An update of the high-power rf constraints based on recent experiments

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Parameters away-day
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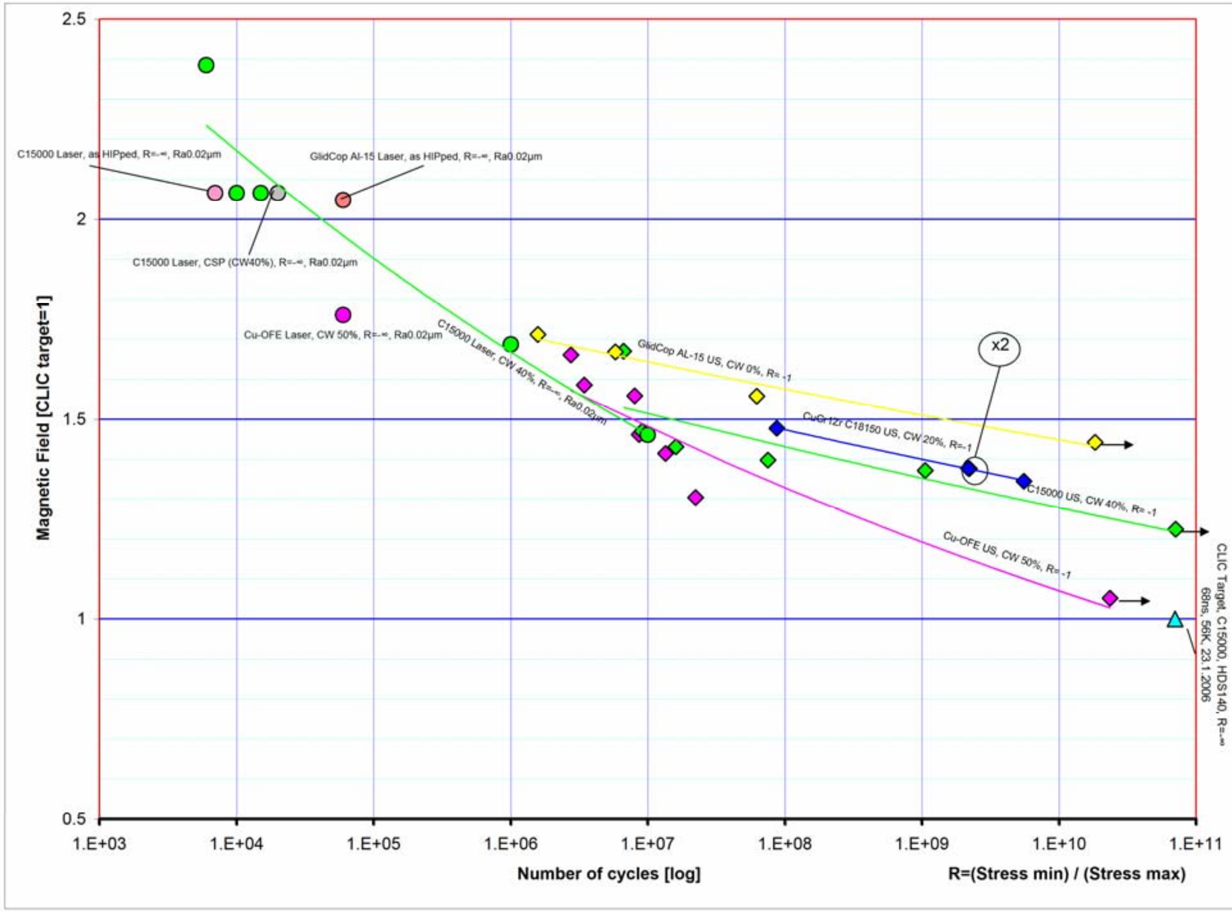
The rf constraints as we see them now,

- Peak surface electric field
- Power flow – pulse energy (pulse length dependence later)
- Pulsed surface heating

Pulsed surface heating



All experimental results indicate that we are likely to make it with the existing limit, 540 MA/m and 70 ns – although there are some questions on how to achieve the necessary metallurgical states in bimetallic pieces.

Power flow - pulse energy: basic performance

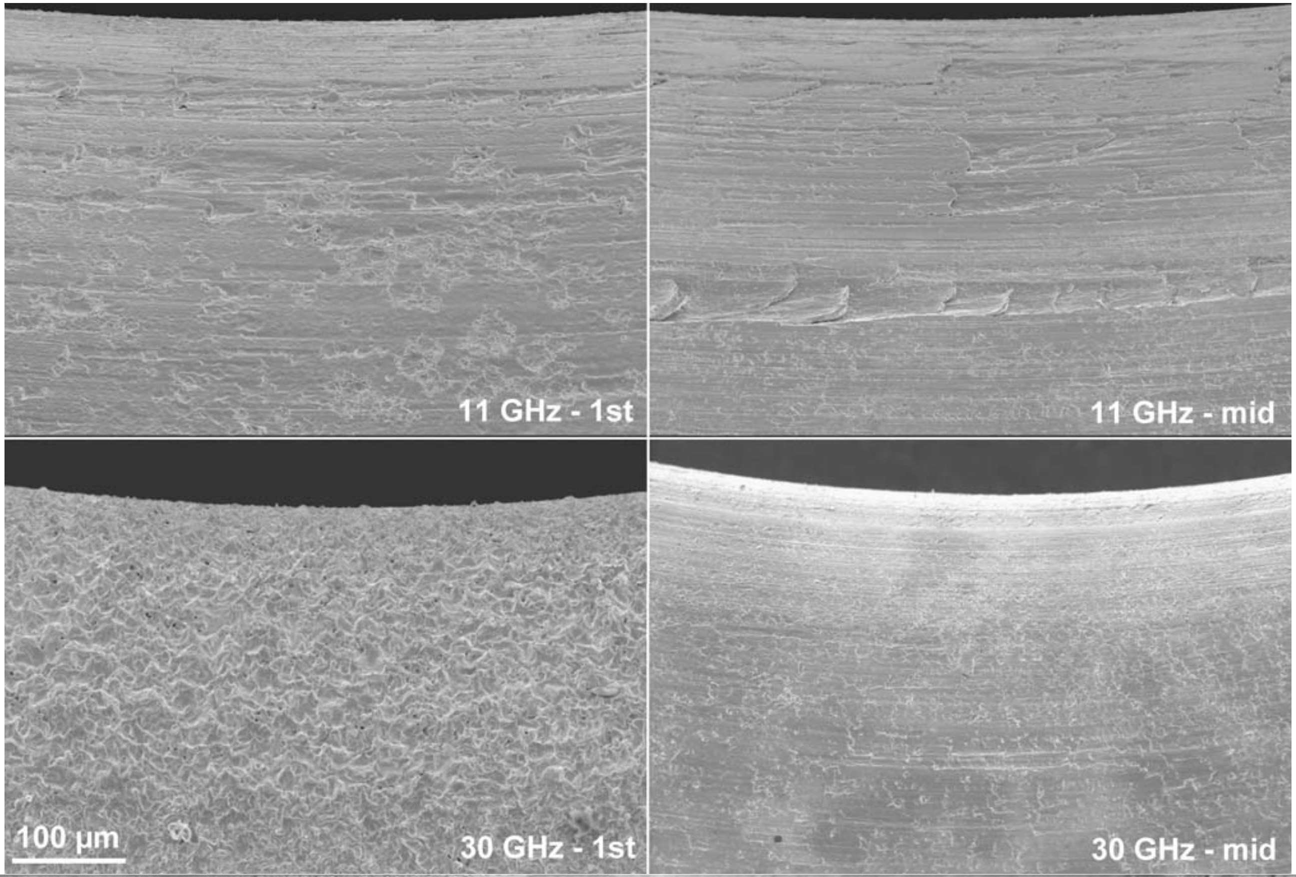
Compare CTF2 and CTF3 runs of identical Mo iris structures

	E_{acc} [MV/m]	T [ns]	Power [MW]	U [J]
CTF2	193	16	93	1.5
CTF3	148	55	70	3.8

Key question: Have we hit the 'pulse energy' limit?

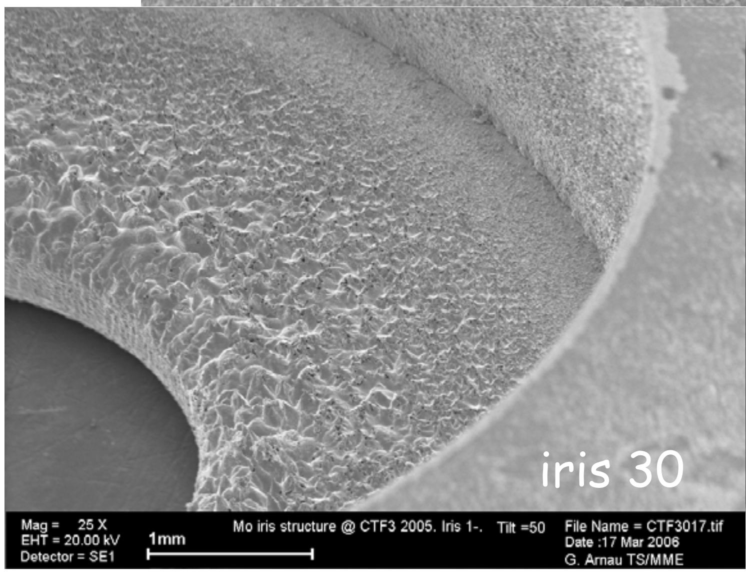
Surface states

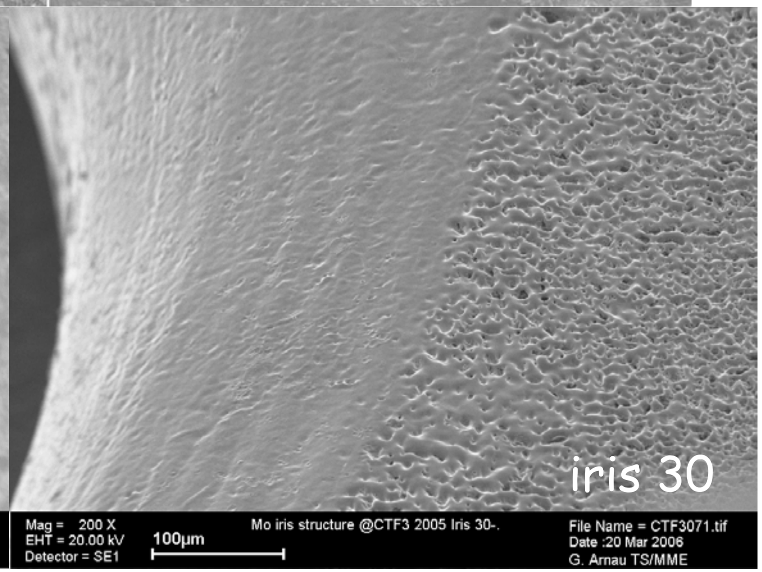
11 GHz

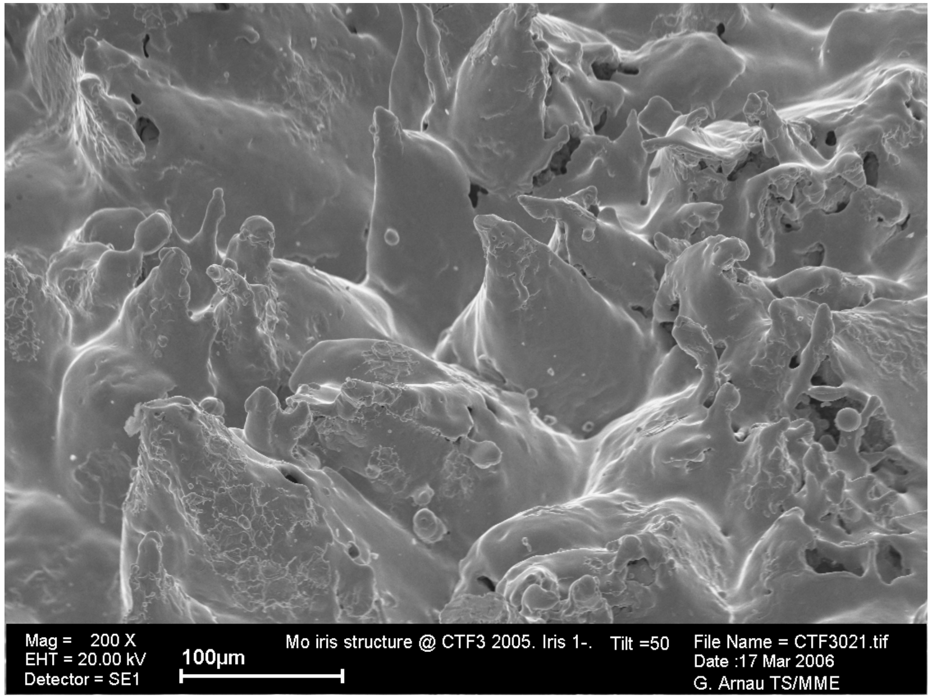


30 GHz, CTF2

30 GHz, CTF3

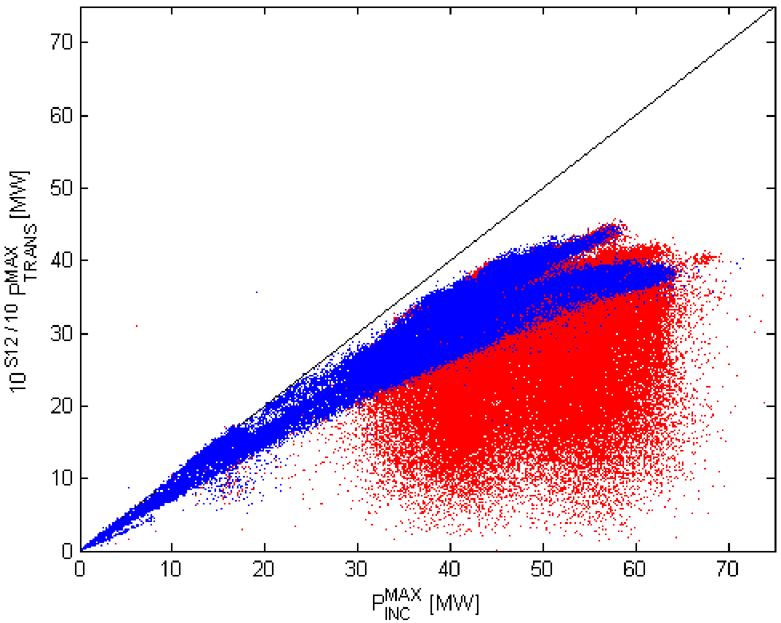






Anybody wanna estimate this surface field?

Perhaps the non-linearity was real.



The CTF3 test had 'lower' surface fields but much more 'damage' which supports the idea of a 'pulse-energy' limit.

So,

My conclusion – Yes we have hit the 'pulse energy' limit at 50 MW, 70 ns in the Mo-iris structure. The appropriate limit in the CLIC HDS should be about the same because it has roughly the same circumference (+20%) and the same pulse length (Scaling to a different pulse length would introduce some uncertainties, more later). The current values are 150 MW, 68 ns.

Corrections to the basic limit of 55 MW, 70 ns

- Conditioning strategy
- Breakdown rate dependence

Conditioning strategy

Idea 1: Overly aggressive conditioning damaged structure. Better diagnostics/interlocking would improve limit.

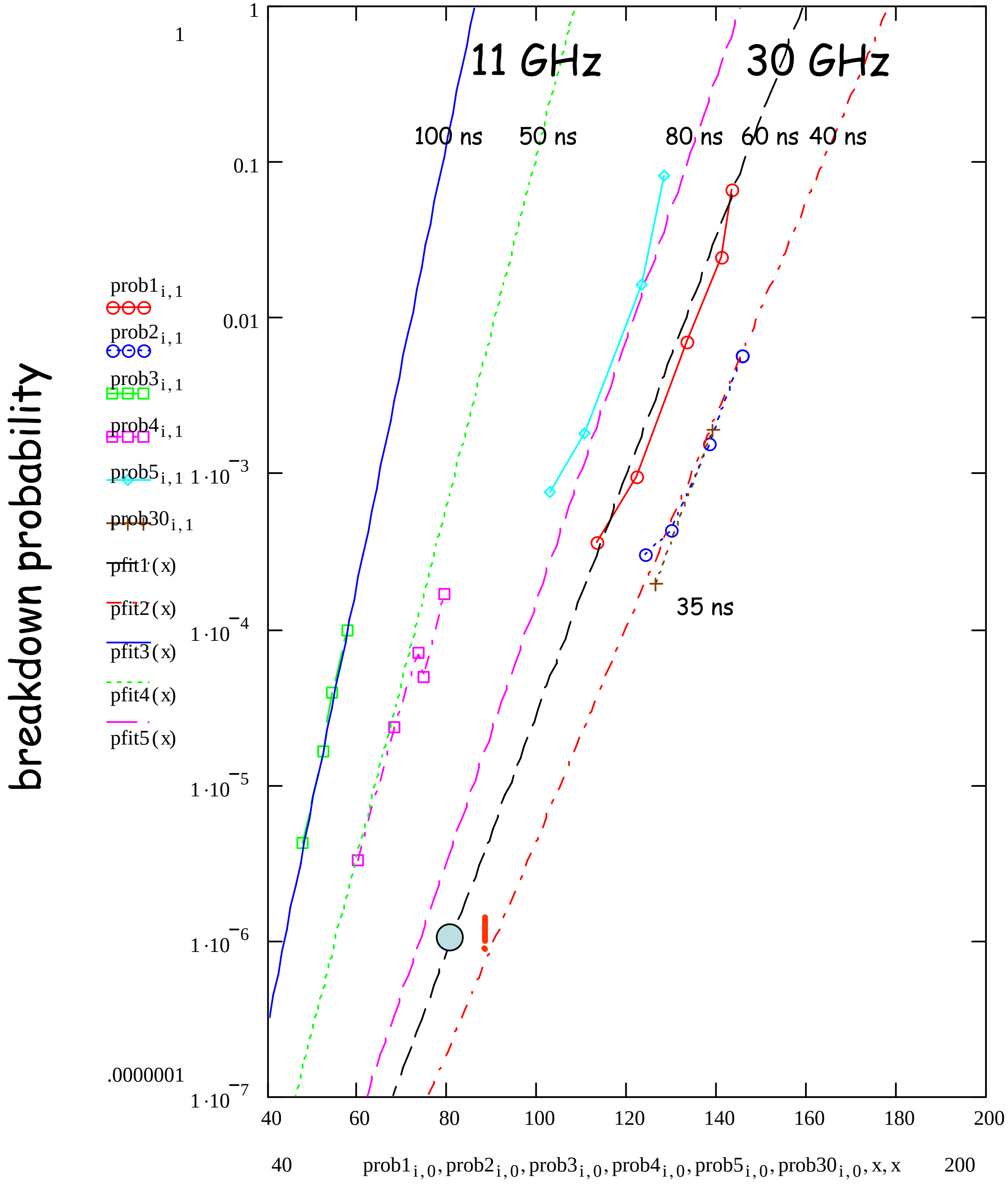
Idea 2: Damage occurred at end of conditioning process when pulse energy was highest. This would mean we would have to downgrade our 50 MW, 70 ns. But perhaps by not very much if we just need to stay below a threshold.

(I believe we are dominated by idea 2)

Peak field vs. pulse energy measurement in dc spark more important than ever.

Breakdown rate

How much do we need to back-off from the maximum conditioned value to achieve a breakdown rate of the order of 10^{-6}?



Peak E_{acc} [MV/m]

Mo iris data

One slope,
0.088*E(10^{-1})/decade

These are the first data - do we take them seriously?

Breakdown rate

- Surface is damaged which screws up breakdown rate: data are consistent with 11 GHz where the surface is not damaged.
- Breakdown rate comes coupled breakdowns all over system (PETS and high-power lined): data are consistent with 11 GHz which used klystron.
- Breakdowns are not counted correctly, ie faraday cup is too sensitive: data are consistent with 11 GHz which used NLC criteria.
- Breakdown rate comes from clamped structure: Mo HDS will be tested this year in CTF3 and possibly NLCTA.
- Low breakdown rate requires different conditioning strategy than peak gradient: how to test this is reasonably clear but this will take a lot of testing time.
- Breakdown rate slope is material dependent: Implies probability cross-over point. Could the gradient actually be much higher with copper at low breakdown rate? Cu structure is in CTF3 now and we will measure this precisely.

Breakdown rate back-off

We do not have a precise estimate but we shouldn't be surprised if in the future we realize that we have to back off by something like 20% in field from the peak value we conditioned to.
This would also mean that the drive-linac needs to produce 56% more power during conditioning than normal operation.

Breakdown rate capability for dc spark more important than ever.

Pulse length dependence

Observed pulse length dependencies vary roughly between $P\tau^{1/3}$ and $P\,\tau^{2/3}$ (from 30 GHz Mo plot) with Cu exponents lower and Mo exponents generally higher.
This is consistent with the temperature rise being closer to power flow in a high thermal conductivity material and to pulse energy in a low thermal conductivity material.
Reasonable to assume compromise $P\,\tau^{\frac{1}{2}}$ for scaling work.

Peak surface field

Data from undamaged structures is needed. Geometrical and surface changes are probably increasing the surface fields by large percentages and probably even factors. It looks like we are mostly in a regime dominated by the power flow limit.

So what are the today's best values for rf constraints (least to most controversial)?

- Pulsed surface heating: Unchanged at 540 MA/m and 70 ns with square root pulse length dependence.
- Peak surface electric field: Unchanged at 380 MV/m. Consistent with dc spark. Consistent with downstream cells in structures.
- Power flow - pulse energy: 50 MW, 70 ns downgraded by 36% (20% in field) to 32 MW, 70 ns for breakdown rate back-off. Assume damage problem is tolerable with a small back-off (threshold effect) offset by better conditioning. Assume compromise $P\,\tau^{\frac{1}{2}}$/circ for scaling work.