Kaon-Induced Spectroscopy with RF-Separation at the M2 Beamline

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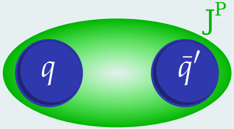
Preceiving the Emergence of Hadron Mass through AMBER@CERN
May 10, 2022

The Strange-Meson Spectrum

Understanding the light-meson spectrum



- Completing $\mathrm{SU}(3)_{\mathrm{flavor}}$ multiplets
- Identifying supernumerous states
  - ➥ Search for exotic strange mesons

Input to other fields of physics

- Strange mesons appear as resonances in multi-body hadronic final states with kaons
- Searches for CP violation
- Searches for physics beyond SM

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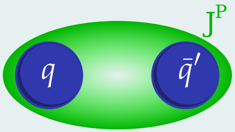

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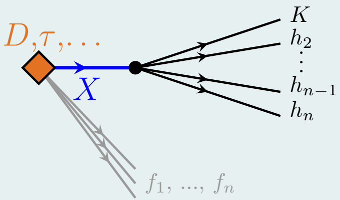

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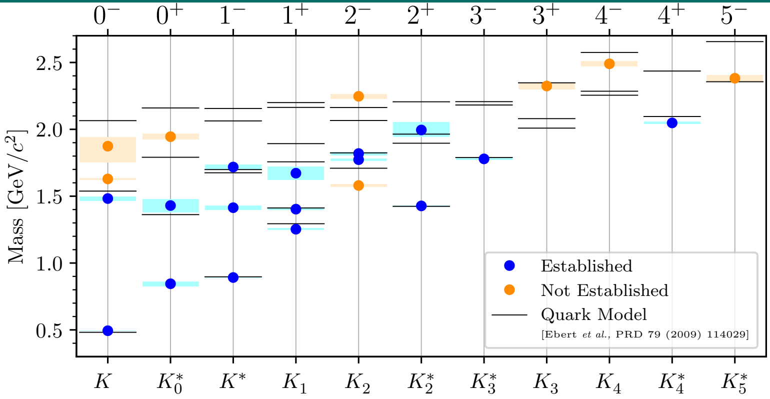

PDG lists 25 strange mesons (2021)

- 16 established states, 9 need further confirmation
- Missing states with respect to quark-model predictions
- Many measurements performed more than 30 years ago

Decays of heavier states

- τ leptons, charmed mesons, and charmonium states: limited mass range
- B mesons: modeling of large Dalitz plots difficult

Diffractive production

- Using high-energy kaon beam
- Strange mesons appear as intermediate resonances
- Allows us to
  - access in principle all strange mesons
  - study a wide mass range
  - study different decay modes

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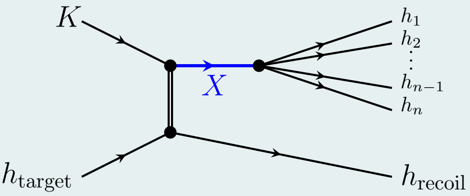
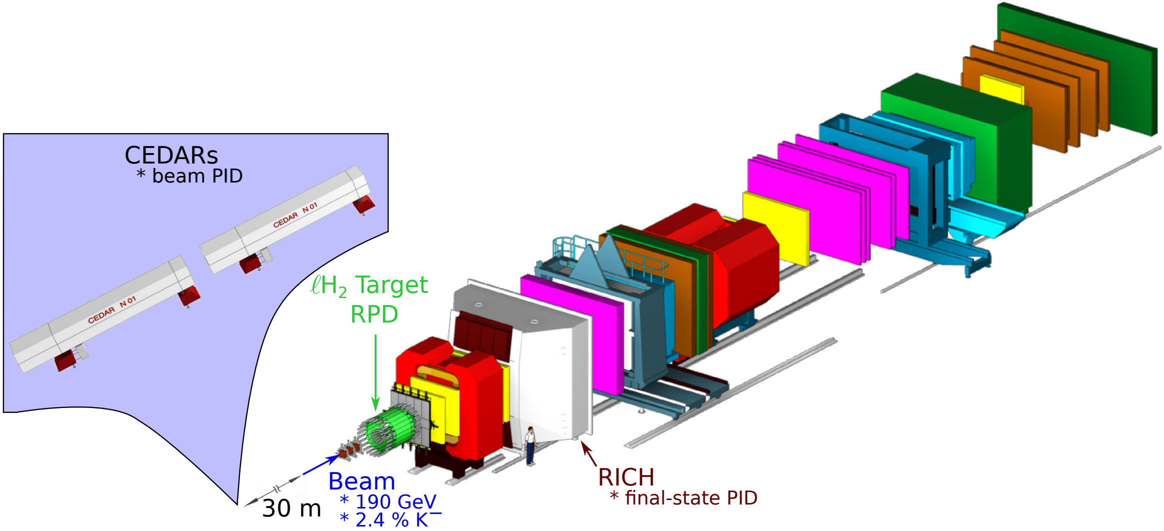


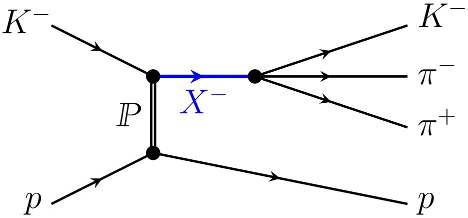
COMPASS Setup for Hadron Beams

[COMPASS, Nucl. Instrum. Methods **779** (2015) 69]

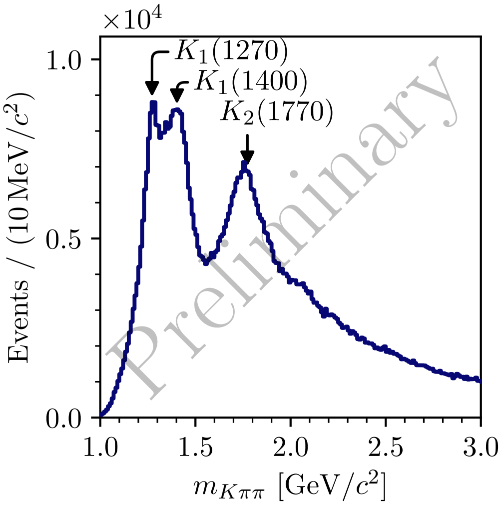


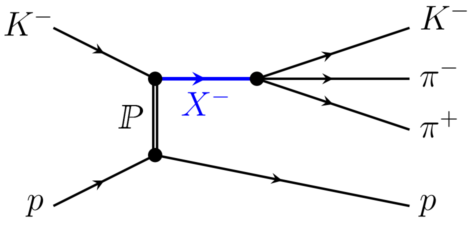
Strange-Meson Spectroscopy at COMPASS

The $K^-\pi^-\pi^+$ Data Sample



- World's largest data set of about 720 k events
- Rich spectrum of overlapping and interfering X^-
  - Dominant well known states
  - States with lower intensity are "hidden"





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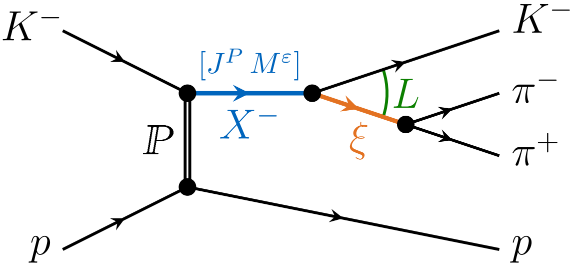
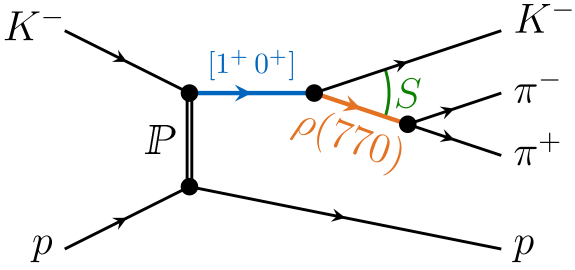


Partial wave: $J^P\ M^\varepsilon\ \xi\ b^-\ L$

- J^P spin and parity
- M^ε spin projection
- ξ isobar resonance
- b^- bachelor particle
- L orbital angular momentum



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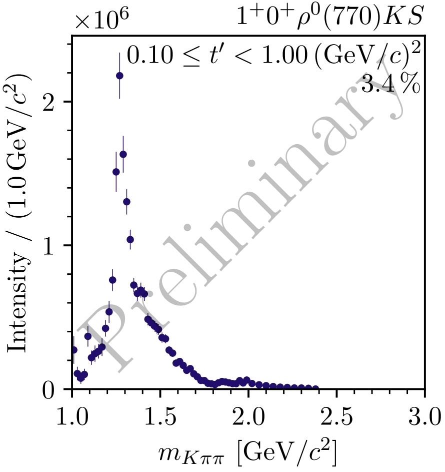
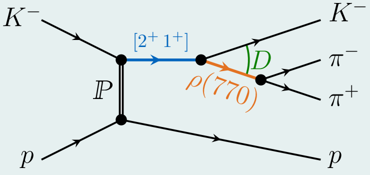
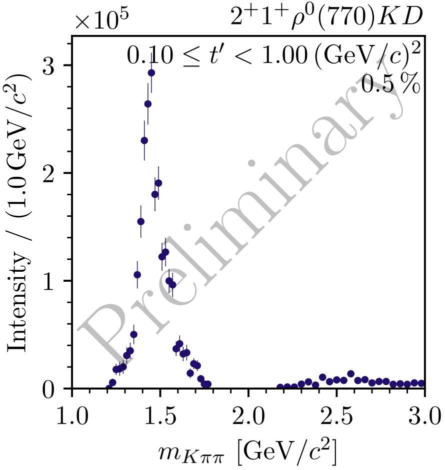


Partial waves with $J^P = 2^+$



- Signal in $K_2^*(1430)$ mass region
- In different decays
  - $\rho(770)\ K\ D$
  - $K^*(892)\ \pi\ D$
- In agreement with previous measurement
- Cleaner signal in COMPASS data



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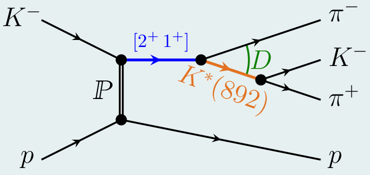

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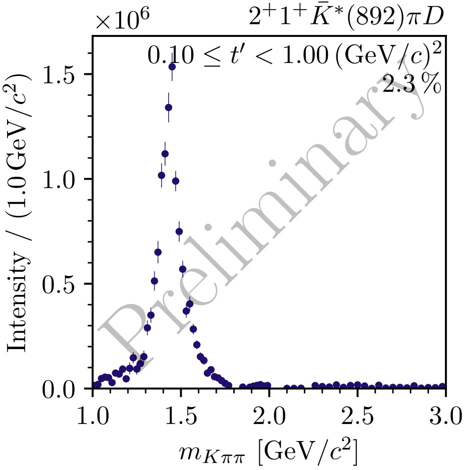

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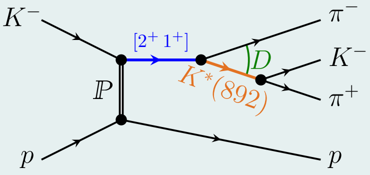

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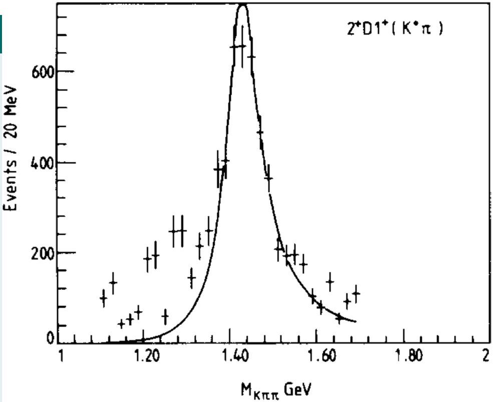

WA03 (CERN), 200 000 events, ACCMOR, Nucl. Phys. B **187** (1981)

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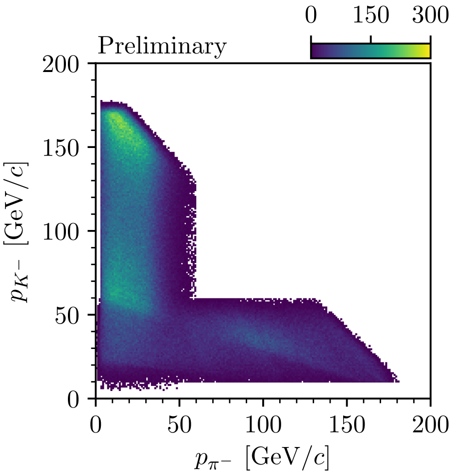
  - ➥ Loss of distinguishing power for some partial waves
- Analysis artifacts in these waves

- Artifacts can be identified
- Only a sub-set of waves affected



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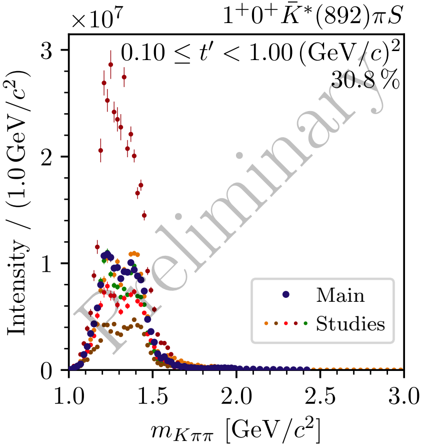

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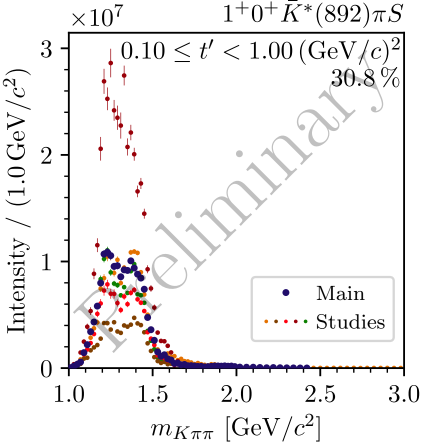

Main limiting factors

- Final-state particle identification
- Low kaon fraction in the beam ($\approx 2\,\%$)

High-Precision Strange-Meson Spectroscopy at AMBER

Goal: 10×larger data sample

- Diffraction of high-energy kaon beam
- RF-separation to increase kaon fraction in beam

- Improved precision
- Study also small signals in data
- Access to novel analysis methods

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- K_0^* mesons appear in $K^-\pi^+$ sub-system of the $K^-\pi^-\pi^+$ final state
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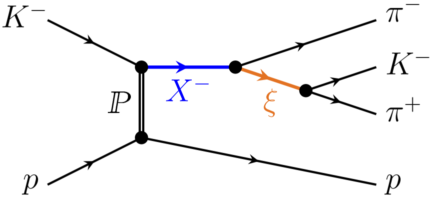

- Upgrade of final-state particle identification
  - Cover wide momentum range
  - Uniform acceptance
- Efficient beam particle identification for high-purity sample
  - High rate capability
  - Small beam divergence
- High-resolution beam telescope and vertex detector
- Recoil target detector
  - Ensures exclusivity
- Efficient photon detection over wide kinematic range
  - Access to final states with neutral particles: $K^-\eta^{(\prime)}$, $K^-\pi^0$, $K^-\omega$, ...
- Trigger for low momentum-transfer events

Conclusion

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- Many strange mesons require further confirmation
- Search for strange partners of exotic non-strange light mesons

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- Collect 10×data sample using high-intensity and high-energy RF-separated kaon beam
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- Rewrite the PDG for strange mesons
  - With a single and self-consistent measurement
- Requires experimental setup
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