Recent Results on Diffractive Dissociations:

$\pi^- \to (5\pi)^-$ at 190 GeV/c from COMPASS

Suh-Urk Chung

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COMPASS Results partly based on the talks presented at:

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Research Awardee (revisit: part-time) Alexander von Humboldt-Stiftung/Foundation
Visiting Professor (part-time) Institute for Advanced Studies (IAS) at TU

Plan of Talk

- Introduction:

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- COMPASS Experiment:

$\pi^- p \, (\mathrm{or Pb}) \to \pi^+\pi^-\pi^+\pi^-\pi^- p \, (\mathrm{or Pb})$ at 190 GeV/c

(Diffractive Dissociation of π^- into $\pi^+\pi^-\pi^+\pi^-\pi^-$)

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- Conclusions and Future Prospects
  Central Diffractive Production of Exotic Mesons (< 3 GeV)

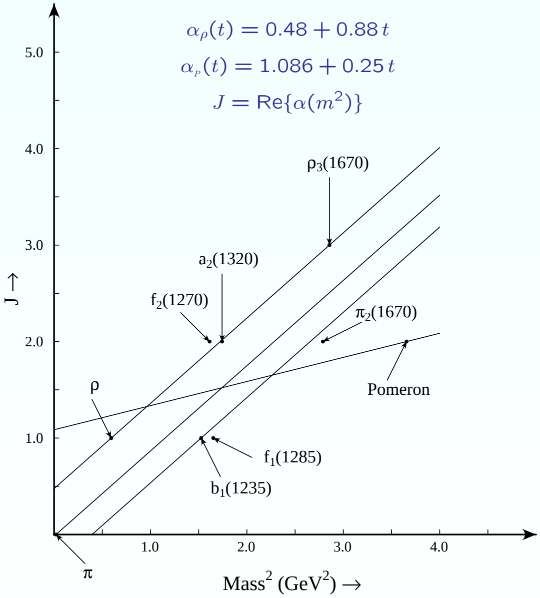
  at ALICE and STAR

Regge Trajectories

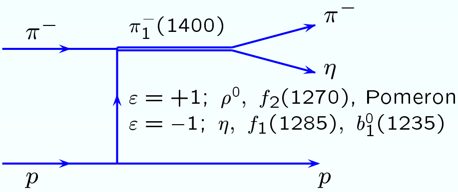
$$\alpha_\rho(t) = 0.48 + 0.88\,t$$

$$\alpha_{_P}(t) = 1.086 + 0.25\,t$$

$$J = \mathrm{Re}\{\alpha(m^2)\}$$



Reggeon exchange:



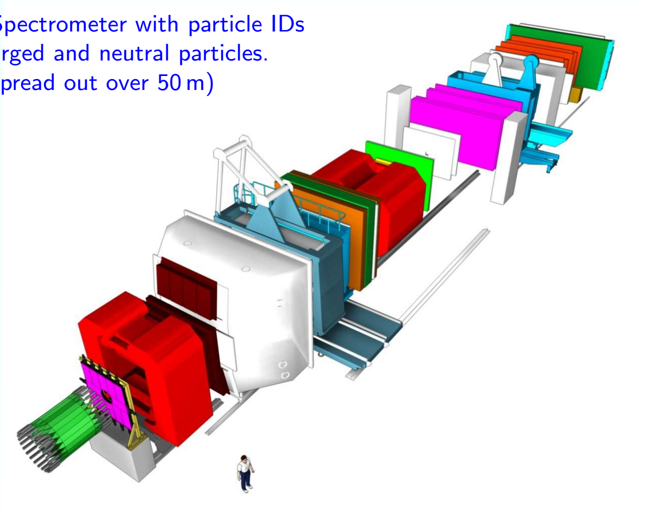
$\varepsilon = +1$ Natural-parity exchange
$\varepsilon = -1$ Unnatural-parity exchange

Notation: $\boxed{J^{PC} M^{\varepsilon} R_1 \left[\frac{L}{S}\right] R_2}$

$\boxed{\text{Replace } \eta \text{ above by } \pi^+\pi^-\pi^+\pi^-}$.

$$\text{Isobars: } \{R_1, \quad R_2\} \longrightarrow \begin{array}{l} \{\pi^-, \quad (\pi^+\pi^-)(\pi^+\pi^-)\} \\ \{\pi^-, \quad \pi^{\pm}\,((\pi^+\pi^-)\pi^{\mp})\} \\ \{\pi^+\pi^-, \quad (\pi^+\pi^-)\pi^-\} \end{array}$$

Two-stage Spectrometer with particle IDs
for both charged and neutral particles.
(Detectors spread out over 50 m)



COMPASS: P. Abbon, *et al.*, NIM A577, 455 (2007)

Hadron Physics Program of COMPASS

- Data-taking runs:

  μ^+ beams at 160 GeV/c in 2002–2004
  π^- beams at 190 GeV/c in 2004 (two weeks)
  μ^+ beams at 160 GeV/c in 2006–2007
  Hadron$^\pm$ beams at 190 GeV/c in 2008–2009
  μ^+ beams at 160 GeV/c in 2010
  μ^+ beams at 200 GeV/c in 2011

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- Pilot hadron run in 2004 with 190 GeV/c π^- beam at 10^6/s on Pb, Cu and C targets

  An example: $\boxed{\pi^- + \mathrm{Pb} \to (\pi^+\pi^-\pi^-) + \mathrm{Pb}}$ Statistics: $\simeq 500\,000$ events

  Exclusive events at low t
  A New Evidence for a $J^{PC} = 1^{-+}$ exotic meson: PRL 104, 241803 (2010)

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- Runs with a Recoil-Proton Detector (RPD) in 2008–2009

  An example: $\boxed{\pi^- + p \to (\pi^+\pi^-\pi^-) + p}$

  2008 Statistics: $\simeq$ 100 000 000 events ($\simeq$ 400 times BNL data)

  Exclusive events at low t
  Search for $J^{PC} = 0^{\pm -}, 1^{-+}, 2^{+-}, 3^{-+} \ldots$ exotic mesons

COMPASS $(5\pi)^{-}$:1

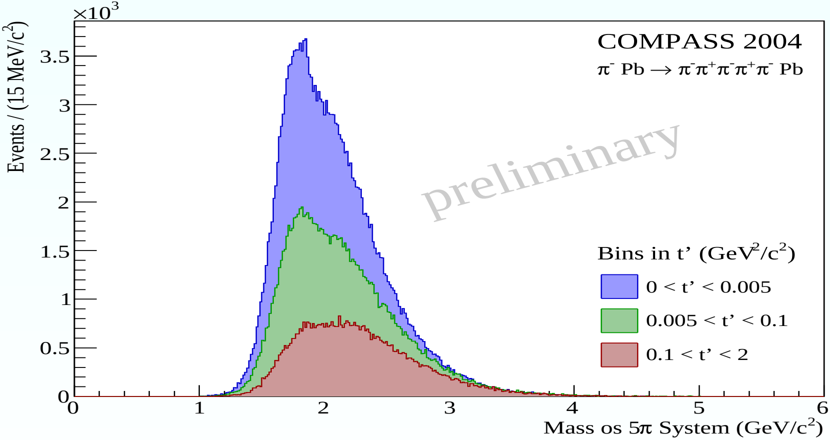
- COMPASS 2004 Data on

$$\pi^{-}\ \mathrm{Pb} \to \pi^{-} + \pi^{+}\pi^{-} + \pi^{+}\pi^{-} + \ \mathrm{Pb}$$

384,000 events for all $t' = |t| - |t|_{\min}$

$\boxed{\text{203,000 events for } t' < 0.005\ (\mathrm{GeV}/c)^2}$

COMPASS $(5\pi)^{-}$:1



Partial-wave Analysis

- Decompose the $(5\pi)^-$ mass spectrum into partial waves in the isobar model.

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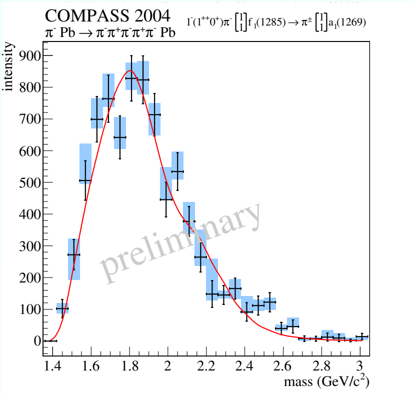
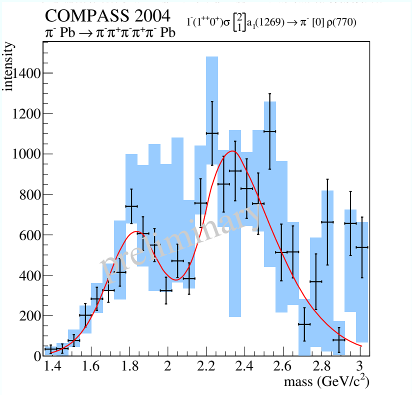
- Using a procedure, the so-called statistical evidence, reduced the needed partial wave to some 40 partial waves
- A final collection of 10 partial waves are fitted to mass-dependent parital waves and their interference terms.
- Search for resonances in the $(5\pi)^-$ system;

$\boxed{\text{Two new } 1^{++} \text{ states around 2.0 GeV}}$

$\boxed{\text{and one } 2^{-+} \text{ state above 2.0 GeV}}$.



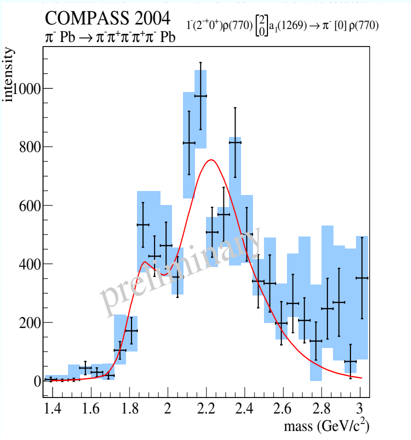


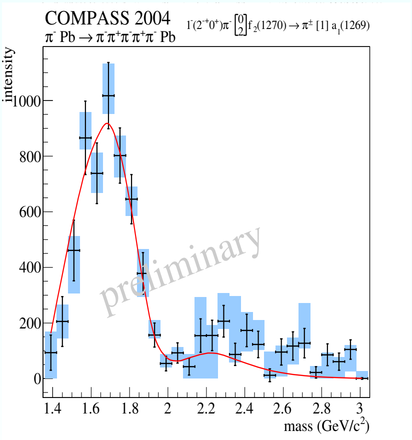
$1^-(1^{++}0^+)\pi\left[{1 \atop 1}\right] f_1(1285)$

$f_1(1285) \to \pi\left[{1 \atop 1}\right] a_1(1269)$

$1^-(1^{++}0^+)\sigma\left[{2 \atop 1}\right] a_1(1269)$

$a_1(1269) \to \pi\left[{0 \atop 1}\right] \rho(770)$



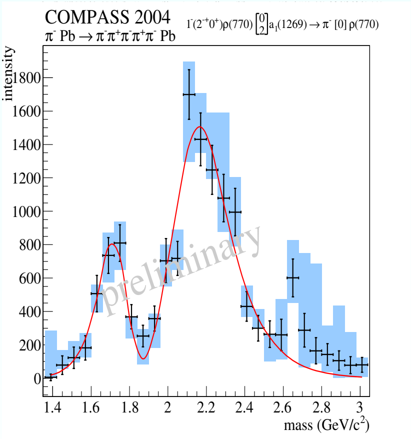


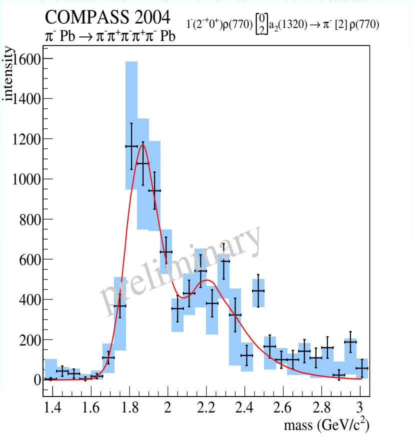
$1^-(2^{-+}0^+)\rho\left[{2 \atop 0}\right]a_1(1269)$

$a_1(1269) \rightarrow \pi\left[{0 \atop 1}\right]\rho(770)$

$1^-(2^{-+}0^+)\pi\left[{0 \atop 2}\right]f_2(1270)$

$f_2(1270) \rightarrow \pi\left[{1 \atop 1}\right]a_1(1269)$





$1^-(2^{-+}0^+)\rho\left[{0 \atop 2}\right]a_1(1269)$ $\quad$ $1^-(2^{-+}0^+)\rho\left[{0 \atop 2}\right]a_2(1320)$

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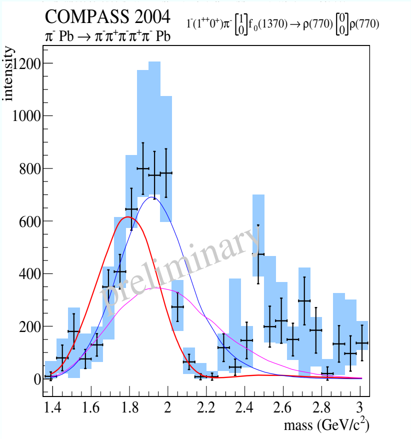
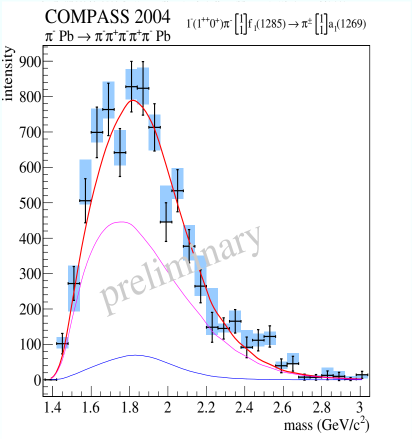




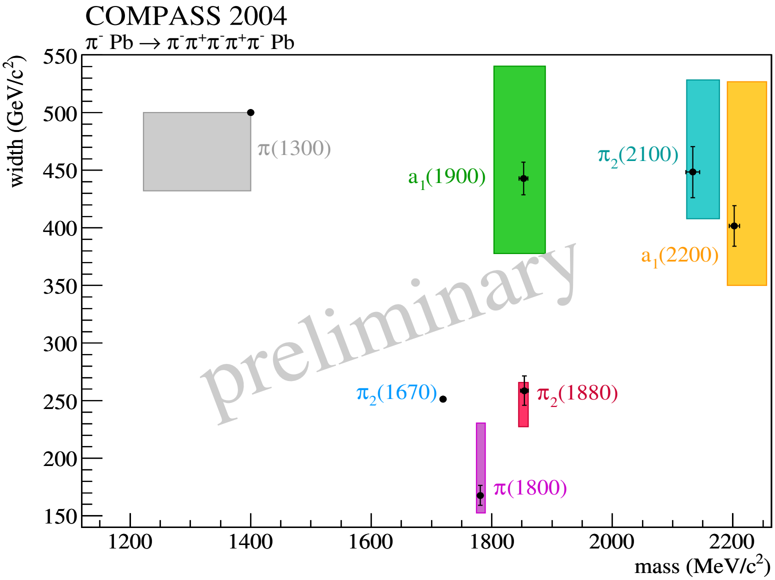
$1^-(1^{++}0^+)\rho\begin{bmatrix}1\\0\end{bmatrix} f_0(1370)$

$f_0(1370) \to \rho(770)\begin{bmatrix}0\\0\end{bmatrix}\rho(770)$

$1^-(1^{++}0^+)\pi\begin{bmatrix}1\\1\end{bmatrix} f_1(1285)$

$f_1(1285) \to \pi\begin{bmatrix}1\\1\end{bmatrix} a_1(1269)$

COMPASS $(5\pi)^-$:12



Conclusions and Future Prospects I

Recent Results and Future Plans at COMPASS:

- Diffractive Dissociations $\pi^-(190\ \mathrm{GeV}/c) \rightarrow \pi^+\pi^-\pi^-$ on Pb and proton targets. The exotic meson $J^{PC} = 1^{-+}$ $\pi_1(1600) \rightarrow \rho\pi$ clearly seen both data samples,

  The data from the proton target is currently under intense study by F. Hass/TUM (for his Ph.D. thesis) and by Dima Ryabchikov/IHEP, Protvino—frequent visitor to TUM.

  Rich Resonance Spectra as a function of t'.
  One or two papers planned on the results

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- $\pi^+\pi^-\pi^+\pi^-\pi^-$ partial-wave decomposition carrried out by

  Sebastian Neubert of TU/München—PhD Thesis

  Three resonances found: $\boxed{a_1(1900),\ a_1(2200),\ \pi_2(2100)}$

  A draft of the paper is in preparation

Conclusions and Future Prospects II

- More results from the partial-wave analysis of the COMPASSdata: $\pi^- p \to X^- p$ with $X^- \to (3\pi)^-,\ (5\pi)^-,\ \ (K\bar{K}\pi)^-$ or $(K\bar{K}\pi\pi\pi)^-$

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- STAR and ALICE provide suitable experimental platforms for future resonance searches including J^{PC}-exotics.

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- The exotic J^{PC}'s for X^0 are

  1^{-+}, 3^{-+}, 5^{-+},etc. for $\mathrm{Pb}+\mathrm{Pb}$

  2^{+-}, 4^{+-}, 6^{+-},etc. for $\gamma+\mathrm{Pb}$

A POSTSCRIPT

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$$\rho^0(770)\begin{bmatrix} L \\ S \end{bmatrix}\rho^0(770)$$

$L + S =$ even

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$$\begin{bmatrix}L\\S\end{bmatrix} = \begin{bmatrix}0\\0,2\end{bmatrix} \text{ or } \begin{bmatrix}2\\0,2\end{bmatrix} \text{ or } \begin{bmatrix}4\\0,2\end{bmatrix}$$

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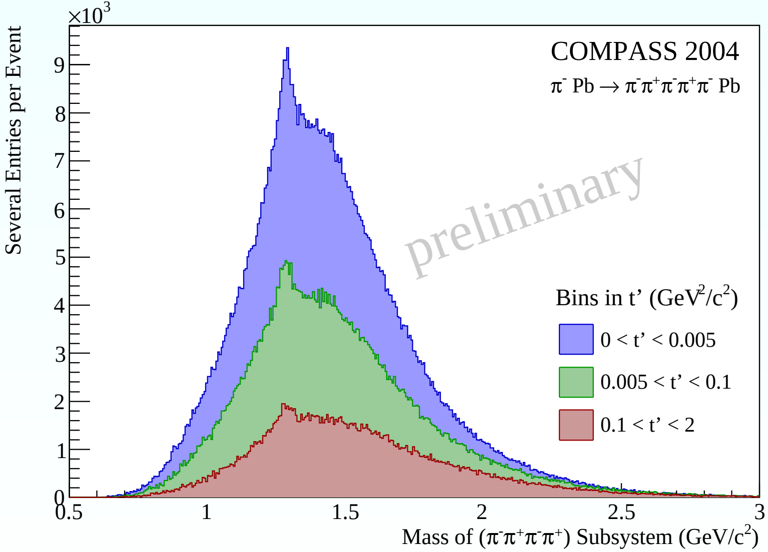
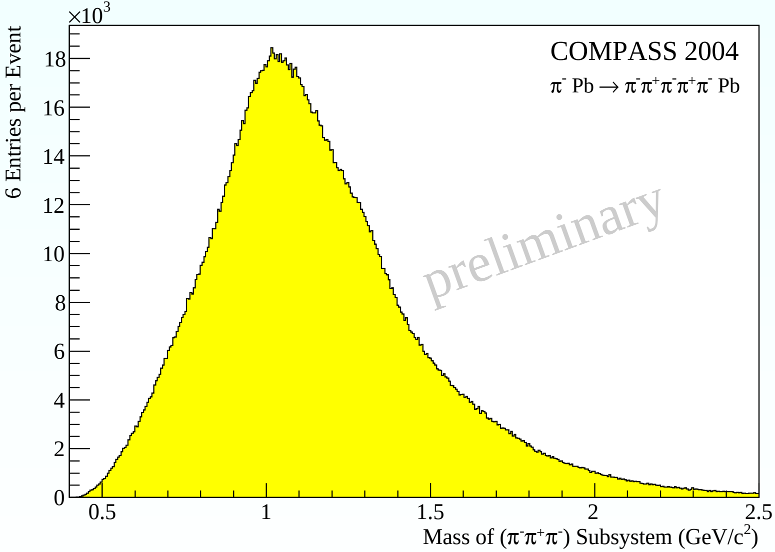
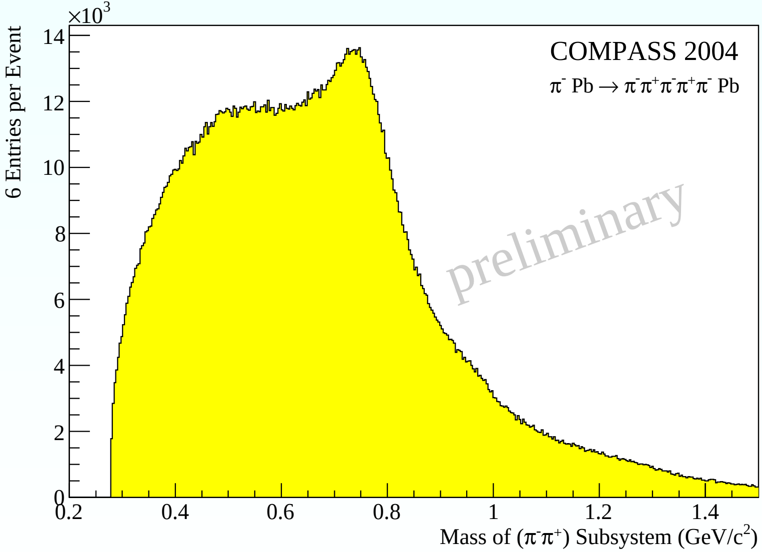
Thank for your attention...



COMPASS 2004
$\pi^- Pb \to \pi^-\pi^+\pi^-\pi^+\pi^- Pb$
preliminary
Bins in t' (GeV^2/c^2)
0 < t' < 0.005
0.005 < t' < 0.1
0.1 < t' < 2
Several Entries per Event
$\times10^3$
0
1
2
3
4
5
6
7
8
9
0.5
1
1.5
2
2.5
3
Mass of ($\pi^-\pi^+\pi^-\pi^+$) Subsystem (GeV/c^2)



COMPASS 2004
π⁻ Pb → π⁻π⁺π⁻π⁺π⁻ Pb
preliminary
×10³
6 Entries per Event
0
2
4
6
8
10
12
14
16
18
0.5
1
1.5
2
2.5
Mass of (π⁻π⁺π⁻) Subsystem (GeV/c²)


COMPASS 2004
$\pi^- Pb \rightarrow \pi^-\pi^+\pi^-\pi^+\pi^- Pb$
preliminary
6 Entries per Event
$\times 10^3$
0
2
4
6
8
10
12
14
0.2
0.4
0.6
0.8
1
1.2
1.4
Mass of $(\pi^-\pi^+)$ Subsystem (GeV/c^2)