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RF Breakdowns in the SPIDER experiment during its first operational phase

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MeVArc 2019

The SPIDER experiment

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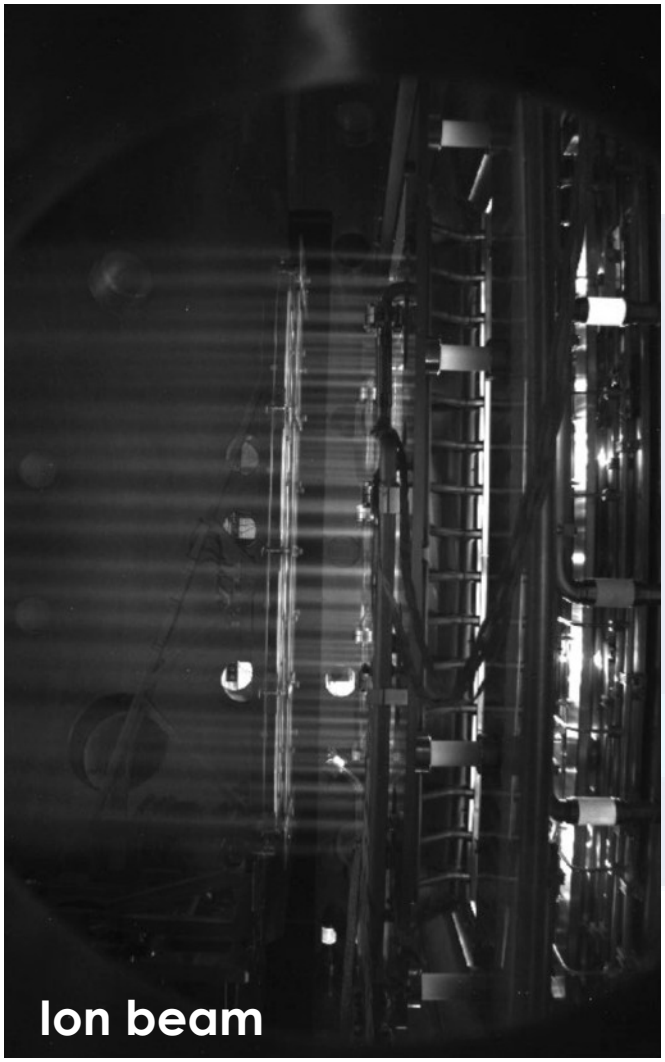

SPIDER is the Ion Source prototype for the ITER Neutral Beam

Ions are generated by means of a Inductively coupled Plasma

Total RF power installed is 800 kW at 1 MHz

8 Drivers

Start of operations:
May 2018

First Ion Beam:
May 2019

but…

More details tomorrow:
Dr. Serianni **First year of operation of SPIDER, prototype source of ITER neutral beam injectors**

Flashovers induced by the RF

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Signs of flashover on the experiment's surfaces

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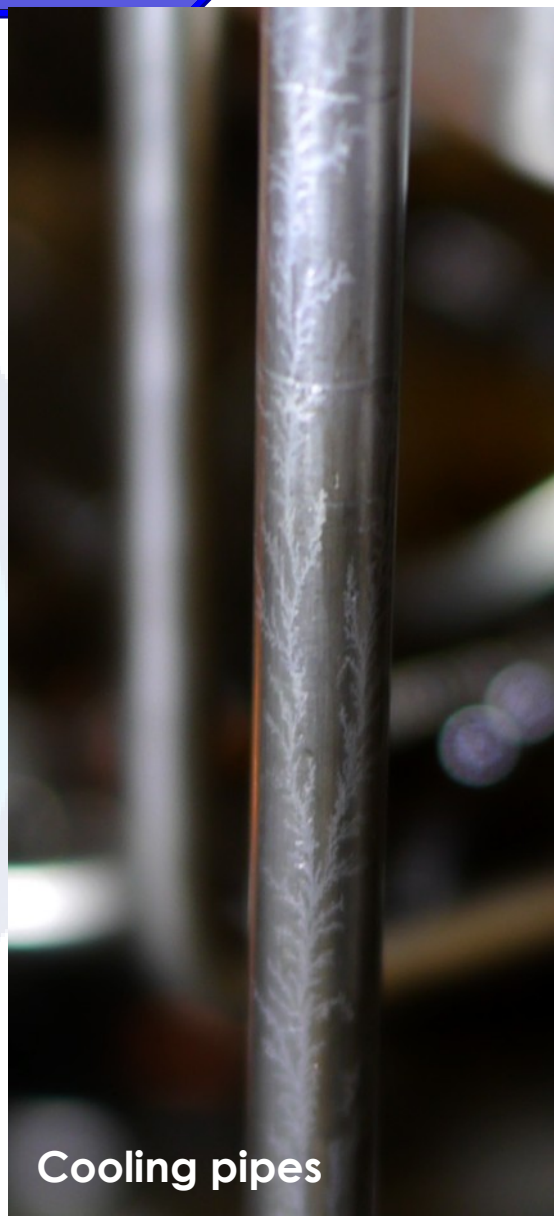
Ceramic breaker

Vacuum Vessel surface



Cooling pipes

The SPIDER Beam Source

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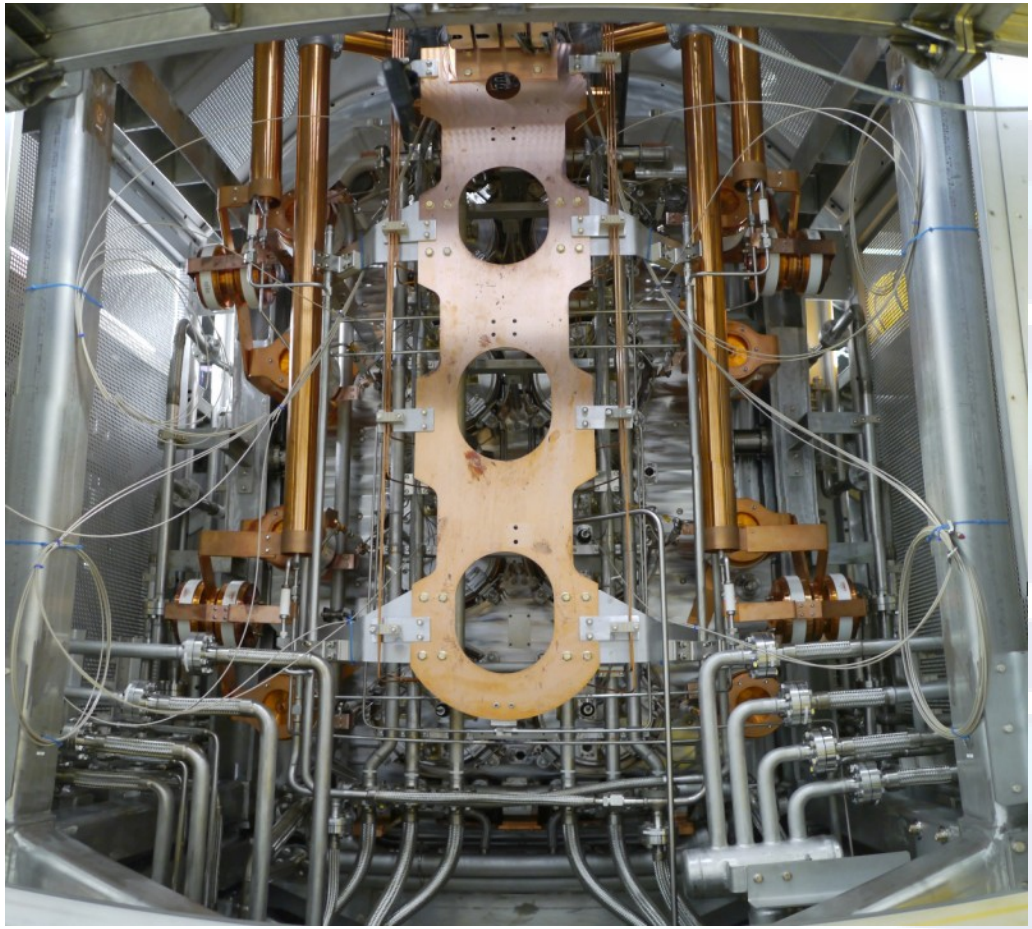
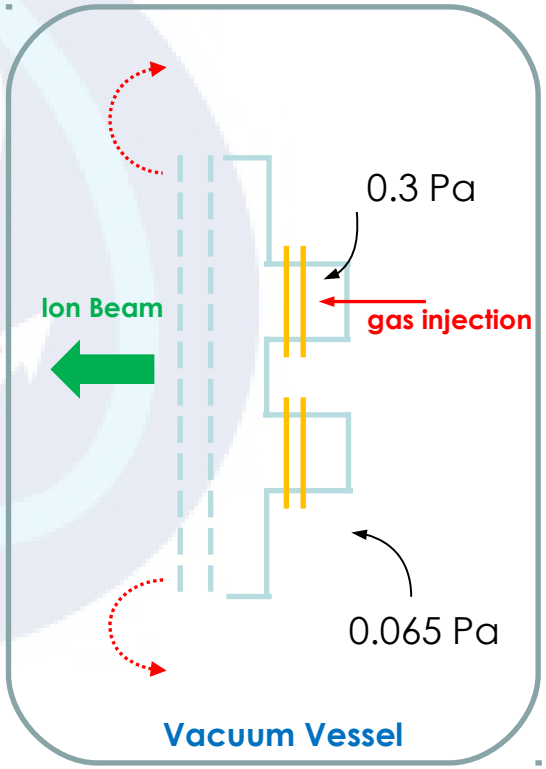


Rear side of the SPIDER experiment: a complex geometry

The Experiment is housed inside a Vacuum Vessel



SPIDER Experiment timeline

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May 2018

No High Voltage Screen installed

- Operations with more than one generator proved difficult due to flashovers
- Signs of discharges on the Vacuum Vessel surface

September 2018

Temporary High Voltage Screen installed

- Flashover continue to beset the experiment

November 2018

A complete mask cover the Plasma Grid: possible to operate with a lower pressure into the Vacuum Vessel

- Flashovers were greatly reduced
- Operations with four generators are now possible
- An «energetic» flashover damaged the Beam Source Thermocouples

April 2019

The final High Voltage Screen was partially installed, a Partial mask was installed

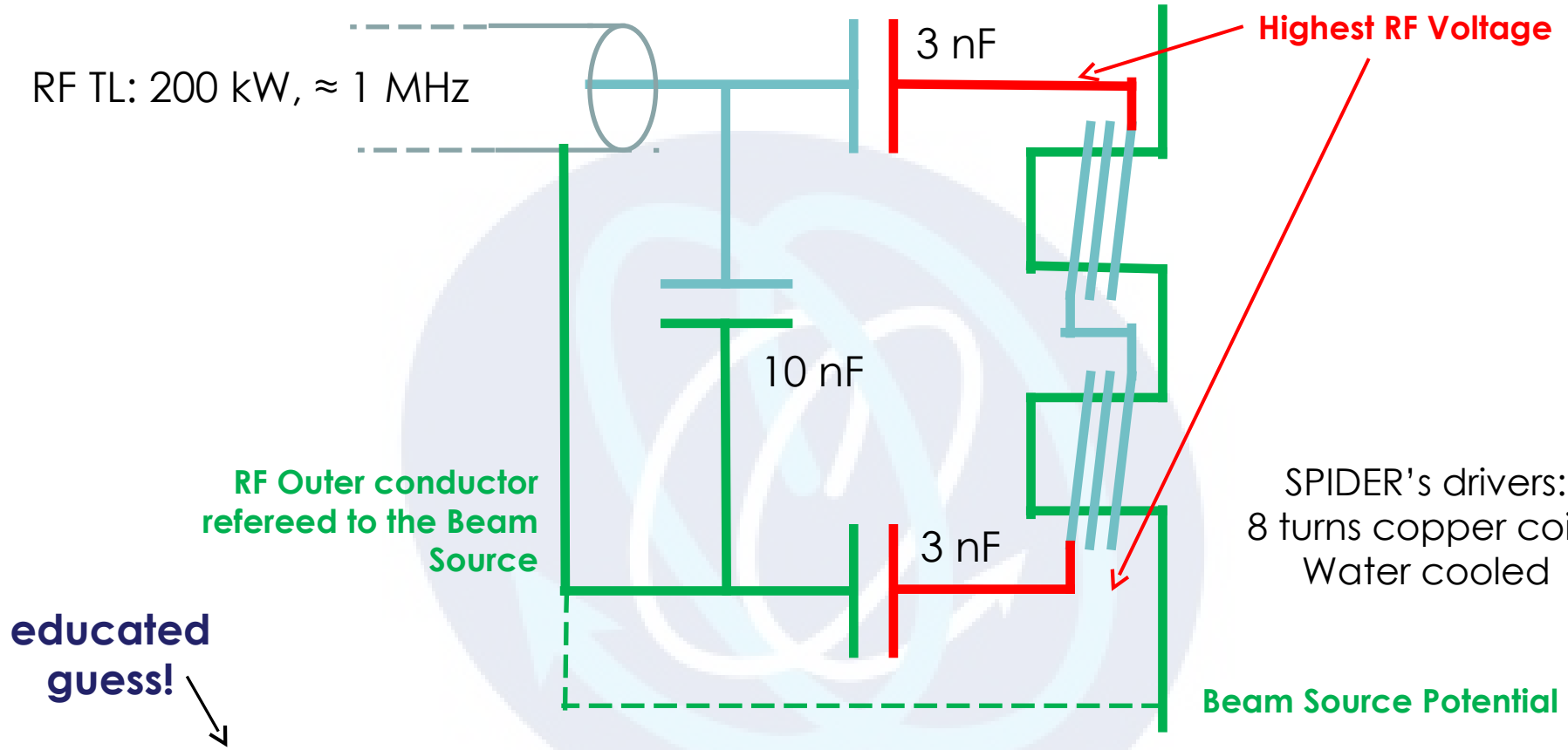
- Operation with four generators are possible
- Flashovers continue to beset the experiments

RF
No HV

RF + HV

Operational improvements due to reduced Vacuum Vessel pressure

What's the highest voltage without Acceleration?



educated guess!

R driver = **4.6 Ω** ↔ 208 A in the resonance circuit to transfer 200 kW

C_S = 3 nF ↔ 53 Ω @ 1 MHz

C_S maximum voltage: 11 kV_{RMS} (**15.5 kV PEAK**)

Working H_2 pressure around the coils: 65 mPa

Slow Camera evidences

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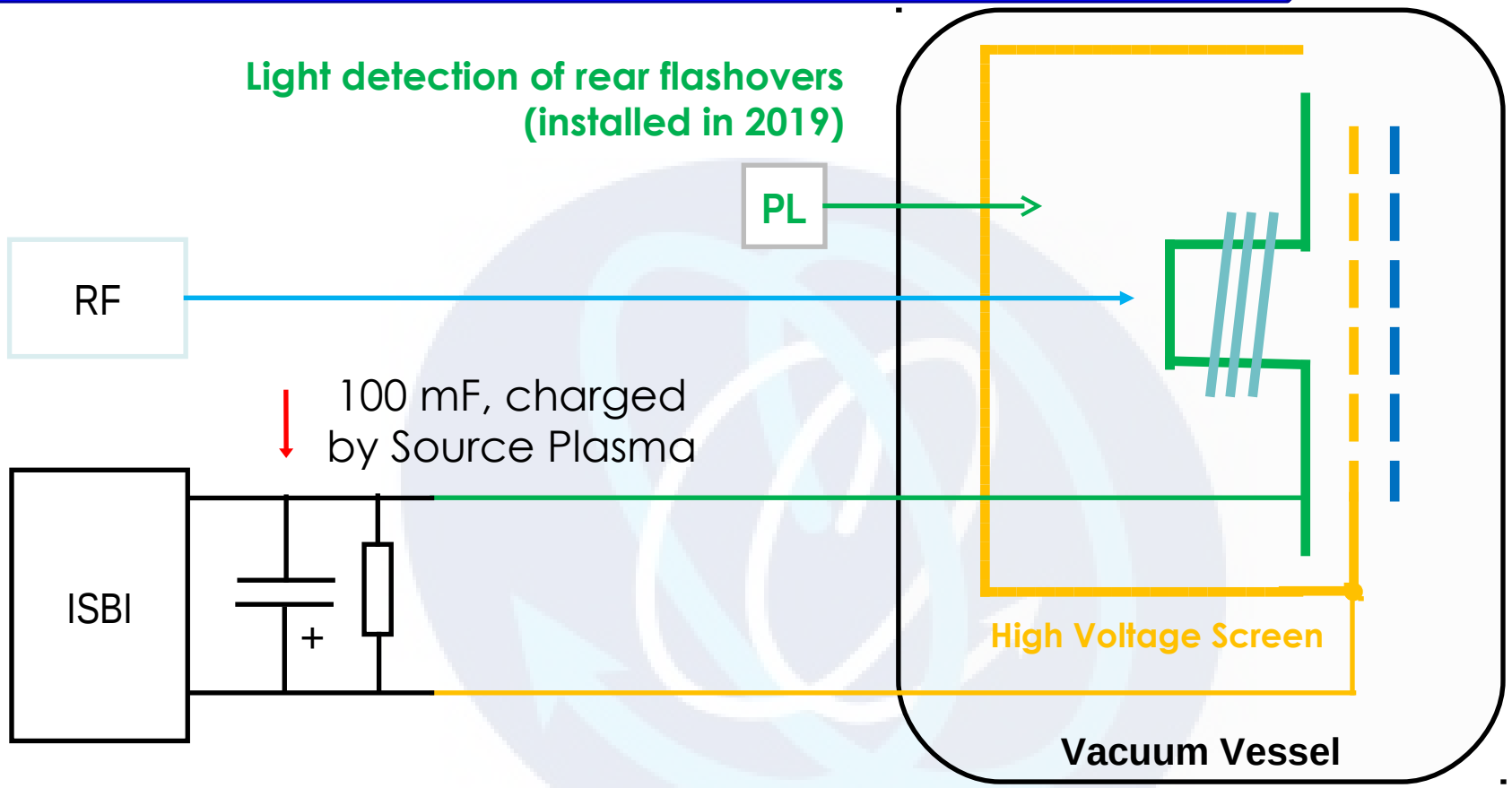
«Arc» Mode

«localized» lights usually on the rear busbar

«Glow» Mode

«diffused» light, localized nearby the RF drivers

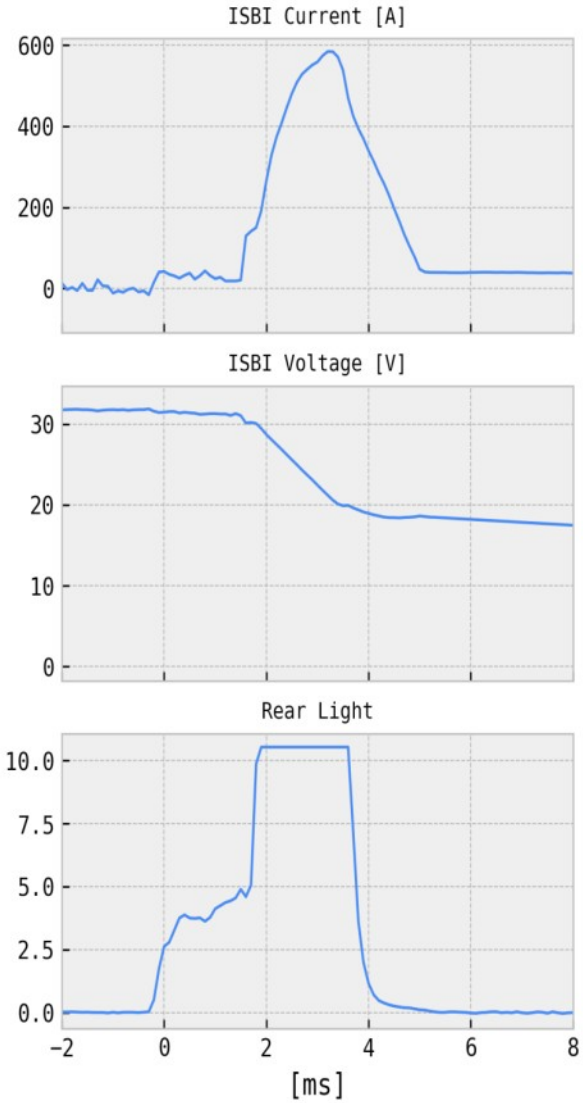
SPIDER Beam Source: a simplified Electrical scheme

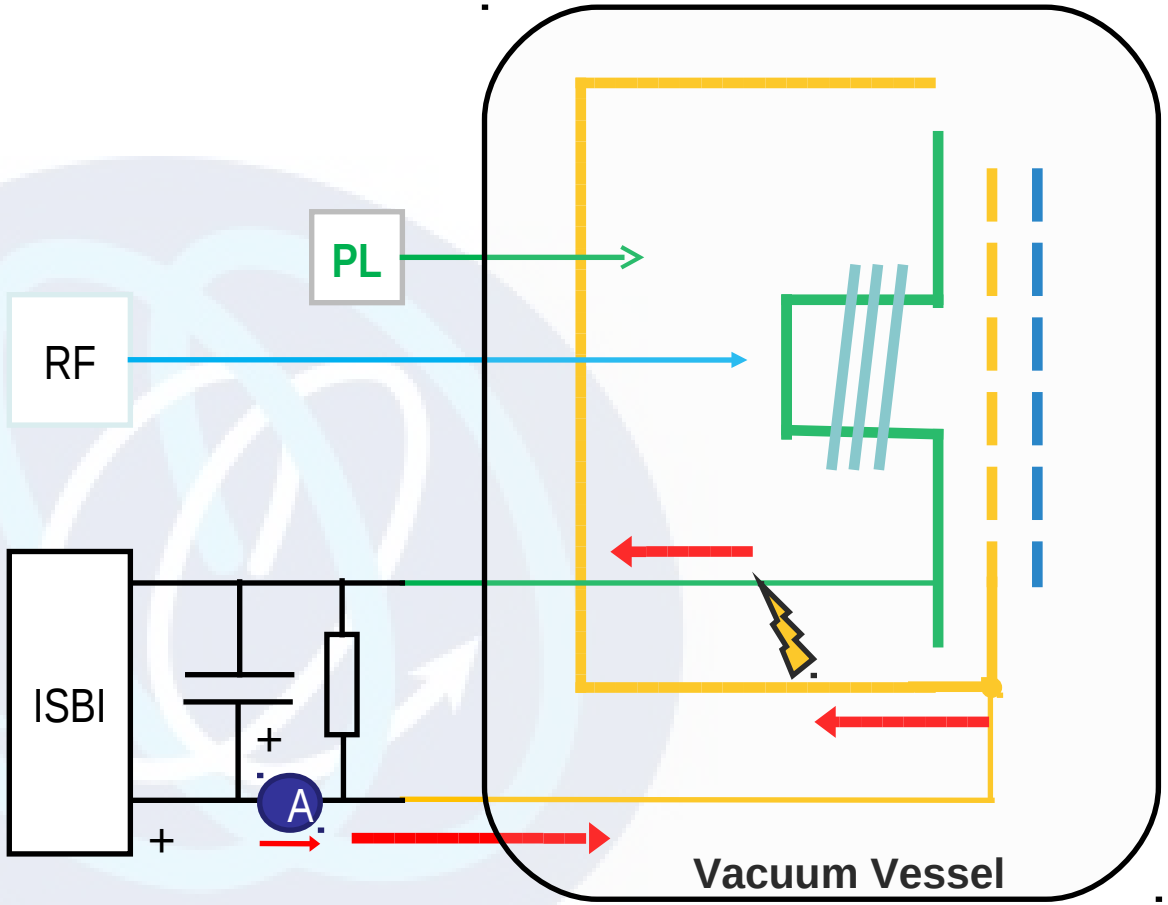


ISBI polarized the Beam Source with respect to the Plasma Grid, and therefore, the High Voltage Screen. 30 V – 600 A. **Usually Disabled**

High voltage not shown

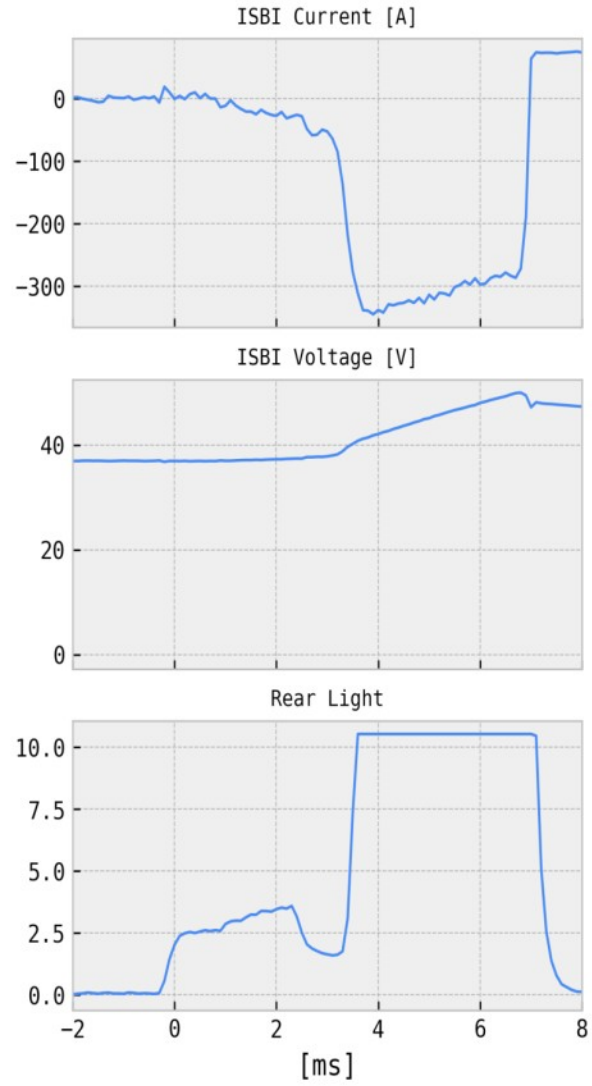
«Arc» Mode

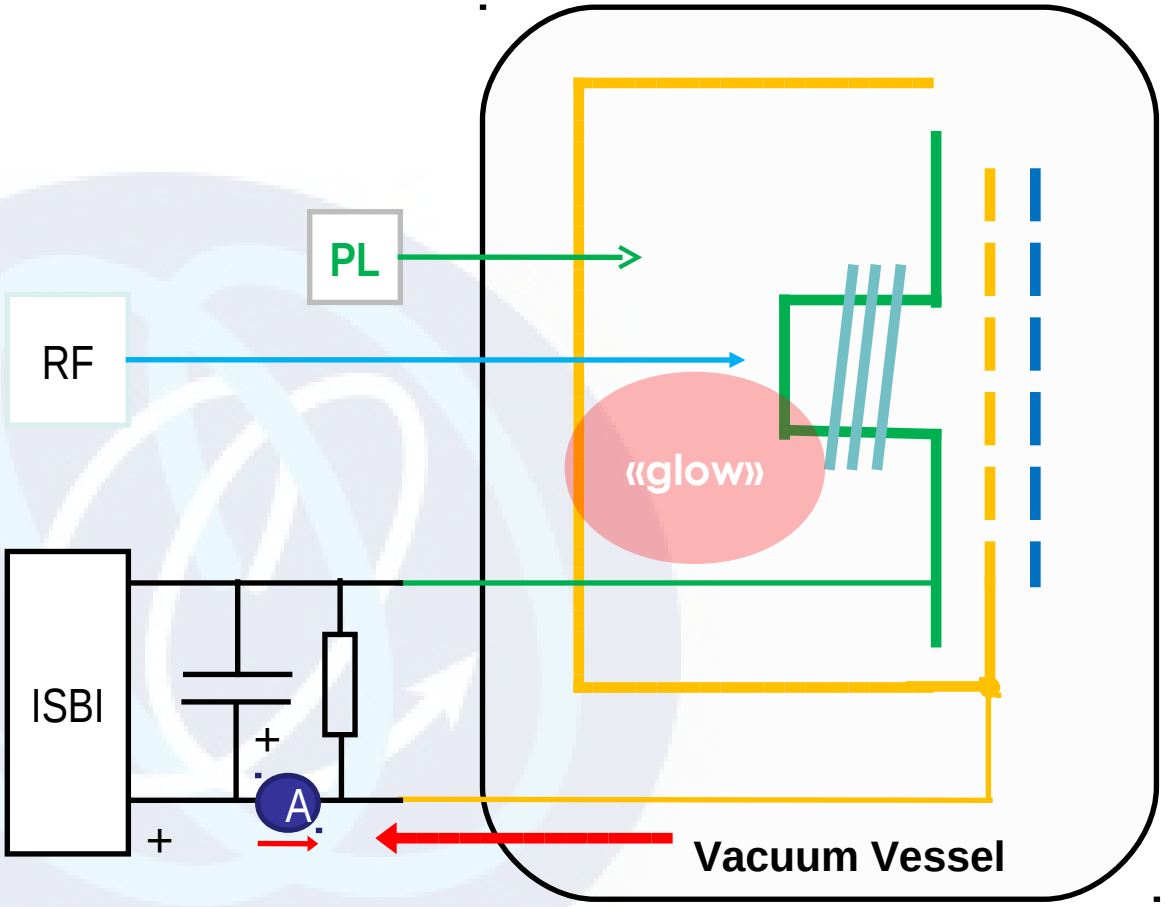




Fast discharge of the ISBI output filter
Arc Energy: tens of Joule
Arc length: few ms
Energy towards the Beam Source

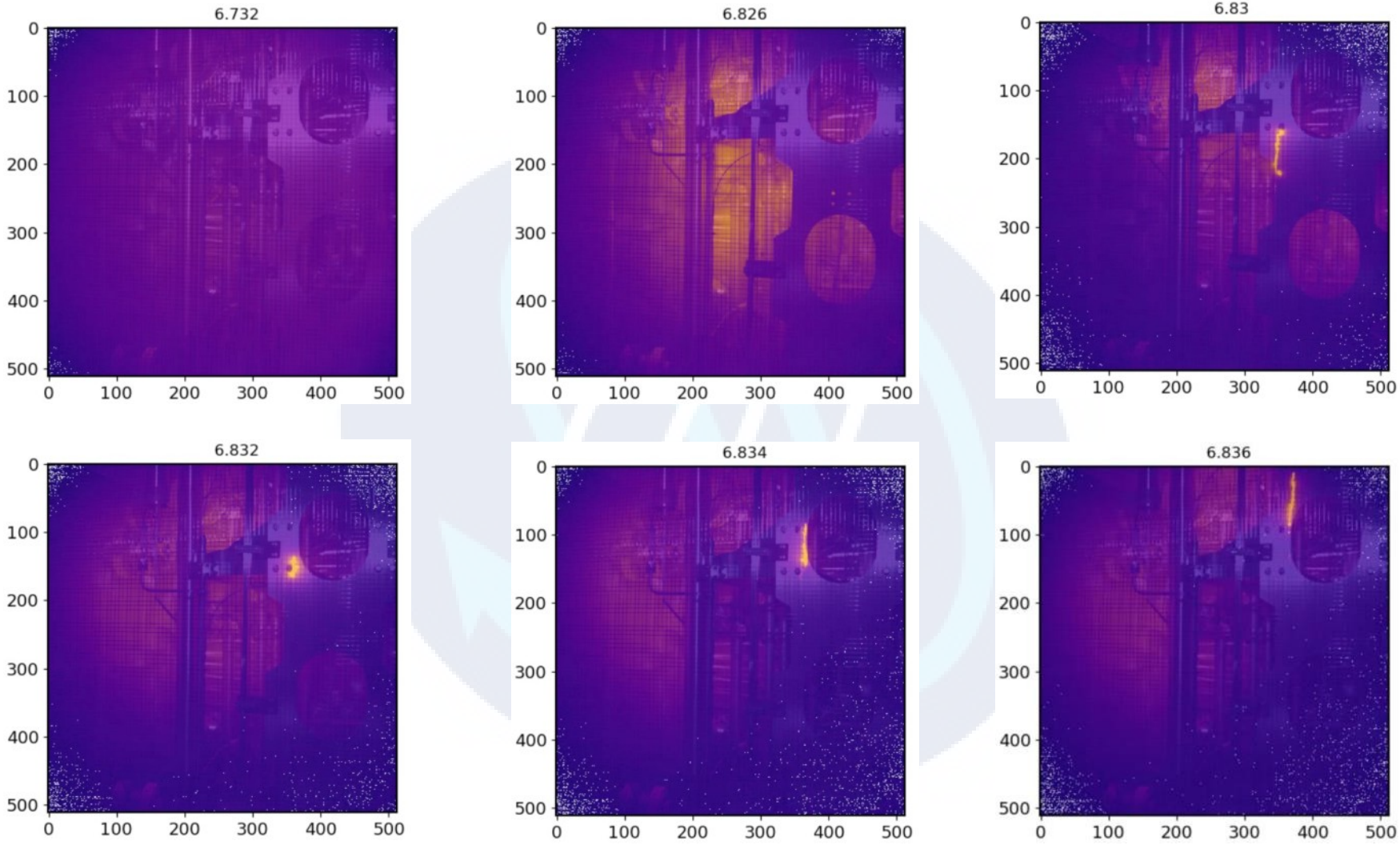
«Glow» Mode





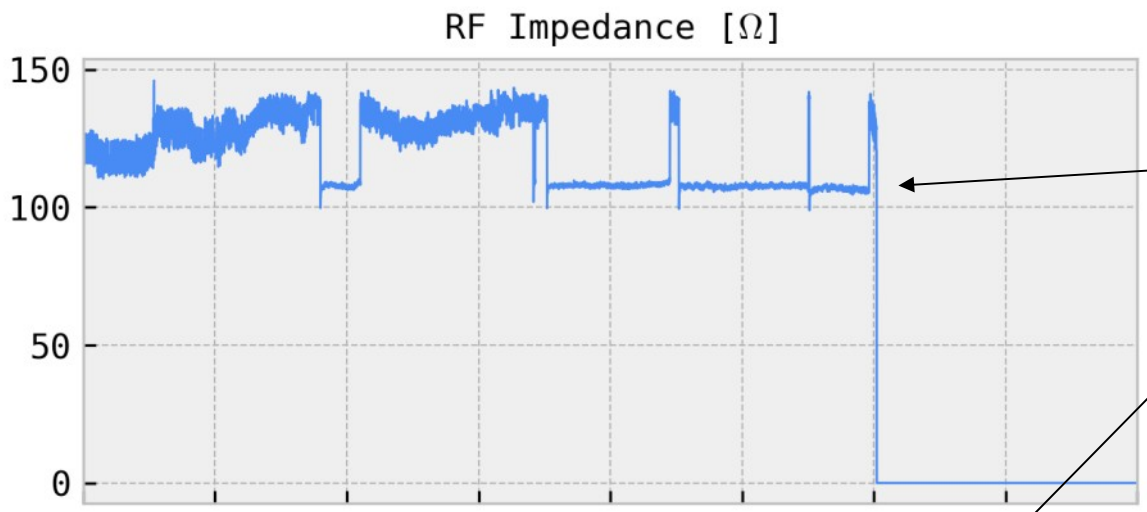
The glow charges the ISBI output filter
Arc length: tens to houndreds of ms
Energy from the Beam Source to the Power supply

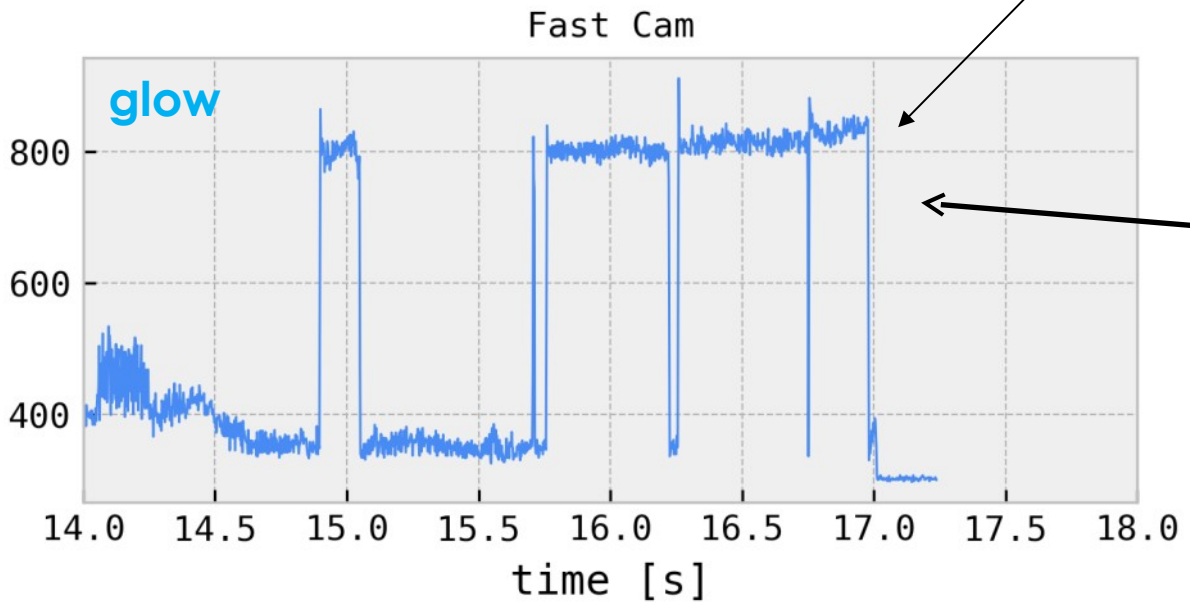
Fast Camera evidences



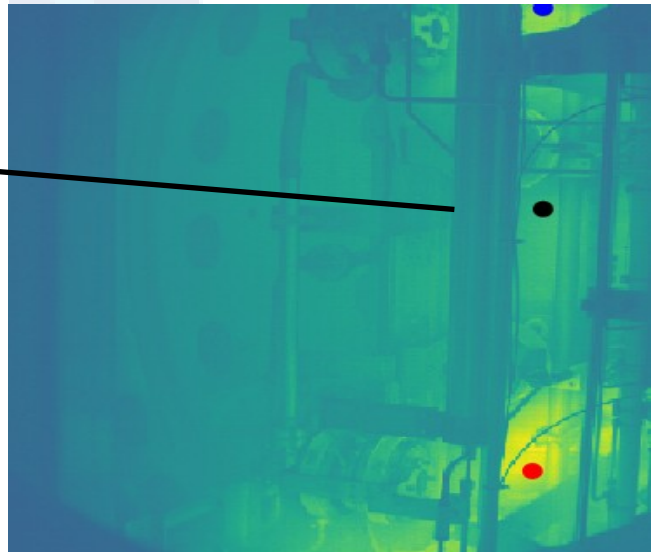
Frame rate: 500 Hz

Fast Camera evidences

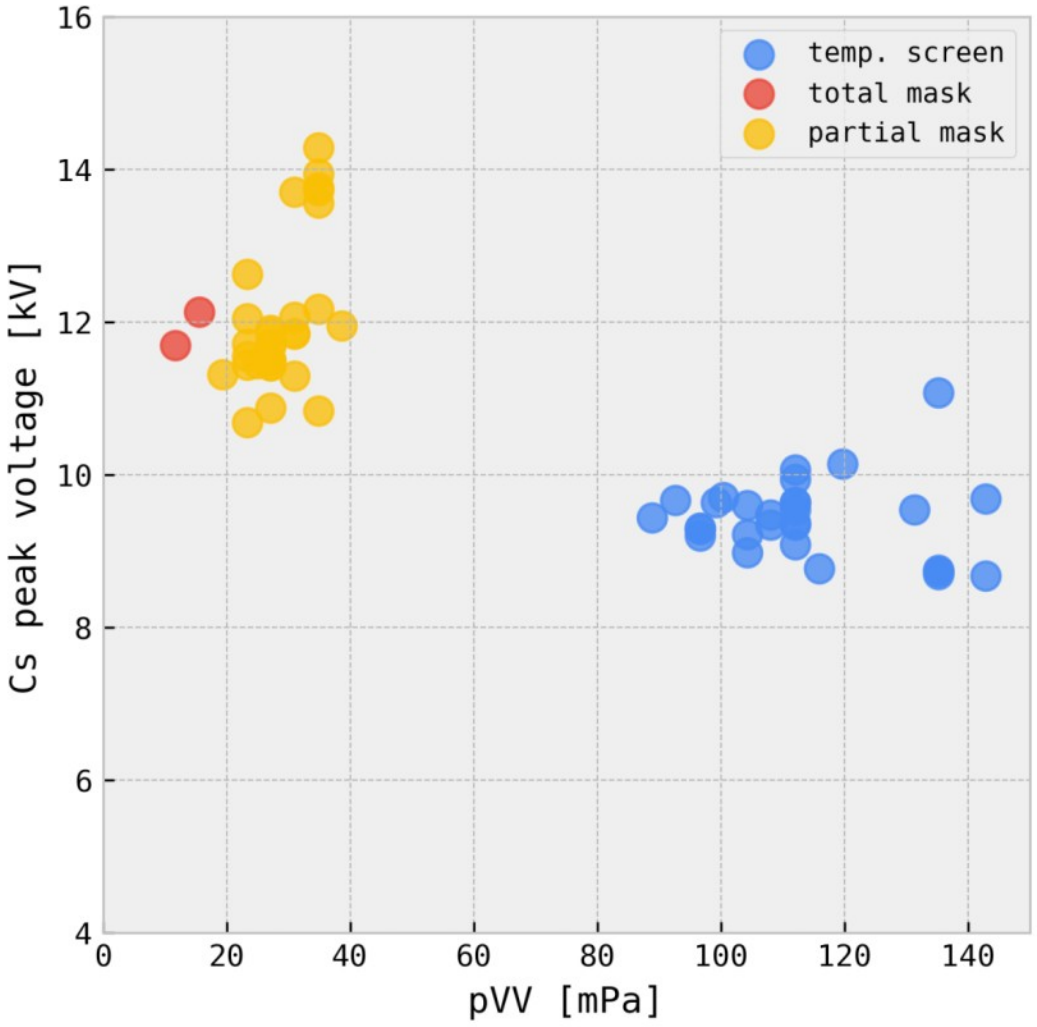




- Significant signals' correlation



What's the trigger for the breakdowns?



Simplest analisys:
•Pulses **without** plasma into the drivers (failed ignition, sudden plasma shutdown..)
•Pulse with only one operating RF generator

Advantages:
•The driver impedance is well known (1.0 Ω per driver, 9 uH)
•No mutual couplings among drivers

But… It is not an operating condition for SPIDER (and should be avoided)

What's the safe operating space for SPIDER now?

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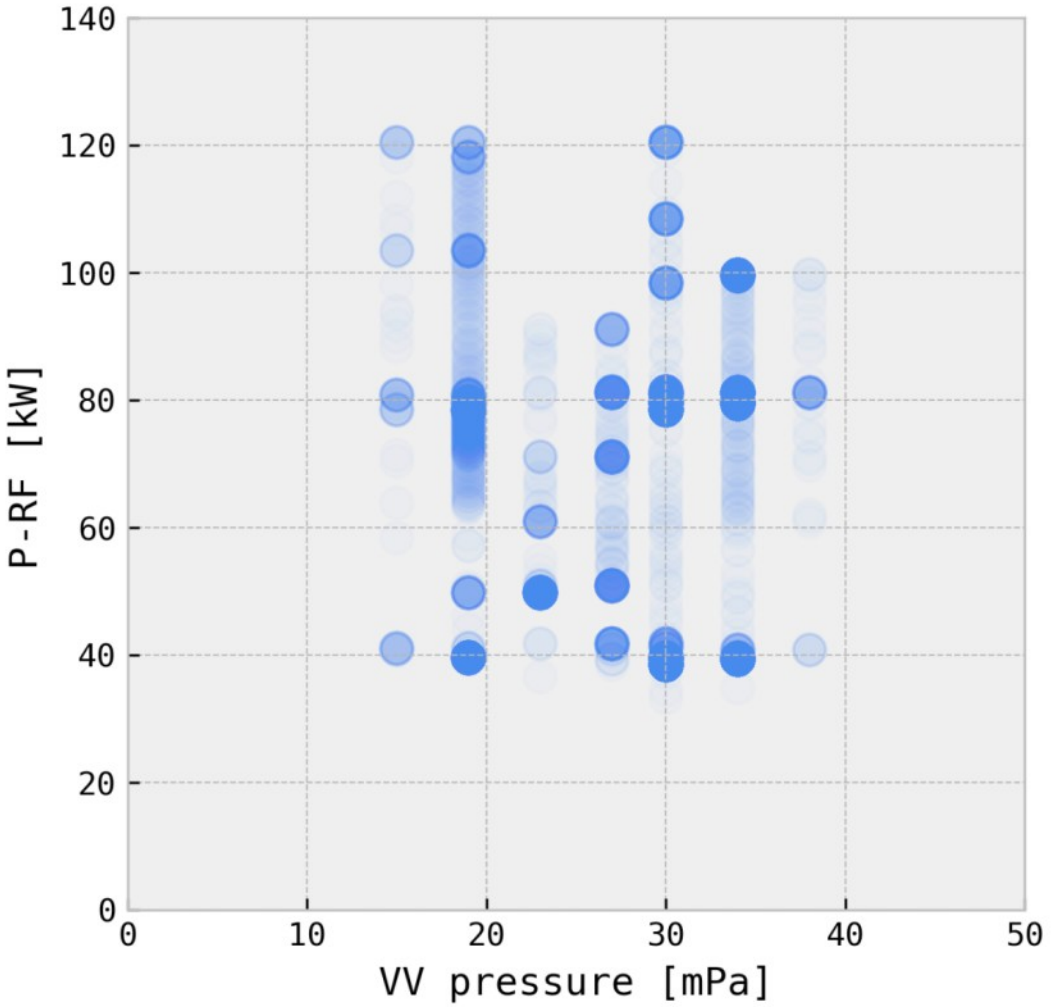
- 2019 pulses with Plasma, single generator
- Partial mask
- No High Voltage breakdown

The presence of plasma reduced the resonant current and therefore the coil voltage



Conclusions

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- The SPIDER experiment is prone to flashovers induced by the RF field

- Reducing the In-Vessel pressure proves beneficial, modifications of the pumping system is necessary

- The interaction between High DC Voltage grids breakdown and RF discharged should to be investigated (HV breakodown seems to shut-off the plasma into the drivers)