Soft hadronic interactions in the COMPASS experiment

Andrea Ferrero - University of Torino and I.N.F.N.
On behalf of the COMPASS Collaboration

Advanced Studies Institute - Simmetries and Spin

Prague July 5 - 10, 2004

- **Physics motivations**
- **Experimental requirements**
- **The COMPASS hadron setup**
- **Summary**

The COMPASS physics progam

COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

lepton probes

photons

hadronic probes

Δ G

Structure functions

π, K, Σ

Polarisability

χ Anomaly

Glueballs

Exotic

Mesons

cc−Baryon

c−prod

μ beam

Hadron beam

Physics with the Muon beam

Gluon polarization

Longitudinal and transversal spin distribution

Polarization of Λ and $\bar{\Lambda}$

Physics with the Hadron beam

Study of charm baryons

Study of gluonic systems

Hadron structure with virtual photons

Exotic hadrons

The COMPASS physics progam

COmmon **M**uon and **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

lepton probes | photons | hadronic probes

Δ G

Structure functions

π, K, Σ

Polarisability

χ Anomaly

Glueballs

Exotic

Mesons

cc−Baryon

c−prod

μ beam | Hadron beam

Physics with the Muon beam

Gluon polarization

Longitudinal and transversal spin distribution

Polarization of Λ and $\bar{\Lambda}$

Physics with the Hadron beam

Study of charm baryons

Study of gluonic systems

Hadron structure with virtual photons

Exotic hadrons

Physics goals

- Primakoff: precise measurement of pion electric and magnetic polarizabilities, as a test of χPT predictions (see previous talk)

- Diffractive production: study of exotic hadrons produced diffractively in the reaction

$$\pi^- N \rightarrow XN$$

with squared four momentum transfer $t < 1(GeV/c)^2$

Diffractive production of exotics

- Several groups have reported the observation of the π_1-resonances with $J^{PC} = 1^{-+}$ at masses of 1.4, 1.6 and 2 GeV in the channels:
  - $\eta(2\gamma, \pi^+\pi^-\pi^0)\pi^-$,
  - $\eta'(\eta(2\gamma)\pi^+\pi^-)\pi^-$,
  - $\rho^0(\pi^+\pi^-)\pi^-$ and
  - $b_1(\Omega(782)\pi)\pi$-systems.
- Still no full consensus on the treatment of the nature of these phenomena
- A PWA of the diffractively produced $\eta\pi$-system shows that 2 waves are significant:
  - $J^P = 2^+$ with the intensively produced $a_2(1320)$ (denoted by $D+$)
  - $J^P = 1^-$ with exotic quantum numbers (denoted by $P+$)

Experimental overview

- Evidence for $J^{PC} = 1^{-+}$ exotics:

Exp.	mass (MeV)	width (MeV)	reaction
BNL	1359^{+16+10}_{-14-24}	314^{+31+9}_{-29-66}	$\pi^- p \rightarrow \eta\pi^- p$
CBar	$1400 \pm 20 \pm 20$	$310 \pm 50^{+50}_{-30}$	$\bar{p}n \rightarrow \pi^-\pi^0\eta$
CBar	1360 ± 25	220 ± 90	$\bar{p}p \rightarrow \pi^0\pi^0\eta$
VES	$(1316 \pm 12)?$	$(287 \pm 25)?$	$\pi^- Be \rightarrow \eta\pi^- Be$

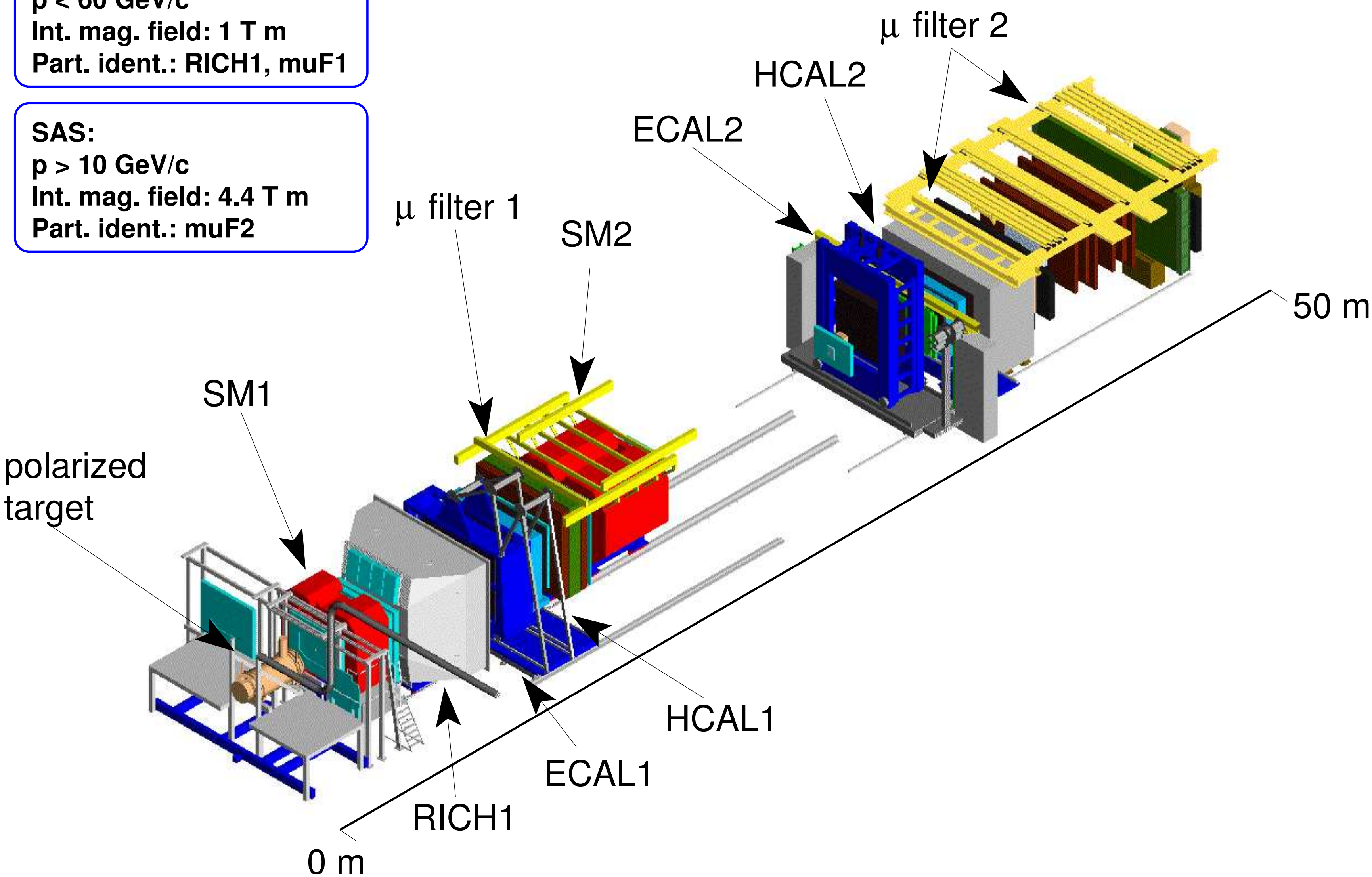
- More accurate measurements are needed to confirm the resonant nature of the $P+$ wave.

- COMPASS has a chance to study the $\eta\pi$, $\eta'\pi$, $\rho^0\pi^-$, $b_1\pi$ and $f_1\pi$-systems with large statistics

The COMPASS spectrometer

LAS:
p < 60 GeV/c
Int. mag. field: 1 T m
Part. ident.: RICH1, muF1

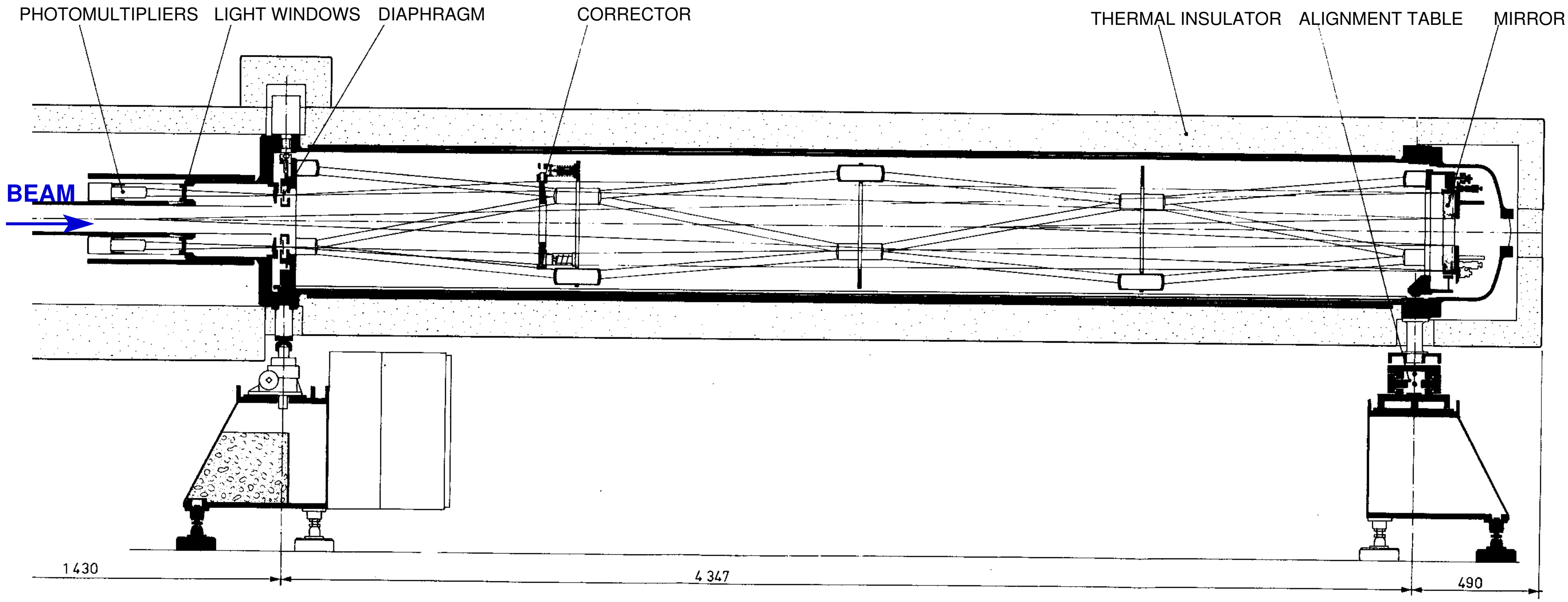
SAS:
p > 10 GeV/c
Int. mag. field: 4.4 T m
Part. ident.: muF2



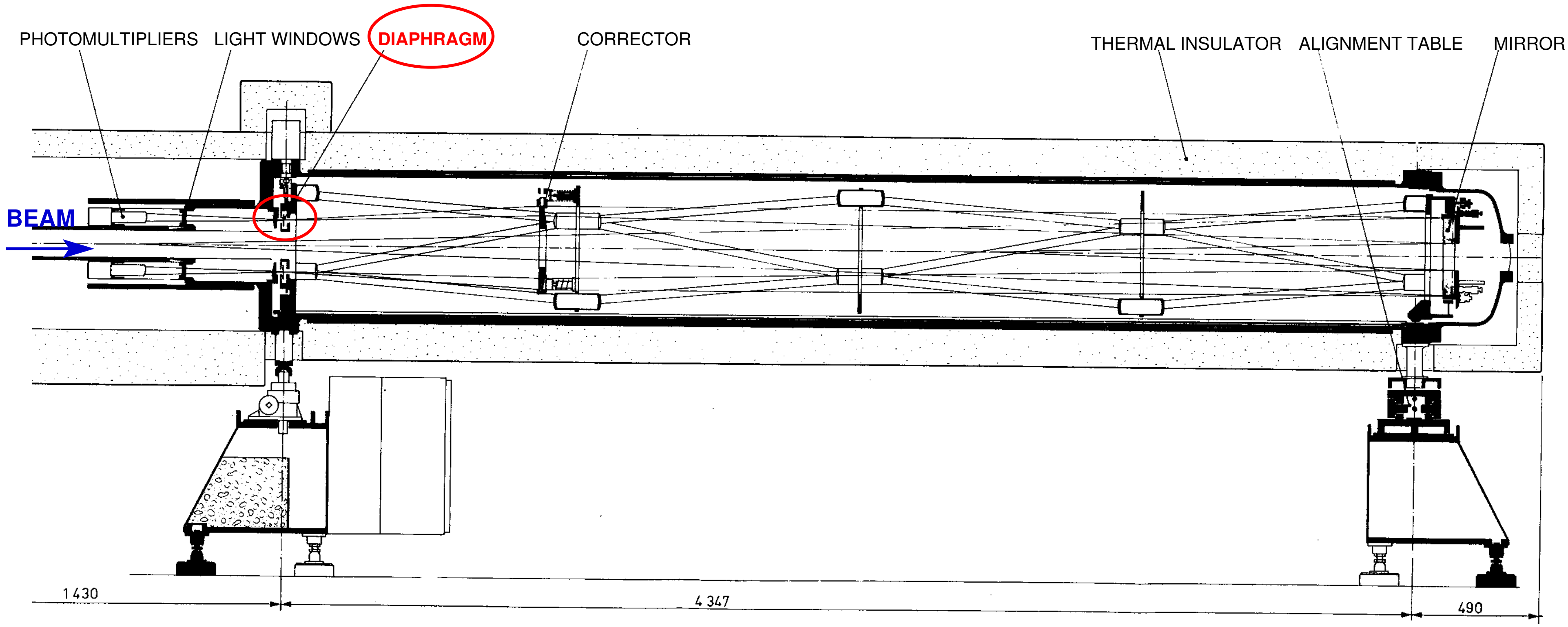
Characteristics of the beam

- Both primakoff and diffractive production programs will use a 190 GeV π^- beam
  - spill structure of 4.8 s every 16.8 s
  - maximum intensity of 10^7 π^-/spill
  - 4% contamination of K^-
  - $\sim 0.5\%$ contamination of $\overline{p}$
- beam momentum spread is $\sim 0.7\%$ $\longrightarrow$ no measurement of beam momentum
- Kaon tagging is performed by means of CEDAR (CErenkov Differential counter with Achromatic Ring Focus) counters:
  - need very high beam parallelism to be operated
  - can allow for
    * K^- background rejection
    * measurement of K^- polarizabilities

The CEDAR counters



The CEDAR counters



Key features:

- Diaphragm to select photons with the required cherenkov angle
- High precision pressure measurement to define the working point of the detector

The measured CEDAR response

Pressure scan @175 GeV performed during original commissioning:

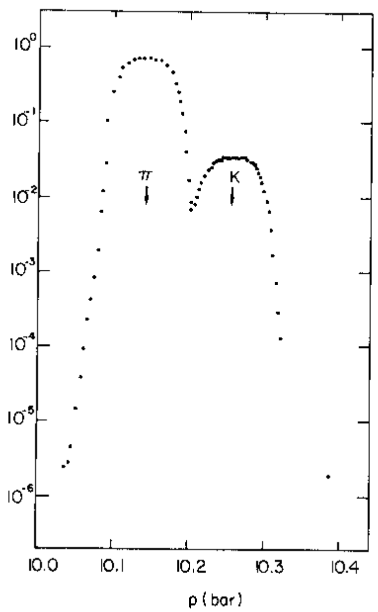


Fig. 22 LD = 0.50 mm

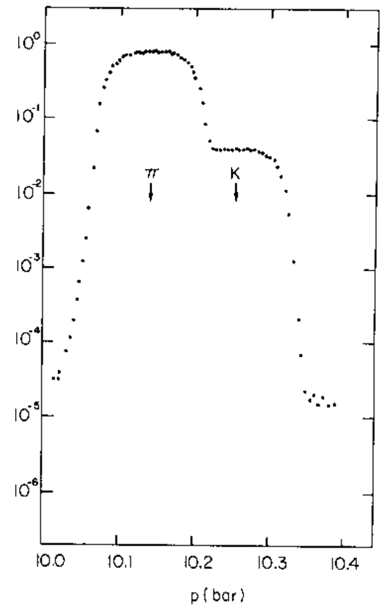


Fig. 23 LD = 0.71 mm

CEDAR-N pressure scan showing the π/K separation in the H6 beam running at -175 GeV/c.

The measured CEDAR response

Pressure scan @175 GeV performed during original commissioning:

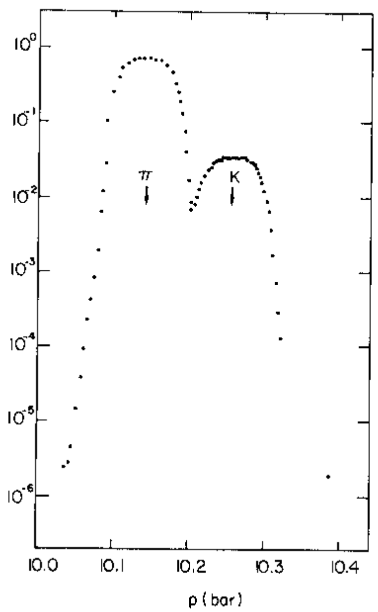


Fig. 22 LD = 0.50 mm

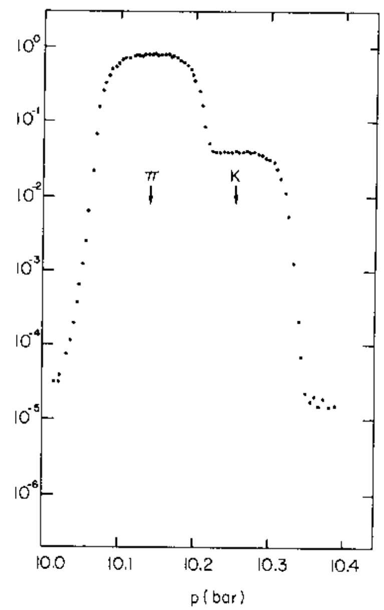
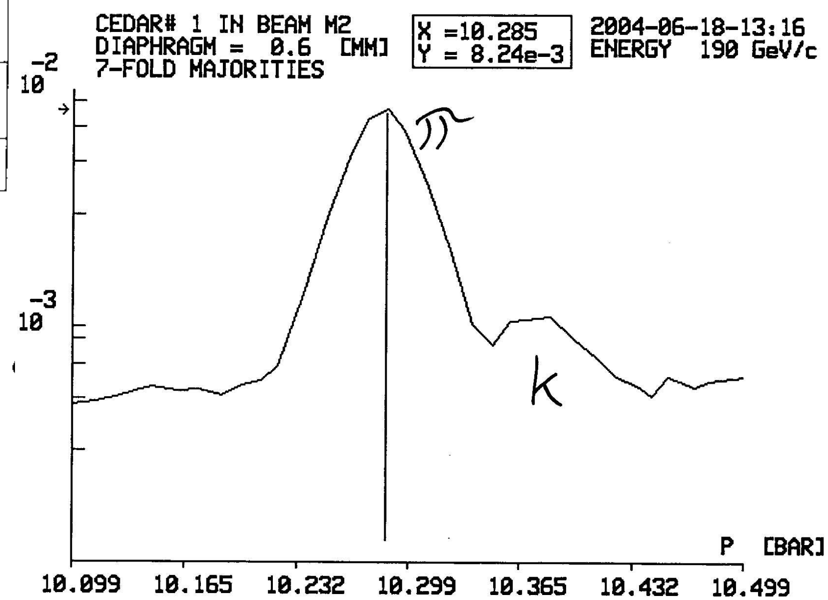


Fig. 23 LD = 0.71 mm

CEDAR-N pressure scan showing the π/K separation in the H6 beam running at -175

Pressure scan @190 GeV performed during test beam this year →



Experimental requirements: Primakoff

- Excellent reconstruction of incident and scattered pion angles

Experimental requirements: Primakoff

- Excellent reconstruction of incident and scattered pion angles
- Separation of beam and scattered pions up to $p_{\pi^-} = 100$ GeV/c

Experimental requirements: Primakoff

- Excellent reconstruction of incident and scattered pion angles
- Separation of beam and scattered pions up to $p_{\pi^-} = 100$ GeV$/c$
- Resolution on scattered pion momentum $\sigma_p/p < 1\%$

Experimental requirements: Primakoff

- Excellent reconstruction of incident and scattered pion angles
- Separation of beam and scattered pions up to $p_{\pi^-} = 100$ GeV$/c$
- Resolution on scattered pion momentum $\sigma_p/p < 1\%$
- Resolution on emitted photon energy $\sigma_E/E < 2\%$

Experimental requirements: Primakoff

- Excellent reconstruction of incident and scattered pion angles
- Separation of beam and scattered pions up to $p_{\pi^-} = 100$ GeV$/c$
- Resolution on scattered pion momentum $\sigma_p/p < 1\%$
- Resolution on emitted photon energy $\sigma_E/E < 2\%$
- Selective trigger for primakoff events in the range

$$0 < p_{\pi^-} < 100 \text{ GeV}/c$$

Experimental requirements: diffractive production

- Full reconstruction of the $\eta\pi^-$ state, through the decay chain

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

Experimental requirements: diffractive production

- Full reconstruction of the $\eta\pi^-$ state, through the decay chain

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

- Selection of events with 3 charged particles $+$ 2 γ

Experimental requirements: diffractive production

- Full reconstruction of the $\eta\pi^-$ state, through the decay chain

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

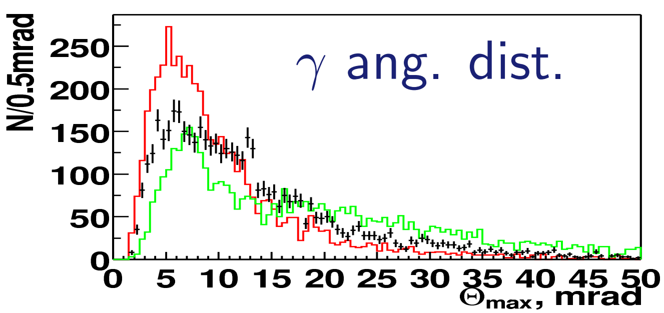
- Selection of events with 3 charged particles $+$ 2 γ
- Constant detection efficiency over the full range of pion emission angles

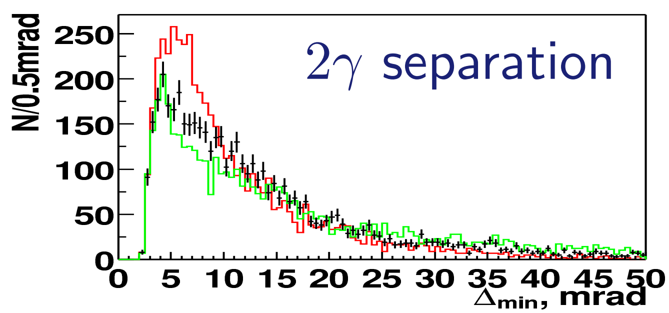
Experimental requirements: diffractive production

- Full reconstruction of the $\eta\pi^-$ state, through the decay chain

$$\eta \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$$

- Selection of events with 3 charged particles + 2 γ
- Constant detection efficiency over the full range of pion emission angles
- Efficient reconstruction of π^0 in the electromagnetic calorimeter
  - angular separation of γs from π^0 decay peaks at ≥ 3 mrad





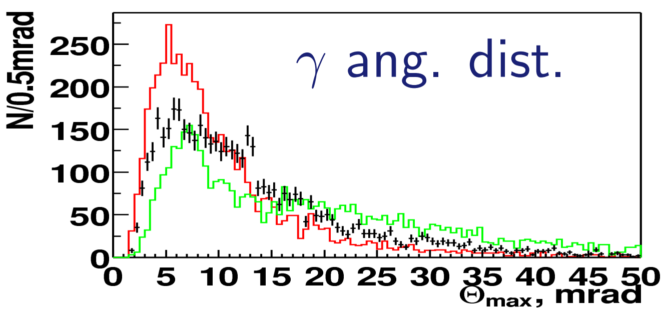
$M_{4\pi} = 0.92$ GeV
$M_{4\pi} = 1.32$ GeV
$M_{4\pi} = 2.12$ GeV

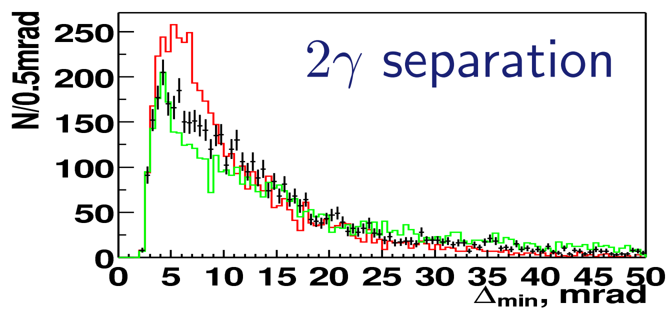
Experimental requirements: diffractive production

- Full reconstruction of the $\eta\pi^-$ state, through the decay chain

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

- Selection of events with 3 charged particles + 2 γ
- Constant detection efficiency over the full range of pion emission angles
- Efficient reconstruction of π^0 in the electromagnetic calorimeter
  - angular separation of γs from π^0 decay peaks at ≥ 3 mrad



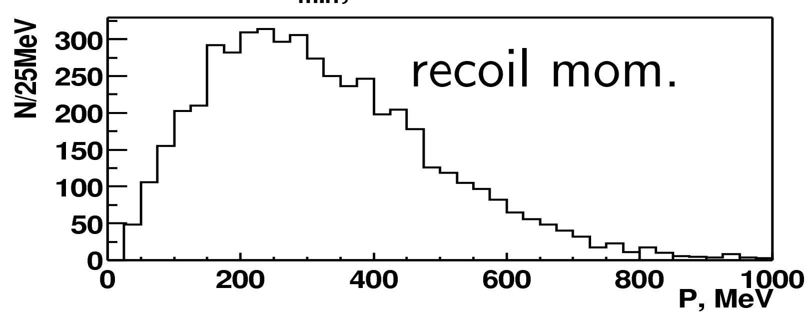


$M_{4\pi} = 0.92$ GeV

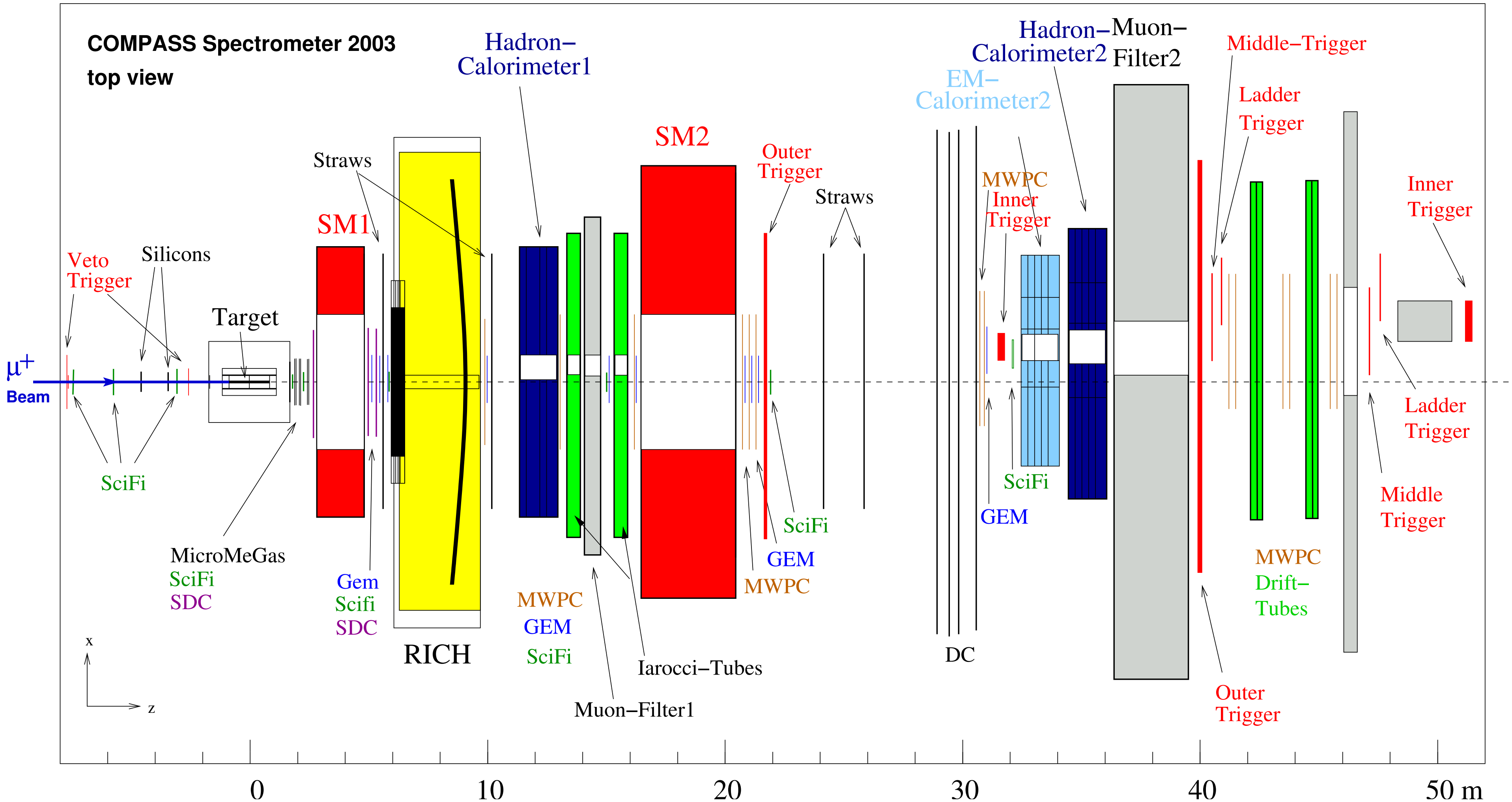
$M_{4\pi} = 1.32$ GeV

$M_{4\pi} = 2.12$ GeV

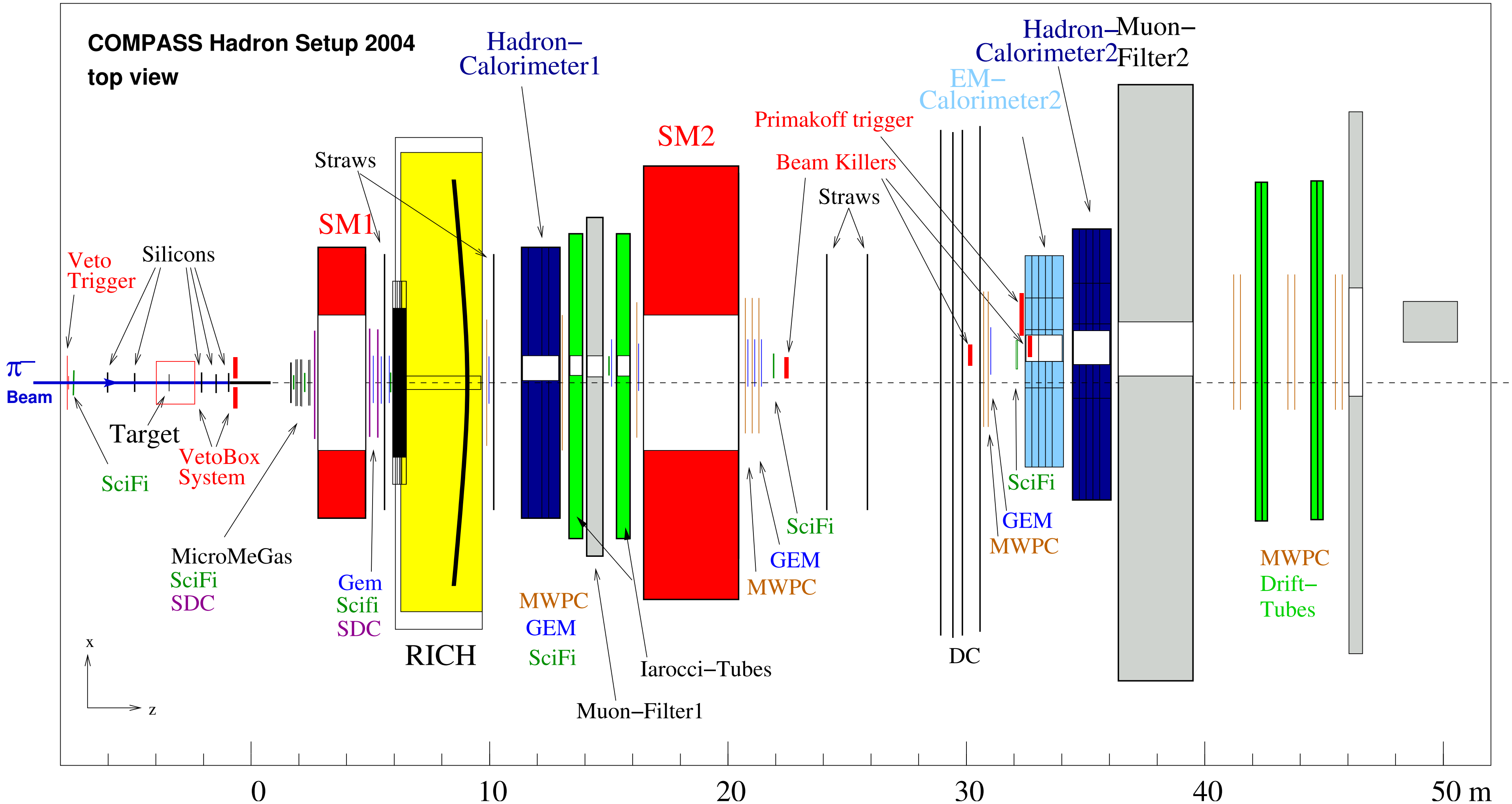
- Rejection of hard interactions in the target:



The COMPASS experimental apparatus

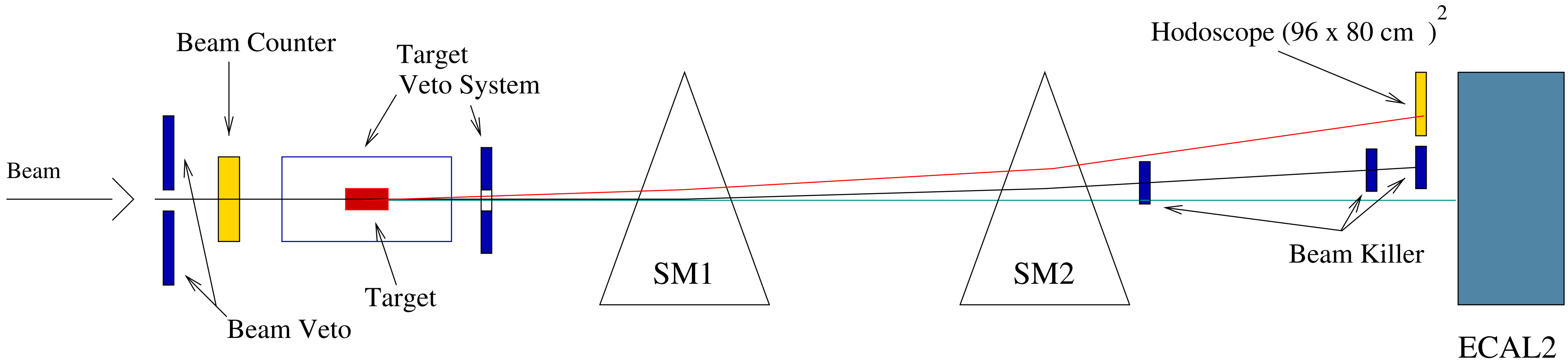


Experimental apparatus for the hadron program



- Primakoff and diffractive programs share the same experimental apparatus
- The different trigger logics compete toghether to form the first level trigger

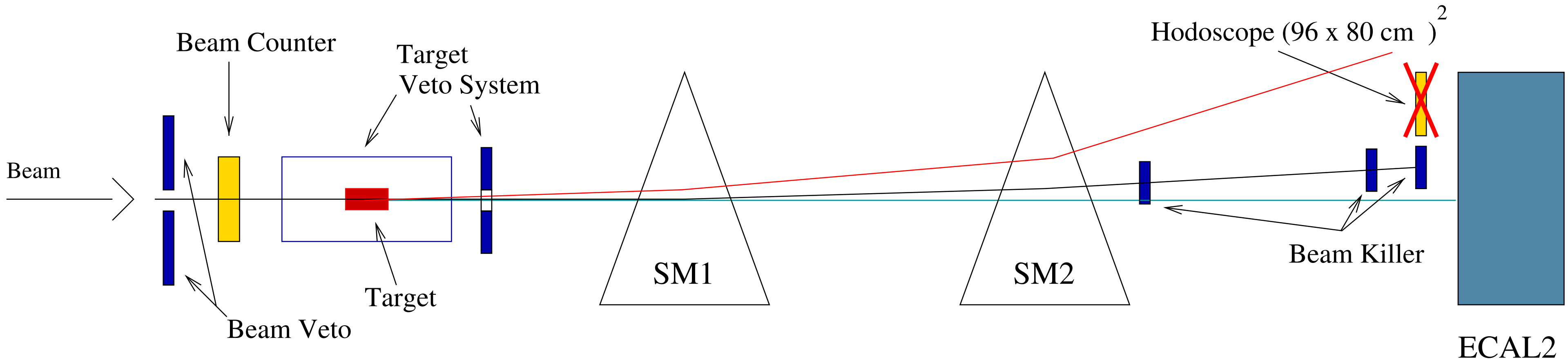
The Primakoff trigger



- Hodoscope acceptance:
  $20 < p_{\pi^-} < 100$ GeV$/c$, corresponding to $90 < E_\gamma < 170$ GeV

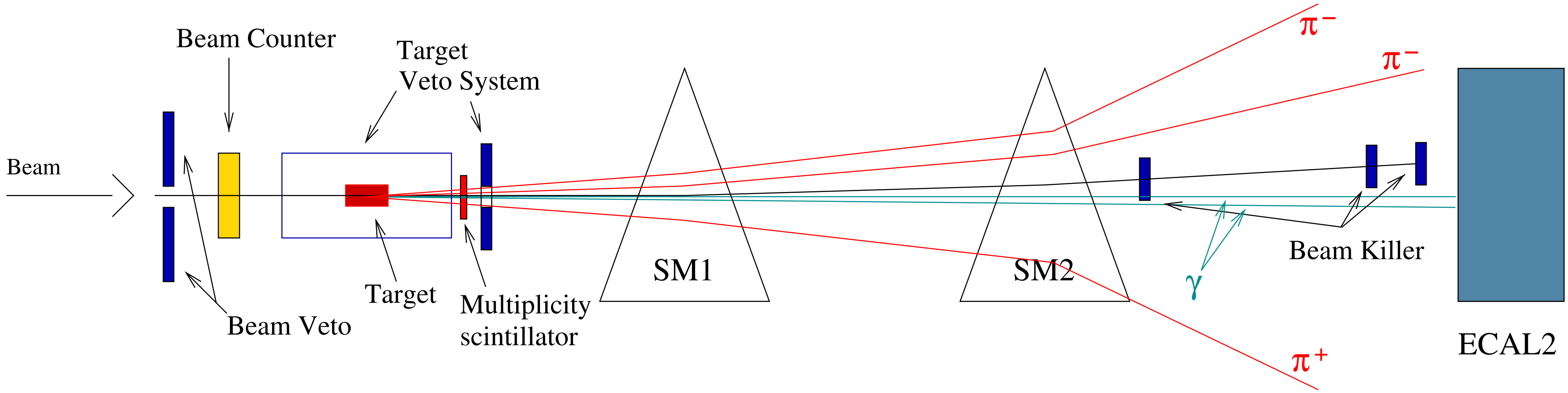
- Trigger logic: $beam + hodo + E_\gamma > 40$ GeV
  - beam is defined by SciFi detector $+$ veto system to select interactions in the target
  - multiplicity logic for the hodoscope selects events with 1 single cluster (1 or 2 adiacent slabs fired)

The Primakoff trigger



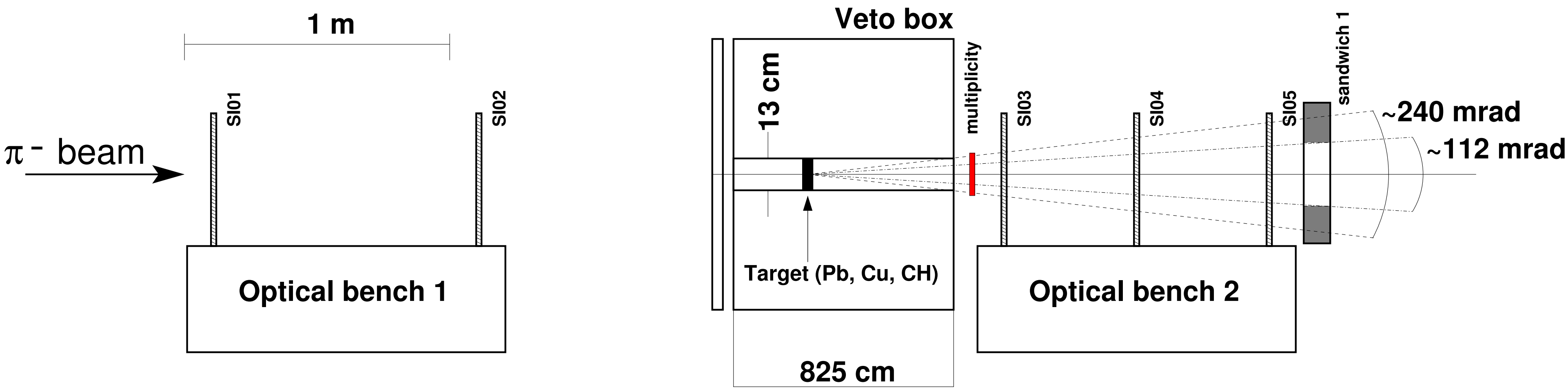
- Hodoscope acceptance:
  $20 < p_{\pi^-} < 100$ GeV$/c$, corresponding to $90 < E_\gamma < 170$ GeV
- Trigger logic: $beam + hodo + E_\gamma > 40$ GeV
  - beam is defined by SciFi detector + veto system to select interactions in the target
  - multiplicity logic for the hodoscope selects events with 1 single cluster (1 or 2 adiacent slabs fired)
- A second γ energy threshold allows to recover events with $p_{\pi^-} < 20$ GeV$/c$.

The diffractive trigger



- Designed to select events with soft recoil proton and ≥ 2 charged particles in the final state
- Trigger logic: $beam + \overline{beamkillers} + \overline{vetobox} + mult \geq 2$
- Beam definition as for the Primakoff case
- Beam killers: rejection of non-interacting pions by means of 3 small scintillators centered on the beam trajectory
- multiplicity: threshold on light produced in a thin scintillator located immediately downstream of the target, combined with cluster multiplicity in the hadronic calorimeters

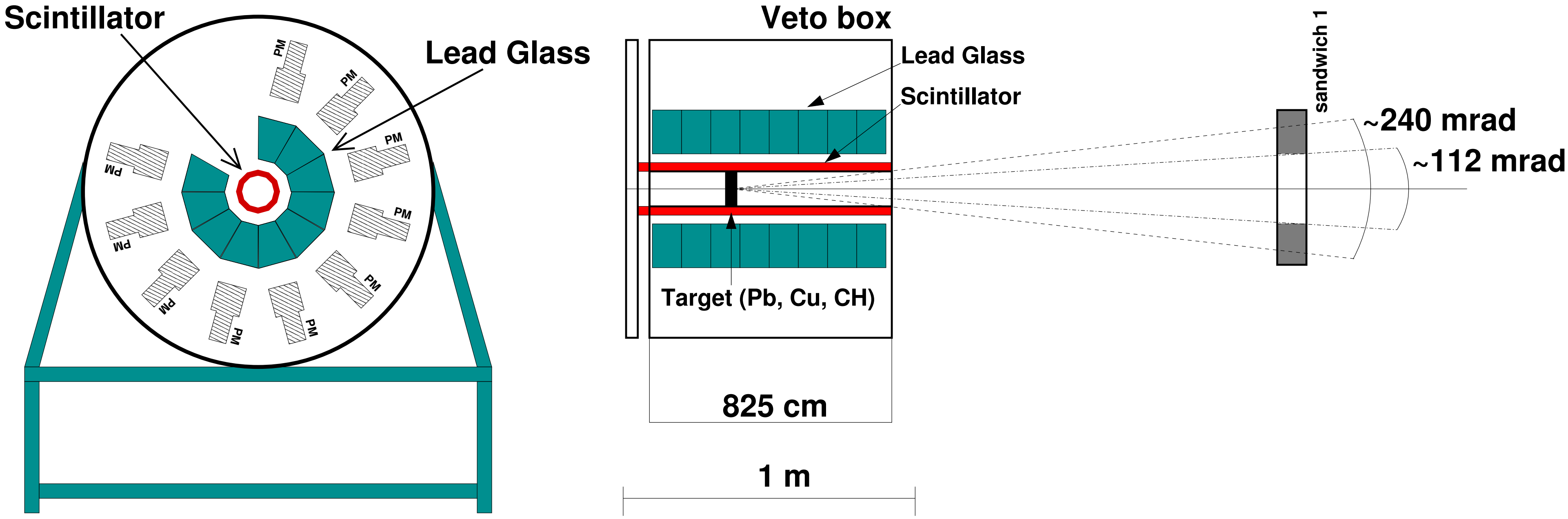
The target region



- Incoming and scattered pion trajectories precisely determined by means of 2 silicon telescopes:
  - each silicon station provides 4 coordinates
  - $\sim 20\ \mu$m spatial resolution
  - ~ 5 ns time resolution
- "Hard" recoil nucleon detected in the Veto Box
- One veto counter downstream the target matches the acceptance of the eletromagnetic calorimeter
- The multiplicity counter provides information on the number of charged particles produced in the target

The Veto Box

Front cross–section Side cross–section



- The detector is a barrel divided into 12 sectors, each composed of:
  - 1 scintillator plate close to the central hole
  - 1 row of 8 lead glass blocks, read by photomultipliers
- A light target holder allows the positioning of discs of different materials at 1/3 of the hole length

The electromagnetic calorimeter

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

Expected event rates

- Primakoff: $2.64 \cdot 10^5$ evt./day (see previous talk)

- Diffractive production:
  $N_{a_2 \to \eta\pi} \approx 5 \cdot 10^4$/day,
  $N_{P+(\eta\pi)} \approx 2.5 \cdot 10^3$/day, assuming
  - 10^8/min incident beam flux
  - detection efficiency $\epsilon = 0.25$

Summary

- The feasibility studies show good perspectives for the Primakoff and diffractive production programs at COMPASS.

Summary

- The feasibility studies show good perspectives for the Primakoff and diffractive production programs at COMPASS.

- The switch between muon and hadron COMPASS setups takes < 10 days.

Summary

- The feasibility studies show good perspectives for the Primakoff and diffractive production programs at COMPASS.

- The switch between muon and hadron COMPASS setups takes < 10 days.

- All the required devices are tested and ready for data taking.