

Measurement of the Pion Polarizability at COMPASS

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for the COMPASS collaboration

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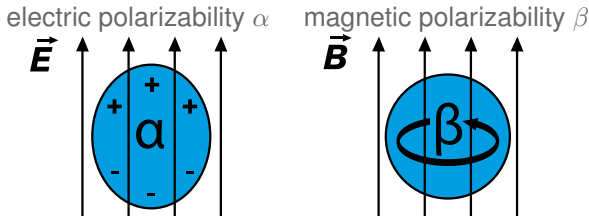




Consider π^- in a strong EM-field ($\approx 300\text{kV}/\text{fm}$)

Lowest order correction to point-like structure

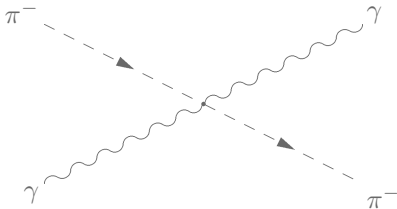
Rigidity towards deformation



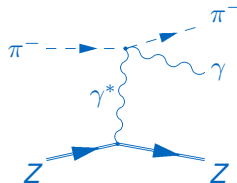
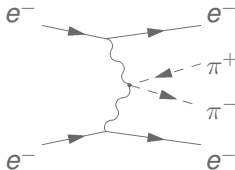
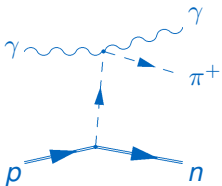
χ PT prediction: $\alpha_\pi - \beta_\pi = 5.7 \pm 1.0 \times 10^{-4} \text{ fm}^3$

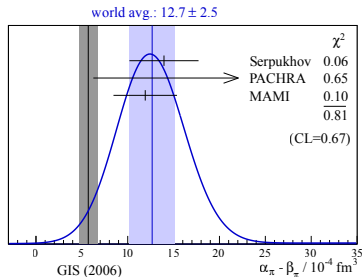
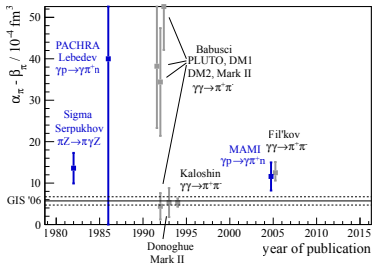
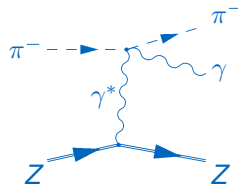
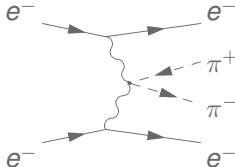
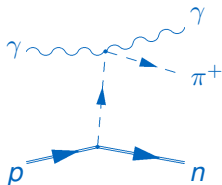
$$\alpha_\pi \approx -\beta_\pi$$

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



- No Pion/Photon target
- Search for related reactions





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

$$\alpha_\pi \approx -\beta_\pi$$

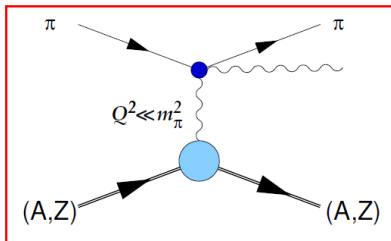


COMPASS: $\pi^- \text{Ni} \rightarrow \pi^- \text{Ni} \gamma$

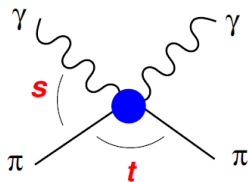
Related to $\pi^- \gamma \rightarrow \pi^- \gamma$ by Weizsäcker-Williams Approximation

$$\frac{d\sigma}{ds dQ^2 d\cos\theta} = \frac{\alpha}{\pi(s-m_\pi^2)} \cdot F^2(Q^2) \cdot \frac{Q^2 - Q_{min}^2}{Q^4} \cdot \frac{d\sigma_{\pi\gamma}}{d\cos\theta}$$

\Rightarrow Smallest momentum transfers $Q^2 < 1.5 \cdot 10^{-3} \text{ GeV}^2/c^2$
Scattering on quasi real photons



\Rightarrow





$\pi^- \gamma \rightarrow \pi^- \gamma$ X-Section

$$\frac{d\sigma_{\pi\gamma}}{d\Omega_{cm}} = \frac{\alpha^2 (s^2 z_+^2 + m_\pi^4 z_-^2)}{s (sz_+ + m_\pi^2 z_-)^2} - \frac{\alpha m_\pi^3 (s - m_\pi^2)^2}{4s^2 (sz_+ + m_\pi^2 z_-)} \cdot \mathbf{P}$$

$$\mathbf{P} = z_-^2 (\alpha_\pi - \beta_\pi) + \frac{s^2}{m_\pi^4} z_+ (\alpha_\pi + \beta_\pi)$$

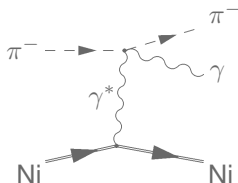
$$z_\pm = 1 \pm \cos \theta_{cm}$$

COMPASS: $\pi^- \text{Ni} \rightarrow \pi^- \text{Ni} \gamma$

Related by Weizäcker-Williams Approximation

$$\frac{d\sigma}{ds dQ^2 d\cos\theta} = \frac{\alpha}{\pi(s - m_\pi^2)} \cdot F^2(Q^2) \cdot \frac{Q^2 - Q_{min}^2}{Q^4} \cdot \frac{d\sigma_{\pi\gamma}}{d\cos\theta}$$

\Rightarrow Smallest momentum transfers $Q^2 < 1.5 \cdot 10^{-3} \text{ GeV}^2/c^2$



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 $x_\gamma = E_\gamma/E_{\text{beam}}$

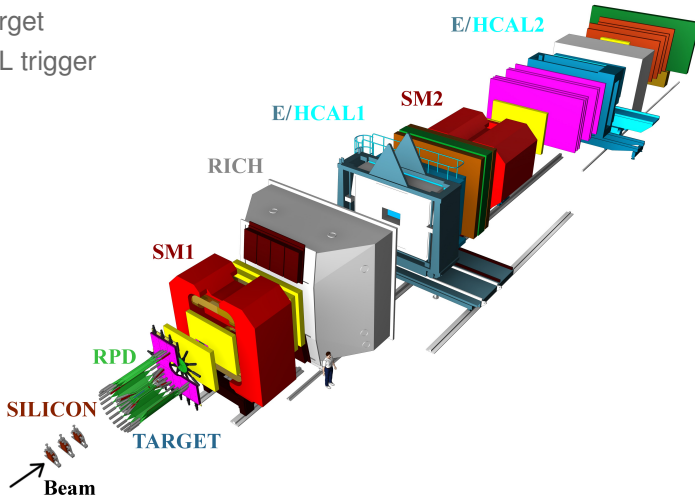
$$R(x_\gamma) = \frac{N_{\text{data}}(x_\gamma)}{N_{\text{sim}}^{\text{born}}(x_\gamma)} \approx 1 + \frac{3}{2} \frac{m_\pi^3 x_\gamma}{\alpha_{em} (1 - x_\gamma)} \alpha_\pi$$



Important components

COmmon MUon PRotun Apparatus for Structure and Spectroscopy

- π^- and μ^- Beams
- Ni target
- ECAL trigger



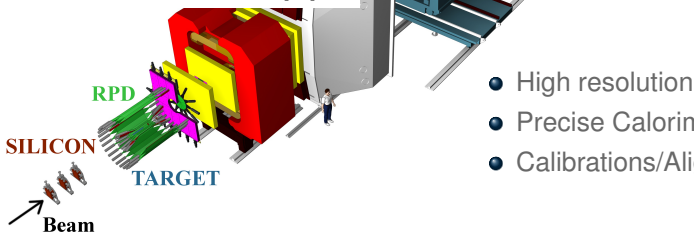
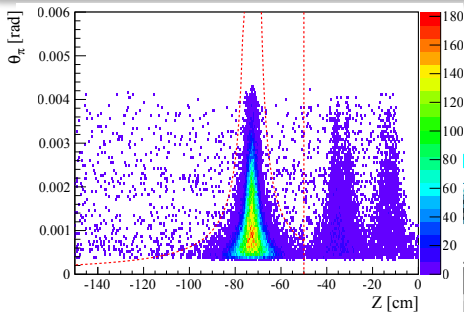


Important components

COmmon MUon PRoton Apparatus for Structure and Spectroscopy



Technische Universität München

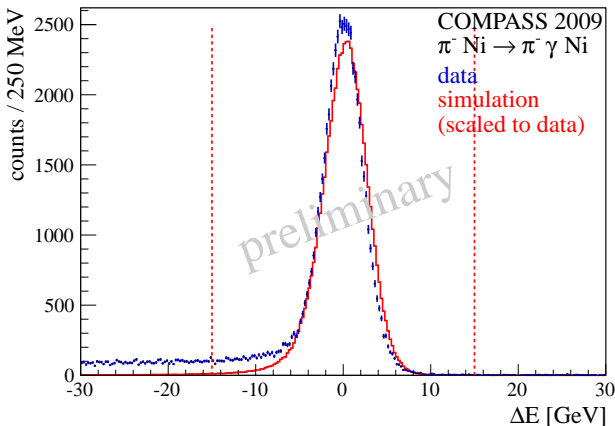


- High resolution vertexing
- Precise Calorimetry
- Calibrations/Alignment



Selection of $\pi\gamma \rightarrow \pi\gamma$ events

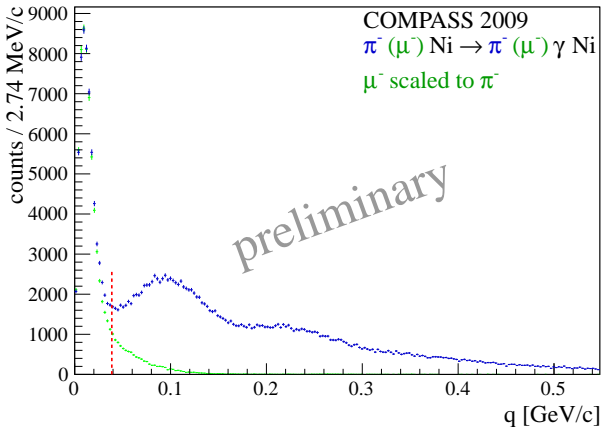
$$\Delta E = E_\gamma + E_{\pi^-} - E_{beam}$$



About 60 000 exclusive events



Four-Momentum transfer

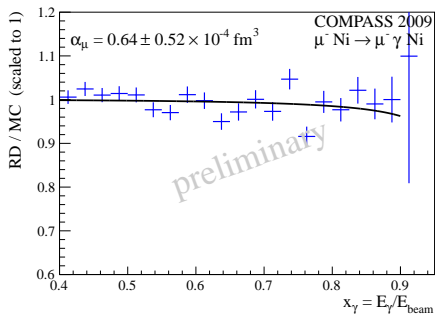
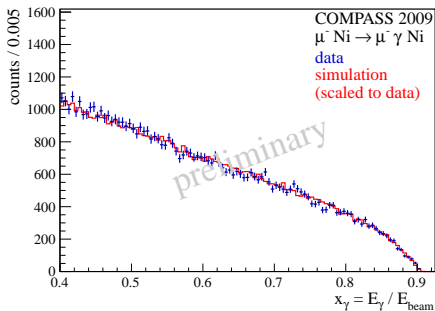


Primakoff production distinguishable from diffraction



Unique Feature

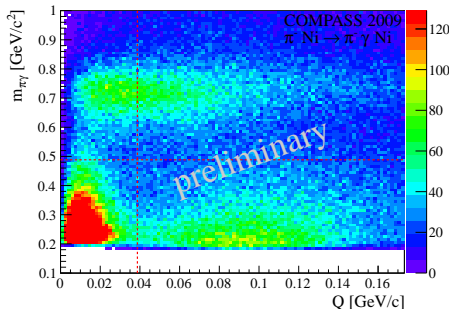
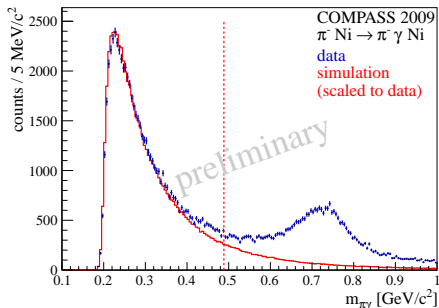
- Switching between π^- and μ^- beams
- Background free reaction of point-like particle
- Allows control of systematic effects



Polarizability for Muons compatible with point-like structure



Backgrounds in the Pion measurement

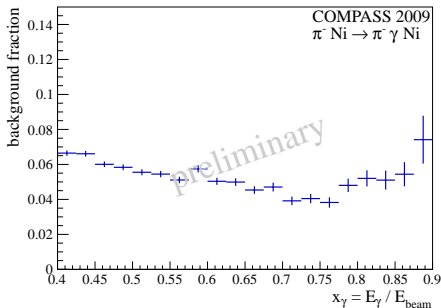
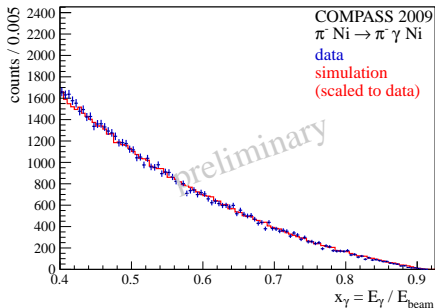


- Different from muons due to spin
- Background coming from miss-identified π^0
- Background from Pomeron exchange



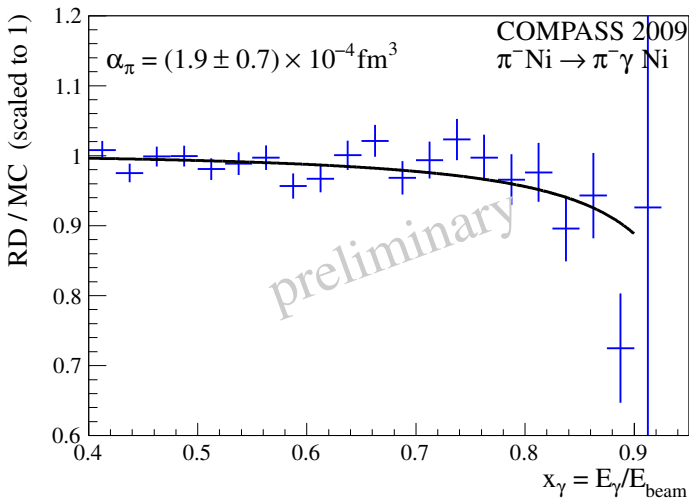
Photon energy distribution with pions

- Background fraction from q spectrum
- $N_{bg} = Q^2 \cdot \exp(-bQ^2)$
- Can be subtracted from data





Fit to the data





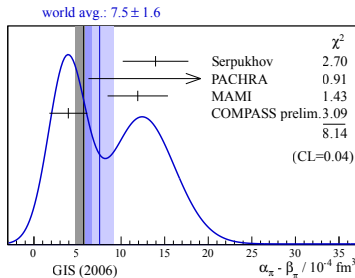
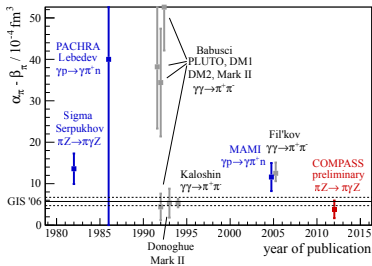
Systematic uncertainties

description	estimated magnitude CL = 68 % [10 ⁻⁴ fm ³]
tracking	0.6
errors on radiative corrections	0.3
background subtraction in q	0.4
pion electron scattering	0.2
quadratic sum	0.8

- COMPASS result:

$$\alpha_\pi = (1.9 \pm 0.7_{\text{stat}} \pm 0.8_{\text{sys}.}) \times 10^{-4} \text{ fm}^3$$

- Assumption: $\alpha_\pi = -\beta_\pi$
- In tension with previous measurements
- Measurement in agreement with χ PT prediction





- COMPASS result:
 $\alpha_\pi = (1.9 \pm 0.7_{\text{stat}} \pm 0.8_{\text{syst.}}) \times 10^{-4} \text{ fm}^3$
 - Strong constraints on previous experiments
 - In tension with previous measurements
 - Measurement in agreement with χ PT prediction
 - Publication in preparation
-
- Bigger data set from 2012
 - Separate measurement of α_π, β_π
 - Kaon polarizabilities