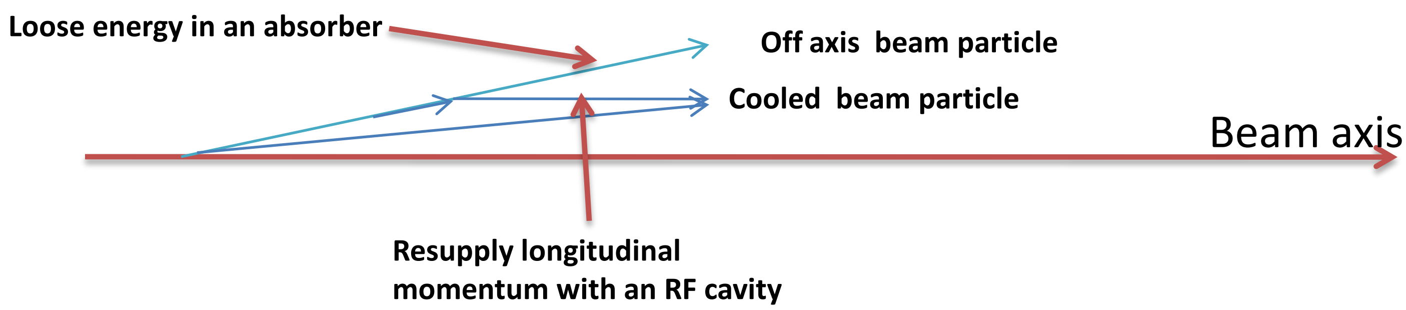
High Pressure Gas Filled RF Cavities:

Over view of their use in cooling muons

Simple Cooling Example:



Cooling requires lots of RF acceleration:

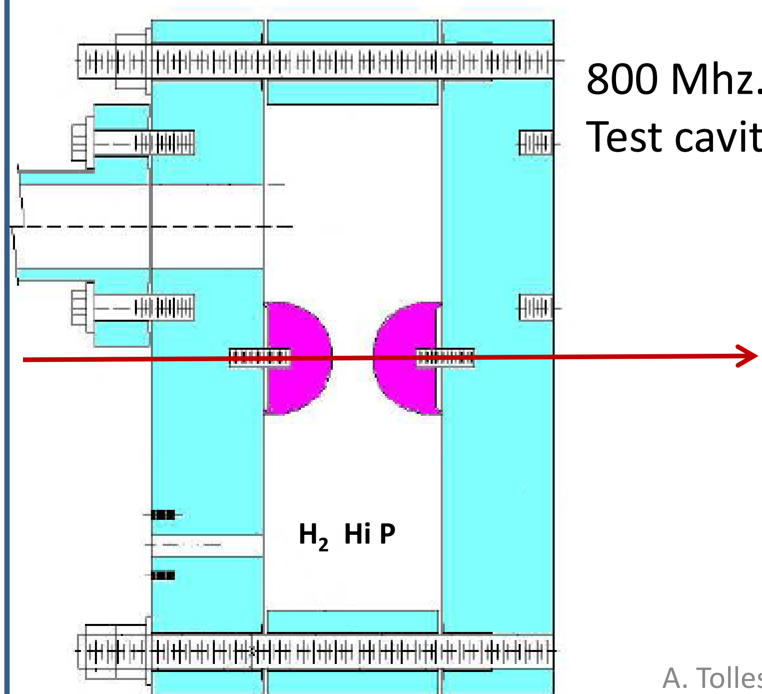
1. Take a 200 MeV/C muon
2. Put it thru 100 MeV/C absorber
3. Re-apply 100 MeV/C from an RF cavity
4. This reduces transverse momentum by a factor of 2.
5. We need about a factor of 4096 or 12 stages or 1200 MeV/C of RF

RF acceleration is the key to cooling

But there has to be strong magnetic fields to focus the particles and RF cavities don't like to work in hi B

Cavity used for High P studies

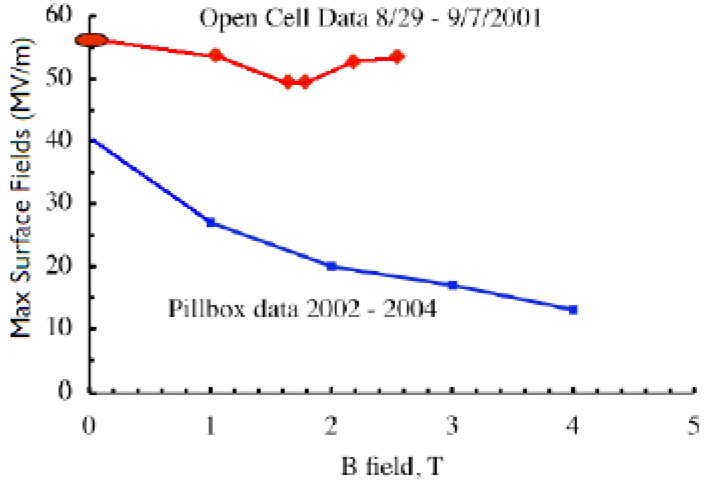
1. H pressure up to 1600 psi
2. E up to 70 MV/m, gap 1.77 cm
3. V across gap up to 1.25 MV
4. Probes monitor field: 1 GHz scope
5. Fiber to pmt
6. Fiber to spectrometer
7. MTA 400 MeV proton beam thru center



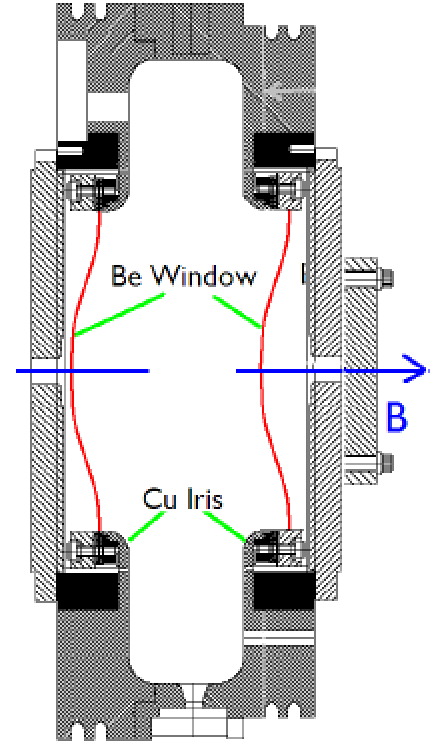
800 Mhz. Test cavity

The Problem

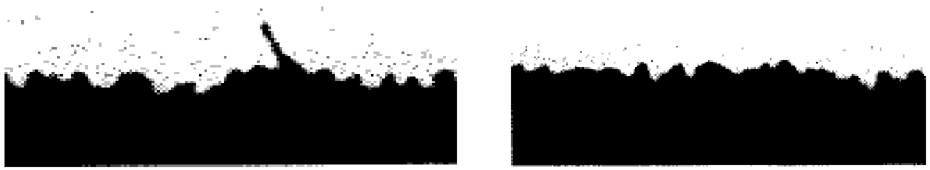
Effect of B on a pill box vacuum cavity



- Pill box cavity has much higher gradient than an open cell type.
- Breaks down easily when an axial B field is applied. Which is typical in a cooling channel with solenoid focusing .



Why do cavities breakdown?



Electron microscope shadowgrams of a optically polished Al surface before (R.) and after (L.) applying a field of 40 MV/m. A field emission current of 1 microamp was observed.

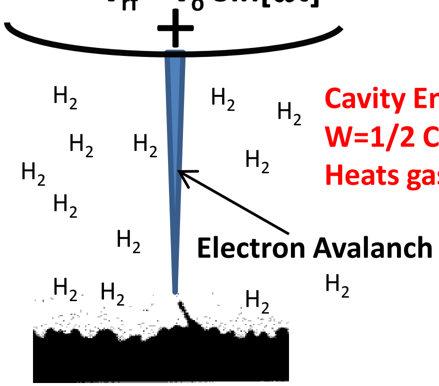
Sharp points on the cavity surface see a high E field. This field can cause field emission of electrons .

1. Current proportional to E^n $9<n<15$
2. X-rays generated by electrons hitting cavity walls.
3. n (see 1 above) is primary source of information about the metal surface in cavities. Non destructive before breakdown.

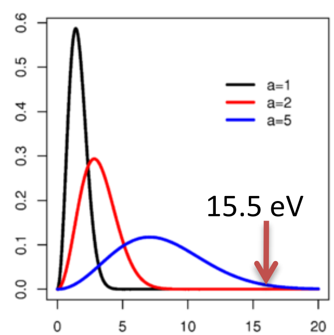
Gas Filled Cavities

No focusing of electron avalanch

$V_{rf} = V_o \sin[\omega t]$



Cavity Energy
W=1/2 C V² 1 joule
Heats gas



Electron dist. eV

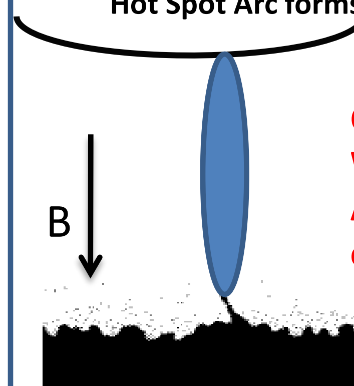
$e + H_2 \rightarrow e + e + H_2^+$

Collision frequency >> cyclotron frequency
B has no effect !

Vacuum Cavities

Hot Spot Arc forms

B Focuses electrons



Cavity Energy
W=1/2 C V² 1 joule
All goes into melting copper.

Uses of HPRF Cavities

1. Helical Cooling Channel:
   - Whole channel filled with hi pressure hydrogen.
   - Hydrogen is the dE/dx material for beam energy loss.
   - Hydrogen fills the cavity to solve B problem.
   - High pressure windows only at the ends of the channel which contains many box cavities with thin windows.

2. Normal FOFO cooling channel :
   - dE/dx material may be LH_2 or LiH.
   - Focusing solenoids independent structures.
   - Pill box cavities each have pressure window. Pressure is kept as low as necessary to insulate the cavity. The scattering in the window is tolerable. H still solves the B problem.

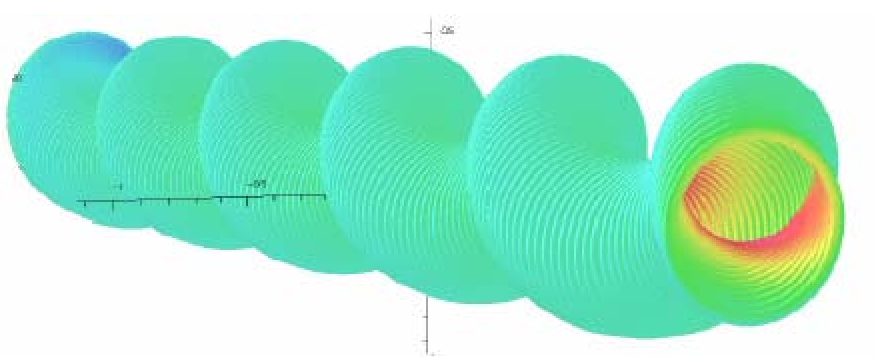
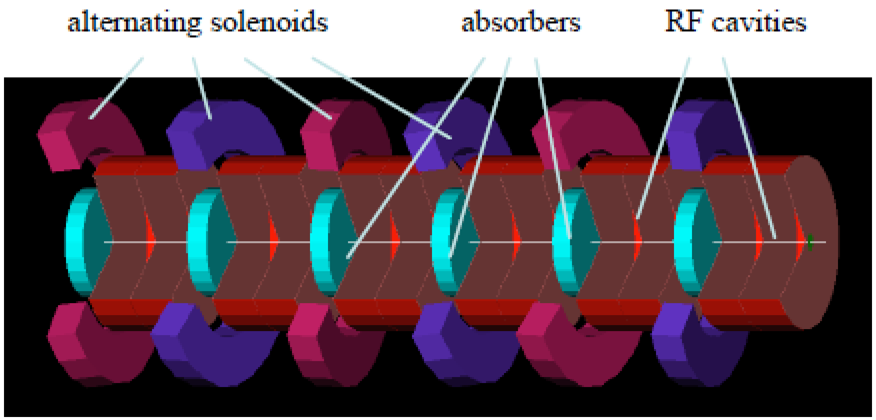
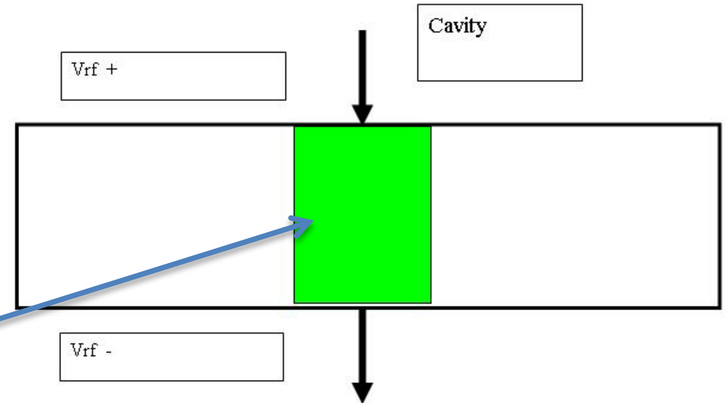


Figure 2: Helical solenoids for low-field section.



Toy Example

1. Number muons = 10e11
2. Gas density =.016 g/cc.
3. E cavity = 16 10e6
4. V cavity 400 KV peak
5. Molecules/cc = 4.8 10e21
6. Ions/cc = 1.0 10e14
7. B=10 T.

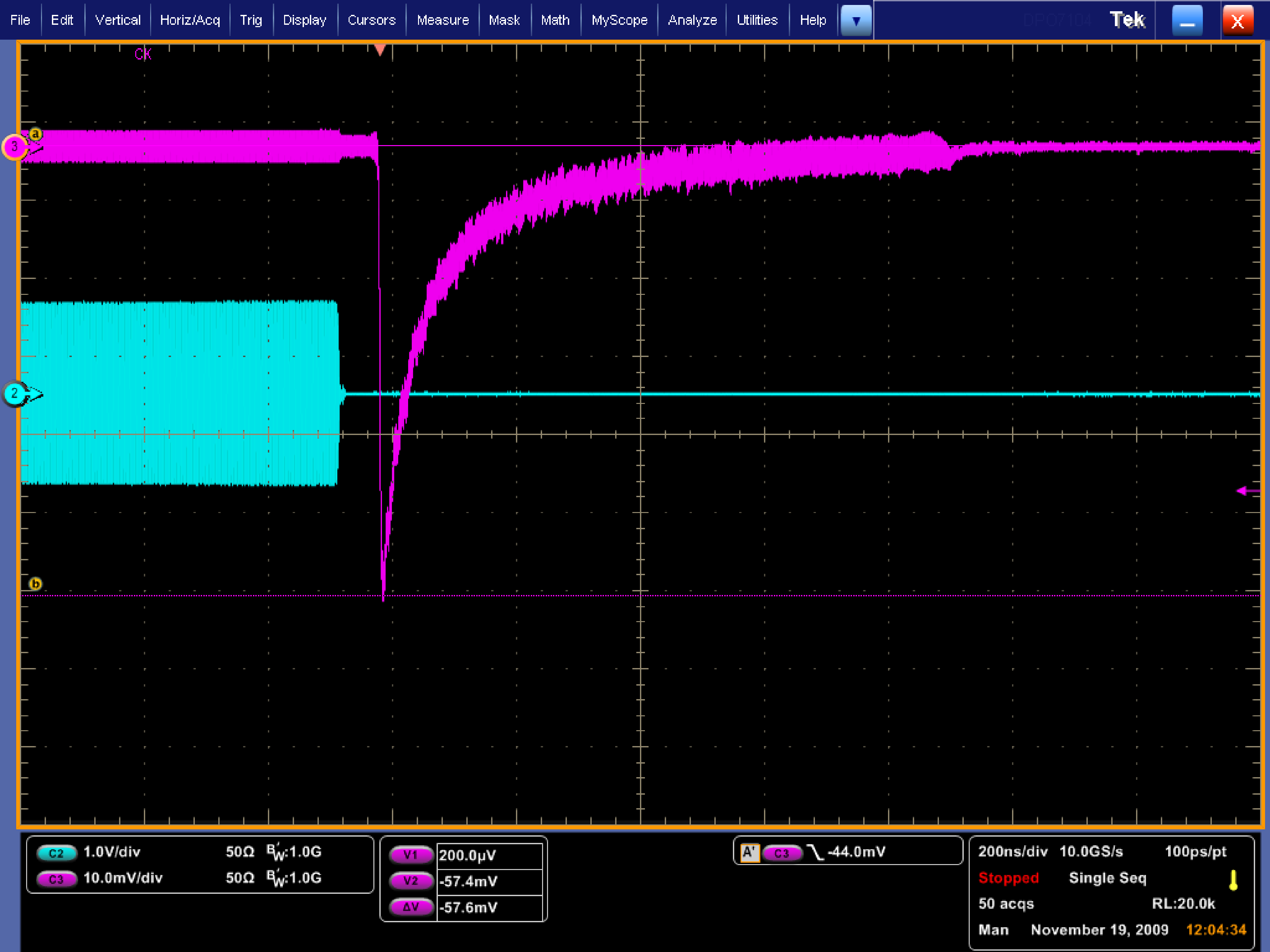


The electrons move back and forth with the electric field but the positive ions are essentially stationary.
J = n e v but v = μ E where μ is the mobility of the electrons. The energy loss in the gas is Wg = j E / cc
Or   Wg = (n e μ E) E = (n e μ) E^2 . So the quantity (n e μ) plays the role of a resistance damping the cavity. In this example, the cavity Q = **330!**

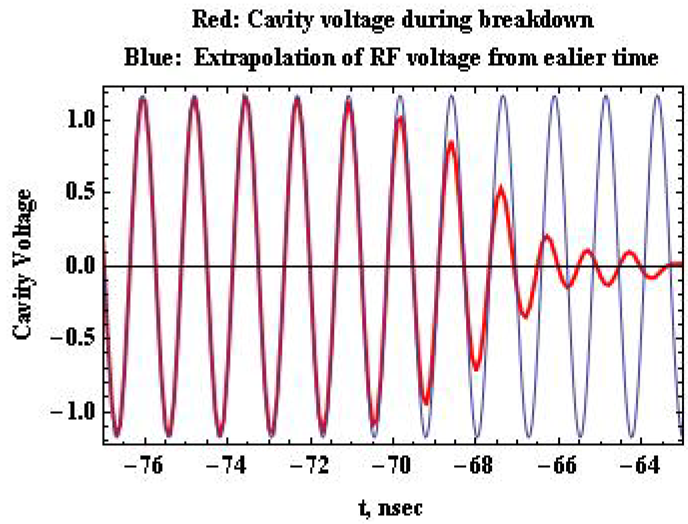
Two Solutions:

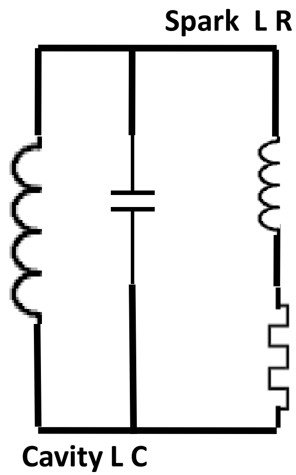
1. The electrons are captured by the positive ions. We think this is too slow and is of the order of a microsecond.
2. Insert an electro-negative gas that captures the electrons. Has been tried and increases the breakdown voltage. It has also been modeled. SF6 has nasty secondary by products.

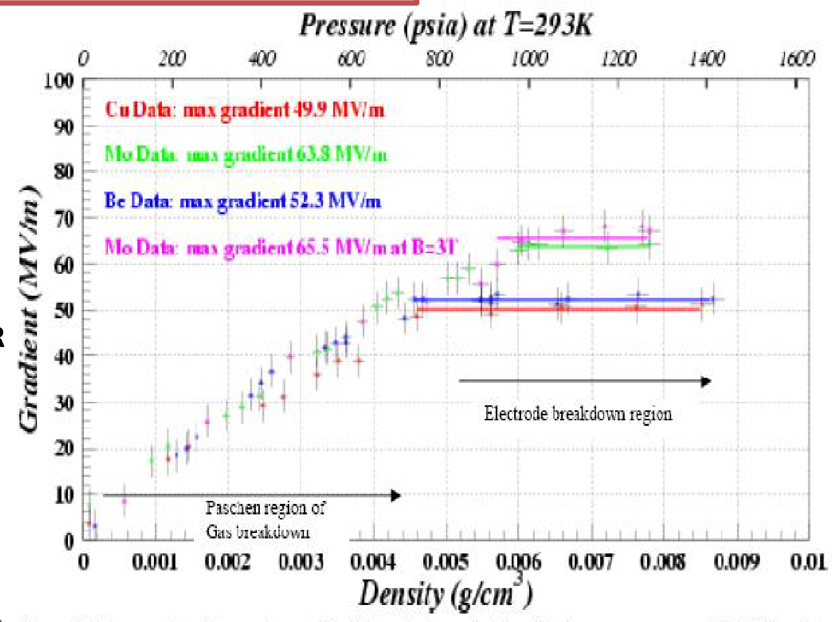
Are these calculations correct? Need beam measurements!

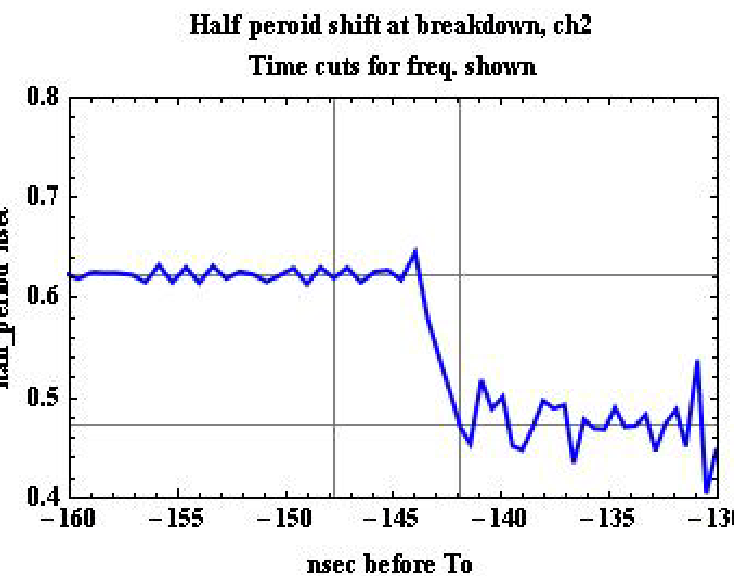

File
Edit
Vertical
Horiz/Acq
Trig
Display
Cursors
Measure
Mask
Math
MyScope
Analyze
Utilities
Help
Tek
CK
C2 1.0V/div 50Ω BW:1.0G
C3 10.0mV/div 50Ω BW:1.0G
V1 200.0μV
V2 -57.4mV
ΔV -57.6mV
A' C3 -44.0mV
200ns/div 10.0GS/s 100ps/pt
Stopped Single Seq
50 acqs RL:20.0k
Man November 19, 2009 12:04:34

Some Results from breakdown studies

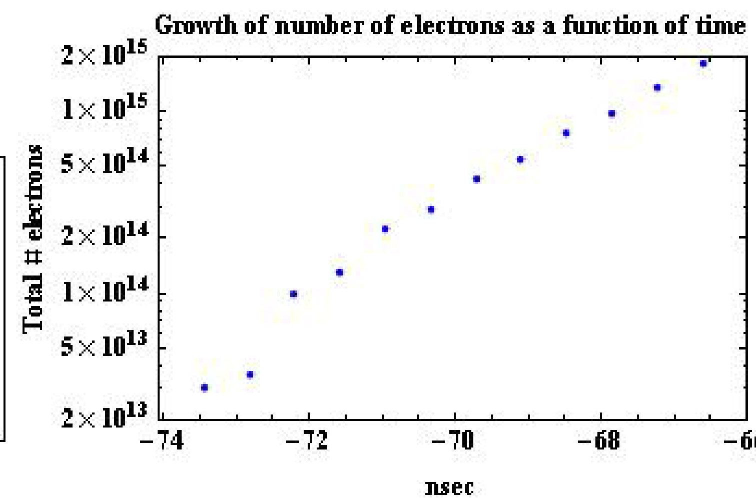








Cav L	2.413×10^{-8}
Cav freq	8.04572×10^{8}
ArcFreq	9.67118×10^{8}
Lmin	1.67004×10^{-8}
L spark	5.42403×10^{-8}
Spark radius	3.25322×10^{-6}
Bmax	24.5296
P in atmos	2394.09



Questions for MTA Studies:

- 1. Are the gas losses correctly calculated?
- 2. How fast does the recombination take place?
- 3. If recombination is too slow, does SF6 work?
- 4. What happens to the plasma after beam passes?

Crew at MTA that have contributed to
HPRF Studies.

M. Chung, A. Jansson, A. Moretti, M. Popovic, A. Tollestrup, K. Yonehara, Fermilab,
M. Alsharo'a, R.P. Johnson, M. Notani, Muons, Inc.,
D. Huang, Illinois Institute of Technology
T. Oka, H. Wang, University of Chicago
D. V. Rose, Voss Scientific
Z. Insepov, Argonne National Lab

Equally important are the studies of
Evacuated RF Cavities