Strange Hadron Spectroscopy with Secondary KL Beam in Hall-D

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Old Dominion University
Norfolk, VA

(on behalf of K LONG FACILITY *Collaboration)*

PAC47, JLab, July 30, 2019

K-long Facility Collaboration

is formed through open opt-in procedure

From White Paper on Future Hall-D Physics:

There are many unresolved issues in hadron physics and the vast opportunities and advances that only become possible with KL facility. This KL facility would revolutionize our understanding of bound systems containing strange quarks, providing the long sought, quality experimental data to reach deeper into strange quark sector. This will enable the tremendous recent progress in spectroscopy in both theory and experiment with electromagnetic beams to continue into a new frontier.

Date: June 14, 2019

Proposal for JLab PAC47

Strange Hadron Spectroscopy with Secondary K_L Beam in Hall D

Experimental Support:

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Theoretical Support:

A. V. Anisovich[8,15], A. Bazavov[13], R. Bellwied[24], V. Bernard[38], G. Colangelo[4], A. Cieply[41], M. Döring[53], S. Eidelman[36,37], A. Eskandarian[53], J. Goity[33,21], H. Haberzettl[53], M. Hadžimehmedović[50], R. L. Jaffe[10], B. Z. Kopeliovich[51], H. Leutwyler[4], M. Mai[53], V. Mathieu[29], M. Matveev[15], U.-G. Meißner[8,26], V. Mokeev[33], C. Morningstar[39], B. Moussallam[38], K. Nakayama[2], V. Nikonov[8,15], Y. Oh[59], R. Omerović[50], H. Osmanović[50], J. R. Pelaez[29], A. Pilloni[33], D. Richards[33], D.-O. Riska[23], A. Rodas[29], J. Ruiz de Elvira[4], H-Y. Ryu[9], E. Santopinto[17], A. V. Sarantsev[8,15], J. Stahov[50], A. Švarc[58], A. Szczepaniak[6,33], R. L. Workman[50], B. Zou[5],

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[2] University of Georgia (UGA), Athens, GA 30602, USA
[3] Lamar University, Beaumont, TX 77710, USA
[4] University of Bern, CH-3012 Bern, Switzerland

Hyperon Spectroscopy

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

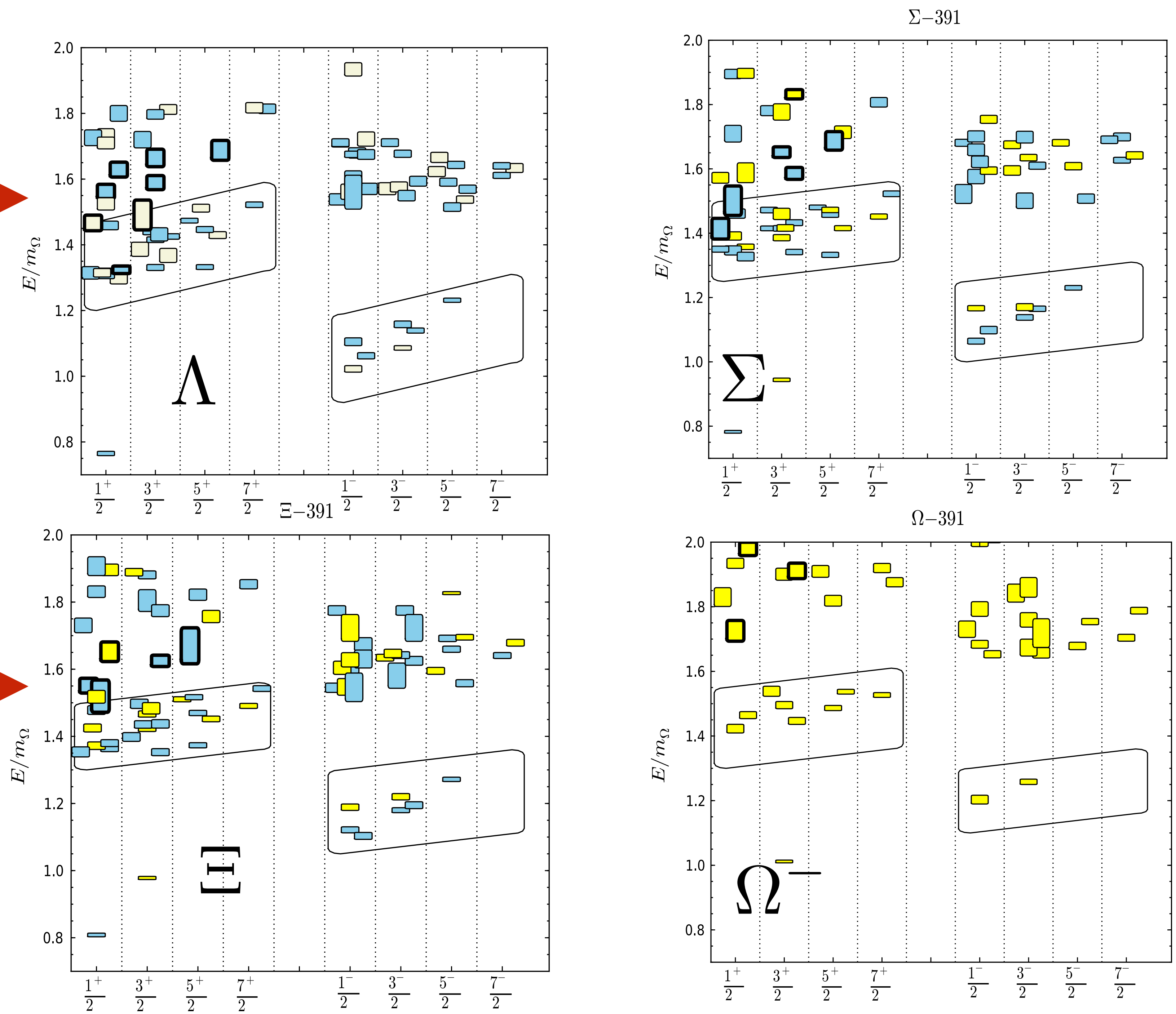
many more states including hybrids (thick bordered)

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)

Outline

Current Status

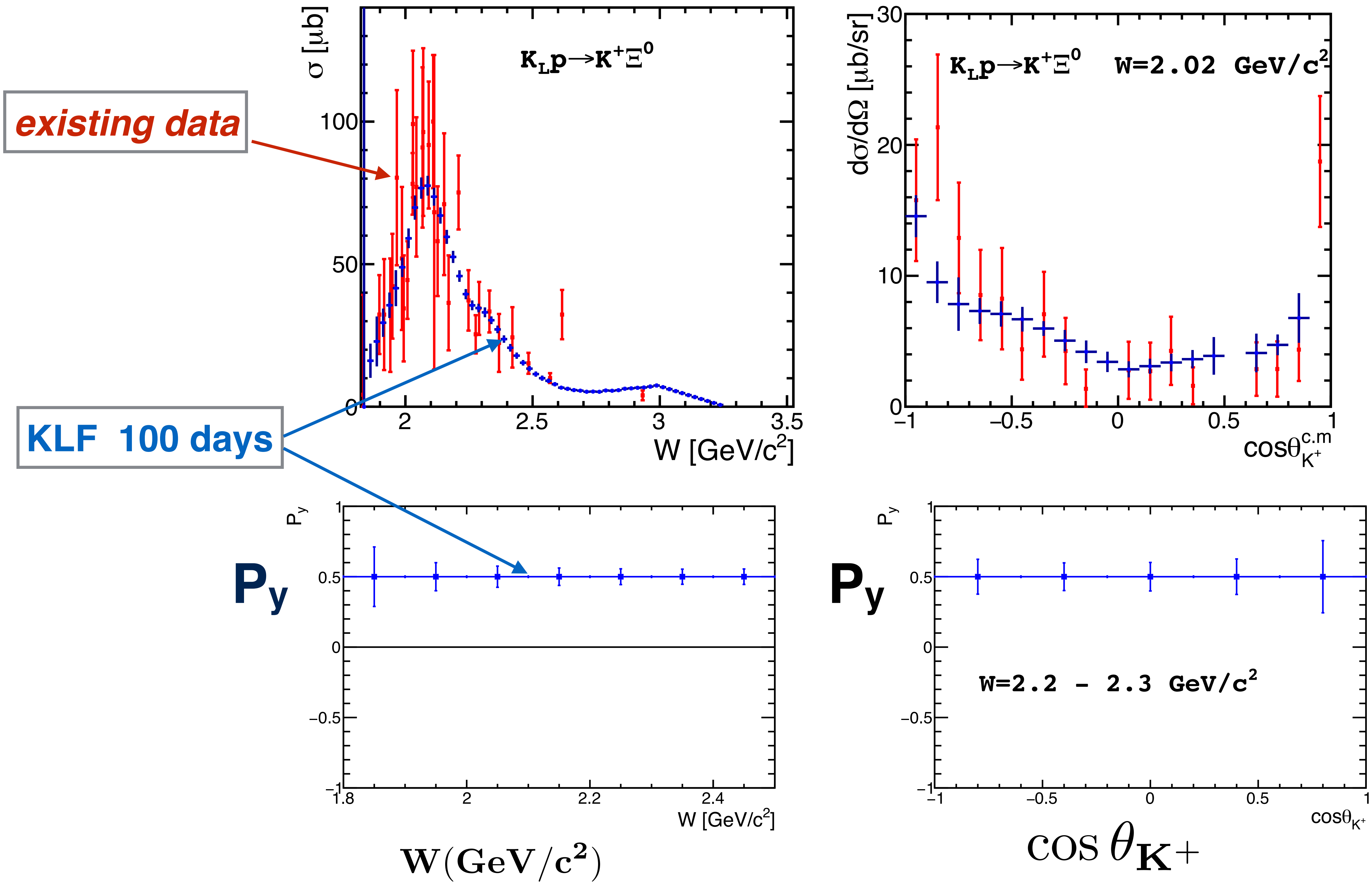
- Hyperon Spectroscopy
- Strange Meson Spectroscopy
- Thermodynamics of Early Universe

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

Measurements on Proton Target



Search for Hyperon Resonances with PWA

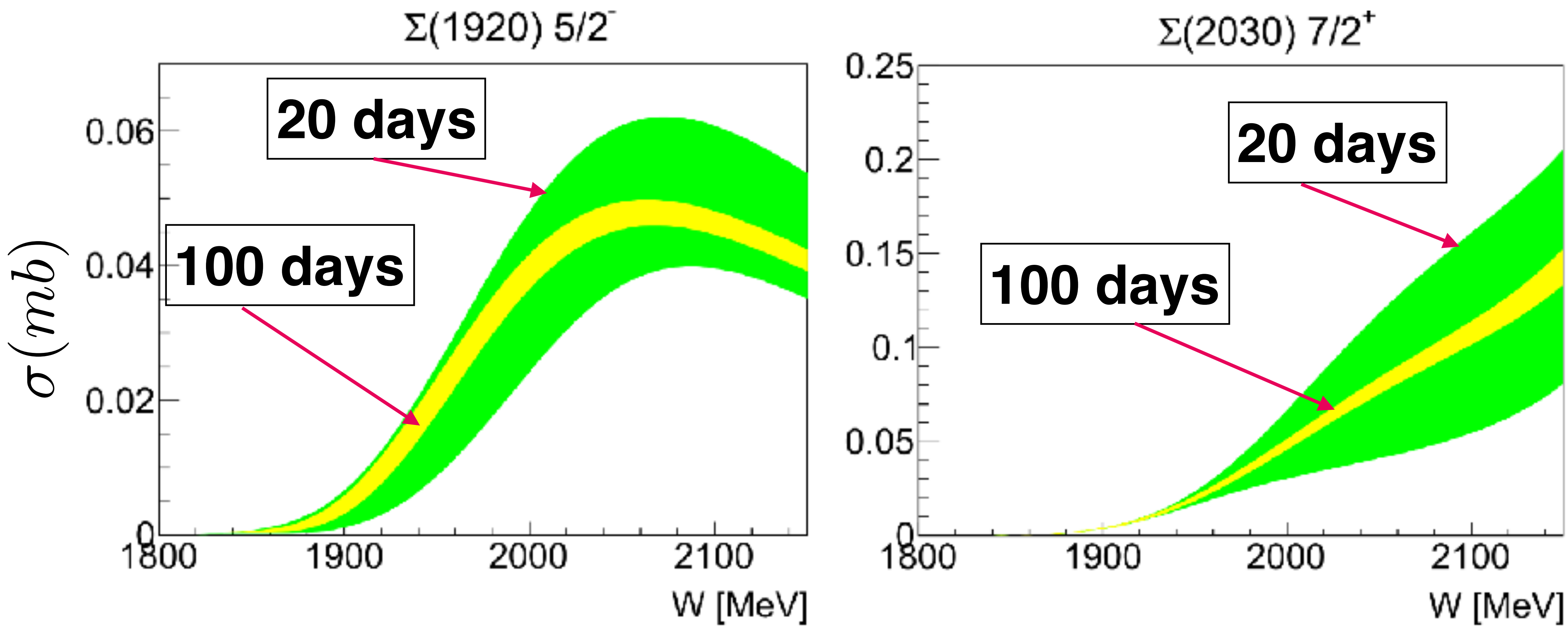
For Scattering experiments on both
proton & neutron targets one needs to determine:

- 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

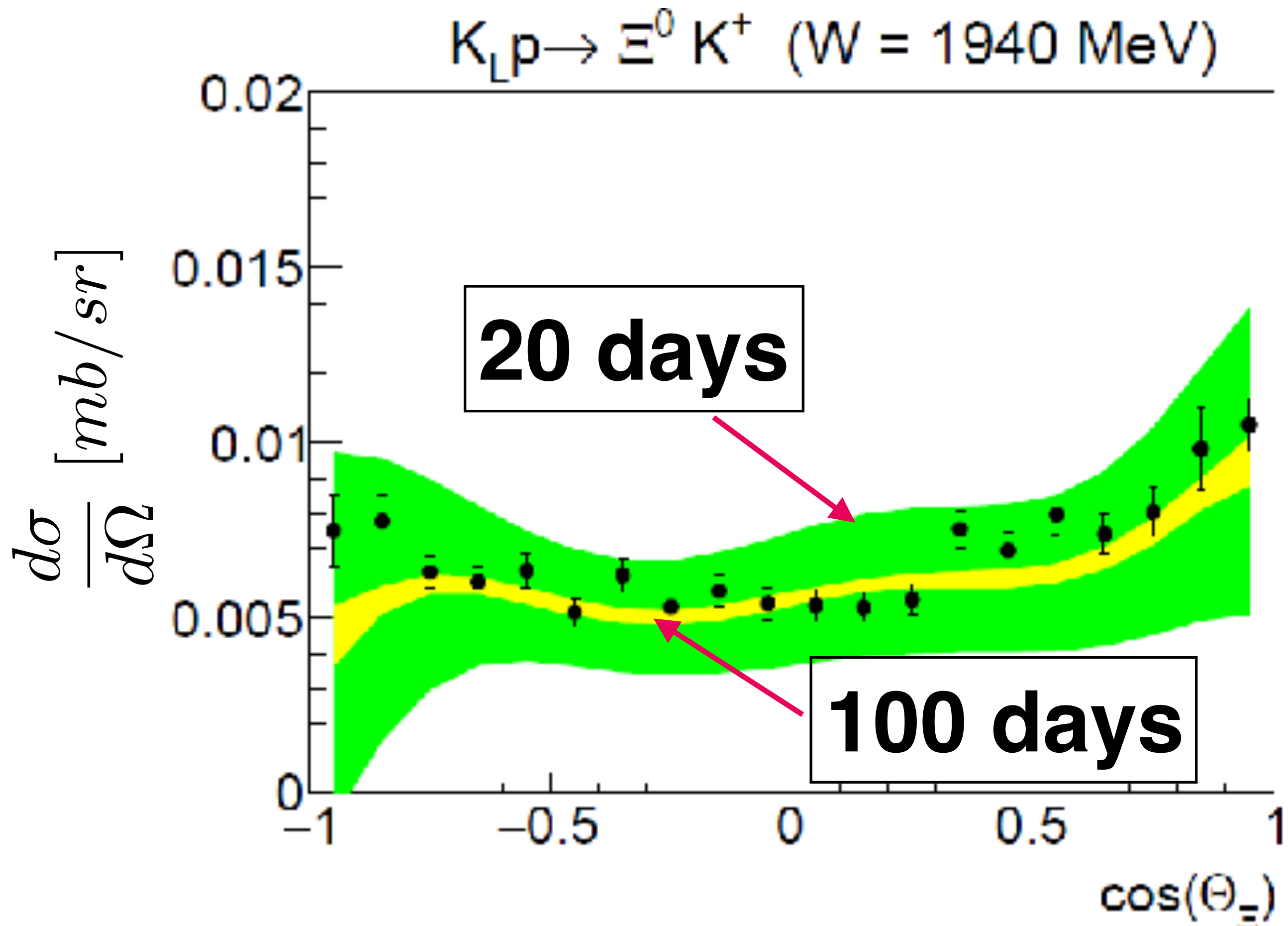
Total Cross Section $K_L p \to K^+ \Xi^0$



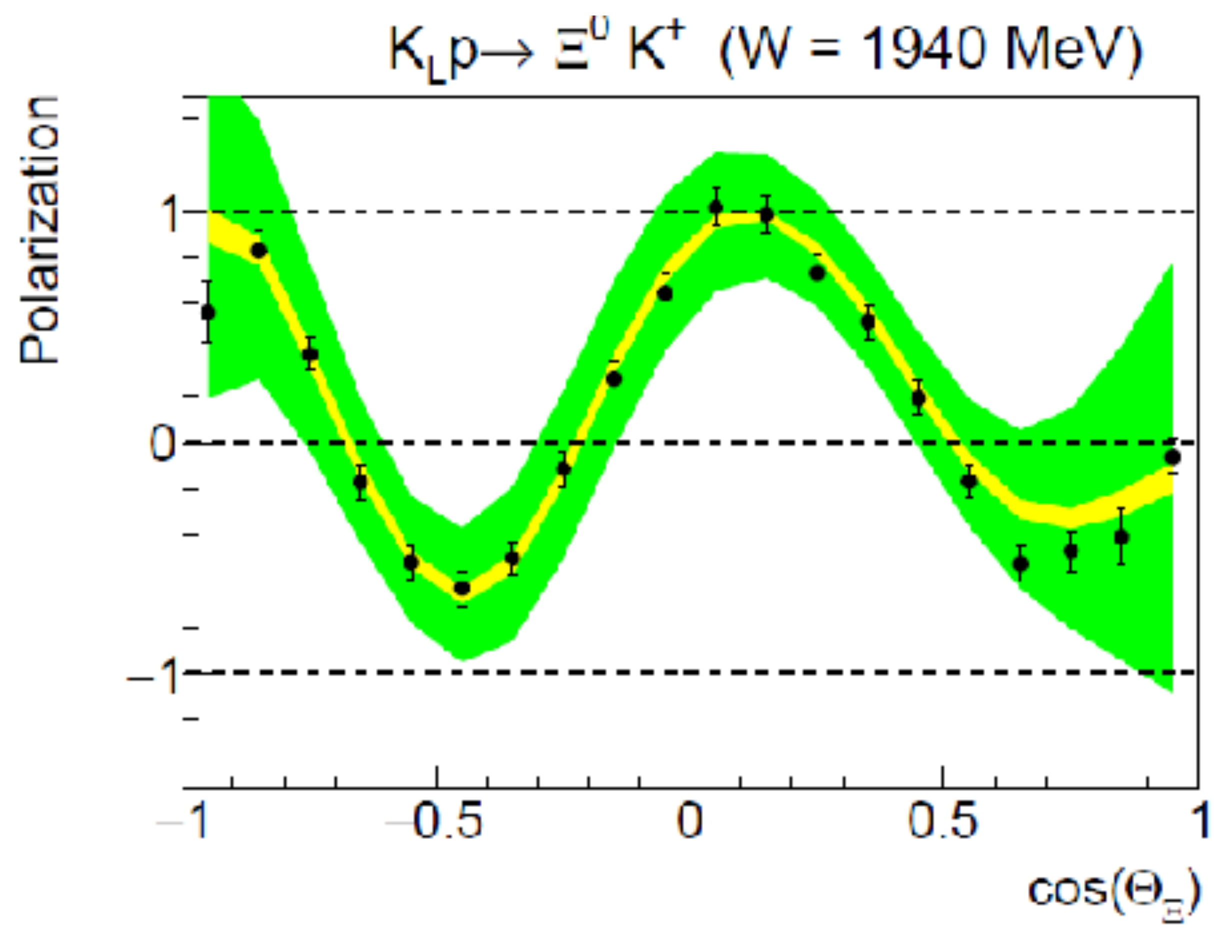
Obviously: at least 100 days needed to get precise solution

Bonn-Gatchina PWA

Diff. Cross Section



Polarization



Again: at least 100 days to get precise solution

Some Numerical Results

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

$$\begin{cases} 100d\ M = \underline{1.923 \pm 0}.010 \pm 0.010\ GeV \\ \Gamma = 0.321 \pm 0.01 \pm 0.010\ GeV \\ 20d\ M = \underline{1.977 \pm 0}.021 \pm 0.025\ GeV \end{cases}$$

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

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

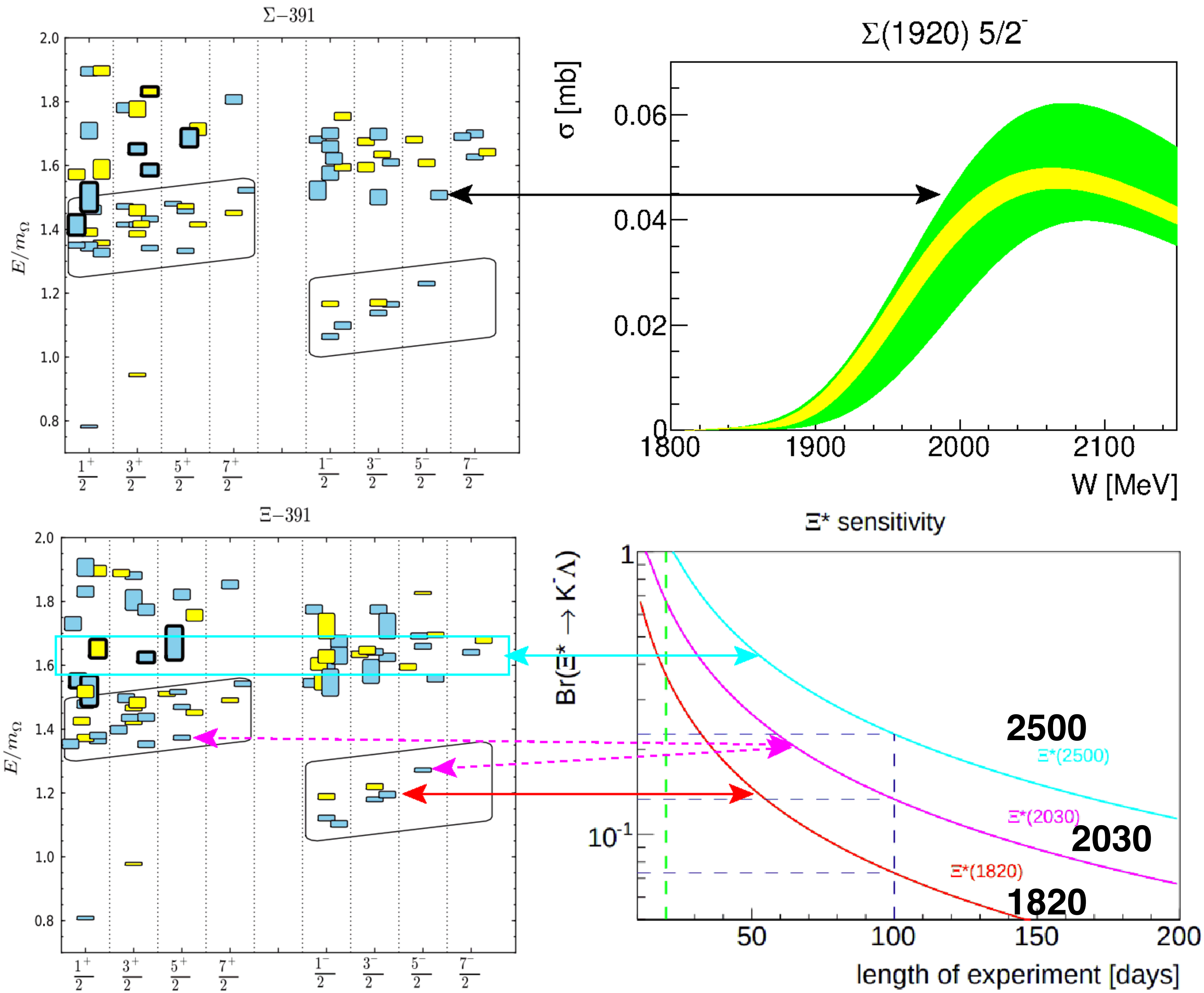
LQCD M=

2.027 GeV
2.487 GeV
2.659 GeV
2.781 GeV

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

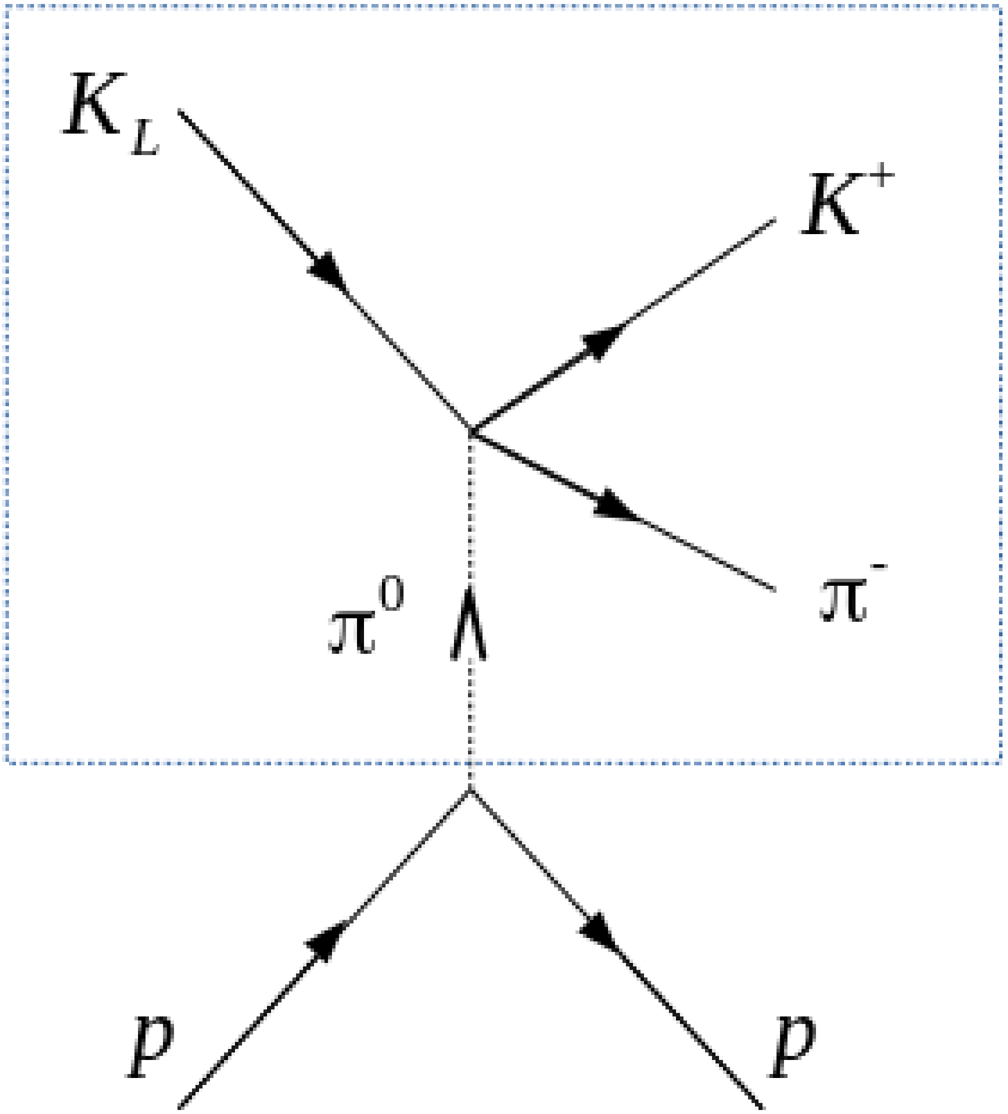
LQCD Results are still in progress

Comparison of KLF Measurements and LQCD



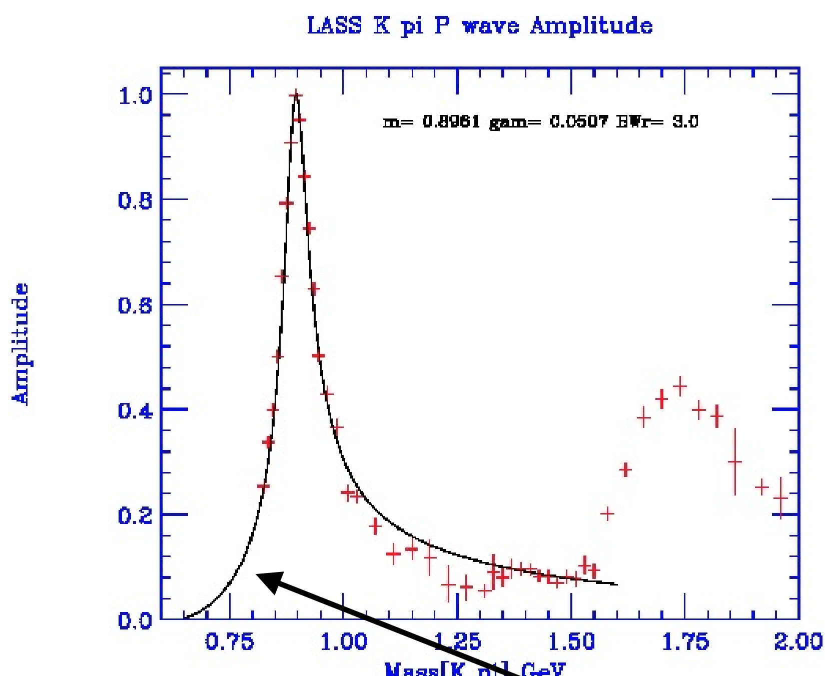
Strange Meson Spectroscopy

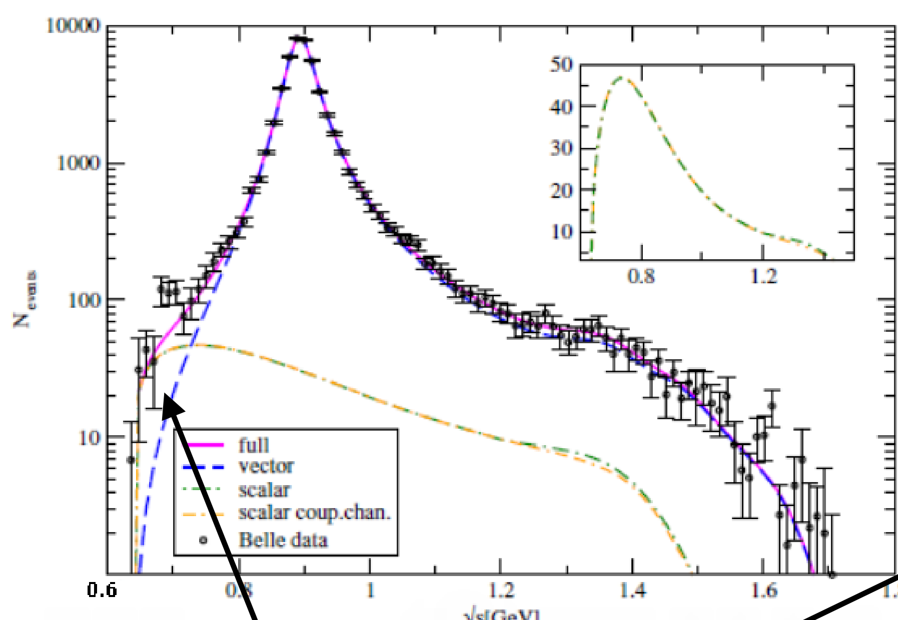
$K\pi$ Scattering

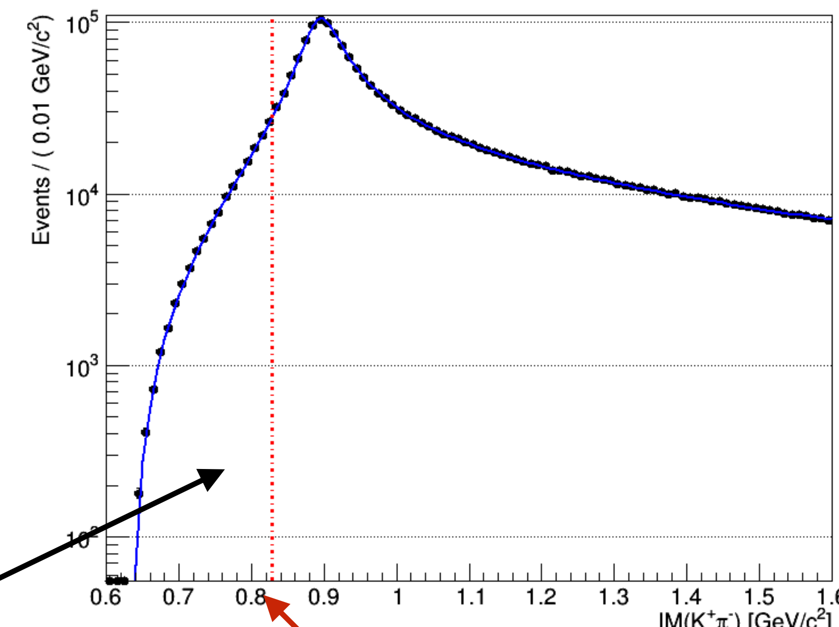


Proposed Measurements

SLAC	Belle	KLF
$K^-\pi^+ \to K^-\pi^+$	$\tau \to K\pi\nu_\tau$	$K_L\pi^0 \to K^+\pi^-$



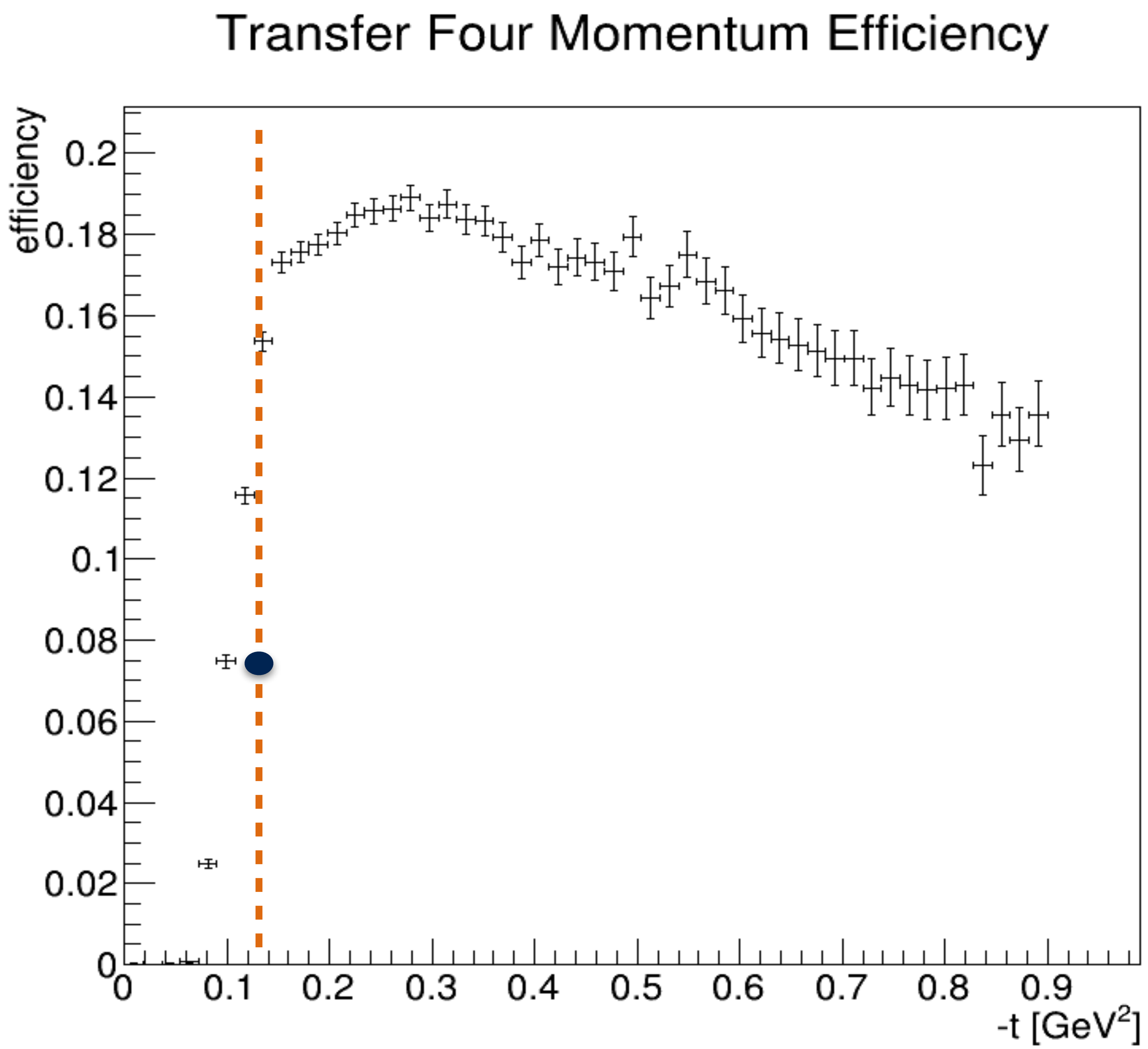


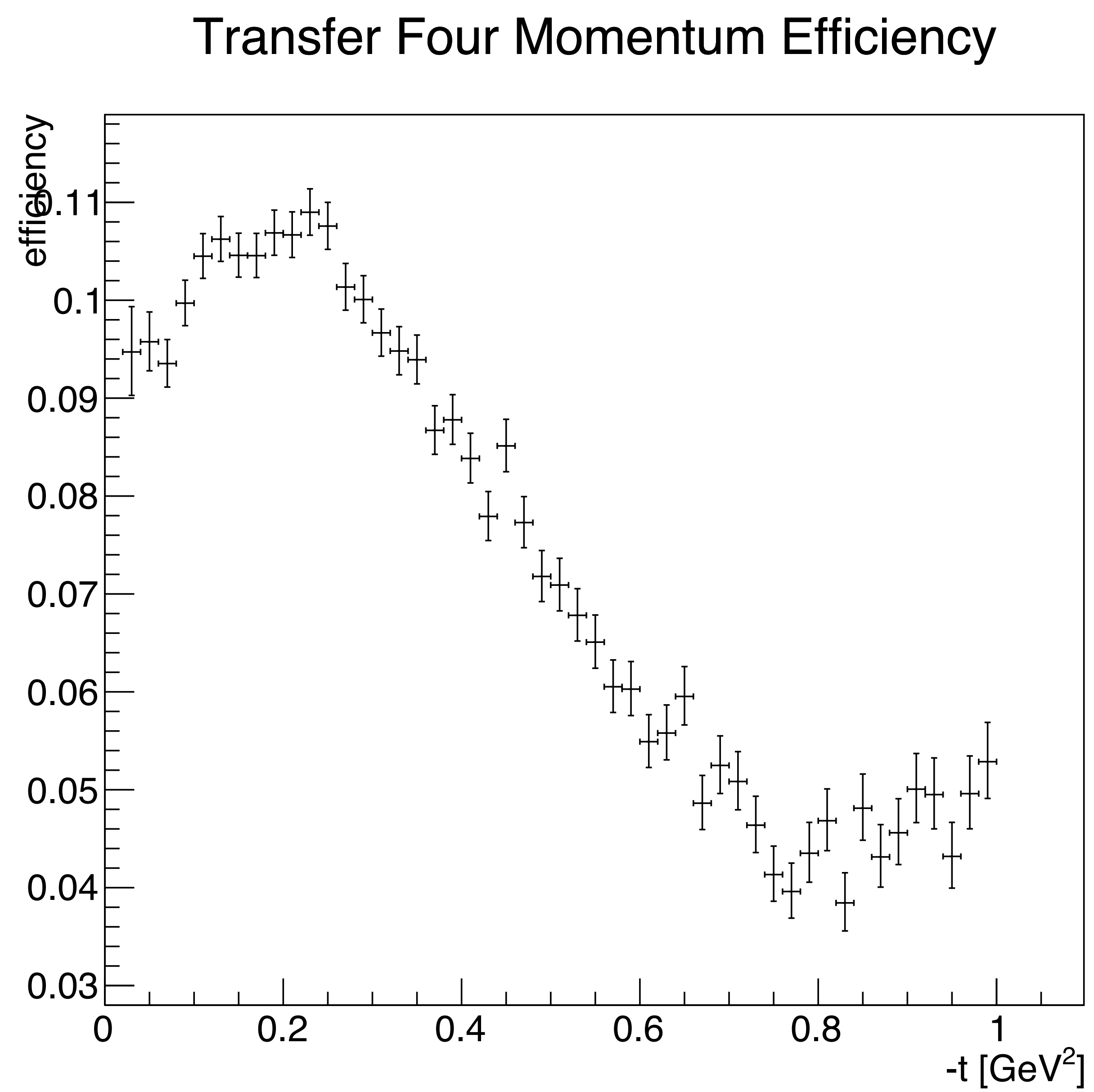


$\mathbf{M(K\pi)(GeV)}$ $\mathbf{M(K\pi)(GeV)}$ $\mathbf{M(K\pi)(GeV)}$

region of $\kappa(800)$

SLAC Lower limit

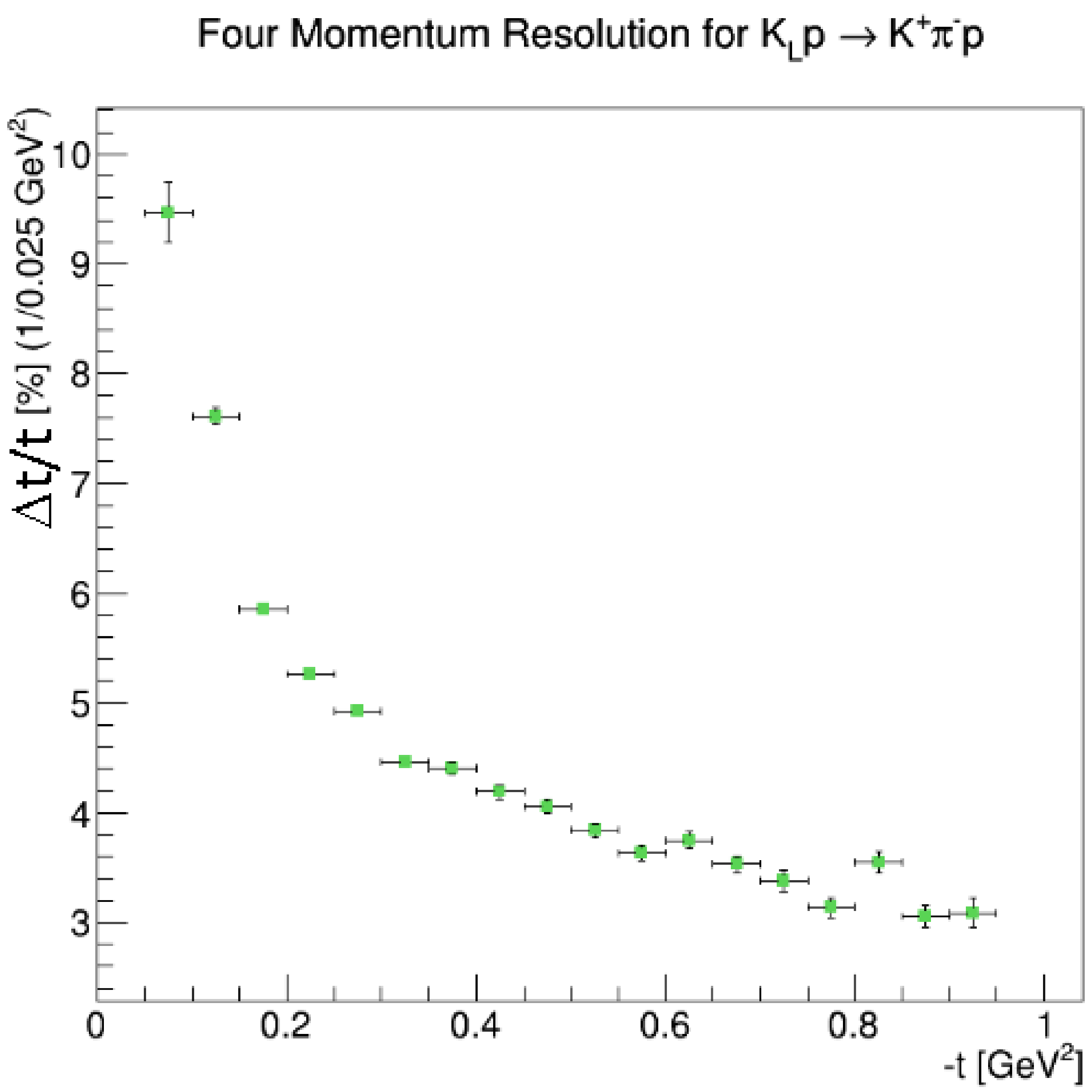


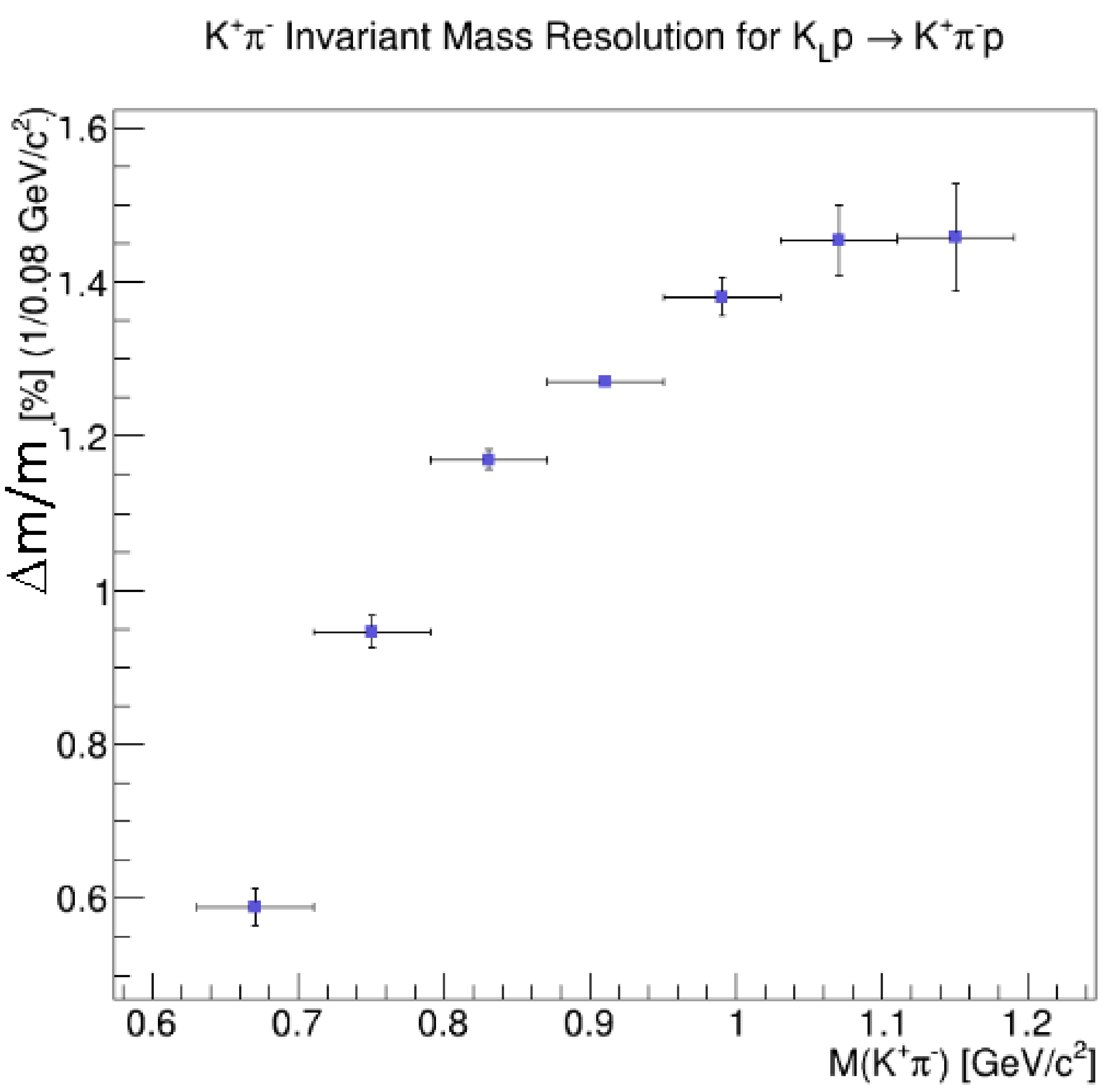


t-down to 0.1 GeV^2 is measurable with proton being detected

t-down to pion pole measurable with proton being undetected

$K\pi$ ***Scattering*** (proton detected)

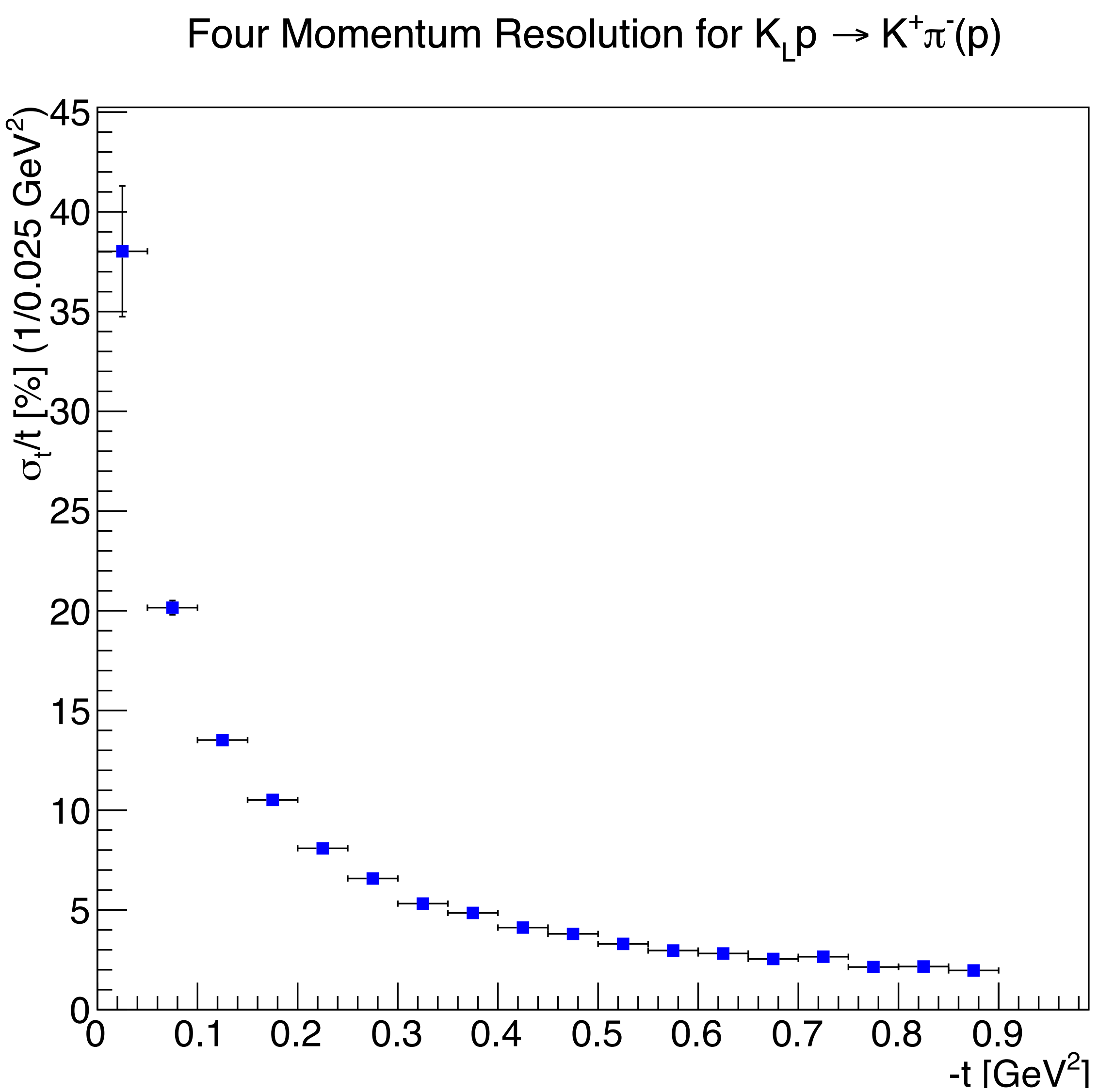


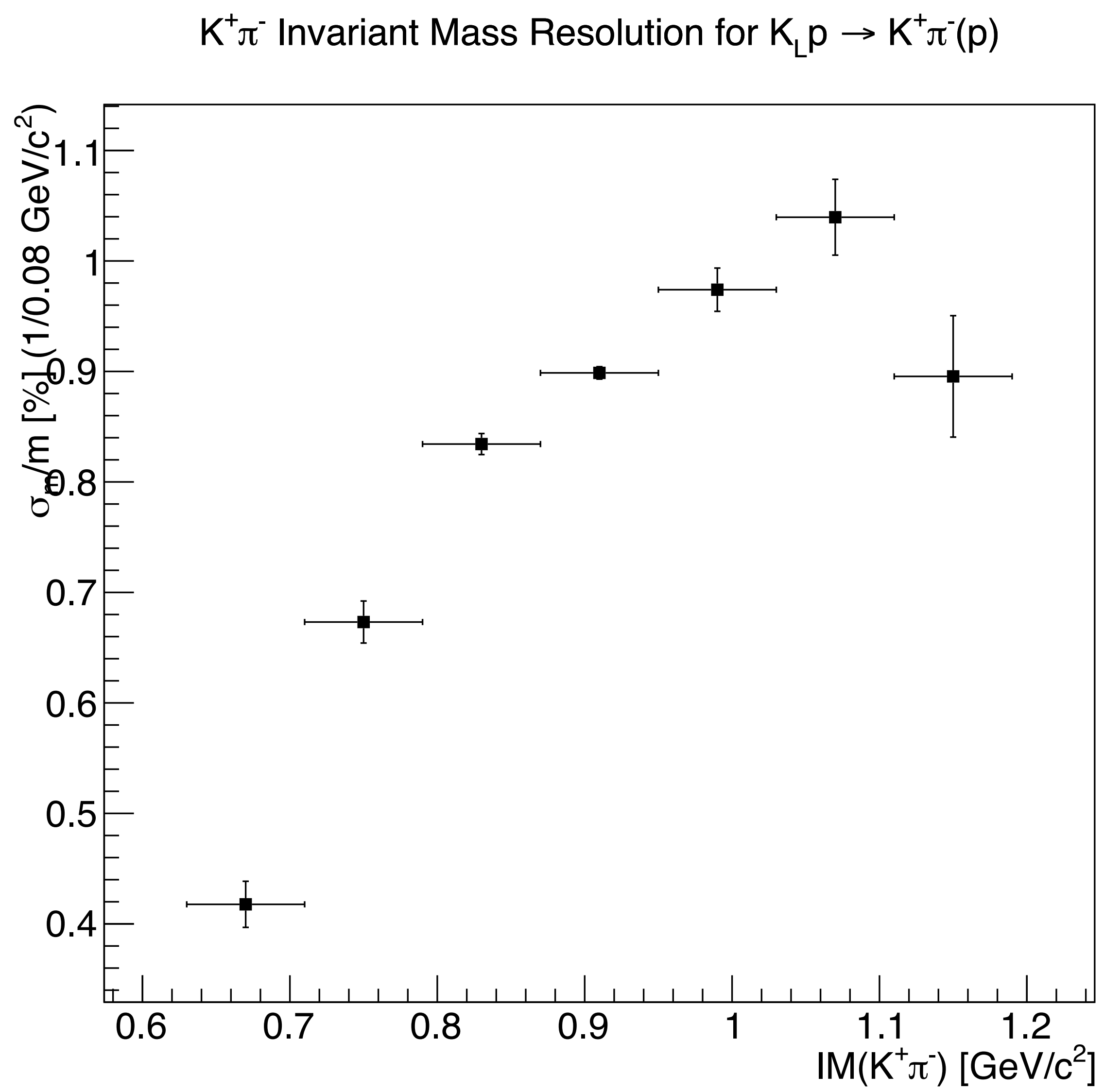


-Good resolution at low-t is needed to be close to pion pole

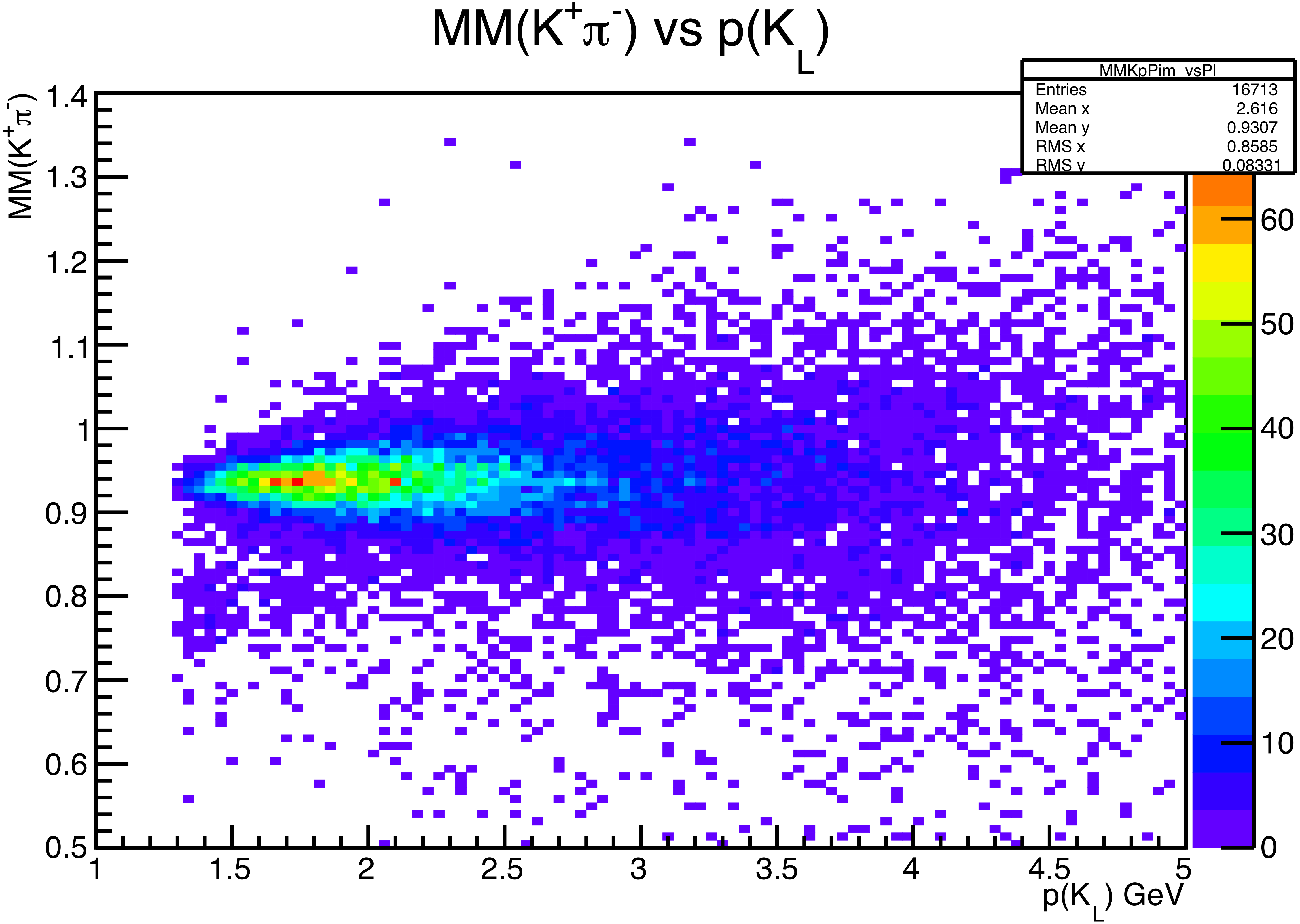
-Binning in ~10 MeV will cover almost entire elastic K-pi scattering range

$K\pi$ ***Scattering*** (proton undetected)

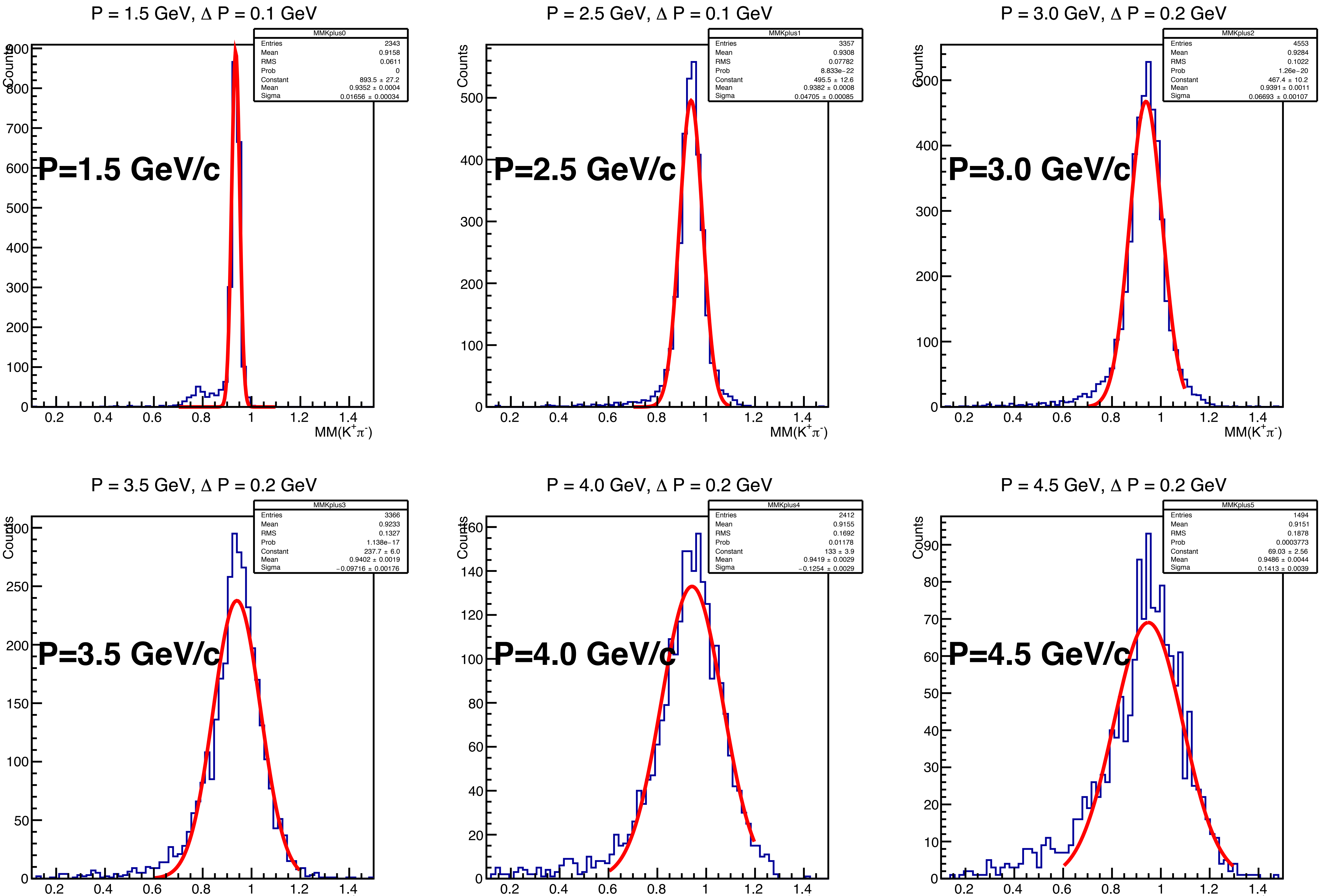




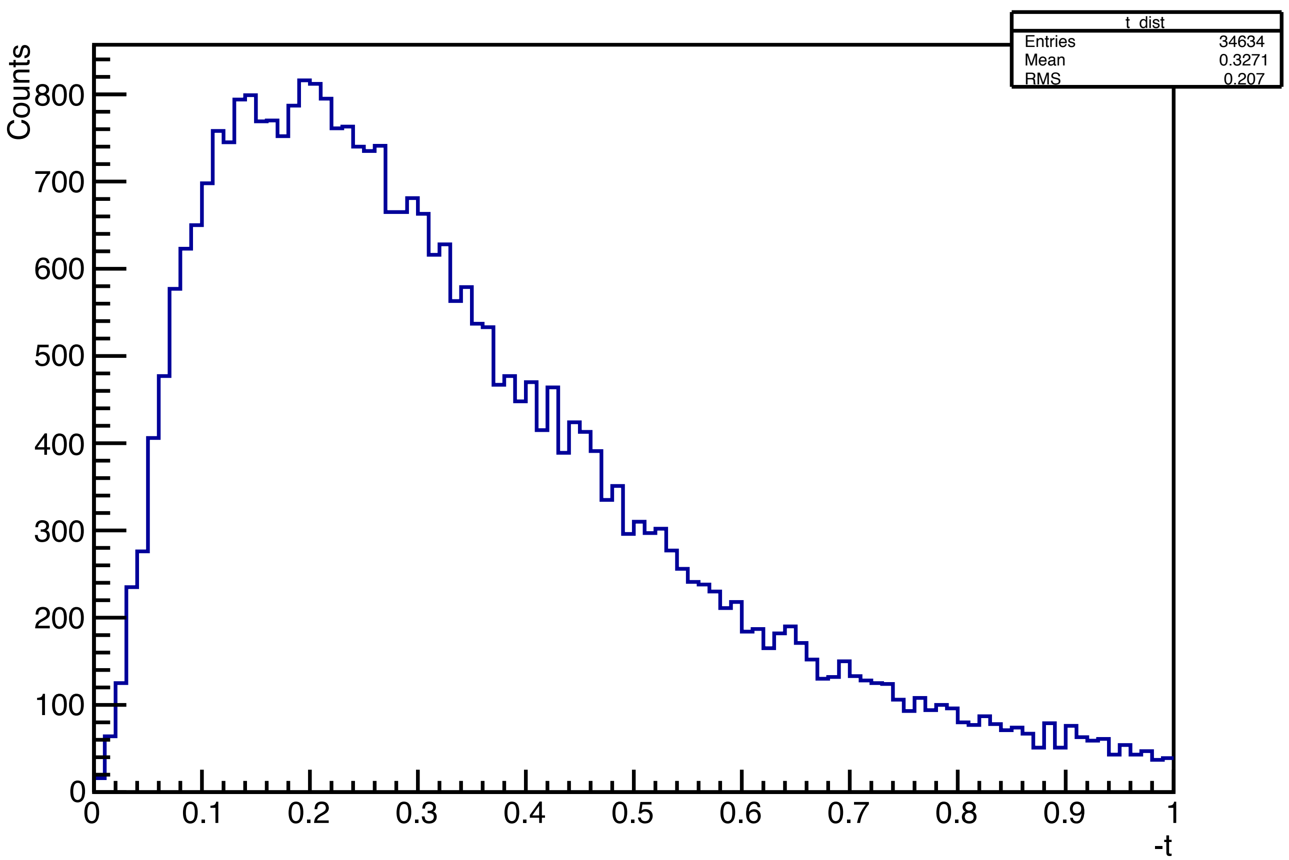
Missing Mass of $K^+\pi^-$ system



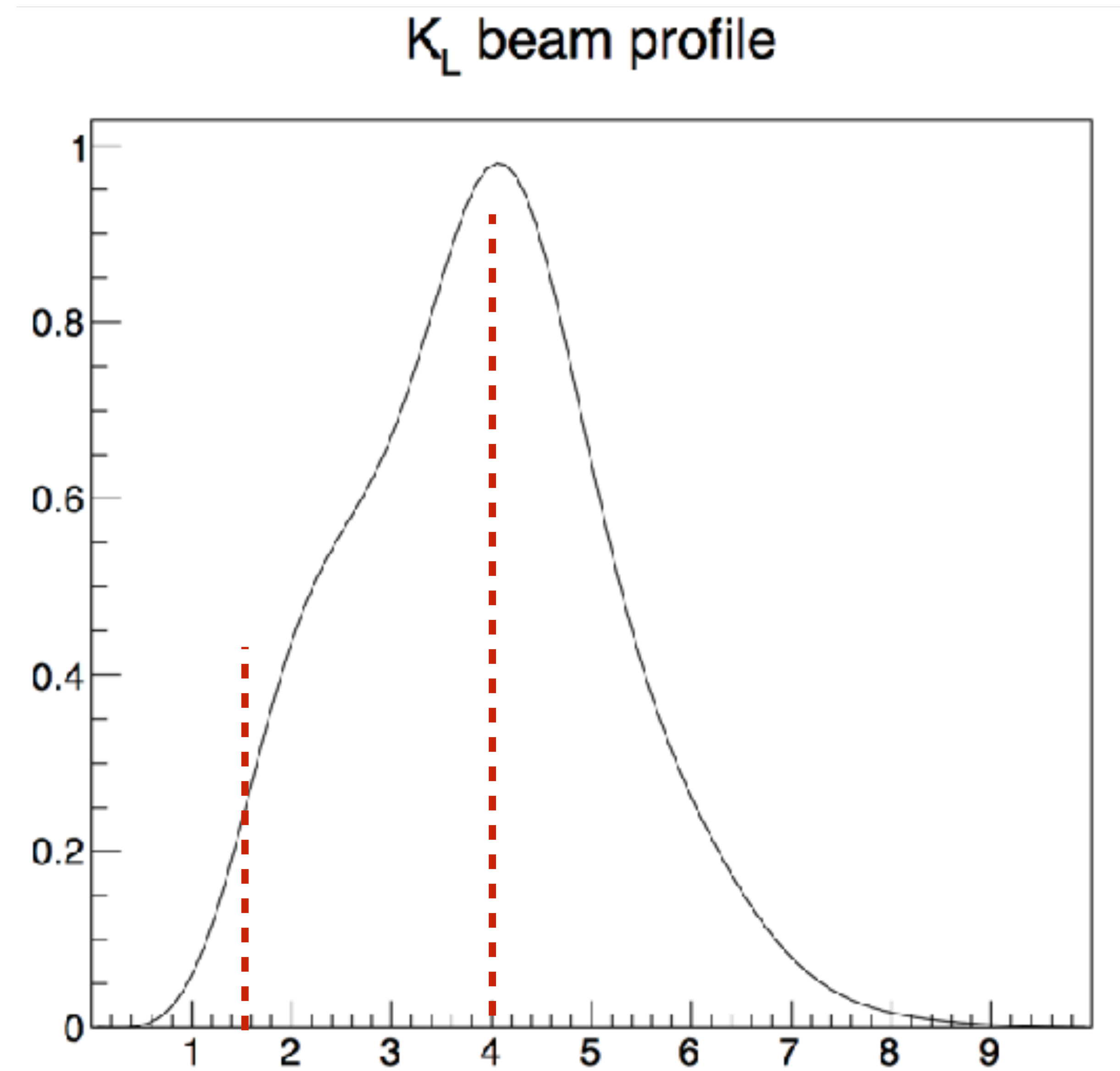
Missing Mass $MM(K^+\pi^-)GeV$



Proton reconstructed via missing mass

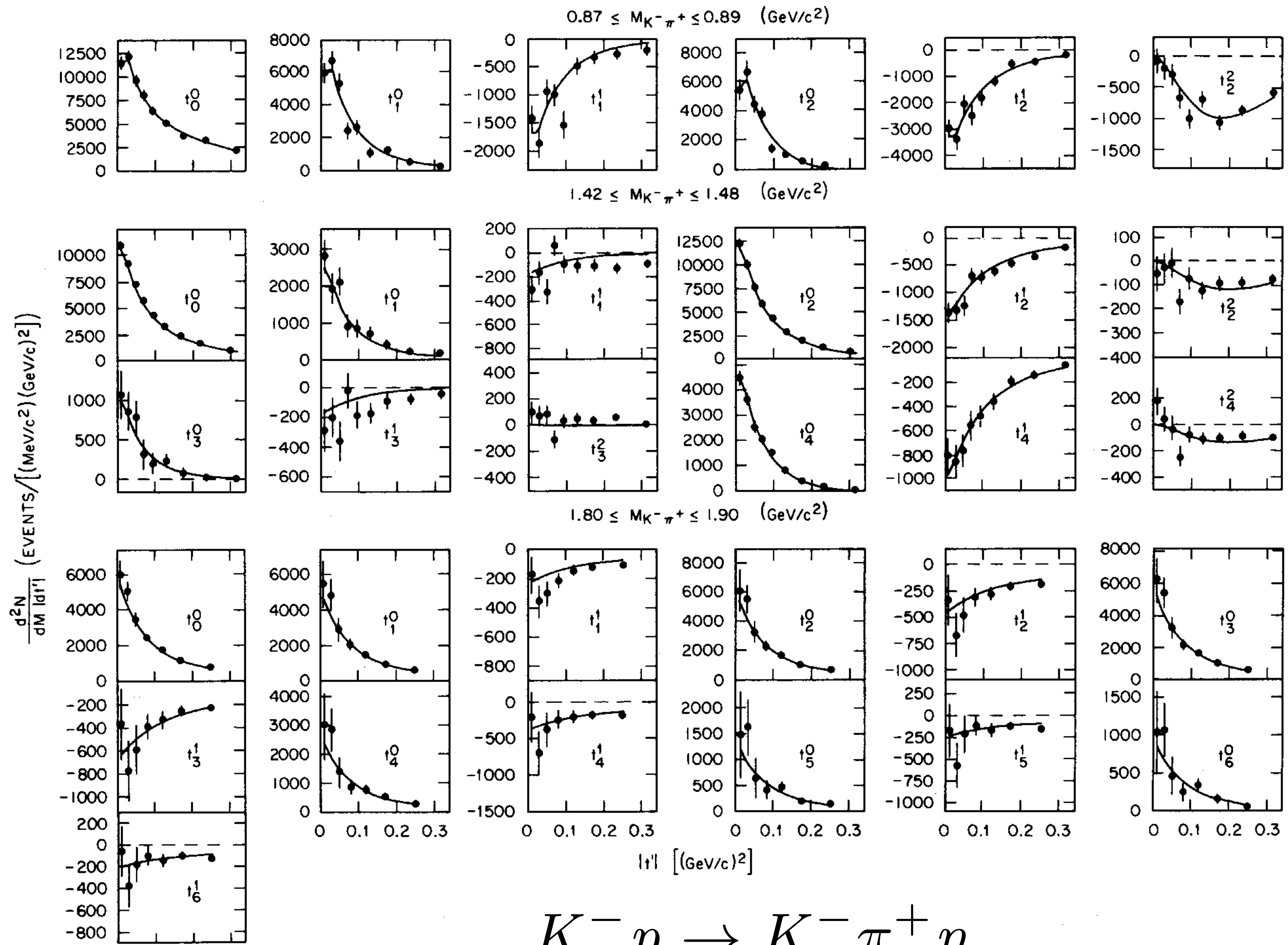


$-t, (GeV/c)^2$



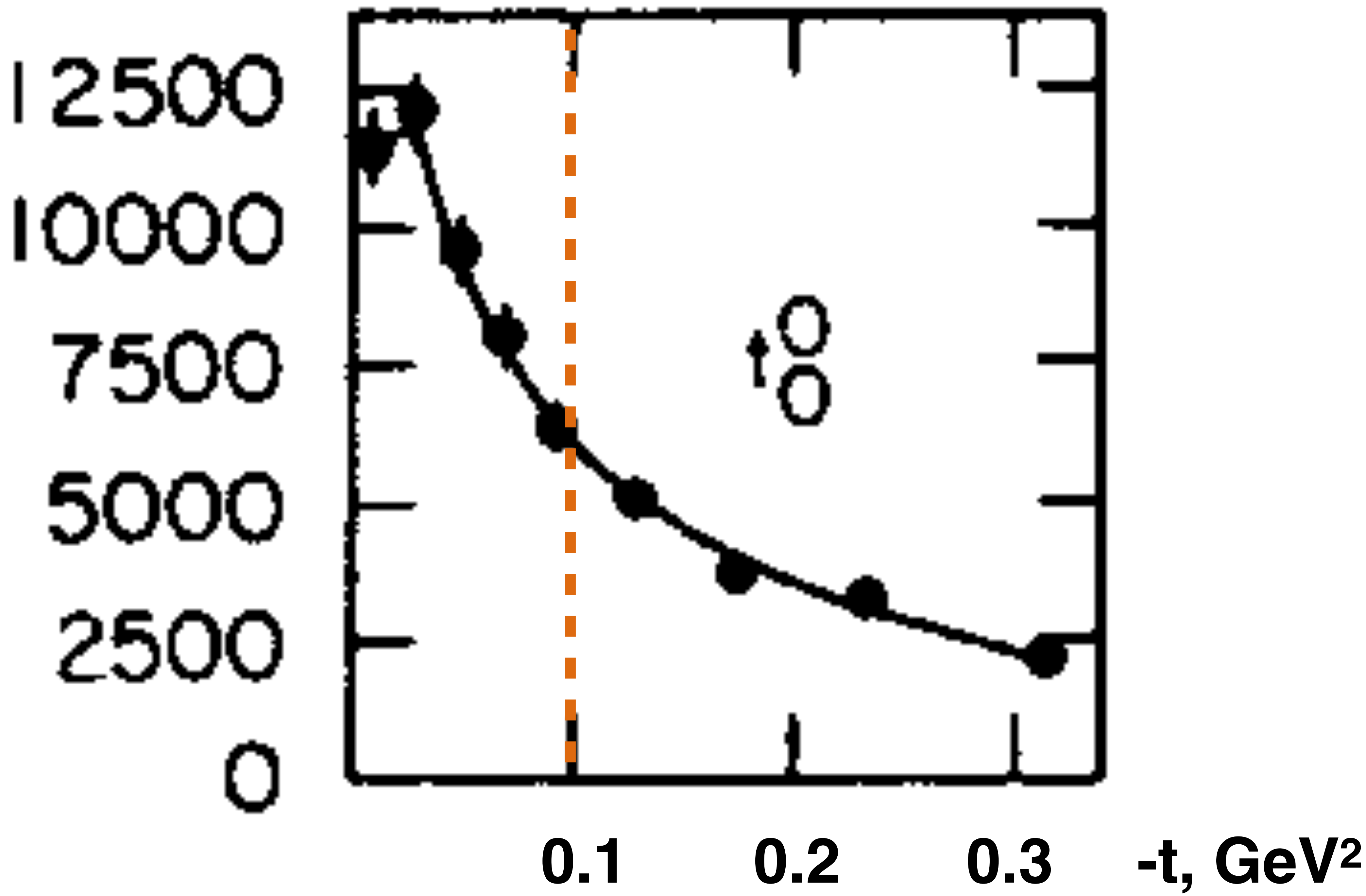
$P(K_L), GeV/c$

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.

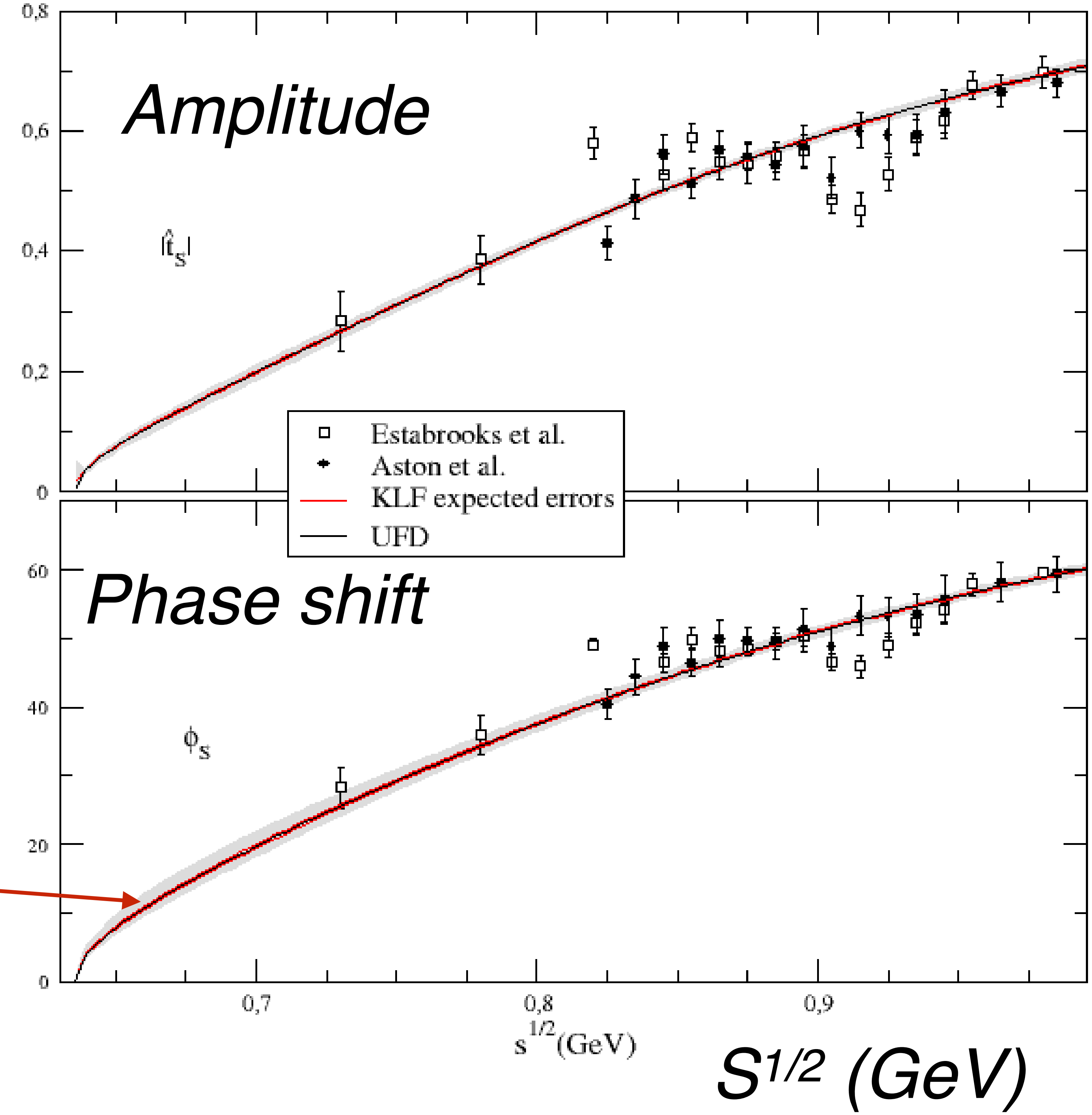


12500
10000
7500
5000
2500
0
0.1
0.2
0.3
-t, GeV²

Projected Measurements

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

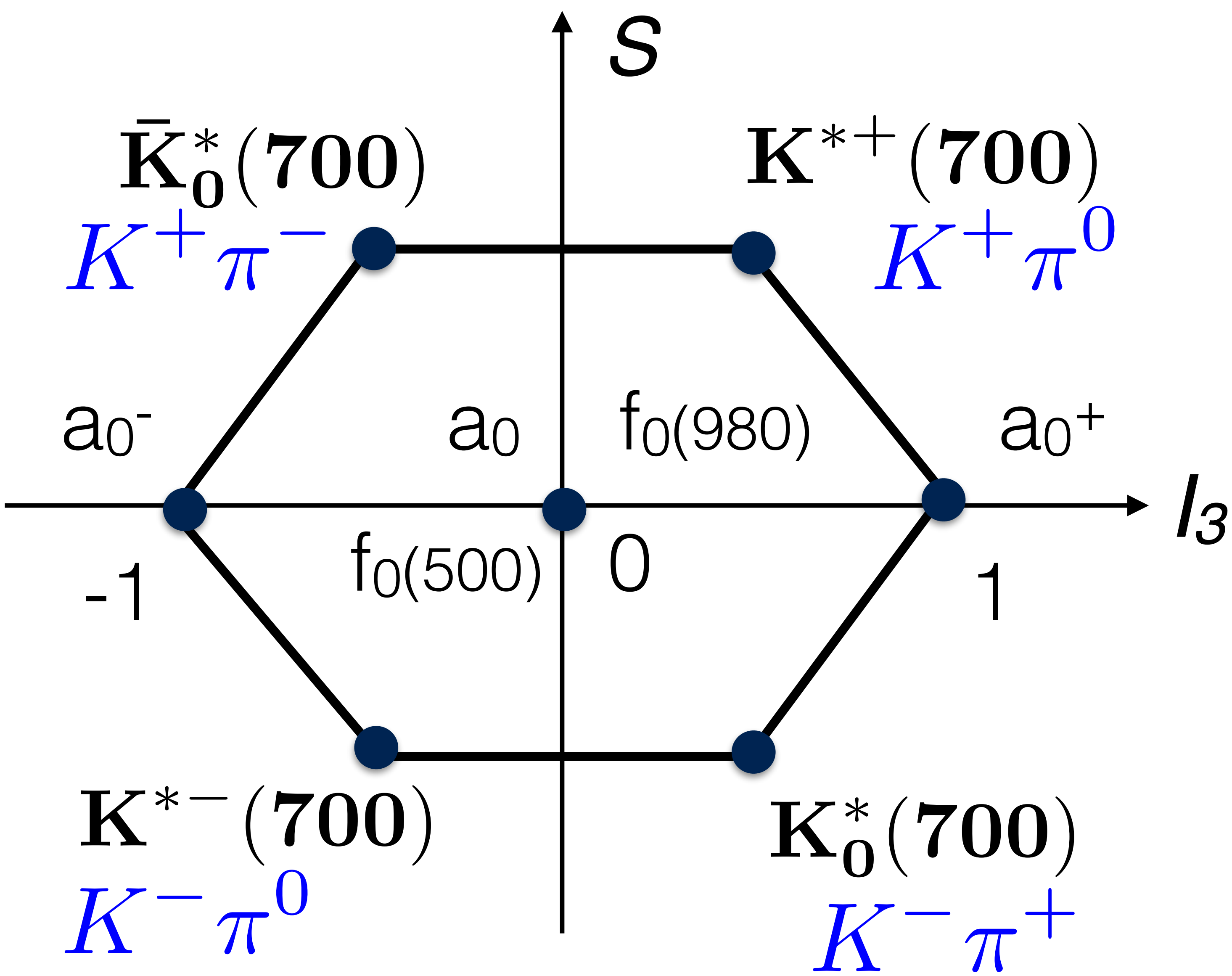
SLAC Data



KLF (100 days)

Scalar Meson Nonet

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

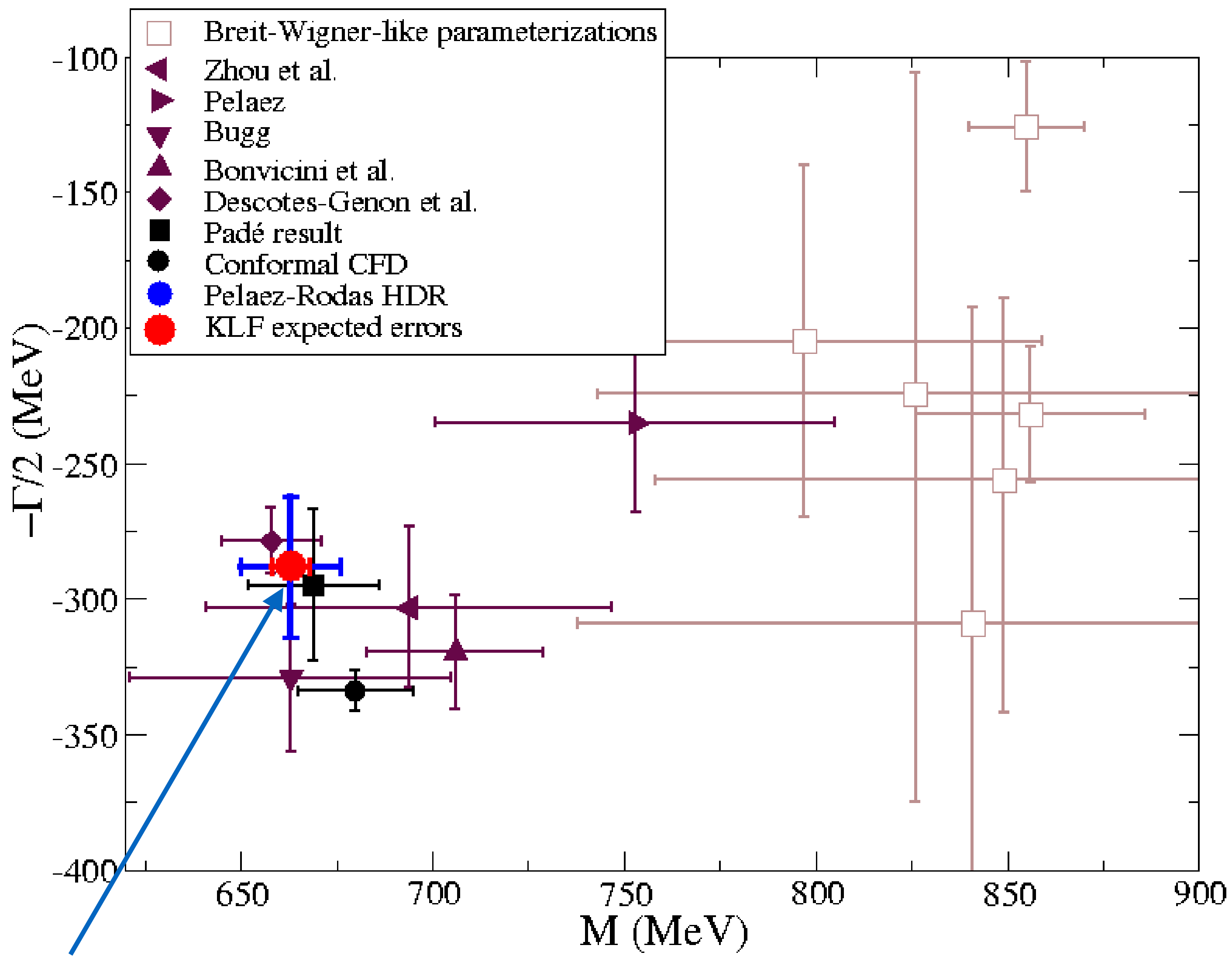


Four states called κ

still need further confirmation(PDG)

We can measure all of them

Width and Mass of $\kappa(800)$



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

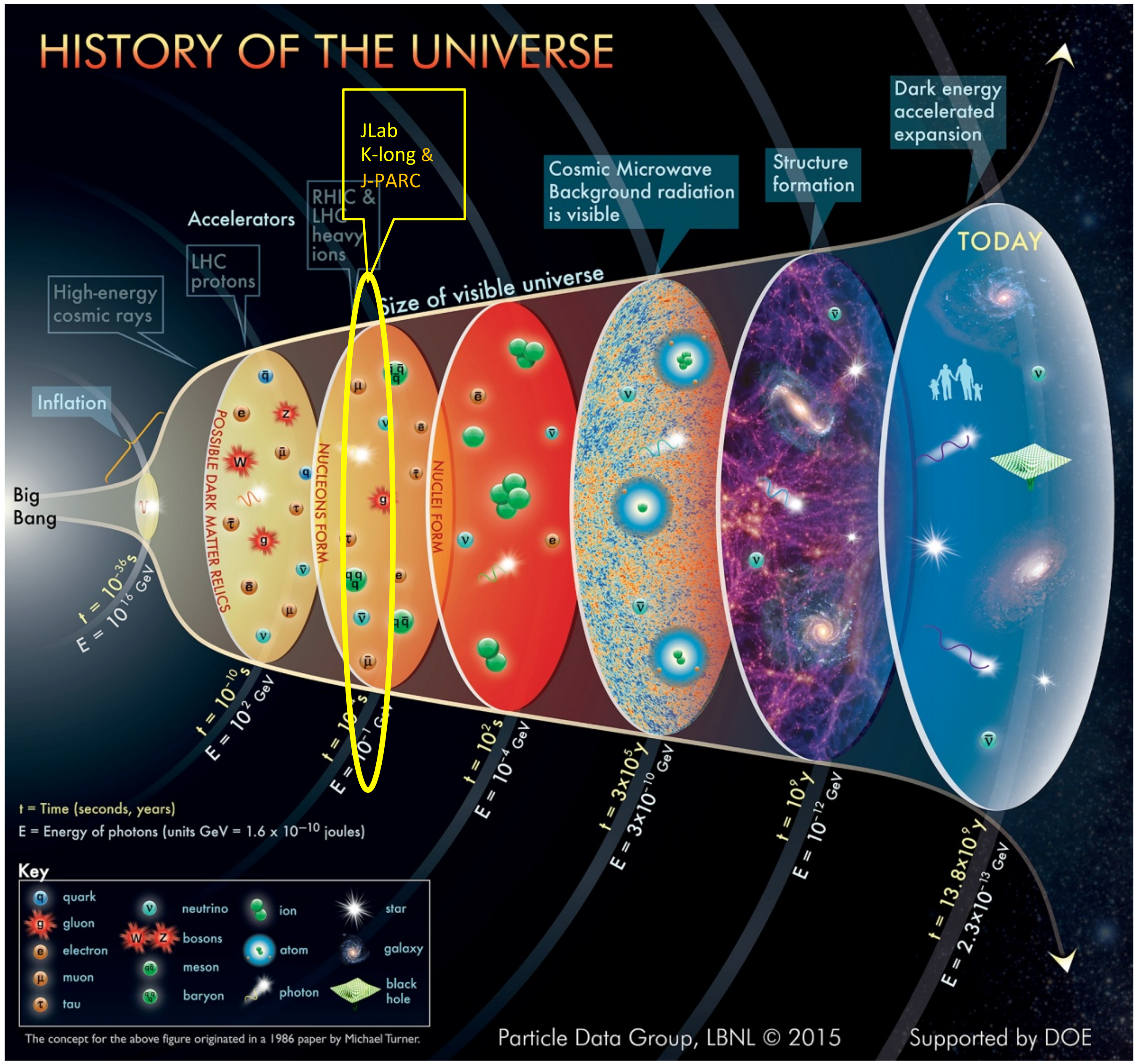
-It will certainly improve still conflictive determination of heavy K*'s parameters

-It will help to settle the tension between phenomenological determinations of scattering lengths from data versus ChPT and LQCD

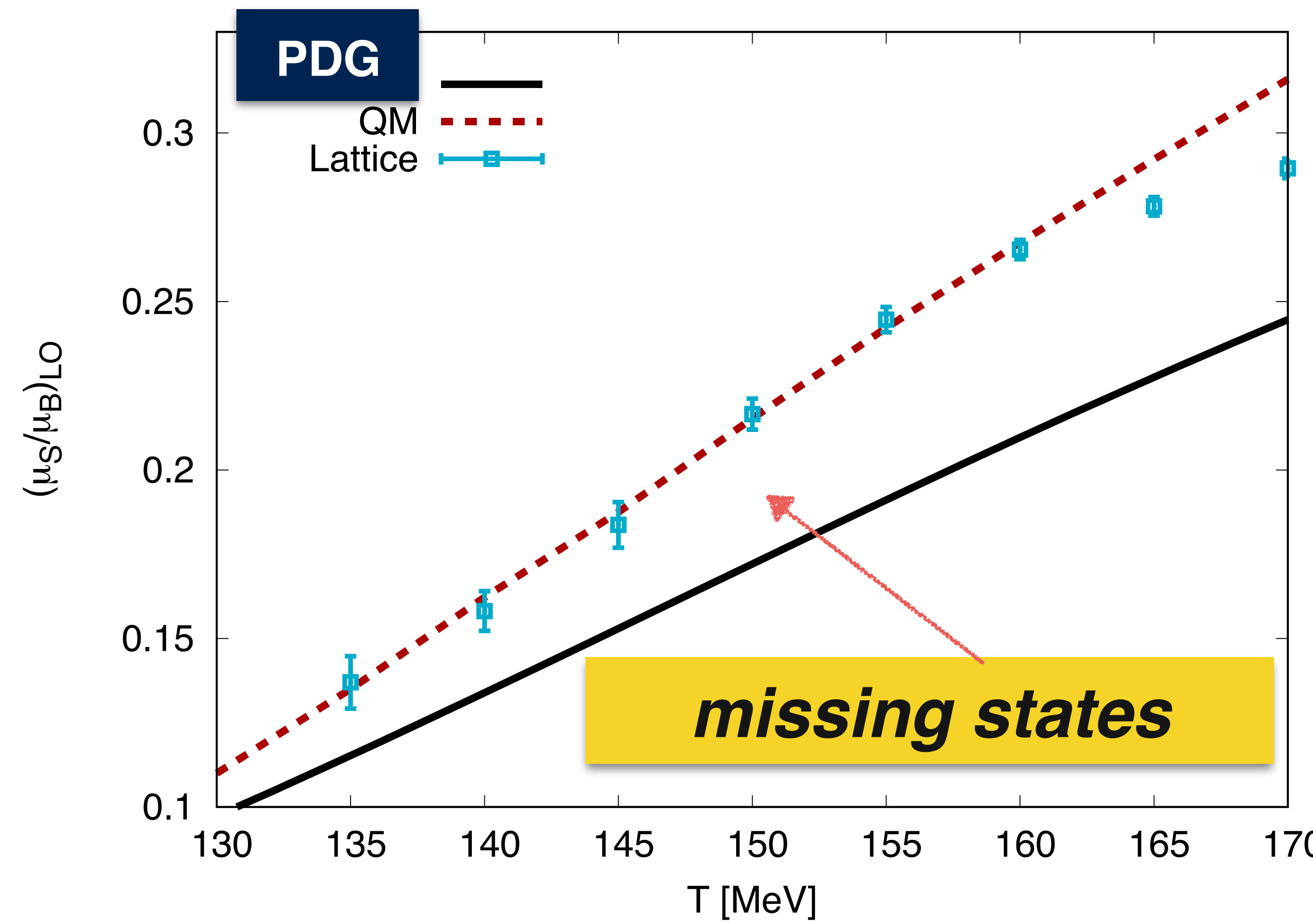
-Finally, and very importantly, it will reduce by more than a factor of two the uncertainty in the mass determination of K*(700) and by factor of five the uncertainty on its width, and therefore on its coupling

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

Evolution of an Early Universe at Freeze-out



Chemical potential

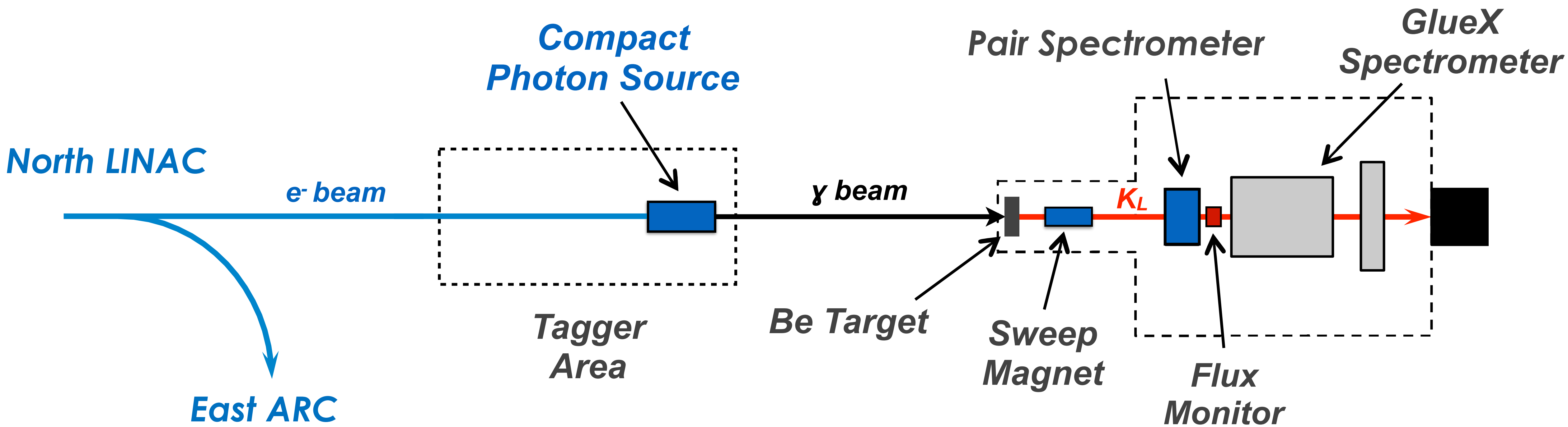


YSTAR2016 Proceedings arXiv: 1701.07346

KL Project will shed a light on thermodynamic properties of EU $1\mu s$ after the Big Bang

The main part of deficit is due to missing hyperon states

Hall-D beamline and GlueX Setup



Electron Beam Parameters

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

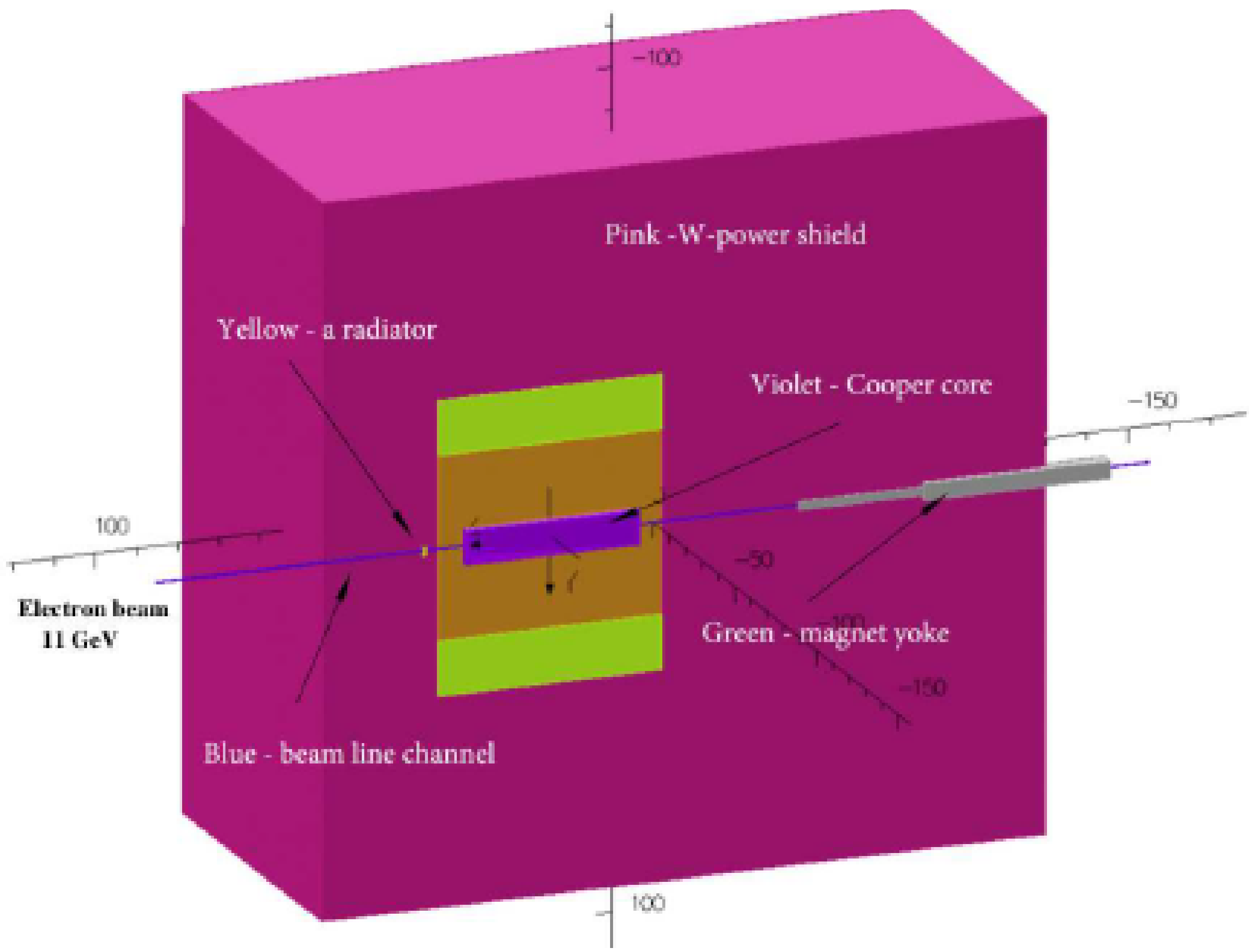
Bunch spacing $64\ ns$

No major problems.

Doable !

Confirmed by accelerator experts

Compact Photon Source

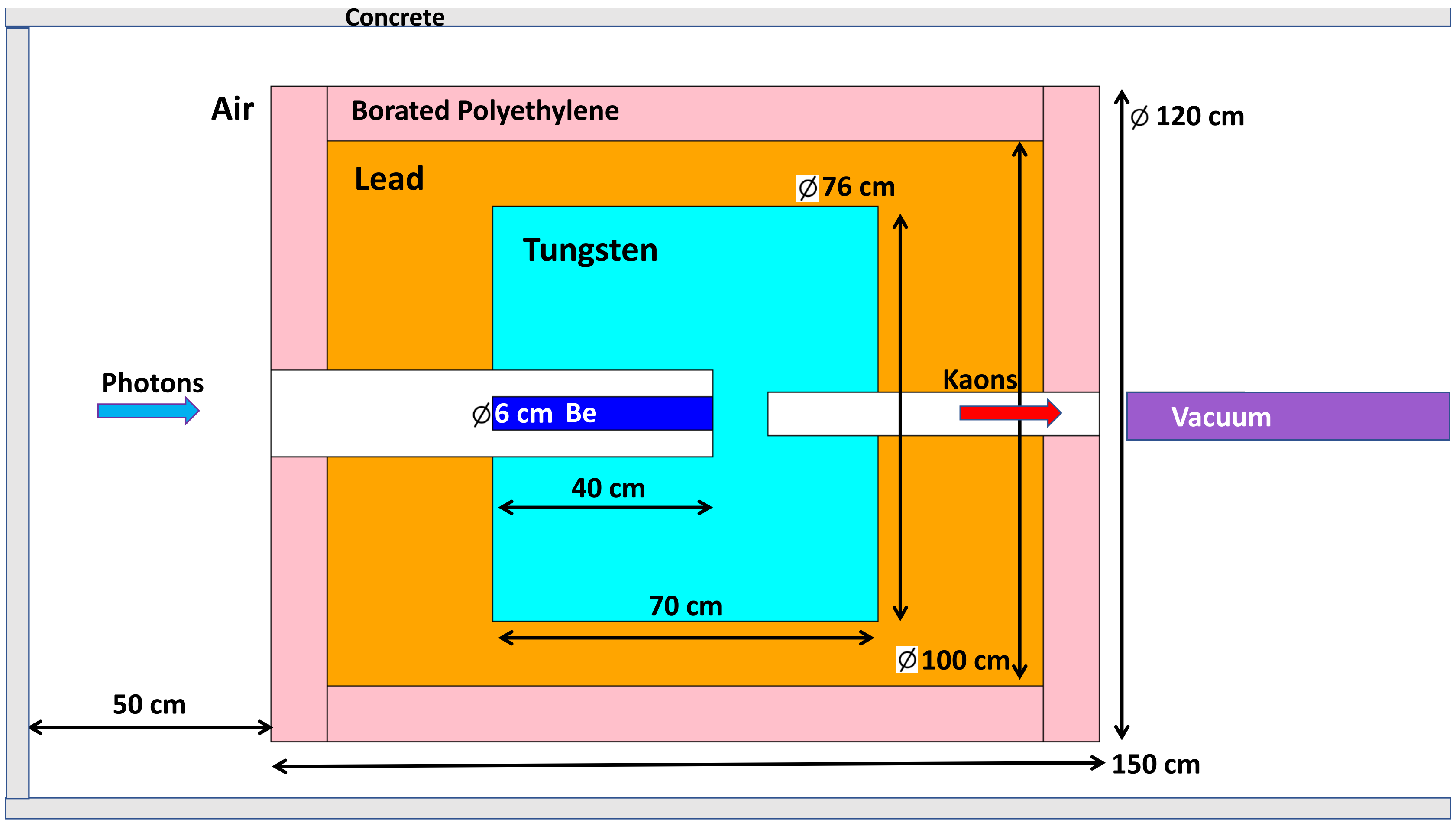


Conceptual design is completed for Halls A&C

The details of the CPS are designed by the CPS Collaboration

Meets RadCon Radiation Requirements

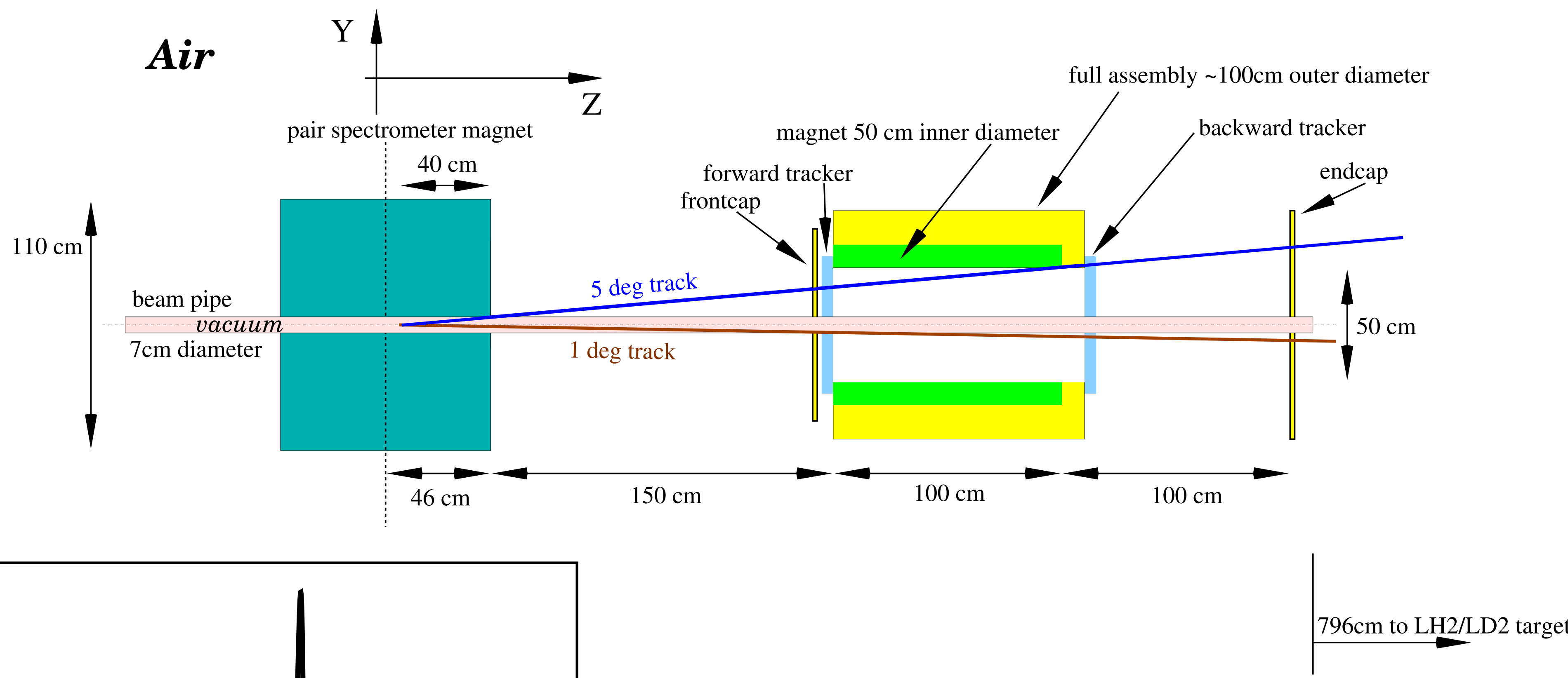
Be Target Assembly: Conceptual Design

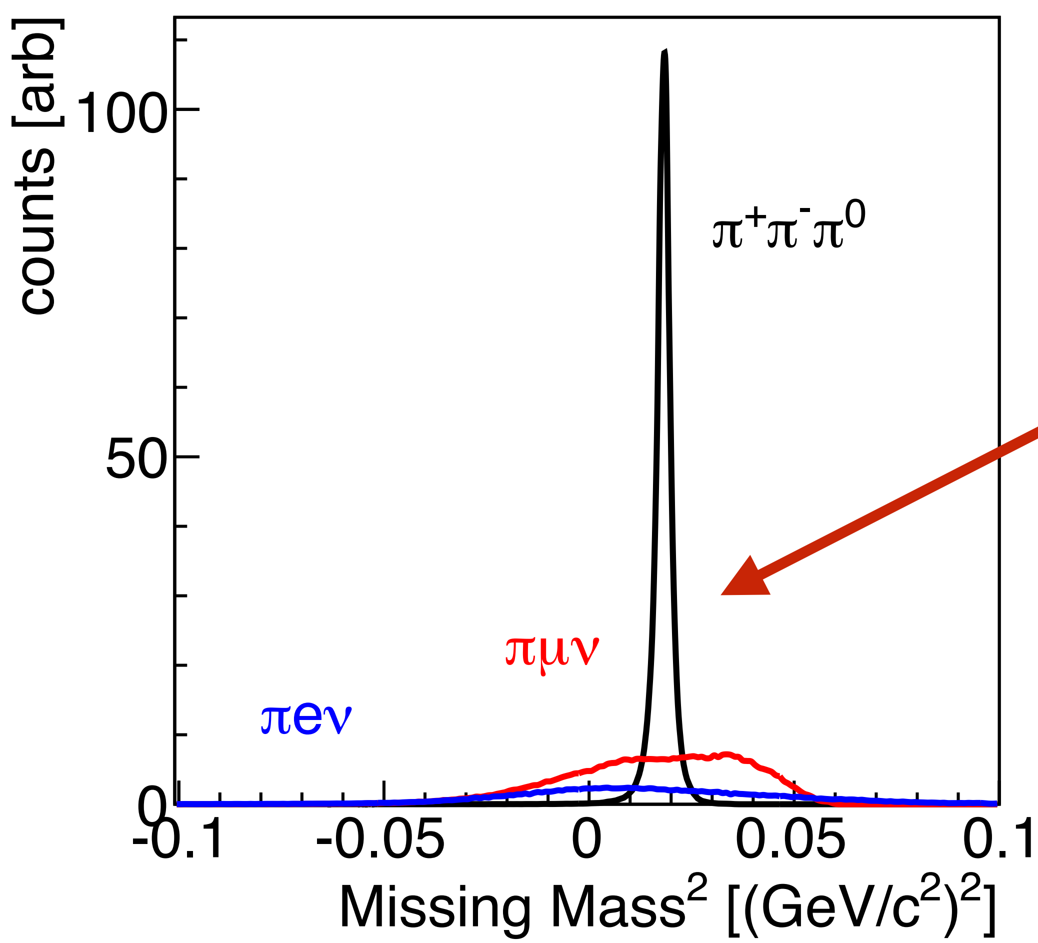


-Meets RadCon Radiation Requirements

-Conceptual Design Endorsed by Hall-D Engineering Staff

Flux Monitor





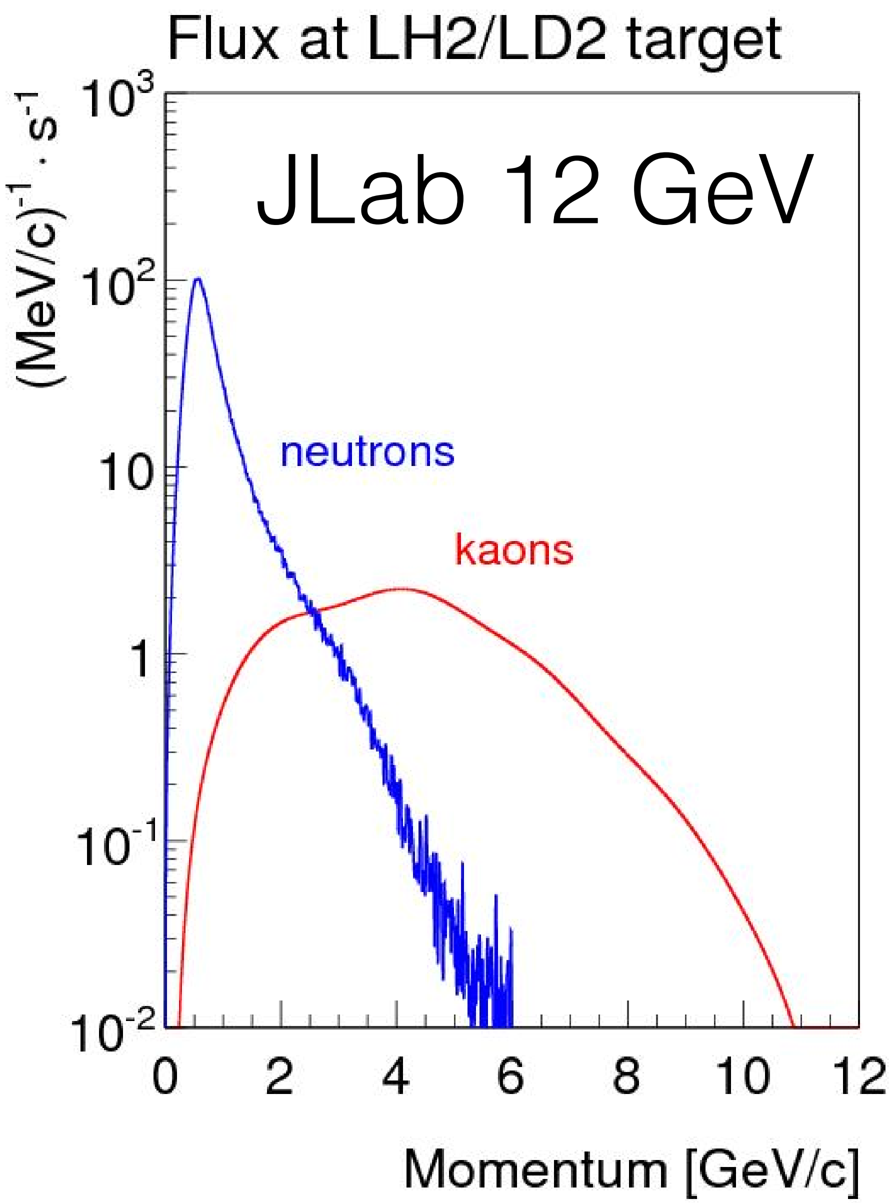
Reconstructed K_L

via missing (π^0)

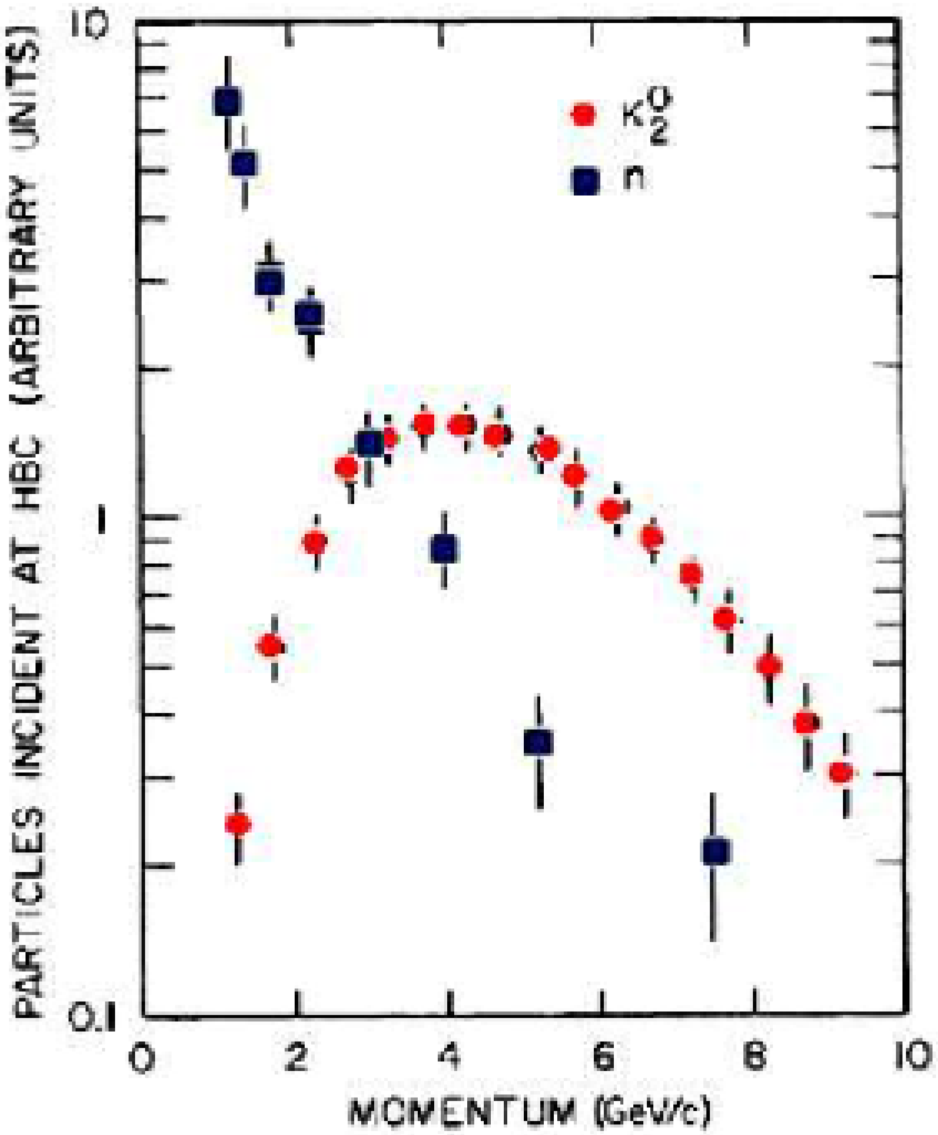
Flux measurement stat. err. <1%

Estimated syst. err. ~5%

K_L Beam Flux



SLAC 16 GeV

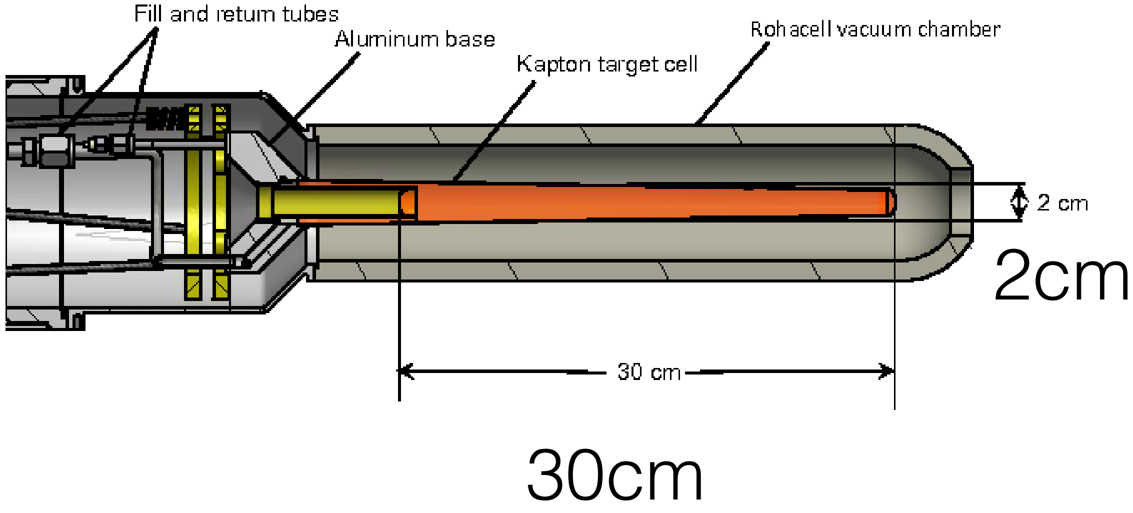


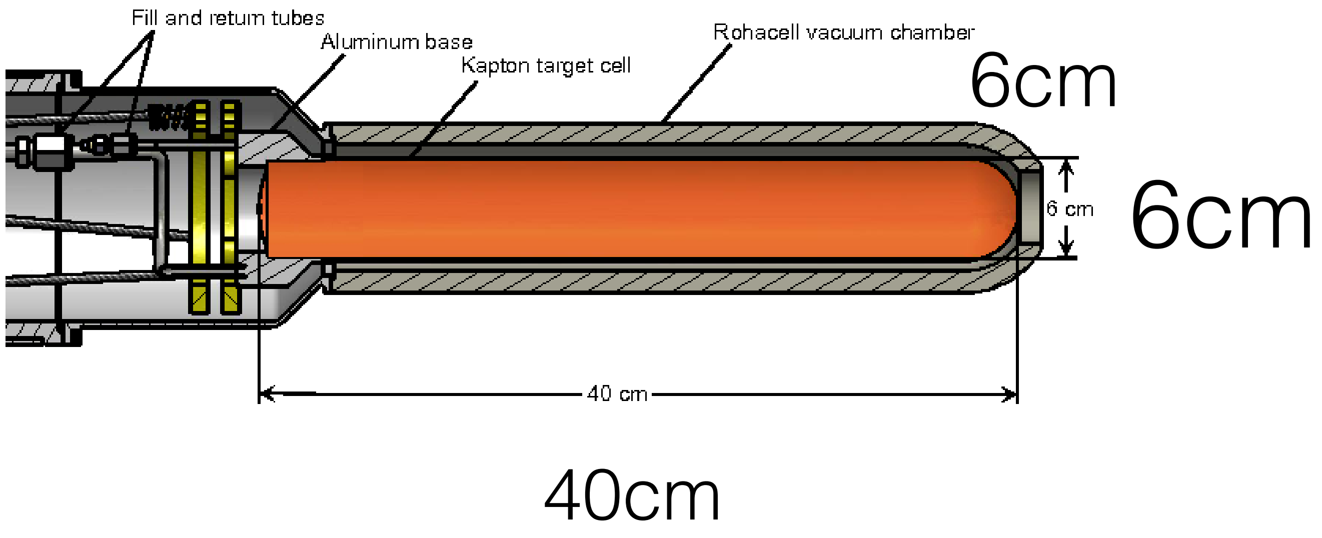
$$N(K_L)/sec \sim 10^4$$

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

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

The GlueX liquid hydrogen target.



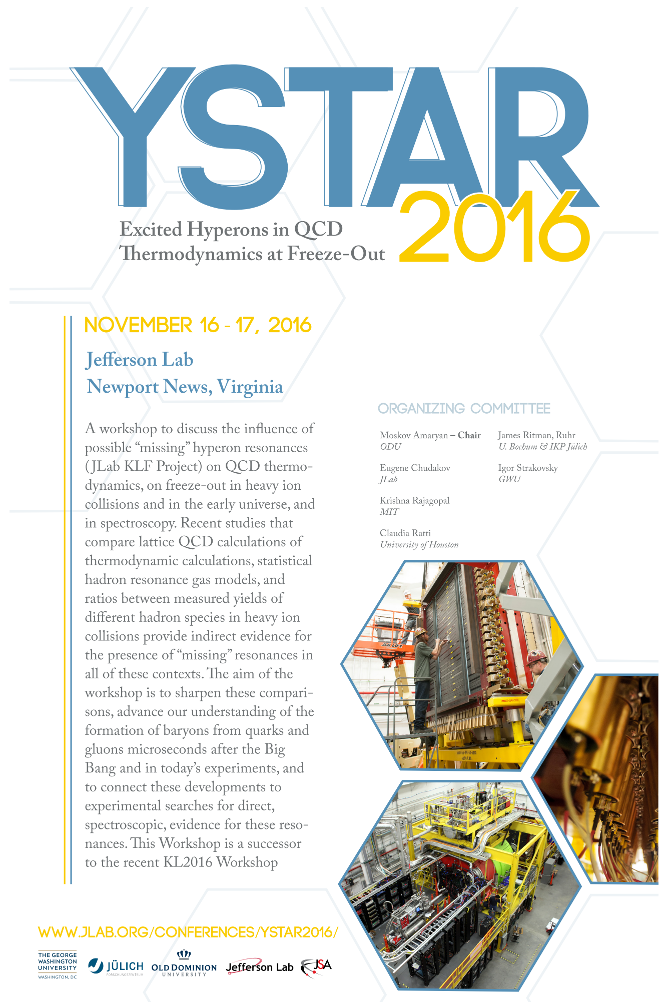


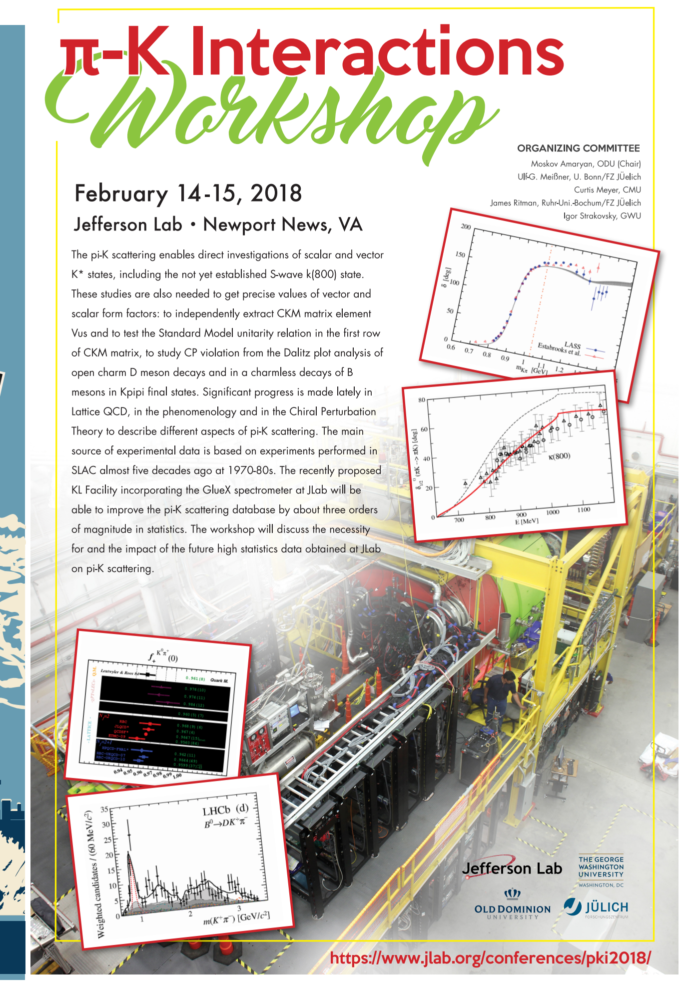
Current

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

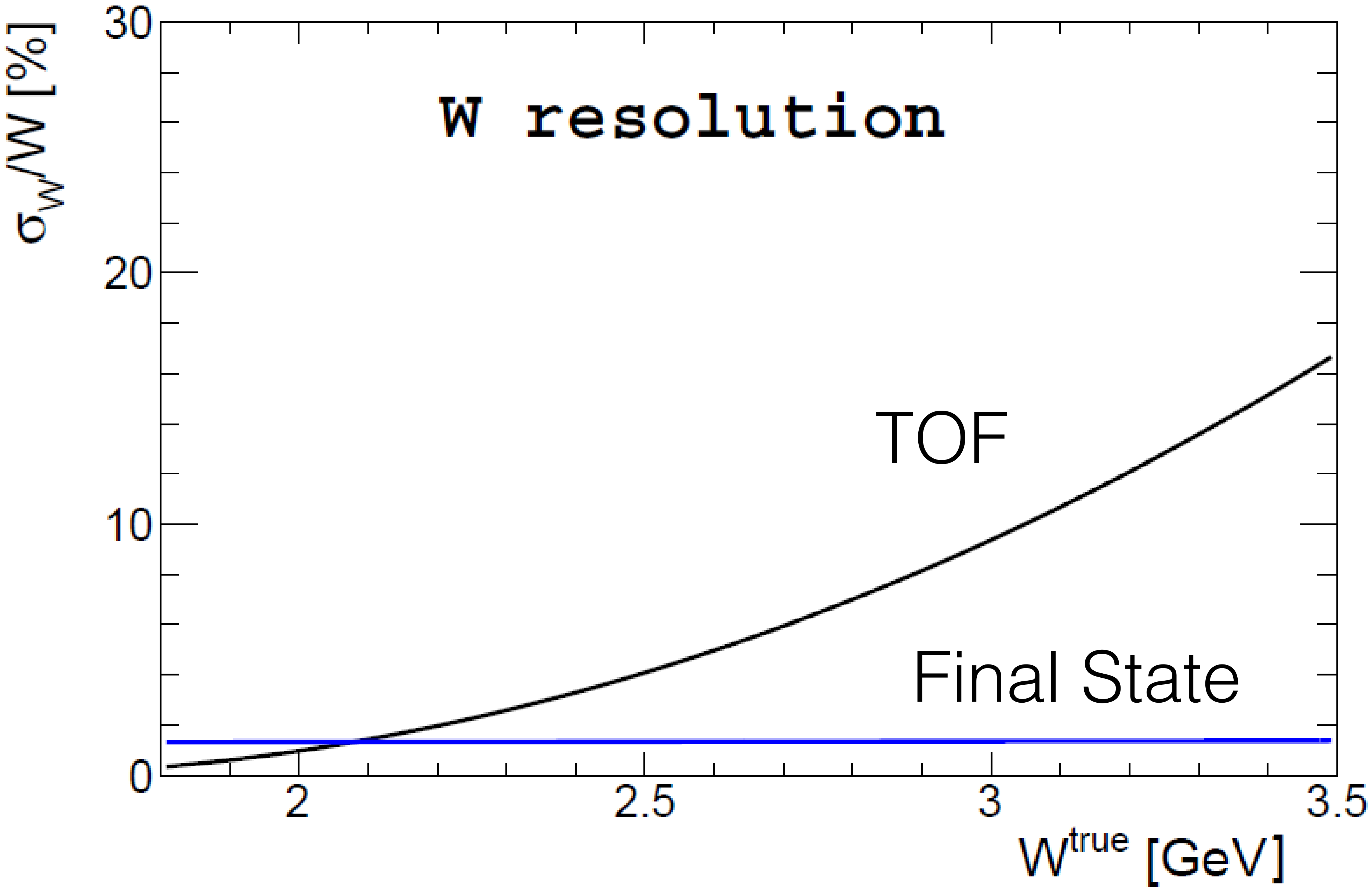
SUMMARY

- **-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 κ

Summary: ***From TAC Report***

Feasibility: The project appears to be technically feasible. The cost (without local labor) was estimated at about $6M (taking into account the recent CPS estimate), including about $1M for the Flux Monitor, which may become a foreign contribution.

Thank you !


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