Proposal for JLab PAC46

Strange Hadron Spectroscopy with Secondary K_L Beam at GlueX

Moskov Amaryan

(For KLF Collaboration)

JLab Management Briefing, May 8, 2018

Outline

Physics Motivation

- Hyperon Spectroscopy
- Strange Meson Spectroscopy

K_L Facility at JLab

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

Summary

Hyperon Spectroscopy

*According **LQCD** there should be*

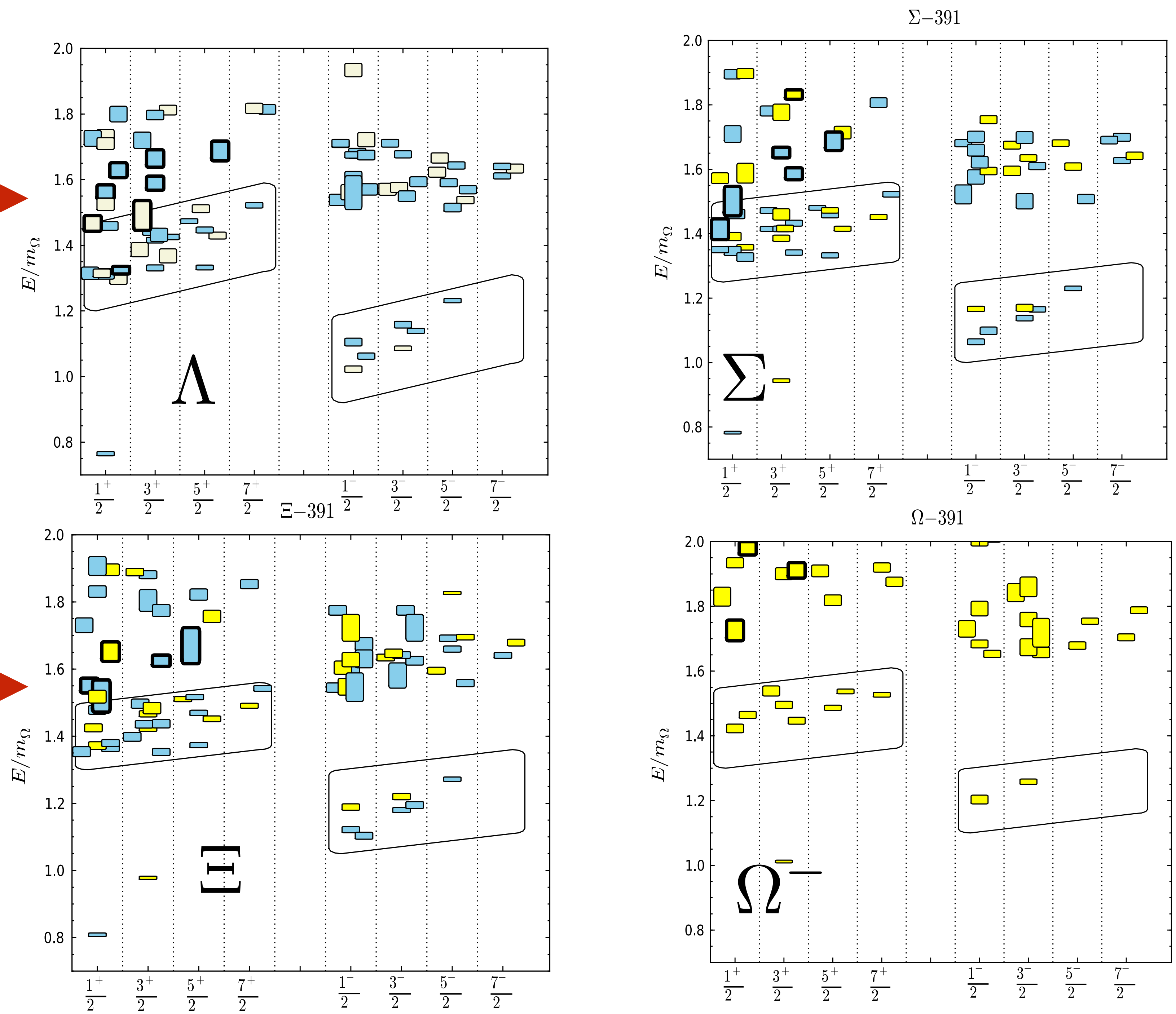
many more states including hybrids (thick bordered)

8-states
****

5-states
***

6-states
****

4-states
***



3-states
****

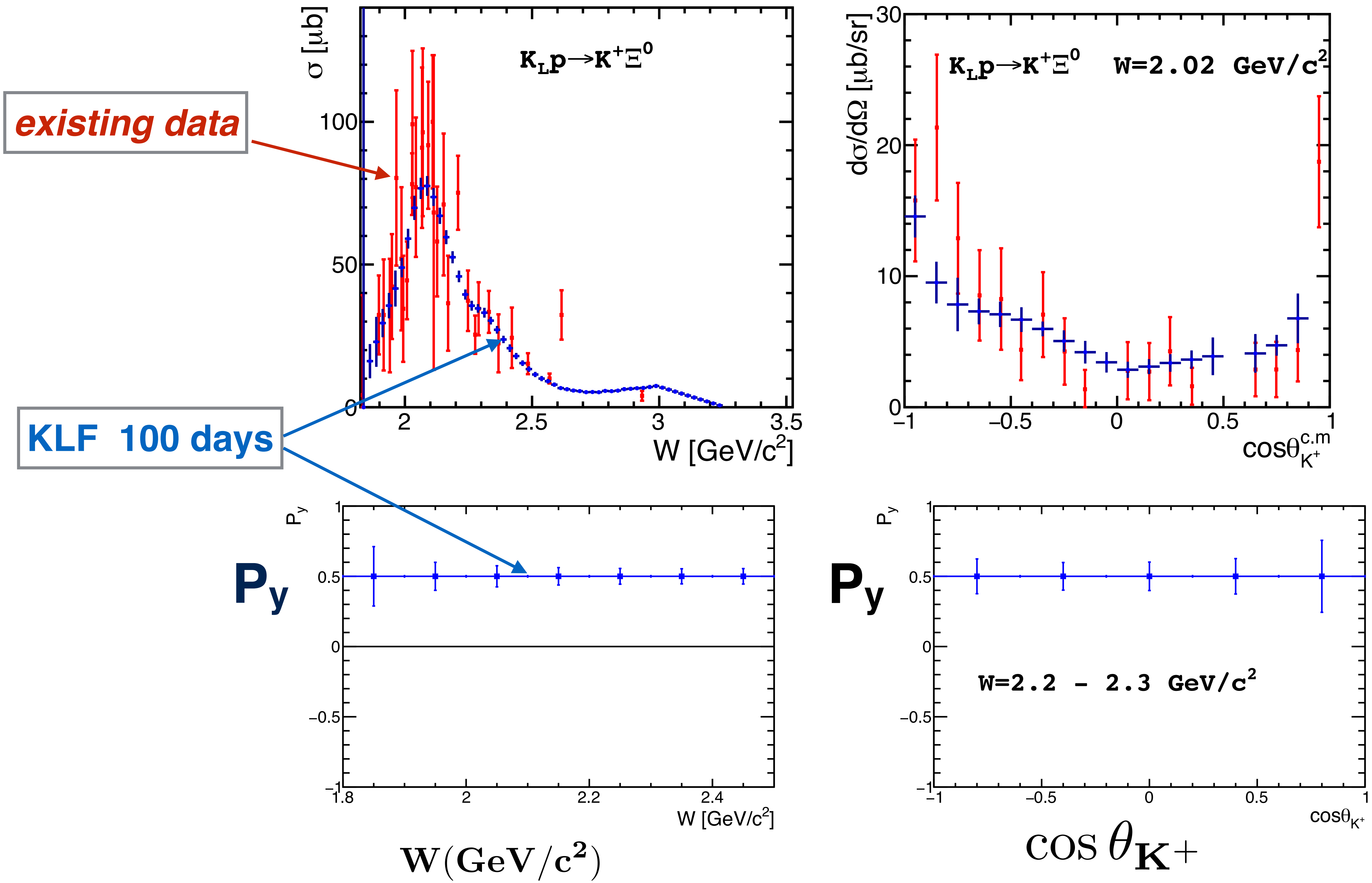
4-states
***

1-state
****

1-states
***

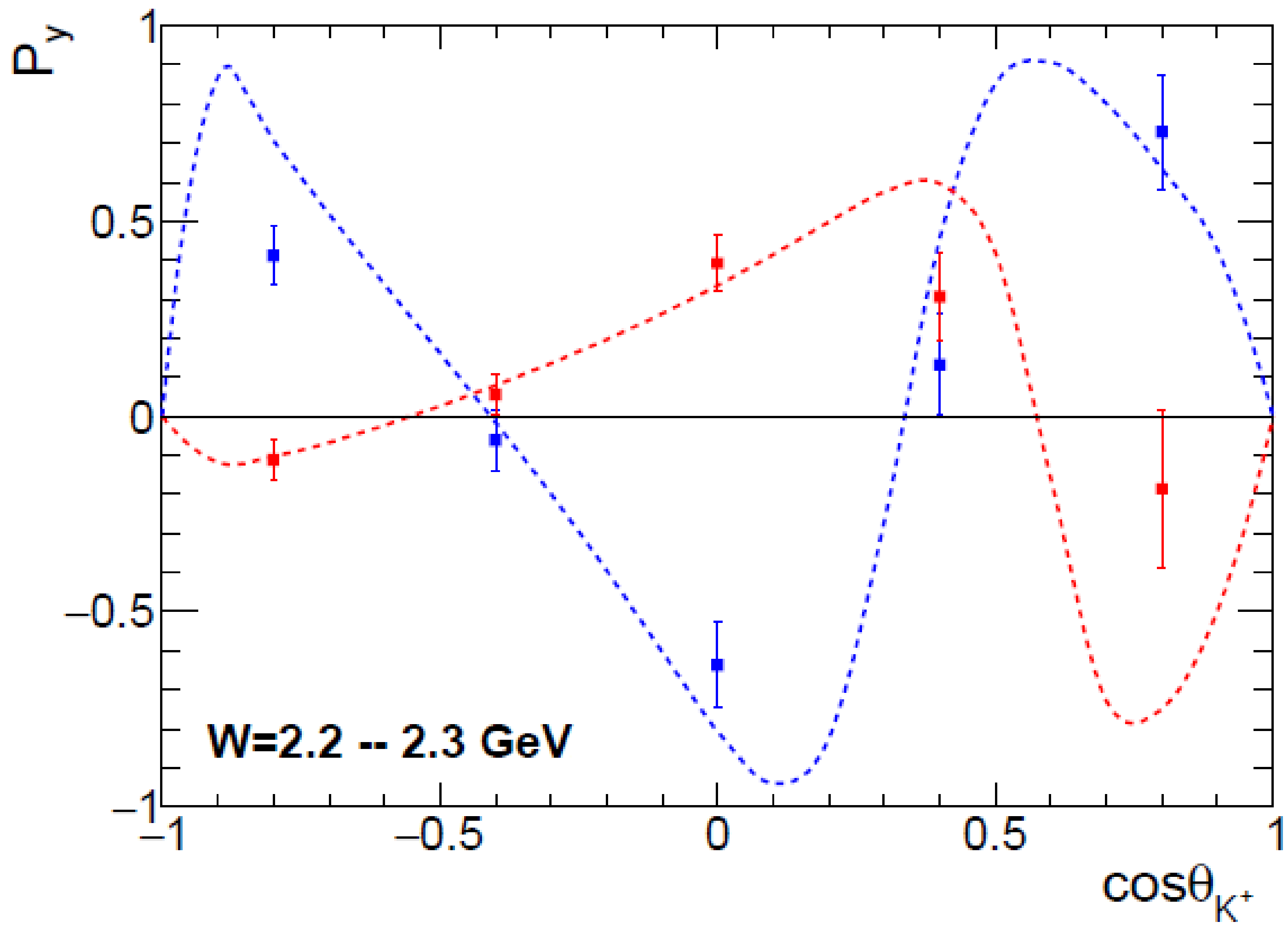
Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

Proposed Measurements on Proton Target



Proposed Measurements on Neutron Target

Sensitivity to different solutions



$K_L n \to K^+ \Xi^-$

100 days on LD_2 target

Search for Hyperon Resonances with PWA

For Scattering experiments on both
proton & neutron targets we need to determine:

-differential cross sections &

-self polarization of strange hyperons

-perform coupled-channel PWA

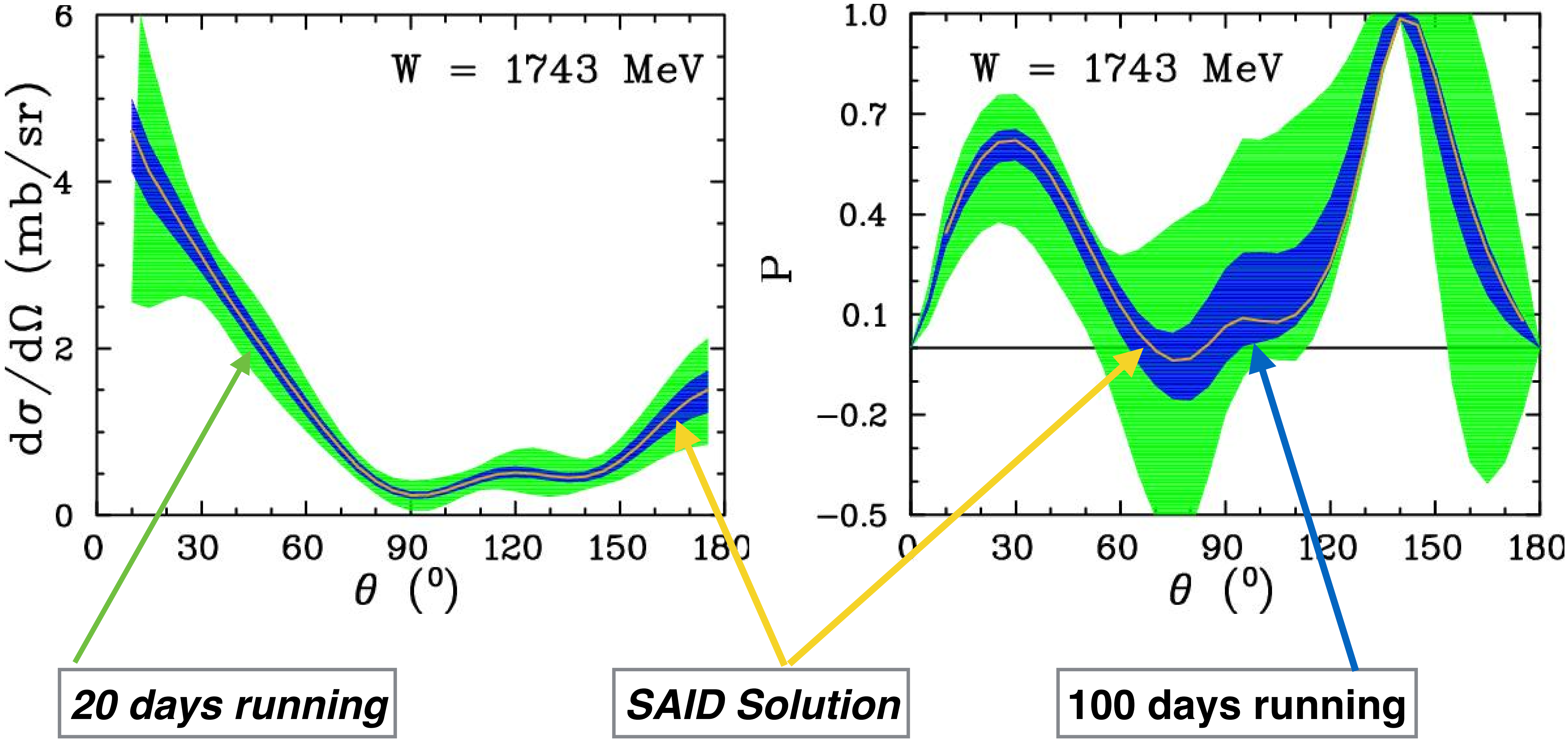
-look for poles in complex energy plane
(not naïve bump hunting)

-identify $\Lambda^*, \Sigma^*, \Xi^* \ \& \ \Omega^*$ **up to 2400 MeV**

As kaon nucleon scattering data are very poor

we use pion nucleon scattering data with statistics generated according to expected KLF data for 20(100) days to show PWA sensitivity to obtain results close to the best fit

Using πp Scattering



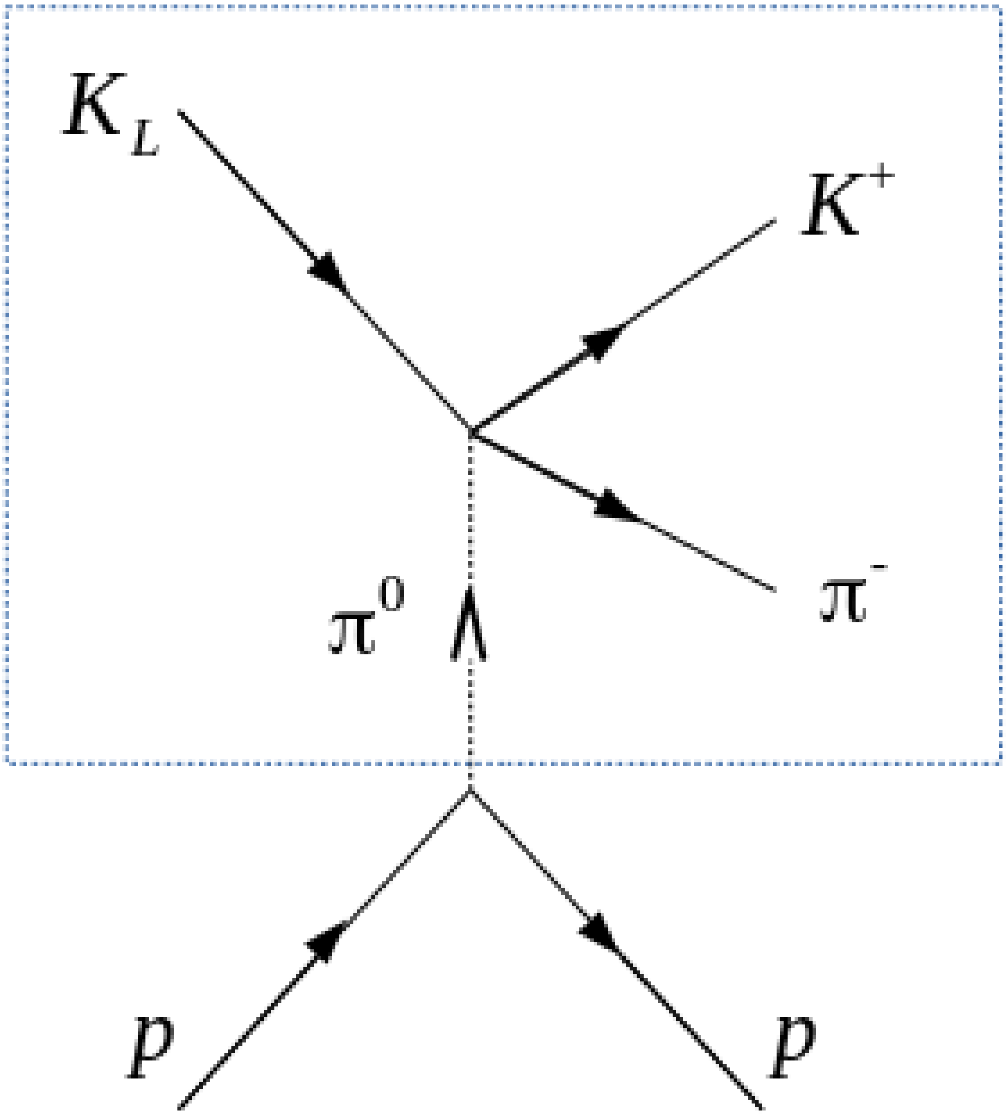
Statistics was generated according to KLF for

$$K_L p \to K^+ \Xi^0$$

Obviously: we need at least 100 days to get unique solution

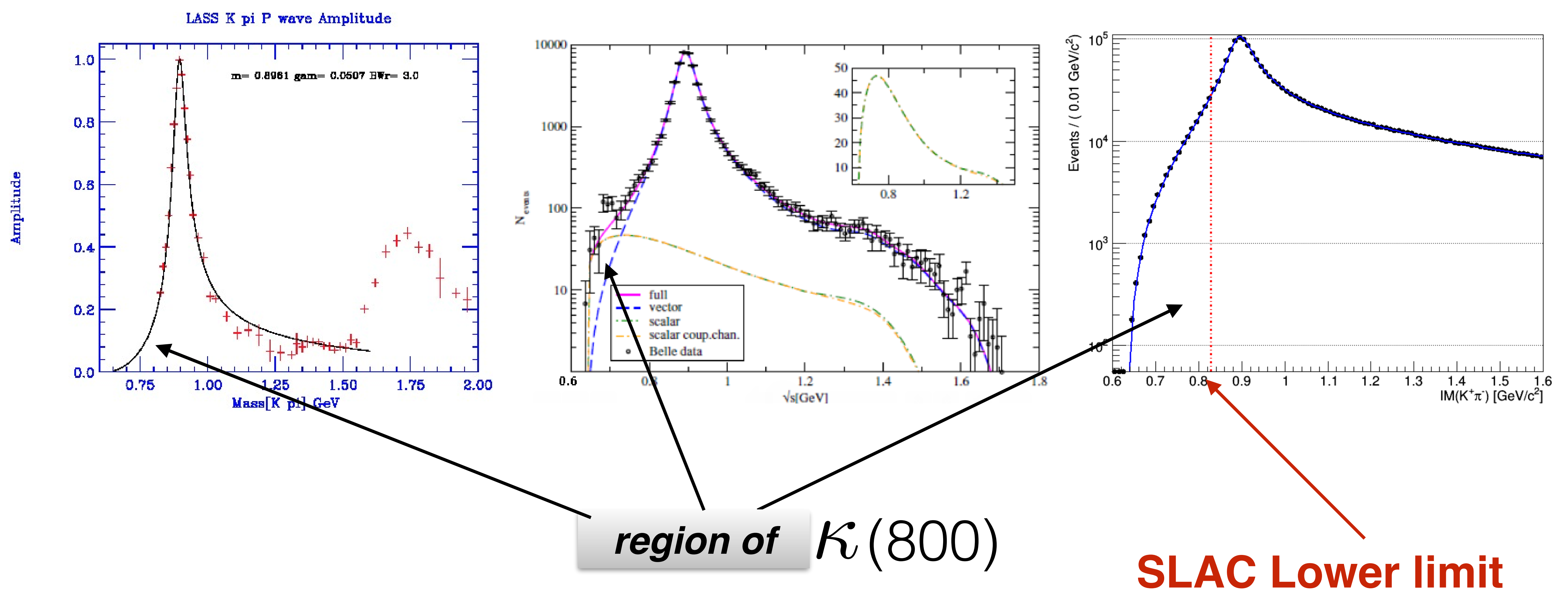
Strange Meson Spectroscopy

$K\pi$ **Scattering**



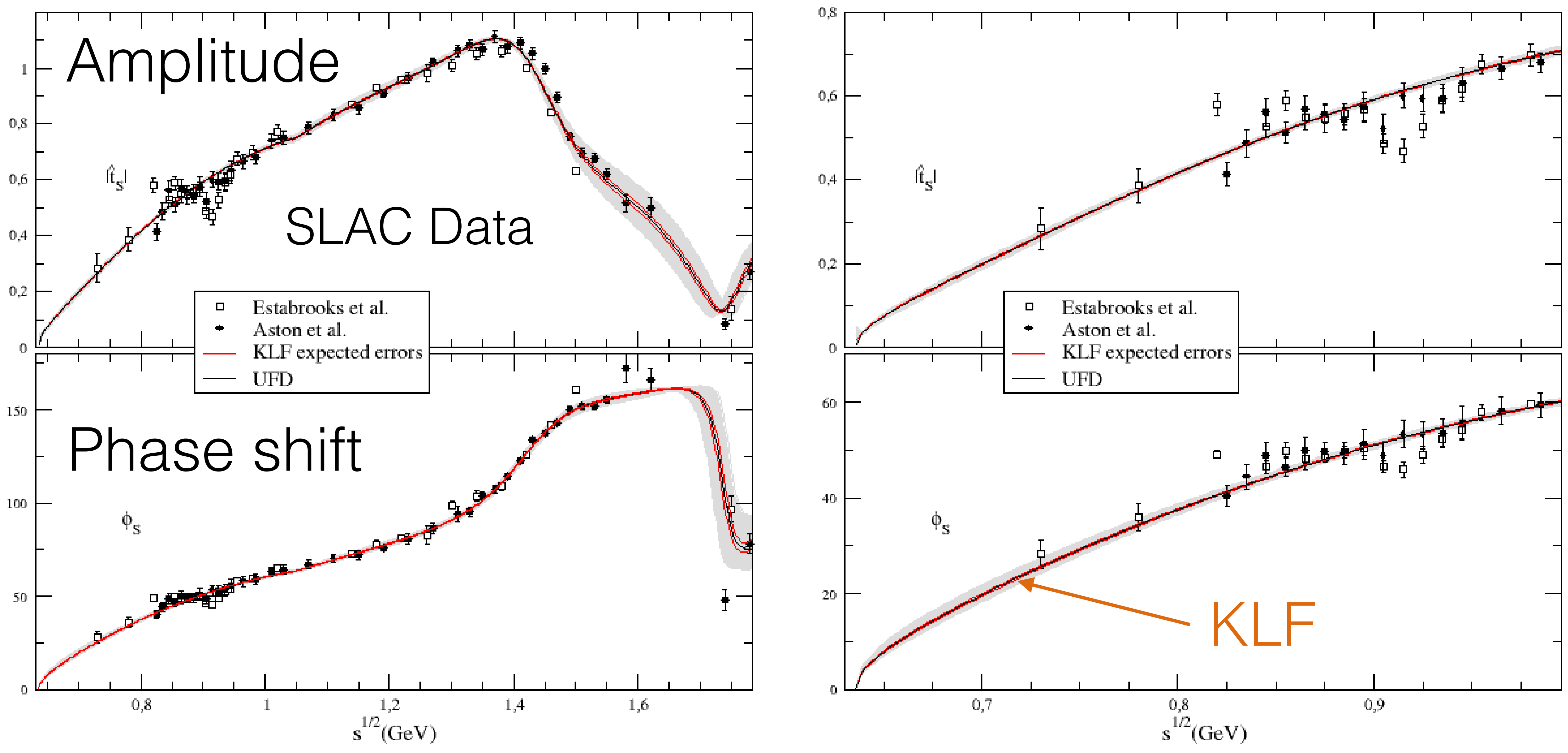
Proposed Measurements

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

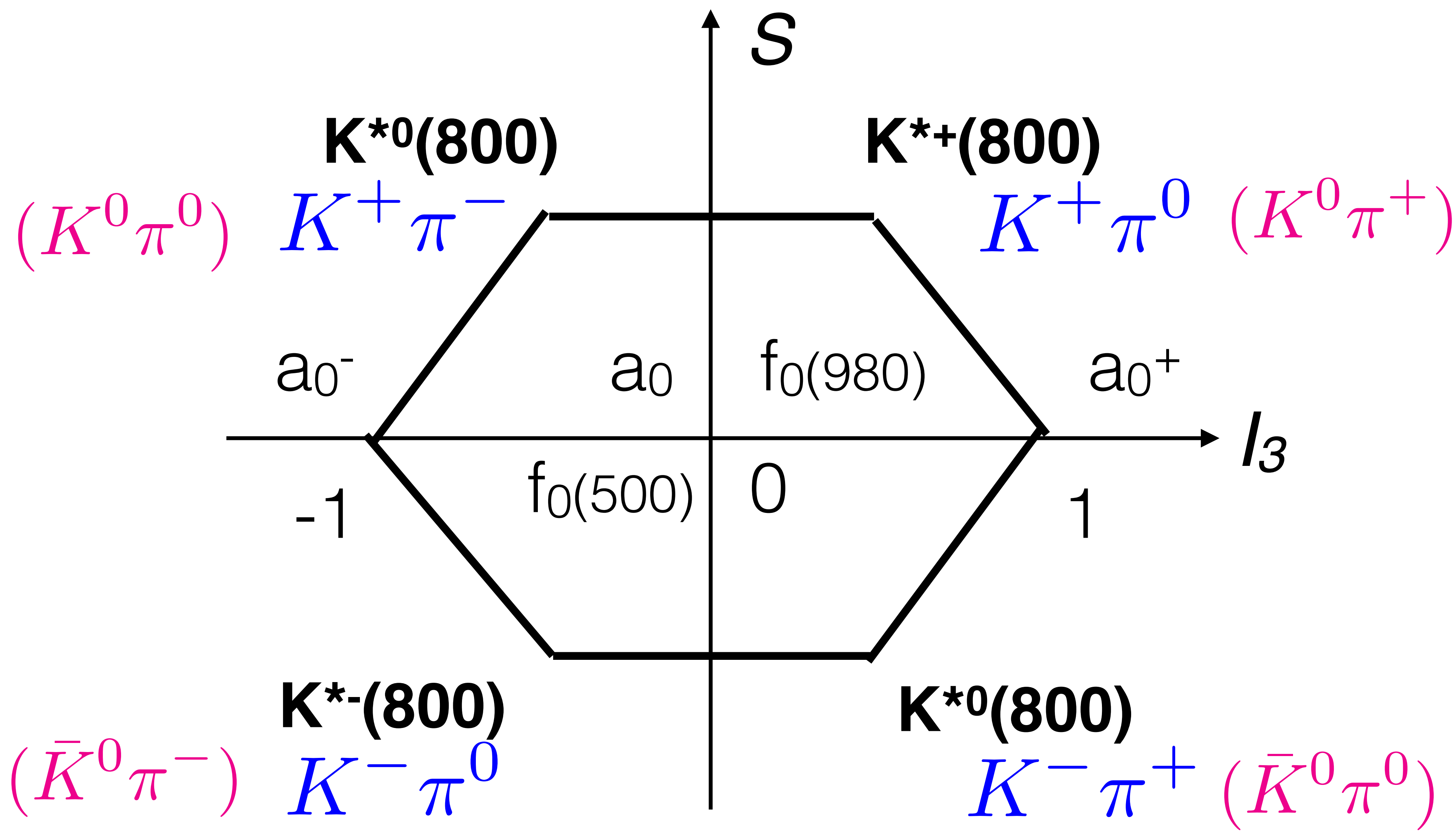


Proposed Measurement

I=1/2 S-Wave



Scalar Meson Nonet

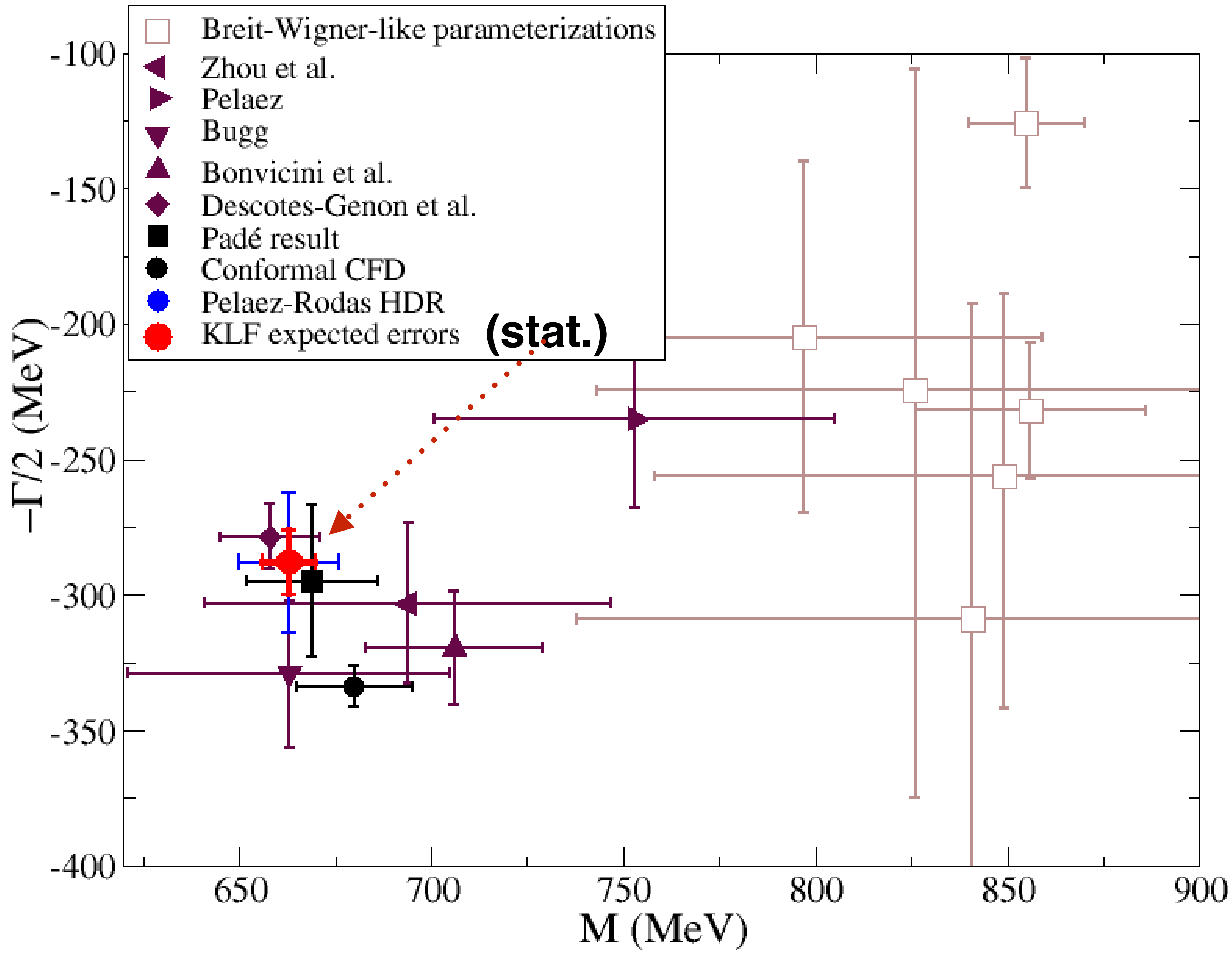


Four states called κ

still need further confirmation(PDG)

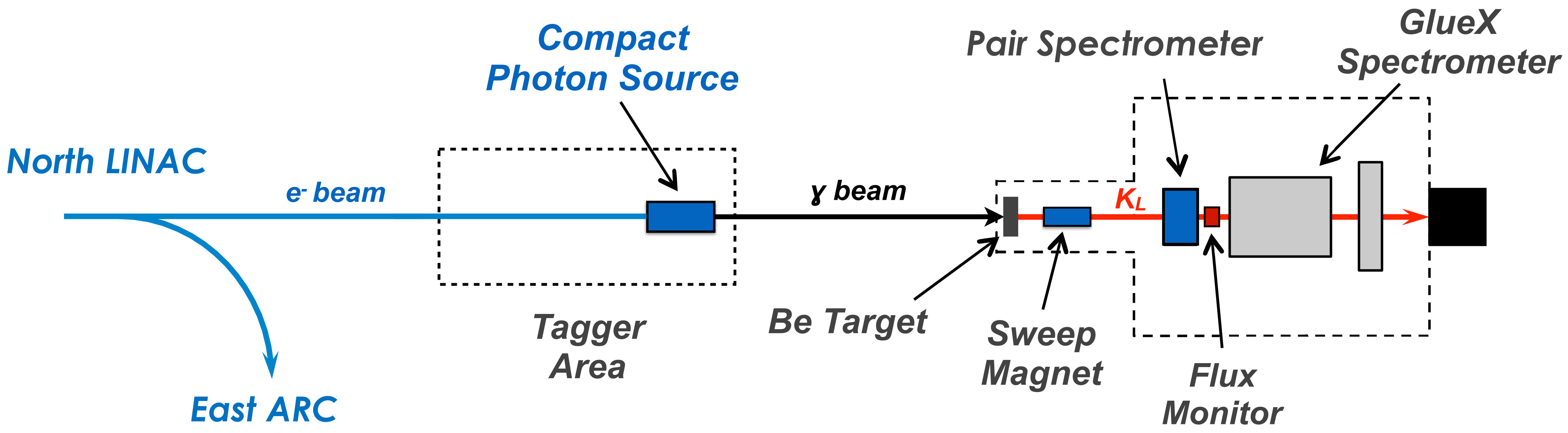
We can mesure all of them

Measurement of $\kappa(800)$



100 days of running

Hall-D beamline and GlueX Setup



Electron Beam Parameters

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

Repetition rate $\qquad 64\ ns$

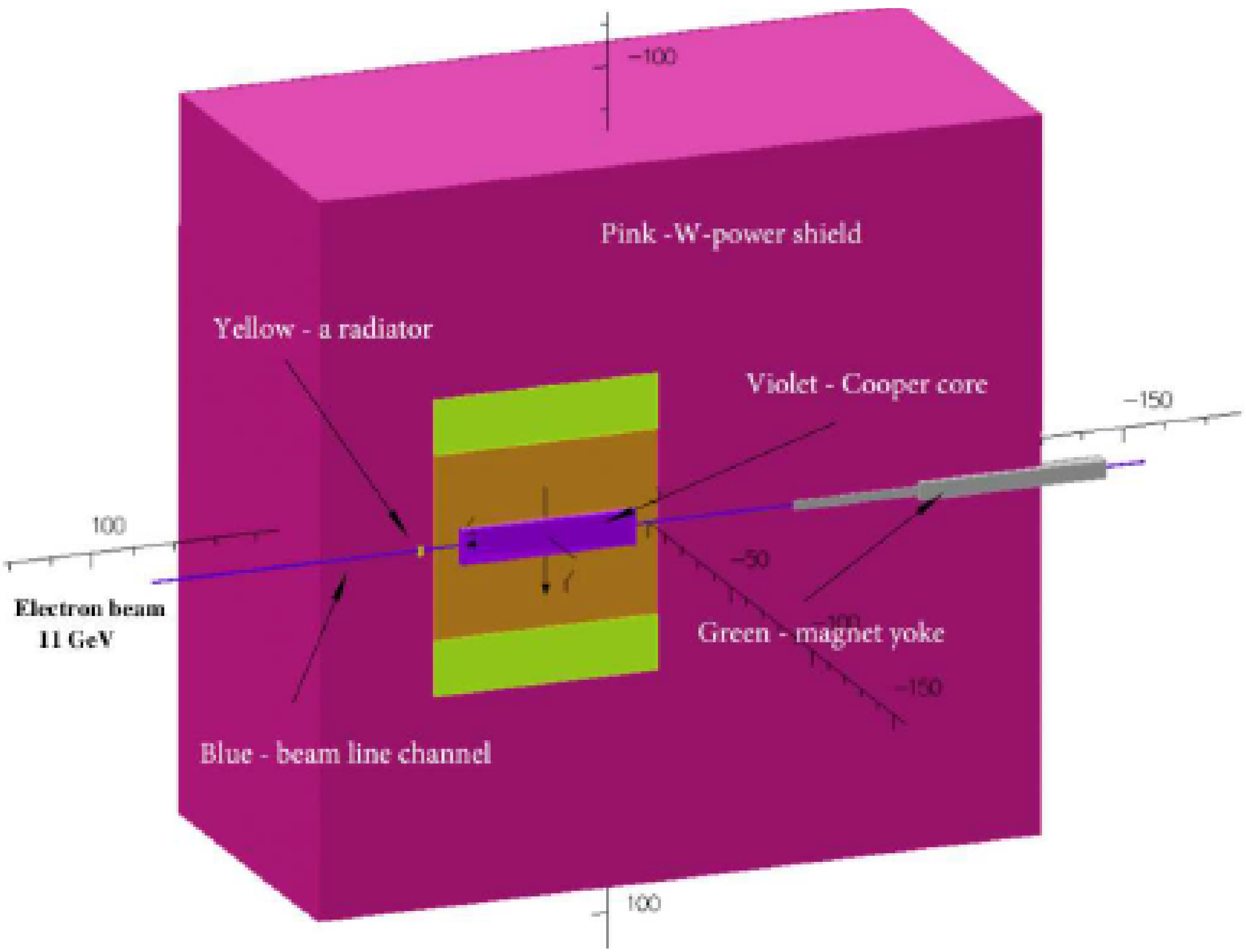
No major problems.

Doable !

Confirmed by Todd Satogata

Estimated investment ~$60 K for injector upgrade

Compact Photon Source



Conceptual design is completed for Halls C/A for I= $2.7\ \mu A$

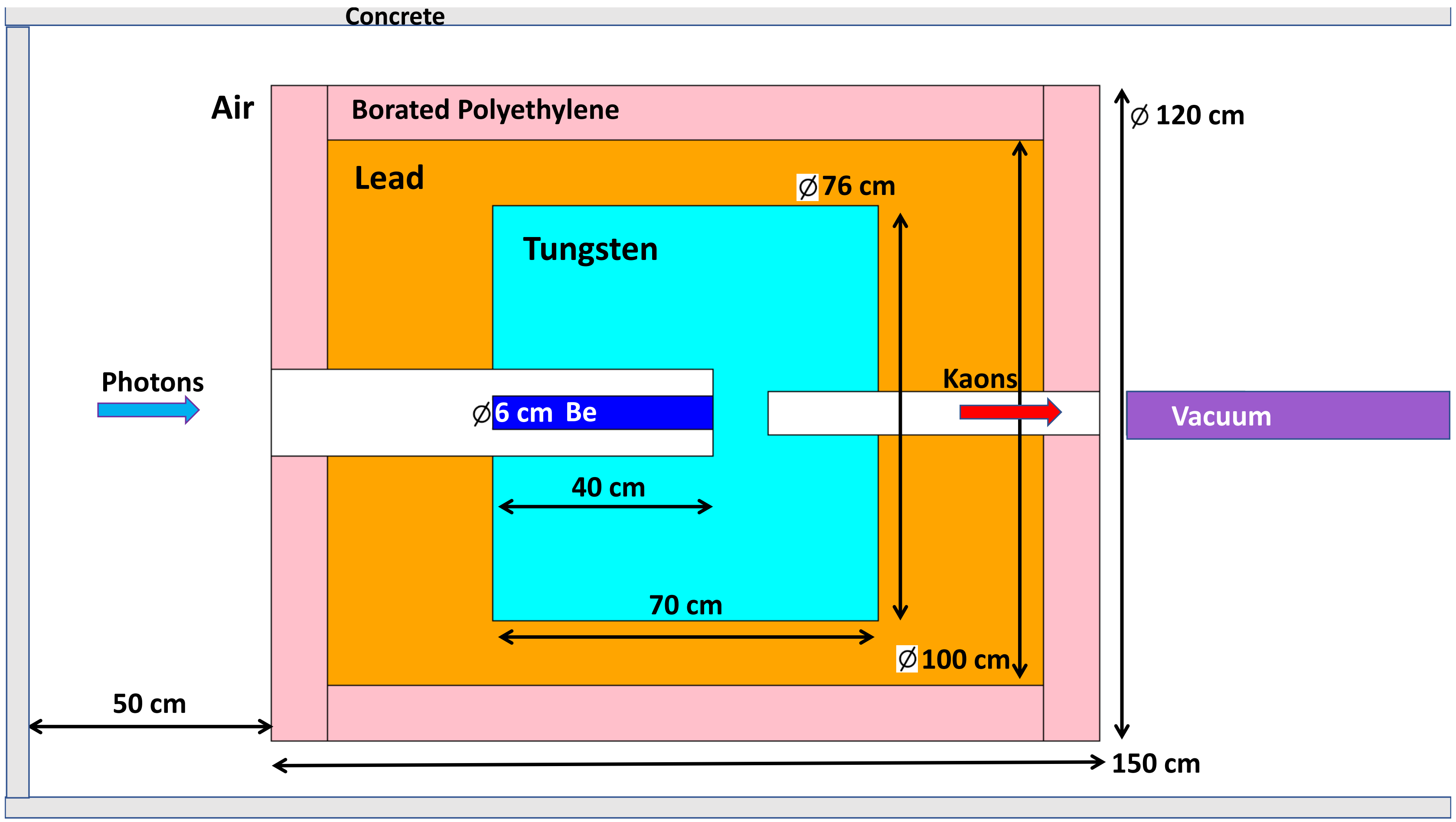
Could be extended for I= $5\ \mu A$ **in Hall D**

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

Estimated cost $1.5-2.0 M

Be Target Assembly: Conceptual Design

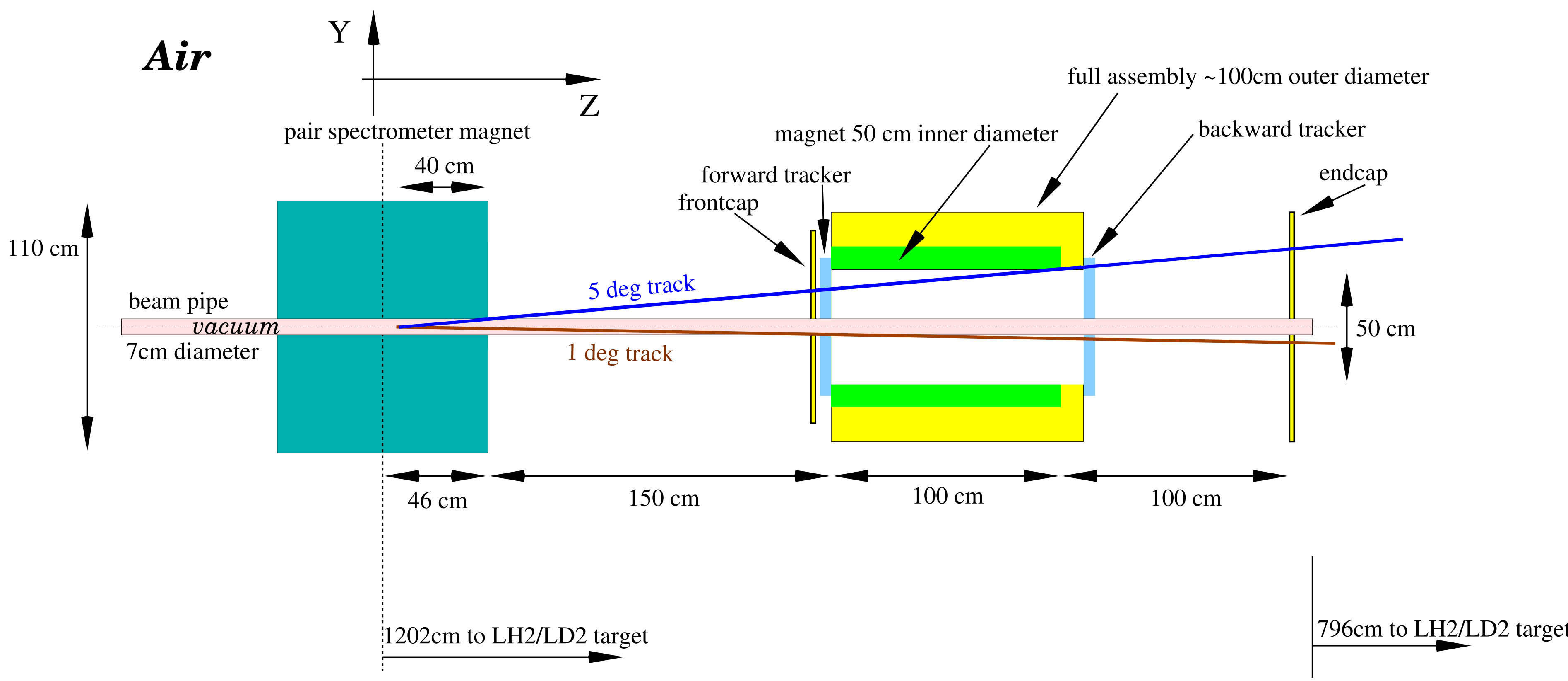


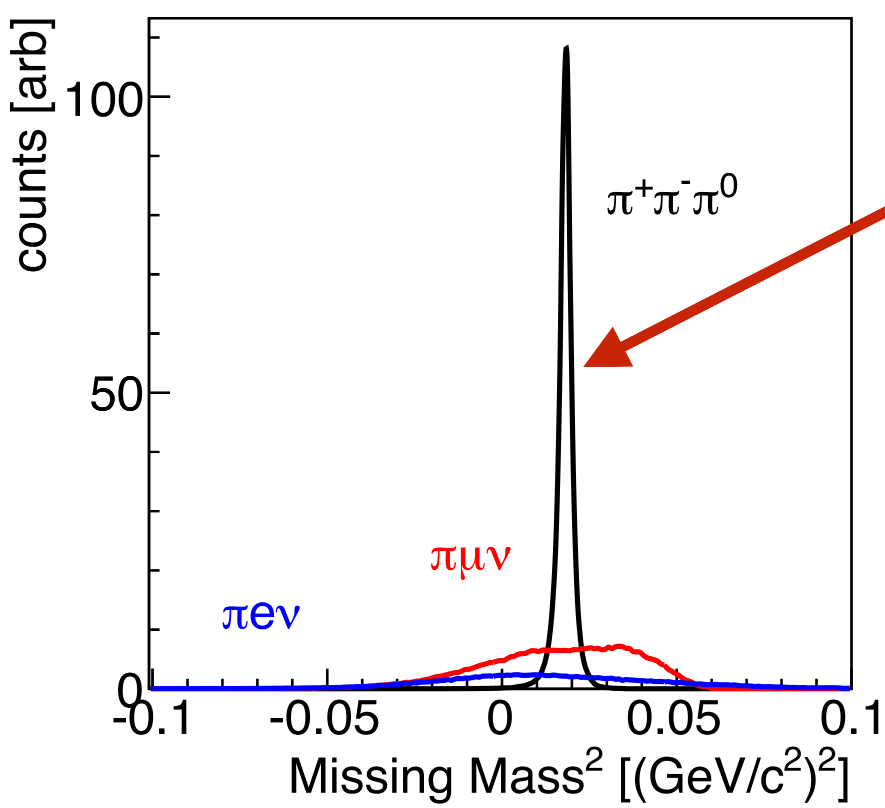
-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff (Tim Whitlatch)

Estimated cost ~$1.2 M

Flux Monitor





Reconstructed K_L mass

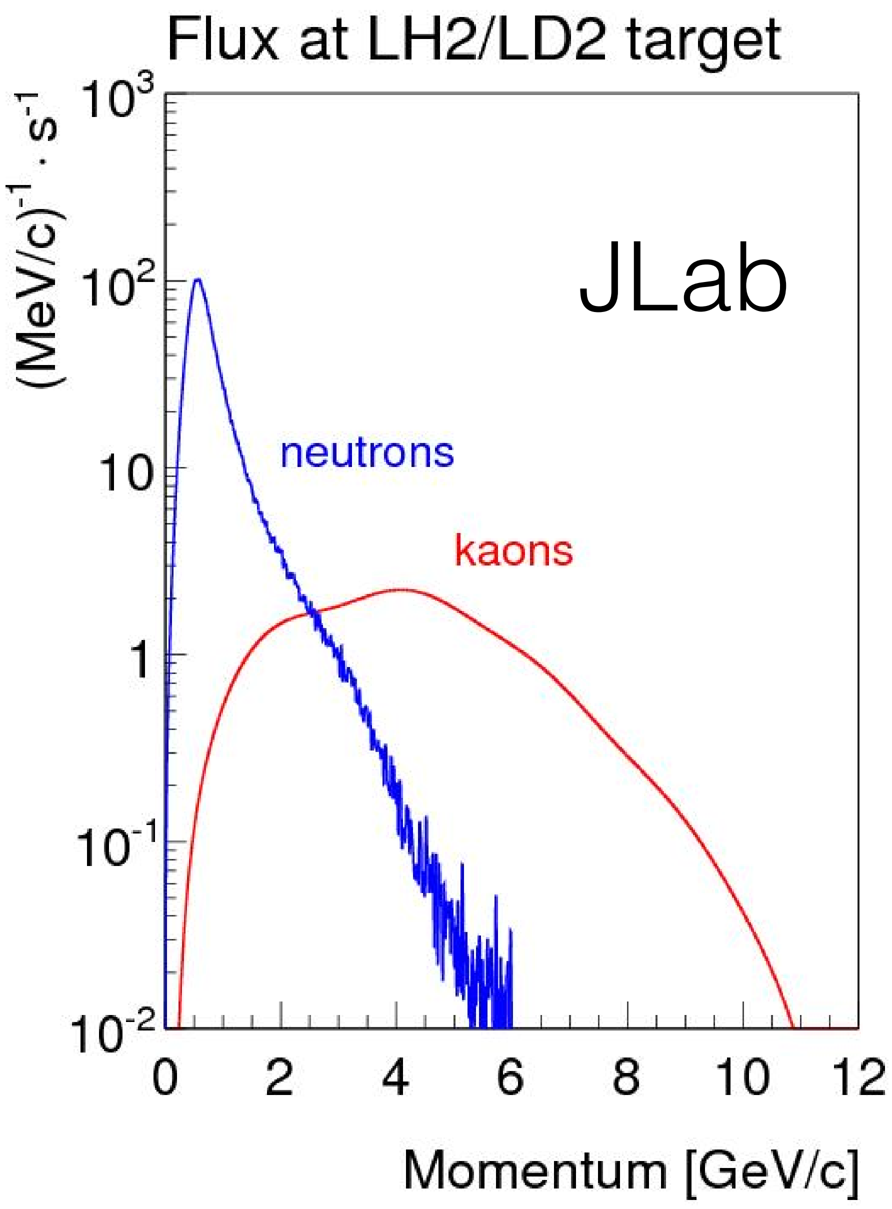
Flux measurement stat. err. <1%

Estimated syst. err. <3%

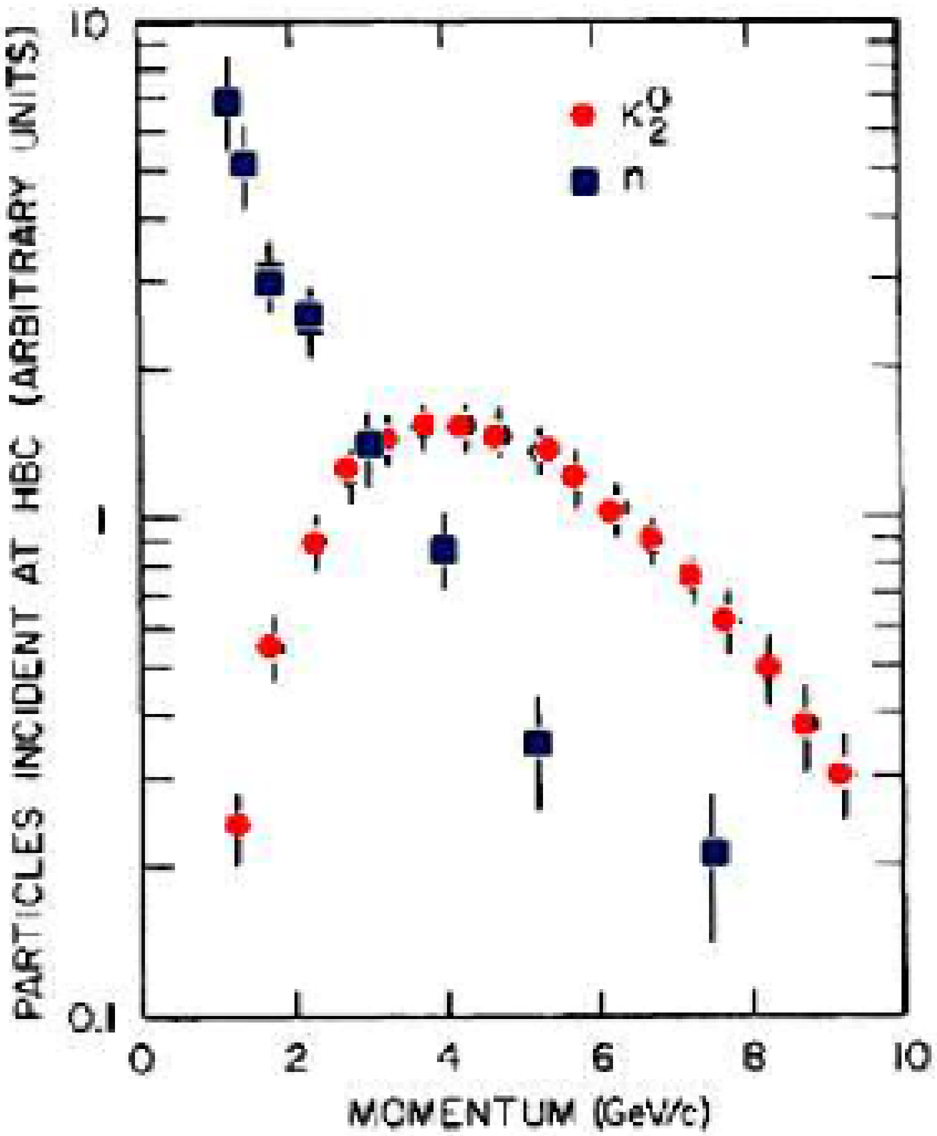
Pursuing UK funding

Estimated cost ~$ 0.7 M

K_L Beam Flux

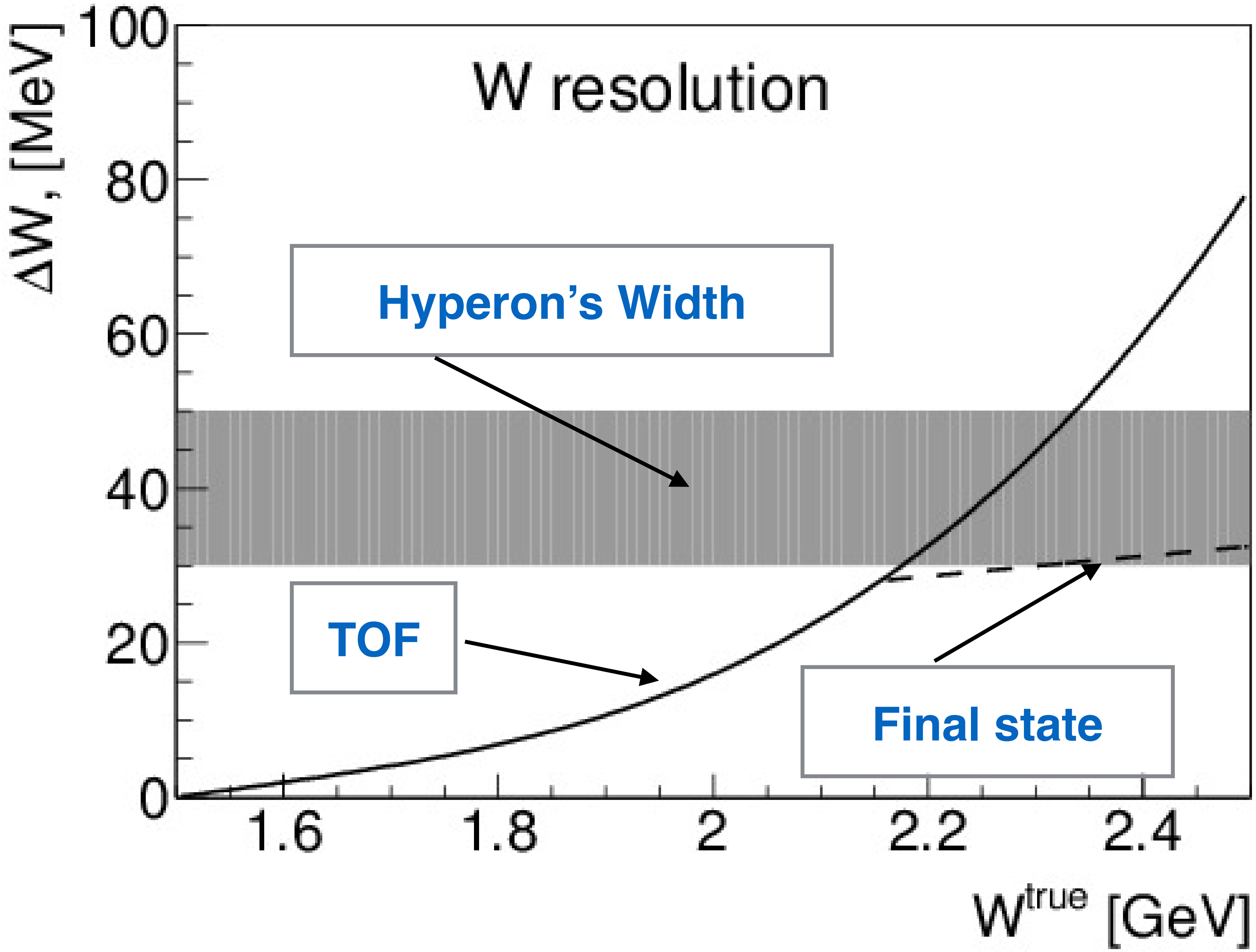


SLAC



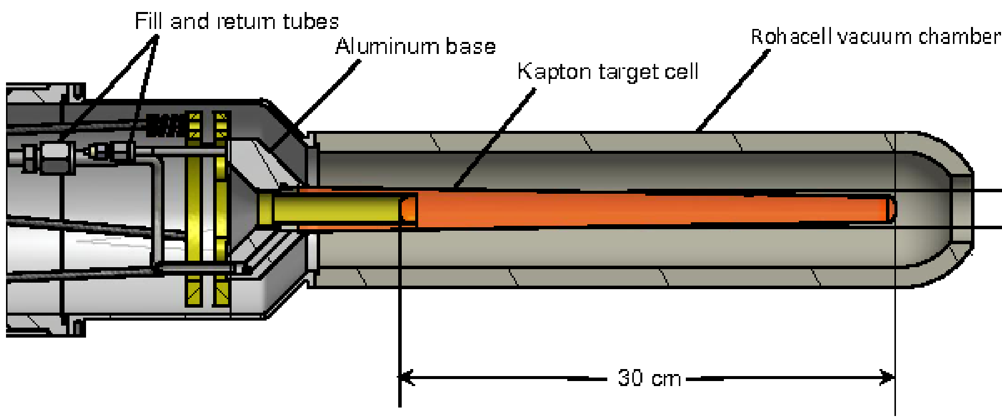
$$N(K_L)/sec \sim 10^4$$

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


W resolution
Hyperon's Width
TOF
Final state
ΔW, [MeV]
0
20
40
60
80
100
1.6
1.8
2
2.2
2.4
W^true [GeV]

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

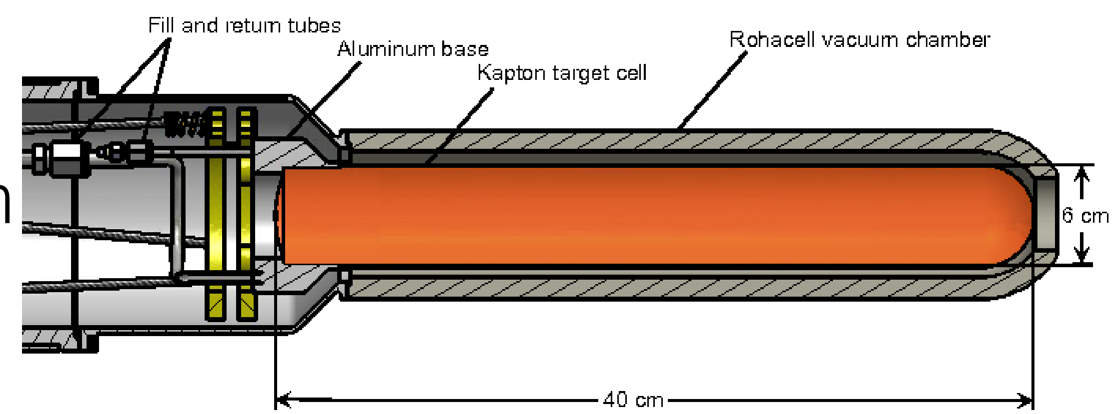
The GlueX liquid hydrogen target.



2cm

30cm

Current



6cm

40cm

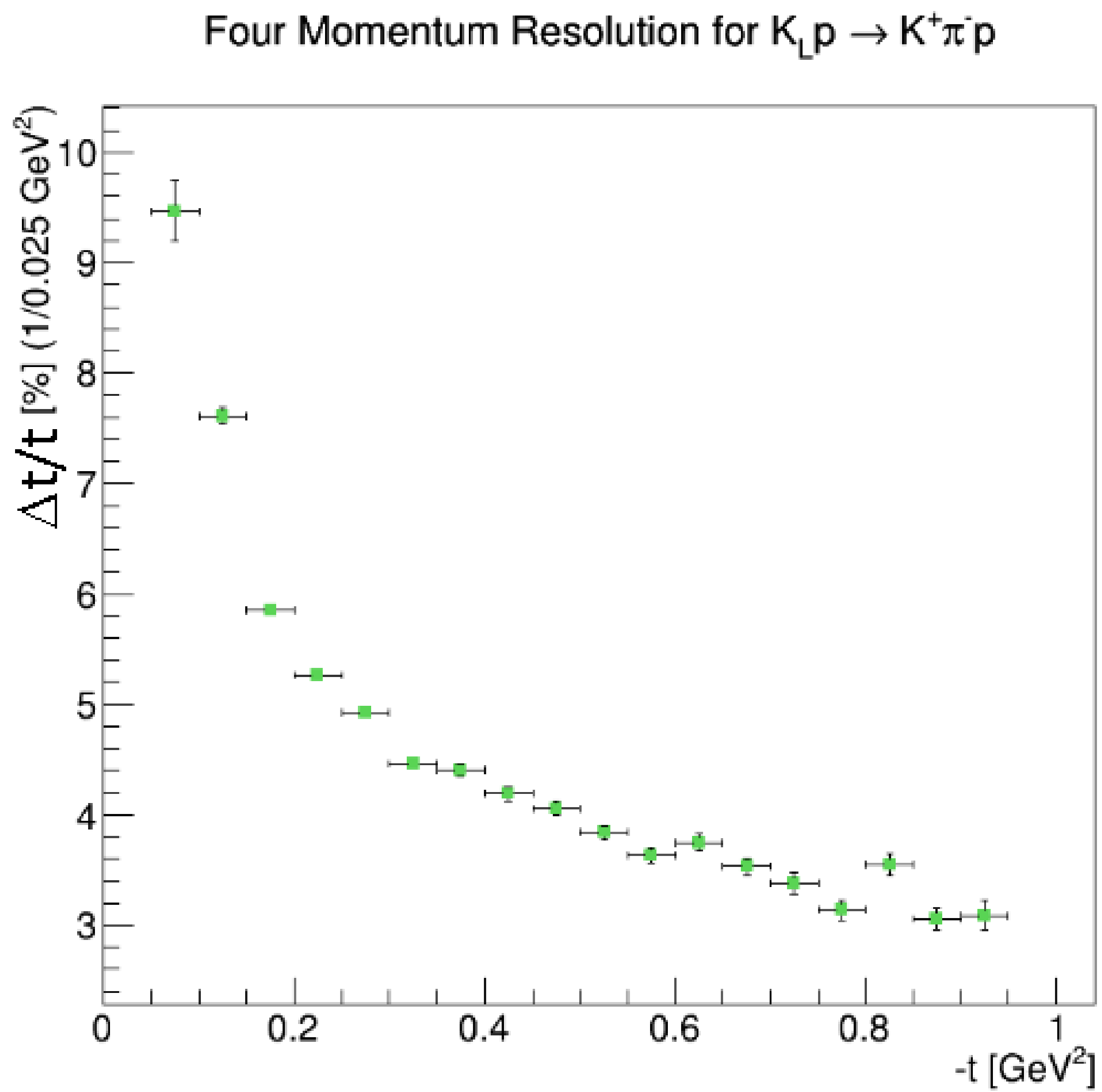
Proposed & Feasible

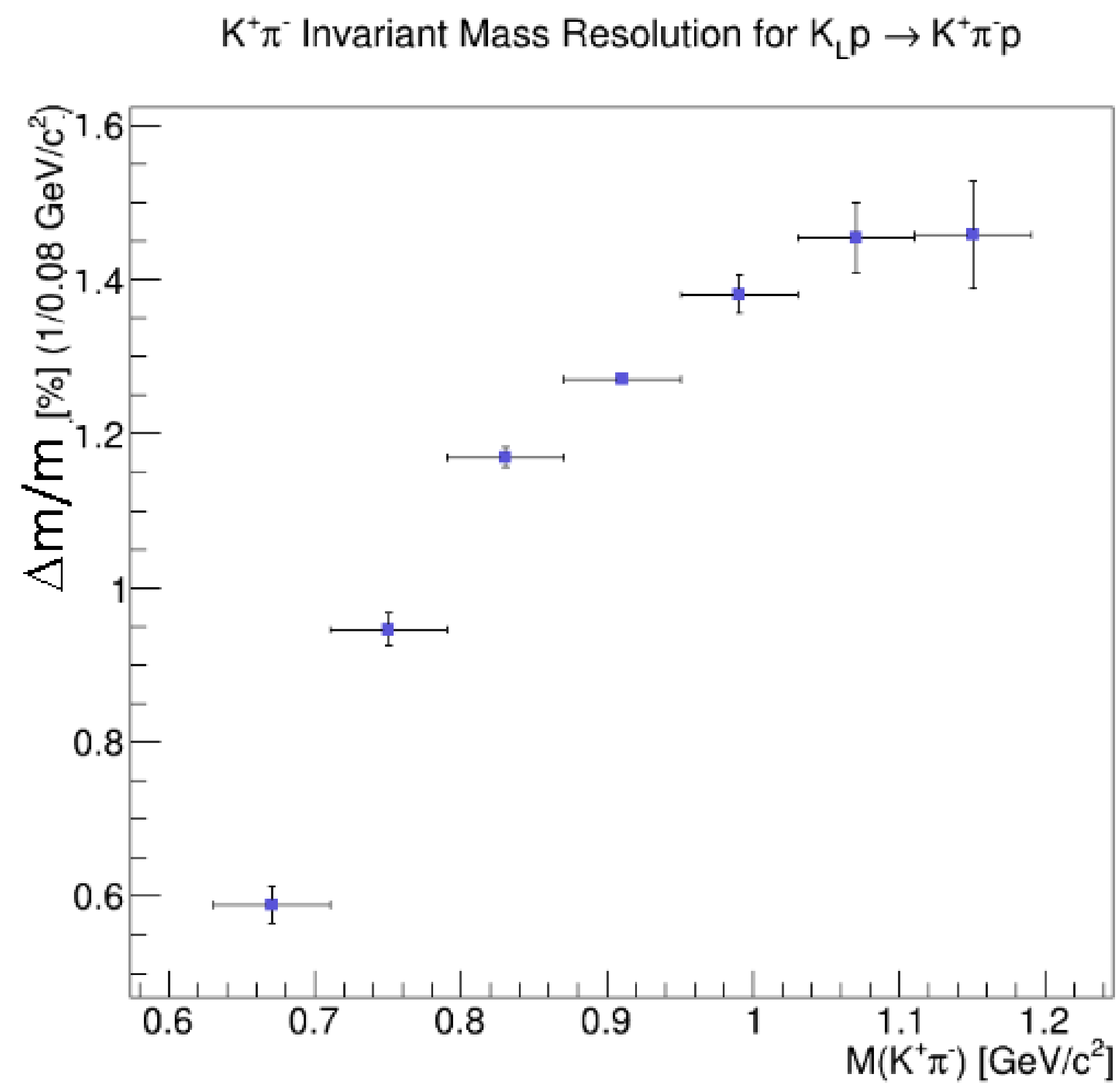
Longer and ticket target is needed to enhance production rate

Conceptual design endorsed by target group (Chris Keith)

Estimated cost ~$ 30 K

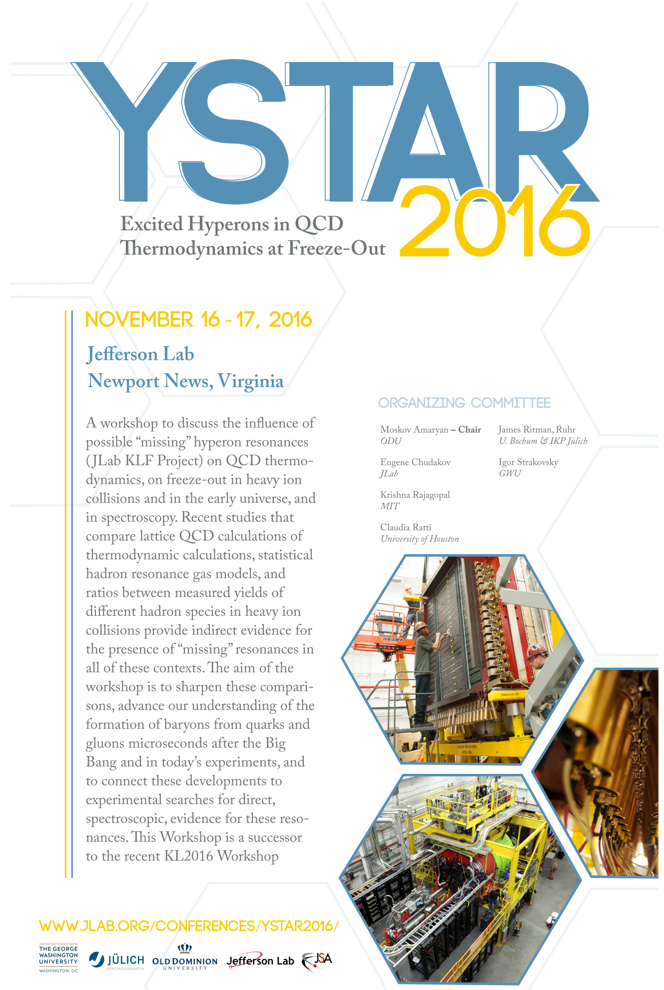
$K\pi$ Scattering Resolutions

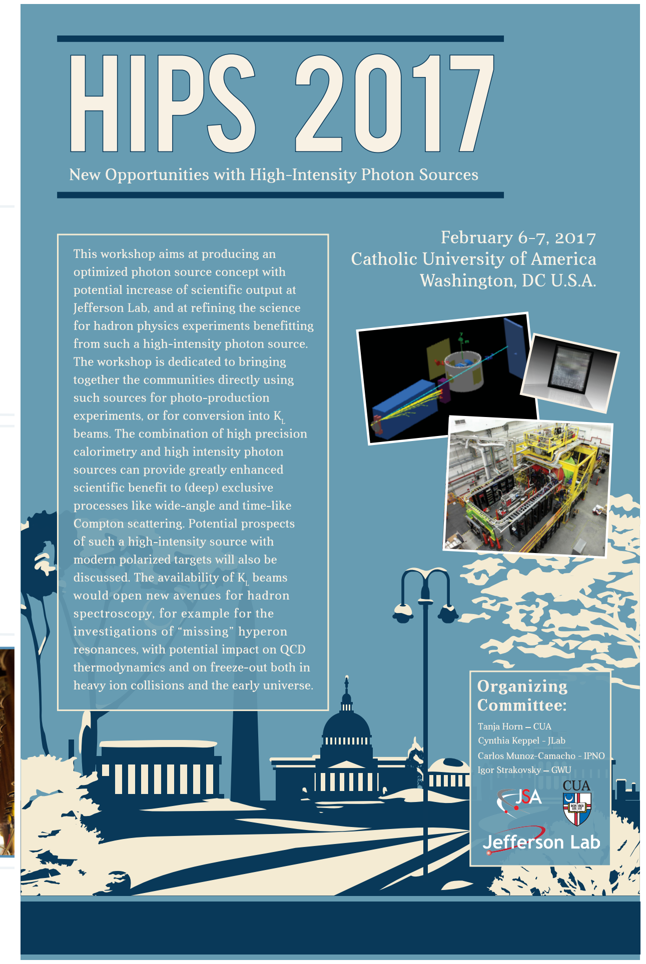


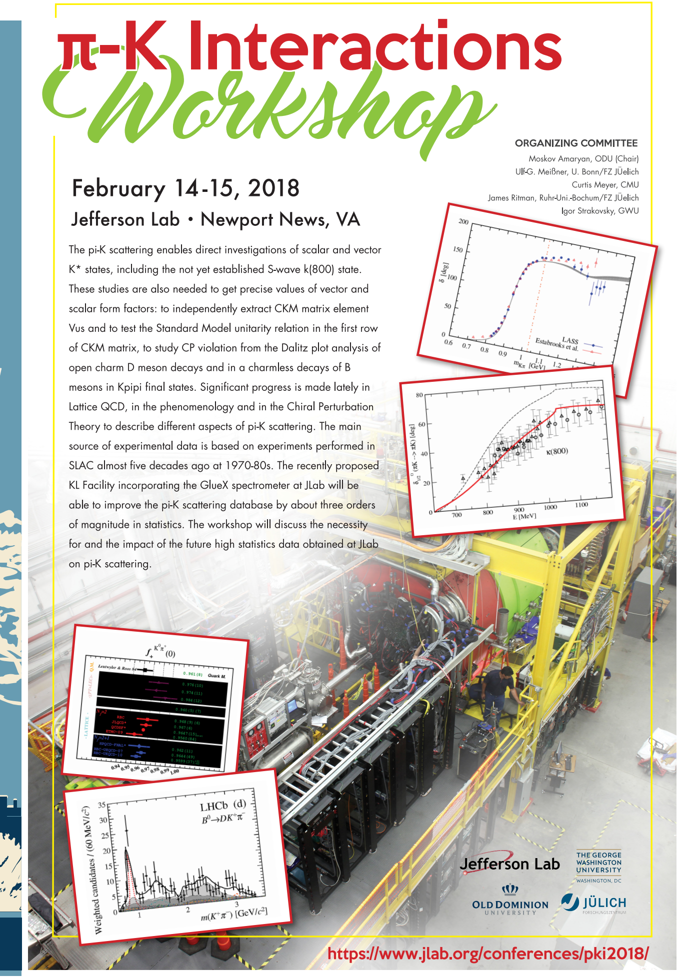


-Good resolution at low-t is needed to be on pion pole

-Binning in ~10 MeV will cover almost entire elastic K-pi scattering range







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

Proposal:

200 Members

61 Institutions

20 Countries

A. Ali[18], M. B. Ali[47], M. J. Amaryan[44,*,†], E. G. Anassontzis[2], A. V. Anisovich[4,48], A. Austregesilo[30], M. Baalouch[45], F. Barbosa[30], J. Barlow[13], A. Barnes[7], E. Barriga[13], M. Bashkanov[10,†], A. Bazavov[39], T. D. Beattie[50], R. Bellwied[20], V. V. Berdnikov[8], T. Black[42], W. Boeglin[12], M. Boer[8], W. J. Briscoe[14], T. Britton[30], W. K. Brooks[53], B. E. Cannon[13], N. Cao[22], E. Chudakov[30], P. L. Cole[21], S. Cole[1], V. Crede[13], M. M. Dalton[30], T. Daniels[42], D. Day[58], P. Degtyarenko[30], A. Deur[30], S. Dobbs[13], G. Dodge[45], A. G. Dolgolenko[27], M. Döring[14,30], M. Dugger[1], R. Dzhygadlo[18], S. Eidelman[5,44], R. Edwards[30], H. Egiyan[30], A. Ernst[13], A. Eskandarian[14], P. Eugenio[13], C. Fanelli[36], S. Fegan[14], A. Filippi[25], A. M. Foda[50], J. Frye[23], S. Furletov[30], L. Gan[42], A. Gasparyan[41], G. Gavalian[30], M. Gauzshtein[54,55], N. Gevorgyan[61], C. Gleason[23], D. I. Glazier[17], J. Goity[30,19], V. S. Goryachev[27], K. Götzen[18], A. Goncalves[13], L. Guo[12], H. Haberzettl[14], M. Hadžimehmedović[57], H. Hakobyan[53], A. Hamdi[18], S. Han[60], J. Hardin[36], A. Hayrapetyan[16], G. M. Huber[50], A. Hurley[59], C. E. Hyde[45], T. Horn[8], D. G. Ireland[17], M. Ito[30], N. Jarvis[7], R. T. Jones[9], V. Kakoyan[61], G. Kalicy[8], M. Kamel[12], C. D. Keith[30], C. W. Kim[14], F. J. Klein[14], C. Kourkoumeli[2], G. Krafft[30], S. Kuleshov[53], I. Kuznetsov[54,55], A. B. Laptev[33], I. Larin[35], D. Lawrence[30], D. I. Lersch[13], M. Levillain[41], H. Li[7], W. Li[59], K. Livingston[17], B. Liu[22], G. J. Lolos[50], V. E. Lyubovitskij[56,54,55,53], D. Mack[30], M. Mai[14], D. M. Manley[31], M. Mazouz[47], H. Marukyan[61], V. Mathieu[30], P. T. Mattione[30], M. Matveev[48], V. Matveev[27], M. McCaughan[30], W. McGinley[7], M. McCracken[7], J. McIntyre[9], U.-G. Meißner[4,29], V. Mokeev[30], F. Nerling[18], C. A. Meyer[7], R. Miskimen[35], R. E. Mitchell[23], F. Mokaya[9], C. Morningstar[7], B. Moussallam[46], K. Nakayama[15], Y. Oh[32], R. Omerović[57], H. Osmanović[57], A. Ostrovidov[13], Z. Papandreou[50], K. Park[30], E. Pasyuk[30], M. Patsyuk[36], P. Pauli[17], R. Pedroni[41], J. R. Pelaez[34], L. Pentchev[30], M. R. Pennington[17], K. J. Peters[18], W. Phelps[14], A. Pilloni[30], E. Pooser[30], J. W. Price[6], N. Qin[43], J. Reinhold[12], D. Richards[30], D.-O. Riska[11], B. Ritchie[1], J. Ritman[51,28,†], L. Robison[43], A. Rodas[34], D. Romanov[37], C. Romero[53], J. Ruiz de Elvira[3], H-Y. Ryu[49], C. Salgado[40], E. Santopinto[24], A. V. Sarantsev[4,48], T. Satogata[30], A. Schertz[59], R. A. Schumacher[7], C. Schwarz[18], J. Schwiening[18], A. Yu. Semenov[50], I. A. Semenova[50], K. K. Seth[43], X. Shen[22], M. R. Shepherd[23], E. S. Smith[30], D. I. Sober[8], D. Sokhan[17], A. Somov[30], S. Somov[37], O. Soto[53], M. Staib[7], J. Stahov[57], J. R. Stevens[59,†], I. I. Strakovsky[14,†], A. Švarc[52], A. Szczepaniak[23,30], V. Tarasov[27], S. Taylor[30], A. Teymurazyan[50], A. Trabelsi[47], G. Vasileiadis[2], D. Watts[10], D. Werthmüller[17], T. Whitlatch[30], N. Wickramaarachchi[45], M. Williams[36], B. Wojtsekhowski[30], R. L. Workman[14], T. Xiao[43], Y. Yang[36], N. Zachariou[10], J. Zarling[23], J. Zhang[58], Z. Zhang[60], G. Zhao[22], B. Zou[26], Q. Zhou[22], X. Zhou[60], B. Zihlmann[30]

SUMMARY

-Proposed KL Facility has unique capability to improve existing world database up to three ordres of magnitude

-In Hyperon spectrsocopy

PWA will allow to mesure pole positions and widths of excited hyperon states

-In Strange Meson Spectroscopy

PWA will allow to measure excited K* states including scalar f0(800) states

- To accomplish physics program 100 days per LH2 and LD2 is required

-All components of KL Facility considered are feasible

-With total cost less than $ 4.0 M

CPS(~$ 1.5-2.0 M)
BeTarget(~$ 1.2 M)
FluxMonitor (~$ 0.7 M)
Electron Beam (~$ 60K)
Cryo-Targets (~$ 30K)

Backup

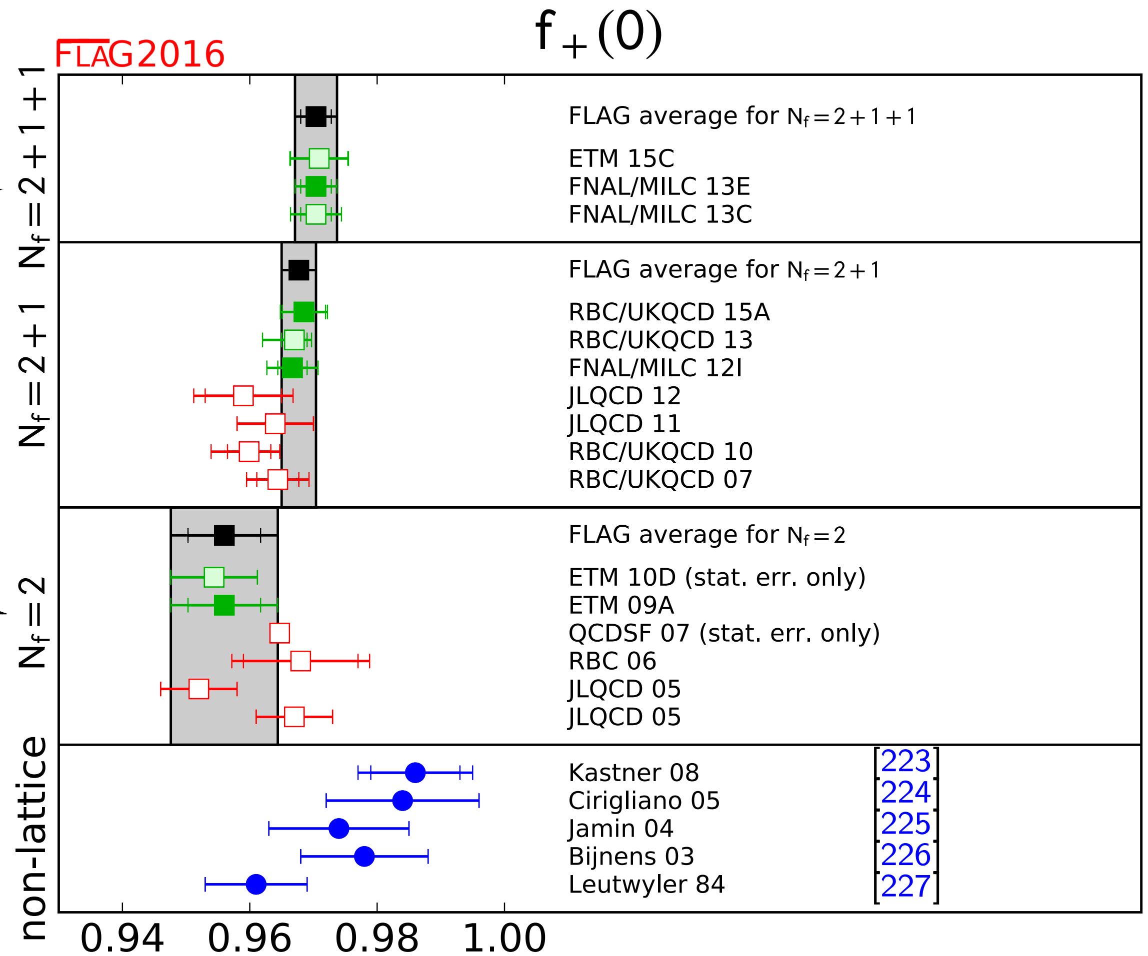
Possible Other Impacts

$$Br(K_L \to \pi e \nu) \sim |f_+(0)V_{us}|^2$$

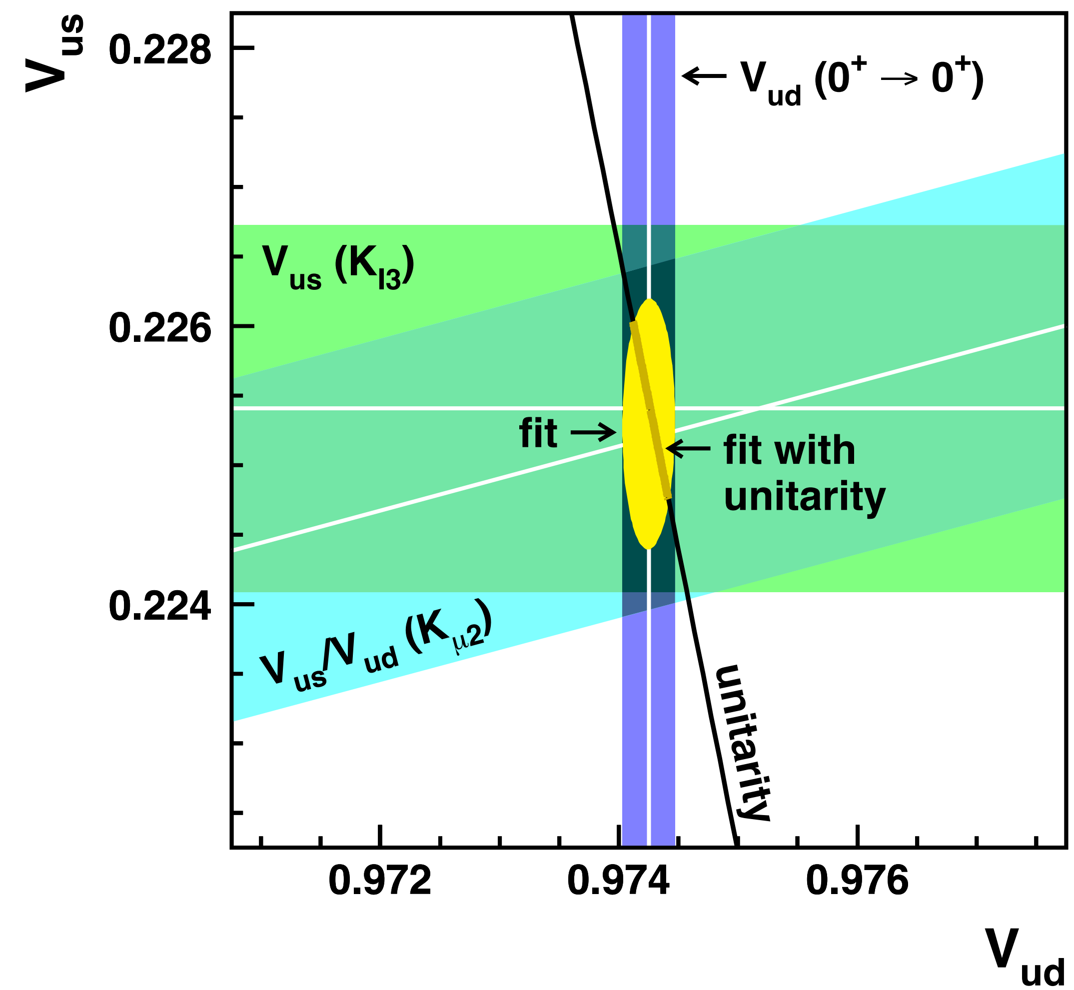
$$Br(\tau \to K \pi \nu) \sim |f_+(0)V_{us}|^2$$

LQCD

χPT



FLAG Collaboration **Eur.Phys.J. C77 (2017) no.2, 112**



Eur.Phys.J. C69 (2010) 399-424

No precise data yet !

test of unitarity:

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$$

Cover Letter for KLF Proposal Submission to PAC46

Issues:

Mounting this experiment will transform the existing Hall D beamline, so it represents an almost irreversible change in direction for the GlueX apparatus. As such, the physics driver must be compelling, and the PAC doesn't feel that a sufficiently convincing physics case has been made. A broad program is suggested, so the PAC would welcome a larger presentation format along the lines of a run group proposal.

The CPS design is progressing but details on the KL target and shielding for the detector need to be fleshed out.

The 64 ns beam structure will also require study to ensure that other halls are not adversely affected.

The beam time request is dominated by the hyperon polarimetry measurements. A simulated example of a PWA, and how it would feed into the proposed spectroscopy measurements, will be needed in a future proposal.

The LOI included doubly strange baryons but this topic was not much expanded upon in the pro- posal.

This topic remains of considerable interest.

Summary:

This experiment would introduce a new and interesting area of physics at JLAB. The PAC recommends that the Collaboration work with the lattice and theoretical nuclear physics community to sharpen the physics case.

In addition, more details on the KL production target and shielding will be needed before we can fully assess the feasibility of the experiment. Despite the progress made in delineating the expanded physics possibilities, the very substantial beam time request would be better motivated if more details could be provided on its impact on the proposed spectroscopic measurements.

The KLF Collaboration for the GlueX Collaboration believes that the current proposal addresses all the concerns following the recommendations expressed by the PAC45:

1. **Q1: Mounting this experiment will transform the existing Hall D beamline, so it represents an almost irreversible change in direction for the GlueX apparatus.**

A1: Changeover from the photon to K_L beamline and from the K_L beamline to photon needs to be further evaluated and in the most conservative scenario may take approximately 6 months or less. This maximal break period may fit the current CEBAF Accelerator schedule. It has to be mentioned that the collimator cave has enough space (with the 4.52 m width) for the Be-target assembly to remain far enough from the beamline.

2. Q2: As such, the physics driver must be compelling, and the PAC doesn't feel that a sufficiently convincing physics case has been made. A broad program is suggested, so the PAC would welcome a larger presentation format along the lines of a run group proposal.

A2: With the current proposal, we aim to show the broad range of outstanding problems related to strange hadron spectroscopy, which can be solved by improving the existing database by orders of magnitude. We believe, the run group proposals will naturally occur when the proposed facility is approved.

In particular, we are focusing on studies of doubly strange cascade baryons and the kappa-meson.

Following Bob McKeown's suggestion, we plan to have three presentations at the PAC46 meeting:

(a)K_L Beam Facility at GlueX;

(b) Hyperon Spectroscopy with a K_L Beam;

(c) Strange Mesons with a K_L Beam.

3. Q3:The CPS design is progressing but details on the KL target end shilling for the detector need to be fleshed out.

A3: Following to that, we improved the conceptual design for both the CPS (Sec. 10.1.2) and the Be- target (KL production target) (Sec. 10.1.3)

4. Q4: The 64 ns beam structure will also require study to ensure that other halls are not adversely affected

A4: According to our discussions with accelerator experts (Geoff Krafft, Matt Poelker, Todd Satogata, Jay Benisch, Reza Kazimi, and Joe Grames) following the iTAC Report for PAC45 it has been explicitly stated that no problems are expected for a 64 ns beam structure from the beam delivery point of view. Todd is member of our team and we do have a Section 10.1.1 addressing this task. In order to build up a beamline delivery system for the secondary K_L beam a rough estimateis for about $10k the pulse picking system and about $50k for the laser amplifier.

5. Q5: A simulated example of a partial wave analysis, and how it would feed into the proposed spectroscopie measurements, will be needed in a future proposal.

A5: We generated quasi-data for the toy PWA model for spectroscopy of hyperons to demonstrate impact of the proposed experiment on the world knowledge (Sec. 11.1.6). The results will be presented during PAC46.

6. Q6: The LOI included doubly strange baryons but this topic was not much expanded upon in the proposal. This topic remains of considerable interest.

A6: We made two cases with doubly strange baryons (Sec. 3.1) and pion-kaon interactions (Sec. 9) more compelling.

7. **Q7: The PAC recommends that the Collaboration work with the lattice and theoretical nuclear physics community to sharpen the physics case.**

A7: We are collaborating closely with the lattice and theory community. In addition, we had the forth Workshop PKI2018 [12] hosted at JLab recently and dedicated to the physics of strange mesons produced by the neutral kaon beam. Meanwhile, many lattice and theory researchers are co-authors of our proposal and our proposal has a significant contribution from them.

8. **Q8: In addition, more details on the KL production target and shielding will be needed before we can fully assess the feasibility of the experiment.**

A8: All is done (see A3).

9. Q9: Despite the progress made in delineating the expanded physics possibilities, the very substantial beam time request would be better motivated if more details could be provided on its impact on the proposed spectroscopic measurements.

A9: We believe that the current proposal addresses all the concerns following the recommendations expressed by the PAC45. The new data will significantly constrain PWAs and reduce model-dependent uncertainties in the extraction of the properties and pole positions of the strange hyperon resonances, and establish the orbitally excited multiplets in the spectra of the Ξ and Ω hyperons.

The experiment will settle the still open issue of the existence or non-existence of the low lying strange scalar meson ϰ(800). All details will be presented during PAC46.