



A Preliminary Partial-Wave Analysis of the Centrally Produced $\pi^+\pi^-$ System in pp Reactions at COMPASS

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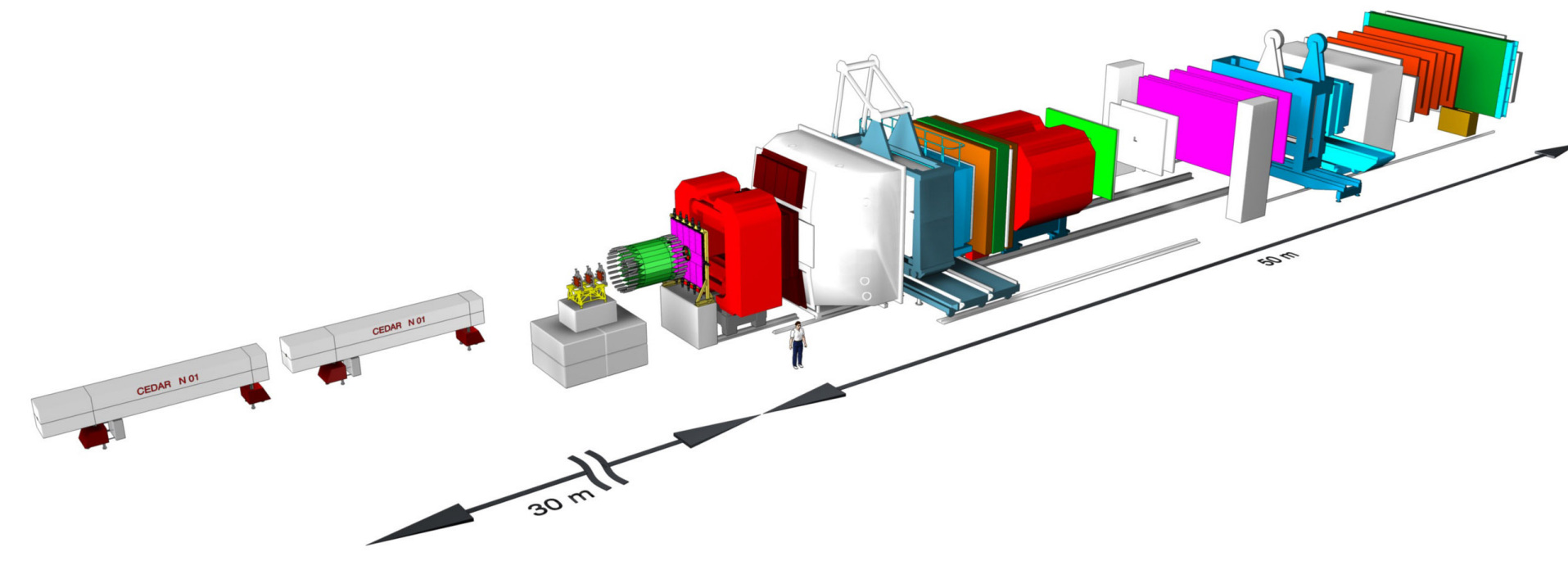
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COMPASS

COMmon Muon and Proton Apparatus for Structure and Spectroscopy

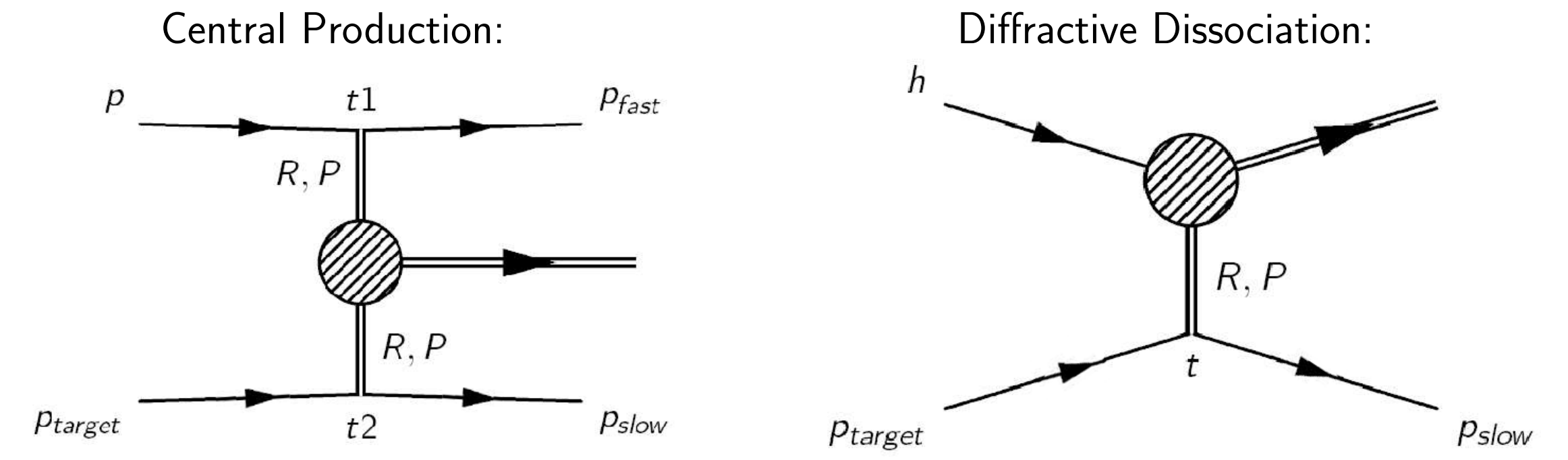
- Fixed target experiment
- Located at CERN SPS
- Data taking since 2002
- Physics objectives:

[P. Abbon et al, NIM A 577, 455 (2007)]



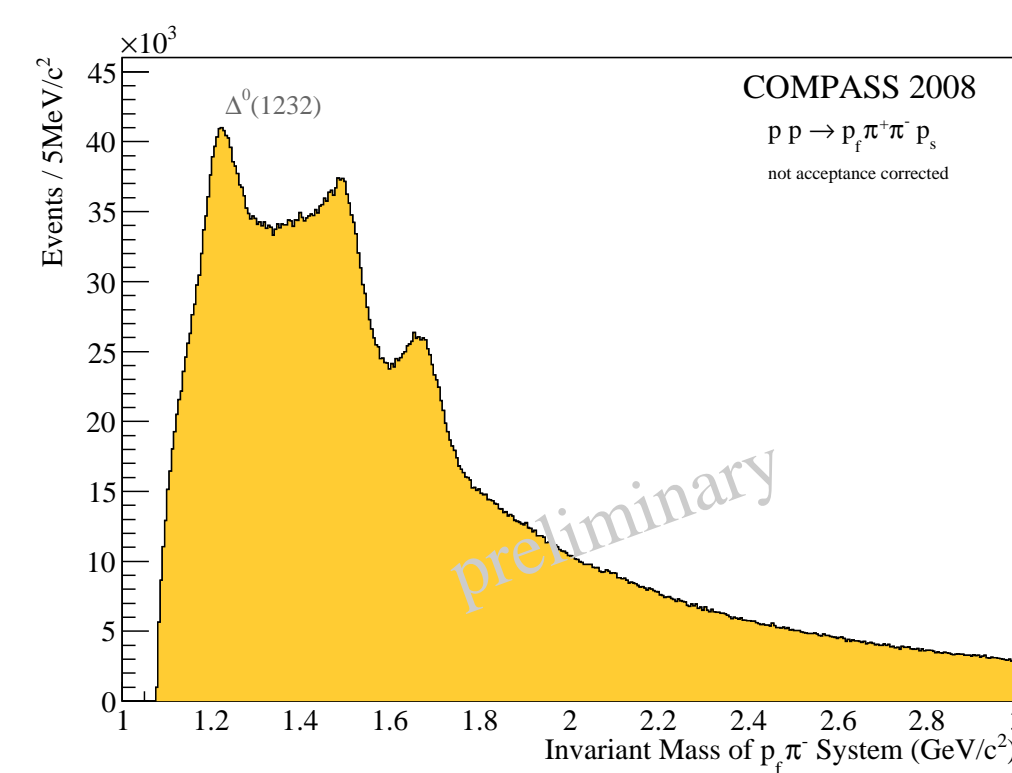
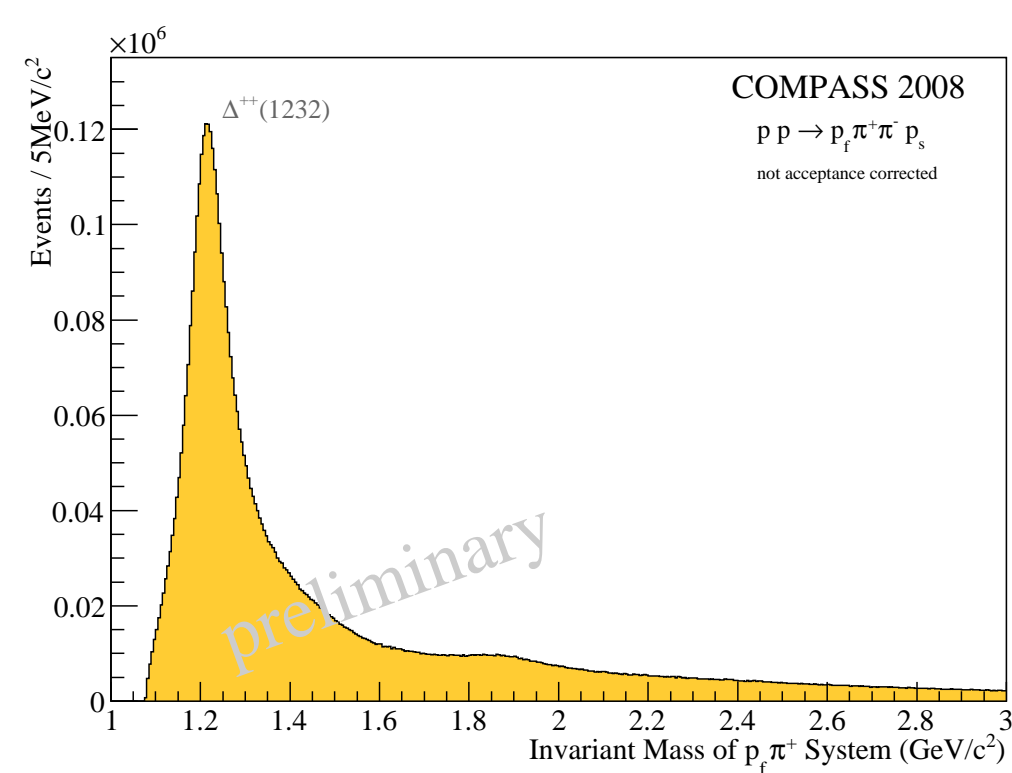
- Hadron spectroscopy
 - Nucleon spin structure
- 2 types of beam
- 190 GeV/c secondary hadron beams (p, π^+ or π^-, K^-)
 - 160 GeV/c tertiary muon beams (μ^+ or μ^-)

Hadron Spectroscopy

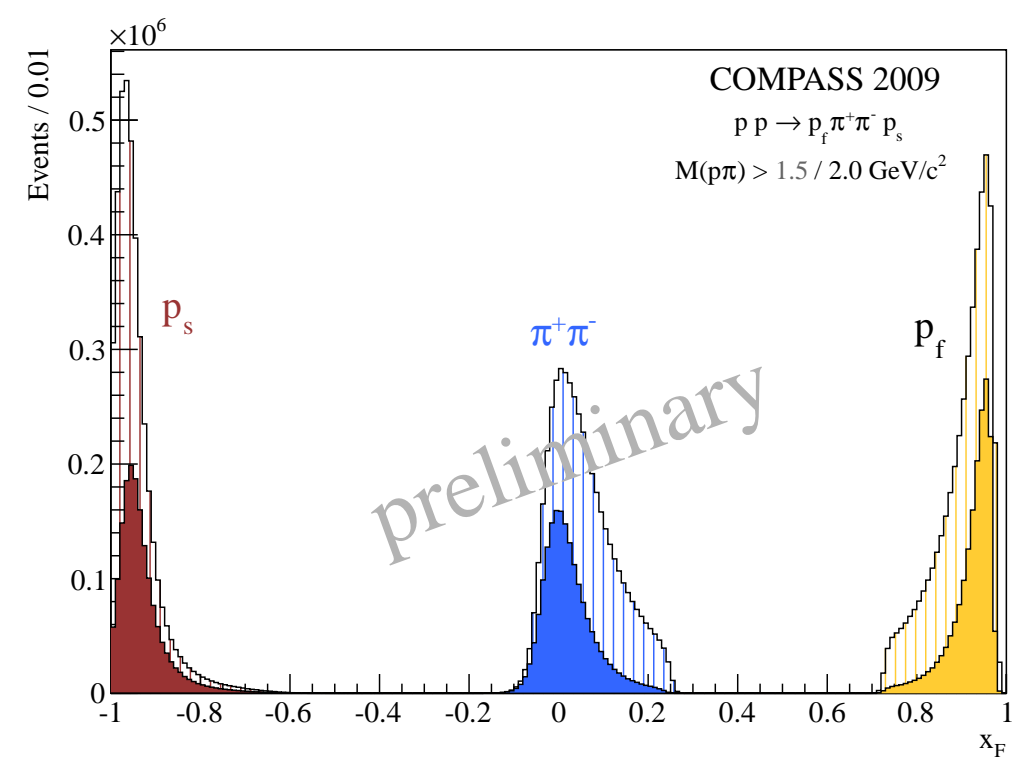


- Liquid hydrogen target
- Production of non- $q\bar{q}$ -mesons (Glue Balls, Hybrids) at central rapidities through double-Pomeron-exchange
- Trigger on recoil proton \rightarrow no rapidity gap between fast proton p_f and central system
- Contribution from diffractive excitation of the proton beam

Selection of a Centrally Produced Sample

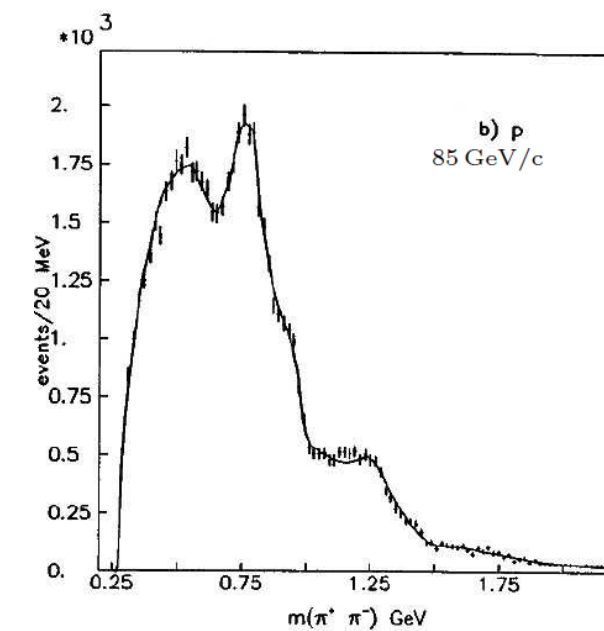


Clear $\Delta(1232)$ signals in $p_f\pi$ sub-systems, evidence for higher mass Δ and N^*
 $\rightarrow M(p\pi) > 1.5 \text{ GeV}/c^2$ required

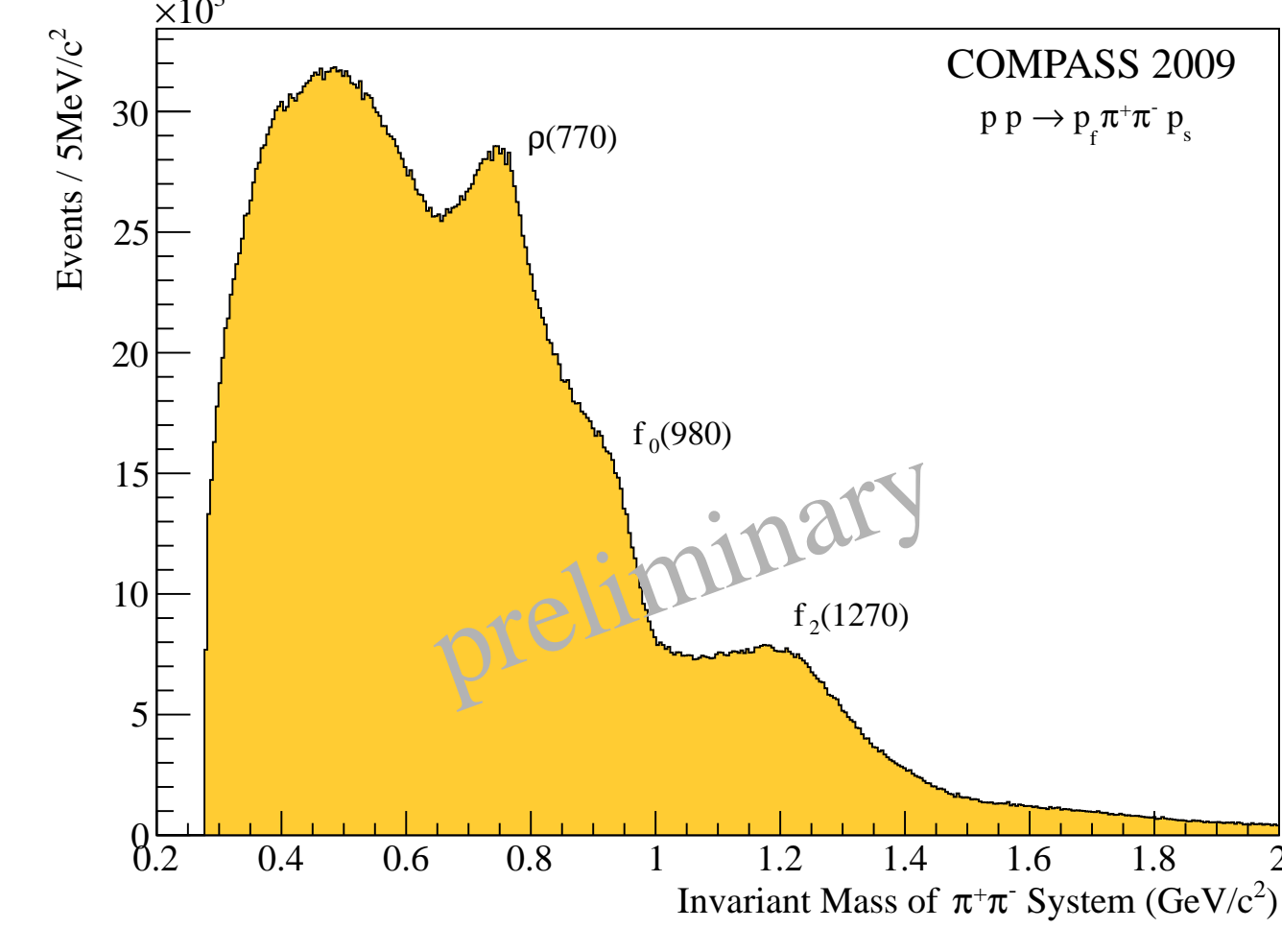


- $\pi^+\pi^-$ system within $|x_F| < 0.25$
 \rightarrow Centrally produced
- Open: $M(p\pi) > 1.5 \text{ GeV}/c^2$,
solid: $M(p\pi) > 2.0 \text{ GeV}/c^2$

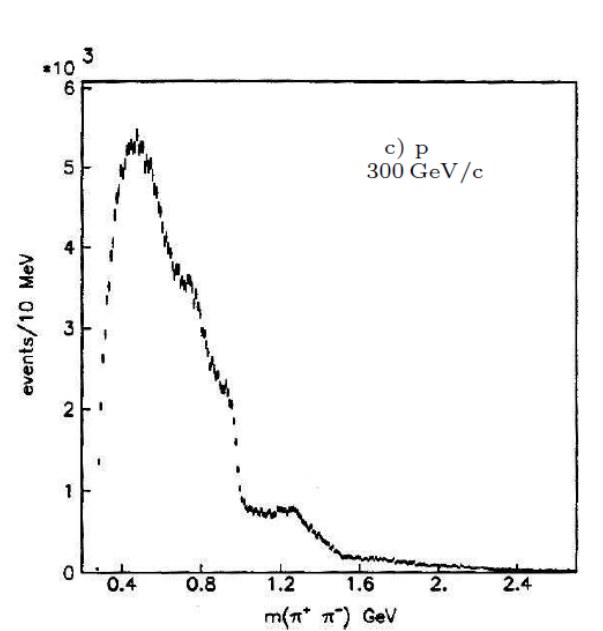
Invariant Mass of $\pi^+\pi^-$ System



$\sqrt{s} = 12.7 \text{ GeV}/c^2$ [1]



$\sqrt{s} = 18.9 \text{ GeV}/c^2$



$\sqrt{s} = 23.7 \text{ GeV}/c^2$ [1]

- $\rho(770)$ and $f_2(1270)$ signals, sharp drop at $1 \text{ GeV}/c^2$: $f_0(980)$
- Production of $\rho(770)$ disappears rapidly with increasing \sqrt{s}
- Enhancement at low mass (σ) and $f_0(980)$ remain practically unchanged
 \rightarrow characteristic for s-independent Pomeron-Pomeron scattering

Reference Frame

- Assumption: central $\pi^+\pi^-$ system produced by the collision of two objects
- Space-like exchange particles define z-axis and production plane
- Decay fully described by $M(\pi^+\pi^-)$, θ and ϕ
- Linear combination of spherical harmonics as eigenstates of reflectivity $\varepsilon = \pm 1$

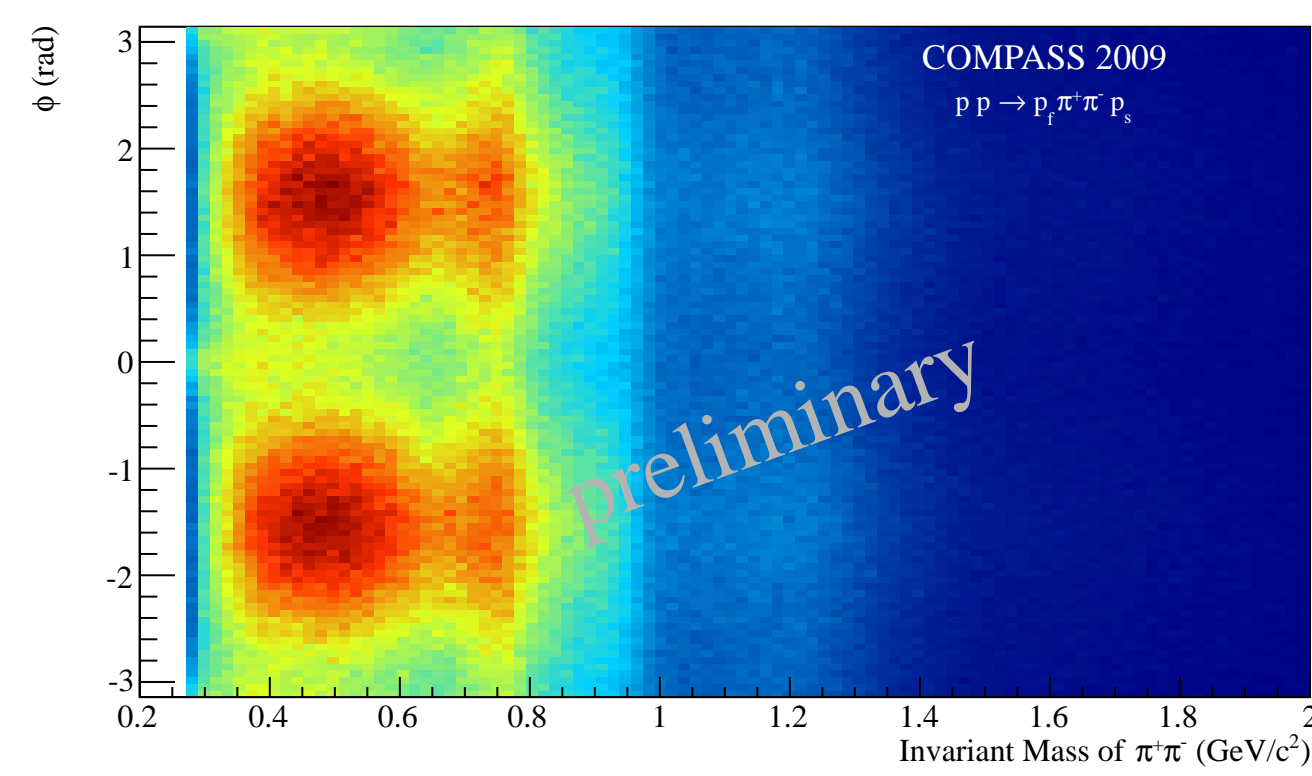
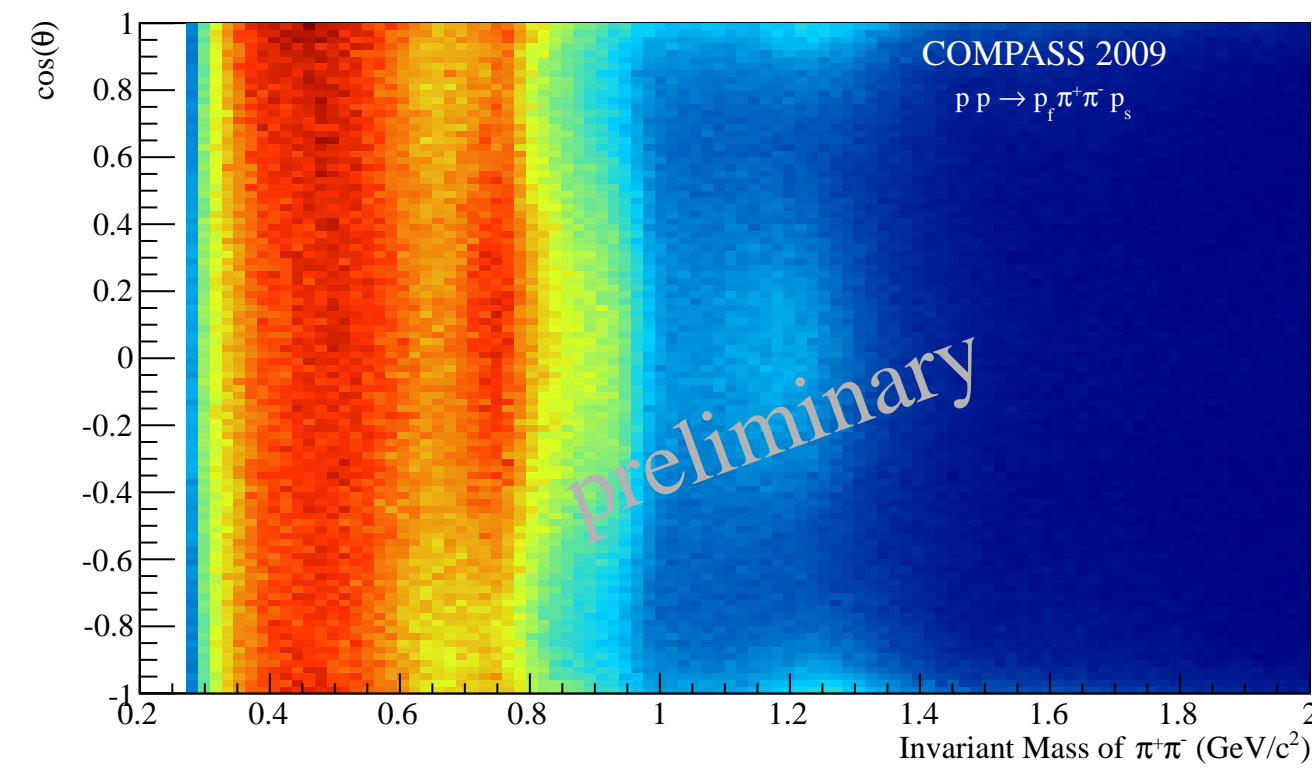
$$Y_m^\ell(\theta, \phi) = c(m) \left[Y_m^\ell(\theta, \phi) - \varepsilon(-1)^m Y_{-m}^\ell(\theta, \phi) \right]$$

Partial Wave Decomposition

Expand intensity $I(\theta, \phi)$ in terms of partial-waves:

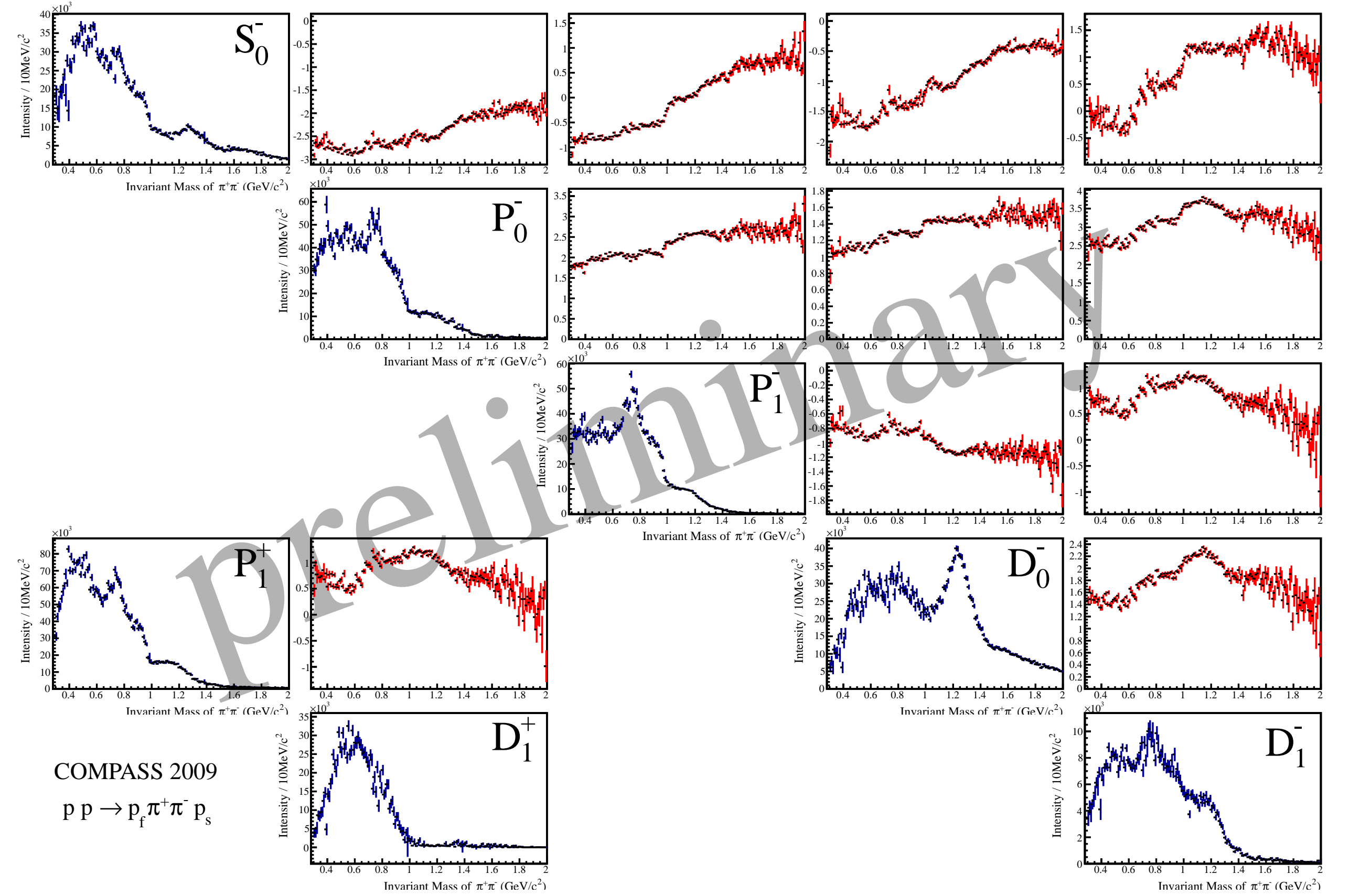
$$I(\theta, \phi) = \sum_\varepsilon \left| \sum_{\ell m} T_{\ell m} Y_m^\ell(\theta, \phi) \right|^2$$

with the complex transition amplitudes $T_{\ell m}$



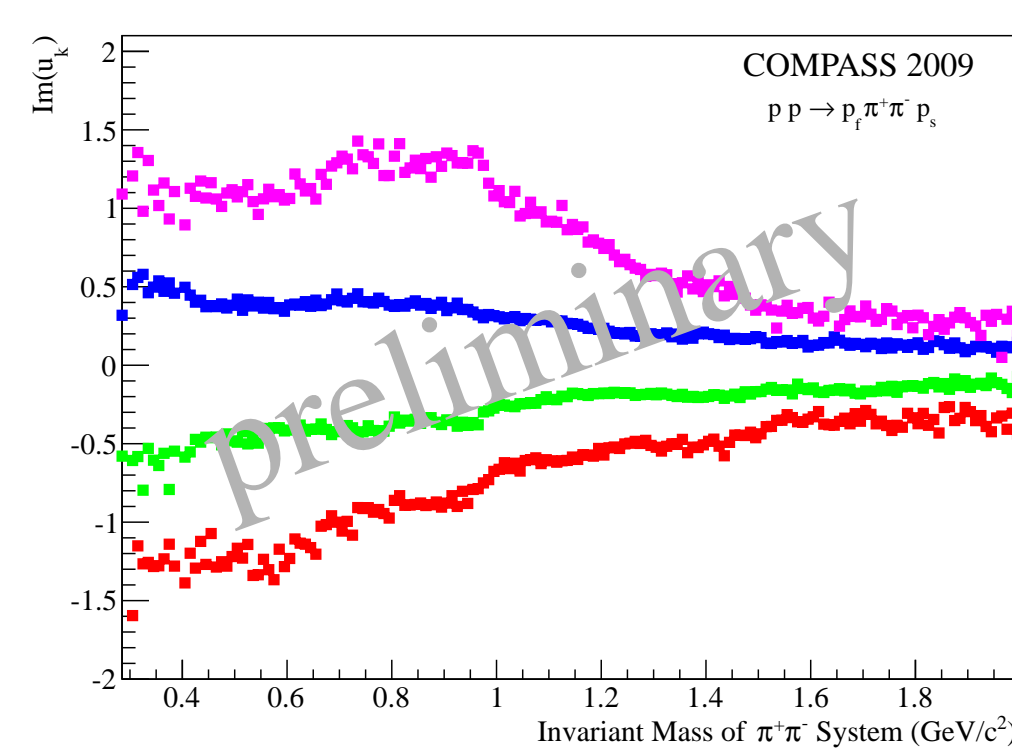
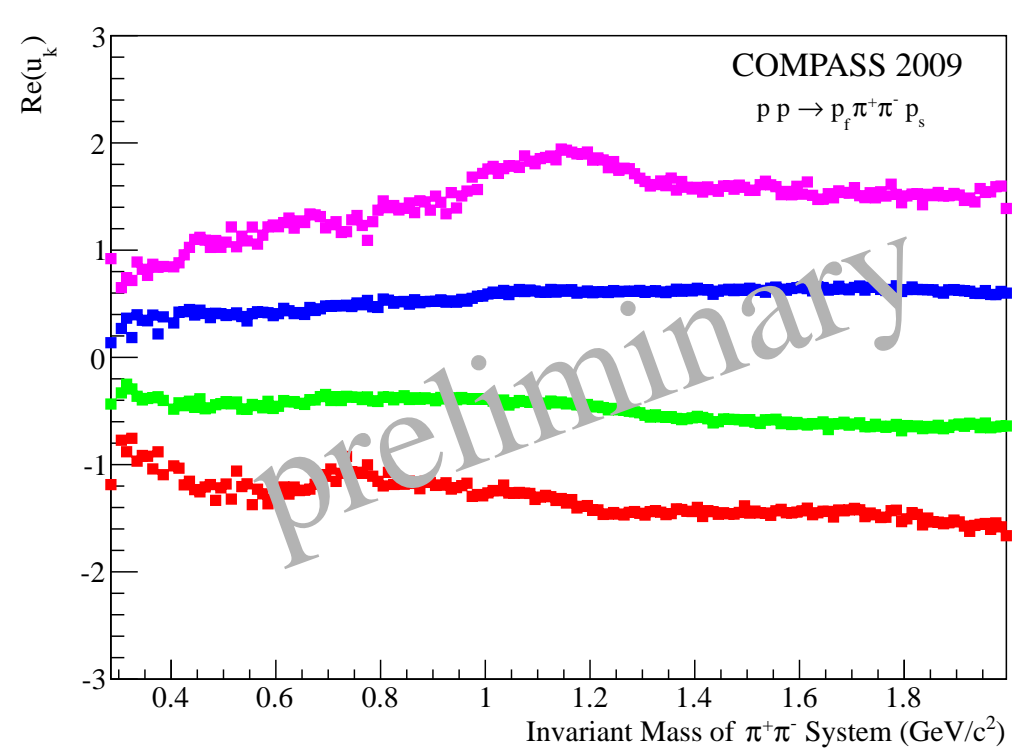
Physical Solution

compatible with physical constraints



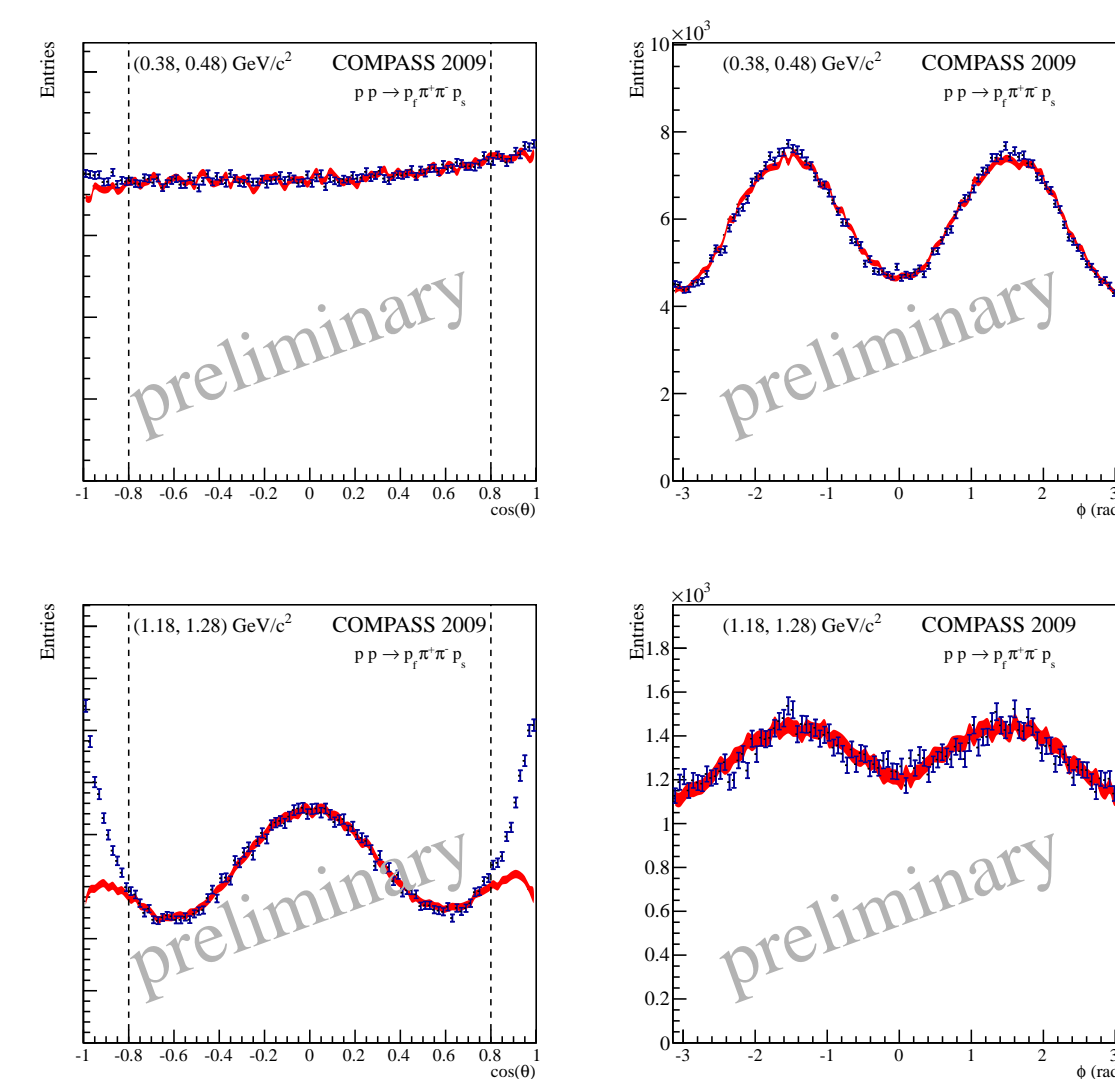
Ambiguities in the Two-Pseudoscalar System

- Intensity expansion can also be written as a 4th-order polynomial
- Complex conjugation of the roots ('Barrelet zeros') results in the same angular distribution



- 8 different ambiguous solutions can be uniquely identified and calculated analytically
- Differentiation requires additional input (e.g. behaviour at threshold, physics content)

Evaluation of Fit with Weighted Monte-Carlo



- Blue: data, red: weighted MC
- Angular distributions well reproduced
- Sharply peaking distribution for $|\cos(\theta)| > 0.8$ cannot be described by fit
- May hint to different production process
 \Rightarrow Excluded from fit, loss of $\approx 20\%$ of data

Conclusion and Outlook

Centrally produced sample with orders-of-magnitude better statistics than previous experiments + Successful partial-wave analysis of two-pseudoscalar systems

\Rightarrow High potential to study light glueball spectrum, combining all accessible decay channels ($\pi^+\pi^-, \pi^0\pi^0, K^+K^-, K_S K_S, \pi^0\pi^0, \eta\eta, \dots$)