Root Causes of Field Emitters in SRF Cavities Placed in CEBAF Tunnel

Rong-Li Geng

Jefferson Lab

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Outline

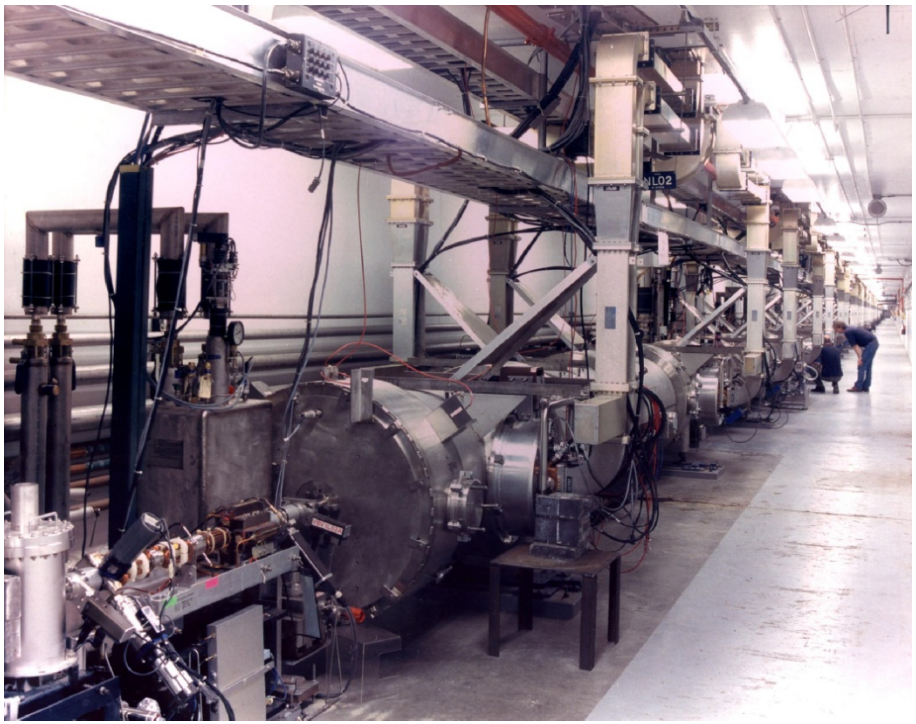
- Introduction
- Sources of Field Emitters
- Particulate Transportation, Activation
- Mitigation
- Conclusion

CEBAF: Continuous Electron Beam Accelerator Facility

Basic research of atoms's nucleus

Construction 1987-1993

Upgrade 2008-2015



First large-scale application of SRF linac technology

CEBAF Evolution

2011 – present

12 GeV Upgrade

Two 1.1 GeV linacs

1995 – 2011

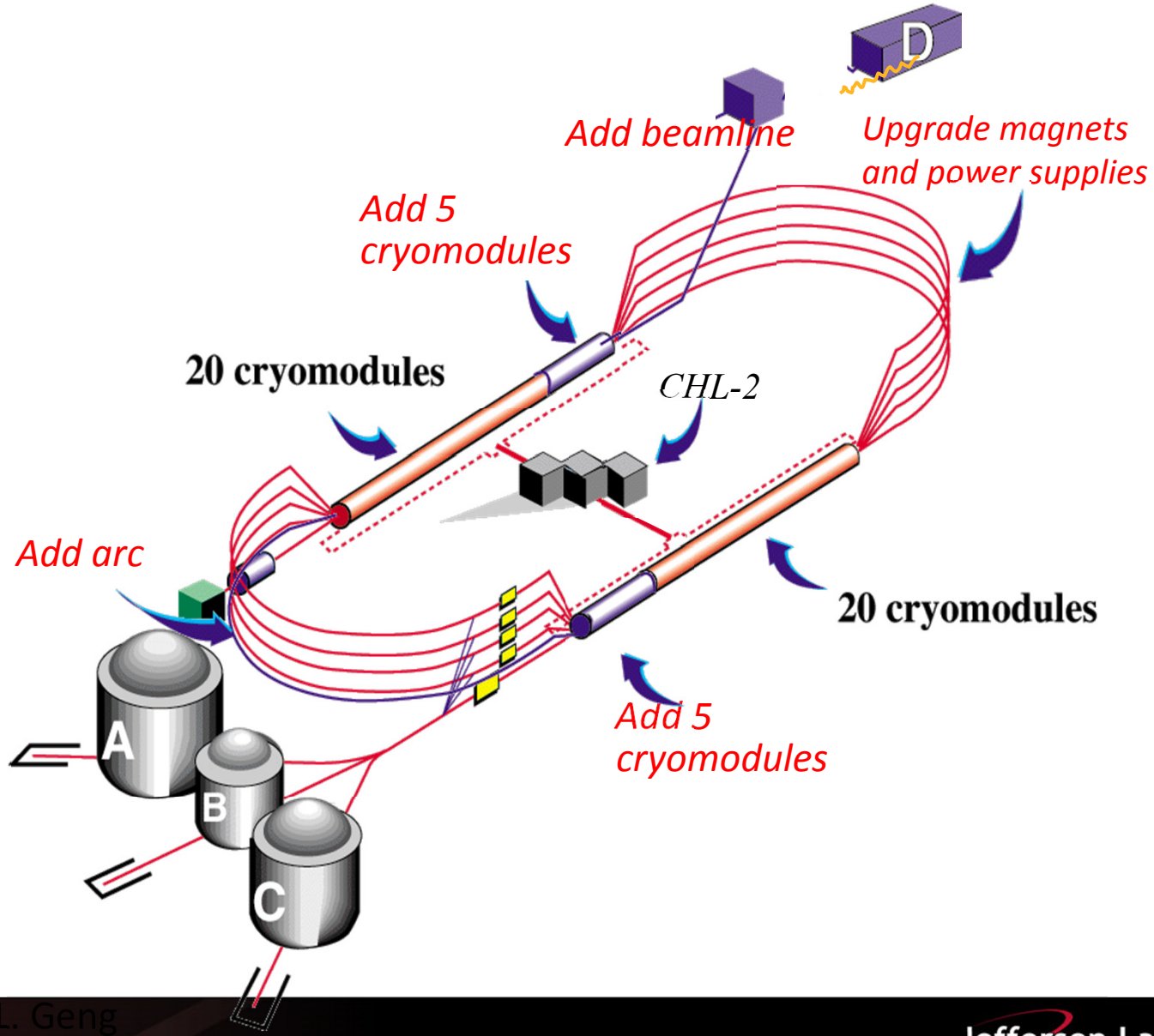
6 GeV improvement

Two 0.6 GeV linacs

1987 – 1994

4 GeV, 200 μA CW

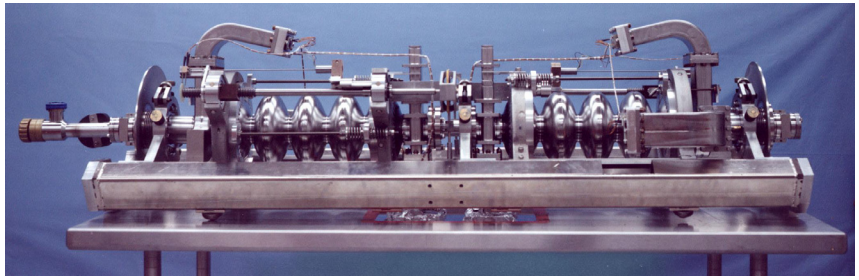
Two 0.4 GeV linacs



CEBAF SRF Cavities

Together for 12 GeV nuclear physics run

Original CEBAF cavity

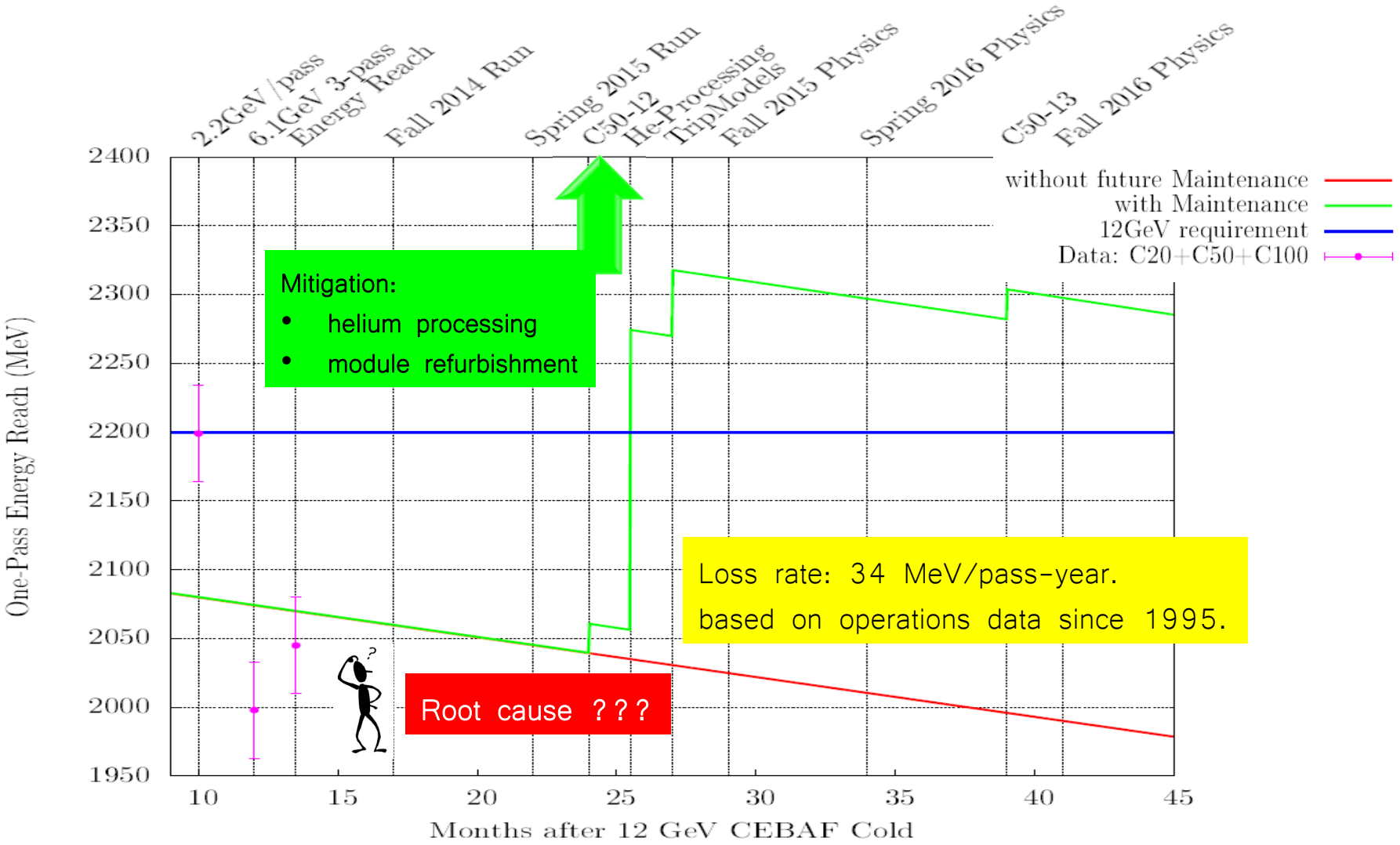


- 5-cell, Cornell-Type
- 338 cavities in 42-1/4 moduels
- Design
  - Ea=5 MV/m
  - Q_0=2.4×10^9 @ 5 MV/m
- Achieved
  - <Ea>=7.5 MV/m, <Q_0>=5×10^9@ 5MV/m
  - Helium processing
- Achieved
  - <Ea>=12.5 MV/m, <Q_0>=5×10^9@ 5MV/m
  - Refurbishing
- 2x 600 MV
- 5 kW 2K cooling power
- 5 MW liquefier operation power

CEBAF upgrade cavity

- 7-cell, Low-Loss Shape
- 80+8 cavities in 10+1 moduels
- Design
  - Ea=19.2 MV/m
  - Q_0=7.2×10^9 @ 19.2 MV/m
- Achieved
  - <Ea> = 20.4 MV/m
  - <Q0 @ 19.2 MV/m> = 8.1×10^9
- 2x (600 + 500) MV
- Add ~5 kW 2K cooling power
- Add ~ 5 MW liquefier operation power

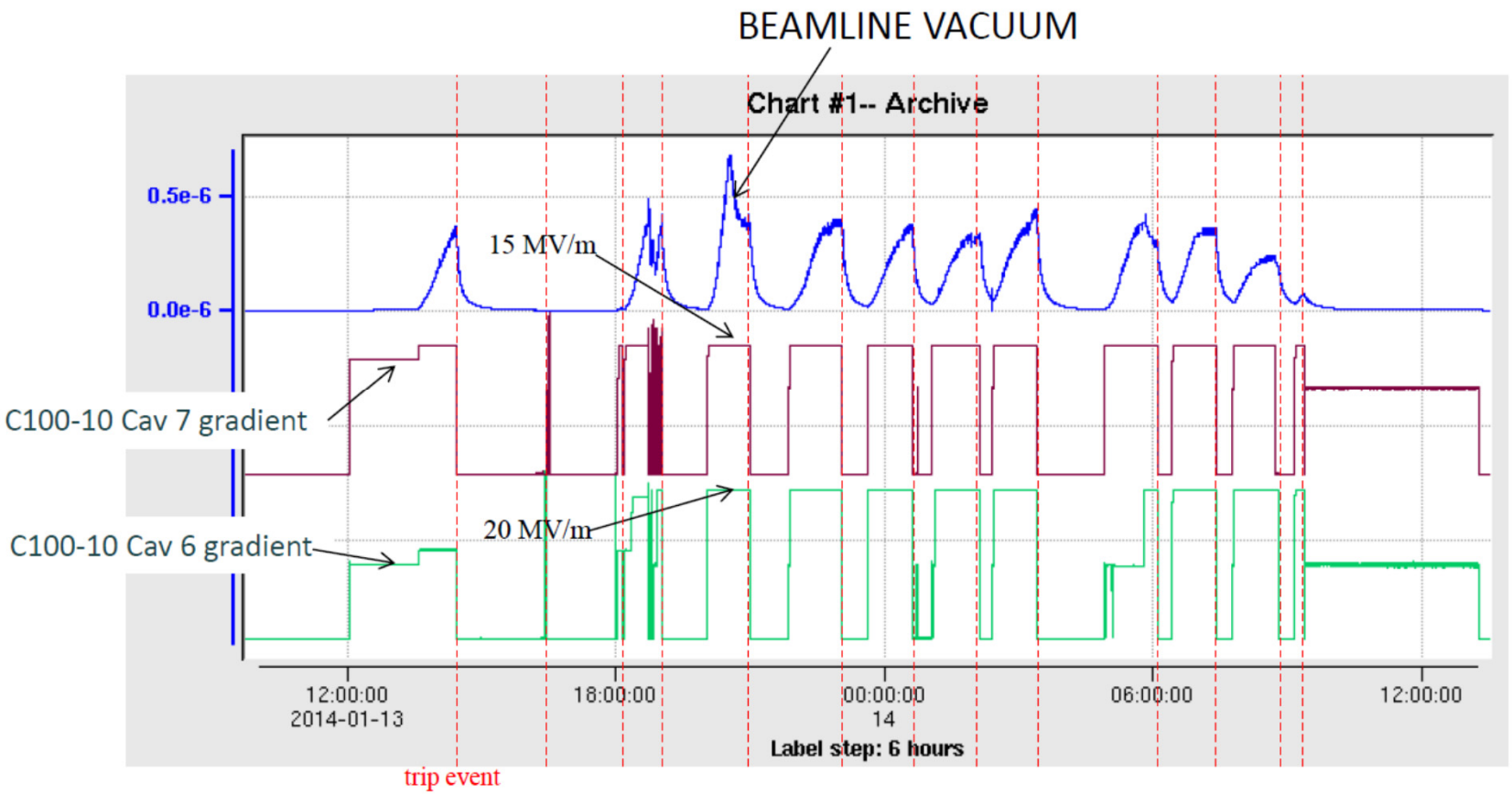
CEBAF Gradient Degradation



J. Benesch, „A longitudinal study of field emission in CEBAF's SRF cavities 1995-2015", http://arxiv.org/abs/1502.06877

R. Bachimanchi, J. Benesch, M. Drury, A. Freyberger, R. Geng, J. Mammosser, "2014 Update: CEBAF Energy Reach and Gradient Maintenance Needs",JLAB-TN-14-024

Phenomena Linked to FE from 7-Cell Cavities



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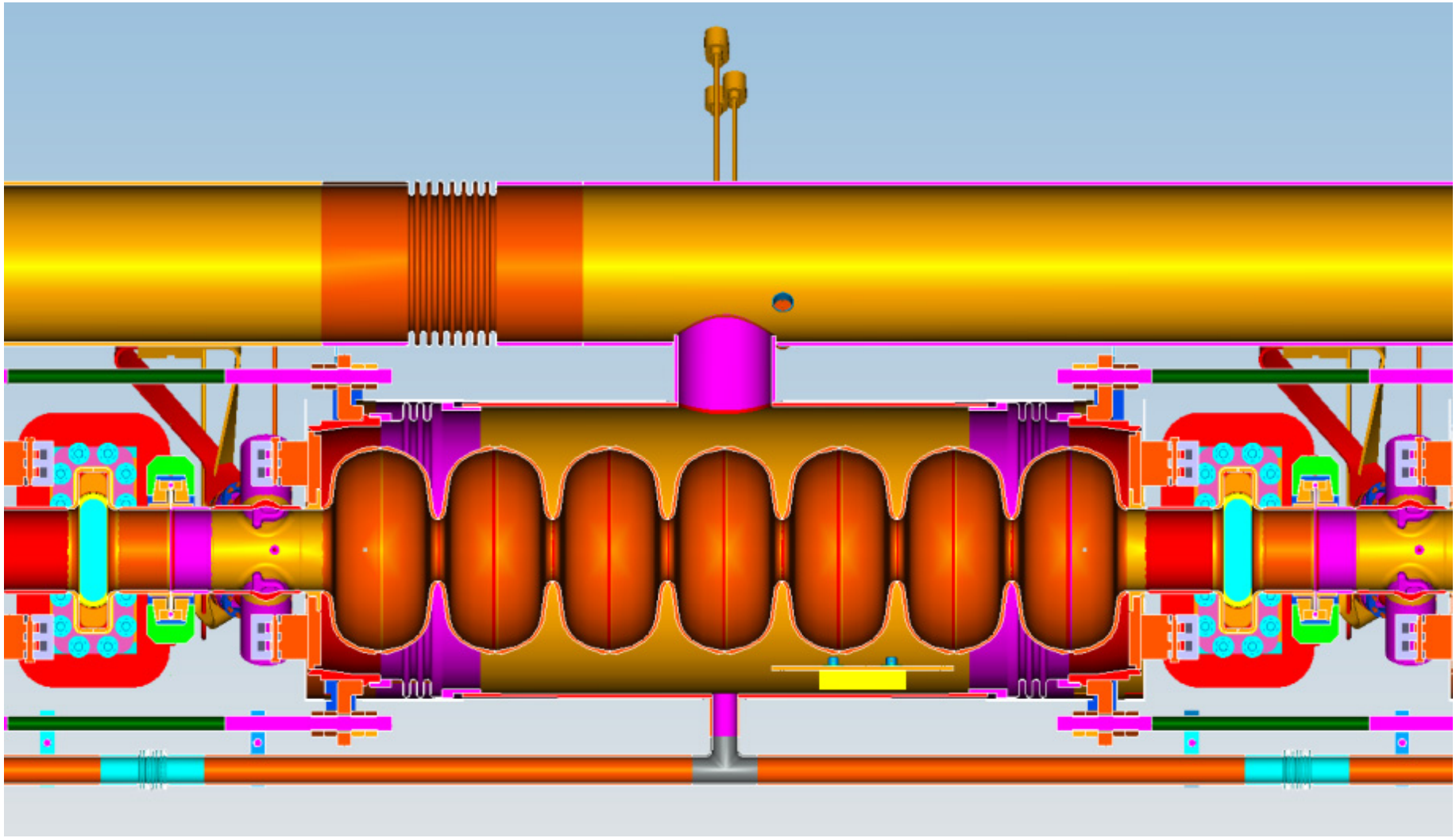

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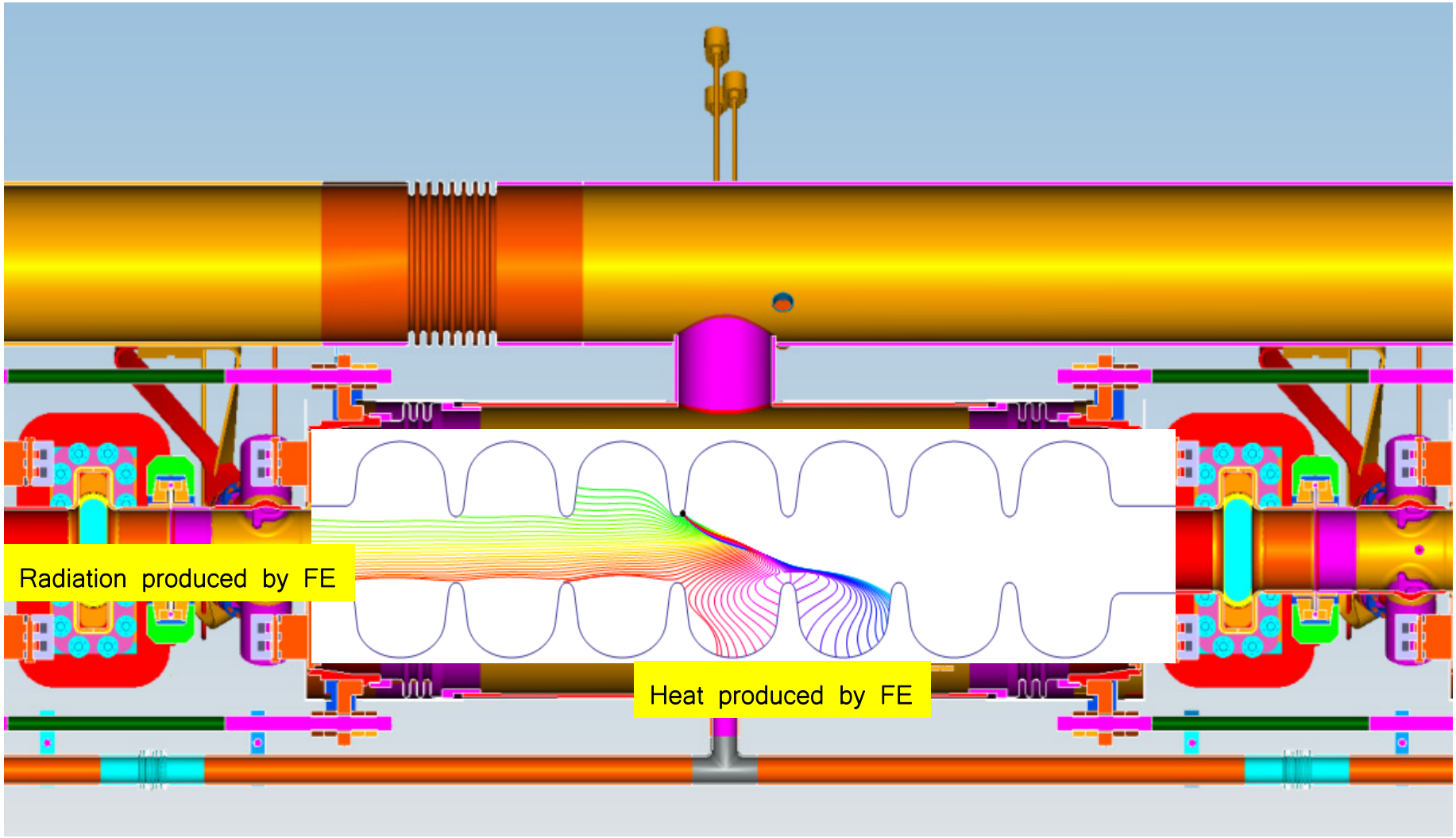
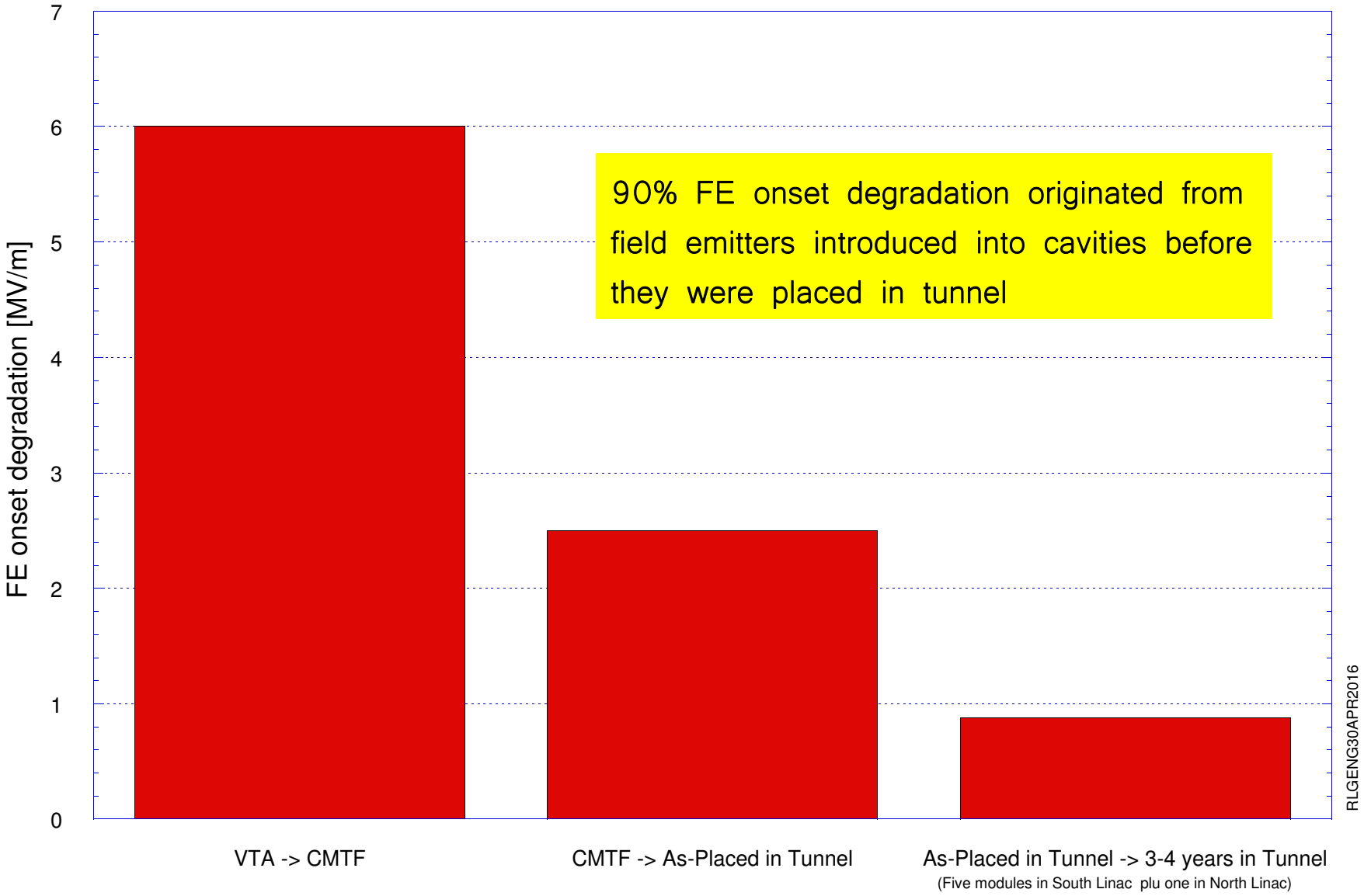
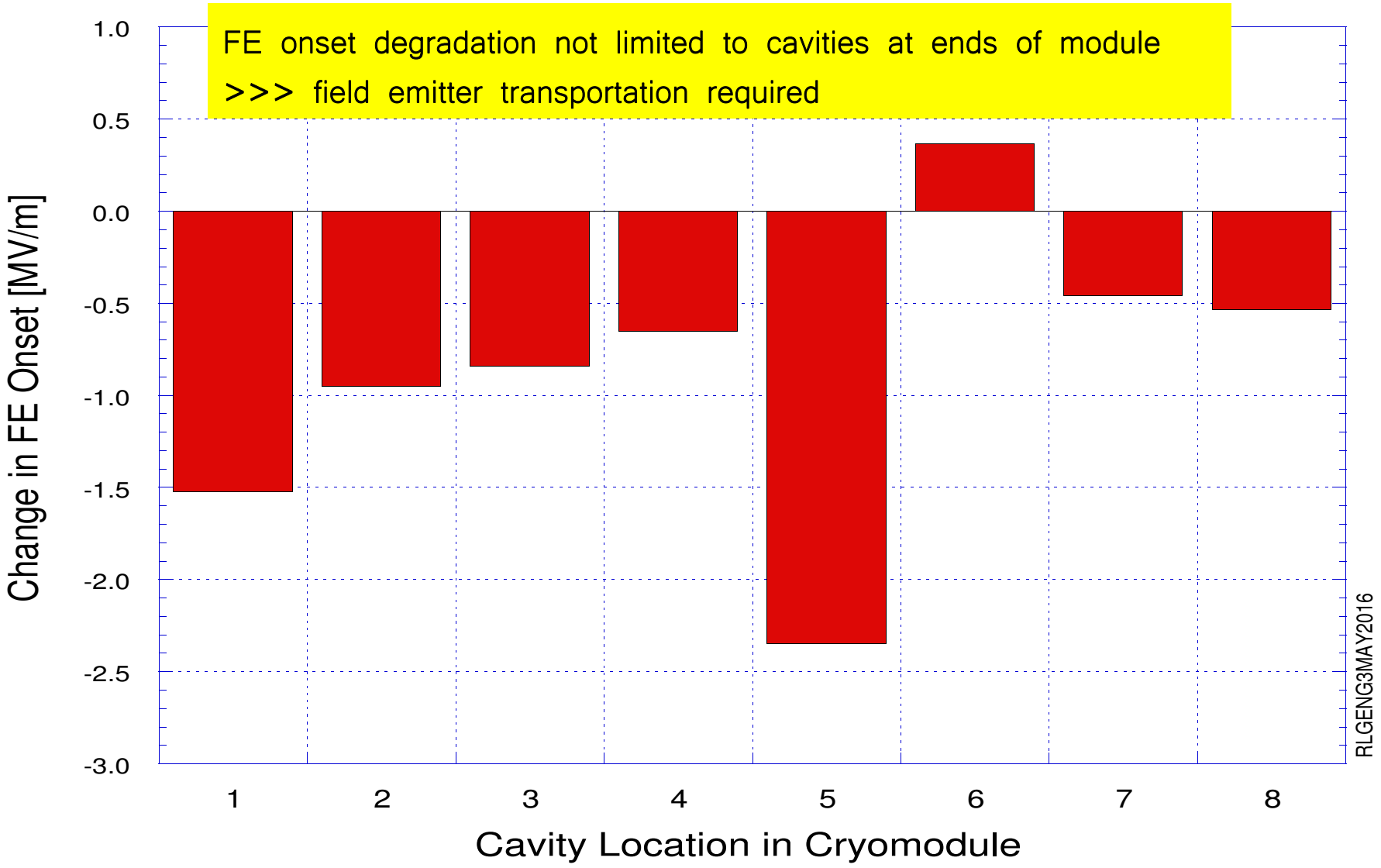


Sources of Field Emitters

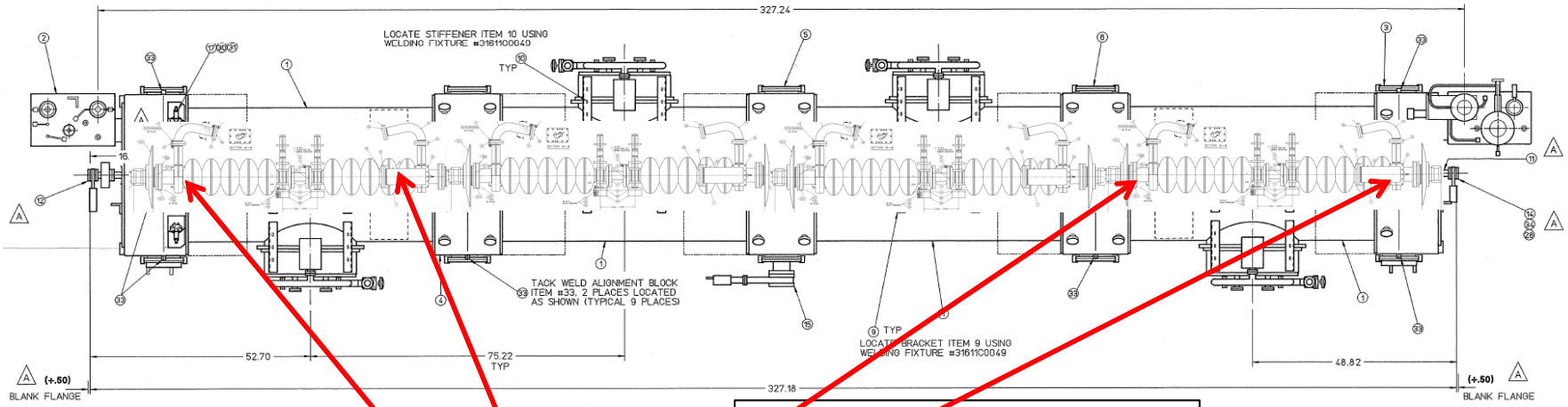


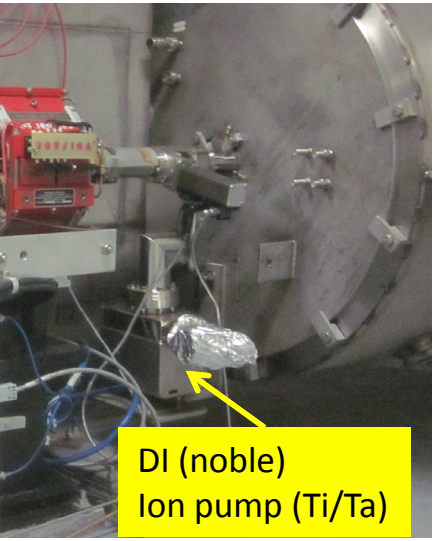
Field Emitters Introduced After Module Placement

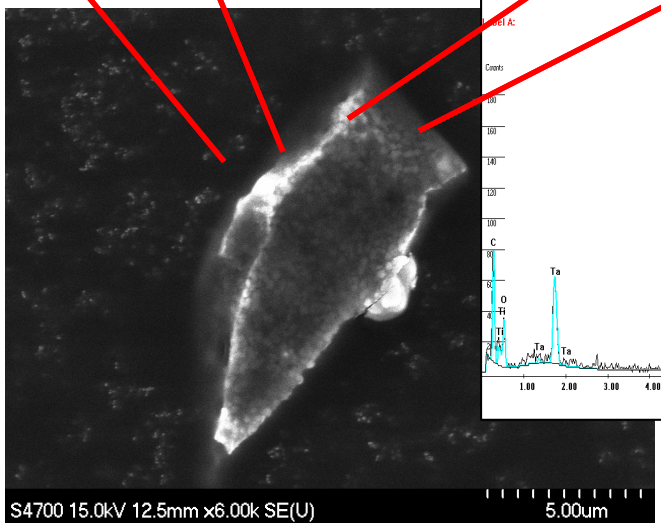


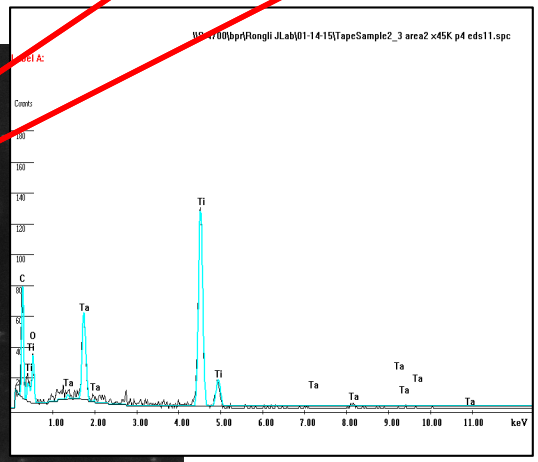
Direct Evidence of Particulate Transportation

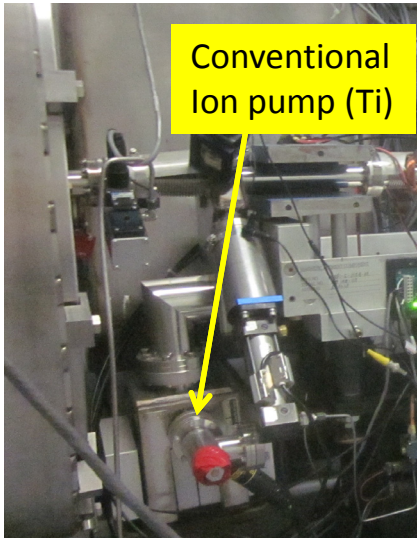
Pilot study with module FEL2 of identical design, previously operated with beam



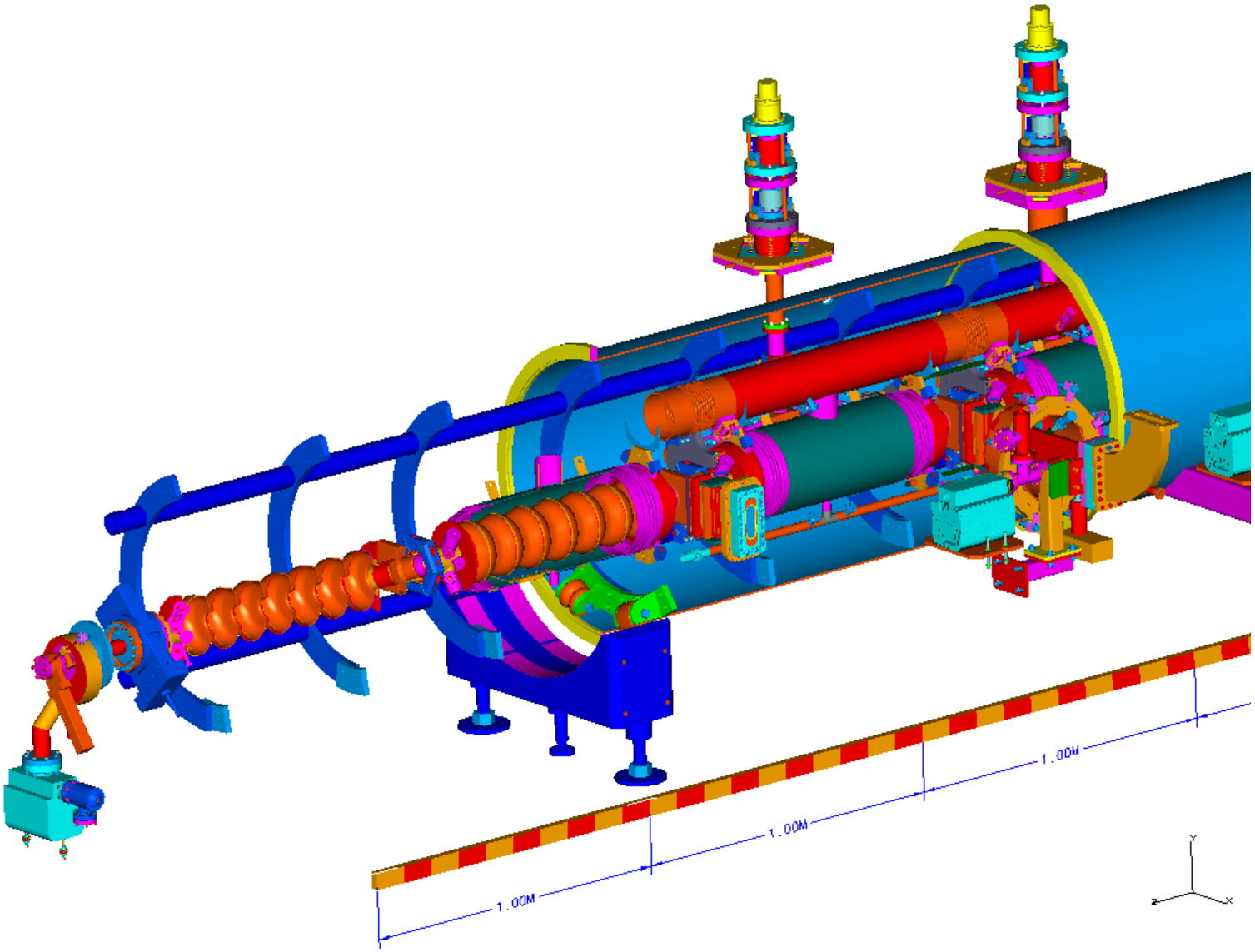




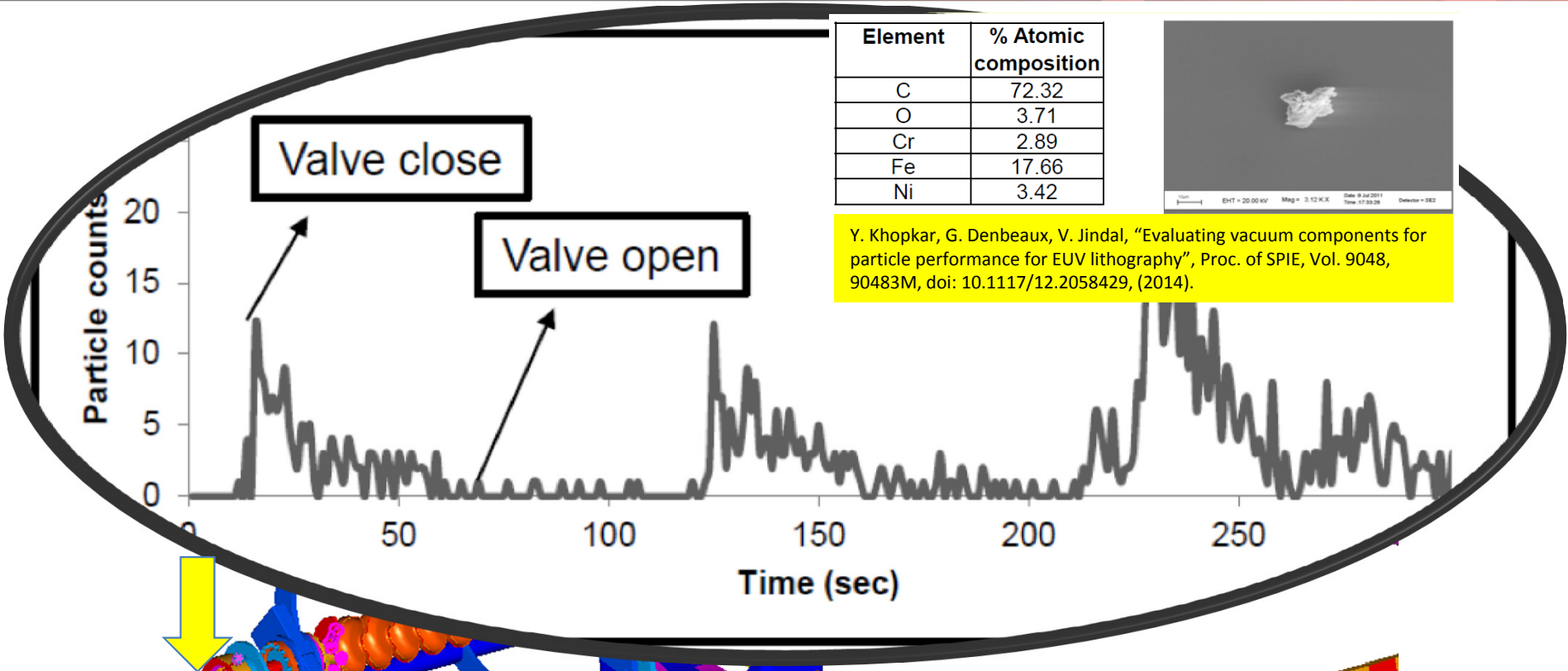




Beamline Gate Valve

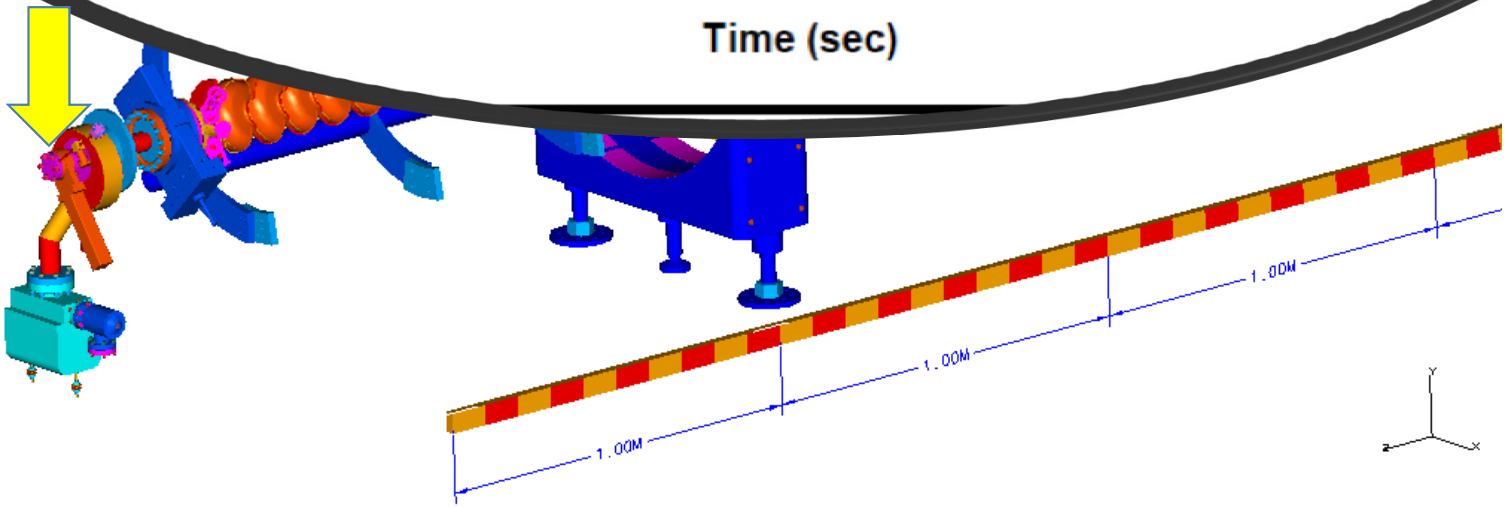


Beamline Gate Valve

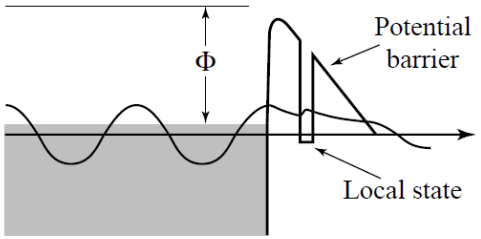


Element	% Atomic composition
C	72.32
O	3.71
Cr	2.89
Fe	17.66
Ni	3.42

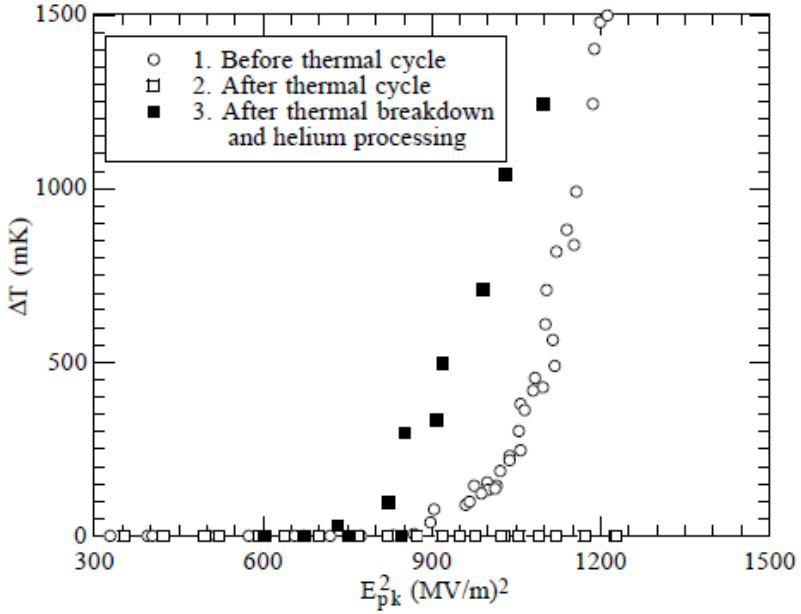
Y. Khopkar, G. Denbeaux, V. Jindal, "Evaluating vacuum components for particle performance for EUV lithography", Proc. of SPIE, Vol. 9048, 90483M, doi: 10.1117/12.2058429, (2014).

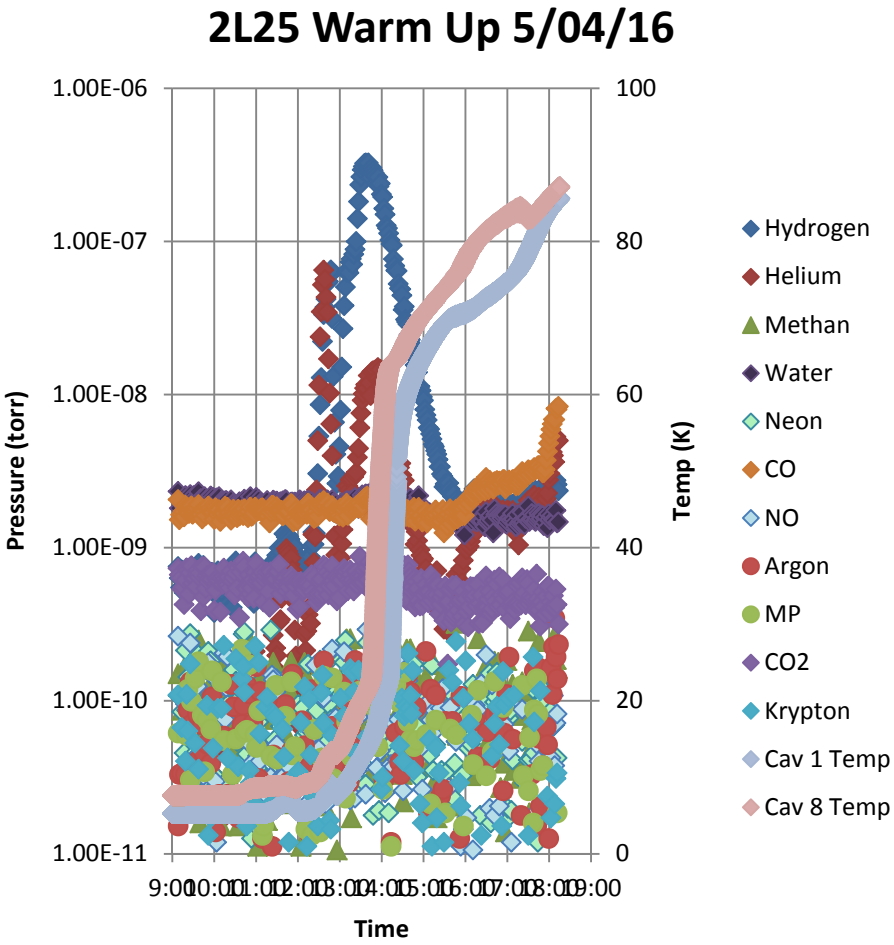


Field Emitter Activation by Residual Gases



Gases condensed on surface creating localized energy levels





J. Knobloch, Ph.D. Dissertation, Cornell University, 1997

Mitigation

- Stop adding new field emitters
  - Stop the practice of "Hi-potting" ion pumps
  - Stop the frequent cycling of beamline gate valves
  - Develop a new apparatus and a new procedure to be implemented for all future beamline UHV components maintenance
- Manage and remove accumulated field emitters
  - Warm up to get rid of frozen gases
  - Develop new techniques for particulate removal without full disassembly of cryomodule
- Understand and develop
  - Source of field emission degradation during the string assembly and tunnel installation
  - Particulate transportation inside beamline
  - Next generation particulate-free beamline UHV system

Conclusion

- Till now 90% and 10% FE onset degradation in new 7-cell cavities occurred before and after, respectively, cryomodule placement CEBAF tunnel.
  - Field emitters predominantly introduced before modules settled in tunnel.
- Field emitters introduced thereafter not insignificant.
  - Their possible sources identified.
- Several mitigations are identified and some being studied.
- Field emission increasingly being realized a central issue faced by CEBAF.
  - Its resolution is valuable in order to achieve high-reliability and low-cryogenic-loss operation of CEBAF at required 12 GeV beam energy.
- Our current understanding of root causes of field emitters in cavities placed in CEABF tunnel not yet complete and further studies needed.
- Such studies valuable to guide development of mitigations so as to end adding new field emitters as well as to remove inherited emitters in future cryomodule operation and maintenance.