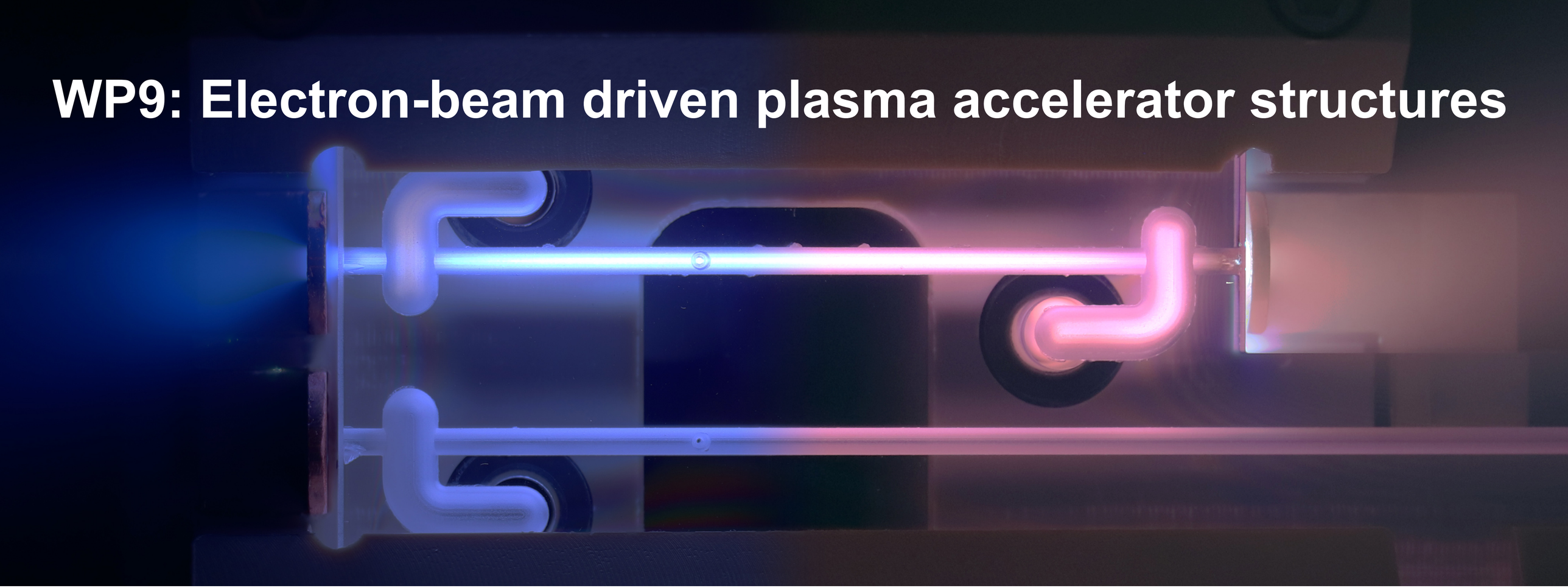
WP9: Electron-beam driven plasma accelerator structures



Jens Osterhoff for the WP9 team (with material by M. Ferrario, S. Romeo, P. Niknejadi, C. Lindstrøm)
MPA, Plasma Accelerator Group, Accelerator Division

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

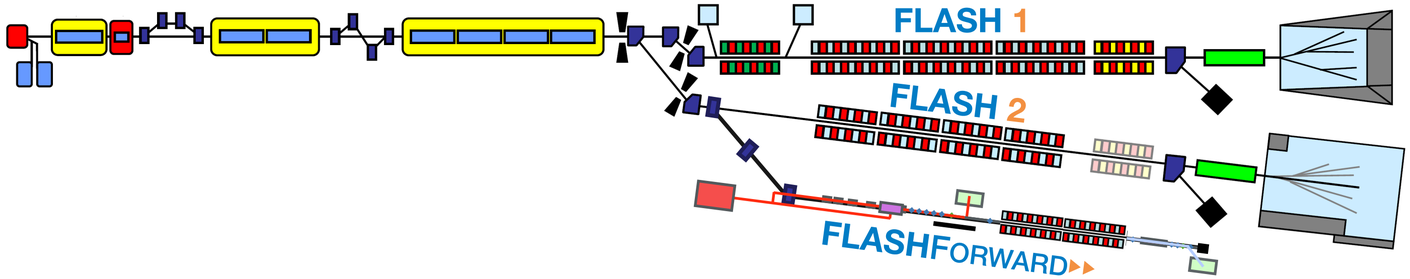
EuPRAXIA

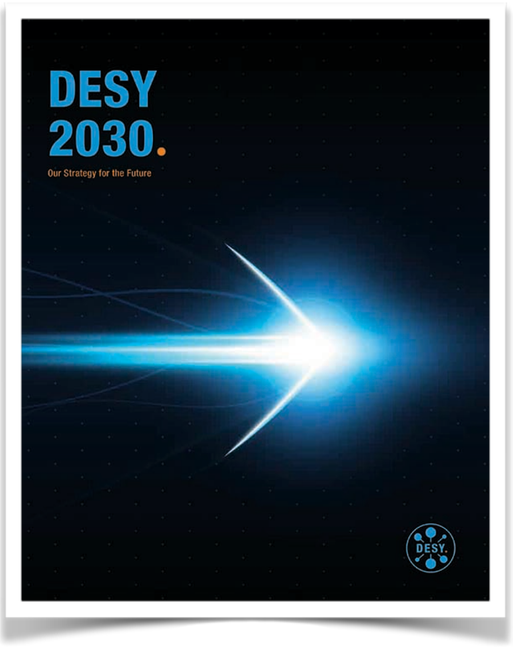
INFN Istituto Nazionale di Fisica Nucleare

DESY.

WP9 covered conceptual design for beam-driven EuPRAXIA case

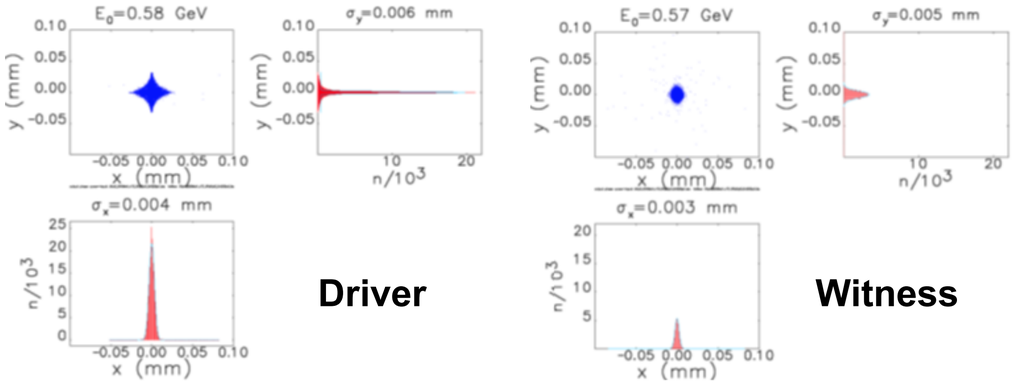
INFN focussed on design for PWFA construction site at Frascati, DESY on high-average power aspects



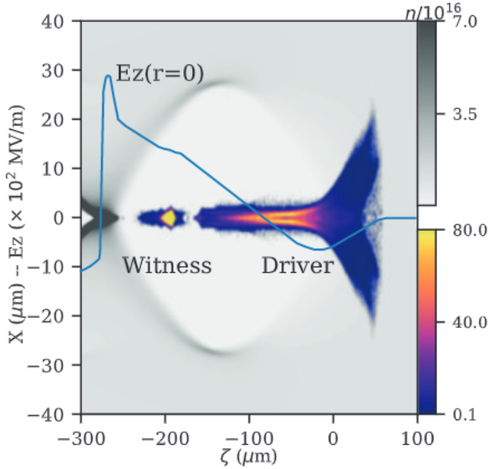


1 GeV beam driven plasma acceleration S2E

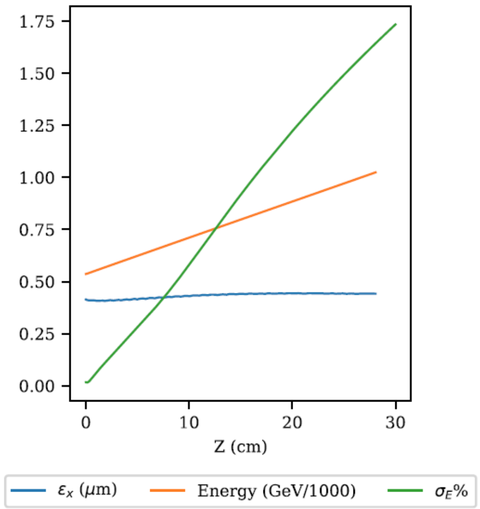
Driver + Witness Beams simulated in T-Step

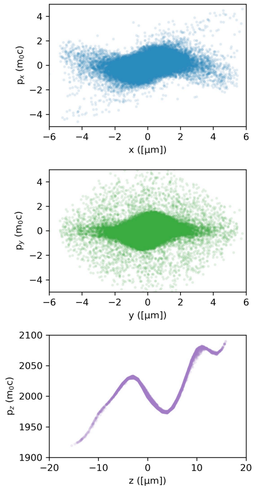


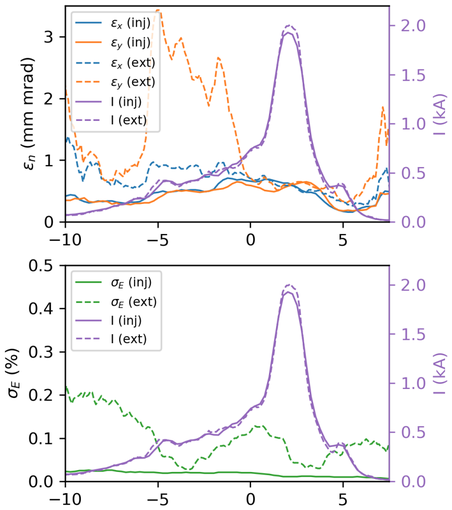
Beam	units	Driver-IN	Driver-OUT	Witness-IN	Witness-OUT
Charge	pC	200	200	30	30
σ_x	μm	8	6.4	1.47	1.42
σ_y	μm	3.1	10	3.17	1.4
σ_z	μm	52	50	3.85	3.8
ε_x	mm mrad	2.56	4.1	0.6	0.96
ε_y	mm mrad	4.8	11.4	0.55	1.2
σ_E	%	0.2	20	0.07	1.1
E	MeV	567	420	575	1030
Best Slice					
current	kA			2	2.0
ε_x	mm mrad			0.59	0.57
ε_y	mm mrad			0.58	0.62
σ_E	%			0.011	0.034



$n_p = 1\times10^{16}\ \mathrm{cm}^{-3}$



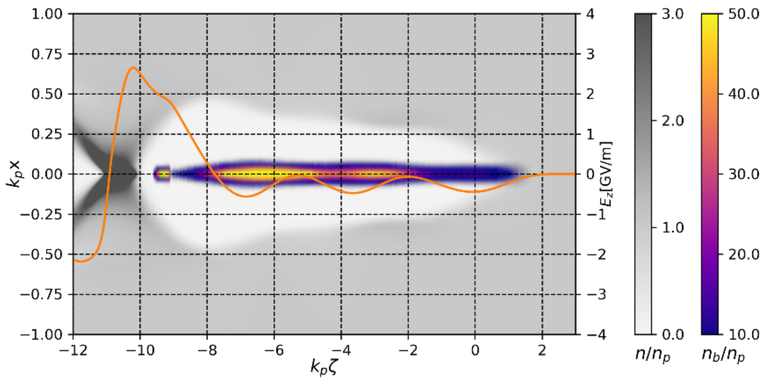




5 GeV beam driven plasma acceleration

3 Drivers + Witness

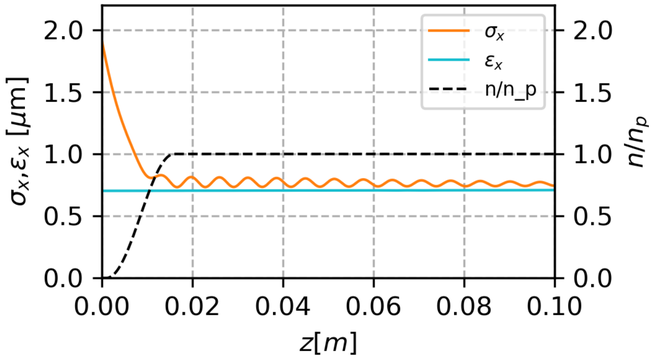
$n_p = 2.5 \times 10^{16}\ \mathrm{cm}^{-3}$



$E_z = 1.65\ \mathrm{GV/m}$

$R_T = 3.65$

$\gamma_{fin} = 9800\ (5\ \mathrm{GeV})$



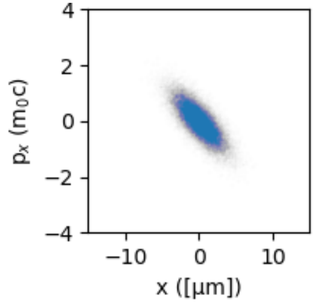
High transformer ratio/High energy transfer

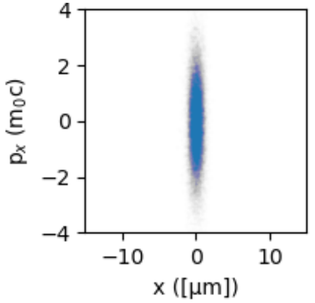
Driving bunches parameters

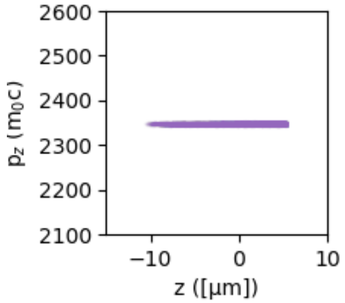
- $\gamma = 2348$
- $\varepsilon_{n(x,y)} = 1\mathrm{mm\ mrad}$
- $\sigma_z = 33\mu\mathrm{m}$
- $Q_{tot} = 40 + 140 + 270\mathrm{pC}$

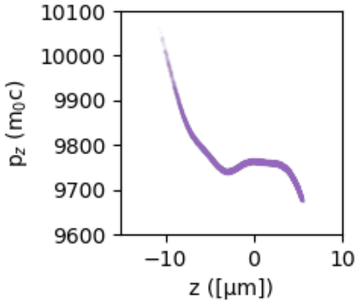
Witness bunch parameters

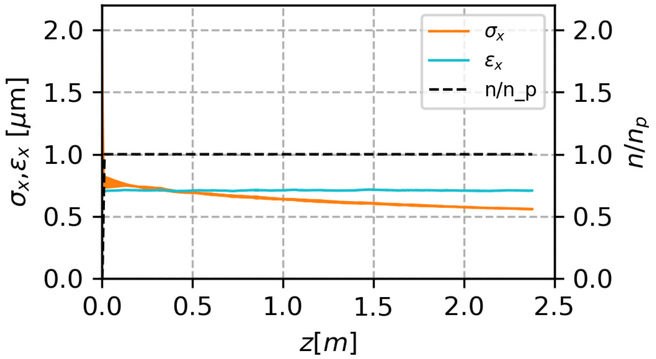
- $\gamma = 2348$
- $\varepsilon_{n(x,y)} = 0.7\mathrm{mm\ mrad}$
- $\sigma_z = 16(3.8\ \mathrm{rms})\mu\mathrm{m}$
- $Q = 30\mathrm{pC}$

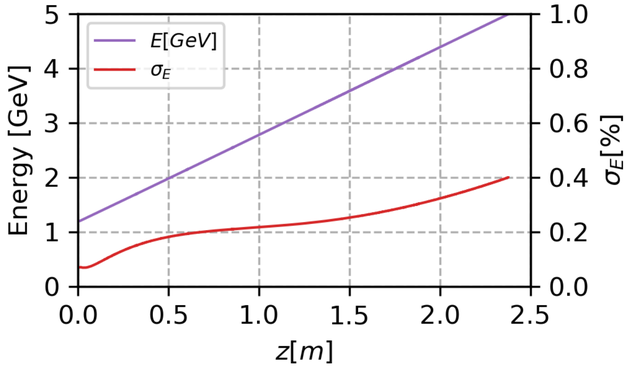






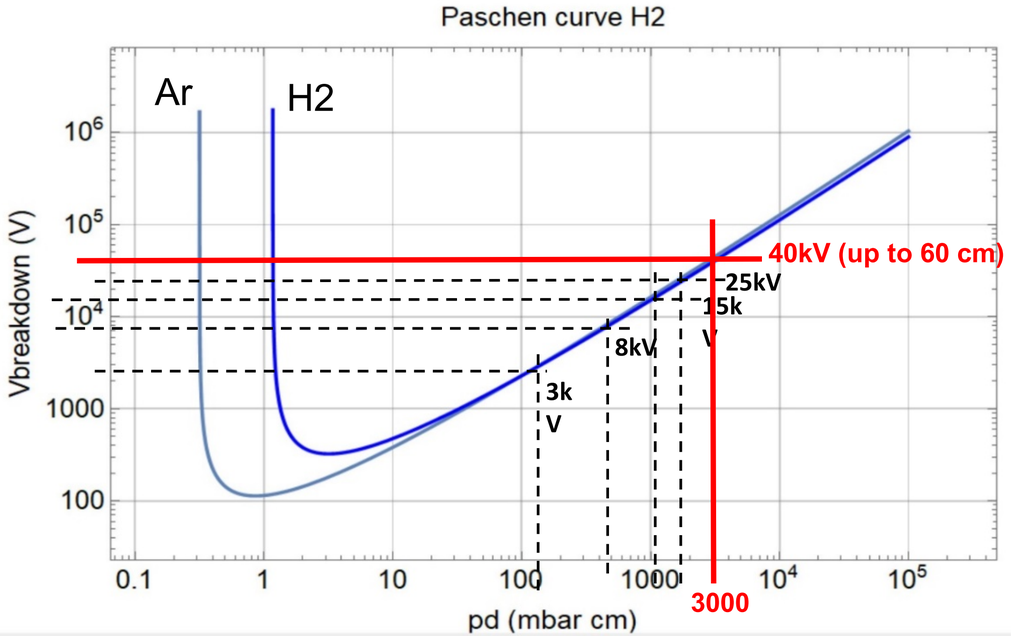




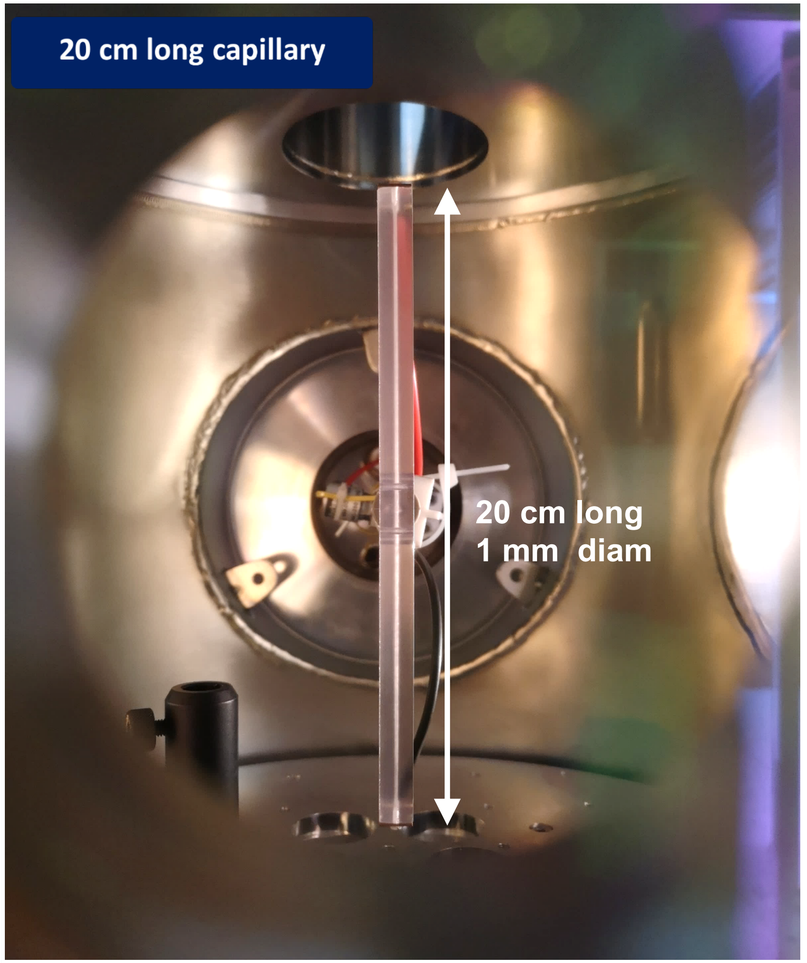


Plasma accelerator module: **EuPRAXIA case**

40 cm-long capillary (1.5 GV/m) (0.5 to 1.1 GeV case)
10^{16} cm^{-3} of the plasma density (E_0 ~ 13 GV/m)

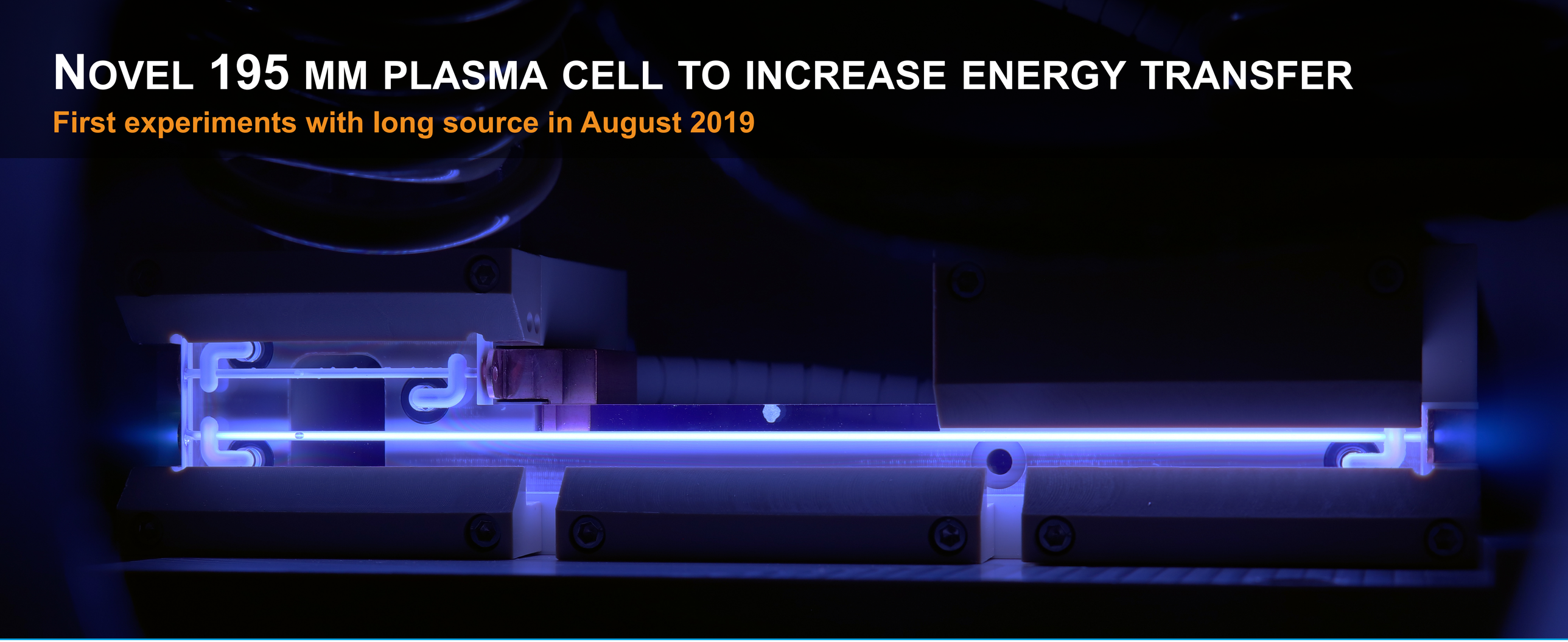


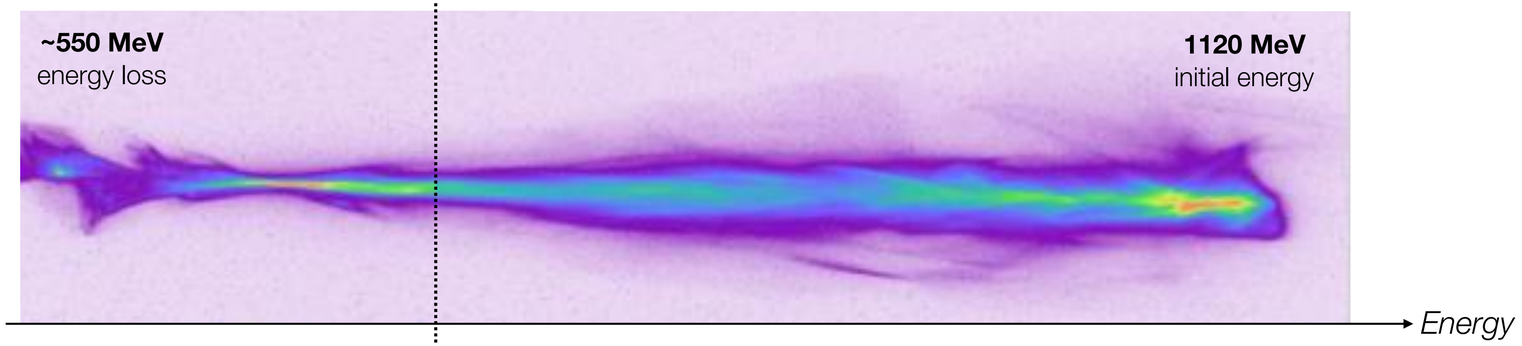
- We are going to test the EuPraxia case by using the plasma module at SPARC_LAB
- We have already tested 10 cm-long capillary and now we are working on 20-cm long capillary (14-15 kV), but we have to optimize the discharge/density
- We expect to reach around 60 cm at maximum voltage around 35-40kV



Novel 195 mm plasma cell to increase energy transfer

First experiments with long source in August 2019





Goals

- > Drive depletion demonstration
- > Beam loading control
- > Efficiency maximization
- > Passive plasma beam dumps

FLASHFORWARD▸▸ roadmap aims at 10 kW plasma booster stage

Plan covers major plasma accelerator challenges

2018 Beam plasma dechirper • D'Arcy *et al.*, **PRL** 122, 034801 (2019)

2019 **Efficiency maximization & beam loading control**

Detection of slice properties with fs resolution

kHz to MHz plasma response

Drive depletion

Low-emittance beams from plasma

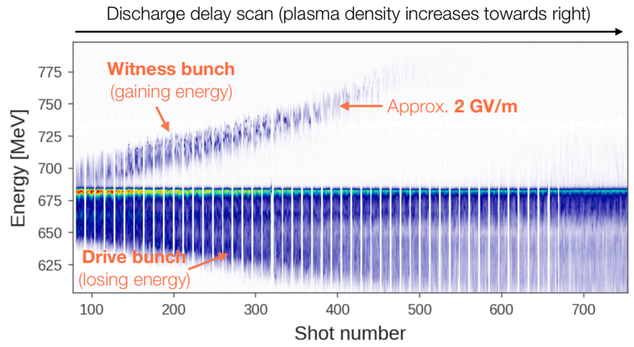
Emittance preservation

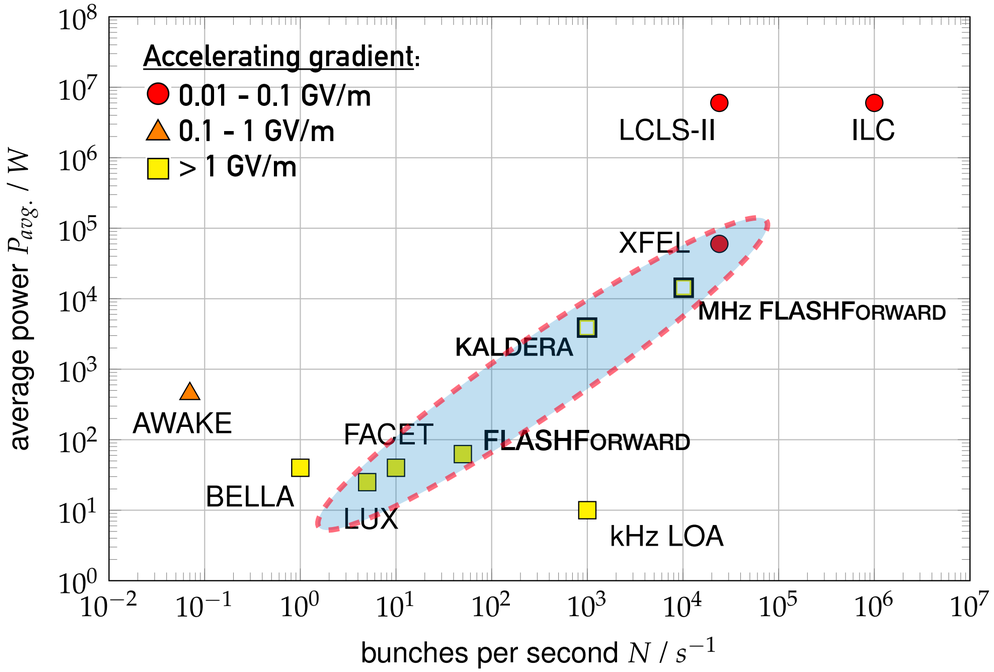
2022 FEL gain studies

2024 **10 kW avg. power operation**

2026 **10 kW stage with 40% efficiency & witness property conservation**

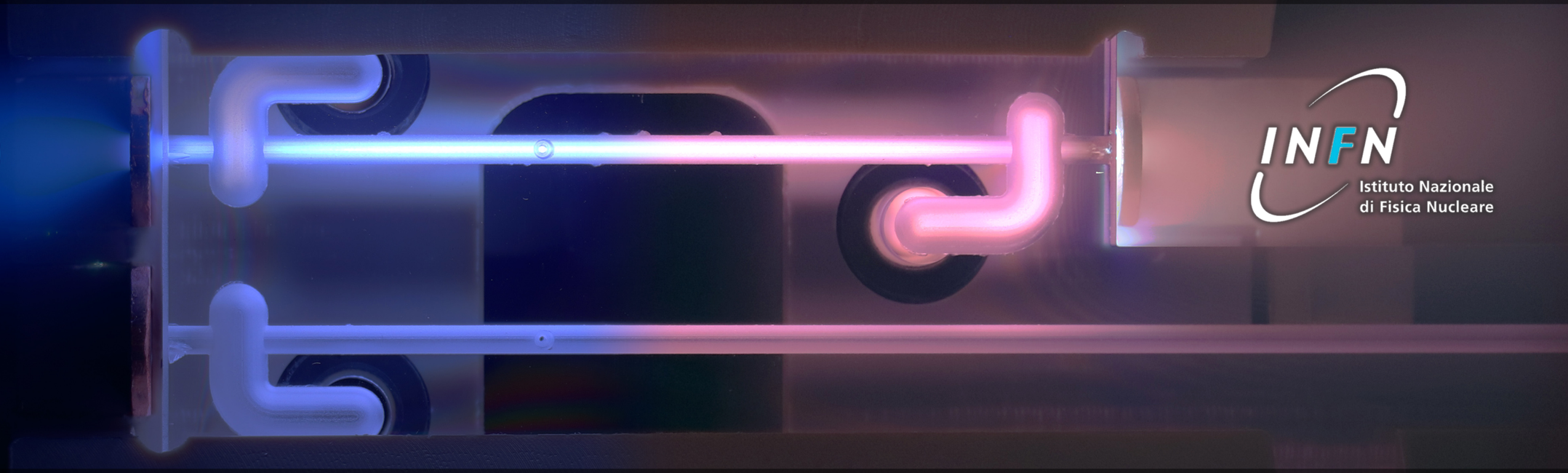
2030





WP9: Electron-beam driven plasma accelerator structures

Summary



- INFN and DESY made significant progress within the scope of EuPRAXIA on beam-driven systems
- INFN → EuPRAXIA@SPARC_LAB / DESY → High average power PWFA at FLASHForward
- To maximize synergies and success of EuPRAXIA in next project phase
  - need to clearly define common goals
  - execute a well planned fully coherent strategy
  - merge efforts to maximize cross-fertilization

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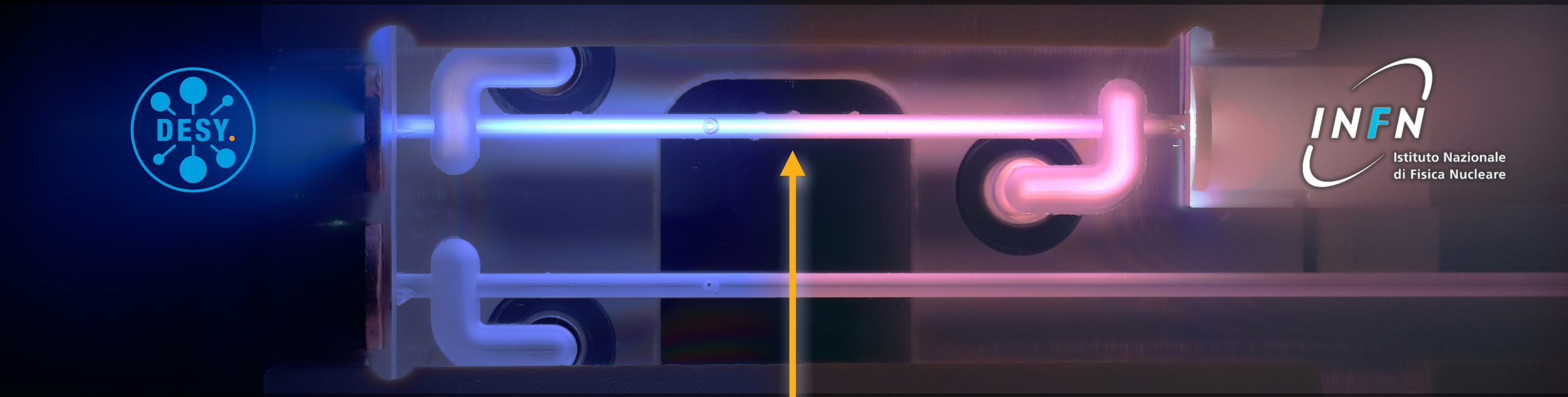

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