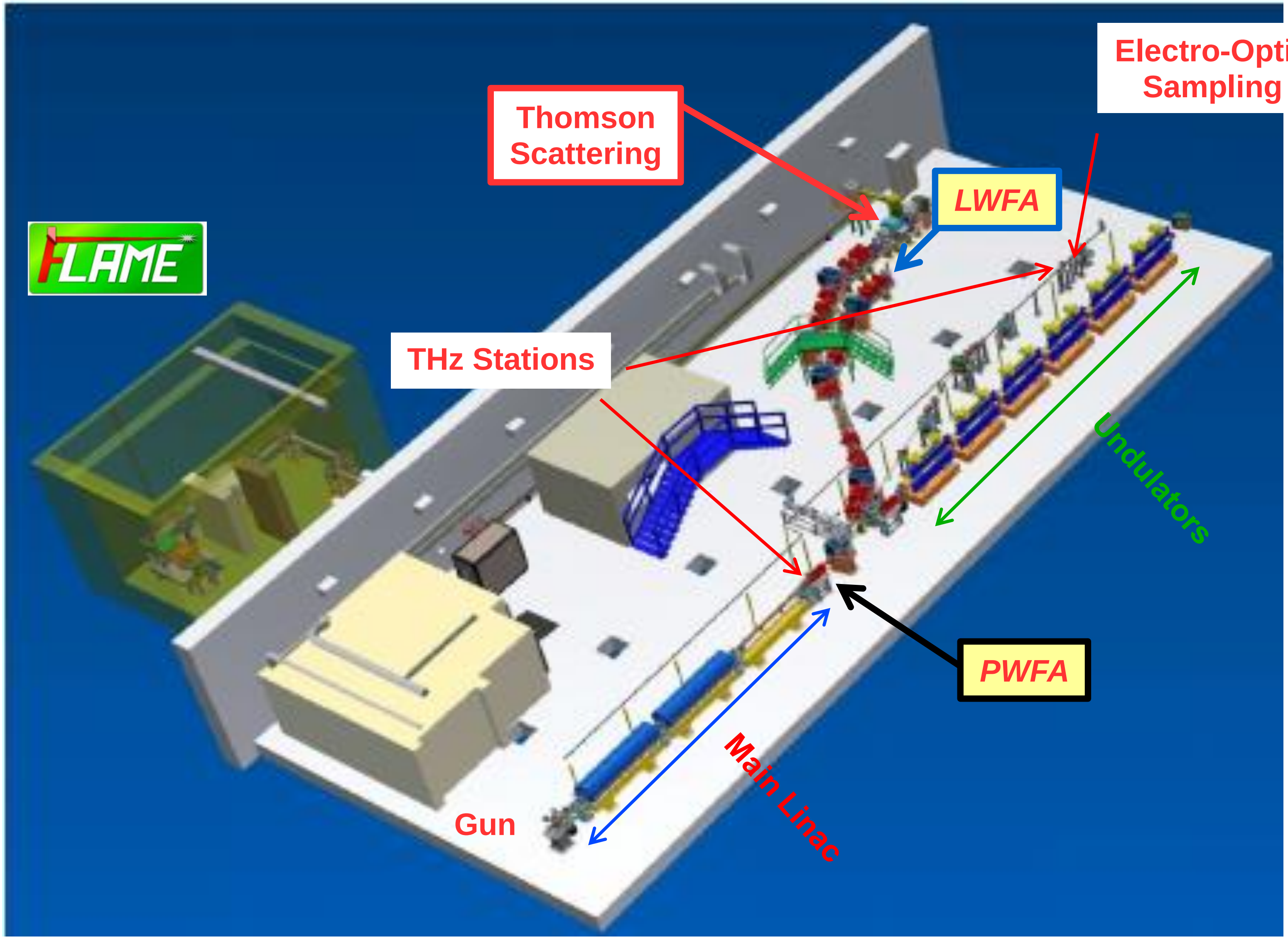
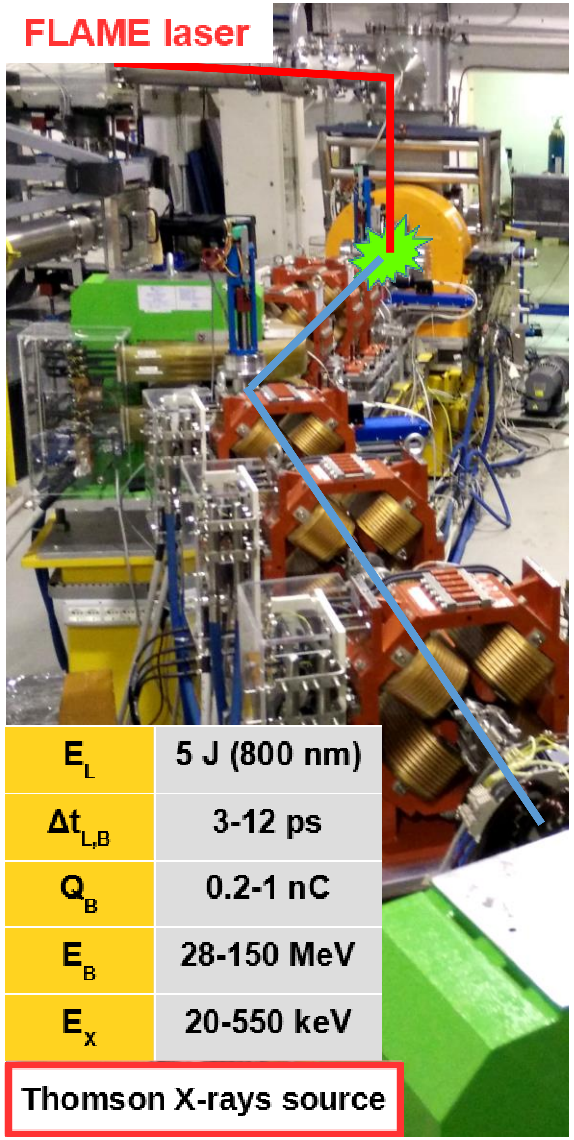
SPARC_LAB



Ferrario, M., et al. "SPARC_LAB present and future." NIMB 309 (2013): 183-188.

Radiation source activities

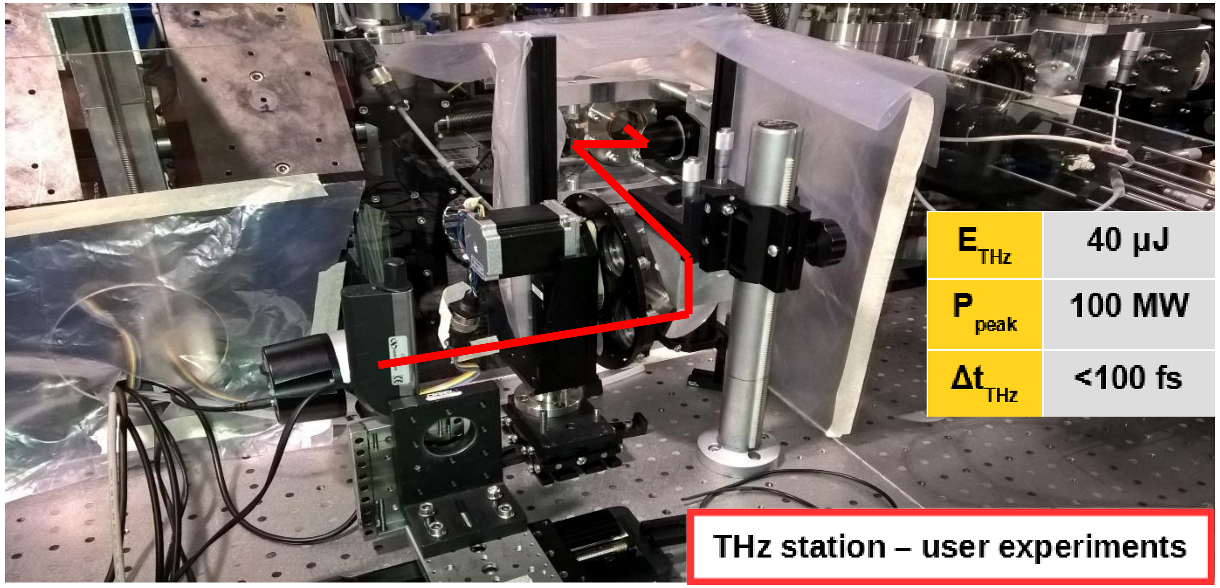


E_L	5 J (800 nm)
$\Delta t_{L,B}$	3-12 ps
Q_B	0.2-1 nC
E_B	28-150 MeV
E_X	20-550 keV

Thomson X-rays source

Free Electron Laser (SASE + seeded)

λ_u	2.8 cm
N_u	77
Gap	0.8-20 cm
K	0.38-2.1
Br	1.31 T



E_{THz}	40 μJ
P_{peak}	100 MW
Δt_{THz}	<100 fs

THz station – user experiments

High brightness photo-injector, before

Low-current operation
30-170 MeV beam energy
1-10 ps bunch duration

→ **Thomson source**
→ **FEL**

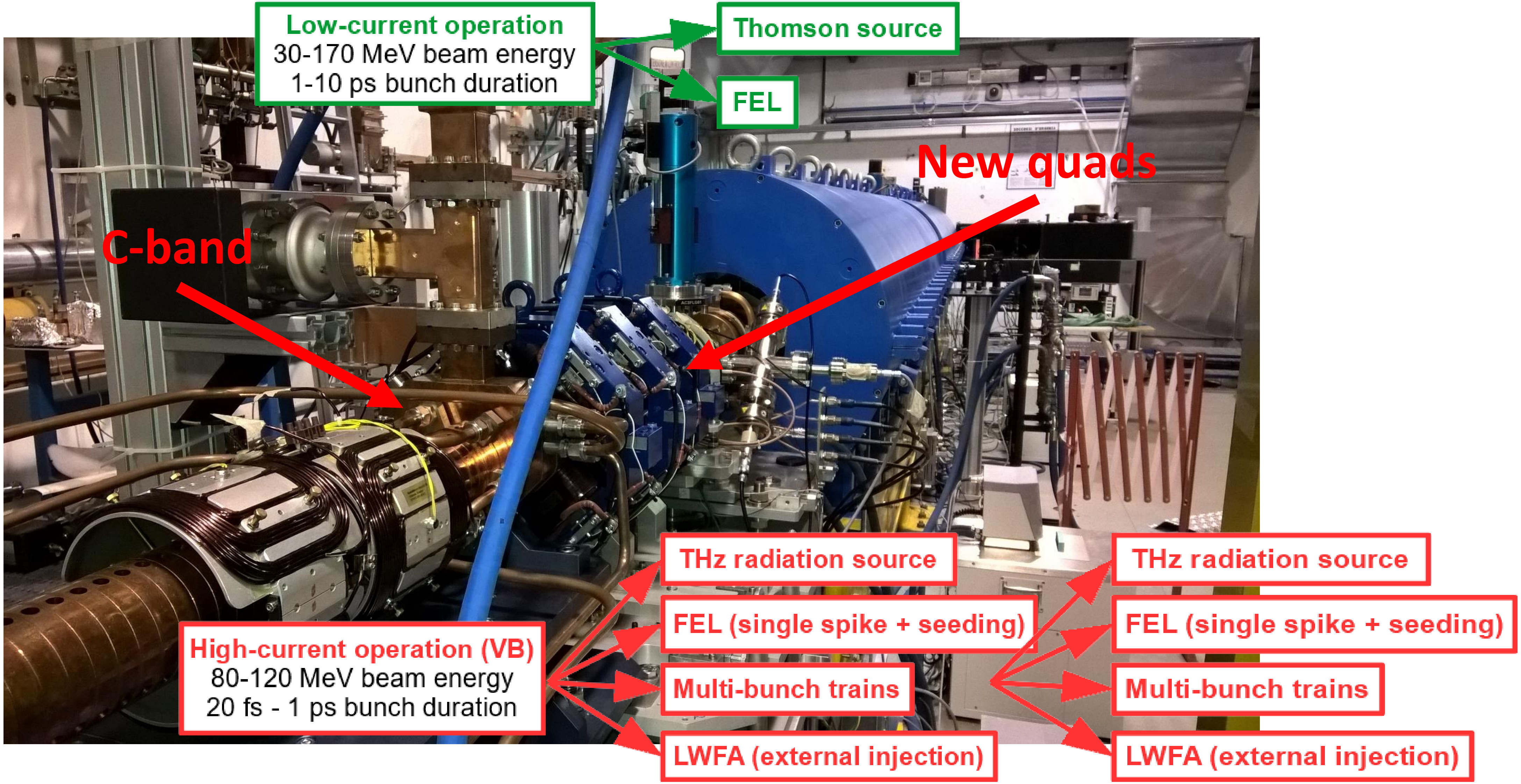
High-current operation (VB)
80-120 MeV beam energy
20 fs - 1 ps bunch duration

→ **THz radiation source**
→ **FEL (single spike + seeding)**
→ **Multi-bunch trains**
→ **LWFA (external injection)**

→ **THz radiation source**
→ **FEL (single spike + seeding)**
→ **Multi-bunch trains**
→ **LWFA (external injection)**

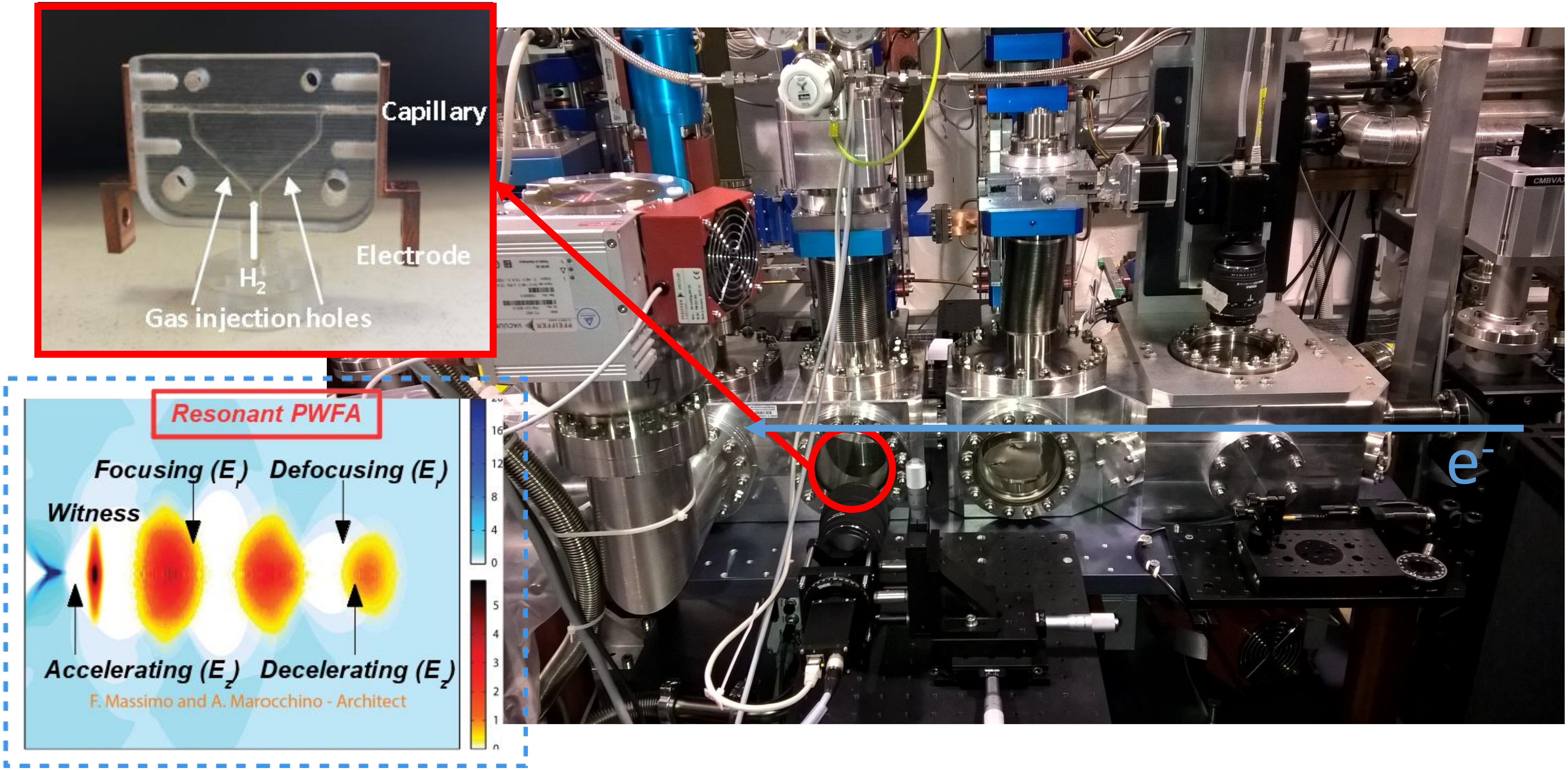
Serafini L., Ferrario M. "Velocity bunching in photo-injectors." AIP conference proceedings. 2001.
Anderson, S. G., et al. "Velocity bunching of high-brightness electron beams." PRSTAB 8.1 (2005): 014401.

High brightness photo-injector, after

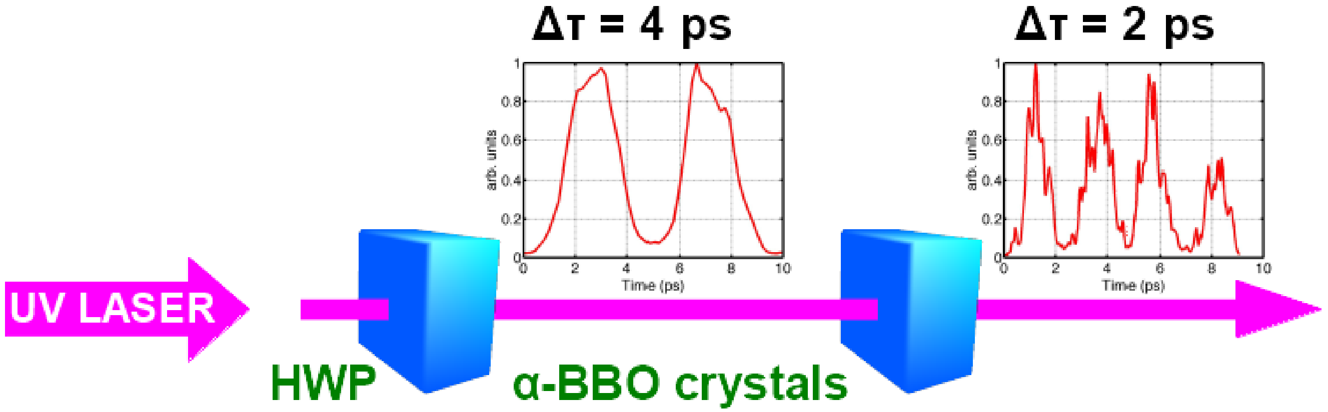


Serafini L., Ferrario M. "Velocity bunching in photo-injectors." AIP conference proceedings. 2001.
Anderson, S. G., et al. "Velocity bunching of high-brightness electron beams." PRSTAB 8.1 (2005): 014401.

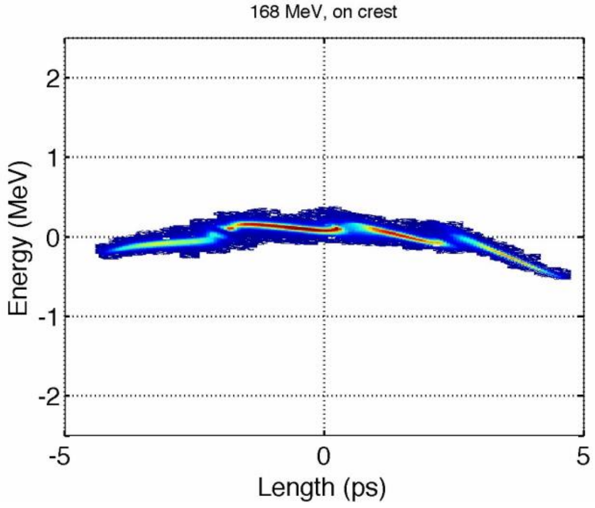
Plasma-based acceleration



- **Laser-comb**: multiple bunches train produced directly at the cathode
  - ✓ Pulses delayed by birefringent crystals, delay lines to take full control of distances
  - ✓ Easy setup, half-wave plates for (un)balancing (charge ramps…)



Ferrario M., **et al.** “Laser comb with velocity bunching: Preliminary results at SPARC.” **NIM 637.1 2011 S43-S46**



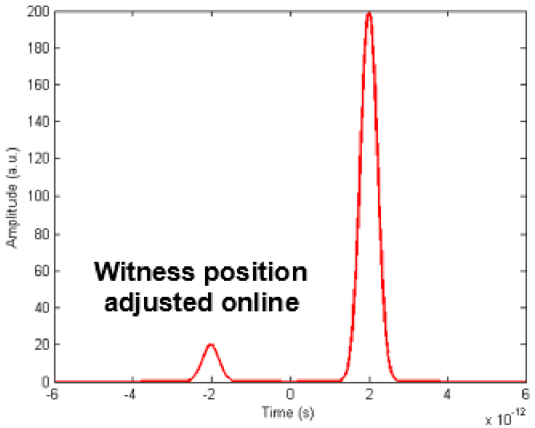
- **Velocity bunching** for bunch compression
  - ✓ Distance and duration tuning by moving S1 phase
  - ✓ Different approsch with respect to other multu-bunches schemes, e.g. @ FACET.

C. Ronsivalle et al. "Large-bandwidth two-color free-electron laser driven by a comb-like electron beam." New Journal of Physics (2014): 033018
Hogan, M. J., et al "Plasma wakefield acceleration experiments at FACET." New Journal of Physics 2010 055030.

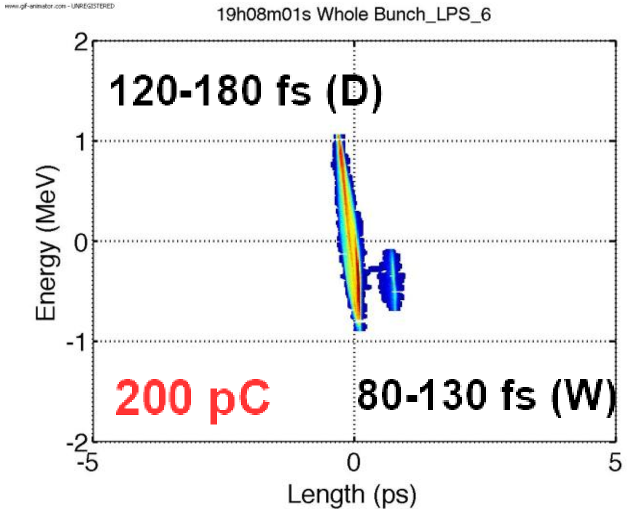
Multi-bunch: 1 driver + witness

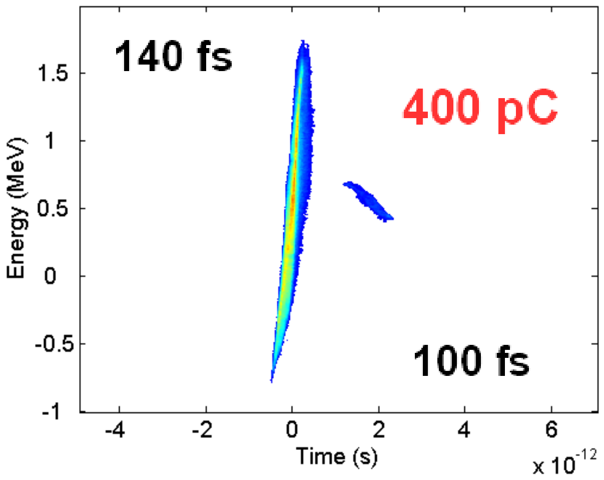
Laser profile on photocathode

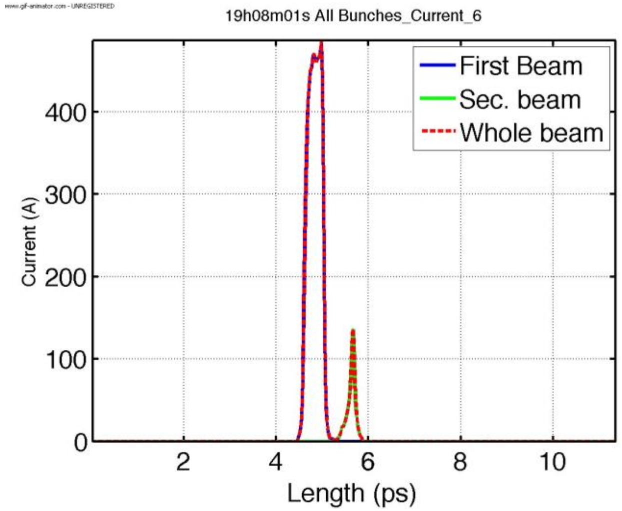
Driver + witness (20 pC)

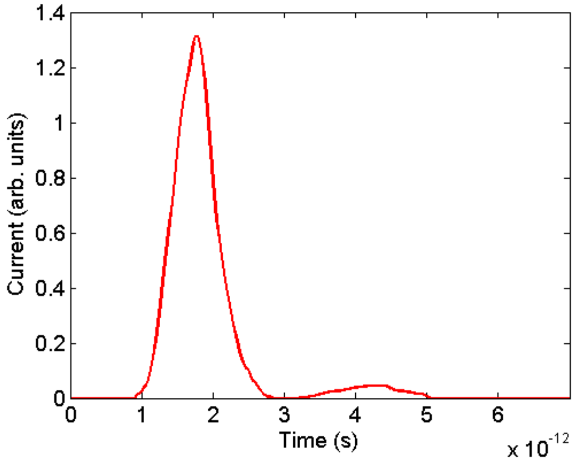


LPS at linac exit









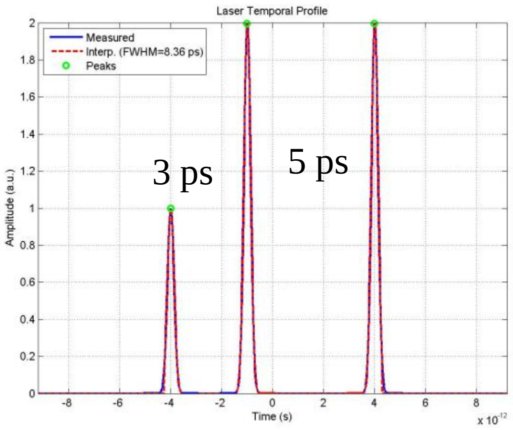
Current profile

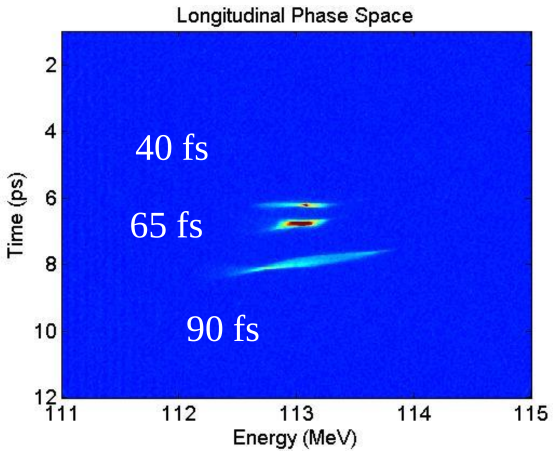
Multi-bunch: several drivers + witness

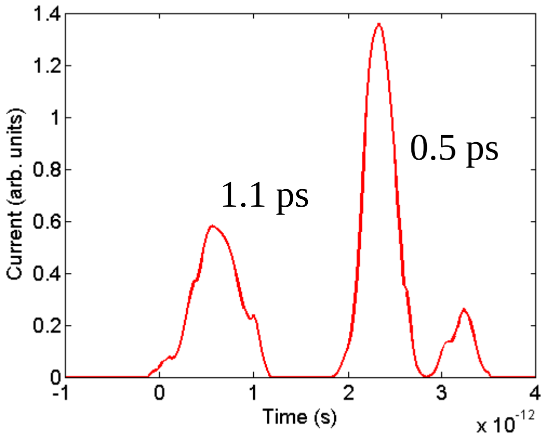
50 pc drivers + 20 pC witness beam

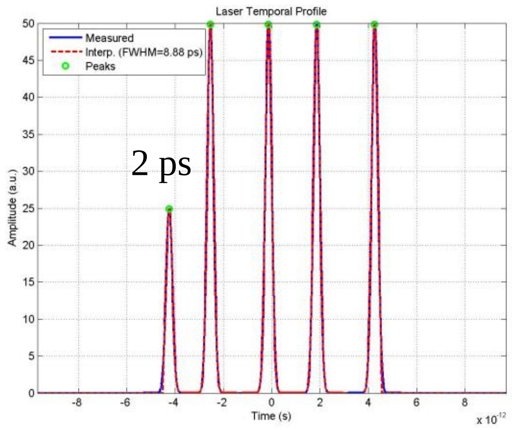
resonant scheme at $n_p = 10^{16}$ cm-3 → distance between beams $\lambda_p \approx 1.1$ ps

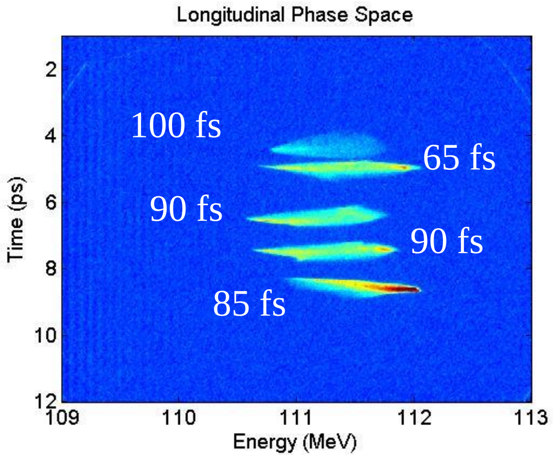
Laser profile on photocathode | LPS | Current profile

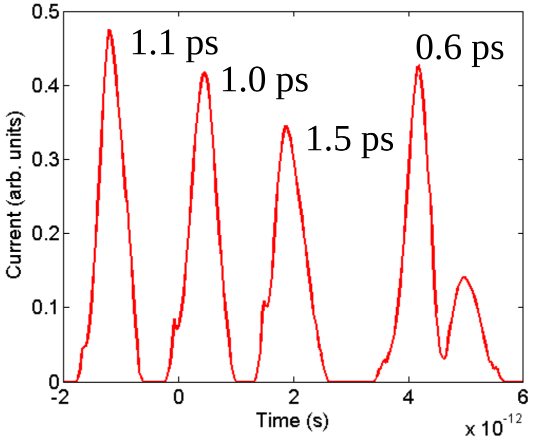




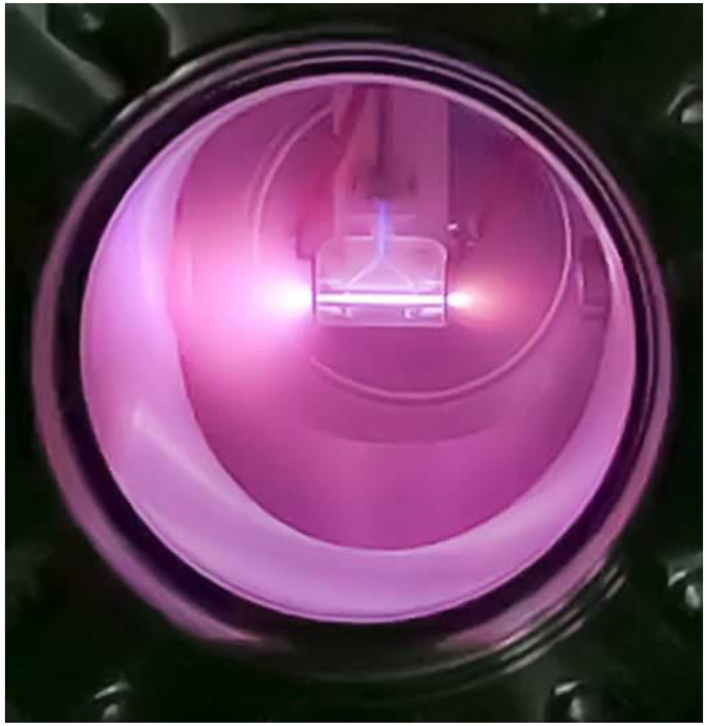








Discharge inside the capillary

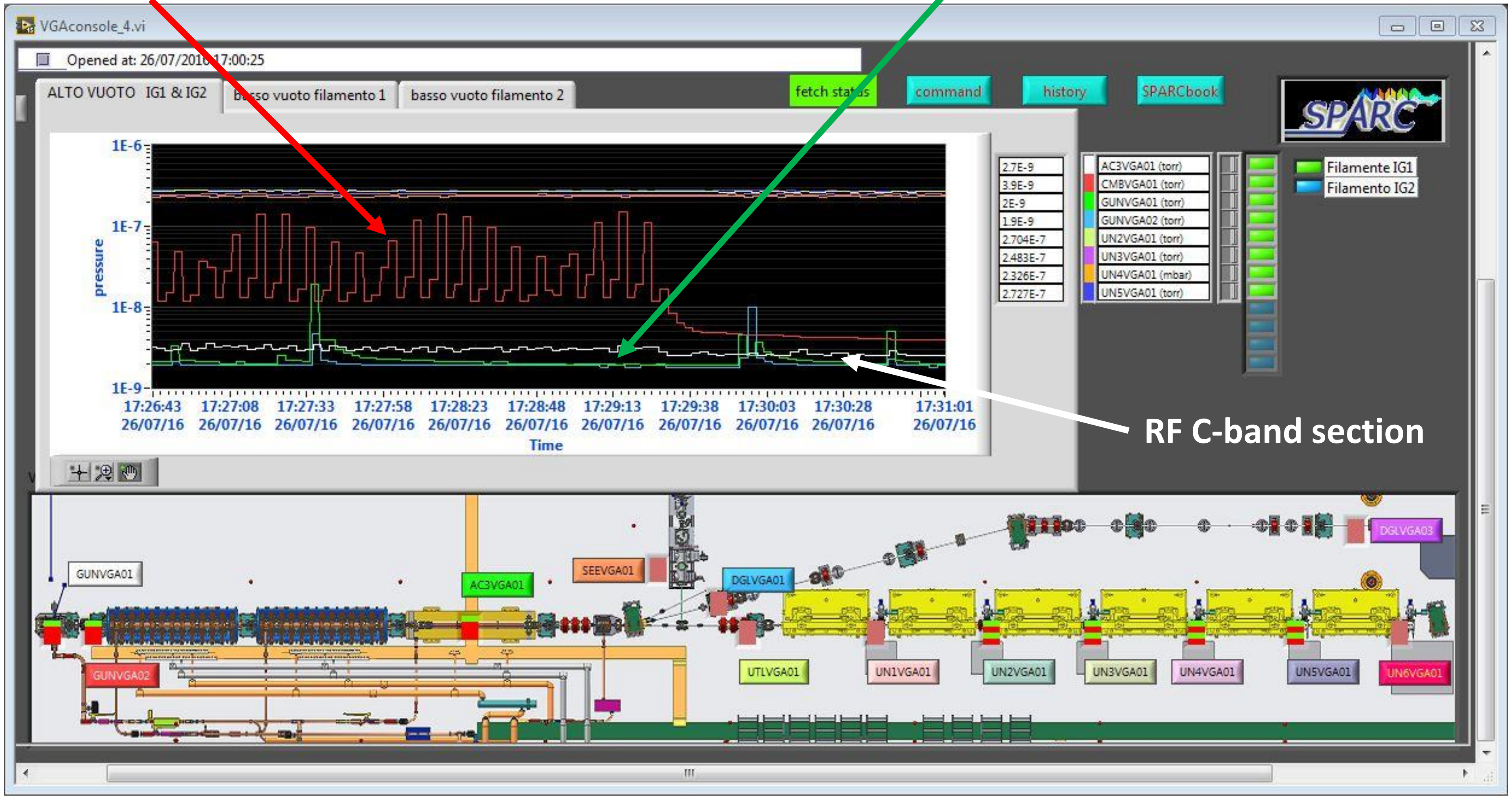


COMB chamber vacuum results

Plasma chamber

RF Gun (11m away)

Gas flow at 1 Hz



RF C-band section

Active plasma lens

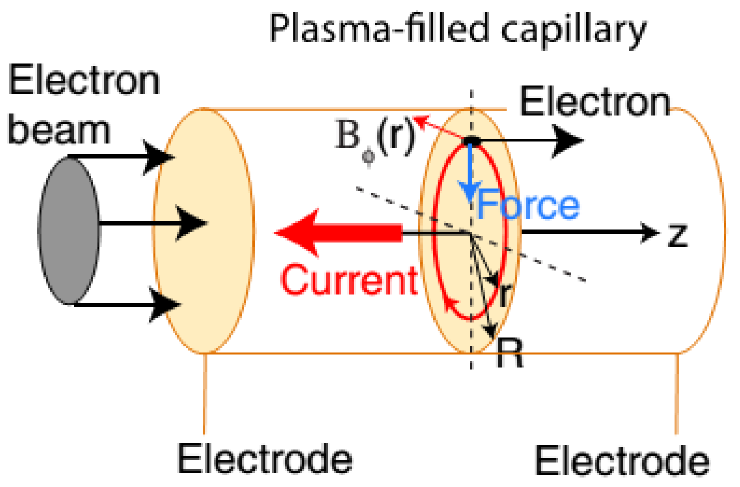
- Focusing field produced by the electric discharge inside plasma filled capillary
  - ✓ According to Amper's law the magnetic field produced by the discharge

$$B_\phi(r) = \frac{1}{2}\int_0^r \mu_0 J(r')\,dr'$$

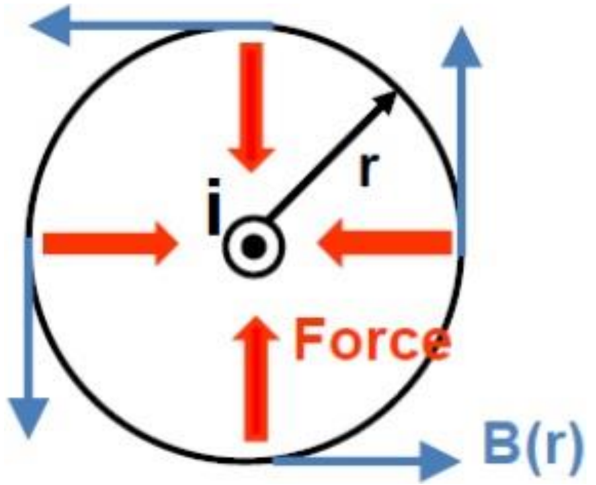
✓ Radial focusing
  - ➢ X/Y planes are not dependent as in quads

✓ Weak chromaticity
  - ➢ Focusing force scales linearly with energy

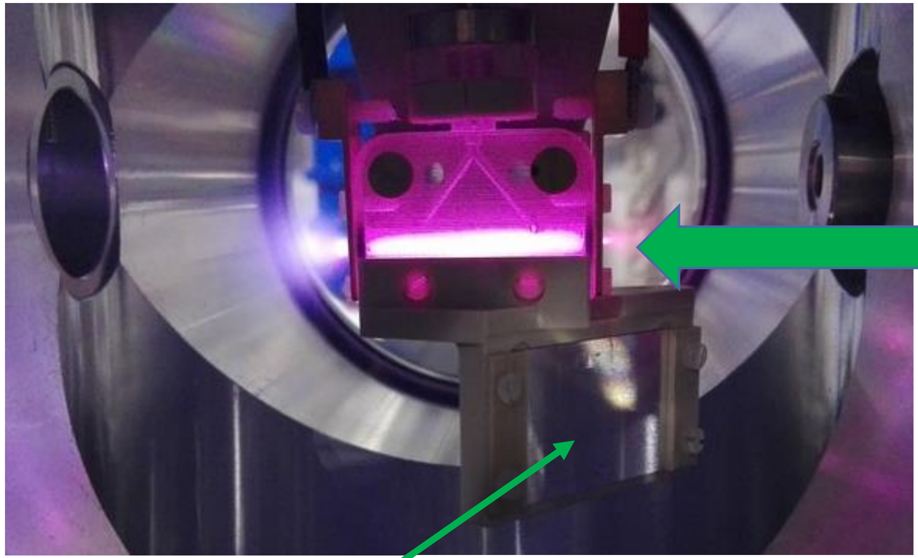
✓ Compactness
  - ➢ Higher integrated field than quad triplets



J. van Tilborg et. al., Phys. Rev. Lett. **115**, 184802 (2015)
DOI:http://dx.doi.org/10.1103/PhysRevLett.115.184802

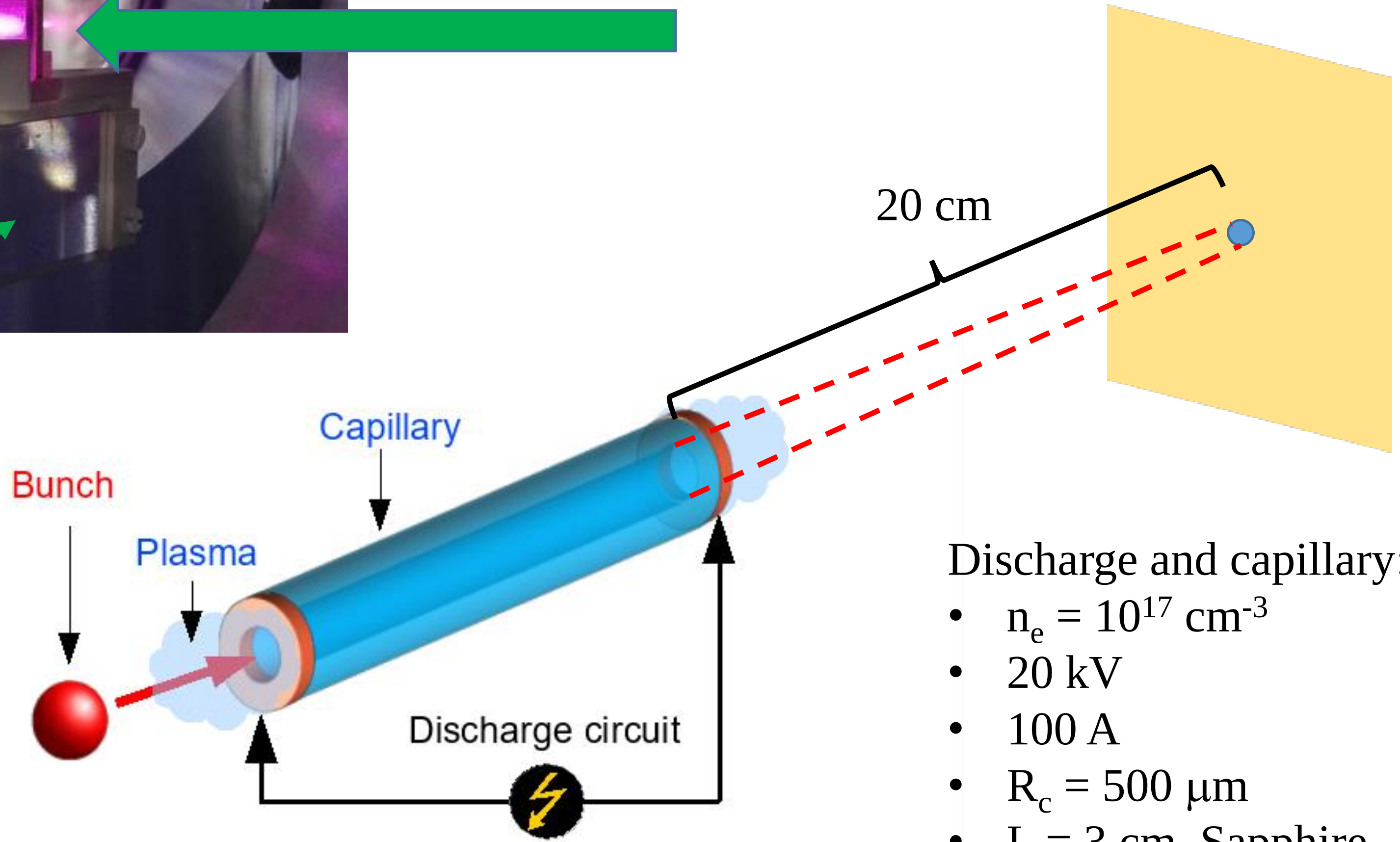


Experimental layout



e^- beam

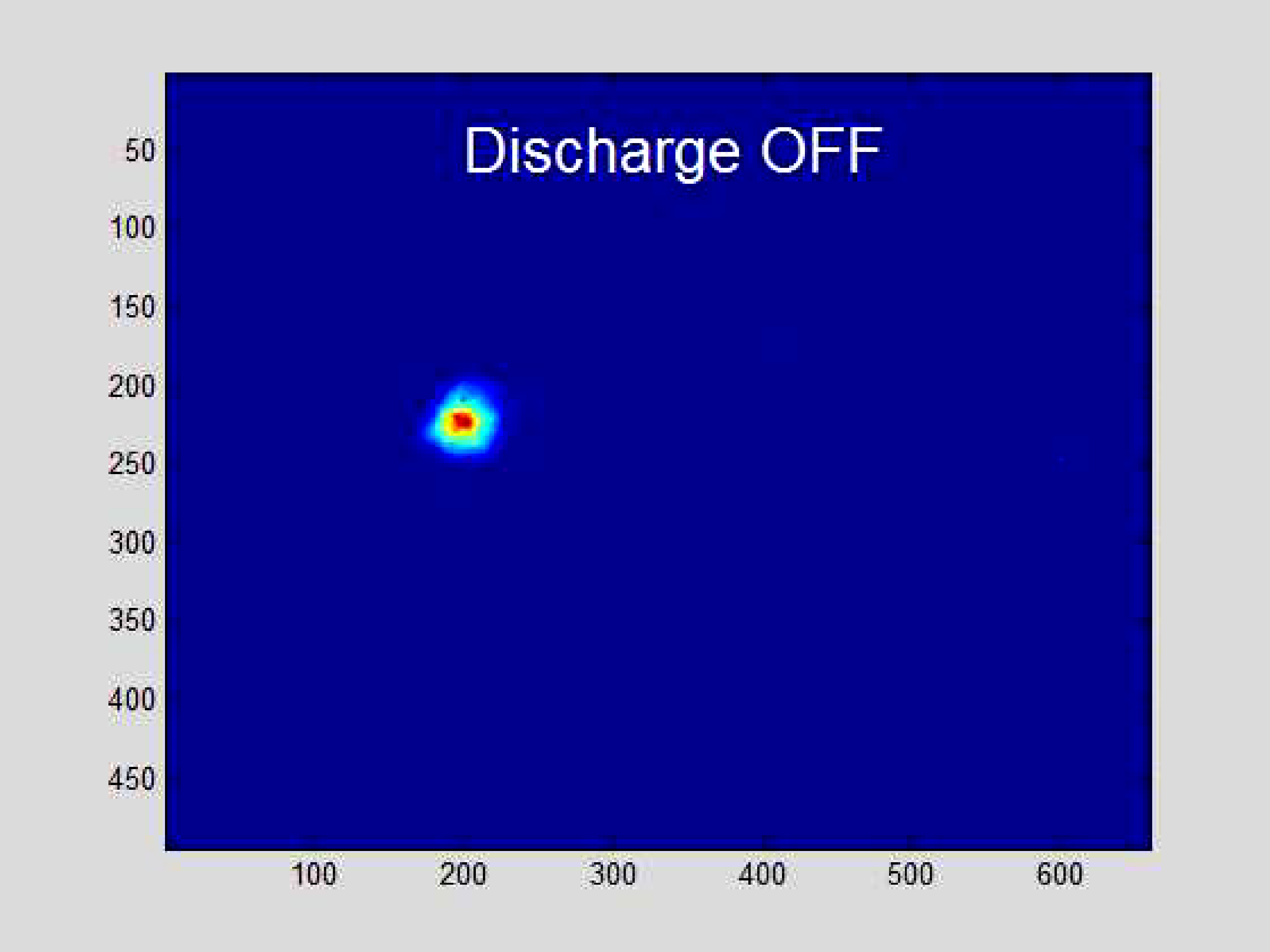
OTR screen

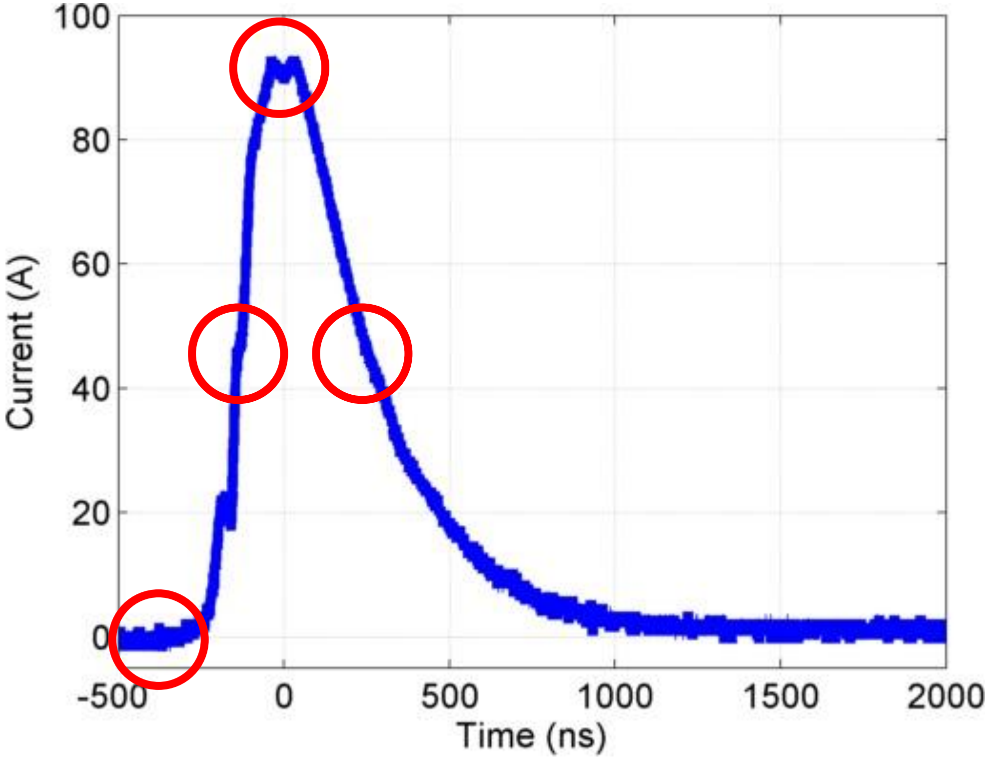


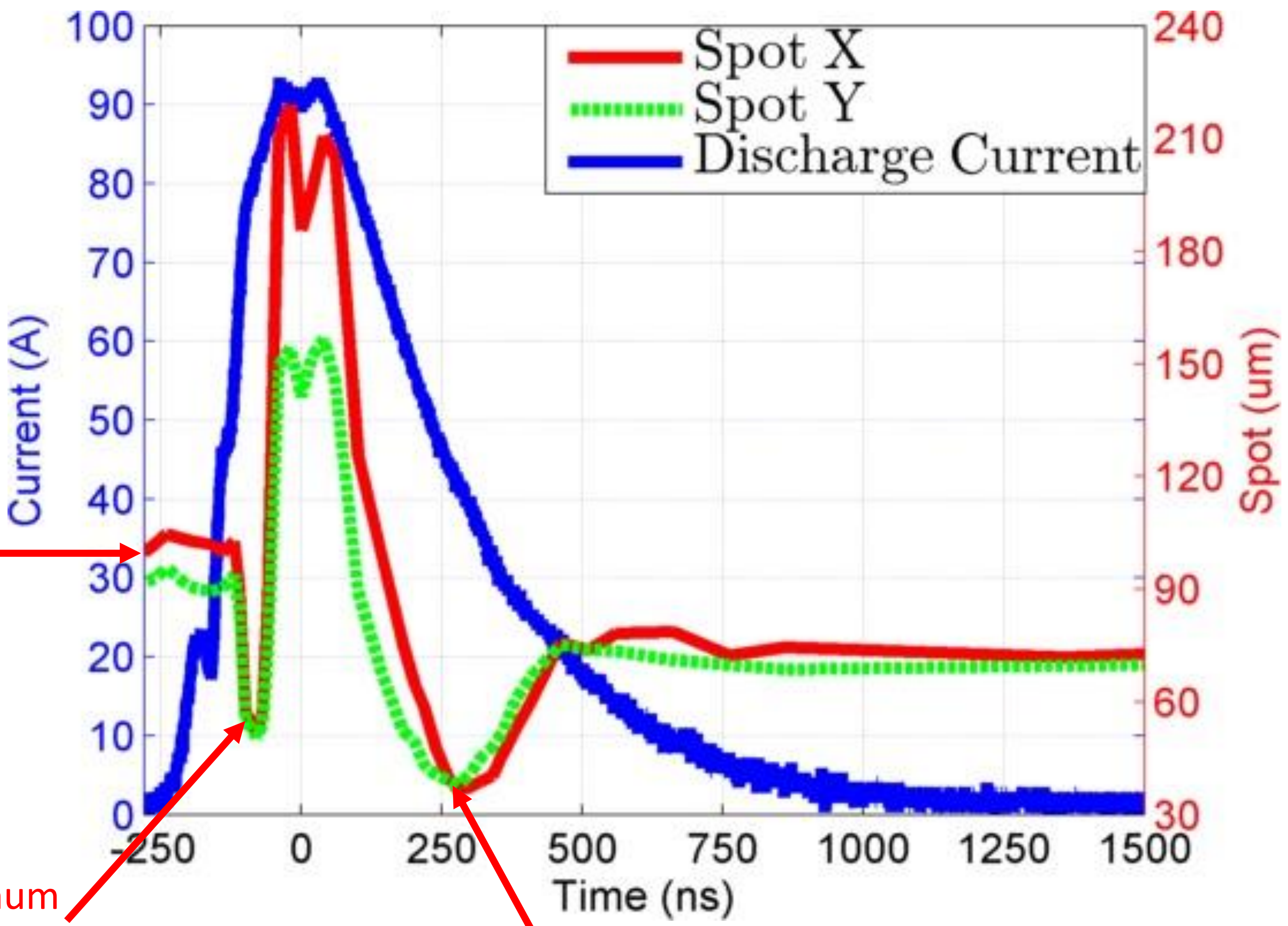
Beam parameters:
- 50 pC
- 1 ps
- 130 μm
- 120 MeV
- 1 mm×mrad

Discharge and capillary:
- $n_e = 10^{17}$ cm^{-3}
- 20 kV
- 100 A
- R_c = 500 μm
- L = 3 cm, Sapphire

Focussing the beam with discharge







original spot size
~ 110 μm

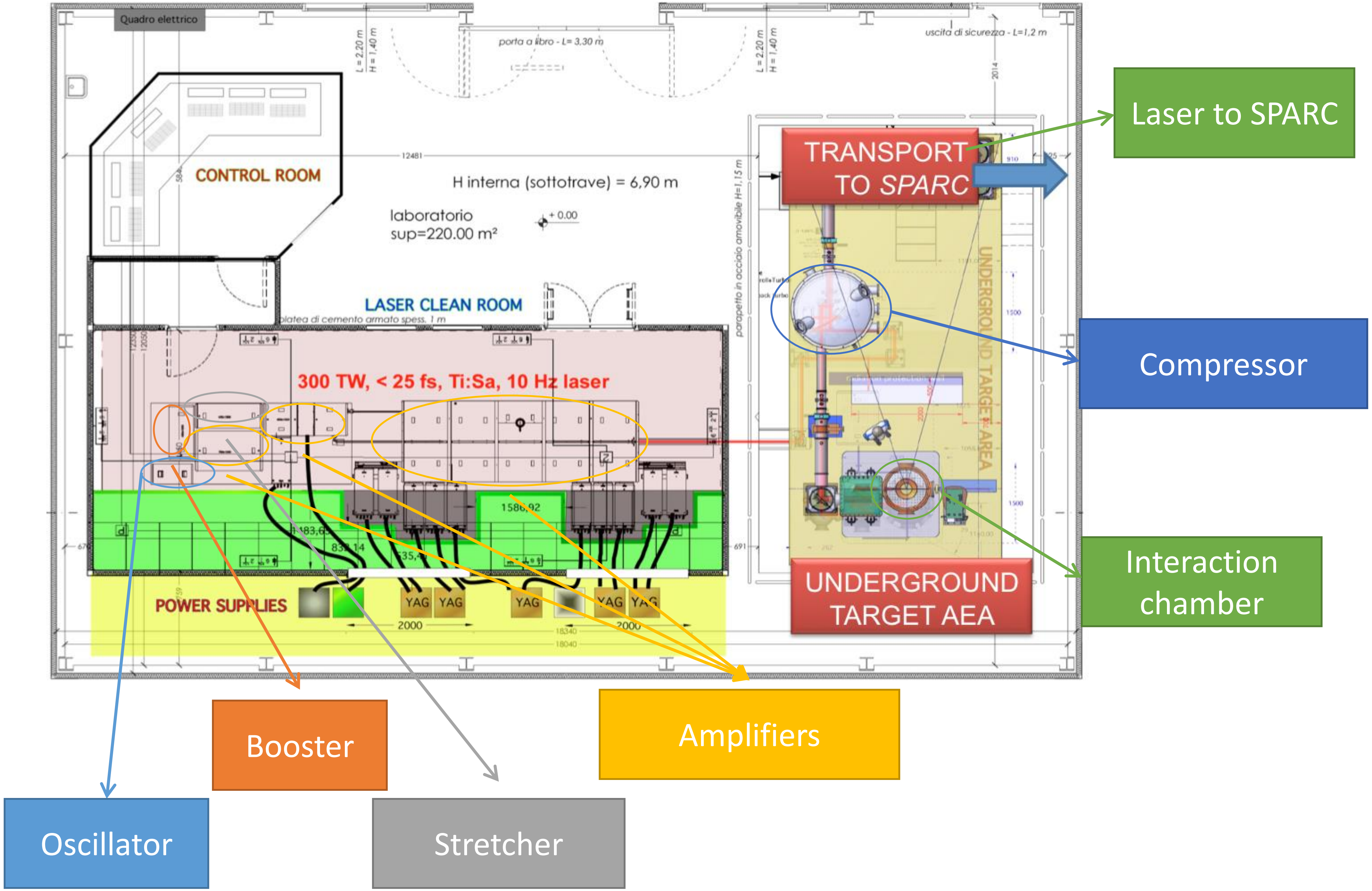
first minimum
~ 50 μm

second minimum
~ 35 μm

FLAME

Energy	6 J
Duration	23 fs
Wavelength	800 nm
Bandwidth	60/80 nm
Spot @ focus	10 µm
Peak Power	300 TW
Contrast Ratio	10^{10}

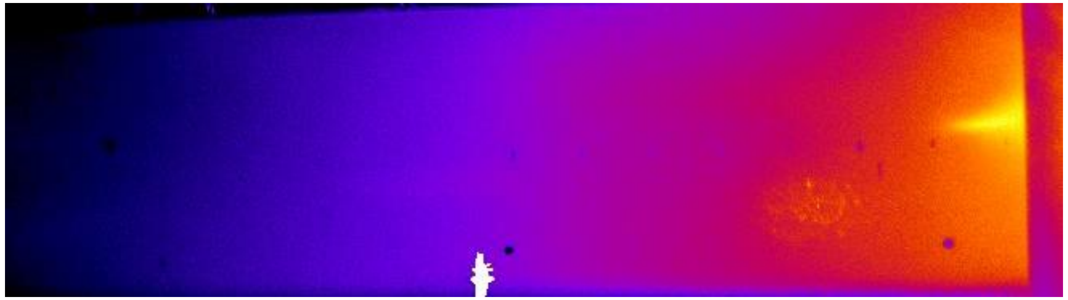
FLAME

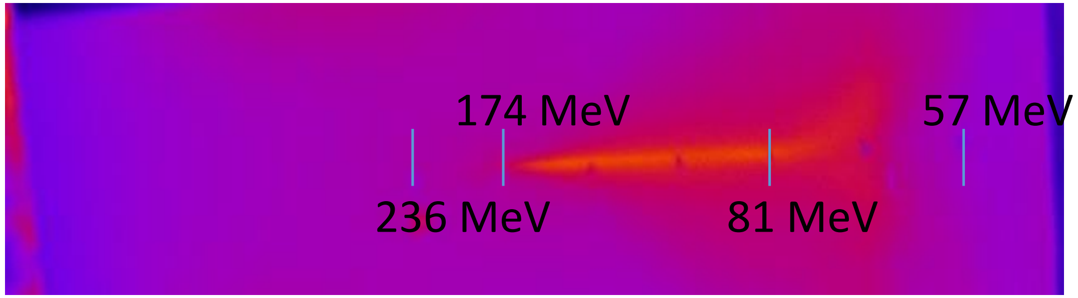


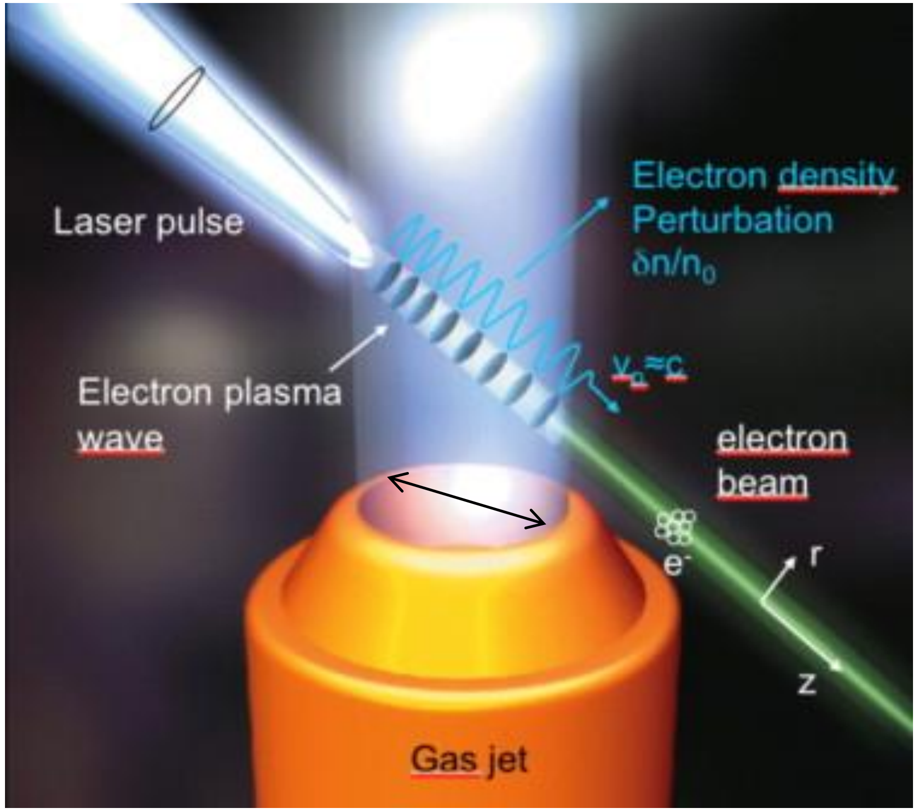
Quadro elettrico
porta a libro - L= 3,30 m
uscita di sicurezza - L=1,2 m
CONTROL ROOM
H interna (sottotrave) = 6,90 m
laboratorio
sup=220.00 m²
LASER CLEAN ROOM
platea di cemento armato spess. 1 m
parapetto in acciaio amovibile H=1,15 m
300 TW, < 25 fs, Ti:Sa, 10 Hz laser
POWER SUPPLIES
YAG
TRANSPORT TO SPARC
UNDERGROUND TARGET AREA
UNDERGROUND TARGET AEA
Laser to SPARC
Compressor
Interaction chamber
Amplifiers
Booster
Stretcher
Oscillator

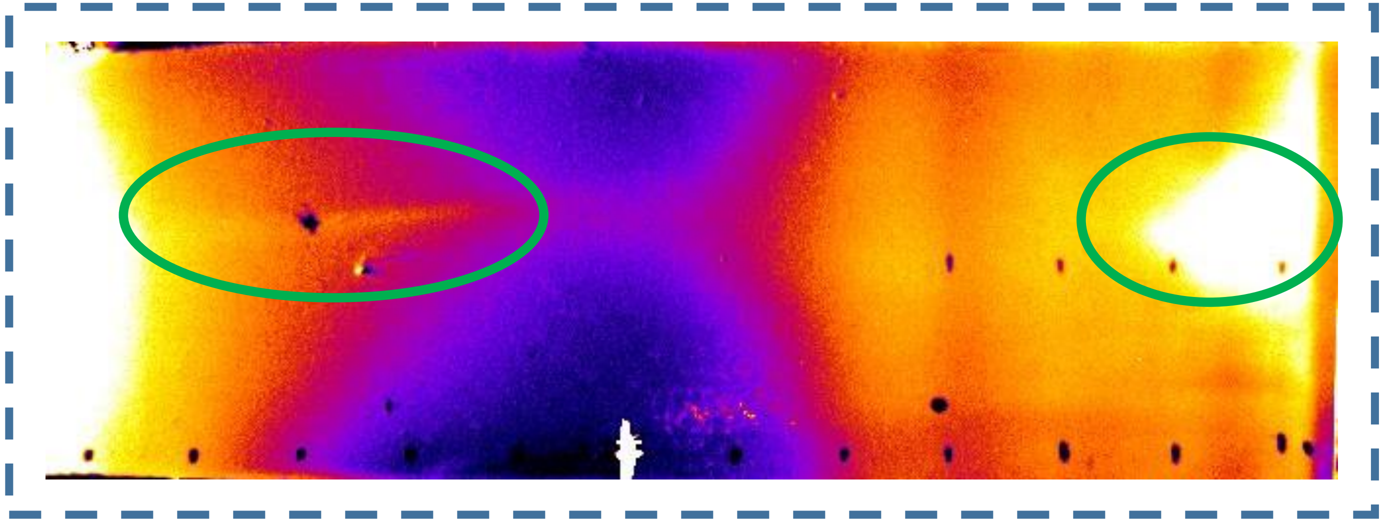
LWFA, self-injection

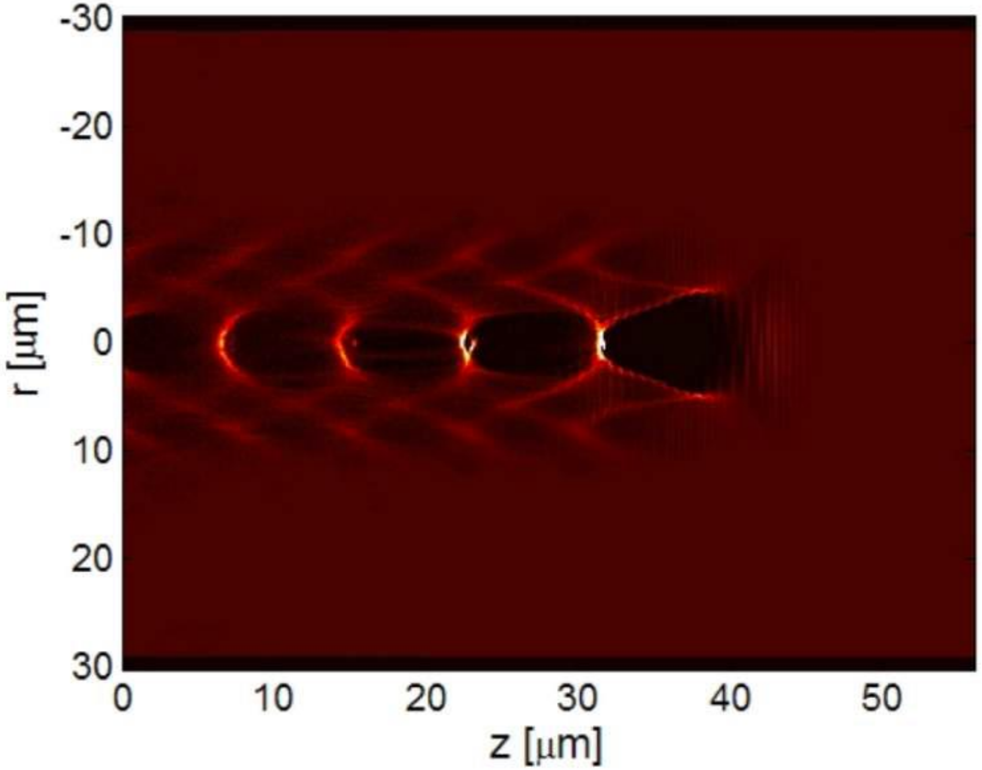
- Plasma accelerations studies
  - E_{laser} = 2 J
  - Pulse length = 35 fs
  - Accelerating length = 2 mm
  - Divergence of e^- beam a few mrad
  - Charge of the beam a few pC











In some cases (and with high repeatability), we have seen "two bunches" separated in energy. A second bubble?

Thank You!