Upgrades of the Rb Vapour Source

AWAKE collaboration meeting, CERN

12/03/2024

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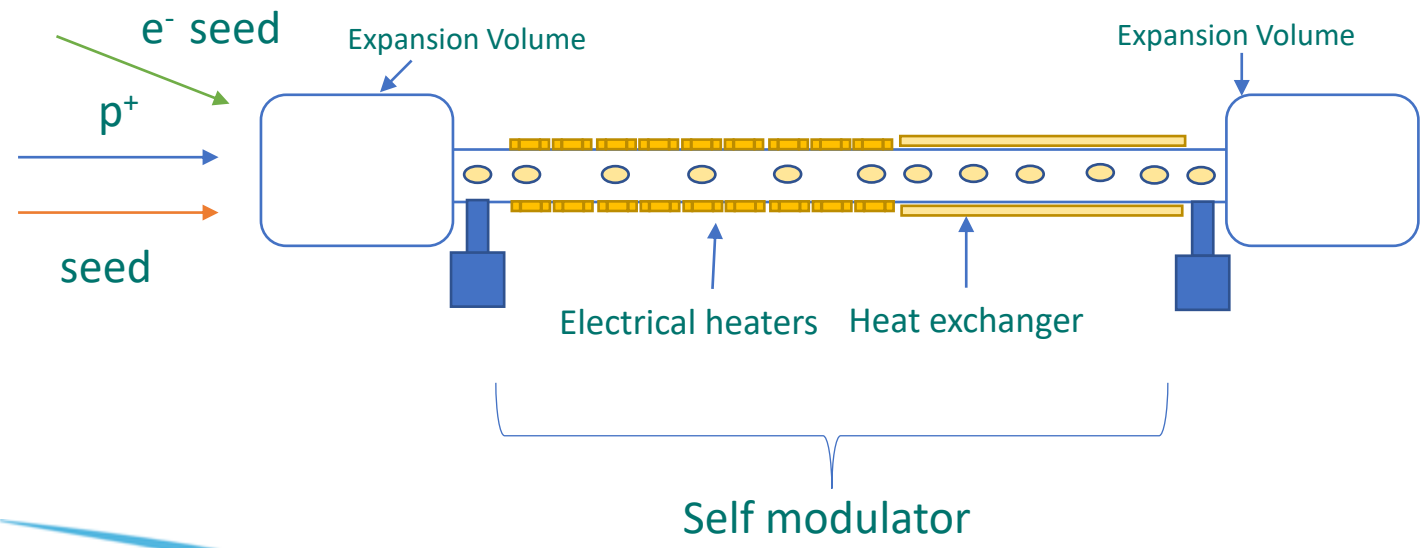
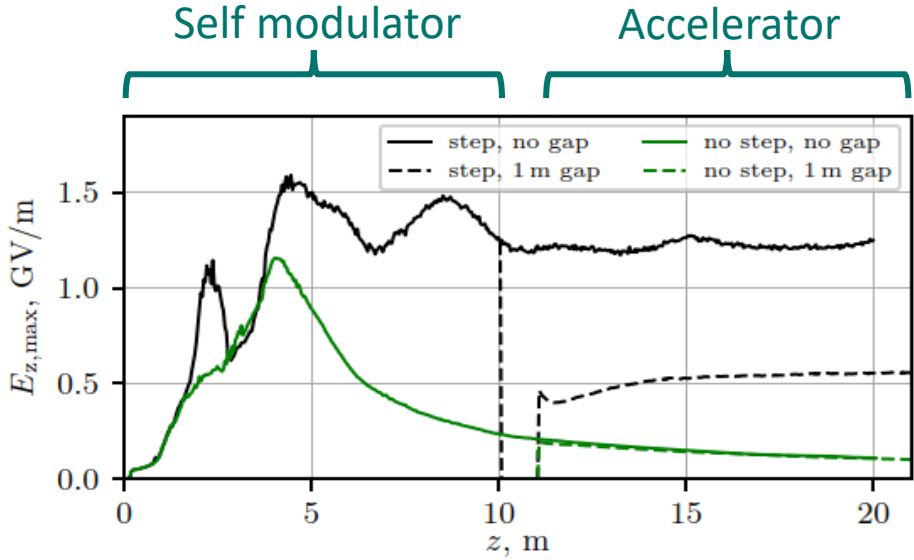
Run 2b Vapour Source

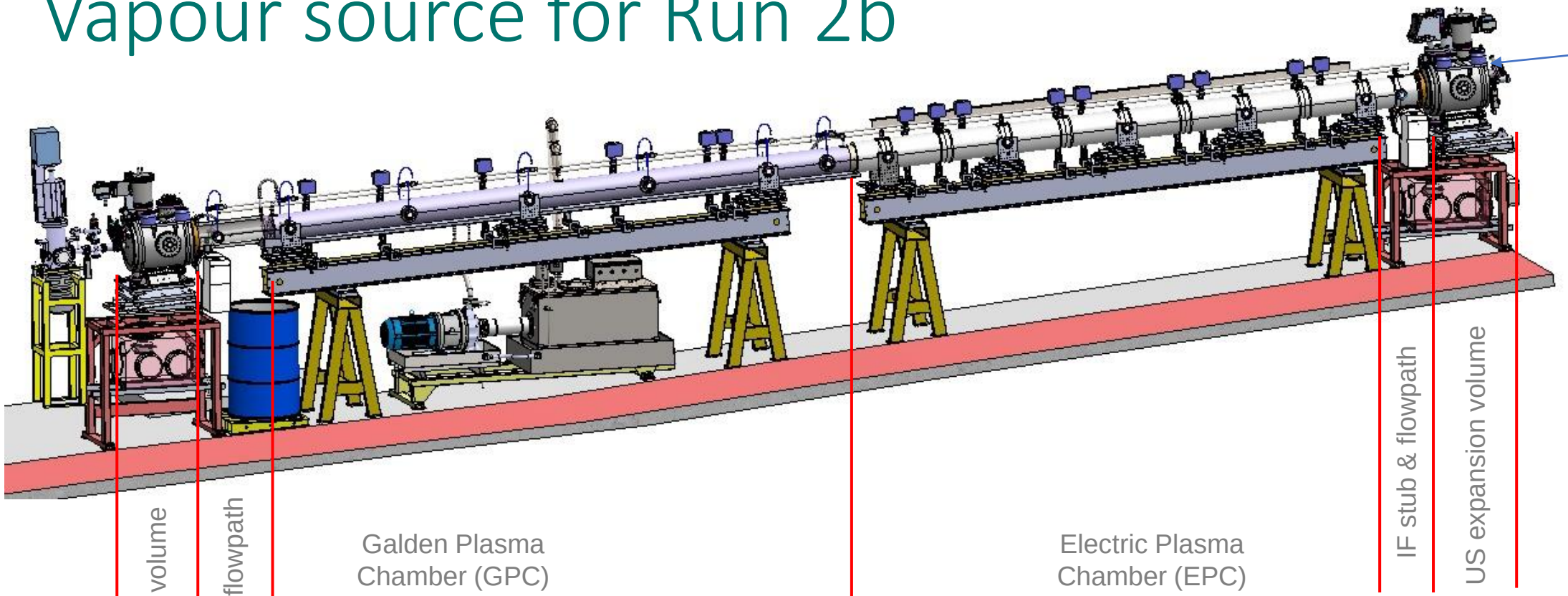
- Same requirements as Run 1 for Rb density uniformity and max value as for Run1 and Run 2a $\delta T\ (^oK)/T(^oK) \approx 0.2\%$
- Additionally have to implement a “sharp” (tens of cm) step from 1% to 10% $\delta T\ (^oK)/T(^oK)$ from 5 to 50°C





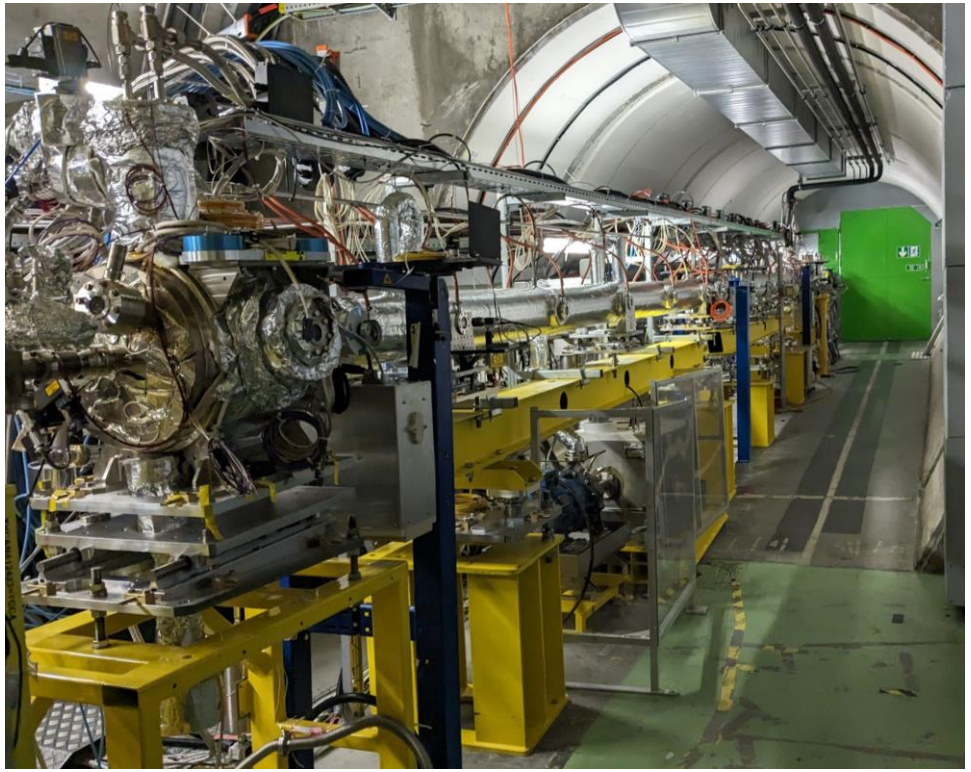
➢ With a density step in the selfmodulator, wakefields maintain a level close to saturation amplitude after the saturation

Vapour source for Run 2b



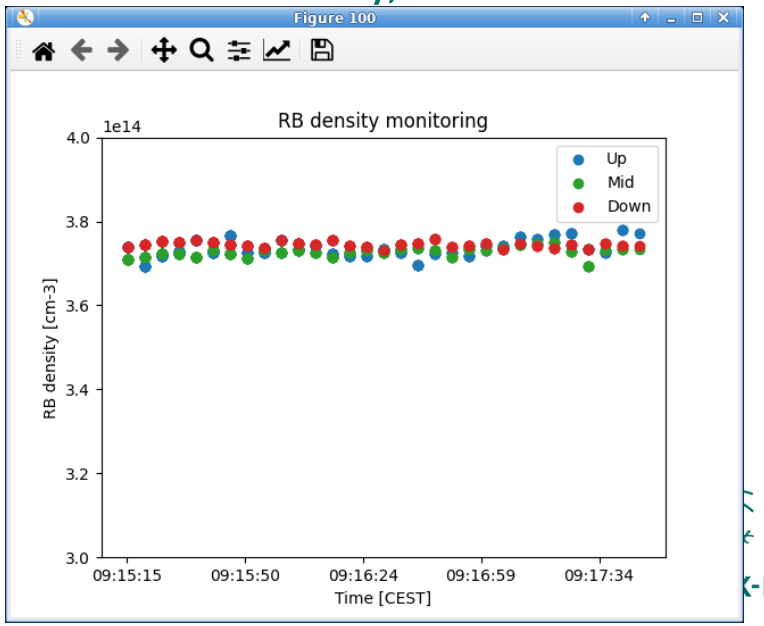
- Length: ~ 10 m
- Independent electrical heater of 50 cm from 0.235 to 4.735 meters
- 5.3m of galden heated section
- Step height up to ±10%
- 10x2 diagnostic viewport, for plasma light + 3x2 for density diagnostic

Installation and commissioning



Run 2b Operations, critical points

- Main cause of downtime during first part of the 2023 run was OTCs (over temperature cutout circuits) failure, happened 4 times. Different causes (to close to threshold, loose connectors, probes cable impedance), needed hardware bypass in the tunnel. Now fixed with two intervention by WDL, did not happen again since then
- Other access needed to reboot the control rack for a failsafe card, now remote reset implemented and tested. Did not cause downtime again
- Density diagnostic tuned between first and second run of 2023, US spectrometer found with wrong factory calibration was giving incorrect values. Now fixed in software that calculate density, measurement between Up, Middle and Downstream viewport show agreement in 0.2%

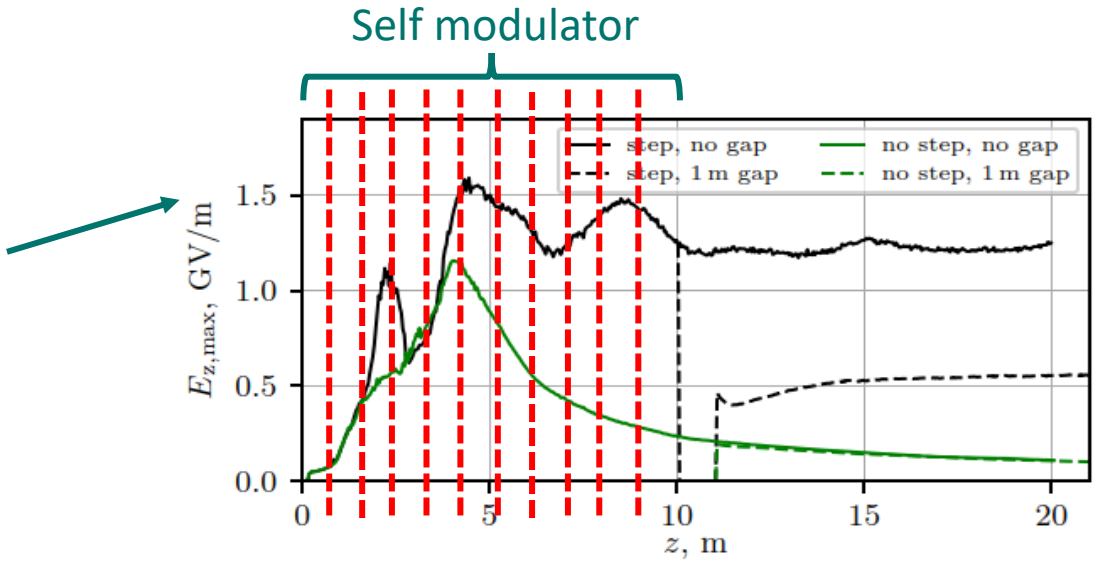


Upgrades since last collaboration meeting

- Mu-metal shielding installed
- Tested effect of magnetic field induced by heaters on electron bunch. Suppression mechanism implemented, all heaters off for 200ms during proton passage through the experiment.
- Veto on expansion volume BTV and Rb reservoirs valves to minimize RB coating of screen in implemented on vapor source control software
- Last Week (04/03 to 07/03/2024):
  - Maintenance of leaky galden pump happened last week: galden circuit poured, pump wet end cleaned and serviced, gaskets (front and back) replaced with higher temperature rated.
  - Two faulty probes during laser in plasma studies (TT421 and TT306) replaced.
  - Probe offset measurement completed with resistance test boxes for beamline probe to take into account for cables/DI calibration. To be implemented in control software
- Shorter plasma: Plungers with laser dump inside the vapor source -> see next slides

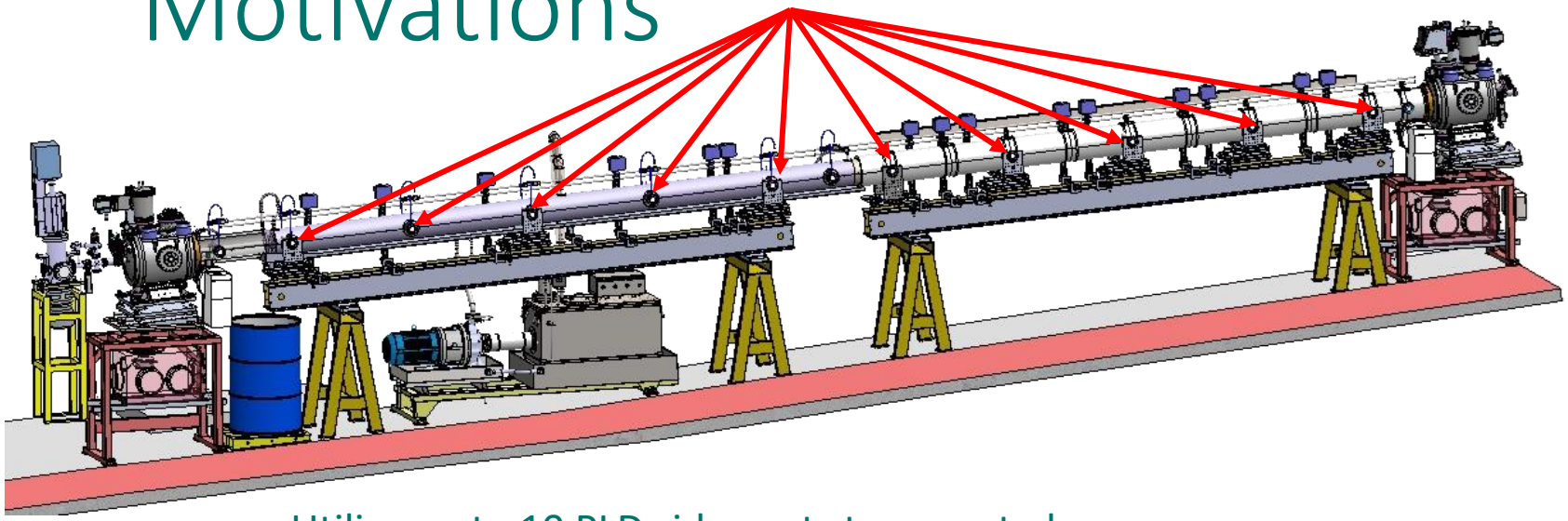
Motivations for plungers

- Need to understand the longitudinal evolution of the wakefieds in the 10m plasma
- Dump the laser pulse at different longitudinal positions but allow proton and accelerated electron beam to continue (see following slide) -> measure accelerate electron energy in a shorter plasma to sample integrated wakefield effect over shorter length
- Additionally, possibility to measure electron bunch position and size at z location -> measure trajectory and focus inside the vapor source to better know electron bunch longitudinal crossing/overlap with proton beam trajectory/plasma (injection)

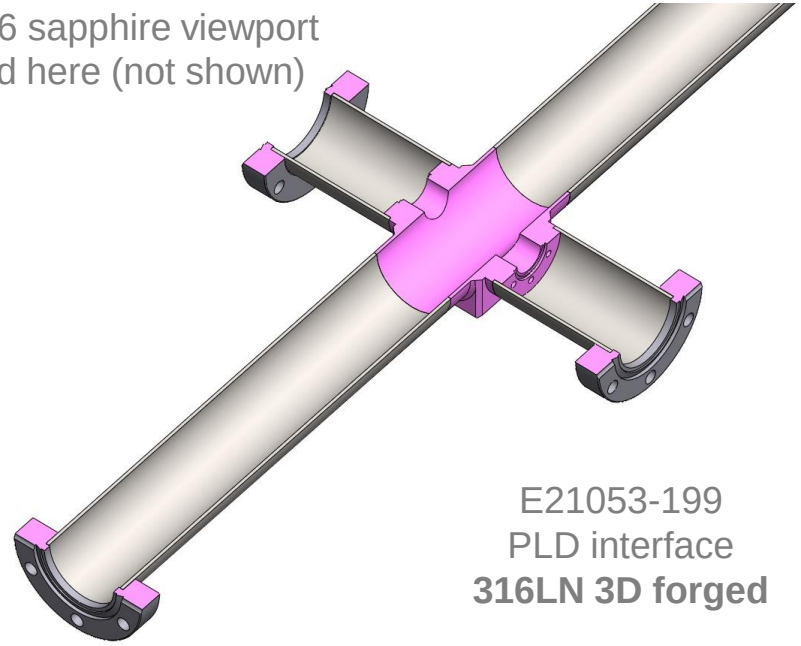


E. Gschwendtener et al. (AWAKE Collaboration), *Symmetry* 14, no. 8: 1680, https://doi.org/10.3390/sym14081680

Motivations



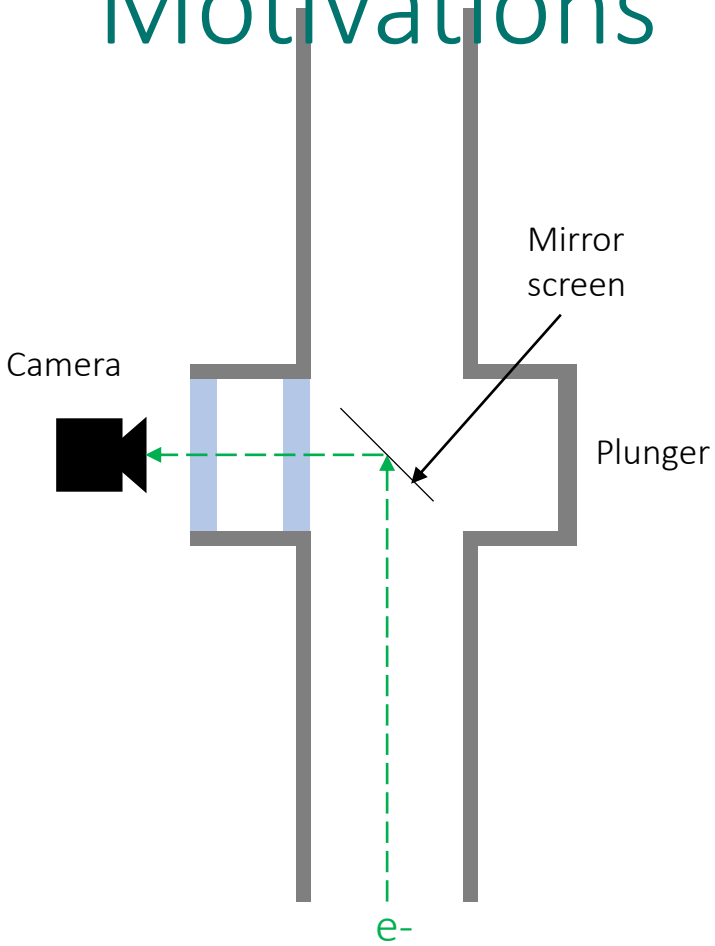
DN16 sapphire viewport
fitted here (not shown)



E21053-199
PLD interface
316LN 3D forged

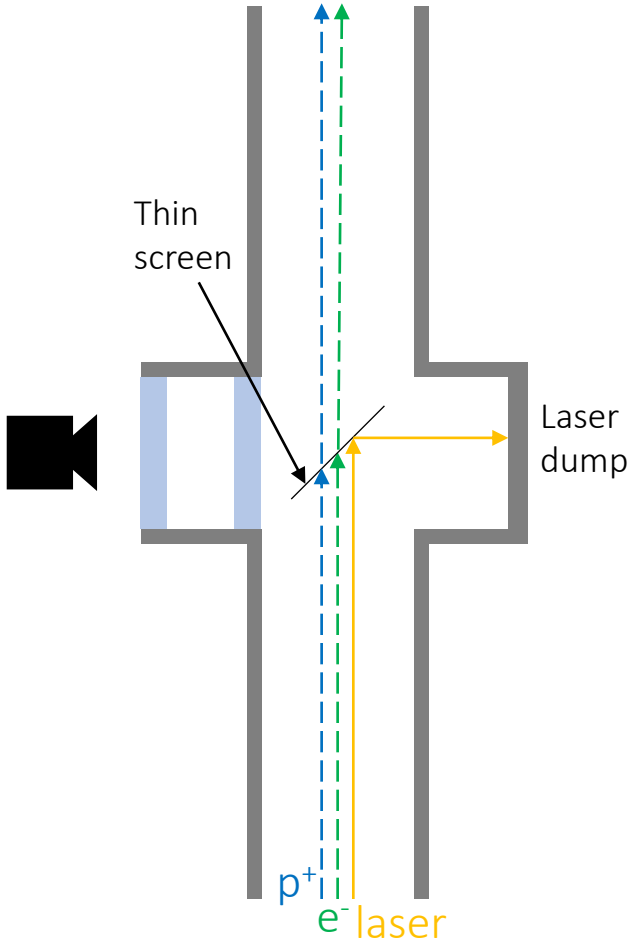
- Utilize up to 10 PLD side ports to mount plungers.
- Side port linear actuator (‘plunger’) needed to allow investigation into energy gain along beamline
  - Min travel ~20mm
  - 3 position
- Plunger control via Siemens digital output signals
- Plunger working in high temperature environment with either Ultra High Vacuum (UHV) or low density rubidium vapour
- Plungers need to be fitted to existing experiment

Motivations



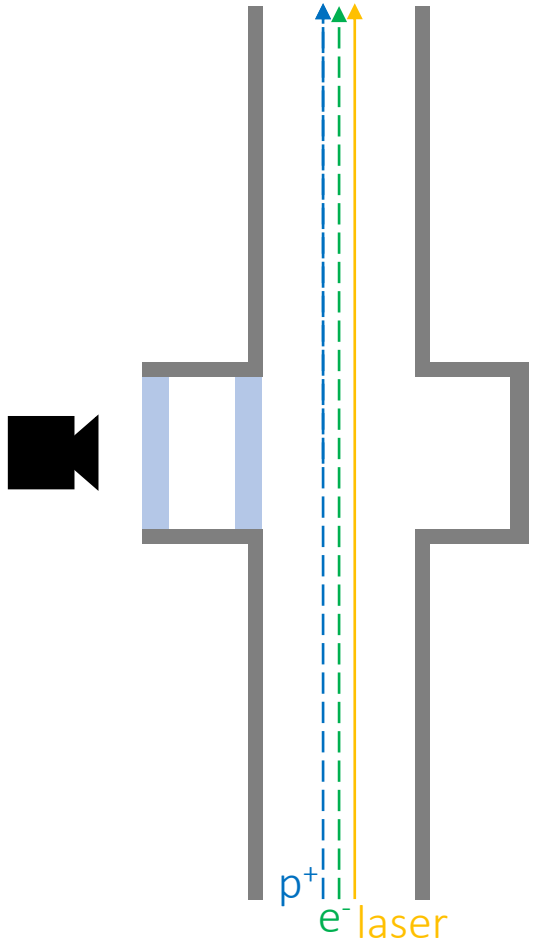
Alignment

(one off set up)



Diagnostic

(plunger 'in' state)

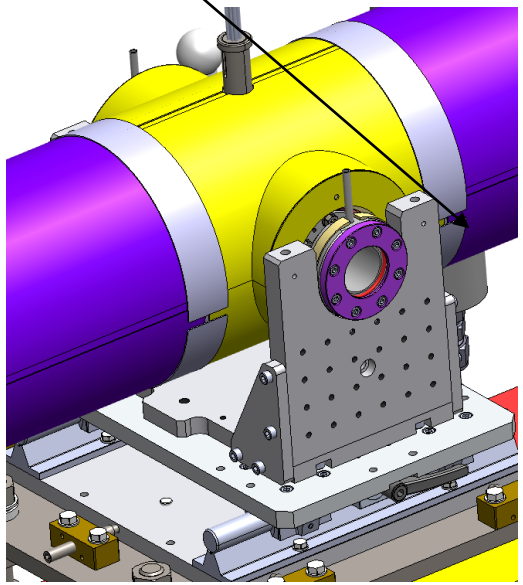


Not in use

(plunger 'out' state)

Design challenges

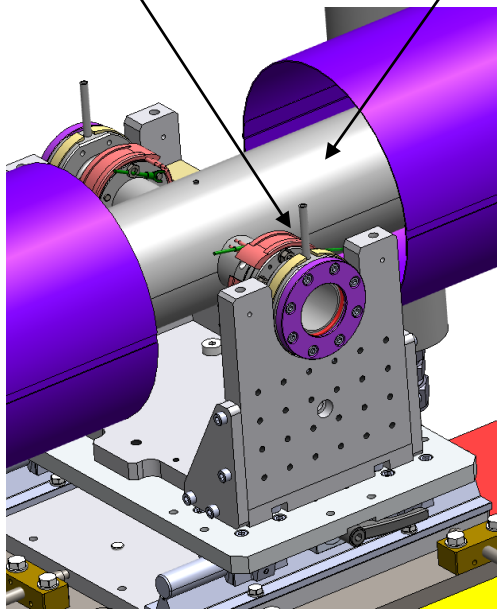
PLD port outer protection window



PLD port (supported version on GPC)

Heated DN40CF flange

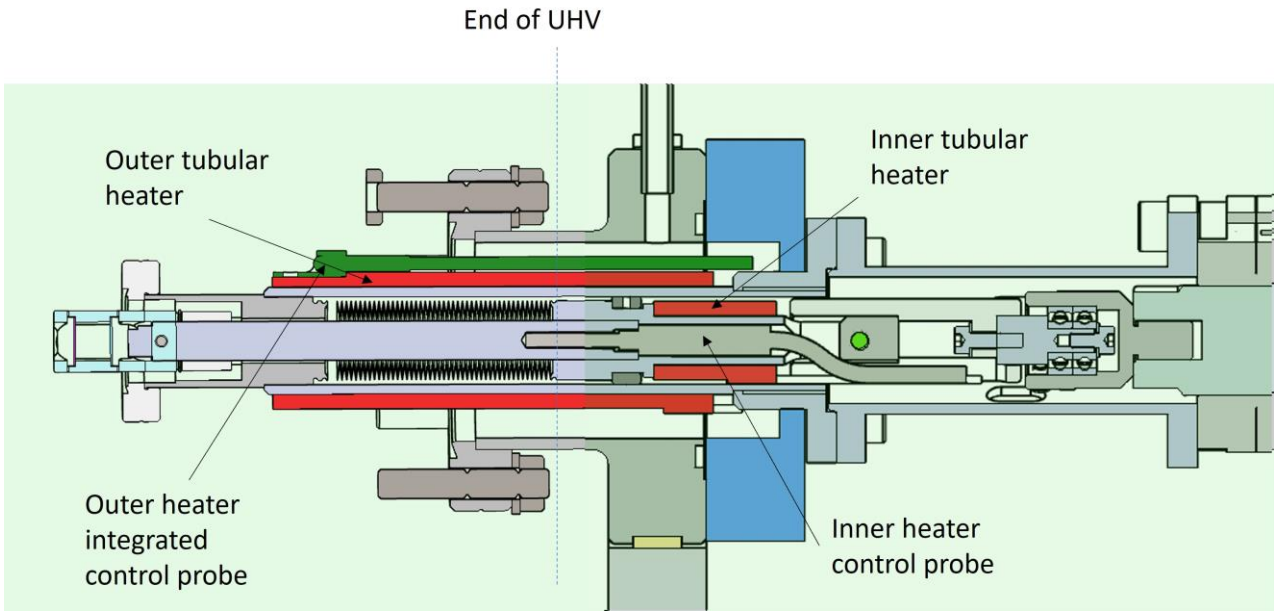
Tube heat exchanger round inner beamline tube (GPC)

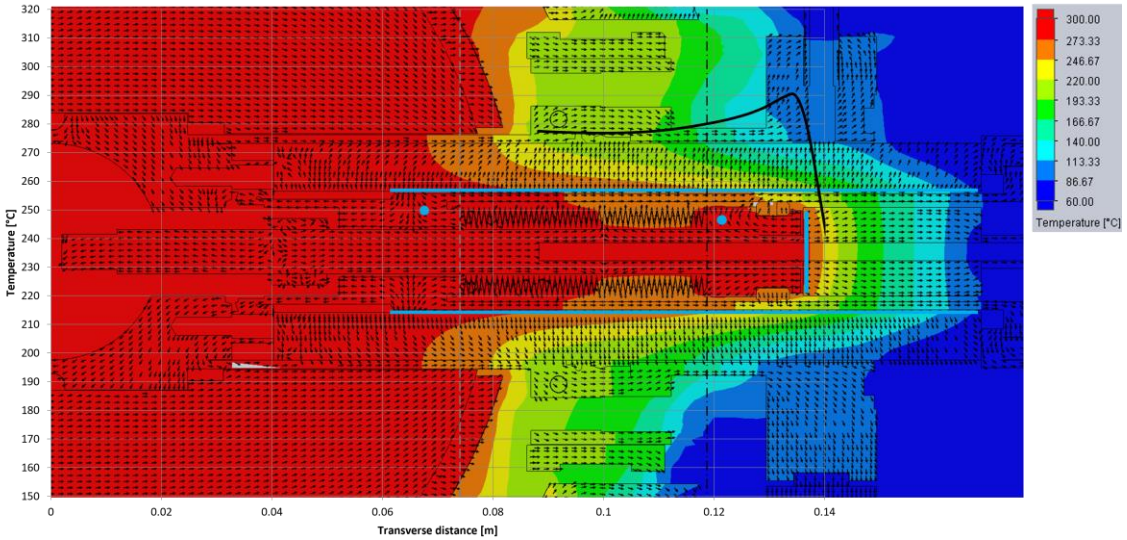


PLD port with beamline mu-metal and insulation removed

- Plunger shall fit to either a DN16CF or DN40CF flange
- Plunger shall be suitable for UHV
- Plunger internal (UHV) surfaces shall be able to be controlled and operated at beamline temperature:
  - Between 180°C and 230°C
  - Stretch goal would be operation at 280°C
- Plunger shall be controlled via simple 24V/12V/5V on/off signal to use existent Siemens control system of vapor source
- No cold spot should develop to avoid perturbing locally Rubidium vapor density

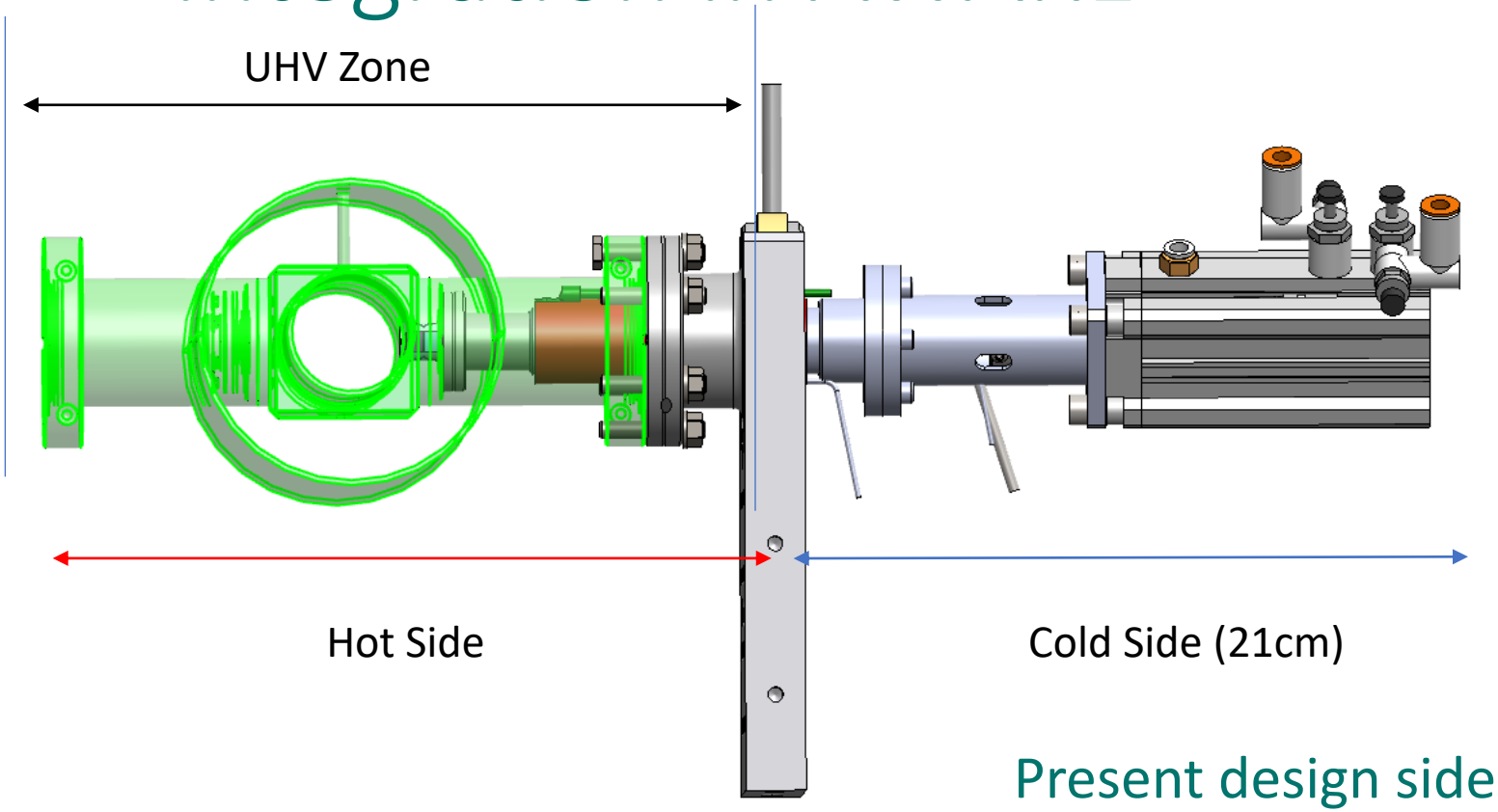
Design challenges

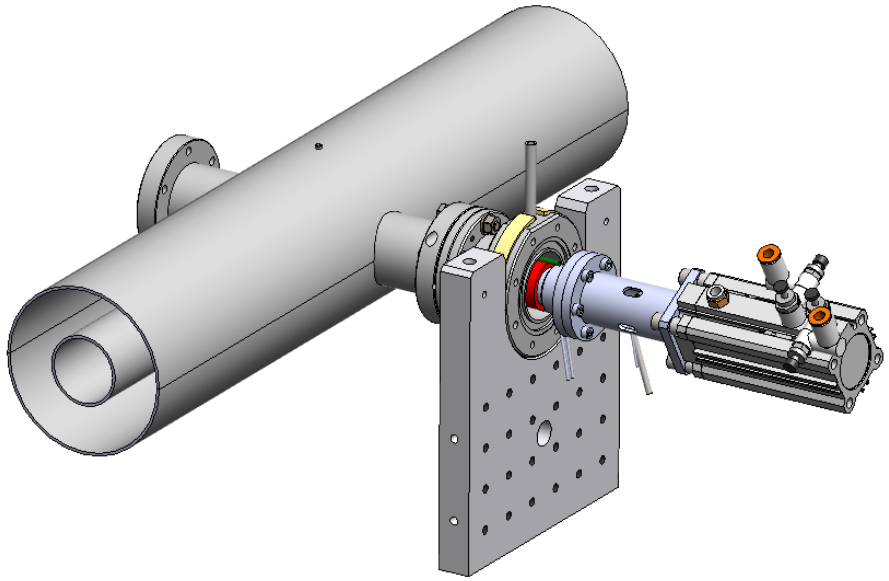




Thermal simulations indicate that temp uniformity is obtained with Temperature uniformity with 2 heaters (1 around plunger body and 1 on plunger shaft) + thermal break between vacuum and compressed air actuator (in addition of external insulation)

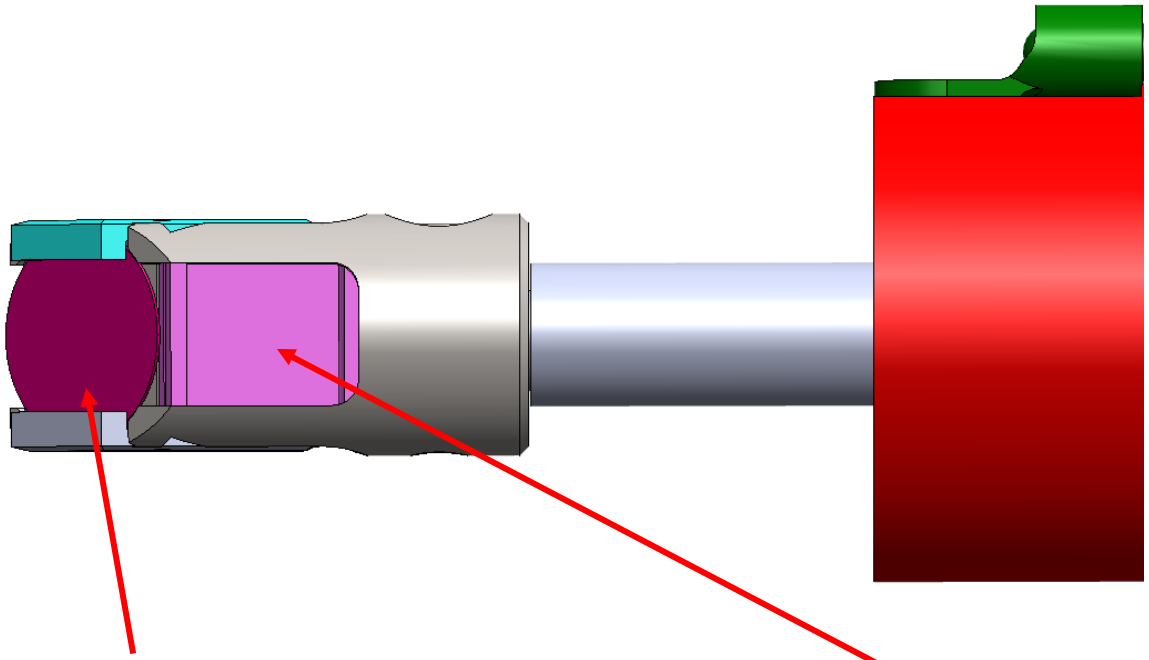
Integration in AWAKE

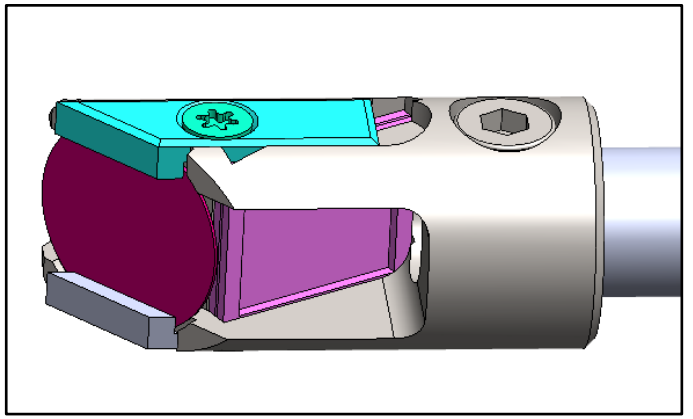


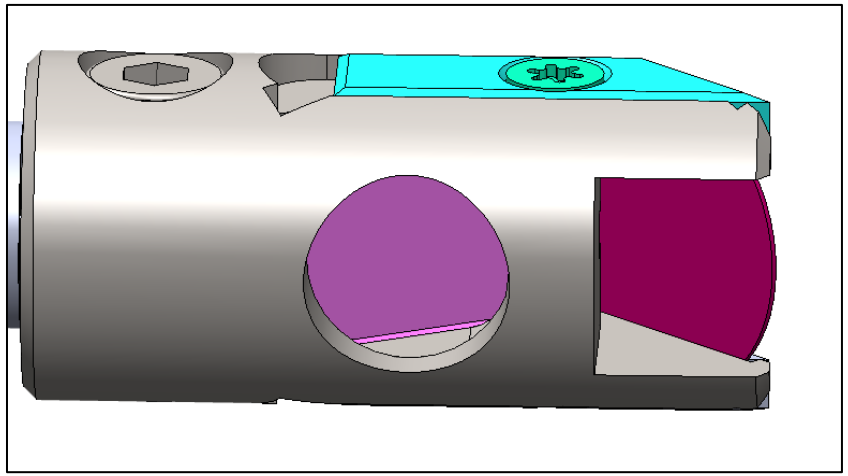


Present design side impact of plunger 21 cm, a bit extra space to allow the support structure needs to be considered

Integration in AWAKE



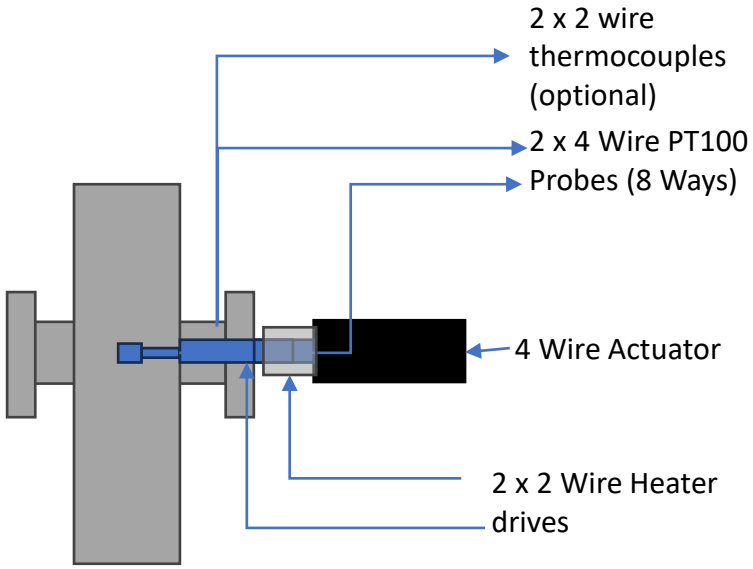




Yag screen for electron alignment and laser dump

Integration in AWAKE

Control System IO



TCC4
(x 10 Plungers)

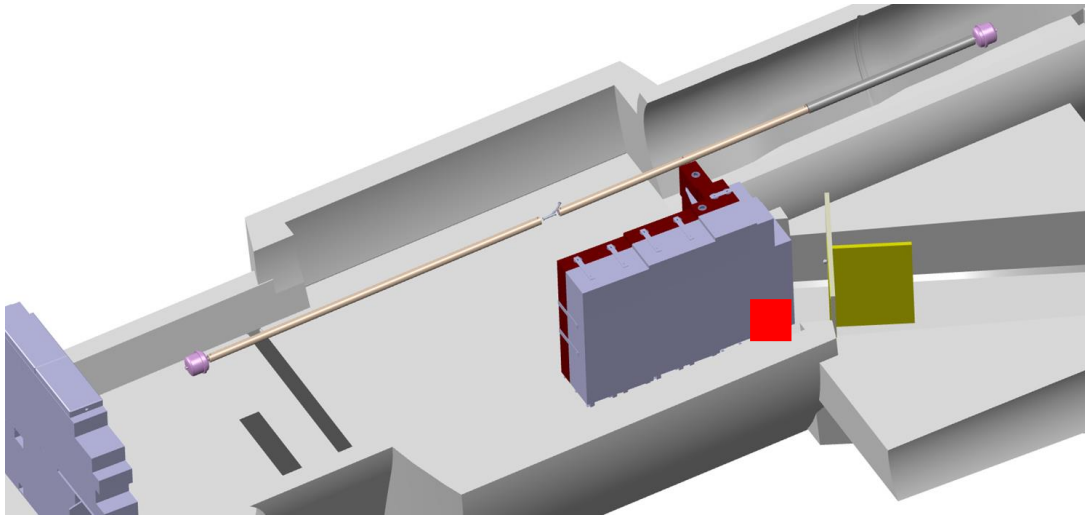
- 80 probe ways
- 40 Actuator Lines
- 40 Heater Drives

TSG4 Rack

Additional Heater Drive Rack

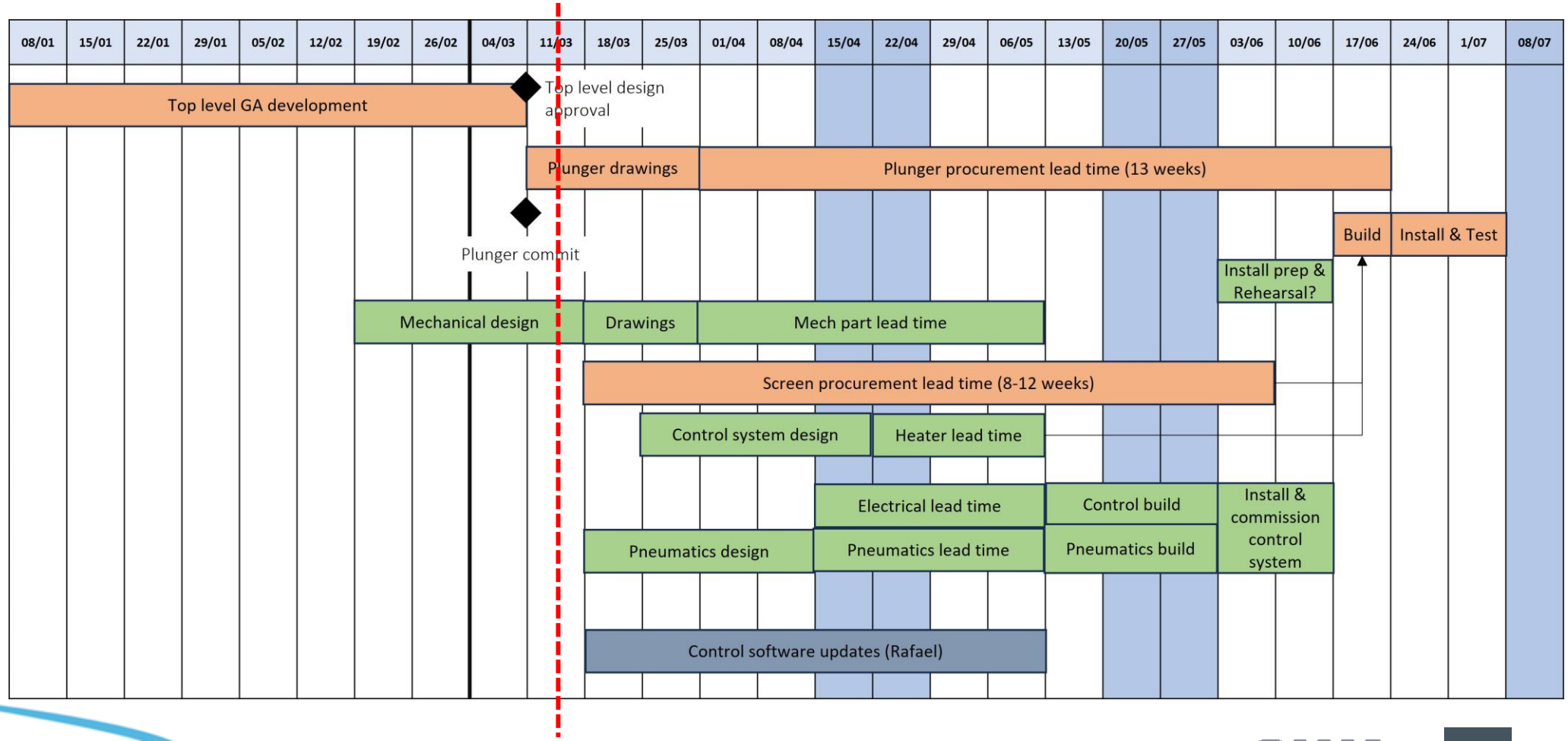
Siemens IO Modules

Insufficient ways to get to TSG4



- Make standalone sub-control rack
- XAWAVS comms via Profibus link, some cables might need to be pulled locally
- Locate behind radiation barrier near chillers, as it was for DPS test in April 2023
- Custom rack but the bulk of control components (Siemens) would be re-used from existing kit in ACC etc

Schedule for 2024 and cost



Summary for plungers' installations

- Design in advanced phase tackled main risks of cold spot on the plunger body/screen
- UHV parts can be built on semi-custom need, UHV Design contacted and part of design choices. Lead time is significant 13weeks
- YAG screen about to be ordered (lead time is 8-10 weeks), re-use of camera and optics from present Plasma light diagnostics.
- Procurement of hardware has been started
- Control system can be adapted with installation of small rack temporary (4 months) in TCC4 behind shielding blocks
- Control system design ongoing, CERN control team actively involved
- System aims to be integrated in laser interlock for devices protection, as light as possible implementation is under study: goal is to reduce hardware intervention as soon as possible given the temporary use of the system (6weeks of beamtime) -> PLCs direct communications

Thank you for your attention

AWAKE

MAX-PLANCK-INSTITUT FÜR PHYSIK

GWA Technology

WDL