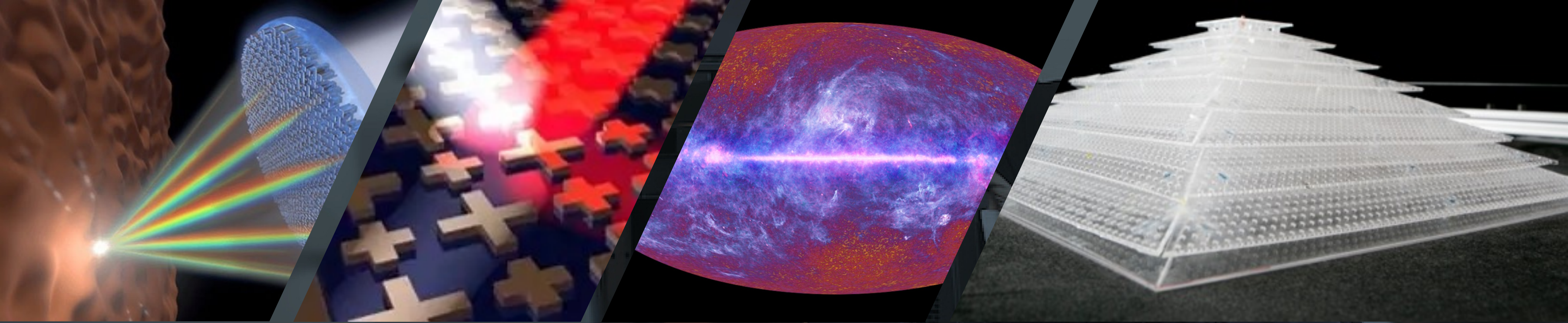

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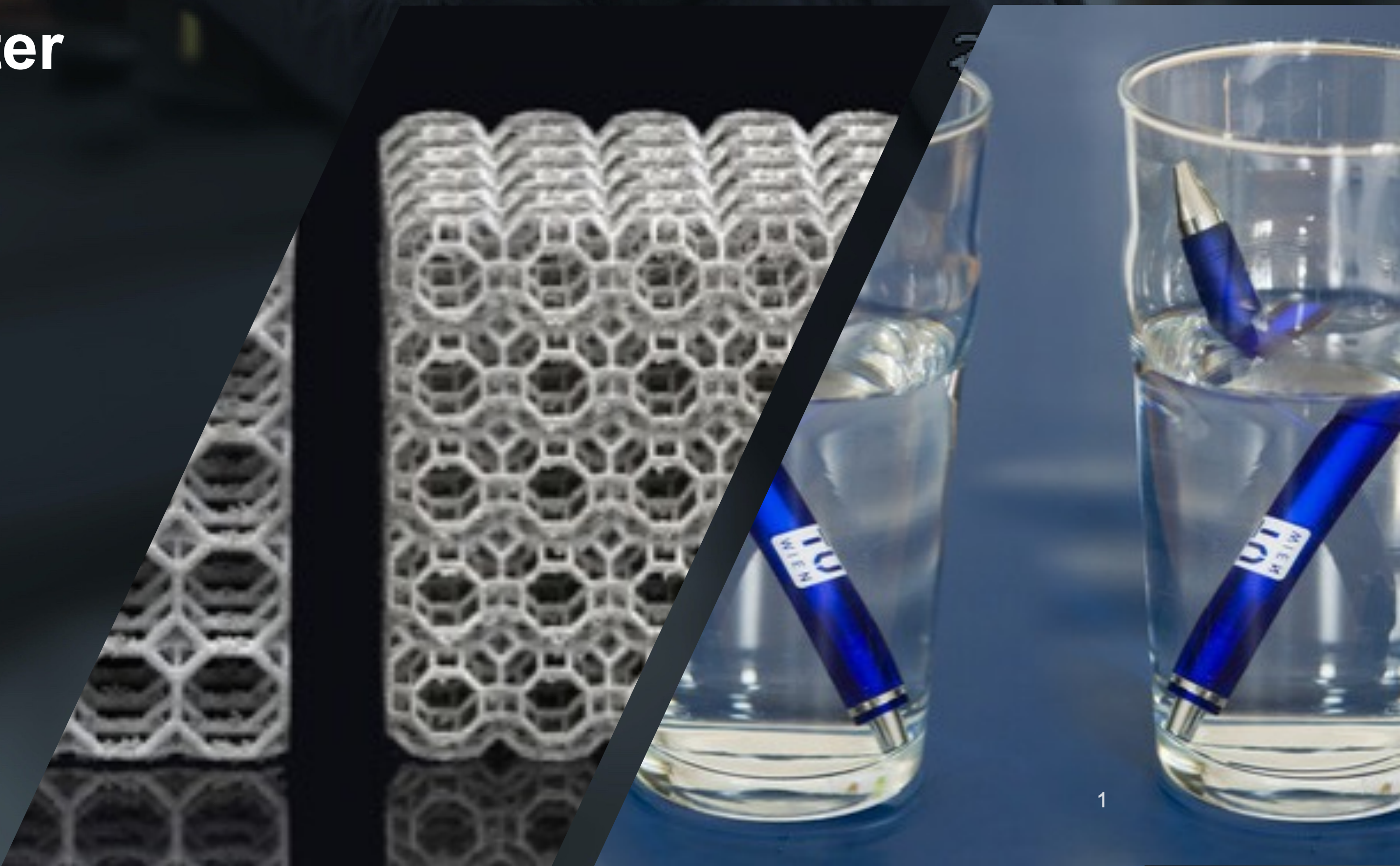
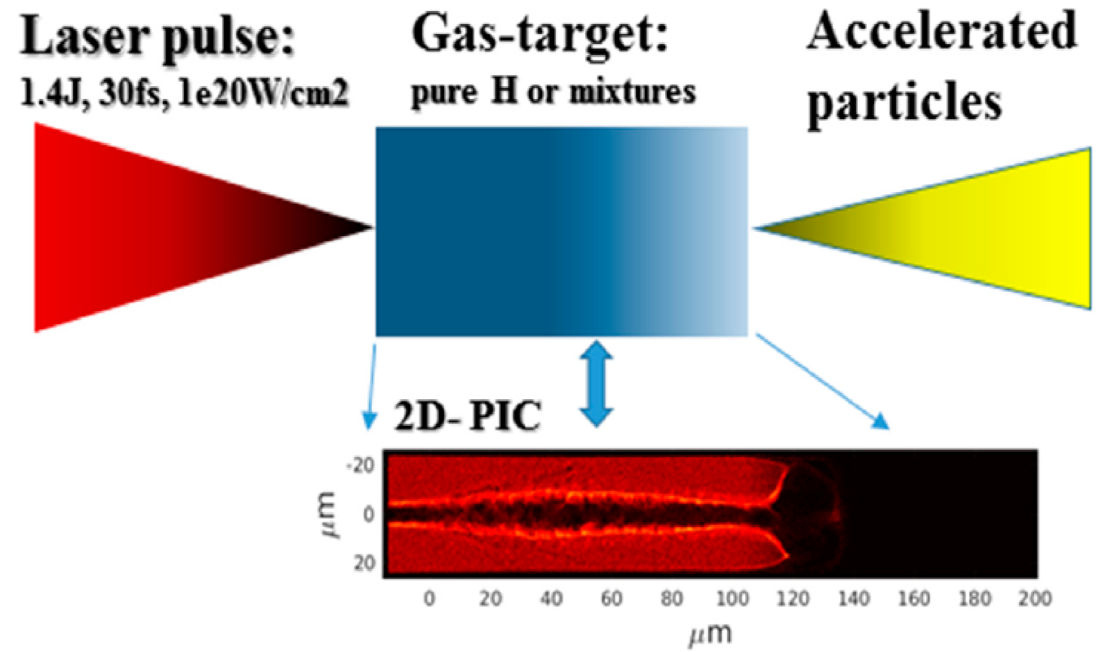
United Arab Emirates

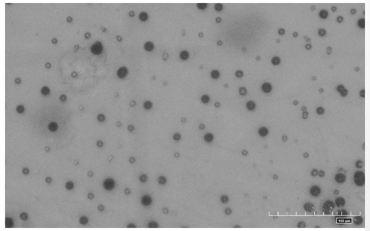
11-12 Gen 24
1° workshop on
High power laser and their applications
INFN-LNS



PROTONS FROM LASER-PLASMA GAS-MIXTURE: A TOOLS FOR FUSION STUDIES.

THE IDEA





T.Levato et al., Laser-plasma accelerated protons: energy increase in a gas-mixture using high mass number atomic species

Fluids **2019**, *4*, 150; doi:10.3390/fluids4030150

HYDROGEN ONLY: BEST DENSITY

Fluids **2019**, *4*, 150; doi:10.3390/fluids4030150

7e19 (e^-/cm^3)

2e20 (e^-/cm^3)

Simulation time 1 ps

Green ➔ electrons
Black ➔ protons

MAX proton energy
3 MeV

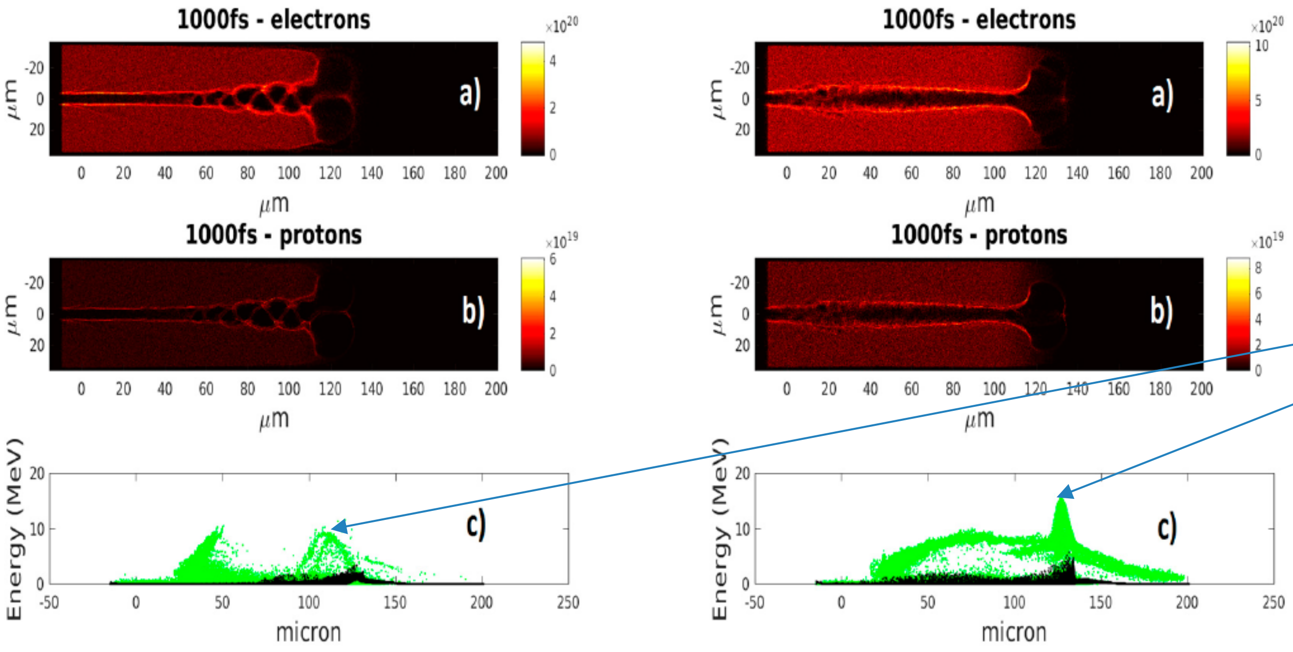


Figure 2. Snapshots of the 2D PICs after 1000 fs from the laser pulse entry in the simulation box of a pure hydrogen plasma at a flat density of 7×10^{19} e^-/cm^3 (**left**) and 2×10^{20} e^-/cm^3 (**right**). The electrons' (frames **a**) and protons' (frames **b**) density distributions are shown for both cases together with the protons' (black) and electrons' (green) energies versus the laser propagation direction (frames **c**).

GAS-MIXTURES IMPROVEMENT

Fluids **2019**, *4*, 150; doi:10.3390/fluids4030150

2e20 (e^-/cm^3)

95% Ar + 5%H

95% N + 5%H

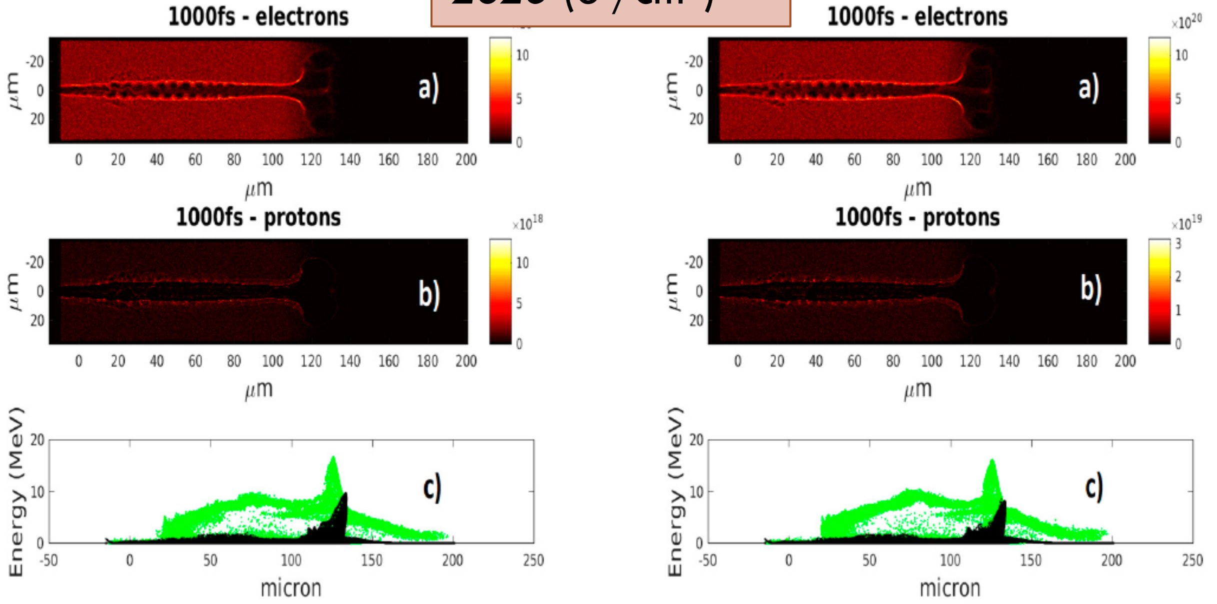


Figure 5. Shows the snapshots of the laser-plasma interactions for a fully-ionized 95%Ar–5%H (**left**) and 95%N–5%H (**right**) plasma mixture simulated by 2D PIC after 1000 fs from the pulse entry (−20 μm) in the simulation box (so that the laser pulse has already left the area). The total electron density is set to be 2×10^{20} e^-/cm^3 for a simpler comparison with the case of Figure 2 (right). Also, the plasma profile considered is the same. The electrons' (frames **a**) and protons' (frames **b**) density distributions are shown with the protons' (black) and electrons' (green) energies versus the laser propagation direction (frames **c**).

MAX proton energy
>10 MeV
(comparison at the same
plasma density and geometry)

PROCEEDING OSA ON A FIRST EXPERIMENT

LASER-PLASMA PROTON ACCELERATION FROM UNDER-CRITICAL DENSITY TARGETS IN A GAS-MIXTURE.

T. LEVATO[1,2], L. GIUFFRIDA[1], V. KANTARELOU[1], M. NEVRKLA[1], S. BONORA[3], F. BAFFIGI[2], F. BRANDI[2], L. FULGENTINI[2], P. KOESTER[2], L. LABATE[2], D. PALLA[2], L. A. GIZZI[2], D. MARGARONE[4,1]

1 INSTITUTE OF PHYSICS OF THE ASCR, ELI BEAMLINES PROJECT, NA SLOVANCE 2, 18221 PRAGUE, CZECH REPUBLIC

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4 CENTRE FOR PLASMA PHYSICS, QUEEN'S UNIVERSITY OF BELFAST, BT7 1NN BELFAST, UNITED KINGDOM

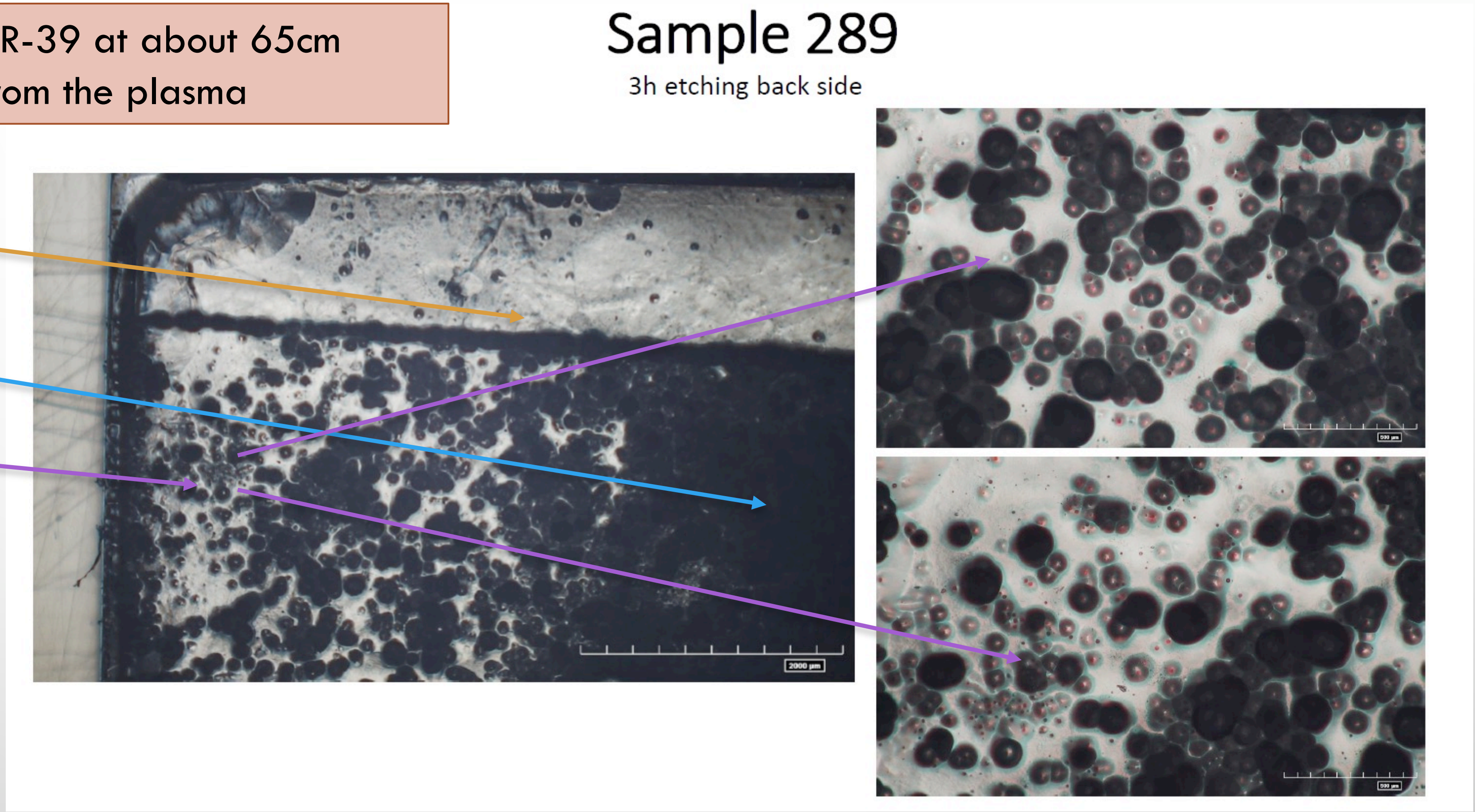
EXPERIMENT – PROTONS ON CR-39

CR-39 at about 65cm from the plasma

Cu-tape area

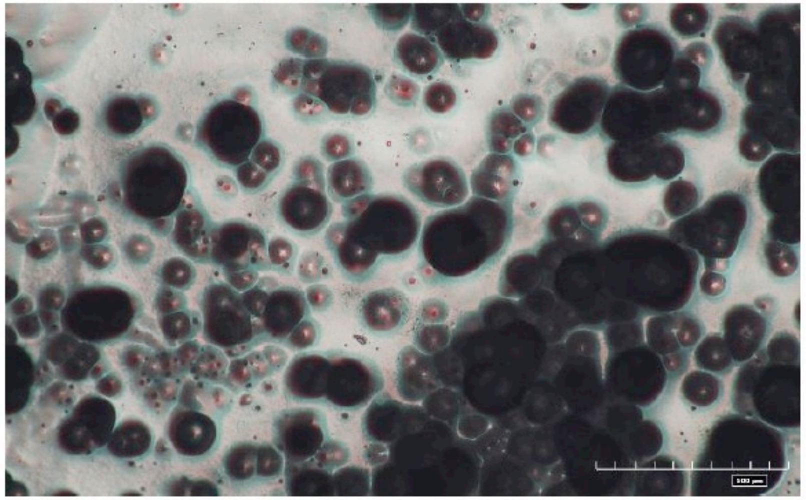
Saturated area

Spectra reconstruction area!



CR-39 was the only detector with signal, no TPS, no TOF

EXPERIMENTAL DATA: PROTON SPECTRA.



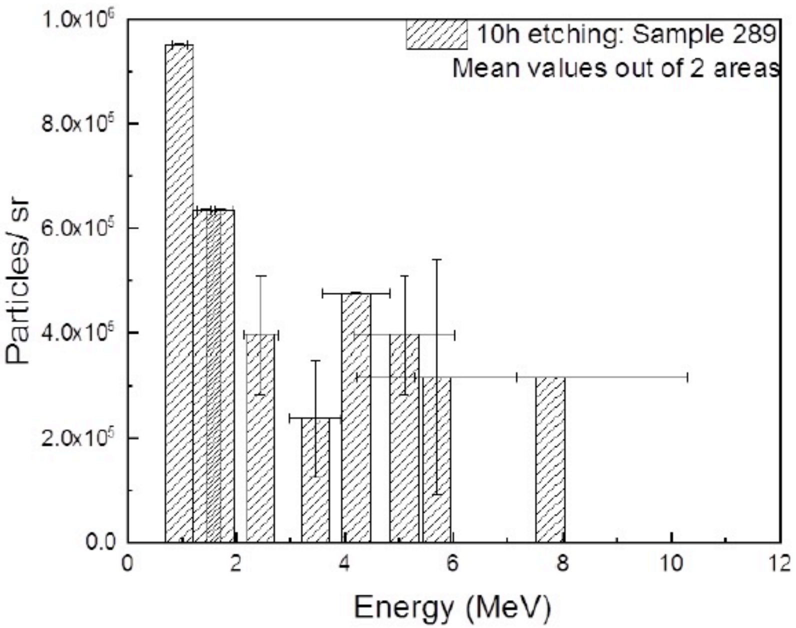


Figure 2: (left) CR-39 non-saturated peripheral area, both Ar ions and protons are visible. (right) Preliminary reconstruction of the proton beam spectra.

Approximately the total charge/shot is around 1/100 times a typical shot from solid.
The unsaturated region allow proton spectra recontruction up to 8MeV.
The saturated region shows protons up to the back side of the 1.4 mm plastic detector
(energy needed >10MeV)

RIASSUMENDO

Usando una valvola veloce….

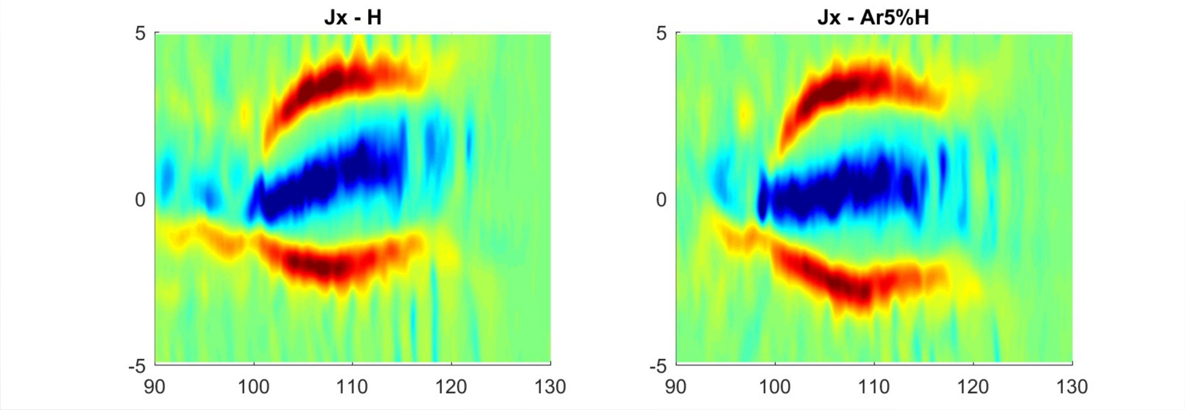
- The proton emission was detected in a narrow cone of few degrees
- The total charge was relatively moderate (10^8-10^9 protons/sr/shot) compared to the typical proton fluxes accelerated using thin solid targets (10-100 times higher).
- The CR-39 detectors, at about 65 cm from the plasma, were saturated with approximately 50 shots in the region of higher signal, and proton particle tracks were emerging from the CR39 detector rear side passing through 1.4 mm of plastic material (estimated energy needed >10MeV).

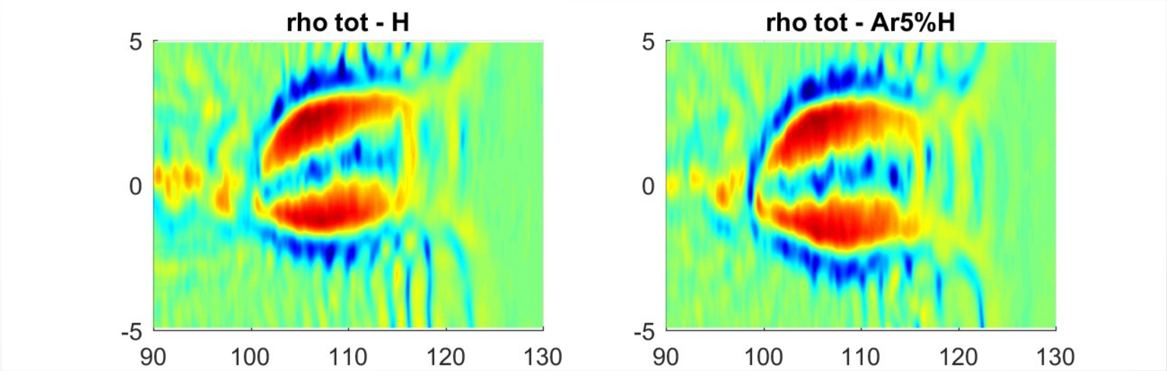
VEDIAMO MEGLIO IL PROCESSO DI ACCELERAZIONE

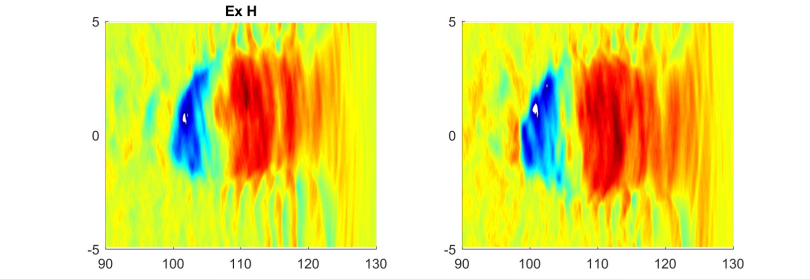
- VOGLIAMO CAPIRE IN CHE MODO LA SPECIE PESANTE AIUTA L'ACCELERAZIONE
- E MAGARI CAPIRE SE E QUALE EFFETTO HA SULLA COLLIMAZIONE

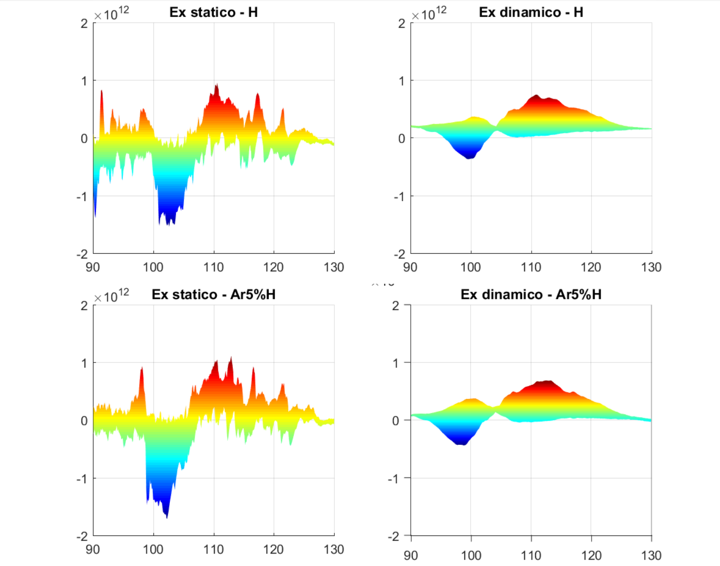
FASE 1 (STEP 25 = 500FS)

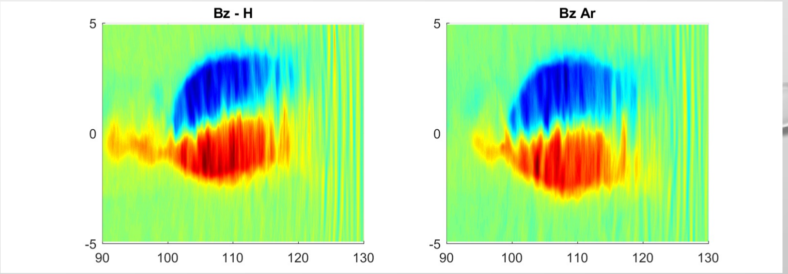
- il laser è autofocallizato e la forza ponderomotiva spinge gli elettroni creando una forte corrente elettronica sull'asse laser. Il sistema reagisce creando correnti elettroniche di ritorno



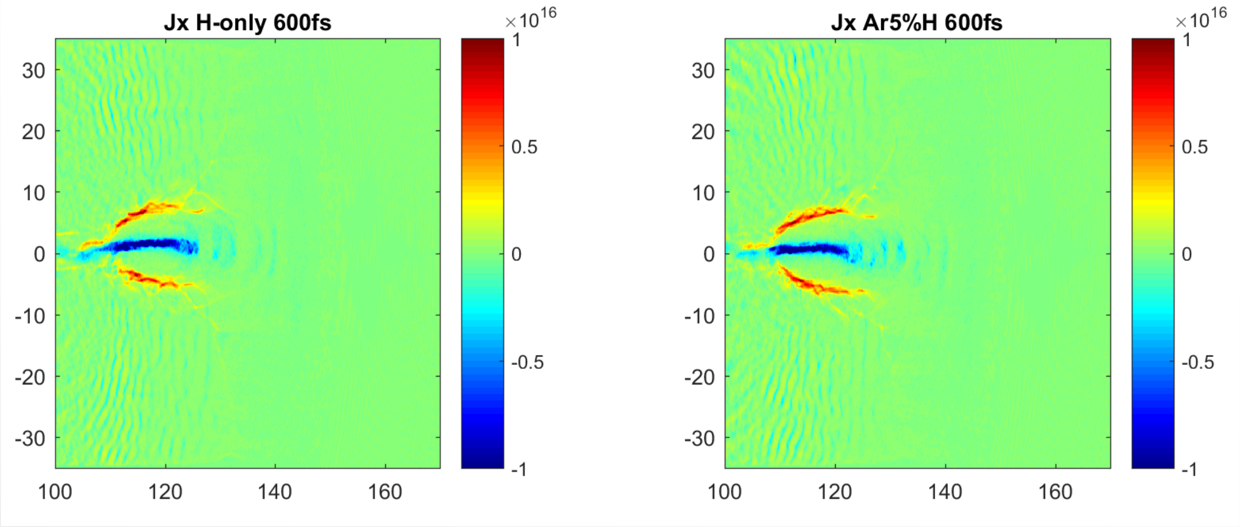


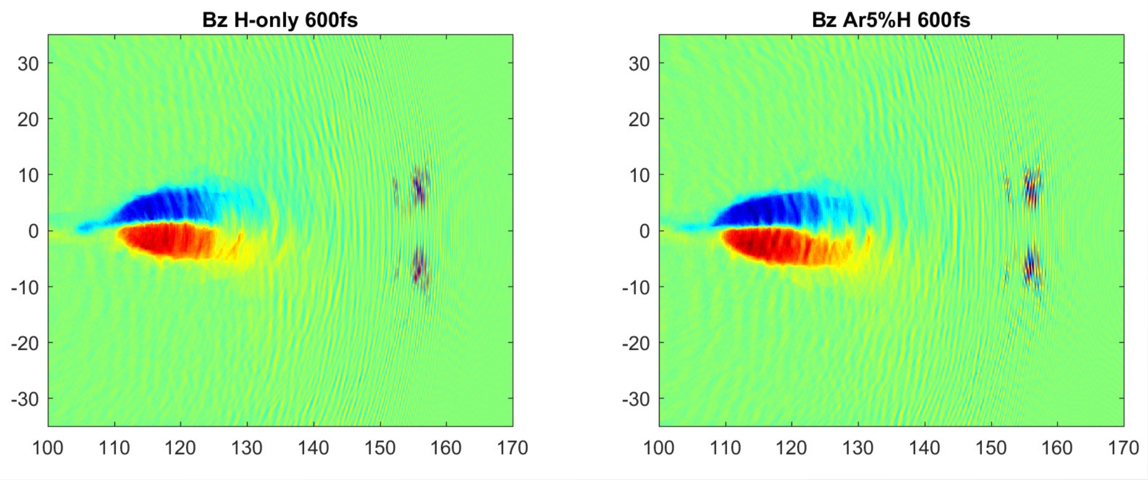






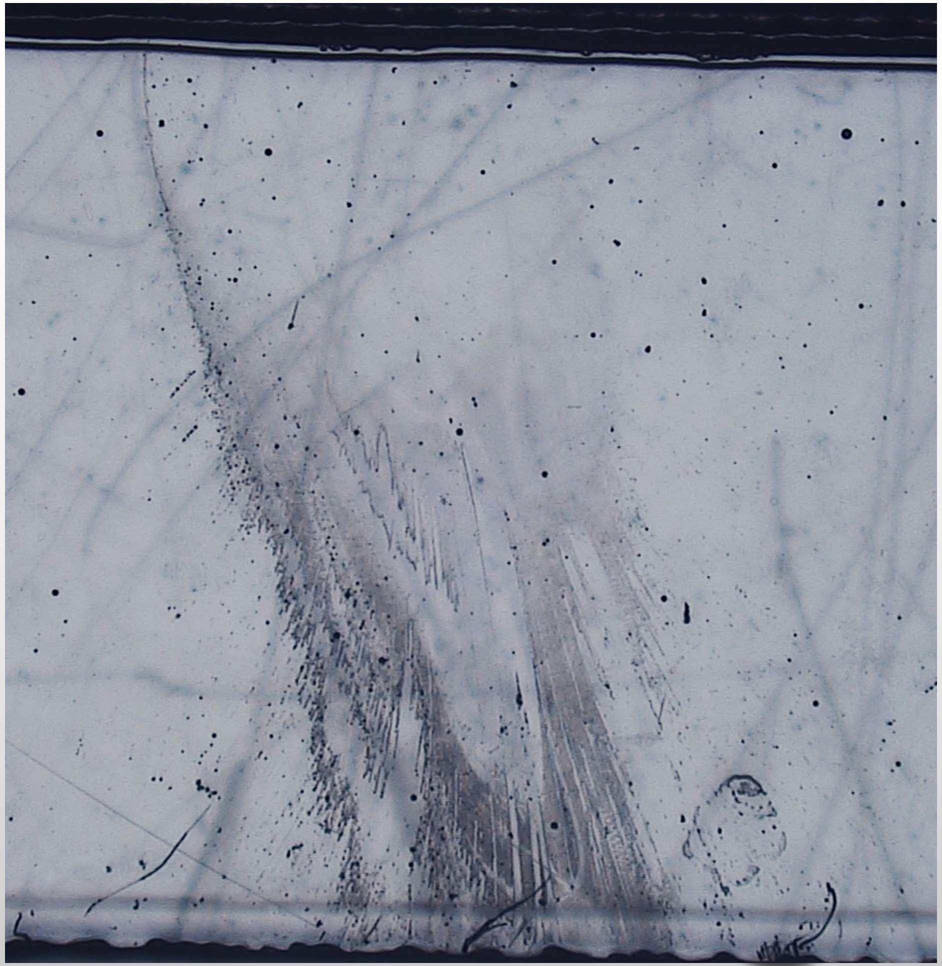
FASE 2 (STEP 30 = 600FS)





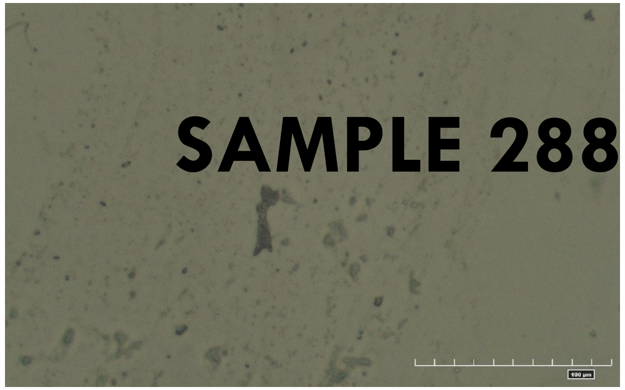
- In questa fase il laser ha appena oltrepassato la densità minima che permetteva l’autofocalizzazione. Allo stesso tempo la diminuizione di densità comporta un allargamento della «bolla di plasma» e la sua «apertura».
- Mentre la bolla si apre trasversalmente rallenta la sua propagazione logitudinale fino a fermarsi, localizzarsi, ed i campi prodotti in essa, insieme a bunch elettronici di alta energia iniziano a fuoriuscire da essa. Questa fase di transizione genera campi transienti di induzione che si allontanano parecchio dalla zona in la bolla si è fermata. L’allargamento trasversale invece continuerà per tempi molto piu lunghi portando al meccanismo del magnetic vortex.

EXPERIMENTAL FINDING

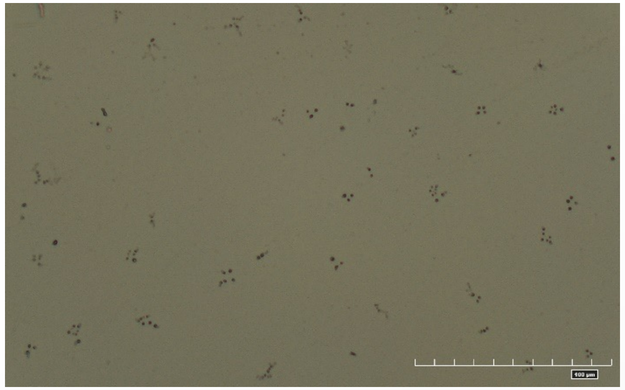


SAMPLE 288

5 minutes etching

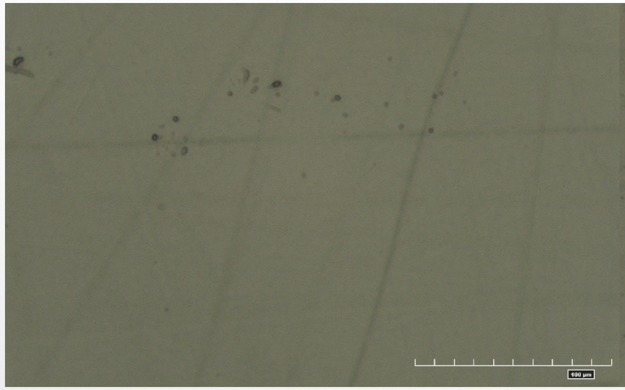


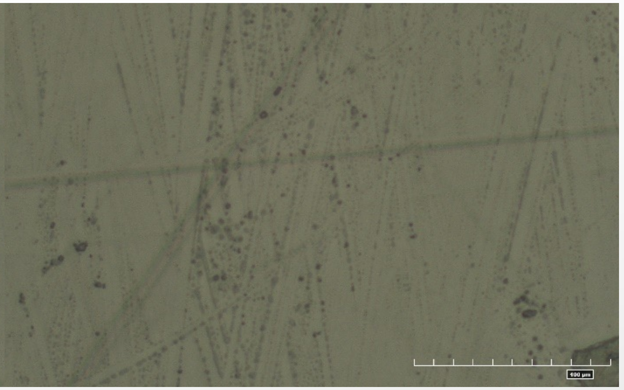
10 minutes etching



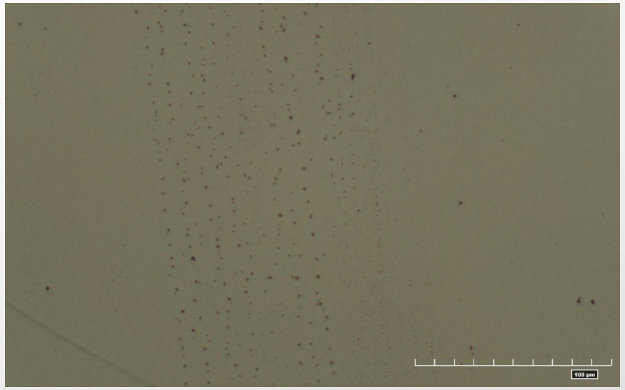
Sample 265

5 minutes etching



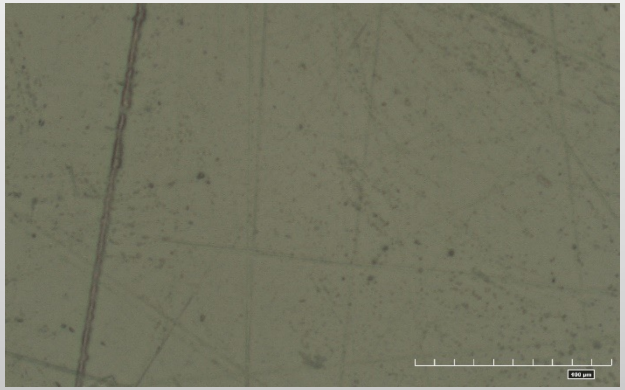


10 minutes etching

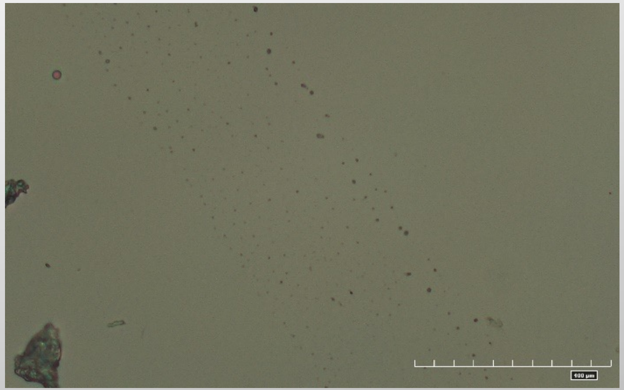


Sample 336

5 minutes etching

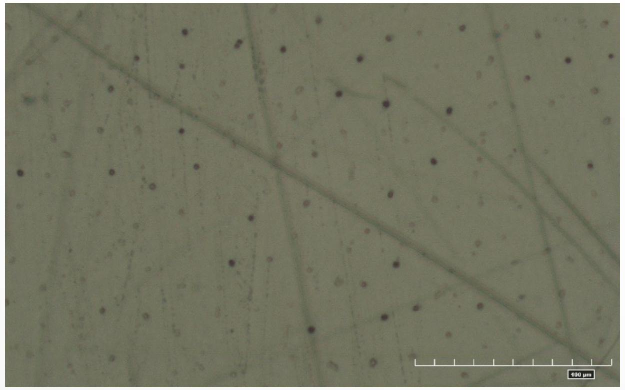


10 minutes etching

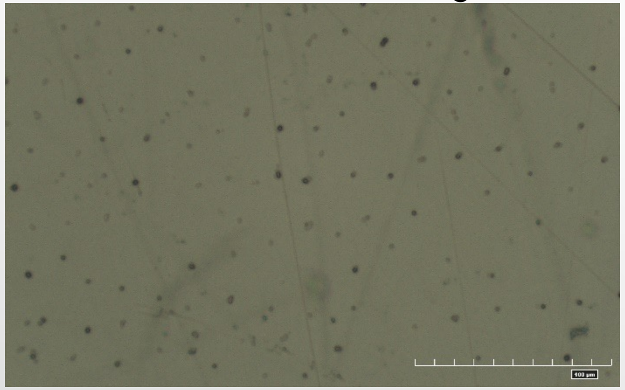


SAMPLE 289

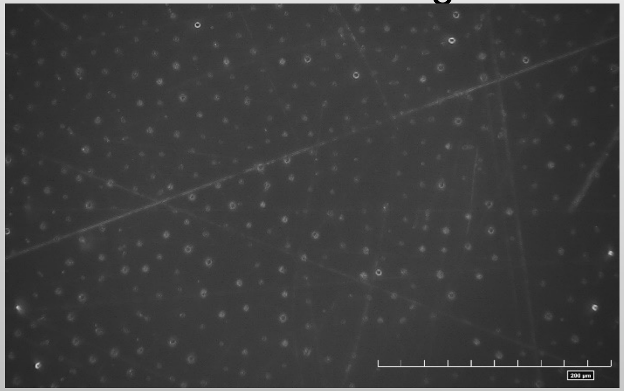
5 minutes etching



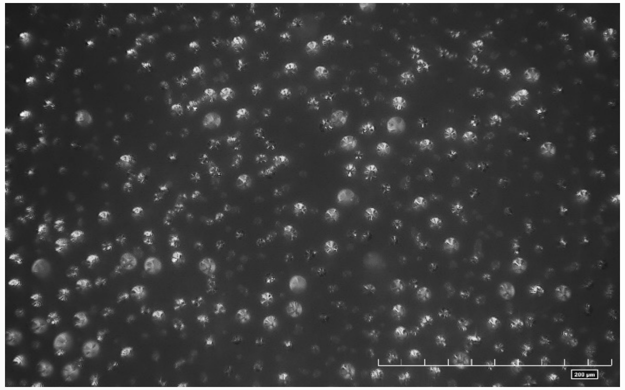
10 minutes etching



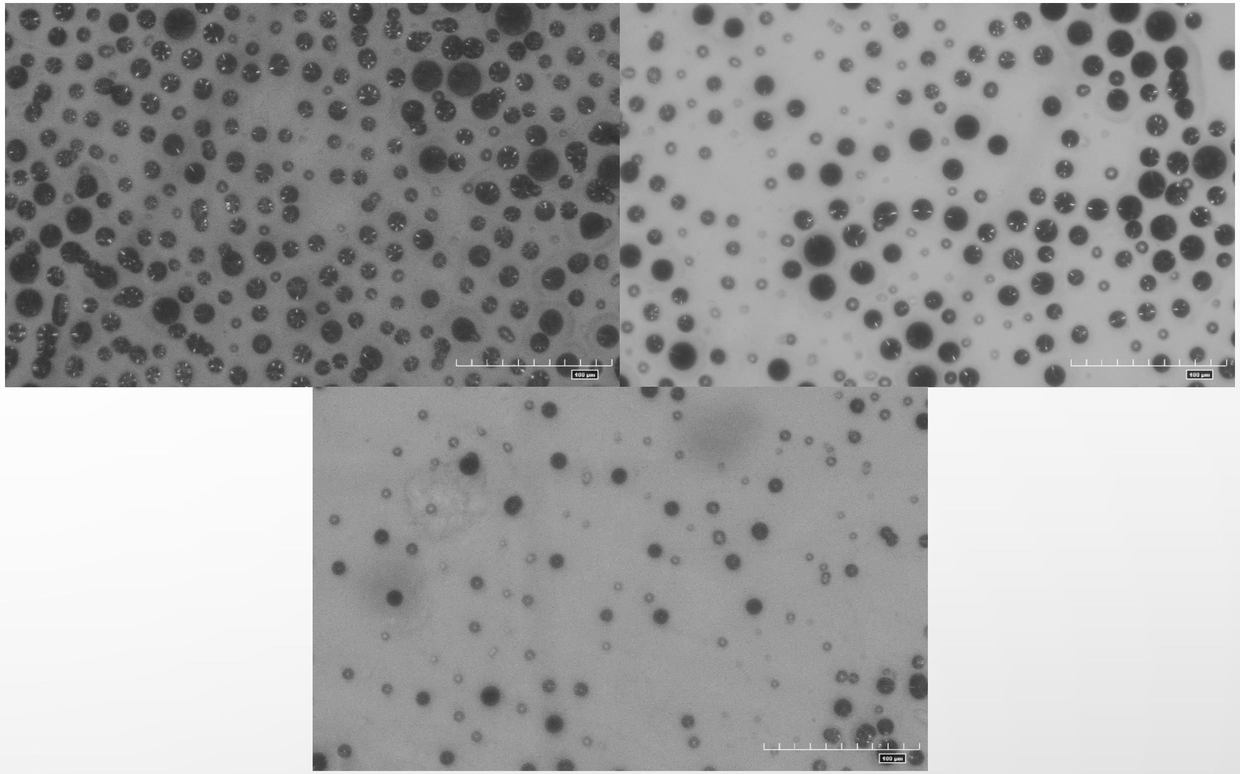
20 minutes etching



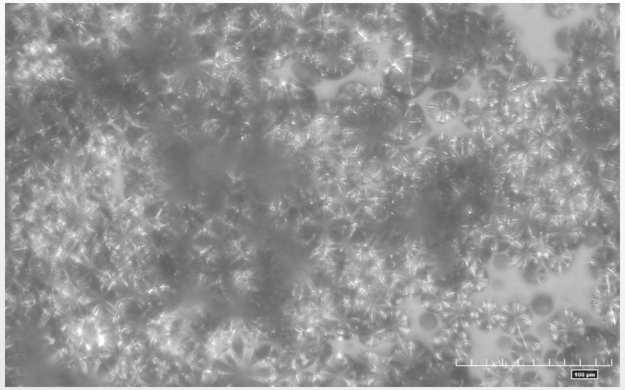
30 minutes etching

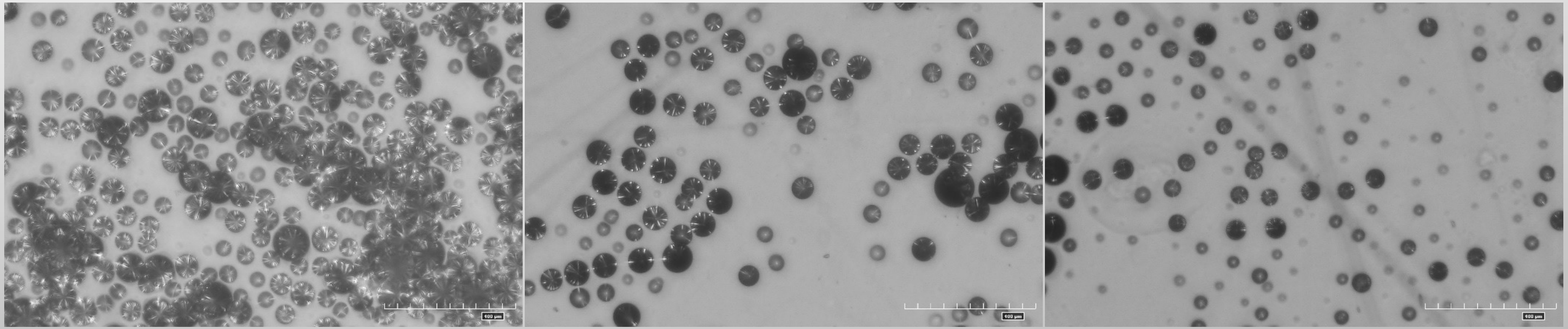


45 minutes etching



60 minutes etching



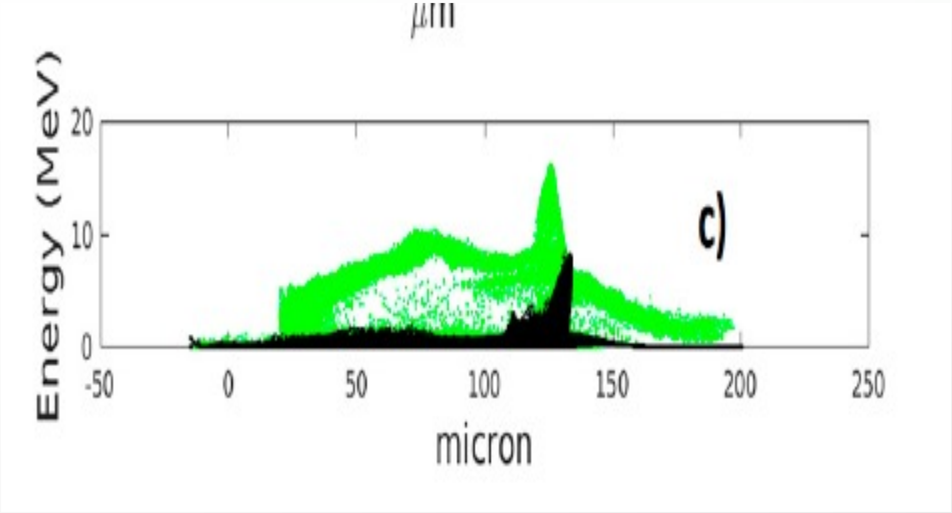


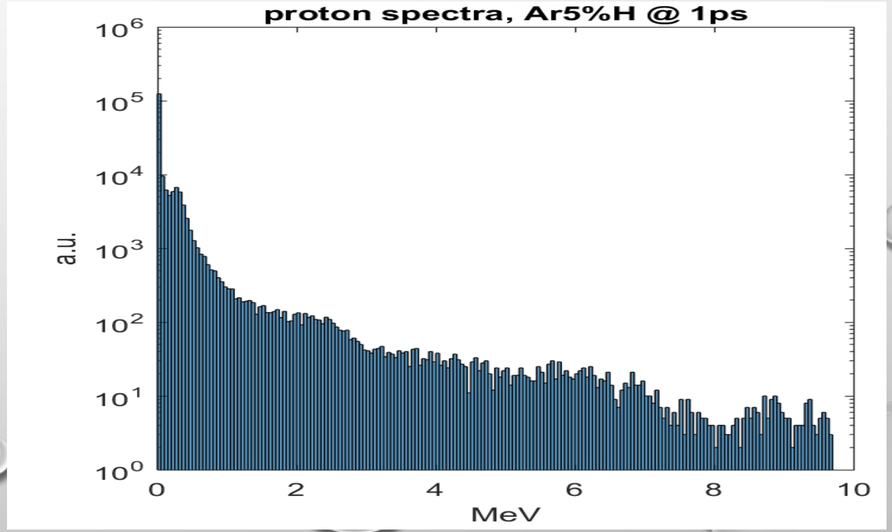
SI PUO USARE PER MISURE DI REAZIONI DI FUSIONE

1) E' facile miscelare diversi tipi di gas
2) Si puo ottimizzare linterazione in tempo reale
3) E' relativamente facile guardare dentro il plasma
4) Un qualunque gas miscelato con H puo' dare luogo a reazioni di fusione nel range fino a decine di MeV vicino all'asse, i campi di uscita danno diverse divergenze per i diversi Z/M e questo aiuta...

5) Per aumentare la probabilita' di reazione basta allungare il plasma, oppure guardare entro pochi MeV in direzione trasversale vicino l'uscita (volume), anche qui si distinguono Z/M diversi

6) **<u>Le reazioni avvengono direttamente nel plasma, percio' a varie temperature e gradi di ionizzazione</u>**





CONCLUSIONE

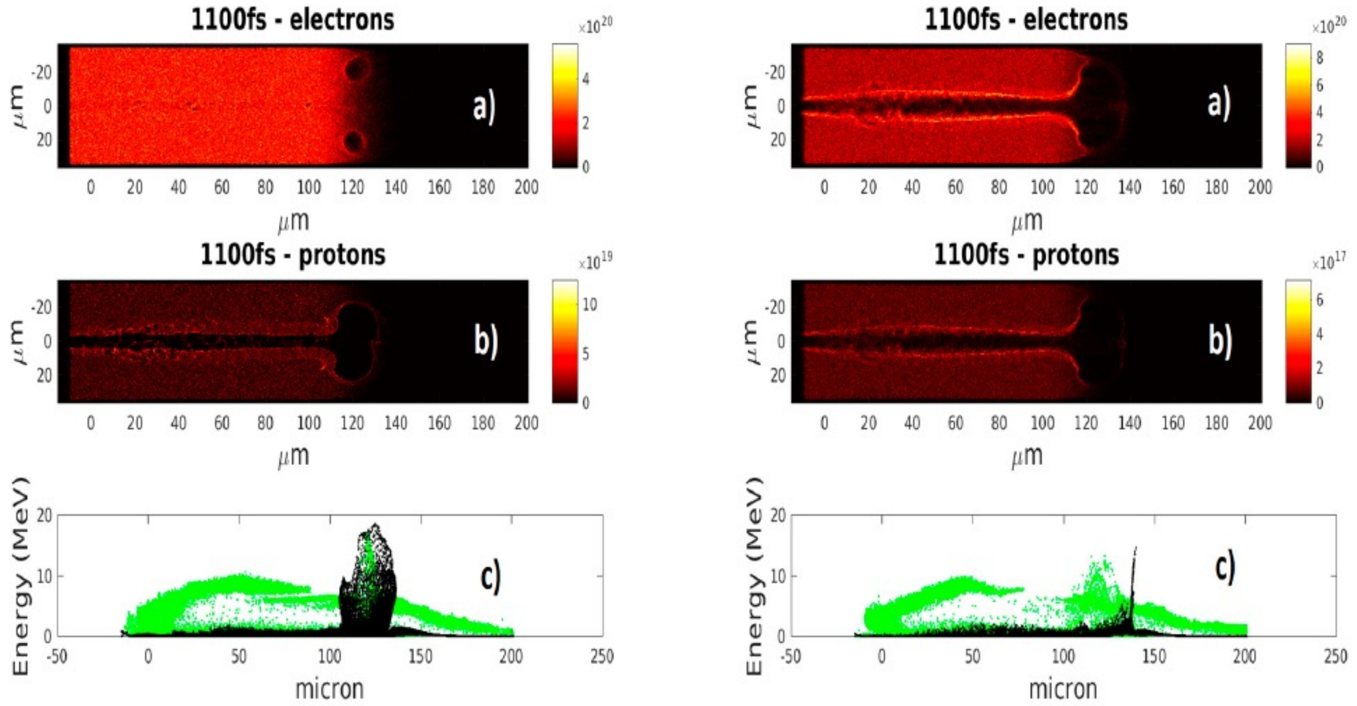


Figure 6. Shows the snapshots of the laser-plasma interactions, considering a fully-ionized artificial specie with $Z = 1$ and $A = 131$ that we call "low charge specie", in a mixture of 95% "low charge specie"–5%H (**left**) and a fully-ionized artificial specie with $Z = 131$ and $A = 131$ that we call "high charge specie", in a mixture of 95% "high charge specie"–5%H (**right**) plasma simulated by 2D PIC after 1100 fs from the pulse entry (−20 μm) in the simulation box (so that the laser pulse has already left the simulated model's area). The total electron density is set to be 2×10^{20} e^-/cm^3, and the plasma profile considered is the same. The electrons' (frames **a**) and protons' (frames **b**) density distributions are shown with the protons' (black) and electrons' (green) energies versus the laser propagation direction (frames **c**).

1) le particelle generate da reazione vicino l'asse vanno in avanti e si accumulano in bunch collimati

2) Quelle generate fuori asse, se sono vicini alla bolla d'uscita, vedranno un volume molto piu grande ma hanno energie piu basse (..MeV)

THANKS FOR YOUR TIME