

Plasma Processing to Mitigate Field Emission in LCLS-II 1.3 GHz SRF Cavities

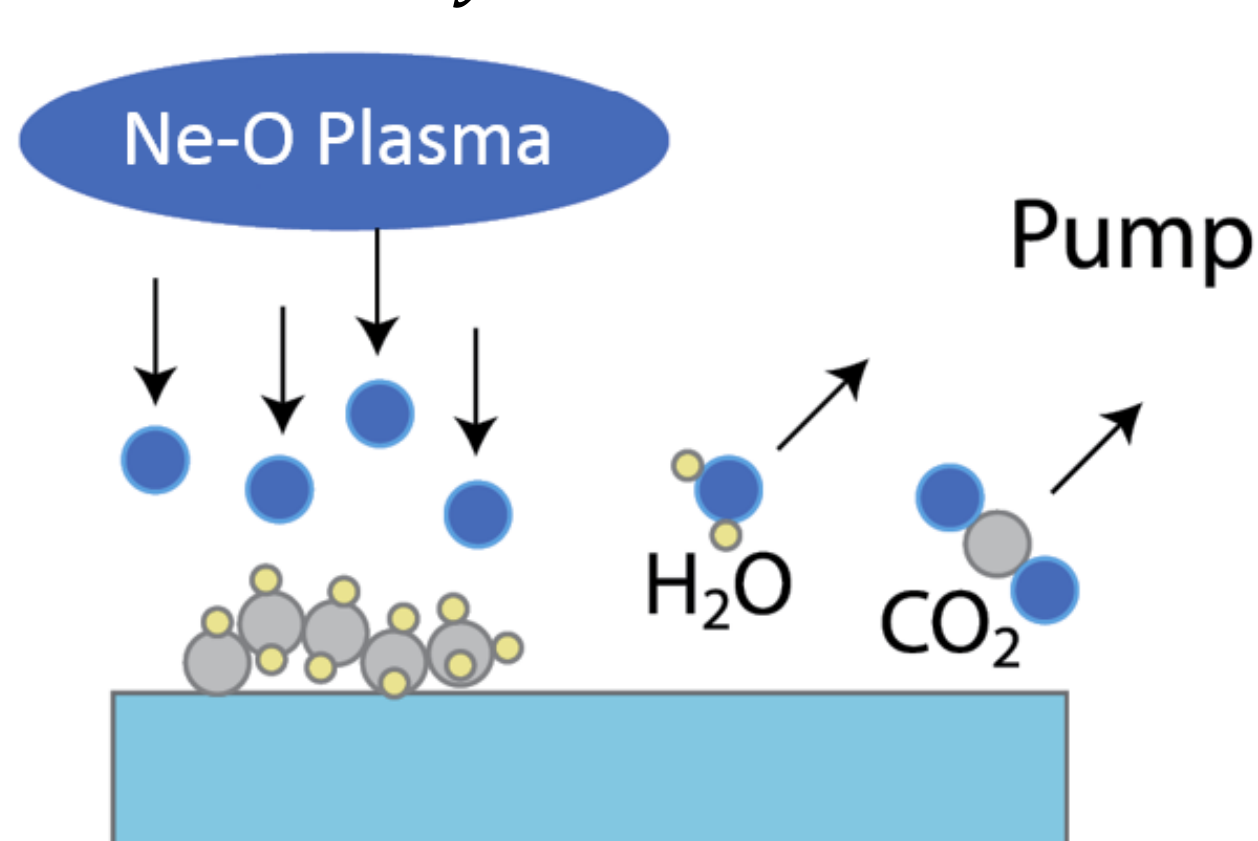
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Plasma Cleaning to Reduce FE

A collaboration between Fermilab, SLAC and ORNL is working to develop plasma processing for 1.3GHz TESLA shaped SRF cavities.

Hydrocarbon (C_xH_y) contaminations and adsorbates lower the cavity surface work function (Φ) increasing Field Emission (FE). Plasma processing removes C_xH_y allowing the cavity to operate at higher E_{acc} .

A 10% increase in Φ gives a 15% increase in E_{acc}



Plasma cleaning: glow discharge ignited at room temperature using an inert gas (Ne or Ar). A low % of O_2 is added to react with C_xH_y . Cavity pressure: 70-200mTorr.

M. Doleans et al. NIMA 812 (2016) 50-59

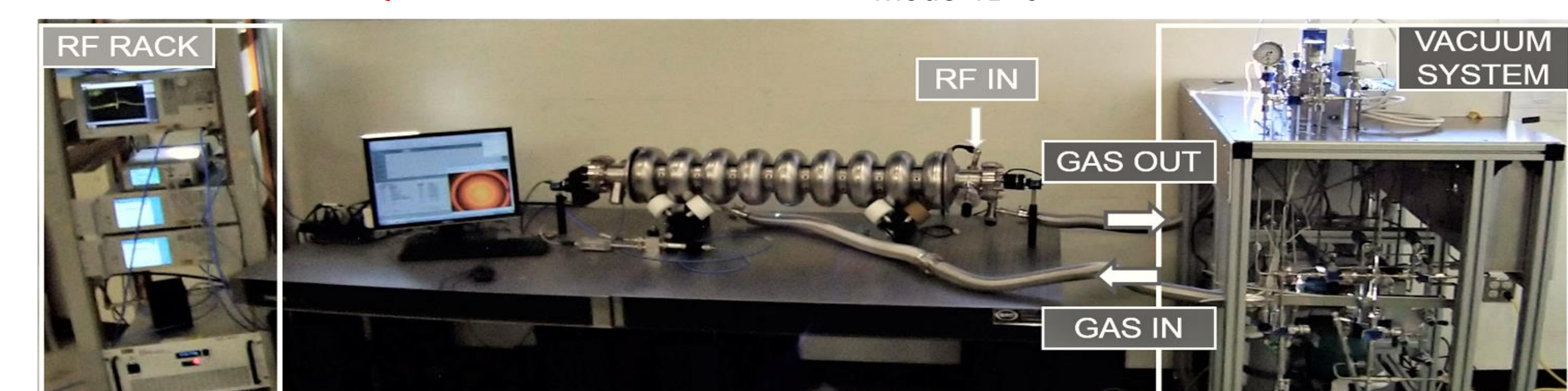
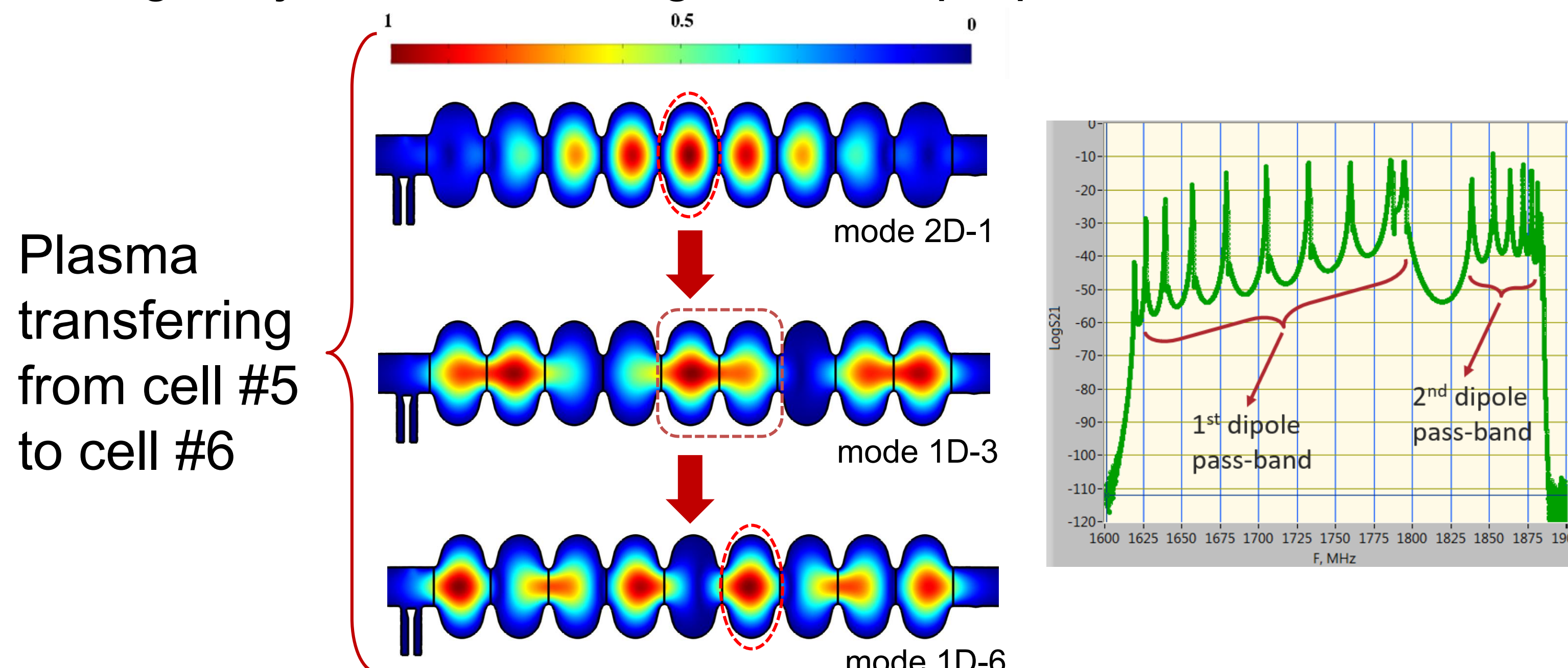
Plasma ignition in LCLS-II cavities

Glow discharge is ignited cell by cell, using cavity resonant modes.

New idea: ignite plasma using HOMs (Higher Order Modes): 1st and 2nd dipole pass-bands → good coupling at room temperature, resulting in plasma ignition with only few watts.

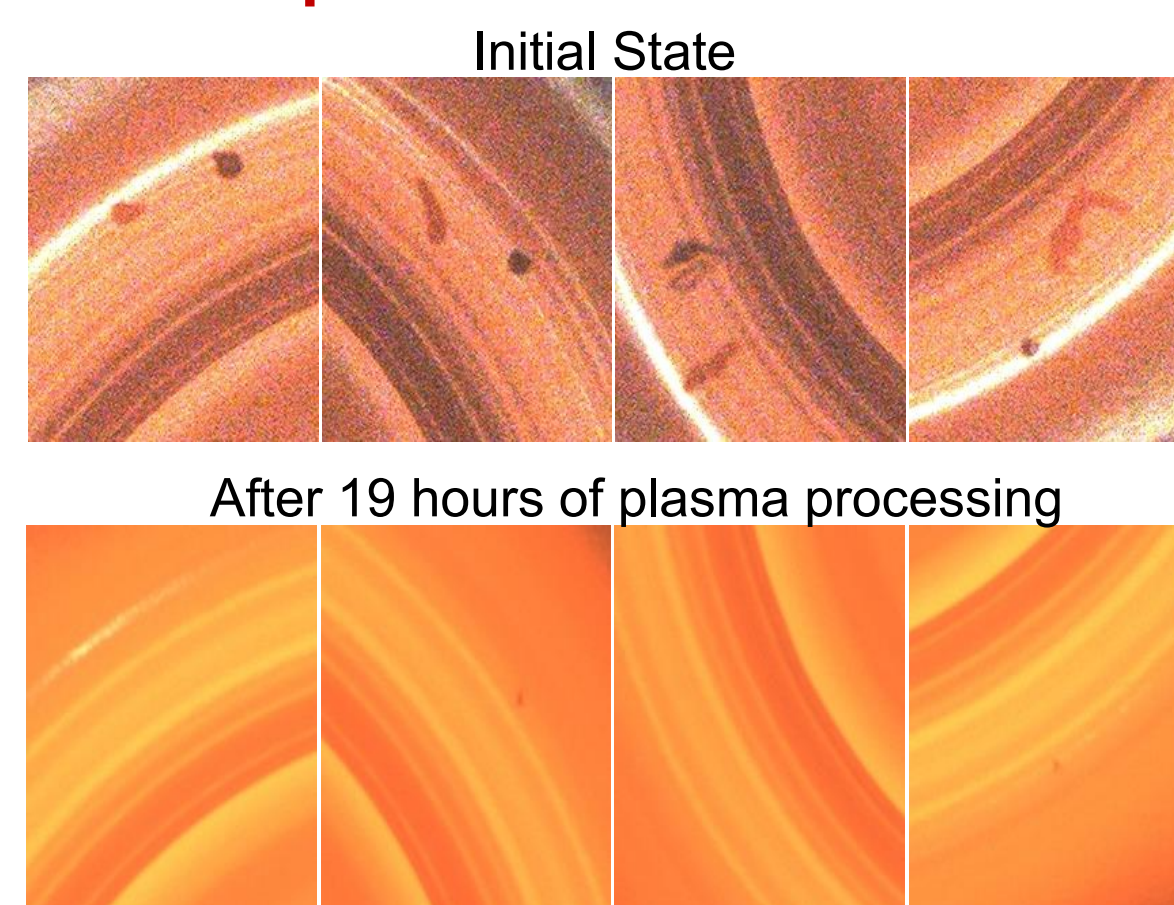
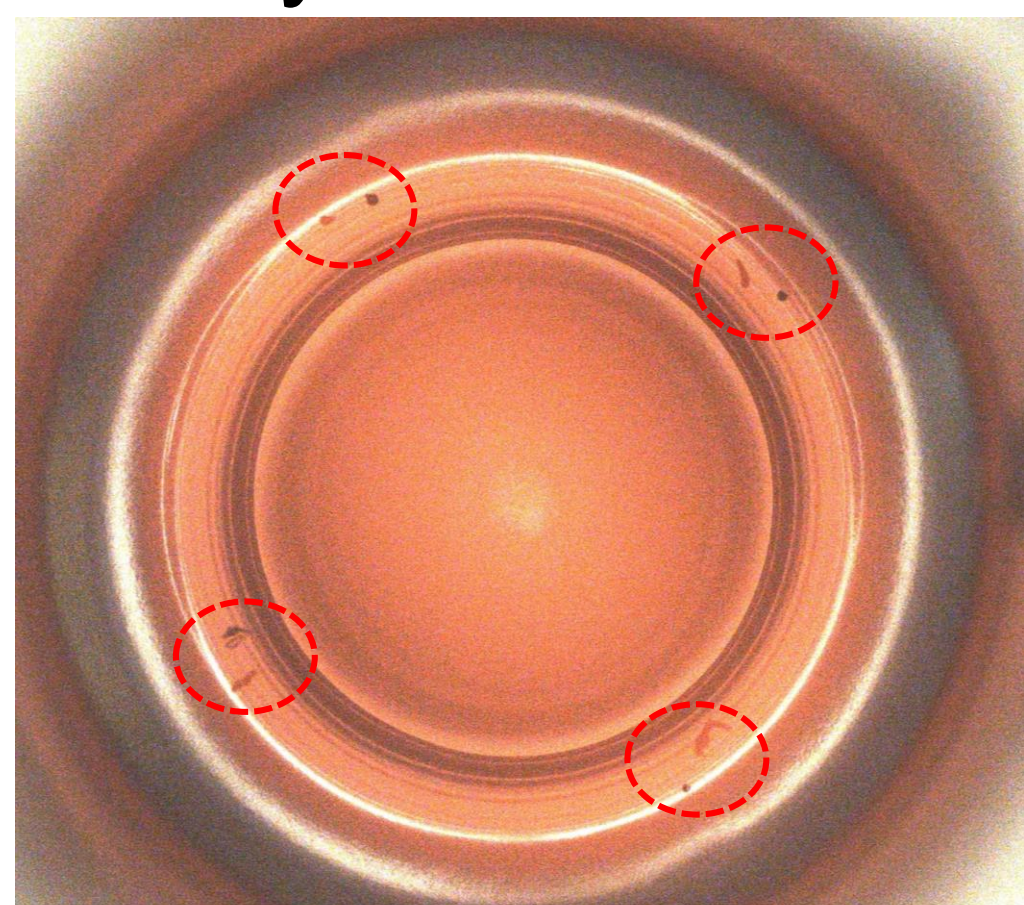
Dual tone excitation to transfer plasma:

plasma ignited in the central cell (mode 2D-1) → transferred through adjacent cells using HOMs superposition.



Removal Studies

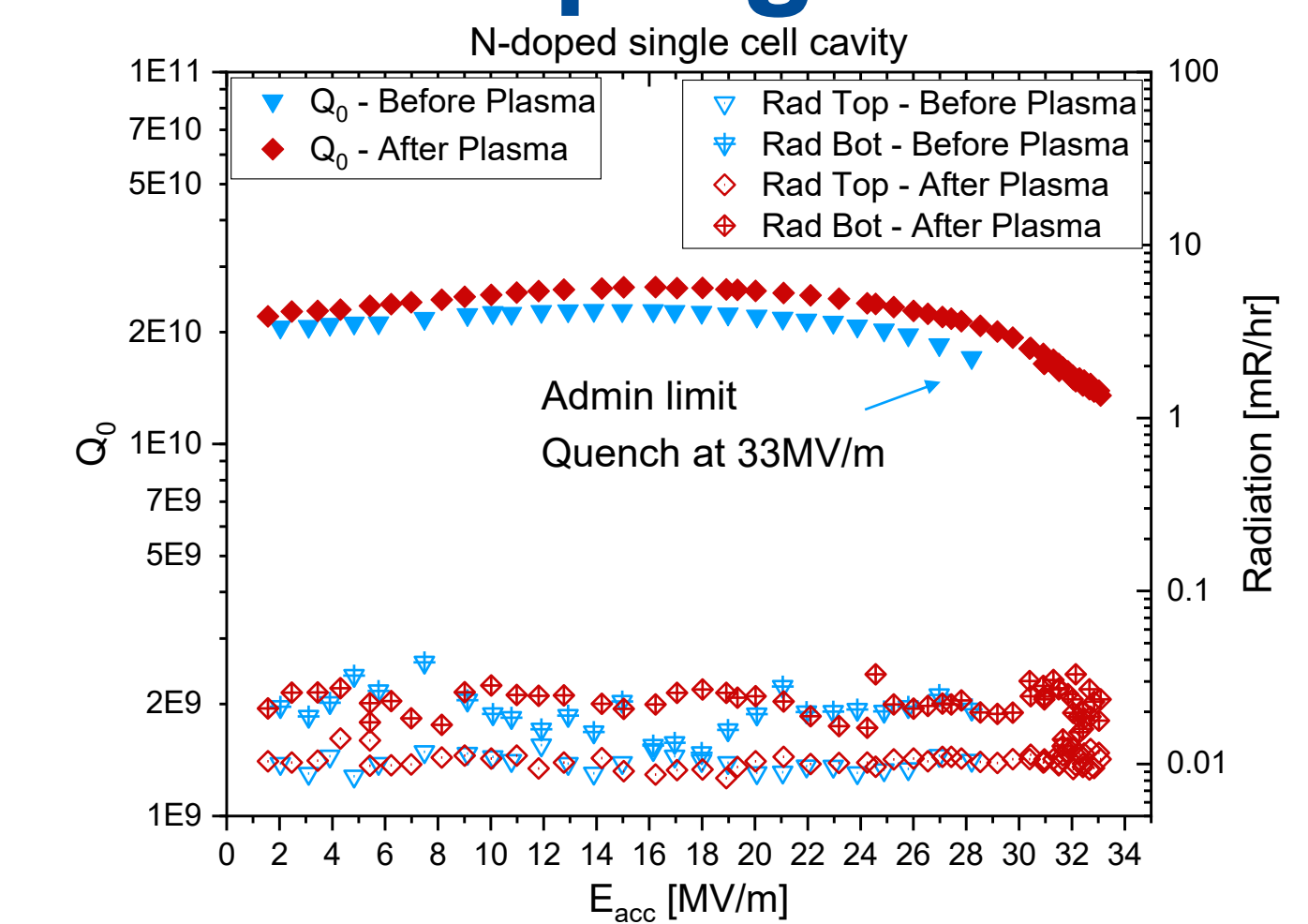
Cavity iris: contaminated with **permanent marker** (ink: C compound)



Developed a first recipe in terms of pressure, O_2 percentage, plasma density.

Effect of plasma on Q- factor of N-doping

RF test proved that **plasma preserves the high Q and quench field** of N-doped cavity



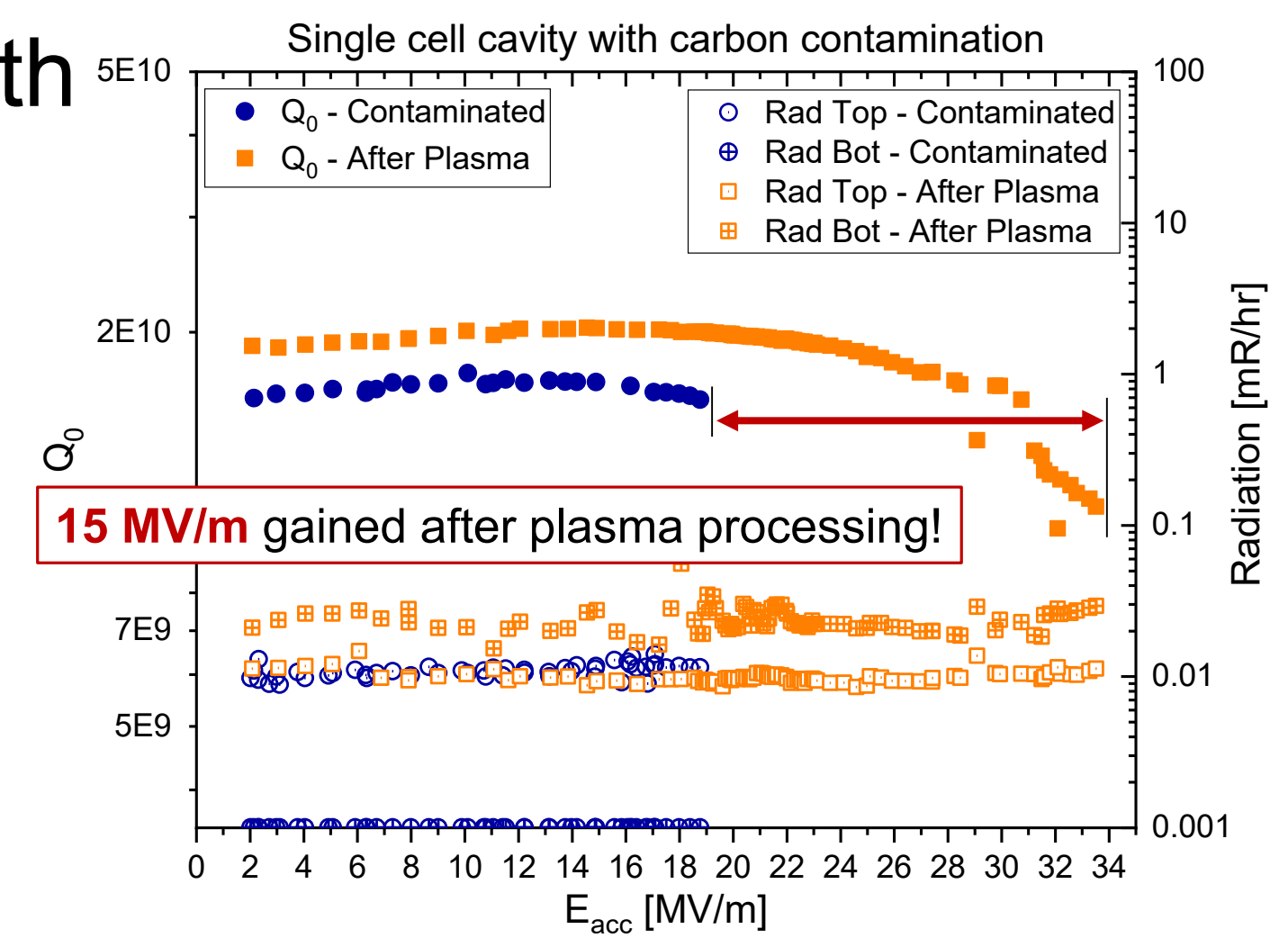
Studies on Contaminated Cavities



Cavity iris contaminated with carbon based conductive paint

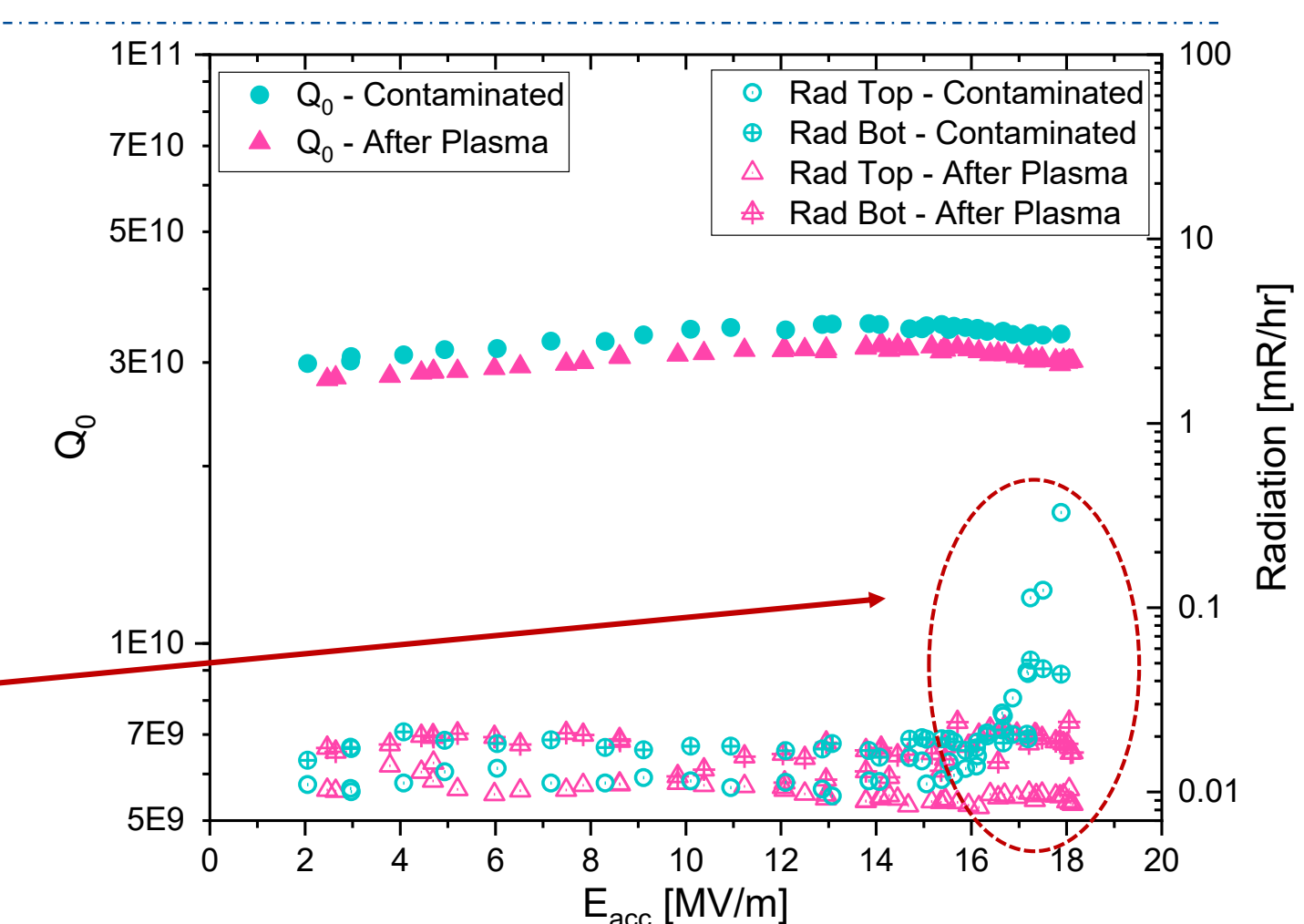
Plasma processing successfully removed the contamination

- **Restored initial E_{acc}**



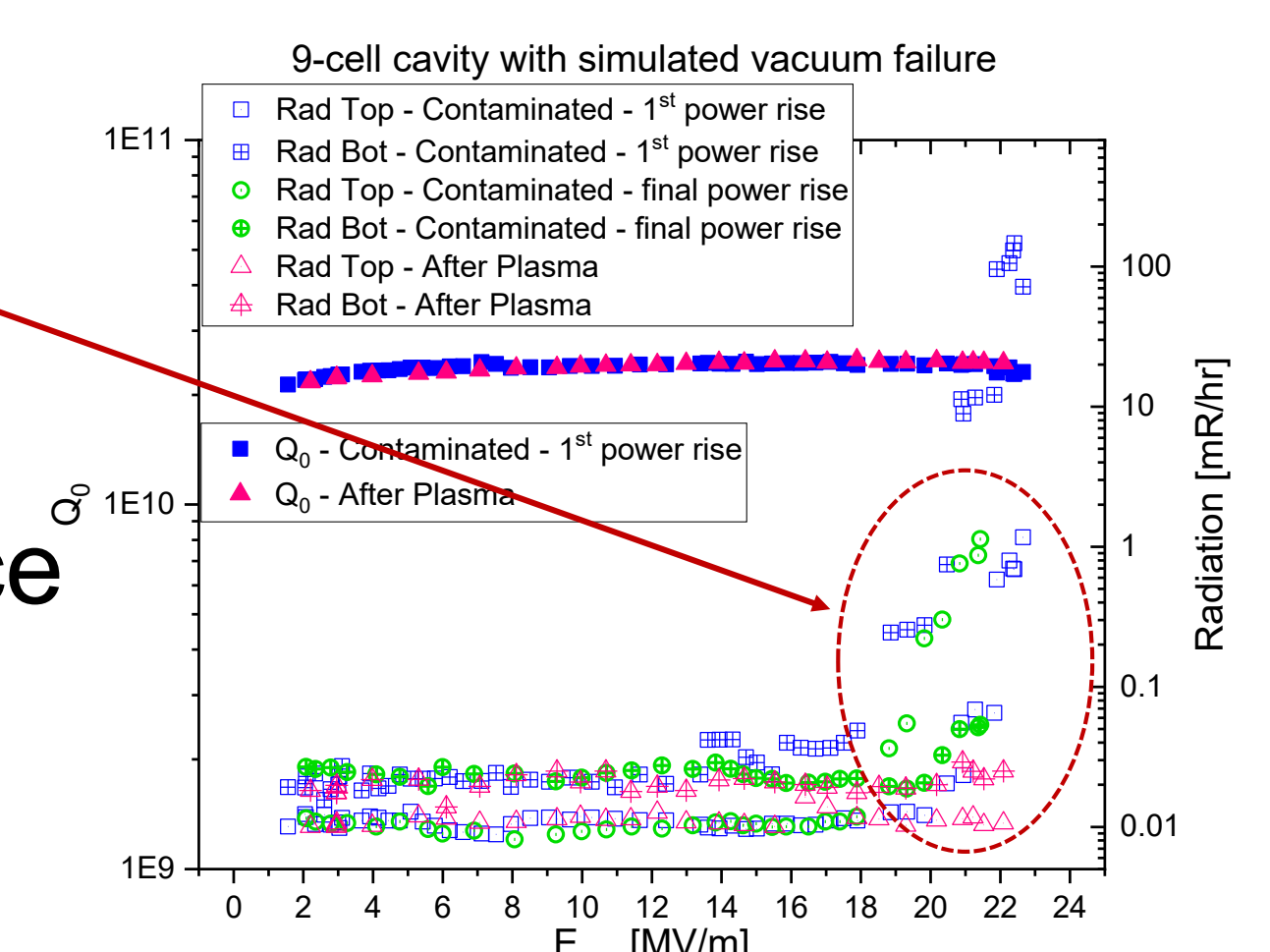
Two 9-cell cavities with **natural FE**:

- 1st cavity: no increase in performance, **FE may be not C-related**
- 2nd cavity: **complete removal of FE after plasma processing**



Simulated Vacuum failures

- Vented inside clean room: **plasma processing completely removed FE**
- Vented outside clean room: **no or moderate increase** in the performance
 - Collect particles introduced during the venting to understand contaminant composition



Conclusions

- **HOMs method**: substantially **reduces the forward power** necessary to ignite plasma discharge
- **Successfully removed C_xH_y contamination** and identified a first working recipe
- RF tests before and after plasma cleaning show:
 - Plasma processing **preserves high Q and quench field** of N-doped cavity
 - Plasma processing can **remove field emission** and **increase quench field** in cavities with various carbon-based contaminations

Current and future work:

- Optimize plasma parameters (pressure, duration, O_2 percentage, plasma density) to increase efficiency
- Acquire more statistics on the effectiveness of plasma processing applied to natural field emission

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