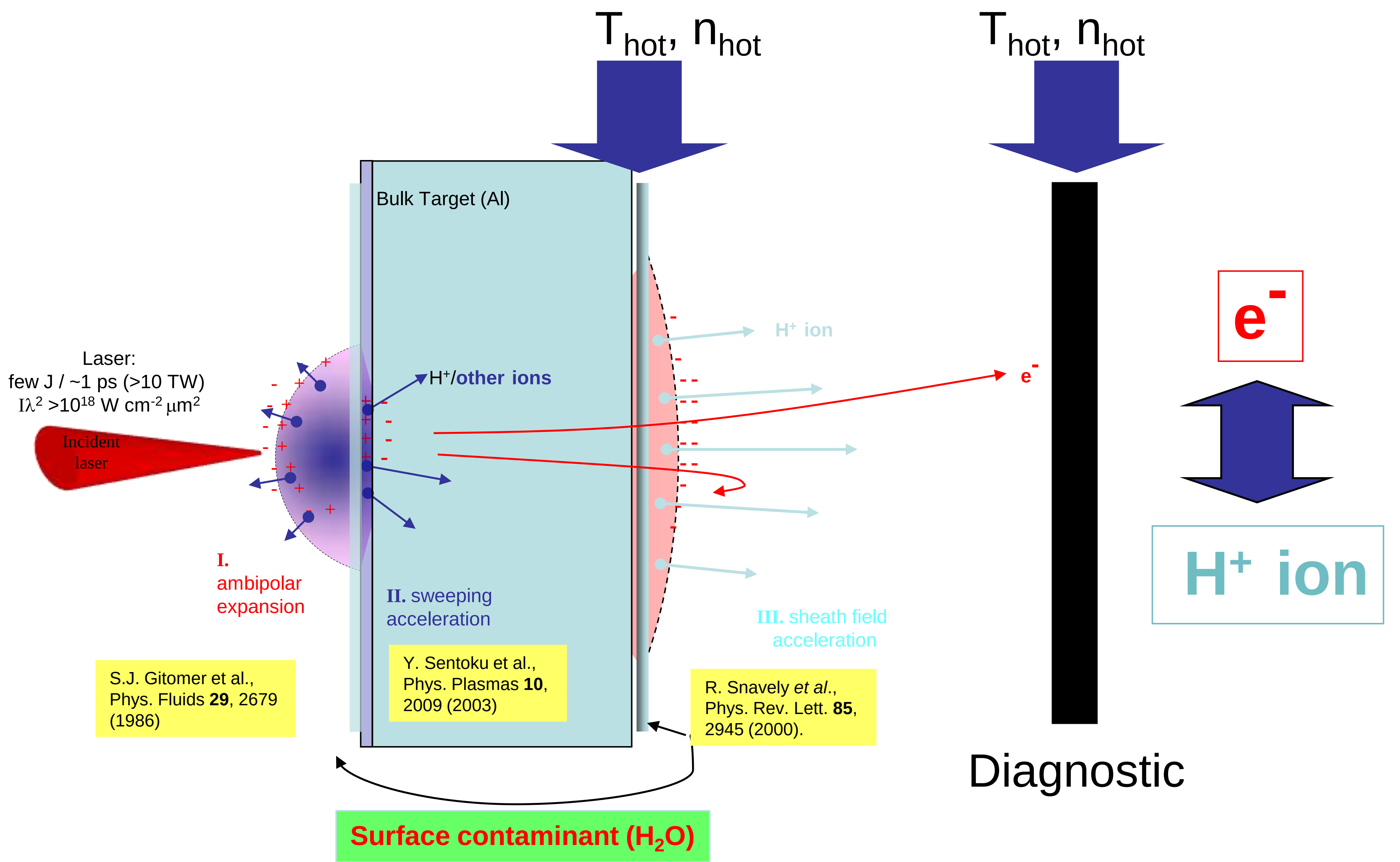
Measurements of hot electrons distributions in intense laser-matter interaction with solids

P. Antici, P. Audebert, S.Buffechoux, A. Mancic, J. Fuchs

Hot electron and proton acceleration mechanism



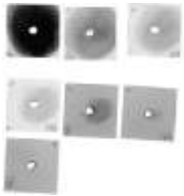
S.J. Gitomer et al., Phys. Fluids **29**, 2679 (1986)

Y. Sentoku et al., Phys. Plasmas **10**, 2009 (2003)

R. Snavely *et al*., Phys. Rev. Lett. **85**, 2945 (2000).

The diagnostic used

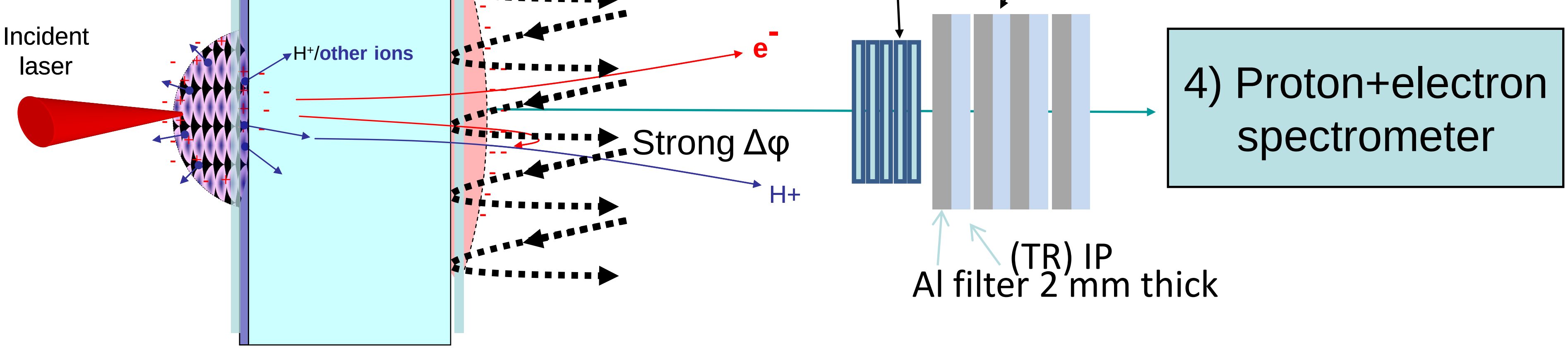
2) Radiochromic Films (RCF)



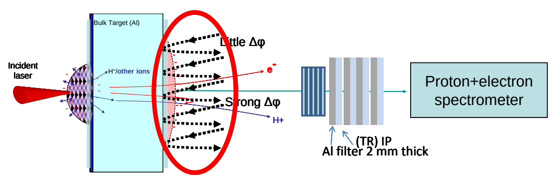
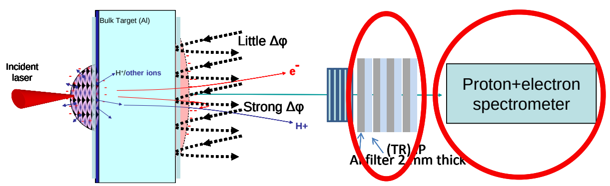
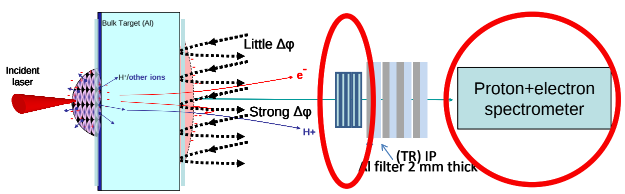
3) Image Plate (IP) Stack

Vacuum Compressor
E=5-20 J
t_{laser}=0.3-5ps
Focal spot~5 μm
1ω: λ=1.053 μm
2ω: λ=0.527 μm

1) Time and space resolved interferometry (TASRI)



Overview

<table>
<tr><th></th><th>Local</th><th>Distant</th></tr>
<tr><td>Direct (electrons)</td><td>TASRI

</td><td>Electron spectrometer
Image Plate

</td></tr>
<tr><td>Indirect (via protons)</td><td></td><td>Proton spectrometer
Radiochromic films

</td></tr>
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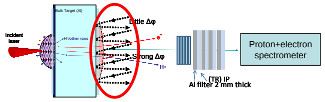
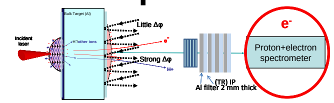
Hot electron temperature

Exp @ 1ω / 10 µm Al

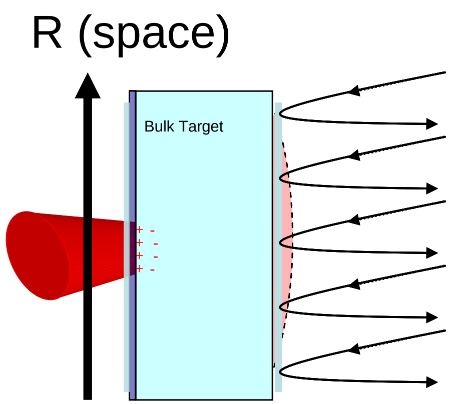
$I = 5\ 10^{19}$ W/cm² / $t_{laser} = 320$ fs

Determination of the hot electron temperature T_{hot} DIRECT



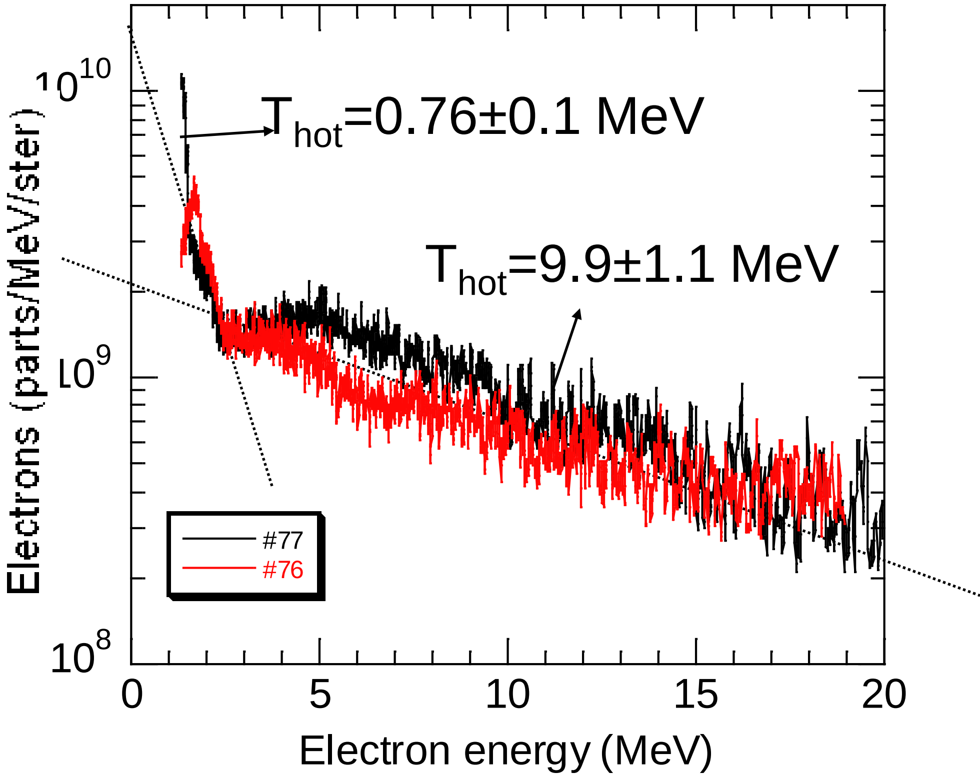


1) TASRI (expansion speed of hot electron cloud)



T_{hot}=0.85±0.2 MeV

2) Electron spectrometer

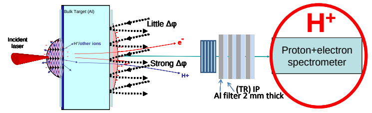


Exp @ 1ω / 10 μm Al

I=5 10^{19} W/cm² / t_{laser}=320 fs

P. Antici et al., PRL **101,** 105004 (2008)

Determination of the hot electron temperature T_{hot} INDIRECT

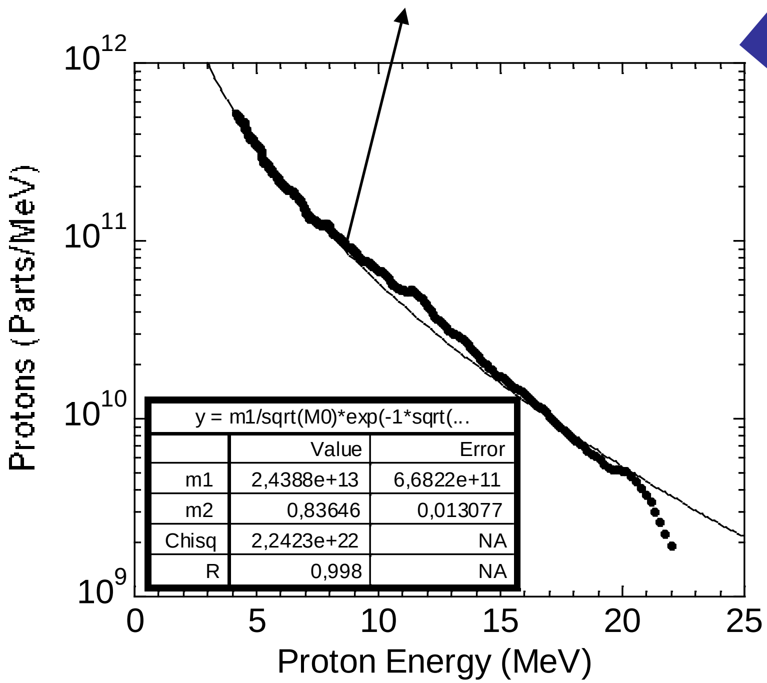


J. Fuchs et al., Nature Physics **2**, 48 (2006).

Proton spectra
(using a model)

$$dN/dE = 1.3 N_{hot} c_s / [c(2E k_B T_{hot})^{1/2}] \exp(-[2E/(k_B T_{hot})]^{1/2})$$

N_{hot} → height; T_{hot} → slope



y = m1/sqrt(M0)*exp(-1*sqrt(...

	Value	Error
m1	2,4388e+13	6,6822e+11
m2	0,83646	0,013077
Chisq	2,2423e+22	NA
R	0,998	NA

T_{hot}=0.84±0.2 MeV

TASRI: T_{hot}=0.85±0.2 MeV
Electron Spectro: T_{hot}=0.76±0.1 MeV

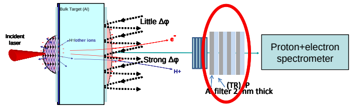
Exp @ 1ω / 10 μm Al
I=5 10^{19} W/cm² / t_{laser}=320 fs

Hot electron temperature

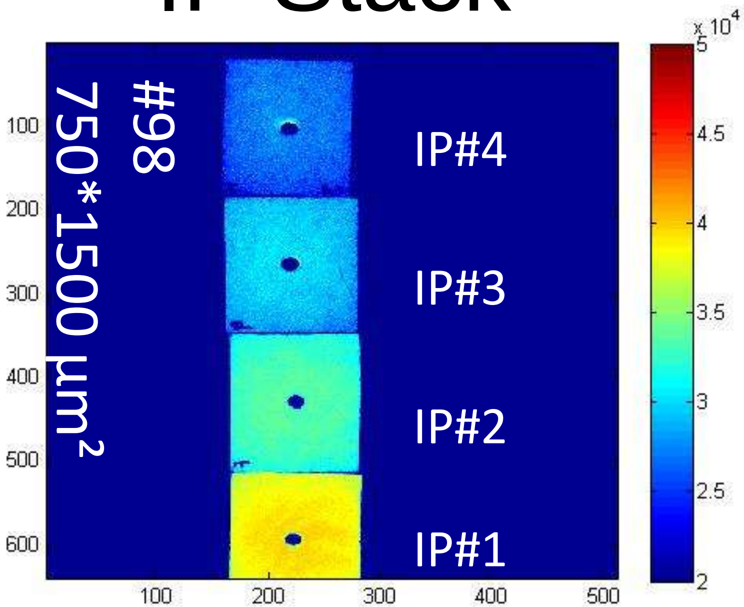
Exp @ 2ω / 2 μm Au

$I = 1\ 10^{19}$ W/cm² / t_{laser}=320 fs

Determination of the hot electron temperature T_{hot} DIRECT

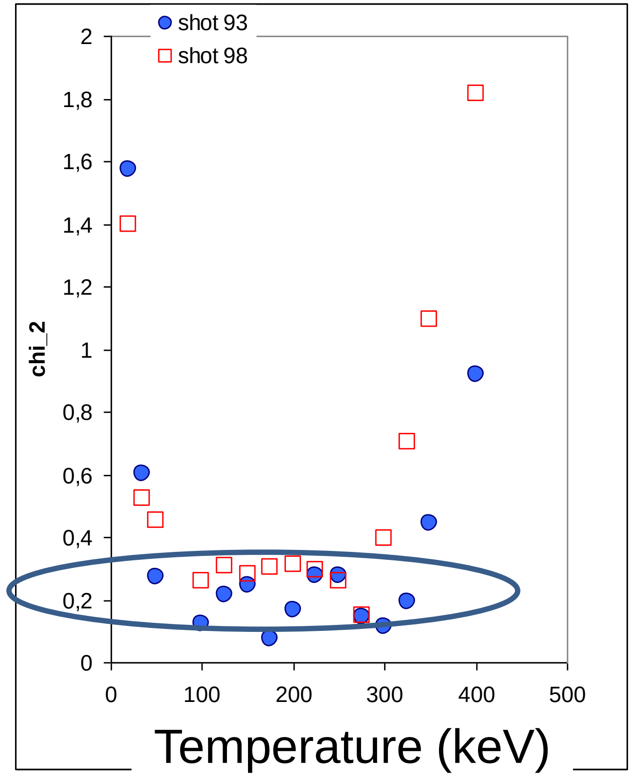


IP Stack



Fitting using Geant 4

& assuming Maxwellian distribution

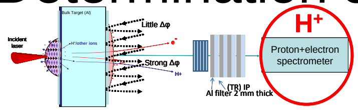


Exp @ 2ω / 2 μm Au

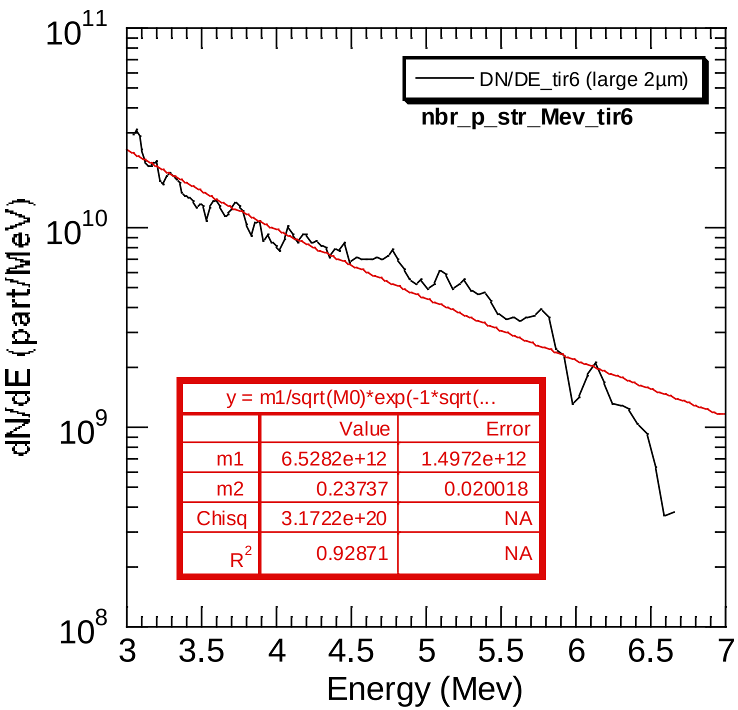
I=1 10^{19} W/cm² / t_{laser}=320 fs

T_{hot}=0.2±0.1 MeV

Determination of the hot electron temperature T_{hot} ÎNDIRECT



Proton spectra (using a model)



T_{hot}=0.24±0.1 MeV

IP: T_{hot}=0.2±0.1 MeV

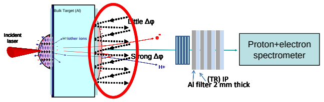
Hot electron number

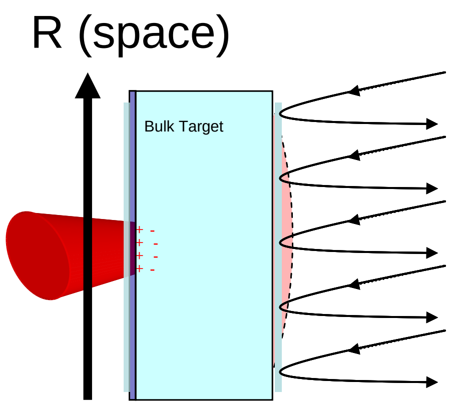
Exp @ 1ω / Al 25 µm

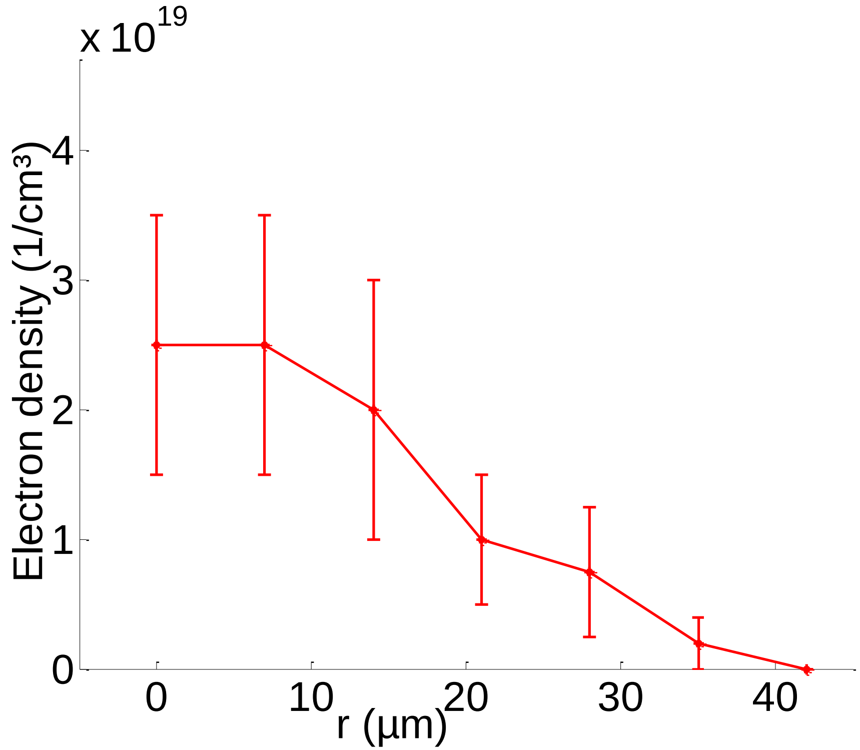
I~3e18 W/cm² / t_{laser}=5 ps

Determination of the hot electron density n_{hot} or total number N_{hot}

n_{hot} DIRECT



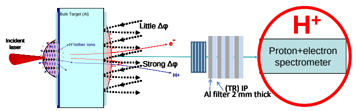




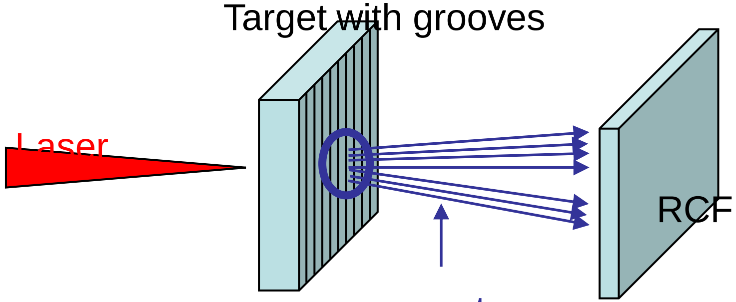
Exp @ 1ω / Al 25 µm

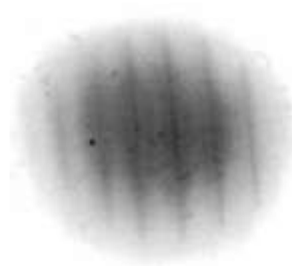
I~3e18 W/cm² / t_{laser}=5 ps

Determination of the hot electron density n_{hot} or total number N_{hot}



n_{hot} INDIRECT





$$E_{proton}=2*Z*k_b*T_h*(\ln(\tau+(\tau^2+1)^{0.5})^2$$
$$\tau=\omega_{pi}*t_{laser}/2.32$$
$$\omega_{pi}=(\mathbf{n_{hot}}Ze^2/m_i\varepsilon_0)^{0.5}$$

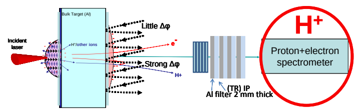
unknown

RCF using grooved target:

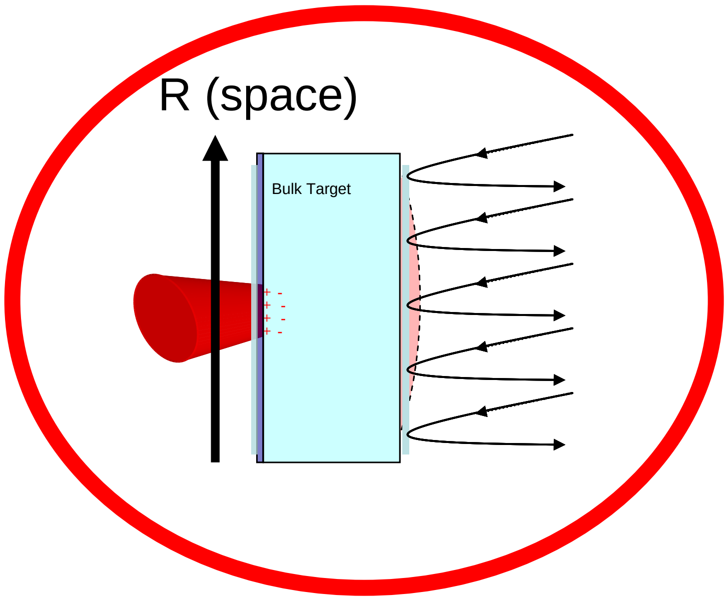
1) Every RCF is associated to one proton energy
2) Grooves on target allow retrieving the source diameter producing this energy
3) A model allows to associate proton energy to electron density:

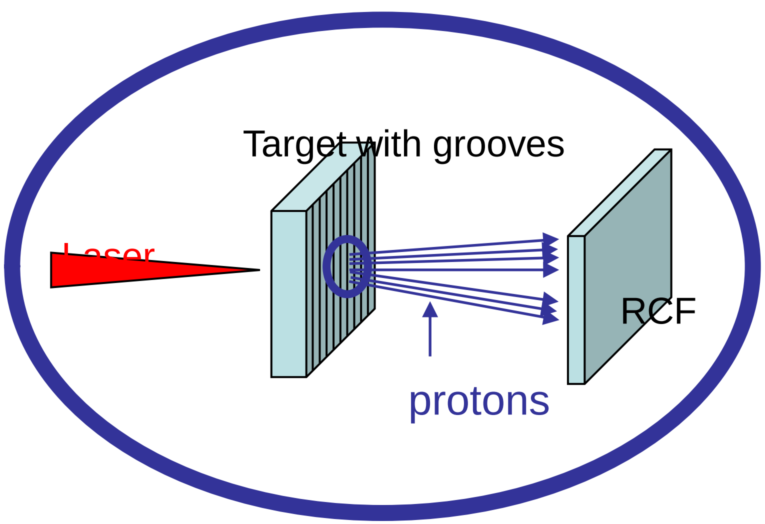
P.Mora, Phys. Rev. Lett. 90,185002 (2003)

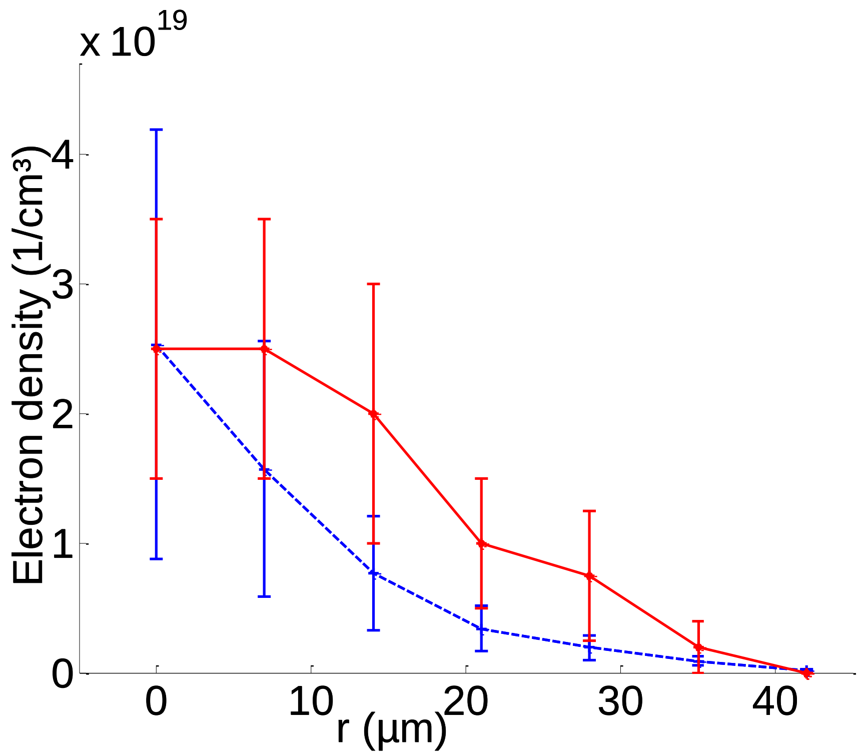
Determination of the hot electron density n_{hot} or total number N_{hot}



n_{hot} INDIRECT





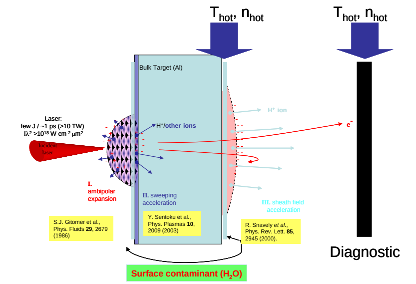


Exp @ 1ω / Al 25 µm

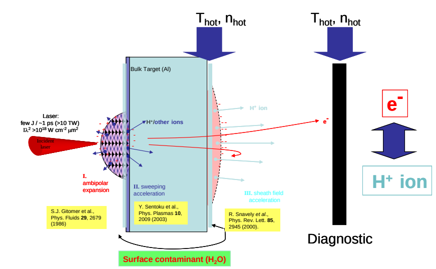
I~3e18 W/cm² / t_{laser}=5 ps

Conclusions

1) We have shown that we can use simple distant measurement for finding information about local parameters



2) We have shown that indirect measurement (via protons) can give information about electrons



3) We have shown that this is applicable for both T_{hot} and n_{hot}