Exploring the Strange-Meson Spectrum with COMPASS

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The Strange-Meson Spectrum

PDG lists 25 strange mesons

- 16 established states, 9 need further confirmation
- Missing states with respect to quark-model predictions
- No experimental evidence for strange exotica (except for $K_0^*(700)/\kappa$)
The Strange-Meson Spectrum

Production of Strange Mesons

- Diffractive scattering of high-energy kaon beam
- Strange mesons appear as intermediate resonances $X^-$
- Decay to multi-body hadronic final states
  - $K^−\pi^−\pi^+$ final state
  - Study in principle all strange mesons
  - Study a wide mass range
  - Study different decay modes
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Strange-Meson Spectroscopy at COMPASS
COMPASS Setup for Hadron Beams

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Exploring the Strange-Meson Spectrum with COMPASS

CEDARs
* beam PID

Beam
* 190 GeV
* 2.4 % K

H₂ Target
RPD

RICH
* final-state PID

30 m

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
- $M^\varepsilon$ spin projection
- $\xi$ 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 measurements
- Cleaner signal in COMPASS data
Partial Waves with $J^P = 2^+$

$K^-(2^+1^+)[2^+1^+]\pi^-$

$K^- \pi^+$

$K^-(892)$

$\rho(770) K D$

$K^*(892) \pi D$

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![Graph showing intensity versus $m_{K\pi\pi}$](image-url)
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- Existence of one or two low-mass $K_2$ state not clear at previous measurements
  - $K_2(2250)$ observed mainly in $\Delta\bar{p}$ final state

$B^+ \rightarrow J/\psi\phi K^+$ from LHCb

- Both $K_2(1770)$ and $K_2(1820)$ considered
- Limited kinematic range
  - Cannot access low- and high-mass states
- Updated analysis of larger sample
  - High- and low mass tail of states outside kinematic range needed to describe data
  - Requires input from other measurements

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CERN Ω′ spectrometer, 10 000 events, Nucl. Phys. B 227 (1983)
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$K^-\pi^-\pi^+$ from COMPASS

- Large signal in $2^- 0^+ K_2^*(1430)\pi S$ wave
- Two resonances in signal region
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Searching for Exotic Strange Mesons

- $K(1460)$ and $K(1830)$
- $K(1630)$
  - Unexpectedly small width of only 16 MeV/$c^2$
  - $J^P$ of $K(1630)$ unclear
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COMPASS $K^-\pi^-\pi^+$ data

- Peak at about $1.4 \text{ GeV}/c^2$
  - Potentially from established $K(1460)$
  - But, $m_{K\pi\pi} \lesssim 1.5 \text{ GeV}/c^2$ region affected by analysis artifacts

- Second peak at about $1.7 \text{ GeV}/c^2$
  - Potential $K(1630)$ signal
  - Accompanied by clear phase motions
  - Width presumably larger than $16 \text{ MeV}/c^2$

- Weak signal at about $2.0 \text{ GeV}/c^2$
  - Potential $K(1830)$ signal

![Graph showing $m_{K\pi\pi}$ distribution with peaks at 1.4 and 1.7 GeV/c^2]
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$K^{-} \pi^{-} \pi^{+}$ from ACCMOR

- Potential $K(1630)$ signal already in ACCMOR analysis

$K^{-} \pi^{-} \pi^{+}$ from LHCb

- Measurement of $D^{0} \rightarrow K^{\mp} \pi^{\pm} \pi^{\pm} \pi^{\mp}$ at LHCb
- Study strange mesons in $K\pi\pi$ subsystem
- MIPWA of $J^{P} = 0^{-}$ amplitude
- Potential signal above 1.6 GeV/$c^2$
- Limited by kinematic range

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![Graph showing complex plane with points labeled LHCb, J^P = 0^-, and masses m = 1.14 GeV/c^2 and m = 1.64 GeV/c^2.](image)
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Indications for 3 excited $K$ from a single analysis

Quark-model predicts only two excited states: potentially $K(1460)$ and $K(1830)$

$\rightarrow$ $K(1630)$ supernumerary state

$\rightarrow$ Candidate for exotic non-$q\bar{q}$ state
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The Strange-Meson Spectrum

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

COMPASS

- World’s largest data sample on $K^- + p \rightarrow K^-\pi^-\pi^+ + p$
  - Most detailed and comprehensive analysis of the $K^-\pi^-\pi^+$ final state so far
  - Studying $K, K_1, K_2^*, K_2, K_3^*, K_3, K_4^*, K_4$
- Signals of states in multiple decay modes
- Studying states in high-mass region
- Searching for exotic strange mesons

High-precision strange-meson spectroscopy at AMBER: A new QCD facility at CERN’s M2 beam line

- Rewrite the PDG for strange mesons, with a single and self-consistent measurement
- AMBER is open for interested collaborators to join
### Summary

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