KLF for Hyperon Spectroscopy

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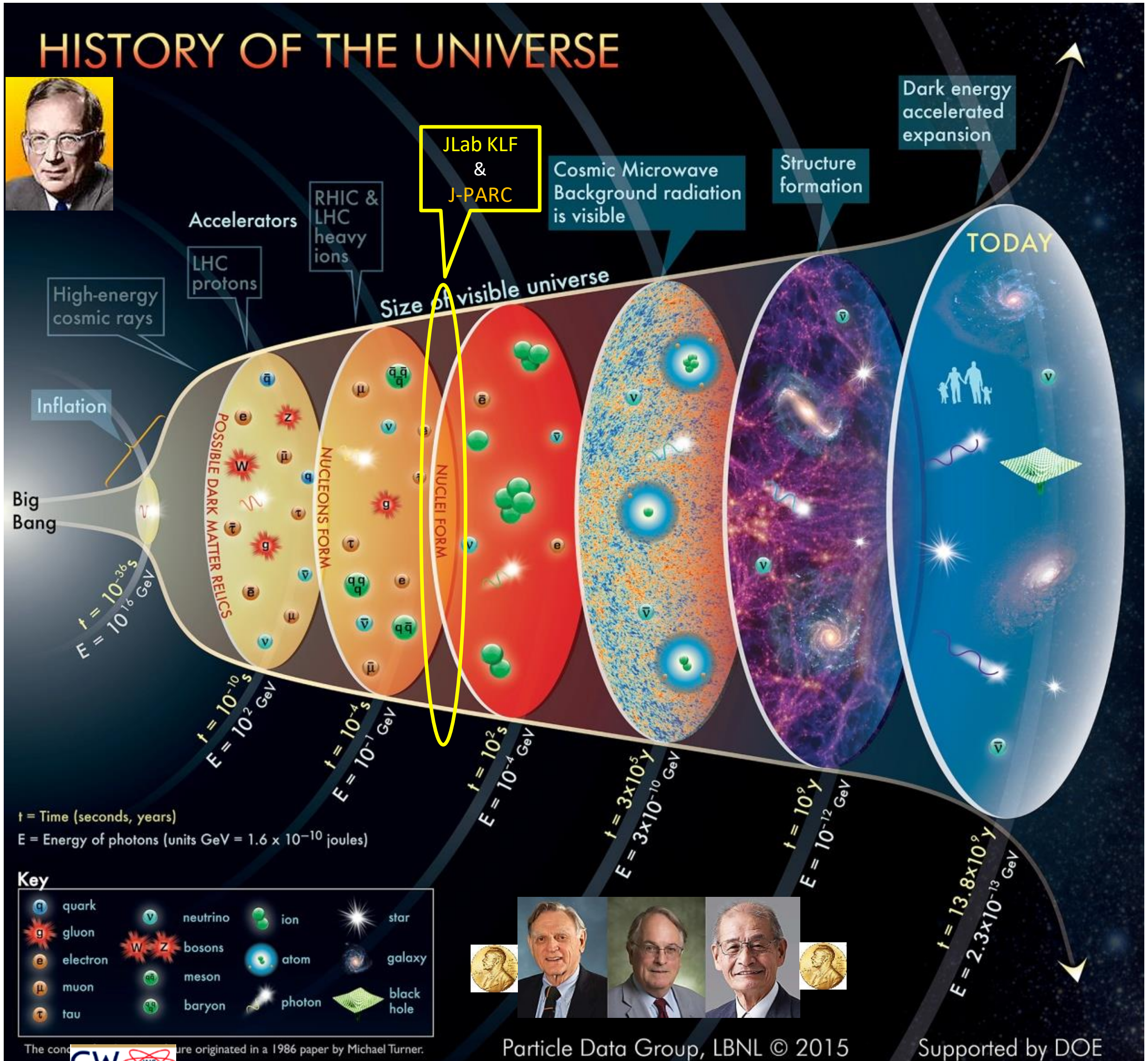
(for KLF Collaboration)

- Thermodynamics @ Freeze-out.
- Spectroscopy of Hyperons.
- KLF Project.
- PWA for Strange Sector.
- $K_L p$ DB.
- Opportunity with K_L beam.
- Expected $K_L p$ data.
- Impact for Spectroscopy.
- Summary.

* Supported by DE-SC0016583

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.

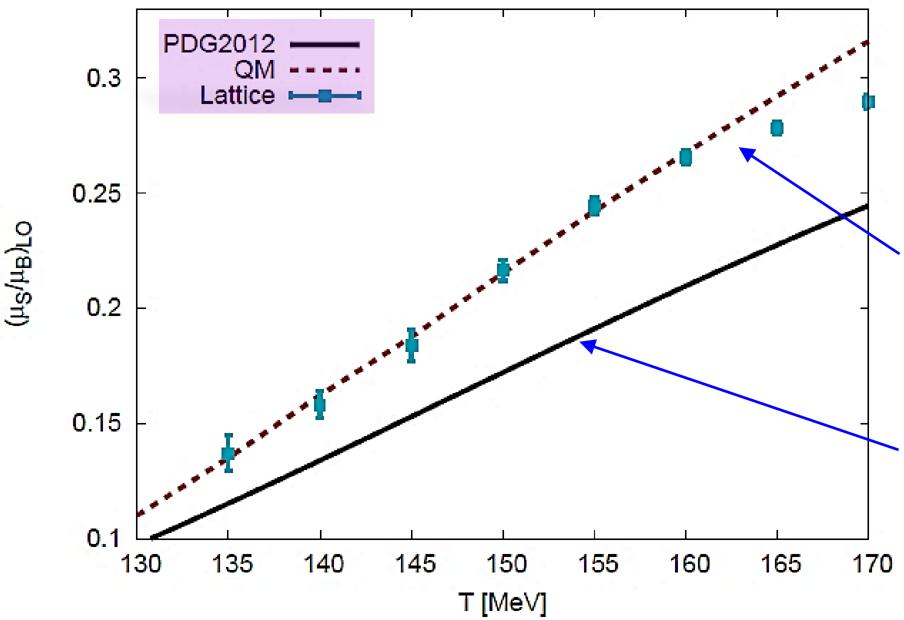
- For that reason, advancing our understanding of formation of baryons from quarks & gluons requires new experiments to search for any missing hyperon resonances.

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

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

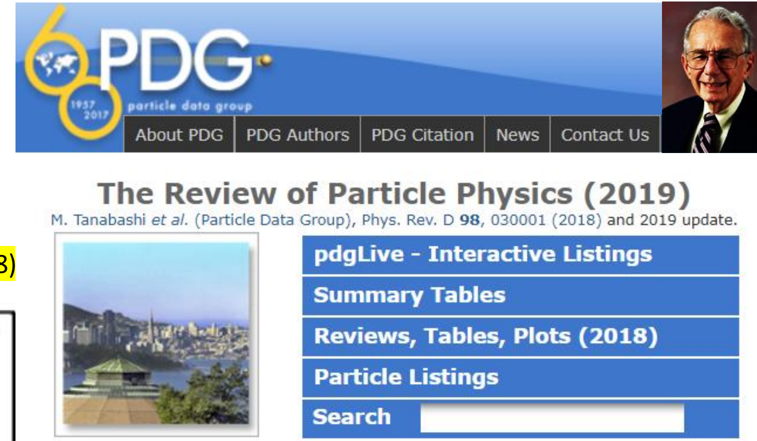


- Hyperons
- Non-strange Baryons
- Mesons
- Nuclei

- + ``Missing" Hyperons (QM/LQCD calculations).
- Contribution from **observed** Resonances.

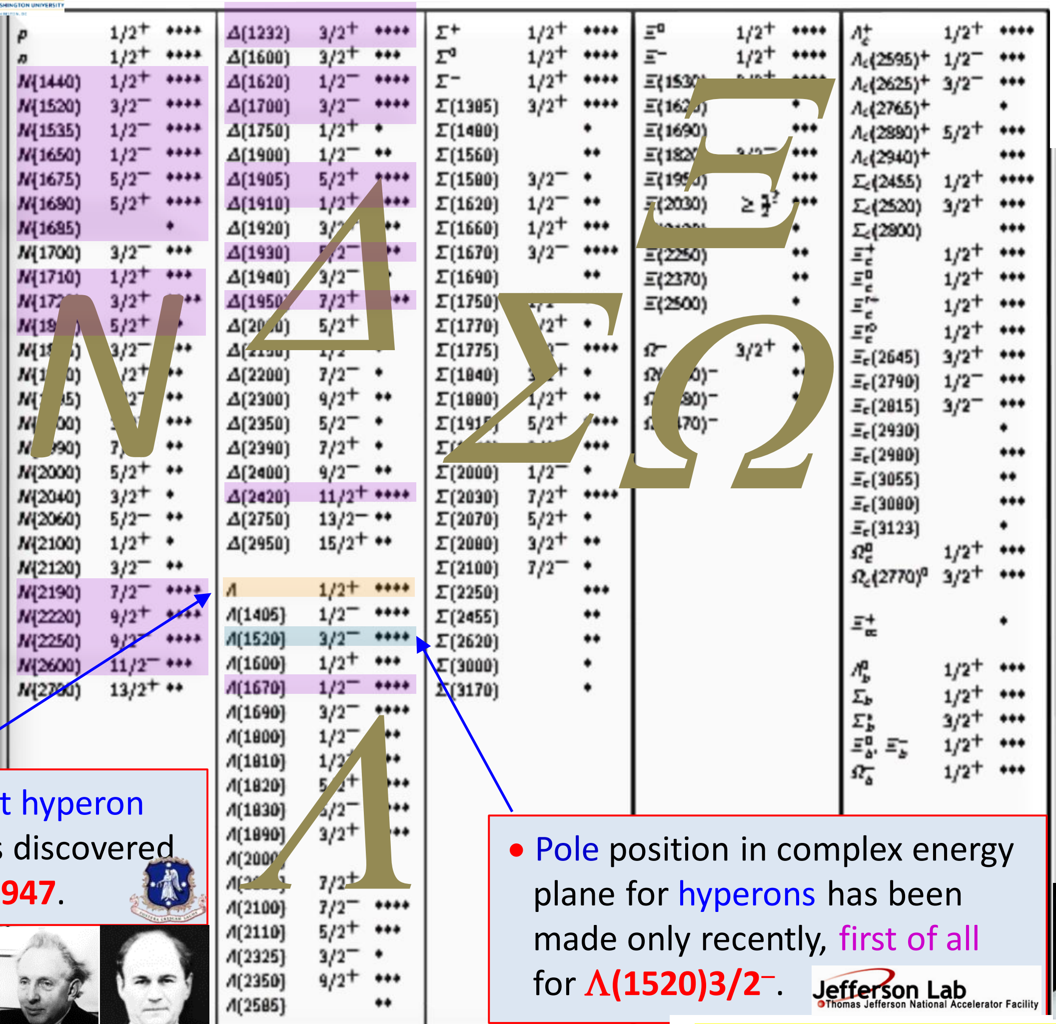
Courtesy of Claudia Ratti, YSTAR2016

Observed Baryons @ PDG18



GW Contribution

M. Tanabashi *et al*, Phys Rev D **98**, 030001 (2018)



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(172[illegible])	3/2+	[illegible]
N(19[illegible])	5/2+	[illegible]
N(18[illegible])	3/2−	[illegible]
N(1[illegible])	[illegible]	**
N([illegible])	[illegible]	**
N([illegible])	[illegible]	***
N([illegible])	7[illegible]	**
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/[illegible]	***
Δ(1930)	[illegible]	[illegible]
Δ(1940)	3/2−	[illegible]
Δ(1950)	7/2+	****
Δ(20[illegible])	5/2+	[illegible]
Δ([illegible])	[illegible]	[illegible]
Δ(2200)	7/2−	*
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−	****
Λ(1690)	3/2−	****
Λ(1800)	1/2−	[illegible]
Λ(1810)	1/2[illegible]	[illegible]
Λ(1820)	5[illegible]	[illegible]
Λ(1830)	[illegible]	[illegible]
Λ(1890)	3/2+	[illegible]
Λ(200[illegible])		[illegible]
Λ([illegible])	7/2+	[illegible]
Λ(2100)	7/2−	****
Λ(2110)	5/2+	***
Λ(2325)	3/2−	*
Λ(2350)	9/2+	***
Λ(2585)		**

Σ+	1/2+	****
Σ0	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)	3/2−	****
Σ(1690)		**
Σ(1750)	[illegible]	[illegible]
Σ(1770)	[illegible]	*
Σ(1775)	[illegible]	****
Σ(1840)	[illegible]	*
Σ(1880)	1/2+	**
Σ(191[illegible])	5/2+	****
Σ([illegible])	[illegible]	***
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)		*

Ξ0	1/2+	****
Ξ−	1/2+	****
Ξ(153[illegible])	[illegible]	[illegible]
Ξ(162[illegible])		*
Ξ(1690)		***
Ξ(182[illegible])	3/2−	***
Ξ(195[illegible])		***
Ξ(2030)	≥ 5/2?	***
[illegible]		*
Ξ(2250)		**
Ξ(2370)		**
Ξ(2500)		*
Ω−	3/2+	[illegible]
Ω([illegible])−		[illegible]
Ω([illegible])−		[illegible]
Ω([illegible])−		

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+	***

- First hyperon was discovered in **1947**.

G. D. Rochester & C. C. Butler, Nature, **4077**, 855 (1947)

- Pole position in complex energy plane for hyperons has been made only recently, first of all for **Λ(1520)3/2⁻**.

Jefferson Lab
Thomas Jefferson National Accelerator Facility

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

- PDG has 109 Baryon Resonances (58 of them are 4* & 3*).

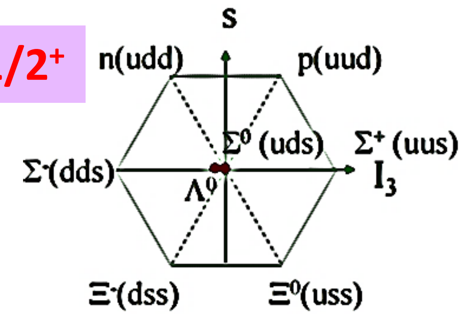
- In case of SU(6) X O(3), 434 states would be present if all revealed multiplets were fleshed out (three 70 and four 56).

- LQCD results are similar.

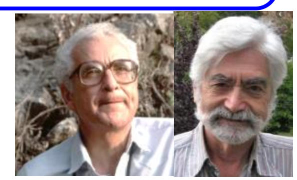
Baryon Resonances

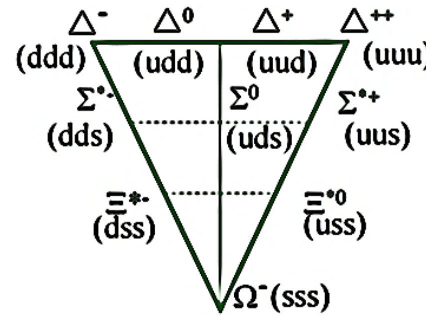
- Three light quarks can be arranged in 6 baryonic families, N*, Δ*, Λ*, Σ*, Ξ*, & Ω*.
- Number of members in family that can exist is not arbitrary.
- If $SU(3)_F$ symmetry of QCD is controlling, then:

1/2⁺



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



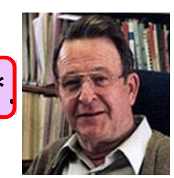


3/2⁺

- 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)

Jefferson Lab
Thomas Jefferson National Accelerator Facility

C2-12-19-001

Proposal for JLab PAC47

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D



Experimental Support:

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Theoretical Support:

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- **93** experimentalists &
- **41** theorists

are co-authors.

Hyperon & Strange Meson Spectroscopy

- We plan to resubmit full Proposal for JLab PAC48 in 2020.

GW Data Analysis Center, Institute for Nuclear Studies, The George Washington University

Aims of Jefferson Lab KLONG FACILITY Project

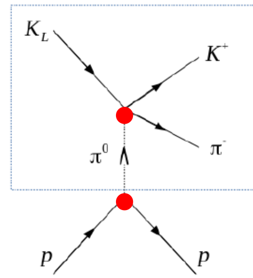
- KLONG FACILITY project has to establish secondary K_L beam line at Jefferson Lab Thomas Jefferson National Accelerator Facility, with flux of *three order of magnitude higher* than SLAC had, for scattering experiments on both proton & neutron (first time !) targets in order

- To determine differential cross sections & self-polarization of strange hyperons with GlueX detector to enable precise PWA in order to determine all resonances up to 2400 MeV in spectra of Λ^*, Σ^*, Ξ^*, & Ω^*.

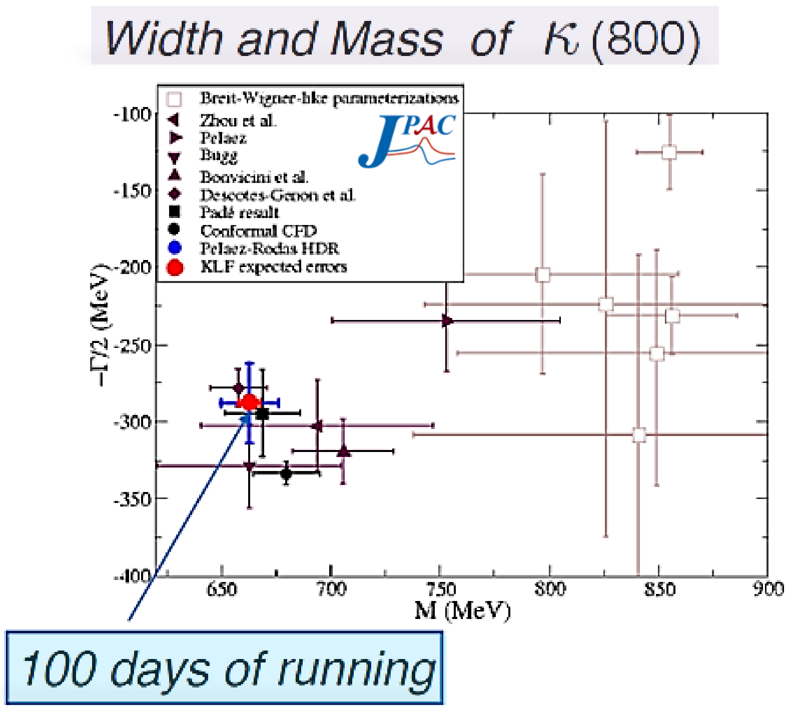
- In addition, we intend to do strange meson spectroscopy by studies of the π-K interaction to locate the pole positions in I = 1/2 & 3/2 channels.

- KLONG FACILITY has link to ion-ion high energy facilities as CERN & BROOKHAVEN NATIONAL LABORATORY & will allow understand formation of our world in several microseconds after Big Bang.

Summary of Kπ Scattering



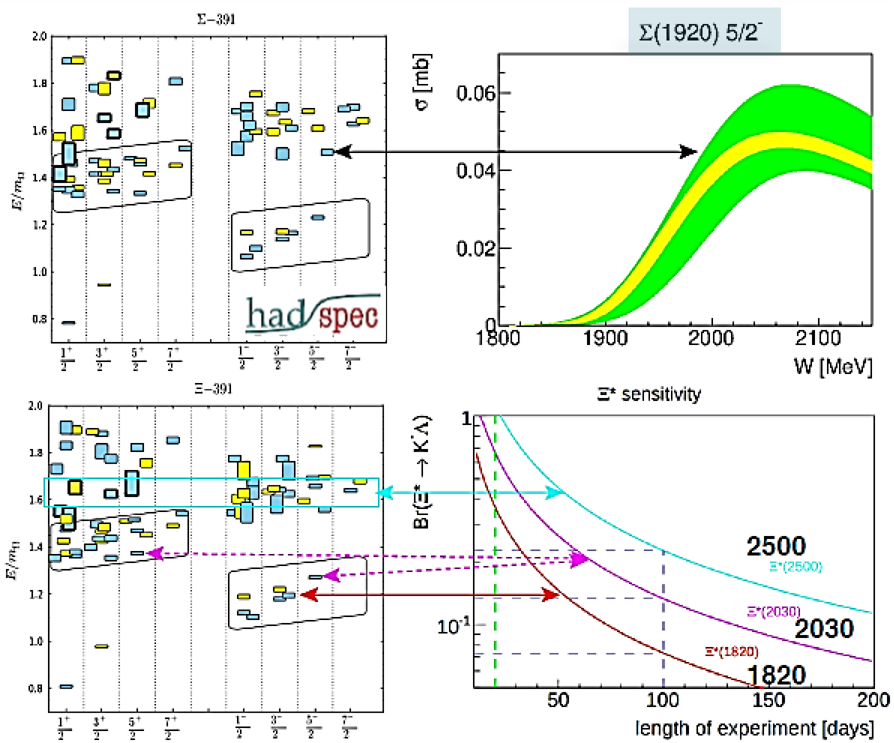
- will have very significant impact on our knowledge on Kπ scattering amplitudes.
- It will certainly improve still conflictive determination of heavy K*'s parameters.
- It will help to settle tension between phenomenological determination of scattering lengths from data vs ChPT & LQCD.
- For K*(800), it will reduce: uncertainties in mass by factor of two & uncertainty in width by factor of five.
- It will help to clarify debated of its existence, &, therefore, long standing problem of existence of scalar meson nonet.



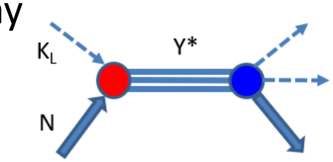
See Moskov Amaryan's talk Oct 11th

Summary of Hyperon Spectroscopy

Comparison of KLF Measurements and LQCD



- We showed that KLF sensitivity with 100 d of running will allow to discovery many hyperons with good precision.
- Why should it be done with KL beam ?
  This is only realizable way to observe **s**-channel resonances having all momenta of KL at once.



- Why should it be done at Jefferson Lab Thomas Jefferson National Accelerator Facility ?
  Because nowhere else in existing facilities this can be done.
- Why should we care that there are dozens of missing states ?

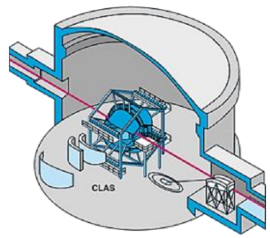
…The new capabilities of the 12-GeV era facilitate a detailed study of baryons containing two and three strange quarks. Knowledge of the spectrum of these states will further enhance our understanding of the manifestation of QCD in the three-quark arena. 2015 Long Range Plan for Nuclear Science

Road Map to Baryon Spectroscopy

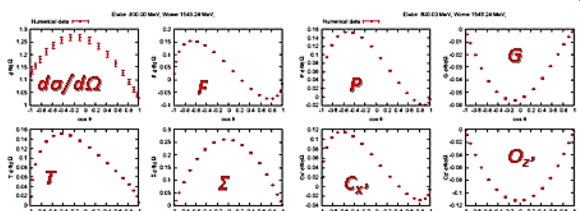
- That is not hunting for bumps.

Facility

Experiment

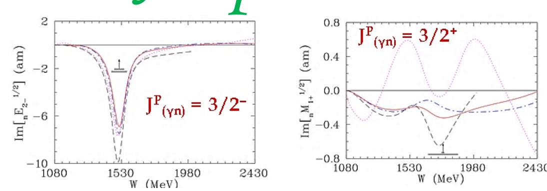


Data

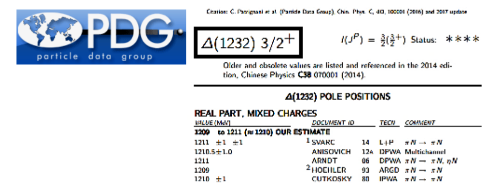


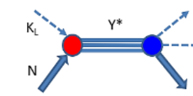
PWA

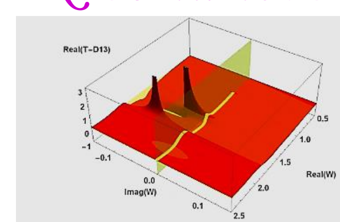
Amplitudes



Resonances







Search for Hyperon Resonances with PWA

- For scattering experiments on both proton & neutron targets one needs to determine:
  - Differential cross sections.
  - Self polarization of strange hyperons.
  - Perform coupled-channel PWA.
  - Look for poles in complex energy plane (contrary to naïve **bump** hunting).
  - Identify all up Λ^*, Σ^*, Ξ^*, & Ω^* up to 2400 MeV.

- We will use KN scattering data with statistics generated according to expected data for **20** and 100 days to show PWA sensitivity to obtain results for best fit.

What Can Be Learned with $K^0{}_L$ Beam ?

Elastic and charge-exchange

$$K^0_L p \to K^0_S p$$
$$K^0_L p \to K^+ n$$

Two-body with S=-1

$$K^0_L p \to \pi^+ \Lambda$$
$$K^0_L p \to \pi^+ \Sigma^0$$

Two-body with S=-2

$$K^0_L p \to K^+ \Xi^0$$
$$K^0_L p \to K^+ \Xi^{0*}$$

Three-body with S=-2

$$K^0_L p \to \pi^+ K^+ \Xi^-$$
$$K^0_L p \to \pi^+ K^+ \Xi^{-*}$$

Three-body with S=-3

$$K^0_L p \to K^+ K^+ \Omega^-$$
$$K^0_L p \to K^+ K^+ \Omega^{-*}$$

How to Search for "Missing" Hyperons

- New data for inelastic $K_L p$ scattering would significantly improve our knowledge of Σ^*, Λ^*, Ξ^*, & Ω^* 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:

K-p=>S0, L0
KLp=>S+

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

⟹ Double Strange Cascades

- 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.

PWA Formalism

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

$$\frac{d\sigma}{d\Omega} = \lambda\!\!\!^{-2}(|f|^2 + |g|^2)$$

$$P\frac{d\sigma}{d\Omega} = 2\lambda\!\!\!^{-2}\,\mathrm{Im}(fg^*)$$

$\lambda\!\!\!^{-} = \hbar/k$ & k is momentum of incoming kaon in CM.

f(W,θ) & g(W,θ) are non-spin–flip & spin–flip amplitudes at W & θ.

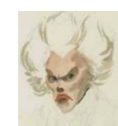
Partial-Wave Expansion

- In terms of partial waves, f(W,θ) & g(W,θ) 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.
$P_l'(\cos\theta)$ 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 (~10^{-3}), we can write

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

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

We have both I = 0 & I = 1 amplitudes for KN & $\overline{\text{K}}$N scattering.

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

$$T_{l\pm} = C_0 T^0_{l\pm} + C_1 T^1_{l\pm}$$

$T^I_{l\pm}$ are partial-wave amplitudes

with isospin I & total angular momentum J = l ± 1/2

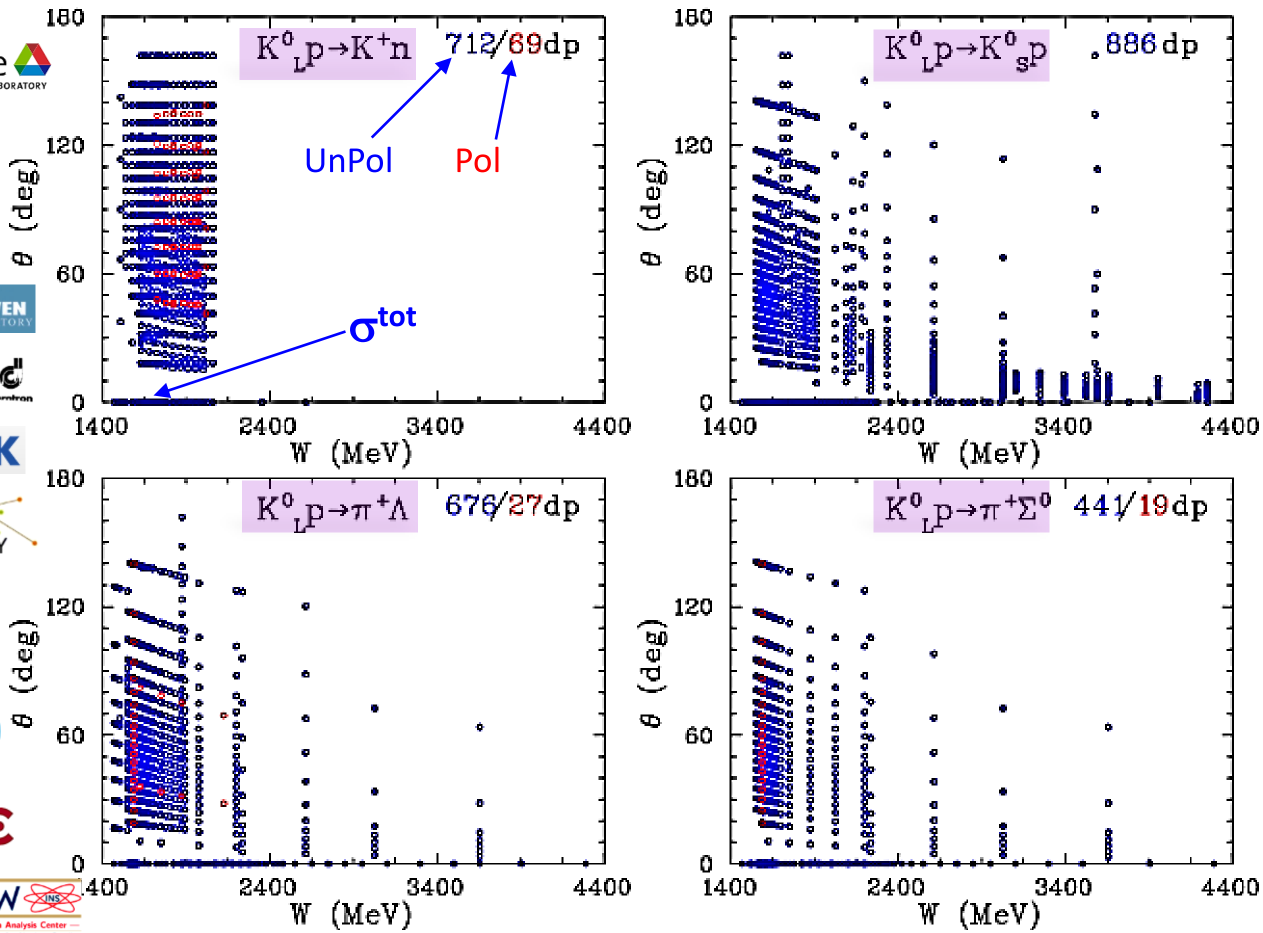
C^I are appropriate Clebsch–Gordon coefficients.

World K–long Data – Ground for Hyperon Phenomenology

W = 1.45 – 5.05 GeV

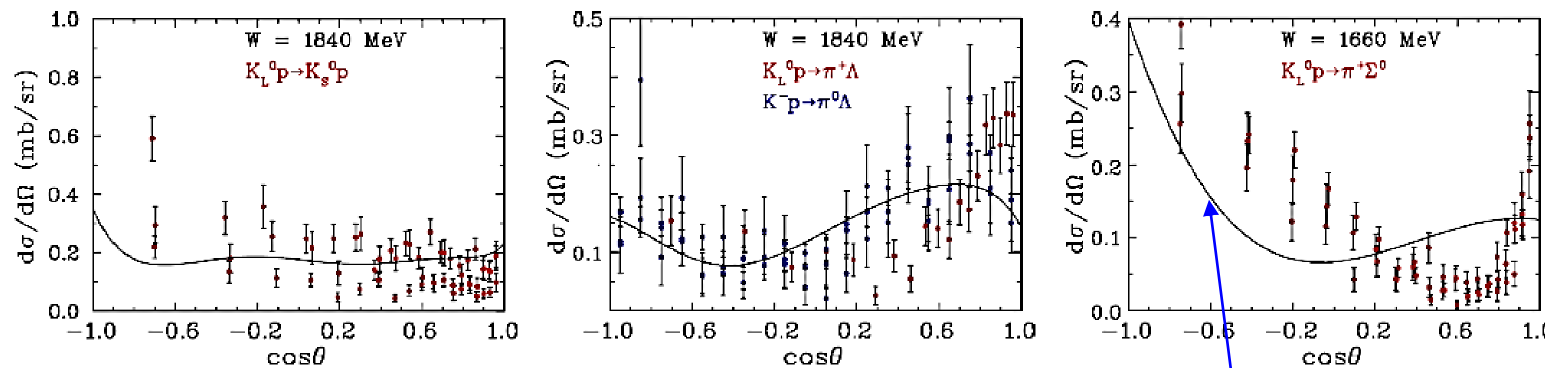
SAID: http://gwdac.phys.gwu.edu/

- 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.

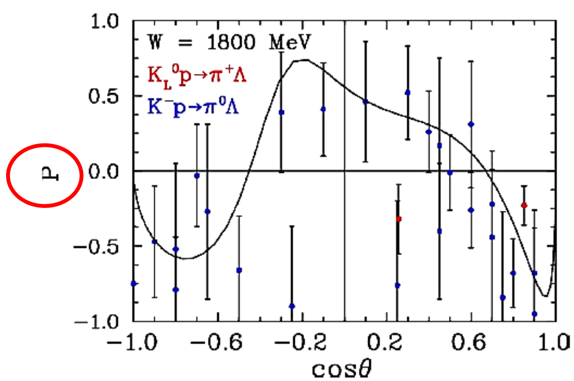


- Limited number of K_L observables in hyperon spectroscopy at present poorly constrain phenomenological analyses.
- Overall systematics of previous experiments varies between 15% & 35%. Energy binning is much broader than hyperon widths.
- There were **no** measurements using polarized target. It means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

Samples of PWA Results for Current DB



- PWA (&) predictions at lower & higher energies have poorer agreement for S ≠ 0 data than for S = 0 data.



- Polarized measurements are tolerable for any PWA solutions.

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

A bit of History

PHYSICAL REVIEW VOLUME 138, NUMBER 5B 7 JUNE 1965

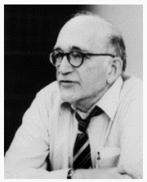
First paper on subject

CP-violation (1964)
Hot topic!

Photoproduction of Neutral *K* Mesons*

S. D. Drell and M. Jacob†
Stanford Linear Accelerator Center, Stanford University, Stanford, California

(Received 6 January 1965)



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.

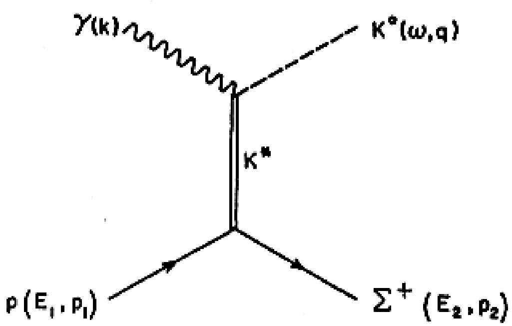


Fig. 1. K^* exchange in photoproduction.

[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.

50 μb/sr

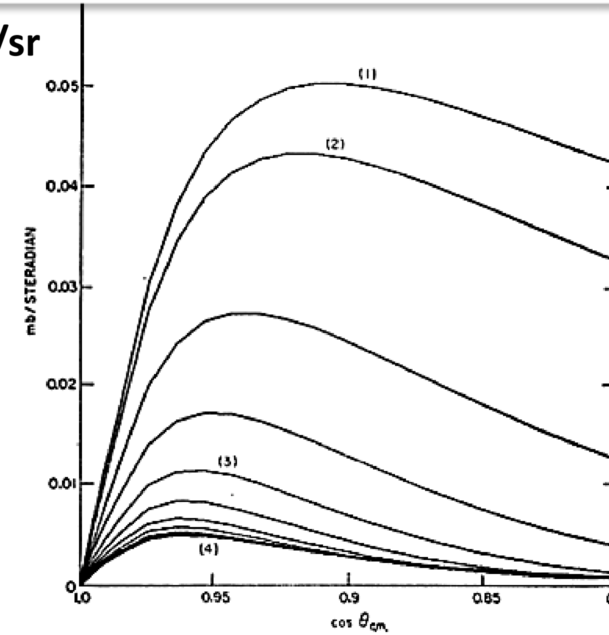


Fig. 3. Center-of-mass differential cross section at 10 BeV. Curve (1) gives the Born approximation. Curve (2) is obtained after subtraction of the $j=\frac{1}{2}$ partial wave. Curves (3) and respectively obtained after the $j=\frac{1}{2}, \frac{3}{2}, \frac{5}{2}, \frac{7}{2}$, and all partial have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

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

VOLUME 22, NUMBER 18 PHYSICAL REVIEW LETTERS 5 MAY 1969

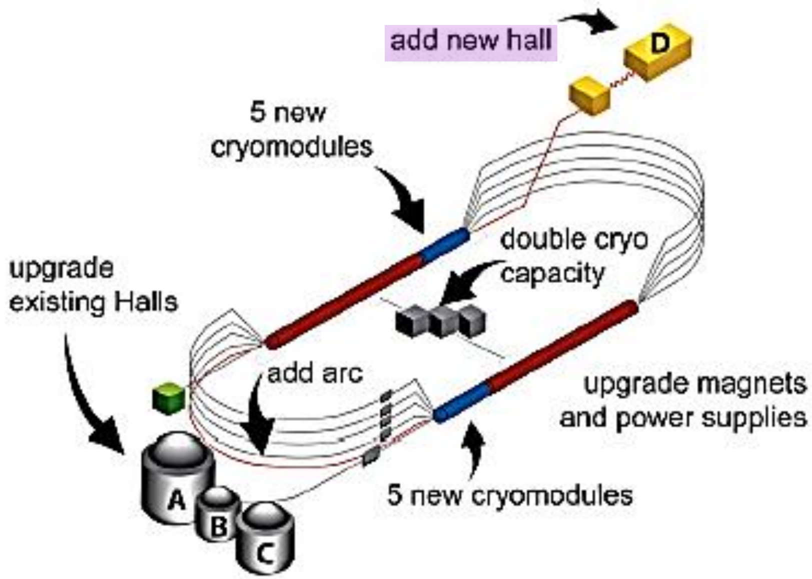
PRODUCTION OF K_2^0 MESONS AND NEUTRONS BY 10- AND 16-GeV ELECTRONS ON BERYLLIUM*

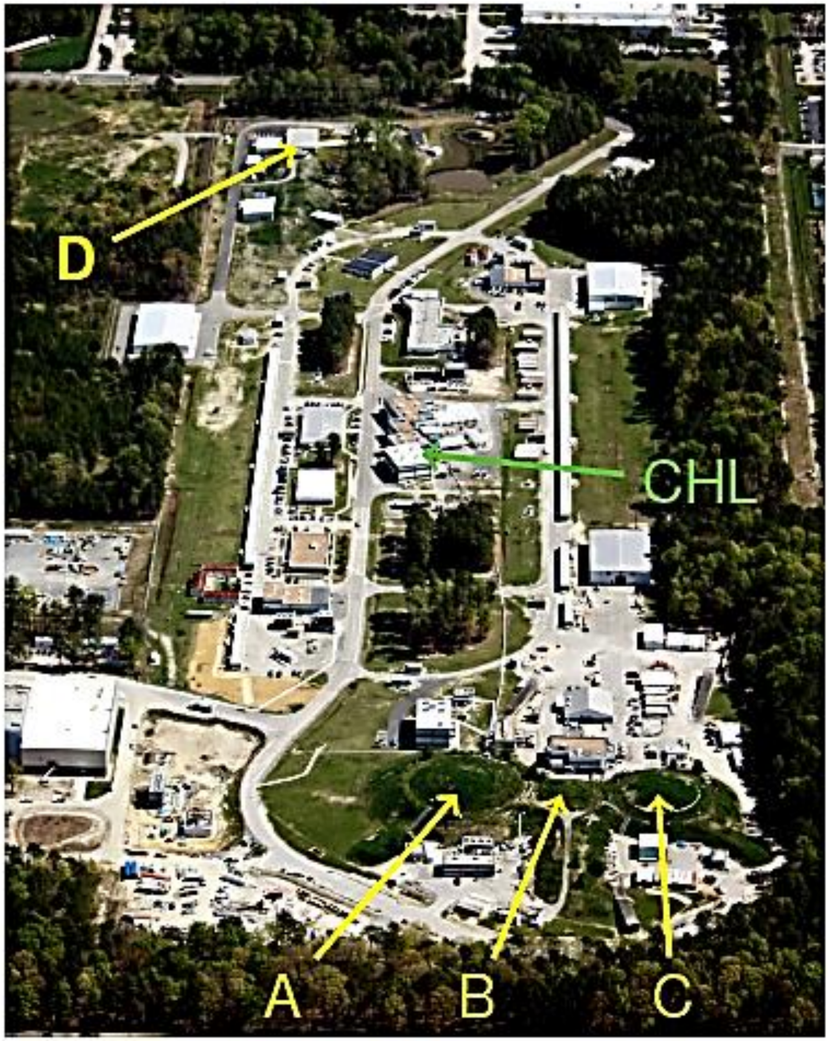
A. D. Brody, W. B. Johnson, D. W. G. S. Leith, G. Loew, J. S. Loos, G. Luste, R. Miller, K. Moriyasu, B. C. Shen, W. M. Smart, and R. Yamartino
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 13 March 1969)

SLAC

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

CEBAF Upgrade to 12 GeV





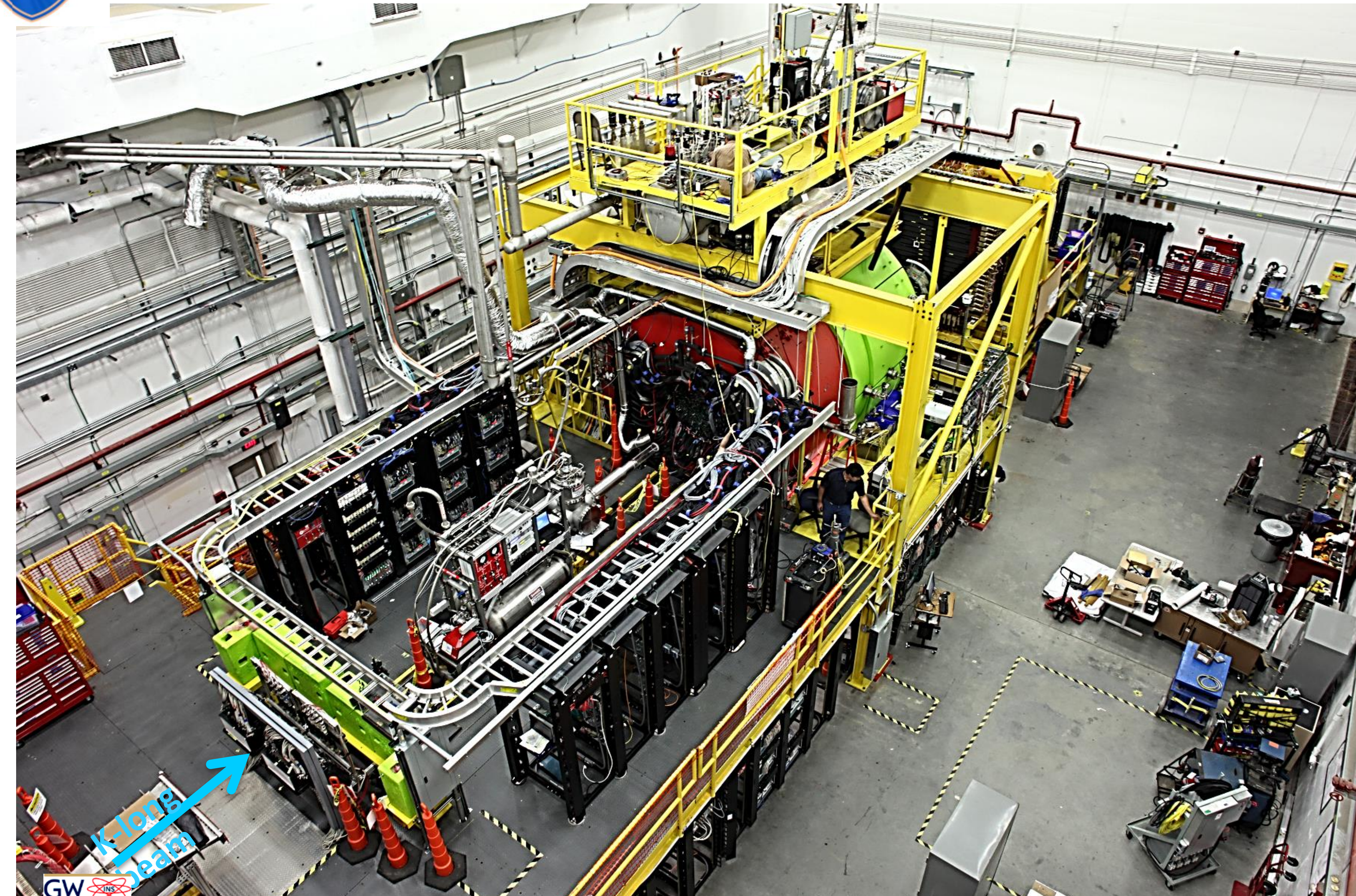
Upgrade Goals

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

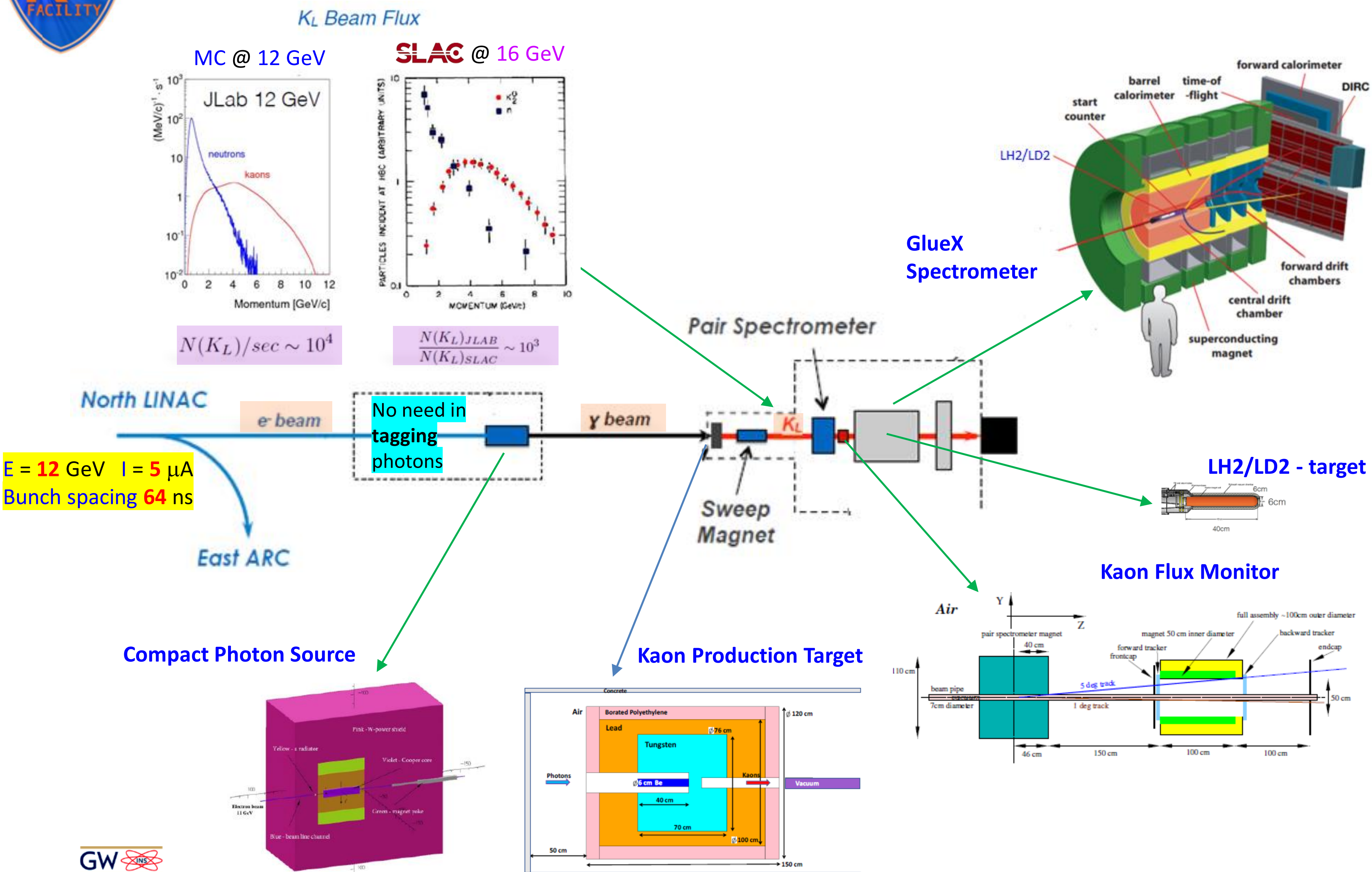
Upgrade Status

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

Hall D/KLF

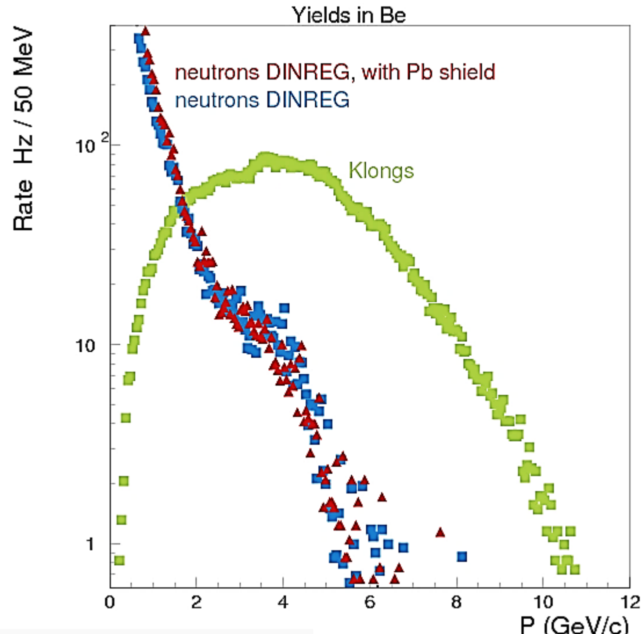


Hall D Beam Line for K-longs



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

MC @ 12 GeV



SLAC Data @ 16 GeV

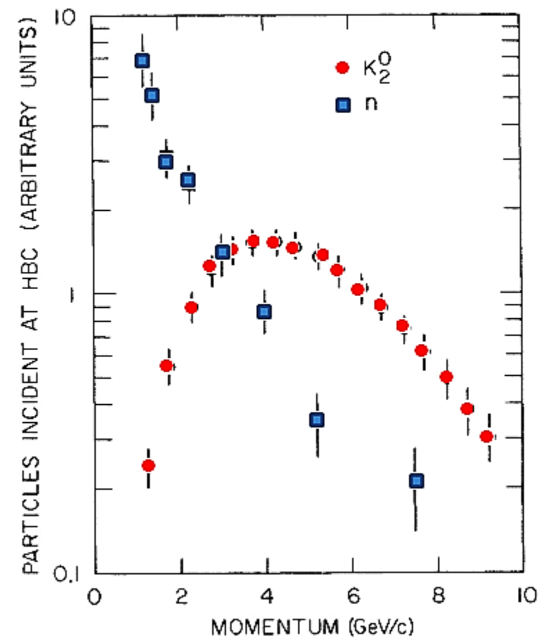
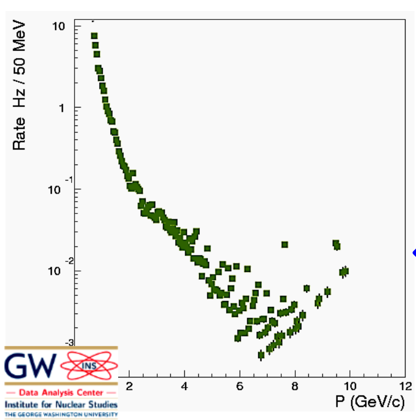


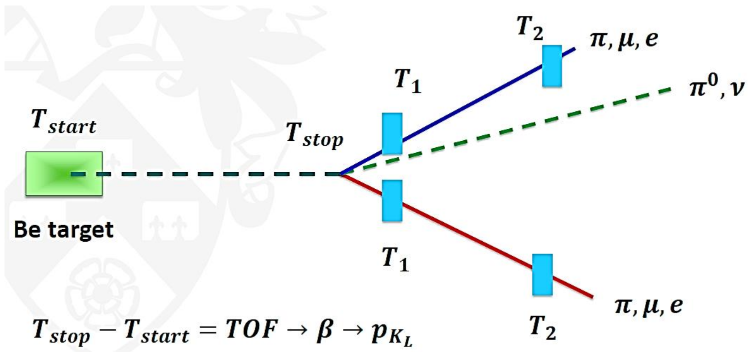
FIG. 2. Comparison of the neutron and $K_2{}^0$ fluxes at the hydrogen bubble chamber for 2° production with 16-GeV electrons. A.D. Brody *et al* Phys Rev Lett **22**, 966 (1969)



Flux ratio n/K_L

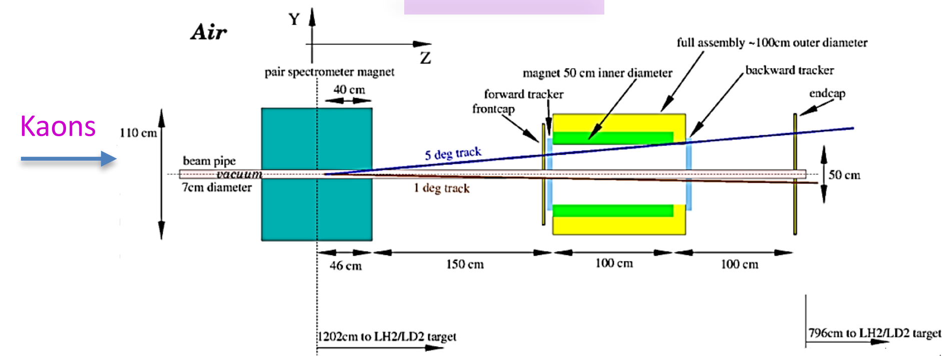
- Delivered with 64 ns bunch spacing avoids overlap in range of p = 0.35 – 10.0 GeV/c.

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

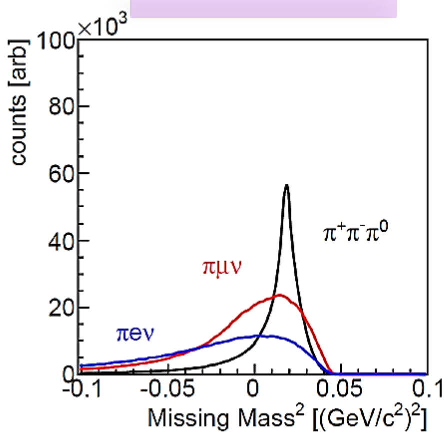


Magnet, 1m long, 50 cm diameter

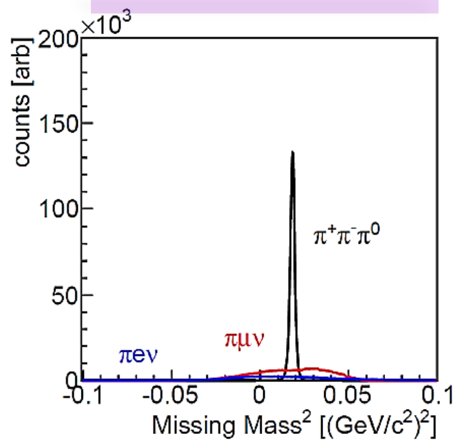
Flux Monitor



TOF reconstruction



Magnetic reconstruction



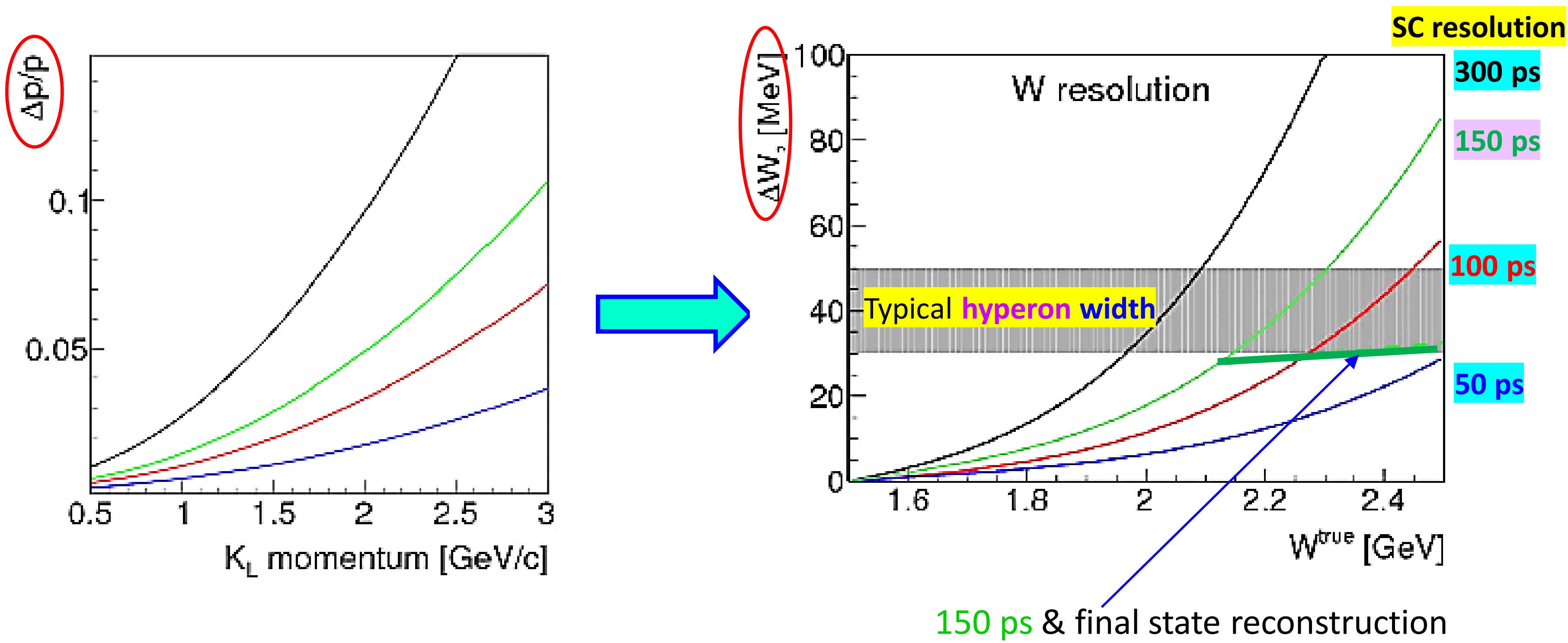
Stat Err < 1%
Syst Err ~5%

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).

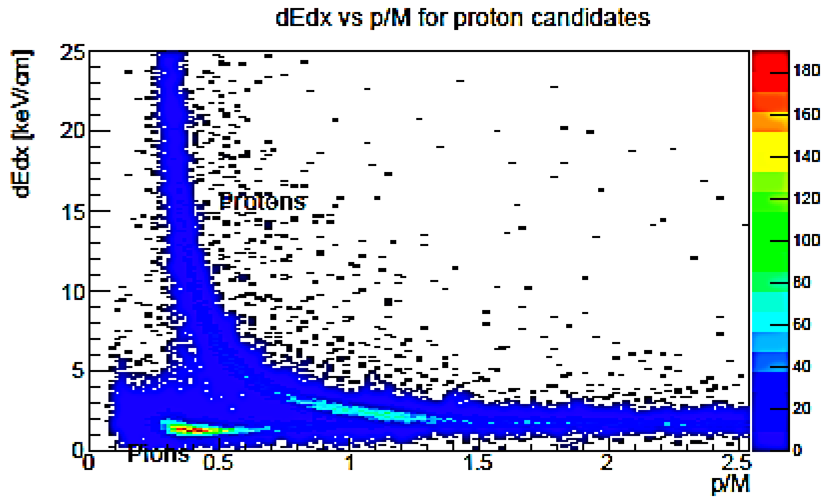
Thus, it is possible to perform measurements of K_Lp scattering at lower energies than K^-p scattering due to high beam flux.

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

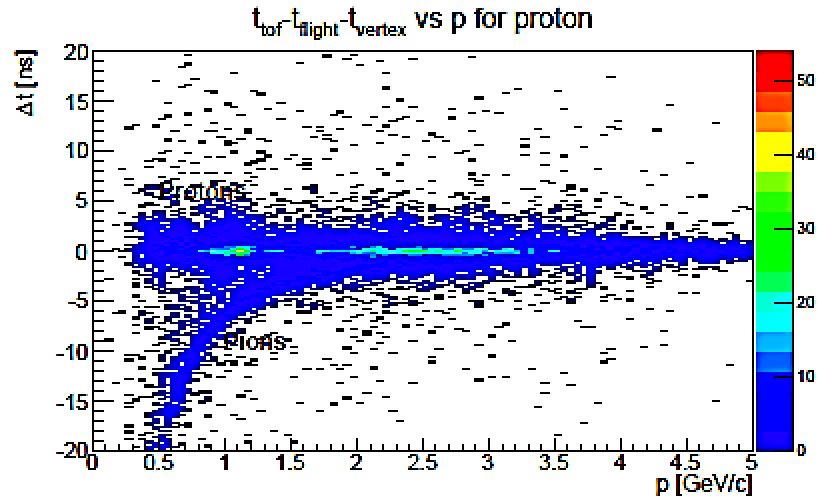


Expected Particle Identification with GlueX

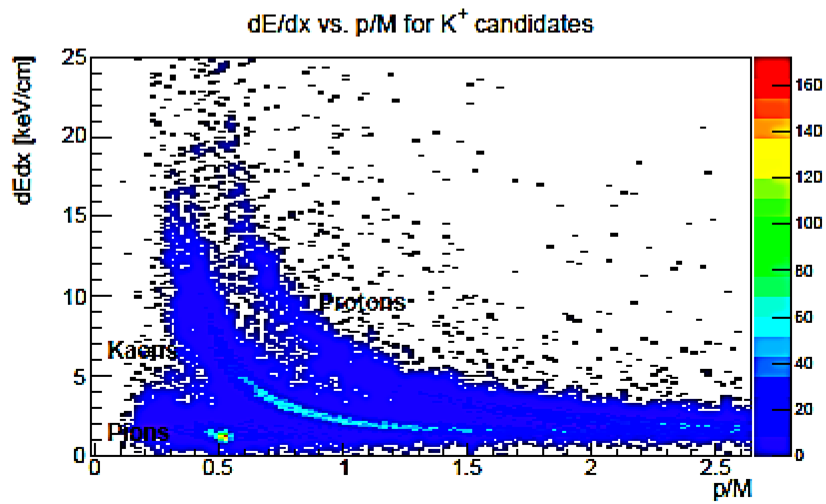
- dE/dx for pK_S.



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



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



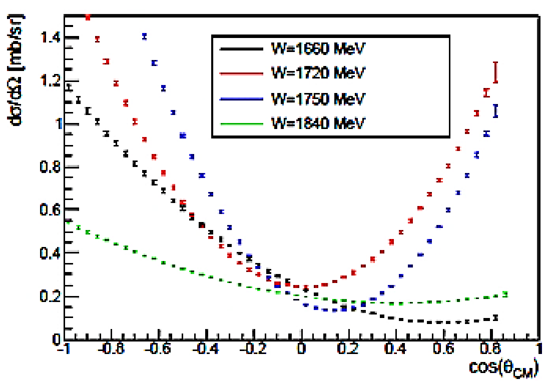
Expected Cross Sections vs Bubble Chamber Data

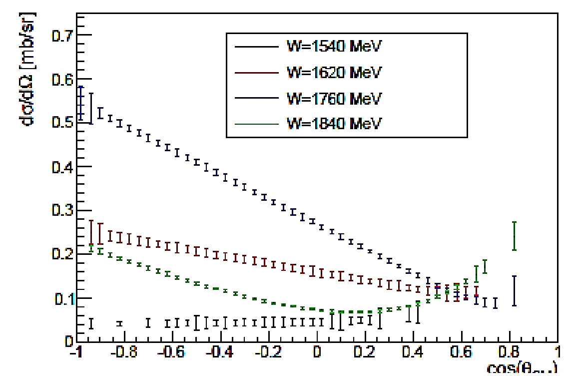
- measurements will span cosθ from –0.95 to 0.95 in CM above W = 1490 MeV.

- K_L rate is 10^4 K_L/s = 2500 x
- Uncertainties (statistics only) correspond to 100 days of running time for:

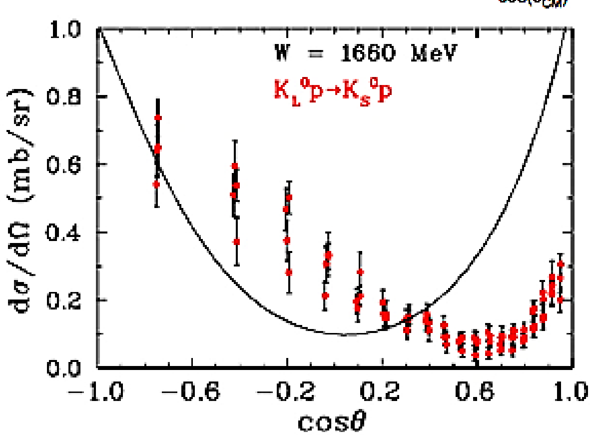
$K_L p \rightarrow K_S p$ | $K_L p \rightarrow \pi^+ \Lambda$

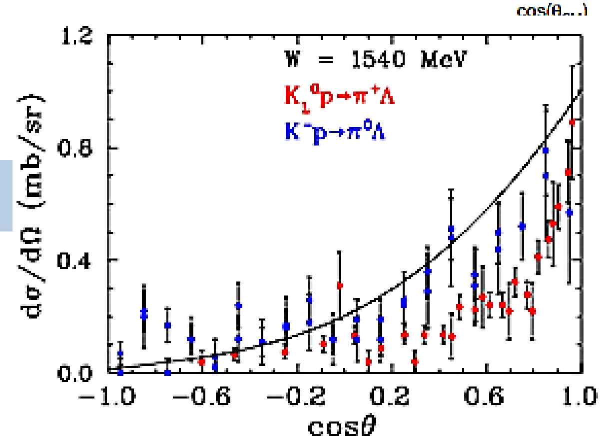
Expected Data





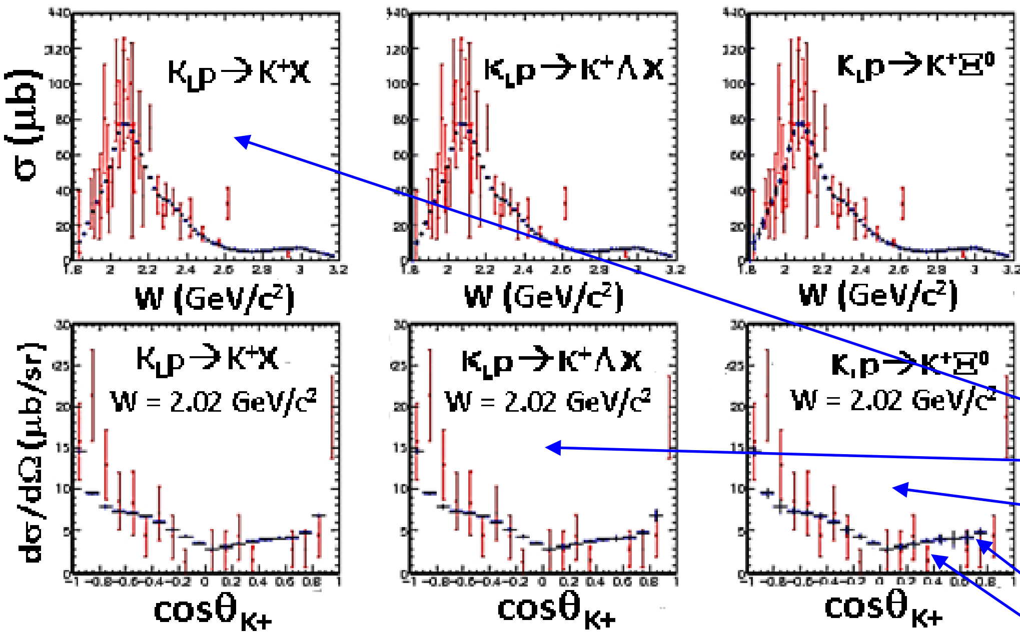
BC Data





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

- Total & diff Xsec for different topologies

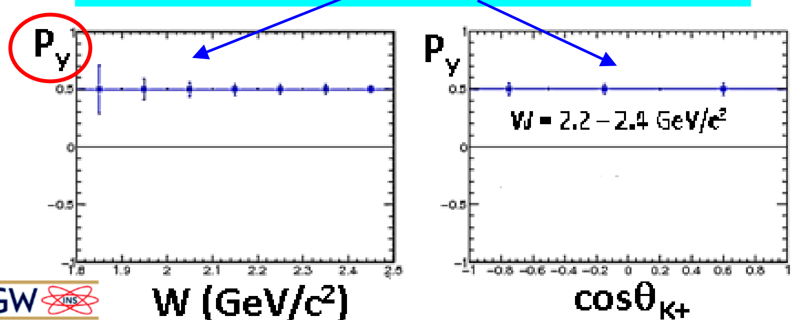


Reconstructed
- K^+
- $K^+\Lambda$
- $K^+\Sigma^0$

KLF data (100 d)
Existing data

PDG 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

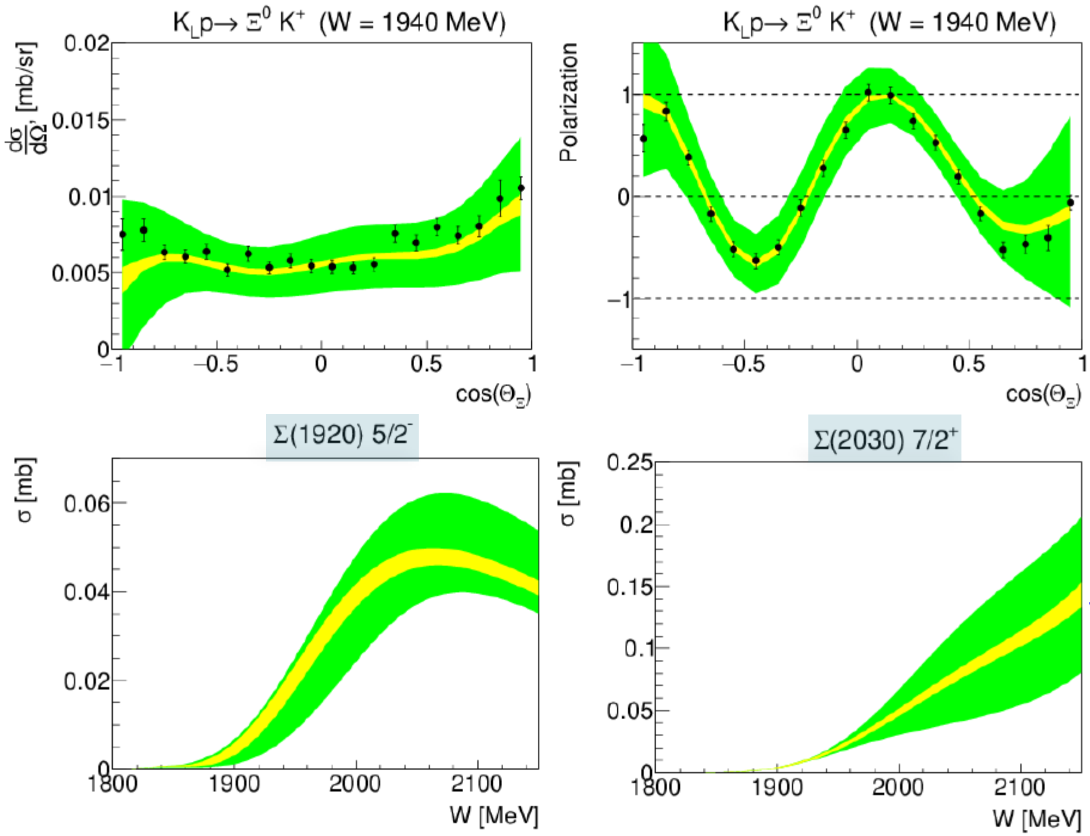
- Recoil Polarization for one-fold differential
  two-fold differential



$$K_l p \to K^+\overrightarrow{\Xi^0} \to K^+\vec{\Lambda}\pi^0 \to K^+p\pi^-\pi^0$$

(measured, reconstructed)

Impact Proposed Data on PWA



- At least **100** days needed to get precise solution.

20 days

100 days

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

Resonance	20 days: M, Γ	100 days: M, Γ	PDG: M, Γ	hadspec M
Σ(1920)5/2⁻	1977±21±25 327±25±25	1923±10±10 321±10±10	?	2027 2487 2659 2781
Σ(2030)7/2⁺	1981±30±30 350±80	1930±20±30 400±40	2030±10 180±30	2686 2709 2793 2806

Summary

- Our goal is
  - To establish KL Facility at Jefferson Lab (Thomas Jefferson National Accelerator Facility).
  - To do measurements which bring new physics.

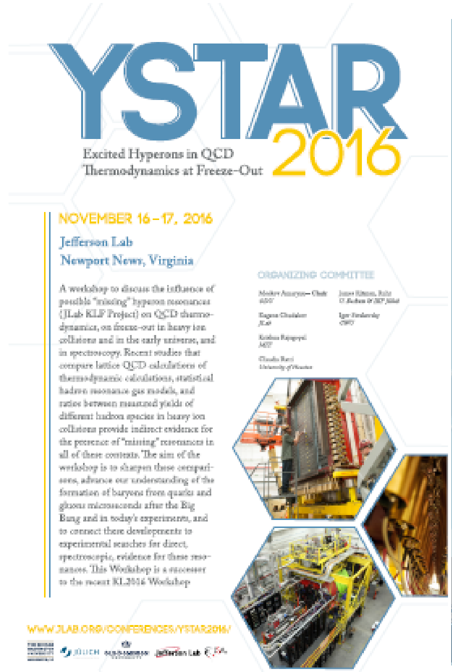
- Here we reviewed what can be learned by studying $K_L p$ & $K_L n$ scattering leading to two–body final states (1st stage).
  <u>At later stages</u>, we plan to do $K_L N$ on aka  with hydrogen & deuterium.

- Jefferson Lab (Thomas Jefferson National Accelerator Facility) 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 PAC48 in 2020, WELCOME to JOIN US.

GW INS — Data Analysis Center — Institute for Nuclear Studies THE GEORGE WASHINGTON UNIVERSITY



KL2016
[60 people from 10 countries, 30 talks] https://www.jlab.org/conferences/kl2016/
OC: M. Amaryan, E. Chudakov, C. Meyer, M. Pennington, J. Ritman, & I. Strakovsky

YSTAR2016
[71 people from 11 countries, 27 talks] https://www.jlab.org/conferences/YSTAR2016/
OC: M. Amaryan, E. Chudakov, K. Rajagopal, C. Ratti, J. Ritman, & I. Strakovsky

HIPS2017
[43 people from 4 countries, 19 talks] https://www.jlab.org/conferences/HIPS2017/
OC: T. Horn, C. Keppel, C. Munoz-Camacho, & I. Strakovsky

PKI2018
[48 people from 9 countries, 27 talks] http://www.jlab.org/conferences/pki2018/
OC: M. Amaryan, U.-G. Meissner, C. Meyer, J. Ritman, & I. Strakovsky

In total: 222 participants & 103 talks

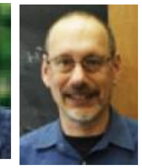
Vielen Dank für die Einladung und Ihre Aufmerksamkeit

Backup Slides

Why We Have to Measure Double-Strange Cascades in Jefferson Lab

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

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

- If they don't, that scaling failure implies that structures of corresponding states are anomalous, & very different from one another.

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

- So far only hyperon resonance multiplet, where this scaling can be ``tested" & seen is lowest negative parity multiplet:

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

Courtesy of Dan-Olof Riska, 2017

- 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.

PDG particle data group

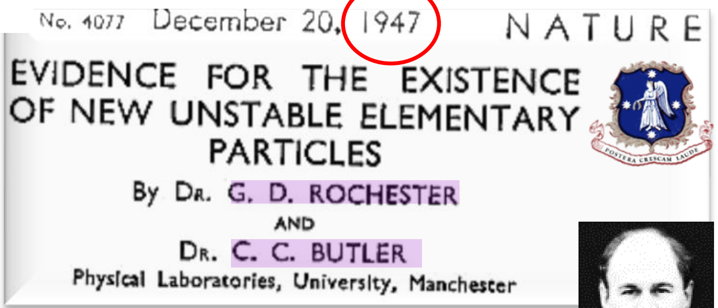
Particle	J^P	Overall status	Status as seen in — $\Xi\pi$	ΛK	ΣK	$\Xi(1530)\pi$	Other channels
$\Xi(1318)$	1/2+	****					Decays weakly
$\Xi(1530)$	3/2+	****	****				
$\Xi(1620)$		*	*				
$\Xi(1690)$		***		***	**		
$\Xi(1820)$	3/2−	***	**	***	**	**	
$\Xi(1950)$		***	**	**		*	
$\Xi(2030)$		***		**	***		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

- Jefferson Lab (Thomas Jefferson National Accelerator Facility) 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)

A bit of History for Hyperons

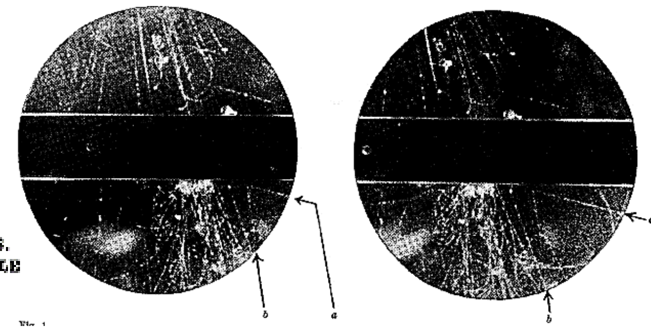

No. 4077 December 20, 1947 NATURE

EVIDENCE FOR THE EXISTENCE OF NEW UNSTABLE ELEMENTARY PARTICLES

By Dr. G. D. ROCHESTER AND Dr. C. C. BUTLER

Physical Laboratories, University, Manchester

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

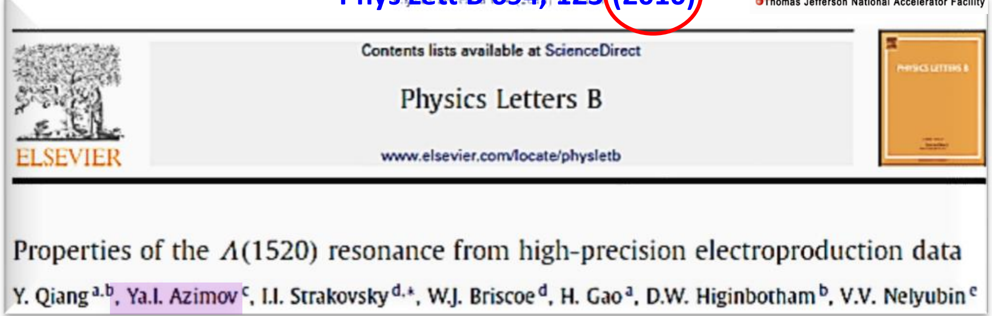


STEREOSCOPIC PHOTOGRAPHS SHOWING AN UNUSUAL FORK (a b) IN THE GAS. THE DIRECTION OF THE MAGNETIC FIELD IS SUCH THAT A POSITIVE PARTICLE COMING DOWNWARDS IS DEVIATED IN AN ANTICLOCKWISE DIRECTION

- Pole position in complex energy plane for hyperons has began 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

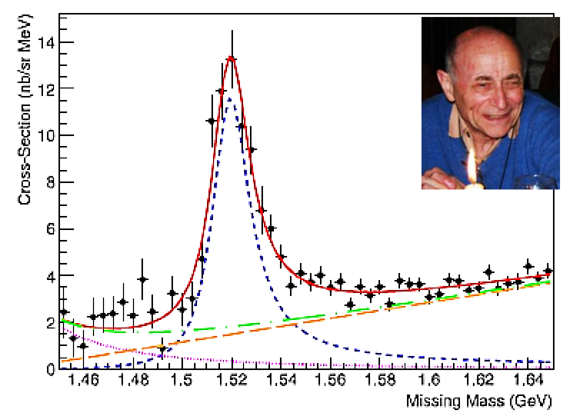
Physics Letters B

www.elsevier.com/locate/physletb

ELSEVIER

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[e]



Time Request

- Expected statistics for differential cross sections of different reactions with LH_2 & below W = 3.0 GeV for 100 days of beam time:

For $d\sigma/d\Omega$

Reaction	Statistics (events)
$K_L p \to K_S p$	2.7M
$K_L p \to \pi^+ \Lambda$	7M
$K_L p \to K^+ \Xi^0$	2M
$K_L p \to K^+ n$	60M
$K_L p \to K^- \pi^+ p$	7M

⟹ For P, statistics is 0.2M

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

- Expected systematics is 10% or less.