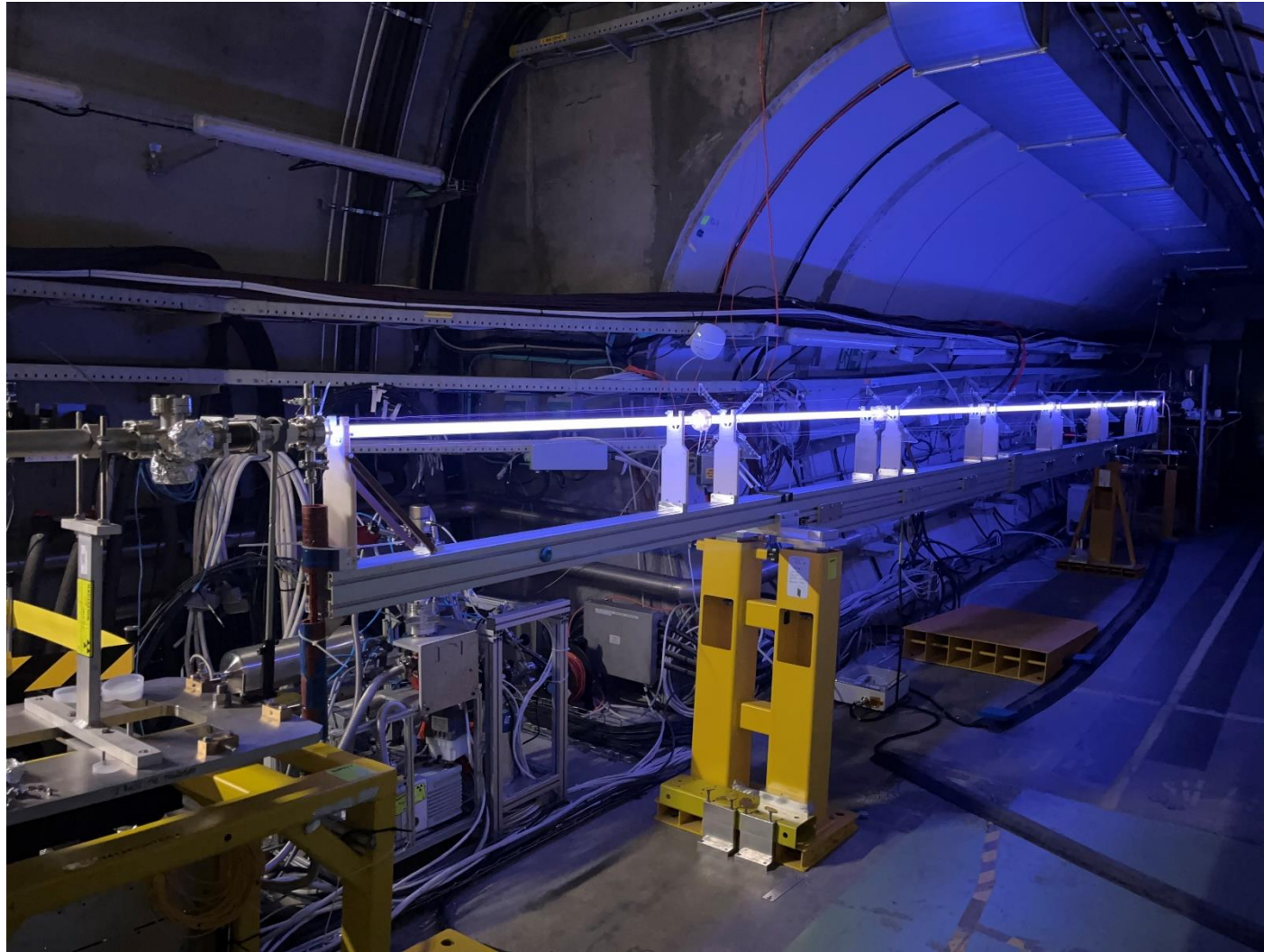


Status of the discharge plasma source and measurement program



Imperial College
London



Alban Sublet, on behalf of the DPS team

AWAKE Collaboration Meeting, 25th April 2023

Project framework and plan

- **Proposal** → EDMS document: <https://edms.cern.ch/document/2740382/1.0>
 - **Main objectives:**
 1. to show that the propagation of the proton bunch in one plasma section results in the usual signature of proton bunch self-modulation instability (SMI)
 2. to determine the effect of plasma density and length L1, L2 and L1+L2 on SMI
 3. to assess the effect of the ion mass on the self-modulation along the proton bunch by changing gas (He, Ar, Xe)
- + explore current filamentation instability (CFI), hose instability and plasma light

→ No laser and no electron beam, SMI only experiment



PROPOSAL

Proposal for a Discharge Plasma Source (DPS) experiment in the AWAKE tunnel during YETS 2022/2023

ABSTRACT:

This document presents a proposal for an experiment to demonstrate the adequacy of a flexible DC discharge plasma source in AWAKE. In this experiment, a plasma source with two independent plasma sections of lengths L1 and L2 (L1 + L2 = 10 m) will be used in place of the current Rubidium vapour source. It uses the 400 GeV proton beam and already installed diagnostics. The proof of principle of this alternative scalable plasma source will be assessed by measuring the proton beam self-modulation instability using existing diagnostic. The effect of the plasma density, length, ion mass on the self-modulation instability and on the hosing instability will be also studied.

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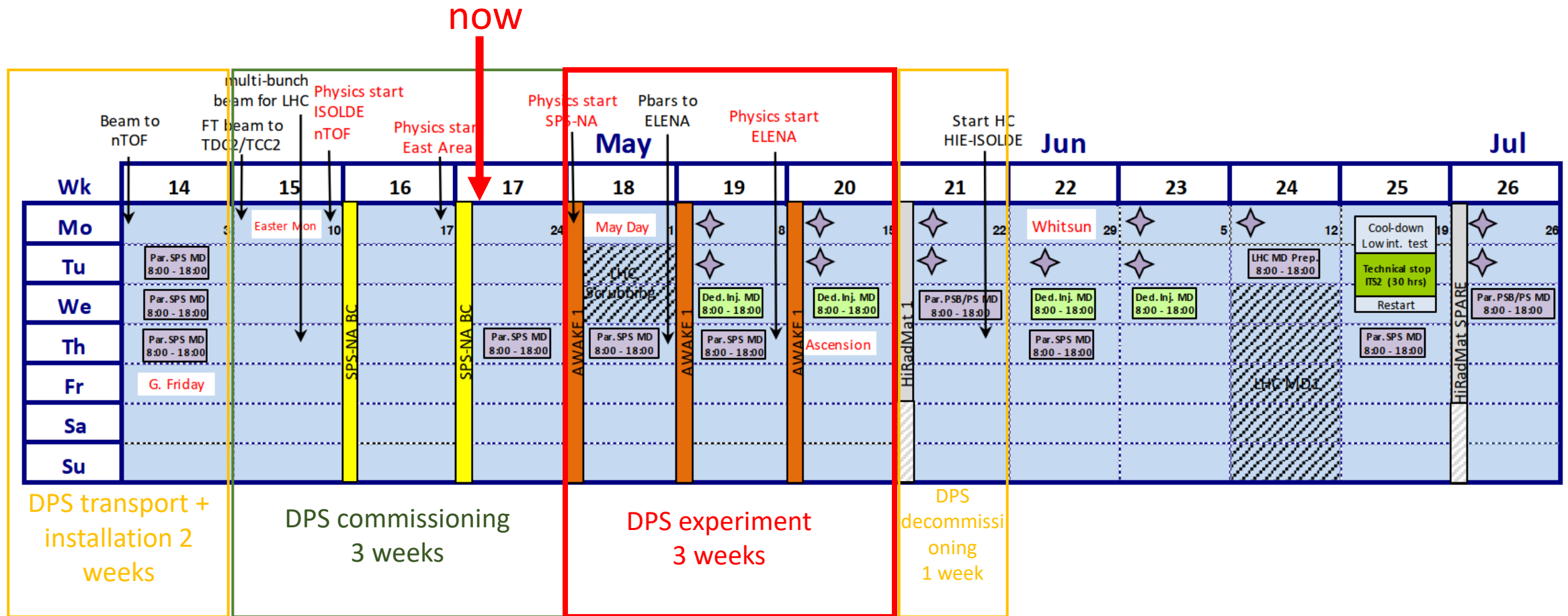
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This document is uncontrolled when printed. Check the EDMS to verify that this is the correct version before use.

Project framework and plan → run with protons next week!

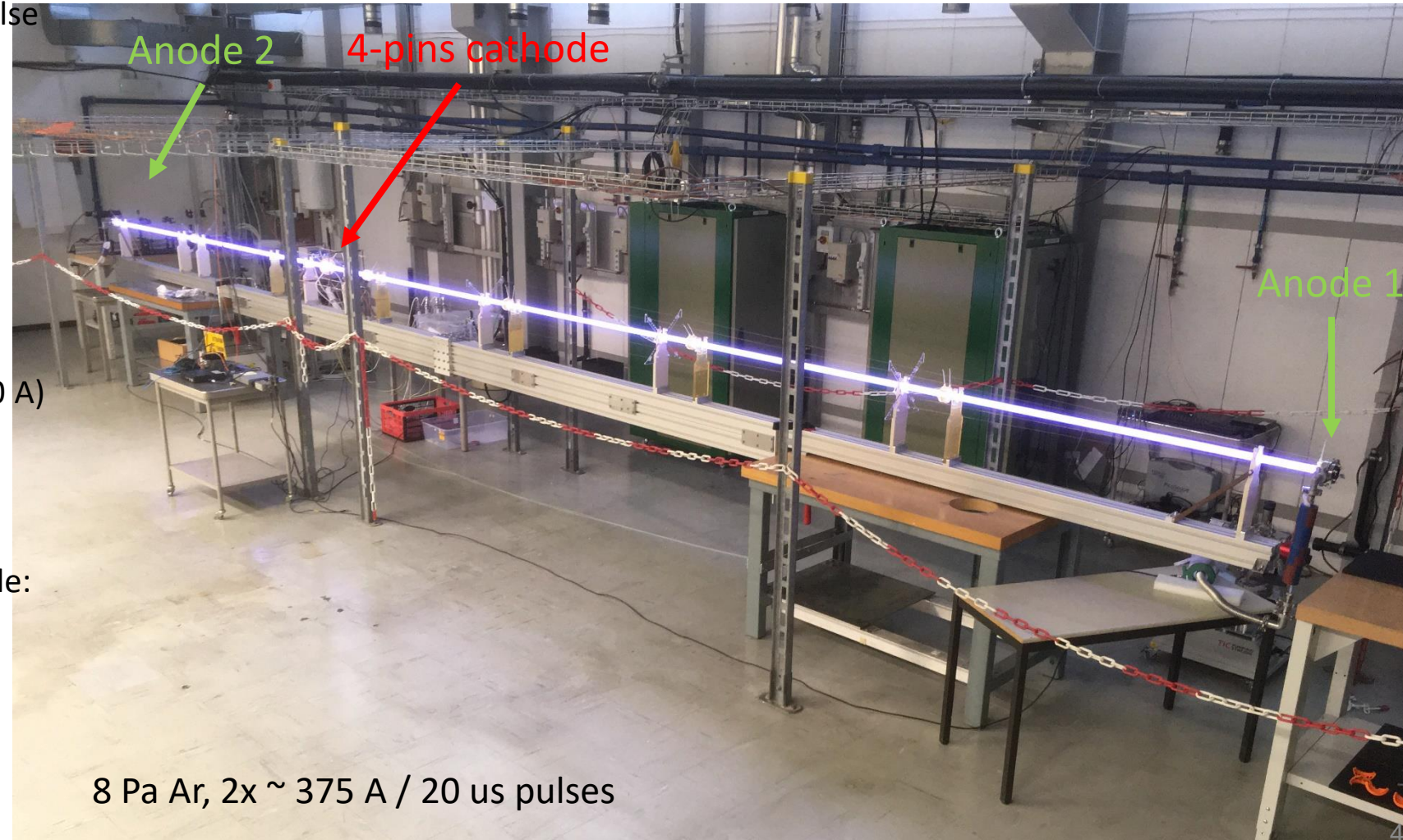


DPS lab → 3.5 + 6.5 m double plasma setup

- **Baseline** = 3.5+6.5 m plasmas
- Qualification of the DPS setup (control/pulse generators/vacuum...)
- Parameter scan with interferometry to assess plasma density for
 - 3 lengths (10/6.5/3.5 m)
 - 3 gases (Ar/He/Xe)
 - different discharge current (200..500 A)
 - different pressures (8..45 Pa)

→ Density range over ~ 2 orders of magnitude:

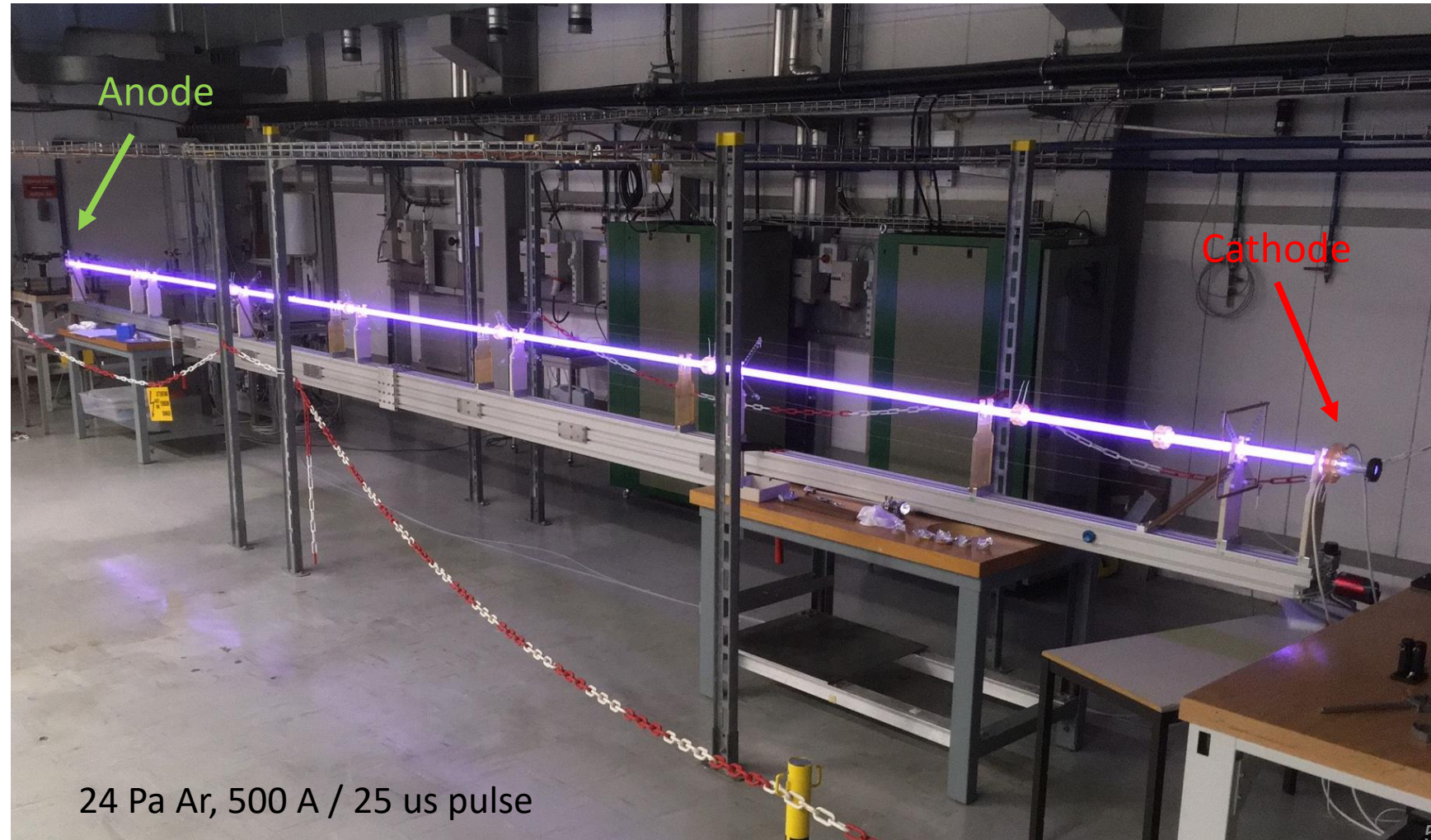
From $\sim 2 \times 10^{13} \text{ cm}^{-3}$ to $\sim 2 \times 10^{15} \text{ cm}^{-3}$



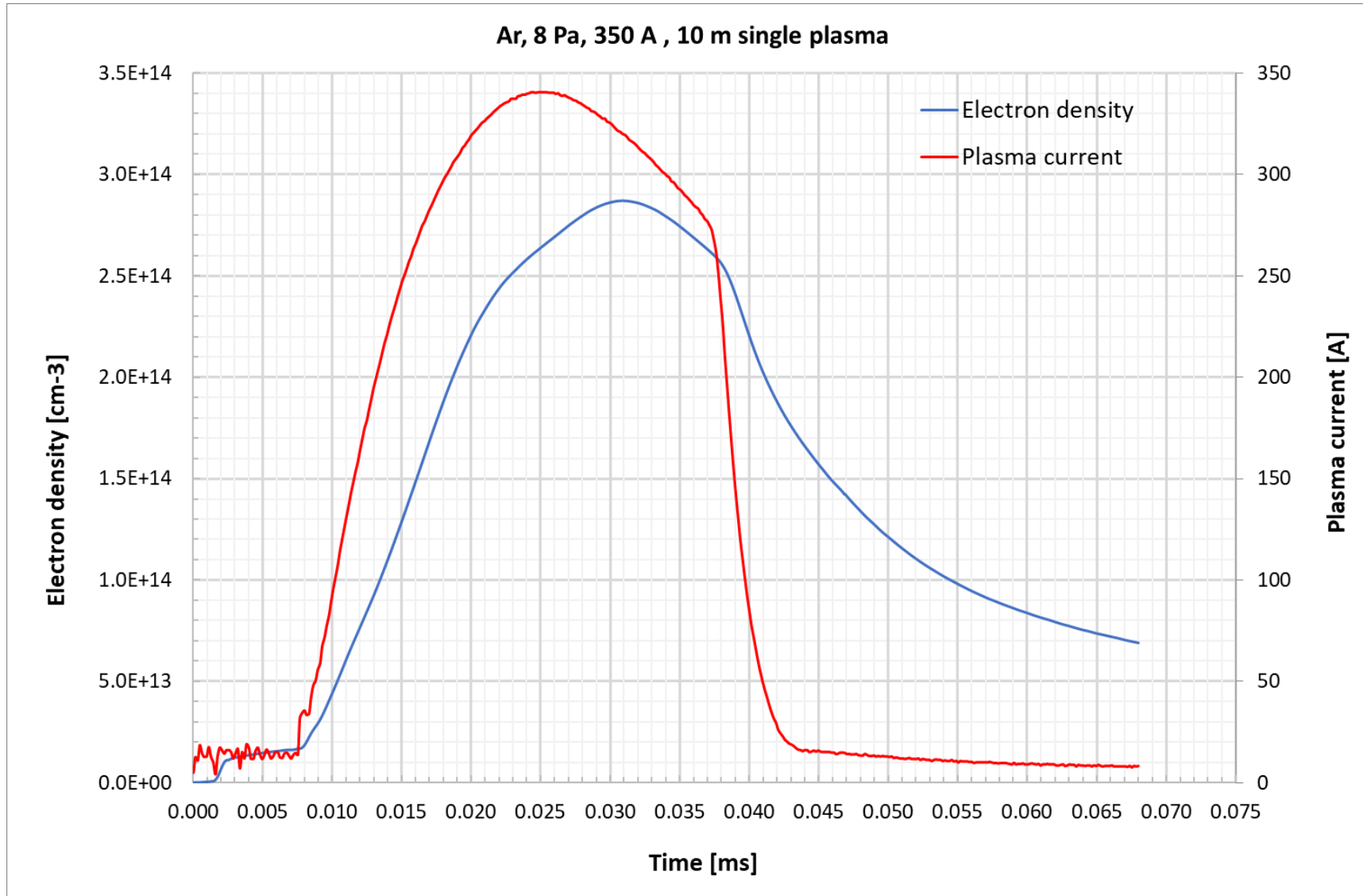
DPS lab → 10 m single plasma setup

- **Alternative** = 10 m single plasma
- Build and tested 2 days before moving to the tunnel
- Parameter scan with interferometry done in argon only

→ After last TEB/PB in March, decision to start with 10 m setup for 1:1 comparison with Rb cell

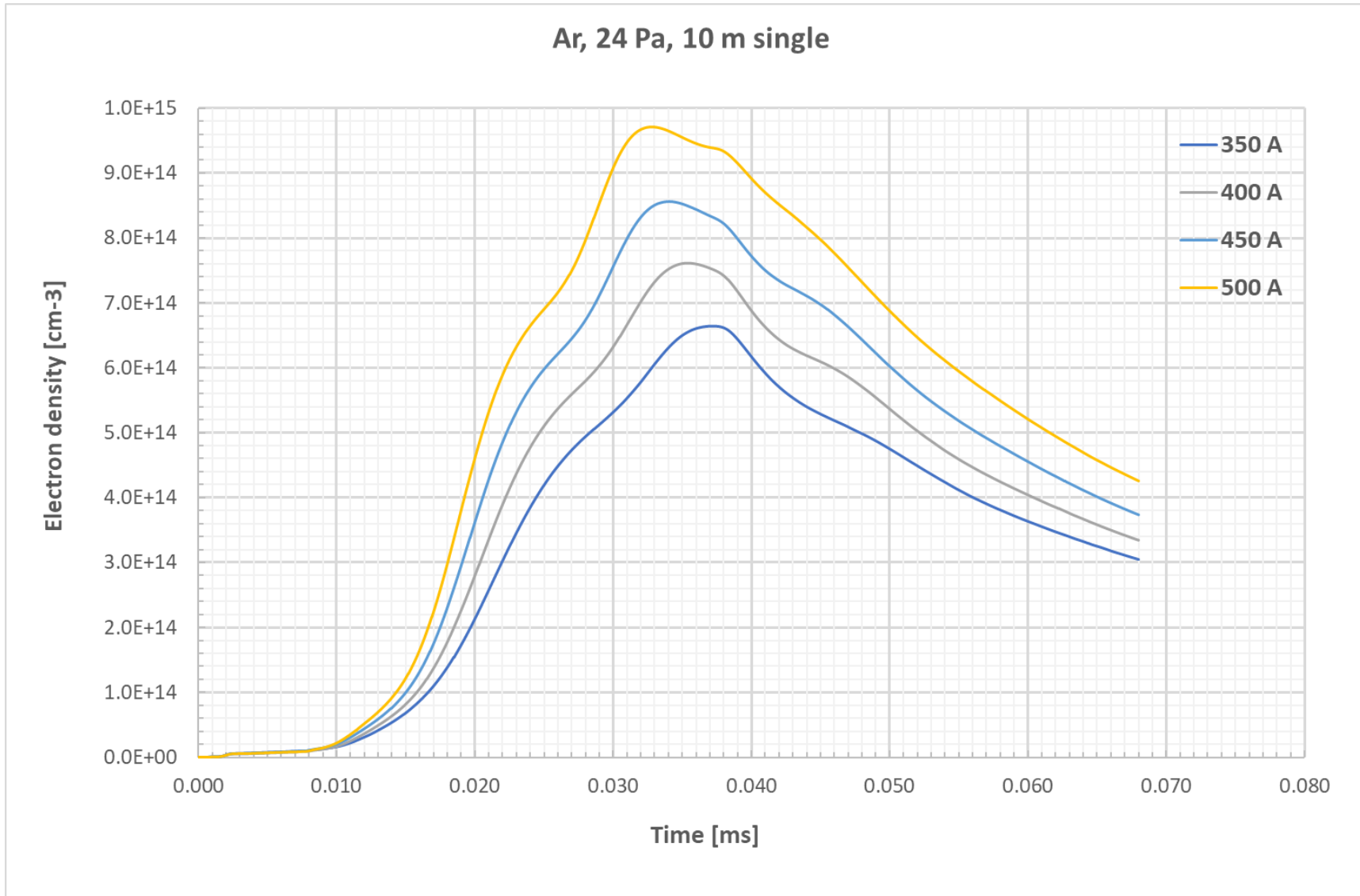


DPS lab → interferometry (IF): line average density and plasma current evolution



→ Adjust current pulse delay to proton beam to scan through density and measure p+ modulation frequency

DPS lab → interferometry (IF): density for different plasma currents



→ 500 A current in 24 Pa argon = density span from $\sim 1 \times 10^{14} \text{ cm}^{-3}$ to $\sim 1 \times 10^{15} \text{ cm}^{-3}$

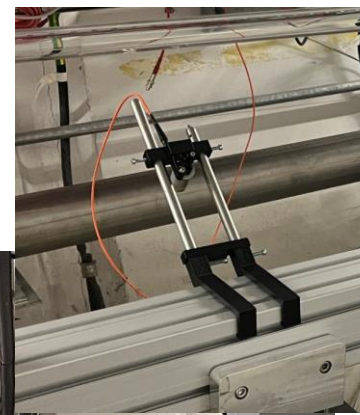
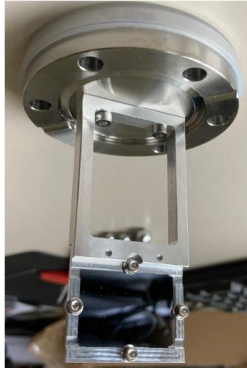
DPS tunnel → new diagnostics

2x PMT at 2 and 8 m for time resolved plasma light

New fixed OTR screen for CFI right after the DPS

See:

<https://indico.cern.ch/event/1263911/>



2x short exposure ($1 \mu\text{s}$) cameras to cover 7 m of plasma for **space resolved** plasma light measurement

1x camera with slit+grating for **spectral resolution** of plasma light

1x camera to cover 10 m (diagonal) of plasma for **space resolved** plasma light measurement

DPS tunnel → 10 m single plasma

→ 3 hours of protons on Thu. 13th April for screens/diagnostics alignment

The image displays a control interface for a proton beam experiment, showing various diagnostic and control windows.

Top Left: Oscilloscope Windows

- SR.SCOPE31-TS:** Shows a series of vertical pulses. A blue arrow points to a pulse.
- SR.SCOPE37-TS:** Shows a signal with a peak labeled $1.776V$ and a pulse labeled $21.93mV$. A pink arrow points to the pulse.
- SR.SCOPE37-TS (bottom):** Shows a signal with a peak labeled $40us$. A cyan arrow points to the signal.

Top Right: Camera Control Panel

- Device Selection: Camera: TCC4.SPECTRO2, Trigger: Extraction, Laser Frame Rate [Hz]: 2.
- Camera Properties: Exposure Time [us]: 40, Delay Time [us]: 636.0, Pixel Size [mm]: 0.0730, Gain: 0.0.
- Display Properties: Select Colormap: jet, Select Color Scale: Linear, Autoscale: Min: 0, Max: 4096, Aspect Ratio: Equal.

Right: 2D Beam Profile Plot

- Time: 2023-04-13 18:49:50, DeltaT: 0.178 s.
- Y-axis: Y [mm] from -60 to 60.
- X-axis: X [mm] from -40 to 40.
- Color scale: 0 to 4000.

Bottom: Parameter Control Window

- SV.ENABLEPSU1-PLA1: Value 0.000, Init 0.000, Value 2.500.
- SV.GSIPSU-PLA1: Value 0.000, Init 0.000, Value 2.600.
- SV.GSHPSU-PLA1: Value 0.000, Init 0.000, Value 2.600.
- SX.AUTO-START: Pulse.
- SX.GENERAL-START: Pulse.
- SX.MANUAL-START: Pulse, Trig.

Annotations:

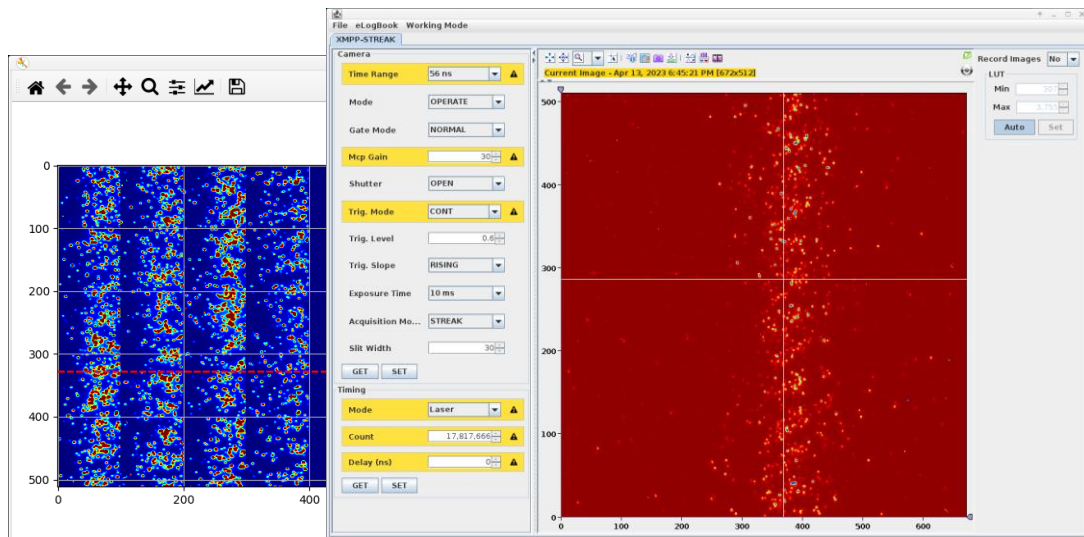
- Pink arrow: Plasma heater current pulse
- Cyan arrow: Proton signal (photodiode)

DPS tunnel → 10 m single plasma

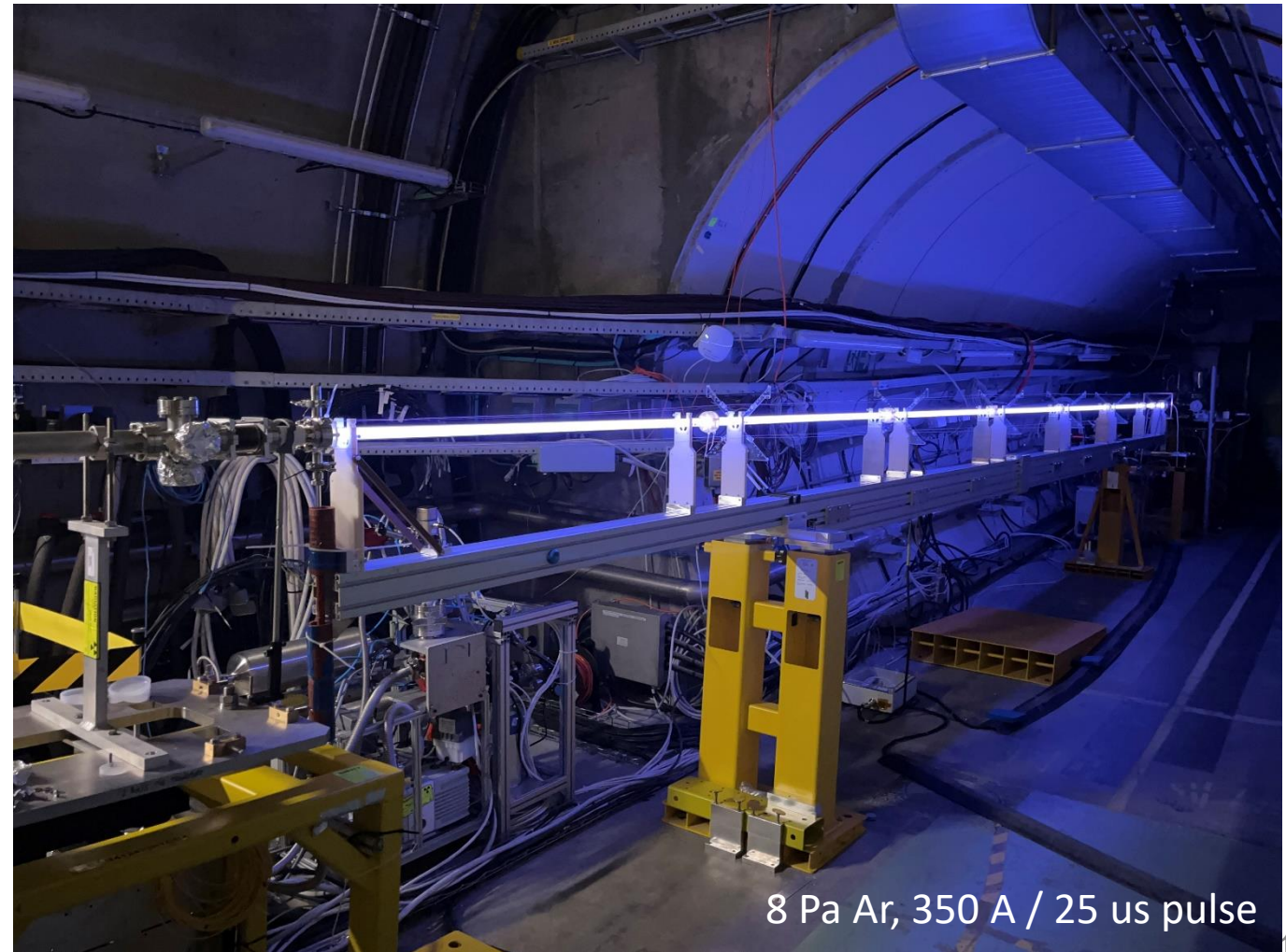
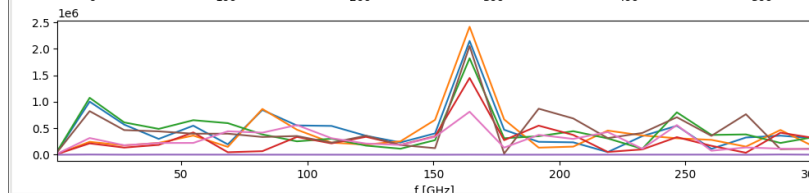
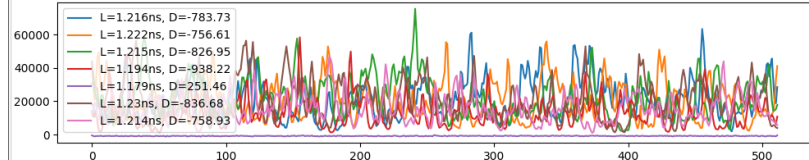
→ Currently = commissioning: timing, triggers, installation of PMTs + cameras for plasma light, etc.

→ 3 hours of protons on Thu. 13th April for screens/diagnostics alignment

→ Trial with plasma → proton SMI visible!



Length=1.2098202439858596+-0.0161912176971308



Run preliminary plan (update of <https://indico.cern.ch/event/1276807/> from Patric)

1. Mo. 1st May -> Tues. 9th: **10 m single plasma** for direct comparison with Rb plasma cell
 - Mo. - Tues.: start, **detailed scan delay in Ar (8 Pa at 350 A and 8/24 Pa 500 A) benchmark IF**
 - Wed. - Thurs.: **SMI, plasma light, Ar, 1-9e14/cc, 1-3e11p+, plasma light**
 - Fri. - Sat.: **scan delay in Xe, CFI narrow/wide bunch, 0.5-2e15/cc, 1-3e11p+, plasma light**
 - Sun. - Mo.: **scan delay in He, ion motion-SMI He/Ar/Xe, 1-4e14/cc, plasma light**
 - Tues.: **Hosing, low density + flat beam, plasma light**
 - *We. 10 + Th. 11th May: change from 10 m single to 6.5 m downstream (6.5+3.5 m) + survey*
2. Fri. 12th -> Tues 16th: **6.5 m plasma**, same plan as week 1 + **density step?** 6.5+3.5 m plasma
 - *Tues 16th + Wed. 17th: change from 6.5 -> 3.5 m downstream (3.5+6.5 m) + survey*
3. Thurs. 18th -> Sun. 21st: **3.5 m plasma**, same plan as week 1

Summary

- DPS qualified (HW/control/IF) in the lab in March and moved to the tunnel end of March
- Installation and commissioning of the cell + installation of new diagnostics in April
- Dense plan with unique DPS setup
- 3 weeks with protons starting next Monday!

Thank you for your attention!