A scintillating fibre beam profile monitor for the experimental areas of the SPS at CERN

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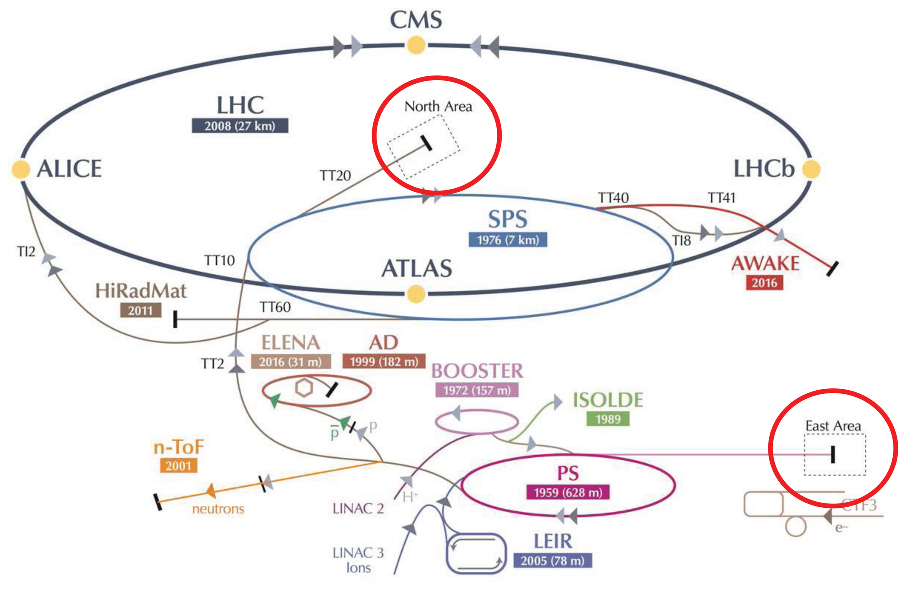
Abstract

The CERN Super Proton Synchrotron (SPS) delivers a wide spectrum of particle beams (hadrons, leptons and heavy ions) that can vary greatly in momentum and intensity. The profile and position of these beams are measured using particle detectors. However, the current systems show several problems that limit the quality of such monitoring. We have researched a new monitor made of scintillating fibres read-out with Silicon Photomultipliers (SiPM) or Multi-Anode Photomultipliers (MAPMT), which has the potential to perform better in terms of material budget, range of intensities measured and available detector size. In addition, it also has particle counting capabilities, extending its use to spectrometry or Time-Of-Flight measurements. Its radiation hardness is good to guarantee years of functioning. We have successfully tested a first prototype of this detector with different particle beams at CERN, giving accurate profile measurements over a wide range of energies and intensities. It only showed problems during operation with lead ion beams, believed to come from crosstalk between the fibres. Investigations are ongoing on alternative photodetectors, the electronics readout and solutions to the fibre crosstalk.

Motivation

- Need to replace existing monitors: multi-wire proportional chambers (MWPC) , delay wire chambers (DWC) and scintillator finger scanner (FISC).
- New beamlines with special requirements:
  - Low energies: down to 500 MeV.
  - Low intensities: 100 particles/second.
  - Large active area: 200mm × 200mm.
  - Particle counting, Time-of-Flight.



The experimental areas at CERN

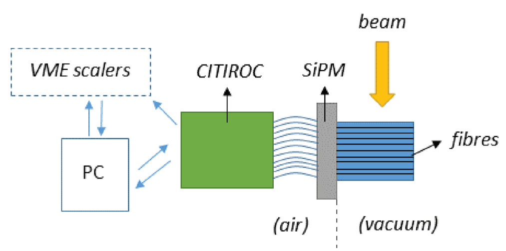
Scintillating fibres

Have emerged as one of the best active materials for a profile monitor:

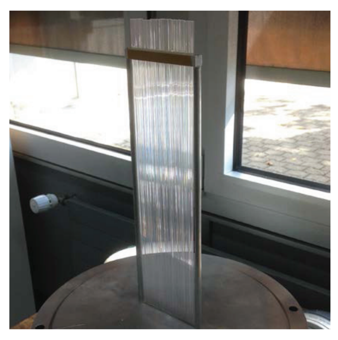
- Low material budget: x/X_0.
- Good spatial and time resolution.
- Radiation hard.
- Suitable for vacuum.
- Big active area.

First prototype

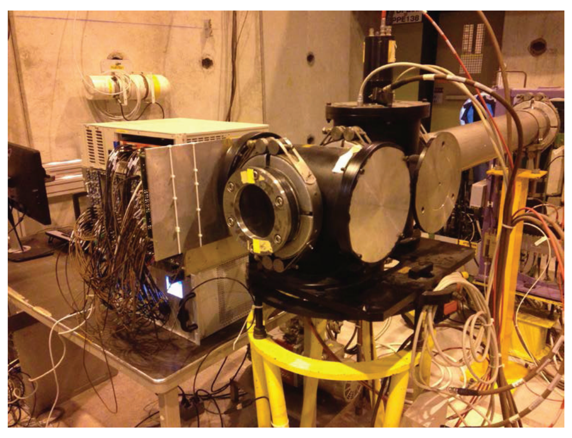
- One plane of 64 square fibres packed together along one row with no space between them → active area of 64mm x 64mm.
- Scintillating fibres Saint-Gobain BCF-12, 1mm thickness, multi-cladded.
- Silicon photomultipliers (SiPM) as photodetector to read the light from the fibres.
- One 1.3mm x 1.3mm SiPM coupled to one end of every fibre.
- An aluminium mirror glued on the other end to increase the light collected.
- The CITIROC ASIC for the readout electronics.
- VME scalers for data acquisition → profile and intensity measurements.
- Detector installed in vacuum: fibres in vacuum and SiPM in air.



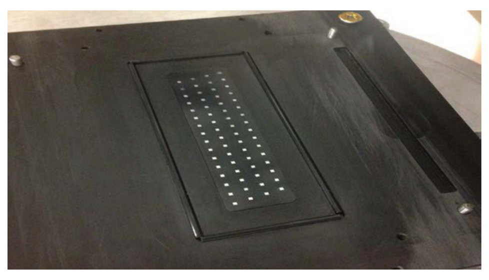
Schematic of the detector showing its main parts



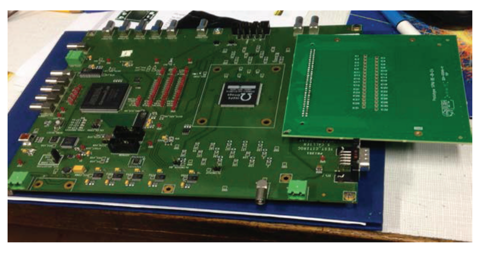
The plane of fibres being glued



The SciFi monitor installed in the H8 beam line at CERN: the vacuum tank in the centre houses the fibres, while the SiPM and the electronics stay on the outside (left of the figure)



Fibre conector showing the part where the SiPM are coupled



The CITIROC board with the SiPM PCB pluged onto it

Beam tests

The prototype was tested in the North Area at CERN:

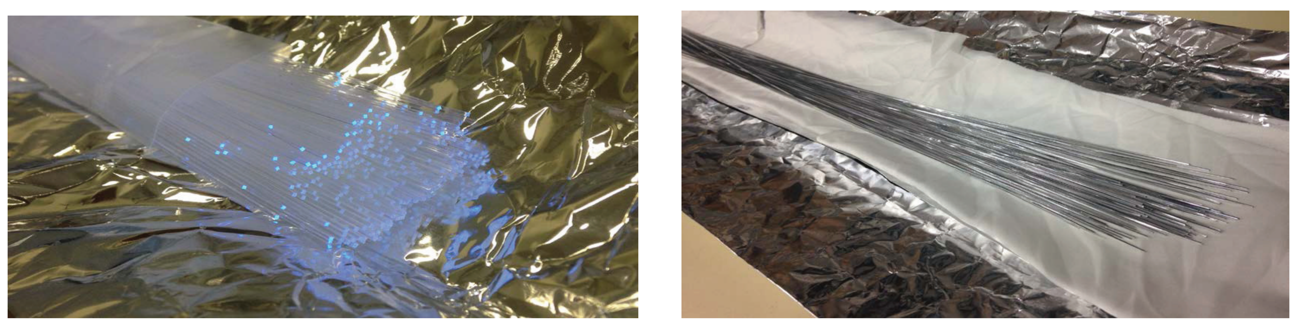
- It monitored hadrons and leptons with momenta between 20 GeV/c and 180 GeV/c and intensities from 10^3 to 10^6 particles/s.
- It was installed close to a DWC and a FISC for comparison.
- The profiles were analysed to find the *r.m.s.*

Intensity(particles/s)	σ(mm) SciFi	σ(mm) DWC	σ(mm) FISC
3.4×10^4	5.6	5.8	6.6
8.2×10^4	5.4	11.2	6.2
6.5×10^5	0.9	4.0	1.1

Table comparing the r.m.s. of the profiles shown on the right

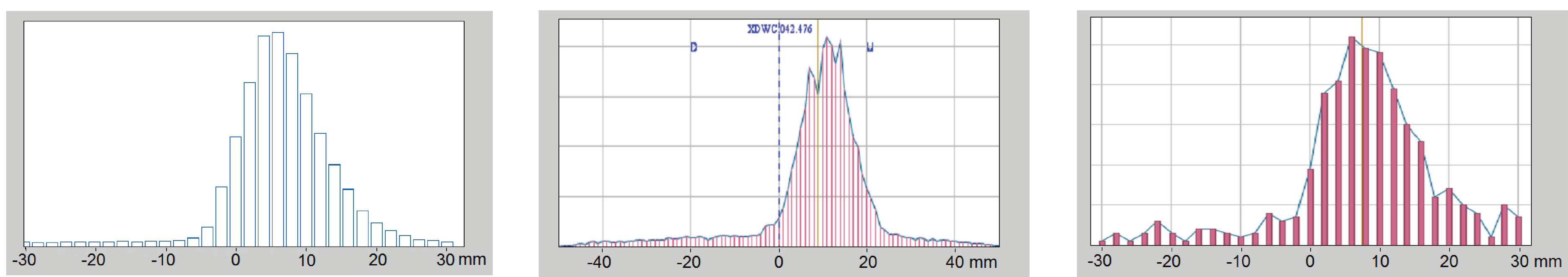
Lead ion run

The detector also monitored beams of lead ions Pb(82,208).
Problem: Pb ions deposit 10,000 times more energy → 10,000 more photons created → crosstalk between fibres → wider profiles.
We are investigating solutions: thin aluminium coating on the fibre.

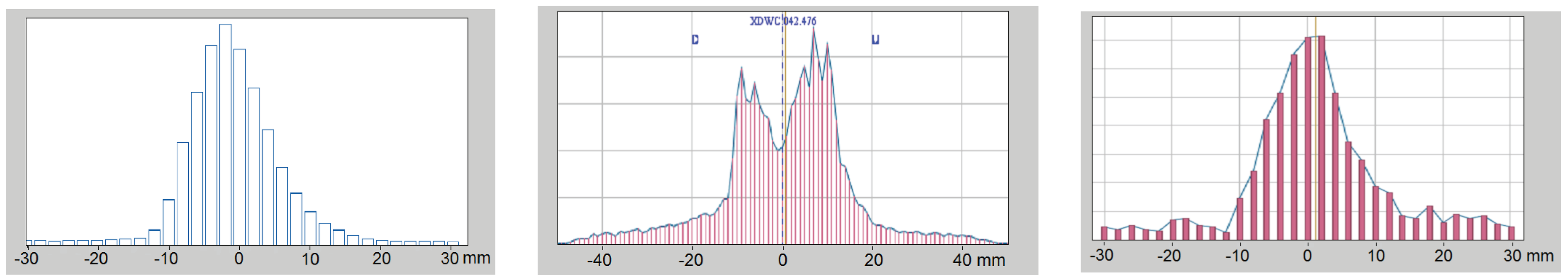


Untreated fibres on the left and aluminium coated fibres on the right: due to presence of ultra-violet photons in the room light, the untreated fibres scintillate while the Al coated do not

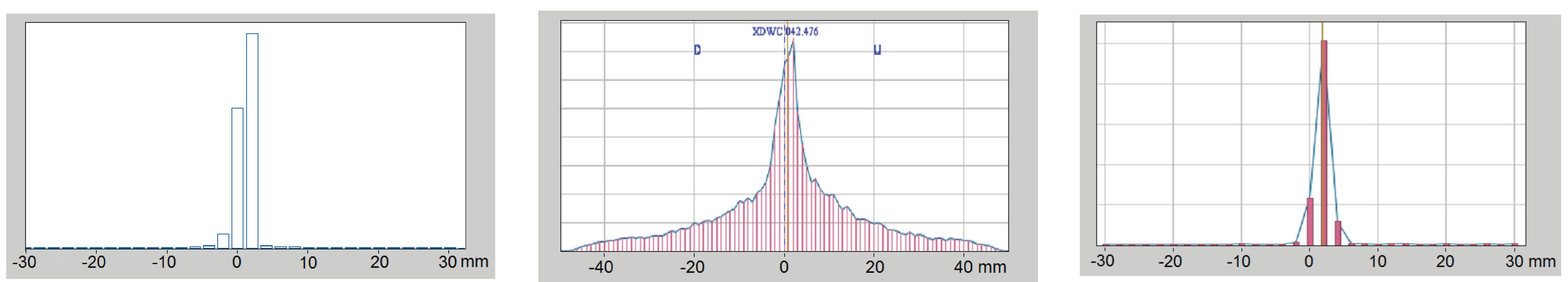
SciFi Profiles | *DWC profiles* | *FISC profiles*



Profiles of a 180 GeV/c proton/pion beam of I=3.4 × 10⁴ particles/s



Profiles of a 180 GeV/c proton/pion beam of I=8.2 × 10⁴ particles/s



Profiles of a 180 GeV/c proton/pion beam of I=6.5 × 10⁵ particles/s

Conclusions

- The scintillating fibre monitor has been successfully tested and it has shown that it can replace the existing monitors.
- It can work over a wider range of intensities, represent less material for the beam and give more accurate profiles.

Future development

- Test a second prototype using MA-PMT instead of SiPM for light detection.
- Investigate solutions to the fibre crosstalk.
- Develop a new front-end electronic board to replace the VME scalers → new features like tagging events with both spatial and time information → possibility of reconstructing both transverse and longitudinal profiles of the beam.