Analysis of $\pi^-\pi^-\pi^+$ COMPASS data: role of $a_1(1260)$ meson and Deck process.

D. Ryabchikov

E18 Technische Universität München

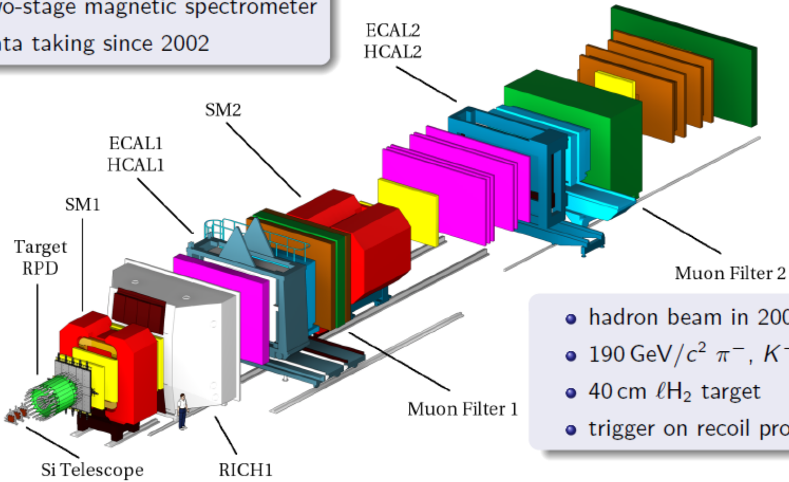
Plan of the talk

The reaction $\pi^- p \to \pi^-\pi^-\pi^+ p$ at $p_{\pi^-} = 190$ GeV

- Mass-independent Partial-Wave Analysis (PWA)
- Mass-dependent analysis
  - brief description of the model
  - results in $m(3\pi)$ bins
  - $a_1(1260)$ parametrization, fit results for $M_{a_1(1260)}$, $\Gamma_{a_1(1260)}$
  - results in t' bins and b -slopes of 1^{++} components
- Deck process
  - Deck amplitude components
  - decomposition of Deck amplitude to partial waves and comparison with mass-dependent fits of 3π data

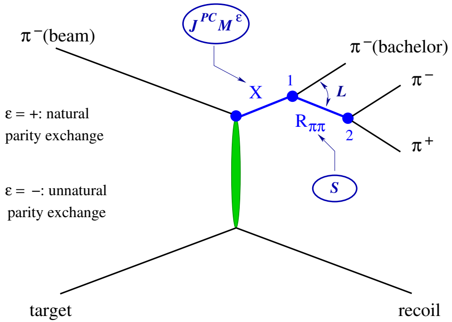
Apparatus

- fixed target experiment
- located at CERN's SPS
- two-stage magnetic spectrometer
- data taking since 2002



- hadron beam in 2008
- 190 GeV/c^2 π^-, K^-, $\bar{p}$
- 40 cm ℓH_2 target
- trigger on recoil proton

The reaction



- Reggeon exchange, naturality $\eta = P_R(-1)^J{}_R$
- Gottfried-Jackson frame: SCM of X: $Z_{GJ} \| \vec{p}^*_{beam}$, $Y_{GJ} = [\vec{p}^*_{recoil} \times \vec{p}^*_{beam}]$
- Reflectivity basis for system of mesons:
  $|JM\epsilon> = |JM> - \varepsilon P(-1)^{J-M}|J - M>$
- At high beam energies: reflectivity ε equal to naturality η
- unpolarised target: $\varepsilon = \pm 1$ states do not interfere

Mass-independent vs. mass-dependent

The mass-independent PWA events density:
$\mathcal{I}(m,t,\tau) = \sum_\epsilon \sum_r \left|\sum_i T^\varepsilon_{ir}(m,t)\bar{\psi}^\varepsilon_i(\tau,m)\right|^2$ (1)
Events intensity including production and propagation of 3π intermediate states :

$\mathcal{I}(m,t,\tau) = \sum_\epsilon \sum_r \left|\sum_i \sum_l C^\varepsilon_{ilr} D_{il}(m,t,\zeta)\sqrt{\int |\psi^\varepsilon_i(\tau',m)|^2\, d\Phi_3(\tau')}\bar{\psi}^\varepsilon_i(\tau,m)\right|^2$ (2)

The spin-density matrix:
$\rho^\varepsilon_{i,k} = \sum_r T^\varepsilon_{ir} T^{\varepsilon *}_{kr}$
comparing (1) and (2) mass-dependent model for spin-density matrix reads:
$\rho^\varepsilon_{i,k}(m,t) =$

$$\sqrt{\int |\psi^\varepsilon_i(\tau)|^2\, d\Phi_3(\tau)}\sqrt{\int |\psi^\varepsilon_k(\tau)|^2\, d\Phi_3(\tau)} \sum_r \sum_{l,m} C^\epsilon_{ilr} C^{\epsilon *}_{kmr} D_{il}(m,t,\zeta) D^*_{km}(m,t,\zeta)$$

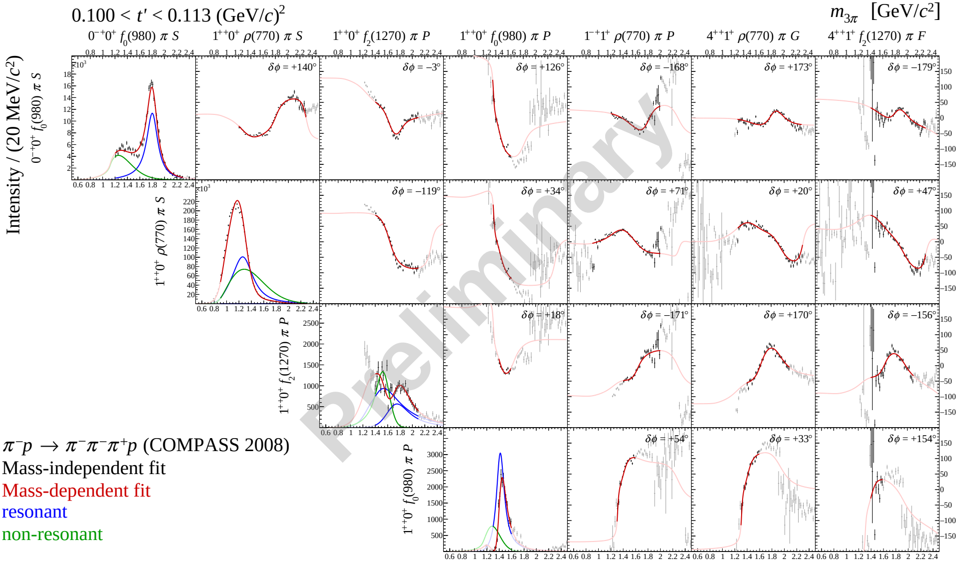
Mass-independent and mass-dependent analysis

Mass-independent:

- partial waves are labelled as $J^{PC}M^{\epsilon}\xi\pi L$
- decay amplitudes for $\pi^-\pi^-\pi^+$ are constructed in the framework of helicity formalism
- 5 standart $\pi^+\pi^-$ isobars: $\rho(770)$, $f_2(1270)$, $\rho_3(1690)$, $(\pi\pi)_S$ (AMP with $f_0(980)$ withdrawn) and $f_0(980)$ (FLATTE)
- rank=1 used (narrow m(3π) and t' bins; helicity non-flip nature of Pomeron)
- 80 waves with $\varepsilon = +1$, 7 waves with $\varepsilon = -1$ and incoherent FLAT wave

Mass-dependent:

- 14x14 sub-density matrices measured independently in $m(3\pi)$-bins and t'-bins are described by resonance model
- each partial wave is described by 1-3 resonant terms and background term
- Masses, widths and decay couplings of resonances do not depend on t', so fit should be done simultaneously in all t' intervals



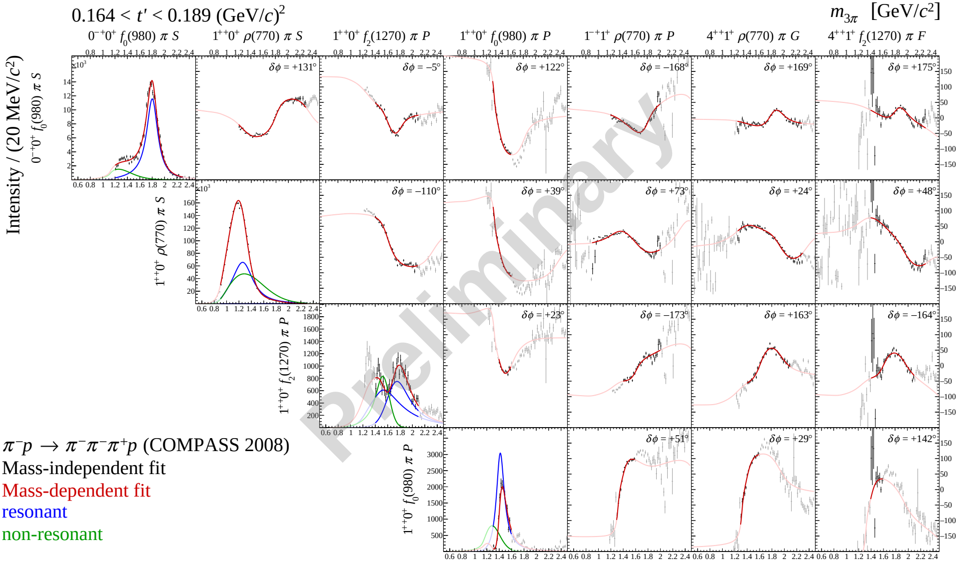
$\pi^- p \to \pi^-\pi^-\pi^+ p$ (COMPASS 2008)

Mass-independent fit

Mass-dependent fit

resonant

non-resonant



$\pi^- p \to \pi^-\pi^-\pi^+ p$ (COMPASS 2008)

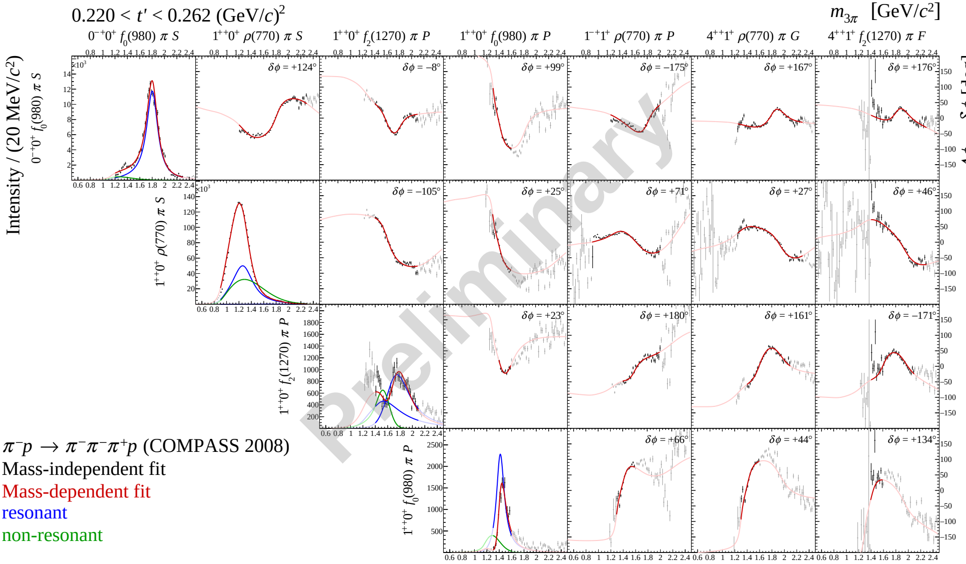
Mass-independent fit

Mass-dependent fit

resonant

non-resonant

sub-density matrix in seventh t' bin



The dominant decay mode is assumed to be $\rho\pi S$

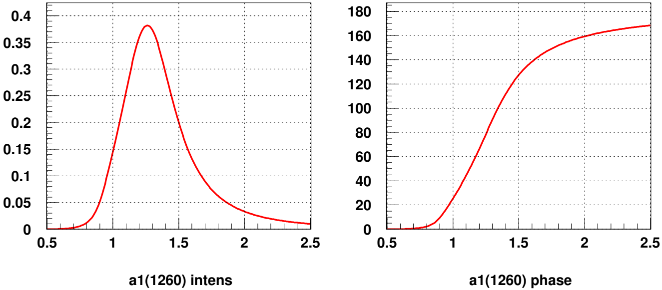
$$\Gamma(m) = \Gamma_0 \frac{m_0}{m} \frac{\int \left|\psi_{1++\,\rho\pi S}(\tau,m)\right|^2 d\Phi_3(\tau)}{\int \left|\psi_{1++\,\rho\pi S}(\tau,m_0)\right|^2 d\Phi_3(\tau)}$$

Intensity:

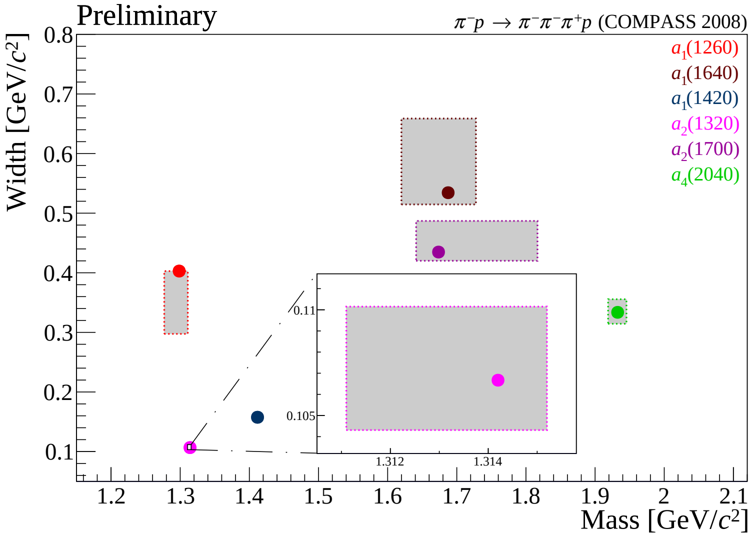
$$\mathcal{I}(m) = \frac{\Gamma(m)}{(m_0^2 - m^2)^2 + m_0^2 \Gamma(m)^2}$$

Phase:

$$\phi(m) = arg\left(\frac{1}{m_0^2 - m^2 - i m_0 \Gamma(m)}\right)$$

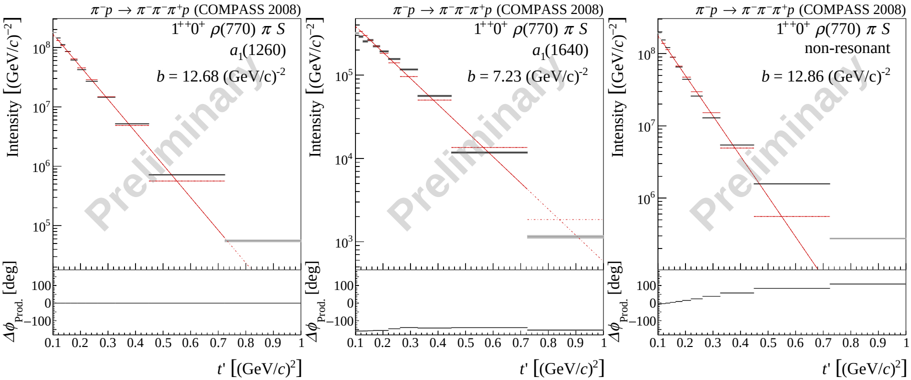


Parameters of a_J resonances, incl. systematics

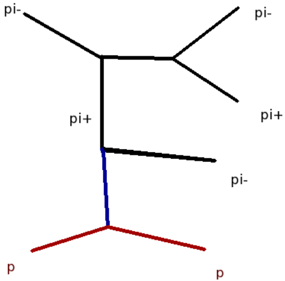


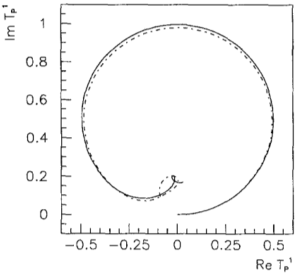
$$M_{a_1(1260)} = 1298\,^{+13}_{-22}\text{ MeV},\ \Gamma_{a_1(1260)} = 400\,^{+0}_{-100}\text{ MeV}$$

t' - intensities and phases of $1^{++}0^{+}\rho\pi$ components



$$b_{a_1(1260)} = 12.68\,^{+0.25}_{-5.25},\ b_{a_1(1640)} = 7.2\,^{+1.9}_{-0.4},\ b_{NR} = 12.9\,^{+3.5}_{-2.7}$$





Amplitudes for $\pi\pi \to \pi\pi$

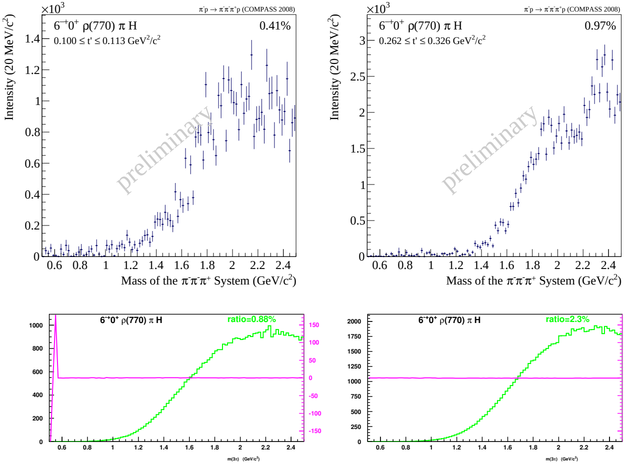
Amplitude of $\pi^- N$ scattering: $T_{\pi N}(s_{\pi N}, t') = s_{\pi N} e^{-8t'}$

Pion propagator: $P(t_\pi) = \frac{m_\pi^2 e^{bt_\pi}}{m_\pi^2 - t_\pi}$ with b $= 1.7\ GeV^{-1}$ and $m_\pi = m_{\pi^c}$

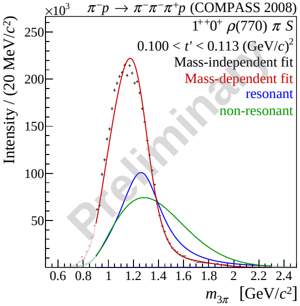
Deck decomposition to partial waves:

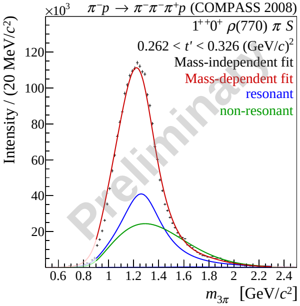
$$\Psi_{Deck}(\tau, m, t') \sim \sum C_i(m, t')\Psi_i(\tau, m)$$

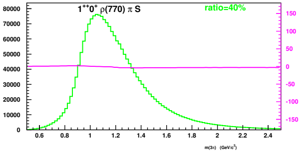
$6^{-+}0^{+}\rho\pi H$ used to normalize Deck contribution

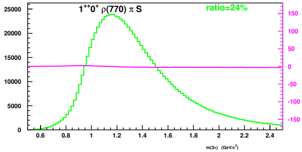


$1^{++}0^{+}$ mass-dep fit of the data vs. Deck decomposition

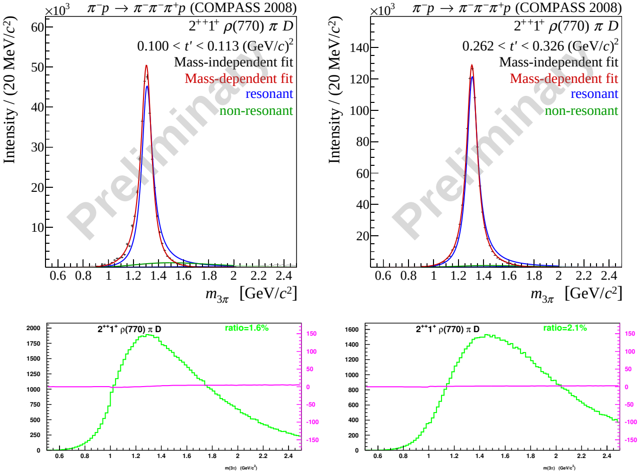




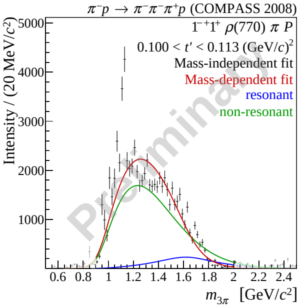


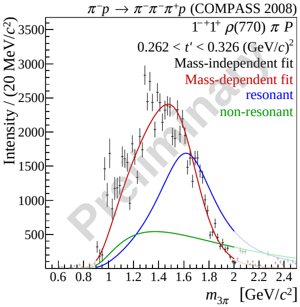


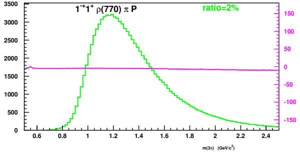
$2^{++}1^{+}$ mass-dep fit of the data vs. Deck decomposition

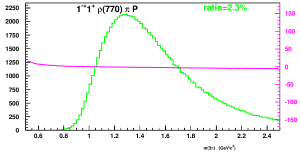


$1^{-+}1^{+}$ mass-dep fit of the data vs. Deck decomposition









CONCLUSIONS

- The mass-independent PWA $\pi^- p \to \pi^-\pi^-\pi^+ p$ of 46 000 000 events is carried out using set of 88 waves and for $0.1 < t' < 1.0$ GeV^2 divided into 11 t' intervals
- First time the t'-resolved mass-dependent analysis of $\pi^-\pi^-\pi^+$ is performed using 14x14 sub-density matrix
  - The extraction of resonance parameters is based on intensity shapes and relative phase motions in $m(3\pi)$ bins
  - fitting simultaneously in set of t' intervals leads to improved separation between resonant and background components
- The $a_1(1260)$ is observed in $1^{++}0^+\rho(770)\pi S$
  - this intensity is dominant contributing to about 30% of the total intensity
  - substantional amount of non-resonating background in $1^{++}0^+\rho(770)\pi S$ leads to large systematic uncertainties of $a_1(1260)$ parameters
- The Deck mechanism is related to backgroud processes in diffractive production of 3π
  - The partial-wave decomposition of Deck amplitude is performed, showing dominance of $1^{++}0^+\rho(770)\pi S$ with increase of its rate at lowest t'
  - Deck model has contributions of high orbital moment states at high $m(3\pi)$
  - It contributes to $M = 1$ partial waves, this can explain, in particular, dominance of background component in exotic $J^{PC}M^\epsilon = 1^{-+}1^+\rho\pi$ at low t'