Max-Planck-Institut für Plasmaphysik

Transferring knowledge gained for pulsed extraction at ELISE to ITER-relevant CW extraction

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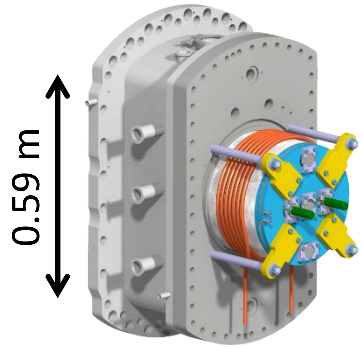
SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN

EUROfusion

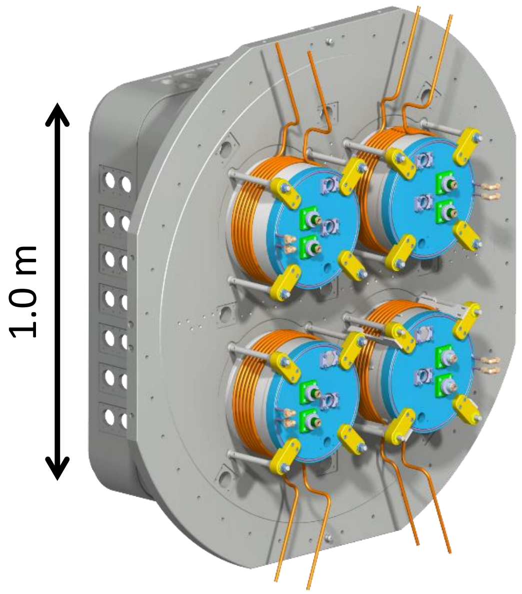
Size scaling towards the ion source for ITER NBI.



IPP prototype source
(59×30 cm²)

- Basic ITER requirements fulfilled. ✓
- Since 2018: BATMAN upgrade with ITER-like extraction system.

×4



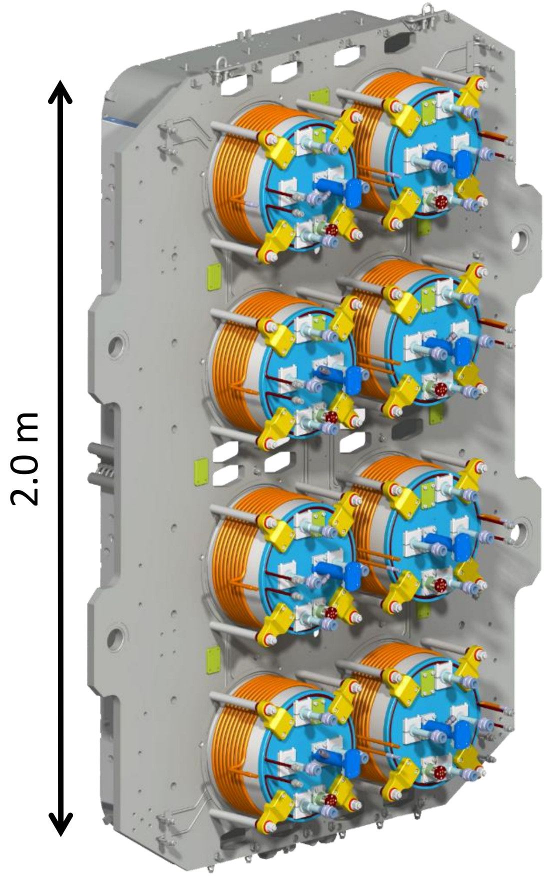
Size scaling: half ITER source size experiment (100×90 cm²)

- Test facility ELISE, in operation since 2013.
- Demonstrated ITER relevant short & long (t_{plasma}=1200 s) pulses in hydrogen. ✓

×2

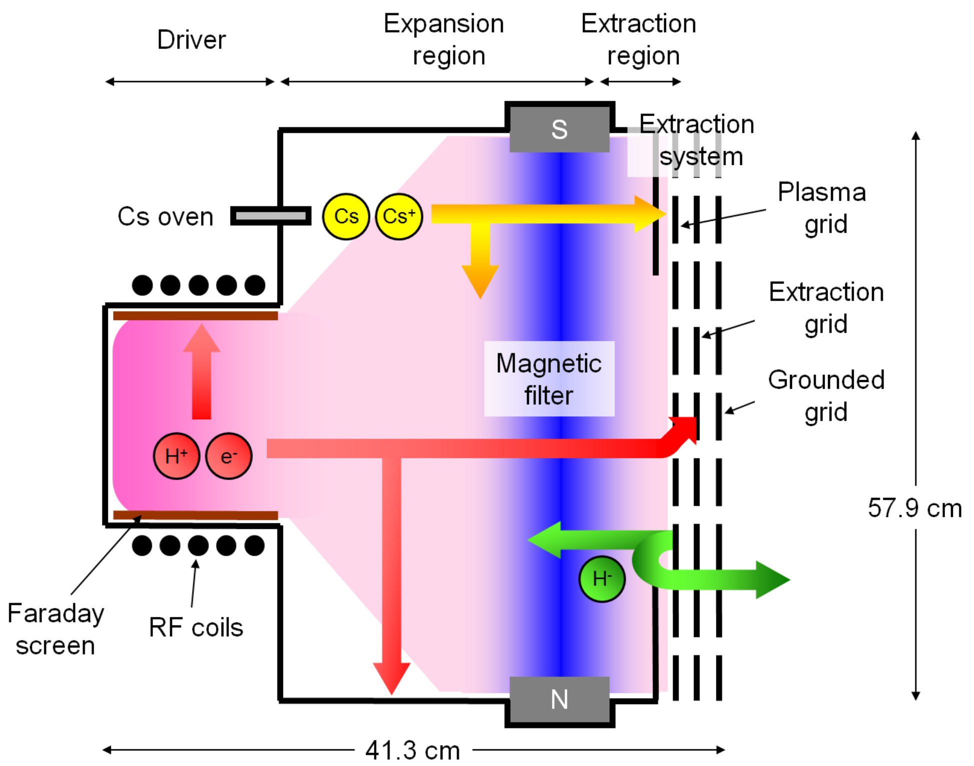
Source for ITER NBI (200×100 cm²)

- Consorzio RFX, based on IPP design.
- SPIDER in operation since 2018.



Size scaling towards the ion source for ITER NBI.

Challenge: generation of a powerful negative ion beam…



	D	H
j_{acc}	200 A/m^2 (1 MeV)	230 A/m^2 (870 keV)
j_{ex}^{*}	286 A/m^2	329 A/m^2
j_e/j_{ex}	<1	
p_{fill}	≤0.3 Pa	
Pulse length	3600 s	1000 s
Beam homog.	>90 %	
Beamlet div.	<7 mrad	

*: assuming 30 % stripping losses as predicted for ITER

Hydrogen: ITER targets can be achieved.

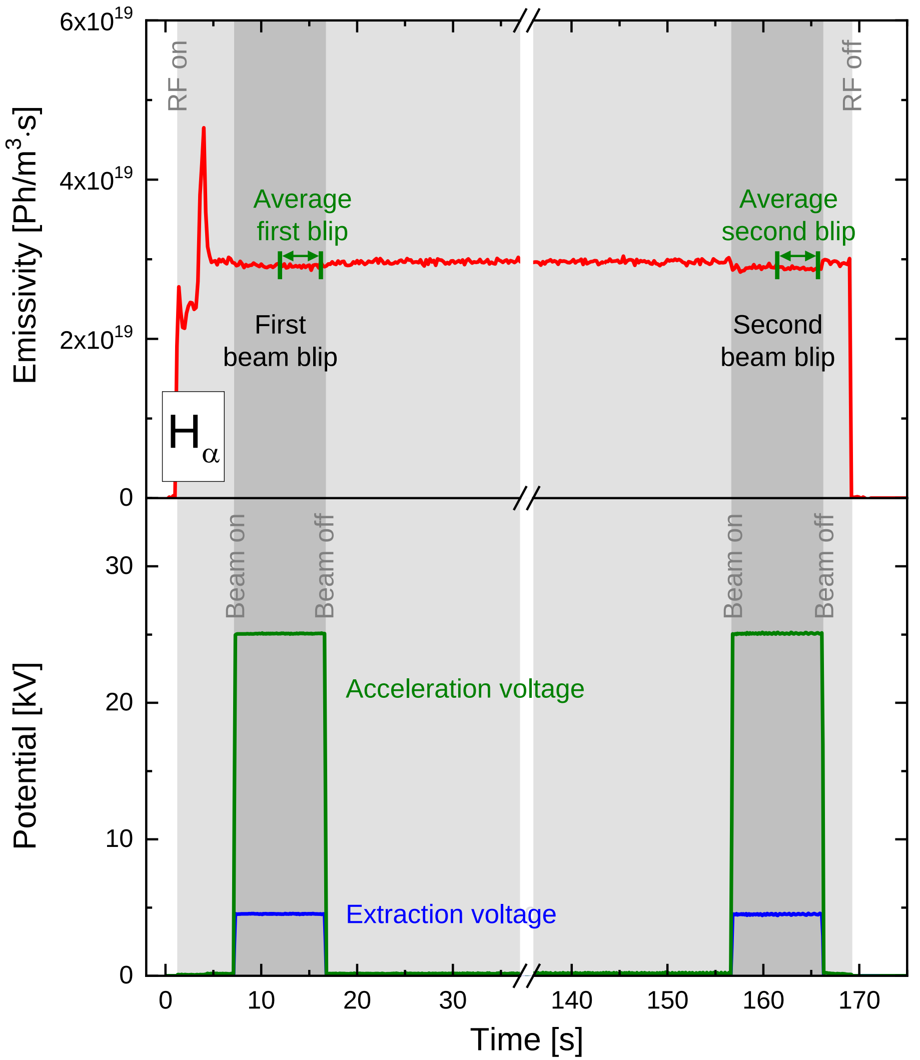
Series of stable and reproducible 1200 s pulses (pulsed extraction).

Typical timing of long pulses, pulsed extraction

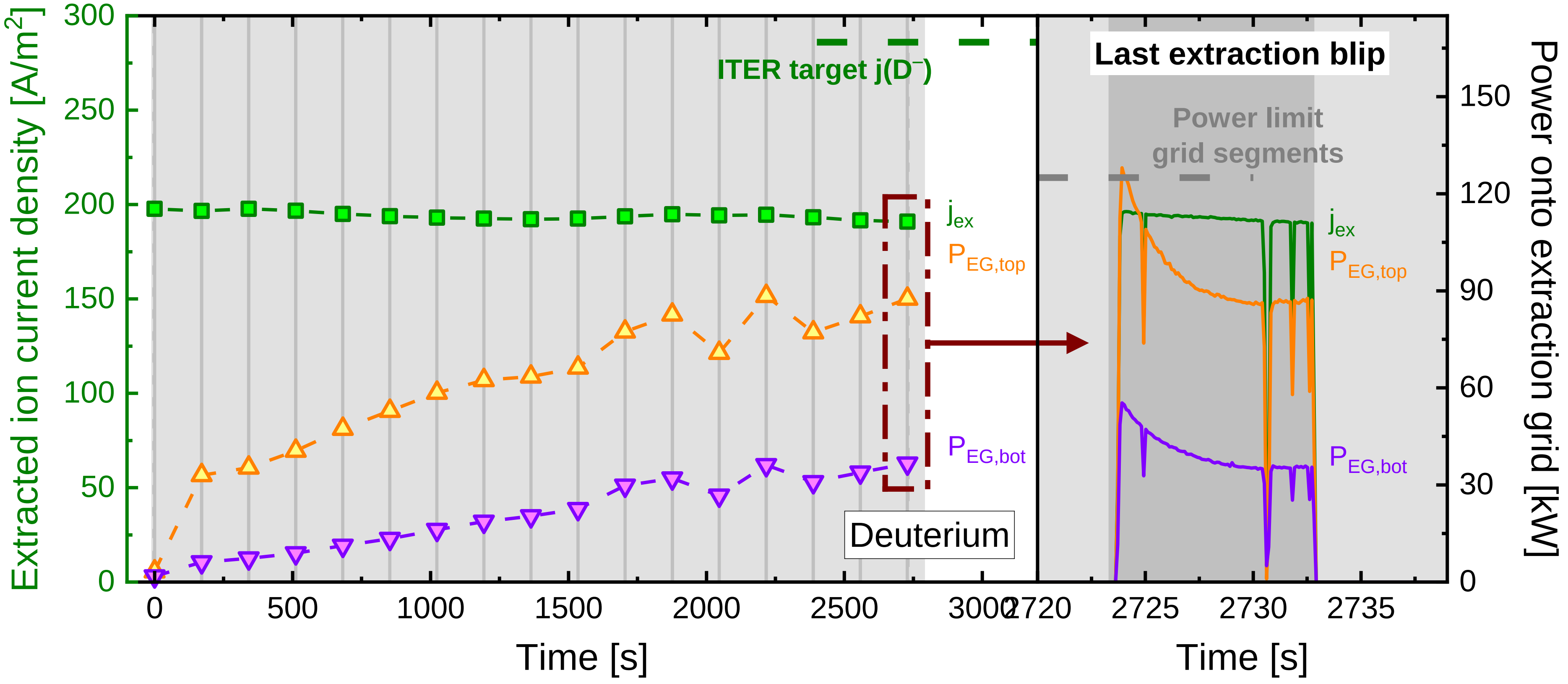
Example: two extraction blips within one plasma pulse

- Plasma ignited at increased pressure ("gas puff"), reduced I_{PG} and P_{RF}.
- Nominal source parameters reached after ≈5 s.
- Extraction is possible for ≤10 s each ≈150 s.
- Pulses done up to lengths of 3600 s.

Averaged results for each beam blip
⇒ database.



Caesium dynamics during long pulses, pulsed extraction



Co-extracted e^- during best long pulses in D_2 at p_{fill}=0.3 Pa up to now (≈67 % of current density target):

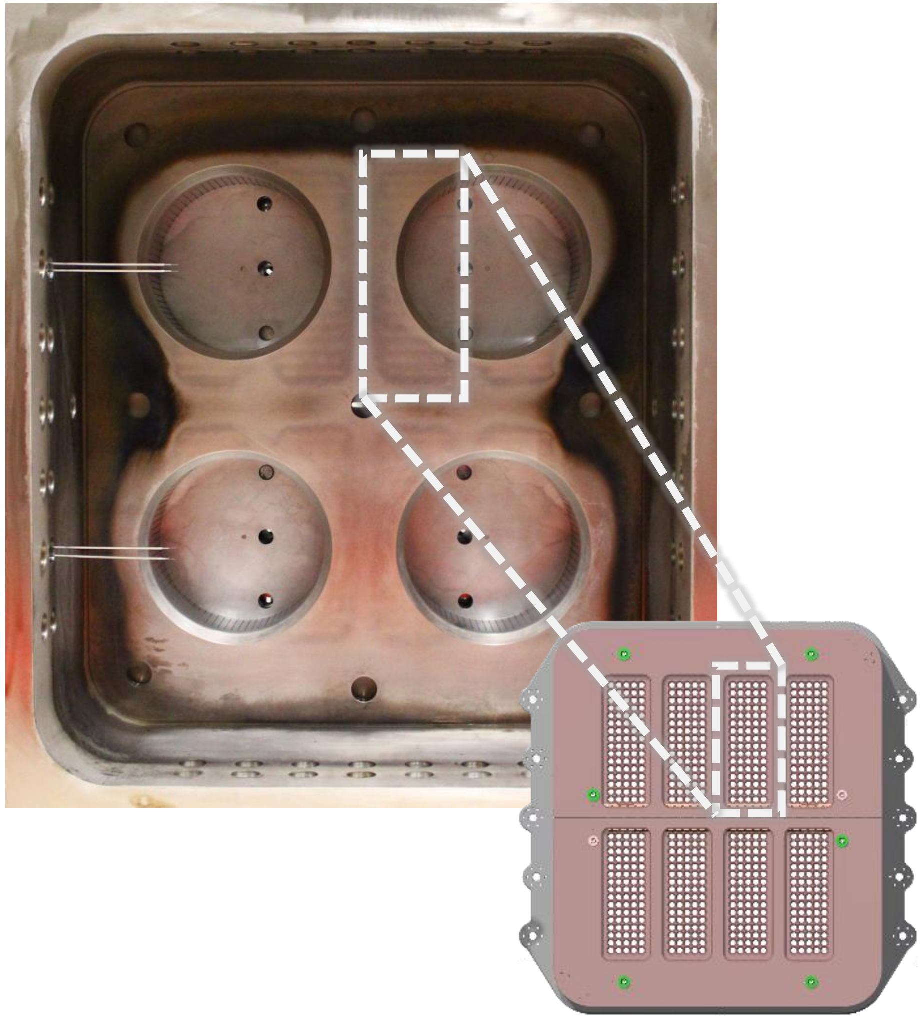
- … show for high P_{RF} a pronounced vertical asymmetry.
- … increase between one blip and the next ↔ decrease during each blip.

Caesium dynamics plasma vs. beam

General difference
Caesium re-distribution plasma – beam

Physical reason

- Impact of back streaming positive ions on Cs reservoirs at source back plate.
  Reservoirs re-filled during the plasma-only phases.
- General agreement with results of Monte Carlo code CsFlow3D.



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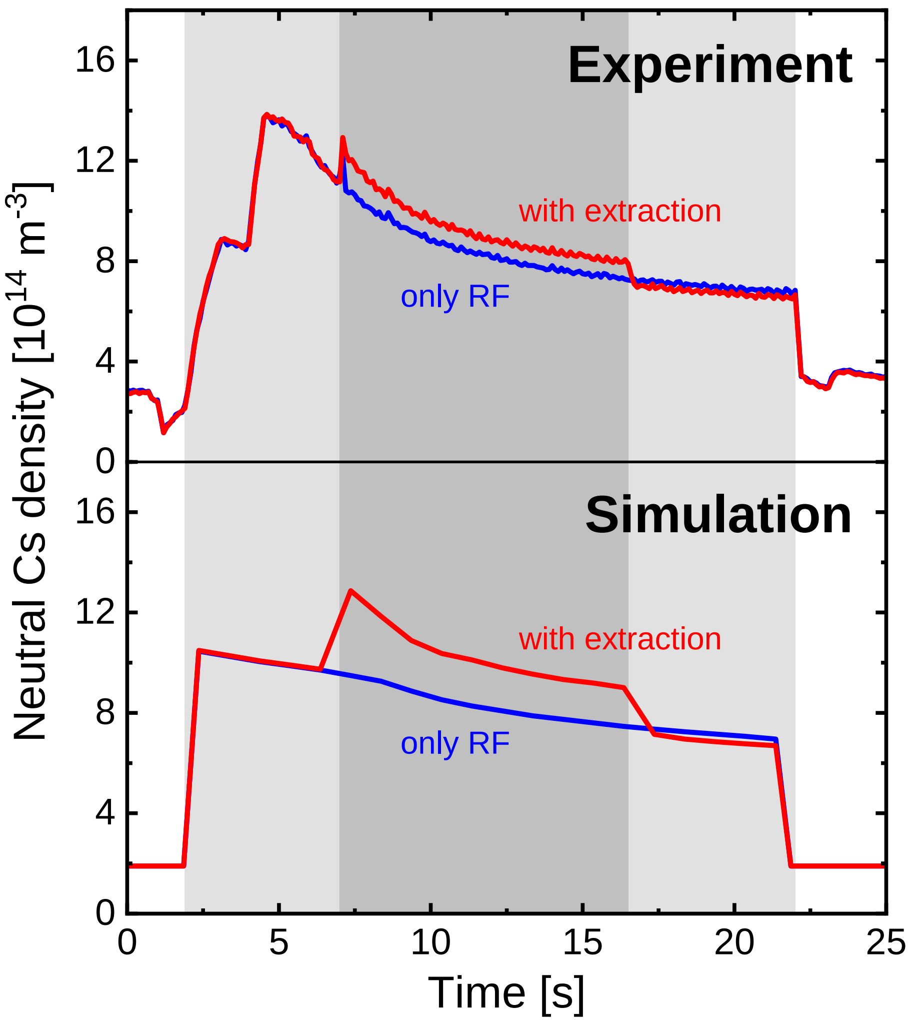

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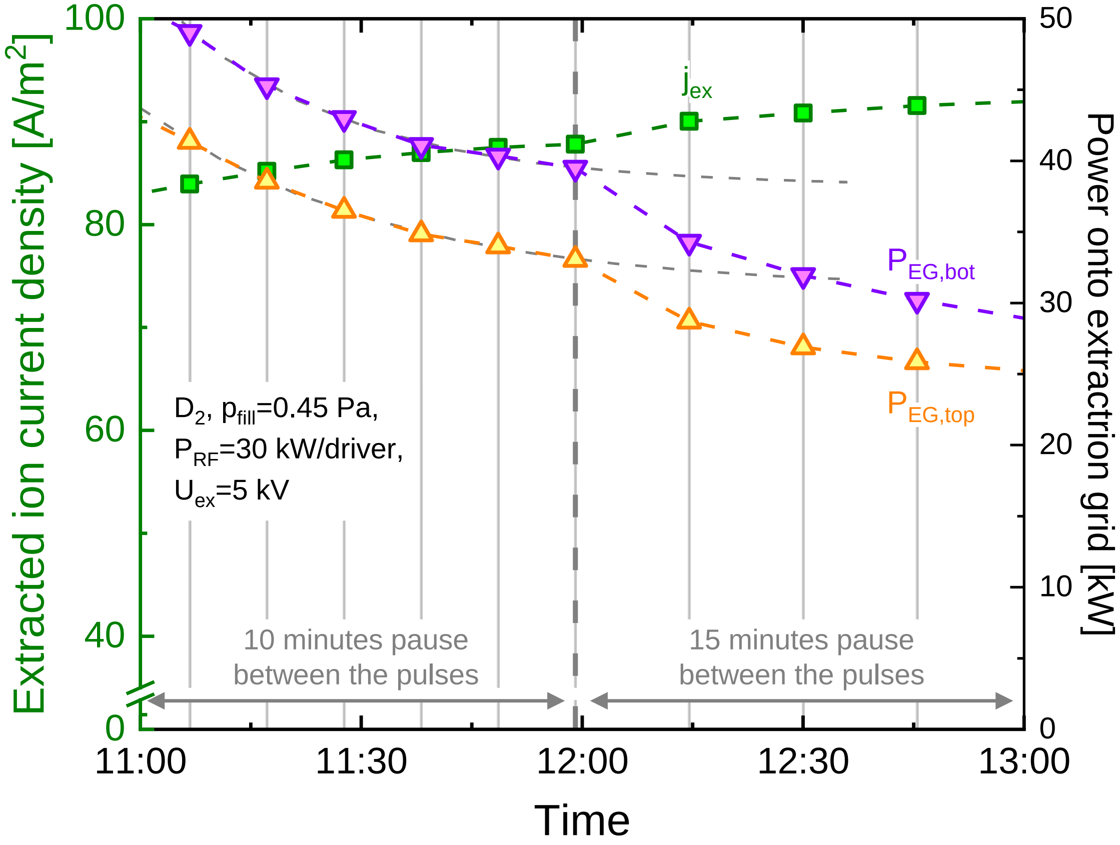
Exploit this effect

- Pure plasma pulses for conditioning.
- Longer break between plasma pulses (increase Cs fluence).
- Switch off B field between blips during long pulses.



Operating ELISE with short extraction blips

ITER values possible in hydrogen

⇒ most pressing issue now is deuterium:

- Much more co-extracted e⁻.
- Stronger temporal increase of co-extracted e⁻.
- Co-extracted e⁻ <u>vertically more asymmetric.</u>

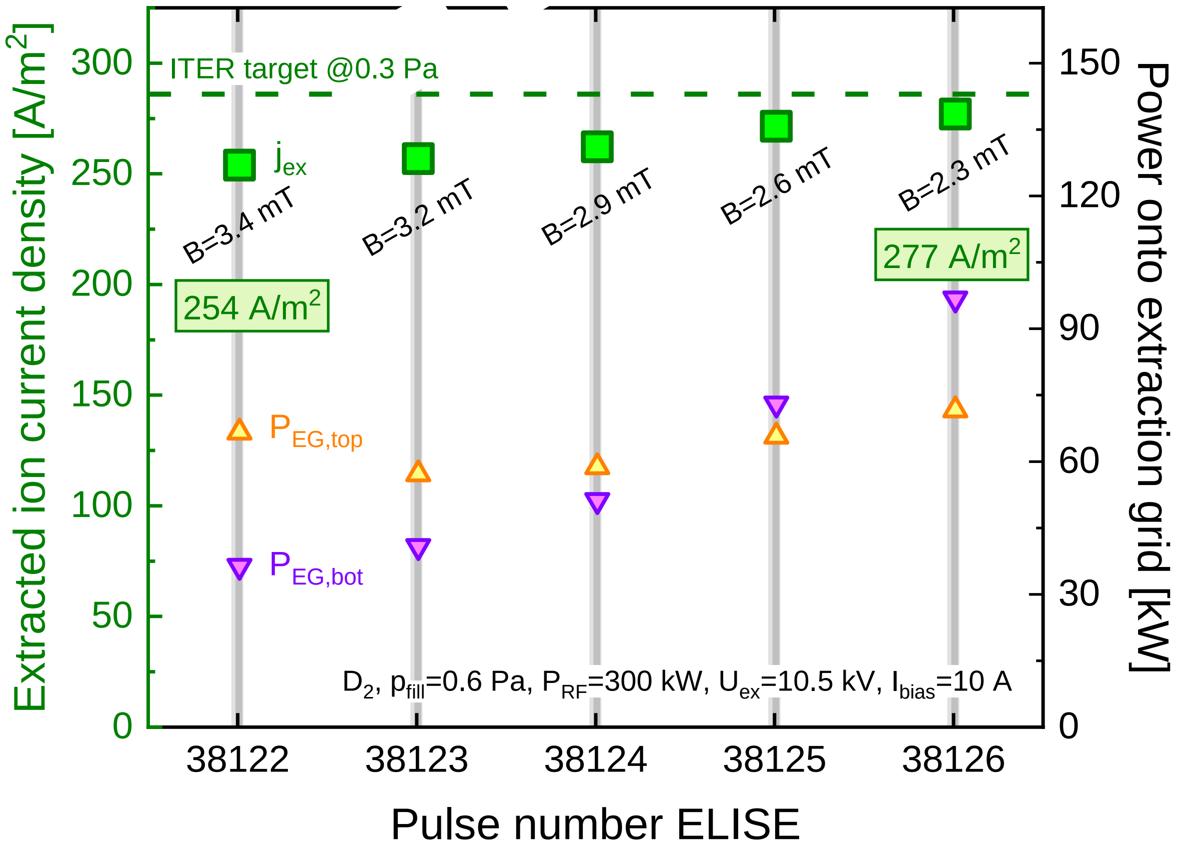
Best results up to now in D_2:

191 A/m² (67 % of target) over 2700 s and 0.3 Pa

224 A/m² (78 % of target) over 10 s and 0.3 Pa

277 A/m² (97 % of target) over 10 s for 0.6 Pa

⇒ **again: relevance of symmetry of co-extracted e⁻!**



Are the developed Cs conditioning techniques applicable to ITER relevant (CW) extraction?

→ Upgrade of ELISE to CW extraction

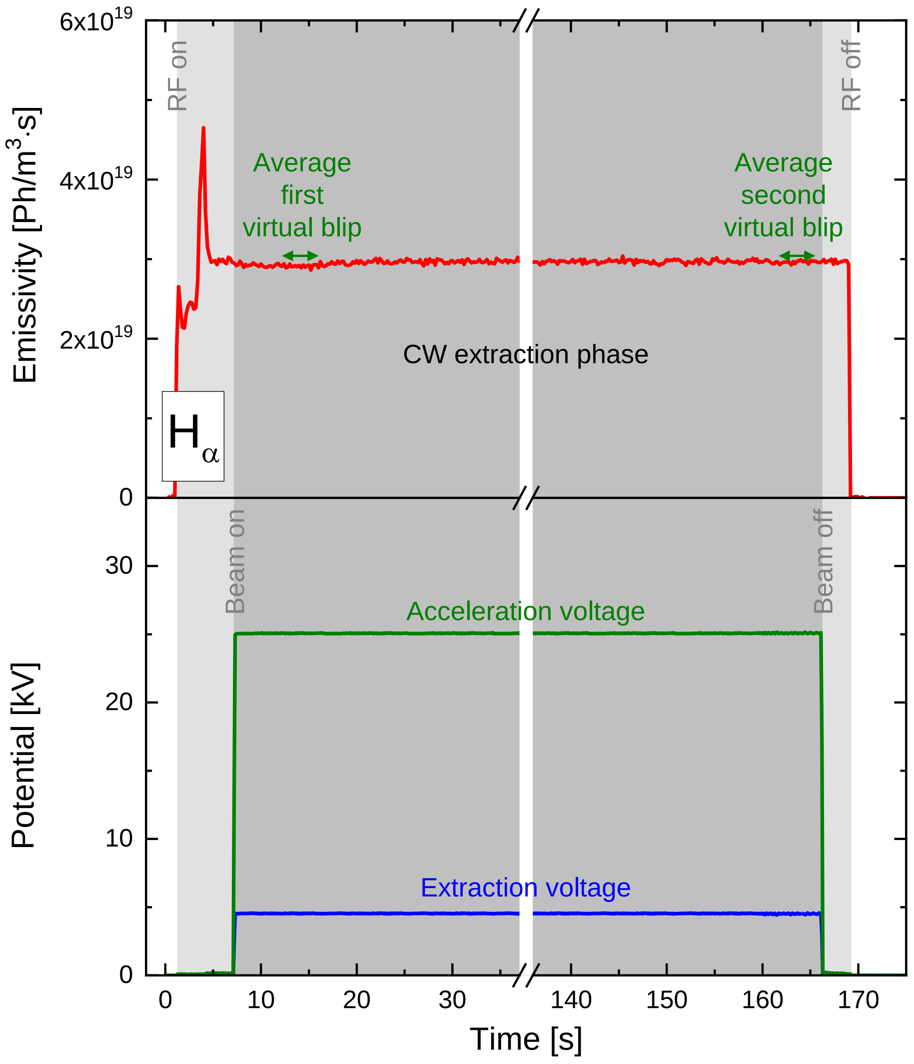
Step from pulsed to CW extraction

Completely different timing

- Database now based on virtual extraction blips.
- These are defined by the control system and distributed to the different diagnostics.

Upgrade to CW results in…

- Changed cooling requirements (mainly: calorimeter).
- Data acquisition and processing needs to be modified.



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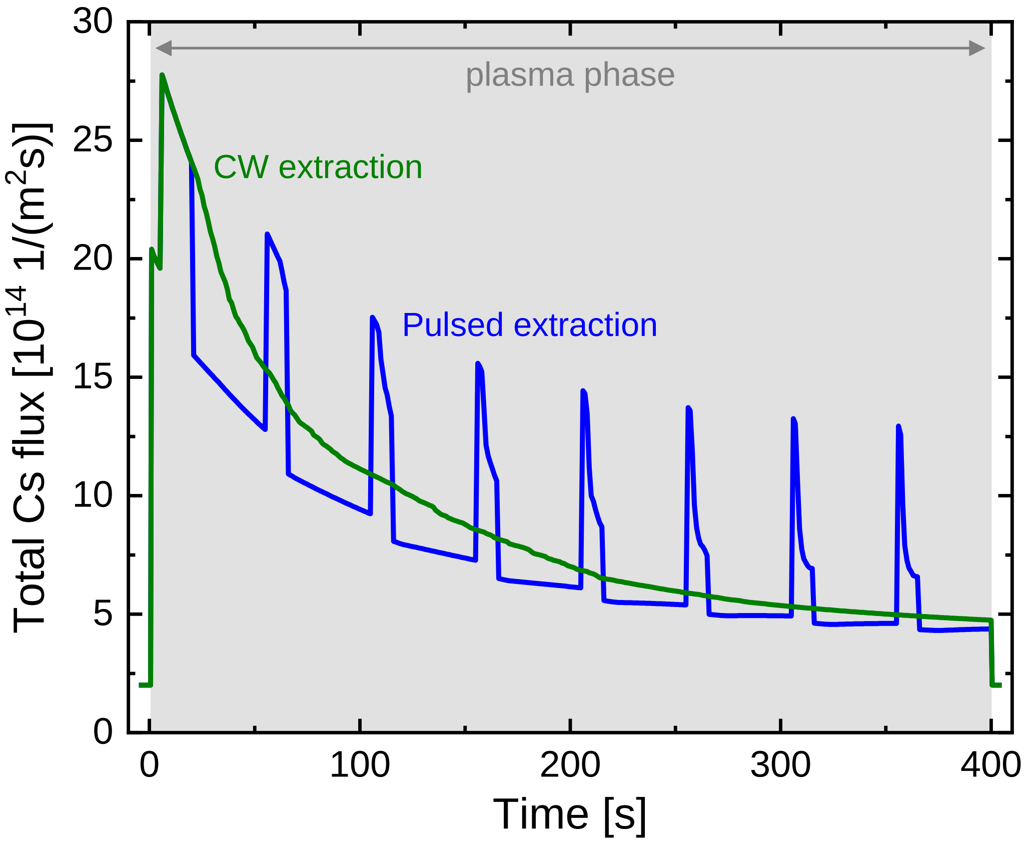
- Huge impact on Cs re-distribution (CsFlow3D).

Alternative Cs distribution procedures may be needed

Needed hardware upgrades

- New CW HV power supply.
- CW beam calorimeter.



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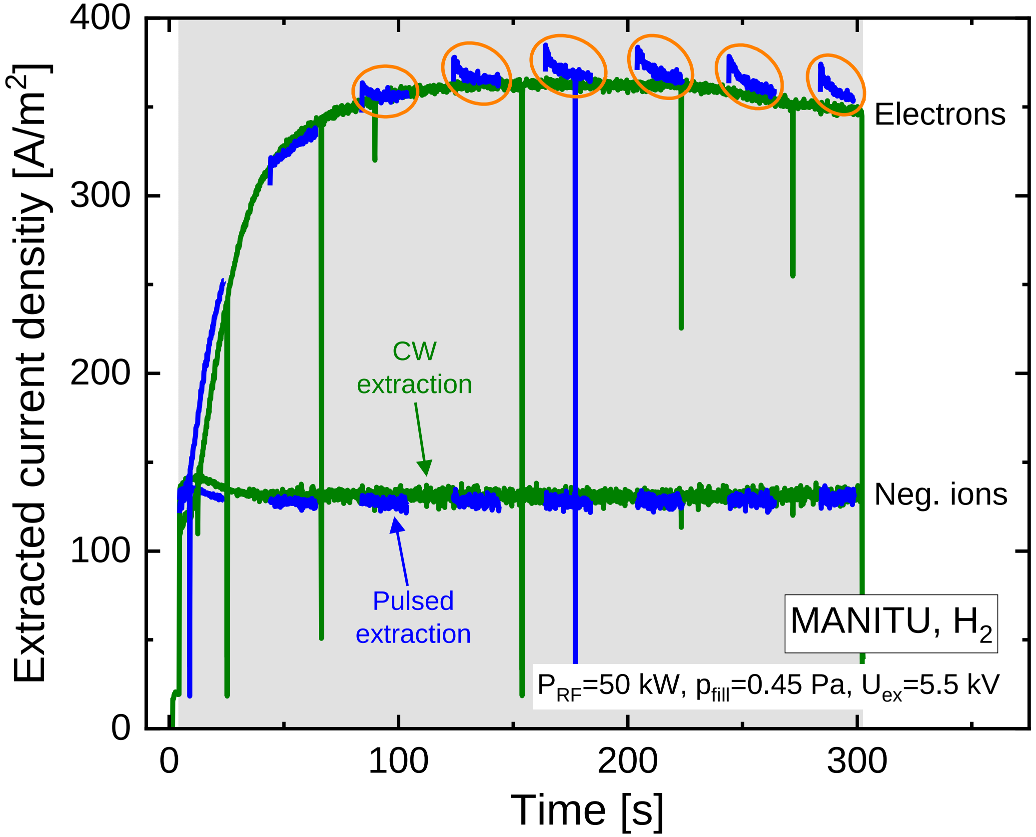


Upgrade to CW operation (I)

New CW HV power supply (OCEM)

- Technical specs comparable to old PS.
- One 12 kV module and one 50 kV module, each consisting of several power modules in series.
- No tube-based HV modulators needed.
- Delivery delayed due to Corona by several months.

Commissioning ongoing.
First pulses (dummy load & ELISE) planned for October.

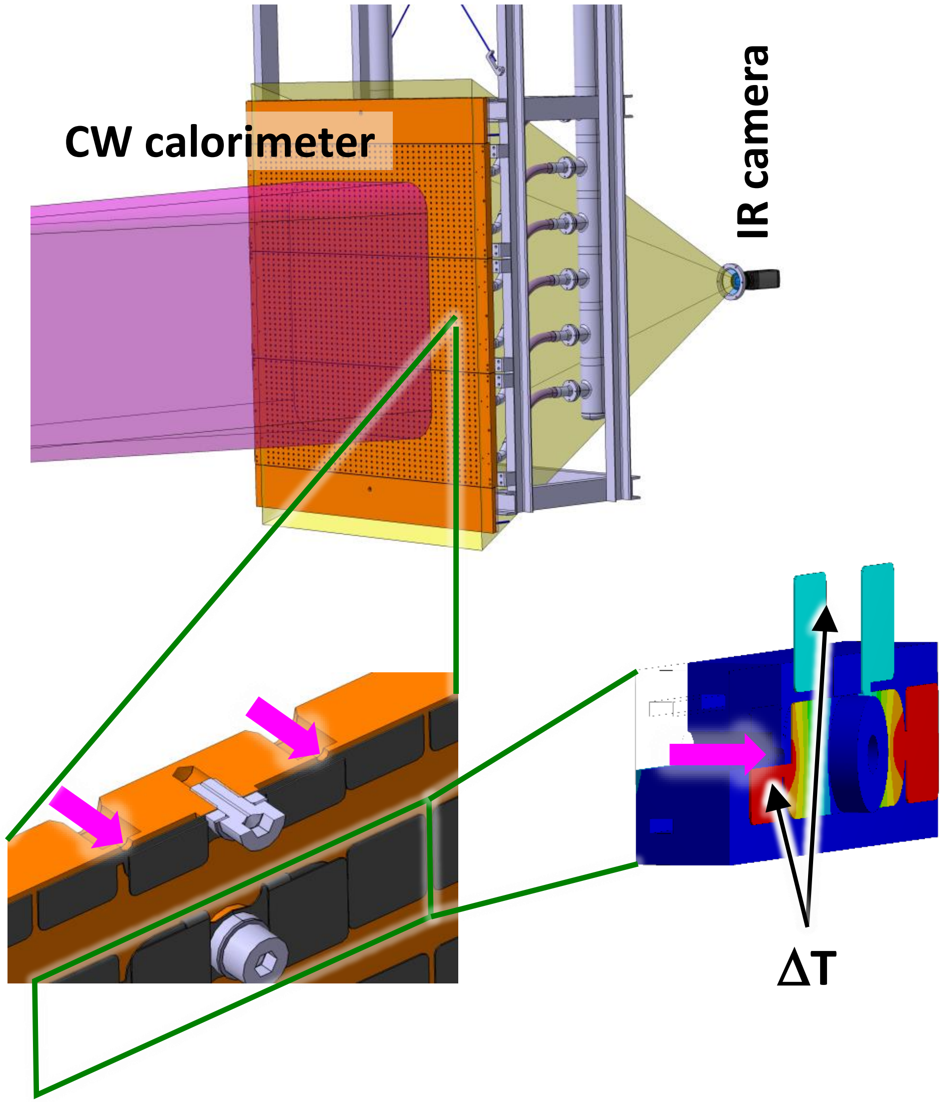
12 kV PS module

12 kV PS transformer

Upgrade to CW operation (II)

CW beam calorimeter (IPP design)

- Active cooling needed
  (max. power load: 4.5 MW/m^2, max. power: 1.8 MW).
- Modular design: 3 horizontal plates, water cooled.
- Beam profile diagnosed by IR camera:
  - Calorimeter back side blackened.
  - Resolution: 20 × 40 mm.



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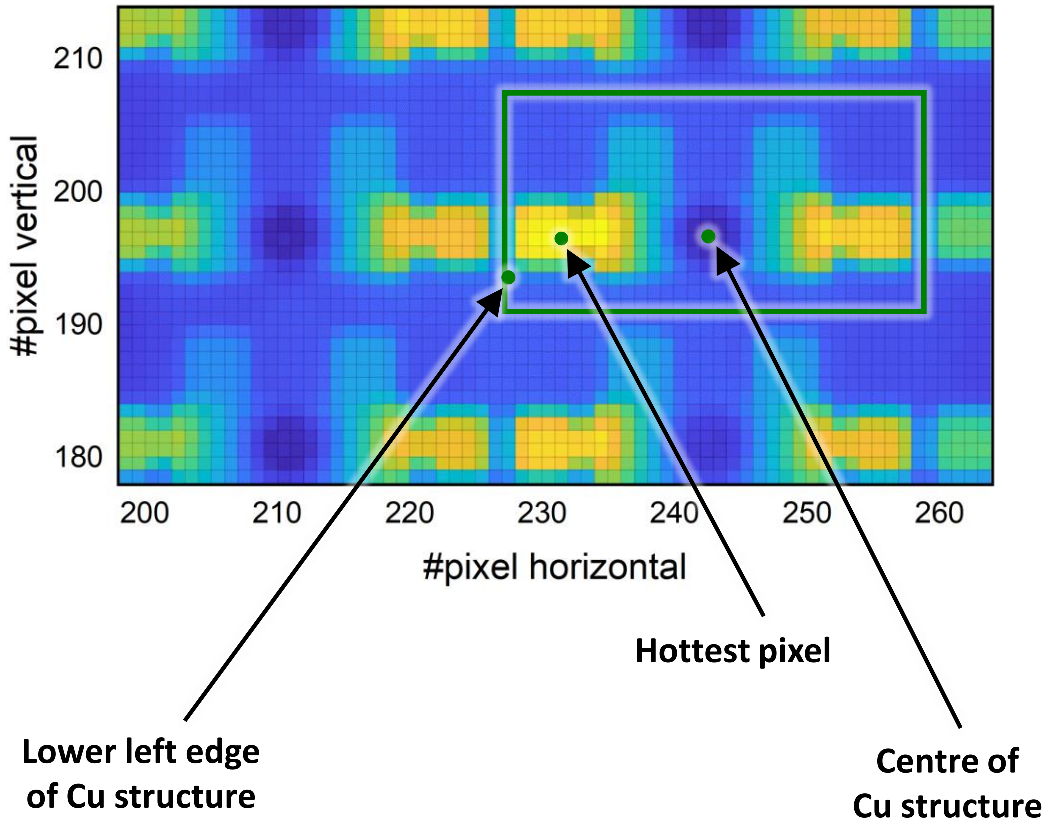
- Modular design: 3 horizontal plates, water cooled.
- Beam profile diagnosed by IR camera:
  - Calorimeter back side blackened.
  - Resolution: 20 × 40 mm.
- Reduced version (one plate) tested at BATMAN Upgrade.
  - MATLAB routine for automatic evaluation



New CW calorimeter design successfully tested at BATMAN Upgrade.

- Commissioning at ELISE first half of 2021.

Upgrade of ELISE to CW extraction

Encouraging results obtained in ELISE in hydrogen for pulsed extraction.

Deuterium: vertical asymmetry of co-extracted e- is the main issue. Can be solved for p_{fill}*=0.6 Pa (only)*

- Some of the developed caesium conditioning techniques exploit the existence of extraction blips.
- Long pulses: caesium reservoirs at source backplate replenished in between extraction blips.

↓

- Challenge: transfer existing conditioning techniques to CW operation.
- Possibly different ways for evaporating and re-distribution caesium are needed for the CW mode.

Upgrade of ELISE to CW extraction; first results expected end of 2020