Towards the optimzation of the Cs evaporation configuration for long pulse operation in negative ion sources

A. Mimo, C. Wimmer, D. Wünderlich, M. Fröschle, U. Fantz

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ELISE test facility

- **Cs evaporated to reduce plasma grid work function:**

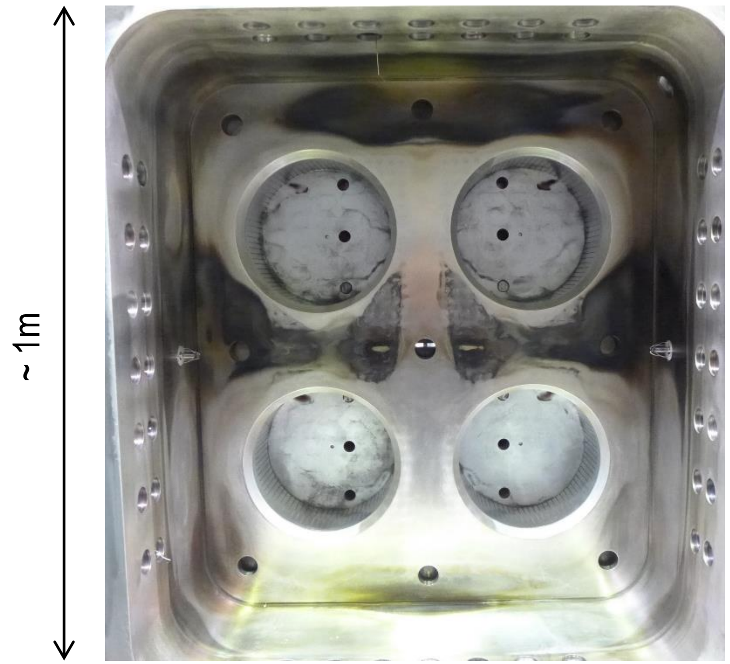
  - increase H-/D- production

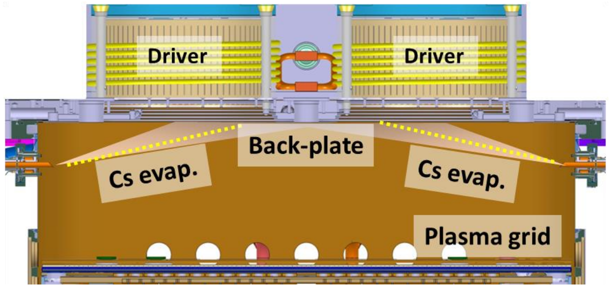
  - decrease co-extracted electrons (limiting factor for long pulses in D_2)

- **Cs evaporation:**

  - 2 Cs oven located on the sides of the ion source

  - Direction evaporation → source back-plate





CsFlow3D Monte Carlo test-particle code

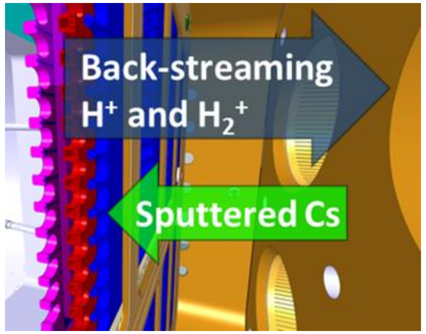
VACUUM PHASE

- **Only neutral Cs**
- **Ballistic transport (p ≈ 10^{-4} Pa)**
- **Dynamics determined by:**
  - Oven outflow profile
  - Source geometry
  - Wall sticking probability (temperature and impurities)

PLASMA PHASE

Beam pulse

- **Both Cs neutrals and ions**
- **Collisions (p ≈ 0.3 Pa) :**
  - Background gas
  - Plasma
- **Cs redistribution by plasma**
- **Cs Sputtering by back-streaming ions**



Consecutive long pulses: experiments vs. simulations

- 3 consecutive pulses of 1 hour performed (15 mins vacuum in between)
- Strong reduction of neutral Cs density in the first 100 s
- Similar absolute value and trend for the simulations
- Increase of Cs in consecutive pulses (~ 30%): however, not enough for an improvement in the stability of co-extracted electrons.
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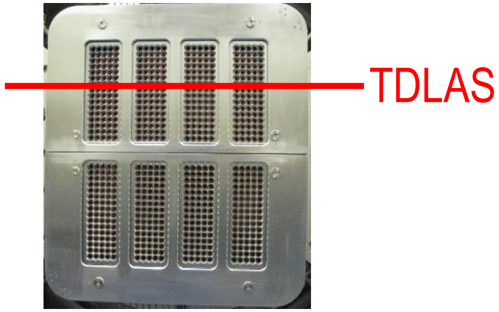
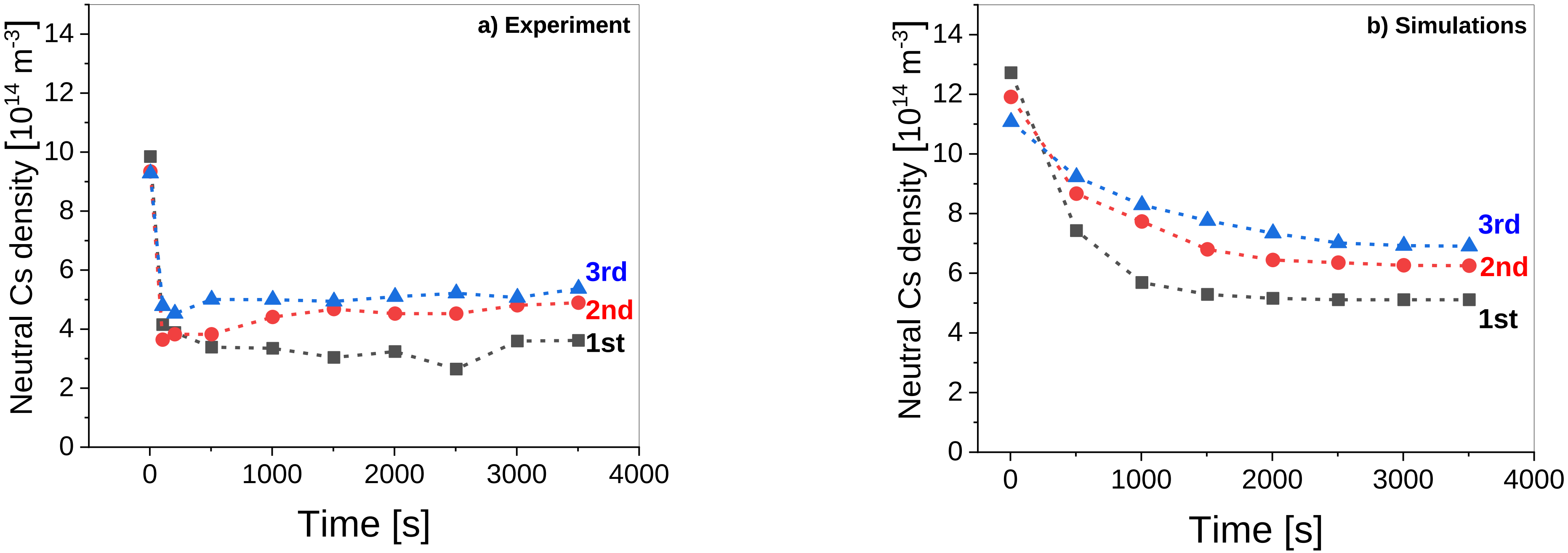
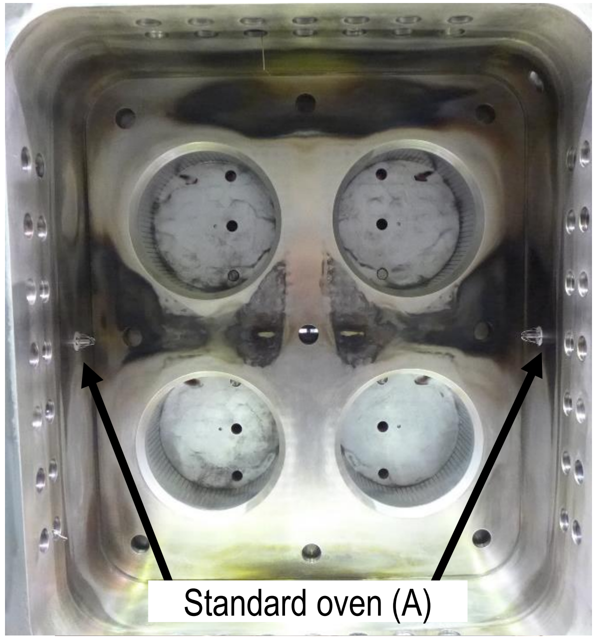
Deuterium
RF power 35 kW/driver
Extraction voltage: 5 kV
Acceleration voltage: 25 kV
Ibias: 5A
IPG: 3.8 kA

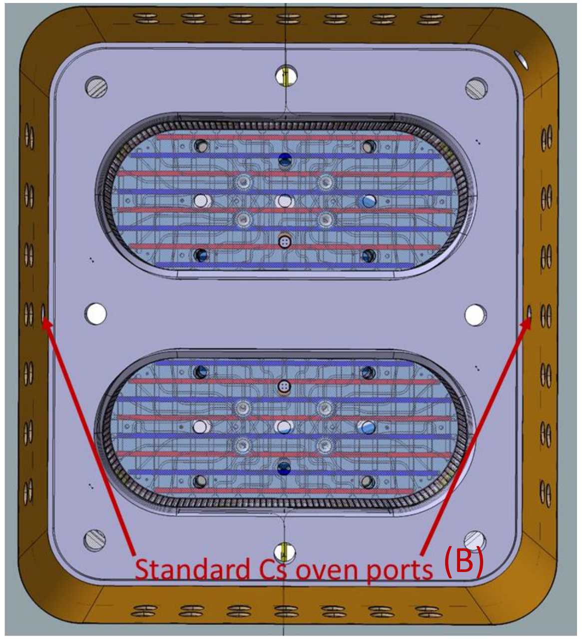


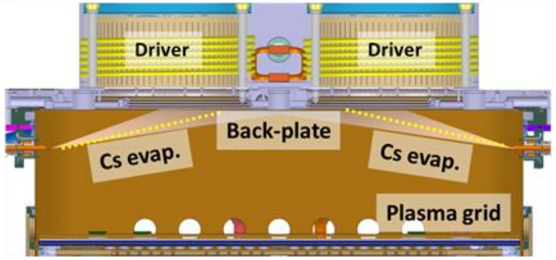


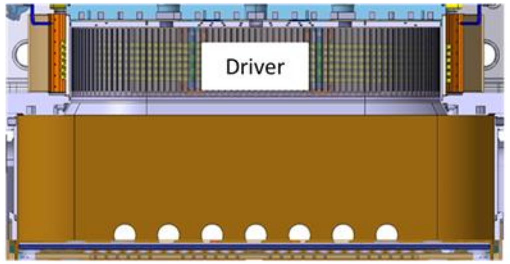
Cs oven position and alternative RF driver concept

- **Alternative driver concept** towards DEMO with a race-track shape: change of plasma interaction with walls









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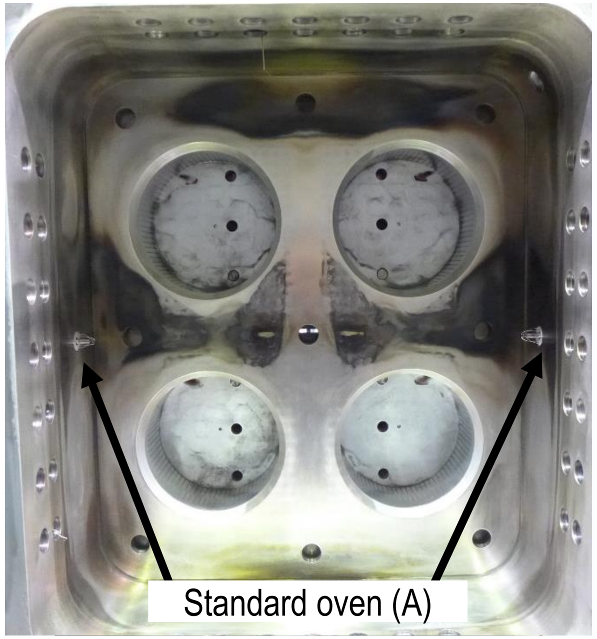

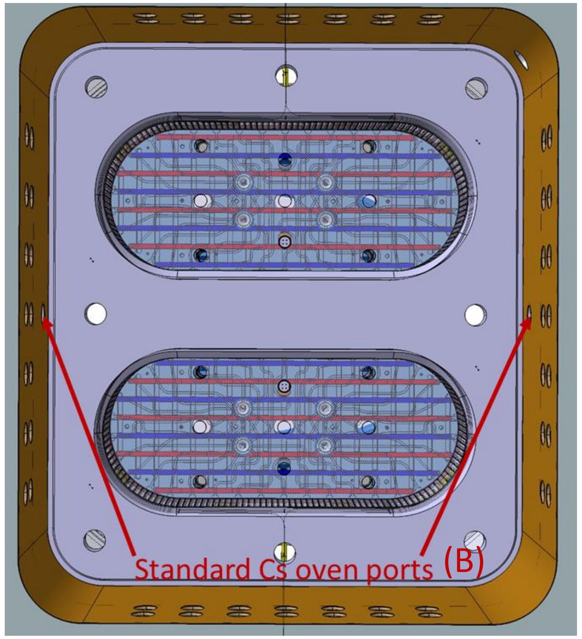

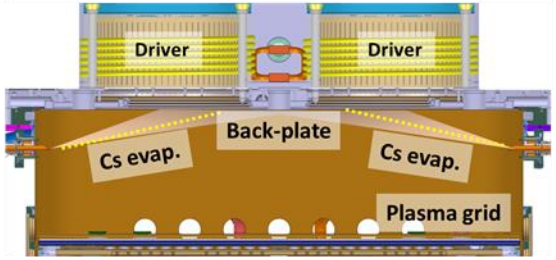

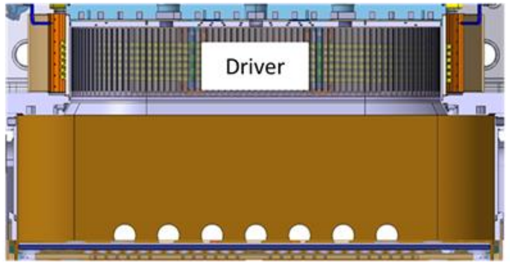

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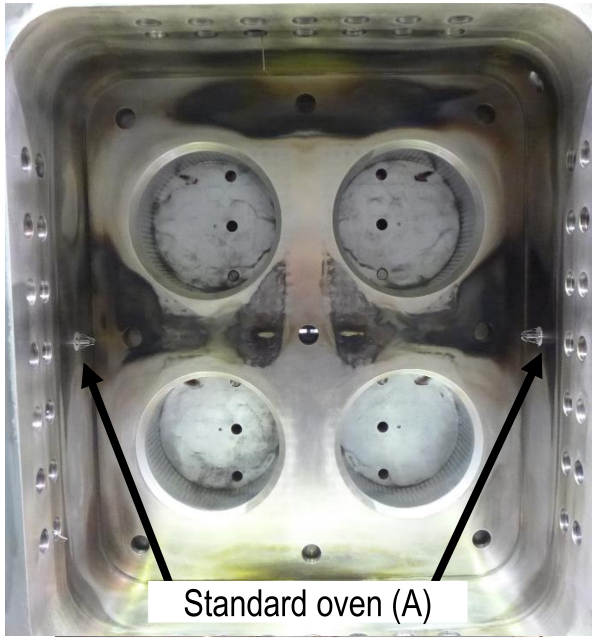

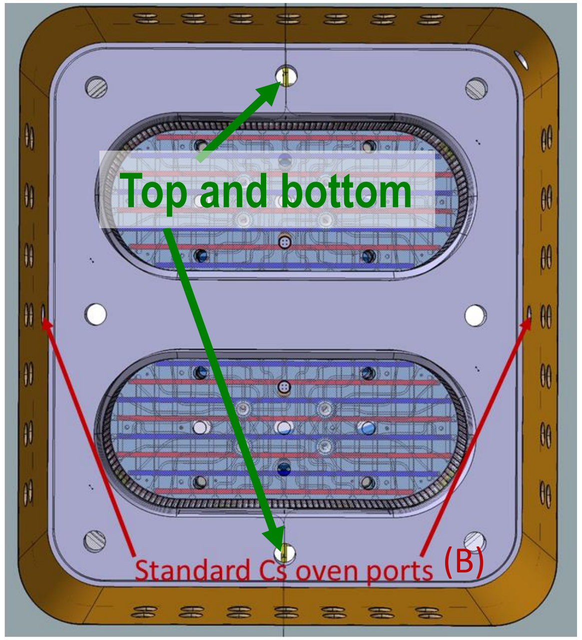

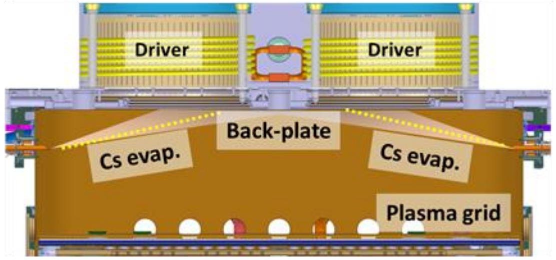

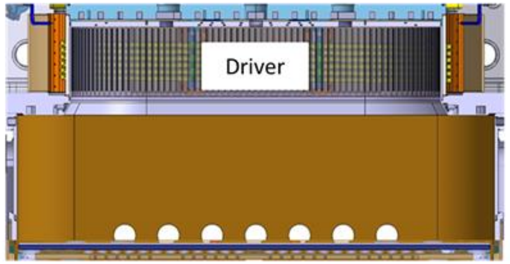

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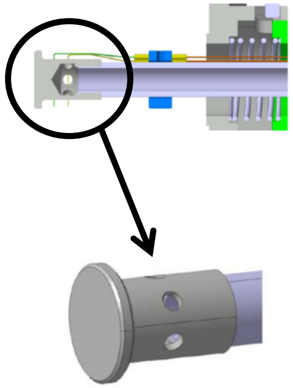
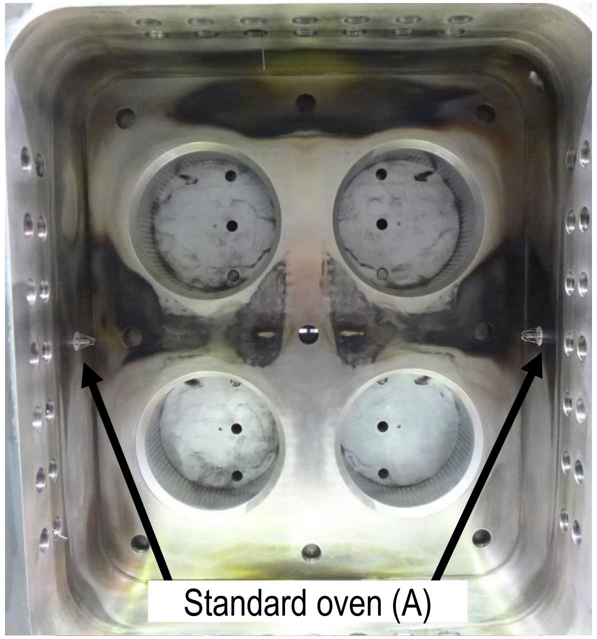
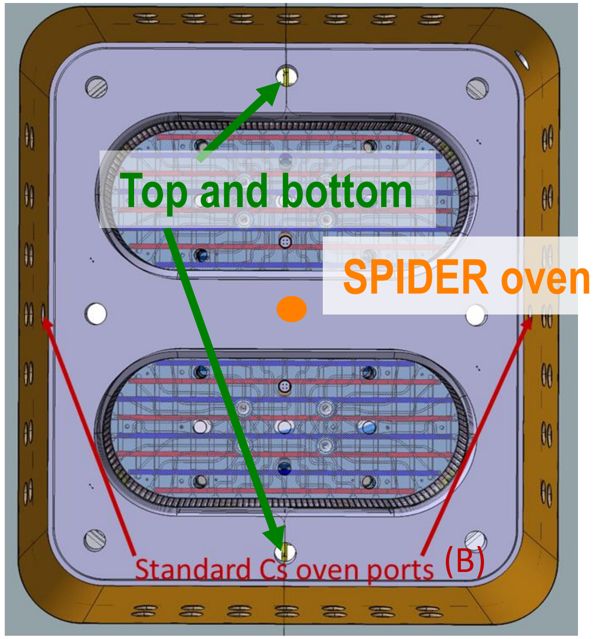
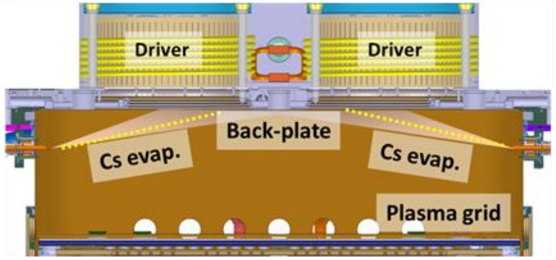
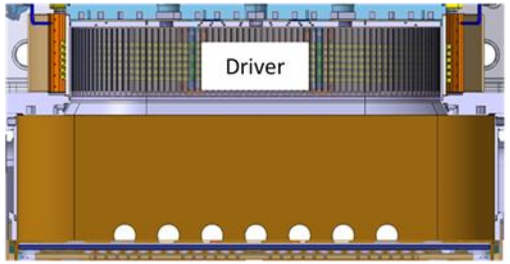
  - Spider like oven between drivers





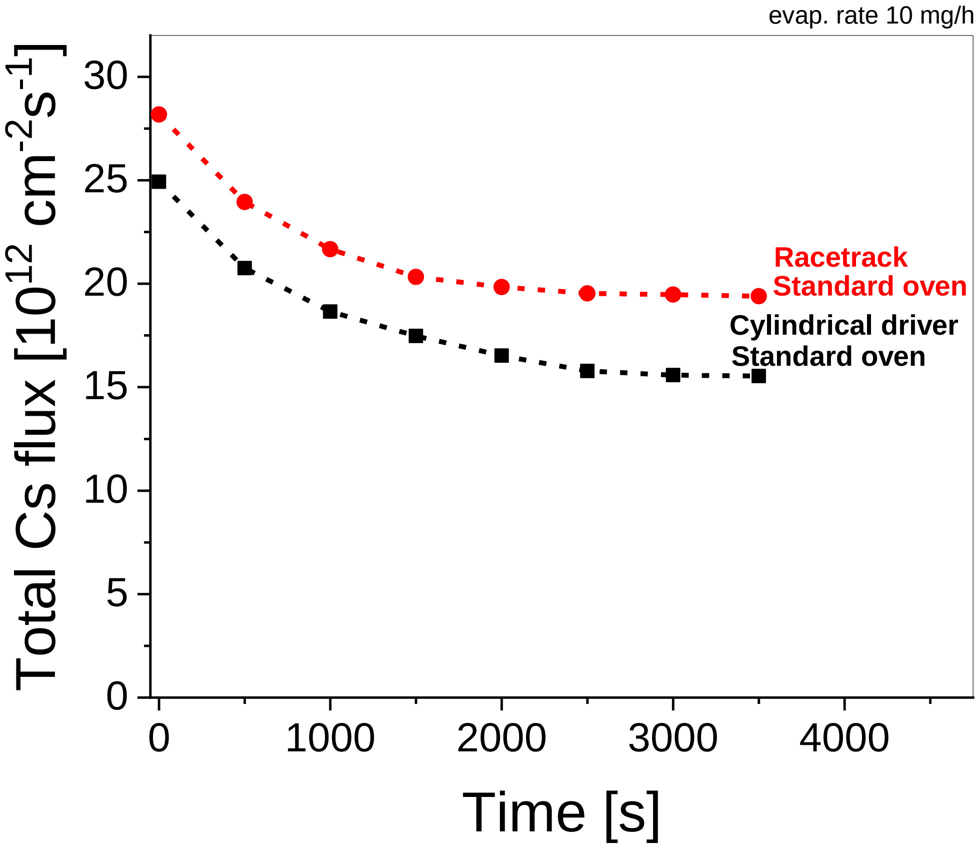






Different Cs evaporation location in long pulses

- Depletion of Cs observed also with racetrack driver, but the different topology of plasma produces slightly higher fluxes



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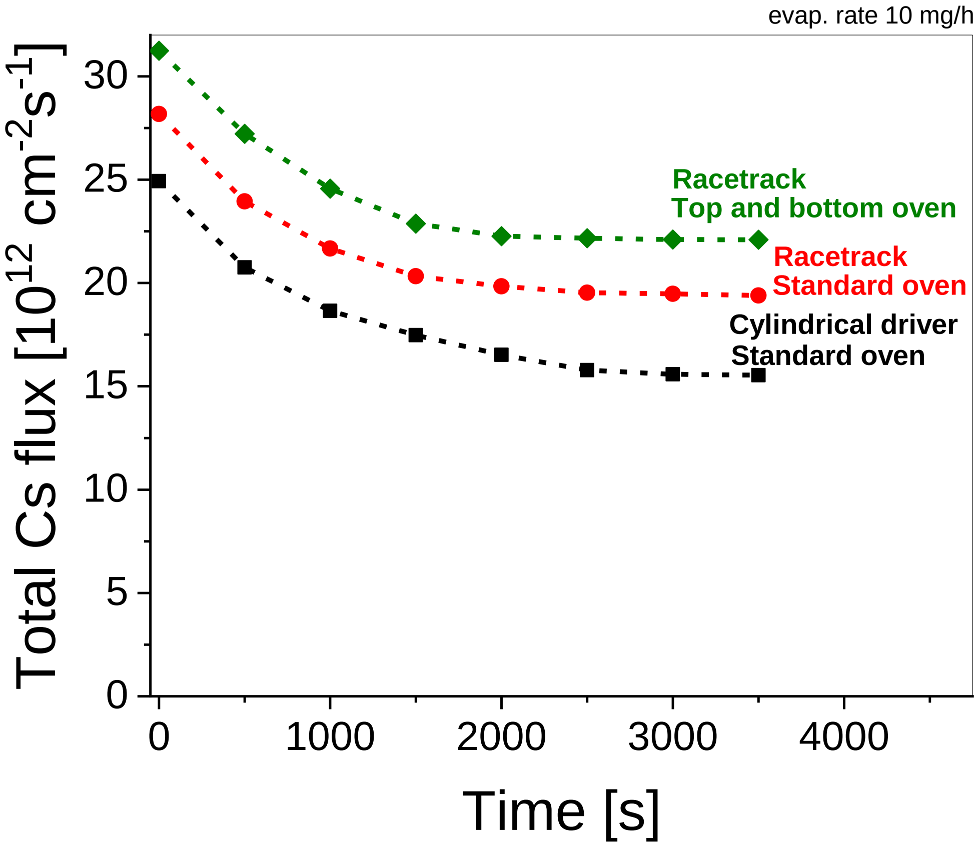
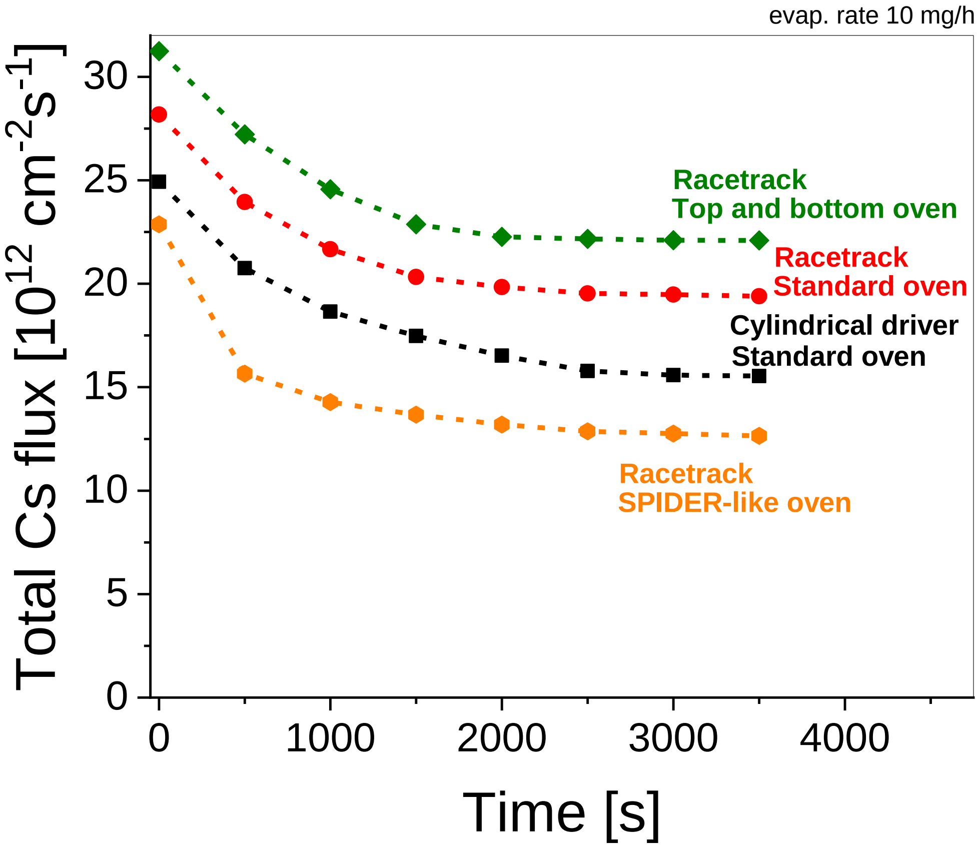
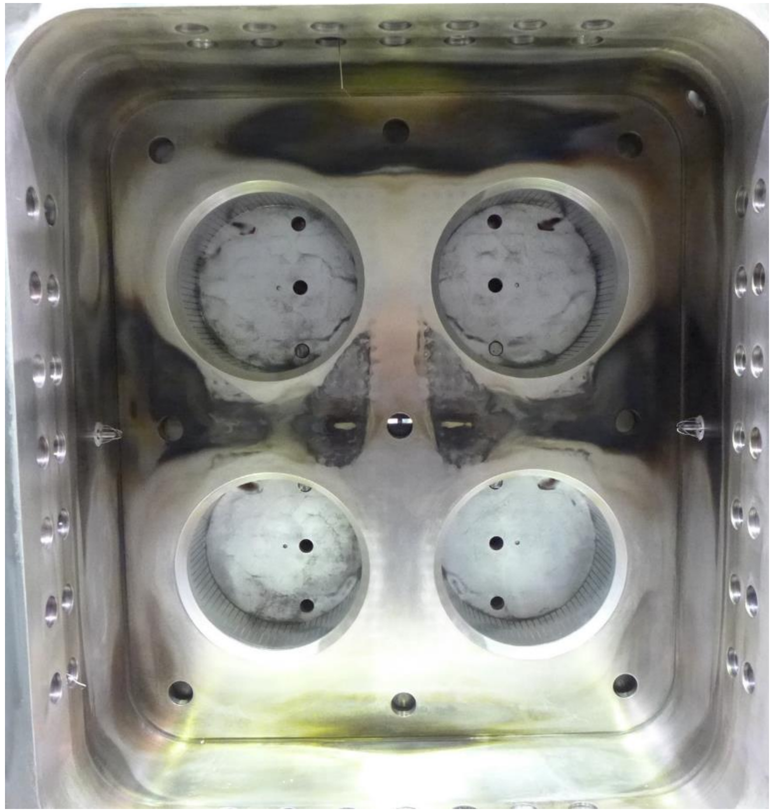


Different Cs evaporation location in long pulses

- Depletion of Cs observed also with racetrack driver, but the different topology of plasma produces slightly higher fluxes
- Further increase of the Cs flux by evaporating with the top and bottom oven (direction of racetrack elongated side)
- Strongest depletion and lowest flux with the SPIDER-like oven positioned in between the racetrack drivers
- **Overall, 50% increase of the Cs flux can be achieved. We can understand the mechanism by determining the originating surface for the Cs flux.**



Contribution of the surfaces to the Cs flux



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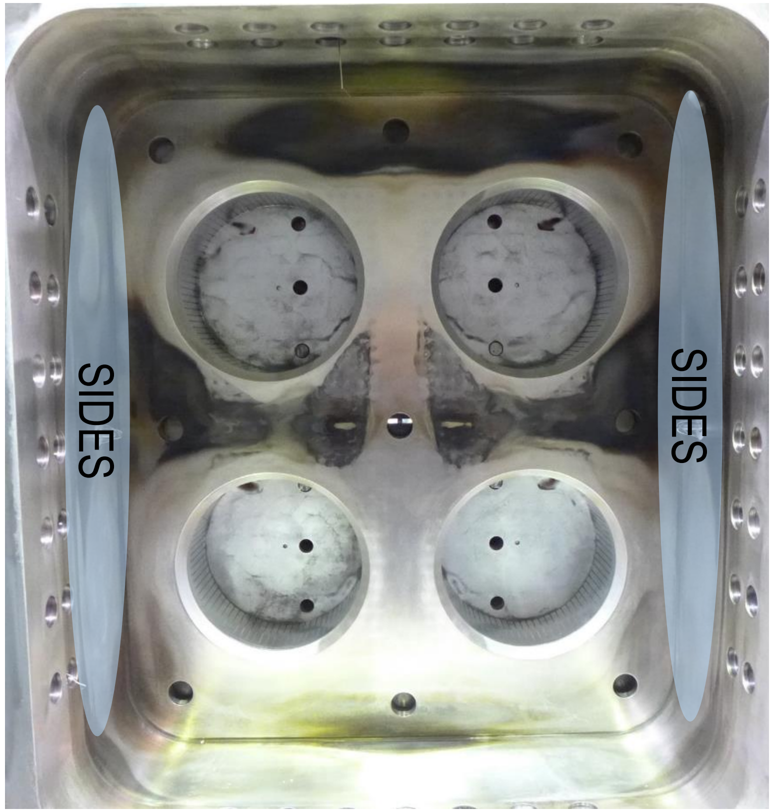

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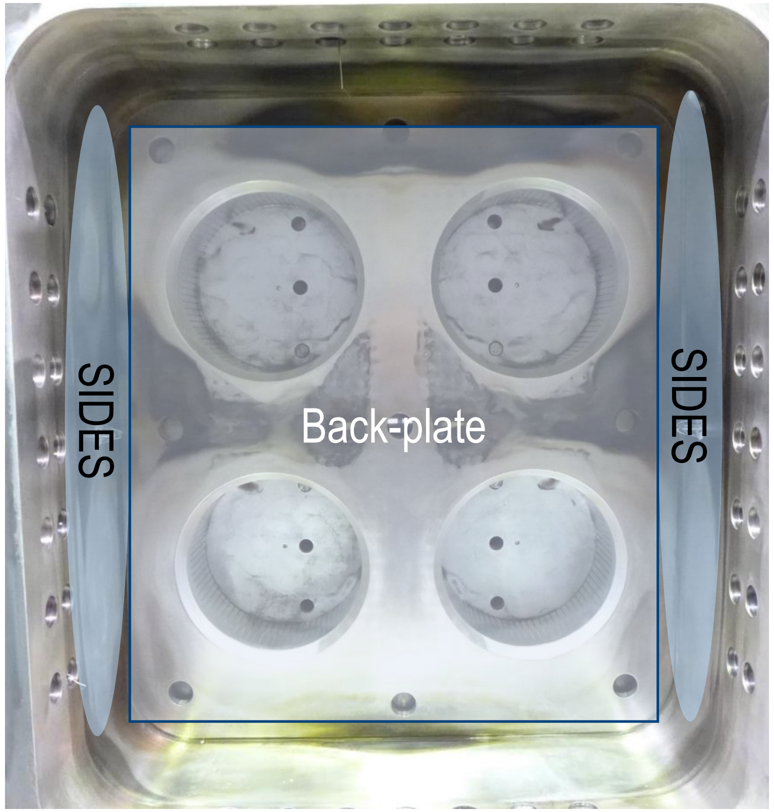

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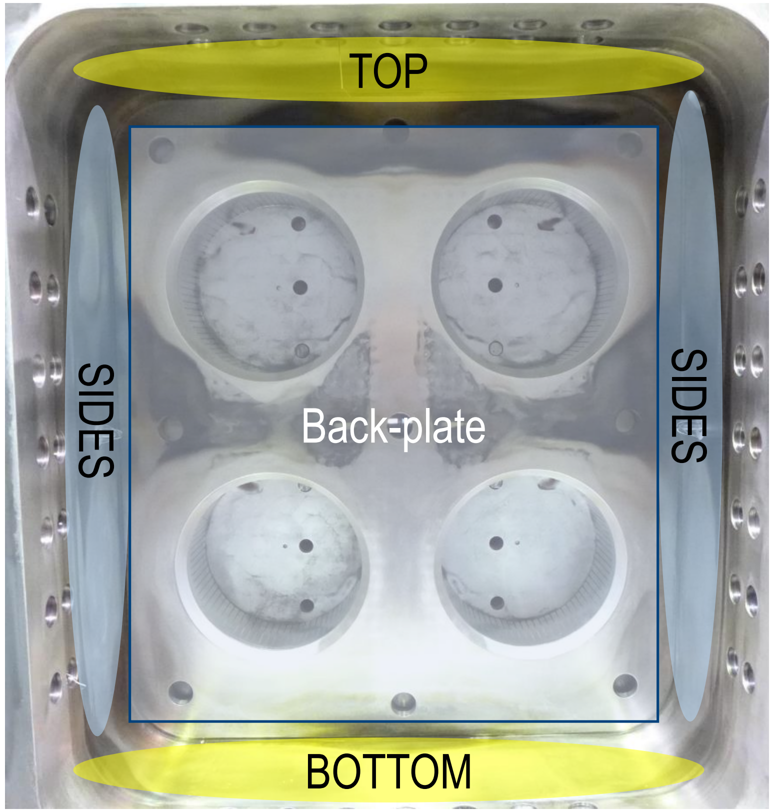

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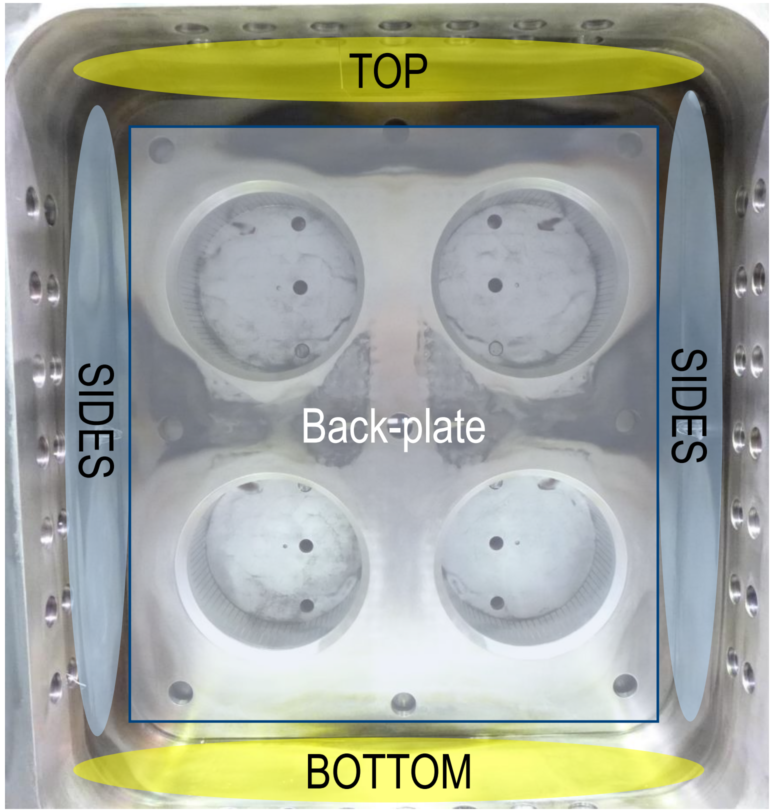

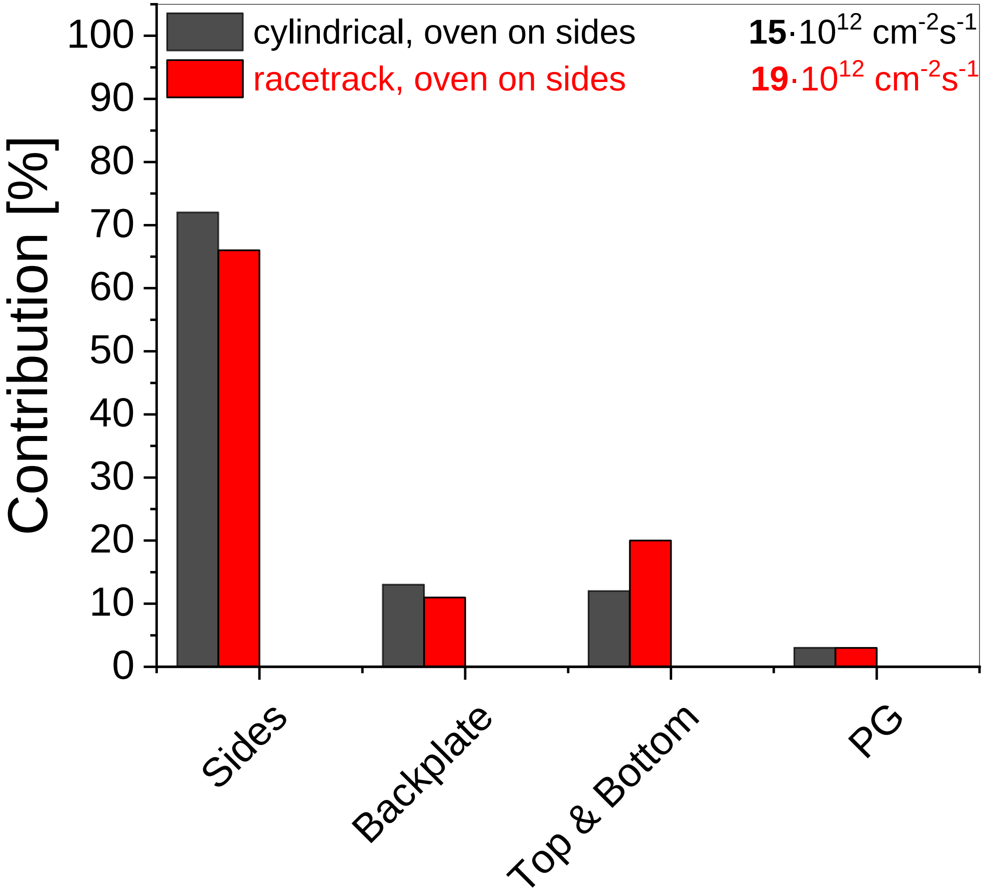

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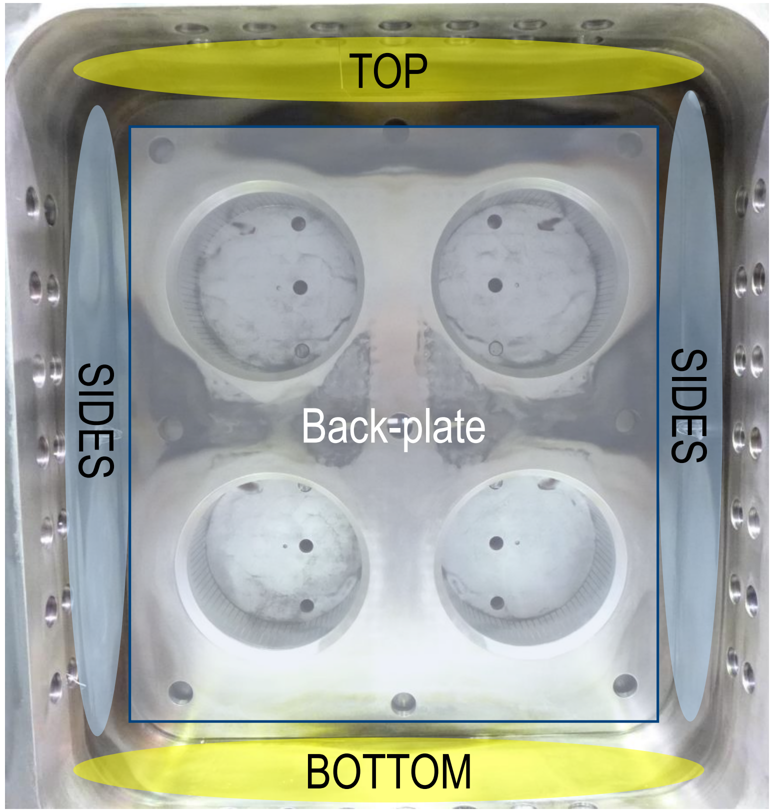

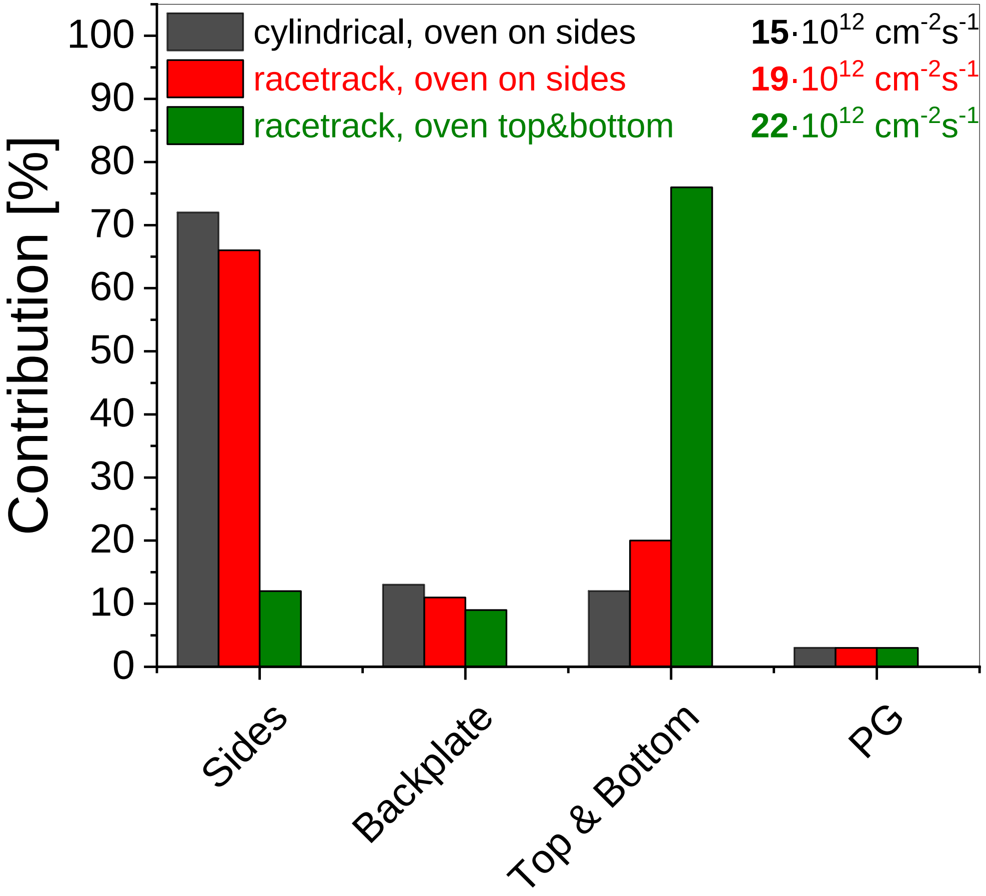

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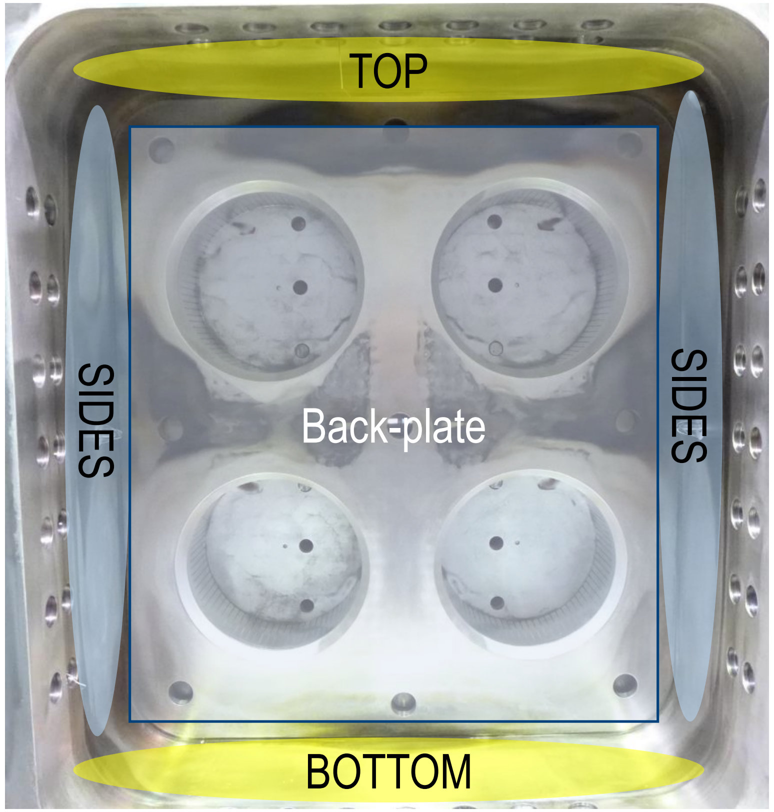

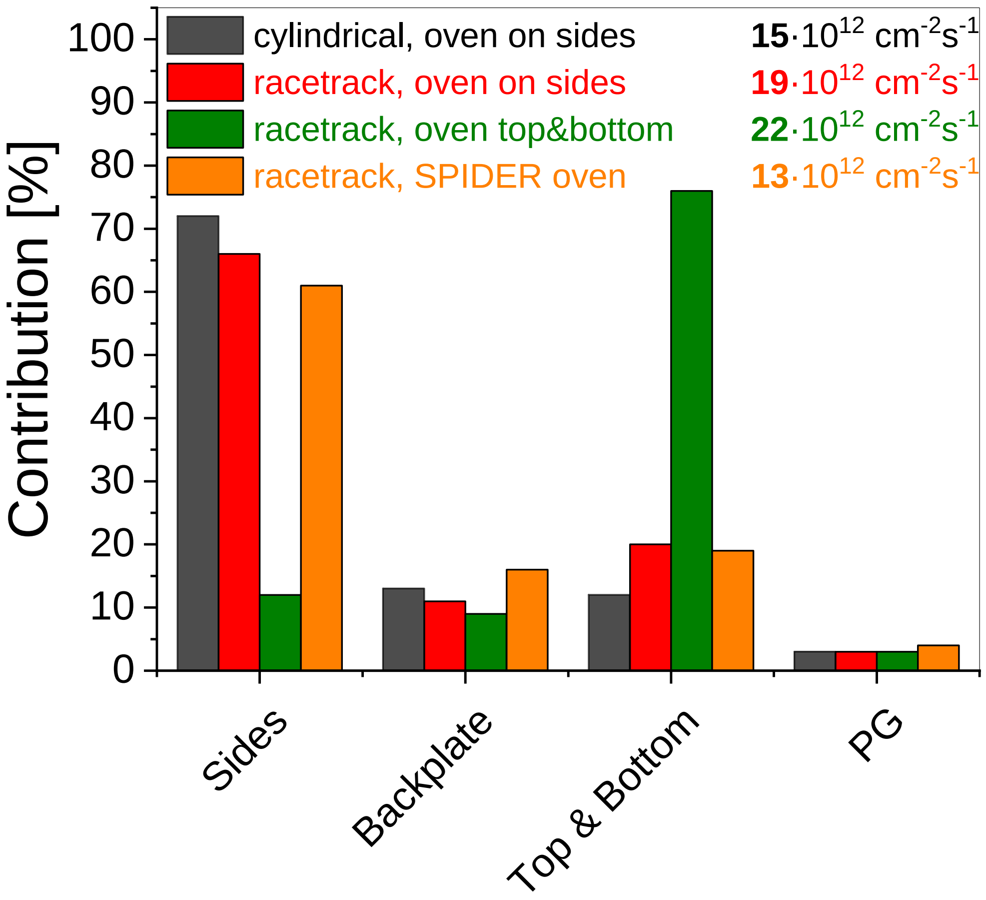

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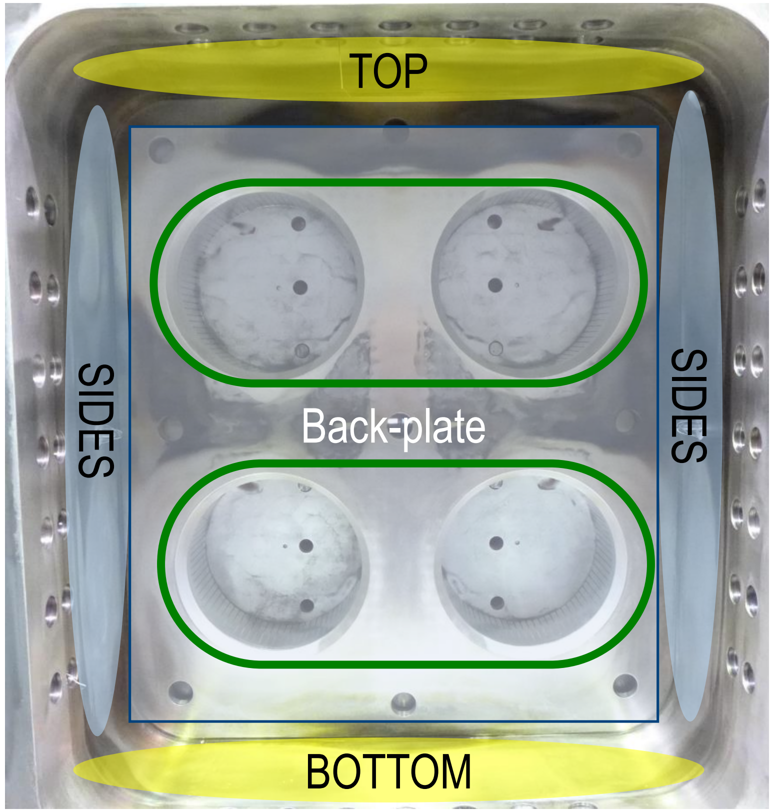
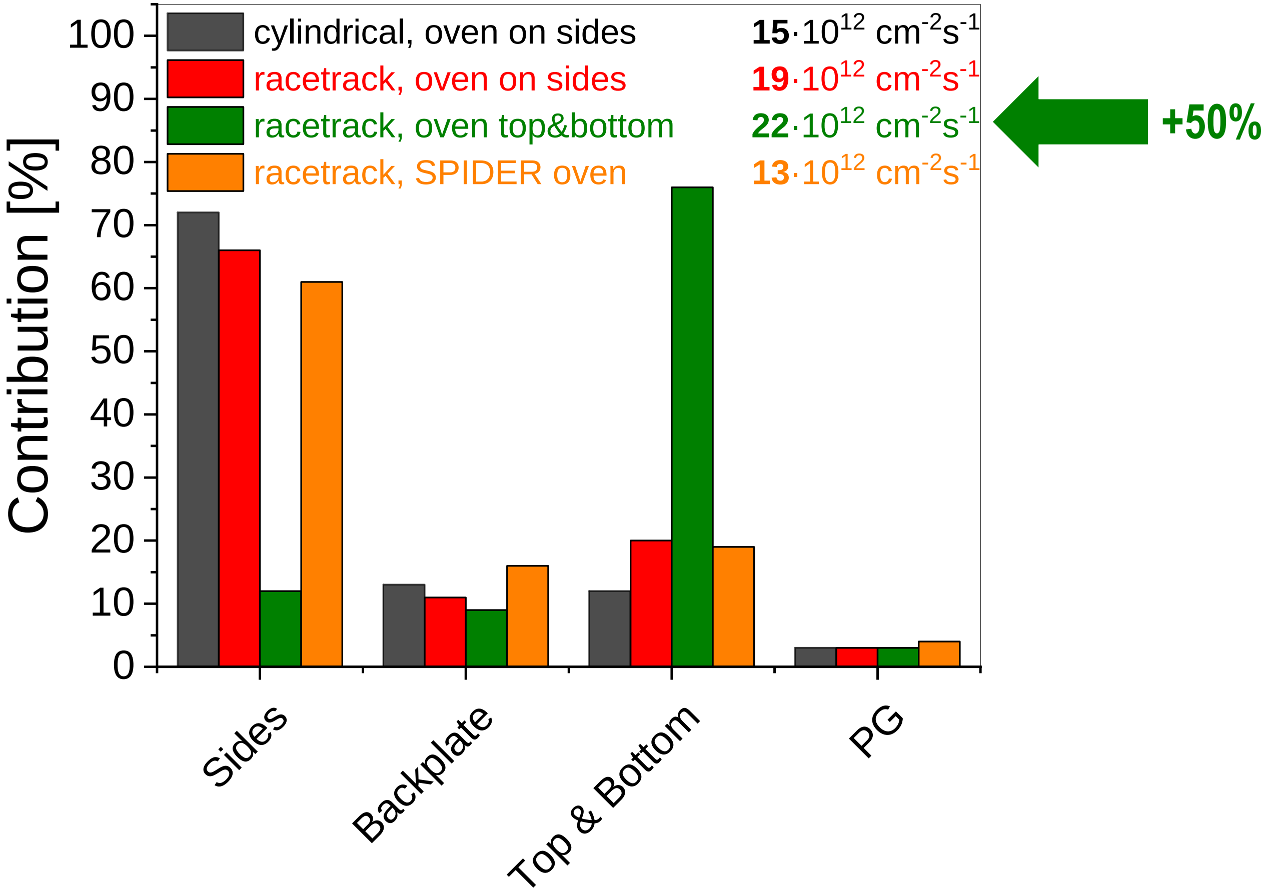
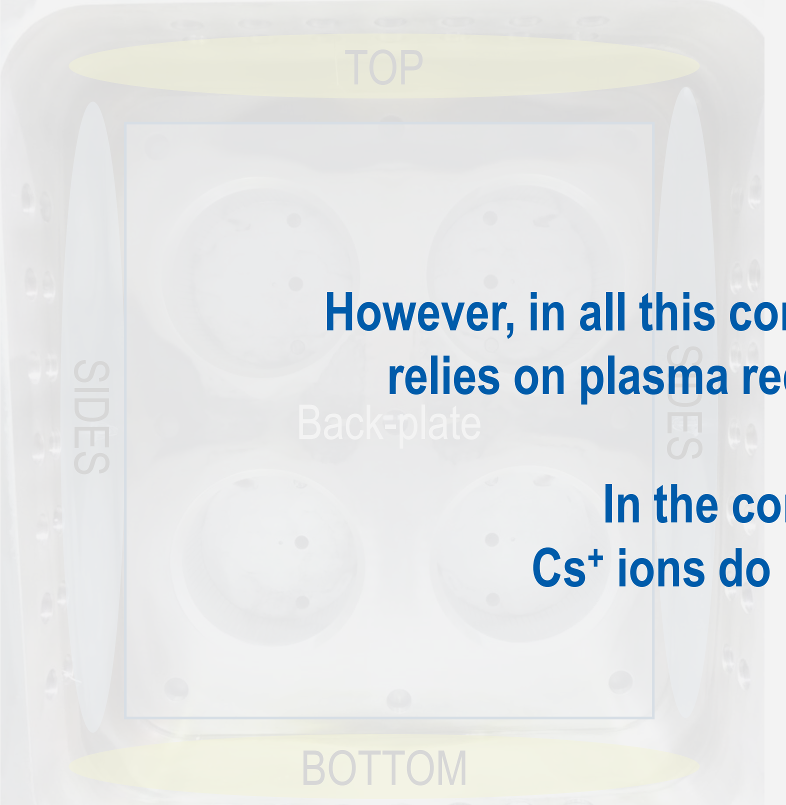
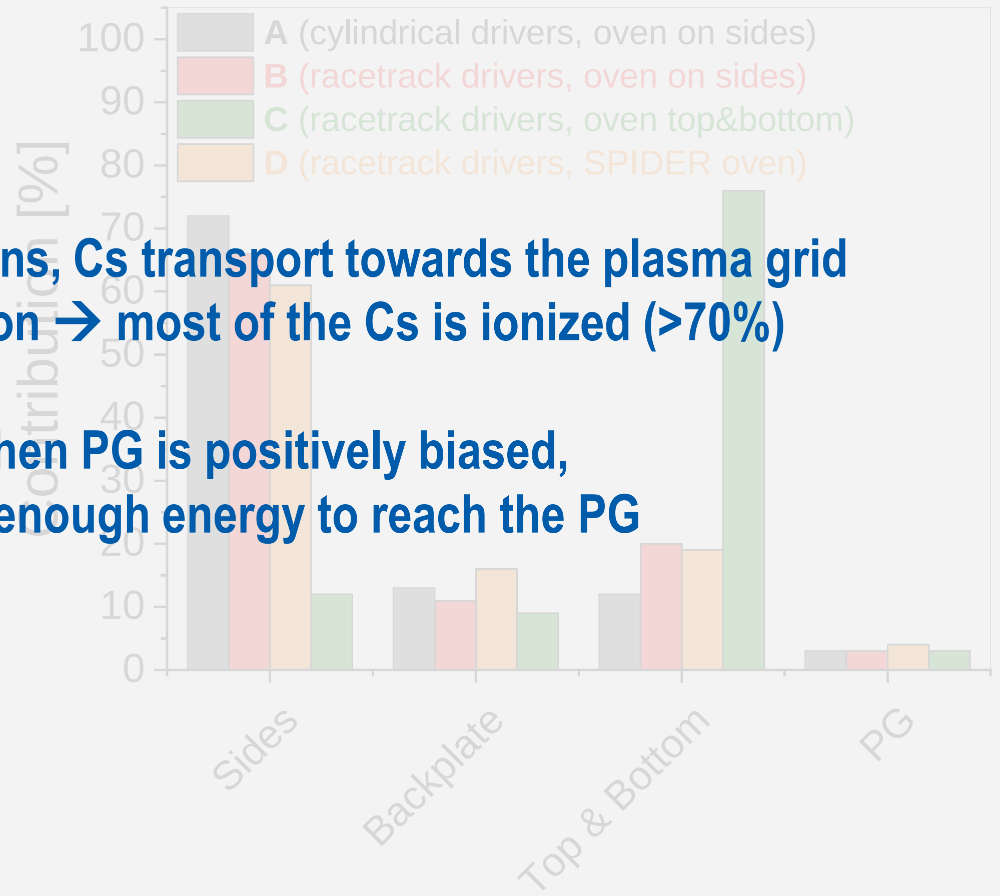




Where is Cs coming from?



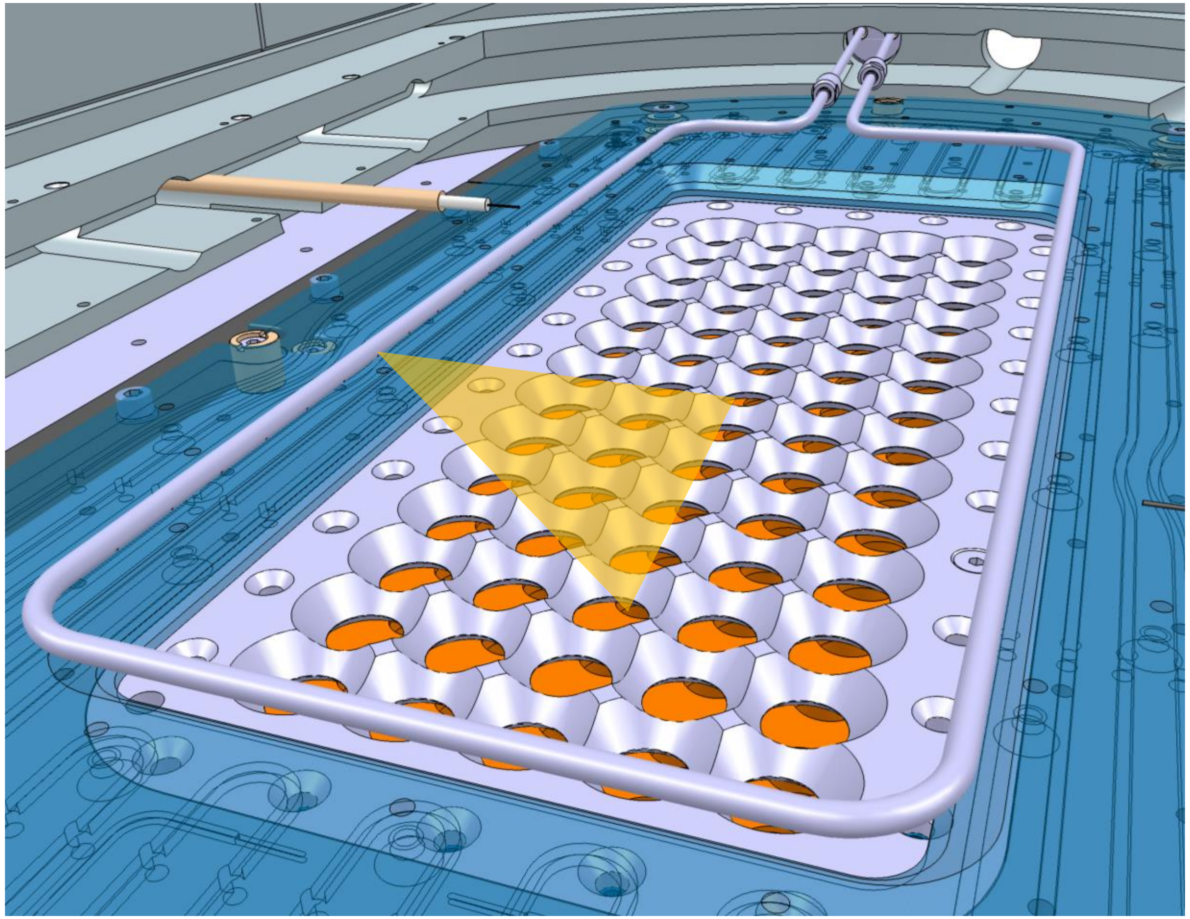


However, in all this configurations, Cs transport towards the plasma grid relies on plasma redistribution → most of the Cs is ionized (>70%)

In the condition when PG is positively biased, Cs^+ ions do not have enough energy to reach the PG

Alternative Cs evaporation concept: “Cs shower”

- **Distributed Cs evaporation[1] close to the PG:**
  - limit Cs ionization (no problem with PG bias voltage)
  - controllable evaporation of Cs where is needed
- **Main idea: pipe with orifices around a beamlet group**
- Test concept designed and developed for **BATMAN Upgrade** (special thanks to Markus Fröschle!)

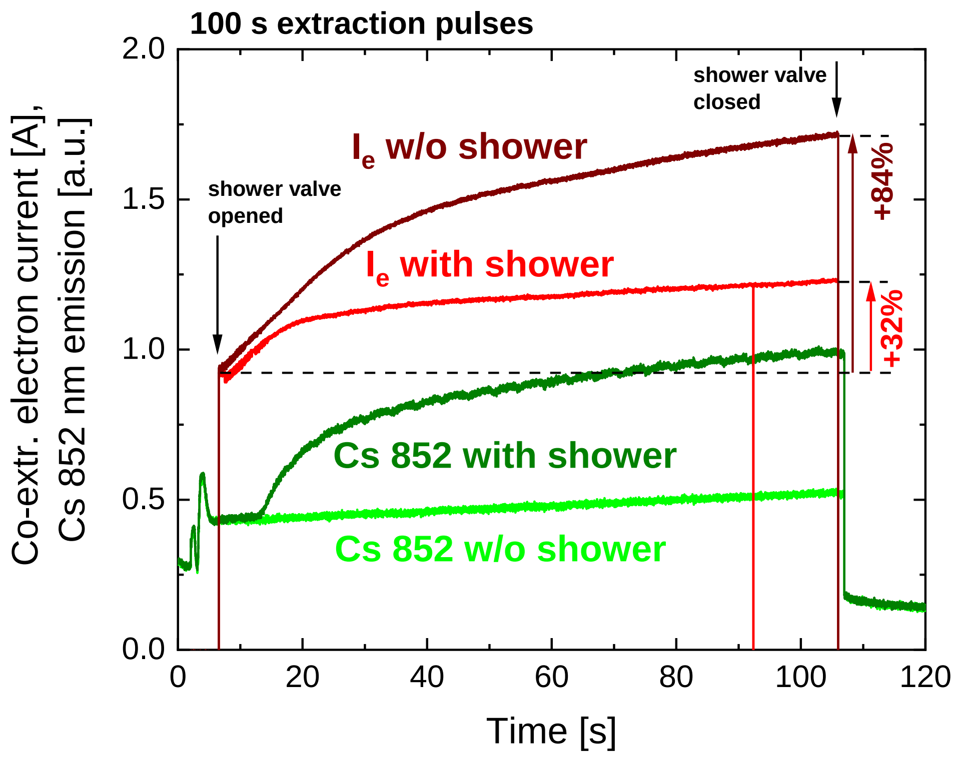


54 orifices (27 on each side of the beamlet group) Ø 0.4 mm
Pipe inner diameter 3 mm

[1] Bansal G, et al., Rev. Sci. Inst. 83, 02B118 (2012)

Test of Cs shower in BATMAN Upgrade

- **Fast reaction of Cs shower**: 10-15 s after opening the valve Cs is detected as well as impact on the performances
- **Required Cs density for a significative stabilization of co-extracted electrons achieved**



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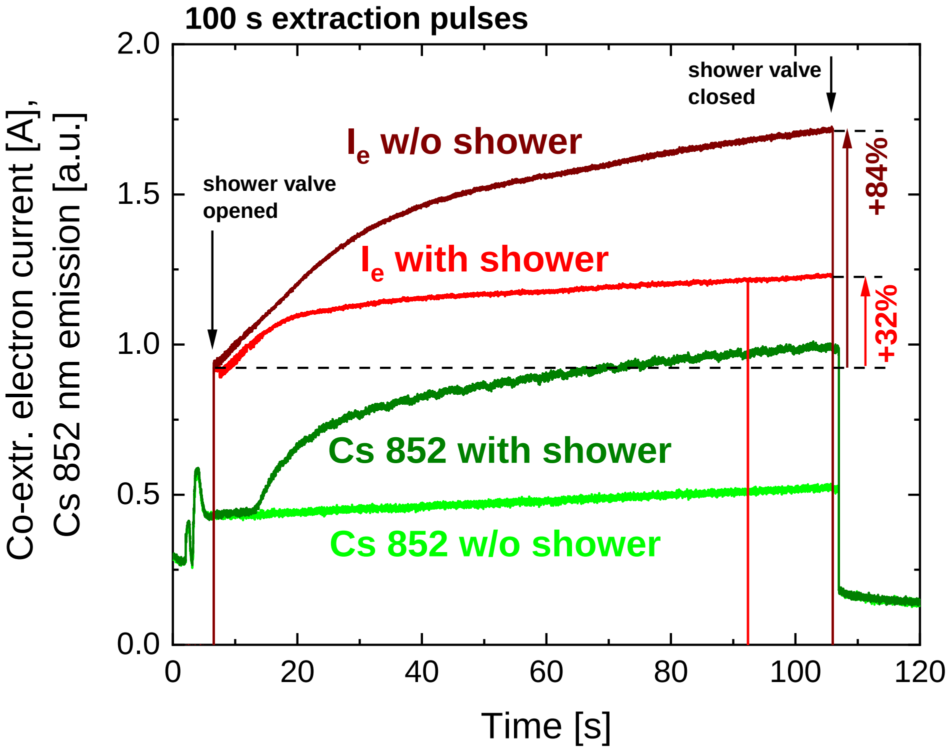

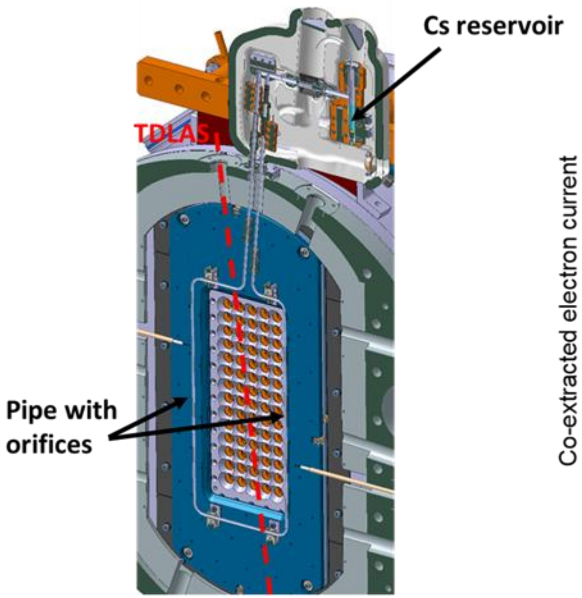

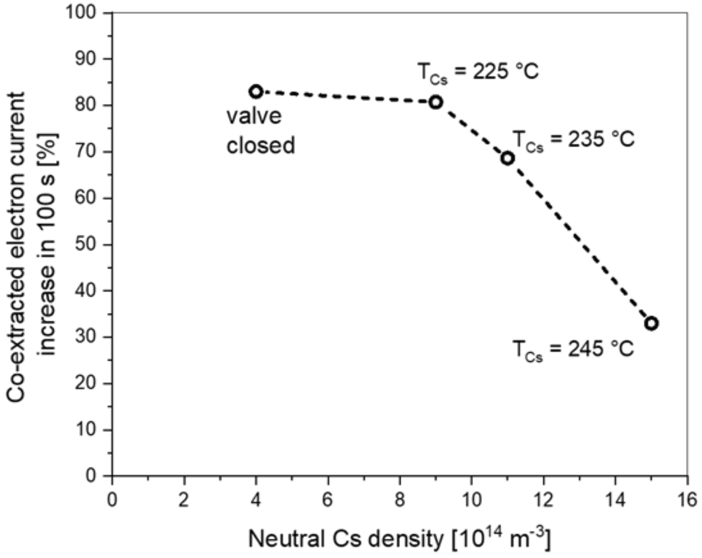

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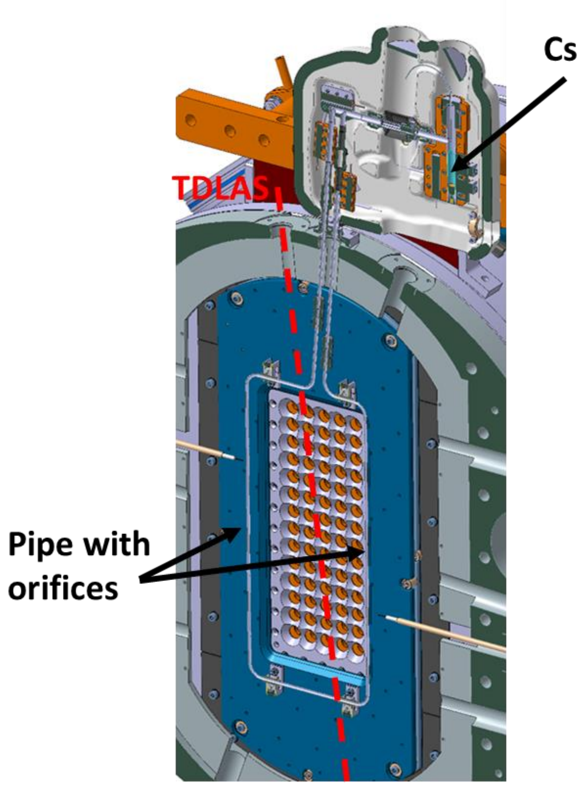
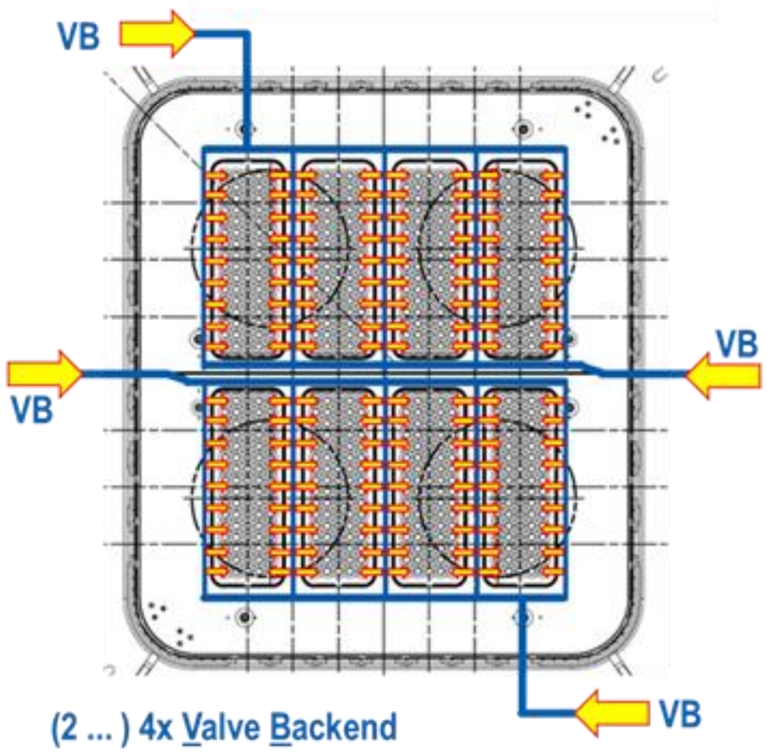
- Further tests on uniformity of evaporation and reliability for the extension to larger sources ongoing.





By M. Fröschle

Conclusions

- Repetition of long pulses (1 hour) with the standard configuration shows a marginal increase of Cs flux but experiments shows no benefit in reducing co-extracted electrons: **not enough Cs to counteract work-function degradation**

- **Optimization of location of the Cs oven** for ELISE with **racetrack driver**: allow an **increase of Cs flux and of the stability**. However: always a **depletion in time is observed and the majority of Cs is ionized**

- **Alternative evaporation concept: "Cs shower"** close to the PG can avoid the problem of Cs ionization and of the plasma transport and can help in reducing Cs consumption:

  - Tested at BATMAN Upgrade: **proved that additional Cs can stabilize co-extracted electrons**

  - Further tests to assess **uniformity of evaporation**, impact on the high voltage system and **reliability** in routine operation in the view of **extending the concept to larger sources**