

***Strange Hadron Spectroscopy
with Secondary K_L beam in Hall D***



Moskov Amaryan

***Old Dominion University
Norfolk, VA, USA***

KLF Collaboration Meeting, May 19, 2020

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D

Experimental Support:

Shankar Adhikari⁴³, Moskov Amaryan (**Contact Person**, **Spokesperson**)⁴³, Arshak Asaturyan¹, Alexander Austregesilo⁴⁹, Marouen Baalouch⁸, Mikhail Bashkanov (**Spokesperson**)⁶³, Vitaly Baturin⁴³, Vladimir Berdnikov^{11,35}, Olga Cortes Becerra¹⁹, Timothy Black⁶⁰, Werner Boeglin¹³, William Briscoe¹⁹, William Brooks⁵⁴, Volker Burkert⁴⁹, Eugene Chudakov⁴⁹, Geraint Clash⁶³, Philip Cole³², Volker Crede¹⁴, Donal Day⁶¹, Pavel Degtyarenko⁴⁹, Alexandre Deur⁴⁹, Sean Dobbs (**Spokesperson**)¹⁴, Gail Dodge⁴³, Anatoly Dolgolenko²⁶, Simon Eidelman^{6,41}, Hovanes Egiyan(**JLab Contact Person**)⁴⁹, Denis Epifanov^{6,41}, Paul Eugenio¹⁴, Stuart Fegan⁶³, Alessandra Filippi²⁵, Sergey Furletov⁴⁹, Liping Gan⁶⁰, Franco Garibaldi²⁴, Ashot Gasparian³⁹, Gagik Gavalian⁴⁹, Derek Glazier¹⁸, Colin Gleason²², Vladimir Goryachev²⁶, Lei Guo¹⁴, David Hamilton¹¹, Avetik Hayrapetyan¹⁷, Garth Huber⁵³, Andrew Hurley⁵⁶, Charles Hyde⁴³, Isabella Illari¹⁹, David Ireland¹⁸, Igal Jaegle⁴⁹, Kyungseon Joo⁵⁷, Vanik Kakoyan¹, Grzegorz Kalicy¹¹, Mahmoud Kamel¹³, Christopher Keith⁴⁹, Chan Wook Kim¹⁹, Eberhard Klemp⁵, Geoffrey Krafft⁴⁹, Sebastian Kuhn⁴³, Sergey Kuleshov², Alexander Laptev³³, Ilya Larin^{26,59}, David Lawrence⁴⁹, Daniel Lersch¹⁴, Wenliang Li⁵⁶, Kevin Luckas²⁸, Valery Lyubovitskiy^{50,51,52,54}, David Mack⁴⁹, Michael McCaughan⁴⁹, Mark Manley³⁰, Hrachya Marukyan¹, Vladimir Matveev²⁶, Mihai Mocanu⁶³, Viktor Mokeev⁴⁹, Curtis Meyer⁹, Bryan McKinnon¹⁸, Frank Nerling^{15,16}, Matthew Nicol⁶³, Gabriel Niculescu²⁷, Alexander Ostrovidov¹⁴, Zisis Papandreou⁵³, KiJun Park⁴⁹, Eugene Pasyuk⁴⁹, Lubomir Pentchev⁴⁹, William Phelps¹⁰, John Price⁷, Jörg Reinhold¹³, James Ritman (**Spokesperson**)^{28,48}, Dimitri Romanov²⁶, Carlos Salgado⁴⁰, Todd Satogata⁴⁹, Susan Schadmand²⁸, Amy Schertz⁵⁶, Axel Schmidt¹⁹, Daniel Sober¹¹, Alexander Somov⁴⁹, Sergei Somov³⁵, Justin Stevens (**Spokesperson**)⁵⁶, Igor Strakovsky (**Spokesperson**)¹⁹, Victor Tarasov²⁶, Simon Taylor⁴⁹, Annika Thiel⁵, Guido Maria Urciuoli²⁴, Holly Szumila-Vance¹⁹, Daniel Watts⁶³, Lawrence Weinstein⁴³, Timothy Whitlatch⁴⁹, Nilanga Wickramaarachchi⁴³, Bogdan Wojtsekhowski⁴⁹, Nicholas Zachariou⁶³, Jonathan Zarling⁵³, Jixie Zhang⁶¹

Theoretical Support:

Alexey Anisovich^{5,44}, Alexei Bazavov³⁸, Rene Bellwied²¹, Veronique Bernard⁴², Gilberto Colangelo³, Aleš Cieplý⁴⁶, Michael Döring¹⁹, Ali Eskanderian¹⁹, Jose Goity^{20,49}, Helmut Haberzettl¹⁹, Mirza Hadžimehmedović⁵⁵, Robert Jaffe³⁶, Boris Kopeliovich⁵⁴, Heinrich Leutwyler³, Maxim Mai¹⁹, Vincent Mathieu³⁴, Maxim Matveev⁴⁴, Ulf-G. Meißner^{5,29}, Colin Morningstar⁹, Bachir Moussallam⁴², Kanzo Nakayama⁵⁸, Viktor Nikonov^{5,44}, Wolfgang Ochs³⁷, Youngseok Oh³¹, Rifat Omerovic⁵⁵, Hedim Osmanović⁵⁵, Eulogio Oset⁶², Antimo Palano⁶⁴, Jose Pelaez³⁴, Alessandro Pilloni⁴⁹, Maxim Polyakov⁴⁸, David Richards⁴⁹, Arkaitz Rodas⁴⁹, Dan-Olof Riska¹², Jacobo Ruiz de Elvira³, Hui-Young Ryu⁴⁵, Elena Santopinto²³, Andrey Sarantsev^{5,44}, Jugoslav Stahov⁵⁵, Alfred Švarc⁴⁷, Adam Szczepaniak^{22,49}, Ronald Workman¹⁹, Bing-Song Zou⁴

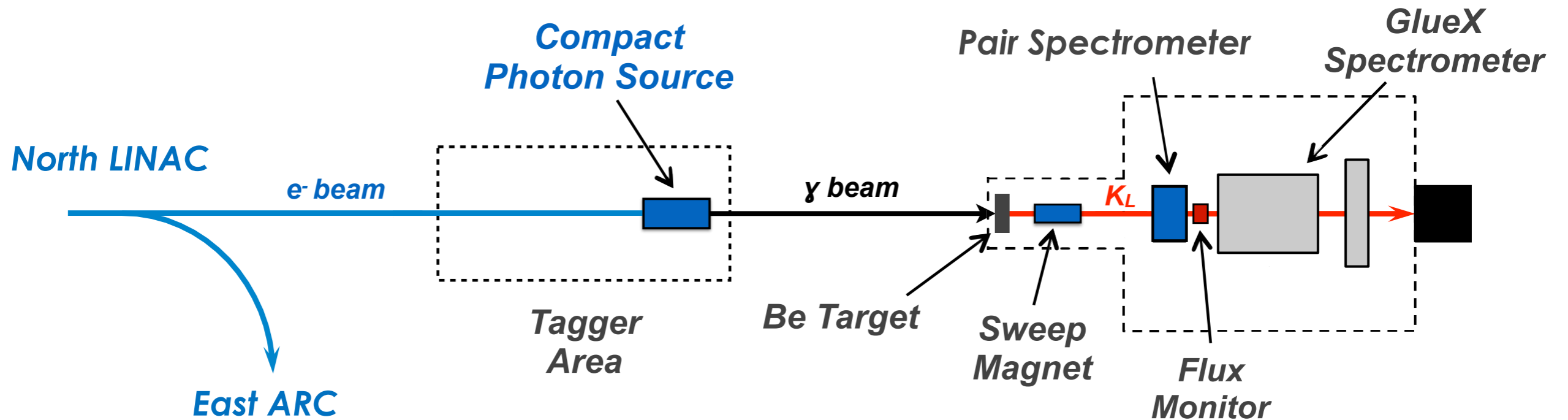
Members of 64 Universities

AGENDA

Tuesday May 19, 2020

- 09:00 (125) Session I --- Project Status.
 - 09:00 (20+5) KLF overview and addressing PAC48 report --- *Moskov Amaryan* [].
 - 09:25 (20+5) Hyperon Spectroscopy Status --- *Mikhail Bashkanov* [].
 - 09:50 (20+5) Meson Spectroscopy Status --- *Shankar Adhikari* [].
 - 10:15 (20+5) Neutron Stars -- *Nick Zachariou* [].
 - 10:40 (20+5) Discussion for PAC48 preparation.
- 11:05 Adjourn

K_L Facility in Hall D



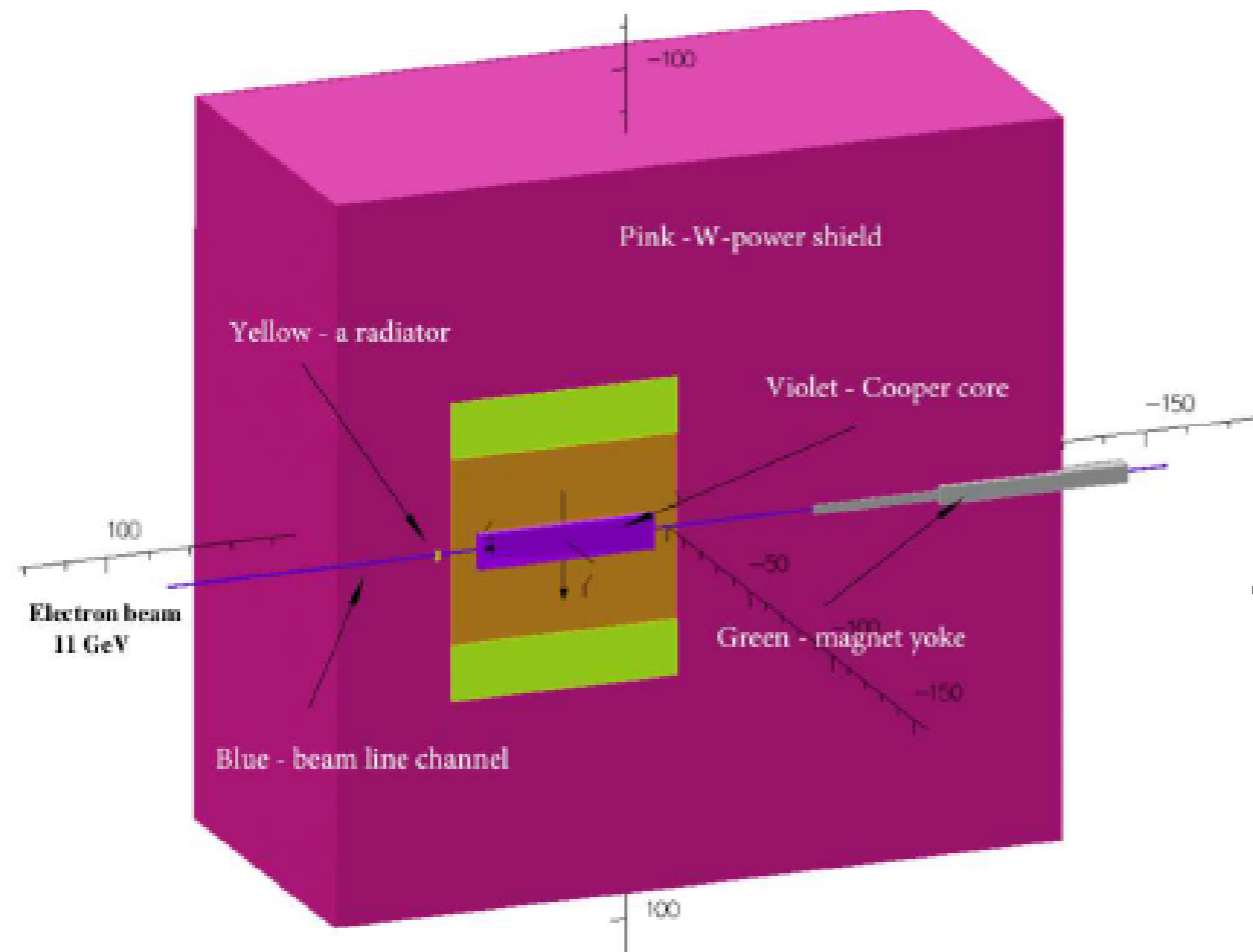
Electron Beam Parameters

$$E_e = 12 \text{ GeV} \quad I = 5 \mu\text{A}$$

$$\text{Bunch spacing} \quad 64 \text{ ns}$$

Feasibility Confirmed by accelerator experts

Compact Photon Source



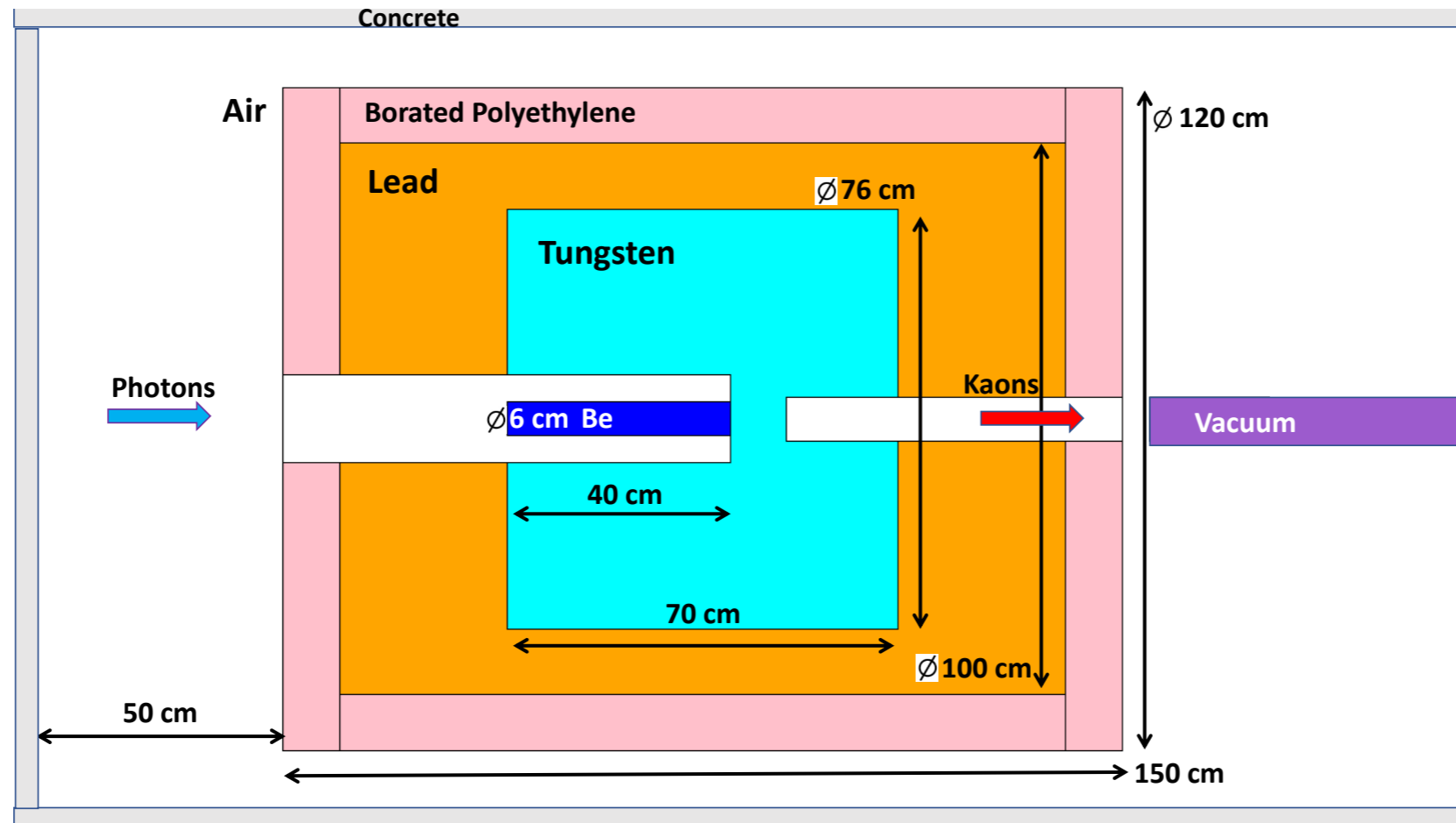
Conceptual design is completed for Halls A&C

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

- **Published in: *NIM A* 957 (2020) 163429**

Be Target Assembly: Conceptual Design



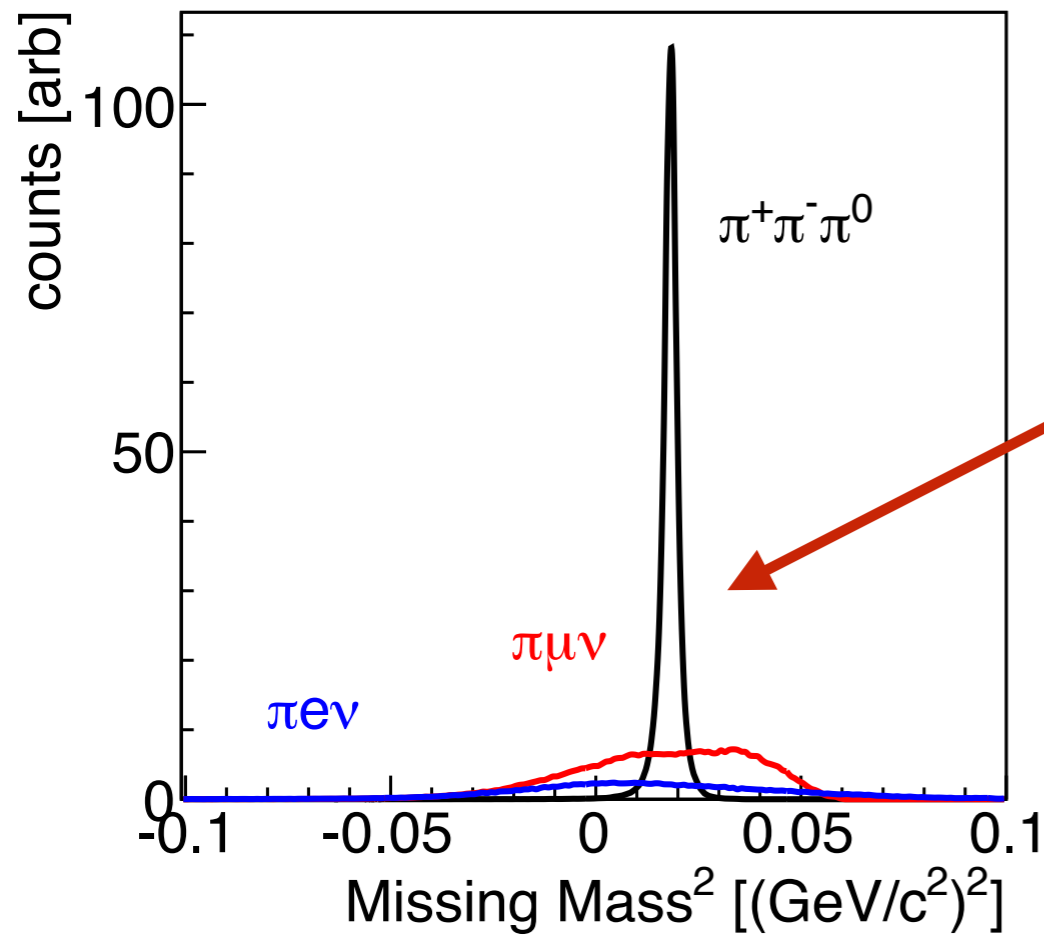
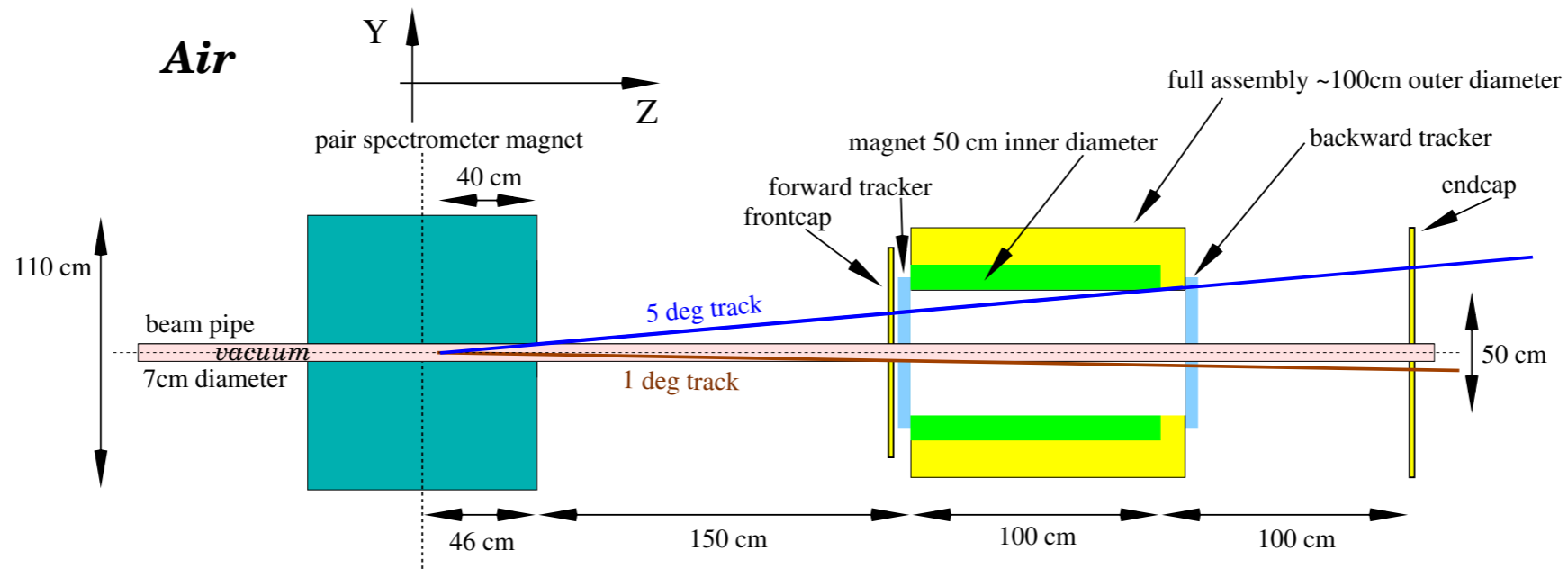
-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff

For more details consult:

<https://arxiv.org/abs/2002.04442>

Flux Monitor



796cm to LH2/LD2 target

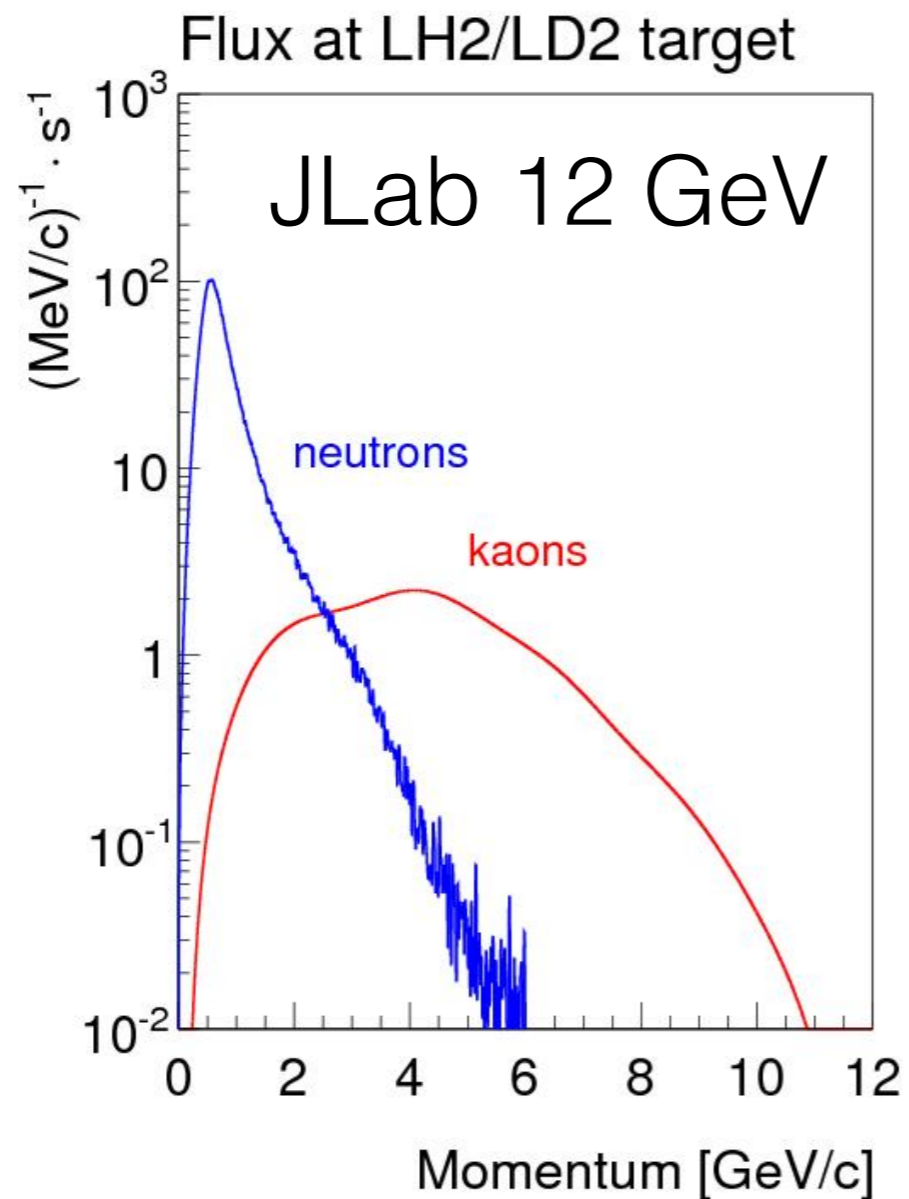
Reconstructed K_L

via missing (π^0)

Flux measurement stat. err. <1%

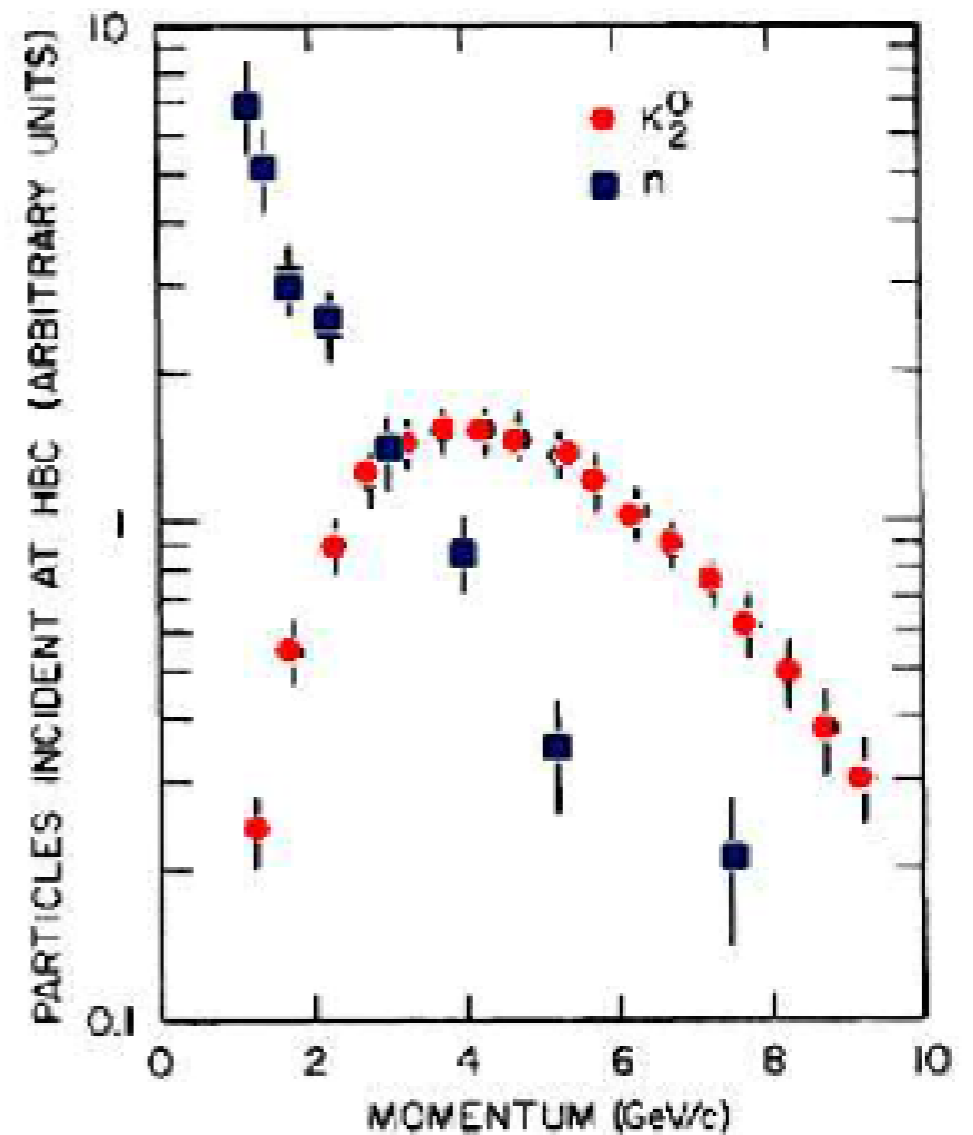
Estimated syst. err. ~5%

K_L Beam Flux



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

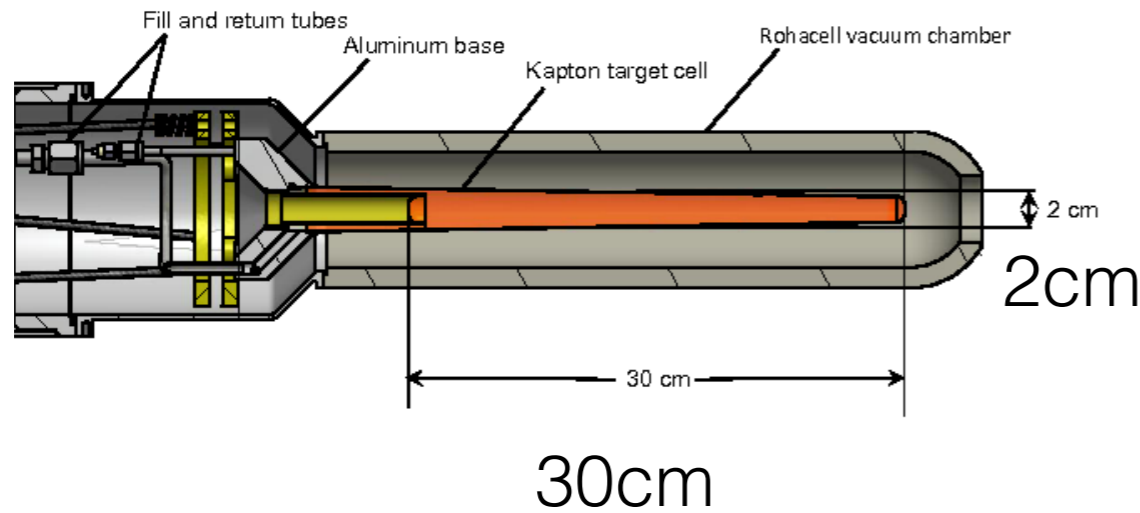
SLAC 16 GeV



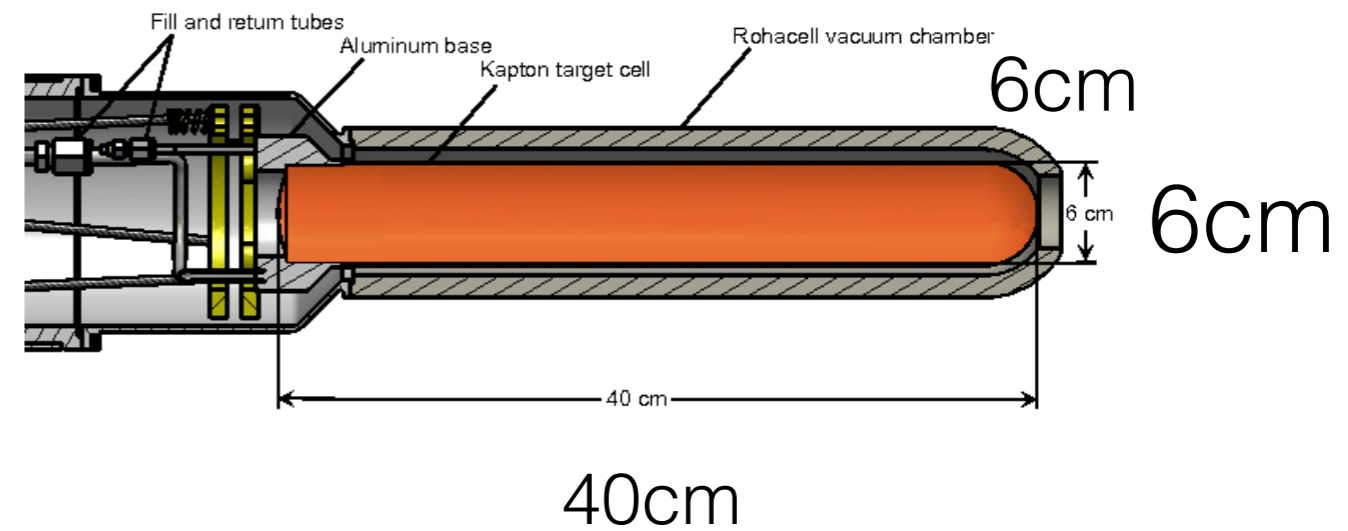
$$\frac{N(K_L)_{JLAB}}{N(K_L)_{SLAC}} \sim 10^3$$

LH₂/LD₂ 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 has been endorsed by the JLAB target group

Wiki Page

<https://wiki.jlab.org/klproject/index.php/PAC48>

- **Supplemental materials for the PAC48 submission:**
 - **Final version of KLF_Analysis_Report (hyperon case).**
 - **KLF_Analysis_Report (meson case) work in progress.**
 - **Final version of New_Equipment.**
 - **Final version of the Raster document.**
 - **Final version of the KPT.**
 - **Final version of KFM.**
 - **Final version of the CPS.**
 - **Final version of the timeline of the design, construction and installation of the KL beam line.**
 - **Cover Letter draft.**

Final version of proposal will be available soon.

The KLF raison d'être

Hyperon Spectroscopy

(talk by M. Bashkanov)

Strange Meson Spectroscopy

(talk by S. Adhikari)

Impact on Cosmology and Astrophysics

(talk by N. Zachariu)

Hyperon Spectroscopy

List of simulated reactions

1. $K_L p \rightarrow K_s p$

2. $K_L p \rightarrow \pi^+ \Lambda$

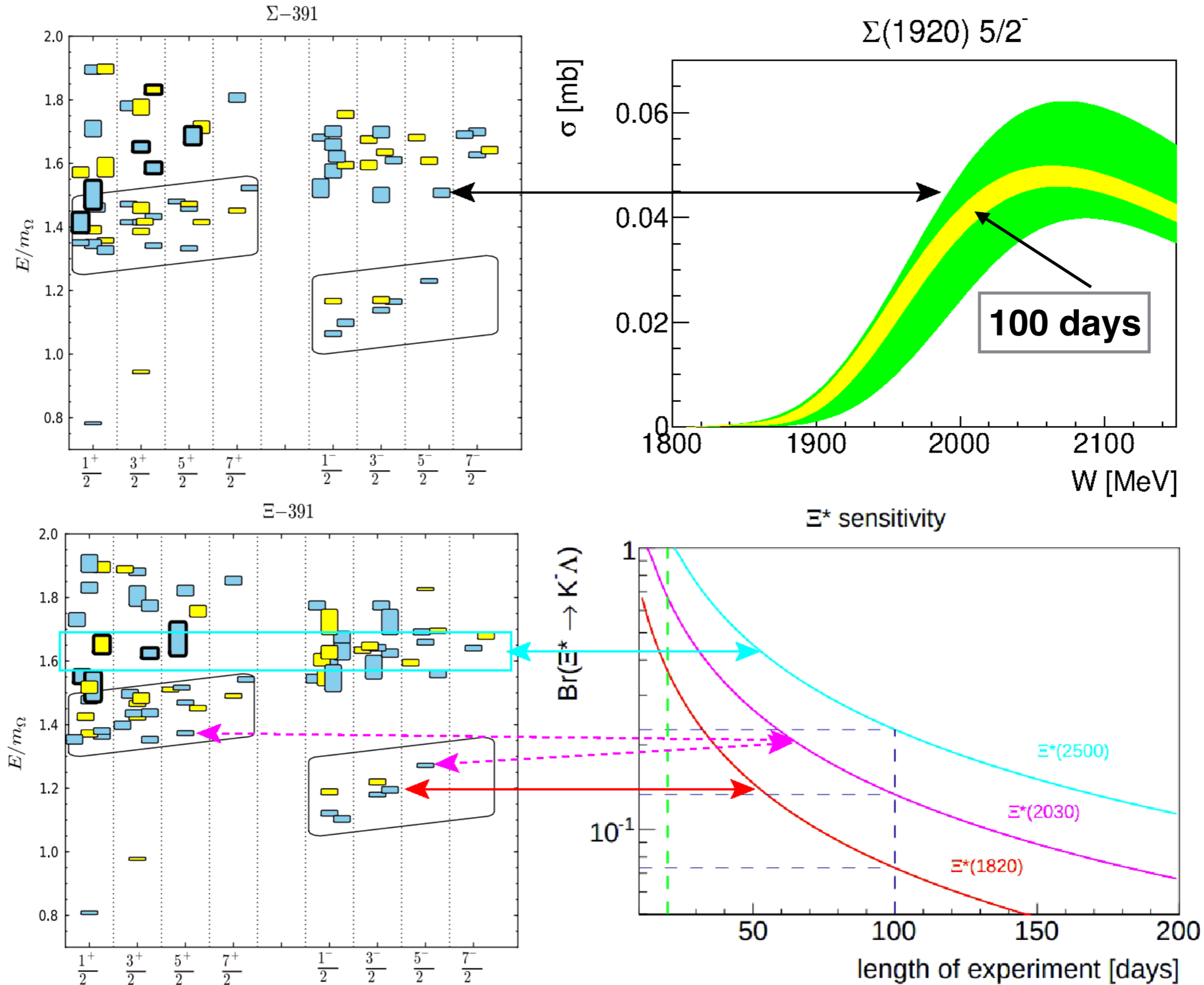
3. $K_L p \rightarrow K^+ \Xi^0$

4. $K_L n \rightarrow K^+ \Xi^-$

5. $K_L n \rightarrow K^+ \Xi^{*-}$

6. $K_L p \rightarrow K^+ n$

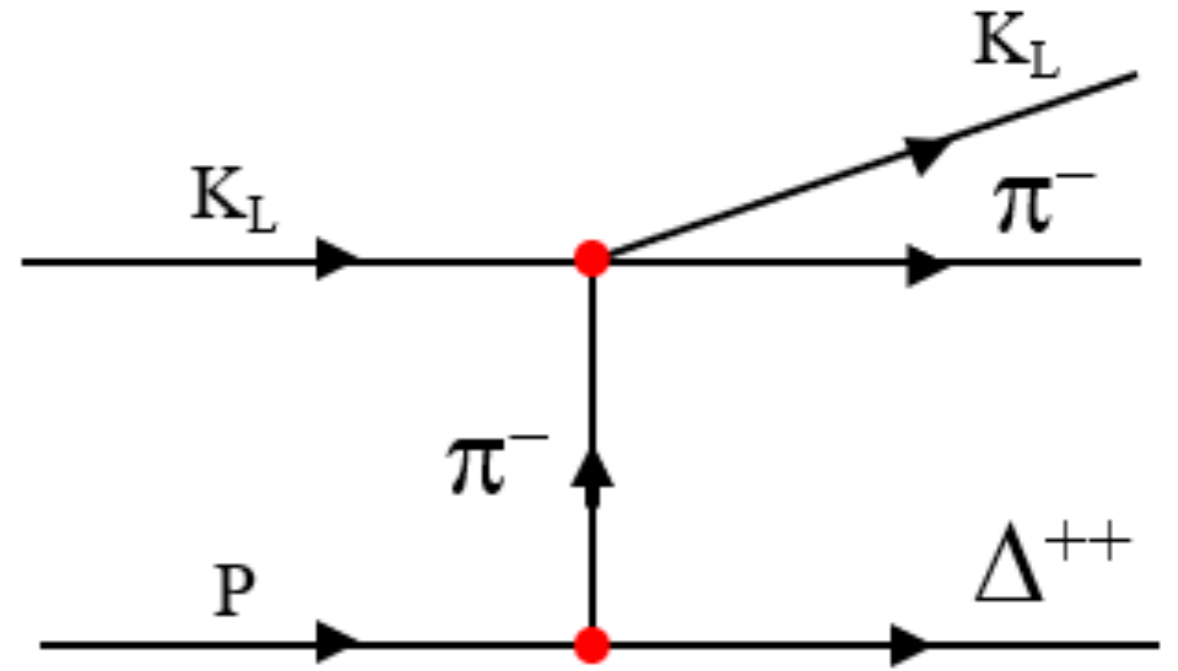
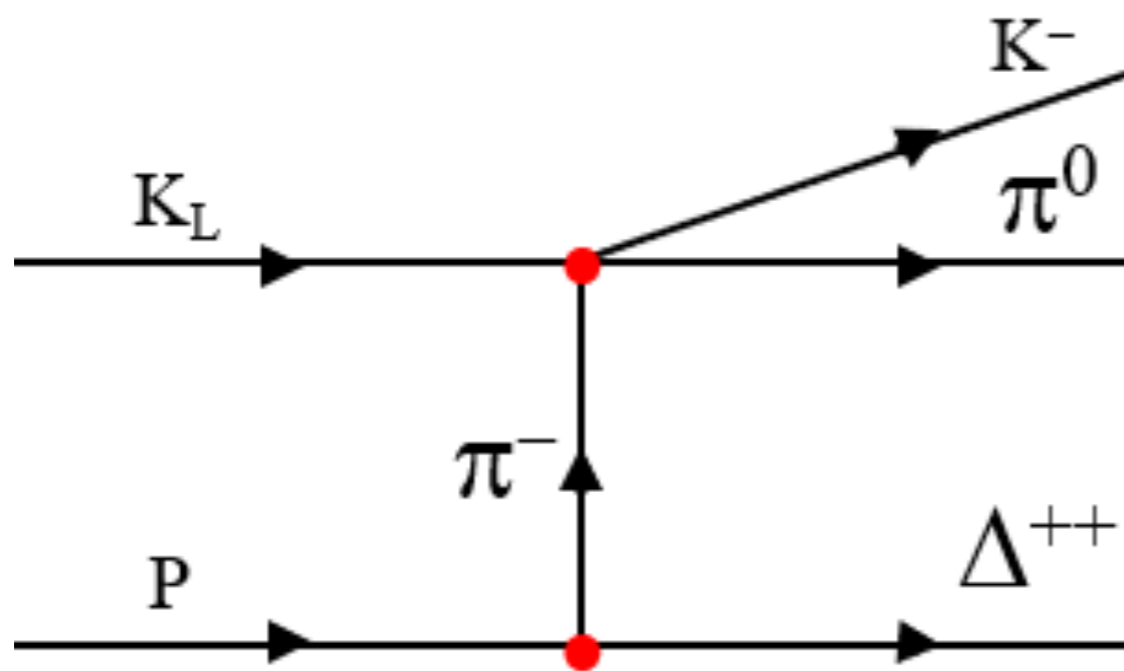
Snapshot of Hyperon Spectroscopy



Strange Meson Spectroscopy

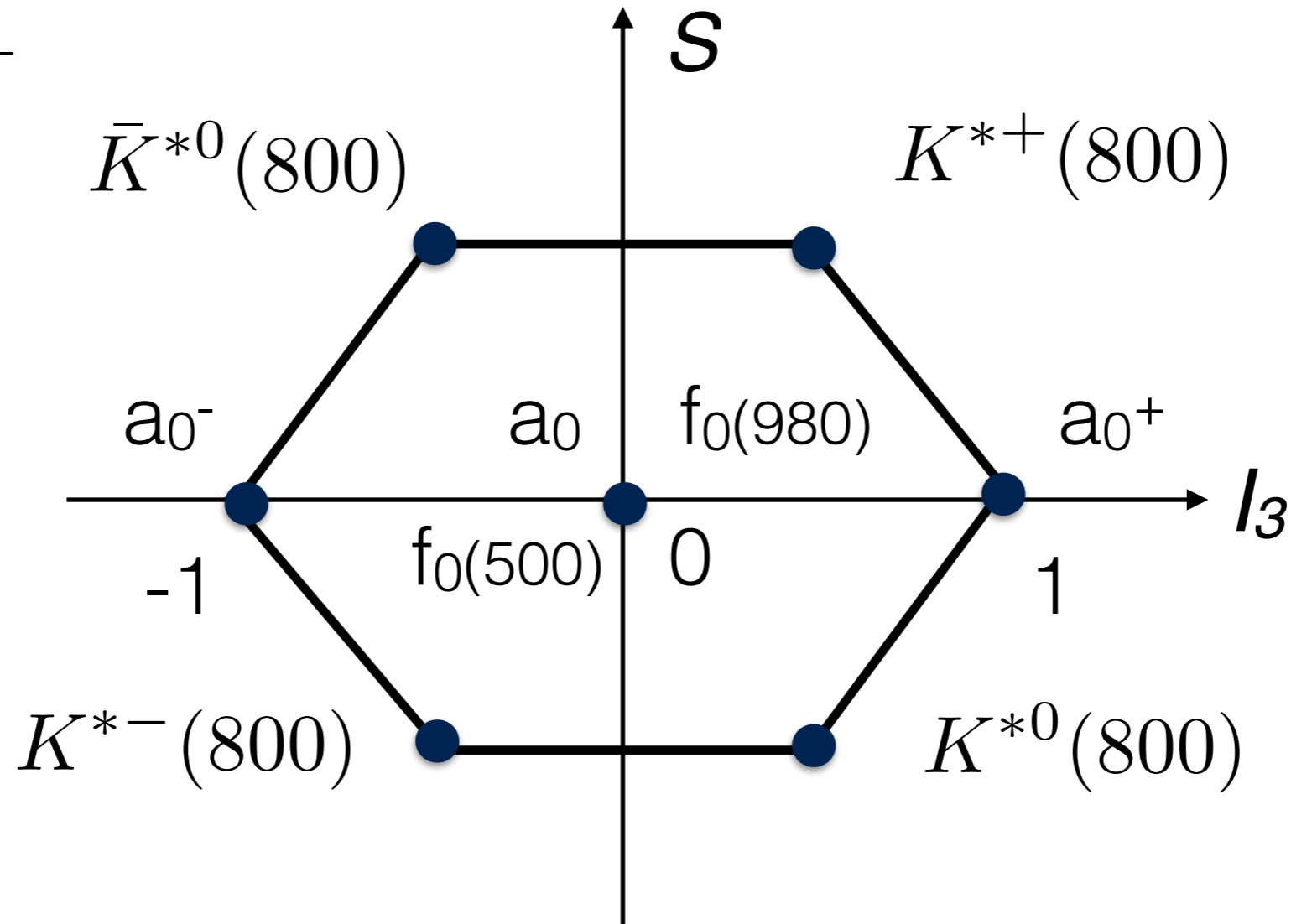


$K\pi$ Scattering



Scalar Meson Nonet

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



Four states called κ
still need further confirmation(PDG)

Proposed Measurements

SLAC

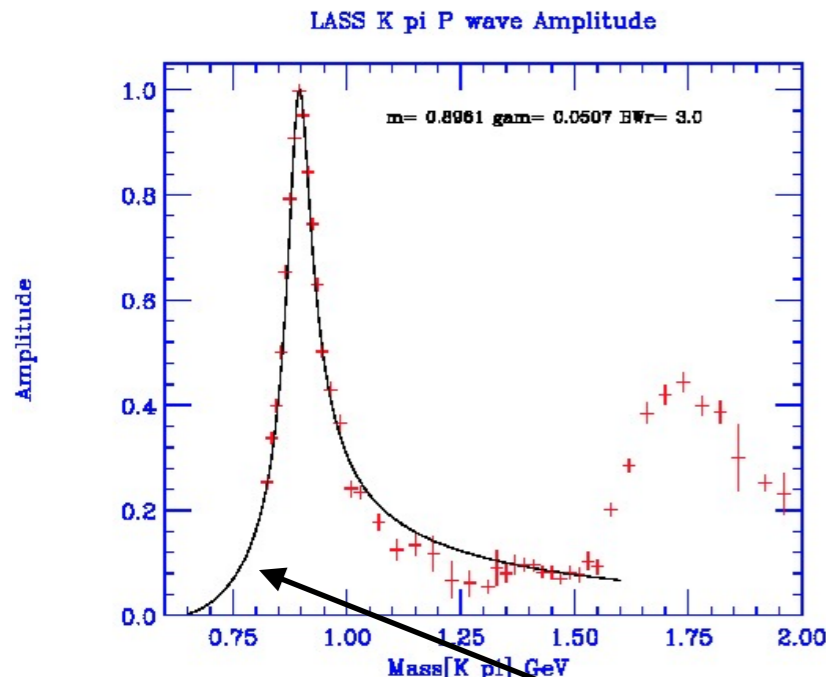
$$K^- \pi^+ \rightarrow K^- \pi^+$$

Belle

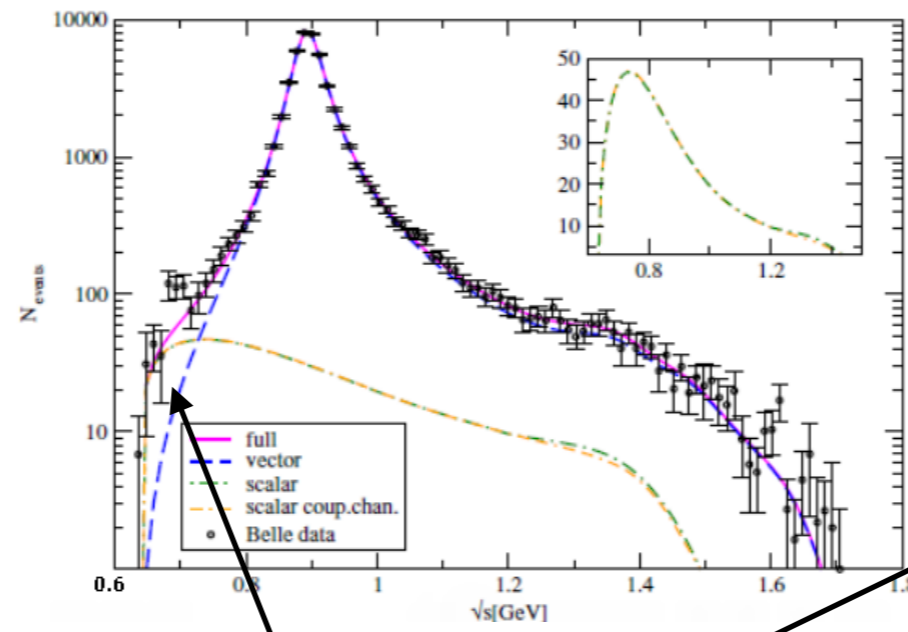
$$\tau \rightarrow K \pi \nu_\tau$$

KLF

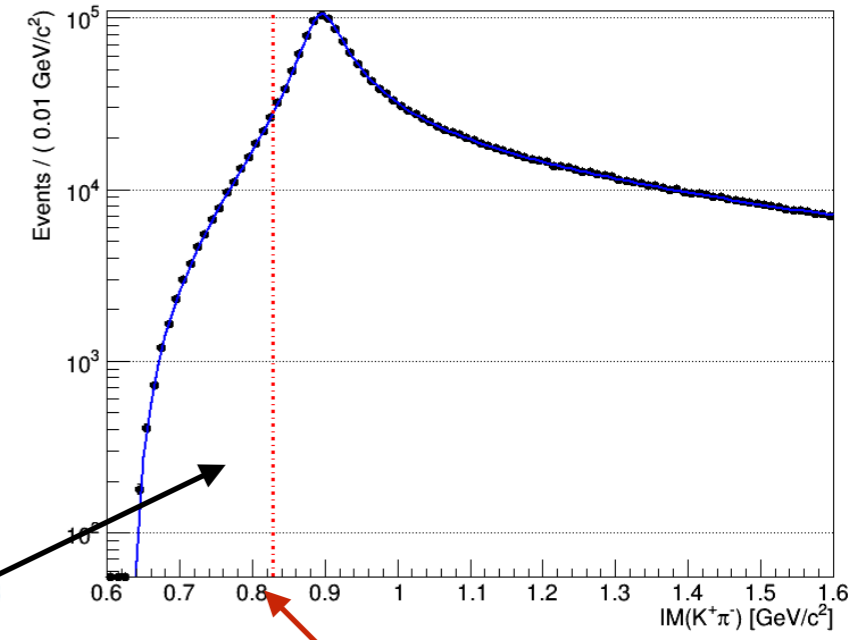
$$K_L p \rightarrow K^- \pi^0$$



$M(K\pi)$ (GeV)



$M(K\pi)$ (GeV)



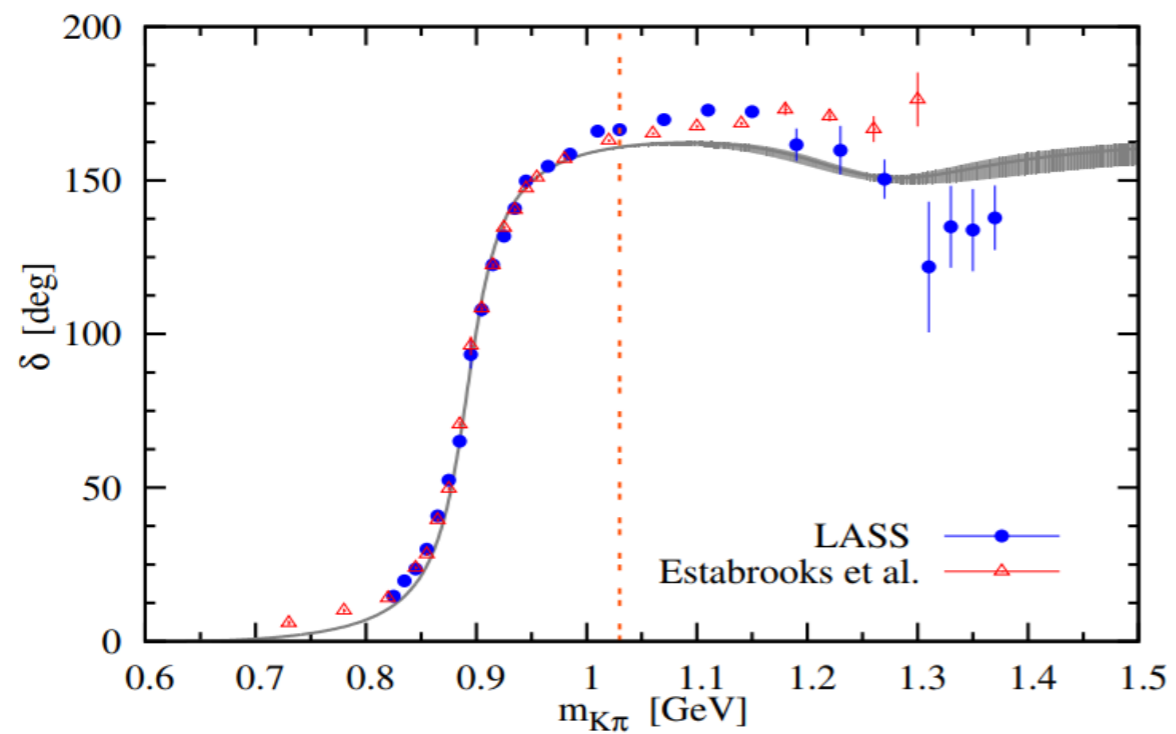
$M(K\pi)$ (GeV)

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

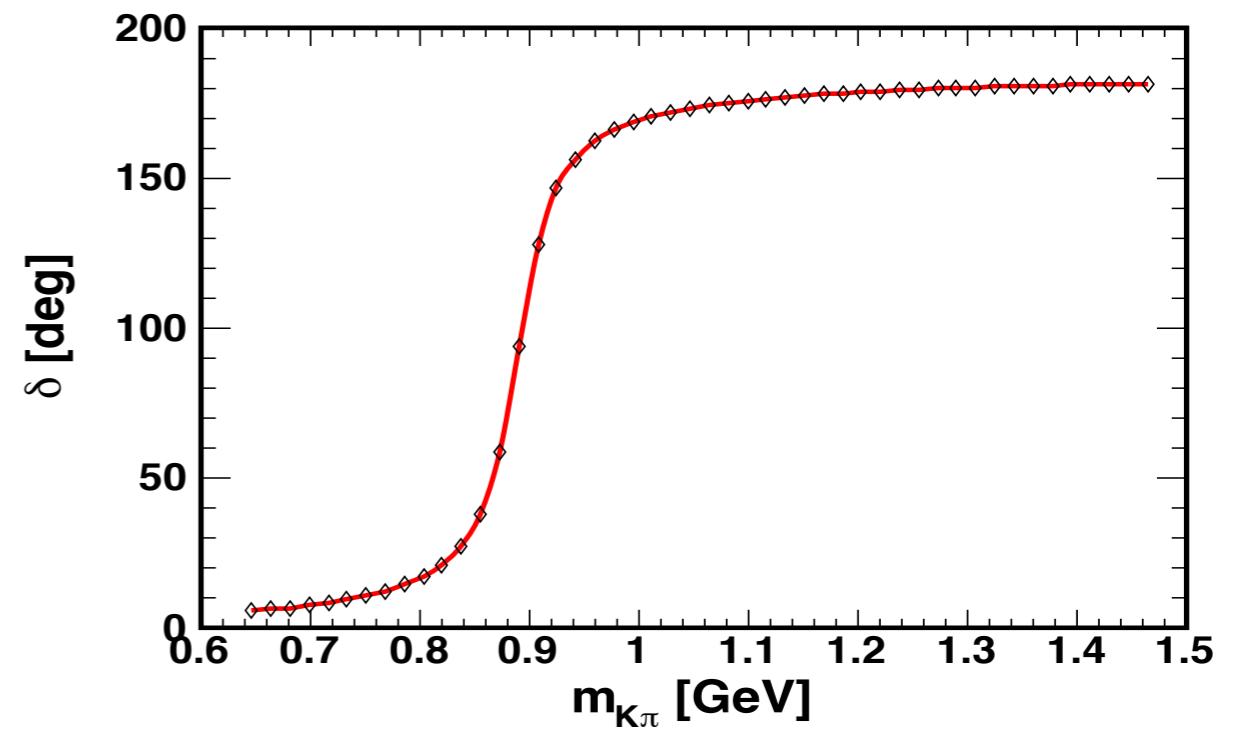
SLAC Lower limit

P-wave phase shift

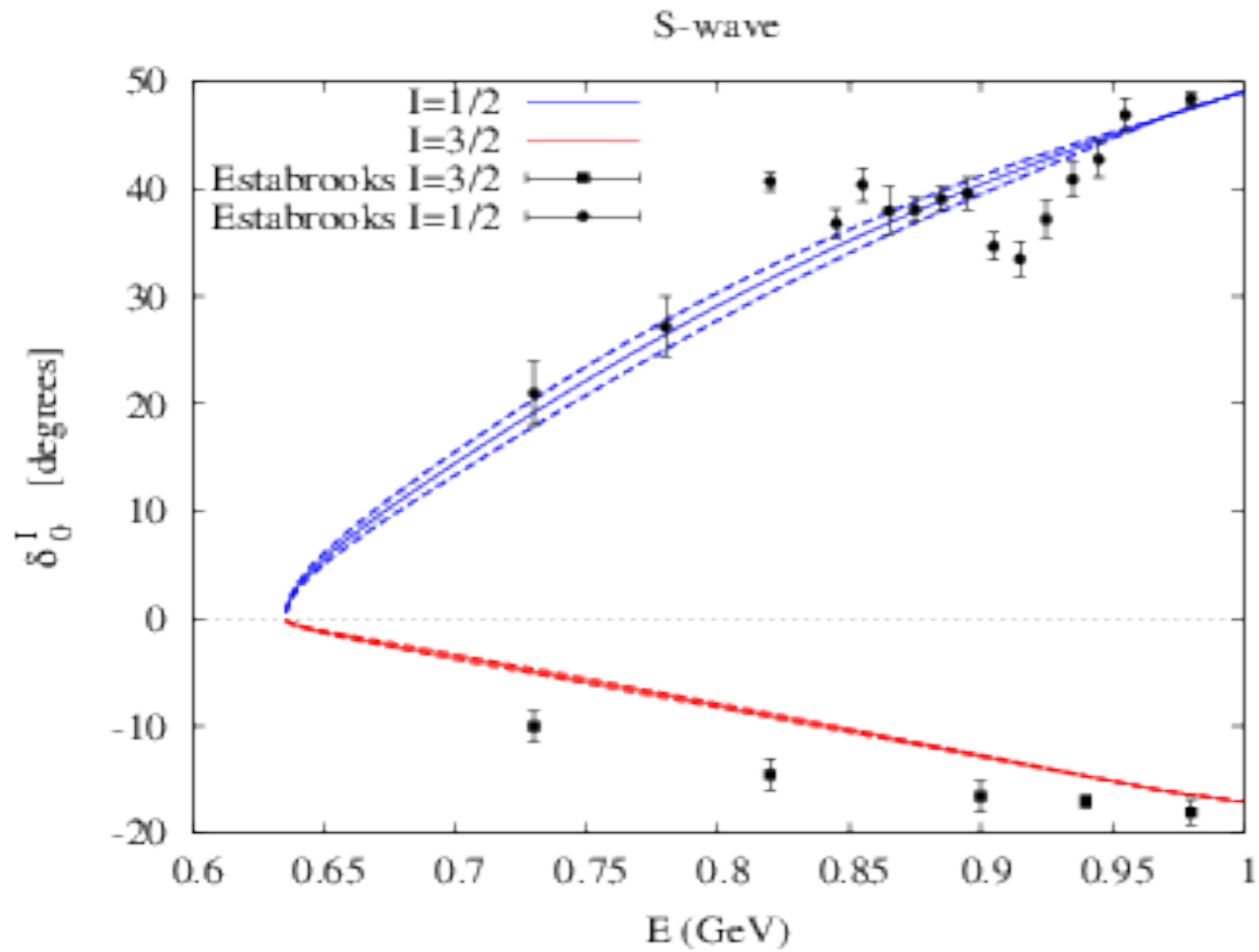
SLAC + Belle ($\mu \rightarrow K\pi\nu_\tau$)



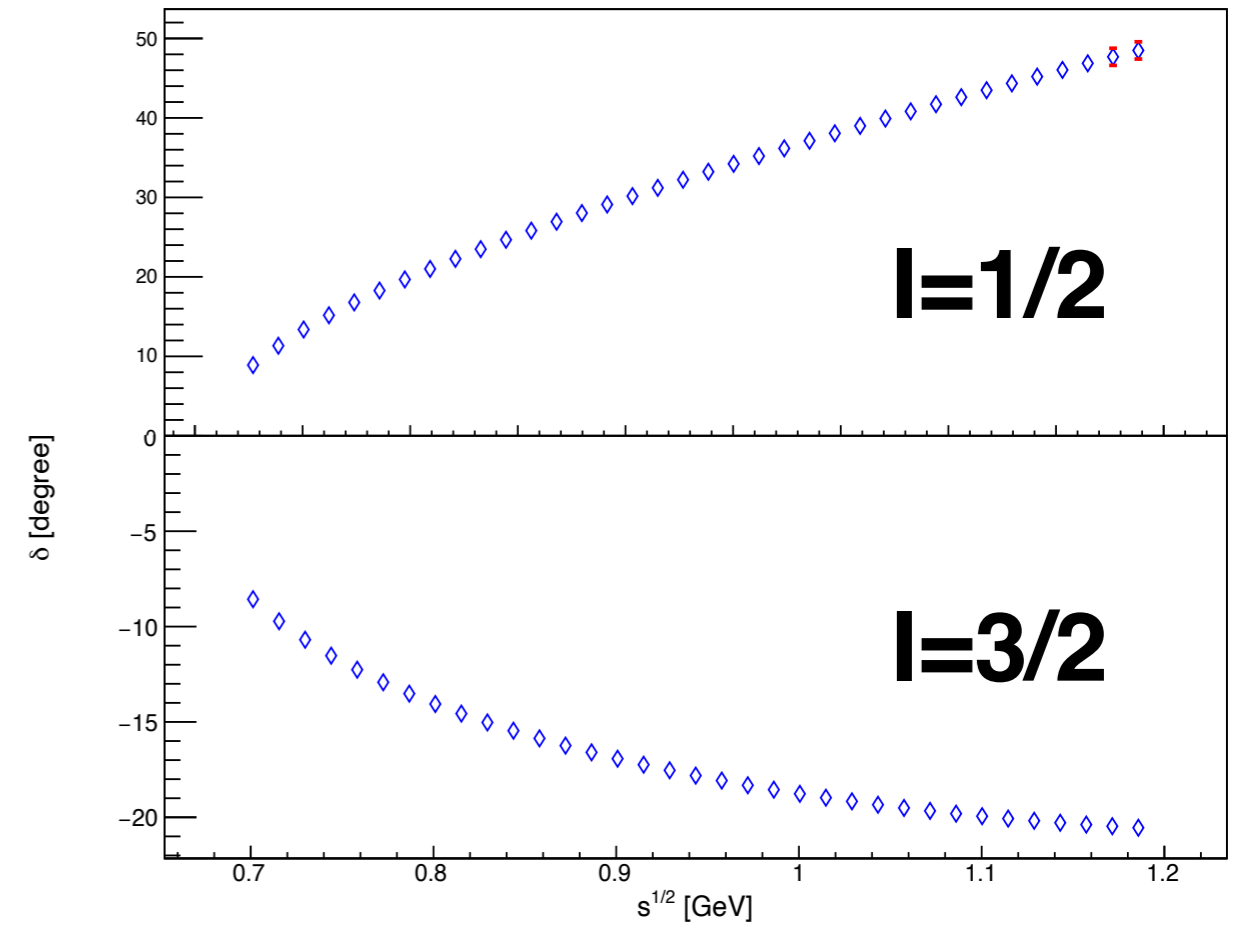
KLF 100 days



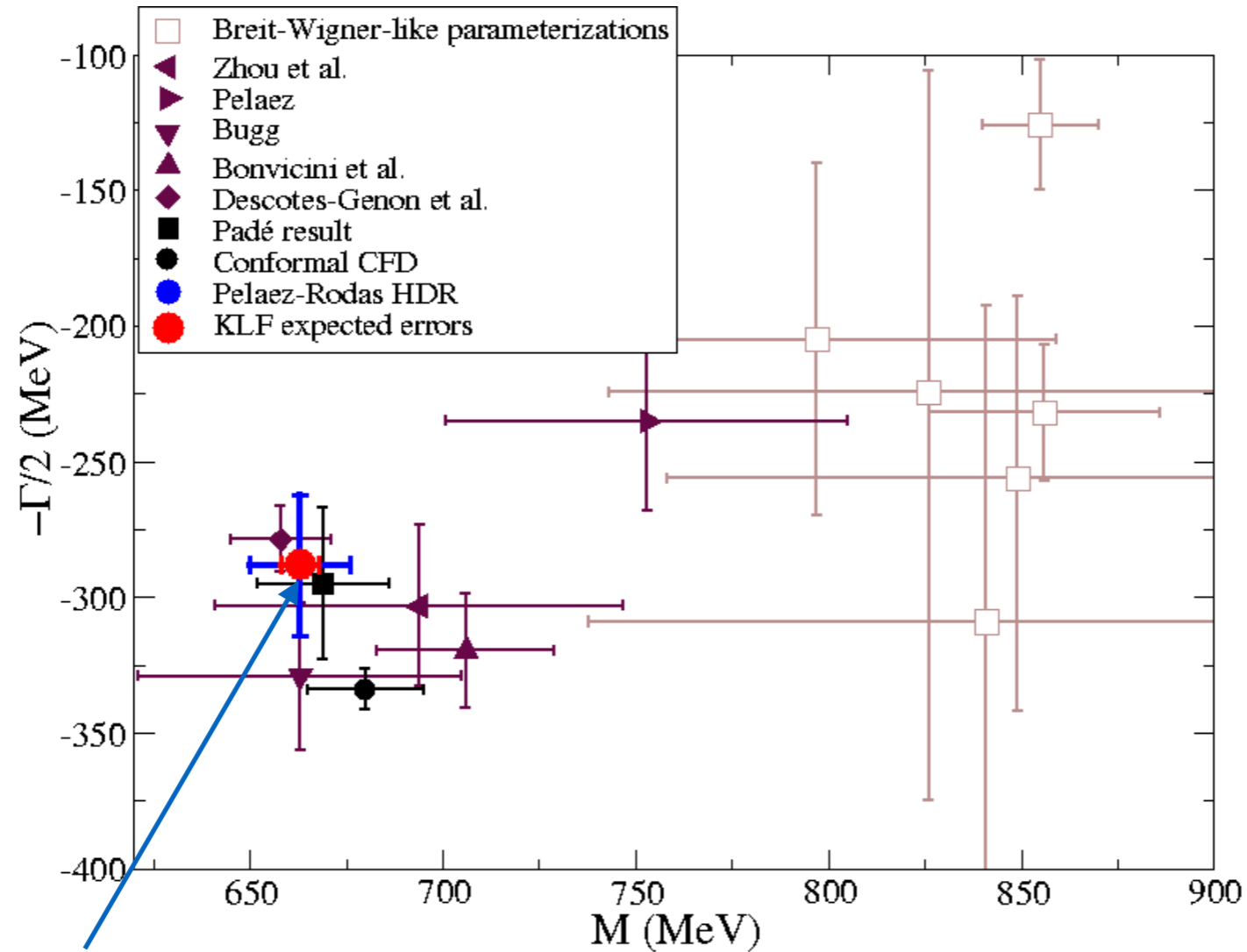
S-wave phase shift



KLF 100 days



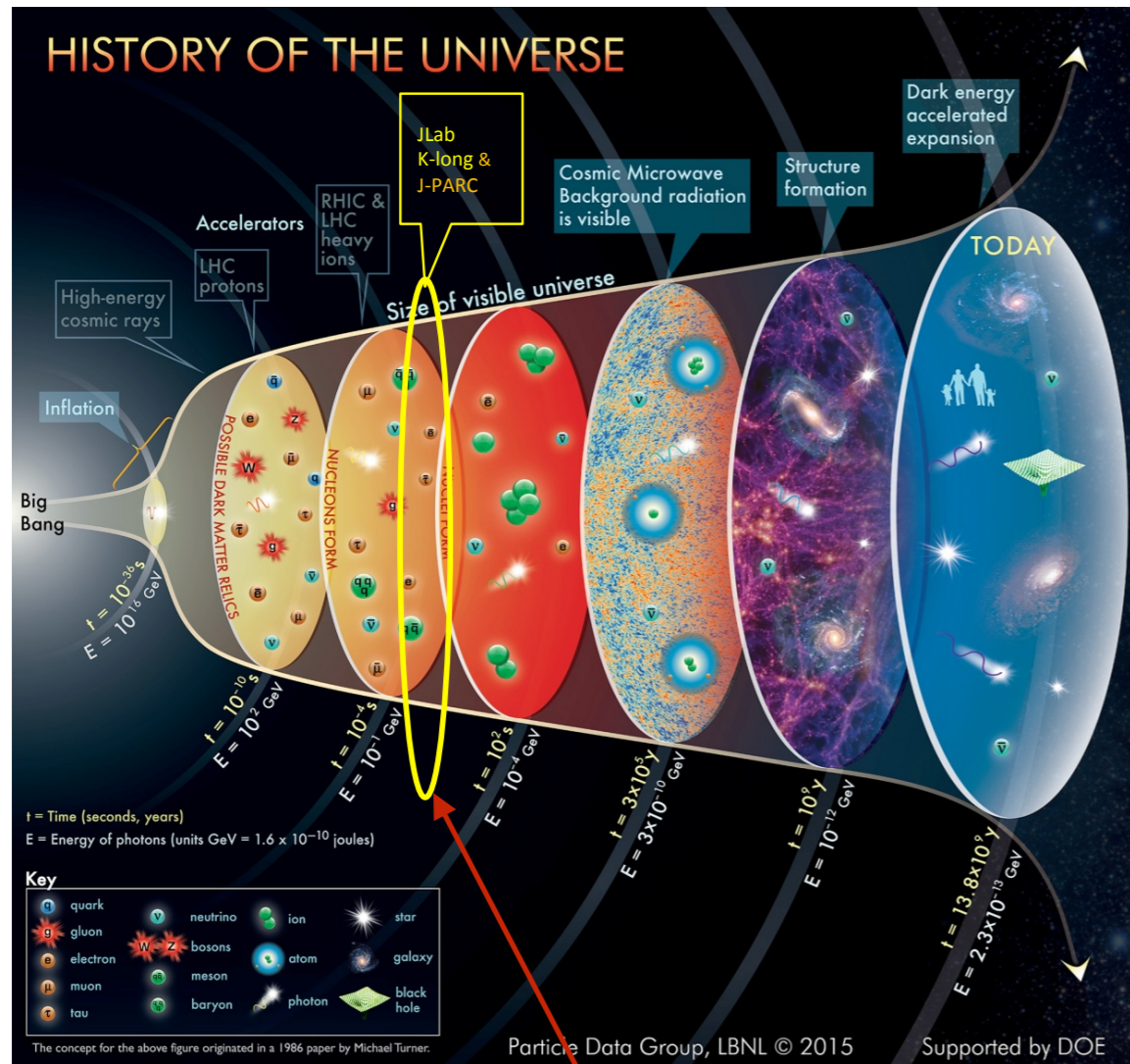
Width and Mass of κ (800)



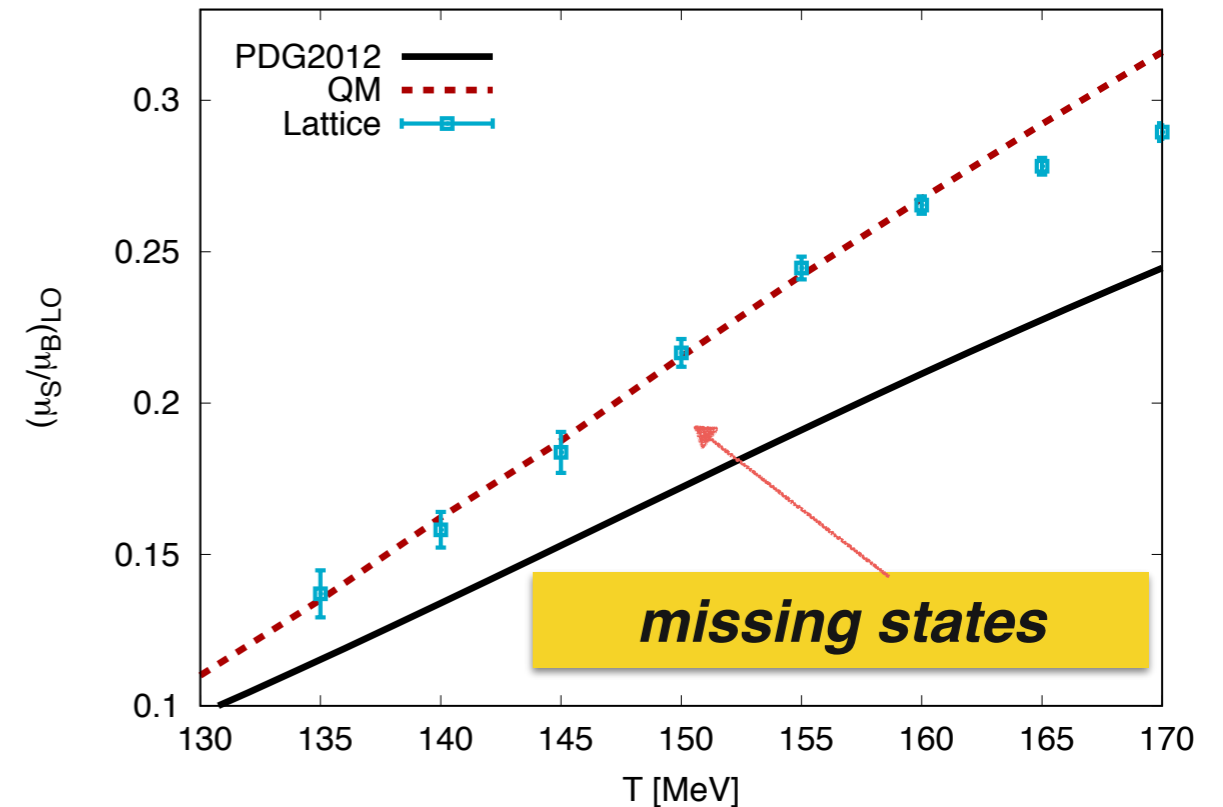
100 days of running

**Measurement with KLF will reduce:
Uncertainty in the mass by factor of two
Uncertainty in the width by factor of five!**

Evolution of Early Universe at Freeze-out



Chemical Potential



YSTAR2016 Proceedings arXiv:
1701.07316

We are here: $1 \mu s$ After the Big Bang

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

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



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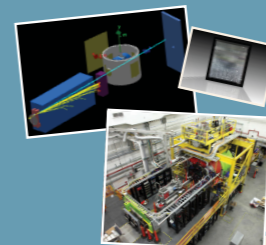


HIPS 2017

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_s 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_s 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

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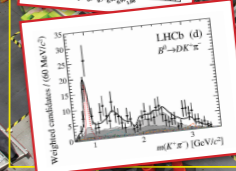
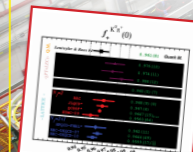
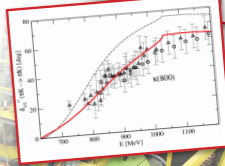
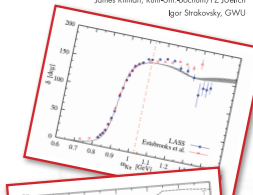
π-K Interactions
Workshop

ORGANIZING COMMITTEE

Moskov Amaryan, ODU (Chair)
U.-G. Meissner, U. Bonn/IFZ Jülich
Curtis Meyer, CMU
James Ritman, Ruhr-Uni-Bochum/IFZ 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_{us} 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_s 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

Epilogue

All questions raised by the PAC47 are addressed

The KL Facility will improve our knowledge on many topics of strange hadron spectroscopy in unprecedented way

Final version of the proposal will be sent to the Collaboration by the end of May

Thank you !