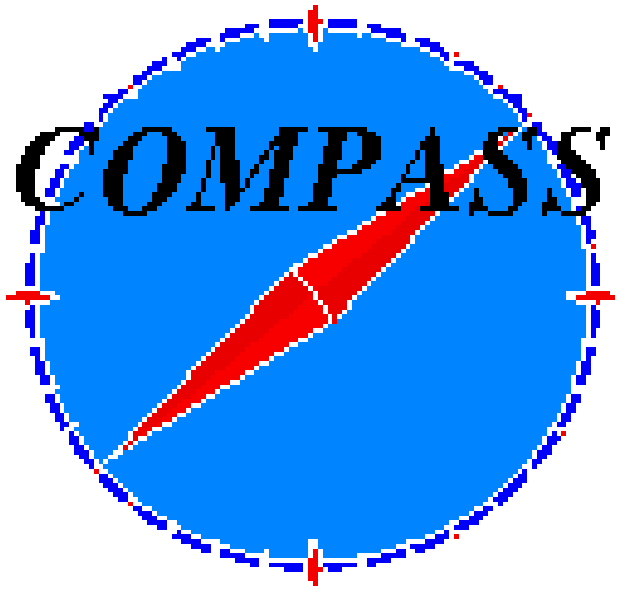
A measurement of the pion polarizabilities in COMPASS



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on befalf of the COMPASS collaboration

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COMPASS experiment

COMPASS - the fixed target experiment on SPS at CERN

1996: COMPASS proposal
1999-2001: construction and installation
2001: technical run
2002,2003,2004: data taking with muon beam
october-november 2004: pilot hadron run
2006 data taking with muon beam
2007 data taking with hadron beam

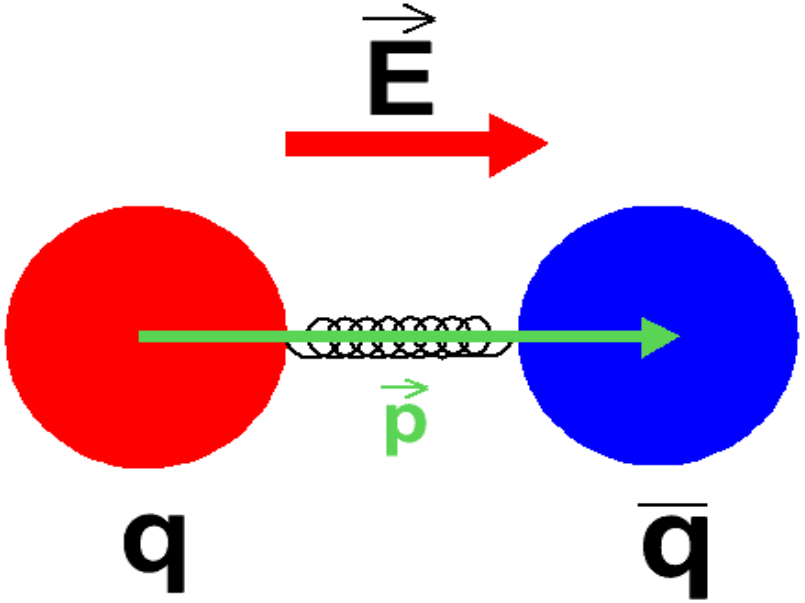
MUON PROGRAM

- $\Delta G/G$
- Structure functions
- Λ-physics
- Exclusive production of vector mesons
- Transversity

HADRON PROGRAM

- Pion polarizabilities
- Chyral anomaly
- Charm barions
- Glueballs and exotic mesons

The pion polarizabilities

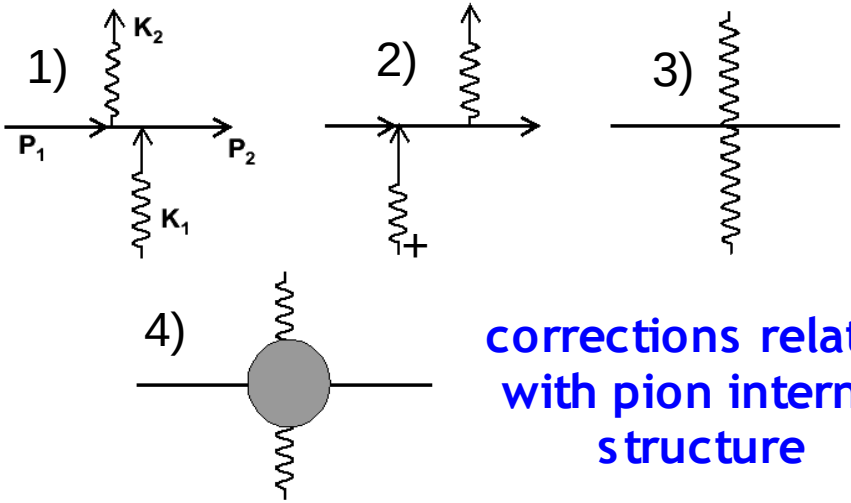


$$\vec{P} = \alpha_\pi \times \vec{E}$$

$$\vec{\mu} = \beta_\pi \times \vec{H}$$

The polarizabilities (electric and magnetic) of π-meson are the quantities which characterize the rigidity of quark - antiquark system

diagrams for πγ scattering for point like pion



corrections related with pion internal structure

In nonrelativistic approximation hamiltonian of pion interaction with external electromagnetic field corresponding to 4th diagram can be presented as:

$$H = -(\alpha_\pi E^2 + \beta_\pi H^2)/2$$

Theoretical prediction for α_π and β_π

χPT 1-loop prediction:

$\alpha_\pi = -\beta_\pi = (2.7 \pm 0.4) \cdot 10^{-43}\ cm^3$

2-loop prediction

$\alpha_\pi = (2.4 \pm 0.5) \cdot 10^{-43}\ cm^3$

$\beta_\pi = (-2.1 \pm 0.5) \cdot 10^{-43}\ cm^3$

U. Burgi, Nucl. Phys. B479 (1996) 392, Phys. Lett. B377 (1996) 147

Other models (dispersion sum rules, QCD sum rule, lattice calculation, ...) :

$2 \cdot 10^{-43}\ cm^3 < \alpha_\pi < 8.0 \cdot 10^{-43}\ cm^3$

$\alpha_\pi + \beta_\pi \approx 0$ for the most of predictions

Experimental measurement of the pion polarizabilities provides stringent test of our understanding of chiral symmetry and its spontaneous breakdown.

Experimental results for α_π and β_π

10^{-43} cm^3 units

$\pi^- + A \to \pi^- + A + \gamma$ process

SIGMA–AYAKS (Protvino)

$\alpha_\pi = 6.9 \pm 1.4_{stat} \pm 1.2_{syst}$ (for $\alpha_\pi + \beta_\pi = 0$)

$\gamma + p \to \gamma + \pi^+ + n$ process

A2 (MAMI)

$\alpha_\pi - \beta_\pi = 11.6 \pm 1.5_{stat} \pm 3.0_{syst} \pm 0.5_{mod}$

Lebedev

$\alpha_\pi = 20 \pm 12_{stat}$

$\gamma + \gamma \to \pi^+ + \pi^-$ process

MARK II

$\alpha_\pi = 2.2 \pm 1.6_{stat+syst}$

PLUTO

$\alpha_\pi = 19.1 \pm 4.8_{stat} \pm 5.7_{syst}$

DM1

$\alpha_\pi = 17.2 \pm 4.6_{stat}$

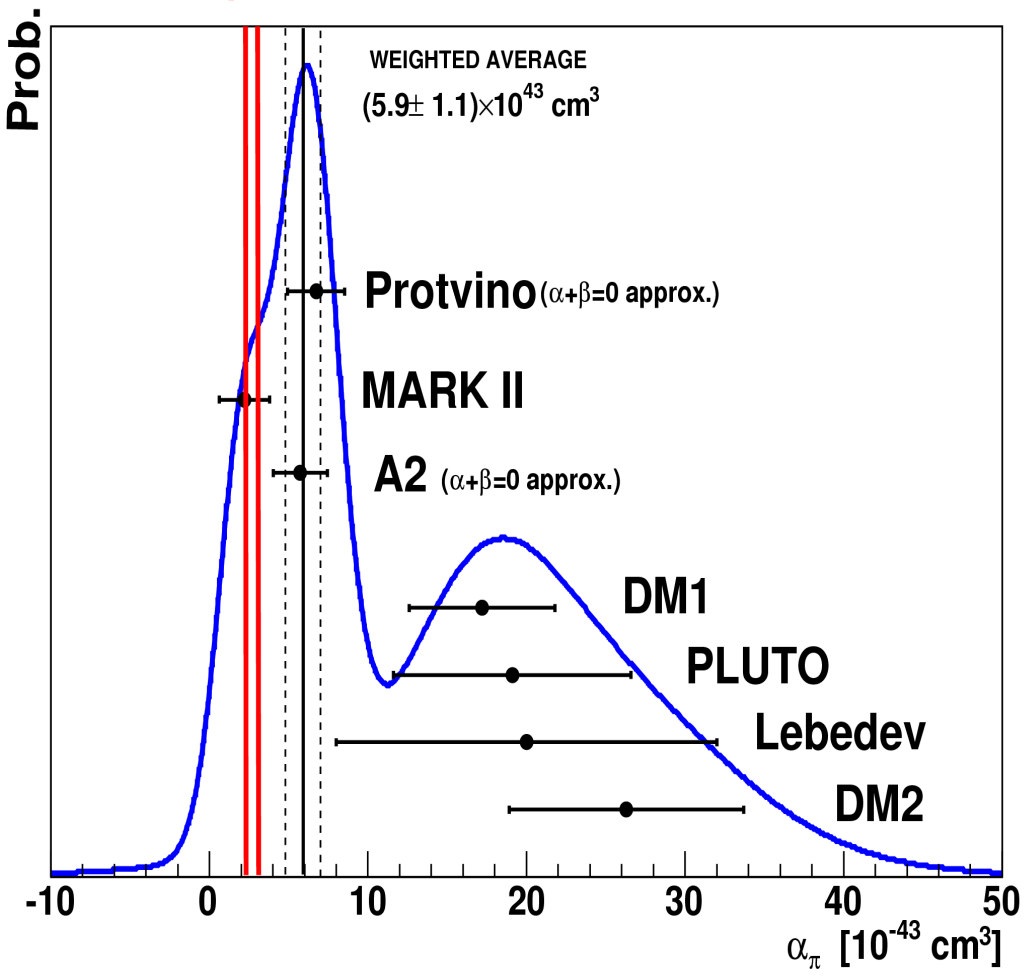
DM2

$\alpha_\pi = 26.3 \pm 7.4_{stat}$

χPT 1-loop prediction:

$\alpha_\pi = -\beta_\pi = (2.7 \pm 0.4) \cdot 10^{-43}$ cm^3

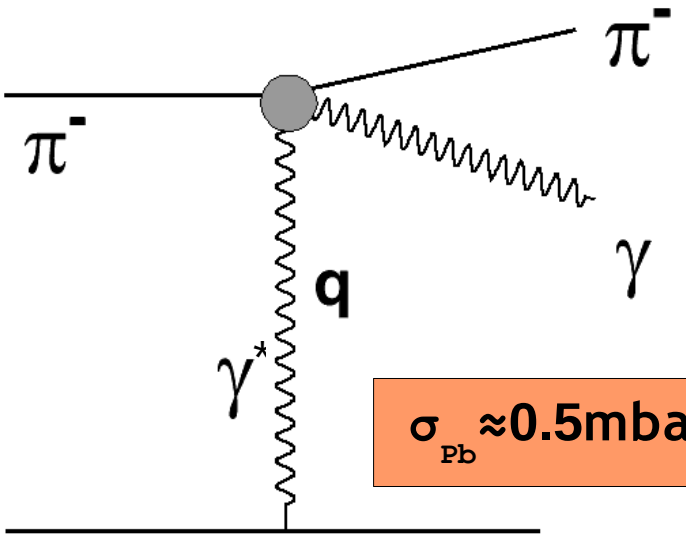
χPT prediction



Pion polarizabilities measurement in COMPASS experiment

$$\pi^- + Pb \rightarrow \pi^- + \gamma + Pb$$

Main signatures: $\sigma \sim Z^2$, $q << m_\pi$



$\sigma_{Pb} \approx 0.5$mbarn

In COMPASS we study quasi-real photon Compton scattering on π^-

$$d\sigma = \int d\sigma_{Compton} \cdot n(\omega_0', k_{0\parallel}') d\omega_0' dk_{0\parallel}'$$

where $q = (\omega_0', k_0')$ is virtual photon 4-vector in antilab. frame

$$\sigma_{Compton} = \sigma(\alpha_\pi, \beta_\pi)$$

For measurement of pion polarizabilities (α and β independently or with α+β=0 approximation) we can compare the measured differencial cross section of Primakoff reaction and theoretically predicted Primakoff cross section for pont like pion

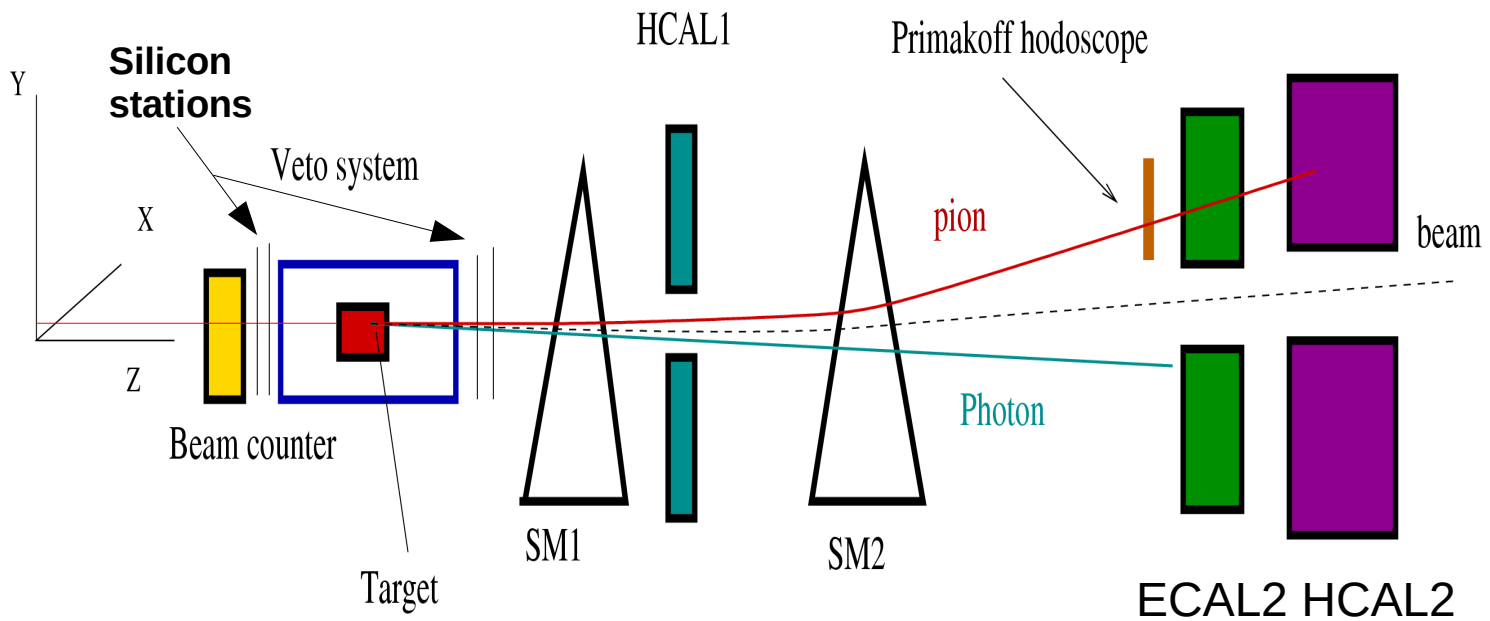
COMPASS hadron run 2004

~10 days of data taking (Pilot run) Integrated beam flux is ~10^{11}

Beam:
secondary beam from SPS
π^- (190 GeV)
μ^- (190 GeV)

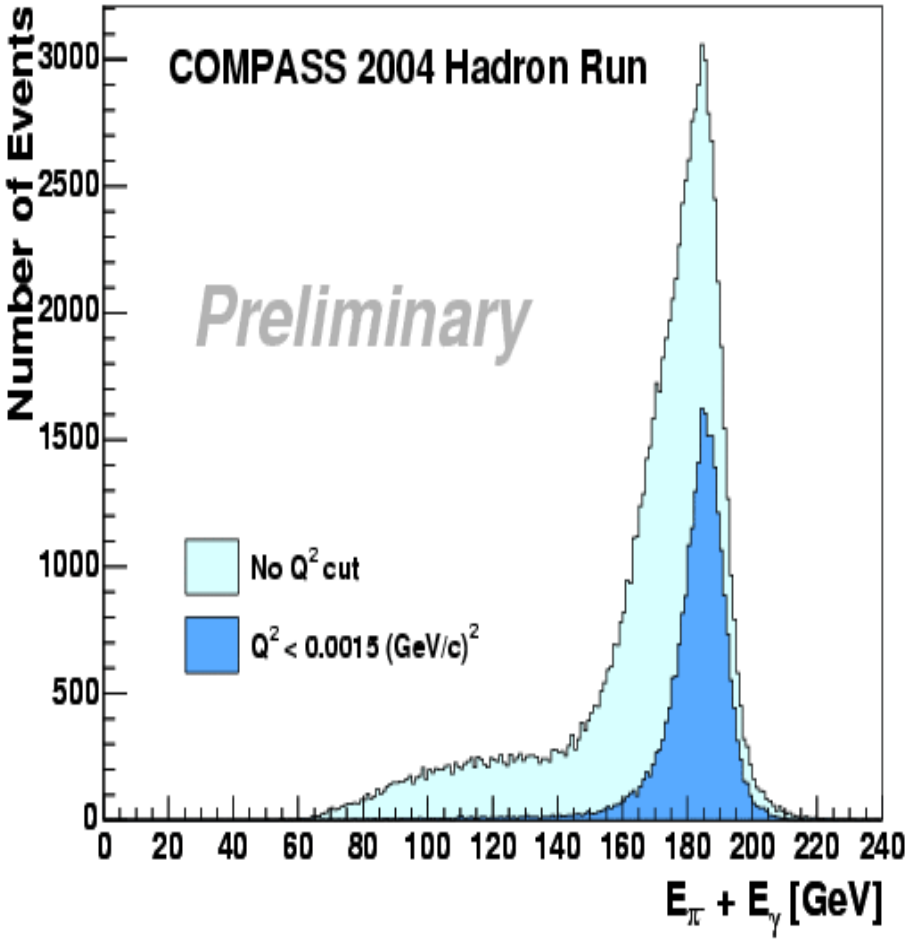
Trigger:
Primakoff1: trigger hodoscope +
>50 GeV in electromagnetic calorimeter +
>18 GeV in hadron calorimeter
Primakoff2: >100 GeV in electromagnetic calorimeter

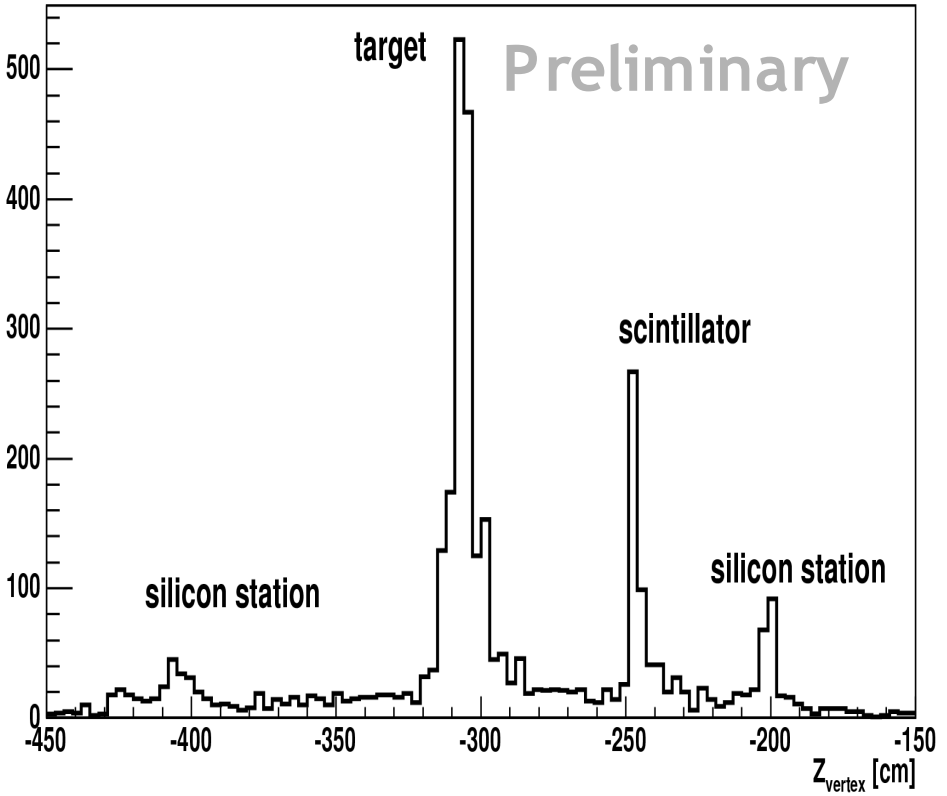
Target:
- Pb 3 mm
- Pb 1.6 mm
- Pb 2 + 1 mm
- C 23,5 mm
- Cu 3.55 mm
- Empty target



Results

Exclusivity peak

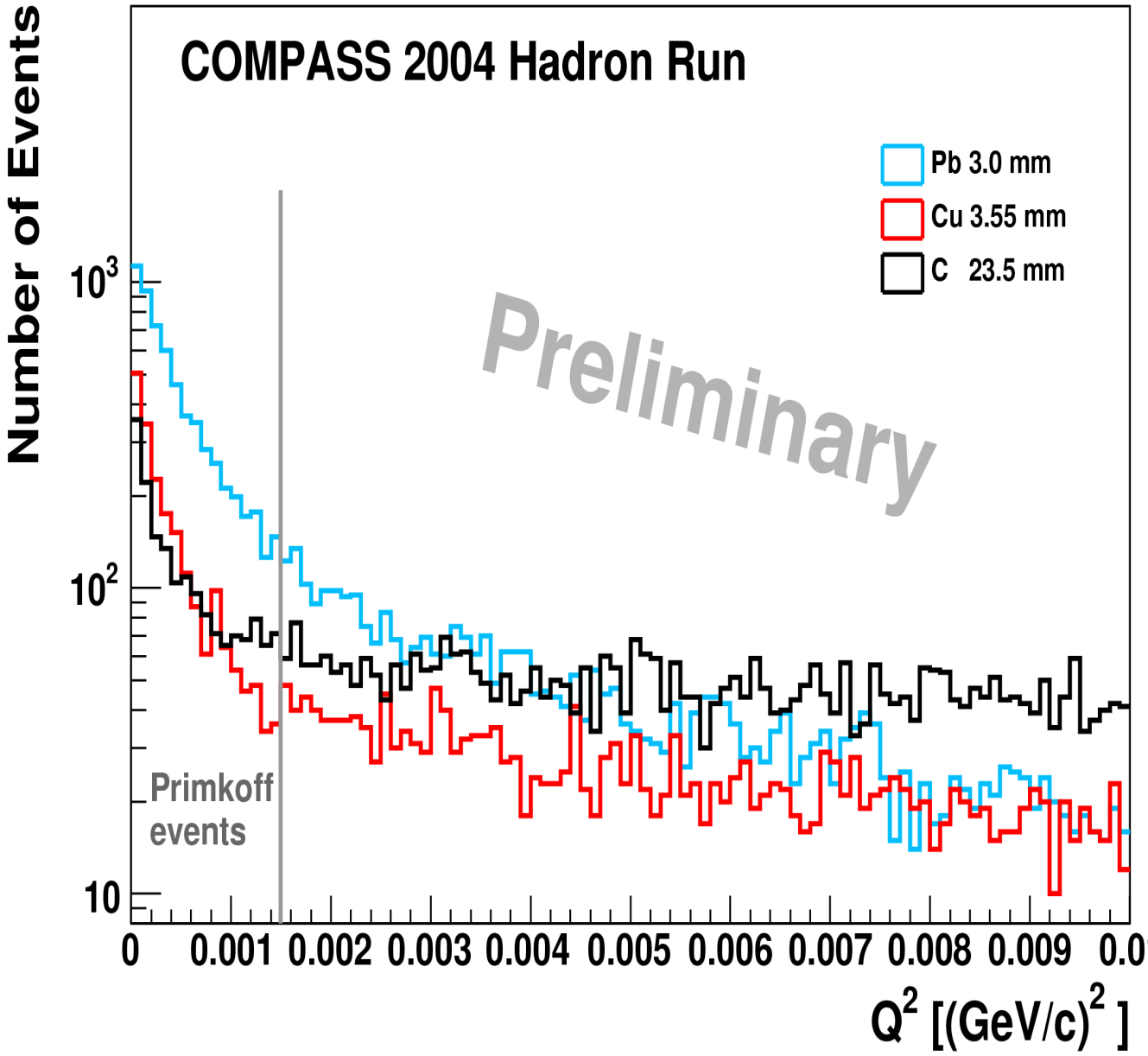




$\pi - \pi\gamma$ vertex reconstruction

Results (II)

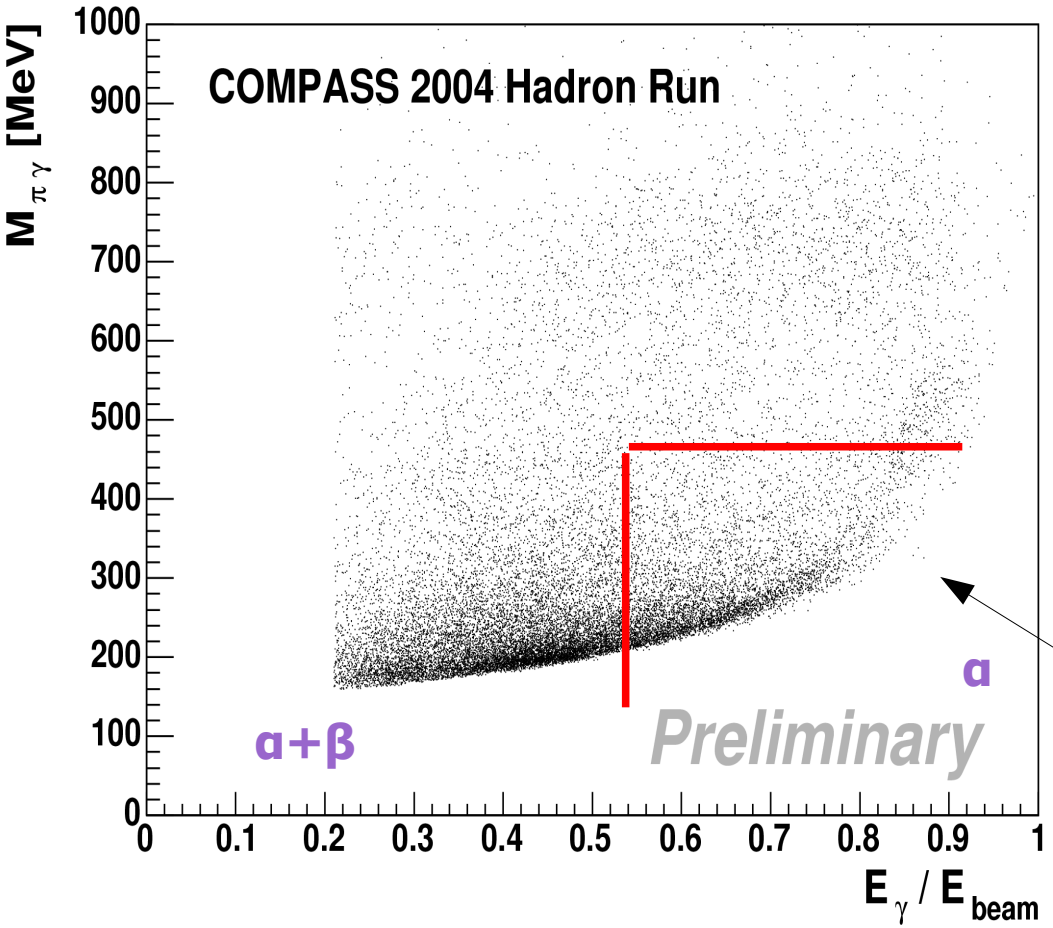
$$Q = P_{beam} - P_{\pi} - P_{\gamma}$$



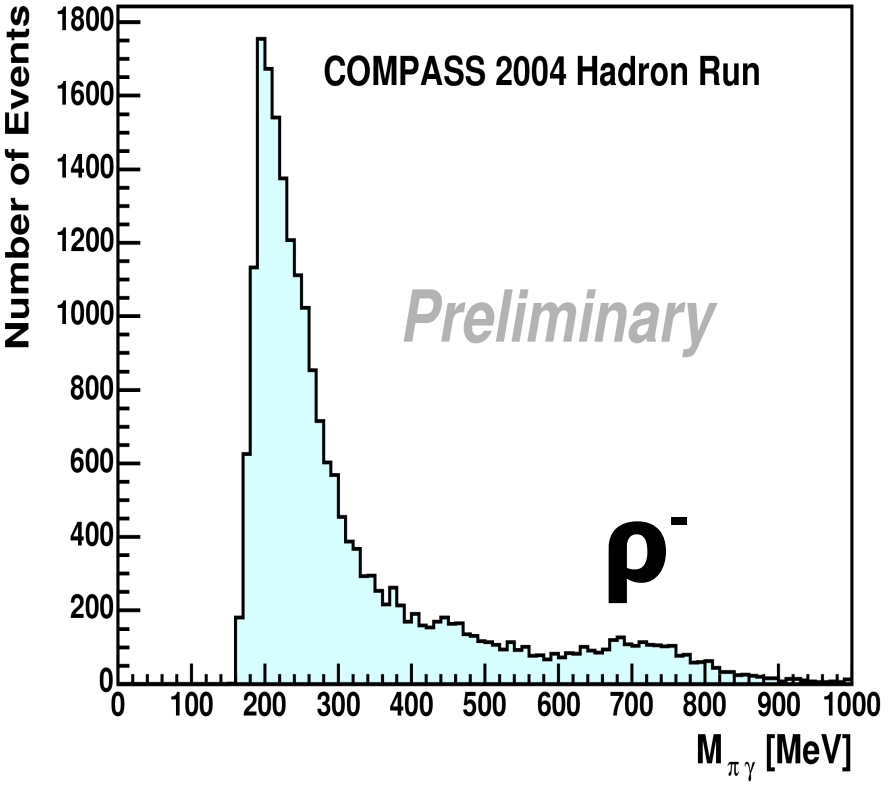
Q^2 – distribution for different targets (Pb, Cu, C)

Total statistics is ~60 000 Primakoff events for Pb target (vs. 7 000 in Protvino)

Results (III)



Reletive energy of scattered photon vs. $\pi\gamma$ invariant mass



$\pi\gamma$ invariant mass

Kinematic range covered by Protvino experiment (roughly)

$$\rho^- \rightarrow \pi^- + \pi^0 \rightarrow \pi^- + \gamma + \gamma$$

Background from ρ^- decay gives the main limitation for the range of invariant masses which can be used in analysis

Conclusion

- During pilot hadron run 2004 integrated beam flux for pion beam and lead target was more than 10^{11}
- Preliminary analysis shows that COMPASS setup has good resolution for pion scattering angle, photon energy and transferred momentum which allows to identify Primakoff events
- Total statistics for Primakoff events is estimated as 60 000 events for lead target (Protvino - 7000 events)
- Data collected with muon beam can be used for systematic errors estimation

COMPASS hadron setup