



Strange Hadron Spectroscopy with Secondary K_L Beam in Hall-D

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*Old Dominion University
Norfolk, VA*

AANL, Yerevan, October 28, 2021

Dedicated to the Memory of Professor Maxim Polyakov Who Unexpectedly Passed Away in August 2021



Outline

-Introduction

-K_L Facility Beamline and Hardware

- Electron Beam

- Compact Photon Source

- Be Target

- Flux Monitor

- K_L Beam

- LH₂/LD₂ Target

-Expected Physics results

- Hyperon Spectroscopy

- Strange Meson Spectroscopy

- Early Universe

2

Summary

48th PROGRAM ADVISORY COMMITTEE (PAC 48)

August 10-14, 2020

September 25, 2020



U.S. DEPARTMENT OF
ENERGY



Prepared for the U.S. Department of Energy
under Contract DE-AC05-06OR23177

Recommendations

PAC 48 SUMMARY OF RECOMMENDATIONS								
Number	Contact Person	Title	Hall	Days Req'd	Days Awarded	Scientific Rating	PAC Decision	Topic
C12-18-005	M. Boer	Timelike Compton Scattering Off Transversely Polarized Proton	C	50			C2	4
C12-19-001	M. Amarian	Strange Hadron Spectroscopy with Secondary KL Beam in Hall D	D	200	200	A-	Approved	1

Title: Strange Hadron Spectroscopy with Secondary KL Beam in Hall D

Spokespersons: M. Amarian (contact), M. Bashkanov, S. Dobbs, J. Ritman, J. Stevens, I. Strakovsky

Motivation: The spectroscopy of strange baryons and mesons, including their fundamental strong interactions, are the focus of this proposal. New and unique data can be obtained with an intense K_L beam aimed at a hydrogen/deuterium target, using the GlueX apparatus to detect final state particles.

Measurement and Feasibility: The proponents have answered all questions outlined in the PAC47 report. Substantial progress has been made on the issues of simulations: details on backgrounds and background reactions have been demonstrated, a demonstration of partial wave analysis for hyperon production was given. The proponents have demonstrated the measuring technique of missing mass reconstruction, allowing them to extend the measuring range both regarding small, four-momentum transfers and isospin decomposition. No show stoppers have been pointed out by the TAC.

Issues: The PAC strongly recommends that the collaboration intensify their cooperation on two issues. (1) Coordinated leadership must be established together with the host laboratory to address the various technical issues connected with the R&D efforts and construction of the K_L beam. (2) Continuous cooperation with JPAC and associated members is recommended for the development of tools to master the challenges connected with the clean extraction of $K\pi$ scattering, the identification of the exchange processes at small momentum transfers, and the amplitude analysis for Δ final states.

Summary: The future K_L facility will add a new physics reach to JLab, and the PAC is looking forward to see the idea being materialized, in conjunction with the plans for Hall D as spelled out in the 2019 White Paper. The collaboration should now devote all its energy to turn this challenging project into an experimental facility and in parallel prepare for a successful data analysis.

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D

Experimental Support:

Shankar Adhikari⁴³, Moskov Amaryan (**Contact Person, Spokesperson**)⁴³, ~~Arshak Asaturyan¹~~, **(Yerevan)**,
 Alexander Austregesilo⁴⁹, Marouen Baalouch⁸, Mikhail Bashkanov (**Spokesperson**)⁶³,
 Vitaly Baturin⁴³, Vladimir Berdnikov^{11,35}, Olga Cortes Becerra¹⁹, Timothy Black⁶⁰,
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 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},
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 Kevin Luckas²⁸, Valery Lyubovitskij^{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,
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 Lubomir Pentchev⁴⁹, William Phelps¹⁰, John Price⁷, Jörg Reinhold¹³,
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 Susan Schadmand²⁸, Amy Schertz⁵⁶, Axel Schmidt¹⁹, Daniel Sober¹¹, Alexander Somov⁴⁹,
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 Holly Szumila-Vance¹⁹, Daniel Watts⁶³, Lawrence Weinstein⁴³, Timothy Whitlatch⁴⁹,
 Nilanga Wickramaarachchi⁴³, Bogdan Wojtsekhowski⁴⁹, Nicholas Zachariou⁶³,
 Jonathan Zarling⁵³, Jixie Zhang⁶¹

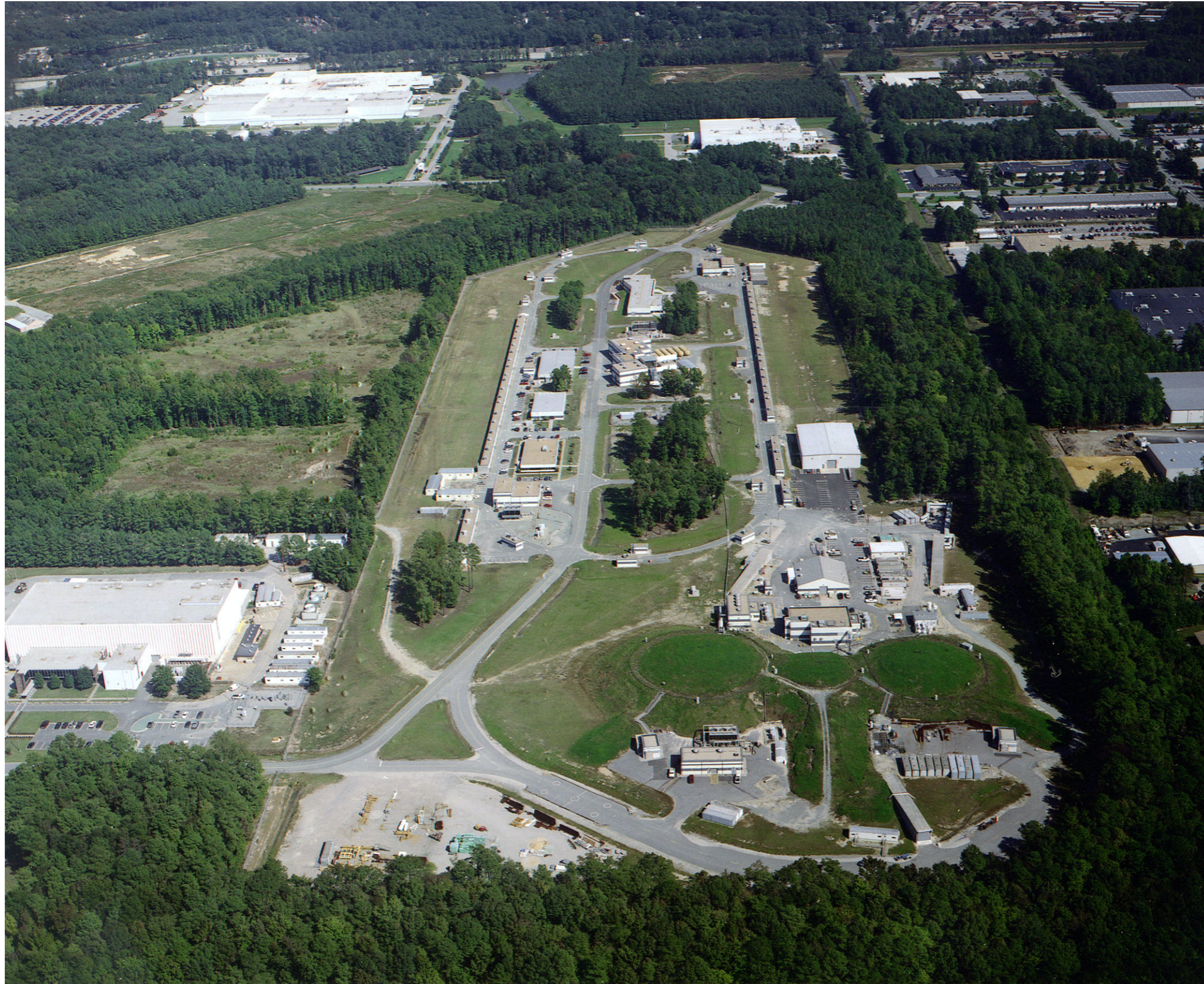
Theoretical Support:

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,
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 Andrey Sarantsev^{5,44}, Jugoslav Stahov⁵⁵, Alfred Švarc⁴⁷, Adam Szczepaniak^{22,49},
 Ronald Workman¹⁹, Bing-Song Zou⁴

There Were Many Questions

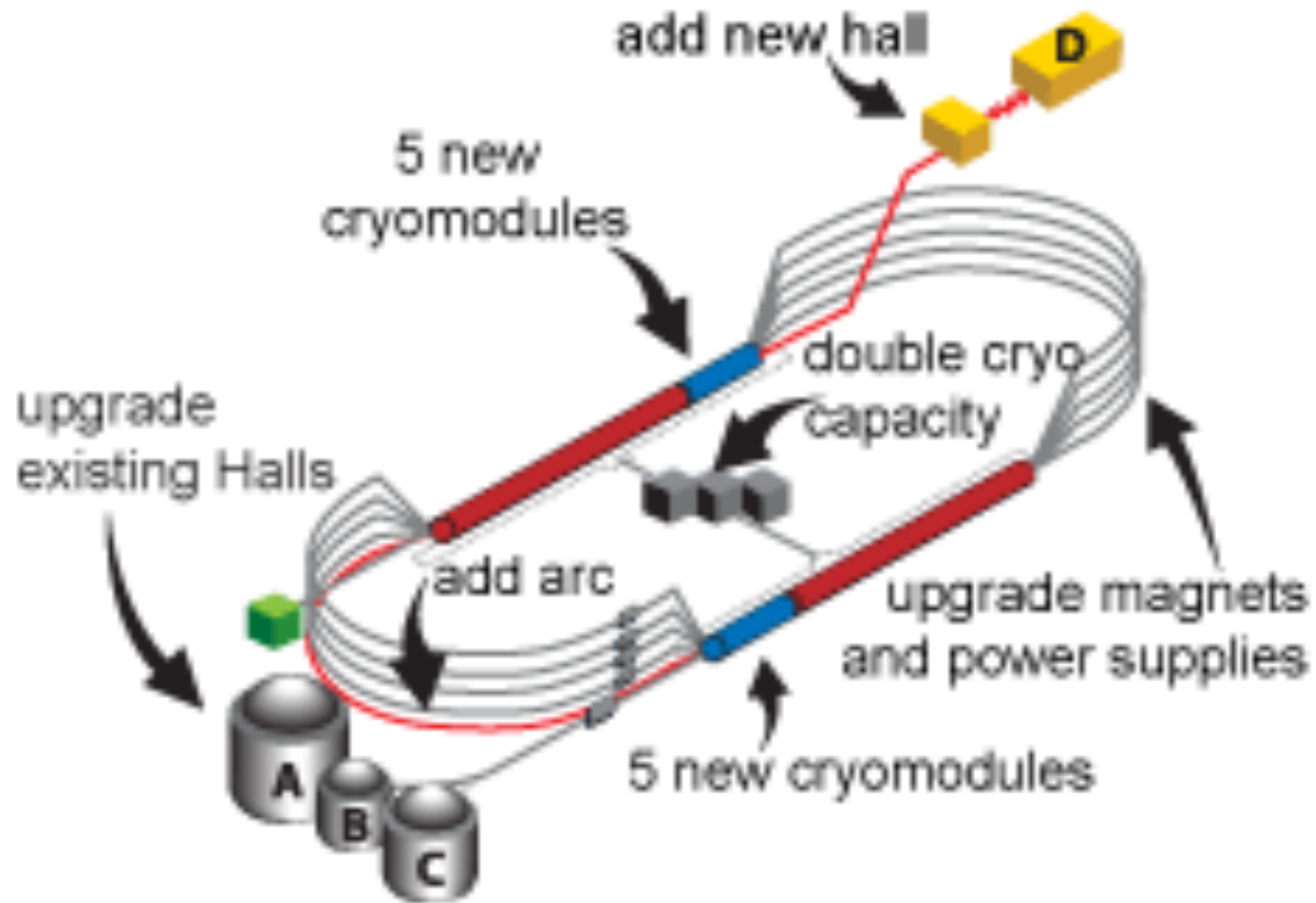
- **Why to use kaon beam? What is the advantage compared to electrons or photons?**
- **What is so special about K-long compared to charged kaon beam?**
- **What is the advantage of producing secondary kaon beam with EM probe, compared to a proton beam?**
- **How much CEBAF accelerator could make a breakthrough compared to previous results at SLAC?**
- **Why to do this experiment, what are we going to learn?**
- **How will it affect our knowledge on hyperon spectroscopy?**
- **What are we going to learn about strange meson spectroscopy ?**
- **Many more questions - some constructive and some less so - answers to which shaped the approved proposal.**

Thomas Jefferson National Accelerator Facility Newport News, Virginia, Aerial View.

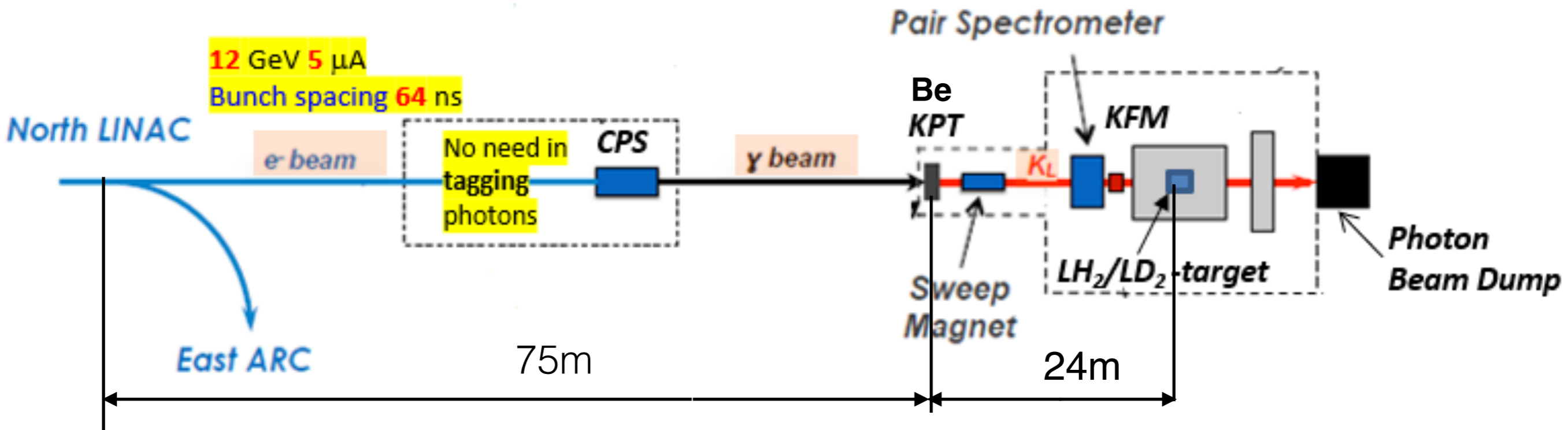


Continuous Electron Beam Accelerator Facility (CEBAF)

12 GeV Electron Beam



Hall-D beamline and GlueX Setup

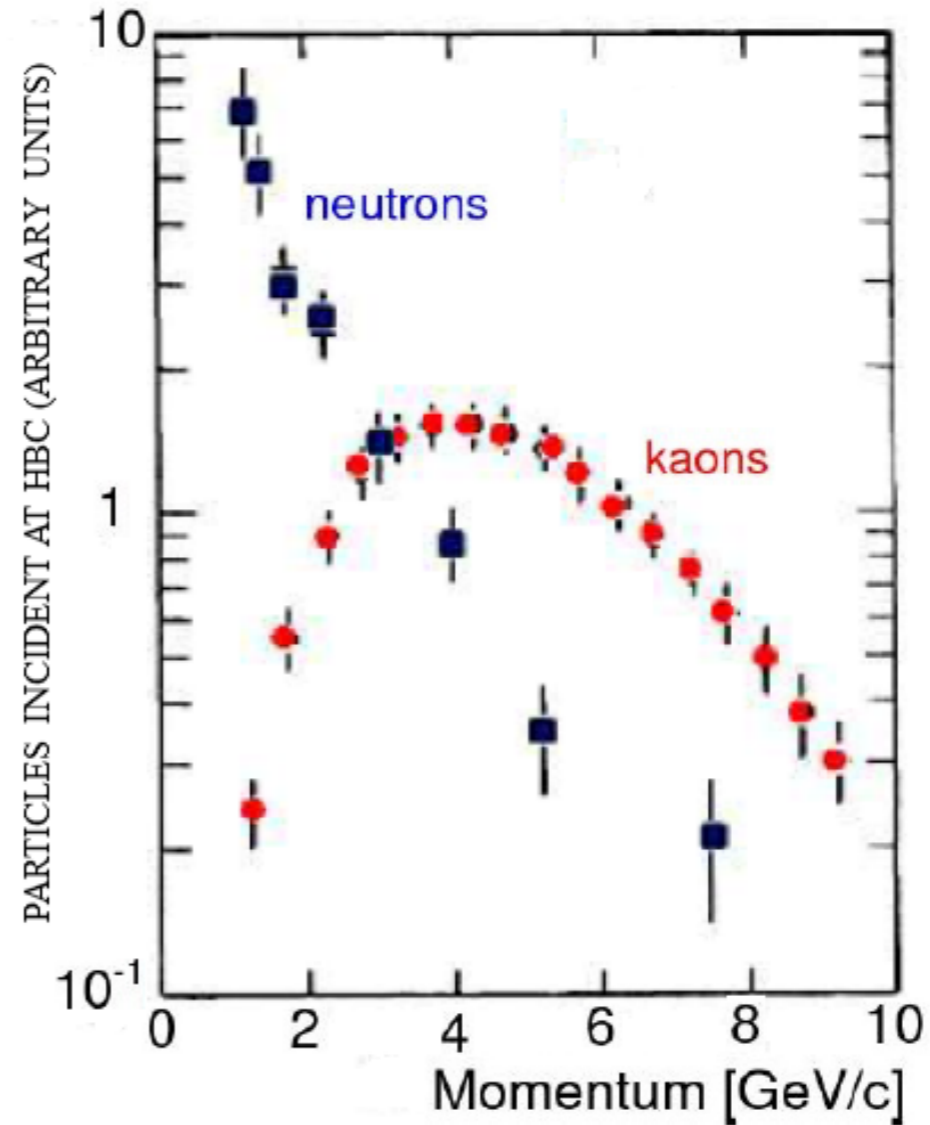
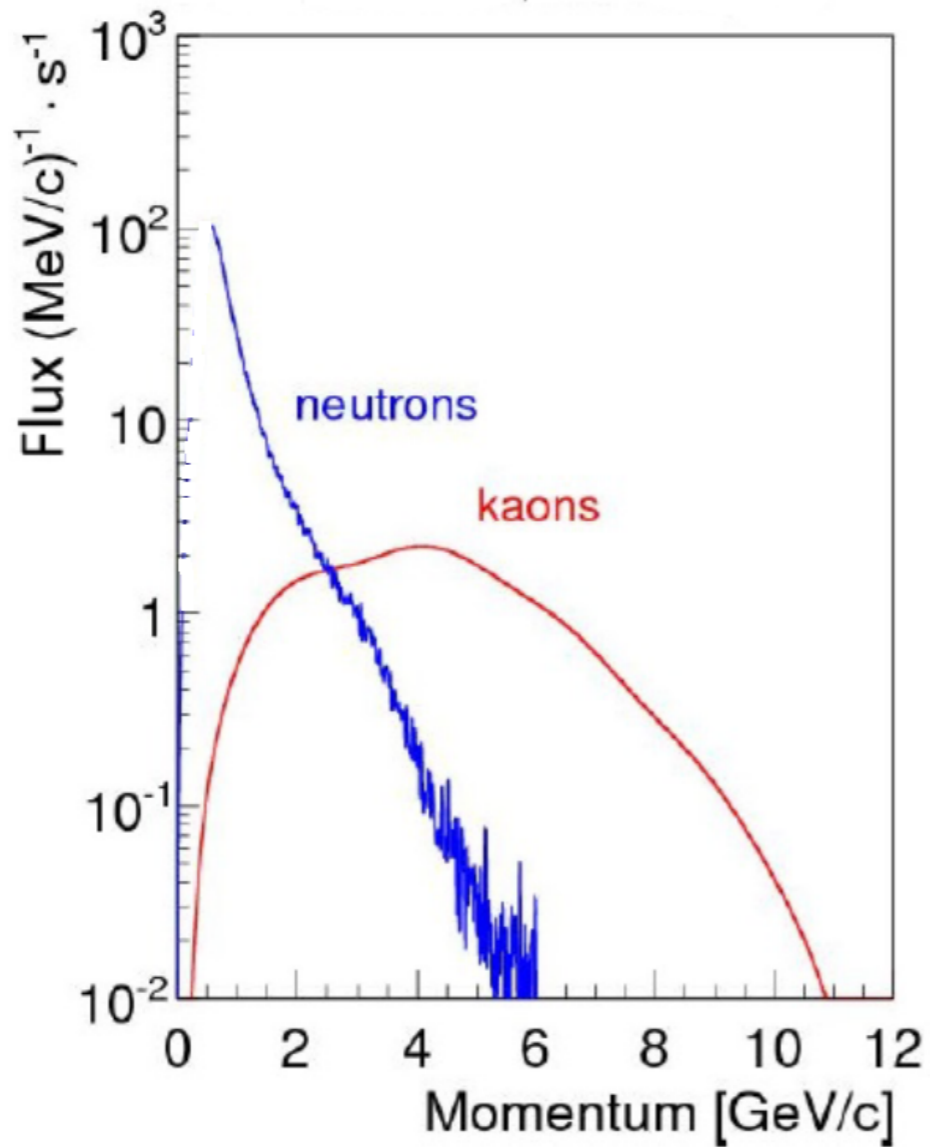


<https://arxiv.org/pdf/2008.08215.pdf>

K_L Beam Flux

JLab 12 GeV

SLAC 16 GeV



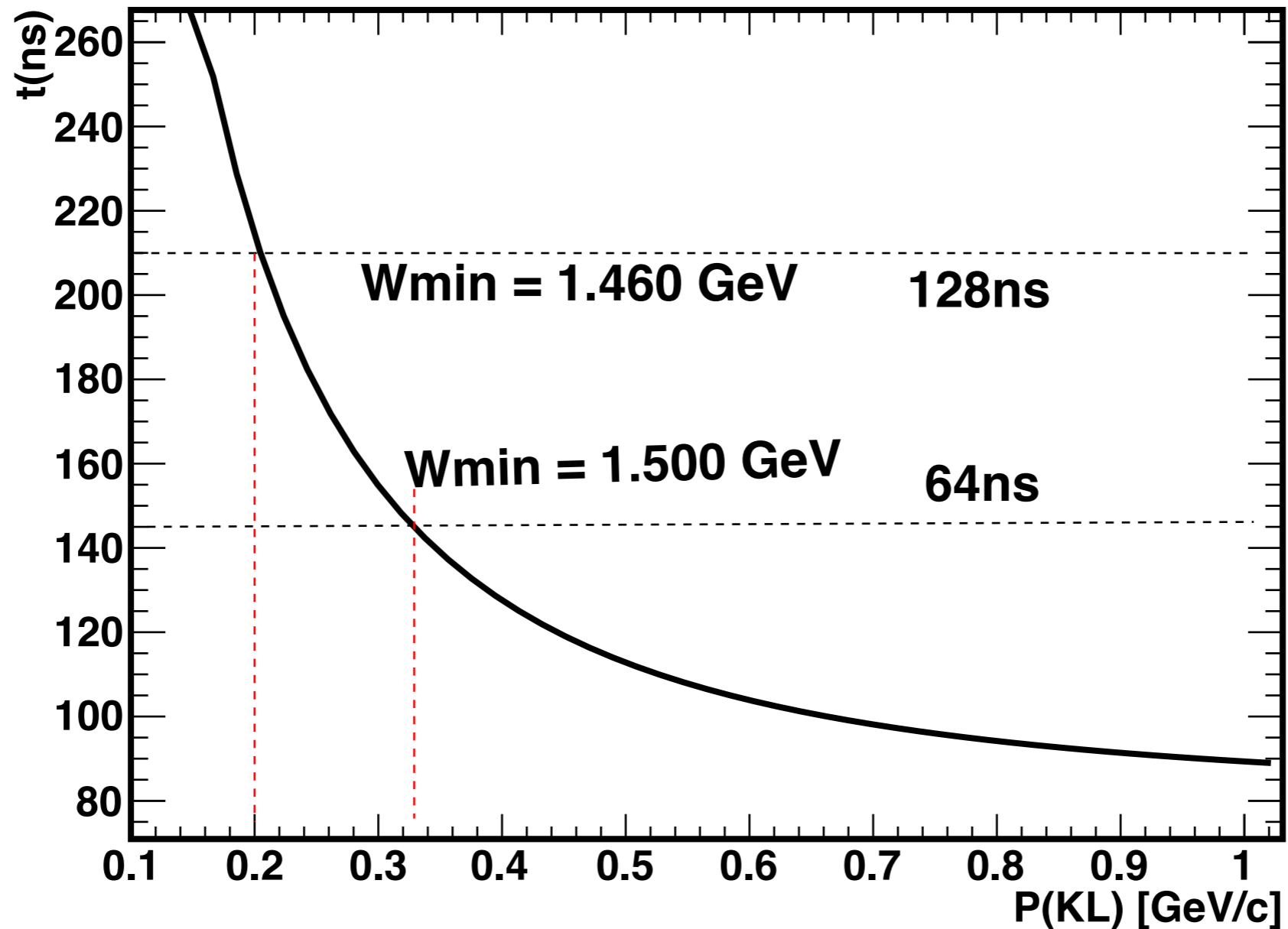
$$N(K_L)/sec \sim 10^4 \quad \longrightarrow \quad \frac{N(K_L)_{JLAB}}{N(K_L)_{SLAC}} \sim 10^3$$

Electron Beam Parameters

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

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

(Now 128 ns confirmed feasible)



5.7 K_L Momentum Determination and Beam Resolution

The mean lifetime of the K_L is 51.16 nsec ($c\tau = 15.3$ m) whereas the mean lifetime of the K^- is 12.38 nsec ($c\tau = 3.7$ m) [1]. For this reason, it is much easier to perform measurements of $K_L p$ scattering at low beam energies compared with $K^- p$ scattering.

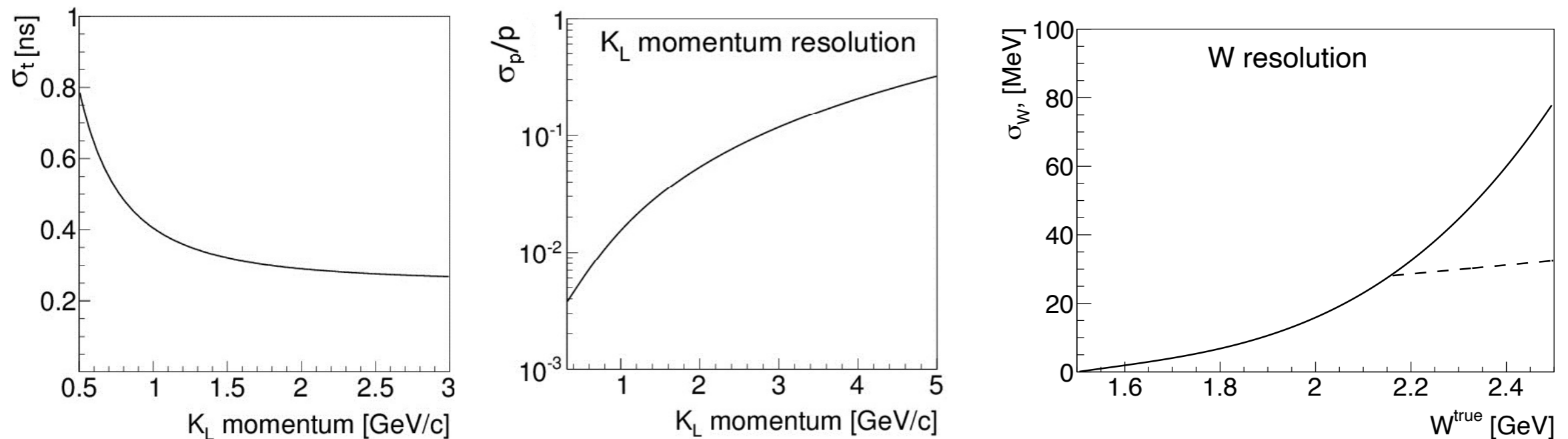


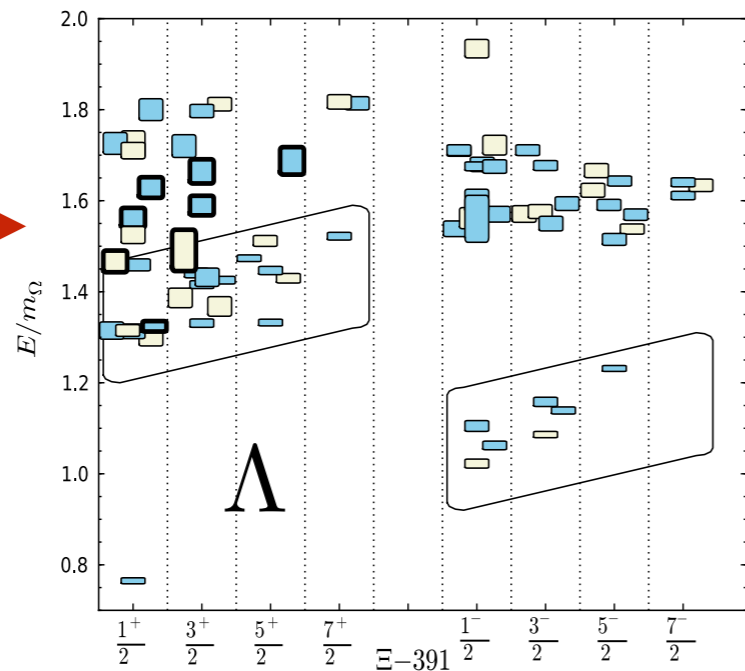
Figure 30: Left: Time resolution (σ_t) for K_L beam as a function of K_L -momentum. Middle: Momentum resolution (σ_p/p) as a function of momentum (note, log scale). Right: Energy resolution (σ_W) as a function of energy. The dashed line shows approximate W resolution from reconstruction of the final-state particles.

Hyperon Spectroscopy

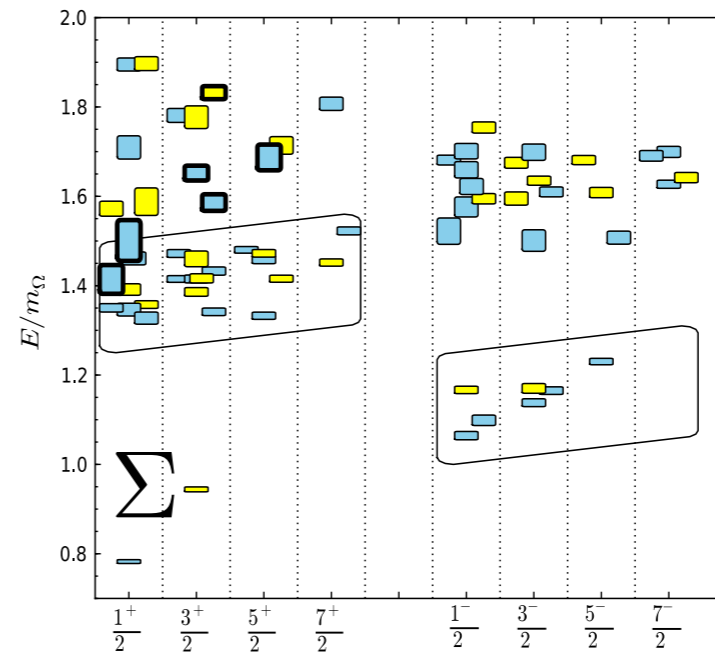
According to *LQCD* there should be many more states including hybrids (thick bordered)

8-states

5-states



$\Sigma-391$



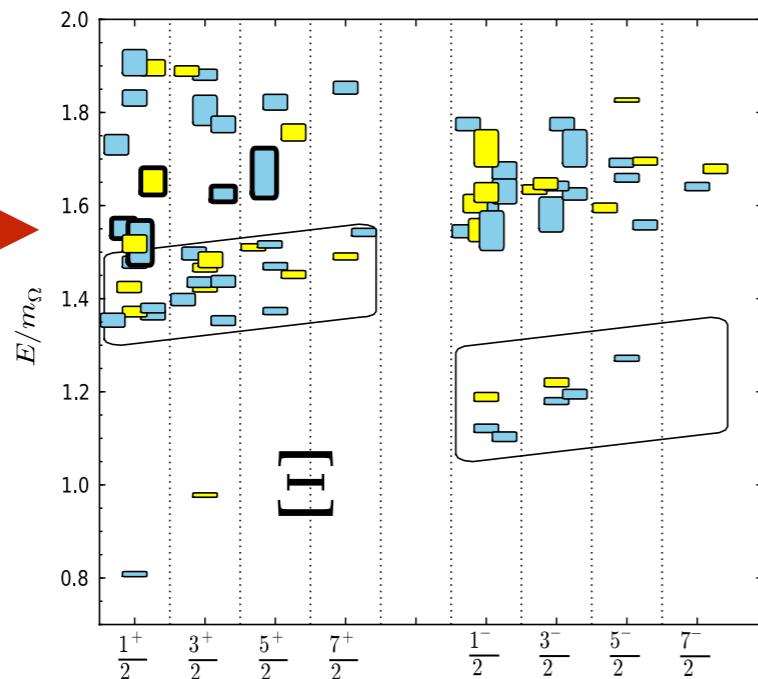
6-states

4-states

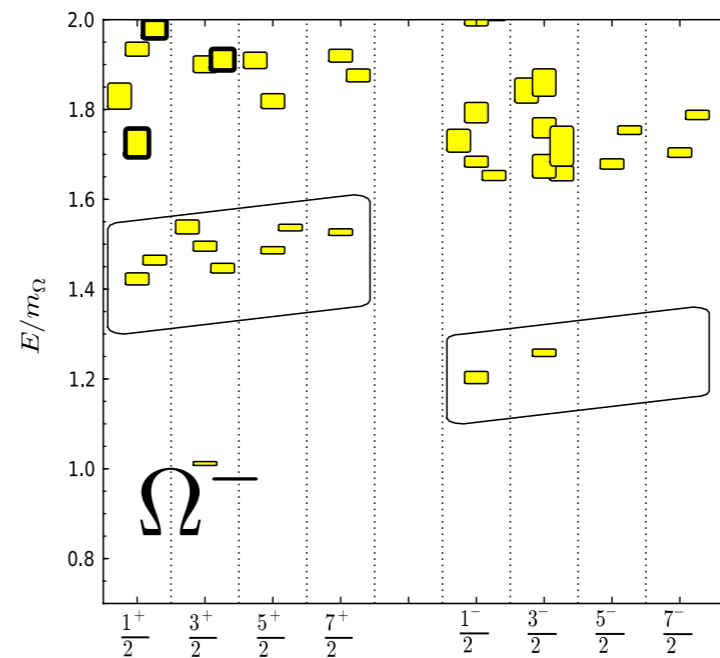


3-states

4-states



$\Omega-391$



1-state

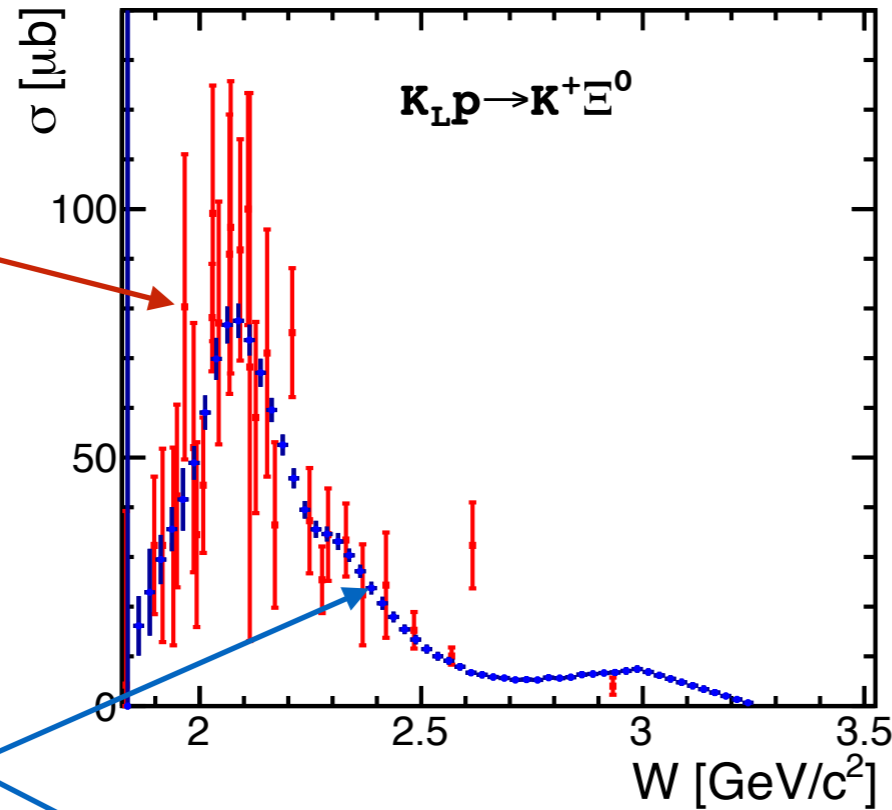
1-state



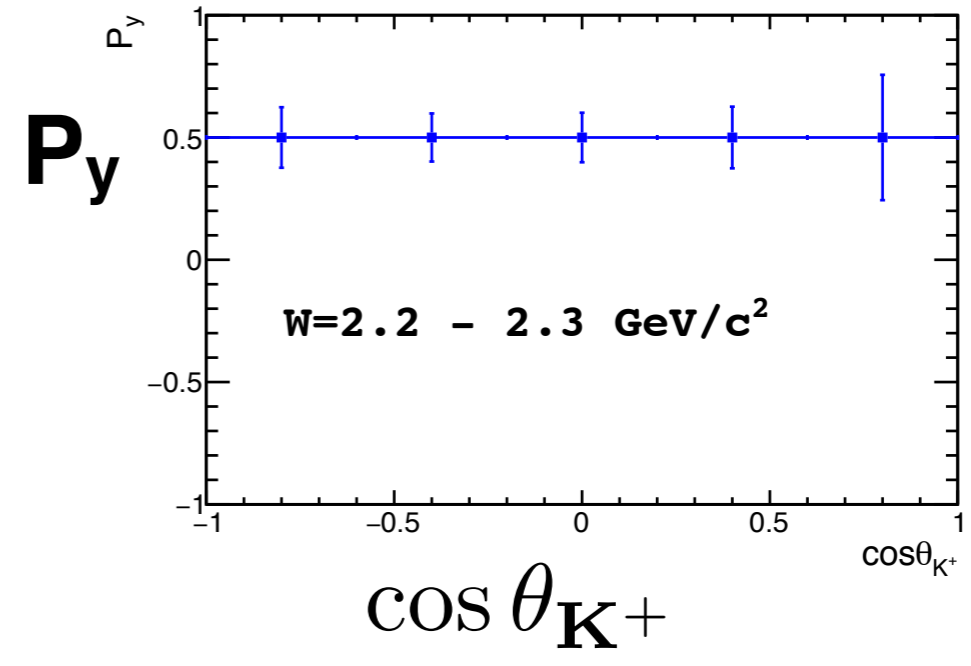
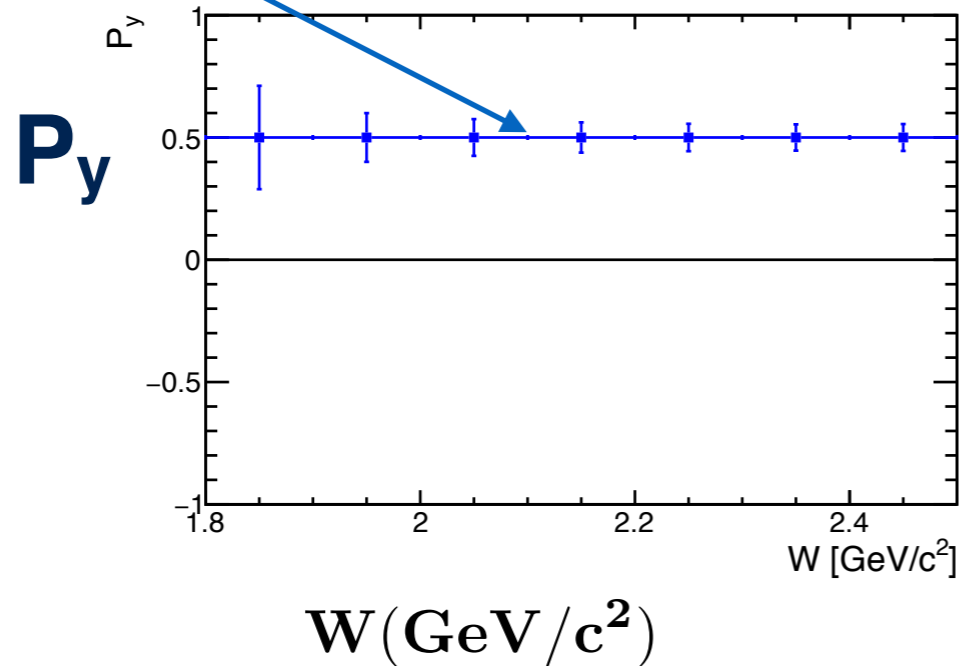
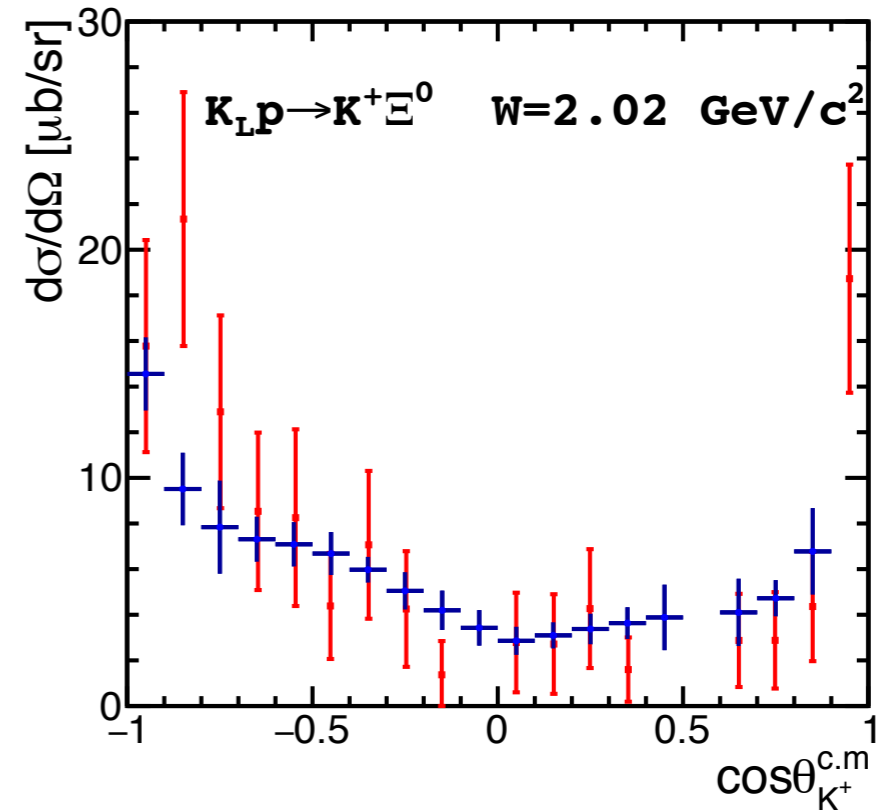
Edwards, Mathur, Richards and Wallace, *Phys. Rev. D* 87, 054506 (2013)

Measurements on Proton Target

existing data

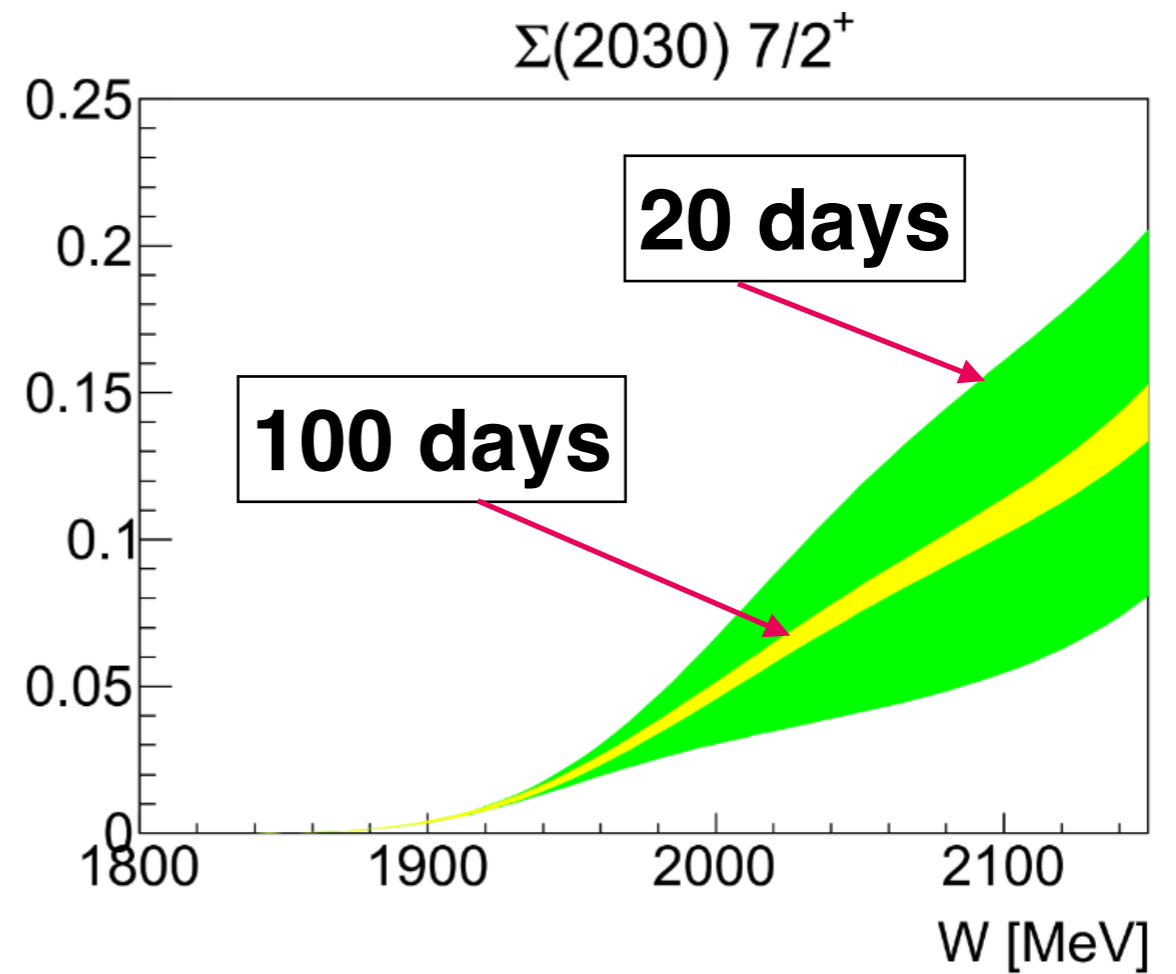
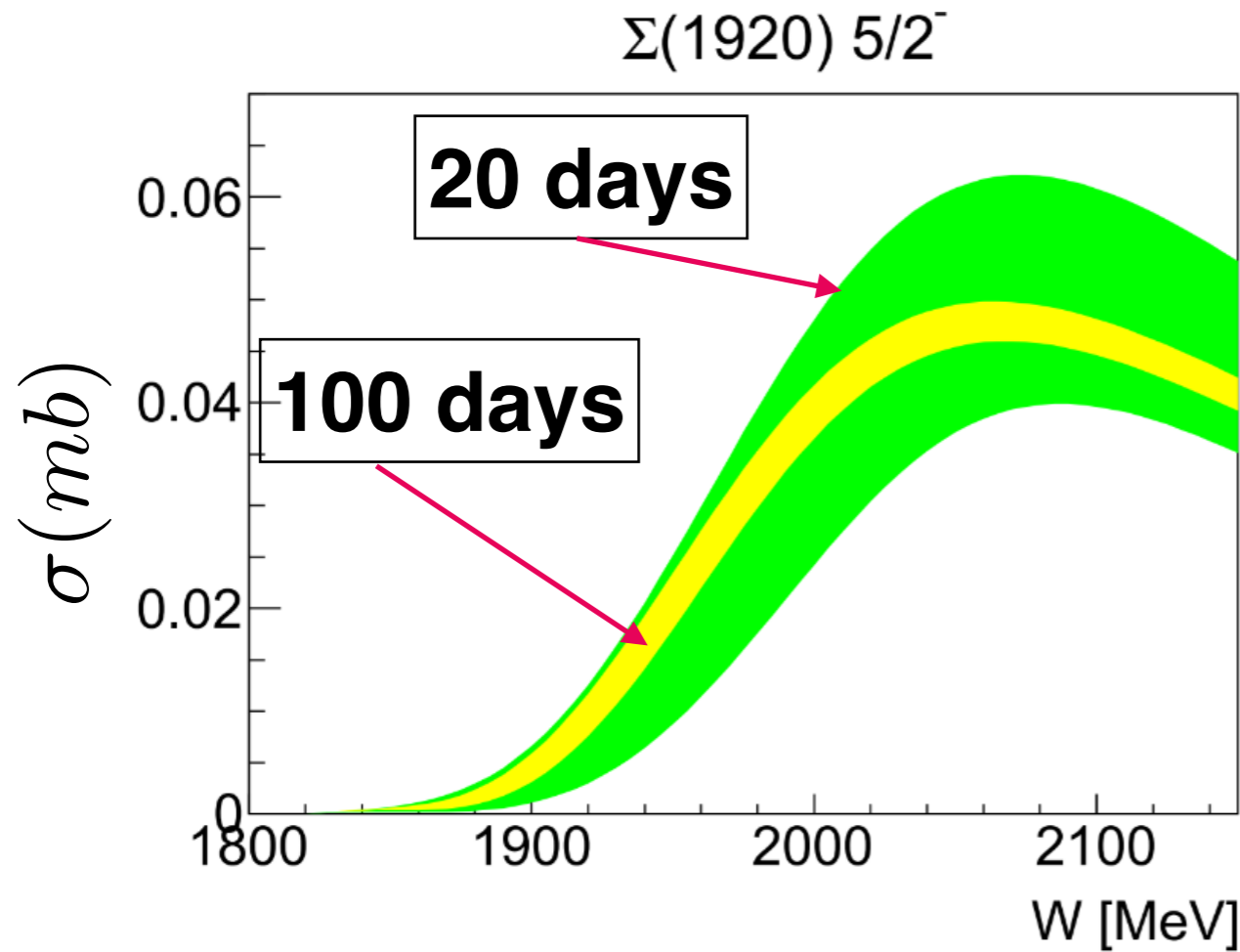
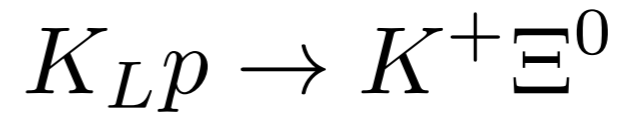


KLF 100 days



Bonn-Gatchina PWA

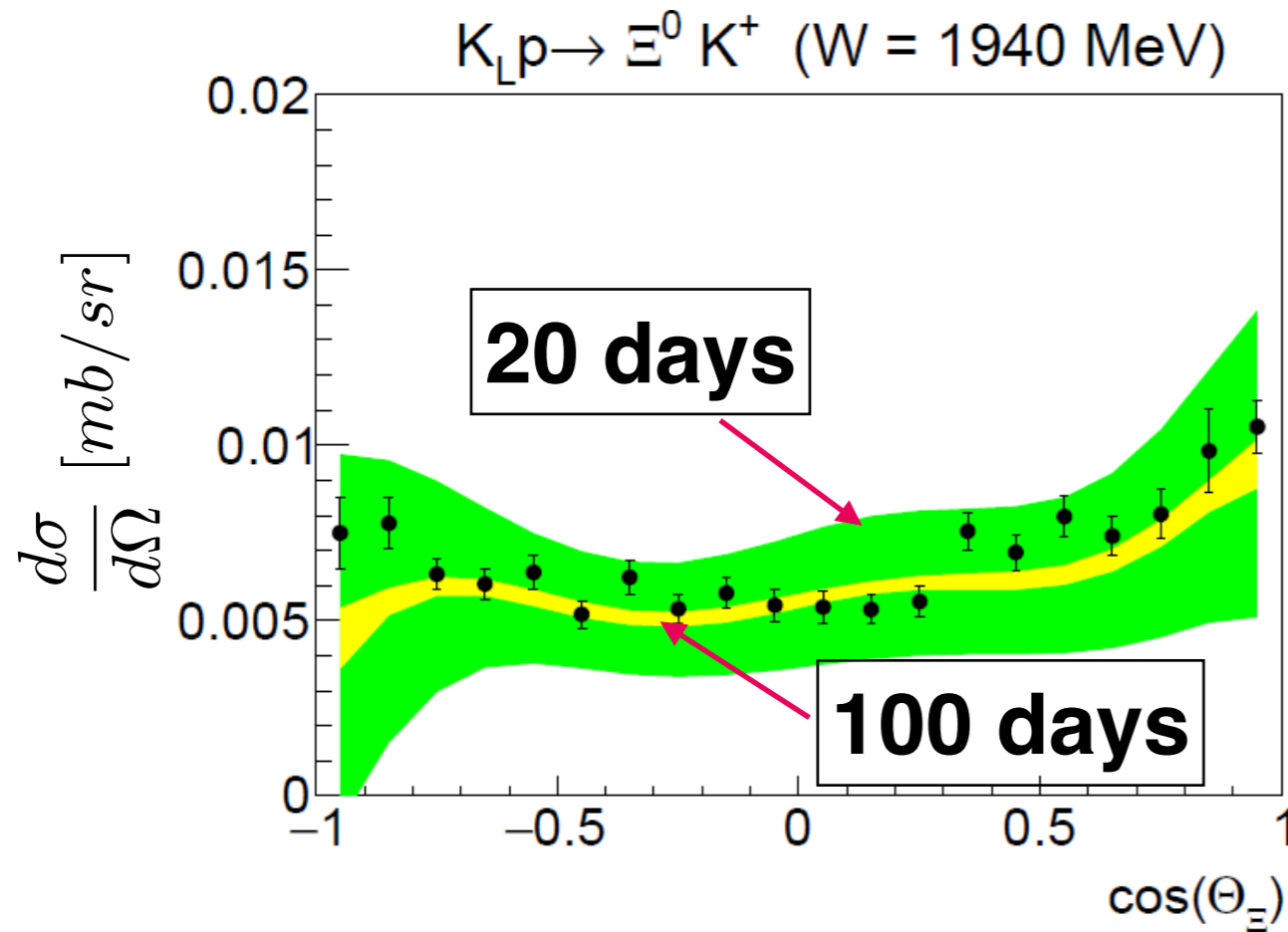
Total Cross Section



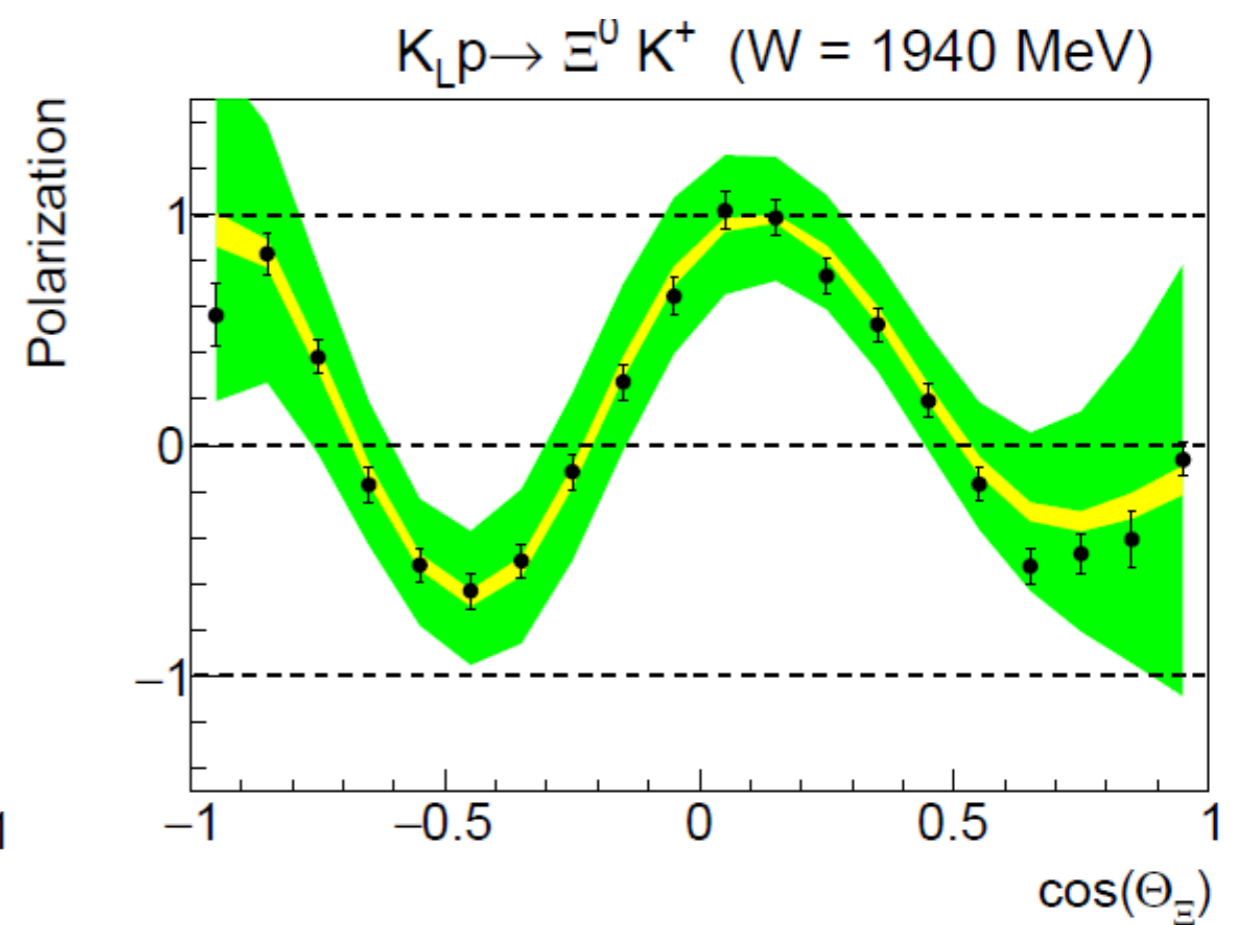
Need 100 days of running to get precise solution

Bonn-Gatchina PWA

Diff. Cross Section



Polarization



Need 100 days of running to get precise solution

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**

- look for poles in complex energy plane**
- identify excited hyperons with masses up to 2400 MeV
In a formation and production reactions**

$$\Lambda^*, \Sigma^*, \Xi^* \text{ \& \ } \Omega^*$$

we use KN scattering data with statistics generated according to expected K-long Facility (KLF) data for 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.

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

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

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

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

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

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

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

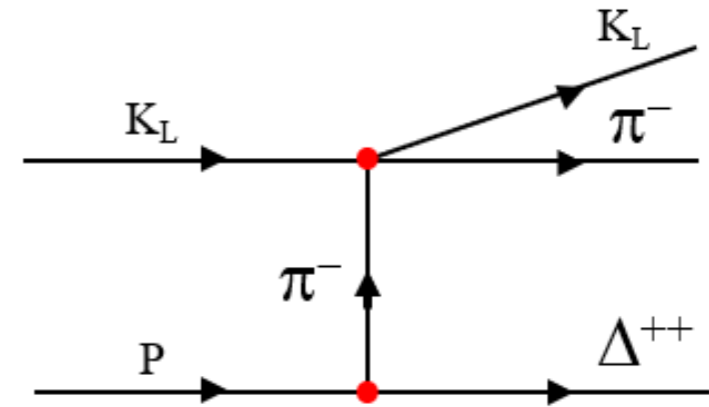
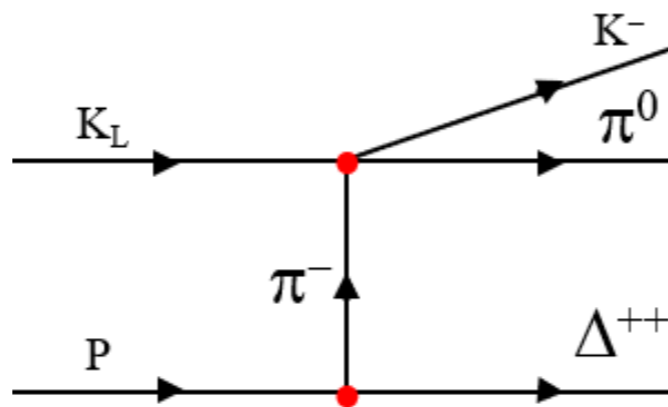
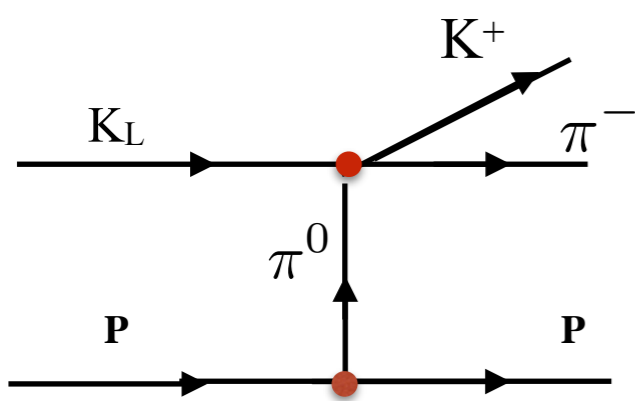
$$K_L n \rightarrow K_L \pi^0 n = \langle K_L \pi^0 | K_L \pi^0 \rangle = \frac{1}{3}(T^{\frac{1}{2}} + 2T^{\frac{3}{2}}),$$

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

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

Strange Meson Spectroscopy

$K\pi$ Scattering



Proposed Measurements

SLAC

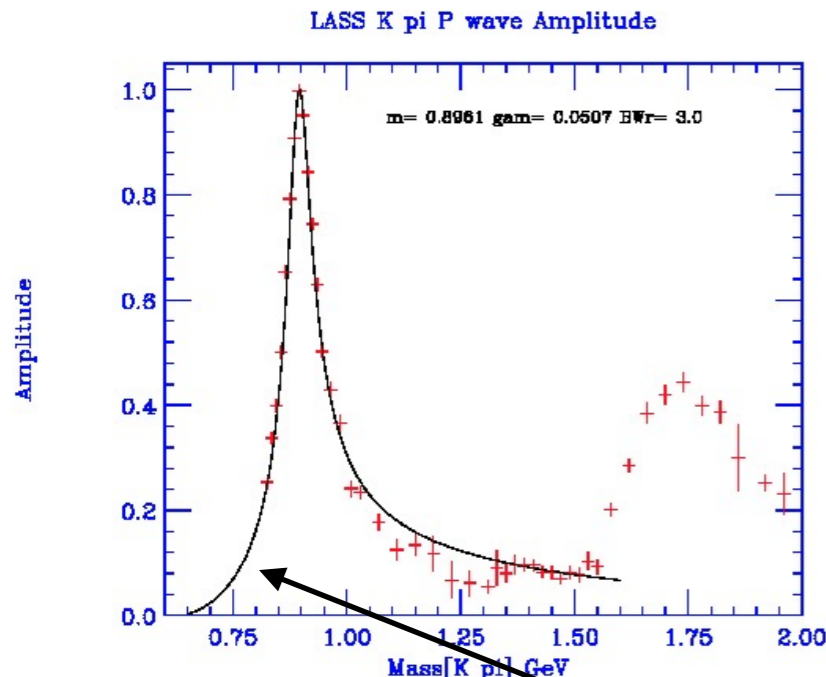
$$K^- \pi^+ \rightarrow K^- \pi^+$$

Belle

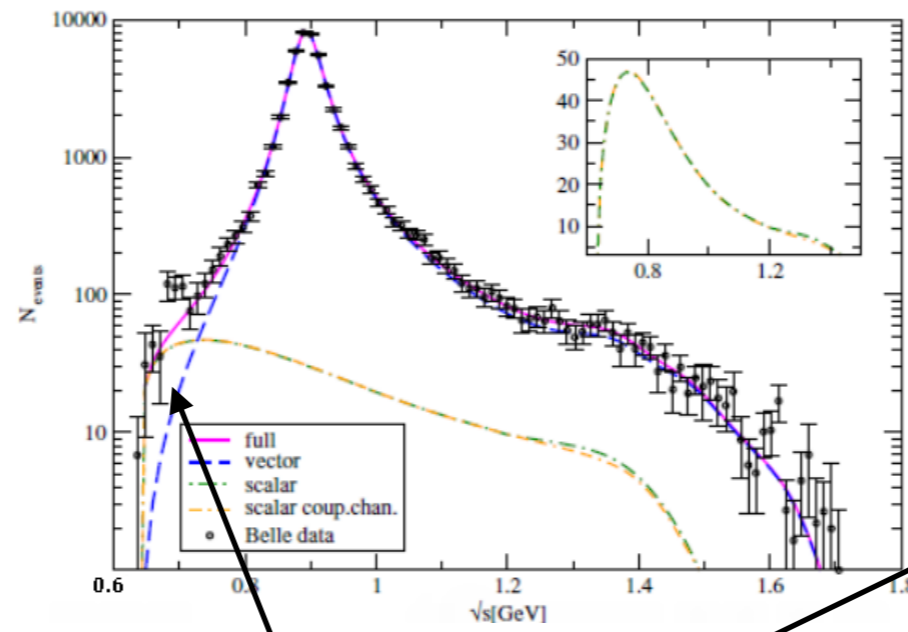
$$\tau \rightarrow K \pi \nu_\tau$$

KLF

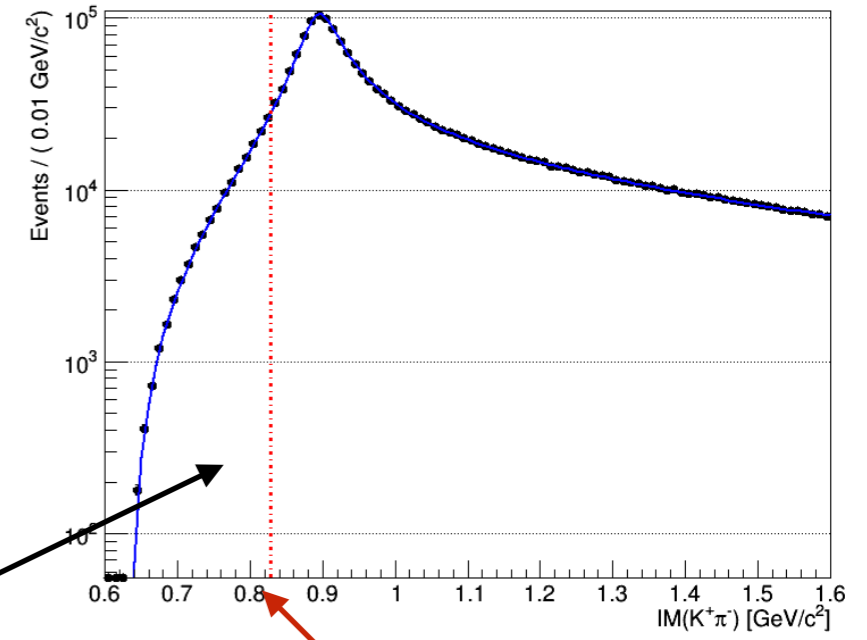
$$K_L \pi^0 \rightarrow K^+ \pi^-$$



$M(K\pi)$ (GeV)



$M(K\pi)$ (GeV)



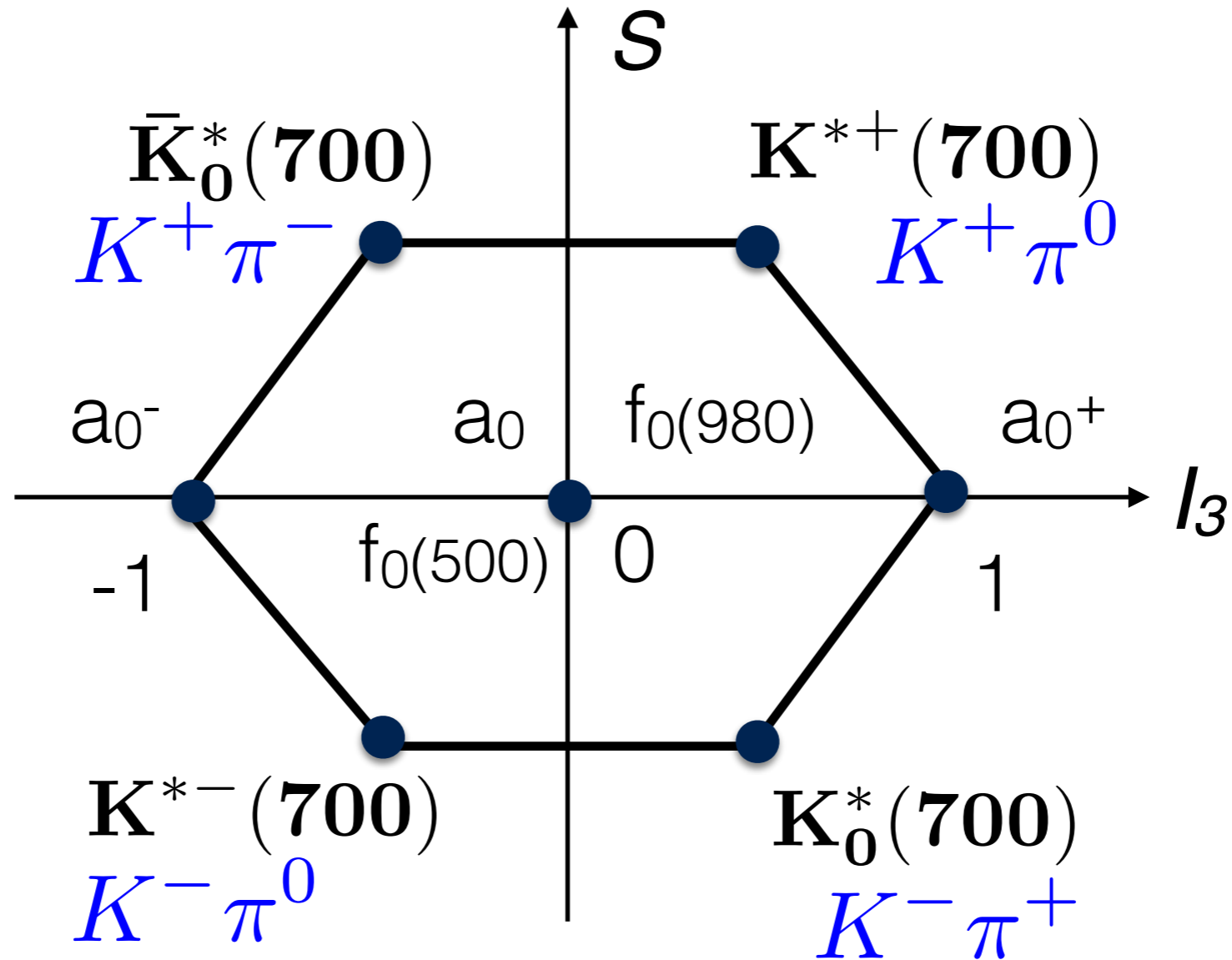
$M(K\pi)$ (GeV)

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

SLAC Lower limit

Scalar Meson Nonet

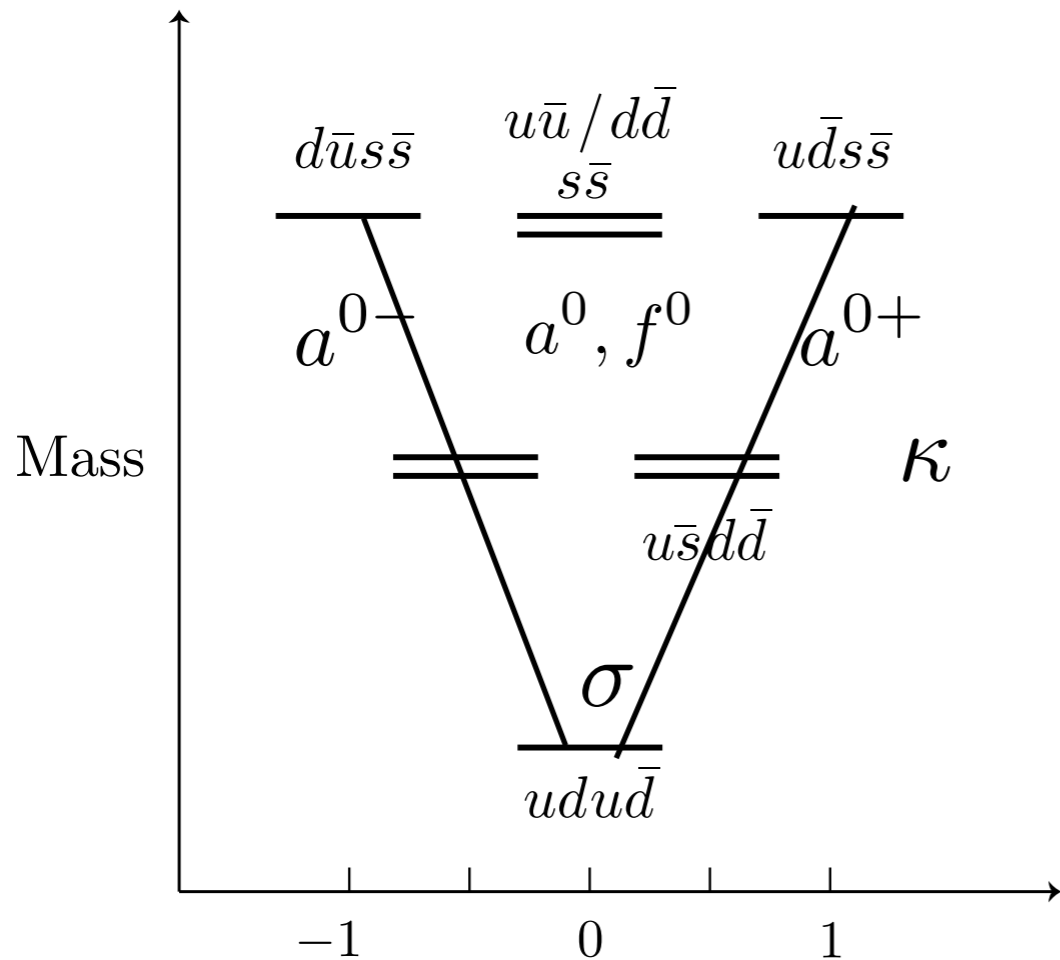
$$J^{PC} = 0^{++}$$



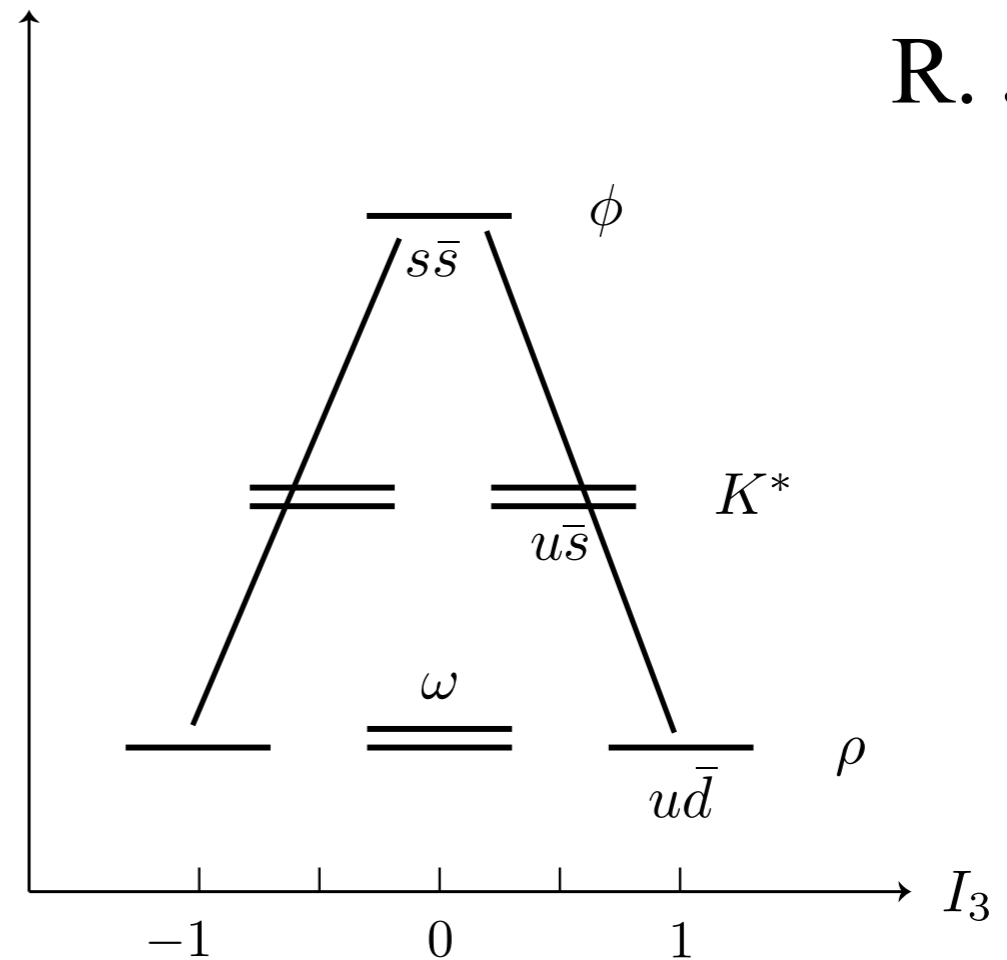
Four states called κ

still need further confirmation(PDG)

Scalar Mesons



Vector Mesons

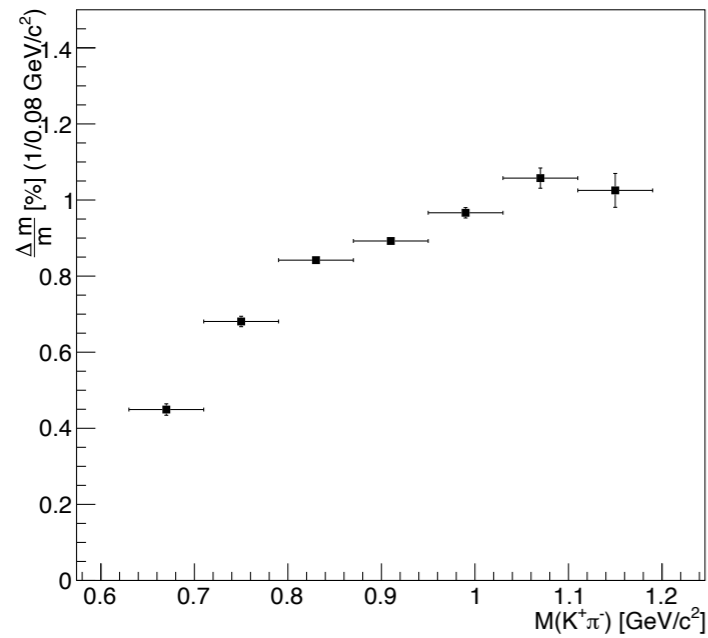


R. Jaffe

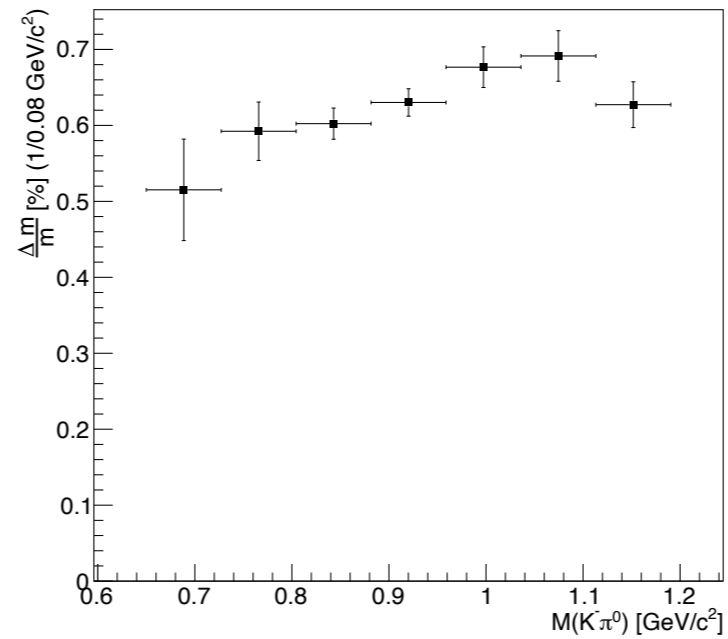
Figure 6. A cartoon representation of the masses of a $\bar{q}\bar{q}qq$ nonet compared with a $\bar{q}q$ nonet.

**Very different mass hierarchy
Possibly suggesting 4q tetraquark
structure of scalar mesons**

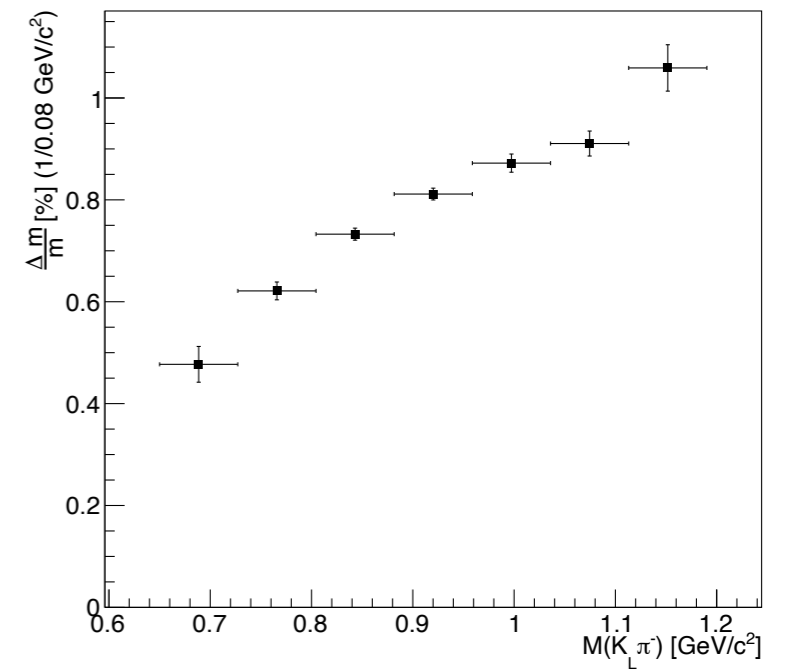
Invariant mass resolution $\Delta m/m$ (%)



$K^+\pi^-$



$K^-\pi^0$



$K_L\pi^-$

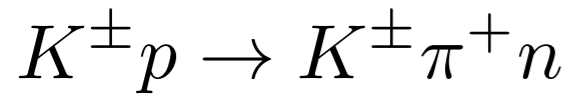
Below 1% in all cases

Projected Measurements

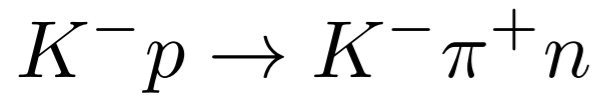
$I=3/2+1/2$

S -wave

SLAC Data

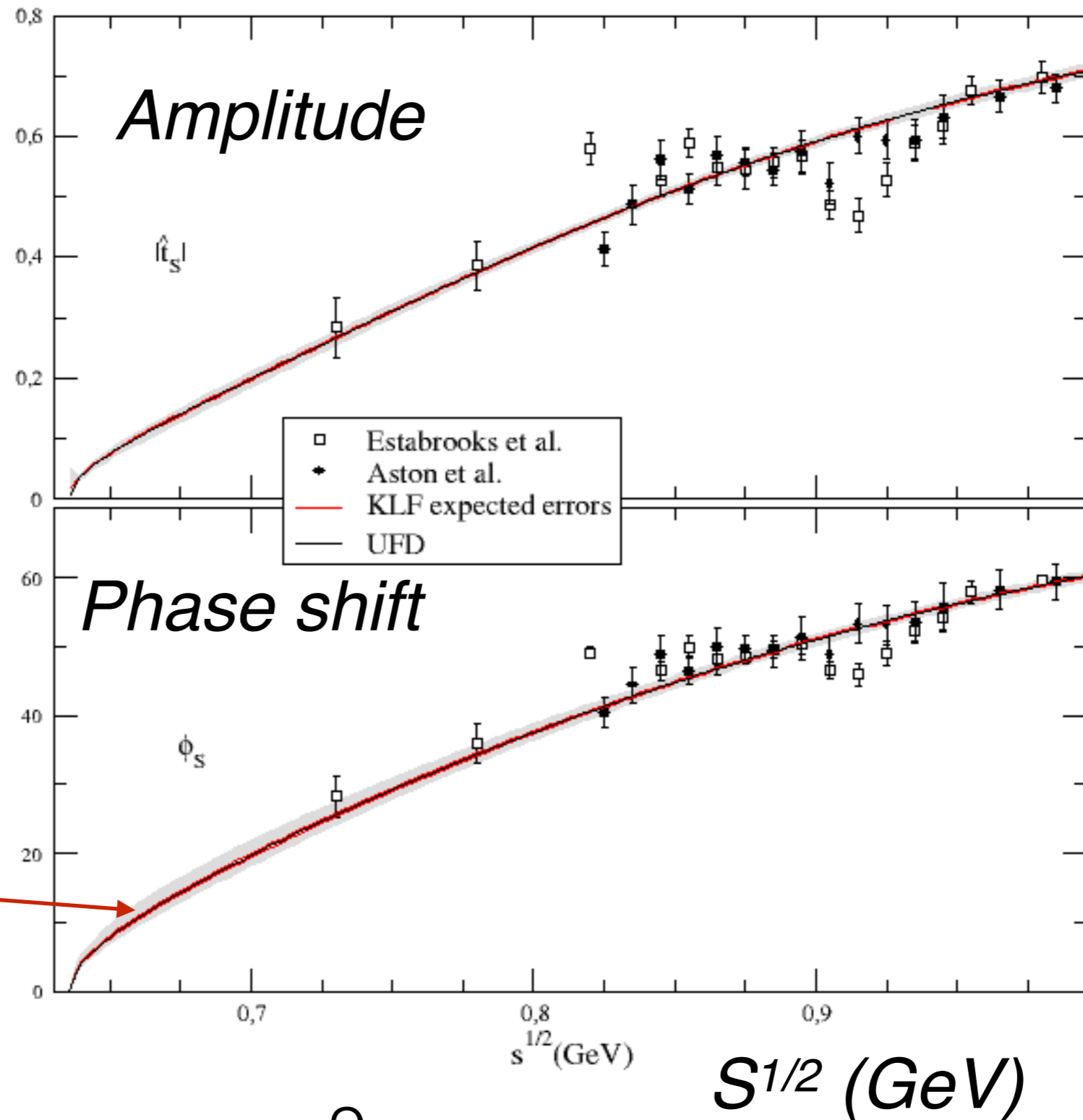


Estabrooks(1978)



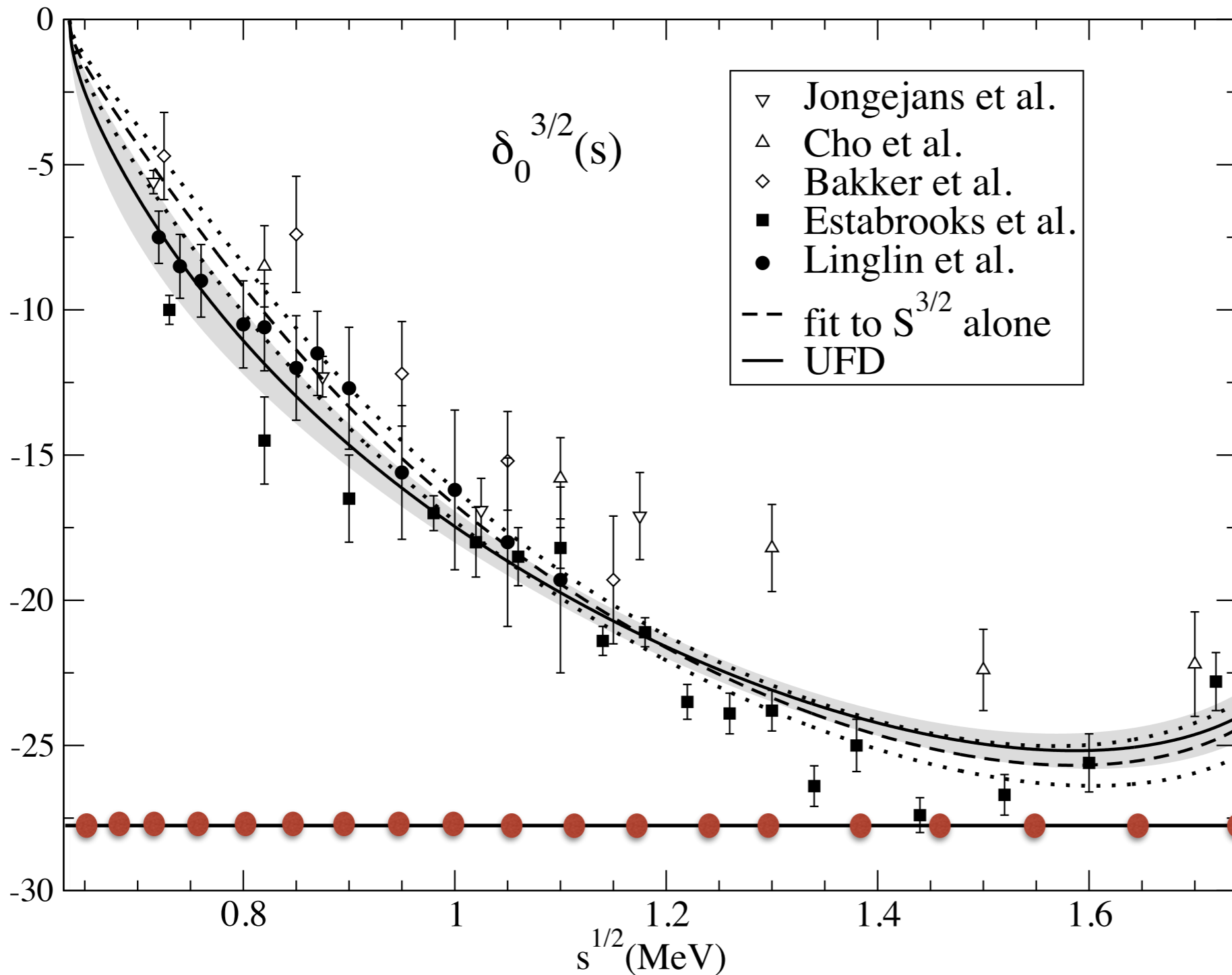
Aston(1988)

**KLF
(100 days)**



$I=3/2$

S -wave



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

Estabrooks(1978)

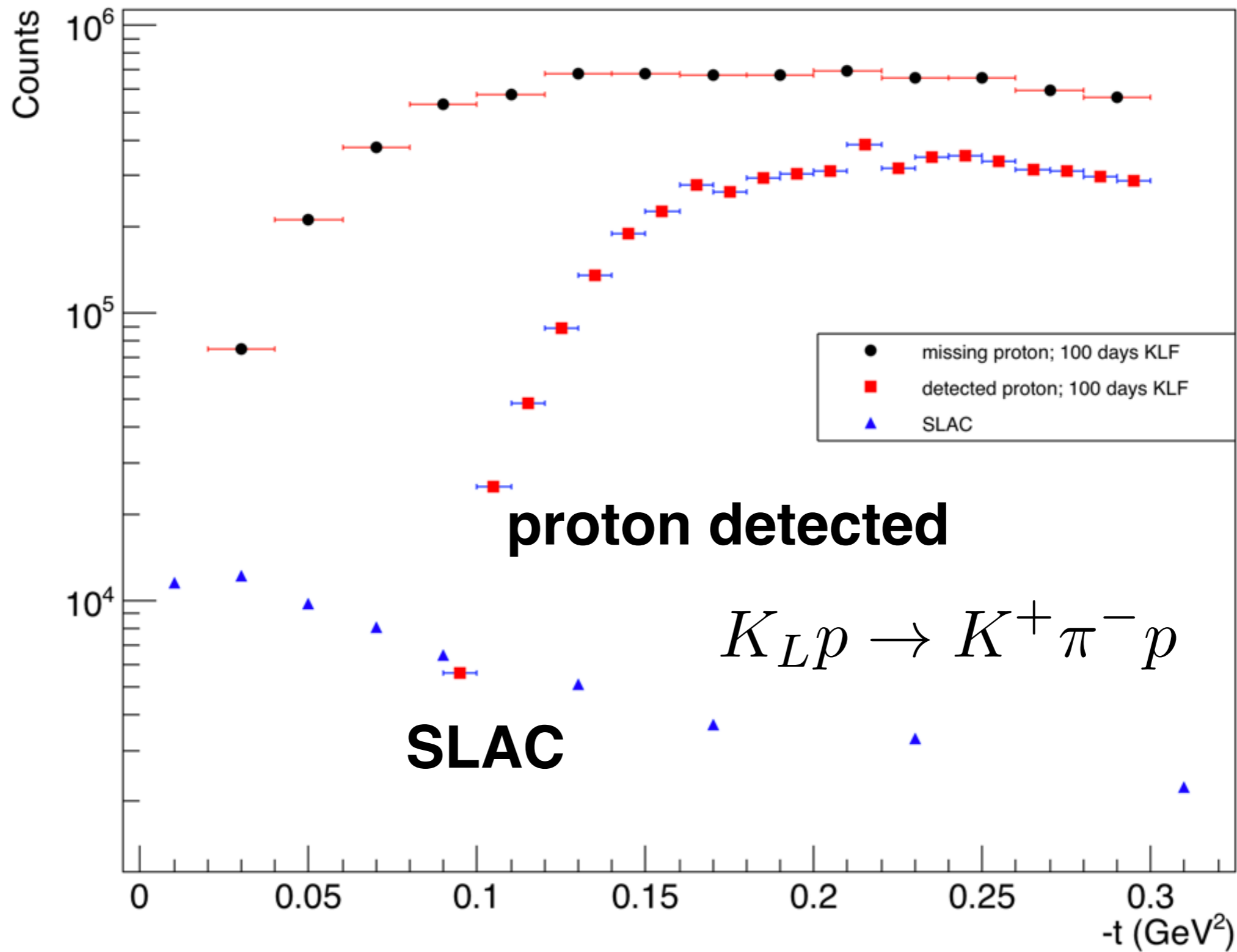
$$K^\pm p \rightarrow K^\pm \pi^+ n$$

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

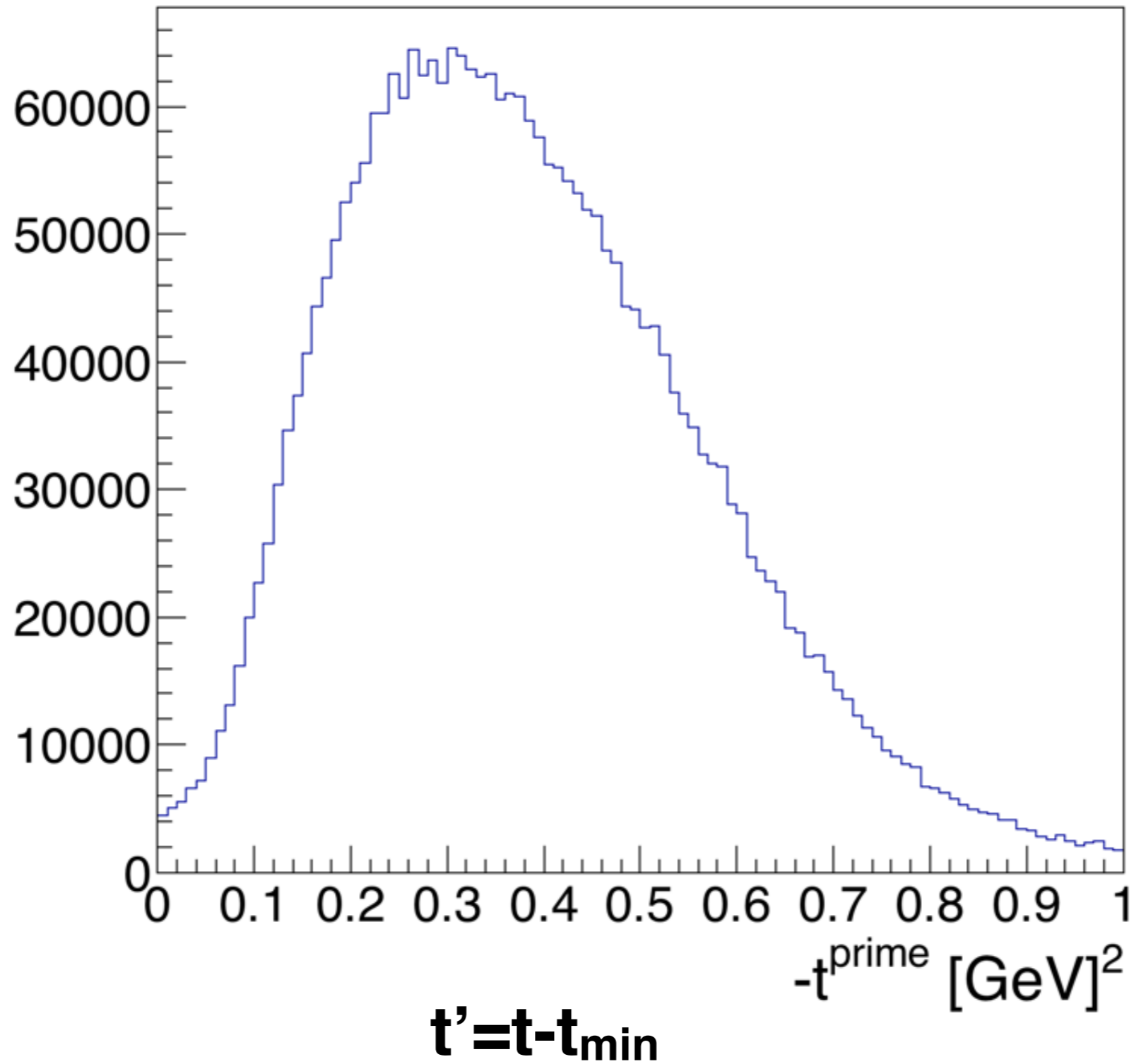
KLF 100 days

From Pelaez and Rodas paper: PRD93(2016)

100 days KLF



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



Phase-shift

For $L=0, 1$

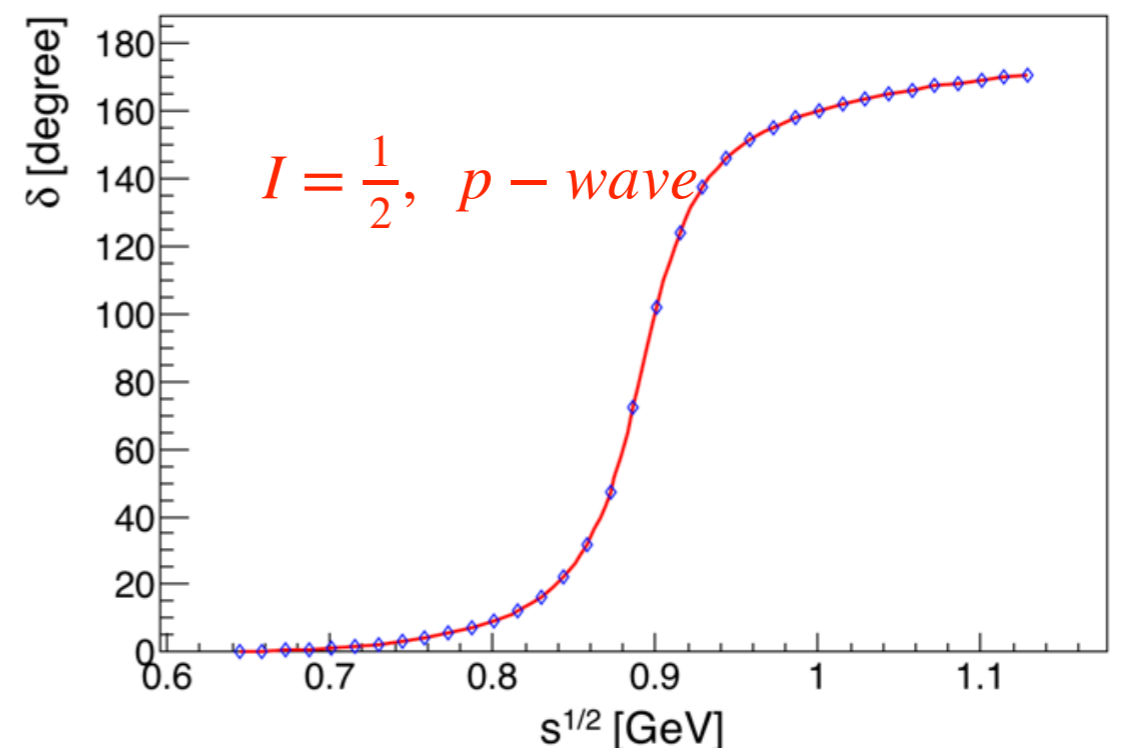
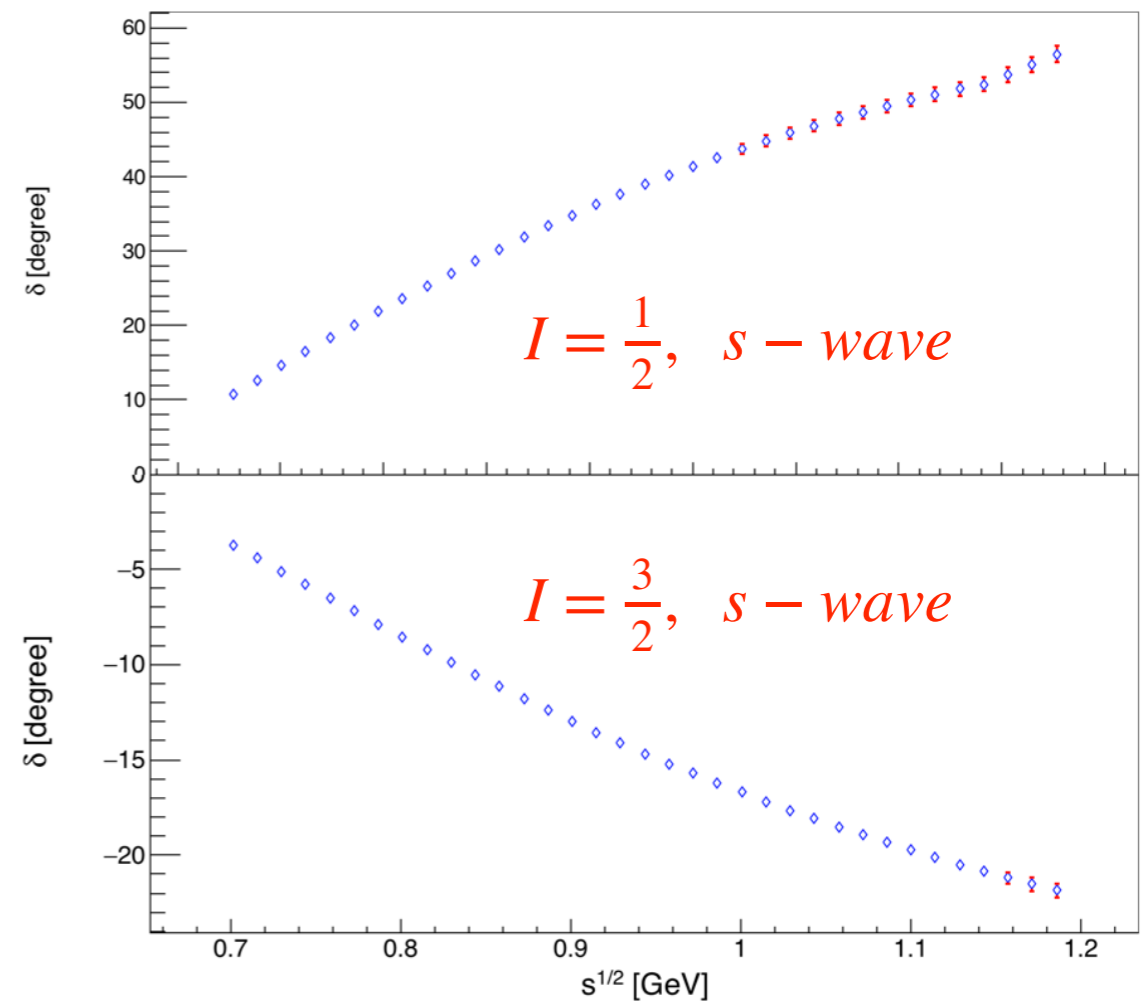
$$A^I(\cos\theta_{GJ}, \phi_{GJ}) = \frac{\sqrt{4\pi}}{q_i} \sum_{l,m} a_l^I (2l+1) Y_l^m(\cos\theta_{GJ}, \phi_{GJ})$$

In the elastic region

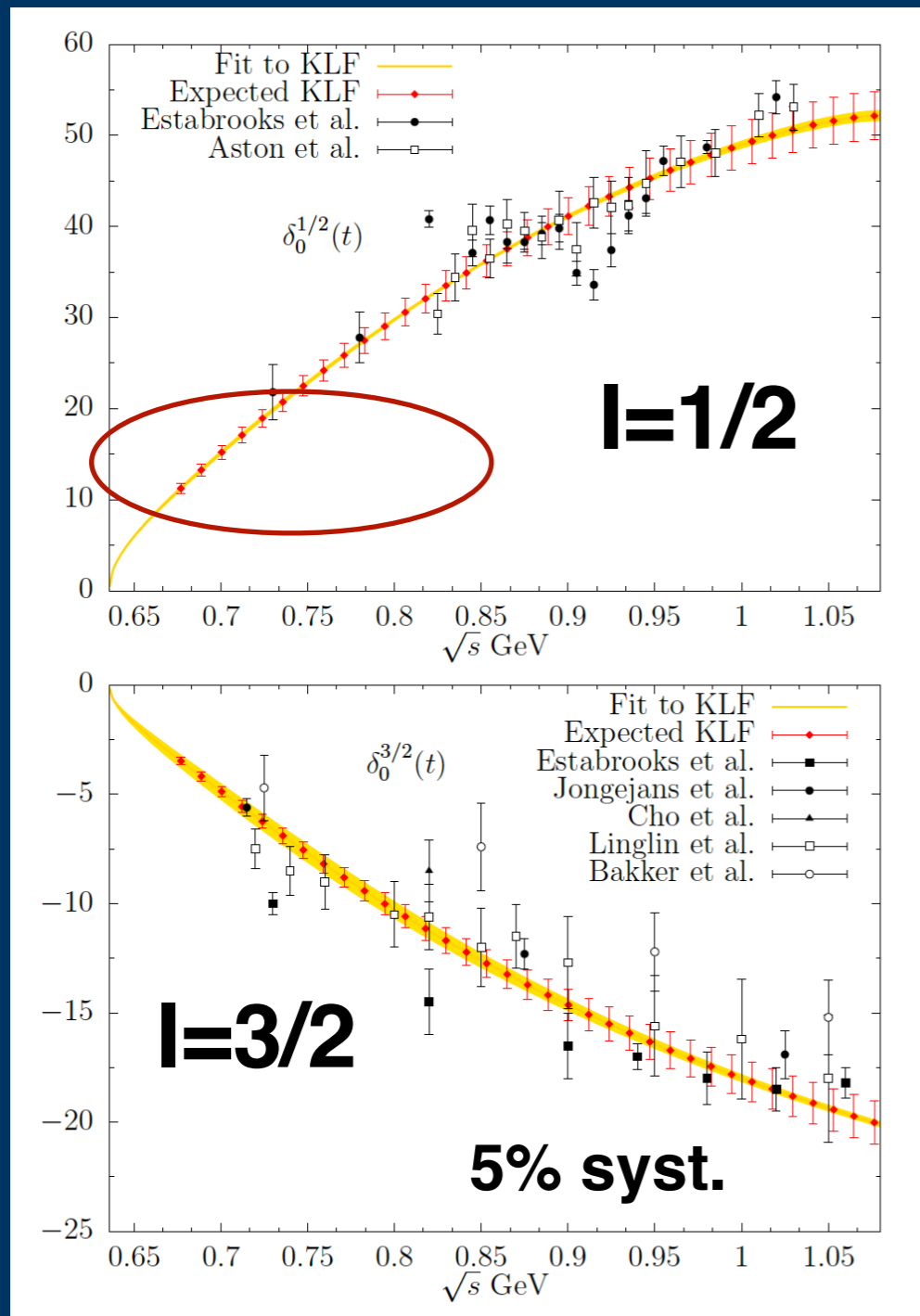
$$a_L^I = a_L^{I=1/2} + \frac{1}{2} a_L^{I=3/2}$$

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

Results include statistical uncertainty only.

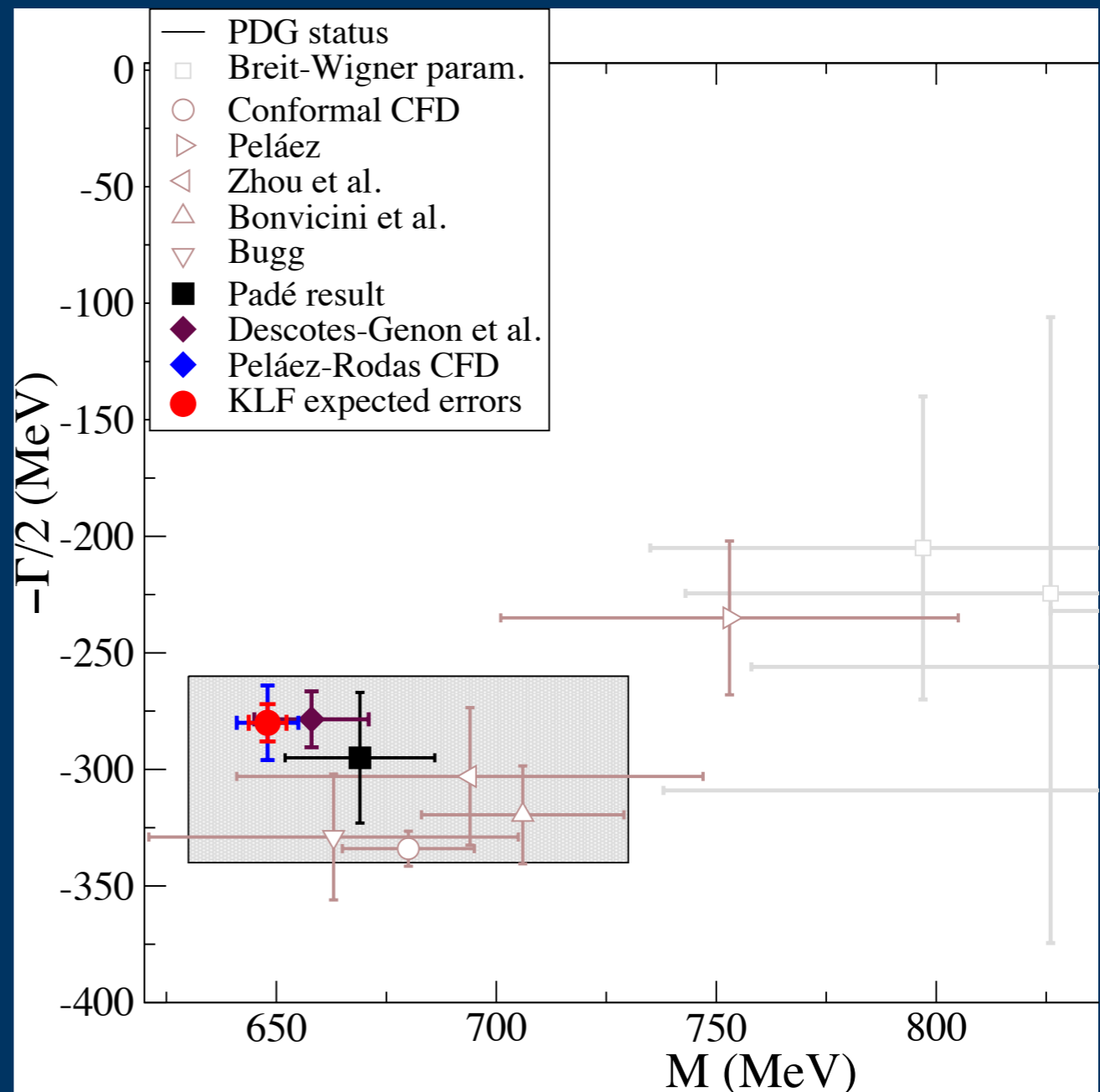


Kappa Mass and Width



S wave phase shift, $l = 1/2$ and $l = 3/2$ with statistical and systematic uncertainties.

More data points are added close to threshold from KLF.



Roy-Steiner dispersion approach

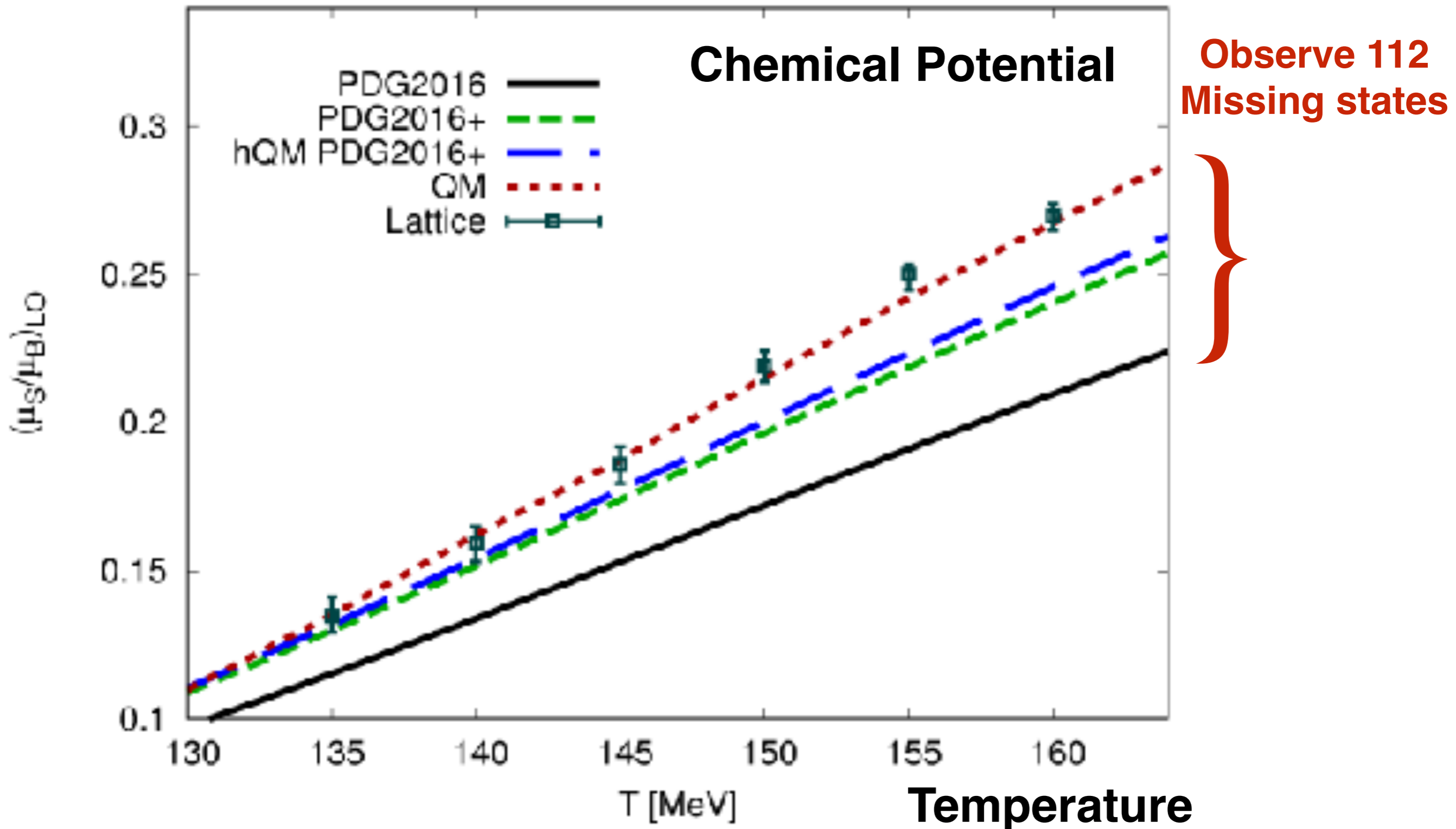
J.R. Pelaez and et.al. Phys. Rev. D 93, 074025

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

Summary of $K\pi$ Scattering

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

Formation of Visible Matter during the Freeze-Out of the Universe after the Big Bang

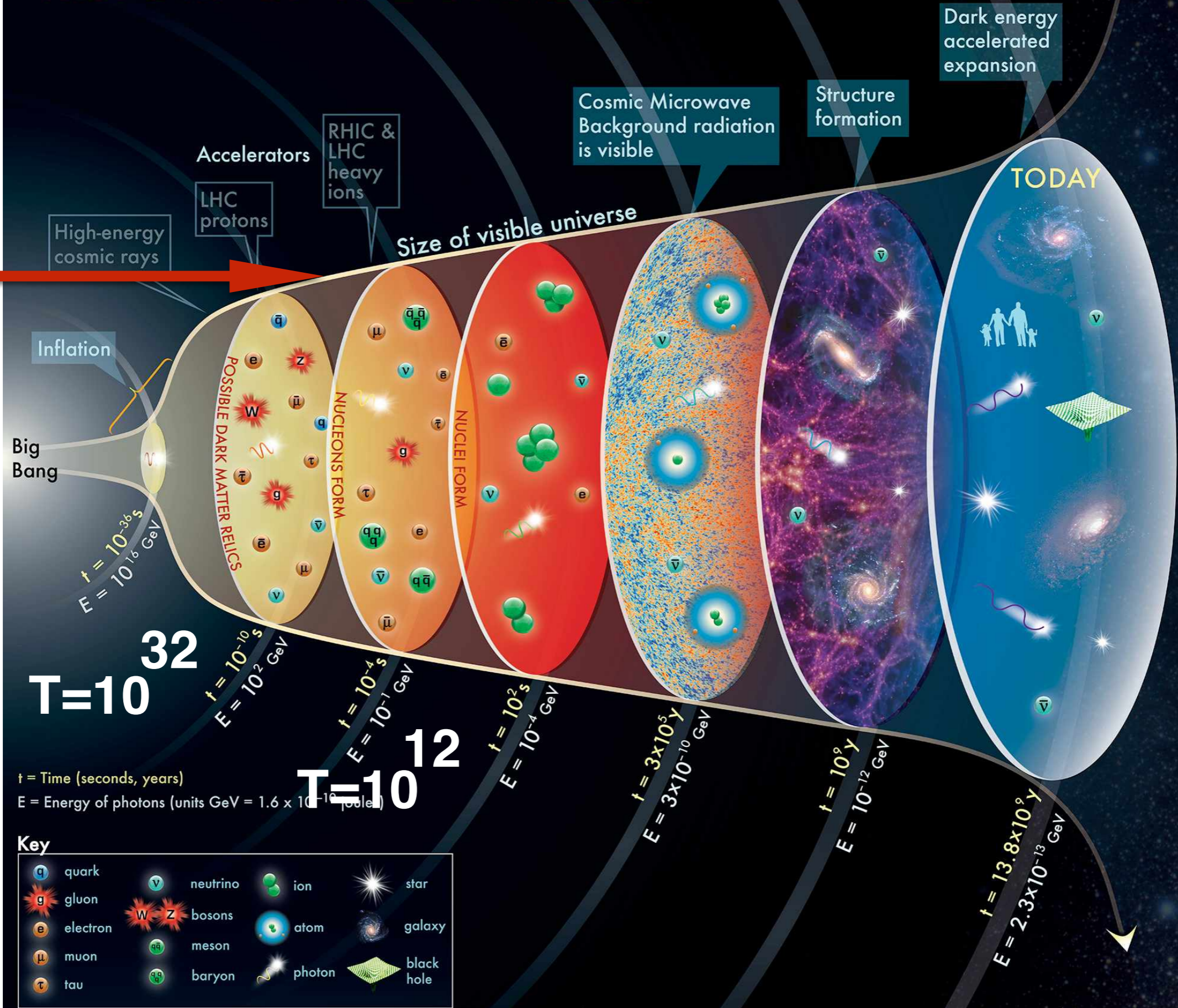


$$dU = T dS - p dV + \mu dN$$

HISTORY OF THE UNIVERSE

1 μ s

KLF



T=10³²

T=10¹²

t = Time (seconds, years)
E = Energy of photons (units GeV = 1.6 x 10⁻¹⁰ joules)

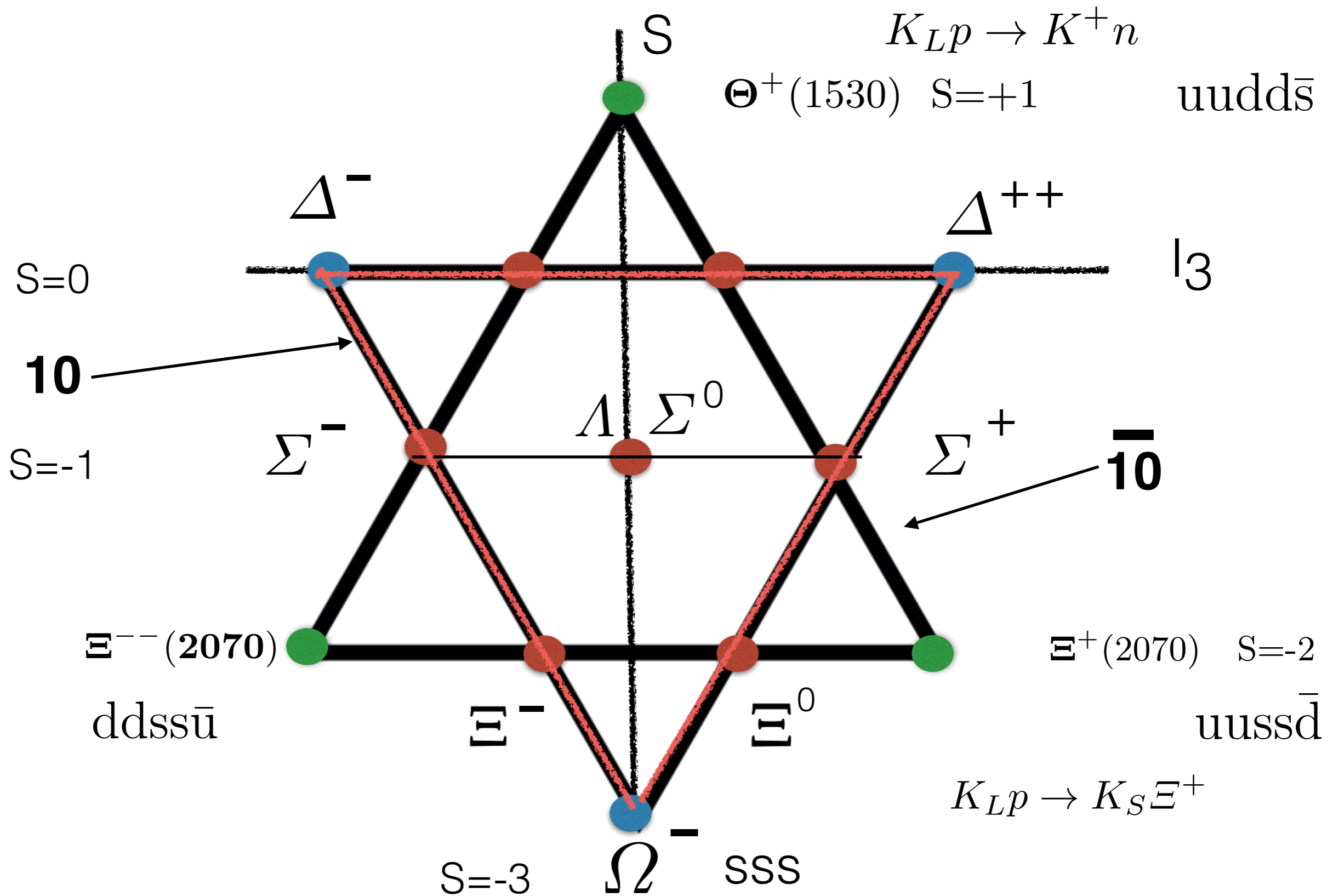
Key

	quark		neutrino		ion		star
	gluon		bosons		atom		galaxy
	electron		meson		photon		black hole
	muon		baryon				
	tau						

The concept for the above figure originated in a 1986 paper by Michael Turner.

What else?

Pentaquarks



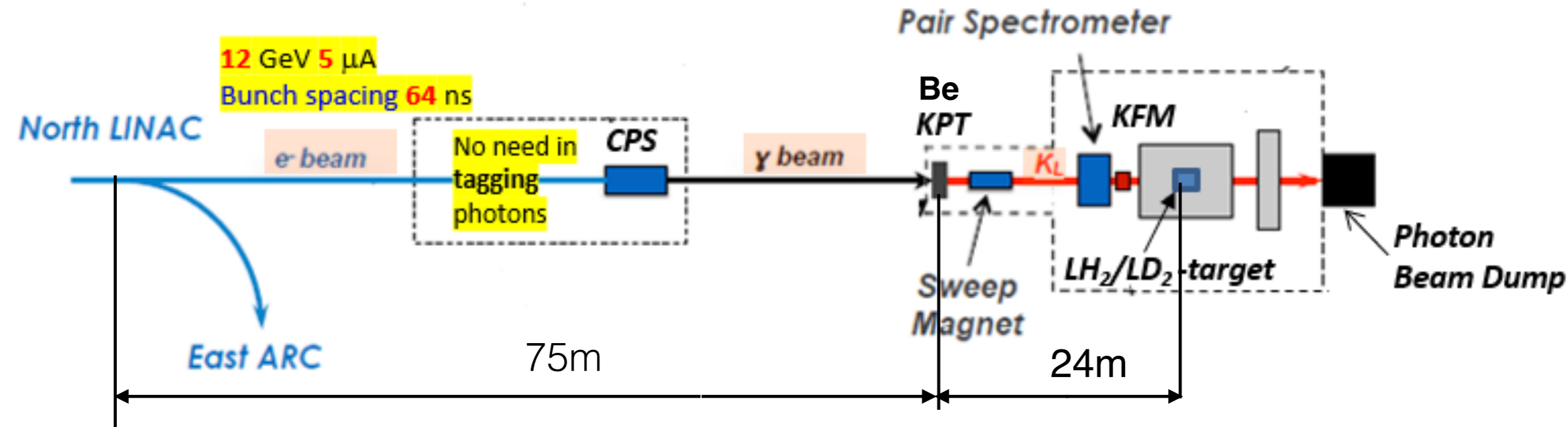
D. Diakonov, V. Petrov and M. V. Polyakov, Z. Phys. A **359**, 305 (1997).

Is everything feasible from hardware point of view?

Next few slides will answer this question.

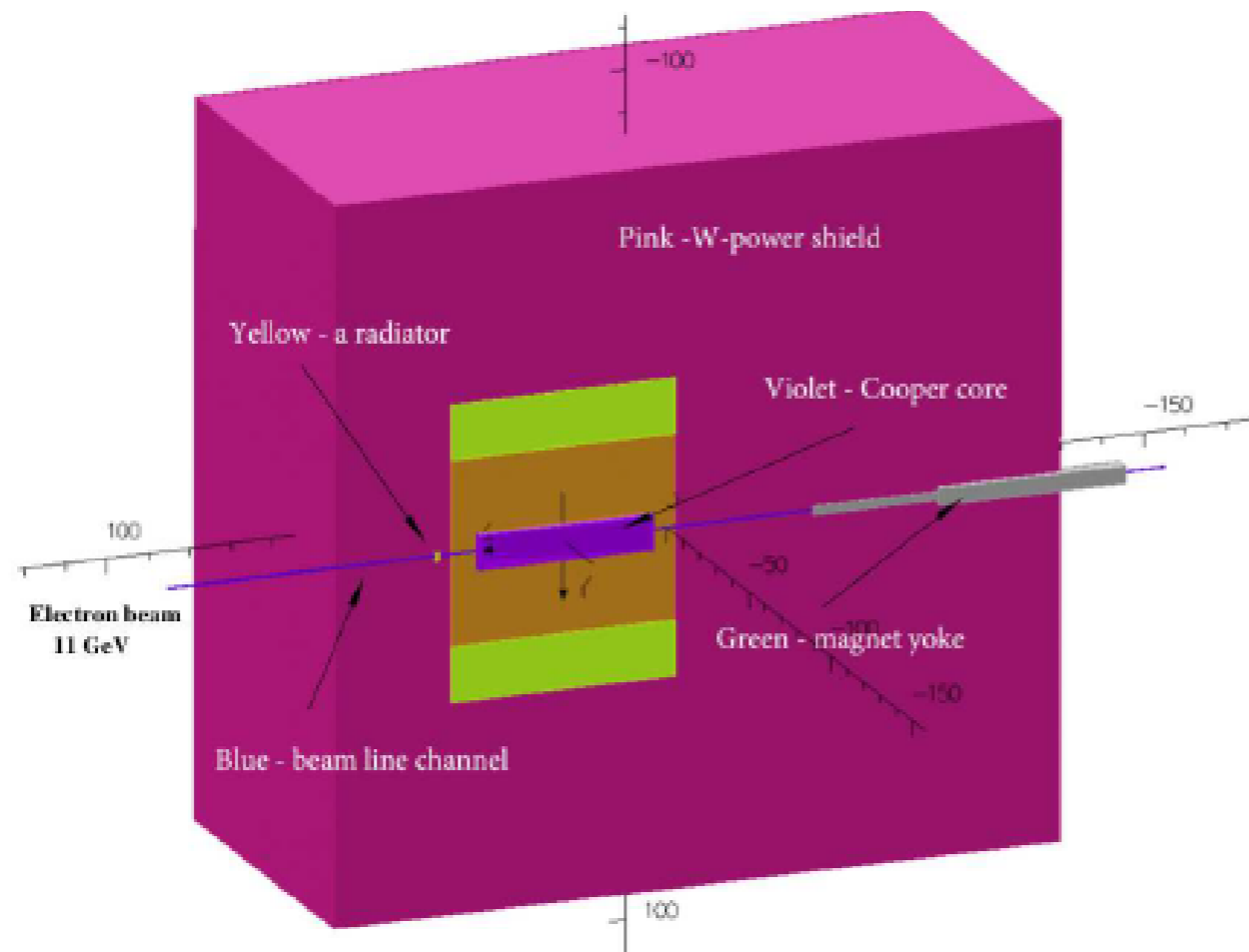
Reminder:

Hall-D beamline and GlueX Setup



<https://arxiv.org/pdf/2008.08215.pdf>

Compact Photon Source



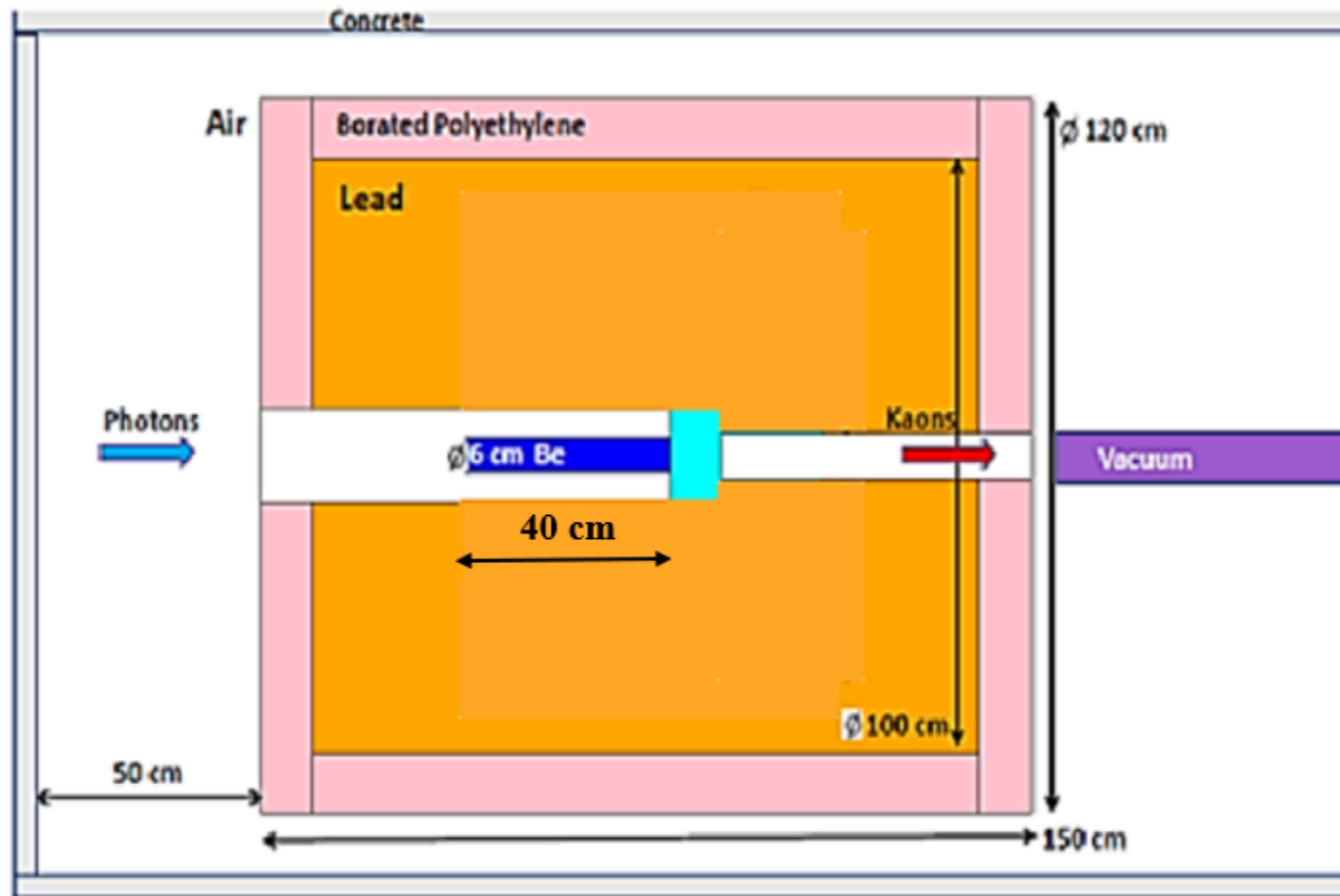
Conceptual design is completed for Halls A&C

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

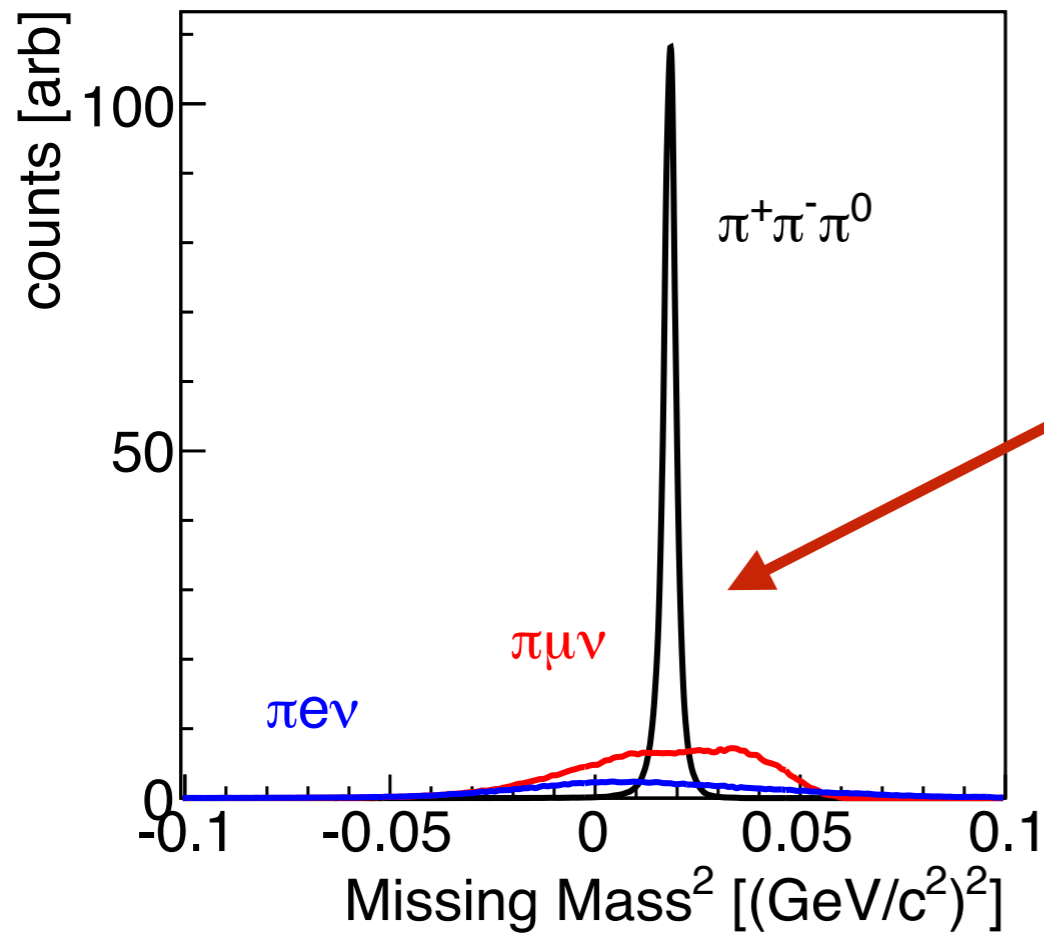
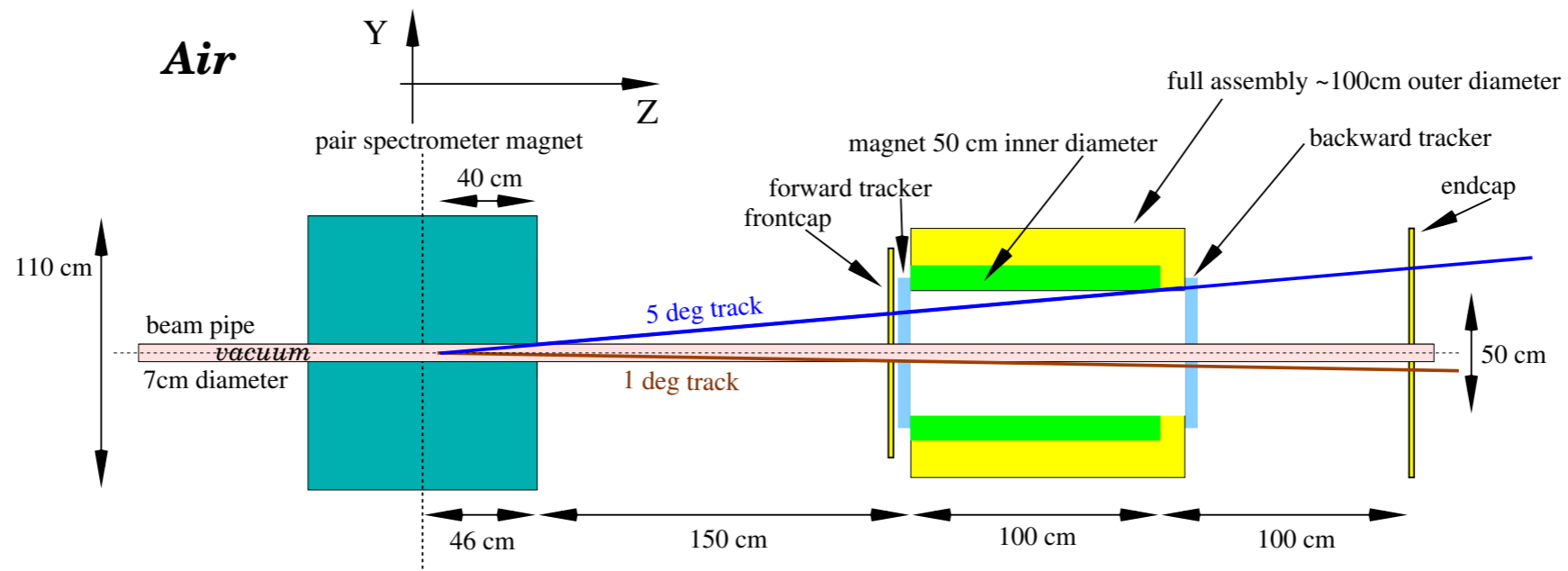


-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff

arXiv: 2002.04442

Flux Monitor



796cm to LH2/LD2 target

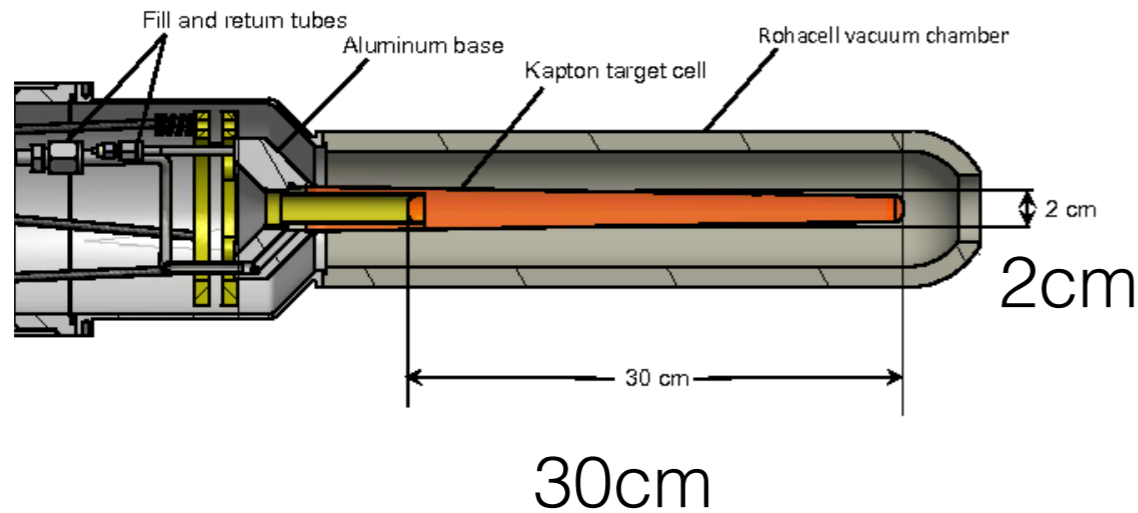
Reconstructed K_L mass

Flux measurement stat. err. <1%

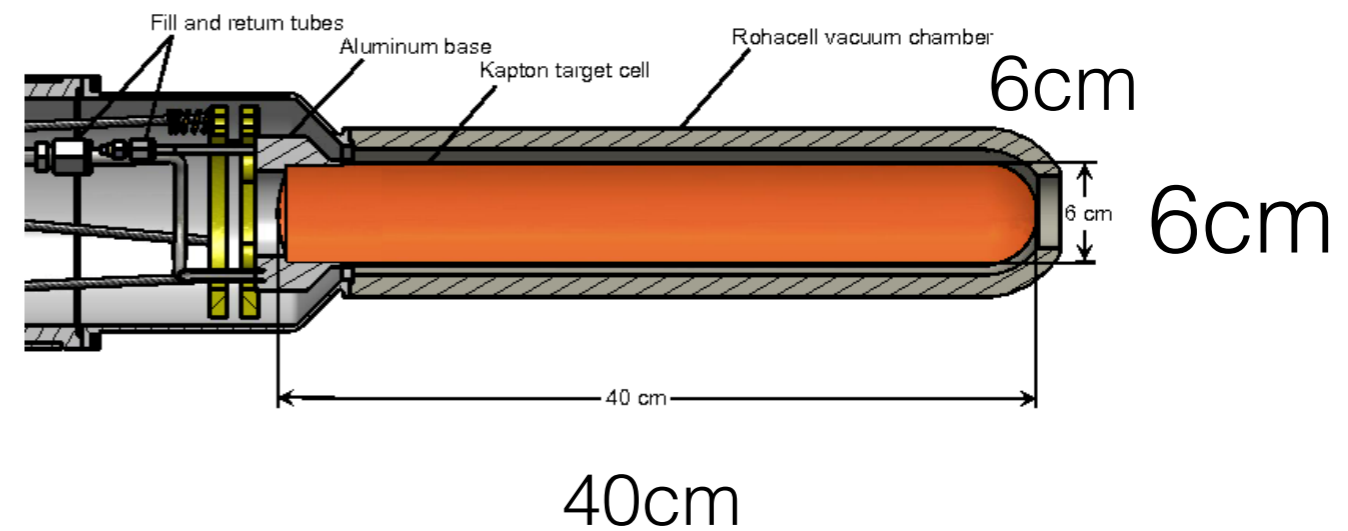
Estimated conservative syst. err. ~5%

LH₂/LD₂ Cryogenic Target for Neutral Kaon Beam at Hall D

The GlueX liquid hydrogen target.



Current



Proposed & Feasible

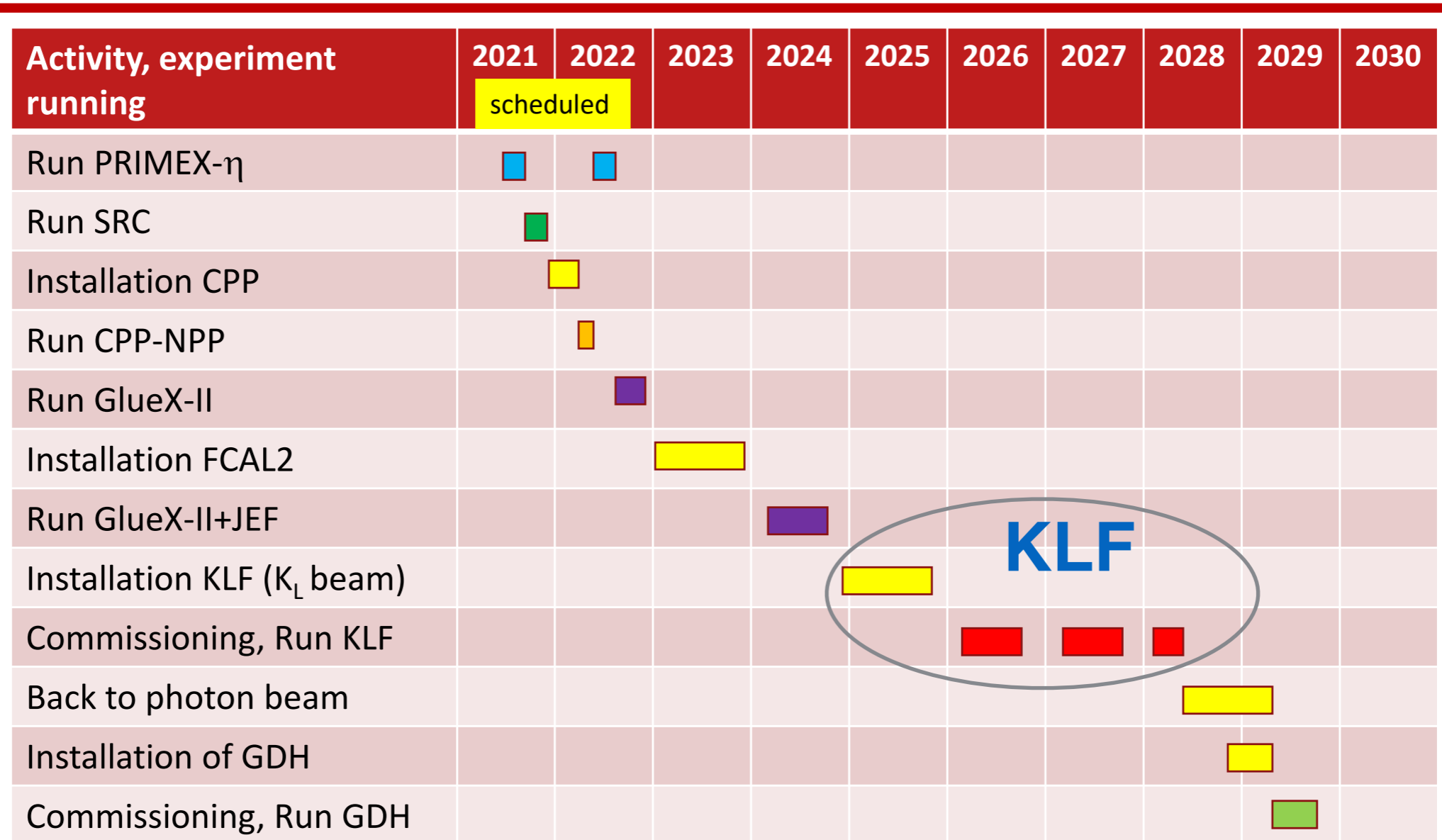
Longer and thicker target is needed to enhance production rate

Conceptual design has been endorsed by the JLAB target group

Timeline of Design, Construction and Installation

Scheduling Outlook

13



- Assumed 25 weeks/year for Hall D running
- Assumed timely budgeting for KLF and GDH

- Assumed timely construction of JEF,KLF,GDH

13

Jefferson Lab

E. Chudakov
GlueX Coll. Meeting, Oct. 2021

The Facility is Flexible and can be switched back to photon beam

PHYSICS WITH NEUTRAL KAON BEAM AT JLAB KL2016

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

SCOPE

The Workshop is following L012-15-001 "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.

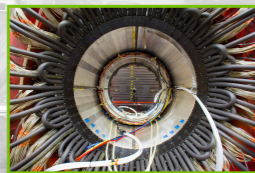
The Workshop will also aim at boosting the international collaboration, in particular between the US and EU research institutions and universities.

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



YSTAR 2016

Excited Hyperons in QCD
Thermodynamics at Freeze-Out

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



WWW.JLAB.ORG/CONFERENCES/YSTAR2016/

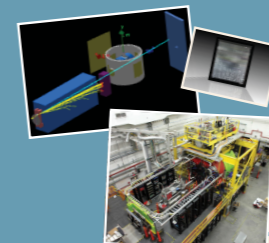


HIPS 2017

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_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:

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



π -K Interactions Workshop

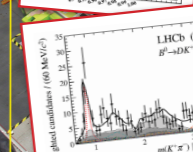
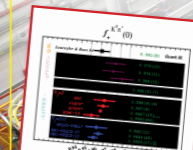
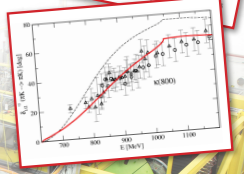
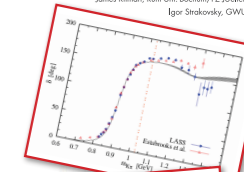
ORGANIZING COMMITTEE

Moskov Amaryan, ODU (Chair)
U.K.G. Meißner, U. Bonn/FZ Jülich
Curtis Meyer, CMU
James Ritman, Ruhr-Uni-Bochum/FZ 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 Kpipi 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

SUMMARY

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

- **-In Hyperon spectroscopy**

PWA will allow to unravel and measure pole positions and widths of a **few dozens** of new excited

- **-In Strange Meson Spectroscopy**

PWA will allow to measure excited K^* states

- To accomplish physics program 200 days running is approved

- **All components of KL Facility considered are feasible**

- **-With total cost of the project below 5M**

At the end we would like to invite everyone to join us.

Thank you !