Model dependence of the $\pi_1(1600) \to \rho(770)\,\pi$ signal

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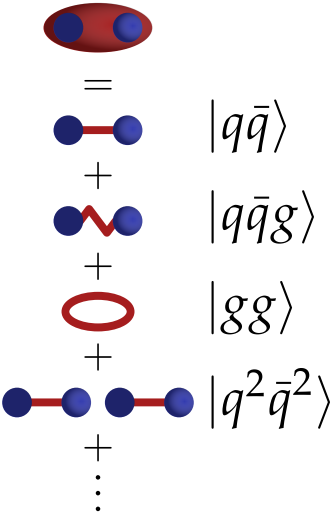
Spin-exotic states

Beyond $q\bar{q}$

- Constituent quark model: Mesons are $|q\bar{q}\rangle$ state
$$P = (-1)^{L+1}$$
$$C = (-1)^{L+S}$$
- Forbitten combinations, e.g. $J^{PC} = 1^{-+}$
- $\rightarrow$ (a superposition) of someting else



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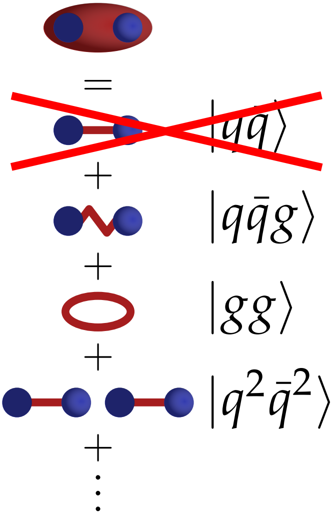
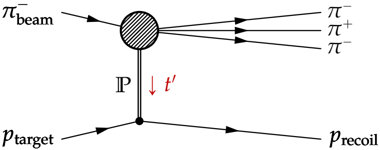
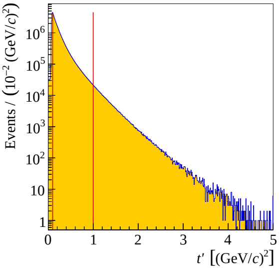


Diffractive 3π production

- COMPASS: Large data set for the diffractive process $\pi^-_{\text{beam}} + \text{p} \to \pi^-\pi^+\pi^- + \text{p}$
- Squared four-momentum transfer t' by Pomeron $\mathbb{P}$
- 46×10^6 exclusive events





COMPASS collaboration, PR **D95** (2017) 032004

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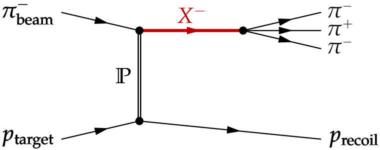

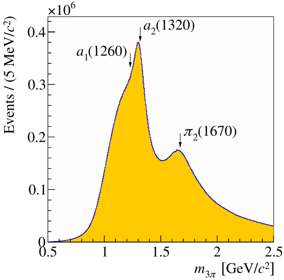

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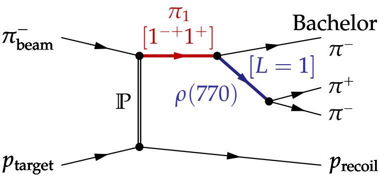
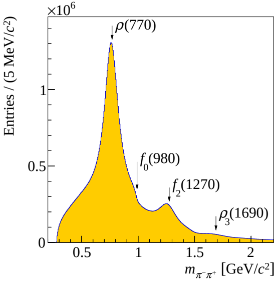
- Squared four-momentum transfer t' by Pomeron $\mathbb{P}$
- 46×10^6 exclusive events
- Rich structure in $\pi^-\pi^+\pi^-$ mass spectrum: Intermediate states X^-
- Also structure in $\pi^+\pi^-$ subsystem: Intermediate states ξ (isobar)





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Spin-exotic wave

Previous results

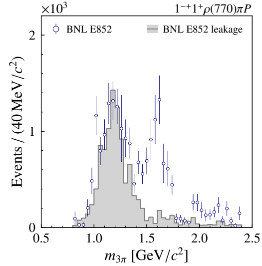


Fig 18(b) of *Phys. Rev. D* **65** (2002) 072001

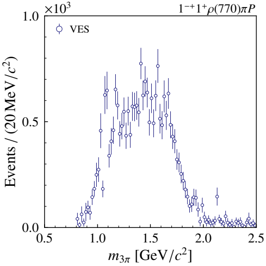


Fig. 4(a) in *Nucl. Phys.* **A675** (2000) 155-160

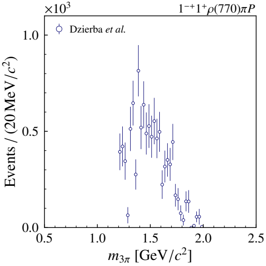


Fig. 25(a) in *Phys. Rev. D* **73** (2006) 072001

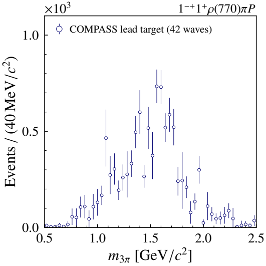
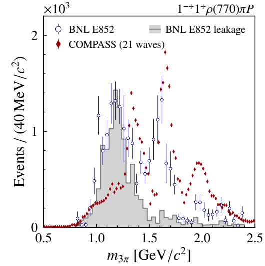


Fig. 2(d) in *Phys. Rev. Lett.* **104** (2010) 241803

Spin-exotic wave

Previous results



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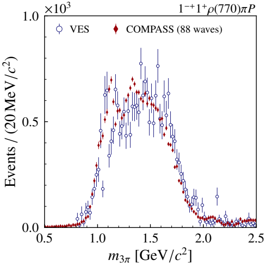

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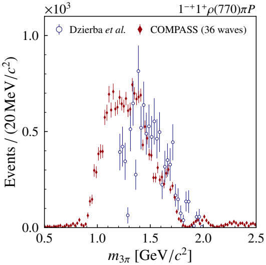

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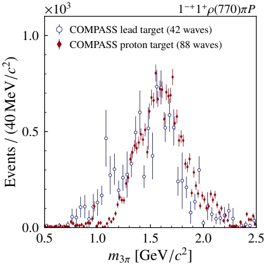

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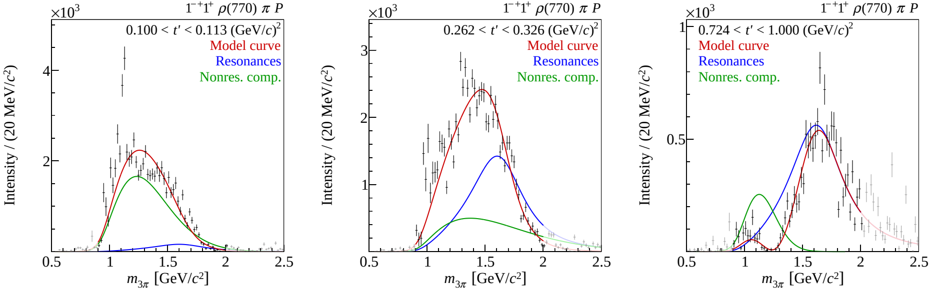
- Set of partial-waves too small
  - Missing 2^{-+} waves
  - Actually $\pi_2(1670)$
- Treatment of t'
  - At low t': non-resonant processes
  - Resonant signal is obscured
- COMPASS: Resolve these issues:
  - Binning in t'
  - Large set of 88 partial waves



COMPASS *Phys. Rev. D* **98** (2018) 9, 092003

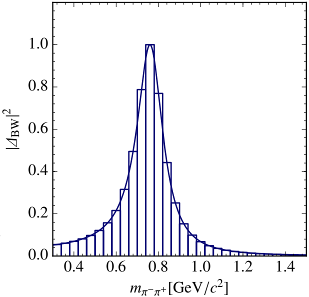
- Resonance model fit to 14 partial waves simultaneously
- Extensive systematic studies

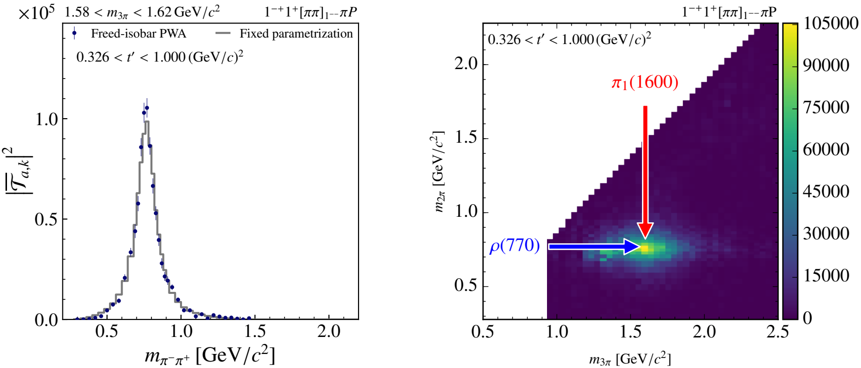
$$m_{\pi_1(1600)} = 1600^{+110}_{-60}(\text{sys.})\,\text{MeV}/c^2; \quad \Gamma_{\pi_1(1600)} = 580^{+100}_{-230}(\text{sys.})\,\text{MeV}/c^2$$

- COMPASS model: largest remaining model dependence:
  - Fixed parameterization of isobars
- However: $1^{-+}1^{+}\rho(770)\,\pi P$ still modeled
  - Fixed shape of $\rho(770)$ as model assumption
  - Breit-Wigner amplitude, no free parameters
- Use freed-isobar approach
  - Replace fixed shape by step-like functions

$$\Delta_i^{\text{bin}}(m_{\pi^-\pi^+}) = \begin{cases} 1, & \text{if } m_{\pi^-\pi^+} \text{ in the bin.} \\ 0, & \text{otherwise.} \end{cases}$$

  - Cover kinematically allowed range
  - Every step: individual partial wave
  - Extract $\rho(770)$ shape from the data





Clear $\pi_1\,(1600) \rightarrow \rho(770)\,\pi$ without assumptions on resonance content

Summary & conclusions

$\pi_1(1600)$

- Spin-exotic quantum numbers
- Not a $q\bar{q}$-state

$1^{-+}1^{+}\rho(770)\,\pi P$ wave

- Various, seemingly contradicting results
- Large model dependence:
  - Partial-wave set
  - Treatment of t' dependence
- Resolved using COMPASS 2008 data

COMPASS

- Freed-isobar approach:
  - Isobar model valid
- $\pi_1(1600)$ not an artifact
- Convincing evidence for $\pi_1(1600) \to \rho(770) + \pi$

Outlook

- Further $\pi_1(1600)$ decay channels

$$\eta^{(\prime)}\pi; \quad b_1\pi; \quad f_1\pi$$