Strange Hadron Spectroscopy with Secondary KL Beam in Hall-D

Moskov Amaryan

Old Dominion University
Norfolk, VA

(on behalf of  *Collaboration)*

PAC47, JLab, July 30, 2019

Outline

Current Status

- *Hyperon Spectroscopy*
- *Strange Meson Spectroscopy*

Future Prospects with K_L Facility at JLab

- *Electron Beam*
- *Compact Photon Source*
- *Be Target*
- *Flux Monitor*
- *K_L Beam*
- *LH_2/LD_2 Target*

Summary

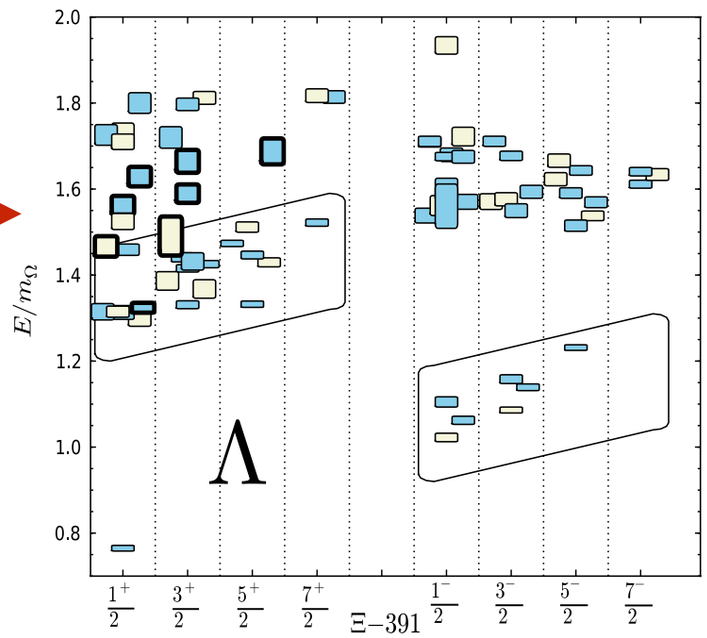
Hyperon Spectroscopy

*According to **LQCD** there should be*

many more states including hybrids (thick bordered)

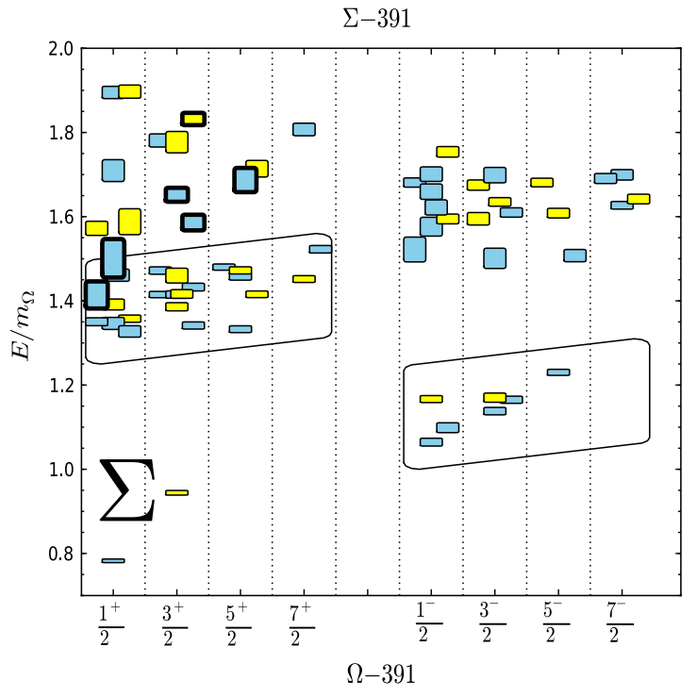
8-states
****

5-states
***



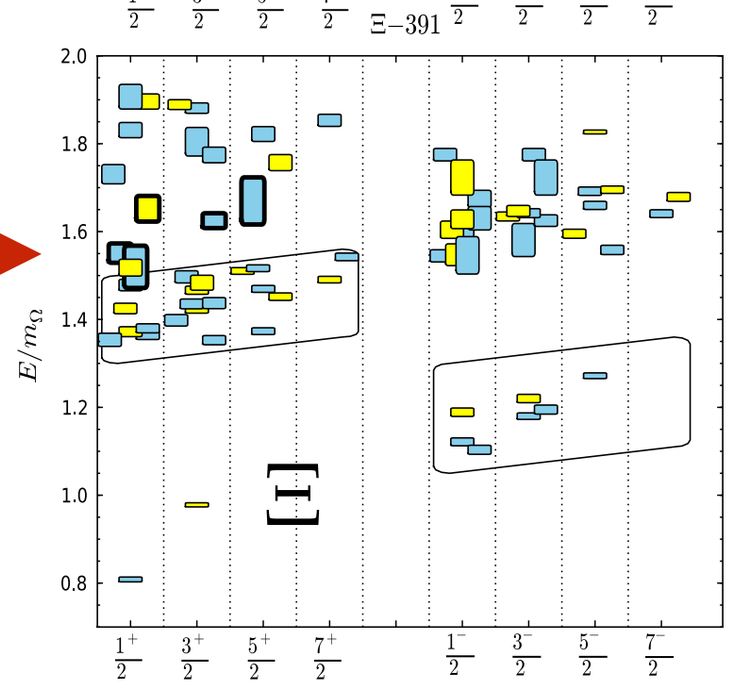
6-states
****

4-states
***



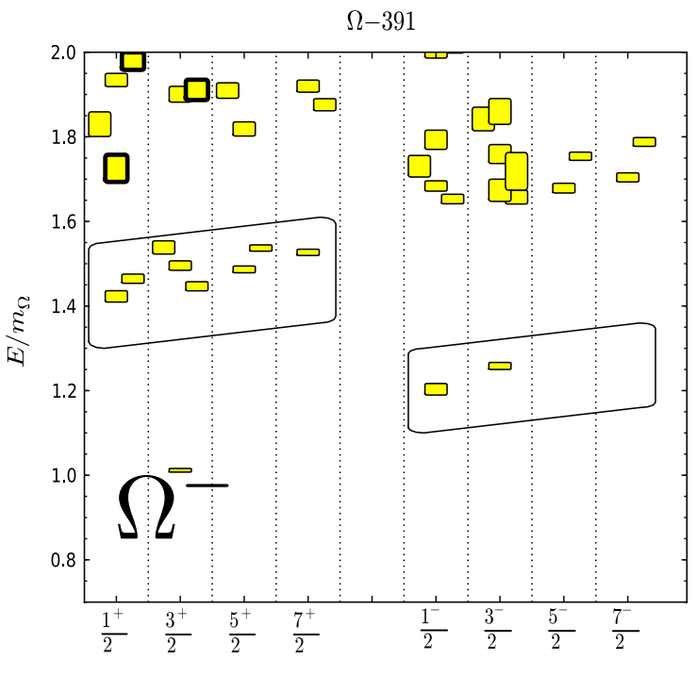
3-states
****

4-states
***



1-state
****

1-state
***

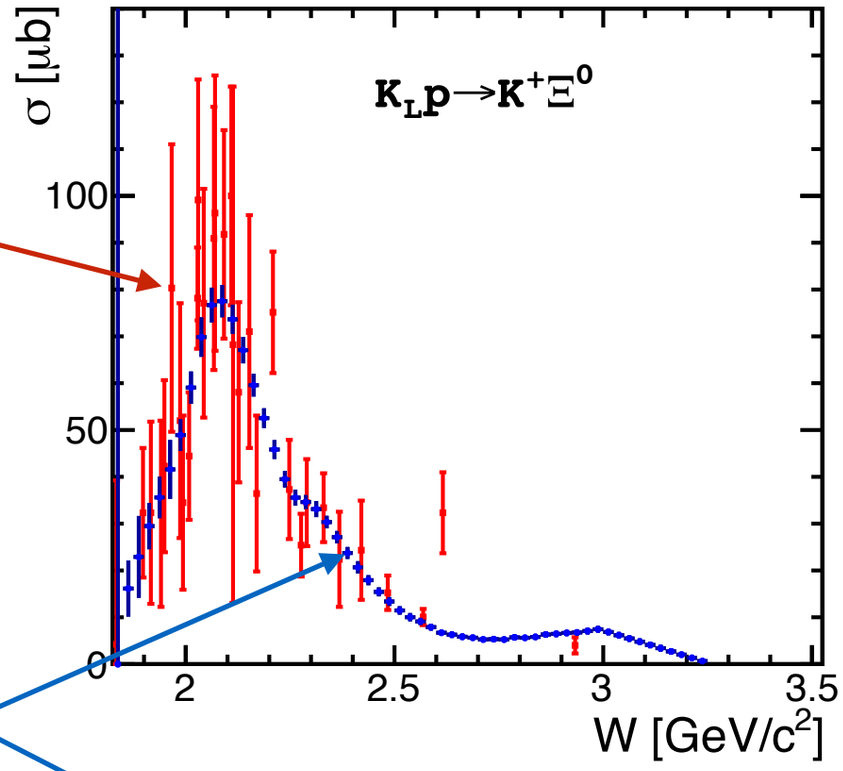


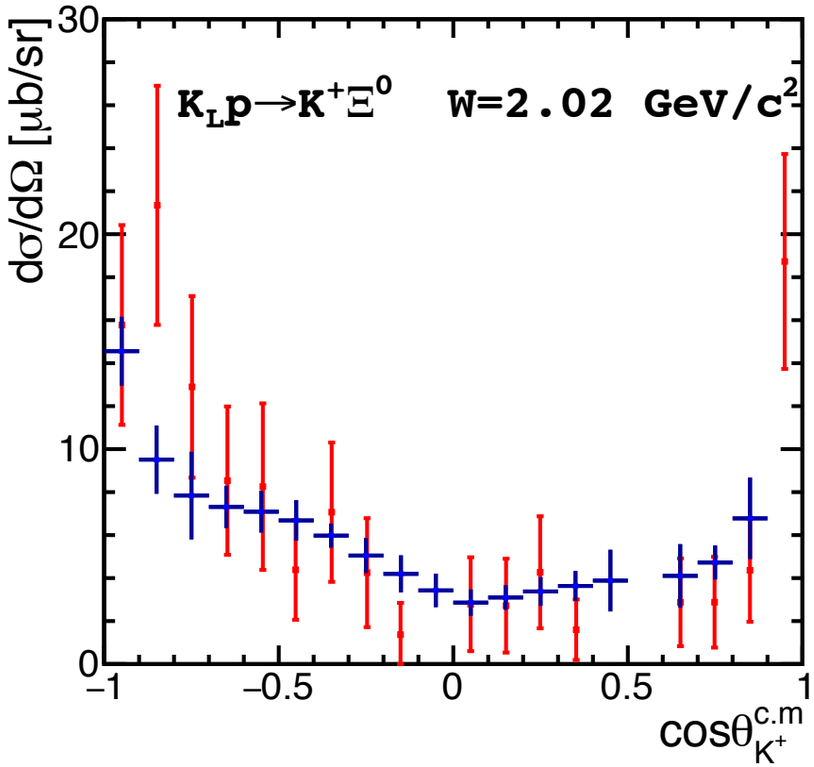
Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

Measurements on Proton Target

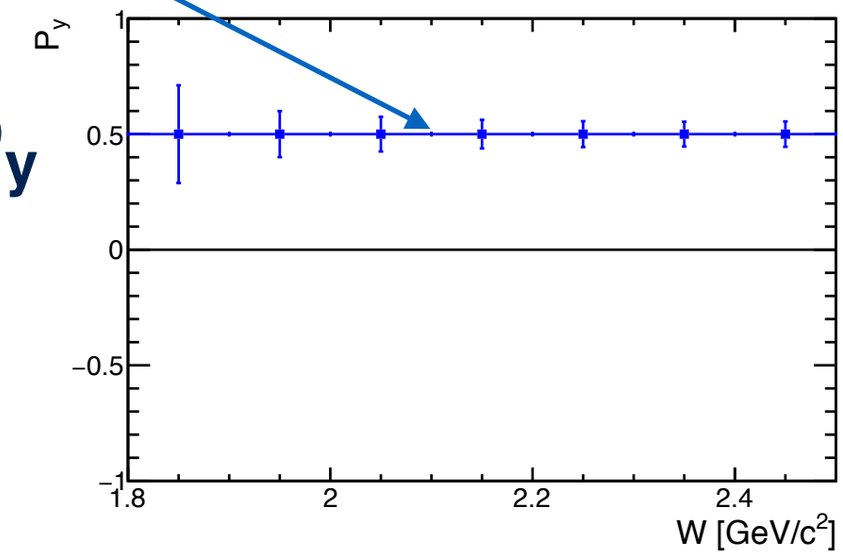
existing data

KLF 100 days



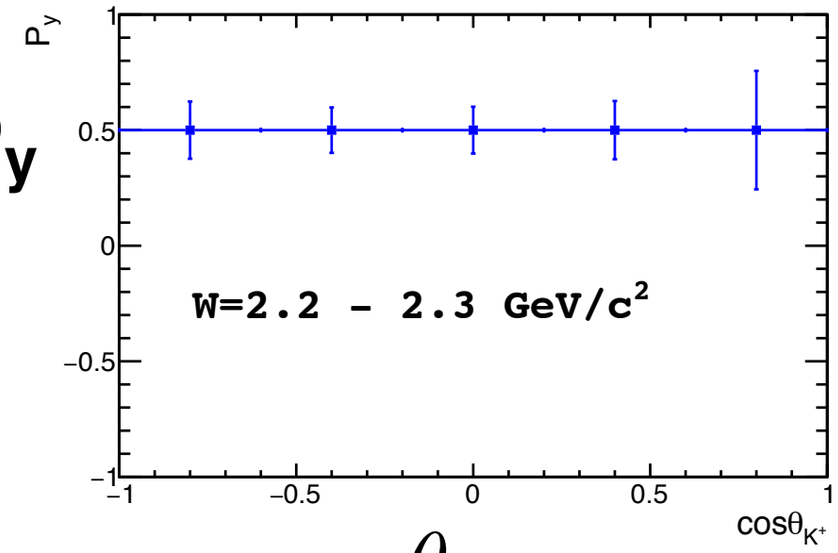


P_y



$\mathbf{W(GeV/c^2)}$

P_y



$\mathrm{COS}\ \theta_{\mathbf{K}+}$

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 coupled-channel PWA

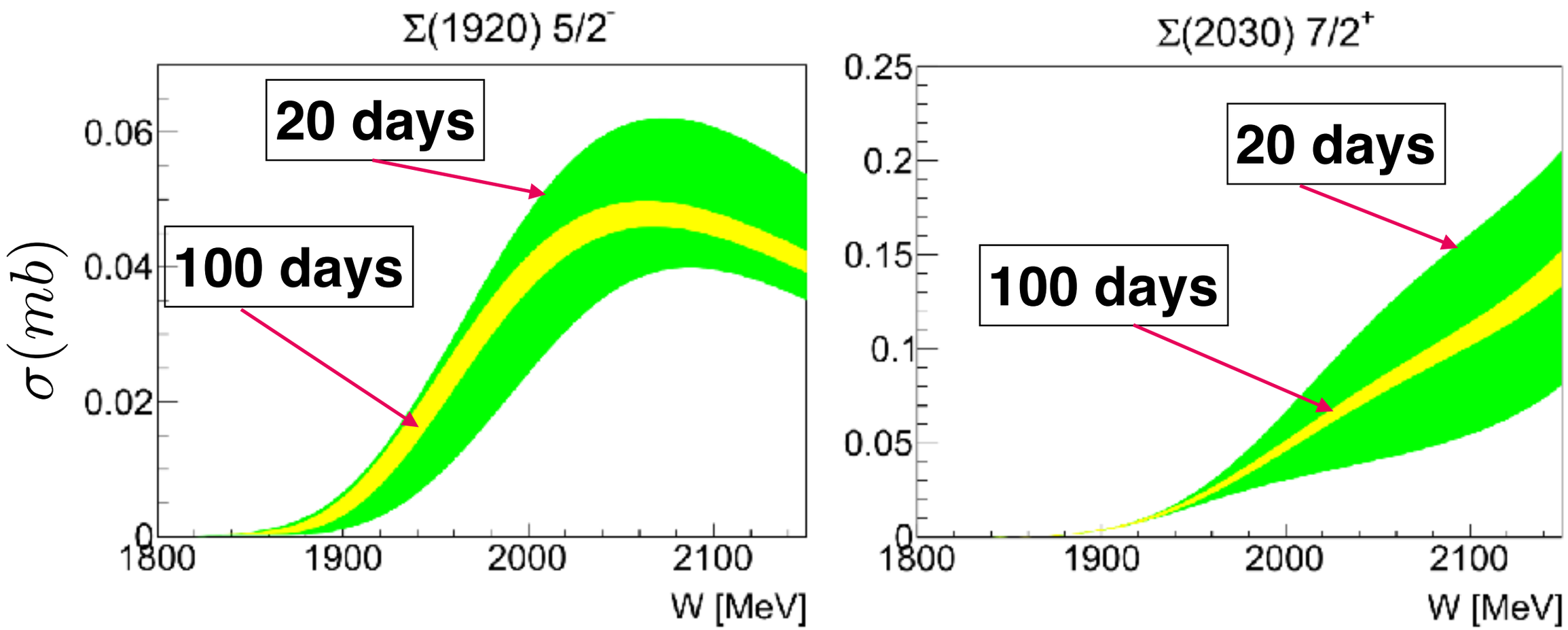
-look for poles in complex energy plane
(contrary to naïve bump hunting)

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

we use KN scattering data with statistics
generated according to expected K-long Facility (KLF)
data for 20 and 100 days to show PWA sensitivity
to obtain results close to the best fit

Bonn-Gatchina PWA

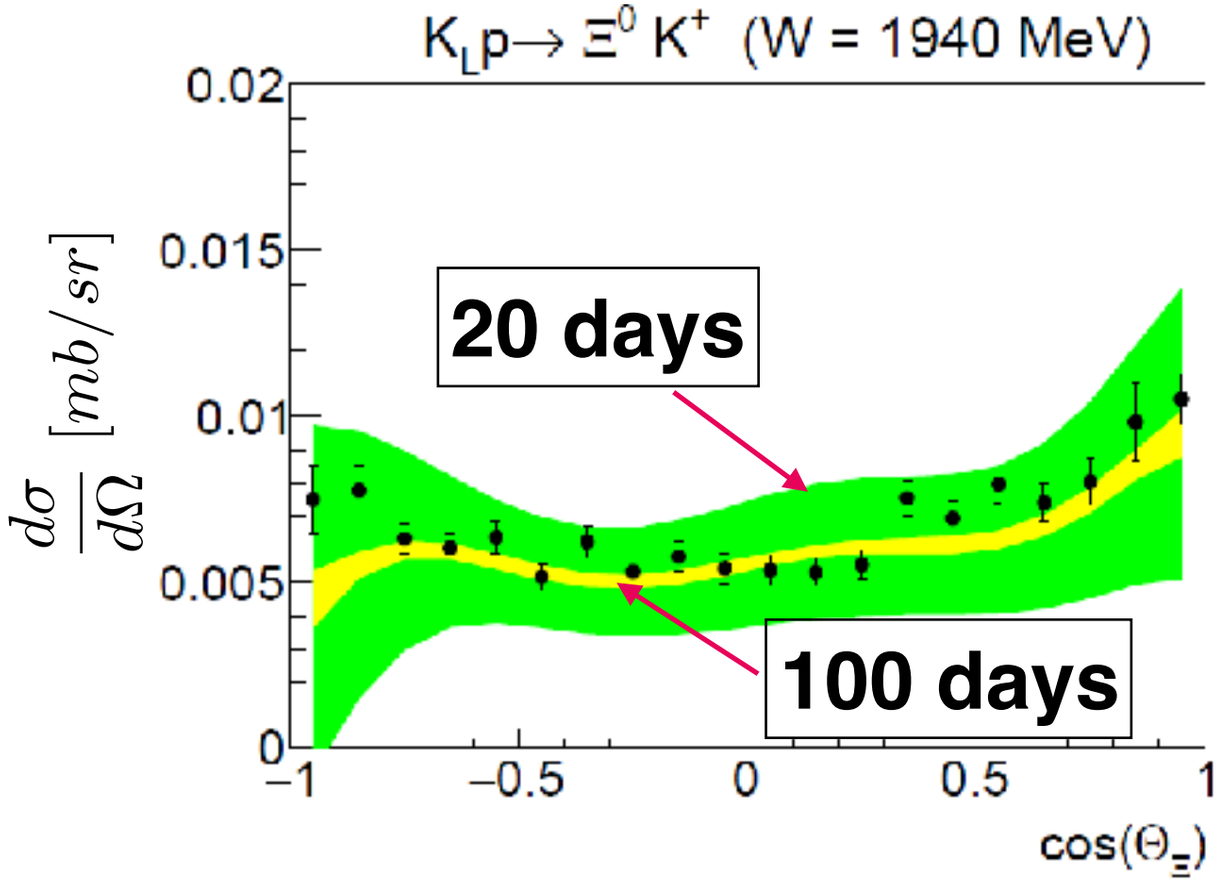
Total Cross Section $K_L p \to K^+ \Xi^0$



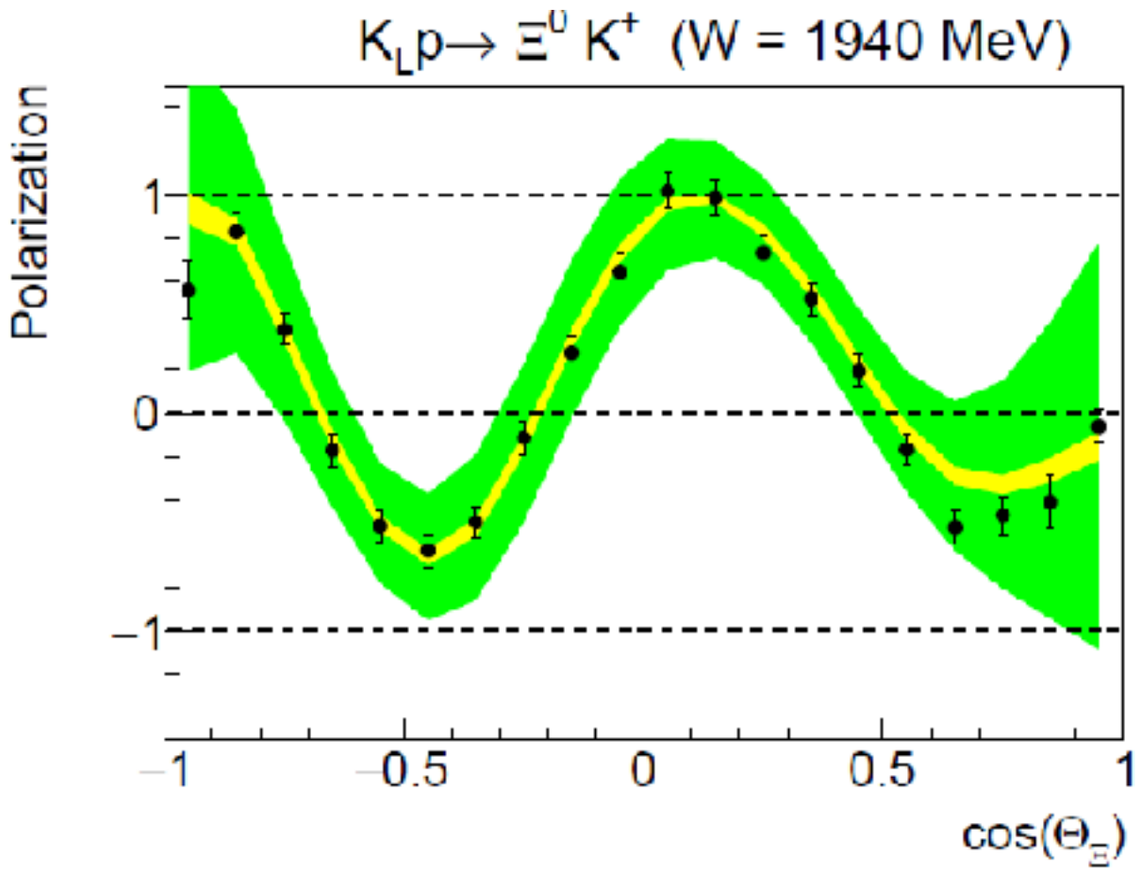
Obviously: at least 100 days needed to get precise solution

Bonn-Gatchina PWA

Diff. Cross Section



Polarization



Again: at least 100 days to get precise solution

Some Numerical Results

Simulated $\Sigma(1920)\ 5/2^-$

$$\begin{cases} 100d\ M = 1.923 \pm 0.010 \pm 0.010\ GeV \\ \Gamma = 0.321 \pm 0.01 \pm 0.010\ GeV \end{cases}$$

$$20d\ M = 1.977 \pm 0.021 \pm 0.025\ GeV$$

$$\Gamma = 0.327 \pm 0.025 \pm 0.025\ GeV$$

$$PDG2018\ M = 1.775 \pm 0.005$$

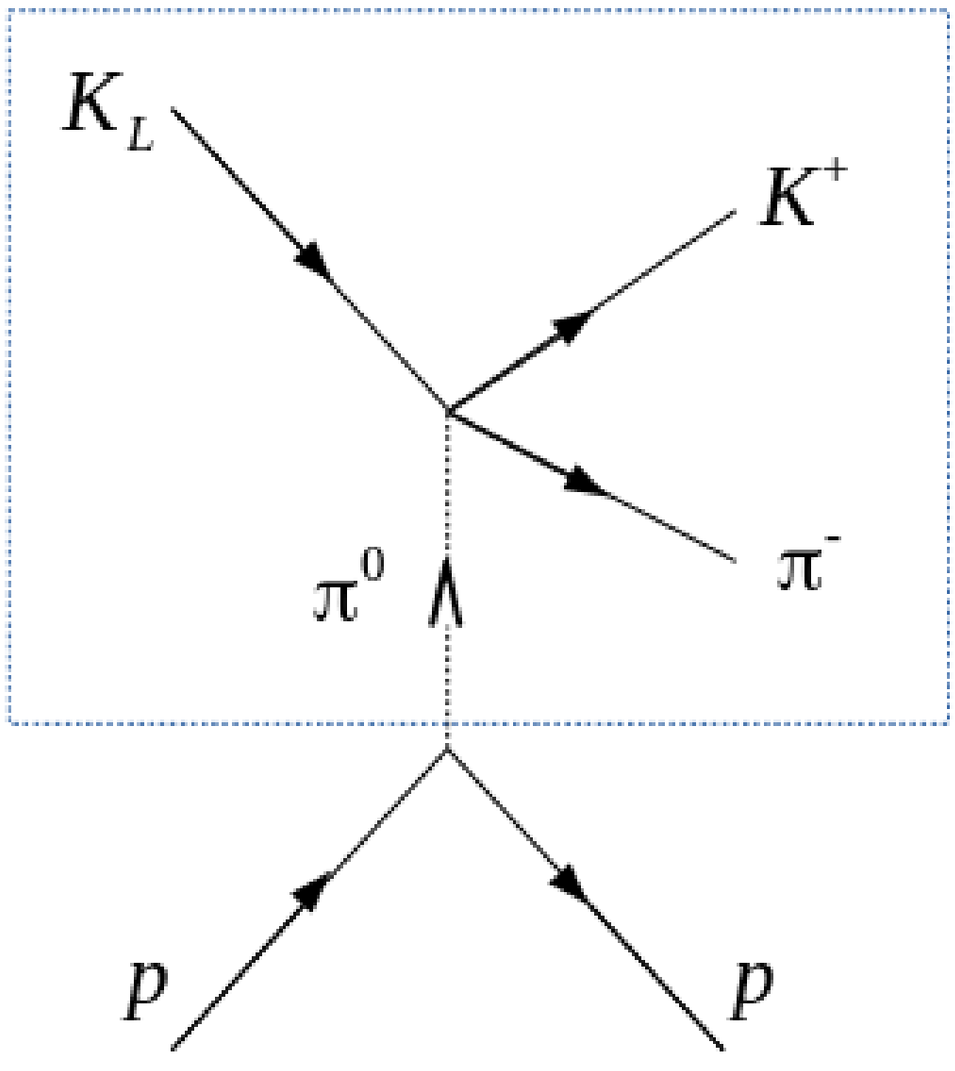
LQCD M=
2.027 GeV
2.487 GeV
2.659 GeV
2.781 GeV

R.G. Edwards et al., PRD 87,no.5. 054506 (2013)

LQCD Results are still in progress

Strange Meson Spectroscopy

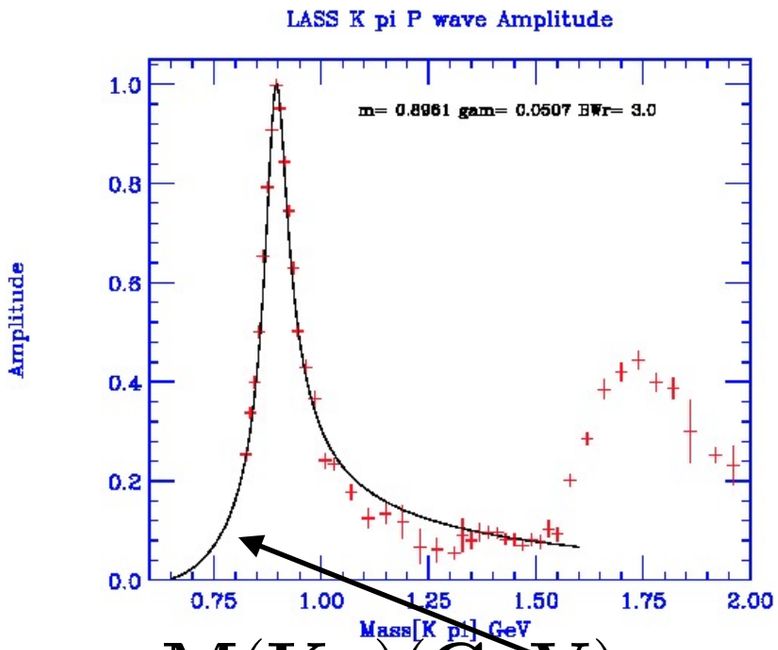
$K\pi$ Scattering



Proposed Measurements

SLAC

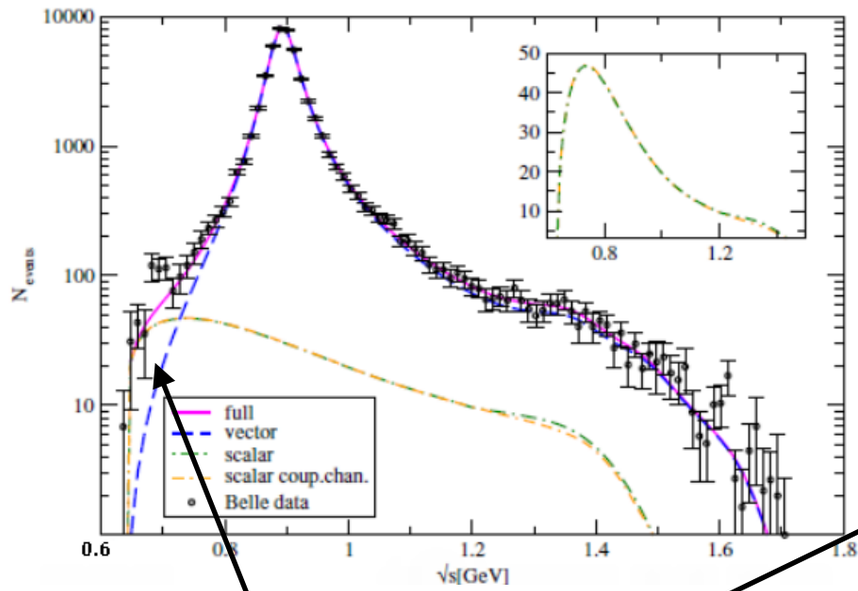
$$K^-\pi^+ \to K^-\pi^+$$



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

Belle

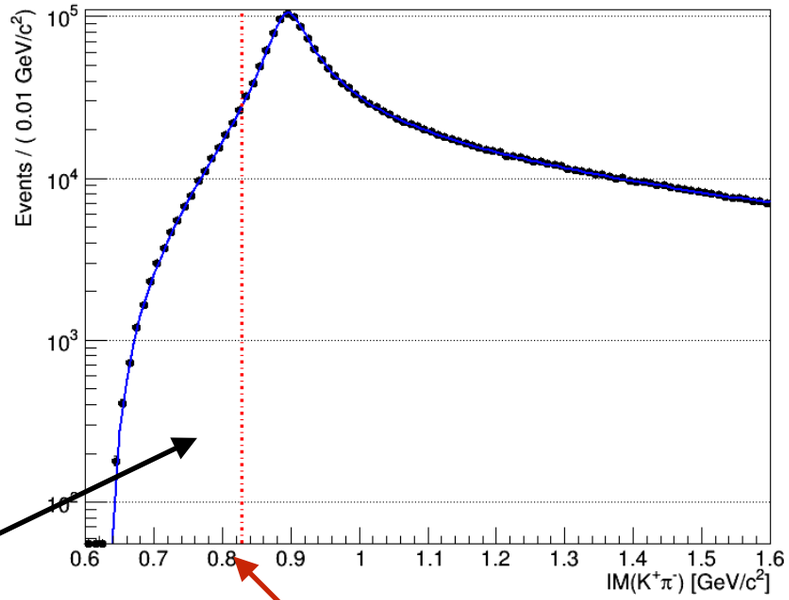
$$\tau \to K\pi\nu_\tau$$



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

KLF

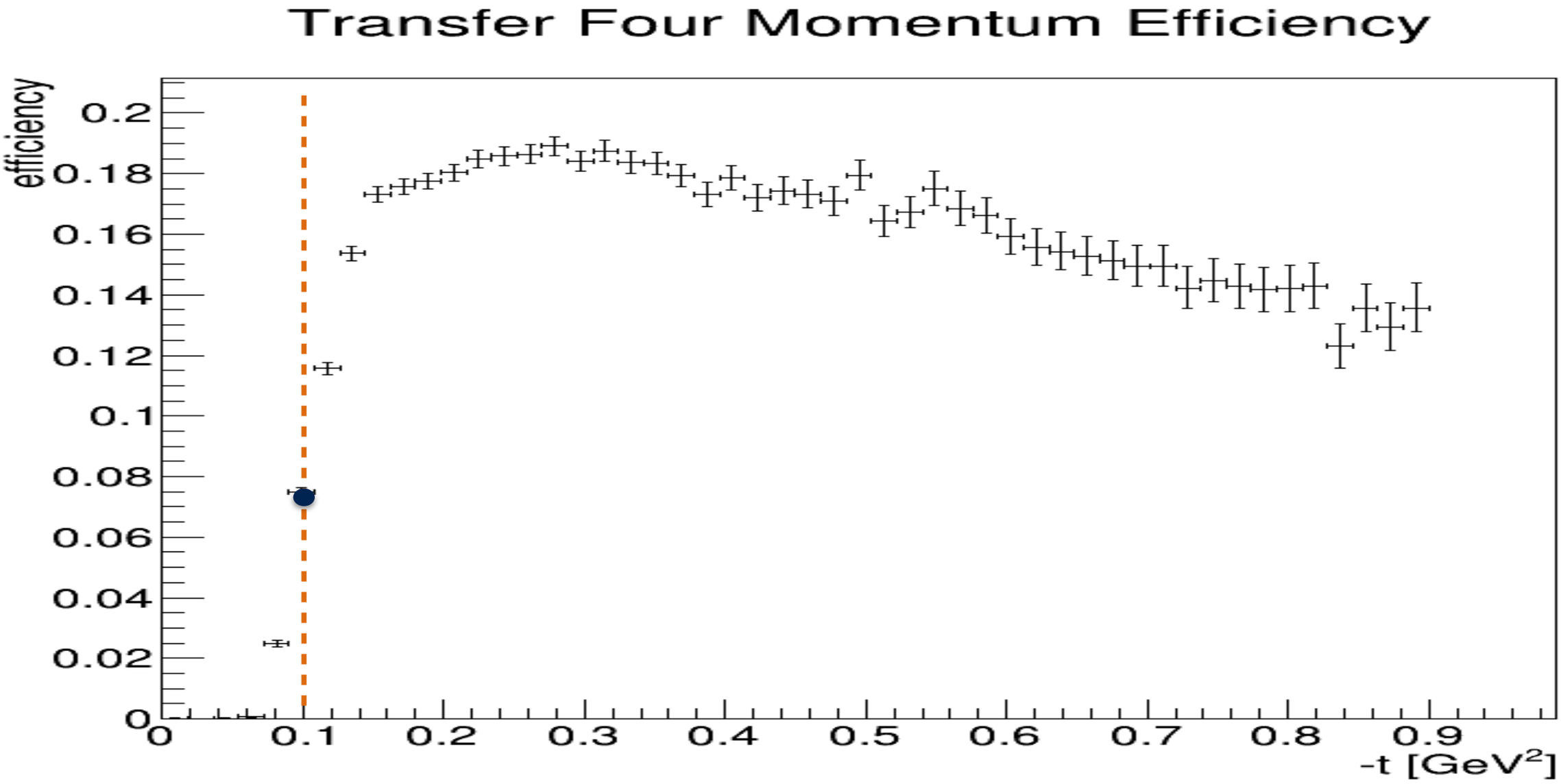
$$K_L\pi^0 \to K^+\pi^-$$



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

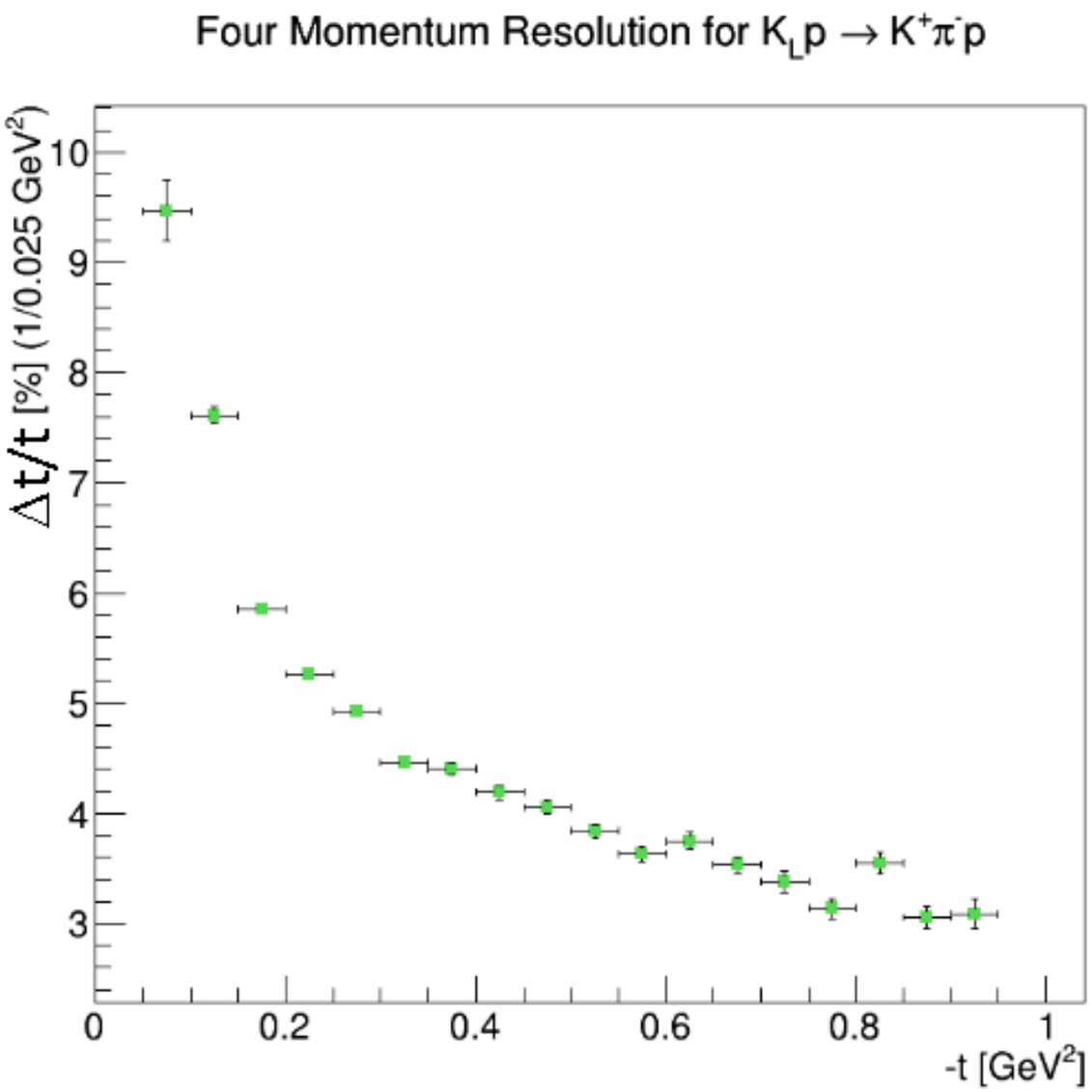
region of $\kappa(800)$

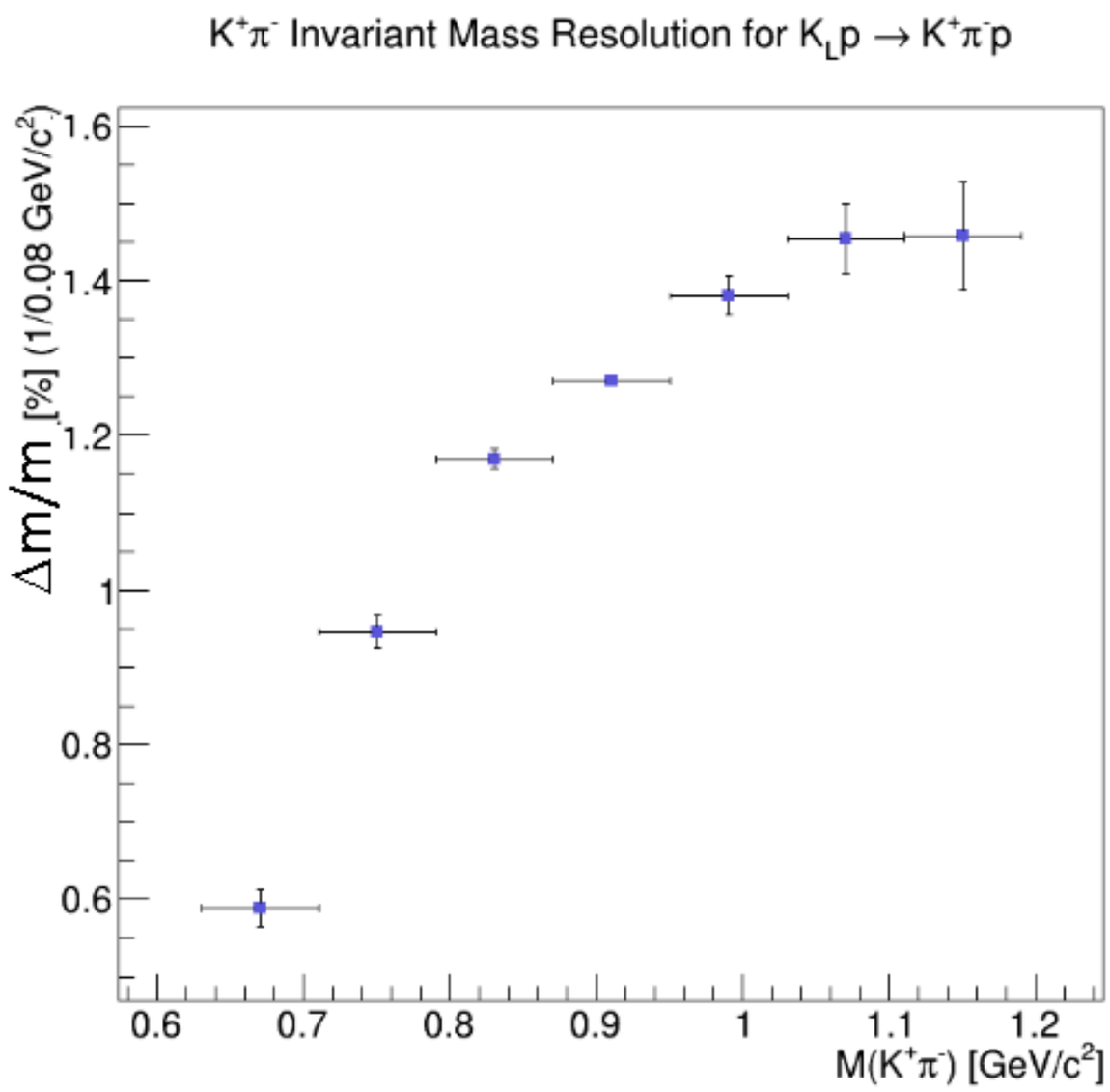
SLAC Lower limit



t-down to 0.1 GeV^2 is measurable
with proton being detected

$K\pi$ *Scattering Resolutions*

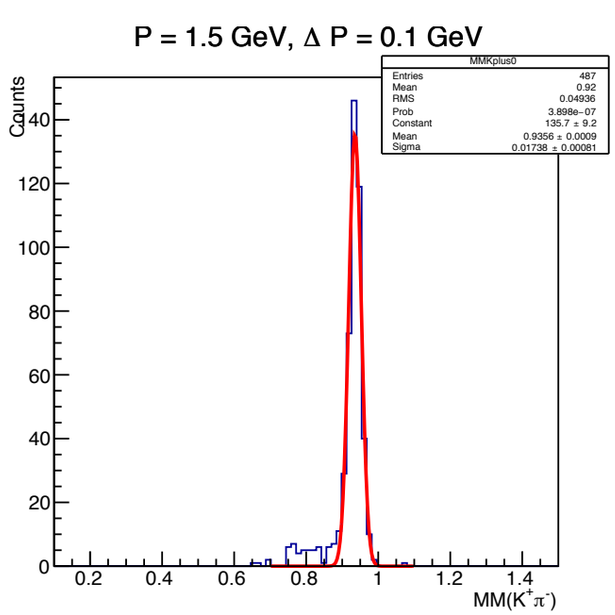


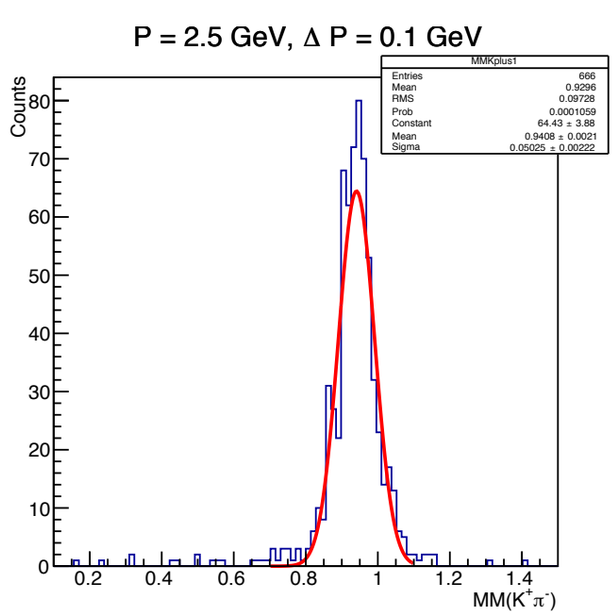


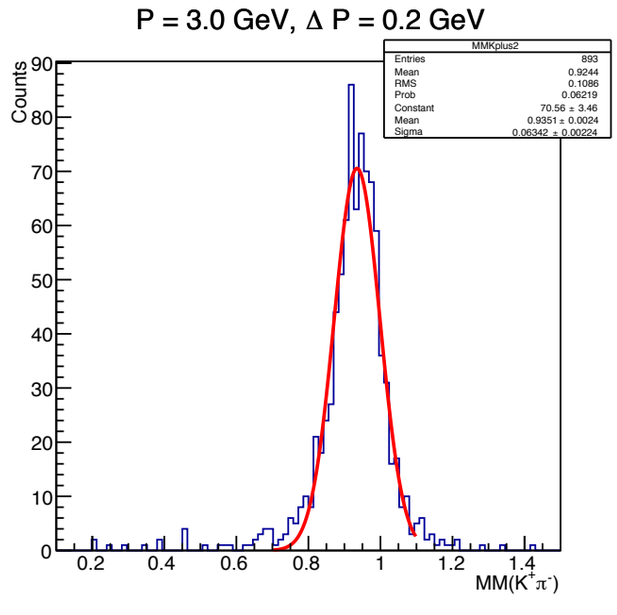
-Good resolution at low-t is needed to be close to pion pole

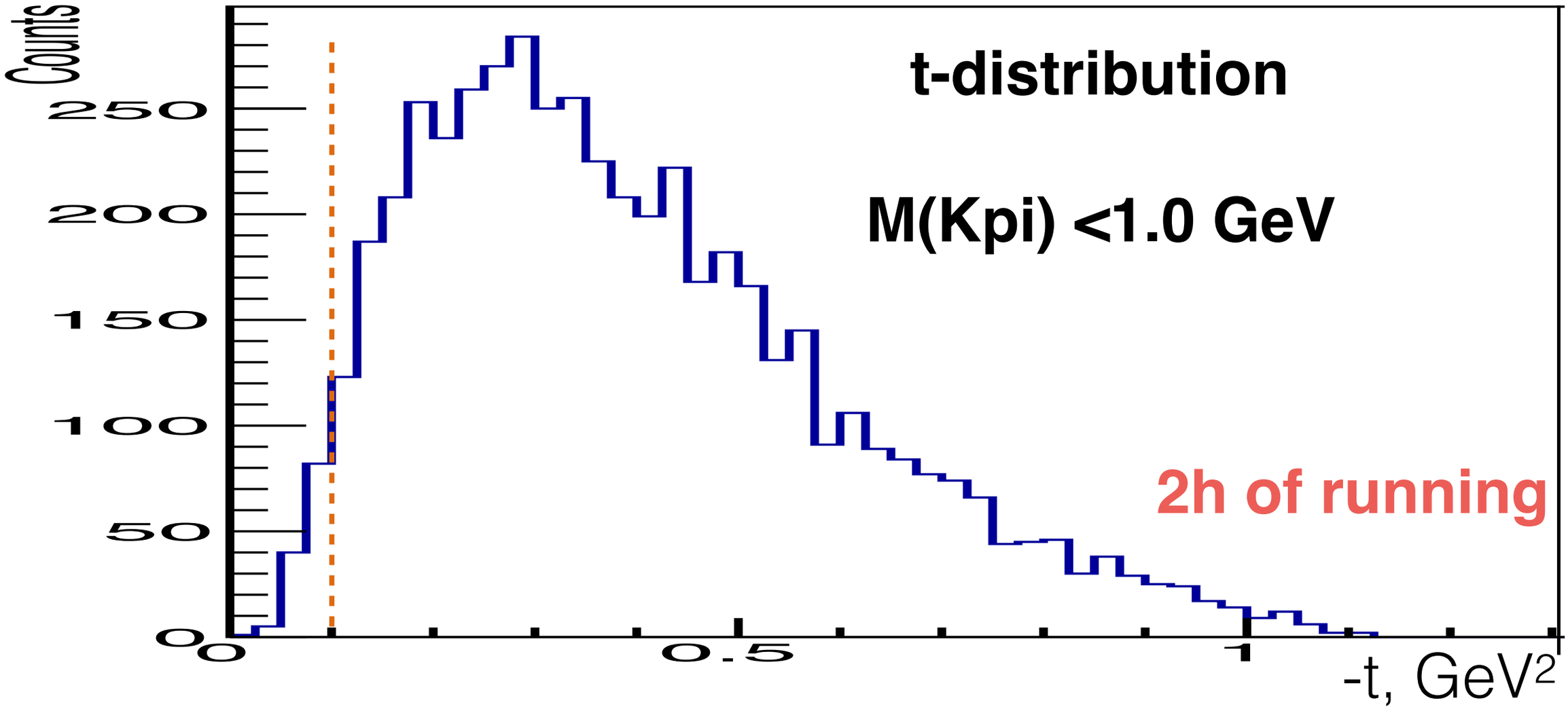
-Binning in ~10 MeV will cover almost entire elastic K-pi scattering range

Missing Mass of $K^+\pi^-$ system in

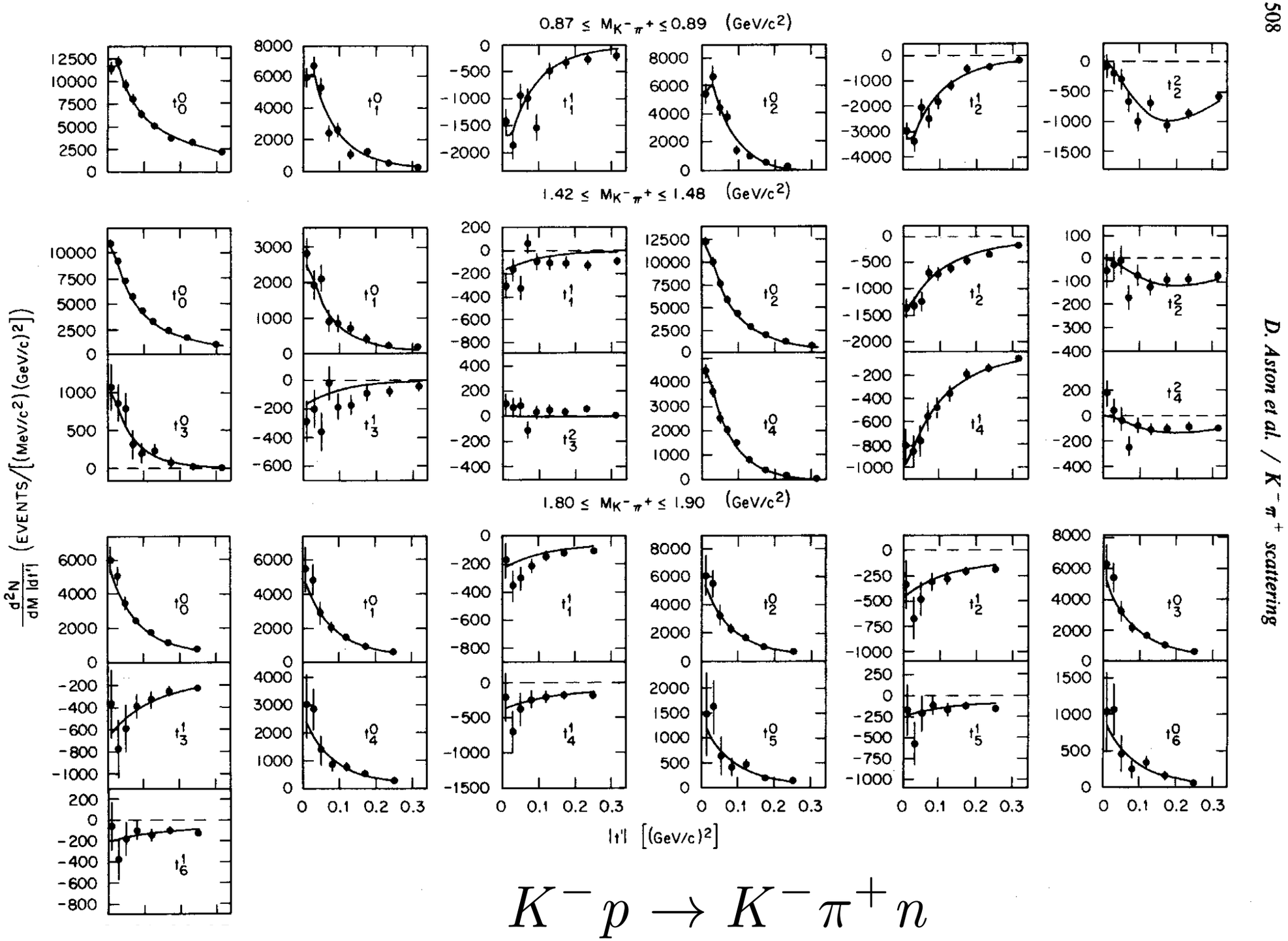






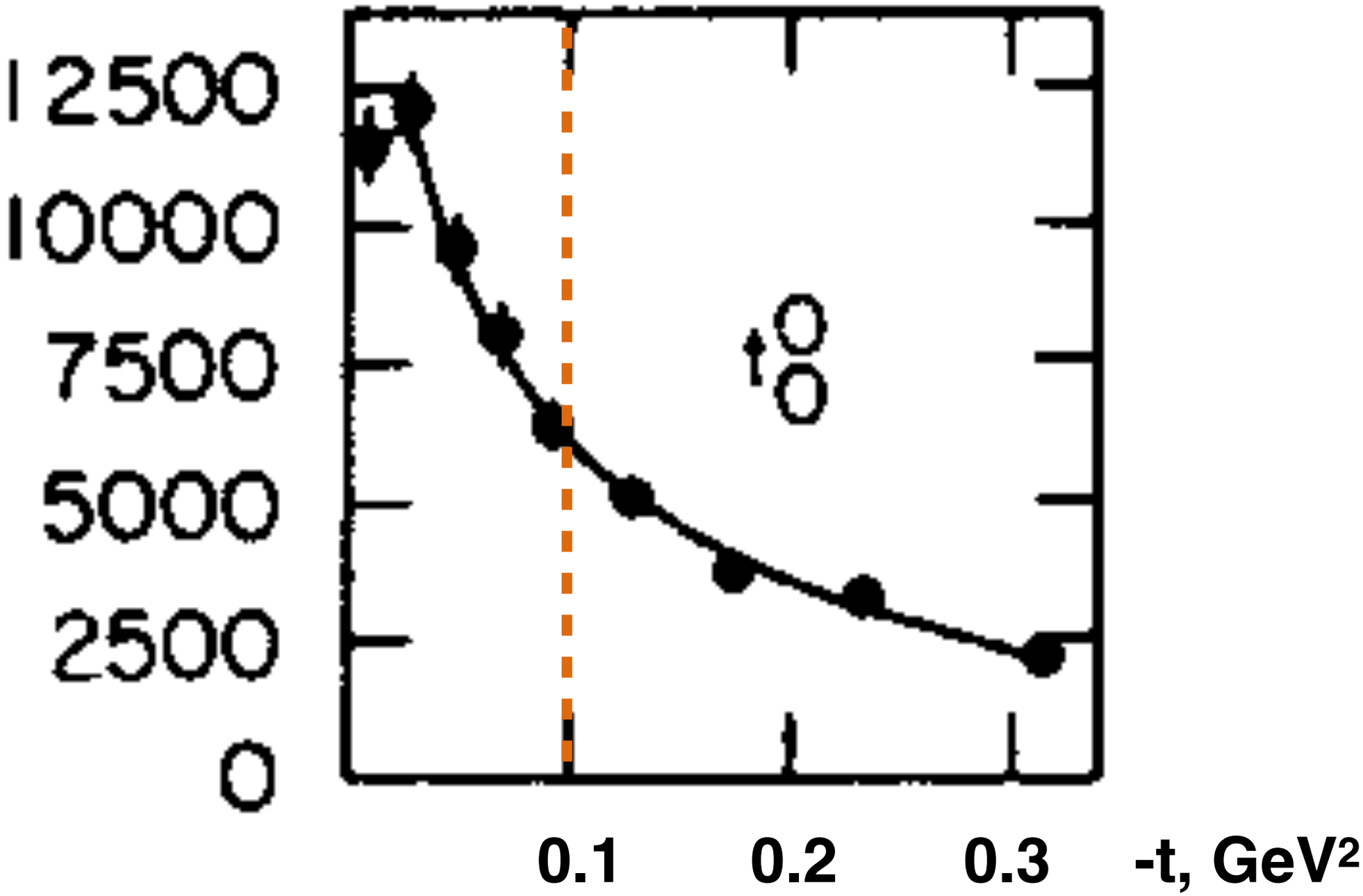


NPB296 Aston et al., LASS at SLAC at 11 GeV



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

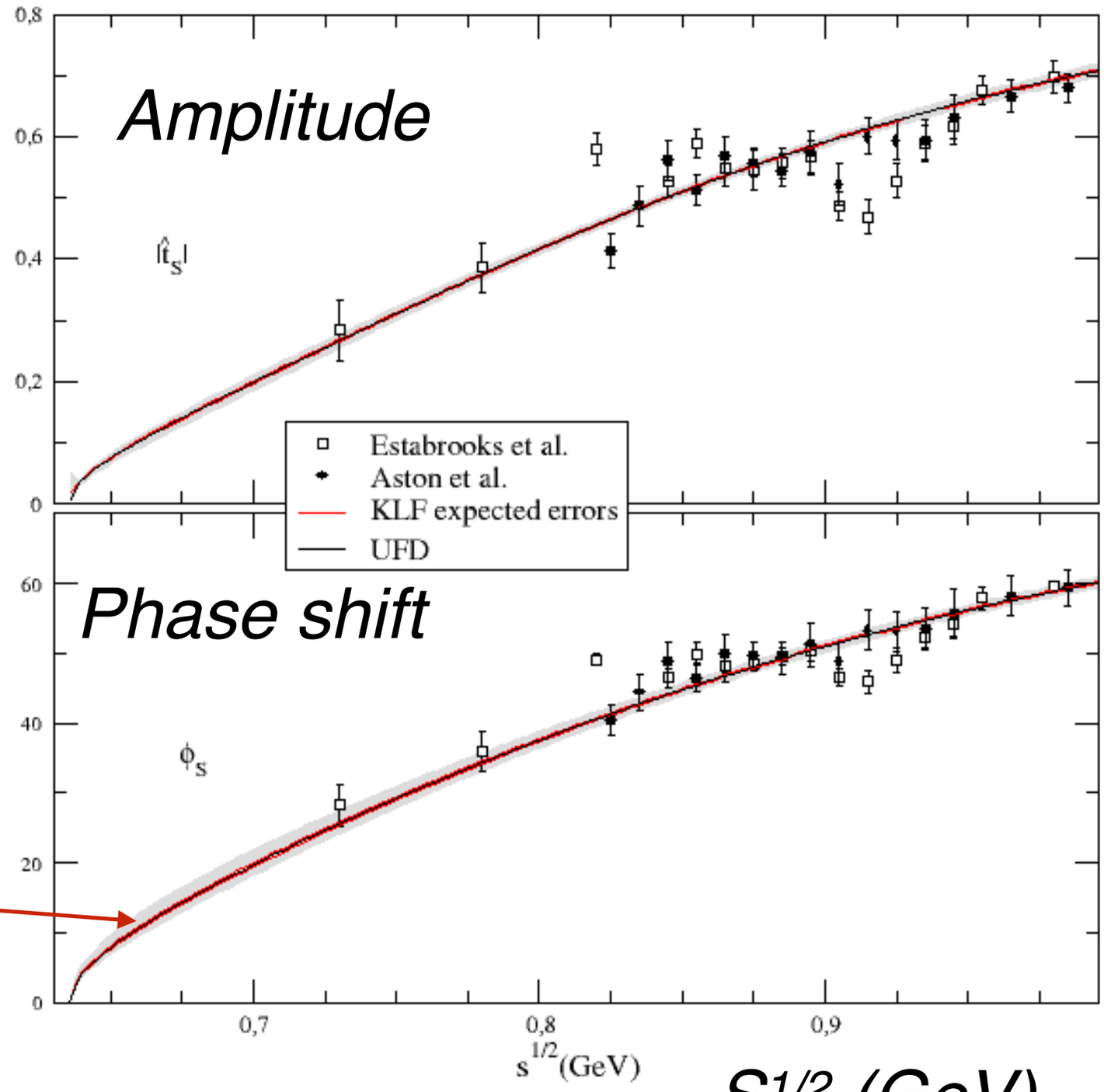
Fig. 9. The acceptance corrected unnormalized $K^-\pi^+$ moments as a function of $|t'|$. Three different mass regions are shown; $0.87 \leqslant M_{K\pi} \leqslant 0.89$ GeV/c^2, $1.42 \leqslant M_{K\pi} \leqslant 1.48$ GeV/c^2, and $1.80 \leqslant M_{K\pi} \leqslant 1.90$ GeV/c^2. The curves are the result of a fit to the production model described in the text.


12500
10000
7500
5000
2500
0
t0
0.1
0.2
0.3
-t, GeV²

Projected Measurements

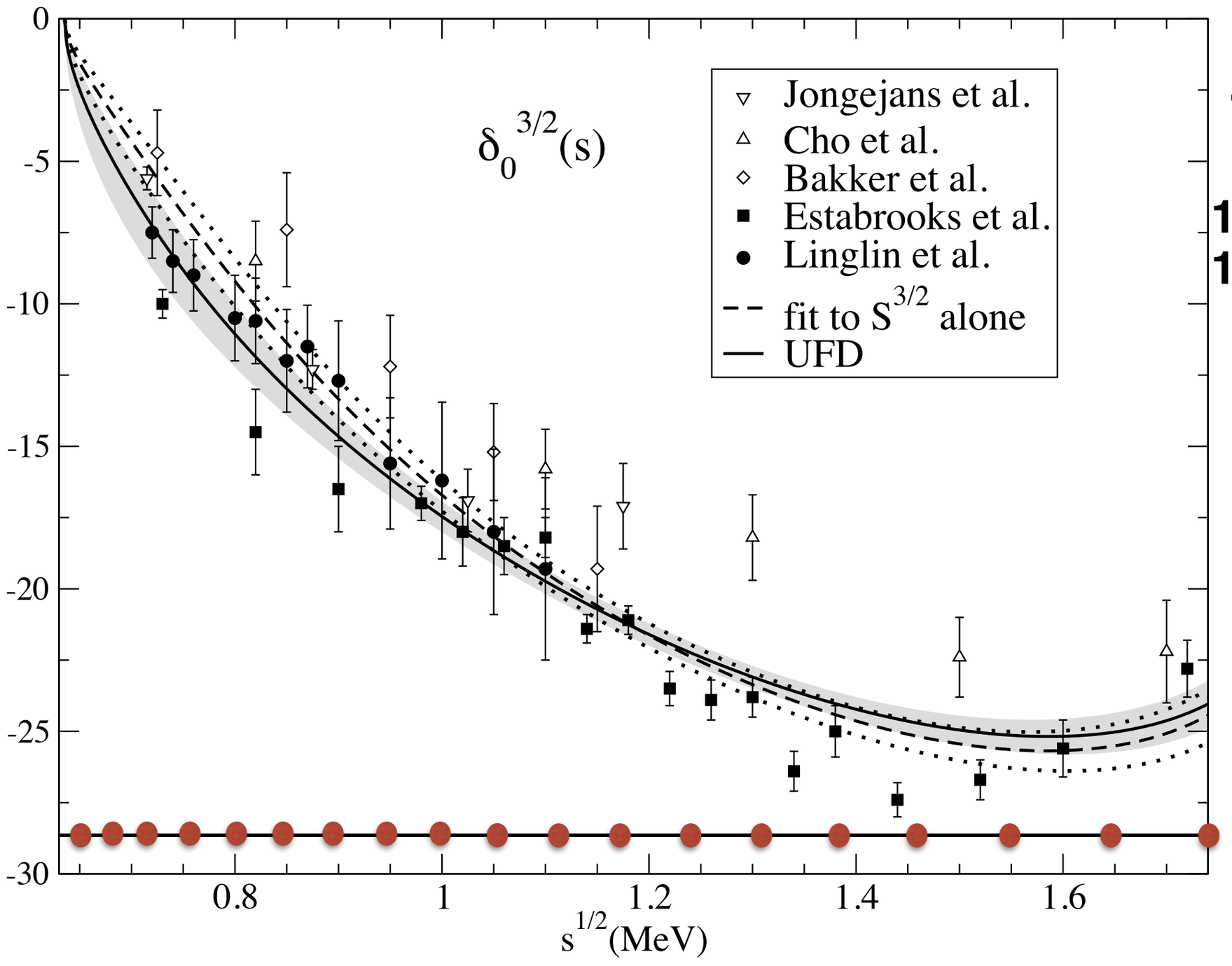
I=3/2+1/2 *S-wave*

SLAC Data



KLF (100 days)

I=3/2 S-wave



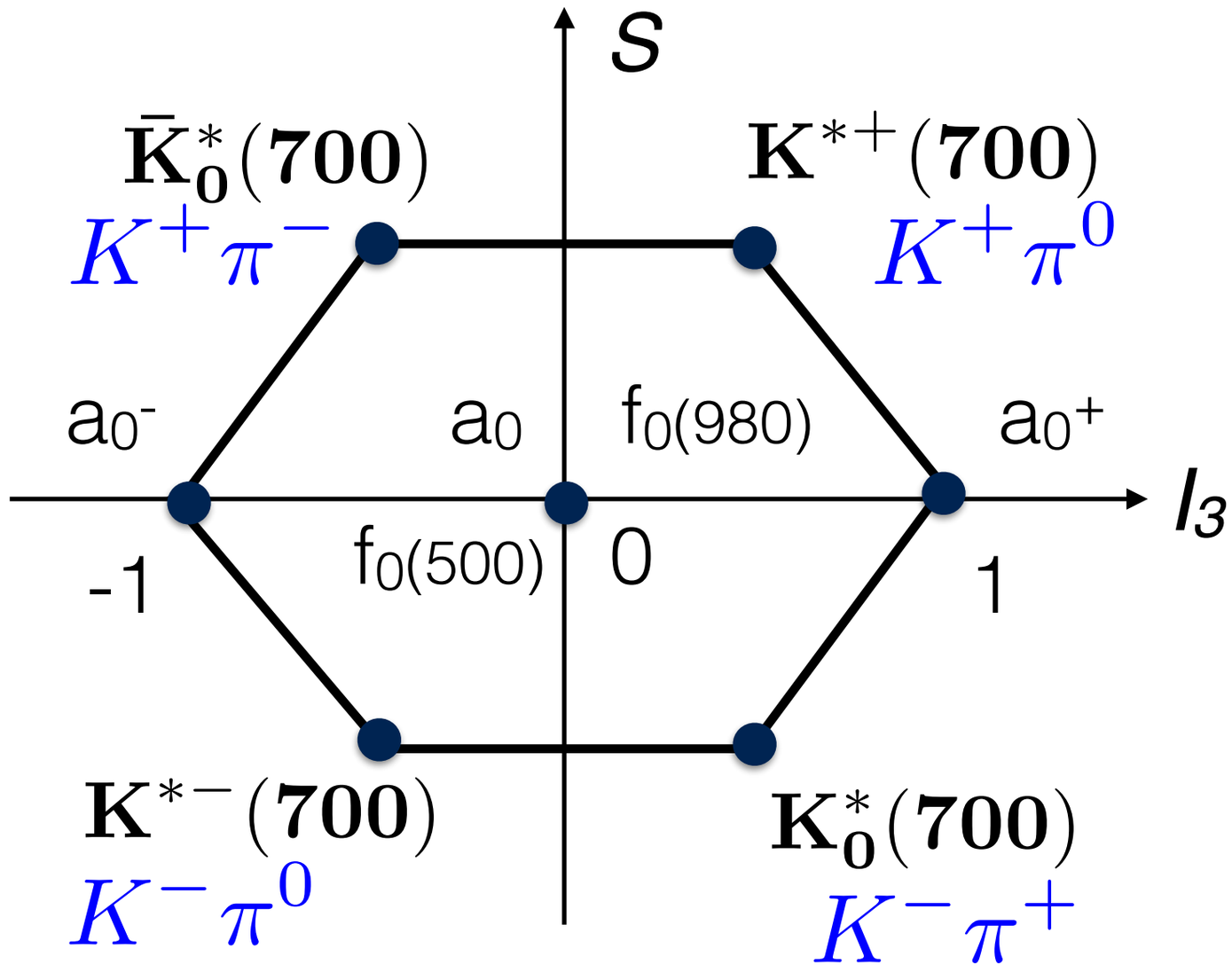
4.25 GeV Saclay
5.5 GeV CERN
3.0 GeV ANL
13.0 GeV SLAC
14.3 GeV CERN

KLF 100 days

From Pelaez and Rodas paper: PRD93(2016)

Scalar Meson Nonet

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

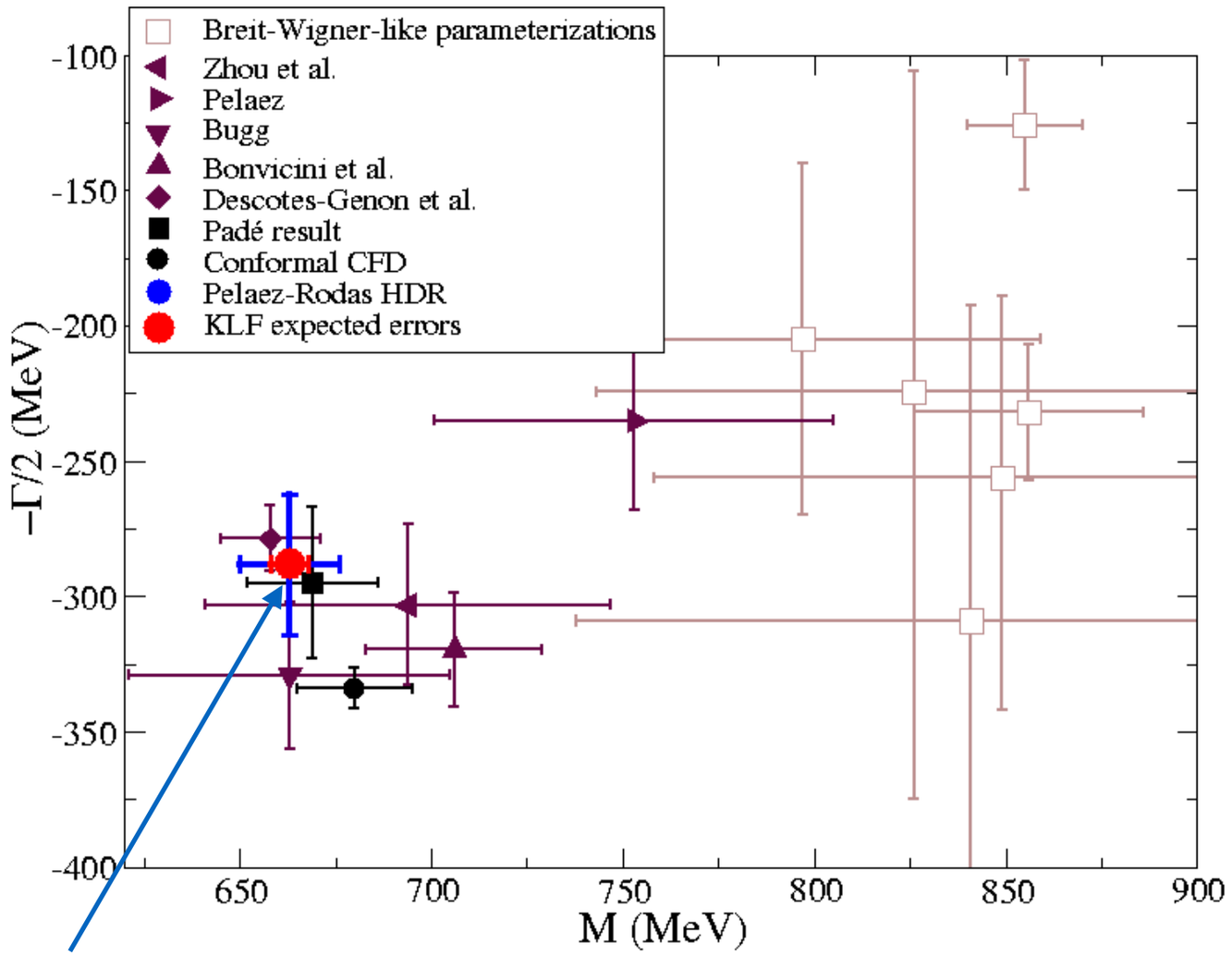


Four states called κ

still need further confirmation(PDG)

We can measure all of them

Width and Mass of κ(800)



100 days of running

Summary of $K\pi$ Scattering

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

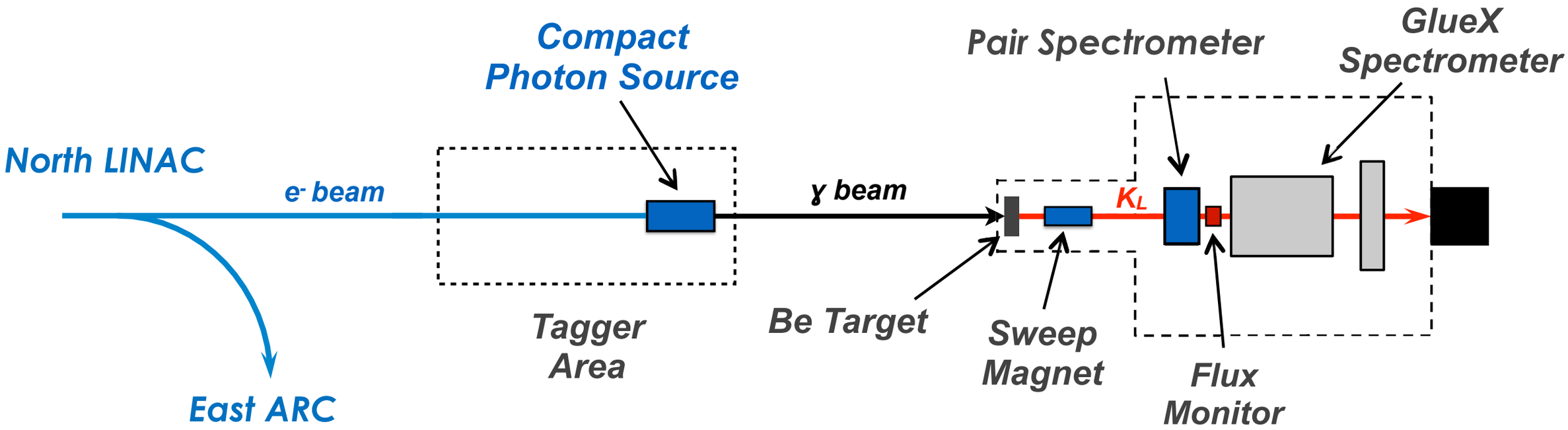
-It will certainly improve still conflictive determination of heavy K*'s parameters

-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

Hall-D beamline and GlueX Setup



Electron Beam Parameters

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

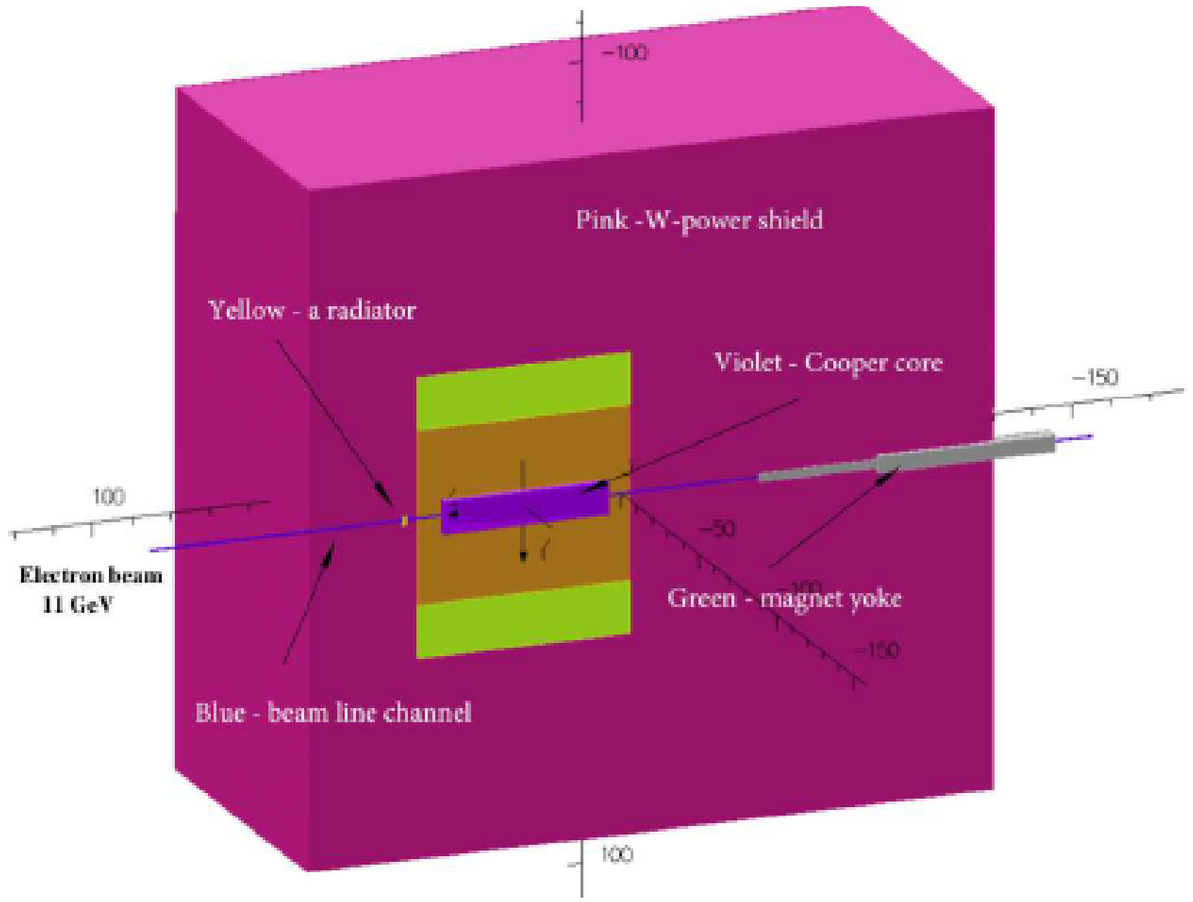
Bunch spacing $\qquad$ $64\ ns$

No major problems.

Doable !

Confirmed by accelerator experts

Compact Photon Source

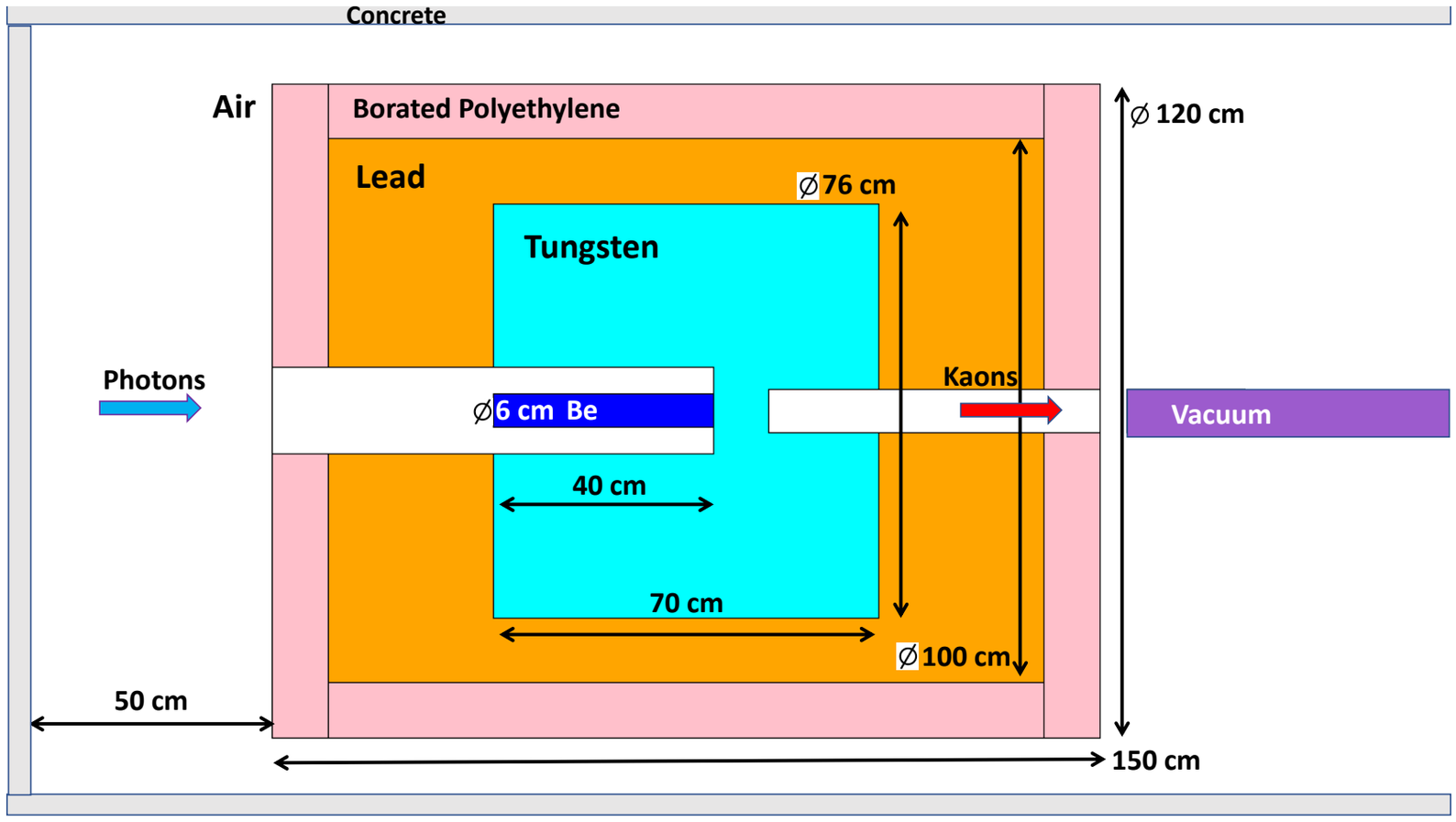


Conceptual design is completed for Halls A&C

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

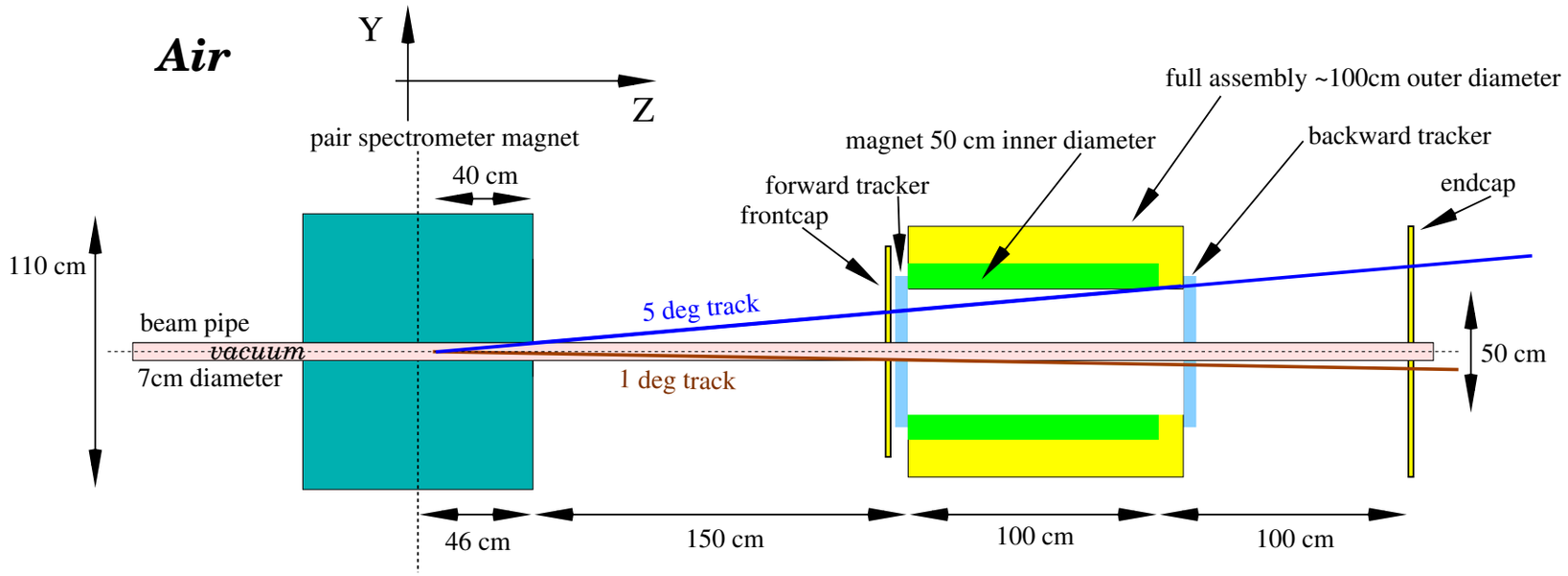
Be Target Assembly: Conceptual Design

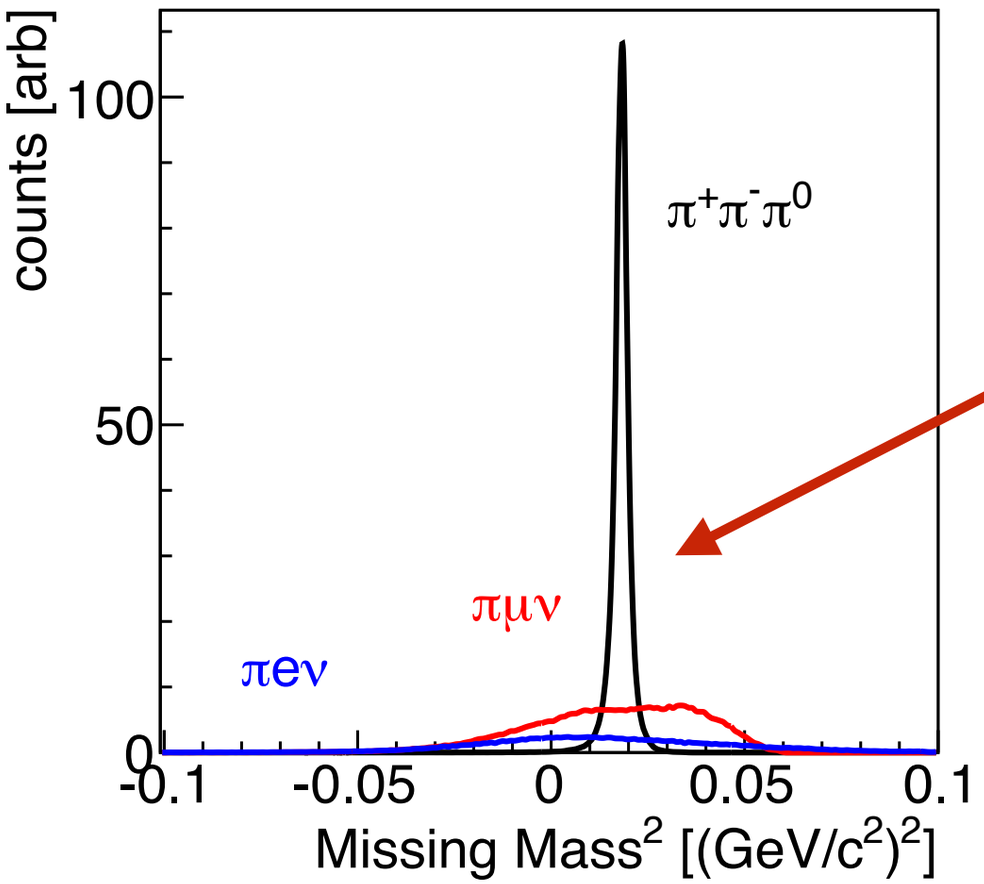


-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff

Flux Monitor



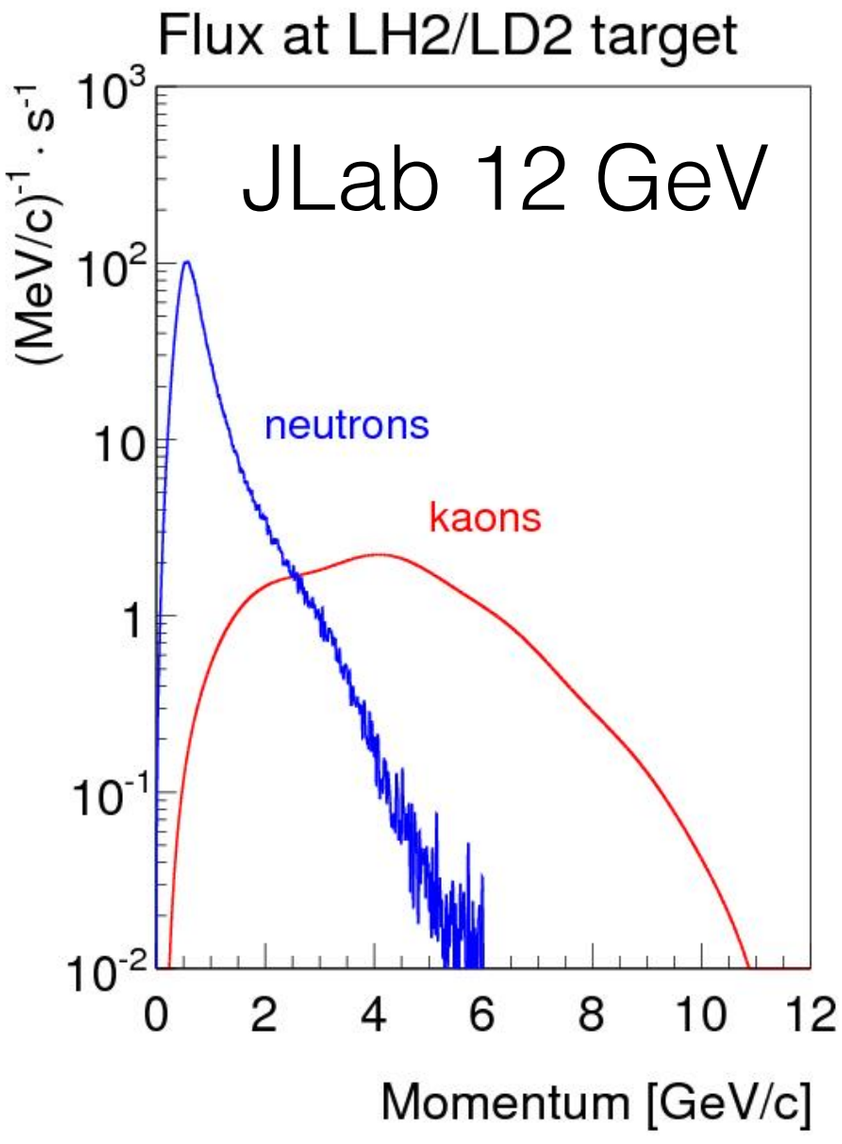


Reconstructed K_L mass

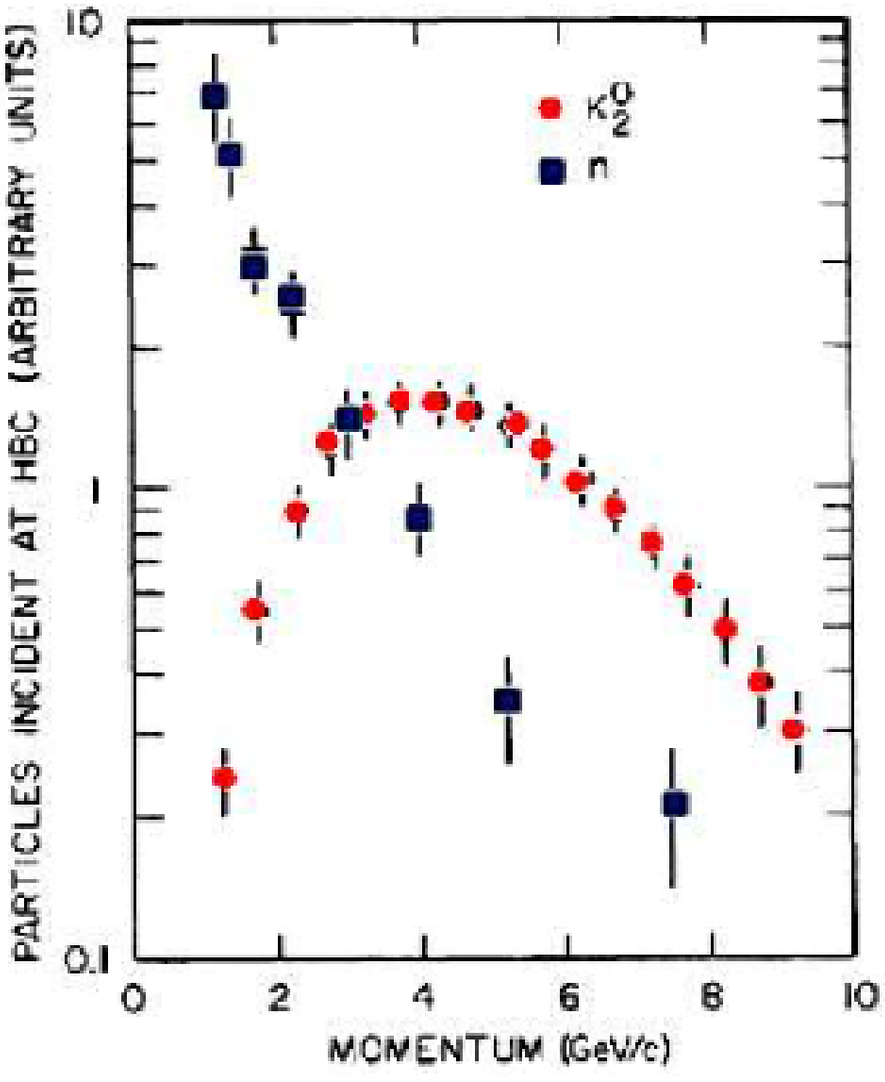
Flux measurement stat. err. <1%

Estimated syst. err. ~5%

K_L Beam Flux

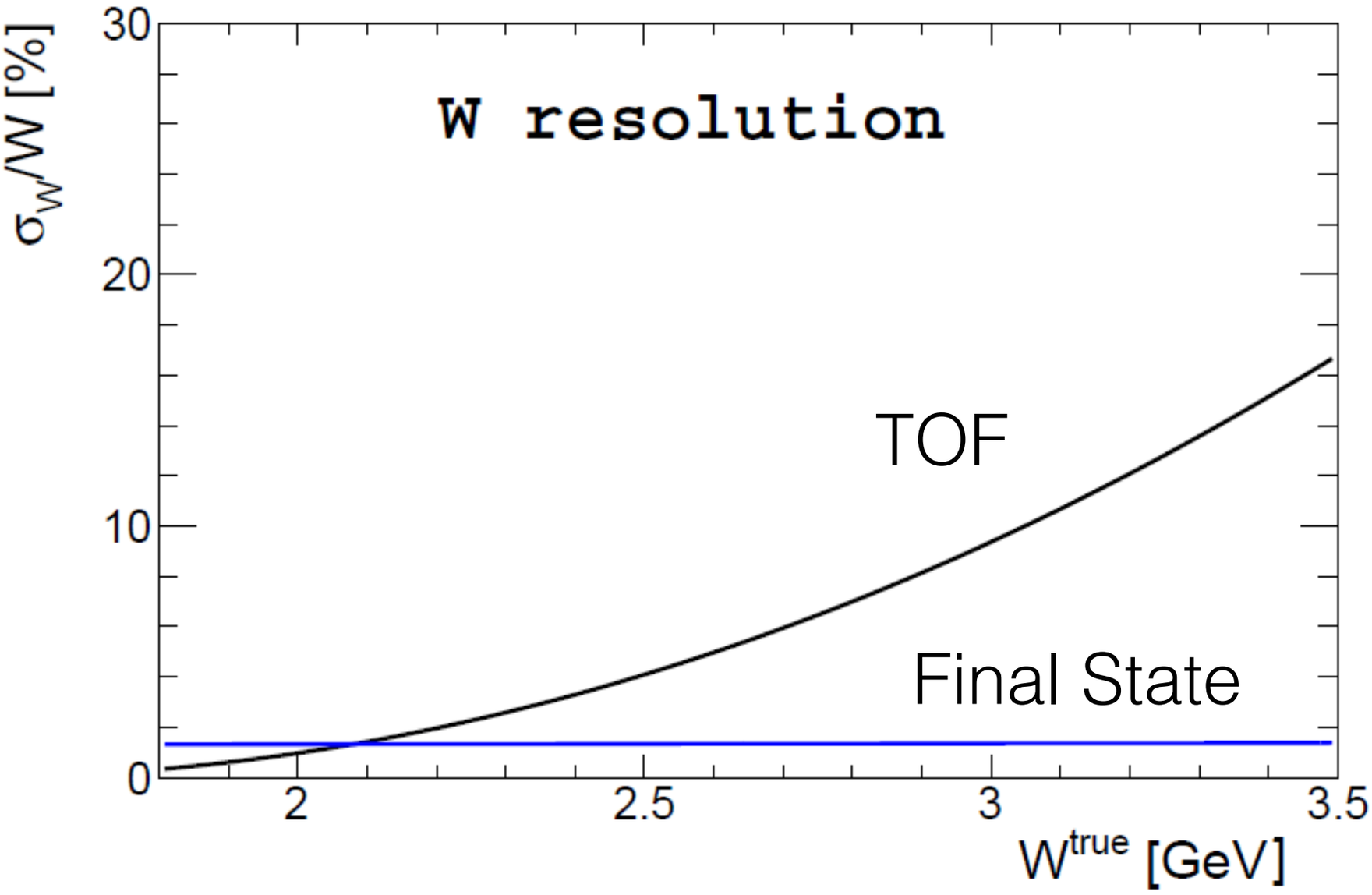


SLAC 16 GeV



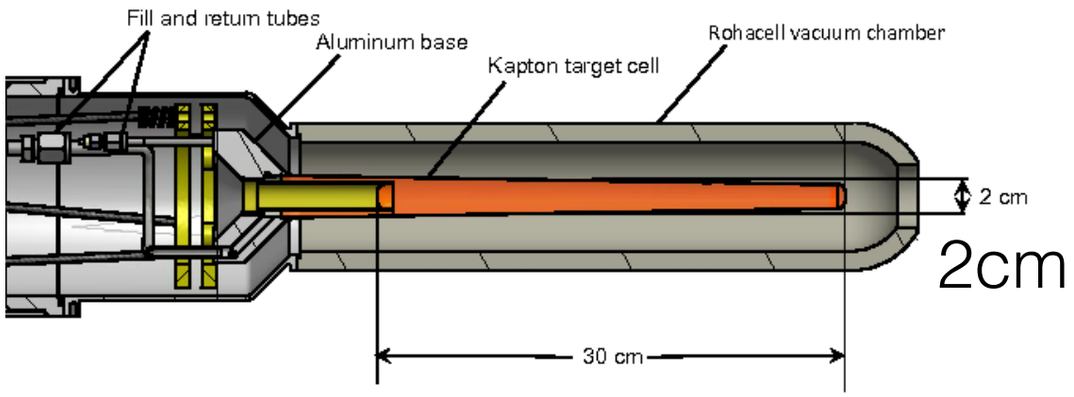
$$N(K_L)/sec \sim 10^4$$

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


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

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

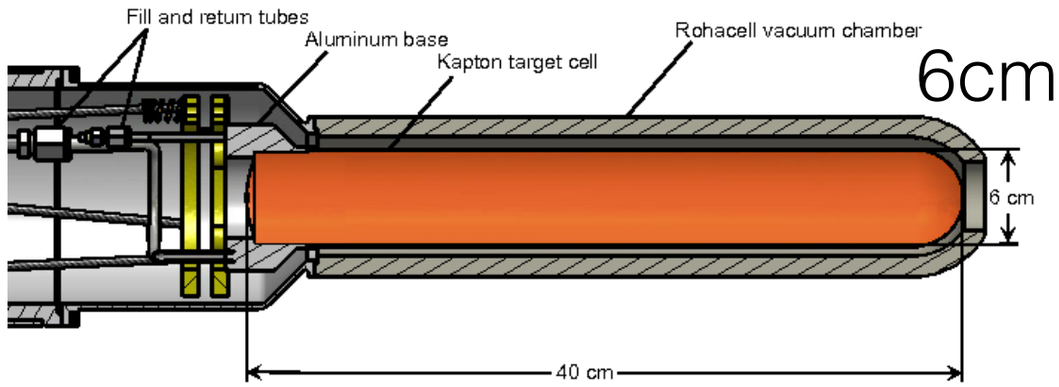
The GlueX liquid hydrogen target.



2cm

30cm

Current



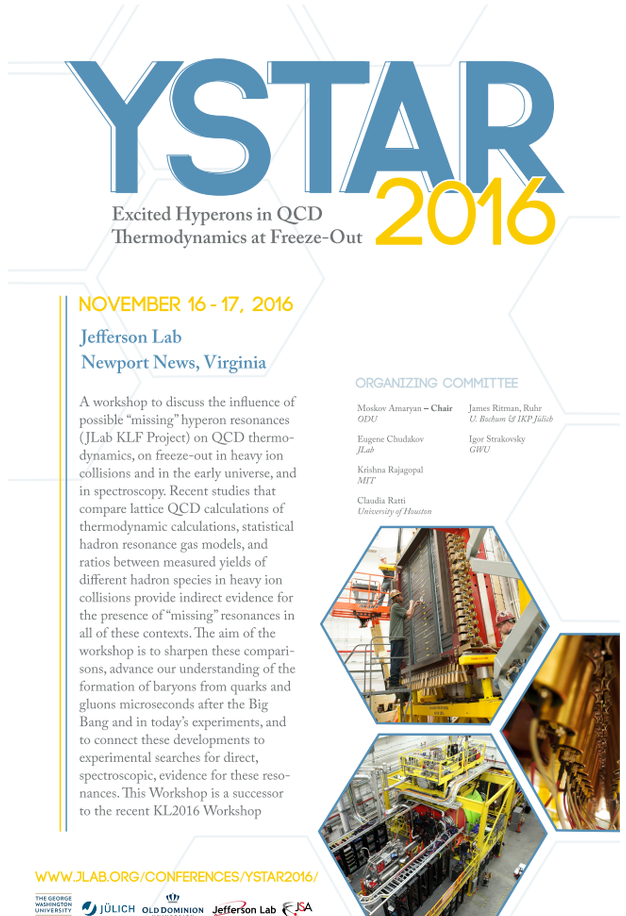
6cm

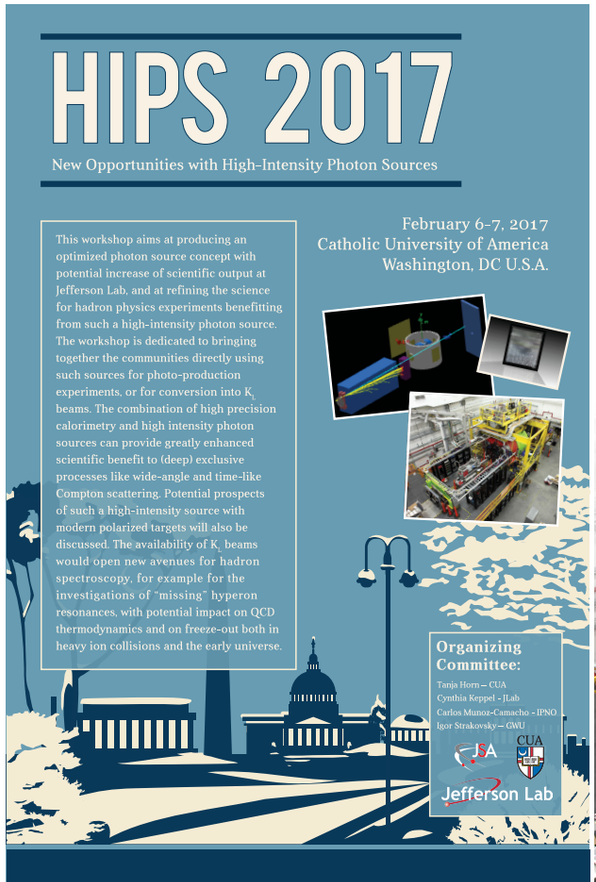
40cm

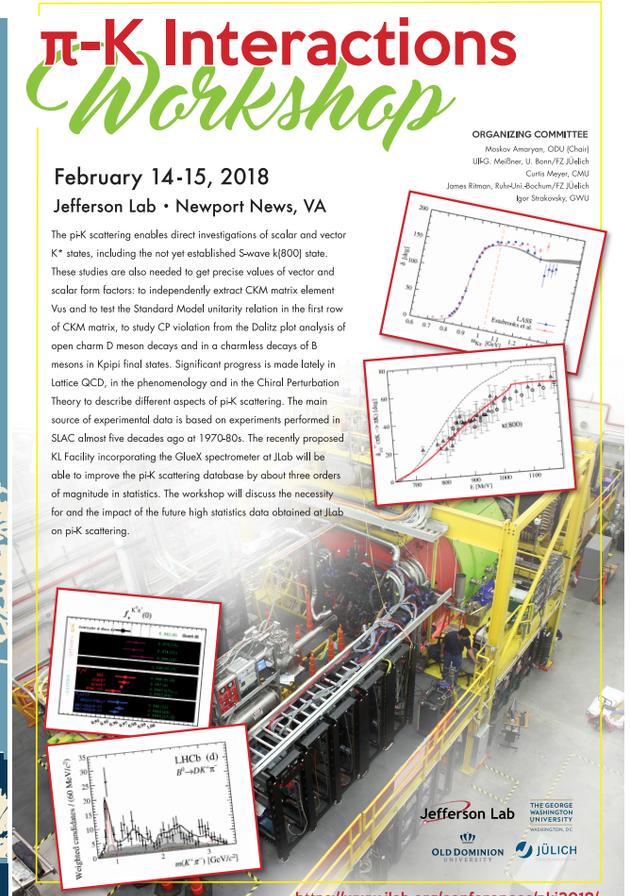
Proposed & Feasible

Longer and ticker target is needed to enhance production rate

Conceptual design has been endorsed by the JLAB target group







KL2016
[60 people from 10 countries, 30 talks] ***https://www.jlab.org/conferences/kl2016/***
OC: M. Amaryan, E. Chudakov, C. Meyer, M. Pennington, J. Ritman, & I. Strakovsky

YSTAR2016
[71 people from 11 countries, 27 talks] ***https://www.jlab.org/conferences/YSTAR2016/***
OC: M. Amaryan, E. Chudakov, K. Rajagopal, C. Ratti, J. Ritman, & I. Strakovsky

HIPS2017
[43 people from 4 countries, 19 talks] ***https://www.jlab.org/conferences/HIPS2017/***
OC: T. Horn, C. Keppel, C. Munoz-Camacho, & I. Strakovsky

PKI2018
[48 people from 9 countries, 27 talks] ***http://www.jlab.org/conferences/pki2018/***
OC: M. Amaryan, U.-G. Meissner, C. Meyer, J. Ritman, & I. Strakovsky

In total: 222 participants & 103 talks

Proposal:

200 Members

61 Institutions

20 Countries

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

SUMMARY

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

  PWA will allow to unravel and measure pole positions and widths of dozens of new excited hyperon states
- -In Strange Meson Spectroscopy

  PWA will allow to measure excited K* states including scalar K*(700) states
- To accomplish physics program

  100 days per LH2 and LD2 is required
- All components of KL Facility considered are feasible

  -With total cost of the project below $10M

Thank you !