Summary of Workshop

Physics with Neutral Kaon Beam at

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Moskov Amaryan

Old Dominion University

The GLUEX Collaboration Meeting

February 20, 2016, JLAB

A Letter of Intent to Jefferson Lab PAC-43.

Physics Opportunities with a Secondary K_L^0 Beam at JLab.

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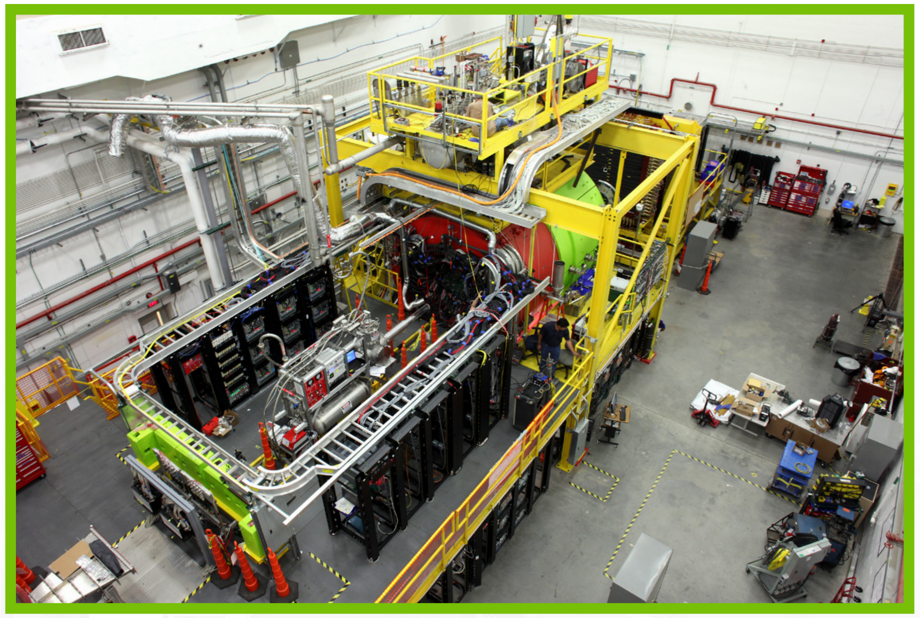
(Dated: May 15, 2015)

PHYSICS WITH NEUTRAL KAON BEAM AT JLAB

KL2016

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



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

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OLD DOMINION UNIVERSITY
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PHYSICS WITH NEUTRAL KAON BEAM AT JLAB

KL2016

Albrow
Chudakov
Amaryan
Ohnishi
Filippi
Manley
Noumi
Nakayama
Goity
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Myhrer
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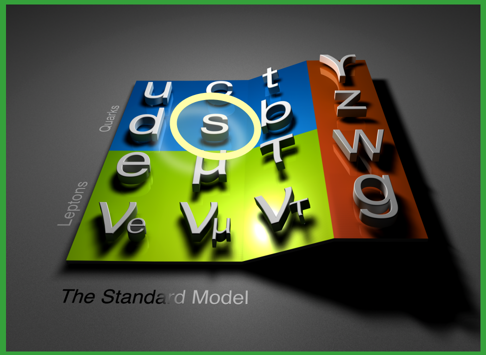


Kohl

Outline

Physics with KL beam

- a)-importance
- b)-uniqueness
- c)-competitiveness
- d)-necessity

Feasibility and beamline

- a)-radiation source
- b)-KL production target
- c)-GLUEX target

GLUEX Detector Response

- a)-simulation
- b)-reconstruction of final states
- c)-Momentum and W Resolution

Polarized Target at GLUEX

Conclusions

Mark Manley

- PWA Formalism
- KN and $\overline{K}N$ Final States (see also talk by A.Filippi)
- $\pi\Lambda$ Final States
- $\pi\Sigma$ Final States
- $K\Xi$ Final States

Mean lifetime of the K^- is 12.38 ns ($c\tau = 3.7$ m) whereas mean lifetime of the K_L^0 is 51.16 ns ($c\tau = 15.3$ m). Thus, it is much easier to perform measurements of K_L^0p scattering at low beam energies than K^-p scattering due to higher beam flux.

$d\sigma/d\Omega$ Data for $K_L^0 p \to K_S^0 p$

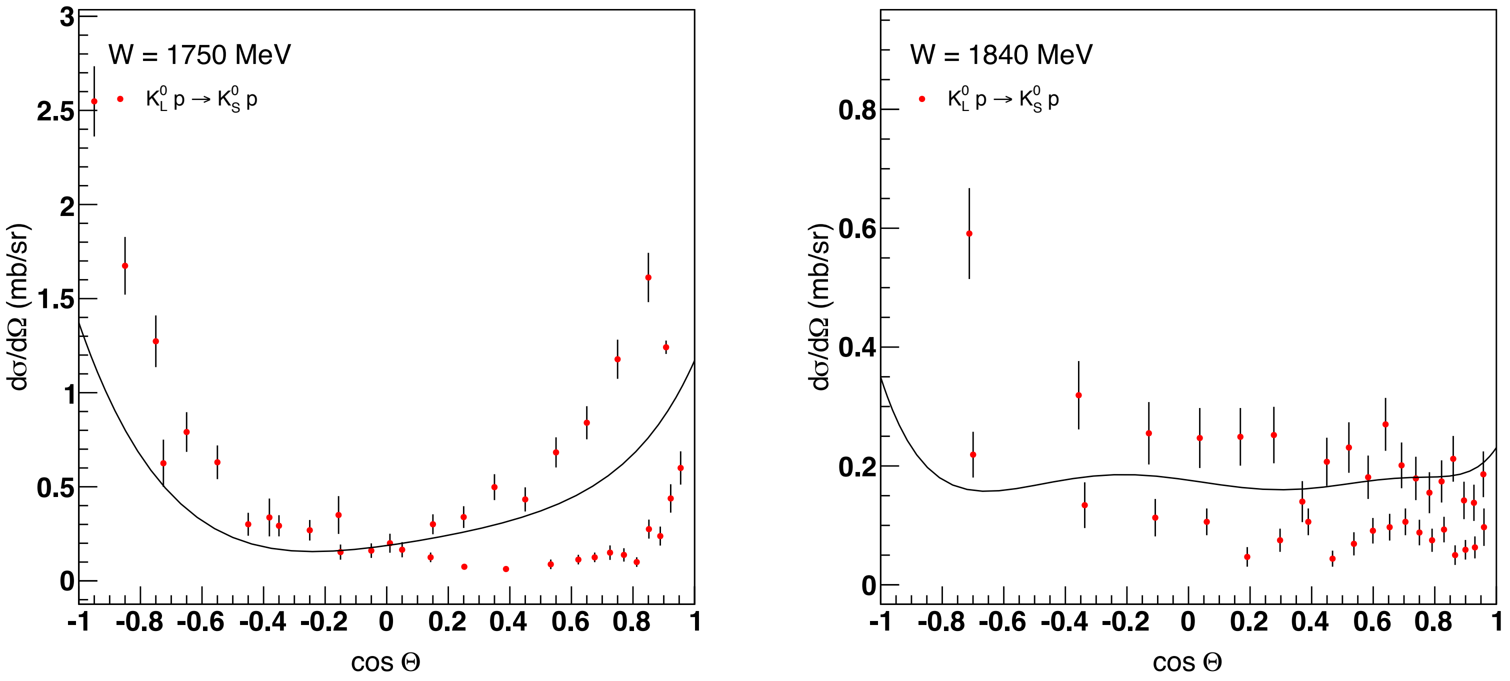


Figure: Selected data for $K_L^0 p \to K_S^0 p$ at 1750 MeV and 1840 MeV. The curves are predictions using amplitudes from our previous PWA of $\overline{K}N \to \overline{K}N$ combined with $KN \to KN$ amplitudes from SAID solution.

Low-energy $d\sigma/d\Omega$ Data for $K_L^0 p \to \pi^+\Lambda$

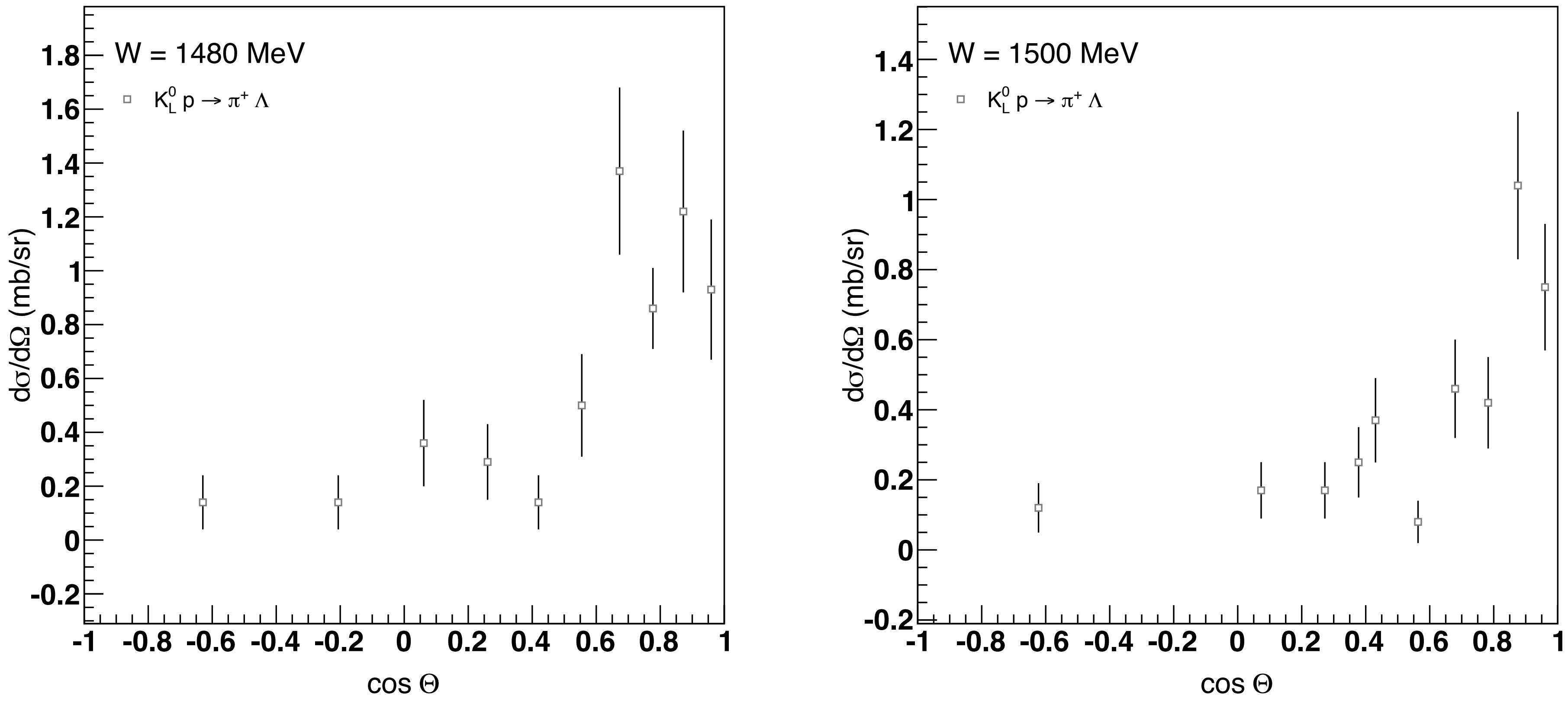


Figure: Data for $K_L^0 p \to \pi^+\Lambda$ at 1480 MeV and 1500 MeV. No data for $K^- p \to \pi^0\Lambda$ are available below 1540 MeV.

$d\sigma/d\Omega$ Data for $K^- p \to \pi^0 \Lambda$ and $K^0_L p \to \pi^+ \Lambda$

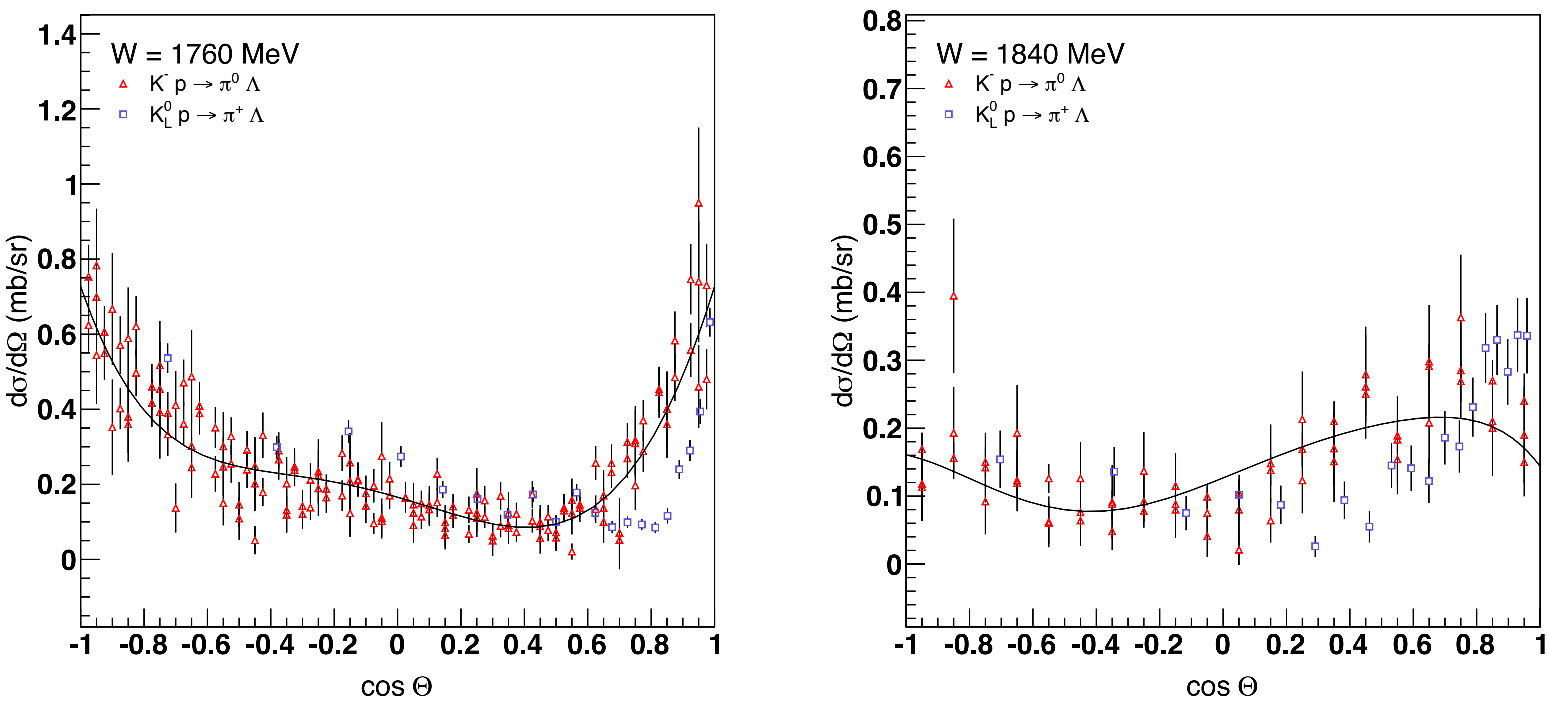


Figure: Comparison of selected $d\sigma/d\Omega$ data for $K^- p \to \pi^0 \Lambda$ (red) and $K^0_L p \to \pi^+ \Lambda$ (blue) at 1760 MeV and 1840 MeV. The curves are from our previous PWA of $K^- p \to \pi^0 \Lambda$ data.

Polarization Data for $K^-p \to \pi^0\Lambda$ and $K_L^0 p \to \pi^+\Lambda$

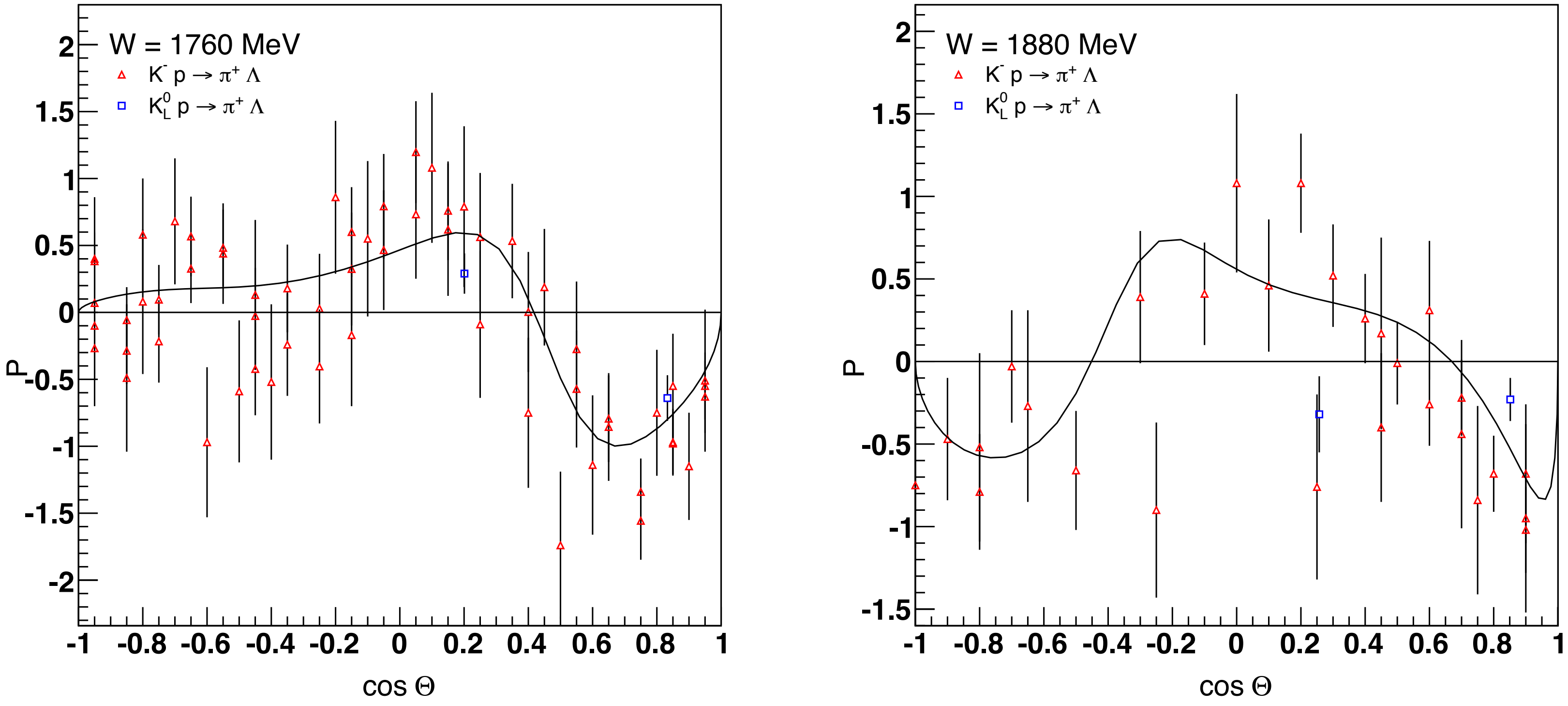


Figure: Comparison of selected polarization data for $K^-p \to \pi^0\Lambda$ (red) and $K_L^0 p \to \pi^+\Lambda$ (blue) at 1760 MeV and 1880 MeV. The curves are from our previous PWA of $K^-p \to \pi^0\Lambda$ data.

Data for $K_L^0 p \to \pi^0\Sigma^+$ and $K_L^0 p \to \pi^+\Sigma^0$

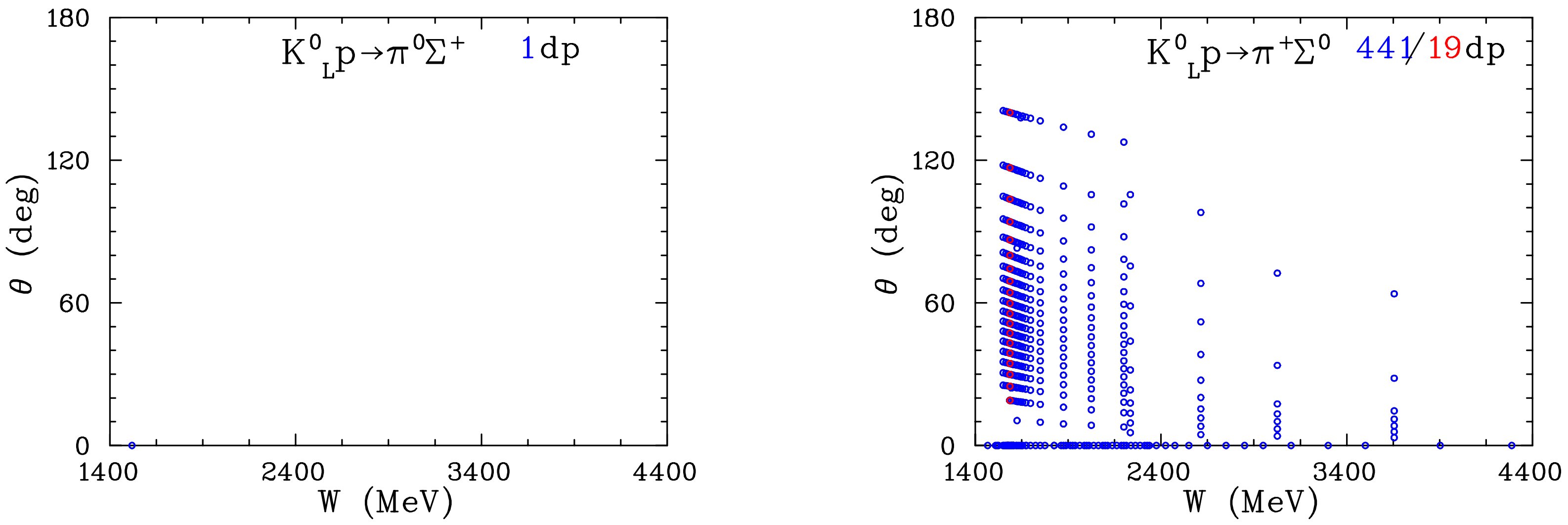


Figure: Distribution of measured data for $K_L^0 p \to \pi^0\Sigma^+$ and $K_L^0 p \to \pi^+\Sigma^0$. $d\sigma/d\Omega$ data are shown as blue open circles and polarization data are shown as red open circles. σ data are shown on the $\theta = 0$ line.

- Reactions $K_L^0 p \to \pi^+\Sigma^0$ and $K_L^0 p \to \pi^0\Sigma^+$ are isospin selective (only $I = 1$ amplitudes are involved) whereas reactions $K^- p \to \pi^-\Sigma^+$ and $K^- p \to \pi^+\Sigma^-$ are not. New measurements with a K_L^0 beam would lead to better understanding of Σ^* states and help constrain amplitudes for $K^- p \to \pi\Sigma$ reactions
- No $d\sigma/d\Omega$ data are available for $K_L^0 p \to \pi^0\Sigma^+$

$K\Xi$ Final States

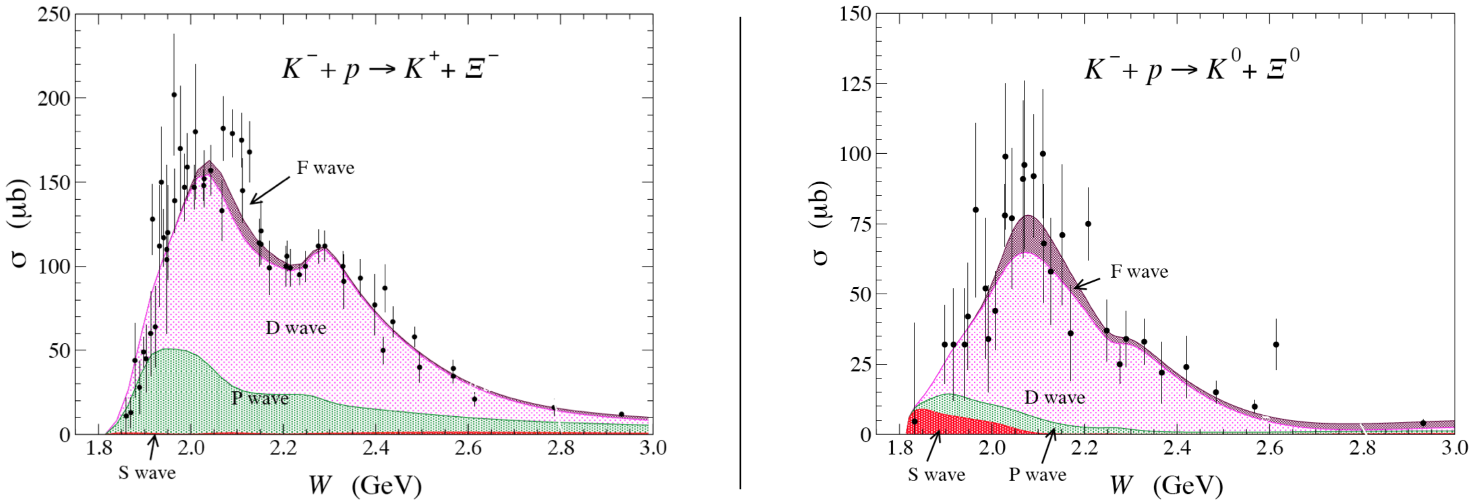
$$
\begin{aligned}
T(K^- p \to K^0 \Xi^0) &= \frac{1}{2} T^1(\overline{K}N \to K\Xi) + \frac{1}{2} T^0(\overline{K}N \to K\Xi) \\
T(K^- p \to K^+ \Xi^-) &= \frac{1}{2} T^1(\overline{K}N \to K\Xi) - \frac{1}{2} T^0(\overline{K}N \to K\Xi) \\
T(K^0_L p \to K^+ \Xi^0) &= -\frac{1}{\sqrt{2}} T^1(\overline{K}N \to K\Xi)
\end{aligned}
$$

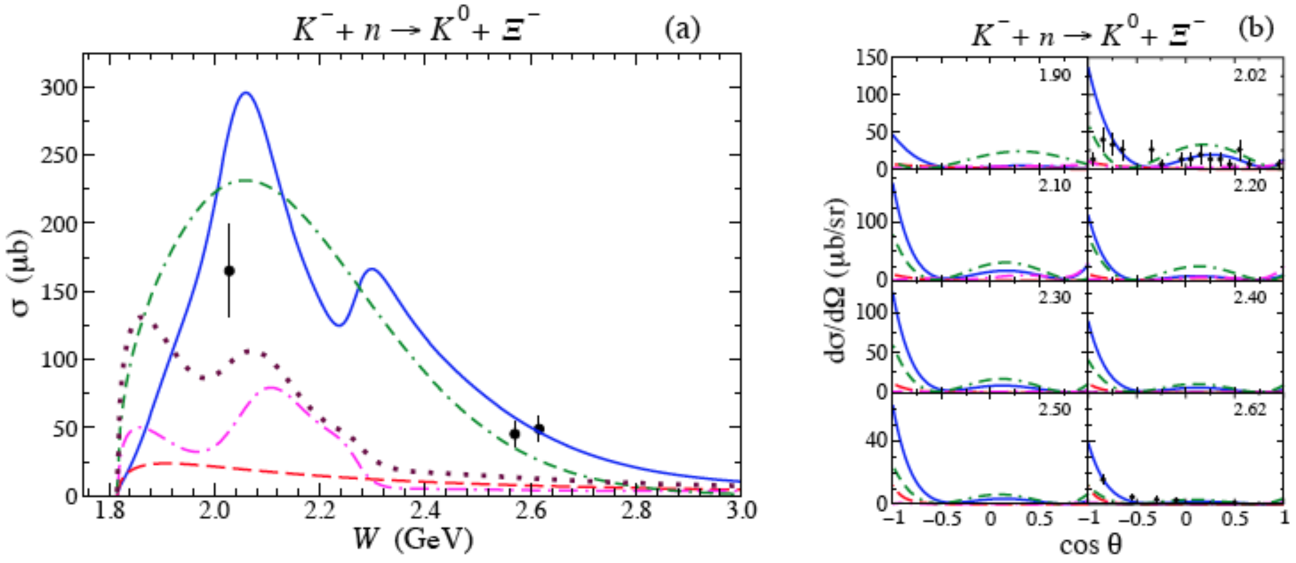
Discussion

- Threshold for $K^- p$ and $K^0_L p$ reactions leading to $K\Xi$ final states is fairly high ($W_{\text{thresh}} = 1816$ MeV)
- There are no $d\sigma/d\Omega$ data available for $K^0_L p \to K^+ \Xi^0$ and very few (none recent) for $K^- p \to K^0 \Xi^0$ or $K^- p \to K^+ \Xi^-$
- Measurements for these reactions would be very helpful, especially for comparing with predictions from dynamical coupled-channel (DCC) models
- $K^0_L p \to K^+ \Xi^0$ is isospin-1 selective, whereas the reactions $K^- p \to K^0 \Xi^0$ and $K^- p \to K^+ \Xi^-$ involve both $I = 0$ and $I = 1$ amplitudes
- The *Review of Particle Physics* lists only two states with branching fractions (BF) to $K\Xi$, namely, $\Lambda(2100)\frac{7}{2}^-$ (BF < 3%) and $\Sigma(2030)\frac{7}{2}^+$ (BF < 2%)

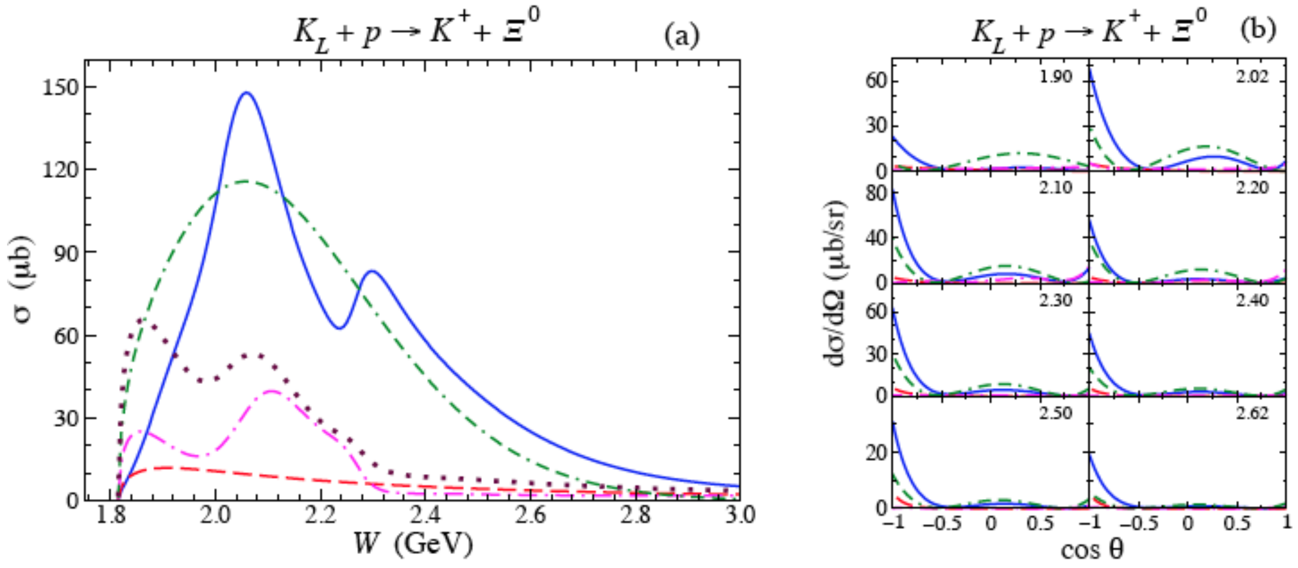
$\bar{K}N \rightarrow K\Xi(1320)$: *model results*

[Jackson, Oh, Haberzettl, K.N., PRC91(2015)065208]





Kanzo Nakayama



Some key questions

Jose Goity

- Missing hyperon states: complete SU(3) multiplets require (ignoring isospin)

$$\begin{array}{rr} & PDG \\ \#\Sigma = \#\Xi = \#N + \#\Delta & 26; 12; 49 \\ \#\Omega = \#\Delta & 4; 22 \\ \#\Lambda = \#N + \#\text{singlets} & 18; 29 \end{array}$$

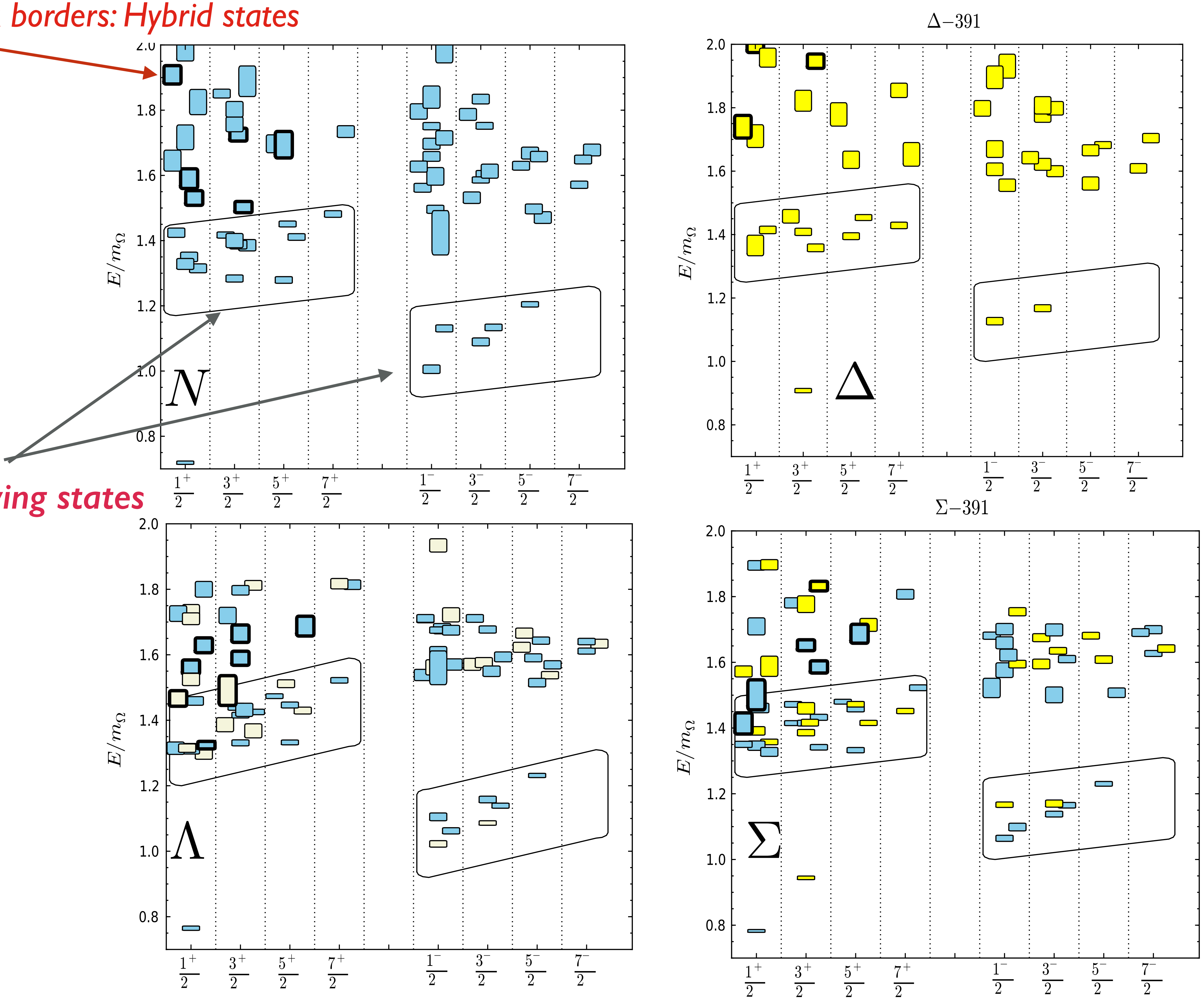
- Should all observed hyperons belong into SU(3) multiplets?: dynamically generated states may not
- Should baryons filling SU(3) multiplets also fill SU(6) multiplets?: probably yes
- Do we have sufficient inputs and theoretical tools to make some predictions: yes!

Comments

- K_L beam opens renewed opportunities to research hyperon physics at JLab.
- Predictions grounded on symmetries can be made once a sufficient number of states in a given multiplet can be identified. Numerous are already available.
- Interesting puzzles exist for PDG listed excited hyperons which do not fit into any of the low lying excited multiplets: they need to be further revisited and investigated.
- Excited Ξs are very poorly known. Establishing and discovering new states is important for establishing the multiplet structure of excited baryons in particular.

Lattice QCD calculations

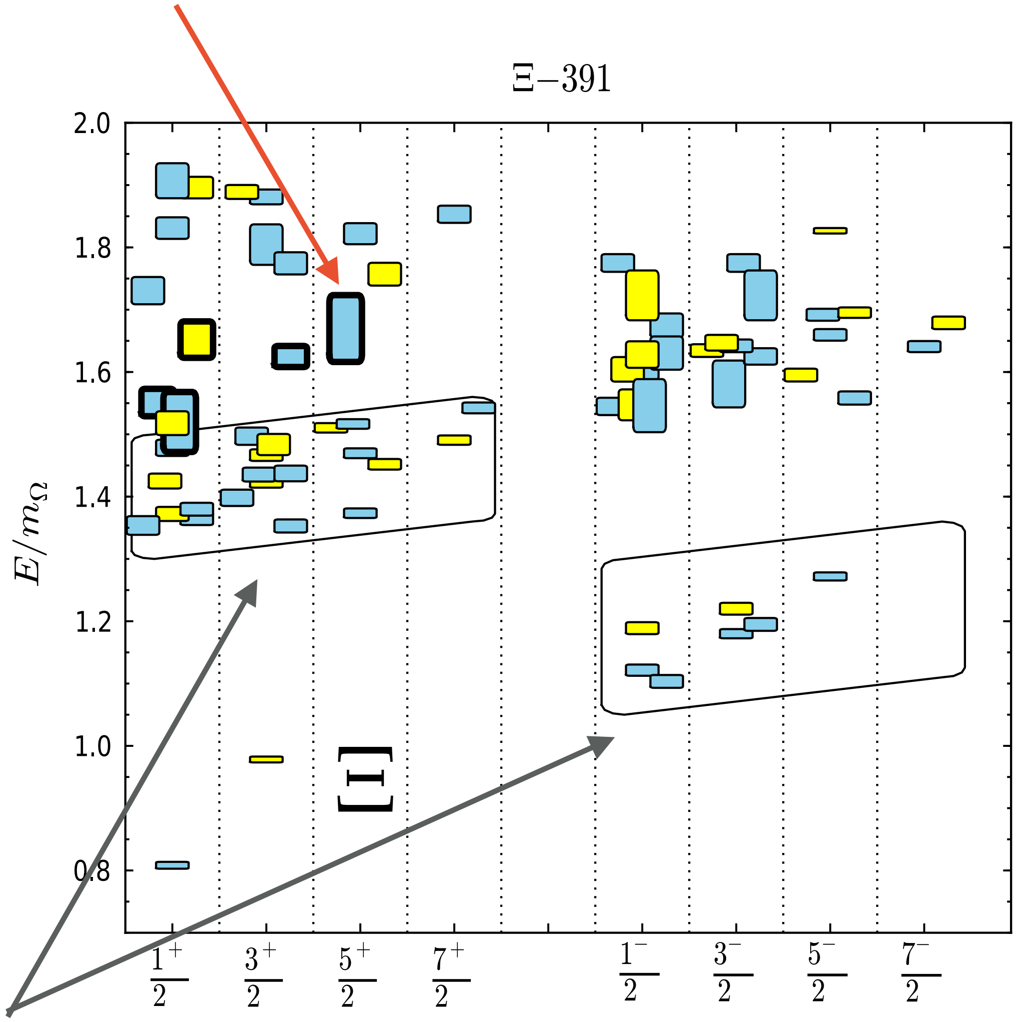
Thick borders: Hybrid states

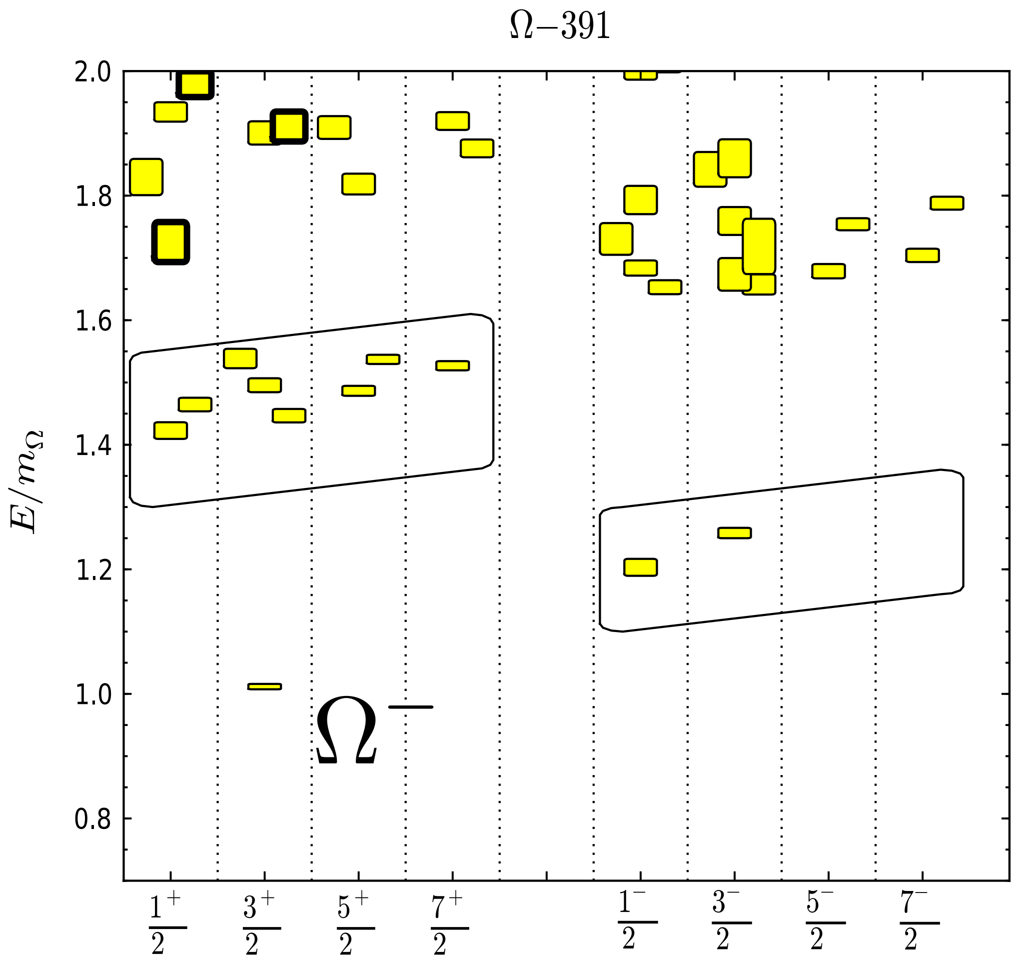


Low Lying states

Lattice QCD calculations

Thick borders: Hybrid states



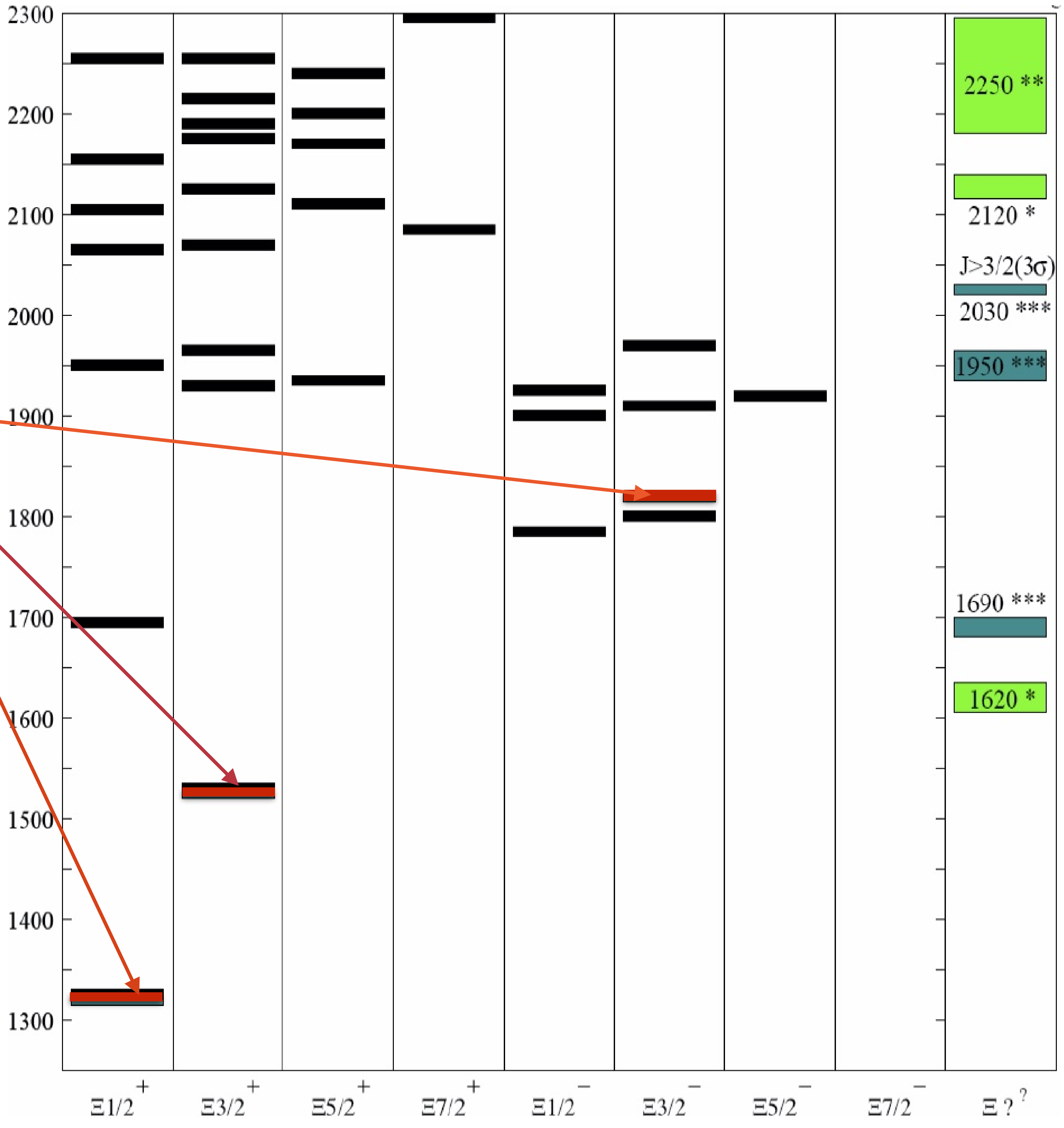


Low Lying states

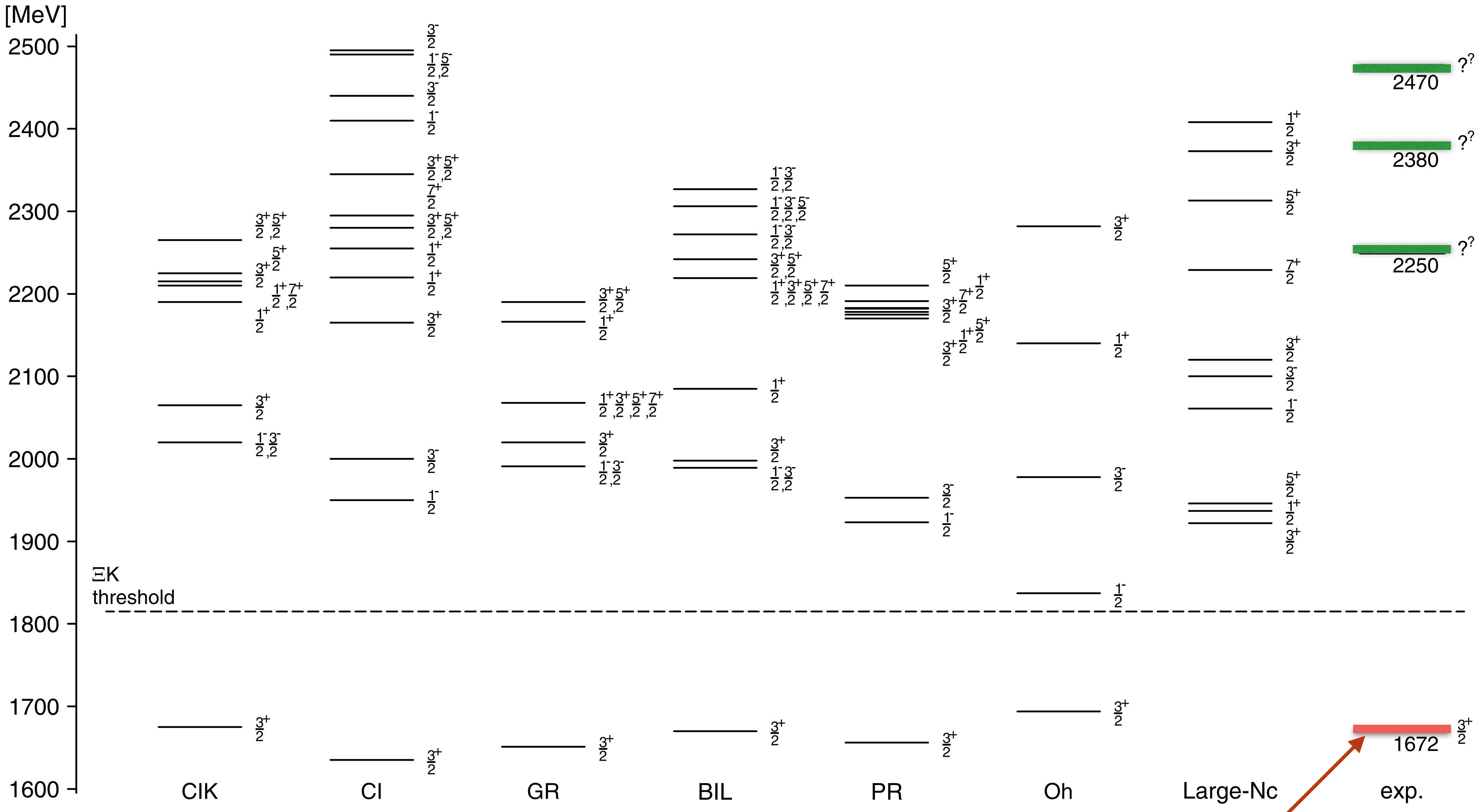
Edwards, Mathur, Richards and Wallace
Phys. Rev. D 87, 054506 (2013)

Status of Ξ^*

well known



Status of Ω^{-*}



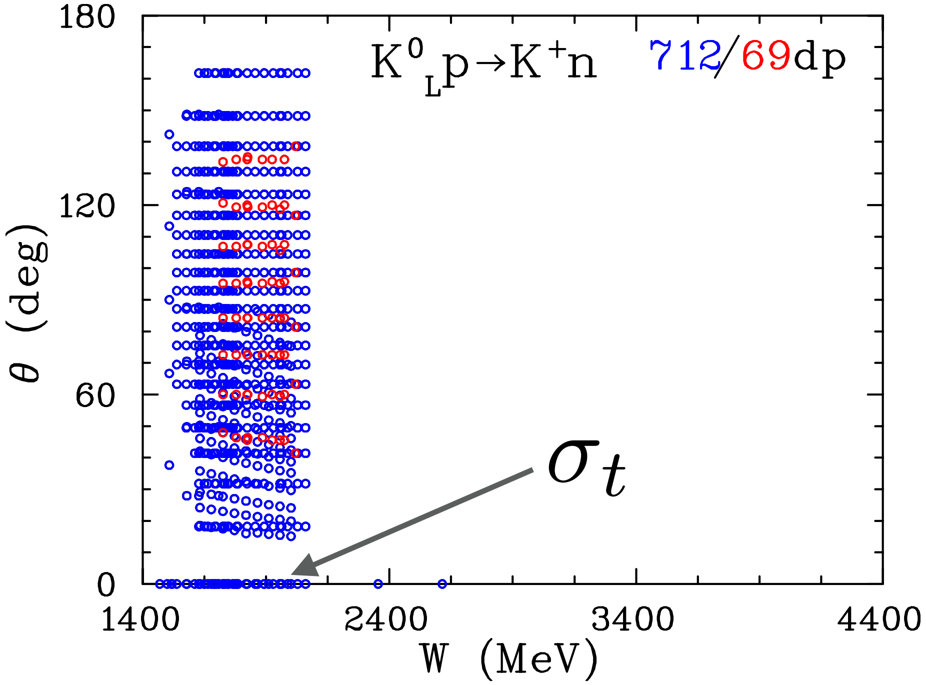
only one well known state?

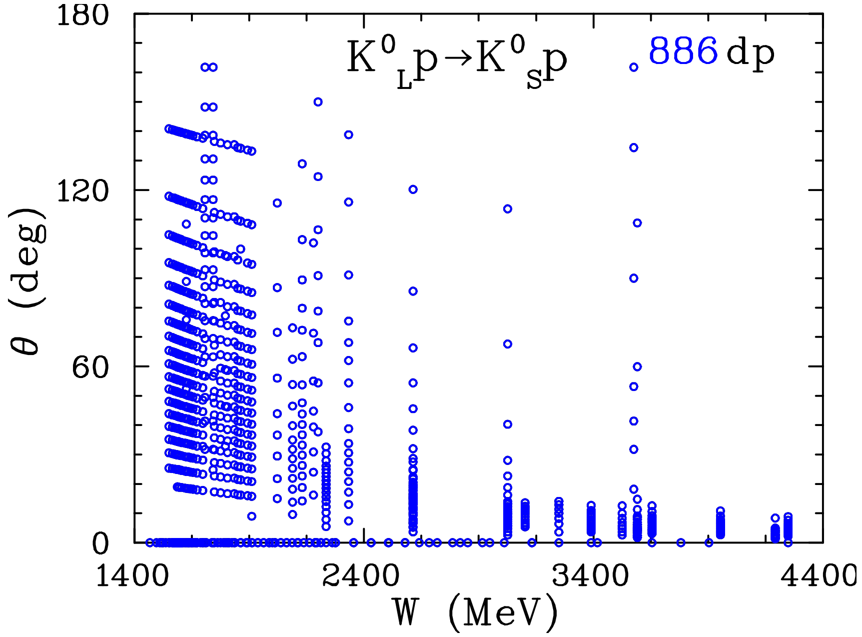
Very Limited World Data with K_L beam

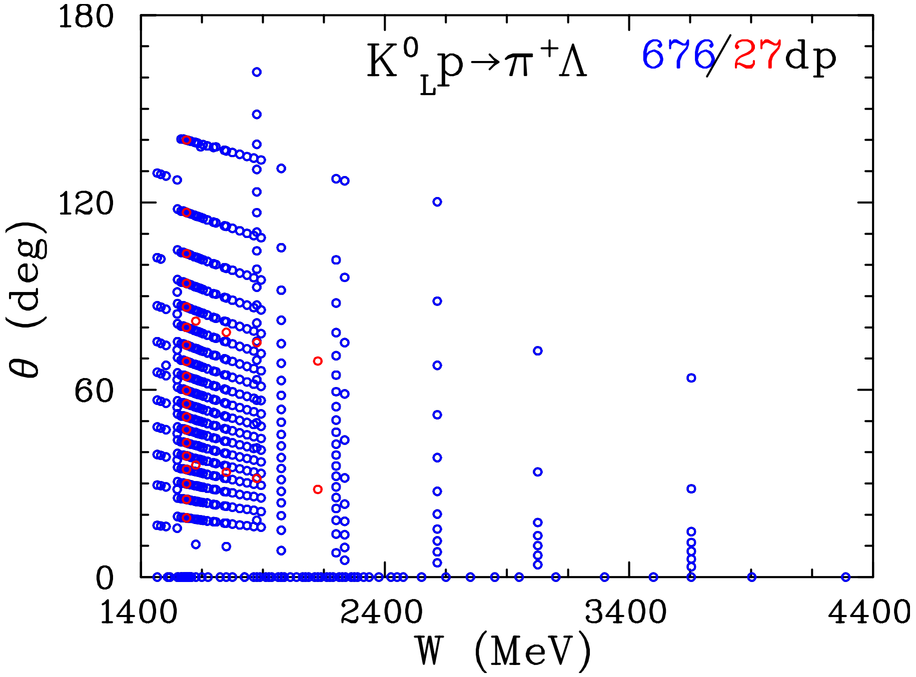
(*mainly low stat. bubble chamber data* compilation by I. Strakovsky)

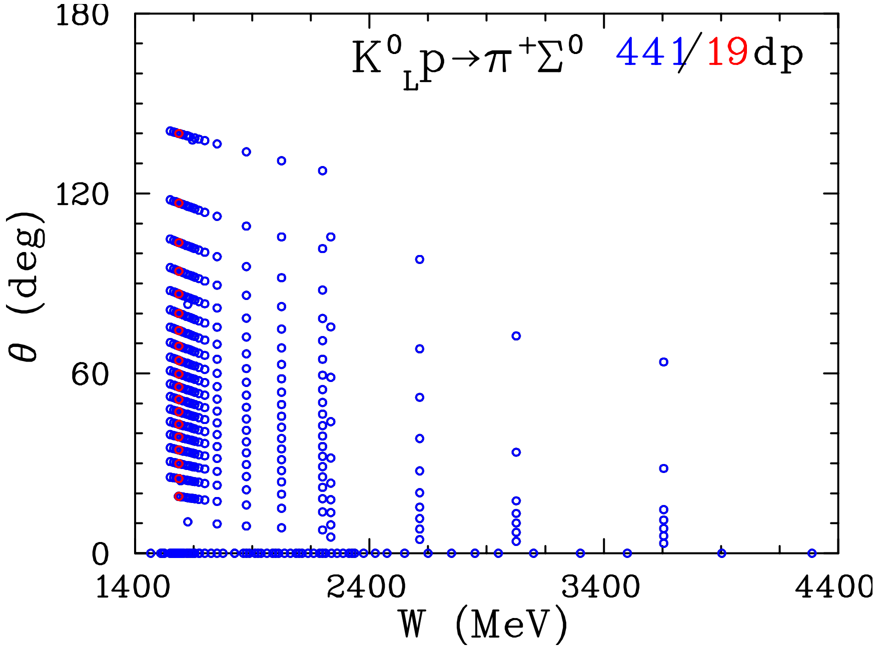
blue points: $d\sigma/d\Omega$

red points: Polarization







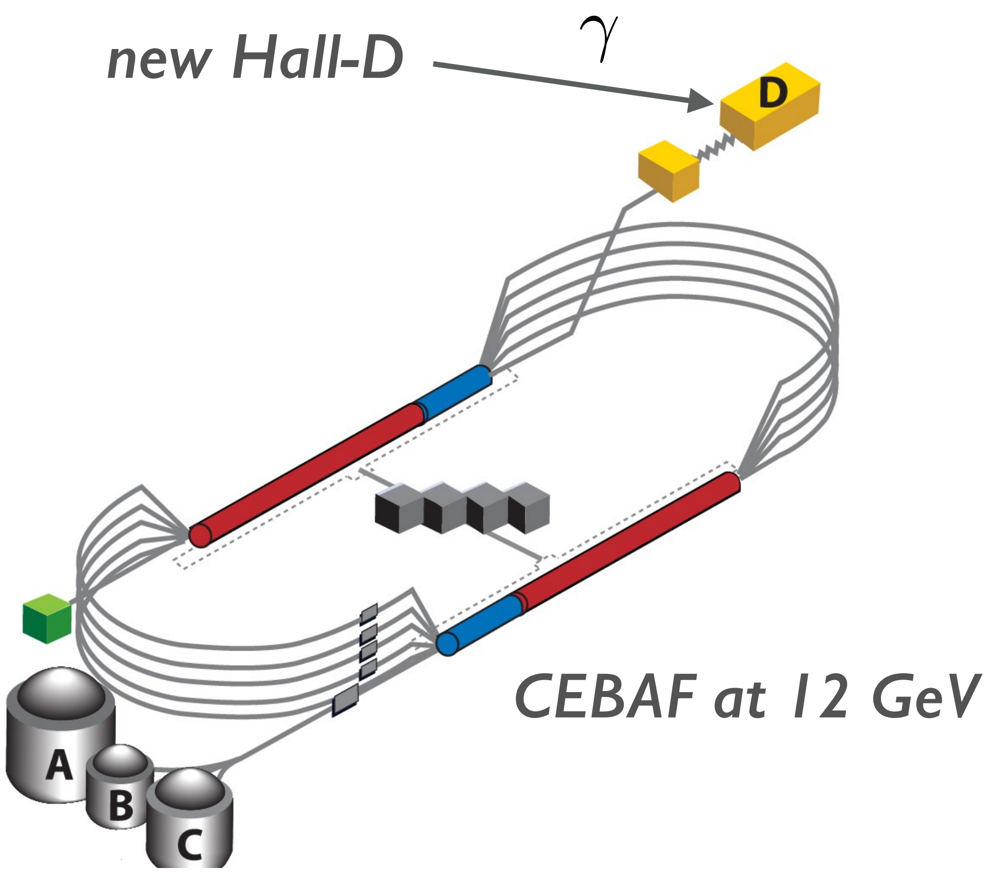


we are not aware of any data on Neutron target

How to make a kaon beam?

Thomas Jefferson National Accelerator Facility

Aerial View



Compact Photon Source Conceptual Design for K^0_L Production at Hall D

Pavel Degtiarenko, Bogdan Wojtsekhowski
Jefferson Lab

February, 2016

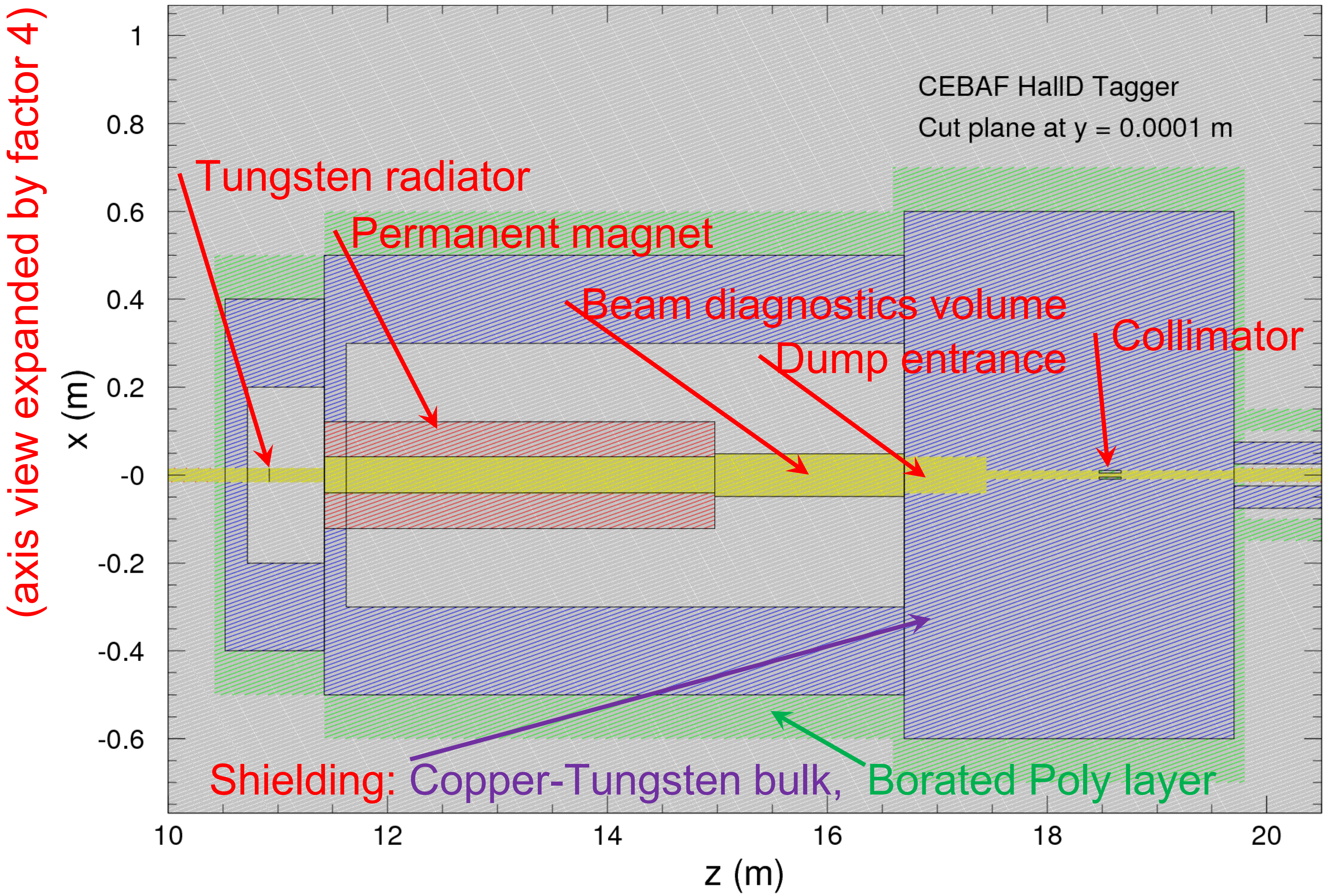
“Brute Force” Approach Problematic

- Radiation environment at the Tagger Area measured recently was reasonably close to original calculations
- Simply increasing radiator thickness would make the expected dose rates and activation unacceptable
- Mitigation would include removal of sensitive electronic components, building new temporary shielding walls, disposal of beam line components
- Dose rate and activation evaluation would require complex simulations, quality and reliability control
- Possible, but costly and lots of headaches for all
- Max radiator R.L. may still be below K^0_L beam needs
- We suggest the “Compact Gamma Source” approach

Compact Photon Source Concept

- Strong magnet after radiator deflects exiting electrons
- Long-bore collimator lets photon beam through
- Electron beam dump placed next to the collimator
- Water-cooled Copper core for better heat dissipation
- Hermetic shielding all around and close to the source
- High Z and high density material for bulk shielding
- Borated Poly outer layer for slowing, thermalizing, and absorbing fast neutrons still exiting the bulk shielding
- No need in tagging photons, so the design could be compact, as opposed to the Tagger Magnet concept

CPS, horizontal plane (1)



(axis view expanded by factor 4)

Tungsten radiator

Permanent magnet

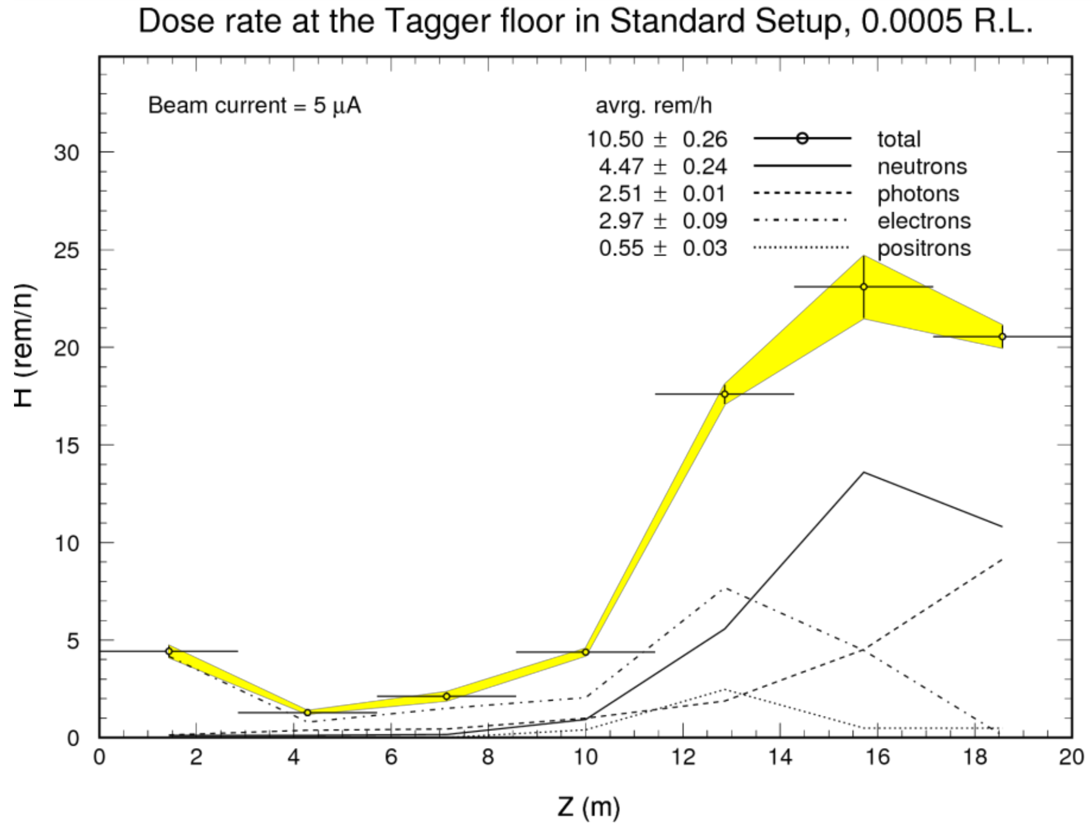
Beam diagnostics volume

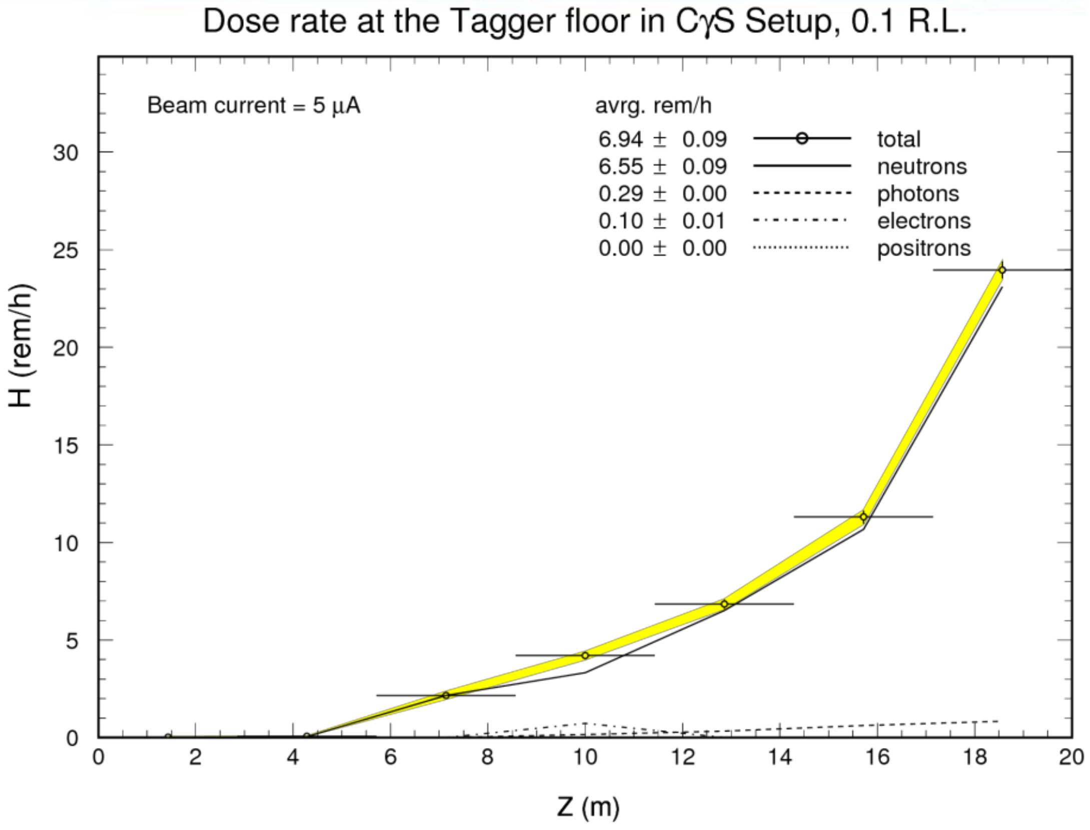
Dump entrance

Collimator

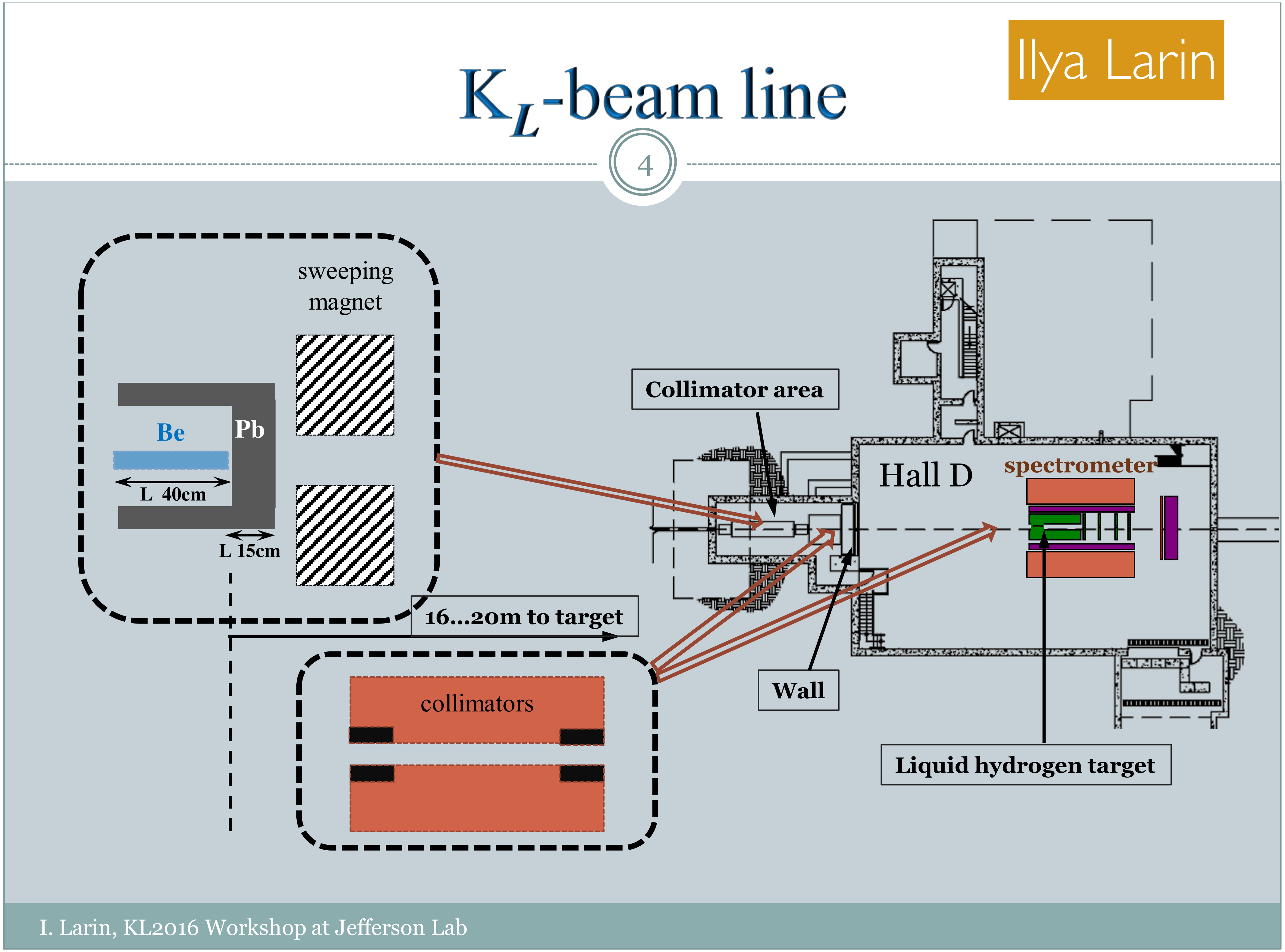
Shielding: Copper-Tungsten bulk, Borated Poly layer

Dose Rate Evaluation and Comparison


Dose rate at the Tagger floor in Standard Setup, 0.0005 R.L.


Dose rate at the Tagger floor in CγS Setup, 0.1 R.L.

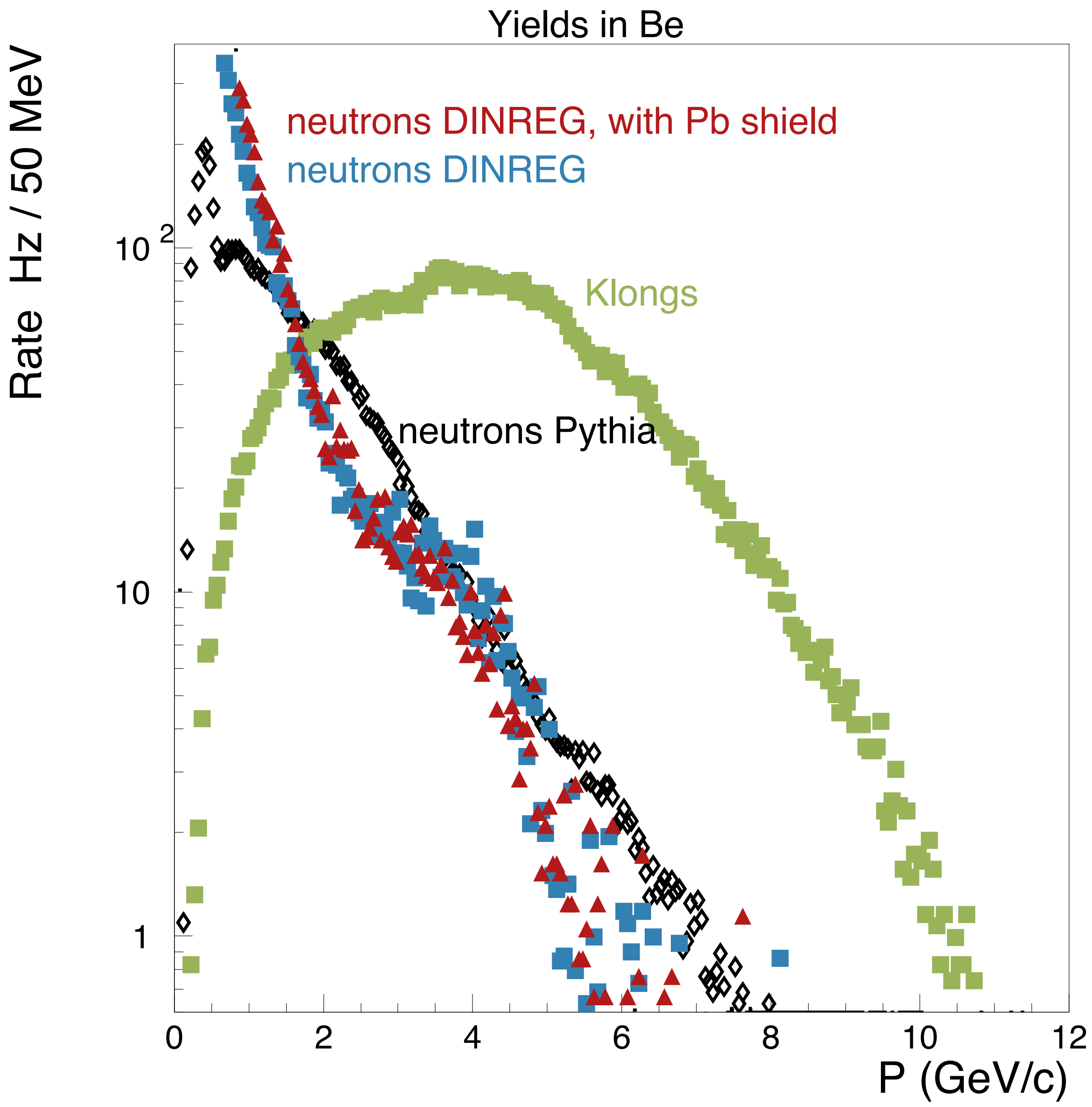
- The dose rates in the Tagger vault for the CPS setup with 10% R.L. radiator are close to Standard XD ops
- The radiation spectral composition is different; most of the contribution in the CPS setup is from higher energy neutrons



Ilya Larin

K_L-beam line

Rate of neutrons and K^0_L on GlueX target

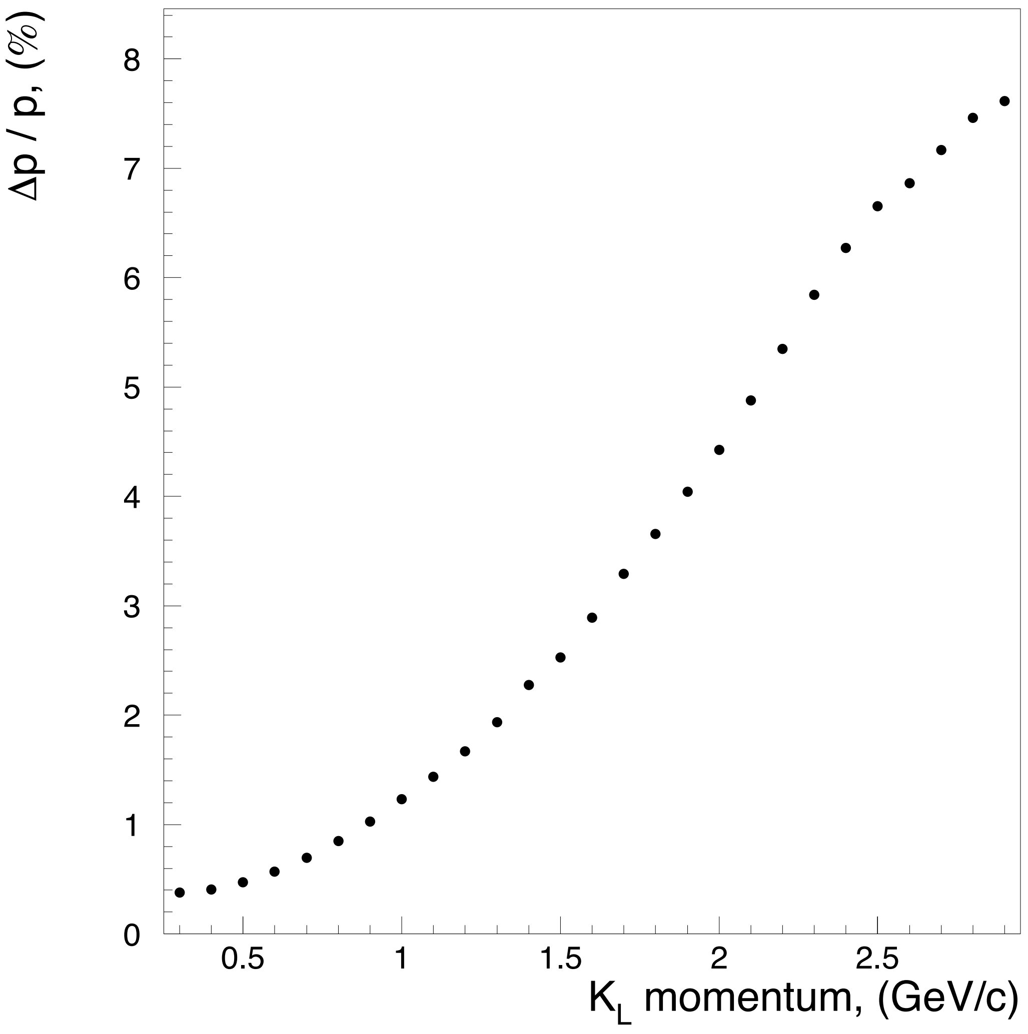


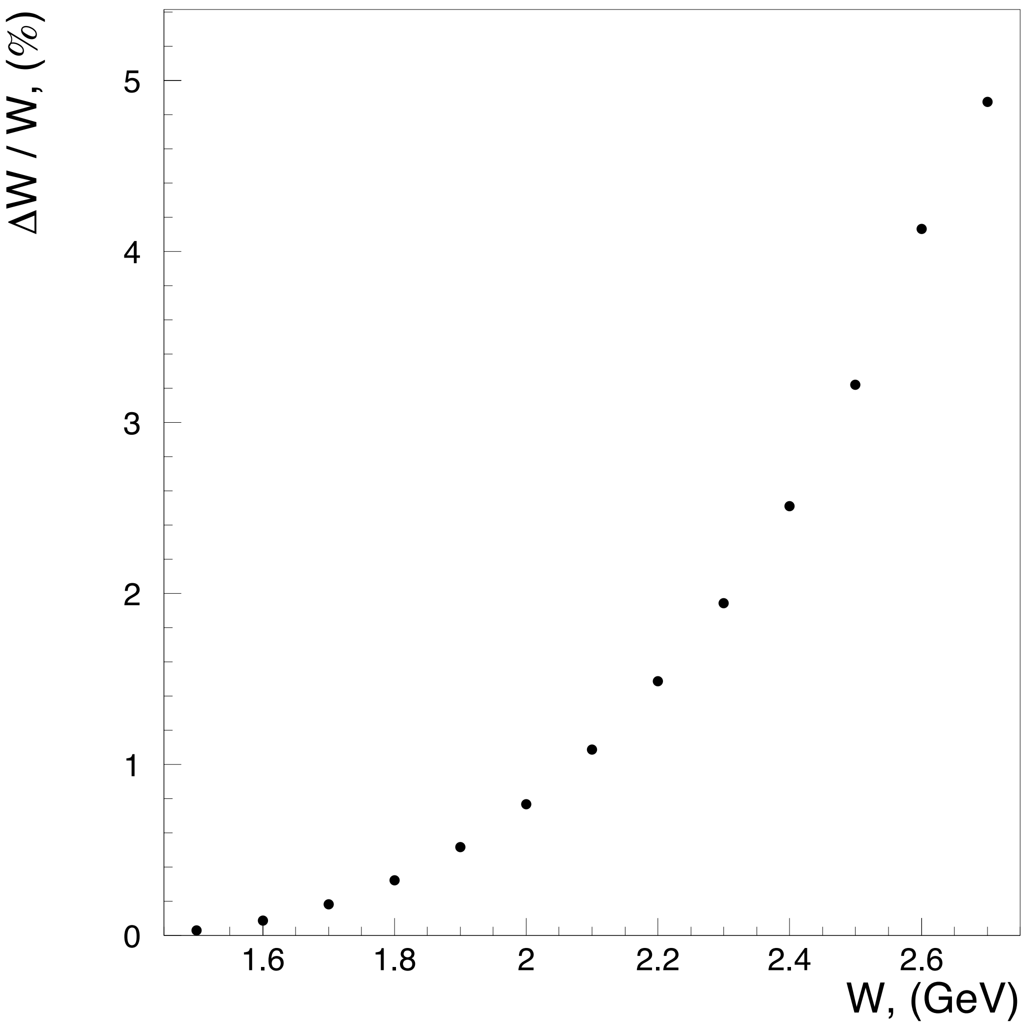
- **With a proton beam ratio $n/K_L = 10^3$-10^4**

K^0_L beam

Electron beam	$E_e = 12GeV; I_e = 5\mu A$	
Radiator (rad. length)	5%	10%
Be target (R=3cm)	$L = 40cm$	$L = 60cm$
LH2 target(L=30cm)	$R = 3cm$	$R = 4cm$
Distance Be-LH2	$24m$	$24m$
K_L Rate/sec	~10^3	~10^4

Momentum and W Resolution





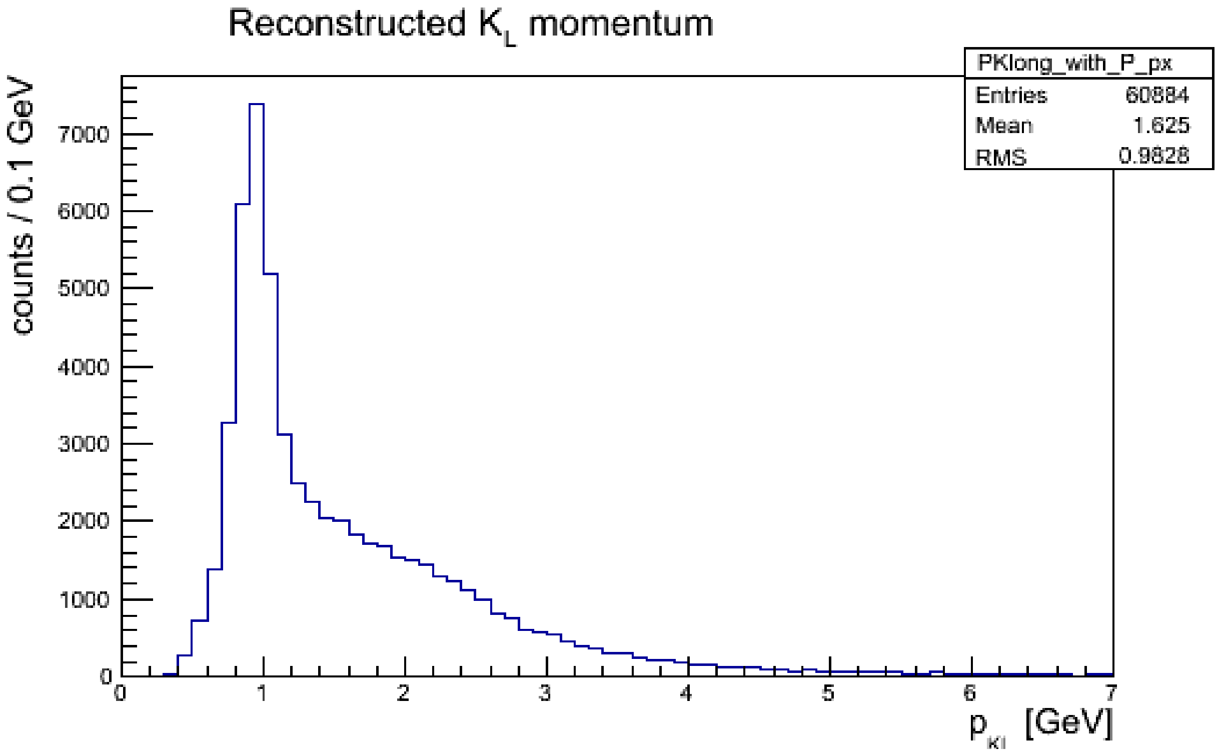
K_L studies with the GlueX detector

Simon Taylor / JLab

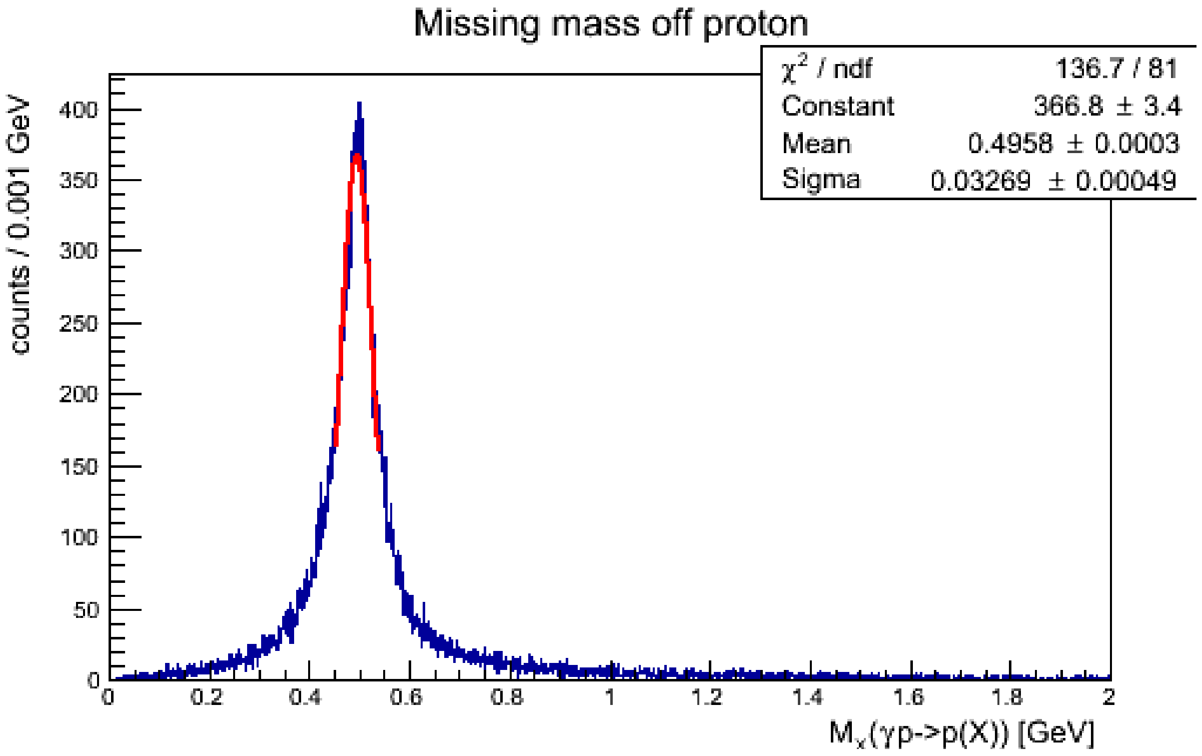
- Event generation
- GlueX detector
- $K_L p \to K_S p$
- $K_L p \to \Lambda \pi^+$
- $K_L p \to K^+ \Xi^0$

Reconstruction of pK_S events

- Generated 100,000 events
  - Allowed GEANT to decay K_S
- Require detection of recoil proton → primary "vertex"
- K_L momentum reconstructed from time-of-flight between proton time at "vertex" and time at Be target
- Particle identification: dE/dx in drift chambers, time-of-flight



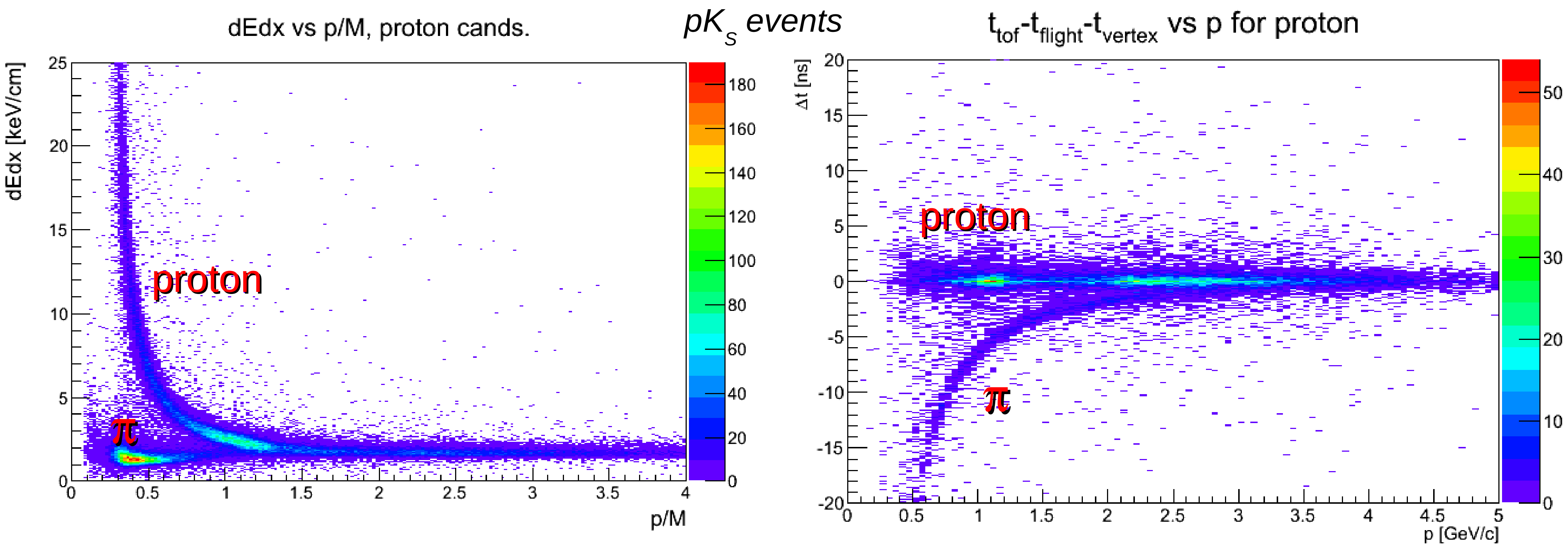
Reconstructed K_L momentum



Missing mass off proton

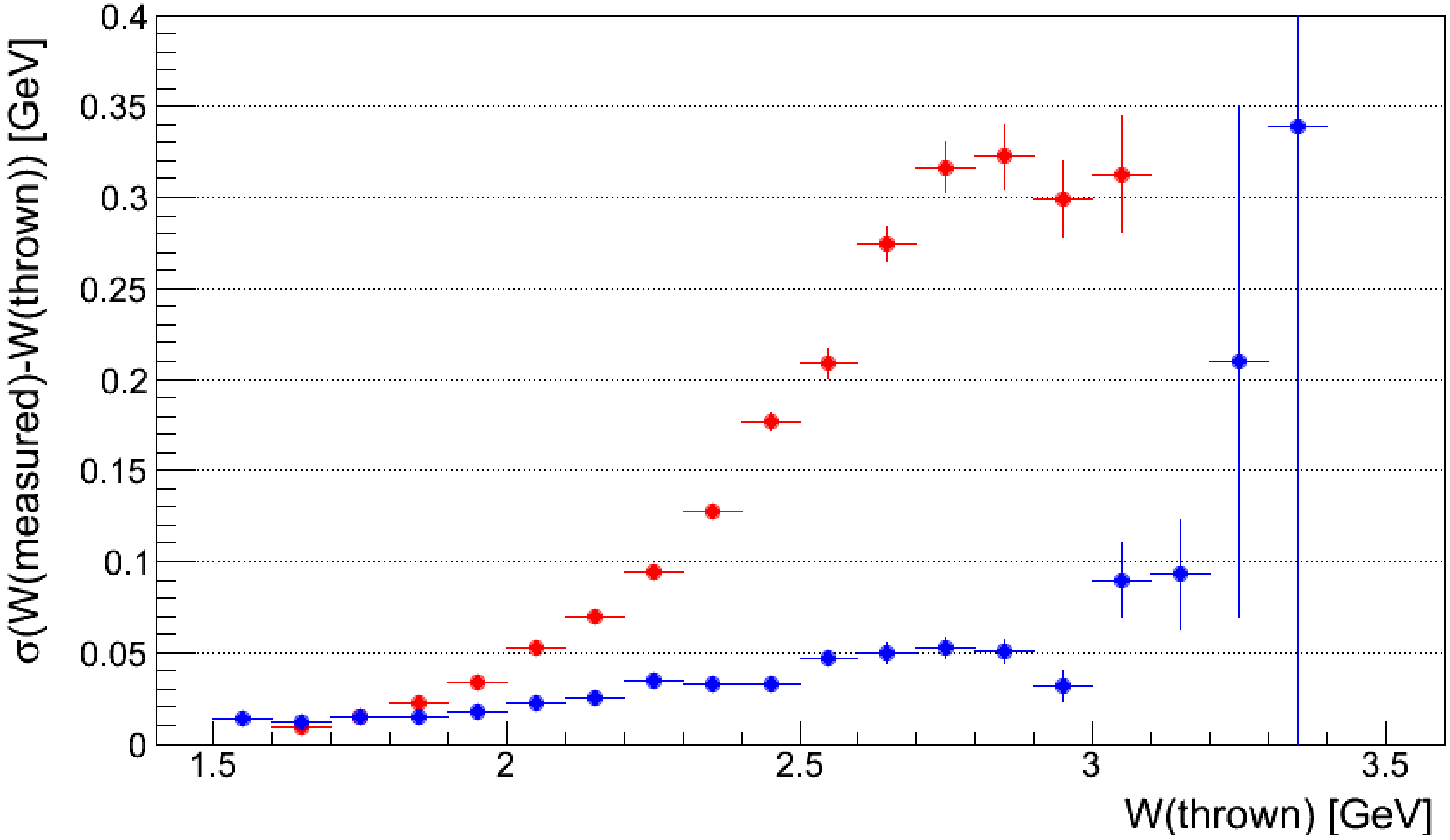
Particle identification

- We can do better if we also reconstruct $K_S \rightarrow \pi^+\pi^-$, at the expense of statistics...



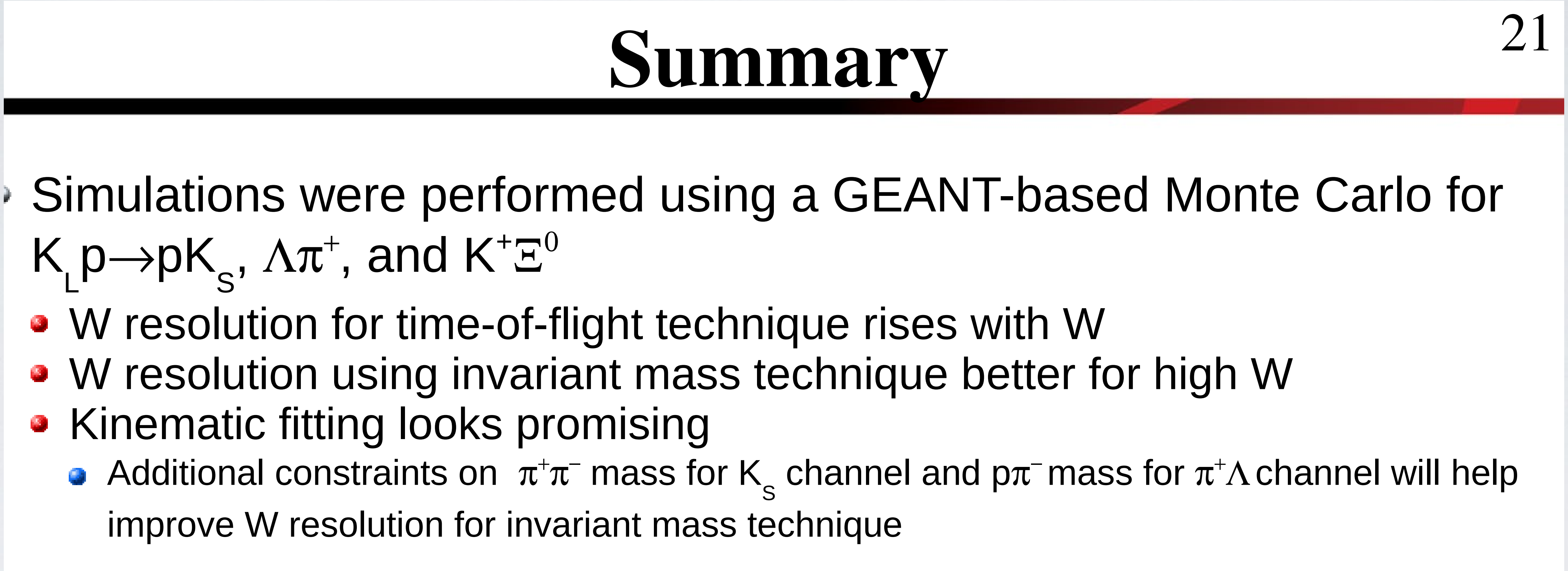
- Each track fitted using several mass hypotheses: $\{p, K^+, \pi^+\}$ for +, $\{K^-, \pi^-\}$ for -
- Measure dE/dx, compute Δt at vertex for each hypothesis → convert to probability

W resolution



Invariant mass technique

K momentum (time-of-flight) technique



Summary

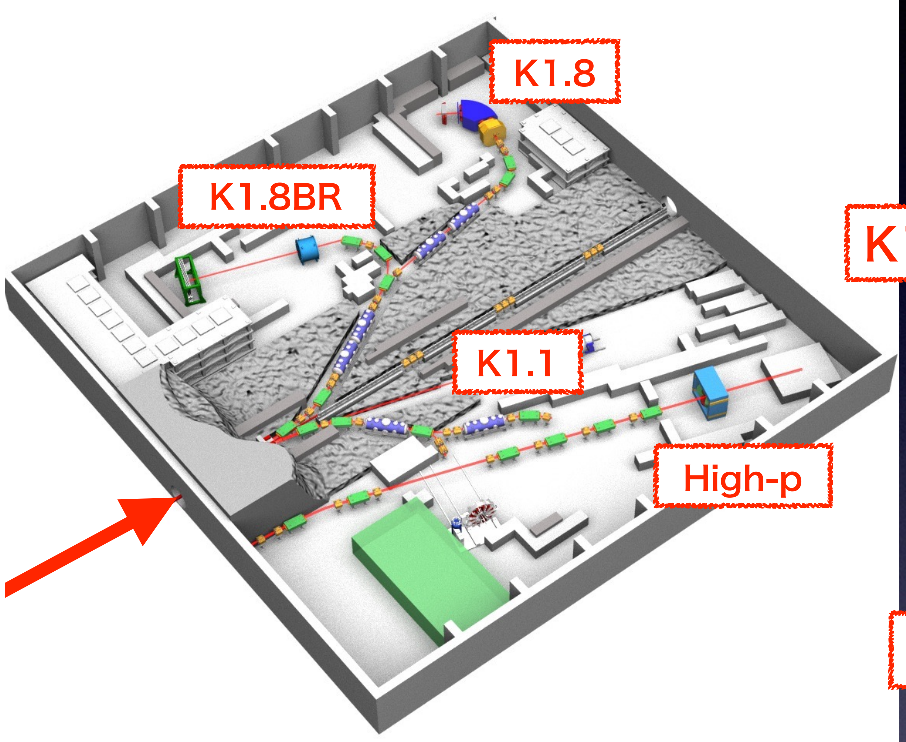
- Simulations were performed using a GEANT-based Monte Carlo for $K_L p \rightarrow p K_S$, $\Lambda\pi^+$, and $K^+\Xi^0$
  - W resolution for time-of-flight technique rises with W
  - W resolution using invariant mass technique better for high W
  - Kinematic fitting looks promising
    - Additional constraints on $\pi^+\pi^-$ mass for K_S channel and $p\pi^-$ mass for $\pi^+\Lambda$ channel will help improve W resolution for invariant mass technique

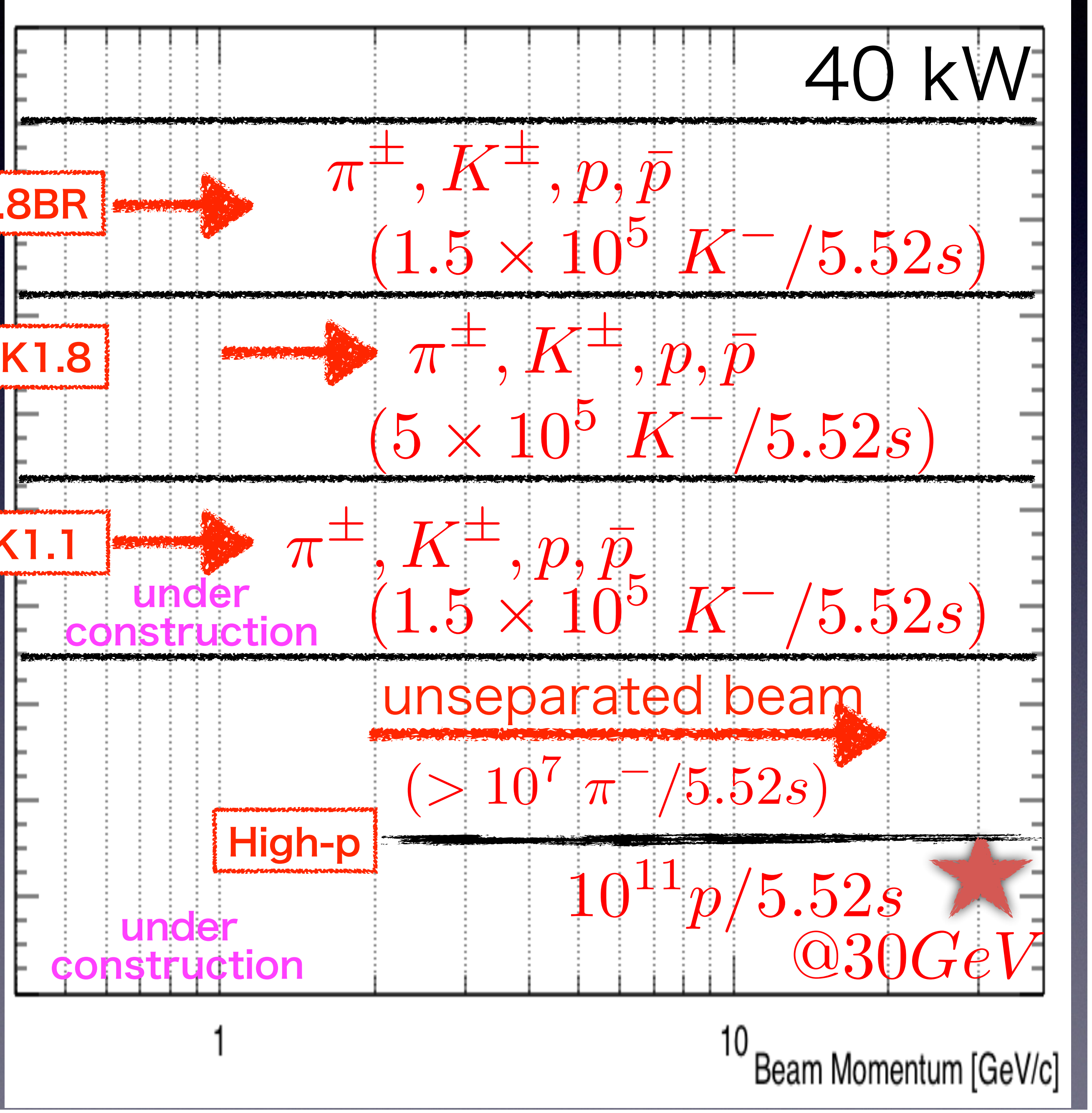
Hadron physics with K- at J-PARC

Hiroaki Ohnishi
RIKEN/RCNP Osaka Univ.

J-PARC

Japan Proton Accelerator Research Complex





K1.8BR → $\pi^{\pm}, K^{\pm}, p, \bar{p}$ $(1.5 \times 10^5\ K^-/5.52s)$

K1.8 → $\pi^{\pm}, K^{\pm}, p, \bar{p}$ $(5 \times 10^5\ K^-/5.52s)$

K1.1 → $\pi^{\pm}, K^{\pm}, p, \bar{p}$ $(1.5 \times 10^5\ K^-/5.52s)$

unseparated beam → $(> 10^7\ \pi^-/5.52s)$

High-p $10^{11} p/5.52s$ @30GeV

Two beam lines are under operation

K1.1 & High-p beam lines are under construction

Chris Keith

Summary: targets for a kaon facility

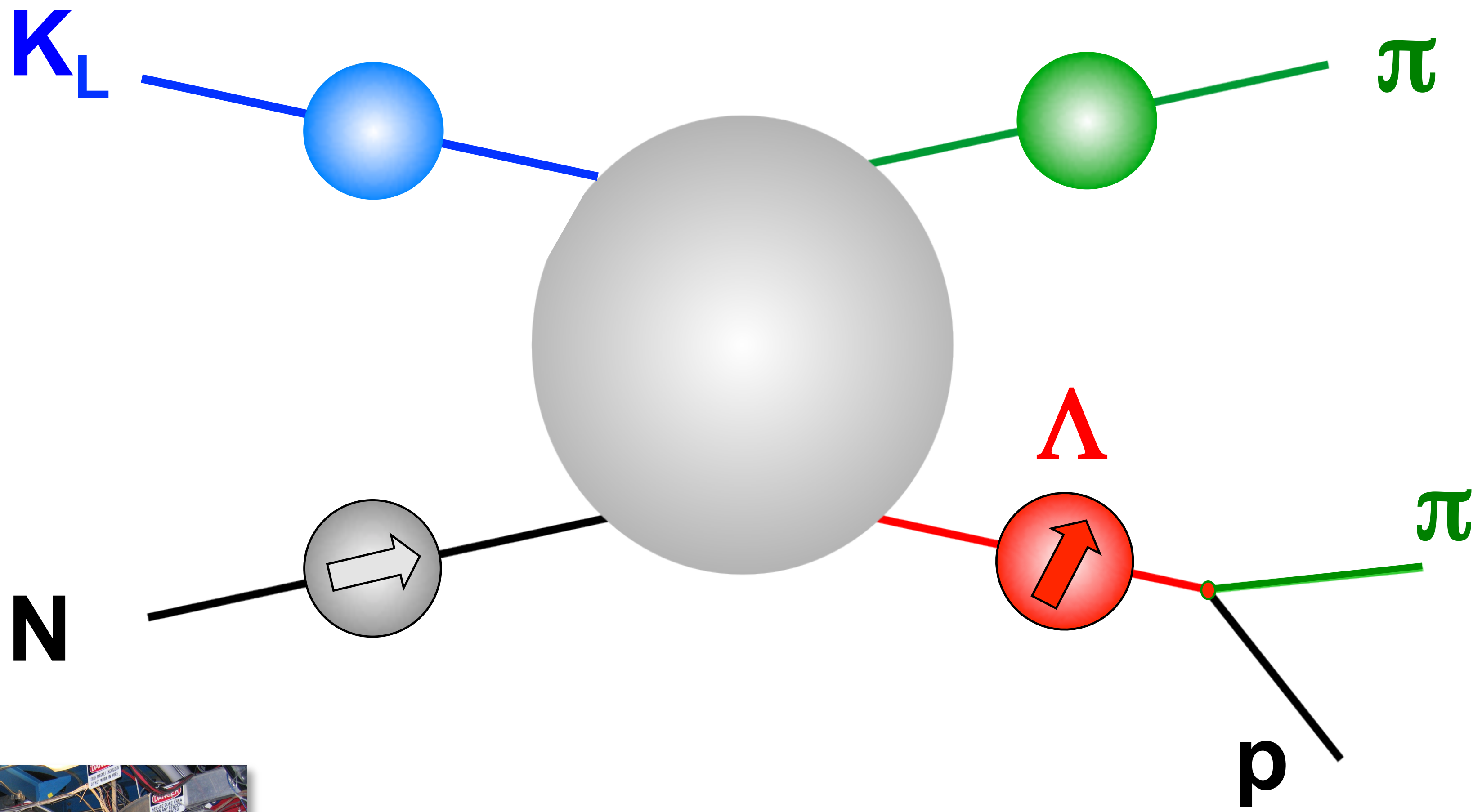
- The existing hall D cryotarget can provide LH2 targets with a diameter of ~6cm and volume up to 400 ml.

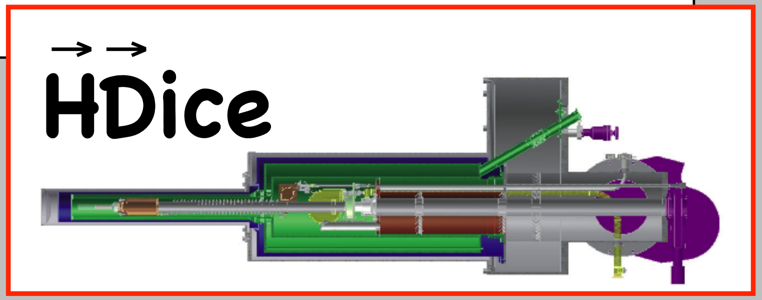
- Larger cells are possible, but will require some modification or new construction.

- Dynamically polarized targets are also a clear possibility, with frozen spin being the most likely choice. Size matters.

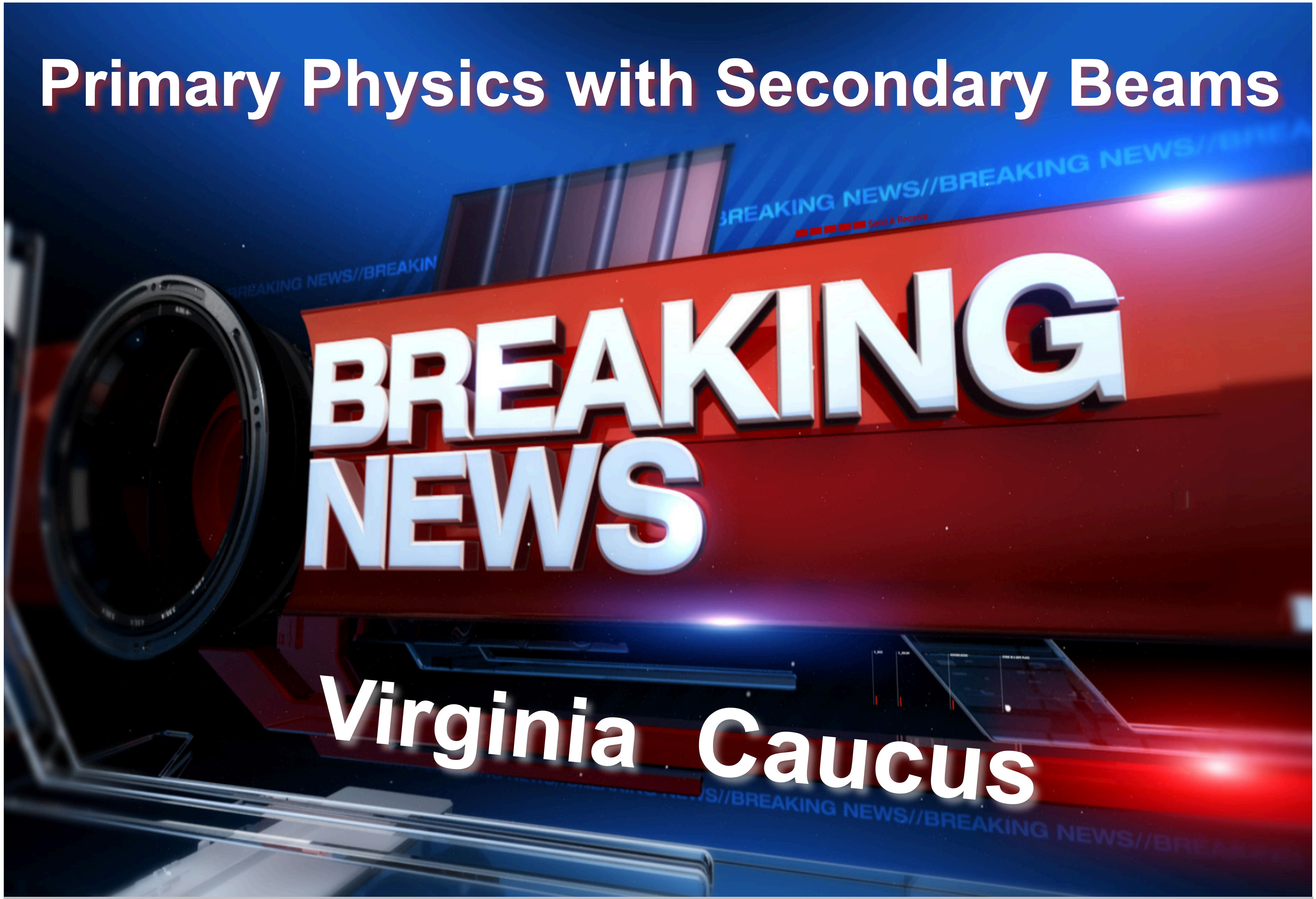
- Cryogenic support for a polarized target will be a concern. A cryogen-free frozen spin target might be a viable option.

Complete experimental measurements





Primary Physics with Secondary Beams



Virginia Caucus

Thank You!

Backup Slides

K^0_L beam at JLAB

-Electron beam with $I_e = 5\mu A$

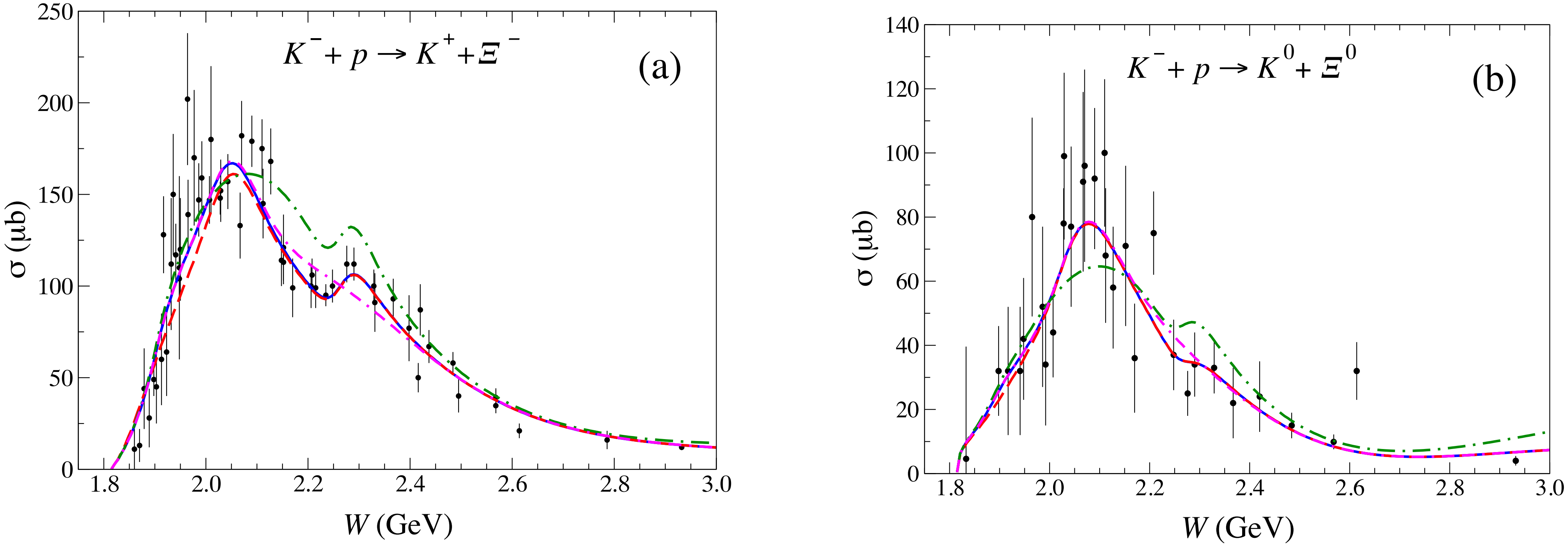
-Delivered with 60ns bunch spacing avoids overlap in the range of P=0.35-10.0 GeV/c

-Momentum measured with TOF

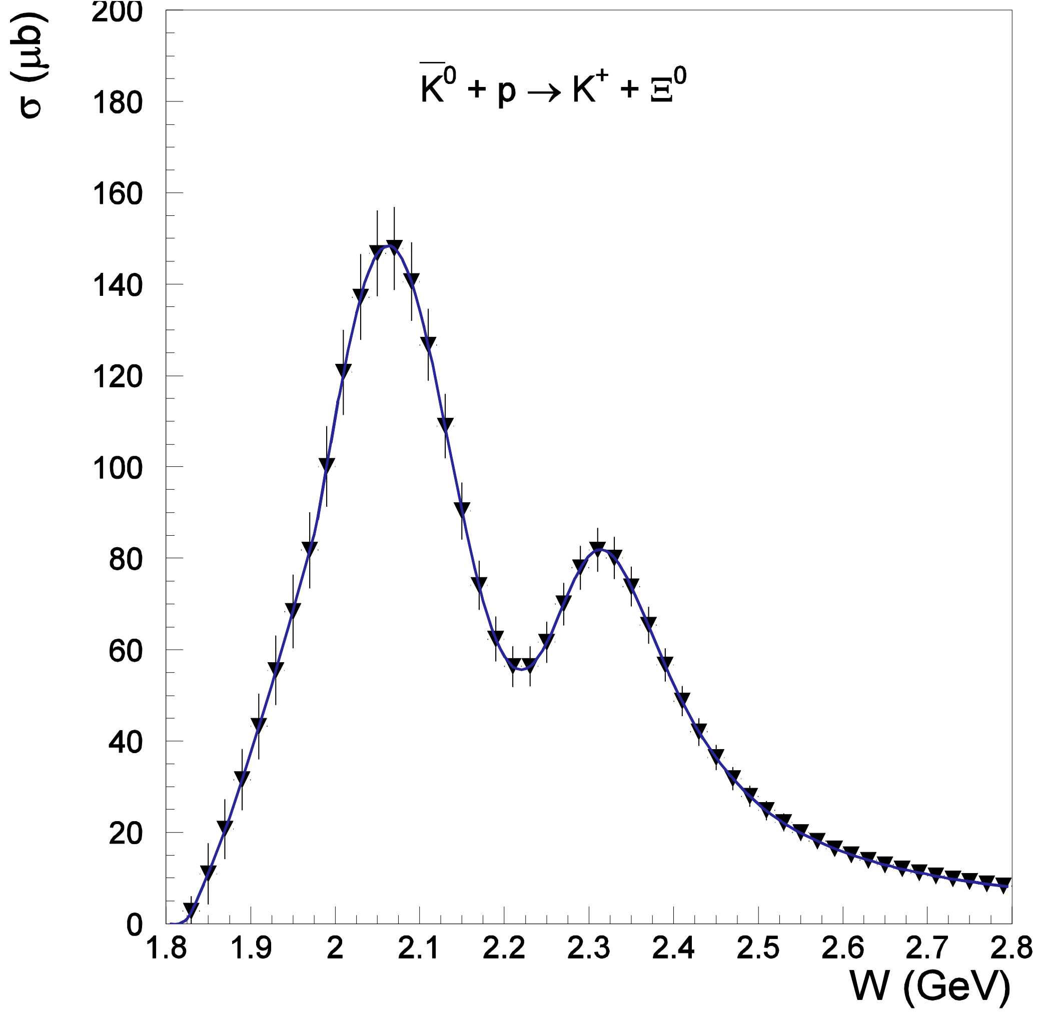
-K^0_L flux mesured with pair spectrometer

-Side remark: Physics case with polarized targets is under study

World Data on Ξ



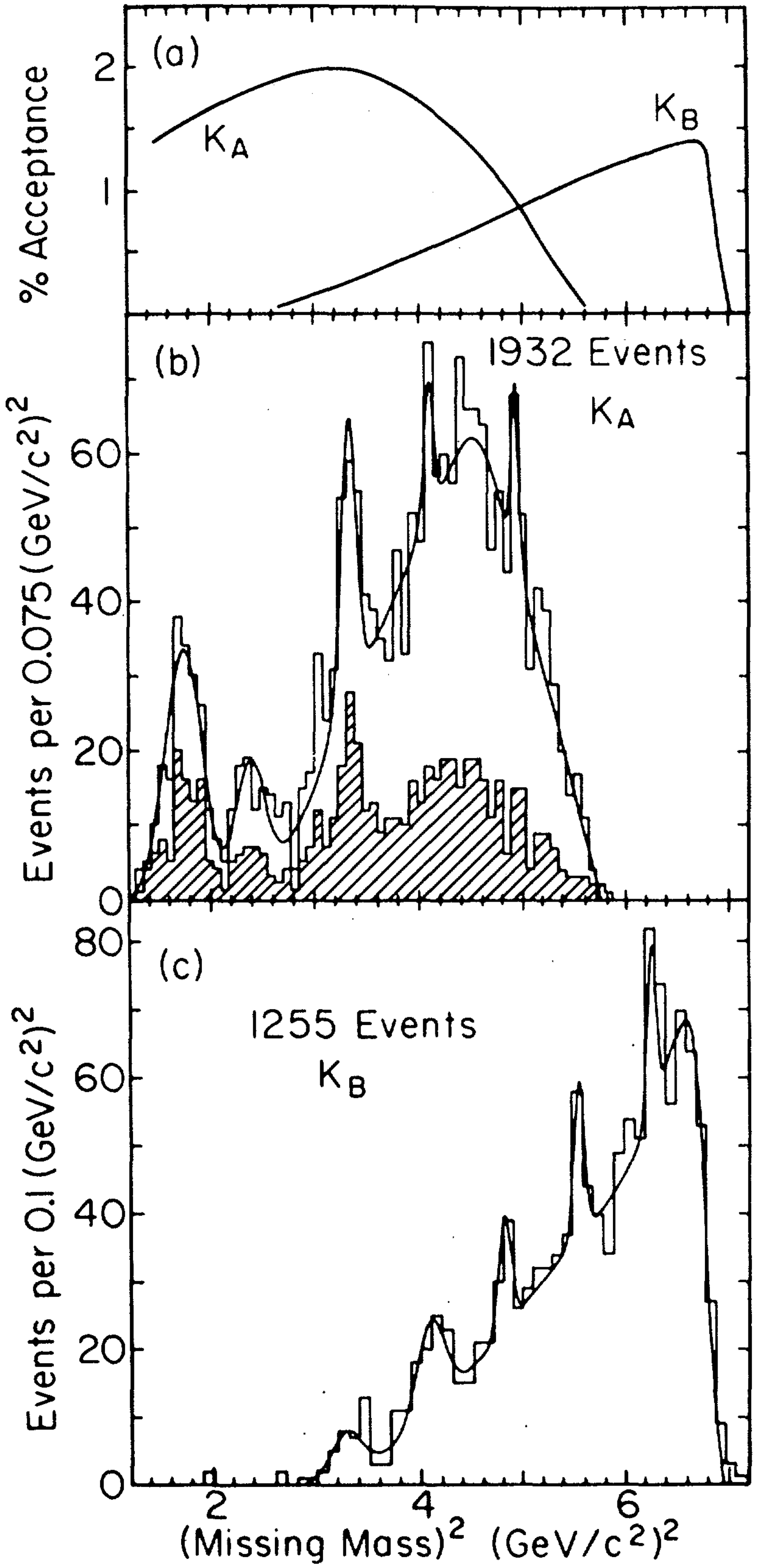
Simulated with GlueX
10^4 K_L/sec, one day of running



Jackson, Oh, Haberzettl, Nakayama
Phys. Rev. C 91, 065208 (2015)

Status of Ξ^*

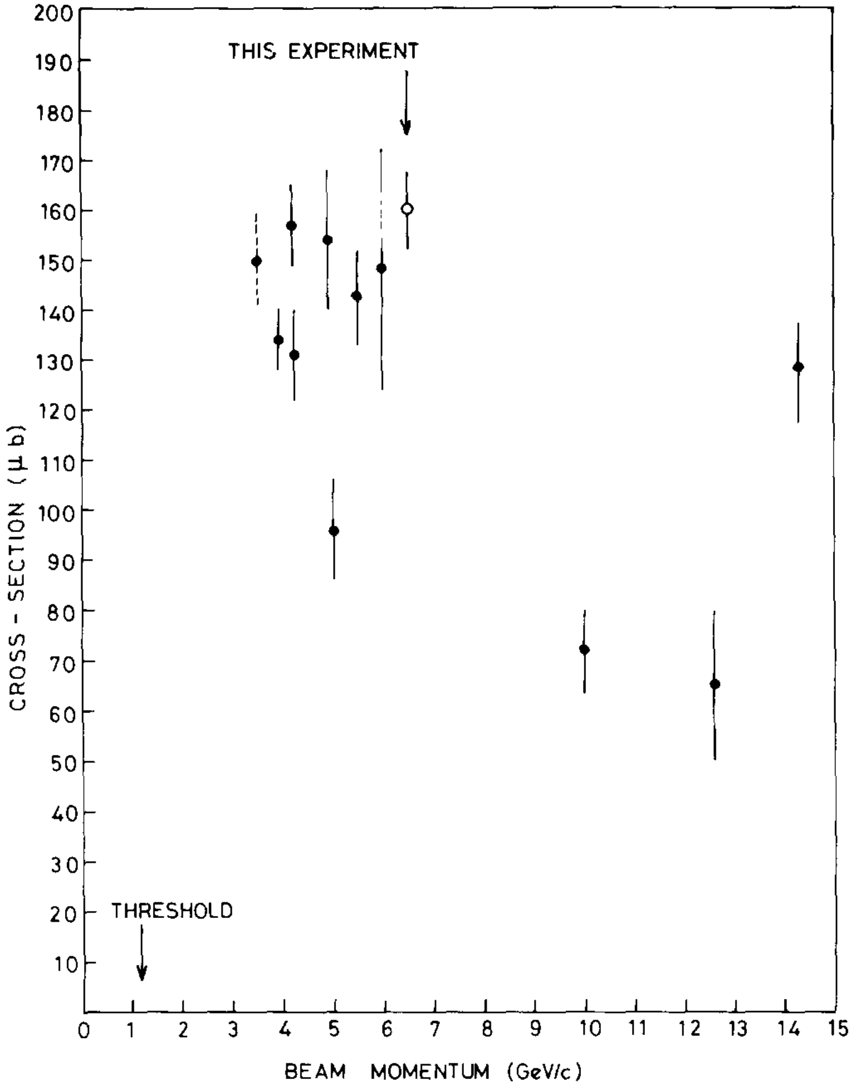
Very poorly measured at AGS (BNL) 32 years ago



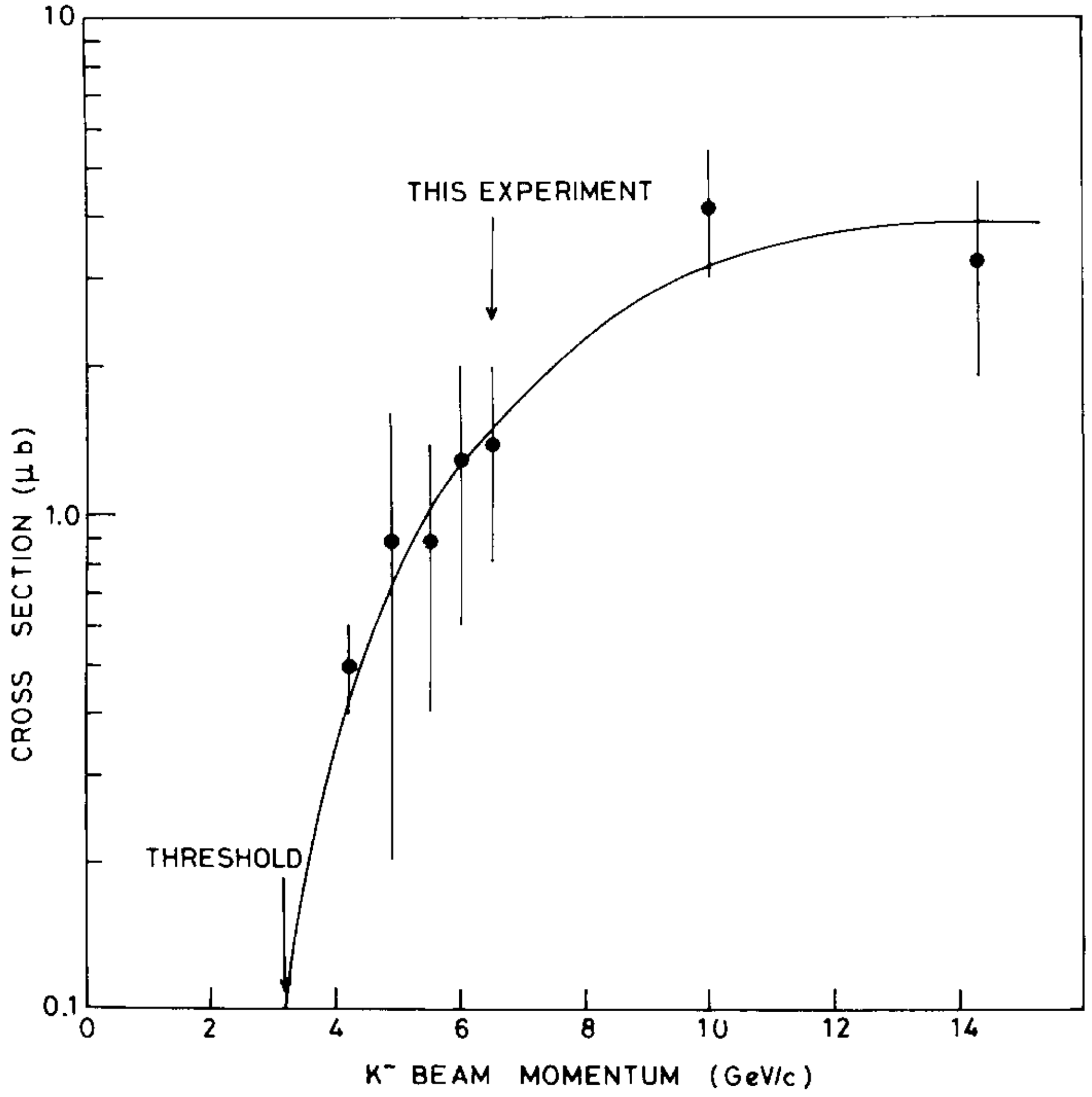
- C.M. Jenkins et al., Phys. Rev. Lett. 51, 951 (1983)

Cross Sections

$$K^- p \to \Xi^- X$$



$$K^- p \to \Omega^- X$$



J.K. Hassal et al., NPB 189 (1981)

Expected rates

Production	*J-PARC**	*Jlab (this proposal)*
flux/s	$3 \times 10^4 K^-$	$10^4 K_L^0$
$\Xi^*/month$	3×10^5	2×10^5
$\Omega^{-*}/month$	600	4000

* *H.~Takahashi, NP A 914, 553 (2013)*
M.~Naruki and K.~Shirotori, LOI-2014-JPARC