Proposal for JLab PAC45

Strange Hadron Spectroscopy with a Secondary KL Beam at GlueX

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GlueX Collaboration

JLab PAC 45 Meeting, July 10, 2017

Outline

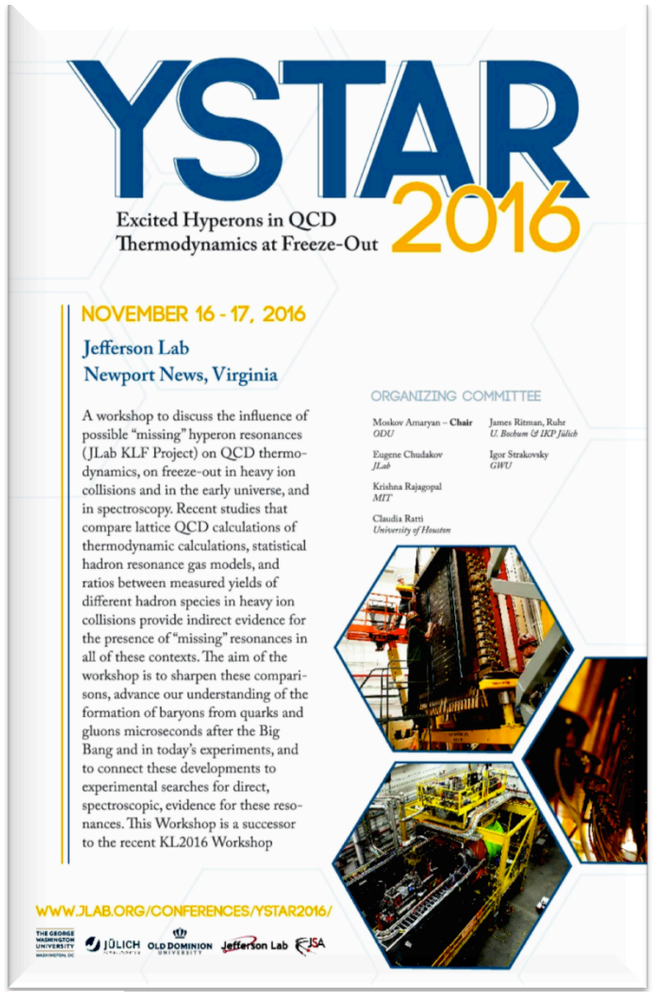
- Physics Motivation:

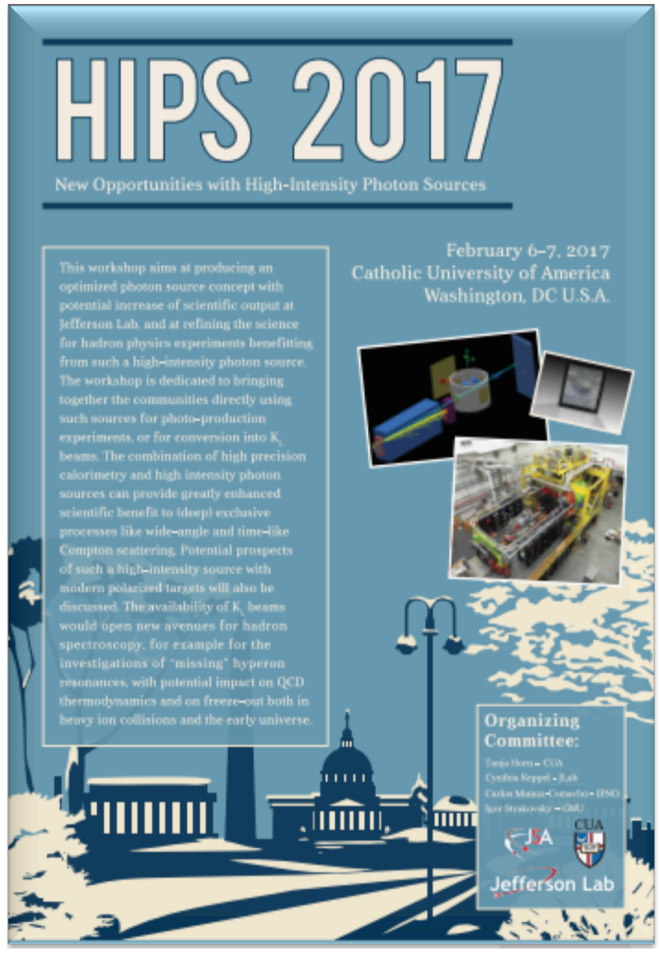
  -Hyperon Spectroscopy

  -Meson Spectroscopy

- Previous measurements
- The KL Facility at JLab
- Proposed measurements
- Summary

- This proposal follows LOI submitted to PAC43 in 2015
- Since then we organized 3 International Workshops to discuss physics and experimental aspects of K_L Facility at JLab:



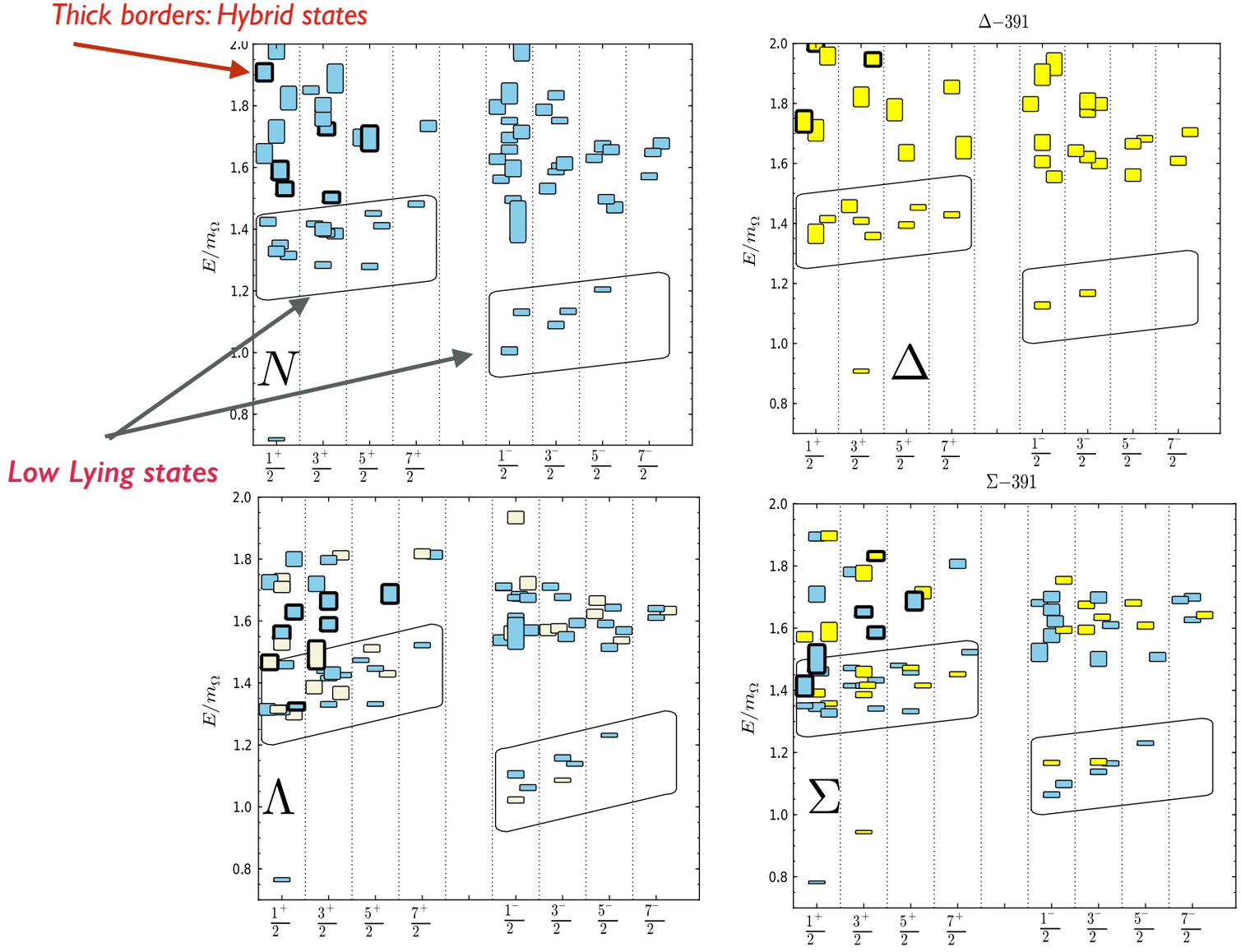


- Our proposal is based on a broader community input and has benefited from all these discussions and talks significantly

Hyperon Spectroscopy

Lattice QCD calculations

Thick borders: Hybrid states

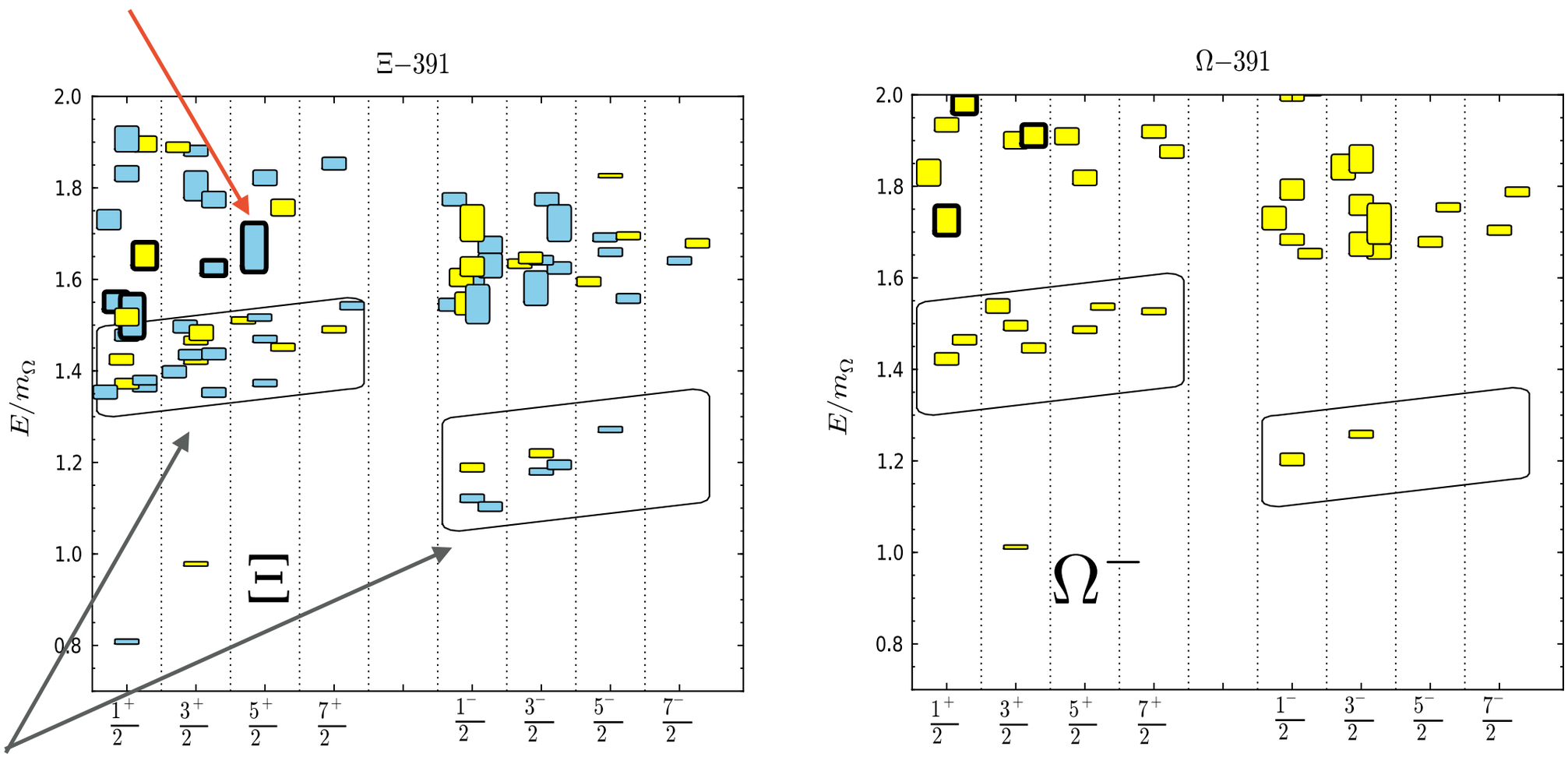


Low Lying states

Edwards, Mathur, Richards and Wallace
Phys. Rev. D 87, 054506 (2013)

Lattice QCD calculations

Thick borders: Hybrid states



Low Lying states

Edwards, Mathur, Richards and Wallace
Phys. Rev. D 87, 054506 (2013)

Strange Mesons

almost half

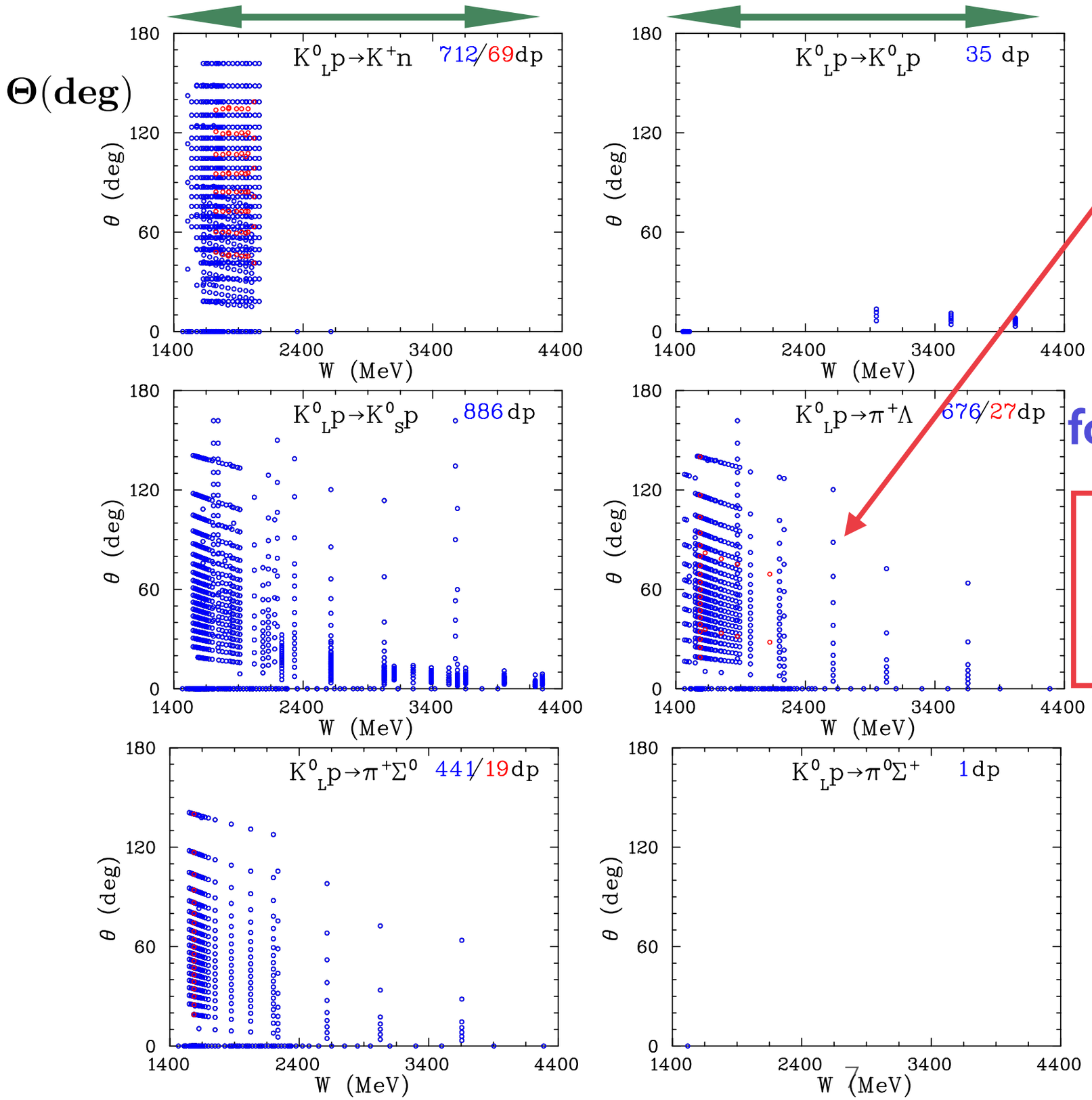
not measured

STRANGE ($S = \pm 1$, $C = B = 0$)	$I(J^P)$	STRANGE ($S = \pm 1$, $C = B = 0$)	$I(J^P)$
• $K^{\pm}$	$1/2(0^-)$	• $K^*(1680)$	$1/2(1^-)$
• K^0	$1/2(0^-)$	• $K_2(1770)$	$1/2(2^-)$
• K_S^0	$1/2(0^-)$	• $K_3^*(1780)$	$1/2(3^-)$
• K_L^0	$1/2(0^-)$	• $K_2(1820)$	$1/2(2^-)$
$K_0^*(800)$	$1/2(0^+)$	$K(1830)$	$1/2(0^-)$
• $K^*(892)$	$1/2(1^-)$	$K_0^*(1950)$	$1/2(0^+)$
• $K_1(1270)$	$1/2(1^+)$	$K_2^*(1980)$	$1/2(2^+)$
• $K_1(1400)$	$1/2(1^+)$	• $K_4^*(2045)$	$1/2(4^+)$
• $K^*(1410)$	$1/2(1^-)$	$K_2(2250)$	$1/2(2^-)$
• $K_0^*(1430)$	$1/2(0^+)$	$K_3(2320)$	$1/2(3^+)$
• $K_2^*(1430)$	$1/2(2^+)$	$K_5^*(2380)$	$1/2(5^-)$
$K(1460)$	$1/2(0^-)$	$K_4(2500)$	$1/2(4^-)$
$K_2(1580)$	$1/2(2^-)$	$K(3100)$	$?^?(?^{??})$
$K(1630)$	$1/2(?^?)$		
$K_1(1650)$	$1/2(1^+)$		

Previous Measurements

JLab KL Facility

JLab KL Facility



Very scarce data

especially at high W

red points: recoil polarization

in total < 2 K points

for a comparison there are:

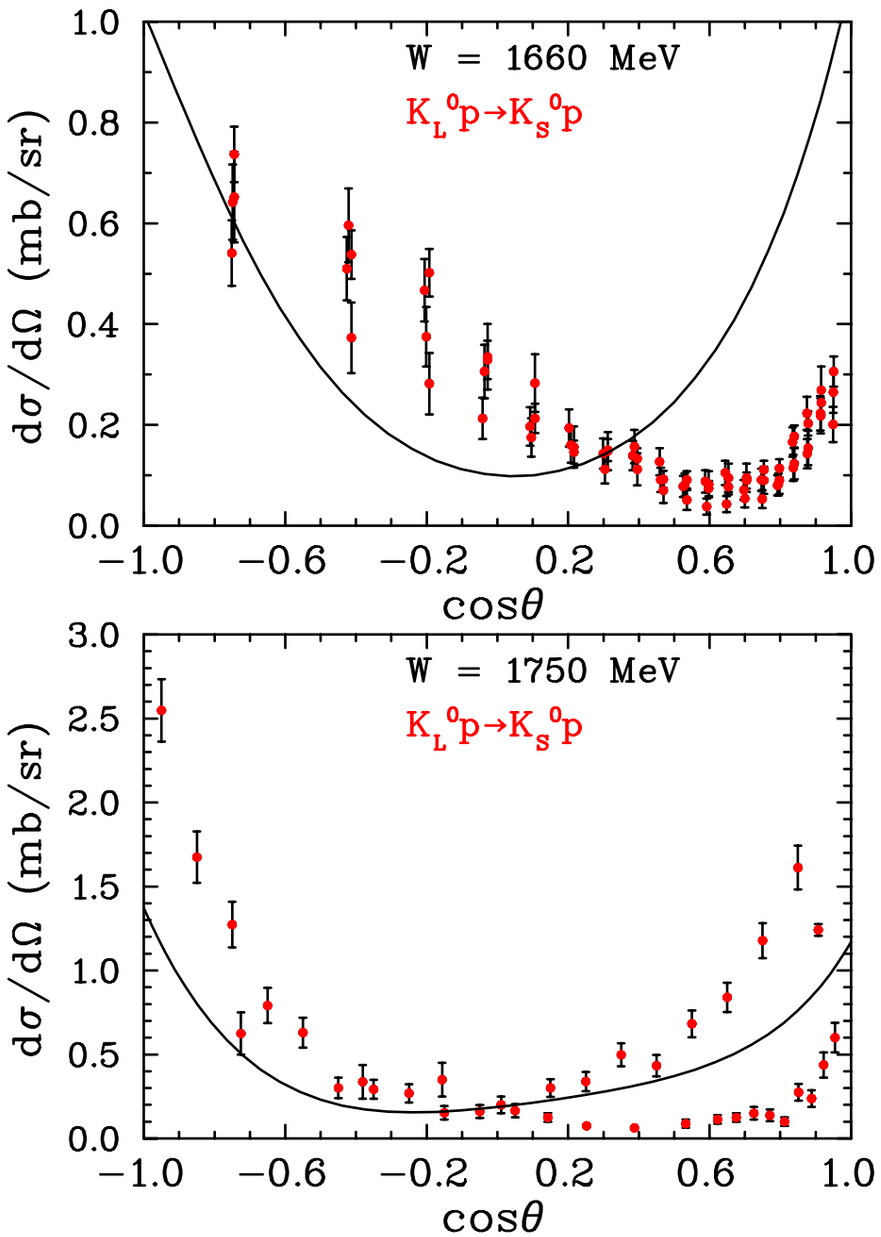
$\pi N \to \pi N$ **51 K points**

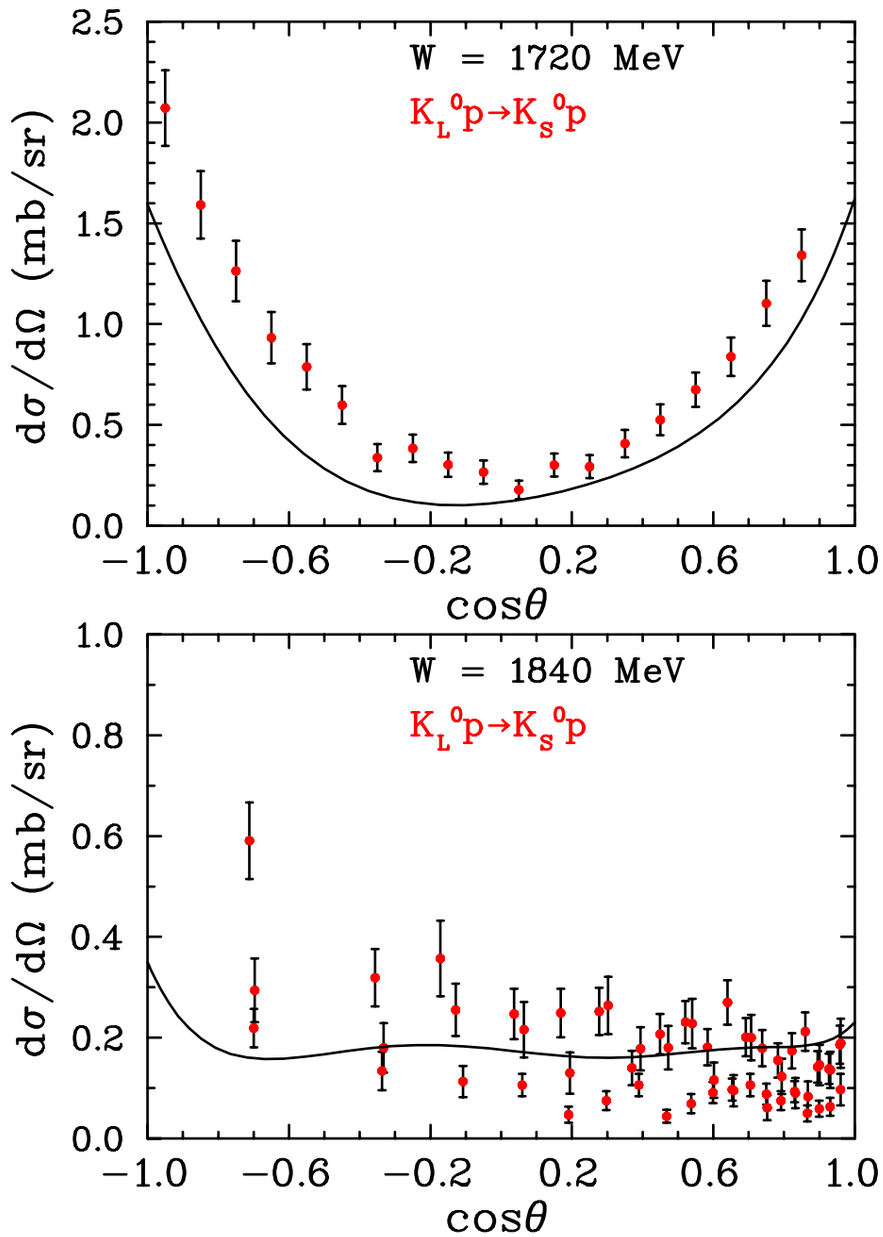
$\gamma N \to \pi N$ **39 K points**

no data on neutron target

W(MeV)

Previous Measurements

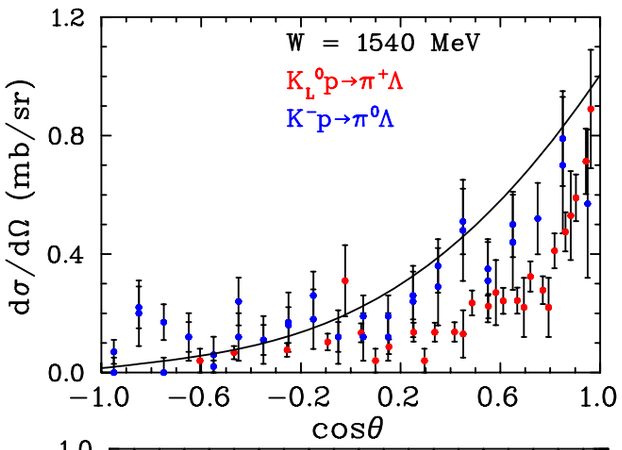


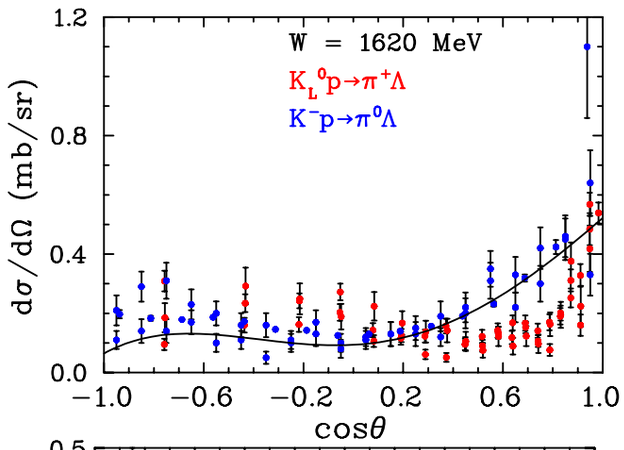


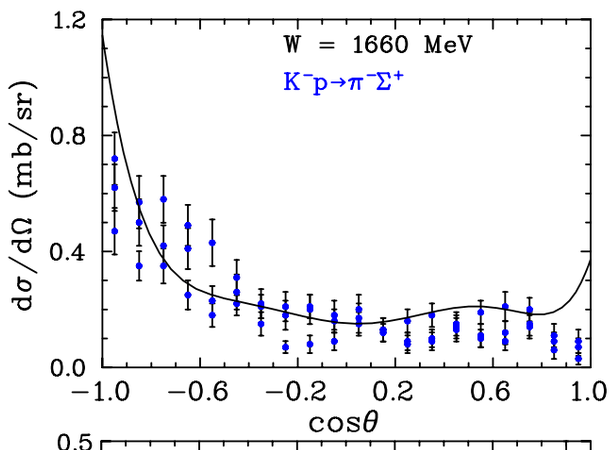
- **Inconsistent data significantly limit confidence level for any model and Partial Wave Analysis**

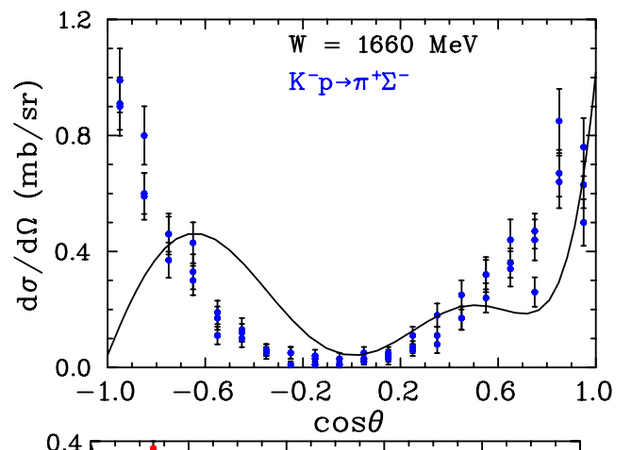
Previous Measurements

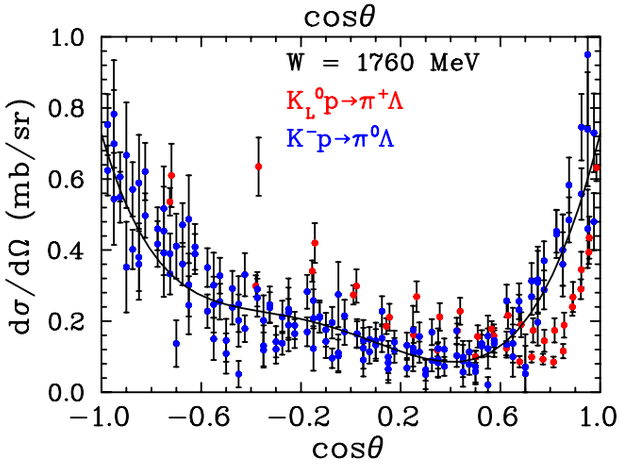
Cross sections

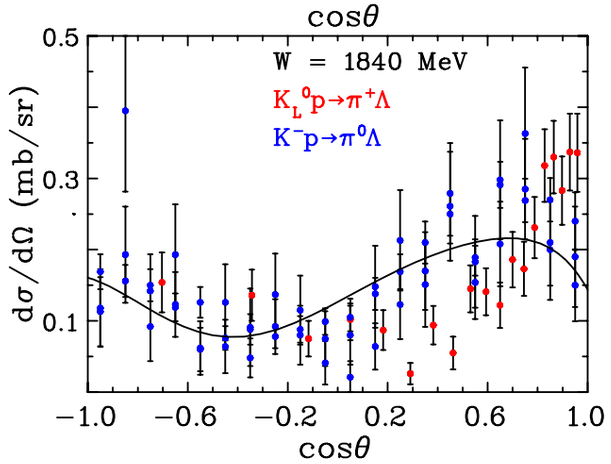


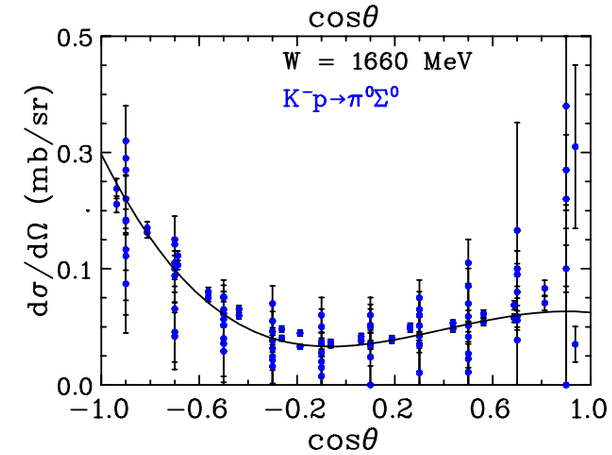


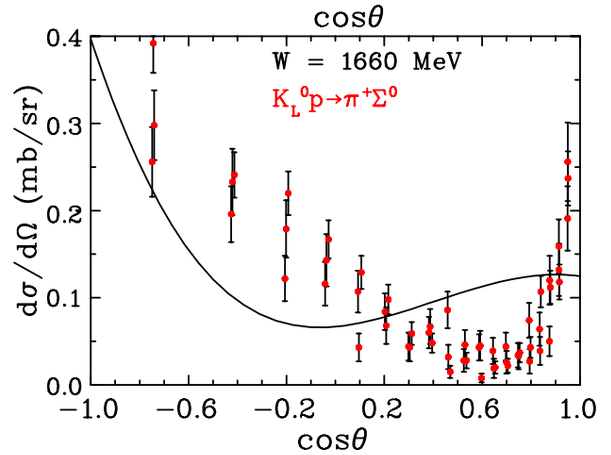


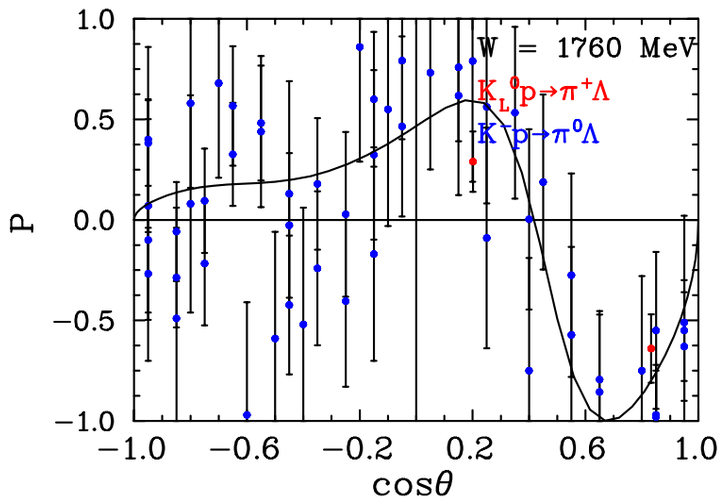


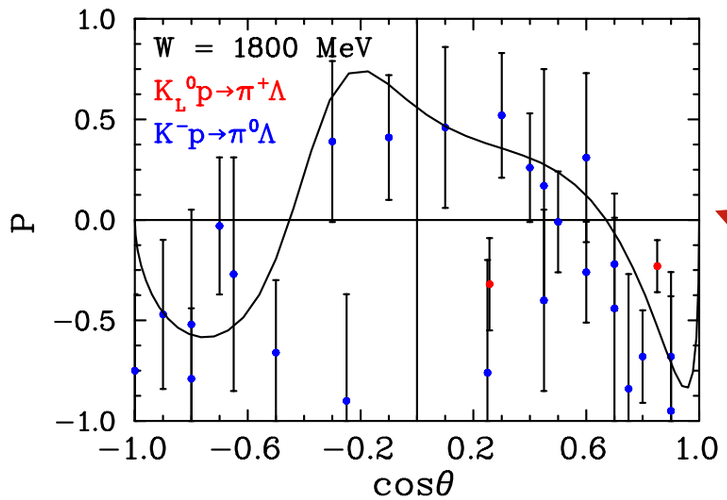












not well measured

recoil polarization

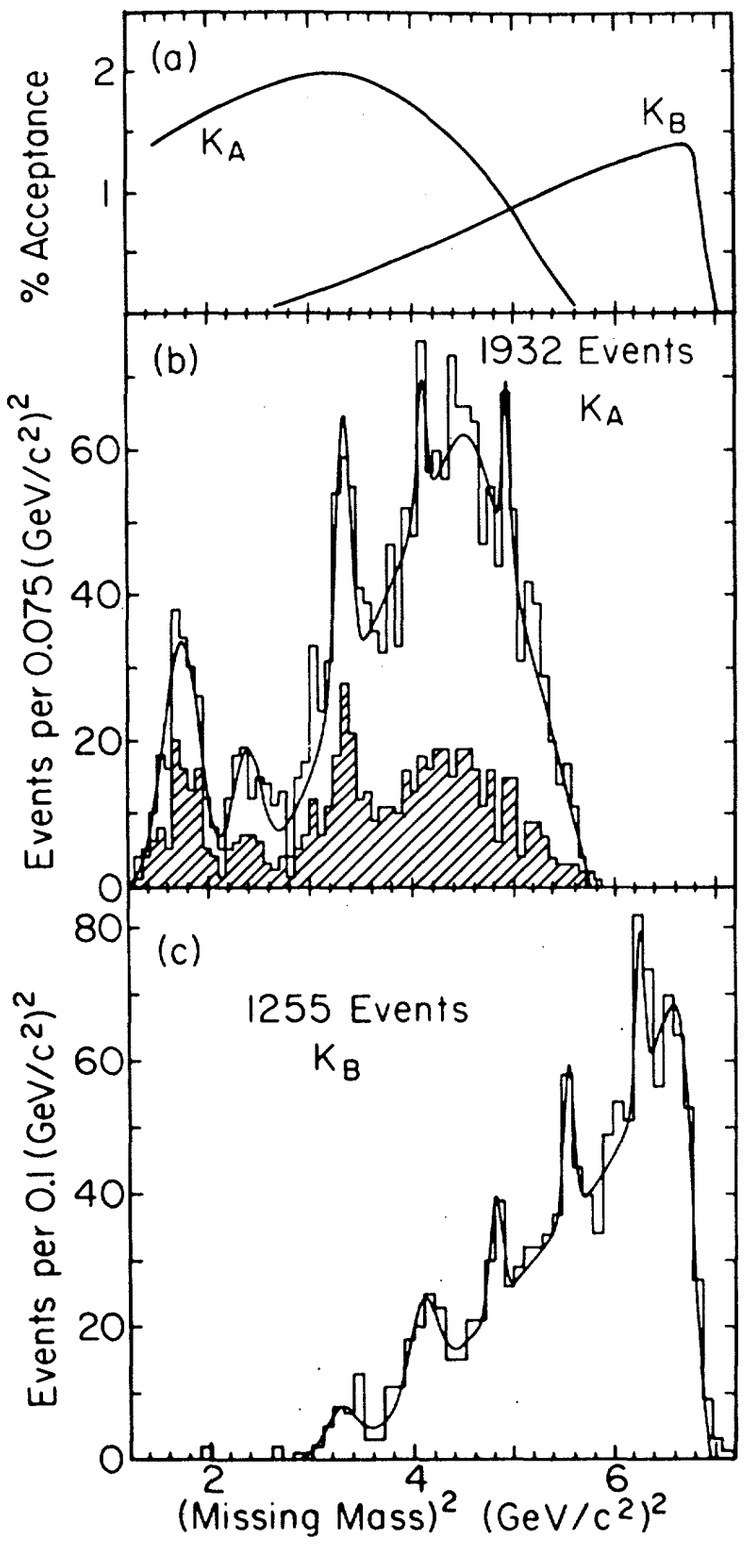
- **not sensitive to any model and PWA**

Experimental data on Ξ^*

Very poorly measured at AGS (BNL) 34 years ago

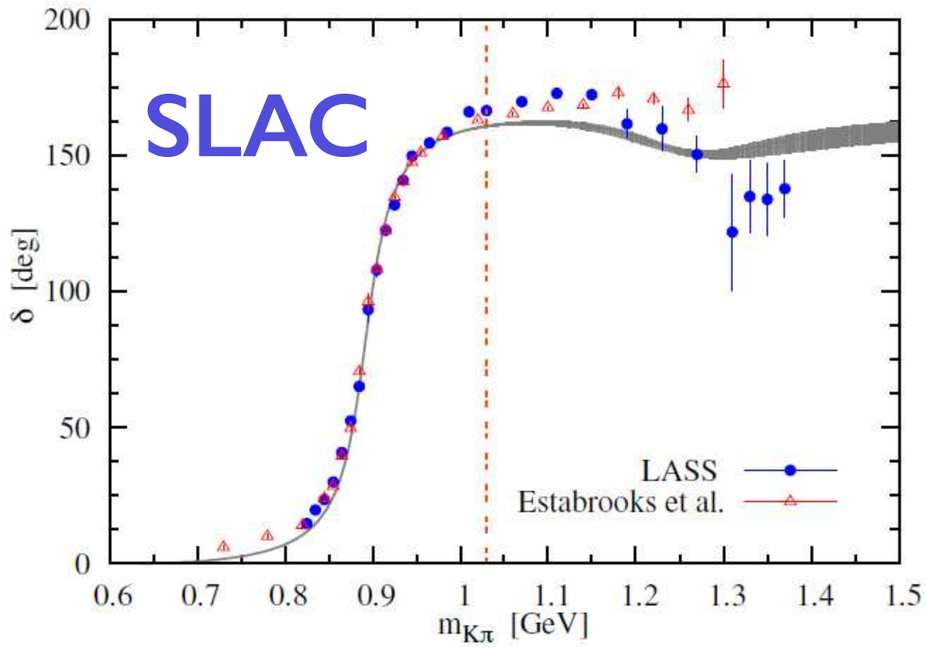
. **C.M. Jenkins et al., Phys. Rev. Lett. 51, 951 (1983)**

- **However clear Indications for excited states**



$K^{\pm}p \to K^{\pm}\pi^{+}n$: $K\pi$ **Scattering**

P-wave I=1/2

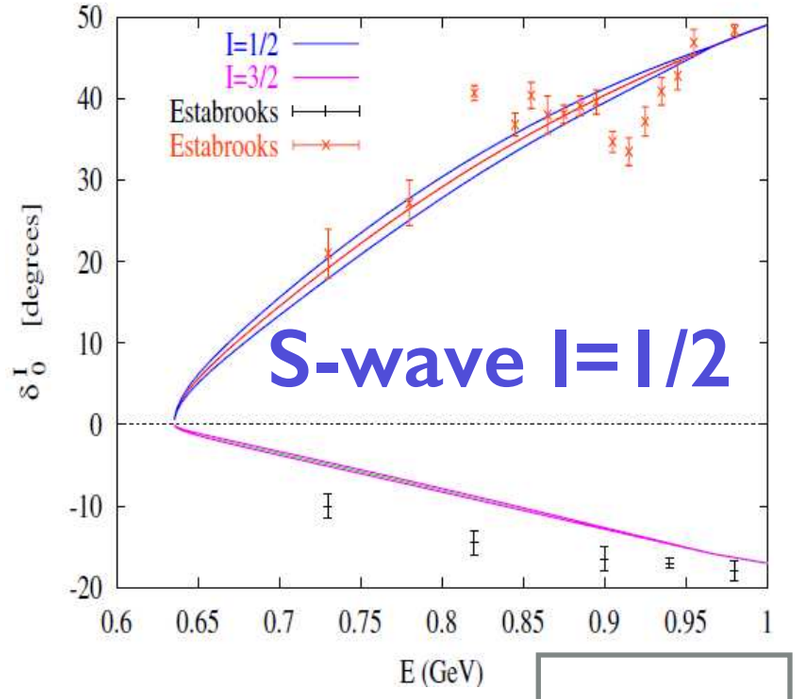


tau data

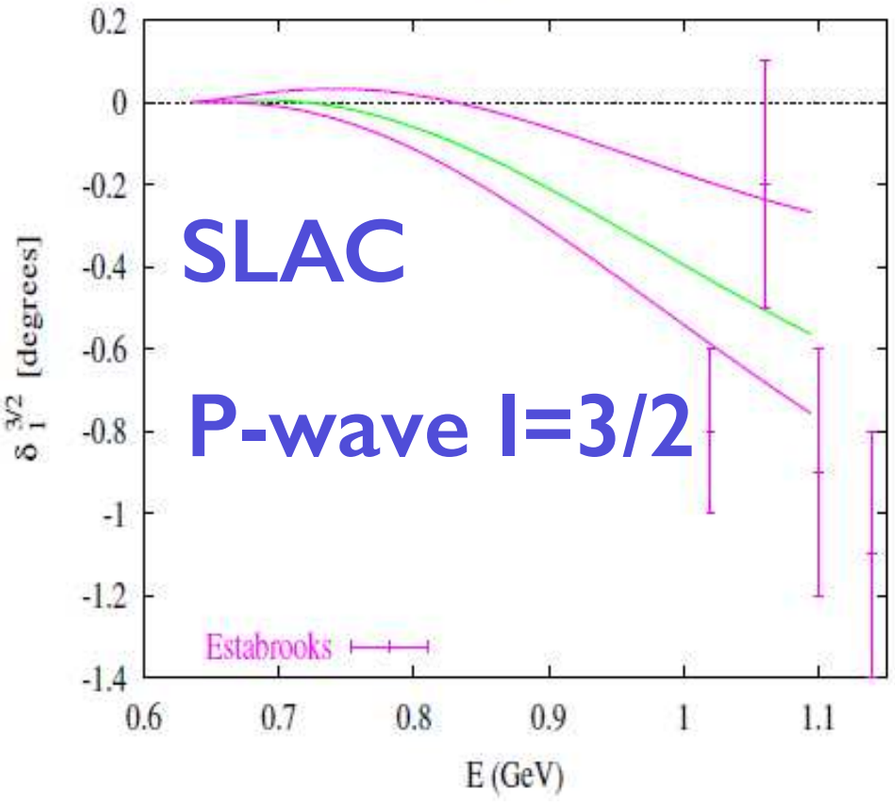
$\tau \to K\pi\nu_\tau$

$\mathbf{M(K\pi)}$

SLAC



$\mathbf{M(K\pi)}$



$\mathbf{M(K\pi)}$

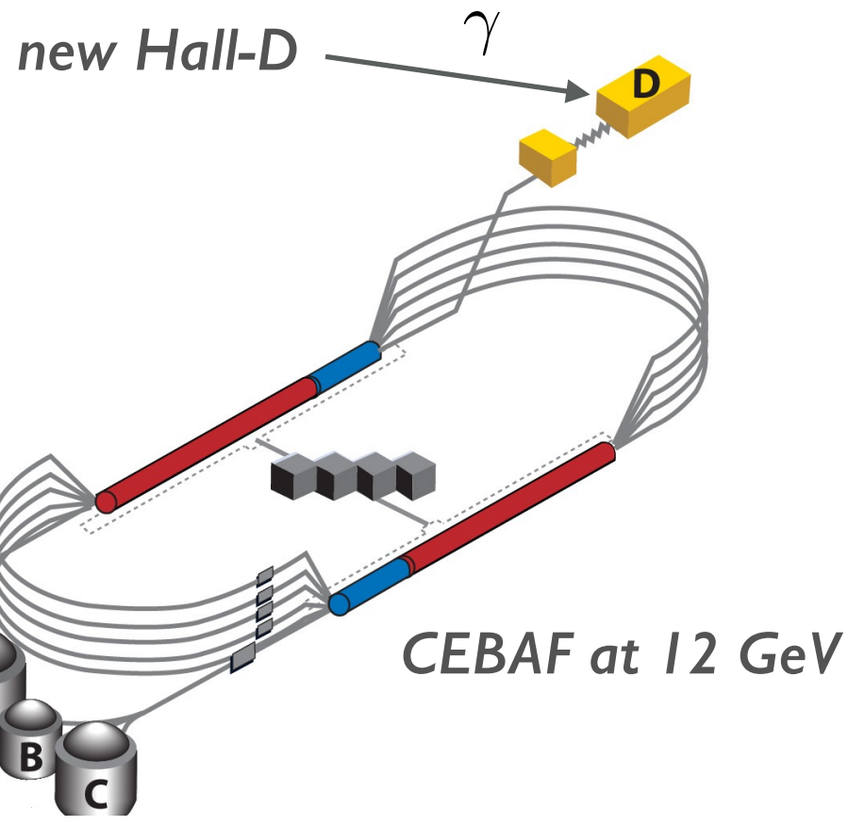
After 50 years still state of the art.

- **New measurements needed !**

How to make a kaon beam?

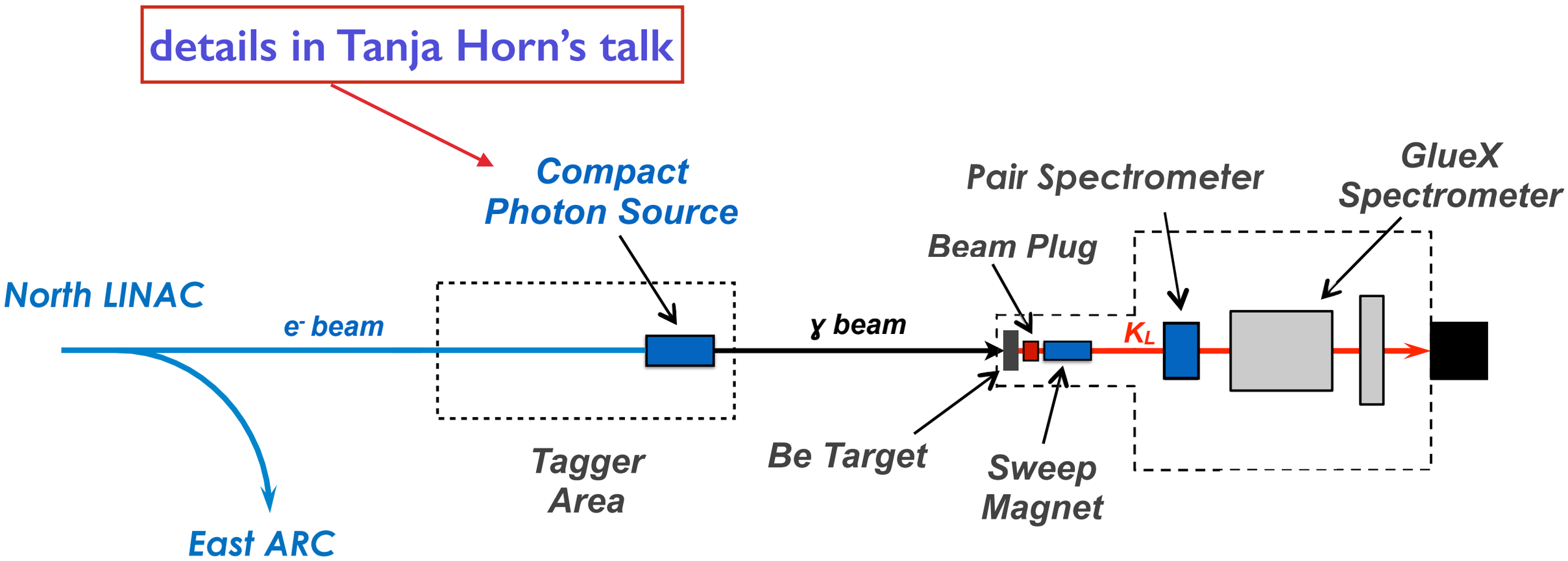
Thomas Jefferson National Accelerator Facility

Aerial View



CEBAF at 12 GeV

KL Beam



- Compact Photon Source
- Radiator 0.1 R.L.

- Be target 40cm
- Distance Be-LH2 16m
- LH2 target 40cm
- LH2 target R=3cm

K^0_L beam (continued)

-Electron beam with $I_e = 5\mu A$

-Delivered with 64 ns bunch spacing avoids overlap in the range of P=0.3-10.0 GeV/c

-Momentum measured with TOF

-K^0_L flux measured from the decay in flight

-*Side remark: Physics case with polarized targets is under study and feasible*

Rate of neutrons and K^0_L on GlueX target

- **SLAC 16 GeV**
- **PRL22.996 (1969) Brody et al.**

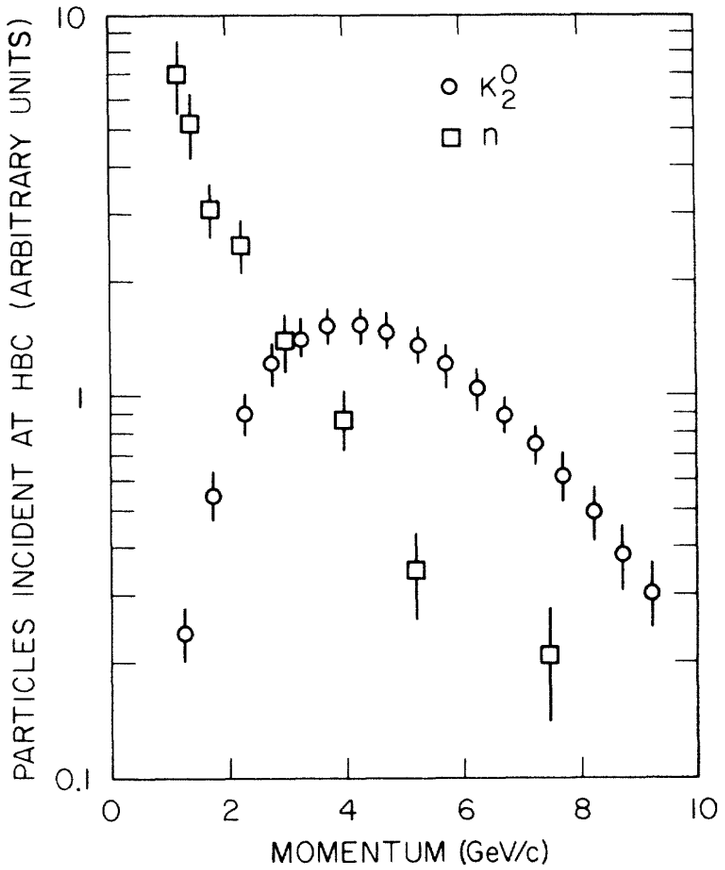
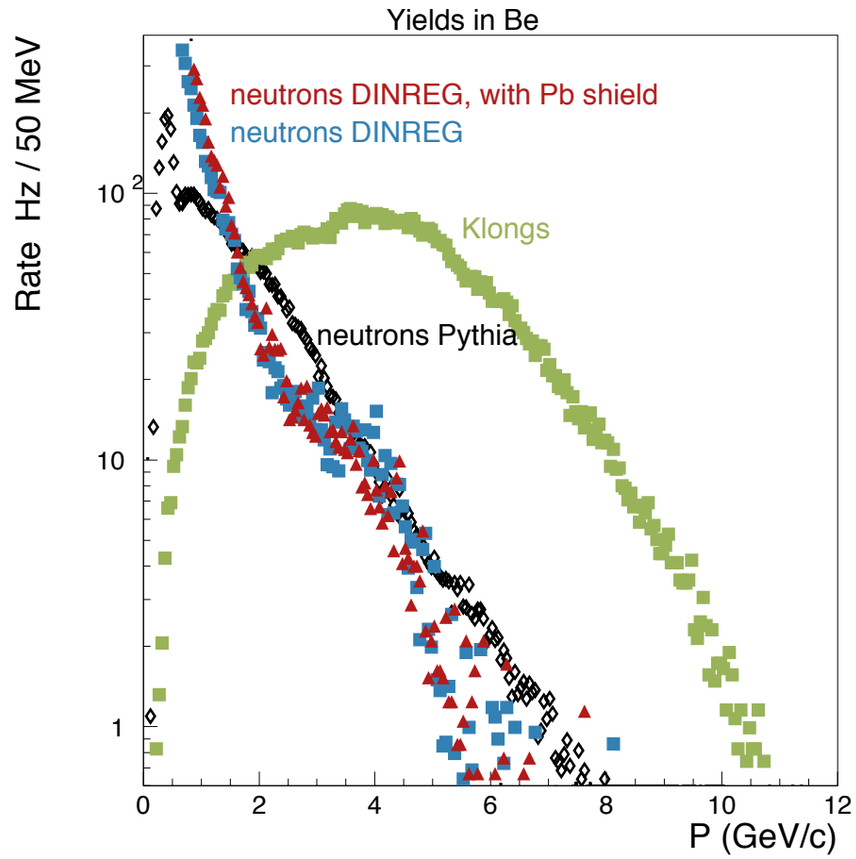


FIG. 2. Comparison of the neutron and K_2^0 fluxes at the hydrogen bubble chamber for 2° production with 16-GeV electrons.

- **JLAB 12 GeV**



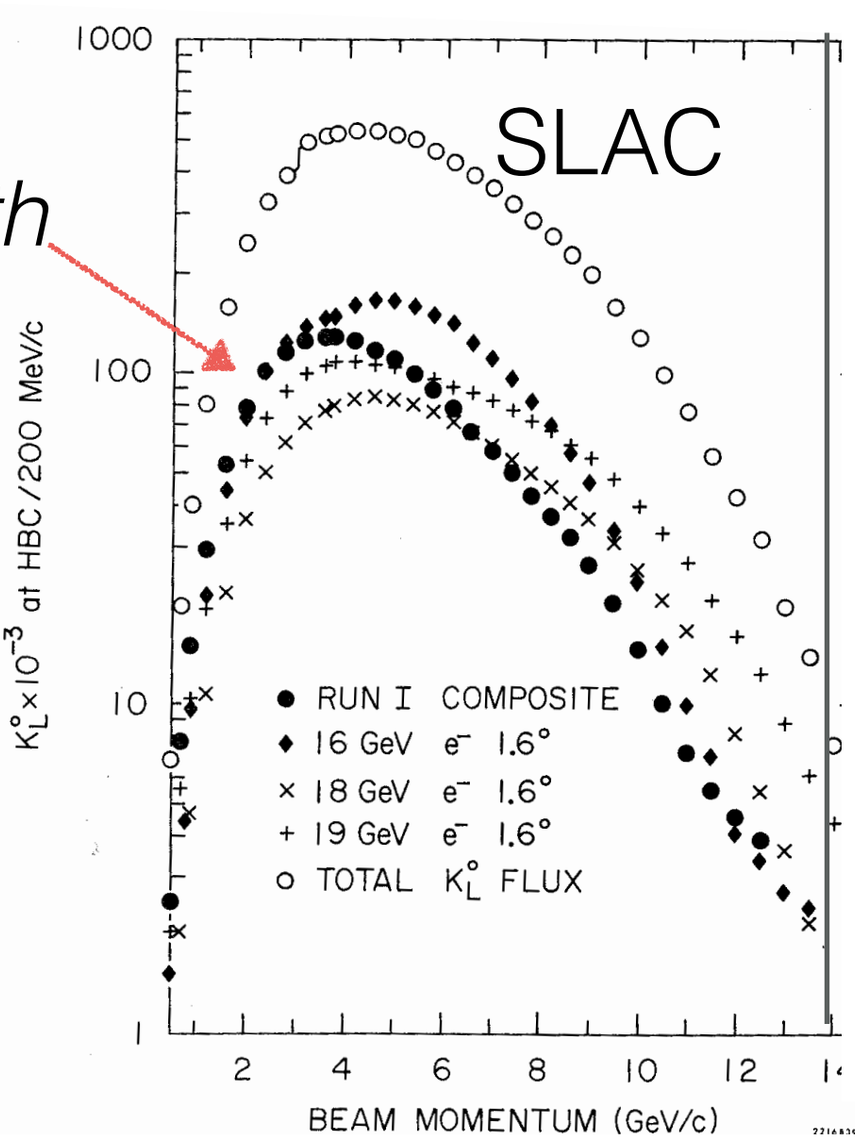
- **using proton beam the ratio n/K_L is 10^3-10^4**

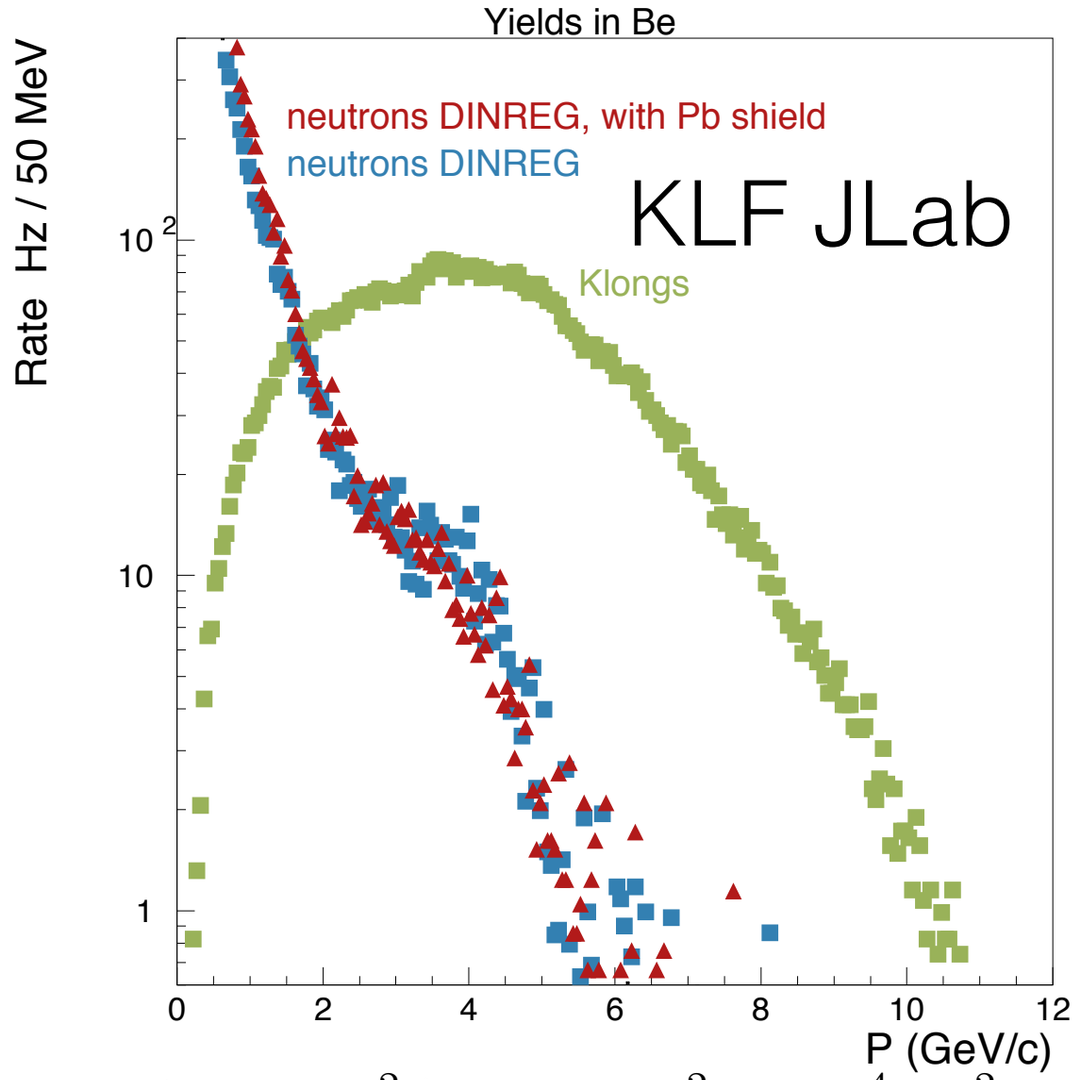
proposed facility is $\epsilon = \dfrac{N_{K_L}(K_L F)\Delta\Omega_{K_L F}}{N_{K_L}(SLAC)\Delta\Omega_{SLAC}} = 2.4 \times 10^3$ *more effective*

one month

$\Delta\Omega = 20\mu sr$

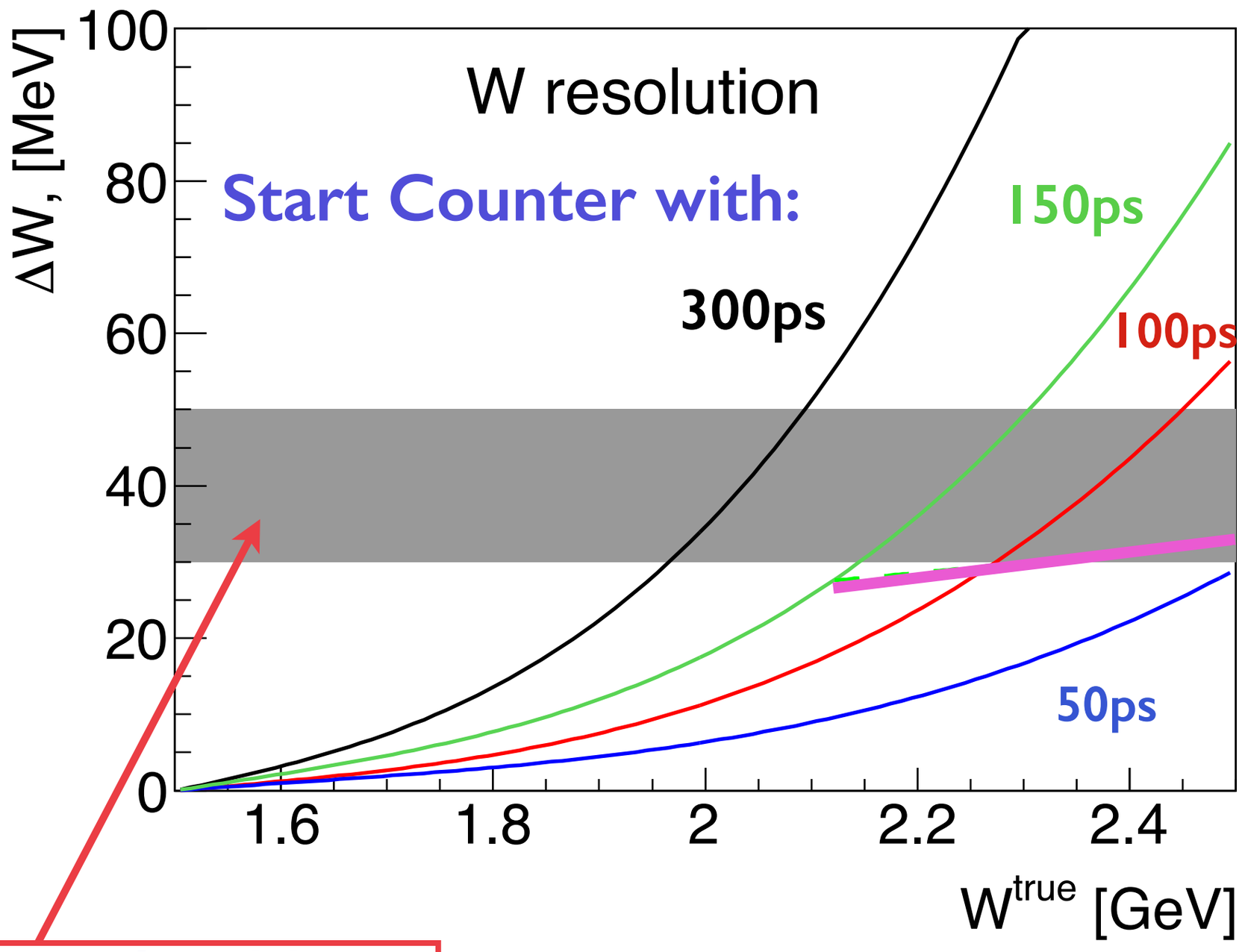
SLAC-177
R.J. Jamartino





$\Delta\Omega = \pi R^2/16 = \pi \times 3^2 \times 10^{-4}/16^2 = 11\mu sr$

- **KL Momentum will be measured with TOF**



Fully reconstructed FS

typical width
of excited hyperons

- Current SC Timing resolution is ~250ps
- It may be modified to reach 150ps

- **ProjectX (Fermi Lab) arXiv:1306.5009**

Table III-2: Comparison of the K_L production yield. The BNL AGS kaon and neutron yields are taken from RSVP reviews in 2004 and 2005. The *Project X* yields are for a thick target, fully simulated with LAQGSM/MARS15 into the KOPIO beam solid angle and momentum acceptance.

Beam energy	Target (λ_I)	$p(K)$ (MeV/c)	K_L/s into 500 μsr	$K_L : n$ ($E_n > 10$ MeV)
BNL AGS	24 GeV	1.1 Pt	300-1200	60×10^6	$\sim 1 : 1000$
Project X	3 GeV	1.0 C	300-1200	450×10^6	$\sim 1 : 2700$

KL beam can be used to study rare decays
However it will be impossible to use it for hyperon spectroscopy because of momentum range and n/K Ratio

Expected rates

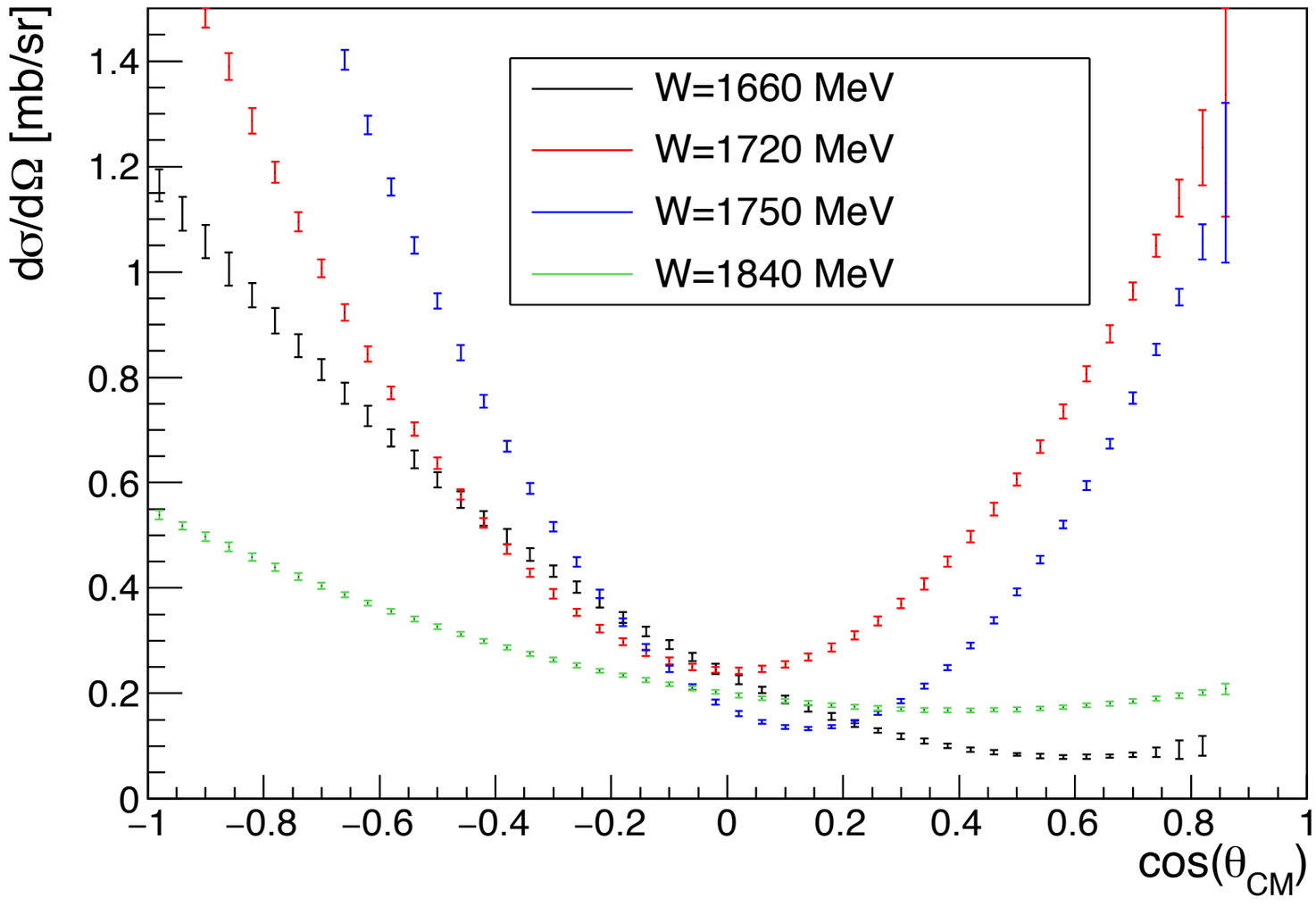
Production	J-PARC*	Jlab (this proposal)
Kaons/s	$3 \times 10^4 K^-$	$3 \times 10^4 K_L$
$\Xi^*/month$	3×10^5	2×10^5
$\Omega^{-*}/month$	600	4000

* *H.~Takahashi, NP A 914, 553 (2013)*
M.~Naruki and K.~Shirotori, LOI-2014-JPARC

- **More details about J-PARC in a talk by Shinya Sawada**

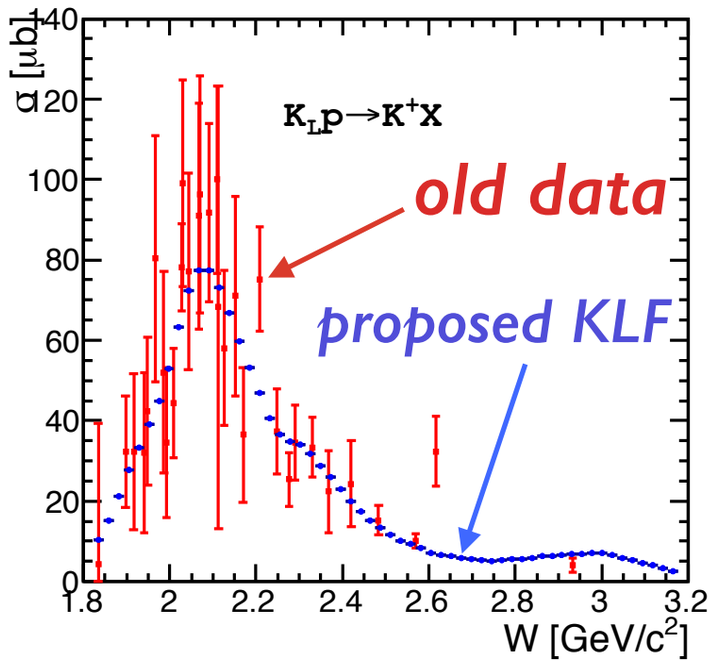
Proposed Measurements

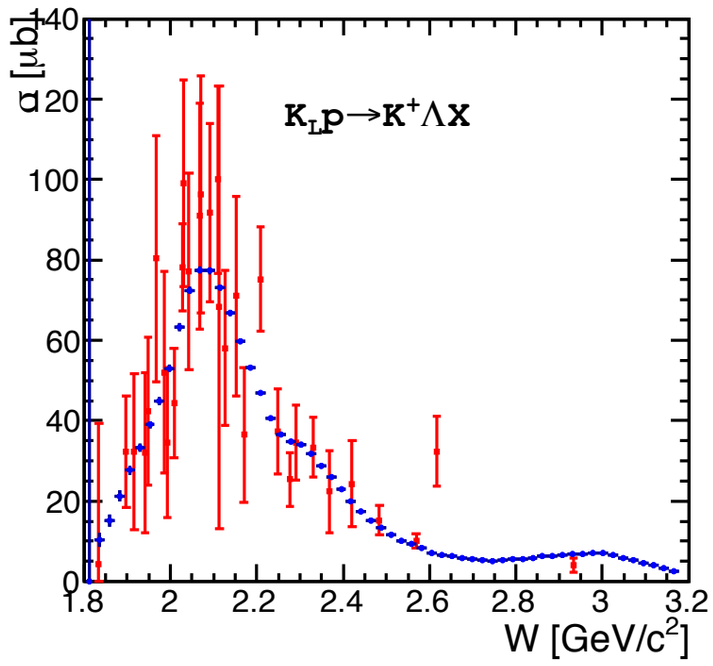
$$\mathbf{K_L p \rightarrow K_S p}$$

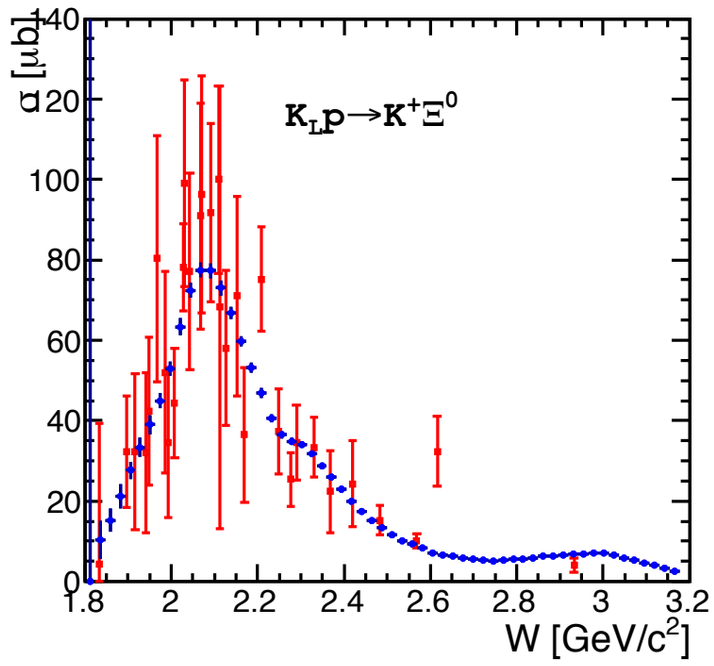


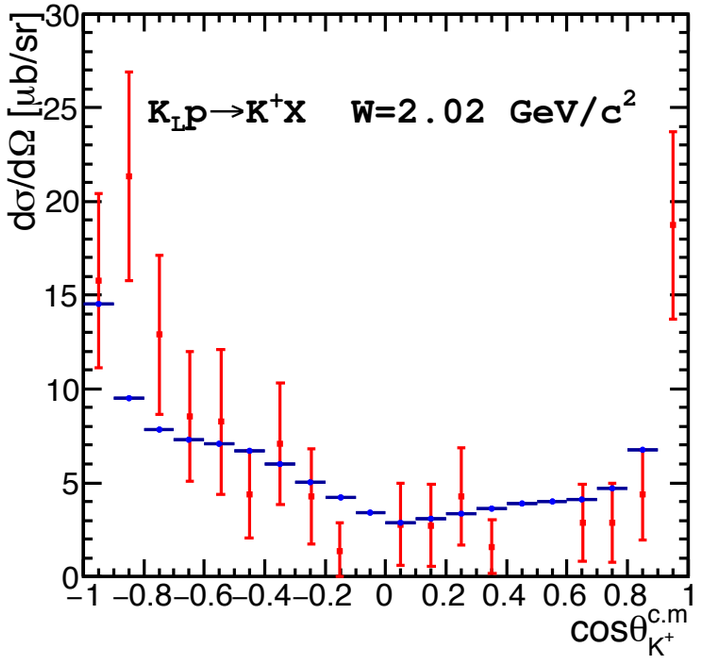
100 days of running

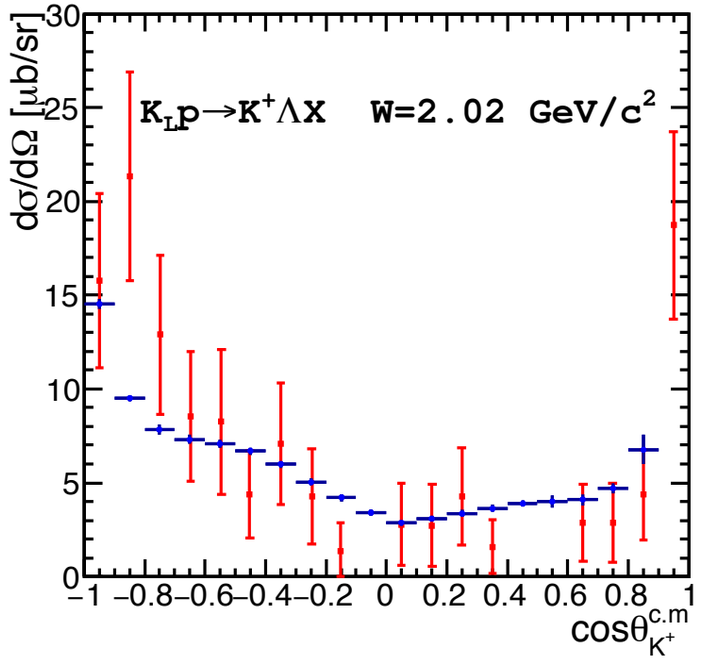
Proposed Measurements

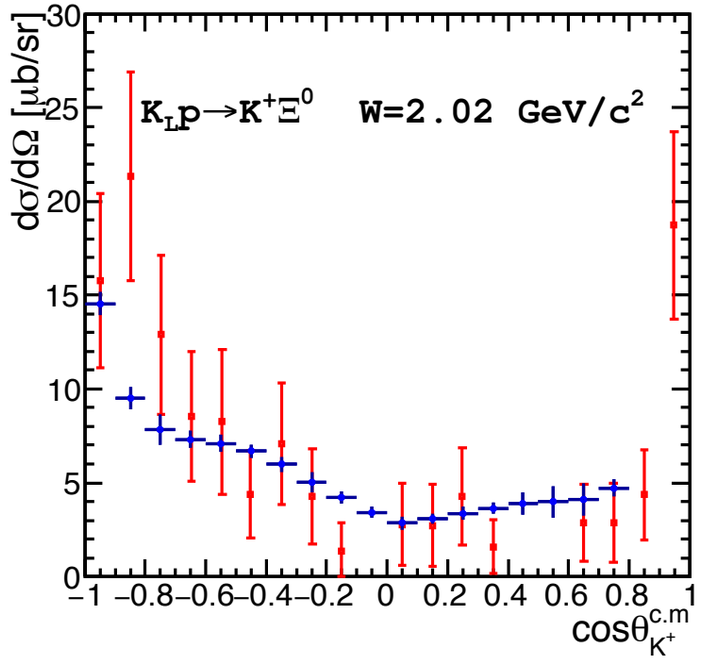








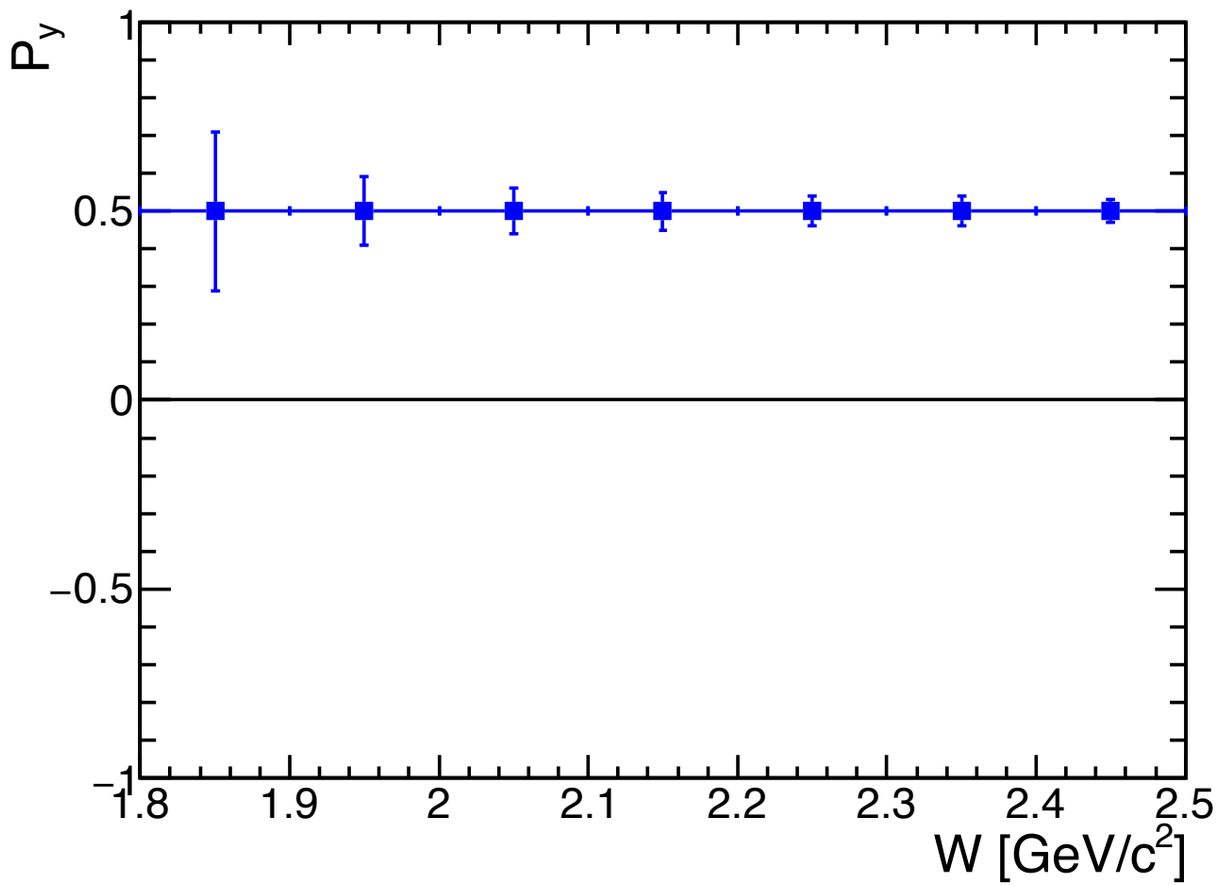


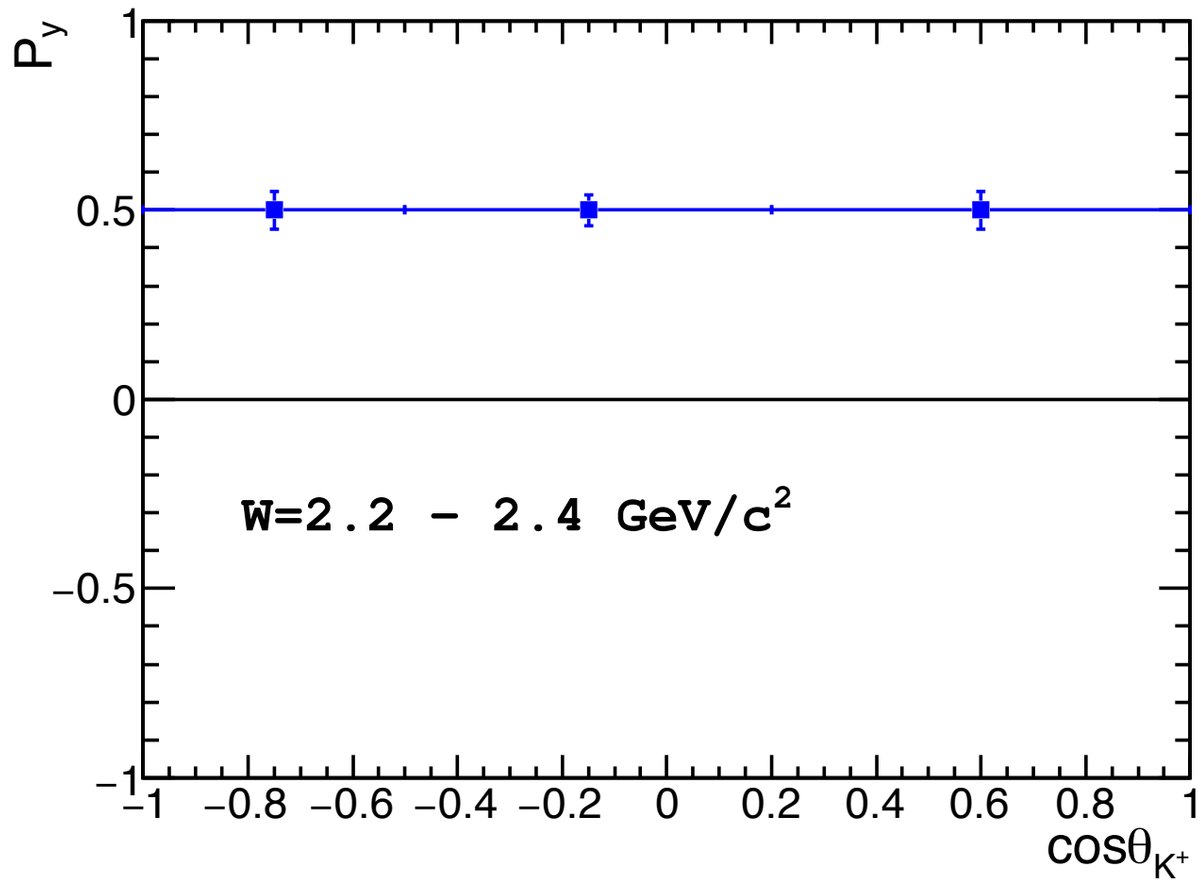


100 days of running

Proposed Measurements: Recoil polarization

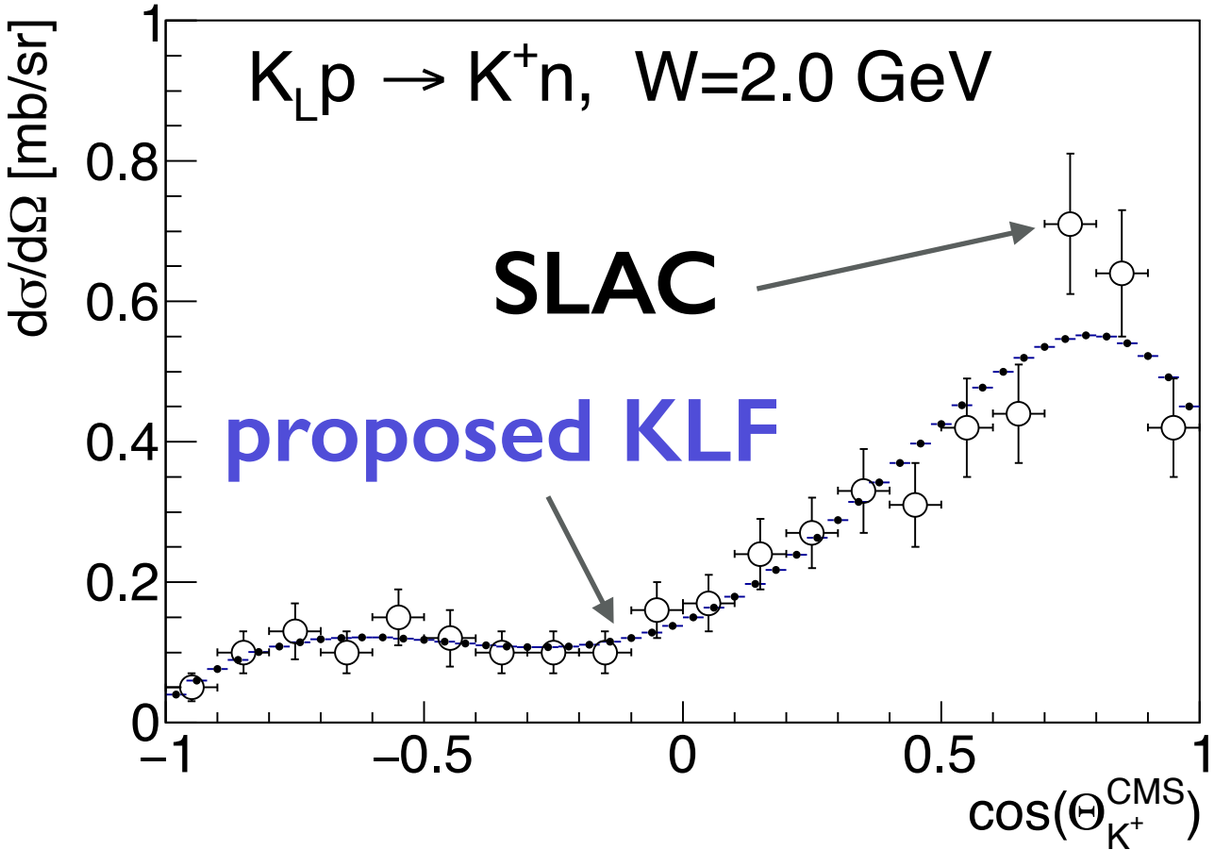
$$\mathbf{K_L p \to K^+ \Xi^0 (\Lambda \pi^0)}$$

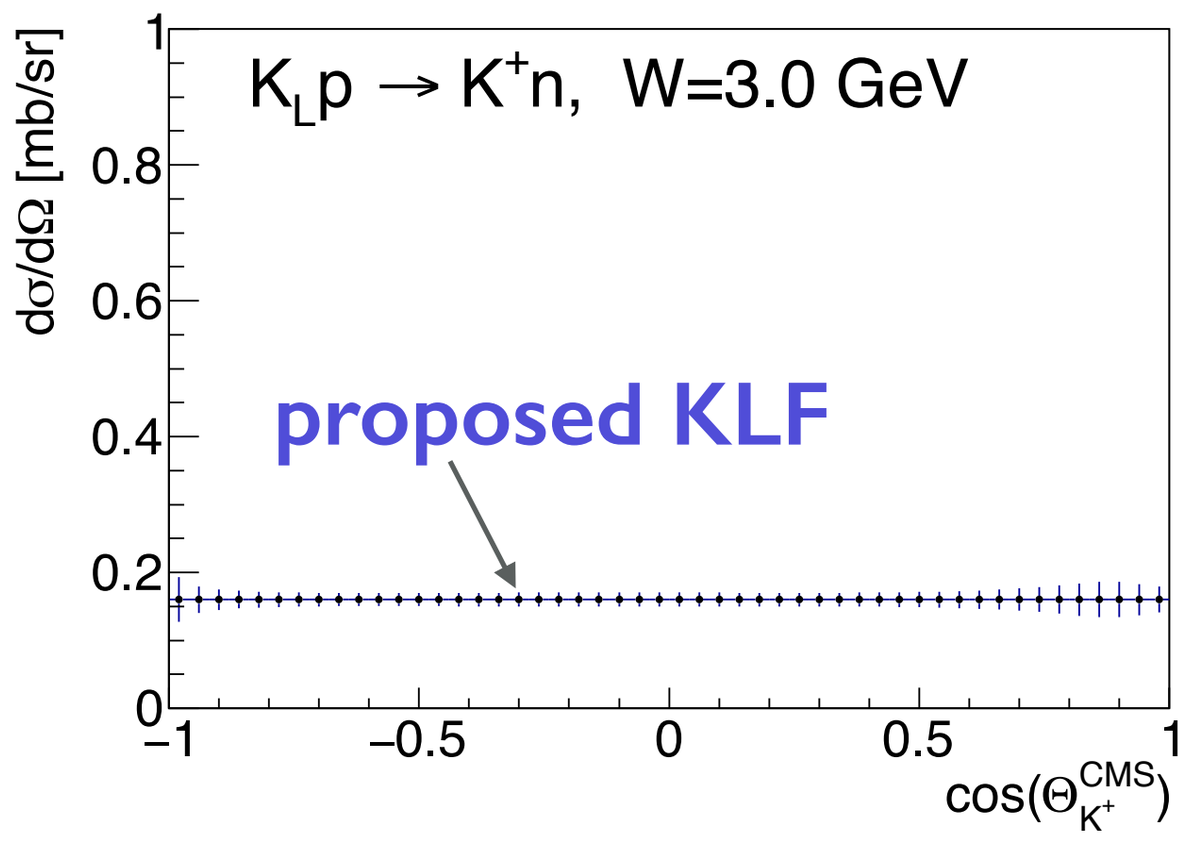




10% stat error on polarization drives 100 days of running

Proposed Measurements





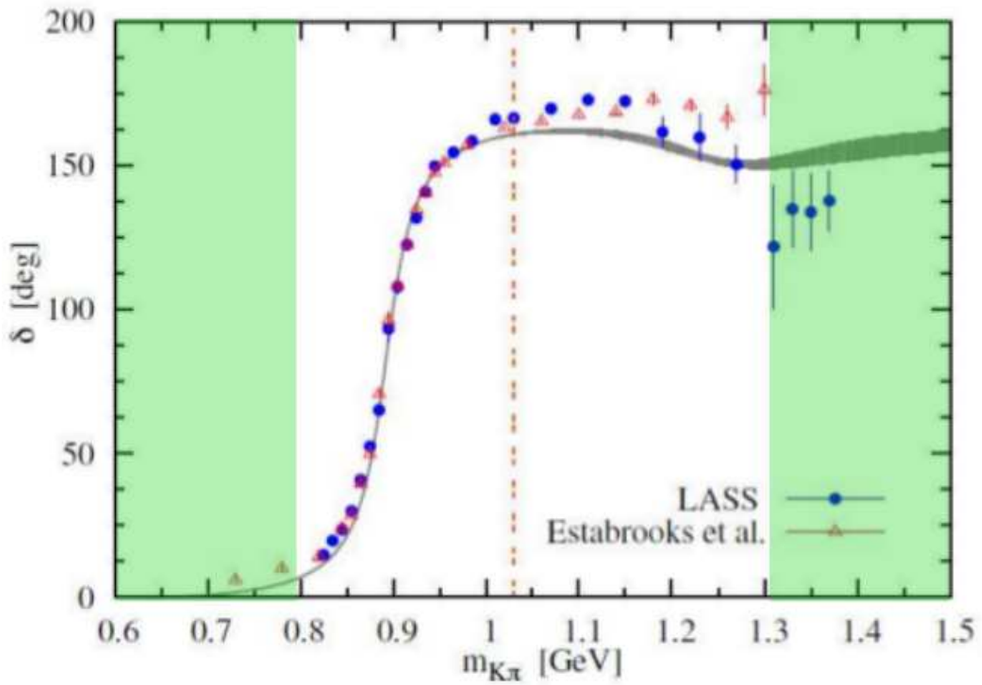
100 days of running

Proposed Measurements

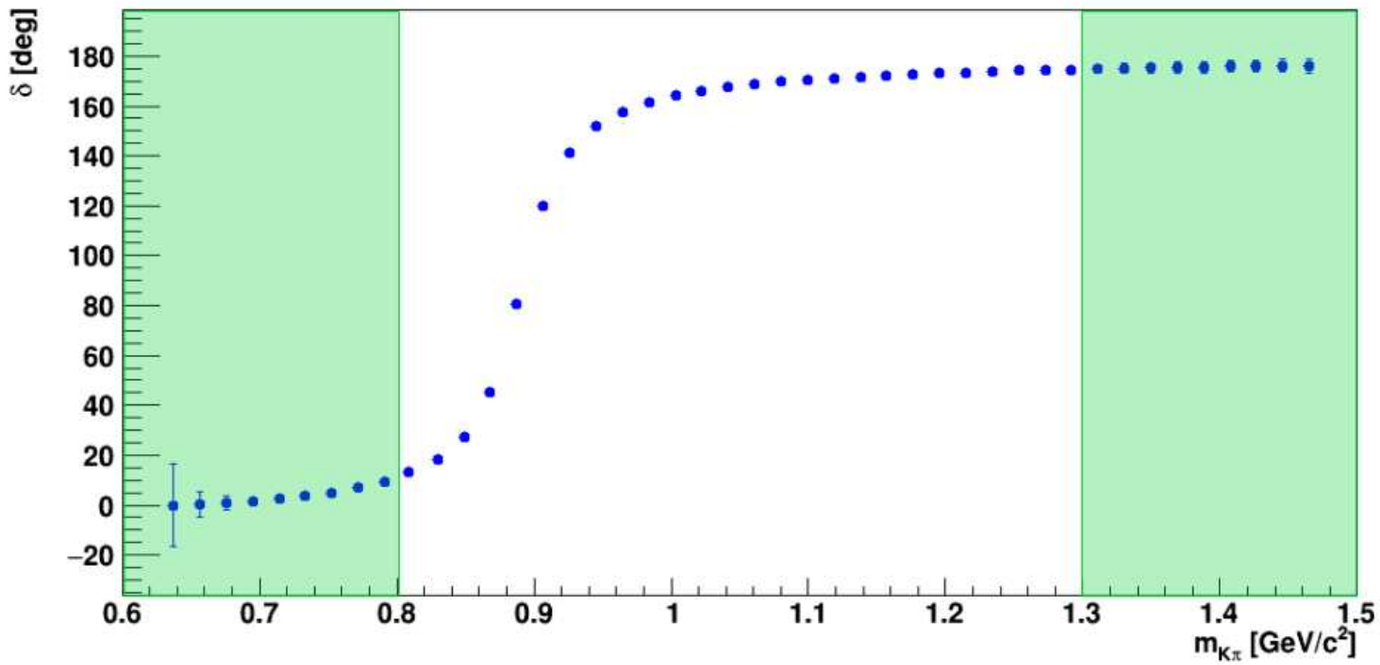
$$K^{\pm}p \to K^{\pm}\pi^{+}n : \qquad K\pi \quad \textbf{Scattering}$$

SLAC

P-wave



$\mathbf{M(K\pi)}$



$\mathbf{M(K\pi)}$

100 days of running

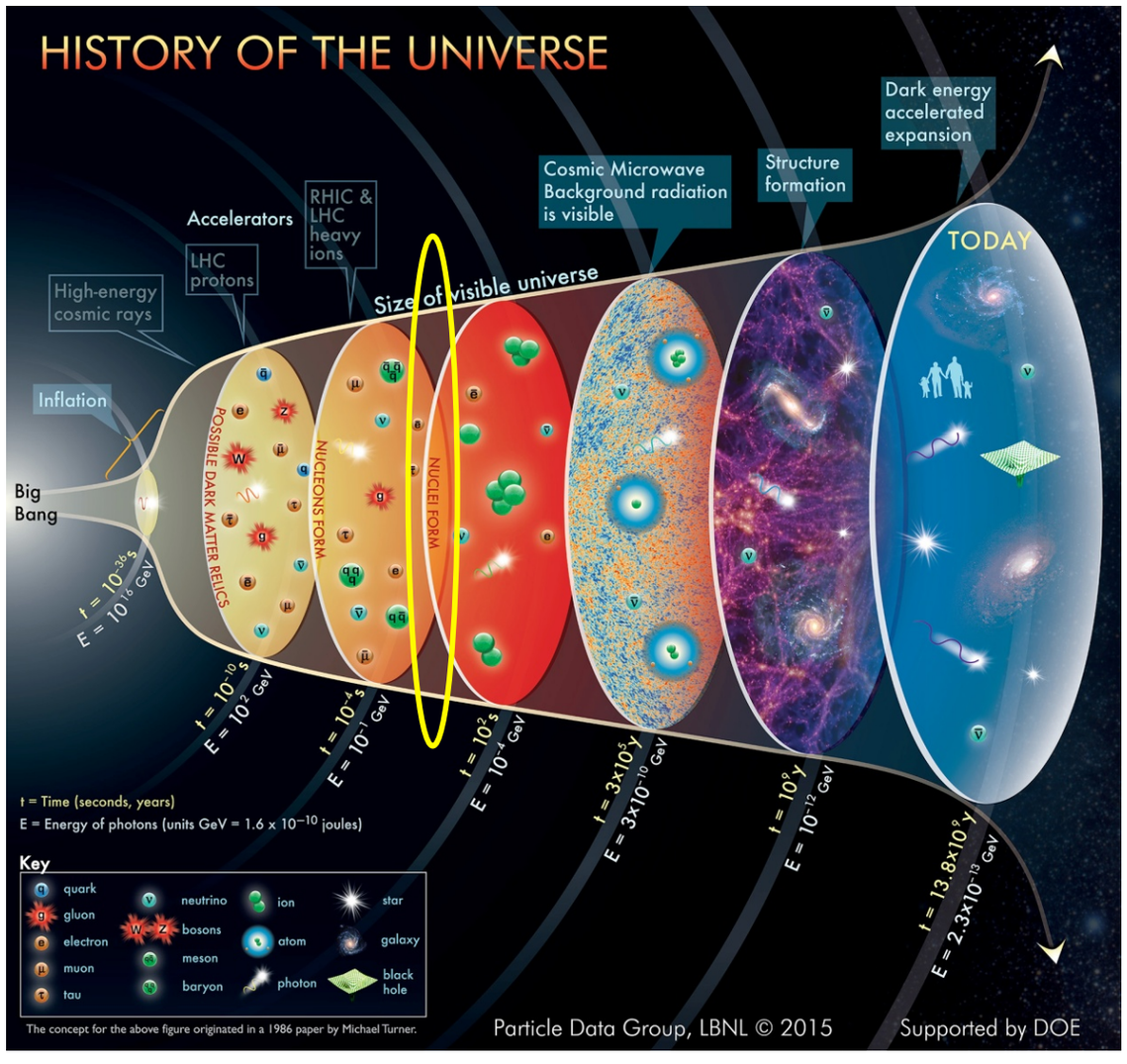
Expected Statistics: 100 days of running

Reaction	Statistics (events)
$K_L p \rightarrow K_S p$	8M
$K_L p \rightarrow \pi^+ \Lambda$	24M
$K_L p \rightarrow K^+ \Xi^0$	4M
$K_L p \rightarrow K^+ n$	200M
$K_L p \rightarrow K^- \pi^+ p$	2M

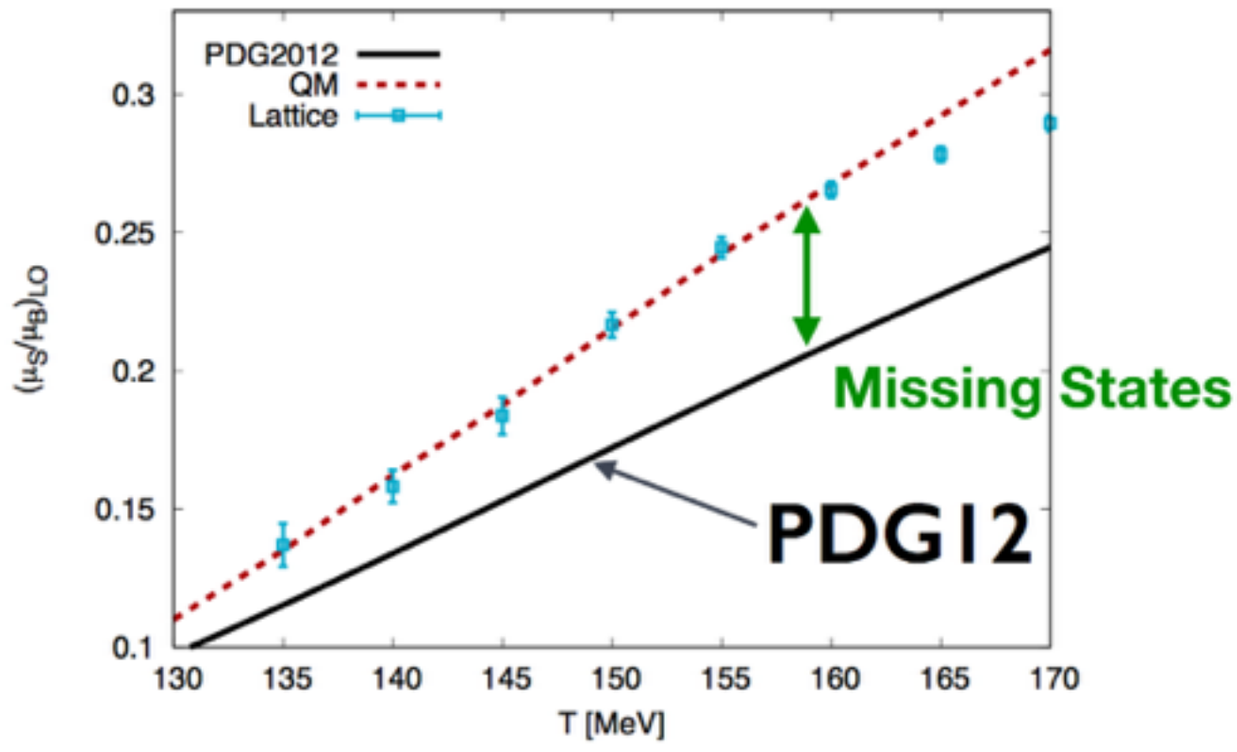
With similar statistics 100 days of running on LD2 target is needed

Other Impacts

Evolution of an Early Universe at Freeze-out



Chemical potential



YSTAR2016 Proceedings arXiv: 1701.07346

Summary

- KN scattering still remains very poorly studied

- Lack of data on excited hyperon states requires significant experimental efforts to be completed

- Experimental data on $K\pi$ system need an update for many different reasons

- Our preliminary studies show that production of few times $10^4 K^0_L$/s at GlueX target in Hall D is feasible

-Proposed setup will have highest intensity K^0_L beam ever used for hadron spectroscopy ~10^3 times higher than in SLAC

-Data obtained at JLab will be unique and complementary to charged kaon data

Thank You!