Review of Laser-Induced Light Ion Acceleration Activities in Italy
Experimental Setup and Detector Devices for the First Proton Acceleration Experiment at Flame

D. Giove on behalf of the Lilia collaboration

Light Ion Acceleration Activities in Italy

- University of Messina and INFN-LNS (prof. Torrisi)
- University and INFN Lecce (prof. Nassisi)
- Lilia Experiment - FLAME at INFN-LNF Frascati
- The Prometheus Project (prof. Turchetti)

University of Messina and INFN-LNS

Long time experience working on projects as PLEIADI (Plasma Laser Energetic Ion Acceleration & DIagnostics) that put national and international laboratories in collaboration (Catania, Messina, Lecce, ASCR of Prague, IPPLM of Warsaw and ILT of Bad Abbach in Germany) to study the electric fields generated in laser-produced plasma.

They studied and characterized non-equilibrium plasmas produced by laser ablation processes and their possible applications. Particular applicative interest on such plasmas is turned to new methodologies of ion acceleration, processes of ion impiantations and injection of ions in classic sources of type ECR.

They have at the Department of Physics of Messina and of Catania two Nd:YAG lasers (1064 and 532 nm) with maximum intensity of the order of 10^9 W/cm2 andi 10^12 W/cm2. Pulse duration are of 3 ns and 9 ns.

University of Messina and INFN-LNS

Experience using Ion detectors called ion collector (IC) used in time of flight (TOF) configuration to show the speed and average energy of the particles produced from plasma and to provide information about angular distribution in backward irradiation direction (for thick targets).

Experience using an Ion Energy Analyzer (IEA) electrostatic deflection to measure the energy to charge state ratio of particles emitted from the plasma.

University and INFN Lecce

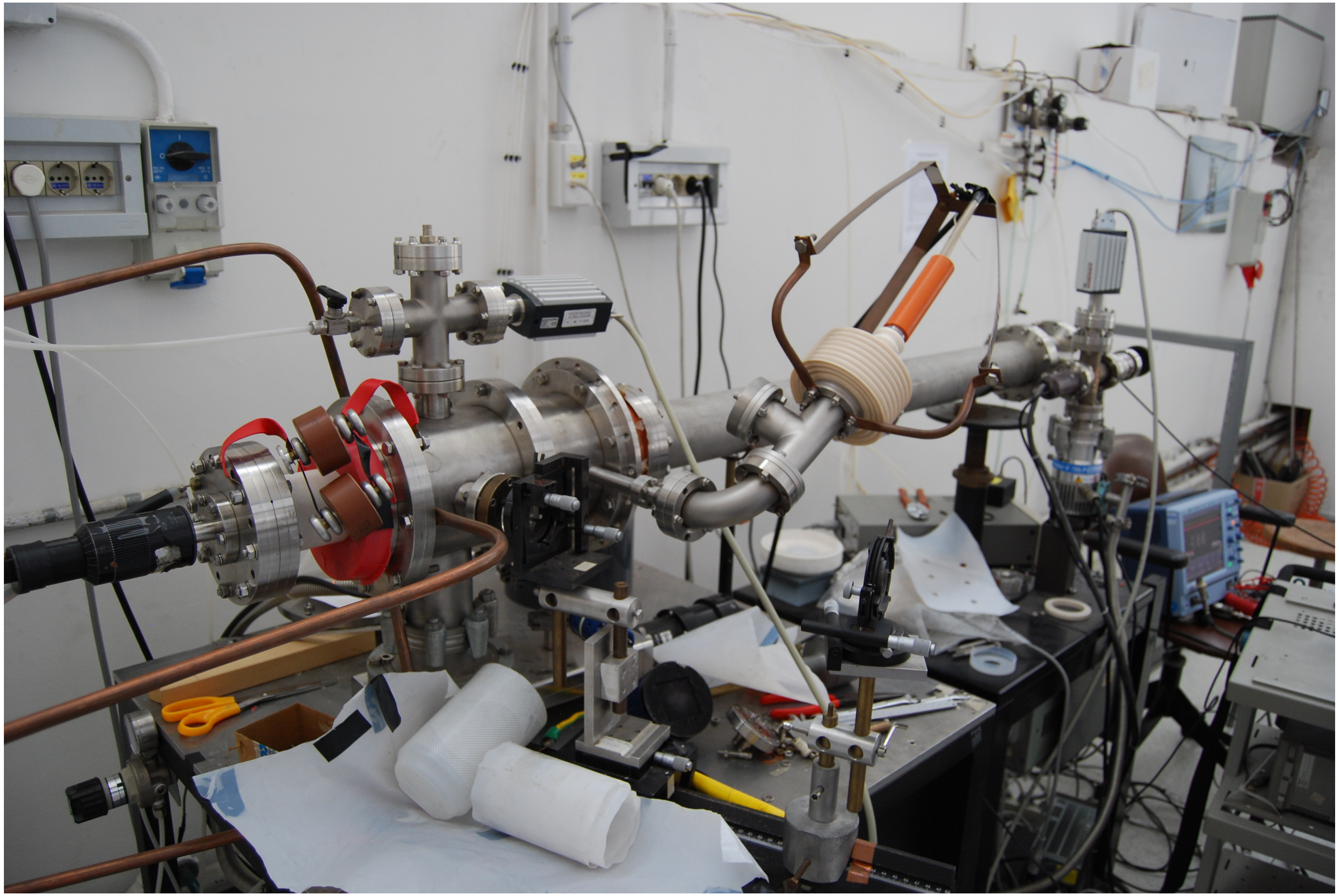
Long time experience in the development of excimer laser systems working with mix of KrCl and XeCl.

Actually they are working on a set up for the preliminary characterization of plasma by a laser operating in the UV (248 nm) in order to determine the charge components and the angular distribution of the plasma from thick targets and thin film of mylar doped with carbon. The evolution of the plasma and the determination of the charge components will be obtained by a Faraday cup of large section enough to cover the whole beam and by an array of small cups arranged in line to determine the angular evolution.

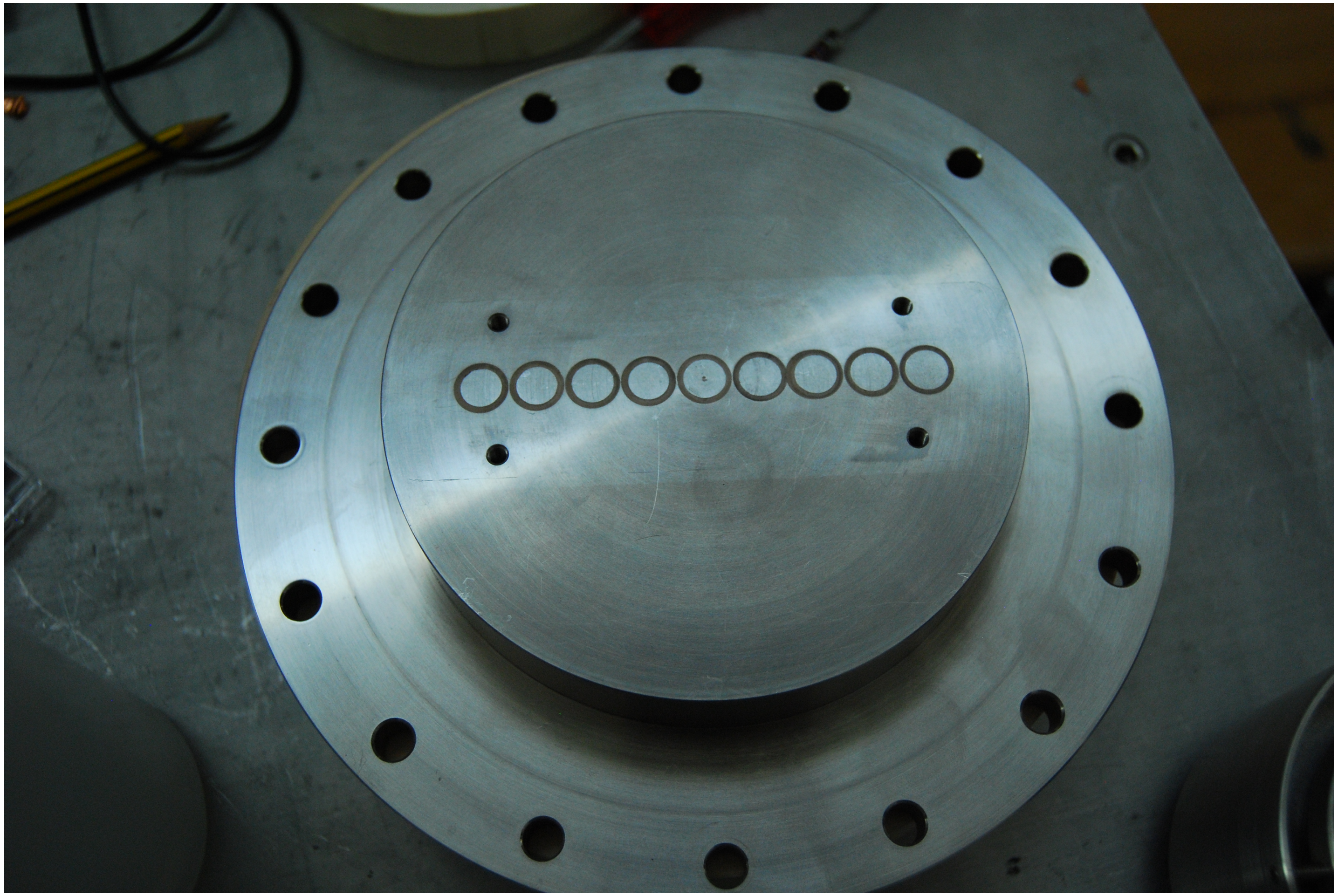
University and INFN Lecce

At the same time, some diagnostic systems will be developed, two for the electromagnetic characterization and one for the geometrical characterization. The electromagnetic characterization will be done by a capacitive probe working like a transmission line able to record pulses of the order of 10 ps (University of Salento Patent No. MI2009A000853 of 05/15/2009) and by diamond sensors under development in collaboration with the Institute of Microfusion in Warsaw for detecting the X ray; the geometrical characterization will be done by a pepper pot system.

University and INFN Lecce



University and INFN Lecce



Lilia

The main aim of the experiment is the parametric study of the correlation of the maximum TNSA accelerated proton energy, with respect to the following parameters:

- Laser pulse intensity (in the range 10^{18} – $5x10^{19}$ W/cm^2)
- Laser pulse energy (in the range 0.1-5 J)
- Laser pulse length (in the range 25 fs- 1ps)
- Metallic target thickness (in the range 1-100 microns)

In such a frame we would like to deeply investigate the experimental scale rules within the possibilities offered by the FLAME facility.

The experimental activities, moreover, will provide the opportunity to gain experience in the development of diagnostic techniques and in target optimization.

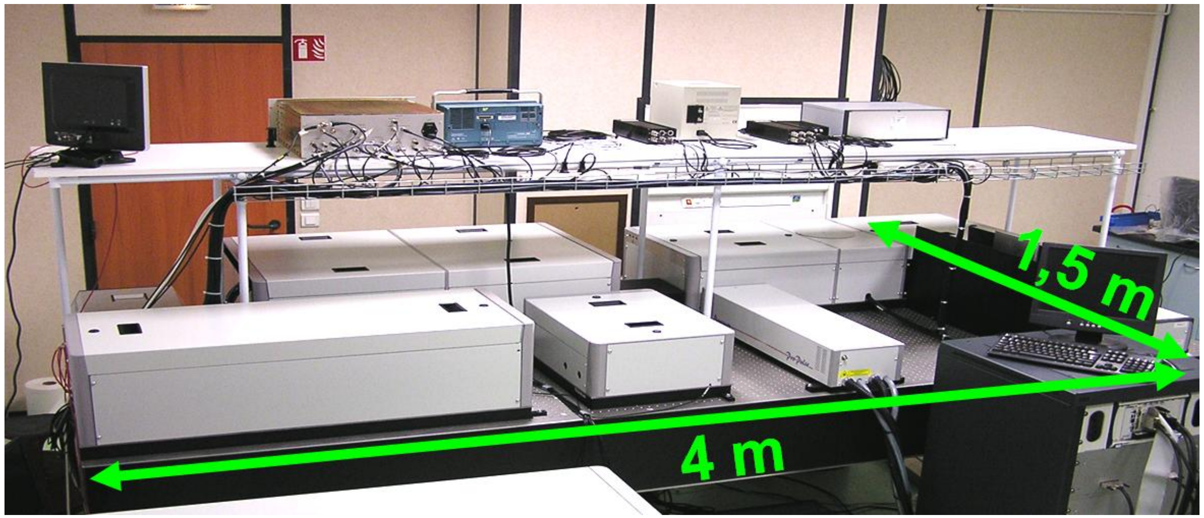
Lilia

After the first year of experimental experience our activities will be focused on the possibility to produce a real proton beam able to be driven for significant distances (50-75 cm) away from the interaction point and which will act as a source for further accelerating structures.

Preliminary analysis has shown that a simple permanent magnet quadrupole based scheme may not fulfill such a requirement.

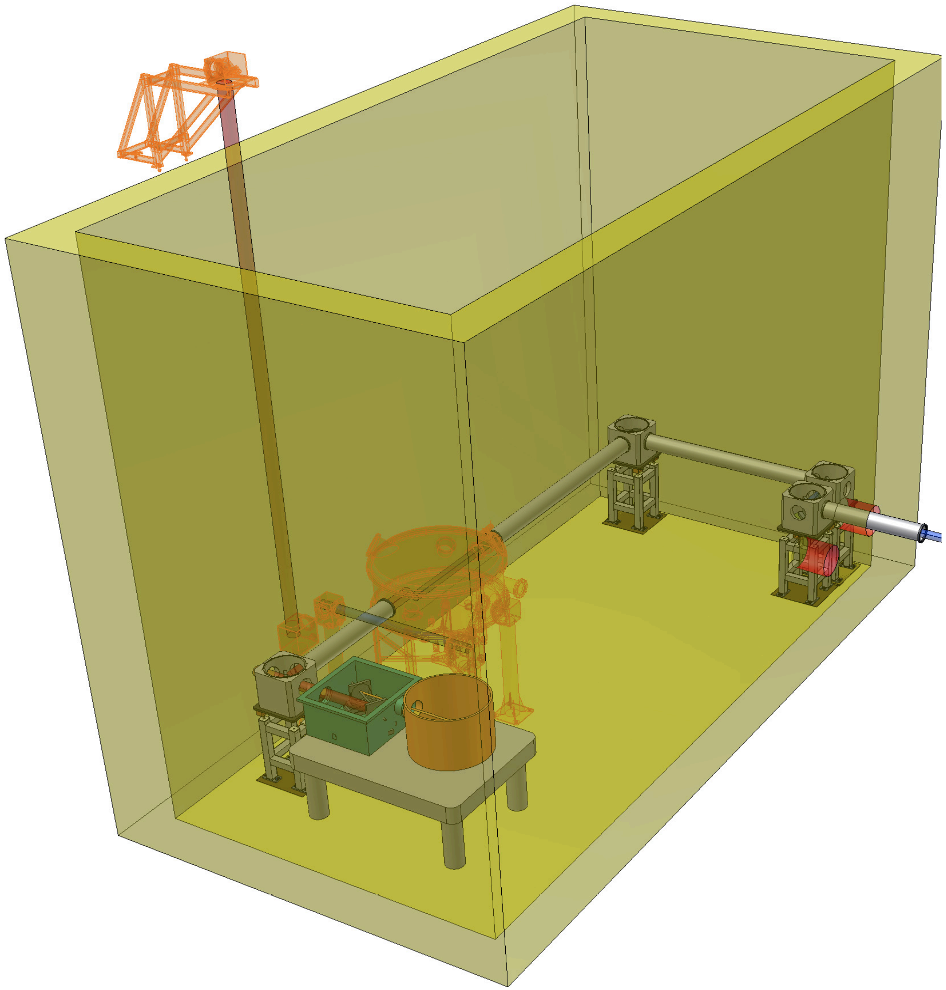
FLAME at INFN-LNF Frascati

Repetition Rate	10 Hz
Energy (after compression)	up to 6 J (typ. exp. 5.6J)
Wavelength	800 nm
Pulse duration	down to 20 fs (typ.23 fs)
Peak power	up to 300 TW
ASE contrast	$< 10^{10}$
Pre-pulse contrast	$< 10^{-8}$

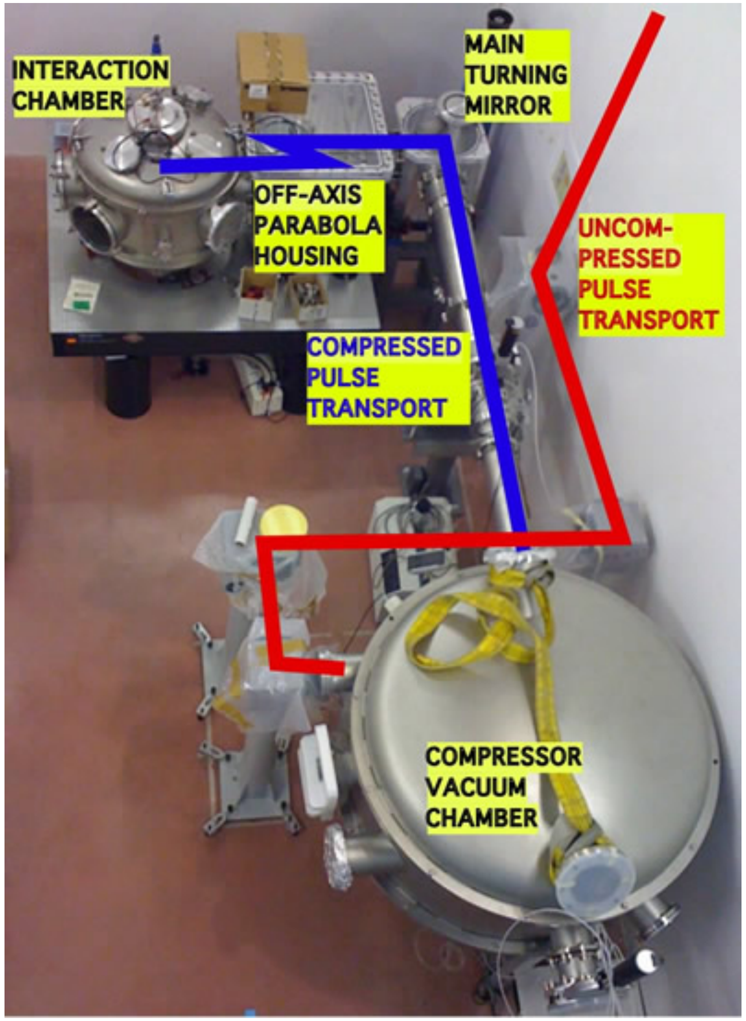


FLAME at INFN-LNF Frascati

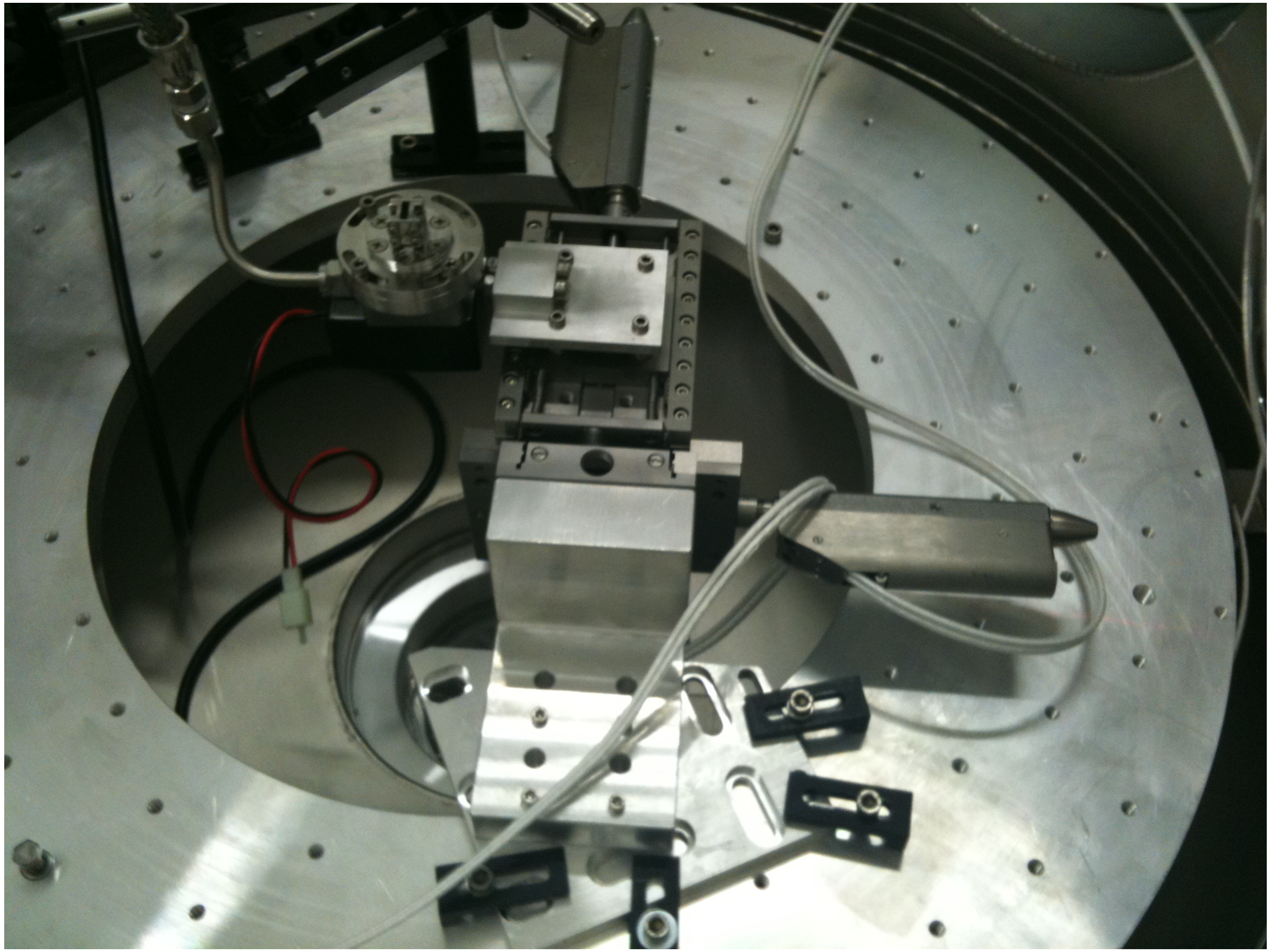
FLAME Target Area



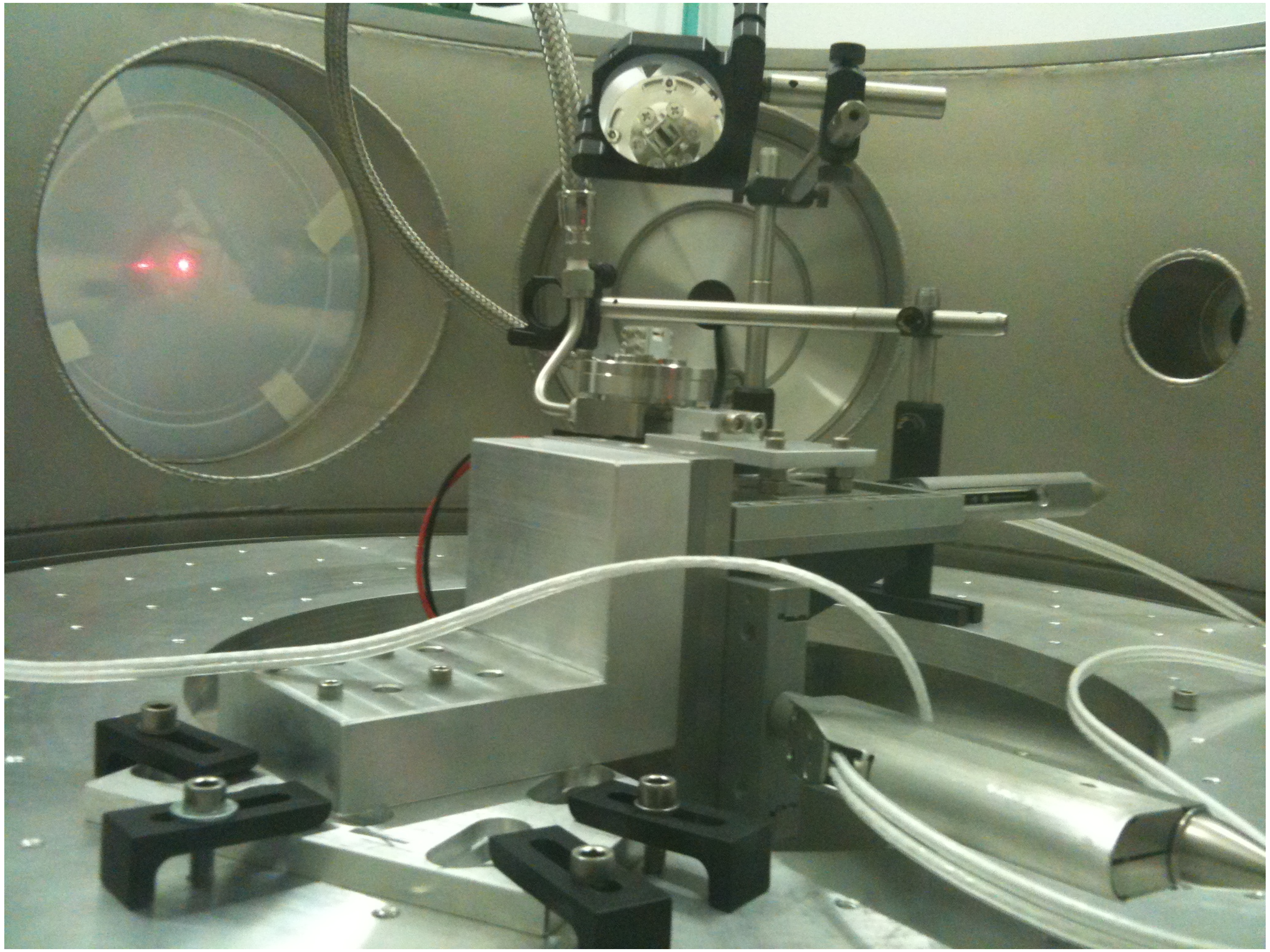
FLAME at INFN-LNF Frascati



Flame interaction chamber

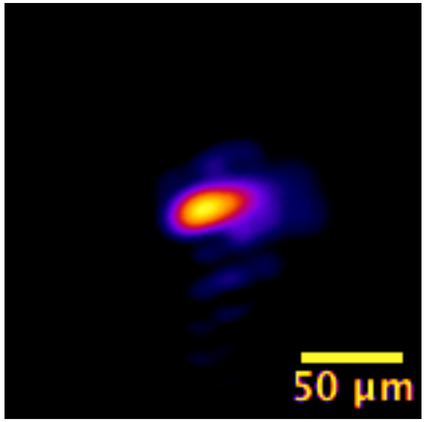


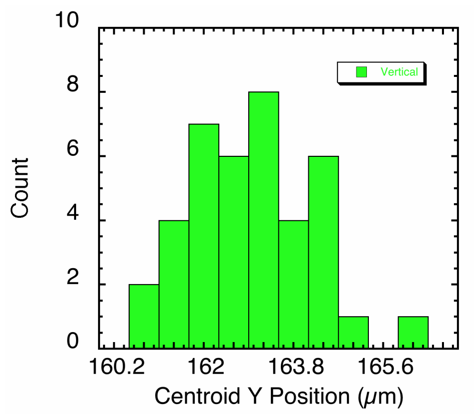
Flame interaction chamber

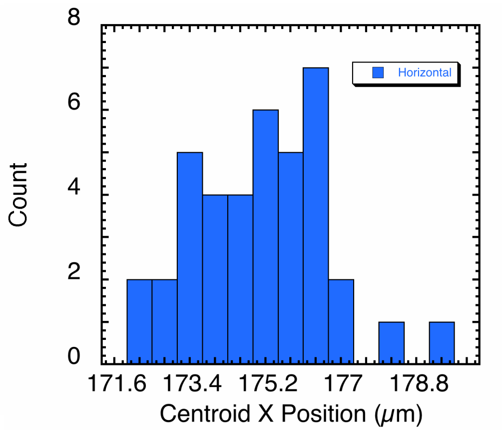


FLAME at INFN-LNF Frascati

2010, June 3rd : First run of beam pointing stability measurements





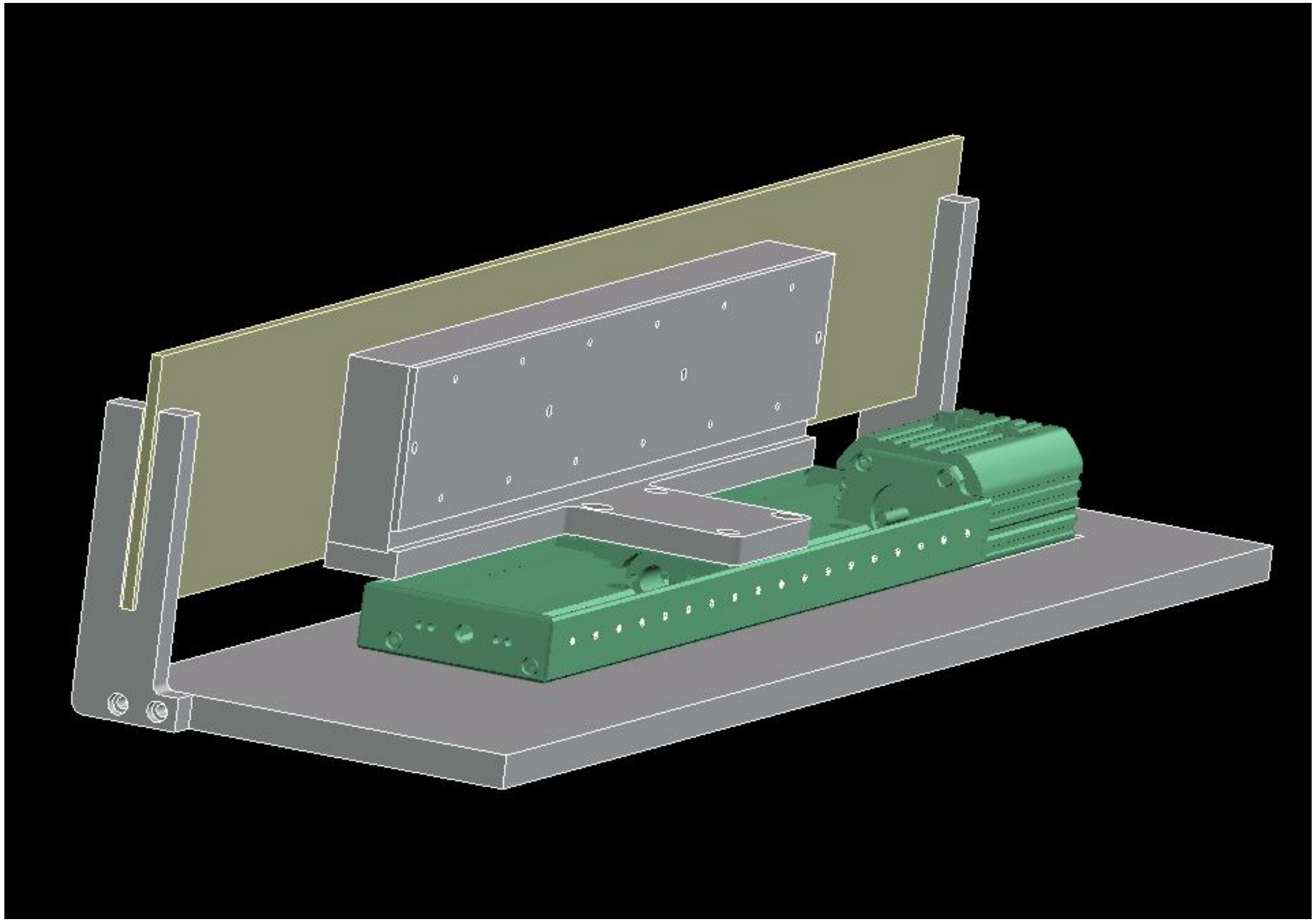


2010, June 4th : Off-axis parabola alignment procedure (previously used and tested at ILIL) established at FLAME. The procedure is based upon the optimization of the forward scattered radiation from laser interaction in air at low power.

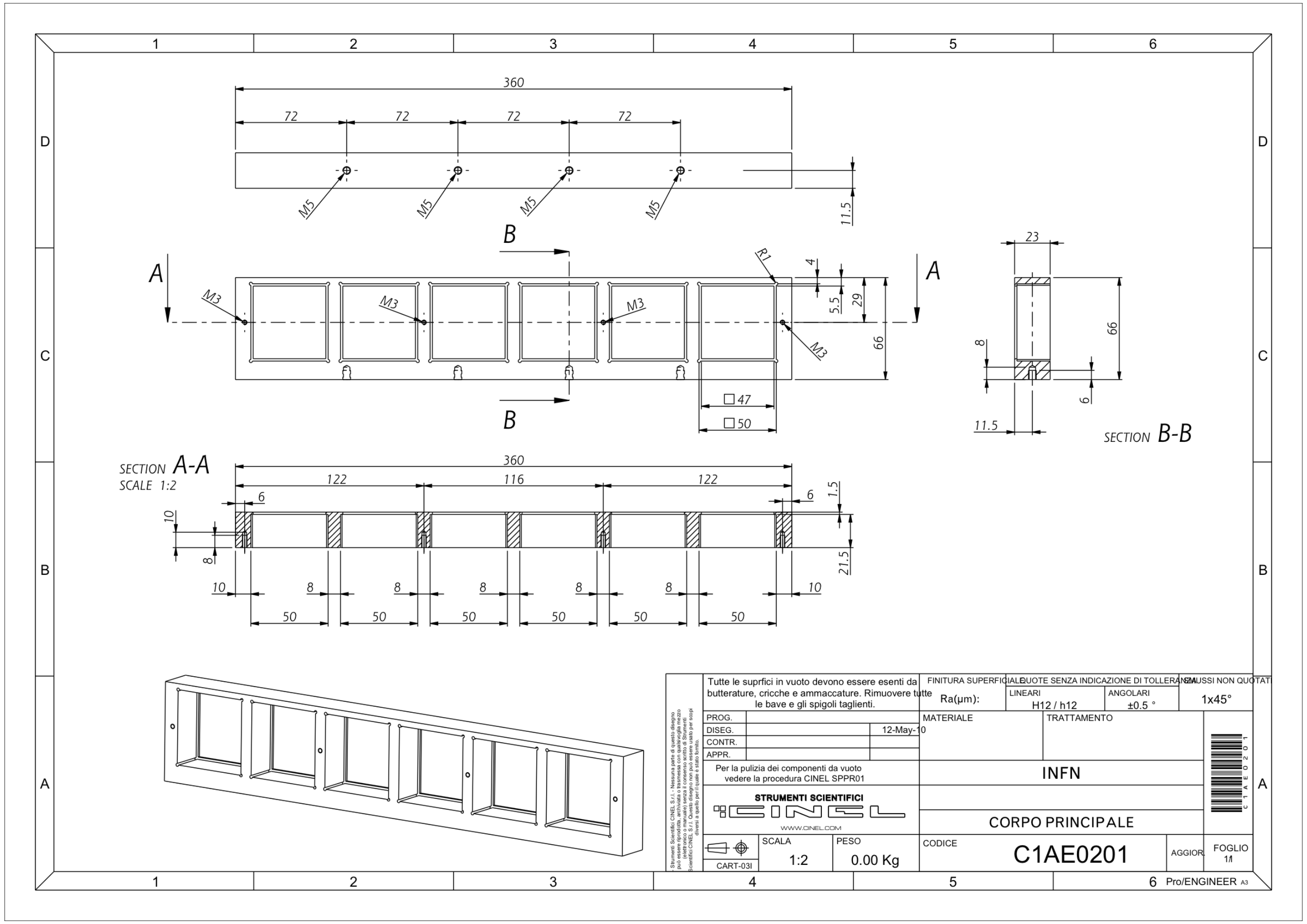
Lilia foreseen diagnostic devices

- Radiochromic films
- Thomson parabola
- Silicon diode arrays along with Hybrid Readout electronics

Radiochromic films



Radiochromic films

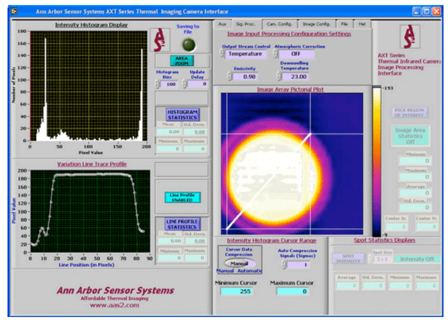


Radiochromic films

To analyze the films we are developing a system based on a good quality plane scanner along with a custom designed LabVIEW based image processing code.

Epson V750 Pro
(6400 dpi, white cold cathode
fluorescent lamp, max 4.0 OD)

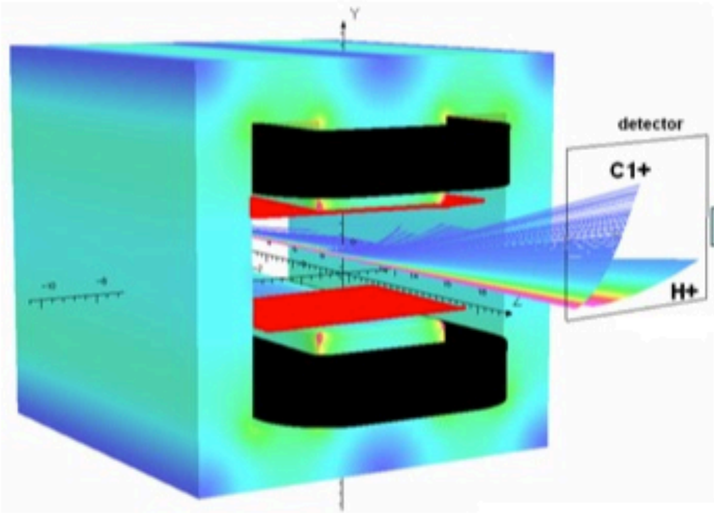
ISO-21550 Dynamic Range Film
Used to Determine Optical Density
Range of Transmission Scanners

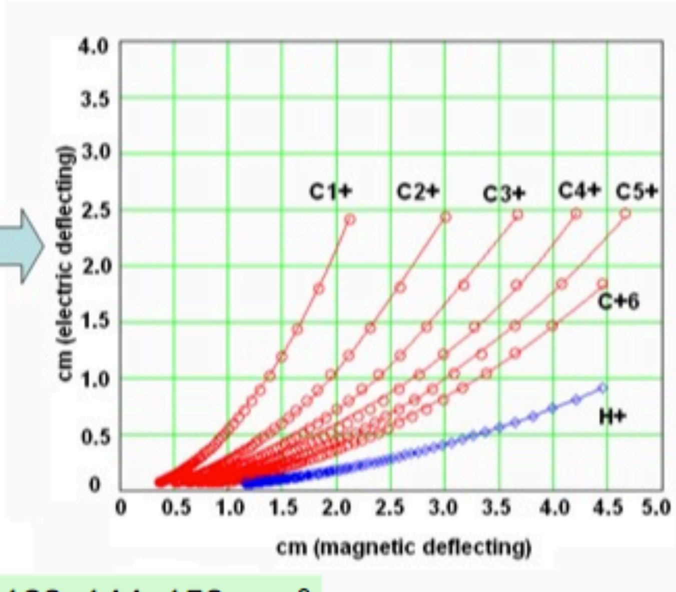


Thomson parabola

THOMSON SPECTROMETERS FOR LASER PLASMA FACILITY
(LNS team for LILIA project)

Analysis of proton and carbon beams (Q=+1 to +6) from 0.1 to 10 MeV





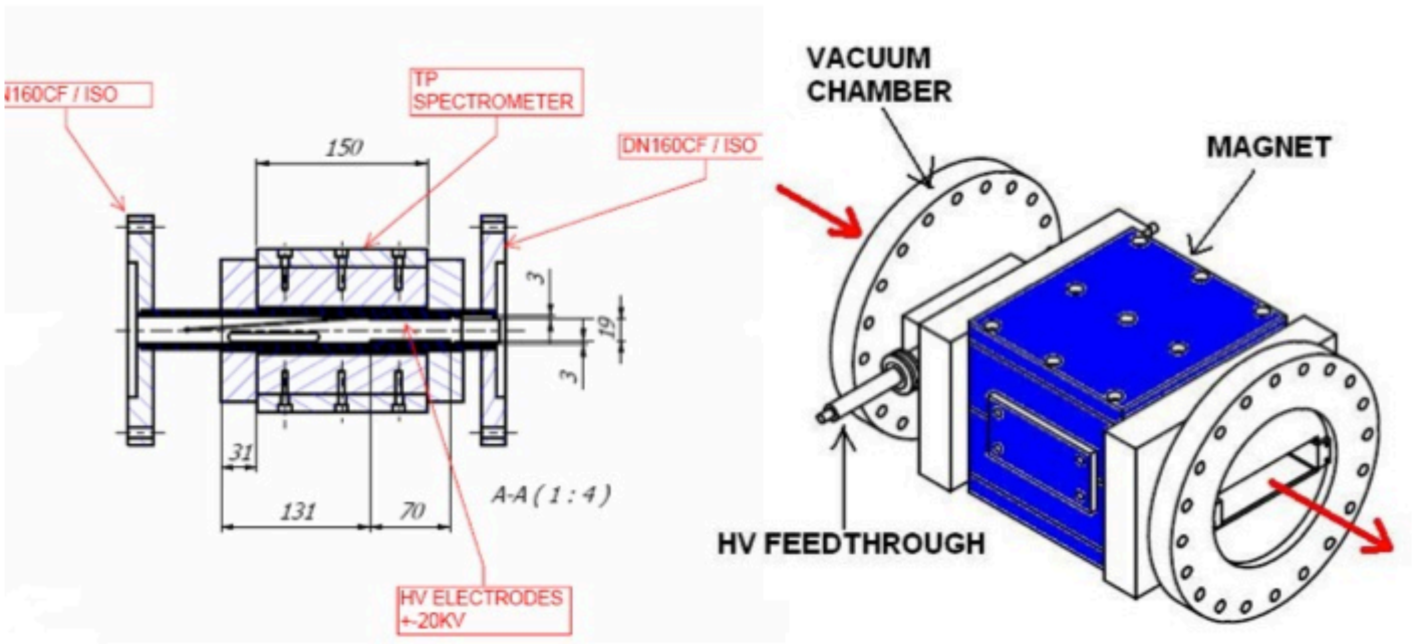
Very compact design → 160x144x150 mm^3

High magnetic field (tunable)→ 2200 gauss

High electric field (tunable) → 20kV/cm

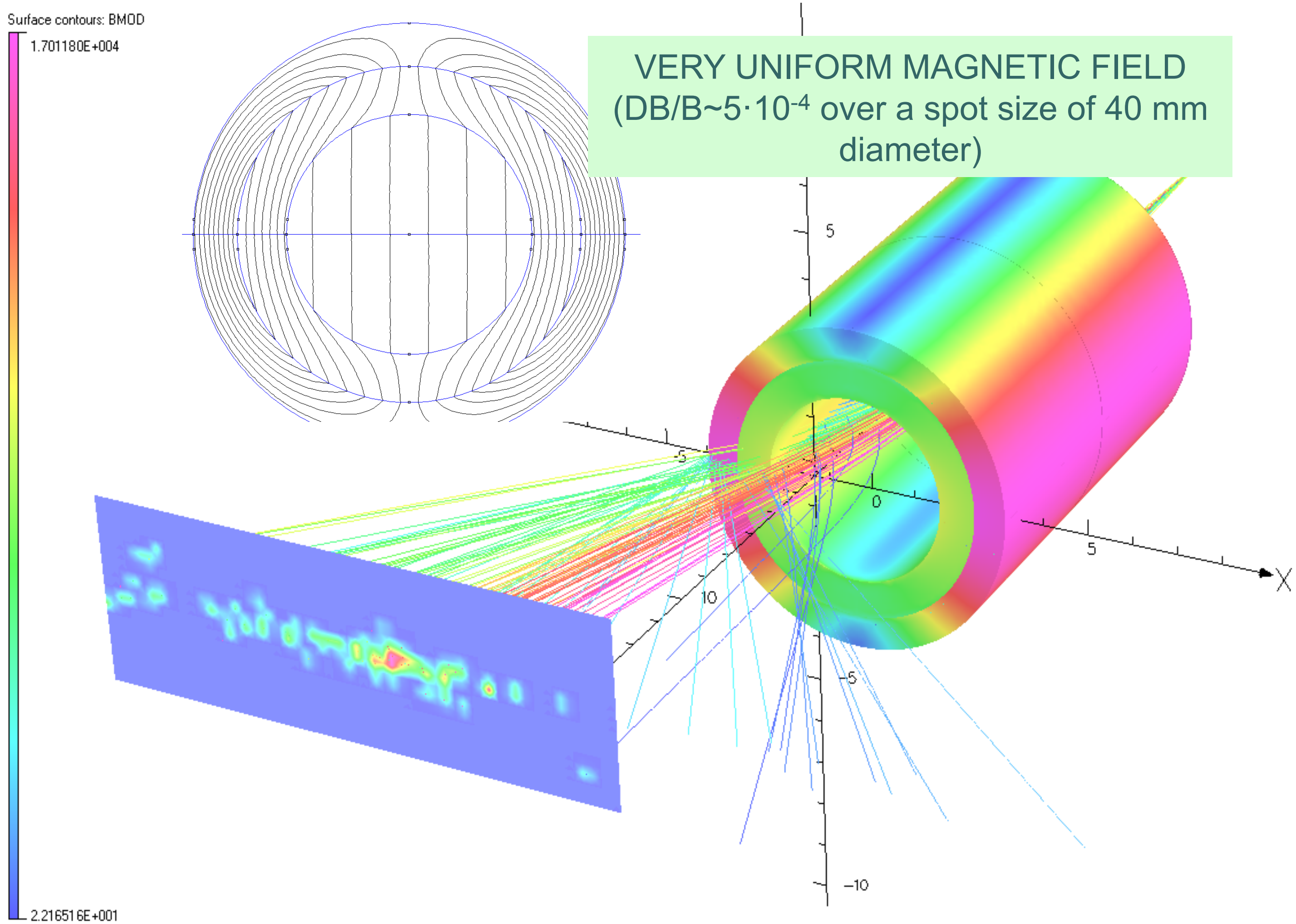
Thomson parabola

FINAL SPECTROMETER LAYOUT



Thomson parabola

VERY UNIFORM MAGNETIC FIELD
($DB/B \sim 5 \cdot 10^{-4}$ over a spot size of 40 mm diameter)



Silicon diode arrays

Develop a position sensitive silicon detector according to a matrix scheme based on simple PIN diodes

Advantages of a Si-PINarray over a MCP+CCD detector:

- The Si-PINarray operate without any requirement about high and clean vacuum conditions
- The Si-PINarray is cheaper and simpler
- The Si-PINarray is much more robust and reliable
- The Si-PINarray solution allows to design detector geometries according to the specific requirements of the experiment (i.e. parabola shapes of the ion trajectories after a TP)

Silicon diode arrays

Ordinary Silicon PIN photodiodes can serve as detectors for X-ray and gamma ray photons.

The detection efficiency is a function of the thickness of the silicon wafer.

A silicon PIN diode can be thought of as a solid-state equivalent to an ionization-chamber radiation detector.

Silicon diode arrays

Different possible sources for Si-PINArrays:

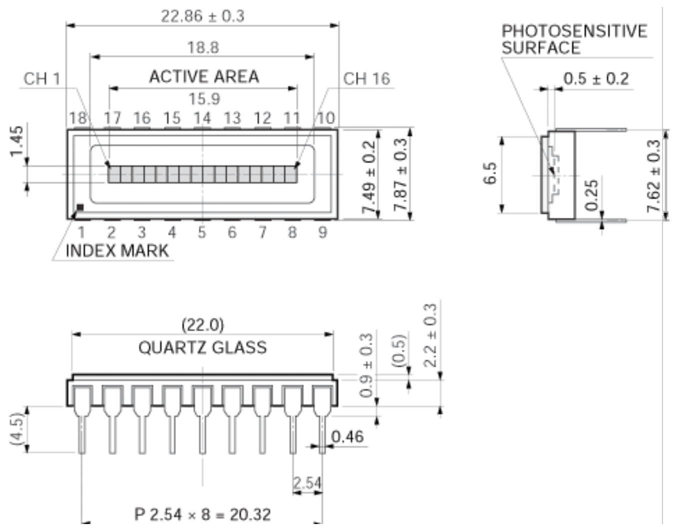
•Custom designs
•Micron Semiconductor
•Hamamatsu

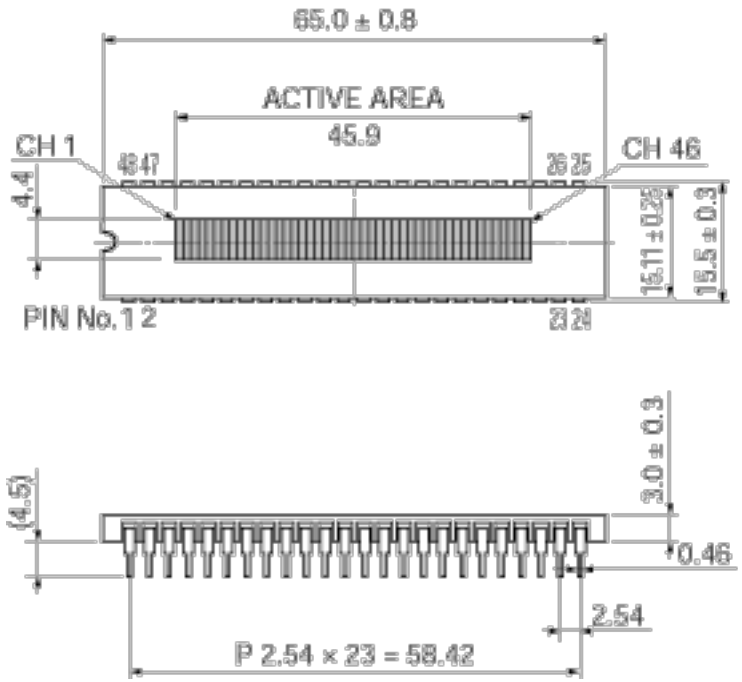
For the first tests we chose to start with Hamamatsu products (although Hamamatsu does not provide any information about the geometry of the detector in term of the PN junction thickness).

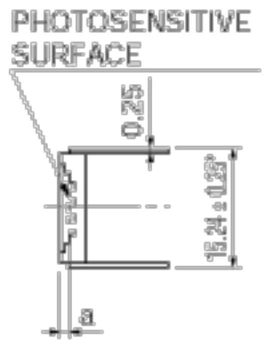
The commercially available packages provides up to 46 elements (model S4114-46N) or a basic architecture which will allow to grow simply stacking more packages (S5668-021/SPL)

The active area of each element is of the order of 1.5 x 0.9 mm

Silicon diode arrays

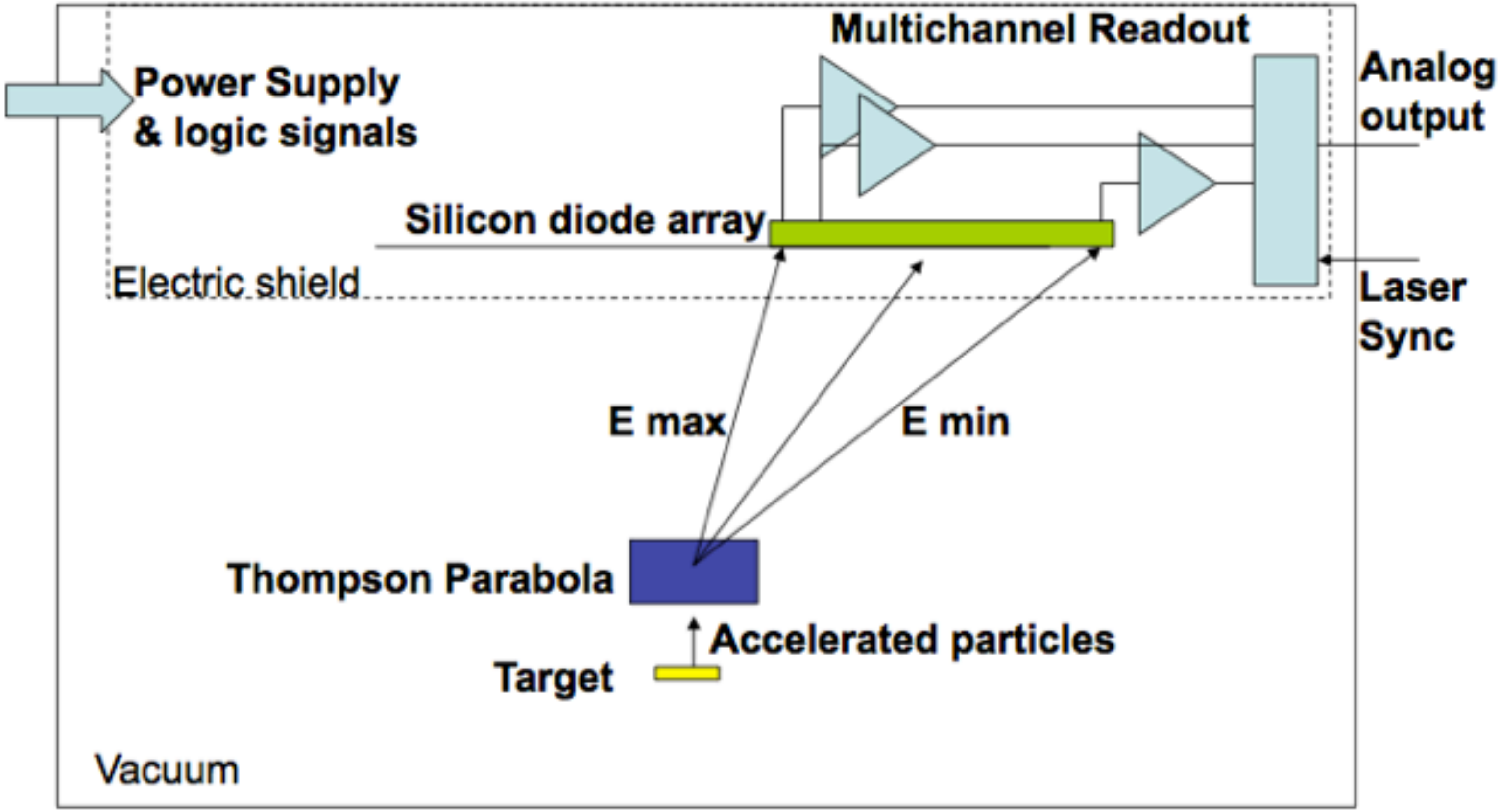






Type No.	a
S4111-46Q	1.65
S4114-46Q	1.55

Silicon diode arrays



July 2010 proton beam tests at INFN LNS

Preliminary tests have been carried out using a well defined 60 MeV proton beam at the CATANA proton therapy beam line at INFN-LNS

The maximum energy of the beam has been reduced using aluminum and Perspex calibrated thickness materials (TRIM code)

The minimum detected energy has been of the order of 1 MeV

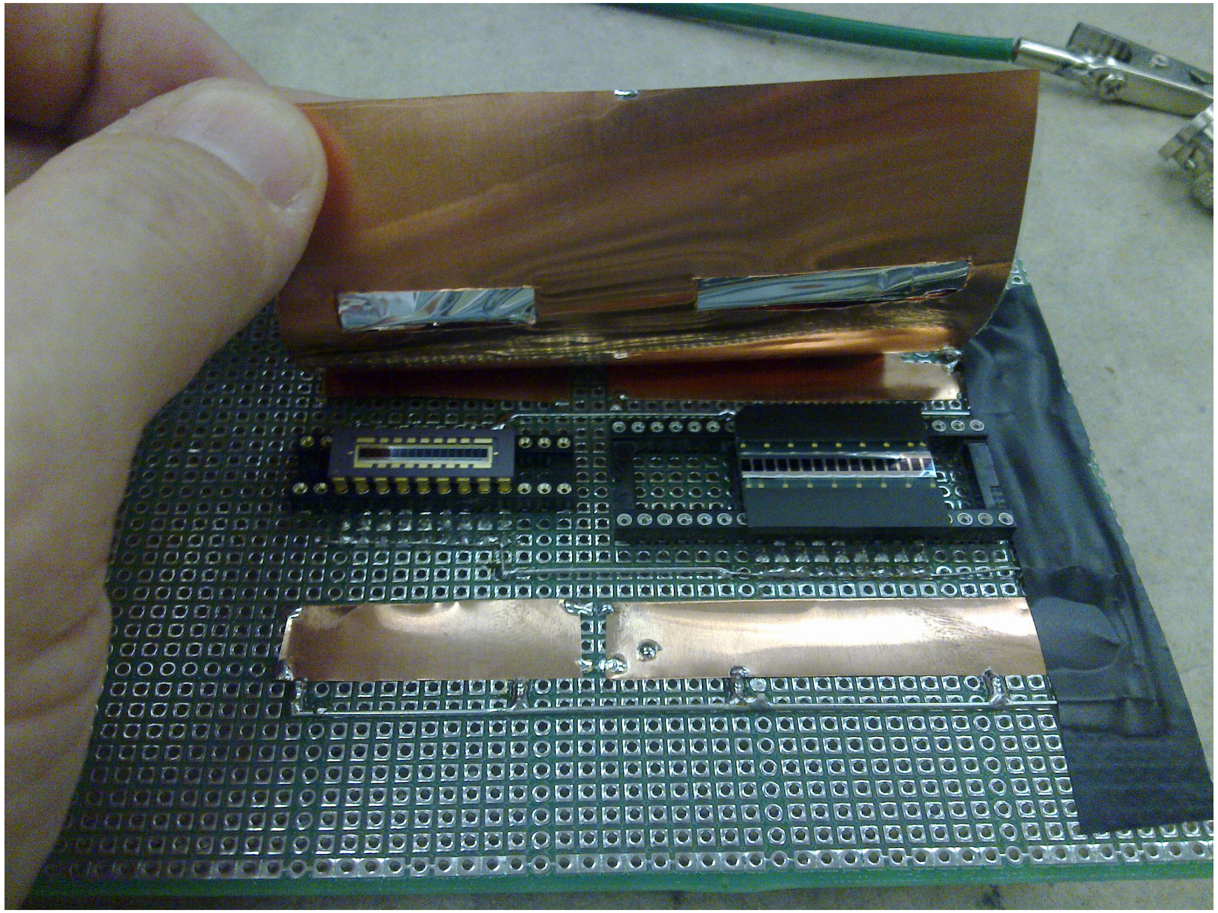
Catana facility at INFN-LNS

Radiochromic films

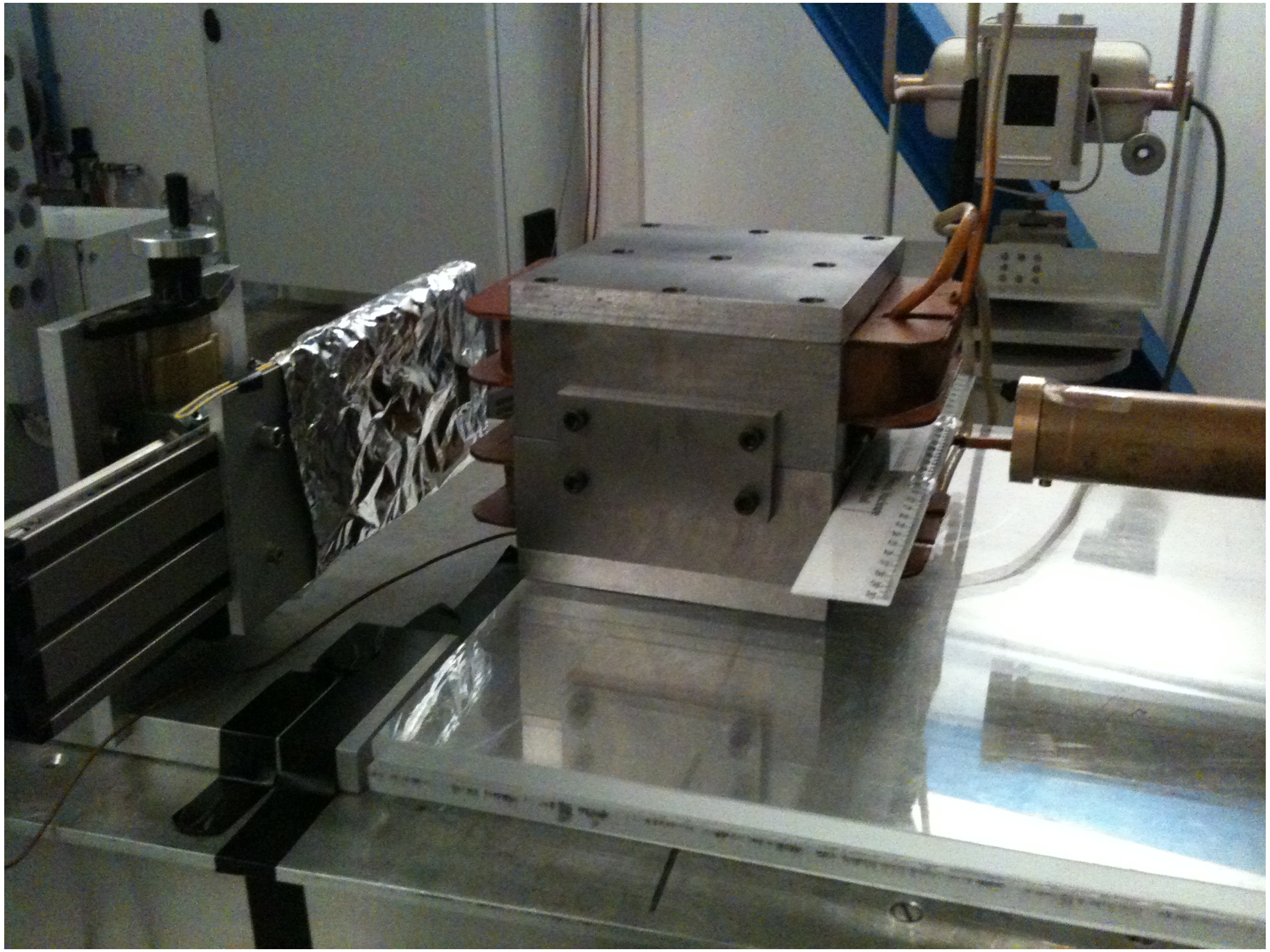
The used films were GAFCHROMIC MD-V2-55

A stack of 7 films was used to provide information about energy deposition in the detectors and to provide us experimental data to be analyzed later

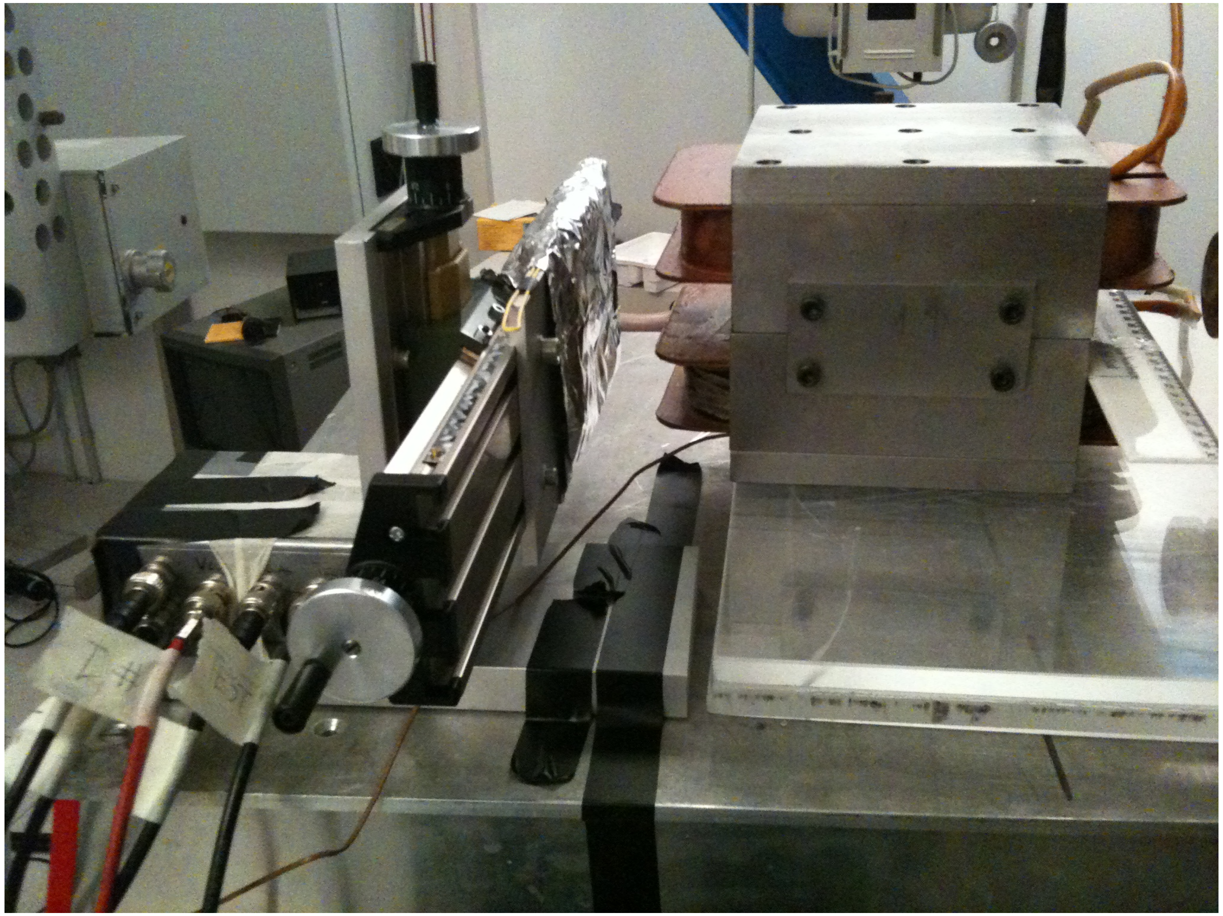
Silicon diode arrays



Silicon diode arrays



Silicon diode arrays



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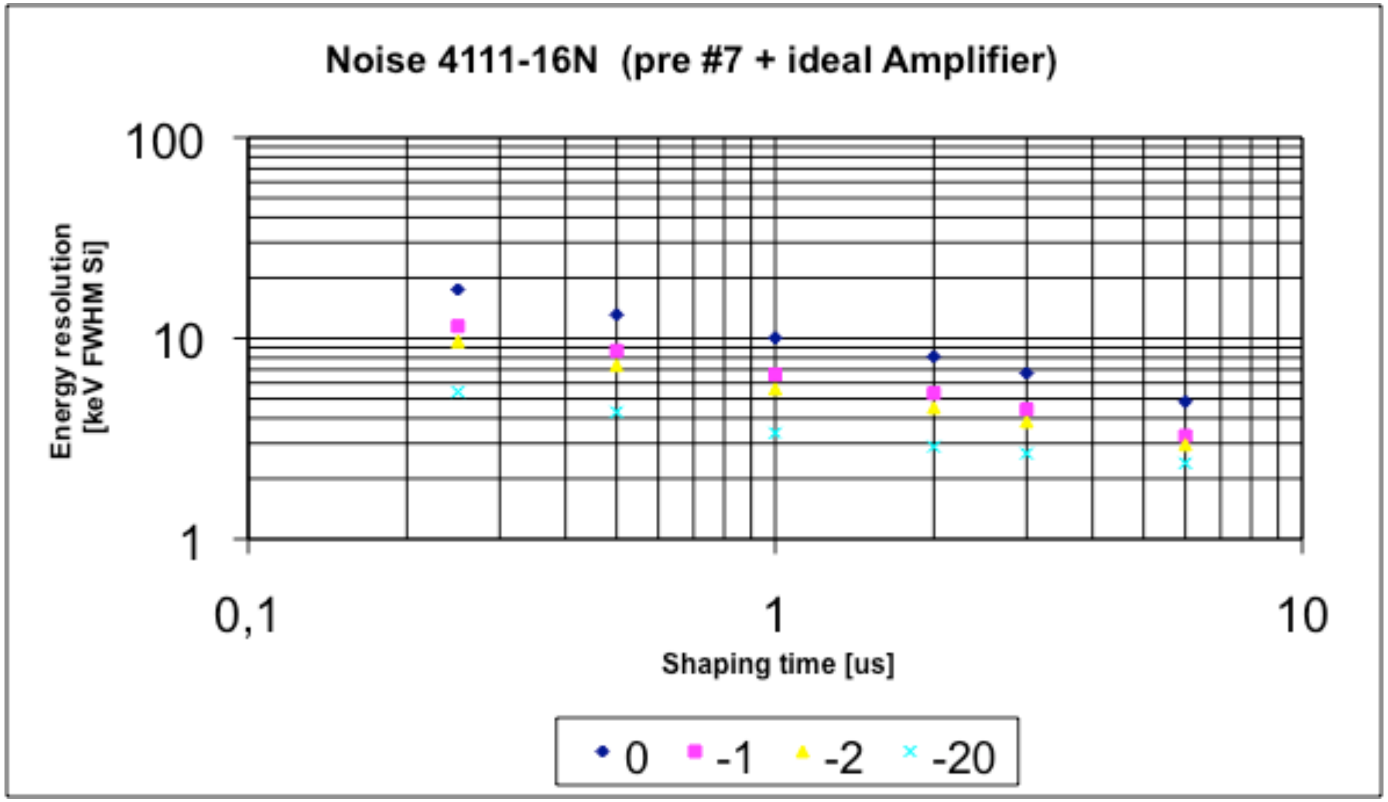
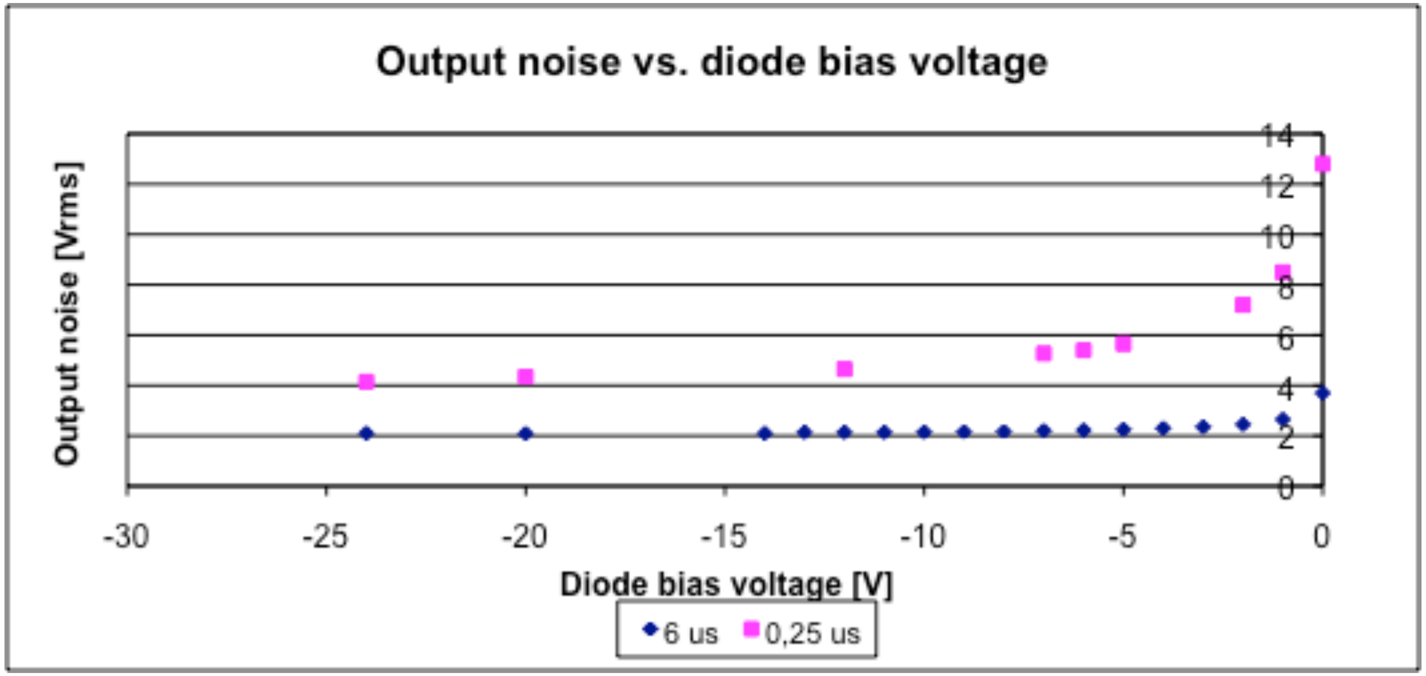
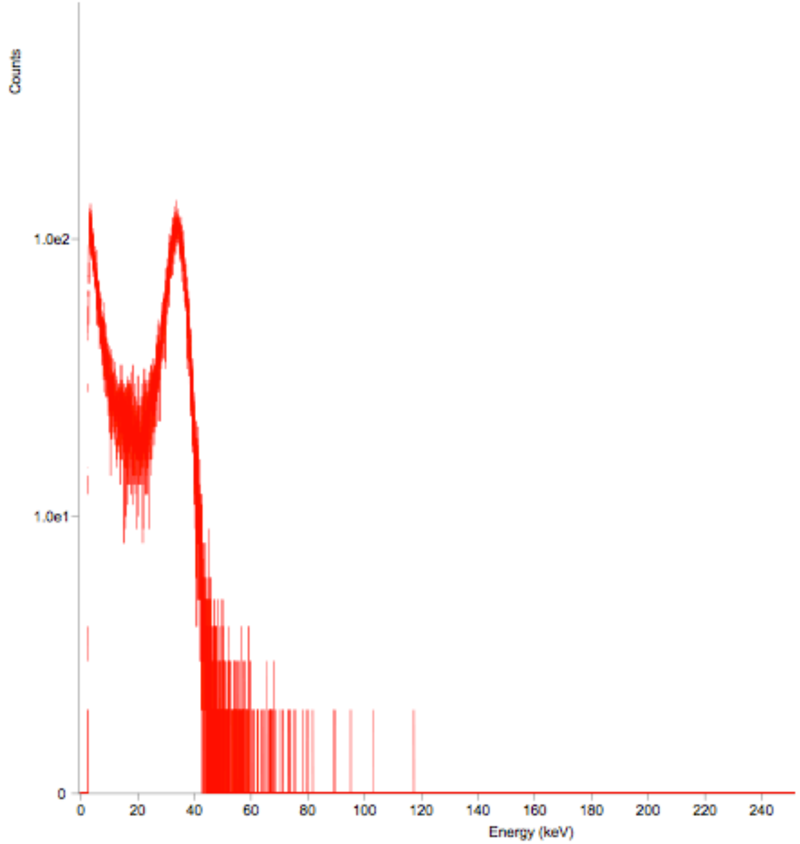


Silicon diode arrays



Silicon diode arrays

Energy spectrum from a MCA (arbitrary units)
Dose delivered: 825 cGy



Energy spectrum from a MCA (arbitrary units)
The beam was stopped before the detectors