Preliminary Study of $\Lambda\eta$ Threshold Dynamics in the J-PARC E72 Experiment

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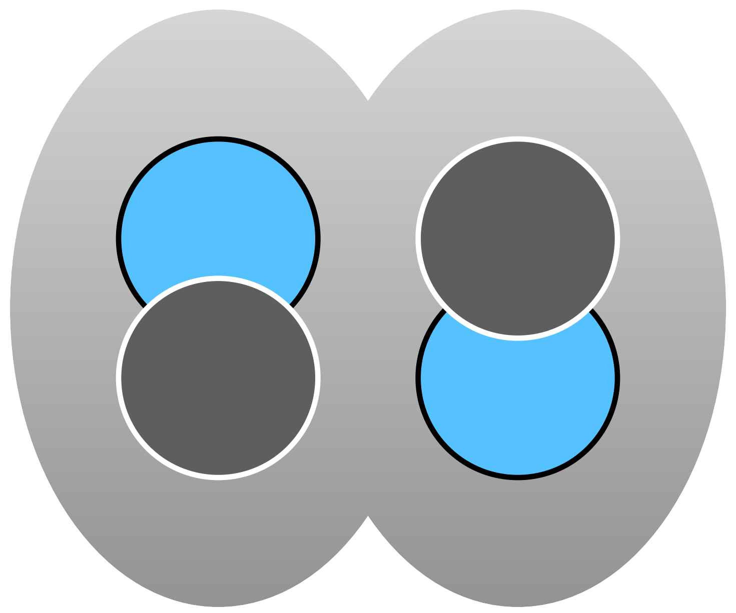
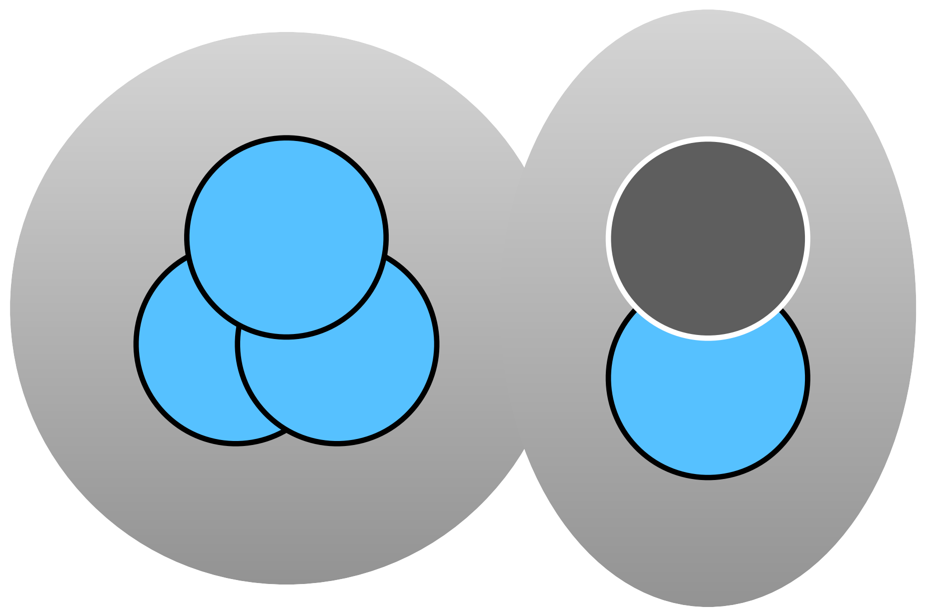
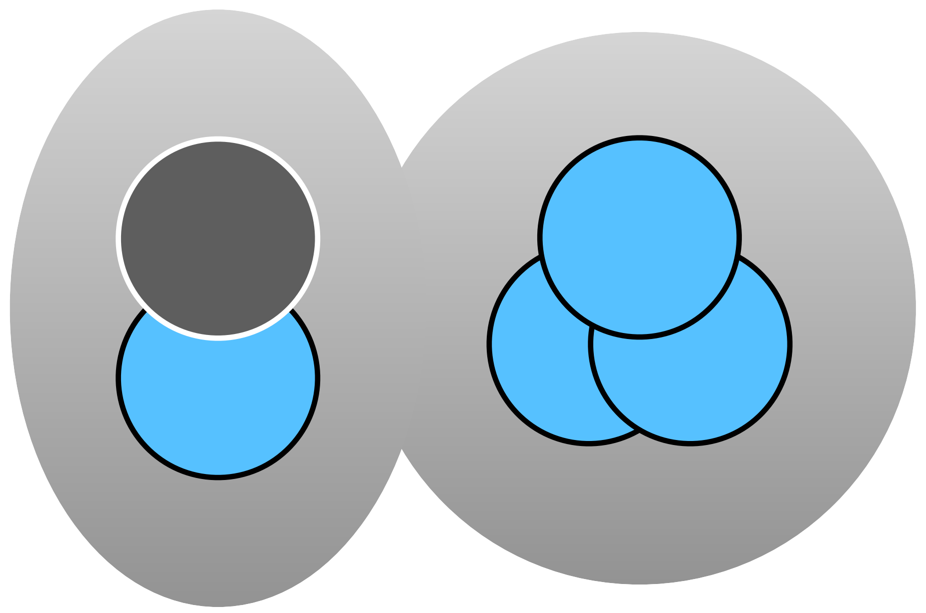
Exotic hadrons and hadron structure

Heavy-quark sector

Strange sector







$X(3872)$, T_{cc} $\qquad$ P_c $\qquad$ $\Lambda(1405)$

$D\bar{D}^*$ $\qquad$ DD^* $\qquad$ $\Sigma_c\bar{D}^{(*)}$ $\qquad$ $\bar{K}N \leftrightarrow \pi\Sigma$

Many exotic candidates lie close to hadronic thresholds.

Threshold spectroscopy probes exotic hadron structure.

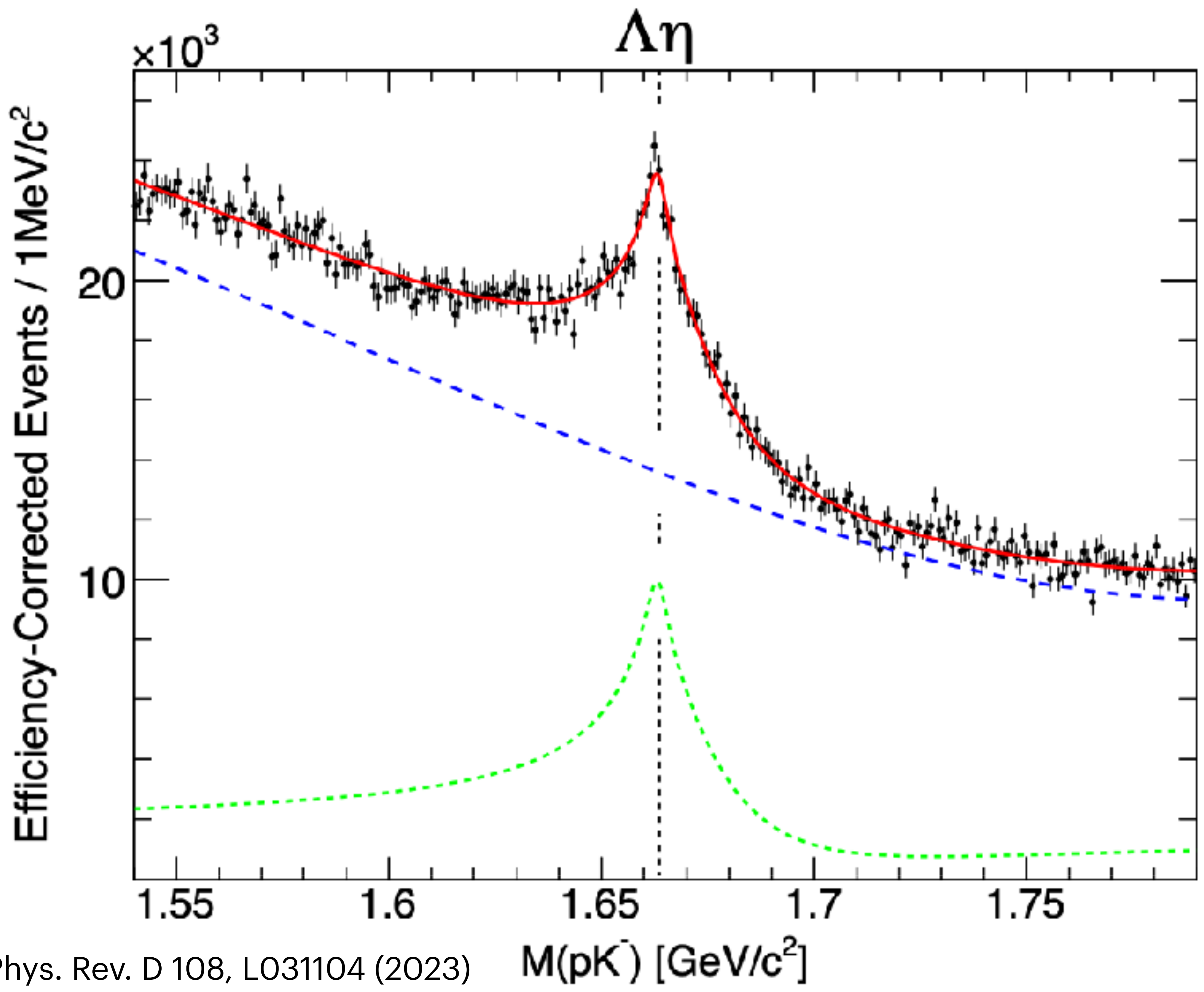
Why is the $\Lambda\eta$ threshold interesting?

- $\Lambda(1670)\ J^P = \frac{1}{2}^-$
- $m_\Lambda + m_\eta \simeq 1663.5$

- $\Lambda\eta$: **pure** $I = 0,\ S = -1$ **channel**
- $\Lambda(1670) \to \Lambda\eta$: **S-wave**
- **Diagonal LO WT** $V_{\Lambda\eta,\Lambda\eta} = 0$
- **Coupled channels:** $\Lambda\eta, \bar{K}N,\ \pi\Sigma, K\Xi$

The $\Lambda\eta$ threshold probes
both coupled-channel dynamics and the structure of the $\Lambda(1670)$.

The $\Lambda\eta$ threshold is visible in another channel



Phys. Rev. D 108, L031104 (2023)

$$\Lambda_c^+ \to pK^-\pi^+$$

Sharp structure at the $\Lambda\eta$ threshold.

Well described as a coupled-channel cusp influenced by the nearby $\Lambda(1670)$.

Threshold dynamics can appear in channels other than $\Lambda\eta$.

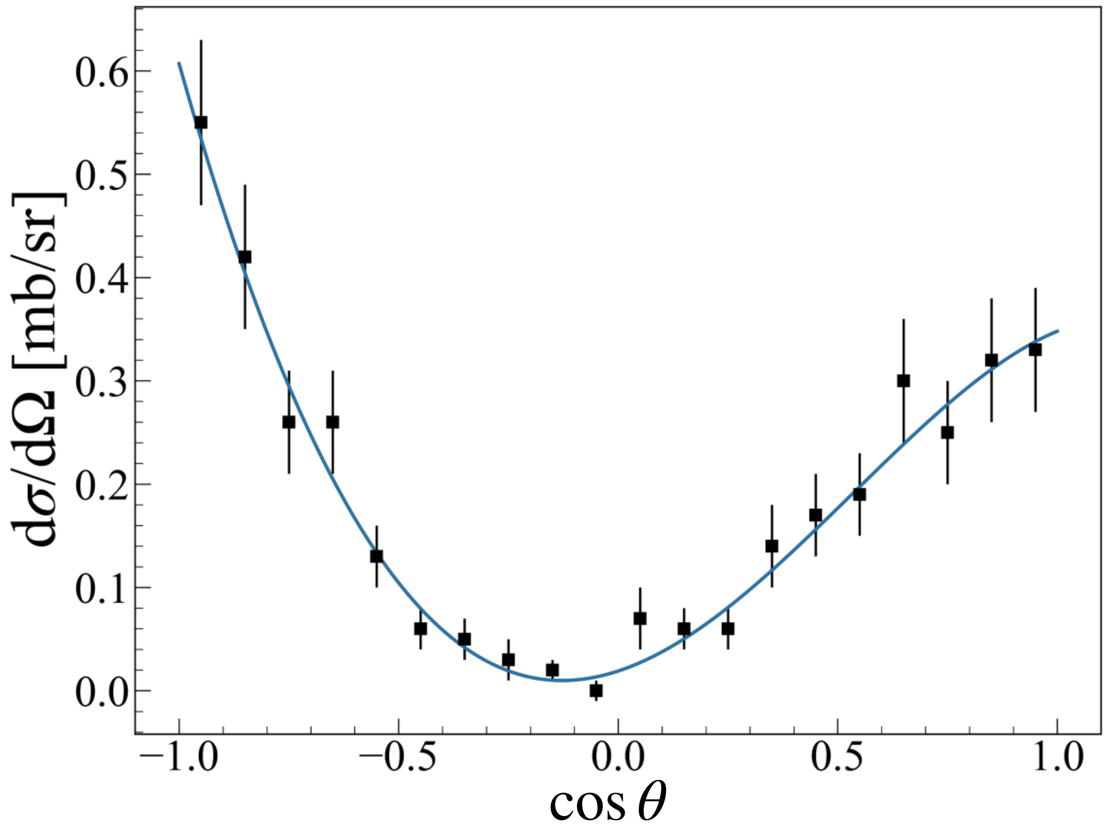
Hints of $\Lambda\eta$ threshold dynamics in old K^-p data

Nucl. Phys. B 21, 15 (1970)
Nucl. Phys. B 96, 54 (1975)
Nucl. Phys. B 8, 233 (1968)
Nucl. Phys. B 90, 349 (1975)
Phys. Rev. D 17, 2226 (1978)
Phys. Rev. C 80, 025204 (2009)

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

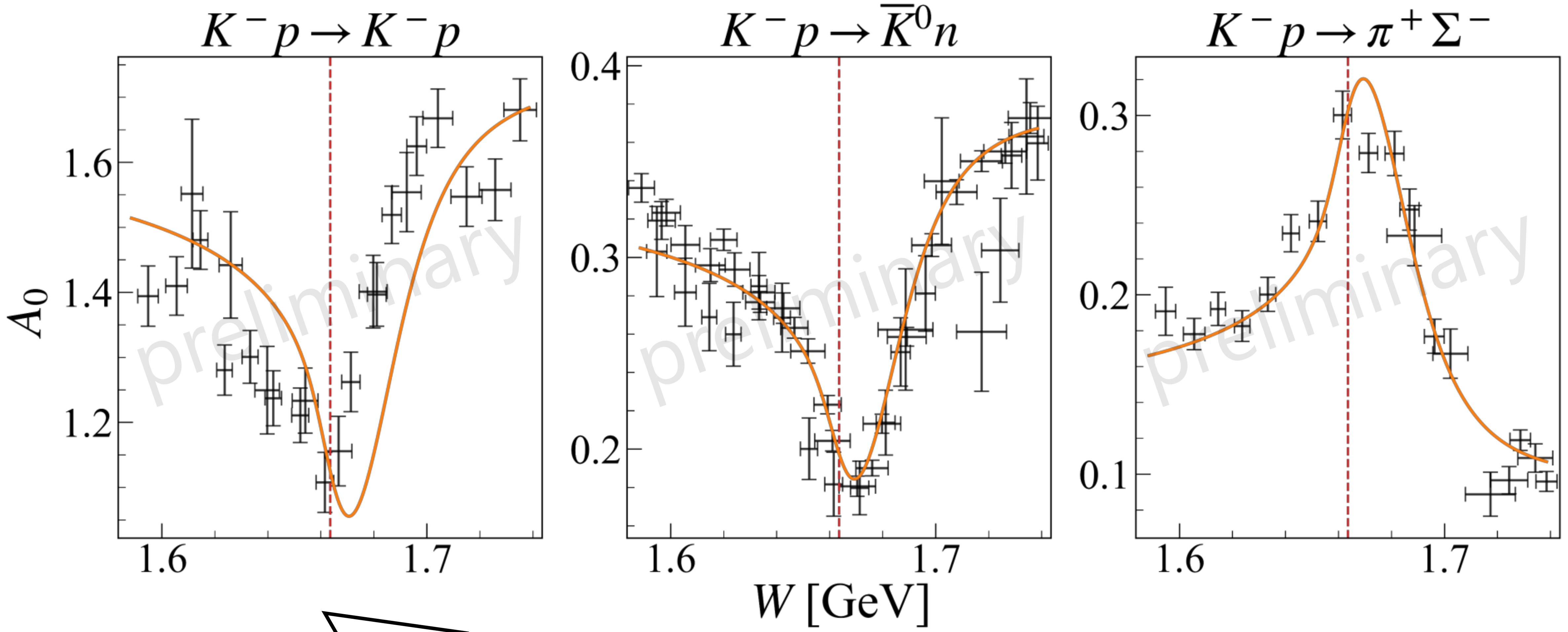
$\cos\theta$ (c.m.)	793 MeV/c
−0.95	0.55 ± 0.08
−0.85	0.42 ± 0.07
−0.75	0.26 ± 0.05
−0.65	0.26 ± 0.05
−0.55	0.13 ± 0.03
−0.45	0.06 ± 0.02
−0.35	0.05 ± 0.02
−0.25	0.03 ± 0.02
−0.15	0.02 ± 0.01
−0.05	0.00 ± 0.01
0.05	0.07 ± 0.03
0.15	0.06 ± 0.02
0.25	0.06 ± 0.02
0.35	0.14 ± 0.04
0.45	0.17 ± 0.04
0.55	0.19 ± 0.04
0.65	0.30 ± 0.06
0.75	0.25 ± 0.05
0.85	0.32 ± 0.06
0.95	0.33 ± 0.06

Fitting with Legendre Polynomials



$$A_0^i = C^i \left| \frac{e^{i\delta^i}\left[\sin\delta^i + i\,\mathrm{Im}\left(e^{-i\delta^i}A\right)k - \frac{1}{2}\,\mathrm{Im}\left(e^{-i\delta^i}AR\right)k^2\right]}{1 - iAk + \frac{1}{2}ARk^2} \right|^2$$

A: $\Lambda\eta$ scattering length ($= a + ib$)
R: $\Lambda\eta$ effective range



Fit result (χ/ndf = 347.5/74)

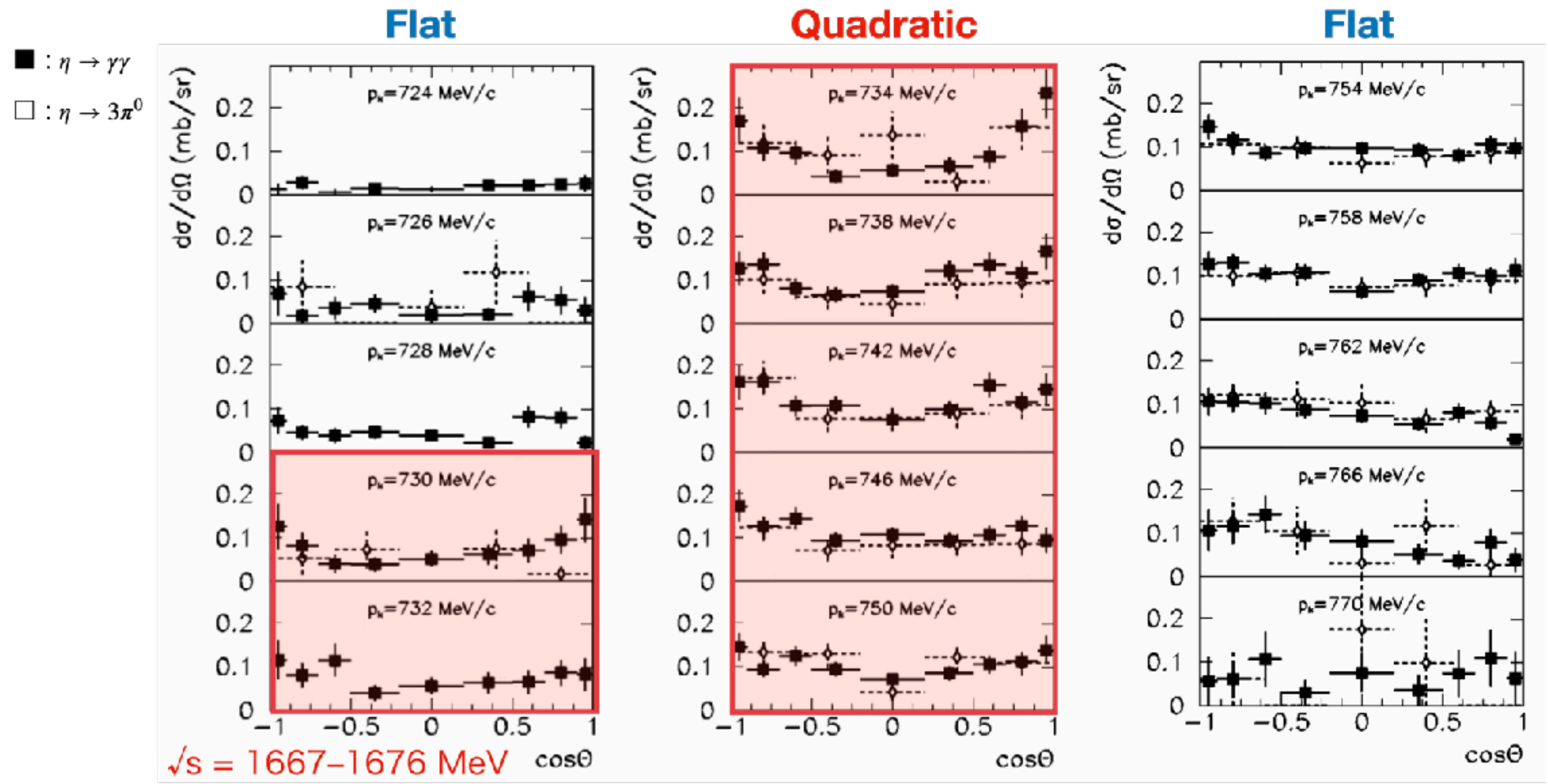
a [fm]		1.61 ± 0.08
b [fm]		0.06 ± 0.01
$\mathrm{Re}(R)$ [fm]		-2.6 ± 0.2
$\mathrm{Im}(R)$ [fm]		-0.08 ± 0.02
$K^-p \to K^-p$	C^{Kp}	19 ± 4
	δ^{Kp}	6.04 ± 0.03
$K^-p \to \bar{K}^0 n$	C^{Kn}	8 ± 2
	δ^{Kn}	2.99 ± 0.02
$K^-p \to \pi^+\Sigma^-$	$C^{\pi\Sigma}$	14 ± 3
	$\delta^{\pi\Sigma}$	0.16 ± 0.02

Sensitive to the $\Lambda\eta$ threshold dynamics,

but old data sets are not mutually consistent.

Another puzzle at the same threshold

Differential Cross Sections of $K^{-}p \to \Lambda\eta$



Phys. Rev. C 64, 055205 (2001)

Possible extra narrow Λ^* not predicted by quark model

$$\Lambda(1665)\ J = \frac{3}{2}?$$

Parity not determined.

Narrow $J = 3/2$ contribution was suggested.

J-PARC E72: high-statistics K^-p data near the $\Lambda\eta$ threshold

$J^P = 1/2^-$ threshold dynamics

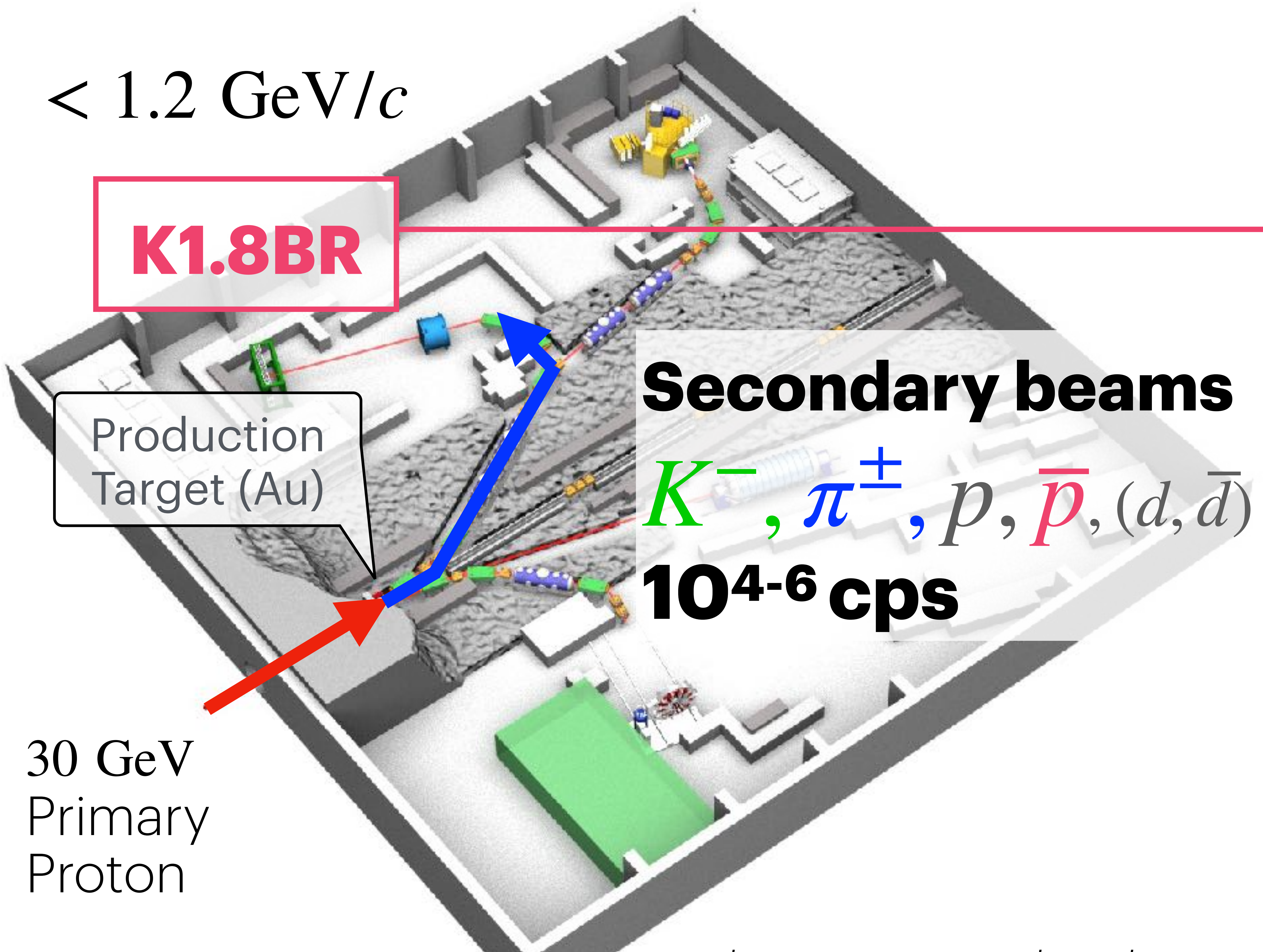
- **S-wave / $A0$**
- **Coupled-channel cusp**
- **Constrain $\Lambda\eta$ scattering parameters**
- **$\Lambda(1670)$ coupling / structure**

Possible $J = 3/2$ contribution

- **Differential cross section**
- **Angular distribution**
- **Test the narrow $J = 3/2$ contribution**

E72 addresses both puzzles with high-statistics K^-p data.

J-PARC Hadron Experimental Facility



Hadron Experimental Facility

$K^- p$ **near** $\Lambda\eta$ **threshold (E72)**

N^*/Δ^* **spectroscopy (E45)**

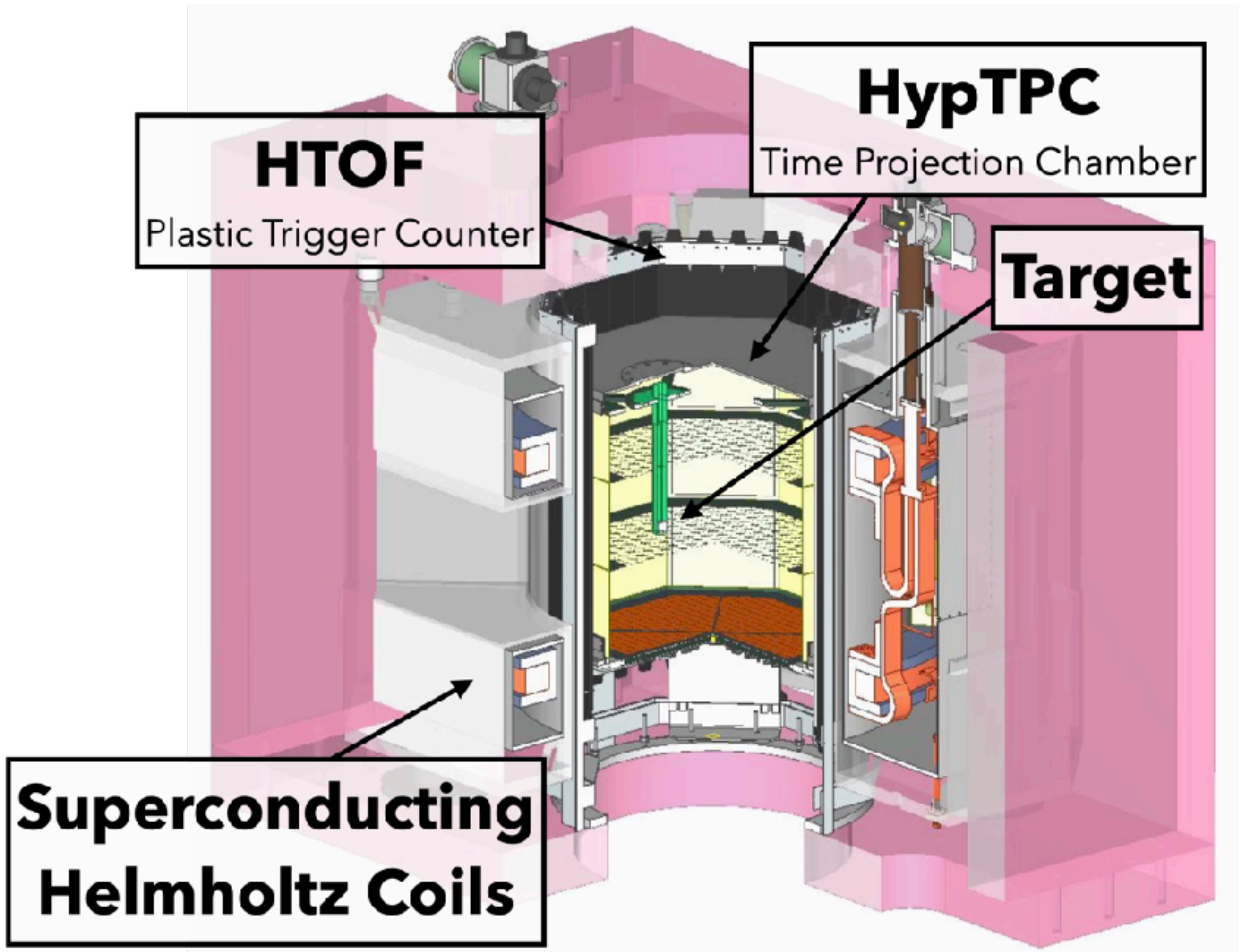
$\bar{p}p \to \phi\phi$ **production (E104)**

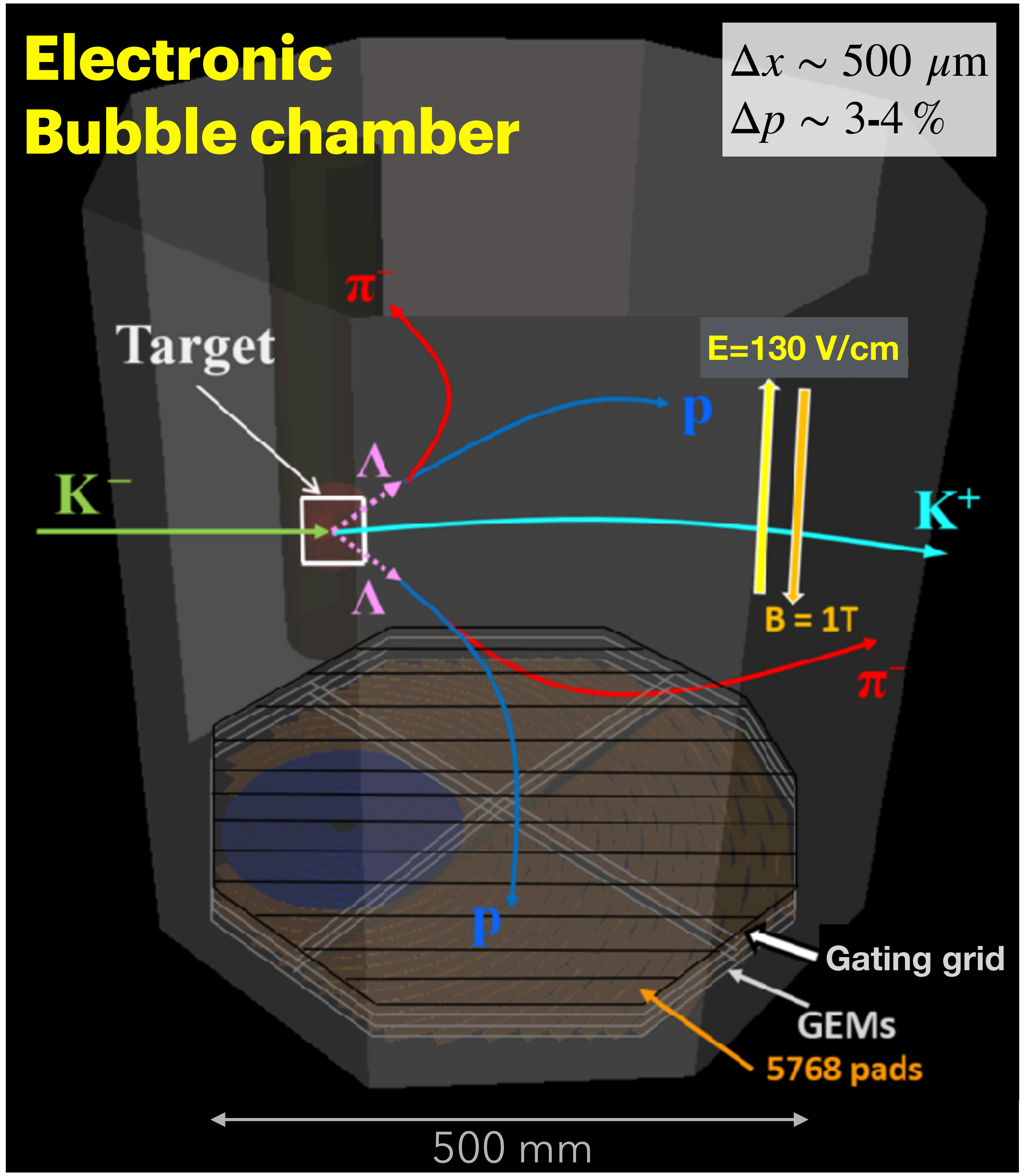
Hadron spectroscopy and exotic hadron searches

Hyperon Spectrometer / HypTPC

Reconstruction of charged multi-particle final states

Hyperon Spectrometer

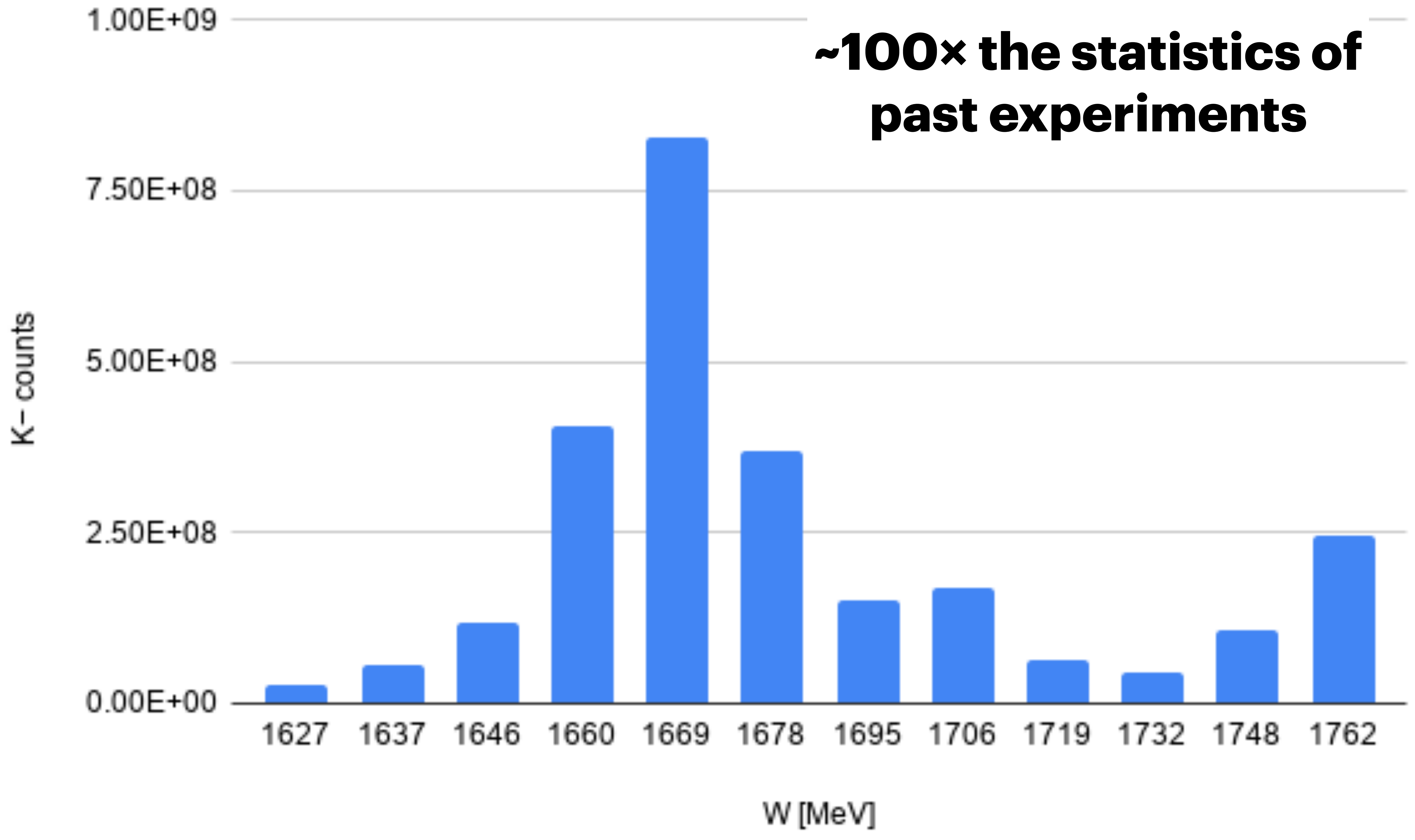




E72 data set covers the $\Lambda\eta$ threshold region

12 beam momenta in $W = 1627\text{–}1762\ \mathrm{MeV}$

2.6 G K^- reaching the target

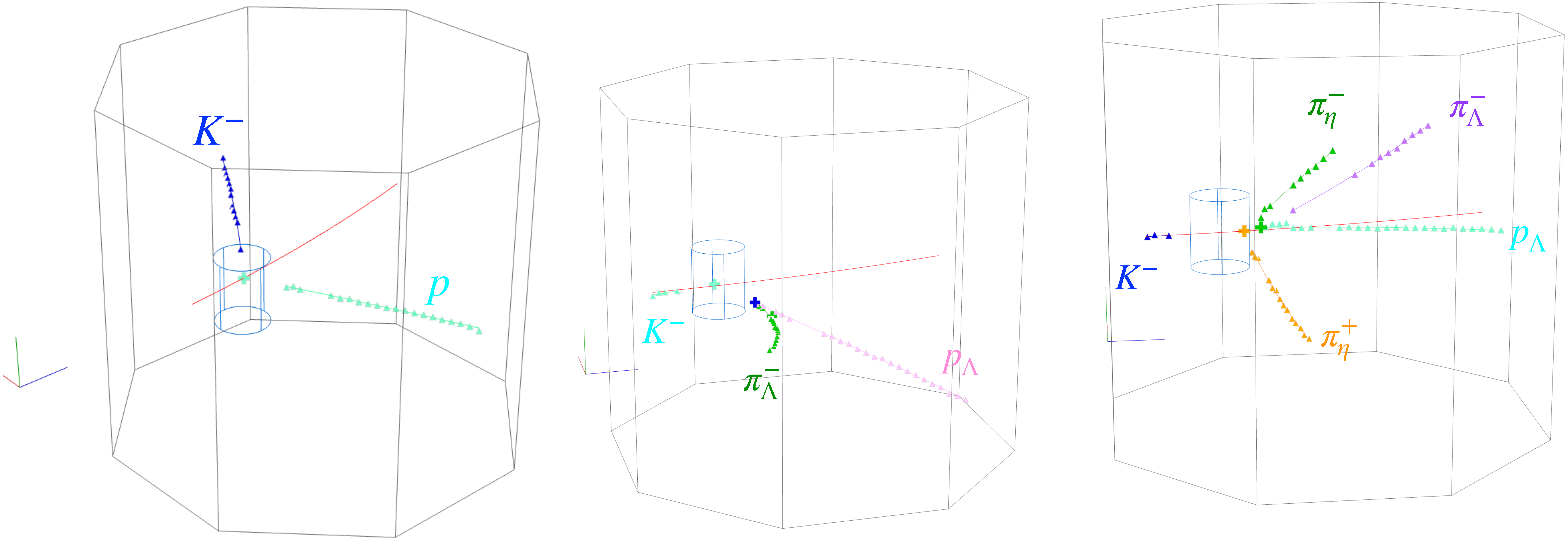


~100× the statistics of past experiments

Nov. 2025

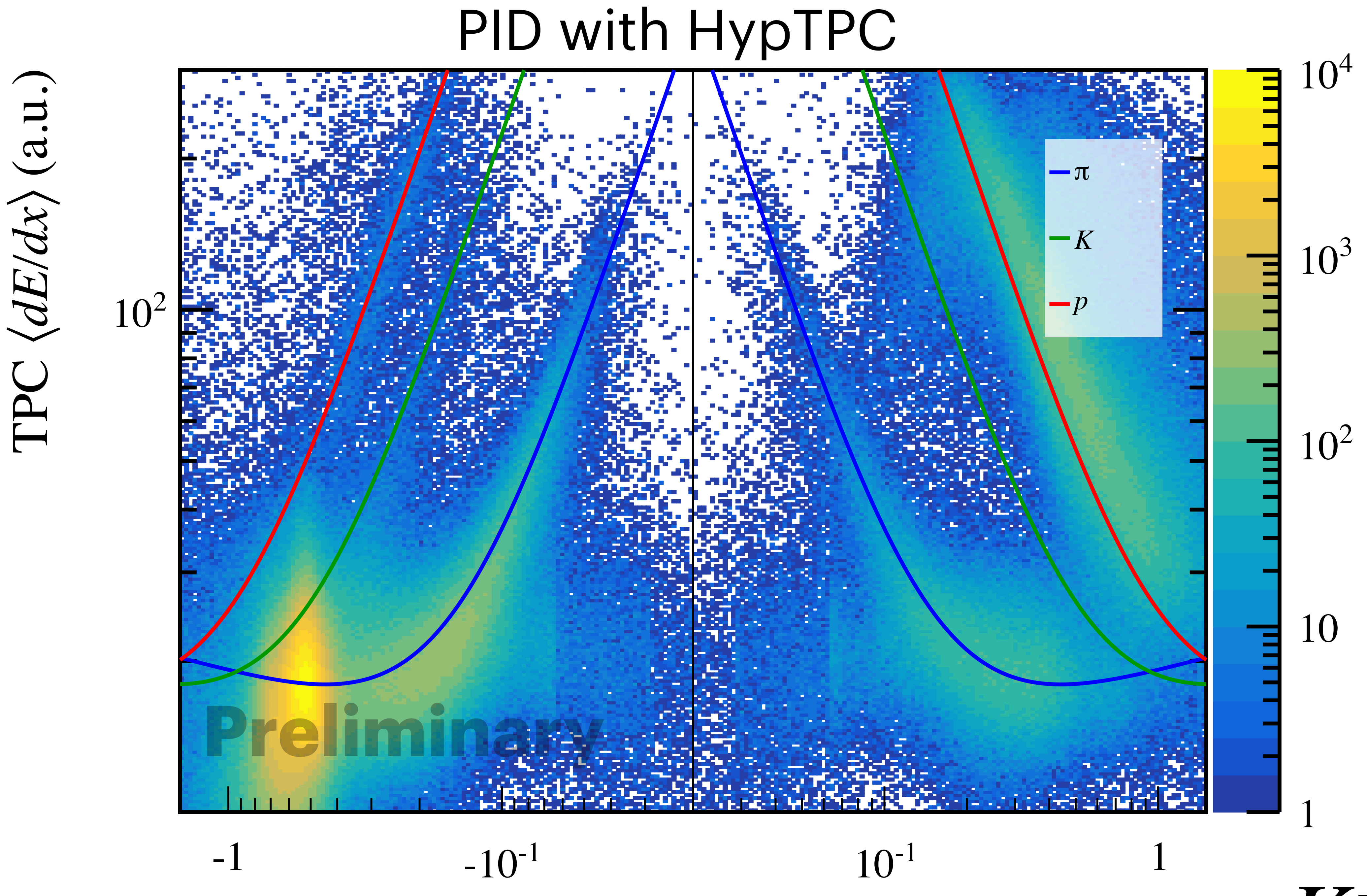
→ Additional data taking scheduled for Nov. 2026

Examples of reconstructed events in E72

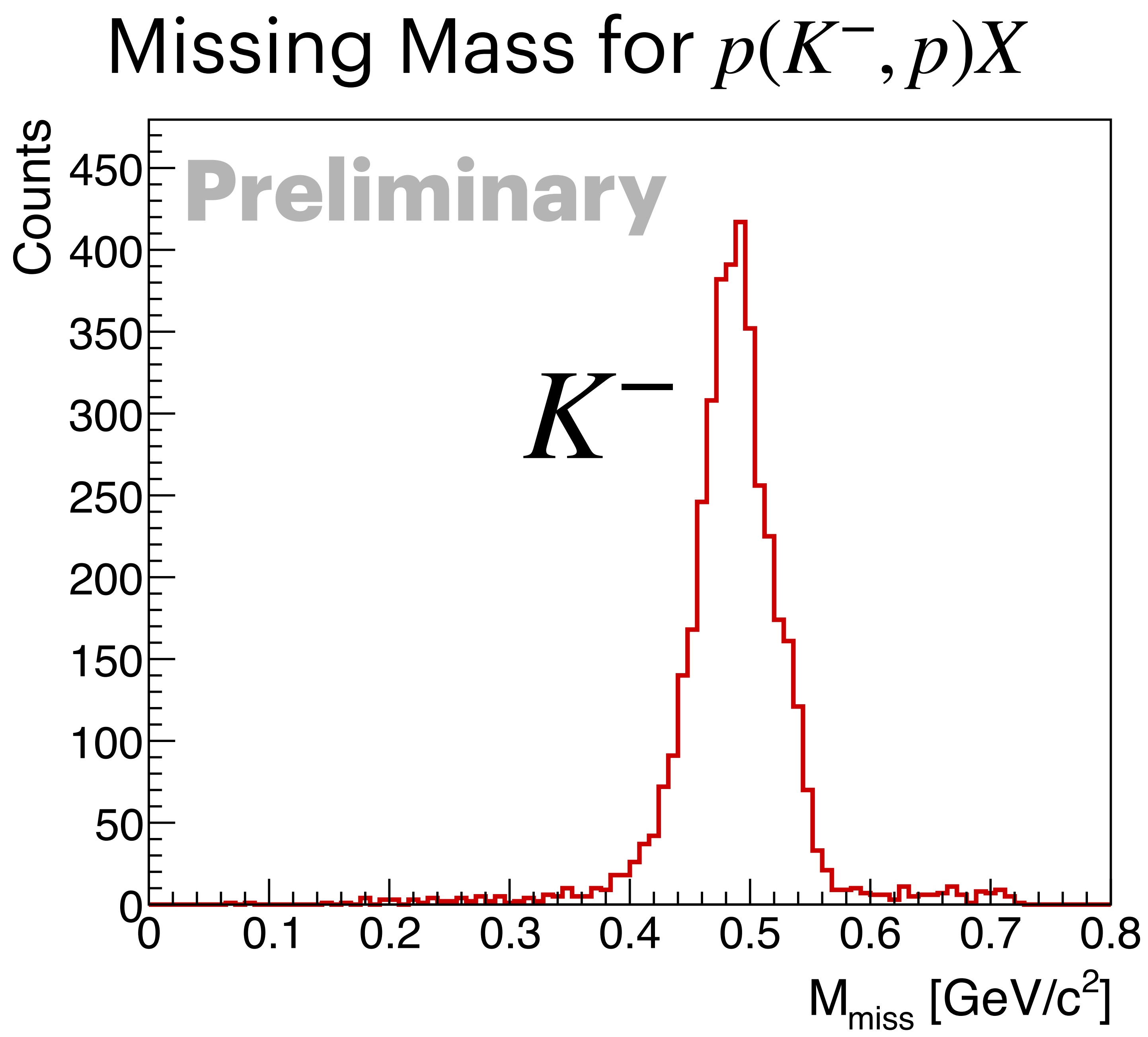


Various K^-p final states are recorded simultaneously.

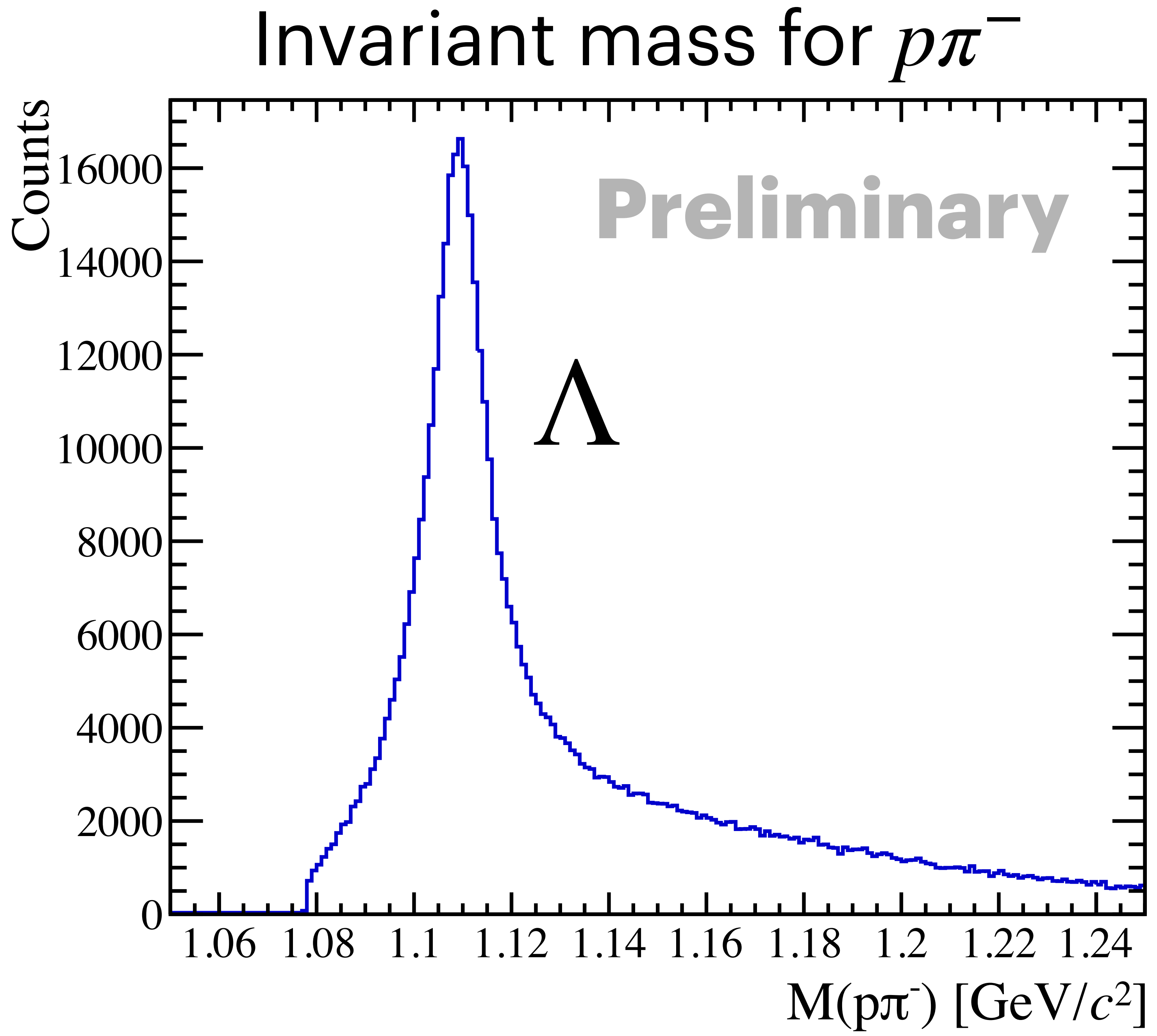
Analysis status



$K^- p \rightarrow K^- p$



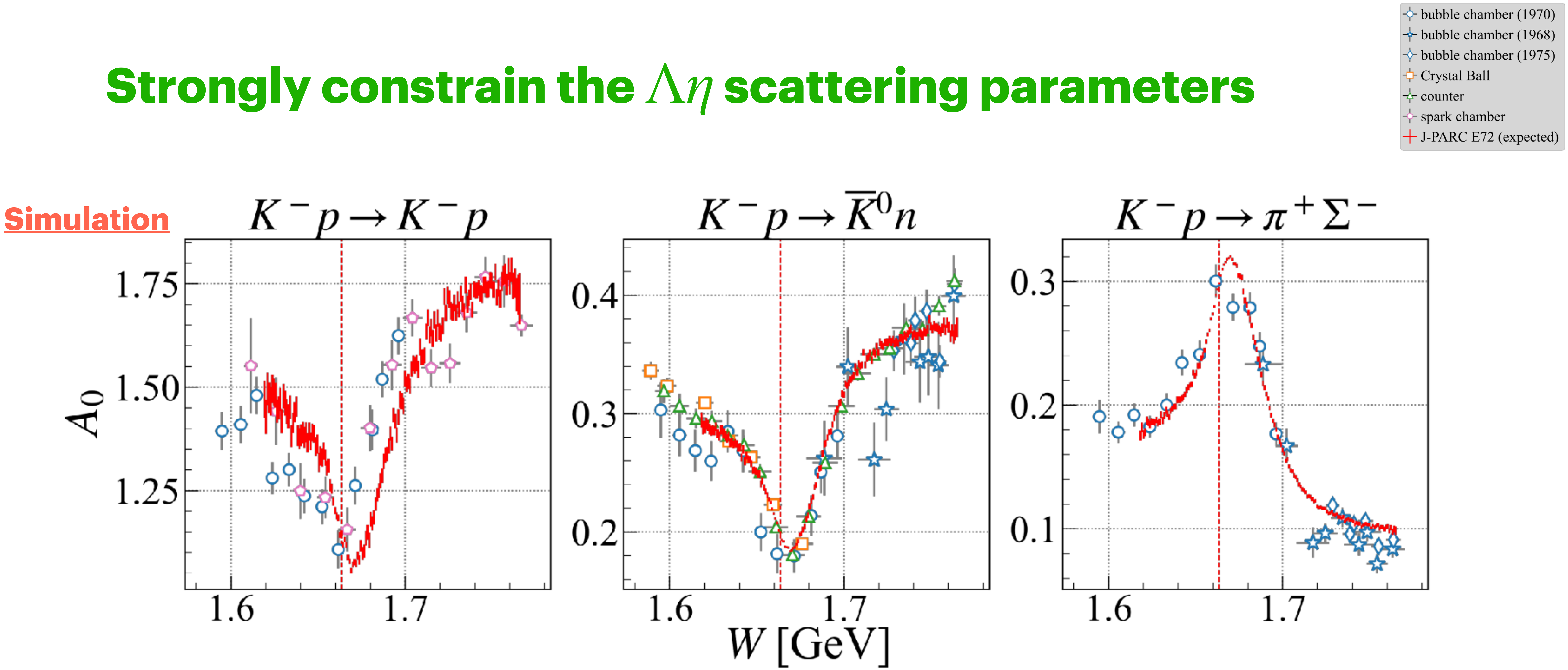
$K^- p \rightarrow \Lambda X$



Basic reconstruction is established;
channel-by-channel analysis is ongoing.

Expected E72 precision for the $\Lambda\eta$ cusp

Strongly constrain the $\Lambda\eta$ scattering parameters



Accessible Λ^*/Σ^* resonances using K^-p reaction

PDG2025

Particle	J^P	Overall status	Status as seen in — $N\overline{K}$	$\Sigma\pi$	Other channels
$\Lambda(1116)$	$1/2^+$	****			$N\pi$ (weak decay)
$\Lambda(1380)$	$1/2^-$	**	**	**	
$\Lambda(1405)$	$1/2^-$	****	****	****	
$\Lambda(1520)$	$3/2^-$	****	****	****	$\Lambda\pi\pi, \Lambda\gamma, \Sigma\pi\pi$
$\Lambda(1600)$	$1/2^+$	****	***	****	$\Lambda\pi\pi, \Sigma(1385)\pi$
$\Lambda(1670)$	$1/2^-$	****	****	****	$\Lambda\eta$
$\Lambda(1690)$	$3/2^-$	****	****	***	$\Lambda\pi\pi, \Sigma(1385)\pi$
$\Lambda(1710)$	$1/2^+$	*	*	*	
$\Lambda(1800)$	$1/2^-$	***	***	**	$\Lambda\pi\pi, N\overline{K}^*$

Particle	J^P	Overall status	Status as seen in — $N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
$\Sigma(1193)$	$1/2^+$	****				$N\pi$ (weak decay)
$\Sigma(1385)$	$3/2^+$	****		****	****	$\Lambda\gamma$
$\Sigma(1580)$	$3/2^-$	*	*	*	*	
$\Sigma(1620)$	$1/2^-$	*	*	*	*	
$\Sigma(1660)$	$1/2^+$	***	***	***	***	
$\Sigma(1670)$	$3/2^-$	****	****	****	****	
$\Sigma(1750)$	$1/2^-$	***	***	**	***	$\Sigma\eta$
$\Sigma(1775)$	$5/2^-$	****	****	****	**	
$\Sigma(1780)$	$3/2^+$	*	*	*	*	
$\Sigma(1880)$	$1/2^+$	**	**	*		

Other opportunities in E72

- $\Sigma\eta$ **threshold:** $\Sigma(1750)$
- $\Lambda(1710)$**: does it exist?**
- $\Sigma(1670)$**: structure and couplings**

→ K1.8 / K10 beam lines for more higher energy

Summary

J-PARC E72: $K^- p$ measurement near $\Lambda\eta$ threshold

- J-PARC E72 collected high-statistics $K^- p$ data across the $\Lambda\eta$ threshold region.
- The data will constrain the $J^P = 1/2^-$ coupled-channel cusp dynamics and $\Lambda\eta$ scattering parameters.
- Also tests the possible narrow $J = 3/2$ contribution in $K^- p \to \Lambda\eta$.