Cherenkov detector for proton Flux Measurement (CpFM)

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on behalf of the UA9 Cherenkov detector team

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Outline

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- UA9 experiment at SPS

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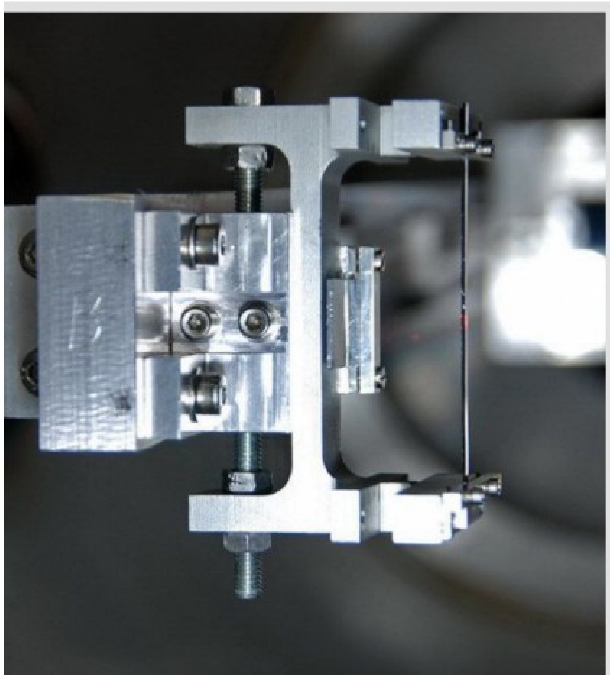
- Geant4 simulation of the CpFM

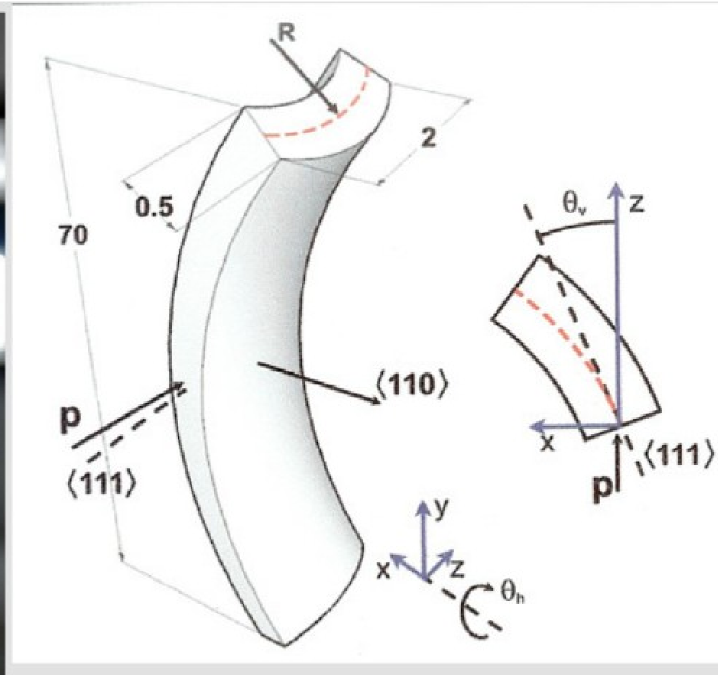
3. Beam test

- Beam tests (at BTF Frascati) of simplified prototypes
- Results of the beam test

4. Conclusion

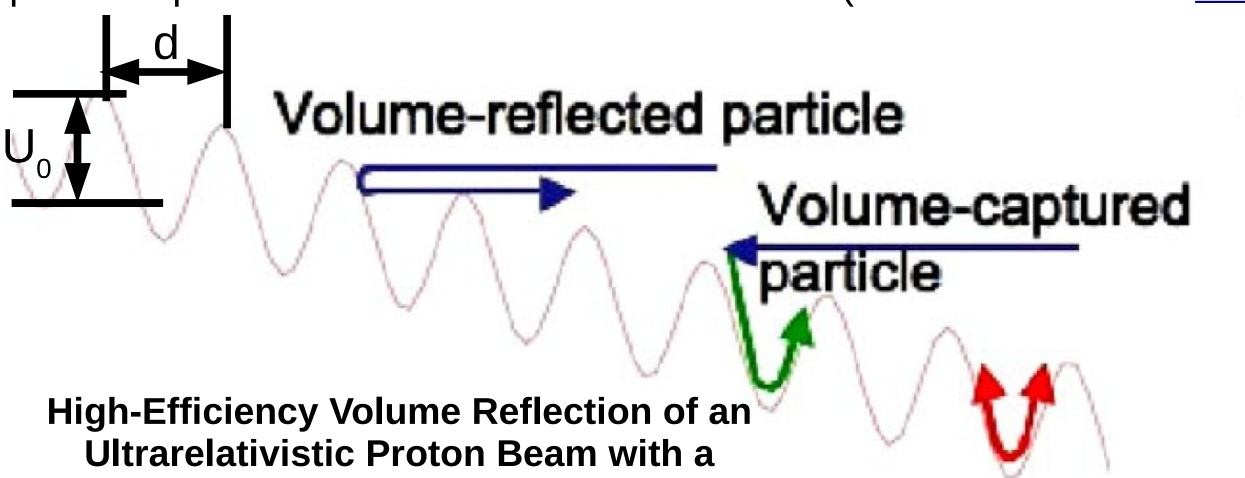
Channeling effect of the charged particles in the bent crystal





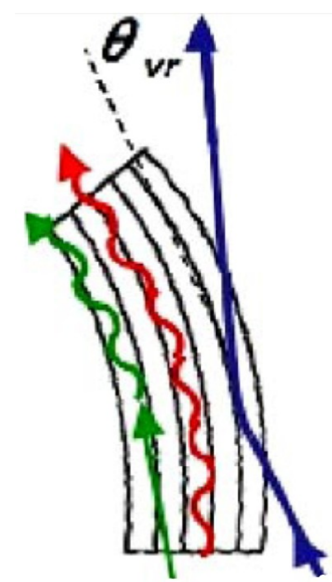
- Mechanically bent crystal
- Using of a secondary curvature of the crystal to guide the particles

If crystal planes are correctly oriented with respect to the incoming particle – particles can be trapped via potential parabolic barrier between the lattices (this effect is called **channeling**).

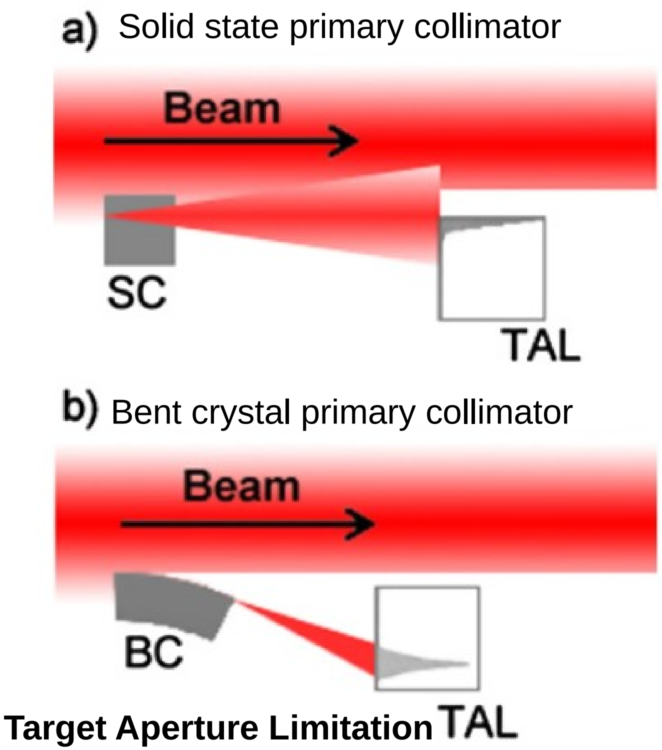


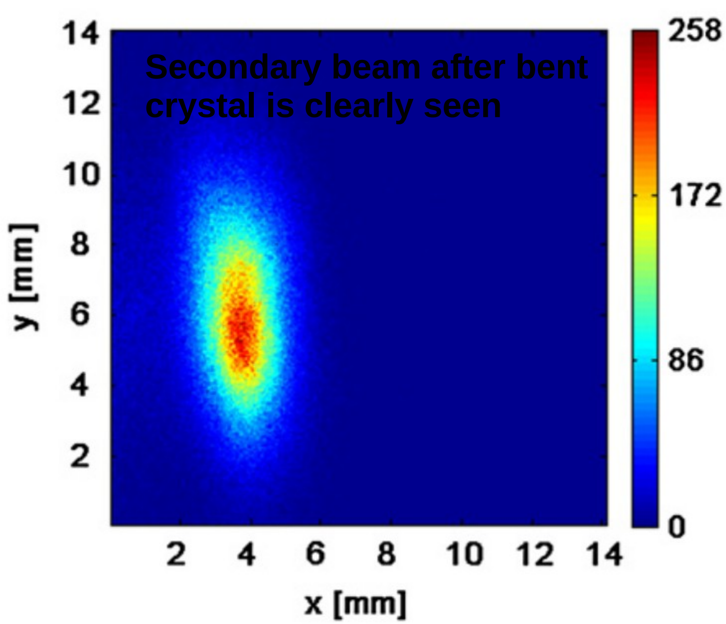
High-Efficiency Volume Reflection of an Ultrarelativistic Proton Beam with a Bent Silicon Crystal
(W. Scandale et al. PRL 98, 154801, 2007)

U_0 = 22.7 eV
d = 0.192 nm



UA9 experiment at SPS





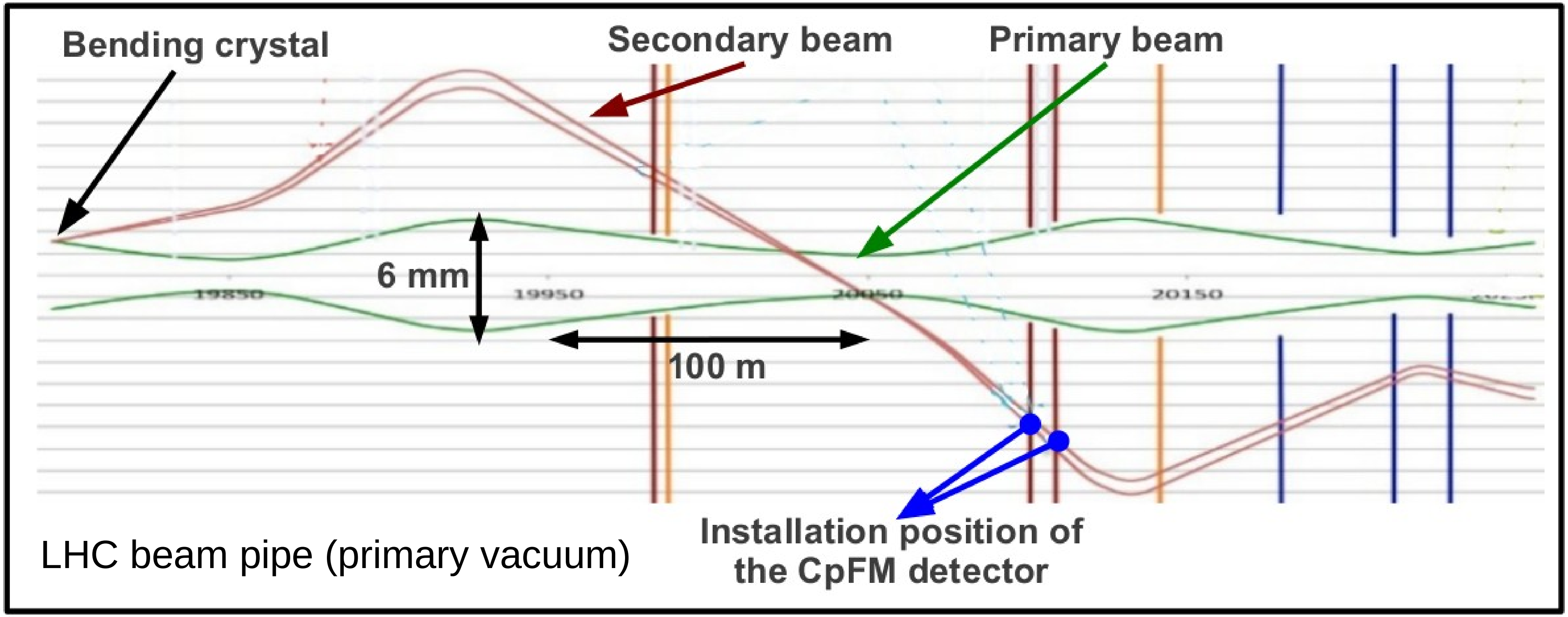
UA9 MISSION: Investigate bent crystals as primary collimators in hadron colliders

- One of the possible applications is "smart" collimation system for particle accelerators.
- Bent silicon crystals are expected to direct the beam halo promptly onto secondary collimator thus ideally reducing outscattering, beam losses and the radiation load in critical regions of the ring.
- Tests of the bent crystal as a primary collimator in the circular accelerator (SPS) since 2009.
- Observation of the secondary beam created by the bent crystal
- Strong reduction of the counts from beam loss monitors has been observed at an optimal angle orientation of the crystal

First results on the SPS beam collimation with bent crystals
(W. Scandale et al. Physics Letters B 692 (2010) 78–82)

LUA9 project

Use bent crystal at LHC as a primary collimator.



To monitor the secondary beam - Cherenkov detector based on quartz radiator can be used. Initial idea belongs to the PNPI group with a prototype tested in SPS.

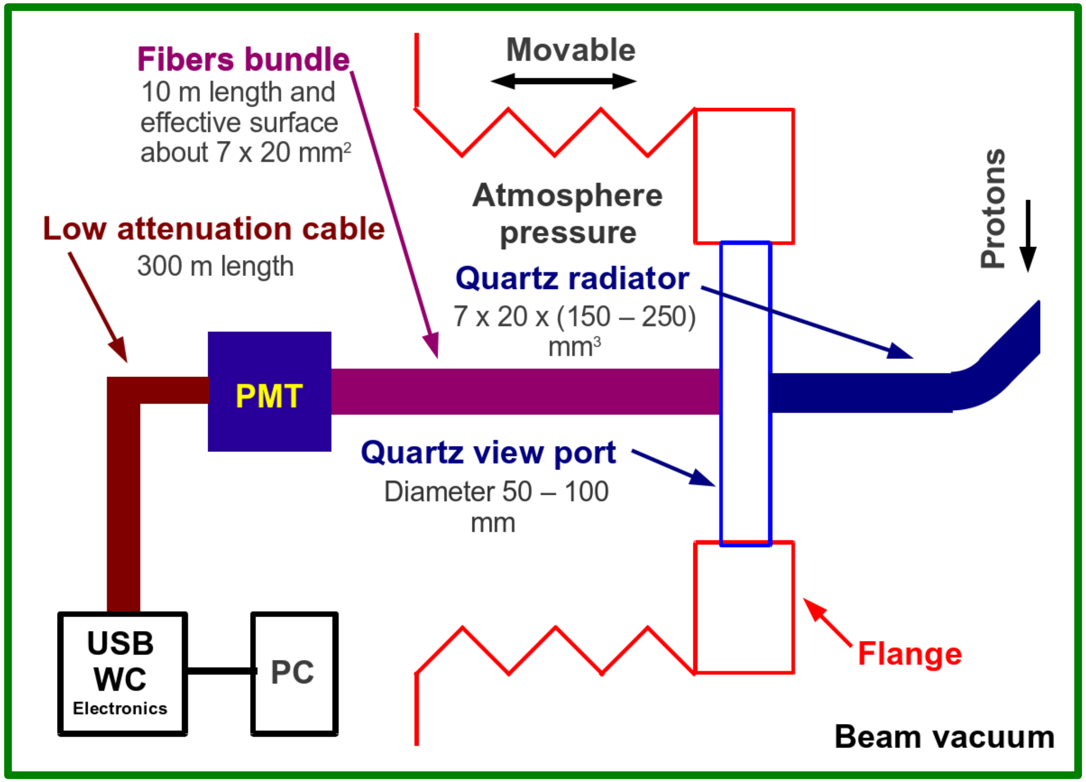
Aim: **count the number of protons** with a precision of about 5% (in case of 100 incoming protons) in the LHC environment.

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

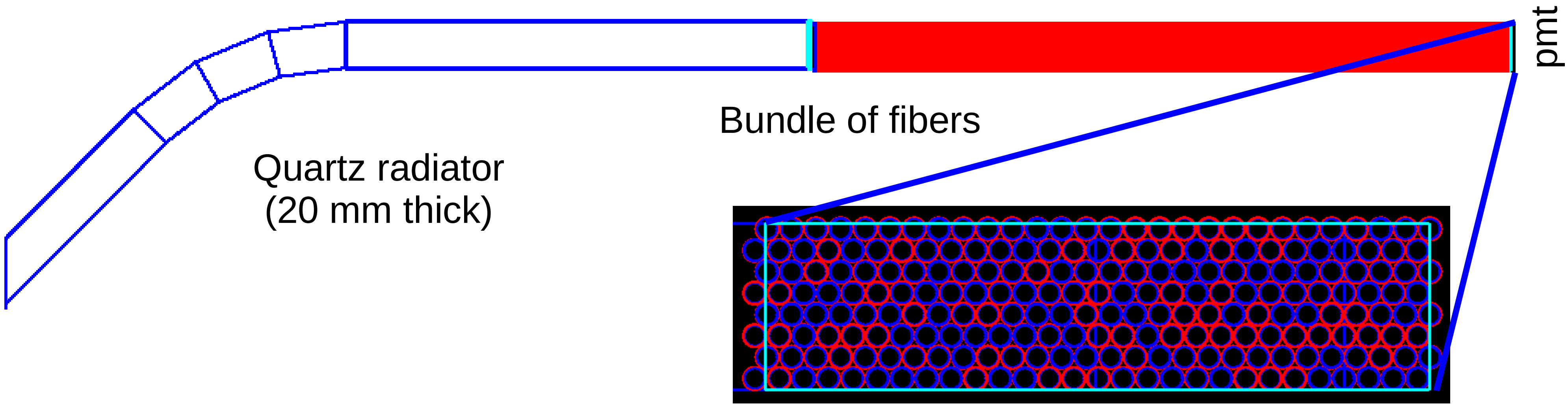


- Radiation hard quartz radiator
- The flange with view port attached to the movable bellow.
- The light will propagate inside the radiator and will then be transmitted to the PMT via a bundle of optical fibers.
- Quartz/quartz (core/cladding) radiation hard fibers.
- 300 m cable
- USB-WC electronics. For more details see :

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

Geant4 simulation of the CpFM

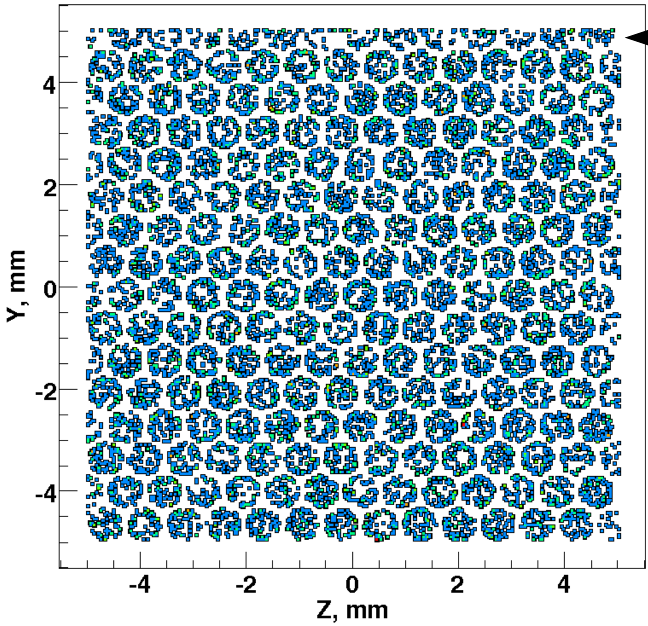
➞ A lot of shapes of the quartz radiator has been simulated. We present the most promising one.



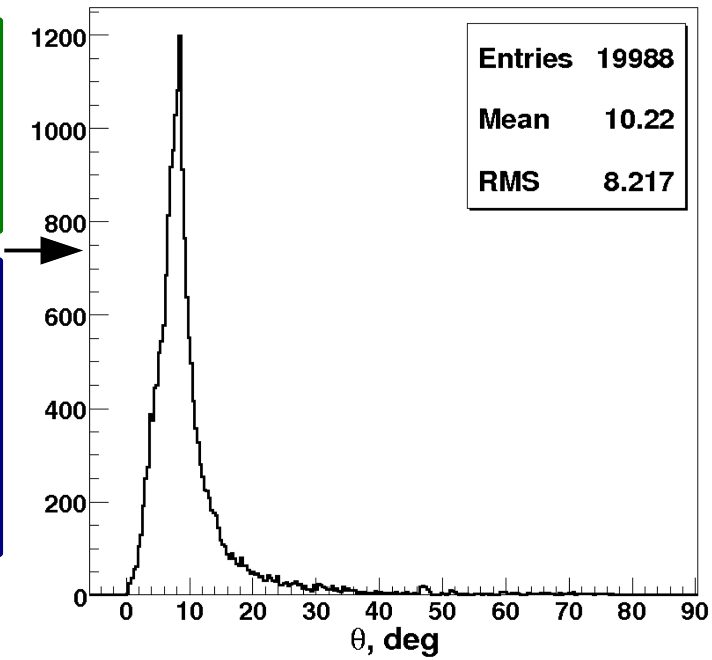
PMT:
- Bialkali photocathod (24 % @ 400 nm)
- Collection efficiency 80 %

Fiber:
- Numerical aperture: 0.22
- Corr diameter: 0.6 mm
- Cladding diameter: 0.66 mm
- Buffer diameter: 0.7 mm

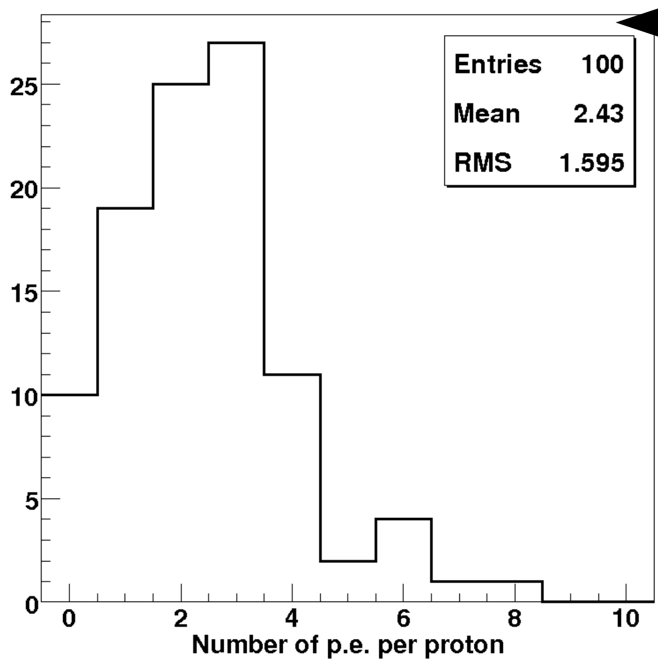
Results of the simulation



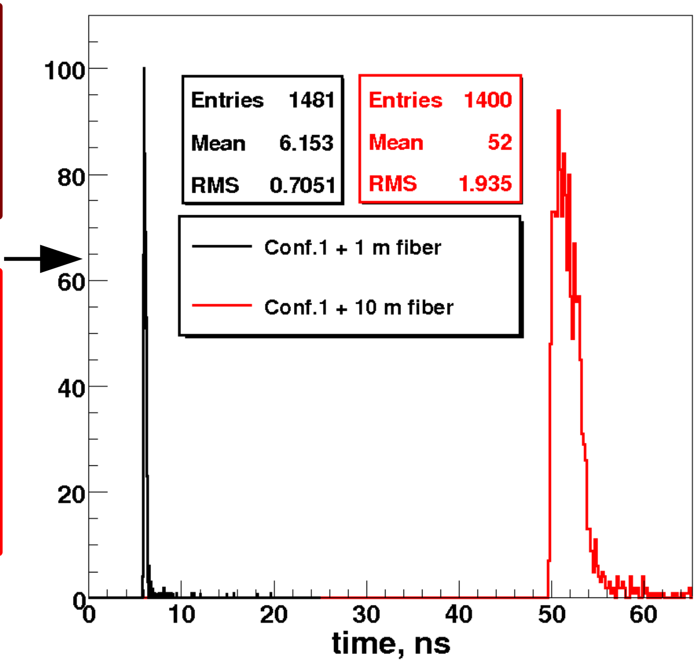
Position distribution of the photons on the PMT surface.



Theta distribution of the photons at the PMT entrance. Cut around 10° shows numerical aperture of the optical fiber.



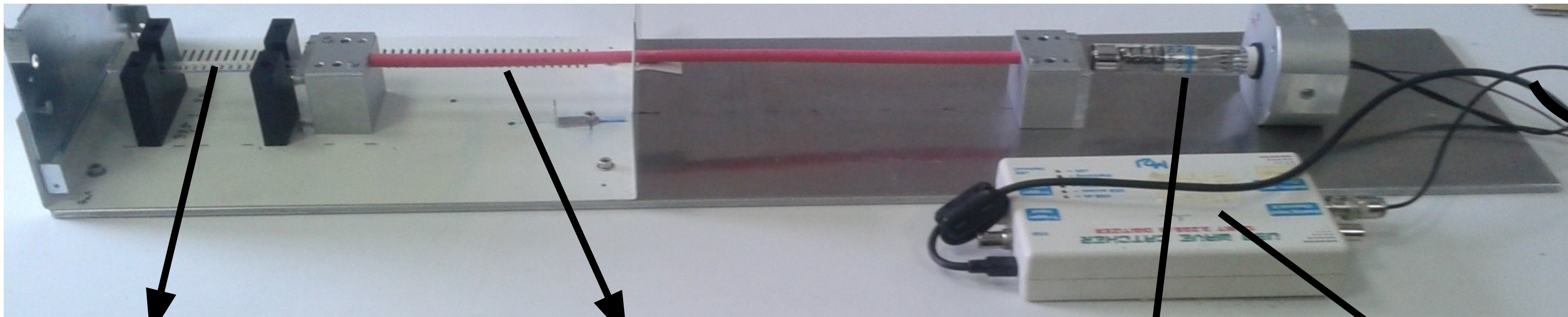
Per proton we are going to detect 2.4 photo-electrons.



The timing length of the photon signal increases with length of the fiber (10 m).

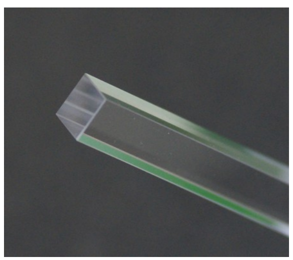
Simplified CpFM prototypes

Simplified prototype

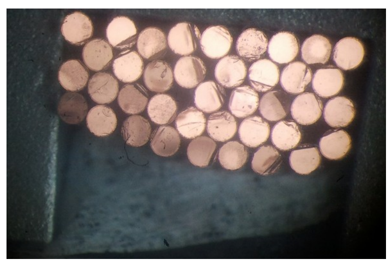


Remotely driven PC

Quartz finger
100 x 10 x 10 mm^3



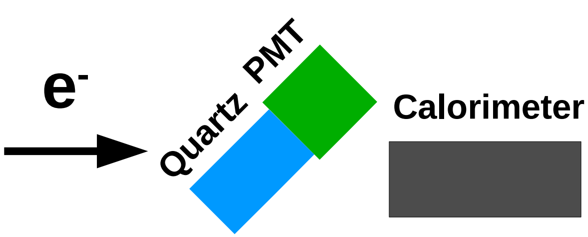
Home made bundle Quartz/quartz
(core/cladding) of fiber
400 x 2.8 x 5 mm^3



PMT R762
(15 mm effective diameter)

(2 or 8) channels
USB - Wavecatcher
electronics

1)



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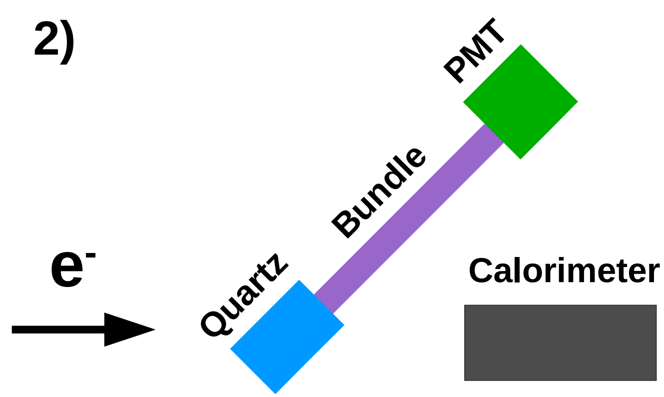

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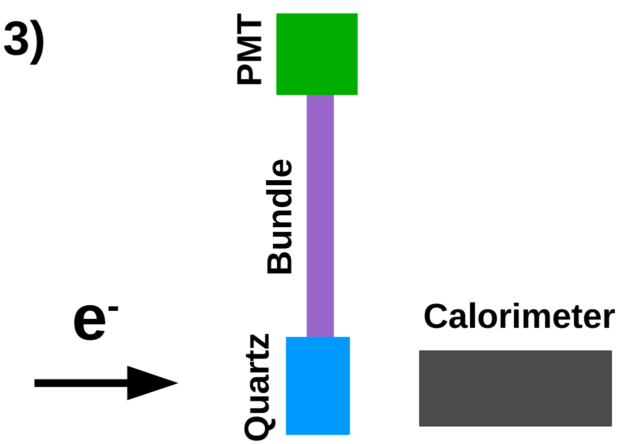
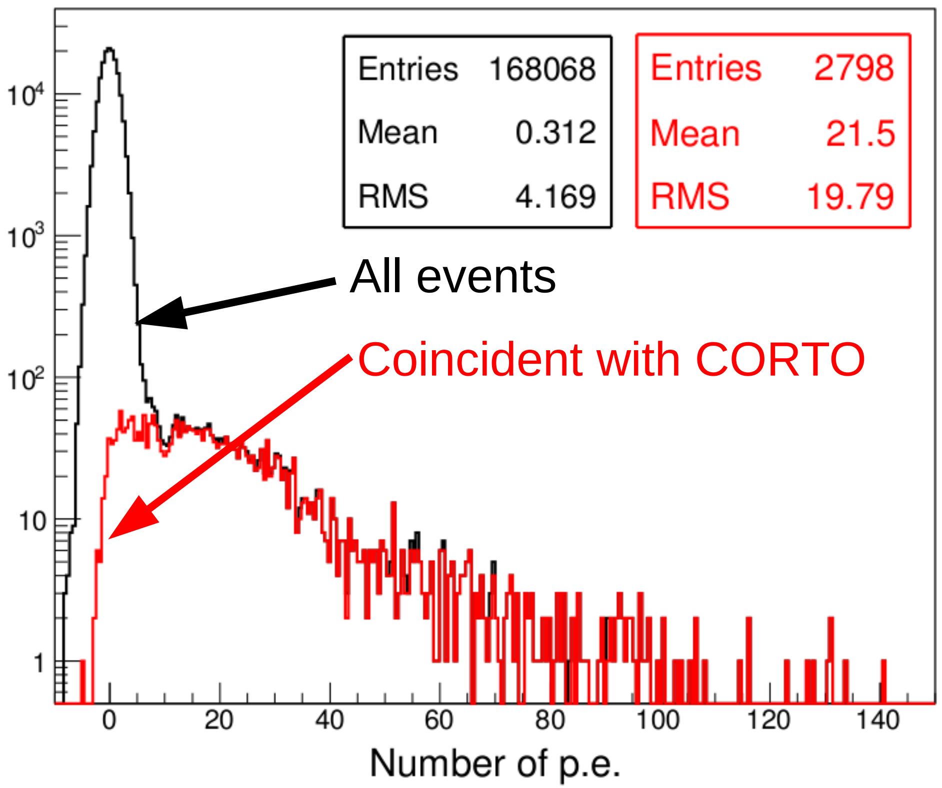


Test with cosmics

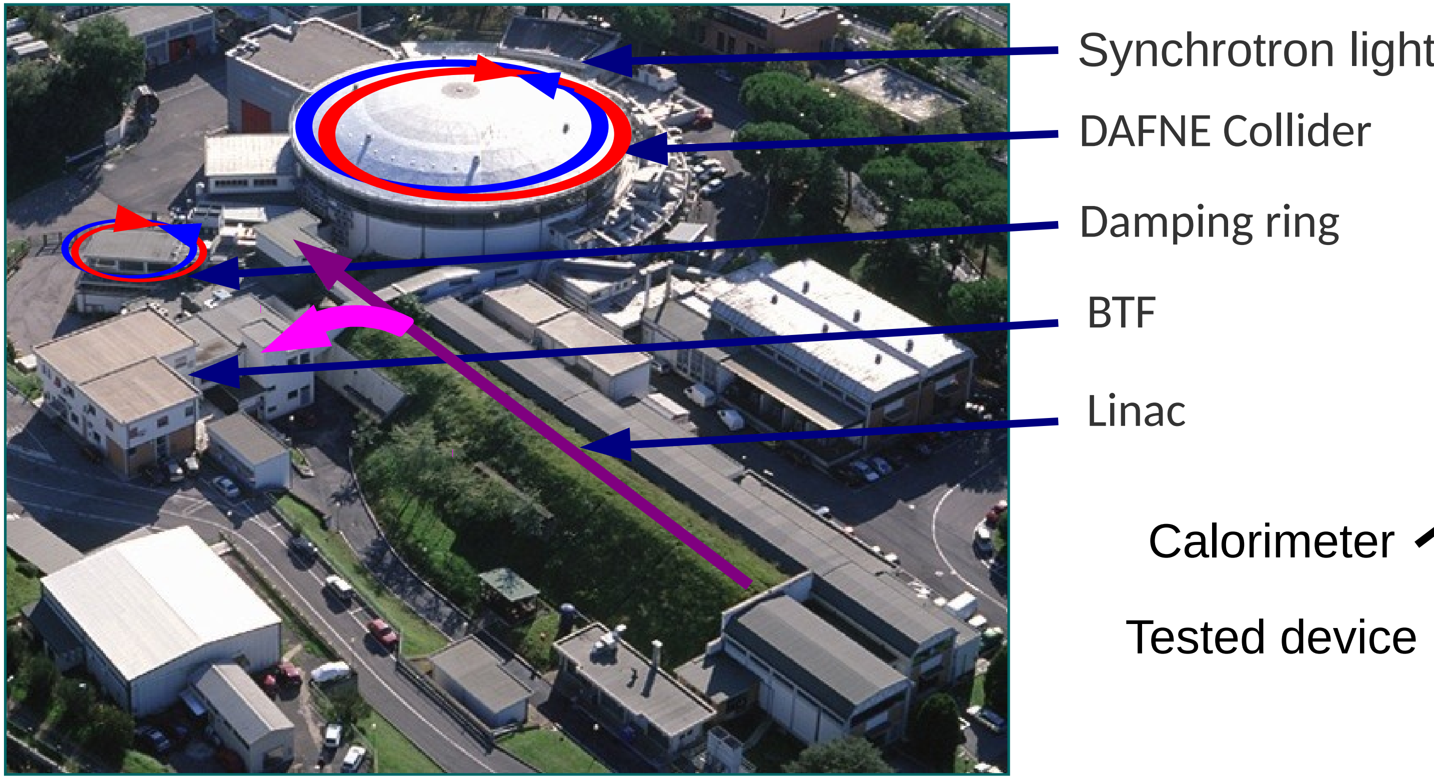
- Before beam tests of the prototype we performed measurements with cosmic muons reconstructed with CORTO (Cosmic Ray Telescope at Orsay)

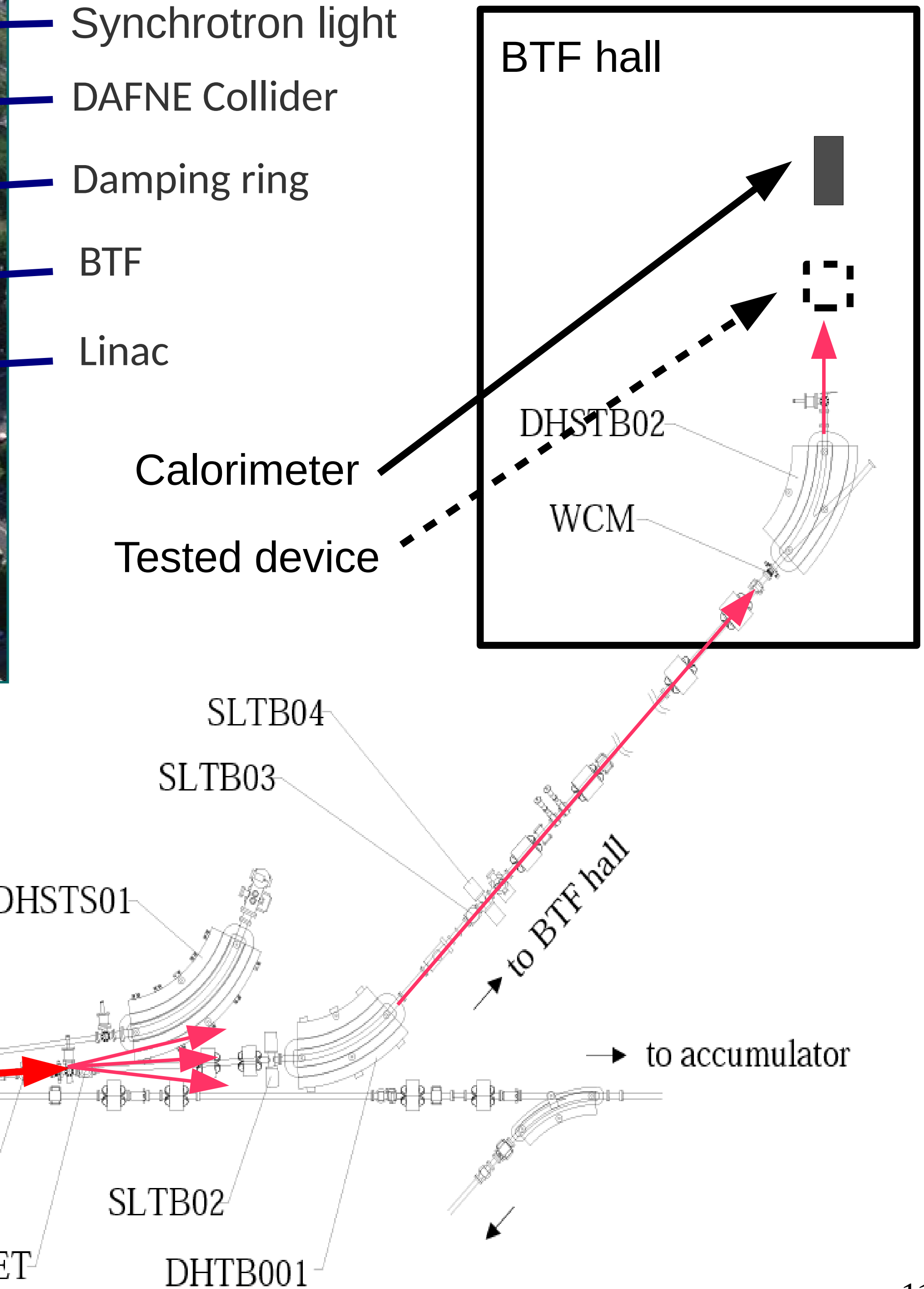
Results



- In average for all incoming muons we detected 21 p.e.

BTF – (Beam Test Facility) at Frascati





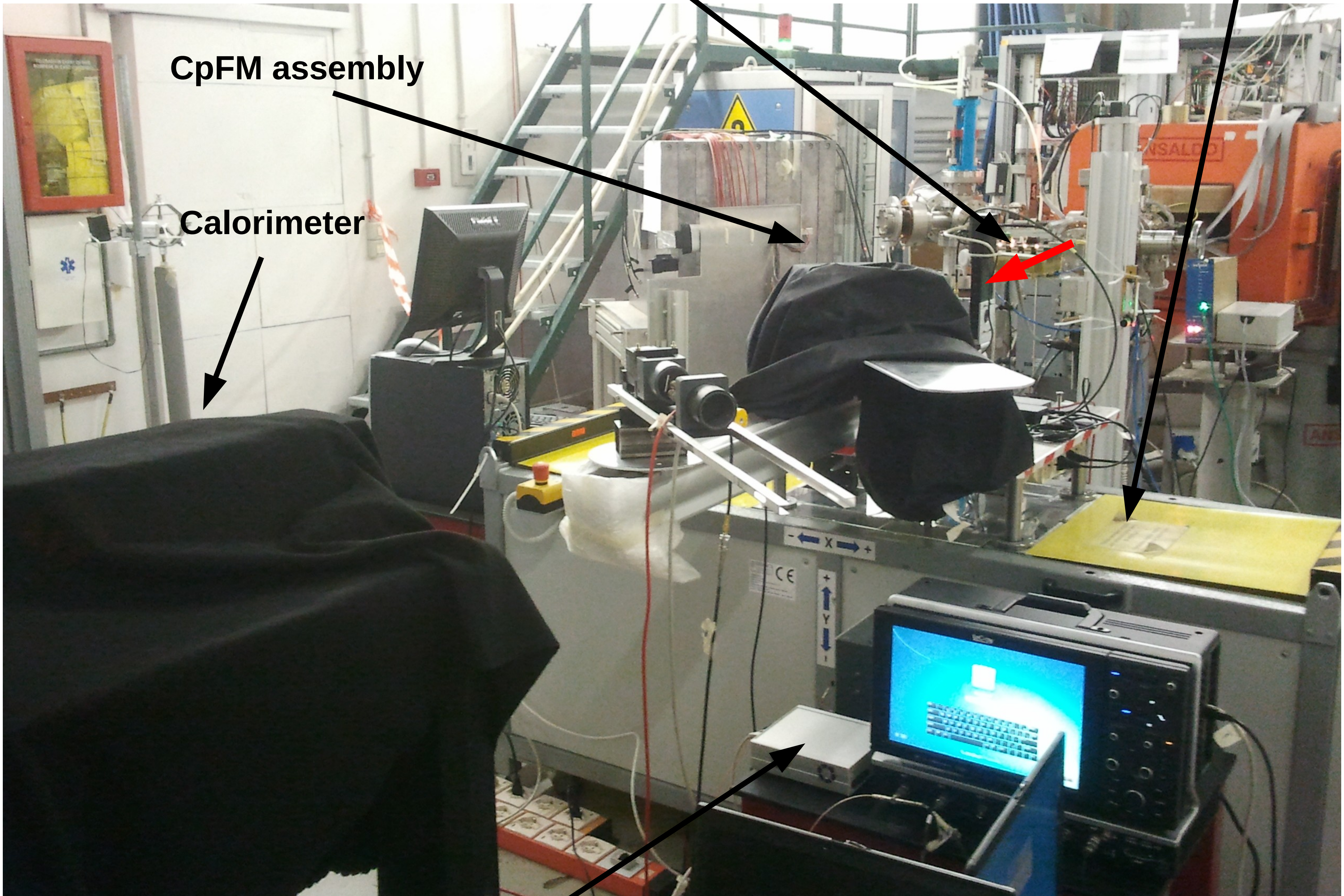
Characteristics of the e^- beam @ BTF

Particles number:	1 - 10^5 e^-/pulse
Energy:	25 – 500 MeV
Frequency:	20 Hz
Pulse duration:	10 ns

Beam tests at BTF (14-18 October 2013)

Electron beam with energy around 446 MeV

Translation stage



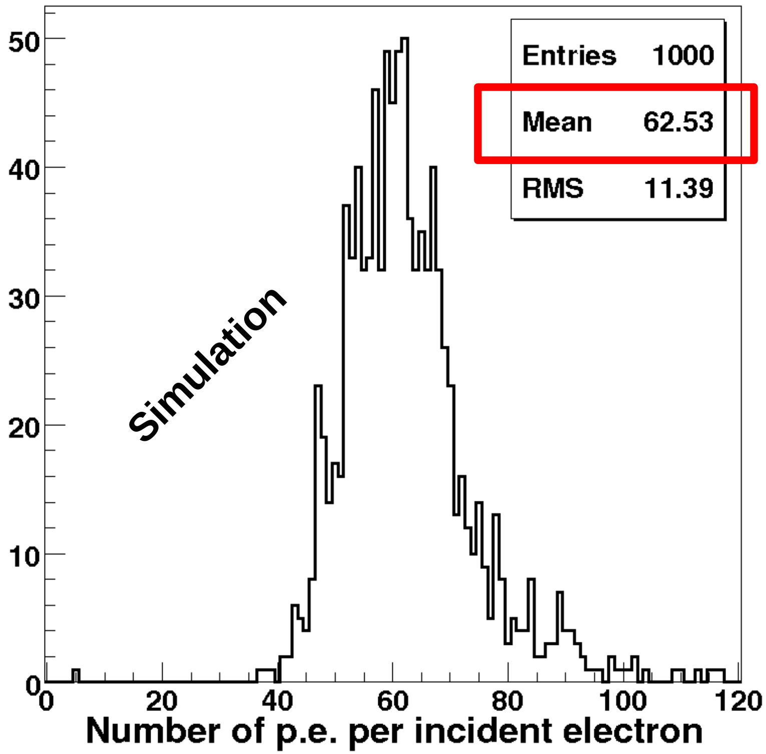
8-channel USB-WaveCatcher

Quartz + PMT (comparison with simulation)

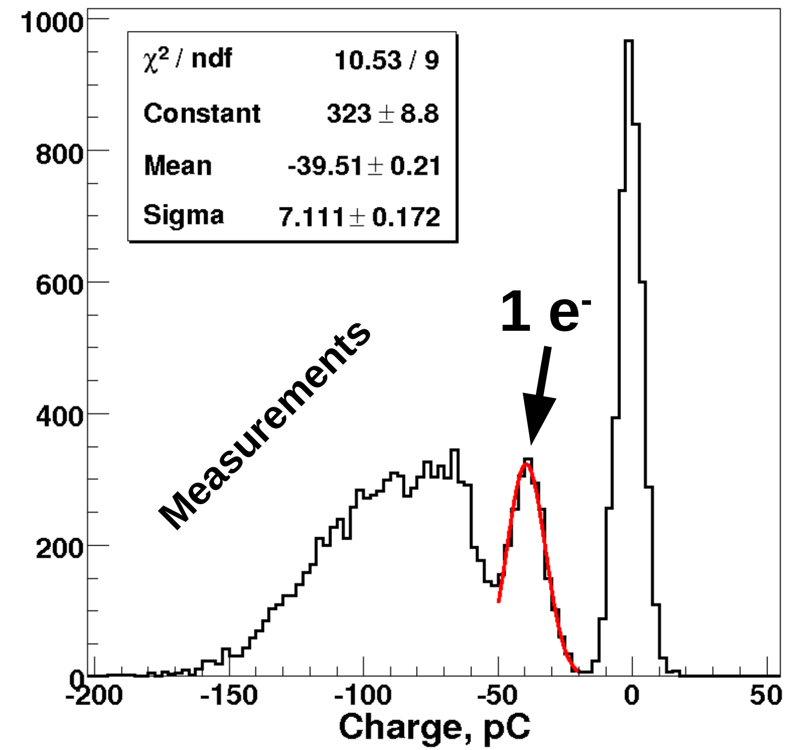
Simulation

446 MeV e⁻ with 45° incident angle

Bialkali photocathode with
100% collection efficiency



Measurements



Gain of the PMT is ~ 4.3*10⁶
for H.V. = -1150 V

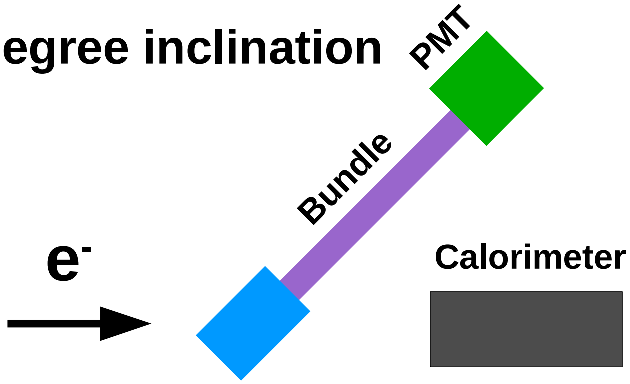
39.5 pC per incident electron

57.4 p.e. per incident electron

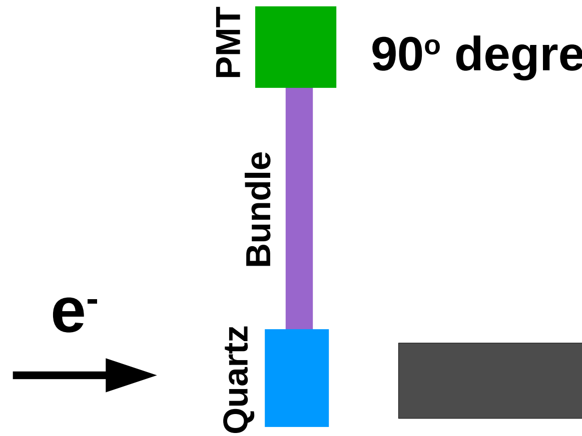
Good agreement !!!

Quartz + bundle of fibers + PMT

45° degree inclination

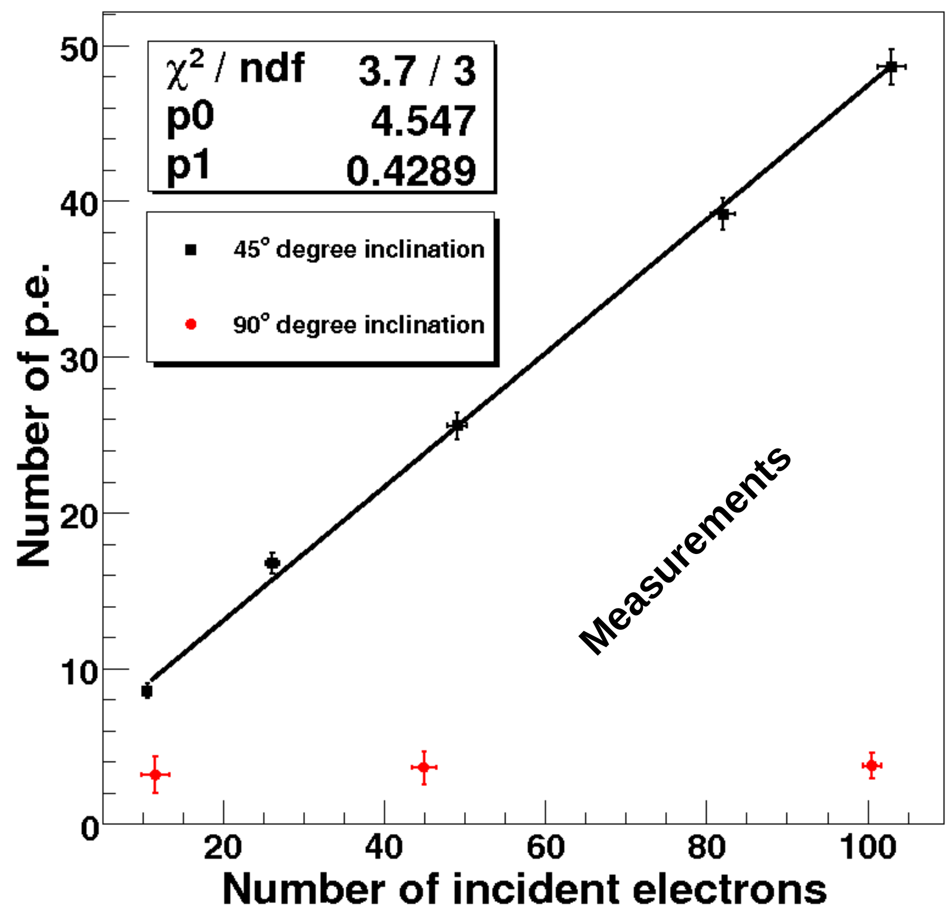


90° degree inclination

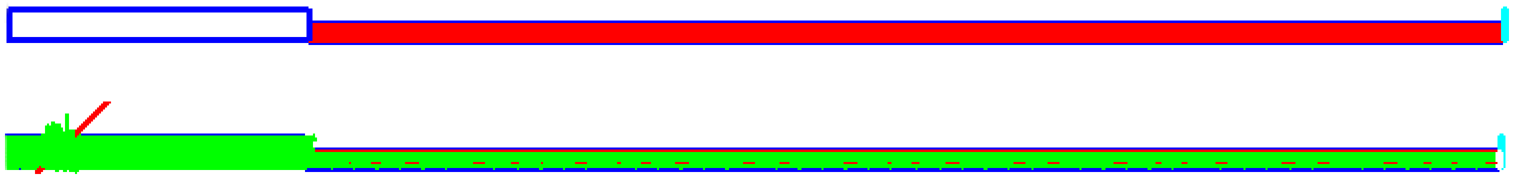


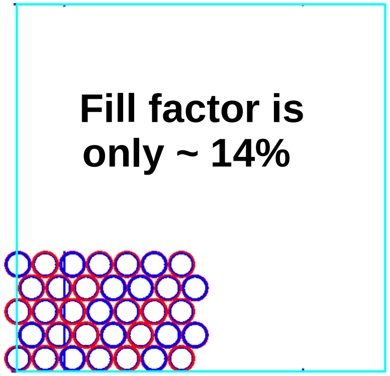
We detect 0.43 p.e. per incident electron

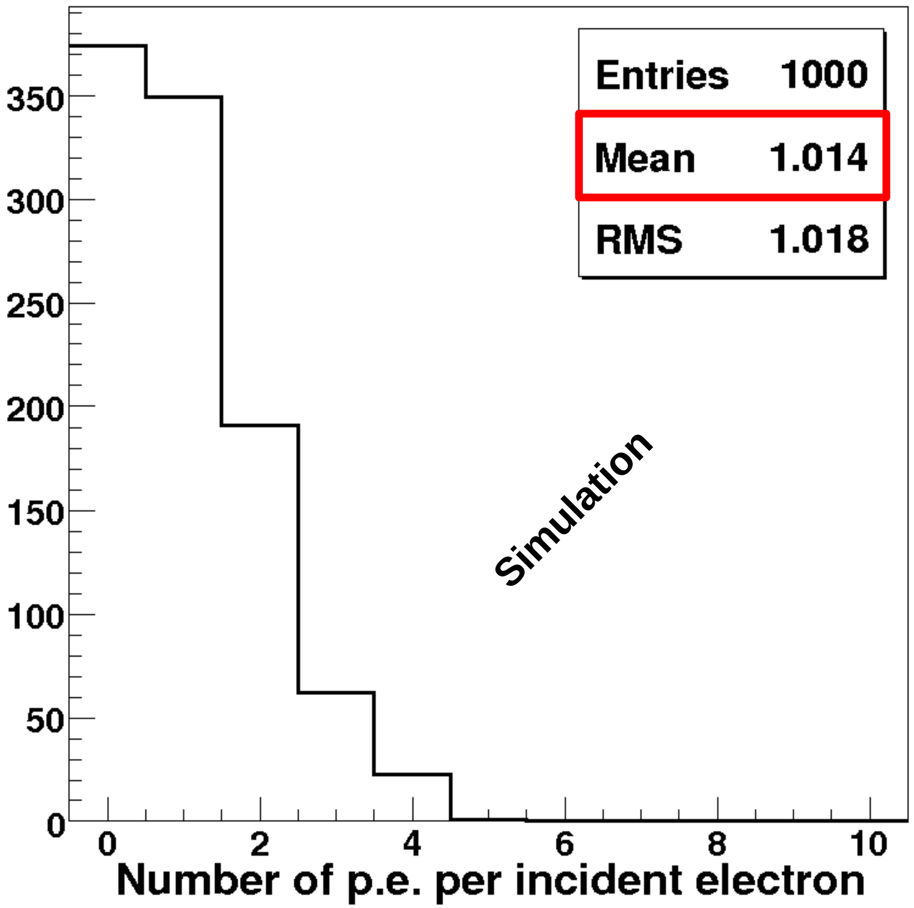
Due to small angular acceptance of the fibers (numerical aperture 0.22) geometry with 90° degree inclination does not detect any light.



Quartz + bundle of fibers + PMT (comparison with simulation)







The difference between measurements and simulation is roughly factor of two. It is probably coming from the poor quality of the home made bundle.

The interfaces efficiency:

quartz finger vs bundle
bundle vs finger
can be estimated: ~70 %

Conclusions

→ BTF tests prove the feasibility of the CpFM detector. However additional tests are needed before construction and calibration of the final version of CpFM.

→ Quality of the optical fiber bundle need to be improved. It will be produced by a specialized company.

→ Mechanical support design on going at CERN.

→ The CpFM prototype will be tested under irradiation (protons and gammas).

→ The CpFM will be calibrated at BTF and then installed.

1. inside the SPS beam pipe in June 2014.
2. inside the LHC beam pipe at the beginning of 2015.