Neutrino Factory and Muon Collider (NFMCC) at ANL
Gradient limits: Causes and Cures

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12/3/8

Collaborators.

Normal Conducting

A. Hassanein	Plasma Phys	Purdue
Z. Insepov	Fracture kenetics	ANL/MCS
A. Moretti	RF	FNAL
A. Bross	RF, instrumentation	FNAL
Y. Torun	RF, instrumentation	IIT
D. Huang	RF, Instrumentation	IIT
R. Rimmer	cavity design, expts.	JLab
D. Li,	cavity design, expts.	LBL
M. Zisman	Expt design	LBL
D.N. Seidman	High E / materials	Northwestern U
S. Veitzer	Plasma modeling	Tech-X
P. Stoltz	Plasma modeling	Tech-X

Superconducting

M. Pellin	ALD, expts	ANL/MSD
G. Elam	ALD, expts.	ANL/ES
A. Gurevich	SCRF theory	NHMFL
J. Zasadzinski	SC theory and exp	IIT
Th. Proslier	SC theory and exp	IIT
L. Cooley	SCRF	FNAL
G. Wu	SCRF	FNAL

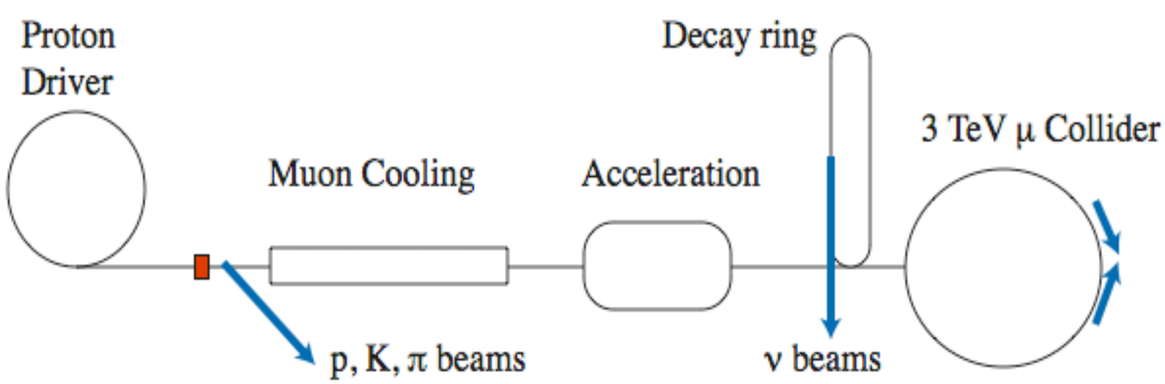
The Neutrino Factory and Muon Collider (NFMCC) Program

Muon cooling needs high gradients at low frequencies - in B fields.
MICE needs to cure Dark Current / Breakdown Problems.

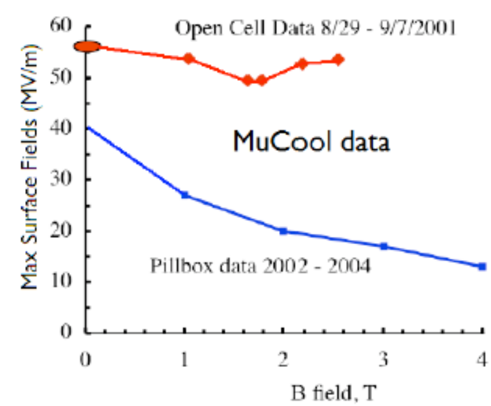
RF Expts started in 2000 – we look mostly at FE dark currents and X rays.
Many papers, new models and methods of analysis.
This work has high priority, many collaborators.
Our conclusion: BD and FE starts with high fields at ~30 nm asperities.

Like CLIC and ILC, we need better NCRF and SRF our B fields complicate things.
Atomic Layer Deposition (ALD) should control all rf surfaces.

The goal



The problem



Argonne accomplishments in the NFMCC Program:

We have developed and tested ALD in SRF. It should work in NCRF.

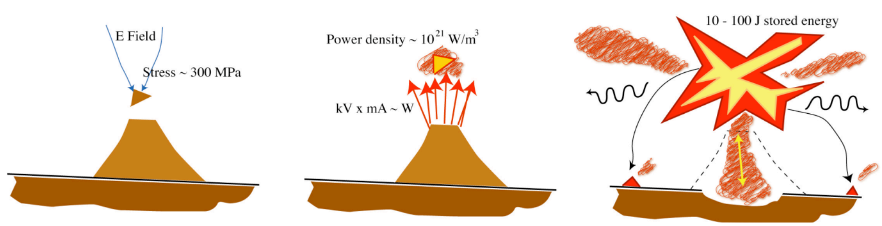
We developed simple analysis methods and models for breakdown.

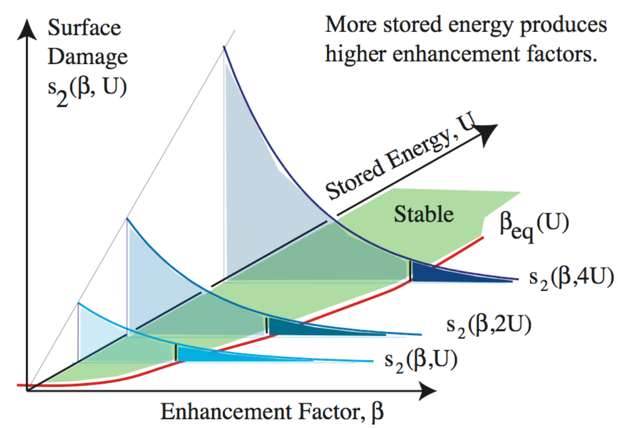
Data analysis fits Fowler-Nordheim as $I \sim E^n$. with $E_{local} = f(\phi, n)$.

Breakdown model (1 parameter) assumes fracture and ionization of solids.

We developed a model for the equilibrium between surface damage and E_{max}.

We use the measured spectrum of damage in cavities $n(\beta)$ and the energy available in the arc to estimate E_{max}.





Present Argonne effort:

1) Modeling and understanding arcs – needs Molecular Dynamics
2) Breakdown-Proof cavities – needs experimental test of ALD surfaces
3) Extending SRF with ALD (not part of AARD program)

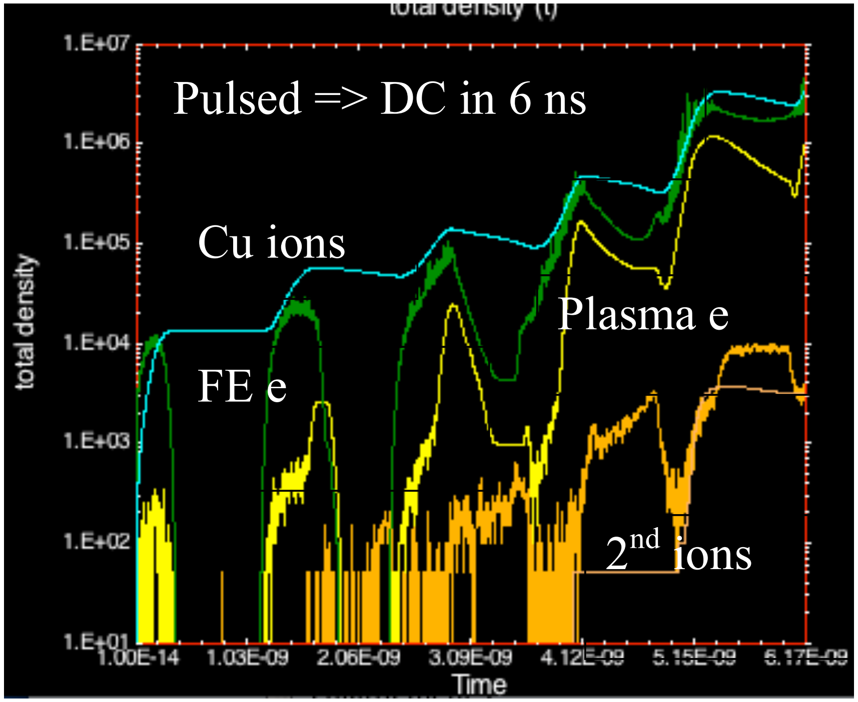
1) Modeling and Understanding Arcs

[TECH-X, IIT, ANL]

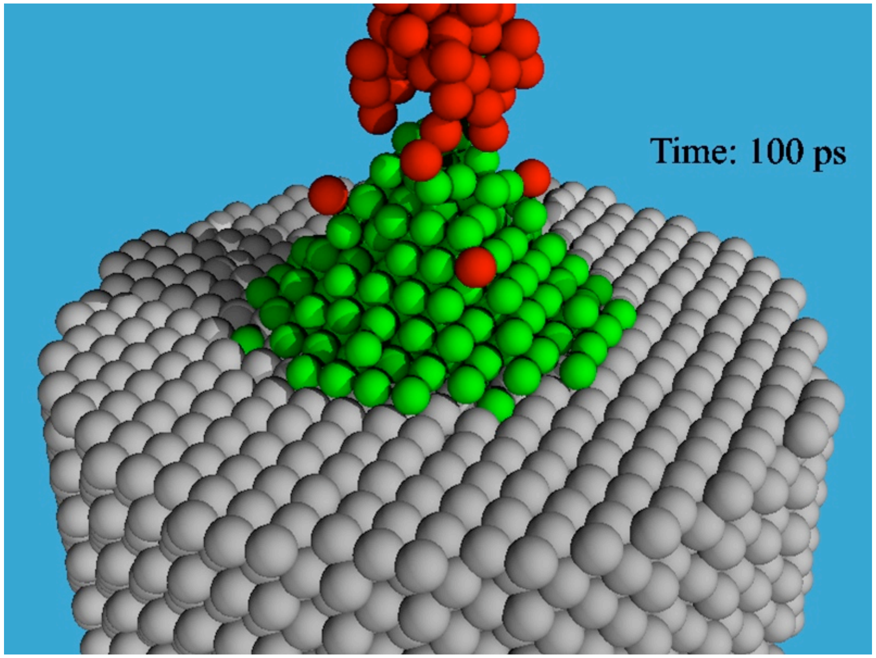
We want to understand how B fields (magnitude and angle) interact with arcs.

We use plasma (OOPIC, VORPAL) and Molecular Dynamics (MD) codes.

MD gives atomic behavior from interatomic potentials – describes materials.



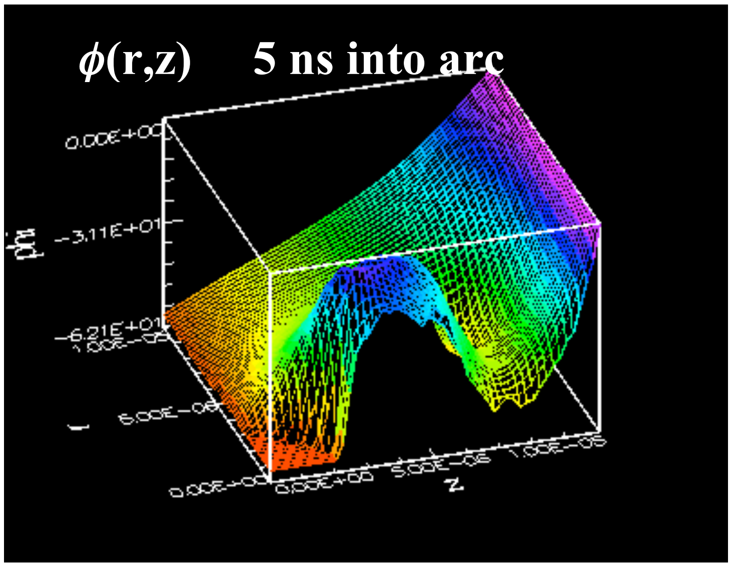
OOPIC Pro results

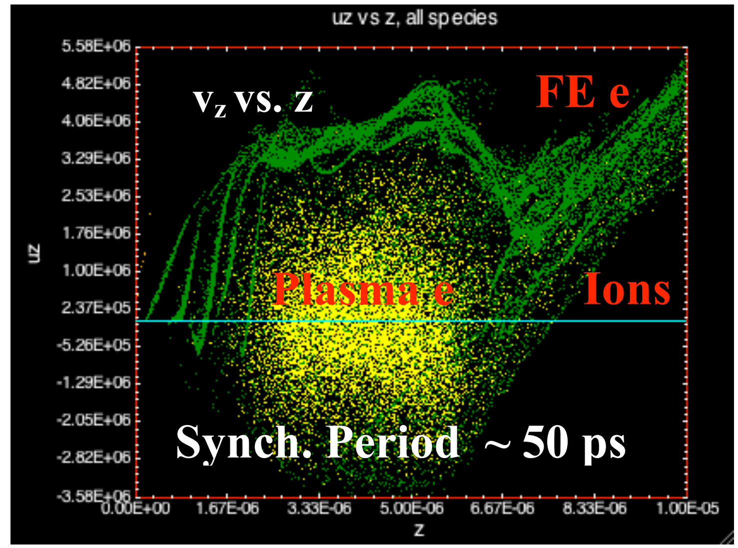


MD simulation of fracture

Breakdown plasmas and Molecular Dynamics

These arcs are high beta, inhomogeneous, non – equilibrium, cold, weakly ionized, non-neutral, collisional, inertially confined plasmas with two weakly interacting electron populations (OOPIC data)





Issues for Molecular Dynamics

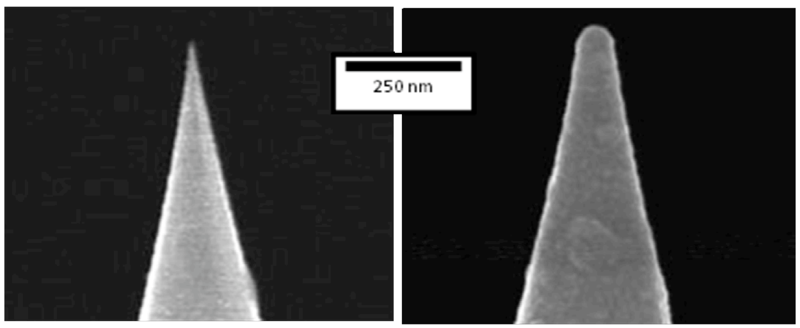
We want to understand the arc trigger, how the plasma is fueled, how particulates are accelerated and when they are stable, how the wall is heated, plasma dimensions, how damage is produced and magnetic field effects. ANL data (Insepov) inspired CLIC to use MD in BD studies.

2) Can we make "breakdown-proof" NCRF cavities?

[ANL FNAL]

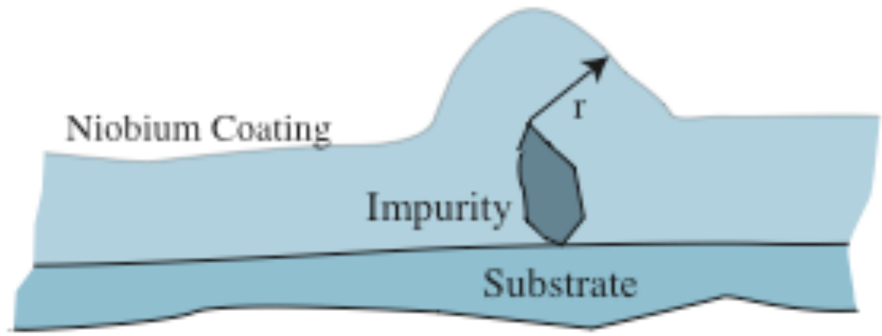
All our experimental data implies breakdown sites are ~30 nm asperities.
Since $E \sim 1/r$, can we bury breakdown sites and lower local fields ?

We have shown that we can round tips
Using ALD. We need to do it in-situ.

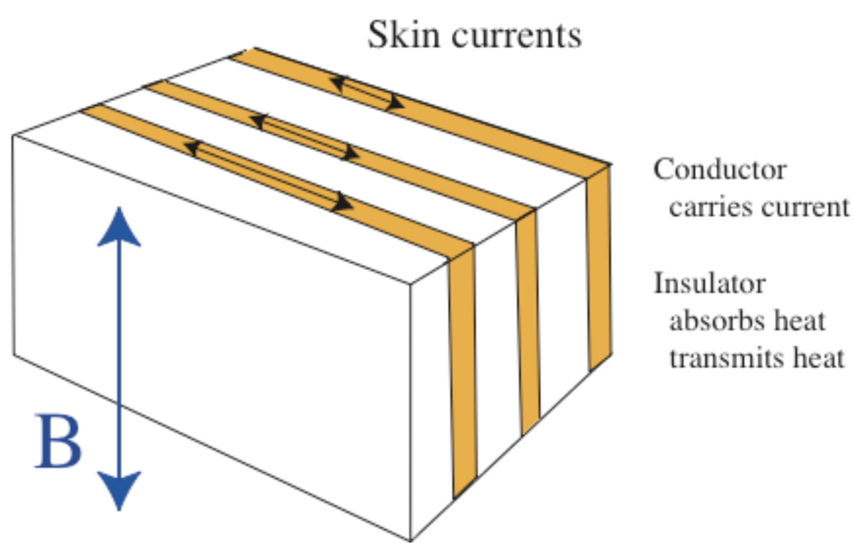


Uncoated Si AFM tip

After 5 nm ALD ZrO_2 + 30 nm ALD Pt



Pulsed heating in the walls can also be a problem. We can use ALD to deposit dielectric heat sinks which should help.
(Pulsed heating tests at SLAC.)



ALD will be done in the Fermilab MuCool Test Area (MTA)

Procedure:

  Condition cavity normally to whatever limit it goes to.

  Coat with ~100 nm of metal to bury active asperities.

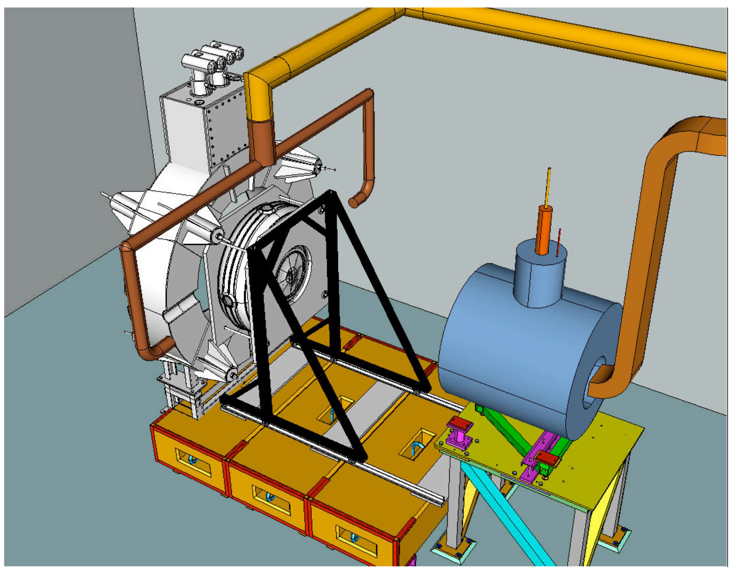
  Retest with and without magnetic field.

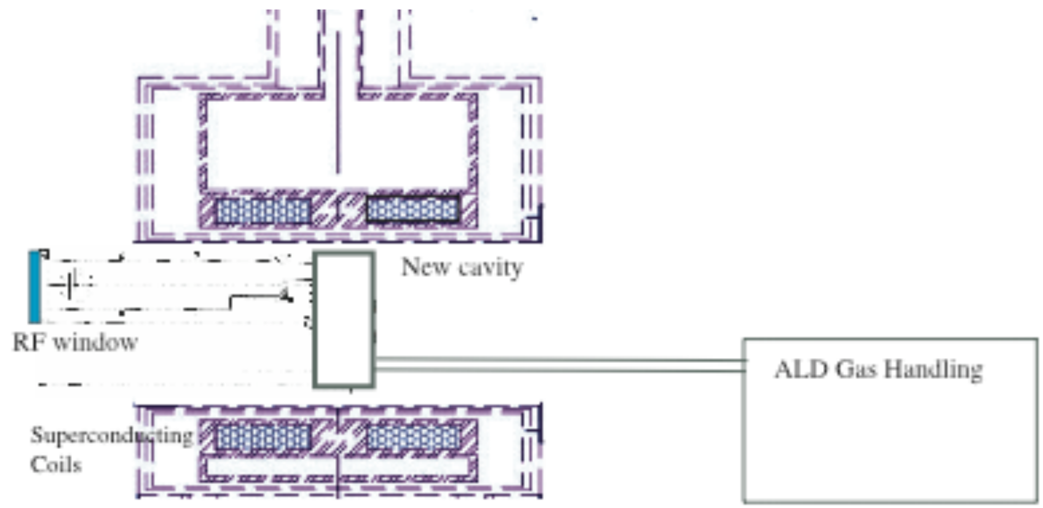
Must be done in-situ to avoid particulate contamination.

Coating of windows may be a problem, and we are developing solutions.

  Particle free valves which can protect the windows.

  Cooling the window can prevent measurable deposition. Needs testing.





3) Can we make better SRF structures with ALD? (not part of AARD)

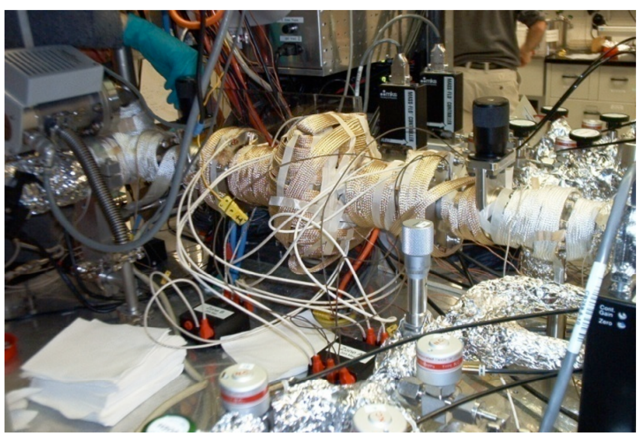
[ANL, JLab, IIT, FNAL, NW]

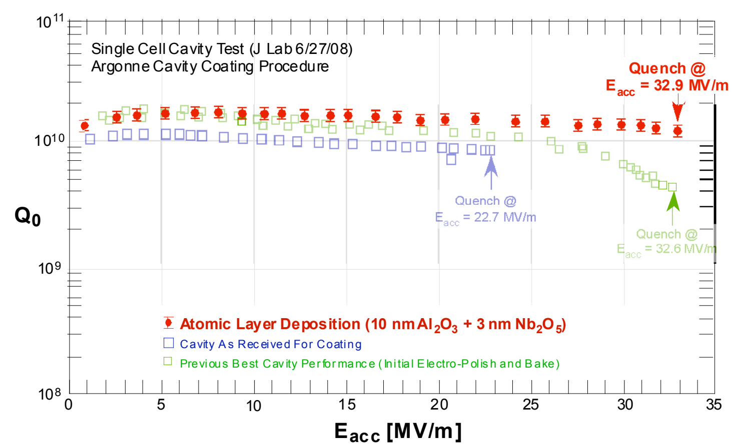
The production of SRF cavities seems to have reached practical limits.

There are many SRF failure modes (Nb quench field, field emission, high field Q drop, mechanical deformation, hot spots, . . .).

Atomic Layer Deposition (ALD) can simultaneously address all these issues by conformally depositing pure metals, one atomic layer at a time, at usefully high rates. We are starting an effort with technology in the ANL Mat'ls Sci. Div

This technology is compatible with high gradients, and permits tests of the Gurevich layer model, new materials, along with improved control of the metal surface.





Summary

The muon program, like everyone else, needs higher gradients, \$ ~ E_{acc}^{-1}.

We have the additional problem of magnetic fields

We are continuing a program to understand and extend gradient limits

Modeling and understanding arcs – needs Molecular Dynamics

Breakdown Proof cavites – needs experimental test of ALD surfaces

Extending SRF with ALD (not part of AARD program)

This program should benefit all accelerator technologies

We should be able to improve rf in magnetic fields.

We want to significantly improve SRF gradients and yield

We may be able to raise CLIC gradients.

Funding request (k)	Present	FY09	FY10	FY11
Modeling (Insepov)	0	50	50	100
Breakdown-proof (MSD M&S)	0	50	200	50
General effort	190+(144 ANL)		=>	=>