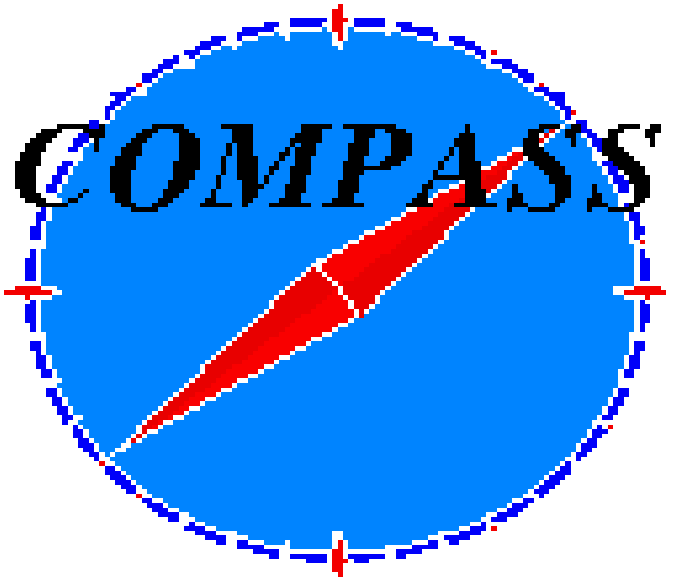
Pion polarizabilities measurement in COMPASS



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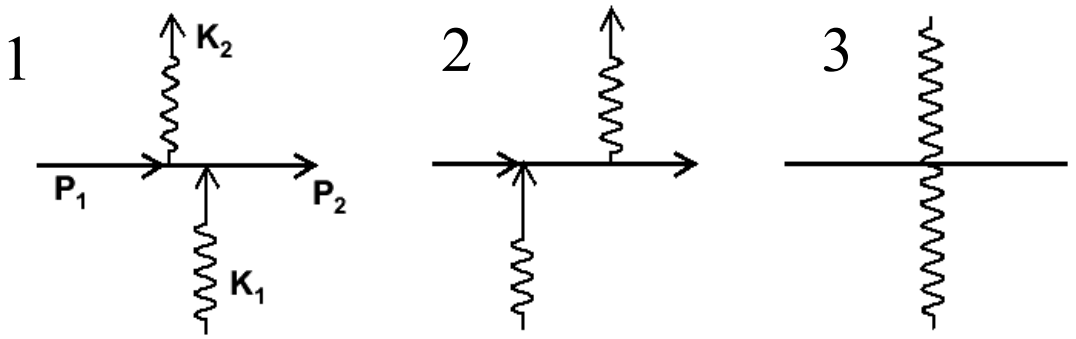
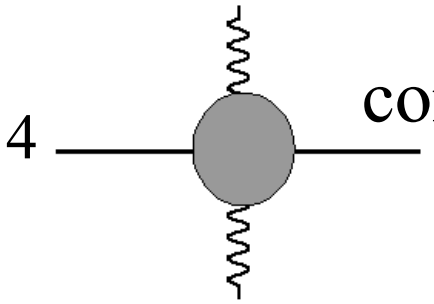
Prague

Pion polarizabilities



diagrams for $\pi\gamma$ 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:

$H = -(\alpha_\pi E^2 + \beta_\pi H^2)/2$ where α_π and β_π are electric and magnetic pion polarizabilities.

Theoretical prediction for α_π and β_π

χPT 1-loop prediction $\alpha_\pi = -\beta_\pi = (2.7 \pm 0.4) \cdot 10^{-43}\,\mathrm{cm}^3$

2-loop prediction $\alpha_\pi = (2.4 \pm 0.5) \cdot 10^{-43}\,\mathrm{cm}^3$

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

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

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

$$\mathbf{2.4 \cdot 10^{-43}\,cm^3 < \alpha_\pi < 8.0 \cdot 10^{-43}\,cm^3}$$

$$\mathbf{-8.0 \cdot 10^{-43}\,cm^3 < \beta_\pi < -2.1 \cdot 10^{-43}\,cm^3}$$

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

Experimental results for α_π and β_π

for assumption: $\alpha_\pi + \beta_\pi = 0$

SIGMA-AYAKS (Protvino) **$\pi^- + A \rightarrow \pi^- + A + \gamma$ process**

$$\alpha_\pi = (6.9 \pm 1.4_{stat} \pm 1.2_{syst}) \cdot 10^{-43}\ cm^3$$

Lebedev **$\gamma + p \rightarrow \gamma + \pi^+ + n$ process**

$$\alpha_\pi = (20 \pm 12_{stat}) \cdot 10^{-43}\ cm^3$$

MARK II **$\gamma + \gamma \rightarrow \pi^+ + \pi^-$**

$$\alpha_\pi = (2.2 \pm 1.6_{stat+syst}) \cdot 10^{-43}\ cm^3$$

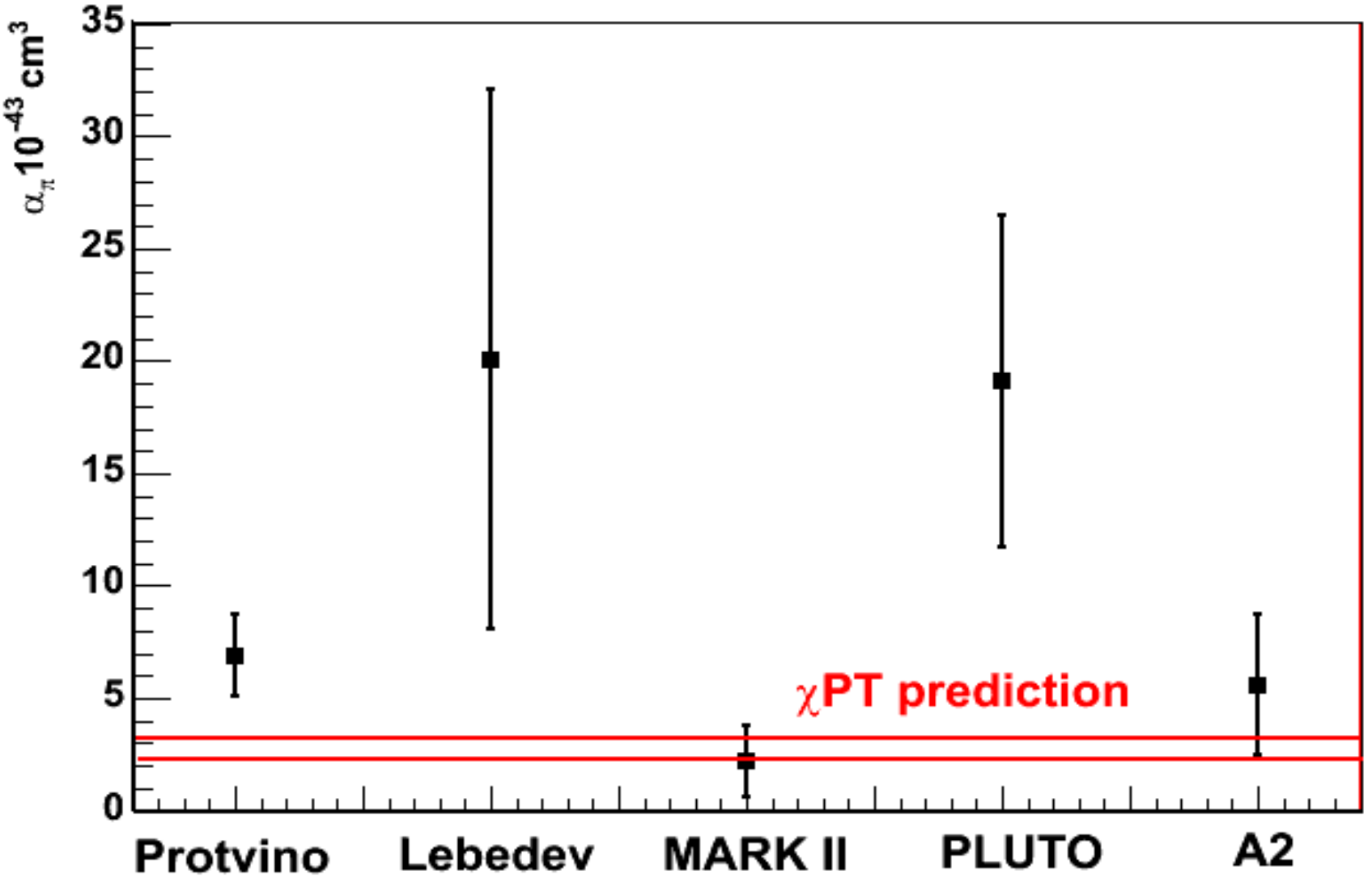
PLUTO **$\gamma + \gamma \rightarrow \pi^+ + \pi^-$**

$$\alpha_\pi = (19.1 \pm 4.8_{stat} \pm 5.7_{syst}) \cdot 10^{-43}\ cm^3$$

A2 (MAMI) **$\gamma + p \rightarrow \gamma + \pi^+ + n$**

$$\alpha_\pi = (5.6 \pm 0.75_{stat} \pm 3.0_{syst} \pm 0.5_{mod}) \cdot 10^{-43}\ cm^3$$

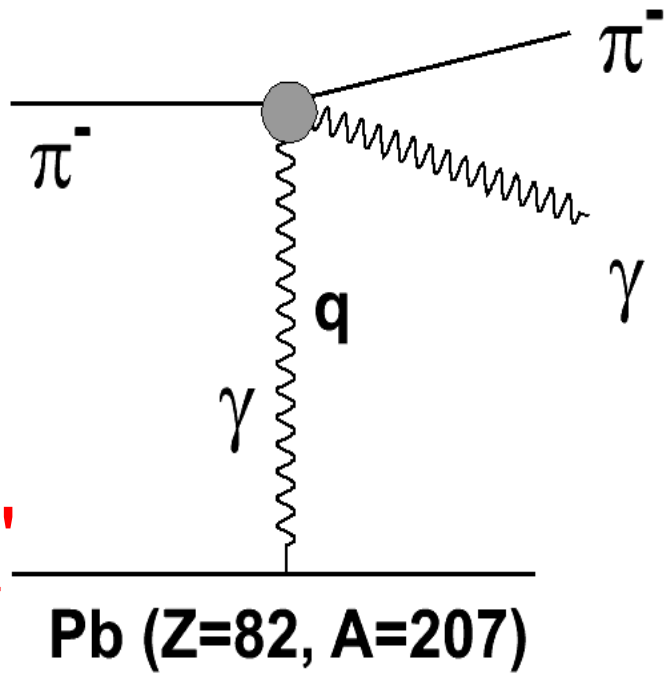
Experimental results & χPT prediction



Pion polarizabilities measurement in COMPASS experiment

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

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



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

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

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

Pion polarizabilities measurement in COMPASS experiment

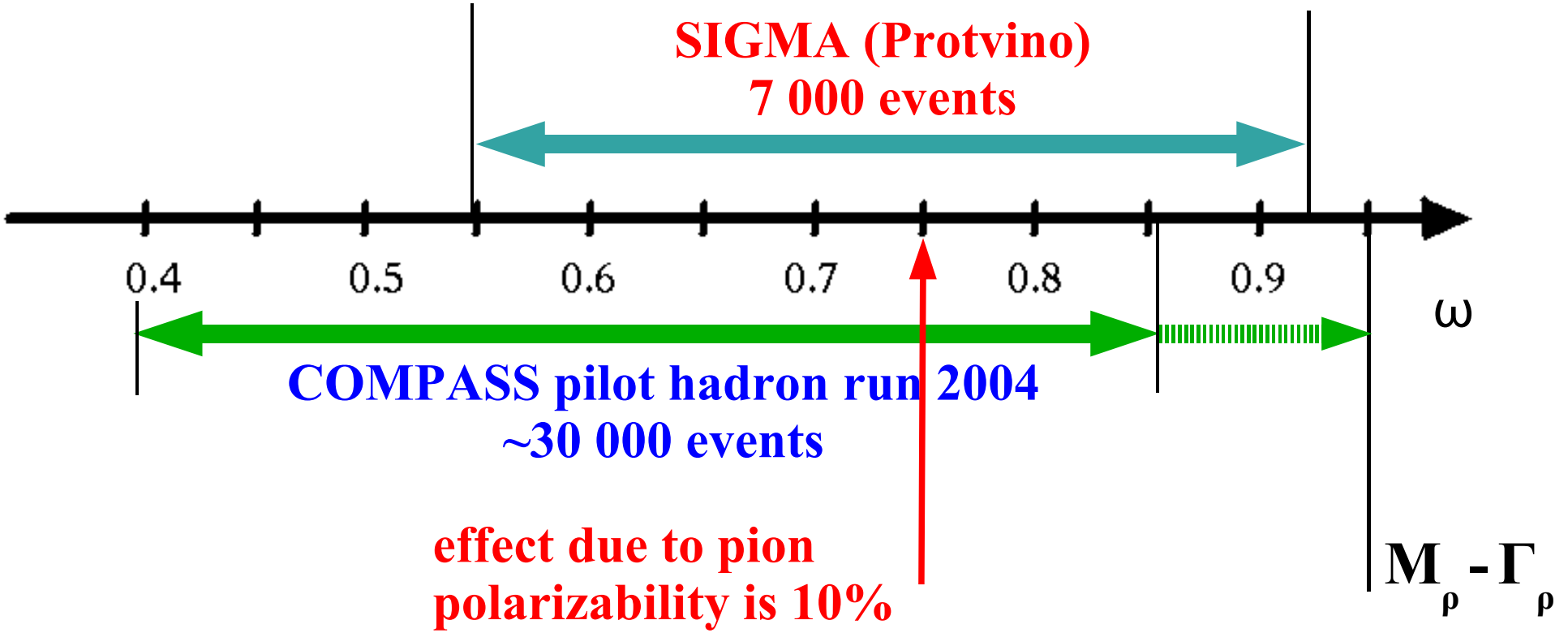
Comparison of measured differencial cross section $d\sigma/d\omega$ with the theoretical cross section for point like pion. ($\omega=E_\gamma/E_0$, lab frame)

for assumption: $\alpha_\pi+\beta_\pi=0$

$$R=\frac{\frac{d\sigma_{\beta_\pi\neq 0}}{d\omega}}{\frac{d\sigma_{\beta_\pi=0}}{d\omega}}=1+\frac{3}{2}\times\frac{\omega^2}{1-\omega}\times\frac{m_\pi^3}{\alpha}\times\beta_\pi$$

information about α_π and β_π

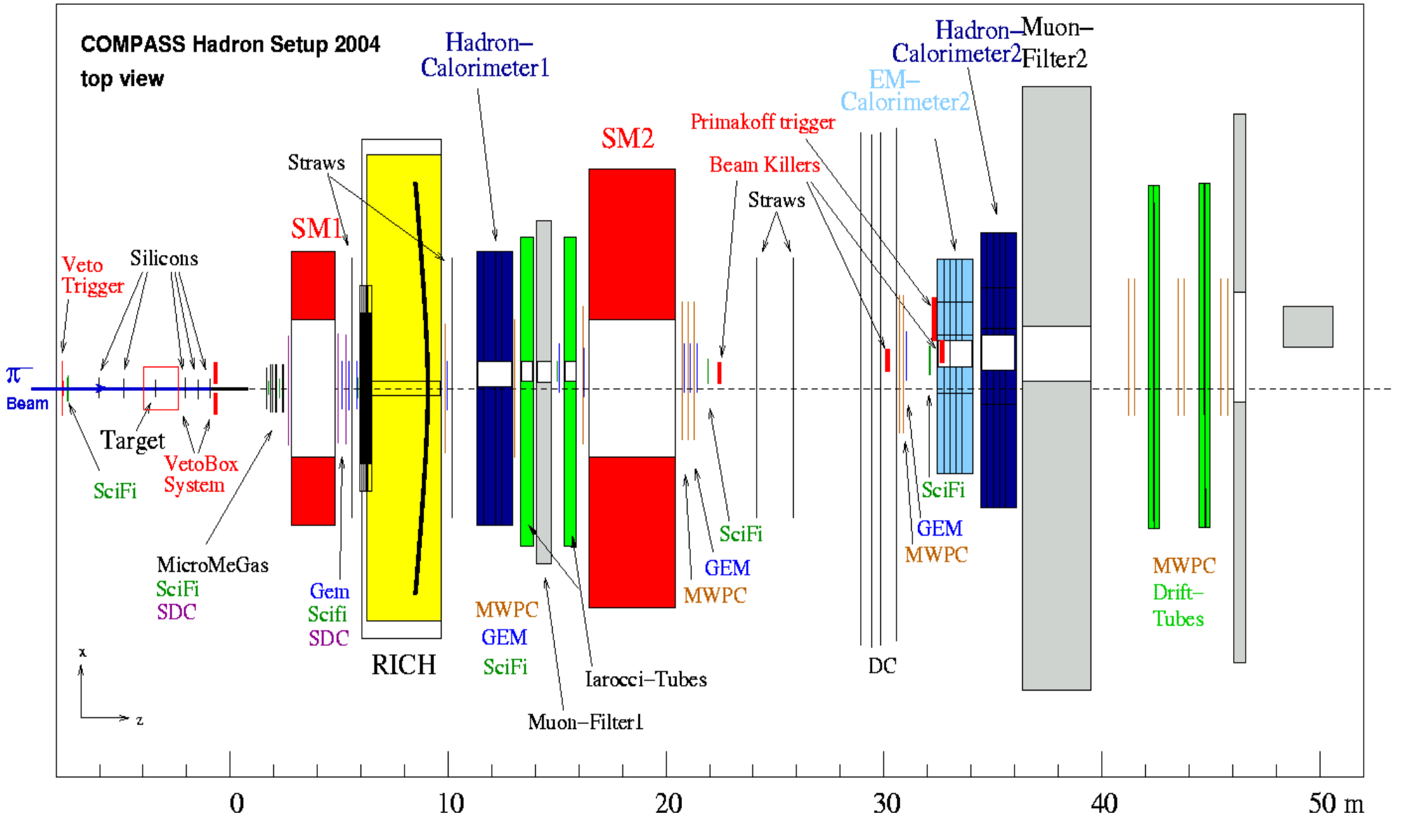
ω range covered in COMPASS



COMPASS detector potentially allows to cover range $0.4<\omega<0.95$

In pilot hadron run 2004 range $0.4<\omega<0.85$ was confidently covered.

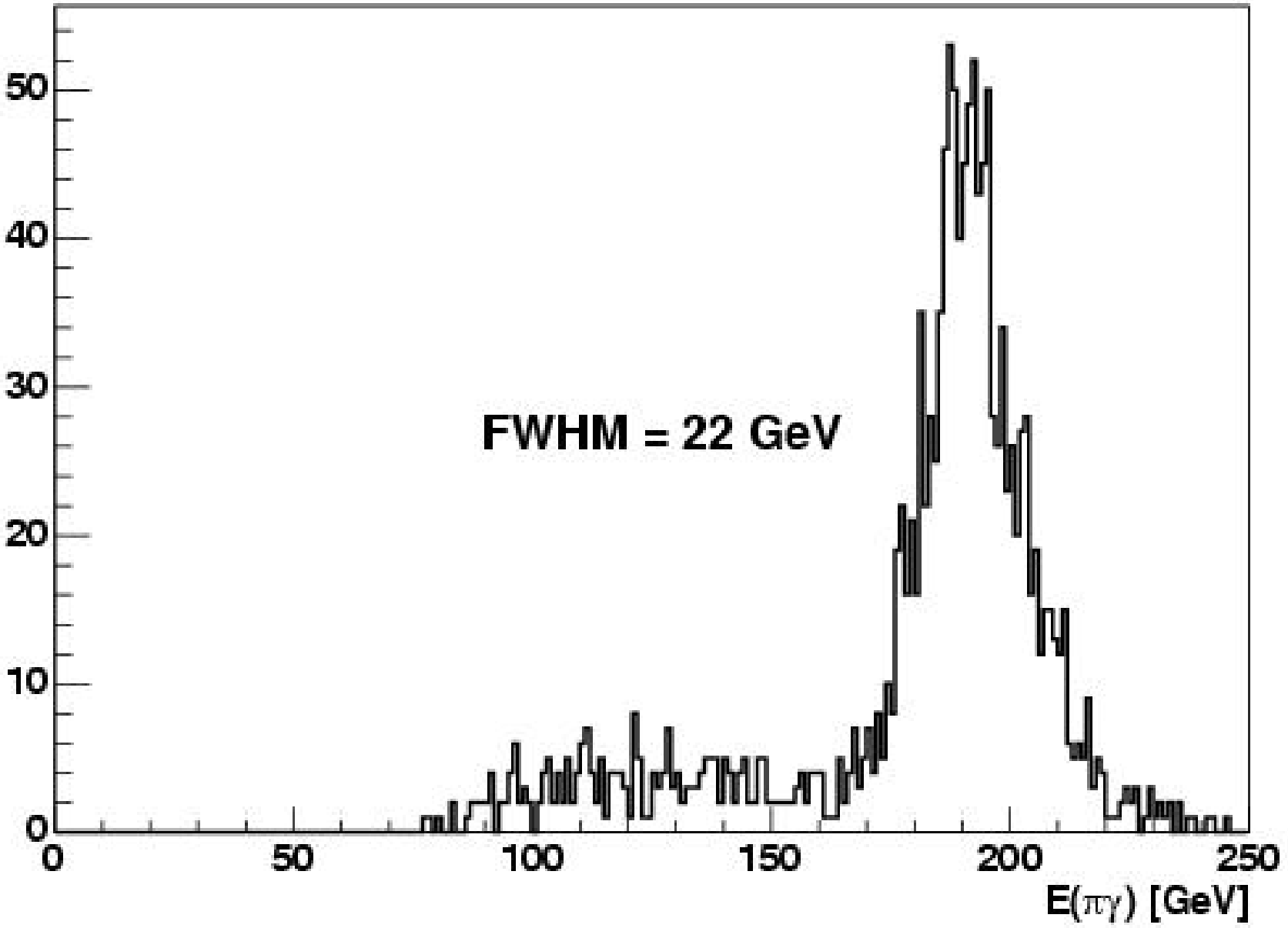
COMPASS hadron setup



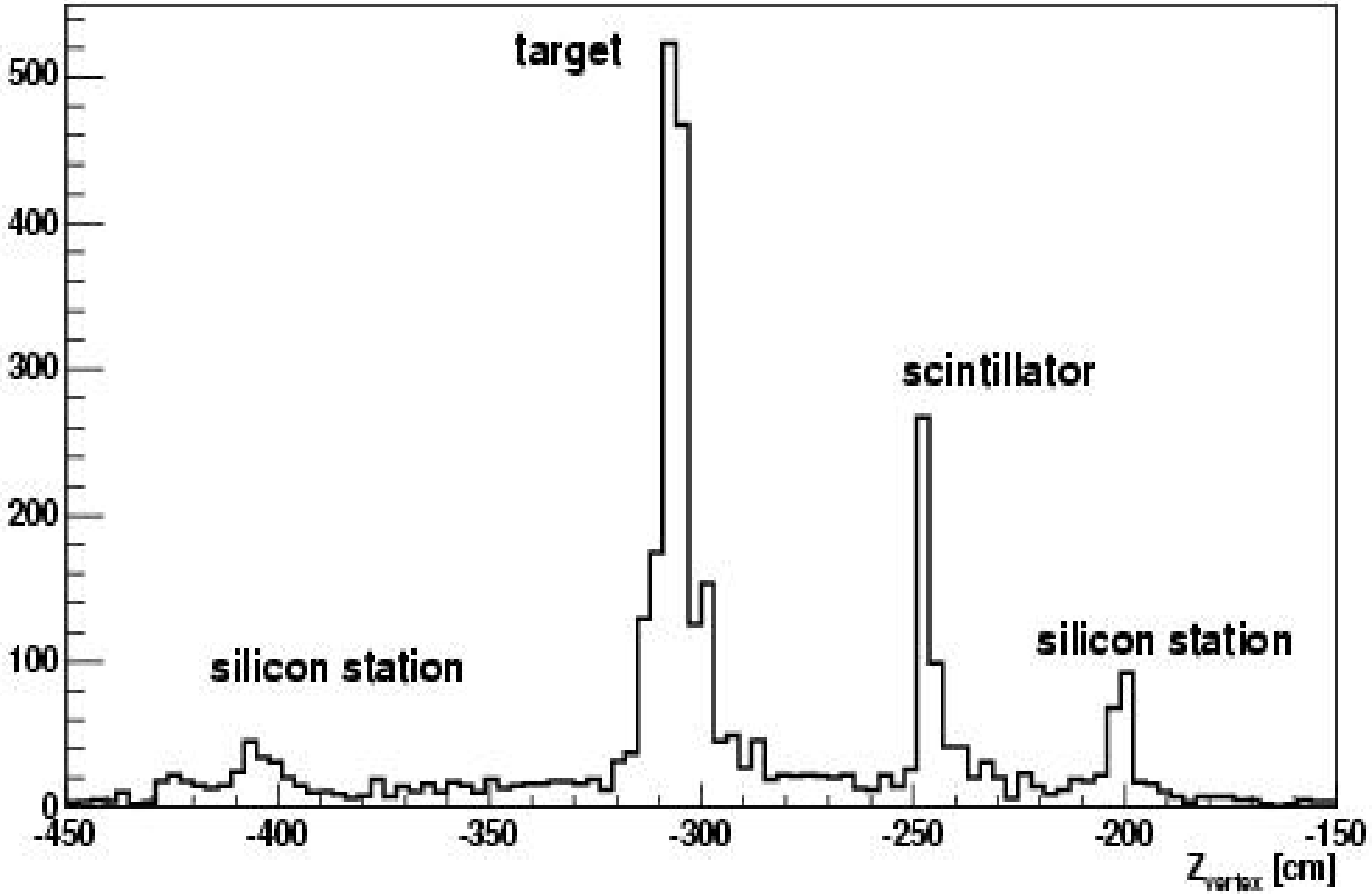
SIGMA and COMPASS experiments comparison

	SIGMA (Protvino)	COMPASS pilot hadron run 2004
Beam	π^- (40 GeV)	π^- (190 GeV) μ^- (190 GeV)
Beam intensity	10^6 / s	π^- $4.5 \cdot 10^6$ / spill μ^- $2 \cdot 10^7$ / spill
Target	C,Be,Al,Cu,Fe,Pb	Pb,C,Cu,empty target
Target thickness	0.2-0.3 X_0	0.25-0.5 X_0
Statistics for $\pi \to \pi\gamma$ events	7 000 events	30 000–40 000 events
α , 10^{-43} cm^3 ($\alpha+\beta\equiv 0$)	$6.9 \pm 1.4_{stat} \pm 1.2_{sys}$	
$\alpha+\beta$, 10^{-43} cm^3 ($\alpha+\beta\neq 0$)	$1.8 \pm 3.1_{stat} \pm 2.5_{sys}$	
β , 10^{-43} cm^3 ($\alpha+\beta\neq 0$)	$-7.1 \pm 2.8_{stat} \pm 1.8_{sys}$	

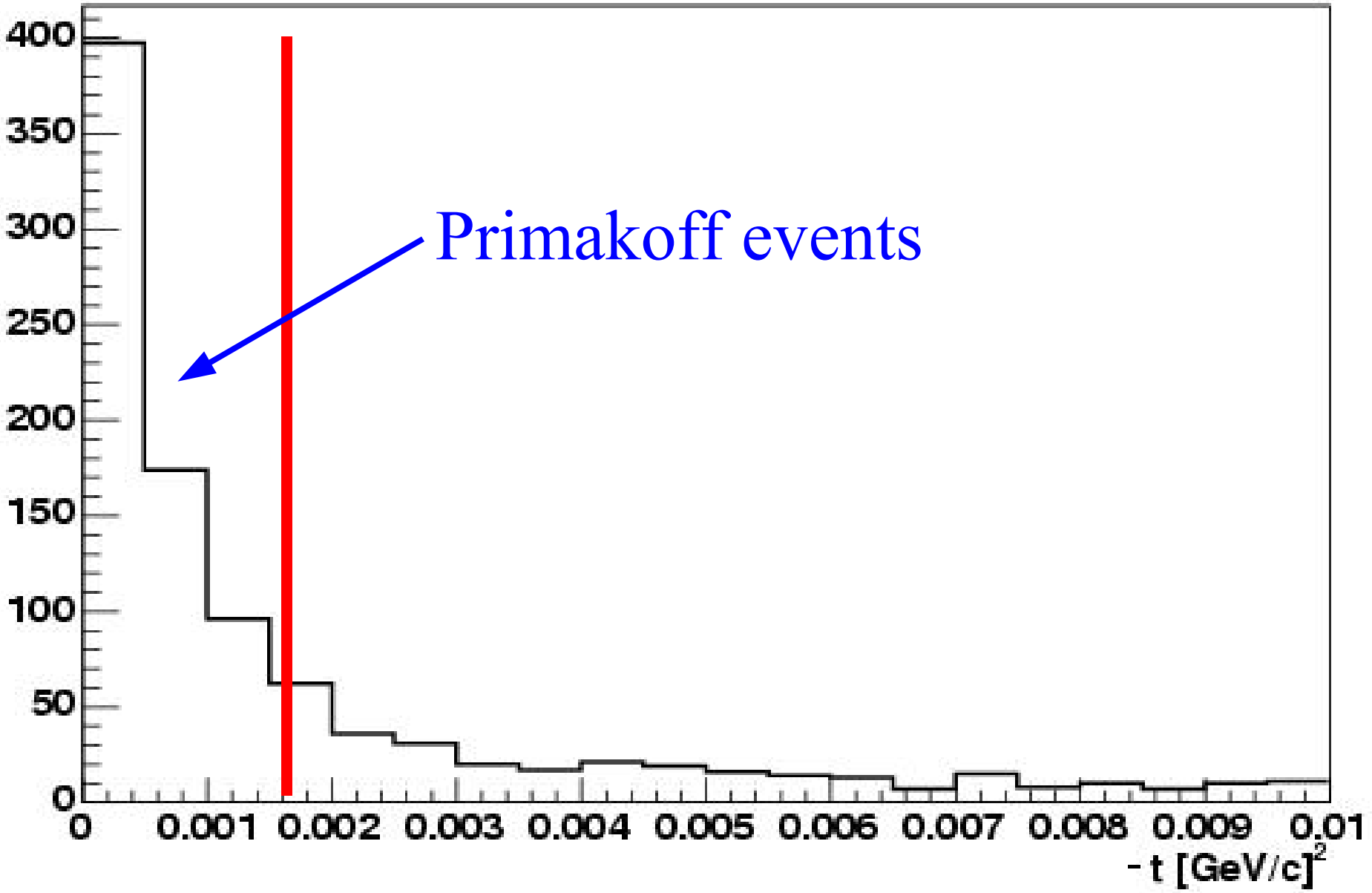
$\pi\gamma$ total energy



Z-vertex position for $\pi\gamma$ - events



t-distribution for $\pi\gamma$ - events



SUMMARY and CURRENT STATUS

- Primakoff scattering process was observed in COMPASS pilot hadron run 2004 data. Expected total statistics is about 30 000 – 40 000 events
- Variety of the full data set (runs with π, μ beams, electron converter, empty target) indeed allows detailed study of background effects
- Current status: data analysis, MC simulation, background processes study