

Spin-exotic search in the $\rho\pi$ decay channel:
**First results on $\pi^-\pi^0\pi^0$ in comparison
to $\pi^-\pi^+\pi^-$ final states**
(diffractively produced on proton)



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Outline:

- **Introduction**
 - Spin-exotic mesons & the COMPASS experiment
 - PWA method
- **First results on diffractive 3π production** (2008 proton target data)
 - 3π final states neutral vs. charged mode
 - PWA results on main & small waves
- **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 $I^G J^{PC}$
- $P = (-1)^{L+1}$ $C = (-1)^{L+S}$ $G = (-1)^{L+L+1}$
- 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: $(q\bar{q})(q\bar{q})$

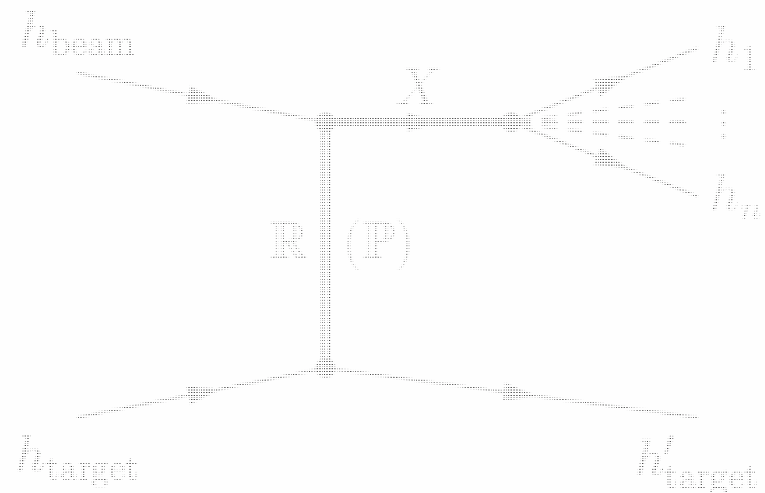
Hybrid candidates (1.3 - 2.2 GeV/c²):

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

- $\pi_1(1400)$: VES, E852, Crystal Barrel $\rightarrow \eta\pi$
- $\pi_1(1600)$: E852, VES $\rightarrow \rho\pi, \eta'\pi, f_1\pi, b_1\pi$
- $\pi_1(2000)$: E852 $\rightarrow f_1(1285)\pi, b_1(1235)\pi$
- ... still controversial \rightarrow COMPASS

Diffraction scattering

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





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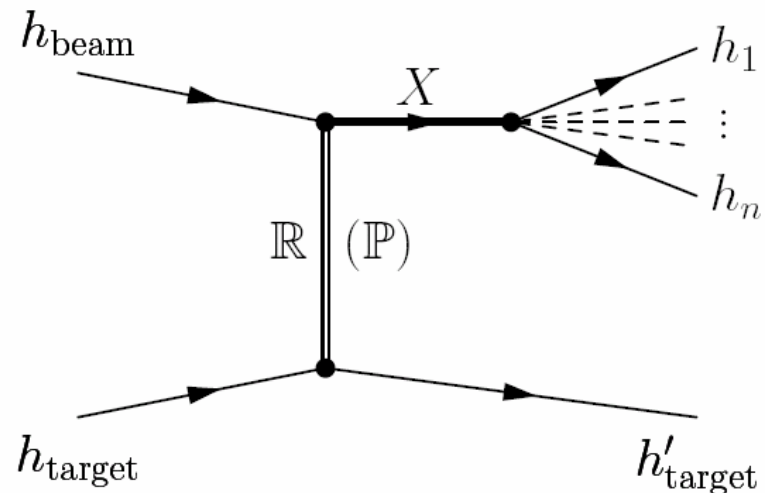
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COMPASS (2004 pilot run)

- 190 GeV π^- beam (Pb target)
- studied $\rho\pi$ decay channel via
 $\pi^- \text{ Pb} \rightarrow \pi^- \pi^+ \pi^- \text{ Pb}$
 \Rightarrow confirmation of a 1^{-+} resonance at 1.66 GeV

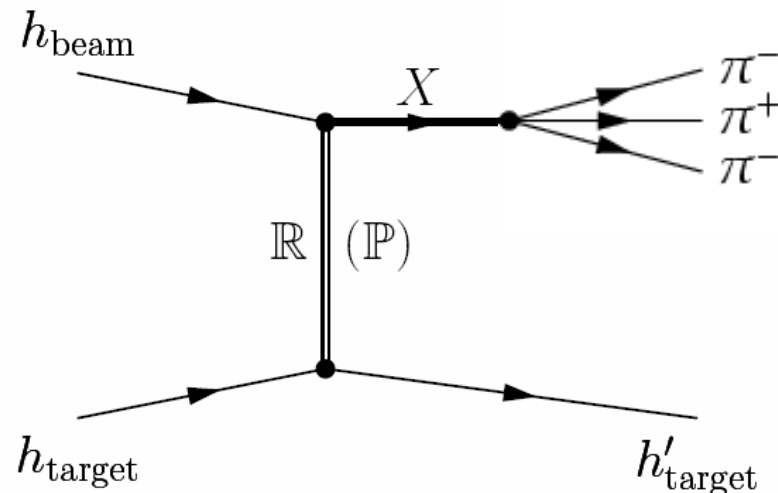
[PRL 104 (2010) 241803]

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Diffraction pion dissociation

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





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COMPASS (2008/09 data)

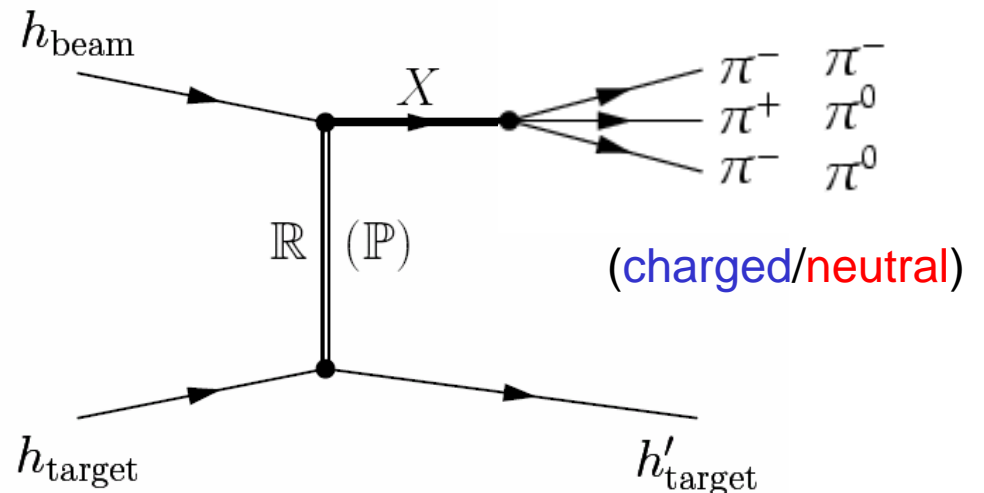
- 190 GeV π^- beam (proton target)
- study of $\rho\pi$ decay channel via:
 - $\pi^- p \rightarrow \pi^- \pi^+ \pi^- p$ (charged mode)
 - $\pi^- p \rightarrow \pi^- \pi^0 \pi^0 p$ (neutral mode)

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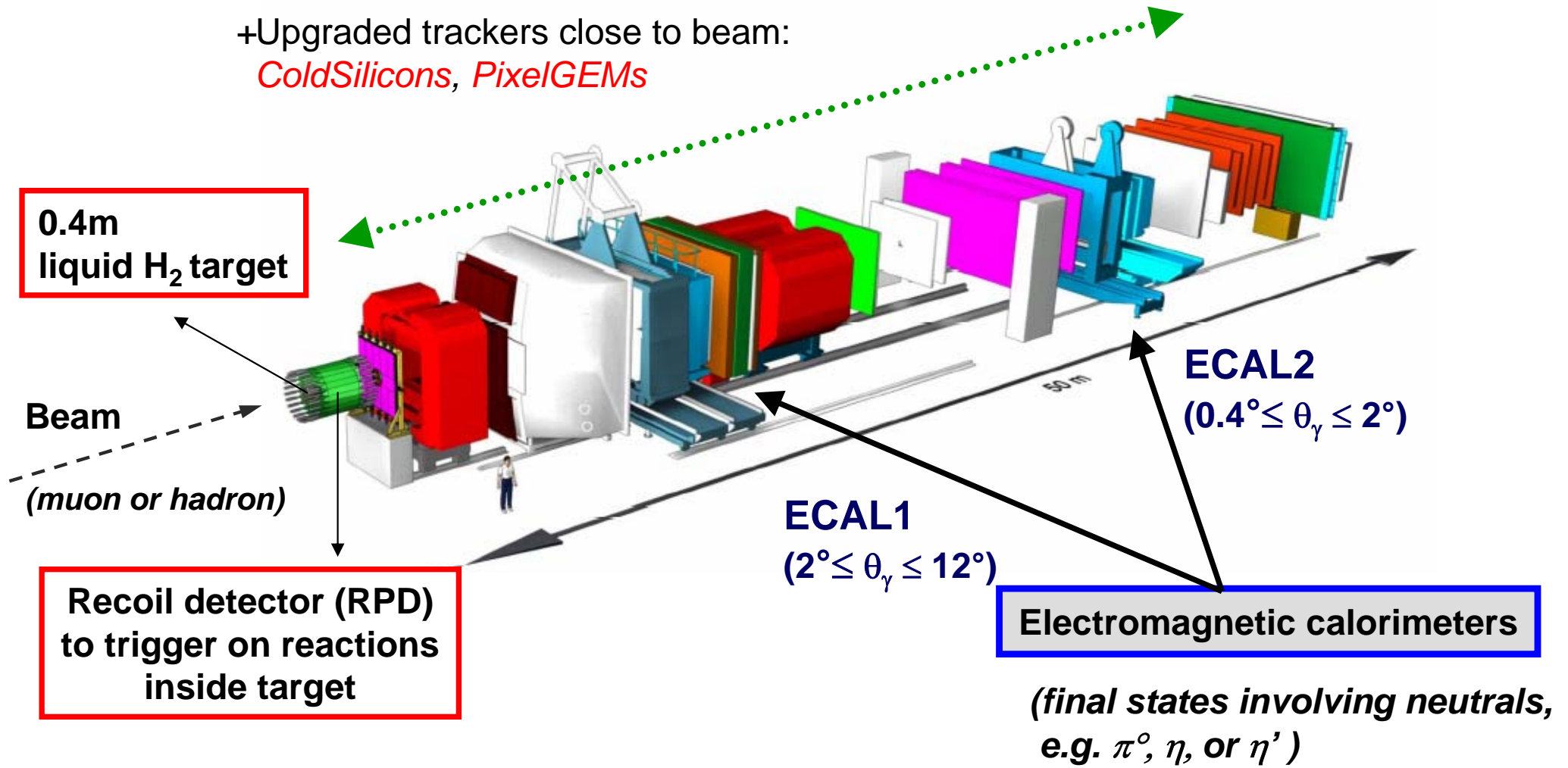


COMPASS spectrometer: Hadron setup 2008/09



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

+Upgraded trackers close to beam:
ColdSilicons, PixelGEMs





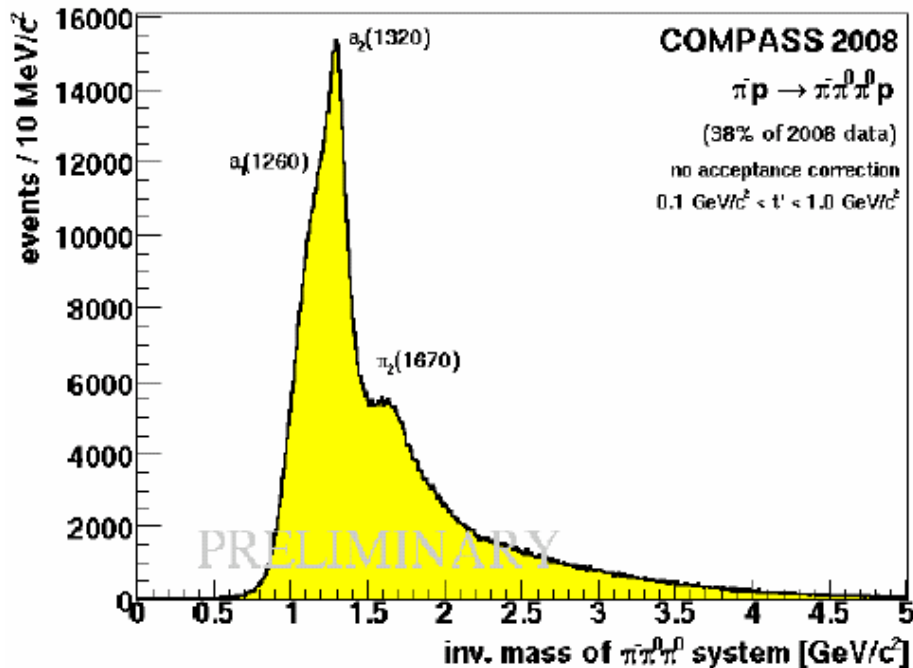
Diffraction dissociation into 3π final states (2008 data, LH₂ target)



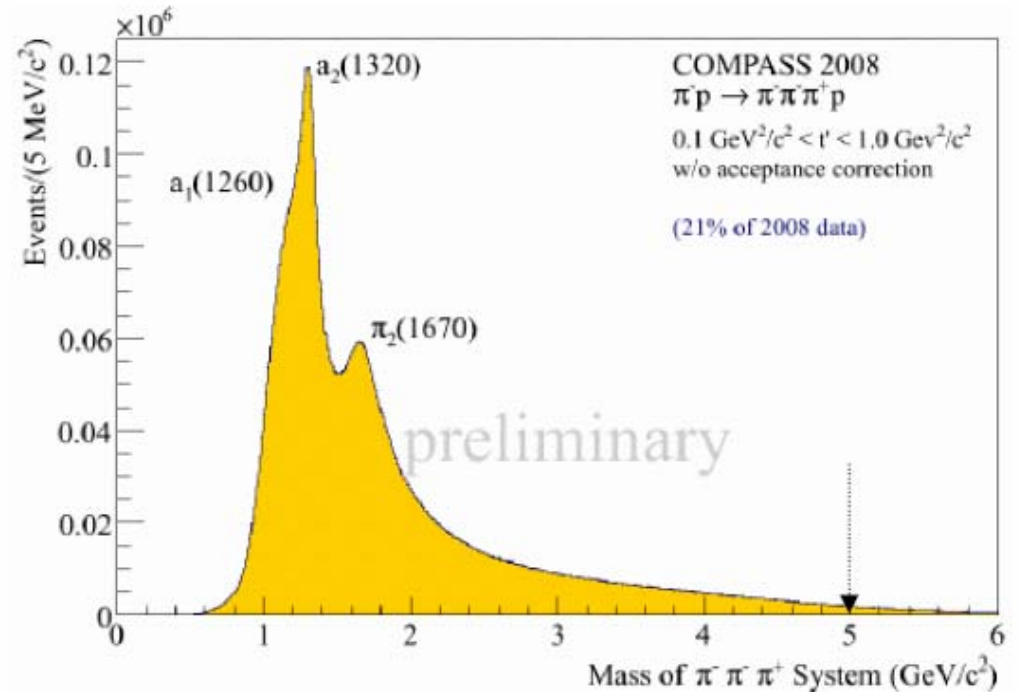
search for $\pi_1(1600)$

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

Mass of outgoing 3π system – **charged**
mode: $\pi^- p \rightarrow \pi^- \pi^+ \pi^- p$ HK 23.3



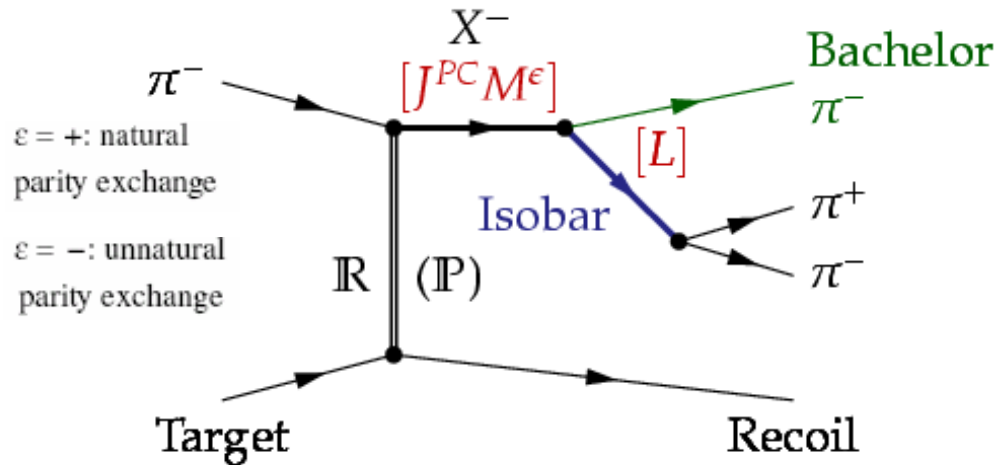
PWA: ~ 1M events



PWA: ~ 24M 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 $f_0(600)+f_0(1370)$], $f_0(980)$, $\rho(770)$, $f_2(1270)$, $f_0(1500)$, $\rho_3(1690)$
- **Acceptance:** corrections included (via normalisation integrals)

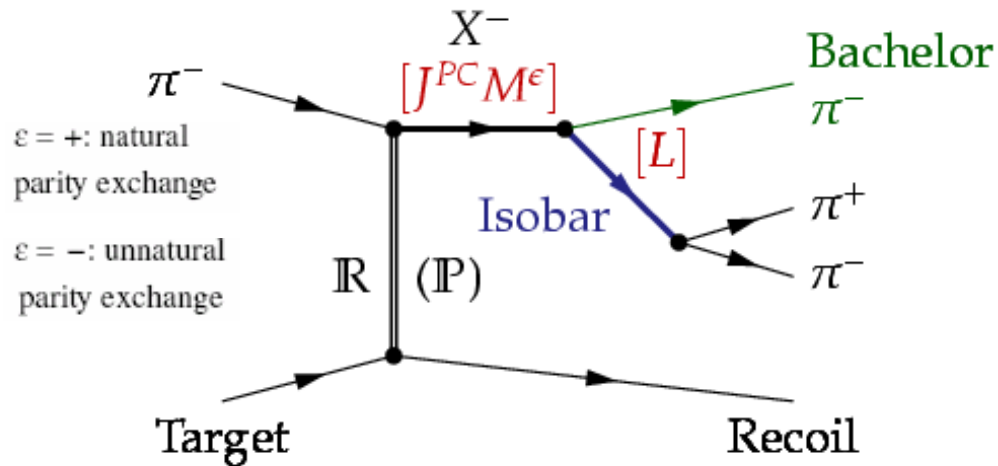
Step 1) Mass independent PWA: (40MeV/c² bins, 53 partial waves)

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

- Main **partial waves chosen**, parameterised by Breit-Wigner
- Non-resonant **background** for some waves



PWA using isobar model



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= following results

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Comparison: Neutral vs. charged mode

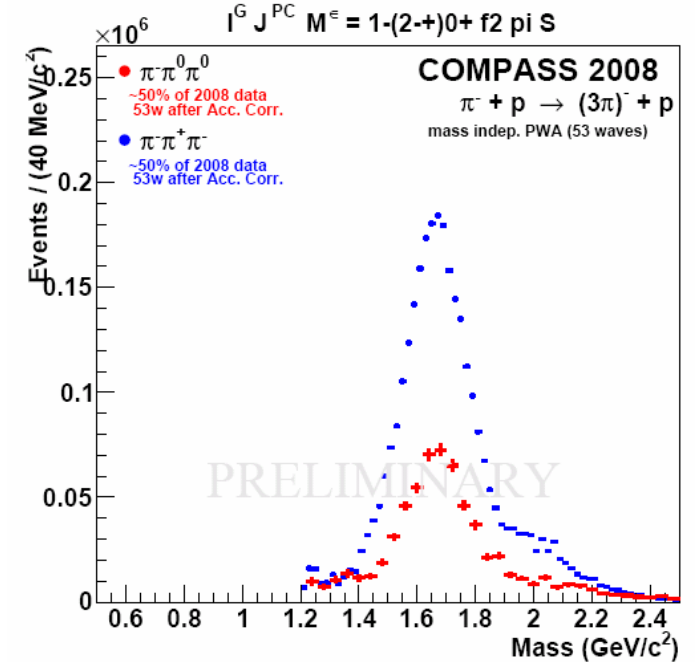
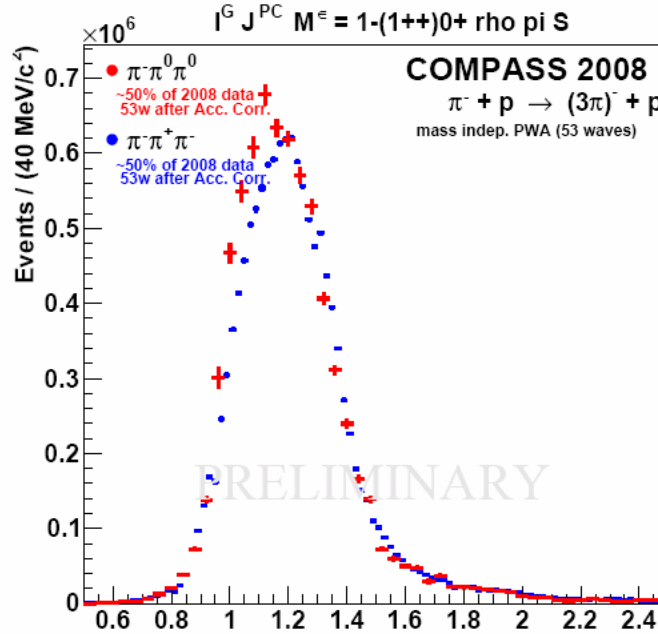
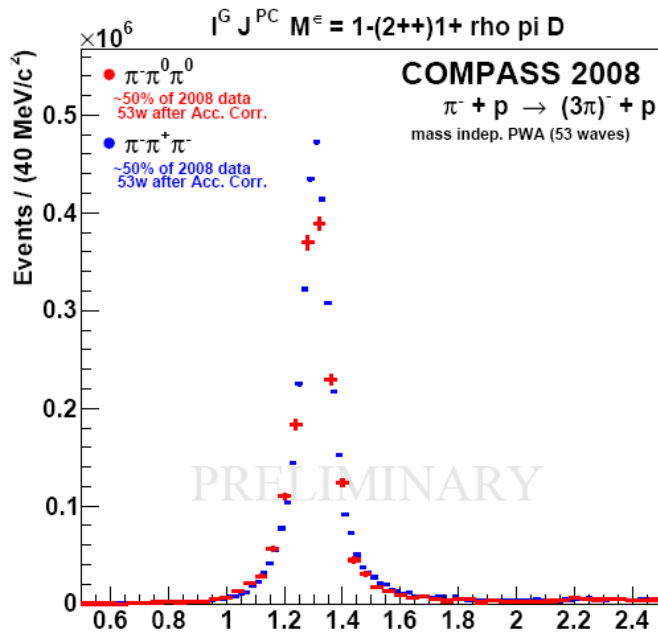
simple isospin symmetry check



$a_2(1320) \rightarrow \rho\pi$

$a_1(1260) \rightarrow \rho\pi$

$\pi_2(1670) \rightarrow f_2\pi$



search for $\pi_1(1600)$

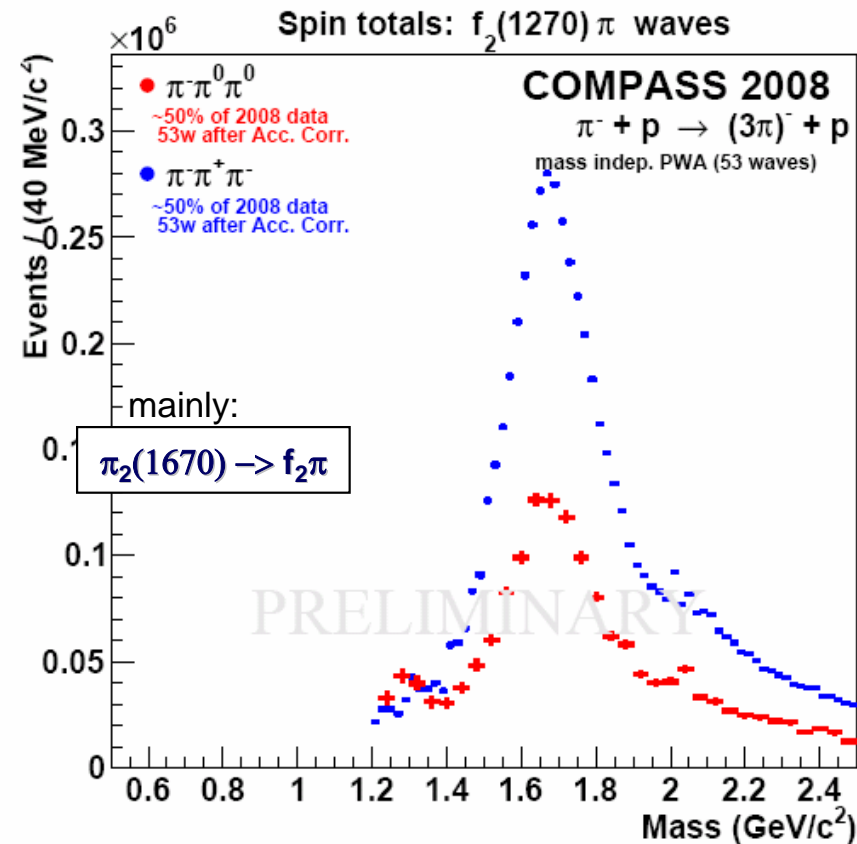
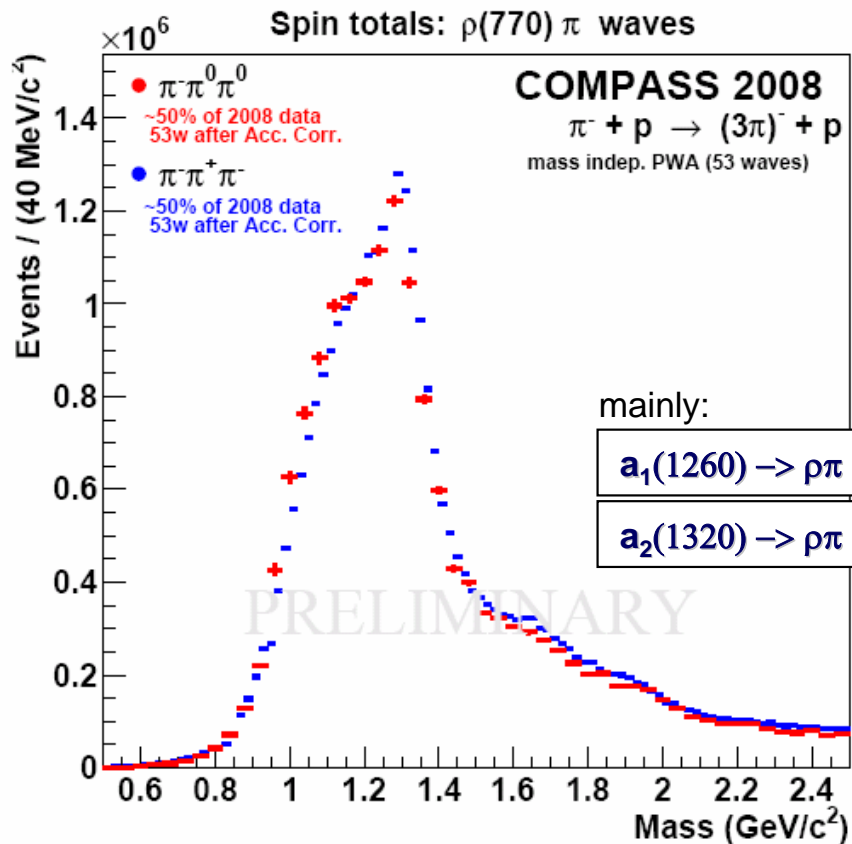
Isospin symmetry: neutral / charge mode

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



Two sets of partial wave totals

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



Isospin symmetry: neutral / charge mode

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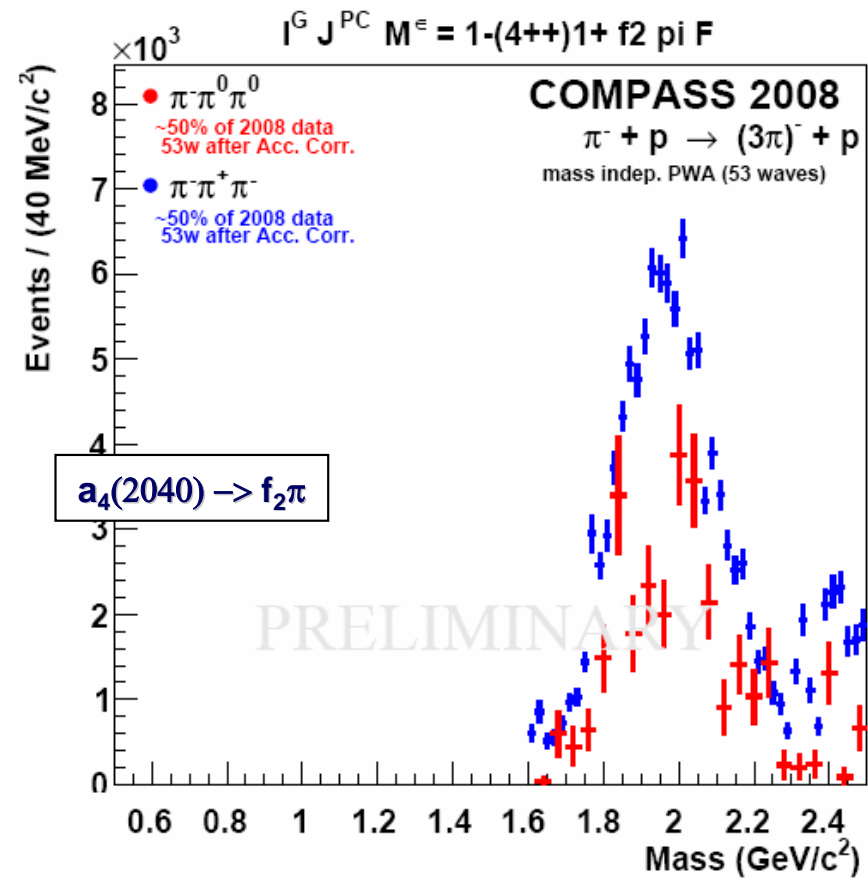
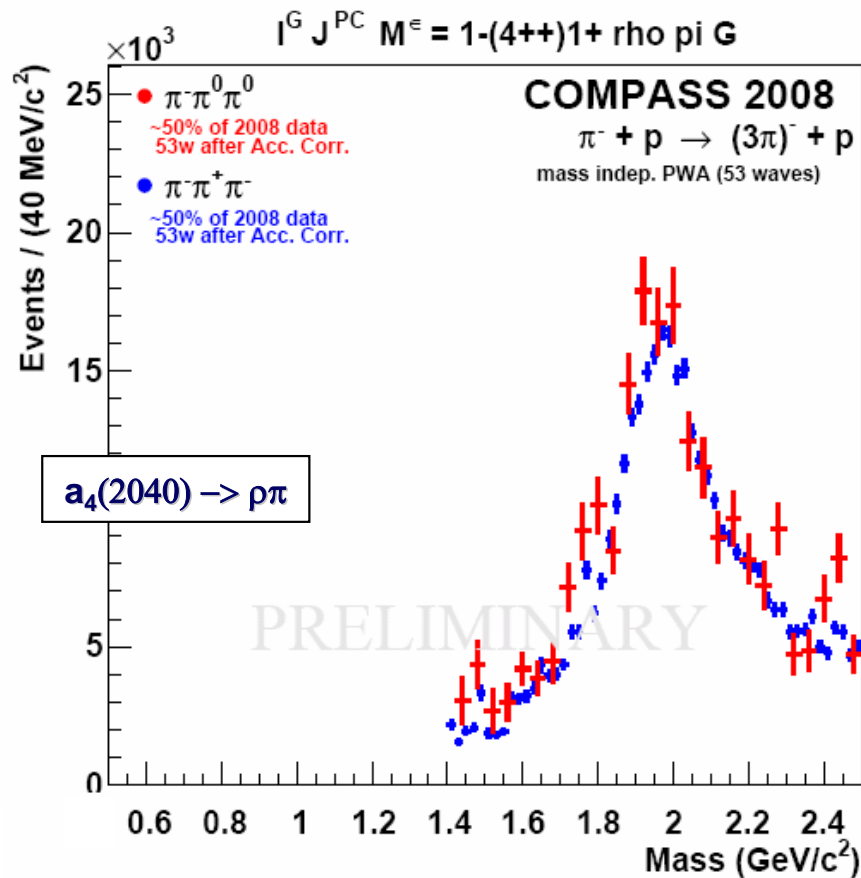
Data follows isospin symmetry:

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



Selected partial waves – small waves

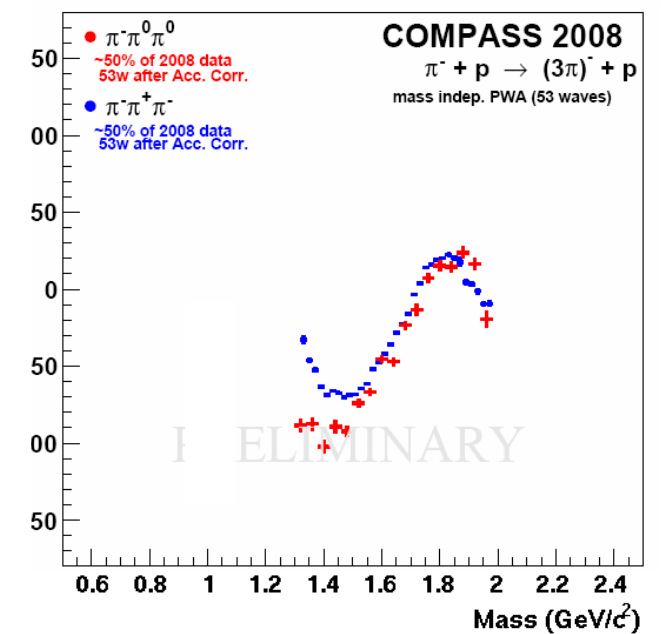
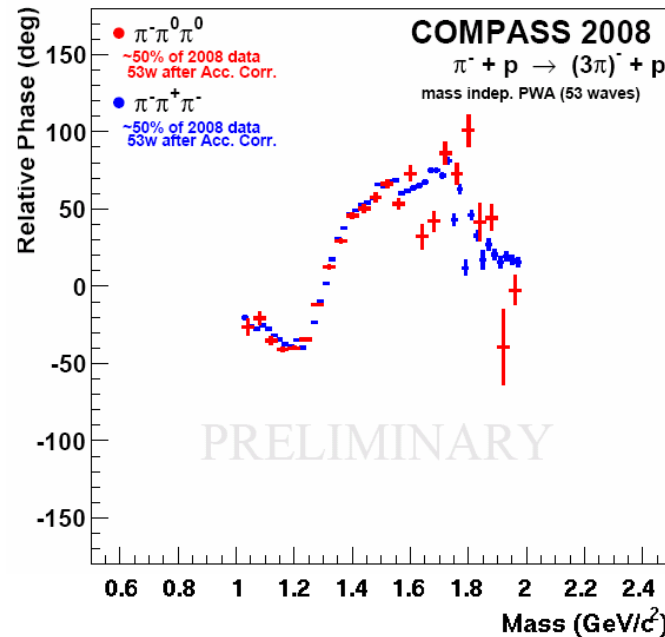
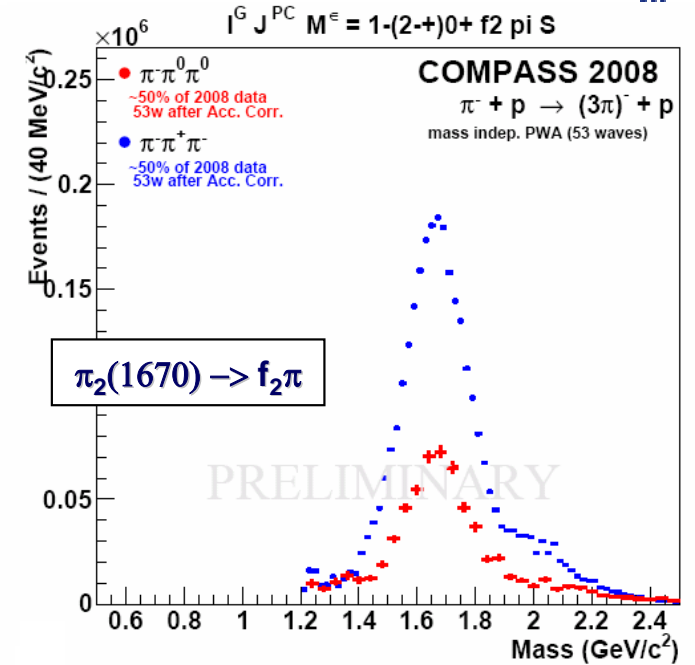
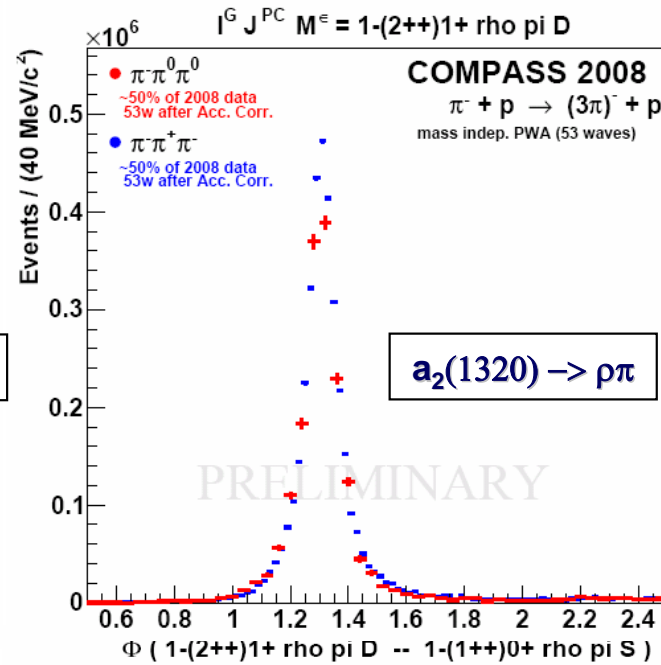
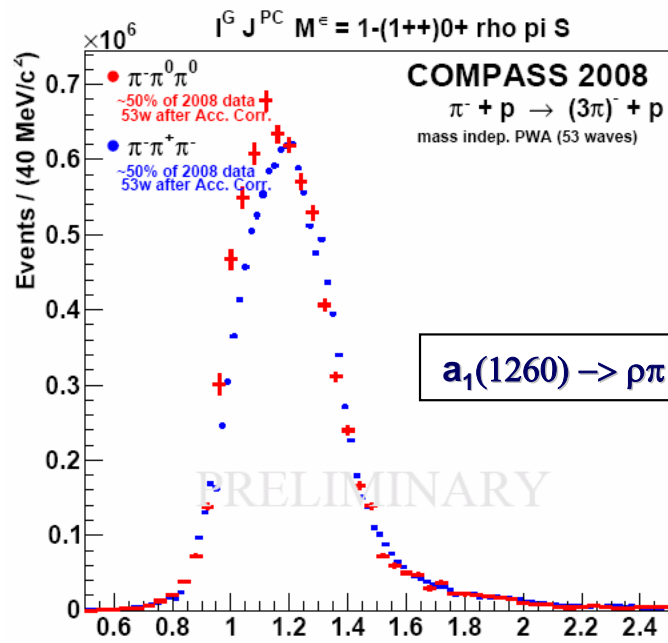
isospin symmetry check ctd.





Selected partial waves & phases

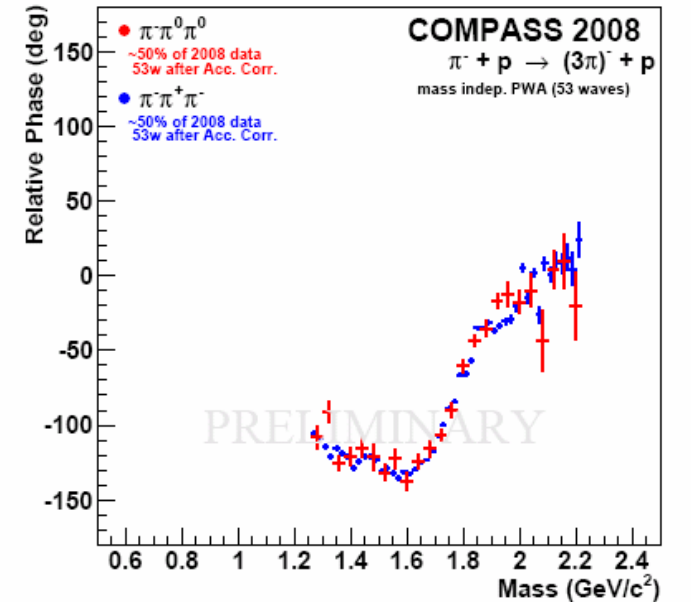
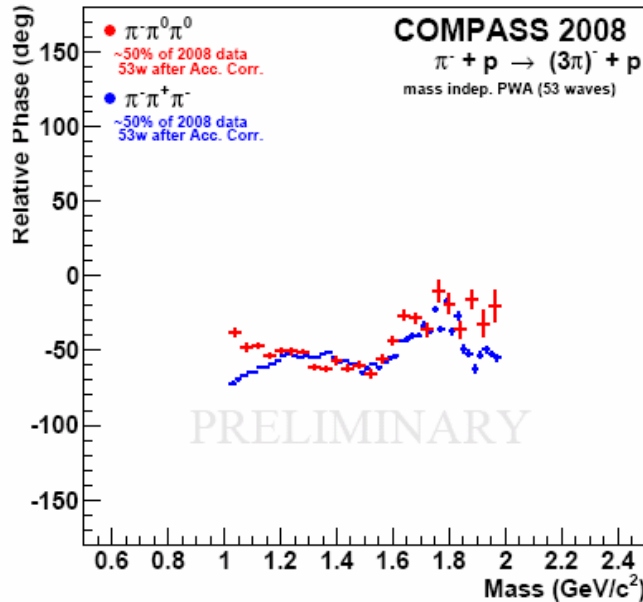
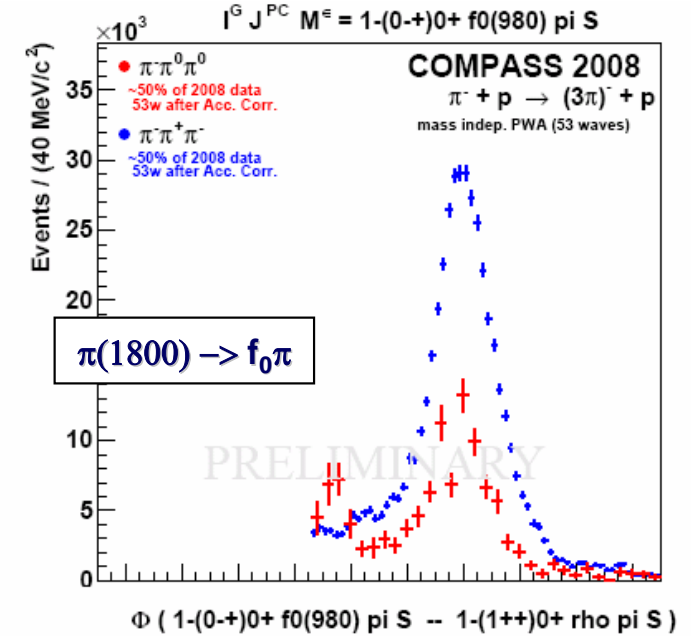
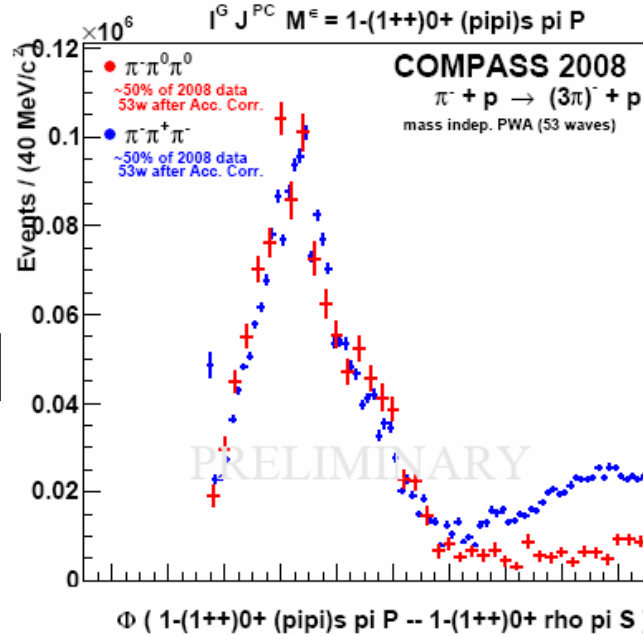
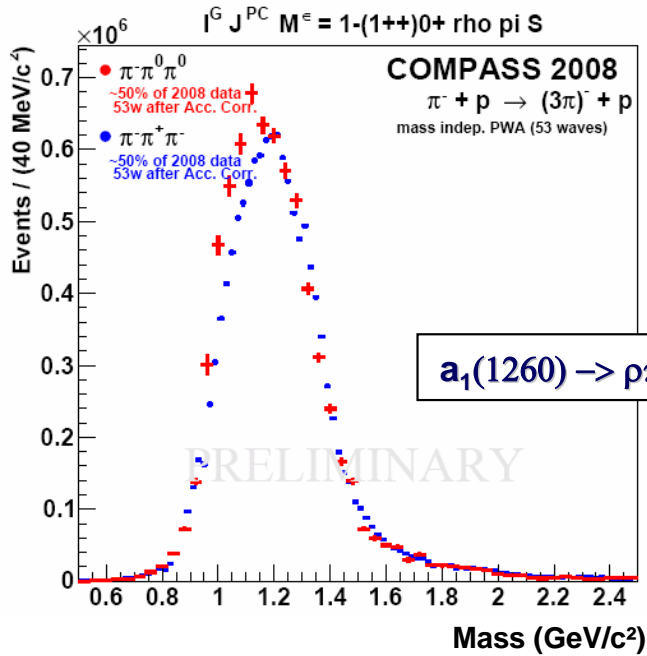
3π diffractive -- Neutral vs. Charged mode: 53 waves





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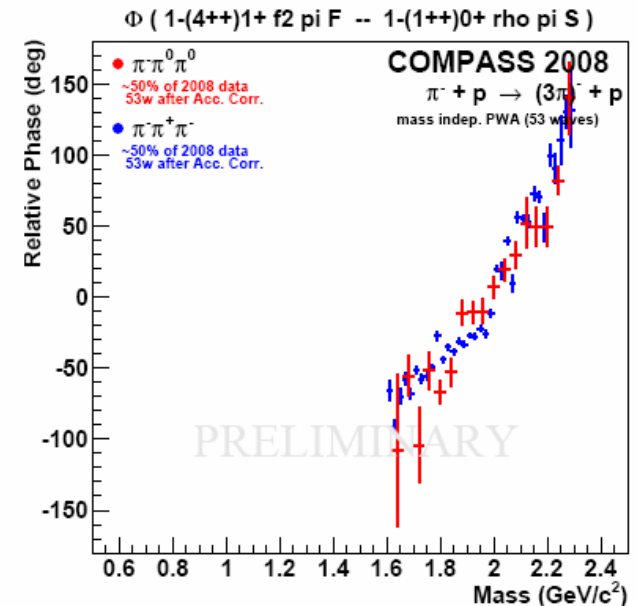
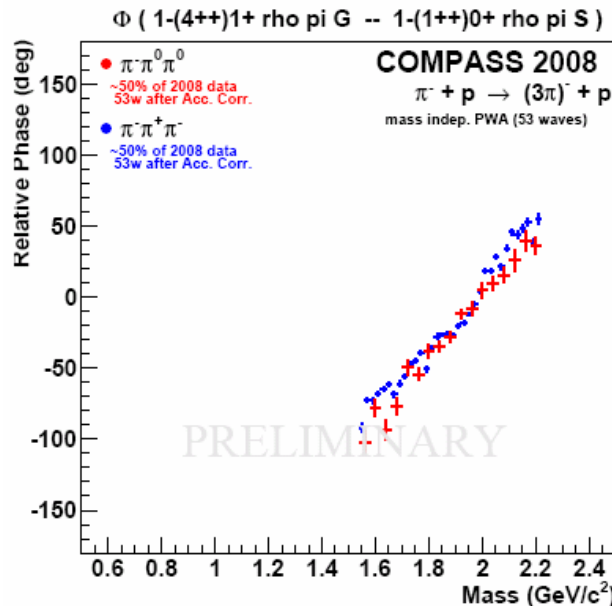
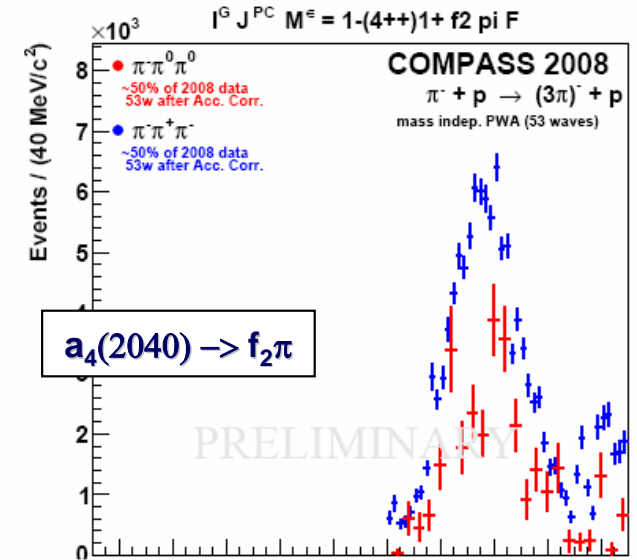
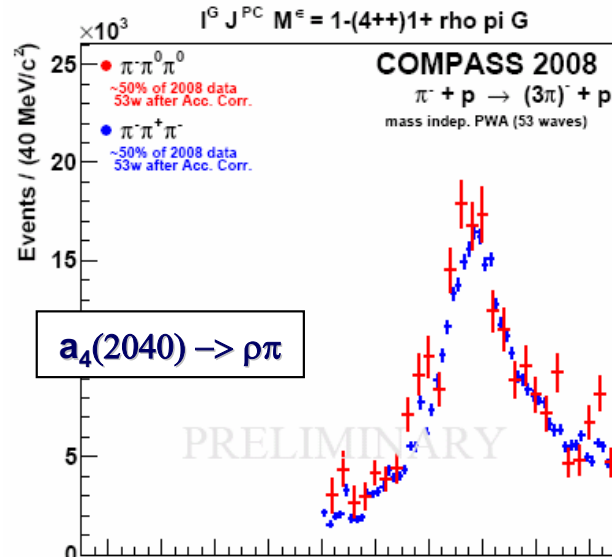
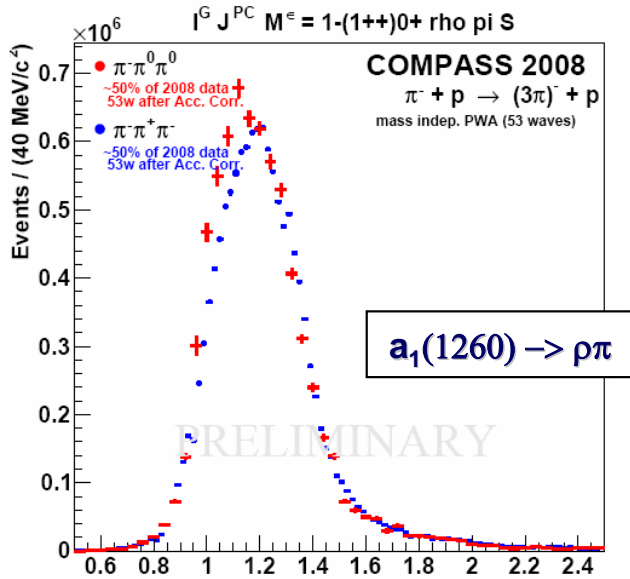
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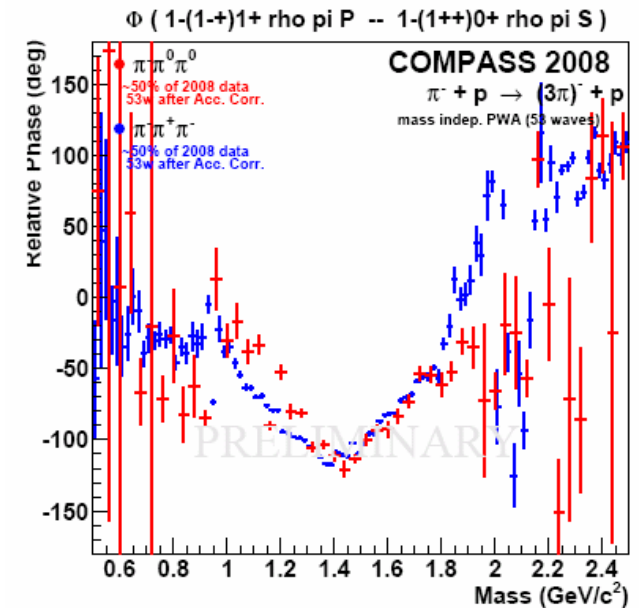
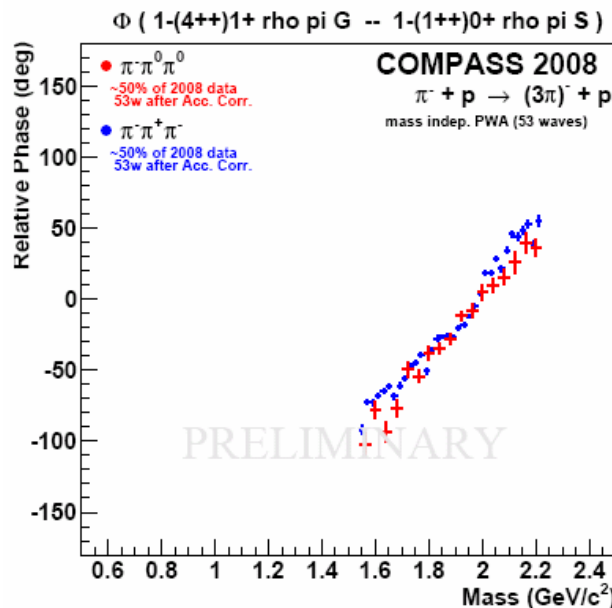
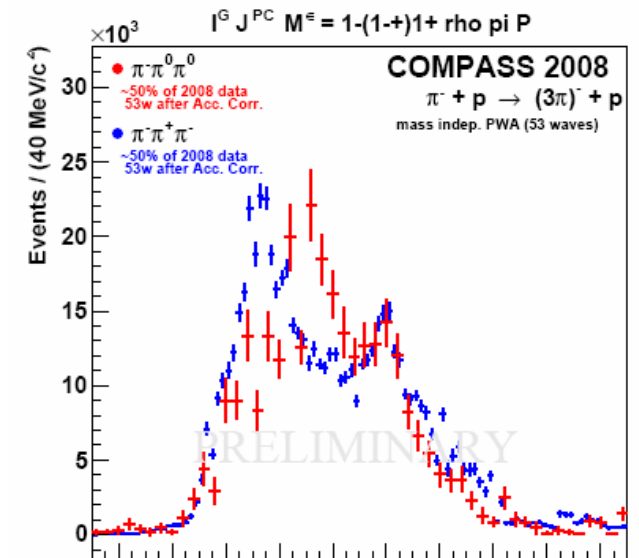
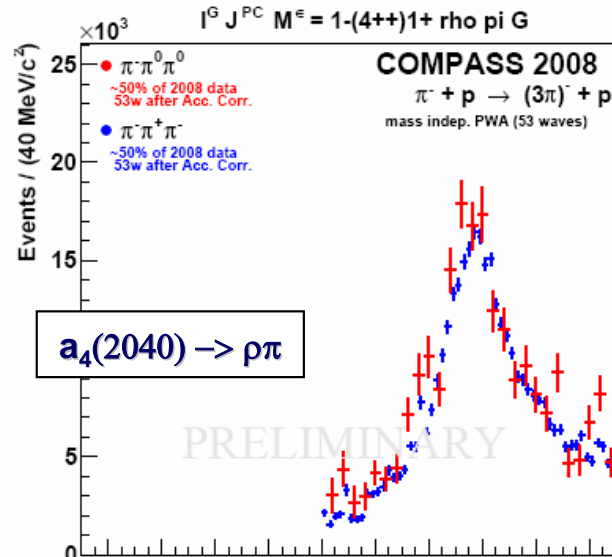
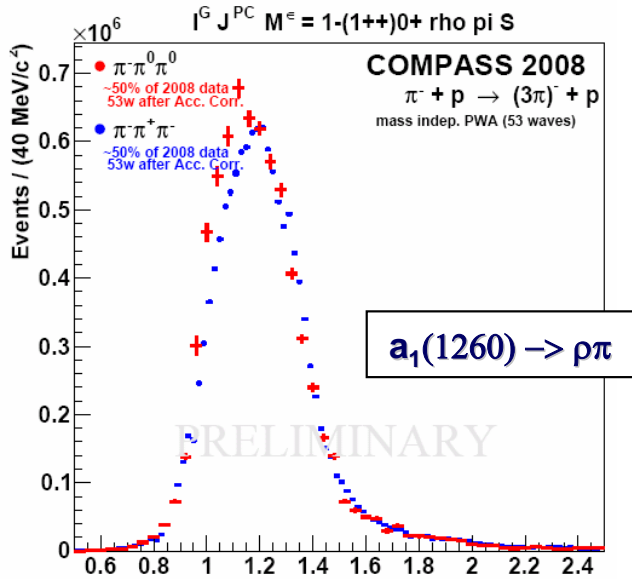
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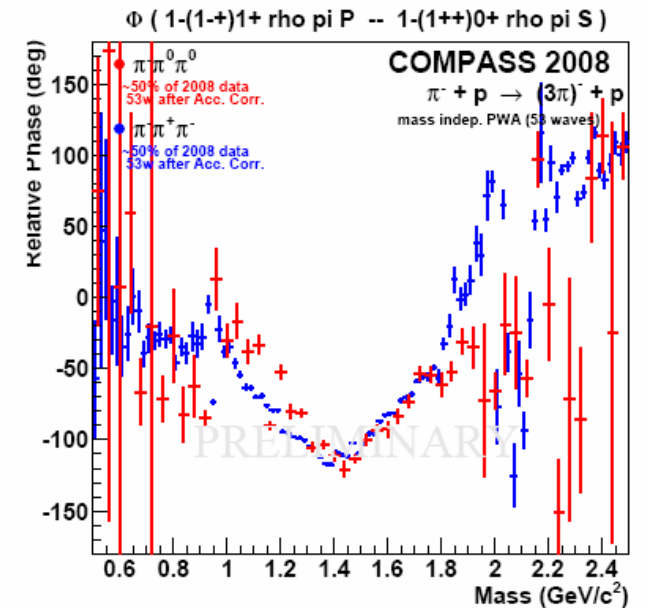
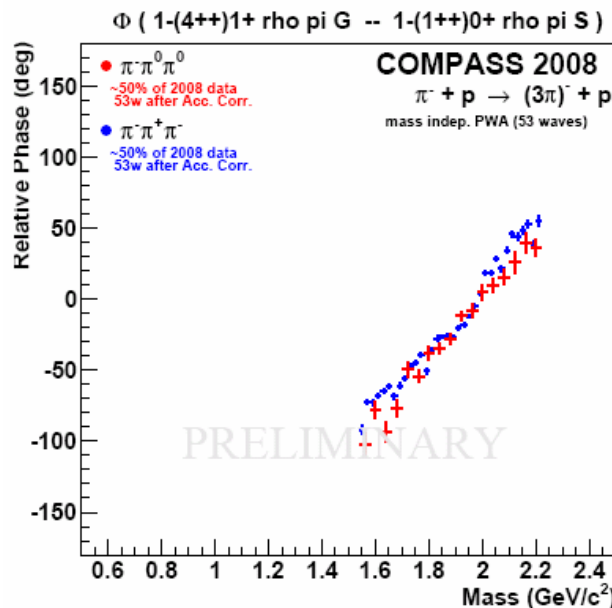
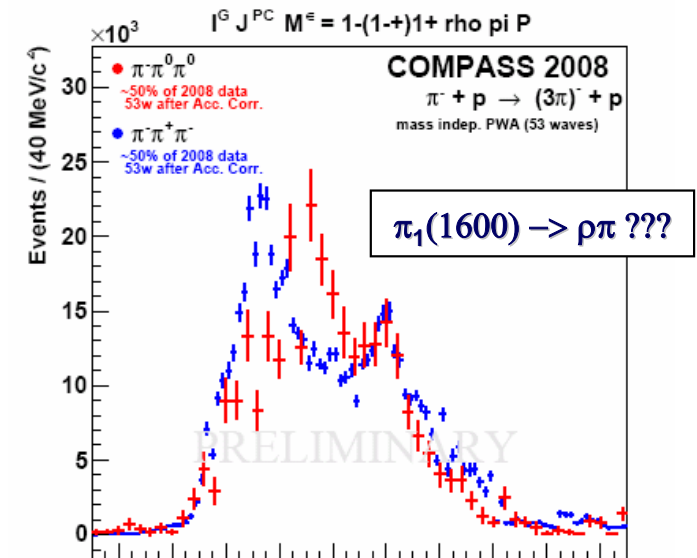
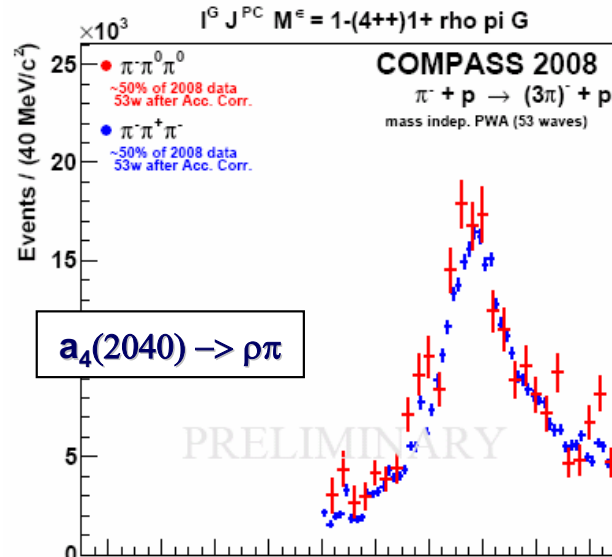
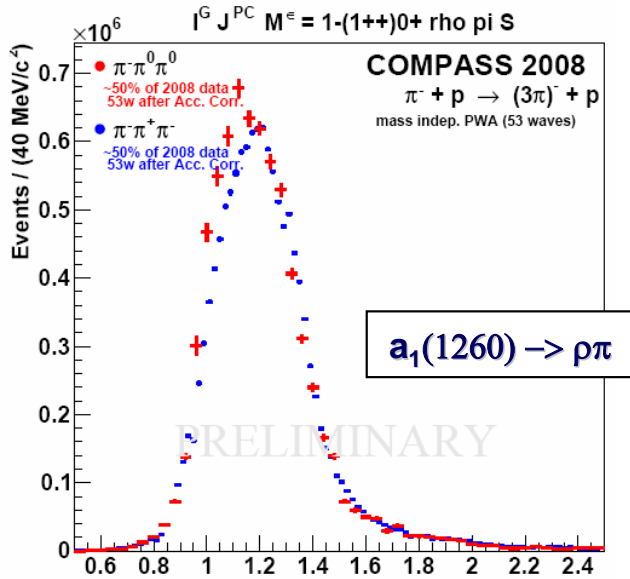
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Selected partial waves & phases

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



$\pi_1(1600) \rightarrow \rho\pi ???$

More systematic studies
 needed (Deck,leakage,thresholds)
 and of course Mass-Dep.Fit!

-> before any strong conclusion!

see also HK 23.3



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** see also HK 23.3
 - => *all relevant channels for spin-exotic search feasible*
see also HK 8.2
- **New physics results presented (incl. exotic wave):**
 - $(3\pi)^-$ system studied in both decay modes: **neutral & charged** (*consistent results*)
 - All resonances, objects robust against wave-set extension
 - => Independent **confirmation of new states** within **same experiment!**

Outlook:

- **More systematic studies, PWA model, Mass-dependent PWA**
→ *more work ahead, before conclusions on $\pi_1(1600)$*