Meson Spectroscopy with COMPASS

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1. Motivation

Constituent quark model:

- color neutral $q\bar{q}$ systems, Quantum numbers $I^G J^{PC}$
- $P = (-1)^{L+1}$ $C = (-1)^{L+S}$ $G = (-1)^{I+L+1}$
- J^{PC} multiplets: 0^{++}, 0^{-+}, 1^{--}, 1^{+-}, 1^{++}, 2^{++},…
- Forbidden: 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+},…

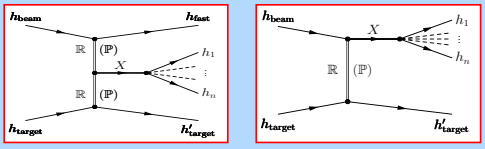
QCD: meson states beyond

- Glueballs: gg, ggg
- Hybrids: $q\bar{q}g$
- Tetraquarks: $(q\bar{q})(q\bar{q})$

Experimental observation:
=> Fundamental confirmation of QCD

Different production mechanisms:

a) Central production b) Diffractive production



Hybrid candidates (1.3 - 2.2 GeV/c²):
lightest hybrid predicted: exotic $J^{PC} = 1^{-+}$

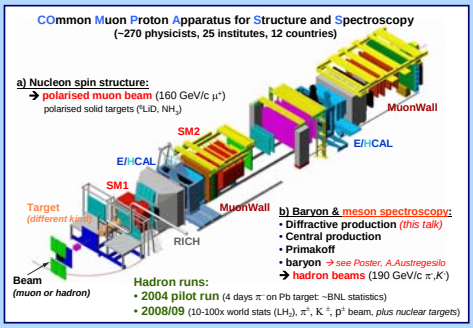
- $\pi_1(1400)$: *VES, E852, Crystal Barrel* –> $\eta\pi$
- $\pi_1(1600)$: *E852, VES* –> $\rho\pi$, $\eta'\pi$, $f_1\pi$, $b_1\pi$
- $\pi_1(2000)$: *E852* –> $f_1(1285)\,\pi$, $b_1(1235)\,\pi$

…. *still controversal* → **COMPASS**

2. The COMPASS experiment

- two stage spectrometer
- high-resolution, large acceptance
- ~250 000 read-out channels, ~1 PB / year

[hep-ex/0703049, NIM A 577, 455 (2007)]



Experimantal set-up 2008/09:

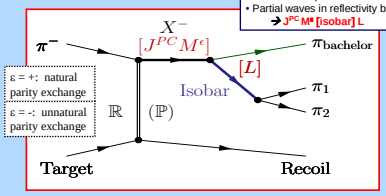
- 190 GeV/c beam ($\pi^{\pm}$, $K^{\pm}$, p), liquid H_2 target
- recoil proton detector (exclusive trigger)
- 2 CEDARs (beam particle PID)
- Calorimetry in both stages – upgraded 2008/09
- RICH in 1st stage – upgraded in 2006
  [NIM-A587:371-387, 2008], [NIM-A616:21-37, 2010]

[Hadron set-up 08/09, NIM A, in preparation (2010)]

3. Partial wave analysis method

Based on isobar model:

X⁻ decay described using isobar model:
- Intermediate di-pion resonance *(isobar)*
  - Spin S *and* rel. orbital angular momentum L *w.r.t* bachelor π^-
  - L+S *couple to* J
- Partial waves in reflectivity basis:
  → $J^{PC} M^{\varepsilon}$ [isobar] L



Partial wave analysis:

- **Program:** Illinois/Protvino/Munich by D.Ryabchikov
- **Isobars:** $(\pi\pi)_S$ [broad $f_0(600)$+$f_0(1370)$], $f_0(980)$, $\rho(770)$, $f_2(1270)$, $\rho_3(1690)$
- **Acceptance corrections included** (2004: ~60%, rather flat)

Step 1) Mass independent PWA:

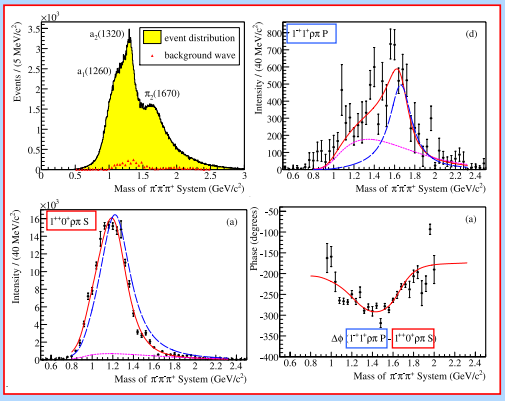
- data sliced into 40MeV/c² mass bins
- 41+1 (flat backgrd.) partial waves *i* :

$$\sigma_{indep}(\tau, m, t') = \sum_{\epsilon=\pm1} \sum_{r=1}^{N_r} \left| \sum_i T^{\epsilon}_{ir} f_i^{\epsilon}(t') \psi_i^{\epsilon}(\tau, m) / N_i^{\epsilon}(m) \right|^2$$

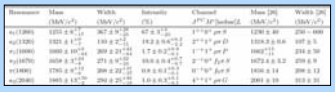
Step 2) Mass dependent χ^2 fit:

- applied to mass independent result
- 6 main partial waves chosen *(Breit-Wigner param.)*
- coherent background for some waves

4. Observation: Spin exotic signal (2004 data)

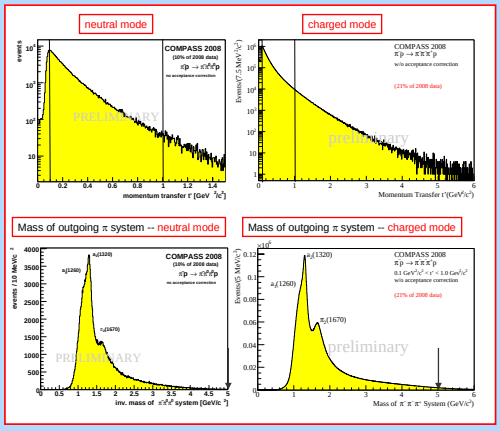


- **Examplarily shown:** 1-1++ vs. exotic 1-1-+
- clear phase motion => resonant behaviour



For more details, see [1] (PRL accepted, hep-ex/0910.5842.v2)

5. First comparison neutral & charged mode

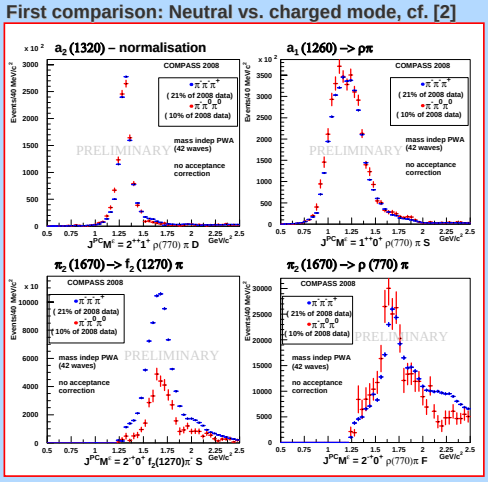


- similar, exponential t' spectra
- most prominent resonances cleanly seen:
  $a_1(1260)$, $a_2(1320)$, $\pi_2(1670)$ → already without PWA

For more details of both analyses, see [2,3]

6. Partial wave analysis – main waves

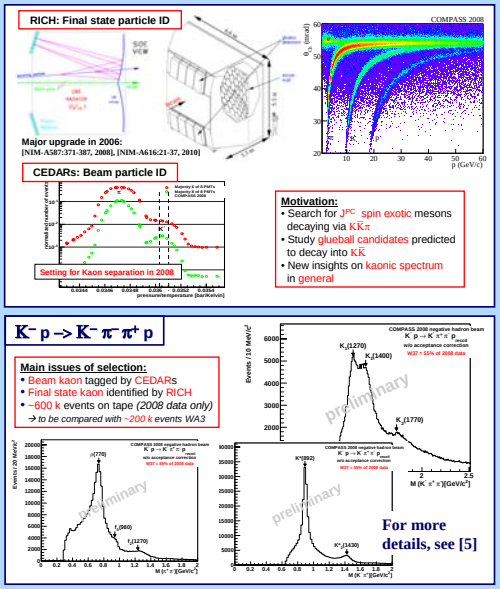
First comparison: Neutral vs. charged mode, cf. [2]



Isospin symmetry: neutral / charged mode

- isobar decaying into $f_2\,\pi$: ½ intensity expected
- isobar decaying into $\rho\,\pi$: 1/1 intensity expected

7. Kaonic final states – Kaon diffraction

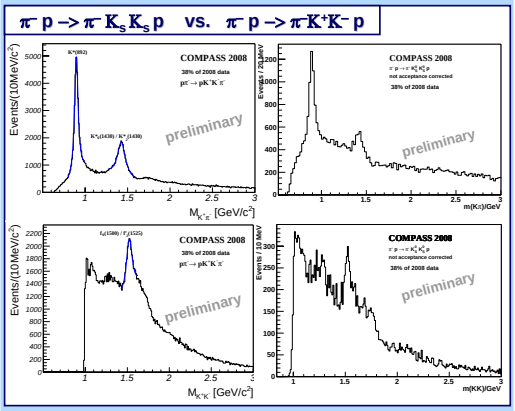


Motivation:
- Search for J^{PC} spin exotic mesons decaying via $K\bar{K}\pi$
- Study glueball candidates predicted to decay into $K\bar{K}$
- New insights on kaonic spectrum in general

8. Kaonic final states – hidden strangeness

Main issues of selection:
- Beam kaon anti-tagged by CEDARs
- Final state kaon identified by V0 vertex ($K_S K_S$) or by RICH (K^+K^-)

$\pi^- p \to \pi^- K_S K_S p$ vs. $\pi^- p \to \pi^- K^+ K^- p$



- Difference near threshold → momentum cut due to RICH
- known resonances seen as expected

For details, see e.g. [4]

9. Summary & outlook

COMPASS:
- ✓ High potential for Hadron Spectroscopy
- ✓ 2004 data: Exotic J^{PC} → $\pi_1(1600)$ *(PRL accepted)*
- ✓ 2008/09: High statistics *(10-100x world statistics)*
- ✓ measures neutral & charged channels

Further ongoing analyses (involving neutrals)
- $\pi^-\eta$, $\pi^-\eta\eta$ & $\pi^-\pi^+\pi^-\eta$ (η –>$\gamma\gamma$ & η –>3π)
  –> $\pi_1(1400)$ –> $\pi^-\eta$
  –> lightest glueball candidate 0^{++} –> $\eta\eta$
- $\pi^-\pi^-\pi^+\pi^0$, $\pi^-\pi^-\pi^+\eta$ & $\pi^-\pi^-\pi^+\pi^0\pi^0$
  => intermediate isobars accessible: f_1, b_1 η, η', ω
=> higher statistics than previous experiments

After hardware upgrades introduced in 2008/09:
- optimisation of ECals reconstruction *(under development)*
=> Will improve statistics outcome & resolutions

Kaonic final states:
- ✓ Kaon diffraction: $K^- p \to K^-\pi^+\pi^- p$
- ✓ $(K\bar{K}\pi)^-$ $\pi^- p \to \pi^- K_S K_S p$ *vs.* $\pi^- p \to \pi^- K^+ K^- p$

Outlook: Further ongoing & promising $(K\bar{K}\pi)^0$:
- $(K_S K\pi)^0$ in: $K_S K^{+/-}\pi^{-/+}\pi^-$ final states
- PWA started, higher masses (*> 2.2 GeV*)
  → PWA of $f_1(1285)\pi$ & $f_1(1420)\pi$ *(never done before!)*

[1] Alekseev et al., COMPASS collab., PRL accepted (2010)
[2/3/4] Nerling/Haas/Schlüter AIP Conf. Proc., Hadron09 (2010)
[5] Jasinsky, EPJ Conf. Proc., SpinPraha09 (2010)

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