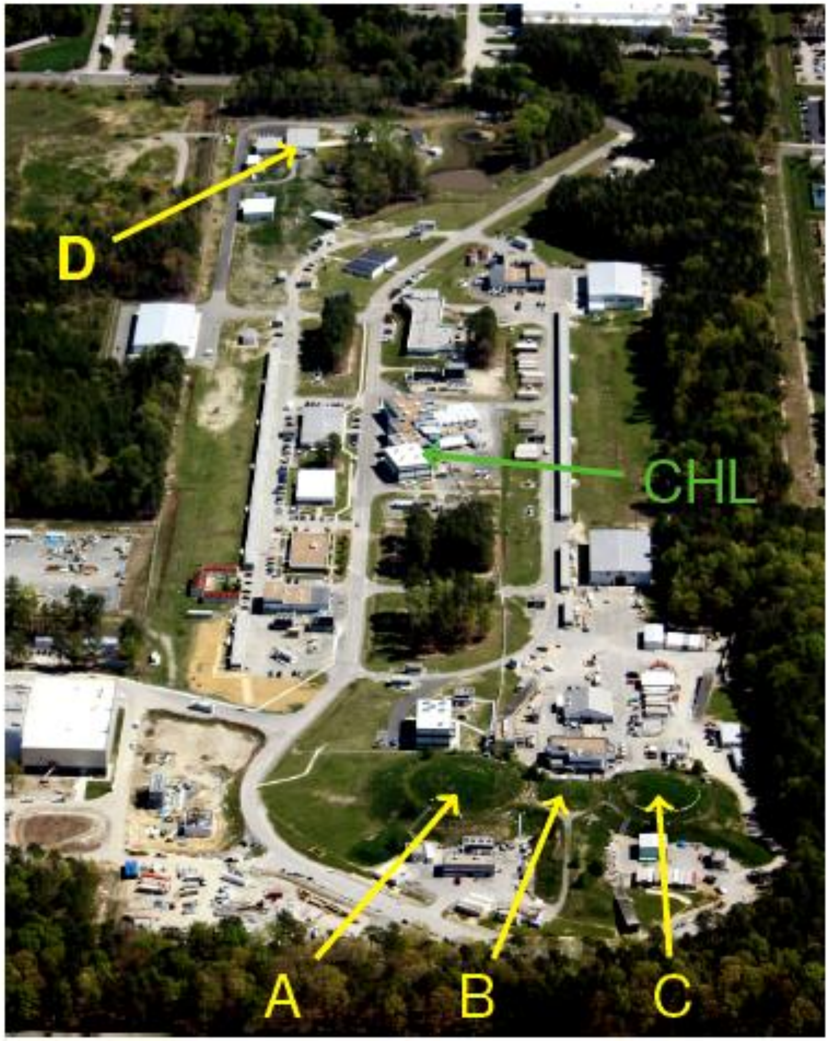


Upgrade Goals

- Accelerator: 6 GeV $\Rightarrow$ 12 GeV
- Halls A,B,C: e^- <11 GeV, < 100 μA
- Hall D: e^- 12 GeV $\Rightarrow$ γ-beam

Upgrade Status

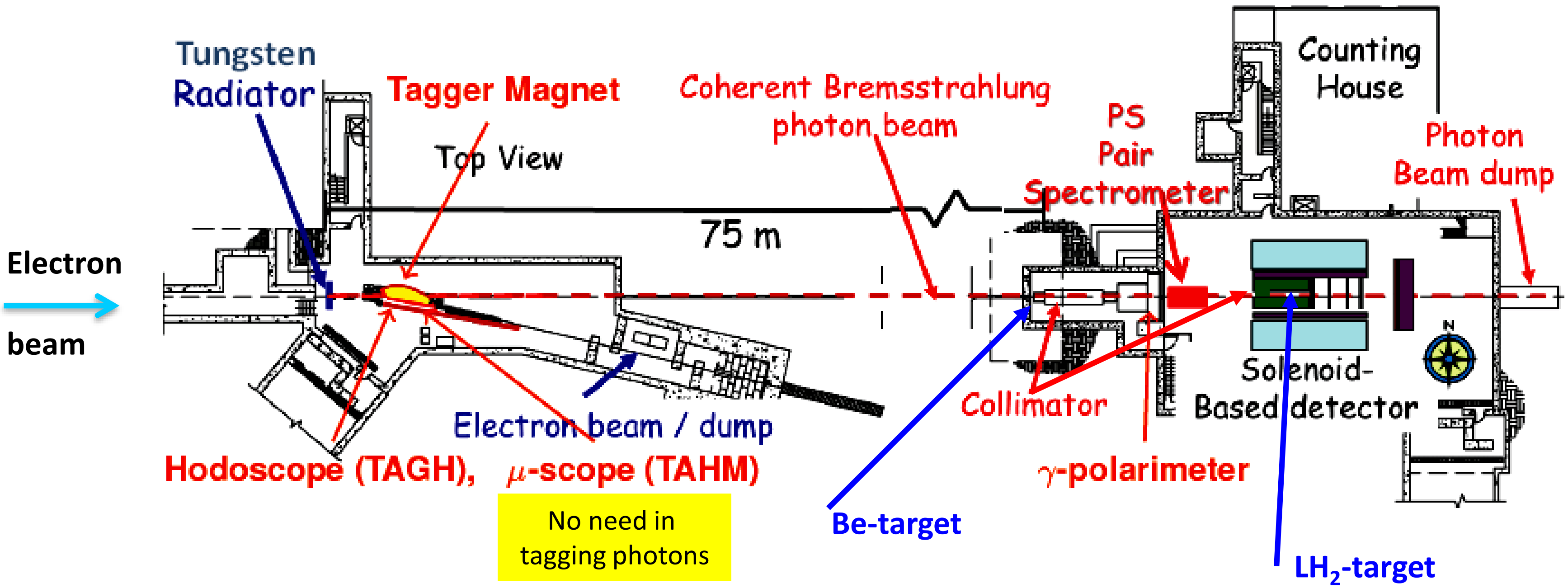
- Reached 12 GeV in Dec 2015
- Halls A,D: finished
- Halls B,C: about a year to go



Courtesy of Eugene Chudakov, KL2016

E.Chudakov KL2016. Feb 2016 Overview of *Hall D* 3 / 32

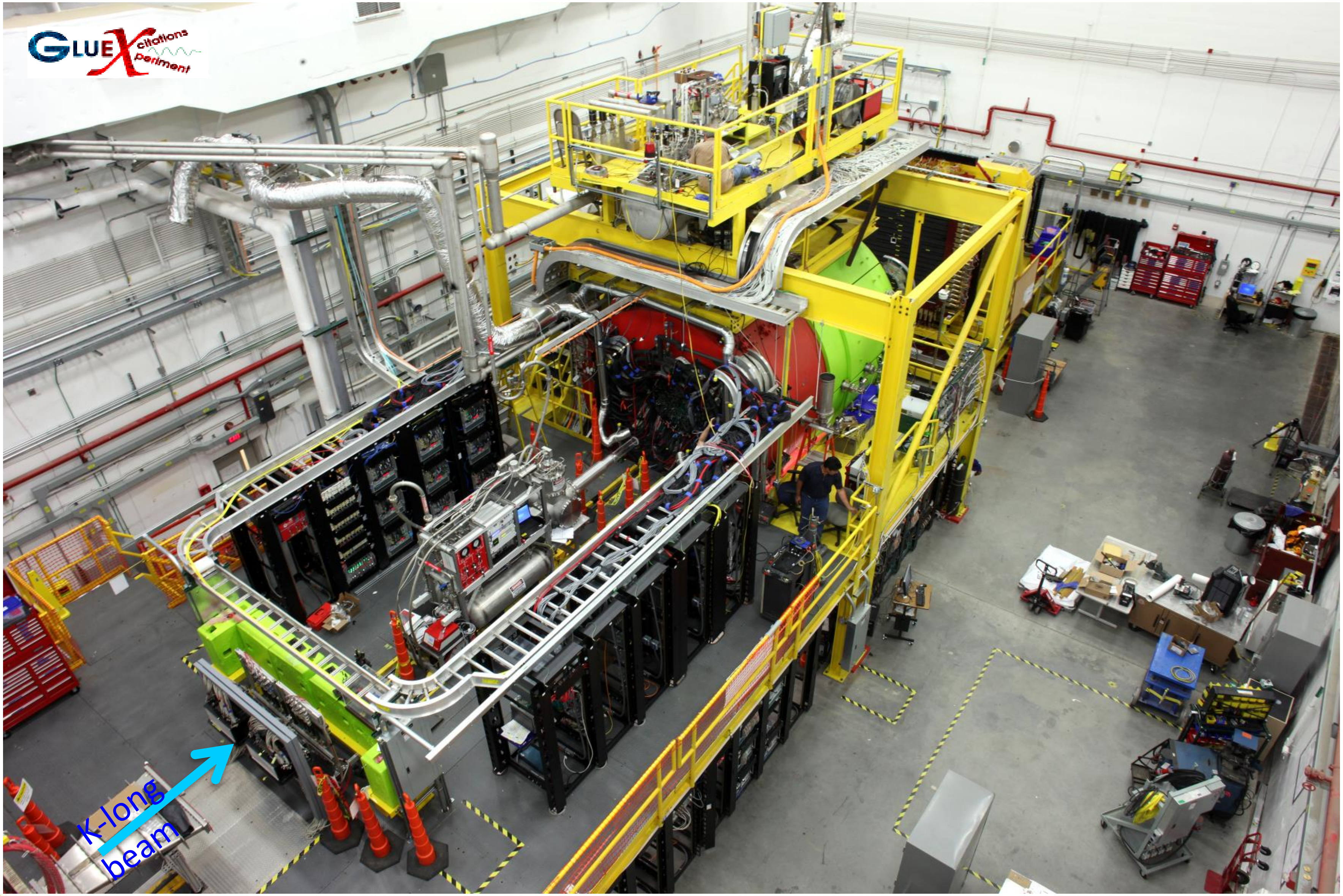
Hall D Beam Line Set up for K-longs



I_e	= **5** μA
W-radiator	= **0.1** R.L.
Be-target	= **1.7** R.L.

- **Electrons** are hitting **W**-radiator.
- **Photons** are hitting **Be**-target.
- **K_Ls** are hitting the **LH_2**-target within **GLueX** setting.

Hall D/GlueX



Hall D/GlueX Spectrometer and DAQ

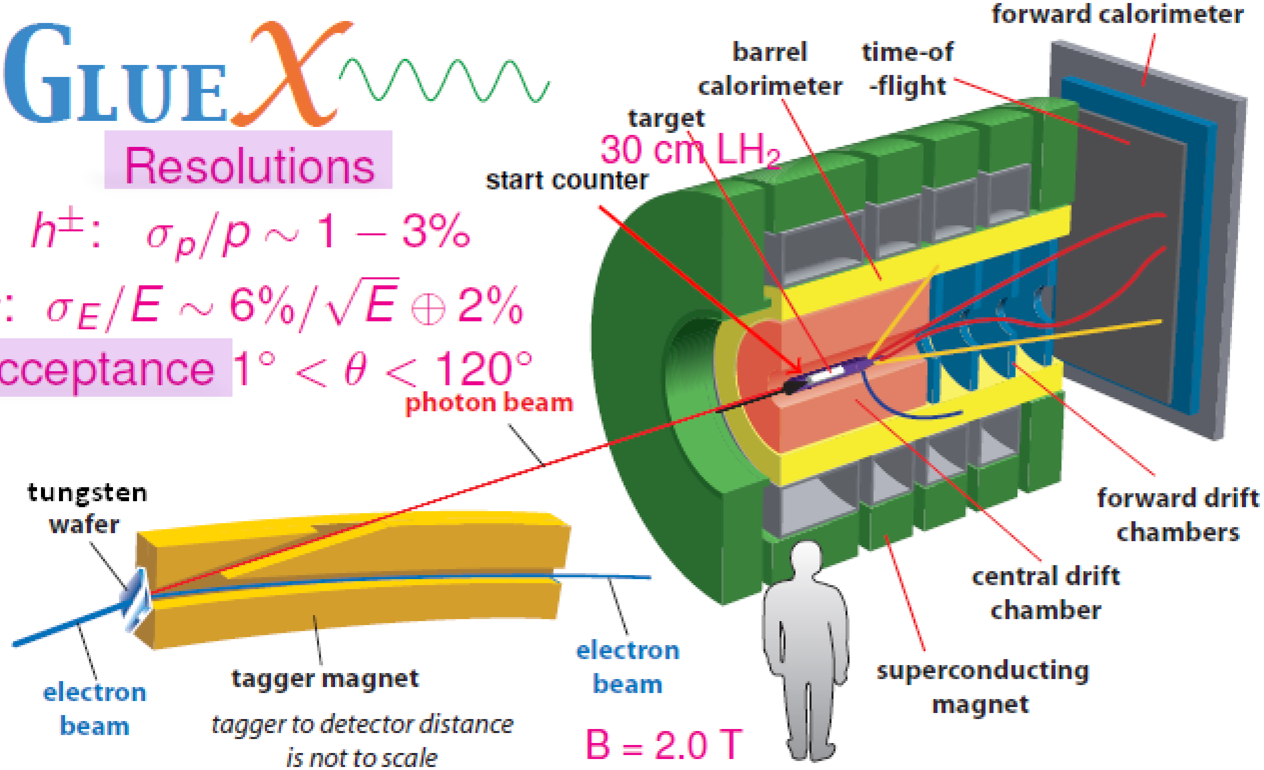
GLUEX

Resolutions

$h^{\pm}$: $\sigma_p/p \sim 1 - 3\%$

γ: $\sigma_E/E \sim 6\%/\sqrt{E} \oplus 2\%$

Acceptance $1^\circ < \theta < 120^\circ$



Detectors

- CDC, FDC
- BCAL, FCAL
- TOF, ST

Plans to add

- 2017 L3
- 2018 DIRC

Photoproduction γp 1.5 kHz for a 10 MHz beam; Trigger $\sum E_{CAL} > X$

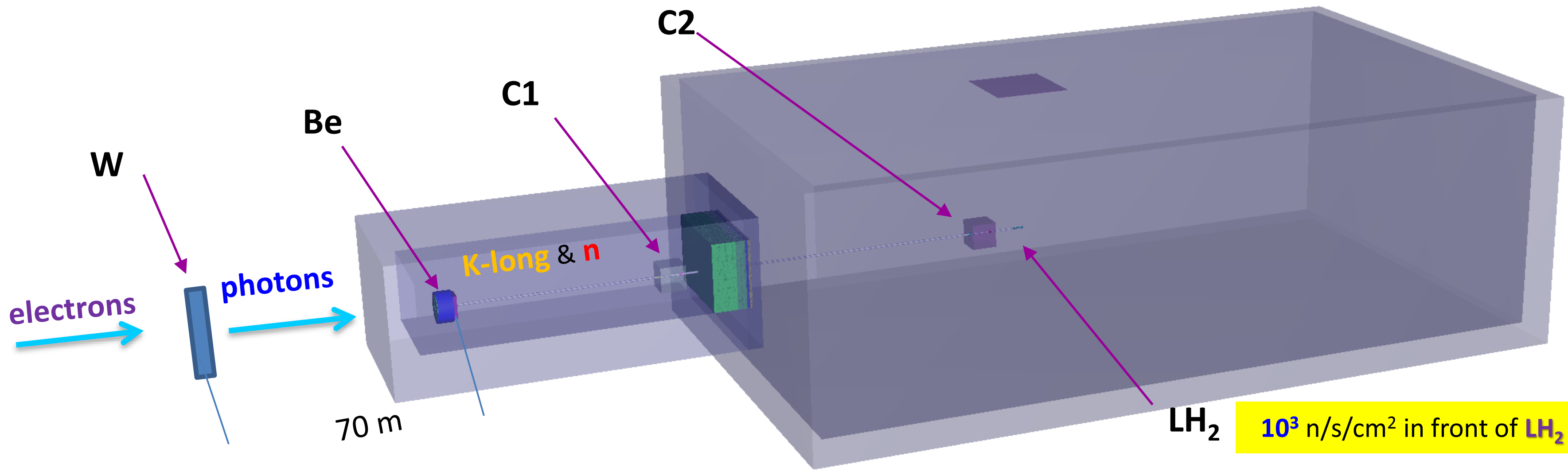
GlueX-I 10 MHz/peak: trigger 20 kHz $\Rightarrow$ DAQ $\Rightarrow$ tape 30 kHz spring 2016

GlueX-II 50 MHz/peak: trigger 100 kHz $\Rightarrow$ DAQ $\Rightarrow$ L3 farm $\sim$ 20 kHz $\Rightarrow$ tape

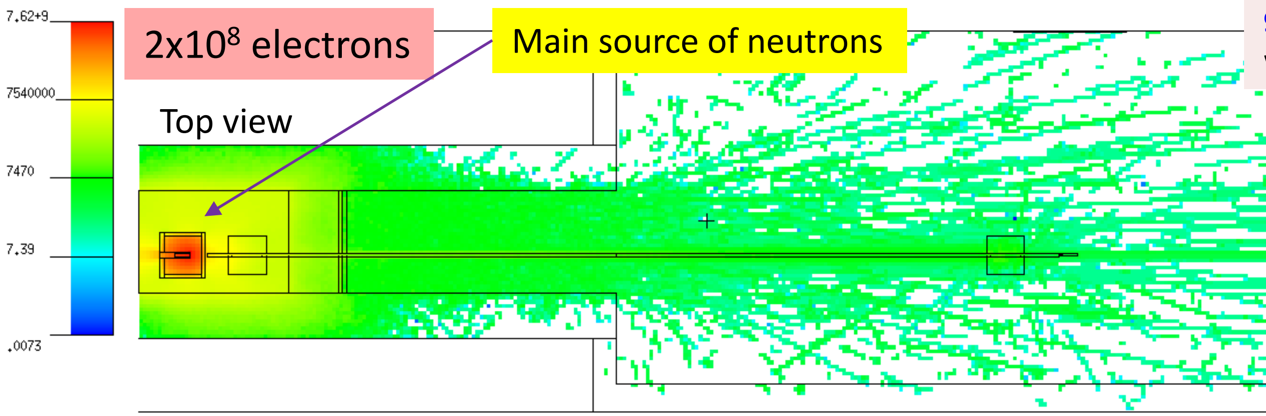
Courtesy of Eugene Chudakov, YSTAR2016

Expected Neutron Background

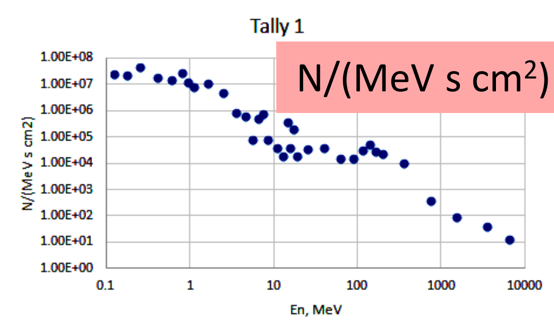
- Most **important** & **unpleasant background** for **K_L** comes from **neutrons**.



10^3 n/s/cm^2 in front of **LH$_2$**



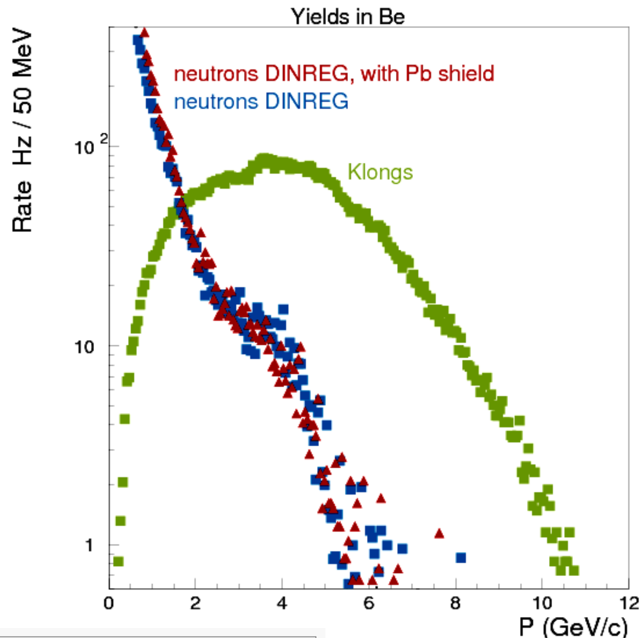
99% of neutrons associated with **T** < **90** MeV while **0.6%** of them are for **T** > **125** MeV.



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

K-long & Neutron Rate on GlueX LH_2-target

GlueX — MC @ **12** GeV



SLAC NATIONAL ACCELERATOR LABORATORY — Data @ **16** GeV

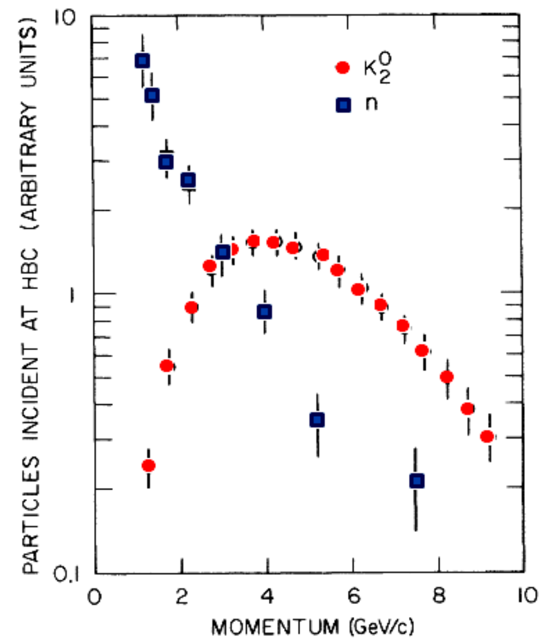
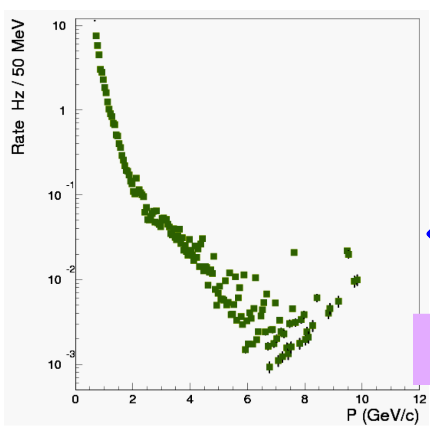


FIG. 2. Comparison of the neutron and K_2^0 fluxes at the hydrogen bubble chamber for 2° production with 16-GeV electrons.

A.D. Brody *et al* Phys Rev Lett **22**, 966 (1969)



Flux ratio **n/K_L**

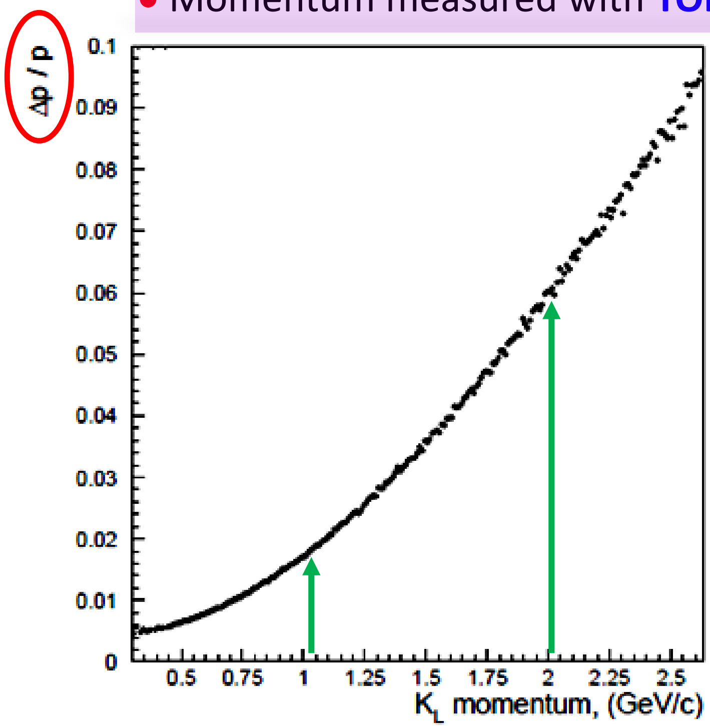
- Delivered with **60** ns bunch spacing avoids overlap in range of **p** = **0.35** – **10.0** GeV/c.

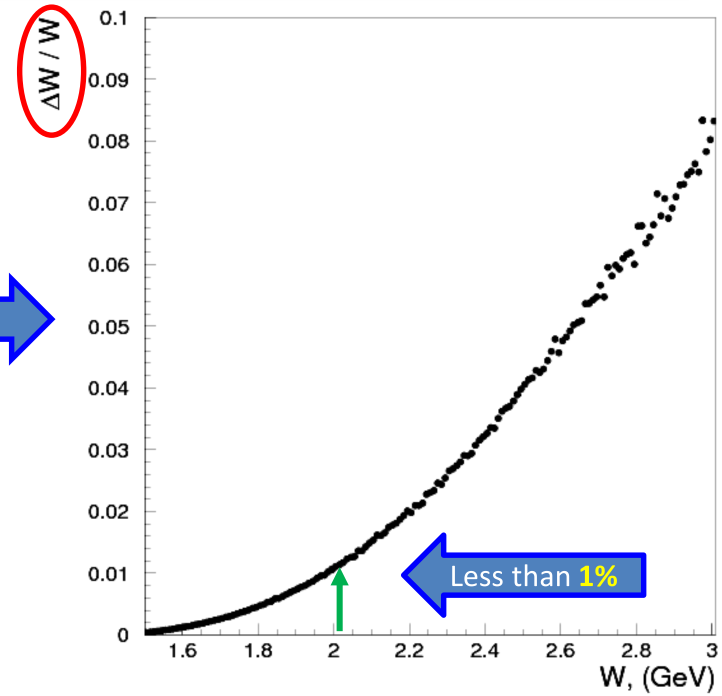
- With **proton** beam, ratio **n/K_L** = **10^3–10^4.**

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_Lp scattering at **lower energies** than K^-p scattering due to higher beam flux.
- Momentum measured with **TOF** between **SC** (surrounded LH_2) & **RF** from **CEBAF**.



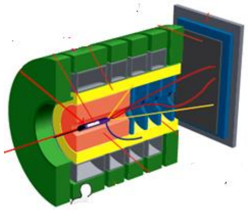


- Momentum resolution **Δp/p** is growing with momentum: for **1** GeV/c is **1.7%**, for **2** GeV/c is **6%**.

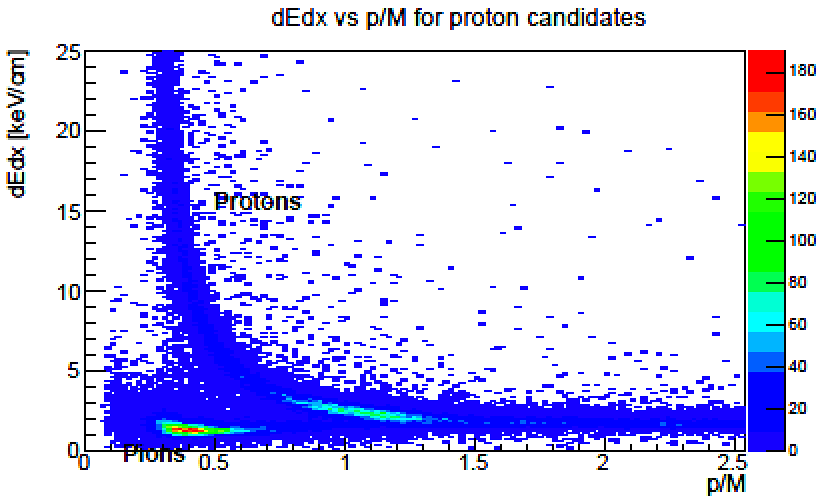
- For W < **2** GeV, **ΔW** < **20** MeV which is suitable to study **Hyperons** with Γ = **30** – **50** MeV.

Courtesy of Ilya Larin, KL2016

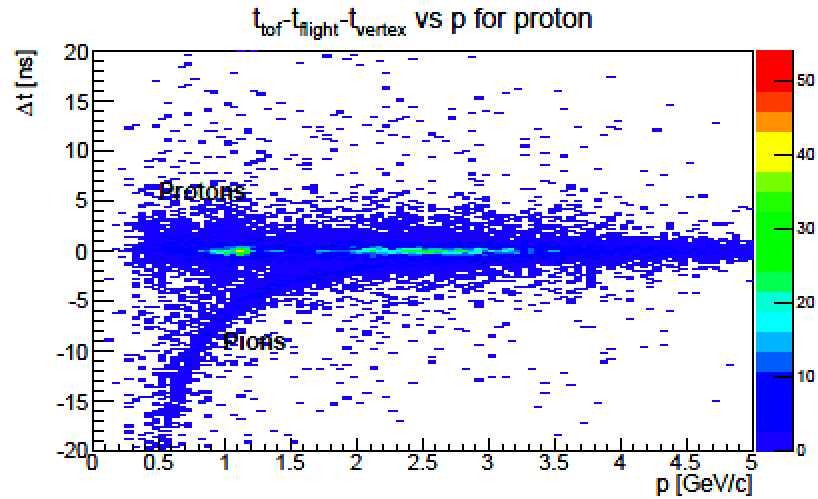
Expected Particle Identification



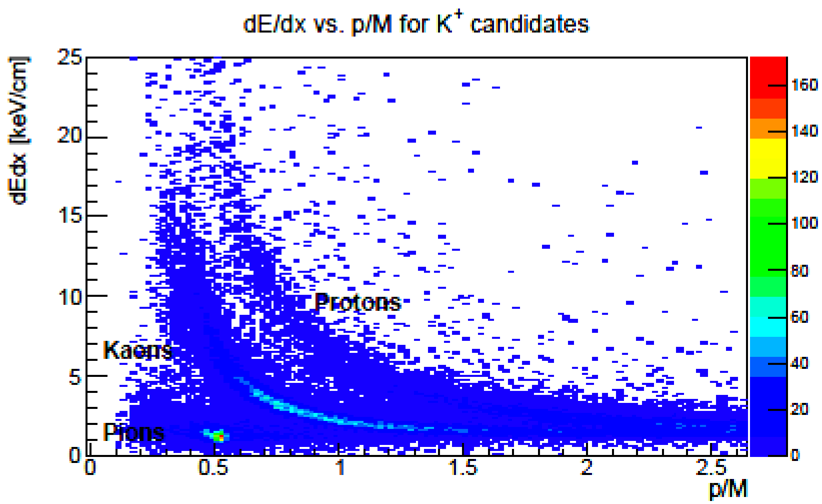
- **dE/dx** for **pK$_S$**.



- Time difference at primary ``vertex" for proton hypothesis for **pK$_S$** using **TOF.**



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



Courtesy of Simon Taylor, KL2016

Expected Cross Sections vs Bubble Chamber Data

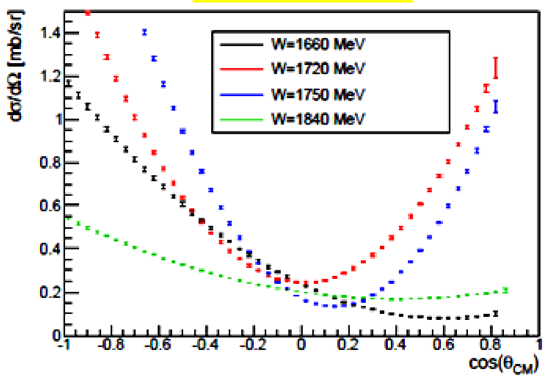
- **GlueX** measurements will span **cosθ** from **–0.95** to **0.95** in c.m. above **W** = **1490** MeV.

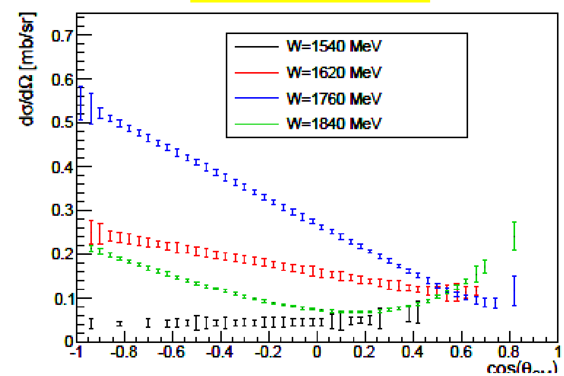
Courtesy of
Simon Taylor, KL2016
Mark Manley, KL2016

- K_L rate is **10^5** K_L/s.
- Uncertainties (statistics only) correspond to **100** days of running time for:

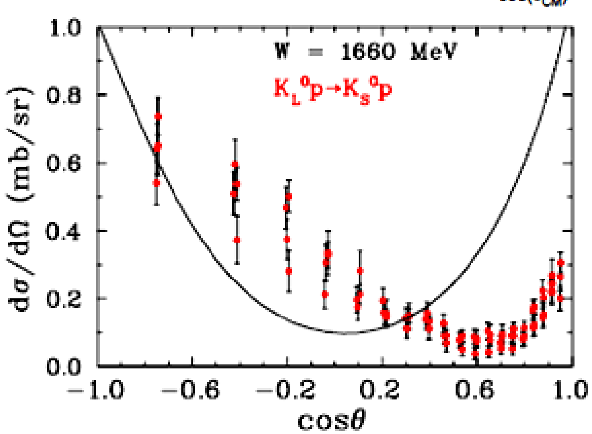
$K_Lp \rightarrow K_Sp$

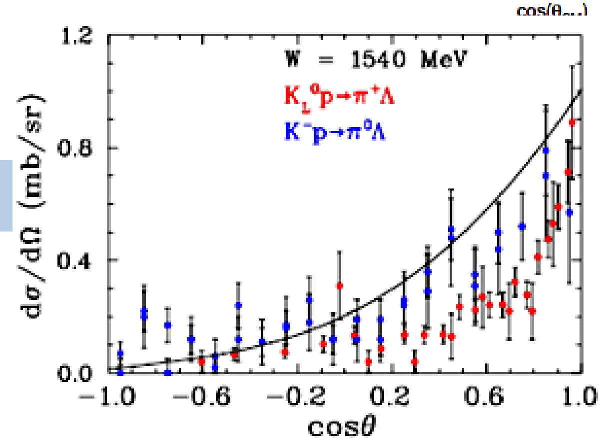
$K_Lp \rightarrow \pi^+\Lambda$





Expected **GlueX** Data



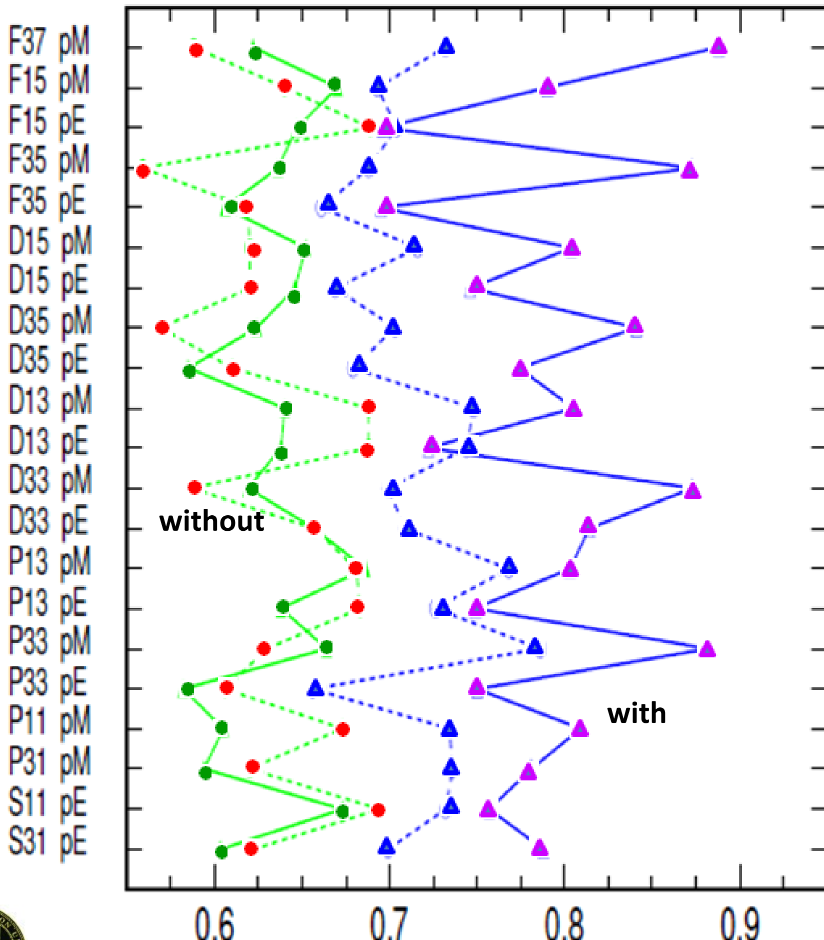


BC Data

JLab E-03-105

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

Transverse Polarization **Longitudinal Polarization**



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

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

ηp E: I. Senderovich *et al* Phys Lett B **755**, 64 (2016)
π^+n E: S. Strauch *et al* Phys Lett B **750**, 53 (2015)
More results are coming…

- **KSU&GW** is doing **PWA** including available **K_Lp** & **K^-p** data plus expected **GlueX** data to show potential impact of new **Hall D** measurements.

Summary

- Here we reviewed what can be learned by studying **$K_L p$** scattering leading to **two-body** final states (1st stage).
  <u>At later stages</u>, we plan to do **$K_L n$** on **LD_2** &
  $K_L N$ 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 **low-lying hypiron states** would assist in advance our understanding of **formation** of **baryons** from **quarks** & **gluons** **microseconds** after **Big Bang**.

- Full Proposal is coming for **PAC45** in **2017**, **WELCOME** to **JOIN US**.

Thank You



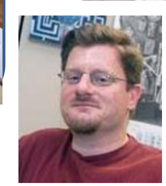



Moskov Amaryan
Yakov Azimov
William Briscoe
Eugene Chudakov
Pavel Degtyarenko
Michael Döring
Alexander Laptev
Ilya Larin
Maxim Mai
Mark Manley
James Ritman
Simon Taylor









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Speakers:

Chudakov Albrow Richards

Amaryan Ramos

Manley Zou

Schumacher

Filippi Oset

Myhrer Montgomery

Degtyarenko Kamano

Nakayama Santopinto

Ohnishi Szczepaniak

Goity Mathieu

Mai Passemar

Ziegler Taylor

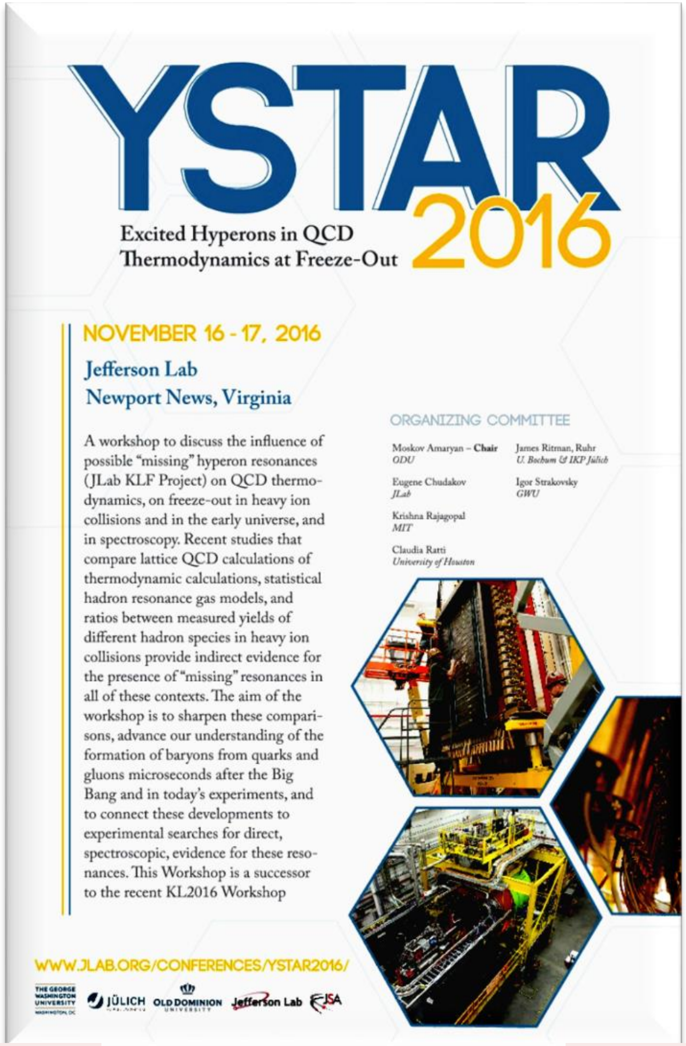
Noumi Oh

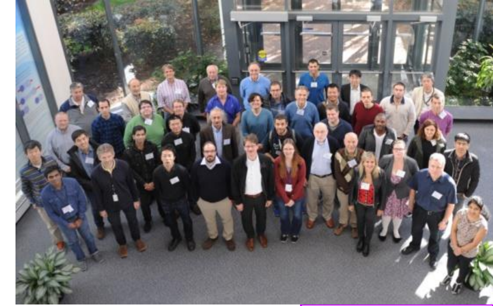
Keith Kohl Larin Pennington

61 people & **30** talks

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

Speakers: Mai, Chudakov, Garcilazo, Amaryan, Begun, Noronha-Hostler, Myhrer, Ohnishi, Ritman, Capstick, Noumi, Bellwied, Doenigus, Huovinen, Tsuchikawa, Arriola, Edwards, Xie, Goity, Montgomery, Manley, Crede, Alba, Guo, Stroth, Tang, Ratti





72 people & **28** talks

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