Strange Hadron Spectroscopy with Secondary K_L Beam in Hall-D

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(on behalf of KLONG FACILITY Collaboration)

PAC48, JLab, August 11, 2020

Outline

Proposal Update

- Hyperon Spectroscopy
- Strange Meson Spectroscopy

K_L Facility Beamline and Hardware

- Electron Beam
- Compact Photon Source
- Be Target
- Flux Monitor
- K_L Beam
- LH_2/LD_2 Target

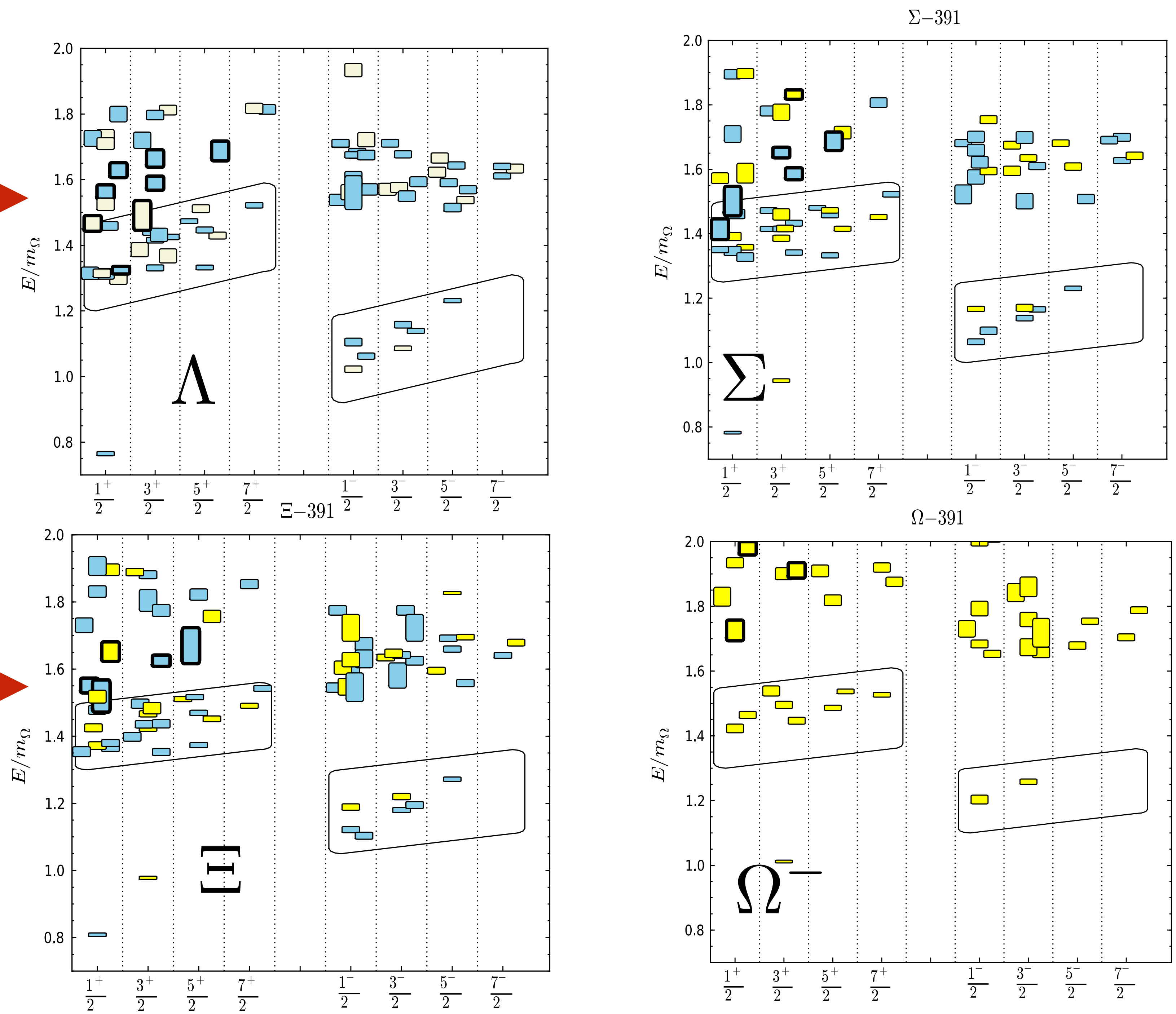
Summary

Hyperon Spectroscopy

*According to **LQCD** there should be many more states including hybrids (thick bordered)*

8-states
****
5-states
***

3-states
****
4-states
***

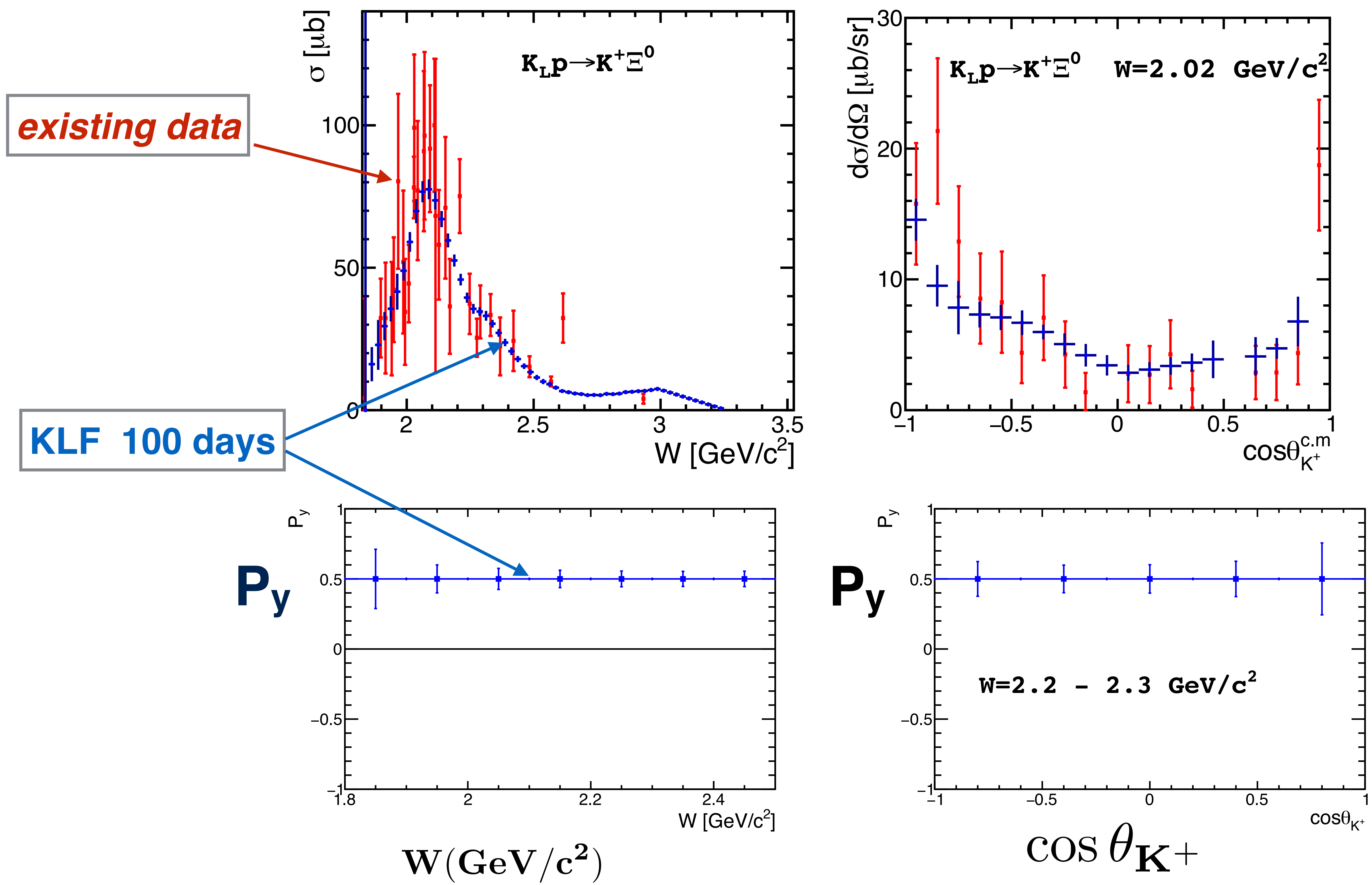


6-states
****
4-states
***

1-state
****
1-state
***

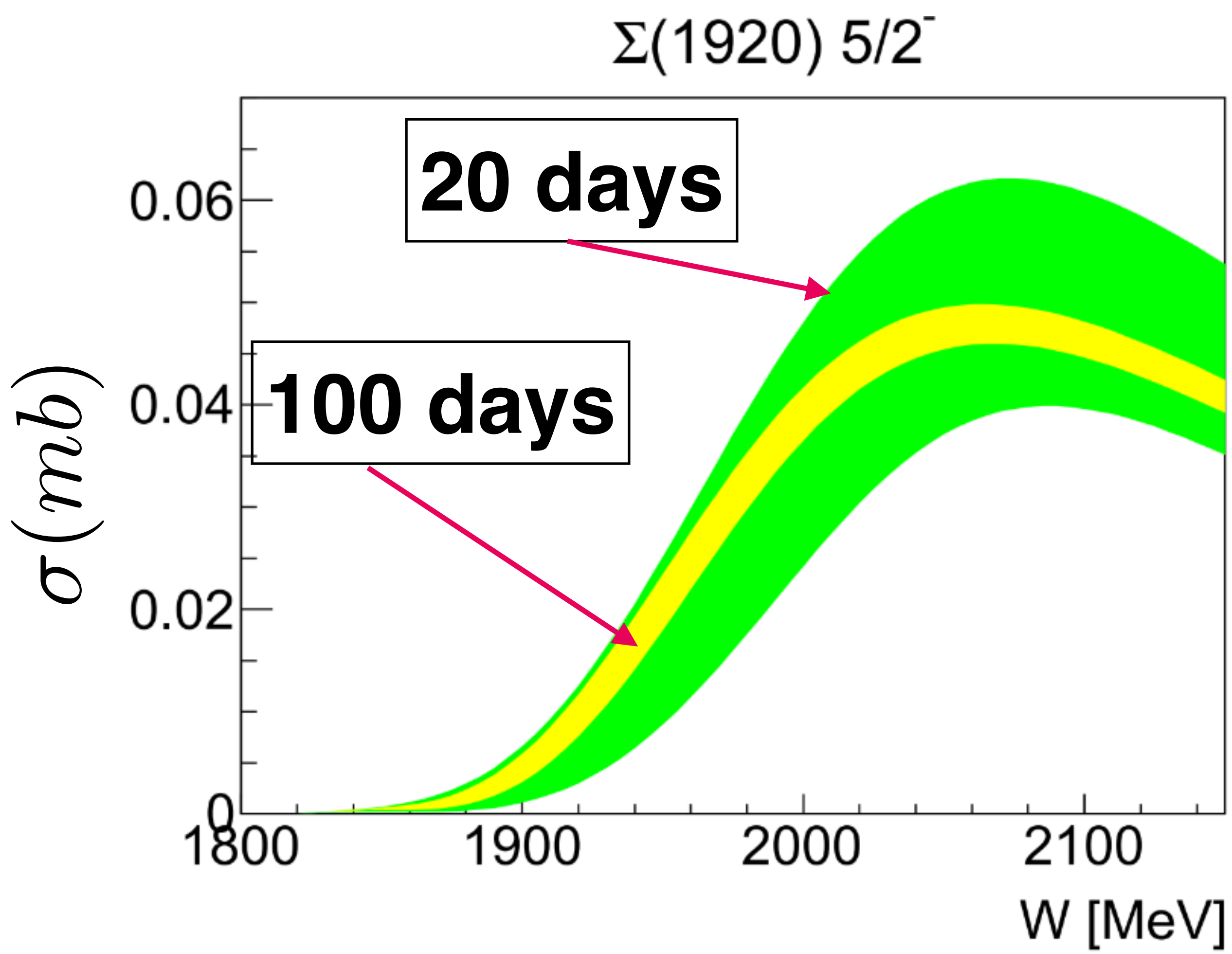
Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

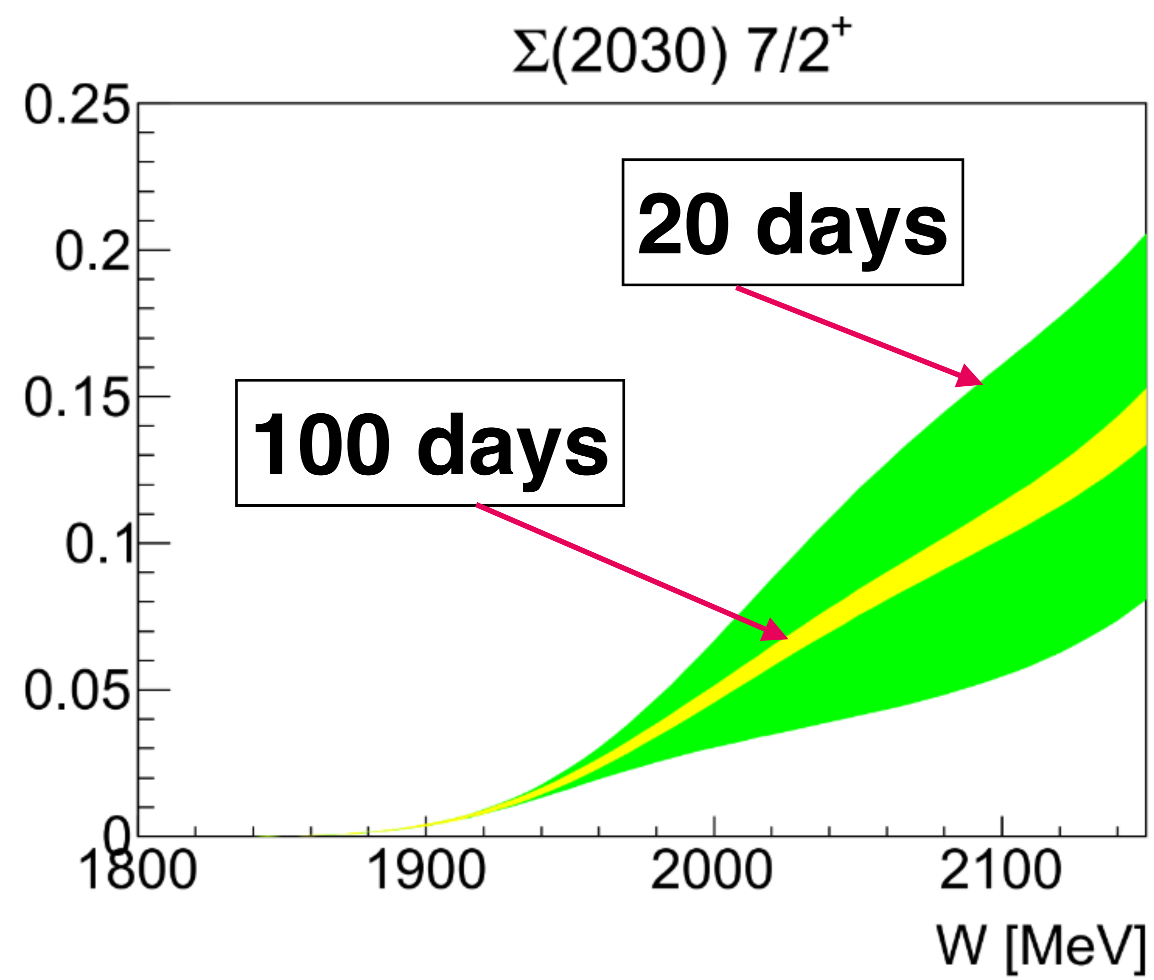
Measurements on Proton Target



Bonn-Gatchina PWA

Total Cross Section $K_L p \to K^+ \Xi^0$

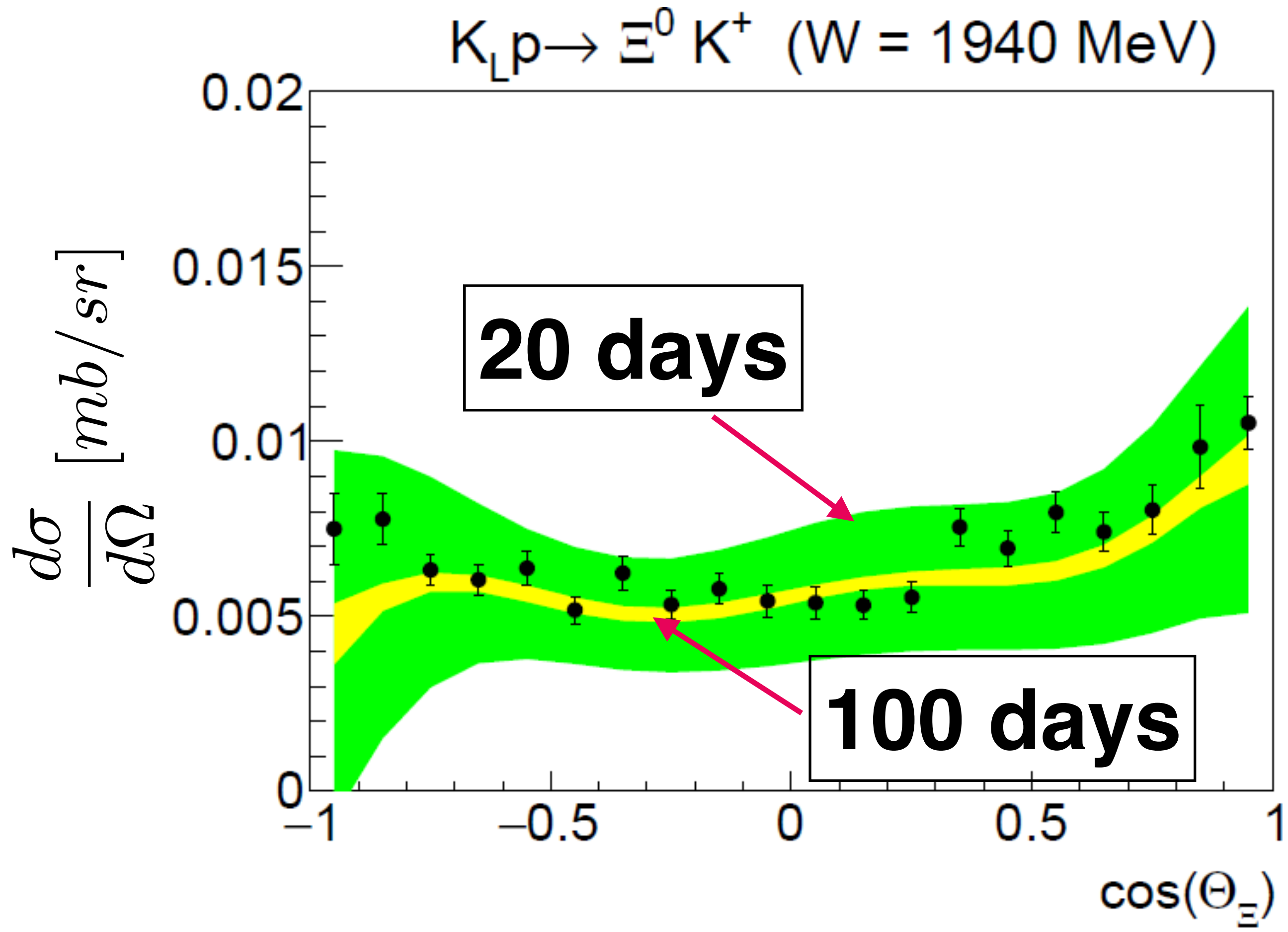




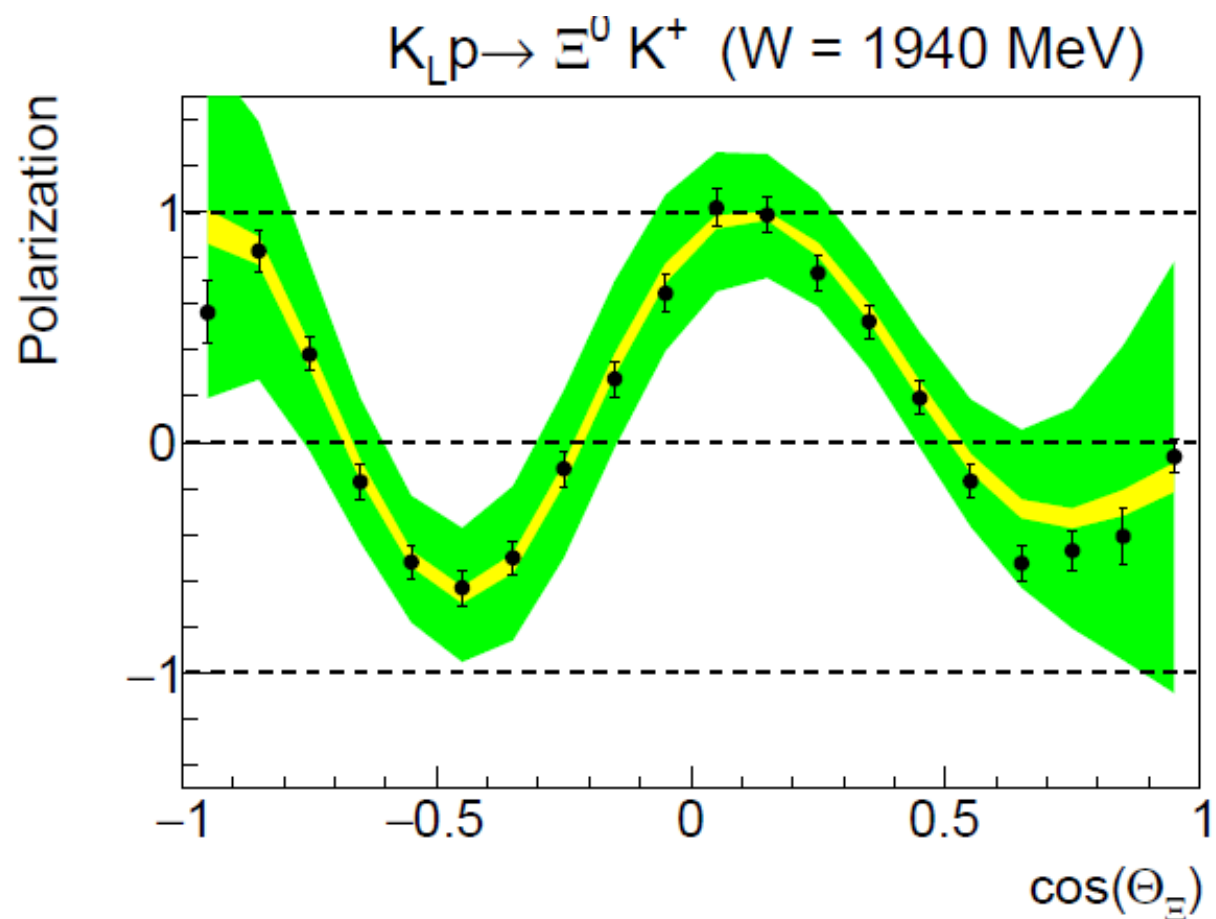
Need 100 days of running to get precise solution

Bonn-Gatchina PWA

Diff. Cross Section



Polarization



Need 100 days of running to get precise solution

Some Numerical Results

Simulated $\Sigma(1920)\ 5/2^-$

$$100d\ M = 1.923 \pm 0.010 \pm 0.010\ GeV$$

$$\Gamma = 0.321 \pm 0.01 \pm 0.010\ GeV$$

$$20d\ M = 1.977 \pm 0.021 \pm 0.025\ GeV$$

$$\Gamma = 0.327 \pm 0.025 \pm 0.025\ GeV$$

PDG2020 M= $1.775 \pm 0.005 GeV$

LQCD M=

2.027 GeV
2.487 GeV
2.659 GeV
2.781 GeV

R.G. Edwards et al., PRD 87,no.5. 054506 (2013)

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 Partial Wave Analysis

Neurons for the first time

-look for poles in complex energy plane

-identify excited hyperons with masses up to 2400 MeV
In a formation and production reactions

$\Lambda^*, \Sigma^*, \Xi^*\ \&\ \Omega^*$

we use KN scattering data with statistics
generated according to expected K-long Facility (KLF)
data for 20 and 100 days to show PWA sensitivity
to obtain results close to the best fit

Strange Meson Spectroscopy

Possible channels with proton and deuterium target and corresponding CG coefficient.

$$K_L p \rightarrow K^{\pm}\pi^{\mp}p = \left\langle K_L\pi^0 \,|\, K^{\pm}\pi^{\mp}\right\rangle = \pm\frac{1}{3}(T^{\frac{1}{2}} - T^{\frac{3}{2}}),$$

$$K_L p \rightarrow K_L\pi^0 p = \left\langle K_L\pi^0 \,|\, K_L\pi^0\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

$$K_L p \rightarrow K_{(L,S)}\pi^+ n = \left\langle K_L\pi^+ \,|\, K_L\pi^+\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

$$K_L p \rightarrow K^+\pi^0 n = \left\langle K_L\pi^+ \,|\, K^+\pi^0\right\rangle = -\frac{1}{3}(T^{\frac{1}{2}} - T^{\frac{3}{2}}),$$

$$K_L p \rightarrow K^-\pi^0\Delta^{++} = \left\langle K_L\pi^- \,|\, K^-\pi^0\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} - T^{\frac{3}{2}}),$$

$$K_L n \rightarrow K^{\pm}\pi^{\mp}n = \left\langle K_L\pi^0 \,|\, K^{\pm}\pi^{\mp}\right\rangle = \pm\frac{1}{3}(T^{\frac{1}{2}} - T^{\frac{3}{2}}),$$

$$K_L p \rightarrow K_{(L,S)}\pi^-\Delta^{++} = \left\langle K_L\pi^- \,|\, K_L\pi^-\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

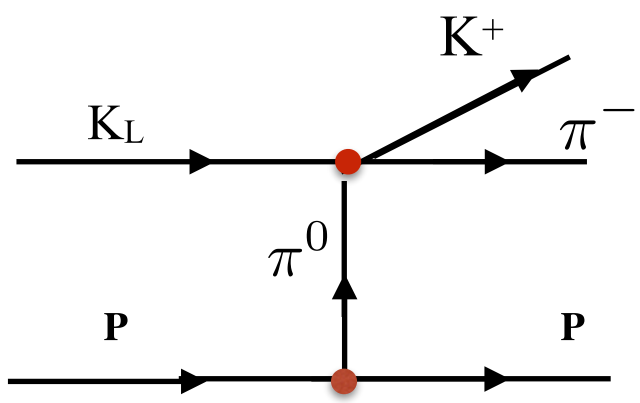
$$K_L n \rightarrow K_L\pi^0 n = \left\langle K_L\pi^0 \,|\, K_L\pi^0\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

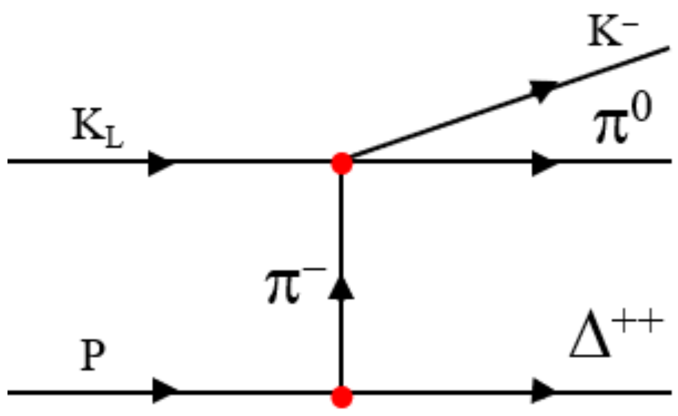
$$K_L n \rightarrow K_{(L,S)}\pi^{\pm}\Delta^{\mp} = \left\langle K_L\pi^{\pm} \,|\, K_L\pi^{\pm}\right\rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

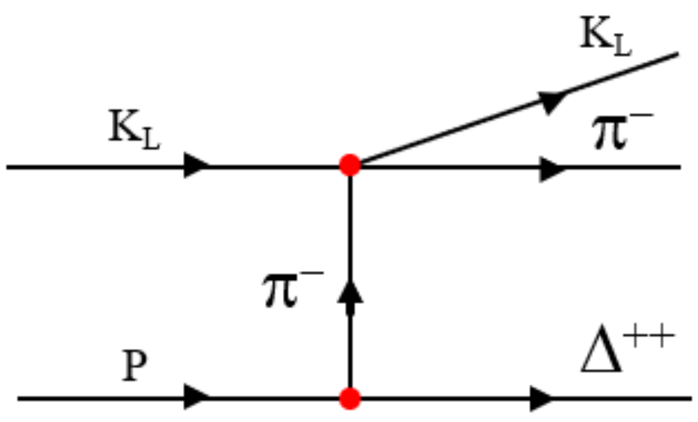
$$K_L n \rightarrow K^{\pm}\pi^0\Delta^{\mp} = \left\langle K_L\pi^{\pm} \,|\, K^{\pm}\pi^0\right\rangle = \pm\frac{1}{3}(T^{\frac{1}{2}} - T^{\frac{3}{2}}),$$

Strange Meson Spectroscopy

$K\pi$ Scattering

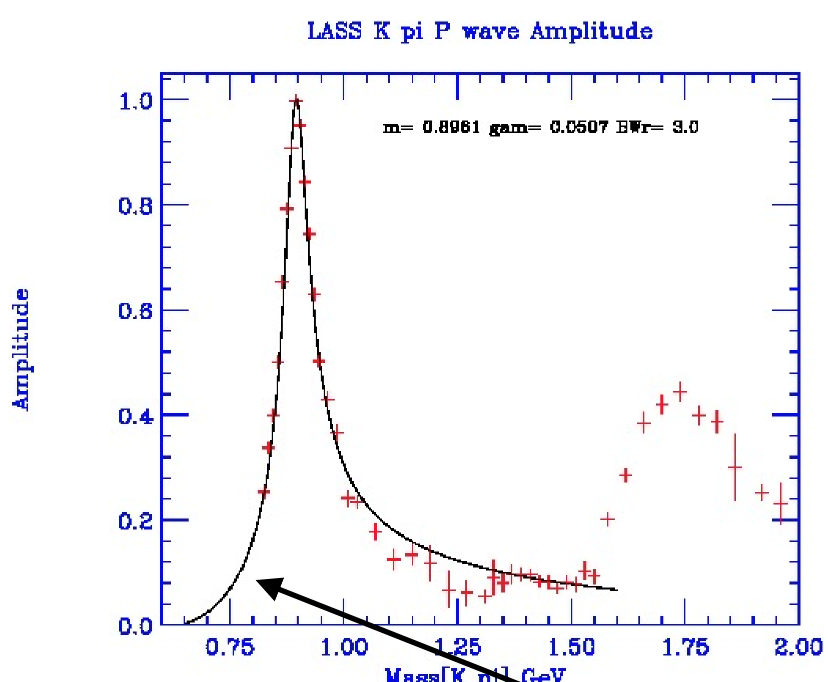


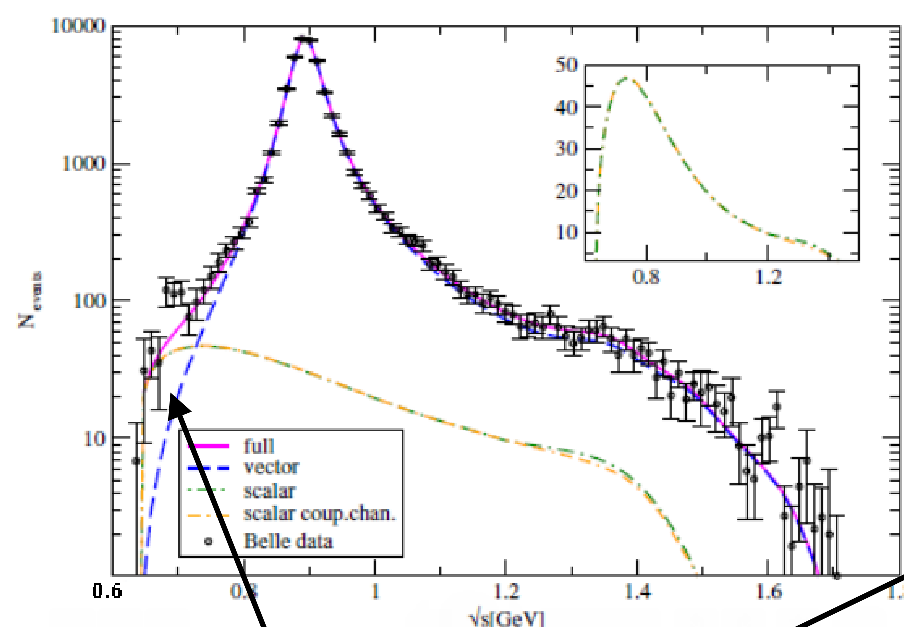


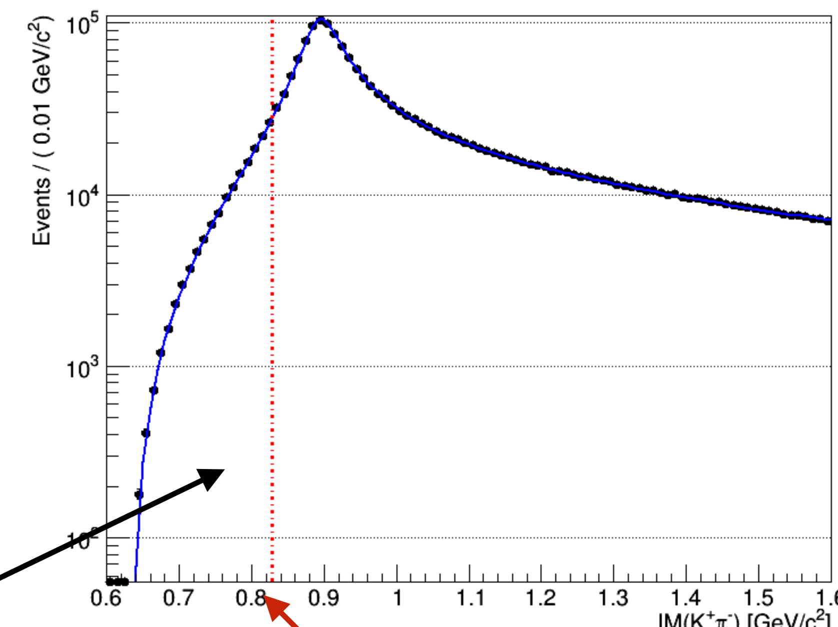


Proposed Measurements

SLAC	Belle	KLF
$K^-\pi^+ \to K^-\pi^+$	$\tau \to K\pi\nu_\tau$	$K_L\pi^0 \to K^+\pi^-$







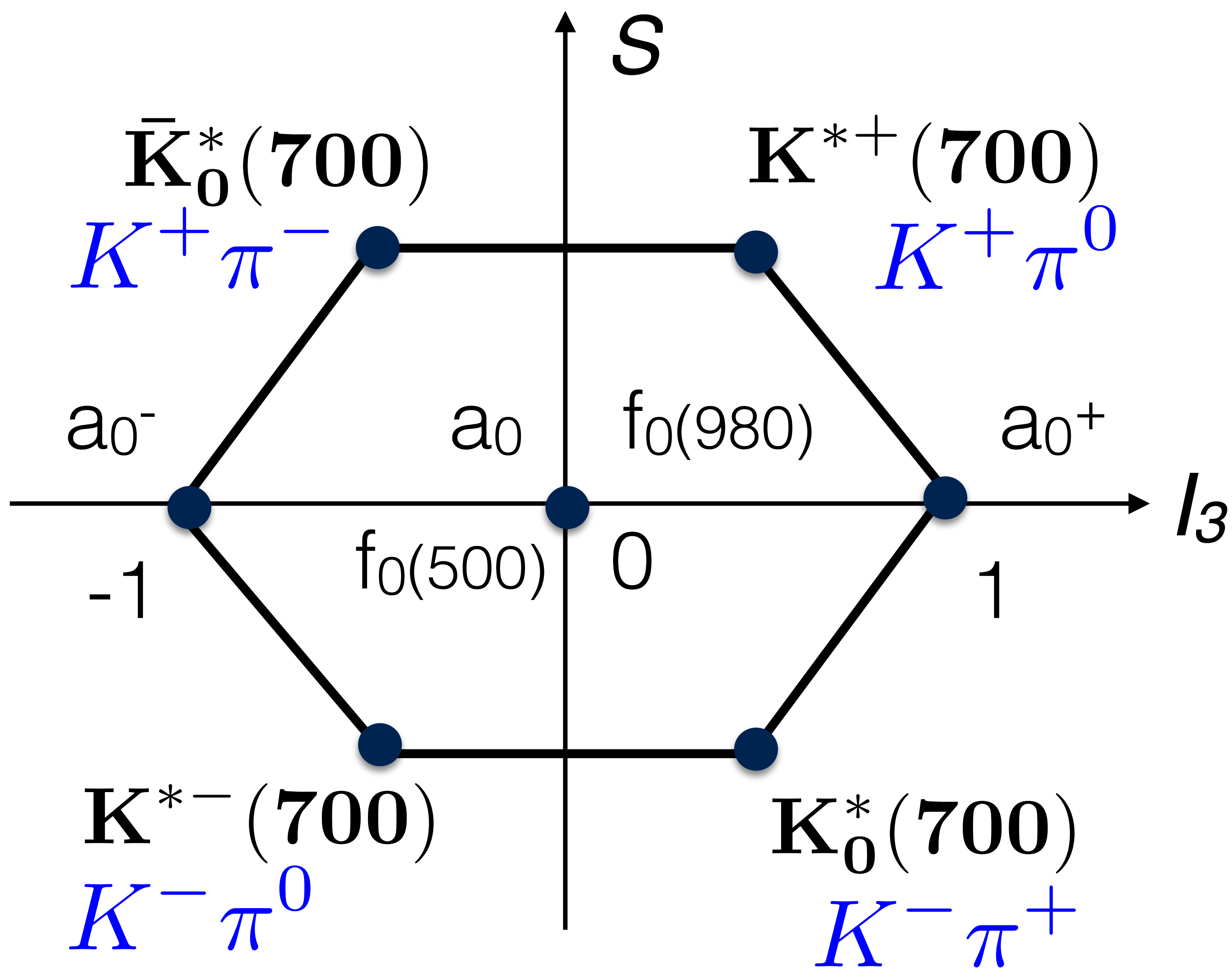
$\mathbf{M(K\pi)(GeV)}$ $\mathbf{M(K\pi)(GeV)}$ $\mathbf{M(K\pi)(GeV)}$

region of $\kappa(800)$

SLAC Lower limit

Scalar Meson Nonet

$J^{PC} = 0^{++}$



Four states called κ

still need further confirmation(PDG)

We can measure all of them

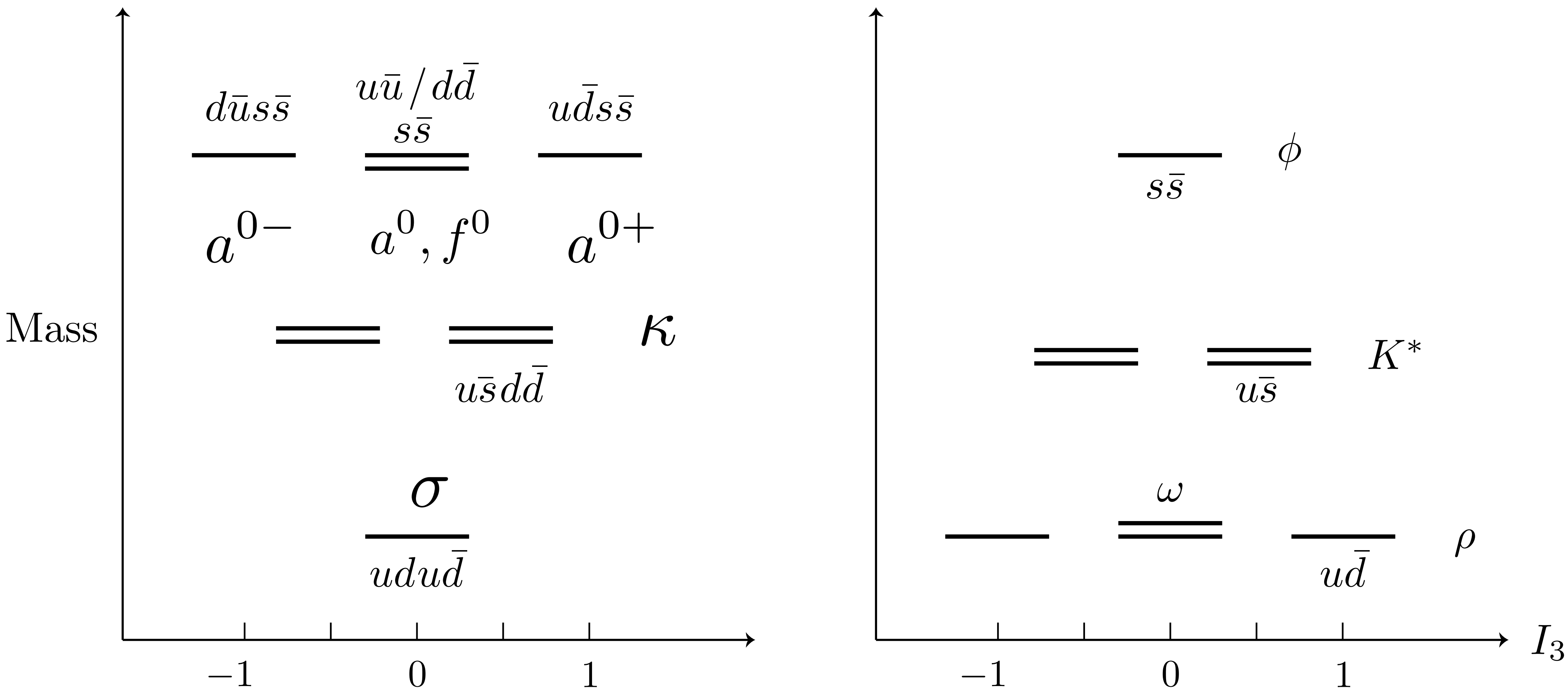
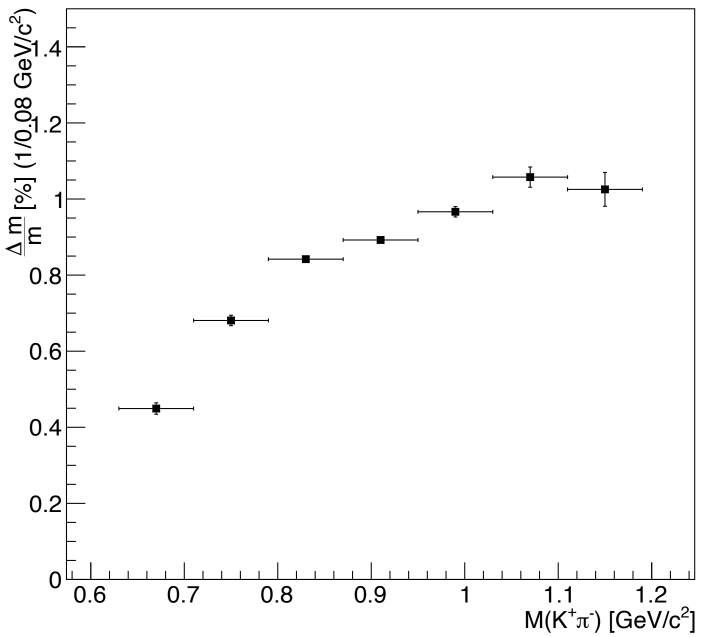


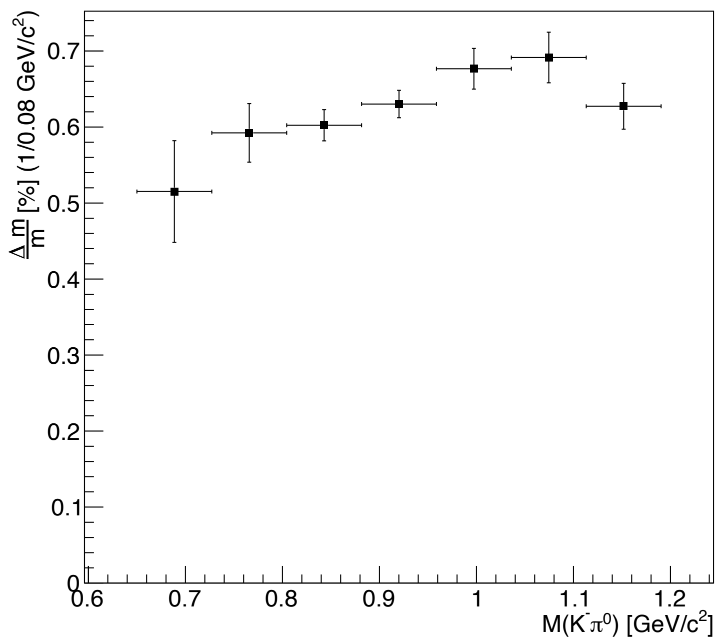
Figure 6. A cartoon representation of the masses of a $\bar{q}\bar{q}qq$ nonet compared with a $\bar{q}q$ nonet.

R. Jaffe hep-ph/0001123

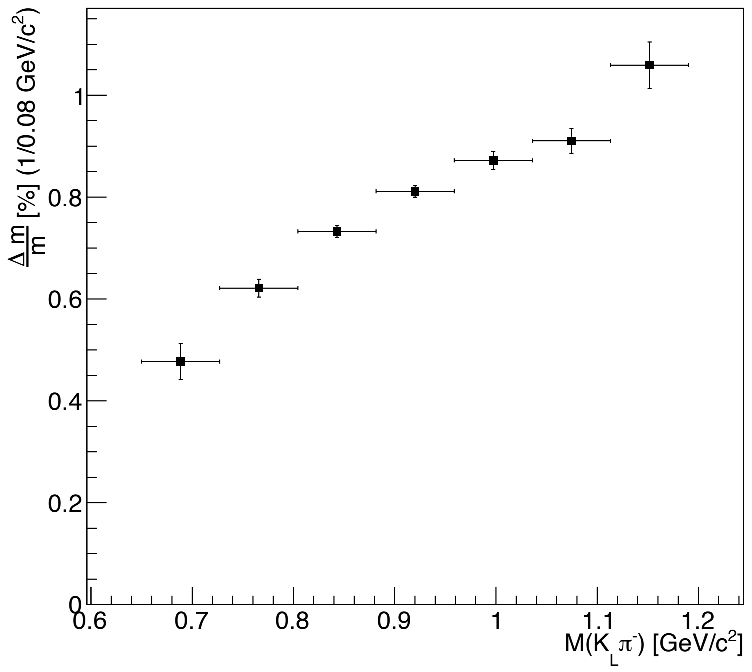
Invariant mass resolution $\Delta m/m$ (%)



$K^+\pi^-$



$K^-\pi^0$



$K_L\pi^-$

Below 1% in all cases

Projected Measurements

I=3/2+1/2 S-wave

PAC47

SLAC Data

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

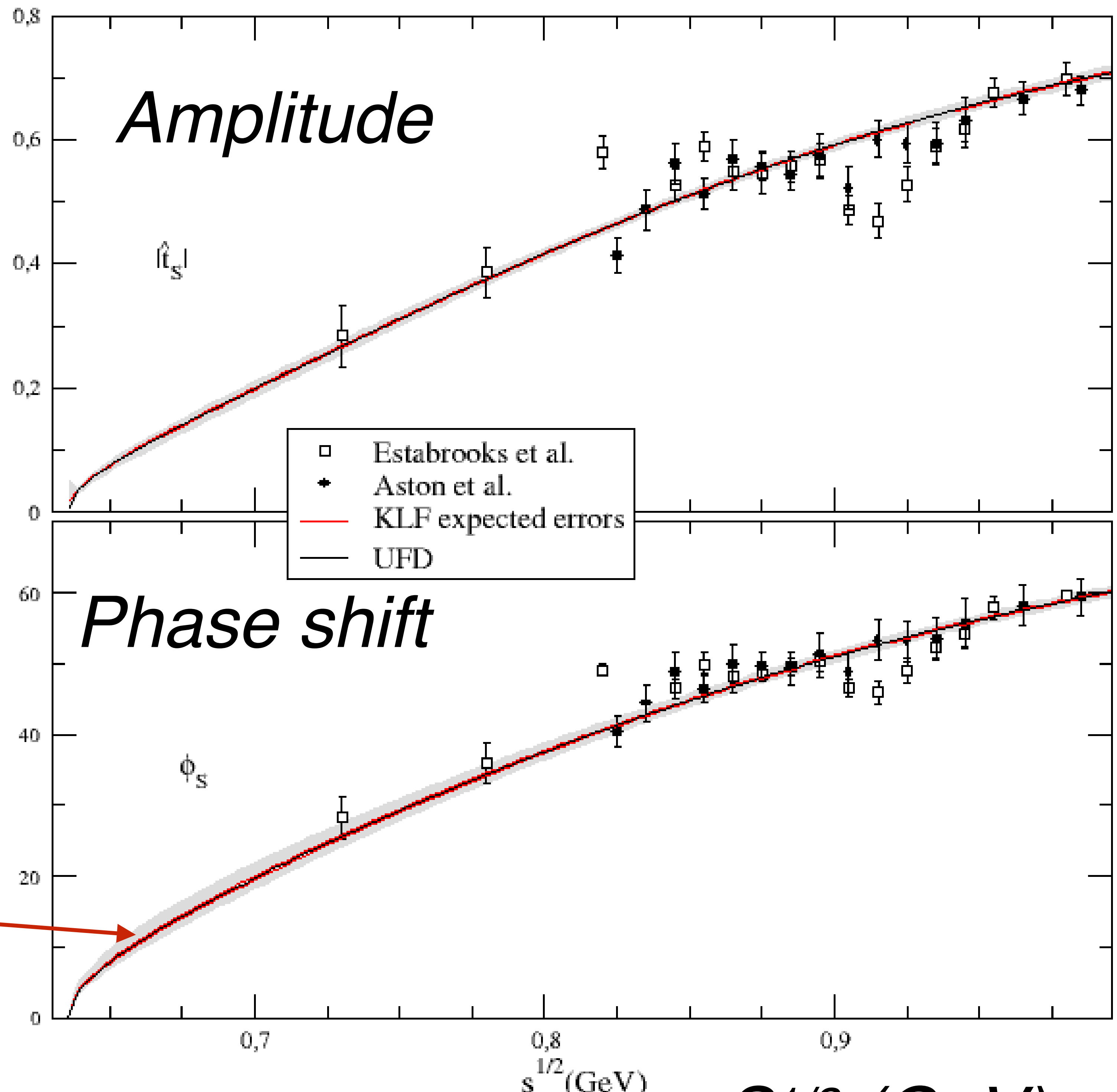
$$K^{\pm}p \rightarrow K^{\pm}\pi^{-}\Delta^{++}$$

Estabrooks(1978)

$$K^{-}p \rightarrow K^{-}\pi^{+}n$$

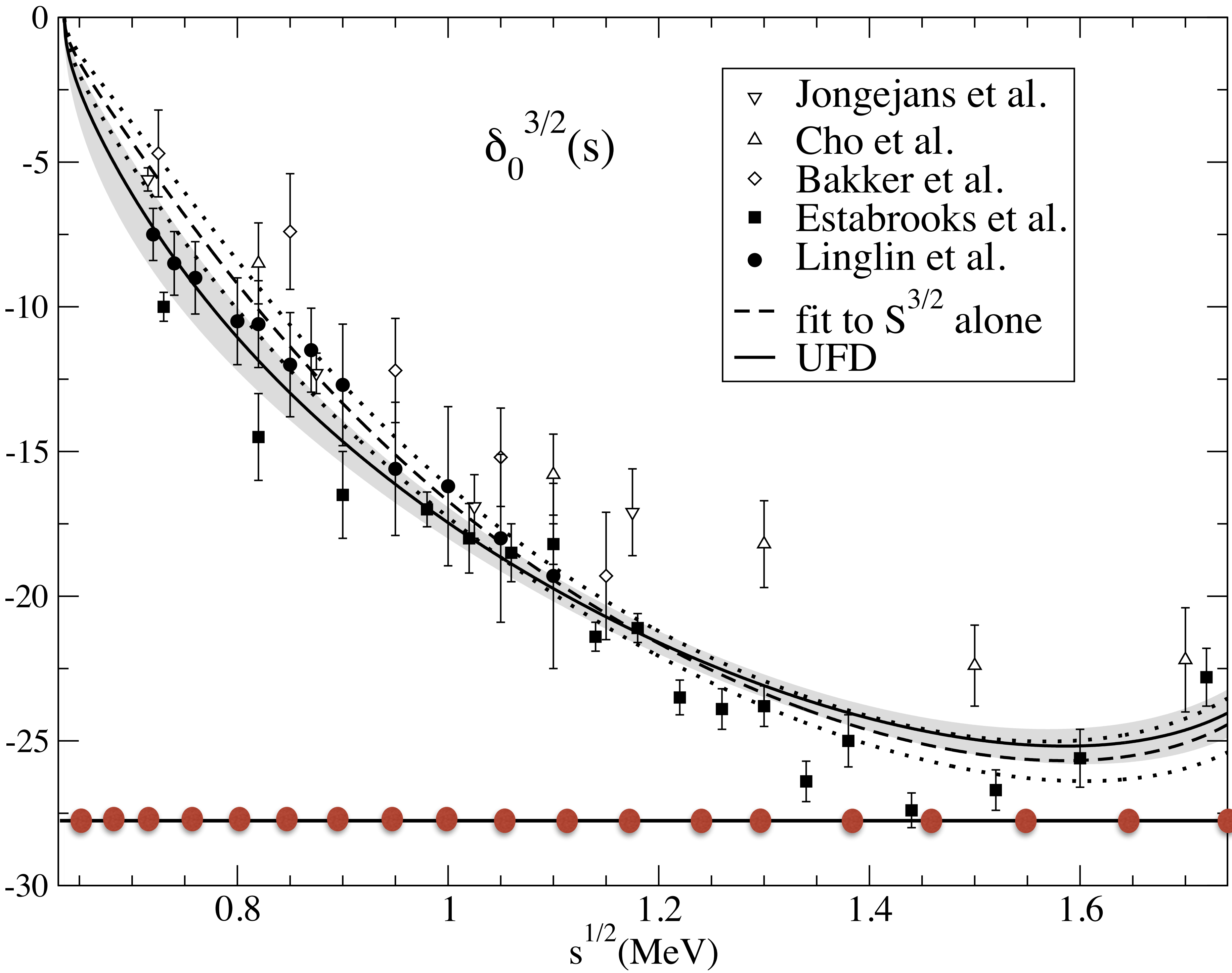
Aston(1988)

KLF (100 days)



$S^{1/2}$ (GeV)

I=3/2 *S-wave*



4.25 GeV Saclay
5.5 GeV CERN
3.0 GeV ANL
13.0 GeV SLAC
14.3 GeV CERN

Estabrooks(1978)

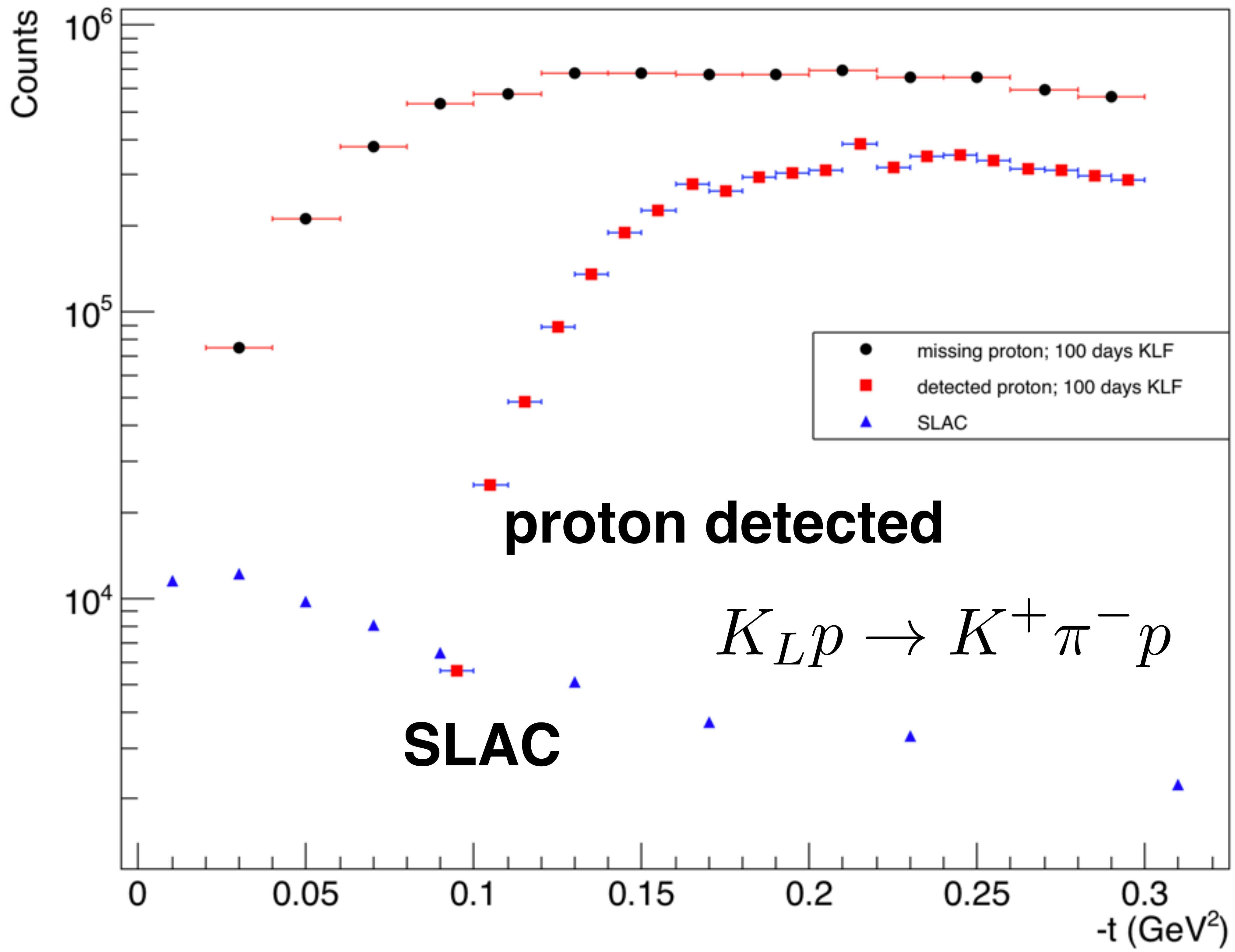
$$K^{\pm}p \to K^{\pm}\pi^{+}n$$

$$K^{\pm}p \to K^{\pm}\pi^{-}\Delta^{++}$$

KLF 100 days

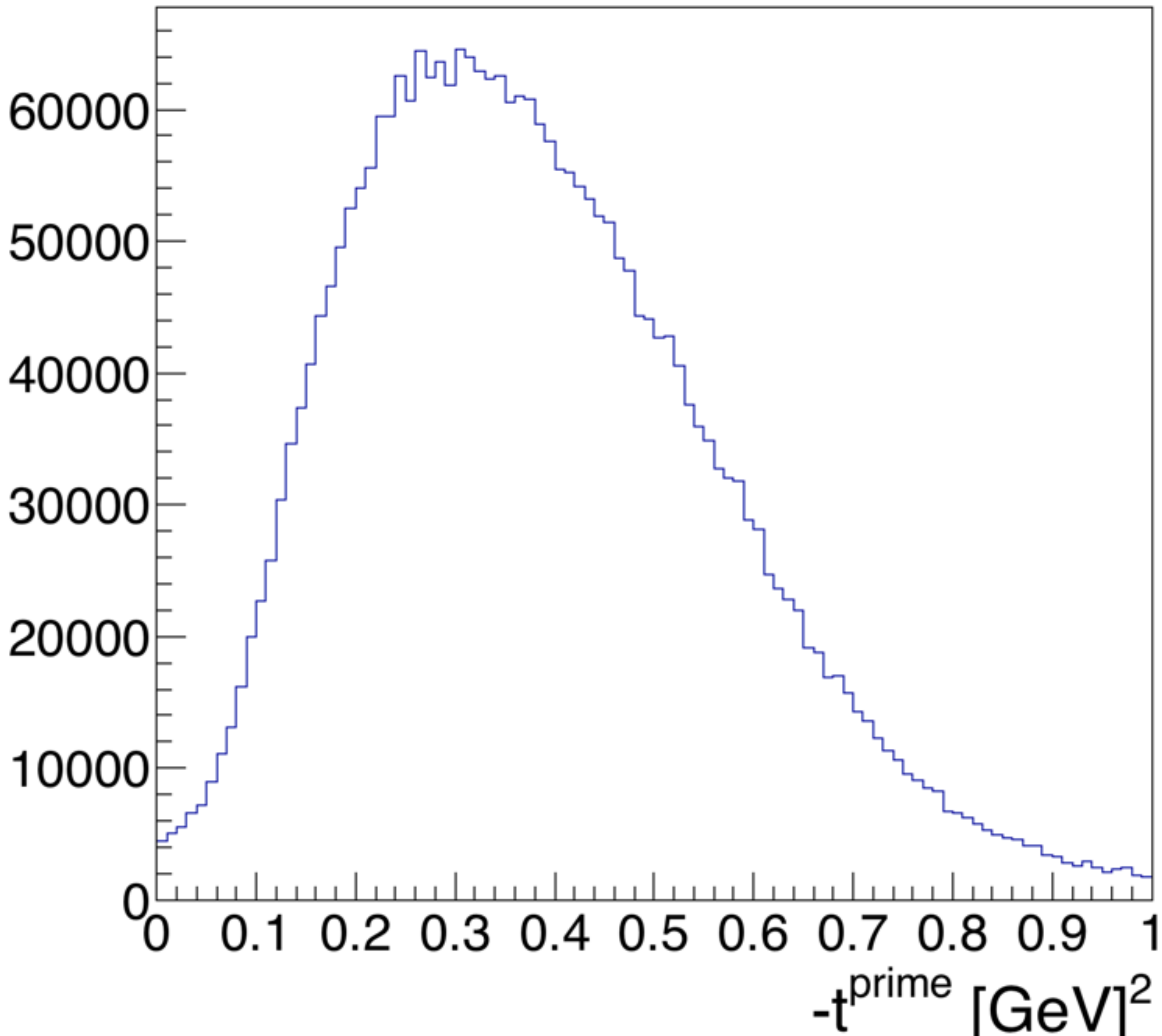
From Pelaez and Rodas paper: PRD93(2016)

100 days KLF



Counts
10^6
10^5
10^4
0
0.05
0.1
0.15
0.2
0.25
0.3
-t (GeV^2)
missing proton; 100 days KLF
detected proton; 100 days KLF
SLAC
proton detected
$K_L p \to K^+ \pi^- p$
SLAC

$$K_L p \to K^{(-,0)} \pi^{(0,-)} \Delta^{++}$$



t'=t-t$_{min}$

Phase-shift

For L=0, 1

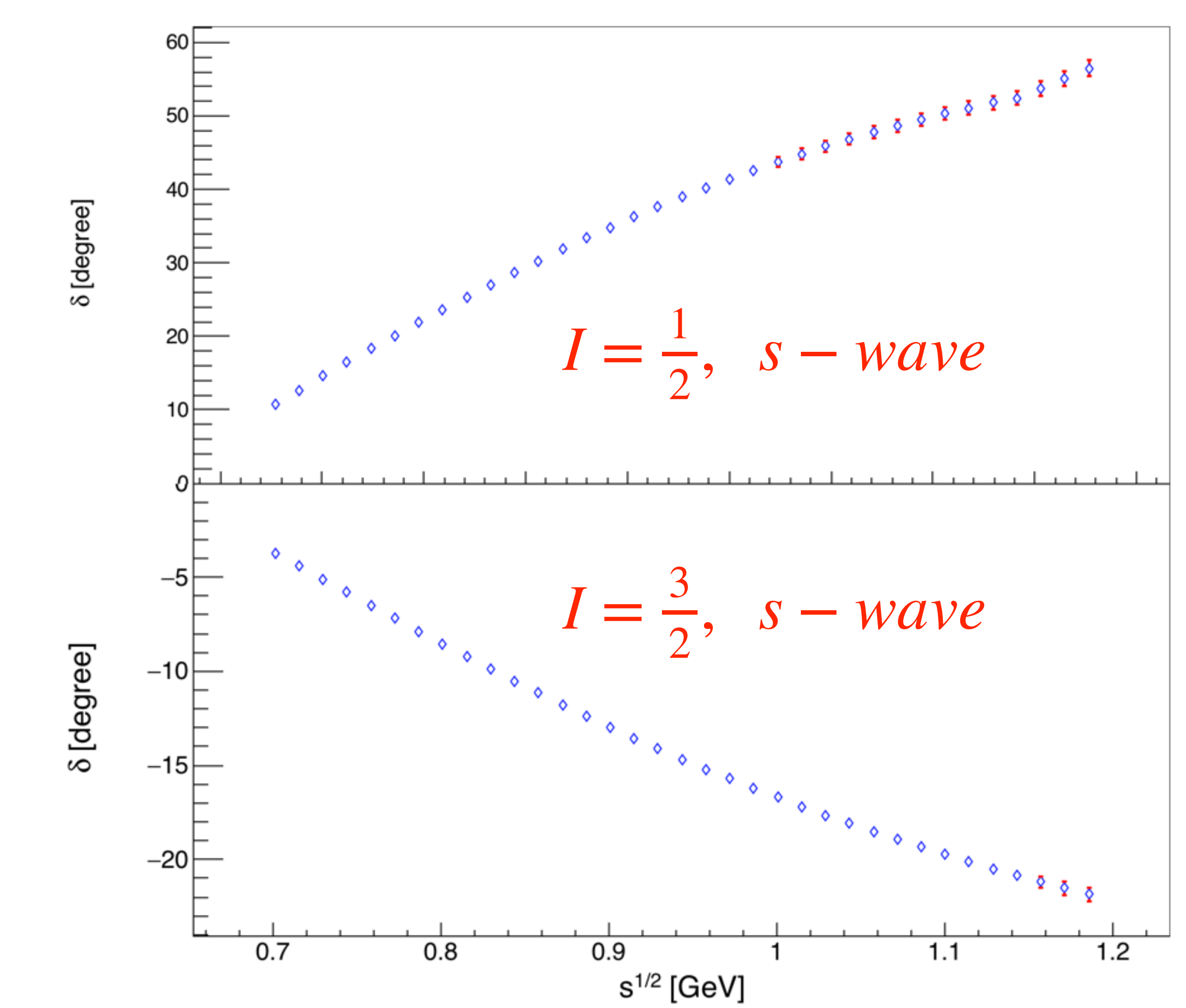
$$A^I(cos\theta_{GJ}, \phi_{GJ}) = \frac{\sqrt{4\pi}}{q_i} \sum_{l,m} a_l^I (2l+1) Y_l^m (cos\theta_{GJ}, \phi_{GJ})$$

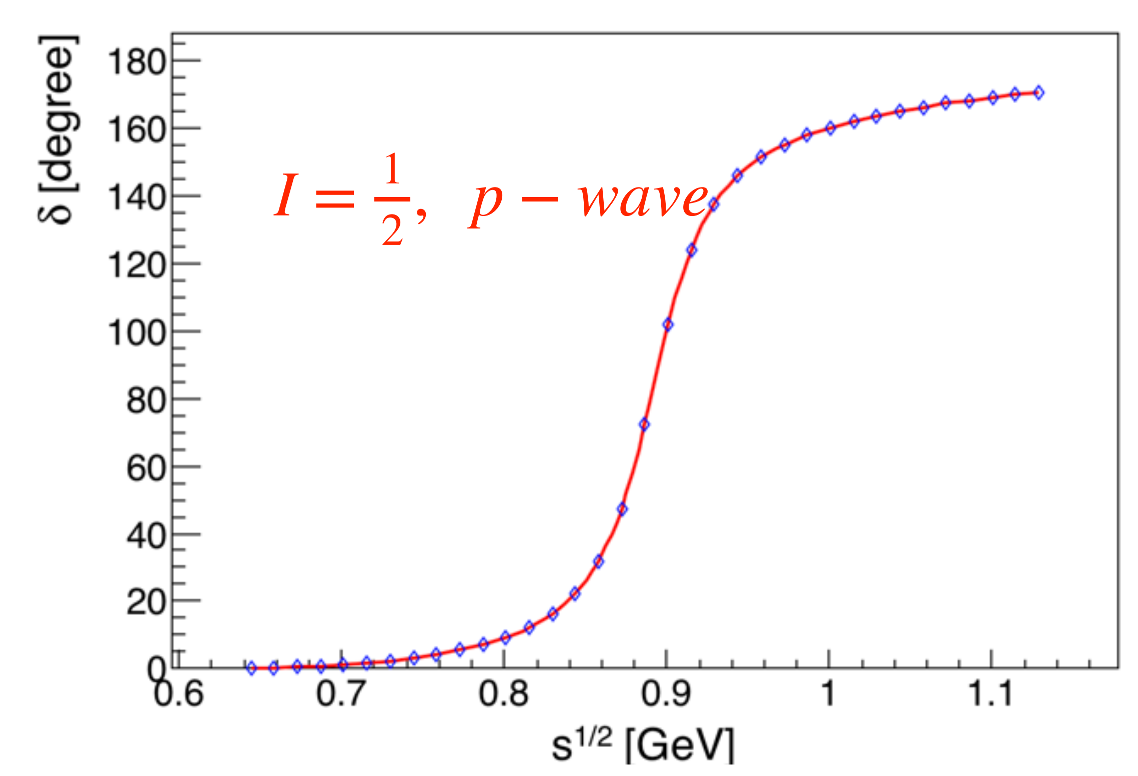
In the elastic region

$$a_L^I = a_L^{I=1/2} + \frac{1}{2} a_L^{I=3/2}$$

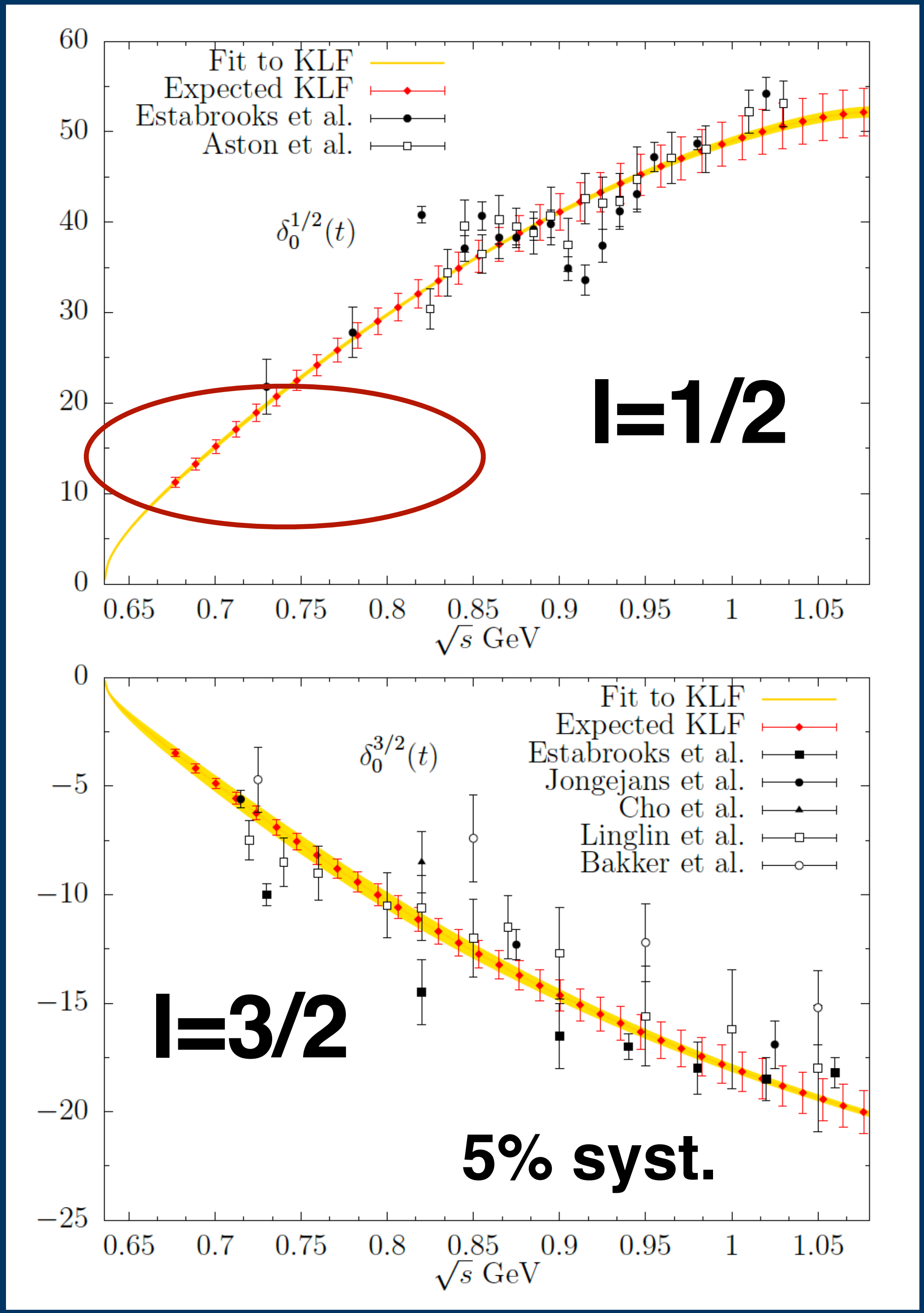
$$a_L^I = \sqrt{(2L+1)}\epsilon^I \sin\delta_L^I e^{\delta_L^I}$$

Results include statistical uncertainty only.



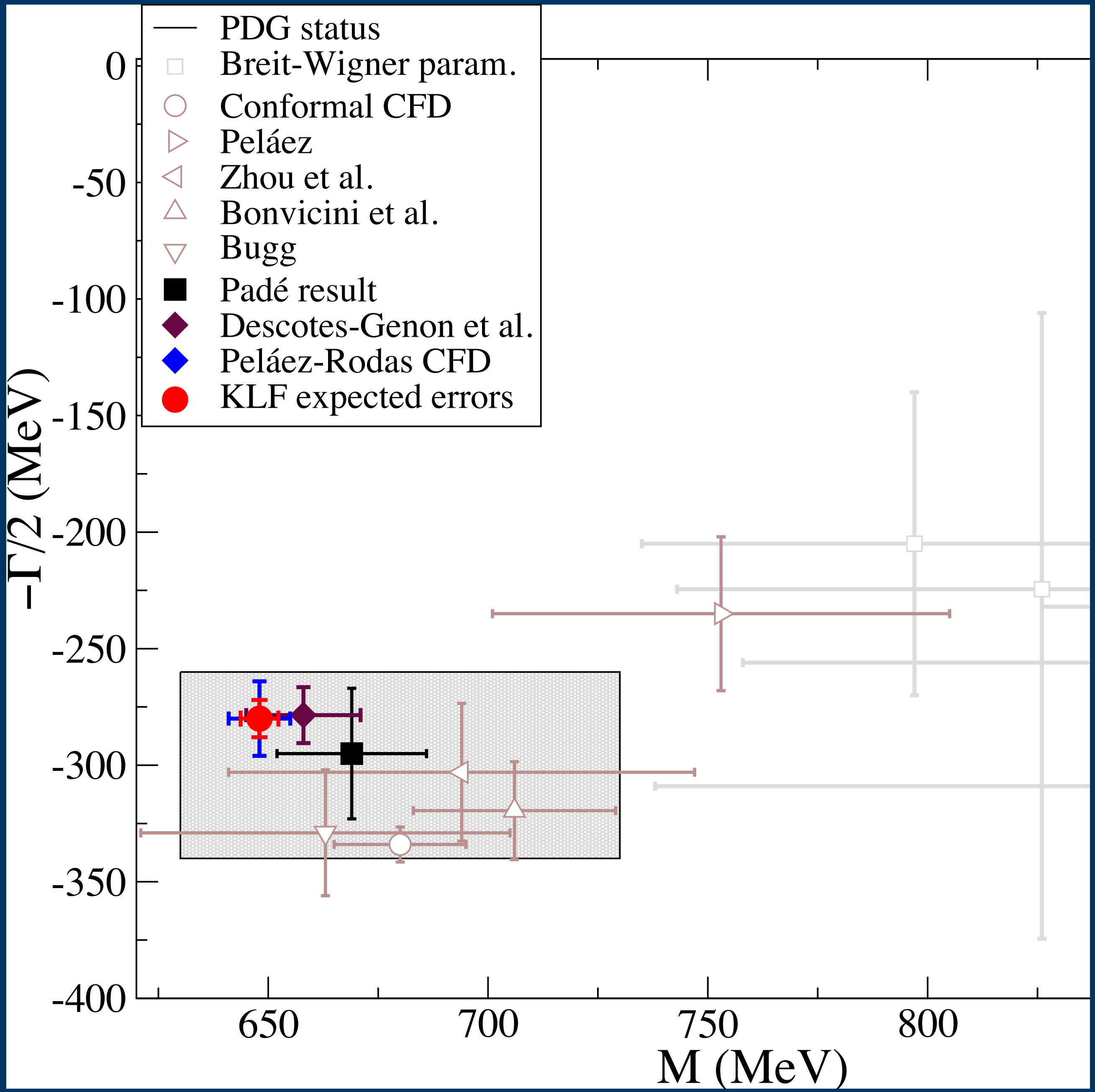


Kappa Mass and Width



S wave phase shift, I =1/2 and I = 3/2 with statistical and systematic uncertainities.

More data points are added close to threshold from KLF.



Roy-Steiner dispersion approach

J.R. Pelaez and et.al. Phys. Rev. D 93, 074025

$$\sqrt{s_\kappa} \equiv M - i\Gamma/2 = 648 \pm 4 \; - \; i280 \pm 8 \; MeV$$

Summary of $K\pi$ Scattering

-The KLF will have a very significant impact on our knowledge $K\pi$ on scattering amplitudes

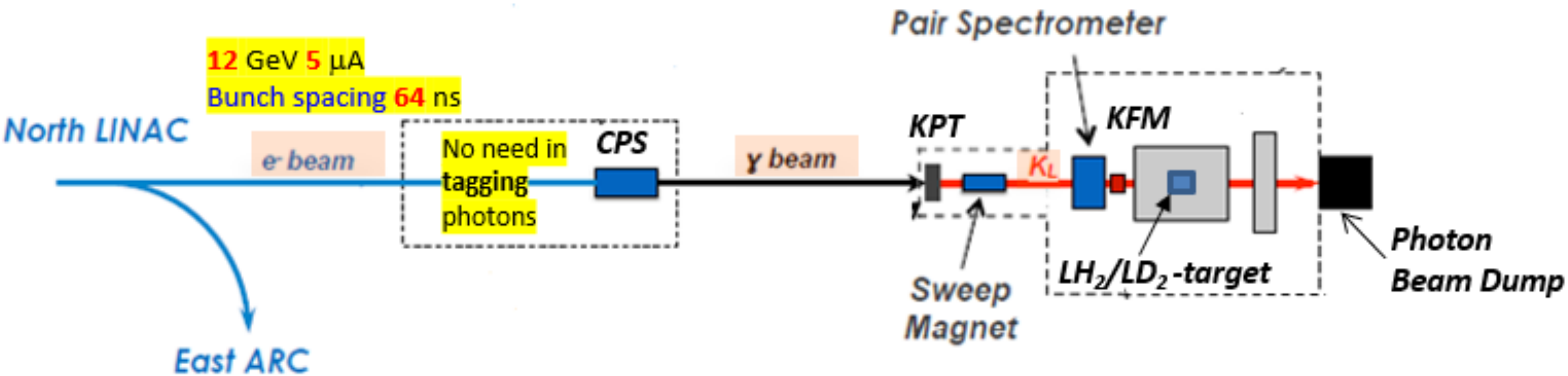
-It will certainly improve still conflictive determination of heavy K*'s parameters

-It will help to settle the tension between phenomenological determinations of scattering lengths from data versus ChPT and LQCD

-Finally, and very importantly, it will reduce by more than a factor of two the uncertainty in the mass determination of K*(700) and by factor of five the uncertainty on its width, and therefore on its coupling

-It will help to clarify debates of its existence, and therefore a long standing problem of existence of the scalar nonet

Hall-D beamline and GlueX Setup



Electron Beam Parameters

$E_e = 12\ GeV$ $\qquad I = 5\ \mu A$

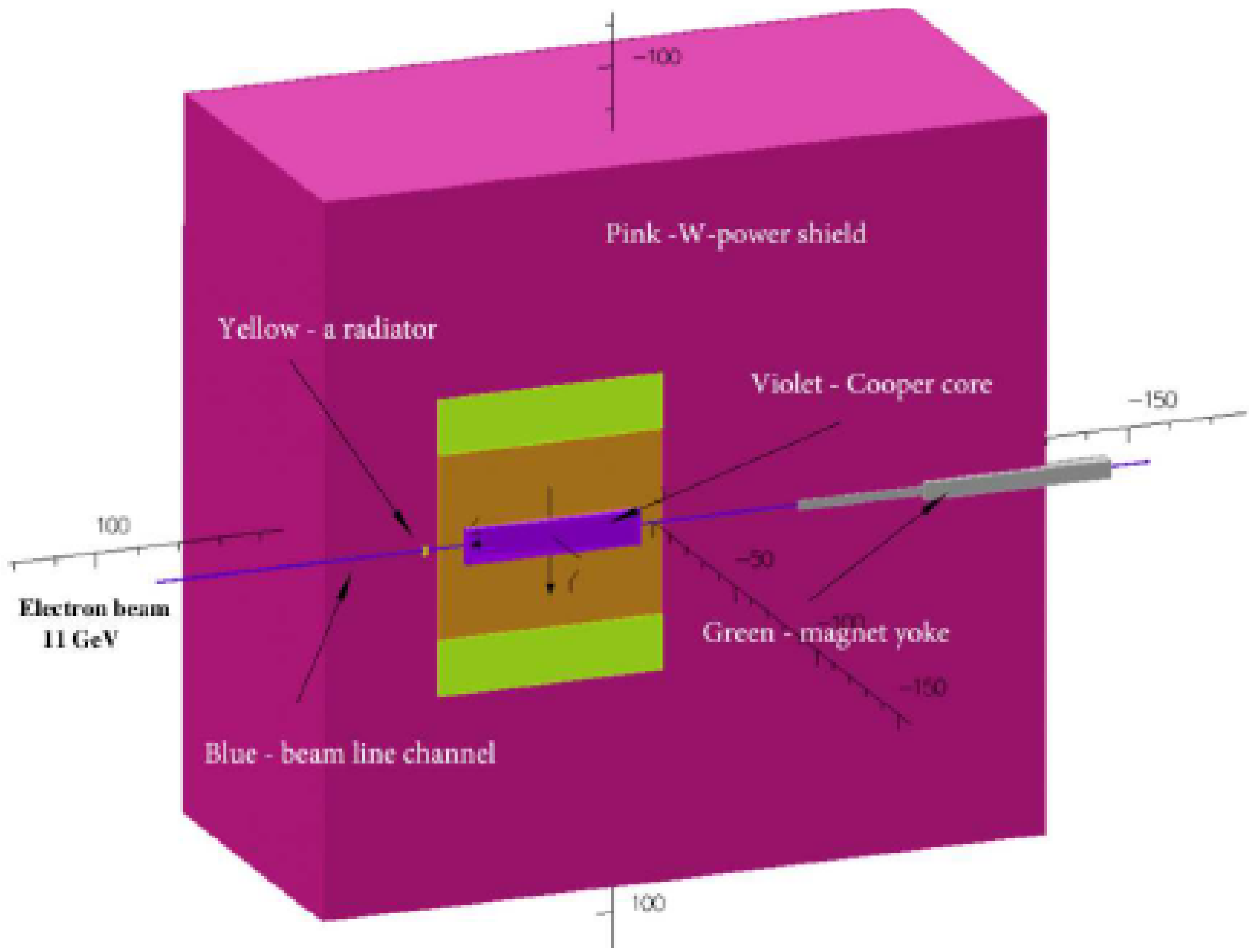
Bunch spacing $\qquad 64\ ns$

No major problems.

Doable !

Confirmed by accelerator experts

Compact Photon Source



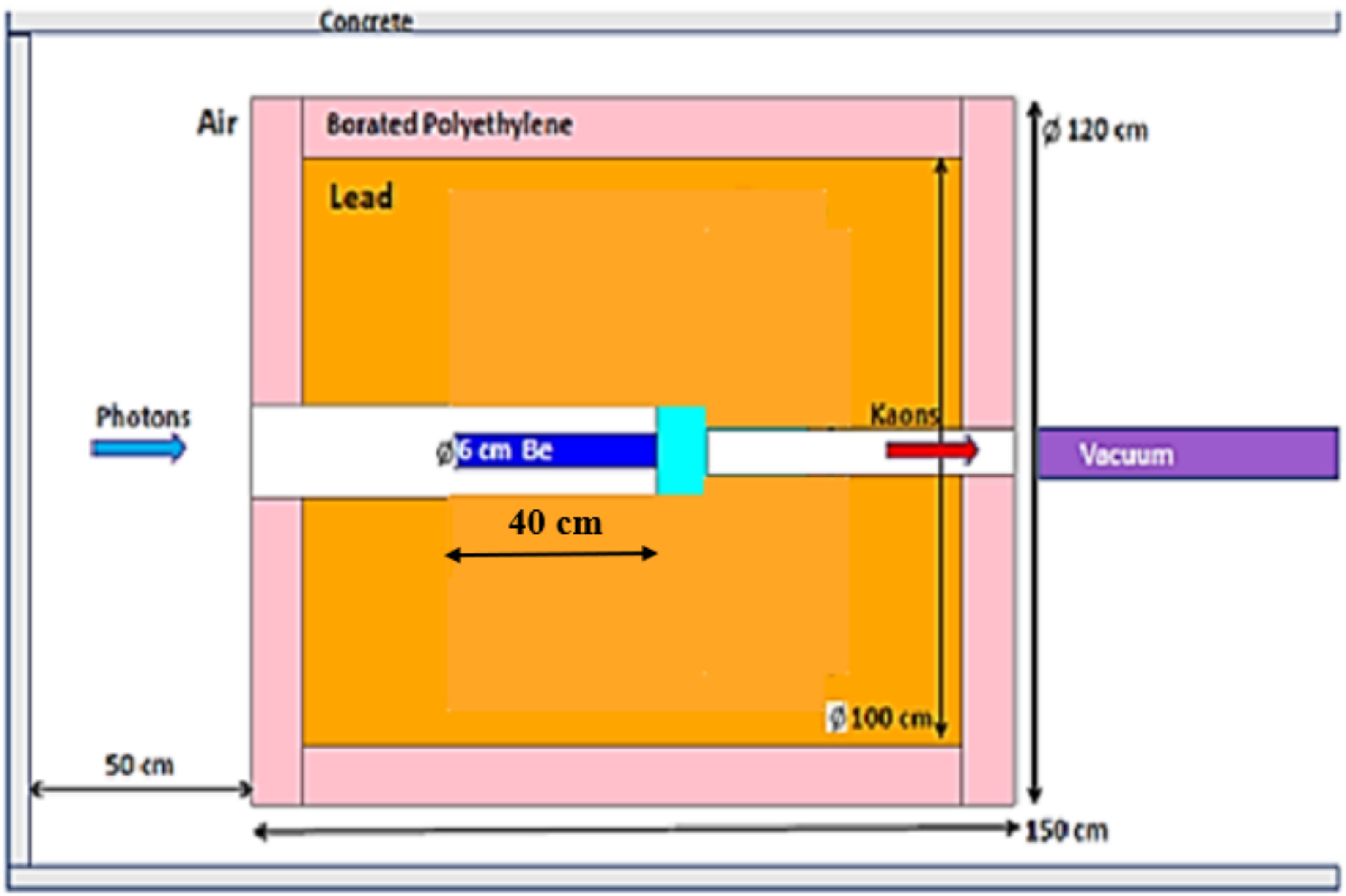
Conceptual design is completed for Halls A&C

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

Paper published in NIM, A957(2020)

Be Target Assembly: Conceptual Design

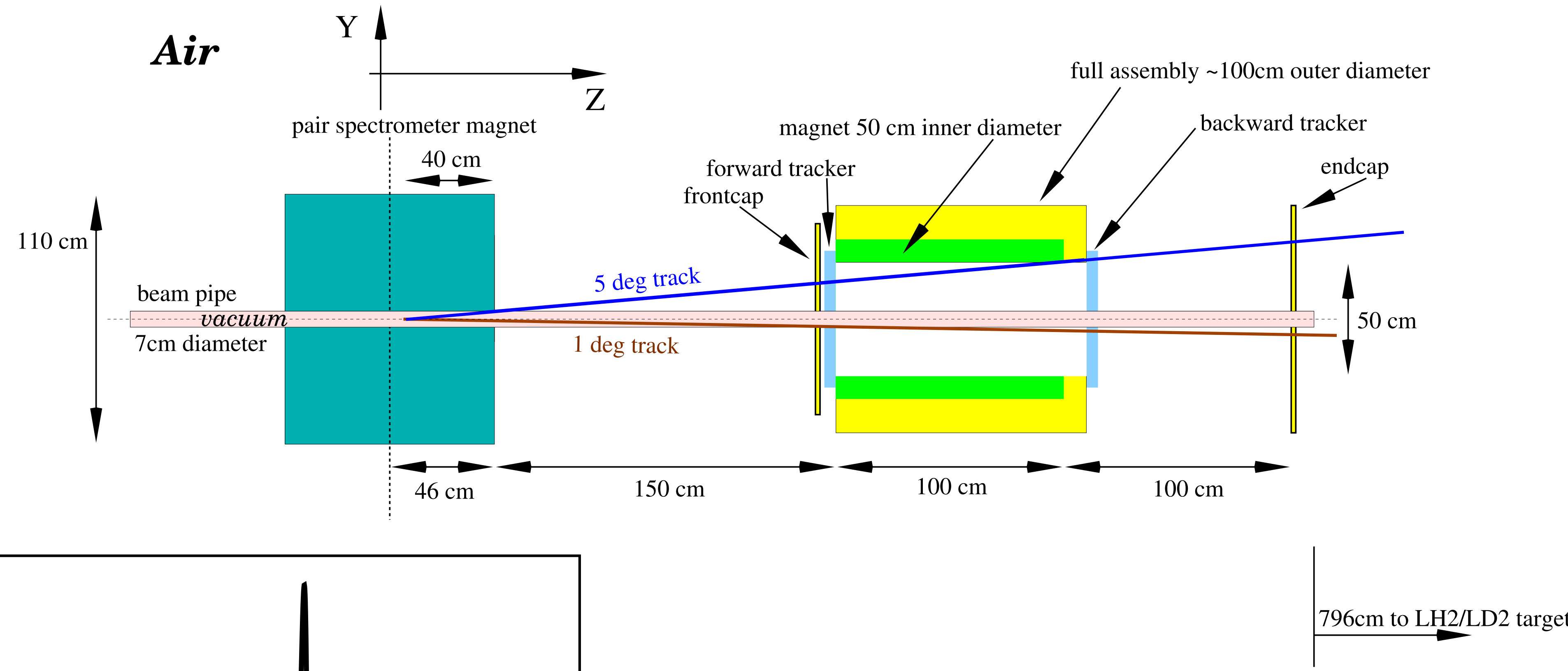


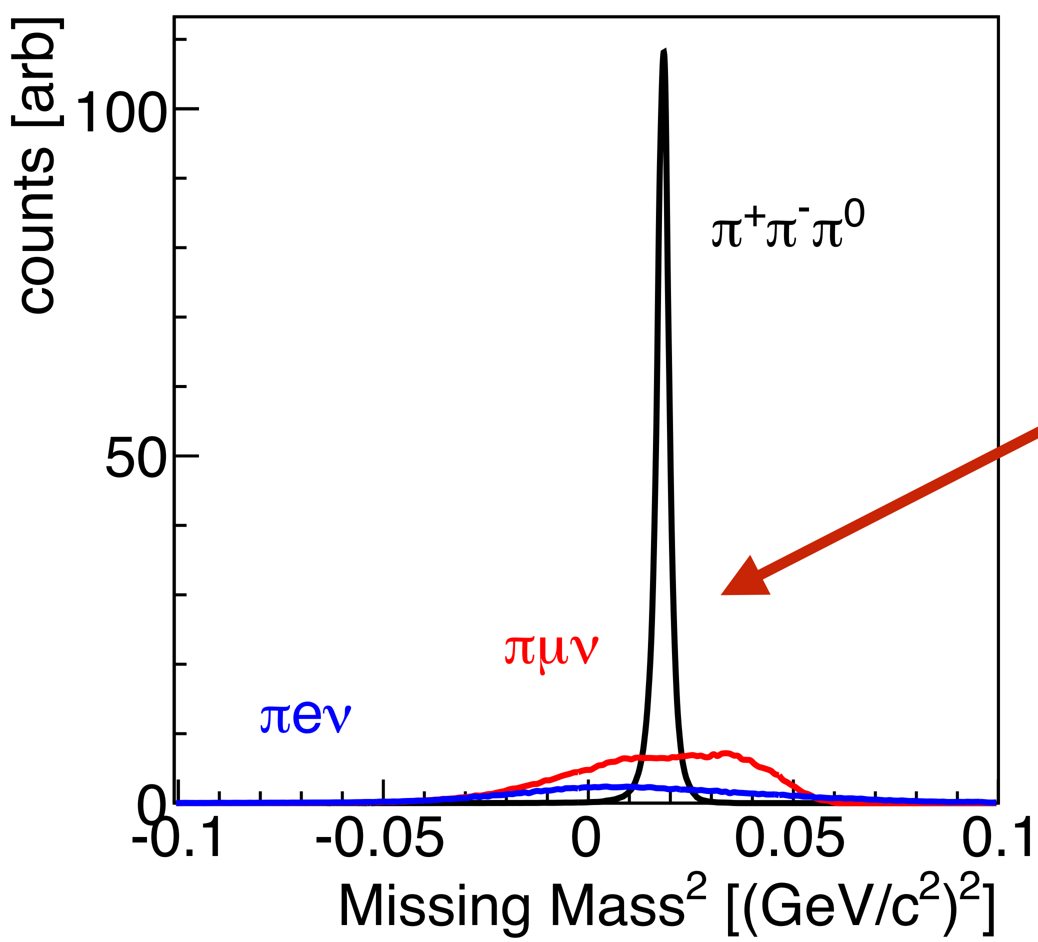
-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff

arXiv: 2002.04442

Flux Monitor





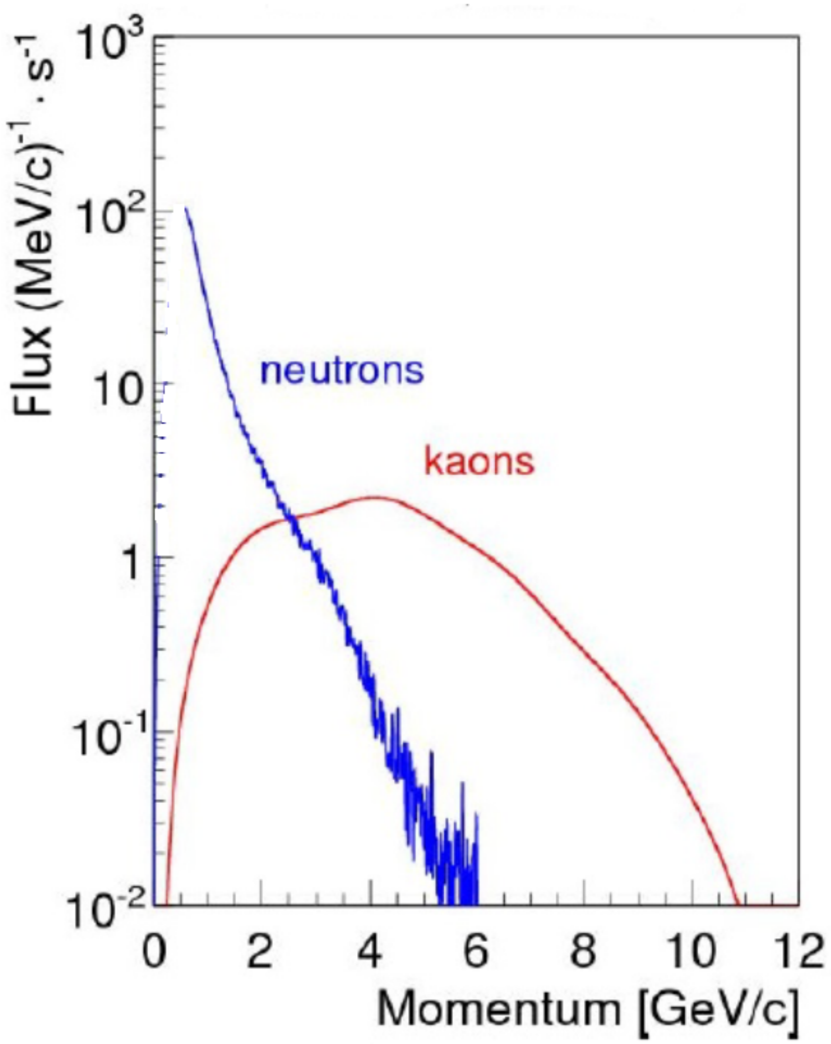
Reconstructed K_L mass

Flux measurement stat. err. <1%

Estimated conservative syst. err. ~5%

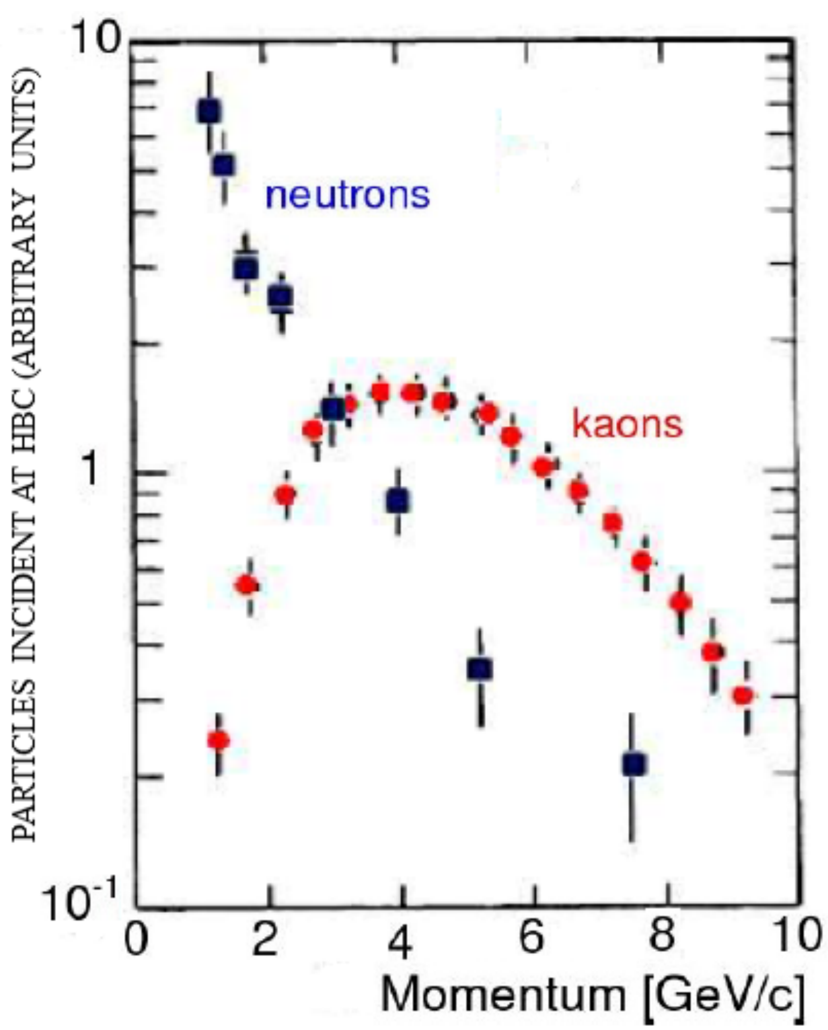
K_L Beam Flux

JLab 12 GeV



$$N(K_L)/sec \sim 10^4$$

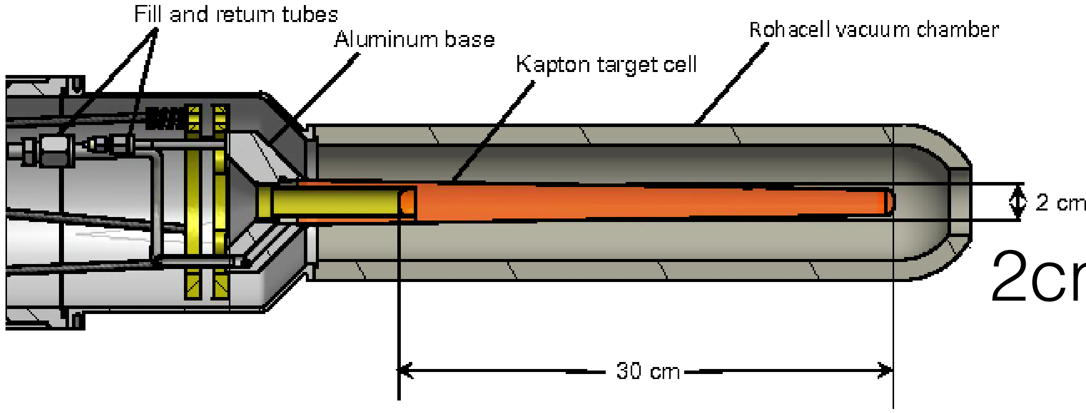
SLAC 16 GeV



$$\frac{N(K_L)_{JLAB}}{N(K_L)_{SLAC}} \sim 10^3$$

LH_2/LD_2 Cryogenic Target for Neutral Kaon Beam at Hall D

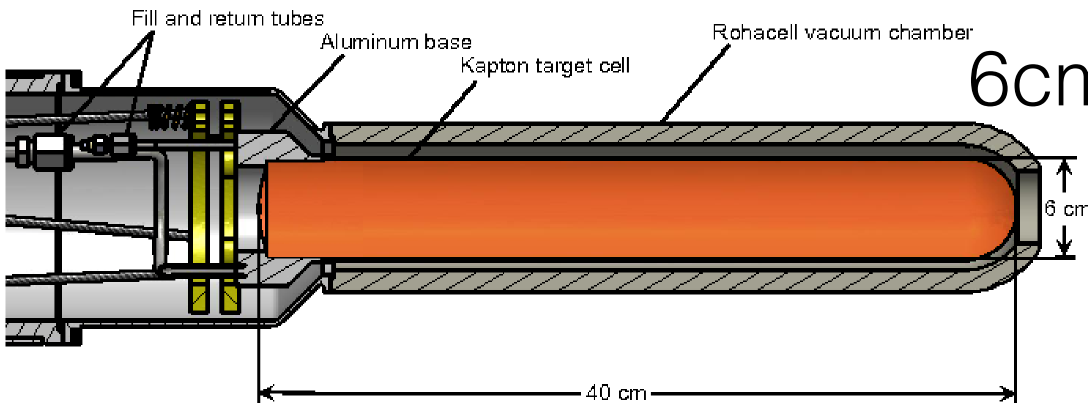
The GlueX liquid hydrogen target.



2cm

30cm

Current



6cm

6cm

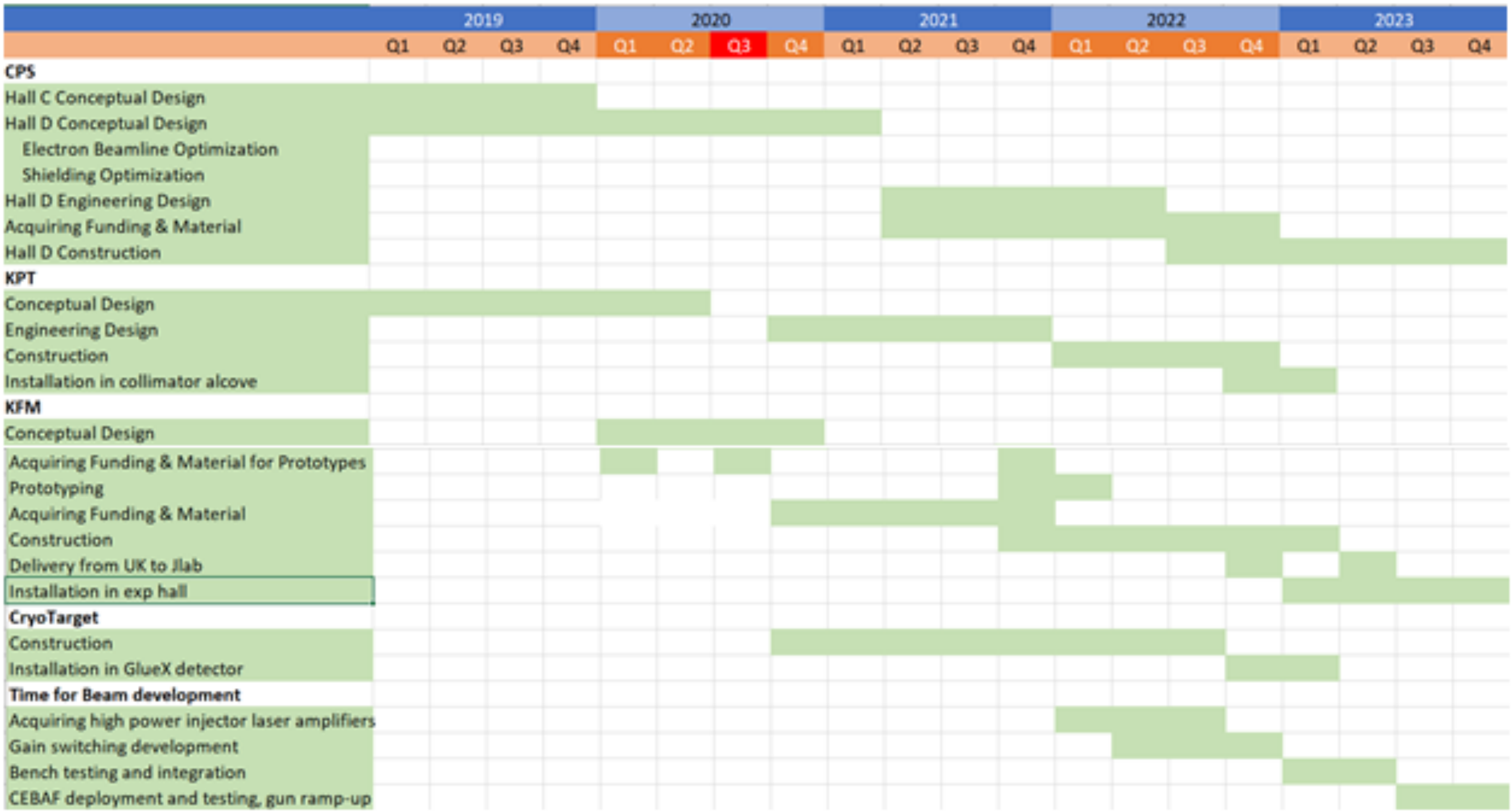
40cm

Proposed & Feasible

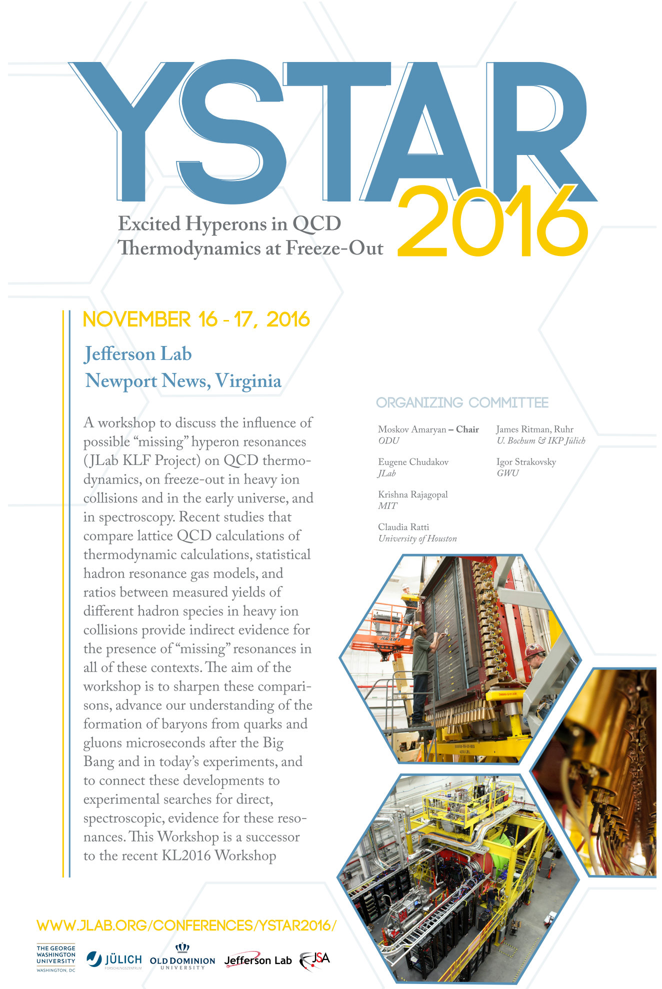
Longer and ticker target is needed to enhance production rate

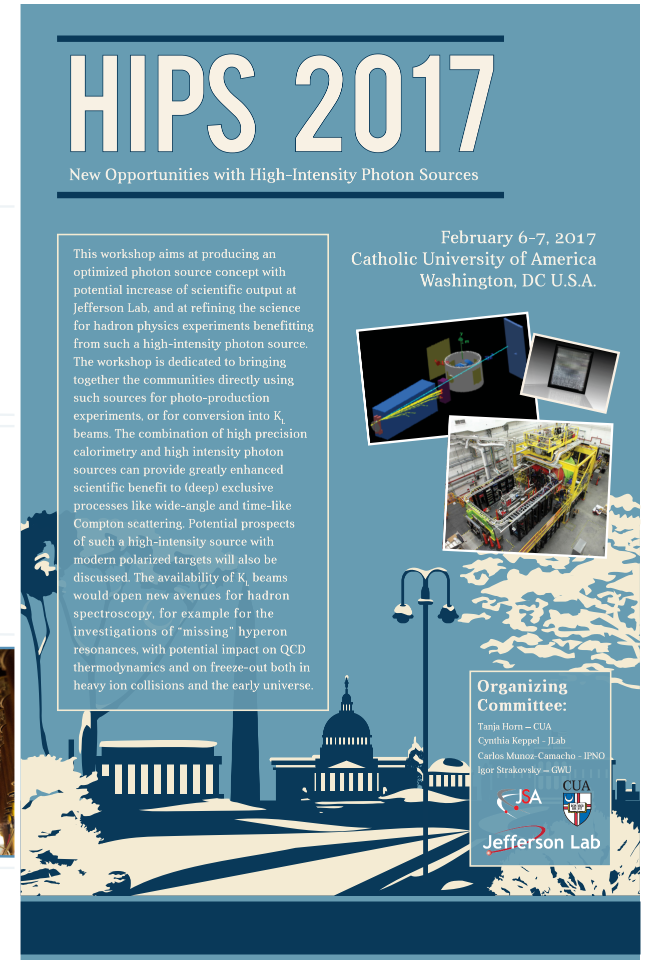
Conceptual design has been endorsed by the JLAB target group

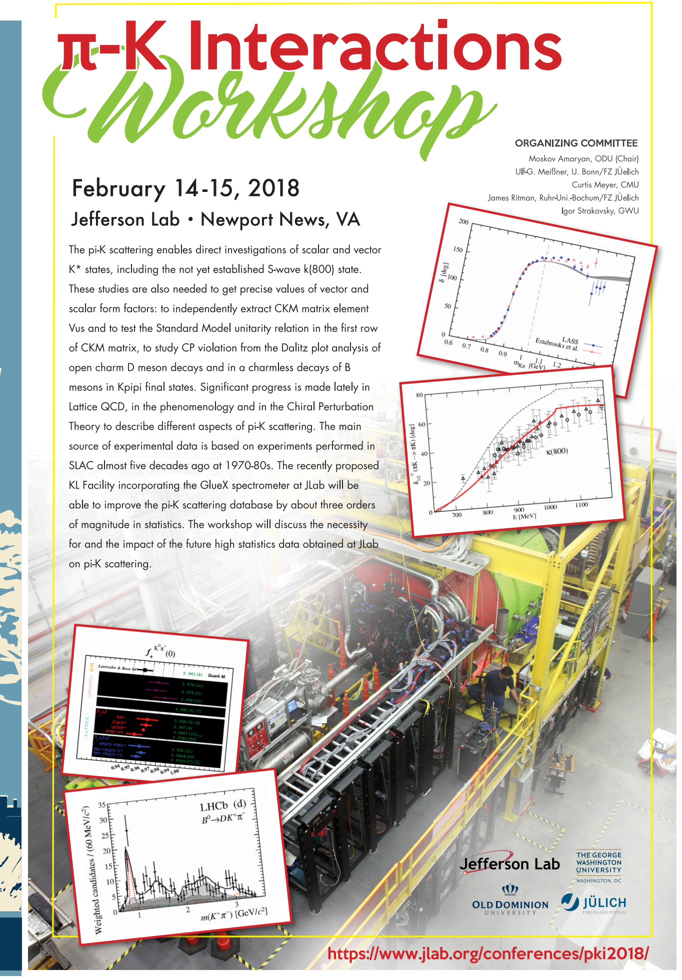
Timeline of Design, Construction and Installation



The Facility is Flexible and can be switched to photon beam in 6 months







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

68 Universities from 19 Countries

SUMMARY

- -Proposed KL Facility has a unique capability to improve existing world database up to three orders of magnitude
- -In Hyperon spectrosocopy
  PWA will allow to unravel and measure pole positions and widths of dozens of new excited hyperon states
- -In Strange Meson Spectroscopy
  PWA will allow to measure excited K* states including scalar K*(700) states
- To accomplish physics program
  100 days per LH2 and LD2 is required
- All components of KL Facility considered are feasible
  -With total cost of the project below $5M

Thank you !