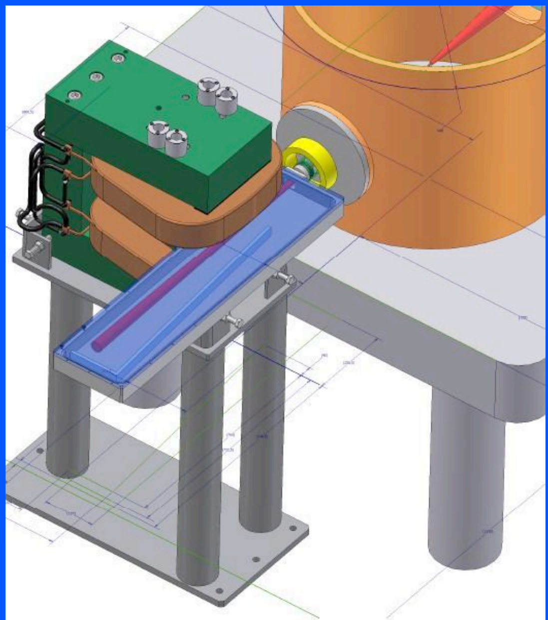
INTERNATIONAL CONFERENCE: ACCELERATOR INSTRUMENTATION AND BEAM

DITANET

9-11 November 2011, Seville

Electron Spectrometer for Multi-GeV Laser-Plasma accelerator



Silvia Martellotti

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PlasmonX collaboration

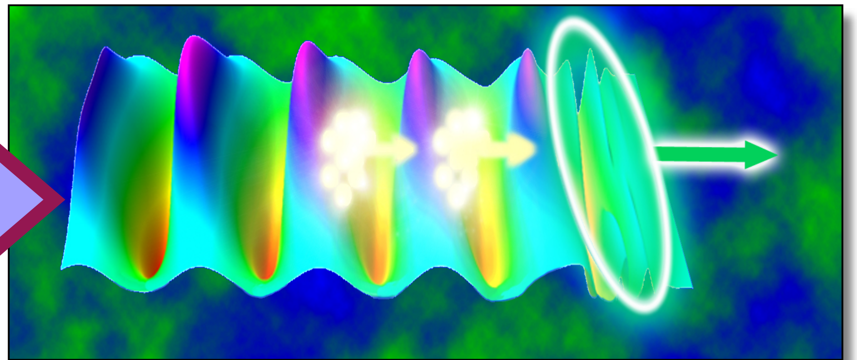
PLASMA TO ACCELERATE PARTICLES

Laser-Plasma interaction can be used for charged particle acceleration

The great interest of this new acceleration technique is that a plasma is an ionized gas and can sustain extremely large electric fields

In the RF cavities, accelerating gradients are limited by the breakdown of materials to a maximal value of **100 MV/m**

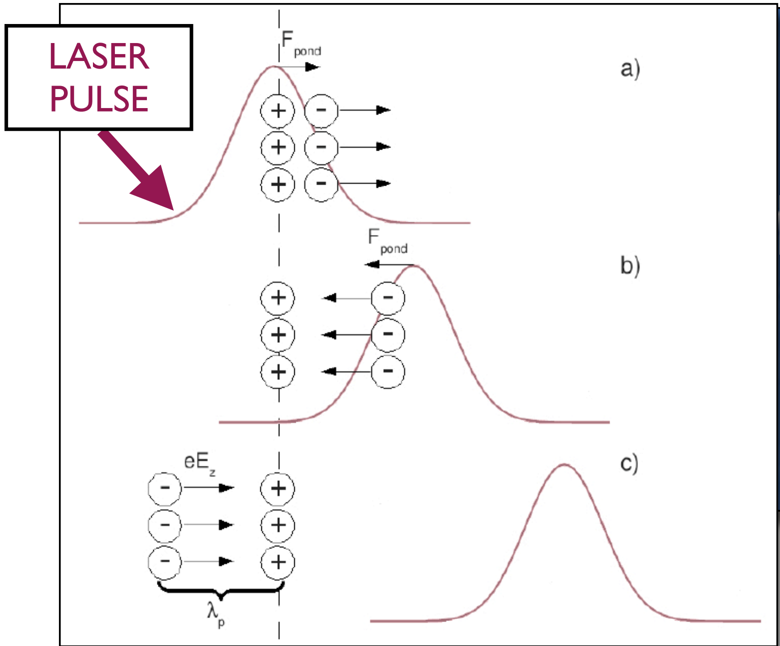
Inside a plasma, accelarating gradients bigger than **100 GV/m** can be realised, this means that it is possible to reach energies of ~ 1 GeV in ~ mm

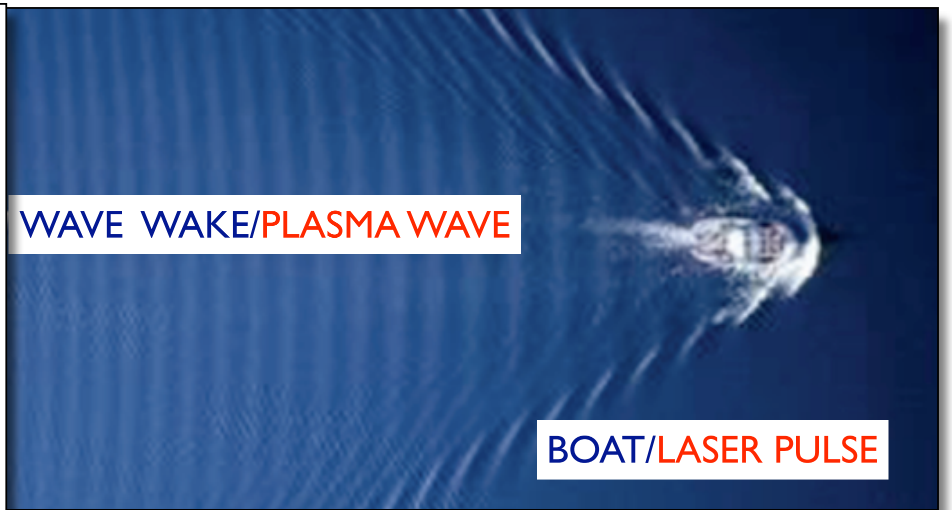


ELECTRON PLASMA WAVES

<u>The accelerating gradient is the one associated with electron plasma waves</u>

To create a plasma wave a high intensity ultrashort-laser-pulse is used





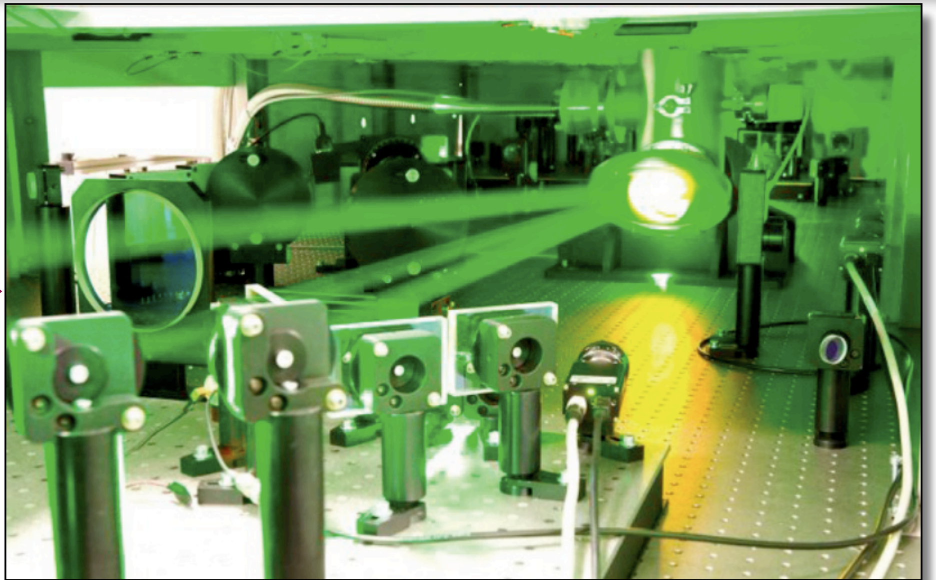
The laser pulse, thanks to its ponderomotive force, pushes out the electrons from their equilibrium position, and, crossing the plasma, creates an electron plasma wave behind it

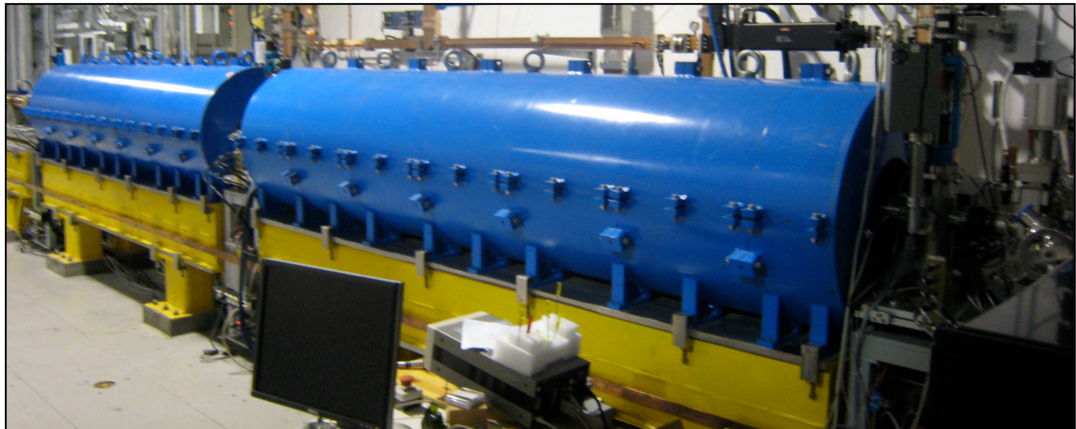
LASER WAKE FIELD ACCELERATION

PLASMONX EXPERIMENT @ LNF (Italy)

LASER FLAME

Ultra-short pulse of 20 fs
Peak pulse power up to 300 TW
Maximun intensity 10^18 W/cm^2
Frequency of 10 Hz



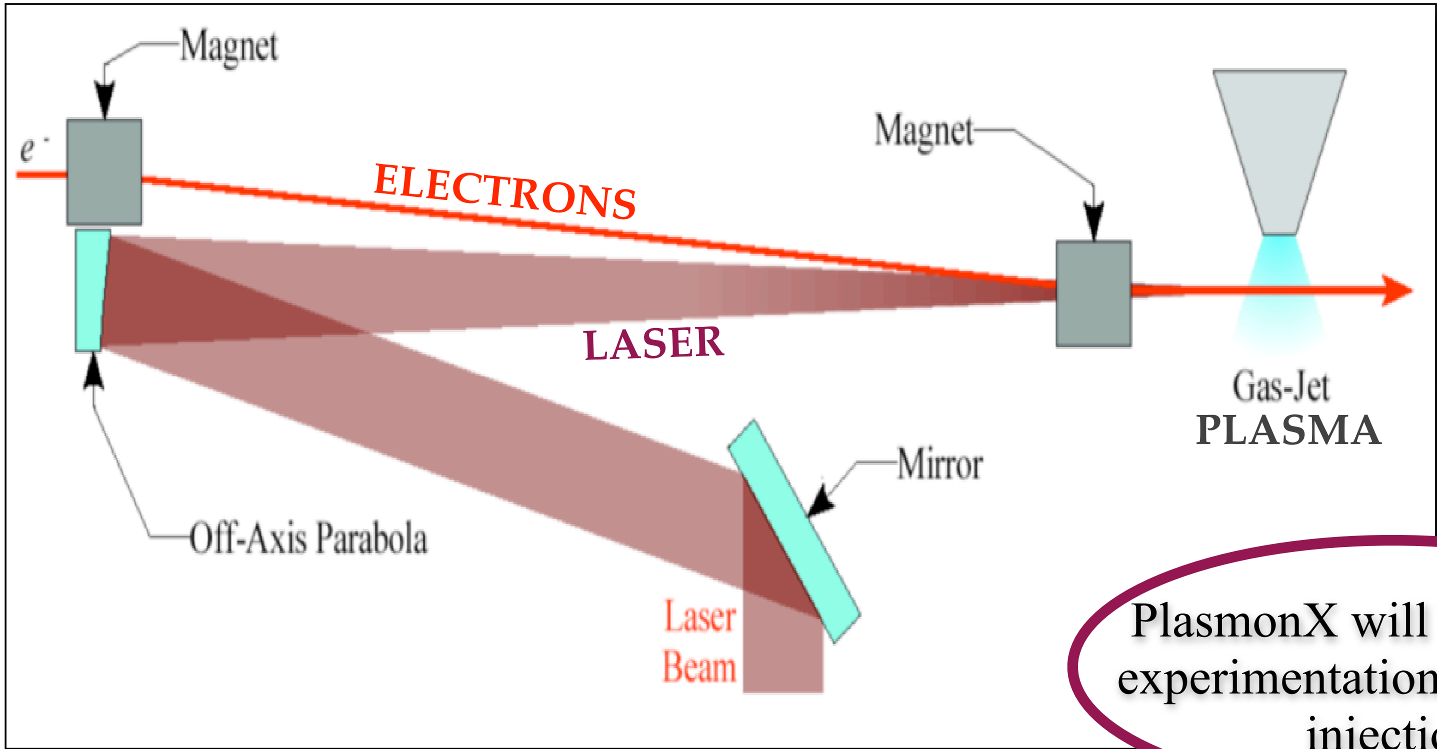


LINAC SPARC

Linear accelerator: produces 200 MeV ultra-short electron bunches that will be synchronized with the laser within fs

PLASMONX EXPERIMENT @ LNF (Italy)

SPARC's electron bunches will be injected in the plasma excited by the laser.
The electric field associated with the plasma wave accelerate electrons forward

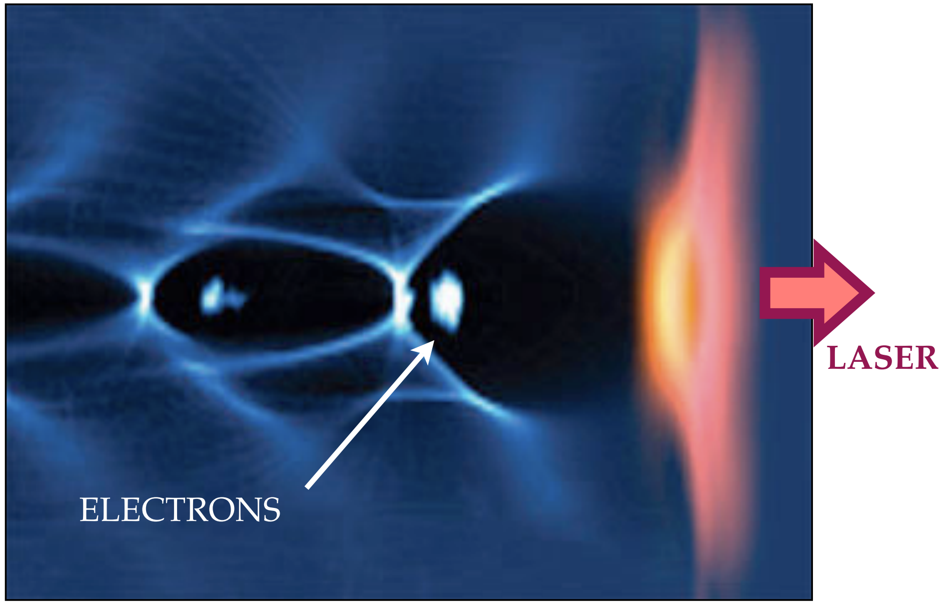


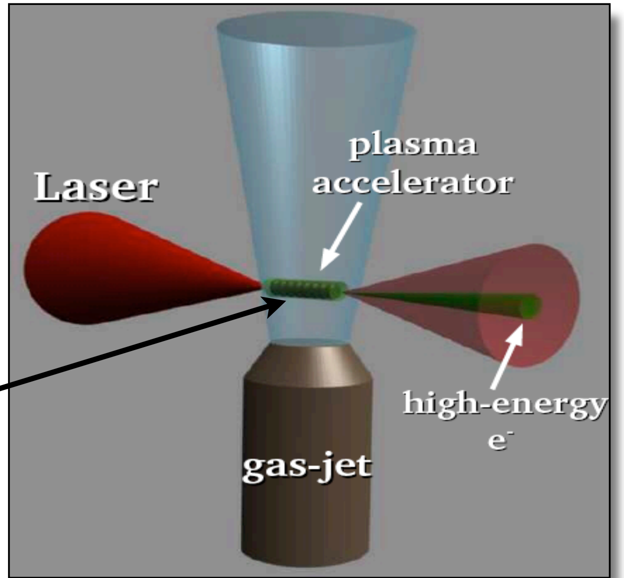
PlasmonX will be the first experimentation of external injection

SITE: SELF-INJECTION TEST EXPERIMENT

Up to now only **self-injection** has been performed:
electrons of the plasma are accelerated

This is what we are presently doing @PlasmonX to test laser performance: SITE Experiment





Self-injection occurs when a suitably intense laser pulse breaks the plasma wave: with the **wavebreaking** a bunch of relativistic electrons oscillating inside the plasma, leave the wave and are accelerated forward

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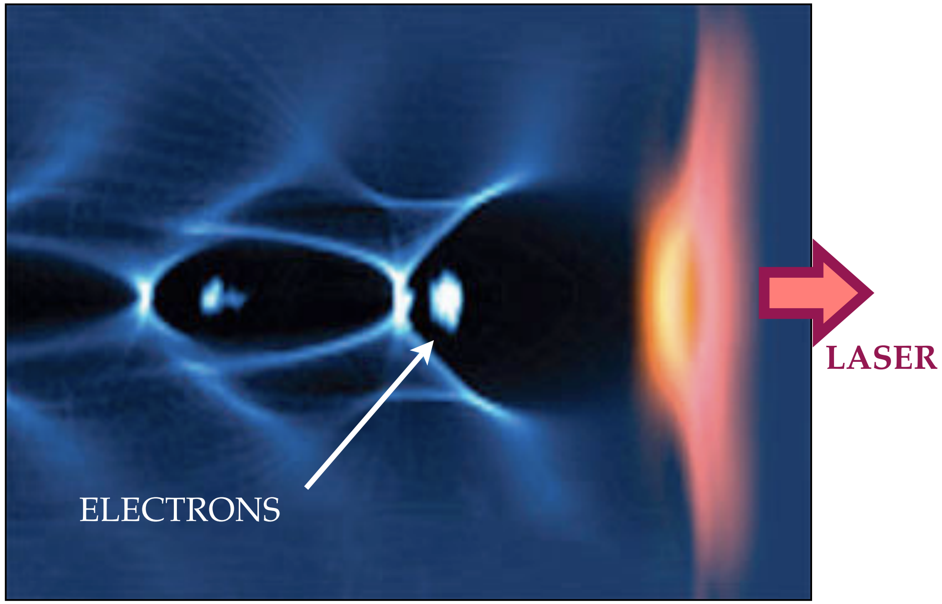

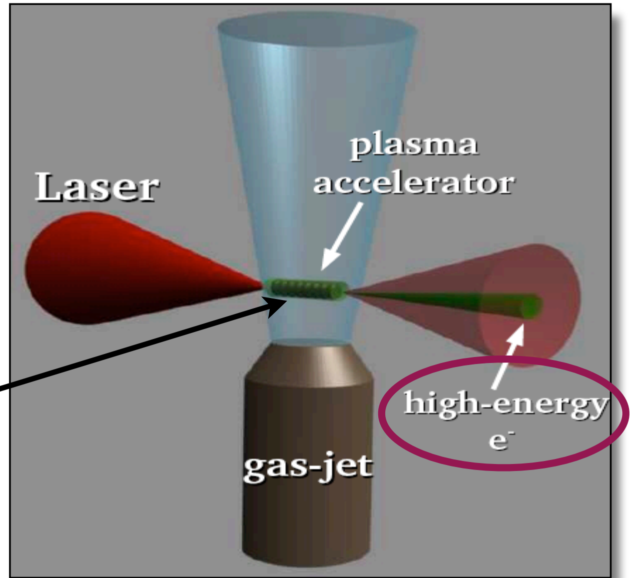

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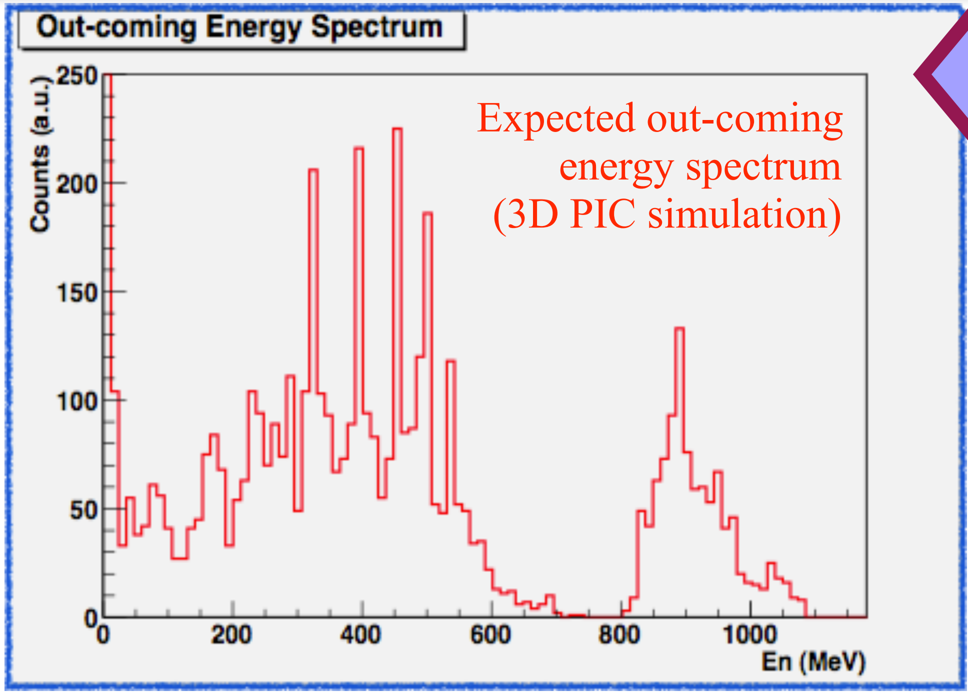
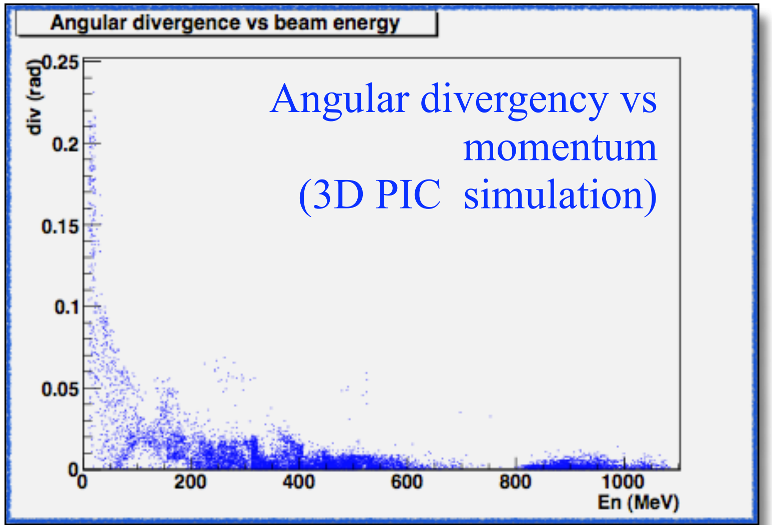
SPECTROMETER REQUIREMENTS



characterized by a peak at 900 MeV and a broad tail at low energy.

~1 GeV in 4 mm of plasma !



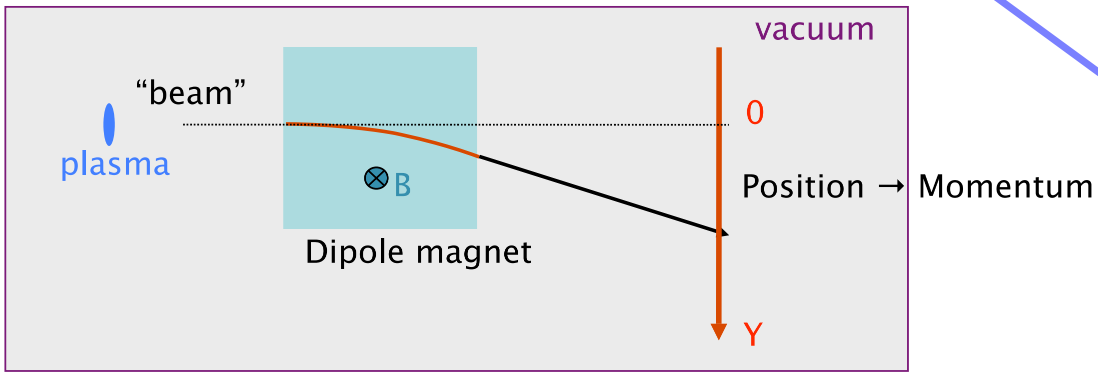
Because of the atypical bunch properties there are unprecedent requirements for our detector:

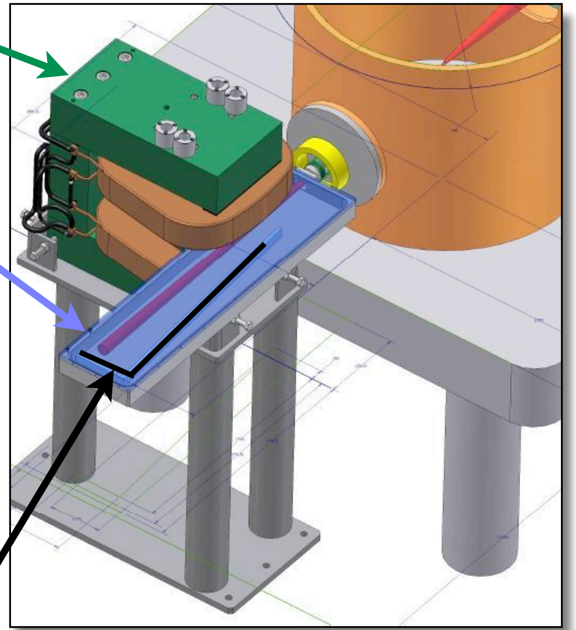
- ☑ detect about 10^10 electrons arrivinig simultaneusly
- ☑ mesure the momentum over three orders of magnitude under a large angular divergency
- ☑ have a resolution <1% over a broad momentum range

LAYOUT

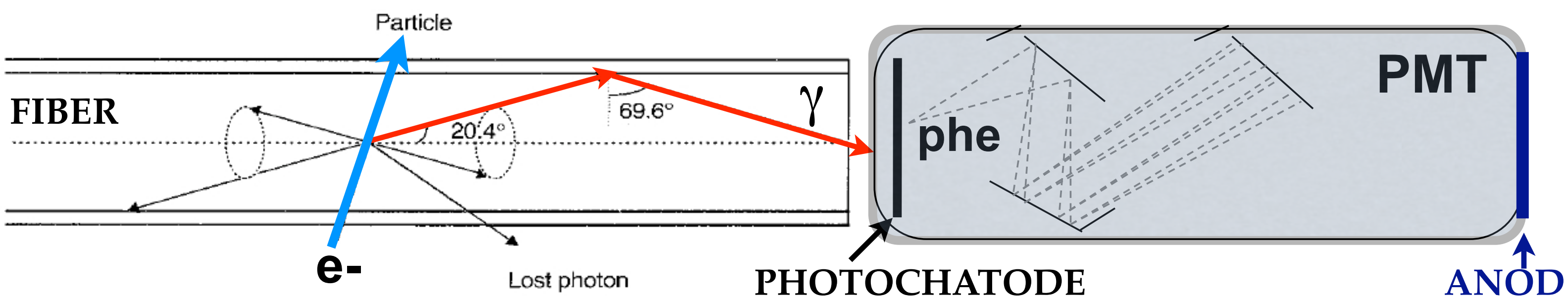
Electromagnet with vertical dipole magnetic field of about 0.5 T

Vacuum chamber where the electrons travel





Detector: scintillating fibers read by photomultipliers



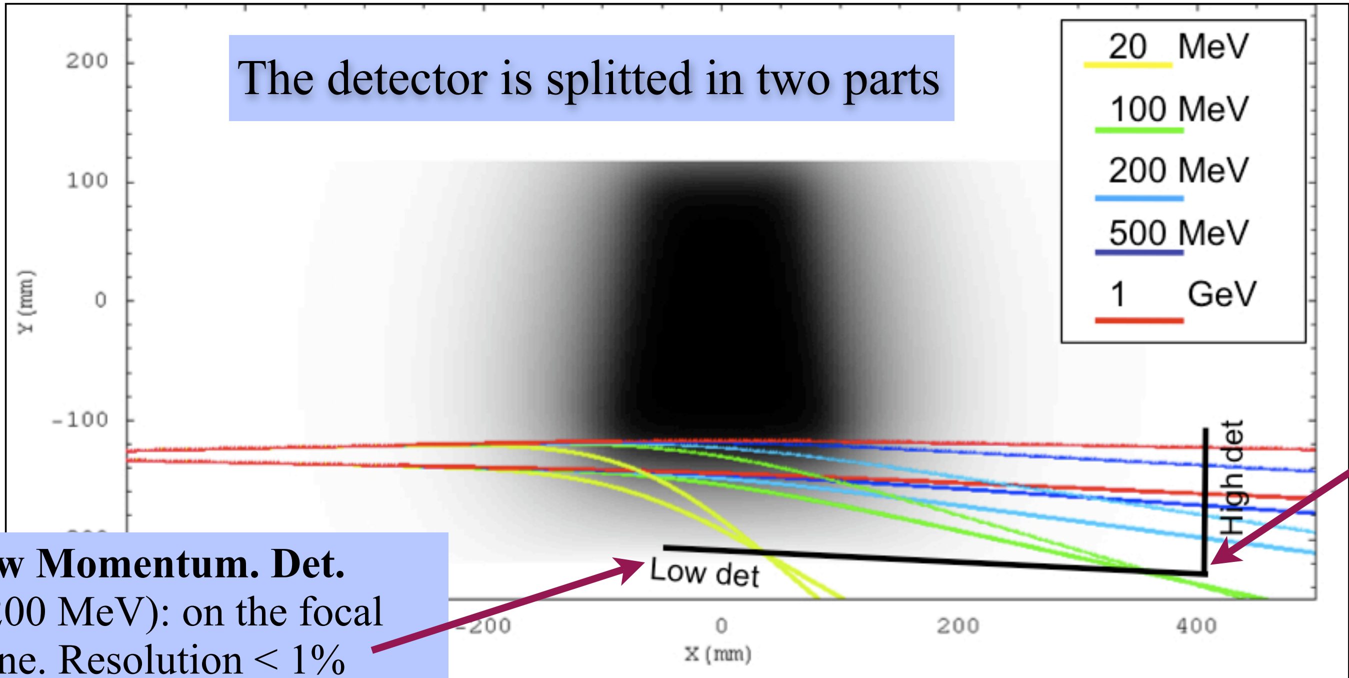
DETECTOR POSITION

Electron bunch comes from a point-like spot ~1 m upstream:

the momentum resolution is dominated by the angular dispersion

which overlays in a given position trajectories from different momenta

If electrons cross the fringe field they undergo a different field depending on their angular divergency and trajectories of the same momentum will converge in a focus



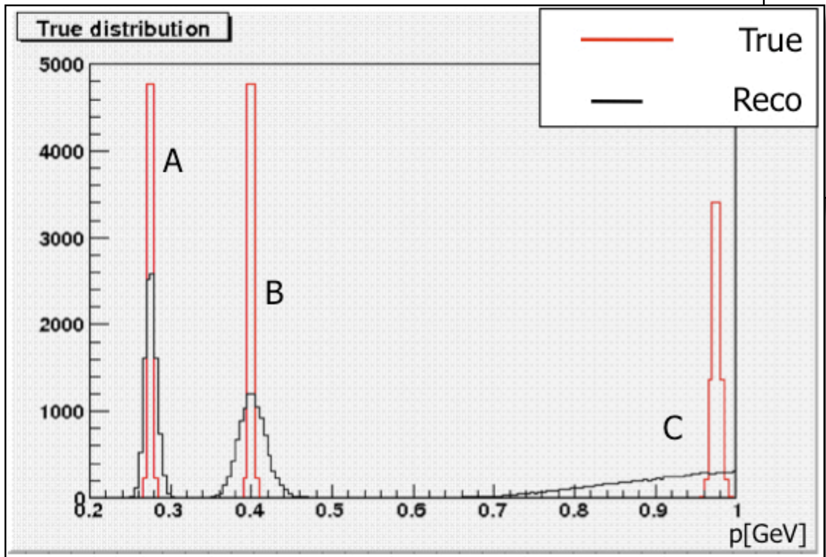
High Mom. Detector: as far as possible. Resolution <5%

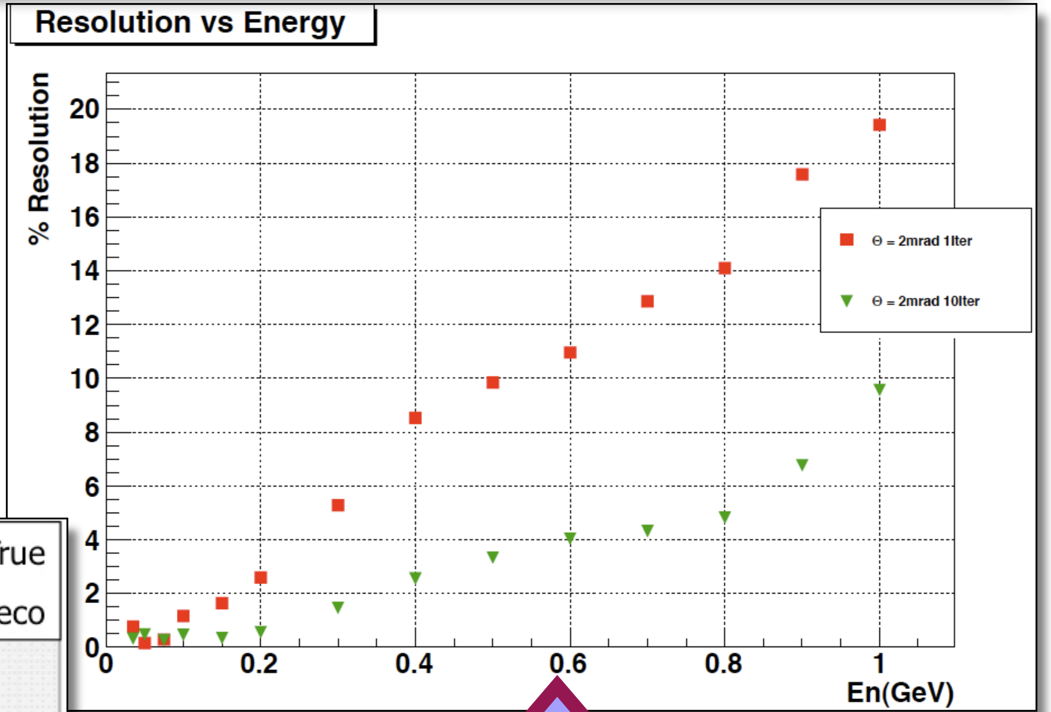
Low Momentum. Det. (<200 MeV): on the focal plane. Resolution < 1%

MOMENTUM RESOLUTION

Data Analysis:

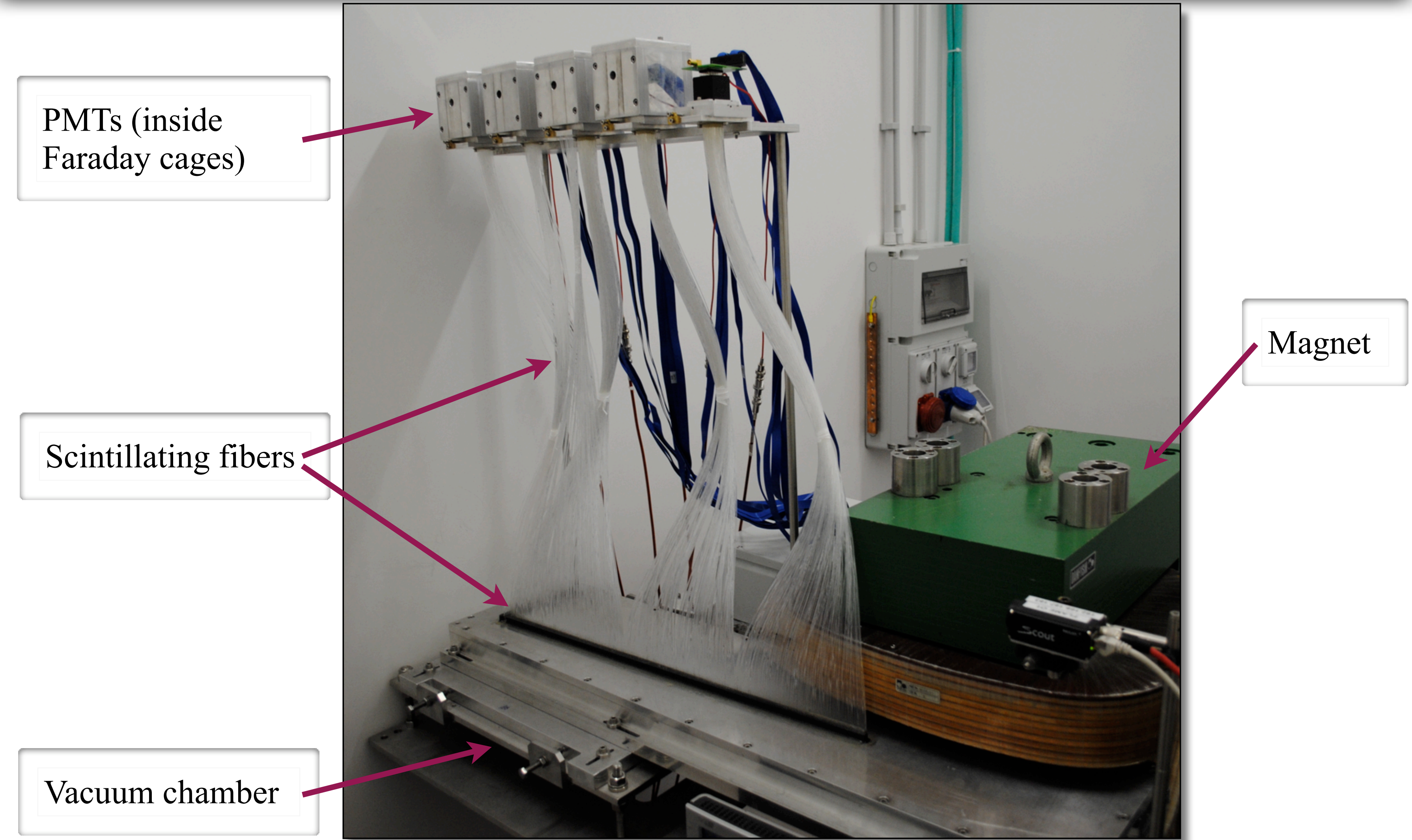
Momentum spectrum is reconstructed from the mesured positions by a Bayesian unfolding





Resolution obtained at different energies with 1 (red) or 10 (green) iterations of the unfolding procedure

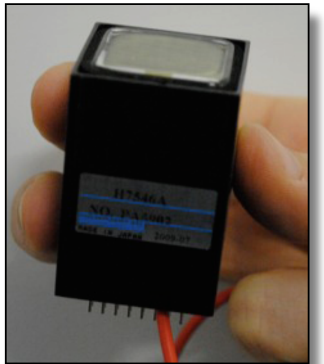
MAGNETIC SPECTROMETER



MULTI-CHANNEL PHOTO-TUBE

HAMAMATSU H7546B 64 channels (8x8) multi-anode PMT

<u>5 PMT x 64 ⇒ 320 electronic channels</u>

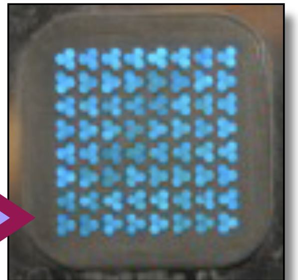


PMT are matched with:

Scintillating fibers KURARAY SCSF-81-SJ. 1 mm diameter

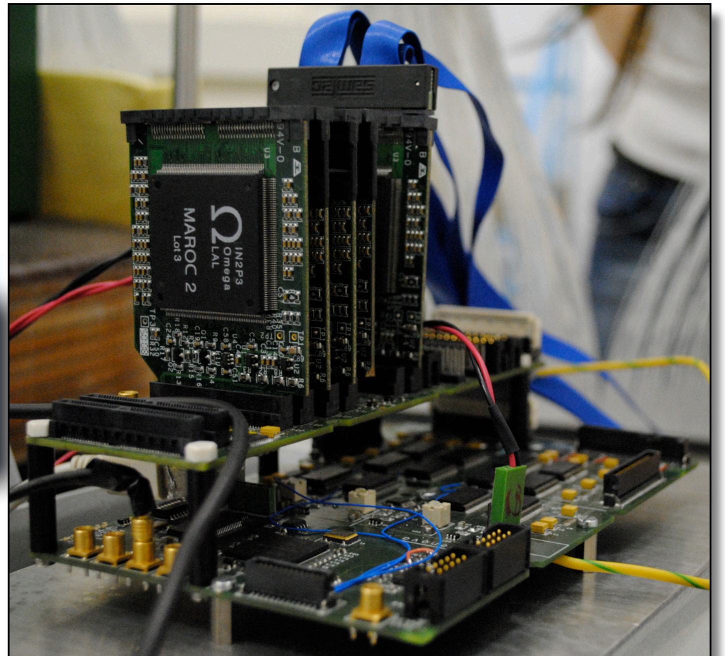
High mom. det:
1 fiber/1 PMT-pixel

Low mom. det:
3 fibers/1 pixel



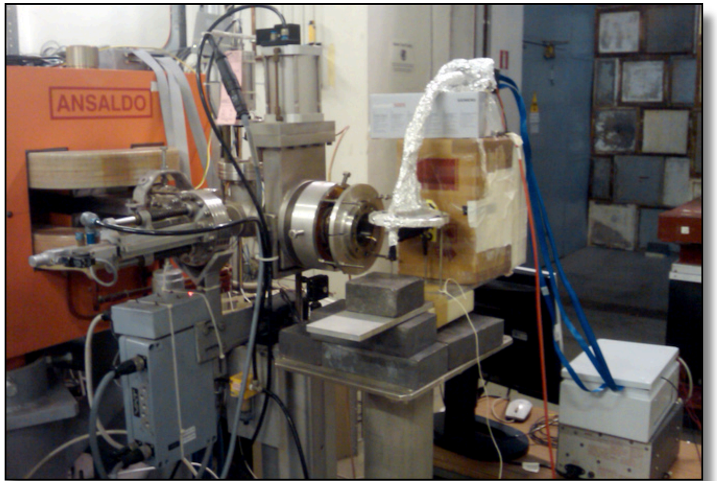
MULTIPLEXING READOUT

Readout with a technology based on MAROC2 chip (allowing to multiplex up to 4096 channels)

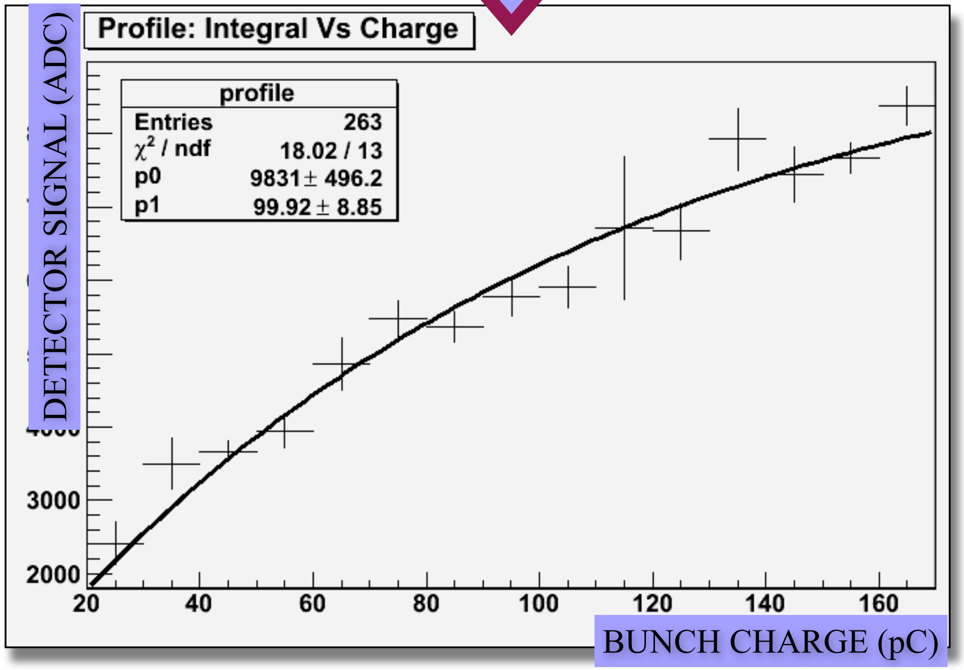


PROTOTYPE TESTS

A protoype has been tested in Frascati Lab at the Beam Test Facility (BTF)



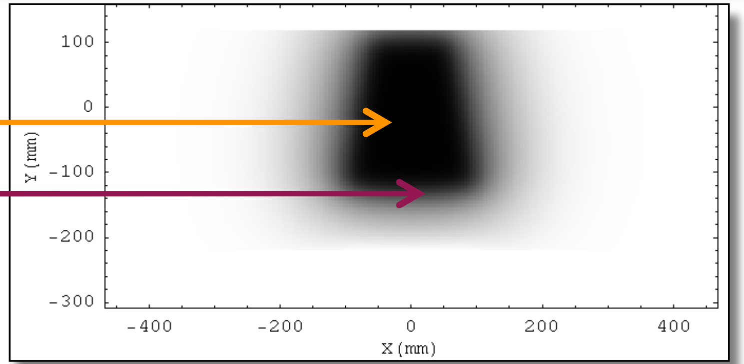
The BTF provides electron bunches, with a known variable total charge. Measuring the prototype detector signal vs the electron charge a **calibration curve** has been obtained



PMT gain and variable parameters of the electronics have been tuned to find the optimal **working point**. Mainly to avoid saturation fenomena (very high number of electrons expected)

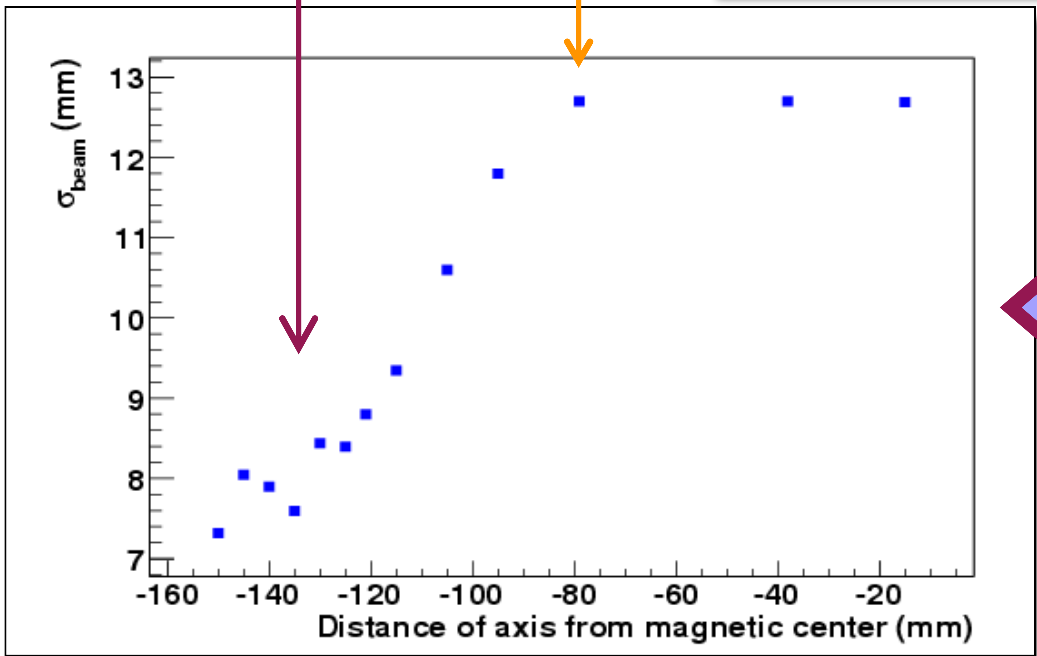
FOCUSING TEST

At BTF the focusing property of the fringe field of the spectrometer electromagnet has been tested



Center

Working point (fringe)



Spot size measurement

DETECTOR COMMISSIONING

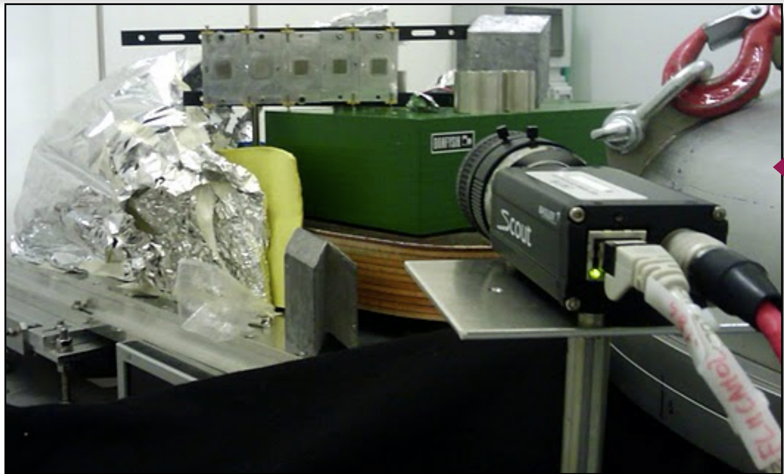
First electron bunches have been accelerated with low laser intensity and preliminary experimental conditions

NOISE PROBLEMS

The readout electronics proved to be not screened enough from the pulsed high energy EM field (GV/m) generated in the laser-plasma interaction, making it impossible to discriminate signal from noise.

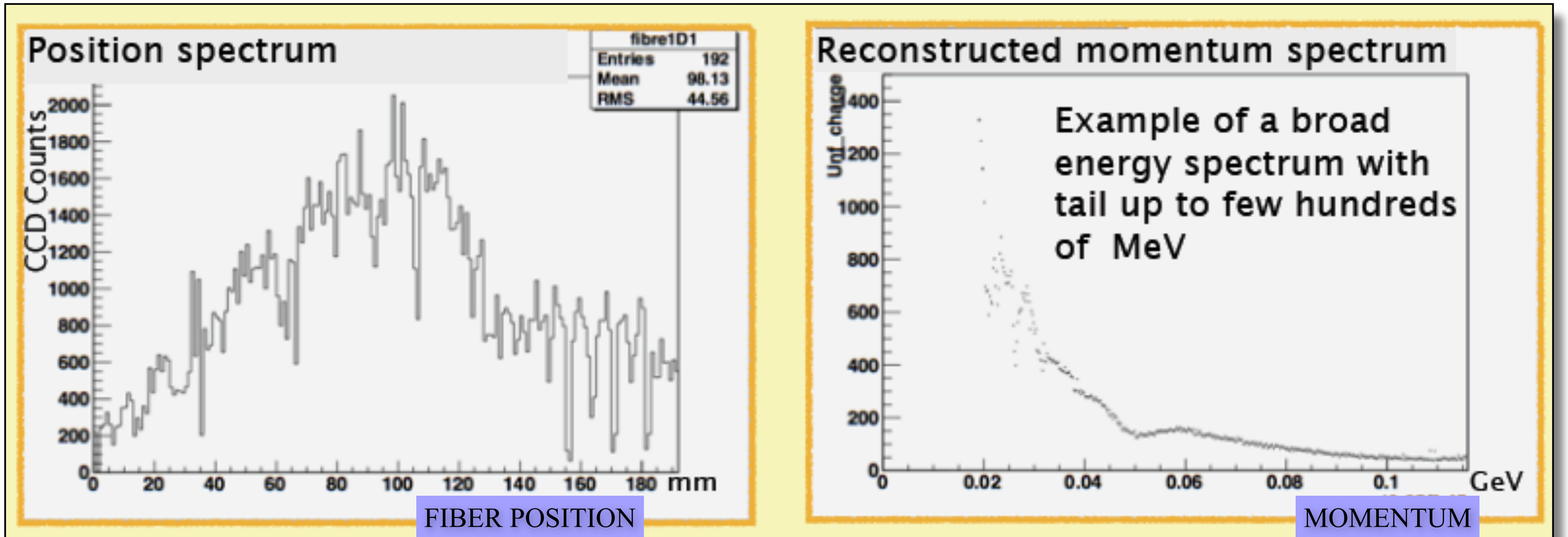
Note that this was the first attempt of using a not purely optical device in a laser-plasma interaction environment.

ALTERNATIVE READOUT SYSTEM: CCD



While commissioning the readout electronics, an alternative purely optical readout system has been realised: the light emitted by the scintillating fibers is recorded by **CCD cameras**.

Preliminary results



ELECTRONIC READOUT UPGRADING

In order to reduce the electromagnetic noise the following actions have been taken:

- **Fiber lenght extended** from 1 to 5 meters to place PMTs and electronics far from the interaction region
- **Attenuator** at the entrance of the MAROC2 chip, designed and tested
- New **grounding** of the whole system
- Better **Faraday cages** for the PMTs, cables and electronics

Next commissioning phase is scheduled for next month and we are confident to overcome the high noise obstacles