

Scalable Plasma Source R&D

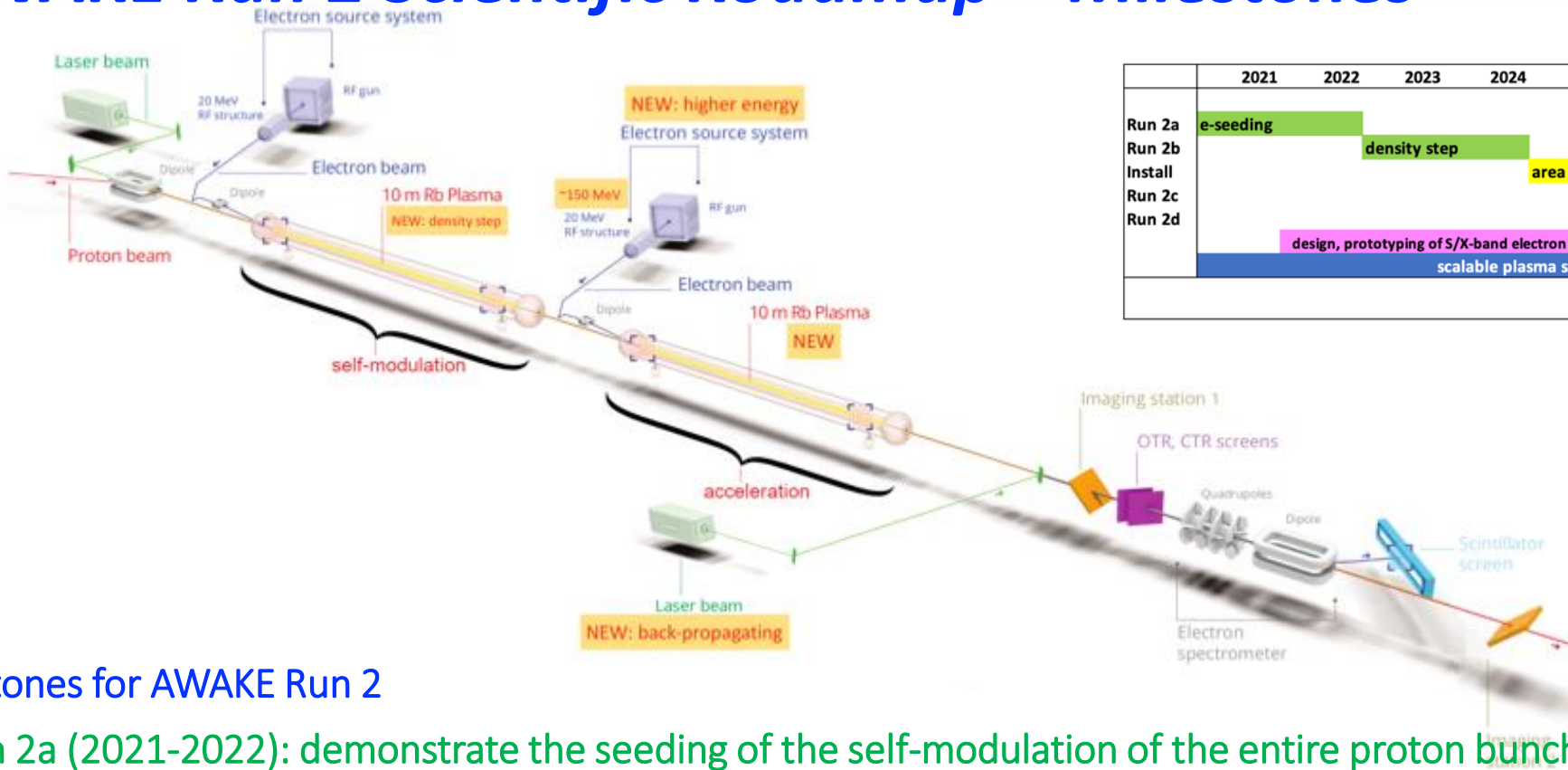
June 6, 2023

Edda Gschwendtner, CERN

To Discuss:

- What is the status of the various groups' contribution?
 - What is their R&D program?
 - What are the committed resources?
 - What is the time-line of the groups?
-
- Agree on a date for review
 - Agree on an agenda for review

AWAKE Run 2 Scientific Roadmap – Milestones



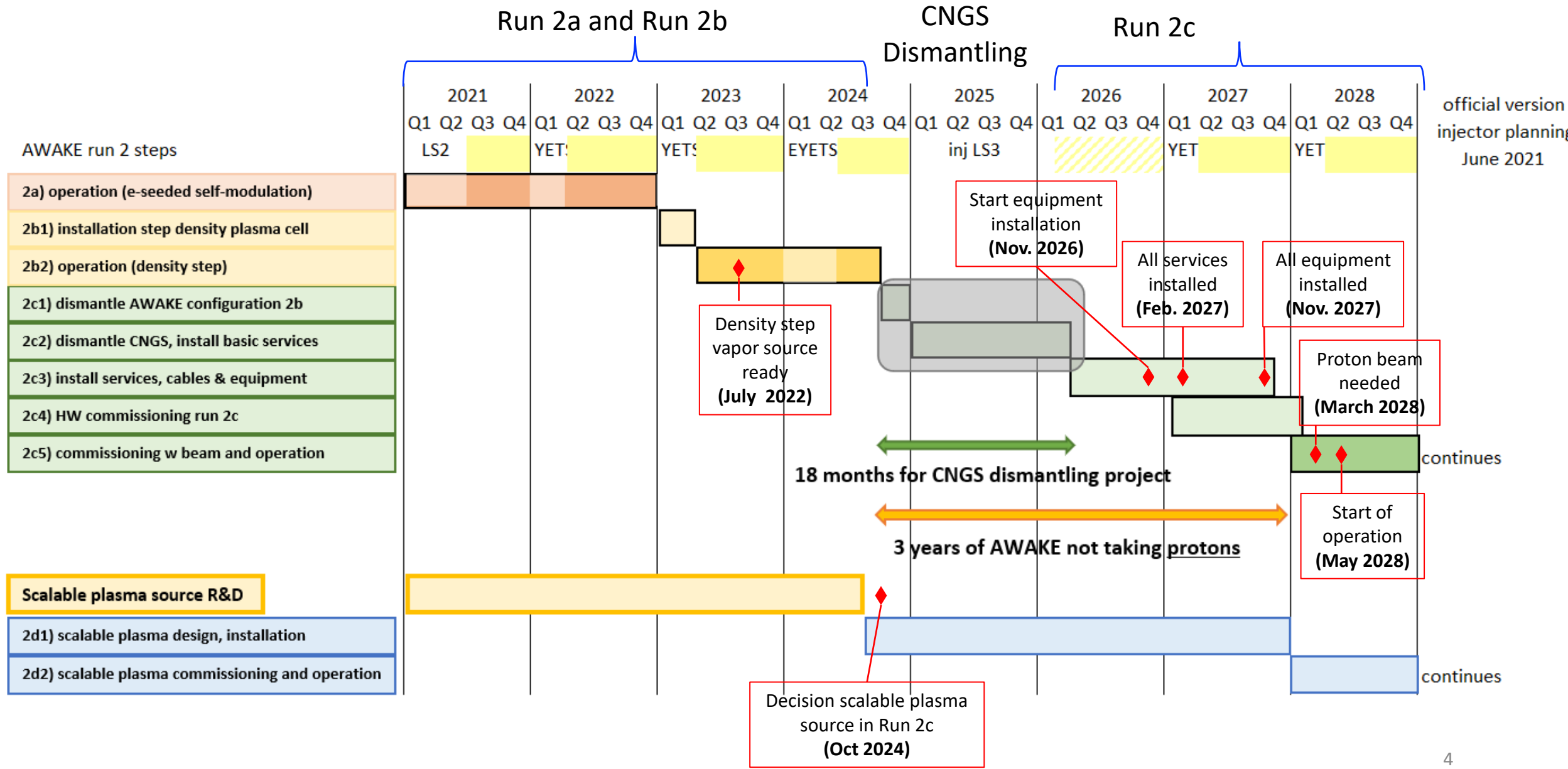
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Run 2a	e-seeding					CERN Longshutdown 3					
Run 2b		density step									
Install				area extension, installation							
Run 2c							external injection				
Run 2d					design, prototyping of S/X-band electron source, beam line, laser system					scalable plasma accel.	
	scalable plasma source development										
											HEP Application

Milestones for AWAKE Run 2

- Run 2a (2021-2022): demonstrate the seeding of the self-modulation of the entire proton bunch with an electron bunch
- Run 2b (2023-2024): maintain large wakefield amplitudes over long plasma distances by introducing a step in the plasma density
- LS3: CNGS dismantling, installation of Run 2c
- Run 2c (2028-2029): demonstrate electron acceleration and emittance preservation of externally injected electrons.
- Run 2d (2021-): development of scalable plasma sources to 100s meters length with sub-% level plasma density uniformity.

➔ Propose first applications for particle physics experiments with 50-200 GeV electron bunches!


AWAKE Run 2 Global Schedule with Milestones



Scalable Plasma Sources: From R&D to Tunnel

1) R&D 2021-2024 Address physics and technical challenges


Helicon Plasma Source



← 2.5 m unit module →

- Design and build **scalable tunnel-compatible prototype**
- Tailor all required parameters to **achieve desired density x homogeneity**
- Guarantee **stable and reproducible control and operation**
- Trade off to scale properly address physics and technical challenges
- Optimize with **extensive modeling** and plasma diagnostics deployment

Discharge Plasma Source



← 2.5 m to 10 m unit module →

- Design and build **scalable tunnel-compatible prototype**
- Tailor all required parameters to **achieve desired density x homogeneity**
- Guarantee **stable and reproducible control and operation**
- Test different common anode/cathode schemes for scalability
- **Proof of principle possible YETS 2022/23 test in tunnel 2a and 2b**

Plasma R&D	2022	2023	2024	2025	Total
Material [kCHF]	556	507	0	0	1063
MtoP [kCHF]	50	100	100	50	300
Total [kCHF]	601	607	100	50	1363

	2022 R&D	2023 R&D	Total
Diagnostics and adaptations	120		120
CERN lab infrastructures for 2.5 m unit module	40	20	60
Tube, supports, vacuum and interfaces	28		28
10x RF generators, matchboxes, antennas, cables, control for 1x 2.5 m unit module	60	367	427
14x coils + DC power supplies for 1x 2.5 m unit module	113		113
Total (kCHF):	361	387	748

+ 1 junior fellow

	2022 R&D	2023 R&D	Total
Diagnostics and adaptations	20	100	120
CERN lab infrastructures for 10 m cell	60	20	80
Tube, supports, vacuum and interfaces	15		15
DC power supplies + cables	100		100
Total (kCHF):	195	120	315

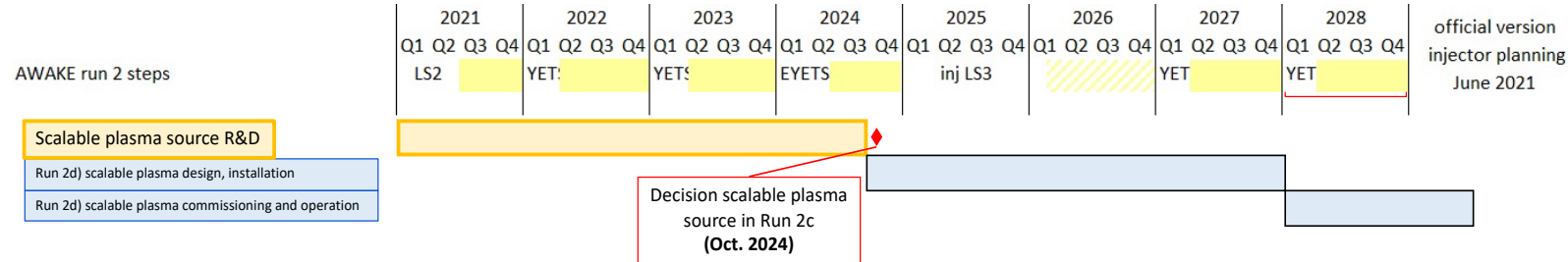
HPS	IPP + U.Greifswald + U. Stuttgart	U. Wisconsin	EPFL-SPC	Total
Total (kCHF)	1091	997	901	2989

Strong collaboration with institutes! (request for 2022 to 2024)

DPS	IST-Lisbon	IC-London	Total
Total (kCHF)	558	378	936

Scalable Plasma Sources: From R&D to Tunnel

2) Implementation 2025-2028 (readiness for Run 2c)



Decision end 2024: three scenarios, cost-neutral:

- Further studies** needed: → keep baseline of Rb vapour source as 2nd plasma source → scalable sources in Run 2d
- Decision for discharge source** in Run 2c: → save ~800kCHF (700kCHF DPS – 1400 kCHF for 2nd laser for 2nd Rb vapour source)
- Decision for helicon plasma source** in Run 2c: 2300kCHF HPS, save ~1400kCHF for 2nd laser, get contributions from institutes

Option 2) or 3): + 1 fellow + 3.2FTE.yrs (2025-2028)



4x 2.5 m modules = 10 m tunnel plasma cell

HPS: ~2.3MCHF



1x 10 m or 2x5 m or 4x 2.5 m modules = 10 m tunnel plasma cell

DPS: ~0.7MCHF

- Build test and document the tunnel 10m prototype cell and diagnostics in dedicated surface infrastructure
- Prepare tunnel integration/facilities/interface/control, installation and commissioning

AWAKE Retreat March 31, 2023

Scalable Plasma Source R&D

Scalable plasma source R&D	What	Responsible	Deadline	Milestones
Scalable plasma source R&D	Organize scalable plasma source R&D intermediate review	Edda, Patric	Summer 2023	Density uniformity at 0.2% level, results from DPS run
	Clarify contributions from collaborating institutes	Alban → input from all institutes	Summer 2023	
	Clarify UK DPS contributions	Matthew , Zulfikar, Alban		
	Npe uniformity of DPS and HPS	Alban, Christine, Birger?	Mid 2024	
	Simulation of npe uniformity for HPS under ideal conditions	Christine	Summer 2023	Is it even feasible
	Development of diagnostics to measure with sufficient accuracy → Raman?	Christine?	Summer 2023	Determine accuracy
	Check for final deadline of decision	Eloise, Ans planning	Review 2023	Deadline for decision

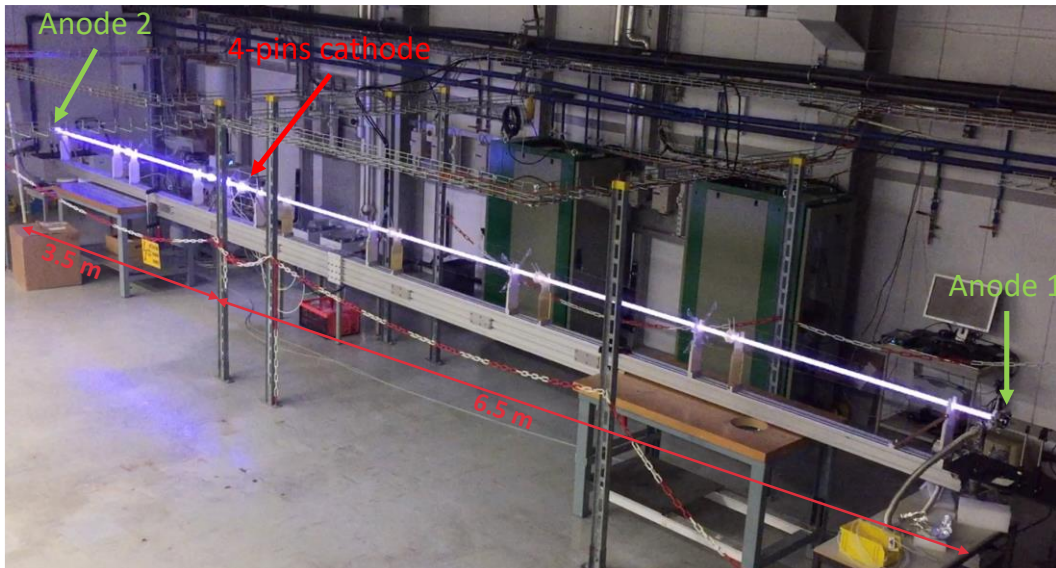
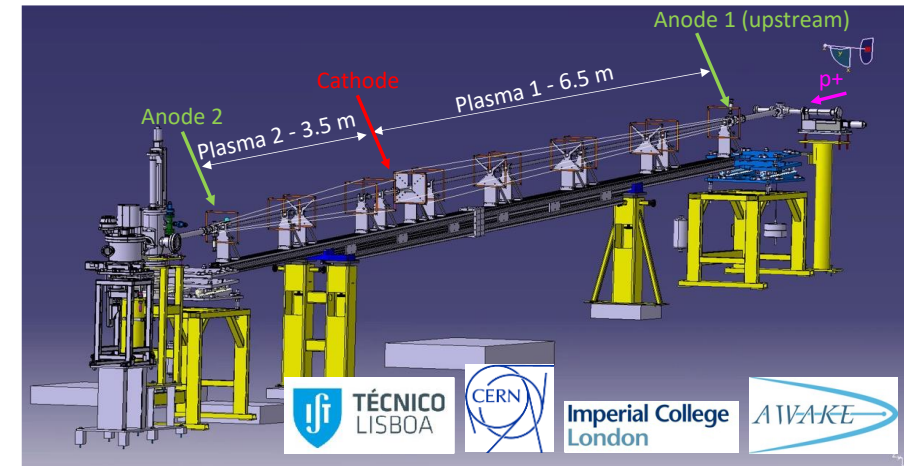
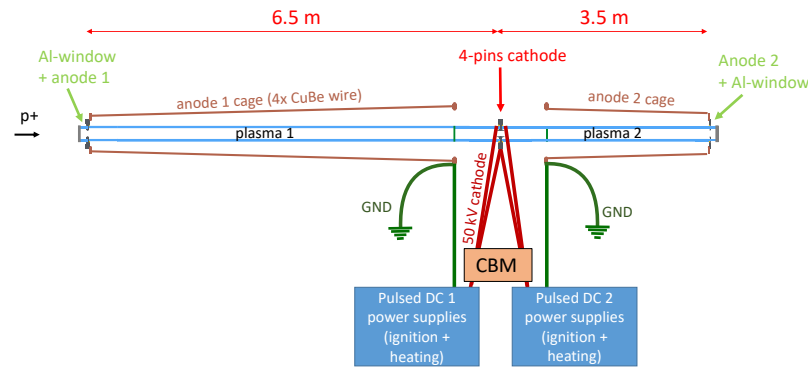
To Discuss:

- What is the status of the various groups' contribution?
 - What is their R&D program?
 - What are the committed resources?
 - What is the time-line of the groups?
-
- Agree on a date for review
 - Agree on an agenda for review

Discharge Plasma Source Tests in May 2023

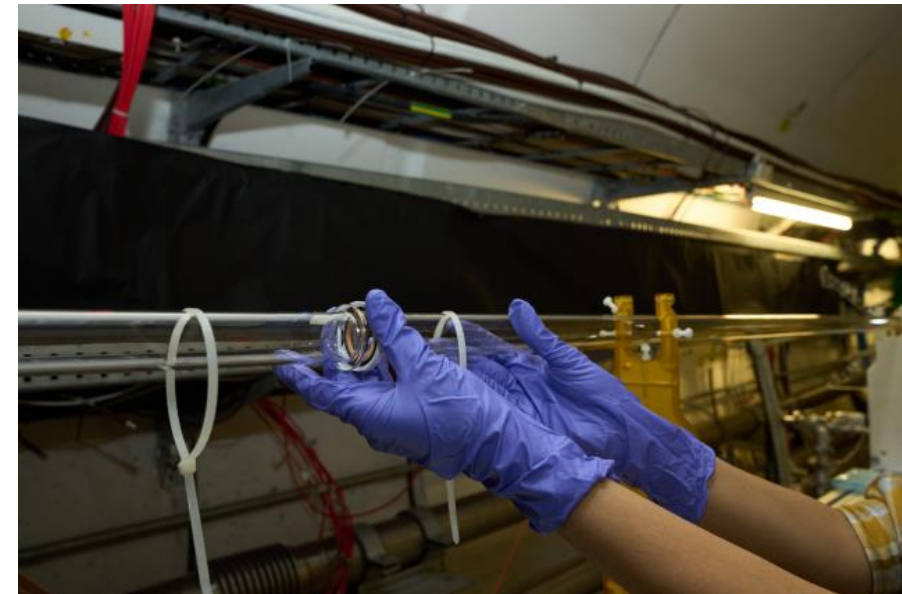
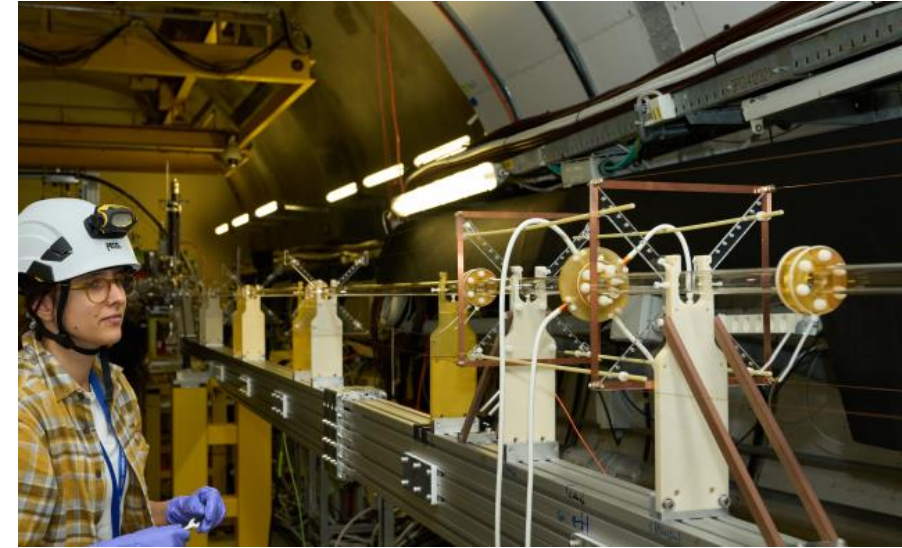
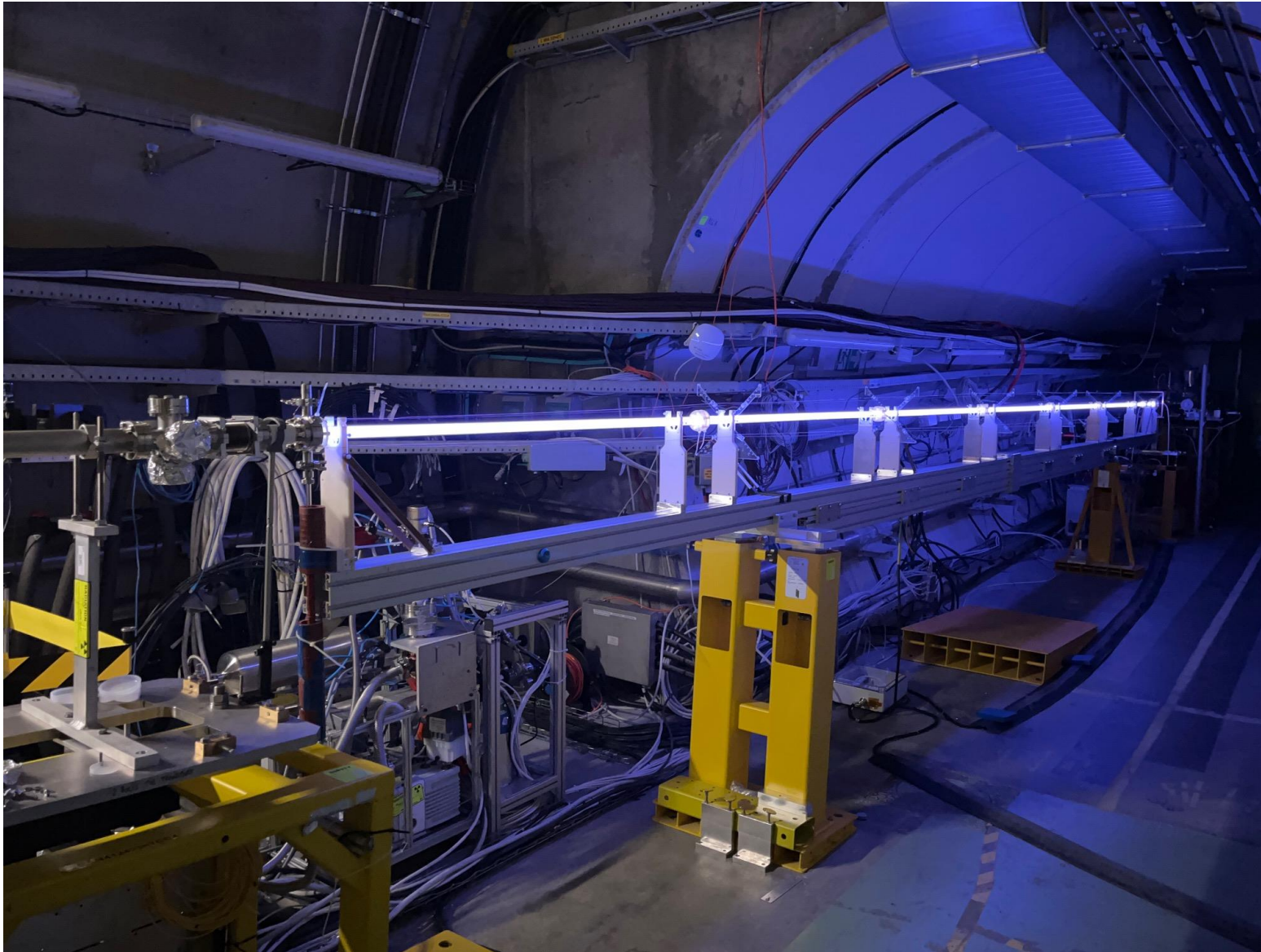
R&D ongoing on **scalable, several-meter long plasma sources**: discharge plasma and Helicon plasma sources.
Discharge Plasma Source (DPS) could be a possible candidate for 2nd plasma source in Run 2c/d

- Much simpler
- Reach very long plasma lengths by stacking them
- wide plasma → no alignment



Unique run during May 2023 with the discharge plasma source. Run is finished after 3 weeks, no 2nd chance.

Discharge Plasma Source in AWAKE

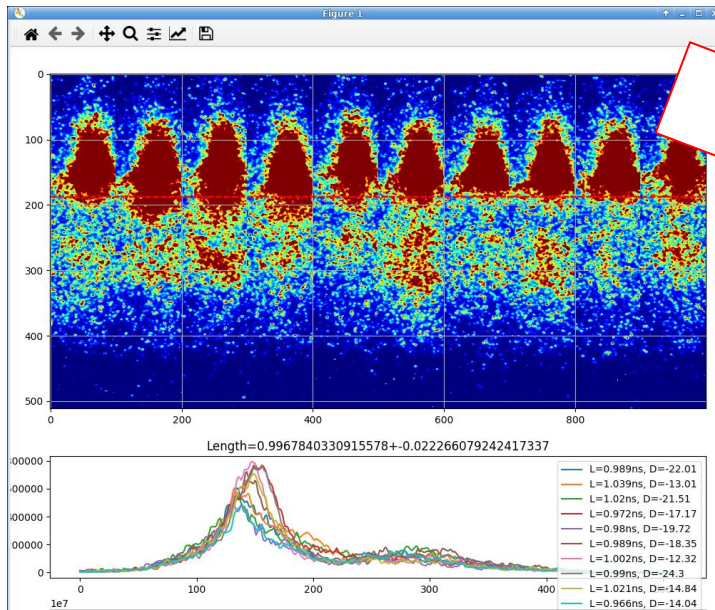


May Run 2023

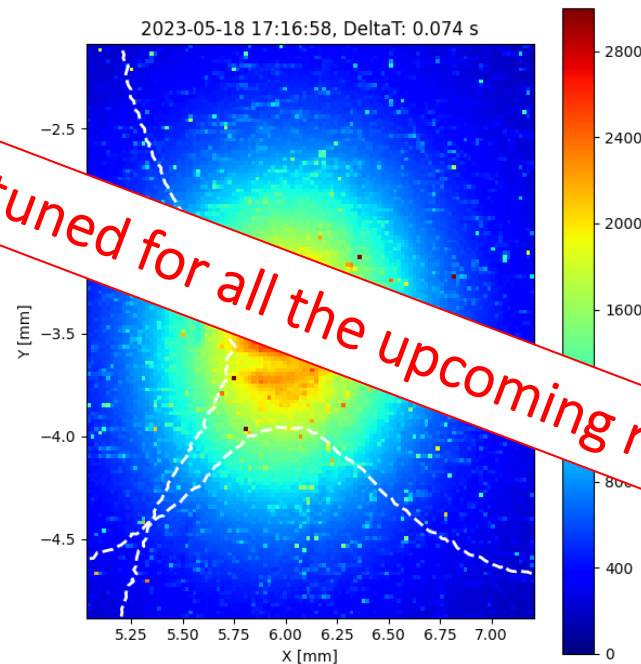
- Well-functioning, very reliable discharge plasma source!
- Run surpassed our expectations and was very successful!

Collected a wealth of impressive data! :

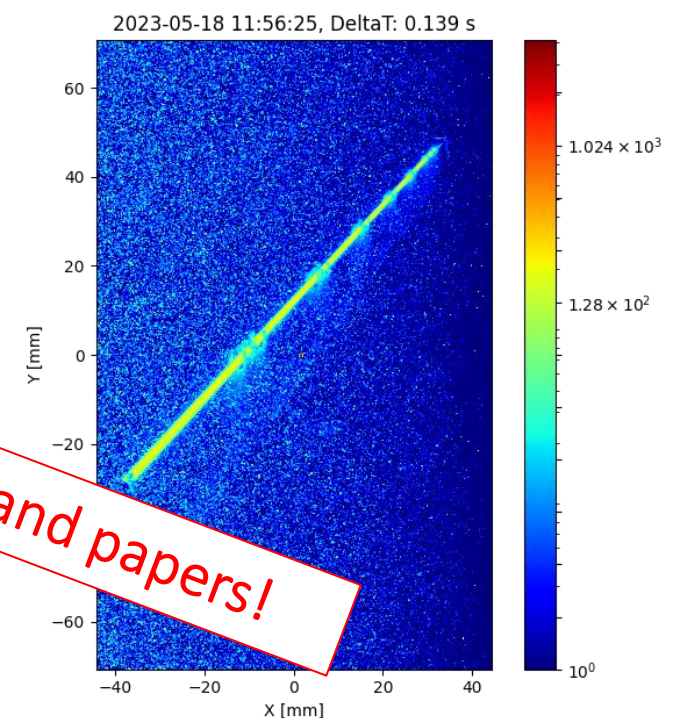
- Vary plasma density over wide range
- Study Self-modulation at different lengths: 6.5m, 3.5m 10m
- Study plasma ion motion: Ar(40), Xe(131), He(4)
- Study current filamentation of very high densities
- Study plasma light as a diagnostics for the wakefield amplitude all along the plasma.



Ion motion studies

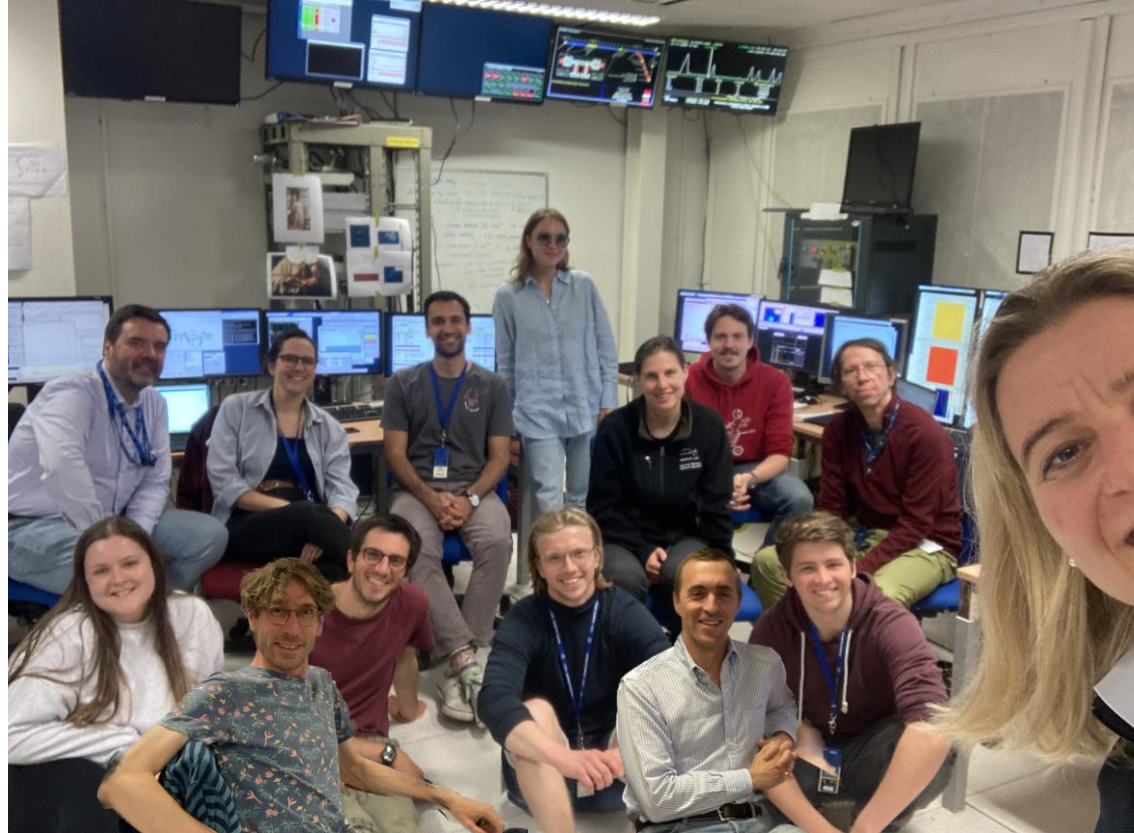


Filamentation



Plasma light

Stay tuned for all the upcoming results and papers!



Thanks to the entire team (also those not on the photo) for all the hard work and commitment!!