Measurements with hadron beams at COMPASS

Andrea Ferrero - Dip. Fisica Generale and INFN, Torino

HEP2005 Conference

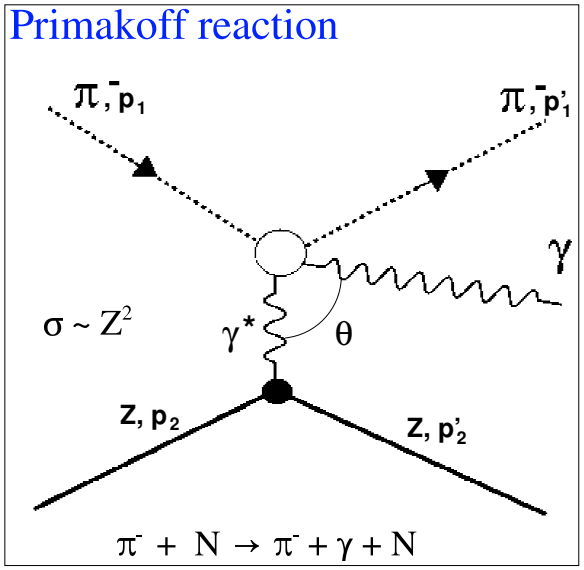
Lisbon, July 21-27 2005

Outline:

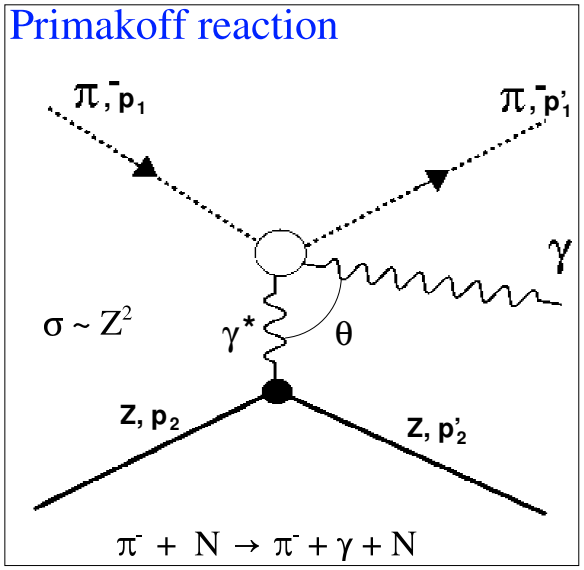
- Measurement of pion polarizabilities
- Study of centrally produced exotic mesons
- Conclusions

The Primakoff reaction

Primakoff reaction



The Primakoff reaction

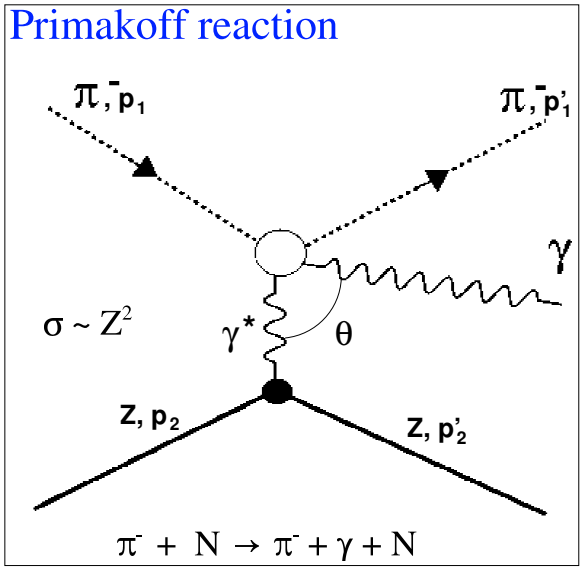


Cross section:

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

$$t = (p_2 - p_2')^2, \quad t \lesssim 1.5 \cdot 10^{-3} \text{ (GeV/c)}^2$$

The Primakoff reaction



Cross section:

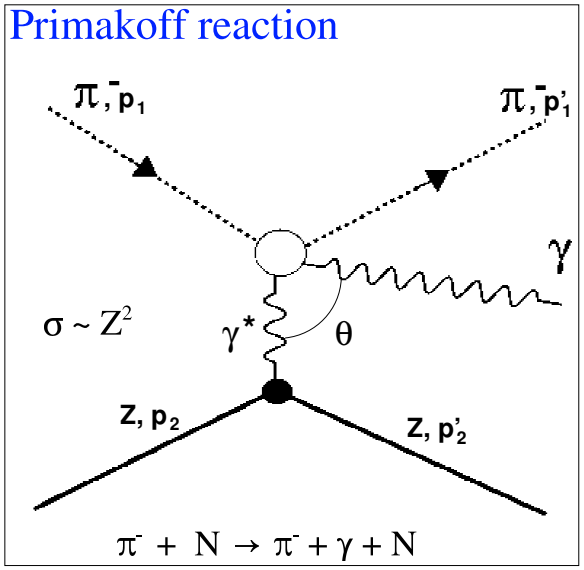
$$\frac{d^3\sigma}{dt\ d\omega\ d\cos\theta} = \frac{\alpha_f Z^2}{\pi\omega}\cdot\frac{t-t_0}{t^2}\cdot\frac{d\sigma_{\pi\gamma}(\omega,\theta)}{d\cos\theta\ d\omega}|F_A(t)|^2$$

$$t=(p_2-p_2')^2, \quad t \lesssim 1.5\cdot 10^{-3}\ \text{(GeV/c)}^2$$

The $d\sigma_{\pi\gamma}$ term contains the electric and magnetic polarizabilities (α_π and β_π):

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

The Primakoff reaction



Cross section:

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

$$t=(p_2-p_2')^2, \quad t \lesssim 1.5\cdot 10^{-3}\ \text{(GeV/c)}^2$$

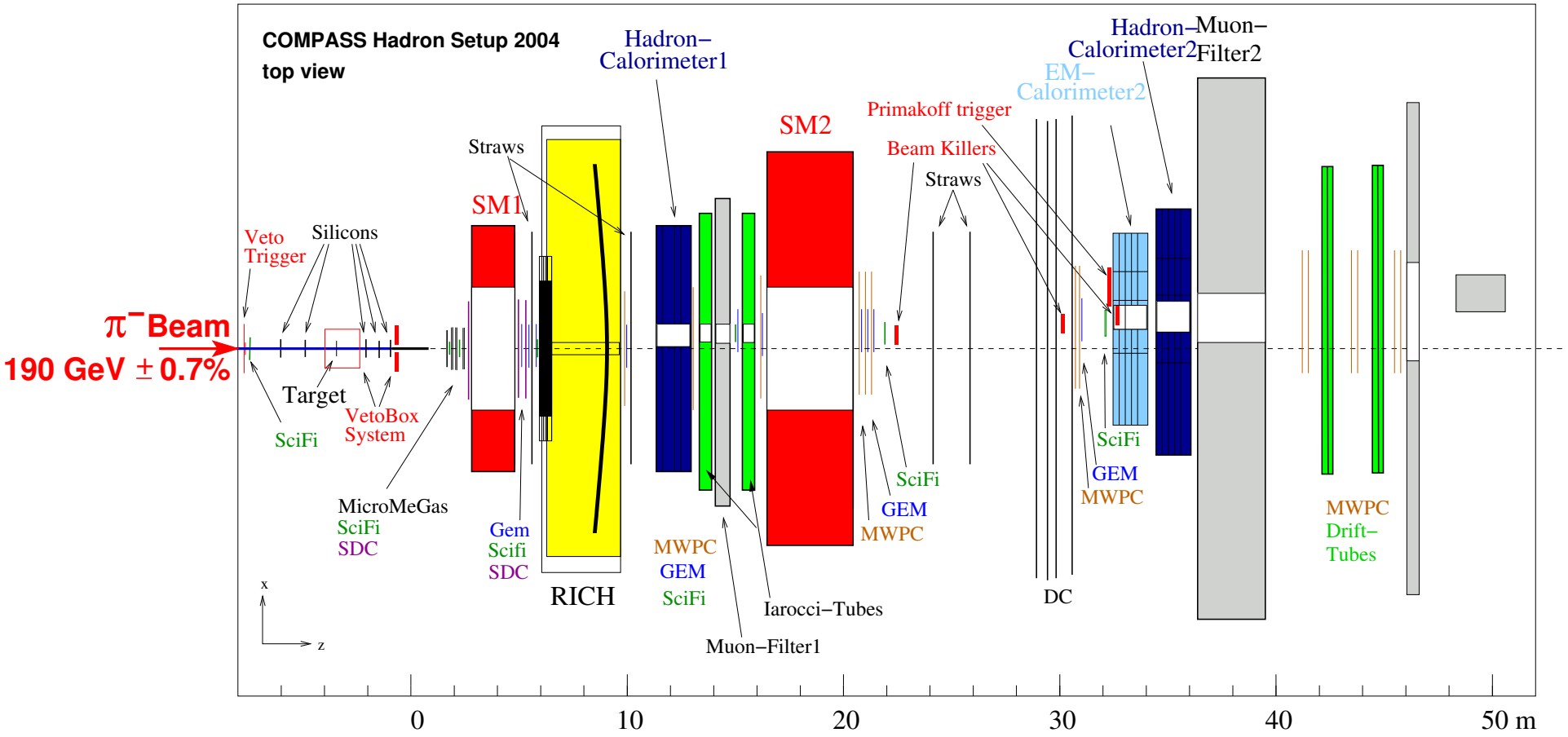
The $d\sigma_{\pi\gamma}$ term contains the electric and magnetic polarizabilities (α_π and β_π):

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

- χPT predictions: $\alpha_\pi = (2.4\pm 0.5)\cdot 10^{-4}$ fm^3, $\beta_\pi = (-2.1\pm 0.5)\cdot 10^{-4}$ fm^3
  U. Burgi, Phys. Lett. **B377** (1996) 147
- previous experiments are affected by too large statistical and/or systematic errors
- the question can be answered by an high statistics, high accuracy experiment...

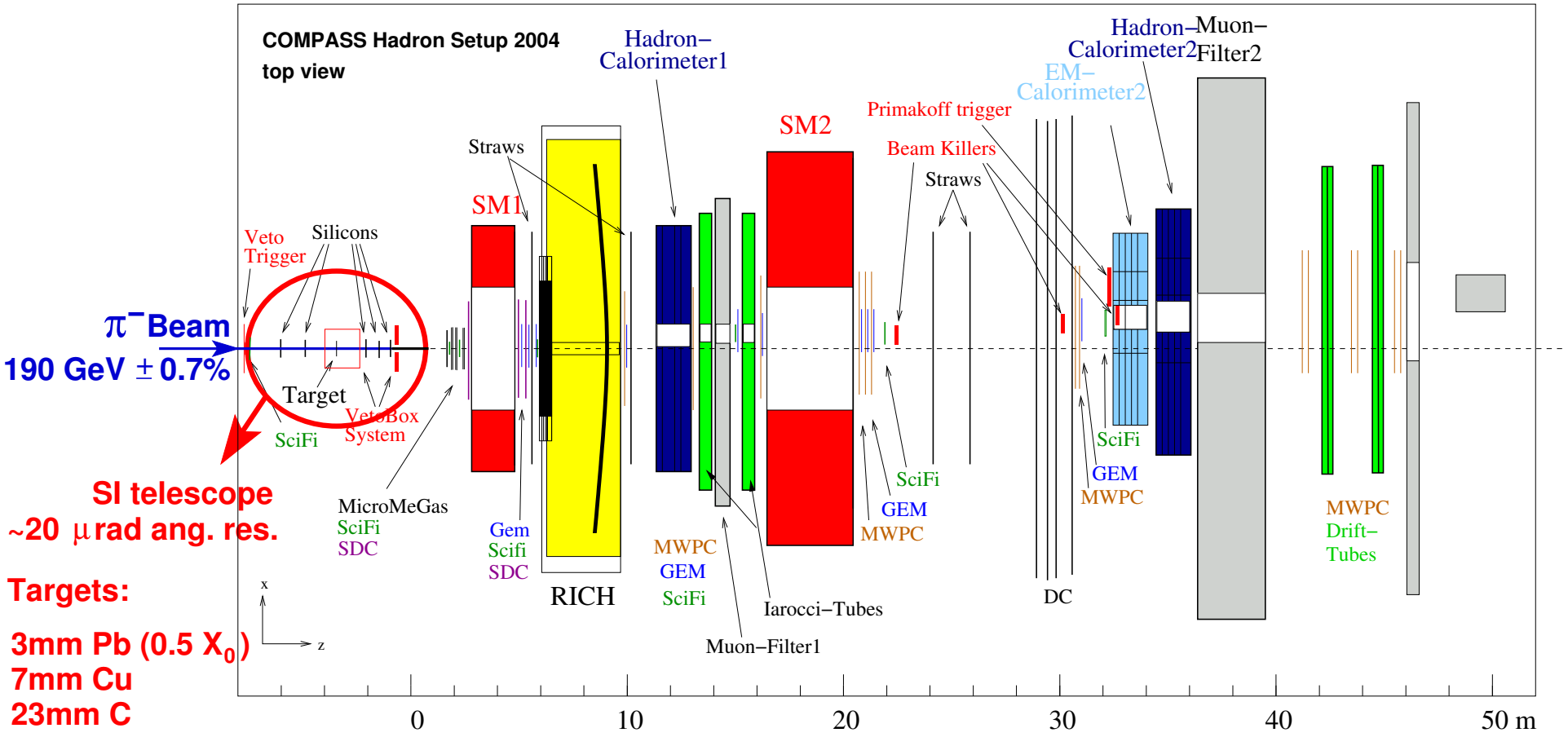
The experimental apparatus

The experimental apparatus must be able to reconstruct the t-variable (the transferred four momentum squared) with a resolution better than $5 \cdot 10^{-4}$ (GeV/c)^2.



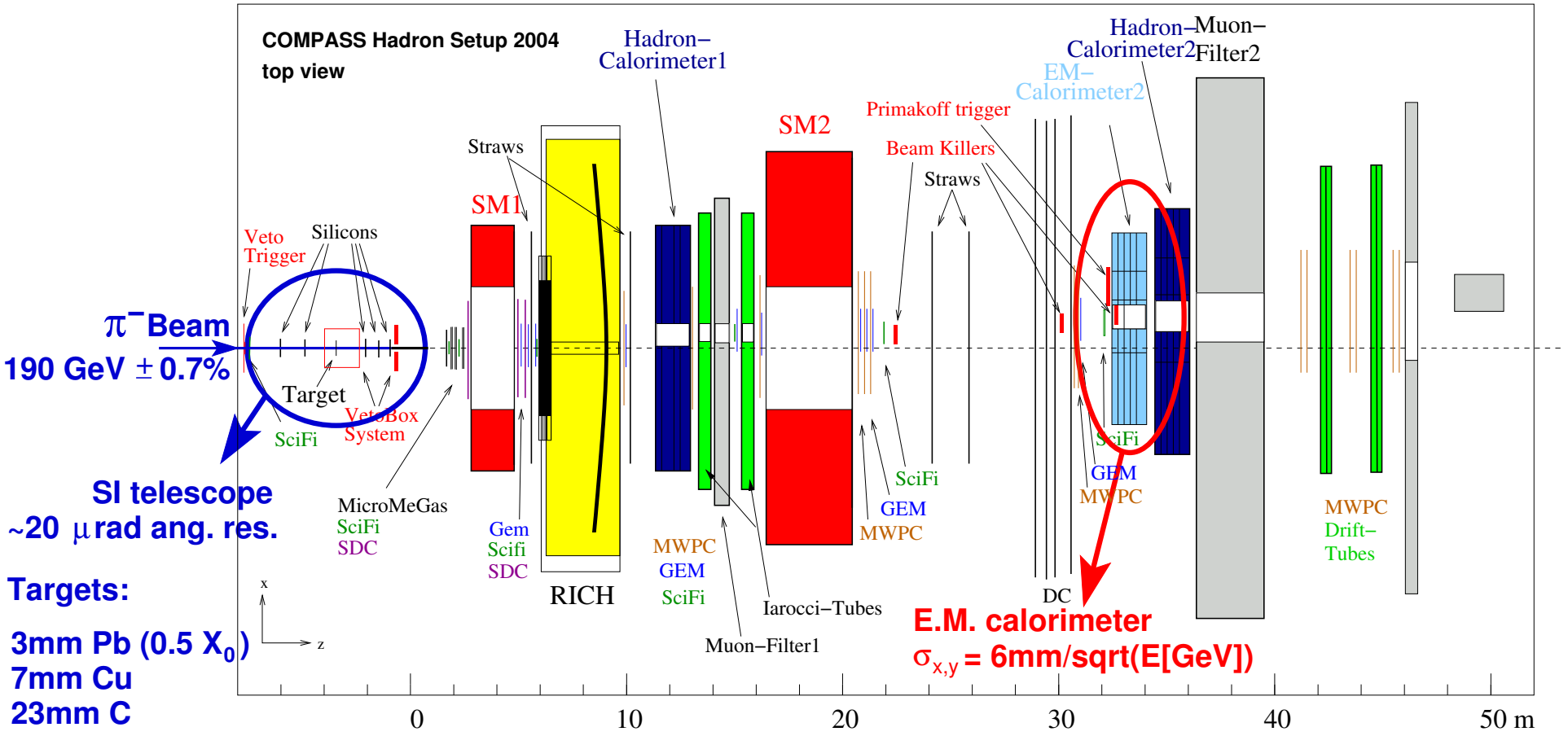
The experimental apparatus

The experimental apparatus must be able to reconstruct the t-variable (the transferred four momentum squared) with a resolution better than $5 \cdot 10^{-4}$ (GeV/c)^2.



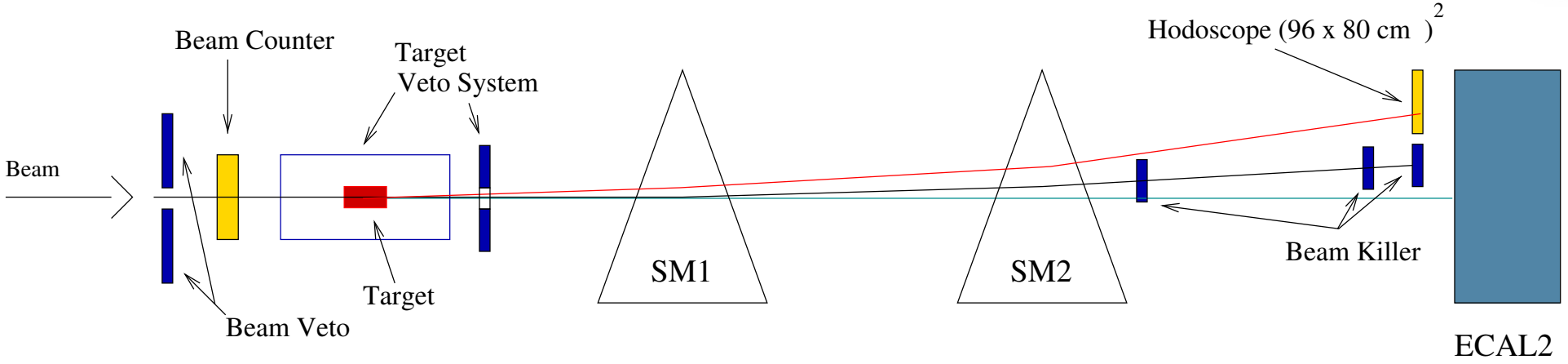
The experimental apparatus

The experimental apparatus must be able to reconstruct the t-variable (the transferred four momentum squared) with a resolution better than $5 \cdot 10^{-4}$ (GeV/c)^2.



See Jörg Pretz's talk later in this session for more details...

The 2004 Pilot Hadron Run



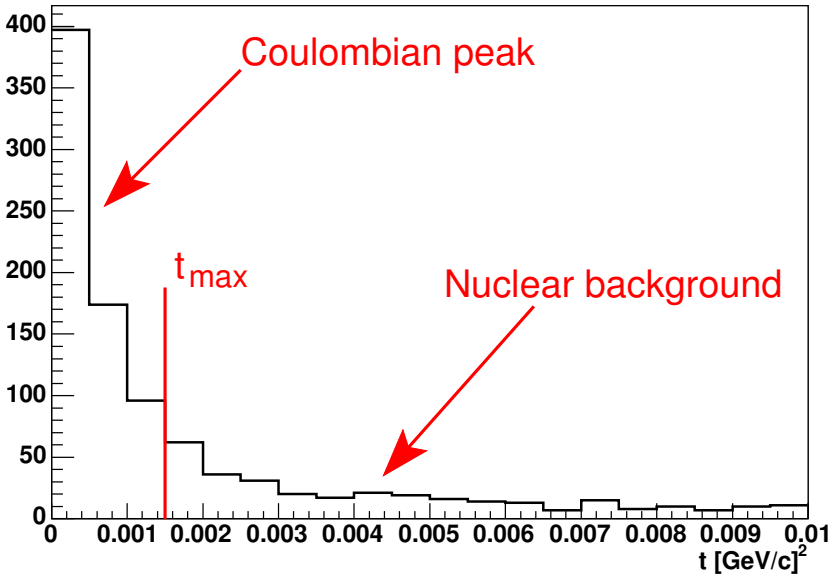
Experimental conditions during the 2004 Pilot Hadron Run:

- Beam: 190 GeV π^-, $\sim 10^6$/s, 4.8s/16s spill SPS structure
- Targets: 3 MM Pb (0.5 X_0), 7 mm Cu, 23 mm C
- Trigger acceptance:

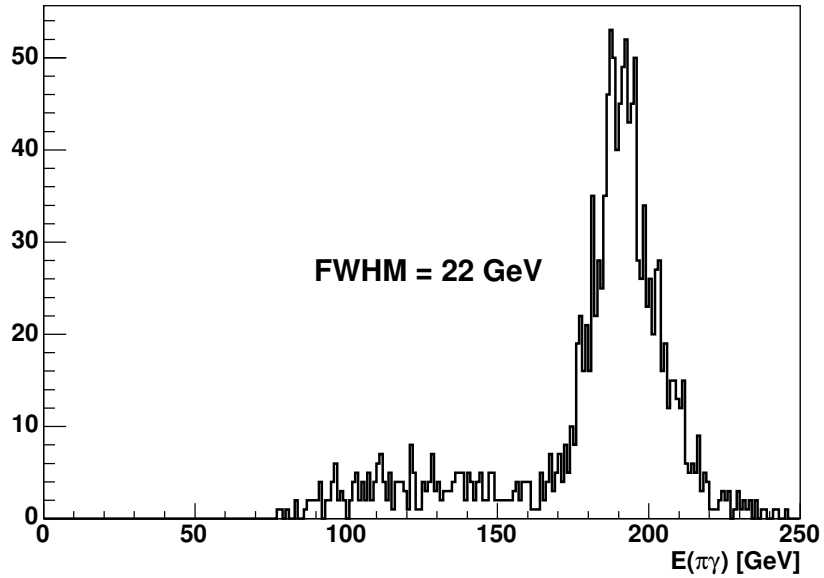
  $0 < p_{\pi^-} < 100$ GeV/c, corresponding to $90 < E_\gamma < 190$ GeV
- A beam veto system with 4 cm hole selects interactions in the target

Preliminary results

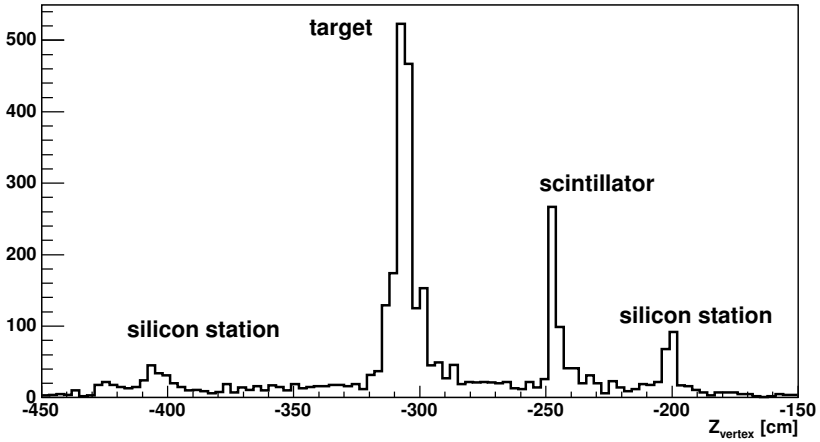
Distribution of the t variable



Exclusivity of the reaction

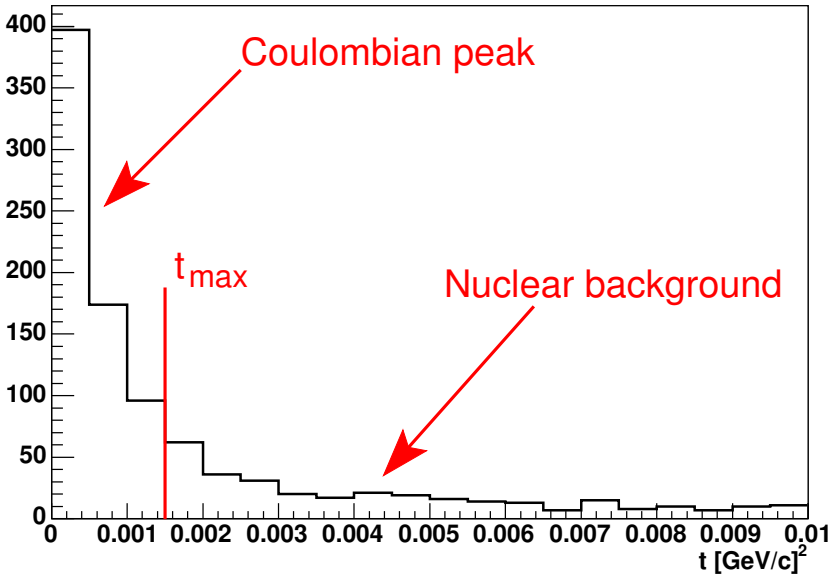


Position of the reconstructed interaction vertex

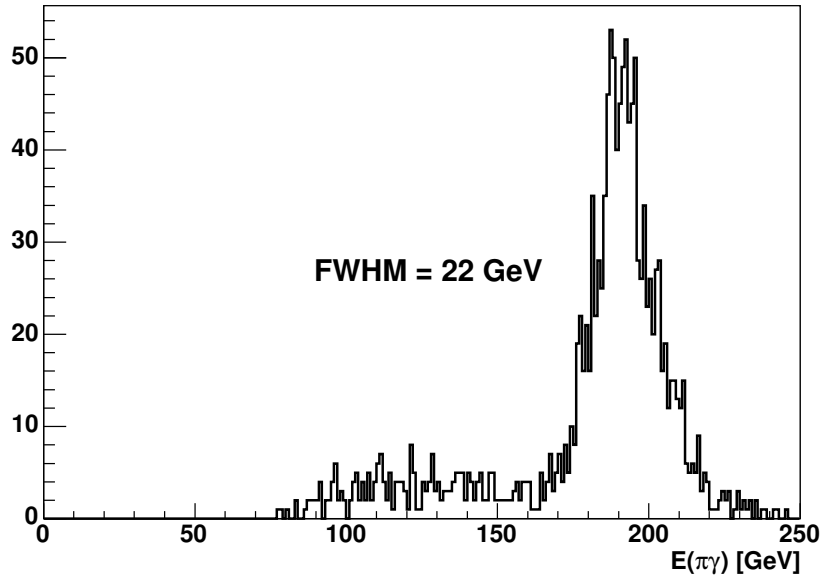


Preliminary results

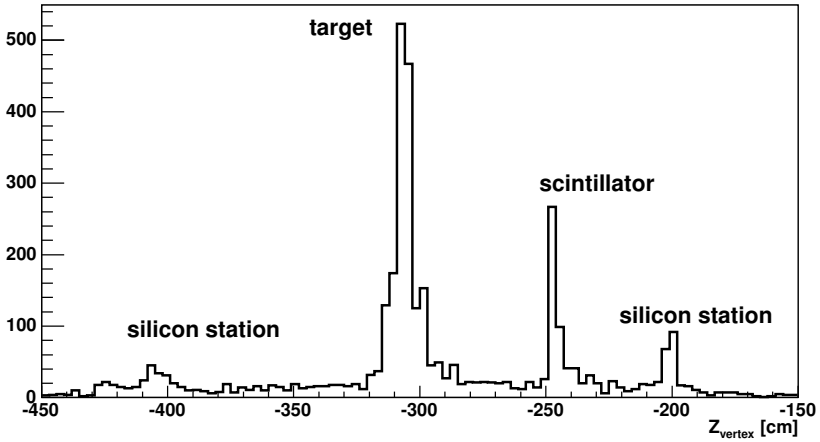
Distribution of the t variable



Exclusivity of the reaction



Position of the reconstructed interaction vertex

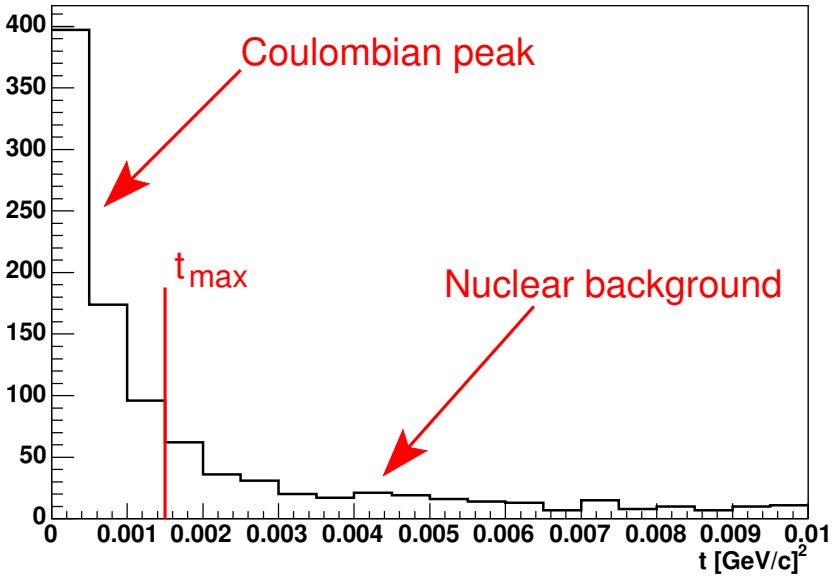


- Systematic effects will be estimated using a sample of data collected with muon beams (pointlike!) in the same experimental conditions

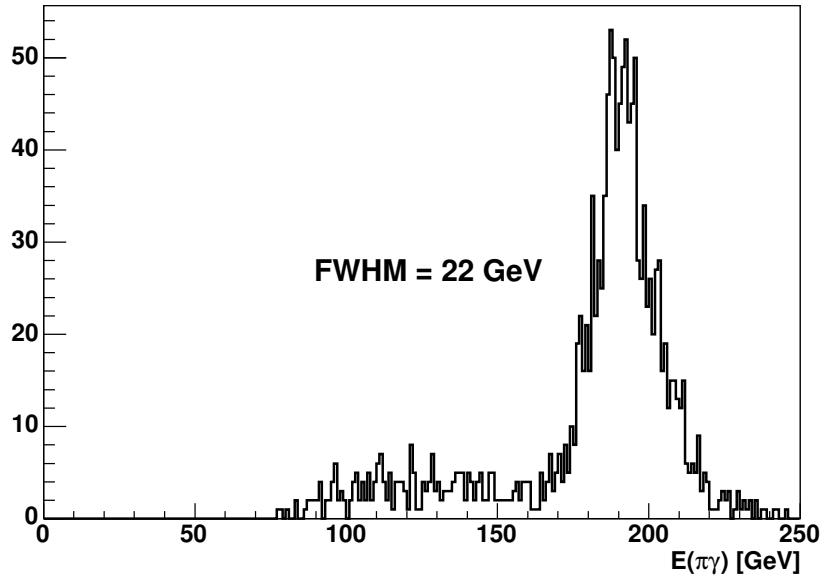
PECULIAR FEATURE OF COMPASS

Preliminary results

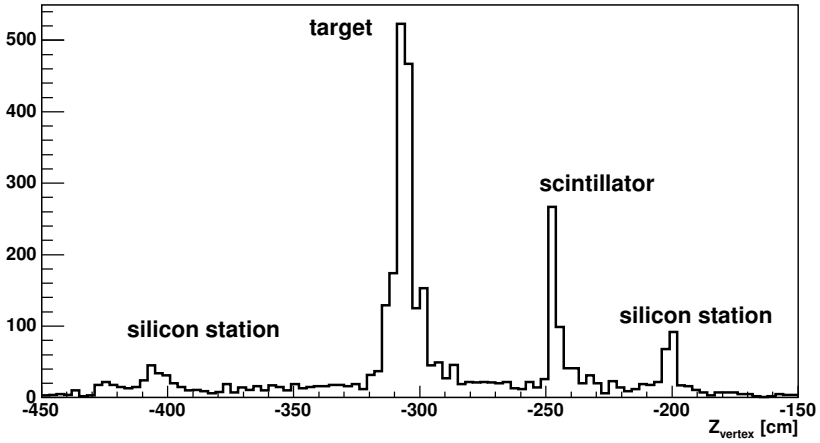
Distribution of the t variable



Exclusivity of the reaction



Position of the reconstructed interaction vertex



- Systematic effects will be estimated using a sample of data collected with muon beams (pointlike!) in the same experimental conditions

PECULIAR FEATURE OF COMPASS

- The expected statistics is at least 4 times larger than previous experiments

Future measurements: exotic mesons

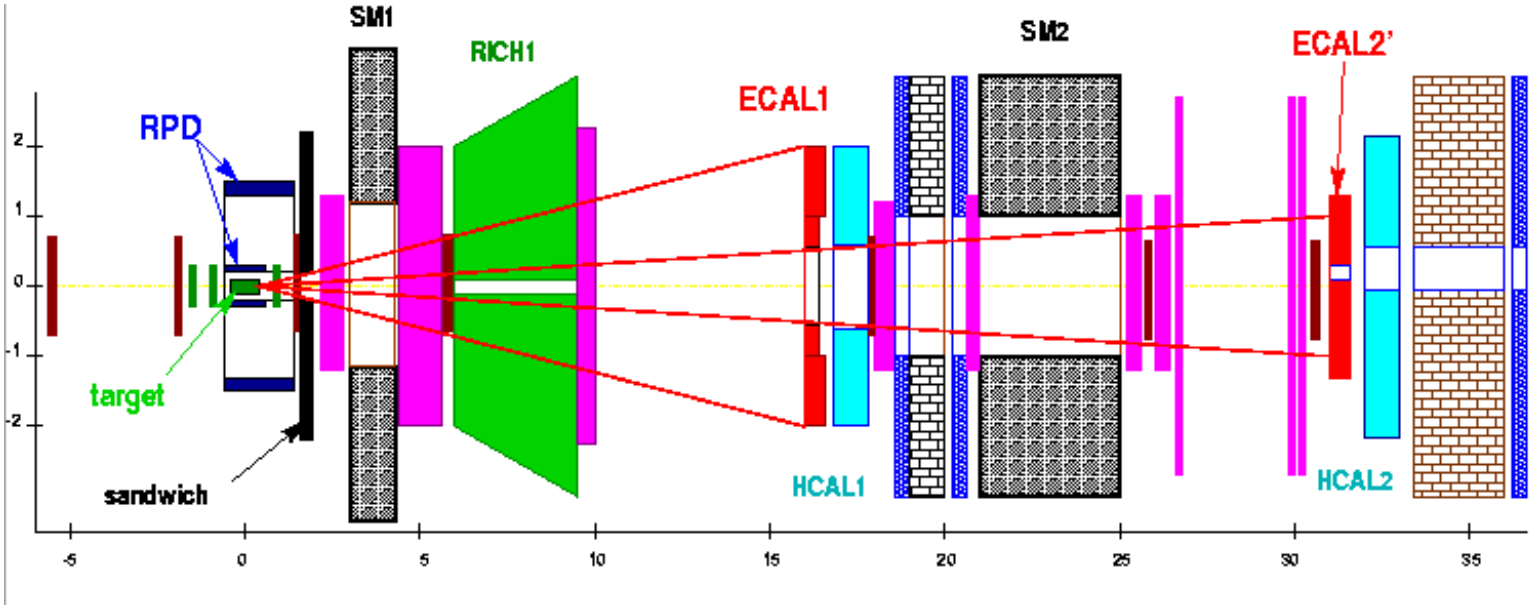
- COMPASS is planning to investigate the production of exotic mesons in central proton-proton collisions

- The feasibility of the measurement has been studied for the case of a centrally produced $\eta\eta$-system, for the decay channels $\eta\eta \to 4\gamma$ and $\eta\eta \to \pi^+\pi^-\pi^0 2\gamma$. That is one possible channel for the study of the lightest glueball candidate ($J^{PC} = 0^{++}$), predicted in the mass range 1.45-1.75 GeV

- The signature of the exotic state is extracted from the PWA of the final state:
  - *a large acceptance for the decay products is needed;*
  - *the detection efficiency must be constant within the acceptance.*

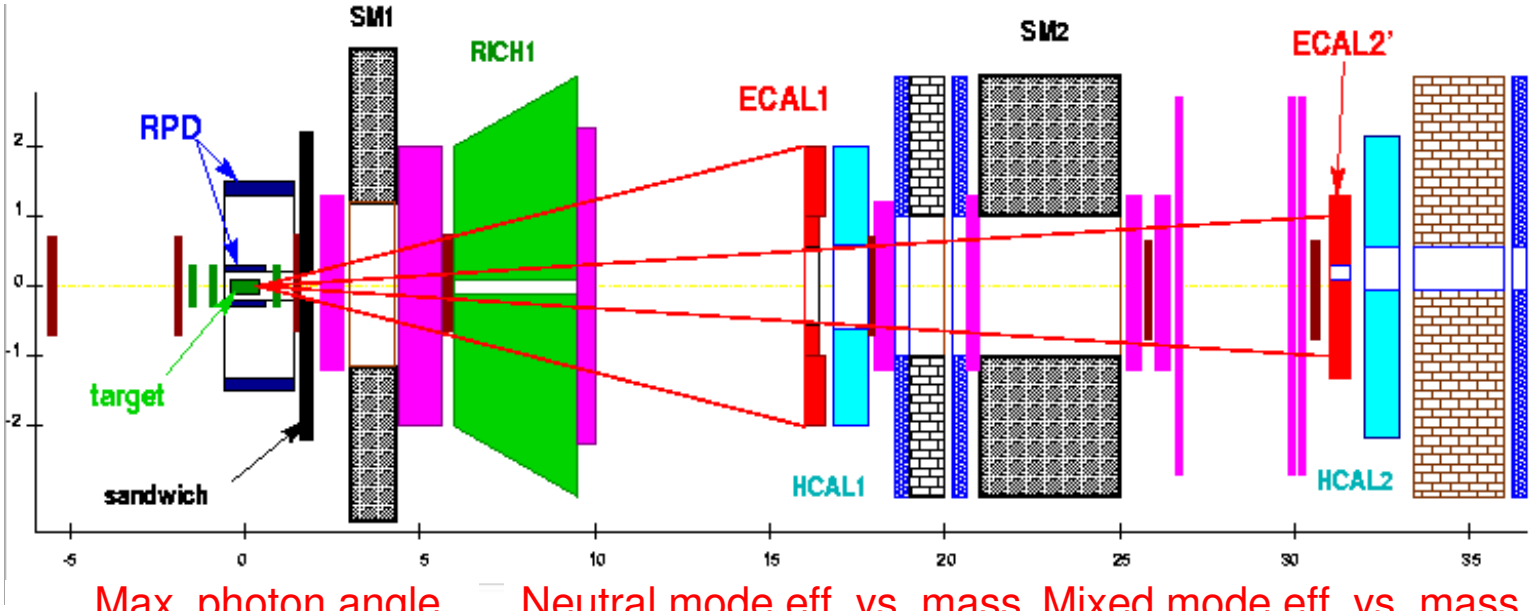
- The first measurement @ COMPASS is foreseen in 2007

The central production experimental layout

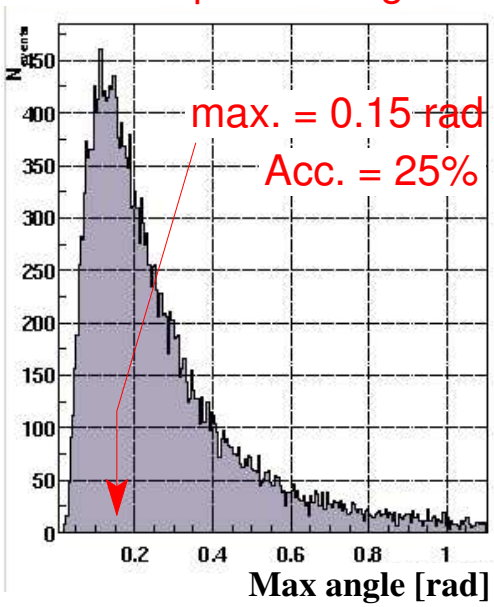


- 280 GeV proton beam
- 40 cm long liquid hydrogen target
- TOF system (RPD) to measure the recoil proton energy
- Two electromagnetic calorimeters (ECAL1 & ECAL2) with complementary acceptances
- RICH1 Cherenkov detector for hadron PID

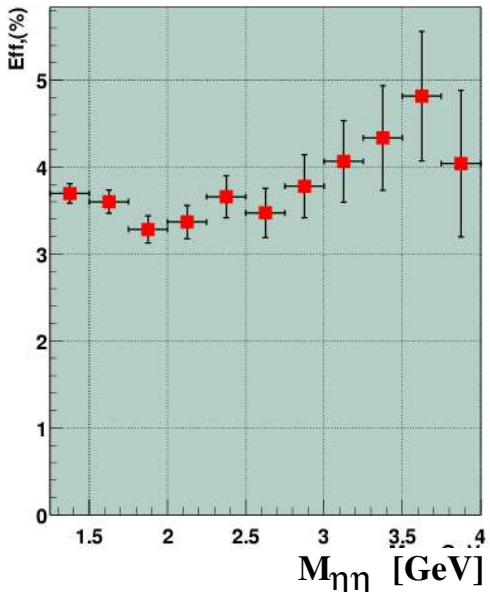
The central production experimental layout



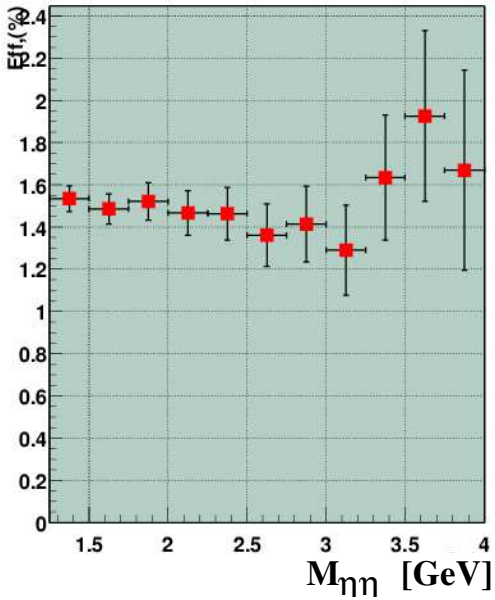
Max. photon angle



Neutral mode eff. vs. mass



Mixed mode eff. vs. mass



Conclusions

- The COMPASS Pilot Hadron Run has been successfully completed during the year 2004; an integrated beam flux of more than 10^{11} pions has been collected for the polarizabilities measurement

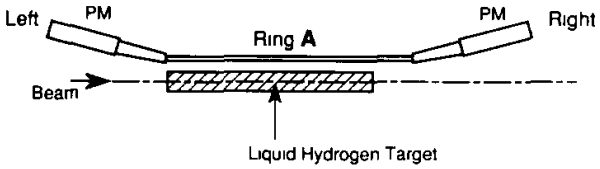
- The preliminary analysis of the hadron data shows that the signature of the Primakoff reaction is clearly seen. The expected statistics is at least 4 times larger than previous experiments.

- In 2007 the study of centrally produced exotic mesons will be addressed, with an expected statistics of ~ 30 events/hour for the $f_0(1500)$ candidate.

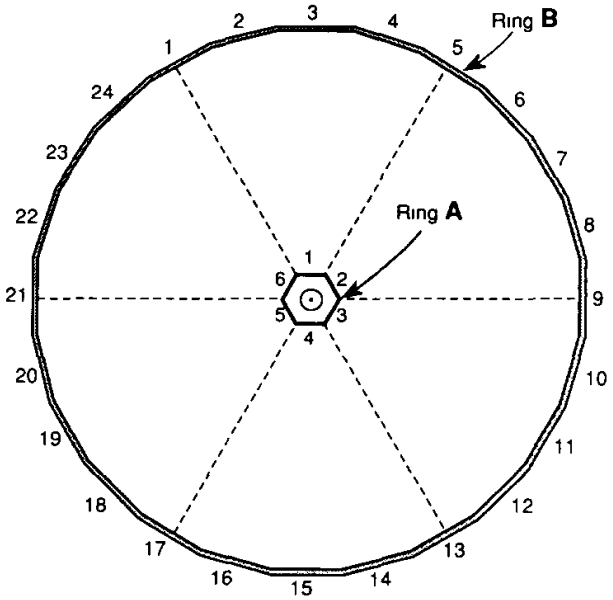
- The feasibility studies show that the COMPASS apparatus is well suited for the PWA of the $\eta\eta$-system. Other channels, as $\eta\eta'$ and K^+K^-, are accessible as well.

The recoil proton detector

Longitudinal cross section



Transversal cross section



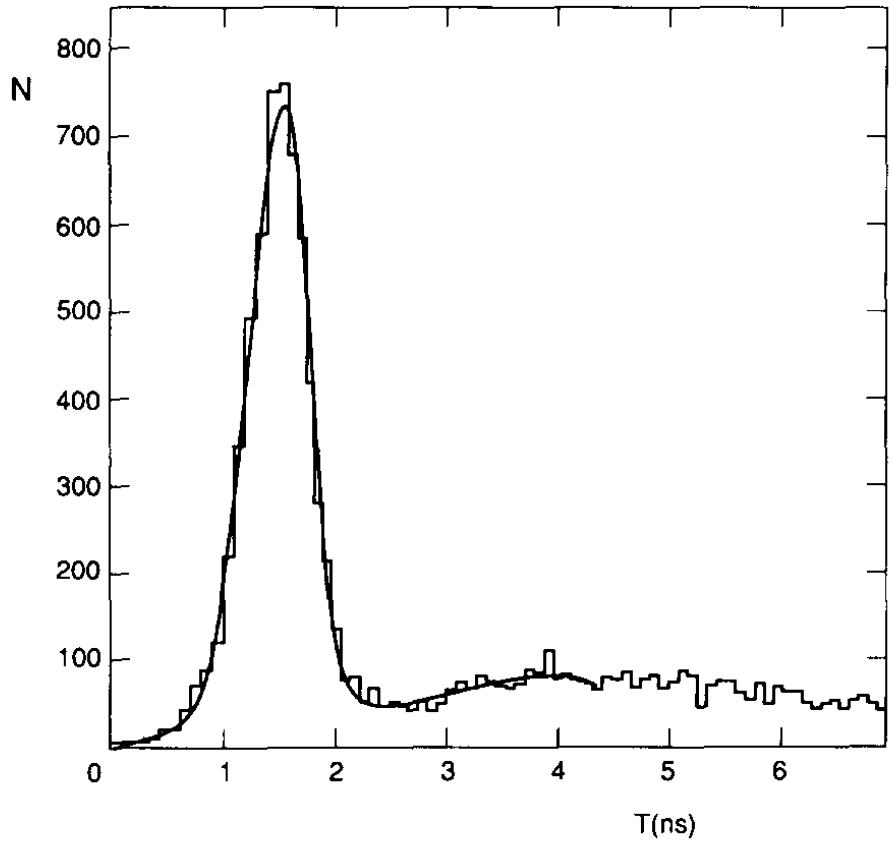


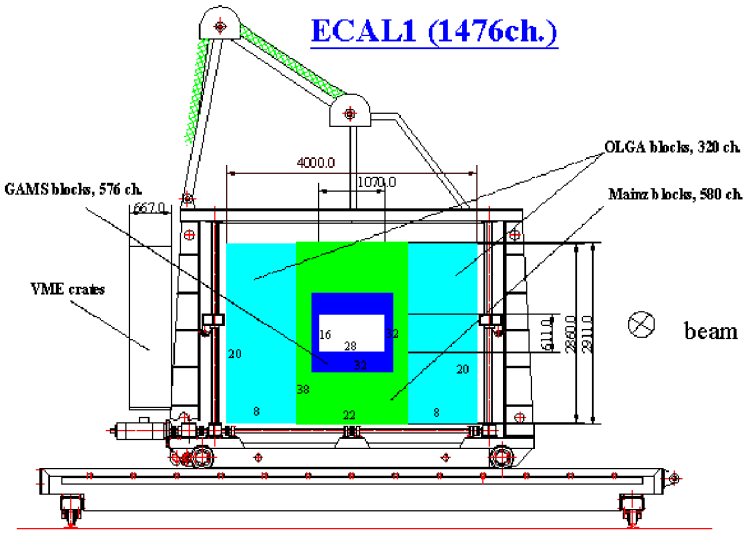
Fig. 7. Typical normalized (flight length) TOF spectrum (T) obtained in a calibration run with a $\beta = 1$ particles, before any corrections. The $\beta = 1$ peak position is located at $T = 1.43$ ns, and $\sigma = 0.263$ ns (combination A6–B23).

The electromagnetic calorimeters

ECAL1:

- ~ 1500 channels in total (3.8×3.8 cm^2, 7.5×7.5 cm^2 and 14.3×14.3 cm^2 blocks)
- Coupled to preshower detector to increase the spatial resolution
- Energy resolution:

$$\frac{\sigma_E}{E} = 2\% + \frac{5.5\%}{\sqrt{E(GeV)}}$$



ECAL2:

- Energy and position of electromagnetic showers measured by a GAMS-type electromagnetic calorimeter
  - 2.44×1.83 *m*^{2} *active area,* 8×8 *cm*^{2} *central hole*
  - *3000 lead-glass blocks, cell size* 3.8×3.8 *cm*^{2}
  - *angular separation* ~ 1 *mrad*
- Energy resolution:

$$\frac{\sigma_E}{E} = 1.5\% + \frac{5.5\%}{\sqrt{E(GeV)}}$$

- Spatial resolution: $\sigma_{x,y} = \frac{6mm}{\sqrt{E(GeV)}}$