$\rho(770)$ Meson Spin-Density Matrix Elements

Update on Systematic Studies

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Physic WG Meeting
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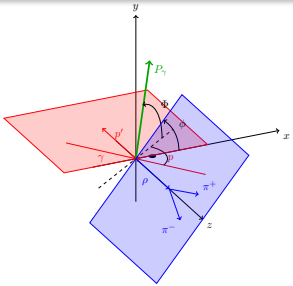
- Full angular distribution of vector meson production and decay is described by **spin-density matrix elements ρ^k_{ij}**
- Linear beam polarization provides access to **nine** linearly independent SDMEs
- Intensity ***W*** is expressed as function of angles **cos ϑ, φ, Φ** and degree of polarization P_γ



$$W(\cos\vartheta,\varphi,\Phi) = W^0(\cos\vartheta,\varphi) - P_\gamma\cos(2\Phi)W^1(\cos\vartheta,\varphi) - P_\gamma\sin(2\Phi)W^2(\cos\vartheta,\varphi)$$

$$W^0(\cos\vartheta,\varphi) = \frac{3}{4\pi}\left(\frac{1}{2}(1-\rho^0_{00}) + \frac{1}{2}(3\rho^0_{00}-1)\cos^2\vartheta - \sqrt{2}\mathrm{Re}\rho^0_{10}\sin 2\vartheta\cos\varphi - \rho^0_{1-1}\sin^2\vartheta\cos 2\varphi\right)$$

$$W^1(\cos\vartheta,\varphi) = \frac{3}{4\pi}\left(\rho^1_{11}\sin^2\vartheta + \rho^1_{00}\cos^2\vartheta - \sqrt{2}\mathrm{Re}\rho^1_{10}\sin 2\vartheta\cos\varphi - \rho^1_{1-1}\sin^2\vartheta\cos 2\varphi\right)$$

$$W^2(\cos\vartheta,\varphi) = \frac{3}{4\pi}\left(\sqrt{2}\mathrm{Im}\rho^2_{10}\sin 2\vartheta\sin\varphi + \mathrm{Im}\rho^2_{1-1}\sin^2\vartheta\sin 2\varphi\right)$$

Schilling *et al.* [Nucl. Phy. B, 15 (1970) 397]

Extraction of SDMEs

$$W(\cos\vartheta, \varphi, \Phi) = W^0(\cos\vartheta, \varphi) - P_\gamma \cos(2\Phi) W^1(\cos\vartheta, \varphi) - P_\gamma \sin(2\Phi) W^2(\cos\vartheta, \varphi)$$

Measured Intensity $I(\Omega) \propto W(\cos\vartheta, \varphi, \Phi)$

Extended Maximum-Likelihood Fit

$$\ln L = \underbrace{\sum_{i=1}^{N} \ln I(\Omega_i)}_{\text{Signal Events}} - \underbrace{\sum_{j=1}^{M} \ln I(\Omega_j)}_{\text{Background}} - \underbrace{\int d\Omega\, I(\Omega)\, \eta(\Omega)}_{\text{Normalization Integral}}$$

- Maximize by choosing SDMEs such that the intensity fits the observed N events
- Accidental background subtracted in likelihood
- Normalization integral evaluated by a phase-space Monte Carlo sample with the acceptance $\eta(\Omega) = 0/1$

Latest Result

$\gamma p \to \rho(770) p$

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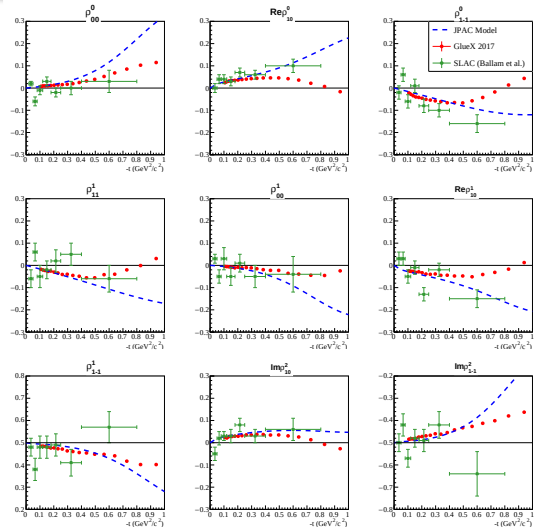
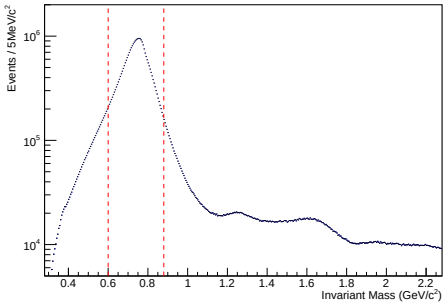
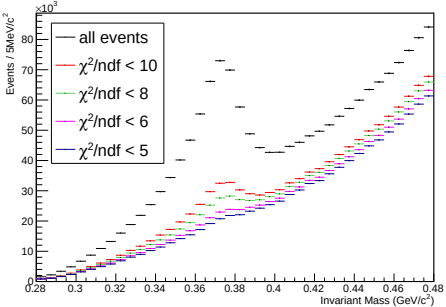


- Combined fit of 4 orientations with constraints
- Excellent agreement with JPAC for $t < 0.5\,\mathrm{GeV}^2$
- Statistical uncertainties only
- Systematic studies ongoing

Kinematic Fit



- Default: $\chi^2/\mathrm{ndf} < 5$
- Motivation: Suppress misidentified kaons
- Variation: ± 2 corresponds roughly to $\pm 10\%$ data



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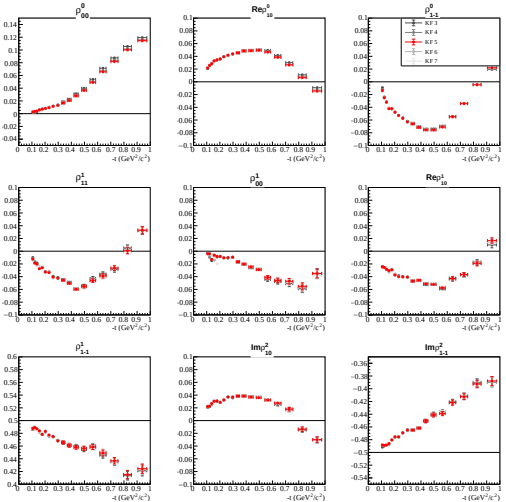

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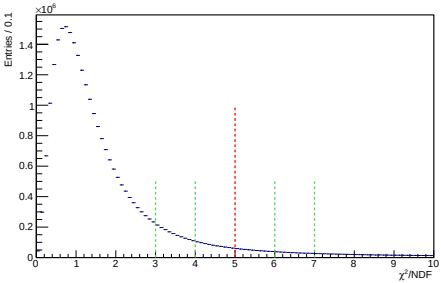
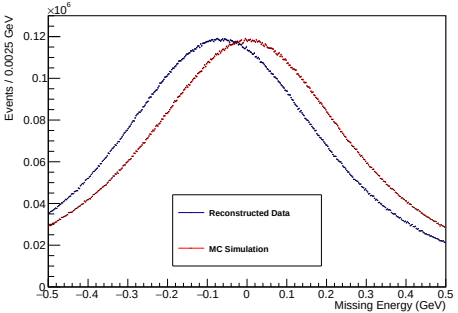
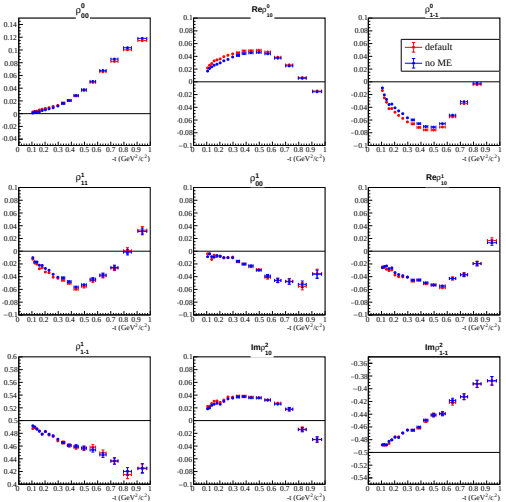


Missing Energy

- Default: $|ME| < 0.5\,\text{GeV}$
- Motivation: Suppress non-exclusive background
- Variation: remove cut, 28% event gain



Missing Energy



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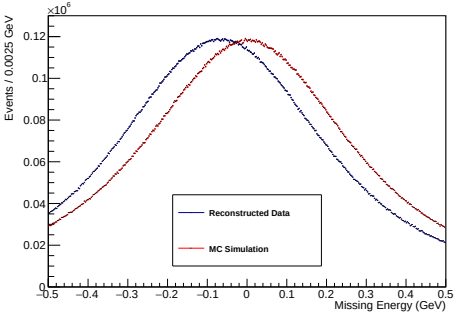

Effect of Target Excitation

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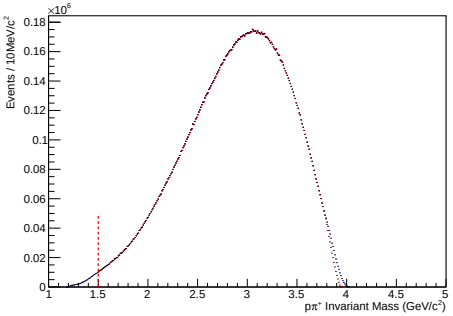
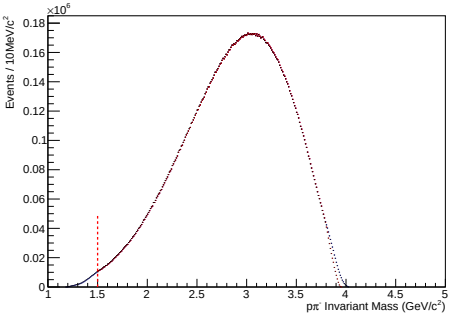
$p\pi^+$ Invariant Mass

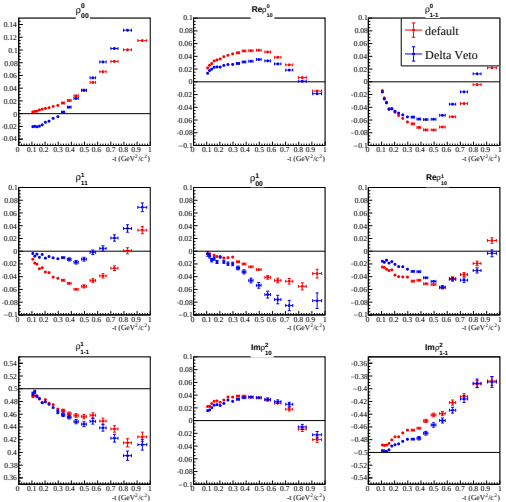


$p\pi^-$ Invariant Mass

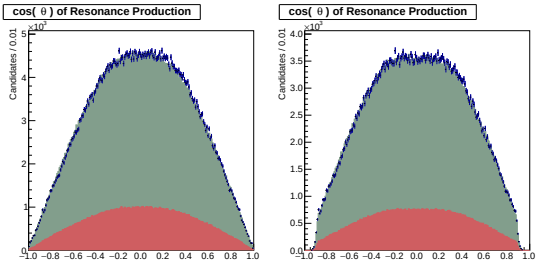


- Nearly no evidence for baryon excitations after selection of $\rho(770)$ mass region
- Systematic study: conservative cut at $M(p\pi) > 1.5\,\mathrm{GeV}/c^2$, reduction of nearly 20%

Effect of Target Excitation



- $M(p\pi) > 1.5\,\mathrm{GeV}/c^2$ has large effect on $\cos\vartheta$ distribution
- Considerable effect on SDMEs
- Repeat study with softer cut



Example bin 8

Summary

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Systematic Studies

- Studies of event selection converge nicely
- Working on a way to present results for uncertainties
- Effects of non-resonant background harder to quantify