Status and objectives of the CLIC X-band and high-gradient activity

Status

As you will hear in this workshop, we have mostly completed the feasibility demonstration of 100 MV/m accelerating gradient for CLIC accelerating structures.

Not only have we operated a number of structures in the range of 80 to 120 MV/m, we have done this:

- At low, order of 10^{-7} bd/pulse/meter rate
- With the CLIC pulse shape
- Predictably
- Reliably

And at a bit above 100 MV/m:

- With higher-order-mode damping features

We have built up a rather clear understanding of *how* the structures behave – geometrical, gradient, pulse length, statistical etc. dependencies.

And to a large extent we also understand *why*. The mists are rapidly clearing from breakdown and other high-gradient and high-power phenomena.

Acknowledgements

Many of you have participated in this effort to raise the practical accelerating gradient from 30-50 MV/m up to 100-120 MV/m.

I would like to thank you all personally, and on behalf of the CLIC collaboration, for this excellent progress.

I would also especially like to thank our Japanese colleagues and hosts for their enormously valuable contributions and their impressive recovery from the big earthquake last year! We also all appreciate that we can have this meeting here this year.

I look forward to hearing in the coming days about all the progress we have made.

But there is still a lot more work, and opportunity, ahead – both for CLIC but also for spreading the technology we have developed to other high-gradient, normal conducting applications.

We are here.

Some thoughts about the next steps

Here's a partial list of some subjects we must address next. Some work you will already hear about in the next days. I will mention some detail on the first four:

- Measure the effect of beam loading on breakdown rate.
- Understand the difference between damped and undamped structures – 20% gradient to be gained.
- Increase and spread high-power generation and testing capability.
- Need to test more structures and for longer.
- Reproduce results with compact power couplers and damping load material installed.
- Re-optimise CLIC linac for staged energies and higher efficiency.
- Investigate alternative structures – choke mode, DDS, quadrants – as well as crab and deflecting cavities.
- Optimize the fabrication method and get ready for mass production.
- Advance theoretical and experperimental study of breakdown and high-gradient phenomena.

The effect of beam loading on breakdown rate

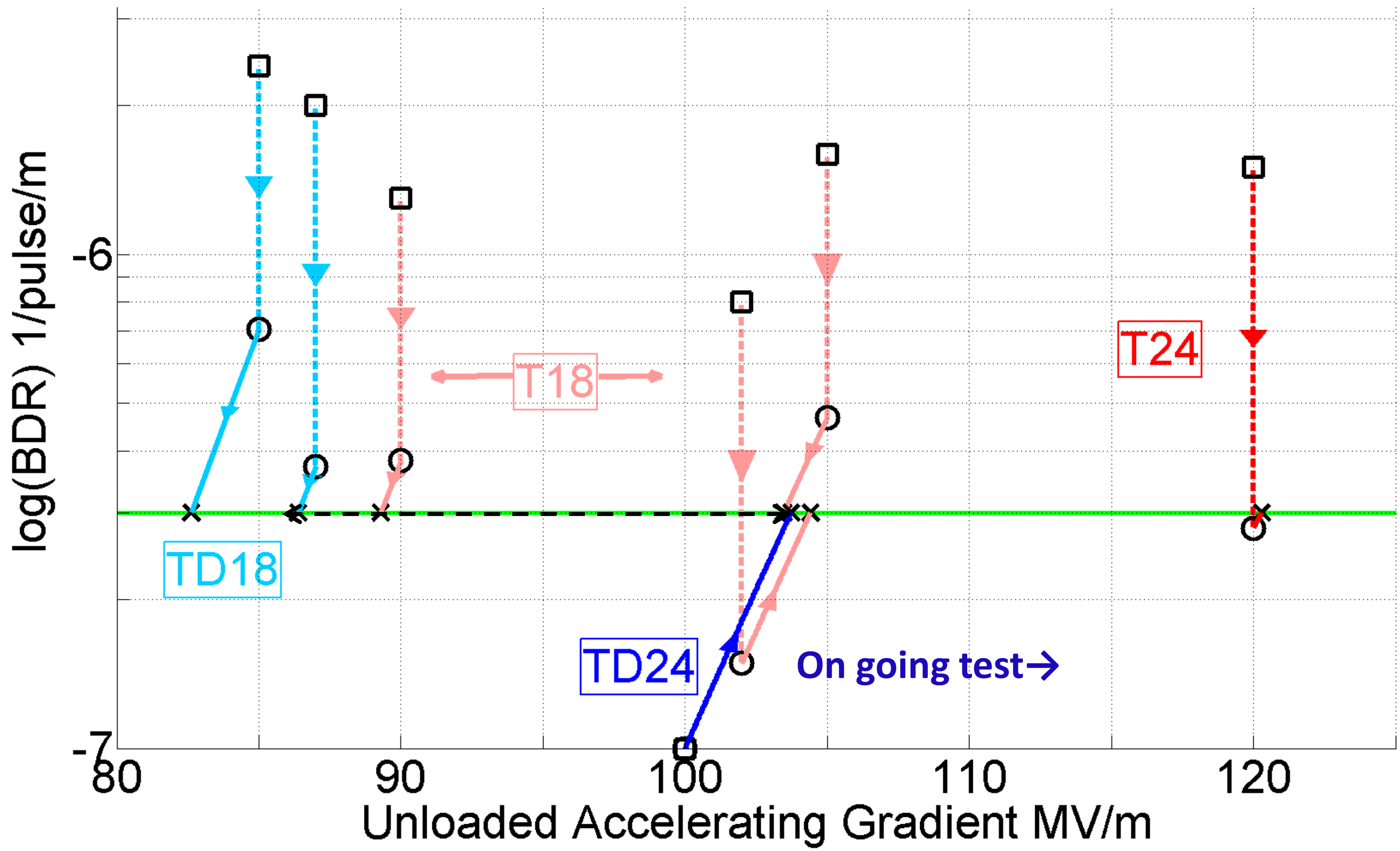
Since we must be efficient, we have significant levels of beam loading in our structures. That is the beam pulls down the fields a lot.

We will need to raise input power to compensate for beam loading as we increase current, even while the ‘average’ fields stay the same.

What happens to the breakdown rate?

Accelerating gradient test status: 6-3-2012

n.b. TD24 point corresponds to no breakdowns in 250 hr → 4.5x10[7] pulses



← - - - - - - - - - - - - - - - - - - - → Uncertainty range due to the effect of beam loading. This will be measured for the first time in the "dog-leg."

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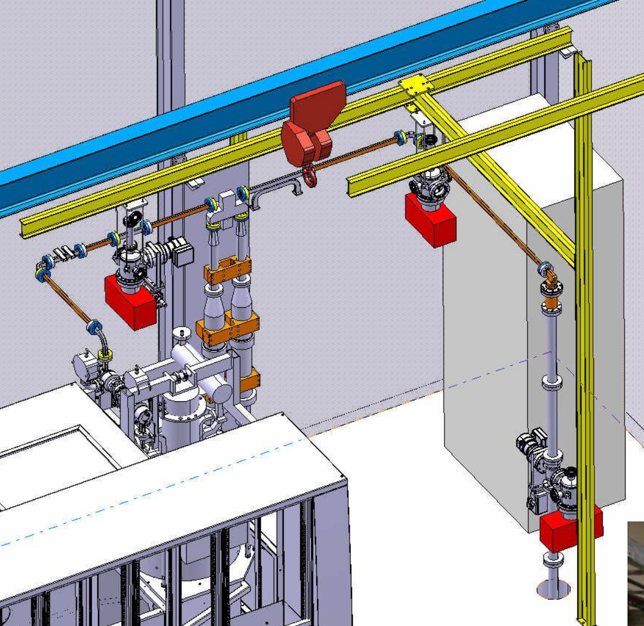
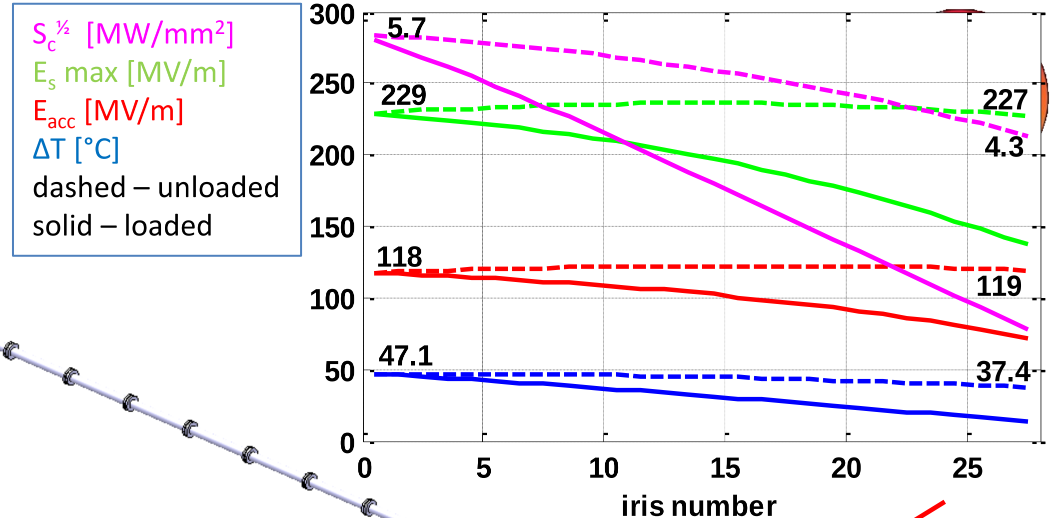
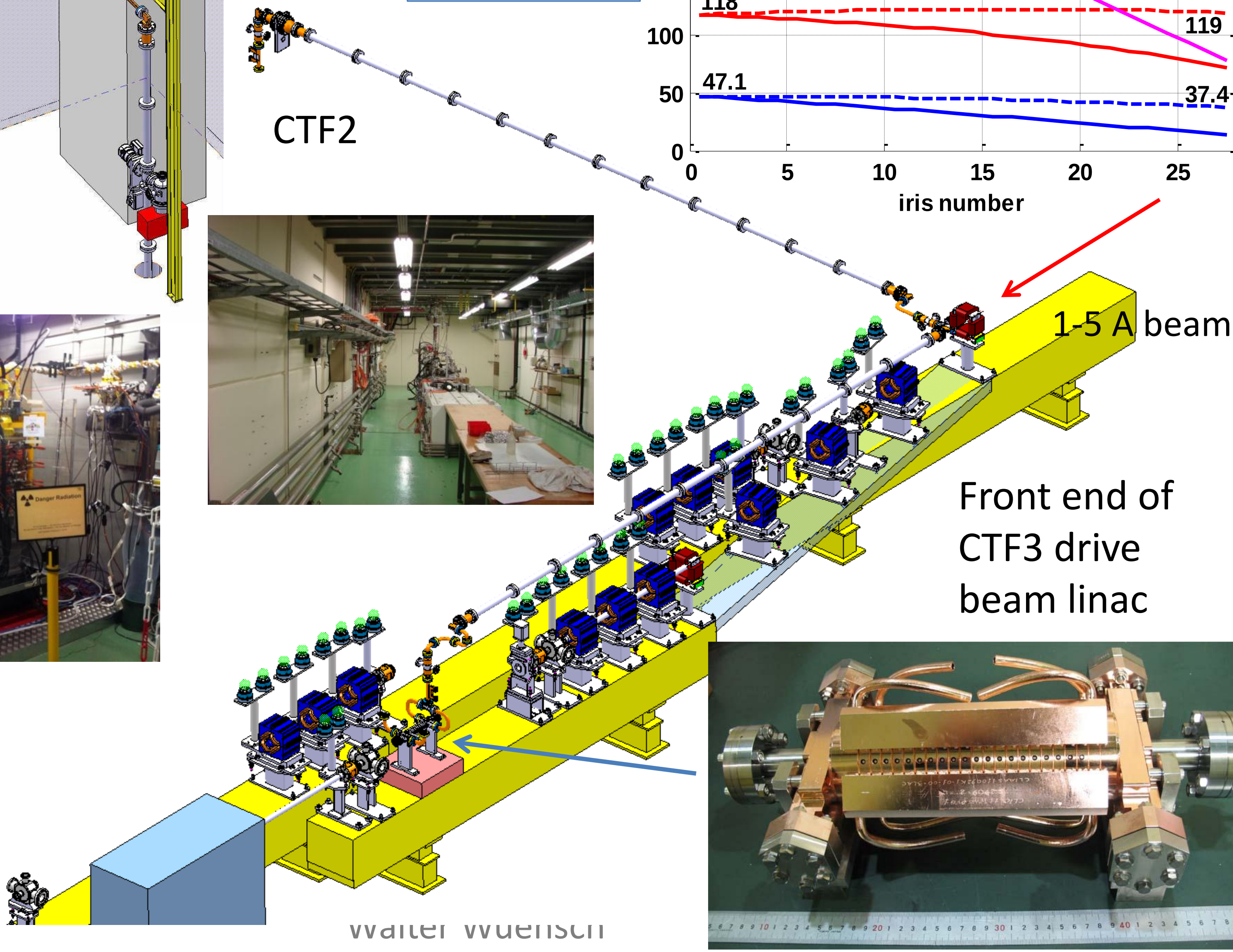
What happens to the breakdown rate?

We are preparing an experiment in CTF3 using mostly existing equipment to measure this effect.





CTF2

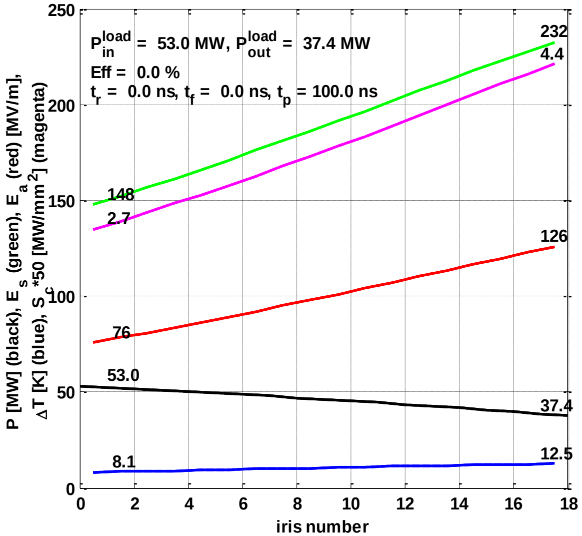


1-5 A beam

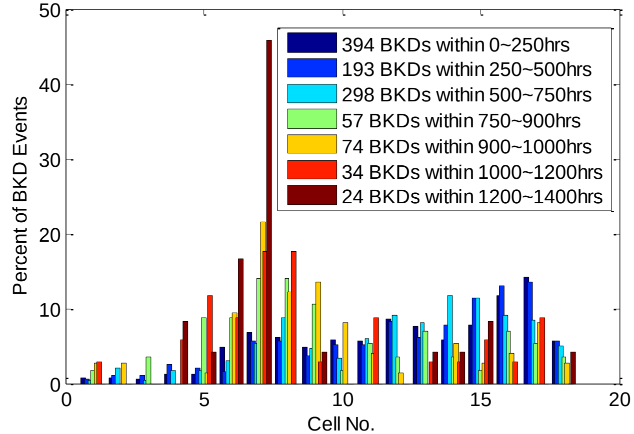
Front end of CTF3 drive beam linac

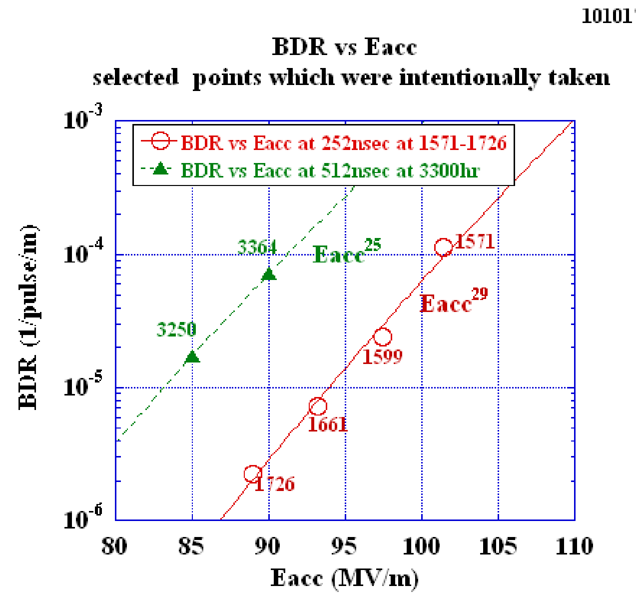
CTF3

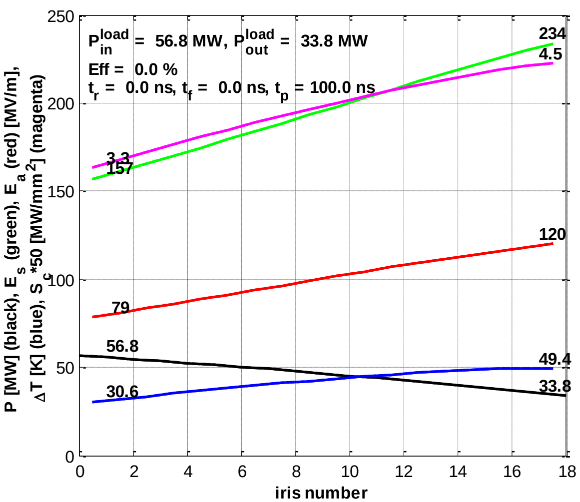
Trying to understand existing data



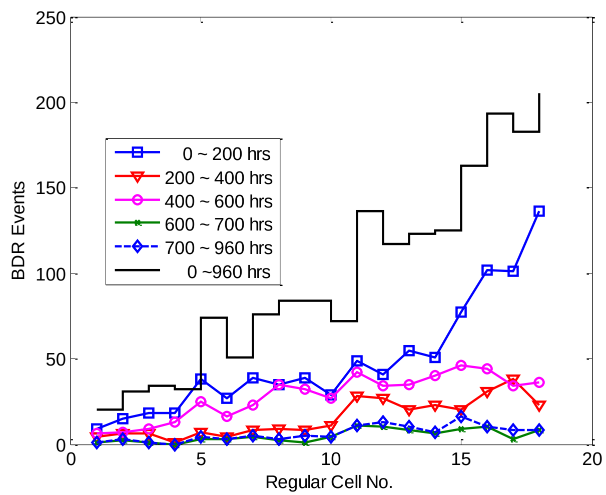
T18







TD18



Why is BDR dependence on fields so strong for the whole structure but so weak inside the structure?

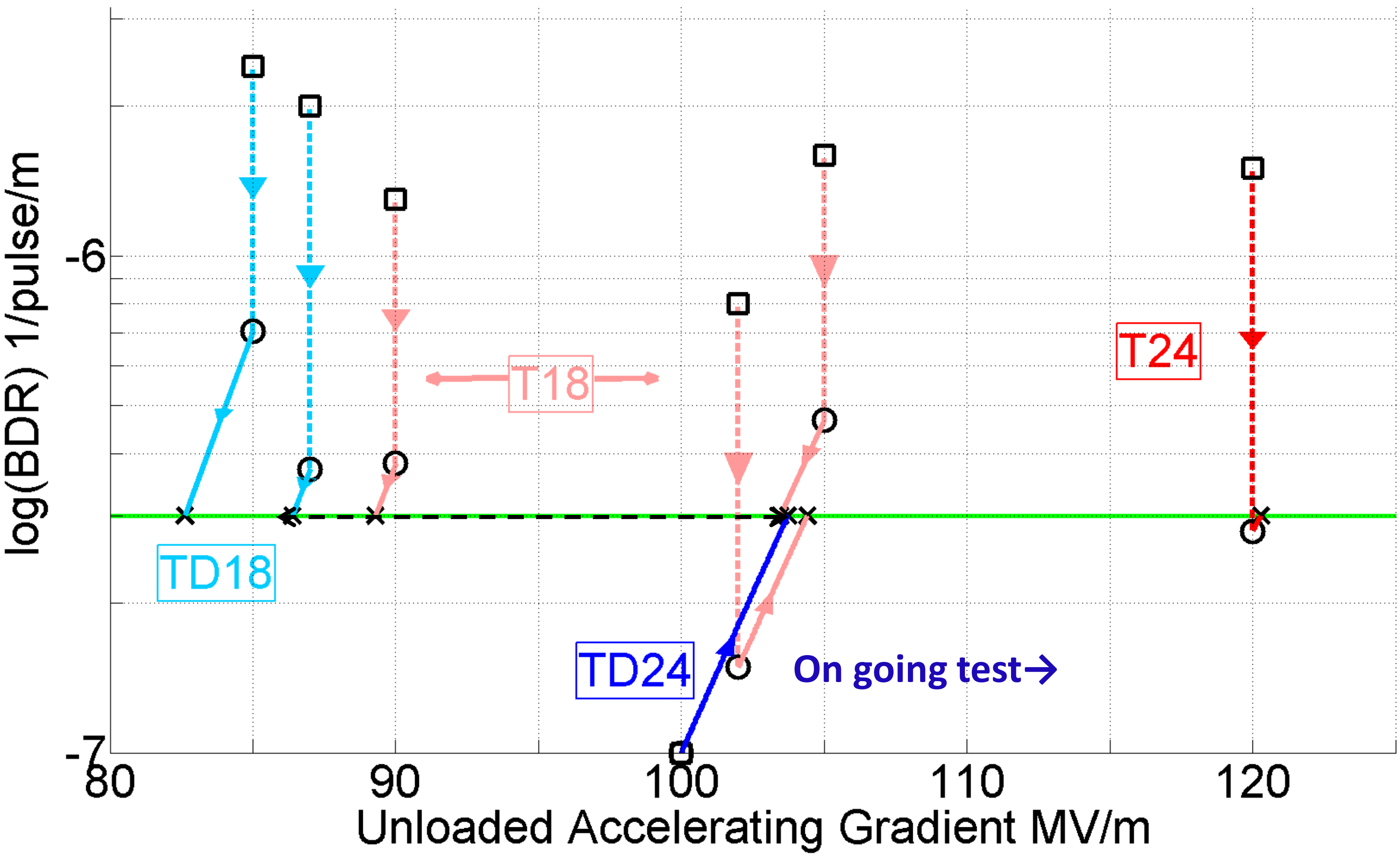
The difference between damped and undamped performance

We see approximately 20% less gradient in damped structures compared to undamped ones with the same irises.

Why?

Accelerating gradient test status: 6-3-2012

n.b. TD24 point corresponds to no breakdowns in 250 hr → 4.5x10^7 pulses



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The difference between damped and undamped performance

During post-mortem inspections of T18 and TD18 structures we have observed evidence of high-power related activity in cell-to-cell contacts.

We see two categories of activity:

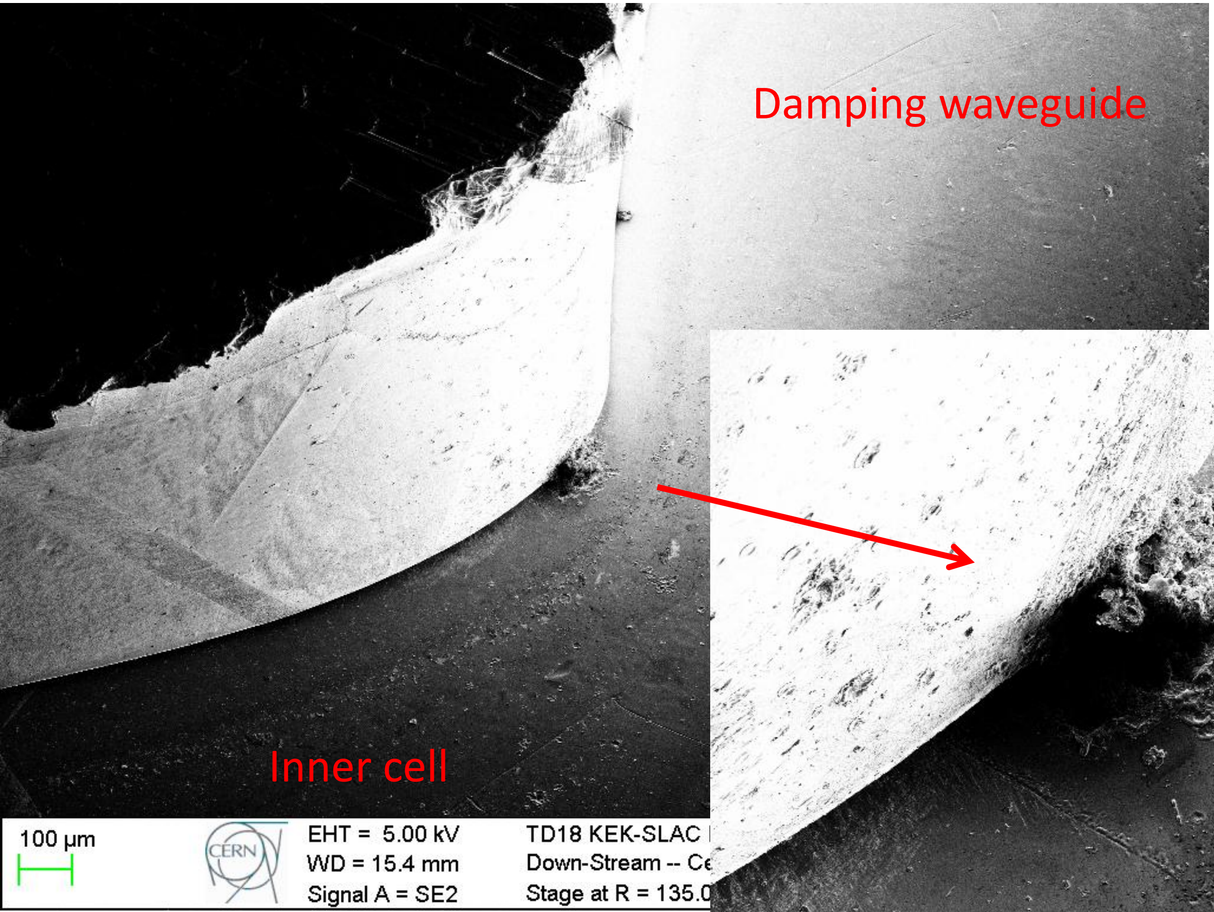
- One fixed at the specific points in the TD18 where the surface current density is highest.

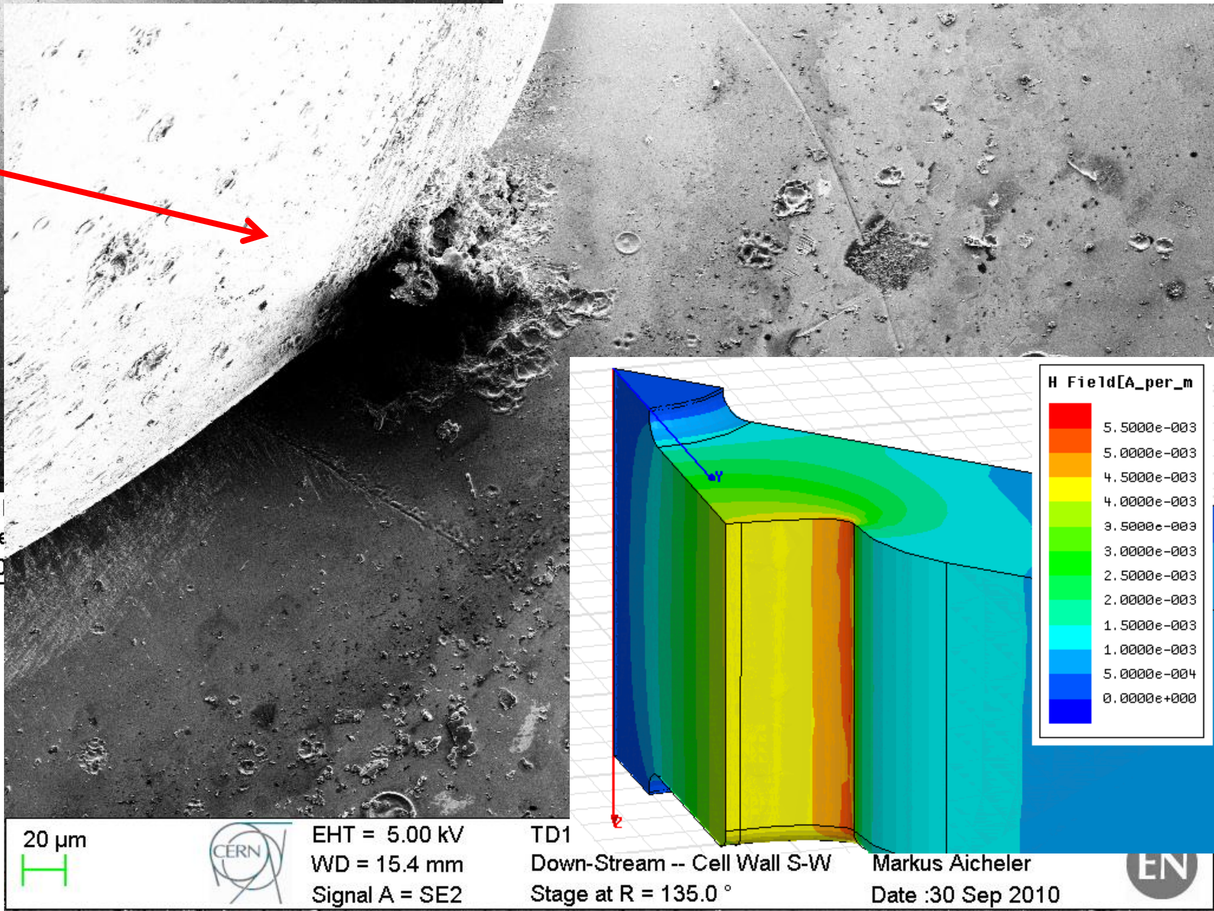
- The other at random points around the circumference at points of much lower current density.

All the images after high power testing I will show are from KEK/SLAC fabrication.

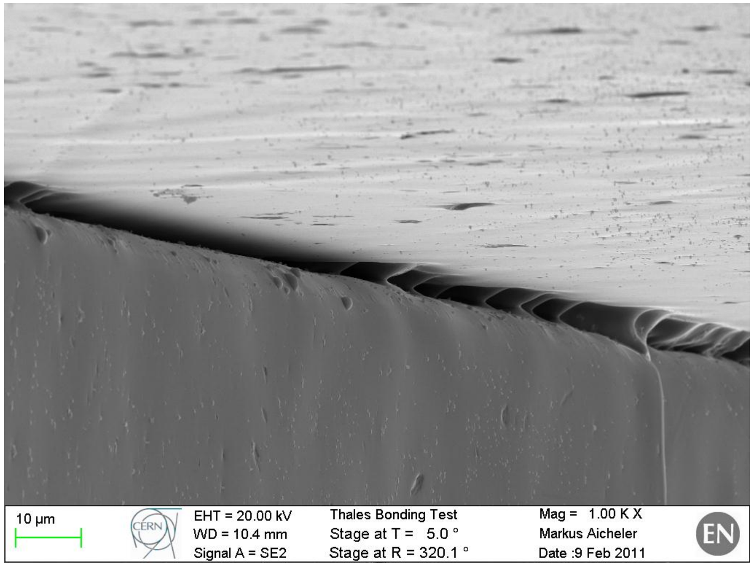
Features in high current region of TD18

Current density around $2 \times 10^8 A/cm^2$ during test

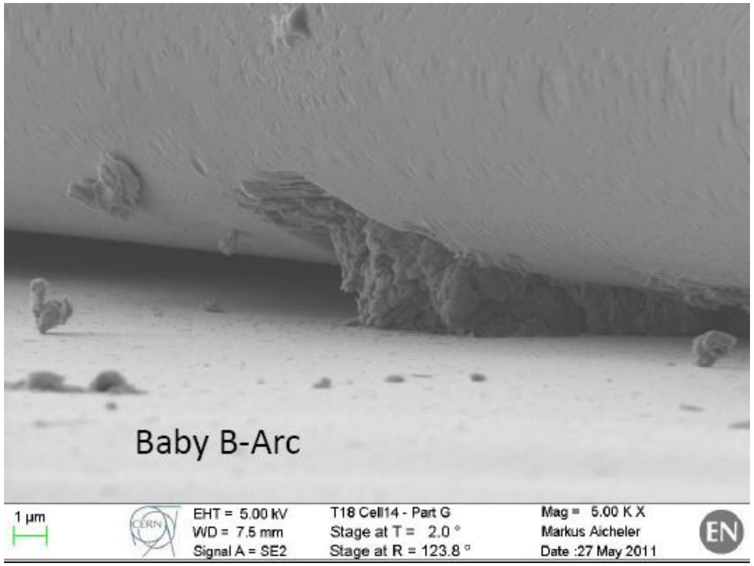




An effect of surface tension plus electromigration?



So does this evolve…



…into this?

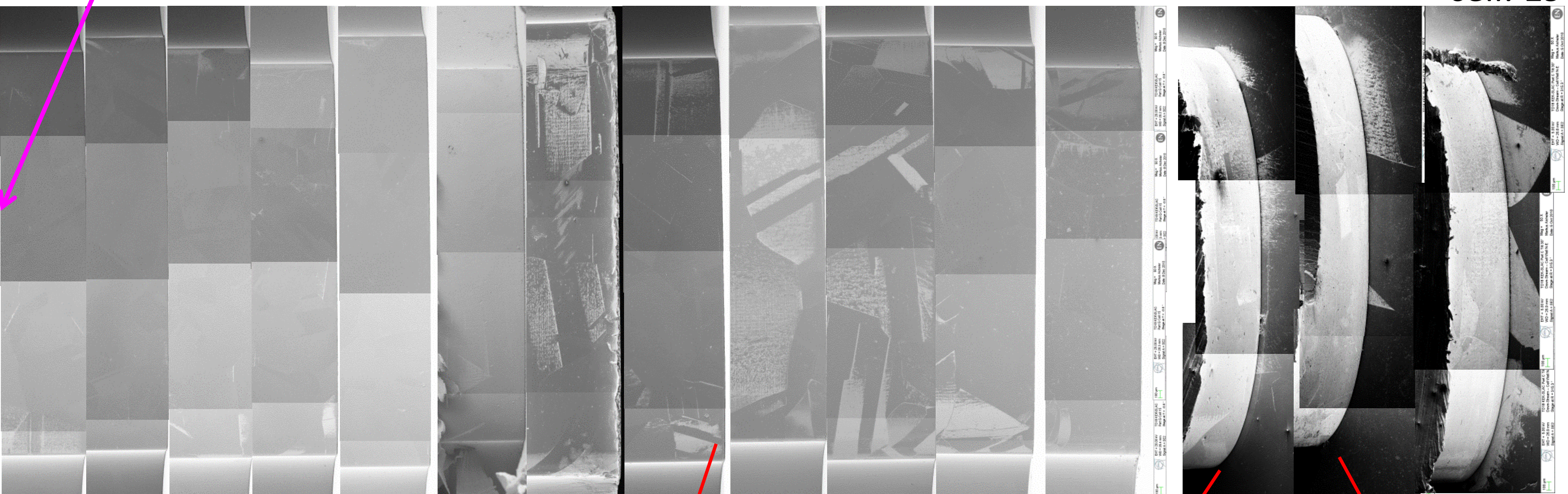
If the such localized flow features exist, the surface currents will preferentially flow though them.
We get a current enhancement, increasing pulsed surface heating and electromigration.
These combined effects could then have a positive feedback and produce an instability.

TD24

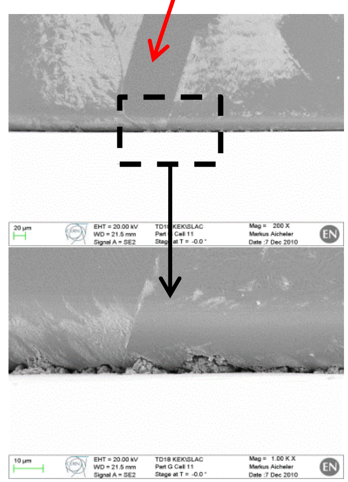
The effect of surface currents

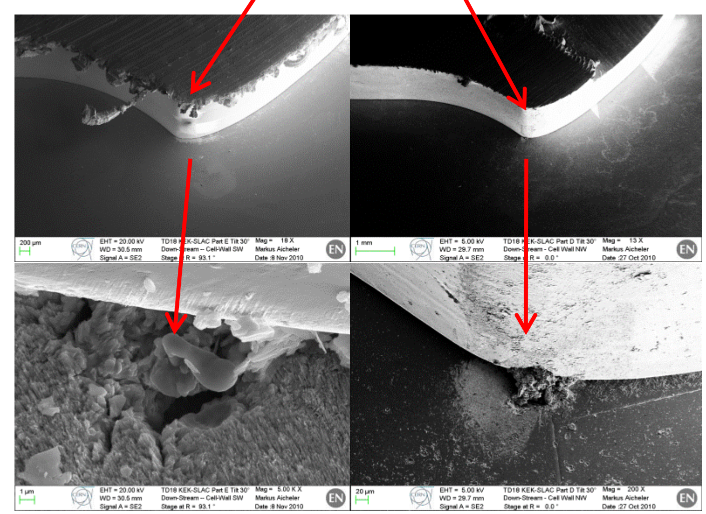
Cell # (cell #1 is a input matching cell):

4 5 6 7 8 9 10 11 12 13 14 15 ?16? 17 18 Last regular cell: 19



It seems that cell #10 (regular cell #9 ~ **middle cell**) exhibits the level of damage which could be considered as **a limit.**





A. Grudiev

Images courtesy of M. Aicheler: http://indico.cern.ch/getFile.py/access?contribId=0&resId=1&materialId=slides&confId=106251

Status of X-band test areas

Existing areas:

- NEXTEF, KEK – Running and running and running. Full program. We hope to continue for many years more.
- NLCTA, SLAC – We had some great times but is now entirely dedicated to photon science.
- ASTA, SLAC – Is available for testing but on a full cost basis only.
- Klyston at CERN – Still commissioning.

We intend to supplement these stands with:

- A test stand at CERN using the first 50 MW XL-5 tube from CPI that we've ordered.
- A test stand at a collaborator using the second 50 MW XL-5 tube from CPI that we've ordered.
- A test stand at CERN based on a combined 5 MW, high-repetition rate tubes.

Budget and technical profile in the medium term

Budget [MCHF]	2012	2013	2014	2015	2016	2017	
Design	0.2	0.2	0.2	0.2	0.2	0.2	
Production	1.2	1.6	1.9	2.4	2.8	2.8	
Test areas	2.8	2.8	2.8	0.0	0.0	0.0	8.4
Testing	0.3	0.4	0.6	0.7	0.8	0.8	
High gradient	0.2	0.2	0.2	0.2	0.2	0.2	
Totals	4.7	5.2	5.7	3.5	4.0	4.0	27.1
Cost inputs							
	Infrastucture	rf	Total				
Initial installation for test stands	1.7		1.7				
Marginal cost for one test stand	0.2	1.8	2				
Full cost structure			0.3				
Testing year cost per stand			0.12				
KEK	Operate						
CERN 1 (SLAC)							
CERN 2 (CPI1)							
Collaborator (CPI2)							
CERN3 (5 MW)							Sum
Number 50 MW stands	1	2	3	4	4	4	18
Number 5 MW stands	0	0	0	0	1	1	
Number structures tested	2	4	6	8	12	12	44