Primakoff physics with COMPASS

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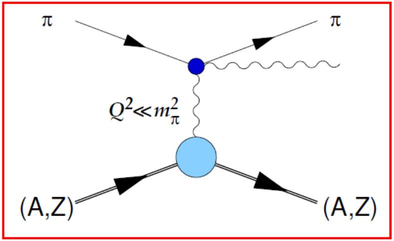
for the
COMPASS collaboration

School on Concepts of Modern Amplitude Analysis Techniques

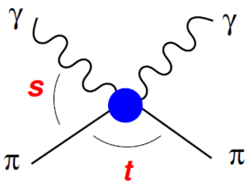
Flecken-Zechlin 24.09.2013

Primakoff reactions

Access to χPT via reactions $\gamma + \pi \to X$
Similarly $\pi + A \to X$ at smalest momentum transfer



$\Rightarrow$



connected to $\pi\gamma$ via Weizsäcker-Williams approximation:

$$\frac{d\sigma}{ds\, dq^2\, d\cos\theta} = \frac{\alpha}{\pi(s - m_\pi^2)} \cdot F^2(q^2) \cdot \frac{q^2 - q^2_{min}}{q^4} \cdot \frac{d\sigma_{\pi\gamma}}{d\cos\theta}$$

Primakoff reactions

X-section proportional $Z^2 \Rightarrow$ Pb/Ni-target

$\pi^- + \gamma \to$

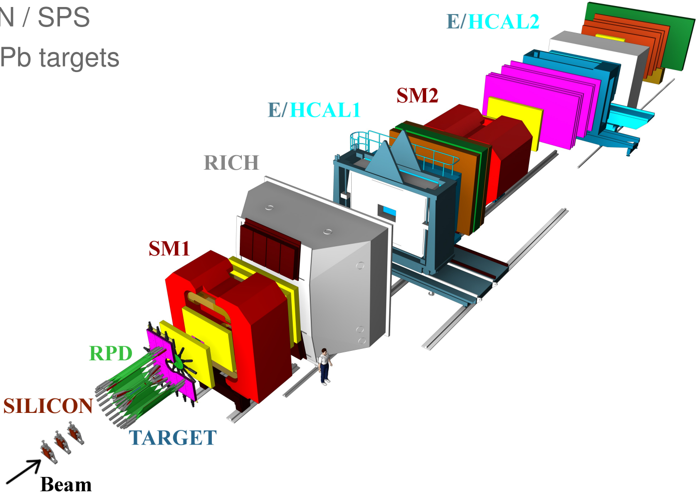
- $\pi^-\gamma$ Polarizabilities
- $\pi^-\pi^0$ Chiral anomaly
- $\pi - \pi^-\pi^+$ Absolute x-section/ radiative coupling
- $\pi - \pi^0\pi^0$ Absolute x-section/ radiative coupling

Same reactions using kaon beam

COMPASS

COmmon **M**uon **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

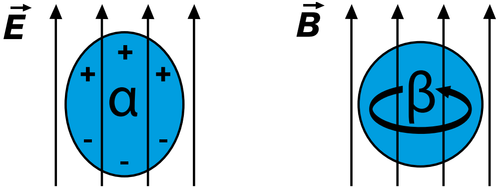
- 190 GeV/c π^- and μ^- Beams
- CERN / SPS
- H/Ni/Pb targets



Polarizabilities

Consider π^- in a strong EM-field ($\approx 300kV/fm$)
Lowest order correction to pointlike structure
Rigidity towards deformation

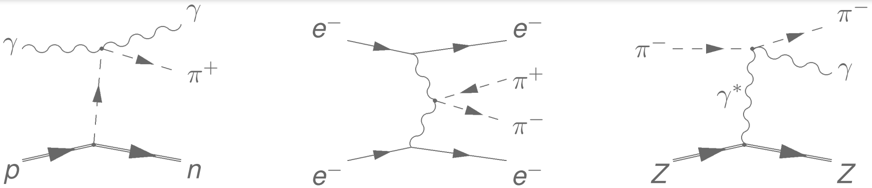
electric polarisability α magnetic polarisability β



χPT prediction: $\alpha_\pi - \beta_\pi = 5.7 \pm 1.0 \times 10^{-4}$ fm^3 $\alpha_\pi \approx -\beta_\pi$

Gasser, Ivanov, Sainio, Nucl. Phys. B 745 (2006)

Polarizabilities



Polarizabilities

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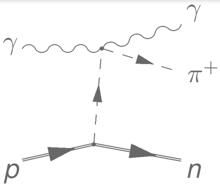

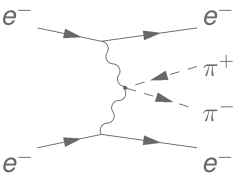

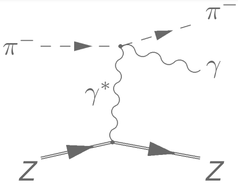

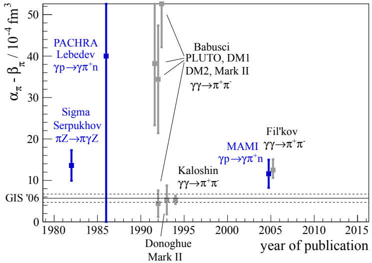

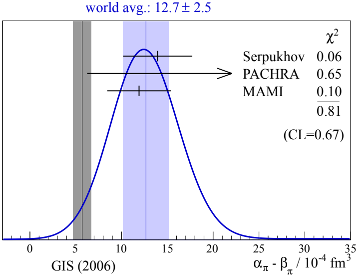

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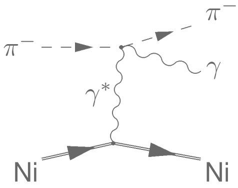
Technique



Primakoff scattering on the Coulomb field of Ni nuclei

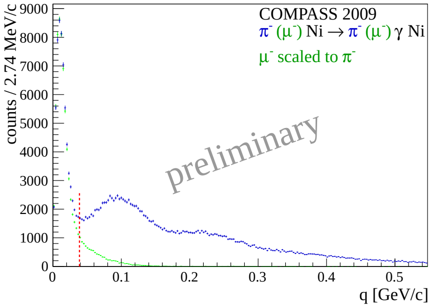
$$\frac{d\sigma_{\pi\gamma}}{dE_\gamma} = \frac{d\sigma_{\text{Born}}}{dE_\gamma} + \frac{d\sigma_{\text{pol}}}{dE_\gamma}$$

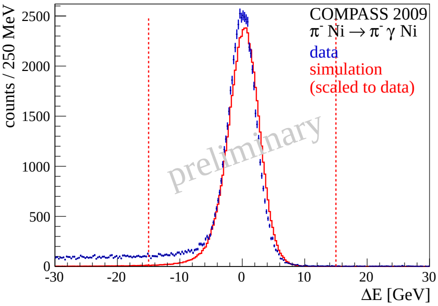
Cross-section ratio dependent on $x_\gamma = E_\gamma / E_{\text{beam}}$

$$R(x_\gamma) = \frac{N_{\text{data}}(x_\gamma)}{N_{\text{sim}}^{born}(x_\gamma)} \approx 1 + \frac{3}{2}\frac{m_\pi^3 x_\gamma}{\alpha_{em}(1 - x_\gamma)}\alpha_\pi$$

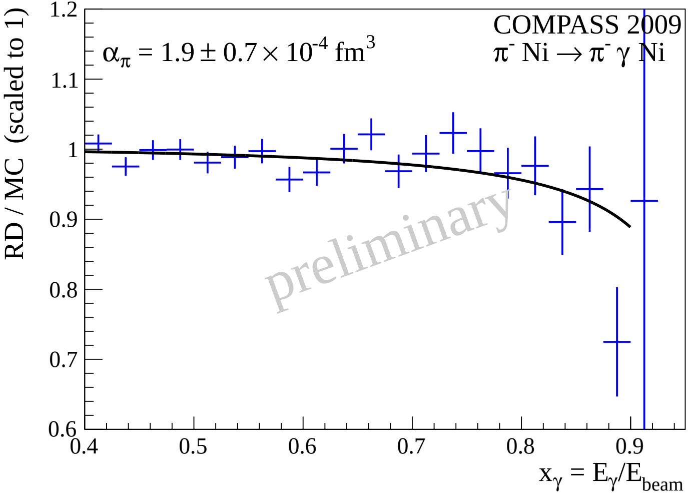
Event selection

- $Q^2 < 1.5 \times 10^{-3}\mathrm{GeV}^2/c^2$ $\quad m_{\pi\gamma} < 3.5\, m_\pi$
- $x_\gamma > 0.4$ $\quad p_T > 40\,\mathrm{MeV/c}$
- Vertex Z position, dependent on scattering angle
- Energy balance: $\Delta E = E_\gamma + E_{\pi^-} - E_{\mathrm{beam}}$





Result


COMPASS 2009
$\pi^- Ni \to \pi^- \gamma Ni$
$\alpha_\pi = 1.9 \pm 0.7 \times 10^{-4}$ fm^3
preliminary
RD / MC (scaled to 1)
$x_\gamma = E_\gamma/E_{beam}$
1.2
1.1
1
0.9
0.8
0.7
0.6
0.4
0.5
0.6
0.7
0.8
0.9

PWA of $\pi\gamma \to \pi^-\pi^-\pi^+$

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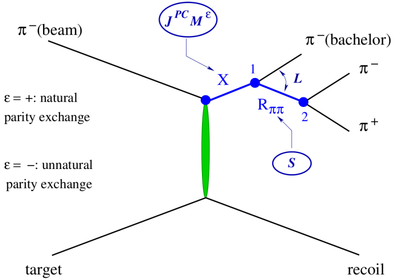
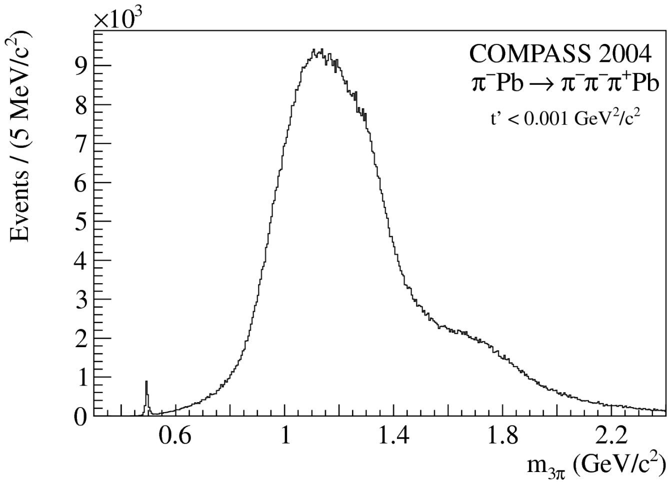
- Isobar model of intermediate 2-body decays
- PWA in $m_{3\pi}$ bins of $40 MeV/c^2$
- Small masses $\Rightarrow \chi PT$ prediction

Exchange particle:

- Primakoff production
  $\to$ quasi-real photon
  $\Rightarrow$ only M=1
- Diffractive dissociation (Pomeron exchange)
  $\sigma \propto t'^{|M|} \exp(-bt')$
  vanishing as t'→0 for M=1

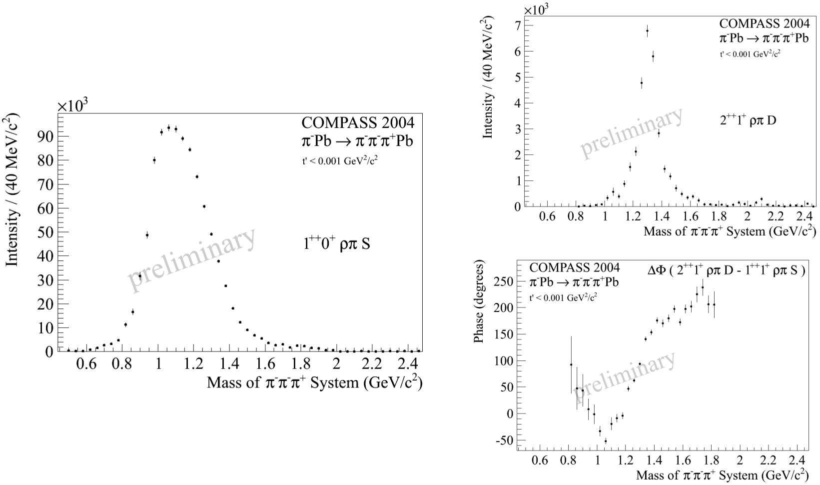


Mass spectrum



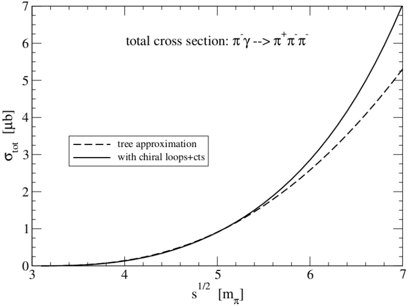
Obvious resonances: $a_1(1260)$, $a_2(1320)$, $\pi_2(1670)$
Kaon contribution

PWA in resonance region



PWA below resonance region

χPT prediction



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- Precise prediction of the x-section
- Loops become important around the ρ-region
- How to implement in PWA?

Chiral wave

- M=0 waves only from diffractive production
- M=1 from diffraction and Primakoff

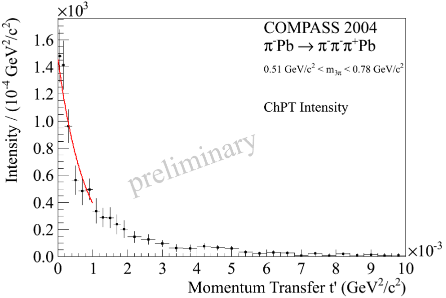
M=1 waves:

- $1^{++}1^{\pm}\rho\pi S$
- $1^{++}1^{\pm}(\pi\pi)_S\pi P$
- $1^{-+}1^{\pm}\rho\pi S$
- $2^{++}1^{\pm}\rho\pi S$
- $2^{-+}1^{\pm}\rho\pi P$
- $2^{-+}1^{\pm}(\pi\pi)_S\pi D$

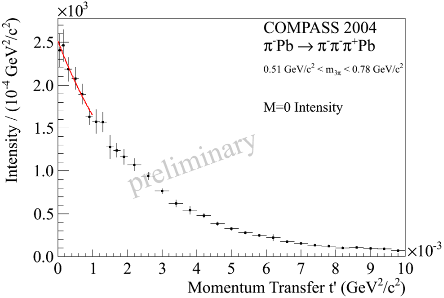
from 3π-threshold to $5m_\pi$ M=1 waves replaced by wave calculated from χPT

Comparison Primakoff / Diffractive

$\sigma \propto \exp(-bt')$



$b \approx 1560\ (\mathrm{GeV/c})^{-2}$
only detector resolution



$b \approx 400\ (\mathrm{GeV/c})^{-2}$
typical diffractive slope

Result

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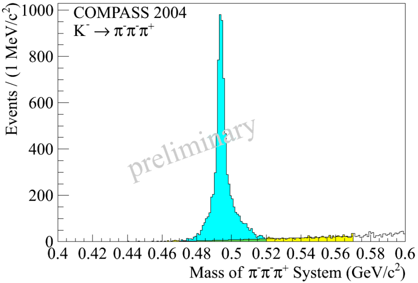
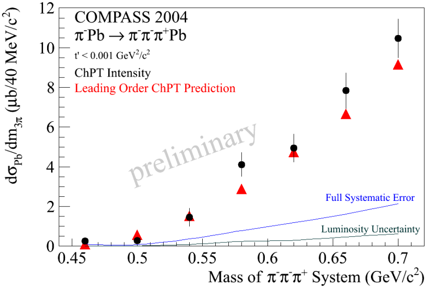
Normalization via free Kaon decay



Absolute x-section



Outlook

Polarisability:

- Finalizing 2009 result
- Extended data set from 2012
  $\Rightarrow$ measure α_π AND β_π
- Kaon Polarizabilities

3π

- Measurement of $\pi\gamma \to \pi^-\pi^-\pi^+$ abolute x-section
- Similar analysis with 2009 data for $\pi\gamma \to \pi^-\pi^0\pi^0$
- Extraction of radiative width of $a_2(1320)$ and $\pi_2(1670)$