

Proposal for JLab PAC45
Strange Hadron Spectroscopy
with a Secondary KL Beam at GlueX

Moskov Amaryan



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:

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 K_L 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 Armaryan, 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



YSTAR

Excited Hyperons in QCD
Thermodynamics at Freeze-Out

2016

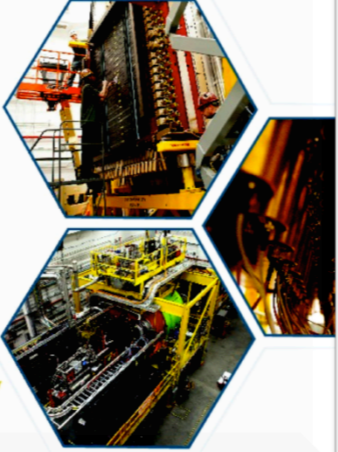
NOVEMBER 16 - 17, 2016
Jefferson Lab
Newport News, Virginia

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

ORGANIZING COMMITTEE

Moskov Armaryan - Chair ODU	James Ritman, Ruhr Un Bochum & IKP Jülich
Eugene Chudakov JLab	Igor Strakovsky GWU
Krishna Rajagopal MIT	
Claudia Ratti University of Houston	

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HIPS 2017

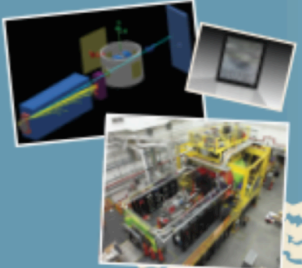
New Opportunities with High-Intensity Photon Sources

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 benefiting 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:

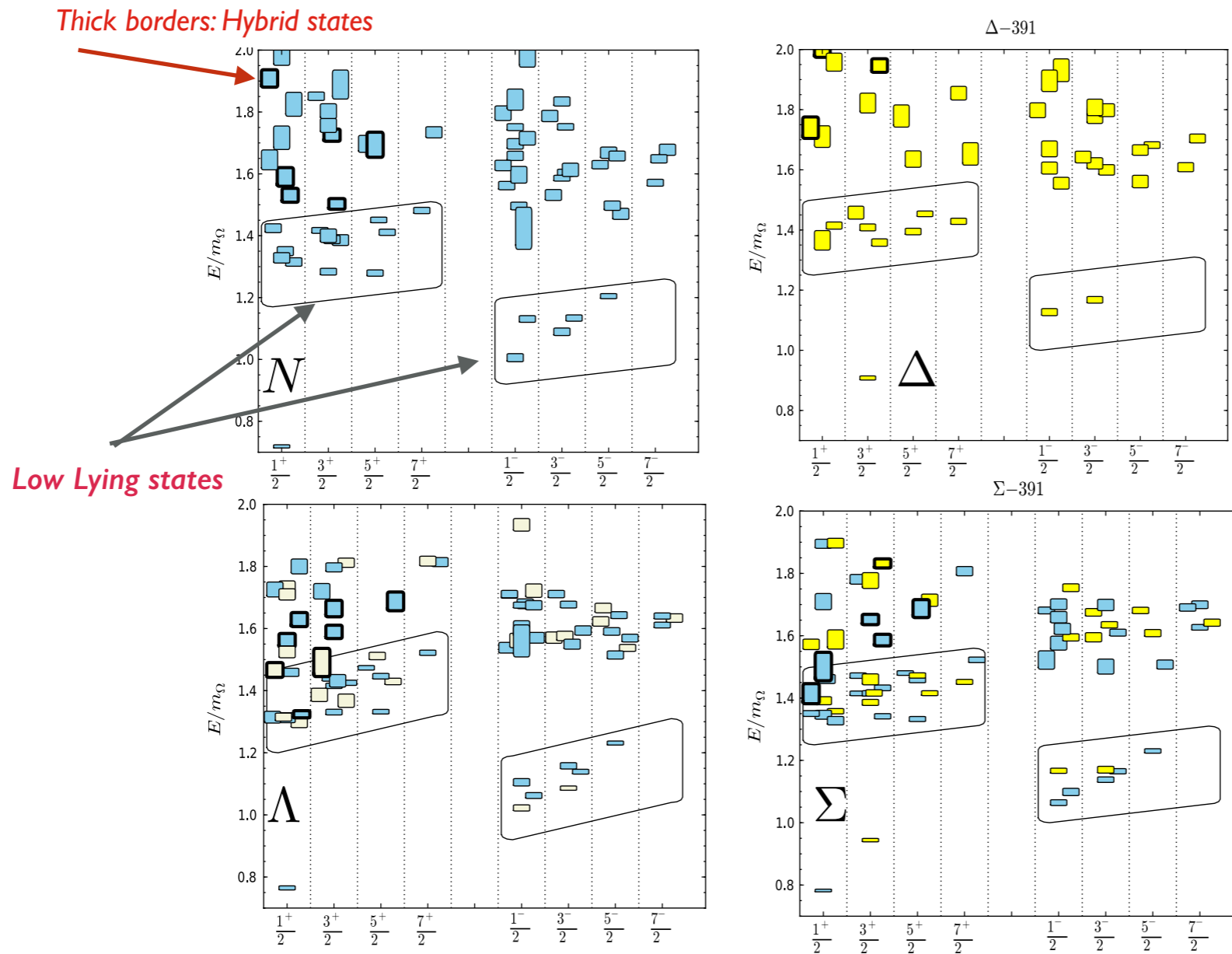
Tania Horn - CUA
Cynthia Keppel - JLab
Carlos Mazon-Canales - IFSC
Igor Strakovsky - GWU



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

Hyperon Spectroscopy

Lattice QCD calculations



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

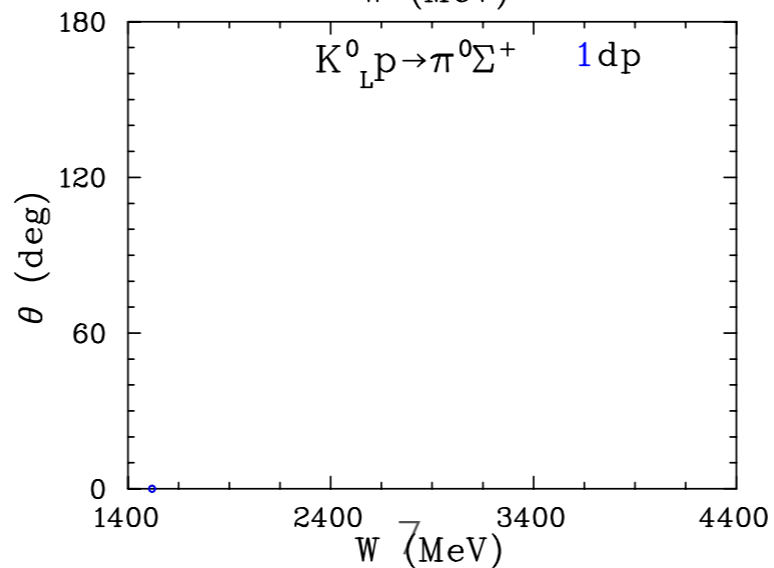
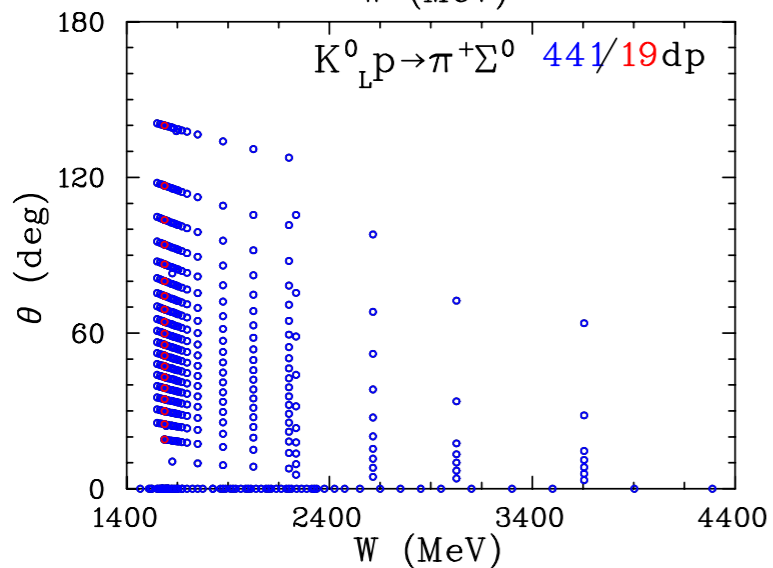
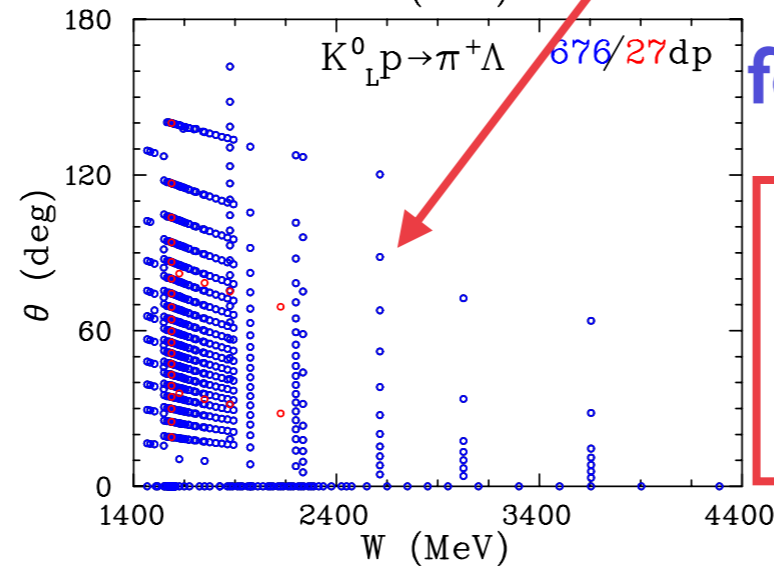
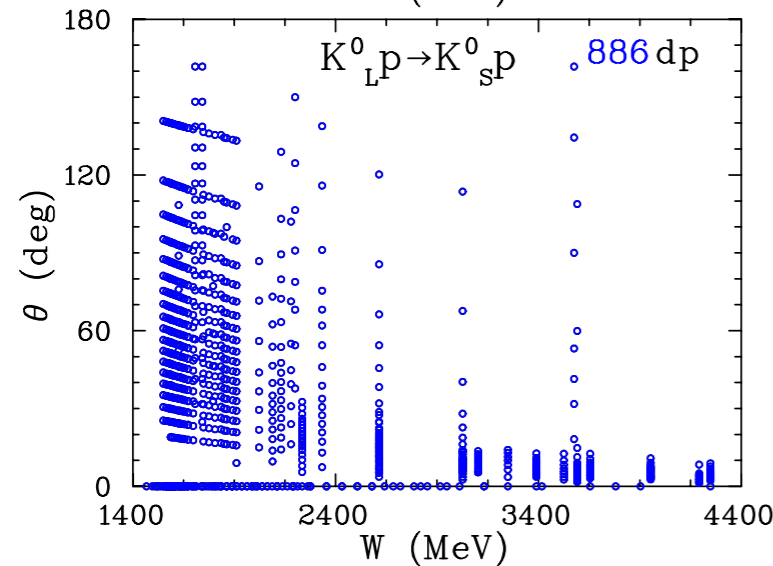
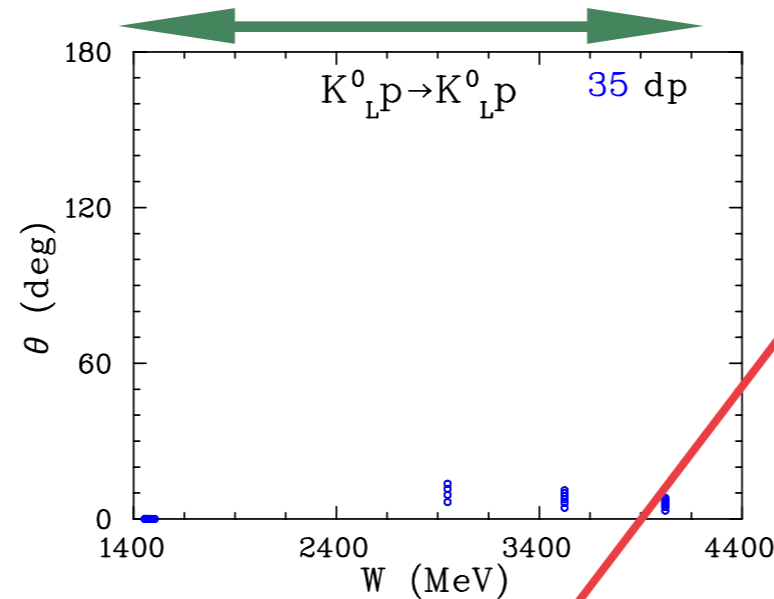
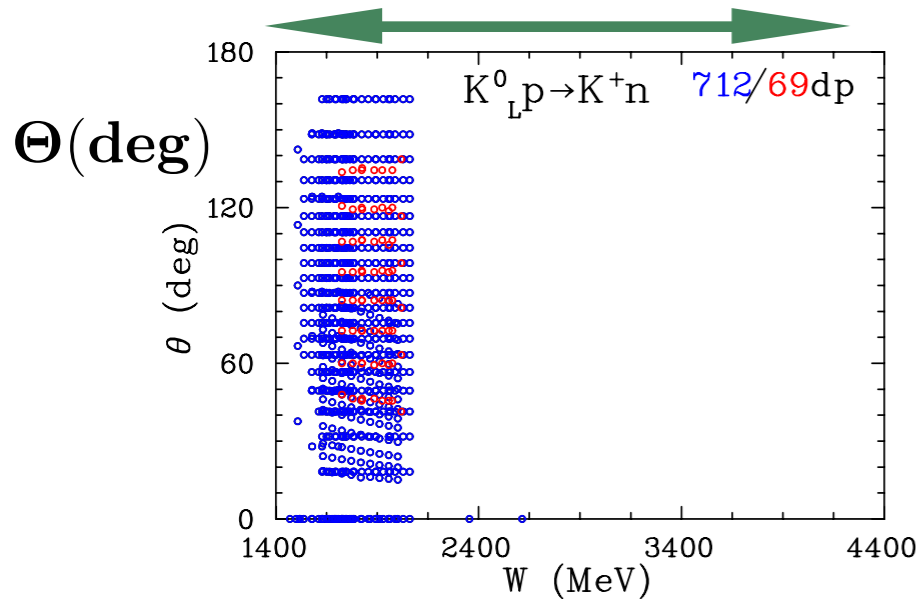
for a comparison there are:

$\pi N \rightarrow \pi N$ 51 K points

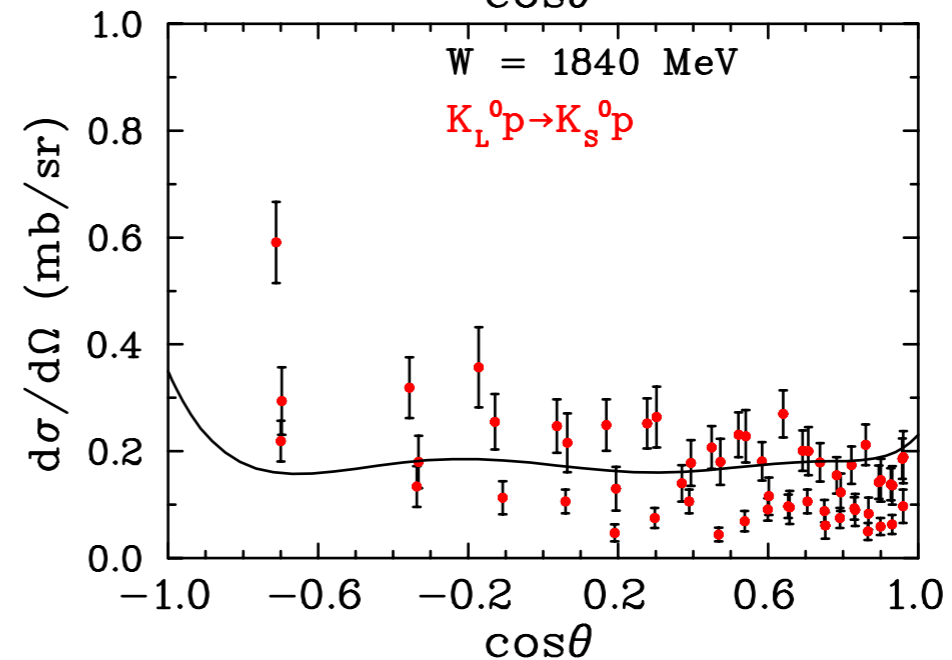
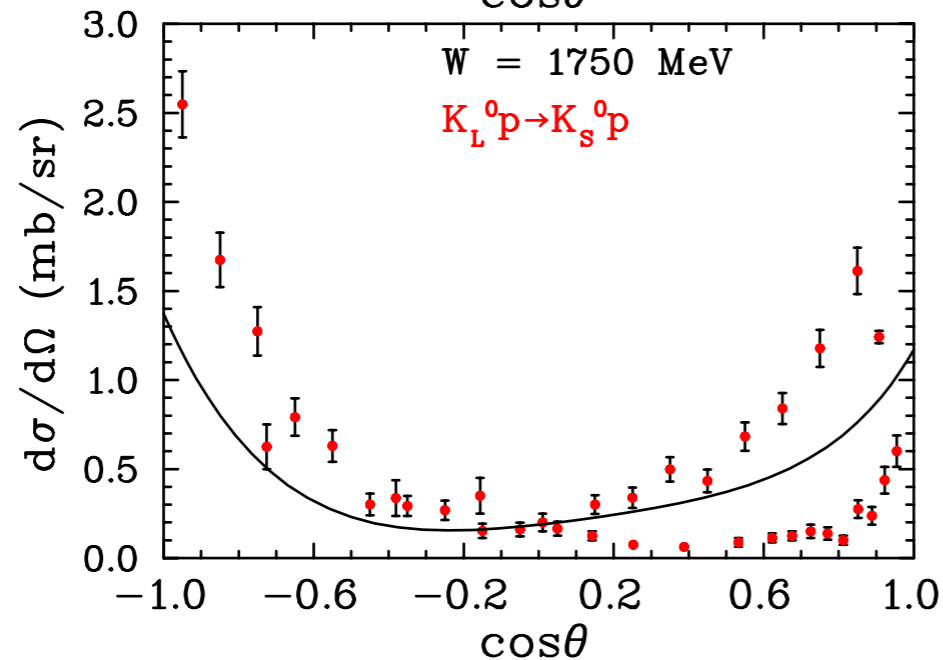
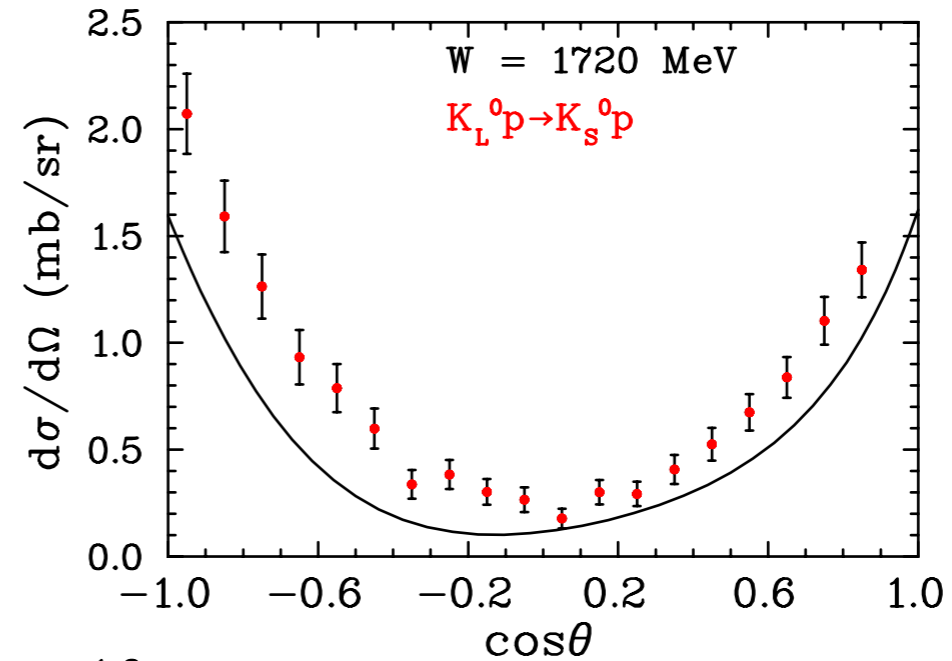
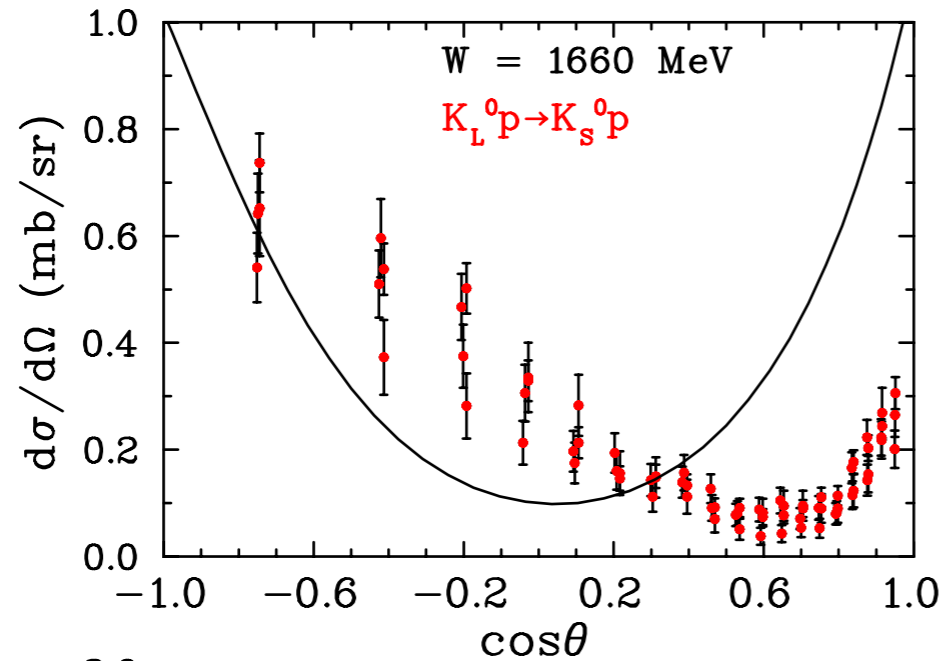
$\gamma N \rightarrow \pi N$ 39 K points

no data on neutron target

W(MeV)



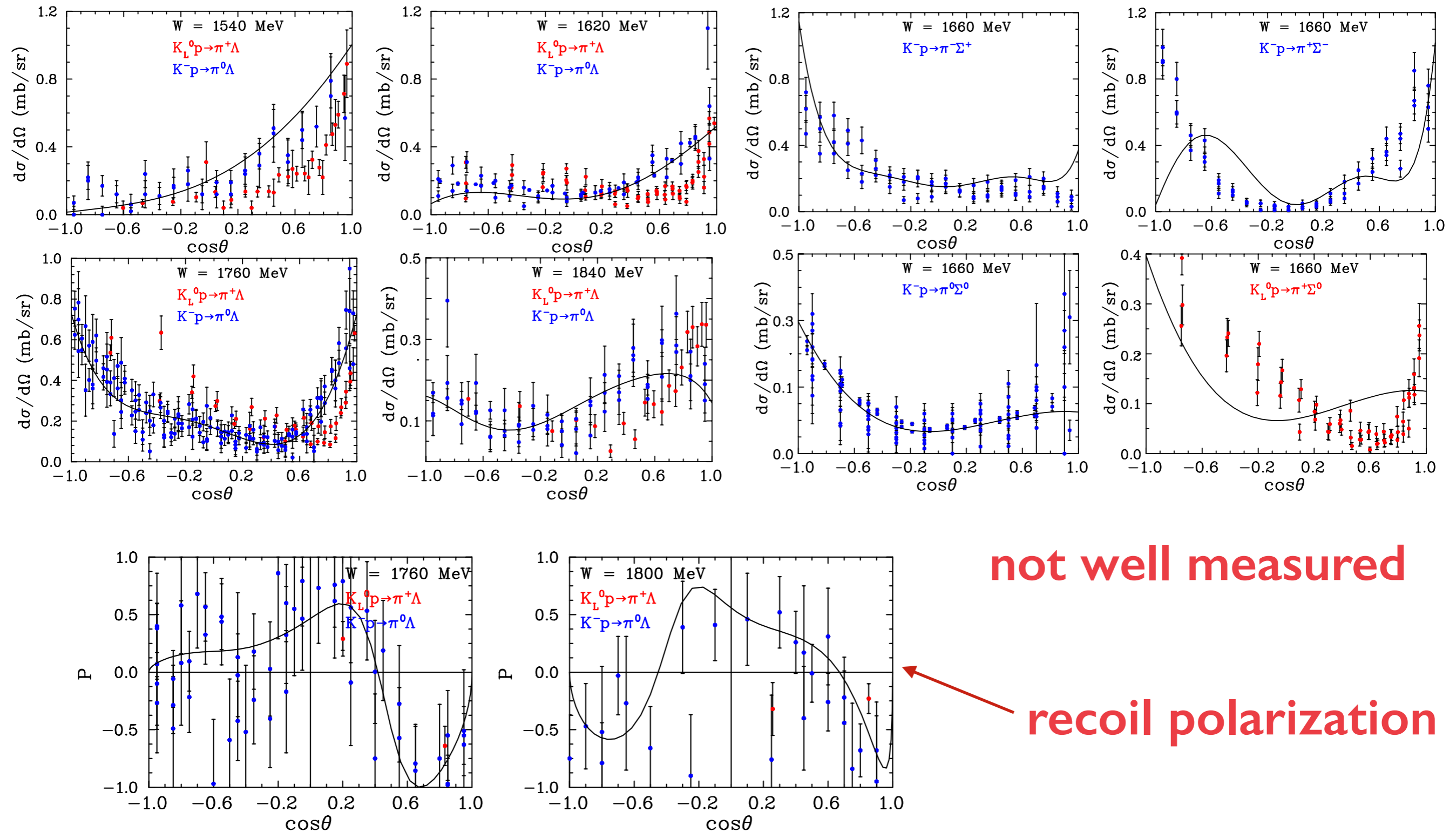
Previous Measurements



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

Previous Measurements

Cross sections



not well measured

recoil polarization

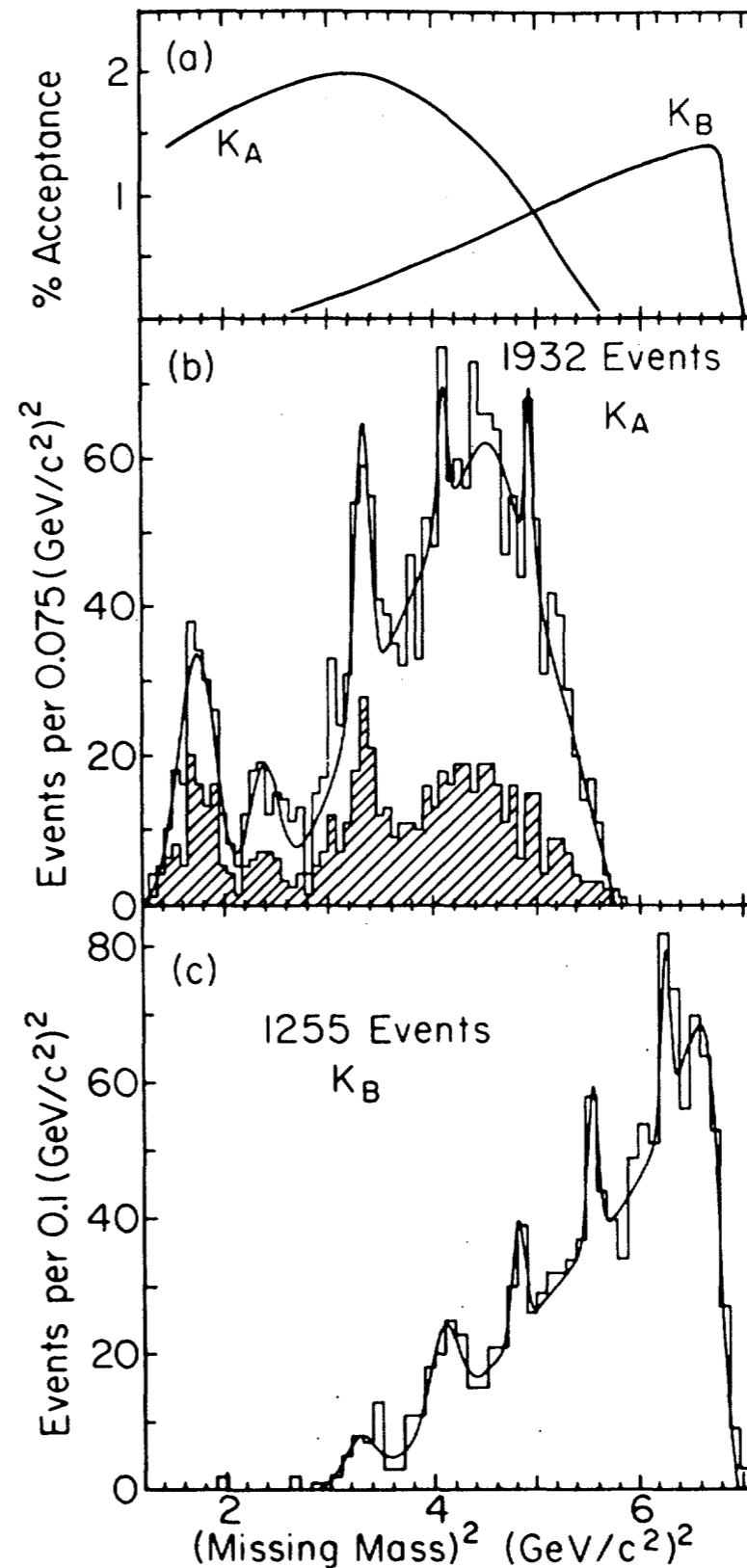
- not sensitive to any model and PWA

Experimental data on $[I]^*$

Very poorly
measured at
AGS (BNL)
34 years ago

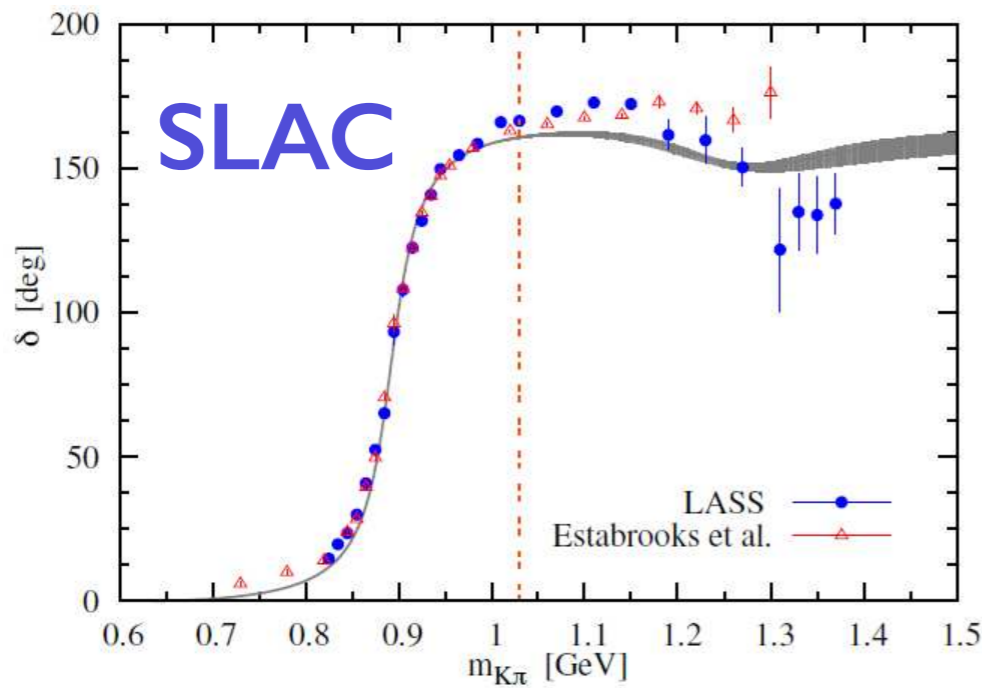
• C.M. Jenkins et al., Phys. Rev. Lett. 51, 951 (1983)

• However clear Indications
for excited states



$K^\pm p \rightarrow K^\pm \pi^+ n$: $K\pi$ Scattering

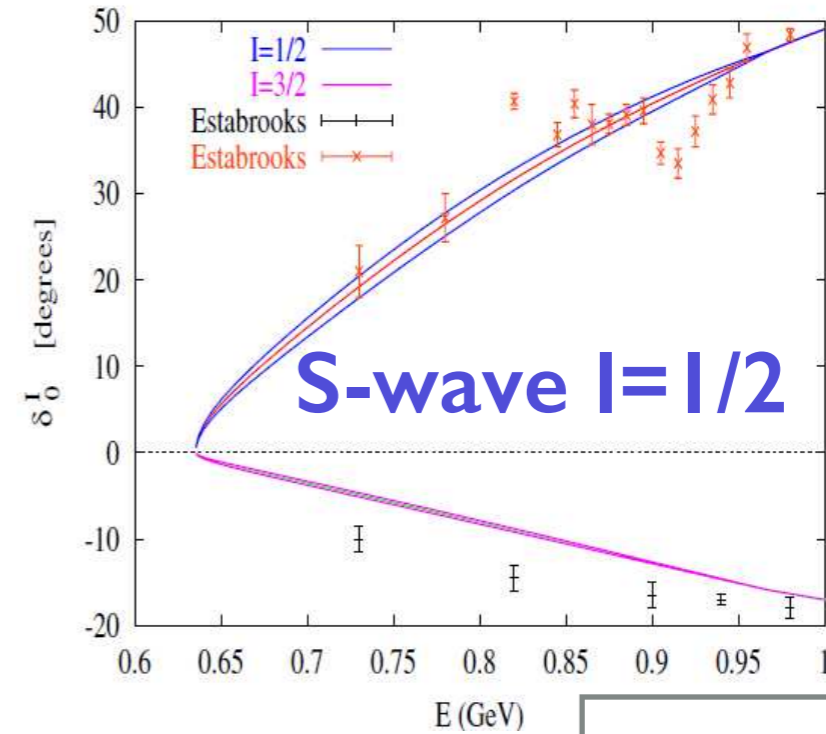
P-wave $I=1/2$



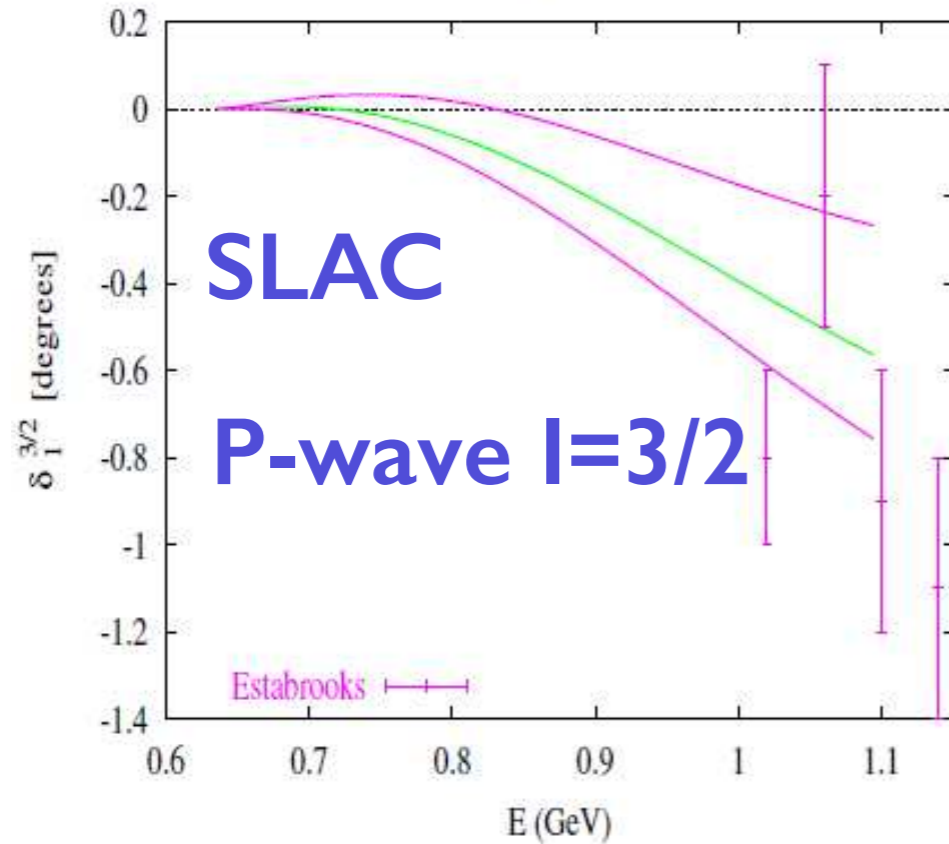
tau data
 $\tau \rightarrow K\pi\nu_\tau$

$M(K\pi)$

SLAC



$M(K\pi)$



$M(K\pi)$

After 50 years still state of the art.

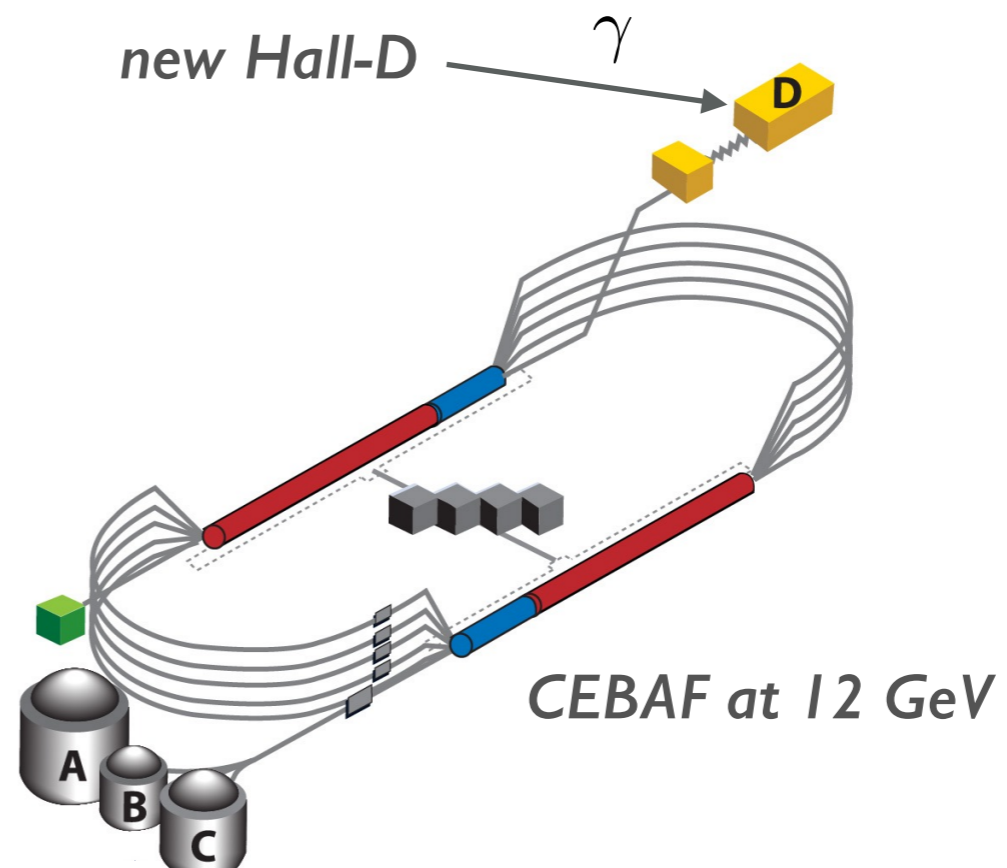
- New measurements needed !**

How to make a kaon beam?

Thomas Jefferson National Accelerator Facility

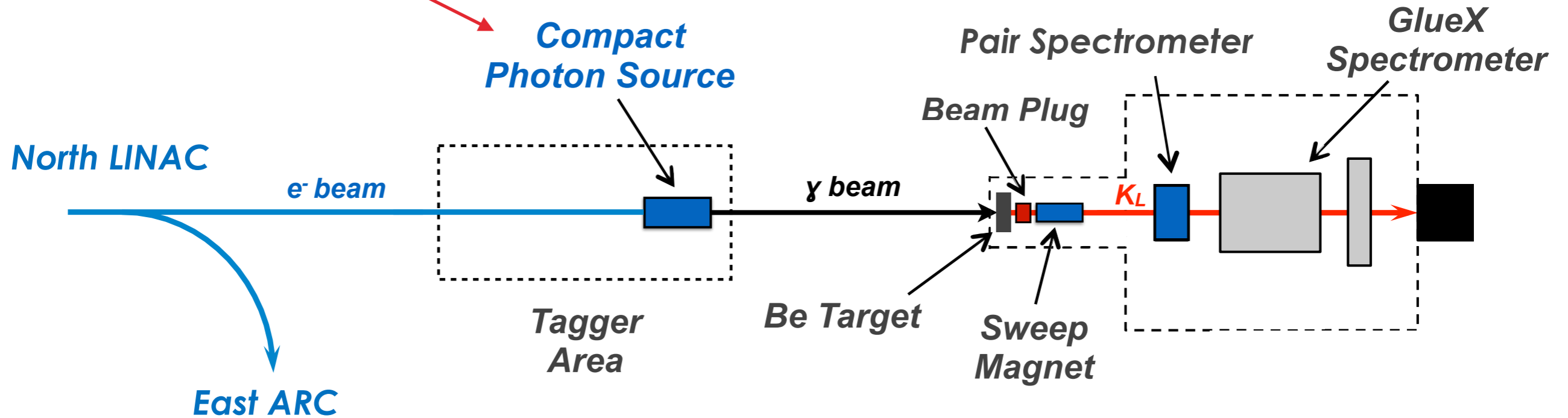


Aerial View



KL Beam

details in Tanja Horn's talk



- **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_L^0 on GlueX target

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

- JLAB 12 GeV

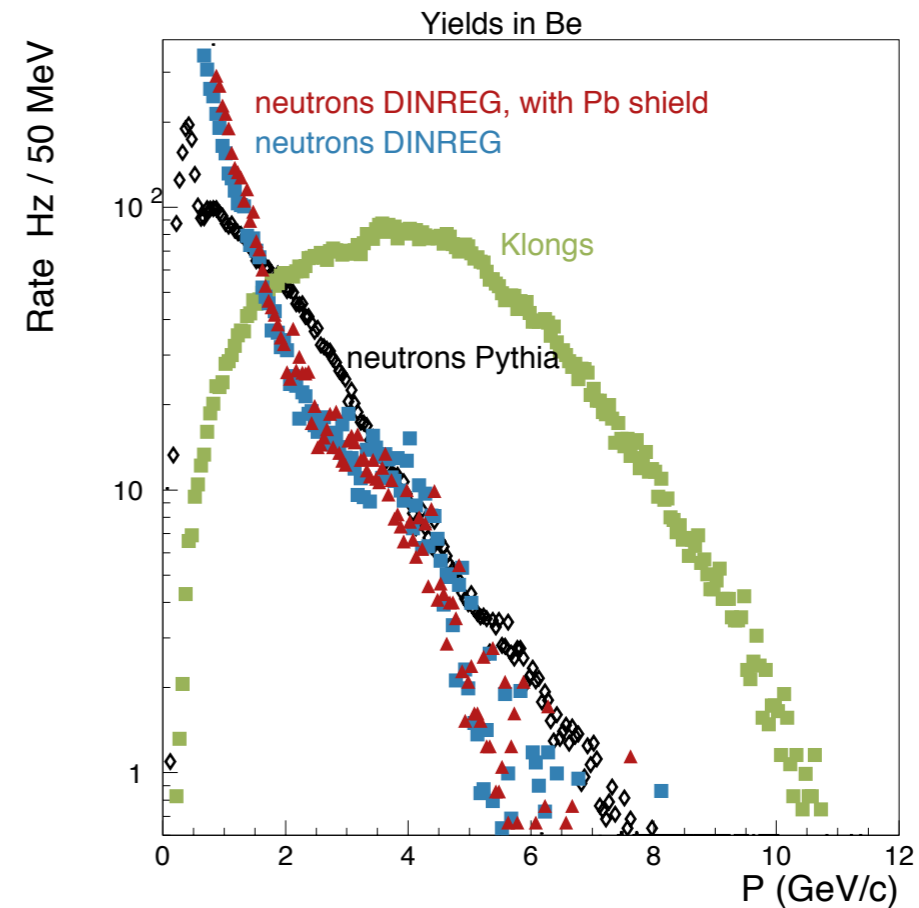
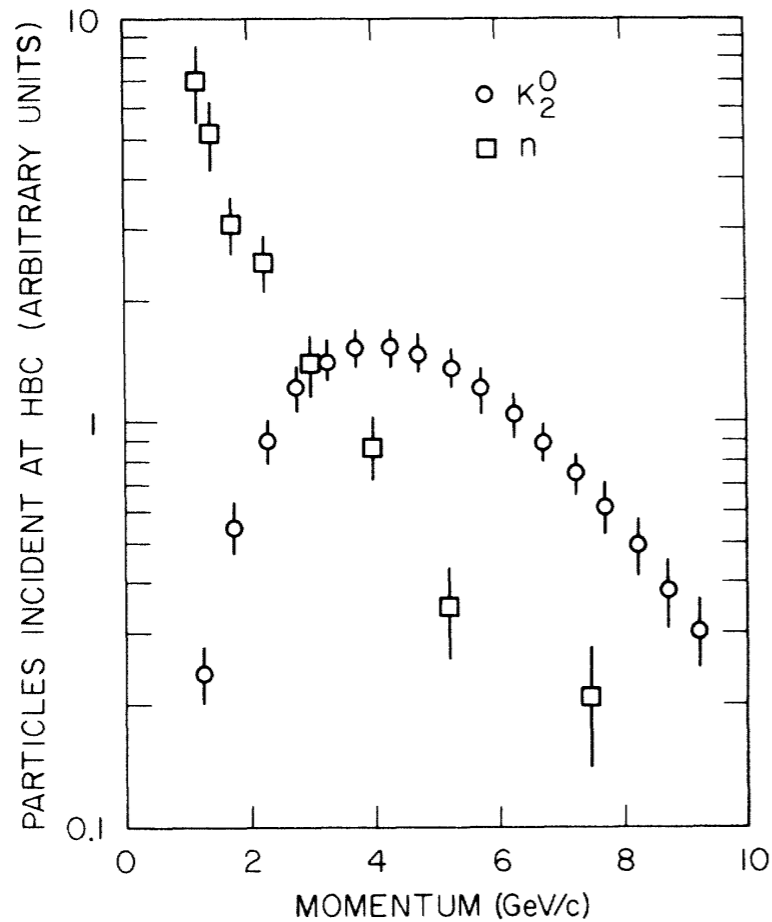
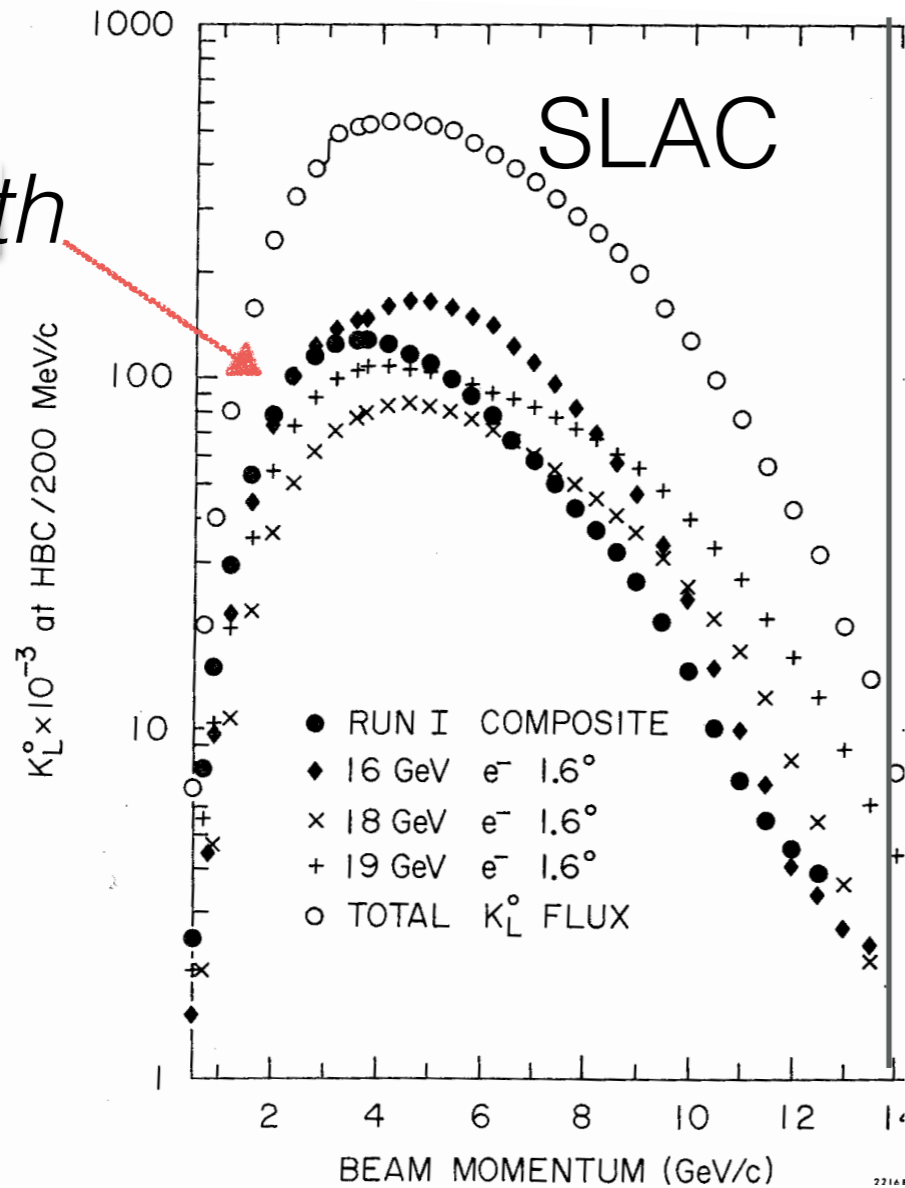


FIG. 2. Comparison of the neutron and K_L^0 fluxes at the hydrogen bubble chamber for 2° production with 16-GeV electrons.

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

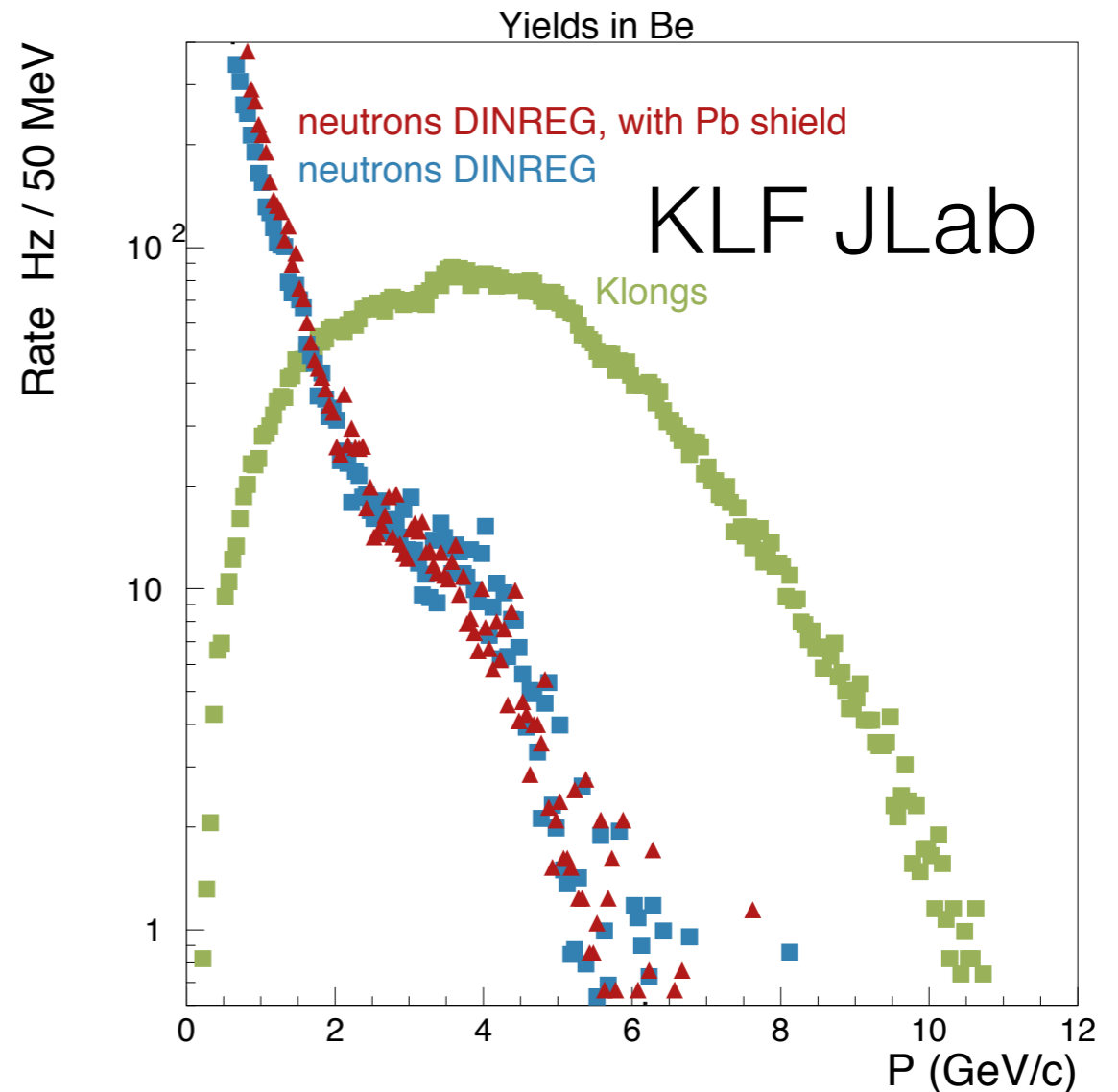
proposed facility is $\epsilon = \frac{N_{K_L}(K_{LF})\Delta\Omega_{K_{LF}}}{N_{K_L}(SLAC)\Delta\Omega_{SLAC}} = \underline{2.4 \times 10^3}$ more effective

one month



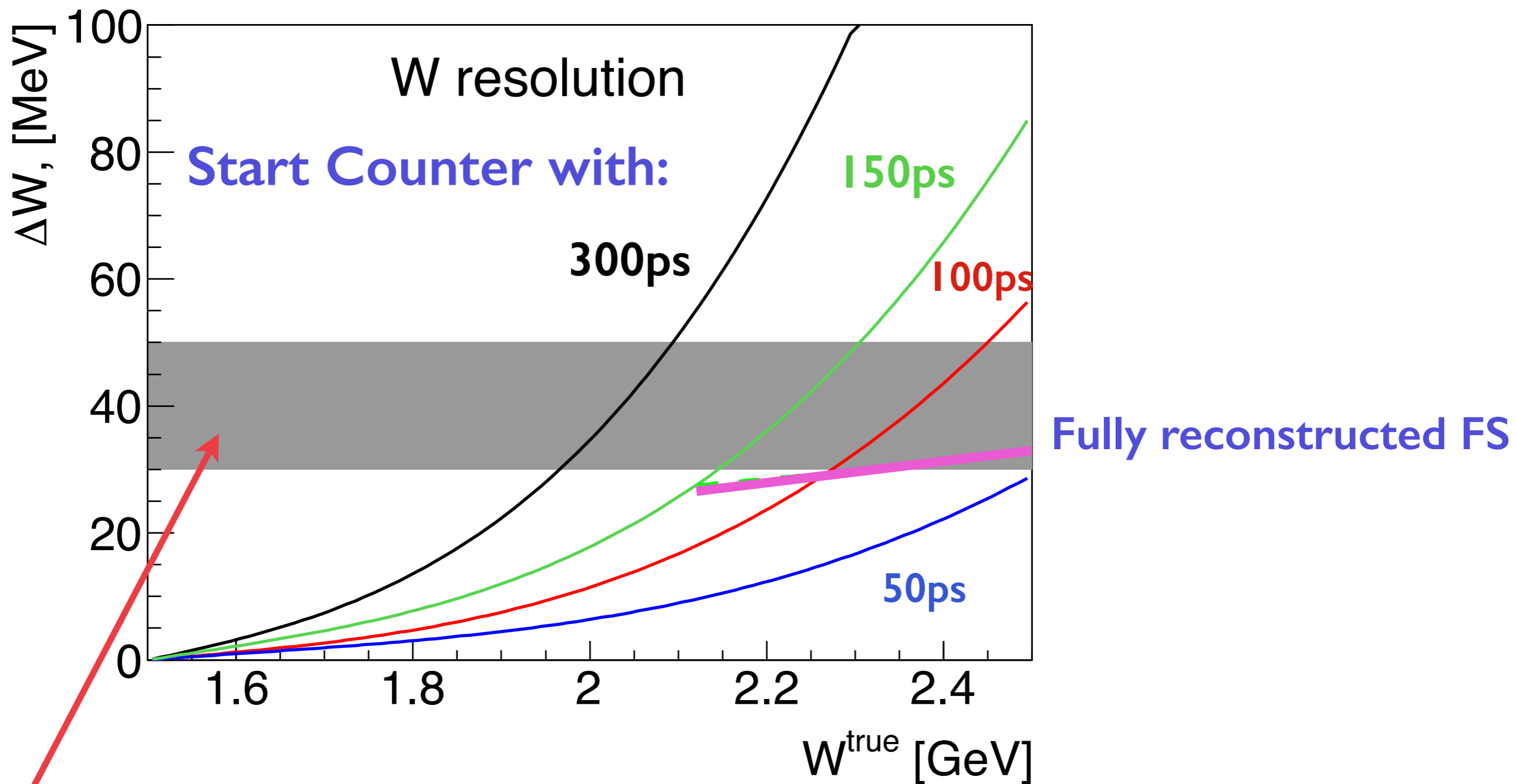
$\Delta\Omega = 20\mu sr$

SLAC-177
R.J. Jamartino



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

- KL Momentum will be measured with TOF



typical width of excited hyperons

- Current SC Timing resolution is $\sim 250\text{ps}$
- 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 $500 \mu\text{sr}$	$K_L : n$ ($E_n > 10 \text{ MeV}$)
BNL AGS	24 GeV	1.1 Pt	300-1200	60×10^6	$\sim 1 : 1000$
<i>Project X</i>	3 GeV	1.0 C	300-1200	450×10^6	$\sim 1 : 2700$

K_L 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

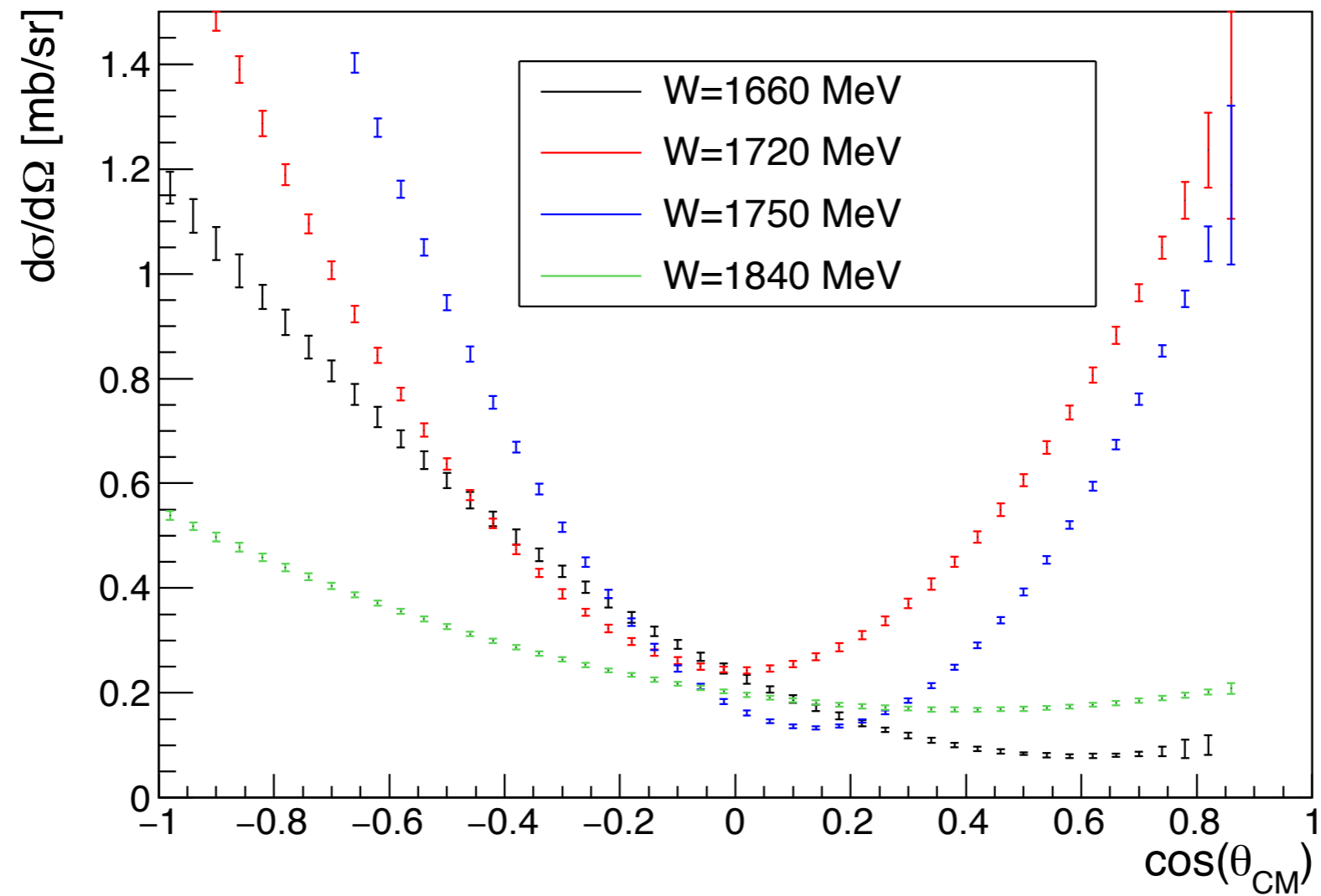
<i>Production</i>	<i>J-PARC*</i>	<i>Jlab (this proposal)</i>
<i>Kaons/s</i>	$3 \times 10^4 K^-$	$3 \times 10^4 K_L$
$\Xi^*/month$	3×10^5	2×10^5
$\Omega^{-*}/month$	600	4000

* *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**

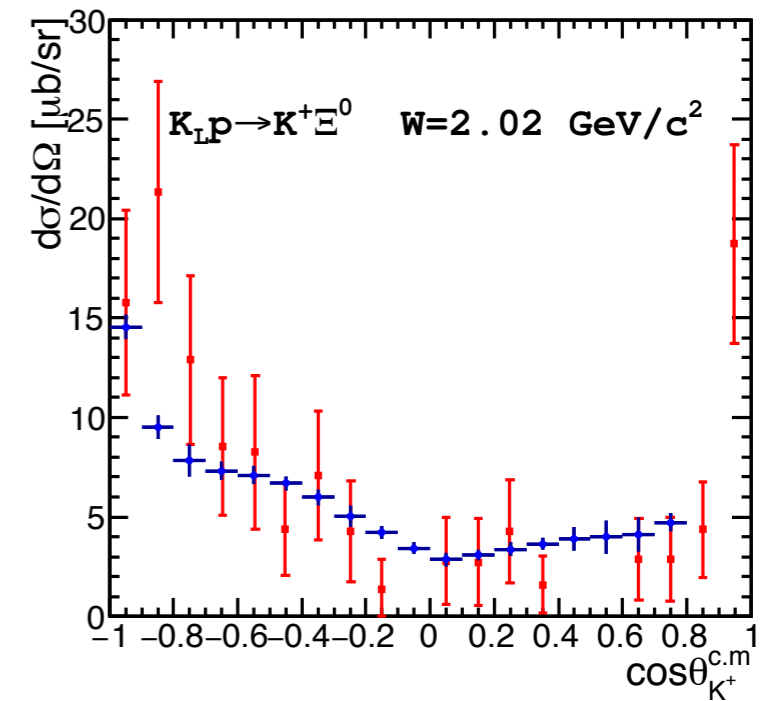
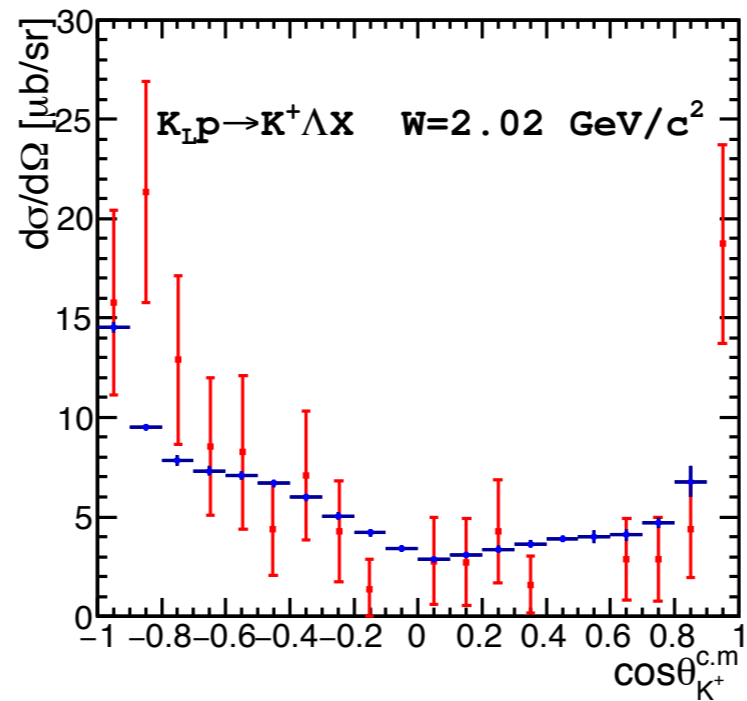
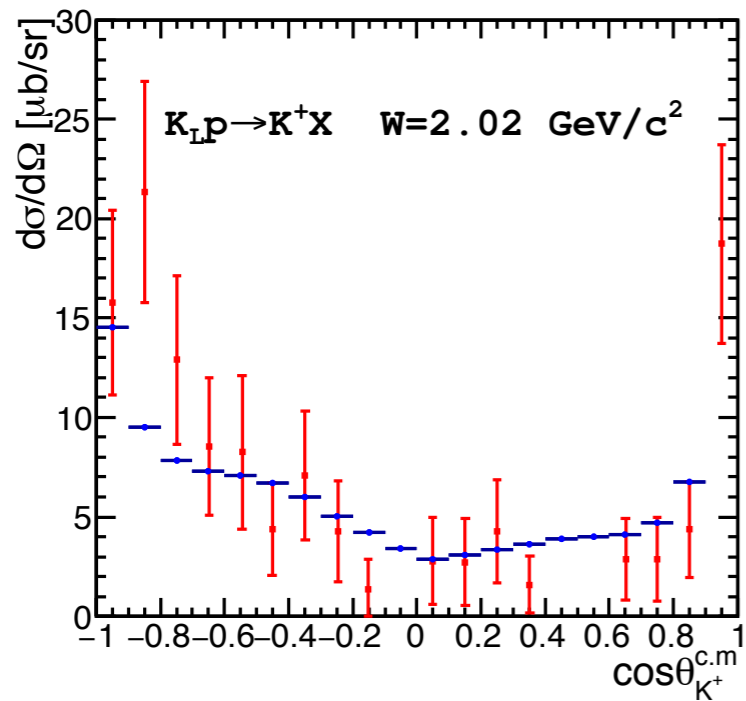
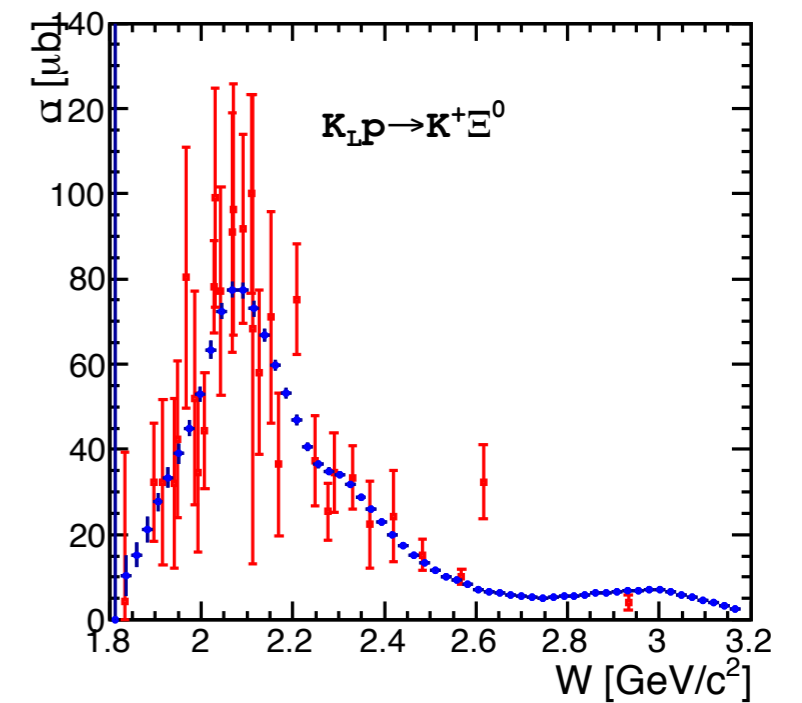
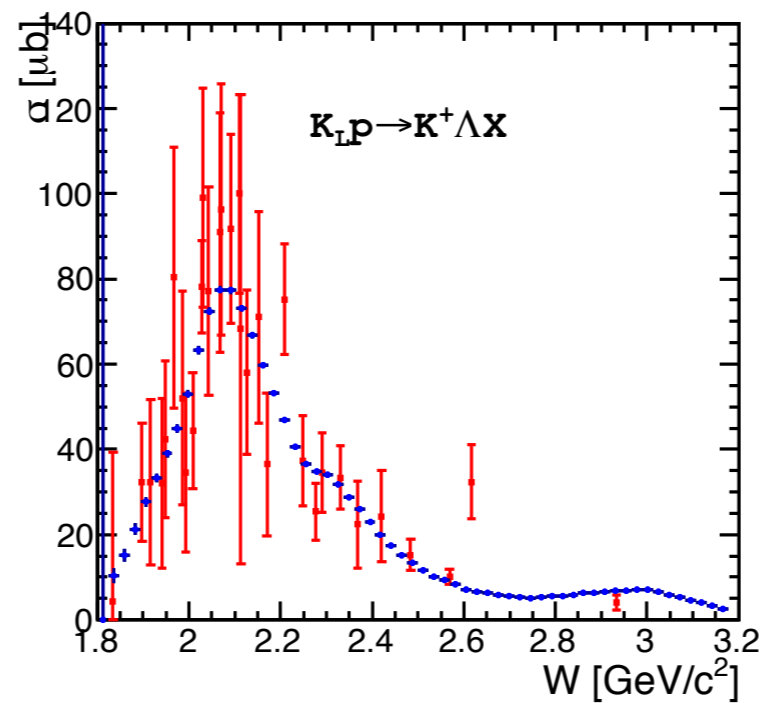
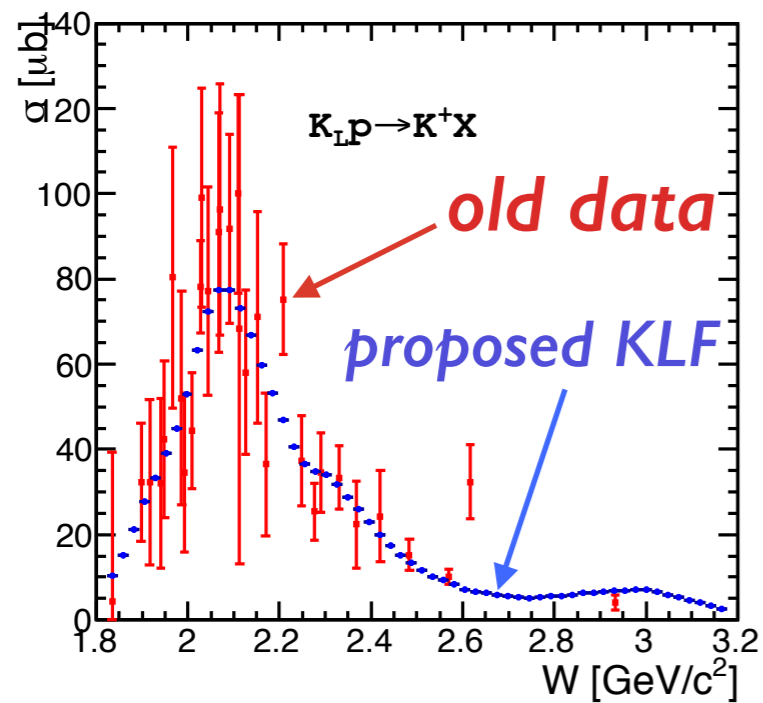
Proposed Measurements

$$\mathbf{K}_L \mathbf{p} \rightarrow \mathbf{K}_S \mathbf{p}$$



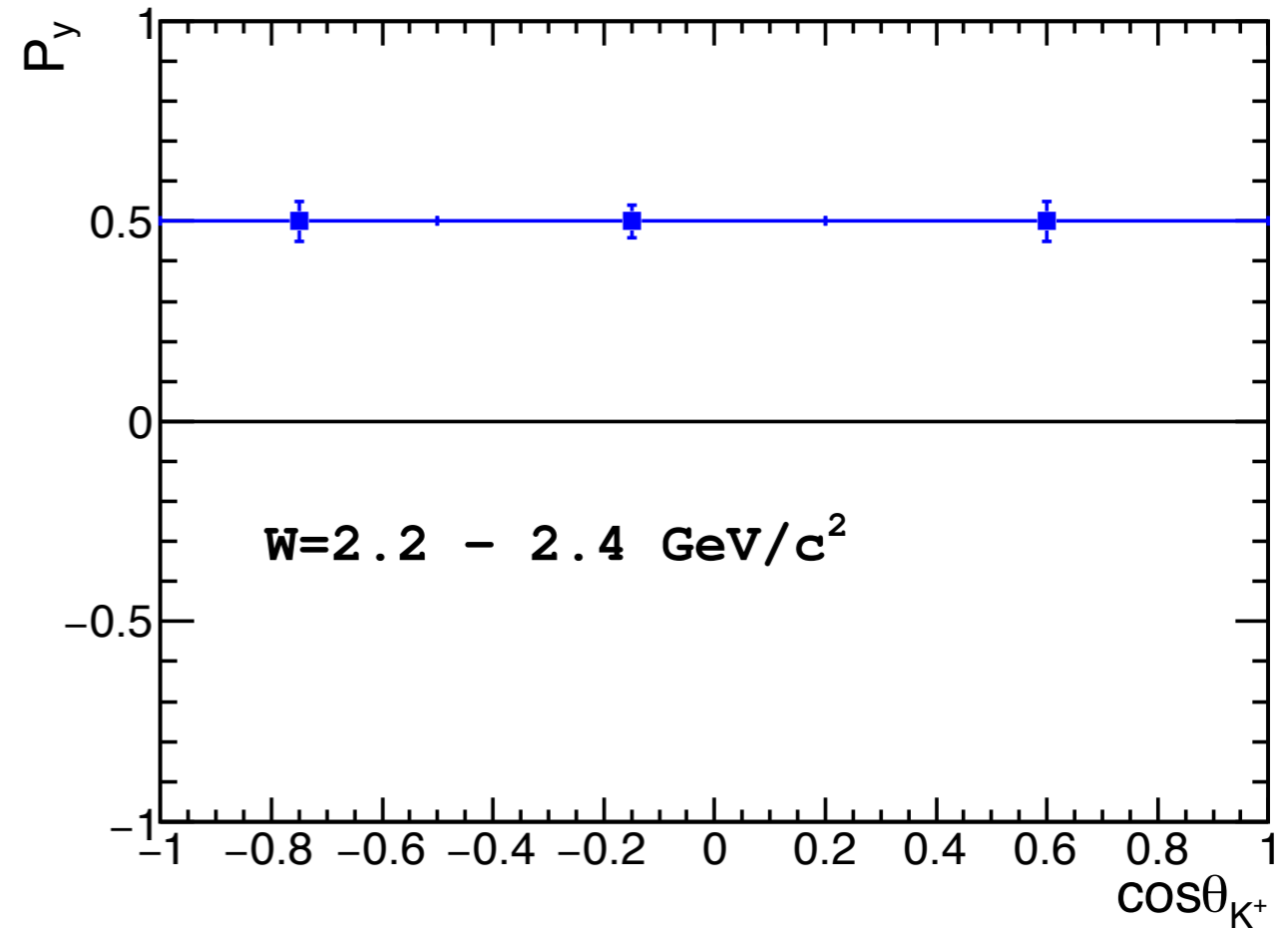
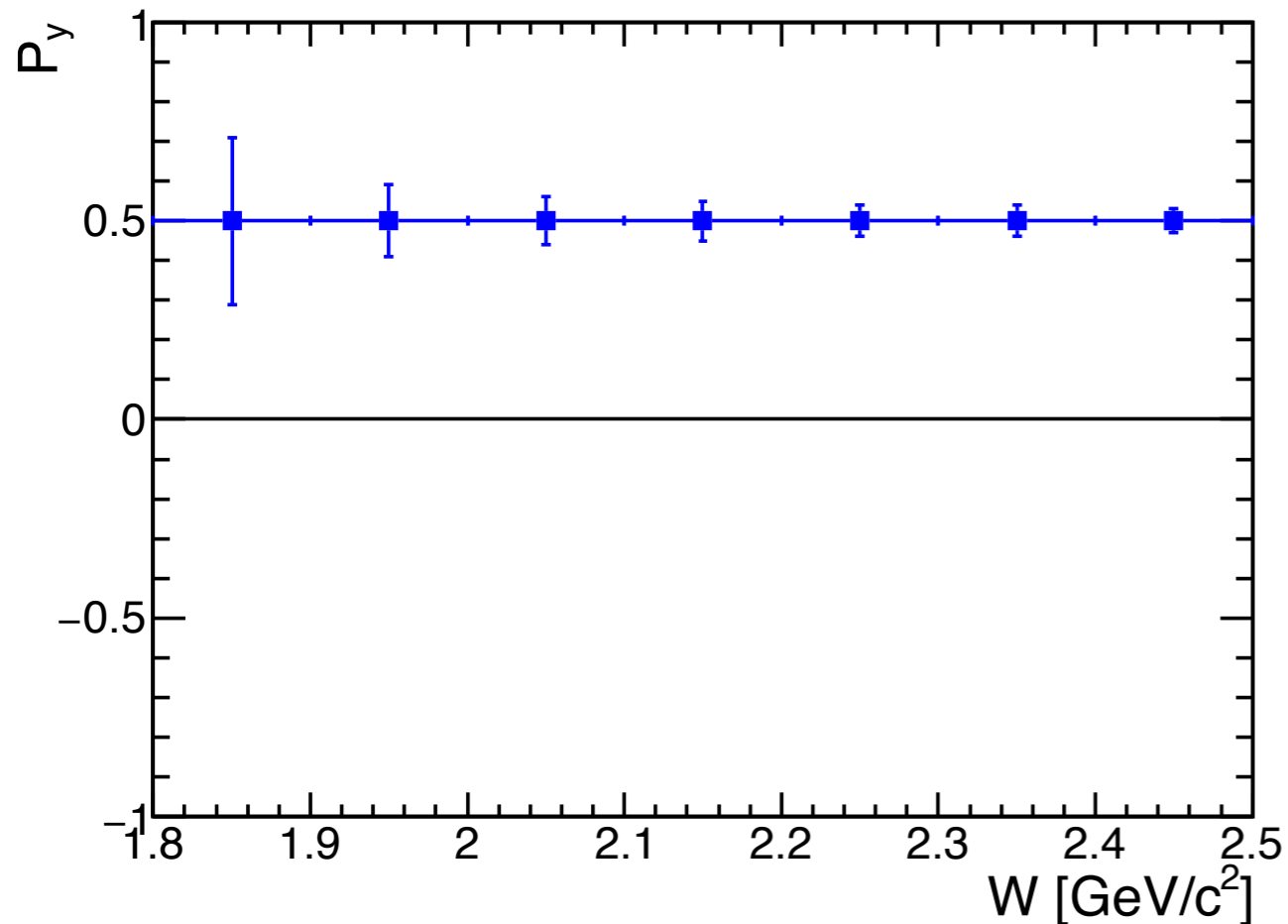
100 days of running

Proposed Measurements



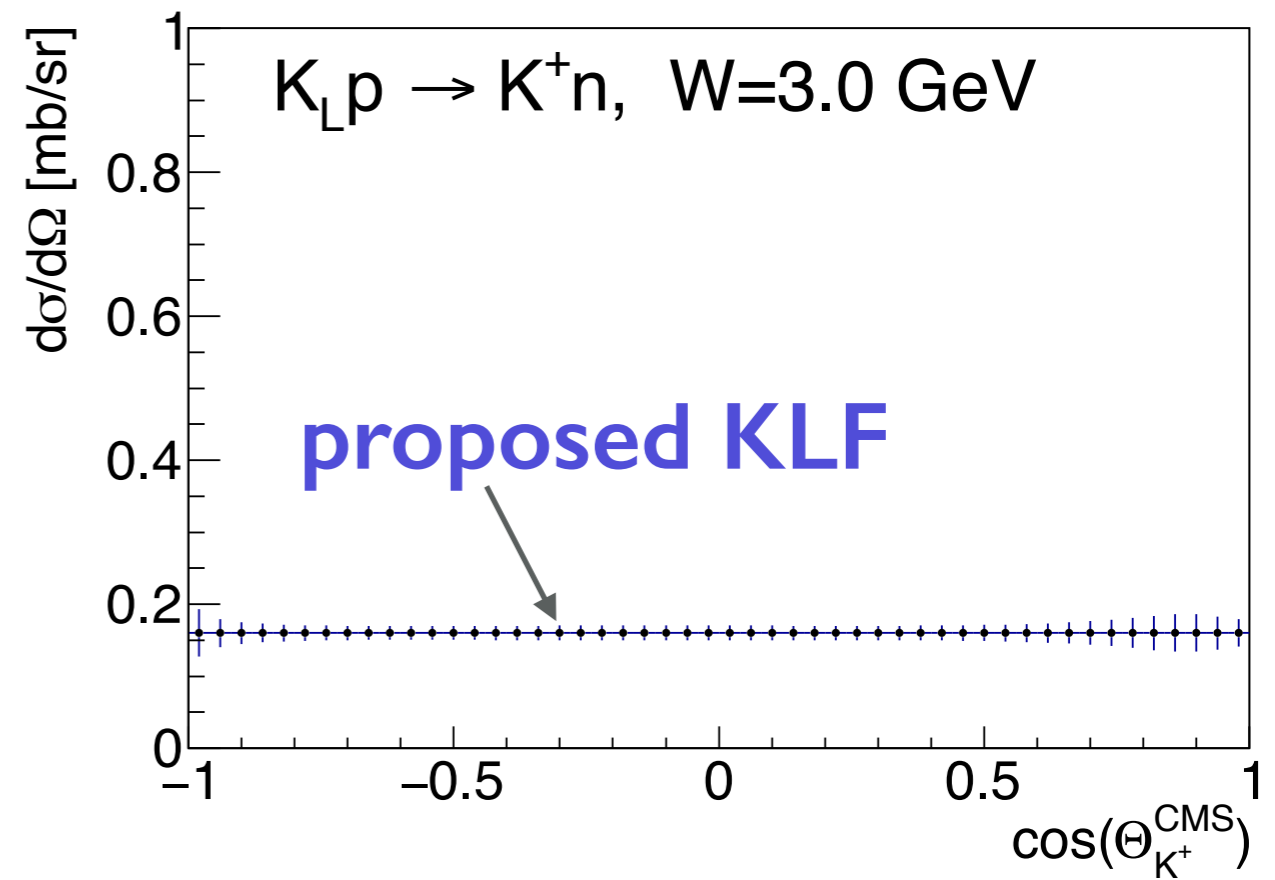
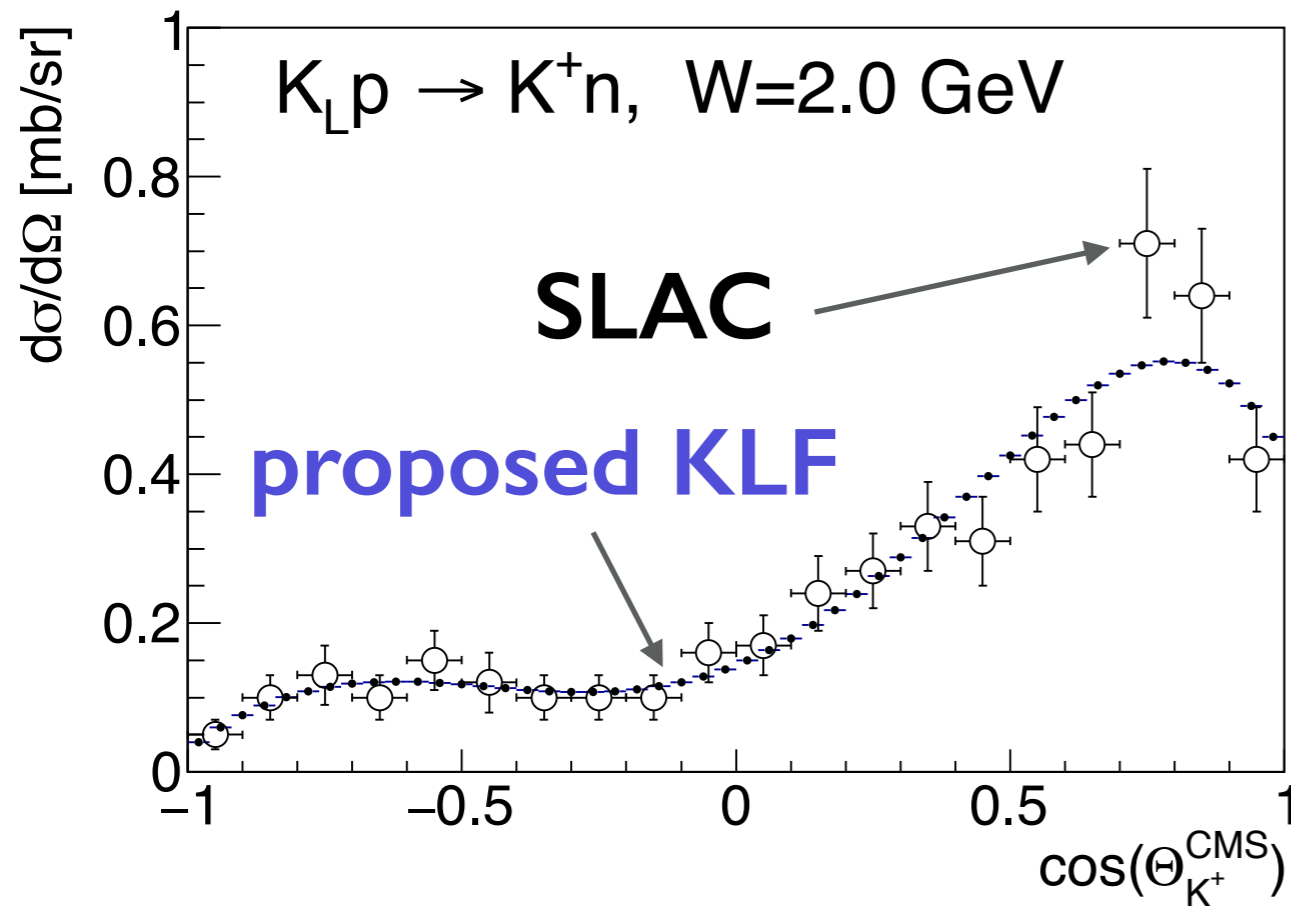
100 days of running

Proposed Measurements: Recoil polarization



10% stat error on polarization drives 100 days of running

Proposed Measurements



100 days of running

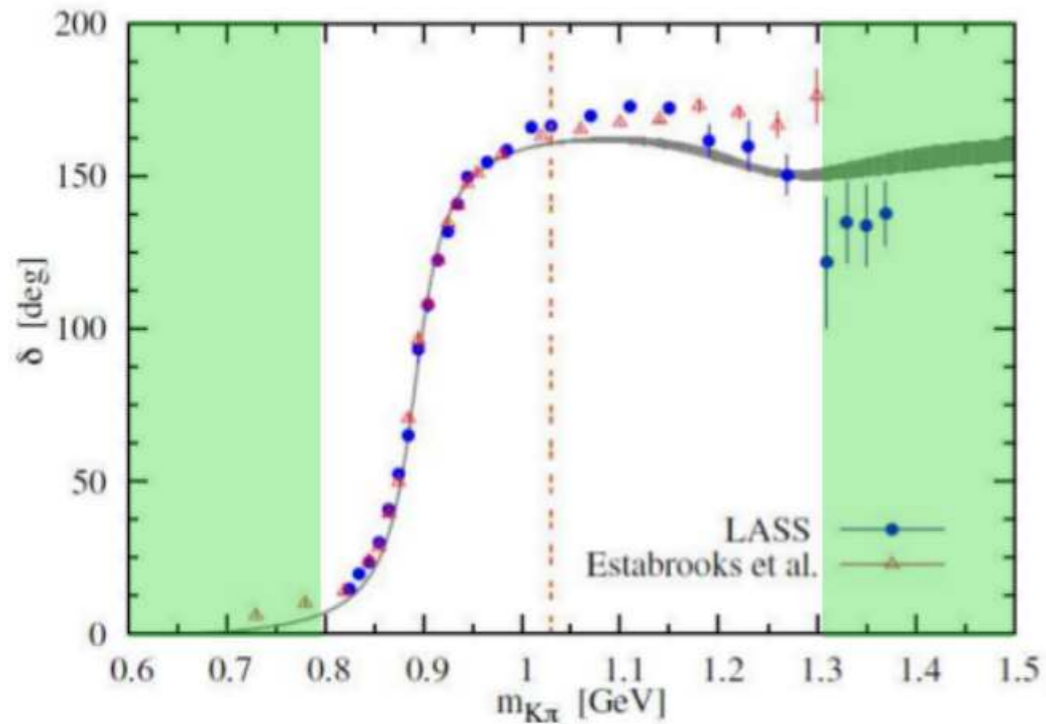
Proposed Measurements

$$K^{\pm}p \rightarrow K^{\pm}\pi^{+}n :$$

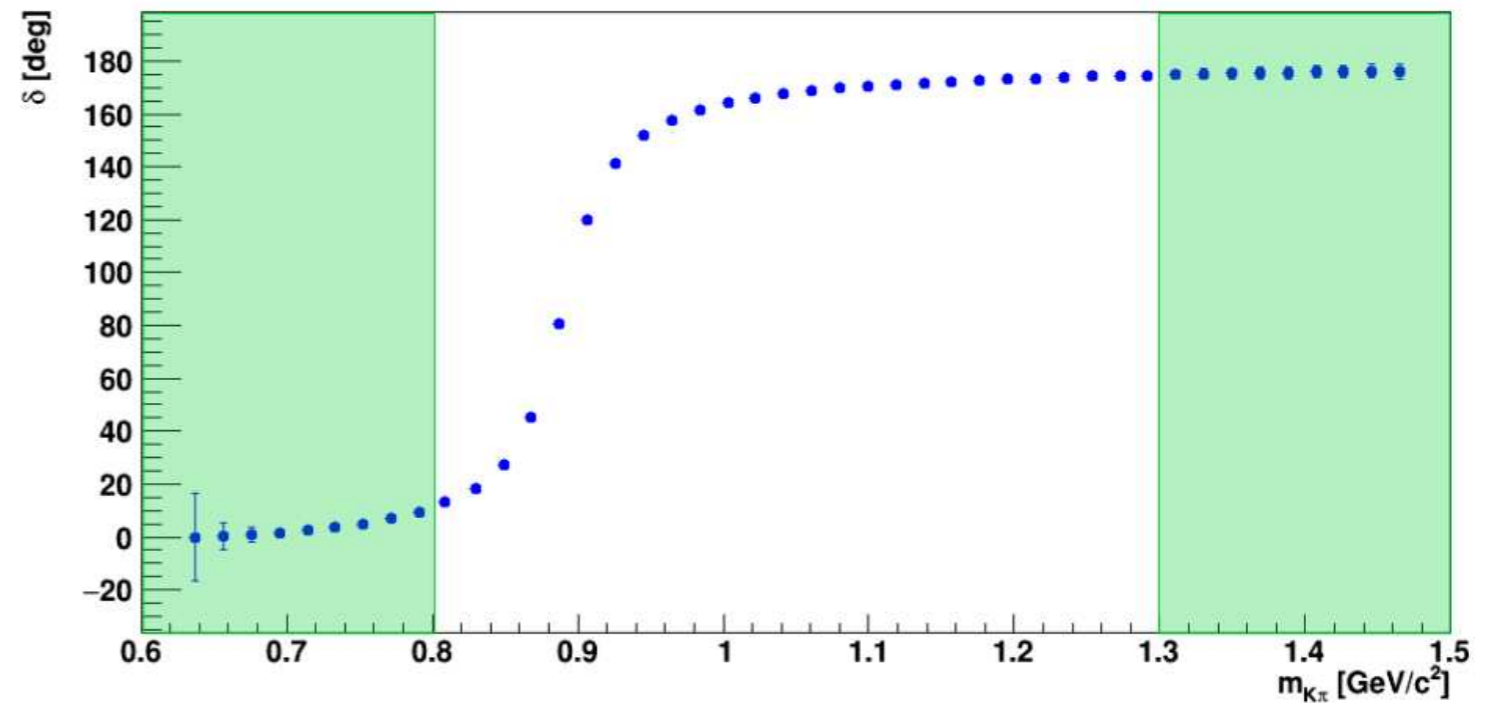
$K\pi$ Scattering

SLAC

P-wave



$M(K\pi)$



$M(K\pi)$

100 days of running

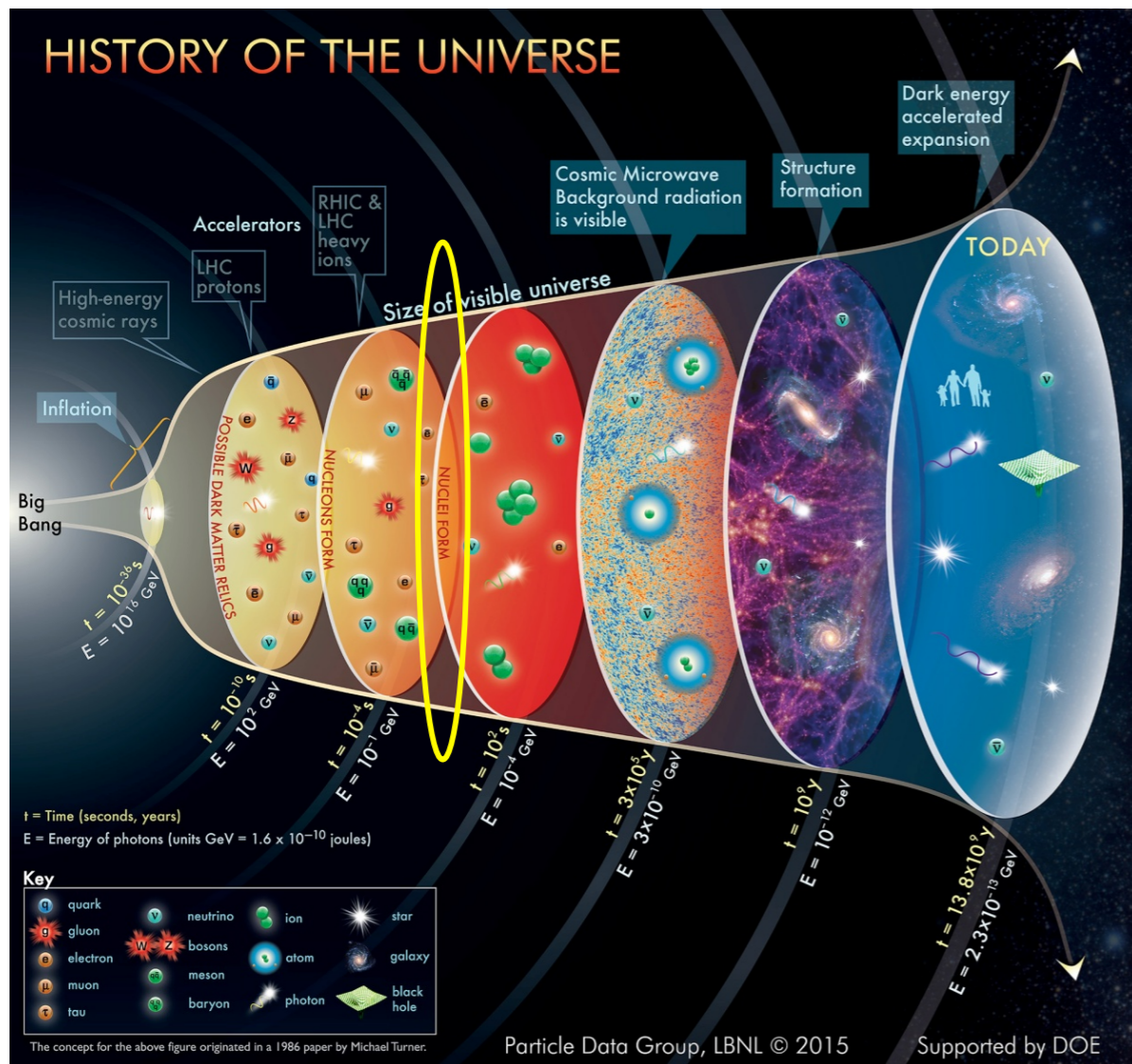
Expected Statistics: 100 days of running

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

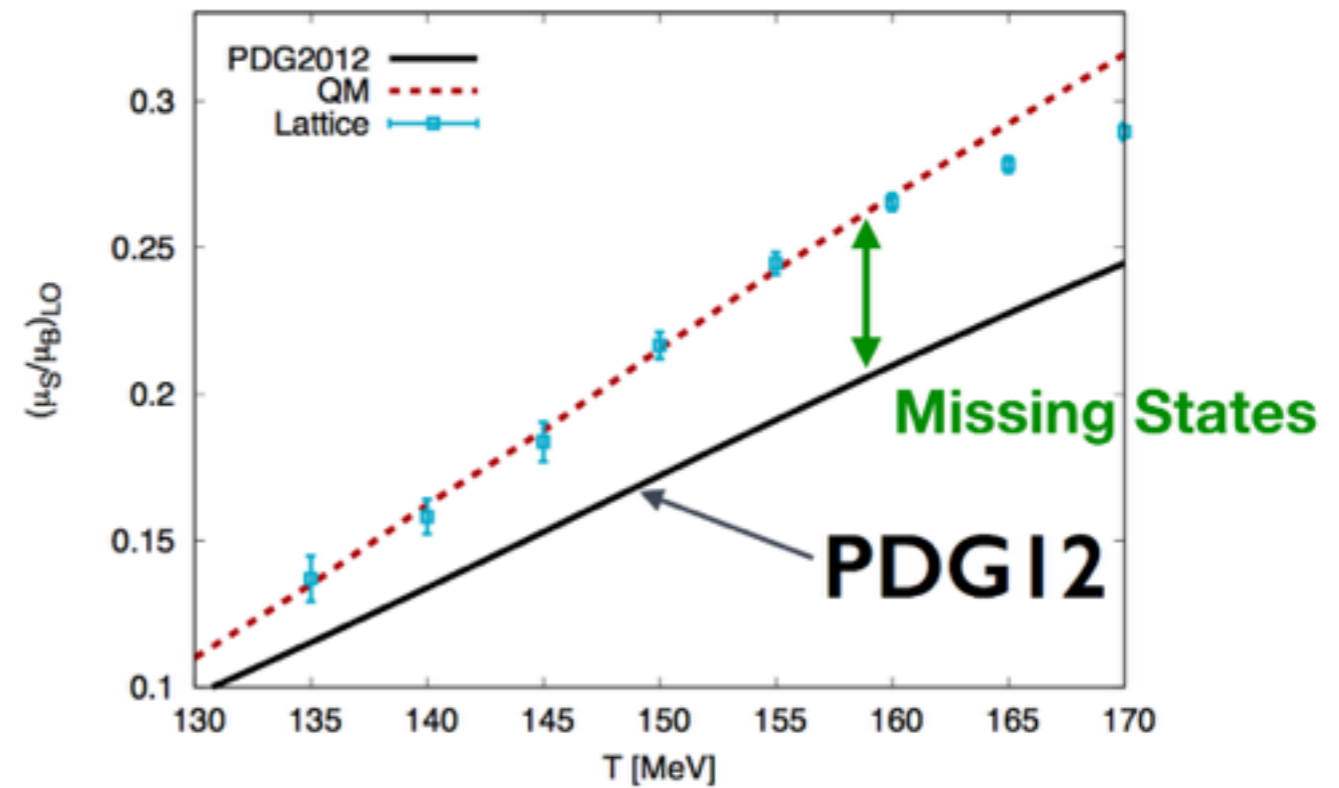
With similar statistics 100 days of running on LD2 target is needed

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 $\sim 10^3$ times higher than in SLAC*
- *Data obtained at JLab will be unique and complementary to charged kaon data*

Thank You!