

***Strange Hadron Spectroscopy with  
Secondary  $K_L$  Beam at GlueX***

*Moskov Amaryan*

*Old Dominion University*

*The GlueX Coll. Meeting, February 20, 2019*

# **Outline**

## ***Physics Motivation***

- *Hyperon Spectroscopy*
- *Strange Meson Spectroscopy*

## ***K<sub>L</sub> Facility at JLab***

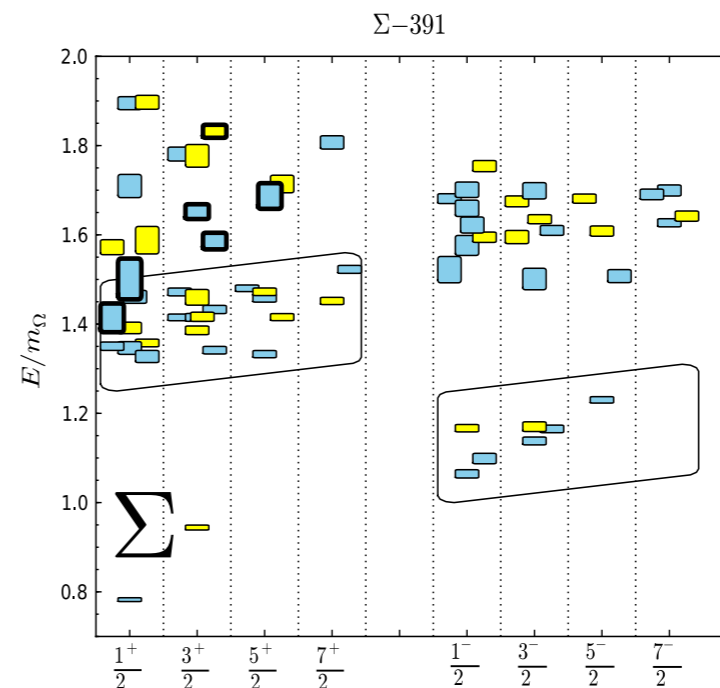
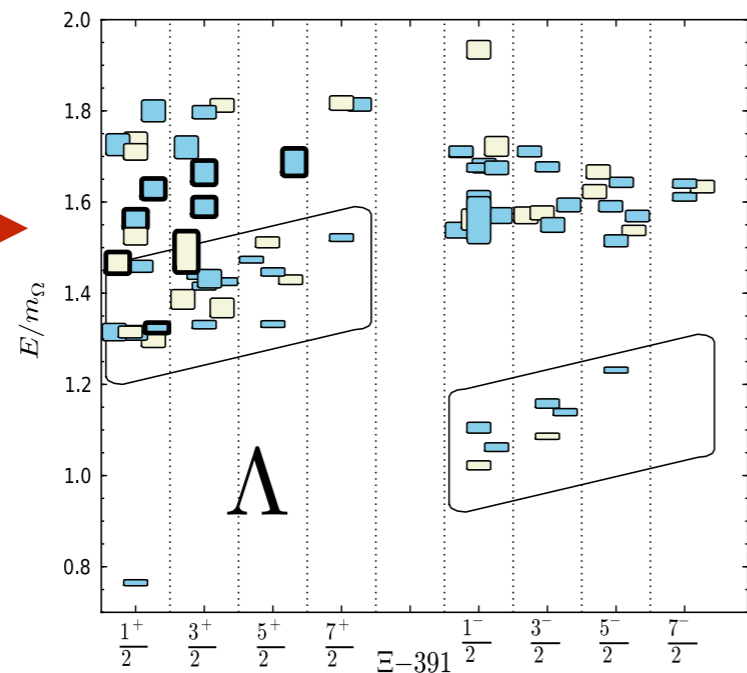
- *Electron Beam*
- *Compact Photon Source*
- *Be Target*
- *Flux Monitor*
- *K<sub>L</sub> Beam*
- *LH<sub>2</sub>/LD<sub>2</sub> Target*

## ***Summary***

# Hyperon Spectroscopy

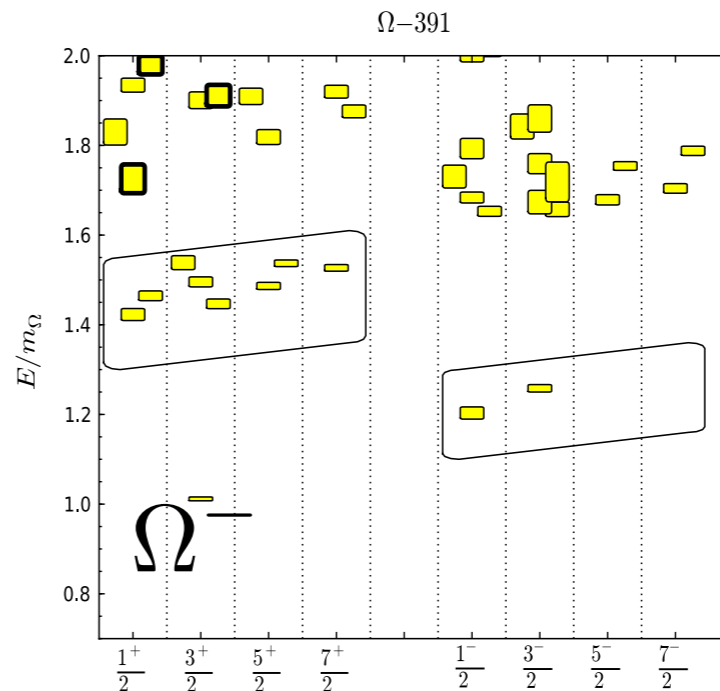
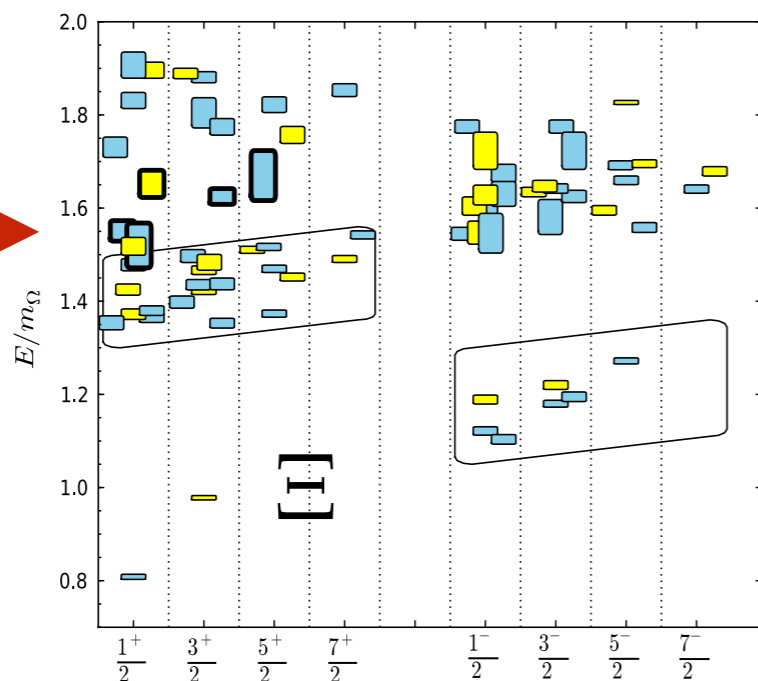
According *LQCD* there should be many more states including hybrids (thick bordered)

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



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

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

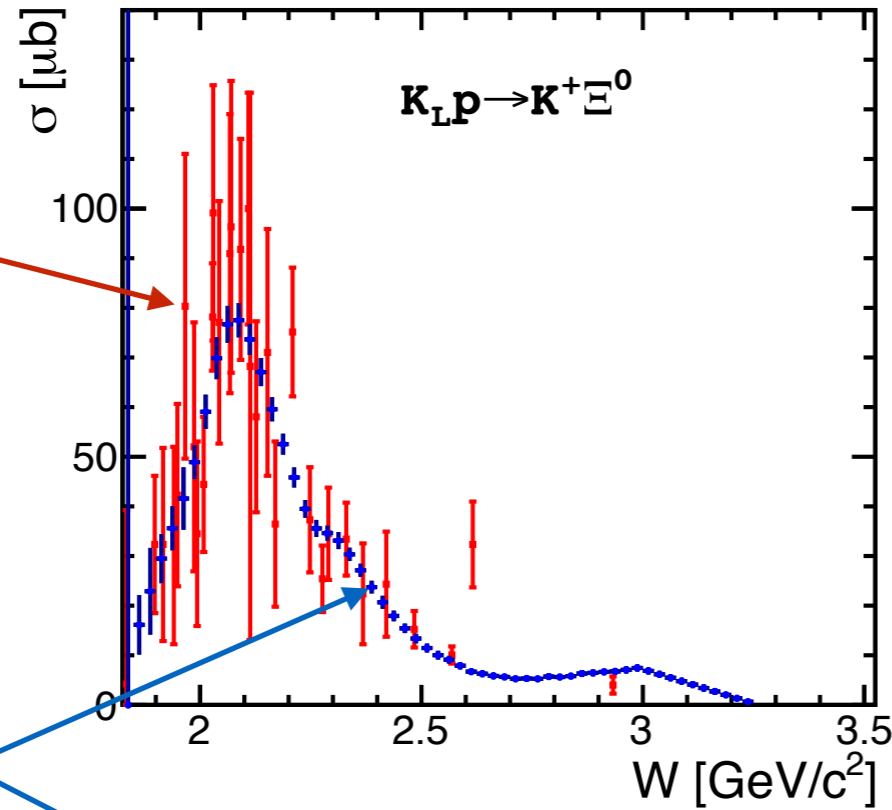


**1-state**  
\*\*\*\*  
**1-states**  
\*\*\*

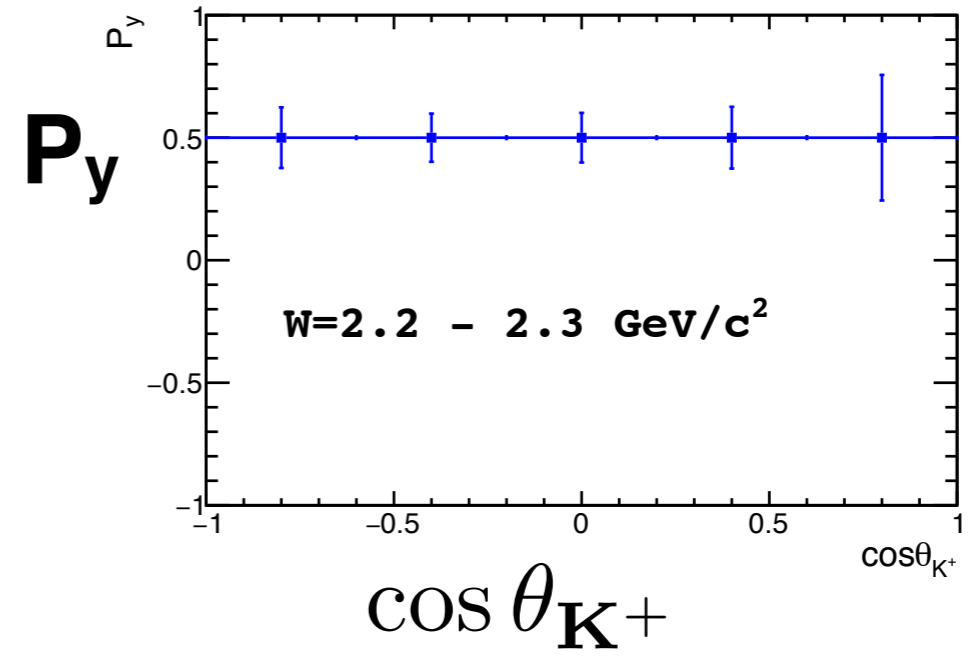
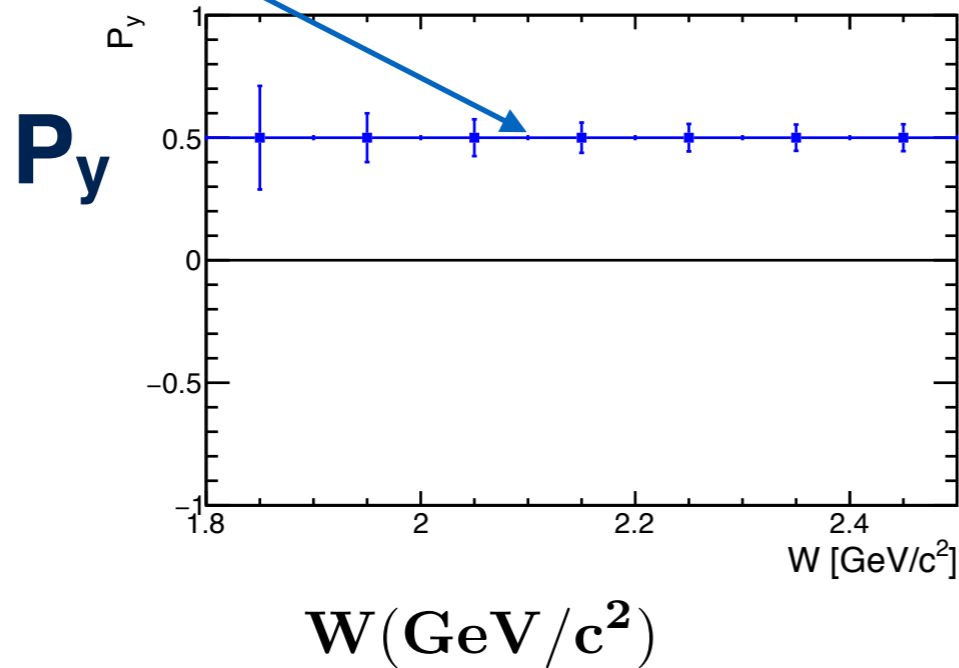
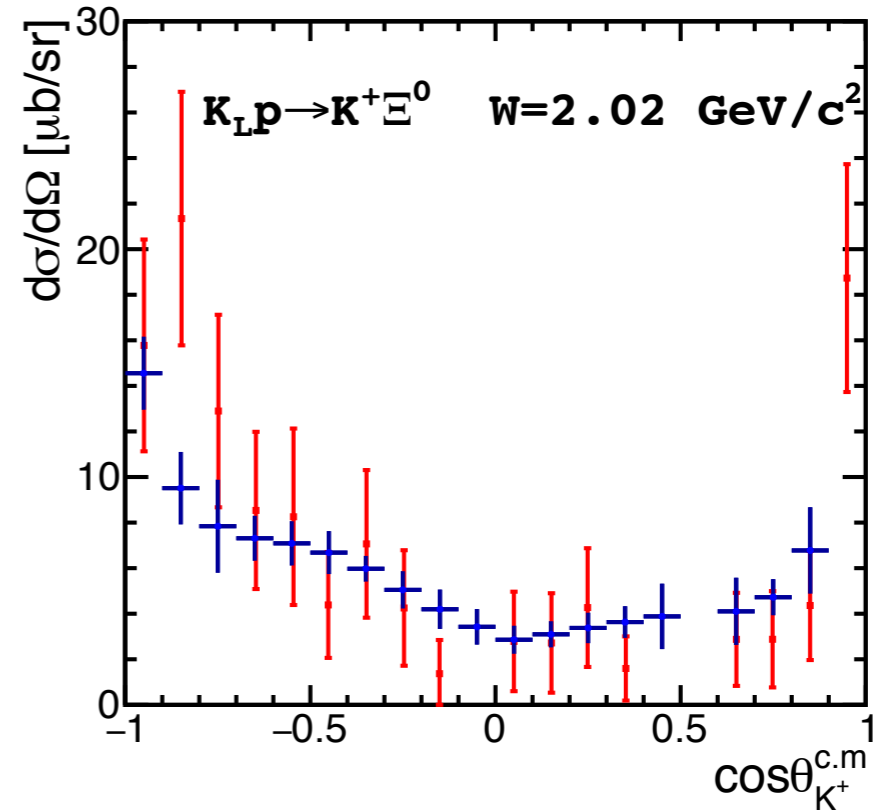
Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

# Proposed Measurements on Proton Target

existing data



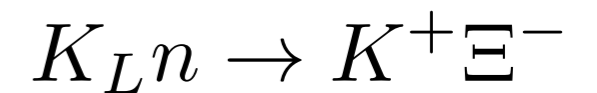
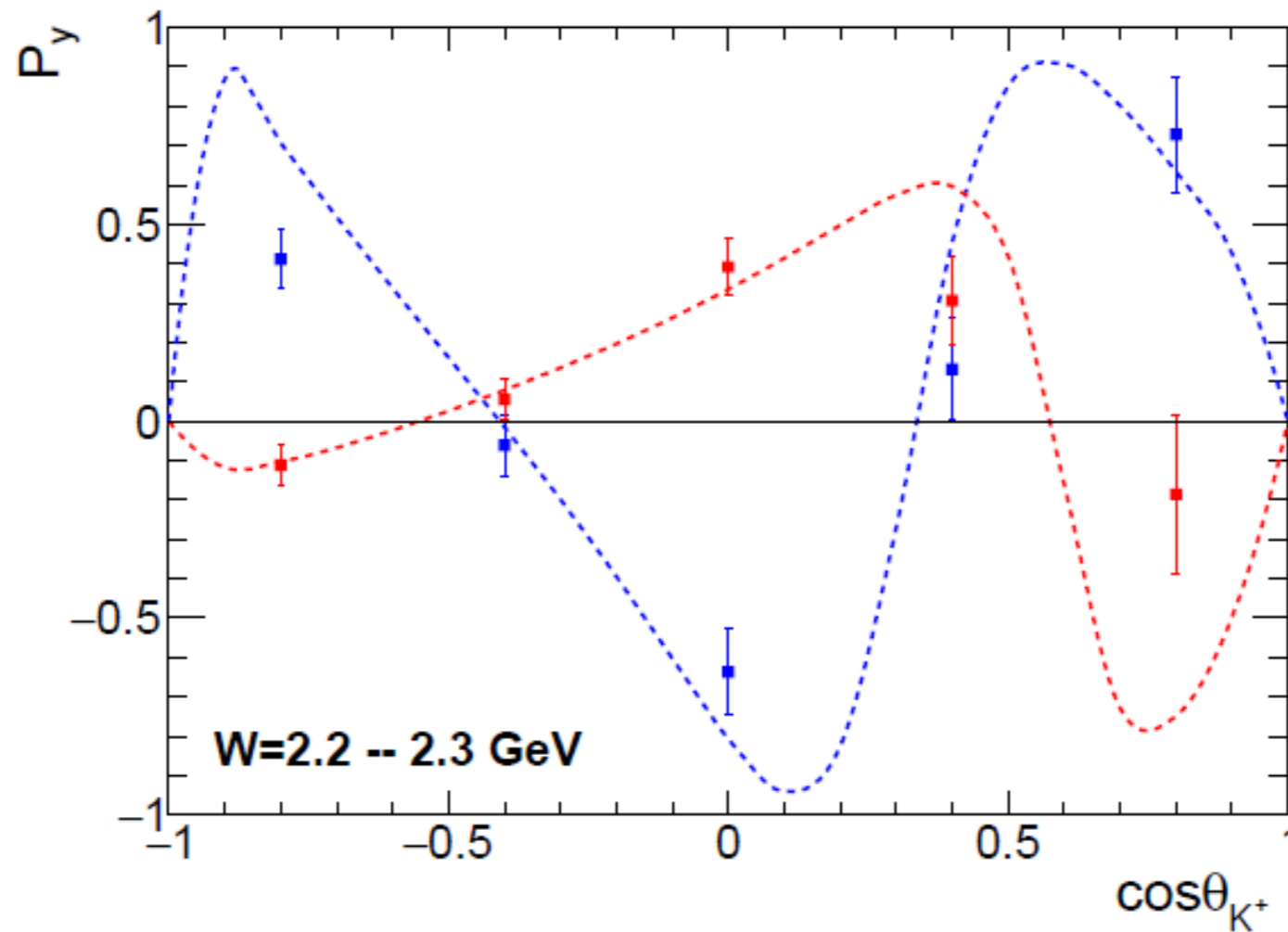
KLF 100 days





# Proposed Measurements on Neutron Target

## Sensitivity to different solutions



100 days on  $LD_2$  target

# ***Search for Hyperon Resonances with PWA***

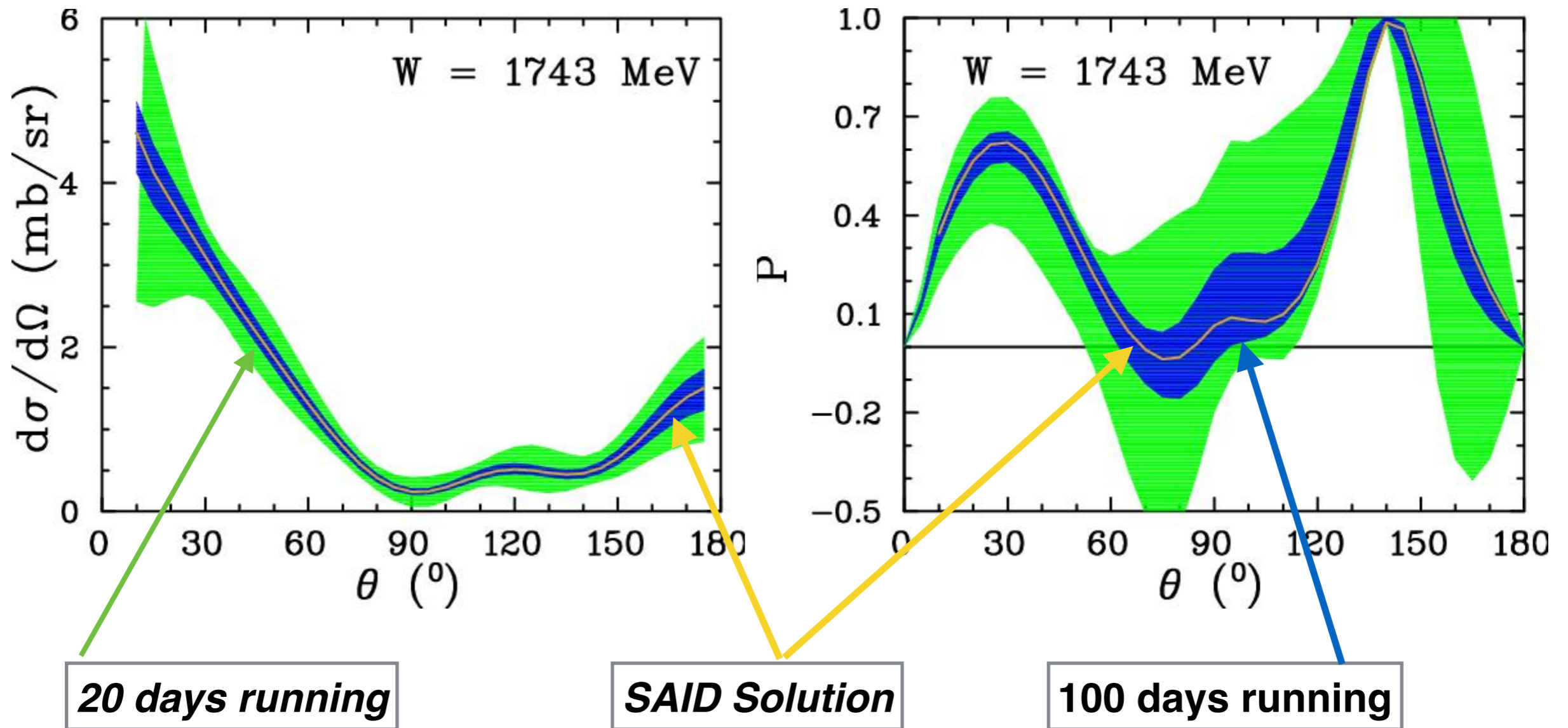
**For Scattering experiments on both proton & neutron targets we need to determine:**

- 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**

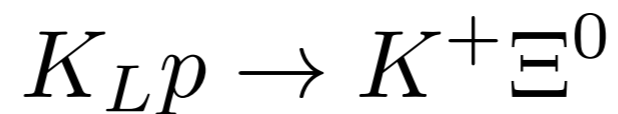
**As kaon nucleon scattering data are very poor**

**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 $\pi p$ Scattering

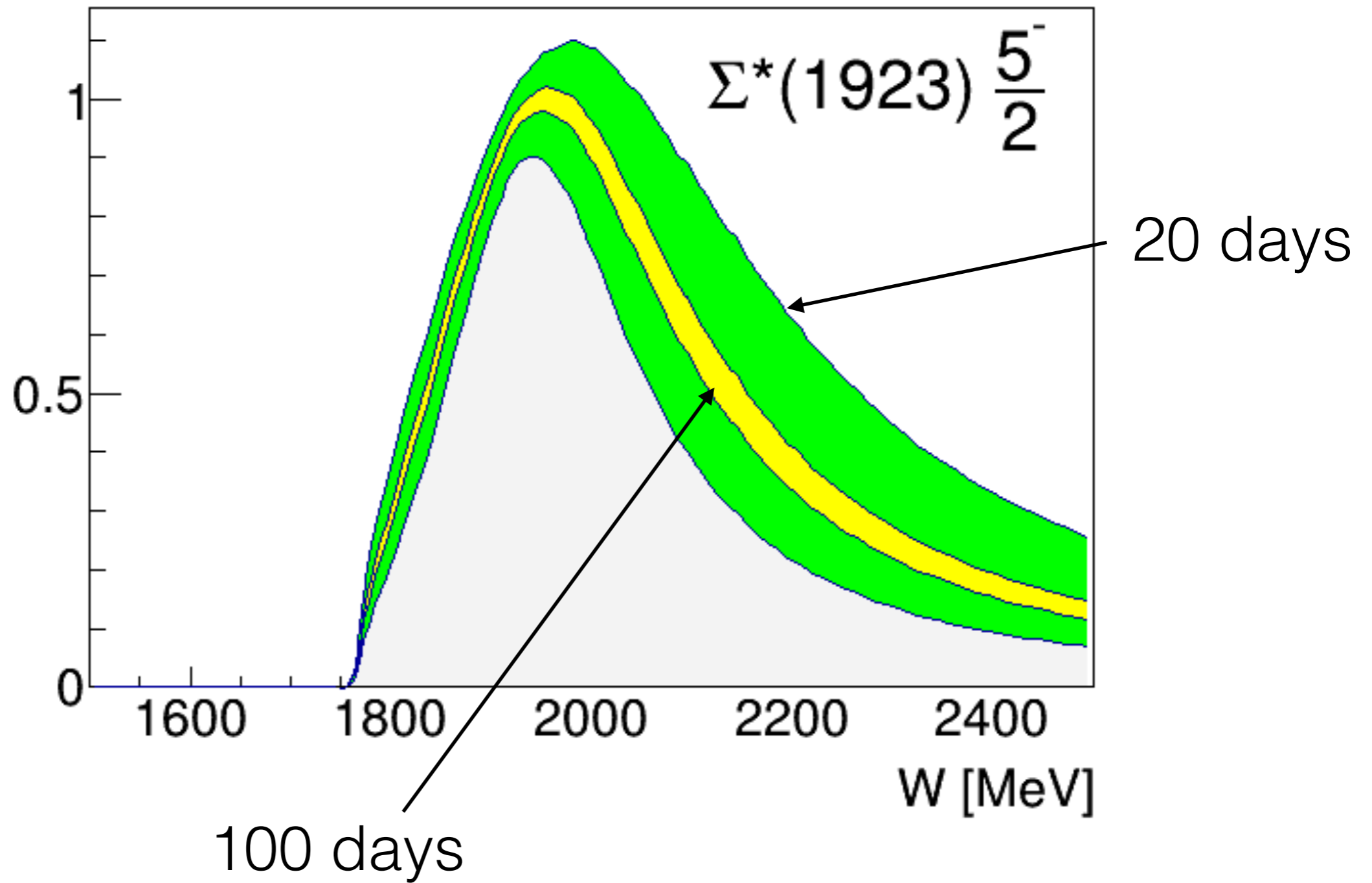


Statistics was generated according to KLF for



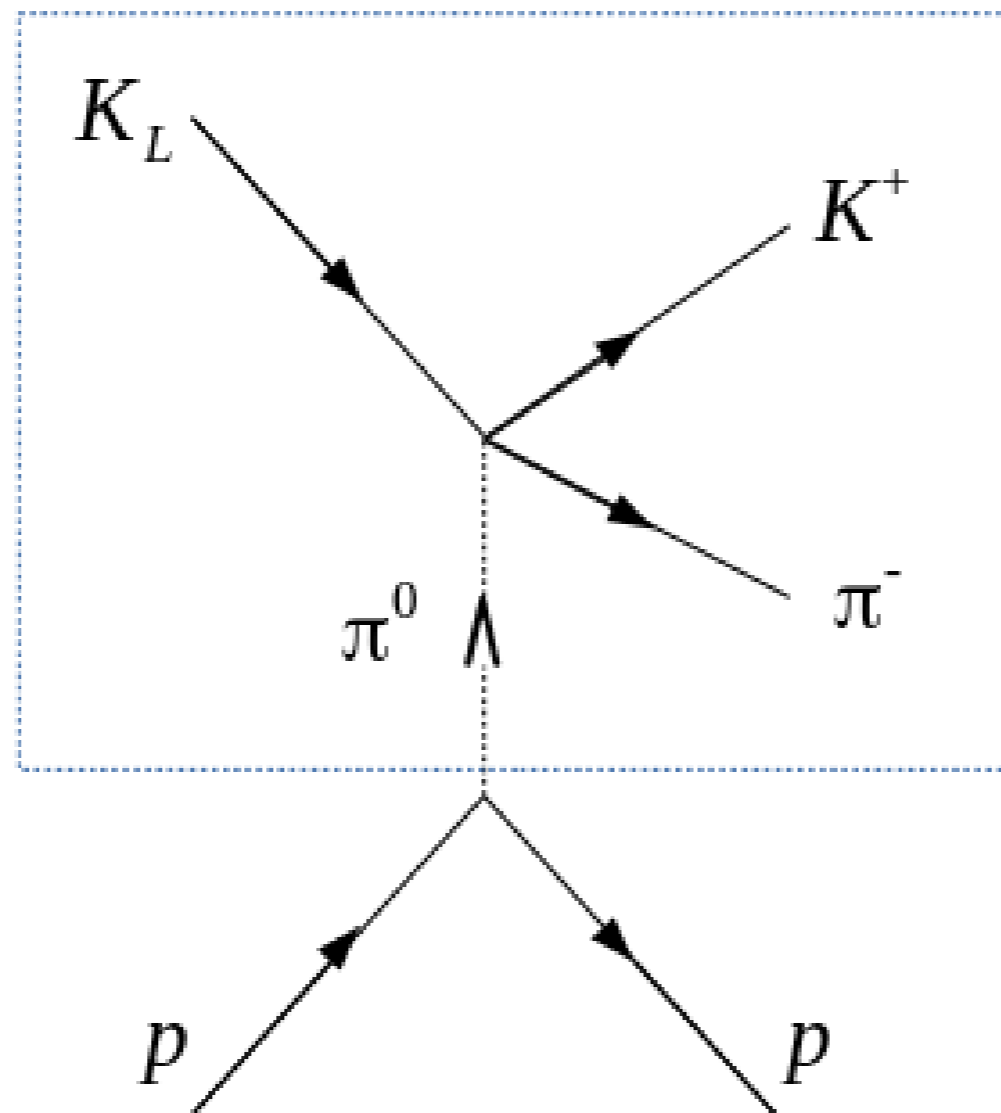
**Obviously:** we need **at least 100 days** to get unique solution

# Bonn-Gatchina PWA Analysis



# Strange Meson Spectroscopy

## $K\pi$ Scattering



# Proposed Measurements

SLAC

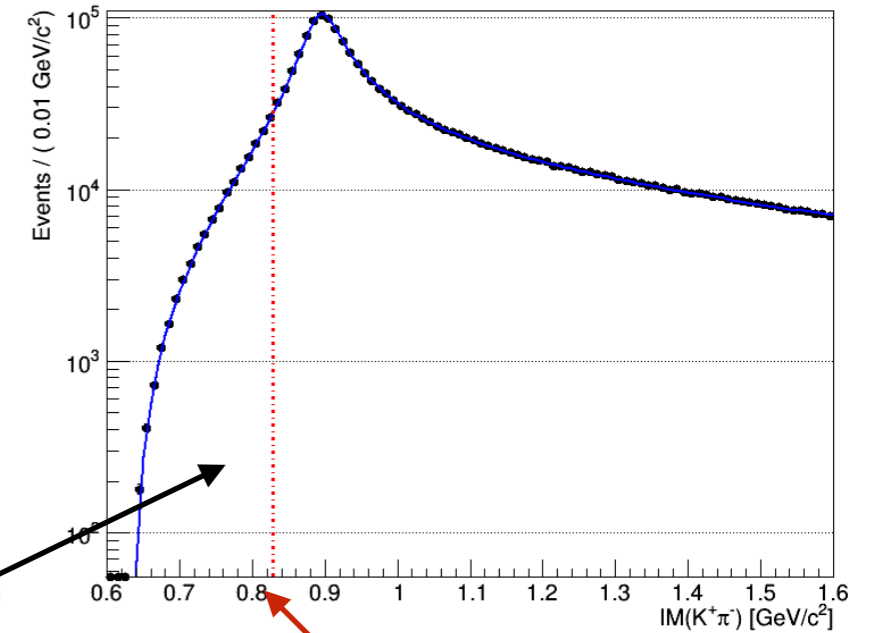
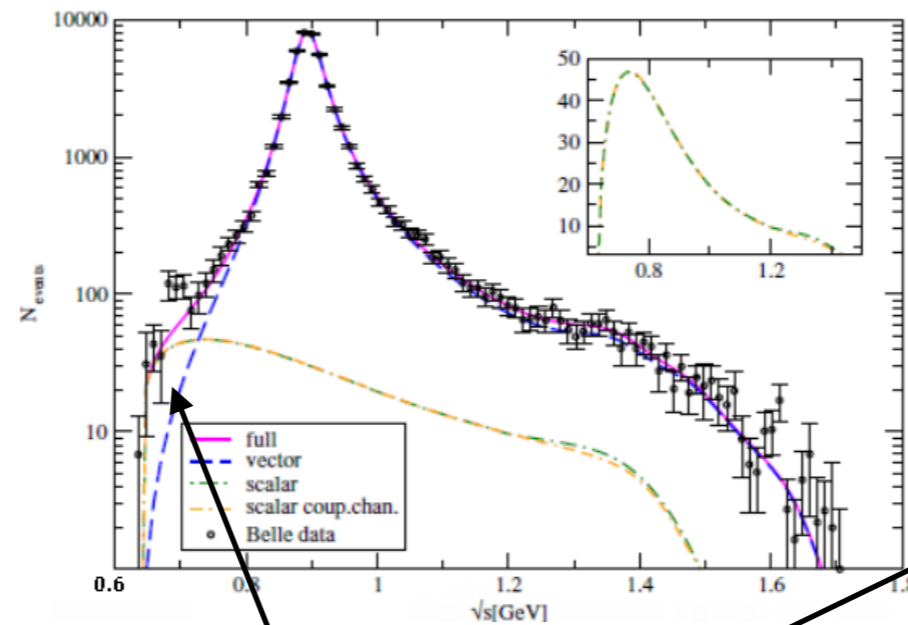
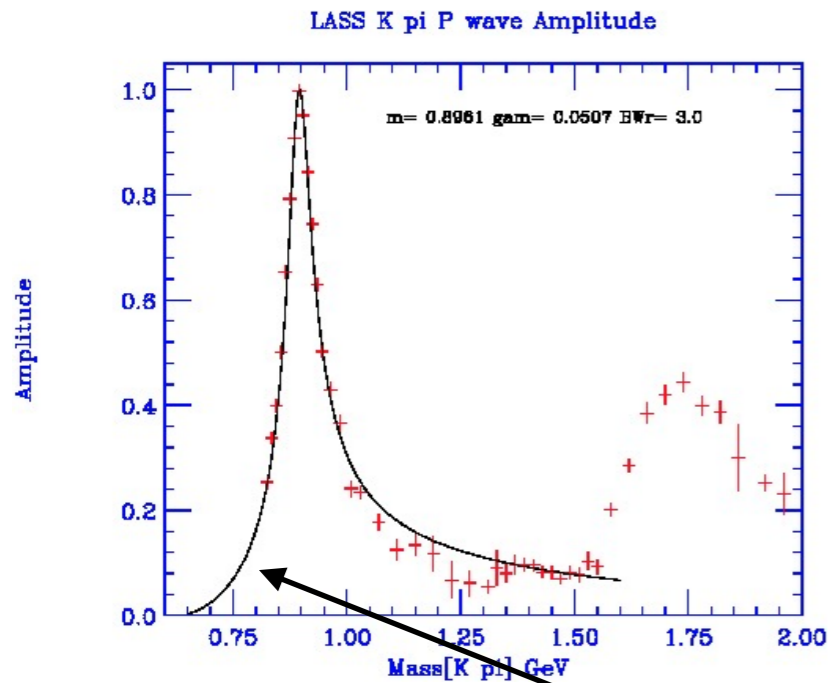
$$K^- \pi^+ \rightarrow K^- \pi^+$$

Belle

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

KLF

$$K_L \pi^0 \rightarrow K^+ \pi^-$$

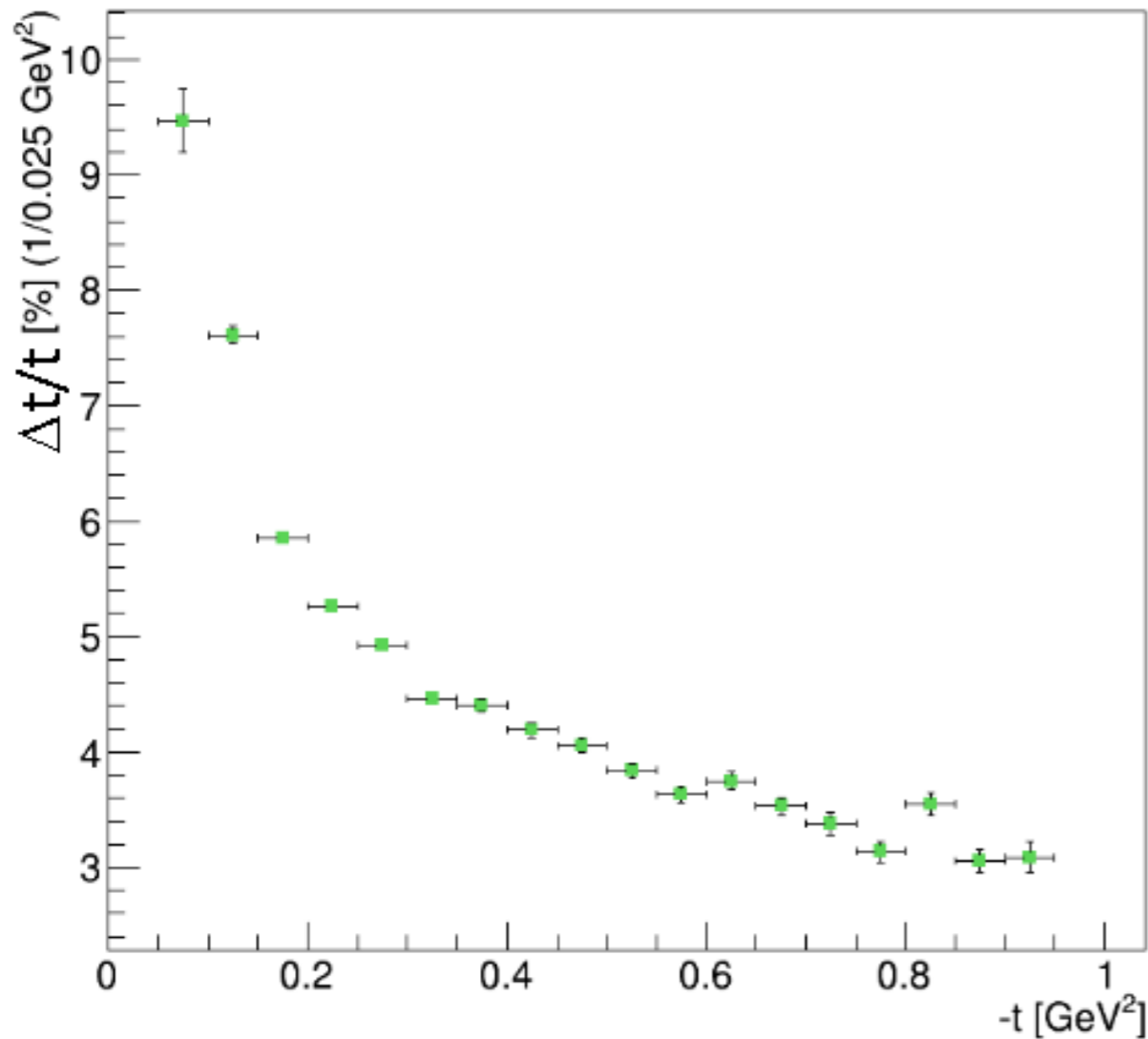


region of  $\mathcal{K}(800)$

SLAC Lower limit

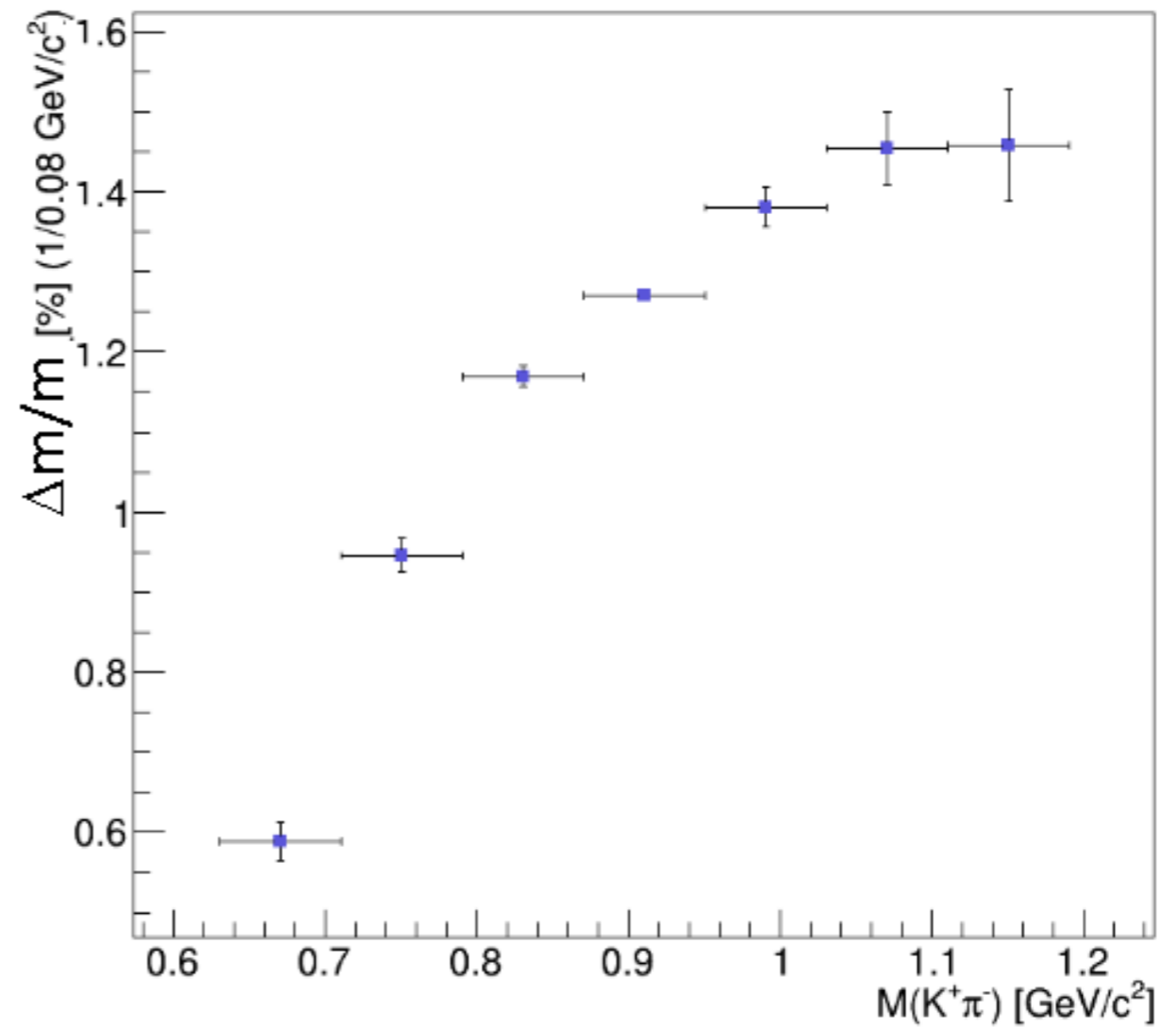
# $K\pi$ Scattering Resolutions

Four Momentum Resolution for  $K_L p \rightarrow K^+ \pi^- p$



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

$K^+ \pi^-$  Invariant Mass Resolution for  $K_L p \rightarrow K^+ \pi^- p$

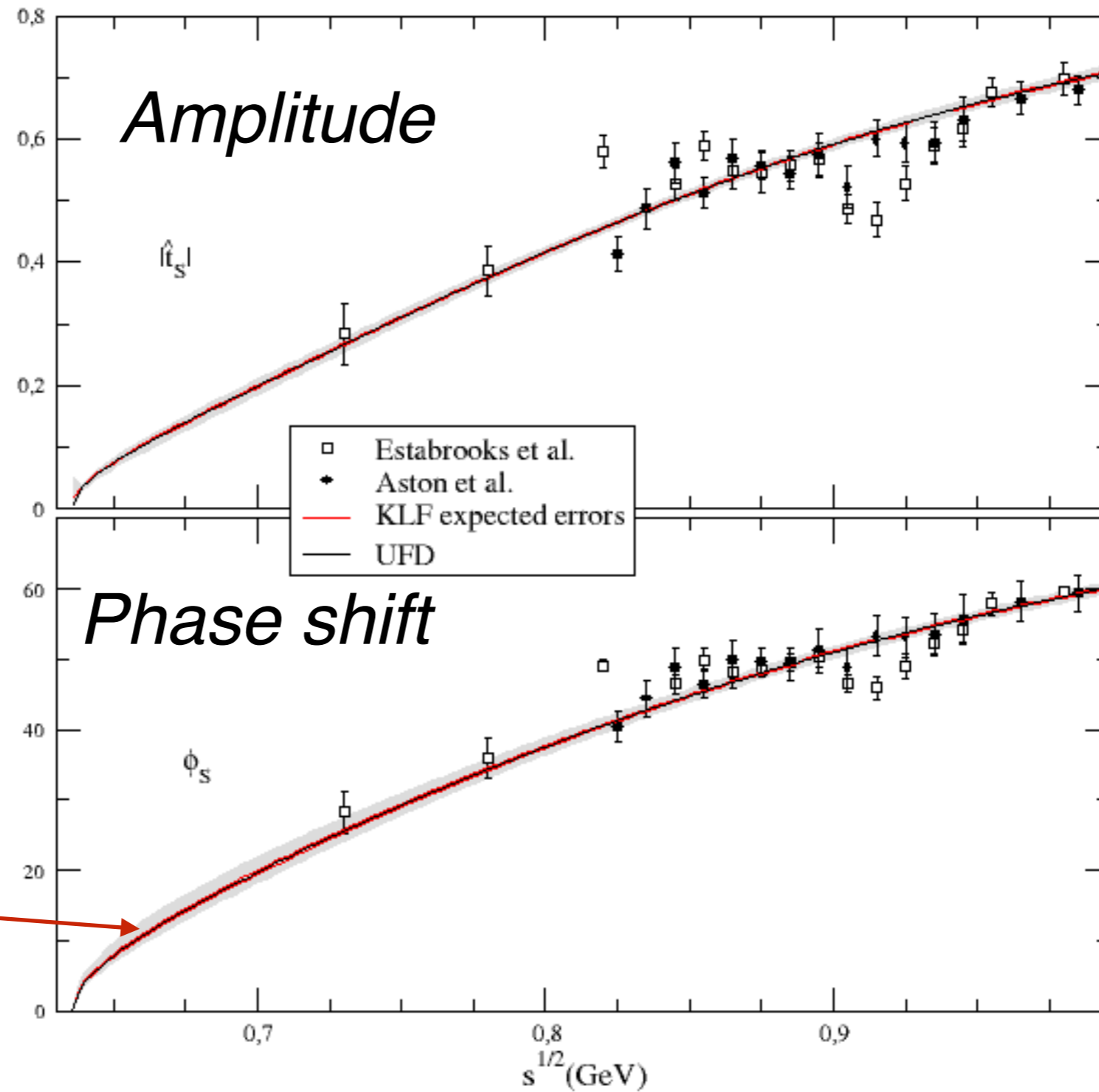


*-Binning in  $\sim 10 \text{ MeV}$  will cover almost entire elastic  $K$ - $\pi$  scattering range*

# Proposed Measurement

**I=1/2 S-Wave**

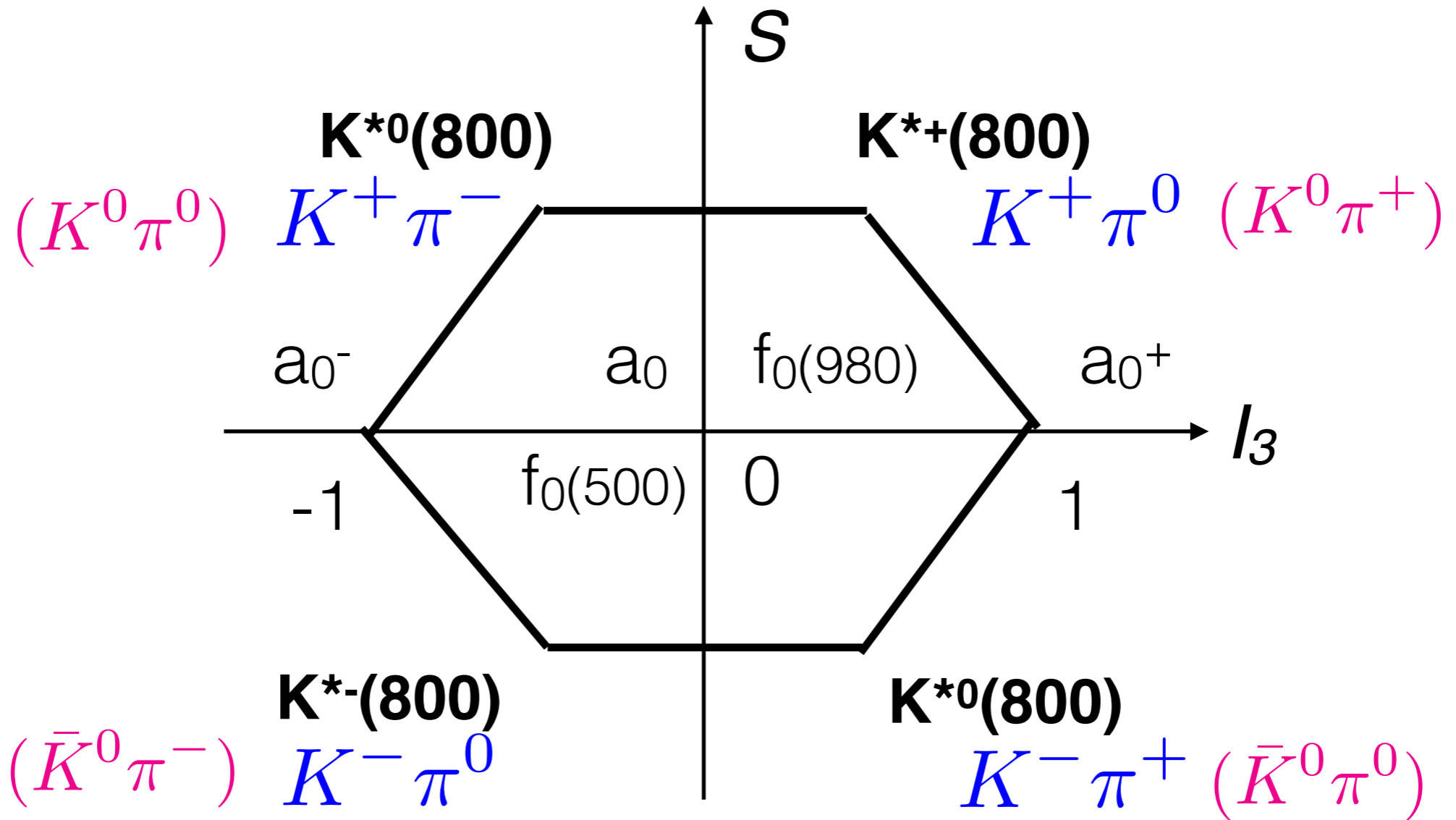
**SLAC Data**



**KLF  
(100 days)**



# Scalar Meson Nonet

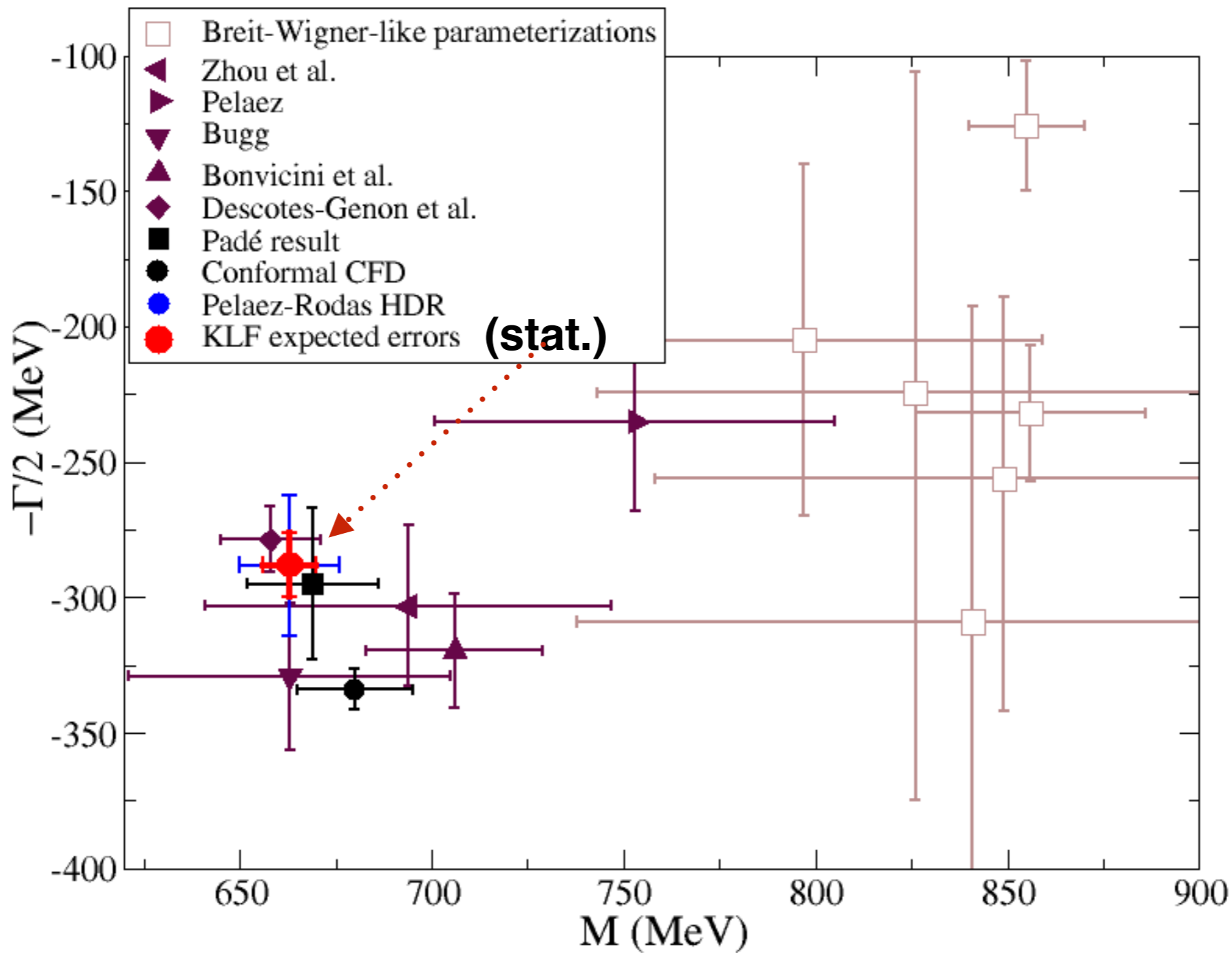


Four states called  $\mathcal{K}$

still need further confirmation(PDG)

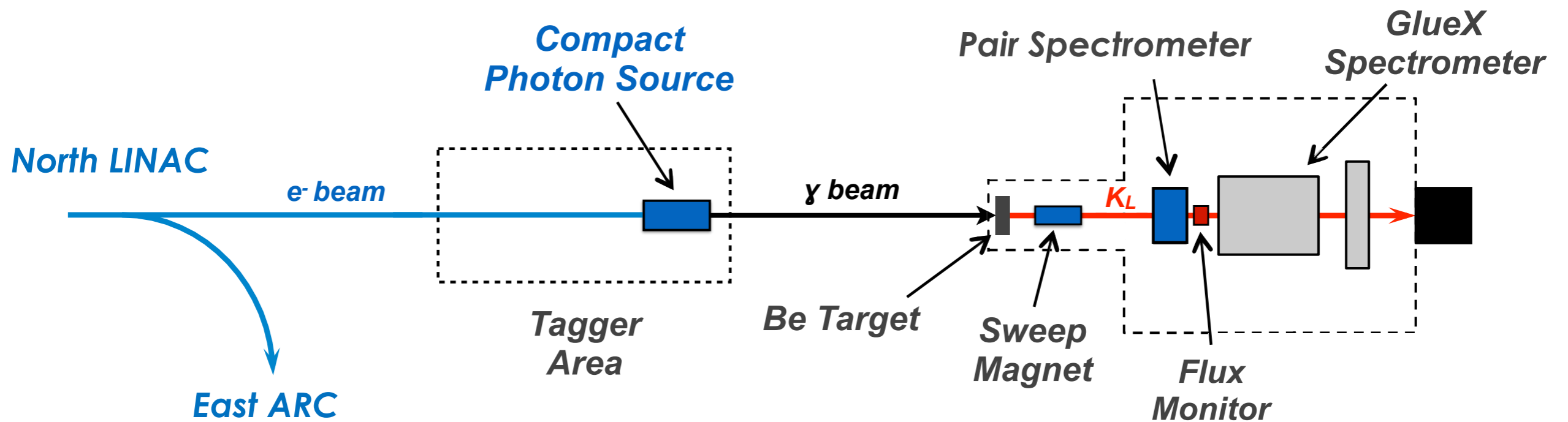
We can measure all of them

# Measurement of $\kappa(800)$



*100 days of running*

# Hall-D beamline and GlueX Setup



## *Electron Beam Parameters*

$$E_e = 12 \text{ GeV} \quad I = 5 \mu\text{A}$$
$$\text{Repetition rate} \quad 64 \text{ ns}$$

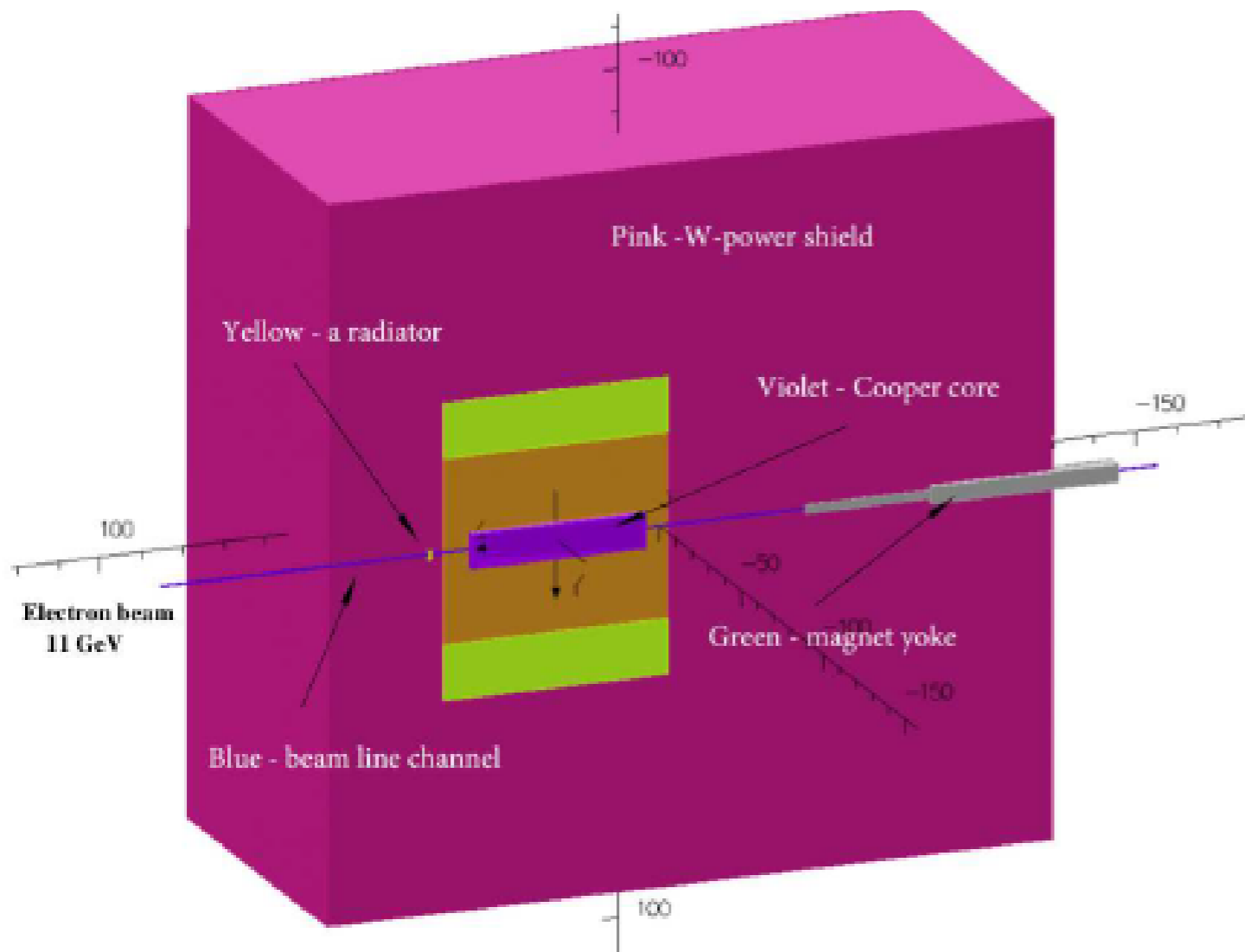
*No major problems.*

**Doable !**

**Confirmed by Todd Satogata**

**Estimated investment ~\$60 K for injector upgrade**

# Compact Photon Source



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

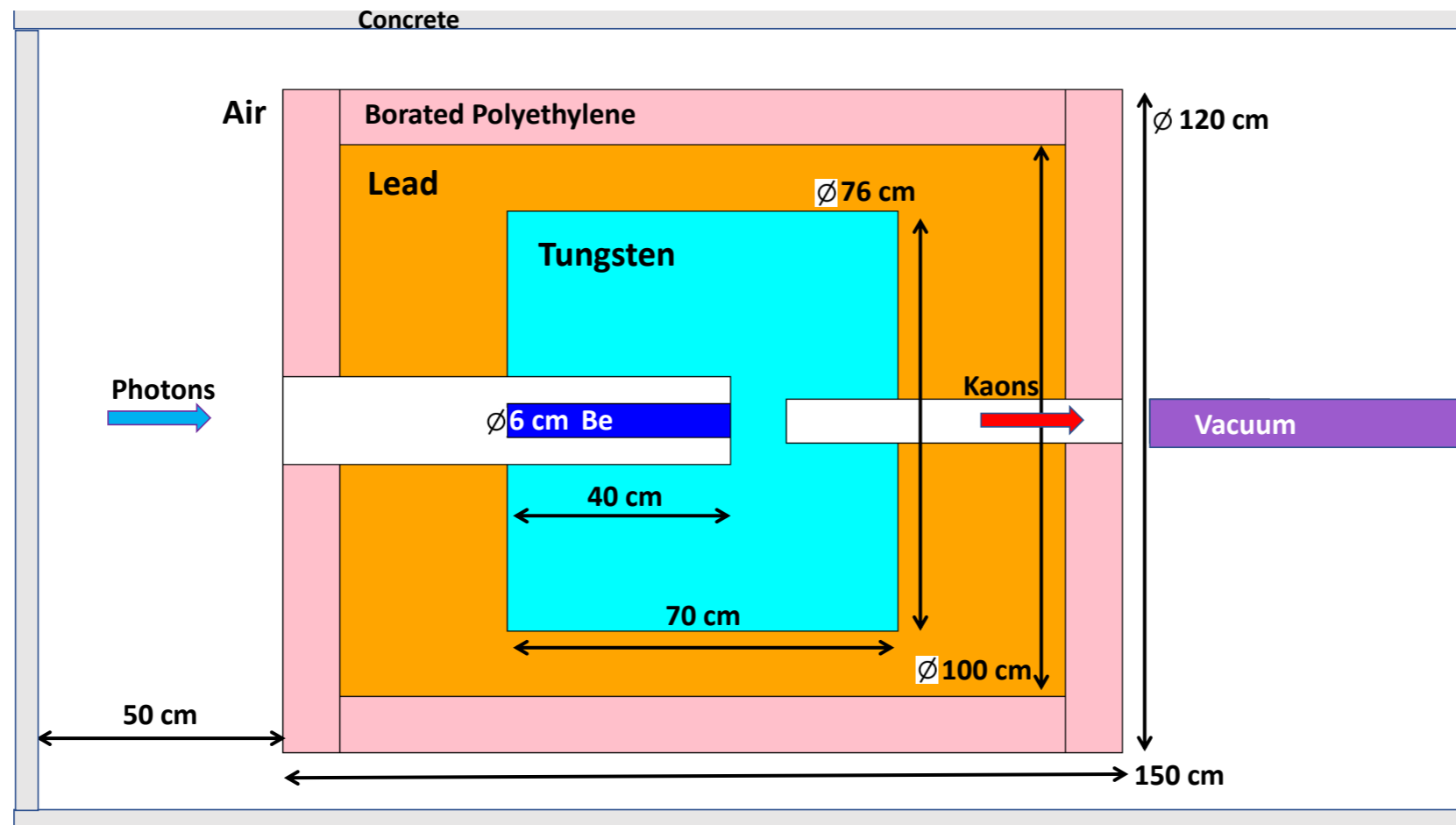
**Could be extended for  $I = 5 \mu A$  in Hall D**

**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

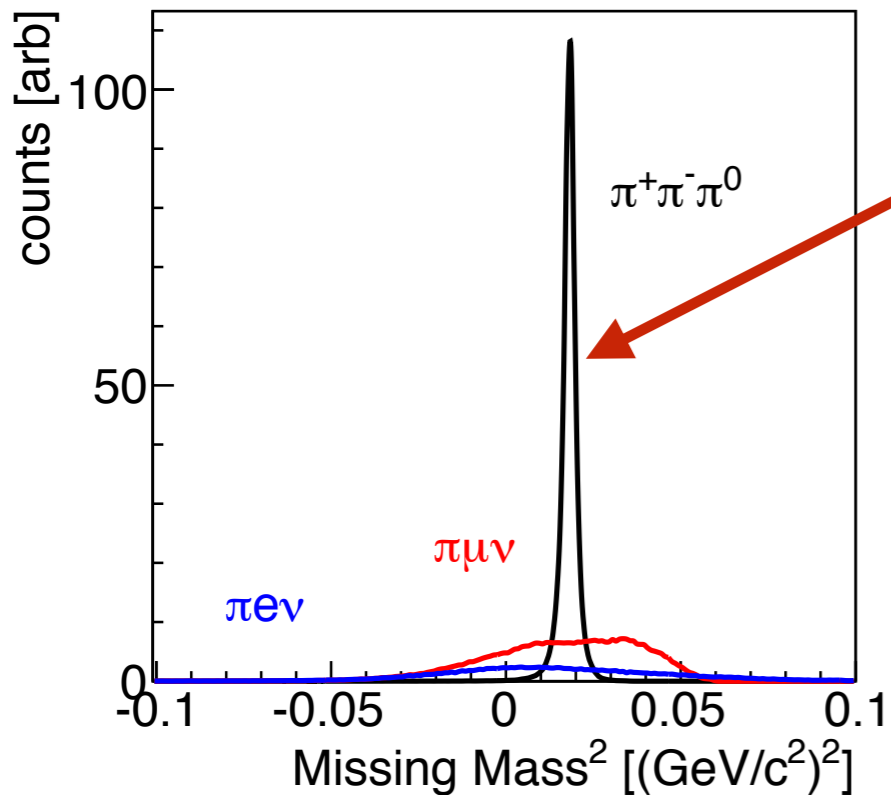
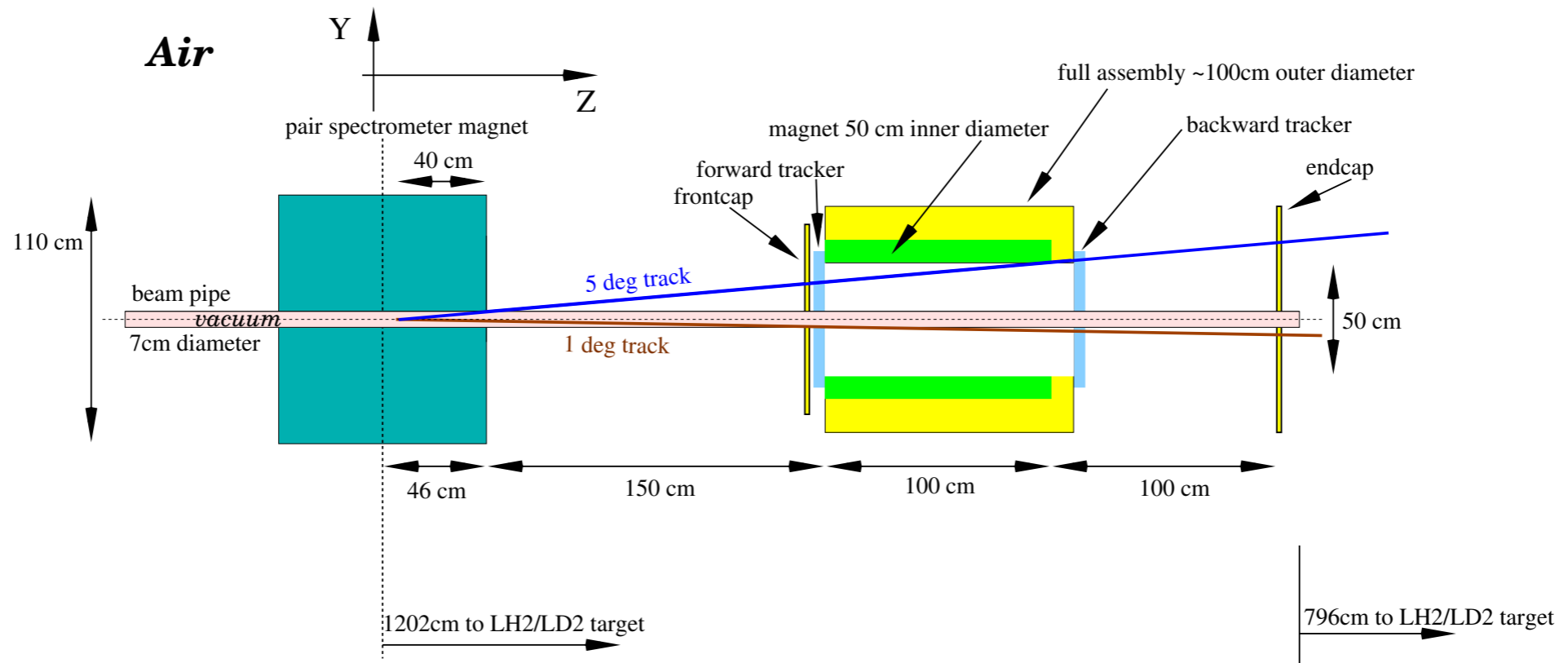


-Meets RadCon Radiation Requirements

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

Estimated cost ~\$1.2 M

# Flux Monitor



**Reconstructed  $K_L$  mass**

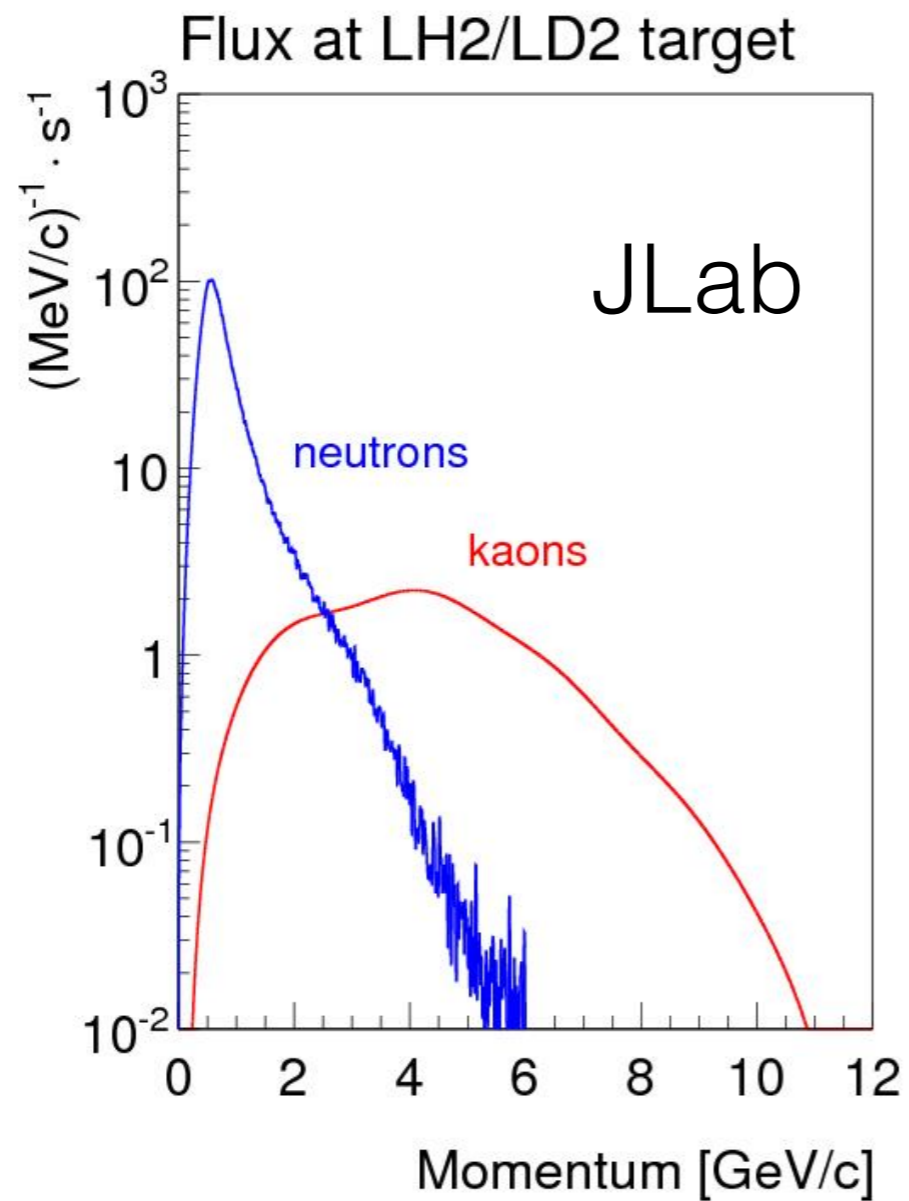
**Flux measurement stat. err. <1%**

**Estimated syst. err. <3%**

*Pursuing UK funding*

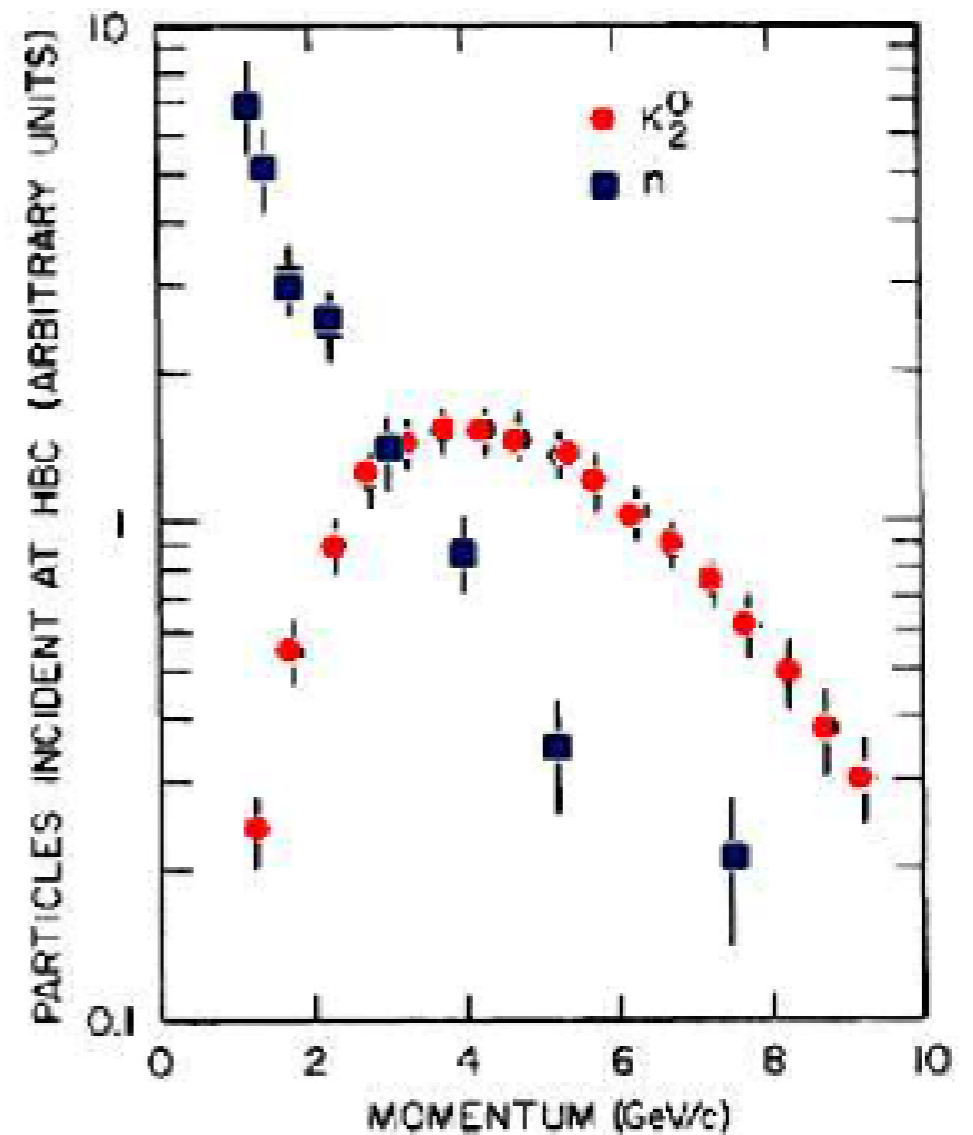
**Estimated cost ~\$ 0.7 M**

# $K_L$ Beam Flux



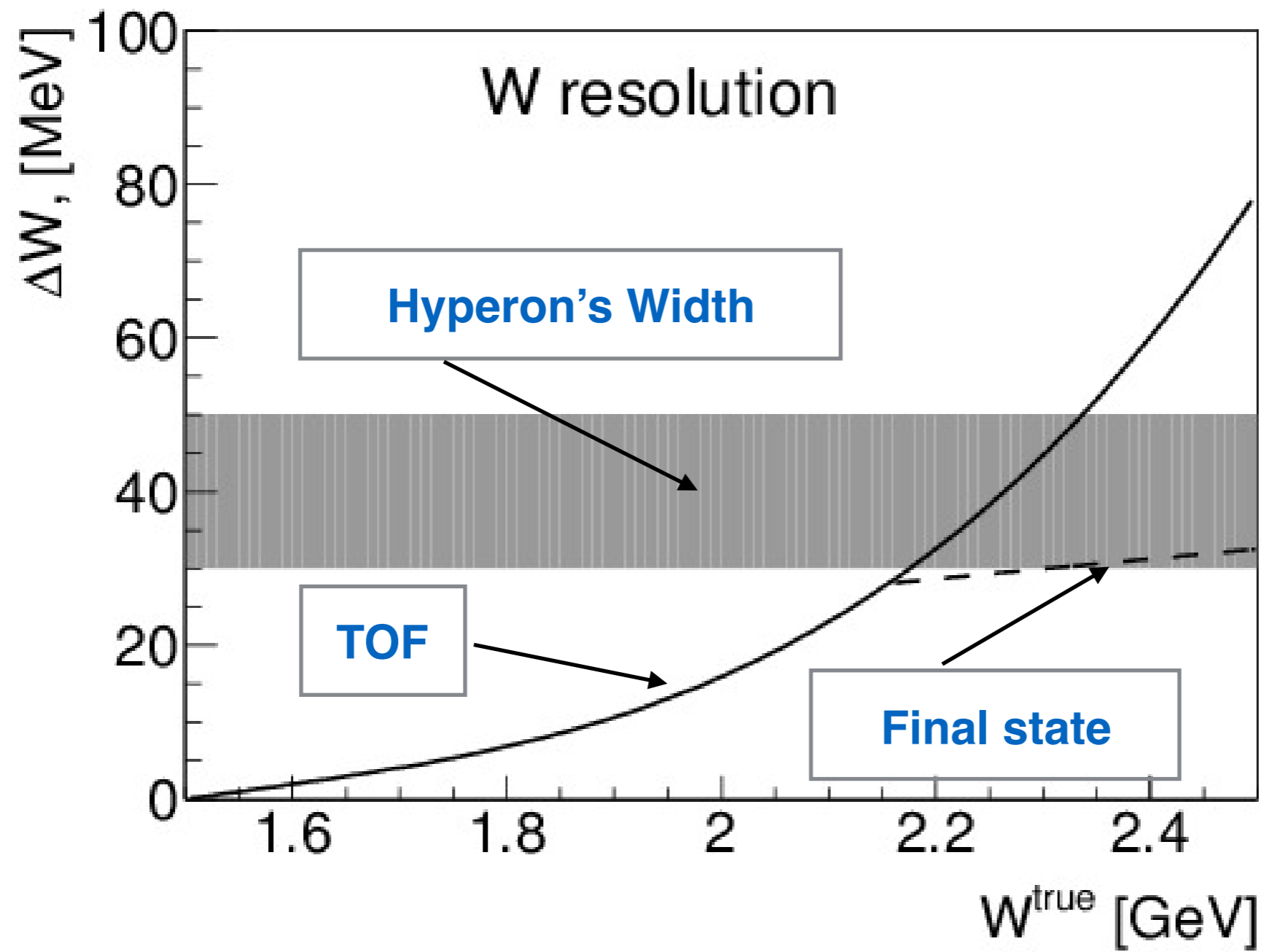
$$N(K_L)/sec \sim 10^4$$

# SLAC



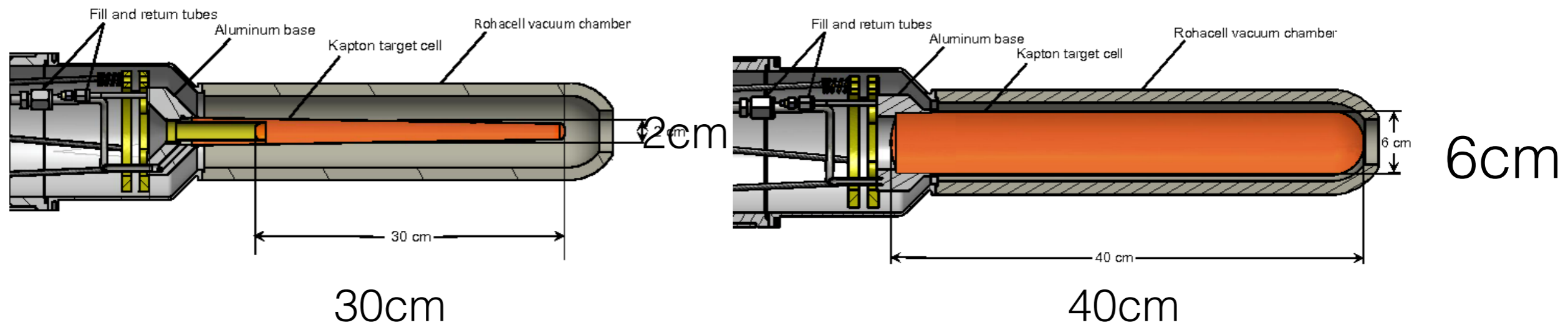
$$\frac{N(K_L)_{JLAB}}{N(K_L)_{SLAC}} \sim 10^3$$





# LH<sub>2</sub>/LD<sub>2</sub> Cryogenic Target for Neutral Kaon Beam at Hall D

The GlueX liquid hydrogen target.



*Current*

*Proposed & Feasible*

**Longer and thicker target is needed to enhance production rate**

**Conceptual design endorsed by target group (Chris Keith)**

**Estimated cost ~\$ 30 K**

PHYSICS WITH NEUTRAL KAON BEAM AT JLAB  
**KL2016**

FEBRUARY 1-3, 2016  
JEFFERSON LAB  
NEWPORT NEWS, VIRGINIA

**SCOPE**

The Workshop is following Lo112-15-001 "Physics Opportunities with Secondary KL 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 Amaryan, 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](http://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

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Eugene Chudakov  
JLab  
Krishna Rajagopal  
MIT  
Claudia Ratti  
University of Houston  
James Ritman, Ruhr  
U. Bochum & IKP Jülich  
Igor Strakovsky  
GWU



[WWW.JLAB.ORG/CONFERENCES/YSTAR2016/](http://WWW.JLAB.ORG/CONFERENCES/YSTAR2016/)

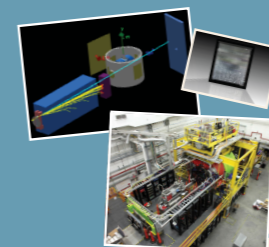


**HIPS 2017**

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<sub>s</sub> 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<sub>s</sub> 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:**

Taule Horn - CUA  
Cynthia Keppel - JLab  
Carlos Munoz-Camacho - IPNO  
Igor Strakovsky - GWU



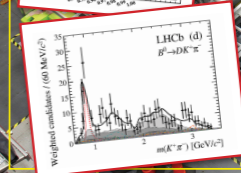
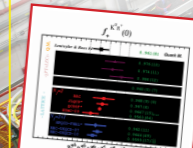
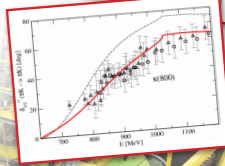
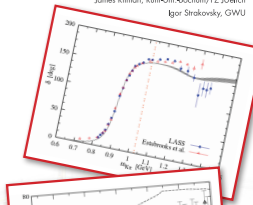
**π-K Interactions**  
*Workshop*

**ORGANIZING COMMITTEE**

Moskov Amaryan, ODU (Chair)  
U.-G. Meissner, U. Bonn/ITZ Jülich  
Curtis Meyer, CMU  
James Ritman, Ruhr-Uni-Bochum/ITZ Jülich  
Igor Strakovsky, GWU

February 14-15, 2018  
Jefferson Lab • Newport News, VA

The π-K scattering enables direct investigations of scalar and vector K\* states, including the not yet established S-wave K(800) state. These studies are also needed to get precise values of vector and scalar form factors: to independently extract CKM matrix element V<sub>us</sub> and to test the Standard Model unitarity relation in the first row of CKM matrix, to study CP violation from the Dalitz plot analysis of open charm D meson decays and in a charmless decays of B mesons in K<sub>s</sub> final states. Significant progress is made lately in Lattice QCD, in the phenomenology and in the Chiral Perturbation Theory to describe different aspects of π-K scattering. The main source of experimental data is based on experiments performed in SLAC almost five decades ago at 1970-80s. The recently proposed KL Facility incorporating the GlueX spectrometer at JLab will be able to improve the π-K scattering database by about three orders of magnitude in statistics. The workshop will discuss the necessity for and the impact of the future high statistics data obtained at JLab on π-K scattering.



<https://www.jlab.org/conferences/pki2018/>

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



# SUMMARY

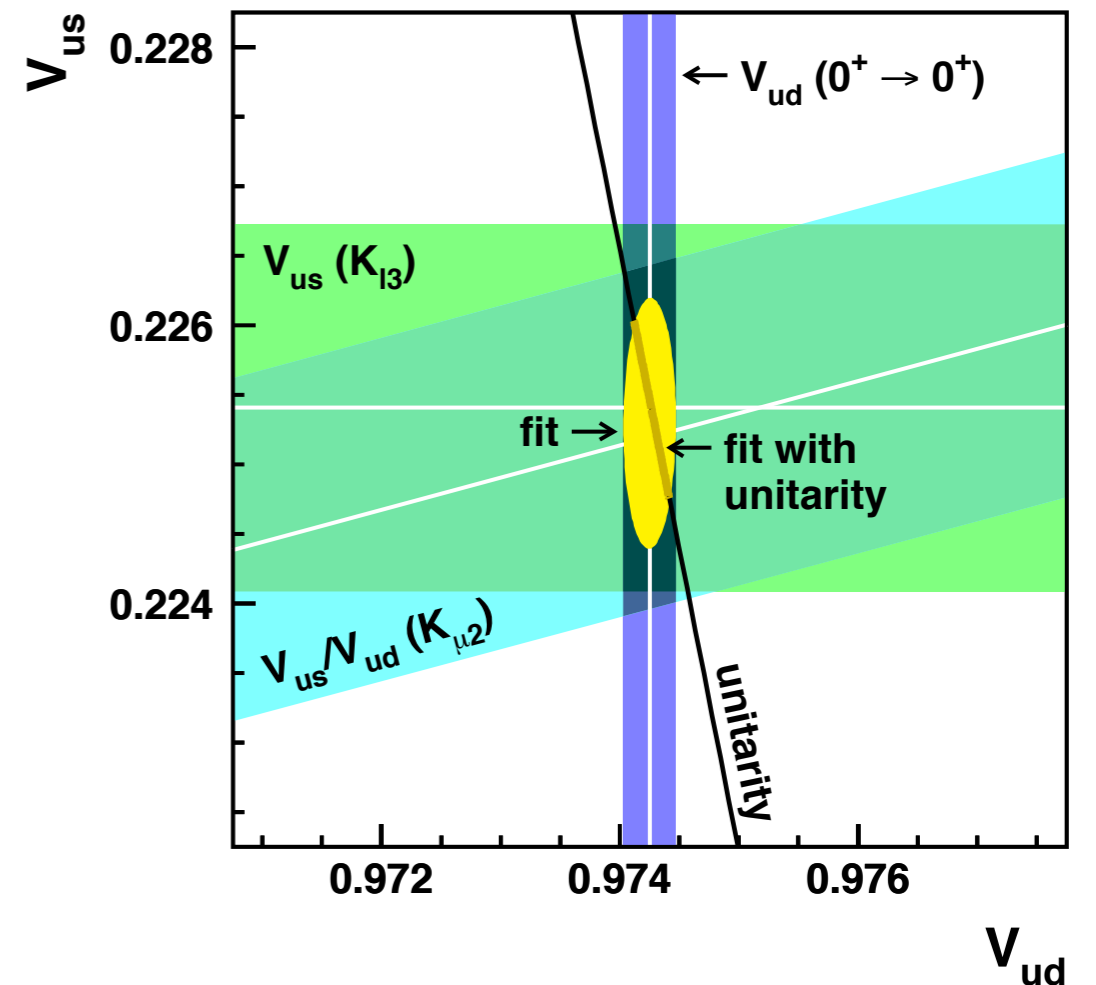
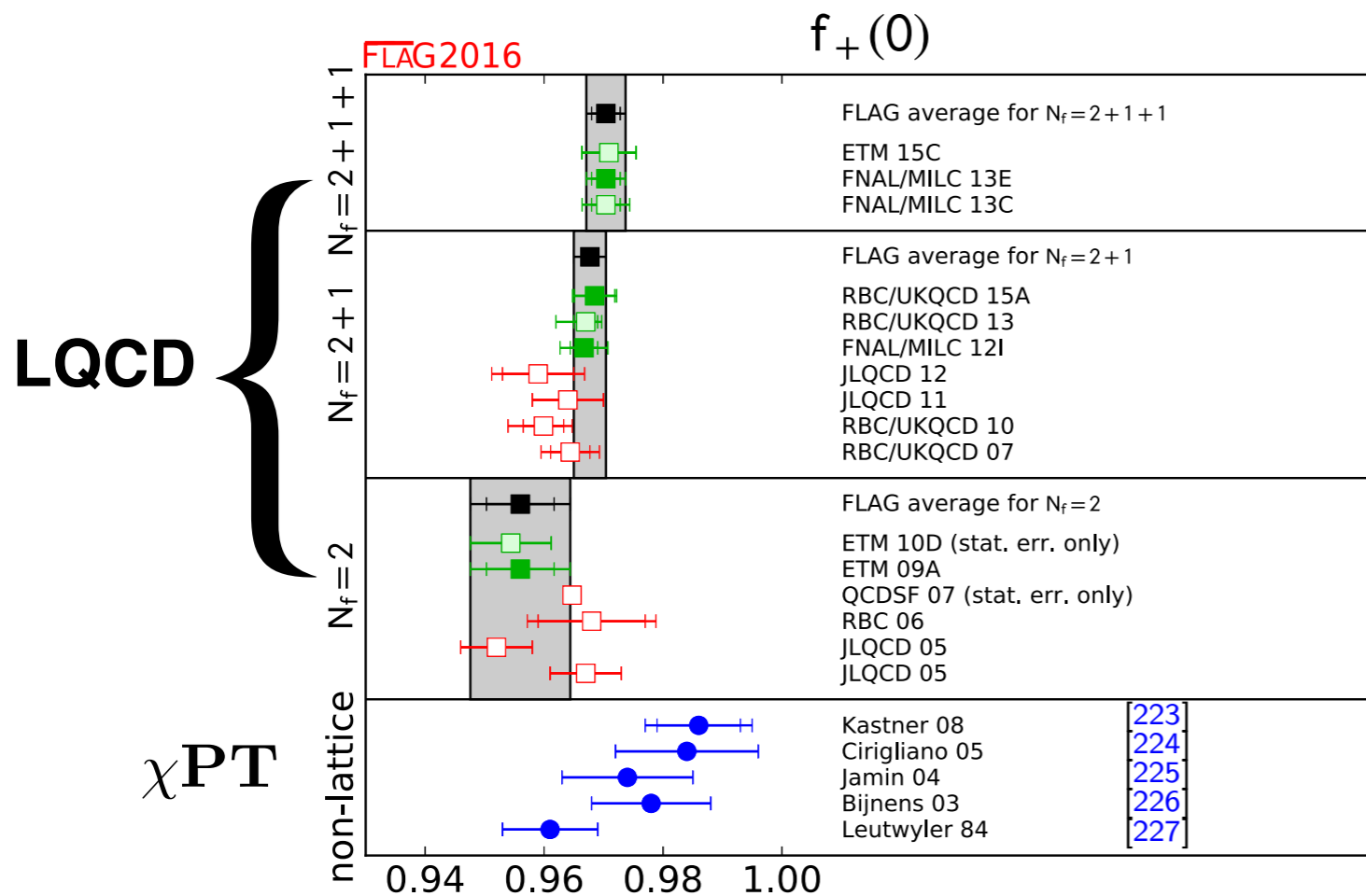
- -Proposed KL Facility has unique capability to improve existing world database up to three orders of magnitude
- -In Hyperon spectroscopy  
PWA will allow to measure pole positions and widths of excited hyperon states
- -In Strange Meson Spectroscopy  
- PWA will allow to measure excited  $K^*$  states including scalar  $f_0(800)$  states
- - To accomplish physics program  
100 days per LH2 and LD2 is required
- -All components of KL Facility considered are feasible  
-With total cost < \$ 7 M
- - Future extension with polarized target is possible

Backup

# Possible Other Impacts

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

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



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*No precise data yet !*

*test of unitarity:*

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