

A Discovery of a new Particle $a_1(1420)$

and a Rediscovery of the exotic $\pi_1(1600)$ at COMPASS

and Future Prospects for ALICE

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- An elementary overview of particle physics

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- DISCOVERY of a NEW particle by COMPASS at CERN:

$$I^G(J^{PC}) = 1^-(1^{++}) \quad a_1(1420) \quad m = 1420_{-12.3}^{+10} \text{ and } \Gamma = 140_{-21}^{+06} \text{ MeV}$$

—NOT yet cited in PDG, 1 July 2012

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$$I^G(J^{PC}) = 1^-(1^{-+}) \quad \pi_1(1600) \quad m = 1608_{-20}^{+20} \text{ and } \Gamma = 587 \pm 40 \text{ MeV}$$

(the errors are my guesses)

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- Conclusions and Future Prospects for ALICE

Central Production of $\pi^+\pi^-$ under way

Central Production of $\pi^+\pi^-\pi^+\pi^-$ planned

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 $J^{PC} = 0^{--}, 0^{+-}, 1^{-+}, 2^{+-}, \dots$ are NOT $\{q \bar{q}\}$ mesons

Mesons can be more complicated—

$\{q \bar{q} + q \bar{q}\}$ (tetraquarks) or gluonic hybrids $\{q \bar{q} + \text{gluon}\}$

Examples: $\pi_1(1400) \rightarrow \eta \pi$ or $\boxed{\pi_1(1600) \rightarrow \rho \pi \rightarrow 3\pi}$ have $J^{PC} = 1^{-+}$ and so *exotic*.

— COMPASS paper in preparation
 To be Published in 2014

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- Exotic mesons of the second kind:* J^{PC} is NOT exotic but its very small cross section points to its *exotic* nature, i.e. NOT a quarkonium.

$$I^G(J^{PC}) = 1^-(1^{++}) \quad \boxed{a_1(1420) \rightarrow f_0(980)\pi, \quad f_0(980) \rightarrow (2\pi)^0}$$

$$\sigma[a_1(1420)]/\sigma[a_1(1260)] \leq 7.5\%$$

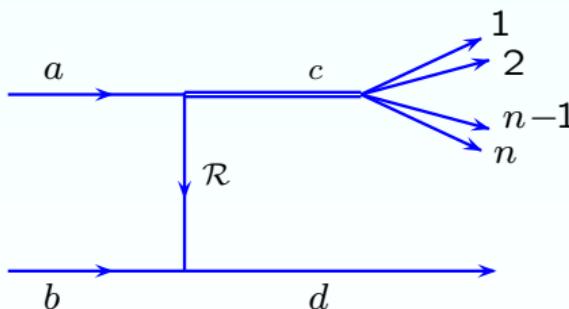
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Diffractive Dissociation Processes for a Meson System c

Consider a reaction

$$a + b \rightarrow c + d, \quad c \rightarrow 1 + 2 + \cdots + (n-1) + n$$

which is mediated by the **Reggeon**-exchange process:

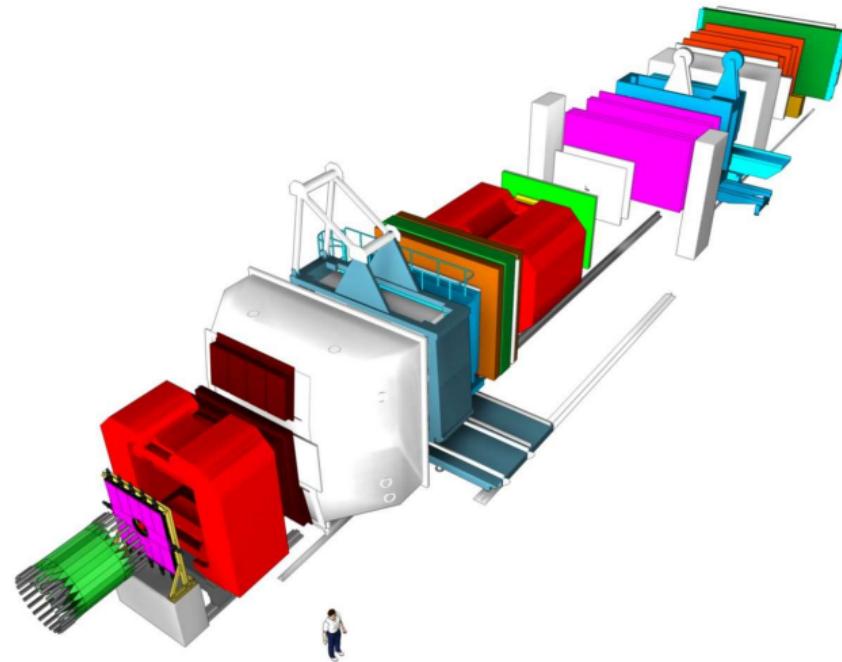


\mathcal{R} is likely to be a **Pomeron** with $I^G(J^{PC}) = 0^+(2^{++})$

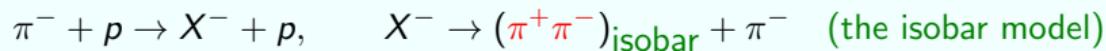
— “**Pomeron Physics and QCD**,”

S. Donnachie, G. Dosch, P. Landshoff, O. Nachtmann
Cambridge University Press (2002)

COMPASS Setup:



- COMPASS data on



at 190 GeV/c (the π^- beam momentum) on a liquid hydrogen target.

The statistics on the 2008 data: 50×10^6 events—some $20\times$ the original BNL-E852 data.

- COMPASS data on

$$\pi^- + p \rightarrow X^- + p, \quad X^- \rightarrow (\pi^+ \pi^-)_{\text{isobar}} + \pi^- \quad (\text{the isobar model})$$

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- Partial waves:

$$I^G J^{PC} (\text{isobar for the neutral } \pi^+ \pi^- \text{ systems}) \pi^- L$$

where L is the orbital angular momentum between the isobar and the bachelor π^-

Here $I^G = 1^-$ and $C = +1$ always.

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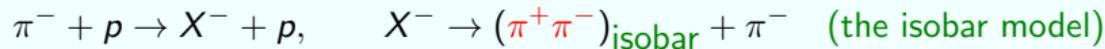
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The Poisson distribution for the observed number of events in a given bin
is included in the likelihood function.

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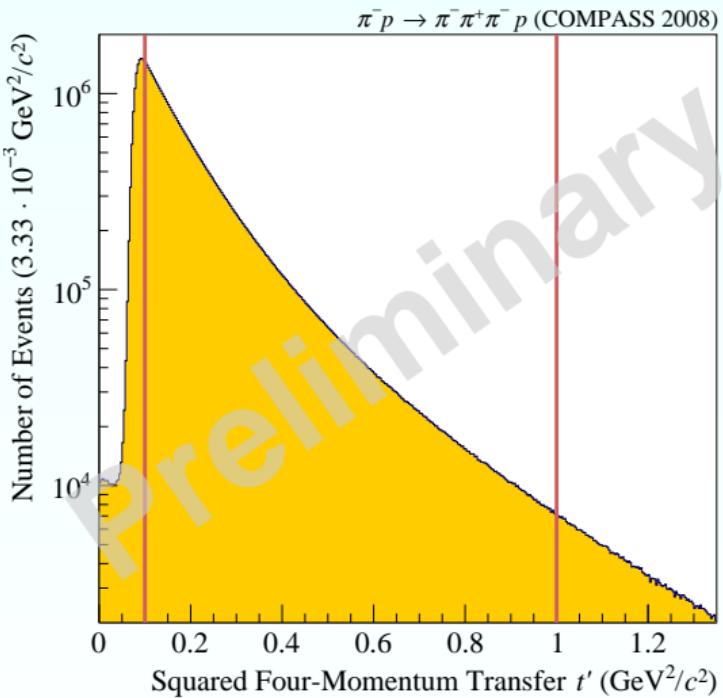
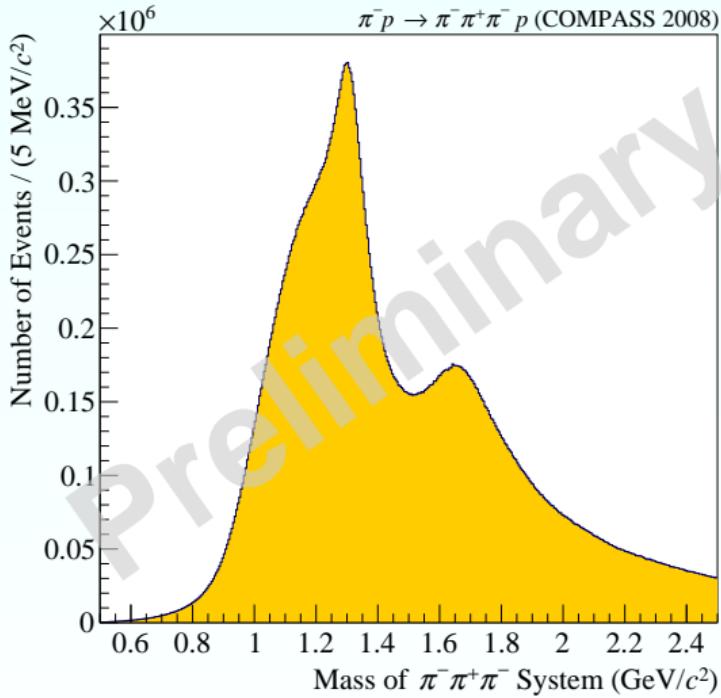
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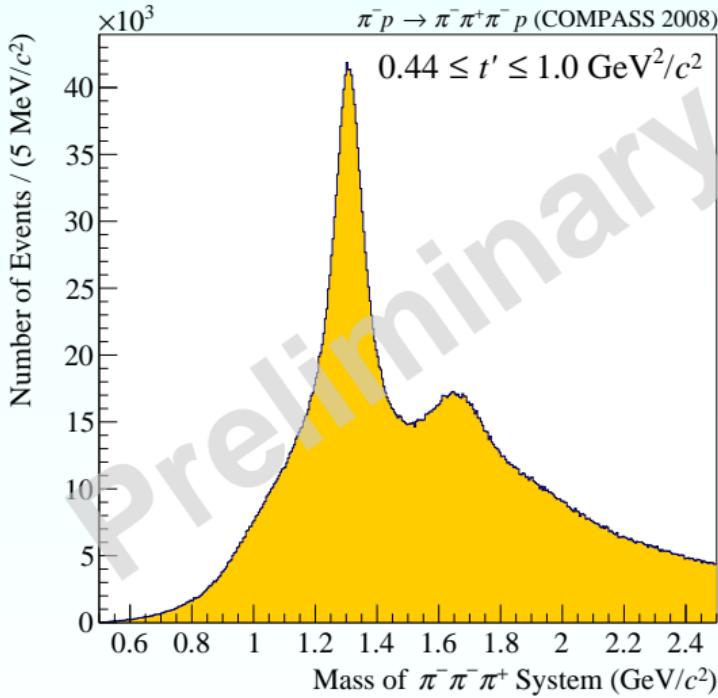
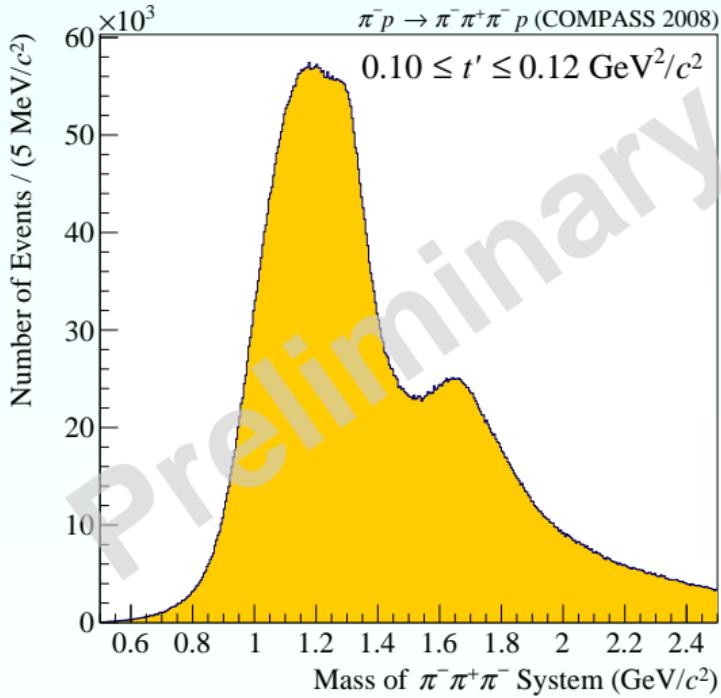
- The techniques of the partial-wave analysis via extended likelihood method:
The Poisson distribution for the observed number of events in a given bin
is included in the likelihood function.
- Fit a set of partial waves for a given mass for X , $m_{3\pi}$ in 20 MeV bins, and the
 $t' = |t| - |t|_{\min}$ in 11 bins, from 0.100 to 1.00 (GeV/c)².

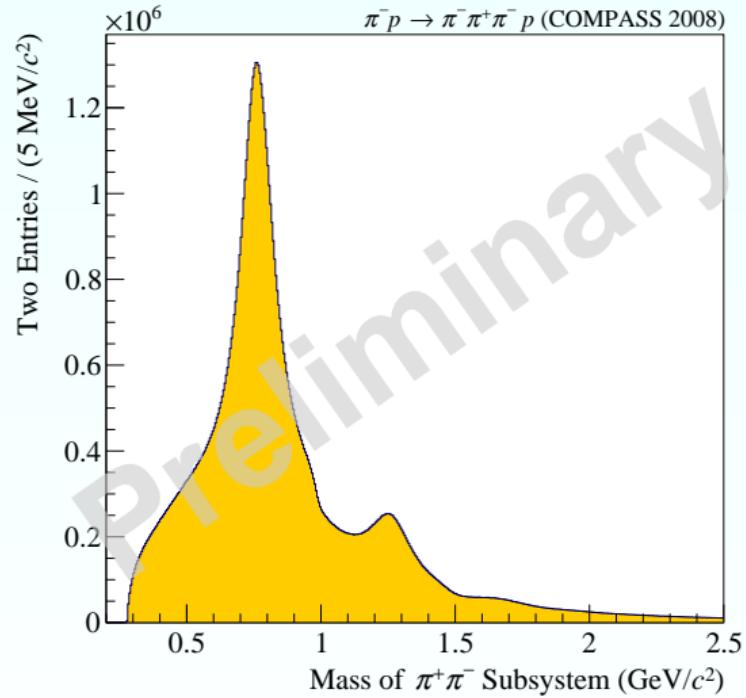
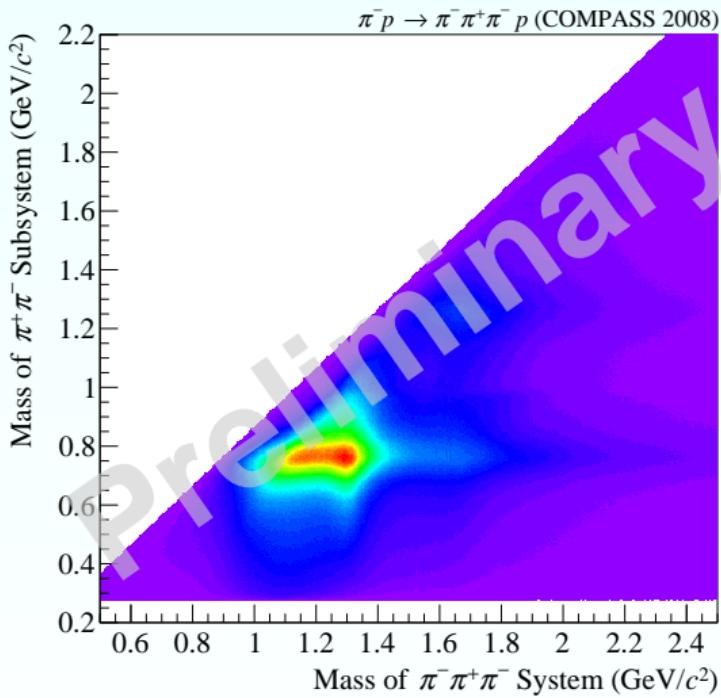
Spins included in the fits: $0 \leq J \leq 6$

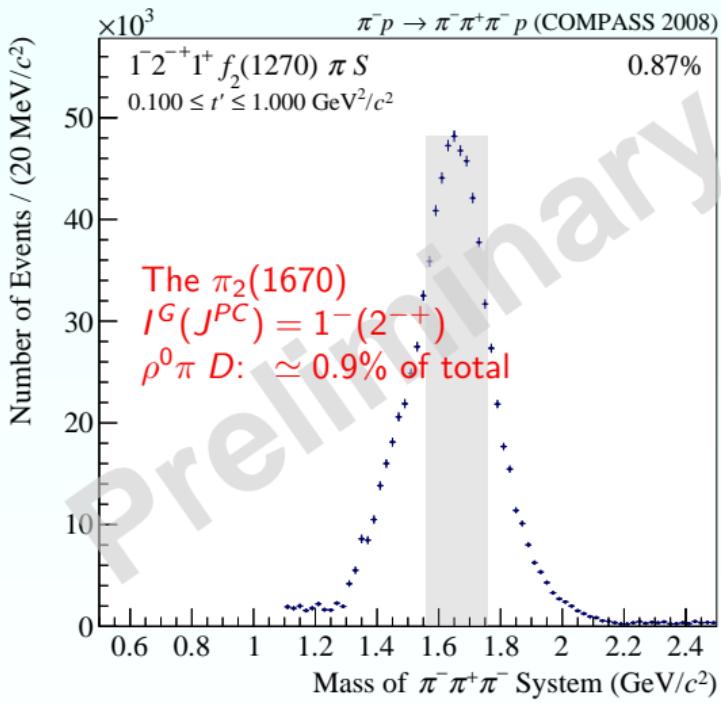
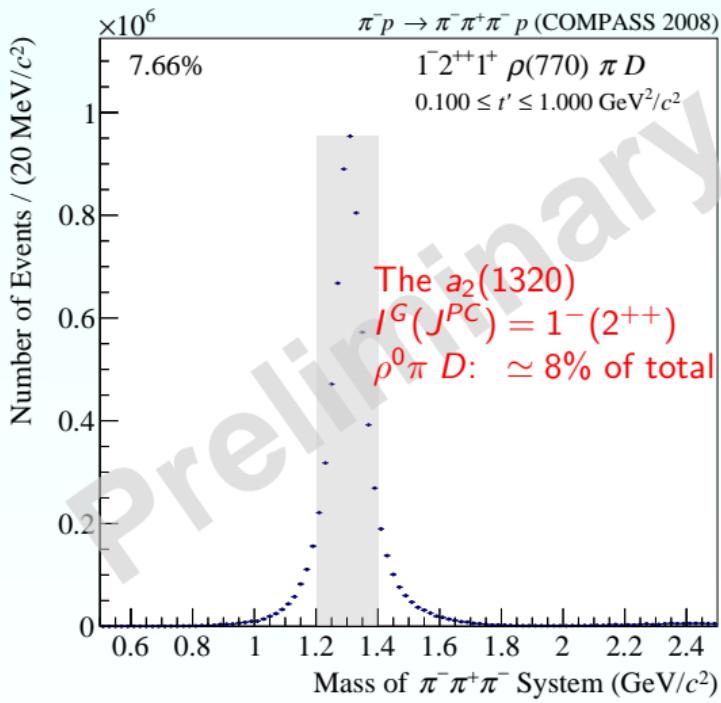
Isobars for **the neutral $\pi^+\pi^-$ systems** used in the current analysis:

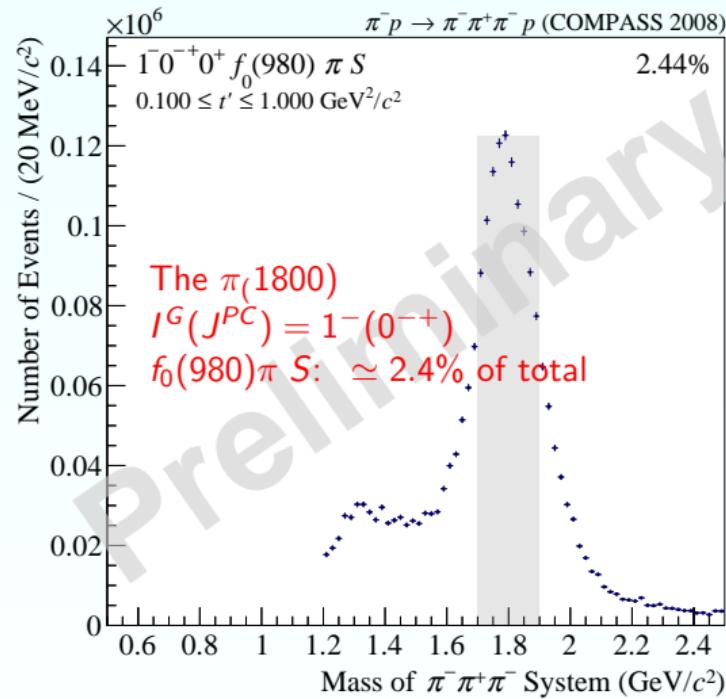
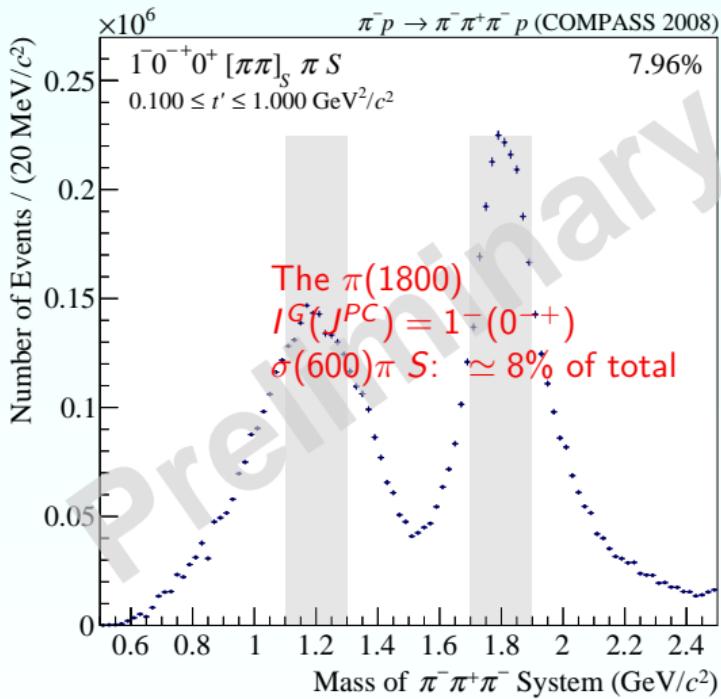
$(\pi\pi)_S$ or $f_0(500)$ (**the σ meson**), $\rho^0(770)$, $f_0(980)$, $f_2(1270)$,
 $f_0(1500)$, $\rho_3(1690)$, $f_4(2050)$

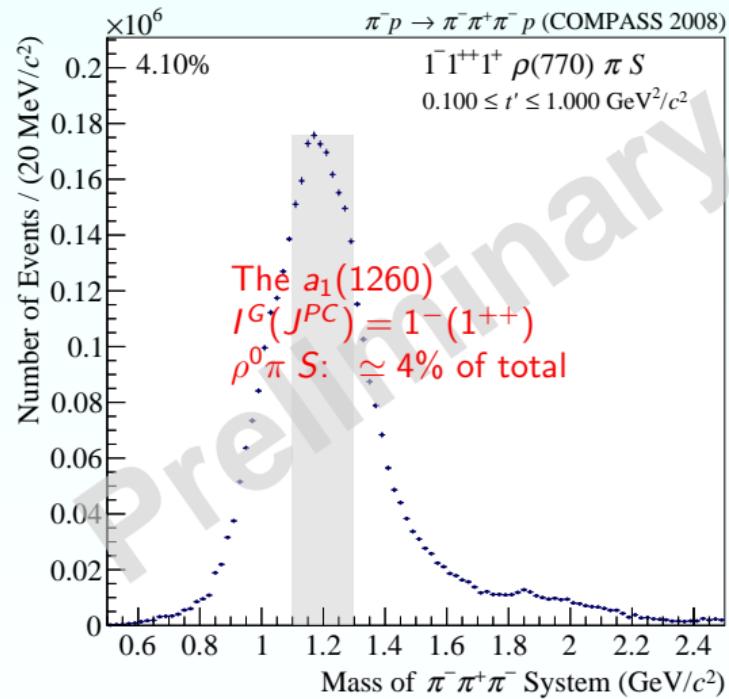
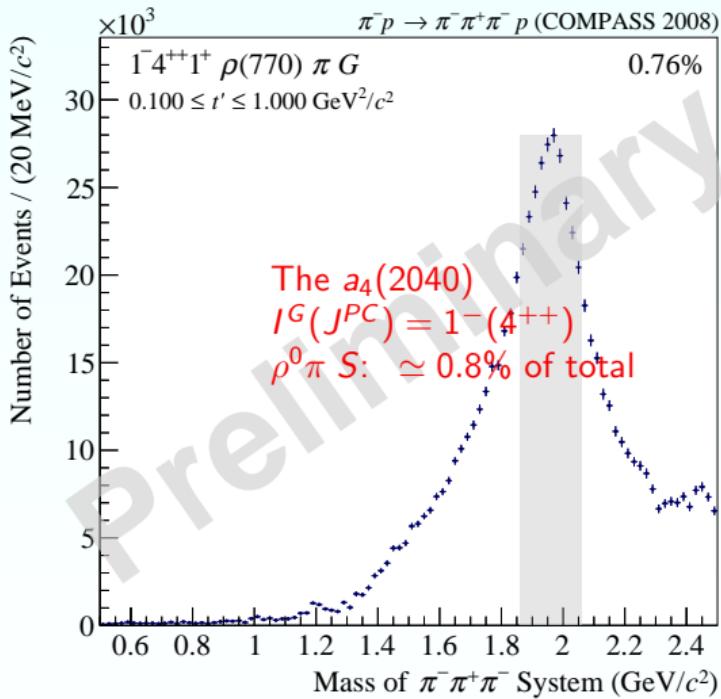


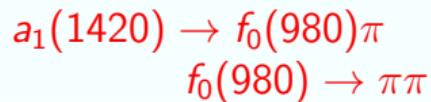
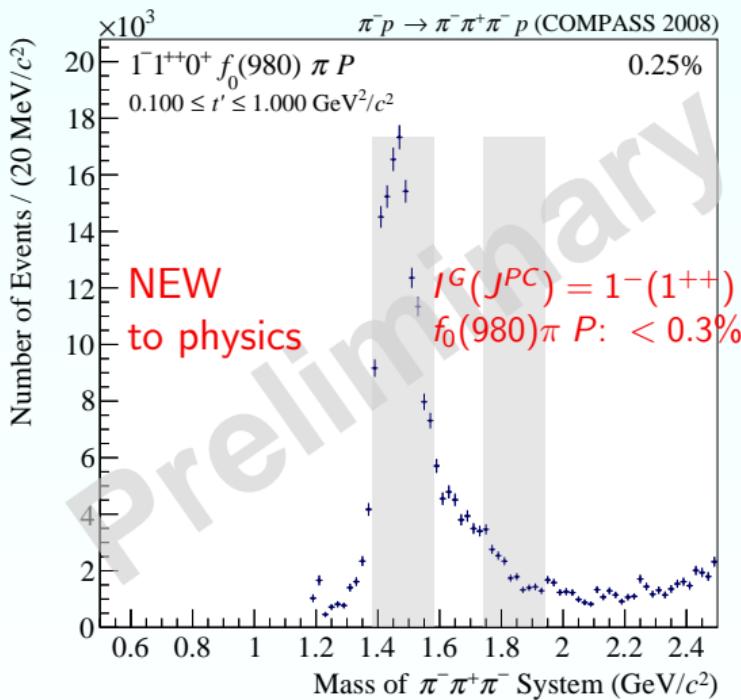








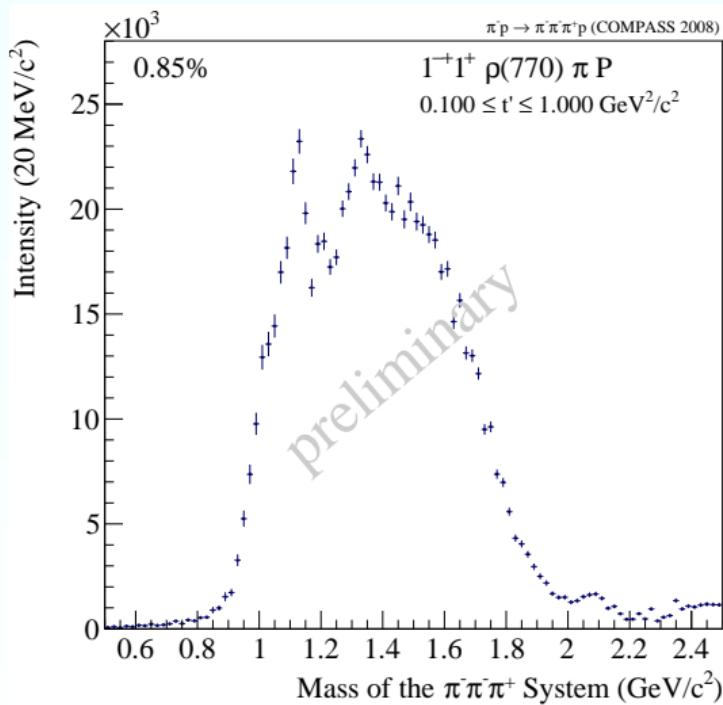


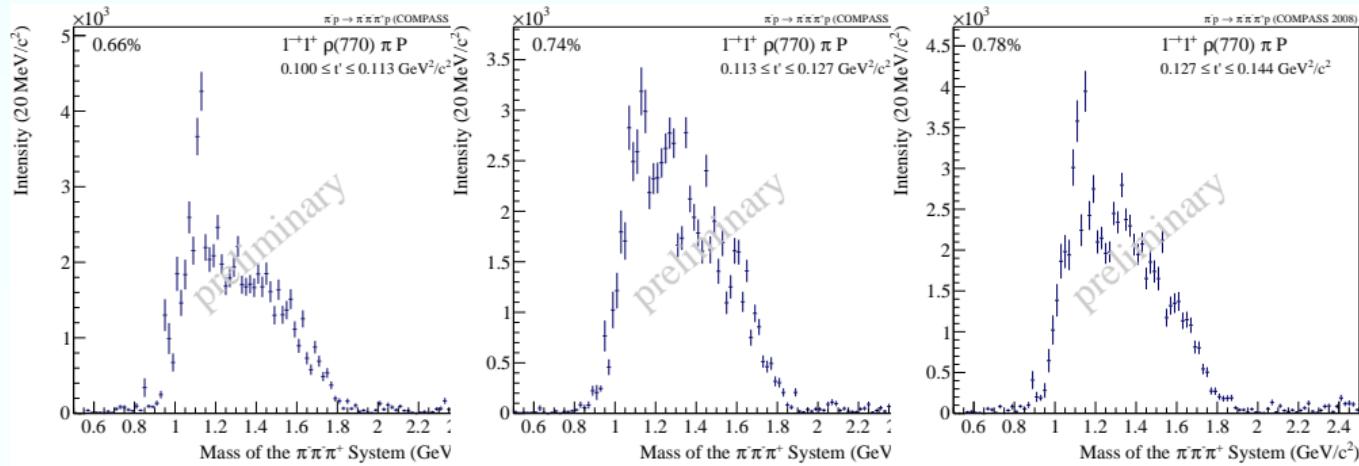


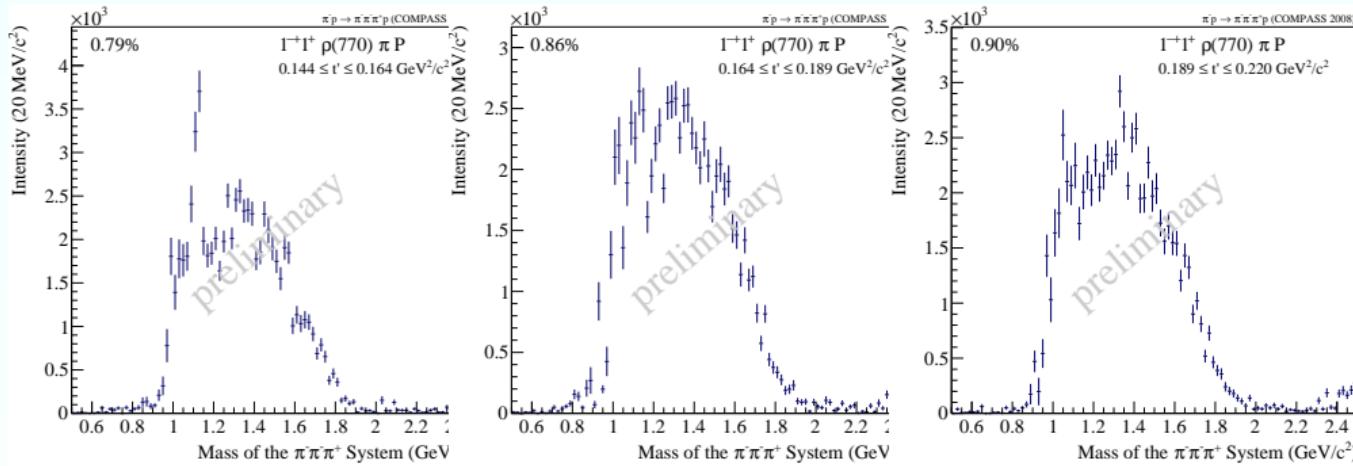
Likely to be EXOTIC:

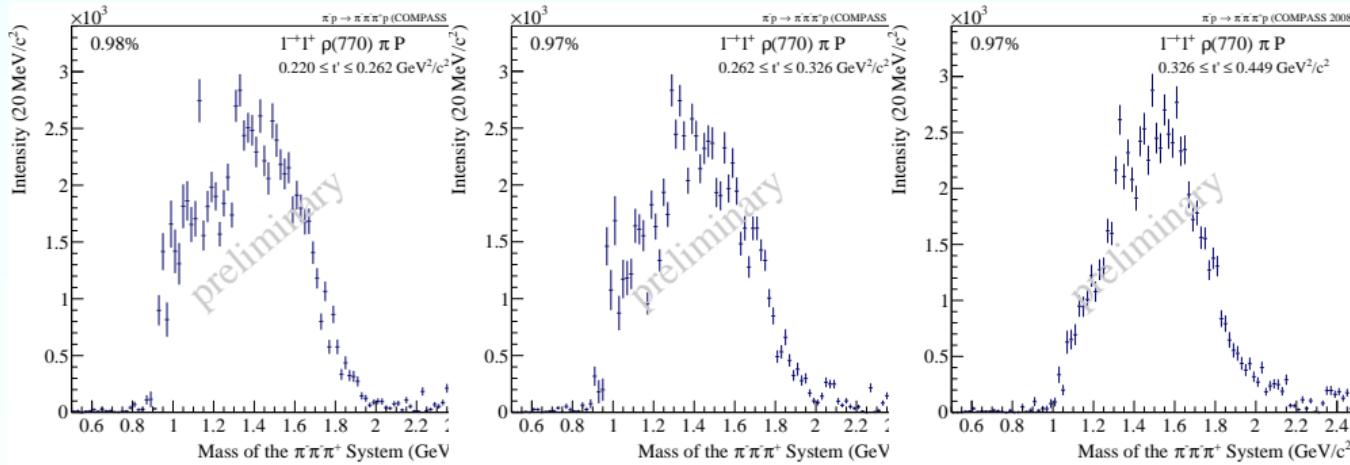
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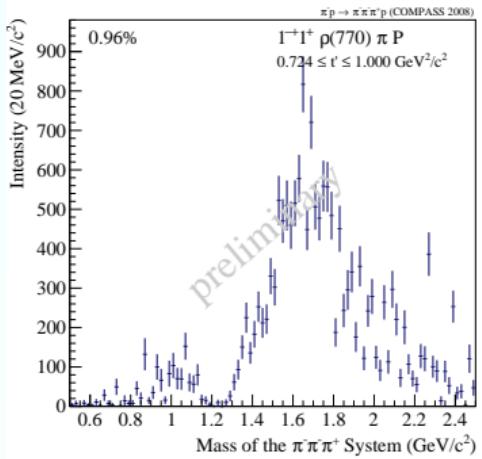
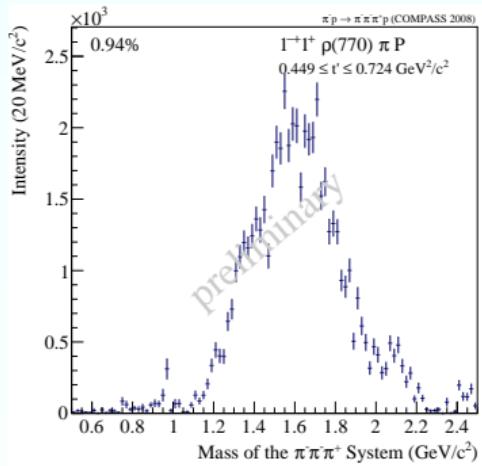
$J^{PC} = 1^{-+}$ Meson: the $\pi_1^-(1600) \rightarrow (\rho)^0\pi^- \rightarrow (3\pi)^-$

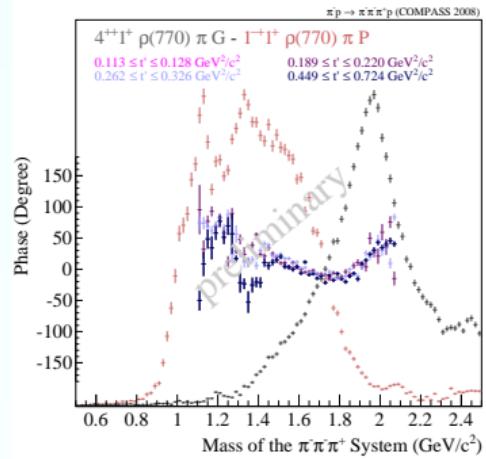
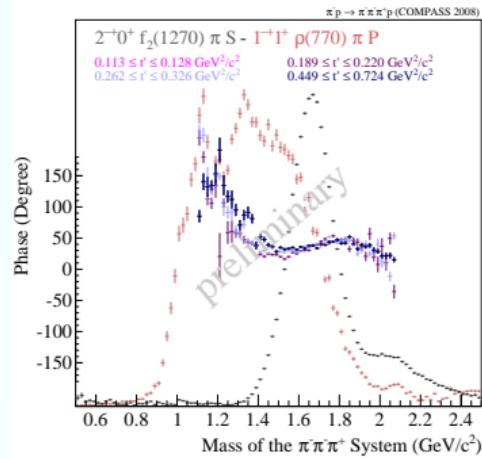


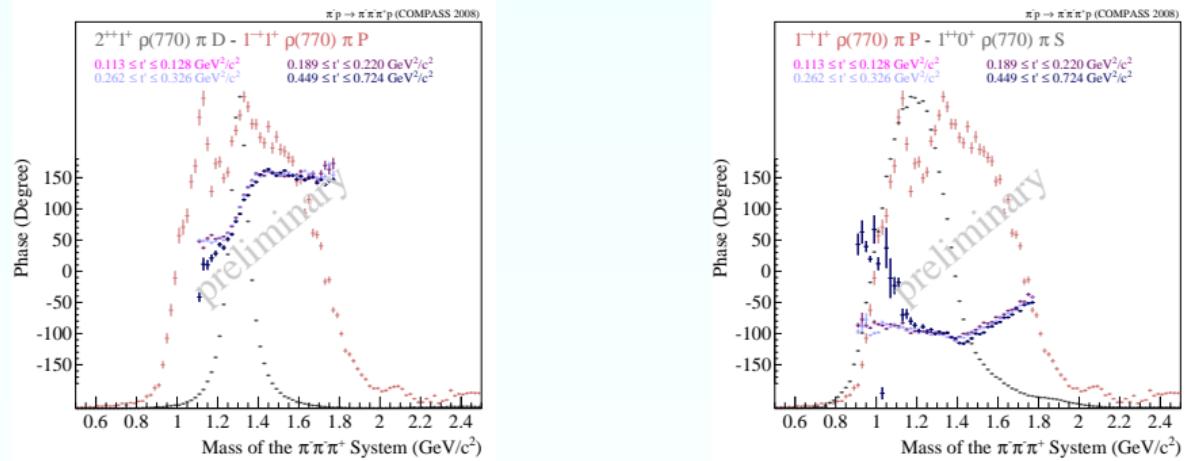












Conclusions I

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- REDISCOVERY of an *Exotic MESON* by COMPASS at CERN:

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Central Production of $\pi^+\pi^-$ and K^+K^- at COMPASS

—A. Austregesilo/TUMüchen

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$\pi_1(1600)$ from $\pi^- + \text{Pb} \rightarrow (\pi^+\pi^-\pi^-) + \text{Pb}$ at 190 GeV/c

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- Expect new results from ALICE on
 - Central production of $\pi^+\pi^-$
 - Central production of $\pi^+\pi^-\pi^+\pi^-$ planned

Thank you for your attention