Adapting the new CERN BE-BI scintillating fibre monitor to hadron therapy

ATS-KT Innovation Day – 26/10/2018 – CERN

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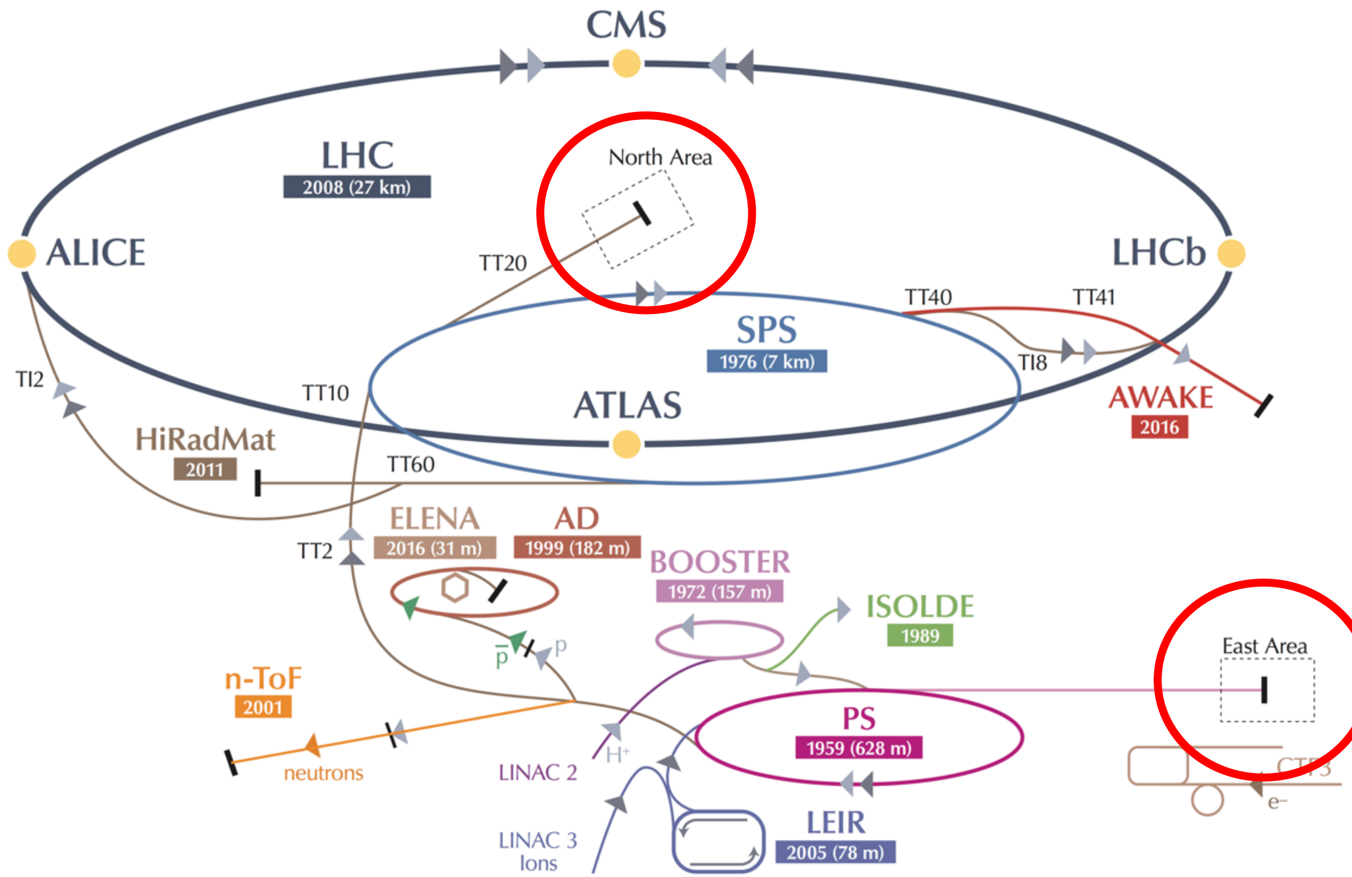
What is a scintillating fibre beam monitor?

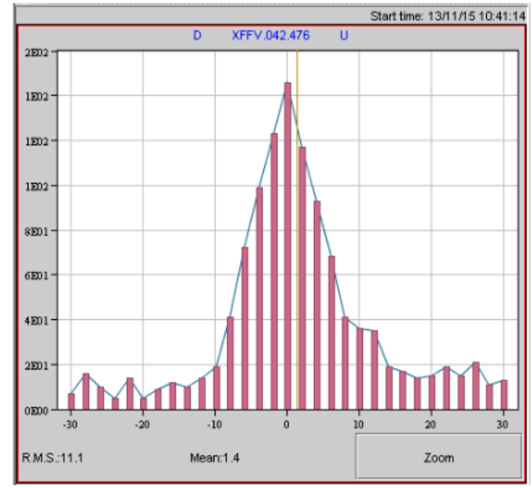
To answer this question, let me introduce you to the experimental areas:

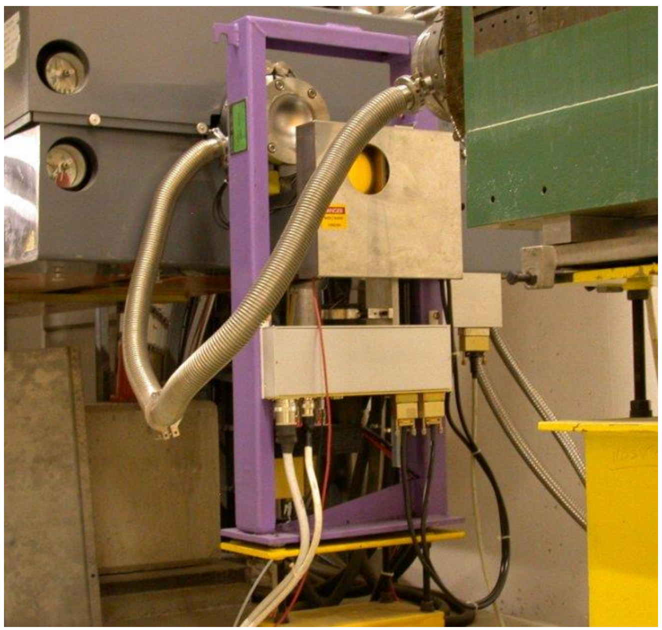


- Experimental facilities.
- Wide spectrum of particles (hadrons and leptons), intensities, and energies.
- Large number of experiments and researchers doing R&D in physics, particle detectors, accelerators technology, Beamline 4 Schools…
- They use ~41% of the protons produced at CERN.

Beam profile monitors in the experimental areas:

- Multi-wire analogue chambers
- Delay wire chambers
- Finger scintillator scanner





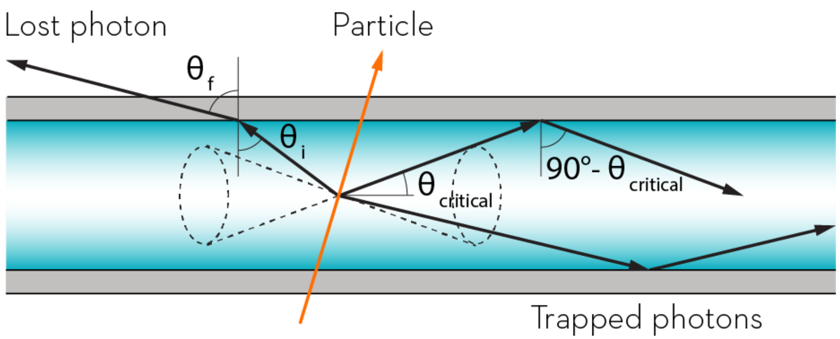
These detectors have greatly performed for decades.

However:

- They are becoming obsolete.
- They cannot fulfil the requirements of new beam lines.

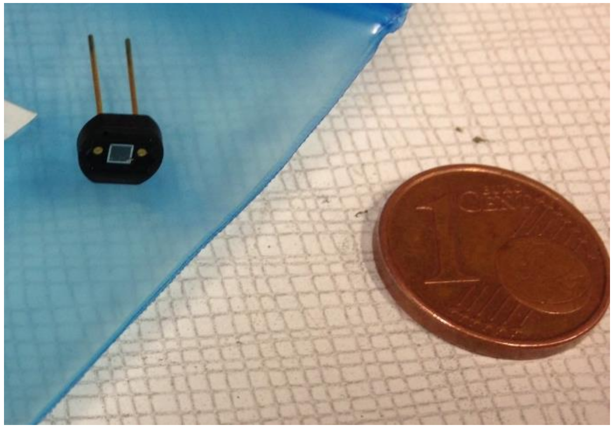
The Beam Instrumentation group at CERN has investigated a new monitor for the EA.

Plastic scintillating fibres:

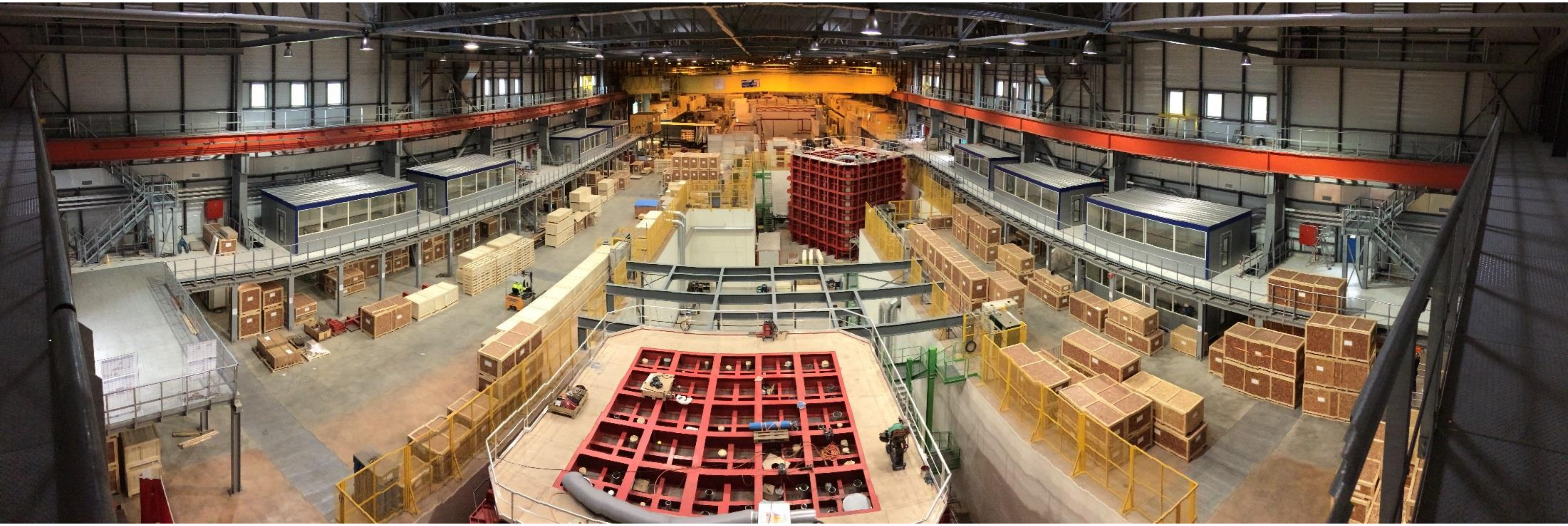


- Mixture of scintillator and optical fibre.
- Low material budget.
- Not expensive.
- Good performance. Reliable.
- Easy to handle and versatile.
- **But:** light signal is low → tricky readout.

This technology is experimenting a spectacular grow in the last years, particularly after the invention of the silicon photomultiplier.

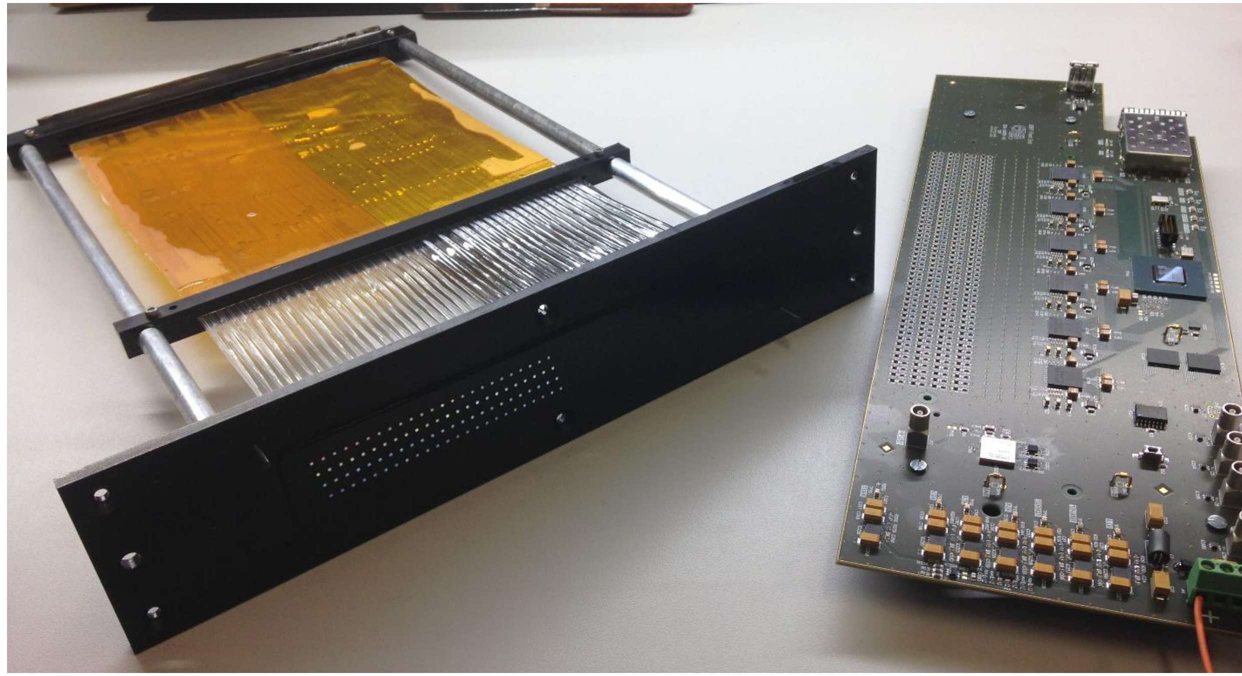


CERN BI had an urgent mandate in 2018: equip the beam lines of the CERN Neutrino Platform

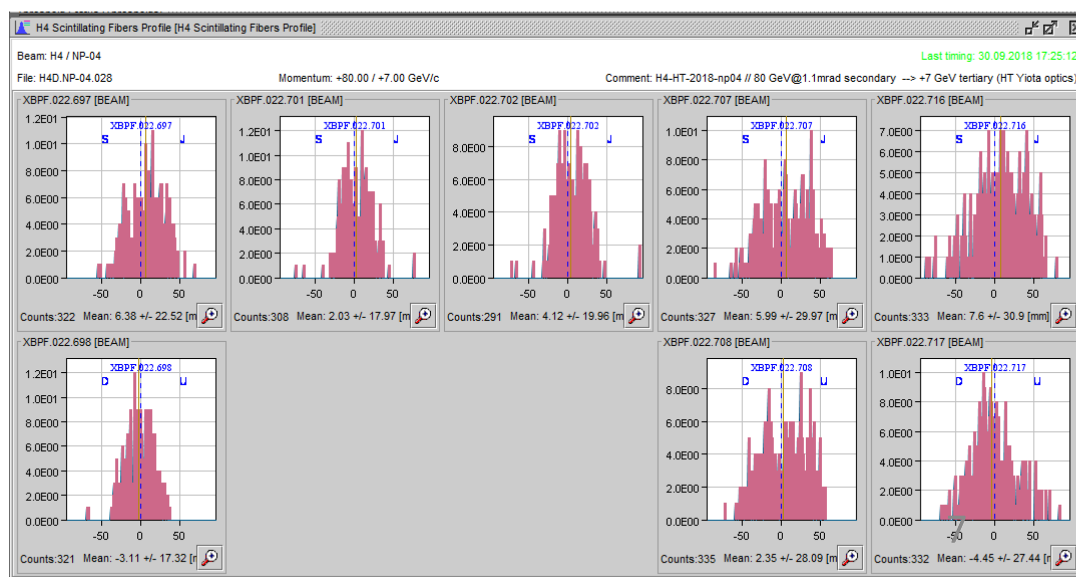


We developed the **XBPF**:

- 20 cm x 20 cm.
- 1 mm fibres.
- Vacuum compatible (primary vacuum).
- Multifunction: profile, intensity, momentum spectrometry, time-of-flight…
- More technical info in the spare slides.

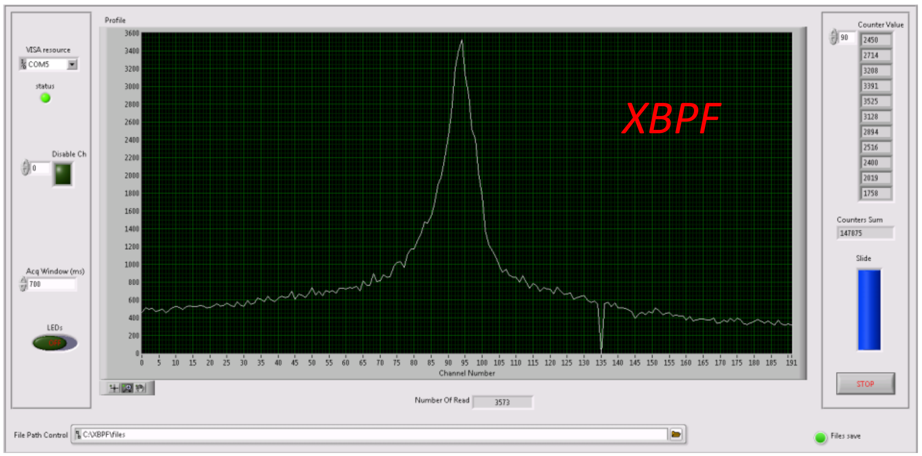


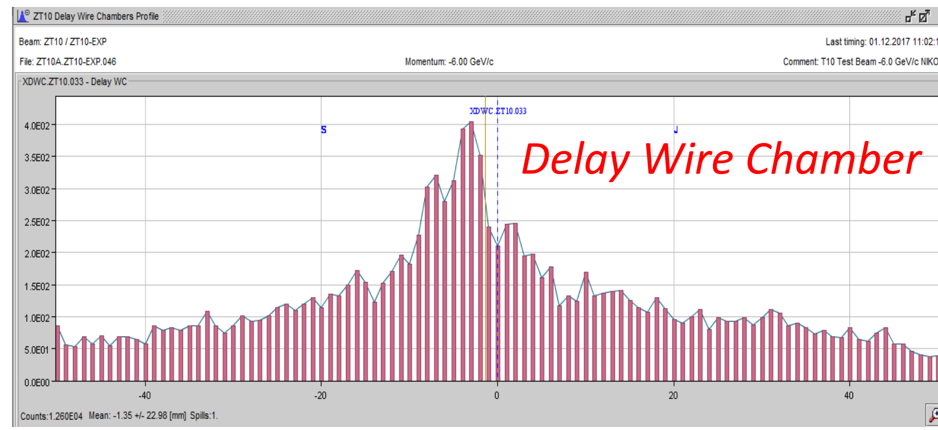
There is a large number of detectors installed in the Neutrino Platform. They are performing very well.



We did dedicated beam tests, to compare the performance of the present gaseous wire chambers and the XBPF:

Example profile of a -6 GeV/c pion beam of I = 1.5 x 10^5 particles.





- The detection efficiency of the XBPF is higher → more precise profiles.

- The XBPF works well in all ranges of intensities. The gaseous wire chambers have troubles with low and high intensities.

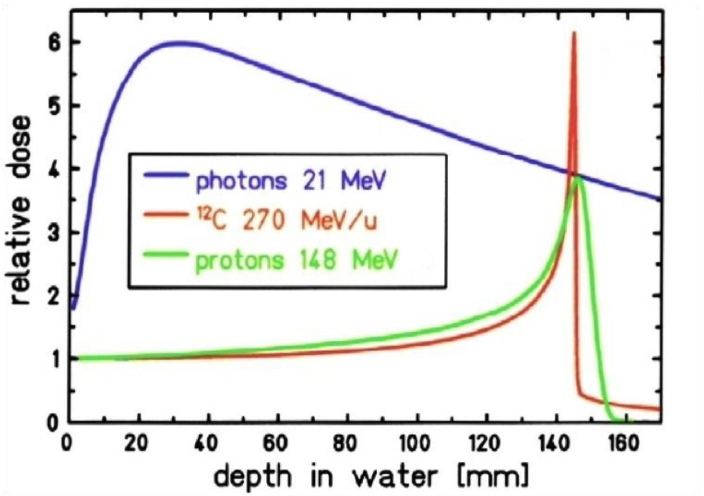
- The spatial resolution of both detectors is comparable.

Could this development be used outside CERN?

Hadron therapy:
medical procedure that treats certain sicknesses, most often cancer, by irradiating tissue with protons or ions of very precise energy.

- More efficient and safer that conventional radio therapy → localised energy deposition.

- Still expensive, but the production costs are lowering.



The number of hadron therapy centres is expected to greatly grow in the coming years.

It turns out that hadron therapy and the experimental areas a have lot in common.

	Experimental areas	Proton therapy
Particle type	Protons, electrons, pions…	Protons
Energy	0.5 GeV to 450 GeV	50 MeV to 300 MeV
Intensities	100 to 10^8 part/s	10^5 to 10^9 part/s

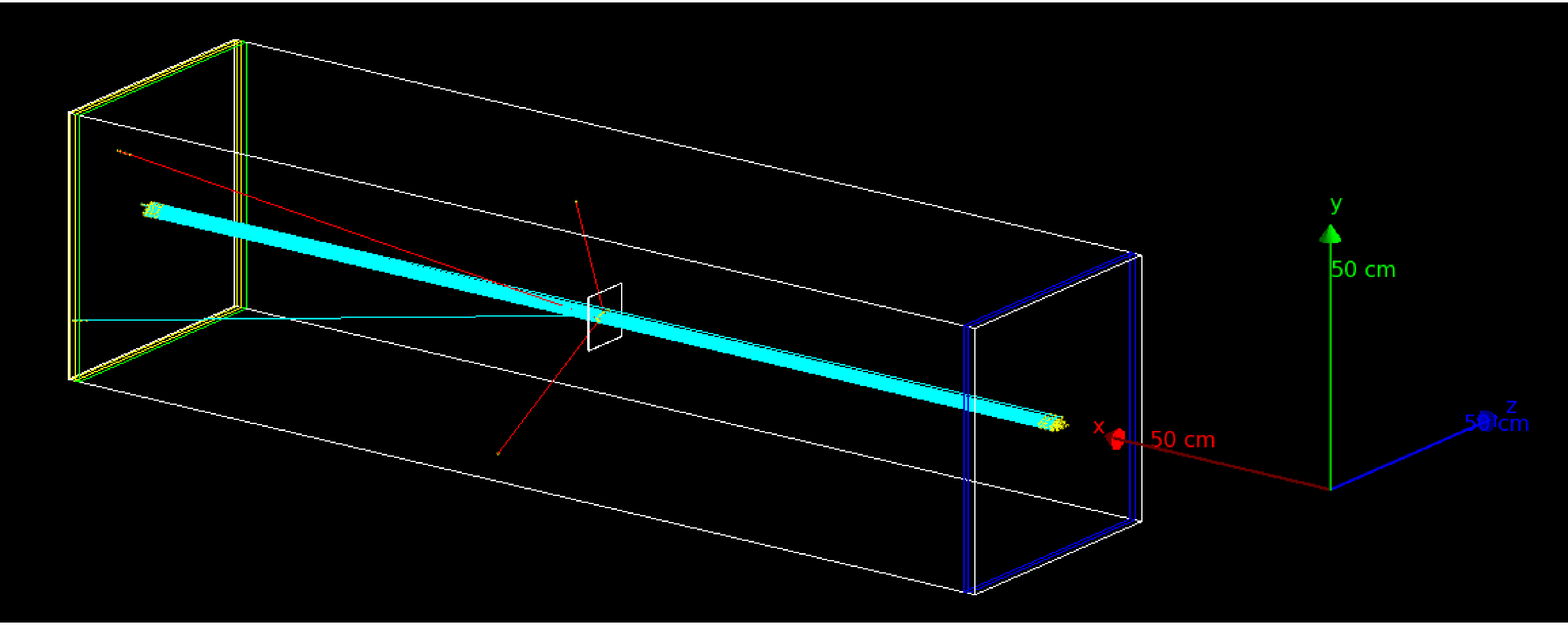
In fact, most of the hadron therapy facilities use instrumentation based on gaseous wire chambers. Just as the CERN Experimental Areas!

→ These facilities could benefit from the development of the XBPF!

When monitoring a hadron therapy beam, is particularly important:

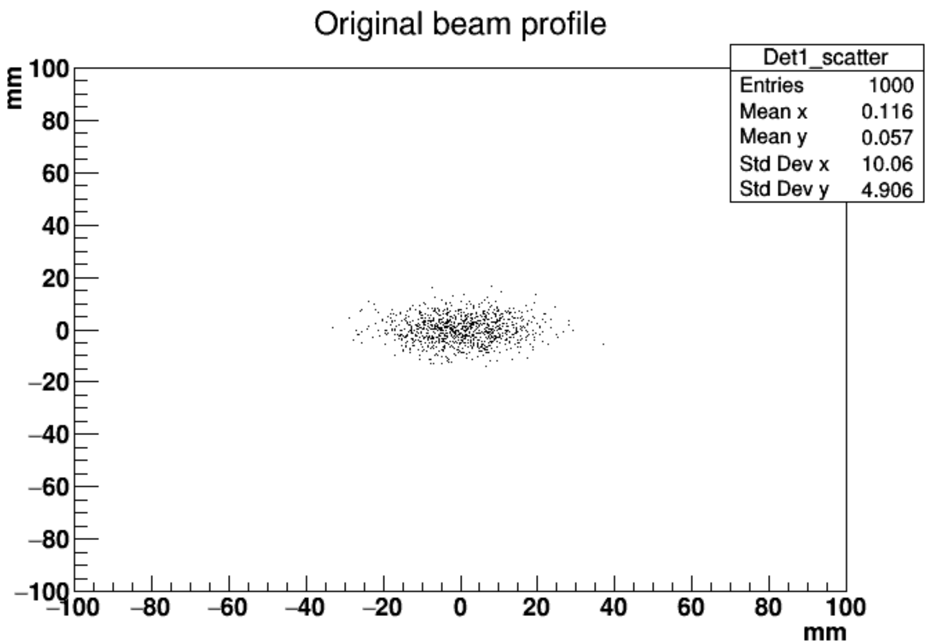
- To minimise the energy loss and scattering of the particles in order to maintain the quality of the beam delivered to the patient.
- Be able to work at high intensities, so the dose can de delivered in a shorter time → improved comfort for the patient and safer treatment.
- Have a reliable instrumentation.

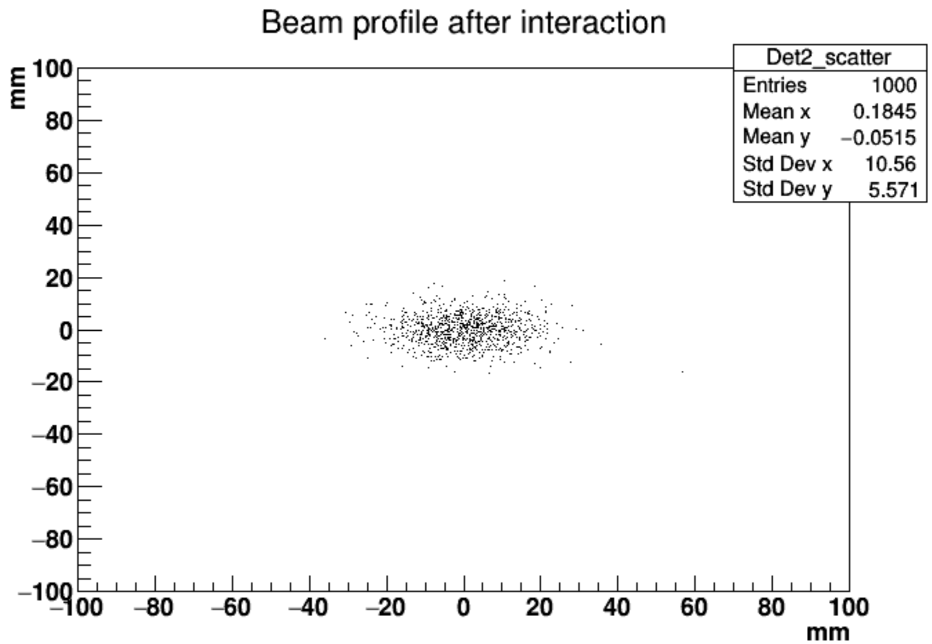
We have run a set of Monte Carlo simulations (Geant4) to study in depth the performance of the XBPF in the energy ranges of hadron therapy beam lines.



Example of a Geant4 simulation of the XBPF in a hadron therapy beam line. The blue tracks are protons of 100 MeV travelling from right to left. The white square in the middle of their trajectory is the XBPF.

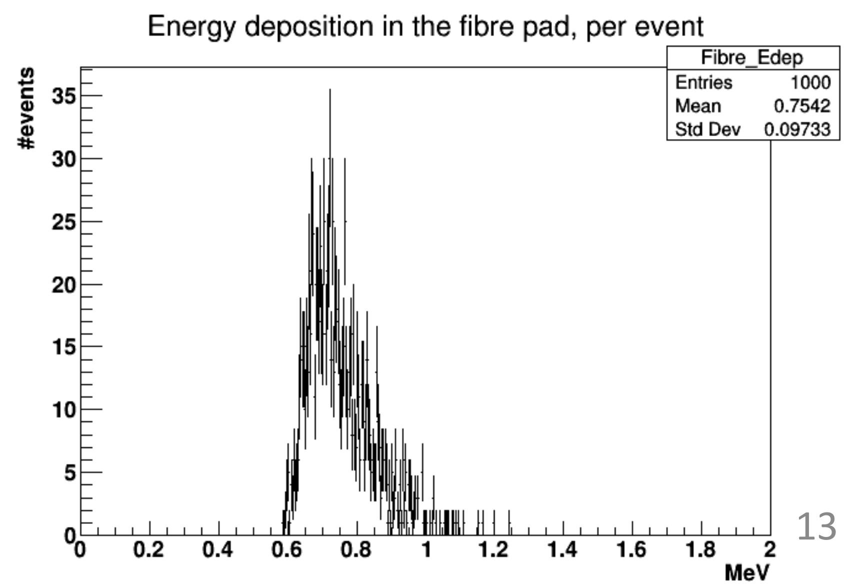
The expected performance of the XBPF is very good!





- The scattering is less than 0.03 degrees.

- The energy loss is lower than 1%.



If we develop a version of the XBPF compatible with high vacuum, it would represent a major improvement for these facilities:

- Performant instrumentation
- Reliable
- Low cost
- Easy to maintain
- Easy to produce

Who has been involved in this development?

Only CERN personnel, mainly BE-BI and EP-DT.

What steps are needed to take it further?

The main phases of the project would be:

1- Investigate the materials and techniques to make a high vacuum version of the monitor.

2- Produce a prototype for a hadron therapy centre.

3- Test the prototype with beam.

Thanks for your attention!

Spare slides

Some technical figures of the XBPF:

- High detection efficiency: 95%.
- Spatial resolution: 1 mm → but could be also 0.25 mm or 0.5 mm.
- Beam intensity: 1 to 10^8 particles per second per mm^2 → individual particle detection.
- Wide dynamic range: from MeV to TeV.
- Low material budget: 0.25% x/X_0 to 0.5% x/X_0 → is almost "transparent" to the beam.
- Active area: 20 cm x 20 cm → easily scalable
- Moderate radiation hard: 100 kGy → long lifespan.
- Operation in vacuum → primary vaccum (10^{-3} mbar)
- Robust and easy to maintain → no gas, cooling or high voltage.
- Easy production and low cost → Other scintillating fibre detectors are harder to build.

The North Area beam lines