Hadron Physics at COMPASS

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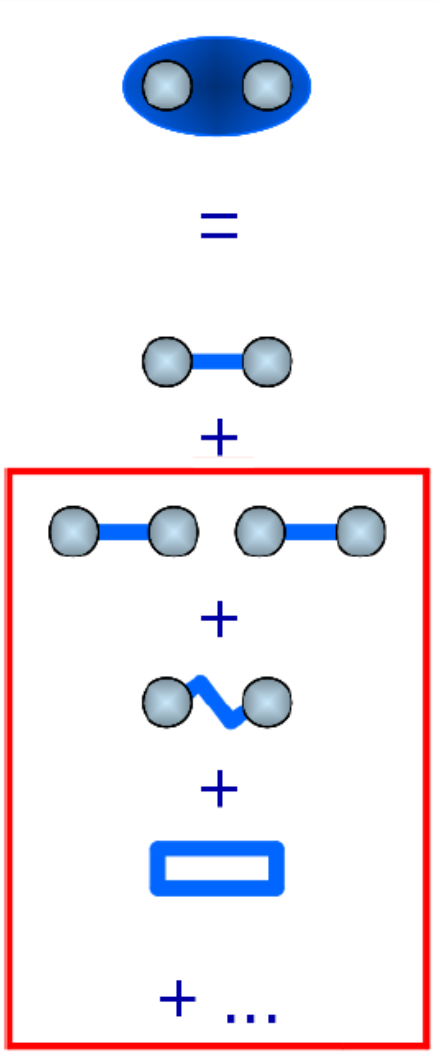
Outline

- Introduction
- The COMPASS experiment
- Diffractive Dissociation of pions
- Coulomb production of pions
- Final states with strangeness
- More hadron physics with COMPASS

Introduction

Meson Spectroscopy:

Study the meson spectrum and search for states other than conventional quark-antiquark pairs. For example *multiquarks*, *glueballs* and *hybrids*.



Introduction

The light meson spectrum

Hybrids:

- Low mass states with spin exotic quantum numbers $J^{PC} = 1^{-+}$ predicted
- Reported candidates:
  - $\pi_1(1400)$: VES, E852, Chrystal Barrel
  - $\pi_1(1600)$: E852, VES
  - $\pi_1(2000)$: E852
- Resonance interpretations still disputed

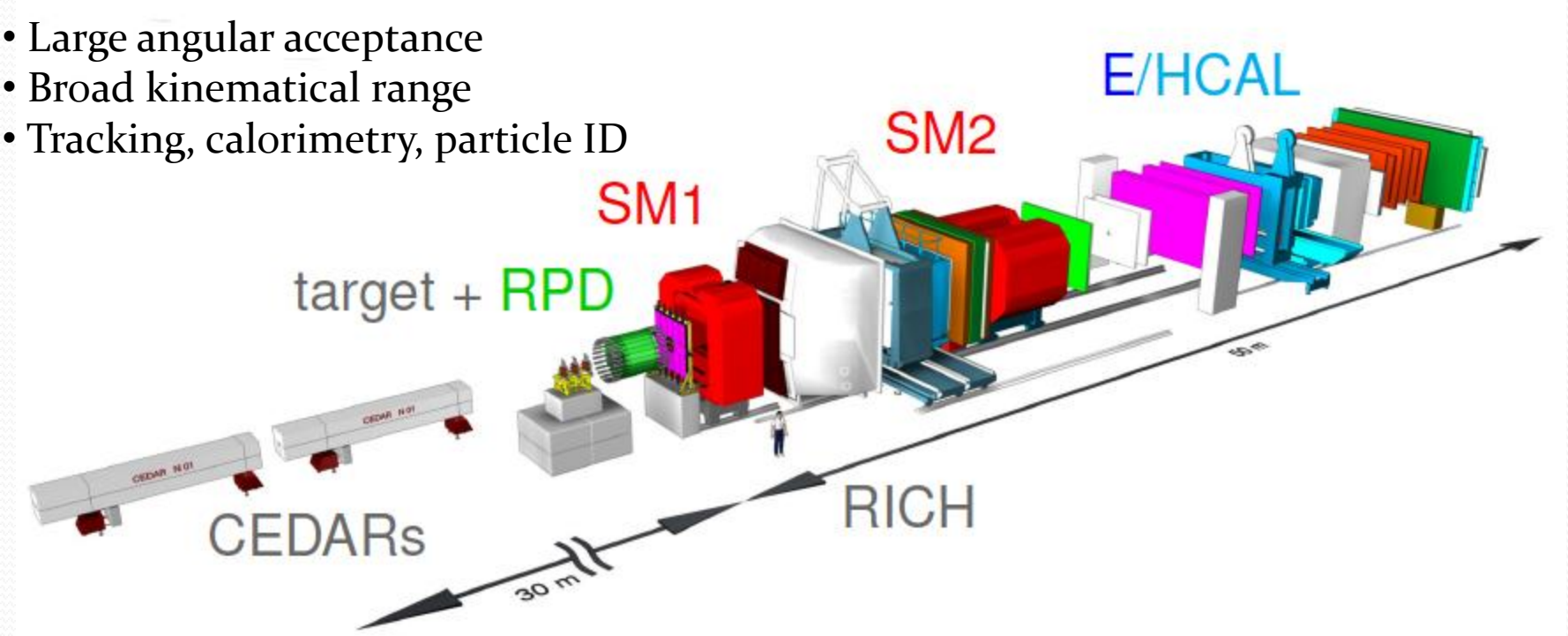
Glueballs:

- Lowest predicted states have the same quantum numbers as ordinary mesons → mixing.
- Candidates: $f_0(1370)$, $f_0(1500)$,$f_0(1700)$ with $J^{PC} = 0^{++}$ and $\eta(1405)$ with $J^{PC} = 0^{-+}$, but their interpretations are still disputed.

The COMPASS experiment

Two-stage magnetic spectrometer:

- Large angular acceptance
- Broad kinematical range
- Tracking, calorimetry, particle ID

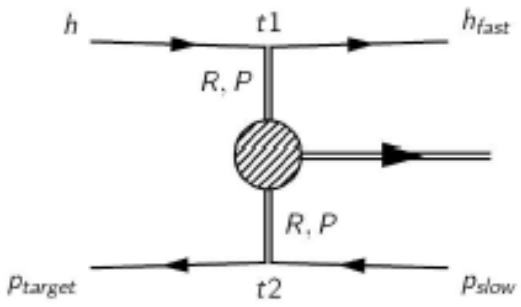


Beam: 190 GeV positive (p, π^+, K^+) or negative (π^-, K^-) hadron beam.
Targets: Liquid H_2, Nuclear targets (Pb, Ni, W).
Final states: charged ($\pi^\pm$, p, ...), neutral (π^0, η, η', ...),
kaonic ($K^\pm$, K_S, ...)

The COMPASS experiment

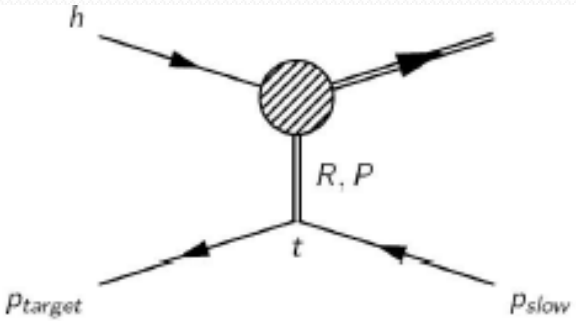
Production mechanisms:

Central production:



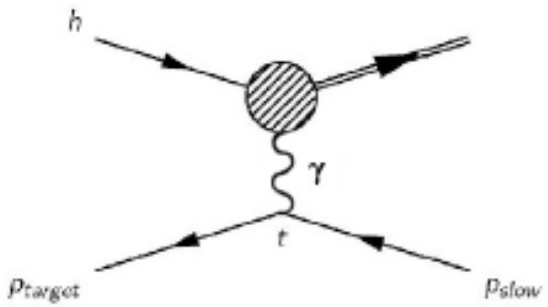
- Gluon-rich environment
- Rapidity gap

Diffractive dissociation:



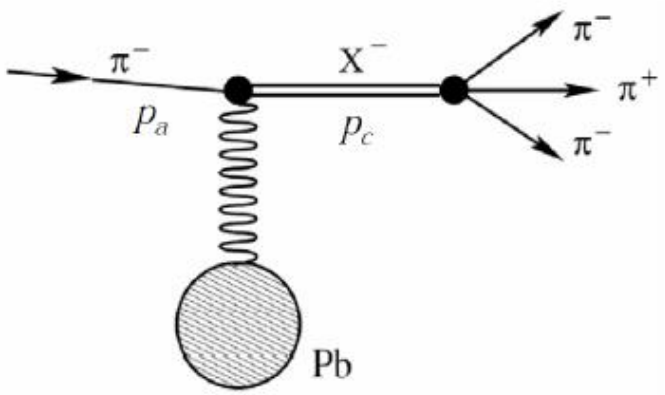
- Spin-exotic mesons
- Forward kinematics

Coulomb production:



- Test of ChPT
- Radiative widths

Diffractive Dissociation of pions



π^- Pb → $\pi^-\pi^+\pi^-$ Pb

- Data from 2004
- 190 GeV/c π^- on Pb
- Momentum transfer 0.1 < t' < 1 $(GeV/c)^2$

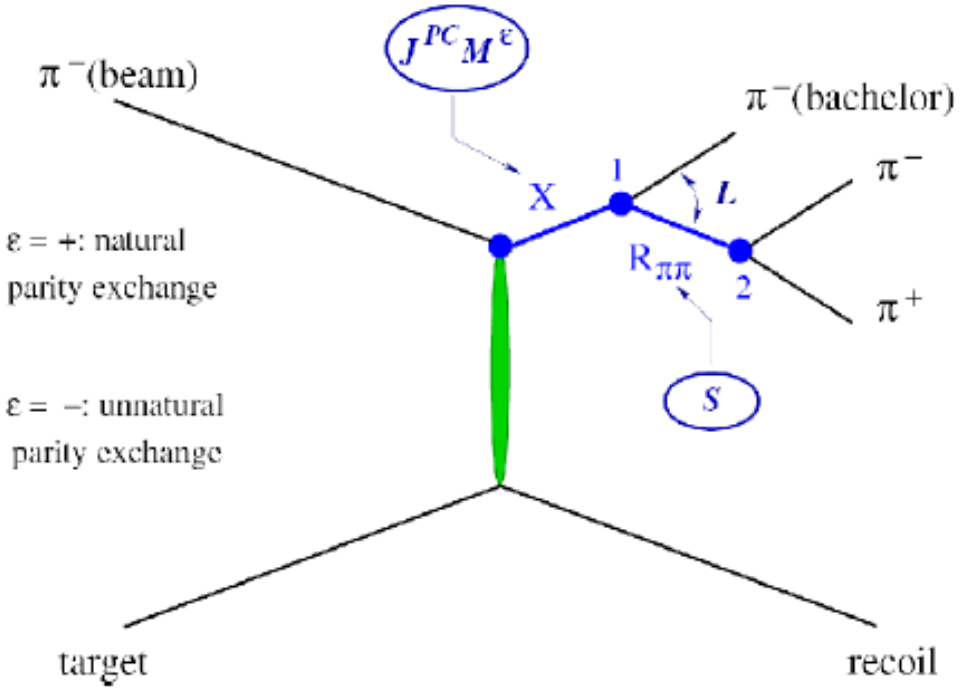
→ quasi-free nucleons in Pb

Partial Wave Analysis (PWA) Model:

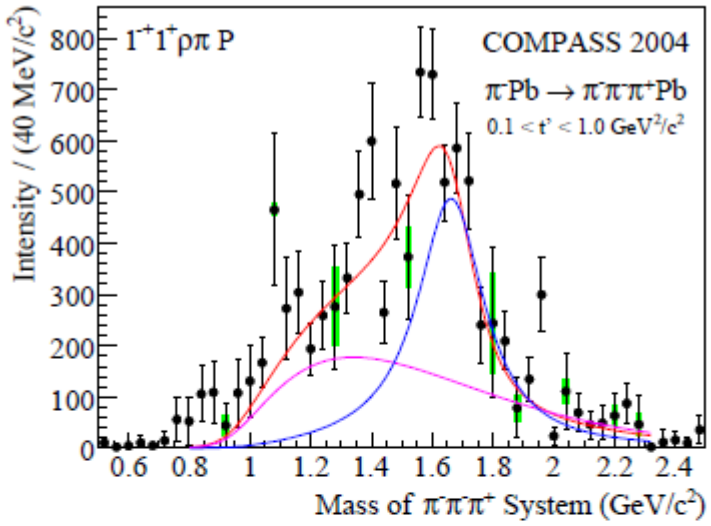
- t-channel Reggeon exchange
- Isobar model

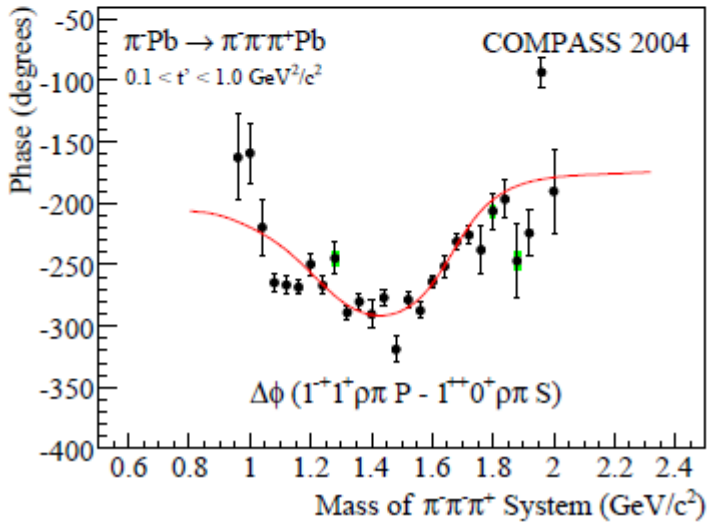
Quantum numbers of X:

Spin J, parity P,
charge conjugation C,
spin projection M
reflectivity ε



Diffractive dissociation of pions



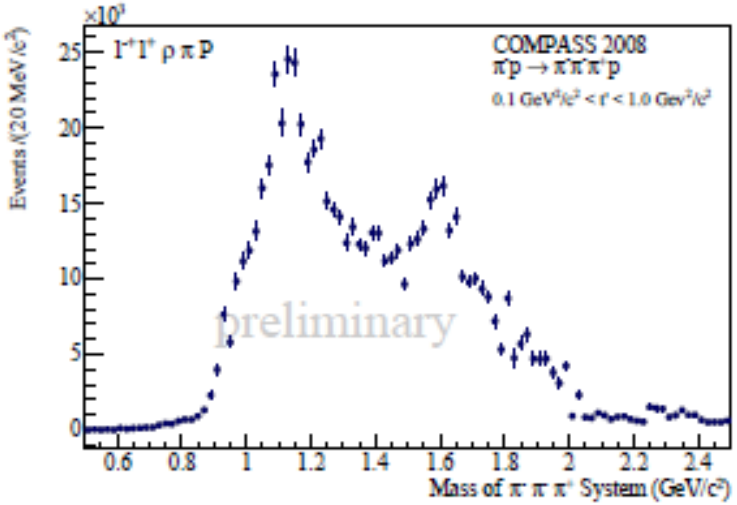


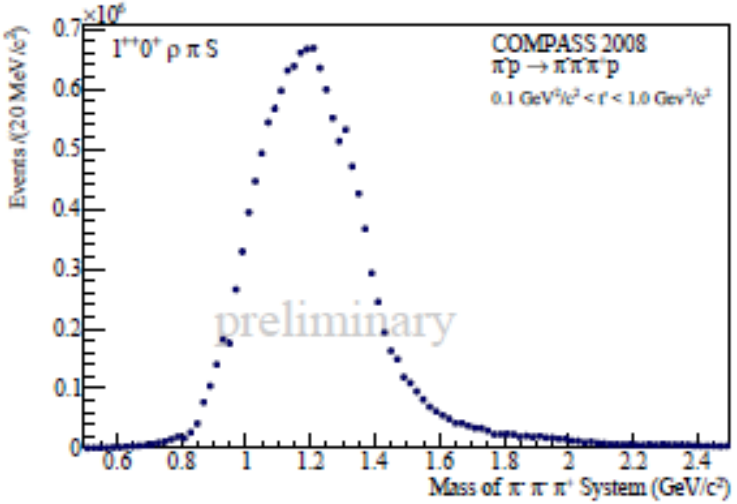
Significant spin exotic $J^{PC} = 1^{-+}$ wave [1]

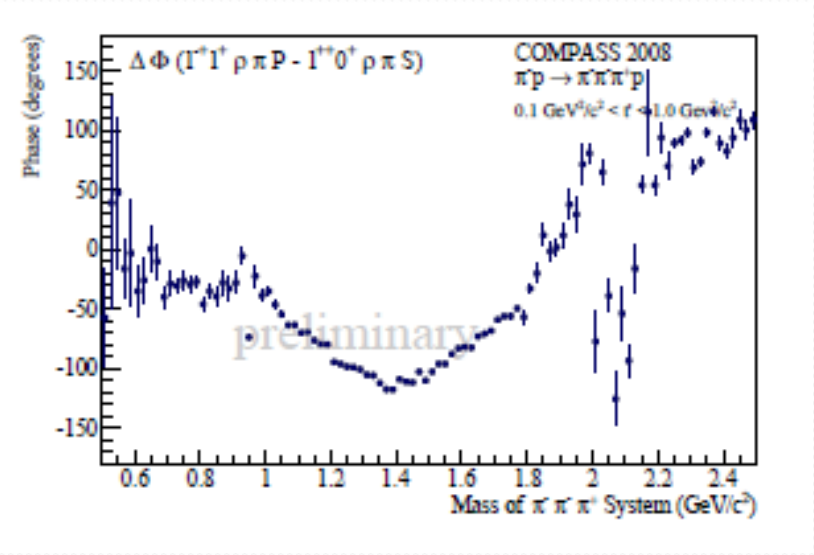
- $M = 1660 \pm 10^{+0}_{-64}$ MeV/c^2
  $\Gamma = 269 \pm 21^{+42}_{-64}$ MeV/c^2
- Consistent with $\pi_1(1600)$ seen by E852 and VES
- Negligible leakage from other waves

[1] COMPASS, Phys. Rev. Lett. 104 (2010) 241803

Diffractive dissociation of pions



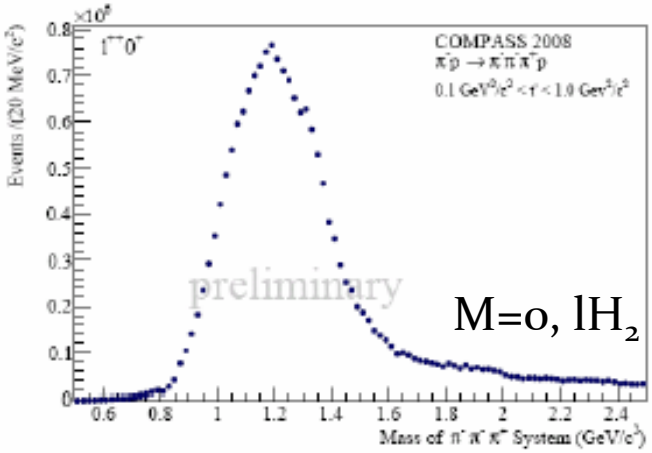


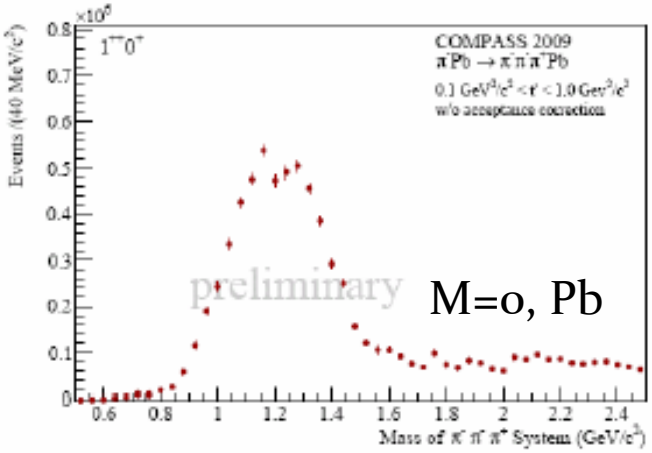


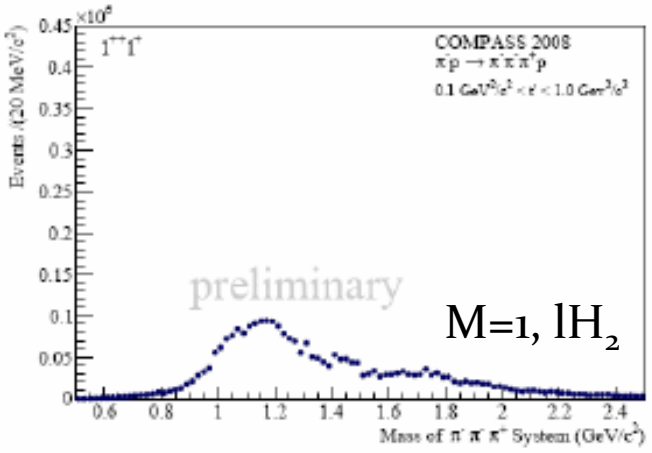
$\pi^- p \to \pi^-\pi^+\pi^- p$

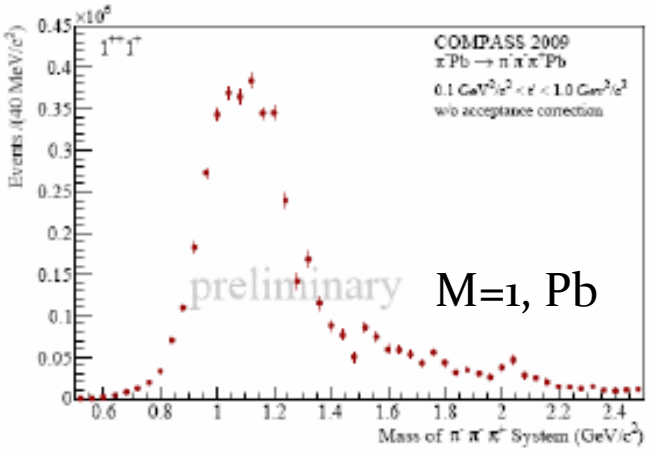
- Data from 2008
- 190 GeV/c π^- on liquid hydrogen
- 24M events (all data from 2008/2009 70 M)
- Enhancement near the $\pi_1(1600)$ mass in the 1^{-+} wave, phase motion w.r.t 1^{++}
- Leakage studies and mass dependent fit necessary for definite conclusions.
- Ongoing analysis of the $\pi^0\pi^0\pi^-$ final state offers a valuable consistency check.

Dependence on M of target material





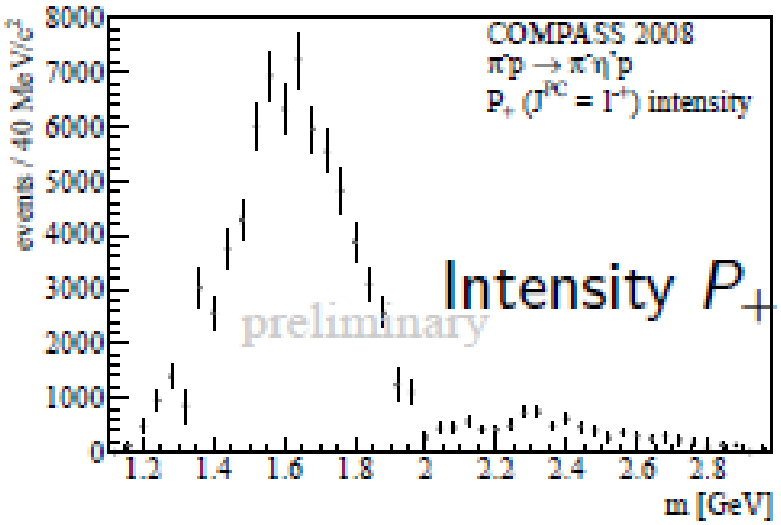


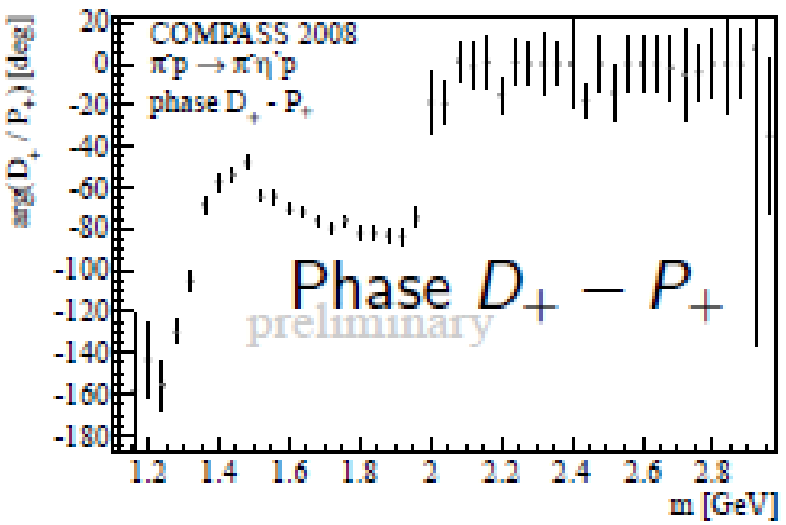


Pb (2009) vs. H_2 (2008) target

- Normalised to $a_2(1320)$
- On Pb: M = 1 enhanced, M = 0 suppressed

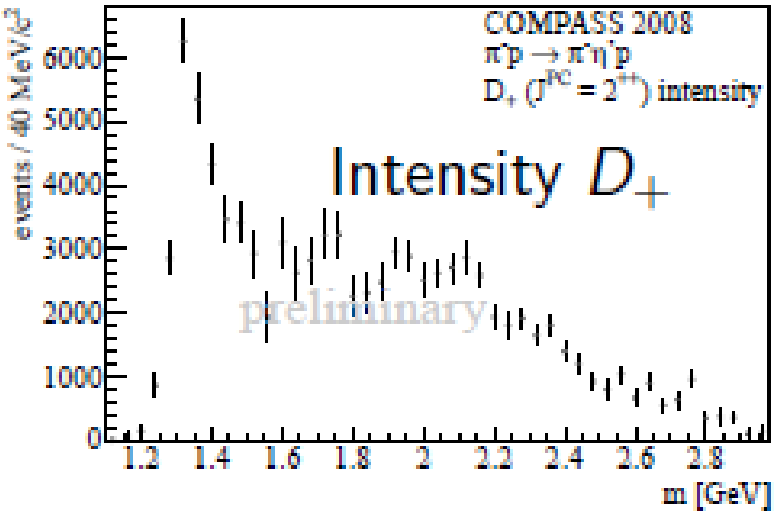
Search for exotics in the $\eta'\pi^-$ final state



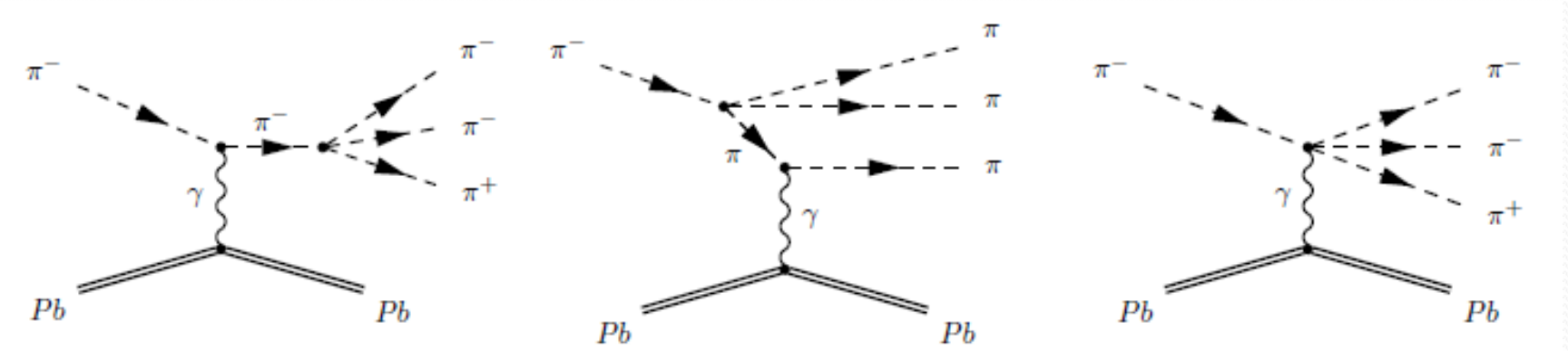


$\pi^- p \to \pi^-\eta' p$

- Data from 2008, 190 GeV/c π^- on lH_2
- Strong 1^{-+} wave
- Ongoing work: to confirm or disprove the resonance interpretation.



Coulomb production of pions

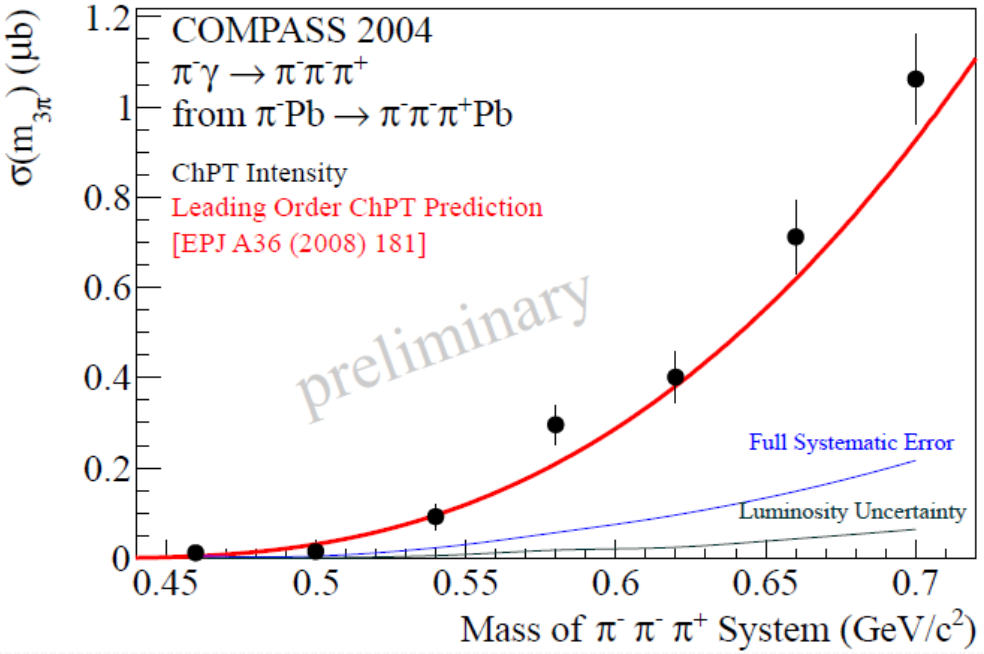


Low momentum transfer:

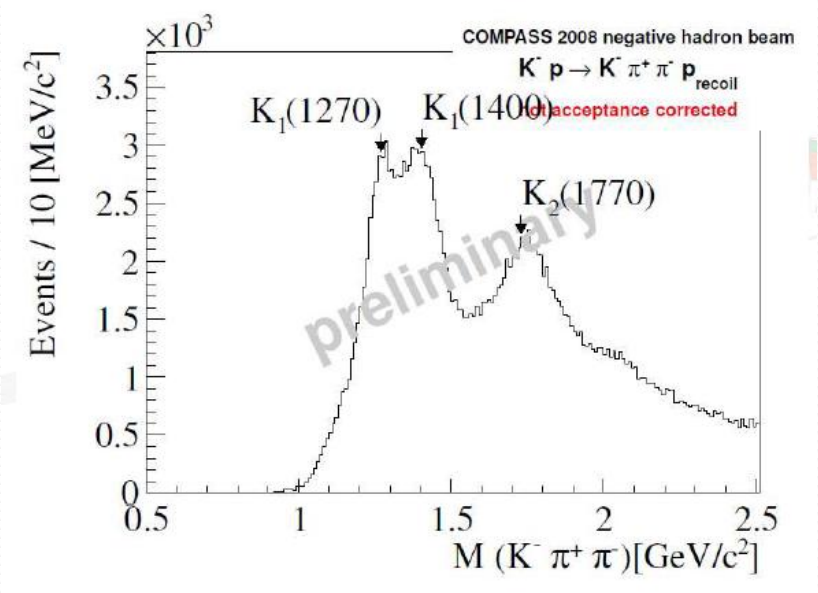
- Contribution from photon exchange

Low masses:

- Only pions produced → ChPT test.
- Results compared to LO ChPT predictions [EPJA 36 (2008) 181.]



Kaon diffraction

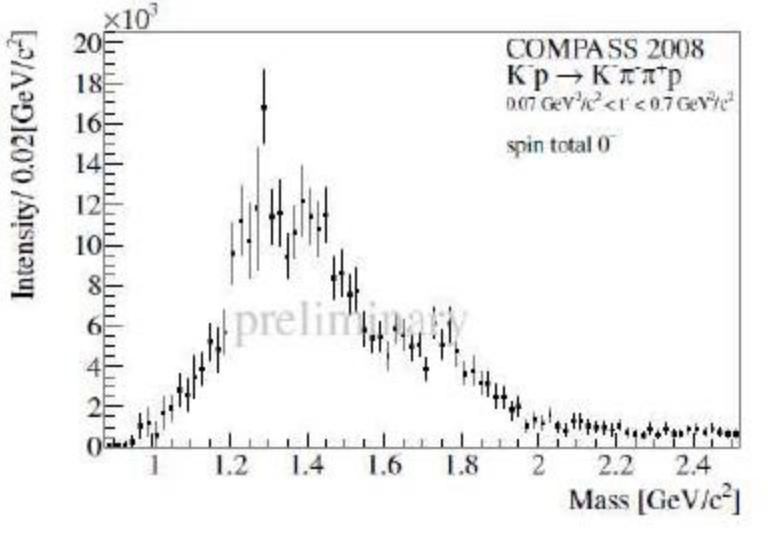


$K^- p \to K^- \pi^+ \pi^- p$

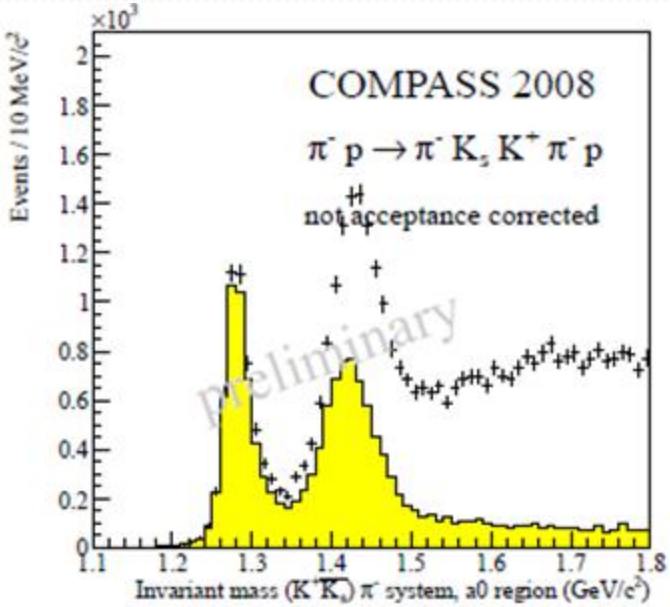
- Tagging incoming beam kaon.
- Most results from mass independent PWA agree with WA03.
- States consistent with $q\bar{q}$ with isospin ½.

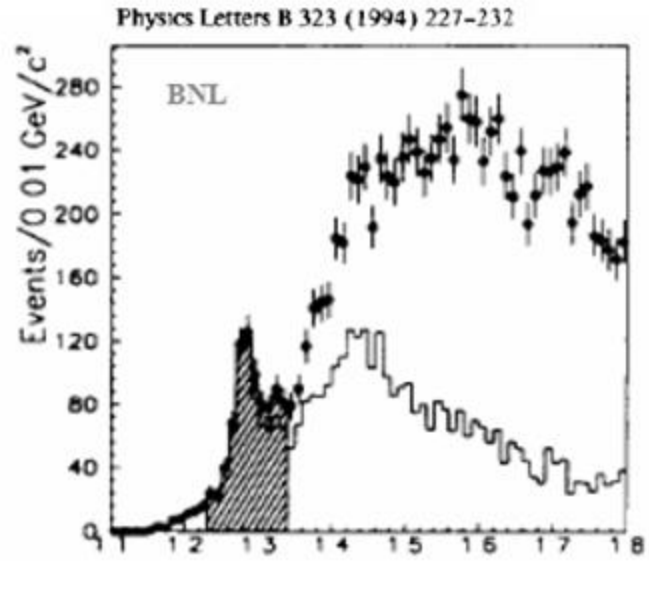
Observed intensity in the 0^- wave near the debated K(1460).

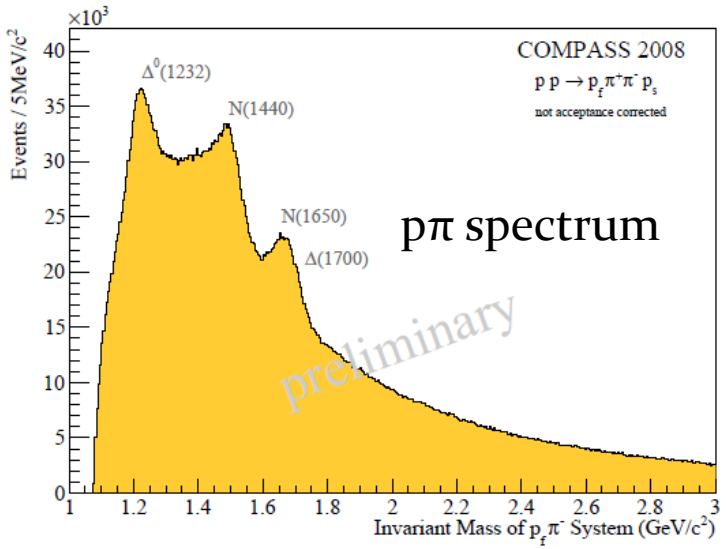
Leakage studies and mass dependent fit needed for definite conclusions.



More hadron physics with COMPASS







- Excellent potential for KKππ final states (high masses, $f_1(1285)\pi$ and $f_1(1420)\pi$ modes accessible).
- Search for glueballs in central *pp* collisions.
- Baryon spectroscopy.
- Precise OZI tests (see separate talk by J. Bernhard).

Summary

- Evidence for QCD allowed states like multiquarks, glueballs and hybrids still not beyond doubt.
- COMPASS has excellent potential to contribute:
  - Already observed the spin exotic wave $\pi_1(1600)$ in data from 2004 pilot run.
  - A large amount of data were collected with hadron beam in 2008/2009 (10 – 100 times the statistics from previous experiments, depending on the channel).
- COMPASS measures charged and neutral channels:
  - Independent consistency check.
- COMPASS measures kaonic final states.
- COMPASS has access to 3 production mechanisms:
  - Diffractive dissociation
  - Central production
  - Coulomb production
- COMPASS low t' data provide test of ChPT – first results agree with LO predictions
- COMPASS also offers excellent opportunities to study
  - Baryon spectroscopy
  - OZI tests and spin alignment measurements