PAC53 Jeopardy

Strange Hadron Spectroscopy with Secondary K_L beam in Hall D

Moskov Amaryan
(for KLF Collaboration)

July 21-25, 2025

Outline

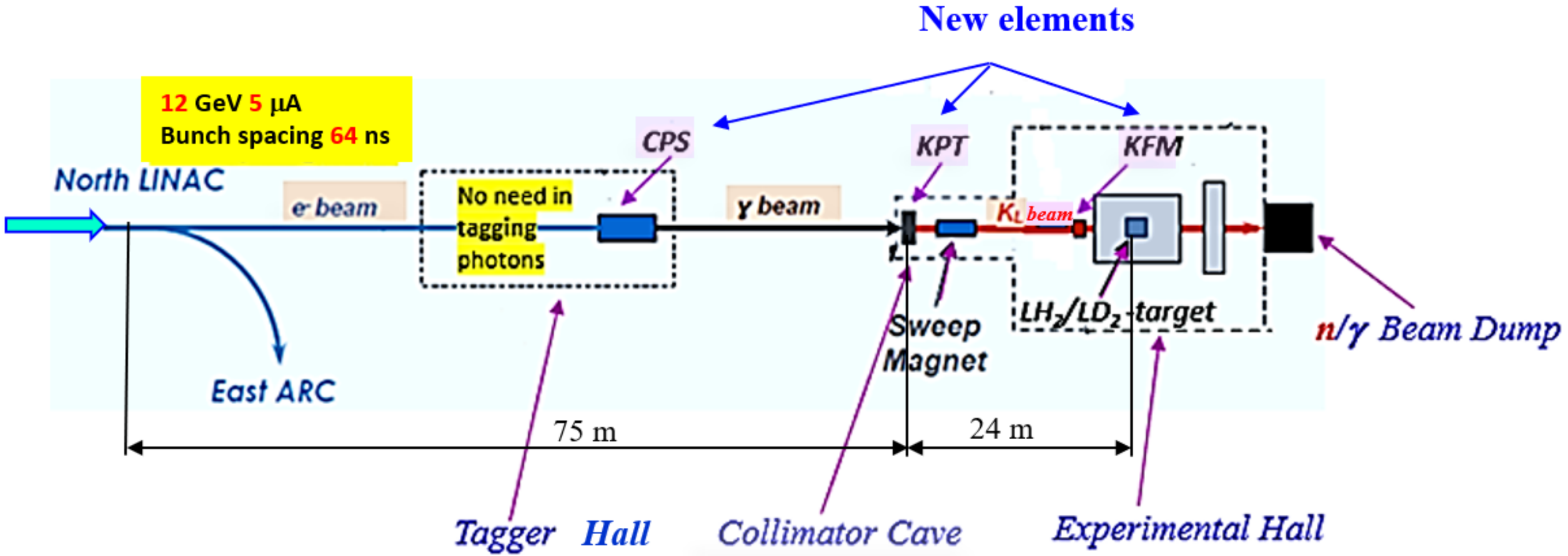
- Introduction
- KLF Beamline
- Strange Hyperon Spectroscopy
- Strange Meson Spectroscopy
- Summary

Introduction

- The proposal was approved by PAC48 in 2020 to run 200 days on LH2 and LD2 targets (for the first time ever) equally divided **https://arxiv.org/pdf/2008.08215**

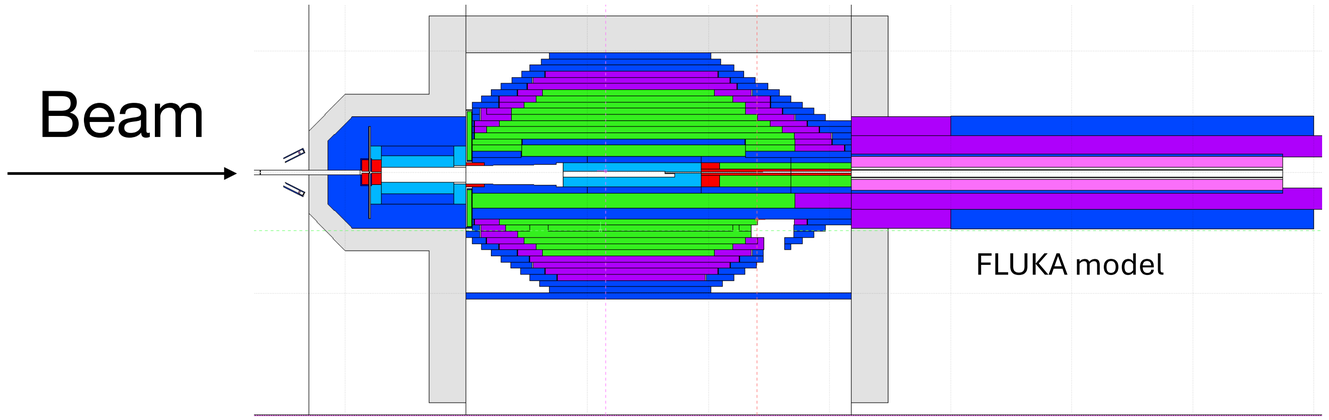
- The main goal of the experiment is hyperon spectroscopy and strange meson spectroscopy

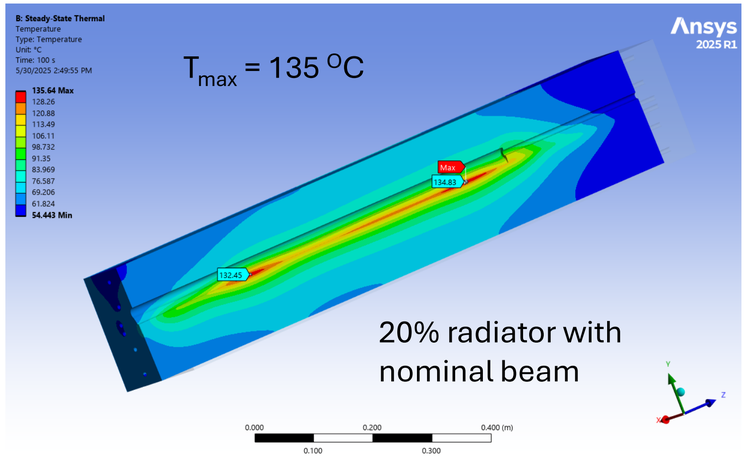
KLF Beamline

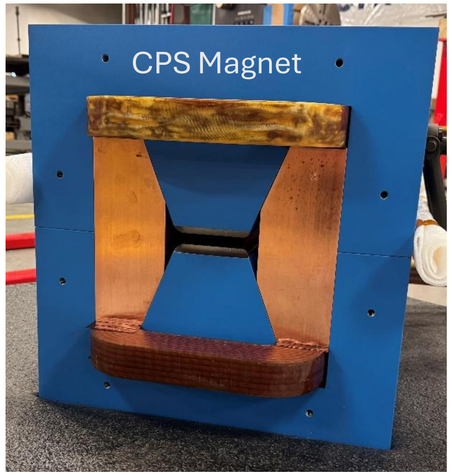


From Executive Committee Meeting on 6/16/2025

- We are evaluating CPS performance with a 20% RL radiator.
  - Currently, no problem is identified.
- CPS magnet and power supply have been procured.
  - $250K total cost for procurement.
  - Both magnet and the power supply are at JLAB.
- The plan is to submit a purchase request for the copper absorber this year.
  - Subject to funding availability.





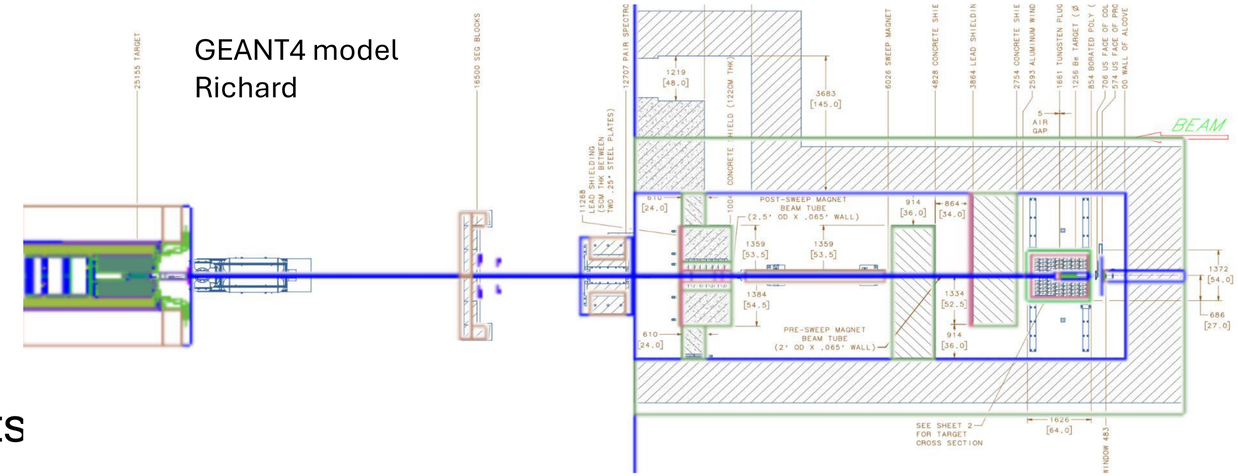


Schedule of installation is under discussion

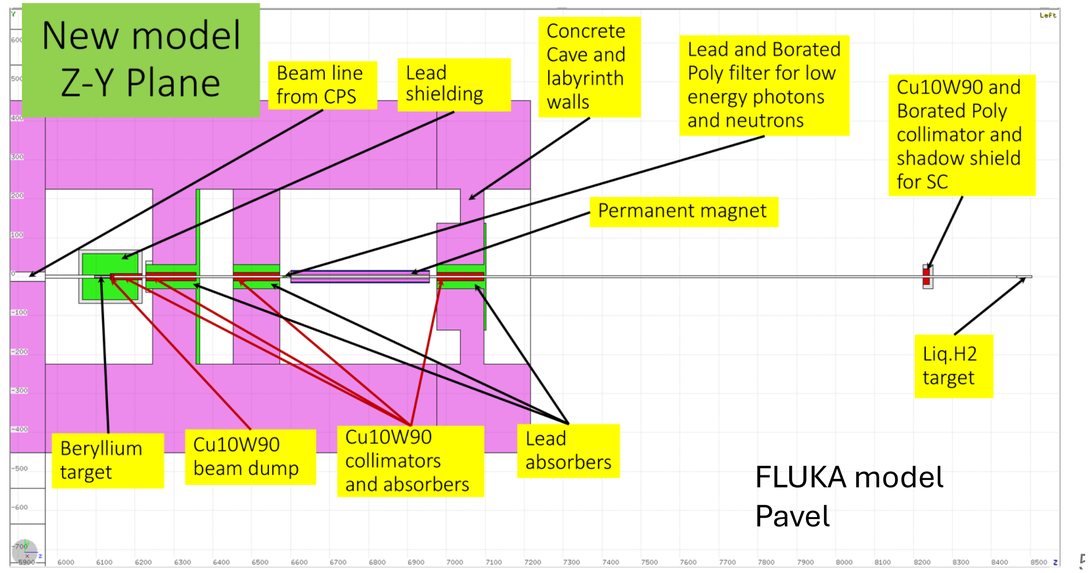
Kaon Production Target (KPT)

- KPT engineering design is nearly ready
- KPT+beamline implemented in Geant4 and FLUKA
- Variable tungsten absorber (~14 cm) to reduce bckg
- Rates of FDC, CDC and TOF are at or below GlueX limits
- No obvious issues
- Radiation level in the hall is acceptable

GEANT4



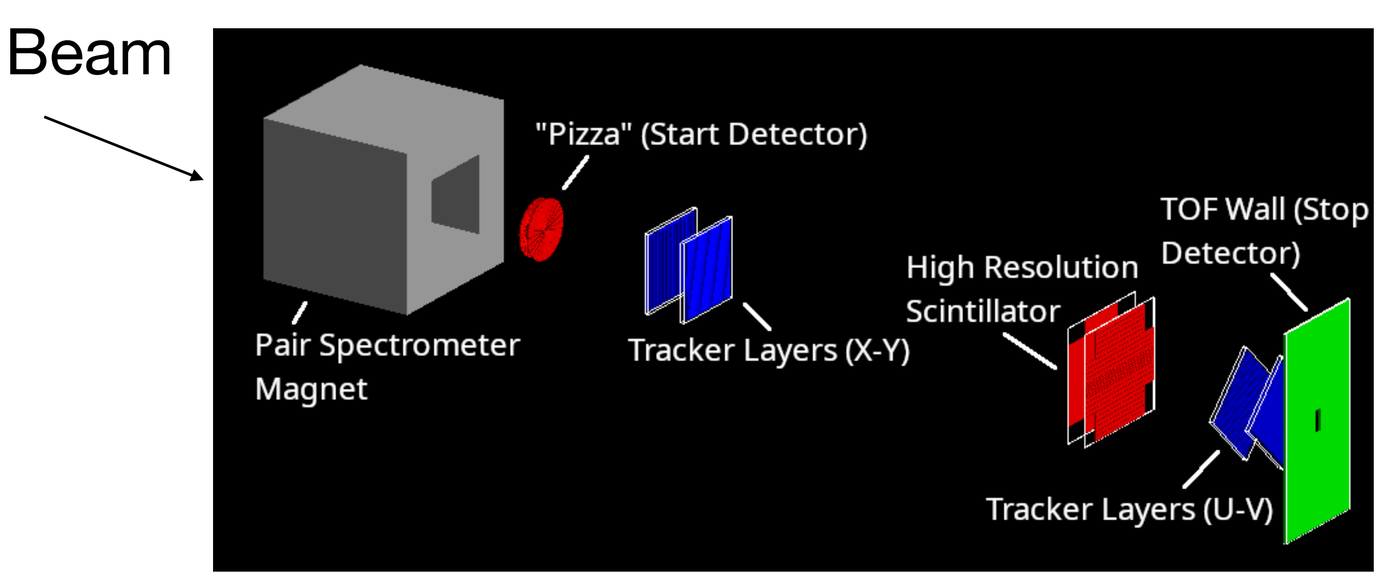
FLUKA

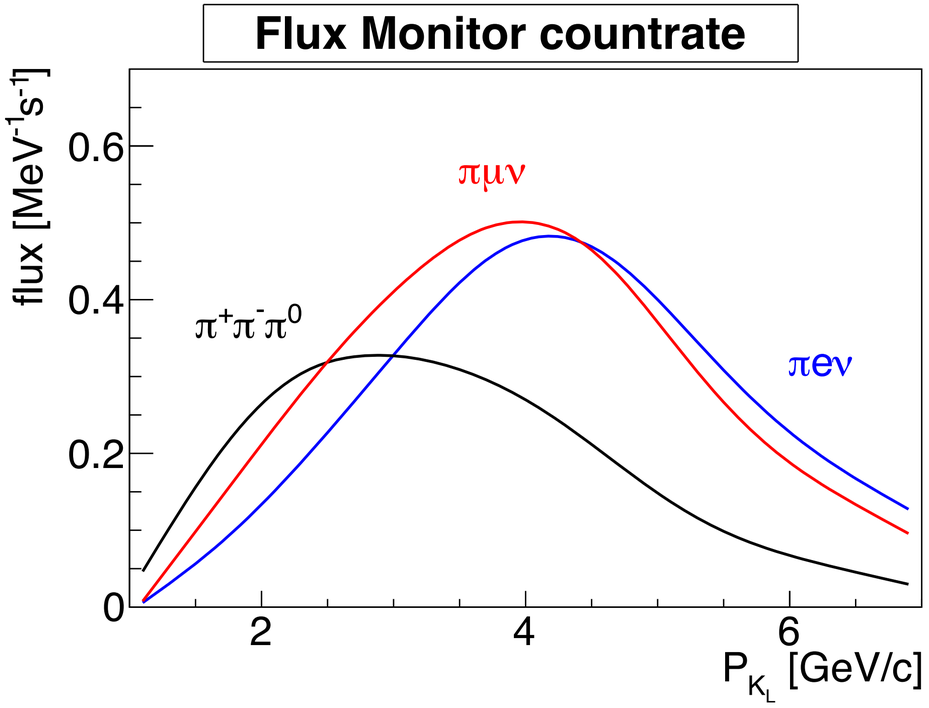


Beam →

Schedule of installation is under discussion

Flux Monitor (expanded view)





-Pizza - 48 layers, two times 24

-Tracker - 4 planes, each plane has 4 layers, 122 straws per layer

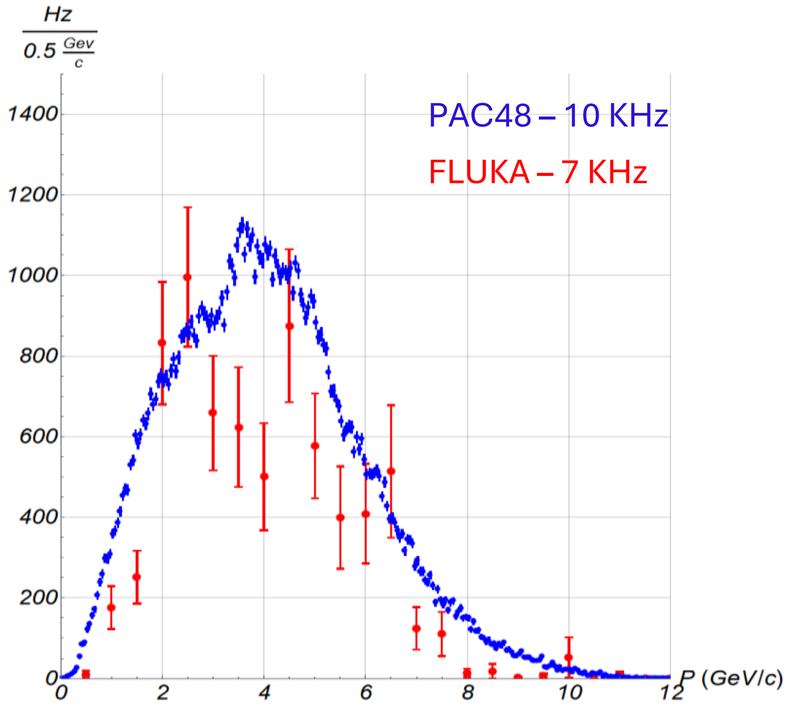
-High Resolution Scintillators- 64 elements in total, 32 per layer

-TOF - 22 Bars, each 10cm wide

Schedule of installation is under discussion

K-long Flux

Analysis	K_L Rate (Hz) (10cm W, 10% RL)	K_L Rate (Hz) (14cm W, 20% RL)	Effective K_L Absorption length used (cm)	Comments
Ilya & Igor	10000			PAC 48
Pavel		8200	10.8	FLUKA
Eugene	3300	1900*	7.8	ϕp production only
Eugene	8500	5000*	7.8	PYTHIA, 7KHz - 10KHz range
Richard		1500	7.8	ϕp production only
Moskov		7600	6.4	Based on SLAC data
Hovanes		3100	7.1	Based on SLAC data



SLAC rate was 10 K_L/s

Phys. Rev. D 7, 708 (1973).

GlueX Start Counter

NIM, A927 (2019) 330-342

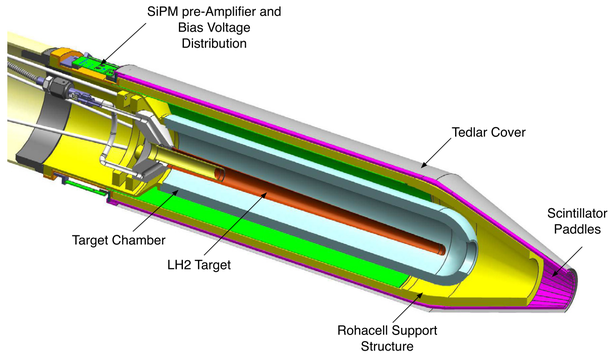


Fig. 1. The GlueX Start Counter mounted to the liquid H_2 target assembly. The beam direction is oriented from left to right down the central axis of the ST.

Beam

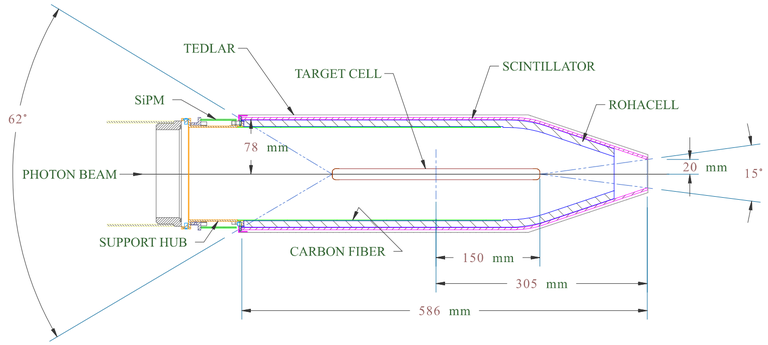
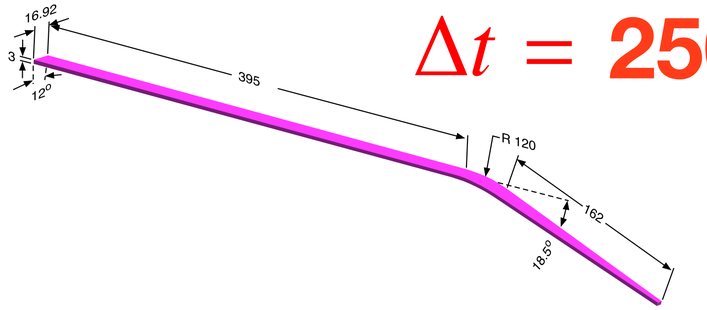


Fig. 2. 2-D cross section of the Start Counter.. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

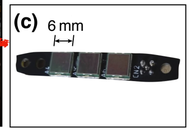


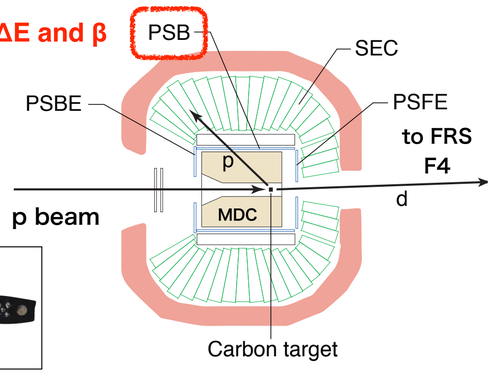
$\Delta t = 250$ ps

Start Counter for KLF

NIM, A1034 (2022) 166745

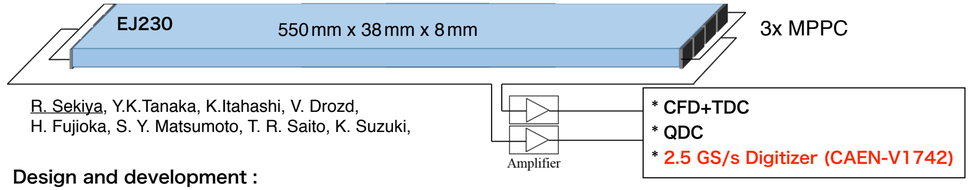
Plastic Scintillator Barrel (PSB) for WASA-FRS





MPPC S13360-6050PE

Readout scheme



R. Sekiya, Y.K.Tanaka, K.Itahashi, V. Drozd,
H. Fujioka, S. Y. Matsumoto, T. R. Saito, K. Suzuki,

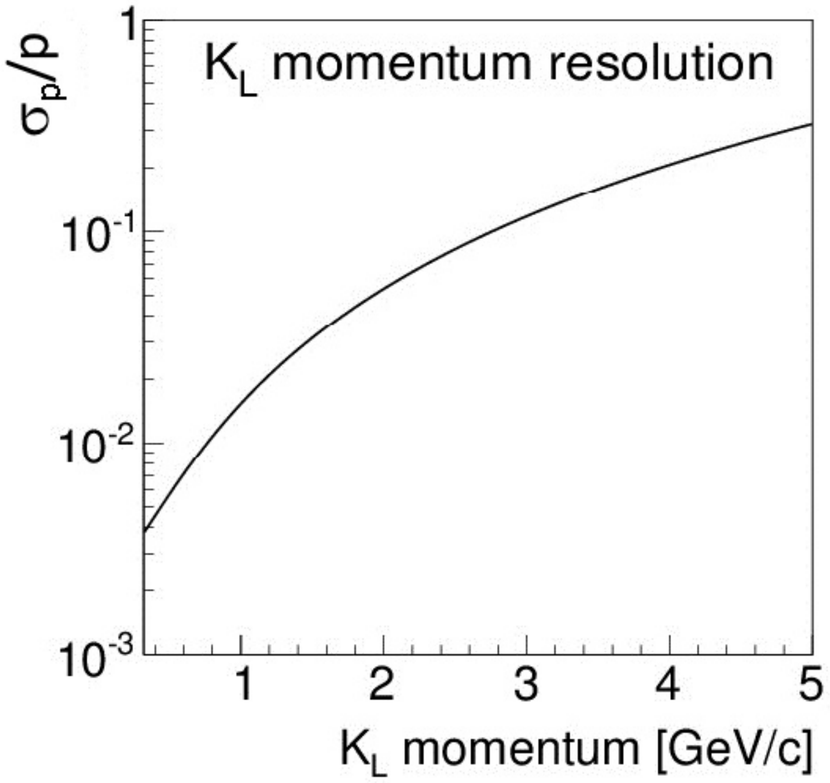
Design and development :
R.Sekiya et.al., NIM A 1034 (2022) 166745

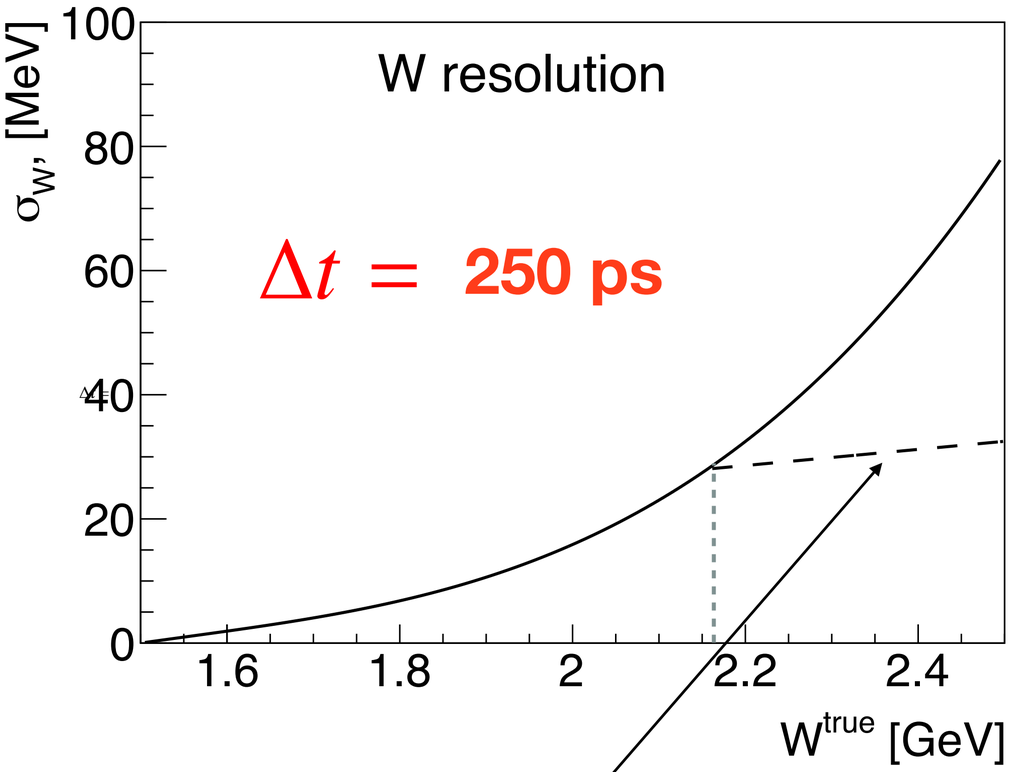
(Note that O(100Hz) clean DAQ trigger from FRS-F4 is used.)

$\Delta t = 50$-80 ps !

Will be ready by the end of 2026

Resolutions





Shaded line shows region of full reconstruction

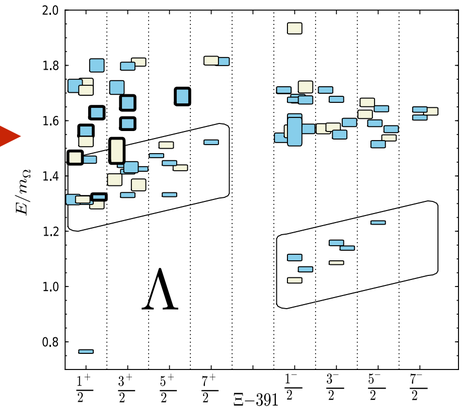
Hyperon Spectroscopy

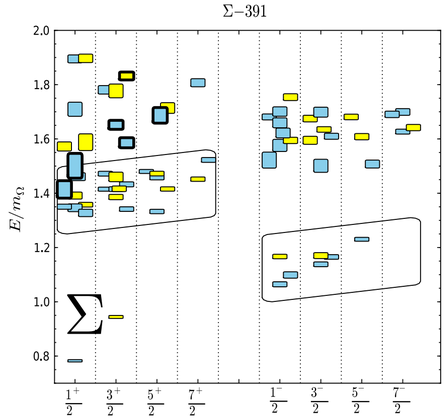
*According to **LQCD** there should be*

many more states including hybrids (thick bordered)

8-states ****

5-states ***



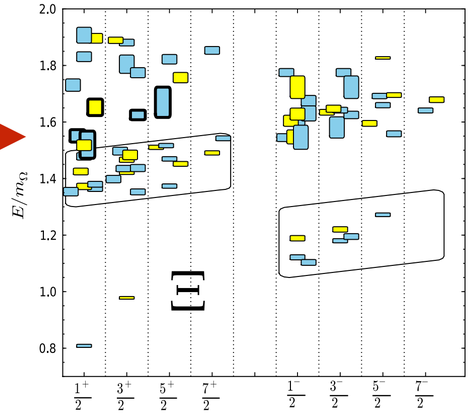


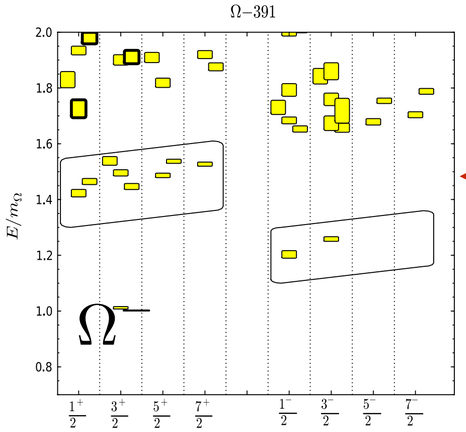
6-states ****

4-states ***

3-states ****

4-states ***



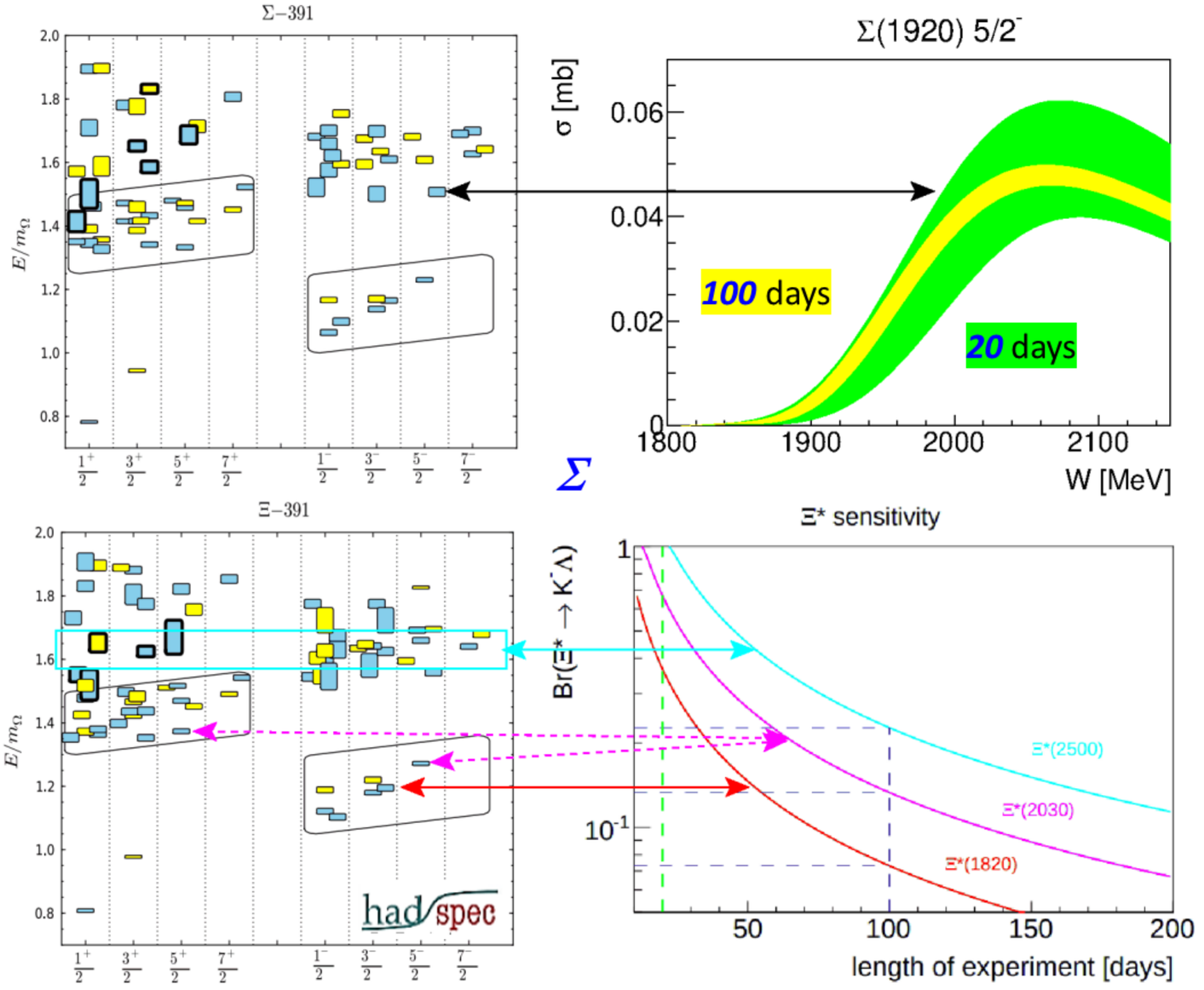


1-state ****

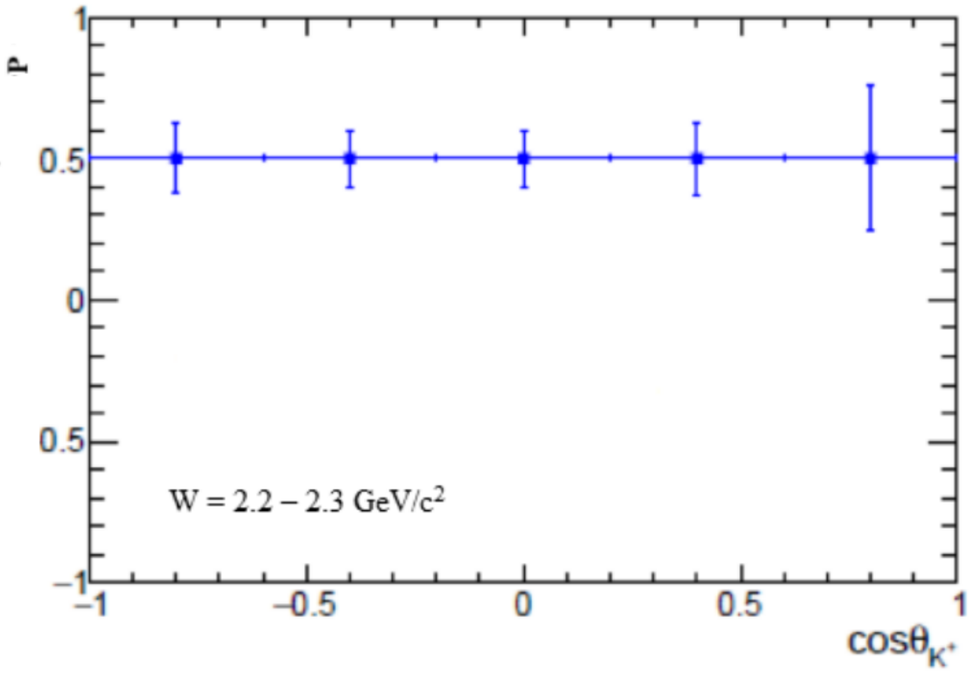
1-state ***

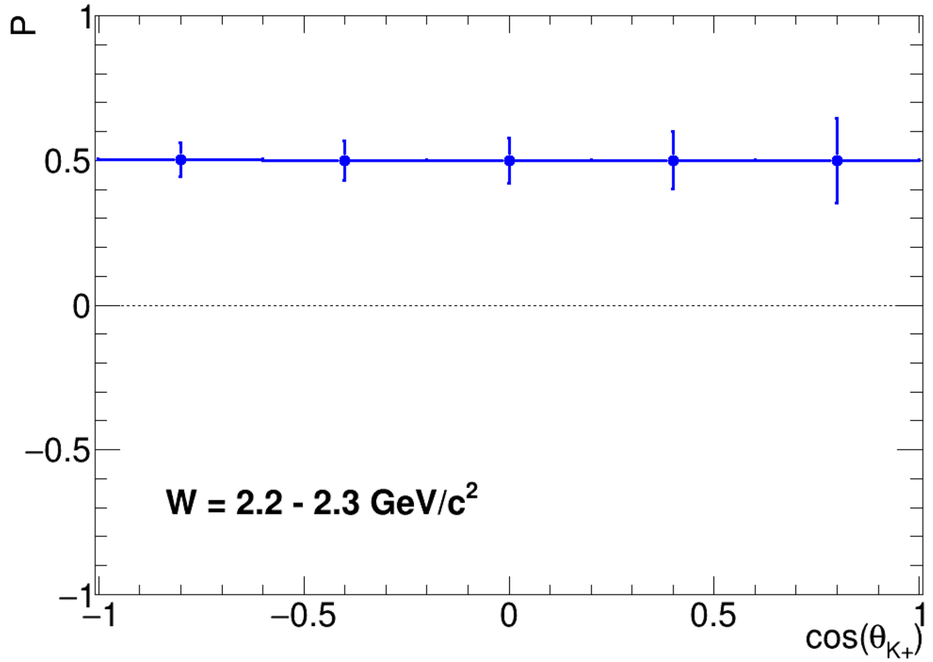
Edwards, Mathur, Richards and Wallace, Phys. Rev. D 87, 054506 (2013)

Some examples



Induced polarization

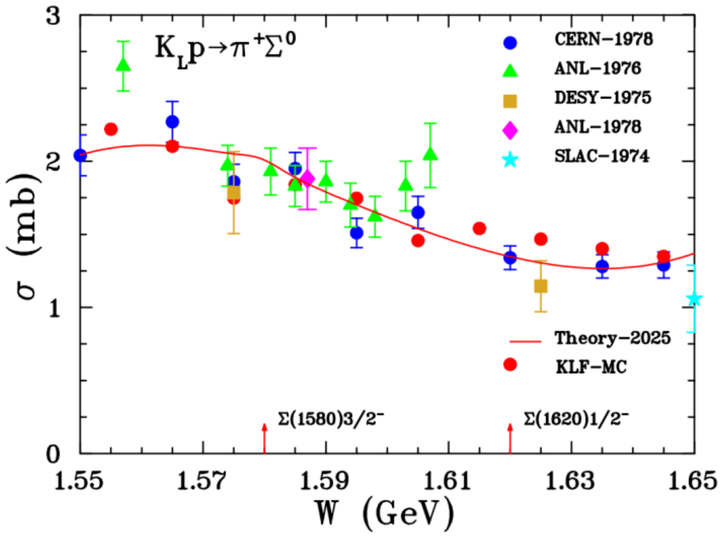




Differential results on the induced polarization of Ξ^0 from $K_L p \to K^+\Xi^0$ events events from simulations corresponding to 100 days of running. Left: From Proposal [**KLF:2020gai**]. Right: From exclusive Ξ^0 reconstruction using current software and including the use of kinematical fitting.

New MC simulations with KLF

Isospin-Selective Reaction $K_L p \to \pi^+ \Sigma^0$ *Provides Clean Probe for Investigating* $I = 1$ Σ^* *Resonances*



Analysis of this reaction using effective *Lagrangian* approach for first time, incorporating well-established (4*): $\Sigma(1189)1/2^+$, $\Sigma(1385)3/2^+$, $\Sigma(1670)3/2^-$, & $\Sigma(1775)5/2^-$ states, while also exploring contributions from other unestablished states.

Dan Guo, Jun Shi, Igor Strakovsky, & Bing-Song Zou, arXiv:2504.21342 [hep-ph]

It was found that besides established resonances, contributions from $\Sigma(1660)1/2^+$ (3*), $\Sigma(1580)3/2^-$ (1*), & $\Sigma(1620)1/2^-$ (1*) improve description.

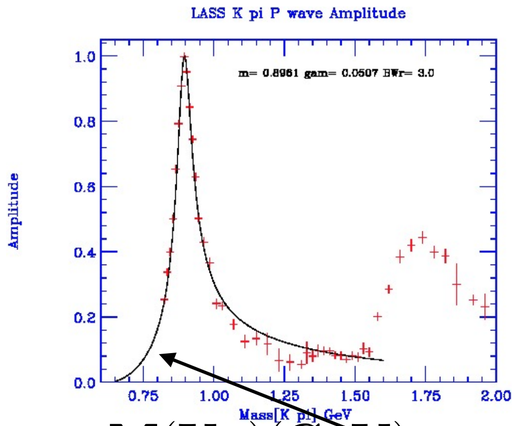
Accepted for publication in PRD

Strange Meson Spectroscopy

Proposed Measurements

SLAC

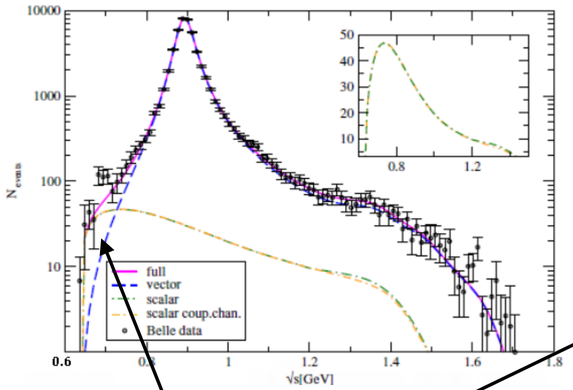
$K^-\pi^+ \to K^-\pi^+$



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

Belle

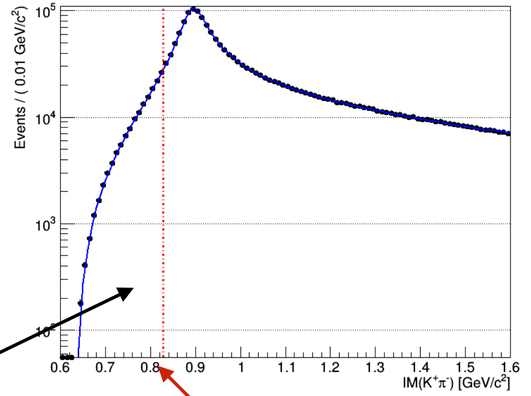
$\tau \to K\pi\nu_\tau$



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

KLF

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



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

region of $\kappa(800)$

SLAC Lower limit

Projected Measurements

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

PAC47

SLAC Data

$K^{\pm}p \to K^{\pm}\pi^{+}n$

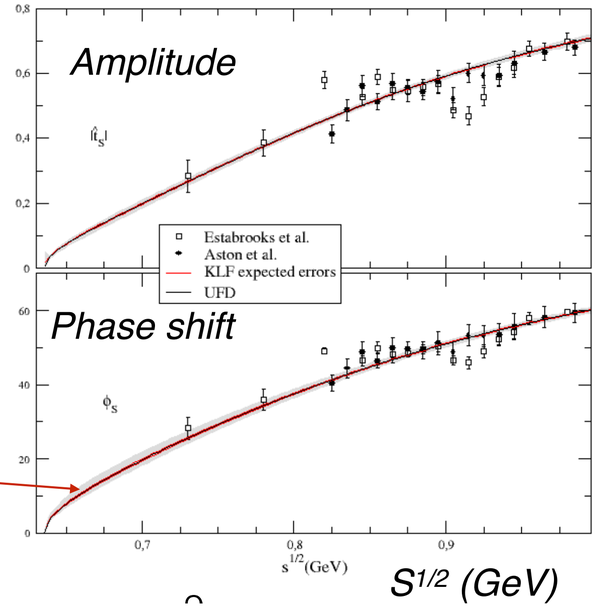
$K^{\pm}p \to K^{\pm}\pi^{-}\Delta^{++}$

Estabrooks(1978)

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

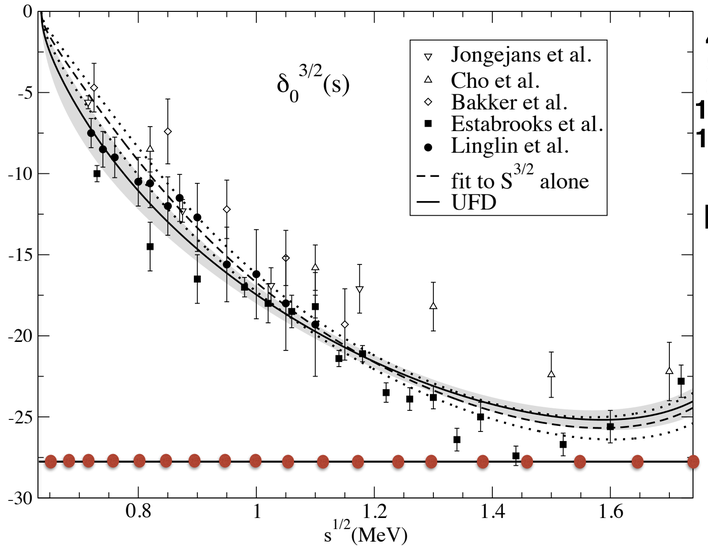
Aston(1988)

KLF (100 days)



$S^{1/2}$ (GeV)

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)

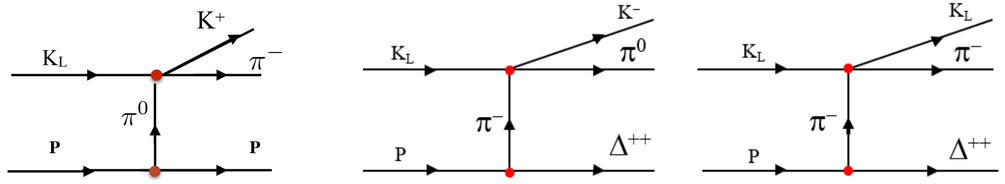
$K^{\pm}p \to K^{\pm}\pi^{+}n$

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

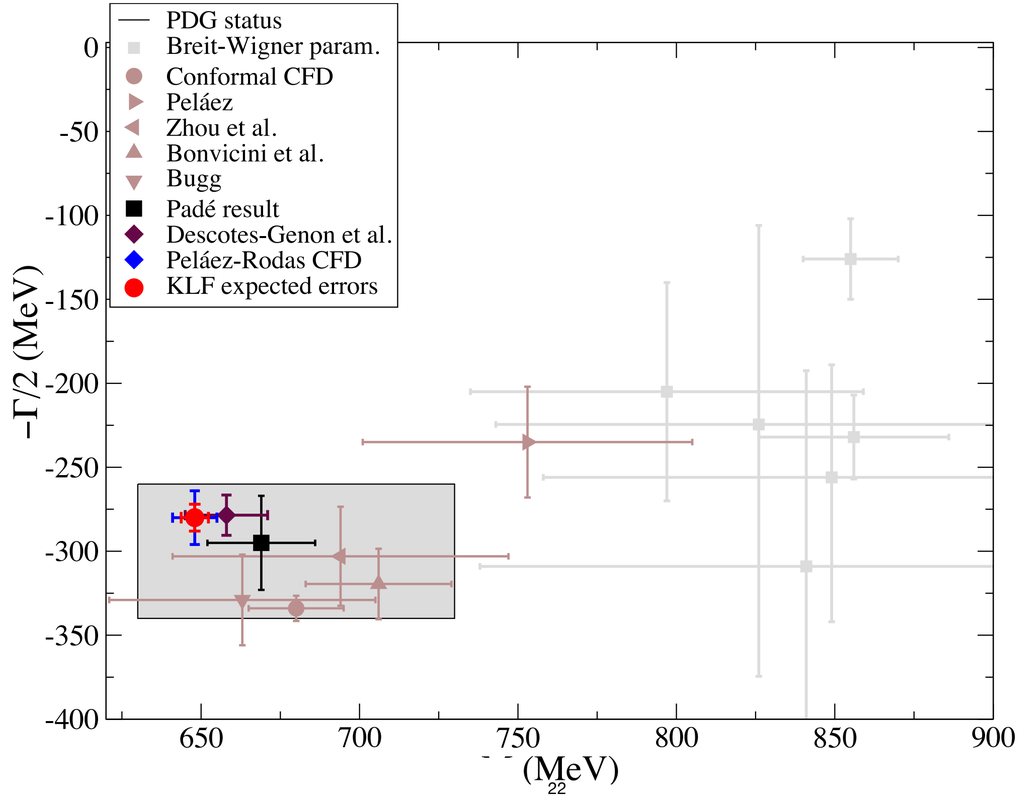
KLF 100 days

From Pelaez and Rodas paper: PRD93(2016)

$K\pi$ Scattering

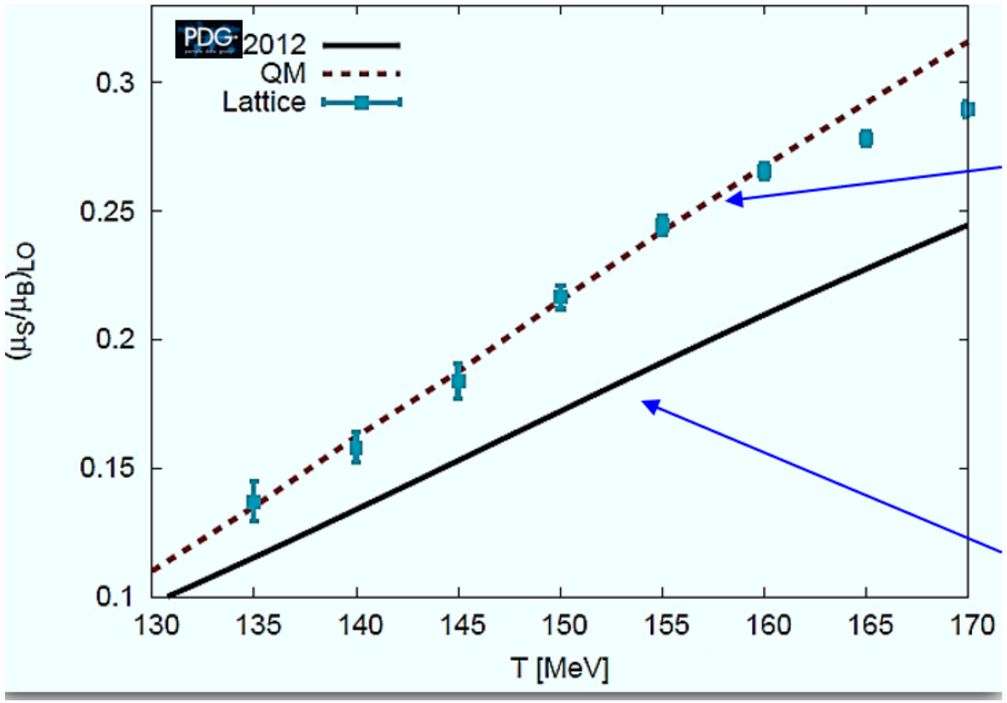


$$\frac{1}{3}(T^{1/2} - T^{3/2}) \qquad \frac{1}{3}(T^{1/2} - T^{3/2}) \qquad \frac{1}{3}(T^{1/2} + T^{3/2})$$



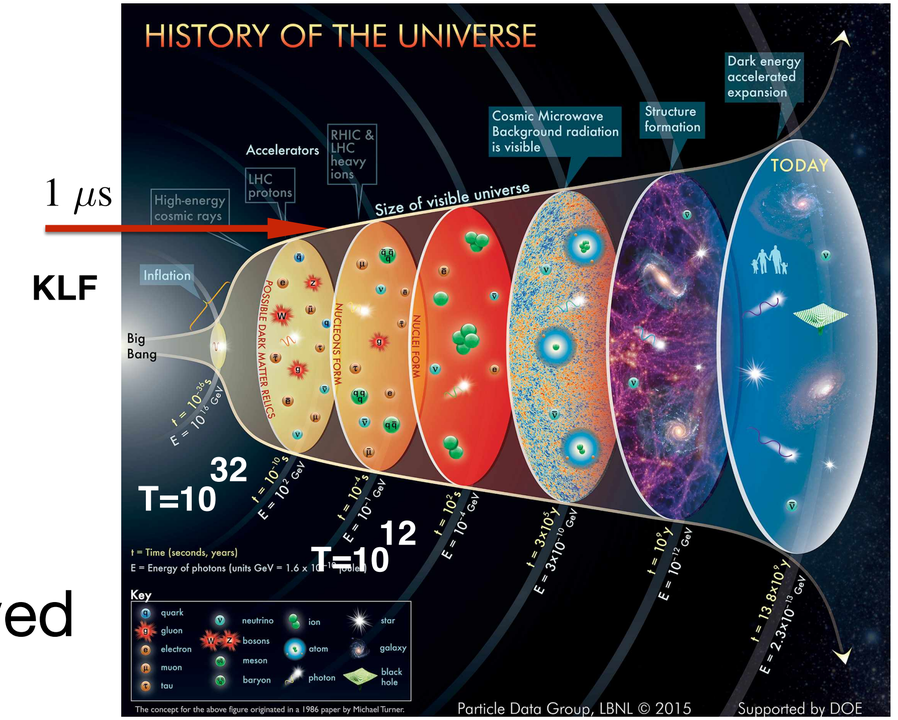
J. Pelaez and A. Rodas, Phys.Rept. 969 (2022)

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



QM

Observed



$1\ \mu s$

KLF

37

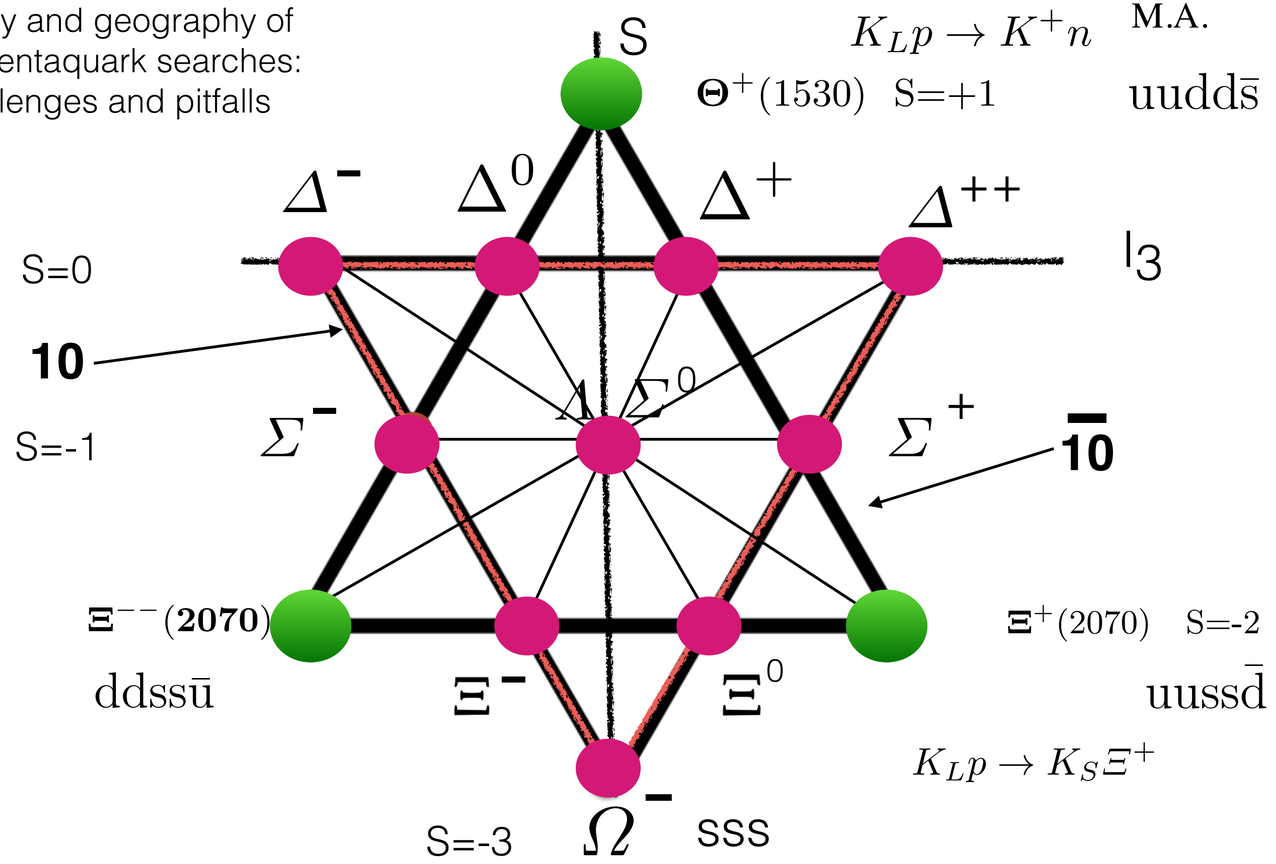
arXiv:1701.07346

Workshop YSTAR2016 Mini-Proceedings

Pentaquarks

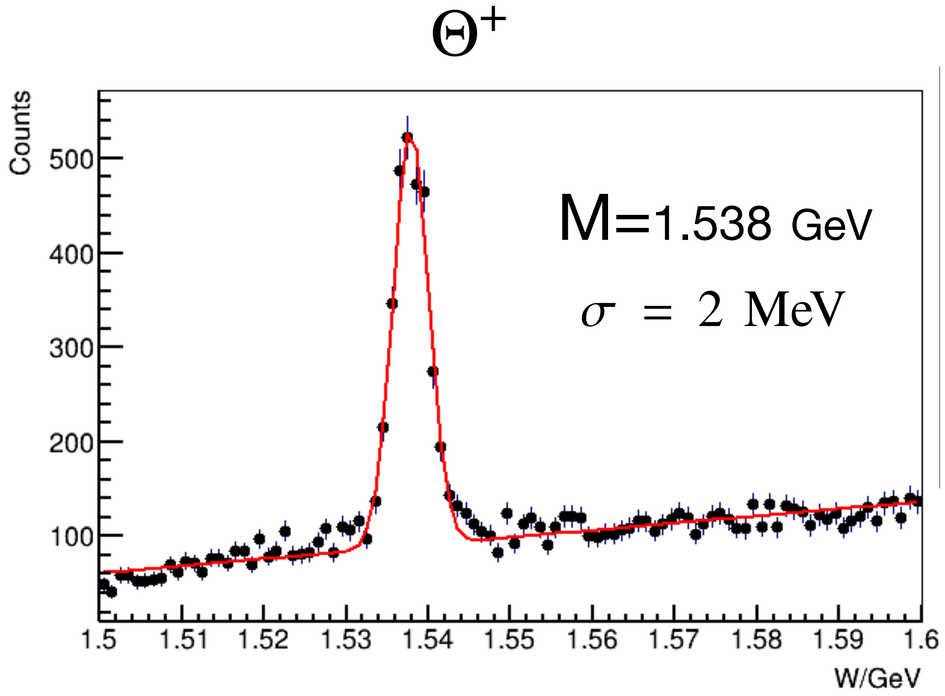
Eur. Phys. J. Plus (2022) 137:684, M.Amaryan History and geography of light pentaquark searches: challenges and pitfalls

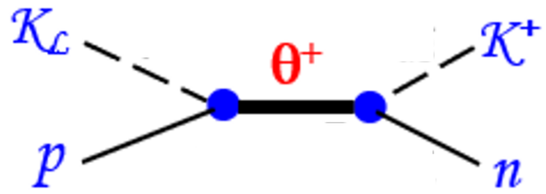
Modern Physics Letters A (2024) 2450063 D.Jido, S.Hirama, I.Strakovsky, M.A.



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

Exotic Pentaquark Simulation





The figure from Geant4 simulation is for 55 days of running.

In 100 days we expect ~4000 events in the peak with

S/B= 5/1. Simulation is done for natural width of 0.5 MeV.

Summary

- For the first time in the history of Particle Physics intensive beam of neutral K_L will be used for the strange hadron spectroscopy.
- In hyperon spectroscopy all excited states of Σ^*'s and Λ^*'s will be measured in the formation reactions.
- The Ξ^*'s will be measured either as a decay product of Σ^*'s in the formation reactions or via direct production mechanisms.
- The Ω^* hyperons will be measured in the production reactions.

- In the strange meson sector it will allow to measure the mass and the width of so-called κ scalar mesons as well as of higher K^* states with unprecedented accuracy.

- The proposed measurements will shed a light on thermodynamic properties of the Early Universe 1 μs after the Big Bang.

- In addition to regular 3-quark states, it will also provide an unprecedented measurement of pentaquark states.

- The proposed experiment is crucial to answer the question of either existence or non-exiatence of Θ^+ pentaquark.

Currently KLF Collaboration consists of 43 experimental groups with 145 members.

Everyone is welcome to join!

Thank you!