LABORATORI NAZIONALI DEL SUD

INVESTIGATION OF ION ACCELERATION MECHANISM THROUGH LASER-MATTER INTERACTION IN FEMTOSECOND DOMAIN

Carmen Altana

2nd European Advanced Accelerator Concepts Workshop
13 – 19 September 2015

Outline

- INTRODUCTION
  - Laser-driven ion acceleration
- EXPERIMENTAL SET-UP
  - Thomson Parabola Spectrometer
- RESULTS
- CONCLUSIONS

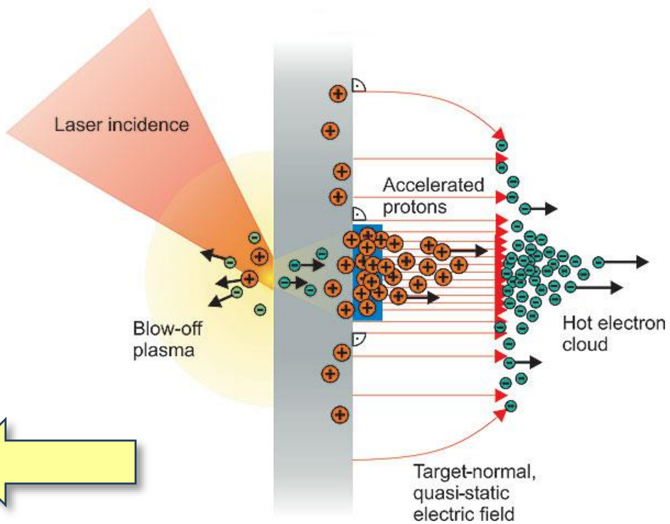
Introduction

Ion acceleration driven by superintense laser – matter interaction

Application in different field

WHY?

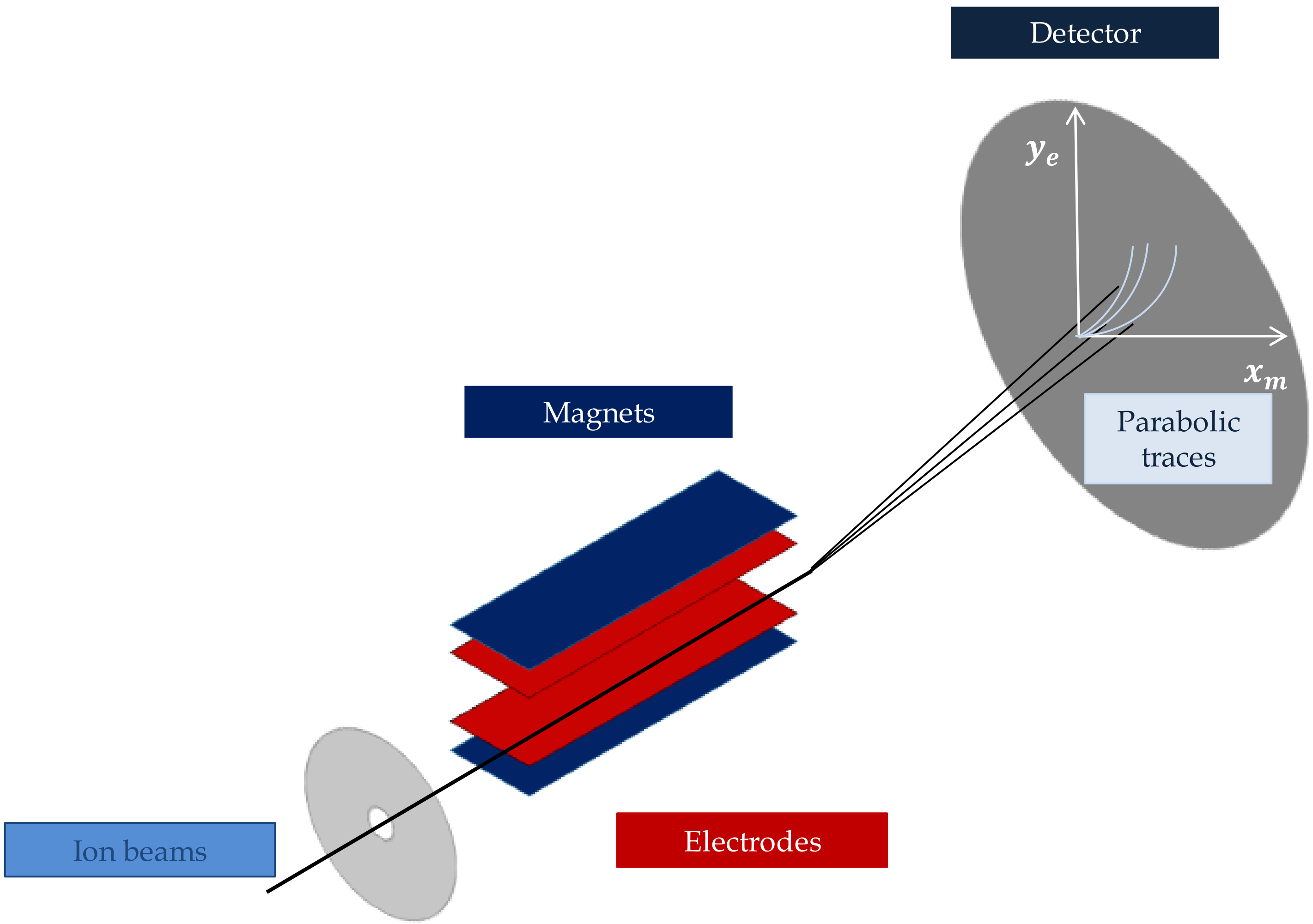
TNSA mechanism



1) Dependence on target thickness
2) Bulk and surface contribution
3) Dependence on target density

Open question

Thomson Parabola Spectrometer

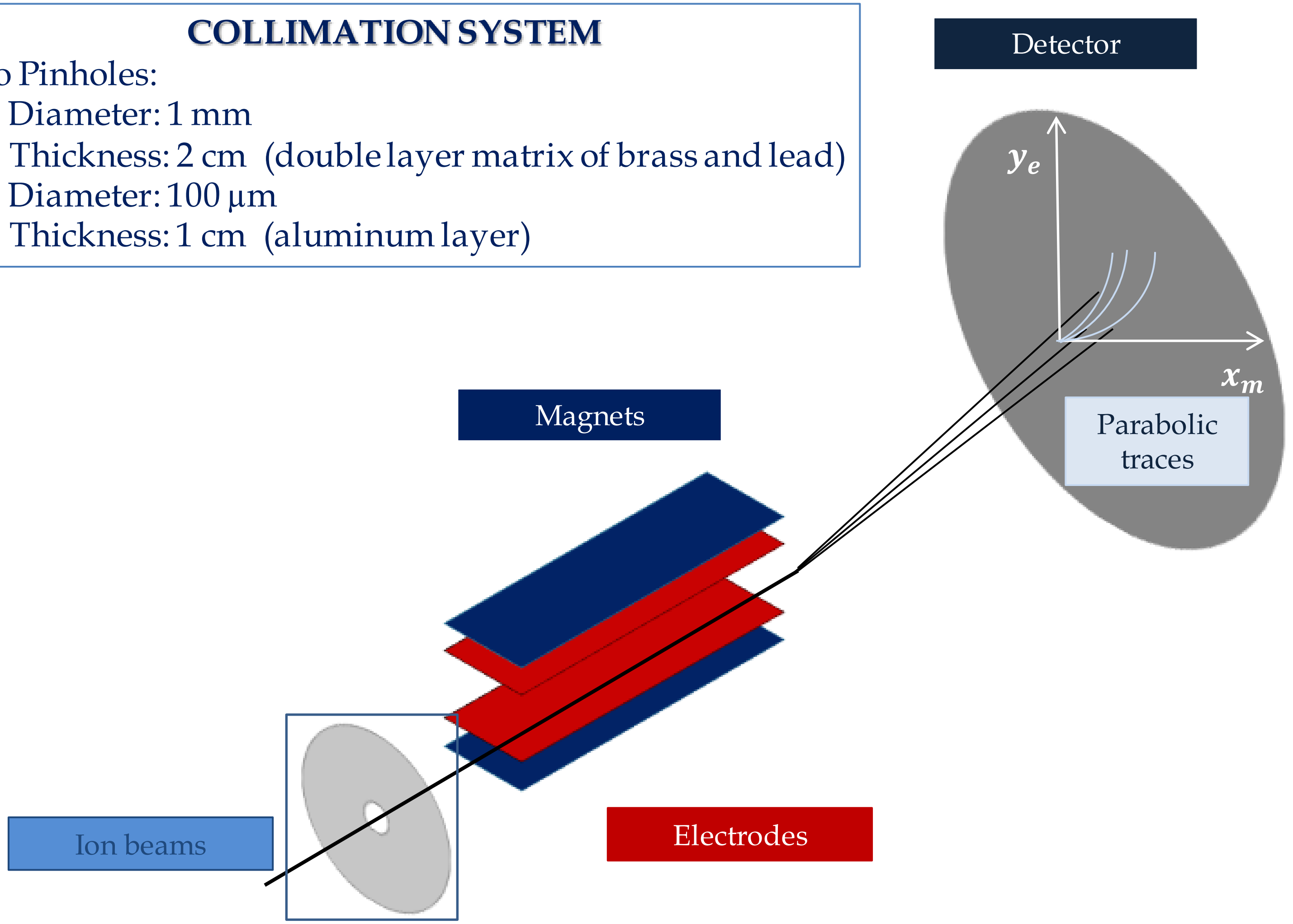


Thomson Parabola Spectrometer

COLLIMATION SYSTEM

Two Pinholes:

1) Diameter: 1 mm
   Thickness: 2 cm (double layer matrix of brass and lead)
2) Diameter: 100 µm
   Thickness: 1 cm (aluminum layer)



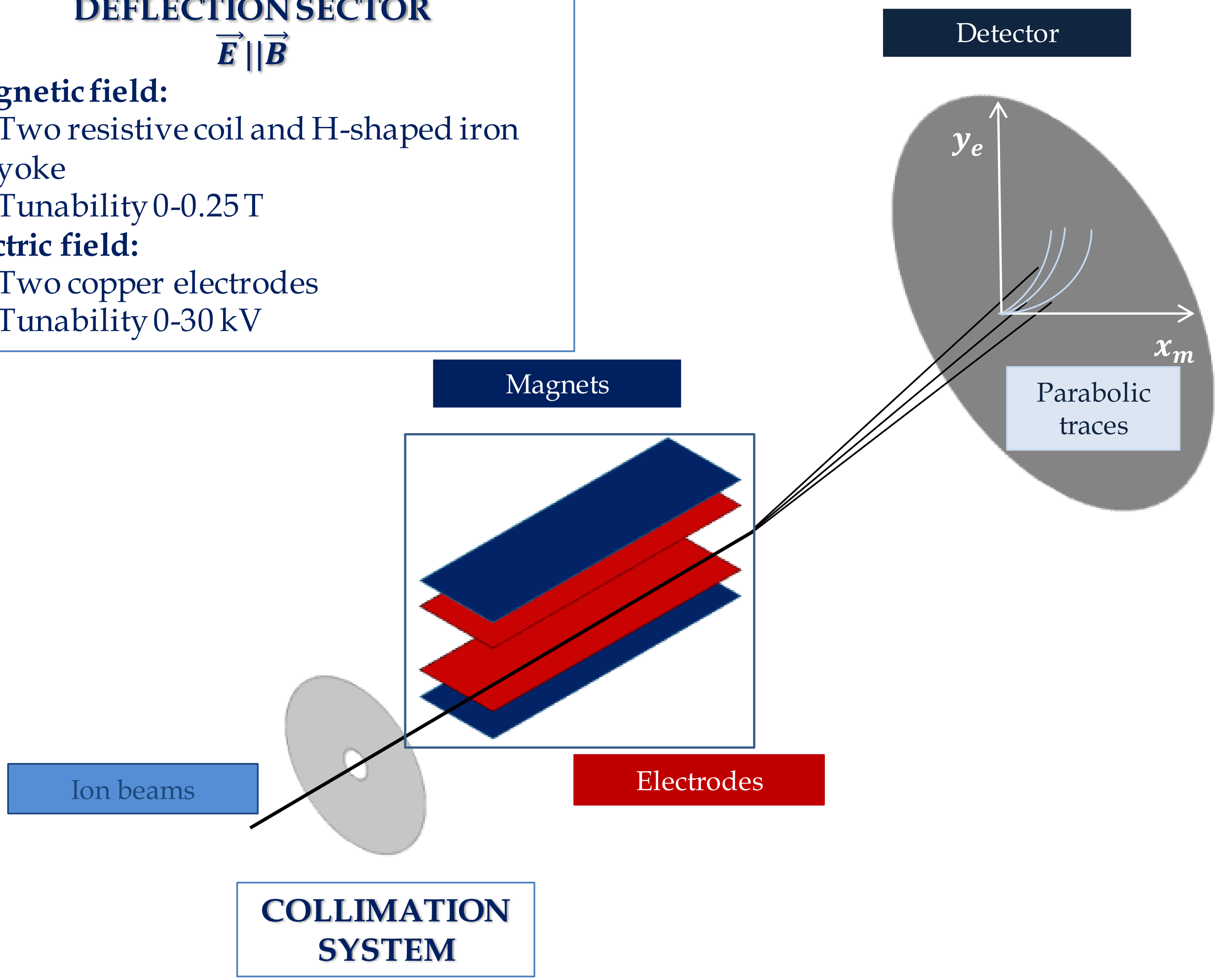
Thomson Parabola Spectrometer

DEFLECTION SECTOR

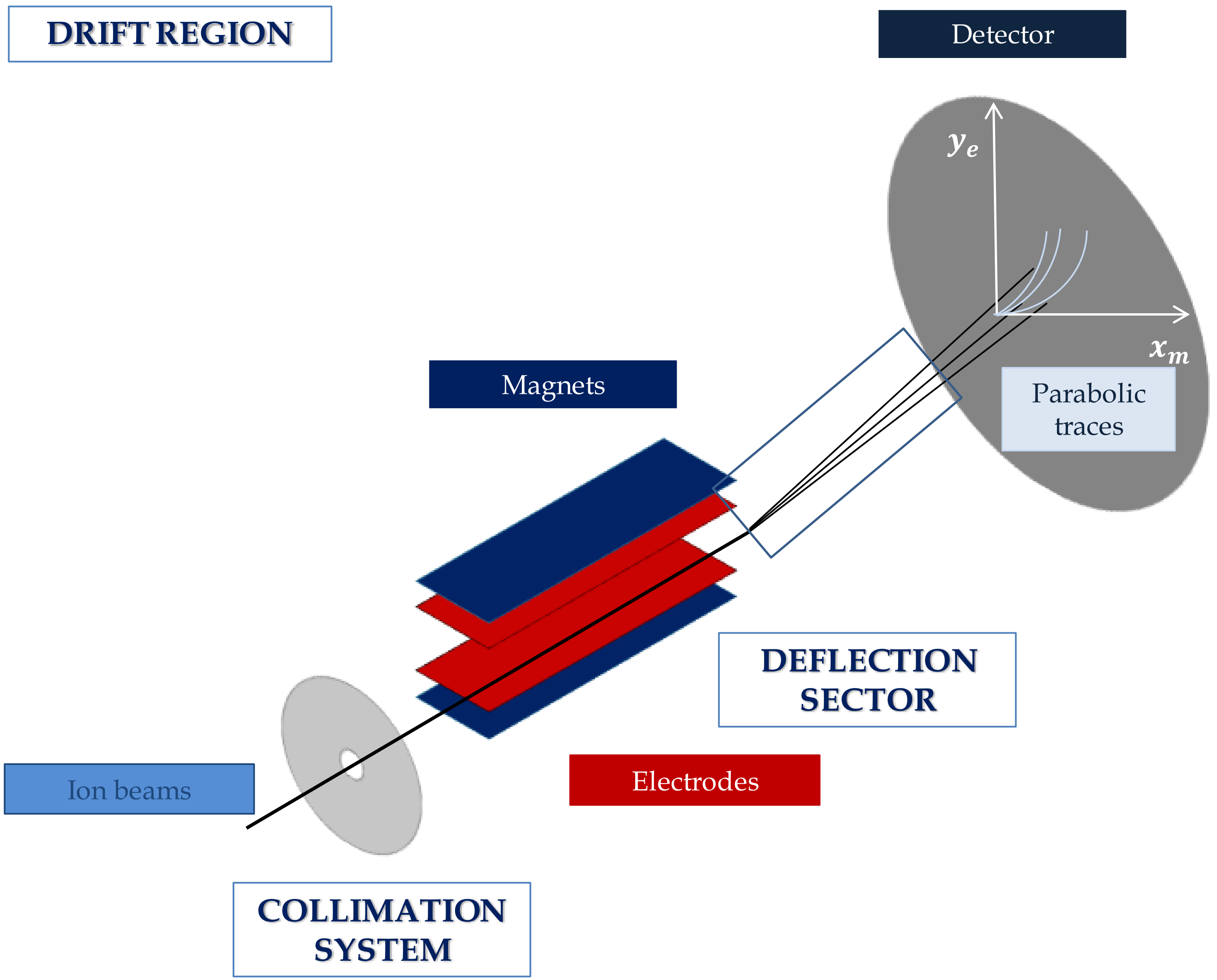
$\vec{E} || \vec{B}$

Magnetic field:
- Two resistive coil and H-shaped iron yoke
- Tunability 0-0.25 T

Electric field:
- Two copper electrodes
- Tunability 0-30 kV



Thomson Parabola Spectrometer

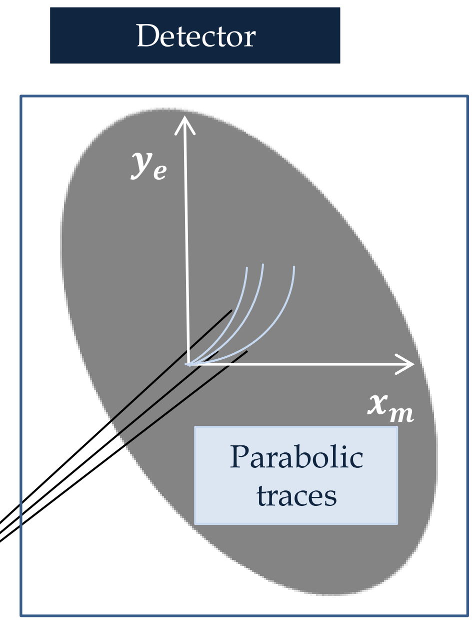


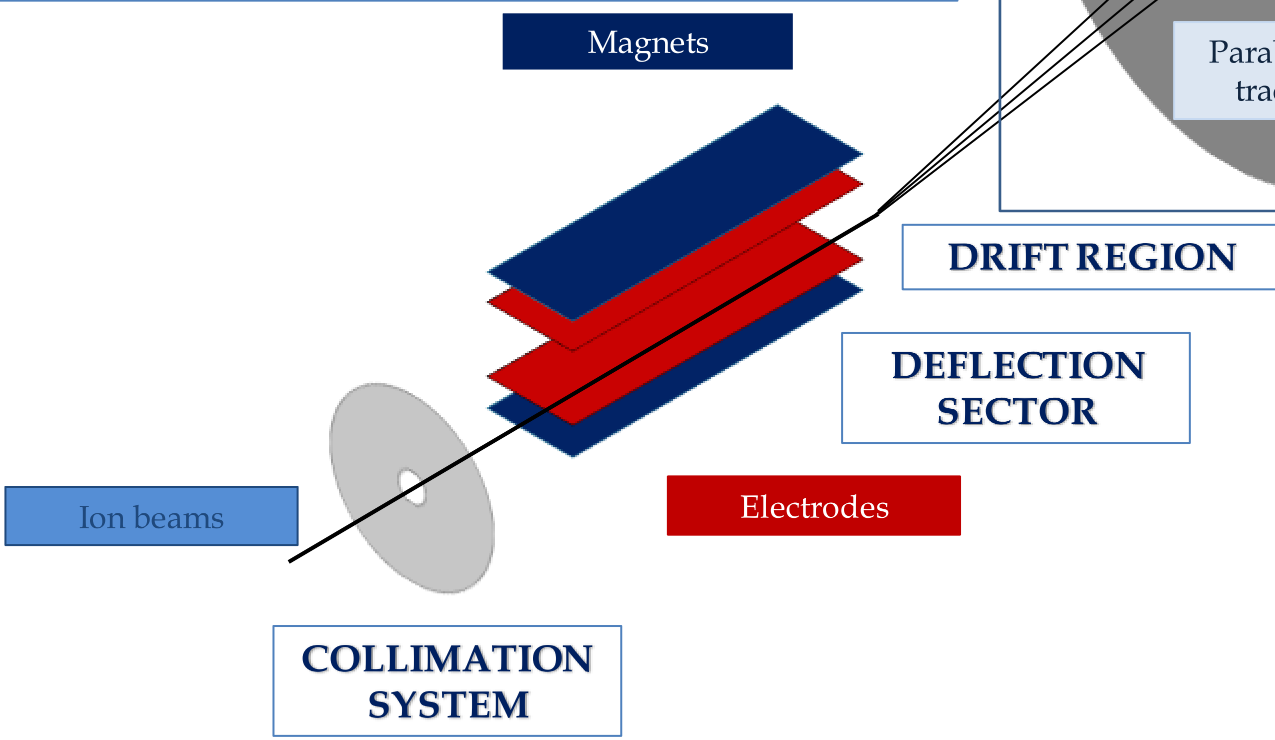
Thomson Parabola Spectrometer

IMAGING SYSTEM

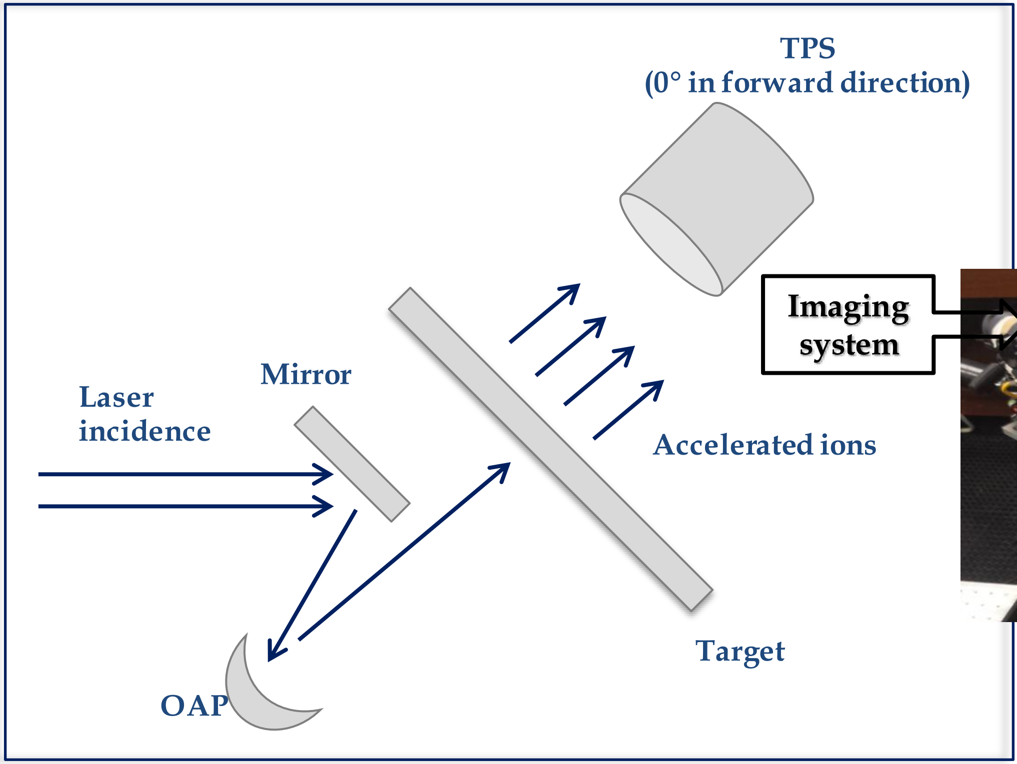
MCP coupled to phosphor screen:
- Diameter: 75 mm

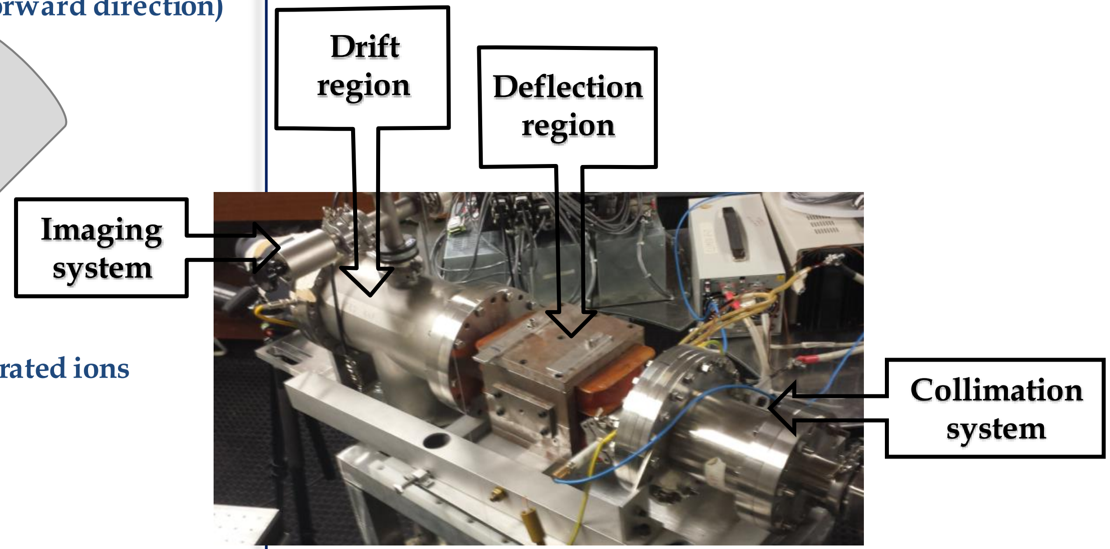
EMCCD camera:
- Triggered
- Small exposure time





Experimental Set-up

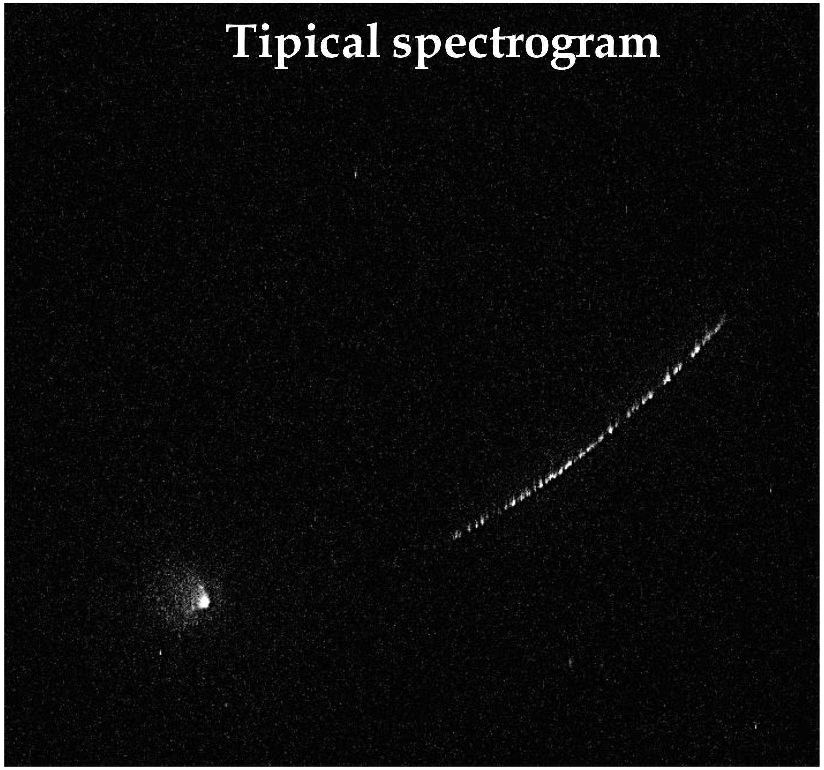




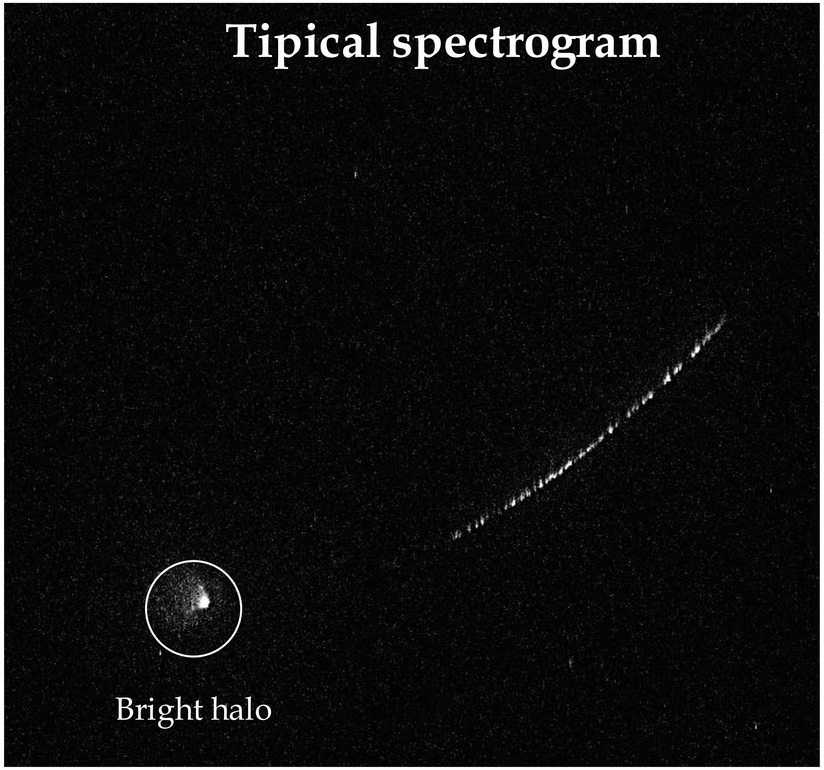
Intense Laser Irradiation Laboratory (ILIL)

- Ti:Sapphire laser system
- Pulse duration: 40 fs
- Fundamental wavelength: 800 nm
- Energy on target up to 400 mJ
- Angle of incidence on target: 15°
- Maximum intensity on target was up to 2 x 10^{19} W/cm^2
- TPS in normal direction

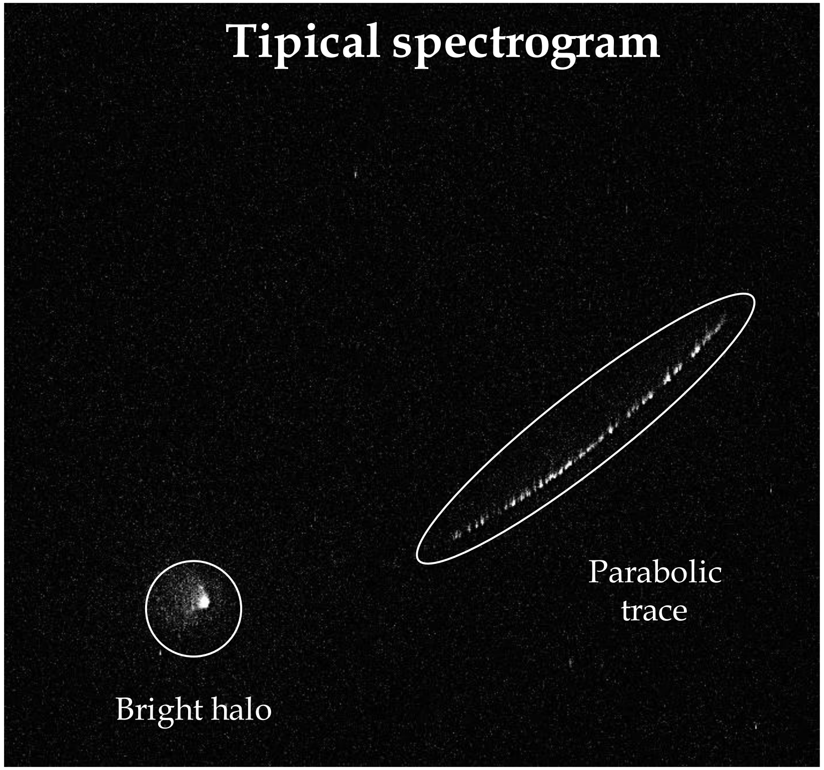
Spectrograms Analysis



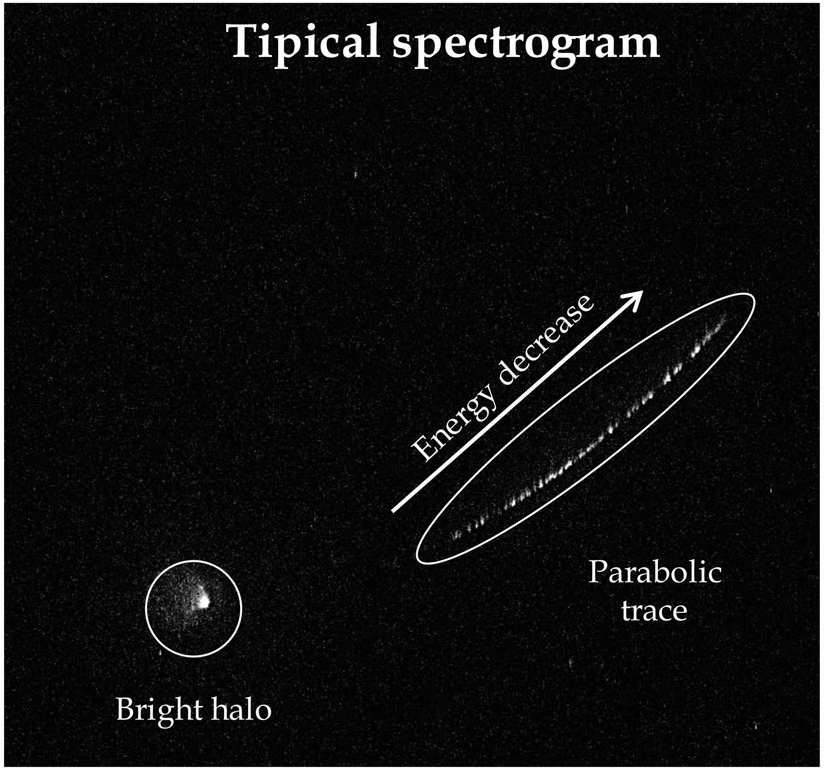
Spectrograms Analysis



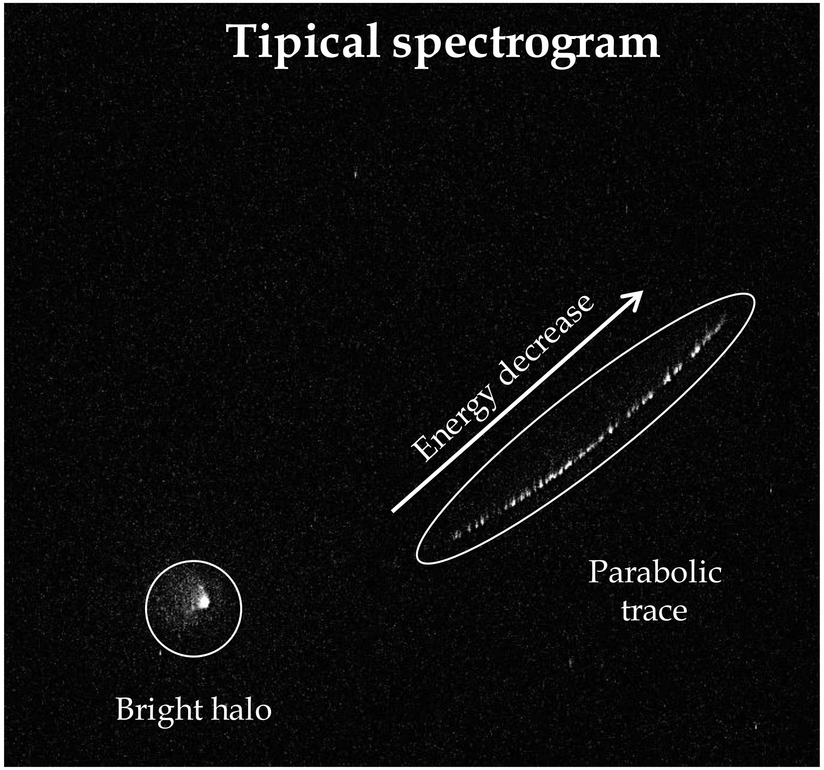
Spectrograms Analysis



Spectrograms Analysis



Spectrograms Analysis



- Q = charge state of the ion
- e = charge of the electron
- m = ions mass
- B = applied magnetic field
- E = applied electric field
- L_m = geometric length of the magnet
- L_e = geometric length of the electrodes
- D_m = drift between the end of the magnet and the detector
- D_e = drift between the end of the electrodes and the detector
- x = magnetic deflection
- y = electric deflection

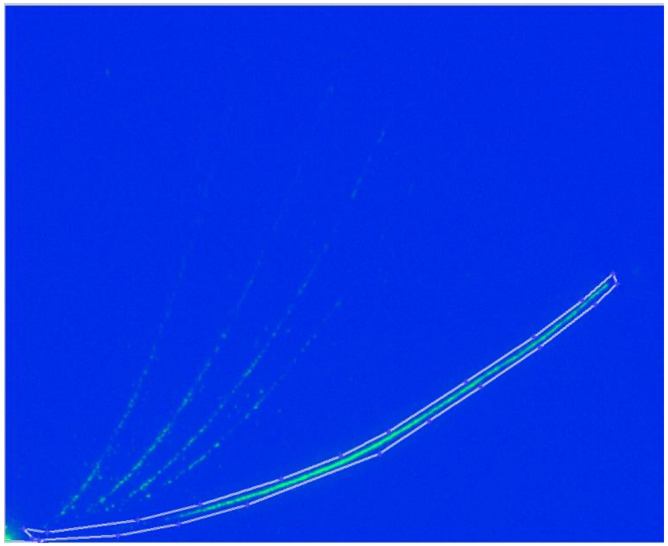
$$E_{kin} = \frac{Q^2 e^2 B^2 L_m^2 \left(D_m + \frac{L_m}{2}\right)^2}{2mx^2}$$

$$E_{kin} = \frac{QeEL_e\left(D_e + \frac{L_e}{2}\right)}{2y}$$

Reconstruct the ENERGY SPECTRUM

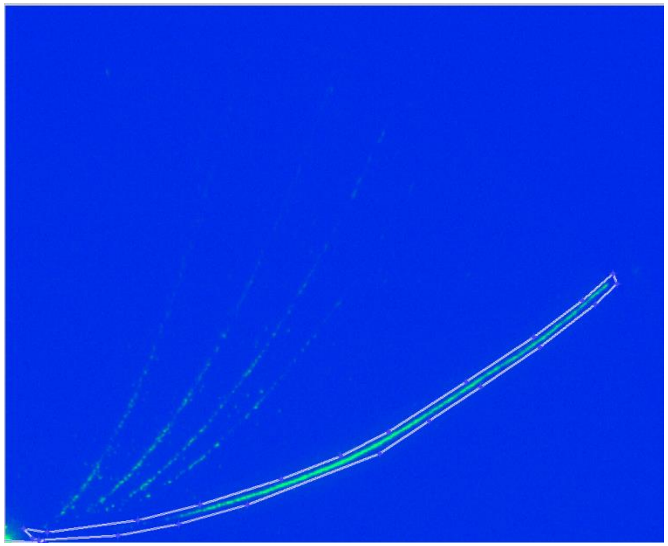
Spectrograms Analysis

The spectra are constructed cutting out the parabolas

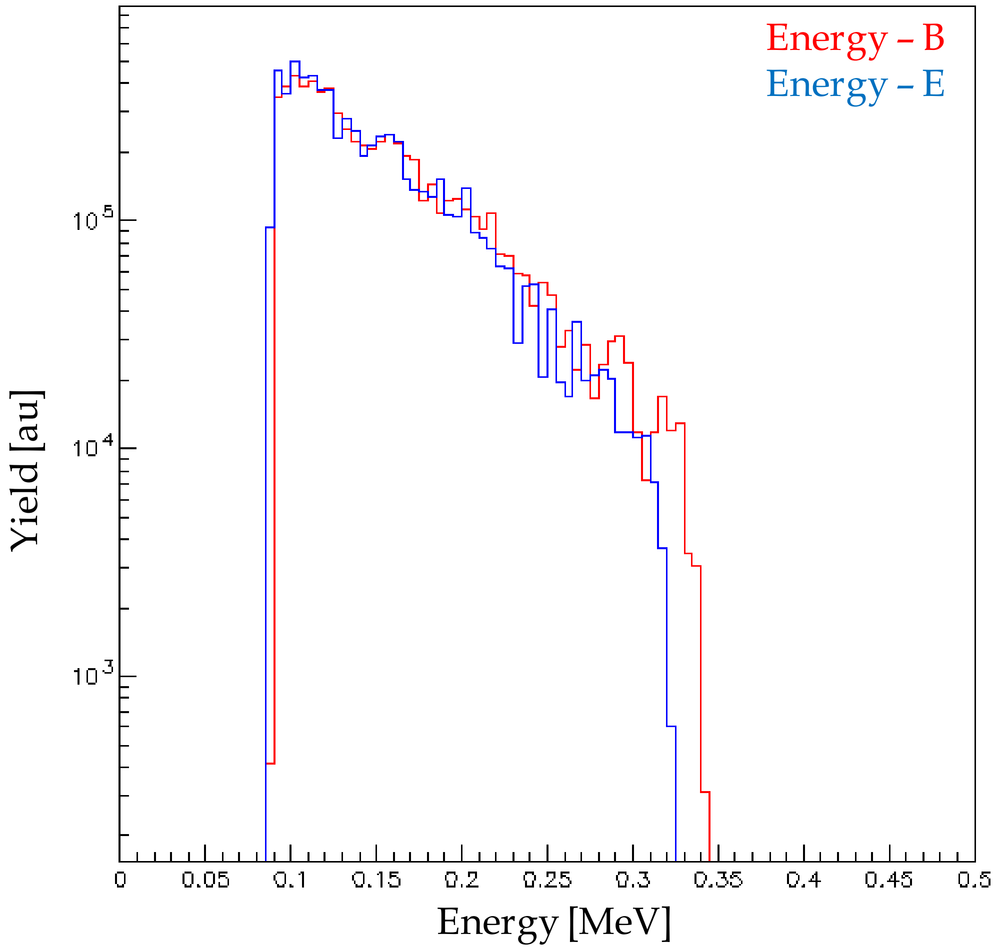


Spectrograms Analysis

The spectra are constructed cutting out the parabolas

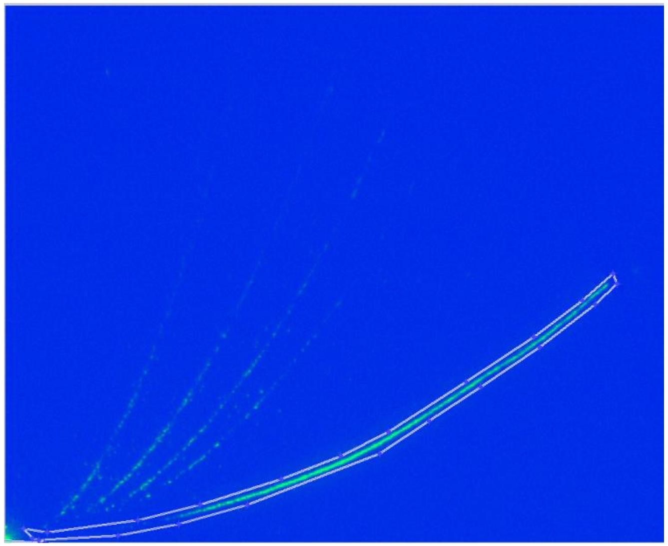


Overlap the proton spectra obtained by means of **magnetic** and **electric** fields on semi-log scale

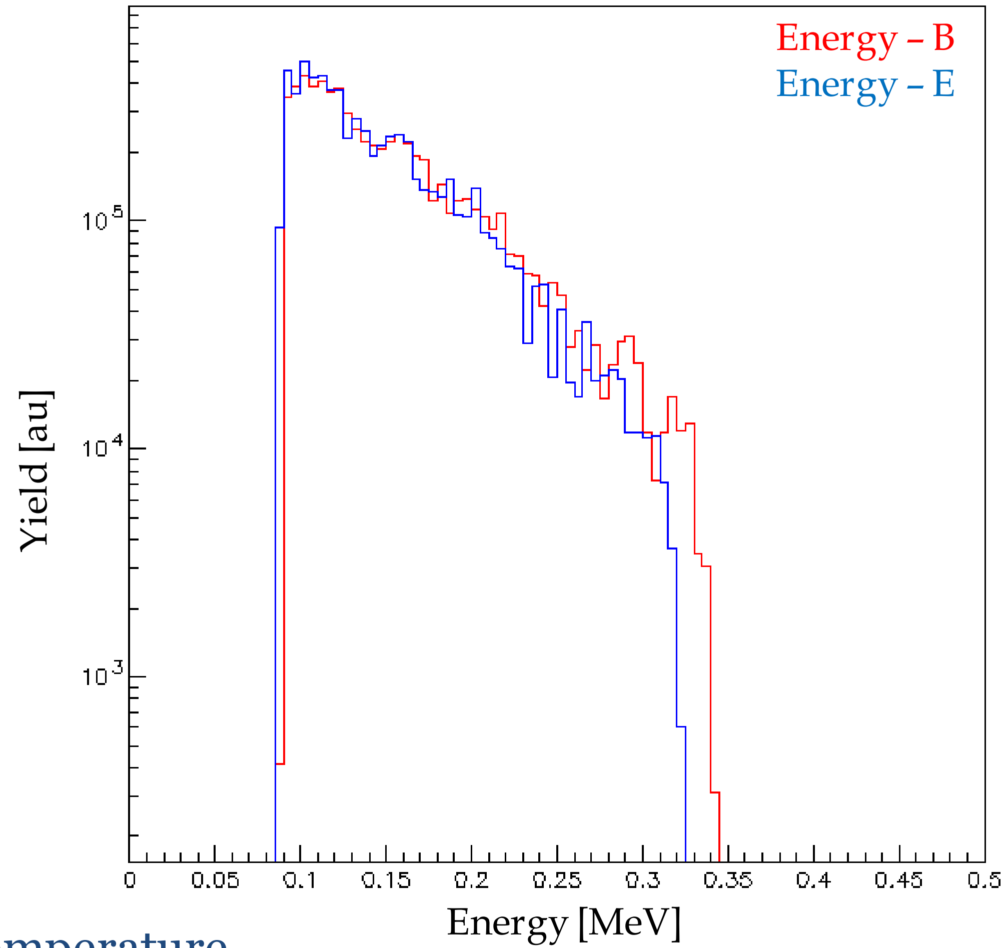


Spectrograms Analysis

The spectra are constructed cutting out the parabolas



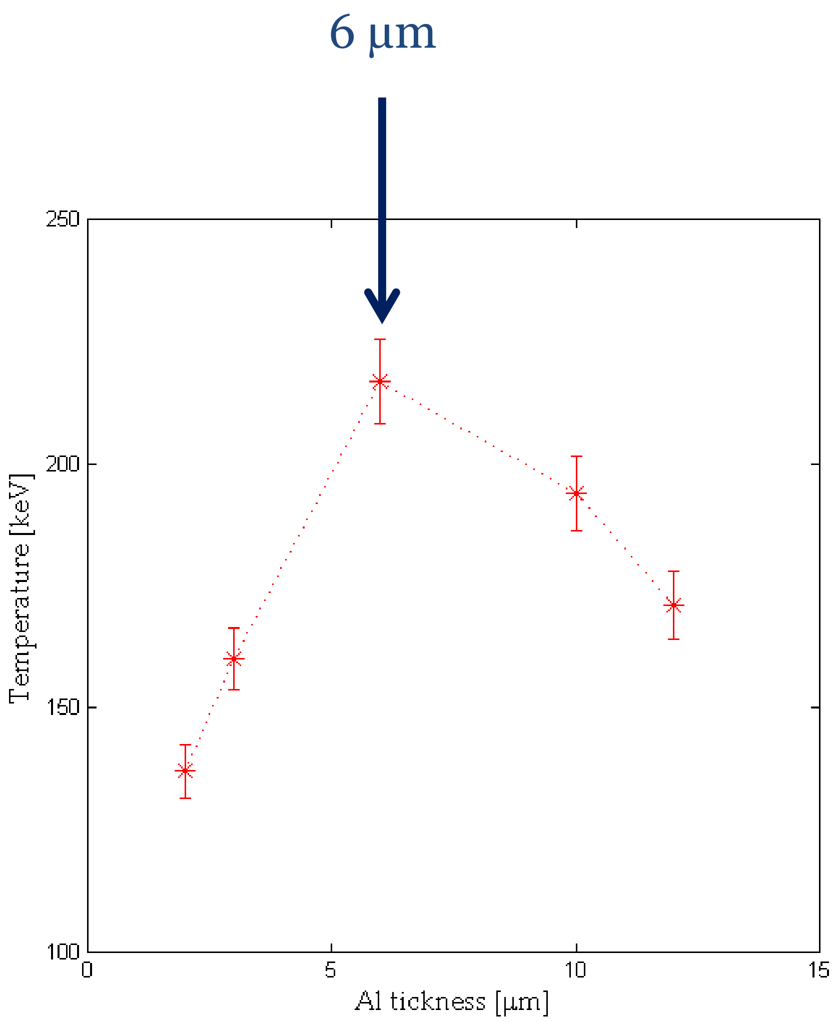
Overlap the proton spectra obtained by means of **magnetic** and **electric** fields on semi-log scale



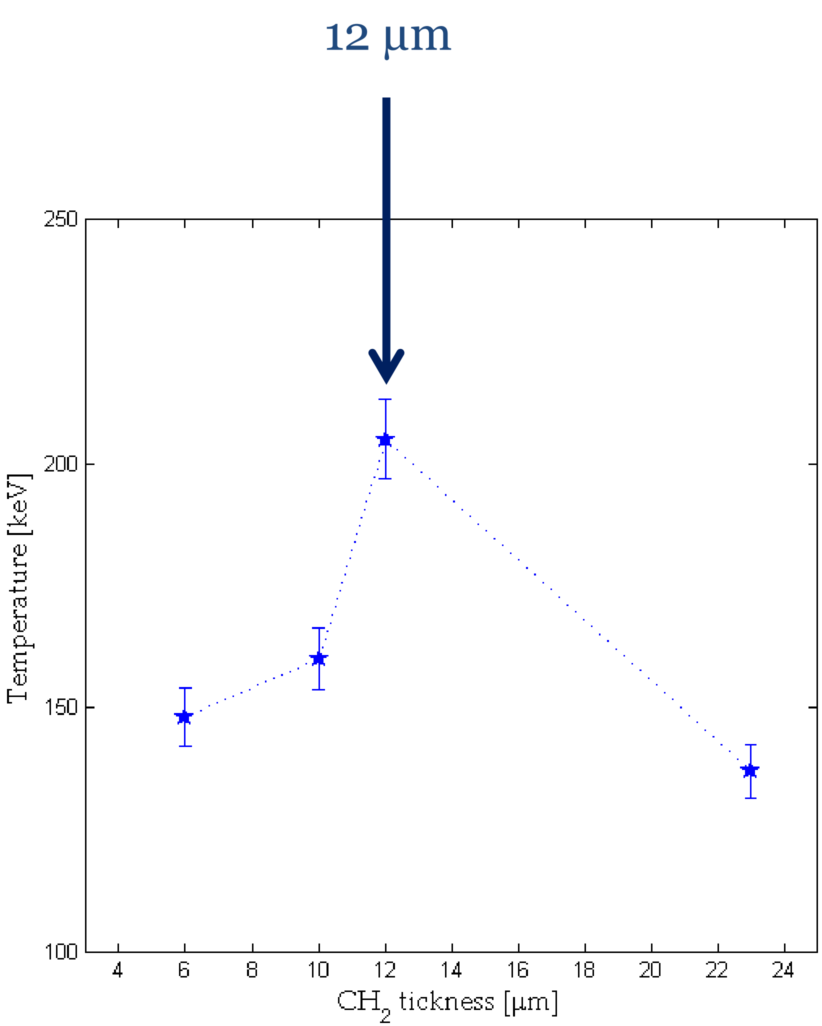
EXPONENTIAL TREND

Fit → Ionic temperature

Results: Thickness



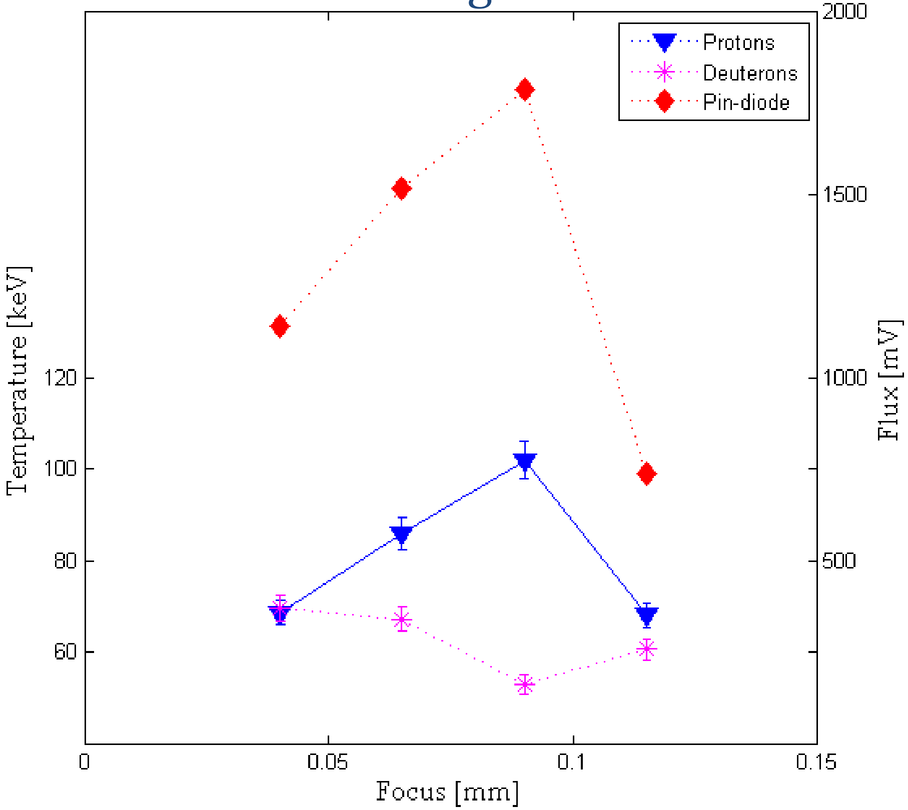
Al Target



CH_2 Target

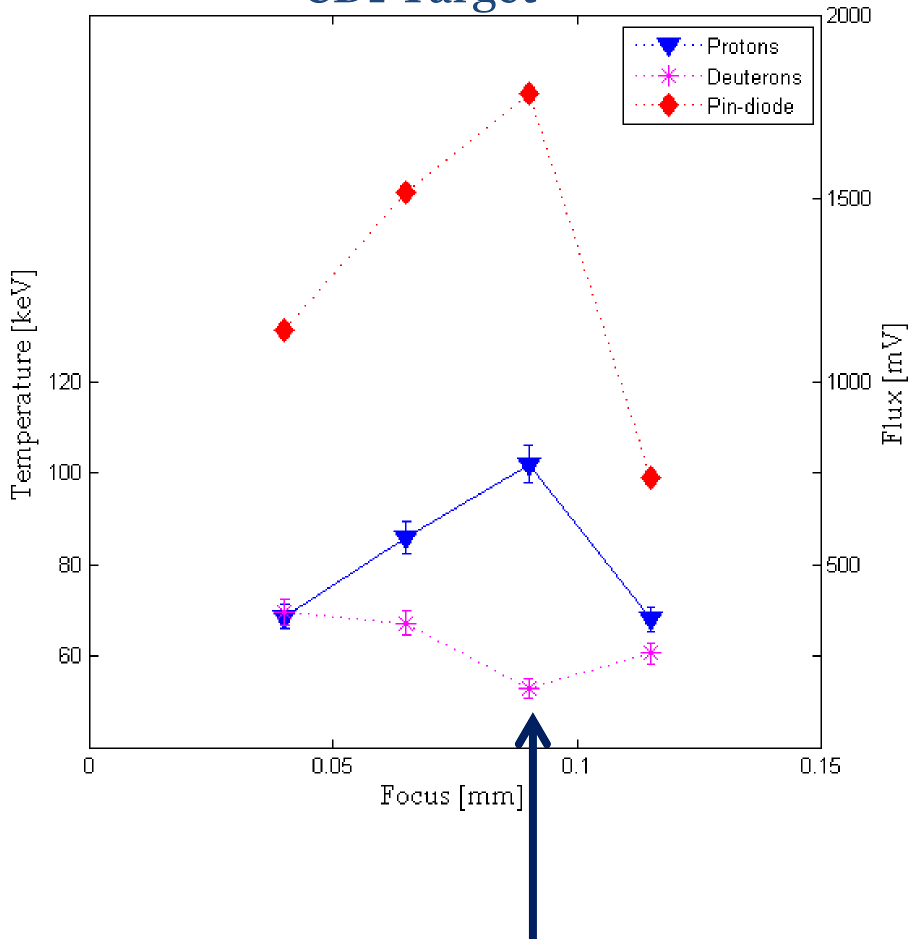
Results: Bulk vs. Surface

CD_2 Target



Results: Bulk vs. Surface

CD₂ Target

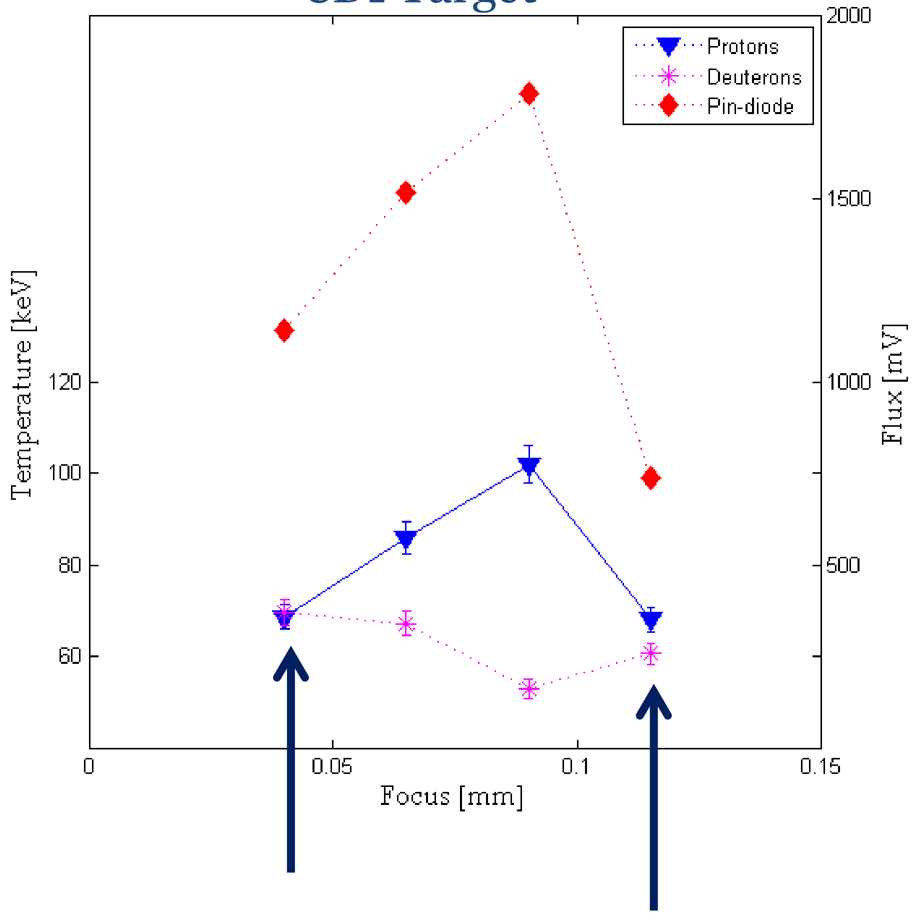


Focusing:

- Max proton temperature
- Min deuterons temperature

Results: Bulk vs. Surface

CD₂ Target

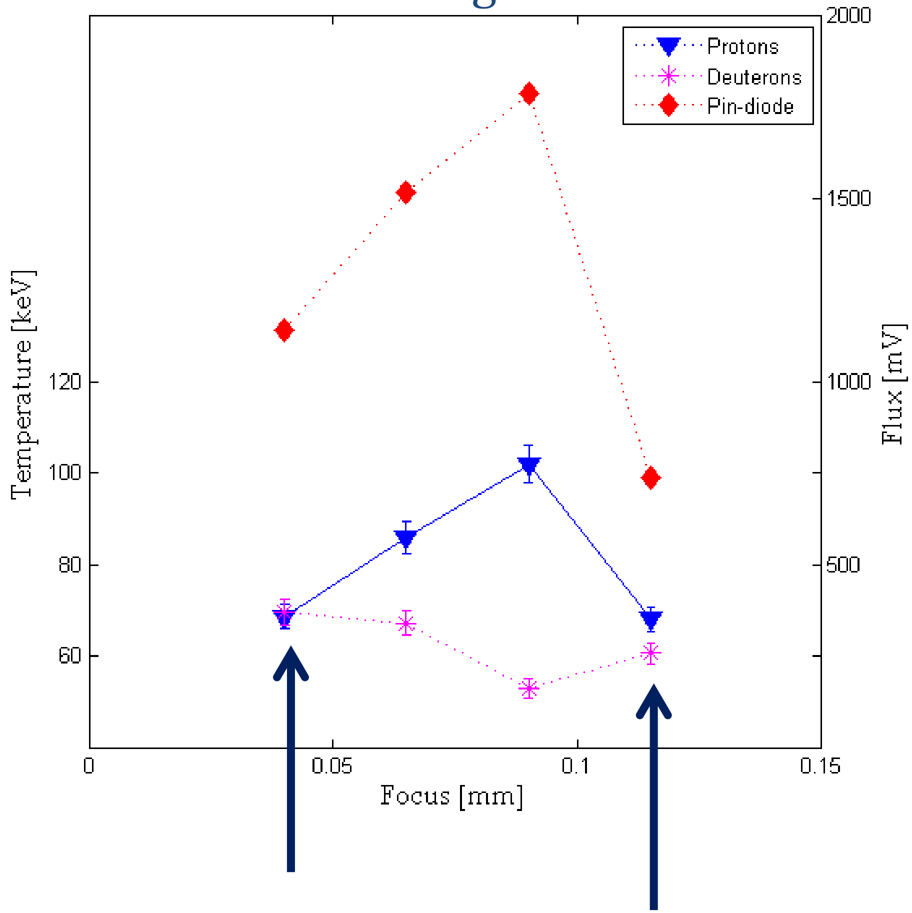


Defocusing:

Proton temperature = Deuterons temperature

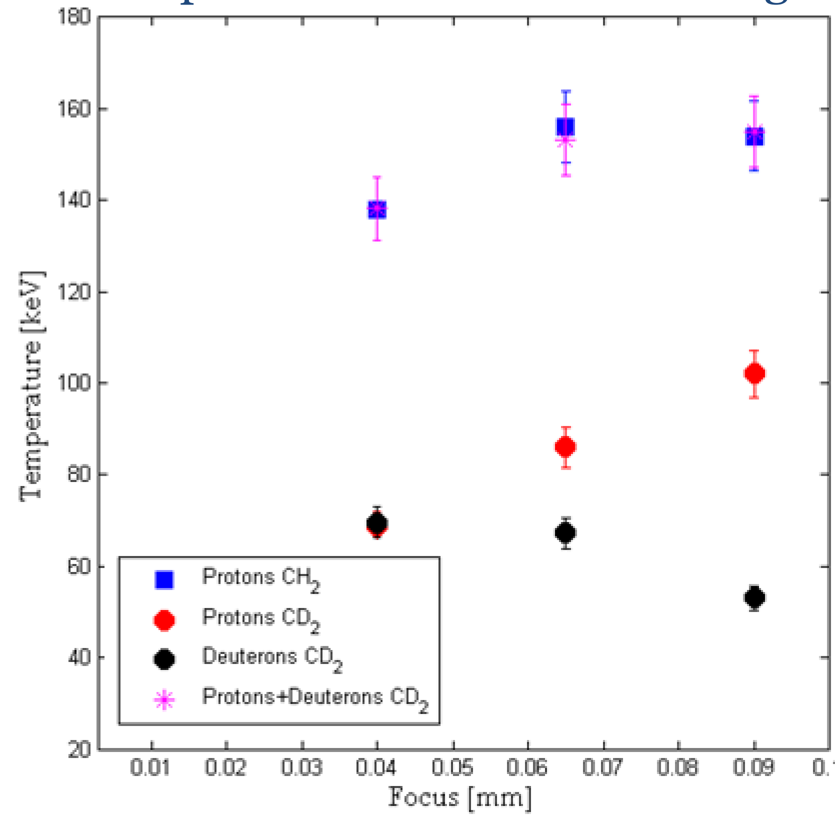
Results: Bulk vs. Surface

CD_2 Target



Defocusing:
Proton temperature = Deuterons temperature

Comparison of CH_2 and CD_2 Target

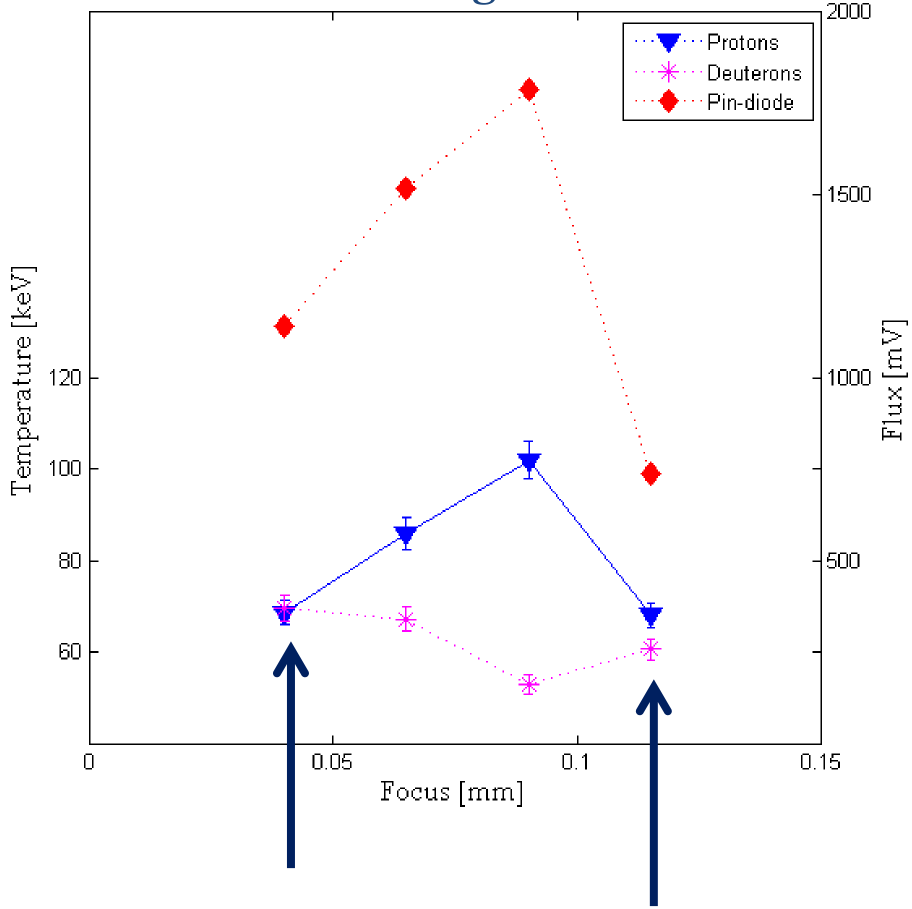


Protons + Deuterons temperature in CD_2 = Protons temperature in CH_2

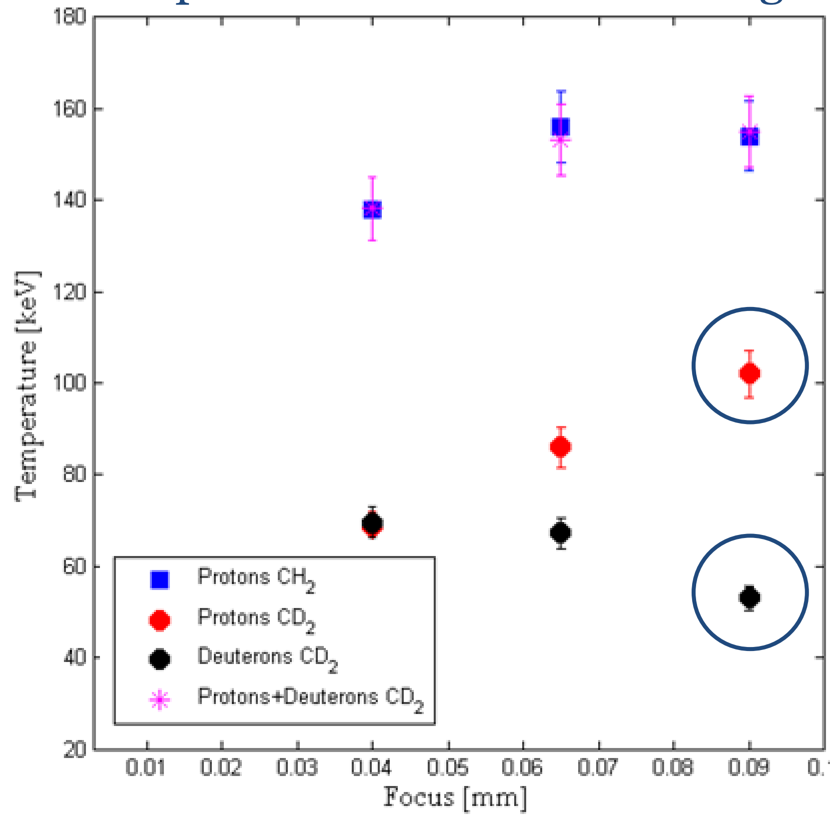
Protons temperature in CD_2 is about 65% of total temperature

Results: Bulk vs. Surface

CD_2 Target



Comparison of CH_2 and CD_2 Target



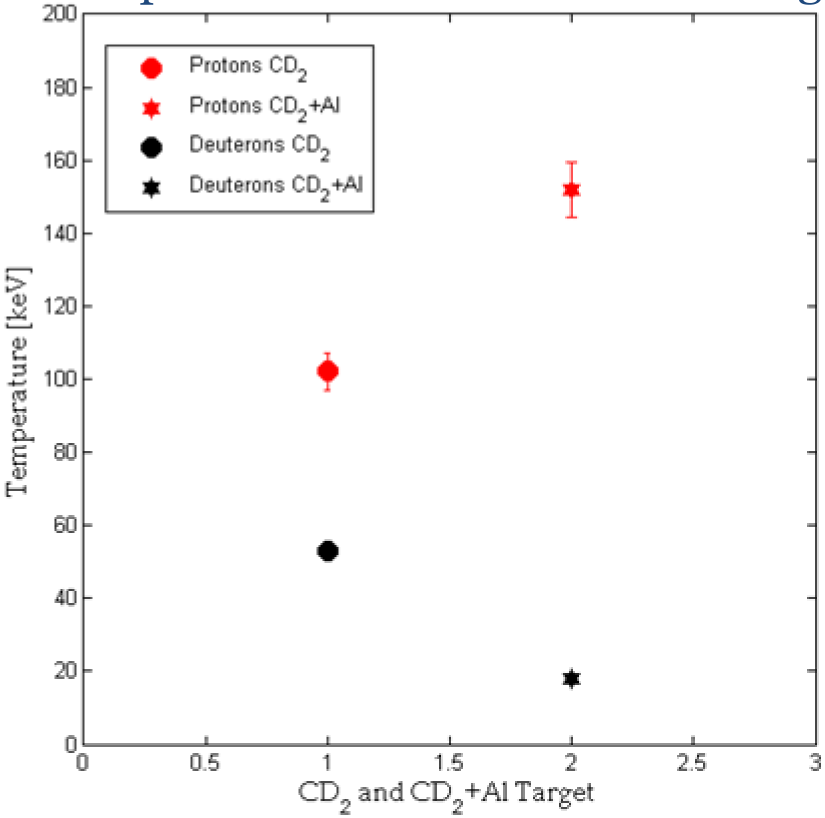
Protons + Deuterons temperature in CD_2 = Protons temperature in CH_2

Defocusing:
Proton temperature = Deuterons temperature

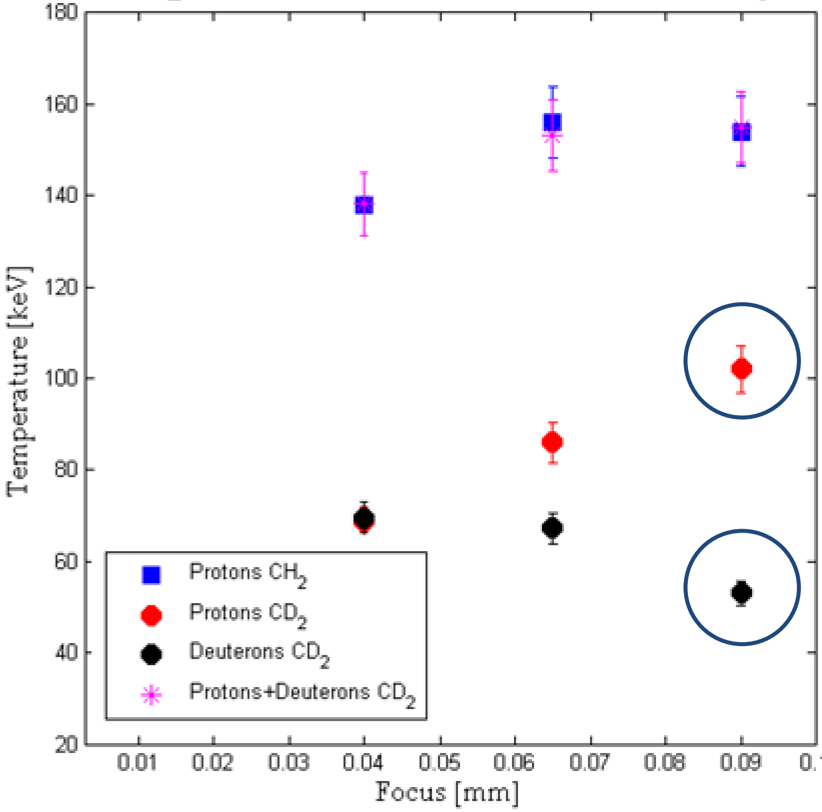
Protons temperature in CD_2 is about 65% of total temperature

Results: Bulk vs. Surface

Comparison of CD_2 and CD_2+Al Target



Comparison of CH_2 and CD_2 Target

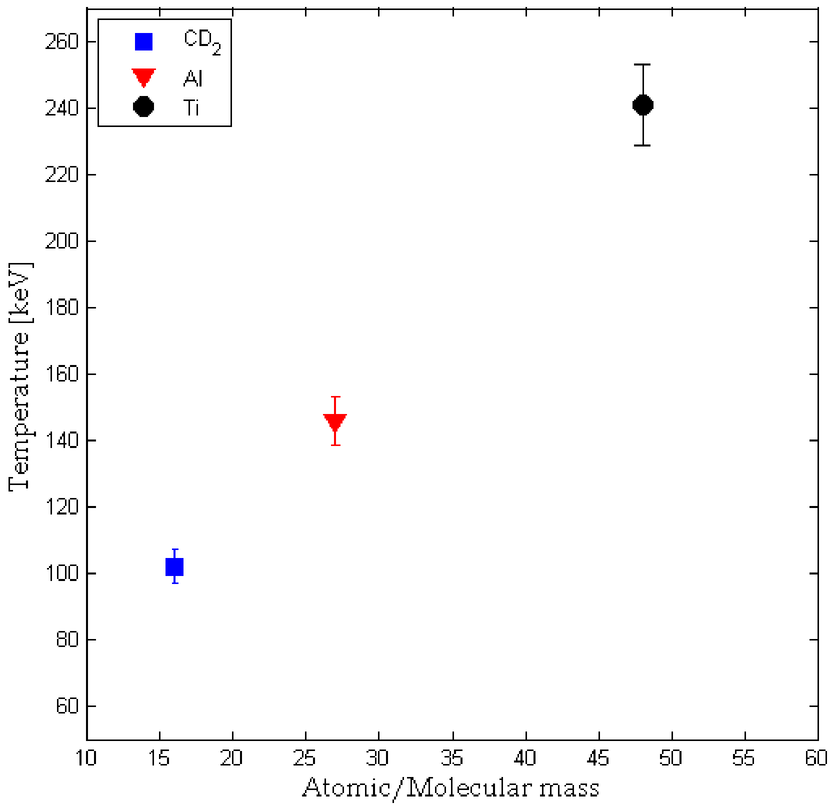


- Increase of Proton temperature in CD_2+Al
- Decrease of Deuterons temperature in CD_2+Al
- Total temperature in CD_2 and CD_2+Al is the same

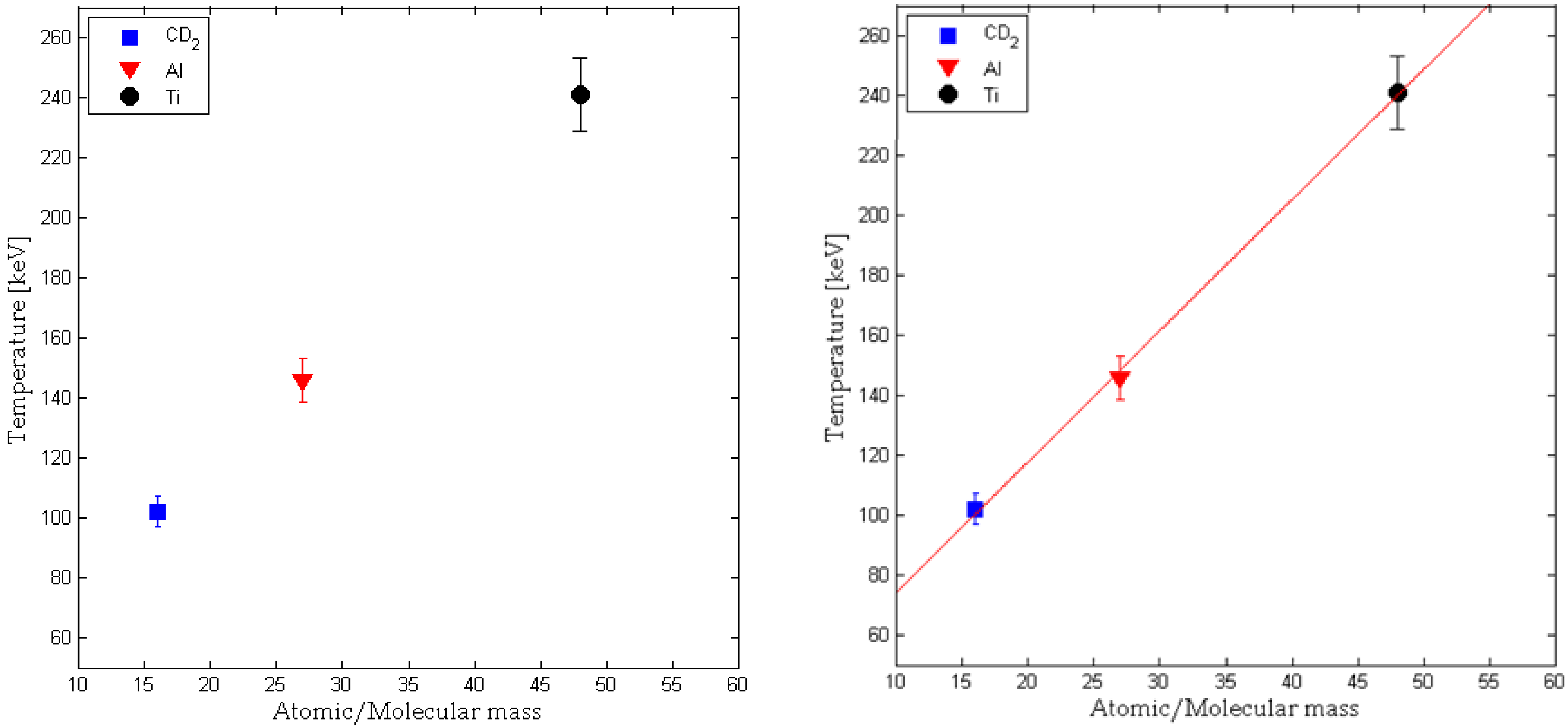
Protons temperature in CD_2+Al is about 90% of total temperature

Enhancement of surface contribution

Results: Target density



Results: Target density



Linear dependence on atomic or molecular mass of the target

Conclusion

❑ Target thickness ⇨	Optimization of proton acceleration in metallic (Al–6 μm) and plastic (CH_2–12 μm) target
❑ Bulk vs. Surface ⇨	Dependence on focus conditions: - If the laser beam is well focused on the target the surface contribution is dominant with respect to volume contribution; - If the laser beam is not focused on the target the surface and volume contributions are equal
❑ Atomic/Molecular mass ⇨	Linear dependence on atomic or molecular mass of the target

INFN

Collaboration

C. Altana, A. Anzalone, F. Brandi, G. Bussolino, G.A.P. Cirrone, G. Cristoforetti, A. Fazzi, P. Ferrara, L. Fulgentini, P. Koester, D. Giove, L.A. Gizzi, L. Labate, G. Lanzalone, A. Muoio, D. Palla, F. Schillaci, S. Tudisco

INO-CNR
Istituto Nazionale di Ottica