
Scalable plasma source R&D

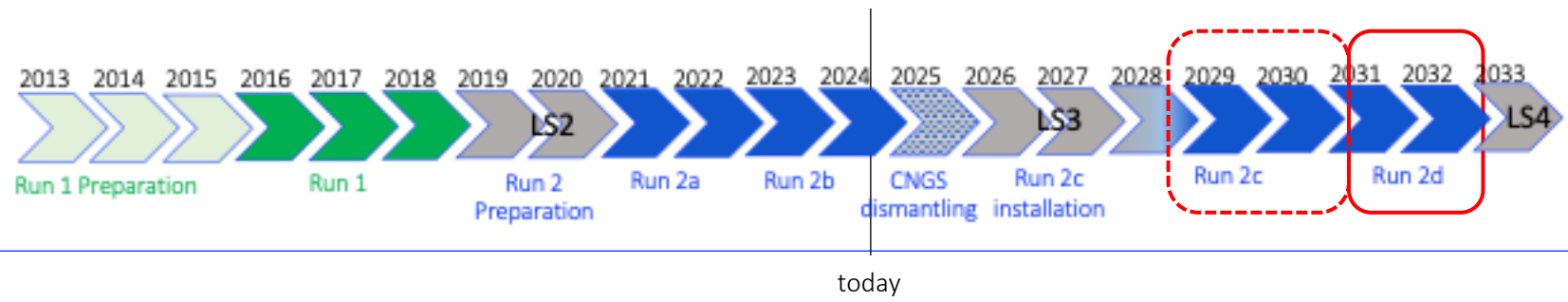
Alban Sublet for the plasma source R&D teams

Motivation, challenges and milestones



- Demonstrate uniformity, scalability and reproducibility within spec.: $n_e = 7 \times 10^{14} \text{ cm}^{-3} / 0.25\%$ uniformity
 - Focus on plasma diagnostics with institutes and get inputs for hardware design/optimization
 - Build and test scalable modules in CERN labs for both sources:
10-12 m in 4 segments for the Discharge Plasma Source (DPS) / 2.5 m for the Helicon Plasma Source (HPS)

- Milestones:
 - 1st milestone achieved = 10 m DPS test with protons in the AWAKE tunnel “DPS May 2023 Run”
 - End 2024 = first density profile for each source
 - End 2025 = Internal review whether scalable technology can already be used for **Run 2c**
 - Scalable Plasma Source review (~ 2027): decision for **Run 2d** scalable source, procurement and design



Scalability and reproducibility (> 2026)

DPS: scalability driven by tunability and arrangement of the source

Double plasma (10 m + 10 m) with common cathode

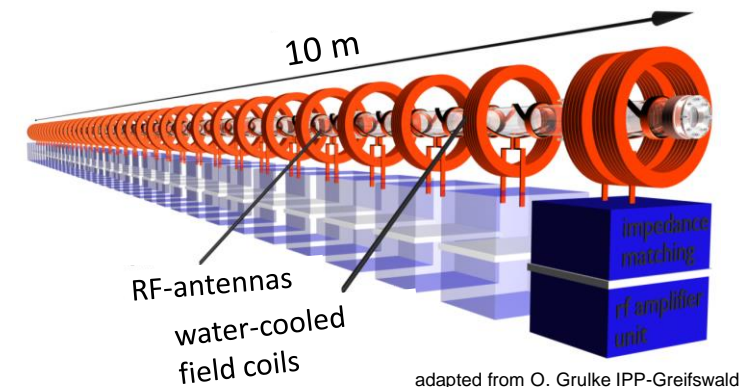
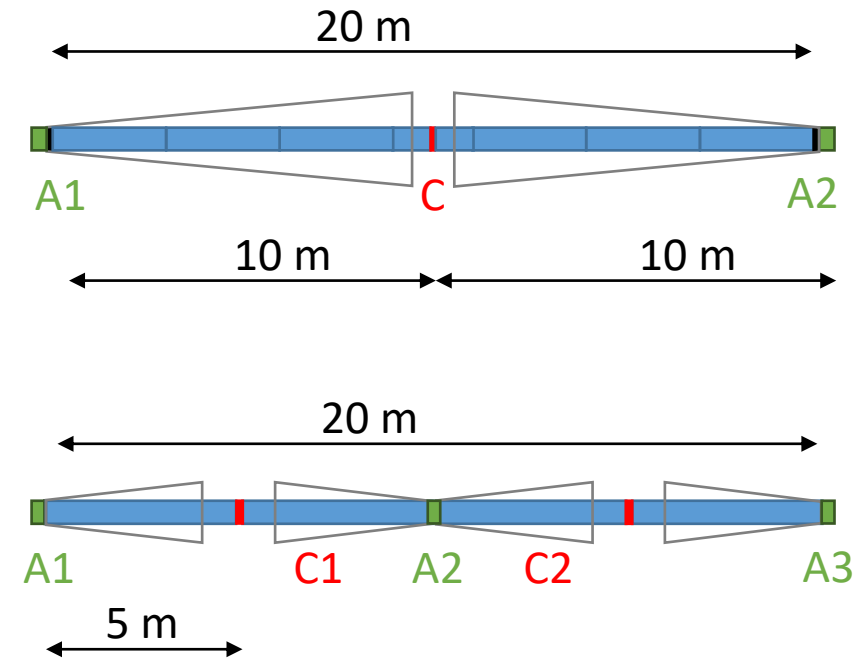
Quadruple plasma (5 m + 5 m + 5 m + 5 m): A/C/A/C/A scheme

→ New generation of high precision pulse generator (outsourced)

HPS: scalability by adding antenna/coils/generators

10 m source (4x 2.5 m unit module) with 40 antennas/RF generators (tbd)

+ Address technical aspects for tunnel integration/operation: control and regulation of tube temperature/pressure/gas/interfaces...



- **Run 2c:** 10 m source, for DPS can be 1 segment (like DPS run 10 m electrodes at extremities), 0.25% uniformity + reproducibility + tunability
 - WP requirements for Run 2c will depend on decision end 2025 for DPS, if DPS qualified, should be reasonable adaptation based on 2023 May run with DPS, although requires consolidation of HW design (pulsed-DC power supplies need industrialization and glass tube + interface new design)
- **Run 2d:** 10-20 m multi-segments source for scalability (on top of 0.25% uniformity + reproducibility + tunability)
 - WP requirements for Run 2d will depend on decision end 2027 for DPS or HPS
 - if DPS, should be reasonable adaptation based on 2023 May run with DPS, although requires consolidation of HW design (pulsed-DC power supplies need industrialization and glass tube + interface new design)
 - if HPS, much more demanding: adapt tunnel infrastructure for power/cabling/cooling...

DPS/HPS technical points to be addressed



Global parameters (common to both sources)

1. Vacuum, gas density, pressure profiles simulations as function of walls materials, pressures, gas, temperatures... → TE/VSC
2. gas injection, re-fill and pumping scheme to guarantee pressure regulation/injection/adjustment → TE/VSC
3. getter pump to get rid of impurities and possibly operate in quasi-static mode, but locality?! Simulations + RGA/OES for monitoring and conditioning measurements → TE/VSC
4. temperature measurements + lab/tunnel environment tolerances → do we need active tube/gas temperature regulation?
5. interfaces: Si_3N_4 windows for e^- (80-150 MeV range) and p^+ (400 GeV, $3e^{11}$ protons bunch) → refers to ongoing windows studies for Muon collider (Jose Ferreira) → TE/VSC
6. glass tube design (quartz/borosilicate, simple straight tubes of 5 m to limit interfaces, interfaces/connections to beam vacuum chambers/Rb plasma source, etc.) → TE/VSC + EN/MME
7. gas and plasma density diagnostics? Lab/tunnel
8. extend 169 lab laser room for space/diagnostics: merge R-026-024?
9. RP and radiation to electronic question in the tunnel → HSE/RP
10. design and integration → EN/MME + EN/ACE + EN/CV
11. survey → BE/GM
12. timing/control/monitoring for daily operation → BE/CEM

DPS technical points to be addressed



DPS specific parameters

1. electrodes design/#pins/geometry → leak/impurities, plasma uniformity at extremities? → TE/VSC + EN/MME
2. tube inner diameter tolerances (mostly for DPS though)
3. HV cable length limitation? ~ 25-30 m possible?, tunnel requirements?
4. current balancing modules design, tubes and generators arrangements → for scalability
5. new generation + industrialisation of DC-pulsed generators? → to be well anticipated for run 2c/d!

HPS technical points to be addressed



HPS specific parameters

1. antenna design + optimum spacing wrt helicon waves...
2. coils design + DC power supply → upgrade for 2.5 m source and scalability → TE/MSC (Philip), SY/EPC
3. 2.5 m HPS module design → EN/MME
4. RF-generators → number/power? tbd
5. matchbox able to operate in radiation area (the closest to the antenna, so to the beam!)
6. RF cable length limitation? ~ 25-30 m
7. Cooling → EN/CV
8. electrical power for RF and DC power supplies → EN/EL
9. cabling → EN/EL