The PixelGEM High-Rate Tracking System of COMPASS

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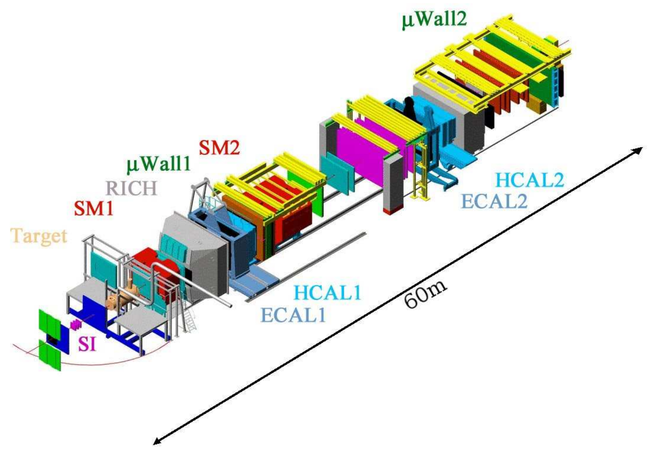
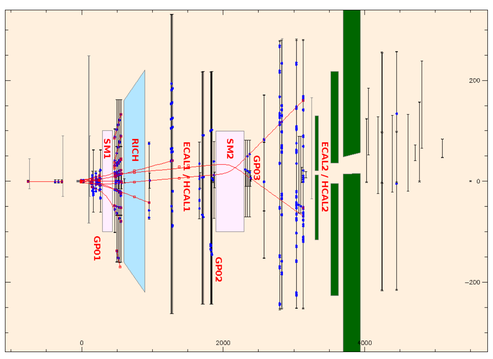
COMPASS COmmon Muon and Proton Apparatus for Structure and Spectroscopy

- fixed target experiment
- located at the SPS at CERN
- data taking since 2002
- Physics objectives
  - hadron spectroscopy
  - nucleon spin structure
- two types of beam
  - $2.5 \cdot 10^6$/s hadronic beams (π^- or p, π^+)
  - $1 \cdot 10^7$/s muonic beams



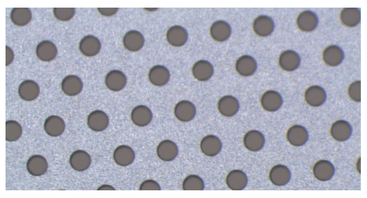
Detectors in operation



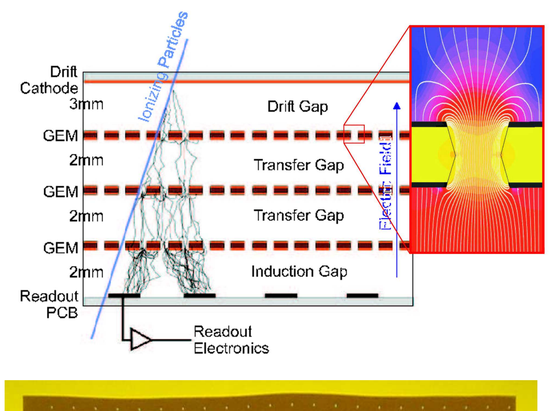
- five detectors installed before the start in 2008
- one single detector (GP01)
- two stations with two detectors (GP02 and GP03)
- replacing scintillating fibre detectors during hadron runs
- increasing the performance of the beam tracking in muon beam: → scintillating fibre detectors and PixelGEMs

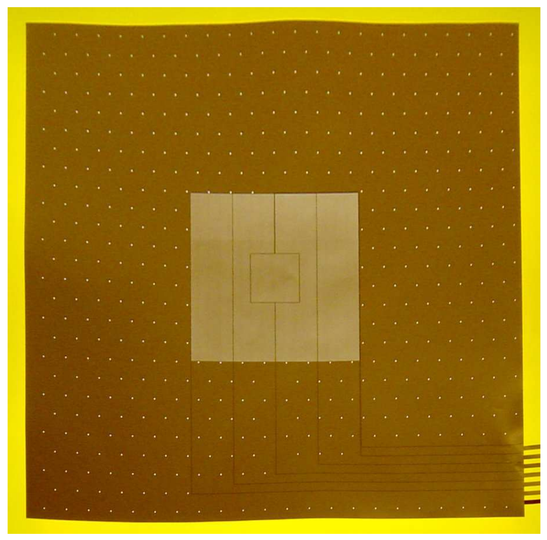
Gas Electron Multiplier

- gas amplification in holes
- three-fold staggered
  - to minimise electric field across one foil (discharge probability)
  - gain still high enough for clear signal detection
    - about 6000 for (one-layered) pixels
    - about 8000 for two-layered strips with equal charge sharing
- electric field in the holes $50\,\mathrm{kV/cm}$, transfer field $5\,\mathrm{kV/cm}$
- $70\,\mu$m hole diameter, $140\,\mu$m pitch



- 10^4 holes per cm^2
- segmented amplification regions
- amplification separated from readout
- GEM foil etched from
  - $50\,\mu$m polyimide foil
  - covered with $2\,\mu$m of copper on both sides

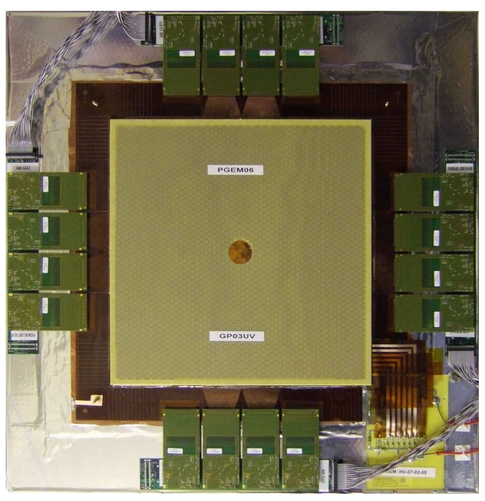




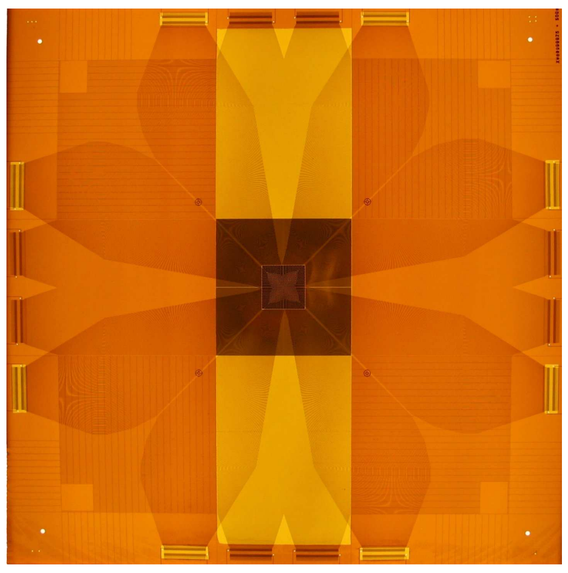
Assembled detector

- lightweight honeycomb structure
- frames made of glass fabric laminate

- material budget $2.2\,‰\,X_0$ in the centre
- $5.5\,‰\,X_0$ in the periphery



Readout foil



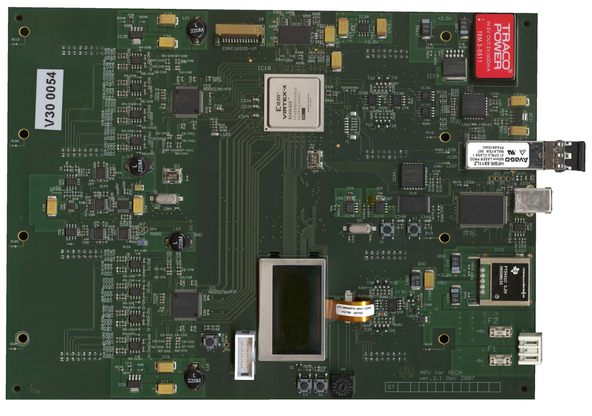
- same base material as GEM foils
- three conductive layers ($5\,\mu$m copper)
- total thickness $100\,\mu$m

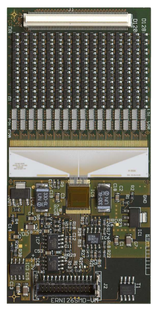
centre
- $32 \times 32\,\mathrm{mm}^2$
- 32×32 pixels

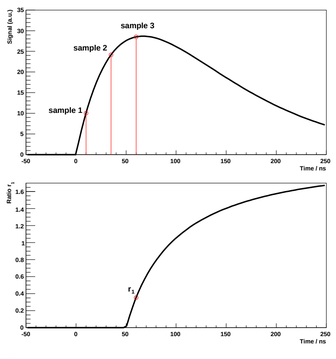
periphery
- total active area $100 \times 100\,\mathrm{mm}^2$
- $2 \times 2 \times 256$ strips (two layers, two hemispheres)
- $394\,\mu$m pitch
- different widths in the two layers for equal charge sharing

Front-end electronics

- ADC card (own development)
  - using Virtex4 FPGA
  - digitalisation of 16 APV chips
  - common mode correction, zero suppression







- APV25-S1 ASIC
  - 128 channels per chip
  - 16 chips per detector
  - analogue sampling with $40\,\mathrm{MHz}$
  - three samples saved upon a trigger
- time reconstruction from known pulse shape of the ratios $r_{1,2}$ of sample 1 (respectively 2) over sample 3

$$r(t) = \frac{r_0}{1 + \exp\left(\frac{t - t_0}{a_0}\right)} \quad \Rightarrow \quad t(r)$$

Strip performance

similar to standard COMPASS GEMs, therefore only performance of the pixel part shown

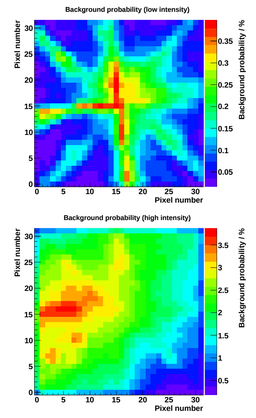
Background correction for efficiency

apparent efficiency $\varepsilon_{\mathrm{app}} = \dfrac{\text{number of detected tracks}}{\text{number of tracks in active area}}$

- sensitive to the size of the area around a track searched for a signal
- false combinations of a track with noise signals

background correction to get the real efficiency $\varepsilon = \frac{\varepsilon_{\mathrm{app}} - b}{1 - b}$

- 1^{st} two-dimensional map counting clusters outside the searched area
- 2^{nd} two-dimensional map to normalise the 1^{st} map to the non-searched area
- background probability per cell is calculated from those maps
- total background probability takes the relative area of the cells covered by the searched area into account



Performance at low beam intensities

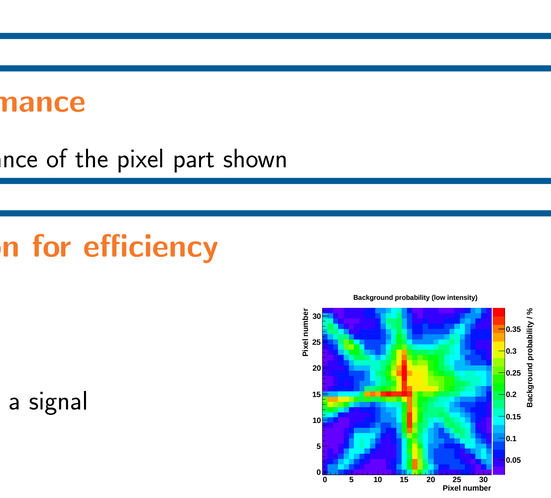
Low beam intensities

- beam intensity $4.7 \cdot 10^5 \pi^-/\mathrm{s}$
- maximal flux $3.5 \cdot 10^3 \pi^- / (\mathrm{mm} \cdot \mathrm{s})$
- efficiency above $99\,\%$
- mean spatial resolution of $91.3\,\mu$m
- temporal resolution better than $8.5\,$ns

High beam intensities

- beam intensity $9.6 \cdot 10^6 \mu^+/\mathrm{s}$
- efficiency better than $96\,\%$
- mean spatial resolution below $155\,\mu$m
- temporal resolution of $10\,$ns

Performance at high beam intensities



Biased performance
(detectors included in reconstruction)

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