Novel spectrometer design for laser driven ion acceleration diagnostic

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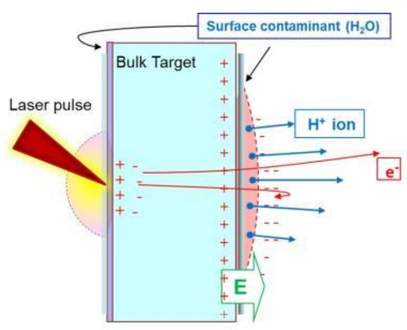
Abstract:

The main goal of this work is to propose a novel spectrometer design for laser driven particles diagnostic capable of detecting the proton spectra from few MeV up to few hundreds MeV. For that purpose different sequences of magnetic and electric field profiles have been studied systematically, varying the fields' parameters, through finite element of numerical simulations. The optimized parameters of the spectrometer allow a study of high energetic particle emission from ultra-intensity laser-matter interaction in a broad energy range providing high energy and species resolution in highly resolved spatial and temporal domain.

Context : Laser driven ion acceleration diagnostics

Target normal sheath acceleration (TNSA)

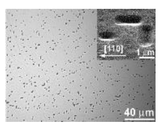


- I>10^{18} W/cm^2
- E: few tens of Joules to hundreds of Joules
- Pulse duration : ps→fs
- Target thickness: several µm → tens of nm

MultiMeV laser-driven ion beams

Diagnostics

CR 39 (nuclear track detector);



Radio chromic films (RCFs);

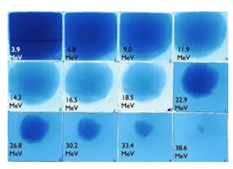
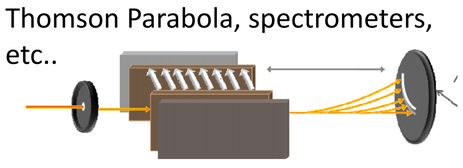


Image plates (Ips)

Thomson Parabola, spectrometers, etc..

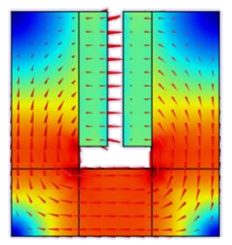


Objective: Design a novel parabola starting from existing combinations

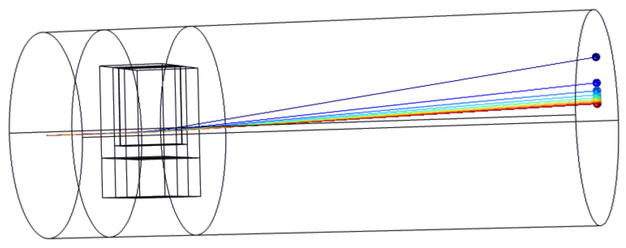
Limitations	Possible reasons
❖ Limited Energy range	❖ ''Low'' energy particle range explored
❖ Energy resolution	❖ High energy particles need increasing energy resolution
❖ Multispecies range	❖ Laser ion sources (protons, carbons ions, x-rays..)
❖ Calibration at high energies particles	❖ Sensitivity of the detectors
❖ Time resolved measurements	❖ Limited achievable time resolution →loss of information
❖ Zero point very bright	❖ Beam x-ray source at the target (gated ion spectrometer)

First results using finite element Comsole simulations

Homogenous field
B: 0.9 T,
L: 5cm



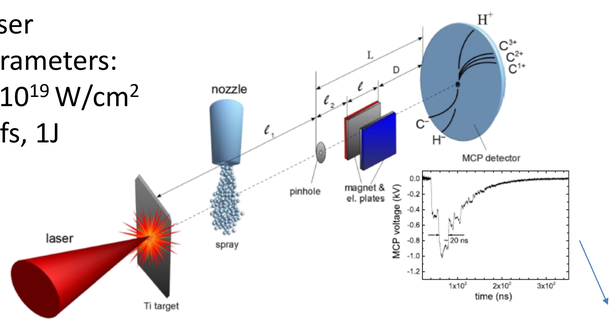
Particle trajetories



Objective: Design a novel parabola starting from existing combinations

Experimental setup

Laser parameters:
I= 10^{19} W/cm^2
40fs, 1J

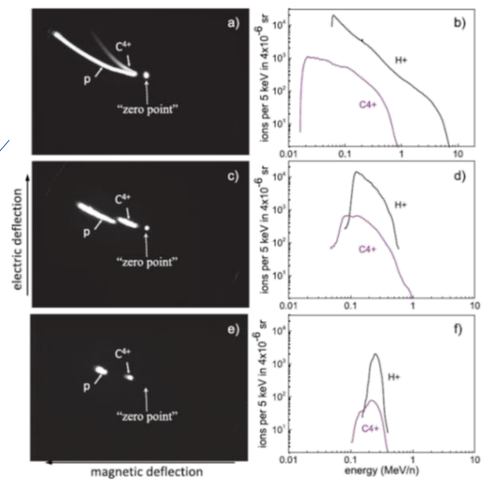


Pinhole (d) = 0.3 mmTP: B: 0.27 T; E: 2-4 kV /cm

Gated pulse applied to the MCP

Experimetal results

CCD images of ion spectra, spray off



MCP gating

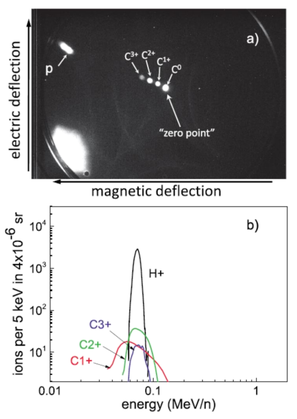
a-b) No gating Only H^+ and C^{4+} are detected (zero pint to bright)

c-d) MCP is gated for a time interval of 100 ns with a delay of 90 ns

e-f) delay of 100 ns for a 60 ns time interval

Spray on;

For the same MCP of 100 ns, the zero point now is visible

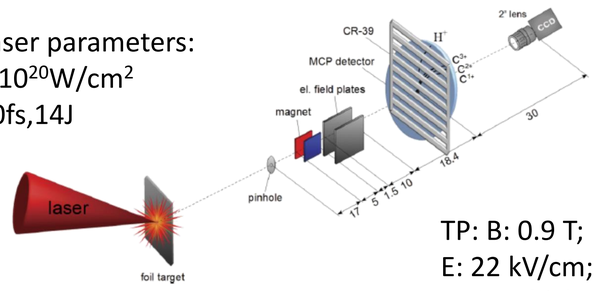


Using a gated MCP mode

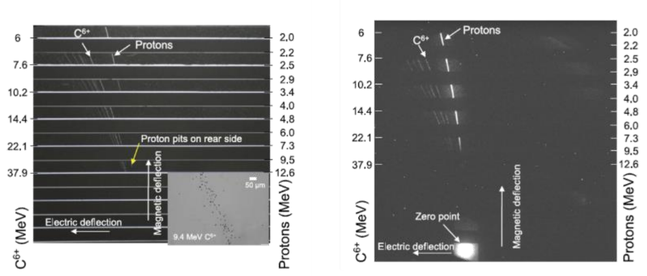
- ❖ discriminate the neutral particles generated by the spray and the x-rays
- ❖ Gating time defines the width of energy interval of the particle
- ❖ The delay between the particel acceleration and the gate pulse determines the maximum energy.

Ion traces comparsion on the CR39 and MCP

Laser parameters:
I=10^{20}W/cm^2
30fs,14J

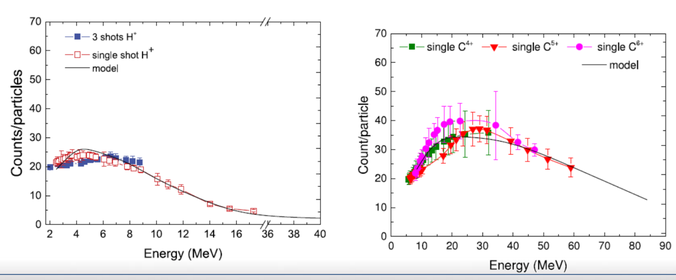


TP: B: 0.9 T;
E: 22 kV/cm;
CR39: thickness: 1mm



Results:
The response of the MCP was measured for:
- ❖ 5–58 MeV carbon ions
- ❖ 2–17.3 MeV protons

A theoretical model was develop in order to predict the MCP response at even high proton energies



Conclusion and Future plans:

- ❖ Work in progress design.
- ❖ Investigation of different combinations
- ❖ Futher increase the temporal and spatial resolution for laser driven ion diagnostics
- ❖ Increase the total information achievable in order to better understand the dynamics and the evolution of the ion acceleration mechanism

References:
[1] Jeong, Tae Won, et al., Experimental evaluation of the response of micro-channel plate detector to ions with 10s of MeV energies. Review of Scientific Instruments, 87(8), 083301.
[2] Sharif, S., et al. Gated ion spectrometer for spectroscopy of neutral particles. Review of Scientific Instruments, 88(8), 083303.
[3] Ter-Avetisyan, Sargis, Mathias Schnürer, and Peter V. Nickles, Time resolved corpuscular diagnostics of plasmas produced with high-intensity femtosecond laser pulses. Journal of Physics D: Applied Physics, 38(6), 863.

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