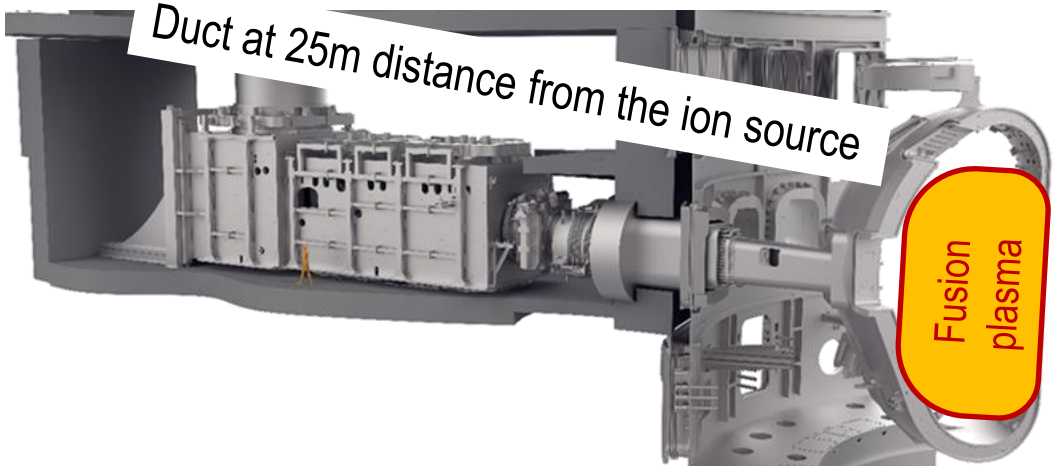
Optimizing the ITER NBI ion source by dedicated RF driver test stand

I. Mario, A. Pimazzoni, E. Sartori, G. Serianni and the NBTF team

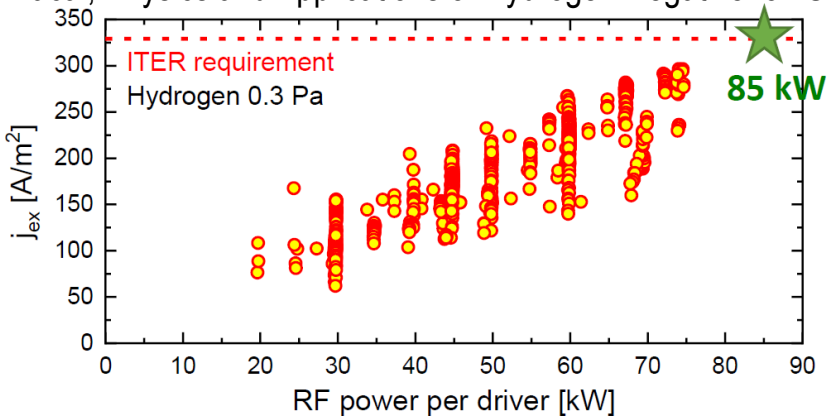
NBI requirements & ITER targets



Requirements: 7 mrad, 329 A/m^2 (350A/m^2) HNB (DNB)
0,3 Pa, 3600 s, 1MeV
beam homogeneity >90%

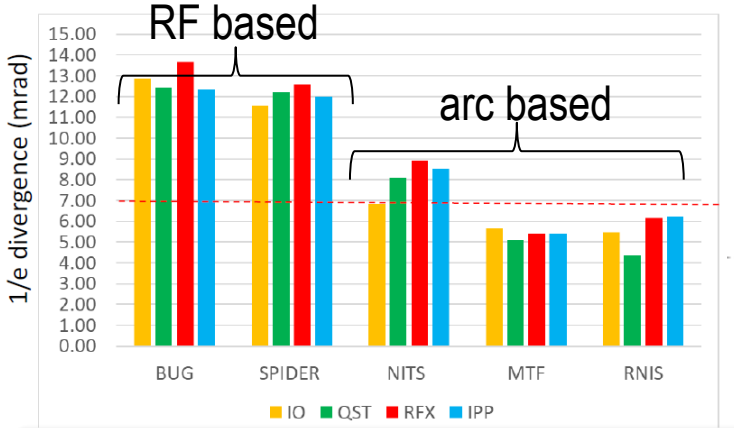
Solutions should be implemented and tested in large machines:
R&D towards solutions <u>now</u>
→ in the **N**eutral **B**eam **T**est **F**acility takes <u>several years</u>

Bacal, Physics and Applications of Hydrogen Negative Ion Sources



- RF power at present state is marginal to reach the ITER HNB / DNB requirements

- High performance operation not routinely achieved
- Beam affected by inhomogeneity of the beam power / divergence
- Beamlet divergence in RF sources is higher compared to arc source



T_{H^-}

P. Veltri, Presented NIBS'22

$Div = Div(I_{ex}/U_{ex}^{1.5}, E_{beam}, T_{H^-})$

Beam performances reflects the plasma properties
R&D towards **better** plasma properties!

Neutral Beam Test Facility – SPIDER and MITICA

- The SPIDER test facility: full size ion source, three grids, 100keV
  - Shutdown time between campaigns is intrinsically long

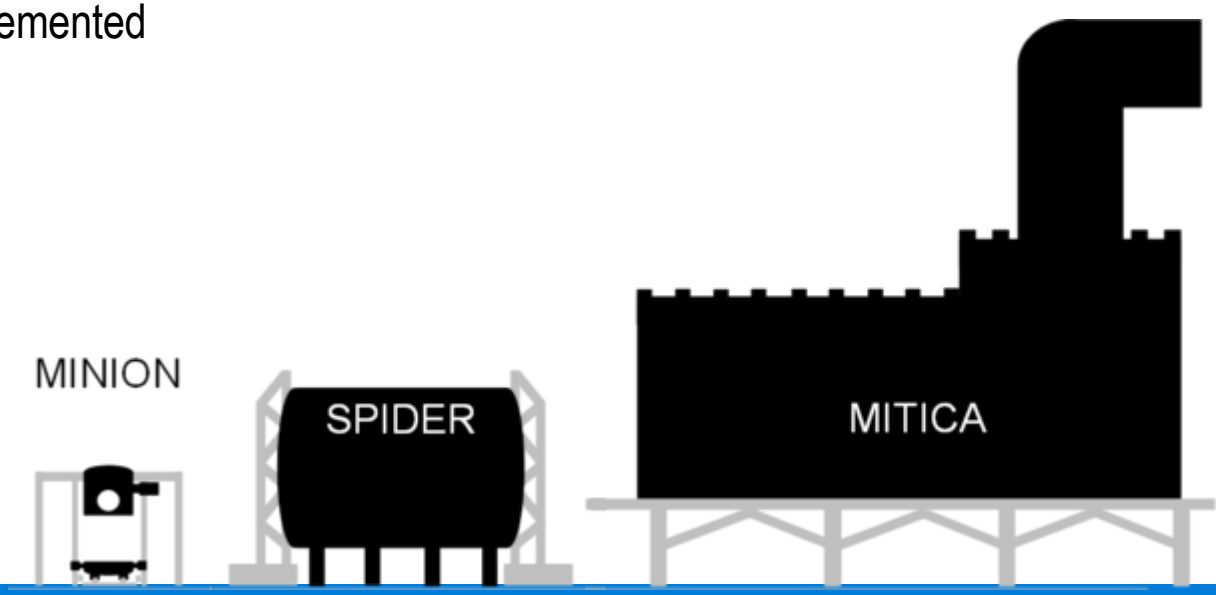
    due to the complexity of the system
  - Every solution takes years (from project to installation) to be implemented
  - Limited access for diagnostics in the source

- MITICA: ITER ion source, 7 grids, 1 MeV
  - More complexity
  - Longer time for implementation
  - Almost no diagnostics access

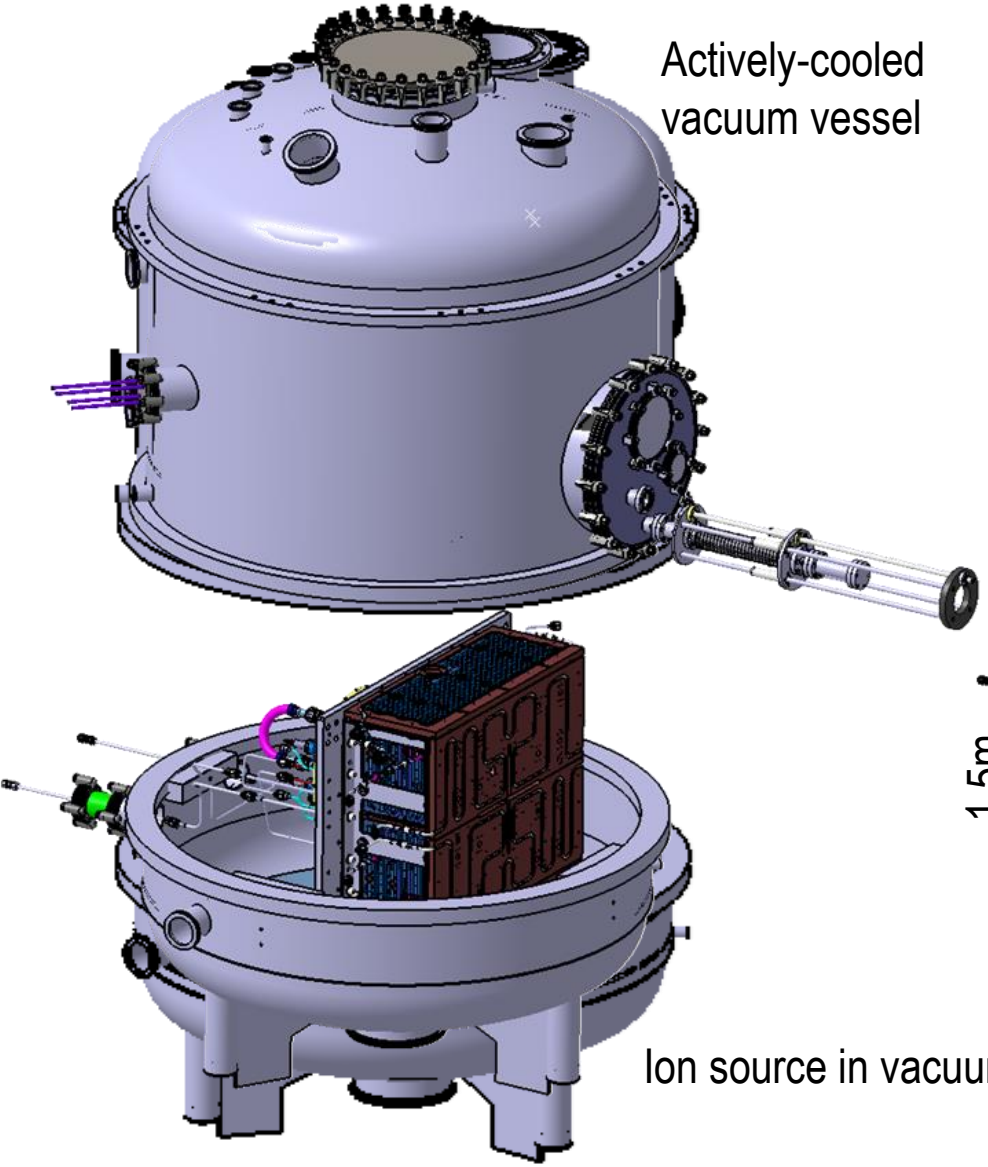
- The MINION experiment:
  - Modifications / tests on alternative setup rapidly (months) implemented
  - Easier diagnostic accessibility

Outline of this presentation:

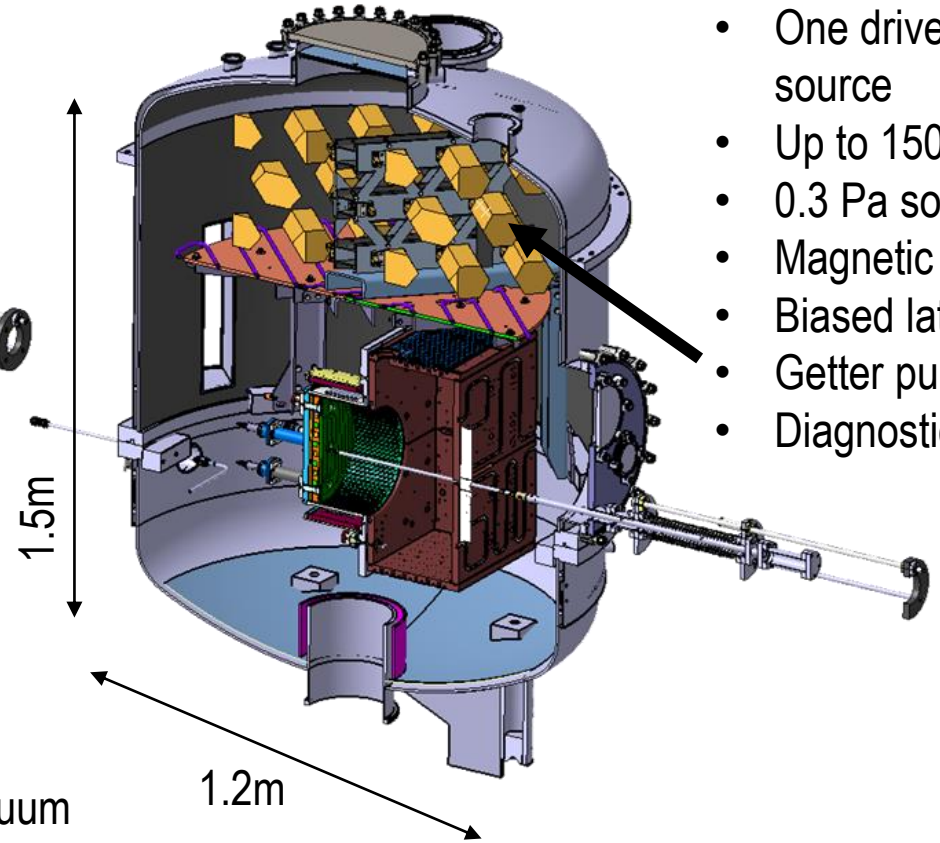
- MINION facility
- Scientific exploitations



The MINION experiment



Magnetized **I**CP for **N**egative **I**on **O**peration in **N**BI

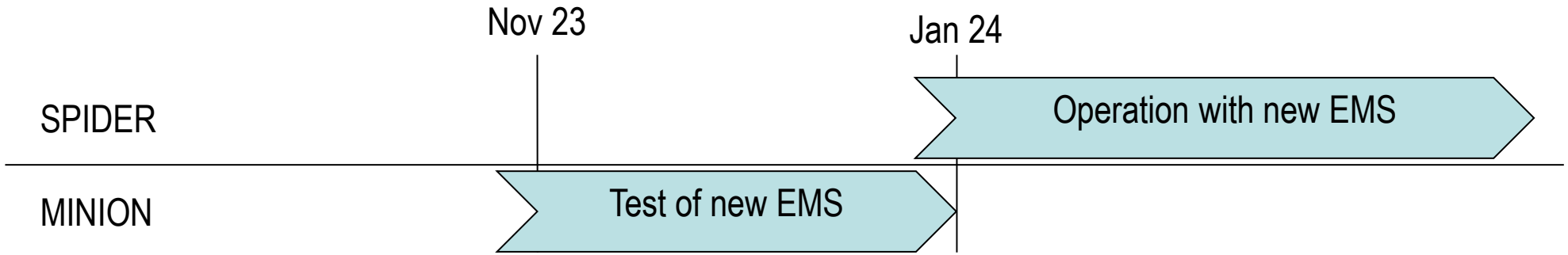


Ion source in vacuum:

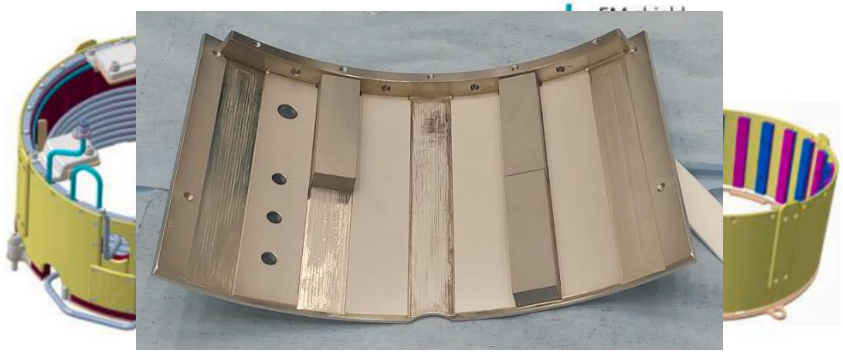
- One driver of SPIDER - 1/8 ITER NBI ion source
- Up to 150 kW of RF power
- 0.3 Pa source filling pressure
- Magnetic filter field adjustable
- Biased lateral walls
- Getter pumps to ensure apertures
- Diagnostic access through several apertures

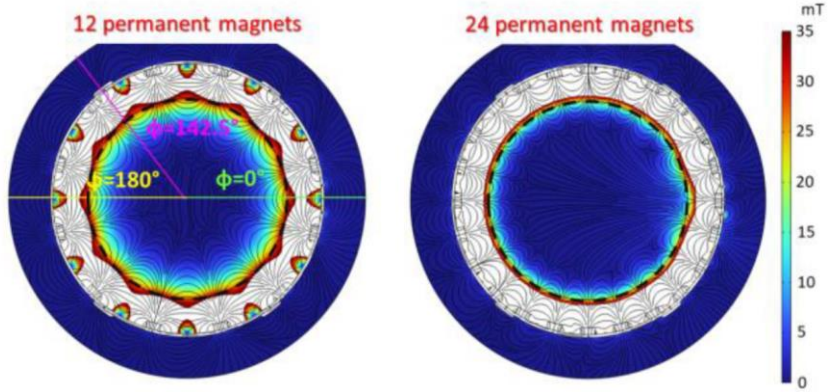
NBTF challenges & MINION's targets

Target	Test on MINION
Improvement of plasma confinement	Test on magnetic configurations for confinement



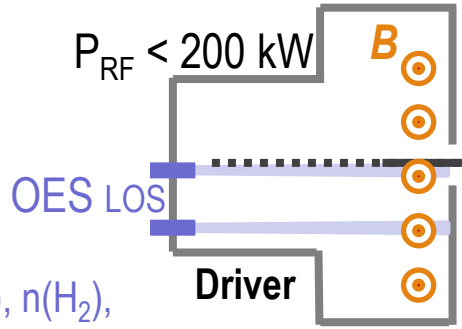
New driver layout:





N. Marconato, https://doi.org/10.1016/j.fusengdes.2023.113805

Diagnostic system:



n(H), n(H_2),
dissociation degree + development of CR models

Calorimetry on driver components
Ready in November 2023

NBTF challenges & MINION's targets

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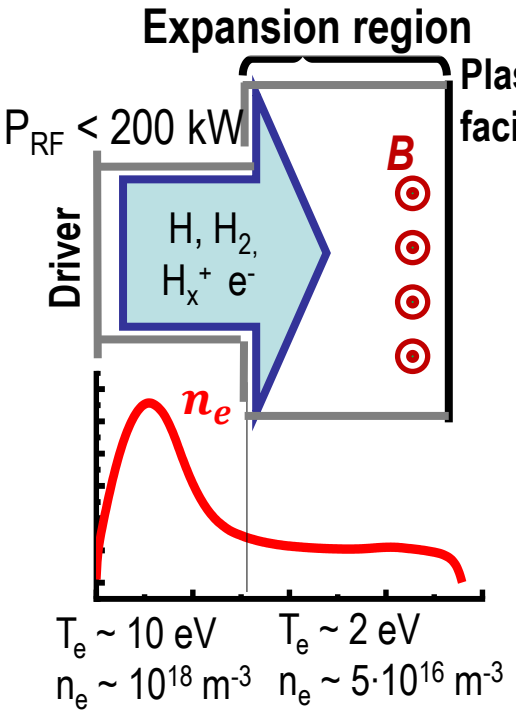
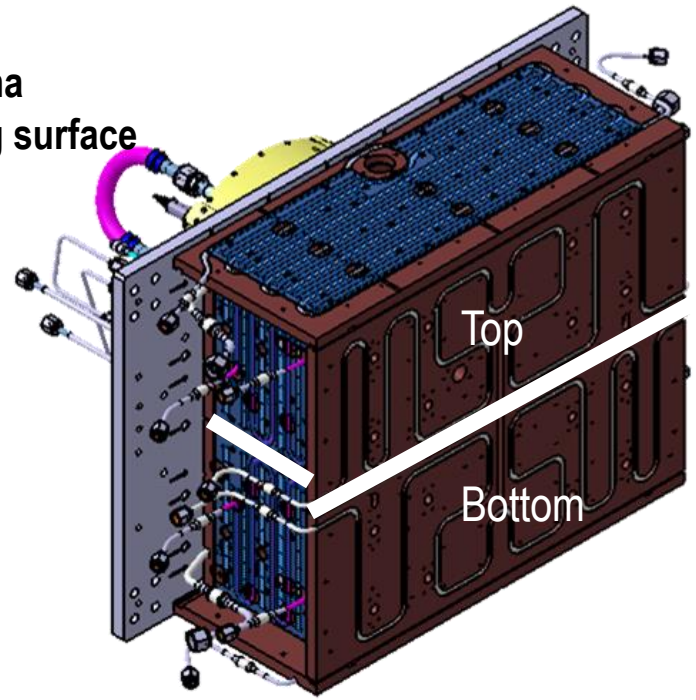
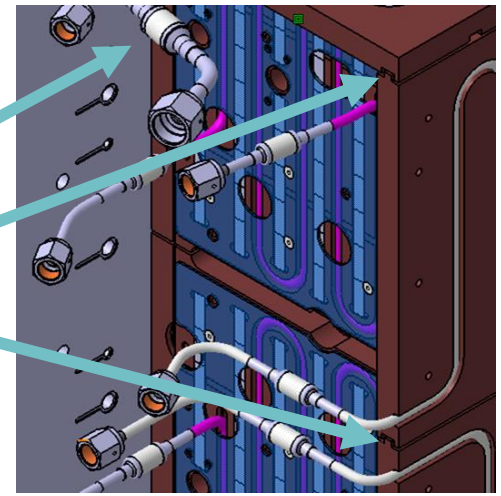
Optimization of plasma expansion from driver (FF, biased surfaces, uniformity ...)	Filter field topology, biasing of source components …





Vessel designed to have walls vertically split and all electrically independent and bias applicable:

- Ceramic breaks on all pipes
- 2mm slits among adiacent elements
- ceramic washers to avoid electrical contact to the support structure



Ready in June 2024

NBTF challenges & MINION's targets

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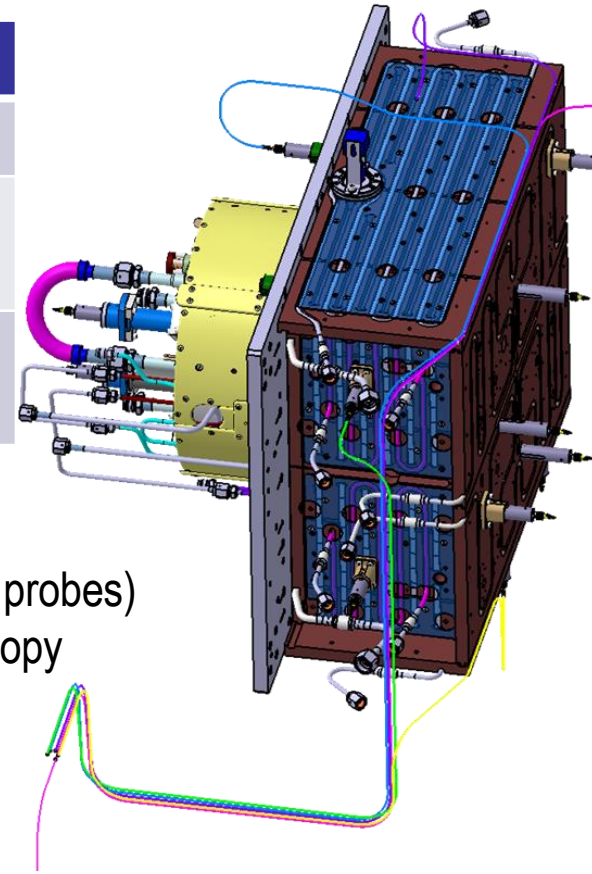
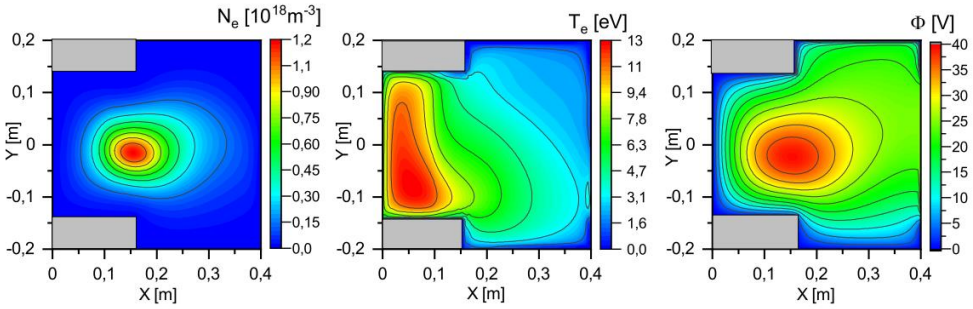
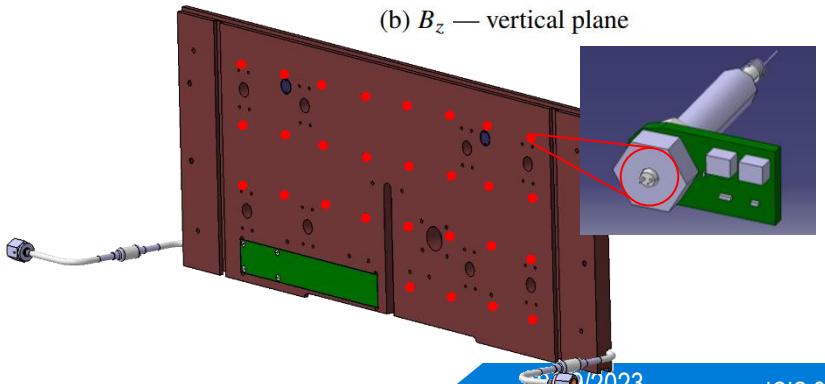
Improve the understanding of plasma physics in RF based negative ion sources	Development and use of dedicated diagnostics, validation of numerical models, …



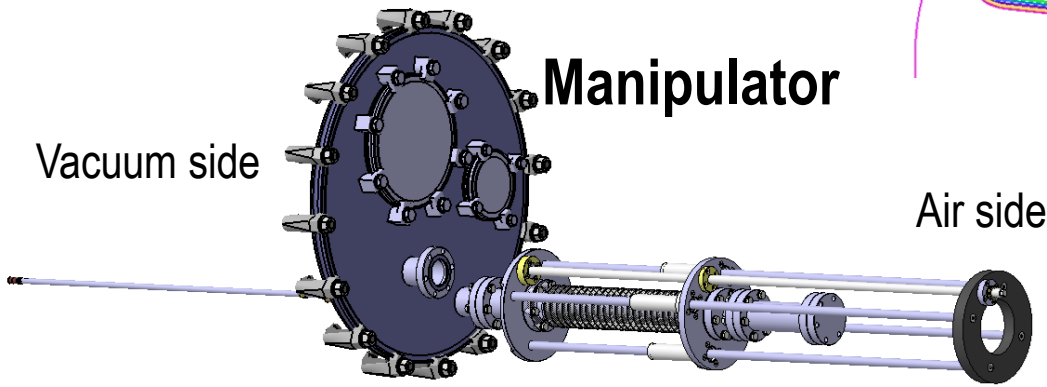
R. Zagórski et al 2023 JINST 18 C08008





Diagnostics:

- Manipulator in and off driver axis (Langmuir probes)
- 36 lines of sight Optical Emission Spectroscopy
- Retarding field energy analyzer
- About 40 fixed Langmuir probes



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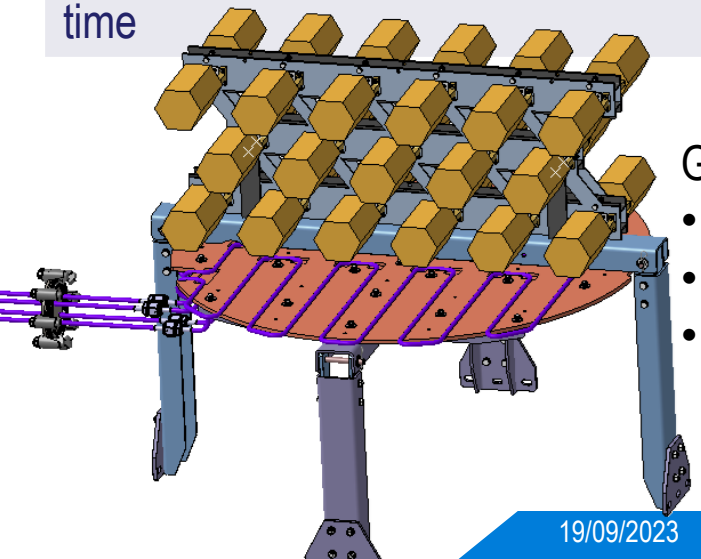
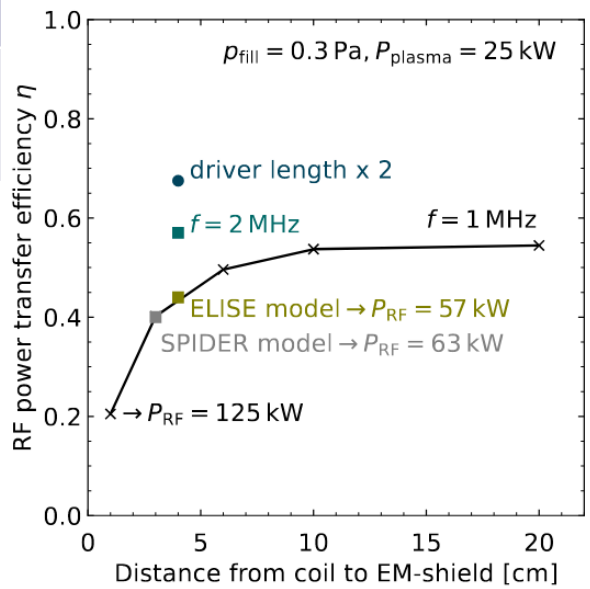
Improve the understanding of plasma physics in RF based negative ion sources	Development and use of dedicated diagnostics, validation of numerical models, …
Optimization of RF coupling efficiency	Test on driver components geometry
Installation of new solid state RF generators	Test on plasma ignition and generator control
Improvement of pumping speed and stability over time	Getter pumps installed on MINION / test on Regeneration



Getter pumps:
- Regeneration
- Impurity level in the source
- Effect on operation

RF generators and efficiency:
- Plasma ignition tests
- Coupling efficiency & plasma parameters

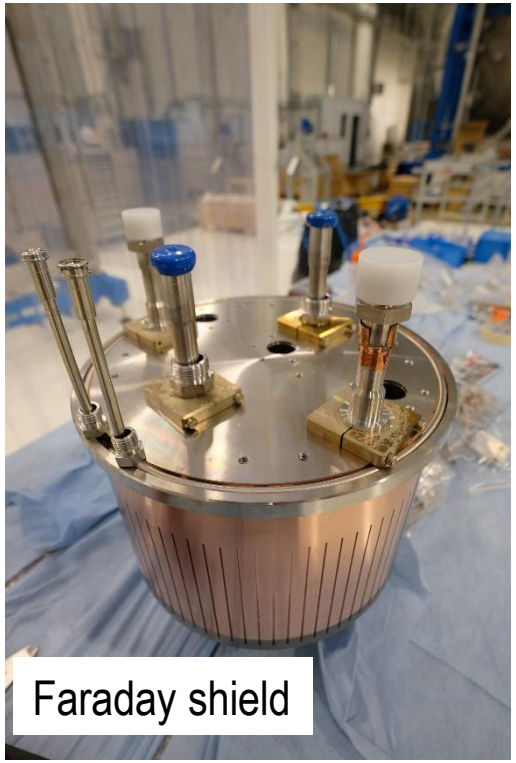


D. Zielke, Presented NIBS'22

Conclusions

- R&D improving the plasma properties is need for sustainability and reliability of ITER NBI system
- MINION facility: playground to learn faster and assist the NBTF activities
- Improve and deepen the understanding of RF-driven ion sources (plasma expansion) through the comparison with modelling

Source & driver components

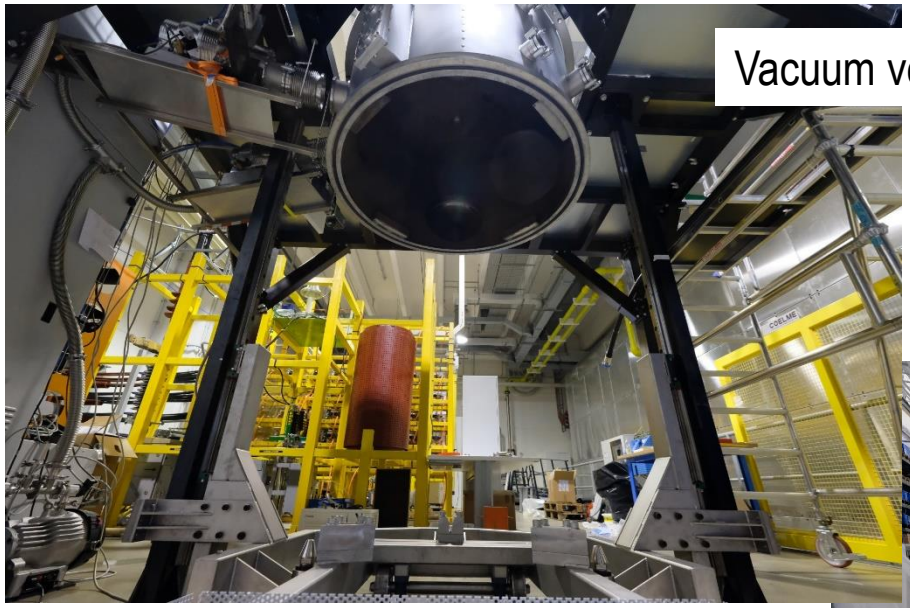


Faraday shield

Source assembly ongoing

Operation in Nov 2023

Thank you for the attention!



Vacuum vessel top

Vacuum vessel bottom

MINION driver mounted

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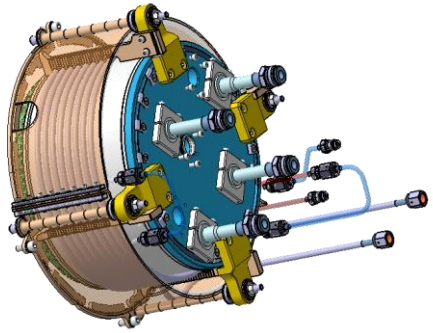
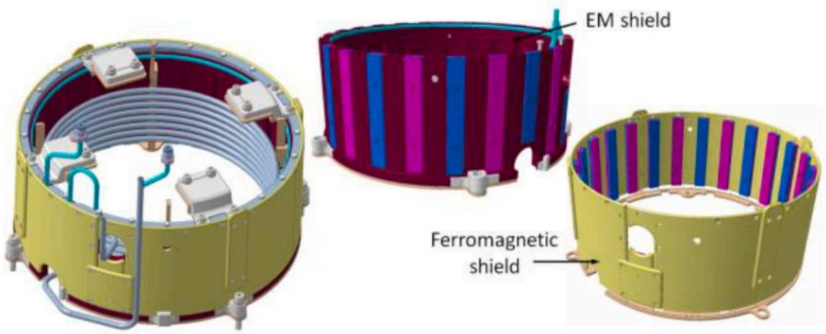
Appendix

MINION: fast track towards SPIDER optimization

Initial test on the driver layout:





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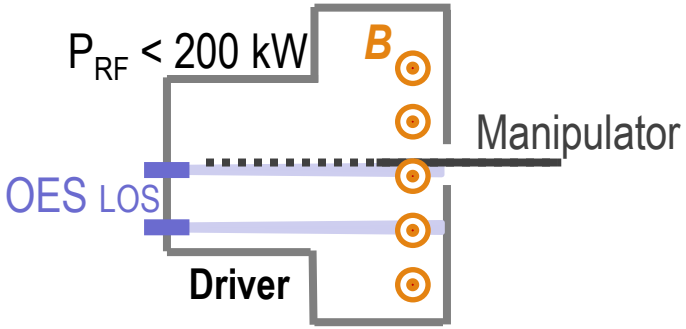
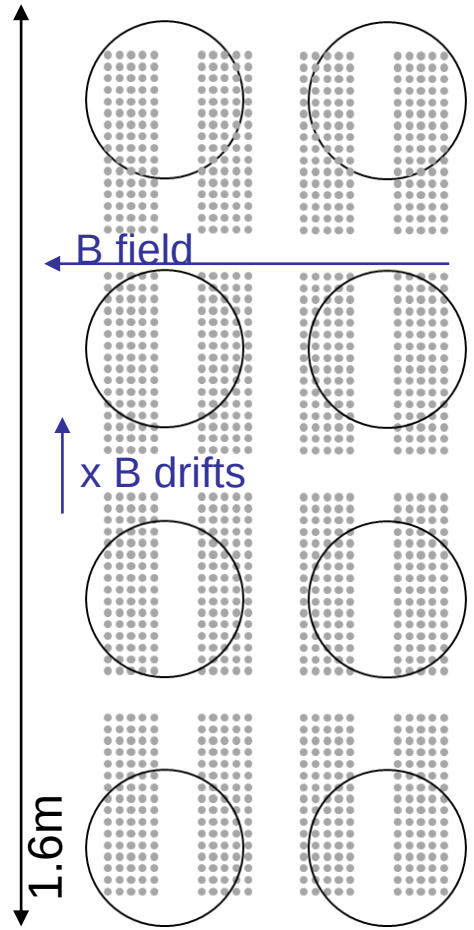


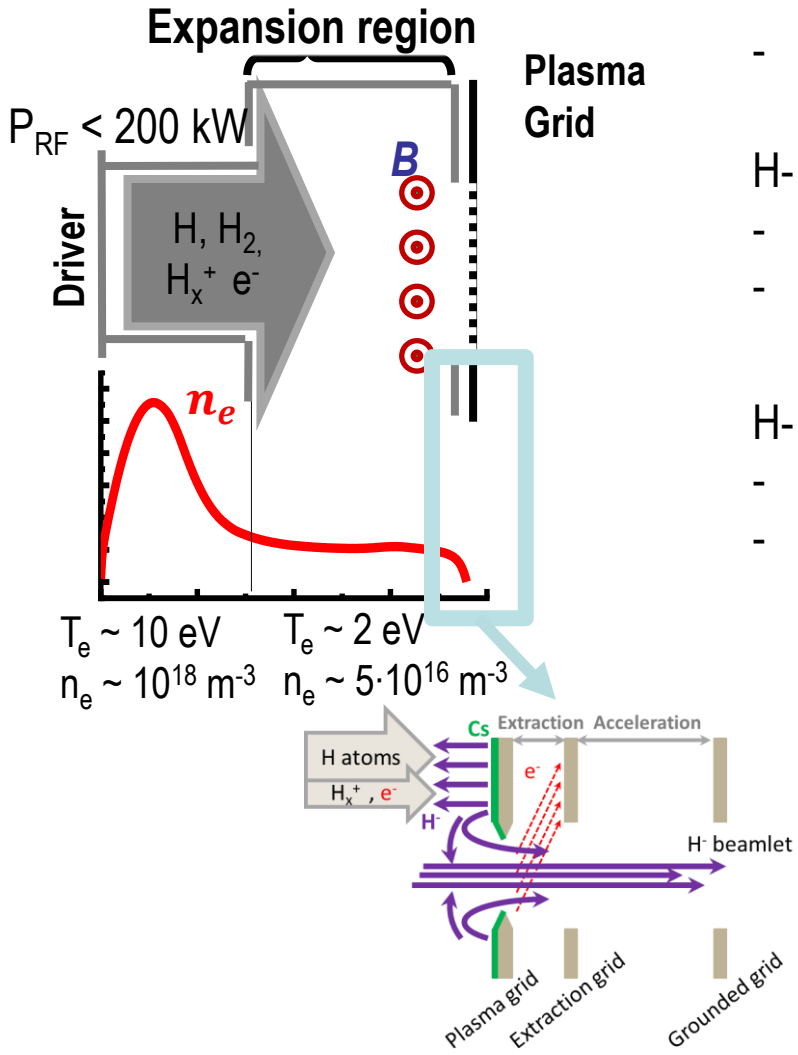
n_+, Te, V_p along axis position

n(H), $n(H_2)$, dissociation degree
+ development of CR models

Calorimetry on driver components

Introduction





Divergence
- Optics term: Accelerator geometry and voltages - already optimized
- Kinetic term: Velocity distribution of H^- at meniscus : "T_{H^-}"

H- density:
- H0 flow towards PG
- Positive ion density (avoid space charge limit at PG surface)

H- uniformity:
- precursors uniformity
- Plasma uniformity