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# Perspectives $K_L$ -Facility

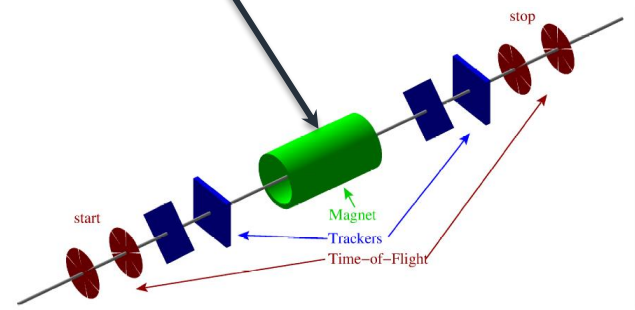
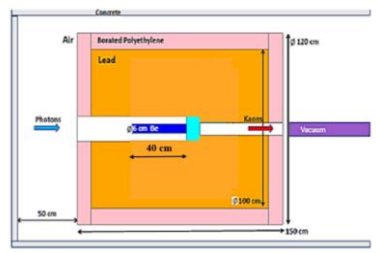
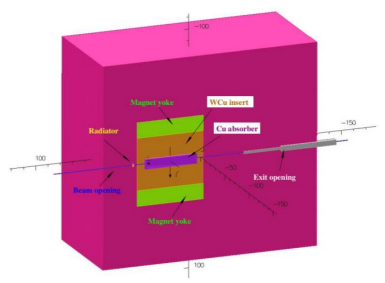
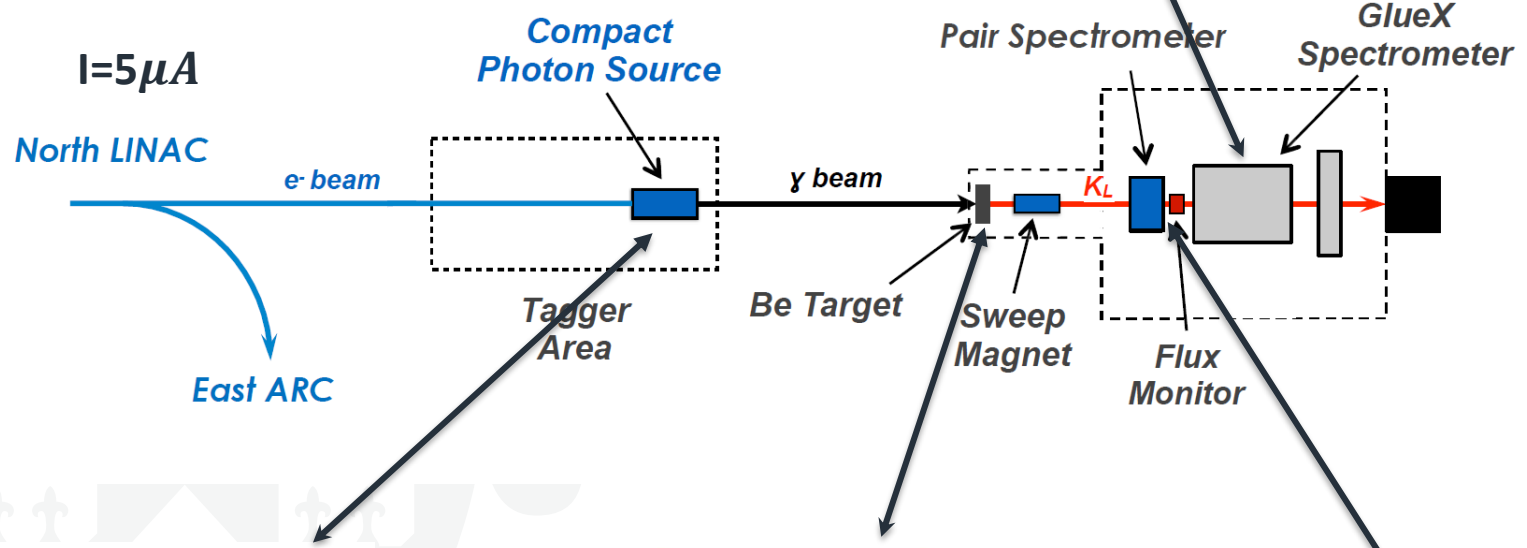
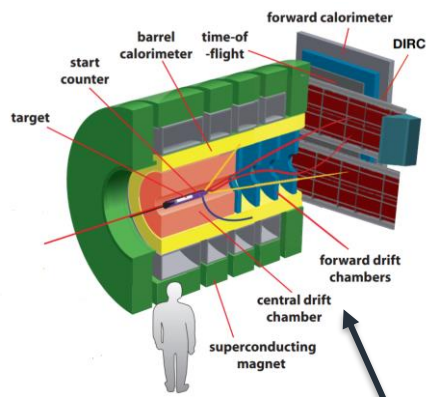
[arXiv:2008.08215v3](https://arxiv.org/abs/2008.08215v3)  
KLF proposal 2020

**Mikhail Bashkanov**

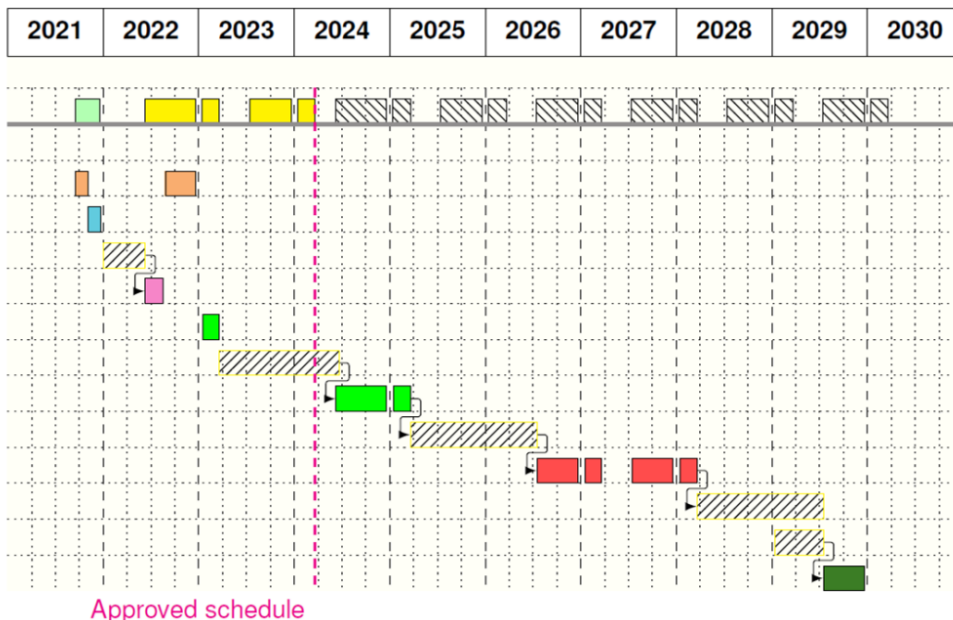
# Outlook



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



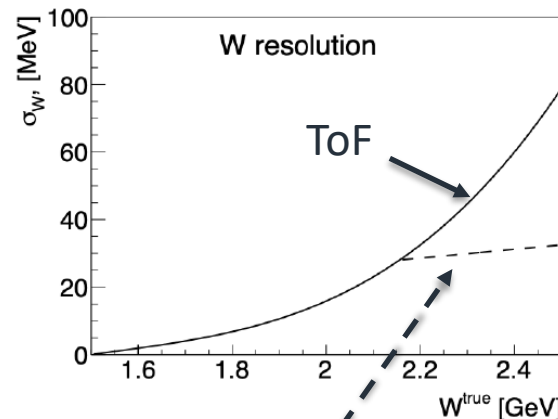
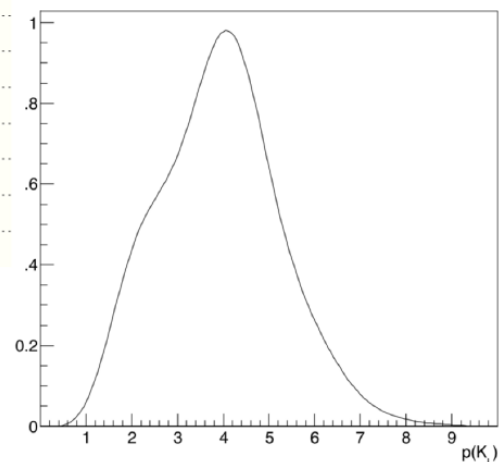
# Hall D plans



- Assumed beam availability
- E12-10-011 PrimeX- $\eta$  Run
- E12-19-003 SRC/CT Run
- Installation of CPP
- E12-13-008 CPP/NPP Run
- Installation of FCAL2
- E12-12-002A GlueX-II+JEF Run
- Installation of KLF
- E12-19-001 KLF Run
- Restoration of photon beam
- Installation of REGGE
- E12-20-011 REGGE Run

- 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

$K_L$  beam profile



Final State 4

# KLF



Be target



cryo target



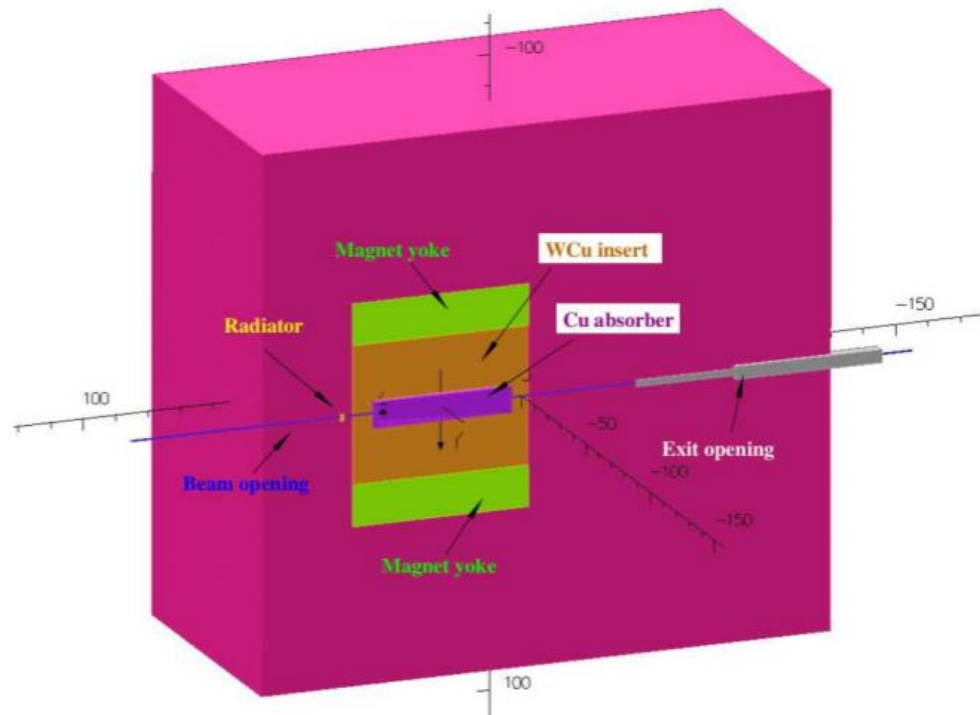
24m time-of-flight

Beam structure:  
 $I = 5\mu A$



64ns

# Compact photon source



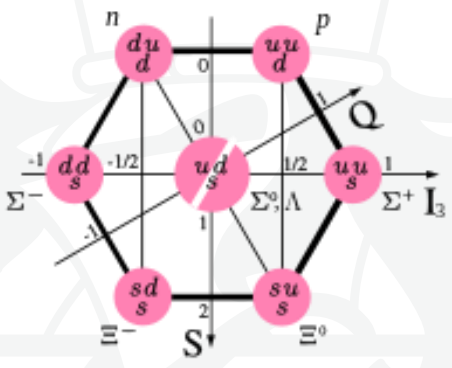
~100 tons



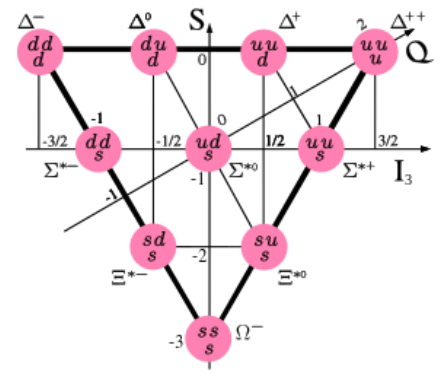
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# Hyperons

# Hyperons



Octet:  $N^*$ ,  $\Lambda^*$ ,  $\Sigma^*$ ,  $\Xi^*$   
 Decuplet:  $\Delta^*$ ,  $\Sigma^*$ ,  $\Xi^*$ ,  $\Omega^*$



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

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



# Theory limitations

Kaon beam brings one unit of strangeness:

- No associated kaons for  $\Lambda^*$ ,  $\Sigma^*$  production
- 1 associated kaon for  $\Xi^*$
- 2 associated kaons for  $\Omega^*$



**Good**

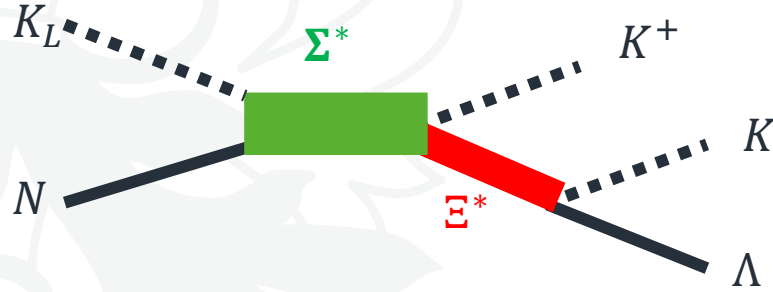


**Acceptable**



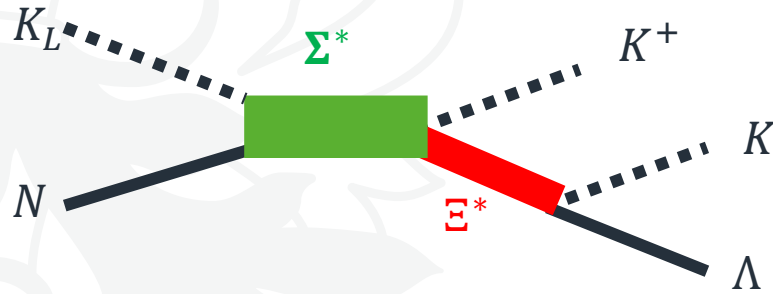
**Simplified,  
model dependent analysis only**

# Strange beams?

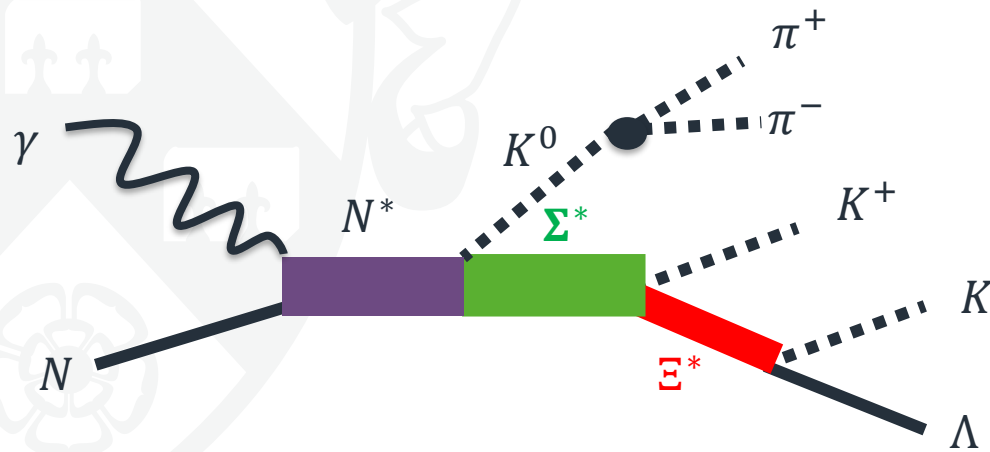


Direct  $\Sigma^*$  production

# Strange beams?



Direct  $\Sigma^*$  production



Associated production

# Sigma factory

$$K_L p \rightarrow \Sigma^* \rightarrow K_S p$$

$$K_L p \rightarrow \Sigma^* \rightarrow \pi^+ \Lambda$$

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

$$K_L p \rightarrow \Sigma^* \rightarrow \pi^0 \Sigma^+$$

$$K_L p \rightarrow \Sigma^* \rightarrow \eta \Sigma^+$$

$$K_L p \rightarrow \Sigma^* \rightarrow \omega \Sigma^+$$

$$K_L p \rightarrow \Sigma^* \rightarrow \eta' \Sigma^+$$

$$K_L p \rightarrow K^+ n$$

2 Body Final state

Pure  $\Sigma^*$  channels

Self-polarising observables

Non-resonant background

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

Isospin amplitudes



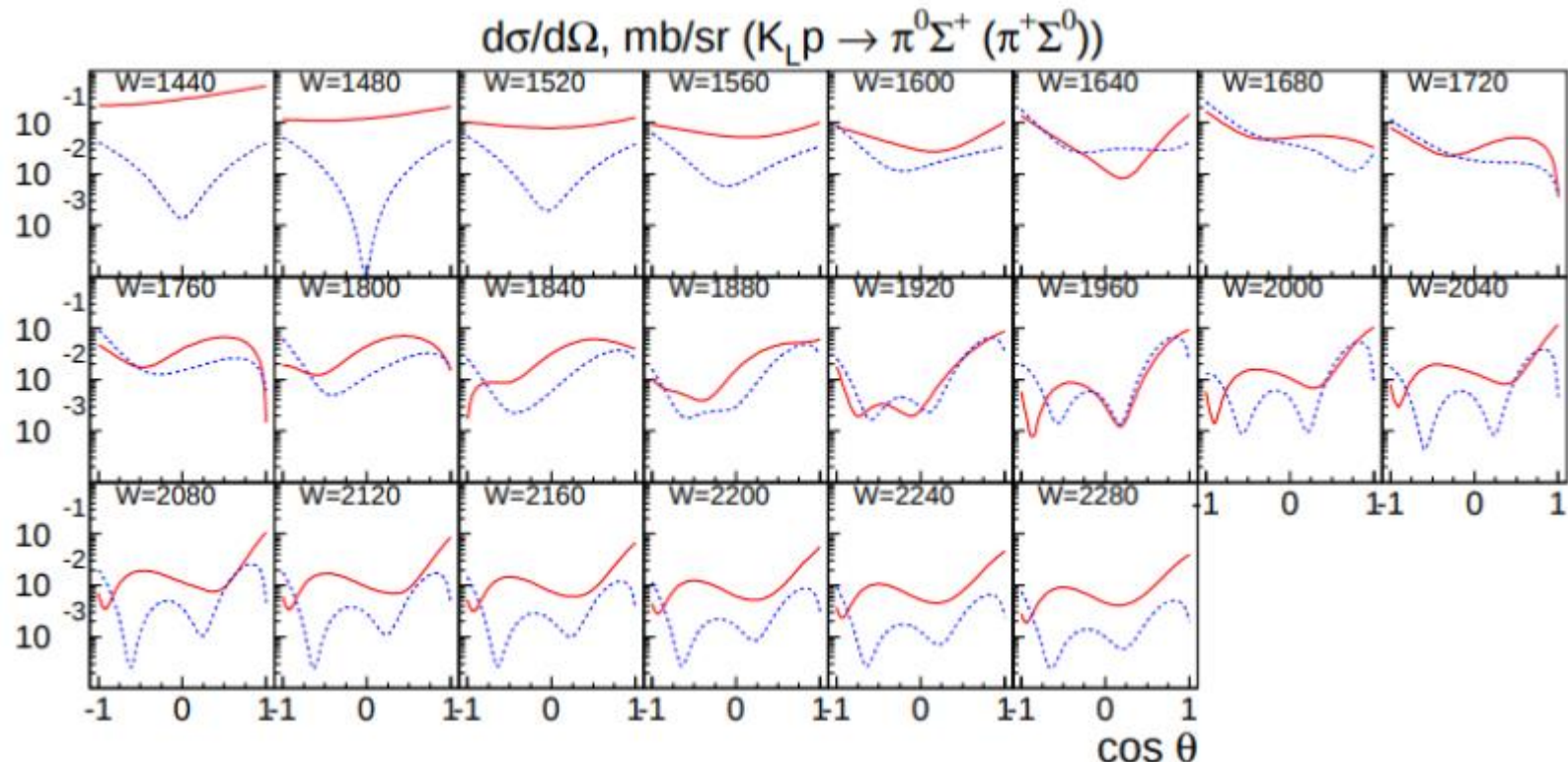
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$$|A(K^- p)|^2 = \frac{1}{2}(|A_1|^2 + |A_0|^2 + 2\text{Re}(A_1 A_0^*))$$

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

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

[arXiv:2008.08215v3](https://arxiv.org/abs/2008.08215v3)  
KLF proposal 2020



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

Isospin amplitudes



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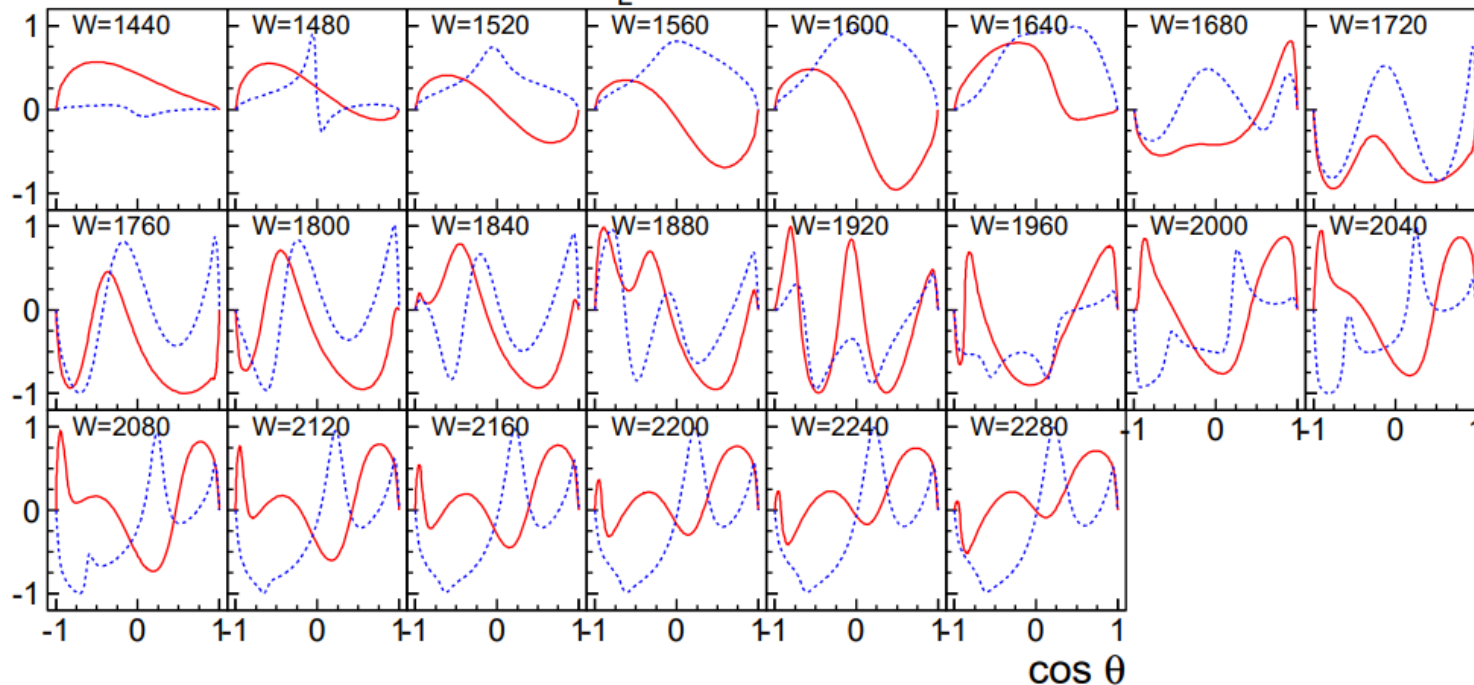
$$|A(K^- p)|^2 = \frac{1}{2}(|A_1|^2 + |A_0|^2 + 2\text{Re}(A_1 A_0^*))$$

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

Recoil asymmetry

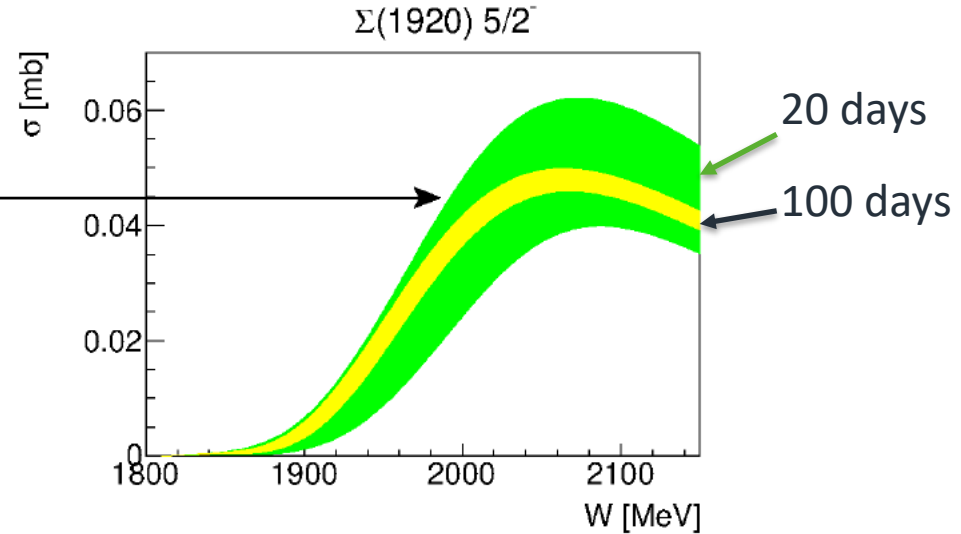
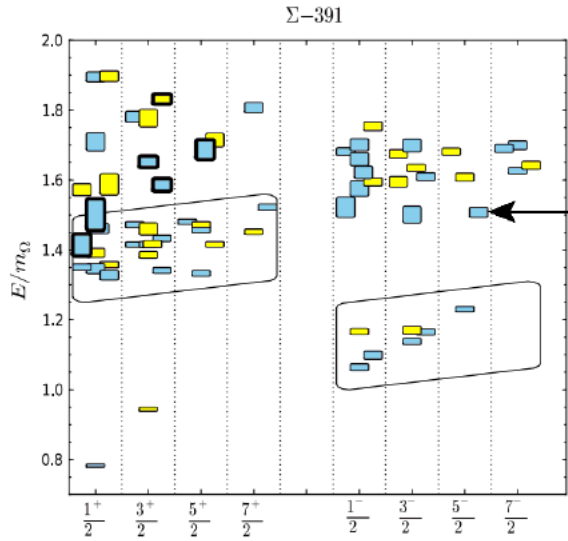
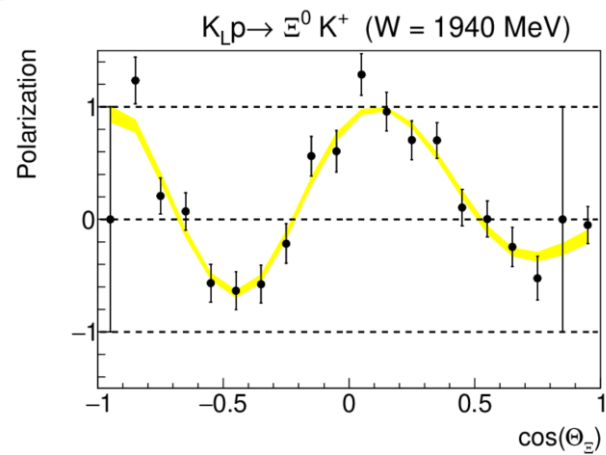
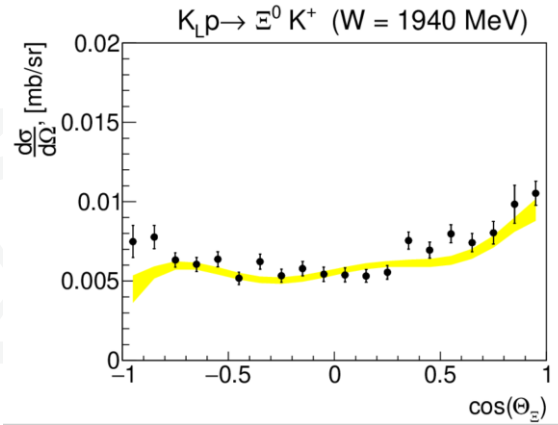
$P(K_L p \rightarrow \pi^0 \Sigma^+ (\pi^+ \Sigma^0))$



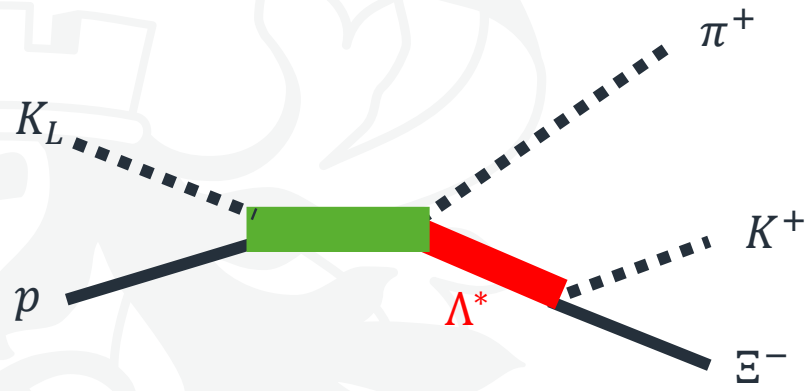
# Expected results



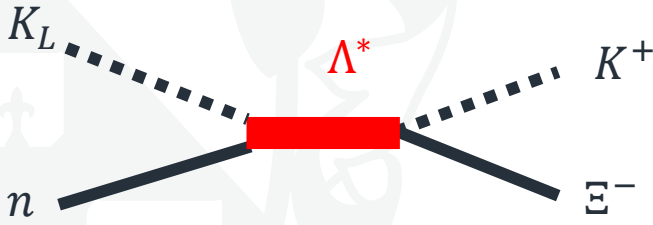
$$K_L p \rightarrow K^+ \Xi^0$$



# Excited $\Lambda^*$



Associated production

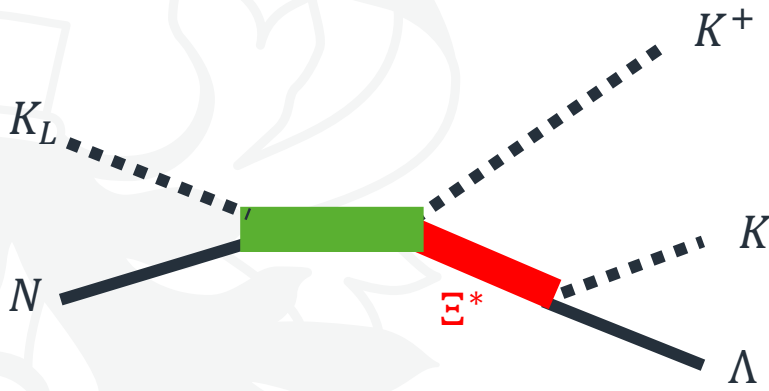


Direct formation

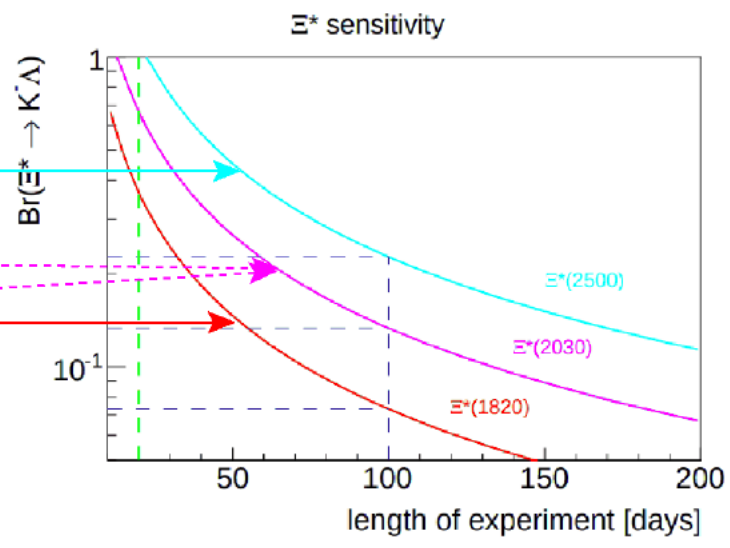
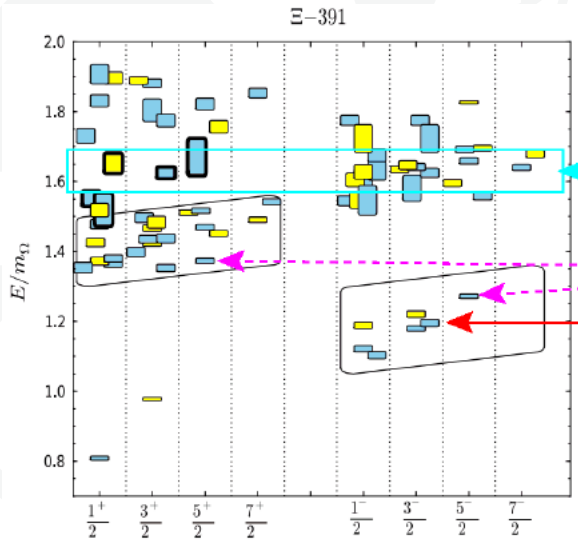
- Interference effects
- $\Lambda - \Sigma$  mixing
- Model-independent PWA
- Different background



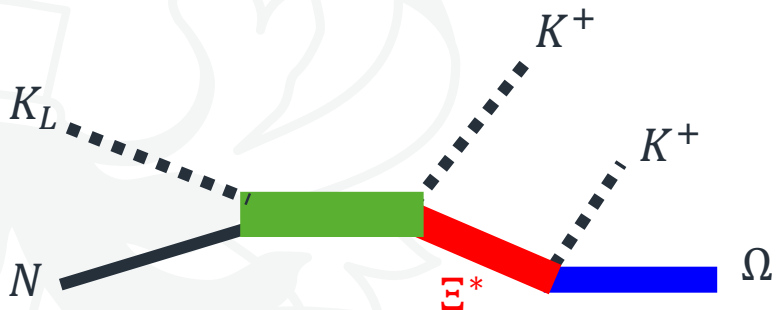
# Excited $\Xi^*$ in associated production



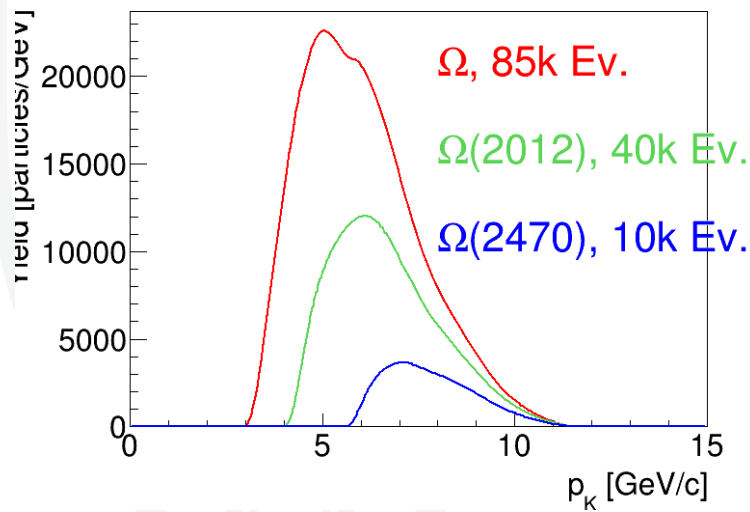
- $\Xi^* \rightarrow \Lambda K$
- $\Xi^* \rightarrow \Xi \pi$
- $\Xi^* \rightarrow \Xi \eta$
- $\Xi^* \rightarrow \Xi \omega$
- $\Xi^* \rightarrow \Sigma K$



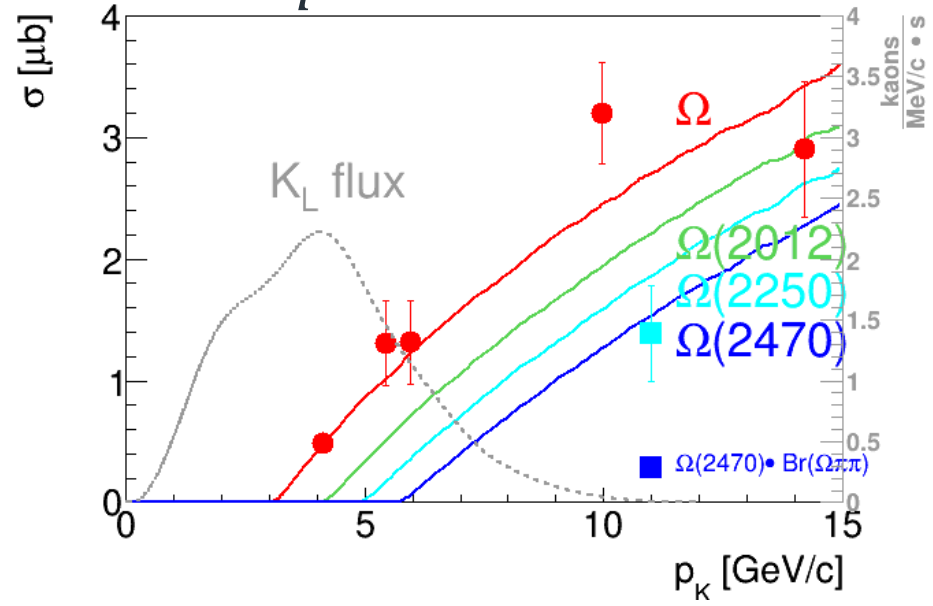
# Excited $\Omega^*$ in associated production



Expected Yield



$$\bar{K}p \rightarrow \Omega^* X$$





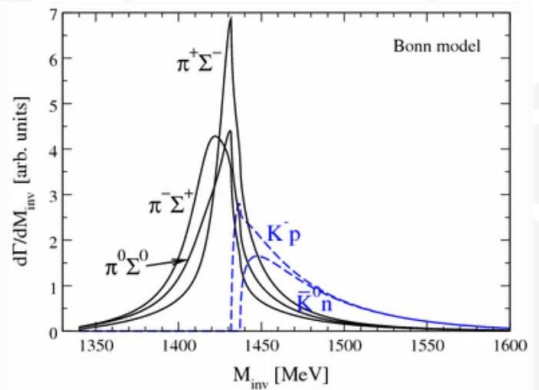
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# Why Strangeness?

# Molecules and cusps



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



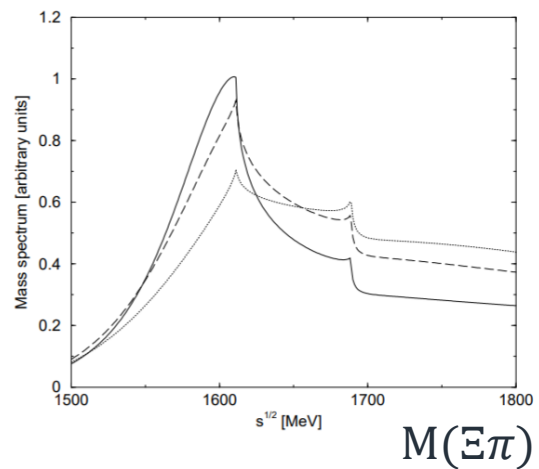
• [L. Roca](#), [M. Mai](#), [E. Oset](#) & [Ulf-G. Meißner](#)

- Many thresholds
  - Cusps
  - Molecules
  - Dynamic resonances

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

States?  
Decay channels?  
Resolution?

$\Xi(1620)$



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

$M(\Xi\pi)$

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

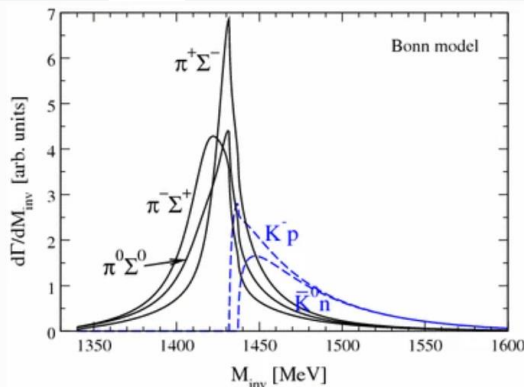
## Heavy quark sector:

- low statistics
- hard to produce
- too narrow

# Strangeness is a key

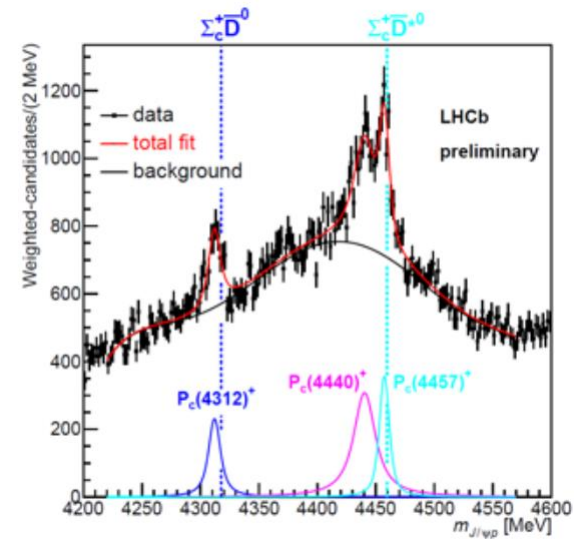
- Many thresholds
  - Cusps
  - Molecules
  - Dynamic resonances

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



• [L. Roca](#), [M. Mai](#), [E. Oset](#) & [Ulf-G. Meißner](#)

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

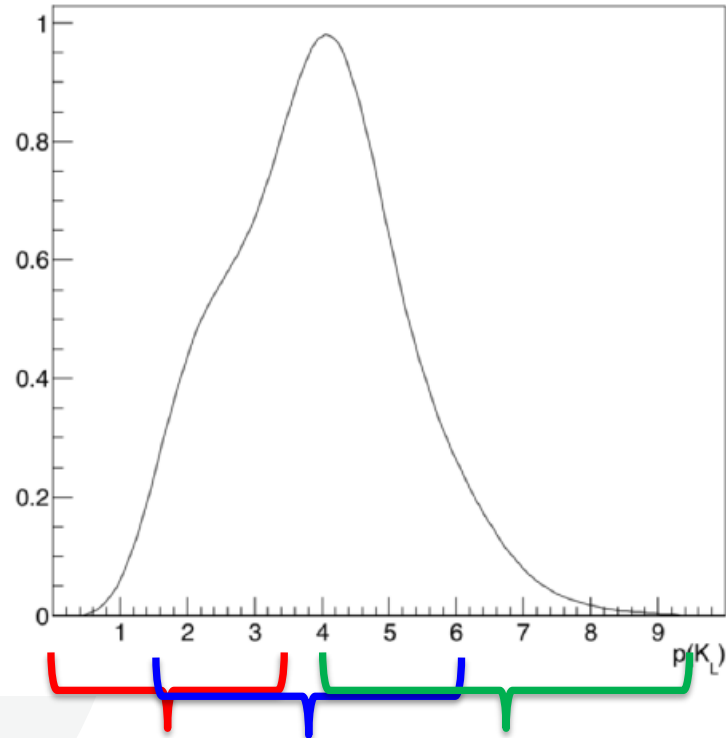


$P(4450) \leftrightarrow \bar{D}^*\Sigma_c$ -molecule

Continuous beam  $\rightarrow$  small systematics

# KLF spectroscopy

$K_L$  beam profile

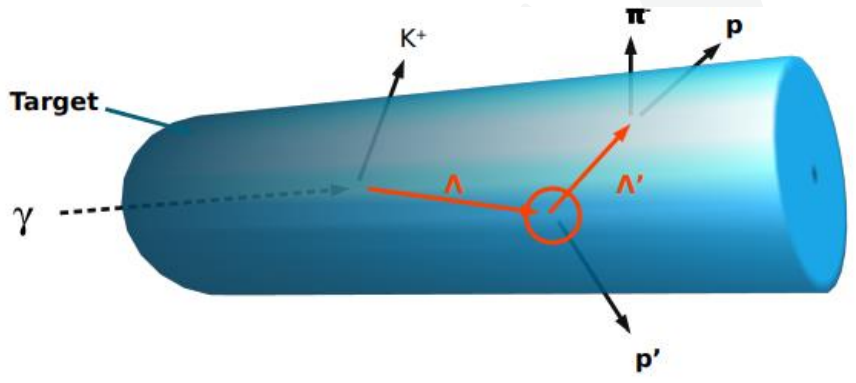


Direct formation

Meson spectroscopy

Associated production

# Hyperon-nucleon Scattering



## Cross sections

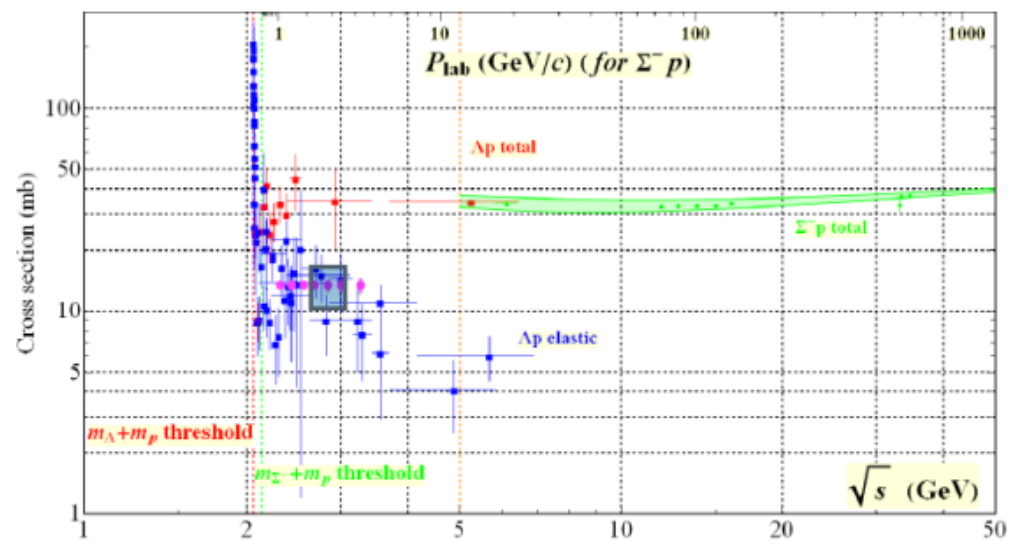
- $\Lambda p$
- $\Sigma^- p$
- $\Sigma^+ p$
- $\Lambda d$

## Polarization observables

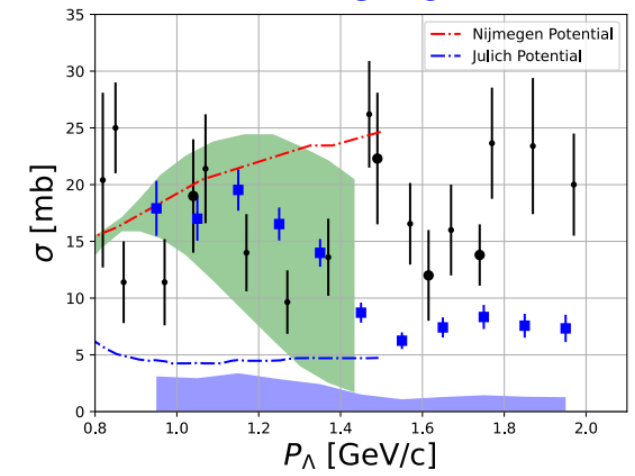
- $\Lambda n$
- $\Sigma^- p$
- $\Lambda d$
- $\Lambda p$

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)

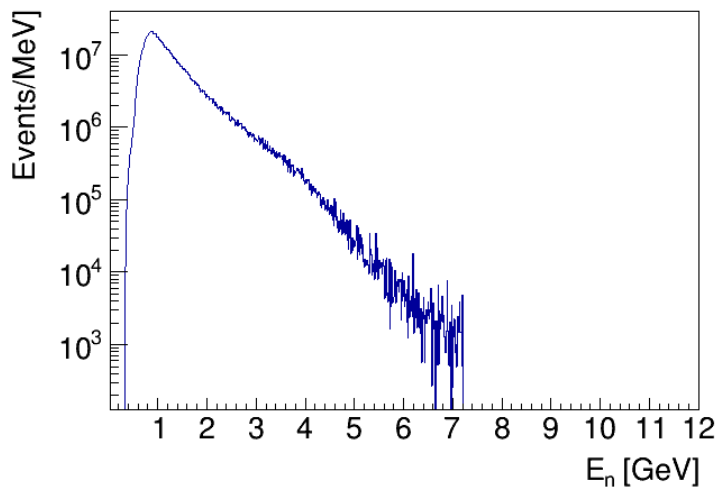
| Reaction                          | Statistics<br>(events) |
|-----------------------------------|------------------------|
| $K_L p \rightarrow K_S p$         | 2.7M                   |
| $K_L p \rightarrow \pi^+ \Lambda$ | 7M                     |
| $K_L p \rightarrow K^+ \Xi^0$     | 2M        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

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

# Neutron beam

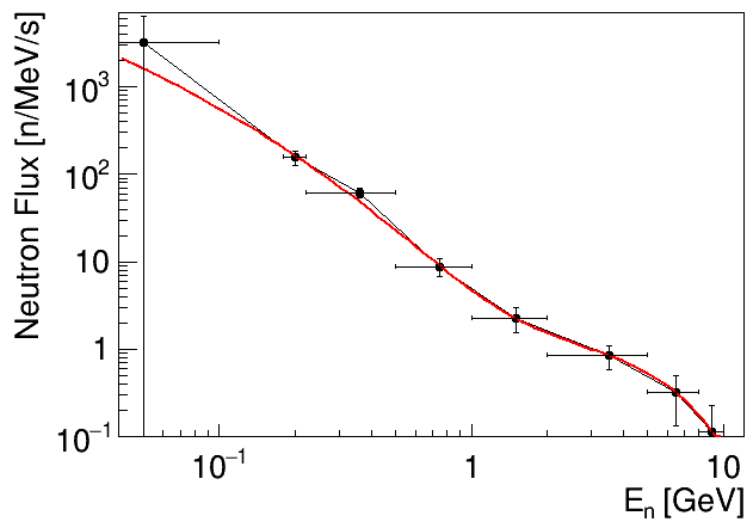


Neutron induced reactions (hadrons)



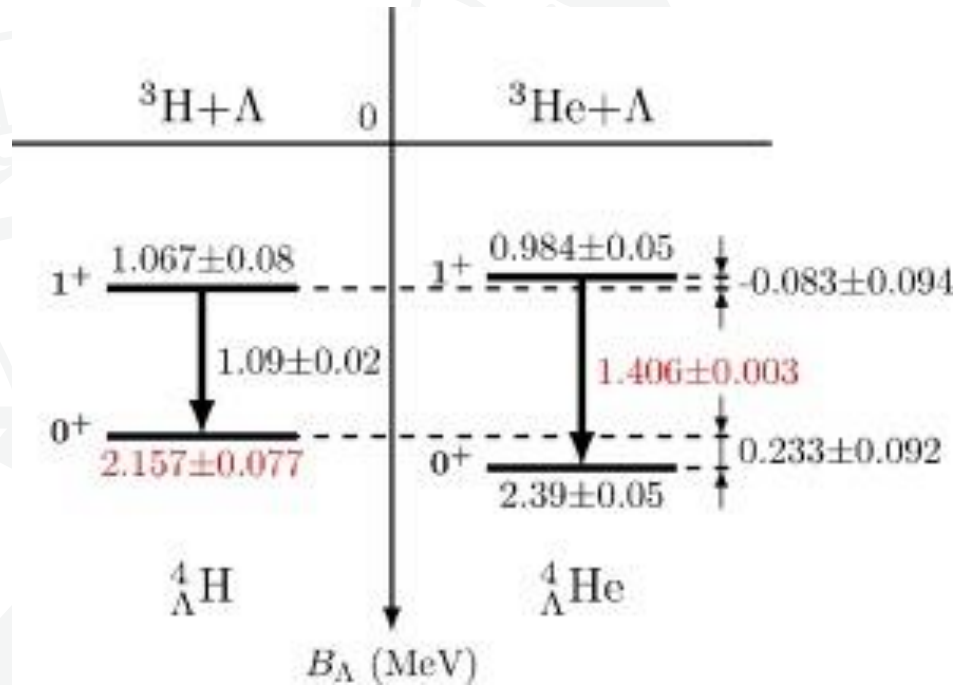
np reaction X-sections from SAID

Neutron flux



Low energy Neutron induced reactions-> Nuclear structure

# Hypernuclei

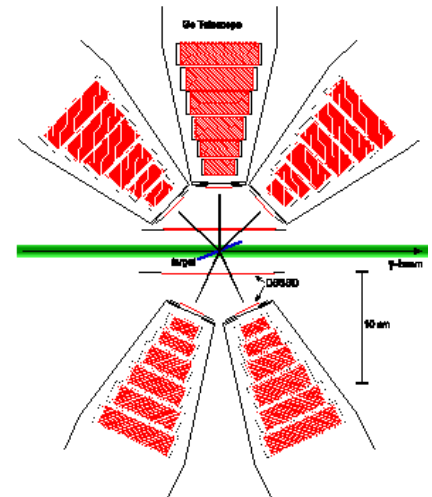


Daniel Gazda, Avraham Gal, NPA 954, 161, (2016)

Usual routes:  $K^- n \rightarrow \Lambda \pi^-$   
 $\pi^+ n \rightarrow \Lambda K^+$

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

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



# Possible improvements



- 24 GeV electron beam →  $\Omega$  production studies
- More intense beam (CPS, shielding, radiator...)
- Theory

New collaborators welcome!!!

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

# NSTAR2024

# York UK

June 17-21<sup>st</sup> 2024

# NSTAR2024

## June 17th-21st

14th International Workshop on the  
Physics of Excited Nucleons

NSTAR2024

- Baryon spectrum through meson photoproduction
- Baryon resonances in experiments with hadron beams and in the e+e- collisions
- Baryon resonances in ion collisions and their role in cosmology
- Baryon structure through meson electroproduction, transition form factors, and time-like form factors
- Amplitude analyses and baryon parameter extraction
- Effective field theory, Phenomenological models, and Functional methods
- Baryon spectrum and structure from first principles of QCD
- Exotic Hadrons
- Advances in the modelling of baryon spectrum and structure
- Facilities and future projects
- Other topics related to N\* physics.

### IMPORTANT INFORMATION

**Venue:** Hilton Hotel, York, United Kingdom

**Abstracts submissions opens:** January 15th, 2024

**Abstracts submissions closes:** April 12th, 2024

**Registration deadline:** June 1st, 2024

[Nstar24-conference@york.ac.uk](mailto:Nstar24-conference@york.ac.uk)

<https://indico.jlab.org/e/NSTAR24>


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