Breakdown Rate Dependence on Gradient and Pulse Heating in Single Cell Cavities and TD18

Faya Wang, Chris Nantista and

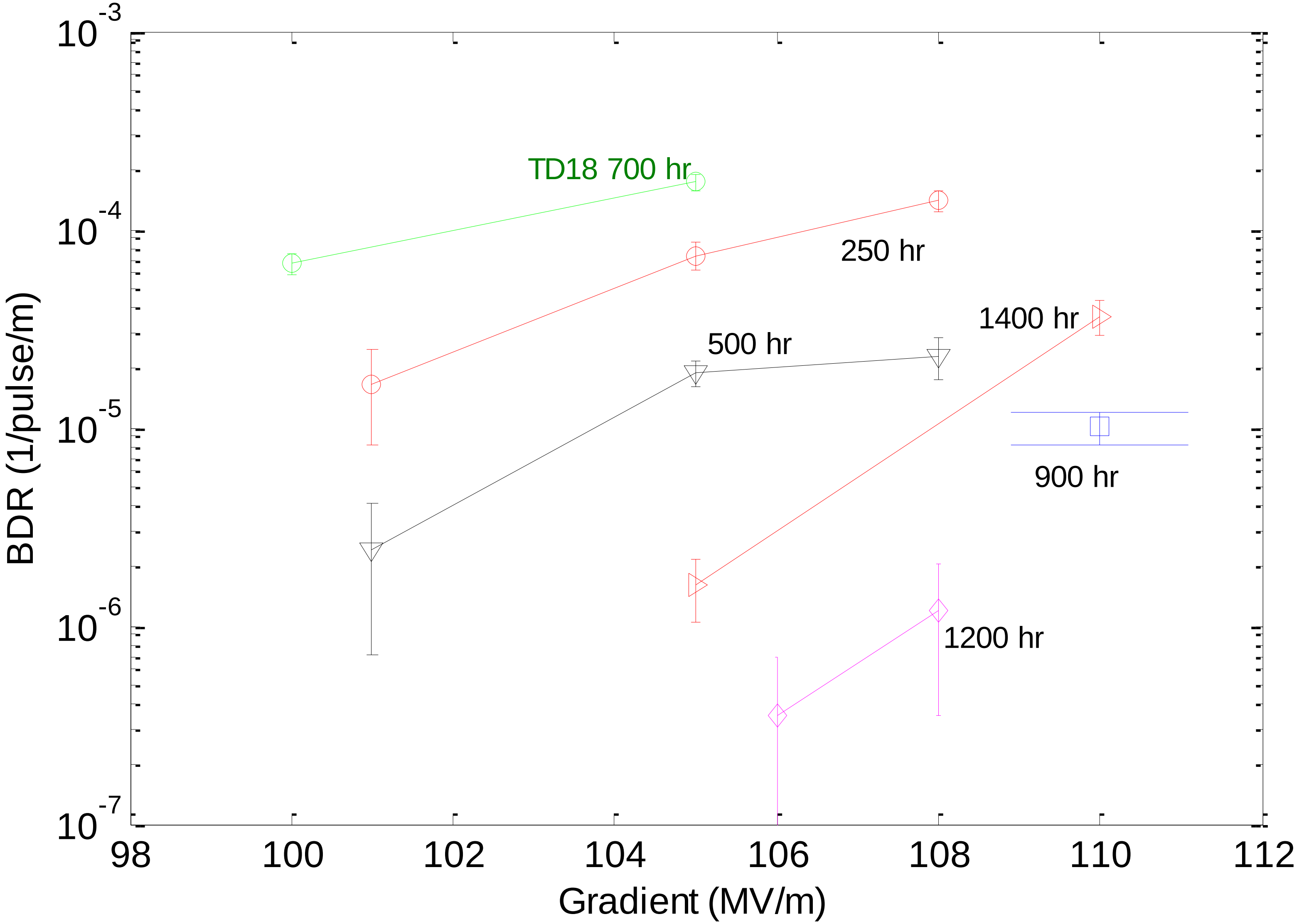
Chris Adolphsen

May 1, 2010

LC Breakdown Limits

- For NLC, the breakdown rate limit was chosen so that the 2% pool of spare rf units would rarely (once a year) be depleted assuming a 10 second recovery period after each breakdown. Operation with a 10 second recovery period has been demonstrated but longer times (30-100 sec) are typically used since the structure monitoring system has a 30 second sampling period. For 60 Hz operation at NLCTA, the breakdown rate limit translates to 0.1 per hour with the nominal 60 cm long structure design. This choice is somewhat soft in that a four-times higher rate would still provide 99% full-energy availability assuming a 5 second recovery time, which has also been demonstrated.
- For reference, at the 0.1 per hour limit, a breakdown would occur in one of the ~ 20,000 NLC X-Band structures once every 120 pulses. Such breakdowns will degrade the luminosity from that pulse, but the beam kicks from the breakdown fields should not inhibit beam operation.
- To 'translate' this limit, for one bkd in 10 hours in a 0.6 m structure at 60 Hz, the rate is 4.6e-7/pulse/structure or 7.7e-7/pulse/m. For CLIC 3-TeV, this same limit gives 1 bkd per 40 pulses, but because of the smaller beam emittance (and hence a smaller collimator aperture), the kicks are more likely to hit the collimators. The bkd kick distribution measured at NLCTA has values as large as 30 keV/c - this level is < 1/10 of the amount needed to hit the collimators at NLC.

Breakdown Rates: T18 and TD18

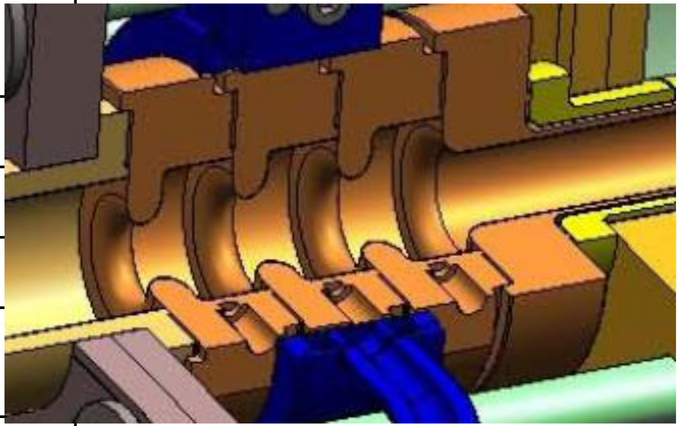


Pulse width 230ns, Green line for TD18, Others for T18

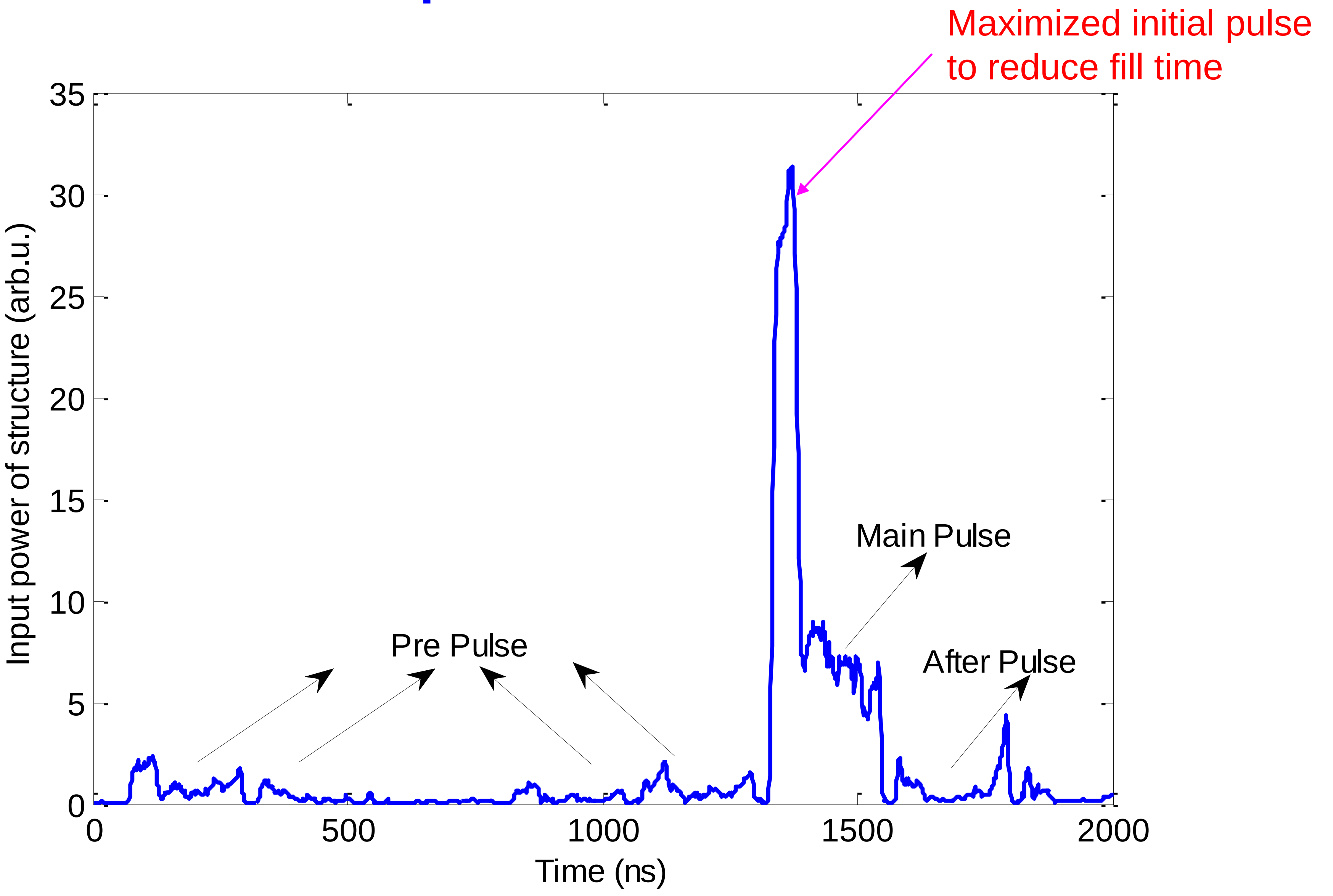
Single Cell SW Cavity

1C-SW-A3.75-T2.60-Cu6N-KEK

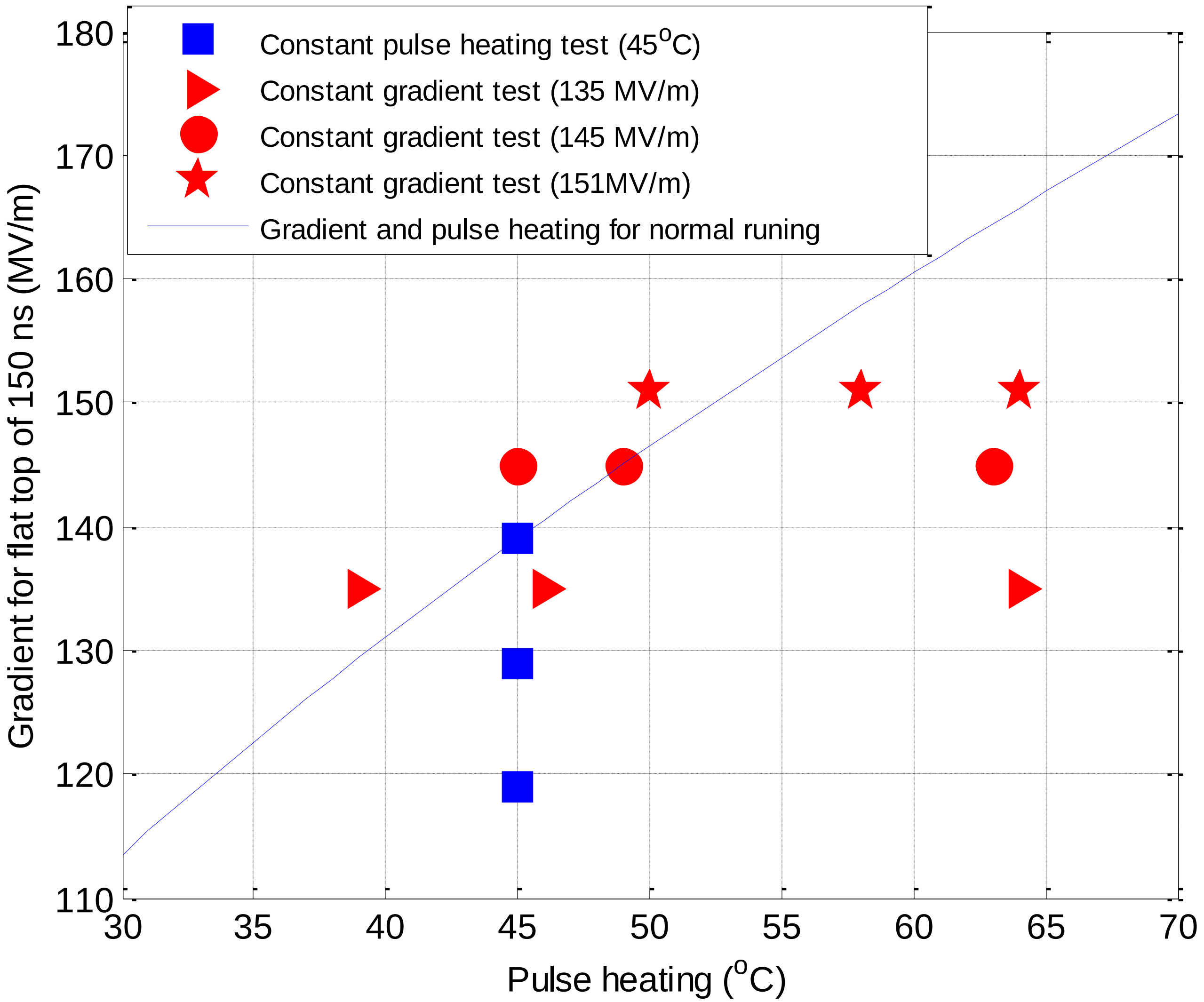
Parameters	Unit	Value
Frequency	GHz	11.427 (Nitrogen, 20 °C)
Cells		1+matching cell + mode launcher
Q (loaded)		4660
Coupling		0.97
Iris Thickness T	mm	2.6
Iris Dia. a / λ	%	14.4
Phase Advance Per Cell	deg	180
E_s/E_a		2.03
Maximum surface electric field for 10 MW	MV/m	399
Maximum surface magnetic field for 10 MW	A/m	6.7e5
Peak pulse heating for 1 μs pulse with flat field of 100 MV/m	°C	24



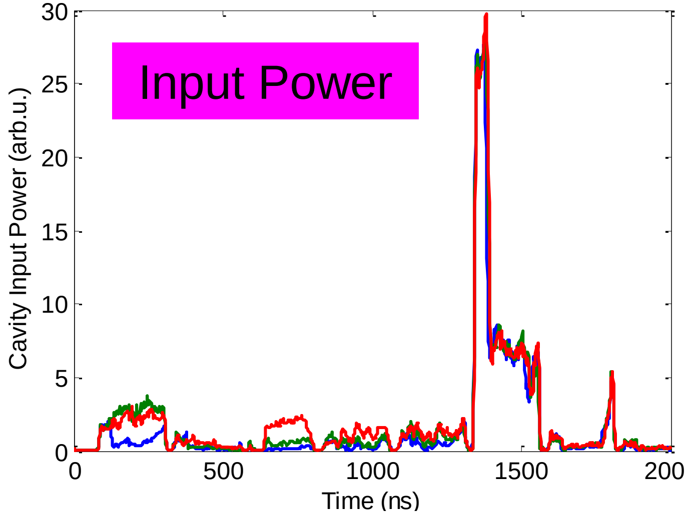
Input RF Pulse

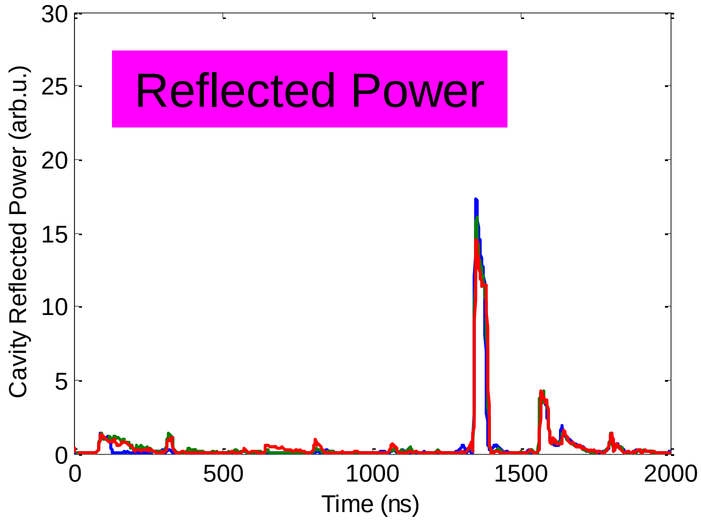


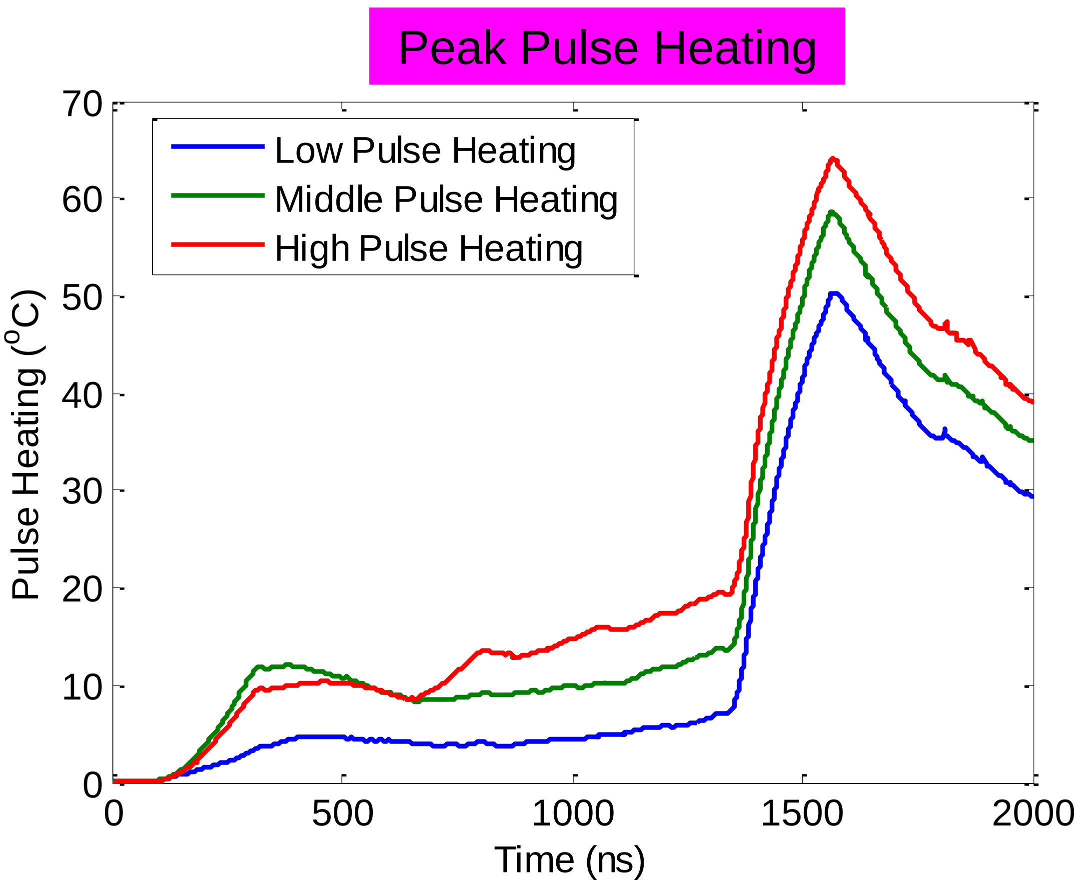
Measurement Points: Vary Either Pulse Heating or Gradient



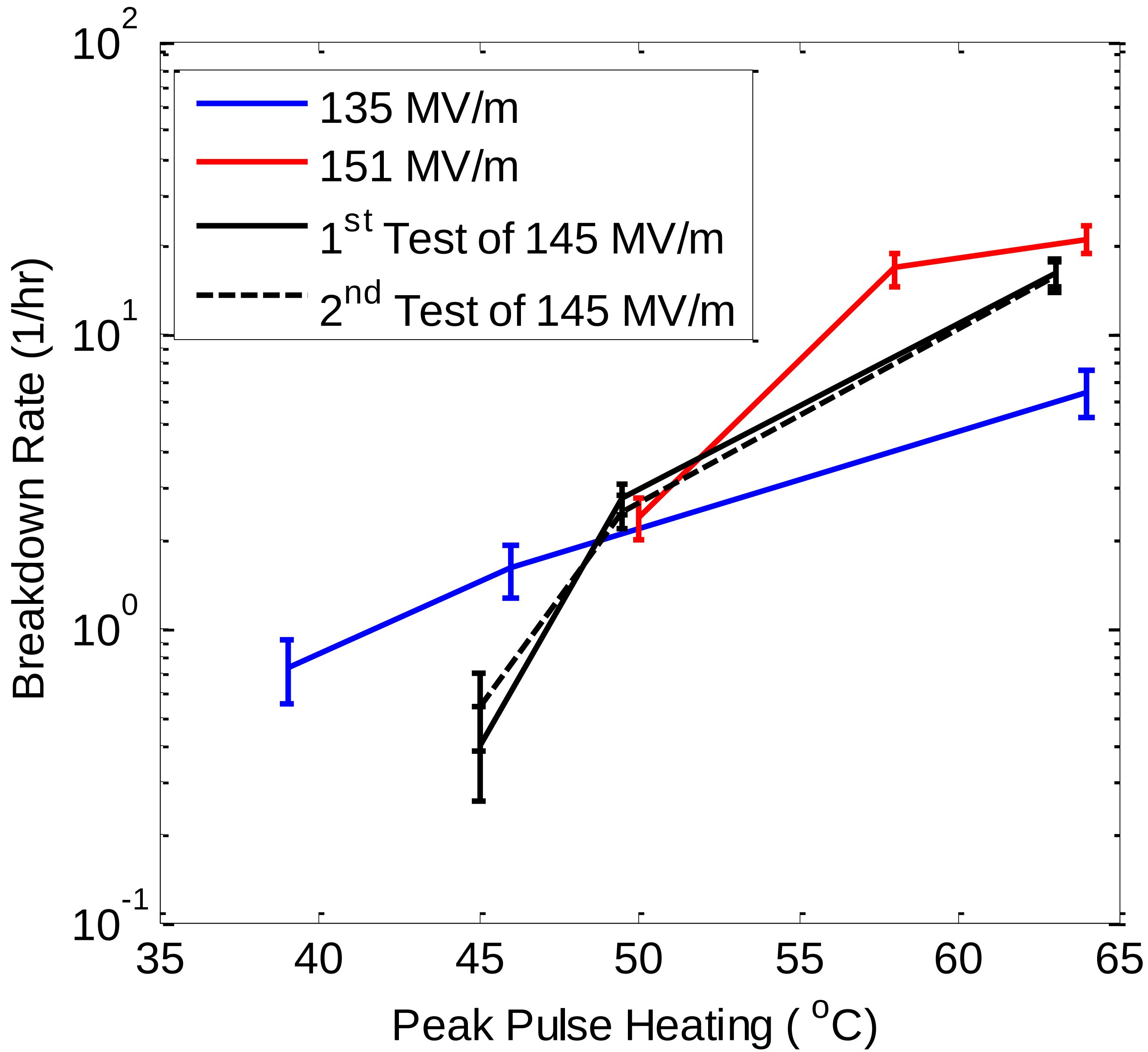
Breakdown Study with Constant Gradient but Different Pulse Heating from the Pre-Fill 'Warm-up'



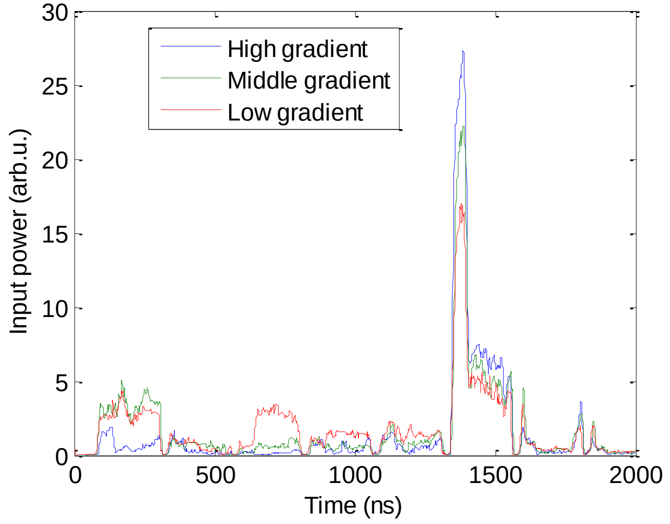


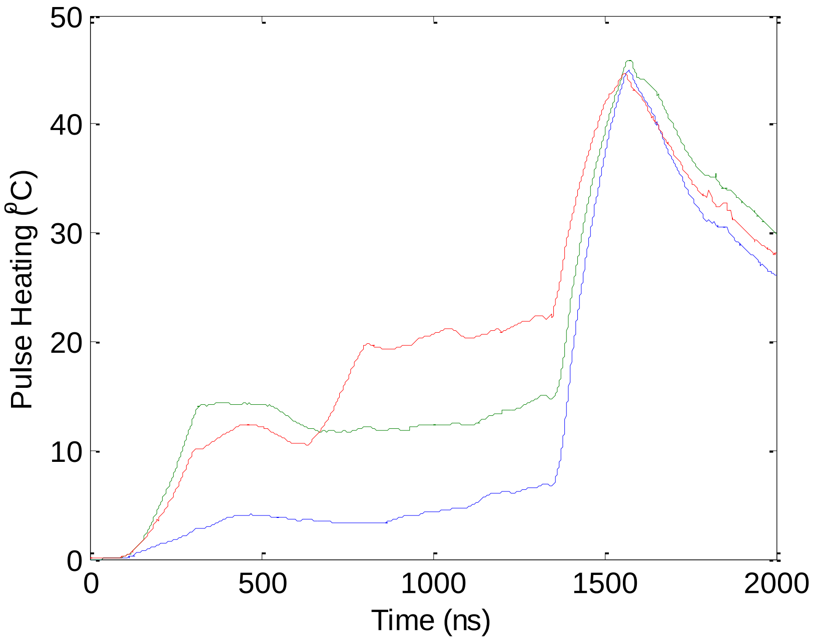


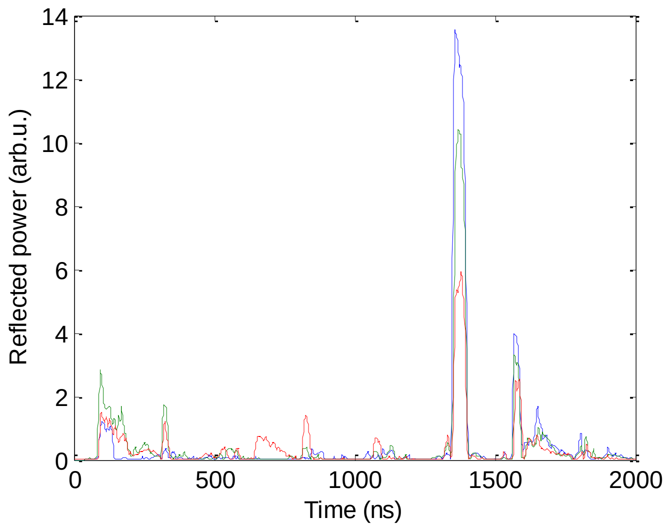
Breakdown Rate for Fixed Gradient

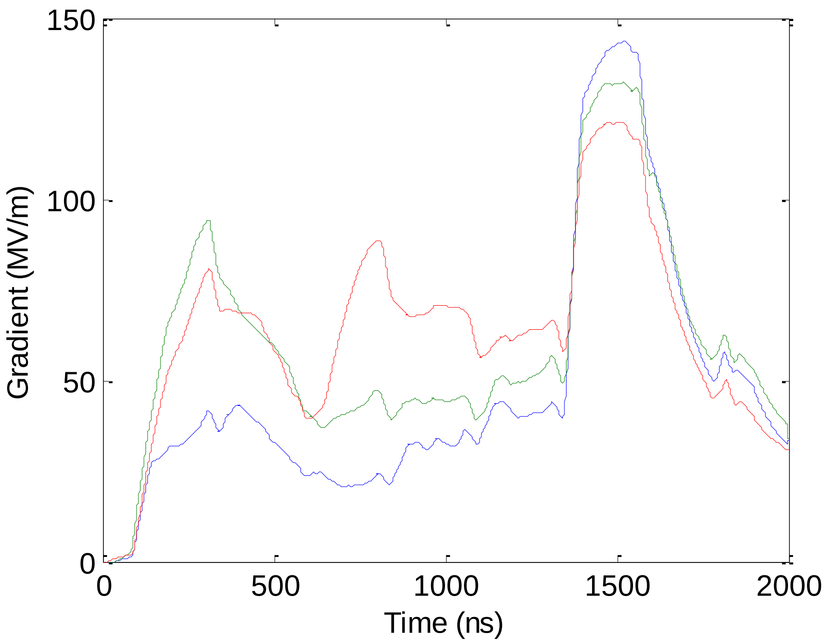


Breakdown Study with Constant Pulse Heating

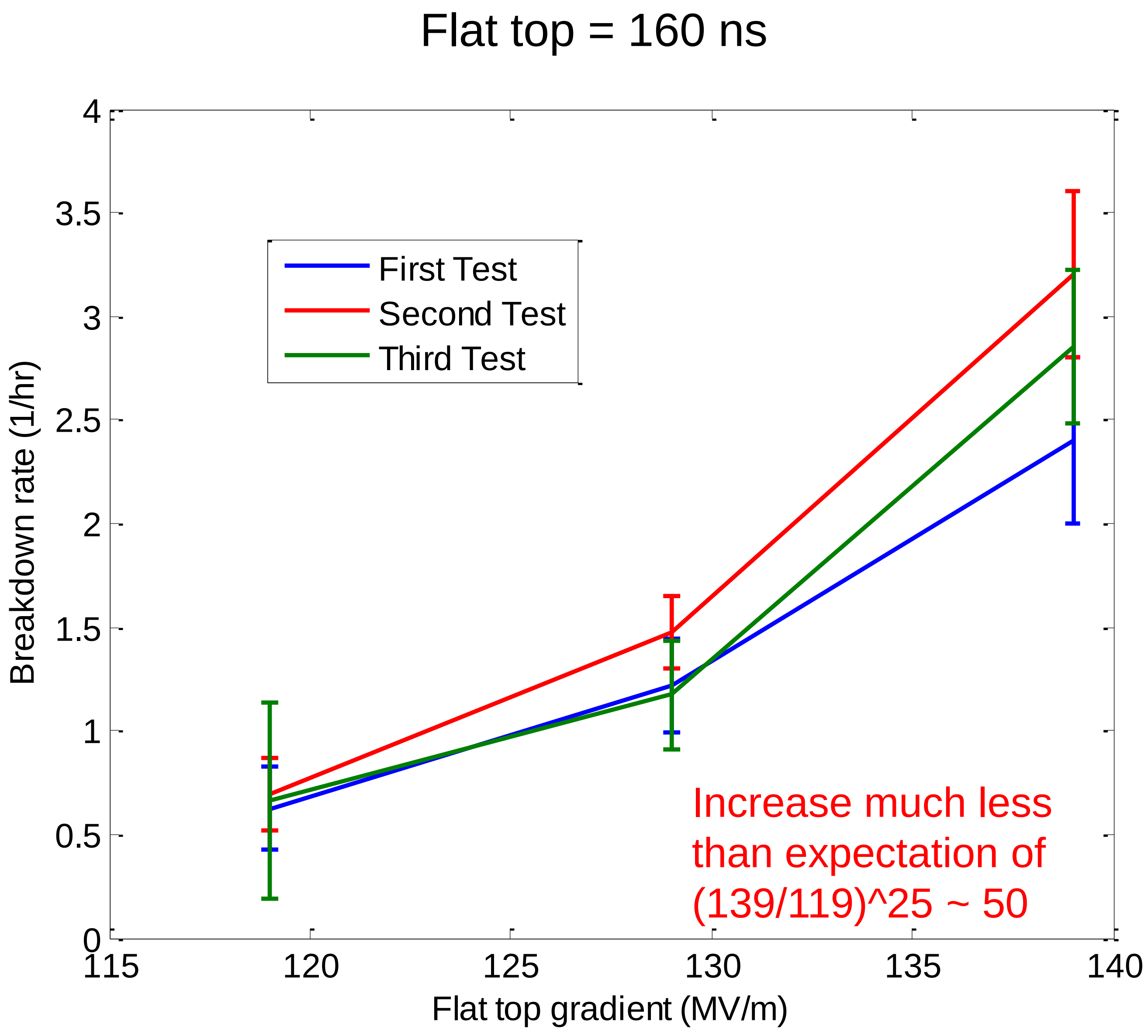




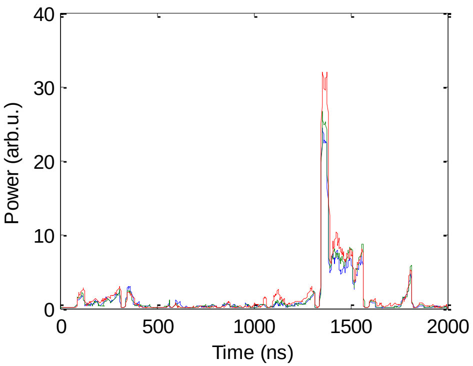


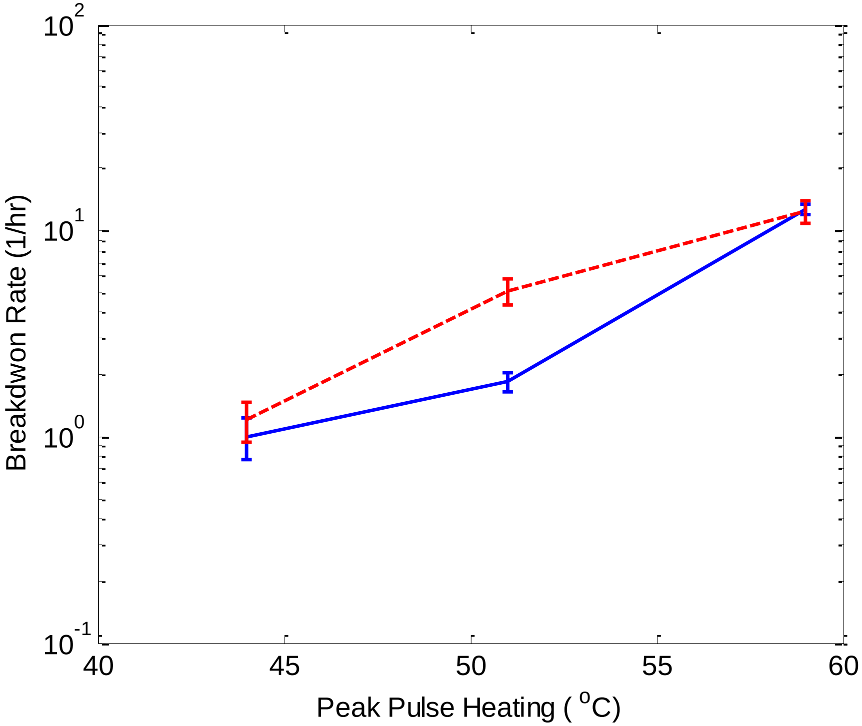


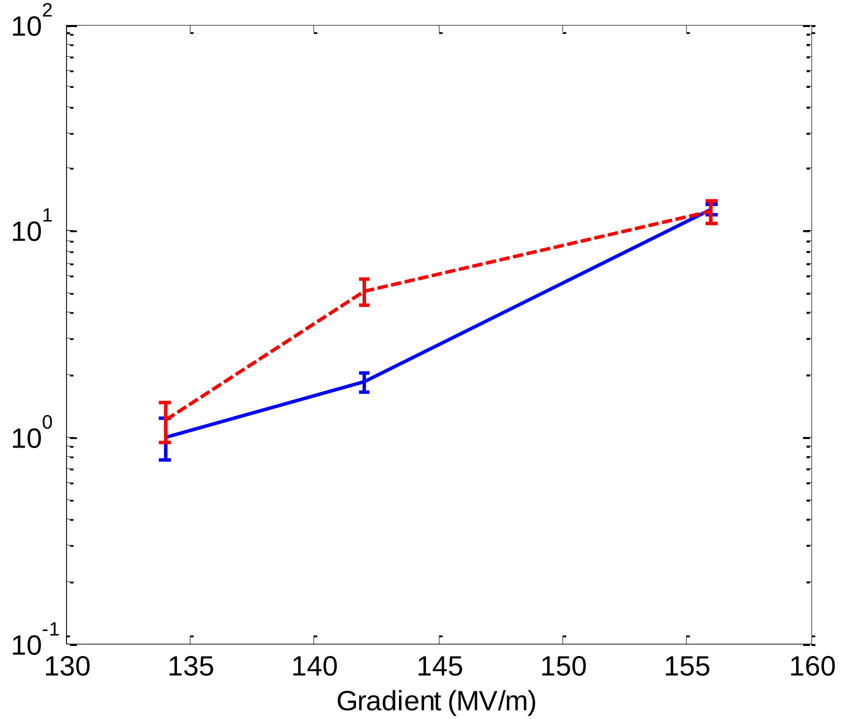
Breakdown Rate for Fixed Peak Pulse Heating



Breakdown Rate with Varying Gradient and Pulse Heating

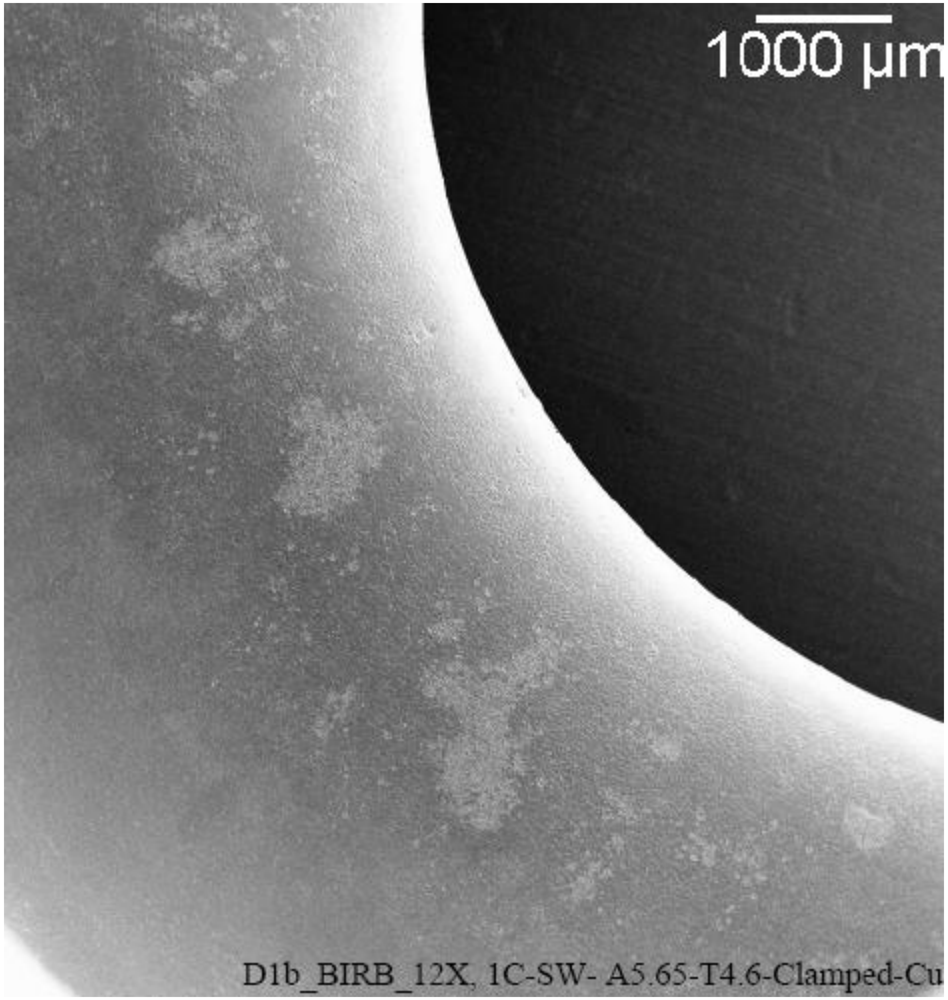


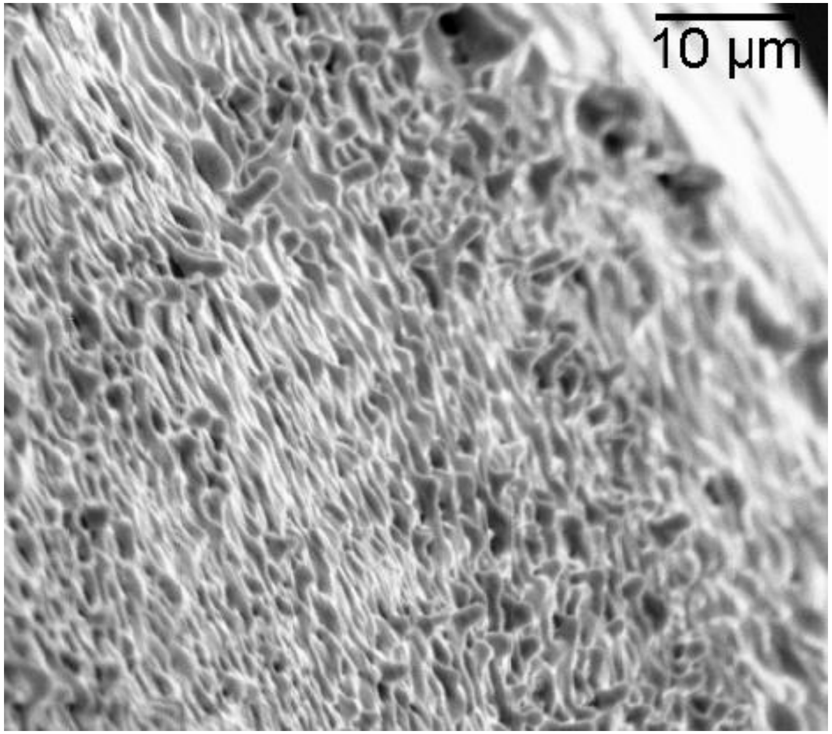




Blue for the 1st test and Red for the 2nd test.

Damage to Single Cell Irises

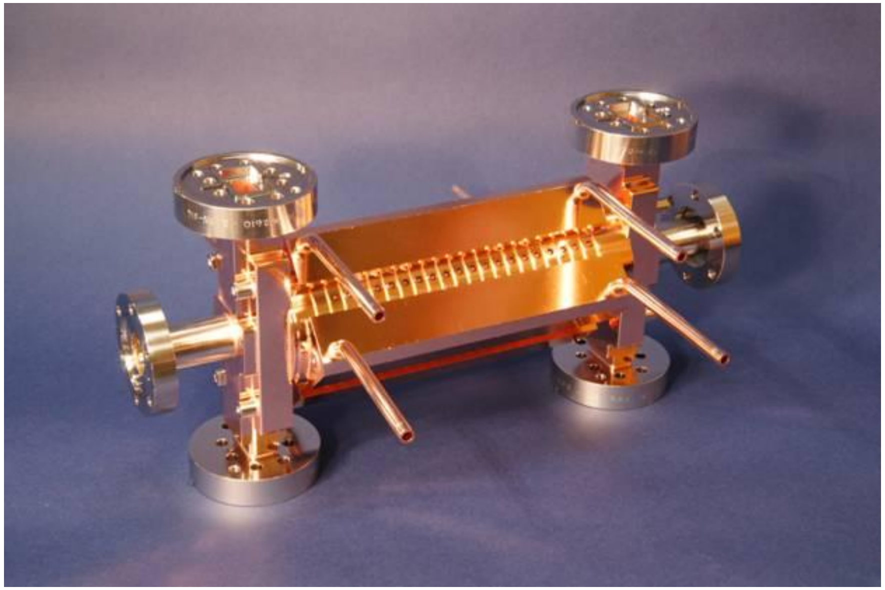




V Dolgashev, L Laurent

TW Structure with Damping (TD18)

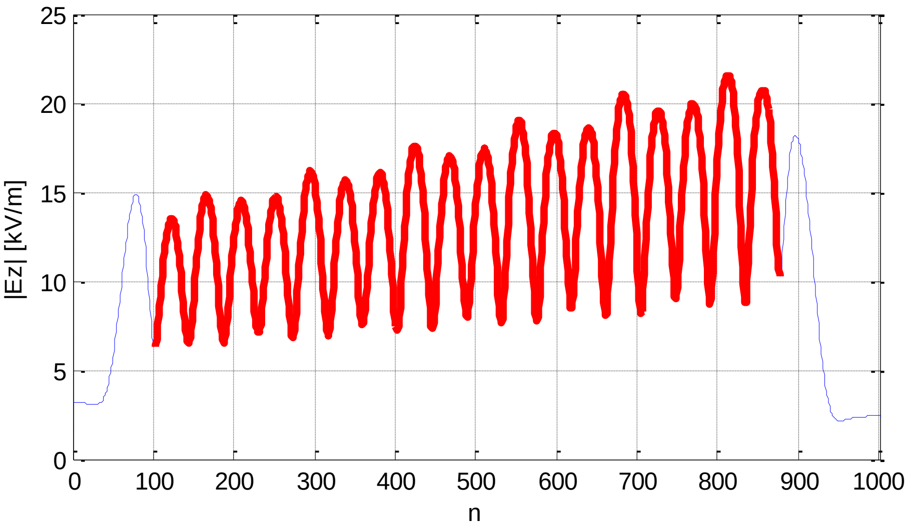
	First	Middle	Last Cell
a [mm]	4.06	3.36	2.66
a/λ (%)	15.4	12.8	10.1
d [mm]	2.794	2.054	1.314
e	1.21	1.18	1.15
f [GHz]	11.424	11.423	11.424
Q(Cu)	5098	5364	5458
vg/c [%]	2.25	1.47	0.87
r'/Q [LinacΩ/m]	10195	12560	15034
Es/Ea	1.97	1.88	1.88
Hs/Ea [mA/V]	5.85	5.2	4.85
Sc/Ea^2 [mA/V]	0.52	0.39	0.3



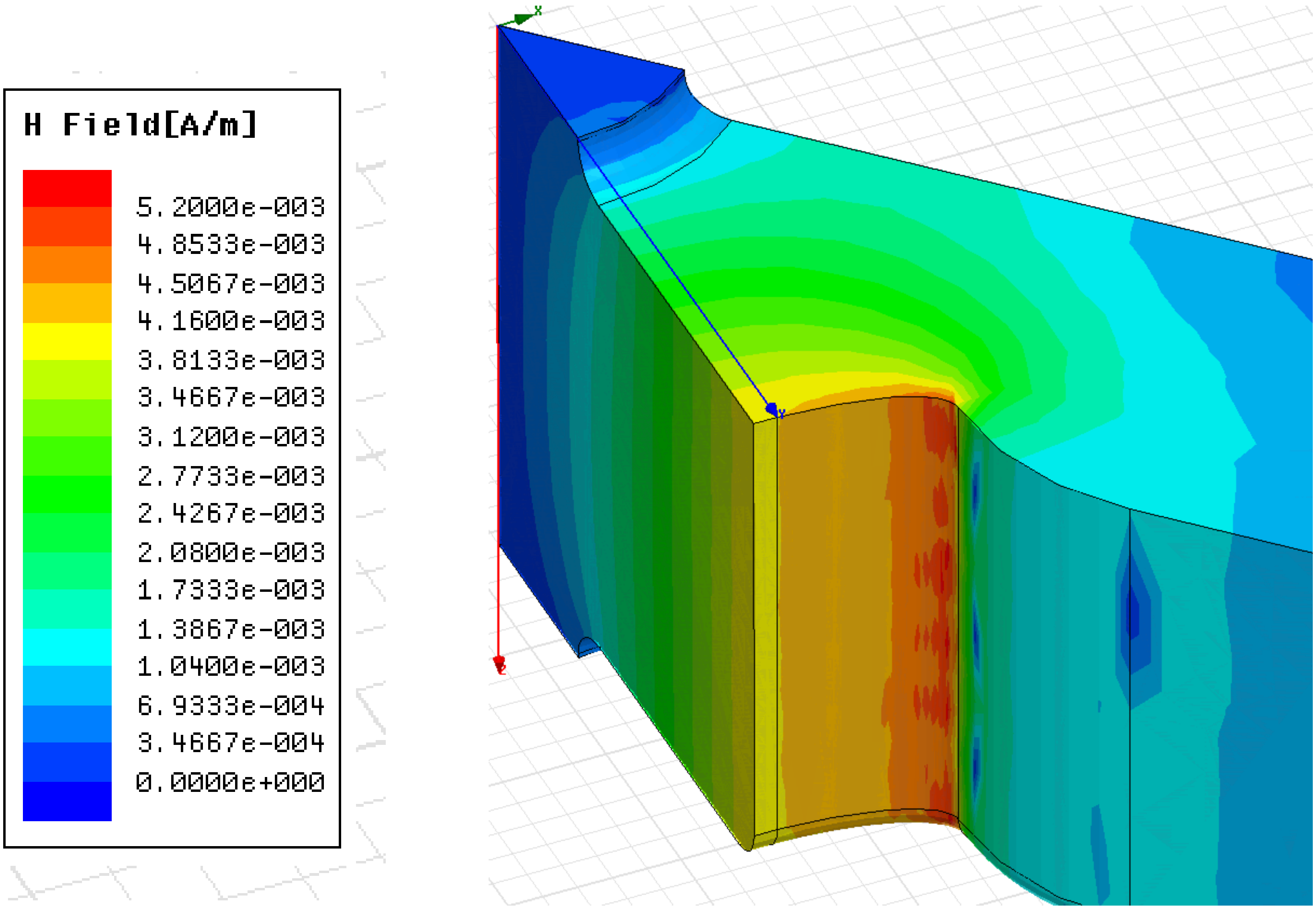
For regular cells

P = 59.8 MW for <G> = 100 MV/m

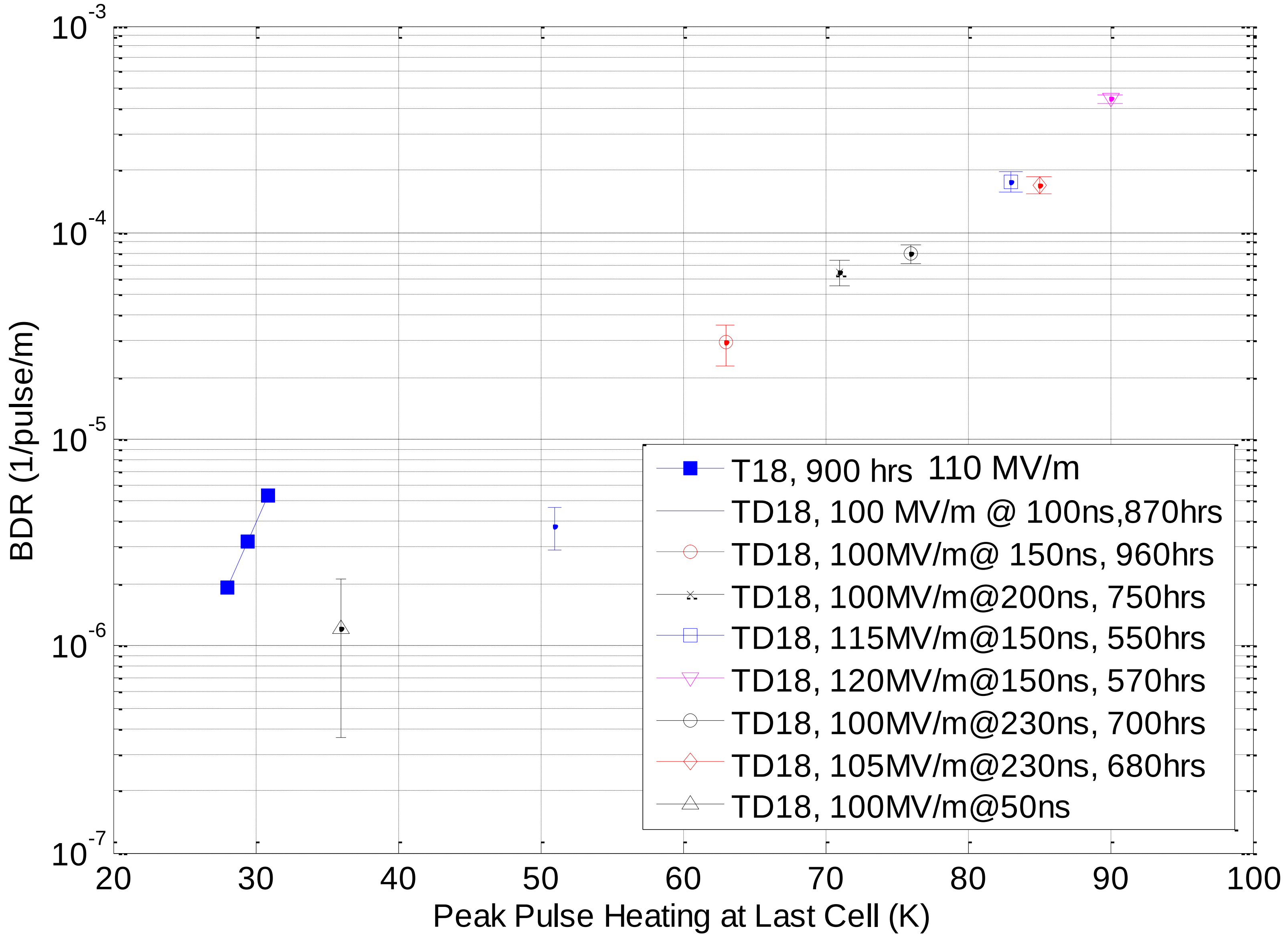
Active Length = 15.8 cm



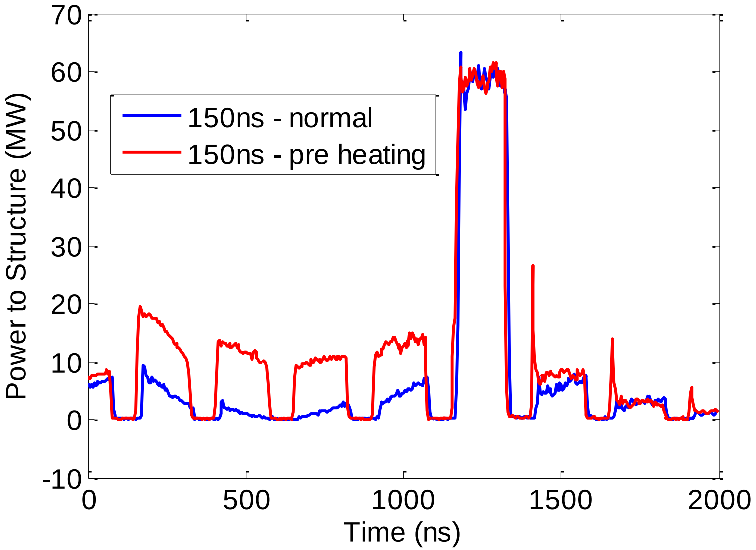
Last Cell Surface Magnetic Field

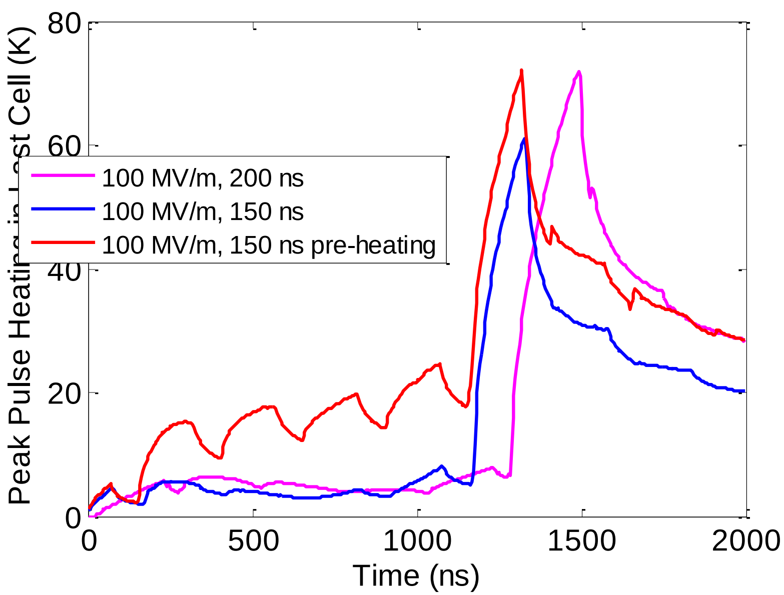


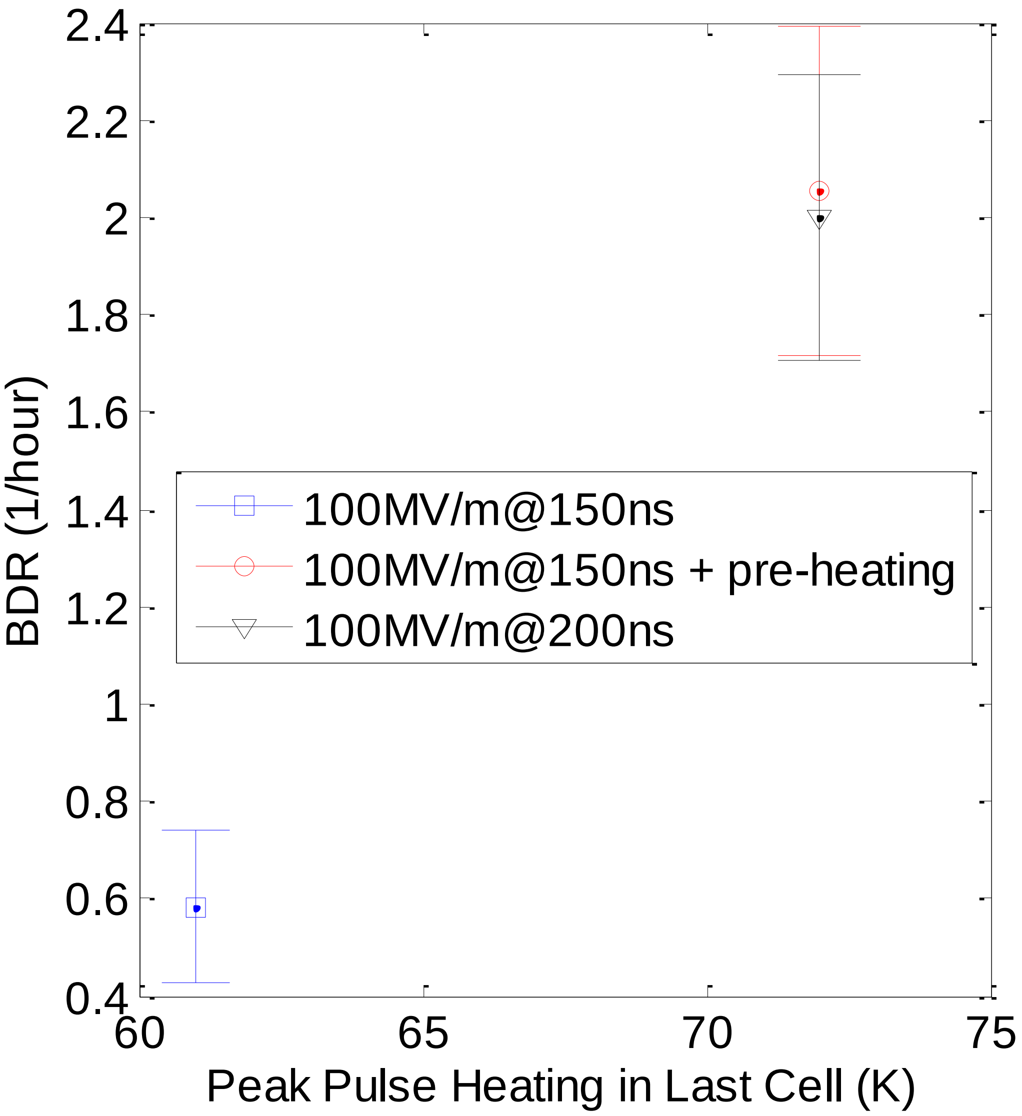
T18 and TD18 BDR Pulse Heating Dependence



Pulse Heating BDR Test







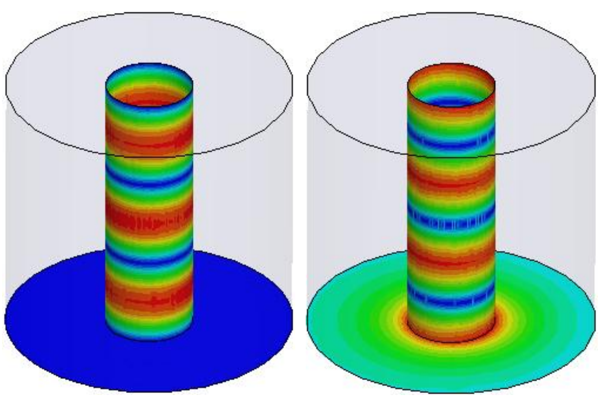
A Coaxial Two Mode Cavity is Being Designed to Study E and B Effects Somewhat Orthogonally

A coaxial cavity resonant with 11.424 GHz TEM_3 and TE_{011} would be excited by two rf sources, one coupling to each mode.

The high E field on the center conductor is determined solely by the TEM_3 excitation, with the peaks at the zero points of the H field.

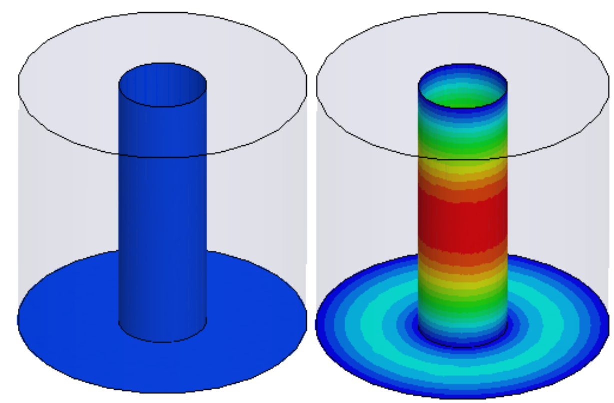
Adding TE_{011} increases the H field, preferentially around the central E field lobe.

TEM_3



$|E_s|$ $|H_s|$

TE_{011}



$|E_s|$ $|H_s|$

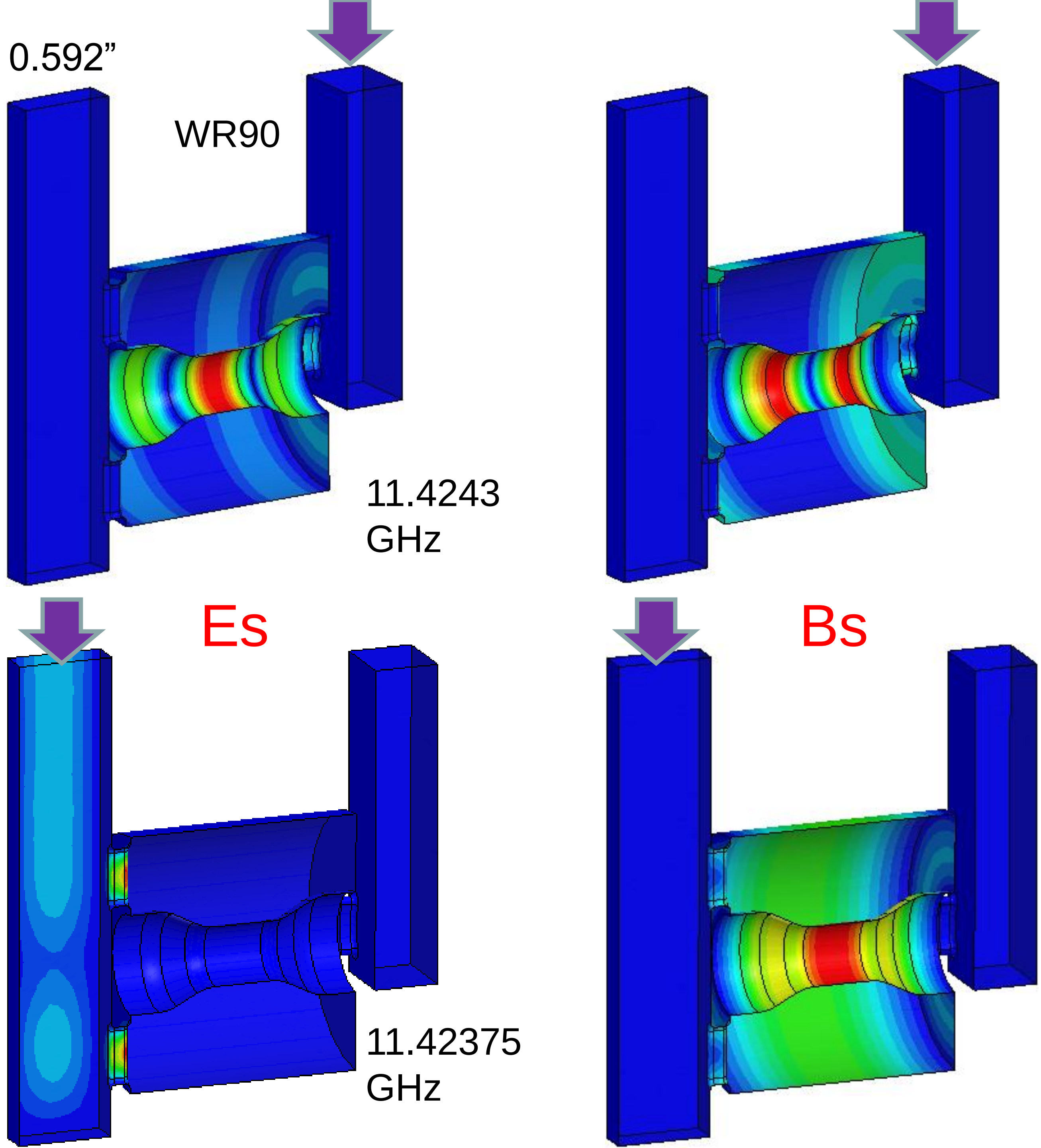
Center conductor:
r = 0.635 cm

C. Nantista

Latest Design

TEM_3

TE_{01}



Pulse Heating Summary

- All NLC structures and undamped CLIC structures operate with pulse heating below 50 degC – do not believe it impacts BDR at this level as damped and undamped NLC structures performed the same despite the 20-40 degC variation in heating (should recheck with T18)
- TD18 and single cell BDR show clear pulse heating dependence above 50 degC
  - Since TD18 differs from T18 mainly in the outer cell wall, indicates that heating (or B field) ~ 0.5 cm from irises has an influence on breakdown at the irises (as did the sharp-edge coupler heating in earlier NLC structures)
- Pre-heating tests at constant gradient confirm the pulse heating sensitivity
  - However, longer exposure to moderate gradient (half of max) during the pre-heating period could be a factor