

Strange-Meson Spectroscopy at COMPASS and Beyond

Stefan Wallner
for the COMPASS Collaboration

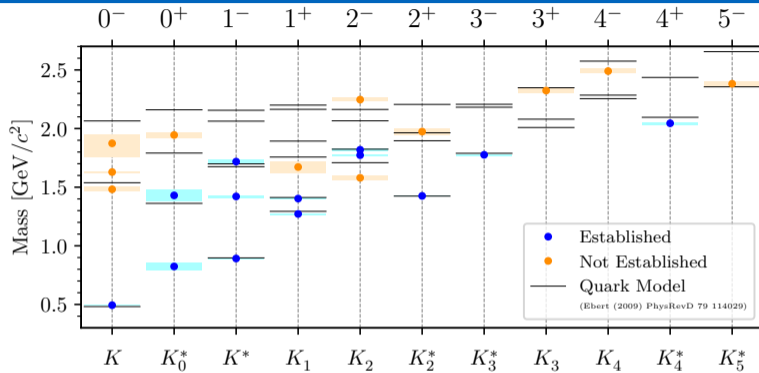
Institute for Hadronic Structure and Fundamental Symmetries - Technical University of Munich

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Strange-Meson Spectroscopy



PDG

(2019)

- ▶ PDG lists 25 strange mesons
- ▶ 13 established states, 12 need further confirmation
- ▶ Missing states with respect to quark-model prediction

K_J^* states

$$P = (-1)^J$$

- ▶ 8 of 11 listed K_J^* states are established
- ▶ Decay to $K\pi$ and other final states
- ▶ From precise measurements of
 - ▶ $K\pi$ scattering, e.g. from $K^\pm p \rightarrow K^\pm \pi^+ n$
 - ▶ heavy-meson (J/ψ , D , B , η_c) and τ decays

K_J states

$$P = (-1)^{J+1}$$

- ▶ Only 5 of 14 listed K_J states are established
- ▶ Cannot decay to $K\pi$ final state
 - ▶ Observed in decays to multi-body final states: $K\pi\pi$, $K\phi$, $K\omega$, $\Lambda\bar{p}$
- ▶ From measurements of
 - ▶ heavy-meson and τ decays
 - ▶ various production experiments

K_J^* states

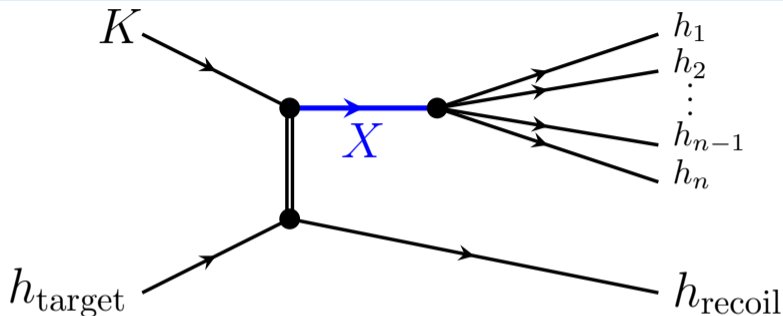
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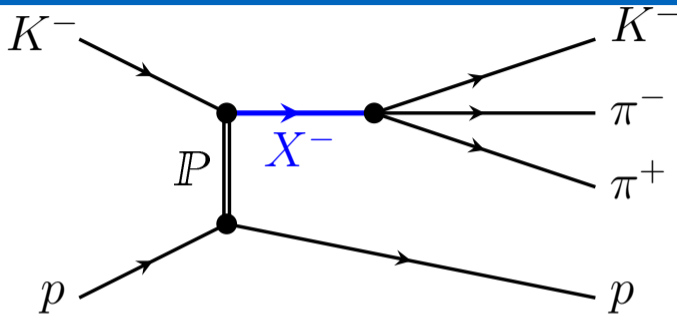
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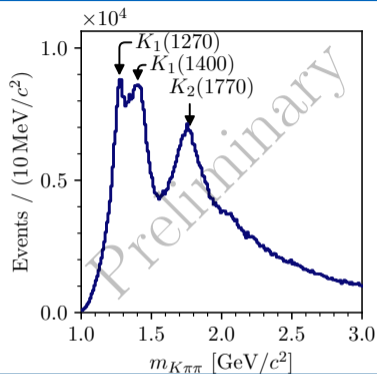
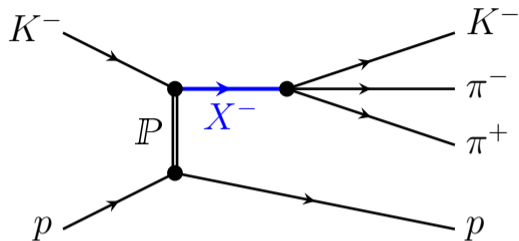
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- ▶ **Production** in scattering of high-energy beam
 - ▶ K^\pm, γ, K_L^0
- ▶ Strange mesons appear as intermediate states X
- ▶ Observed in decays into quasi-stable particles
- ▶ $K^- \pi^- \pi^+$ final state produced in diffractive K^- scattering at COMPASS
 - ▶ Access to all K_J^* and K_J states (except for $J^P = 0^+$)

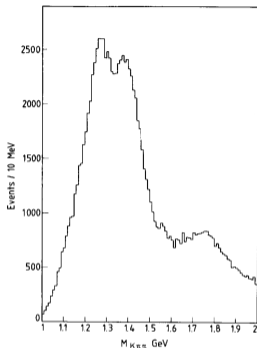


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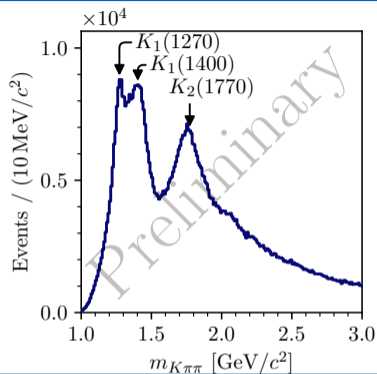


- ▶ Rich spectrum of **overlapping and interfering X^-**
 - ▶ Dominant well-known states
 - ▶ States with lower intensity are “hidden”
- ▶ Largest data set of diffractively produced $K^- \pi^- \pi^+$
 - ▶ $\approx 720\,000$ exclusive events (cf. ACCMOR 200\,000 exclusive events)

Kinematic Distributions

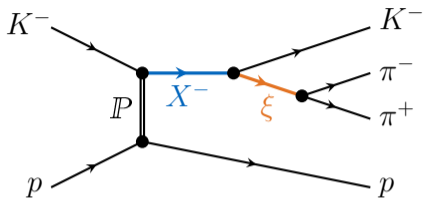


WA03 (CERN)
200 000 events
ACCMOR, NPB 187
(1981)

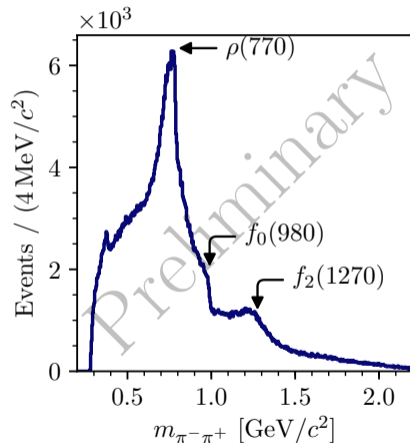


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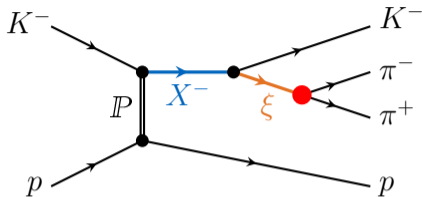
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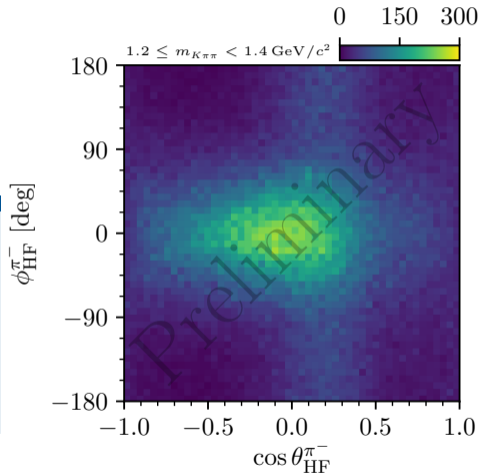
- ▶ Successive 2-body decay via $\pi^-\pi^+$ / $K^-\pi^+$ resonance called **isobar**
- ▶ Structures in angular distributions of X^- and **isobar** decays
- ▶ Characteristic signature for spin and parity of the decaying state



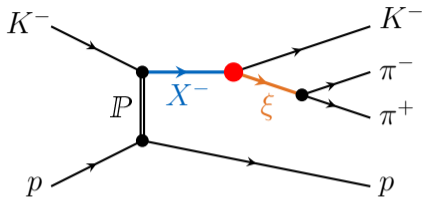
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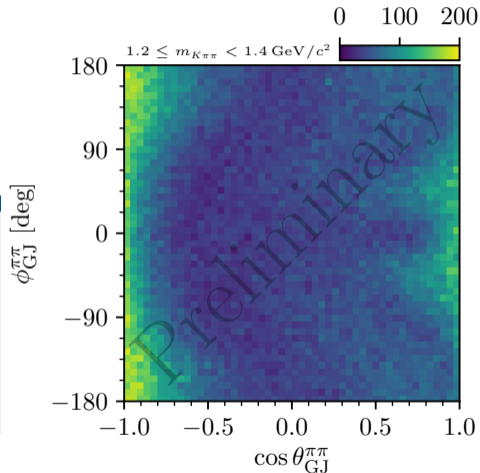
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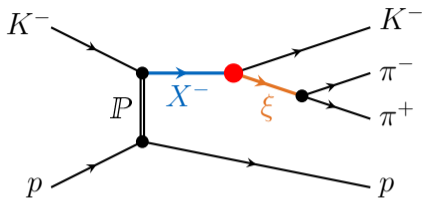
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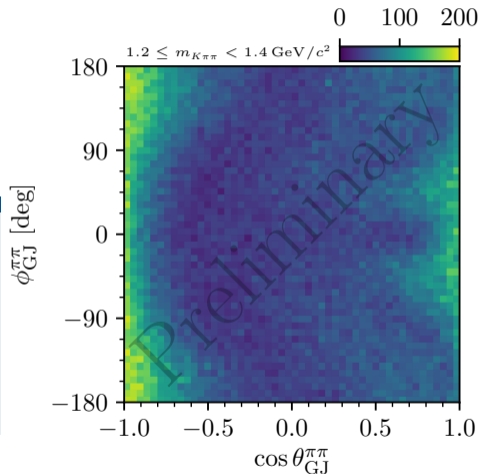
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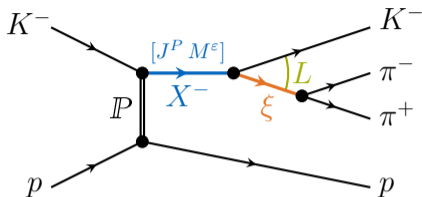


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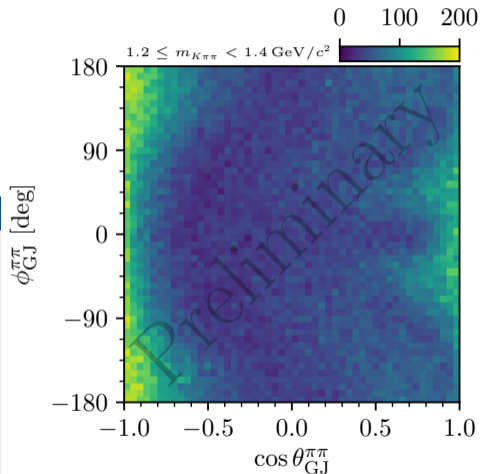


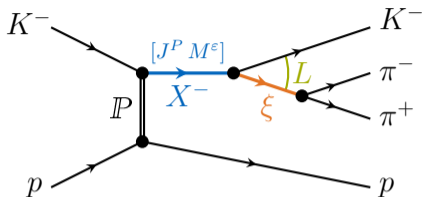


Partial wave

$$J^P M^\epsilon \xi b L$$

- ▶ $J^P M^\epsilon$: Spin, parity, and spin projection of X^-
- ▶ ξ : Isobar
- ▶ b : Bachelor particle. Here: Spectator K^-
- ▶ L : Angular momentum between bachelor and isobar
- ▶ Partial-wave amplitudes extracted from data in maximum-likelihood fit

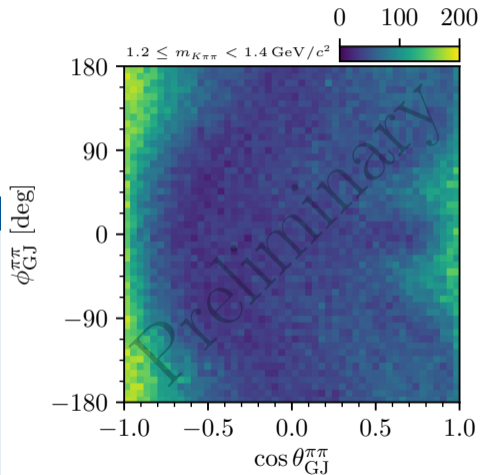




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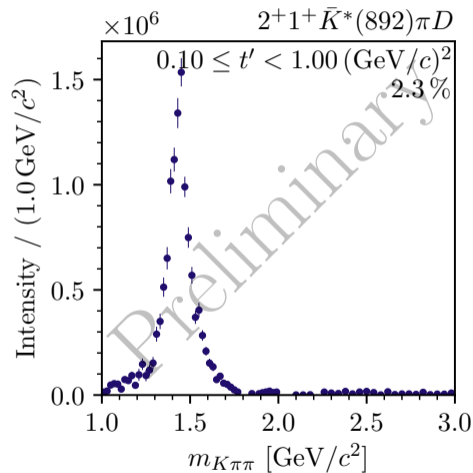


Selected Partial Waves

$$J^P = 2^+$$

$2^+ 1^+ K^*(892) \pi D$

- ▶ Signal in $K_2^*(1430)$ mass region
- ▶ Clear phase motion in $K_2^*(1430)$ region
 - ▶ Characteristic of narrow isolated resonances

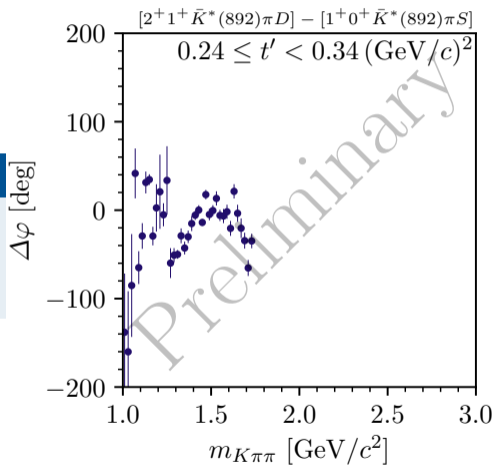


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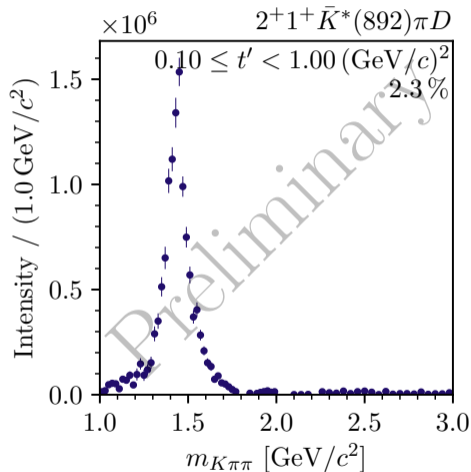


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$K_2^*(1430)$

- ▶ In agreement with previous measurement of $K^- \pi^- \pi^+$ final state at WA03
- ▶ Recent precise measurement from BES III
 - ▶ $J/\psi \rightarrow K^+ K^- \pi^0$
- ▶ Various measurements in $K\pi$ scattering
 - ▶ $K^\pm p \rightarrow K_S^0 \pi^\pm p$
 - ▶ $K^- p \rightarrow K^- \pi^+ n$
- ▶ PDG lists different parameters for charged and neutral $K_2^*(1430)$
- ▶ Different cluster of parameters

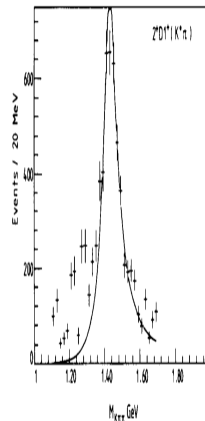


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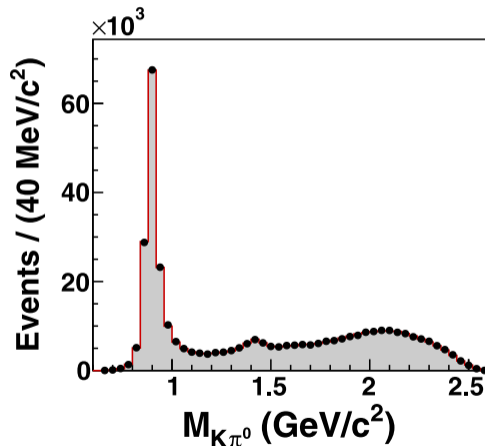
WA03 (CERN), 200 000 events, ACCMOR, Nucl. Phys. B **187** (1981)

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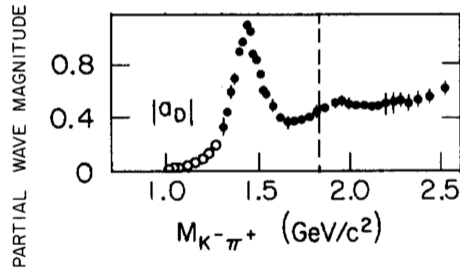
BESIII, 183 000 events, Phys. Rev. D **100** (2019)

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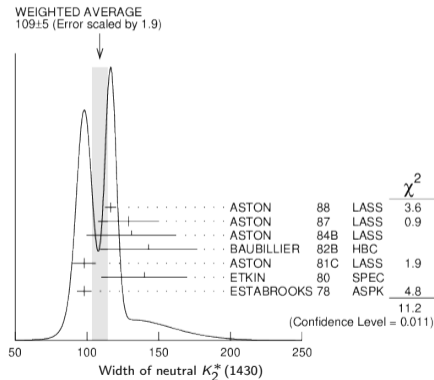
LASS, 151 000 events, Nucl. Phys. B **269** (1988)

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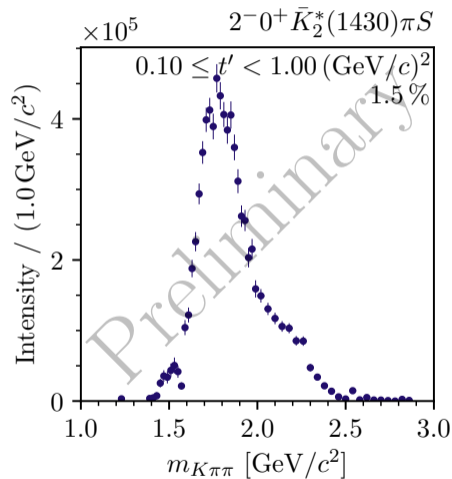
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$$2^- 0^+ K_2^*(1430) \pi S$$

- ▶ Strongest 2^- wave
- ▶ Two resonances in signal region
 - ▶ $K_2(1770)$, $K_2(1820)$
- ▶ Bump in high-mass shoulder
 - ▶ Potential $K_2(2250)$

$$2^- 0^+ \rho(770) K F / 2^- 0^+ K^*(892) \pi F$$

- ▶ Similar signals also in



Selected Partial Waves

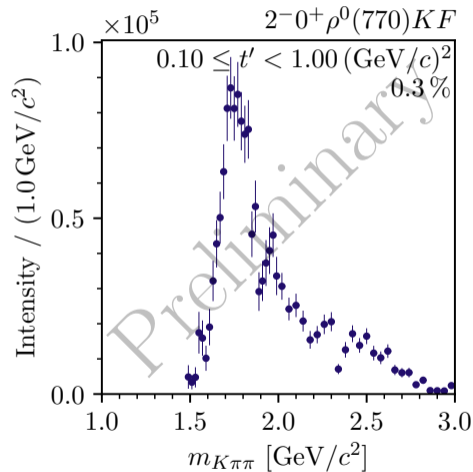
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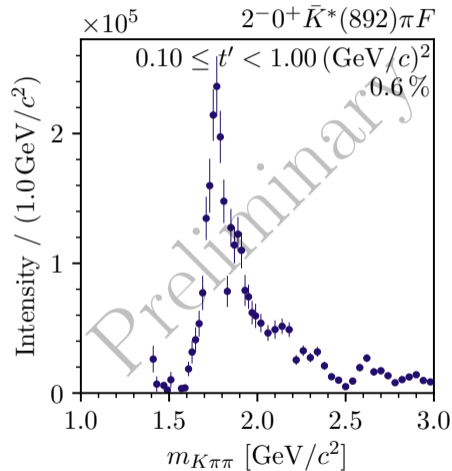
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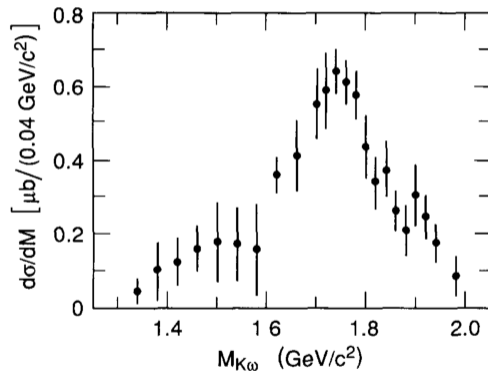


Selected Partial Waves

$$J^P = 2^-$$

$K_2(1770)$

- ▶ Observed in $K\omega$ final state at LASS
- ▶ Recent measurement from LHCb in $B^+ \rightarrow J/\psi\phi K^+$
- ▶ Mass and width determined from these two measurements only
- ▶ Further observations from decays to $K2\pi$, $K\phi$, $K\omega$ final states from production experiments at CERN, SLAC, ...



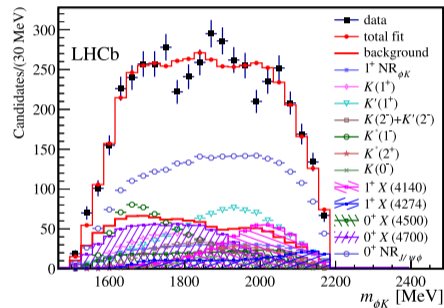
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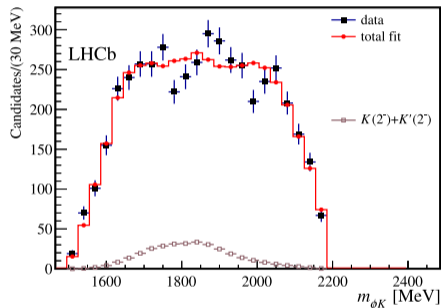
LHCb, 4 289 events, Phys. Rev. Lett. **118** (2017)

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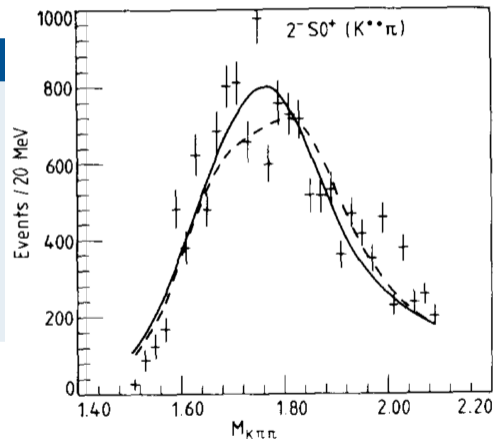
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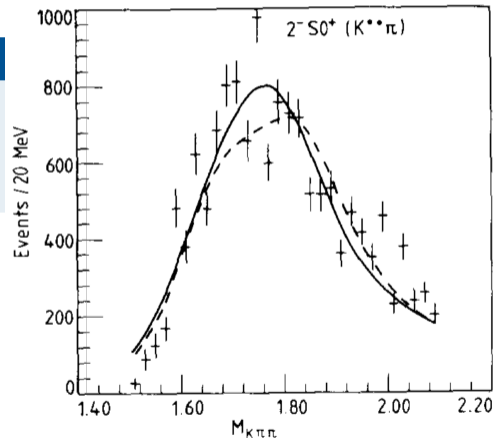
WA03 (CERN), 200 000 events, ACCMOR, Nucl. Phys. B **187** (1981)

Selected Partial Waves

$$J^P = 2^-$$

$K_2(1820)$

- ▶ Observed only in
 - ▶ $K\omega$ final state at LASS
 - ▶ ϕK^+ final state at LHCb
 - ▶ $K^-\pi^-\pi^+$ final state at WA03



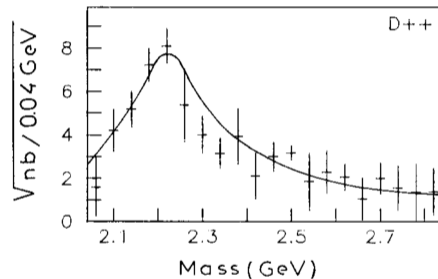
WA03 (CERN), 200 000 events, ACCMOR, Nucl. Phys. B **187** (1981)

Selected Partial Waves

$$J^P = 2^-$$

$K_2(2250)$

- ▶ Observed mainly in $\Lambda\bar{p}$ final state from production experiments



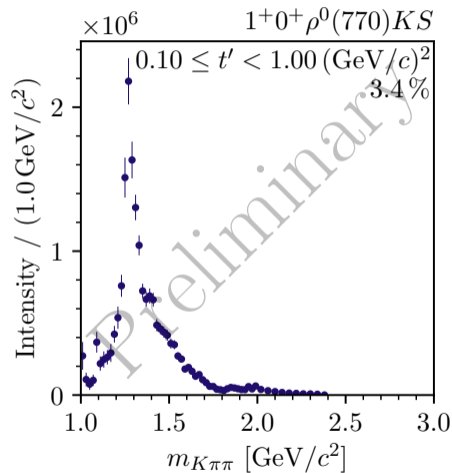
CERN Ω' spectrometer, 10 000 events, Nucl. Phys. B **227** (1983)

Selected Partial Waves

$$J^P = 1^+$$

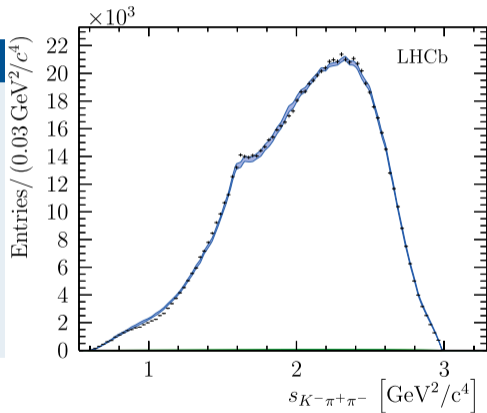
$1^+ 0^+ \rho(770) K S$

- ▶ 3.4% of total intensity
- ▶ Dominated by $K_1(1270)$
- ▶ Small potential signal from $K_1(1650)$



$K_1(1270) / K_1(1400)$

- ▶ Recent measurements in
 - ▶ $D^0 \rightarrow K^\pm \pi^\pm \pi^\pm \pi^\mp$ from LHCb
 - ▶ $B^+ \rightarrow J/\psi K^+ \pi^+ \pi^-$ at Belle
 - ▶ $\tau^- \rightarrow K^- \pi^+ \pi^- \nu_\tau$ at Cleo II
- ▶ Potential bi-modality in the width of the $K_1(1270)$
 - ▶ Proposals that $K_1(1270)$ has two-pole structure similar to $\Lambda(1405)$ coupling differently to different decay modes



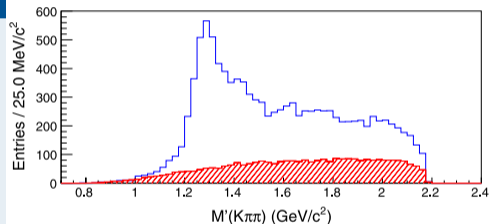
LHCb, 893 000 events, Eur. Phys. J. C **78** (2018)

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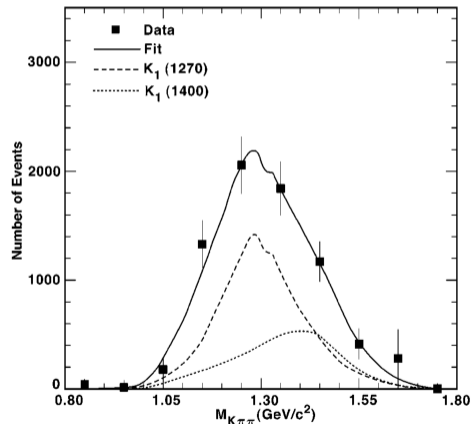
Belle, 11 000 events, Phys. Rev. D **83** (2011)

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$K_1(1270) / K_1(1400)$

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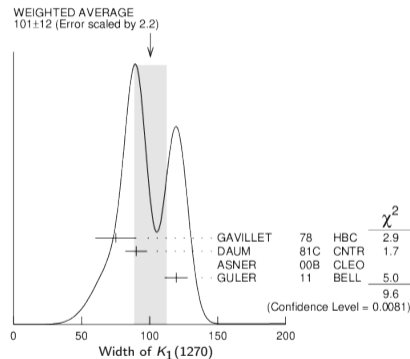
CLEO II, 7 000 events, Phys. Rev. D **62** (2000)

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 - ▶ $D^0 \rightarrow K^\pm \pi^\pm \pi^\pm \pi^\mp$ from LHCb
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$K_1(1650)$

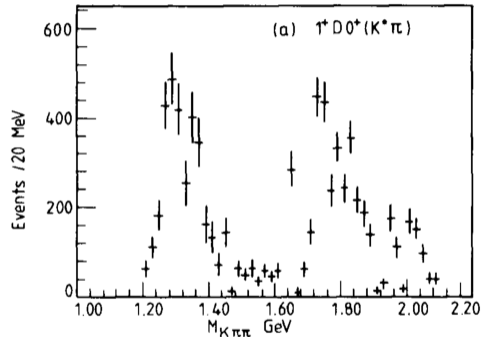
- ▶ Cannot be accessed in D or τ decays
 - ▶ $K_1(1650)$ low-mass tails can contribute
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 - ▶ ϕK and $K\pi\pi$ final states from production experiments at CERN
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Selected Partial Waves

$$J^P = 1^+$$

$K_1(1650)$

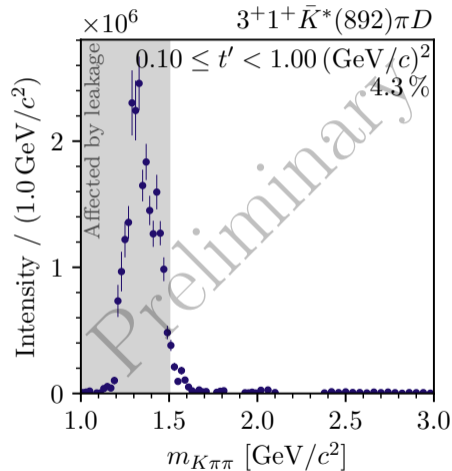
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WA03 (CERN), 200 000 events, ACCMOR, Nucl. Phys. B **187** (1981)

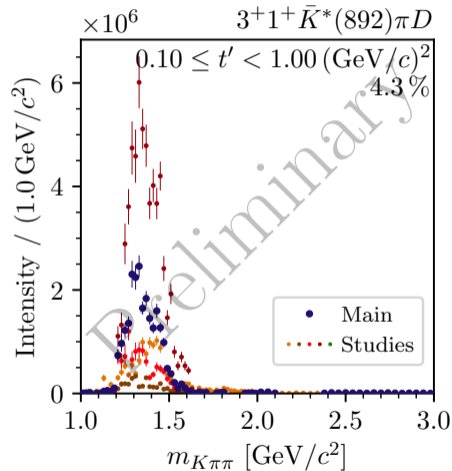
Leakage Effect in COMPASS Data

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- ▶ Final-state PID does not cover full kinematic range
 - ↳ Reduced distinguishability of partial waves
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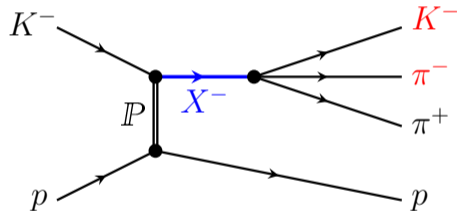
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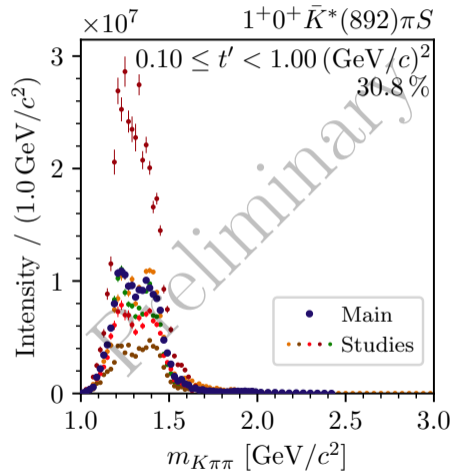


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Strange-meson spectroscopy

- ▶ Many states need further clarification
- ▶ Many measurements performed more than 30 years ago
- ▶ Most of the recent measurements from heavy-meson or τ decays

$K^- \pi^- \pi^+$ final state at COMPASS

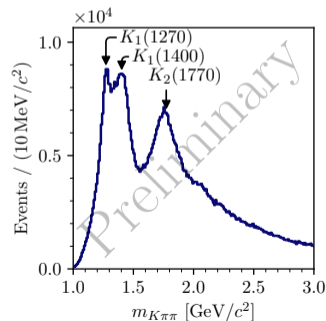
- ▶ World's largest data set of diffractively produced $K^- \pi^- \pi^+$
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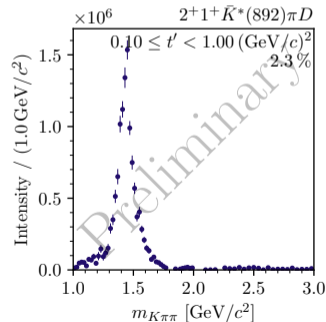


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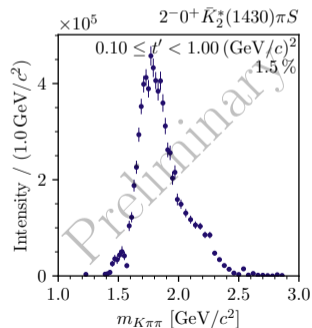


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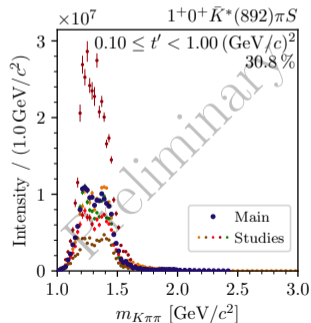


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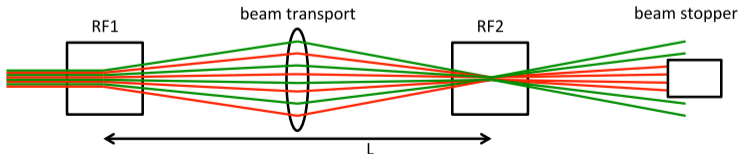
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Spectroscopy of strange mesons

- ▶ Radio-frequency separated high-intensity high-energy kaon beam
 - ▶ Series of workshops at CERN
- ▶ At least $\times 10$ larger data set than collected by COMPASS
- ▶ Map out strange-meson spectrum with similar precision as unflavored light-meson spectrum
- ▶ Letter of intent: arXiv:1808.00848
- ▶ Proposal for phase-1: CERN-SPSC-2019-022
 - ▶ Recommended by SPSC
 - ▶ Formation of new collaboration in process



Backup

Outline