Acceleration and focusing capabilities integrated in a new plasma-based device

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On behalf of the SPARC_LAB collaboration

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Laboratori Nazionali di Frascati

Acceleration and matching in a plasma

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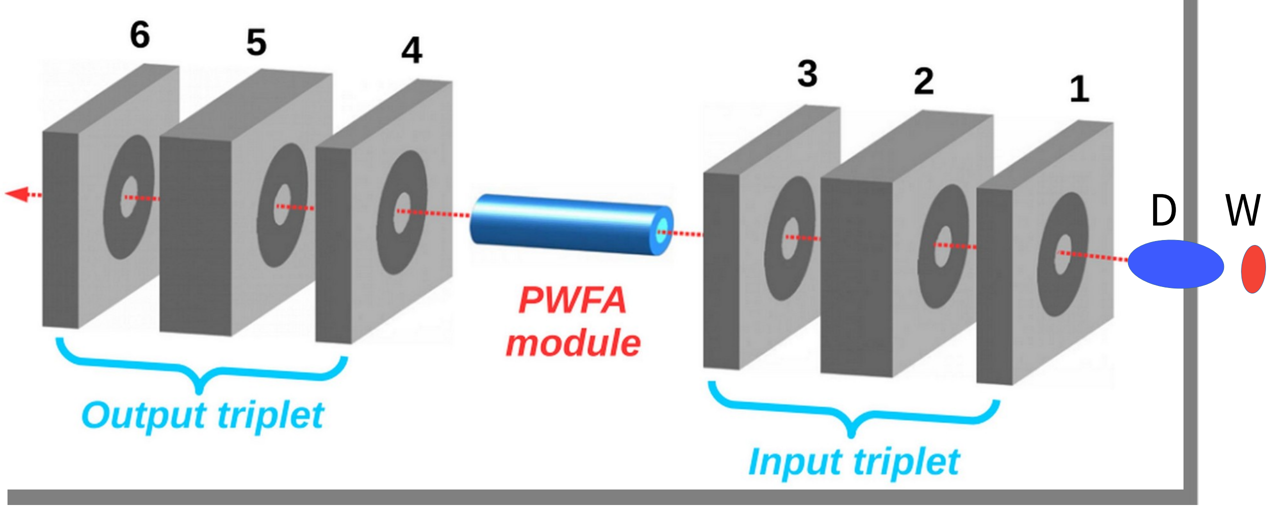


In a **PWFA** the beam must be transversely focused at the plasma entrance

Driver beam charge density (together with plasma density) sets the accelerating gradient

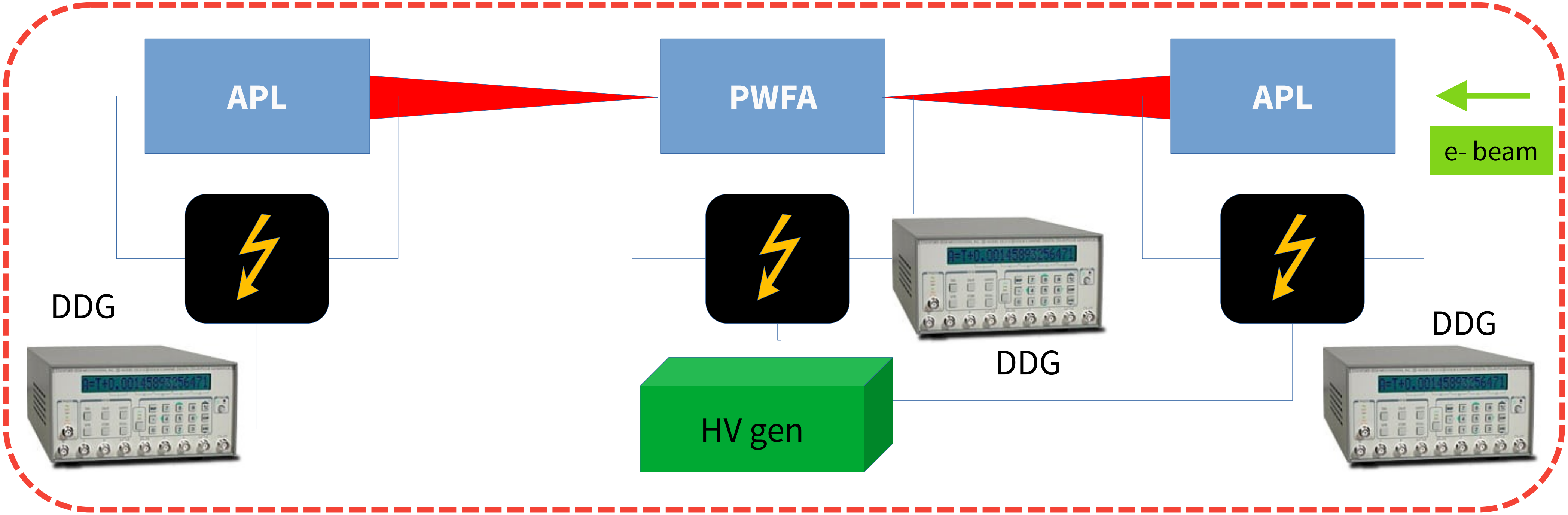
Witness beam must be transversely matched to avoid emittance spoiling

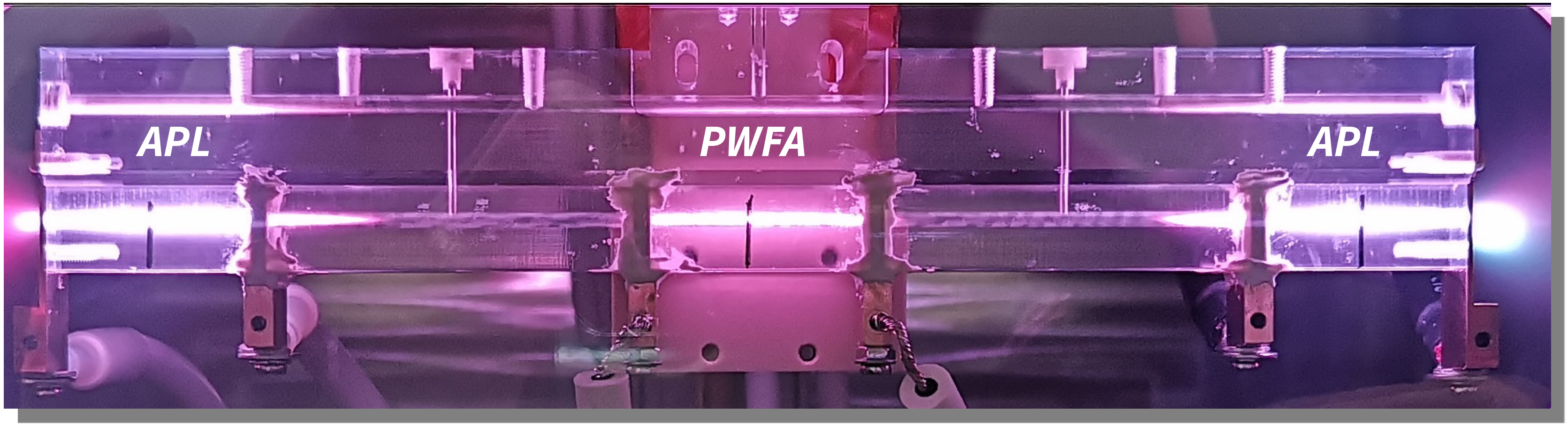
$$\beta_{eq} = \sqrt{\frac{\gamma}{2\pi r_e n_p}}$$

Barov, N., et al., Physical Review E 49.5 (1994): 4407.

The PWFA needs focusing optics upstream (matching) and downstream (capture)

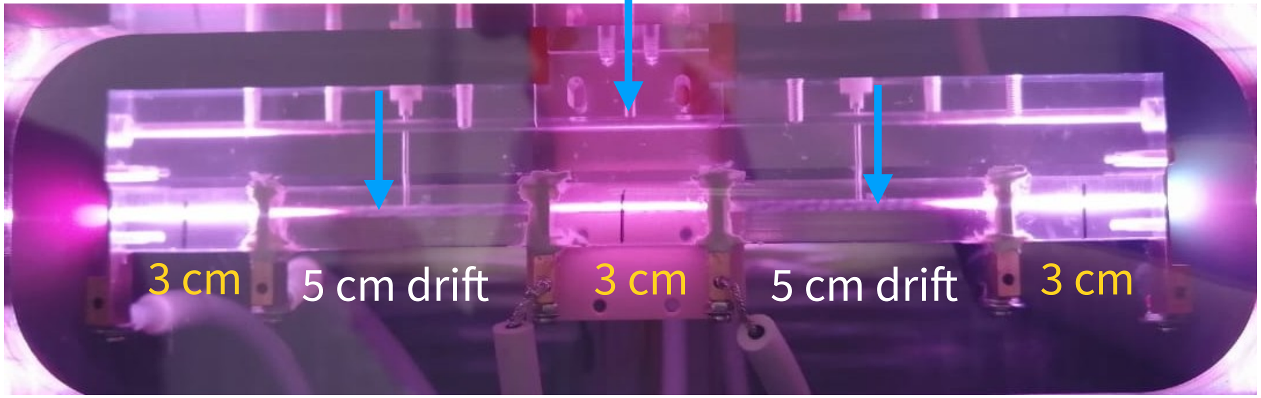
Basic idea of the "all-in-one" capillary



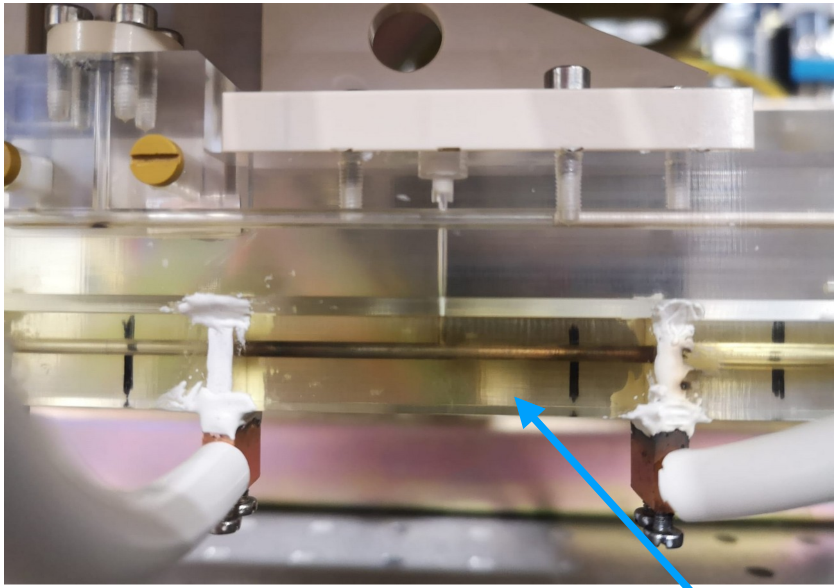


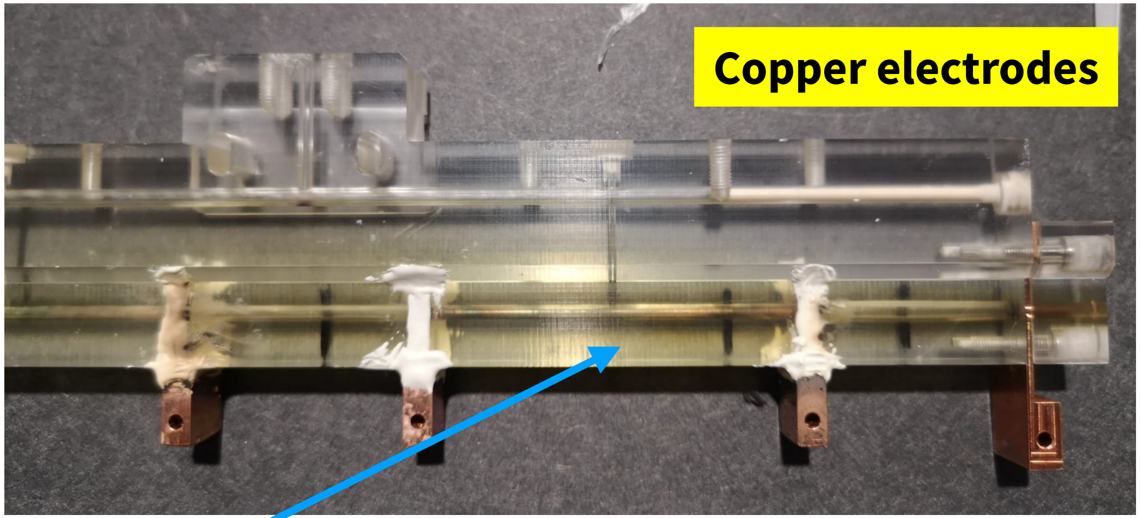
First offline tests (2 inlets prototype)

H$_2$ or N$_2$



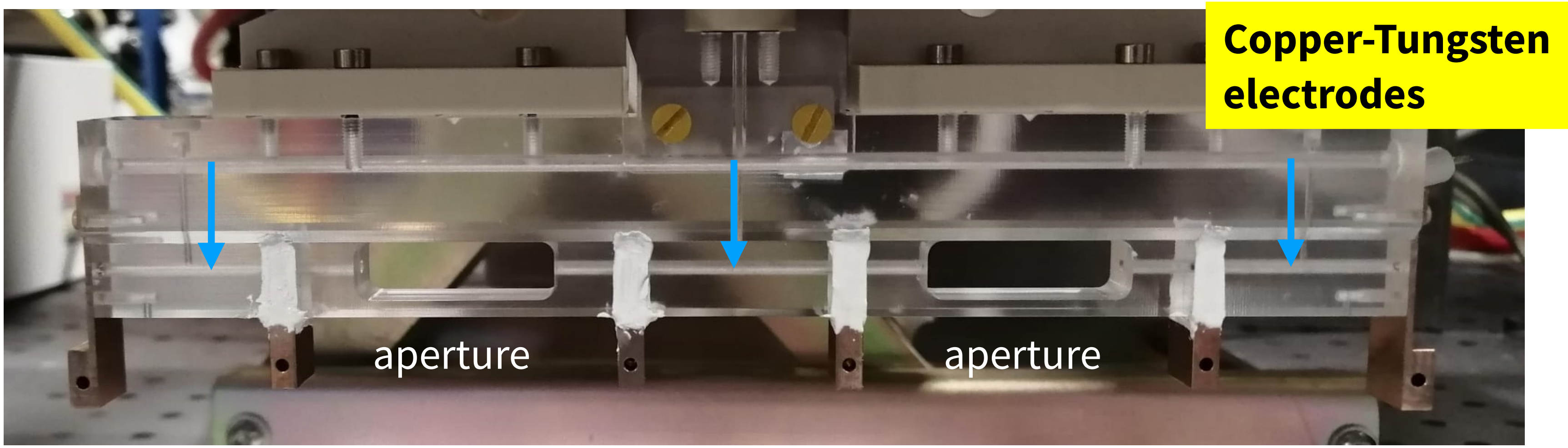
Offline tests
@ PLASMA_LAB

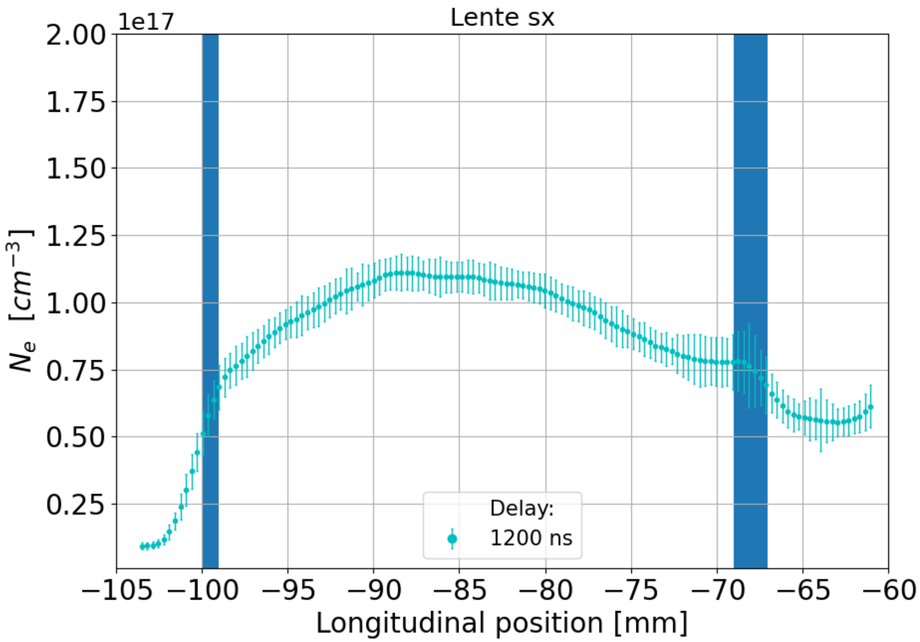


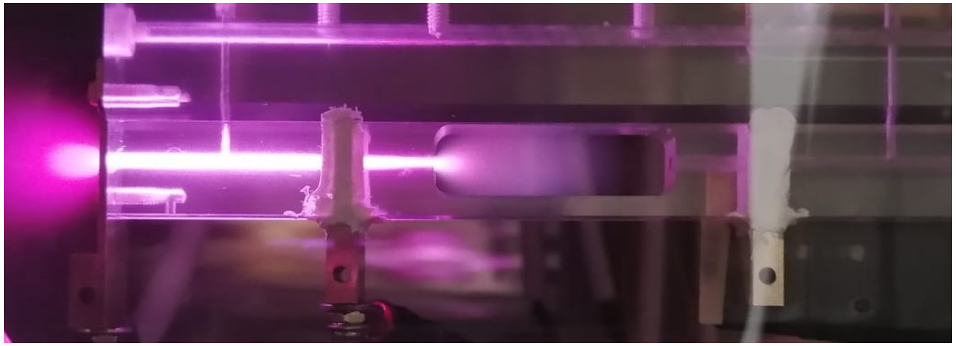


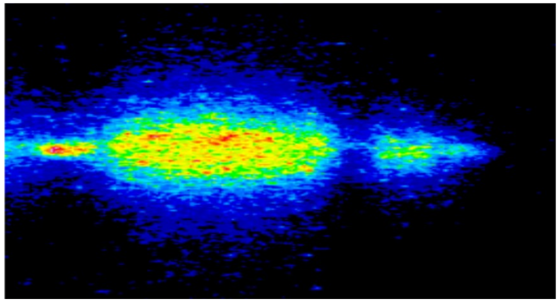
Spattered copper

New prototype (3 inlets)



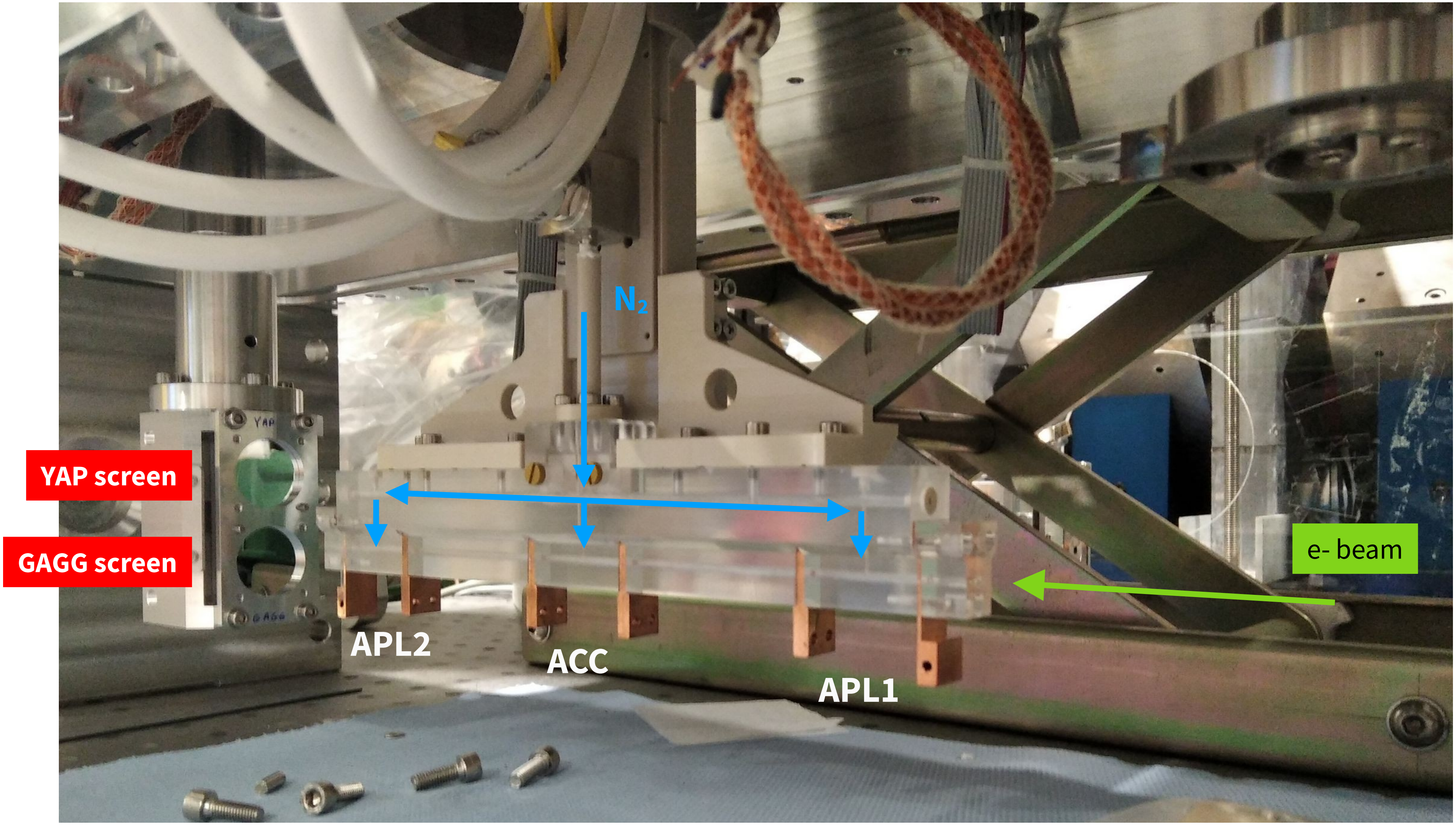




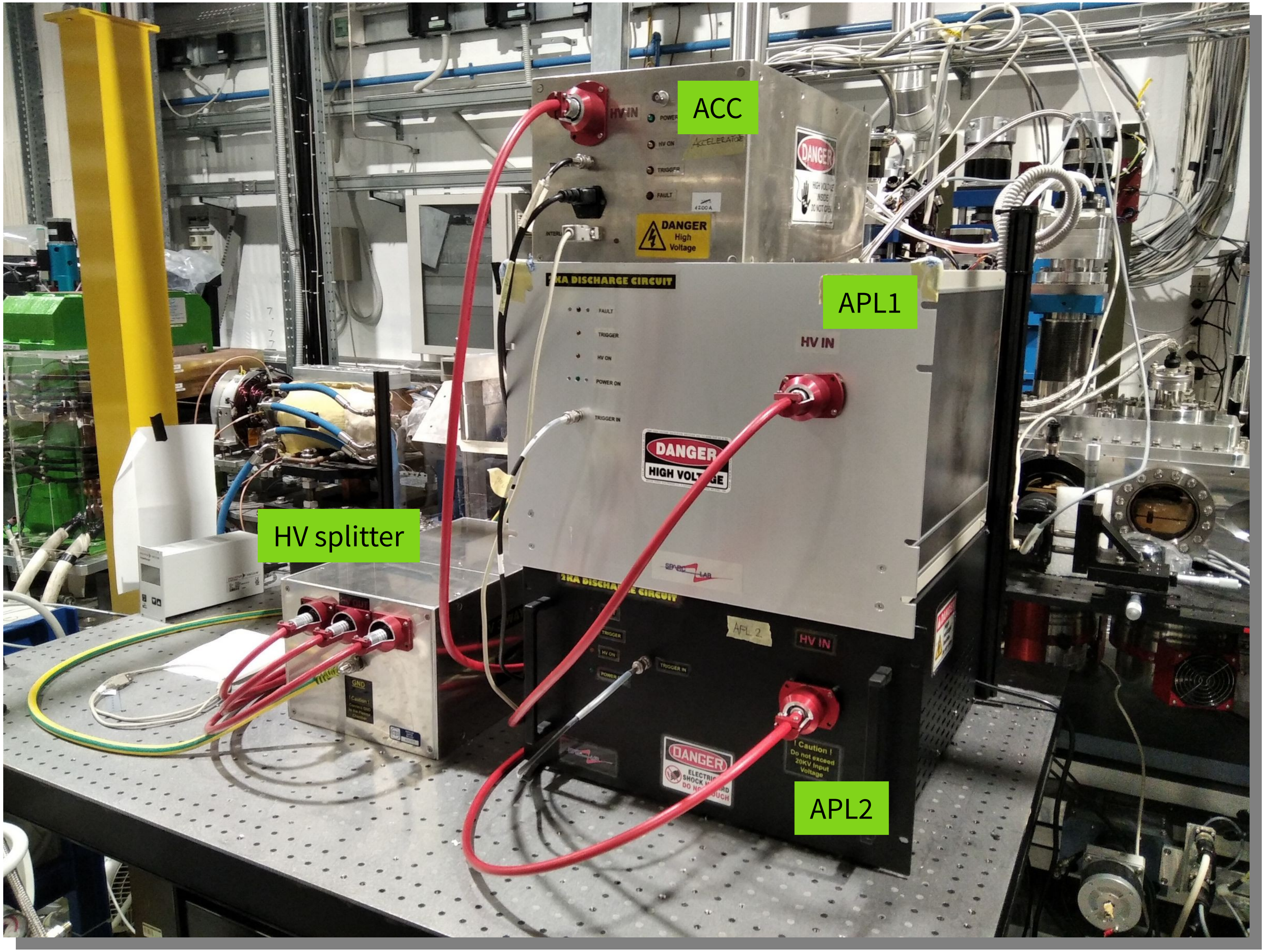


Stark-broadening Measurement with Hydrogen

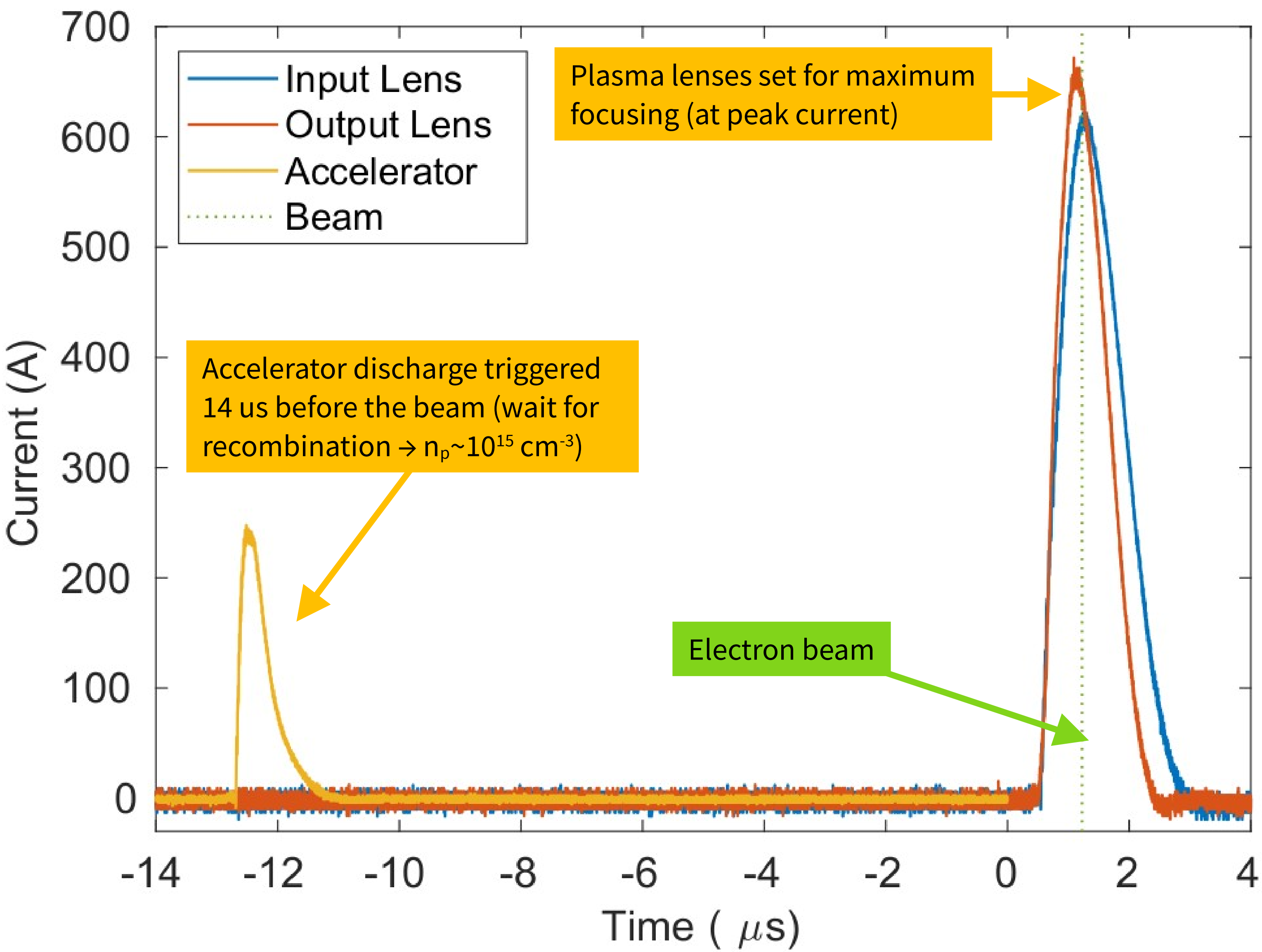
Installation in the vacuum chamber



HV setup



Discharges timing setup



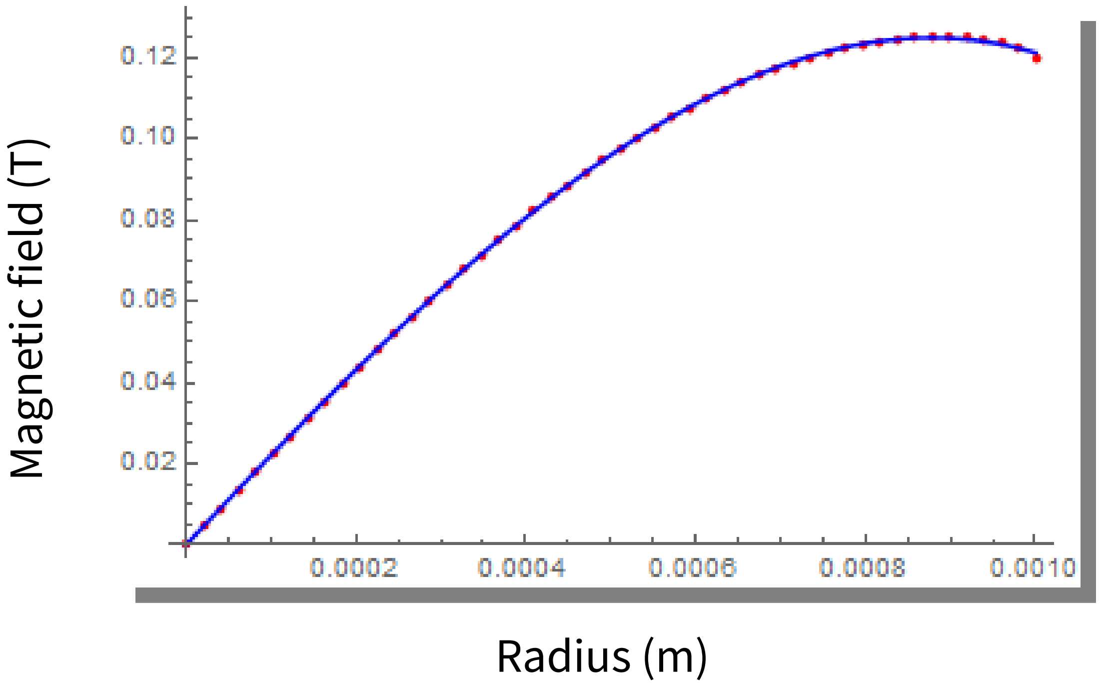
APL considerations

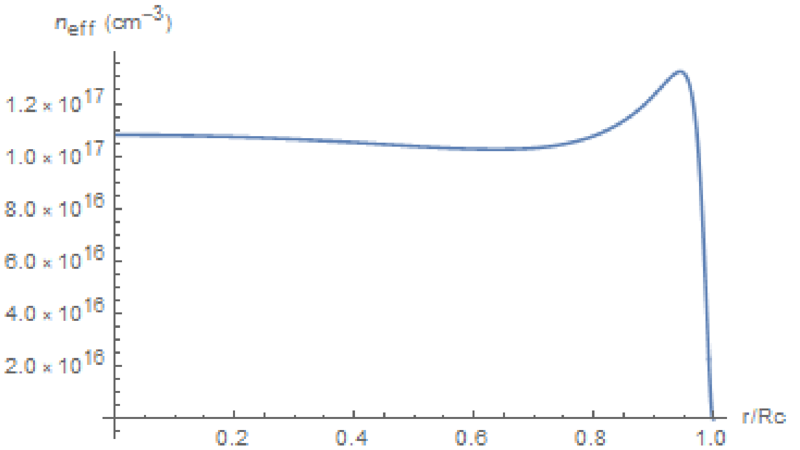
The two APLs are driven by ~600 A to achieve f=5 cm focal lengths @ 75 MeV

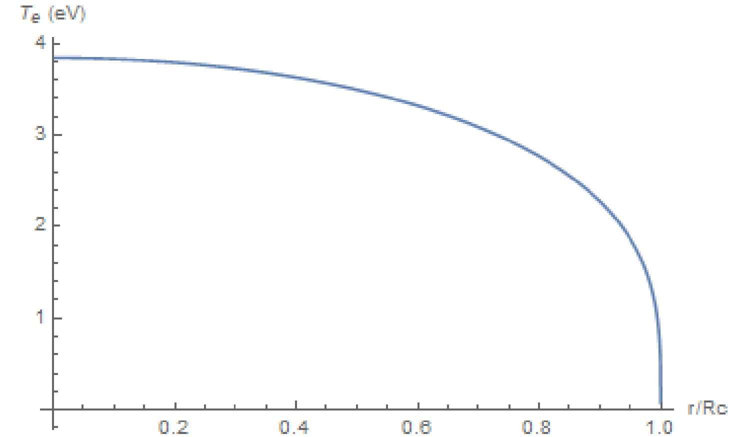
Typical nonlinearity of the magnetic field at large radii → can induce emittance growth/reduced focusing

Bobrova model used for computations

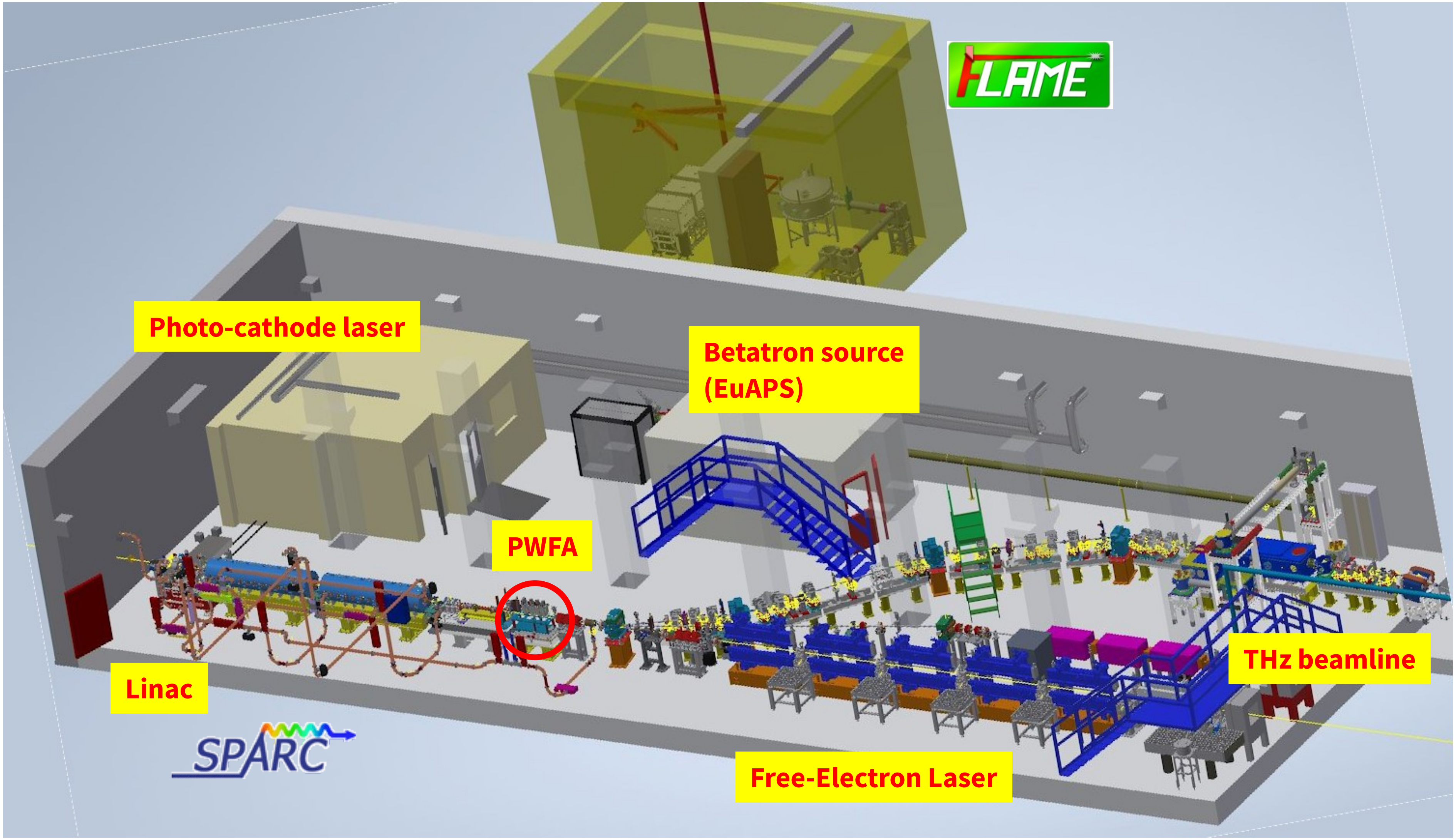
Bobrova, N. A., et al. "Simulations of a hydrogen-filled capillary discharge waveguide." Physical Review E 65.1 (2001): 016407.







SPARC_LAB facility



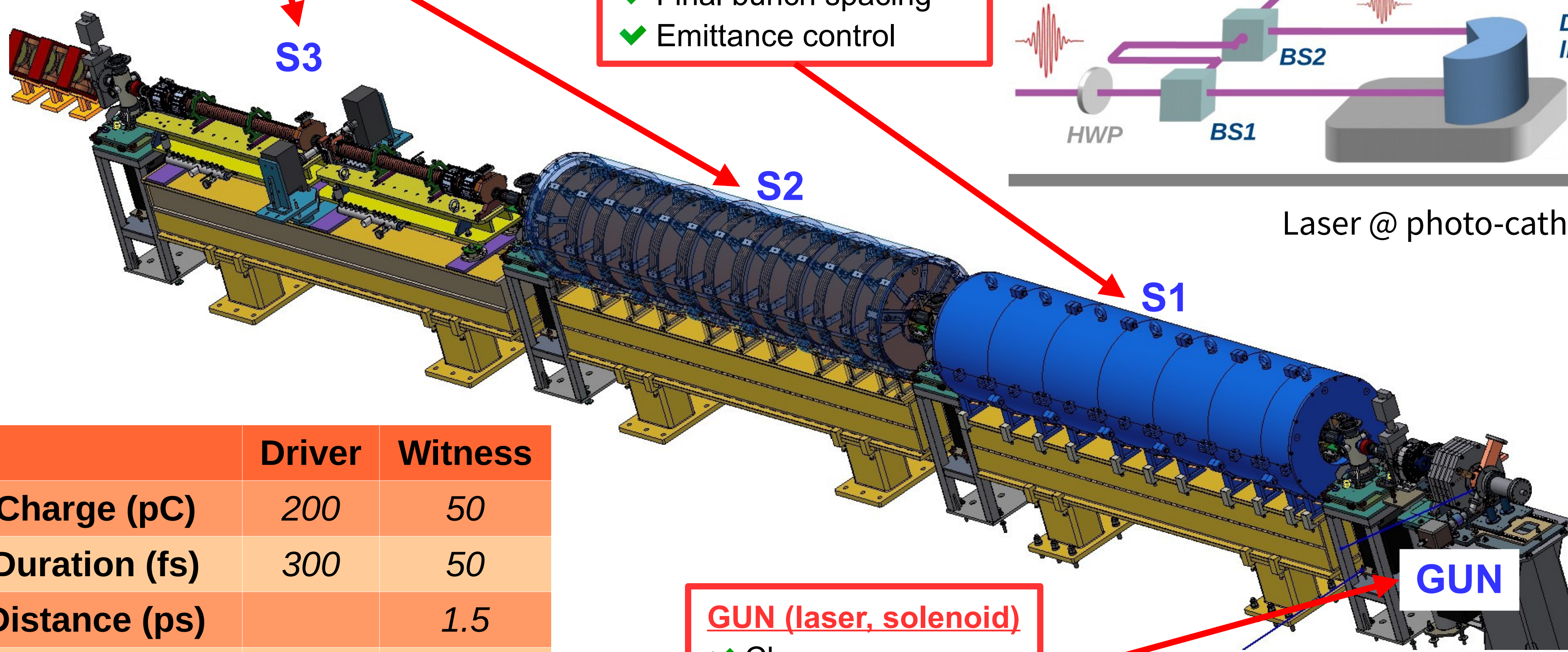
Ferrario, M., et al. "SPARC_LAB present and future." NIMB 309 (2013): 183-188.

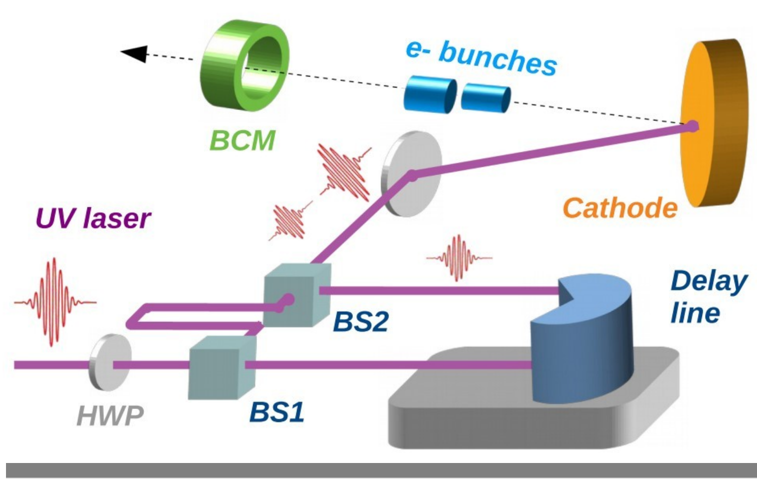
Generation of the driver-witness beam

S2-S3 (gradient and phase)
- Energy spread tuning
- Final energy

S1 (gradient and phase)
- Bunch compression
- Final bunch spacing
- Emittance control

GUN (laser, solenoid)
- Charge
- Initial bunch spacing
- Emittance control

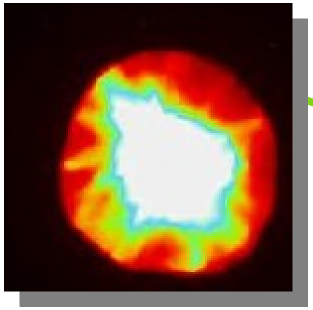




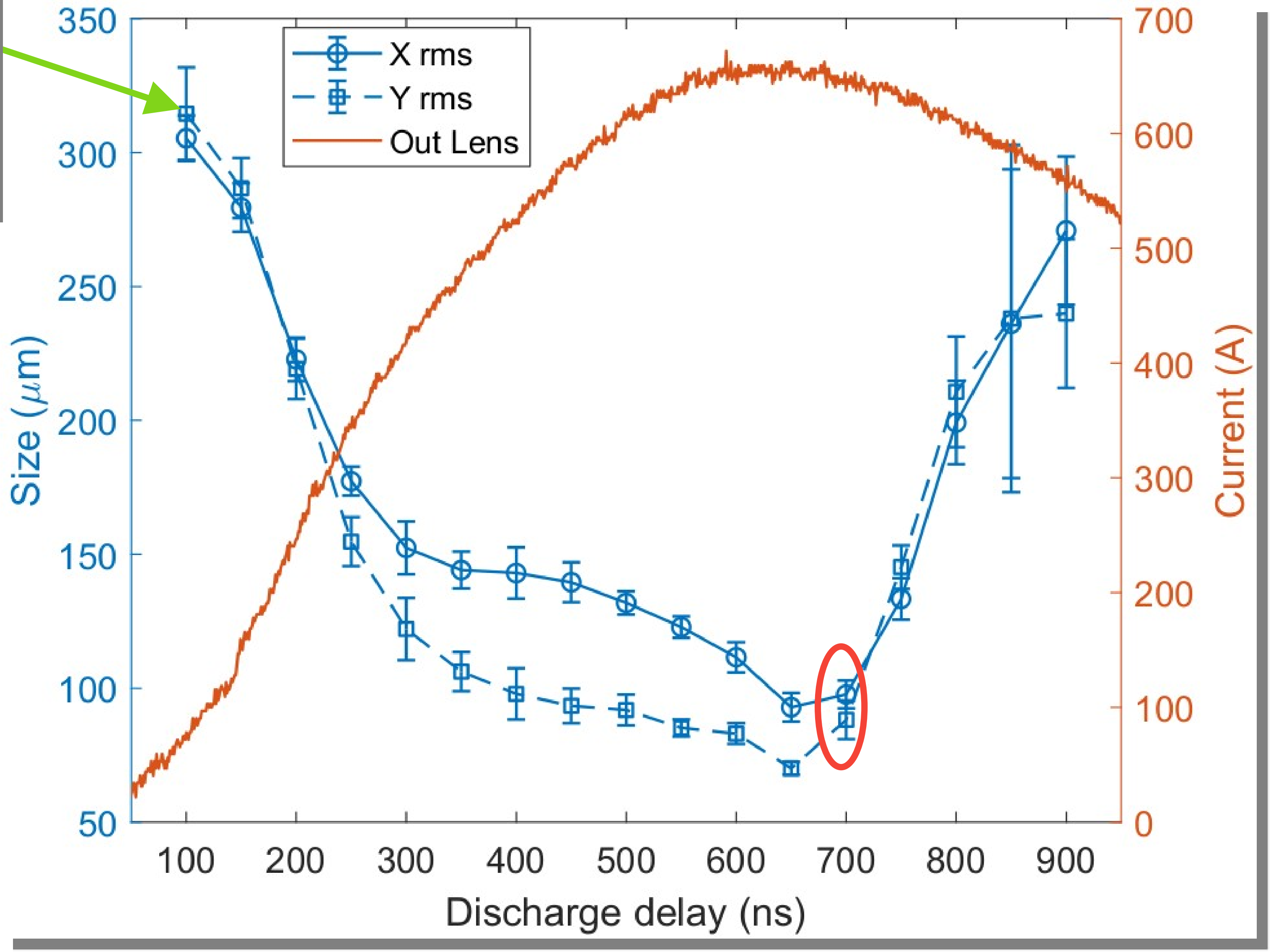
Laser @ photo-cathode

	Driver	Witness
Charge (pC)	200	50
Duration (fs)	300	50
Distance (ps)		1.5
Spot size (um)	260	200
Emittance (um)	7	4

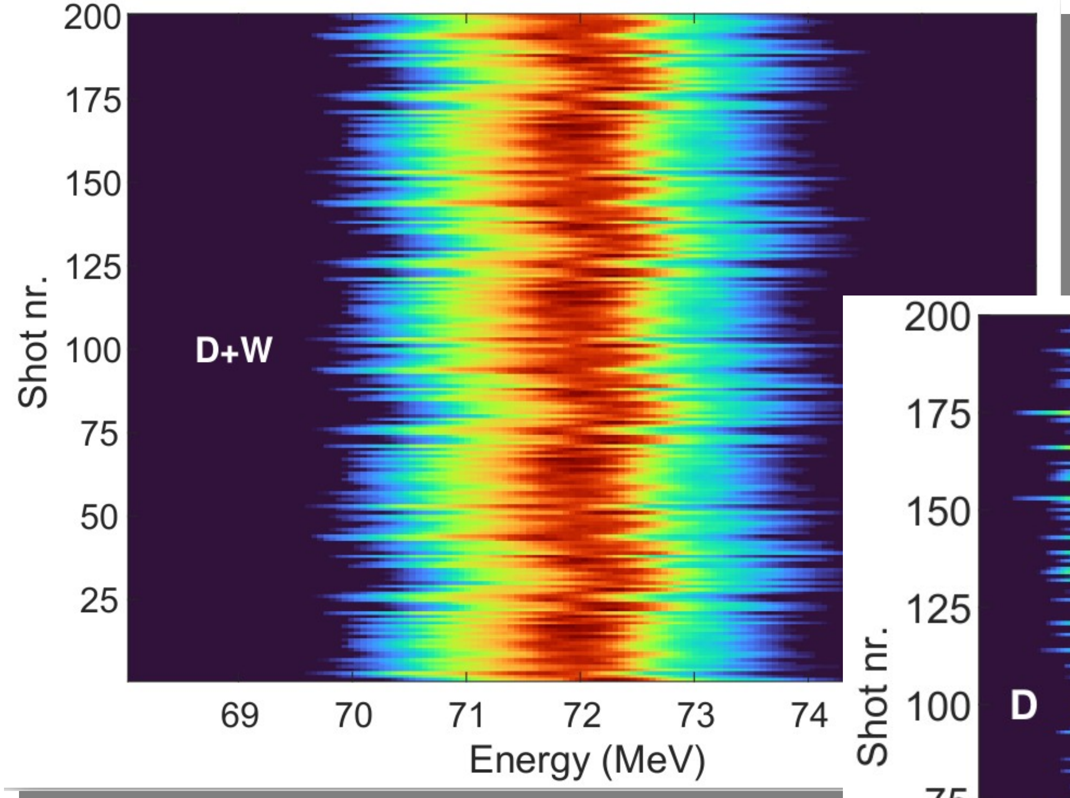
APL scan



Scan obtained using only the APL2 (APL1 and ACC turned OFF)

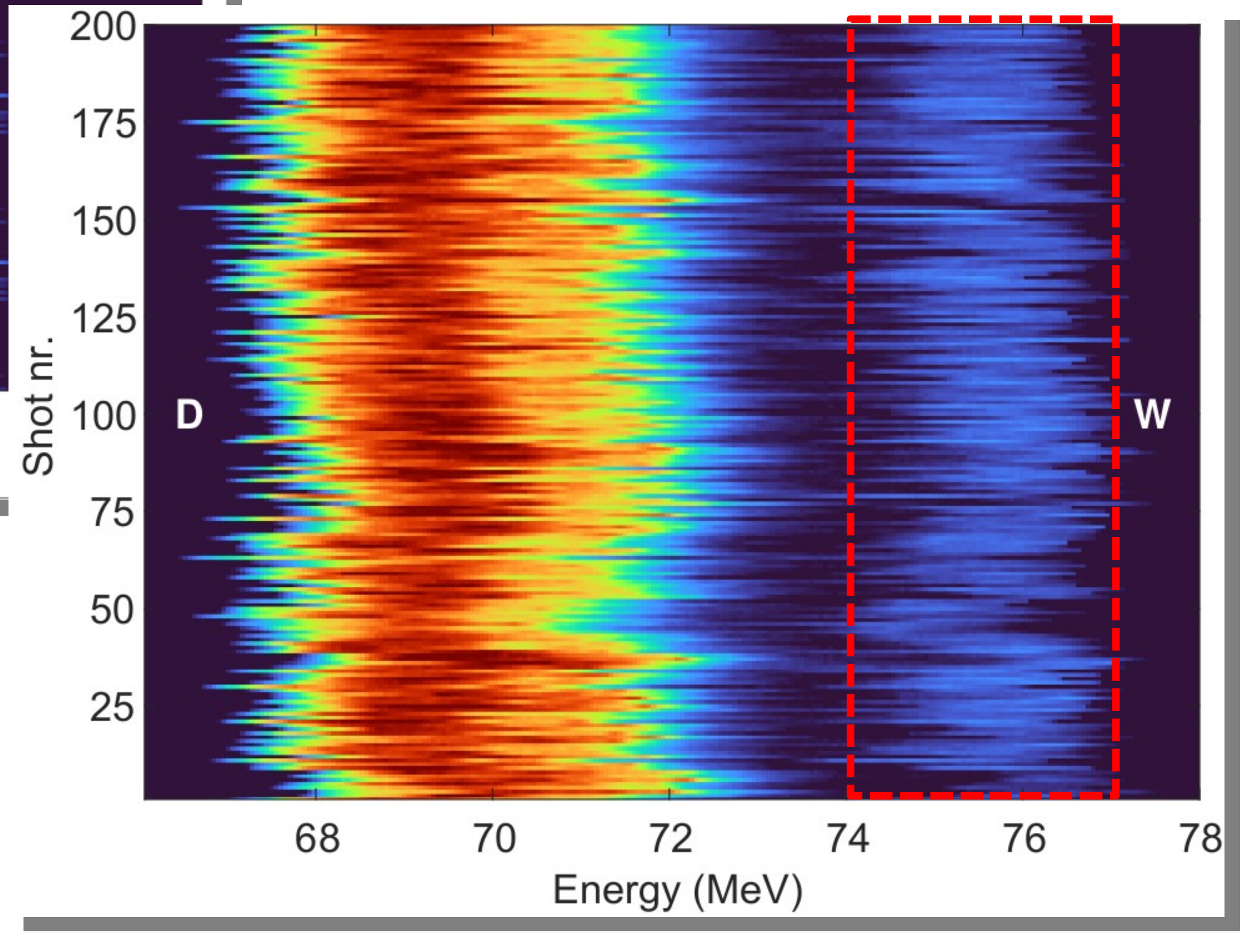


First accelerated witness



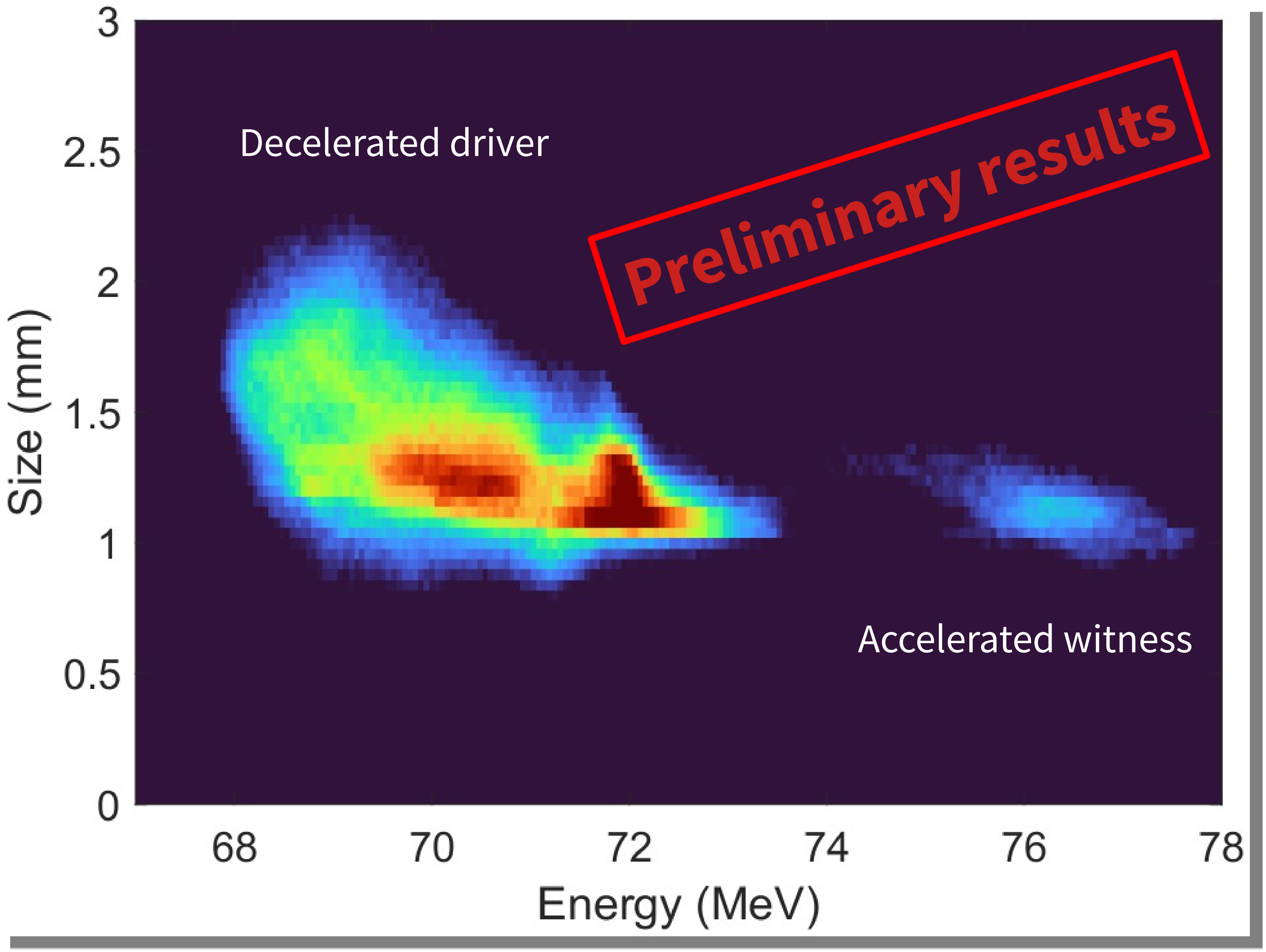
Lenses ON, Accelerator **OFF**

Lenses ON, Accelerator **ON**



Preliminary results

Single-shot spectrum



Conclusions

In a PWFA is essential to properly handle the electron beams before the injection into the plasma

Need to make the focusing optics compact too

The proposed prototype provides an integrated solution merging a PWFA module with two active-plasma lenses

Preliminary results show a proof of witness acceleration with ~130 MV/m

The small obtained gradient is probably due to the poor focusing obtained with the input APL

Need to optimize the input beam spot size to avoid emittance growth due to APL nonlinearity

Proof of concept → nothing has been optimized yet for the accelerated witness (spread, emittance, etc.)

To be done in the next experimental run

Thanks!

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