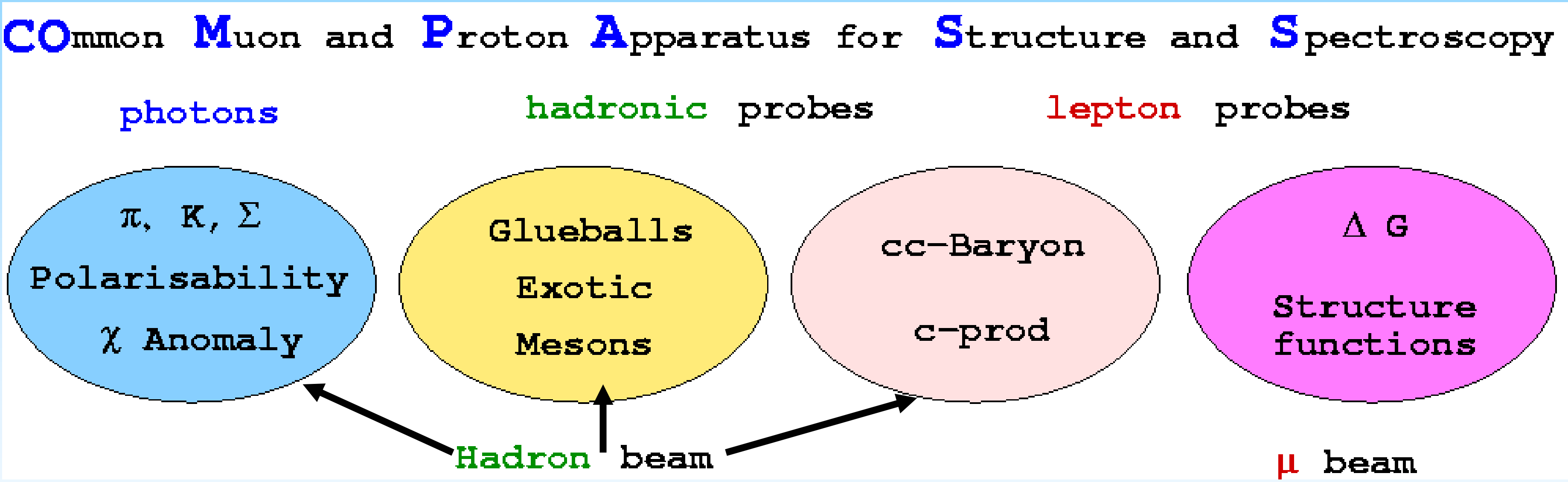
Workshop on Hadron Structure and Spectroscopy

Marialaura Colantoni*
on behalf of the COMPASS coll.

*Universita' del Piemonte Orientale

Pion polarizabilities and diffractive scattering at Compass

Compass physics program



Outline

- Two objectives of the hadron program:
  - Primakoff reaction $\pi + Z \rightarrow \pi' + Z + \gamma$

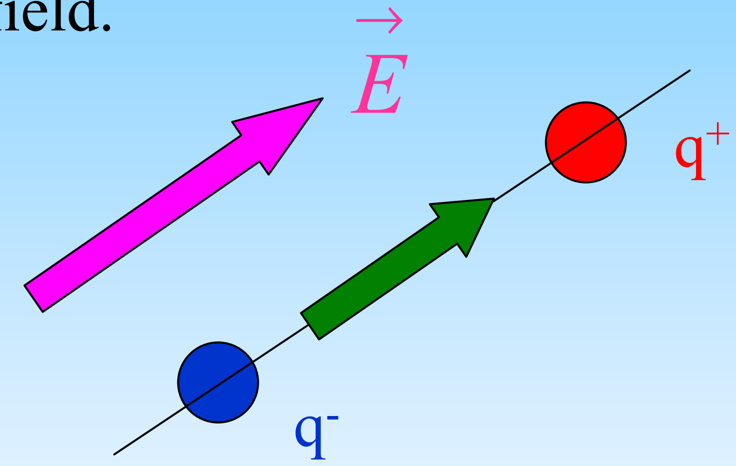
    $\rightarrow$ pion polarizabilities

  - Diffractive scattering $\pi + p \rightarrow (\pi + \eta) + p$

    $\rightarrow$ search for exotic particles

The polarizability

The polarizability (electric α and magnetic β) relates the average dipole (electric $\vec{p}$ and magnetic $\vec{\mu}$) moment to an external electromagnetic field.



$$\vec{p} = \alpha \vec{E}$$

$$\vec{\mu} = \beta \vec{H}$$

The polarizability is a quantity which characterizes a particle like its charge, radius ….

The χPT

L_{QCD} (quark,gluon) $\rightarrow$ at low energy $\rightarrow$ L_{eff} (π,K,η,p,n..)

The χPT provide a rigorous way to determine α_π, β_π via the effective chiral lagrangian

The numerical values are: $\bar{\alpha}_\pi = (2.4 \pm 0.5) \cdot 10^{-4}\, fm^3$

$$\bar{\beta}_\pi = (-2.1 \pm 0.5) \cdot 10^{-4}\, fm^3$$

U. Burgi, Phys.Lett. B 377 (1996) 147

Consistent with the chiral simmetry $(\bar{\alpha}_\pi + \bar{\beta}_\pi) = 0$

Polarizability measurements

- Photon – Photon collision

  $\alpha_\pi = (2.2 \pm 1.6_{stat+sys}) \cdot 10^{-4}\ fm^3$ [1]

- Pion Photoproduction

  $\alpha_\pi = (20 \pm 12_{stat}) \cdot 10^{-4}\ fm^3$ [2]

- Primakoff reaction

  $\alpha_\pi = (6.8 \pm 1.4_{stat} \pm 1.2_{sys})\ 10^{-4}\ fm^3$ [3] $(\alpha_\pi + \beta_\pi) = 0$

  $\beta_\pi = (-7.1 \pm 2.8_{stat} \pm 1.8_{sys})\ 10^{-4}\ fm^3$

  $(\alpha_\pi + \beta_\pi) = (1.4 \pm 3.1_{stat} \pm 2.5_{sys})\ 10^{-4}\ fm^3$ [4]

[1] J. Boyer et al., Phys. Rev D 42 (1990) 1350, P. Babusci et al., Phys. Lett. B 277 (1992) 158

[2] T.A. Aibergenov et al., Cezch J. Phys B36, 948 (1986)

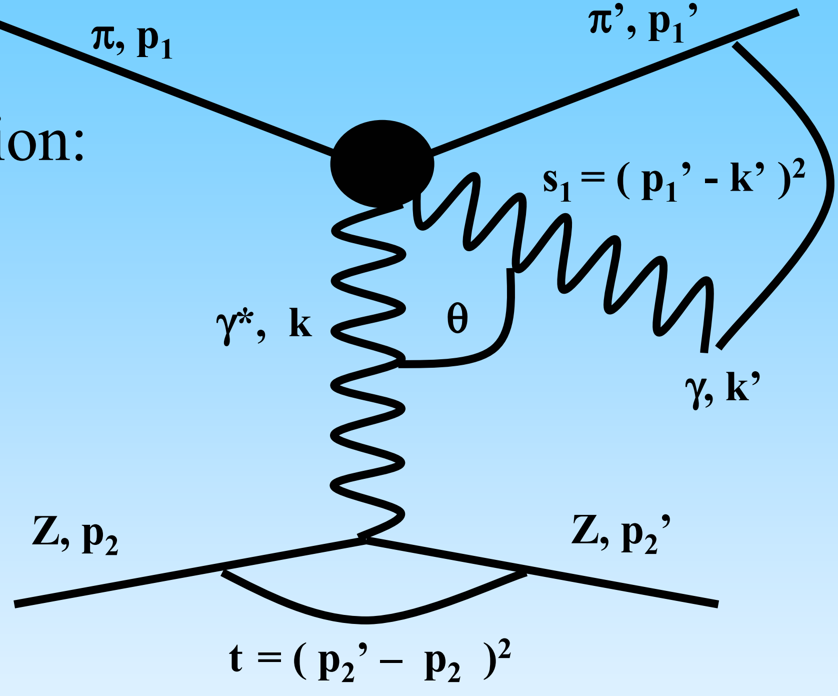
[3] Yu M. Antipov et al., Phys. Lett. 121 B (1985) 445

[4] Yu M. Antipov et al., Z. Phys. C 26 (1985) 495

The Primakoff reaction

For the reaction $\pi + Z \rightarrow \pi' + Z + \gamma$
one measures the Primakoff cross section:

$$\frac{d^3\sigma}{dt\,d\omega\,d\cos\vartheta} = \frac{\alpha_f Z^2}{\pi\omega}\frac{t-t_0}{t^2}\frac{d\sigma_{\pi\gamma}(\omega,\vartheta)}{d\cos\vartheta}\left|F_A(t)\right|^2$$



ω photon energy in the antilab system

$$t = (p'_2 - p_2)^2$$

$$t_0 = \left(\frac{m_\pi \omega}{p_{beam}}\right)$$

θ real photon scattering angle

Electric & Magnetic polarizability

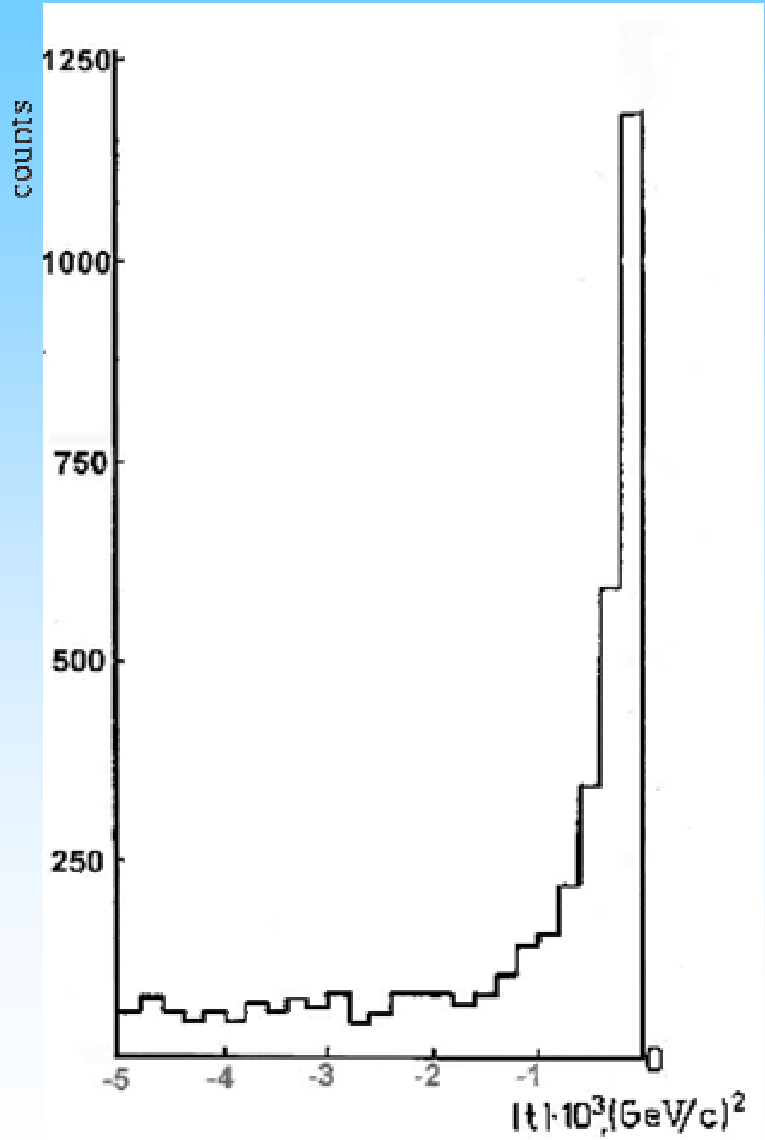
$$\frac{d\sigma_{\pi\gamma}(\omega,\vartheta)}{d\cos\vartheta} = \frac{2\pi\alpha_f^2}{m_\pi^2}\cdot\left(F_{\pi\gamma}^{Th} + \frac{m_\pi\omega^2}{\alpha_f}\cdot\frac{\alpha_\pi(1+\cos^2\vartheta)+\beta_\pi\cos\vartheta}{\left(1+\frac{\omega}{m_\pi}(1-\cos\vartheta)\right)^3}\right)$$

The goals

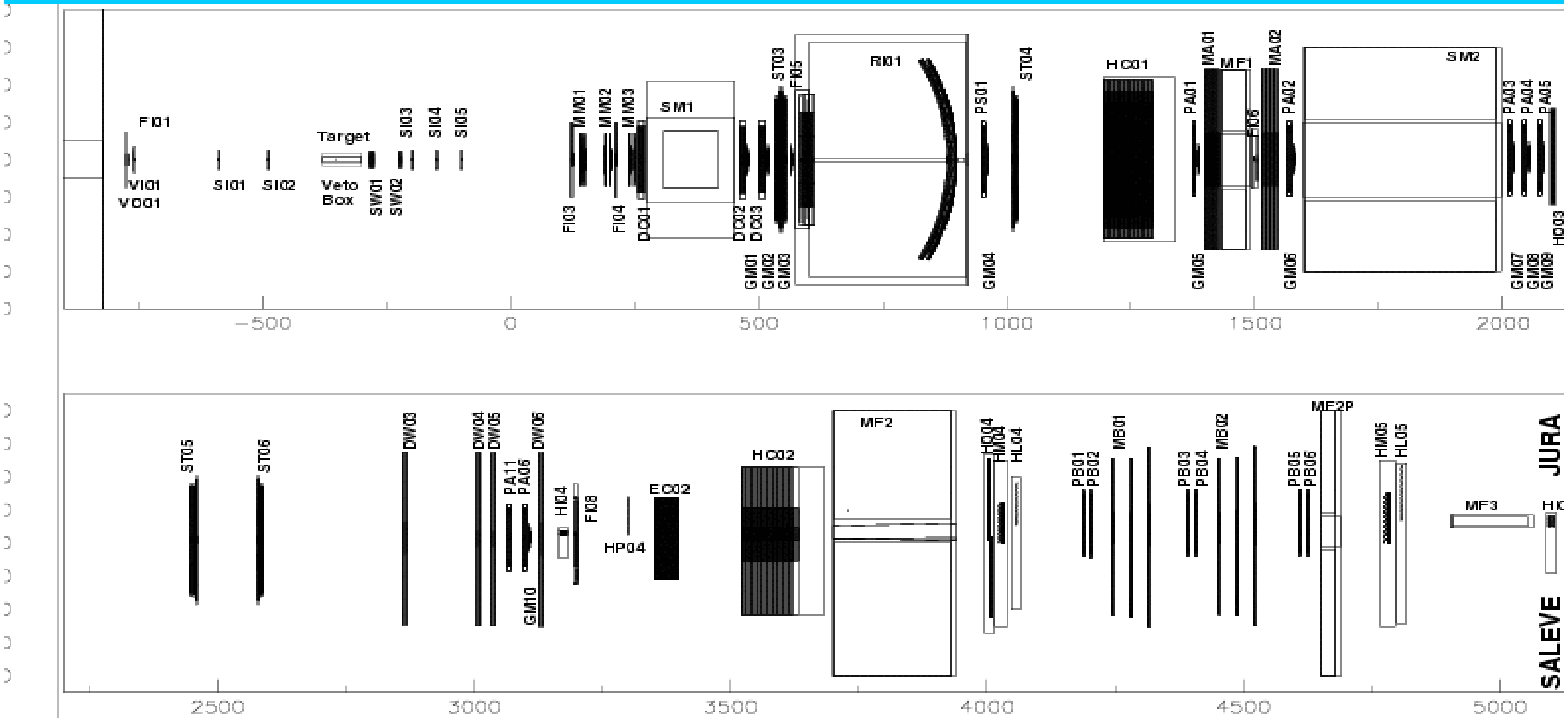
• P_{beam} =190 GeV/c to increase the ratio of the coulombian/nuclear cross section and less multiple scattering effect

GOALS:

- measure independently $(\alpha_\pi + \beta_\pi)$, α_π
- enough statistics:
  - to get the statistical errors negligible versus the systematic one
  - evaluate systematic errors due to different cuts
  - more complete angular distribution



The *COMPASS* hadron setup 2004



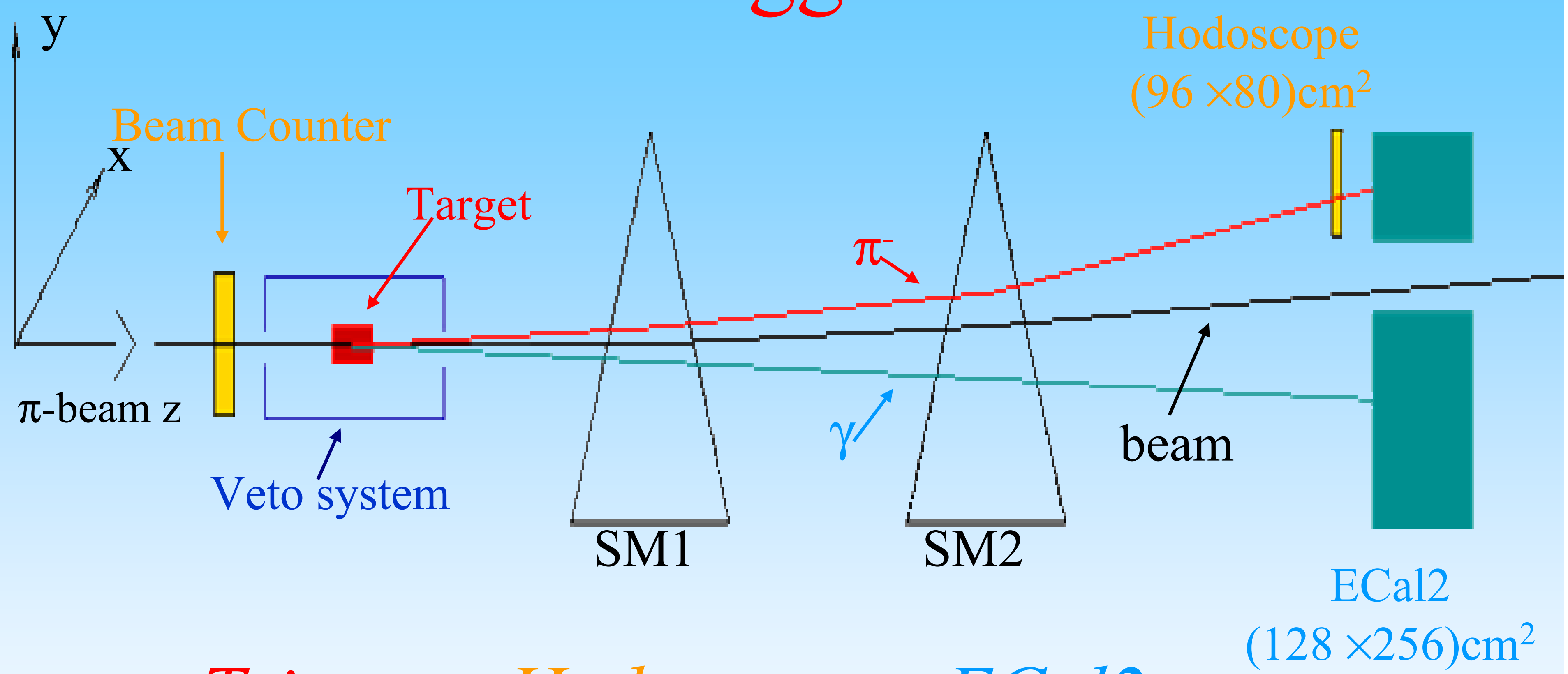
First Spectrometer: LAS

Geometrical Acceptance: θ>30 mrad
Gap: 172 × 229 cm^2
Integral field: 1 Tm
Analyzed momentum: p<60 GeV/c

Second Spectrometer: SAS

Geometrical Acceptance: θ<30 mrad
Gap: 200× 100 cm^2
Integral field: 4.4 Tm
Analyzed momentum: p>10 GeV/c

Trigger



Trigger: *Hodoscope* × *ECal2*

π^- γ

Simulation shows [5]:

Resolution of transversal components of the four-momentum transfer of (γπ):

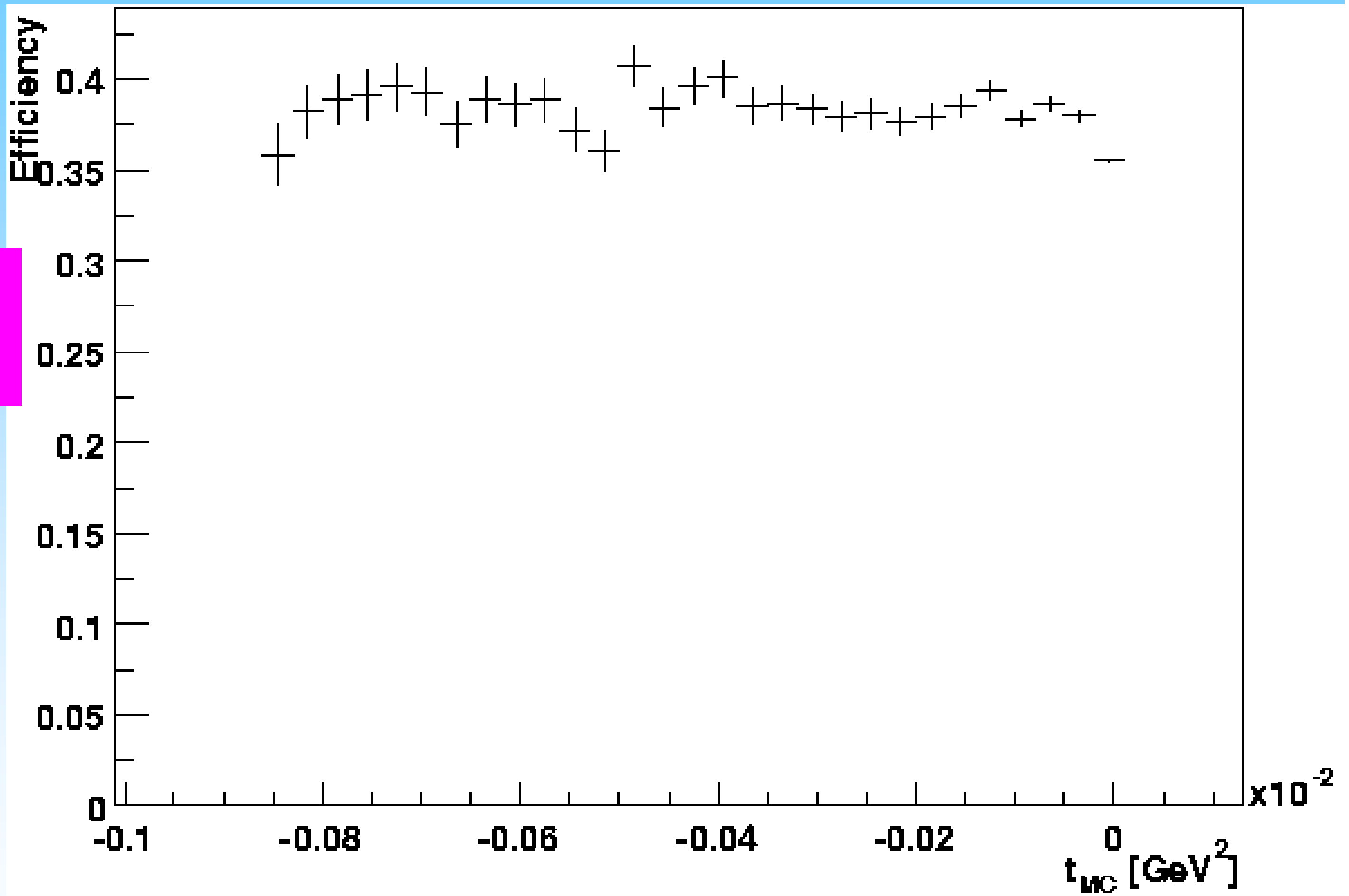
$$\sigma_{p_T} = 18 \cdot 10^{-3}\, GeV/c$$

$$\Delta t \approx 5 \cdot 10^{-4} (GeV/c)^2$$

[5]: Colantoni, Future Physics at COMPASS, 27-29 Sept 2002

The efficiency = N_{rec}/ N_{gen}

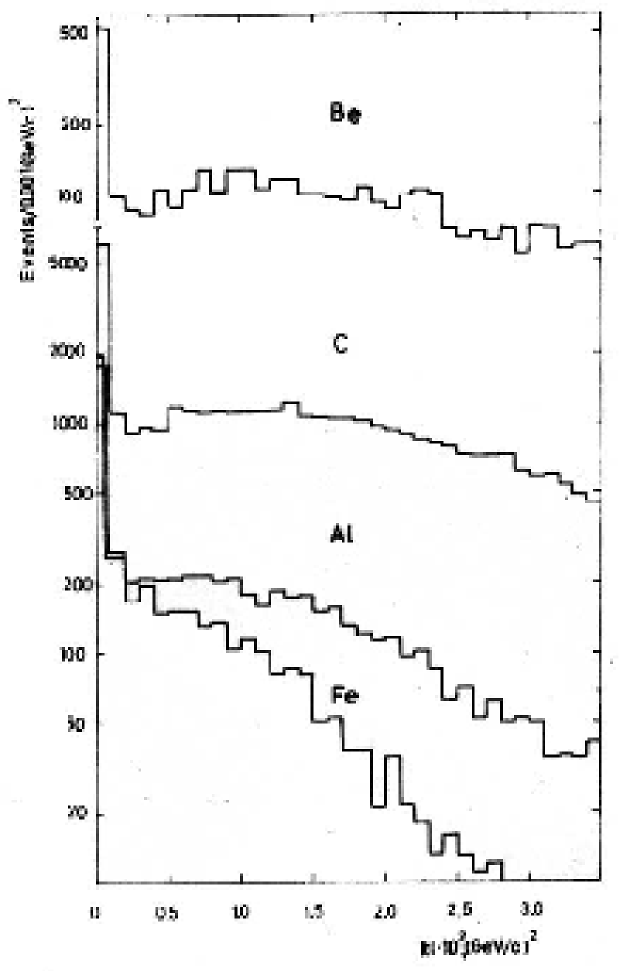
Constant efficiency vs t →



Comparison with the Serpukhov data

	@ Serpukhov	@COMPASS
beam momentum	40 GeV/c	190 GeV/c
beam intensity	10^6 π/spill	10^7 π/spill
target	Be, C, Cu, Fe	C, Cu, Pb
scattered pion	$\sigma_\theta \approx 1.2 \cdot 10^{-4}$ rad	$\sigma_\theta \approx 4 \cdot 10^{-5}$ rad
	$\sigma_p/p \approx 1\%$	$\sigma_p/p \approx (0.3 \div 1)\%$
outgoing photon	$\sigma_\theta \approx 1.5 \cdot 10^{-4}$ rad	$\sigma_\theta \approx 3.1 \cdot 10^{-5}$ rad
	$\sigma_E/E \approx 3.5\%$@27GeV	$\sigma_E/E \approx (5.5/\sqrt{E} + 1.5)\%$
total flux	10^{11}	10^{13} π/day
Primakoff events	$\sim 6 \cdot 10^3$ in total	$6.4 \cdot 10^4$/day

Primakoff summary



- Different target → Z^2 dependence in the the cross section
- Possible comparison with point like particle via the reaction: $\mu + Z \rightarrow \mu + Z + \gamma$
- Constant efficiency on t
- t resolution → $5\ 10^{-4}\ (GeV/c)^2$
- Error on polarizabilities (syst. + stat) $\delta\alpha \approx 0.4 \cdot 10^{-4}\ fm^3\ (\approx\sigma_{theory})$
- Also kaon polarizabilities can be measured

The exotic state $(non-q\bar{q})$

- Hybrids $(q\bar{q}g), J^{PC} = 0^{--};0^{+-};1^{-+};1^{--};2^{+-}$

  quantum number not accesible for conventional mesons

  Problem $\rightarrow$ lightest exotic state (mass 1.8 ÷1.9 GeV/c^2) [6] are in a mass region populated by conventional mesons

[6] Barnes et al. Phys. Rew D 52 (1995) 5242

Experiments searching for exotic resonance structure (1^{-+}) in $\eta\pi$ system

Exp	mass[MeV]	width[MeV]	reaction
BNL[6]	1370 ± 50	385 ± 100	$\pi^- p \rightarrow \eta\pi^- p$
CBar[7]	1400 ± 20	310 ±70	$\bar{p}n \rightarrow \eta\pi^-\pi^0$
CBar[8]	1360 ± 25	220 ± 90	$\bar{p}p \rightarrow \eta\pi^0\pi^0$
VES[9]	1316 ± 12	287 ± 25	$\pi^- Be \rightarrow \eta\pi^- Be$
Theory[10]	1900	200	

[6] Chung et al. Phys. Rev. D 60 (1999) 092001
[7] Abele et al. Phys. Lett B423 (1998) 175
[8] Abele et al. Phys Lett B 446 (1999) 349
[9] Dorofee et al. "The $J^{PC}=1^{-+}$ hunting season at Ves" Hadron Spectroscopy IX Int. Conference pp 143-154
[10] N. Isgur et al. Phys. Rev. Lett. 54, 869 (1985)

Hybrid at COMPASS via:

Diffractive scattering ($t < 1\ (GeV/c)^2$):

$\pi + p \rightarrow (Hybrid) + p \rightarrow \pi + \eta + p$

$\eta \rightarrow \pi^- \pi^+ \pi^0$, $\pi^0 \rightarrow \gamma\gamma$

$\eta \rightarrow \gamma\gamma$

$$\frac{d\sigma}{dt} \propto e^{-bt};$$

$b = 6.5\ (GeV/c)^{-2}$ for H target;

$b = 400\ (GeV/c)^{-2}$ for Pb target;

A PWA of diffractively produced system shows that two partial waves are significant:

$J^P = 2^+$ produced $a_2(1320)$-meson (wave D);

$J^P = 1^-$ exotic quantum number (wave P)

Simulation shows [10]:

- Flat reconstruction efficiency in D and P wave
- Mass resolution $\sigma(M) \sim 6$ MeV/c
- Small dependence of $\sigma(M)$ on the mass of hybrids
- Expected events for hybrids

$$N_{a2\rightarrow\eta\pi}=5K/day \quad \& \quad N_{P\rightarrow\eta\pi}=0.25K/day$$

[10] Dorofee, Future Physic at COMPASS, 27-29 Setp. 2002

Summary & Outlook

- Primakoff reaction to test the χPT measuring the pion polarizabilities.
- Measurement of the kaon polarizabilities is also possible
- COMPASS can contribute to the search for hybrids measuring the shape of 1^{-+} resonance