New results on the search for spin-exotic mesons with COMPASS
(diffractively produced on proton)

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Universität Freiburg, Physikalisches Institut
for the COMPASS Collaboration

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Outline:

- **Introduction**
  - Spin-exotic mesons & the COMPASS experiment
  - PWA method
- **First results on diffractive 3π production** (2008 proton data)
  - 3π final states neutral vs. charged mode
  - PWA results on main & small waves
- **Status on further relevant decay channels**
  - η`π, f_1π decay channels
- **Conclusions & outlook**

bmb+f - Förderschwerpunkt
COMPASS
Großgeräte der physikalischen Grundlagenforschung

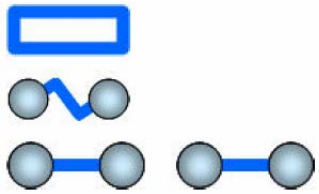
Mesons and Spin Exotic States

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: $0^{++}, 0^{-+}, 1^{--}, 1^{+-}, 1^{++}, 2^{++}, \ldots$
- Forbidden: $0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, 3^{-+}, \ldots$

QCD: meson states beyond

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



Hybrid candidates (1.3 - 2.2 GeV/c²):

lightest hybrid predicted: exotic $J^{PC}=1^{-+}$

- $\pi_1(1400)$: VES, E852, Crystal Barrel –> $\eta\pi$
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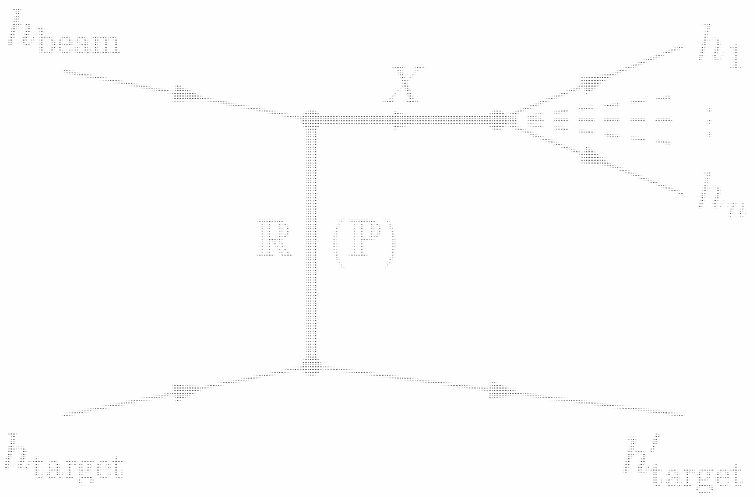
.... *still controversial* → *COMPASS*

Diffractive scattering

- study of J^{PC} exotic mesons
- t-channel Reggeon exchange
- forward kinematics, target stays intact
- small momentum transfer



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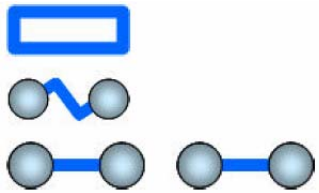

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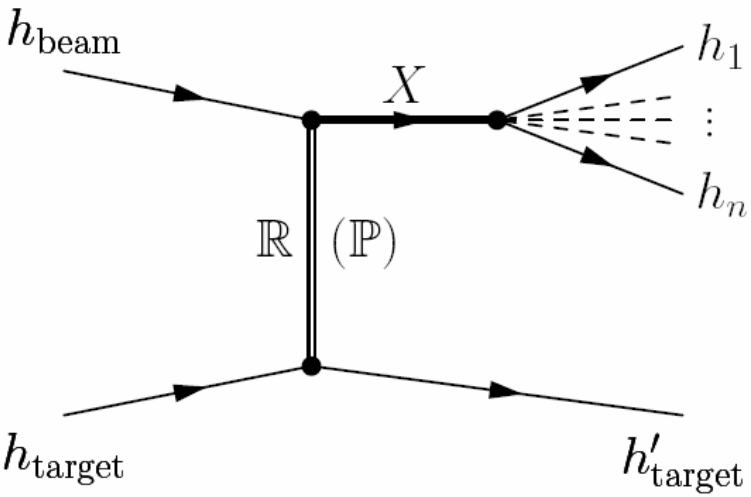

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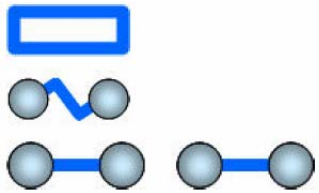

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COMPASS (2004 pilot run)

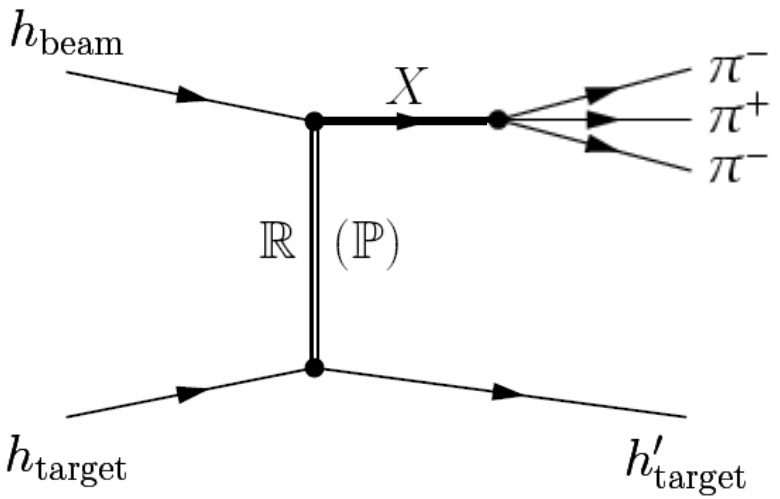
- 190 GeV π^- beam *(Pb target)*
- studied $\rho\pi$ decay channel in $\pi^-\pi^+\pi^-$ final states *diffr. produced on Pb*

=> **confirmation of a 1^{-+} resonance at 1.66 GeV**

[PRL 104 (2010) 241803]

Diffractive pion dissociation

- incoming π^- excited to resonance X^-
- X^- decays into final state, e.g. $(3\pi)^-$:



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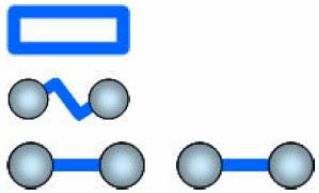

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  - a) π^- **p** —> $\pi^-\pi^+\pi^-$ **p** (charged mode)
  - b) π^- **p** —> $\pi^-\pi^0\pi^0$ **p** (neutral mode)

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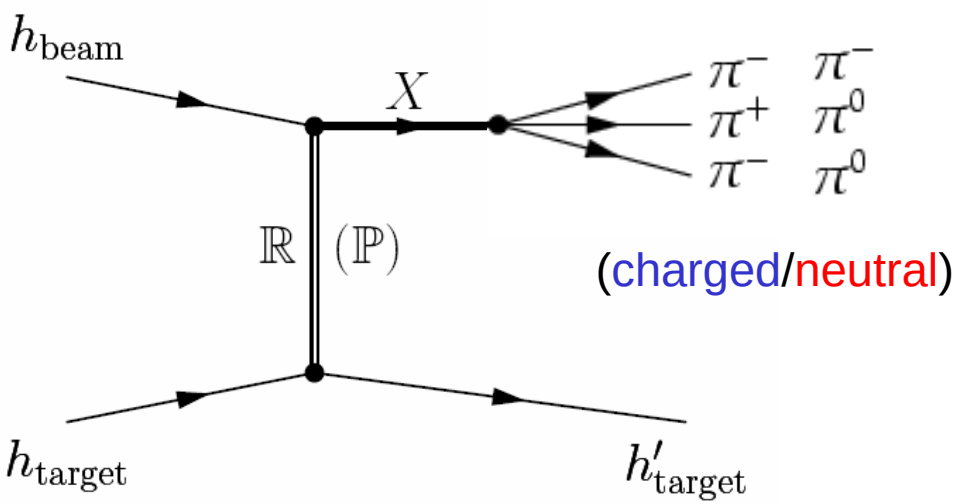
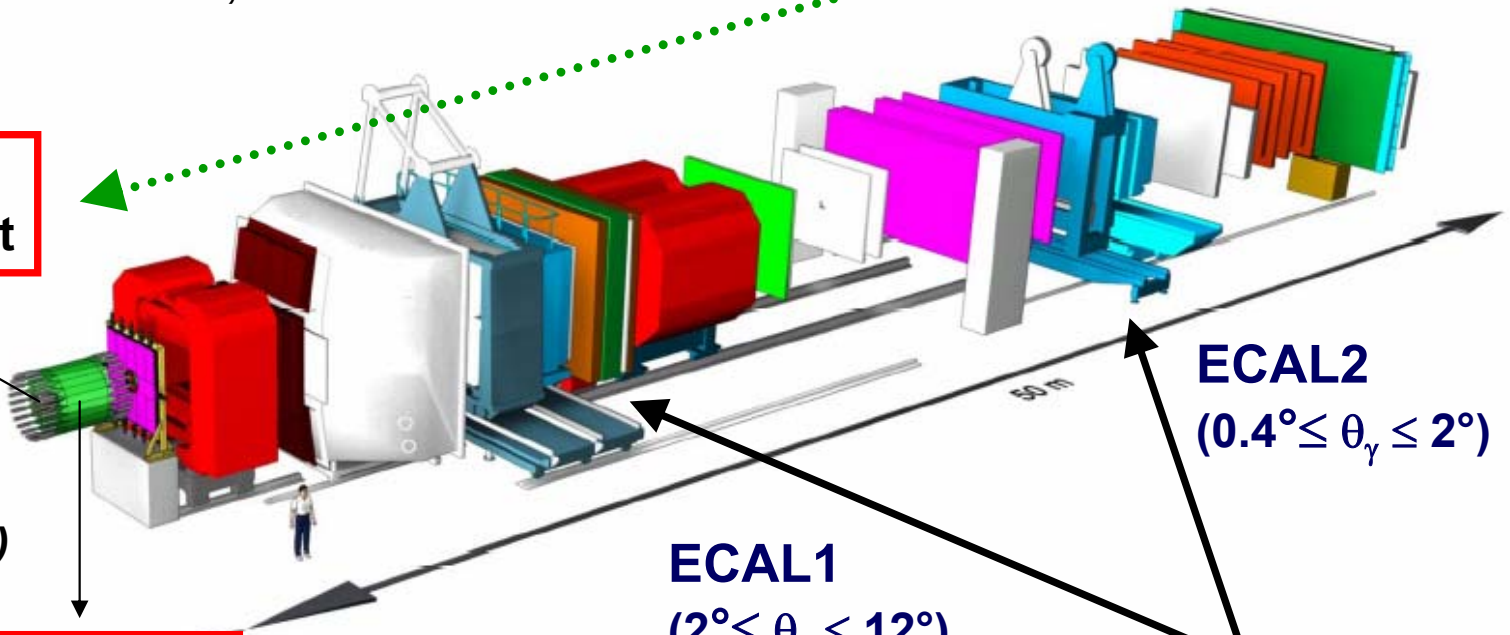


(charged/neutral)

COMPASS spectrometer: Hadron setup 2008/09

all COMPASS trackers:
SciFi, Si, MM, GEM, DC, Straw, MWPC

+Upgraded trackers close to beam:
ColdSilicons, *PixelGEMs*



0.4m liquid H_2 target

Beam

(muon or hadron)

Recoil detector (RPD) to trigger on reactions inside target

ECAL2
($0.4° \leq \theta_\gamma \leq 2°$)

ECAL1
($2° \leq \theta_\gamma \leq 12°$)

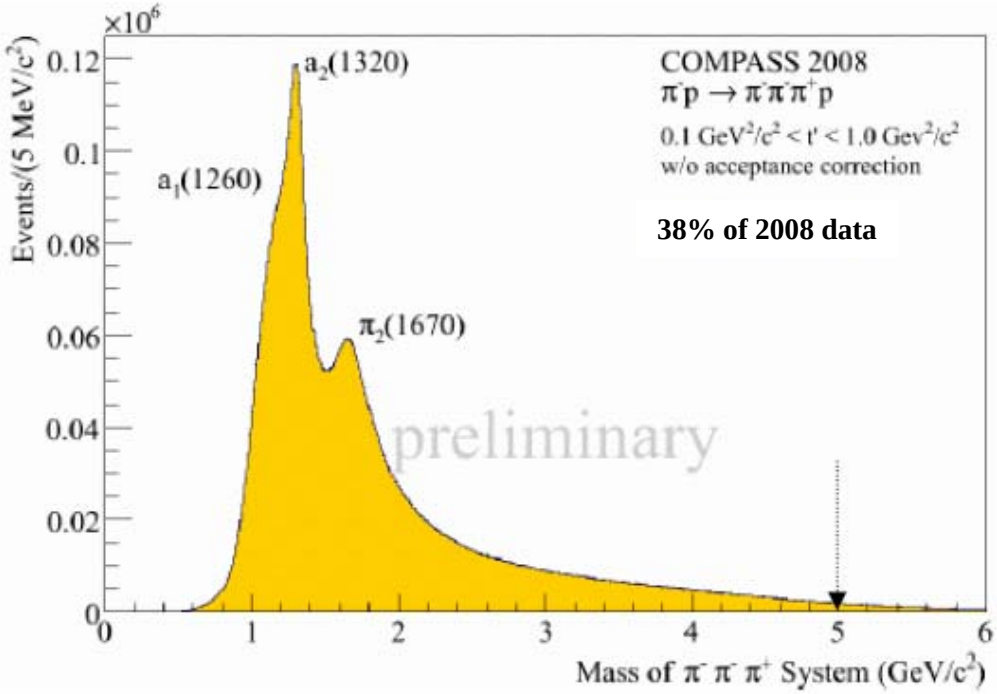
Electromagnetic calorimeters

(final states involving neutrals, e.g. π^0, η, or η')

Diffractive dissociation into 3π final states
(2008 data, LH_2 target)

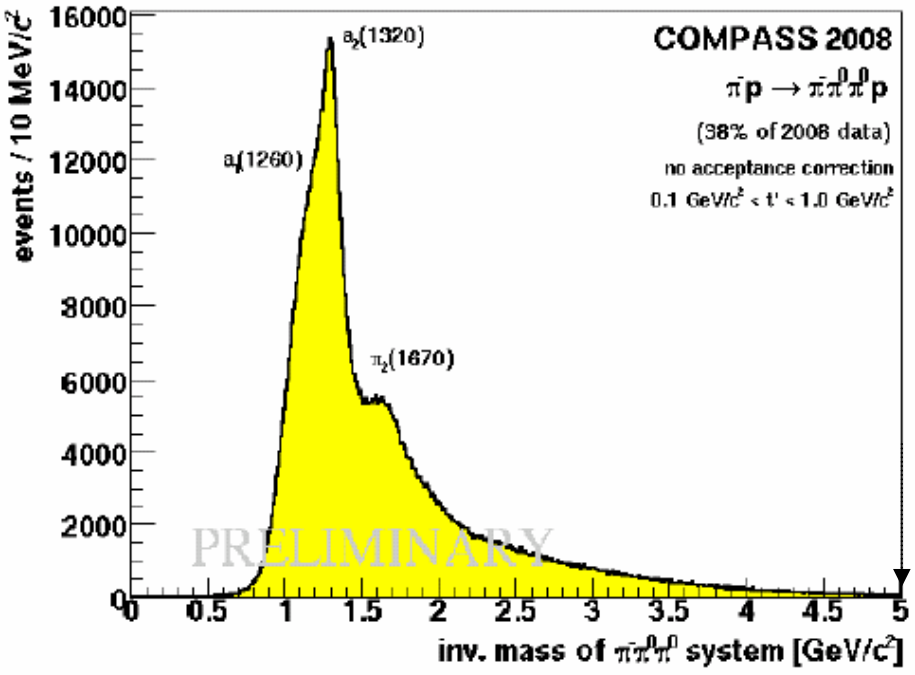
search for $\pi_1(1600)$

Mass of outgoing 3π system – charged mode: π^- **p** —> $\pi^-\pi^+\pi^-$ **p**



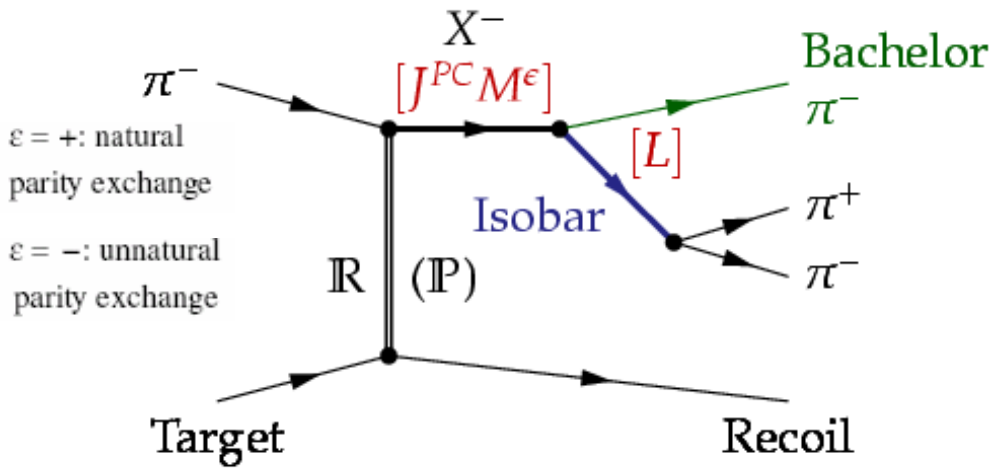
PWA: ~ 24M events (acceptance corrected)

Mass of outgoing 3π system – neutral mode: π^- **p** —> $\pi^-\pi^0\pi^0$ **p**



PWA: ~ 1M events

PWA using 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 (reflectivity basis): $J^{PC}\ M^{\varepsilon}$ [isobar] L

Partial wave analysis:

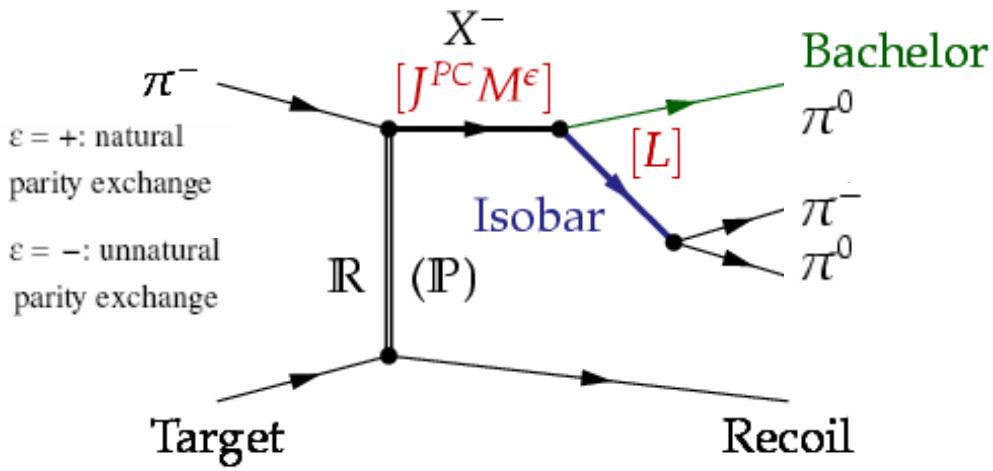
- **program:** Illinois/Protvino/Munich (D.Ryabchikov) software (IHEP/VES, TUM/COMPASS)
- **Isobars:** *$(\pi\pi)_S$ [broad $f_0(600)$+$f_0(1370)$], $f_0(980)$, $\rho(770)$, $f_2(1270)$, $\rho_3(1690)$*
- **Acceptance:** corrections (2008: rather flat for charged, neutral not yet included)

Step 1) Mass independent PWA: (40MeV/c² bins, 42 / 53 partial waves)

Step 2) Mass dependent χ^2 fit: (to mass independent result)

- Main partial waves chosen, parameterised by Breit-Wigner
- Coherent background for some waves

PWA using isobar model



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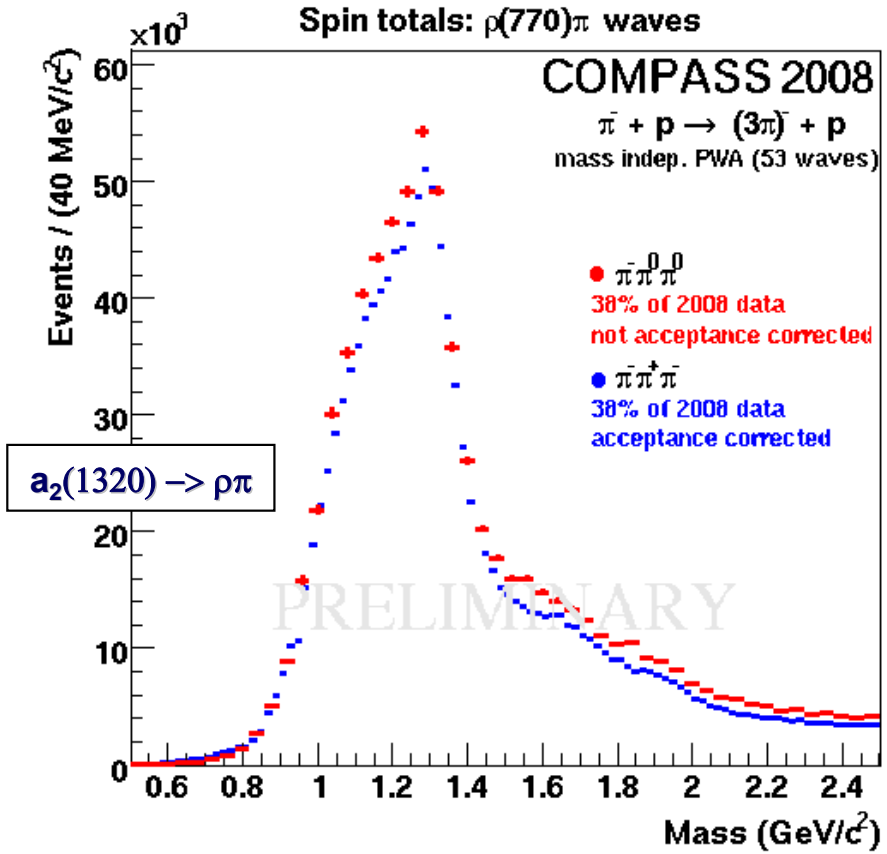
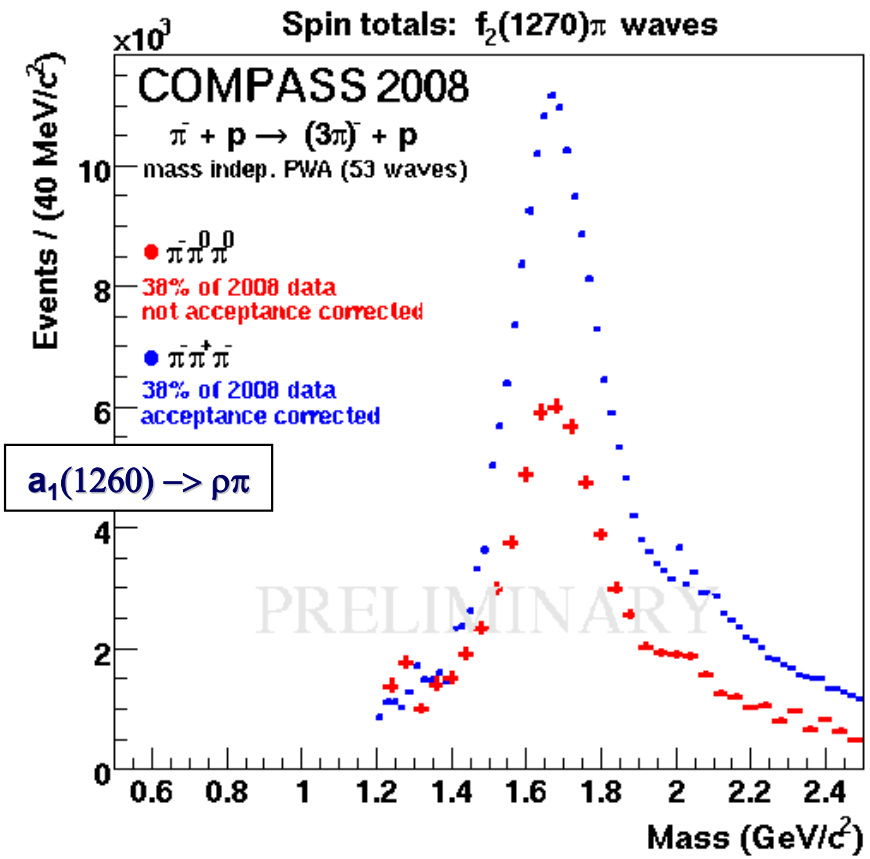
Two sets of partial wave totals

3π diffractive -- Neutral vs. Charged mode: 53 waves





Isospin symmetry: neutral / charge mode

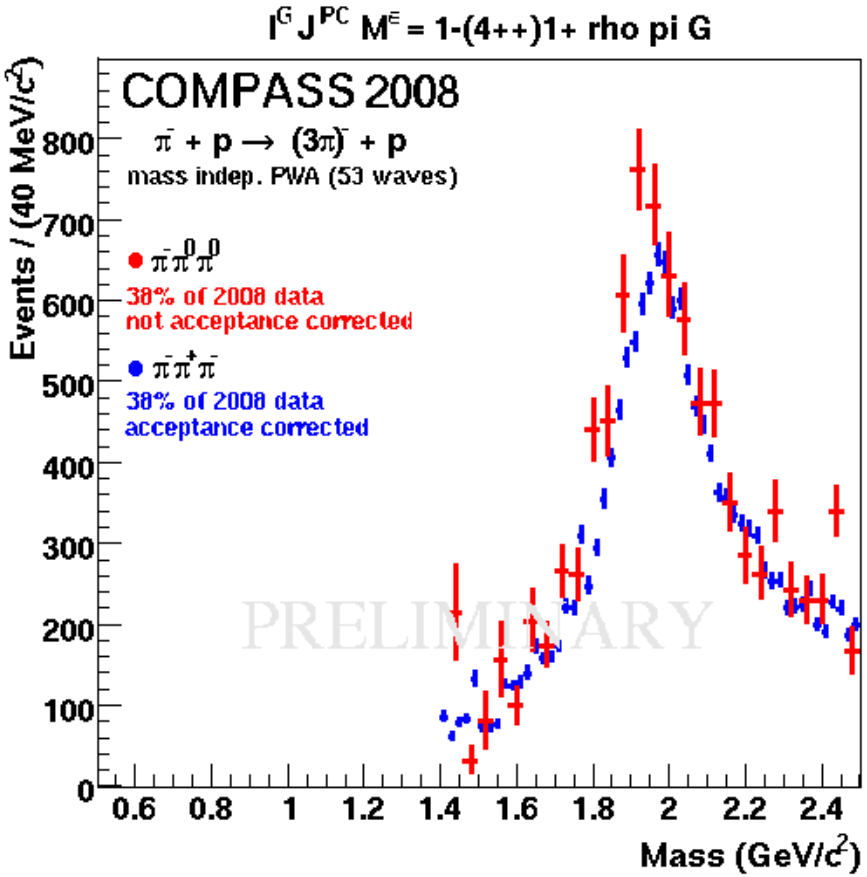
- X^- decaying into $f_2\,\pi$: 1/2 intensity expected
- X^- decaying into $\rho\,\pi$: 1/1 intensity expected

Data follows isospin symmetry:

- throughout full wave-set
- main and small waves, *next slides*

Selected partial waves
isospin symmetry check ctd.

$a_4(2040) \rightarrow \rho\pi$



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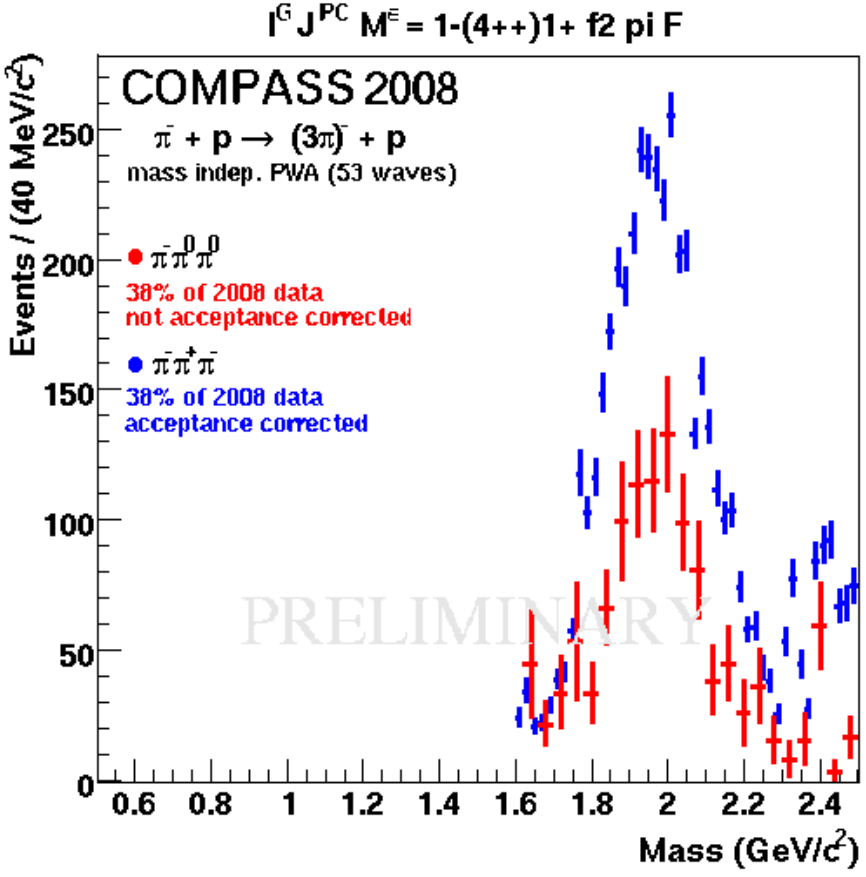
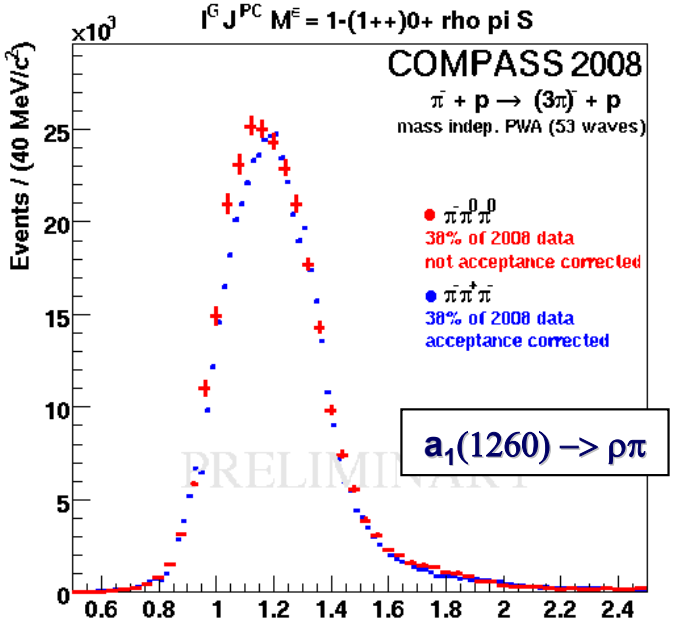
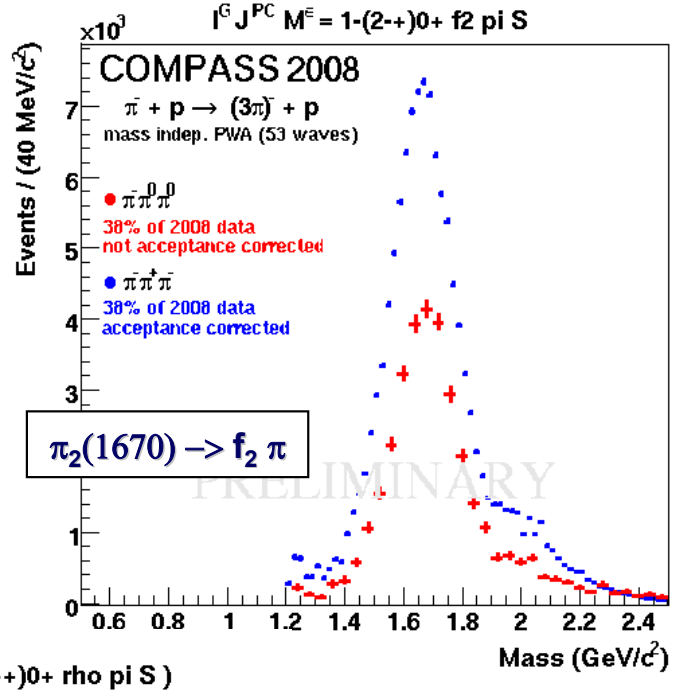
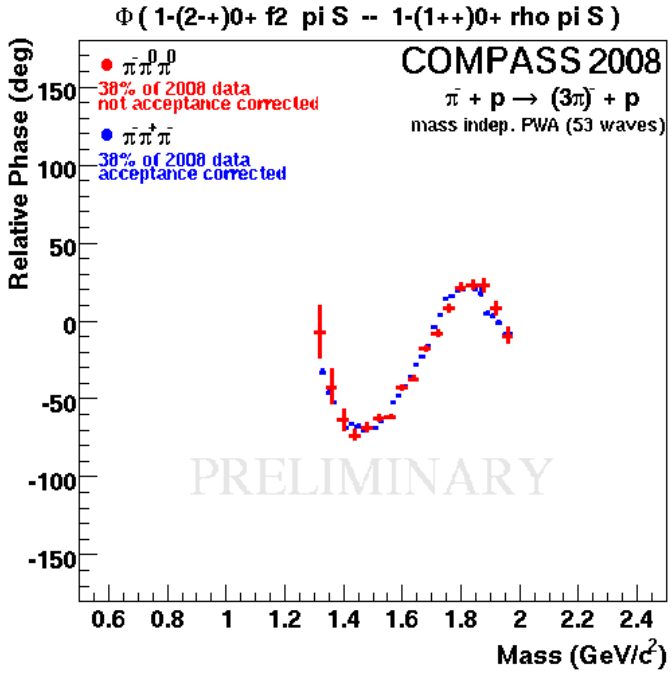


Selected partial waves & phases

3π diffractive -- Neutral vs. Charged mode: 53 waves







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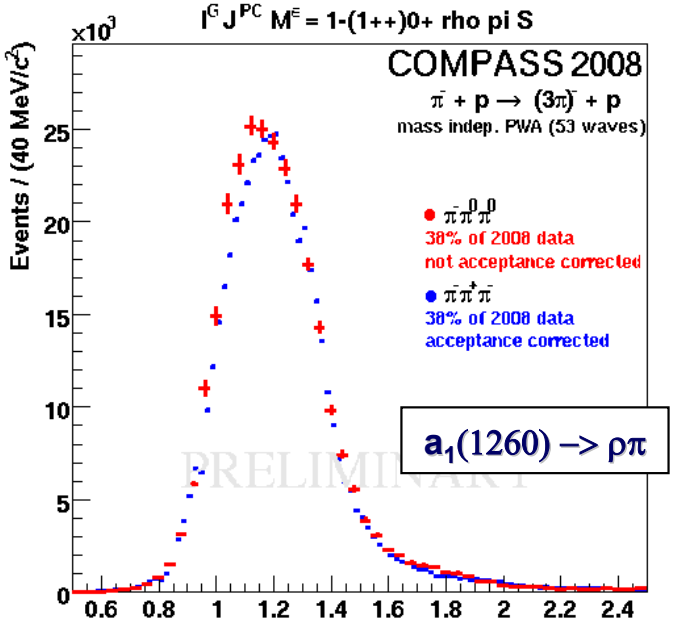

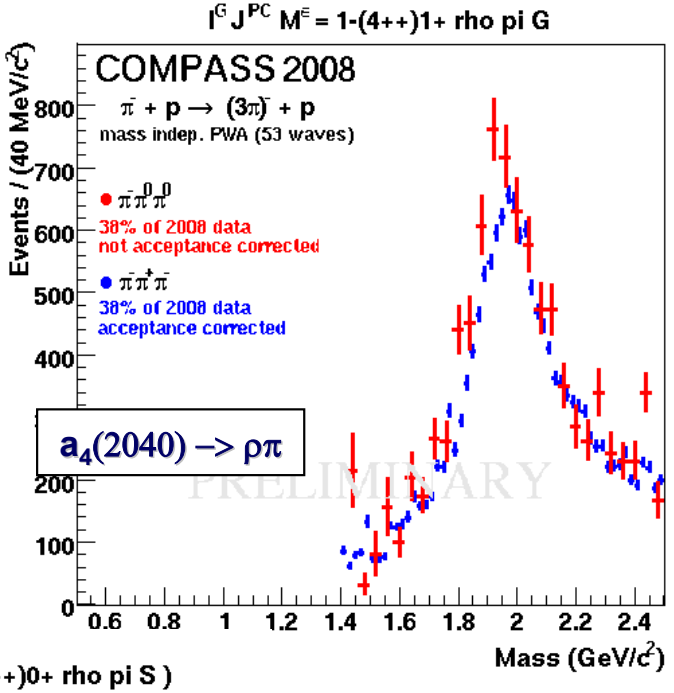

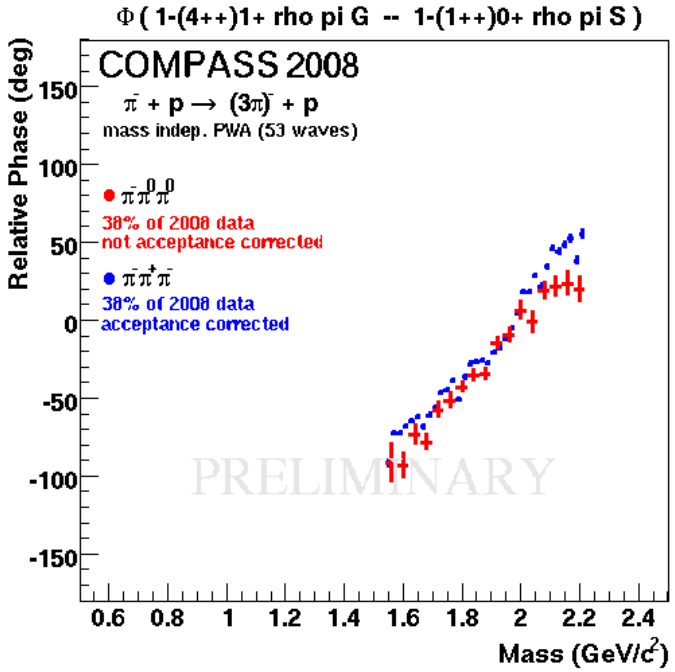

First glimpse on the exotic wave

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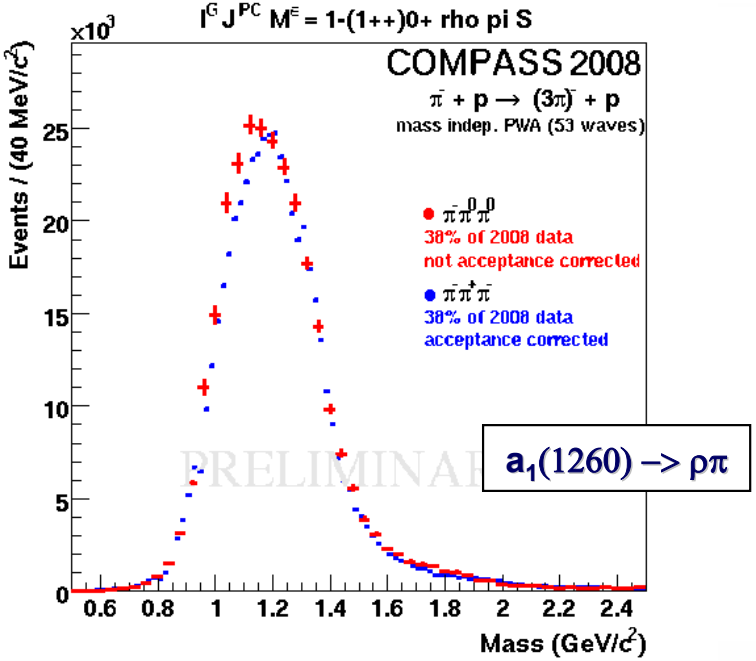

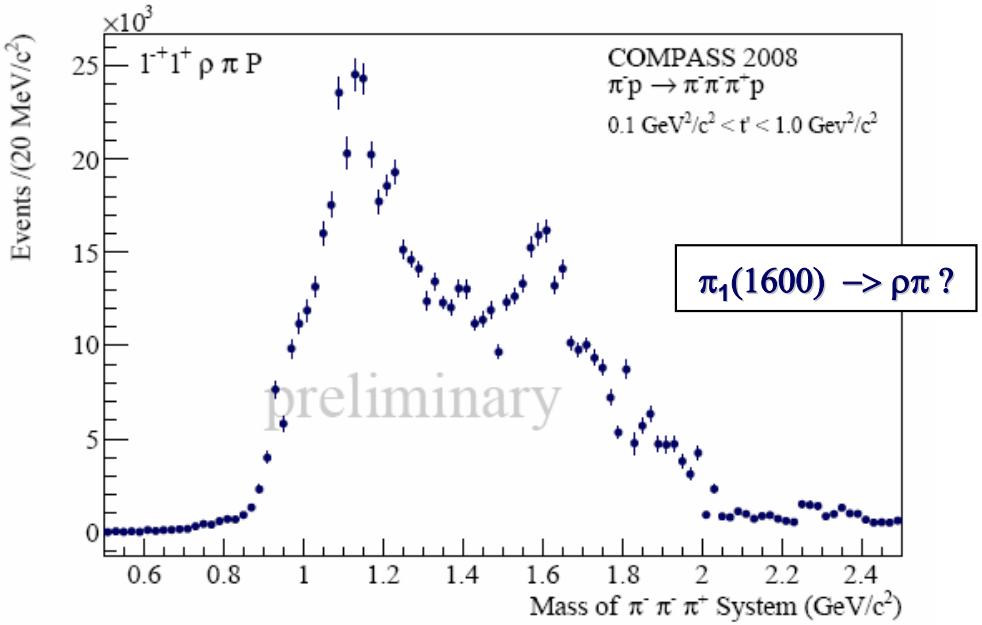

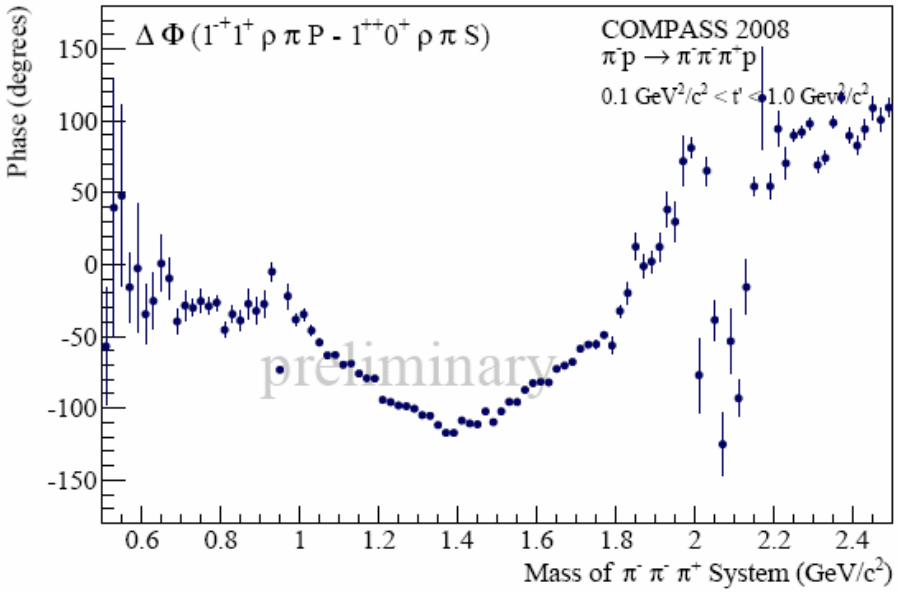

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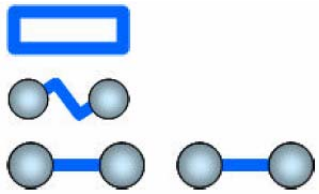

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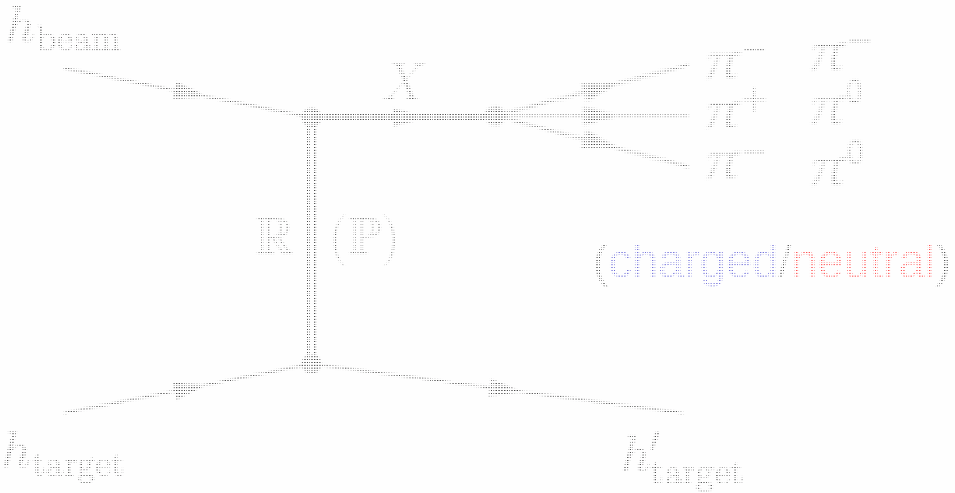

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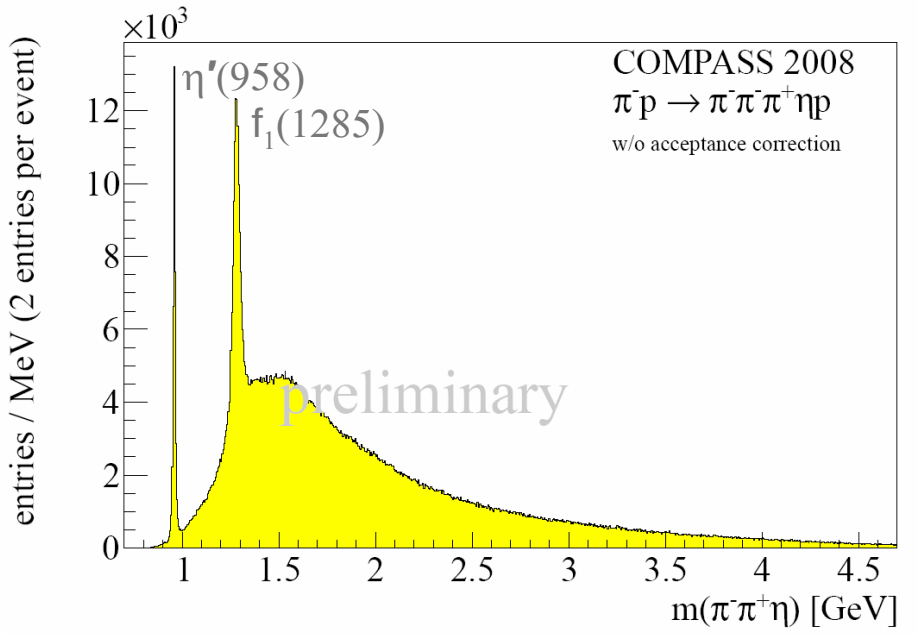
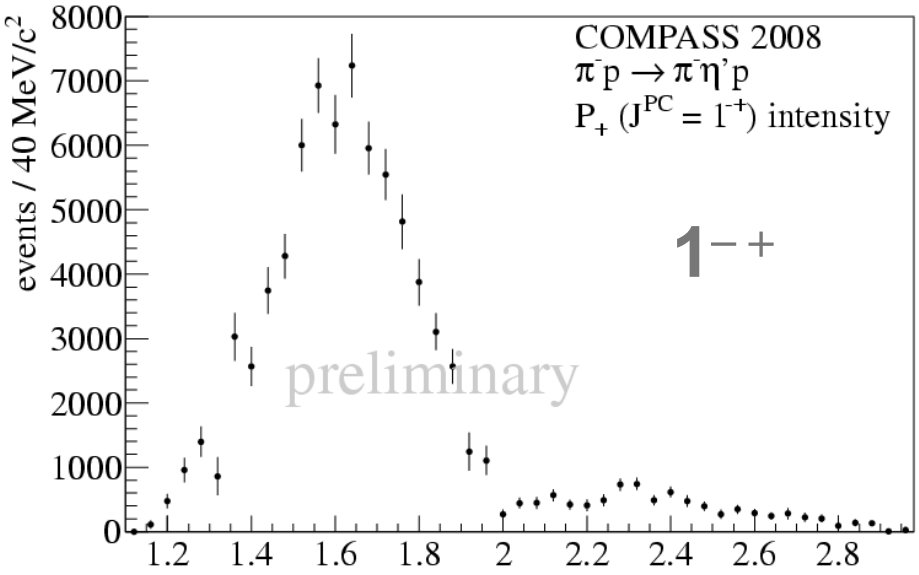
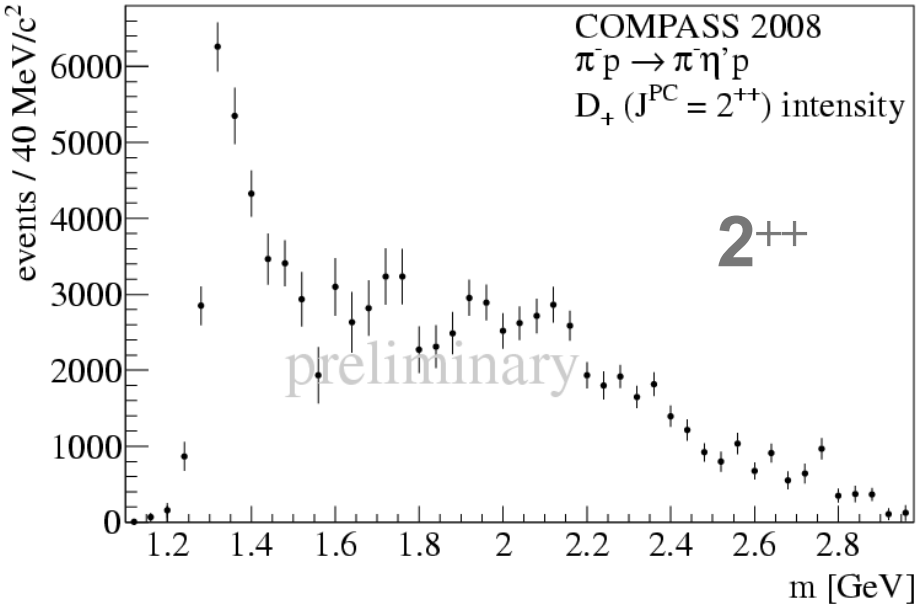
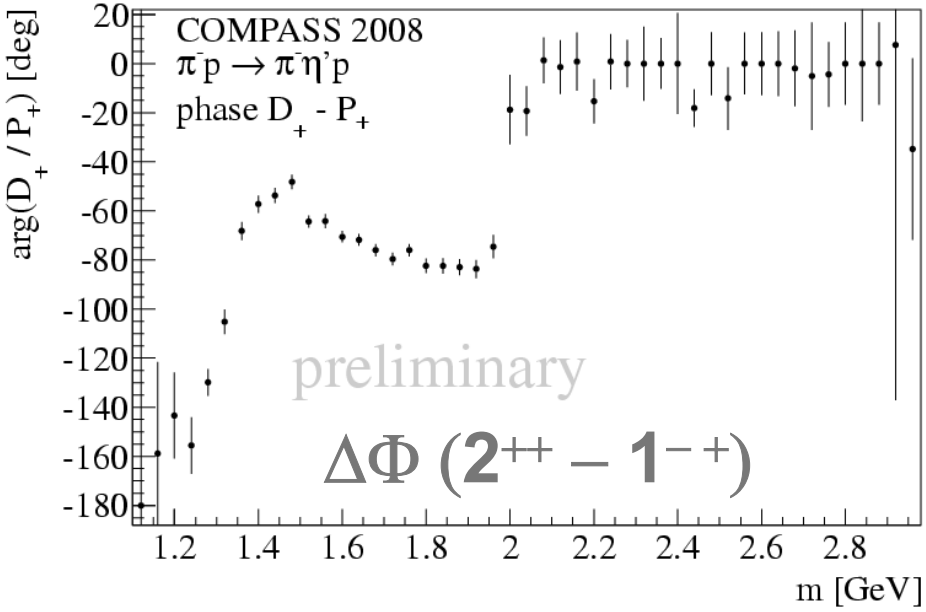
The Exotic $\eta'\pi^-$ Wave in 190 GeV $\pi^-+p \rightarrow \eta'+\pi^-+p$

search for $\pi_1(1600)$









First studies of diffractive dissociation into $K\bar{K}\pi\pi$ final states

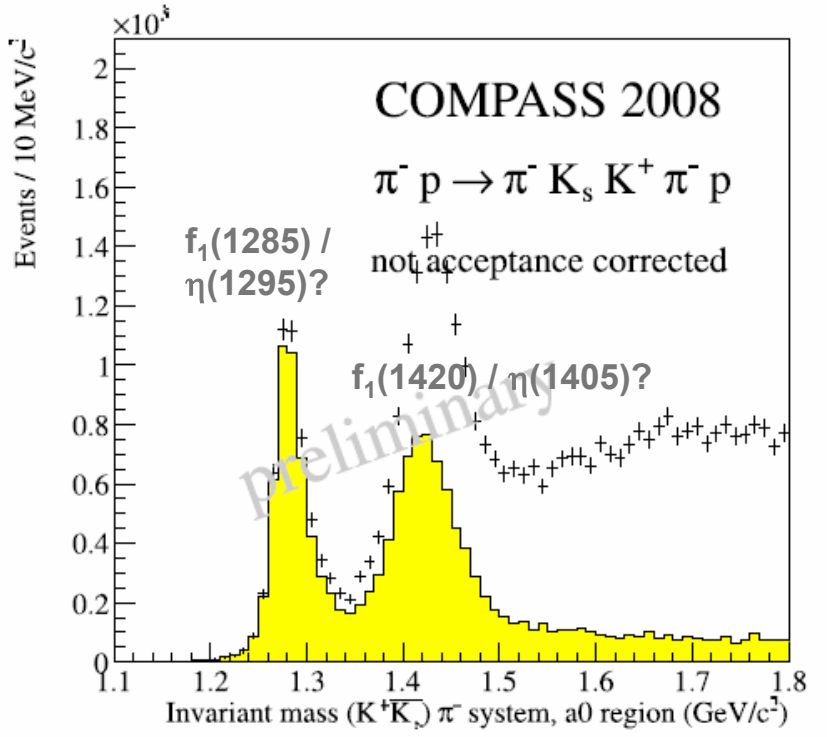
Physics channel: $\pi^- p \rightarrow K\bar{K}\,\pi\,\pi^-\,p$

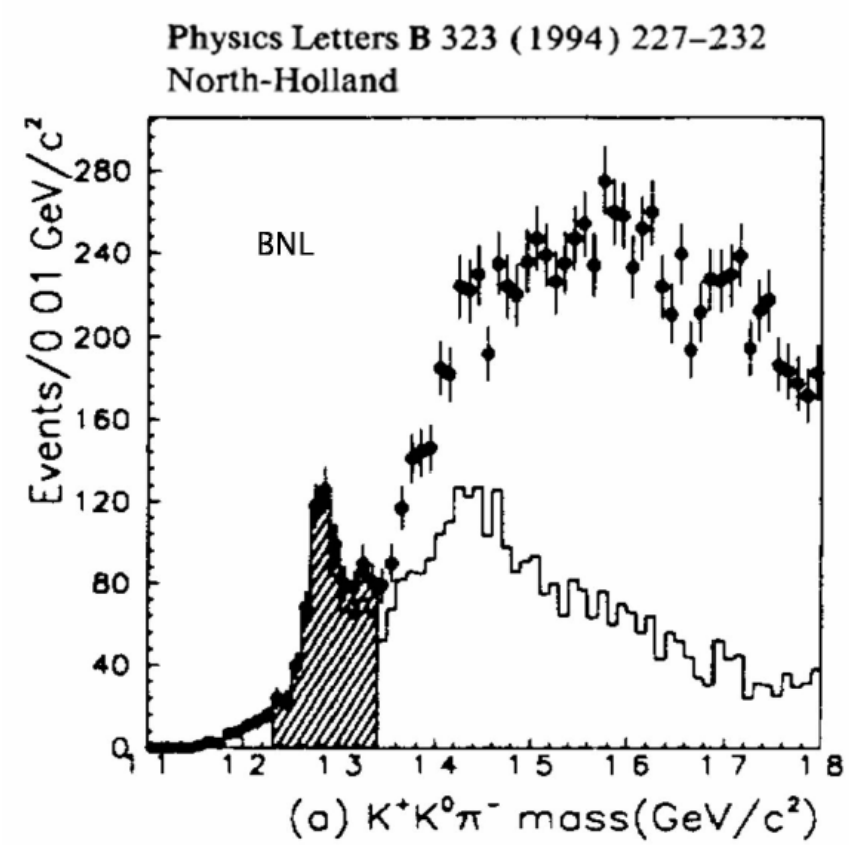
Motivation: Search for diffr. X^- coupling to $s\bar{s}$ final states

First preliminary PWA started: $\overline{K^0}\,K^+\,\pi^-\,\pi^-$

search for $\pi_1(1600)$, $\pi_1(2000)$

$(K\bar{K}\pi)^0$ subsystem:





Statistics: 2008 data => ~ factor 10 w.r.t. BNL (~20 for 2008/09)

Summary & conclusions

- **COMPASS: high potential for spin-exotic search**
  - ✓ **2008/09: Very high statistics taken** *(hadron beams, proton & nuclear targets)*
  - ✓ **COMPASS measures Neutral & Charged channels**

  => all relevant channels for spin-exotic search feasible

- **New physics results presented (incl. exotic signals):**
  - ➢ $(3\pi)^-$ **system studied in both decay modes: charged & neutral** *(consistent results)*

  => Independent confirmation of new states within same experiment!

  - ➢ $(\eta'\pi)^-$ **system shows large intensity in exotic wave** *(high mass range, to be understood)*
  - ➢ $(K\bar{K}\pi\pi)^-$ **system: feasibility shown for** $f_1\pi$ **decay channel(s)!**

    → *exemplarily, further kaonic channels, also:* Kaon diffraction *(using Kaon beam)*

Outlook:

- **More systematic studies, PWA model, Mass-dependent PWA** → *more work ahead*

Not discussed: Low t', Primakoff, Central production, Baryon spectroscopy, OZI violation

→ *Quite rich physics programme: various further ongoing analsyes & results!*