Nuova Proposta/CALL
L3IA

Line for Laser driven Light Ion Acceleration

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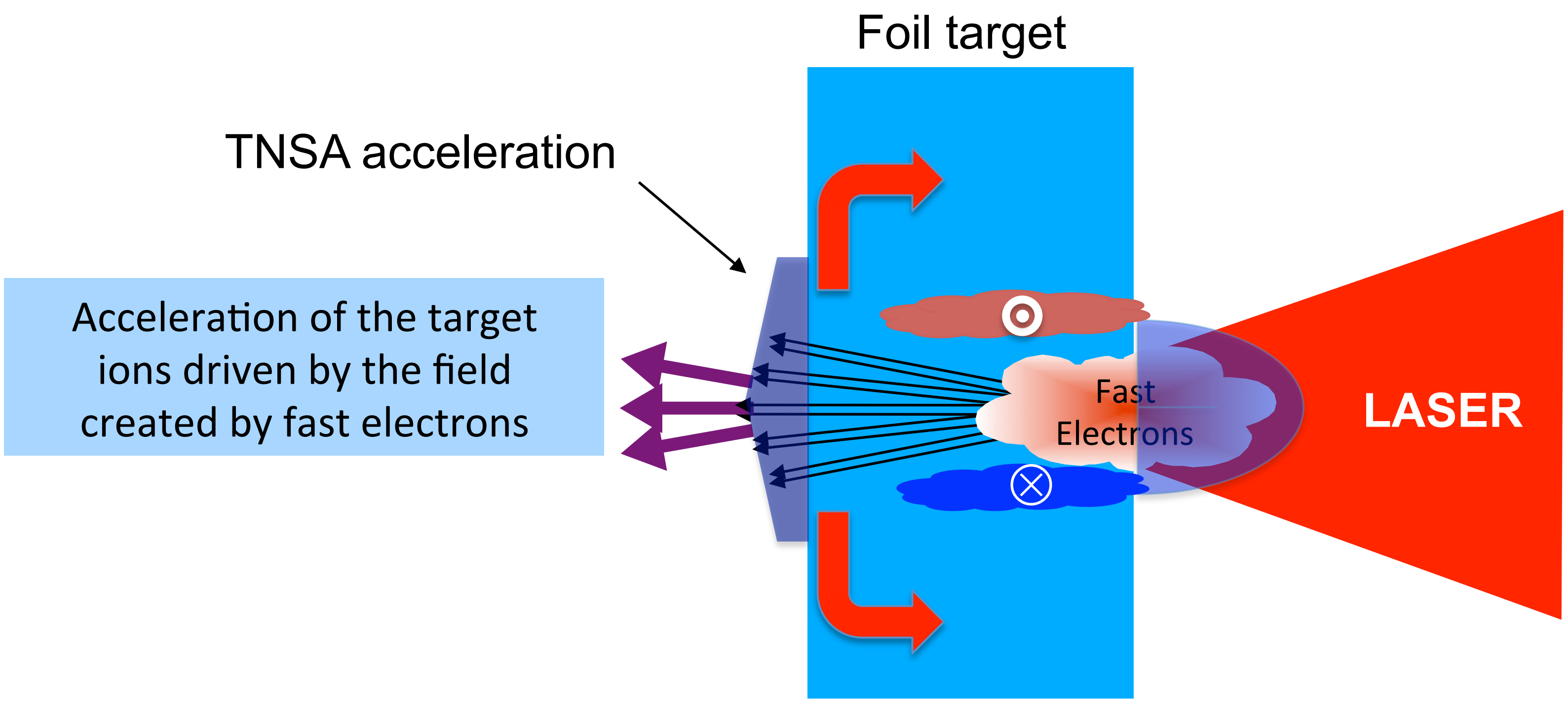
INO_CNR and INFN, Pisa

Milano, Pisa, Catania, Bologna, Frascati, Napoli

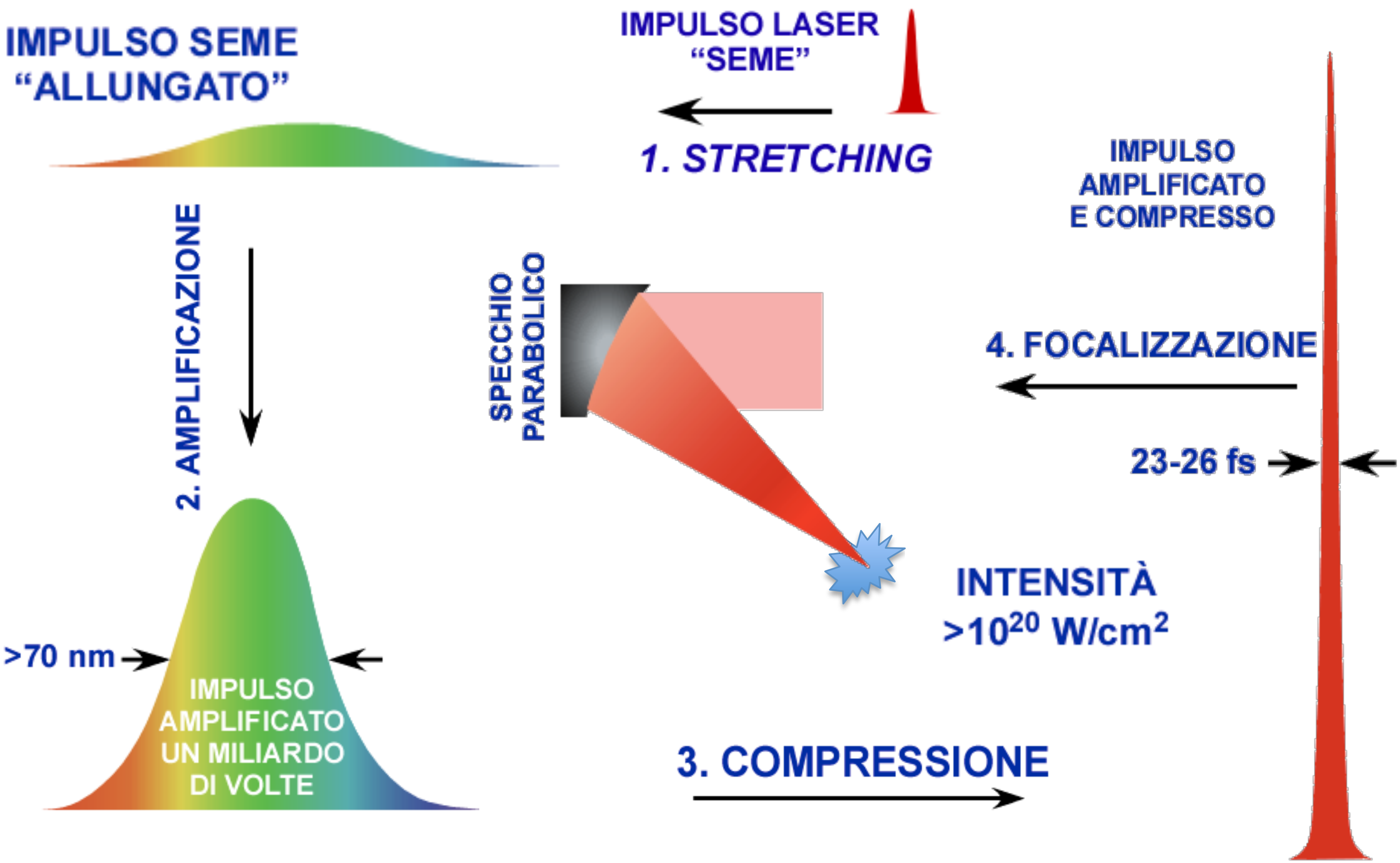
Target Normal Sheath Acceleration

Laser-foil interactions creates huge currents of relativistic eletrons propagating in the solid and giving rise to intense X-ray emittion and, ultimately, ion emission from the rear surface of the foil



R.A.Snavely et al., Phys. Rev. Lett. **85**, 2945 (2000)
L. Romagnani *et al.*, Phys. Rev. Lett. **95** 195001 (2005).
S. Betti *et al.*, Plasma Phys. Contr. Fusion **47**, 521-529 (2005).
J. Fuchs et al. Nature Physics **2**, 48 (2006).
X.H.Yuan et al., New Journal of Physics **12** 063018 (2010)

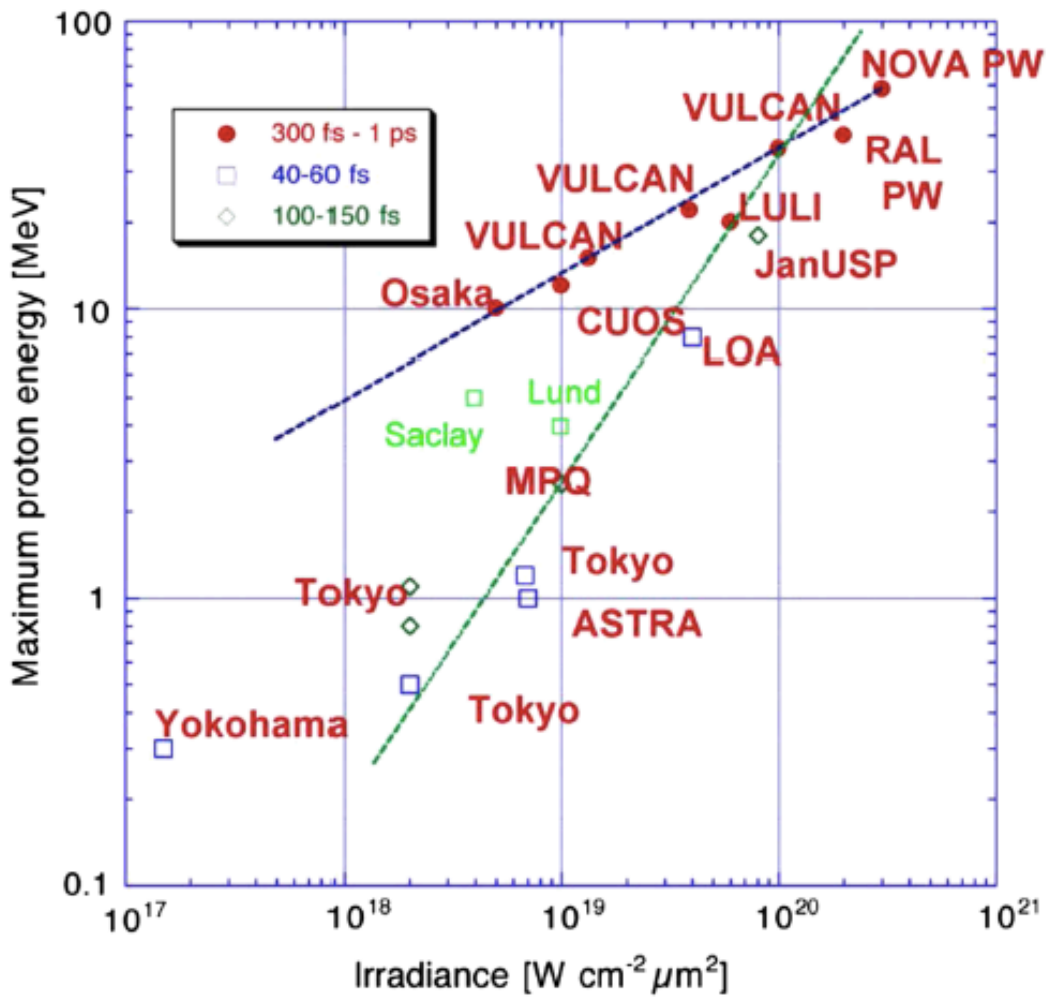
ULTRAINTENSE Laser: Chirped Pulse Amplification



D. Strickland and G. Mourou, "Compression of amplified chirped optical pulses", Opt. Commun. 56, **219** (1985)

ICUIL World Map of Ultrahigh Intensity Laser Capabilities

Proton Acceleration - TNSA



Macchi, Passoni, Borghesi, RMP, **8**5,751 (2013)

Laser driven ion acceleration

- High gradient acceleration: MeVμm−1, compared with ~MeV m−1 provided by radio frequency (RF) based accelerators;
- Ultra-short duration at the source of the ion bunch of the order of picoseconds;
- Very small effective source size: ≈10 μm;
- highly laminarity and very low emittance;
- Broad energy spectrum, low collimation
- High charge: 10^8-10^9 particles

Macchi, Passoni, Borghesi, RMP, **8**5,751 (2013)

Current effort

- New acceleration mechanisms at ultrahigh intensity
  - Radiation pressure acceleration
  - Collisionless shock acceleration
- Target engineering: surface, geometry, conductivity
- Post acceleration: selection, collimation, injection
- Dosimetry and radiobiology: fast (ps) ion source

Previous activity (CN5)

- **LILIA** – Laser Induced Light Ion acceleration
  R&D and first preliminary experiments at Flame;
  Completed 2013

- **PlasmaMeD -** Proton LAser-drive beam transport, diagnostic and Multidisciplinary Applications
  Ends 2015

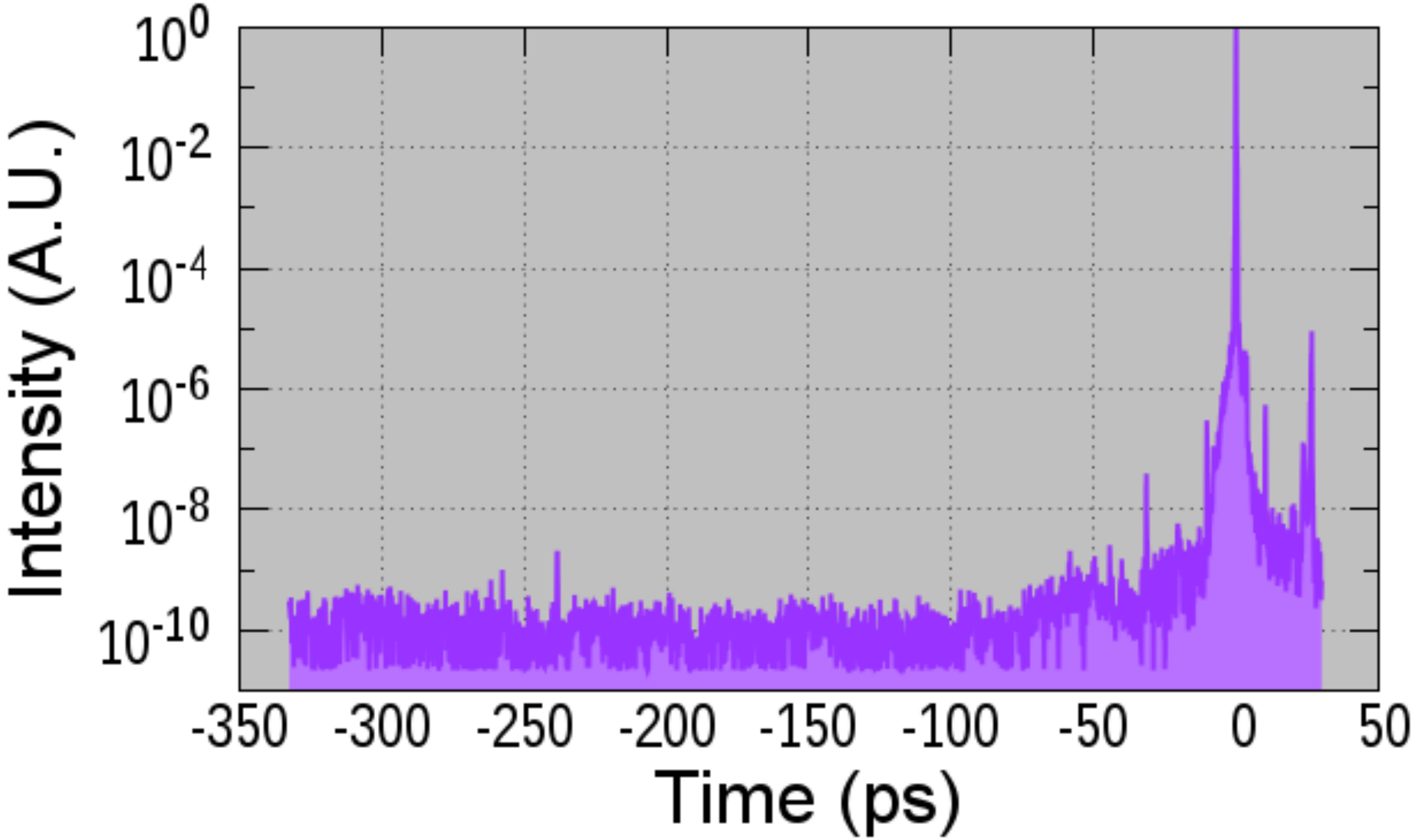
Recent progress
(PlasmaMED 2013-14)

- Dedicated experimental chamber for ion acceleration commissioned 2014 (Pisa, ILIL laser);
- Ion acceleration runs started Oct. 2014 with existing laser parameters (10 TW);
- Successful collaboration Pisa, Milano, Catania, Bologna;

ILIL@ INO-CNR(Pisa)

10 TW on target - >100 TW Upgrade in progress

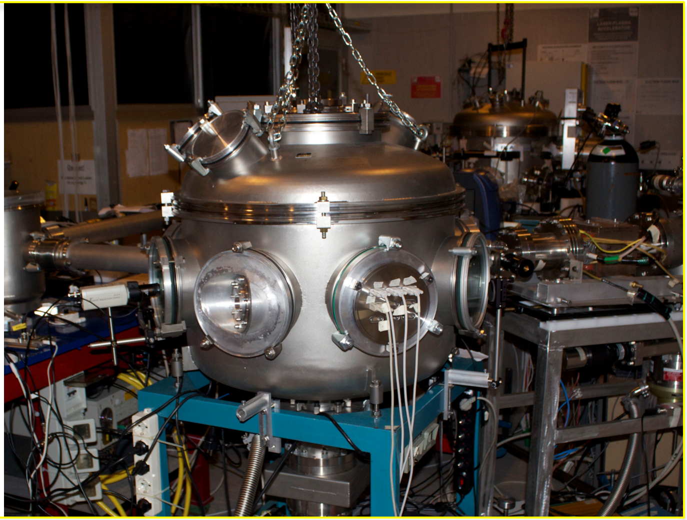
ILIL Laser: contrast



2014-2015 activity (Pisa)

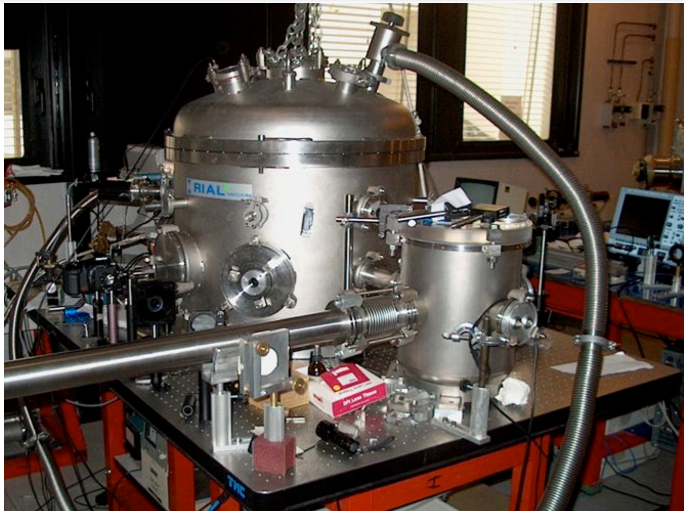
Since October 2014 a new experimental chamber "Pavone" is operational for laser-solid interaction, dedicated to:

1. TNSA acceleration of light ions;
2. Fast electron transport;
3. Shock generation in nanoengineered target;
4. X-ray generation and applications

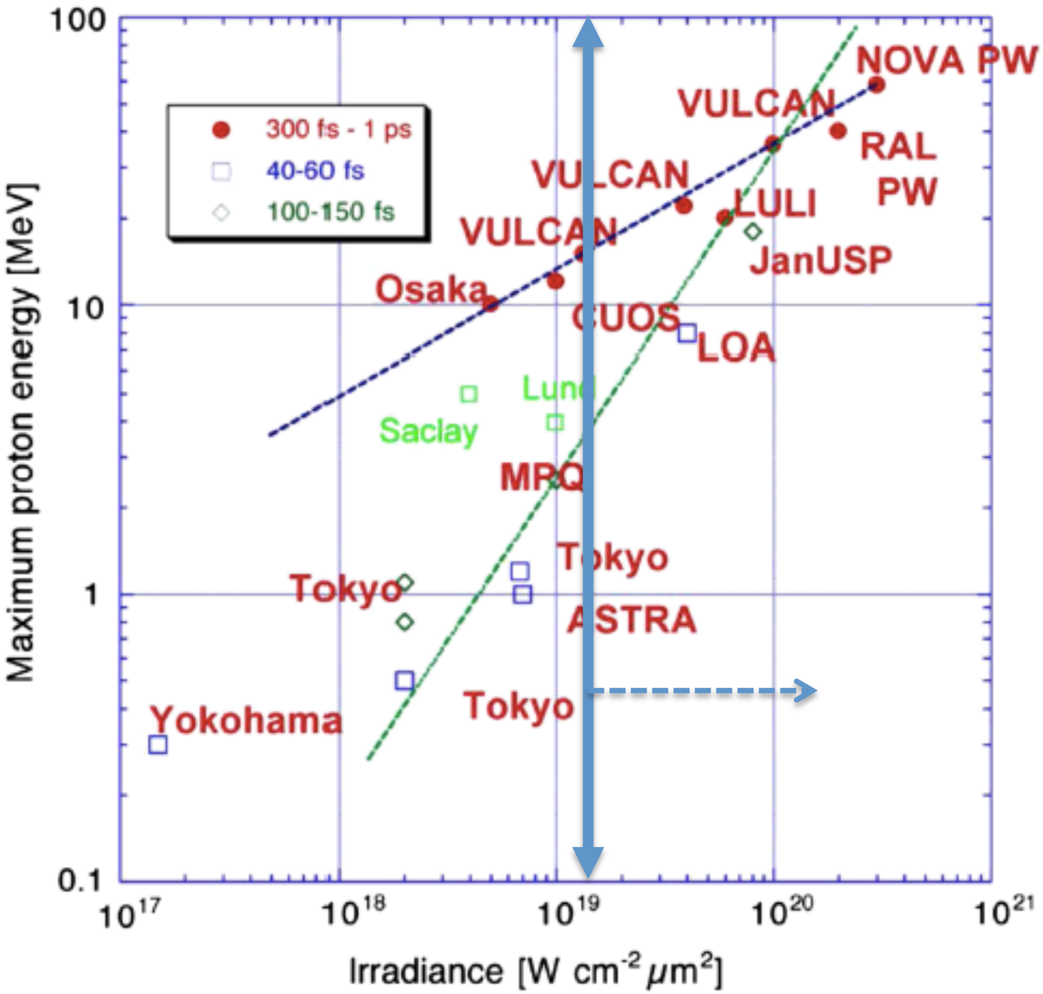


A separate target chamber is dedicated to laser-gas interaction for:

1. electron acceleration with self injection,
2. radiobiology applications
3. γ-ray generation (Thomson scattering and bremsstrahlung) and



Light ion acceleration

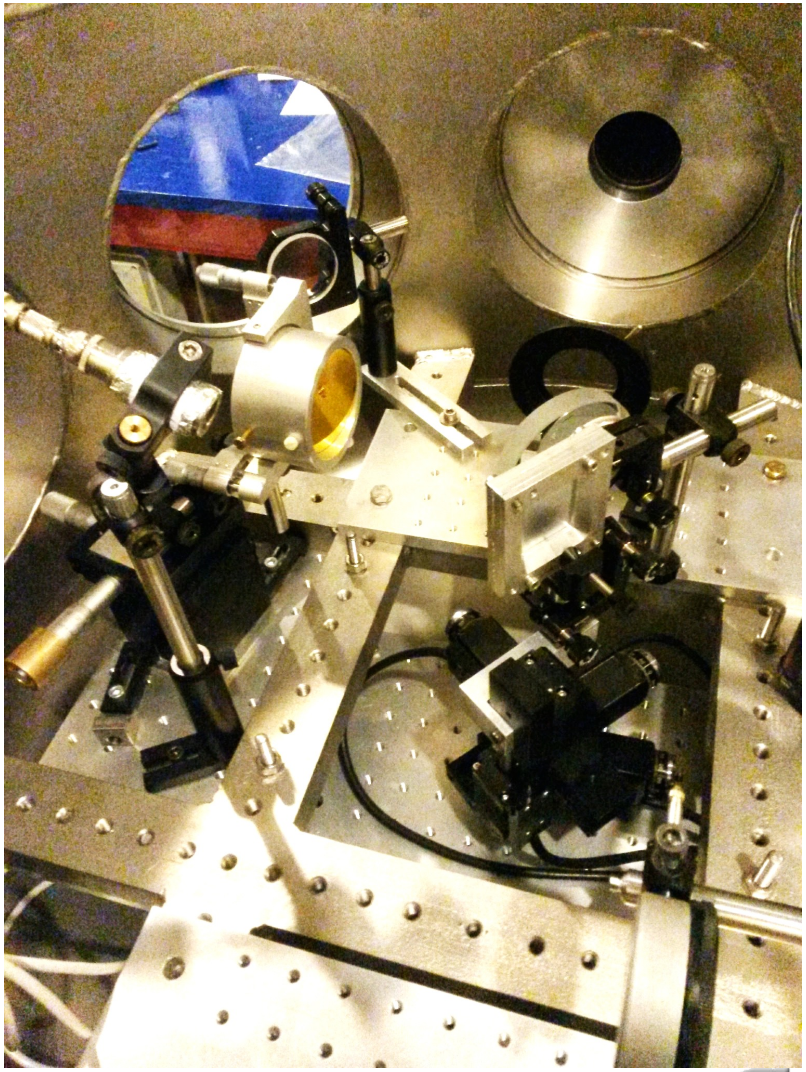


Macchi, Passoni, Borghesi, RMP, **8**5,751 (2013)

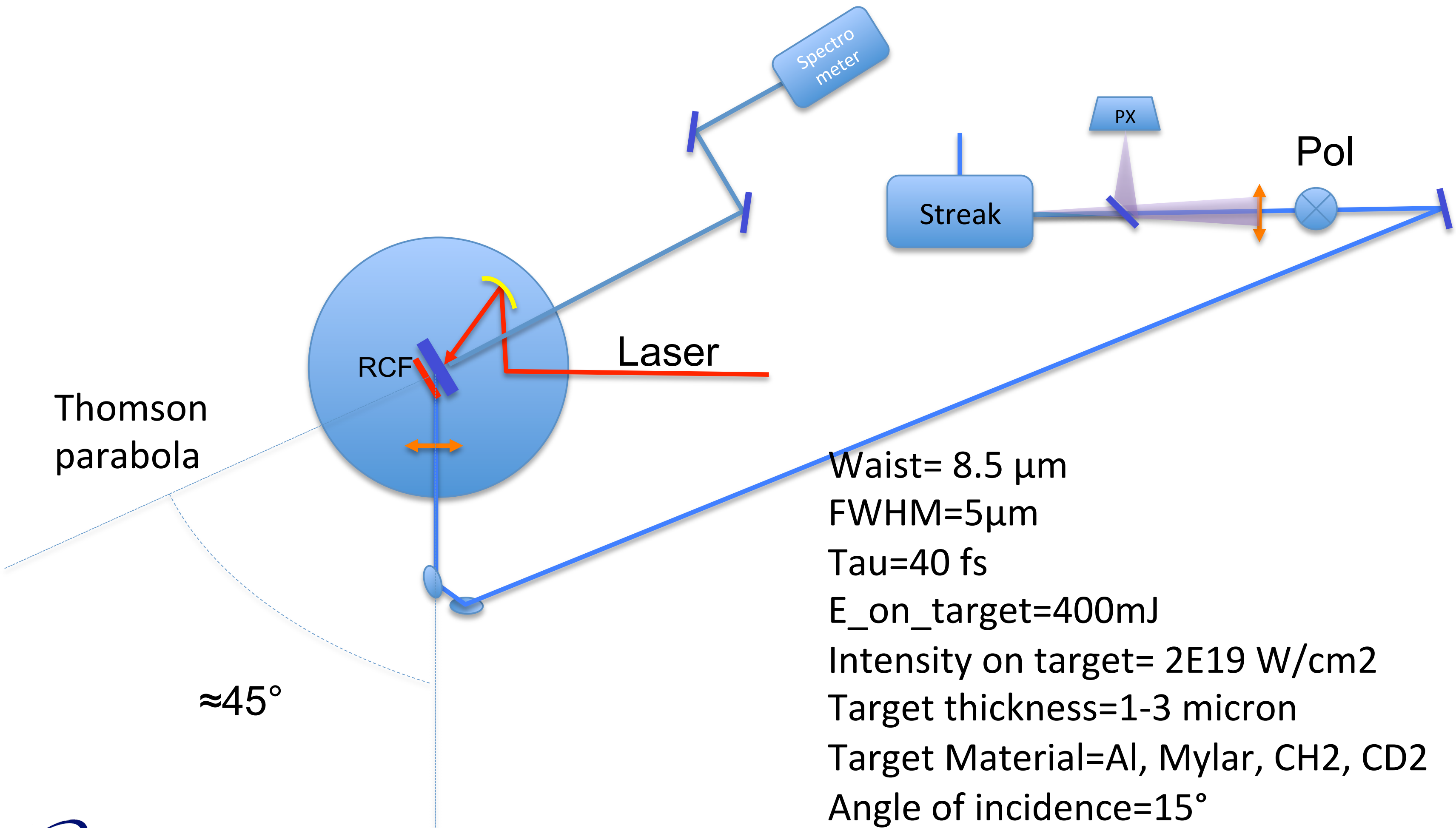
Ion acceleration experimental runs

Approximately 15 one-day runs have been carried out since October which have been dedicated to:

1. Optimization of focusing and target control;
2. Identification of the interaction regime;
3. Thomson-parabola measurements;
4. Solid state detectors;
5. RCF and CR39 measurements

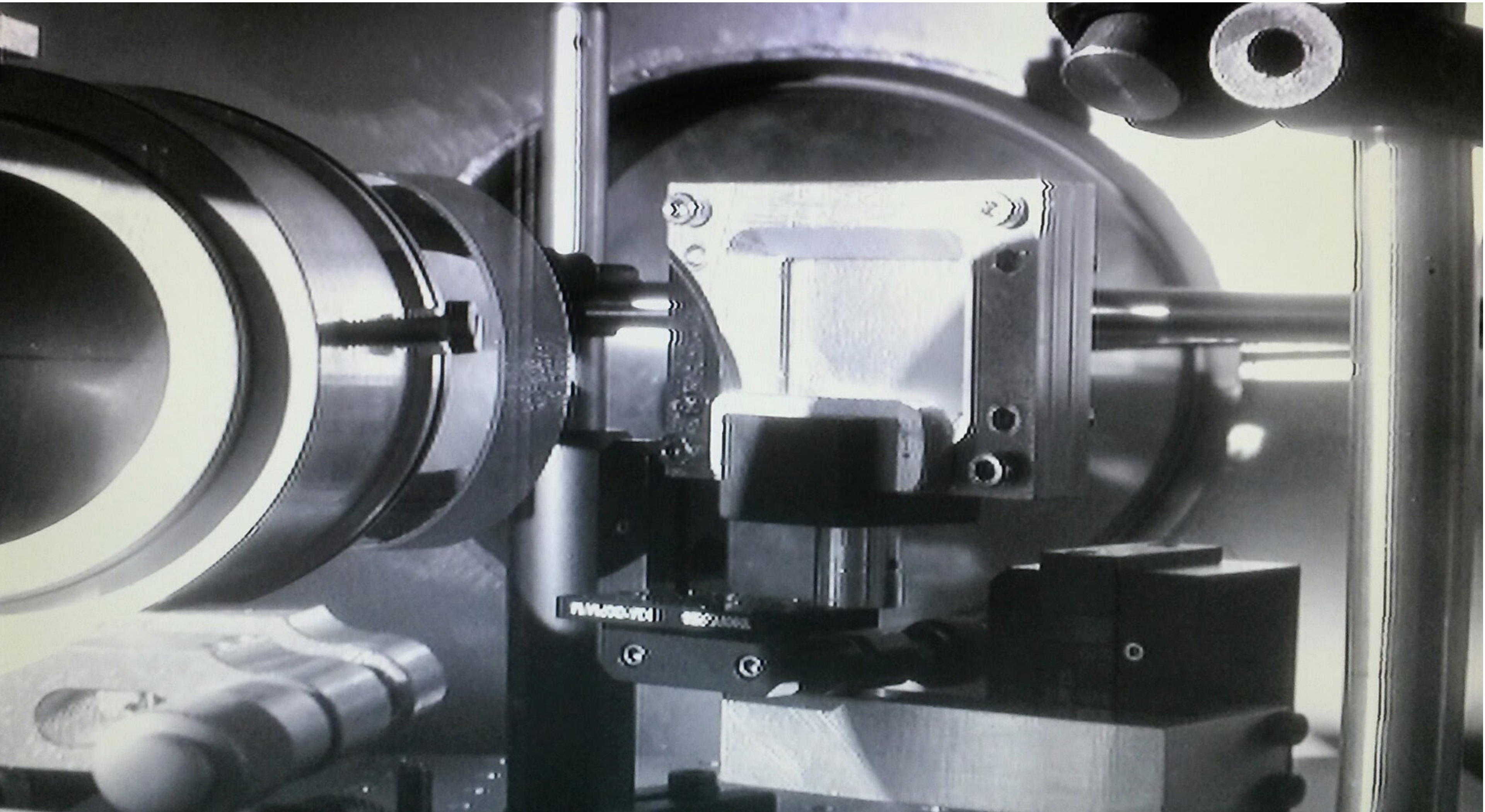


Experimental set - up

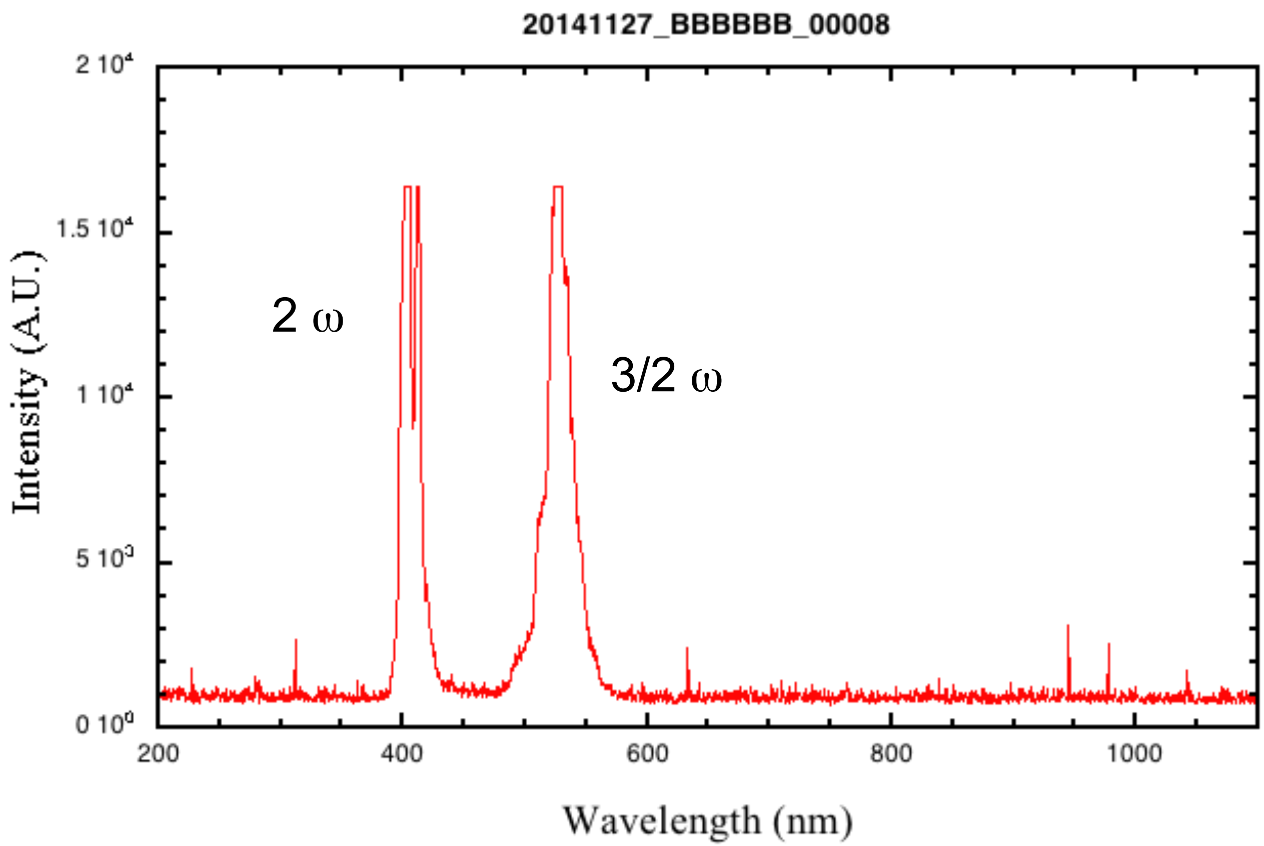


Waist= 8.5 µm
FWHM=5µm
Tau=40 fs
E_on_target=400mJ
Intensity on target= 2E19 W/cm2
Target thickness=1-3 micron
Target Material=Al, Mylar, CH2, CD2
Angle of incidence=15°
Contrast: >1E9

Target

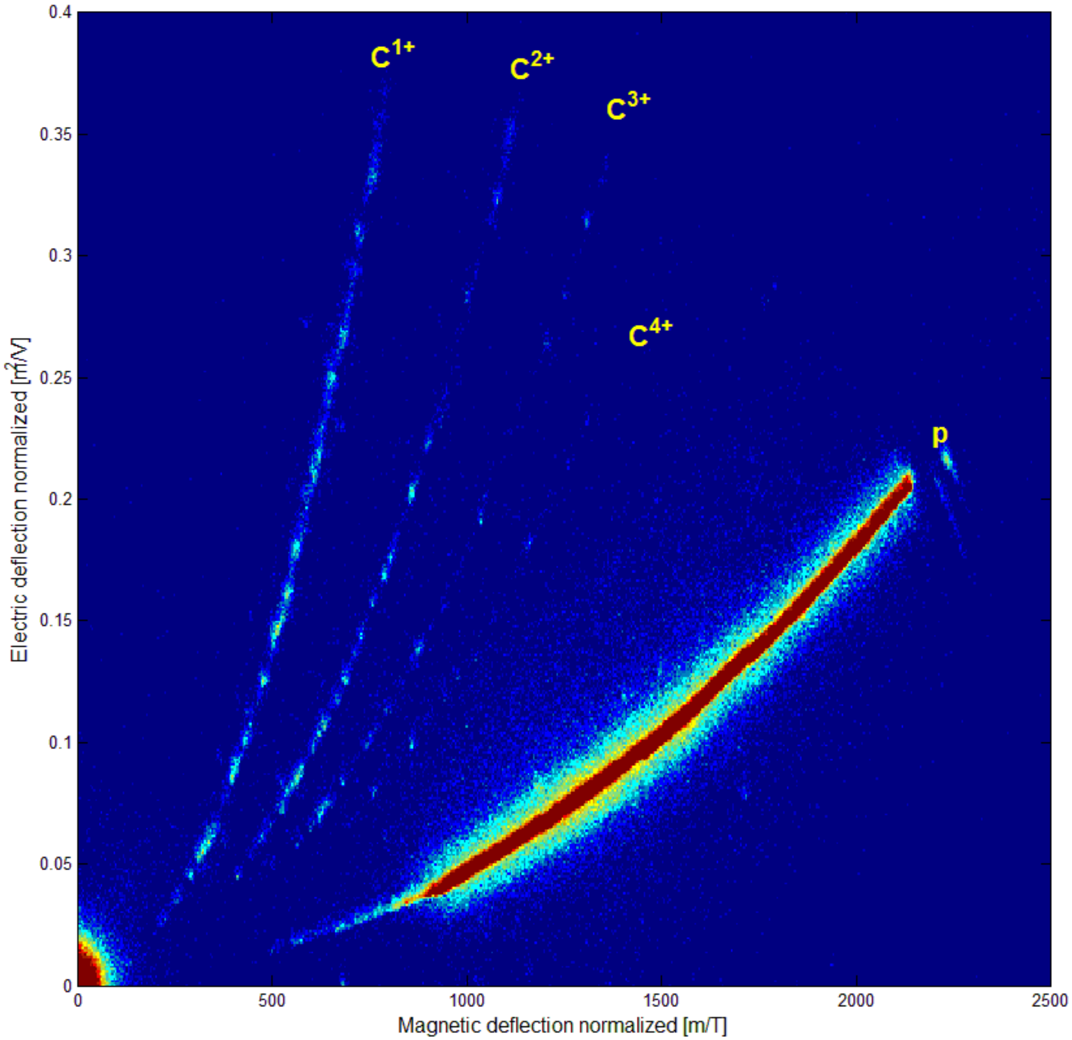


Spectrum of reflected light



$2\ \omega_L$ emission => interaction at the critical density layer
$3/2\ \omega_L$ - two-plasmon decay from underdense plasma

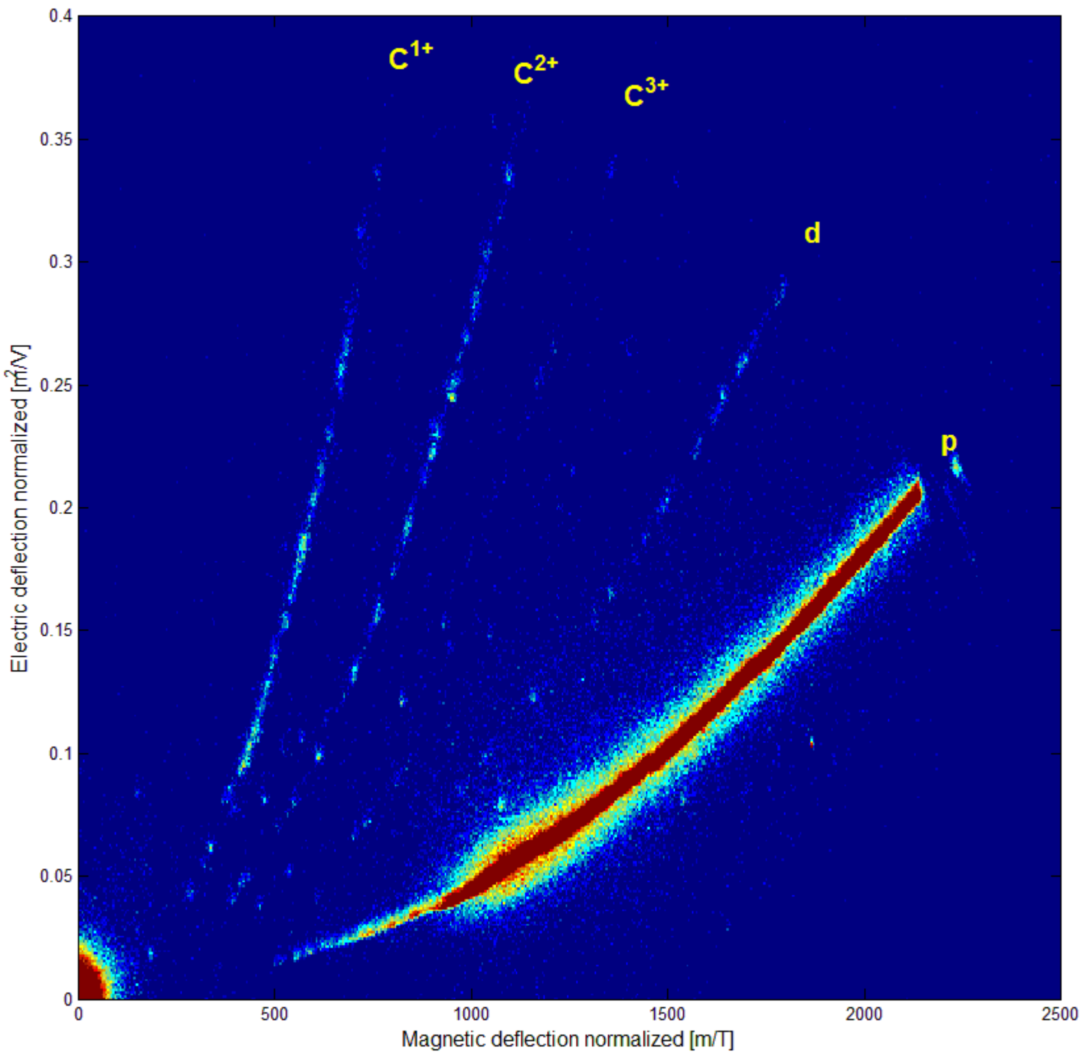
Thomson parabola: raw data 1



p	1,328 MeV
C1+	709,3 keV
C2+	828,2 keV
C3+	979,4 keV
C4+	955,5 keV

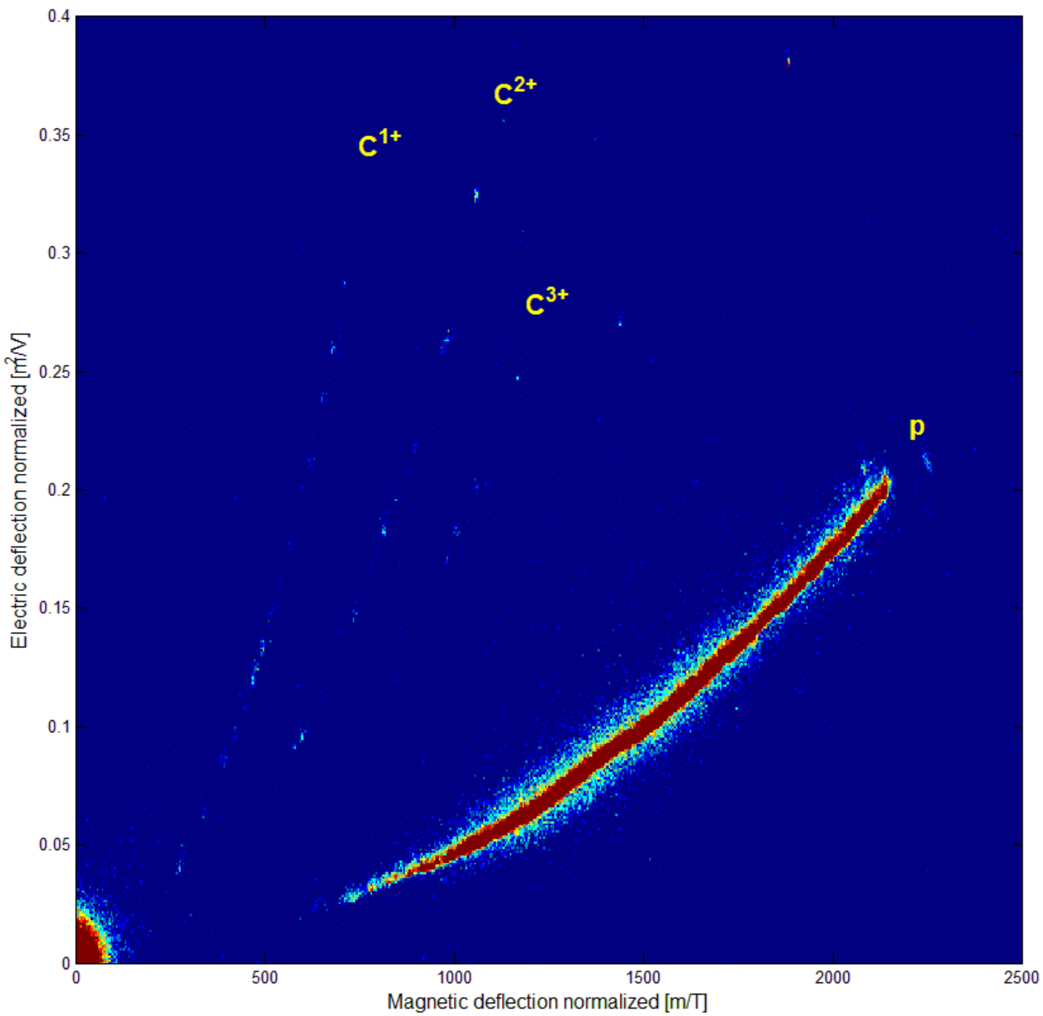
L.A.Gizzi, CN5, 8.7.2015

Thomson parabola: raw data 2



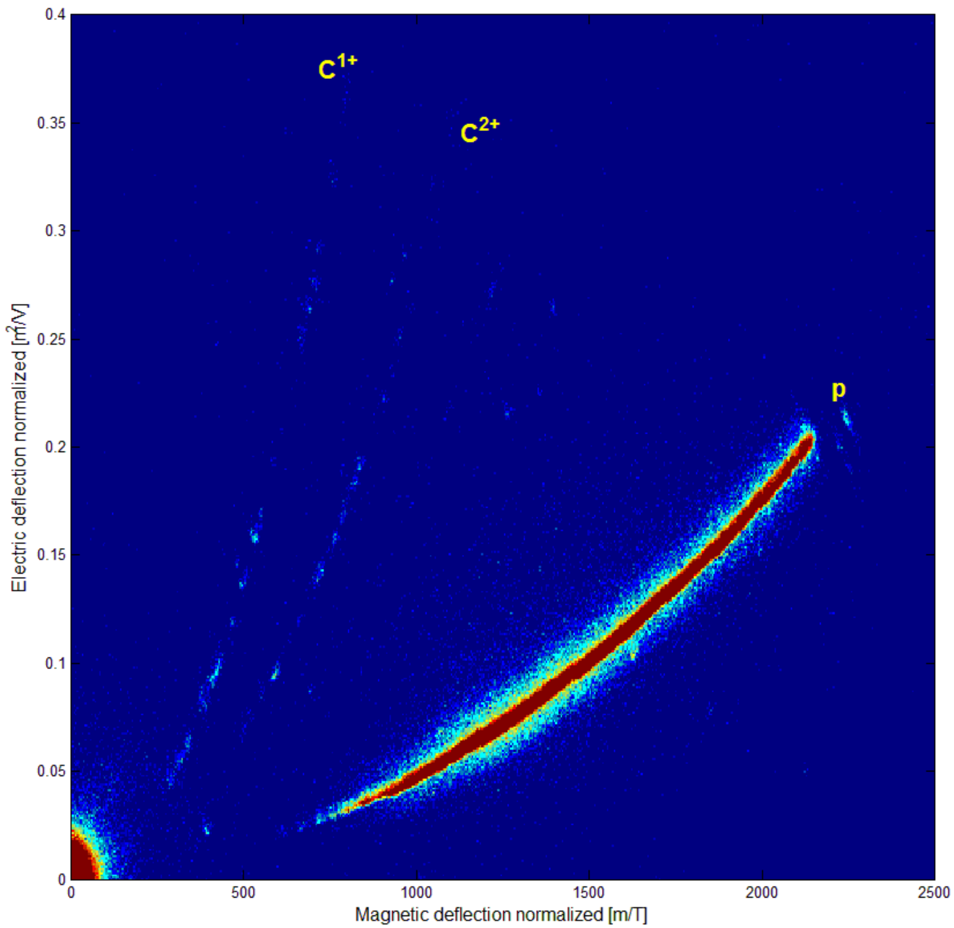
p	1,612 MeV
d	155,3 keV
C1+	1,145 MeV
C2+	933,2 keV
C3+	1,499 MeV
C4+	1,115 MeV

Thomson parabola: raw data 3



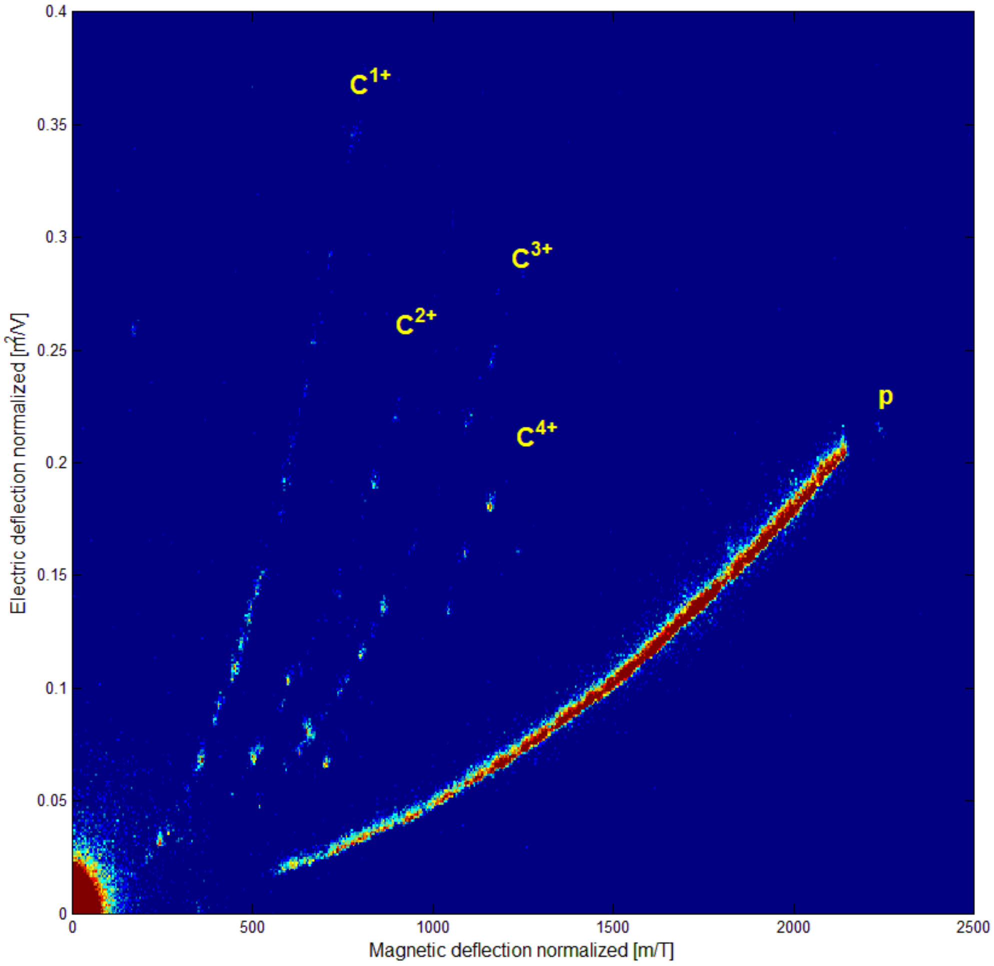
p	1,017 MeV
C1+	450,1 keV
C2+	407,7 keV
C3+	316,8 keV

Thomson parabola: raw data 4



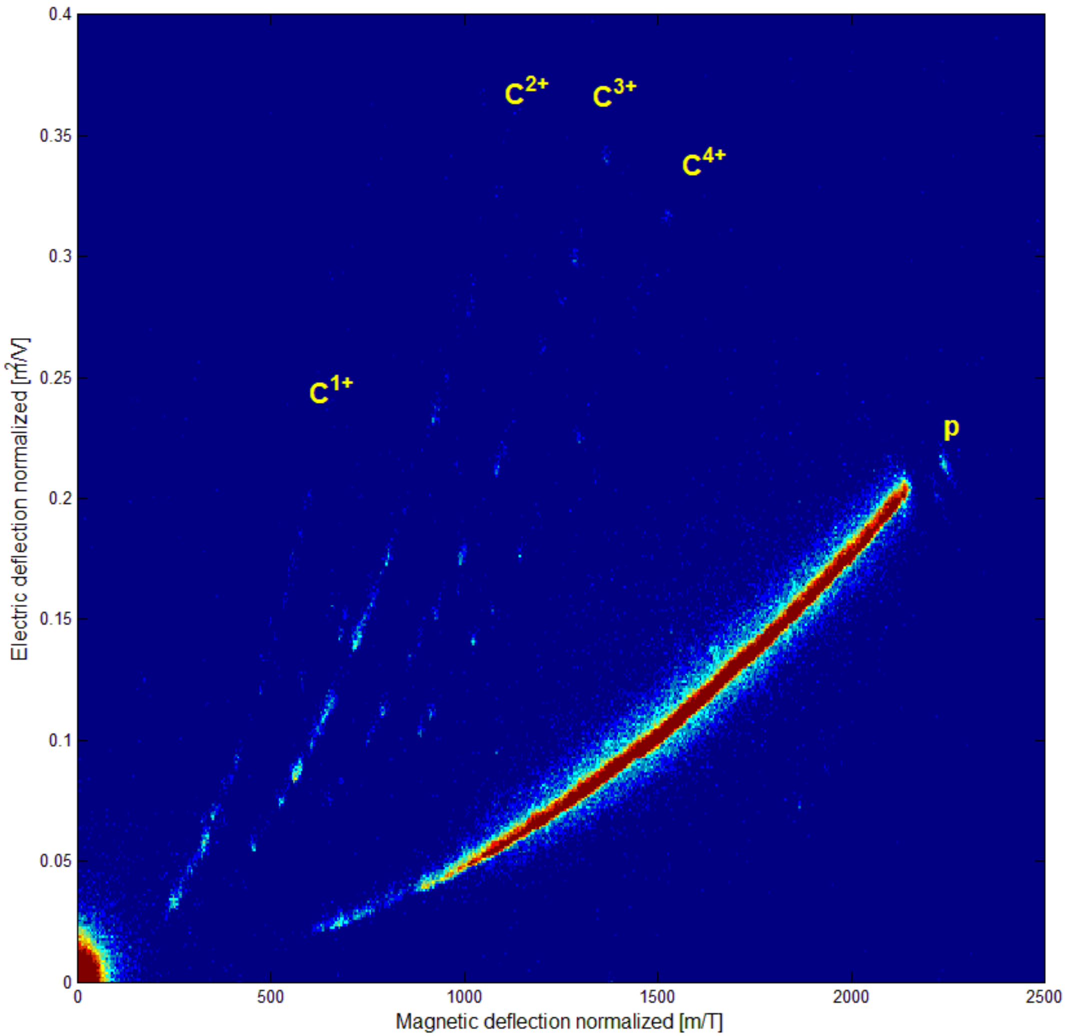
p	1,096 MeV
C1+	407,6 keV
C2+	573,4 keV

Thomson parabola: raw data 5



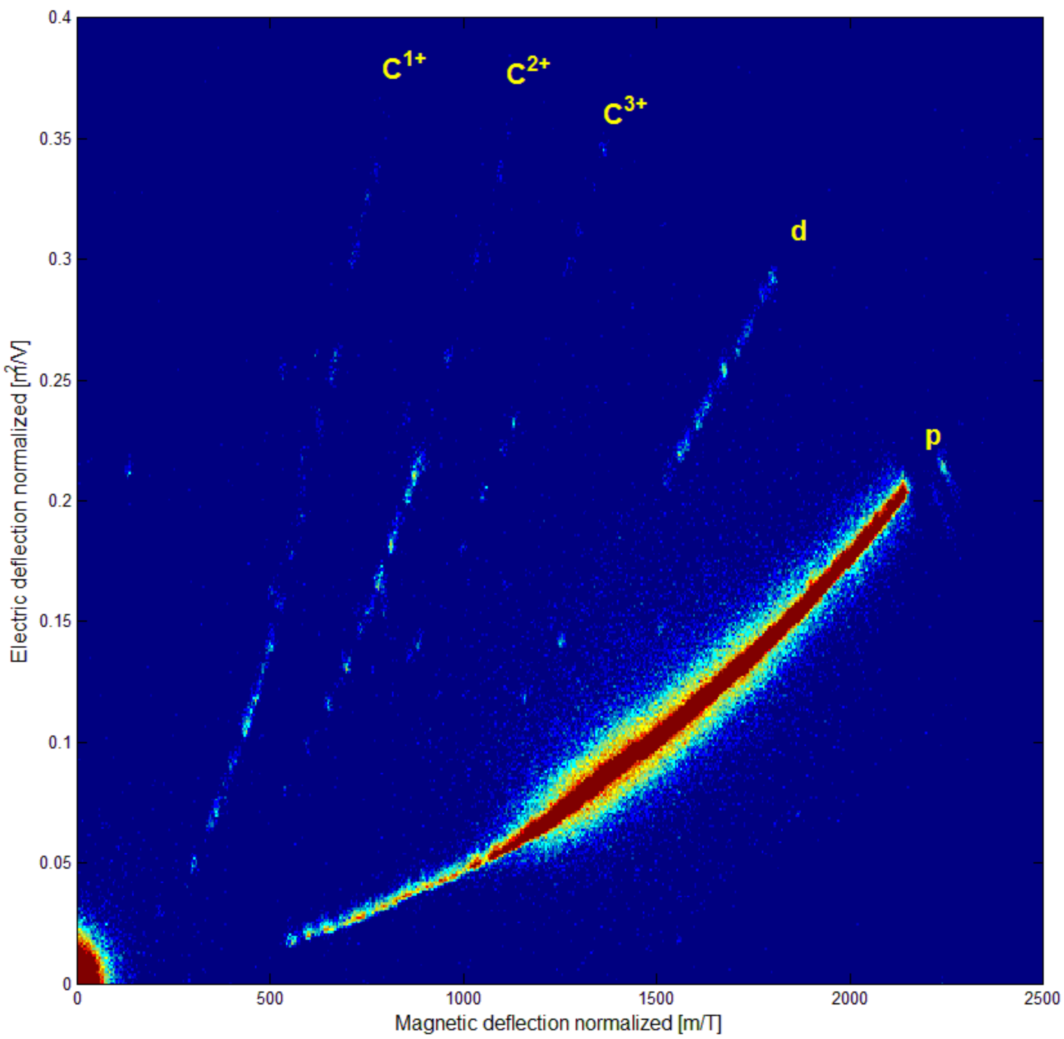
p	1,306 MeV
C1+	557,8 keV
C2+	834,7 keV
C3+	1,098 MeV

Thomson parabola: raw data 6



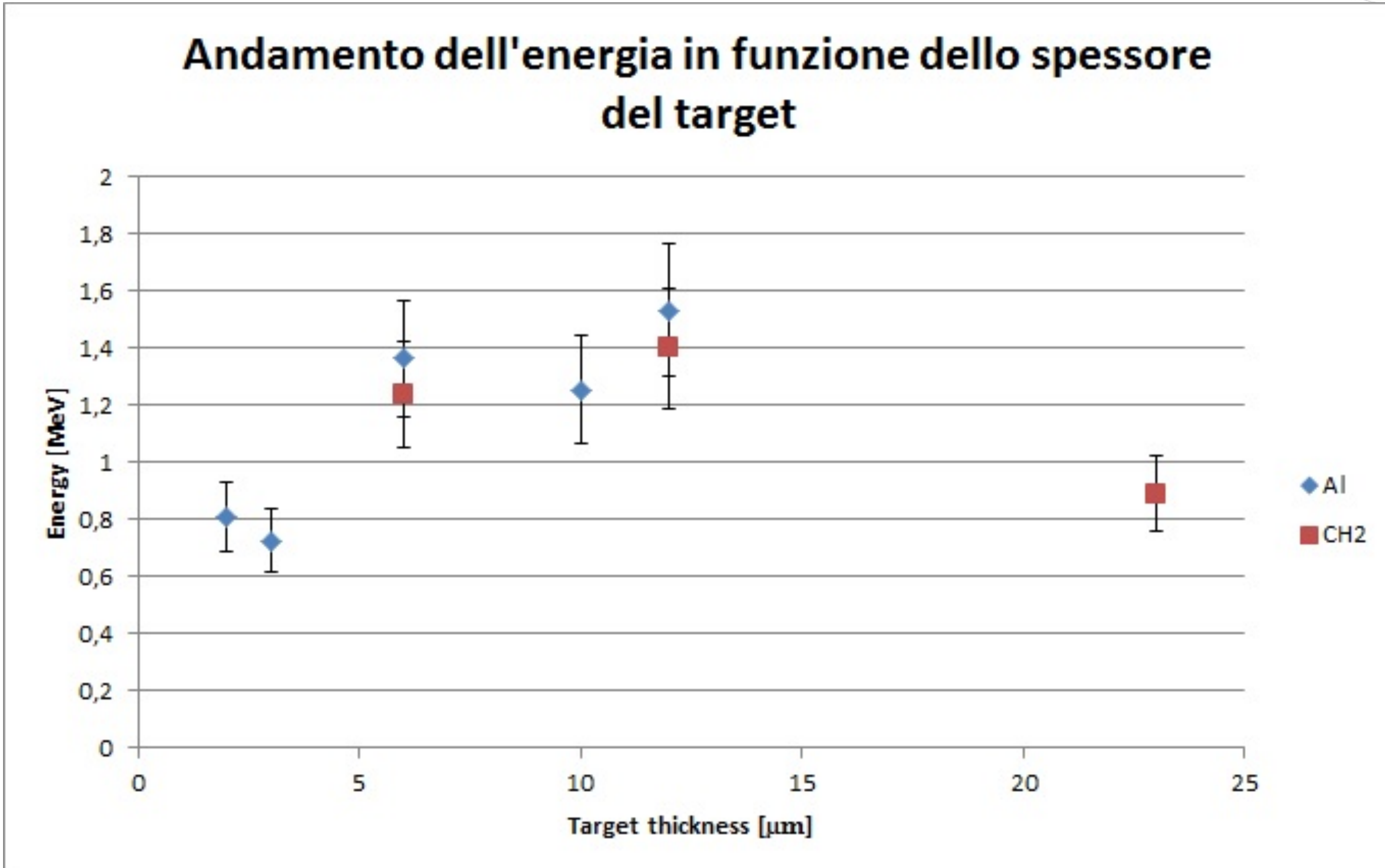
p	1,096 MeV
C1+	652,8 keV
C2+	652,8 keV
C3+	719,6 keV
C4+	694,5 keV

Thomson parabola: raw data 7



p	1,351 MeV
d	156,7 keV
C1+	407,6 keV
C2+	334,0 keV
C3+	416,6 keV

L.A.Gizzi, CN5, 8.7.2015


Andamento dell'energia in funzione dello spessore del target
Energy [MeV]
2
1,8
1,6
1,4
1,2
1
0,8
0,6
0,4
0,2
0
0
5
10
15
20
25
Target thickness [μm]
Al
CH2

Preliminary conclusions

- Preliminary conclusions:
  - Process reproducible and controllable
  - Multiple diagnostics tested (TP, Diamond, RCF …)
  - Standard targets fully explored
  - New results on surface vs. volume acceleration
  - Target engineering still to be explored
  - Scaling with laser intensity confirmed

Proposed activity

A laser-accelerated beamline for light ions:

- Develop ion acceleration with ultraintense lasers;
- New target techniques for control of energy spectrum and beam collimation;
- Establish a proton beam line for detector development;
- Provide a dedicated test beamline for ELI (e.g. ELImed@LNS)
- A platform for radiobiology studies with laser accelerated ions
- …

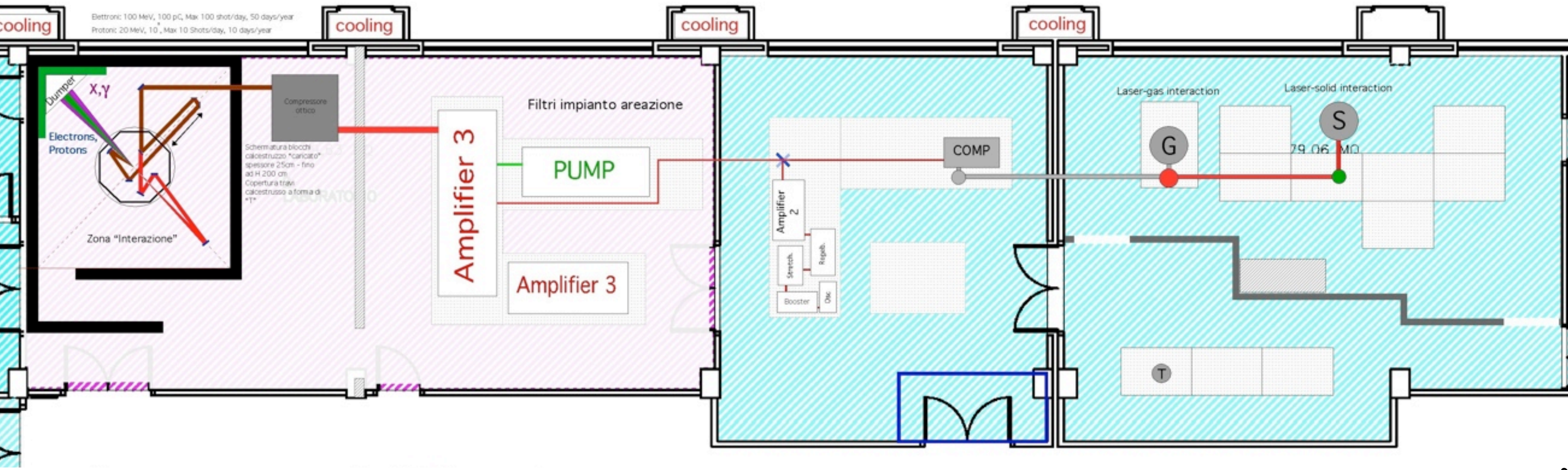
Laser upgrade

ILIL(Pisa) - MAIN LASER BEAM PARAM.	Current (dec.2015)	1° phase (6-2016)	Final
Wavelength (nm)	800	800	800
Pump Energy (J)	1.8	6(12)	24
Pulse duration(fs)	40	30	25
Energy before compression (J)	0.6	2(4)	7
Energy after compression (J)	0.4	1.5(3)	5
Rep rate (Hz)	10	1	1
Max Intensity on target	2E19	7.5E19(1.2E20)	4E20
Contrast (ns)	>1E9	>1E9	>1E10
Expected proton beam energy (MeV)	2	6(8)	12

Current upgrade will be developed in phases:
1° phase (mid 2016) will deliver a minimum of 1.5 J on target, >4x current energy.
Ion energy scaling sets max ion energy around 5 MeV
Final goal is 12 MeV, to be achieved with 5 J of energy on target.

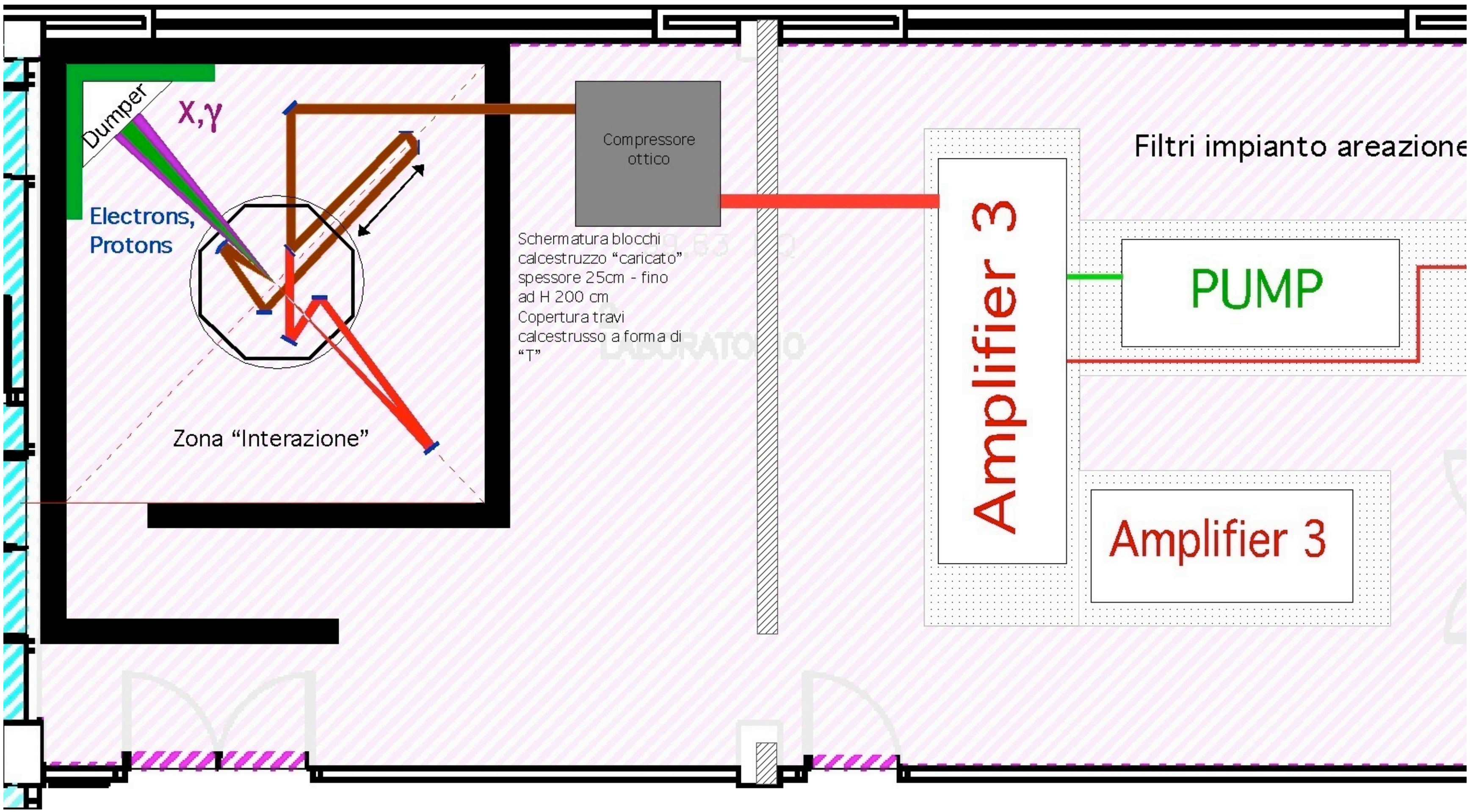
INO-CNR (PI): Infrastructure development

LASER UPGRADE TO 200 TW AND NEW, SHIELDED TARGET AREA

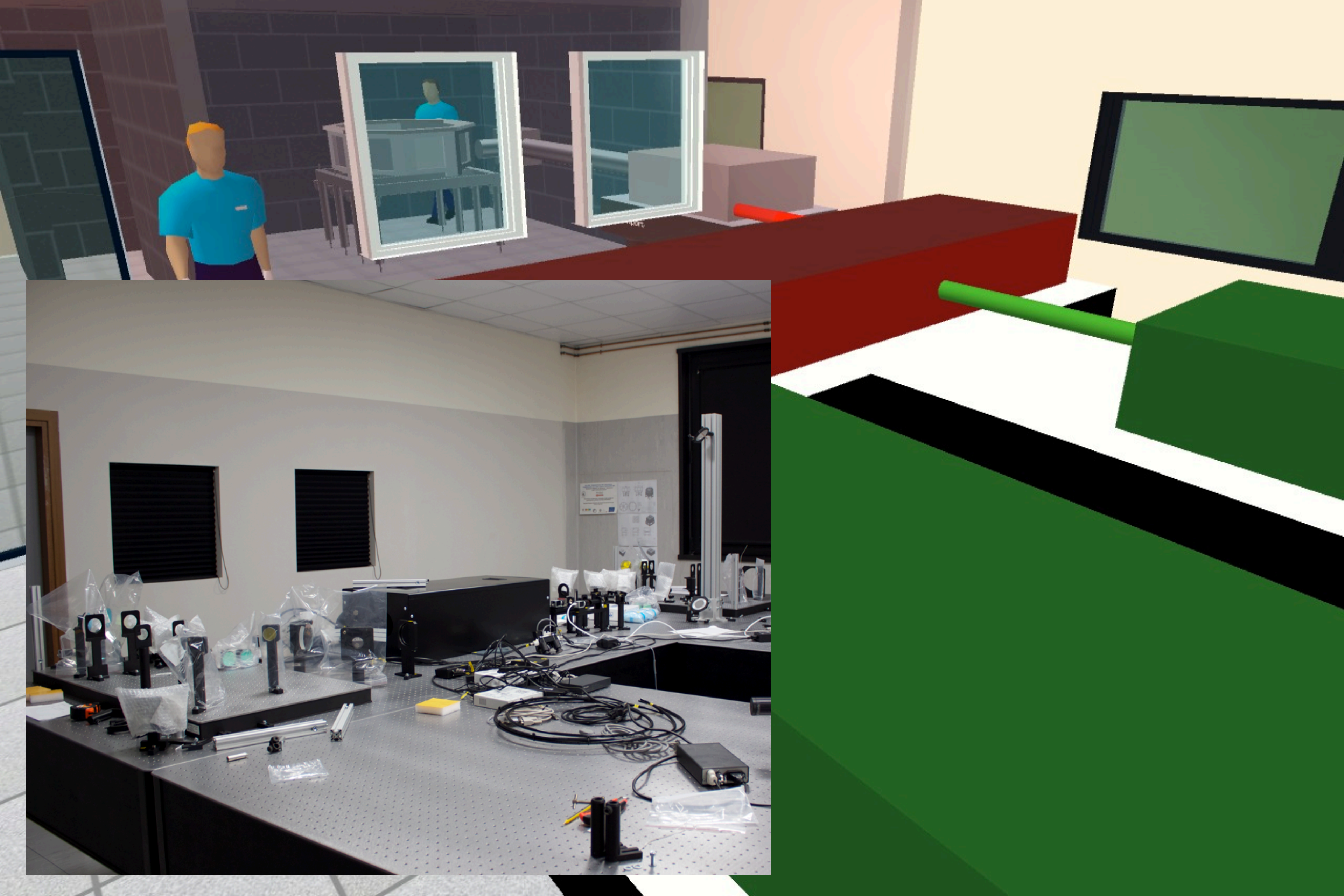


L.A.Gizzi, CN5, 8

ILIL-PW – Layout



New 250 TW amplifier



UNITS

Milano: detectors development – dedicated TP, Beam manipulation and post acceleration;

Pisa: laser, laser-plasma acceleration, laser and plasma diagnostics and control

Bologna: Theory: particle in cell modelling, beam dynamics modeling

Catania: beam characterization, dosimetry, medical applications;

Frascati: detectors and post acceleration

Napoli: radiobiology and medical applications, analitical laser-plasma modelling