RF Breakdown: Experiments and Goals

- Goals
- Phenomena at 30 GHz and 11 GHz

For more detailed high gradient results please see:

KEK workshop on X-band structures, May 2008

http://indico.cern.ch/conferenceDisplay.py?confId=30911

The x-band structure design and testing workshop: June 2007

http://indico.cern.ch/conferenceDisplay.py?confId=15112

The High-Gradient workshop, October 2006

http://hg2006.web.cern.ch/HG2006

CLIC Structure Goals

Develop and demonstrate a CLIC prototype accelerating structure:

12 GHz,

100 MV/m average loaded gradient,

240 ns (200-300 ns),

10^{-7} trip probability,

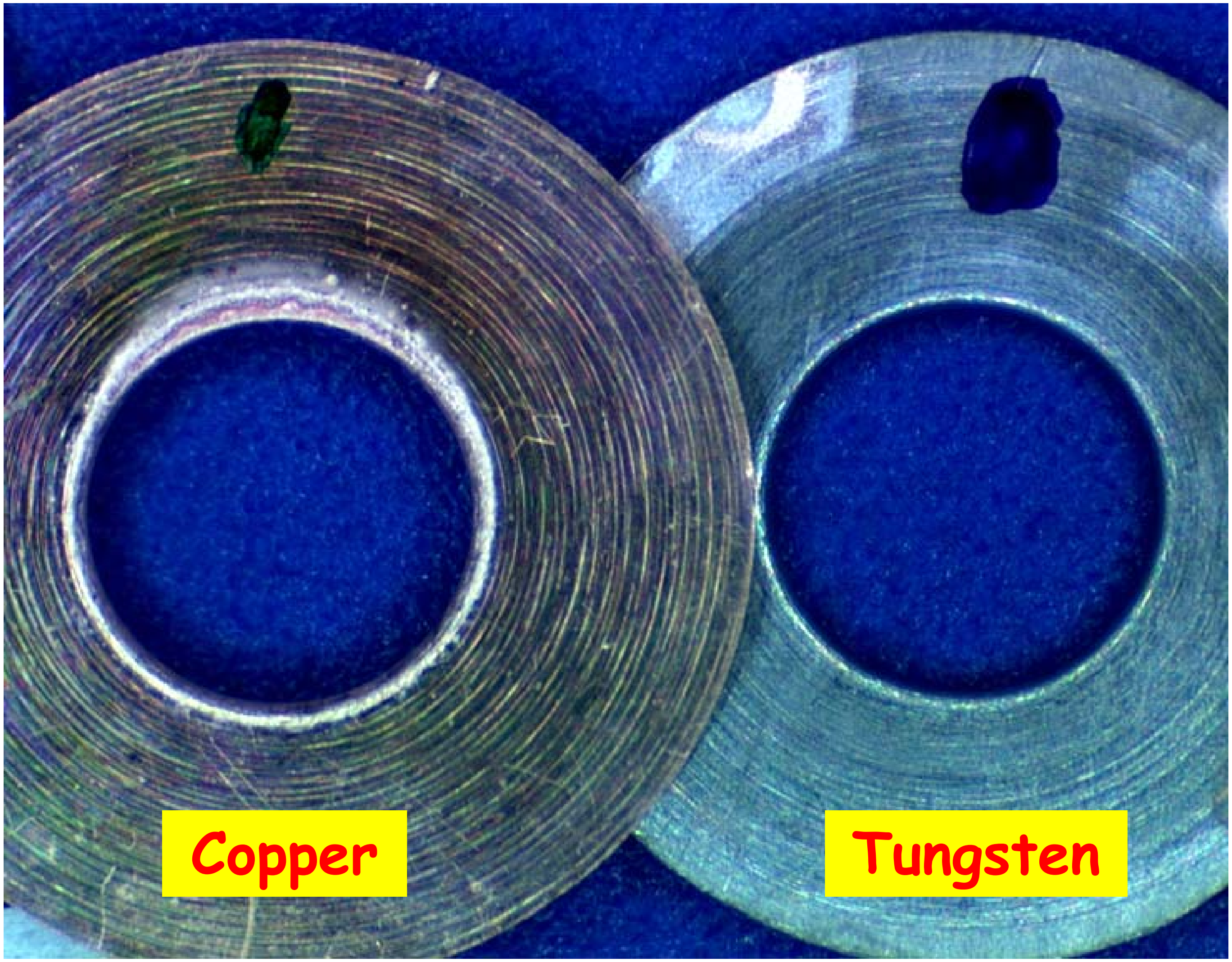
Acceptable wake fields, strong damping in each cell, average aperture restrictions

Affordable in mass production

Various alignment and stability issues

> 10 years of live time without degradation

Damage in high field areas

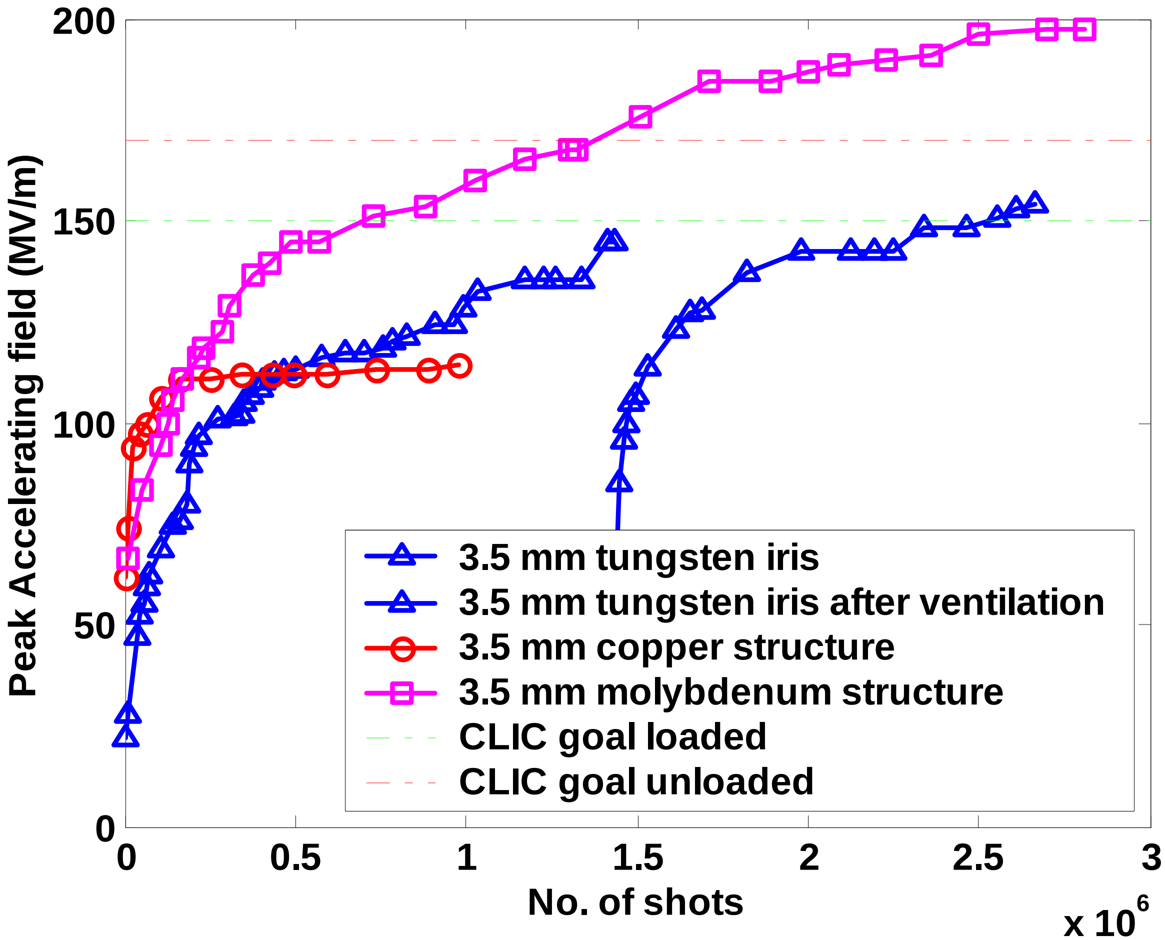


Damage was nicely correlated with electrical surface field distribution

Clamped-Iris Structure Tests in CTF II

Accelerating Structure Tests in CTF II

Short, 16 ns rf pulses

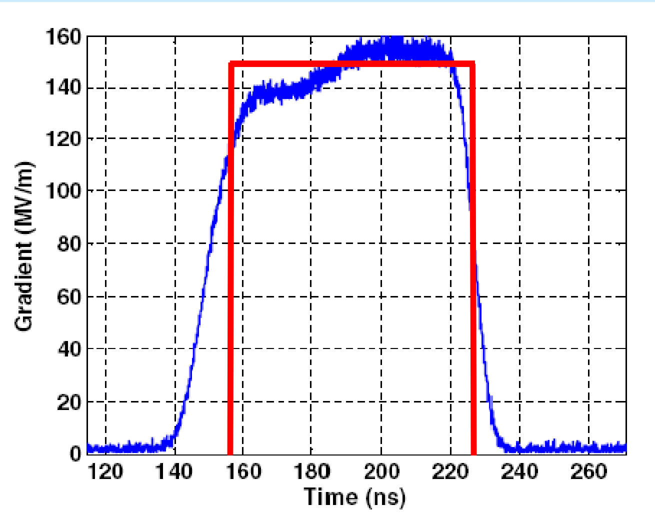


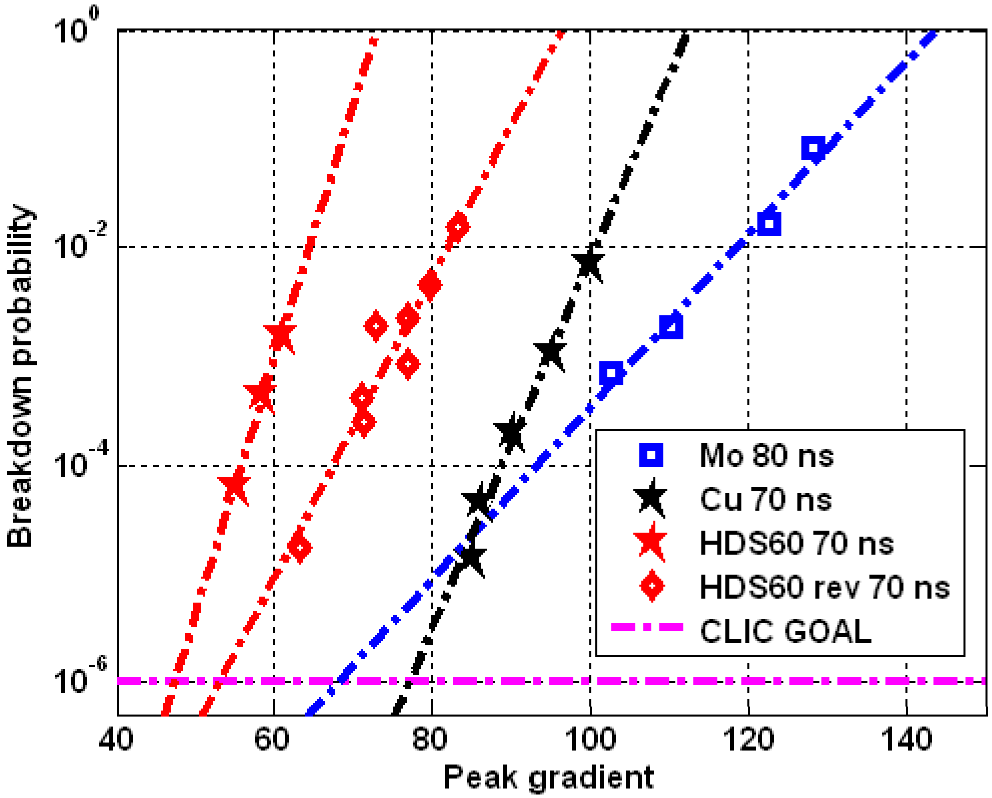
New Record for classical accelerating structures !

Overview of 30 GHz results

Reached nominal 30 GHz CLIC values :

150 MV/m 70 ns

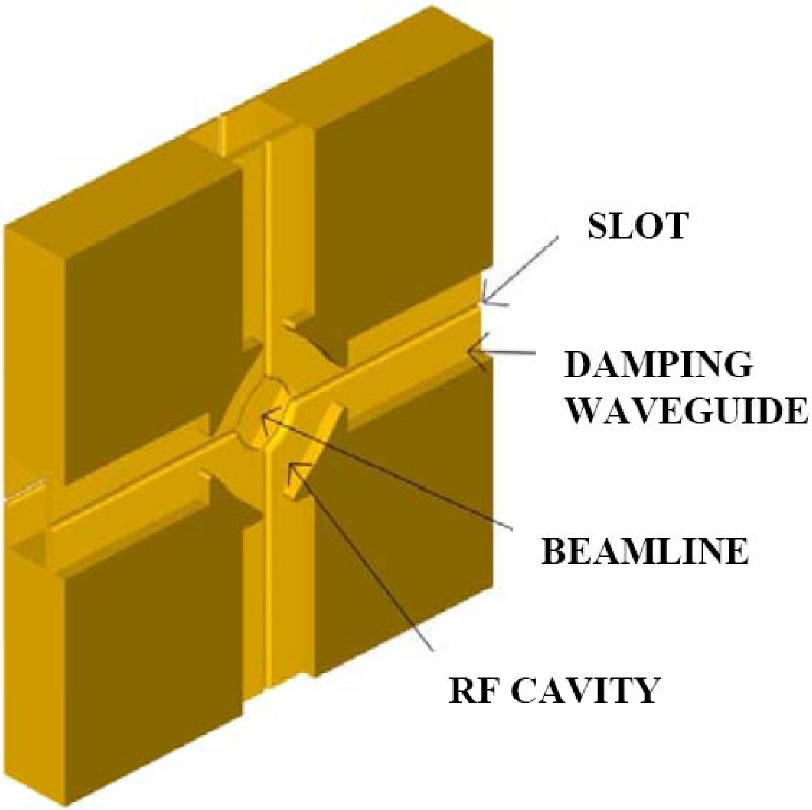


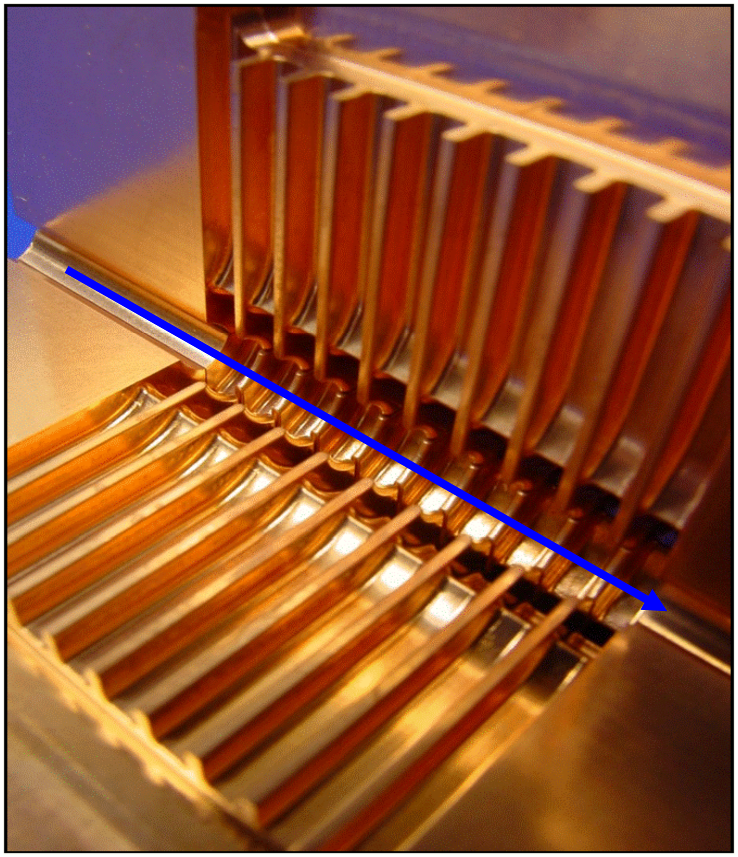


Molybdenum shows higher gradient but different slope

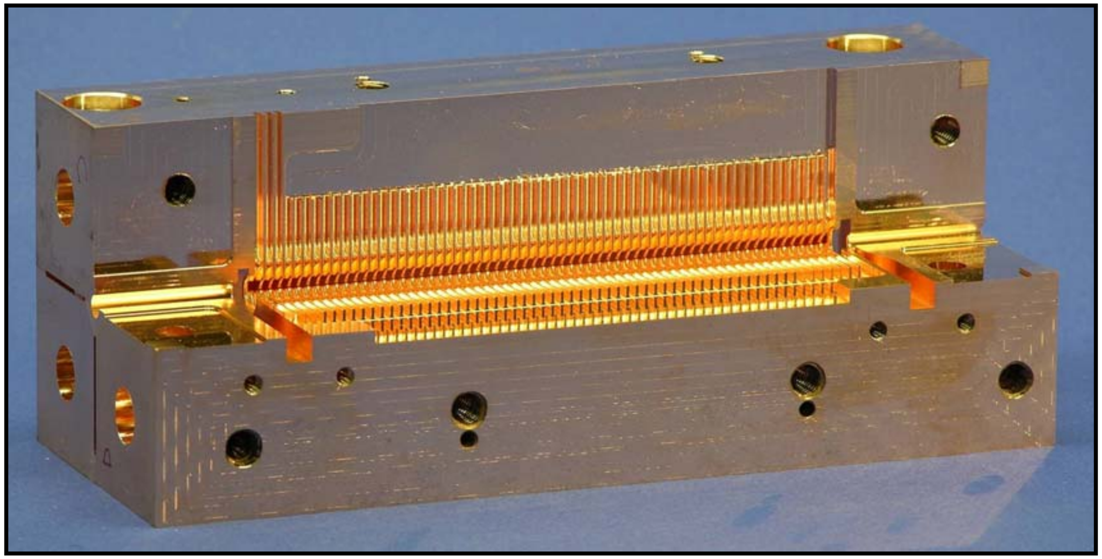
HDS performs worse than round brazed structure

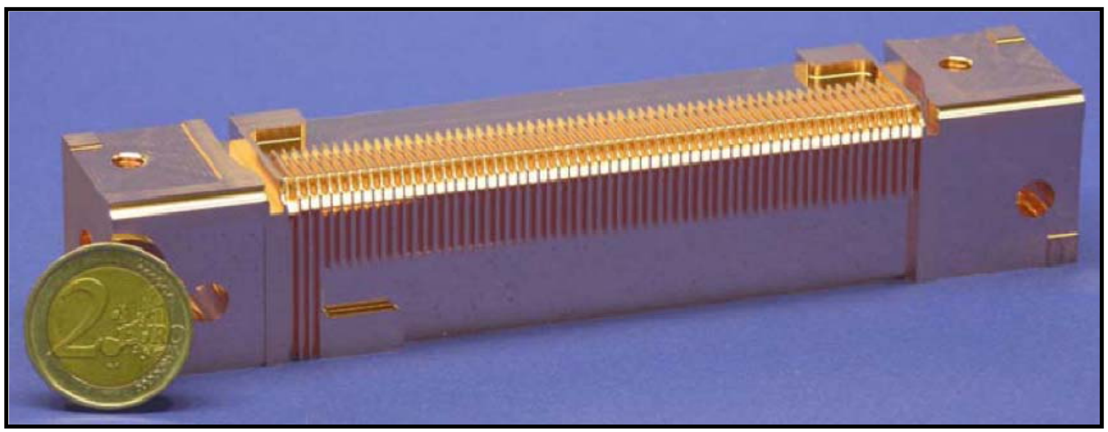
Hybrid Damped Structure (HDS)





Accelerating Structures made out of milled quadrants

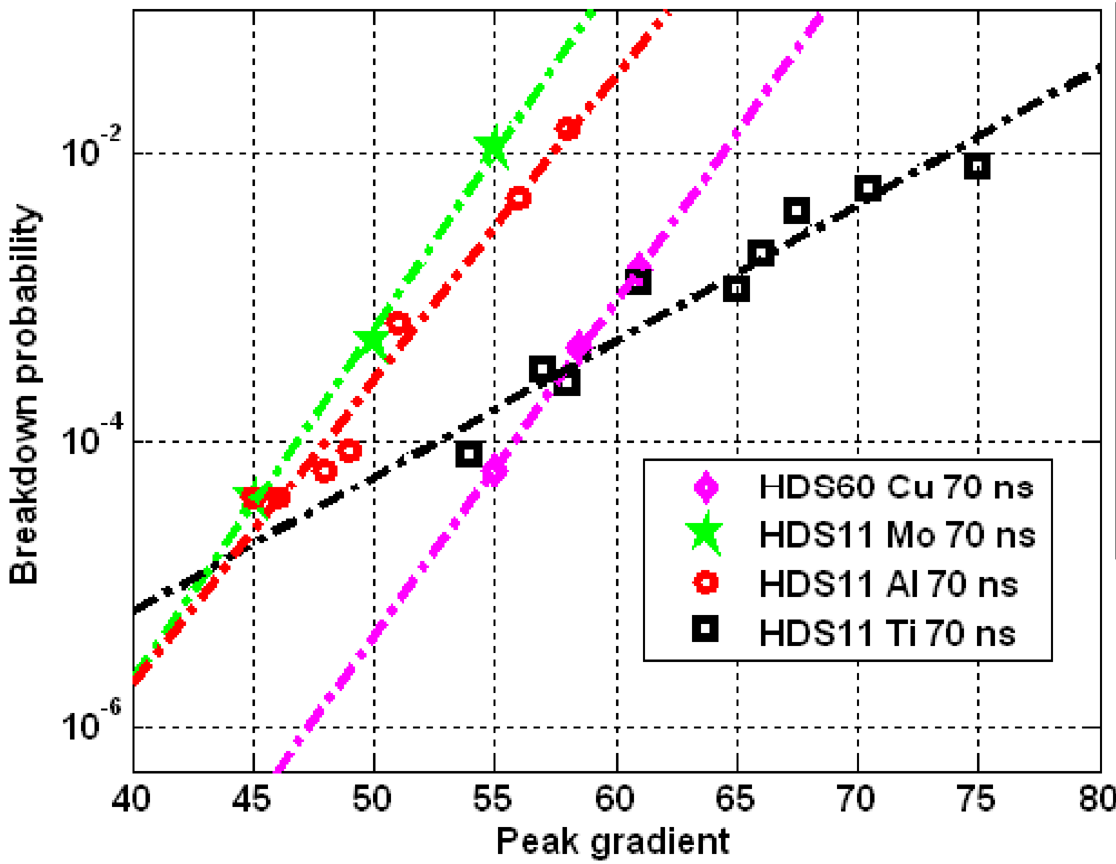




HDS60

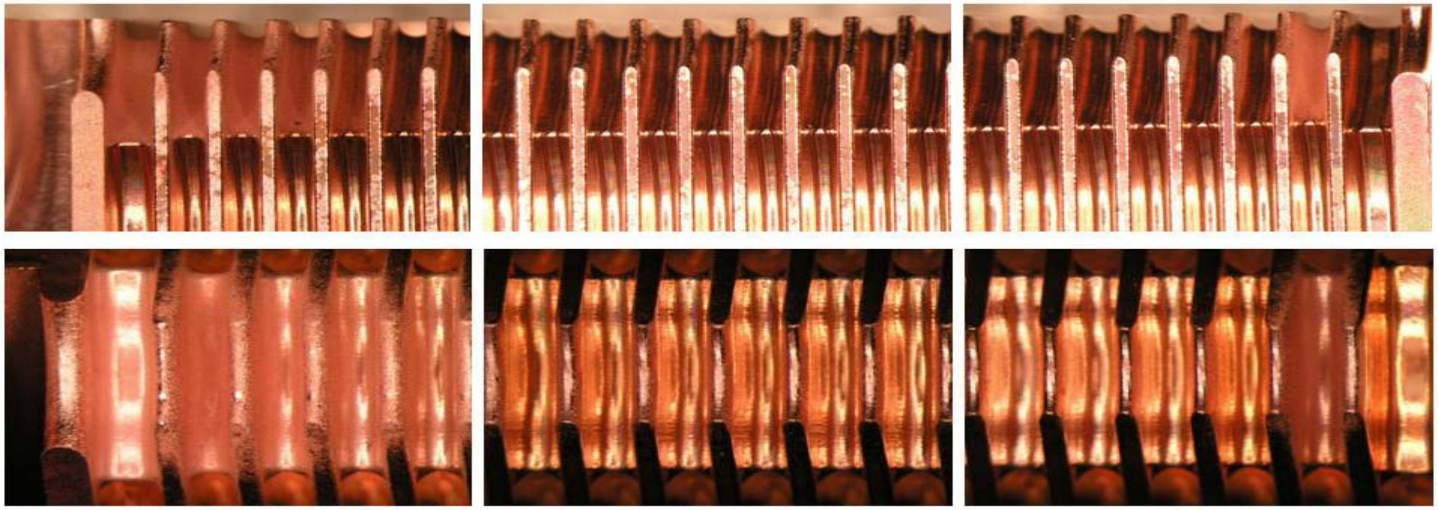
$<E_{acc}>$ [MV/m]	150
f [GHz]	29.985
$\Delta\varphi$ [°], l_c [mm]	60, 1.66635
$a_{1,2}$ [mm]	1.9, 1.6
$d_{1,2}$ [mm]	0.55, 0.55
$Q_{1,2}$	2356, 2316
$r/Q_{1,2}$ [LinacΩ/m]	29000, 34000
$v_g/c_{1,2}$ [%]	8.0, 5.1
$<a>/\lambda$	0.175
N	2.45×10^9
$L_{b\times}$ [m^{-2}]	1.02×10^{34}
N_c, l [mm] (active)	60, 100
N_s	12
N_b	160
τ_p ,τ_f [ns]	68.4, 5.2
P_{in} ,P_{out} [MW]	98, 64.5
η [%]	13.9

New Materials for High-Gradient



Copper has still the best performance at low break down rate

Damage vs aperture or group velocity



HDS60 Large HDS60 Small

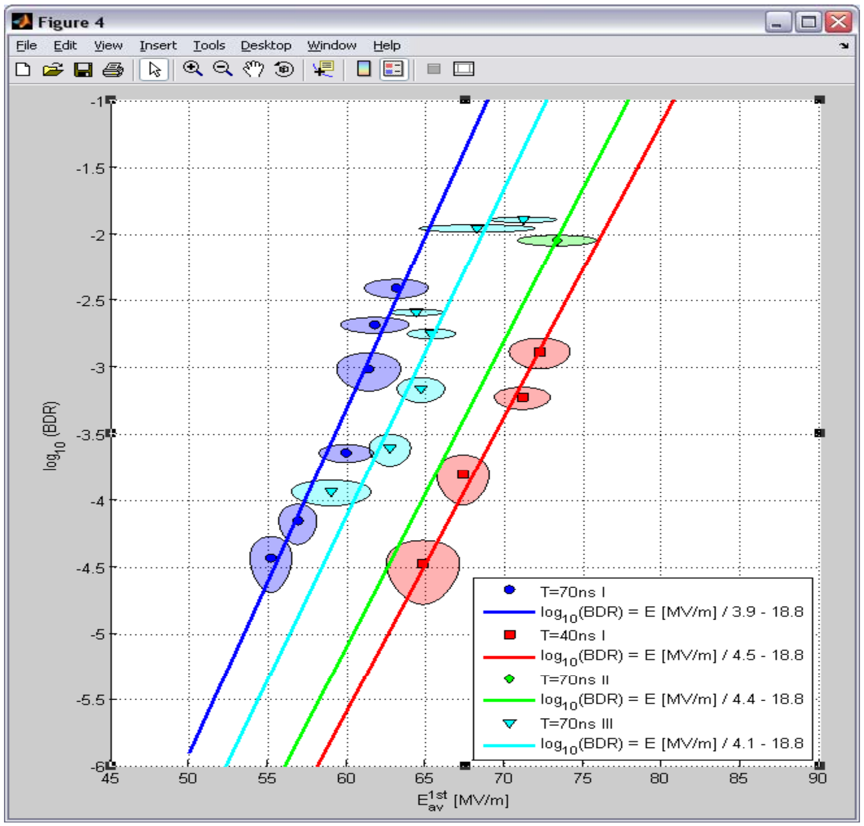
Evidence for correlation between damage and power flow (a,vg,P):

Criteria for optimizing rf designs (P/C):

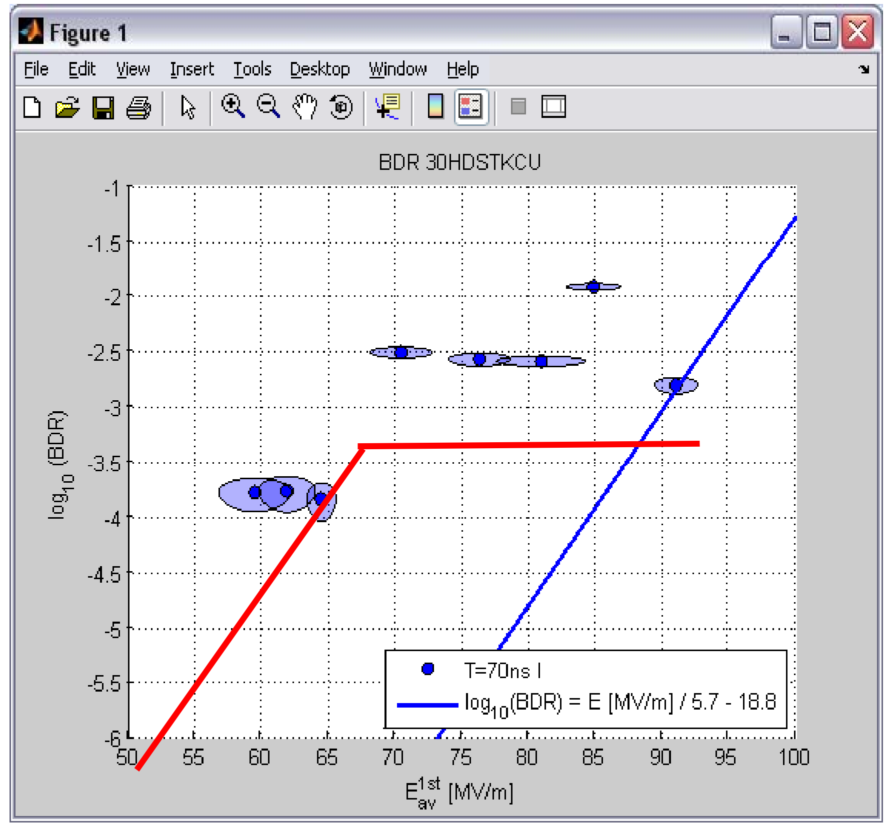
$Px(\tau^{1/3})/\pi/2a < \text{threshold}$

Recent 30 GHz results

C40vg8_pi/2



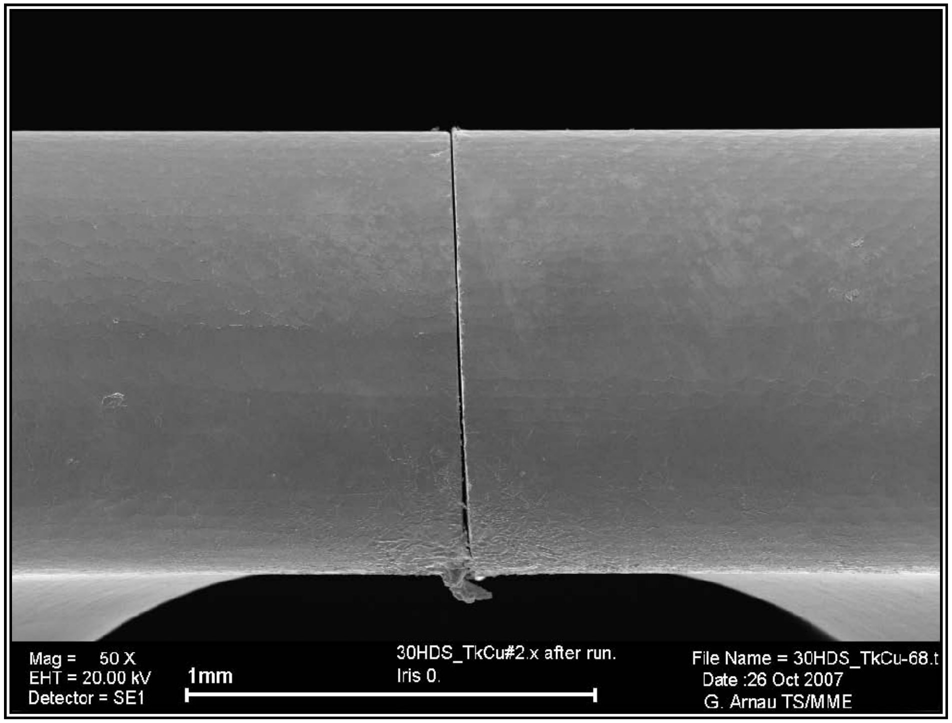
HDS4vg2.6_thick_150deg

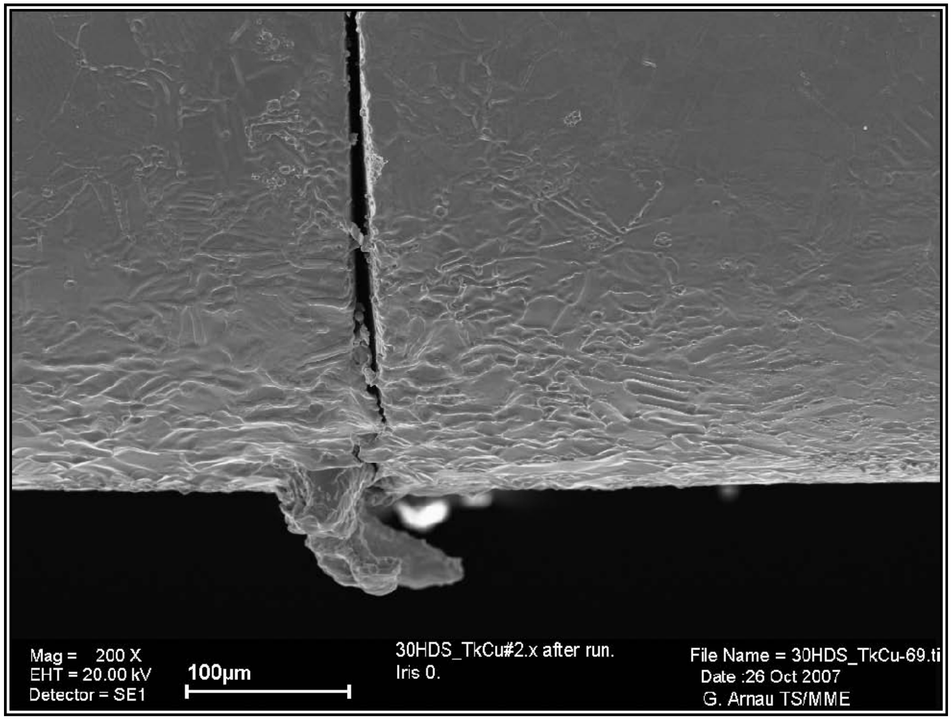


Example of deterioration during conditioning.

However normally structures get damaged but perform better than before !

HDS4_thick post mortem



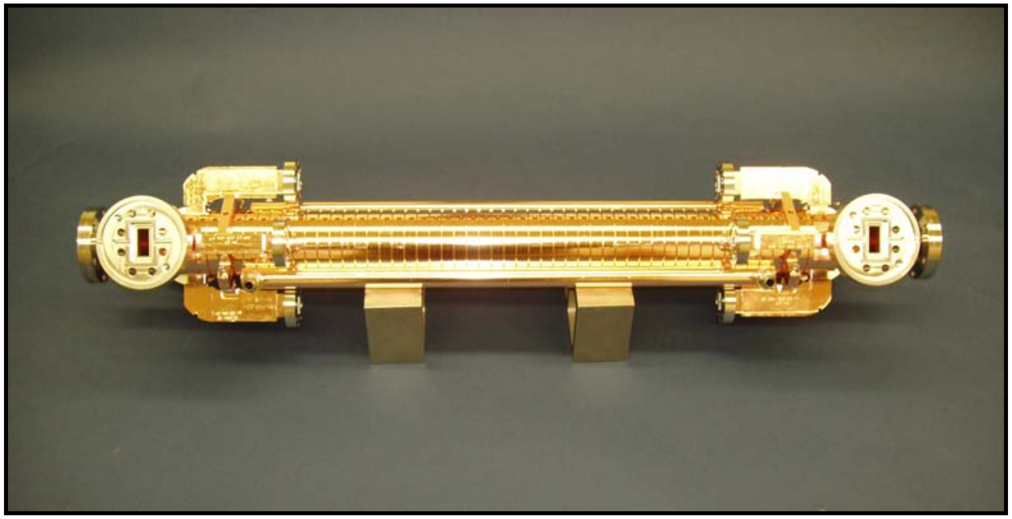


Summary of 30 GHz results

All measured data at 70 ns pulse length and 10^{-3} breakdown rate

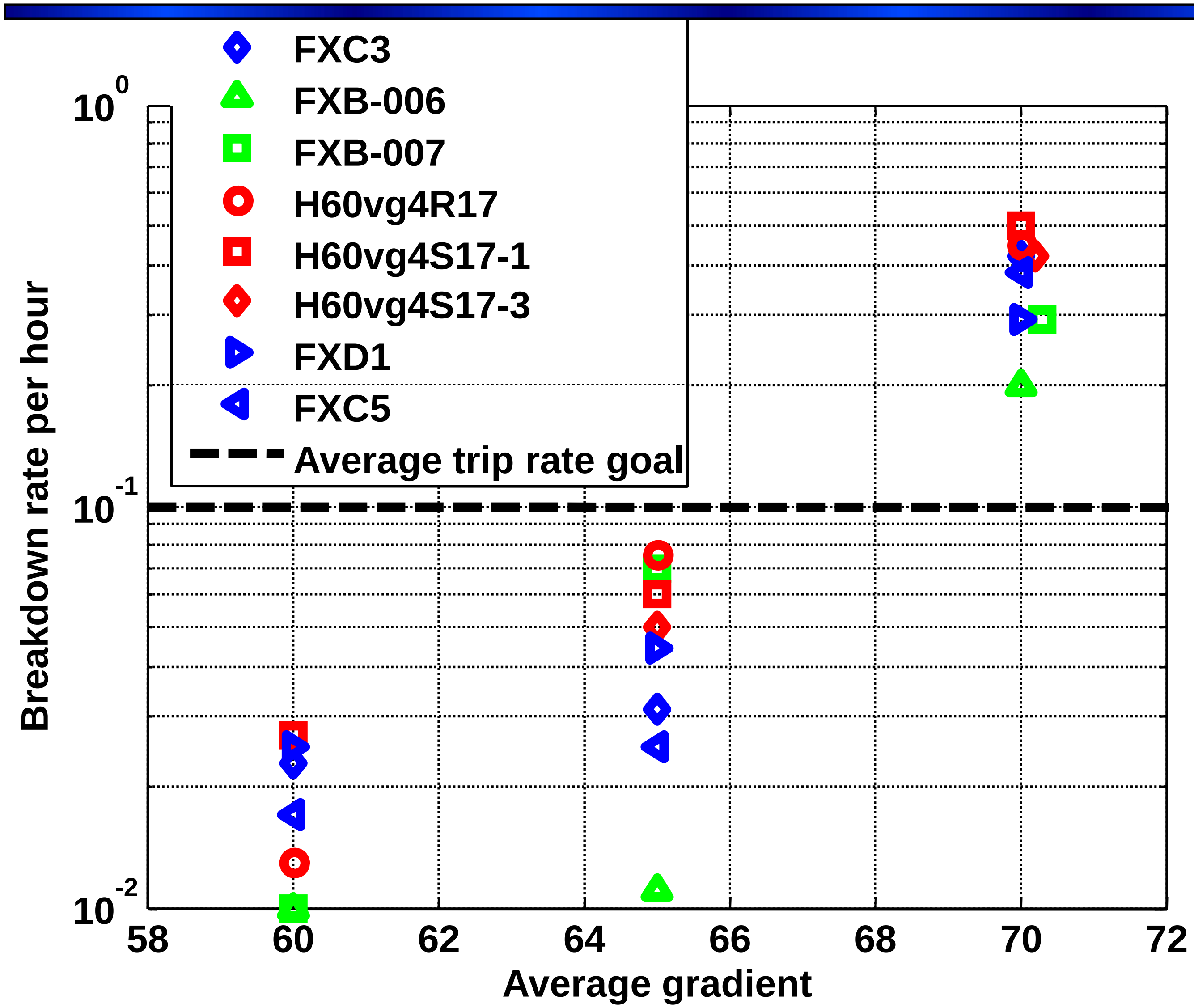
Structure	2a (mm)	P (MW)	E (MV/m)	$PT^{1/3}/C$ (wue)
C30vg4.7	3.5	20.2	92	7.5
HDS60vg8.0	3.8	16.1	61	5.6
HDS60vg5.1	3.2	13.3	75	5.5
C40vg7.4_pi/2	4.0	19.2	65	6.2
HDS4vg2.6_thick	3.5	7.5	67	2.8
NDS4vg2.5_thick	3.5	8.6	75	3.2

Typical NLC/GLC prototype structures



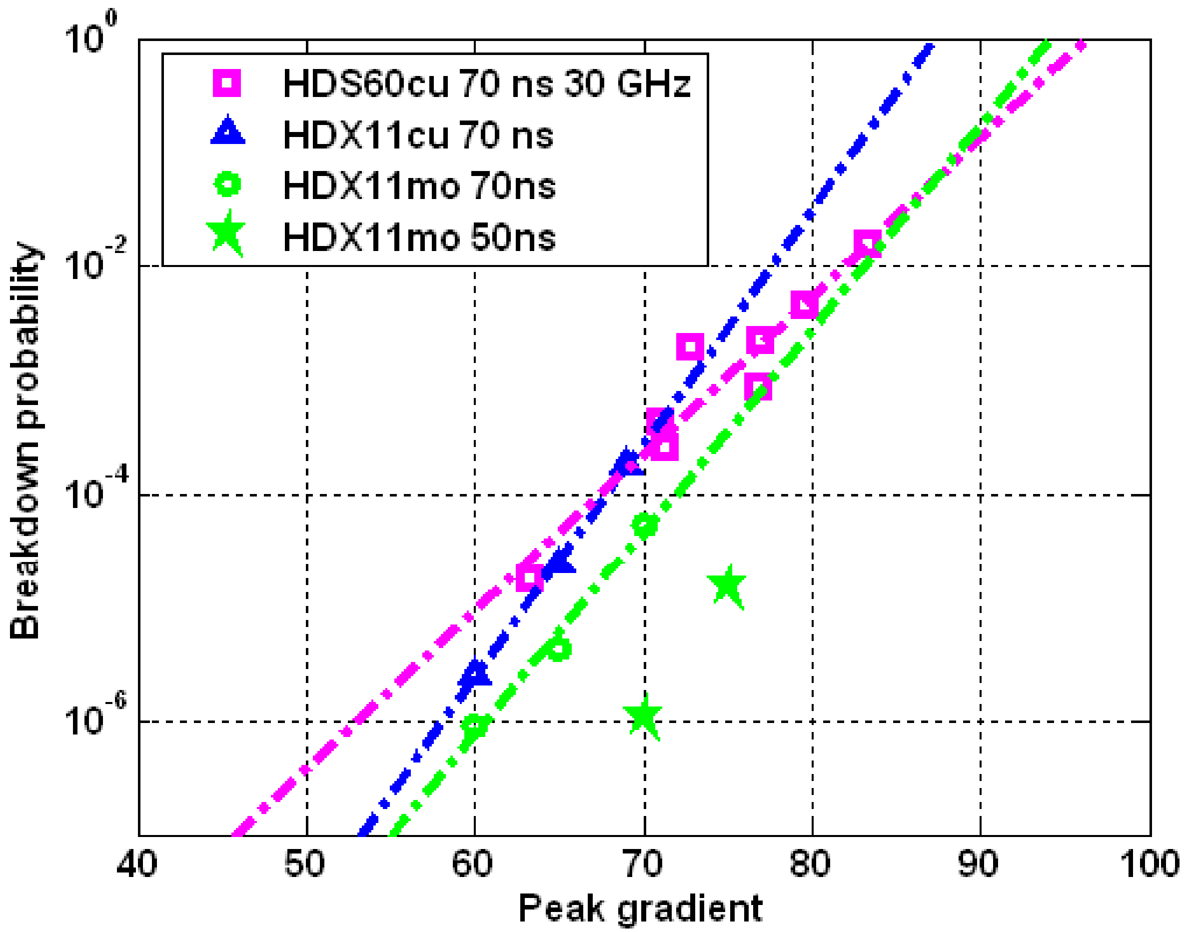
Length:	60 cm
Phase advance:	120 deg
Group velocity:	4 %
a/λ:	0.17
Es/Eacc:	2.2
P_{in} (65 MV/m):	59 MW
Coupler:	mode luncher
Preparation:	H-brazing, diamond turning

Performance of NLC/GLC structures



Spread in performance for 'identical' structures

Hybrid damped structures (HDX) at x-band
Frequency scaling



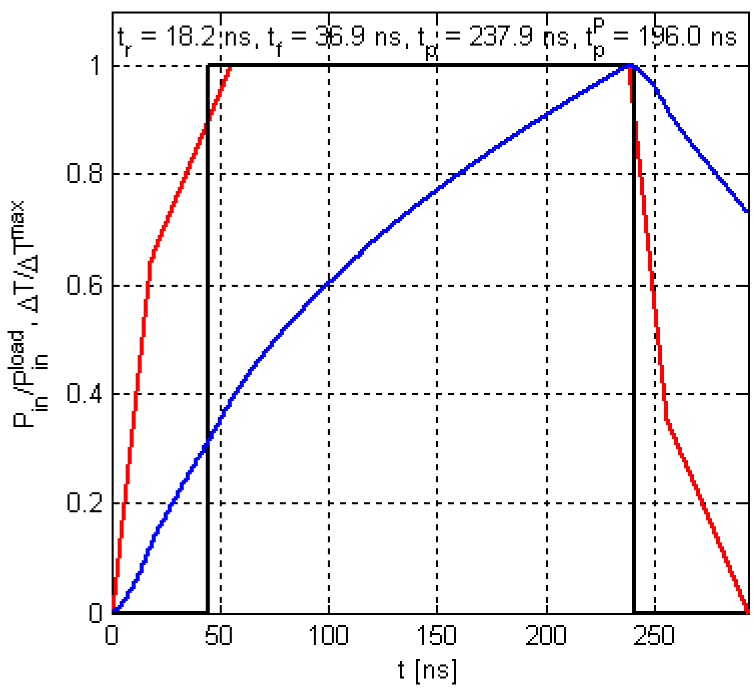
Scaled structures show very similar performance

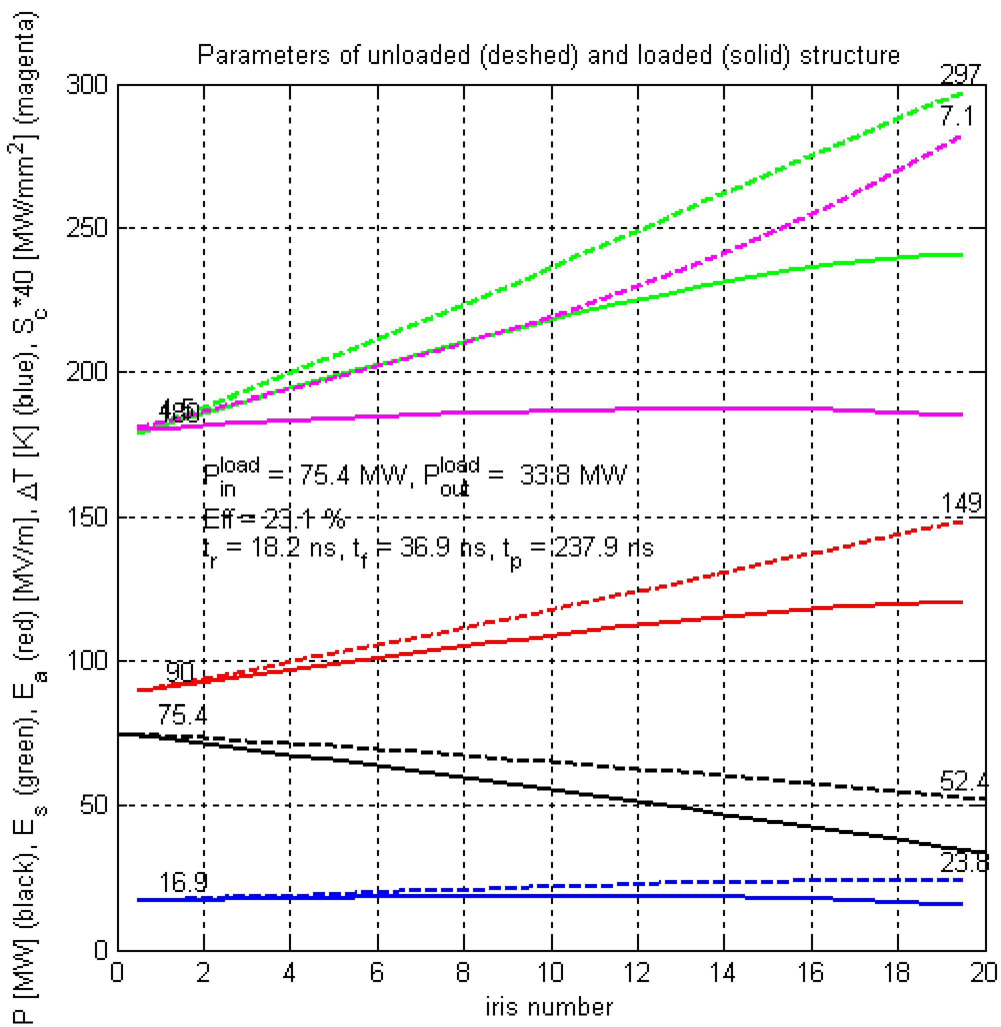
HDS-type structures show consistently limited performance

High Power test of T18_VG2.4_disk [2]

Our best results to date !

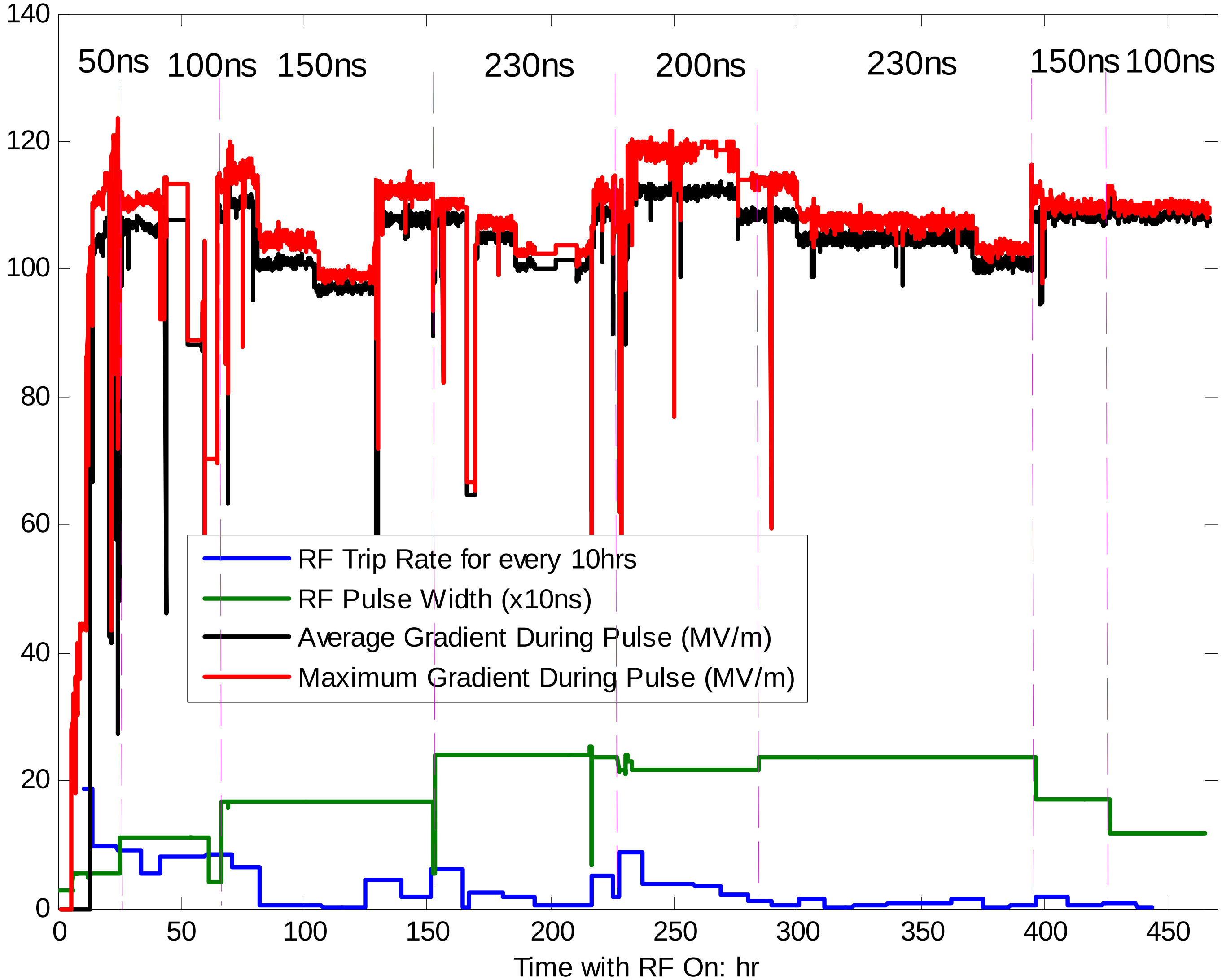
Field quantities of T18_VG2.4



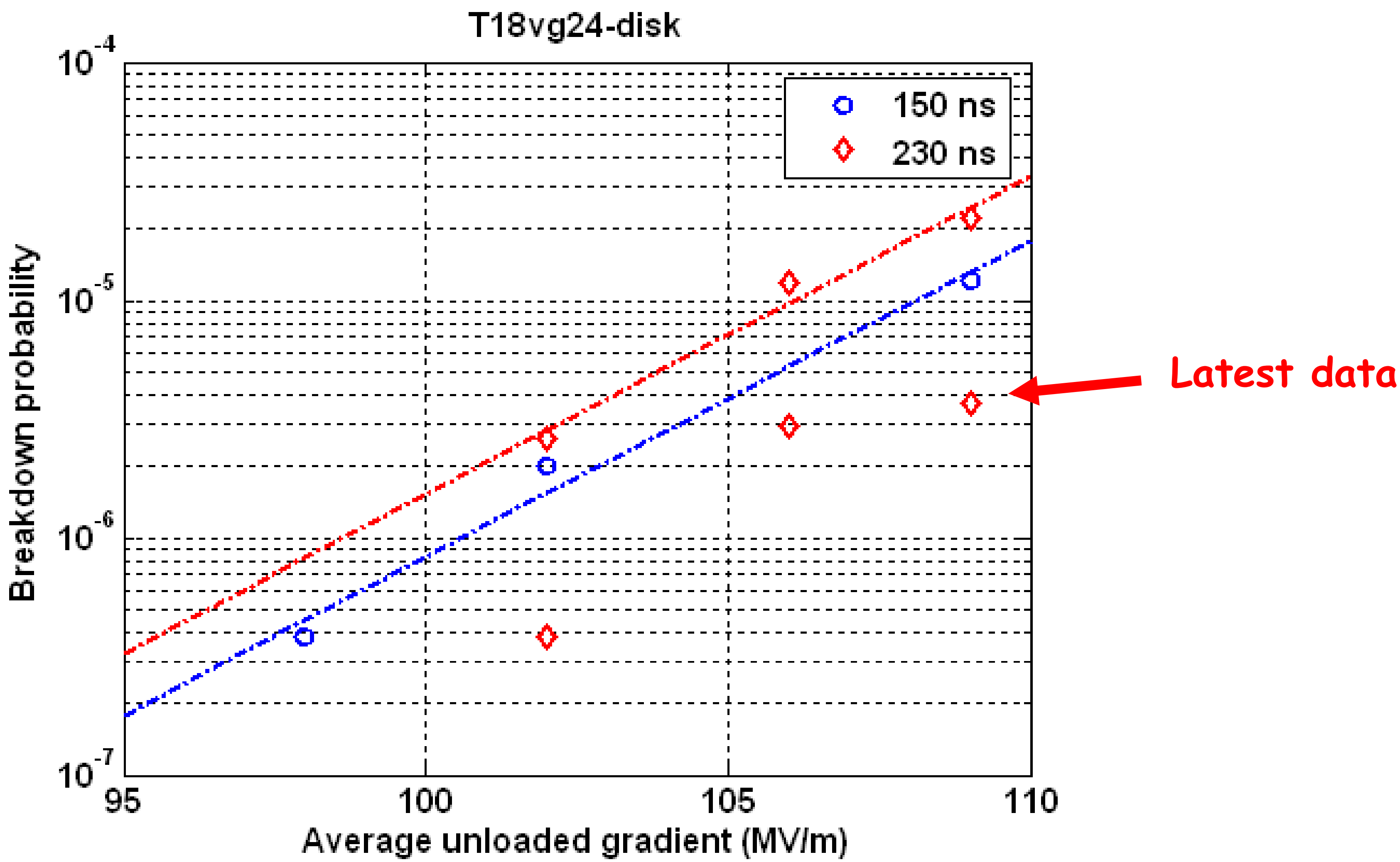


Alexej Grudiev

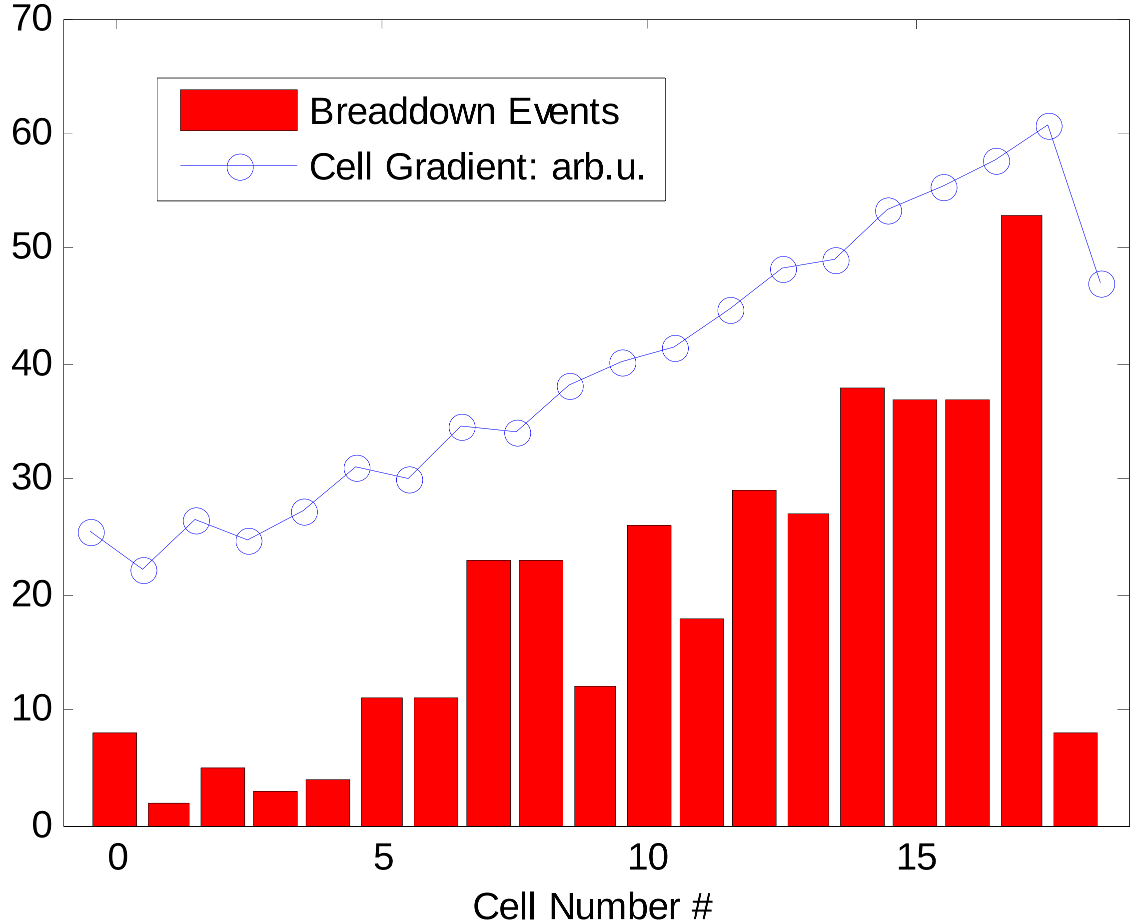
T18VG26_disk conditioning history

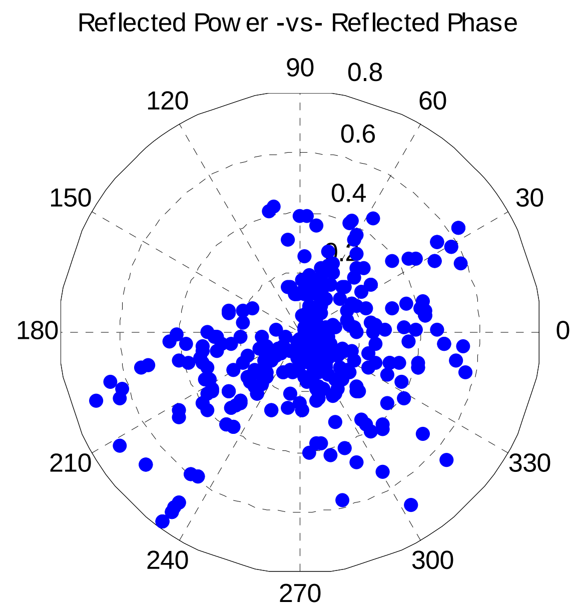


Break down rate vs gradient (unloaded)



Position of rf breakdowns

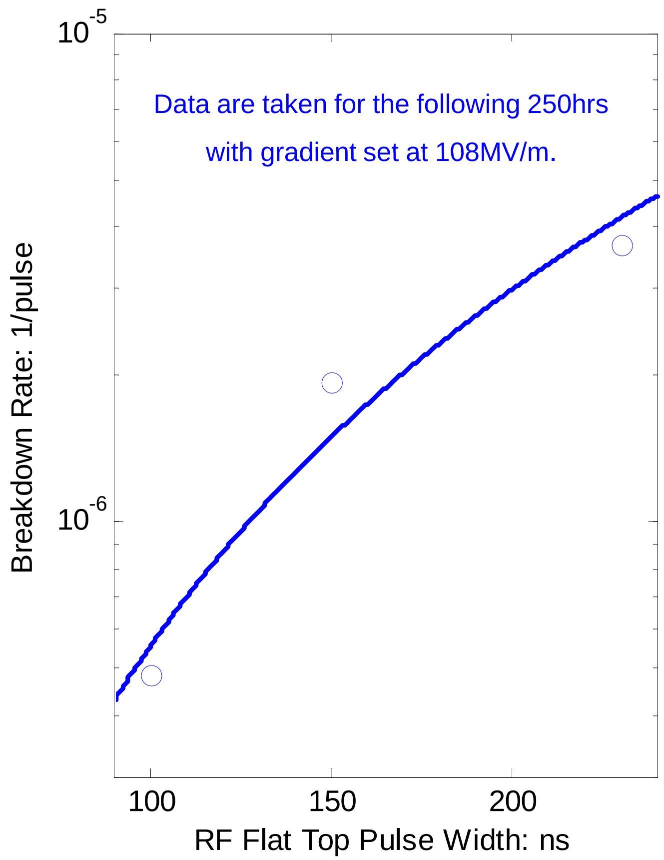


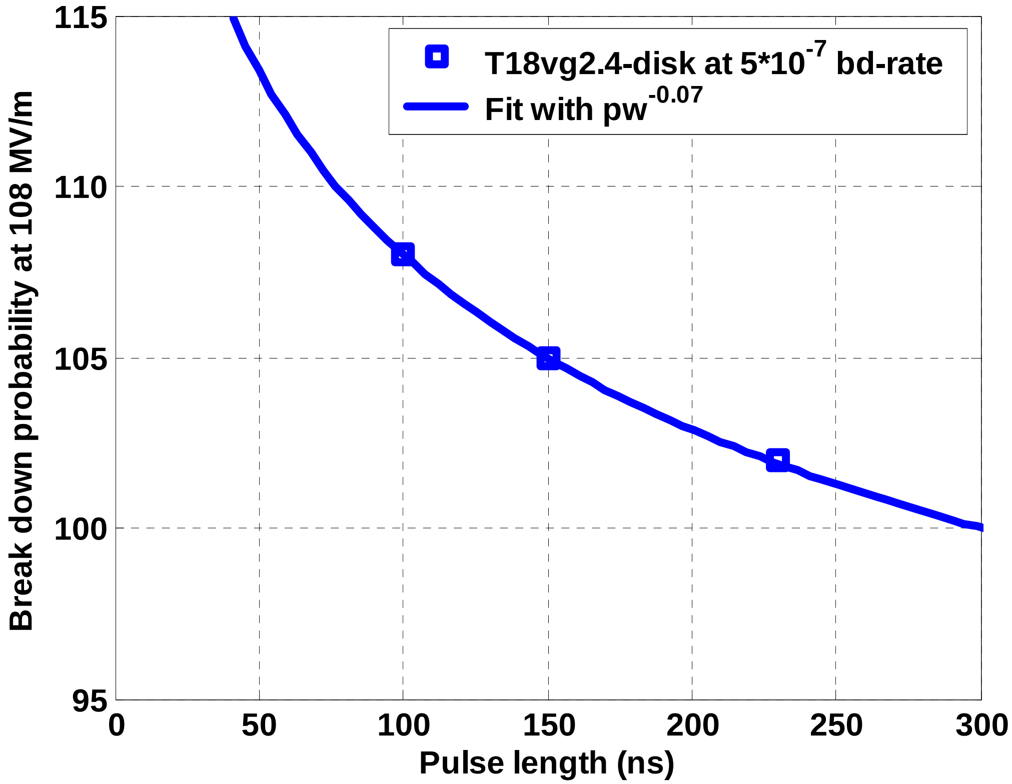


Faya Wang

Here very nice correlation between rf parameters and break down position.
We have however many example which haven't shown this correlation.

T18_vg2.4 pulse length dependence

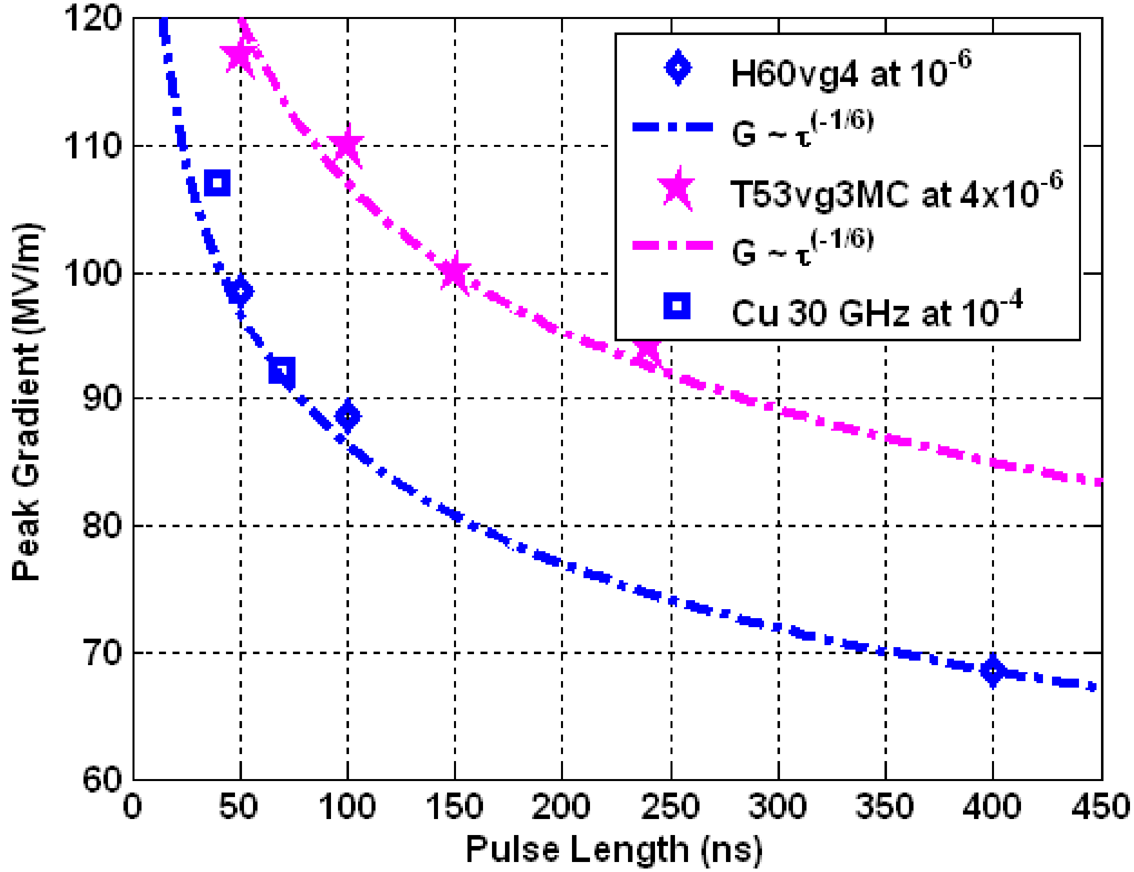




Breakdown rate has a gradient dependence ~ G^{32}

and pulse width dependence ~ $PW^{2.4}$

Pulse Length Dependence



Curiosity: Breakdown delay seems to be homogeneously distributed within the pulse duration. One pulse seems enough to loose all memory about previous time structure.

Summary of 11 GHz results

All data around ~10^{-6} breakdown rate

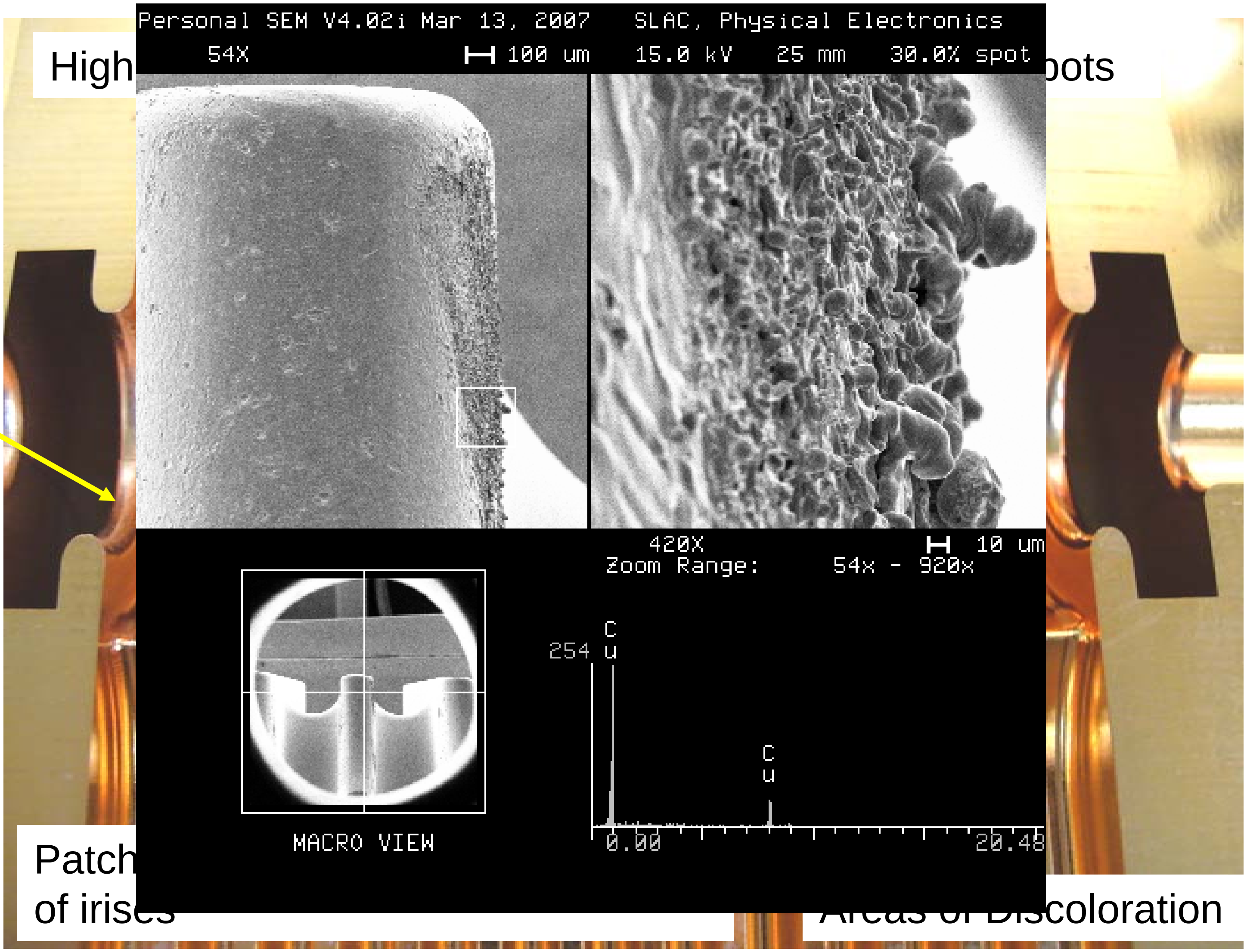
Structure	P (MW)	E (MV/m)	$PT^{1/3}/C$ (wue)
T53vg3MC (50ns)	118	110	18
T53vg3MC (100ns)	107	105	20
H75vg3 (150 ns)	155	97	27
HDX11vg5 (70 ns)	59	60	9
T18vg2.4_disk [2] (230 ns)	59	103	14

First result on power ramping during filling:

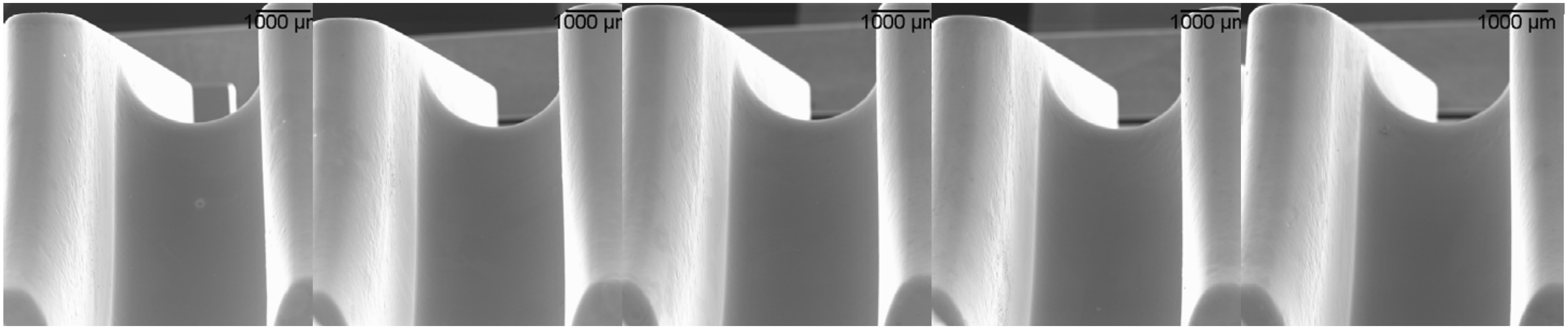
100 ns ramp (50%-100%) + 100 ns flat top: 97 MV/m at 10^{-6} BDR

Post mortem inspection of HDX11cu

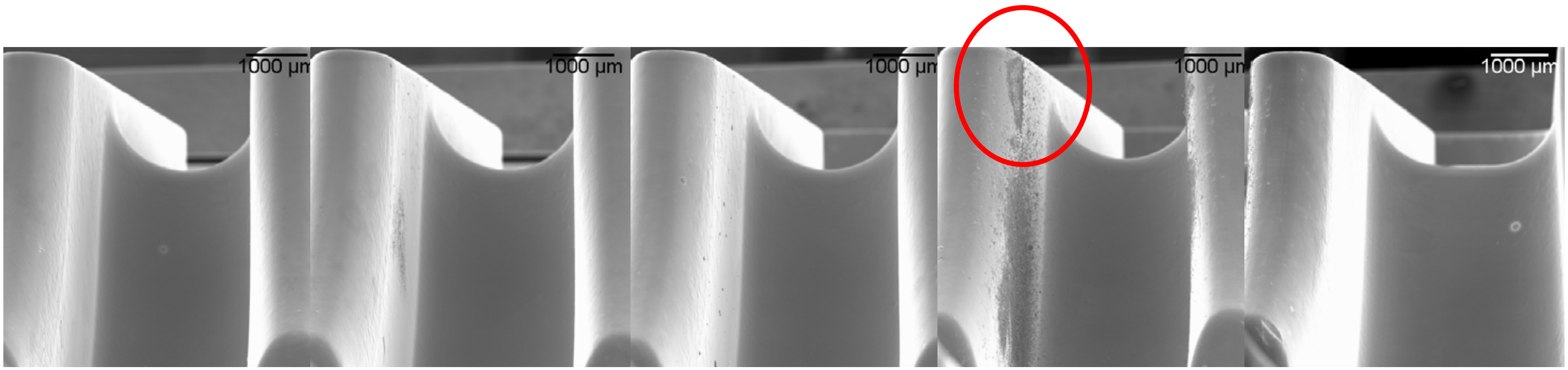
Input
Coupler
Iris



SEM pictures after electro polishing and retesting of HDX11



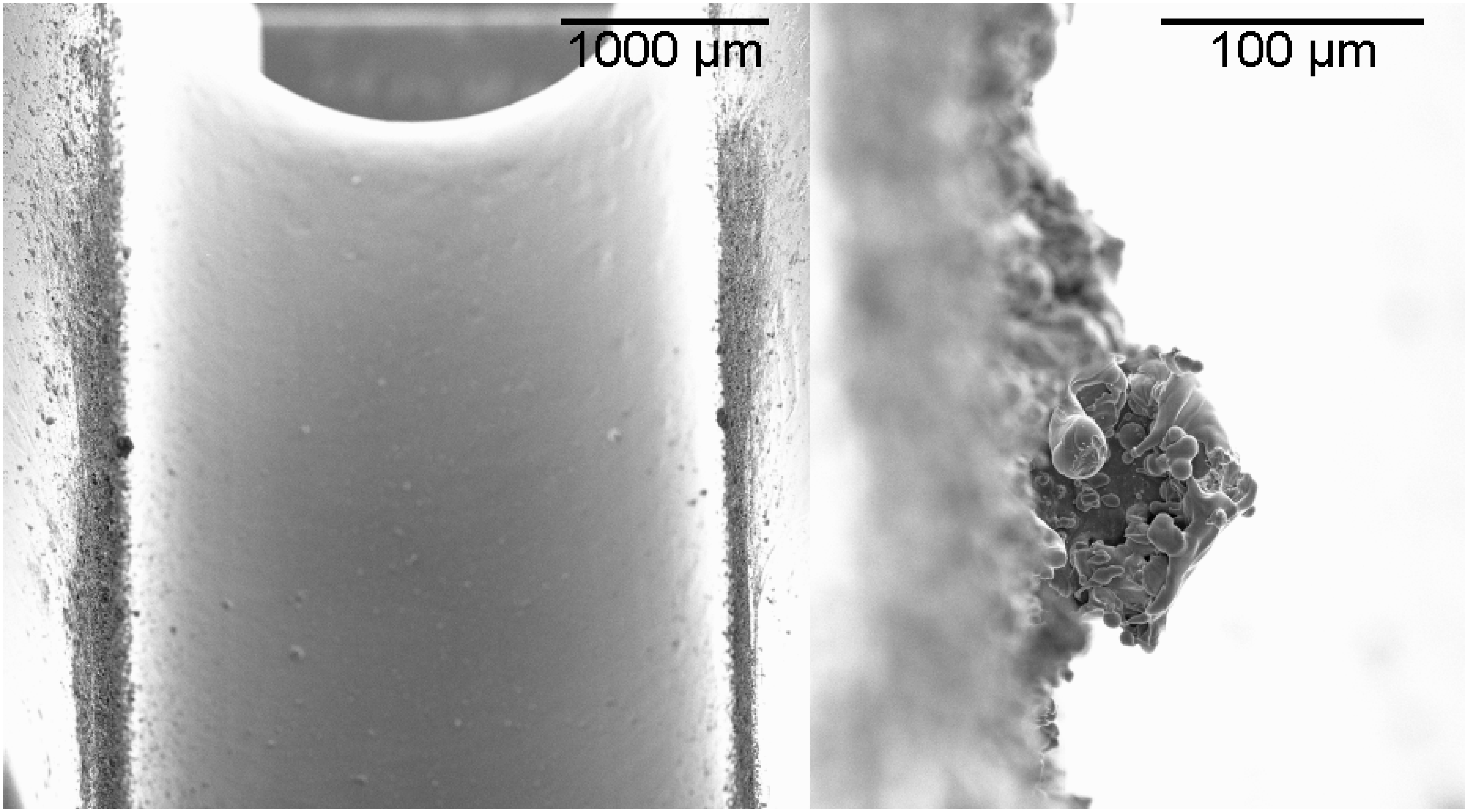
9 cell | 8 cell | 7 cell | 6 cell | 5 cell



4 cell | 3 cell | 2 cell | 1 cell | 0 cell

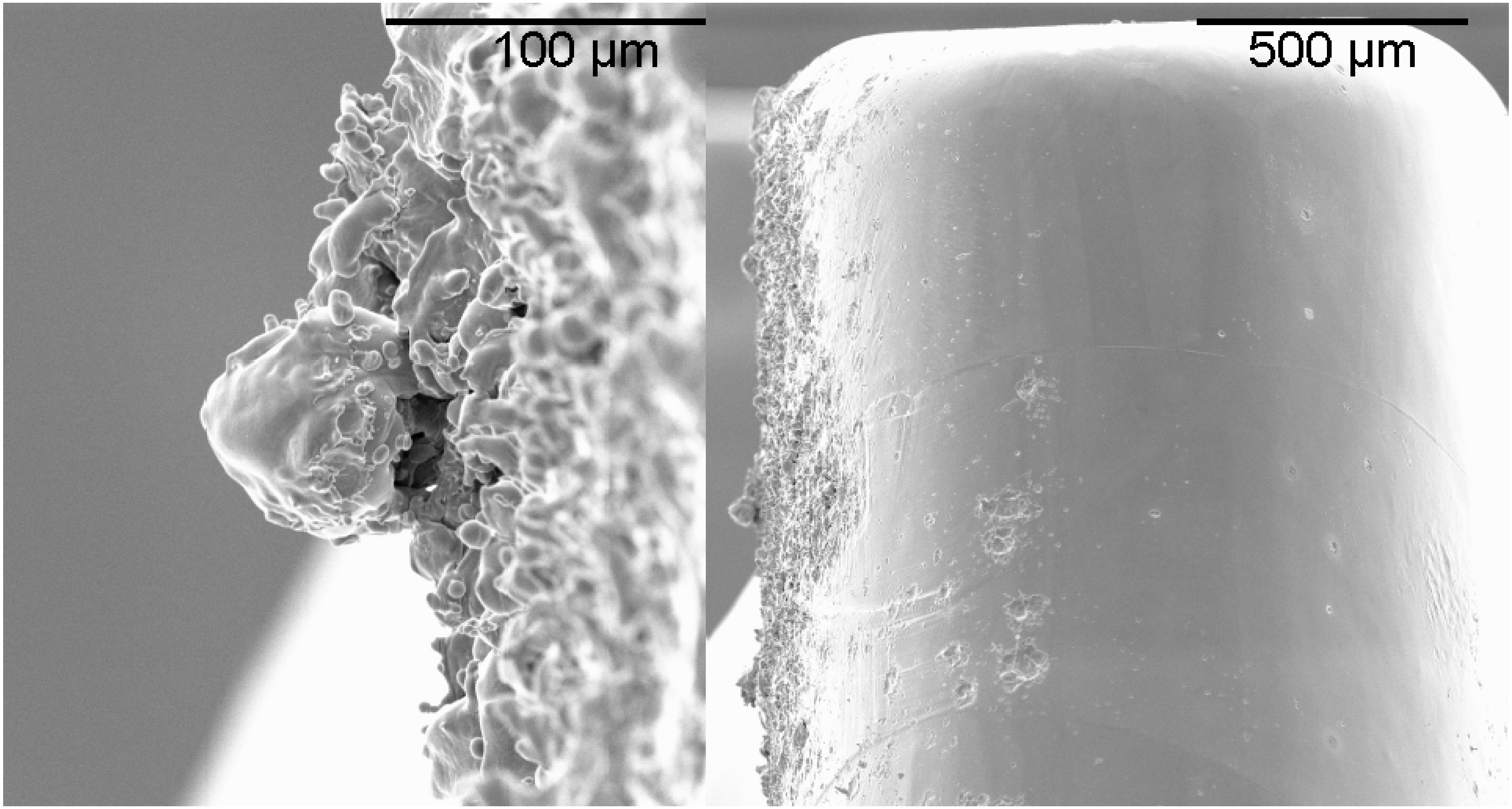
Mainly first regular cell damaged

SEM pictures



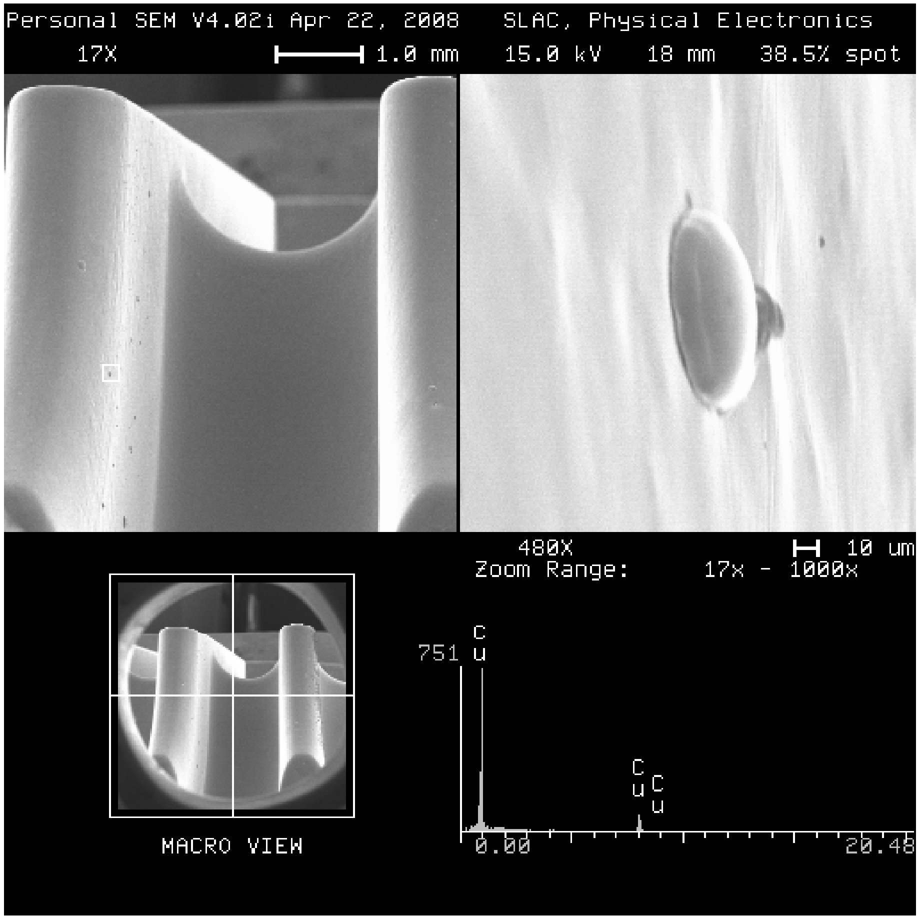
Cell No. 1 , growing tips
are they connected ?

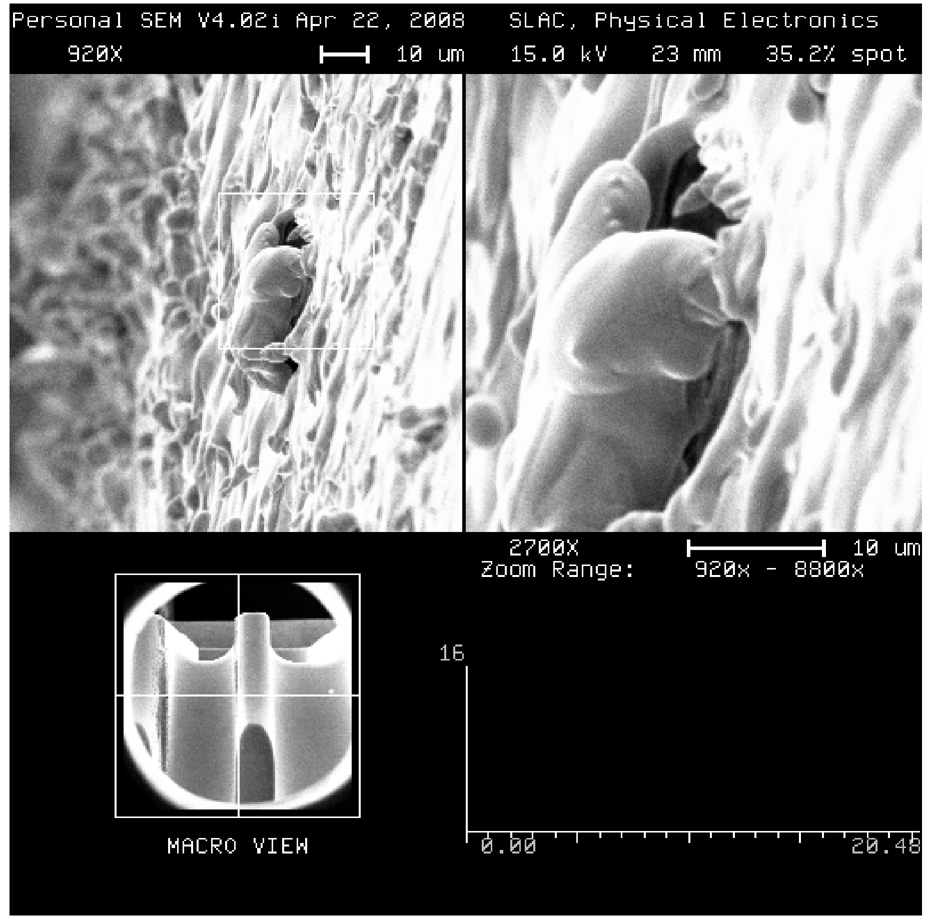
SEM pictures



Cell No. 1 , growing tips

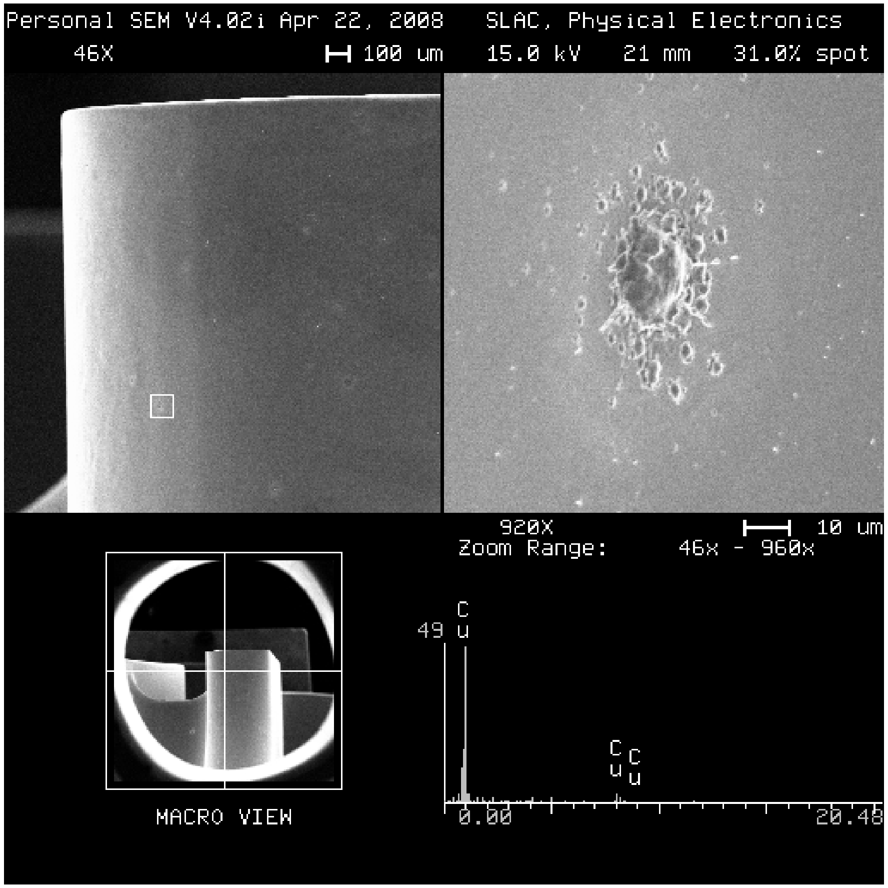
SEM pictures

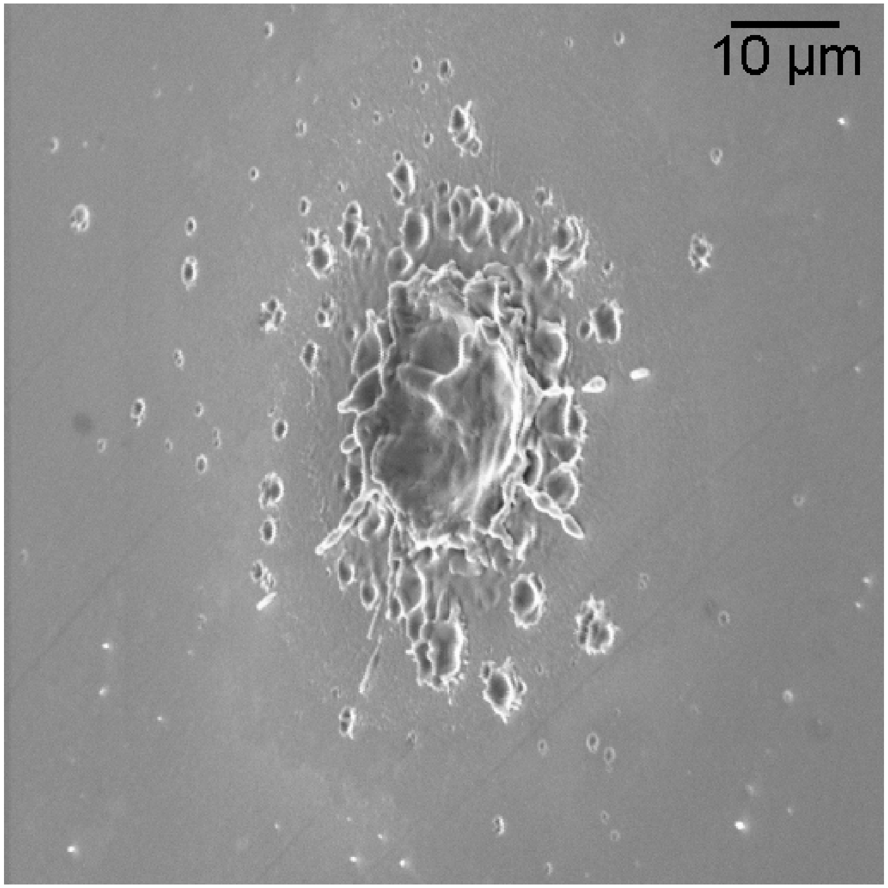




Curiosities

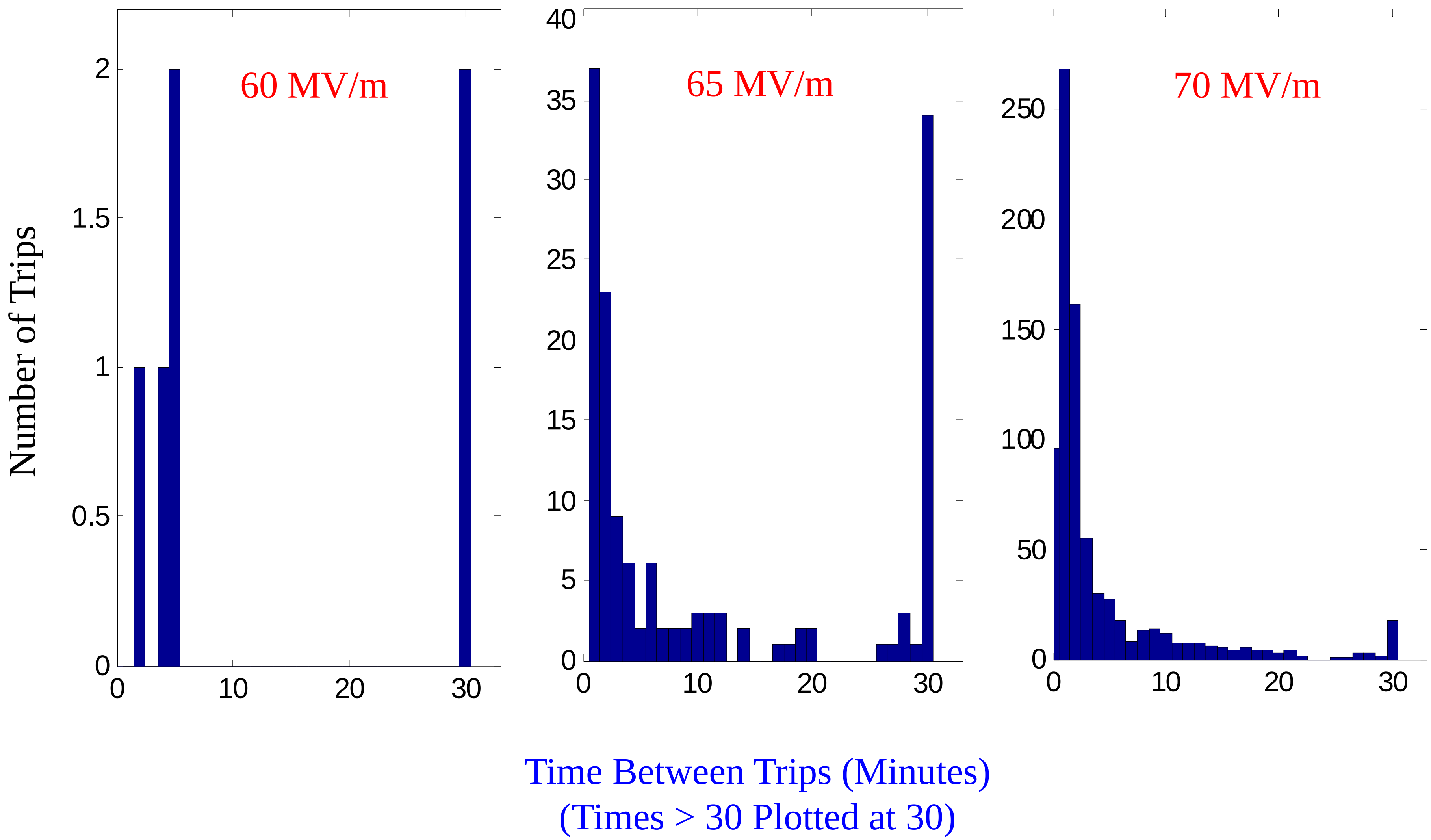
SEM pictures





Splash, mechanism, where does it come from

‘Spitfest’ Statistics for H60VG3S18 at 400 ns



The end, reserve slides following