K-long Facility at JLab for the Strange Hadron Spectroscopy

Moskov Amaryan

Old Dominion University
Norfolk, VA. USA

JLab, IERR, 29 August, 2024

Outline

-Introduction

-Physics Motivation

- *Hyperon Spectroscopy* (Talks by V. Baturin, S. Marshall, S. Fegan)
- *Strange Meson Spectroscopy* (Talk by Keigo Mizutani)

-K_L Facility Beamline and Hardware (Brief introduction)

- *Electron Beam*
- *Compact Photon Source*
- *Be Target*
- *Flux Monitor* *(Talk by M.Bashkanov)*
- *K_L Beam*
- *LH_2/LD_2 Target*

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Summary

48th PROGRAM ADVISORY COMMITTEE (PAC 48)

August 10-14, 2020

September 25, 2020

U.S. DEPARTMENT OF ENERGY

JSA

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. Amaryan (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.

This happens because of strong support and dedicated efforts of the KLF Collaboration

New Collaborators from Japan

160 physicists from 68 Universities across 19 countries

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D

Experimental Support:

Shankar Adhikari[43], Moskov Amaryan (Contact Person, Spokesperson)[43], Arshak Asaturyan[1], Alexander Austregesilo[49], Marouen Baalouch[8], Mikhail Bashkanov (Spokesperson)[63], Vitaly Baturin[43], Vladimir Berdnikov[11,35], Olga Cortes Becerra[19], Timothy Black[60], Werner Boeglin[13], William Briscoe[19], William Brooks[54], Volker Burkert[49], Eugene Chudakov[49], Geraint Clash[63], Philip Cole[32], Volker Crede[14], Donal Day[61], Pavel Degtyarenko[49], Alexandre Deur[49], Sean Dobbs (Spokesperson)[14], Gail Dodge[43], Anatoly Dolgolenko[26], Simon Eidelman[6,41], Hovanes Egiyan (JLab Contact Person)[49], Denis Epifanov[6,41], Paul Eugenio[14], Stuart Fegan[63], Alessandra Filippi[25], Sergey Furletov[49], Liping Gan[60], Franco Garibaldi[24], Ashot Gasparian[39], Gagik Gavalian[49], Derek Glazier[18], Colin Gleason[22], Vladimir Goryachev[26], Lei Guo[14], David Hamilton[11], Avetik Hayrapetyan[17], Garth Huber[53], Andrew Hurley[56], Charles Hyde[43], Isabella Illari[19], David Ireland[18], Igal Jaegle[49], Kyungseon Joo[57], Vanik Kakoyan[1], Grzegorz Kalicy[11], Mahmoud Kamel[13], Christopher Keith[49], Chan Wook Kim[19], Eberhard Klemp[5], Geoffrey Krafft[49], Sebastian Kuhn[43], Sergey Kuleshov[2], Alexander Laptev[33], Ilya Larin[26,59], David Lawrence[49], Daniel Lersch[14], Wenliang Li[56], Kevin Luckas[28], Valery Lyubovitskij[50,51,52,54], David Mack[49], Michael McCaughan[49], Mark Manley[30], Hrachya Marukyan[1], Vladimir Matveev[26], Mihai Mocanu[63], Viktor Mokeev[49], Curtis Meyer[9], Bryan McKinnon[18], Frank Nerling[15,16], Matthew Nicol[63], Gabriel Niculescu[27], Alexander Ostrovidov[14], Zisis Papandreou[53], KiJun Park[49], Eugene Pasyuk[49], Peter Pauli[18], Lubomir Pentchev[49], William Phelps[10], John Price[7], Jörg Reinhold[13], James Ritman (Spokesperson)[28,68], Dimitri Romanov[26], Carlos Salgado[40], Todd Satogata[49], Susan Schadmand[28], Amy Schertz[56], Axel Schmidt[19], Daniel Sober[11], Alexander Somov[49], Sergei Somov[35], Justin Stevens (Spokesperson)[56], Igor Strakovsky (Spokesperson)[19], Victor Tarasov[26], Simon Taylor[49], Annika Thiel[5], Guido Maria Urciuoli[24], Holly Szumila-Vance[19], Daniel Watts[63], Lawrence Weinstein[43], Timothy Whitlatch[49], Nilanga Wickramaarachchi[43], Bogdan Wojtsekhowski[49], Nicholas Zachariou[63], Jonathan Zarling[53], Jixie Zhang[61]

Theoretical Support:

Alexey Anisovich[5,44], Alexei Bazavov[38], Rene Bellwied[21], Veronique Bernard[42], Gilberto Colangelo[3], Aleš Cieplý[46], Michael Döring[19], Ali Eskanderian[19], Jose Goity[20,49], Helmut Haberzettl[19], Mirza Hadžimehmedović[55], Robert Jaffe[36], Boris Kopeliovich[54], Heinrich Leutwyler[3], Maxim Mai[19], Terry Mart[65], Maxim Matveev[44], Ulf-G. Meißner[5,29], Colin Morningstar[9], Bachir Moussallam[42], Kanzo Nakayama[58], Wolfgang Ochs[37], Youngseok Oh[31], Rifat Omerovic[55], Hedim Osmanović[55], Eulogio Oset[62], Antimo Palano[64], Jose Peláez[34], Alessandro Pilloni[66,67], Maxim Polyakov[48], David Richards[49], Arkaitz Rodas[49,56], Dan-Olof Riska[12], Jacobo Ruiz de Elvira[3], Hui-Young Ryu[45], Elena Santopinto[23], Andrey Sarantsev[5,44], Jugoslav Stahov[55], Alfred Švarc[47], Adam Szczepaniak[22,49], Ronald Workman[19], Bing-Song Zou[4]

6 KLF Personnel

KLF Planning Committee has 39 members (experimental group representatives).
JLab PAC48 approved the KLF experiment for 200 days of running time.
It means that we will run 400 calendar days. So, we must cover 2400 shifts.

The KLF personnel is enough to cover 5 blocks of shifts
per KLF Collaboration member for this running time.

For the physics topics discussed in the KLF proposal,
14 institutions have already expressed an intention to
contribute to the Hyperon Spectroscopy part

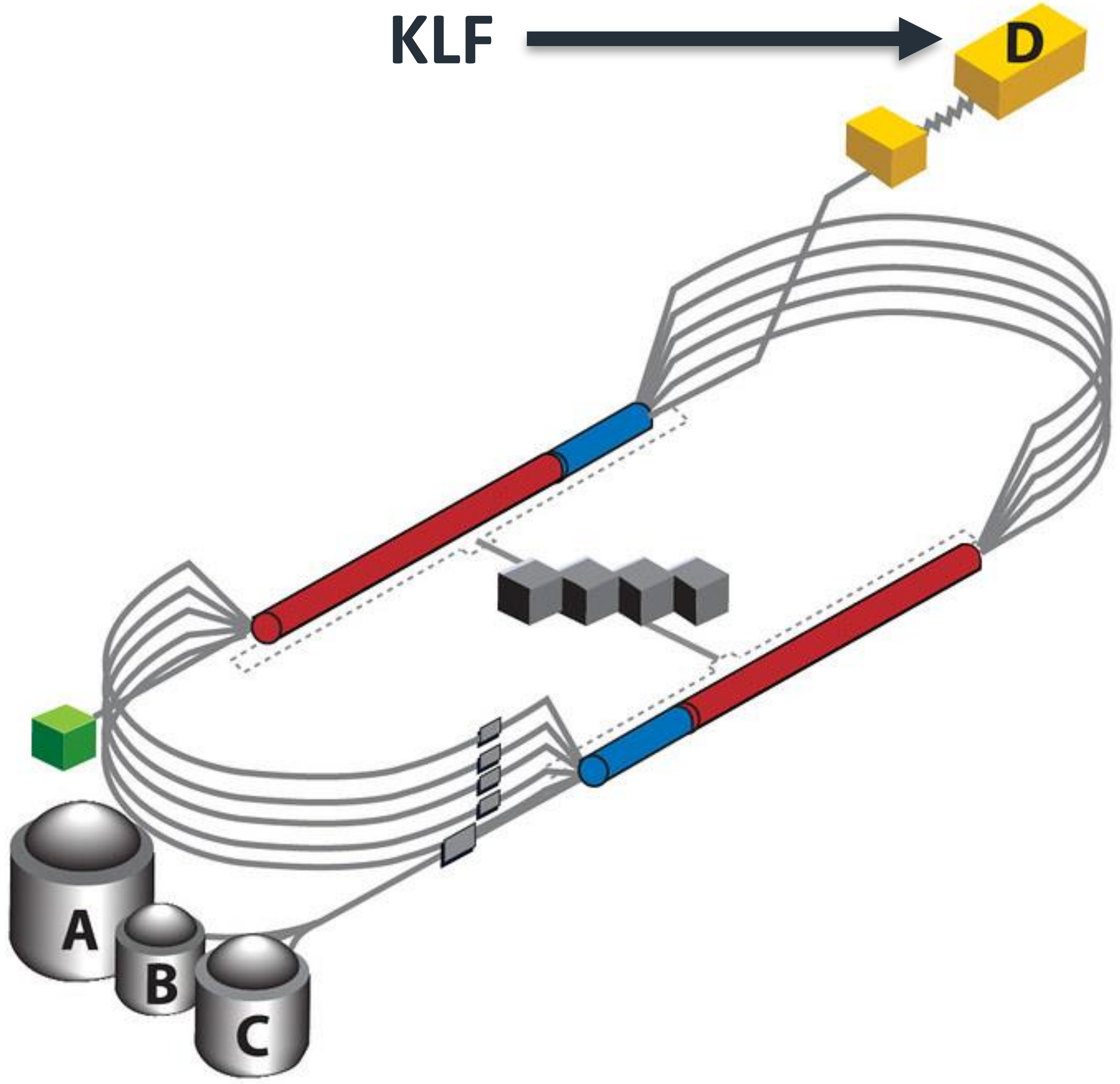
and 7 institutions have expressed an intention to
contribute to the Kaon Spectroscopy part,

with 6 institutions intending to contribute
to both physics topics.

A detailed distribution of reaction channels
to analyzers will be done closer to when data collection begins.

JLAB

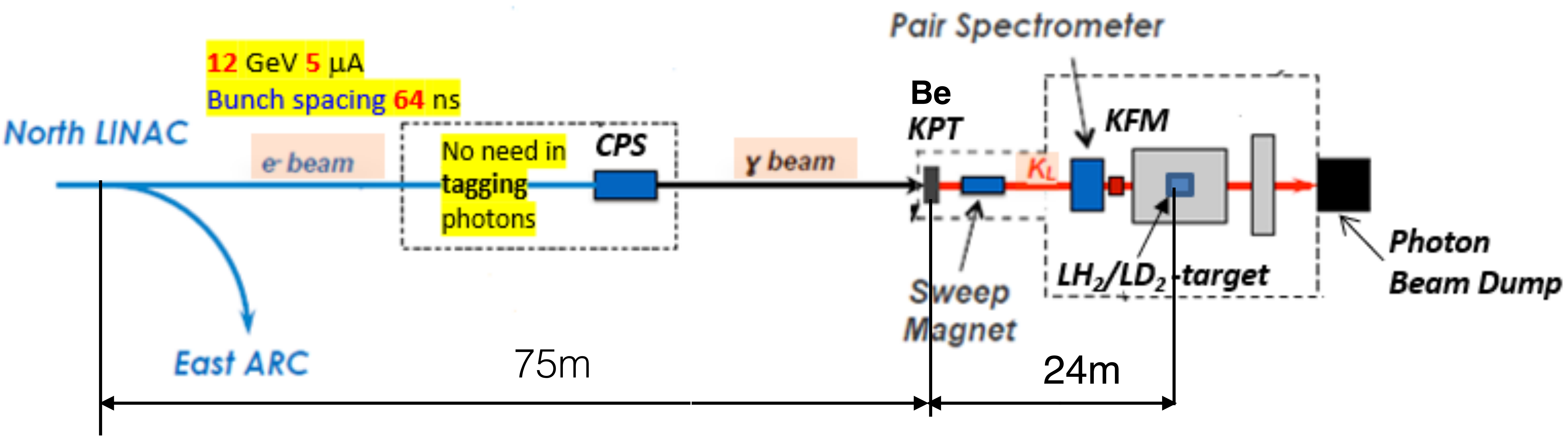
KLF



Electron Beam:

- 12 GeV
- $5\mu A$
- 128ns bunch spacing

Hall-D beamline and GlueX Setup

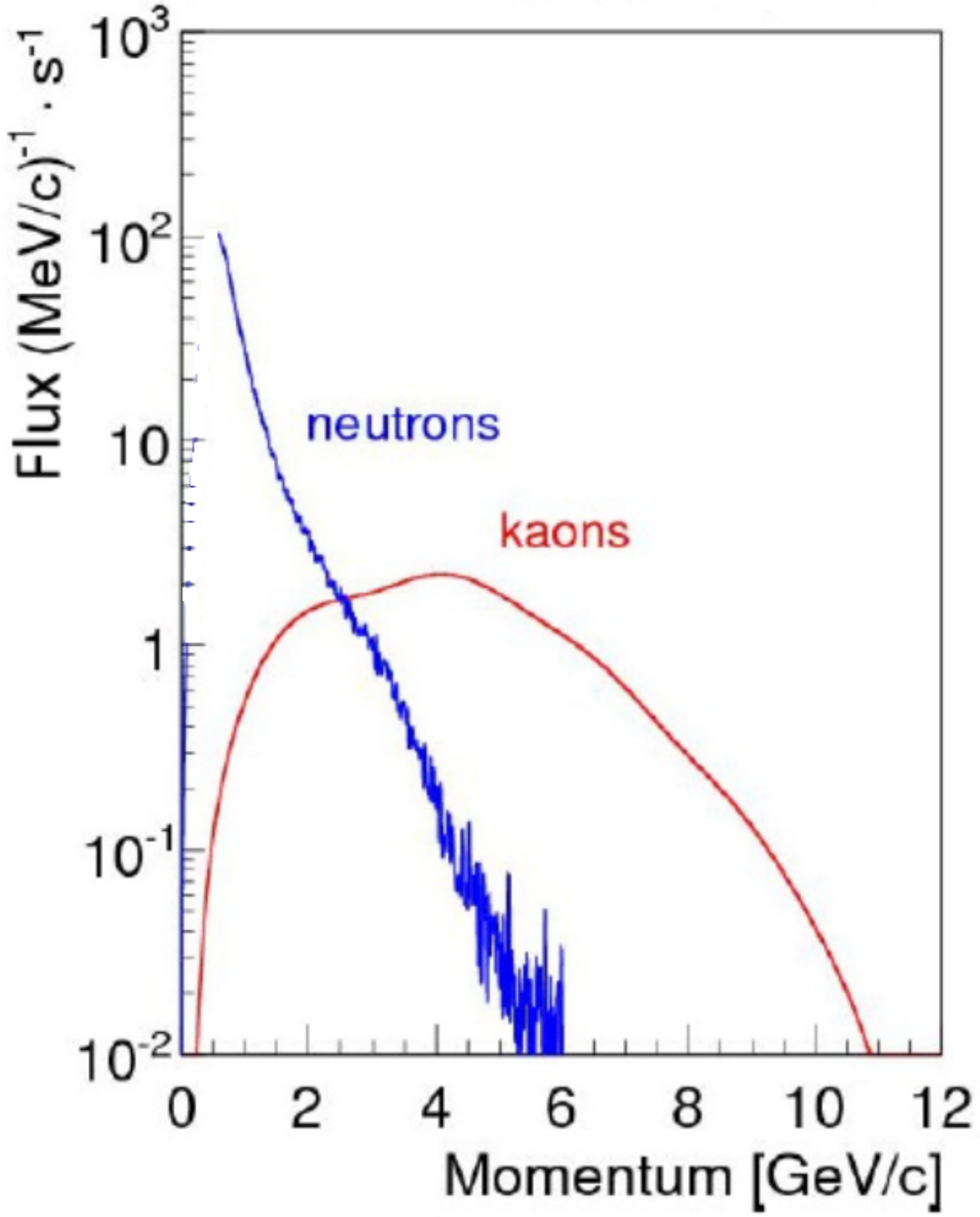


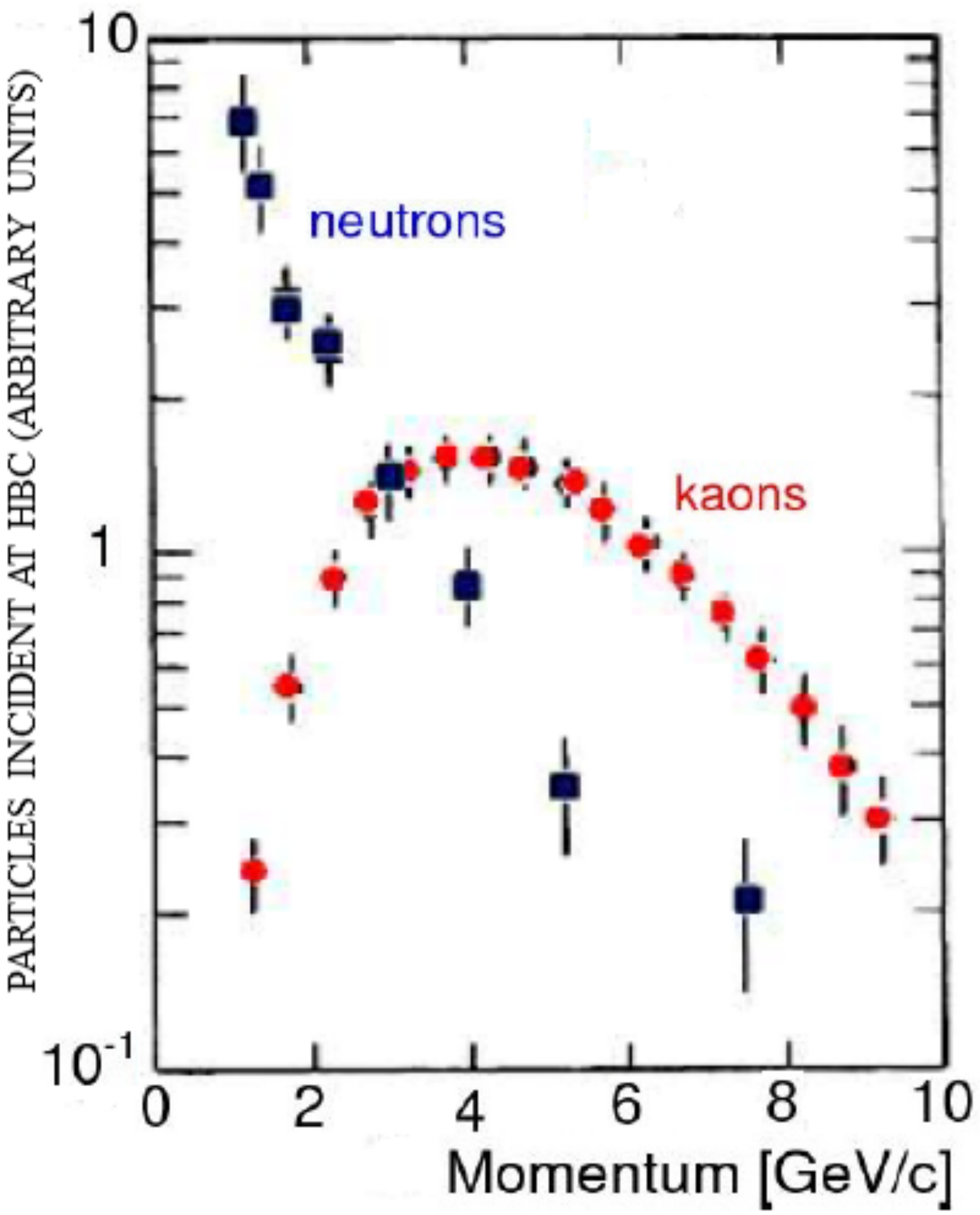
https://arxiv.org/pdf/2008.08215.pdf

K_L Beam Flux

JLab 12 GeV

SLAC 16 GeV





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

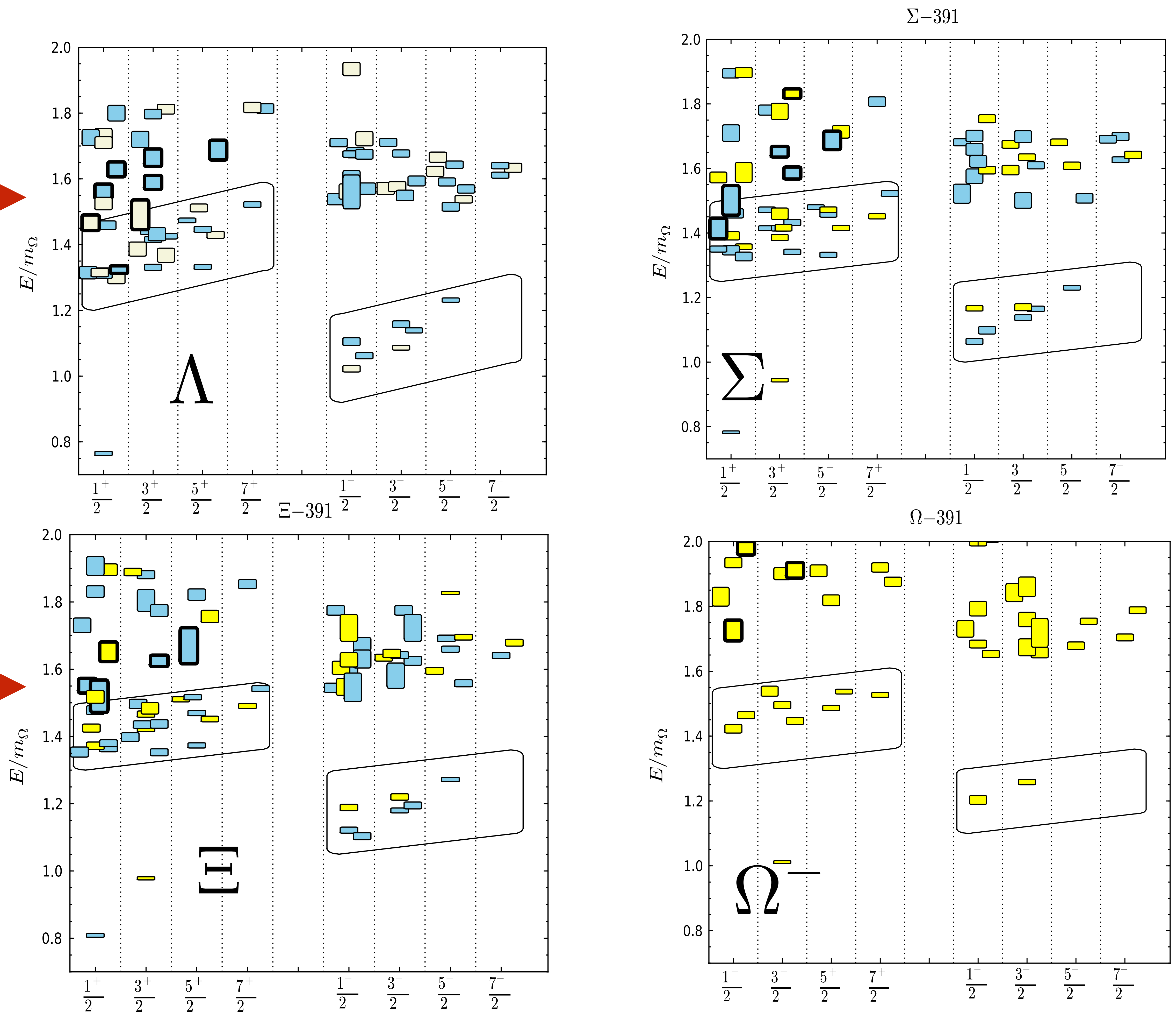
Hyperon Spectroscopy

LQCD in addition to already known states

predicts many more including hybrids (thick bordered)

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

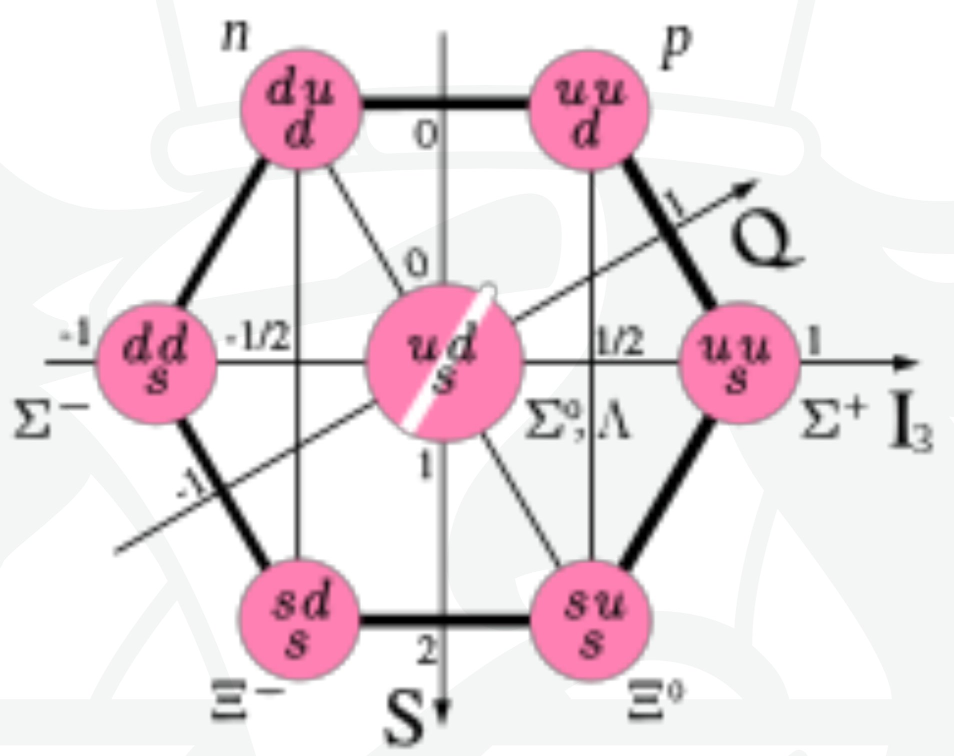
3-states
****
4-states
***



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

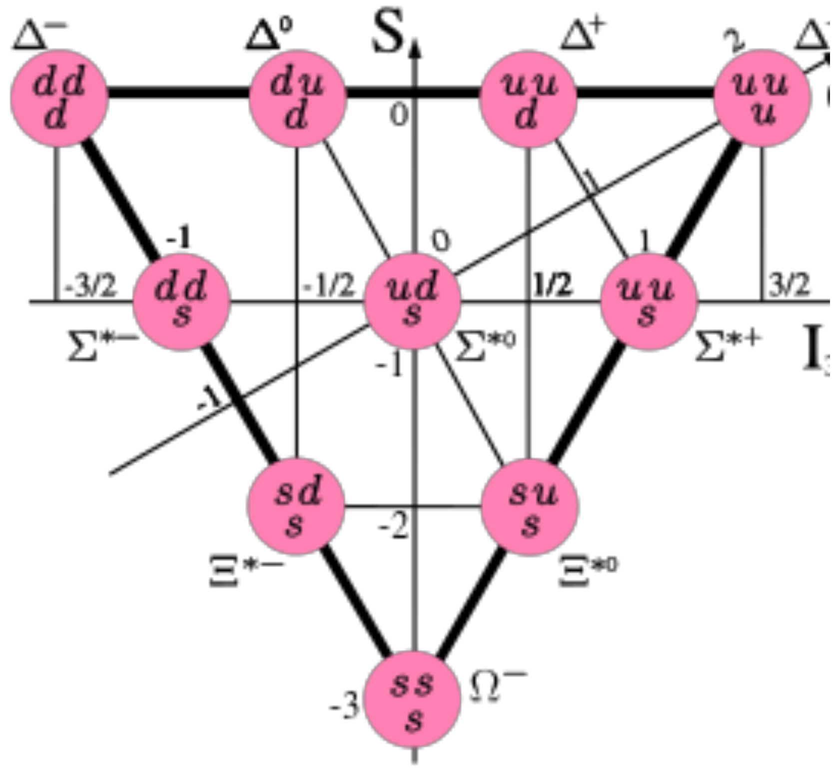
1-state
****
1-state
***

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



Octet: N^*, $\boldsymbol{\Lambda^*}$, $\boldsymbol{\Sigma^*}$, $\boldsymbol{\Xi^*}$

Decuplet: Δ^*, $\boldsymbol{\Sigma^*}$, $\boldsymbol{\Xi^*}$, $\boldsymbol{\Omega^*}$



	Predicted LQCD, $M_B < 2.5\ GeV$	"Observed", PDG
N^*	64	21
Δ^*	22	12
Λ^*	17	14
Σ^*	43	9
Ξ^*	42	6
Ω^*	24	2

212

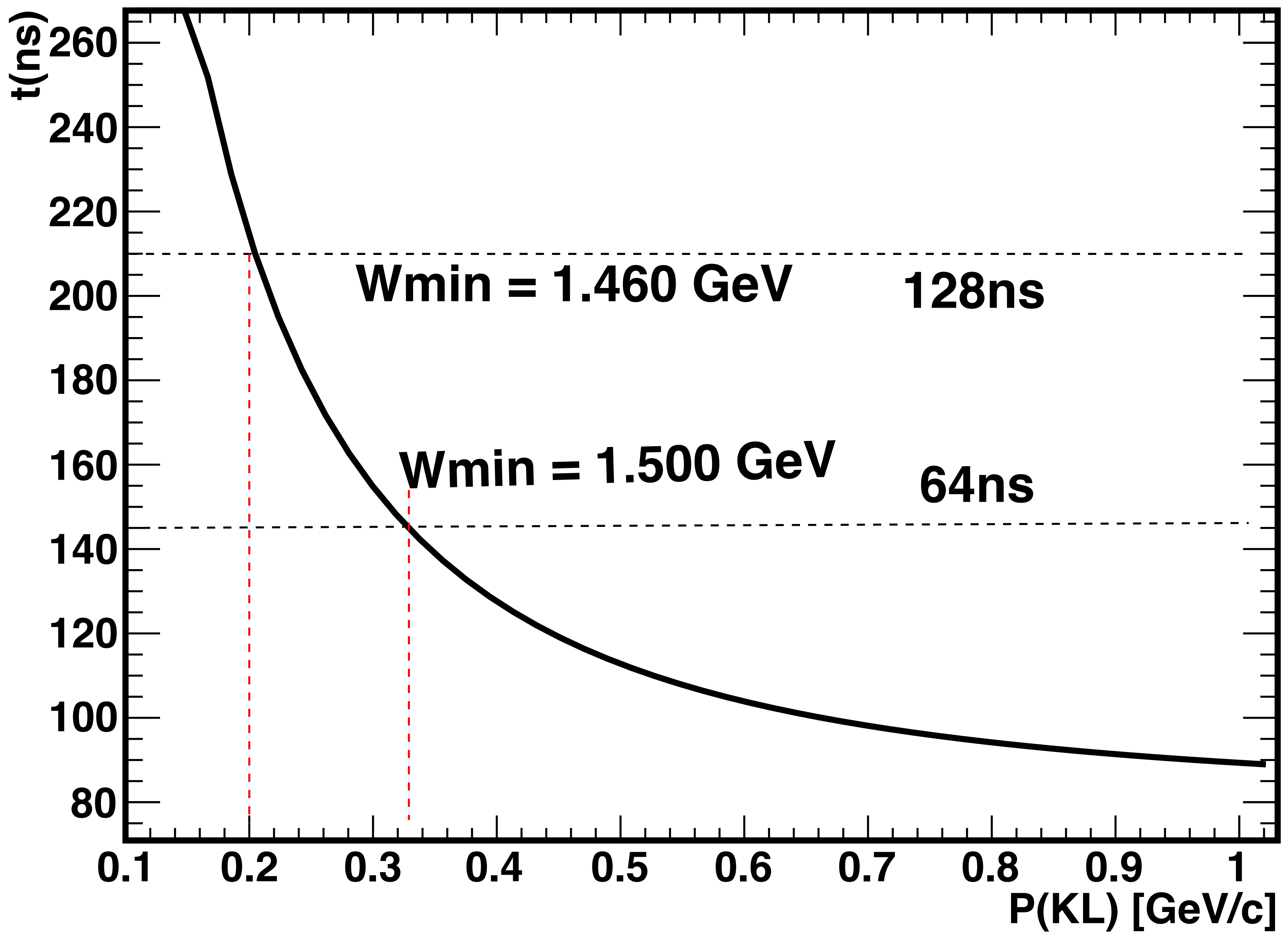
64

Electron Beam Parameters

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

Bunch spacing $64\ ns$

128 ns confirmed feasible



K+N Elastic Scatterings for Estimation of the In-Medium Quark Condensate with Strange Quarks

Yutaro Iizawa(Tokyo Inst. Tech.), Daisuke Jido(Tokyo Inst. Tech.), Stephan Hübsch(Tokyo Inst. Tech.) (Aug 18, 2023)

Published in: *PTEP* 2024 (2024) 5, 053D01

- **e-Print: 2308.09397 [hep-ph]**

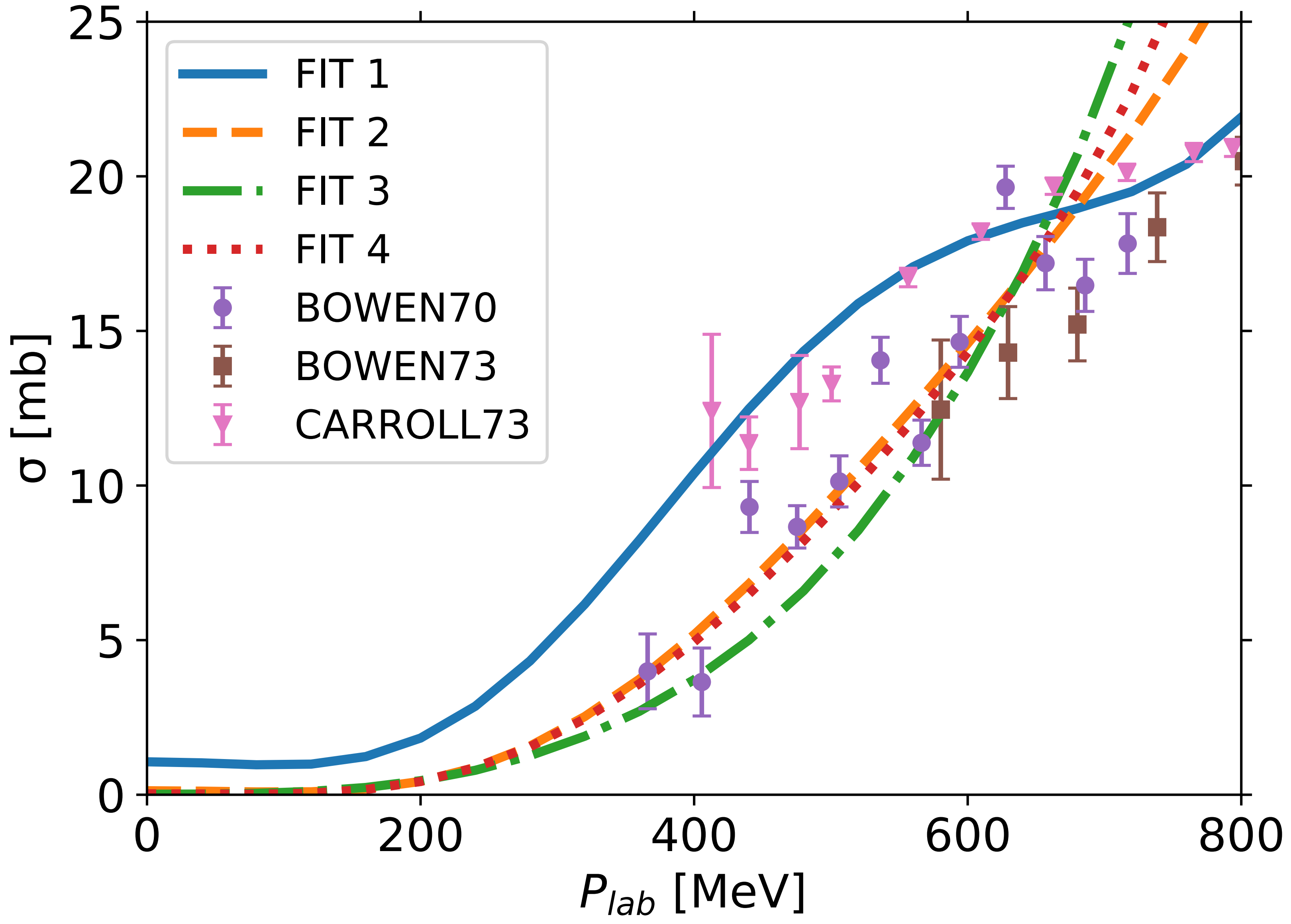


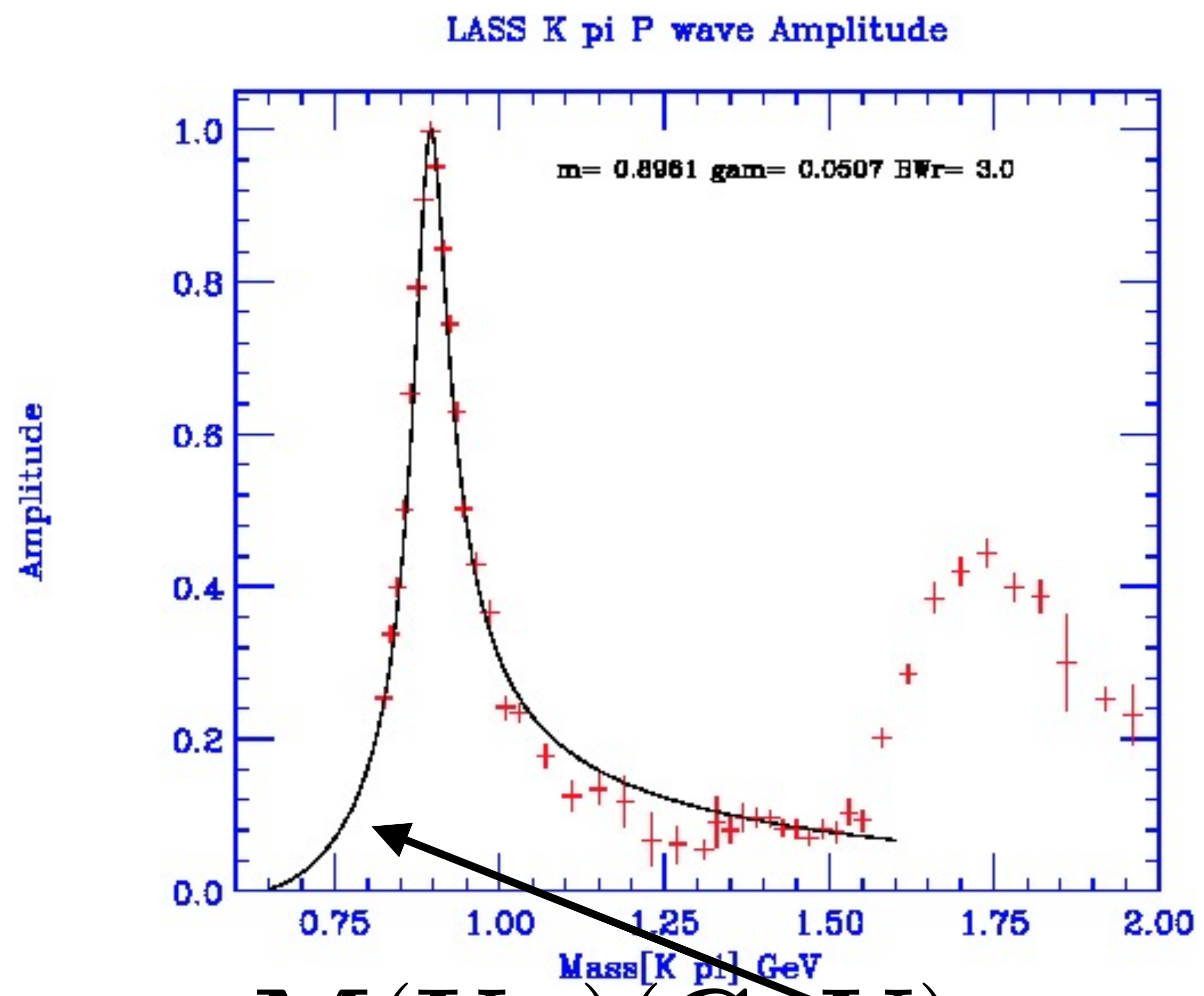
Fig. 3: $I = 0$ K^+N total cross sections calculated with the determined LECs given in Table. 3 in comparison with the experimental data [32, 39, 41].

More in a talk of V. Baturin

Proposed Measurements

SLAC

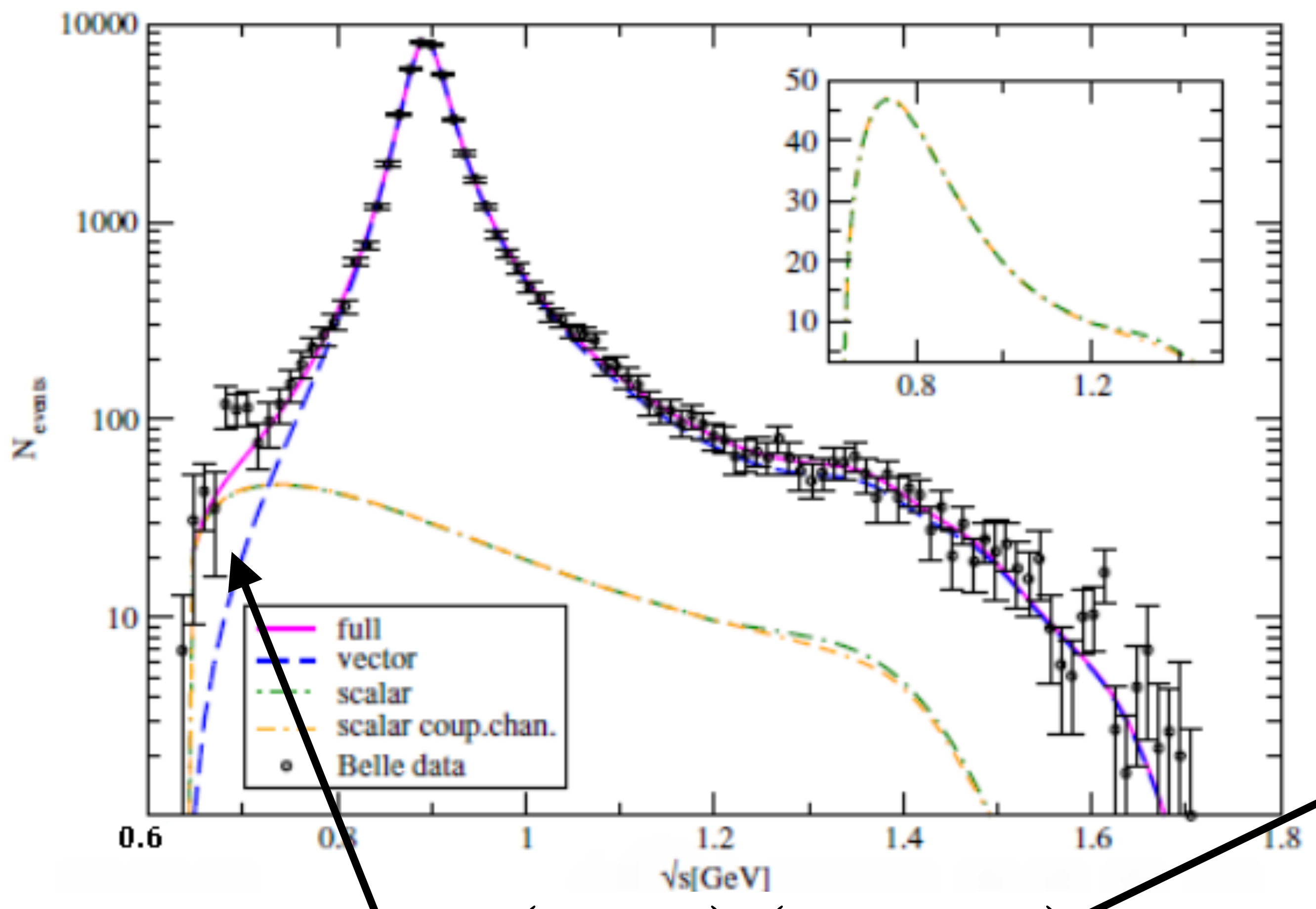
$K^-\pi^+ \to K^-\pi^+$



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

Belle

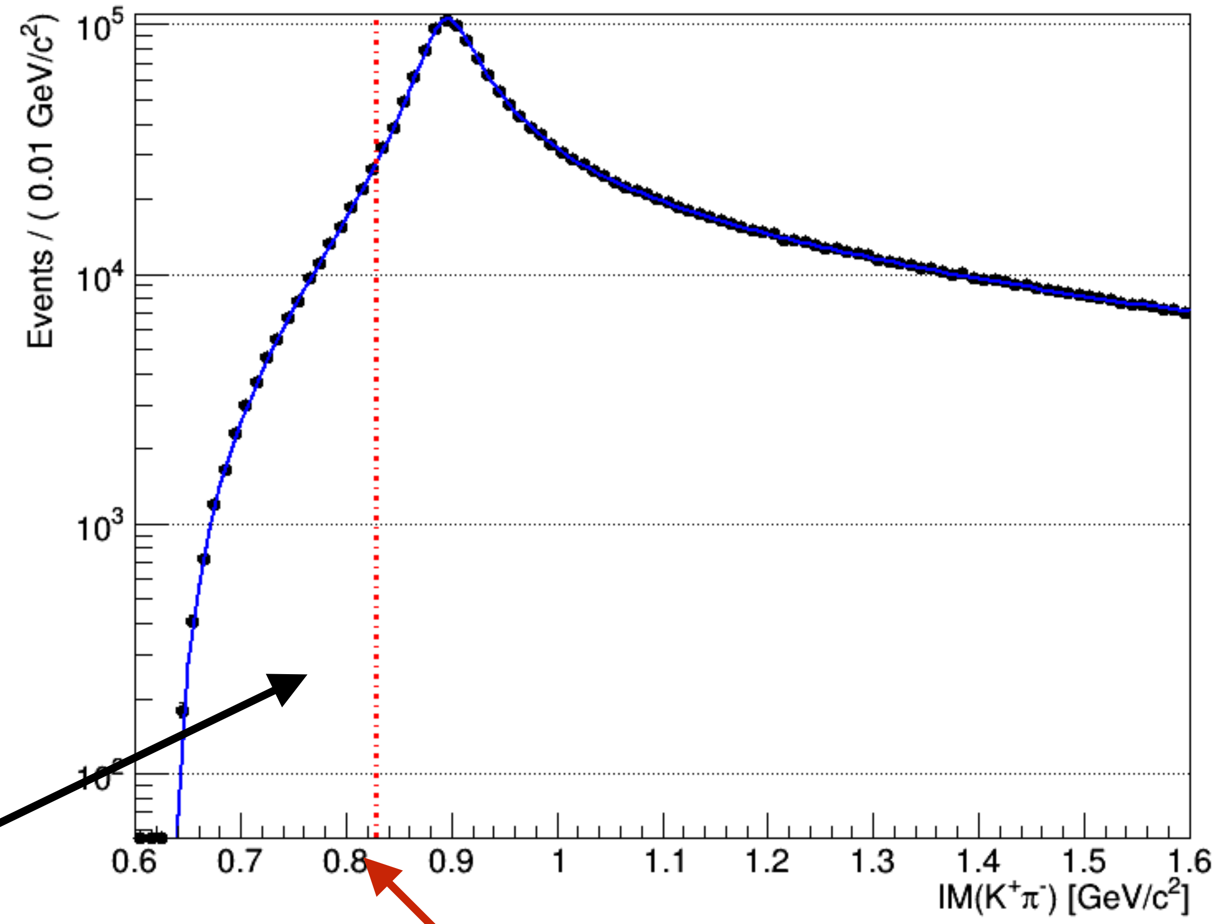
$\tau \to K\pi\nu_\tau$



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

KLF

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



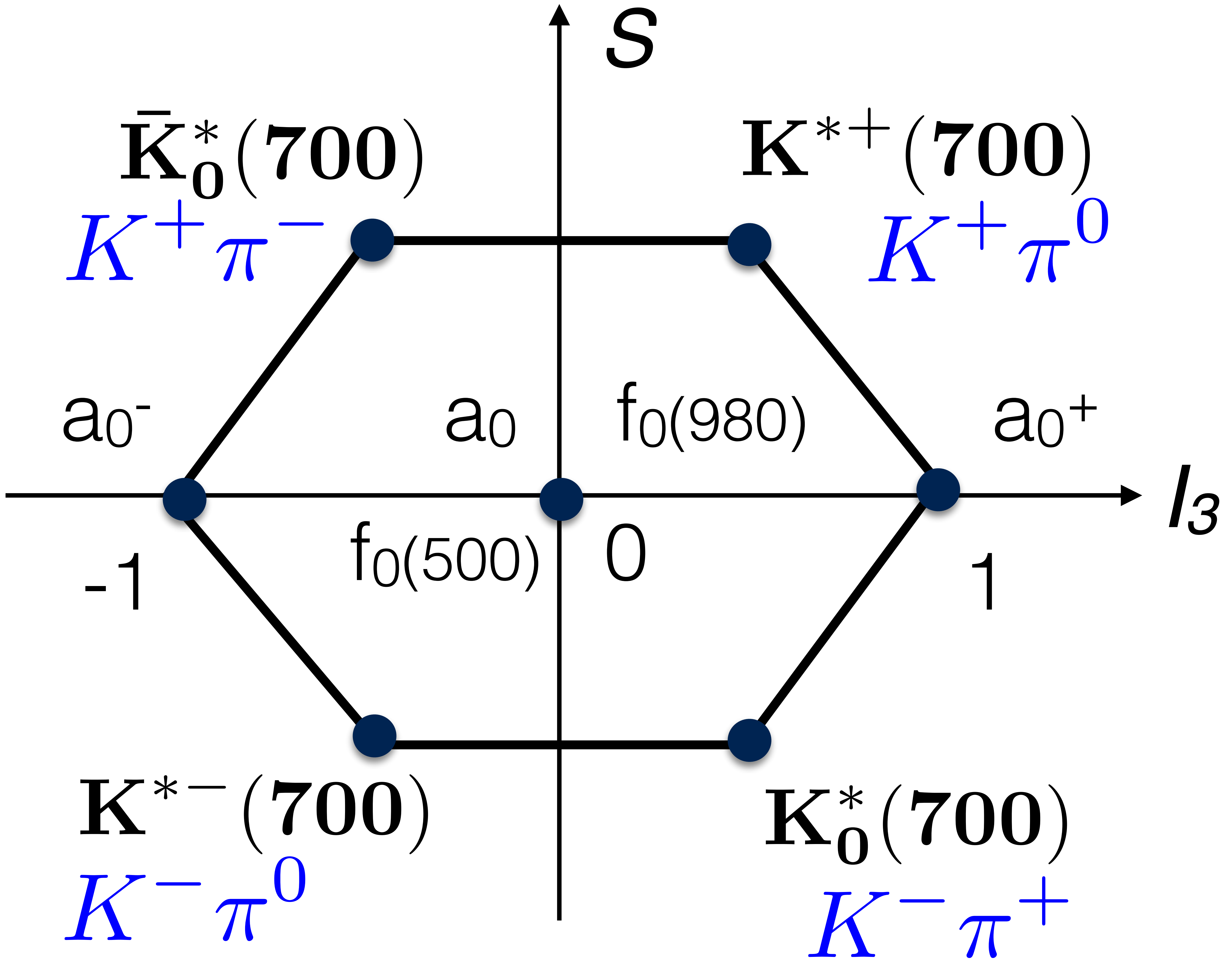
$\mathbf{M(K\pi)(GeV)}$

region of κ

SLAC Lower limit

Scalar Meson Nonet

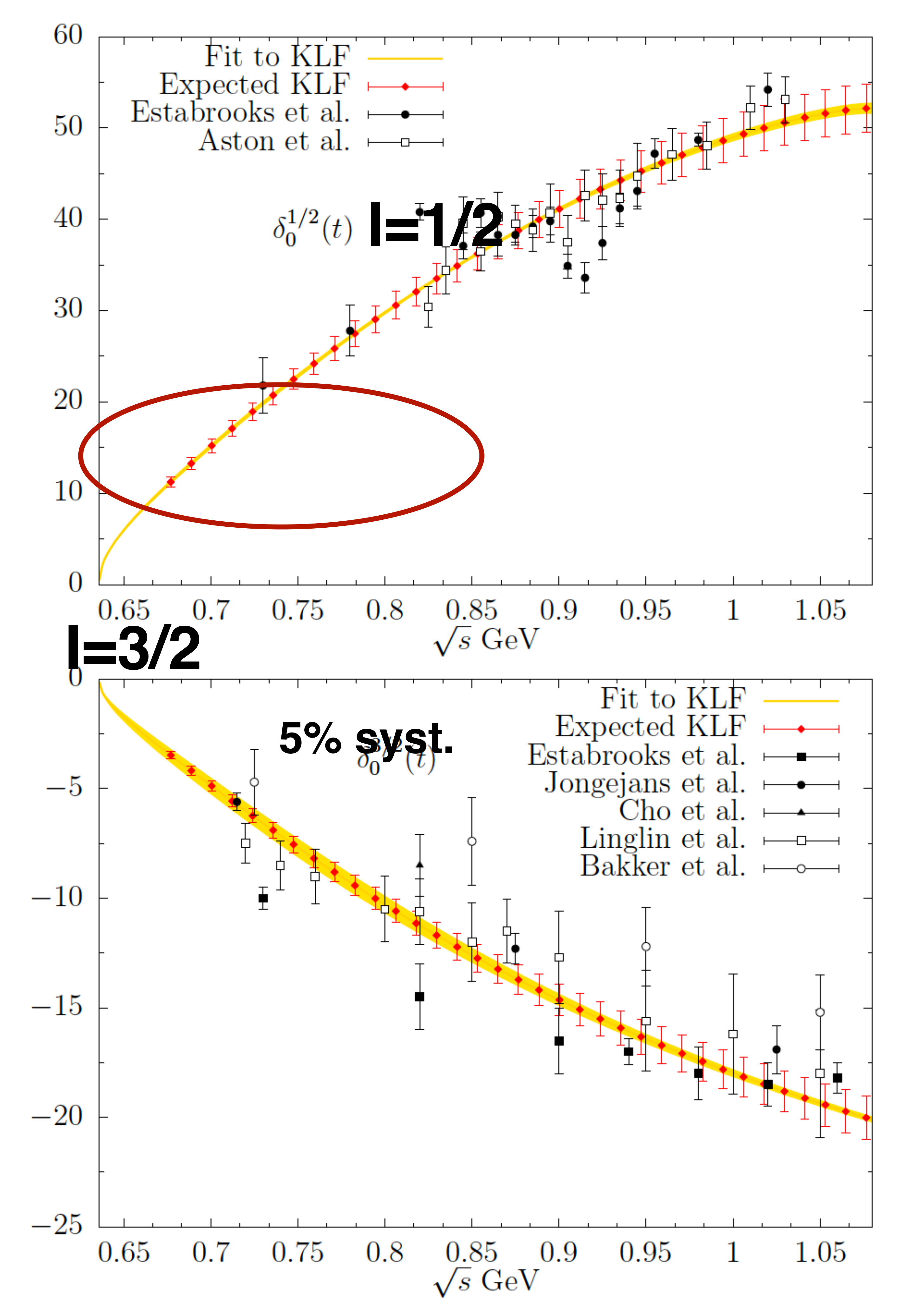
$J^{PC} = 0^{++}$



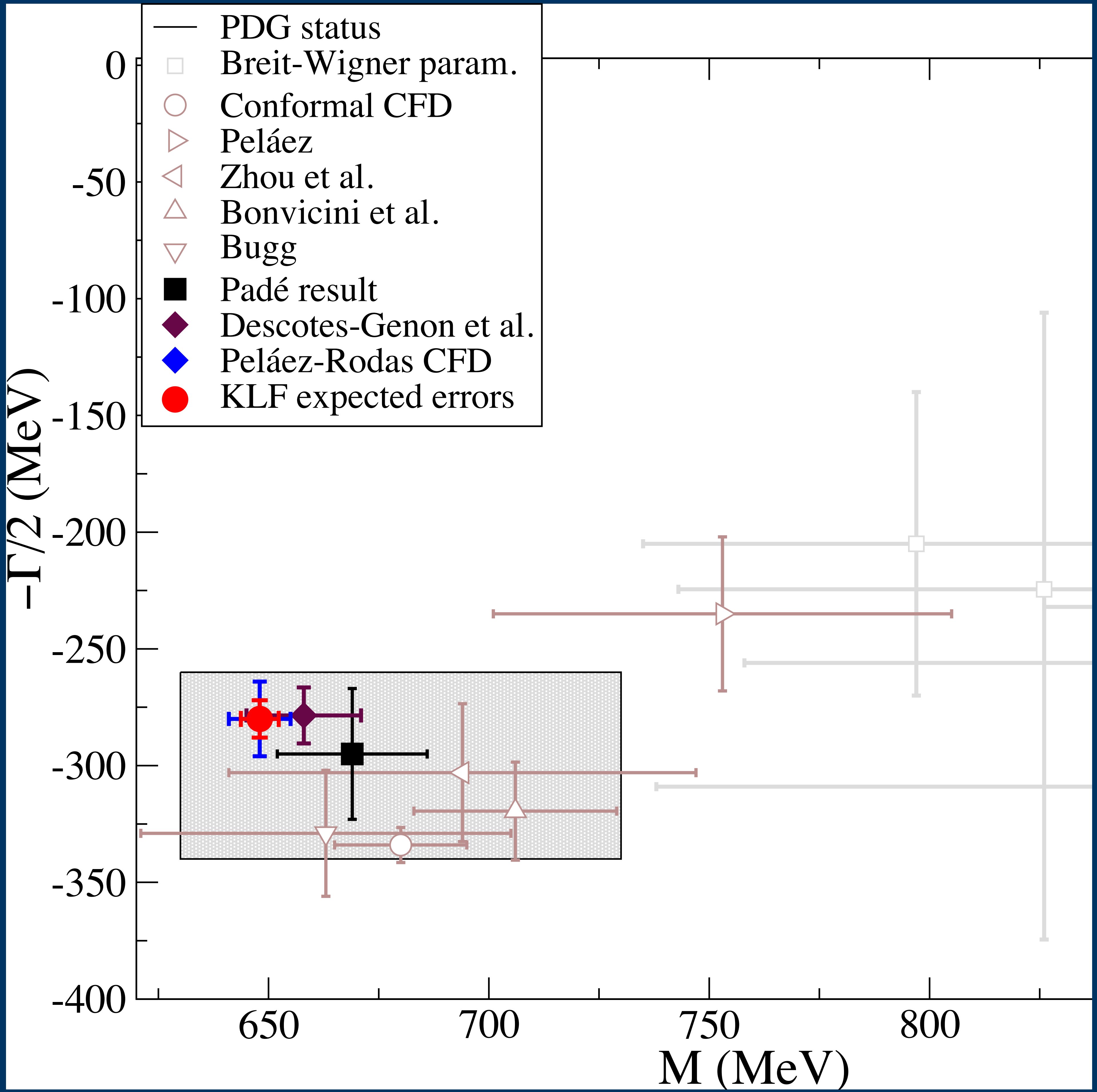
Four states called κ

still need further confirmation(PDG)

Kappa Mass and Width



S wave phase shift, I =1/2 and I = 3/2 with statistical and systematic uncertainities.
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

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

Summary of $K\pi$ Scattering

-The KLF will have a significant impact on our knowledge on $K\pi$ scattering amplitudes

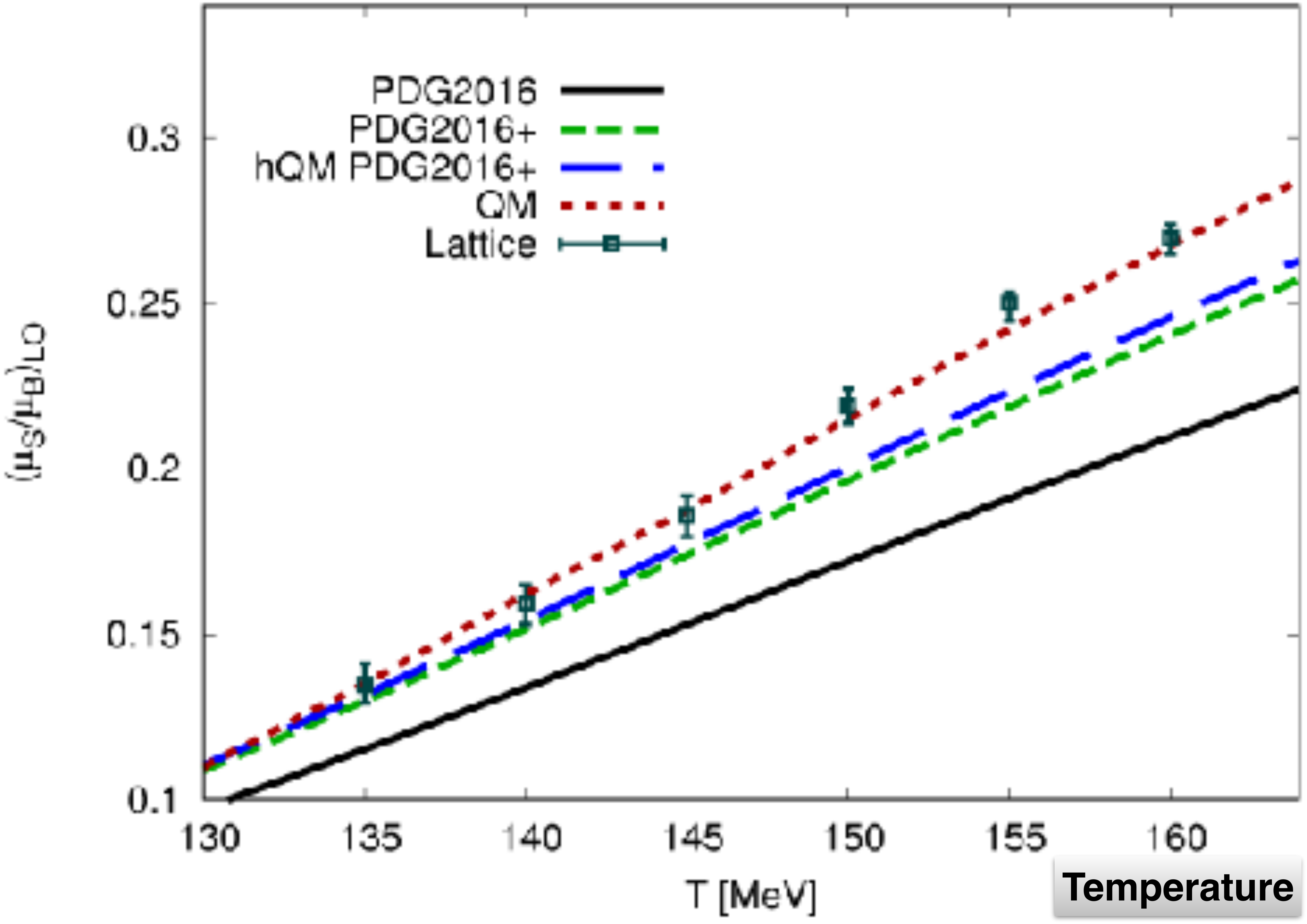
-It will improve on still conflictive determination of heavy K*'s parameters

-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 the uncertainty in the mass determination of K*(700) and by by more than a factor of two and by factor of five the uncertainty on its width

-It will further clarify debates of its existence, and therefore a long standing problem of the existence of the scalar meson nonet

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



Temperature

Observe dozens Missing states

SUMMARY

- -Proposed KL Facility has a unique capability to improve existing world database up to three orders of magnitude
- -In Hyperon spectrosocopy
  PWA will allow to unravel and measure pole positions and widths of a few dozens of new excited states
- -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 2M

Thanks for your attention!