PR-12-18-002

Strange Hadron Spectroscopy with Secondary K_L Beam at GlueX

I. The KL Facility at GlueX:Challenges and Feasibility

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(For KLF Collaboration)

PAC46, July 17, 2018

Outline

Physics Motivation

- Hyperon Spectroscopy (more from Mark Manley)
- Strange Meson Spectroscopy (more from Jose Pelaez)

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*

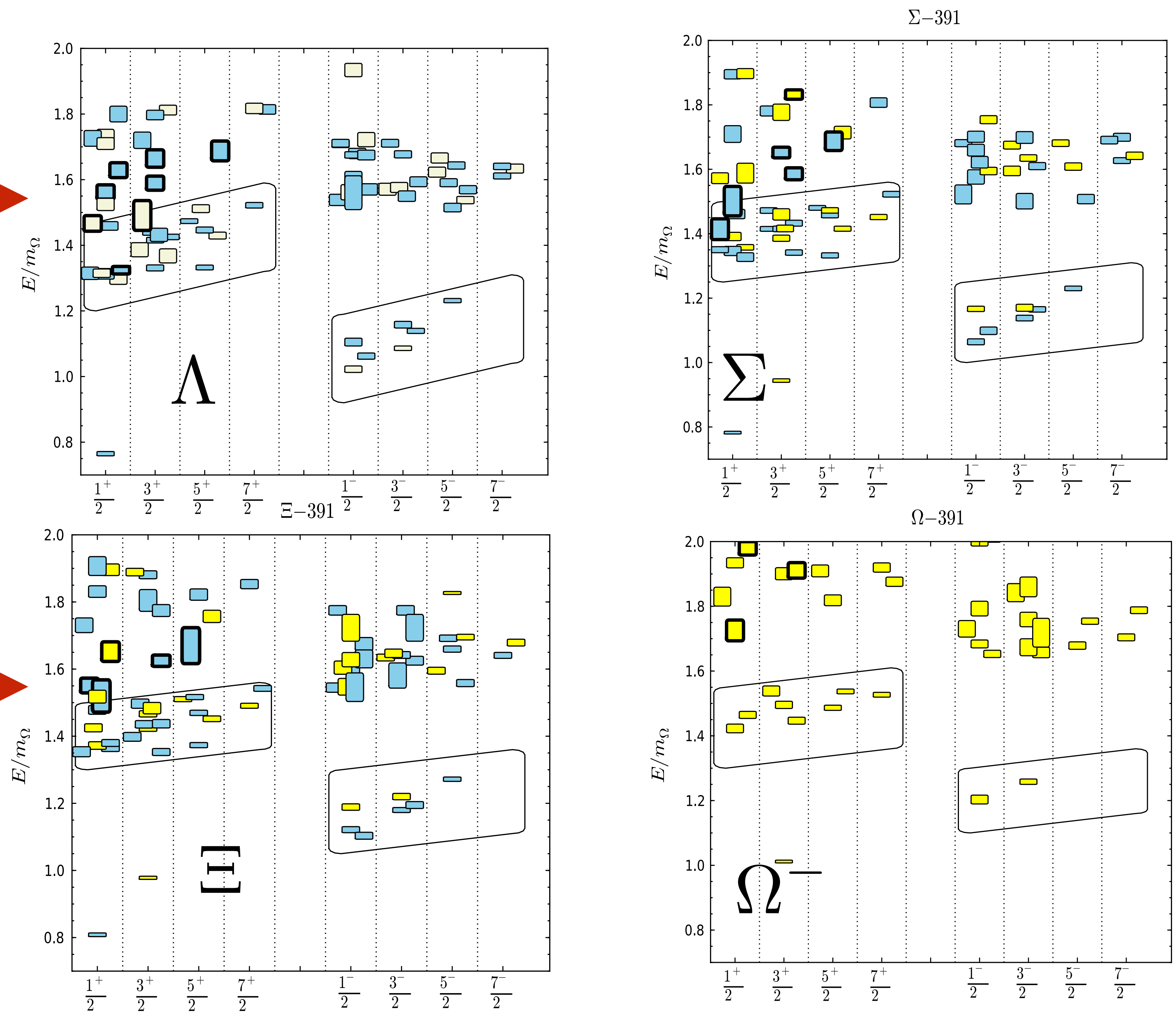
many more states including hybrids (thick bordered)

8-states
****

5-states
***

6-states
****

4-states
***



3-states
****

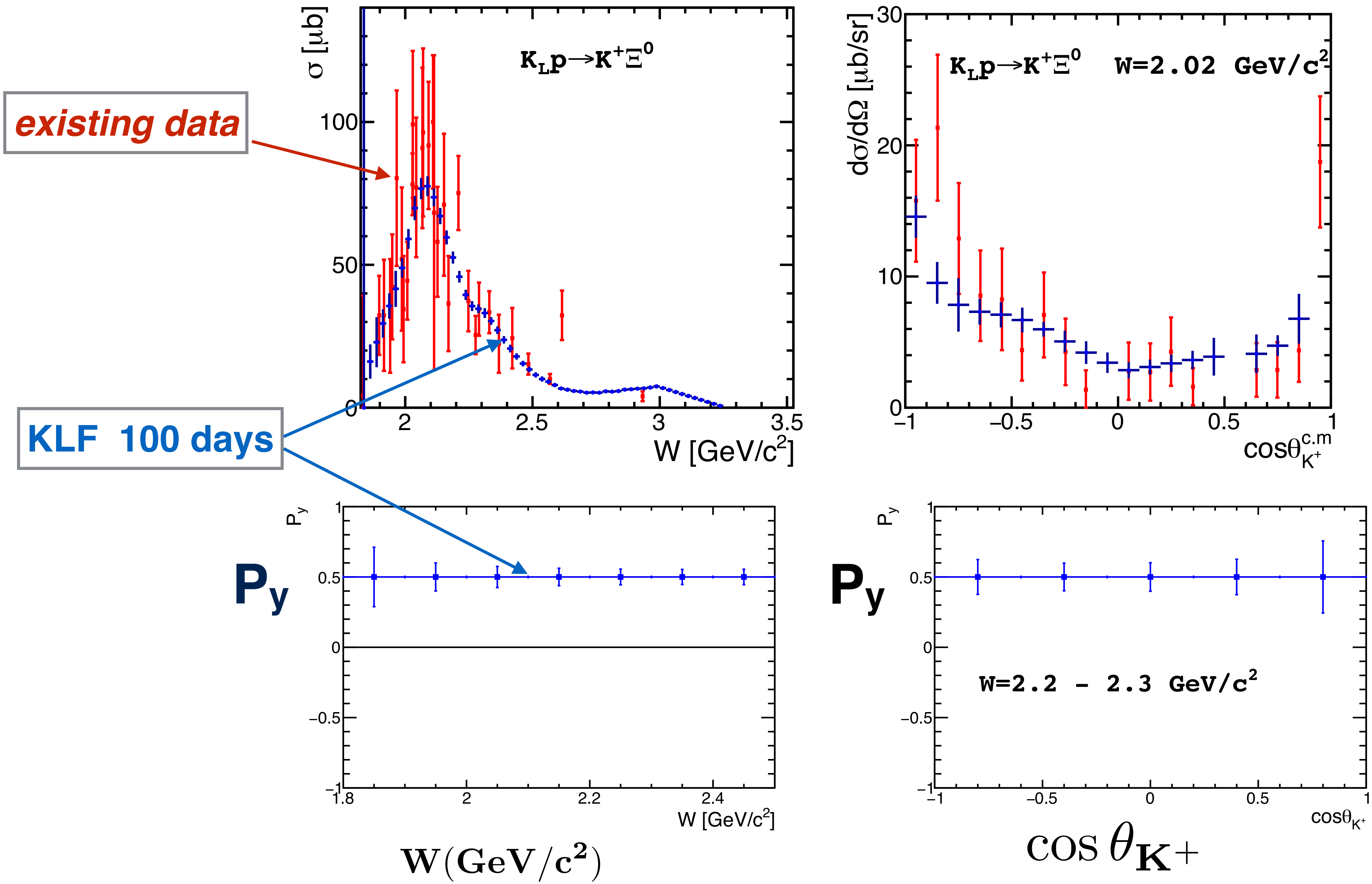
4-states
***

1-state
****

1-state
***

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

Proposed Measurements on Proton 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)

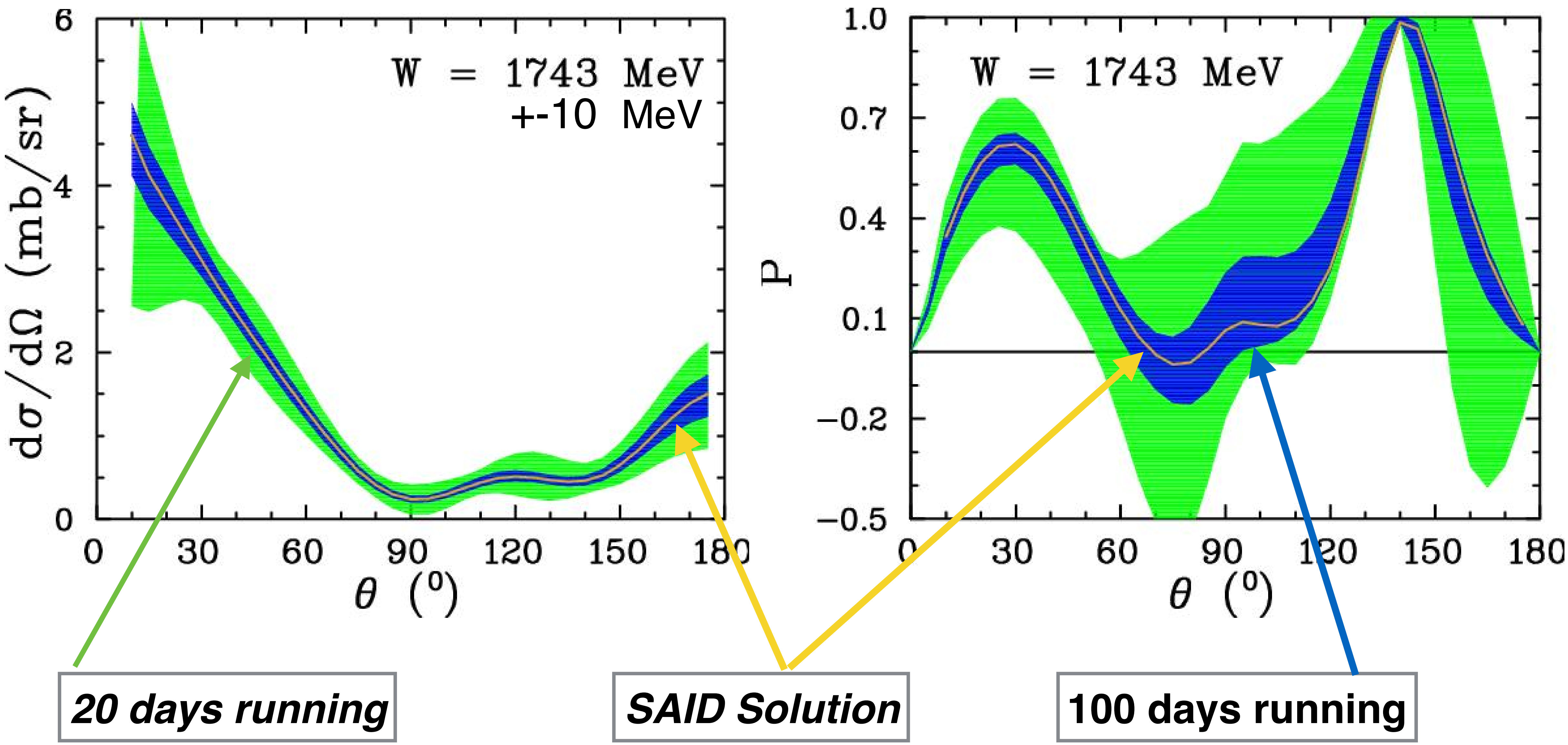
-identify $\Lambda^*, \Sigma^*, \Xi^* \ \& \ \Omega^*$ up to 2400 MeV

As kaon nucleon scattering data are very poor

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

Using πp Scattering surrogate

Cross Section | Recoil polarization



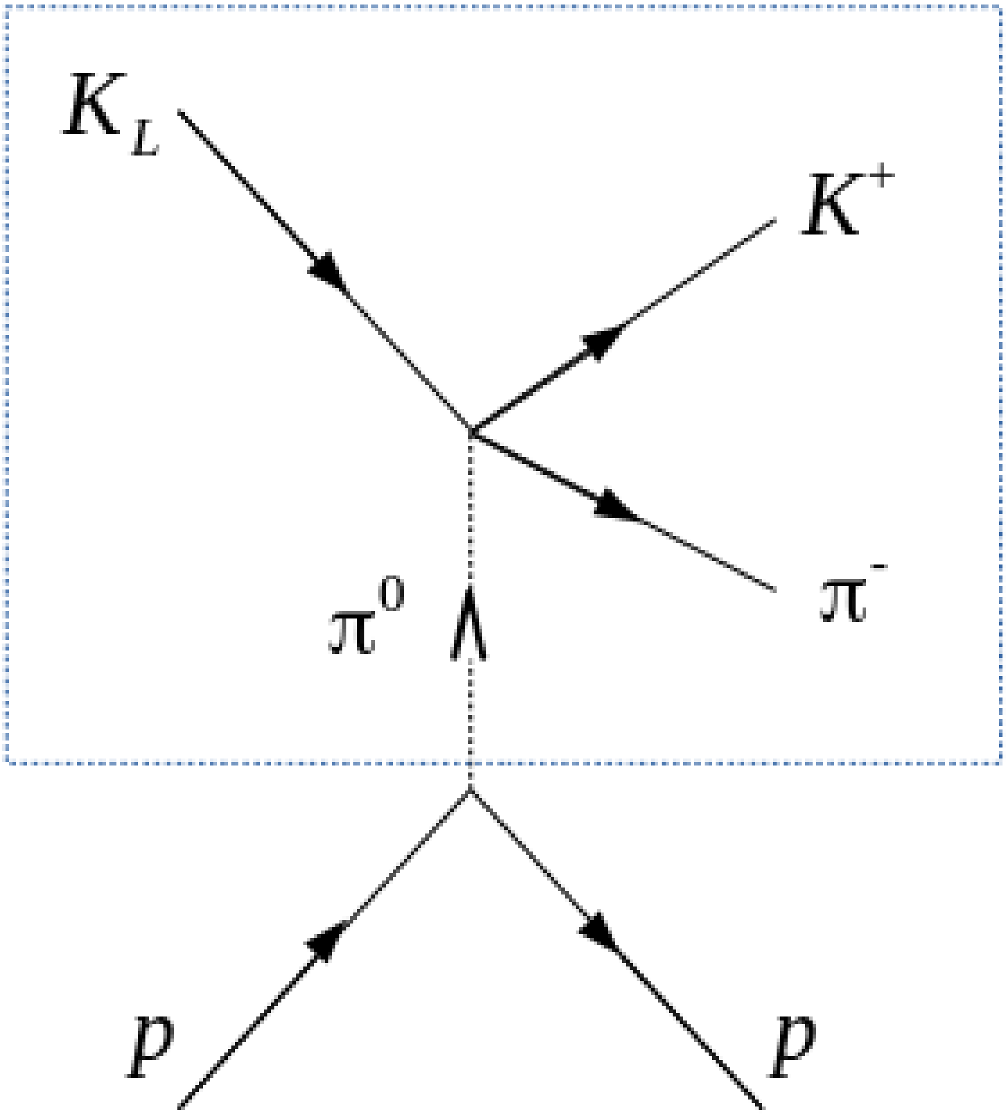
Statistics was generated according to KLF for

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

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

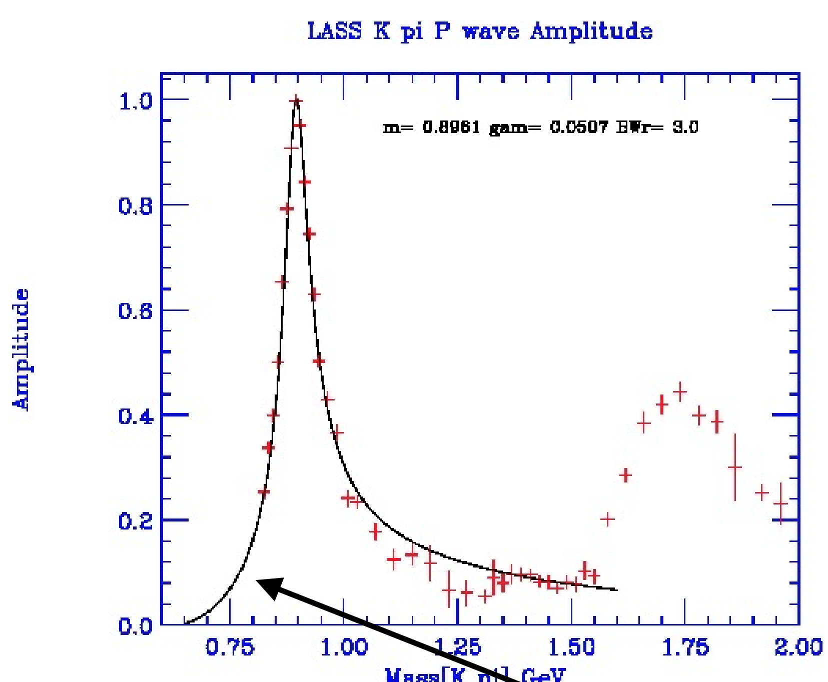
Strange Meson Spectroscopy

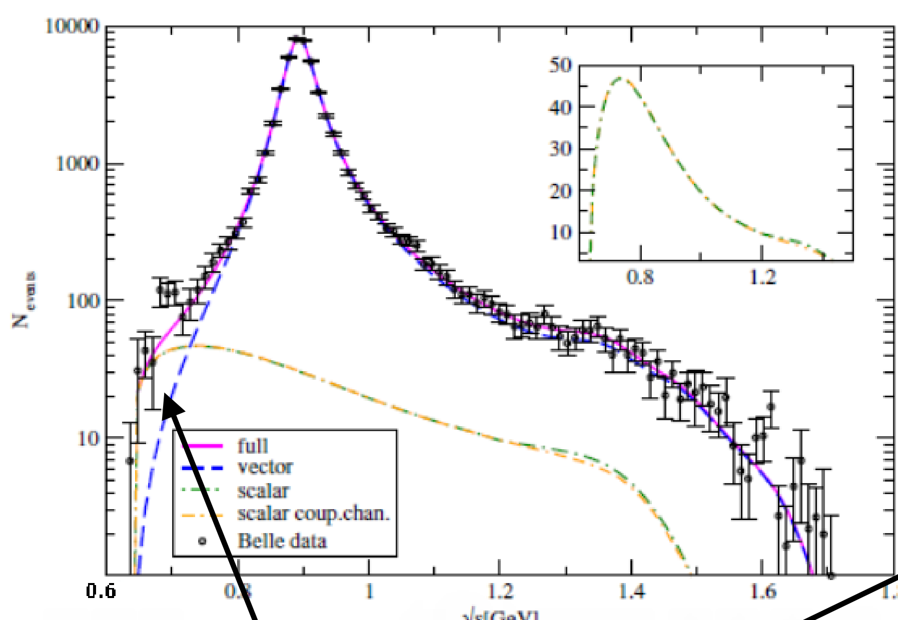
$K\pi$ **Scattering**

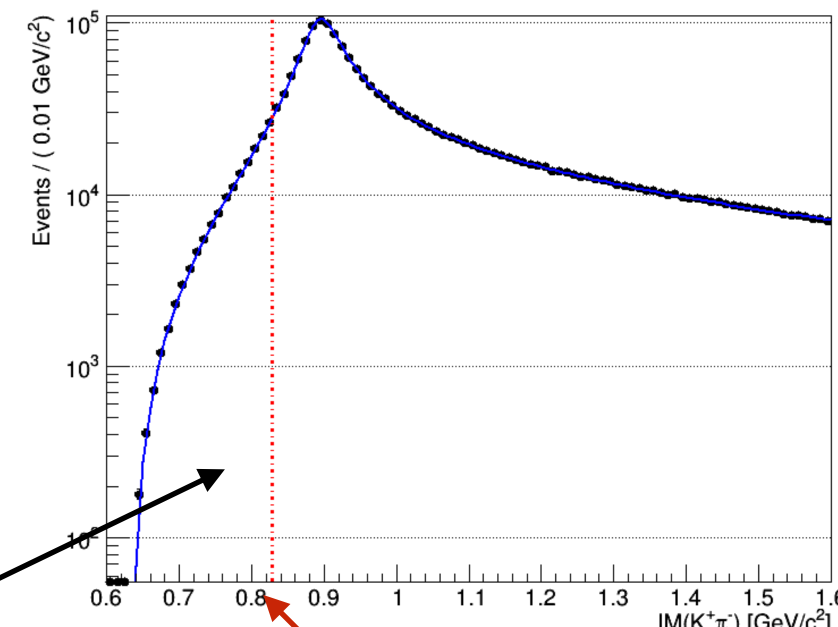


Proposed Measurements

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







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

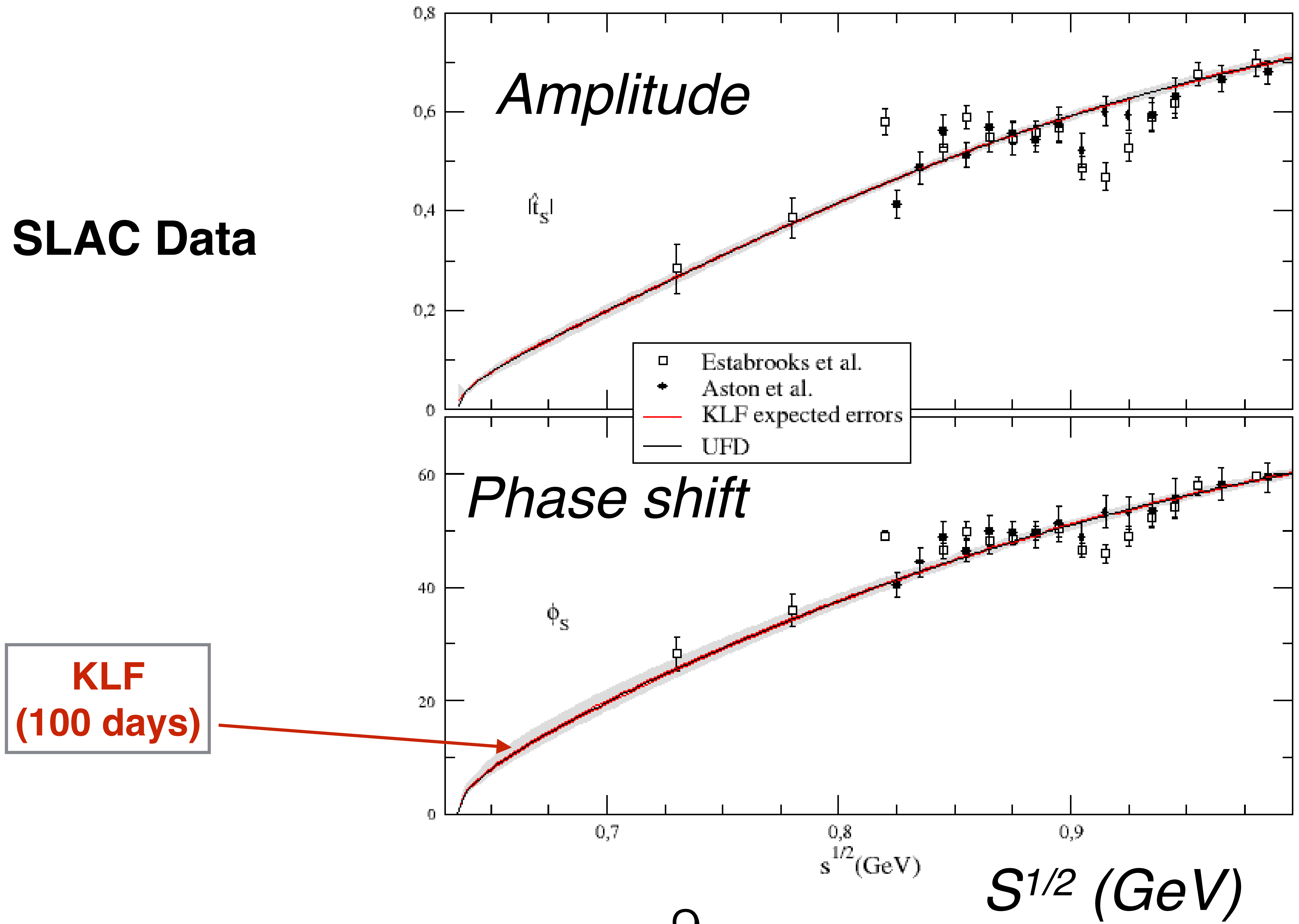
region of $\kappa(800)$

SLAC Lower limit

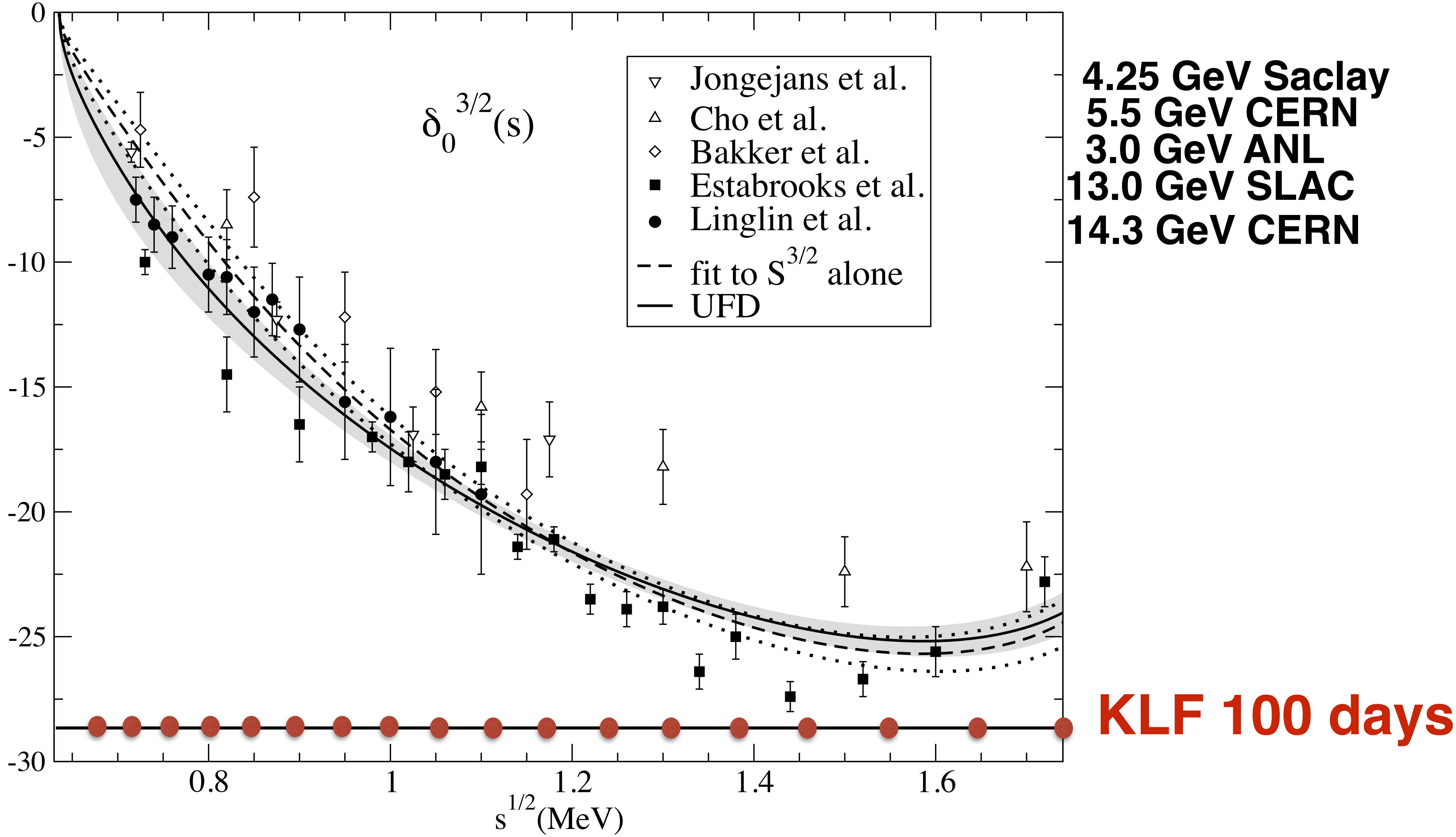
Proposed Measurement

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

SLAC Data



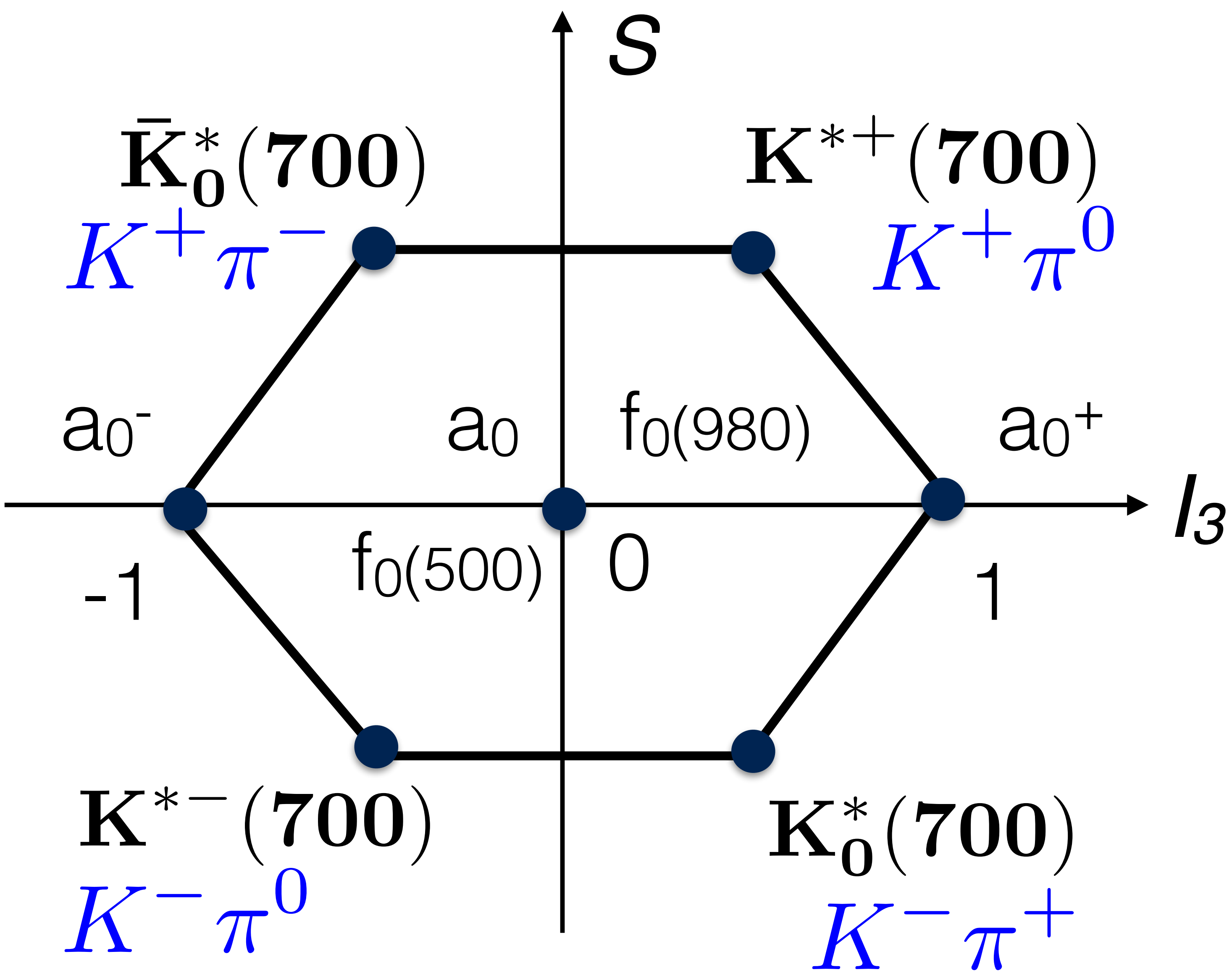
I=3/2 S-wave



From Pelaez and Rodas paper: PRD93(2016)

Scalar Meson Nonet

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



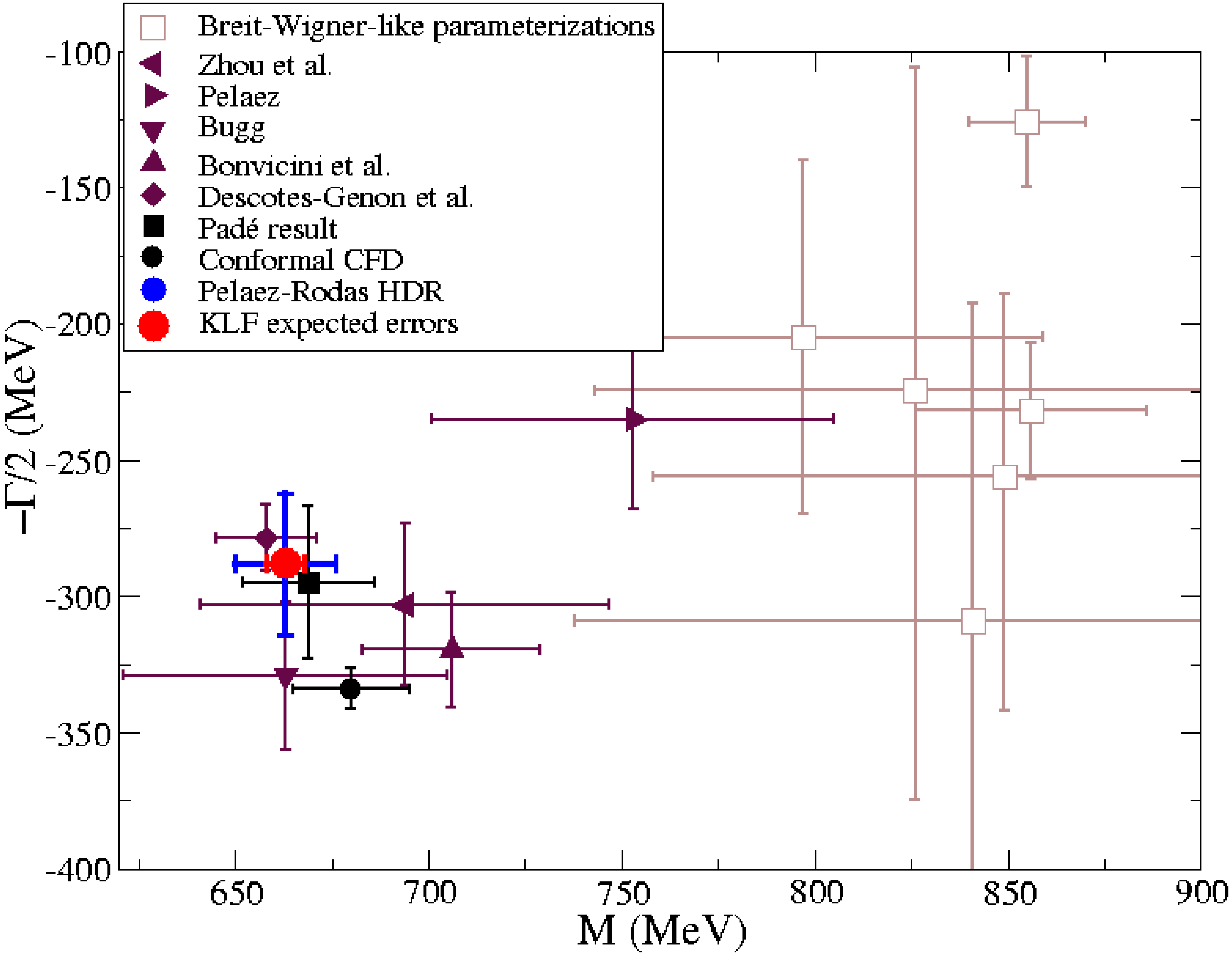
Four states called κ

still need further confirmation(PDG)

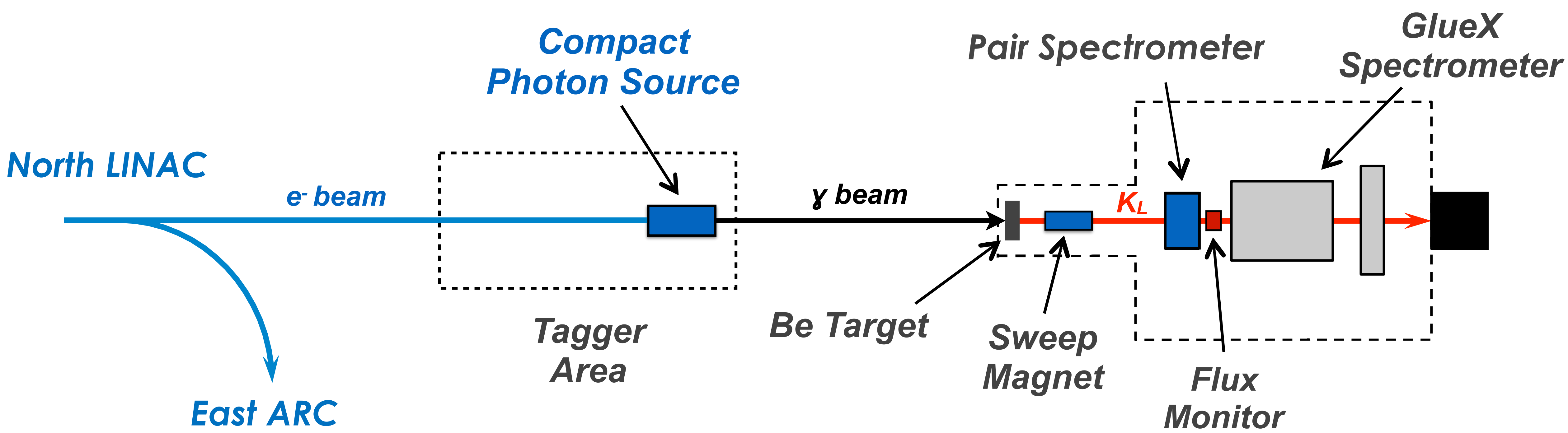
We can measure all of them

Measurement of $\kappa(800)$

100 days of running



Hall-D beamline and GlueX Setup



Electron Beam Parameters

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

Bunch spacing $64\ ns$

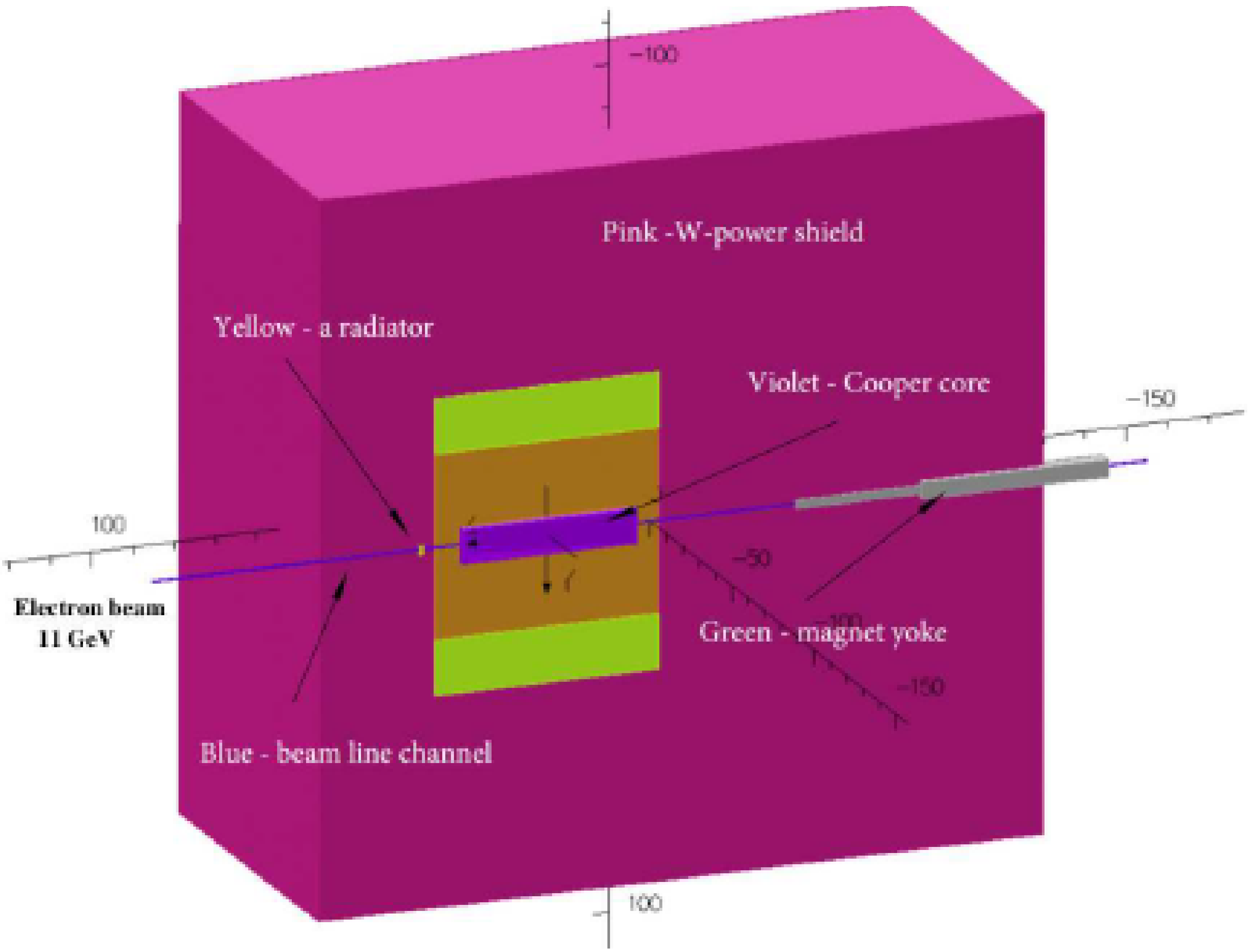
No major problems.

Doable !

Confirmed by accelerator experts

Estimated investment ~$100 K for injector upgrade

Compact Photon Source



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

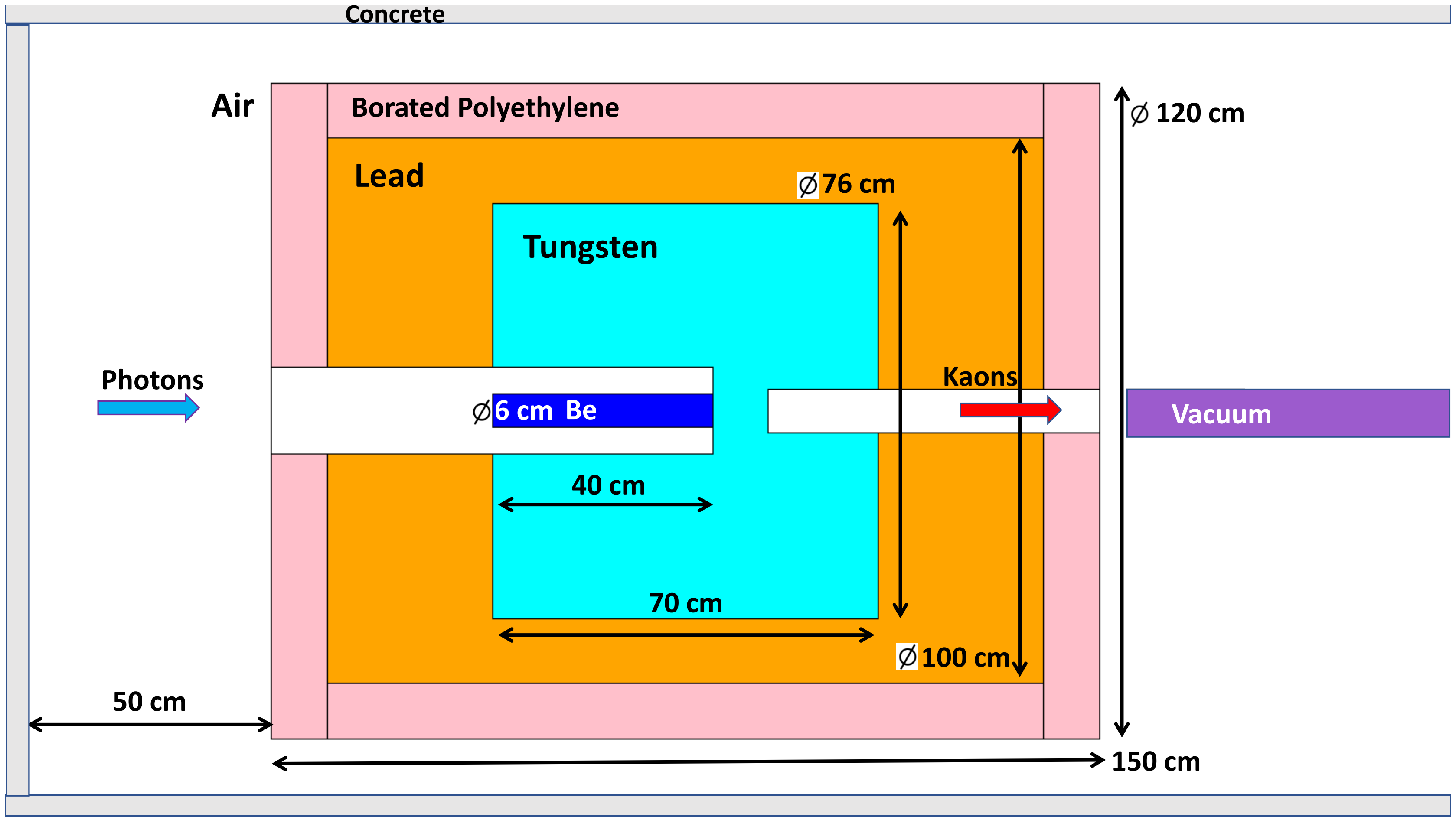
Could be extended for I= $5\ \mu A$ in Hall D

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

Estimated cost ~$4.0 M

Be Target Assembly: Conceptual Design

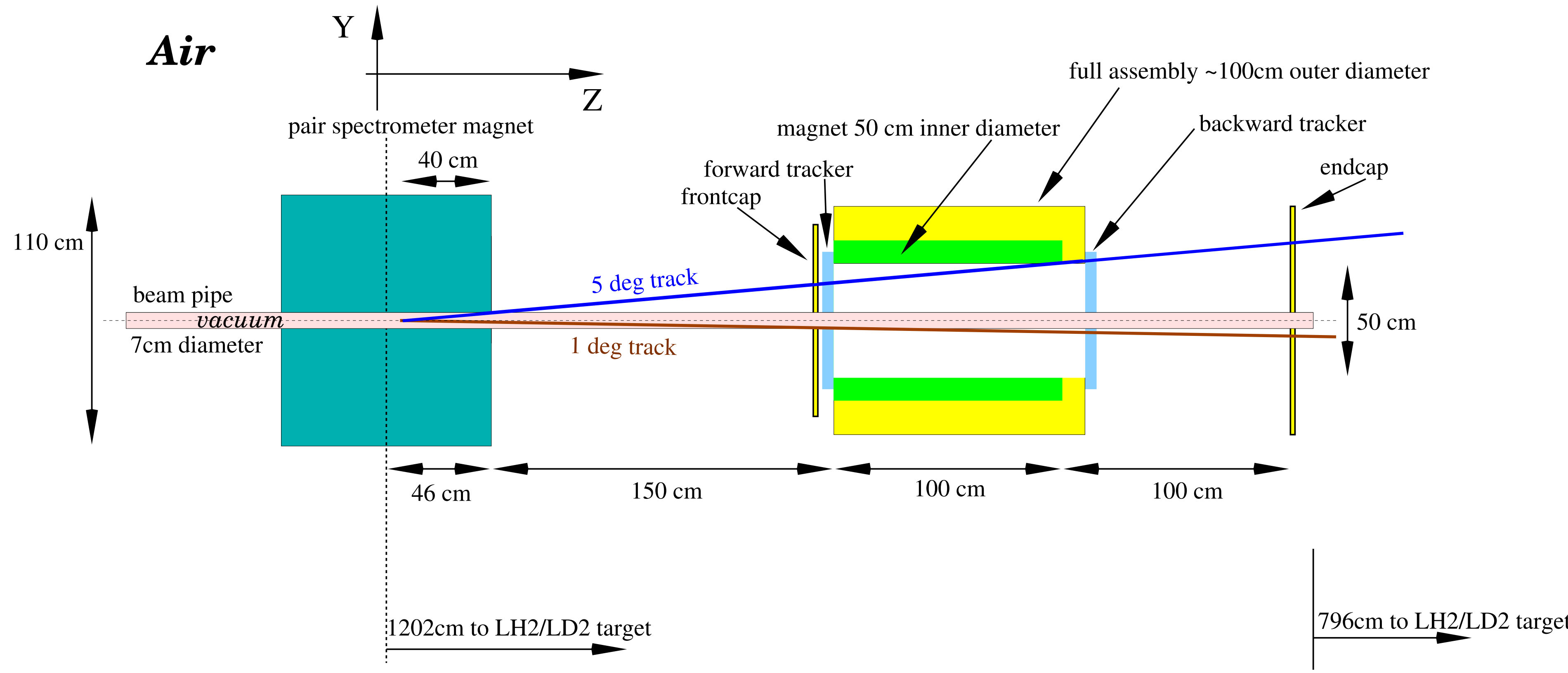


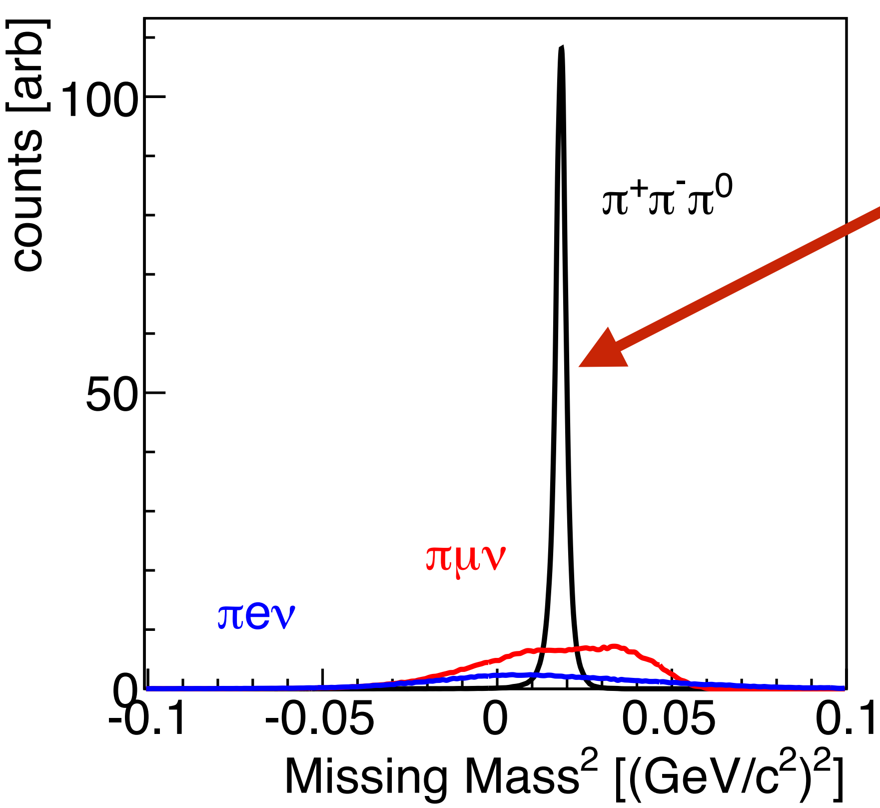
-Meets RadCon Radiation Requirements

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

Estimated cost ~$1.2 M

Flux Monitor





Reconstructed K_L mass

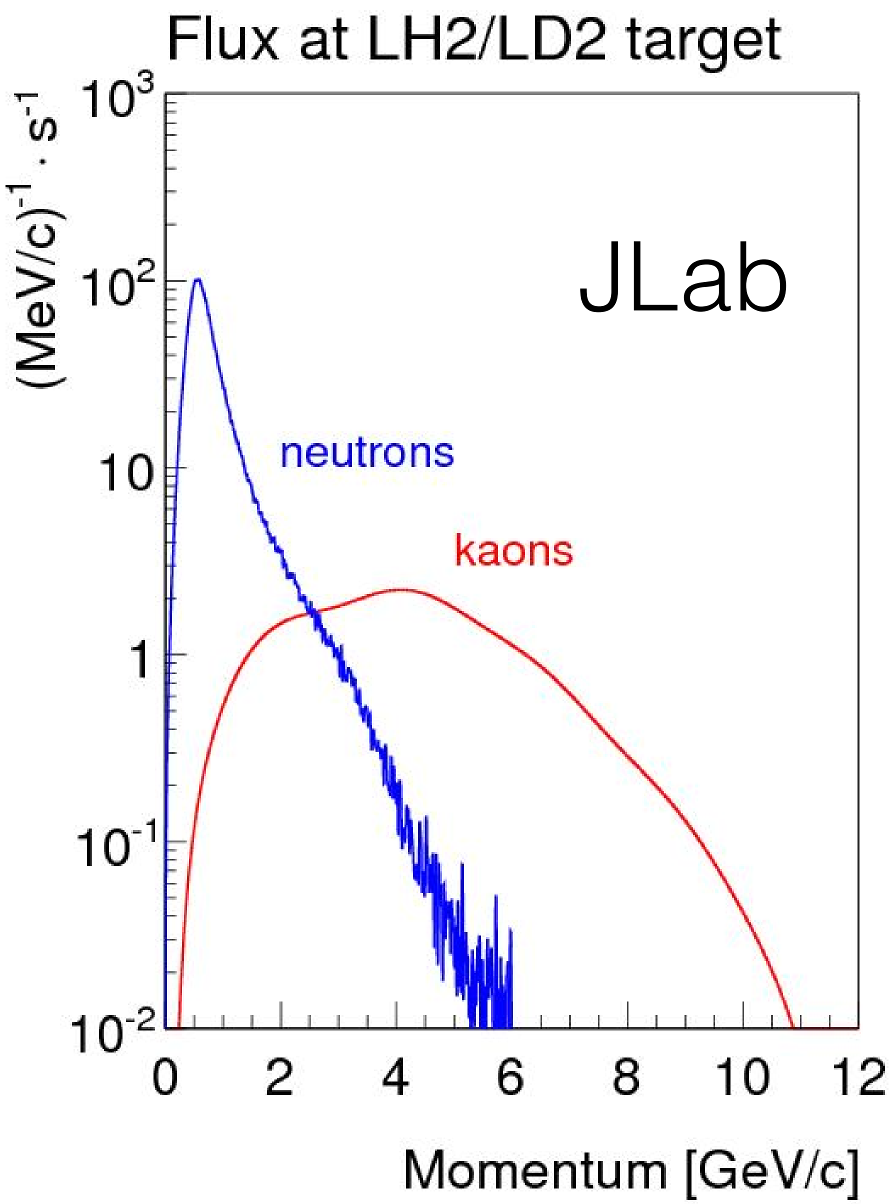
Flux measurement stat. err. <1%

Estimated syst. err. ~5%

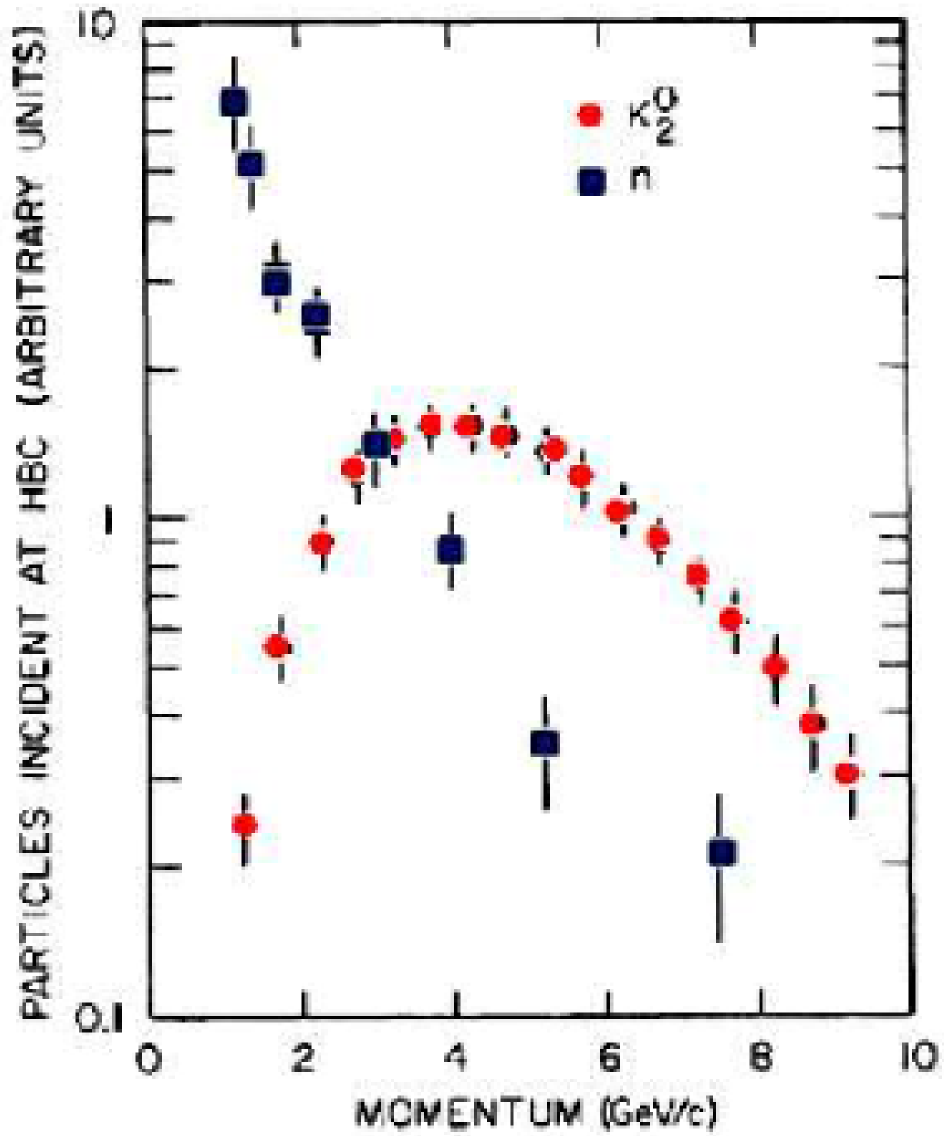
Pursuing UK funding

Estimated cost ~$ 1.0 M

K_L Beam Flux

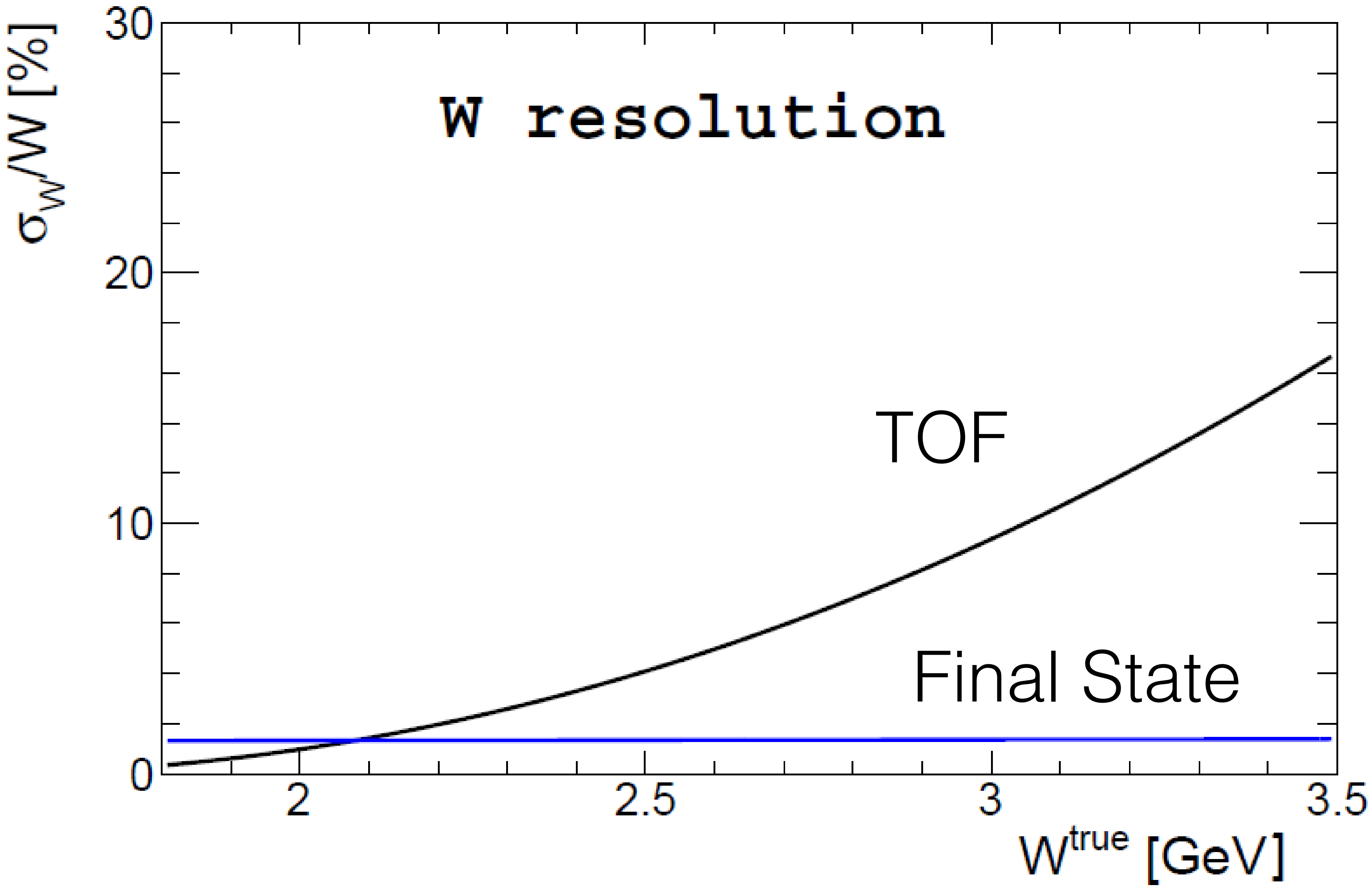


SLAC



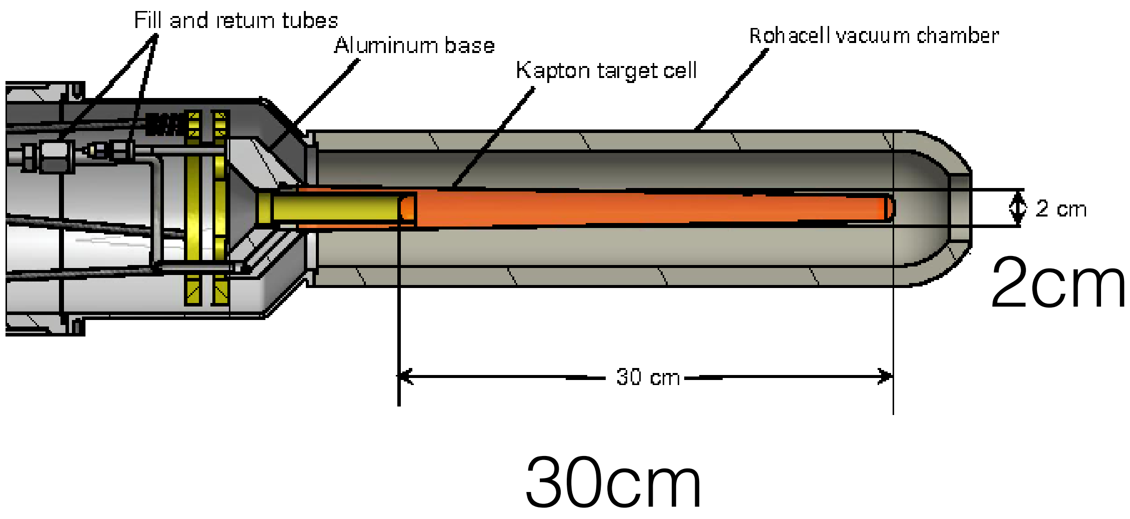
$$N(K_L)/sec \sim 10^4$$

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

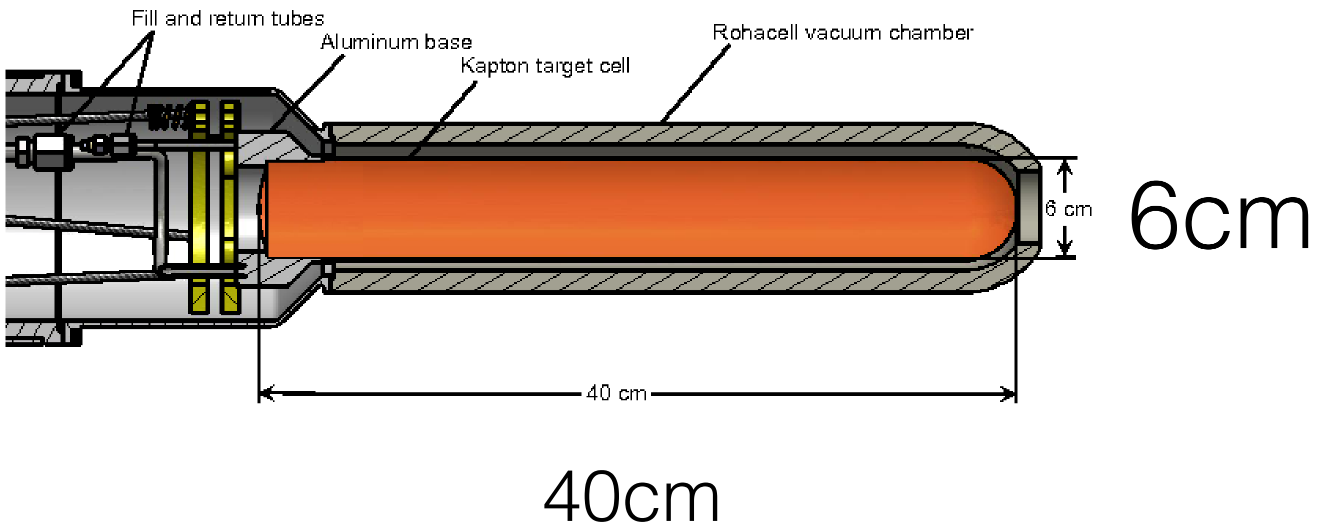

W resolution
TOF
Final State
σ_W/W [%]
W^{true} [GeV]
0
10
20
30
2
2.5
3
3.5

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

The GlueX liquid hydrogen target.



Current



Proposed & Feasible

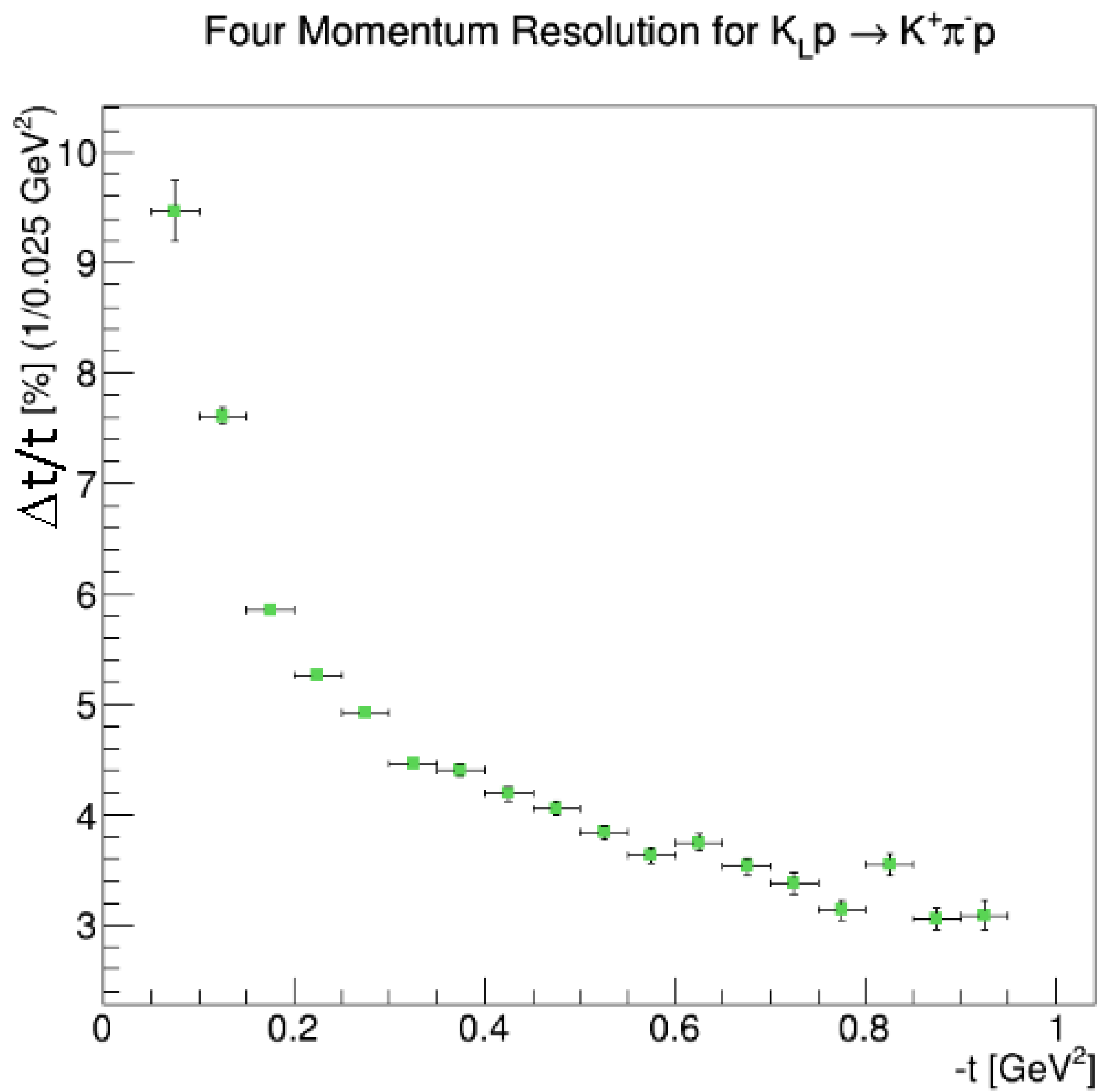
Longer and ticker target is needed to enhance production rate

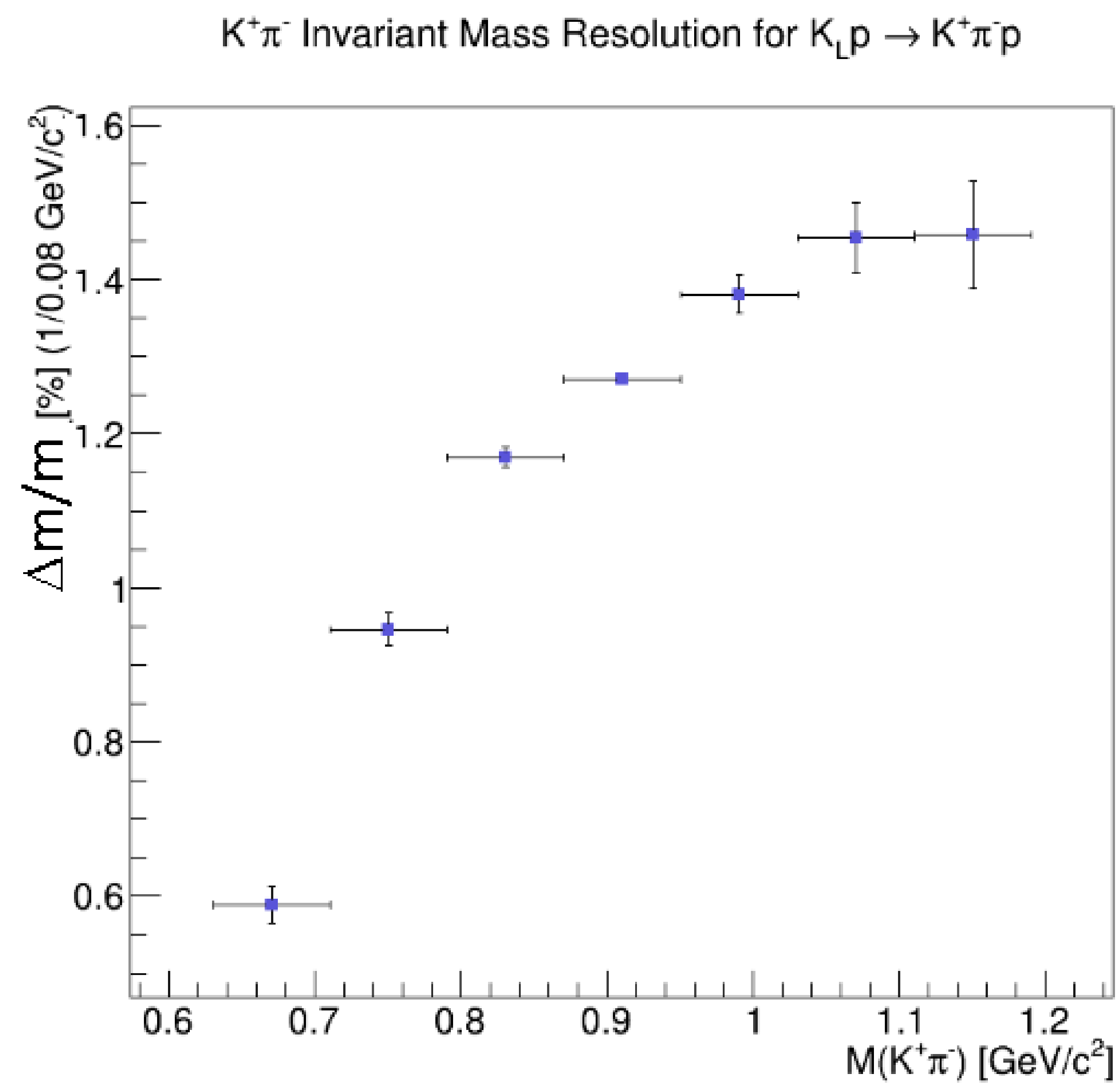
Conceptual design endorsed by target group (Chris Keith)

Estimated cost ~$ 30 K

Total cost of KLF~$ 7.0 M

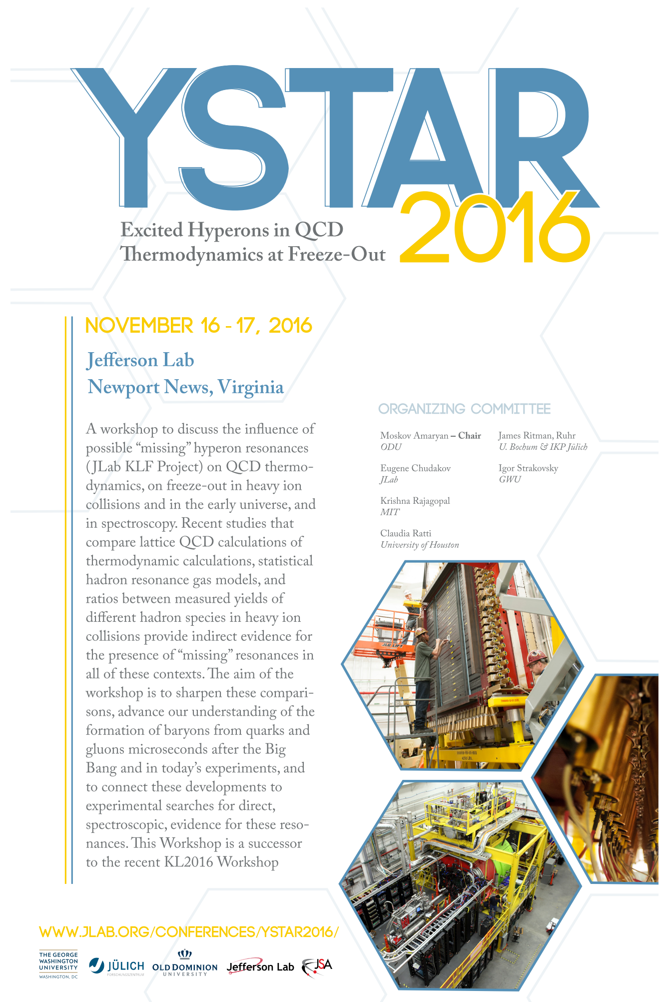
$K\pi$ Scattering Resolutions

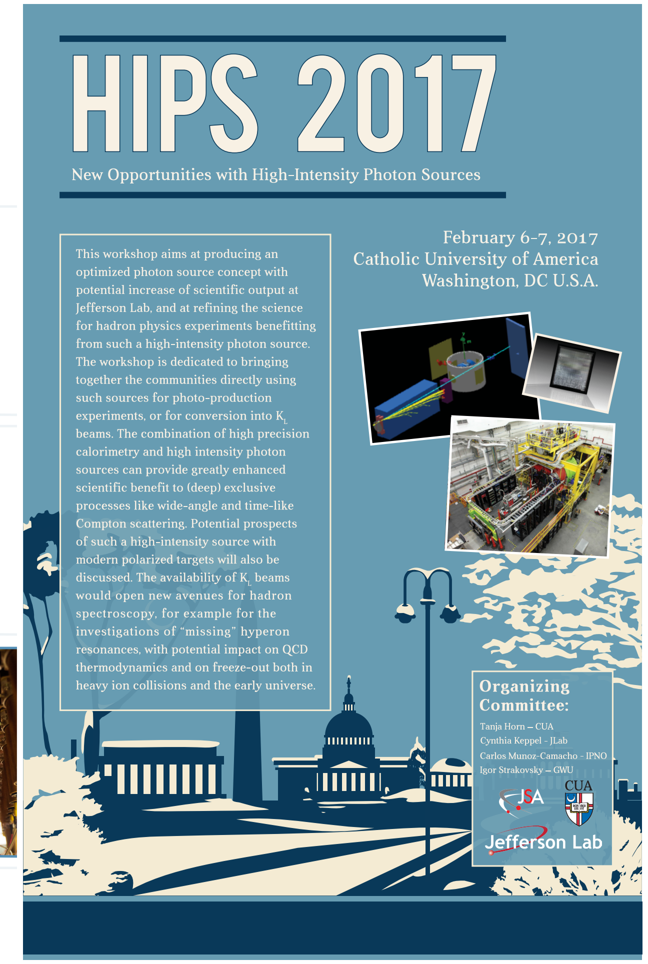


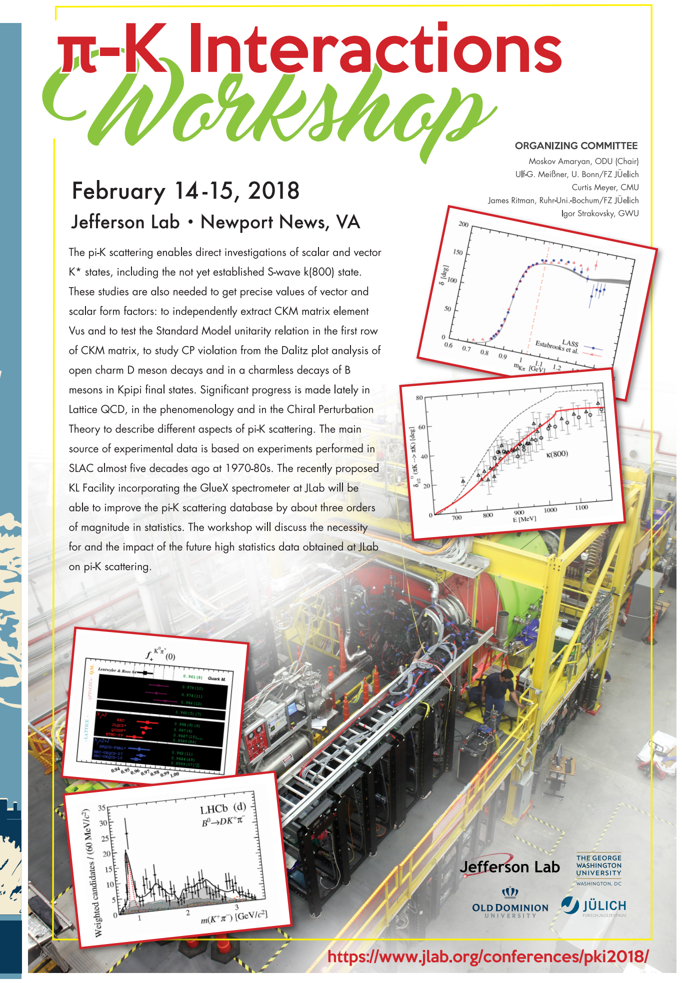


-Good resolution at low-t is needed to be on pion pole

-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

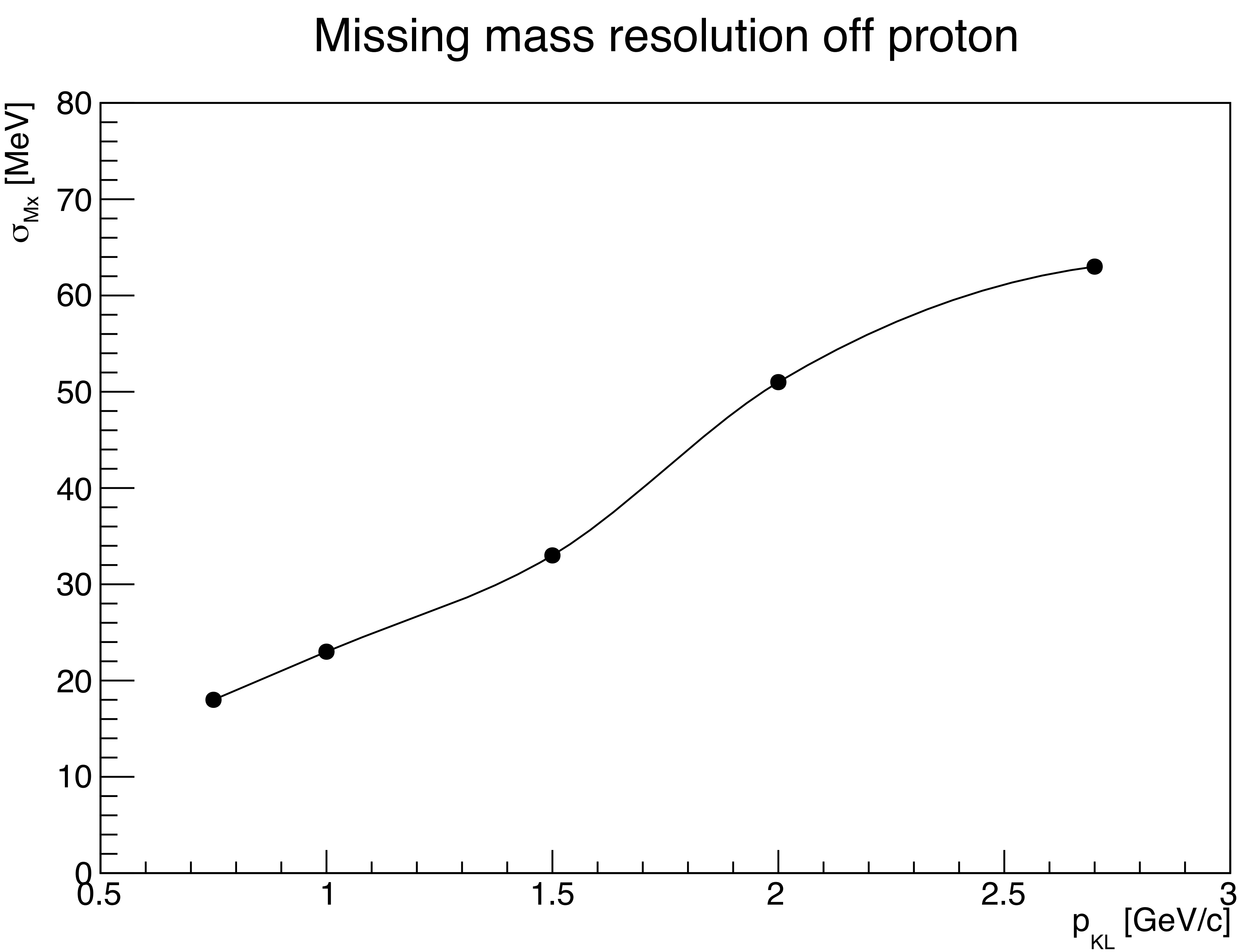
A. Ali[18], M. B. Ali[47], M. J. Amaryan[45,*,†], E. G. Anassontzis[2], A. V. Anisovich[4,48], A. Austregesilo[30], M. Baalouch[45], F. Barbosa[30], J. Barlow[13], A. Barnes[7], E. Barriga[13], M. Bashkanov[10,†], A. Bazavov[39], T. D. Beattie[50], R. Bellwied[20], V. V. Berdnikov[8], V. Bernard[46], 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], G. Colangelo[3], P. L. Cole[21], S. Cole[1], O. Cortes-Becerra[14], 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], R. Jaffe[36], 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], B. Z. Kopeliovich[53], 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], H. Leutwyler[3], 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], M. Matveev[48], V. Matveev[27], M. McCaughan[30], W. McGinley[7], M. McCracken[7], J. McIntyre[9], U.-G. Meißner[4,29], C. A. Meyer[7], R. Miskimen[35], R. E. Mitchell[23], F. Mokaya[9], V. Mokeev[30], C. Morningstar[7], B. Moussallam[46], F. Nerling[18], 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], 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. M. 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 orders of magnitude
- -In Hyperon spectrsocopy
  PWA will allow to measure 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 of project ~$ 7.0 M including $1.0 M from UK

Backup

$$K_L + p \rightarrow (K_L) + \pi^0 + p$$



We use that

$$I(\pi) = 1, I_3(\pi^0) = 0, \tag{1}$$
$$I(K) = 1/2, I_3(K^0) = -1/2, I_3(\bar{K^0}) = 1/2, \tag{2}$$

and that

$$\langle K_L| = \frac{\langle K^0| + \langle \bar{K^0}|}{\sqrt{2}}, \tag{3}$$
$$\langle K_S| = \frac{\langle K^0| - \langle \bar{K^0}|}{\sqrt{2}}, \tag{4}$$

now by construction

$$\langle K_L\pi^0| = \frac{\langle K^0\pi^0| + \langle \bar{K^0}\pi^0|}{\sqrt{2}}, \tag{5}$$
$$\langle K_S\pi^0| = \frac{\langle K^0\pi^0| - \langle \bar{K^0}\pi^0|}{\sqrt{2}}, \tag{6}$$

so that

$$\langle K_L\pi^0| T |K_S\pi^0\rangle = \frac{1}{2}\left(\langle K^0\pi^0| T |K^0\pi^0\rangle - \langle \bar{K^0}\pi^0| T |\bar{K^0}\pi^0\rangle\right). \tag{7}$$

The minus sign was a plus in the previous calculation

Now one can use the Clebsch-Gordan coefficients for the states with defined I_3

$$\langle K^0\pi^0| = \frac{1}{\sqrt{3}}\langle 1/2, -1/2| + \frac{\sqrt{2}}{\sqrt{3}}\langle 3/2, -1/2|, \tag{8}$$
$$\langle \bar{K^0}\pi^0| = -\frac{1}{\sqrt{3}}\langle 1/2, 1/2| + \frac{\sqrt{2}}{\sqrt{3}}\langle 3/2, 1/2|. \tag{9}$$

Finally by introducing this coefficients in Eq. (7) we get

$$\langle K_L\pi^0| T |K_S\pi^0\rangle = \frac{1}{2}\left(T^{1/2}/3 + 2T^{3/2}/3 - T^{1/2}/3 - 2T^{3/2}/3\right) = 0 \tag{10}$$

$$\langle K_L\pi^0| T |K_L\pi^0\rangle = \frac{1}{2}\left(T^{1/2}/3 + 2T^{3/2}/3 + T^{1/2}/3 + 2T^{3/2}/3\right), \tag{11}$$
$$= T^{1/2}/3 + 2T^{3/2}/3 \tag{12}$$