An in-vacuum Cherenkov detector for proton Flux Measurement (CpFM) for UA9 experiment

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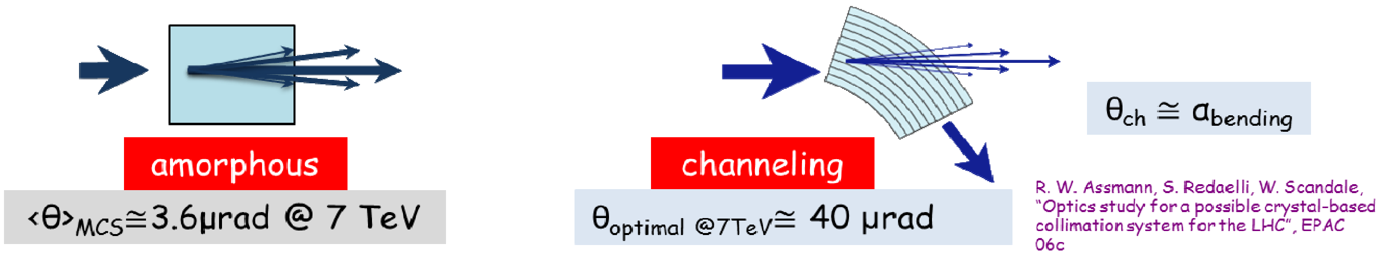
Outline

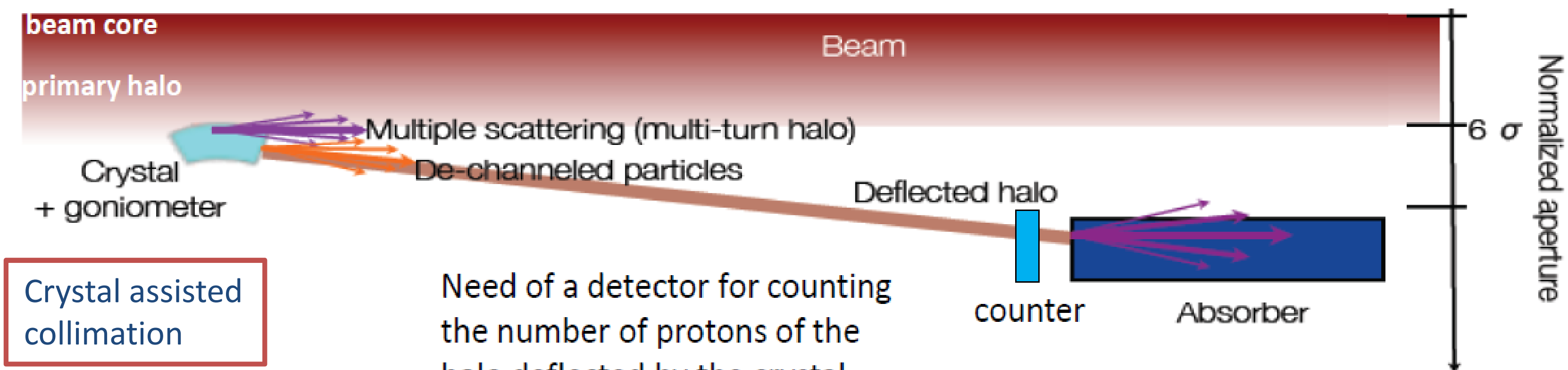
- UA9 experiment at SPS
- LUA9 project (LHC)
- CpFM detection chain components
- Beam tests at BTF and SPS installation
- CpFM features
- SPS Slow Extraction flux monitor
- Conclusions

UA9 experiments

- The main purpose of UA9 is to demonstrate the possibility of using a bent silica crystal as primary collimator for hadron colliders. Bent crystal works as a “smart deflectors” on primary halo particles



- If the crystalline planes are correctly oriented, the particles are subject to a coherent interaction with crystal structure (channeling).
- This effect impart large deflection which allows to localize the losses on a single absorber and reduces the probability of diffractive events and ion fragmentation



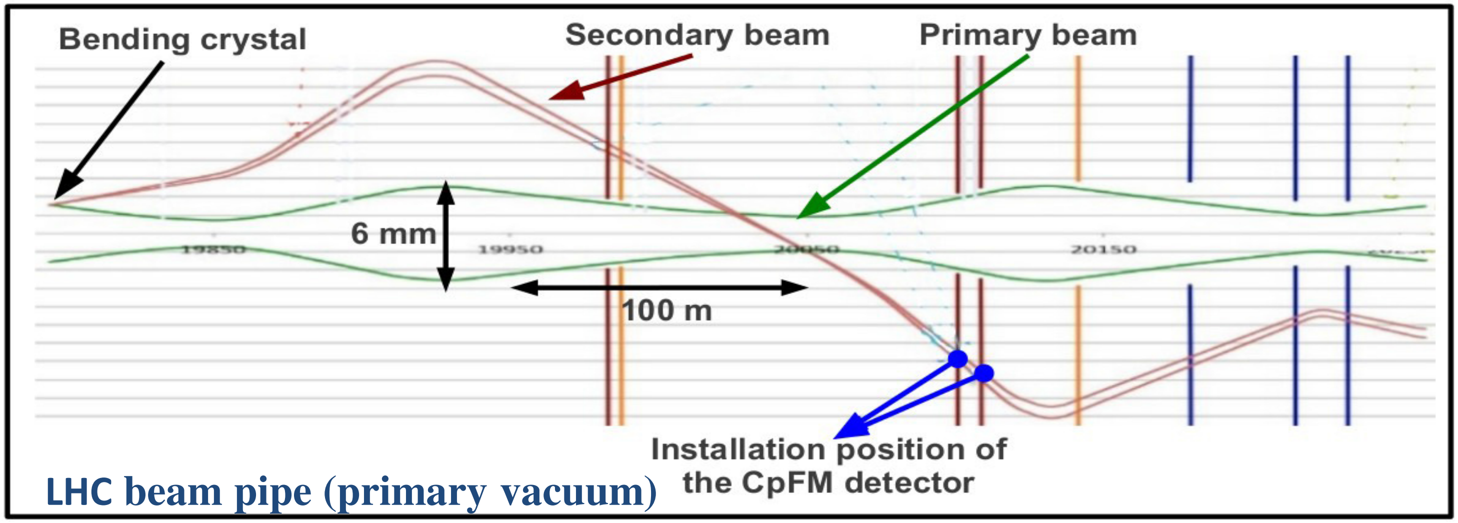
Crystal assisted collimation

Need of a detector for counting the number of protons of the halo deflected by the crystal

UA9 experiment runs in SPS since 2009

LUA9 project

Use bent crystal at LHC as a primary collimator

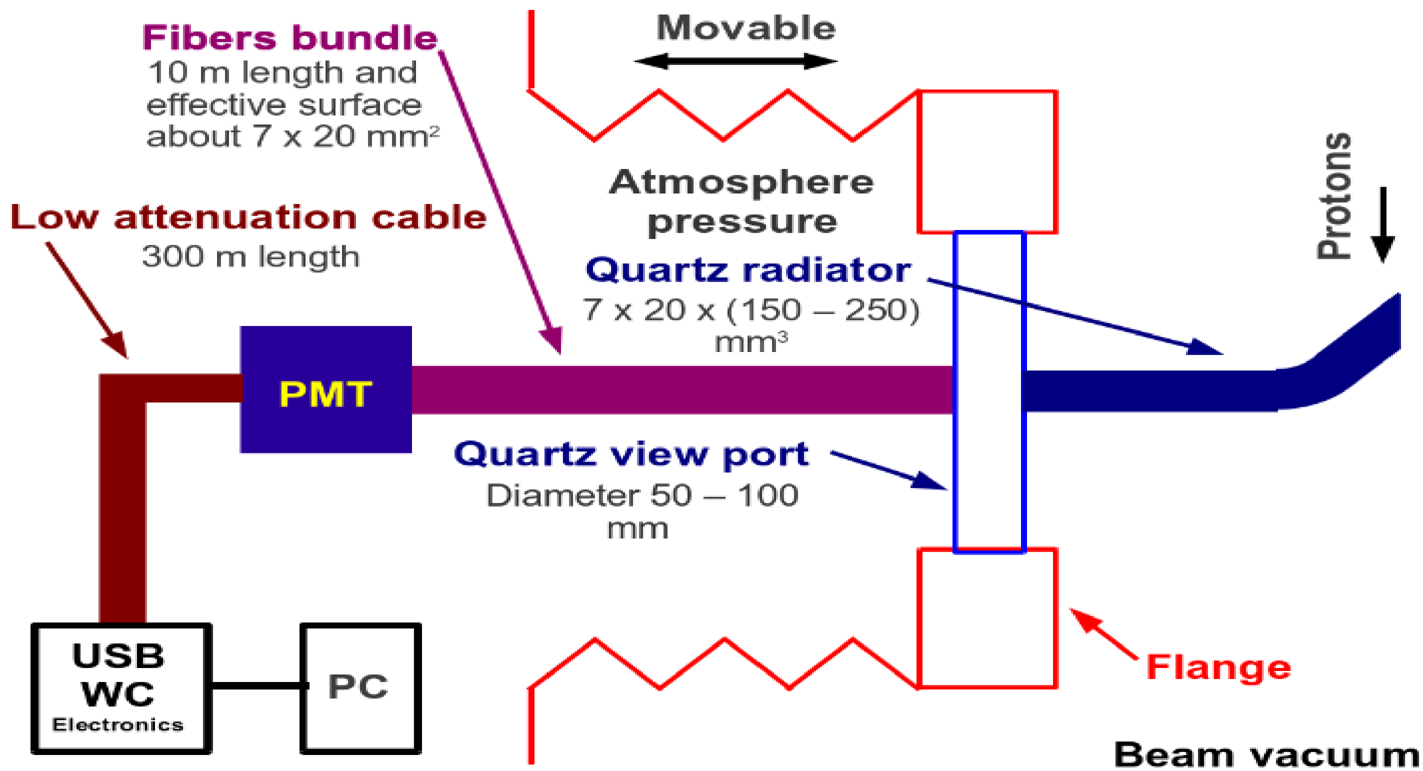


To monitor the secondary beam a Cherenkov detector, based on quartz radiator, can be used. **Aim**: **count the number of protons with a precision of about 5%** (in case of 100 incoming protons) in the LHC environment so as to monitor the secondary channelized beam.

Main constrains for such device:
- **No degassing materials** (inside the primary vacuum).
- **Radiation hardness of the detection chain** (very hostile radioactive environment).
- **Compact radiator inside the beam pipe** (small place available)
- **Readout electronics at 300 m**

→ Cherenkov detector for proton Flux Measurements (CpFM)

CpFM detection chain components



✓USB-WaveCatcher read electronics. For more details see :

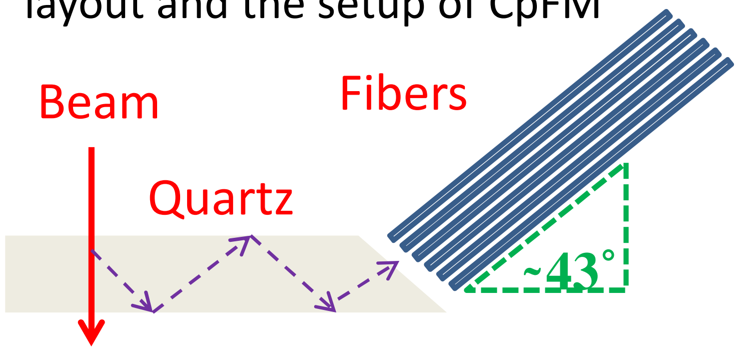
USING ULTRA FAST ANALOG MEMORIES FOR FAST PHOTO-DETECTOR READOUT (D. Breton et al. PhotoDet 2012, LAL Orsay)

The Cherenkov light will propagate inside the radiator and will be transmitted to the PMT throughout the bundle of optical fibers.

Radiator must work as waveguide.

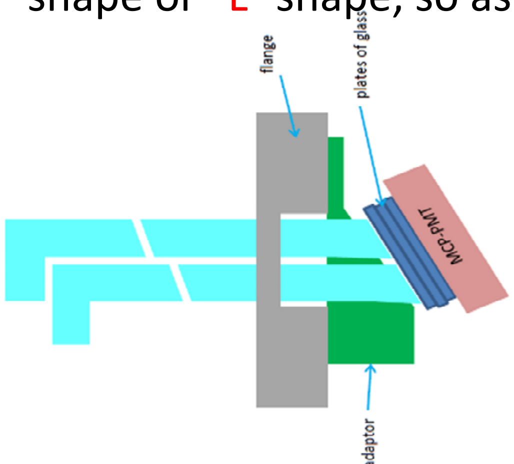
Best configuration for CpFM

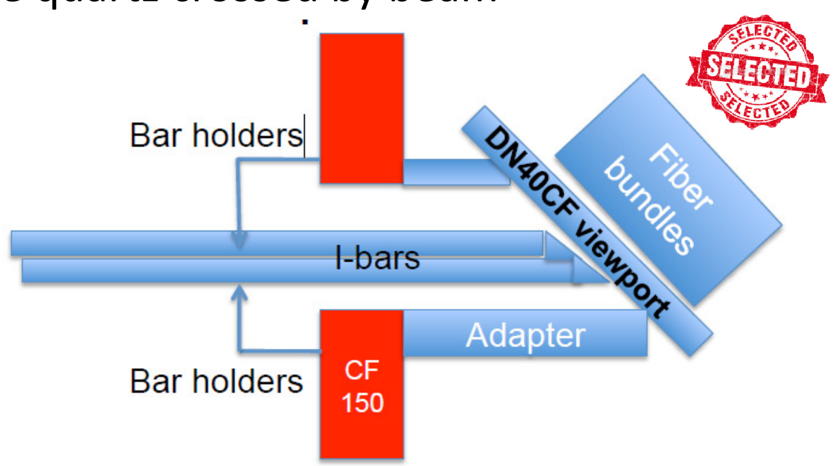
- Many tests (@BTF 2013-2014, @H8 2014) were performed to optimized the layout and the setup of CpFM



- Radiator cross the beam perpendicularly, due to small place available
- Fibers are coupled with 43° angle, so as the incoming light is at 47° angle

- Flange brazed configuration or commercial viewport configuration
- "I" shape or "L" shape, so as to increase the quartz crossed by beam

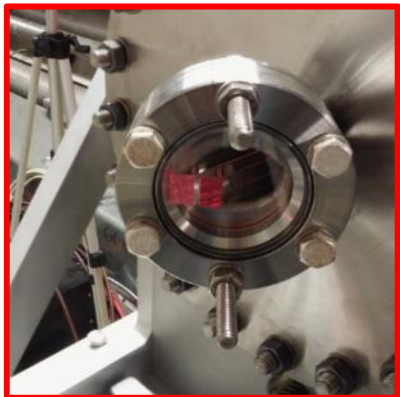


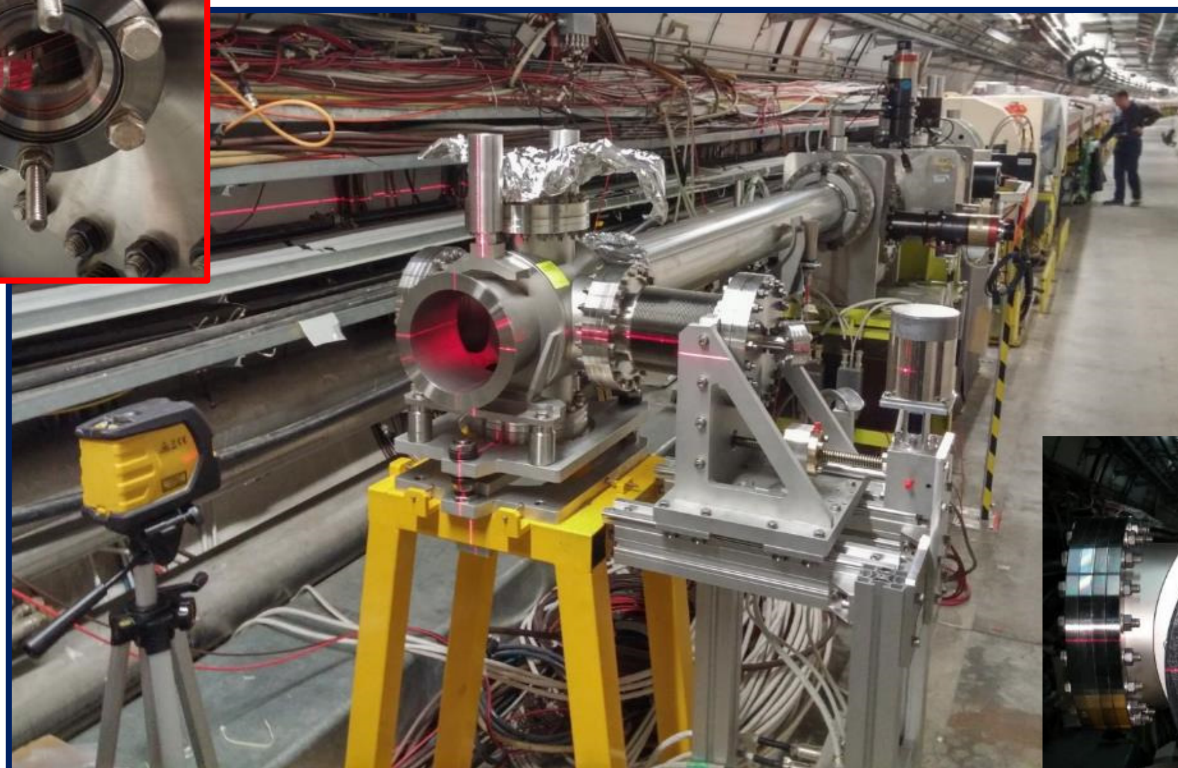


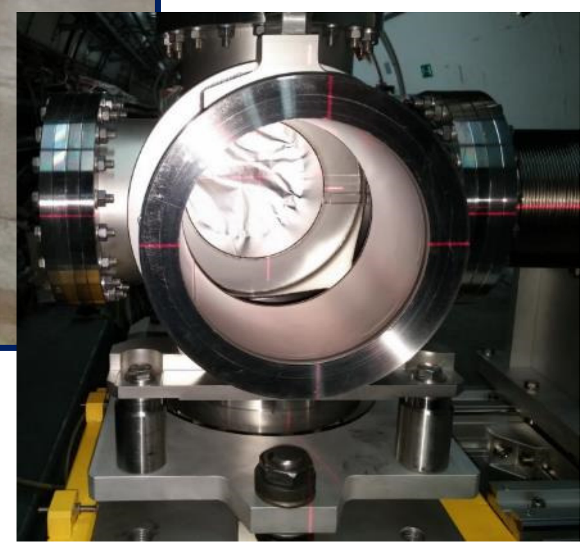
The "double bar" configuration will be useful to measure the diffusion of the beam and the background

Fused silica radiator
works as waveguide for
the laser spot of level

CpFM installed on SPS

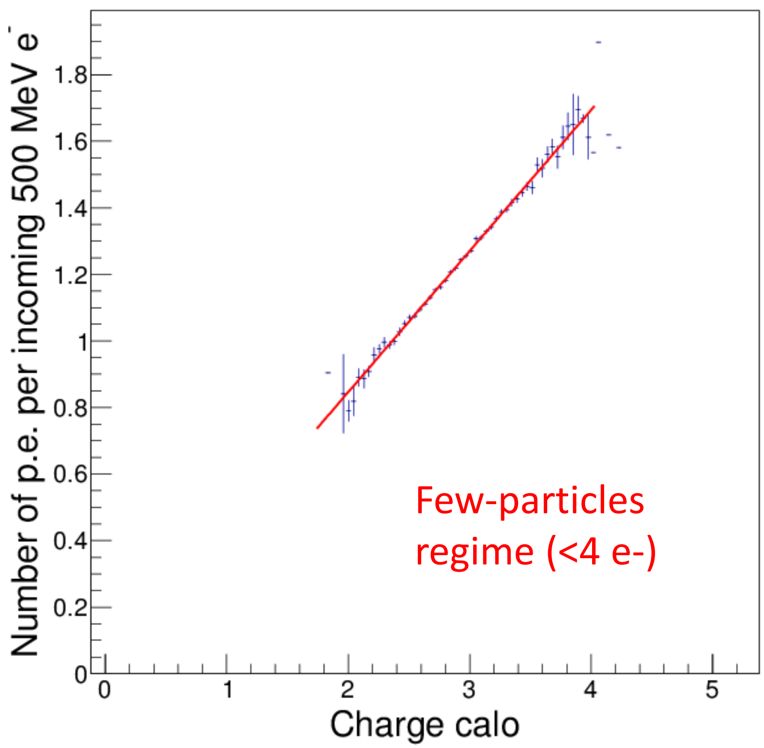


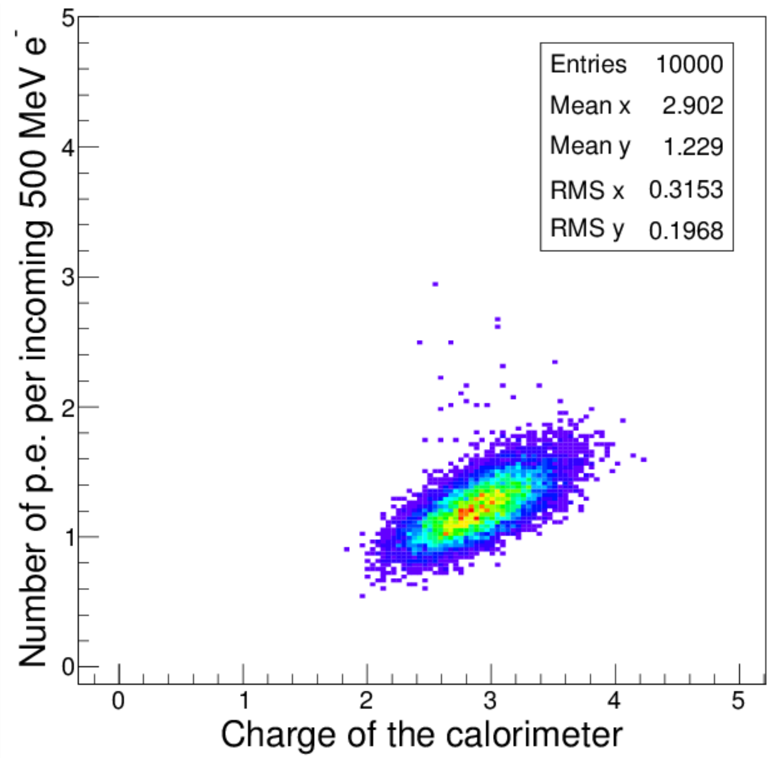




- The first CpFM with 2 “I” shaped radiators and 4m long fibers bundle was just installed on SPS

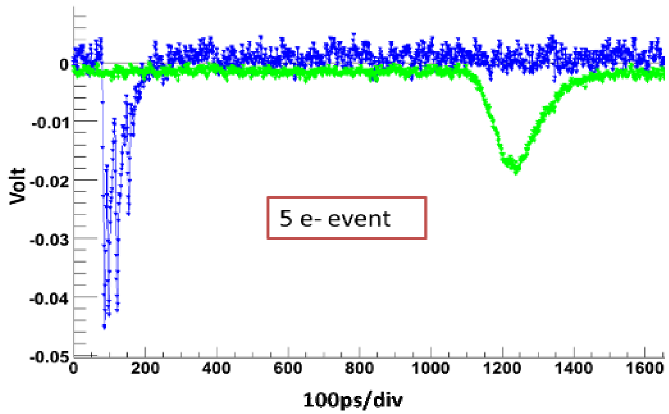
CpFM and BTF Calorimeter correlation

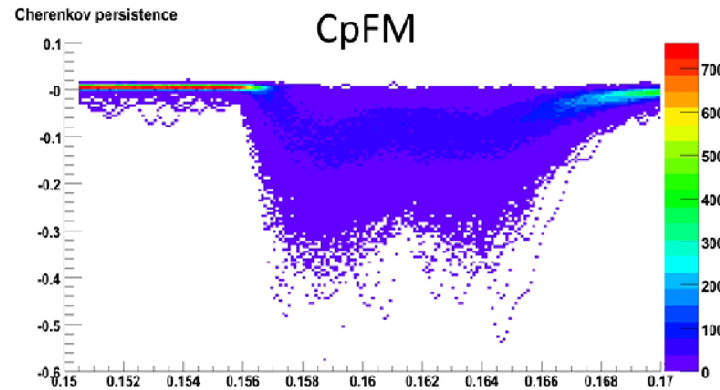




The study of measured CpFM charge (normalized on the charge of single p.e.) as a function of BTF calorimeter charge shows a rather linear dependence.

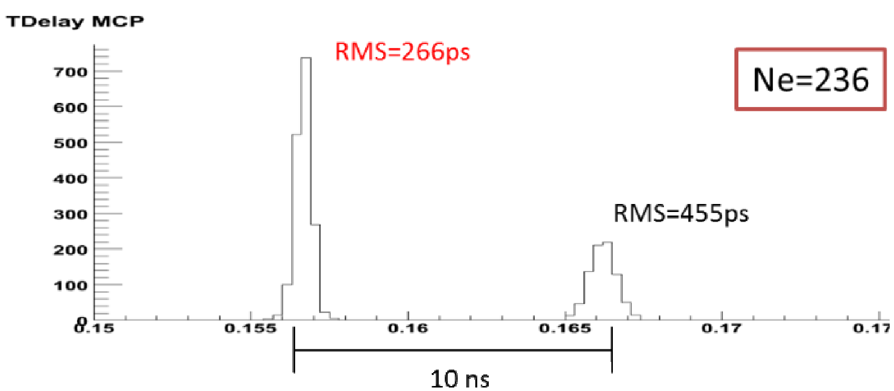
Timing features





- Due to fast time response of MCP-PMT, Waveforms can show the peak of each micro bunch. (The BTF beam has a 350ps microbunch structure).

- The persistence of waveform shows that the CpFM prototype can discriminate the distribution of particles within the 10ns long bunch of BTF

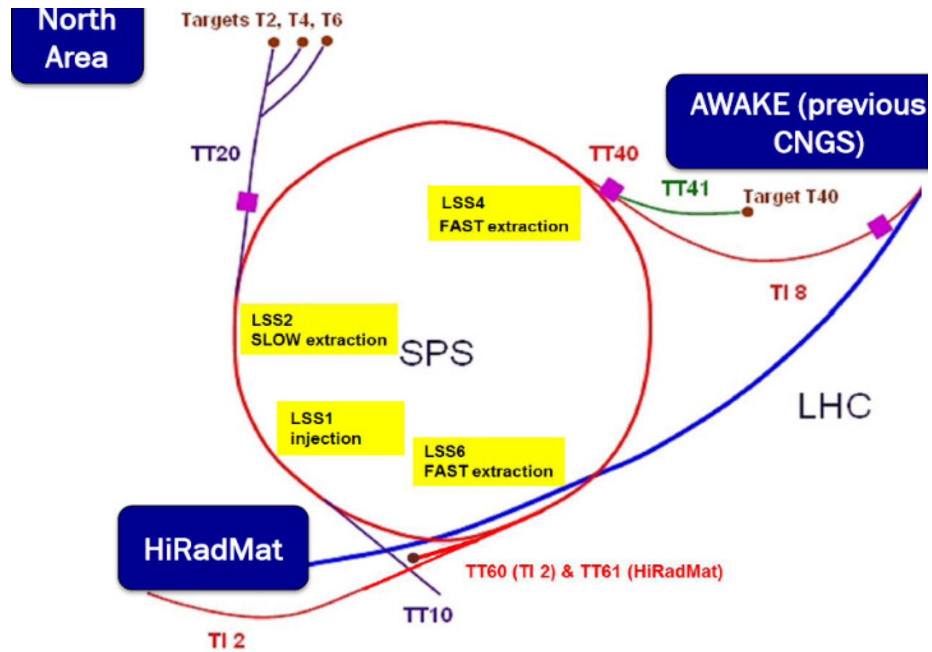


- We measure the delay from trigger edge (LINAC NIM Timing signal) of the first particle of each event with multi-particles events (Ne=236) (so as to have at least 1 particles in the first microbunch)
- **The CpFM take out a distribution similar to the CALO's one but by far less light**

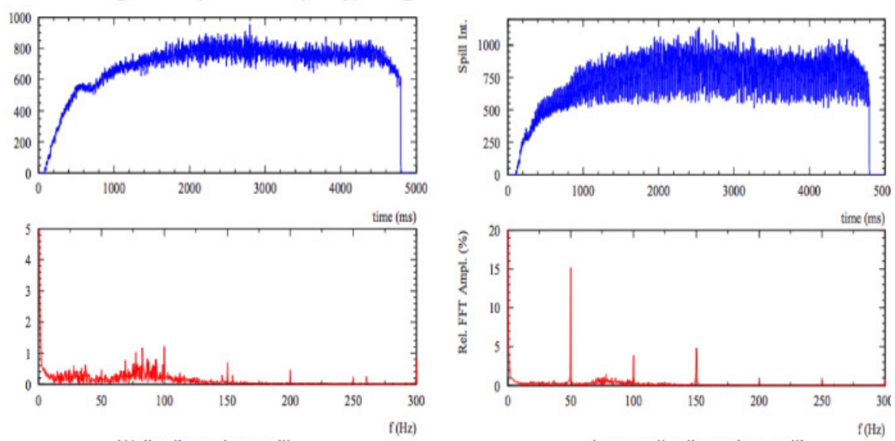
SPS Slow Extraction flux monitor

- A new CpFM is developing for installation on SPS Slow Extraction Area (TT20)

- The detector will used to monitor the modulation of extracted beam flux intensity (essential for some NA experiments like *SHiP*)



- Needs regular adjustment (daily) for good correction.



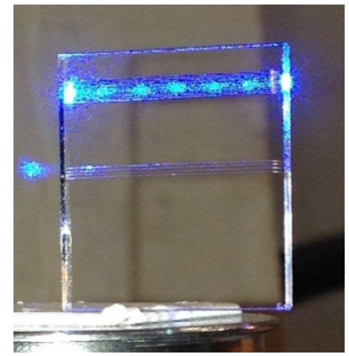
Well-adjusted p+ spill

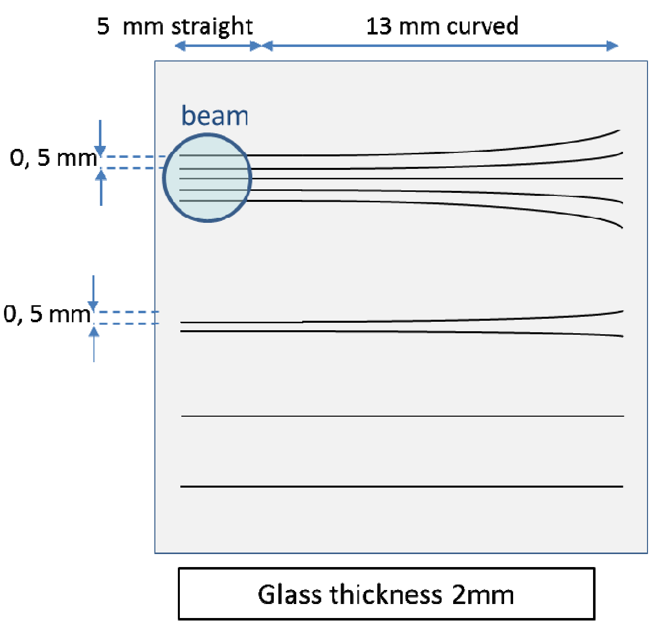
Less well-adjusted p+ spill

- Fast readout electronics with sample rate >400Mhz and large acquisition memory is required so as to output real time FFT (with large frequency span)

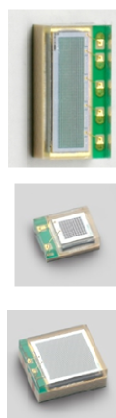
Smart Cherenkov Screen

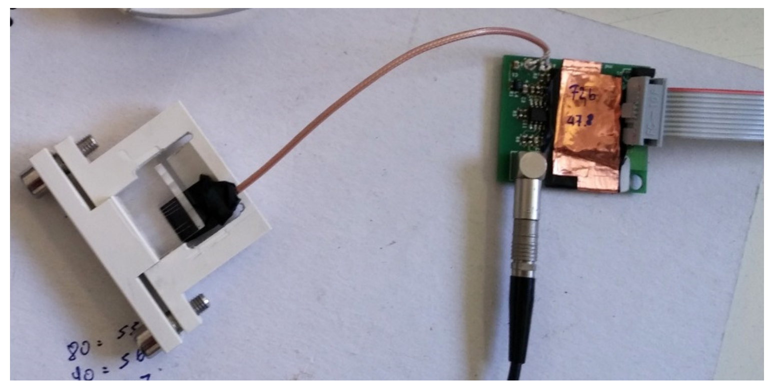
- The Cherenkov screen for beam profile monitoring made up of an array of planar waveguides .
- The waveguides are realized by means of fs-laser μ-processing.
- An instrumented window can output a beam profile by a spatial selective imaging of Cherenkov radiation





Many kinds of SiPM under test





Smart Cherenkov Screen with ArduSiPM readout electronics (realize by INFN-LABE Roma)

Conclusions

• We have evidence that the full chain (radiator + quartz window + fiber bundle + PMTs) works well, also for low fluxes

• We chose the "**I**" shape bars and the mounting with viewport for the first CpFM (installed @ SPS in Dec.2014)

• The sensitivity is barely less than 1 MIP. Anyway technological improvement can be employed to enhance it (well polished "L" bar, radiator feed through, light focusing)

•Thanks to the fast response , to the low jitter and to the radiation hardness of its components , CpFM can be easily used for timing and intensity measurement of particles' flux for high luminosity beams too.

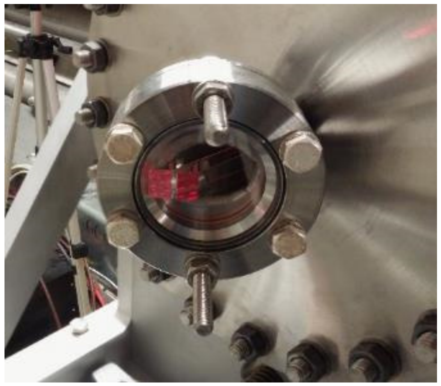
• Position sensitive detector can be developed with Cherenkov Screen technology

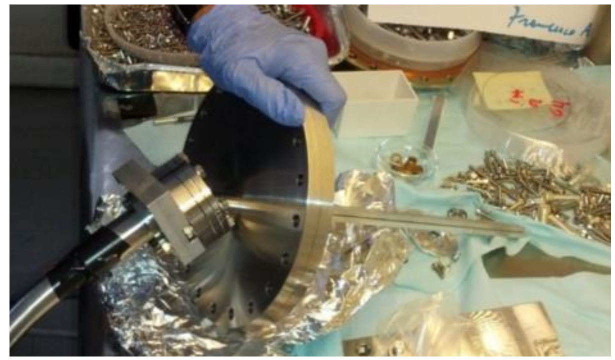
Thank you for attention

SPARE

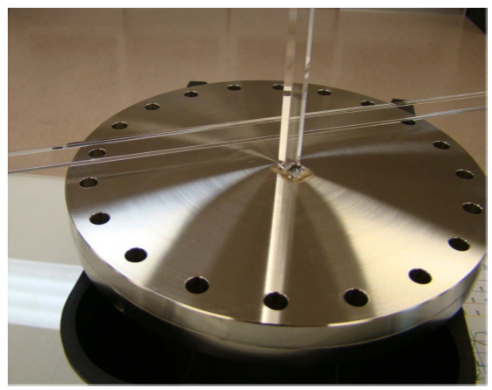
Air-Vacuum Optical Interface

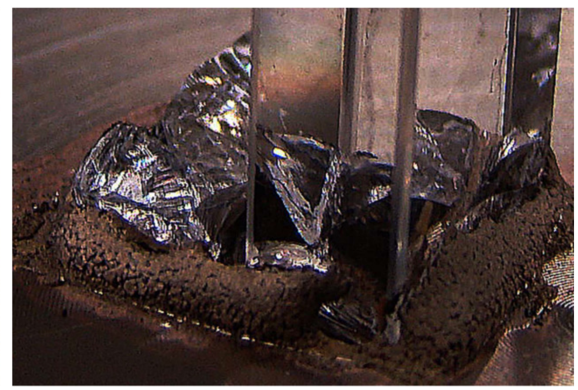
The CpFM UA9-SE will be equipped with commercial viewport optical interface





The manufacturing of a brazed air-vacuum interface is a difficult task, Morgan Wesgo failed in the brazing iron flange and fused silica together (CTE problem)





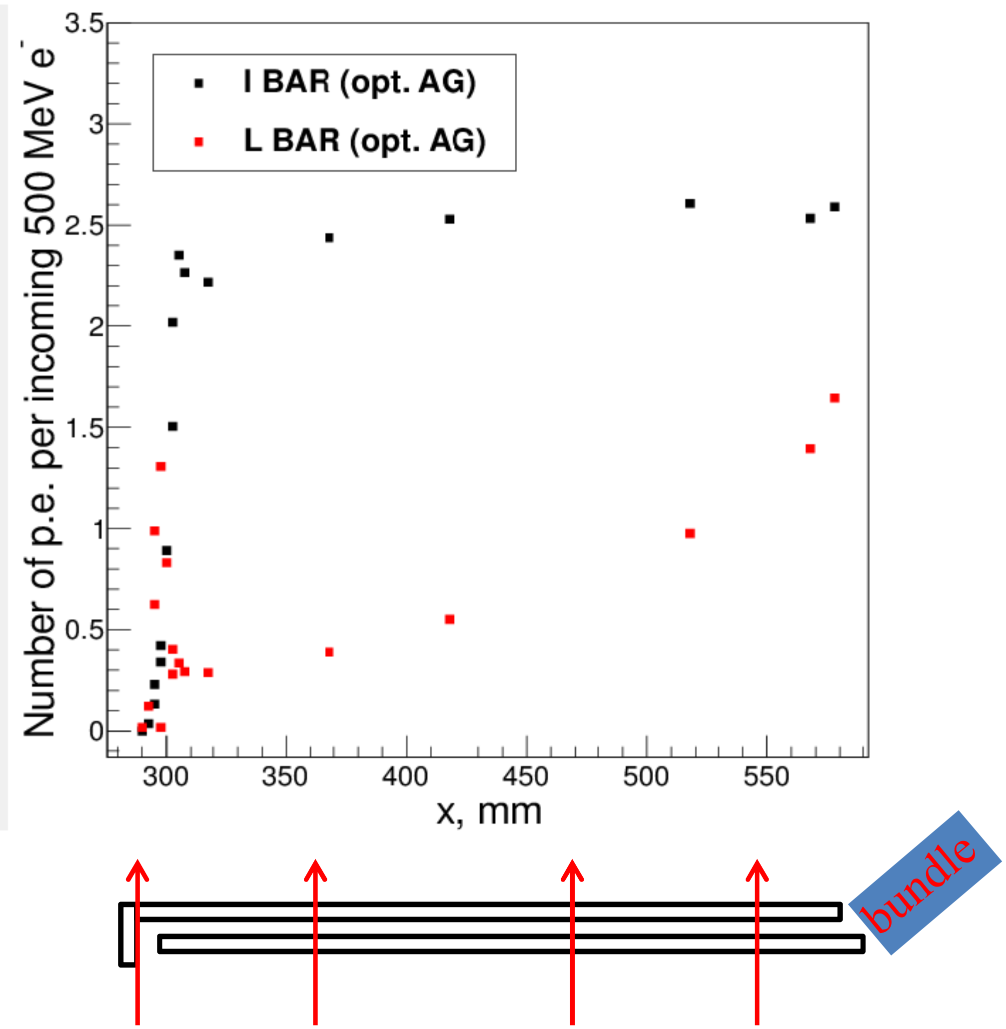
We are working with LNF vacuum experts (Valerio Lollo and Marco Miliucci) to find a more suitable solution

- The idea is to grow a metal ring around the radiator and then put together with a iron flange by means of a tungsten inert gas (TIG) welding
- The metal ring will be made by sputtering and galvanization process:
  - by sputtering a 100 um thin-film of molybdenum will be deposited on the fused silica
  - by galvanization a tick coating (10 mm) of copper will be formed

–At last, copper coating and iron flange will be put together by TIG welding

“L” and “I” bars + bundle + PMTs (R7378A)

“L” yield less signal than “I”



“ I ” bar configuration

- Higher light signal, due to a better surface polishing
- Number of detected p.e. quite linear

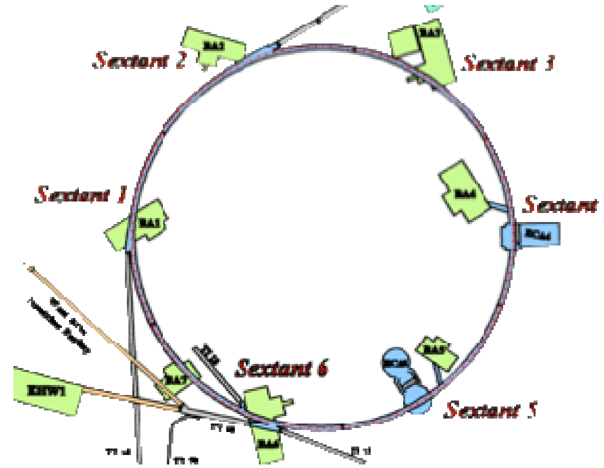
“ L” bar configuration

- Lower light signal, **due to a worst surface polishing**
- **Detected p.e. increase when beam came near to the fiber bundle**
- In principle more light produced in the 3 cm fused silica along the beam direction (“L” shorter arm)

The polishing, difficult because of the “L” shape, must be enhanced. Reflectivity is essential feature of radiator

Loss rate along the SPS ring

- Loss map measurement in 2011: intensity increased from 1 bunch ($I = 1.15 \times 10^{11}$ p) to 48 bunches, clear reduction of the losses seen in Sextant 6.



- Loss map measurement in 2012: maximum possible intensity: 3.3×10^{13} protons (4 x 72 bunches with 25 ns spacing), average loss reduction in the entire ring !