Light-Meson Spectroscopy with COMPASS

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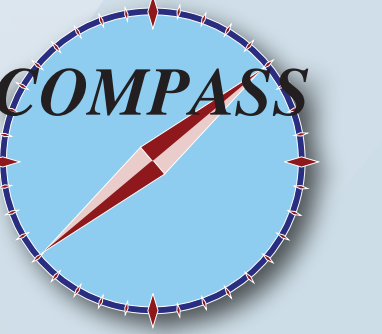
for the COMPASS Collaboration

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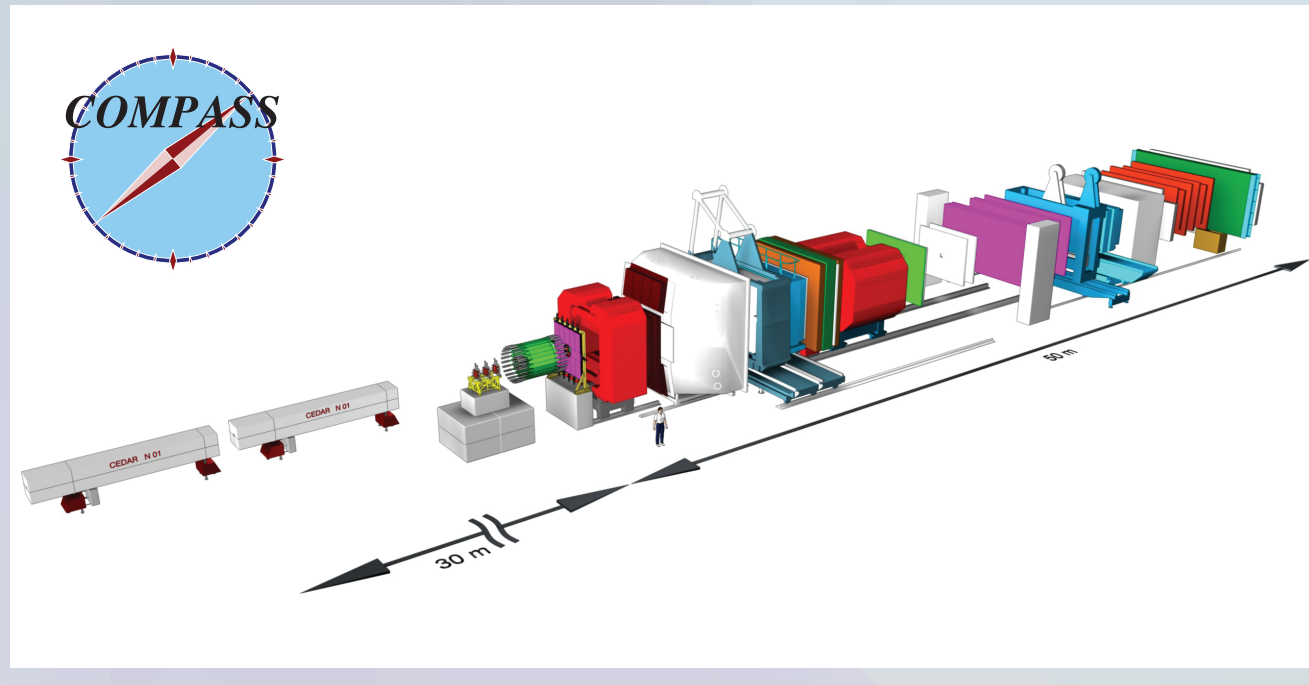[2]Brookhaven National Laboratory, Upton, NY 11973, U.S.A.   [3]Institute for High-Energy Physics, 142284 Protvino, Russia.

Experimental Setup

Common Muon and Proton Apparatus for Structure and Spectroscopy

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

- Fixed-target two-stage spectrometer
- Excellent acceptance
- High-intensity beams from CERN SPS
  - Primary p
  - Secondary π and K
  - Tertiary μ
- Taking data since 2002 (600 TB/y)

Production of $\pi^- \pi^+ \pi^-$ Final States

Diffractive dissociation

- Soft scattering of π^- beam off nuclear target (remains intact)
- At high energies Pomeron exchange dominates
- Rich meson spectrum

[Results for other diffractive final states and central production: talk by R. Geyer]

Photonuclear Production (Primakoff)

- Scattering of π^- beam in Coulomb field of target nucleus
- Separable from diffractive reactions via t' dependence

Data Sets

2004 Pilot Run

- 190 GeV/c π^- beam on **Pb target**
- Trigger on multiplicity of outgoing particles

2008 High-Statistics Run

- 190 GeV/c π^- beam on **H_2 target**
- Major spectrometer upgrades:
  - CEDAR detectors for beam particle ID
  - Recoil-proton detector (momentum transfer $t' > 0.1$ (GeV/c)^2)
  - Improved tracking and electromagnetic calorimetry
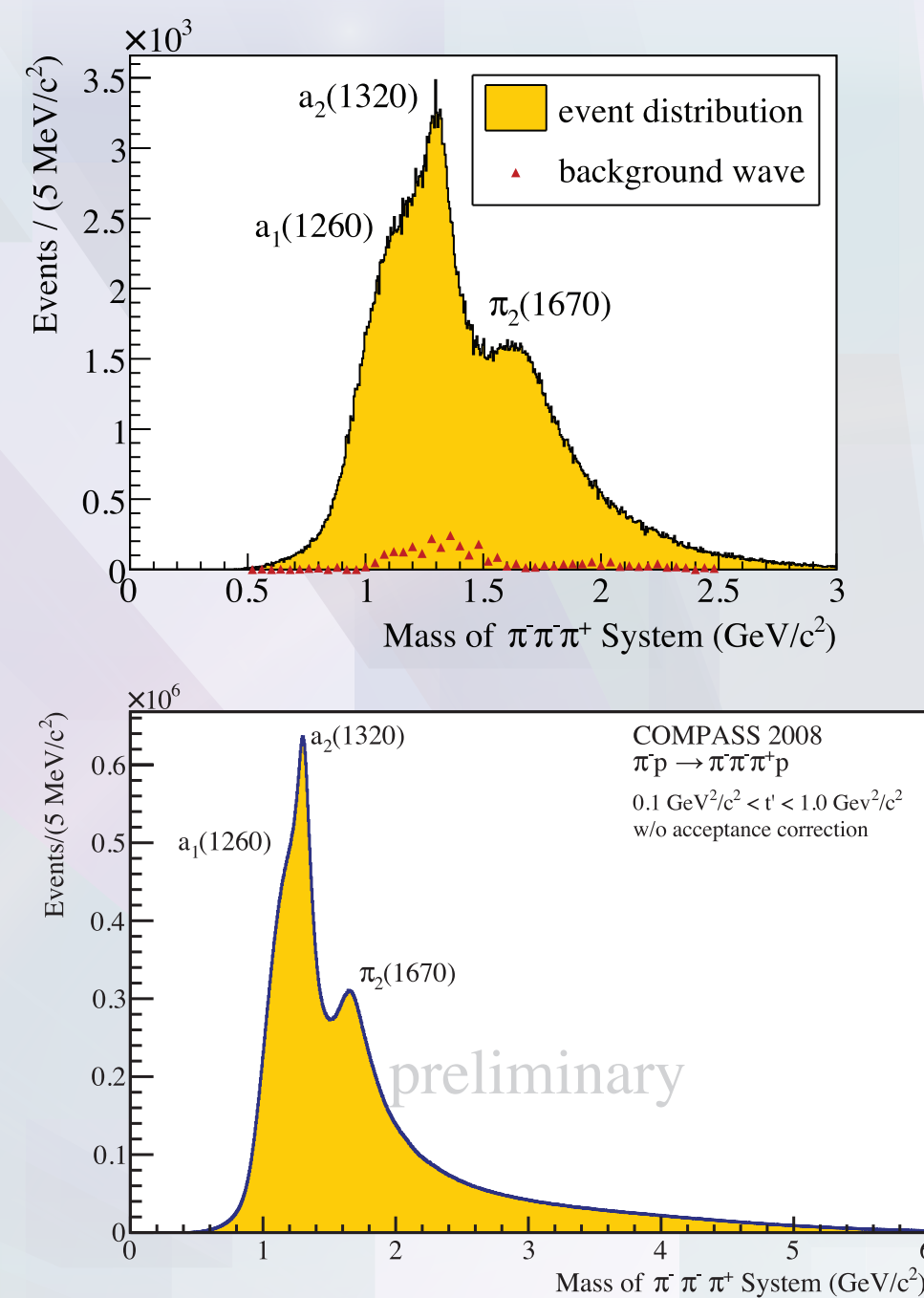
Analysis Technique

- Partial-wave analysis with isobar model (no final-state interactions)
- Partial wave in reflectivity basis: $J^{PC} M^\epsilon$ [isobar π^-]L
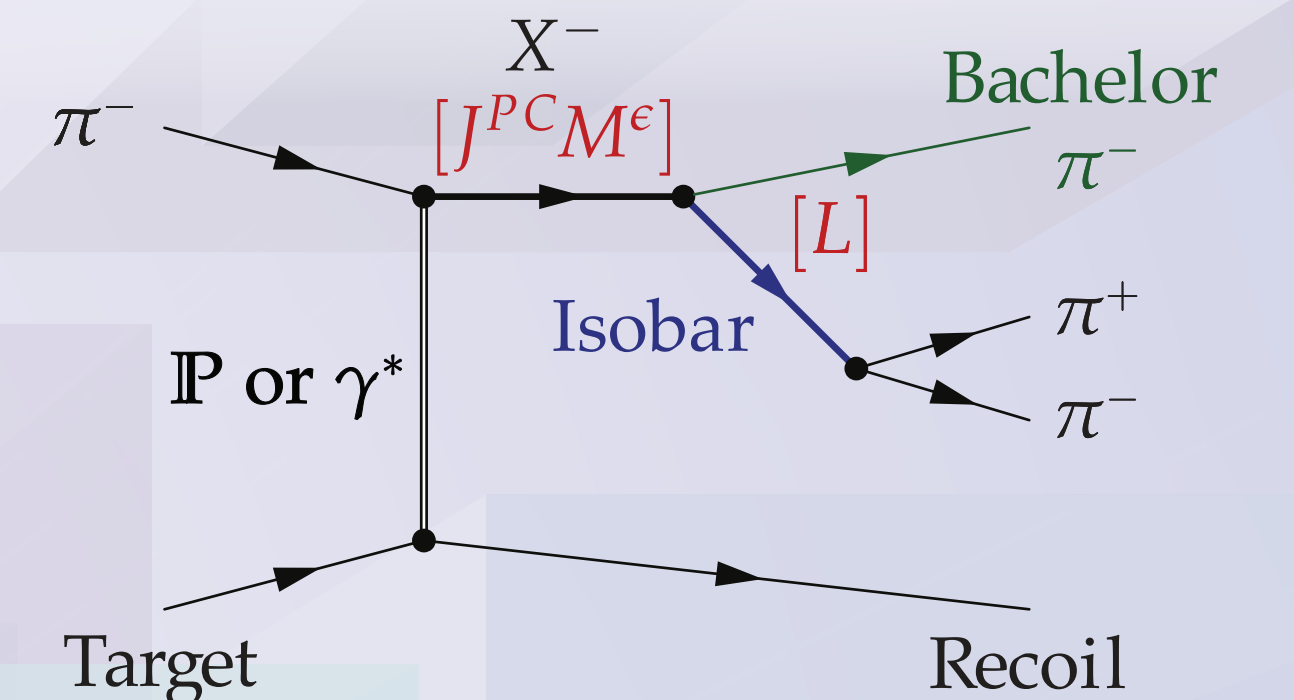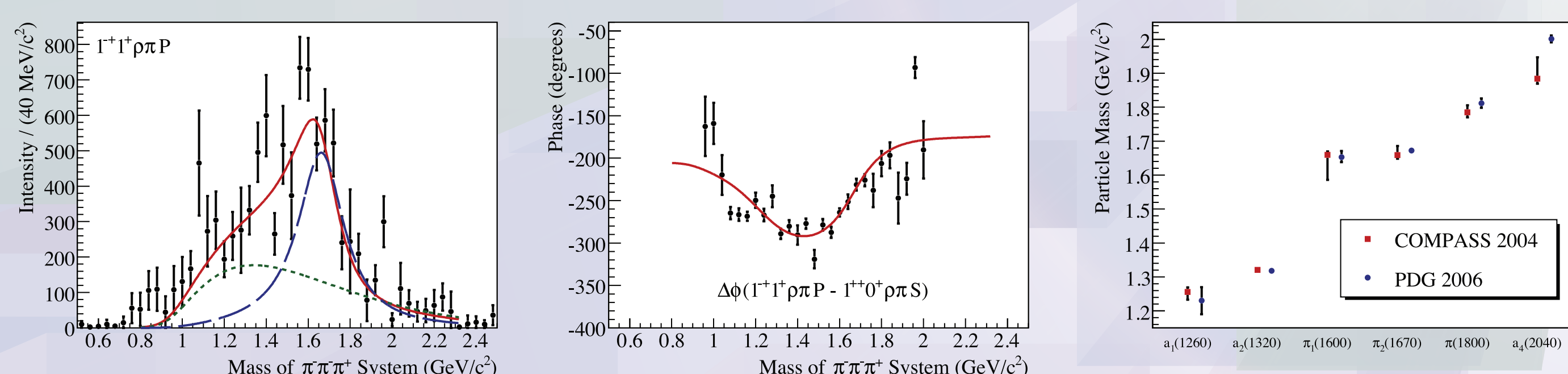
Partial-Wave Analysis: Two-Step Procedure

1. Extended maximum likelihood fit in 40 MeV/c^2-wide mass bins
   - Isobars: $(\pi\pi)_s$ with separated $f_0(980)$, $\rho(770)$, $f_2(1270)$, and $\rho_3(1690)$
   - Fit takes acceptance into account
2. χ^2-fit of mass dependence of spin-density submatrix
   - Parameterization: Breit-Wigners + coherent exponential background

Large Momentum Transfer $0.1 < t' < 1$ (GeV/c)^2

2004 Pilot Run Data (Pb target)   A. Alekseev *et al.*, PRL **104**, 241803 (2010)

- 41 waves + isotropic background wave, rank-2 spin-density matrix
- Significant spin-exotic $J^{PC} = 1^{-+}$ wave
- Resonant behavior consistent with controversial $\pi_1(1600)$
  - $M = 1660 \pm 10^{+0}_{-64}$ MeV/c^2, $\Gamma = 269 \pm 21^{+42}_{-64}$ MeV/c^2
  - Negligible leakage (< 5 %)

First Partial-Wave Analysis of 2008 Data (H_2 target)

- No acceptance correction, mass-independent fit only

Nuclear Effect in Meson Production

- Data sets: **Pb target** (2004) and **H_2 target** (2008) normalized to $a_2(1320)$
- Different intensity of spin projections:
  - **On Pb:** $M = 1$ strongly enhanced, whereas $M = 0$ suppressed
- Intensity sum over spin projections comparable

Small Momentum Transfer $t' < 10^{-2}$ (GeV/c)^2

Low-t' Diffraction and Primakoff in 2004 Data (Pb Target)

- 37 waves + isotropic background wave rank-2 spin-density matrix
- "Low-t' region": $1.5 \cdot 10^{-3} < t' < 10^{-2}$ (GeV/c)^2
- "Primakoff region": $t' < 0.5 \cdot 10^{-3}$ (GeV/c)^2
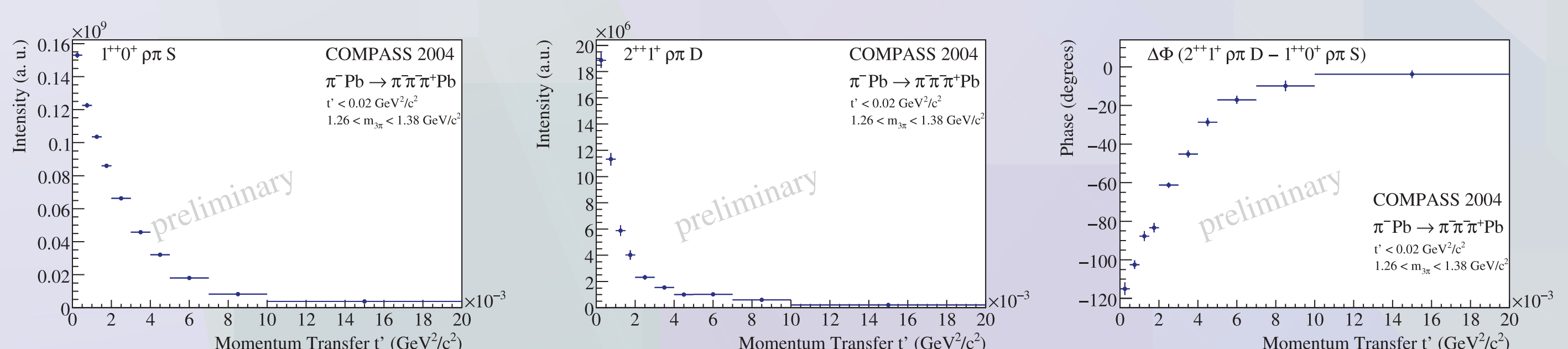 - t' spectrum dominated by resolution effects
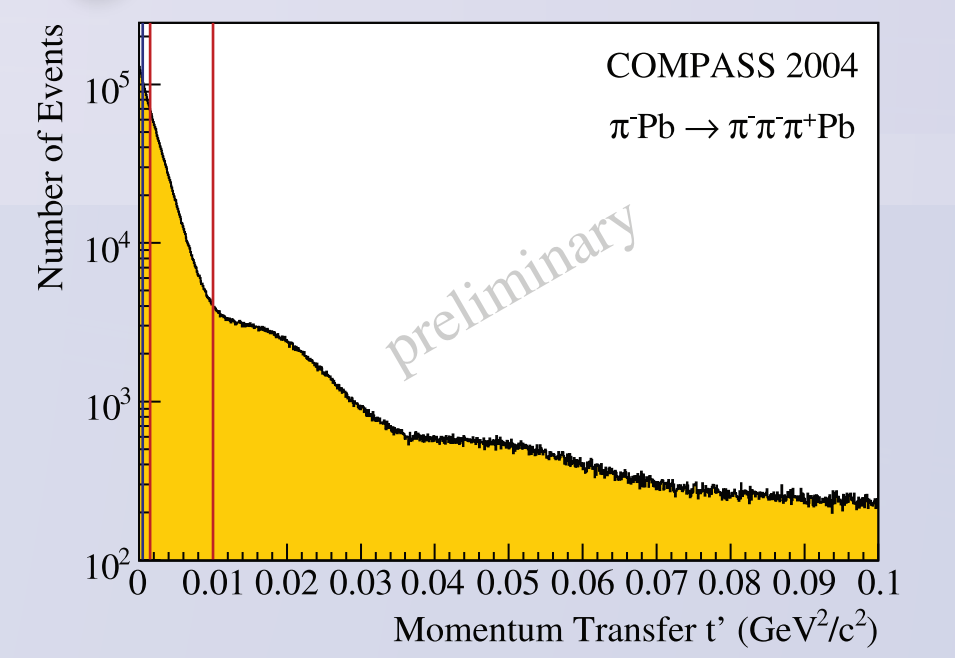
Main resonances

- $a_1(1260)$ produced diffractively
- $a_2(1320)$ production for $t' \to 0$
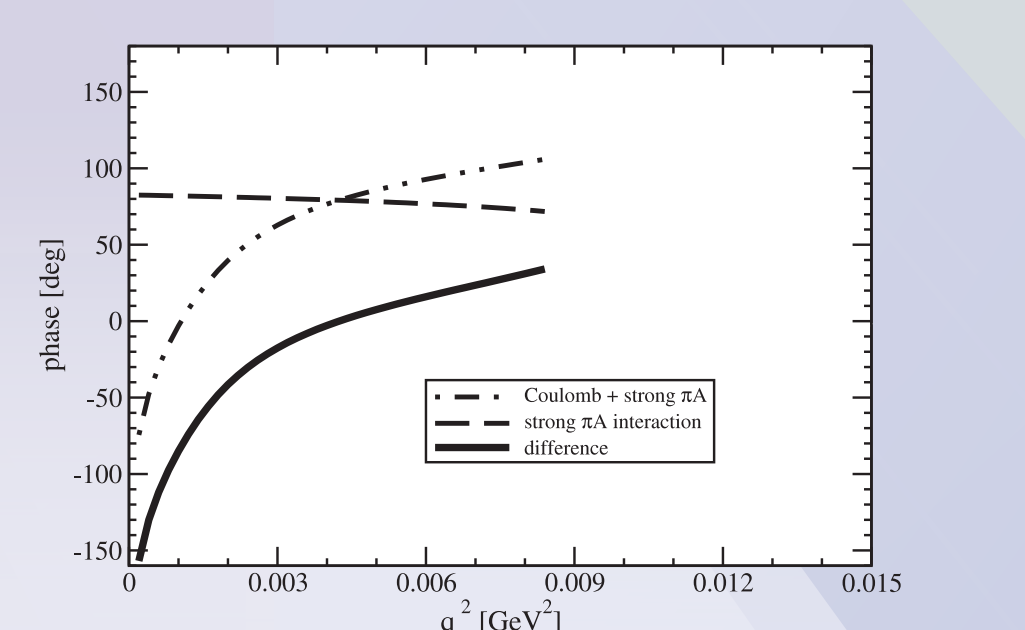 - **Diffractive production** vanishes
  - **Photoproduction** increases
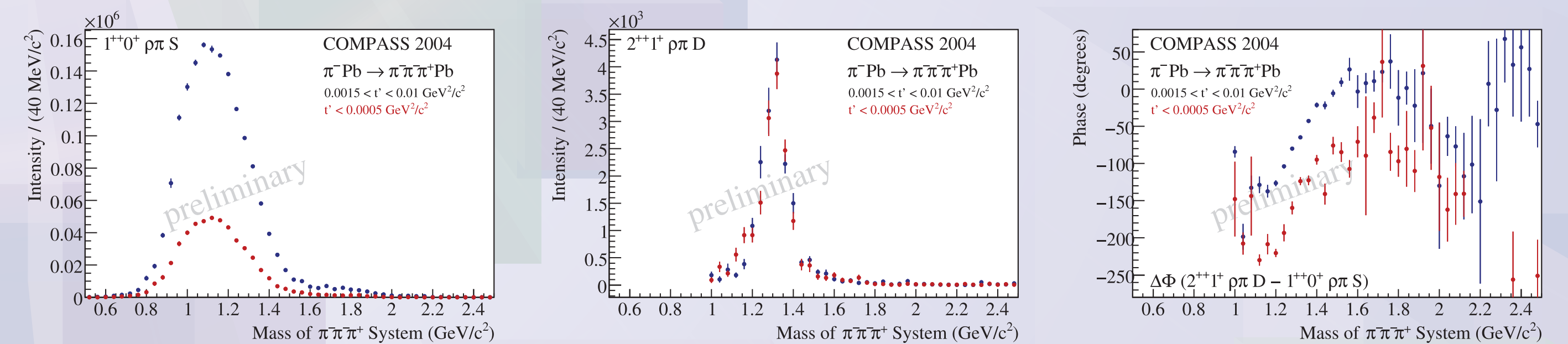
t' Dependence of Phase Difference $a_2(1320) - a_1(1260)$

- PWA fit in $a_2(1320)$ mass region in t' bins
- Interference of contributions from Coulomb and strong interaction
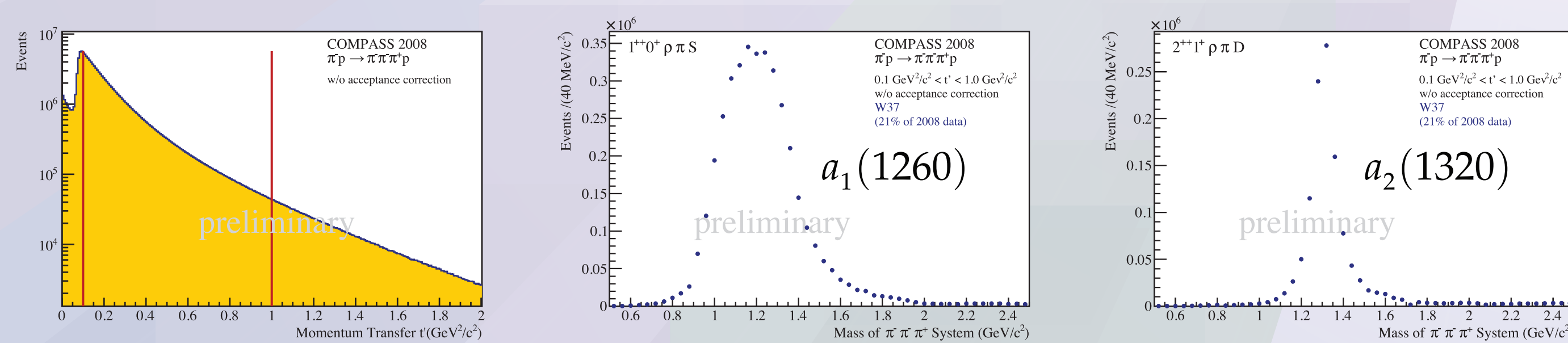- Phase $\gtrsim 90°$ for $t' \to 0$

Predictions from Glauber Model

- Analogous to calculation of Primakoff Compton reaction $\pi\gamma^{(*)} \to \pi\gamma$

  G. Fäldt and U. Tengblad, PRC **79**, 014607 (2009)

- Basic features of data described by model
- Data allow to study details of exchange mechanism and nature of resonances

Courtesy of N. Kaiser (TU München)