UNIVERSITY of York

The K_{Long} Experiment in Hall D at Jefferson Lab

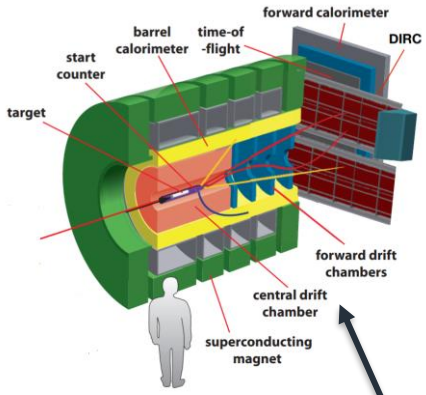
Stuart Fegan (Slides from Mikhail Bashkanov)

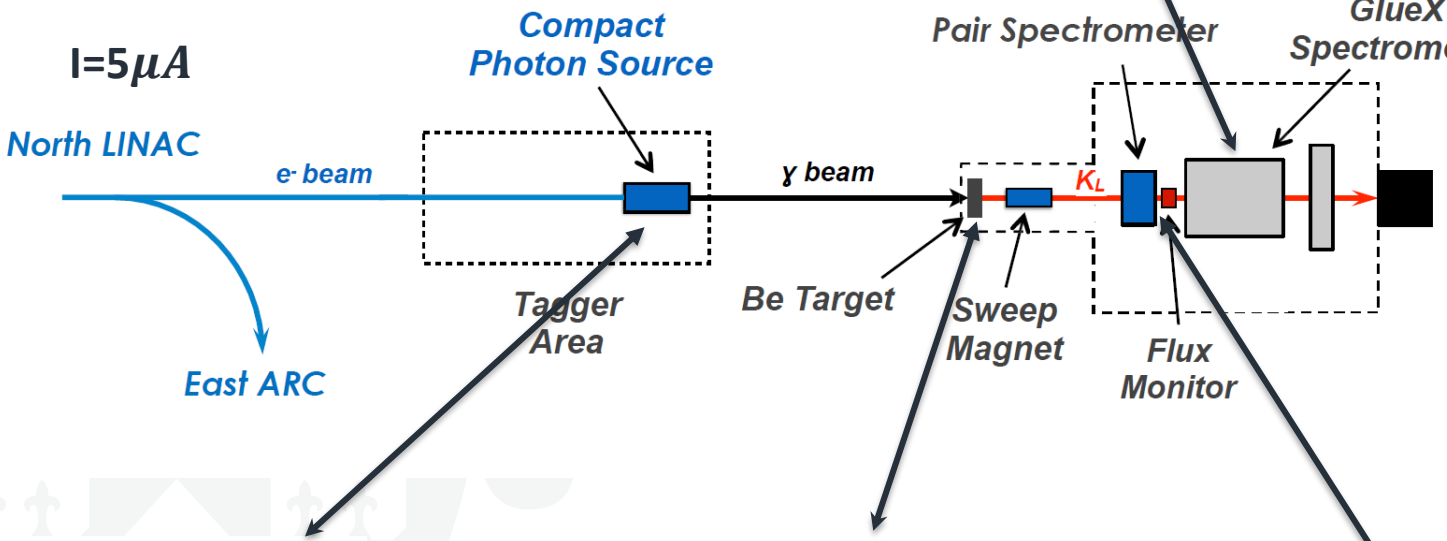
arXiv:2008.08215v3
KLF proposal 2020

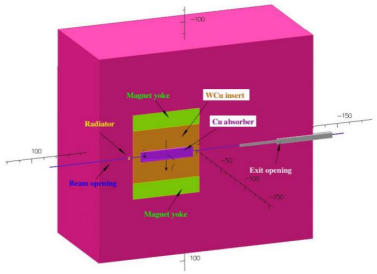
Outlook

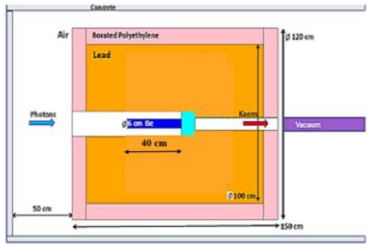
- K_L FACILITY IN A NUTSHELL
- TIMELINE
- LIMITATIONS
- HYPERONS
  - Σ-factory
  - $\Lambda^*, \Xi^*, \Omega^*$
  - Exotic states (cusps, dynamically generated resonances, hadronic molecules)
- Y-N INTERACTIONS
- NEUTRON BEAMS
- HYPERNUCLEI

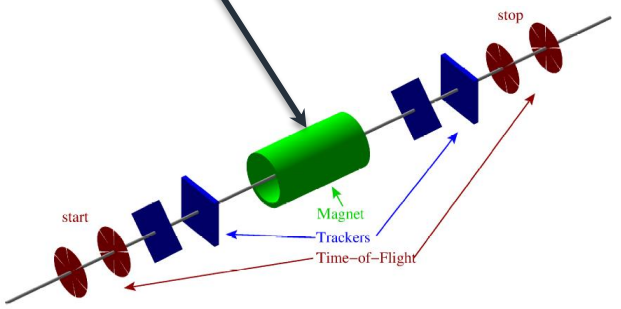
KLF


forward calorimeter
barrel calorimeter
time-of -flight
DIRC
start counter
target
forward drift chambers
central drift chamber
superconducting magnet

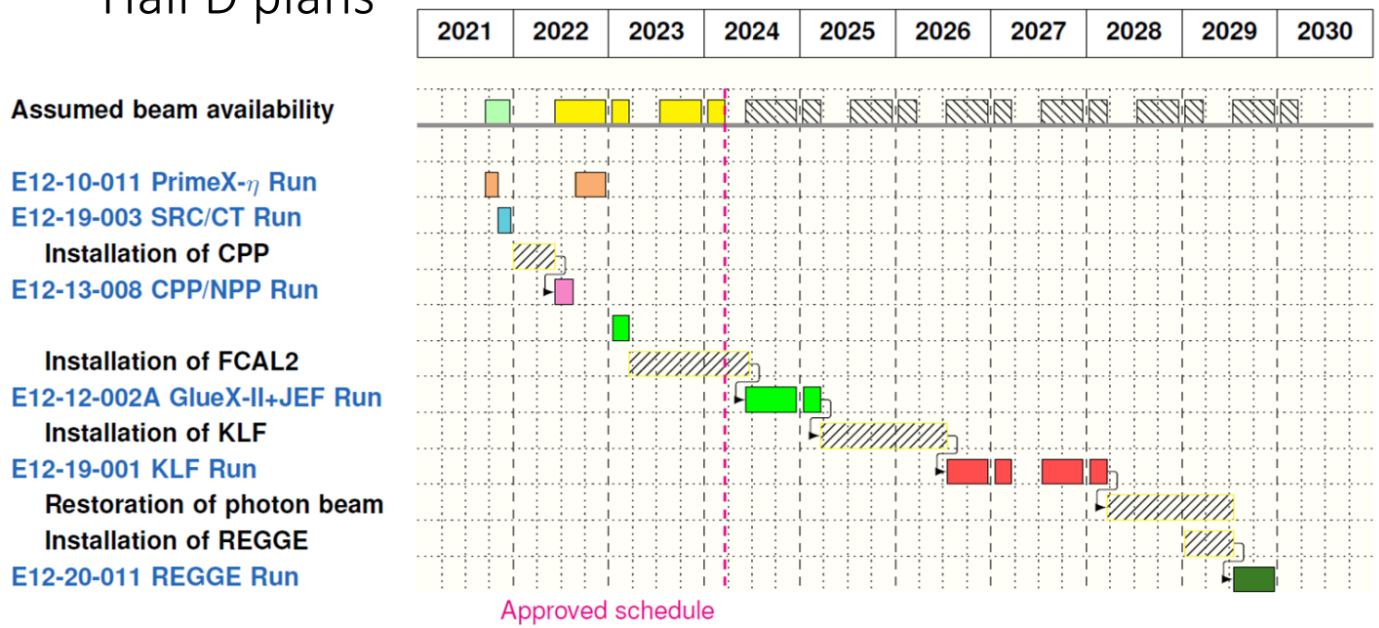

I=5μA
Compact Photon Source
Pair Spectrometer
GlueX Spectrometer
North LINAC
e- beam
γ beam
K_L
East ARC
Tagger Area
Be Target
Sweep Magnet
Flux Monitor

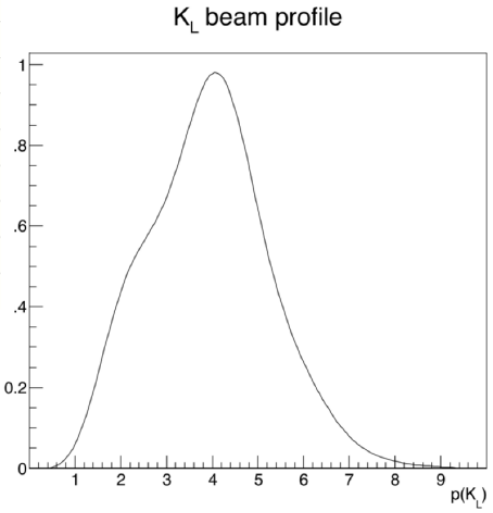

Magnet yoke
WCu insert
Radiator
Cu absorber
Beam opening
Exit opening
Magnet yoke


Concrete
Air
Borated Polyethylene
Lead
Photons
Be
Kevlar
Vacuum
40 cm
50 cm
150 cm

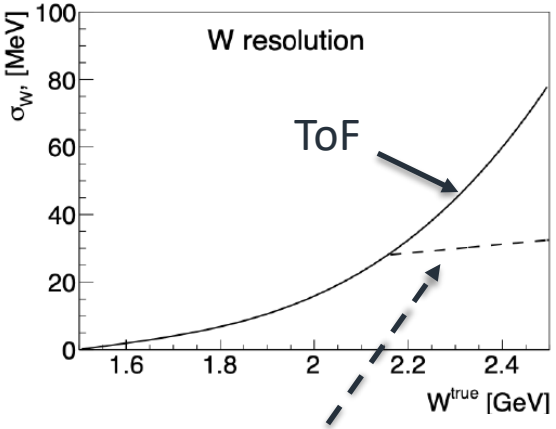

stop
start
Magnet
Trackers
Time-of-Flight

Hall D plans

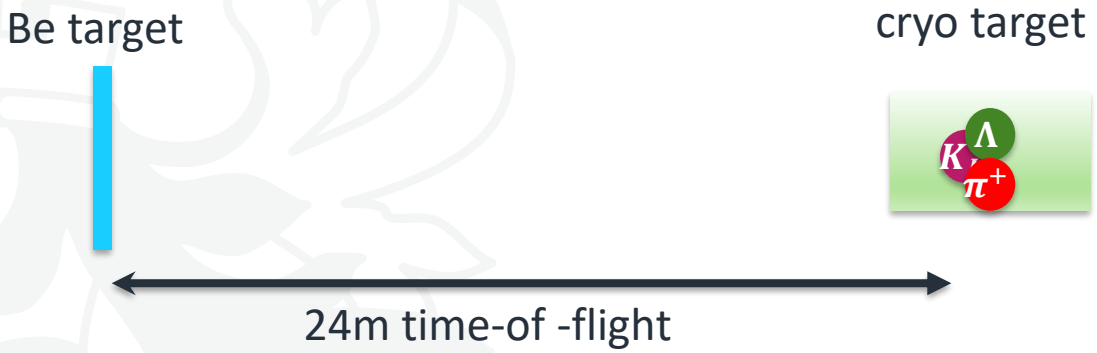




- Intense K_L beam $\sim 10^4$kaons/s on a target
  - Broad momentum range
    - Controlled by Flux Monitor
  - Excellent W reconstruction
    - Time-of-flight
    - Final state
- Proton and neutron target
  - Approved 100 days LH_2 target
  - Approved 100 days LD_2 target
- Low background level
- Exclusive final states

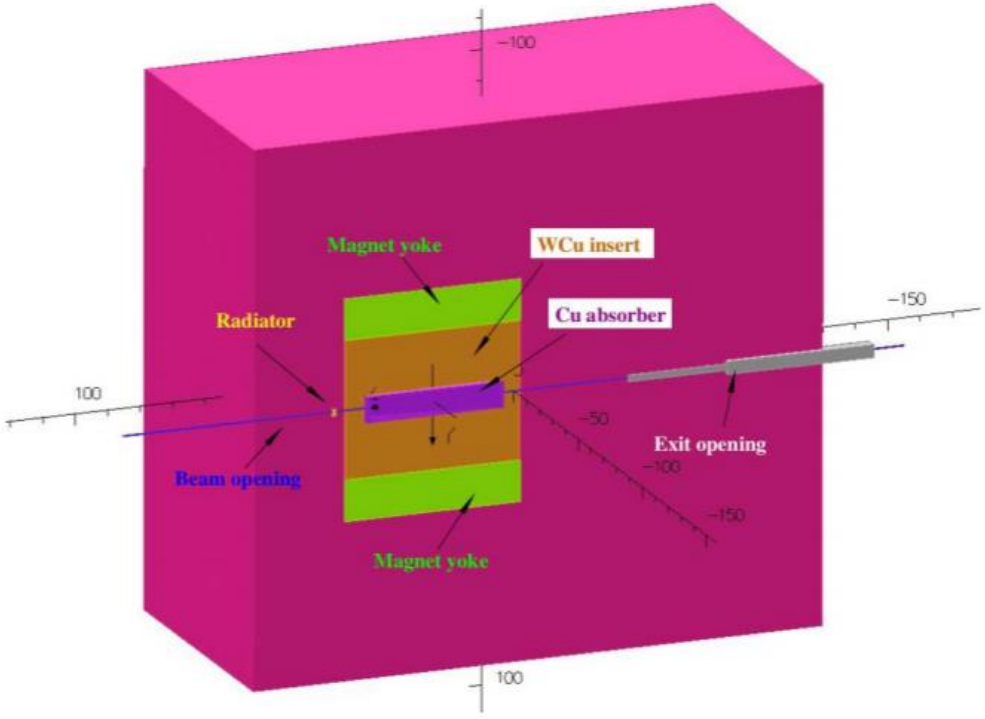


KLF

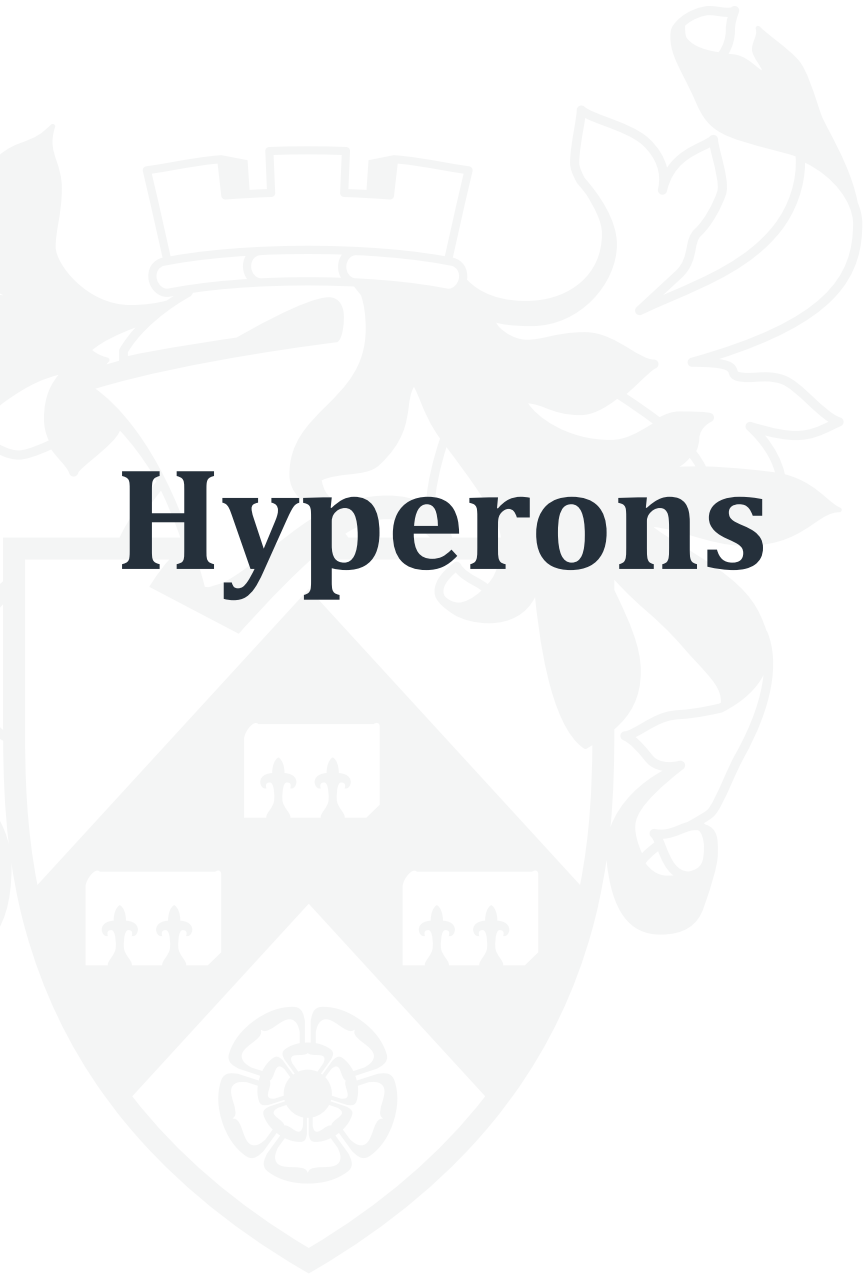


Beam structure:
$I = 5\mu A$

Compact photon source



~100 tons



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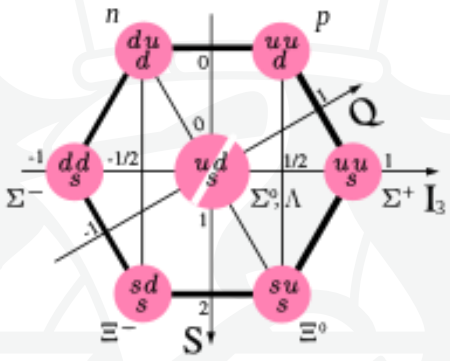
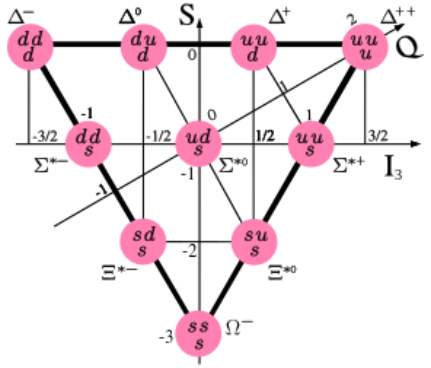
Hyperons

Hyperons



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

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



	LQCD* ($M < 2M_\Omega$)	"Observed", PDG
N^*	62	21
Δ^*	38	12
$\boldsymbol{\Lambda^*}$	**71**	**14**
$\boldsymbol{\Sigma^*}$	**66**	**9**
$\boldsymbol{\Xi^*}$	**73**	**6**
$\boldsymbol{\Omega^*}$	**36**	**2**

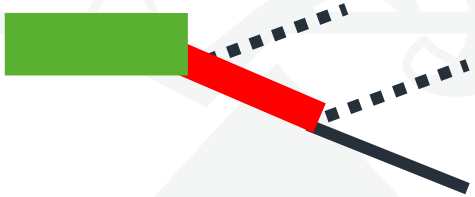
*R.G. Edwards et al, Phys.Rev.D 87 (2013) 5, 054506

Theory limitations

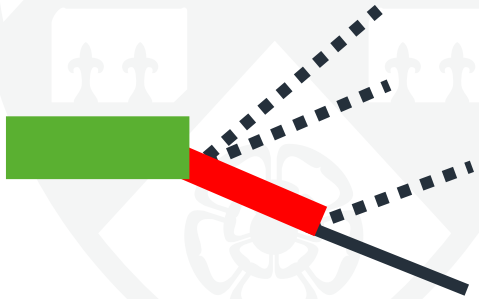
Good

Kaon beam brings one unit of strangeness:

- No associated kaons for Λ^*, Σ^* production
- 1 associated kaon for Ξ^*
- 2 associated kaons for Ω^*

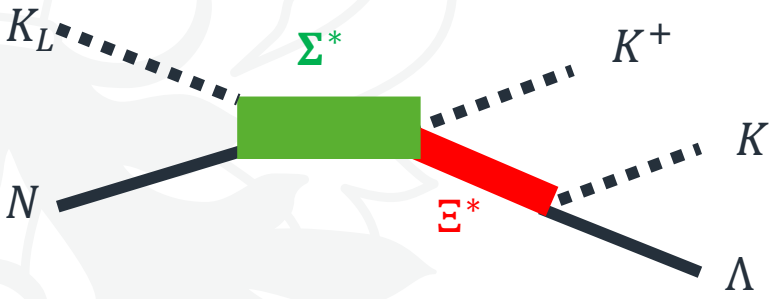


Acceptable



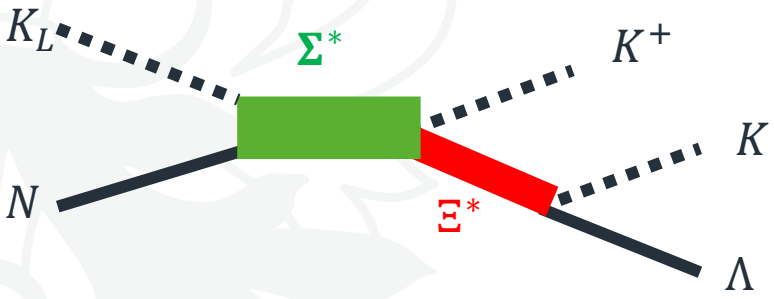
Simplified,
model dependent analysis only

Strange beams?

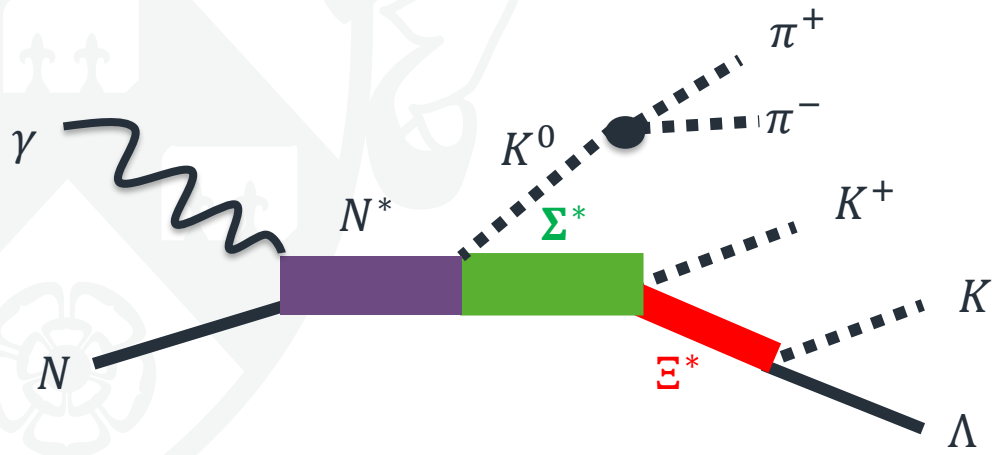


Direct Σ^* production

Strange beams?



Direct Σ^* production



Associated production

Sigma factory

$K_L p \to \Sigma^* \to K_s p$
$K_L p \to \Sigma^* \to \pi^+ \Lambda$
$K_L p \to \Sigma^* \to K^+ \Xi^0$
$K_L p \to \Sigma^* \to \pi^0 \Sigma^+$
$K_L p \to \Sigma^* \to \eta \Sigma^+$
$K_L p \to \Sigma^* \to \omega \Sigma^+$
$K_L p \to \Sigma^* \to \eta' \Sigma^+$

2 Body Final state
Pure Σ^* channels
Self-polarising observables

$K_L p \to K^+ n$

Non-resonant background

New findings: $\pi\Lambda/\pi\Sigma$

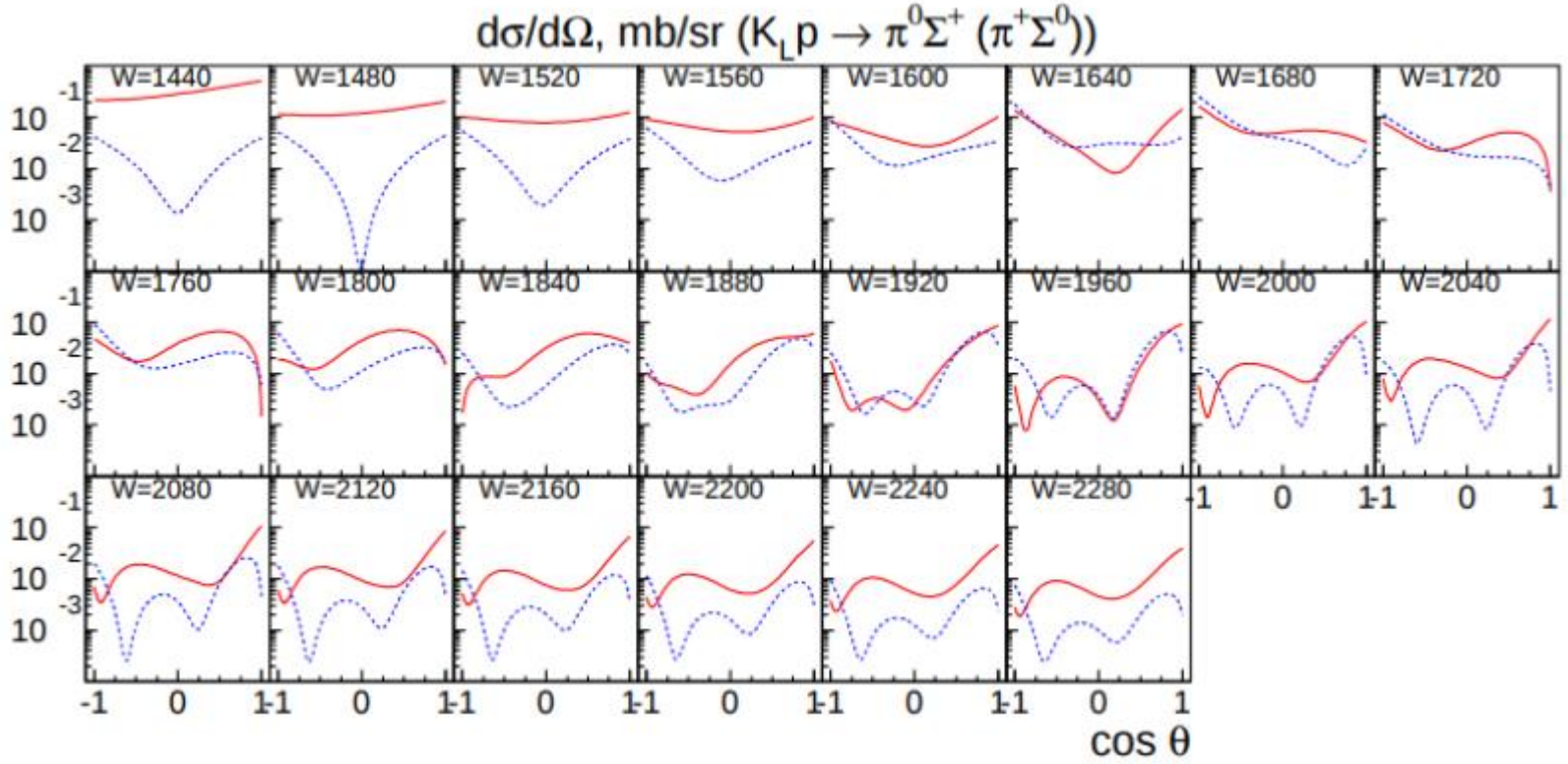
Isospin amplitudes

$$|A(K^-p)|^2 = \frac{1}{2}(|A_1|^2 + |A_0|^2 + 2Re(A_1A_0^*))$$

$$|A(K^0n)|^2 = \frac{1}{2}(|A_1|^2 + |A_0|^2 - 2Re(A_1A_0^*))$$

$$|A(K^0p)|^2 = |A_1|^2.$$

arXiv:2008.08215v3
KLF proposal 2020



New findings: $\pi\Lambda/\pi\Sigma$

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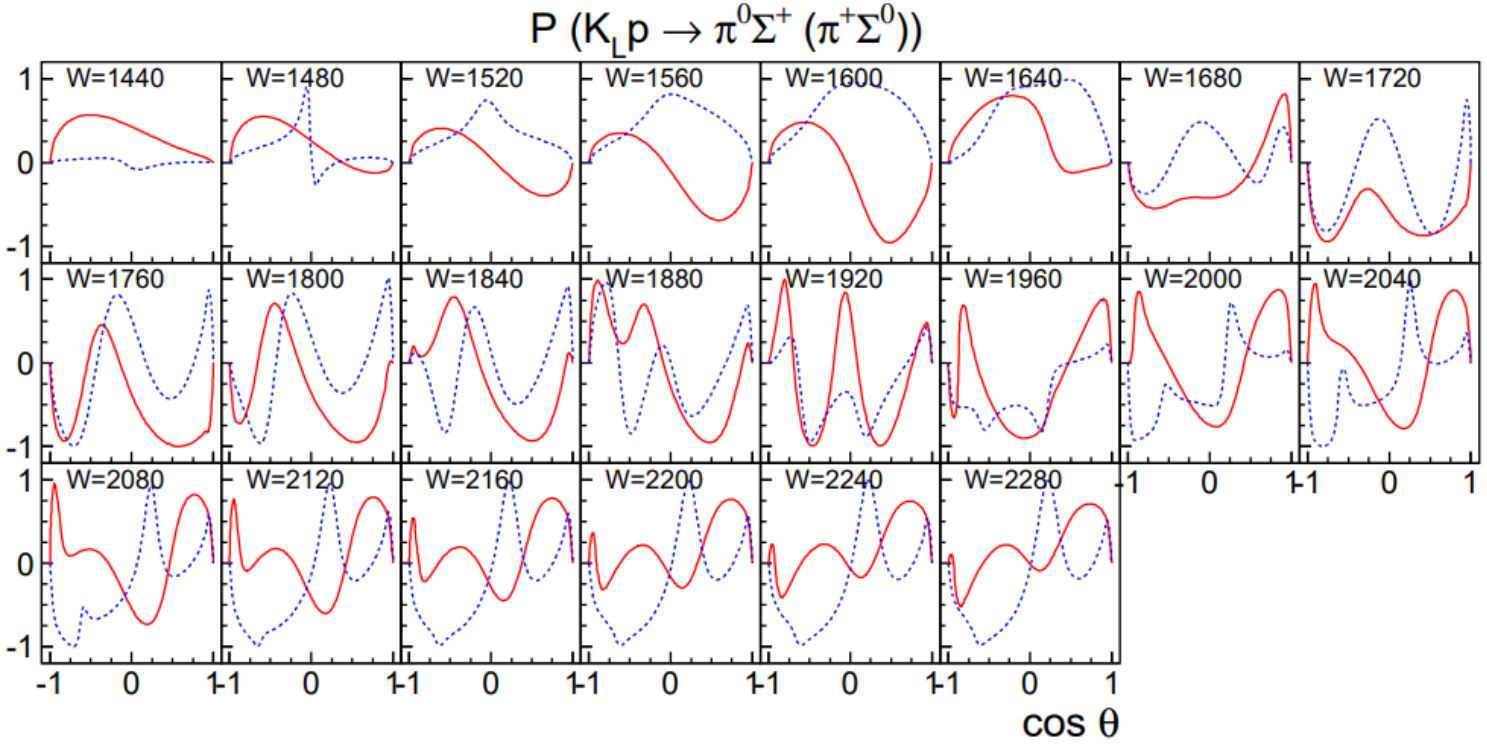
$$|A(K^0n)|^2 = \frac{1}{2}(|A_1|^2 + |A_0|^2 - 2Re(A_1A_0^*))$$

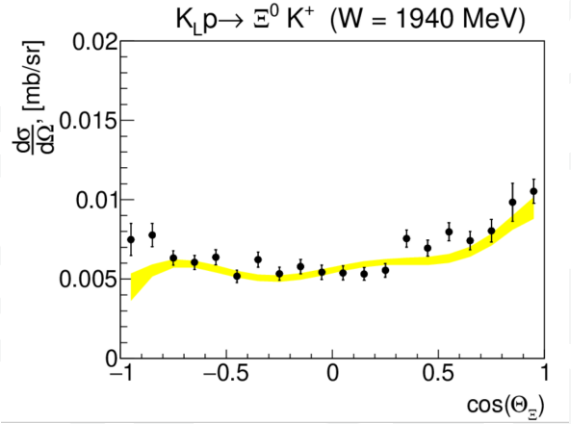
$$|A(K^0p)|^2 = |A_1|^2.$$

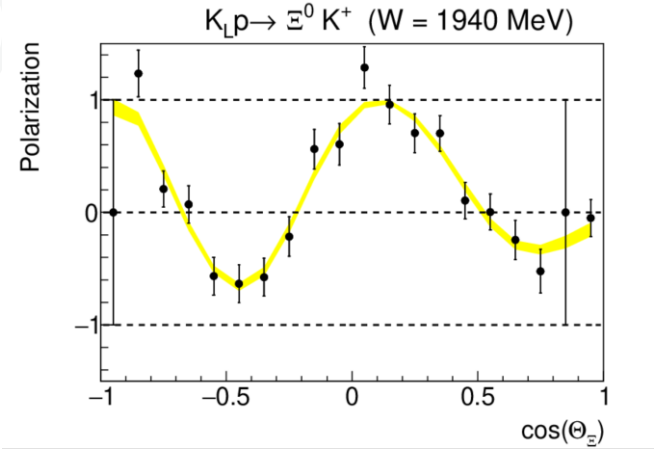
Recoil asymmetry

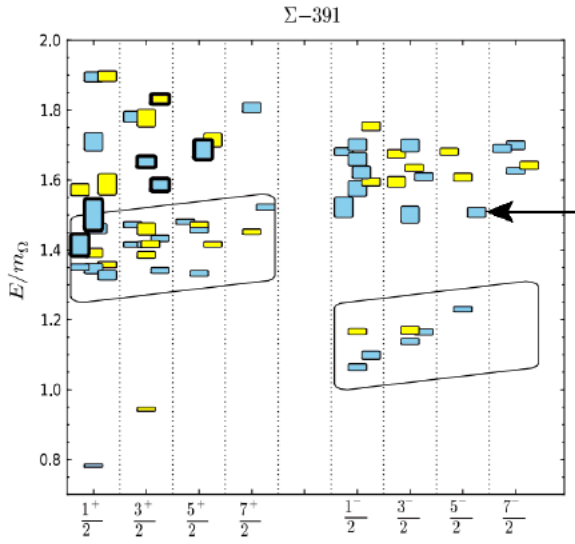


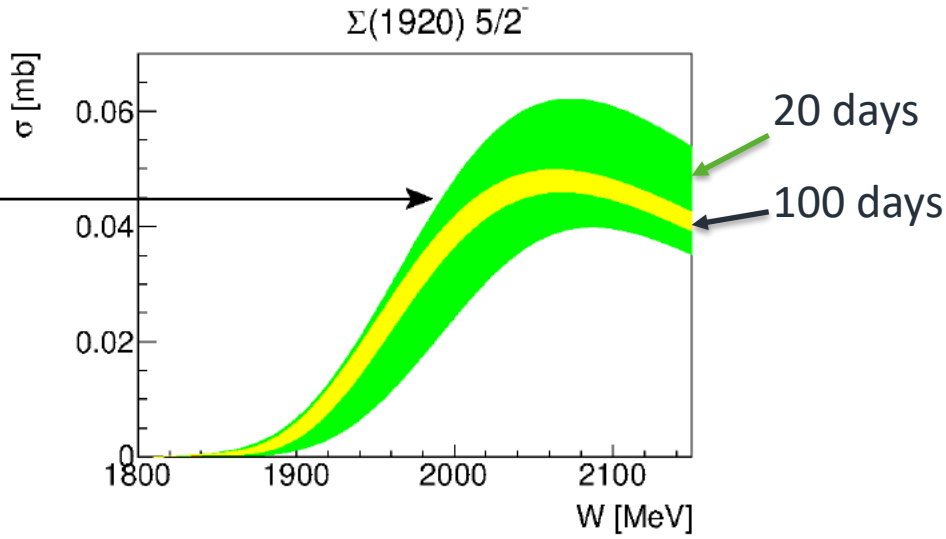
Expected results

$$K_L p \rightarrow K^+ \Xi^0$$

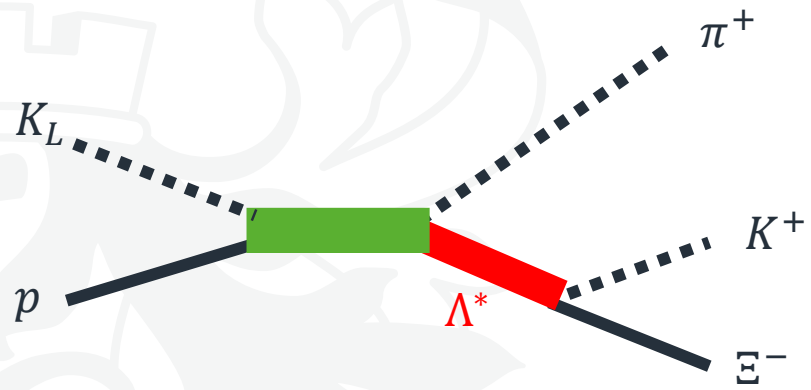




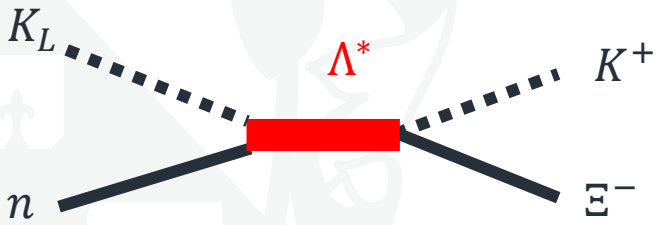




Excited Λ^*



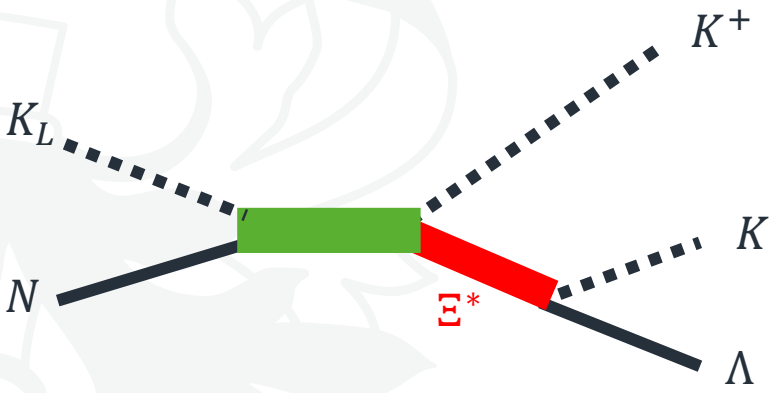
Associated production



Direct formation

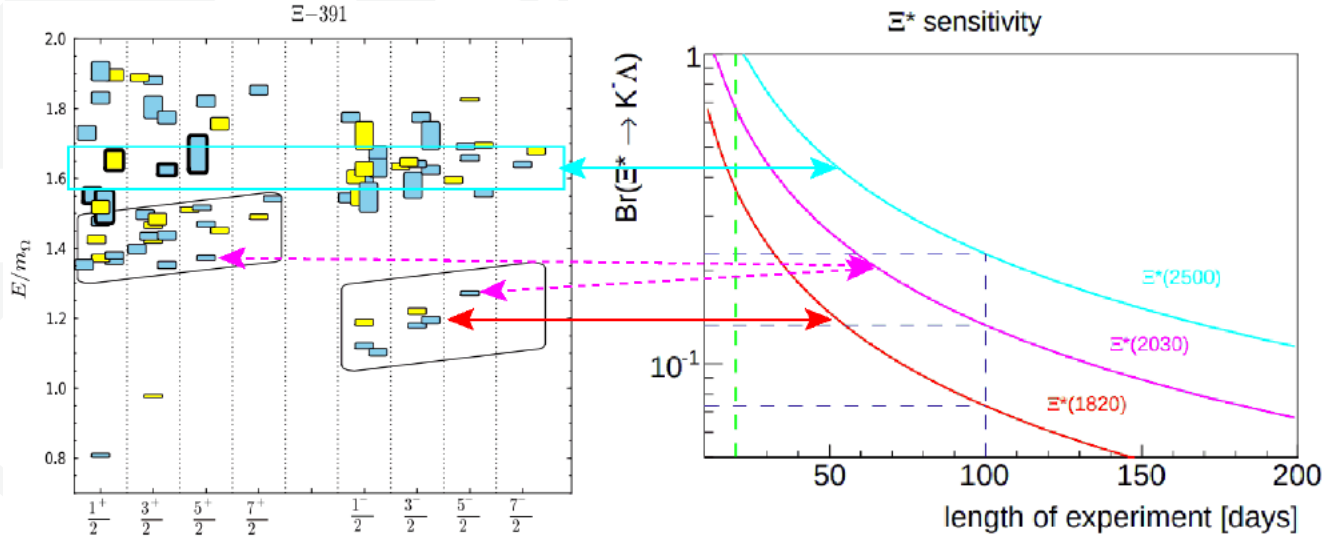
- Interference effects
- $\Lambda - \Sigma$ mixing
- Model-independent PWA
- Different background

Excited Ξ^* in associated production

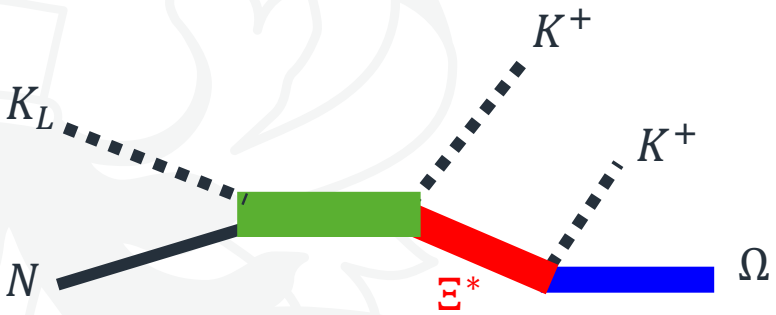


$\Xi^* \to \Lambda K$
$\Xi^* \to \Xi\pi$
$\Xi^* \to \Xi\eta$
$\Xi^* \to \Xi\omega$
$\Xi^* \to \Sigma K$

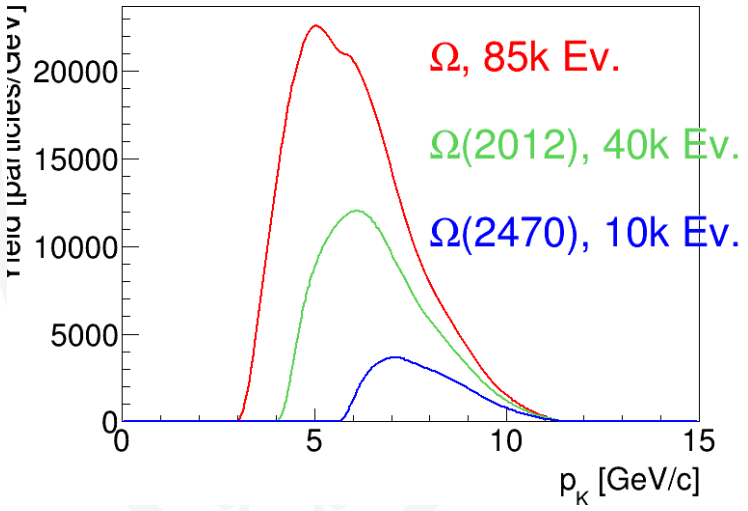
$$K_L n \to K^+ \Xi^- \to K^+ \Lambda K^-$$

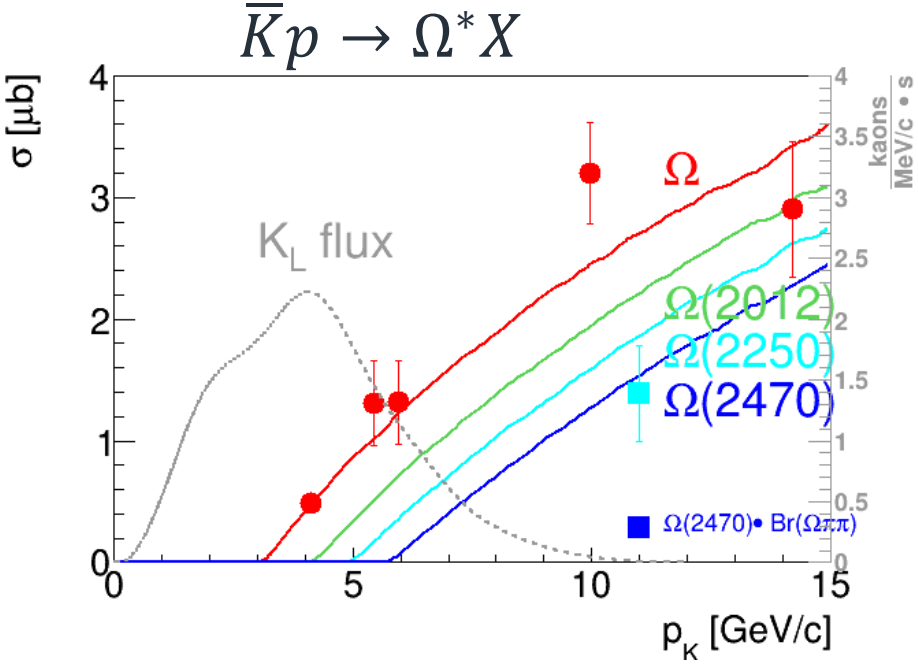


Excited Ω^* in associated production



Expected Yield

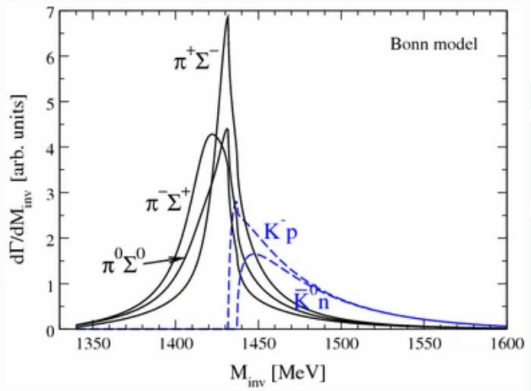




Why Strangeness?

Molecules and cusps

$\Lambda_b \to J/\psi \Lambda(1405)$



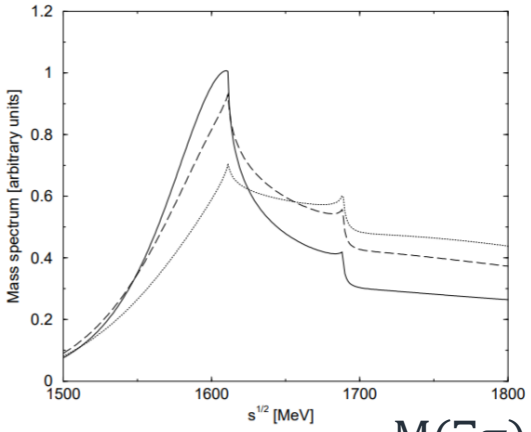
•L. Roca, M. Mai, E. Oset & Ulf-G. Meißner

- Many thresholds
  - Cusps
  - Molecules
  - Dynamic resonances

- $\Lambda(1670)$, $\bar{K}N$ vs $\pi\Sigma$ vs $\eta\Lambda$
- $\Sigma(1620)$

States?
Decay channels?
Resolution?

$\Xi(1620)$



$M(\Xi\pi)$

$\Xi\pi, \Lambda\bar{K}, \Sigma\bar{K}, \Xi\eta$

A. Ramos, E. Oset , C. Bennhold

Strangeness is a key

- Many thresholds
  - Cusps
  - Molecules
  - Dynamic resonances

Light quark sector:

+ high statistics
+ easy to produce
- too broad
- too many interferences

Strange sector:

+ high statistics
+ easy to produce with K_L
+ perfect width
+ decent spacing

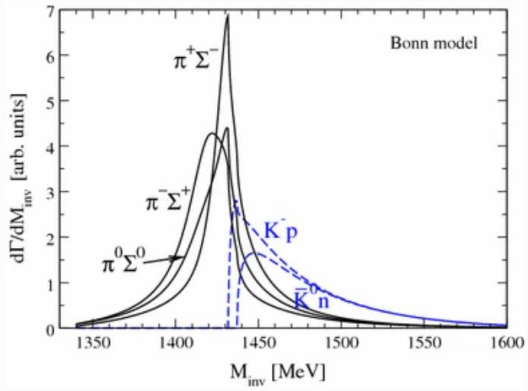
Heavy quark sector:

- low statistics
- hard to produce
- too narrow

Strangeness is a key

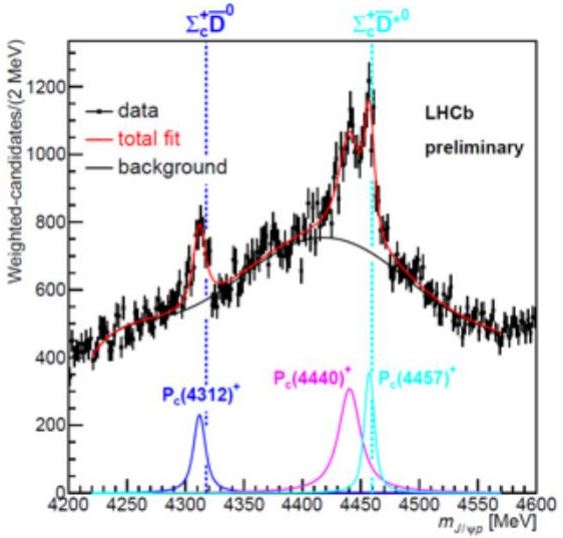
- Many thresholds
  - Cusps
  - Molecules
  - Dynamic resonances

$\Lambda_b \to J/\psi\Lambda(1405)$



•L. Roca, M. Mai, E. Oset & Ulf-G. Meißner

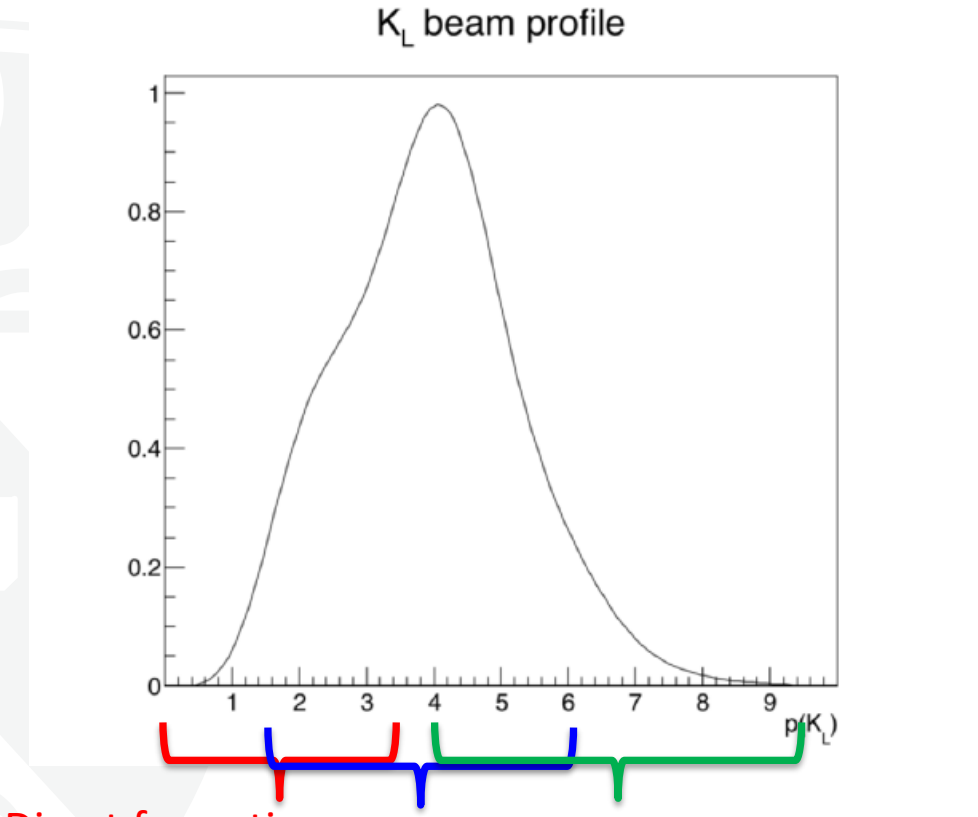
$\Lambda(1405) \leftrightarrow \pi\Sigma/\bar{K}N$-molecule



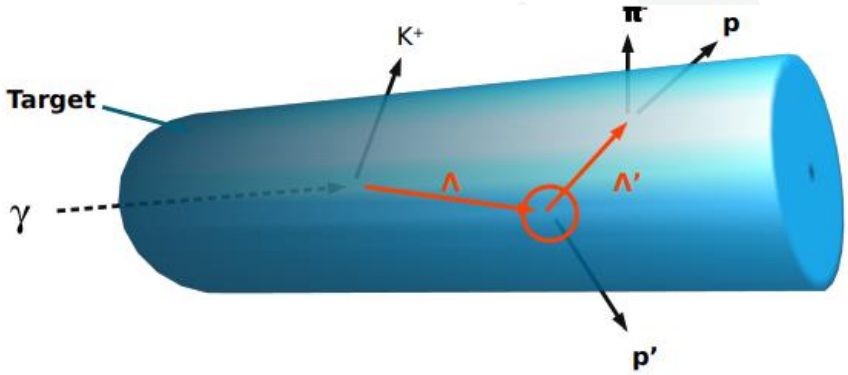
$P(4450) \leftrightarrow \bar{D}^*\Sigma_c$-molecule

Continuous beam → small systematics

KLF spectroscopy



Hyperon-nucleon Scattering

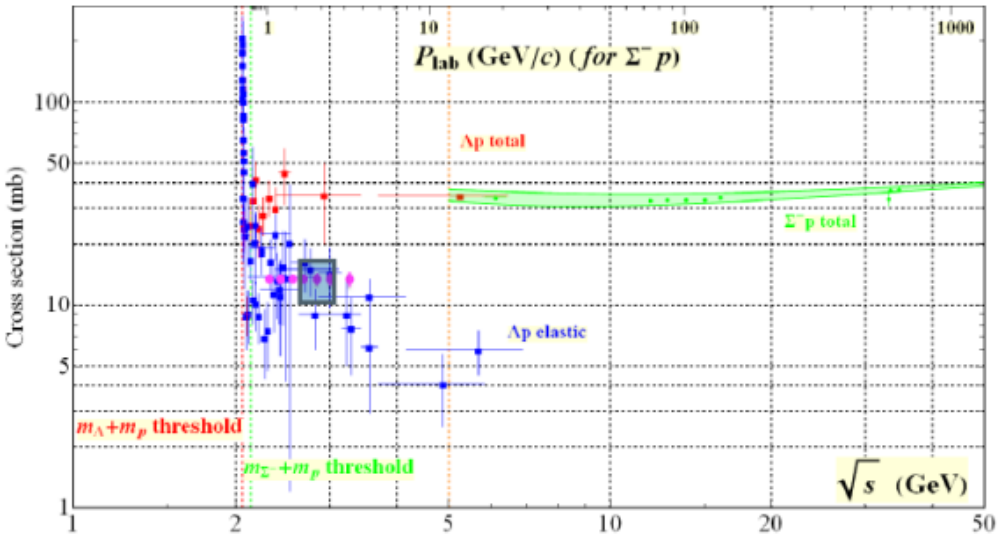


Cross sections
- Λp
- Σ^-p
- Σ^+p
- Λd

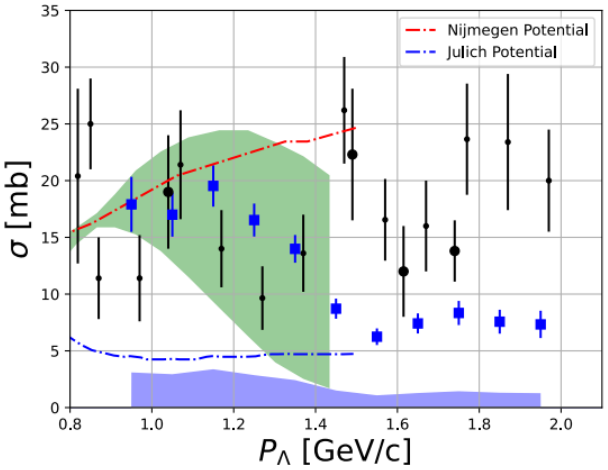
Polarization observables
- Λn
- Σ^-p
- Λd
- Λp

PhysRevLett.127.272303 (2021)

KLF



CLAS



J. Haidenbauer and U.-G. Meißner, Phys. Rev. C 72, 044005 (2005)
T. A. Rijken, V. G. J. Stoks, and Y. Yamamoto, Phys. Rev. C 59, 21 (1999).

Statistics

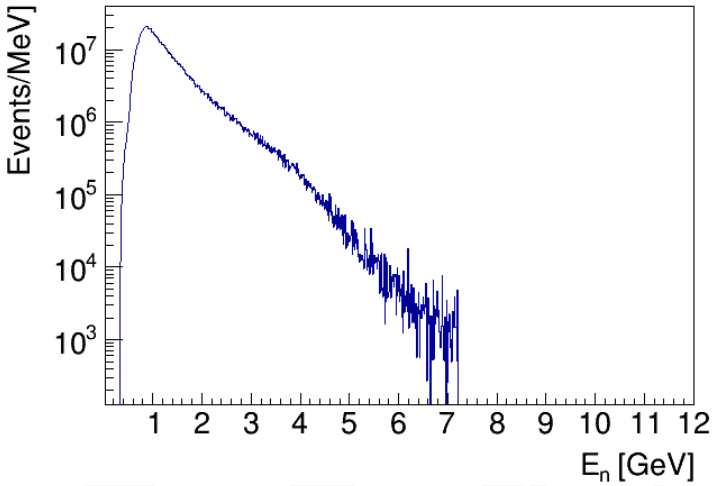
Inclusive reconstruction (with background suppression)

Reaction	Statistics (events)
$K_L p \to K_S p$	2.7M
$K_L p \to \pi^+ \Lambda$	7M
$K_L p \to K^+ \Xi^0$	2M
$K_L p \to K^+ n$	60M
$K_L p \to K^- \pi^+ p$	7M

Inclusive → Fully exclusive ($K_L p \to K^+ \Xi^0$):
2M→200k

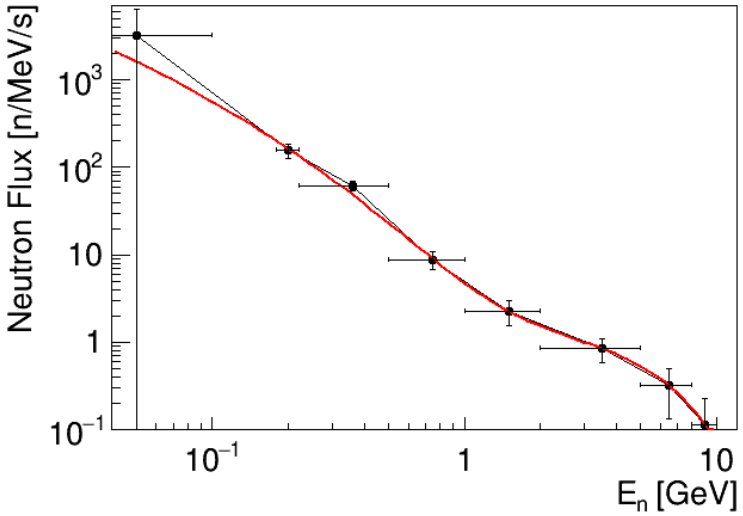
Neutron beam

Neutron induced reactions (hadrons)



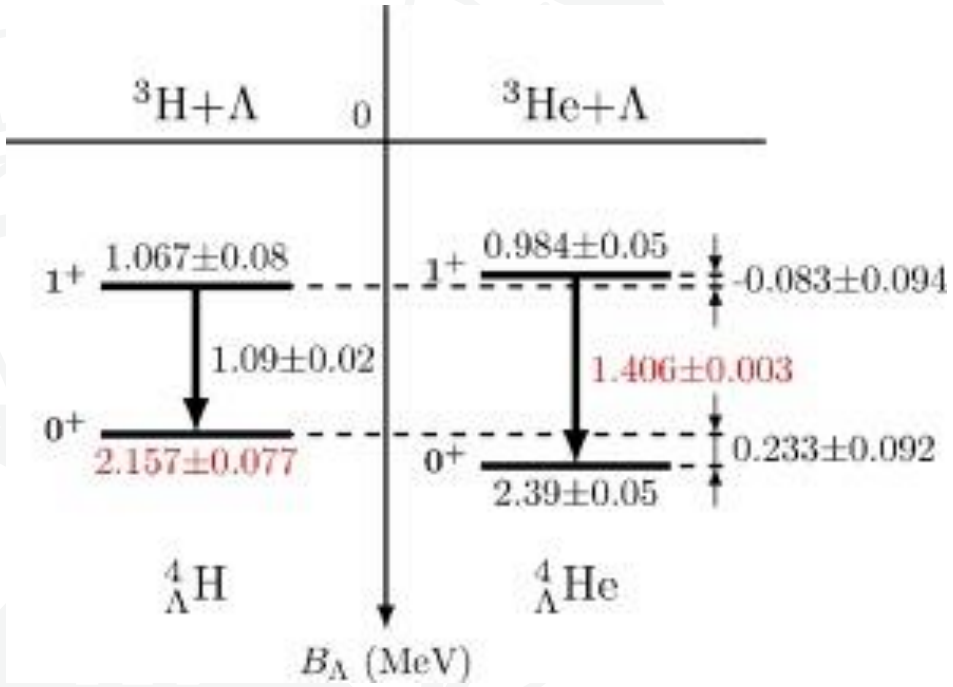
np reaction X-sections from SAID

Neutron flux

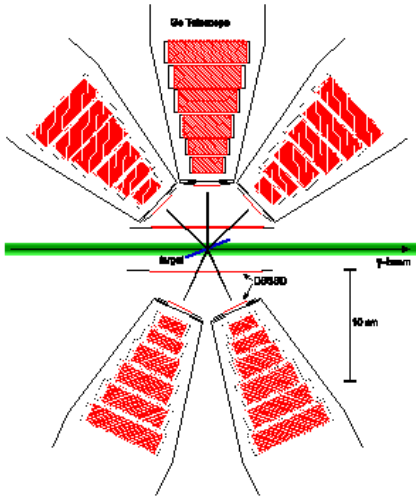


Low energy Neutron induced reactions-> Nuclear structure

Hypernuclei



Daniel Gazda, Avraham Gal , NPA 954, 161, (2016)



Usual routes: $K^- \boldsymbol{n} \rightarrow \Lambda\pi^-$

$\pi^+ \boldsymbol{n} \rightarrow \Lambda K^+$

KLF route: $K^0 \boldsymbol{p} \rightarrow \Lambda\pi^+$

Double-strangeness KLF route: $K^0 \boldsymbol{p} \rightarrow \Xi K^+$

Possible improvements

- 24 GeV electron beam → Ω production studies
- More intense beam (CPS, shielding, radiator…)
- Theory

New collaborators welcome!!!

More information at https://wiki.jlab.org/klproject

NSTAR2024
York UK

June 17-21st 2024

York