Structure Tests, Results and Program

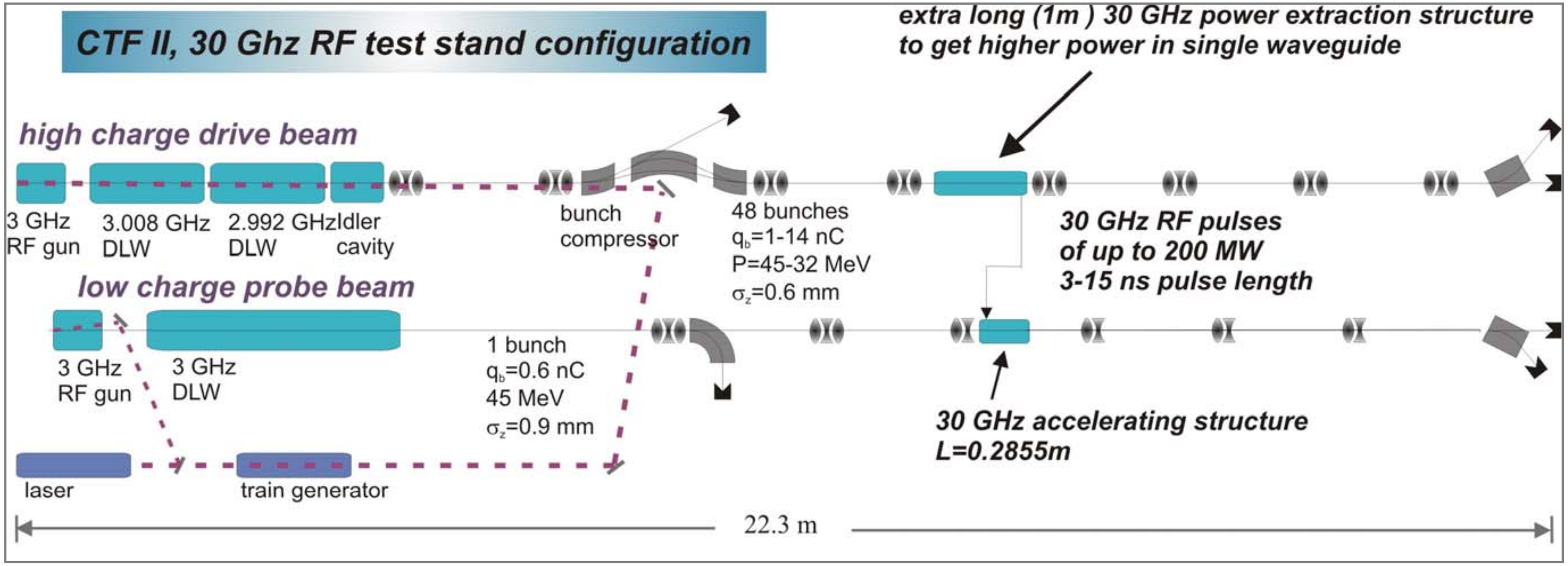
- Introduction
- 30 GHz results and test facilities
- 11.4 GHz results and test facilities
- Collaborations
- Future testing program
- Conclusion

RF Parameter Evolution of CLIC

<1994	80 MV/m	single bunch (10 ns)	30 GHz
	100 MV/m	multi bunch (130 ns)	30 GHz
1999	150 MV/m	multi bunch (130 ns)	30 GHz
2007	100 MV/m	multi bunch (300 ns)	12 GHz

30 GHz results and test facilities

CTF II the two beam test facility



<u>Two Beam Test stand in CTF II:</u>

Up to 300 MW, 16 ns

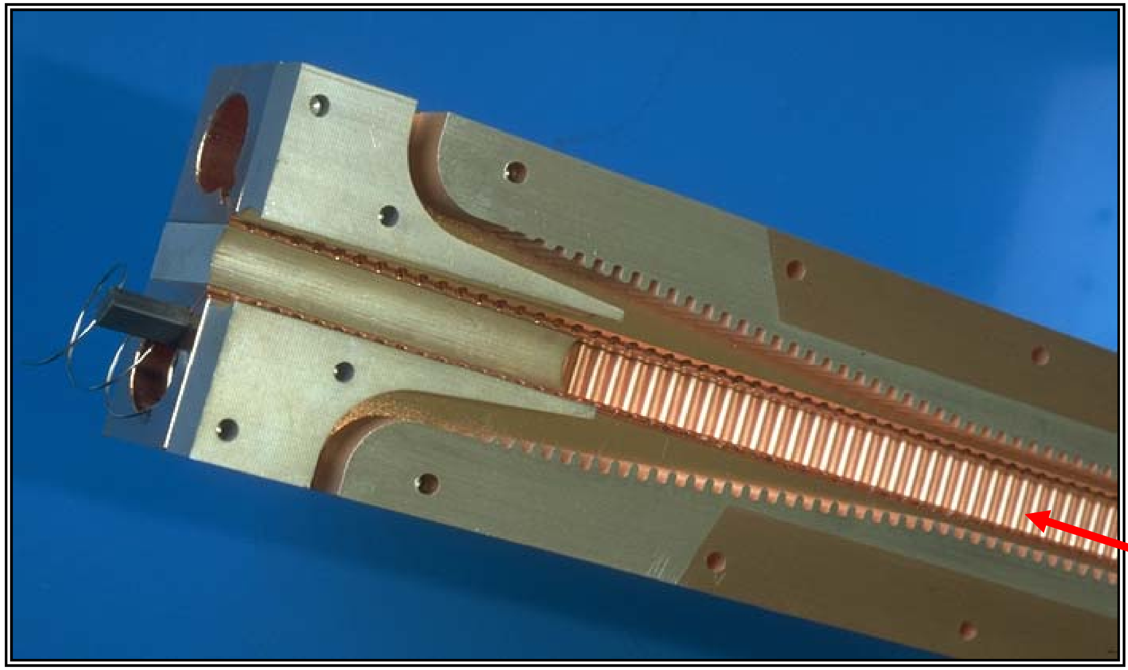
Successful acceleration in 5 modules

at moderate gradient

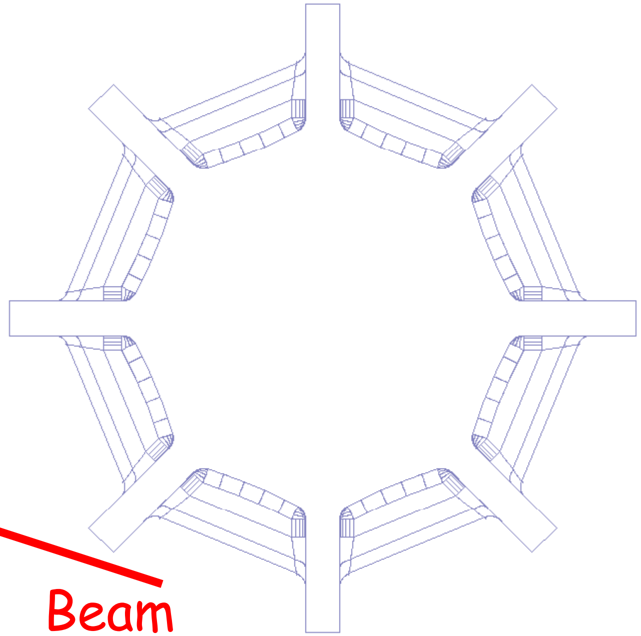
30 GHz Power Production

PETS = Power Extraction Structure

CTFII PETS, 300 MW peak power, 16 ns



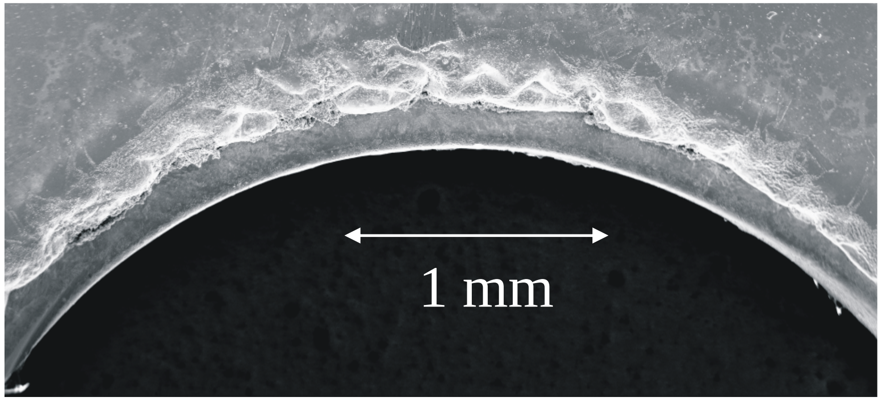
CLIC PETS
140 MW, 300 ns

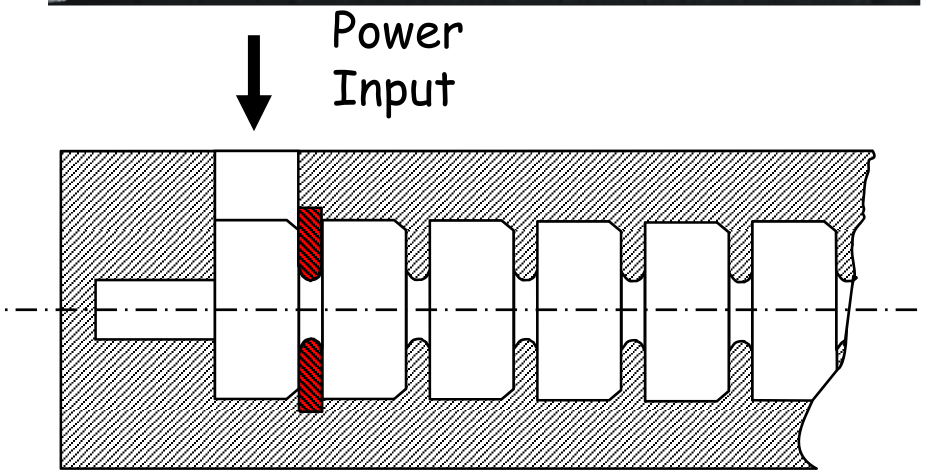


Beam

The beginning of a long story, Damage in high field areas

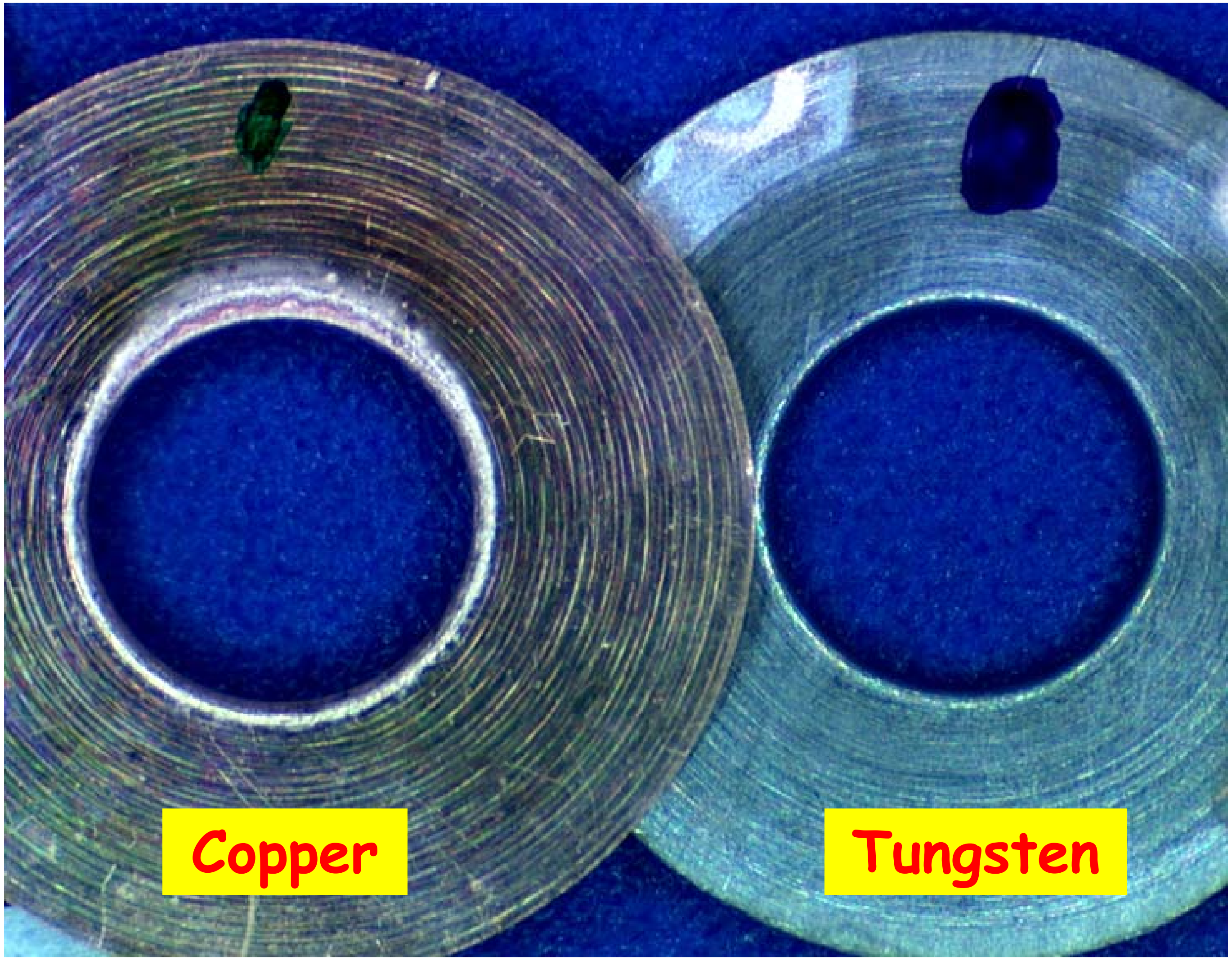
In 1999, damage was found in high field areas of the first CLIC prototype accelerating structures at a gradient ~ 60-70 MV/m (Surface field on Copper ~ 300 MV/m)





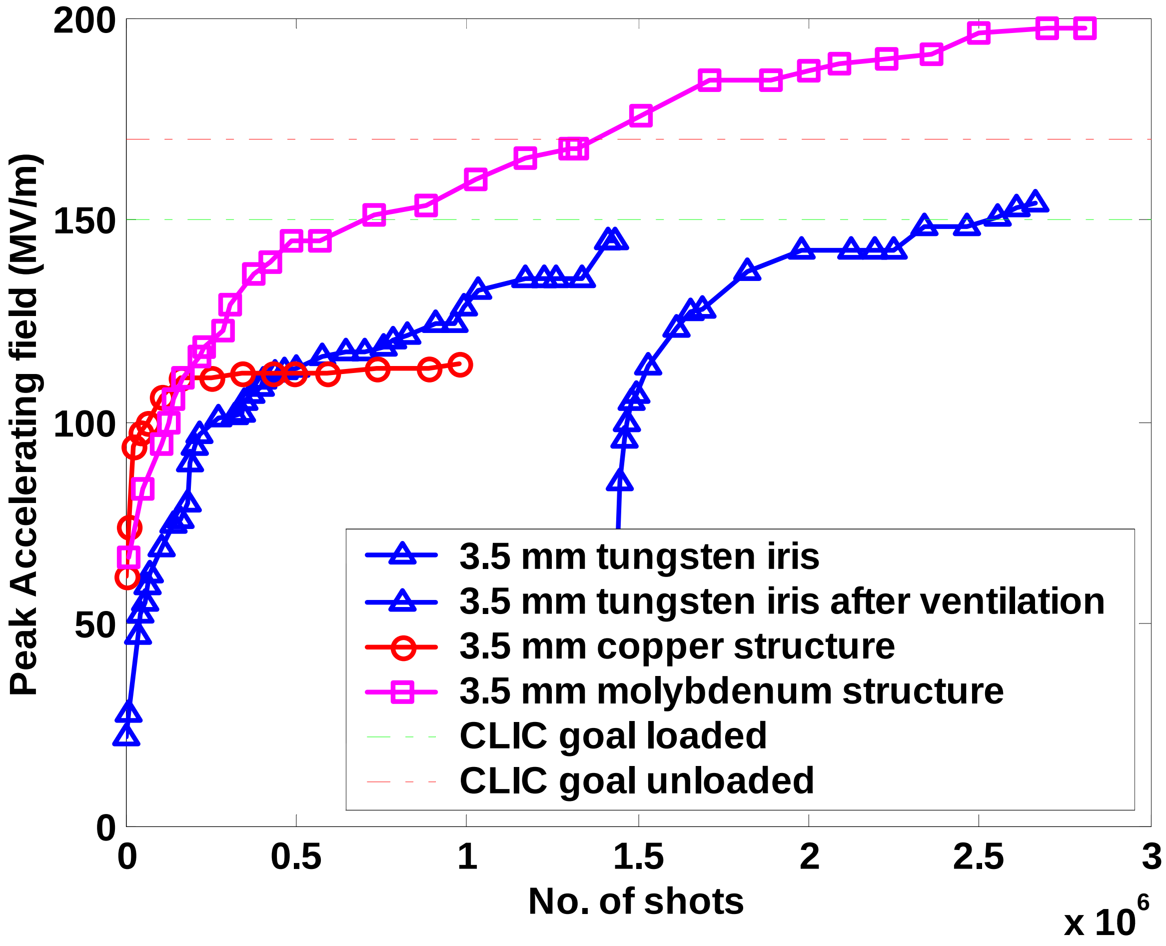
Clamped-Iris Structure Tests in CTF II

Damage in high field areas



Accelerating Structure Tests in CTF II

Short, 16 ns rf pulses

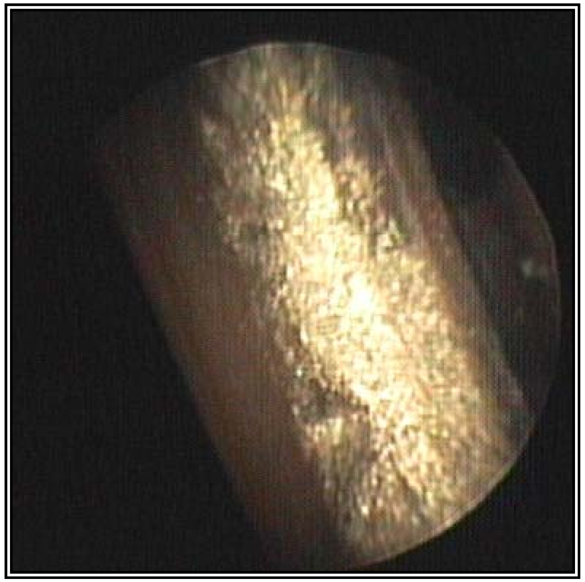


New Record for classical accelerating structures !

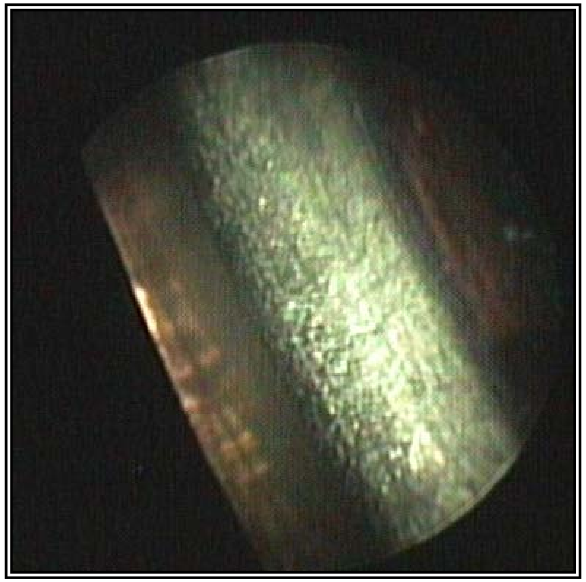
Accelerating Structure Tests in CTF II

Surface field on first iris

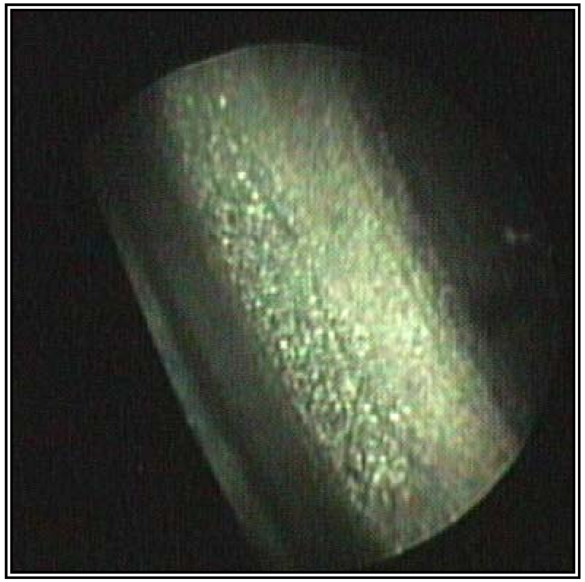
Copper 260 MV/m



Tungsten 340 MV/m

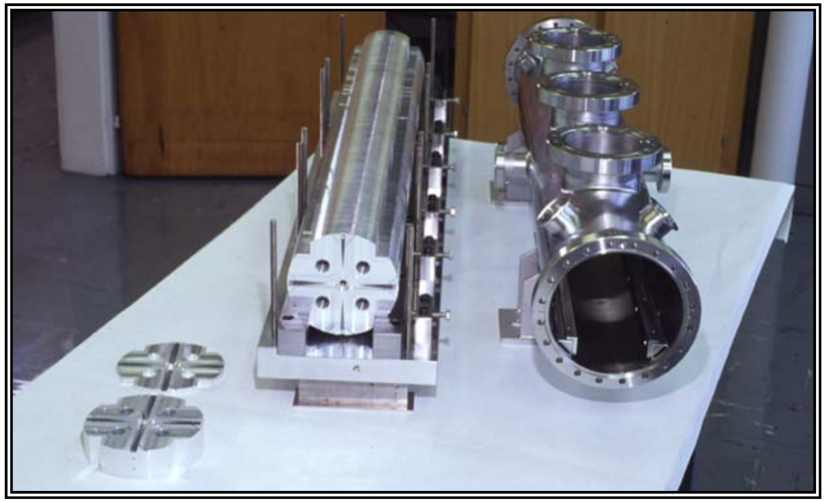


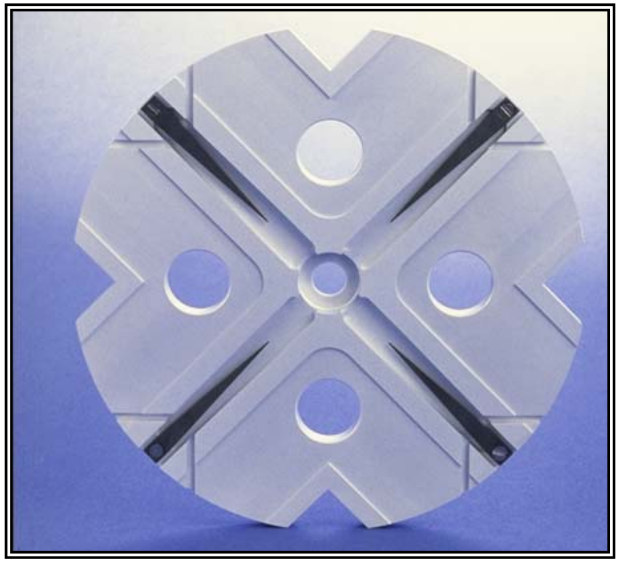
Molybdenum 426 MV/m

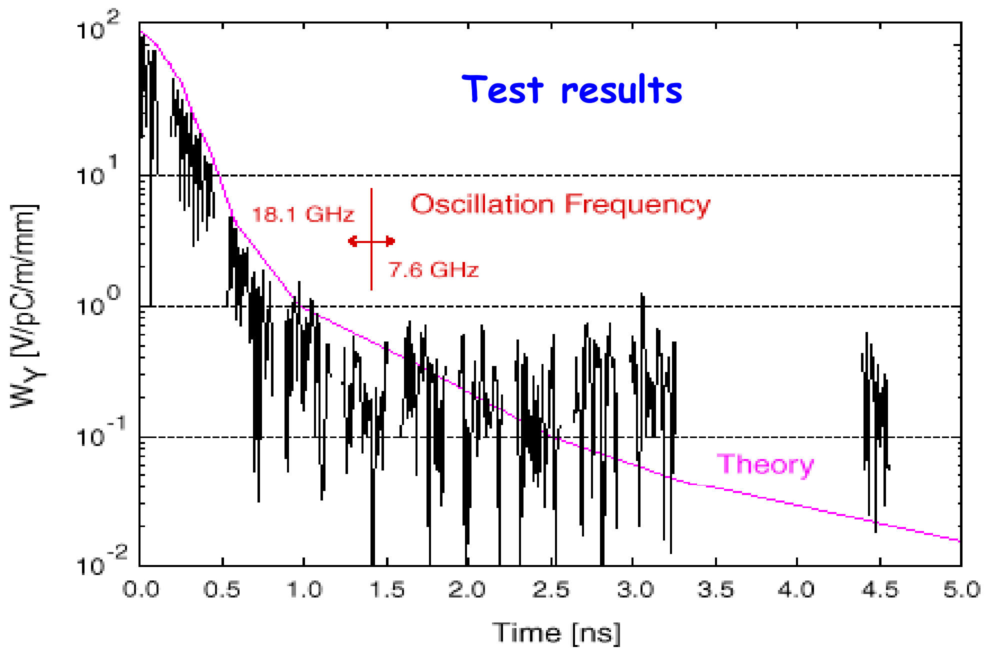


Tapered Damped Structure Test in ASSET

Successful experimental verification of strong cell damping and benchmarking of codes

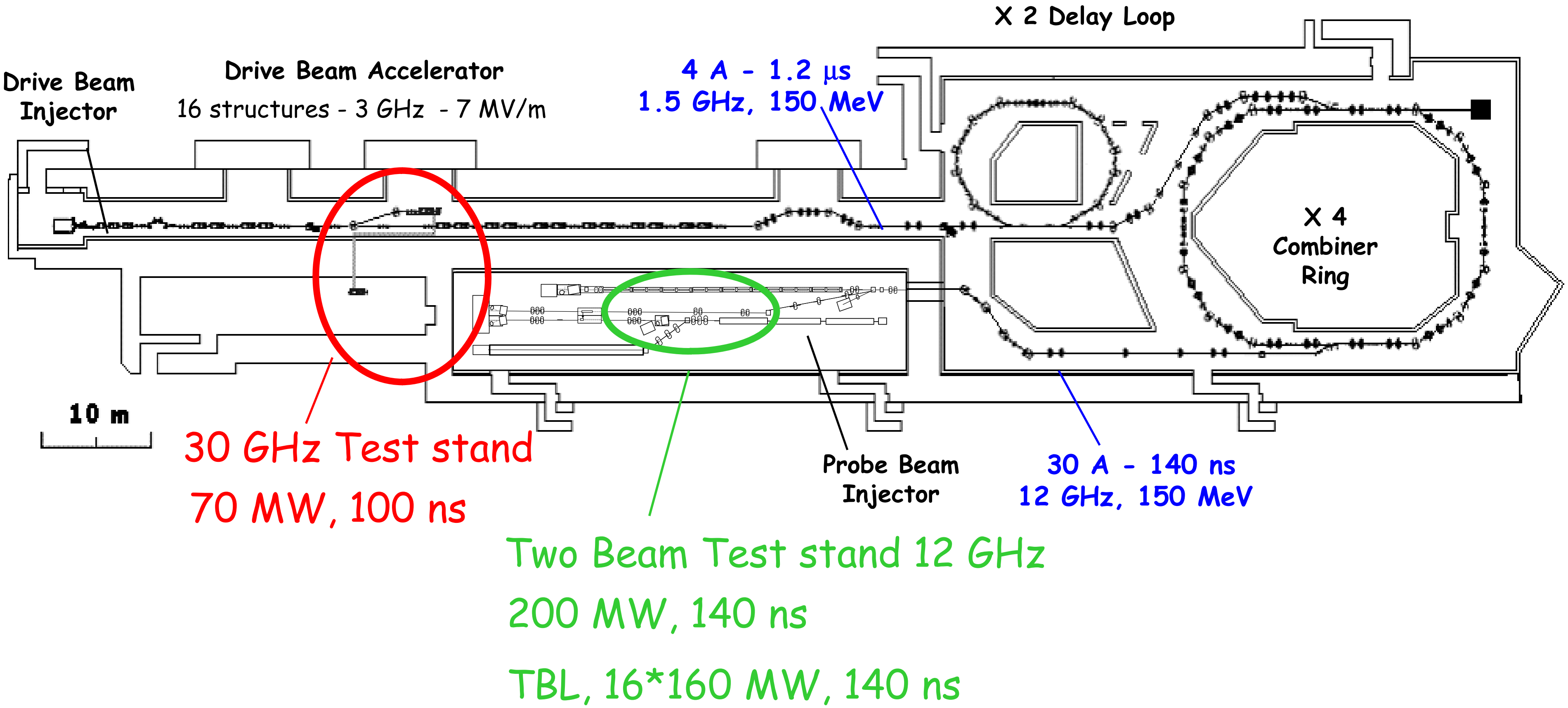




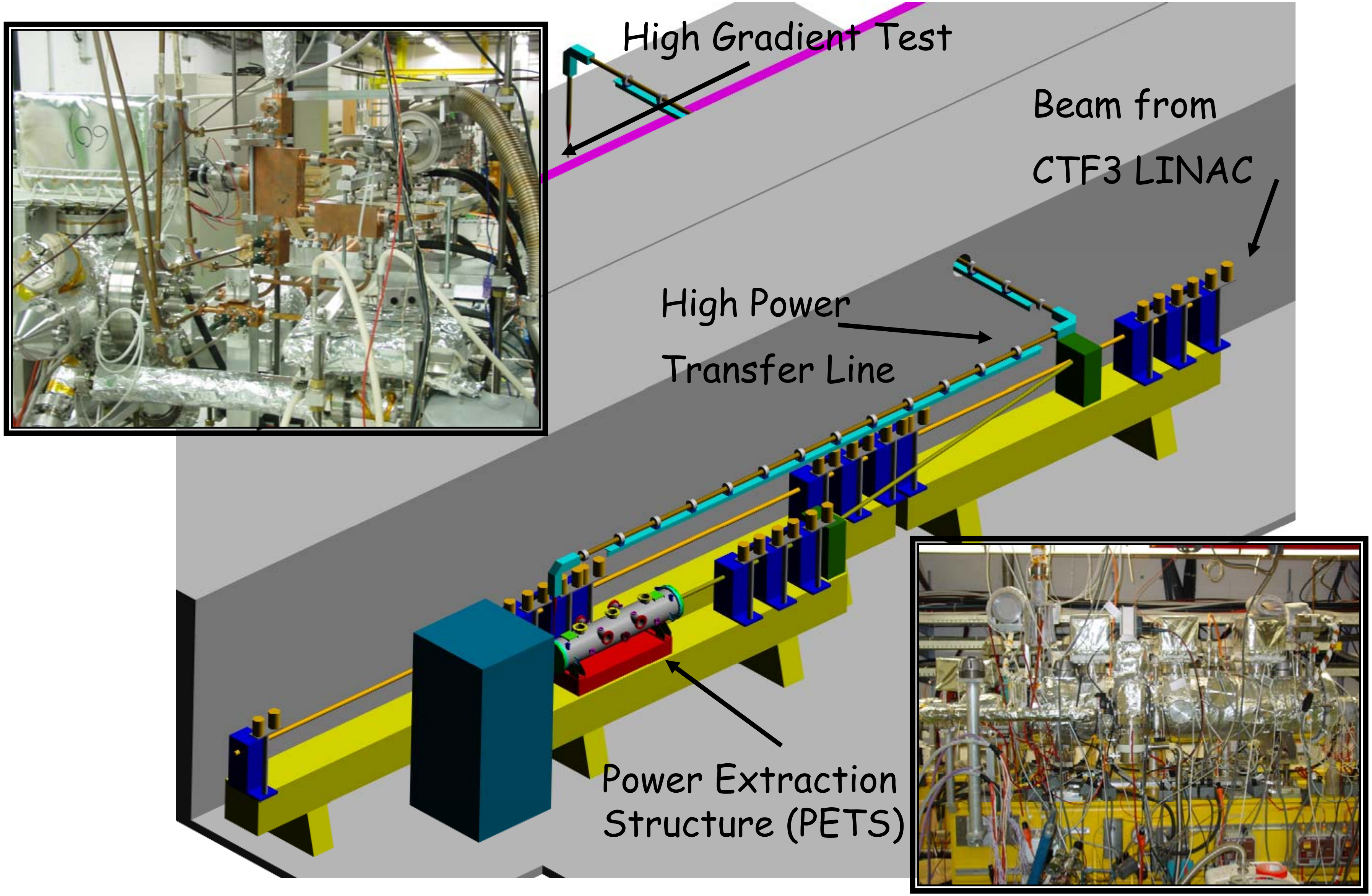


CTF3, towards a CLIC-type drive beam

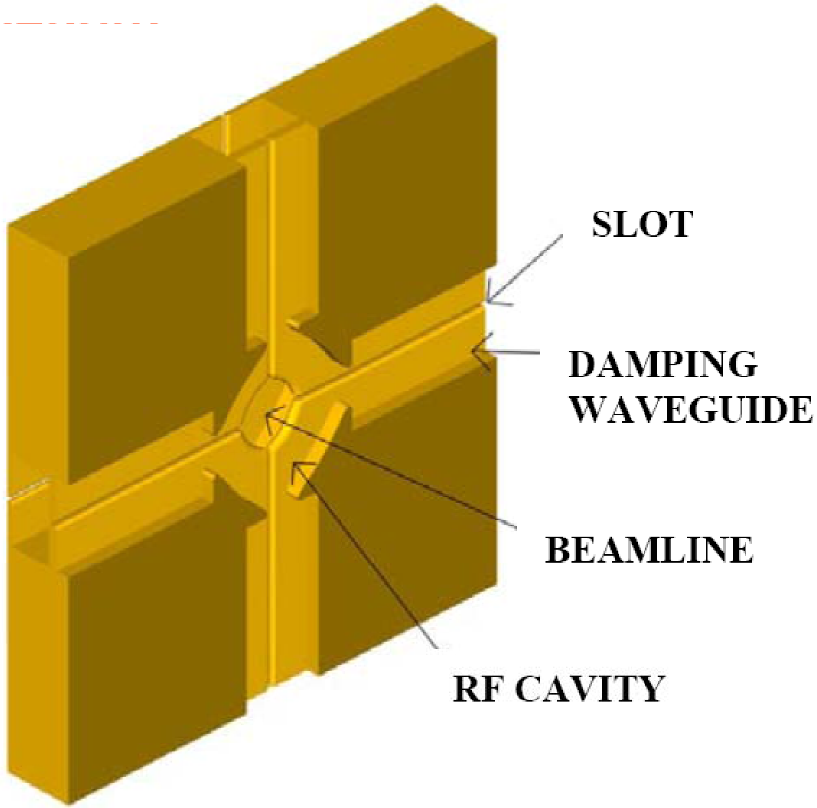
Rf power production with CTF3

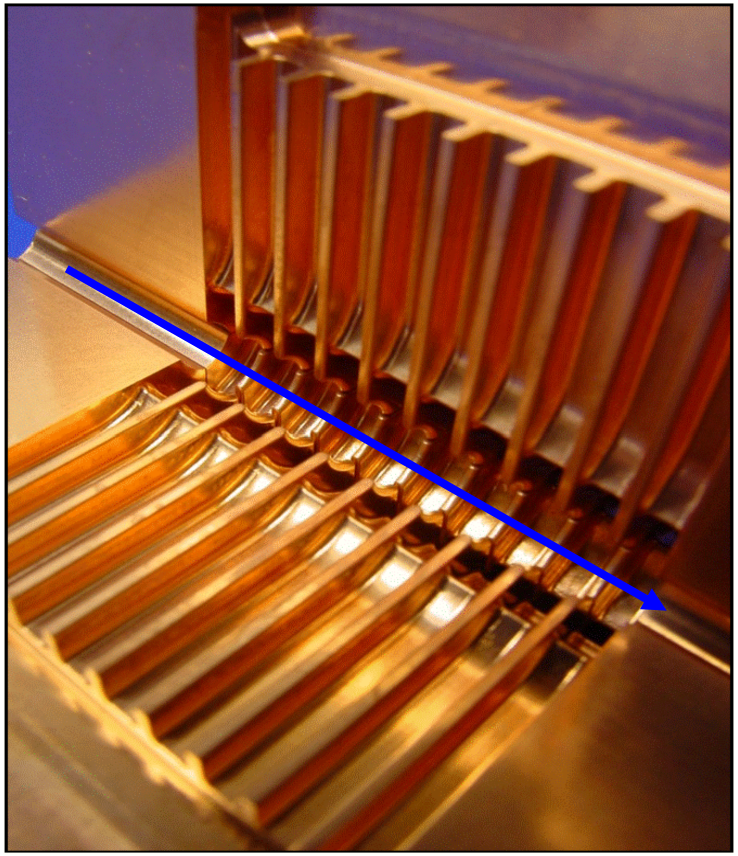


30 GHz Power Production in CTF3



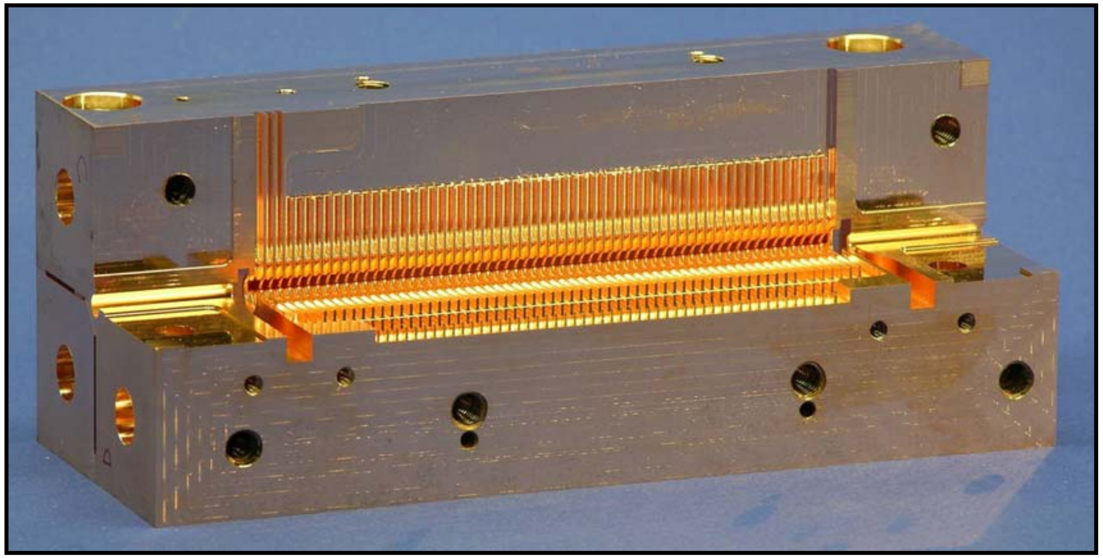
Hybrid Damped Structure (HDS)

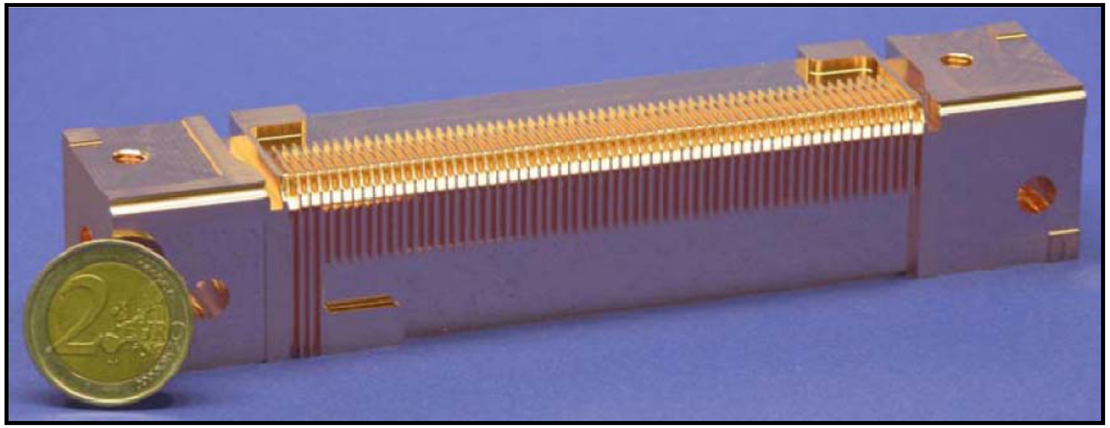




CLIC damped and detuned accelerating structure:
30 GHz, 150 MV/m, 70 ns, < 10^{-6} trip probability

Accelerating Structures made out of milled quadrants





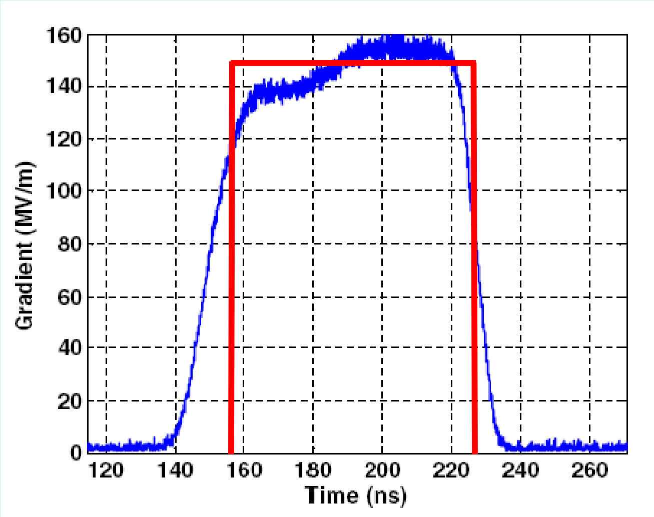
HDS60

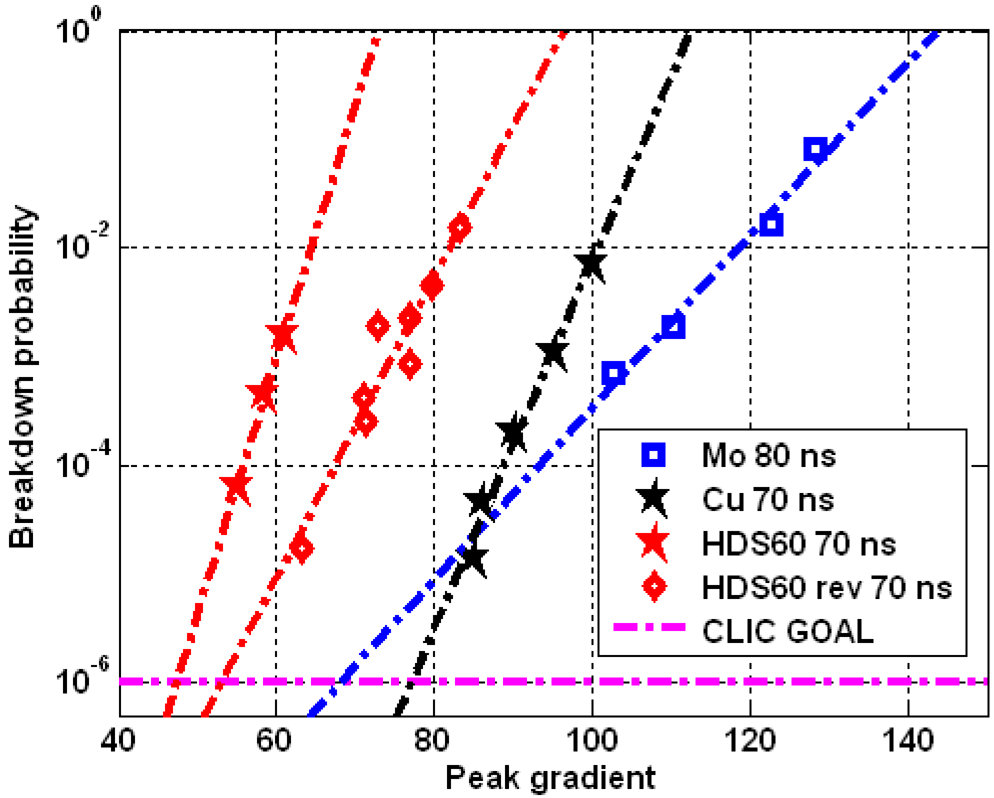
$<E_{acc}>$ [MV/m]	150
f [GHz]	29.985
$\Delta\varphi$ [°], l_c [mm]	60, 1.66635
$a_{1,2}$ [mm]	1.9, 1.6
$d_{1,2}$ [mm]	0.55, 0.55
$Q_{1,2}$	2356, 2316
$r/Q_{1,2}$ [LinacΩ/m]	29000, 34000
$v_g/c_{1,2}$ [%]	8.0, 5.1
$<a>/\lambda$	0.175
N	2.45×10^9
$L_{b\times}$ [m^{-2}]	1.02×10^{34}
N_c, l [mm] (active)	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

Overview of recent 30 GHz results

Reached nominal 30 GHz CLIC values :

150 MV/m 70 ns

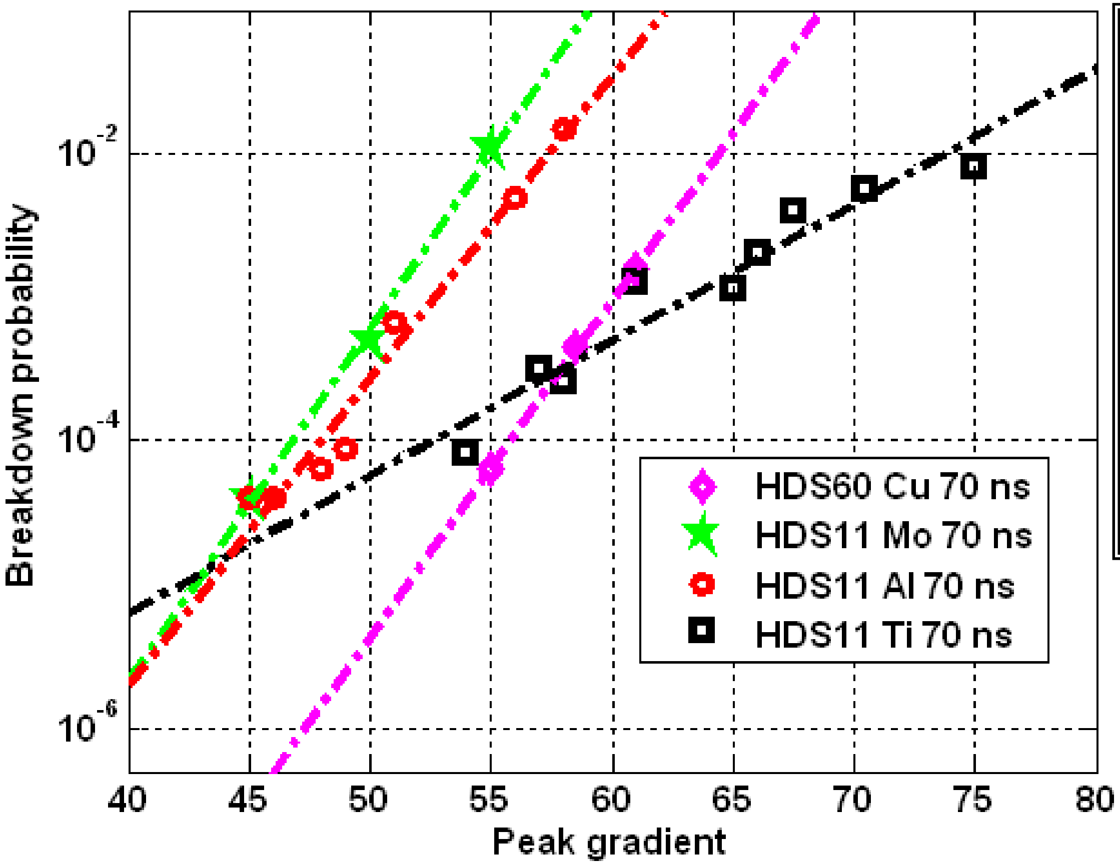




Molybdenum shows higher gradient but different slope

HDS performs worse than round brazed structure

New Materials for High-Gradient

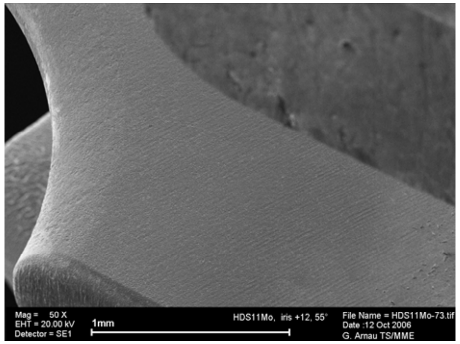


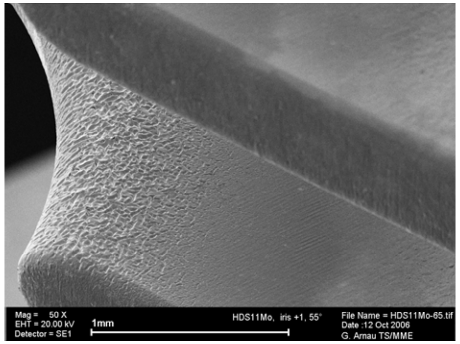
Copper has still the best performance at low break down rate

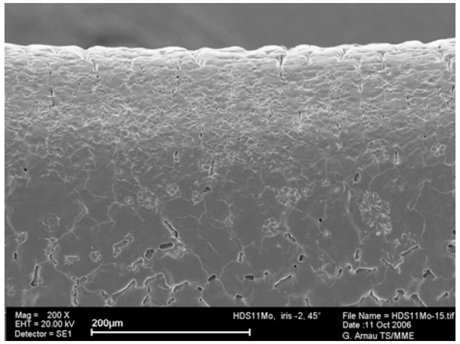
New Materials for High-Gradient

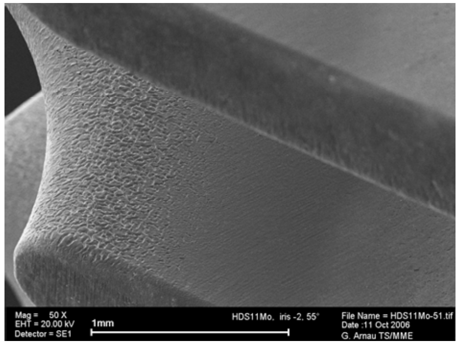
HDS11 Molybdenum	HDS11 Titanium

HDS11 Molybdenum

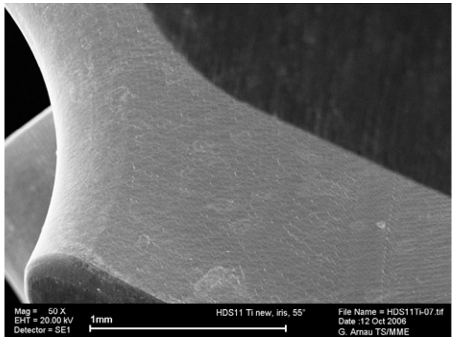


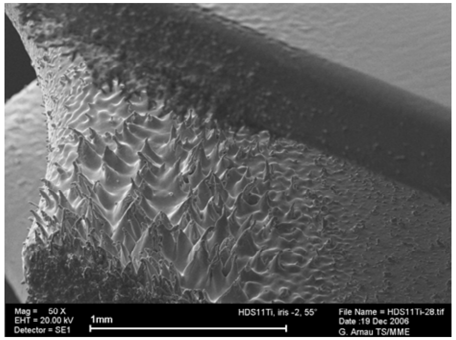


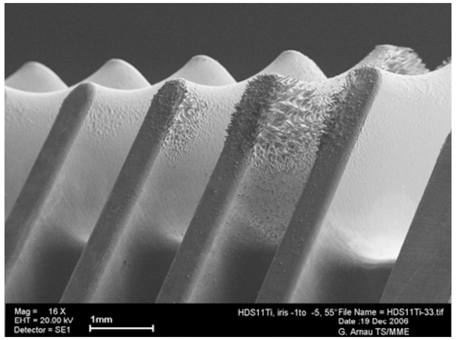


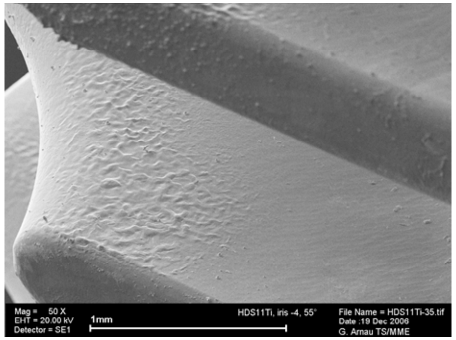


HDS11 Titanium

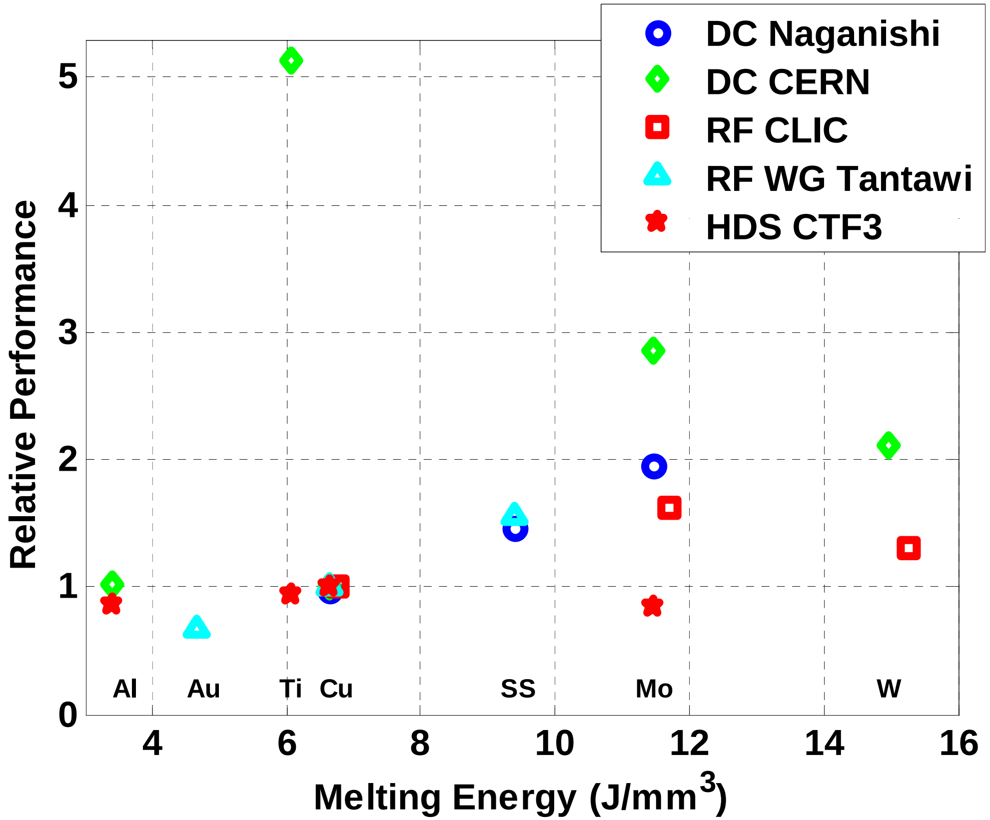








New Materials for High-Gradient

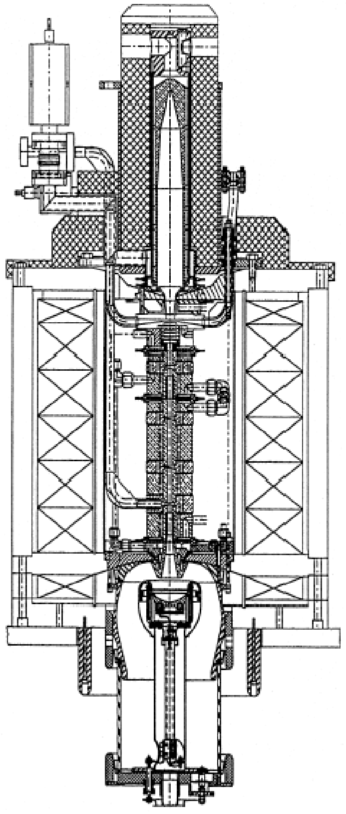


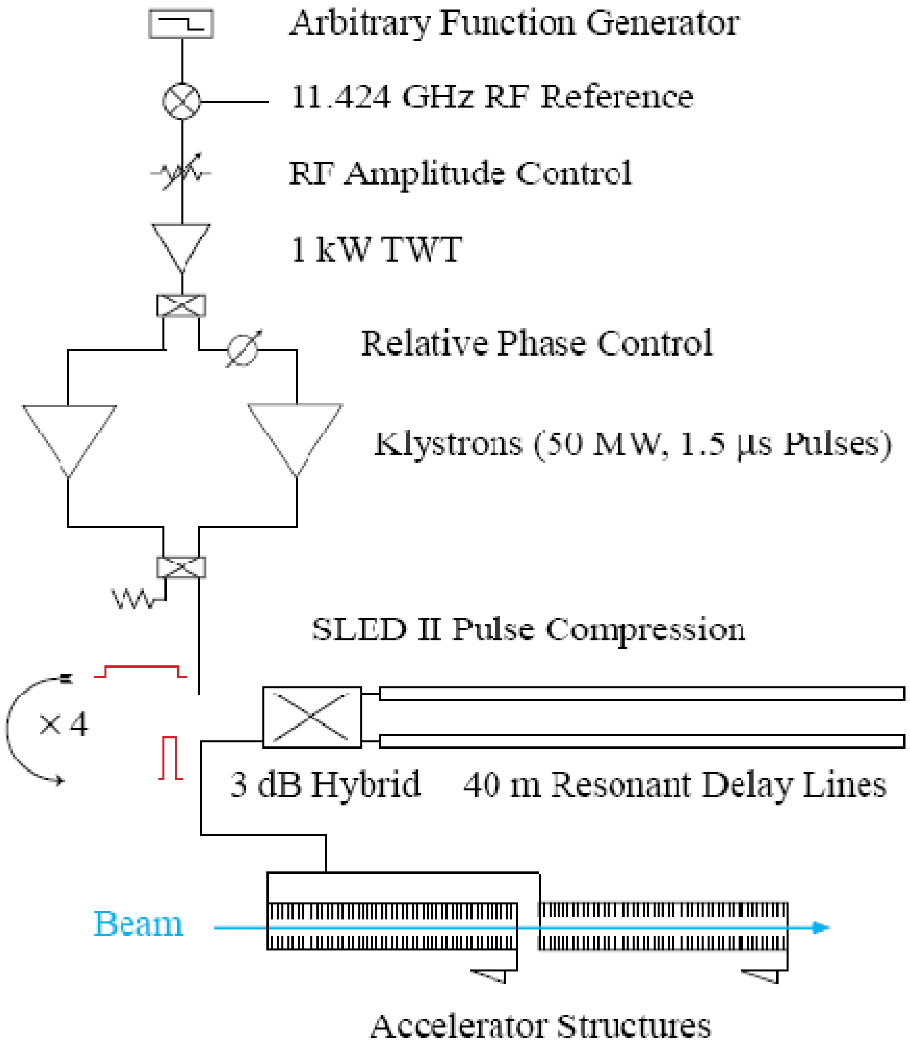
So far, most promising materials have higher melting energy/volume

11.4 GHz results and test facilities

Test facilities based on 50 MW klystrons made by SLAC or Toshiba

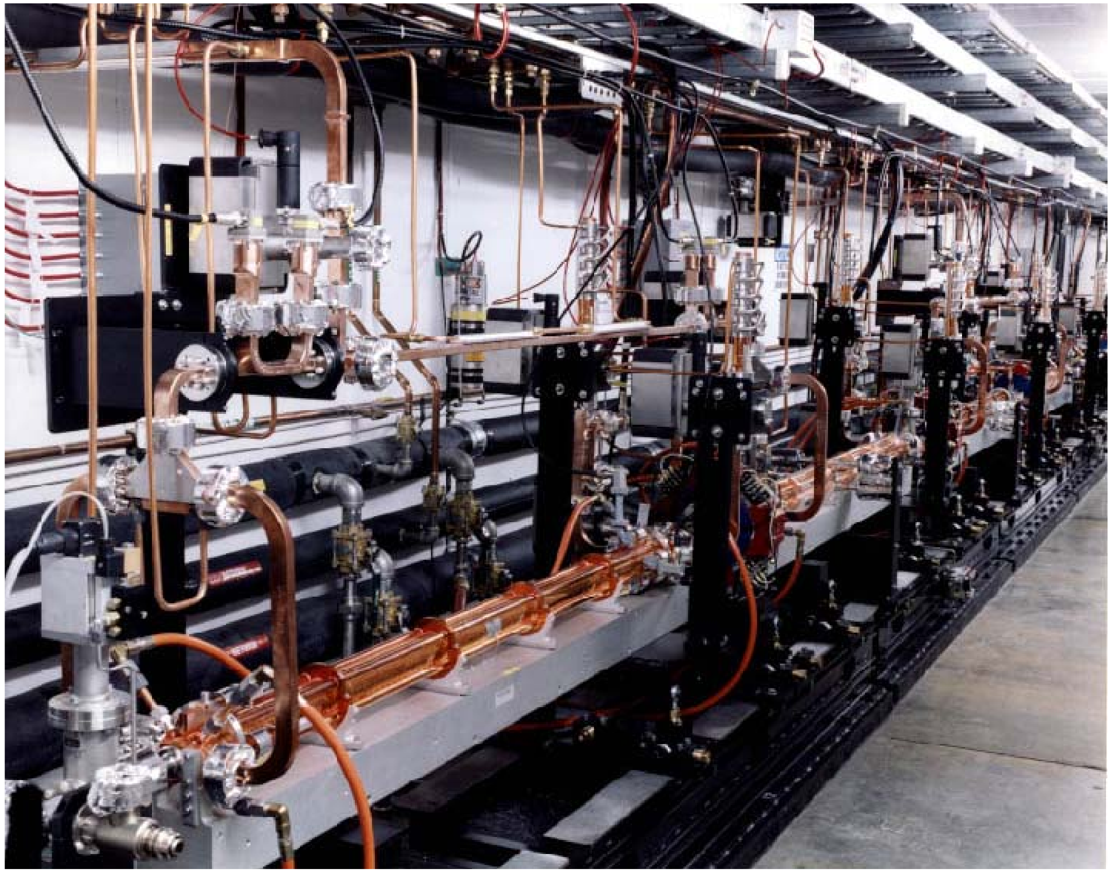
Developed for NLC/GLC





NLCTA X-band power source at SLAC

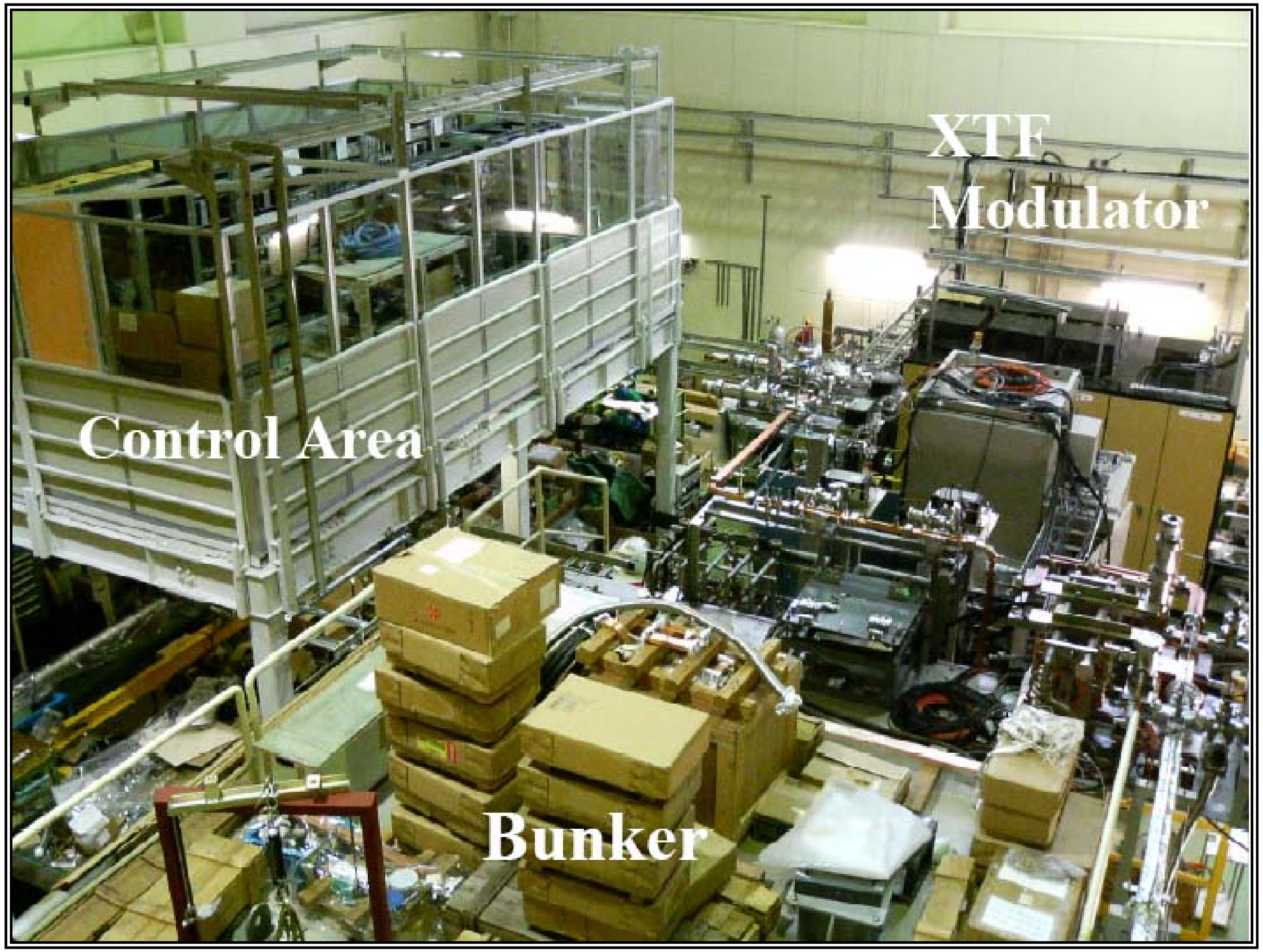
- 60 MeV electron beam for energy and phase measurement
- 3 Test Stations:
  2x50 MW into SLEDII,
  300 MW for 2-4 slots
- Numerous test stands in the Klystron Test Lab
  2 single Klystron test stands
  2x50 MW into SLED II



New X-band Test Facility at KEK

Single Klystron (50 MW) test stand up and running

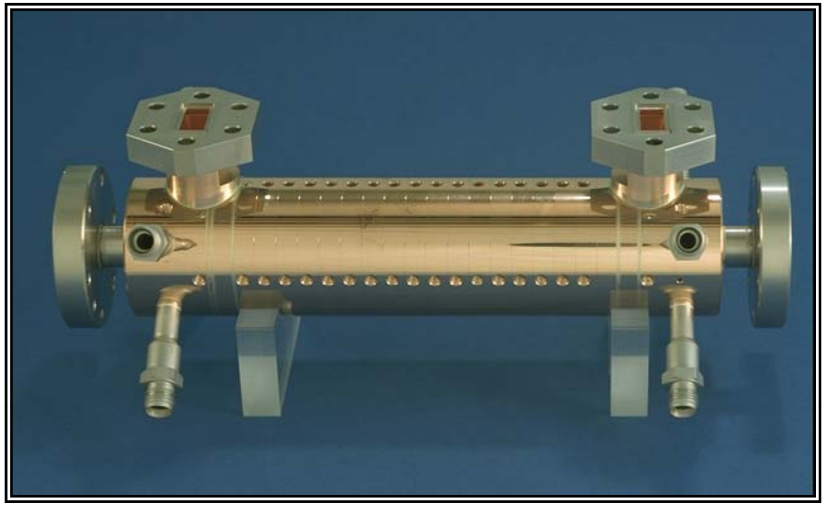
XTF: Again available from fall 2007, 2x50 MW, 400 ns, 24/7 operation

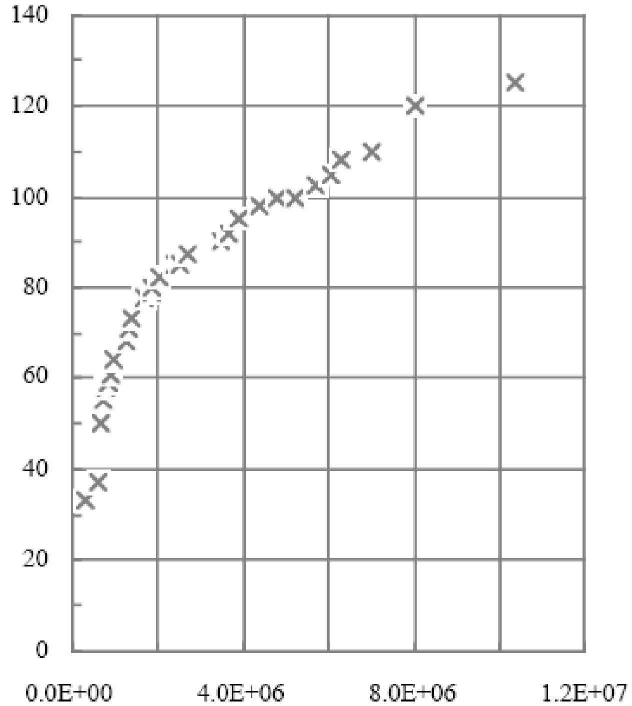


First CLIC x-band structure

One tested at KEK and one tested at SLAC

Beam hole radius	3 mm
Disk thickness	2 mm
Effective length (26+2cells)	.2449 m
Group velocity, v_g/c	1.1% *
Impedance, r/Q	16.0 [kΩ/m]
Shunt impedance, r	106.8 [MΩ/m]
Q	6680*
Attenuation parameter	1.61 [neper/m]*
Filling time, t_f	58 [ns]*
Surface/Accelerating field	1.9



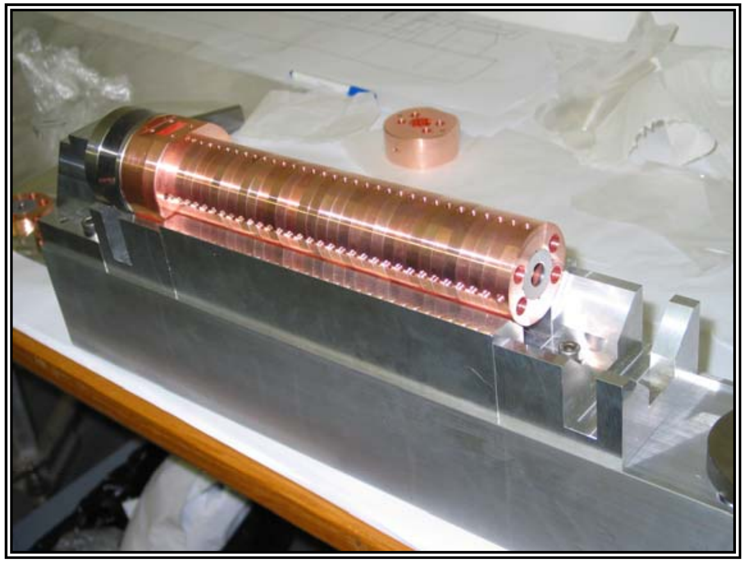


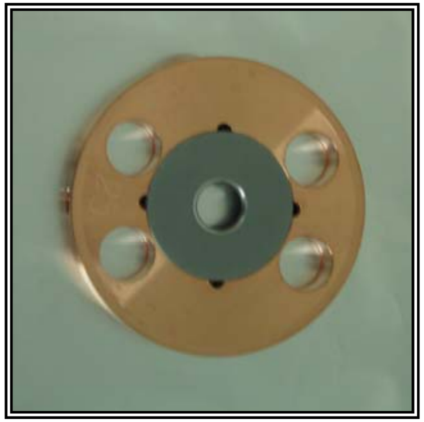
150 MV/m peak, 125 MV/m avg

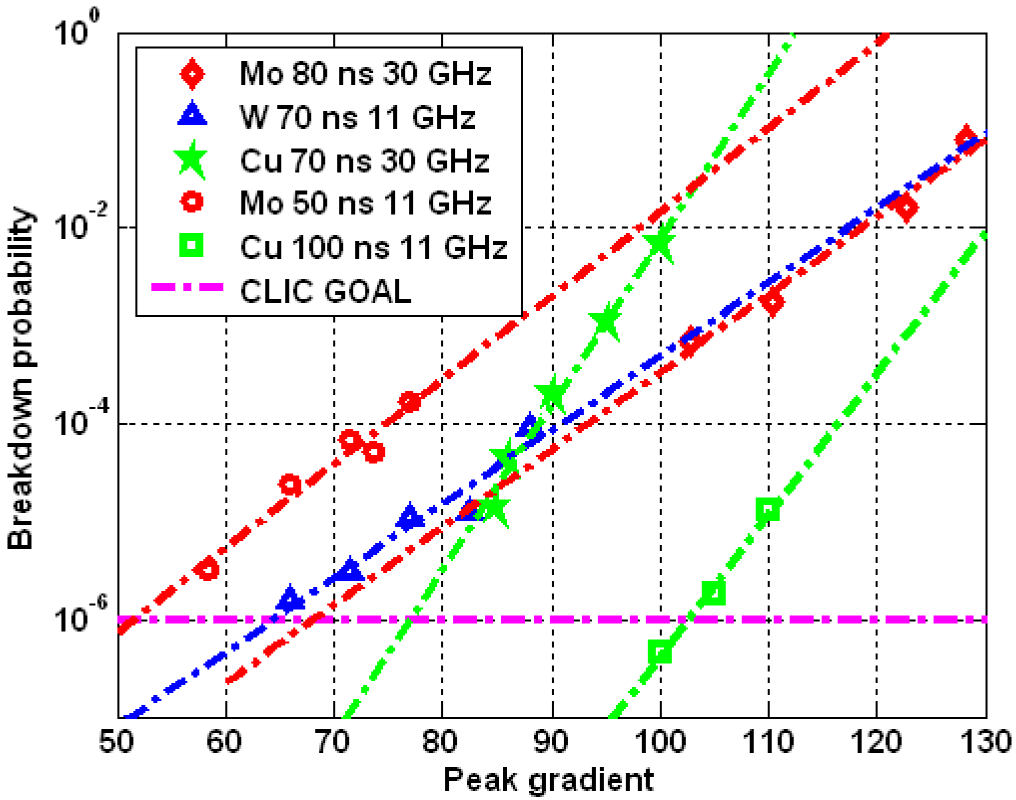
150 ns pulse length

No breakdown monitoring

Round Clamped Iris Structures



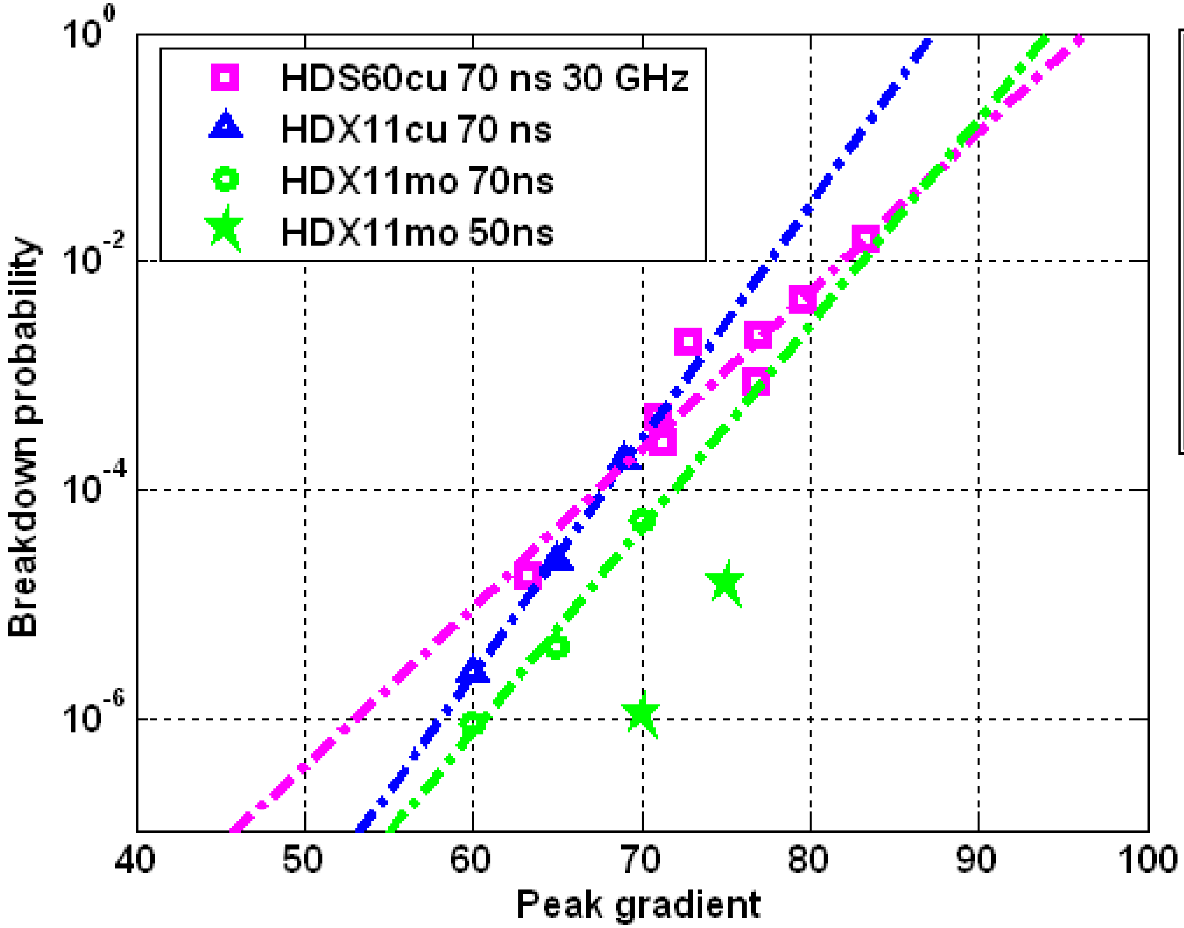


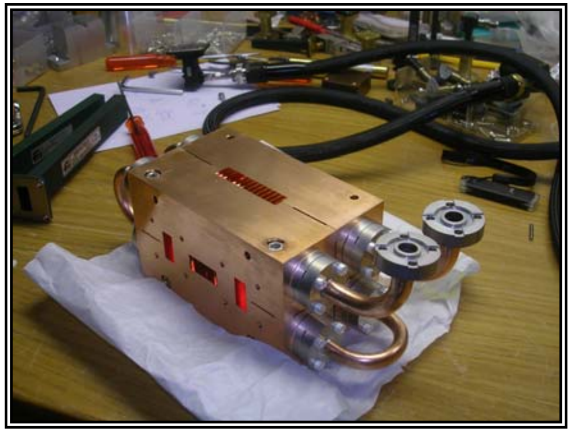


Superior gradient for new materials at x-band not confirmed

Shallower slope unique to clamped structures ?

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

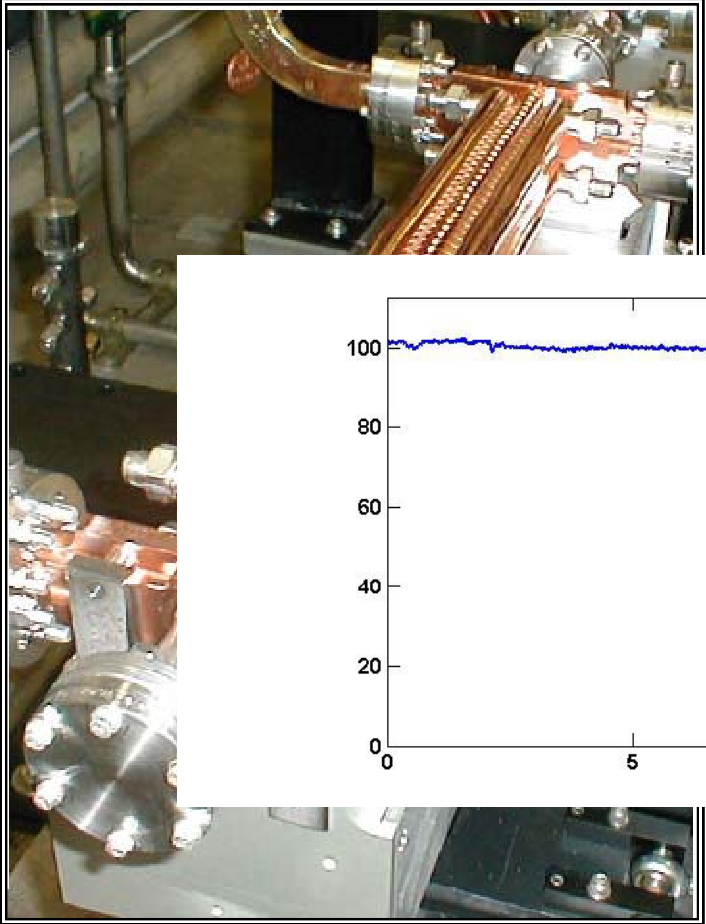


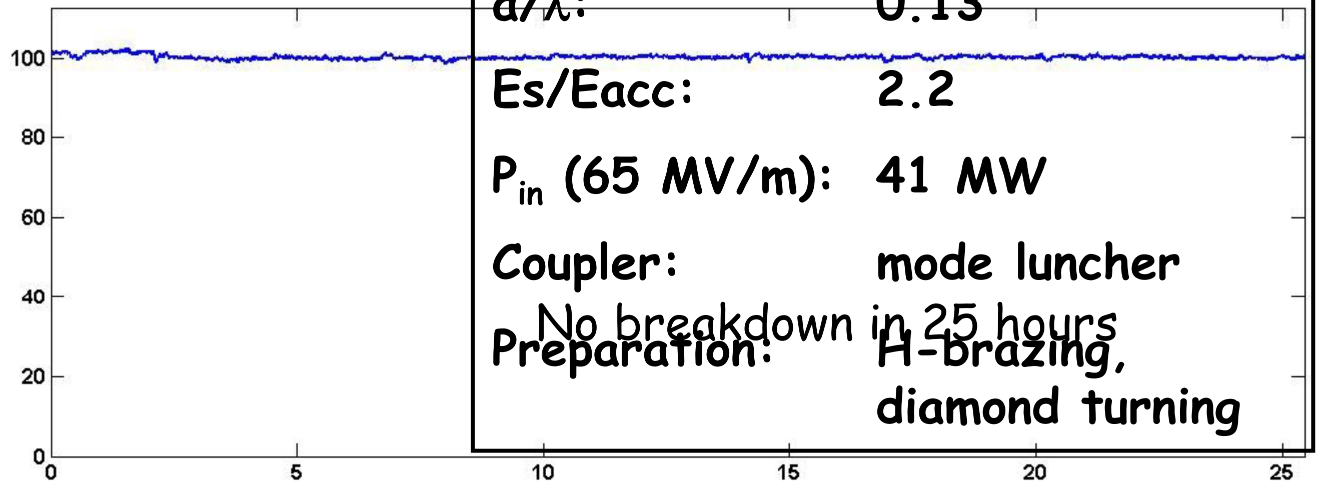


Scaled structures show very similar performance

HDS-type structures show consistently limited performance

A reference structure for CLIC from NLC

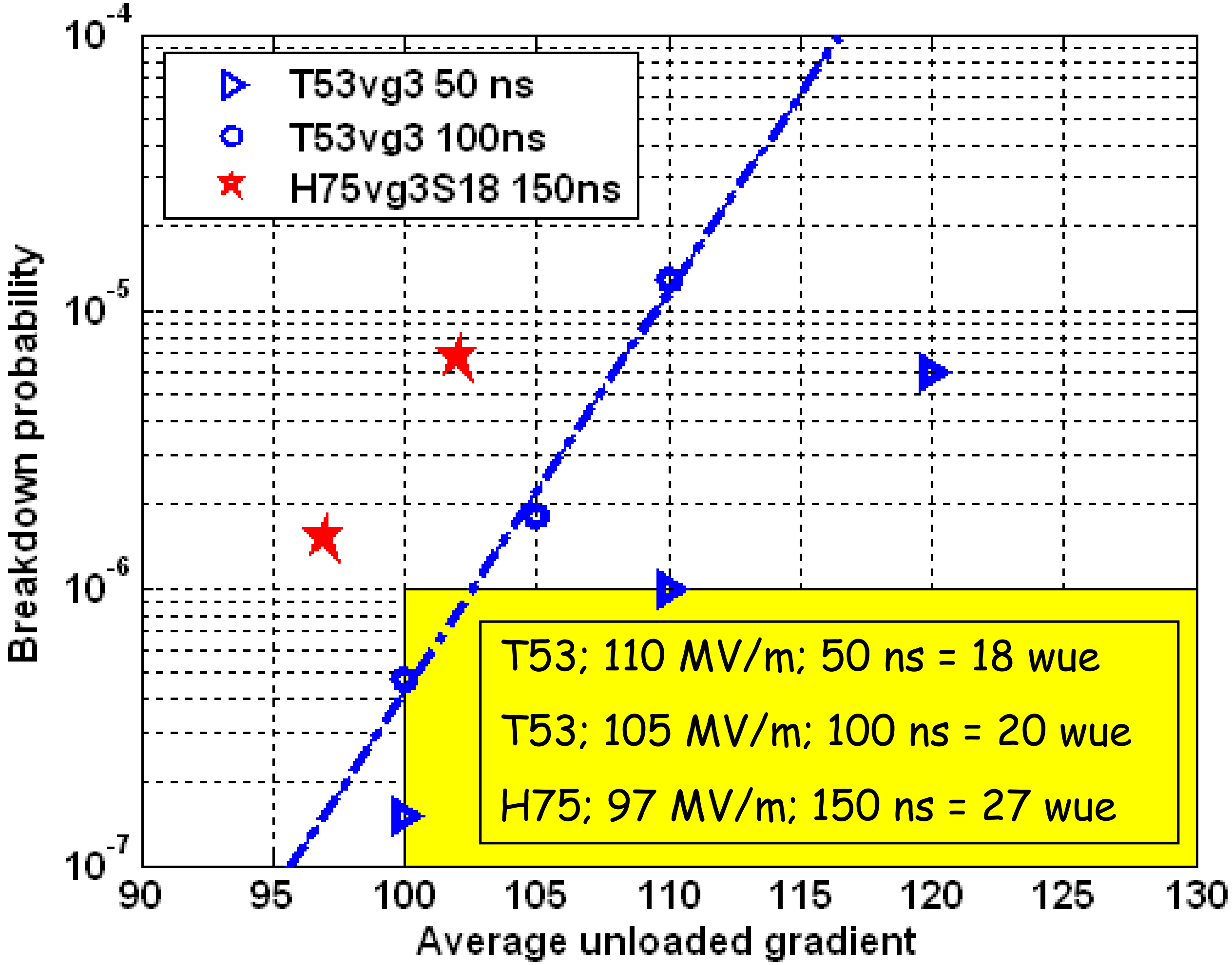




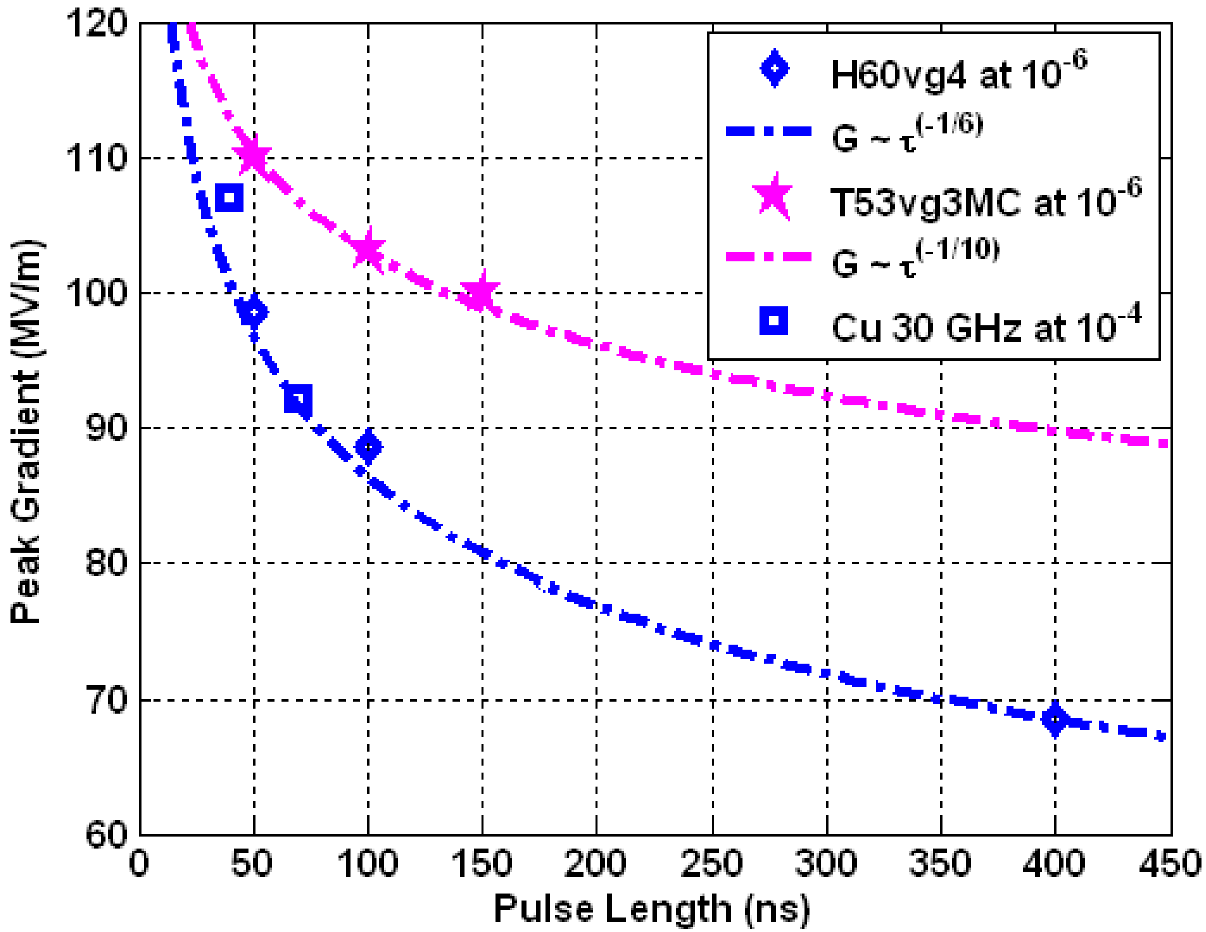
Length:	53 cm
Phase advance:	120 deg
Group velocity:	3 %
a/λ:	0.13
Es/Eacc:	2.2
P_{in} (65 MV/m):	41 MW
Coupler:	mode luncher
Preparation:	H-brazing, diamond turning

Tests of old NLC structures at short pulses

T53vg3MC can be used as a first reference for the new CLIC parameters



Pulse Length Dependence



Conclusions on recent structure tests

- Current CLIC design within experimentally demonstrated region

✓ 27 wue have been measured (Design used 18)

✓130 MW input Power for 100 ns into first cell of T53

- The T53 could be used as a reference structure for CLIC
- Hybrid Damped Structures show performance deficit
- Copper is still the best material to make accelerating structures (Molybdenum still has some potential)
- Exactly scaled structures seem to perform independent of frequency (therefore 30 GHz test are still meaningful)
- Structure manufacturing technology seems to play an important role
- Damping has to be integrated and demonstrated

Healthy Collaborations

CLIC structure: SLAC KEK Saclay

We are the hot topic !

SLAC today

Tuesday - May 8, 2007

SLAC And CERN Collaborate in Testing a New Accelerator

by Maria José Viñas

Parts of the Compact Linear Collider (CLIC)—CERN's experimental project to accelerate electrons in a unique and powerful way—are currently being tested at SLAC. Raquel Fandos, an electrical engineer from CERN, is using SLAC's Next Linear Collider Test Accelerator (NLCTA) in Endstation B to conduct trials of prototype accelerator structures that would be used at CLIC. This research is part of the CLIC feasibility study expected to be completed in 2010.

Raquel Fandos, an electrical engineer from CERN, in the Next Linear Collider Test Accelerator control room at SLAC where she conducts experiments.

Fandos' group at CERN wants to build radio-frequency accelerator structures that work at a gradient of 100 MV/m (accelerating electrons up to 100 MV per meter of machine) and produce 70-nanosecond pulses. "We have already reached those parameters with some structures," says Fandos. "However the breakdown probability is still too high, and we observe damage on the surface of the structures after a few weeks of testing." This is why Fandos is currently testing the sturdiness of different accelerator structures at the NLCTA, applying different combinations of pulse lengths and gradients in each trial to observe how many breakdowns occur in the devices in a certain period.

This is the third time in two-and-a-half years that CERN personnel have come to SLAC to test CLIC parts, and Fandos says the collaboration between the two centers will probably increase in the future. Although CLIC was initially designed to work at an accelerating frequency of 30 GHz (the same level at which the test facility at CERN works), CERN recently decided to switch CLIC's frequency to 12 GHz, very close to the 11.424 GHz at which NLCTA operates, making the facilities at SLAC uniquely suited for testing the components of CLIC.

ILC-News Letter

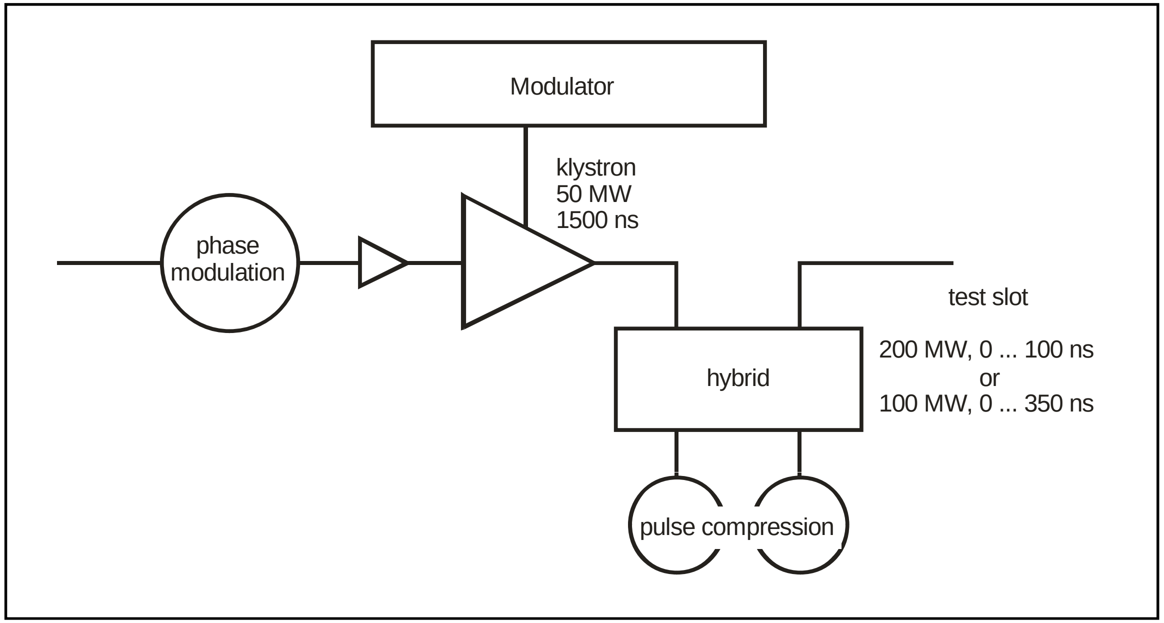
In the News

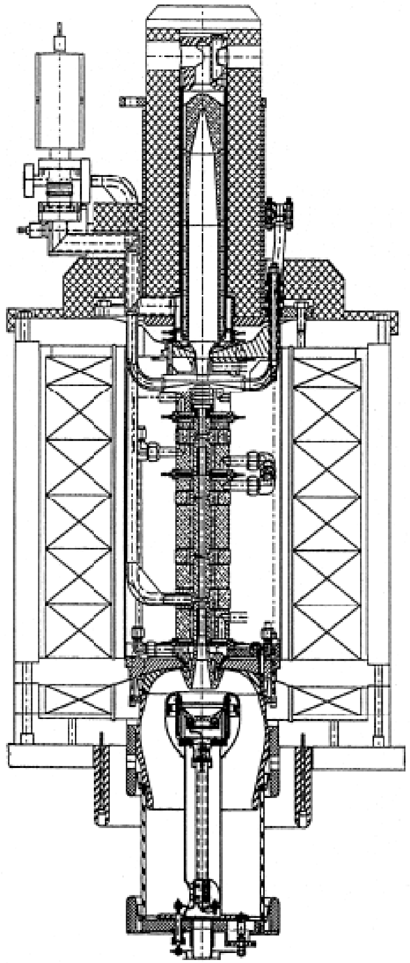
From *SLAC Today*
8 May 2007
SLAC and CERN Collaborate in Testing a New Accelerator
Parts of the Compact Linear Collider (CLIC)-CERN's experimental project to accelerate electrons in a unique and powerful way-are currently being tested at SLAC.
Read more...

12 GHz stand alone power source

12 GHz power source: PSI INFN-Frascati Trieste

Based on a scaled 11.4 GHz klystron





Independent 24/7 testing with fast turn around

Variable pulse length

Long term testing

Synchronized with CTF3

Future Testing Program

2007: Study Parameter Space at 30 GHz and testing of real structures at 11 GHz (focus on copper structures)

2008: Focus on two main geometries, develop damping, optimize structure

2009: CLIC prototype structure

2010: Longer term testing and better statistics

Number of tests (optimistic)

	2007	2008	2009	2010	sum
30 GHz	5	3	0	0	8
12 GHz	0	1	4	4	9
11.4 GHz	2	4	4	4	14
Stand alone at CERN	0	0	8	8	16
sum	7	8	16	16	47

30 GHz program in CTF3

30 GHz will be used for fundamental studies of rf designs, preparation methods and materials

30 GHz:

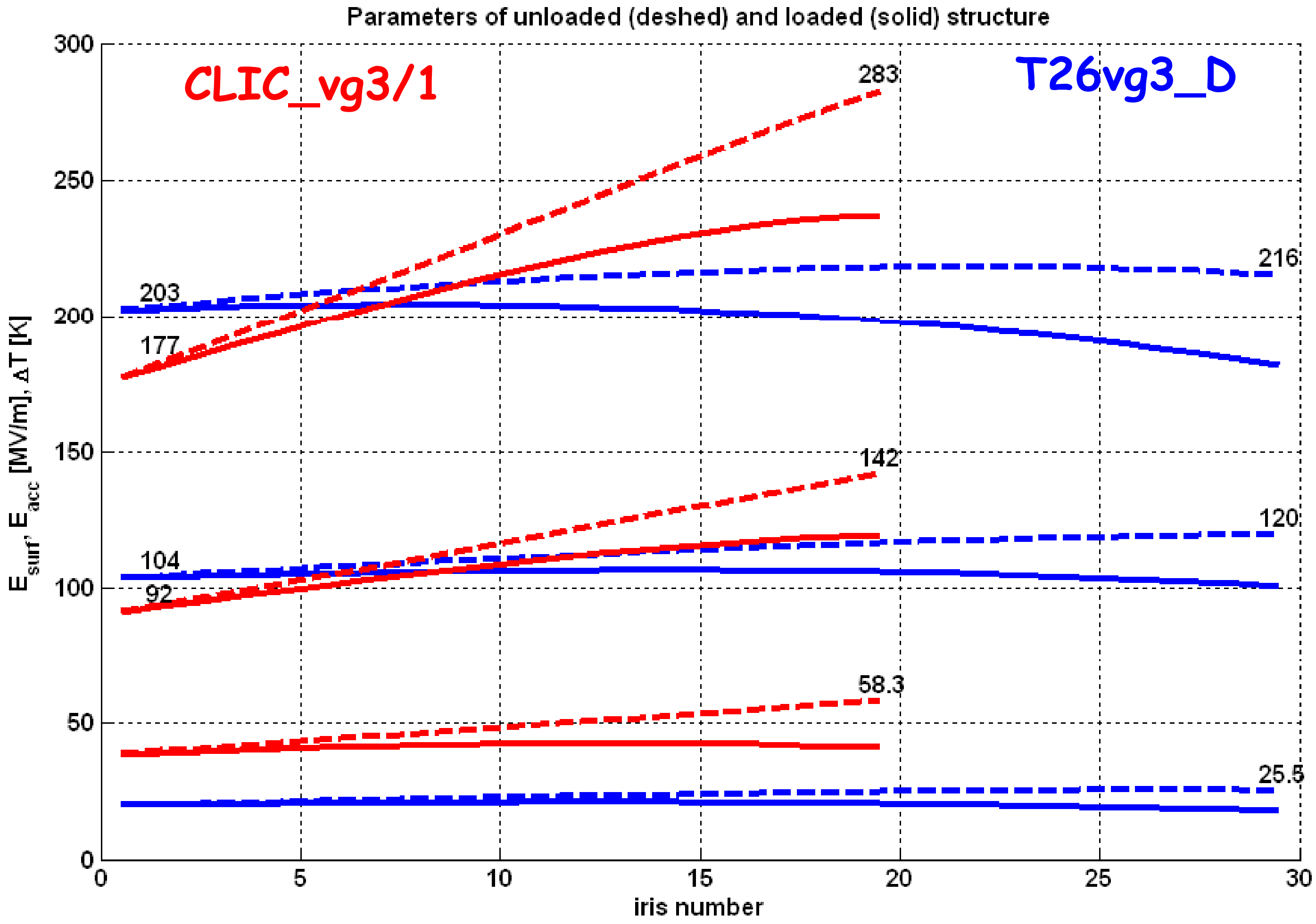
- pi/2 structure (test of short phase advance, fabrication tech.)
- HDS 11 copper/molybdenum (for better statistics)
- HDS 11 very small (r=1.2) (clear P/C experiment without other changes)
- Round 3.5 mm made out of quadrants (clear experiment for fab. Tech.)
- HDS4_150deg_thick_r=1.75 (iris thickness, phase advance, length, P/C)
- HDS4_150deg_thick_clean (compares cleaning with previous)
- NDS4_150deg_thick_r=1.75 (fab. Tech between HDS and NDS quadrants)
- NDS4_ 150deg_thin (iris thickness in comparison with NDS4_150deg_thick)
- Coupler test structure (not defined yet)

The two relevant geometries for the CLIC R&D program

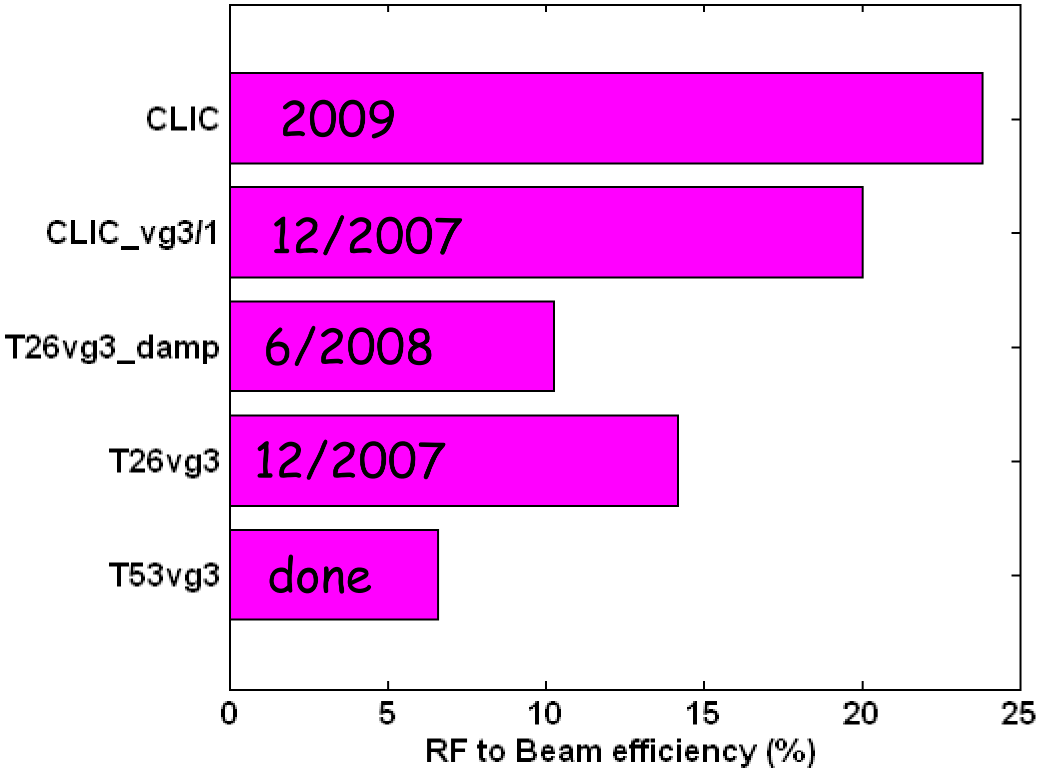
		CLIC	CLIC_vg1	T26vg3 damped
Frequency: f [GHz]		12	12	11.424
Average iris radius/wavelength: $\langle a \rangle/\lambda$		0.12	0.128	0.134
Input/Output iris radii: $a_{1,2}$ [mm]		3.87,2.13	3.87, 2.53	3.89, 3.17
Input/Output iris thickness: $d_{1,2}$ [mm]		2.66, 0.83	2.66, 1.25	1.66
Group velocity: $v_g^{(1,2)}/c$ [%]		2.39, 0.65	2.4, 0.95	2.86, 1.42
N. of cells, structure length: N_c, l [mm]		24, 229	18, 179	30, 265
Bunch separation: N_s [rf cycles]		8	8	8
Number of bunches in a train: N_b		311	359	66
Pulse length, rise time: τ_p		297	295	102
Input power: P_{in} [MW]		65	70	111
Max. surface field: E_{surf}^{max} [MV/m]		298	283	216
Max. temperature rise: ΔT^{max} [K]		56	58	25
Efficiency: η [%]		23.8	20	10.3
Bunch population: N		4.0×10^9	4.0×10^9	4.0×10^9

Parameters along the structures

CLIC_vg3/1 is more extreme in maximum surface field, pulsed heating and lowest group velocity



Efficiency milestones



P = 65 MW; 297 ns ⇔ nb = 311

P = 70 MW; 295 ns ⇔ nb = 359

P = 111 MW; 102 ns ⇔ nb = 66

P = 102 MW; 113 ns ⇔ nb = 93

P = 134 MW; 104 ns ⇔ nb = 27

100 MV/m loaded, 10^{-6} break down rate, qb=4*10^9,
8 rf period bunch spacing, P*pl/C = 18 Wue

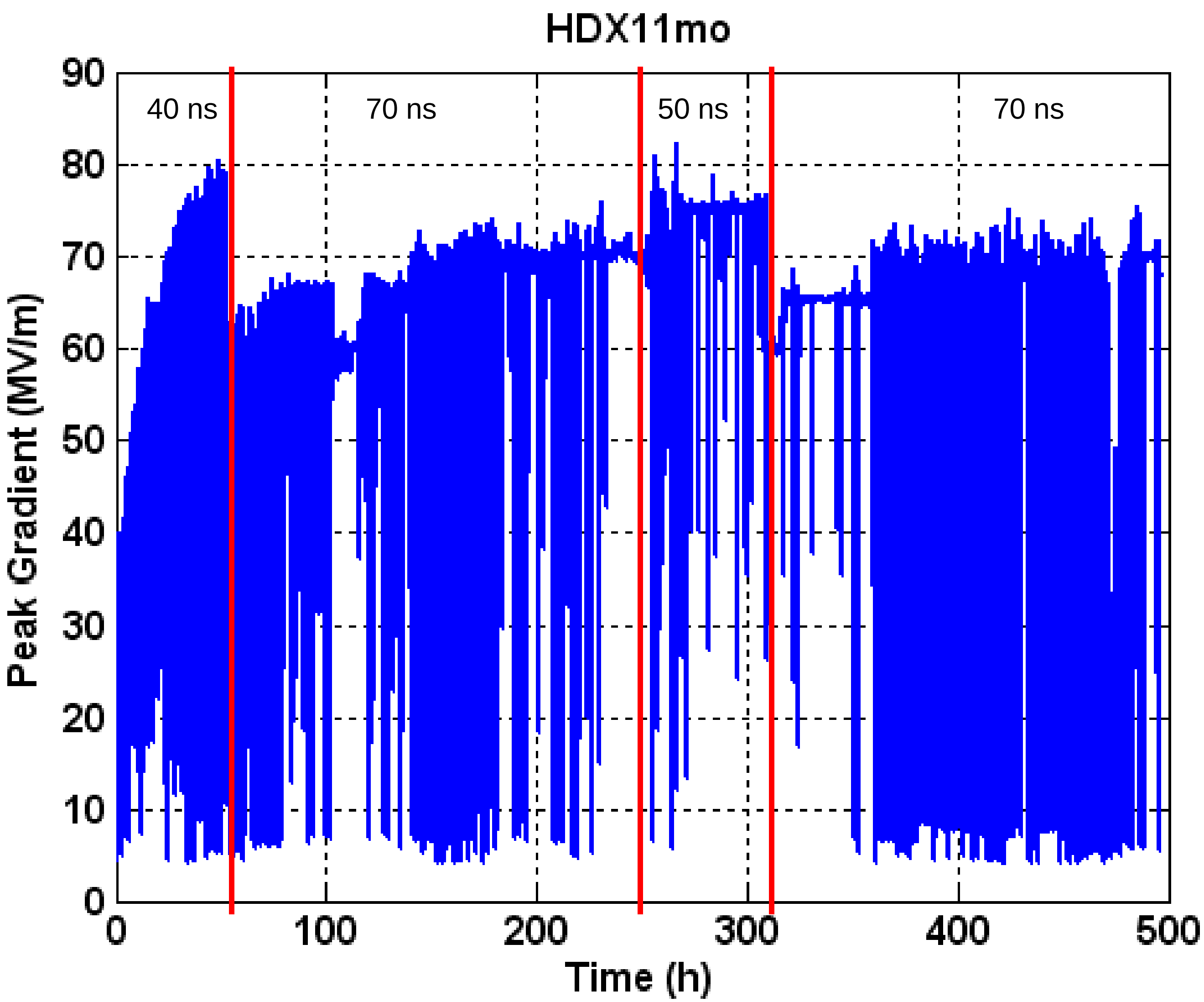
Tentative CERN x-band R&D program

When	Structure	Technology	Lab
Dec 2007	CLIC_vg1	quadrants, damped	CERN
	T26vg3MC	disks, brazed, undamped	SLAC
March 2008	CLIC_vg1	quadrants, undamped	CERN
	T26vg3MC	quadrants, undamped	CERN
June 2008	CLIC_vg1	disks, brazed, undamped	CERN/KEK
	T26vg3MC	disks, brazed, damped	CERN
2009	CLIC prototype	fully featured, best technology	CERN/SLAC/KEK

Conclusions

- Good chance to demonstrate in time the new structure parameters
- Assembled a powerful world wide collaboration
- Nevertheless busy and tight program to follow up
- 12 GHz stand alone power source is essential for our program

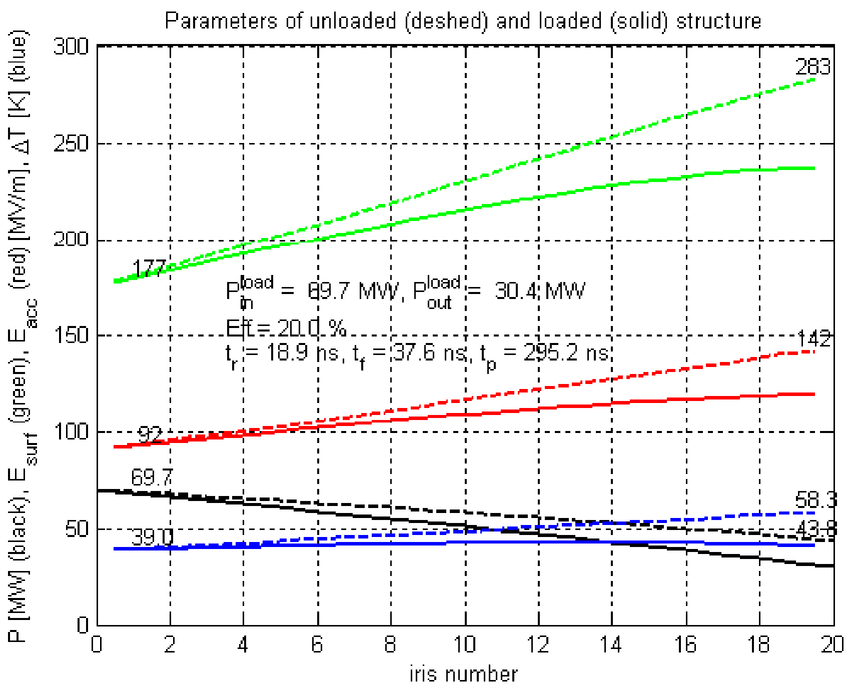
Total Conditioning history so far



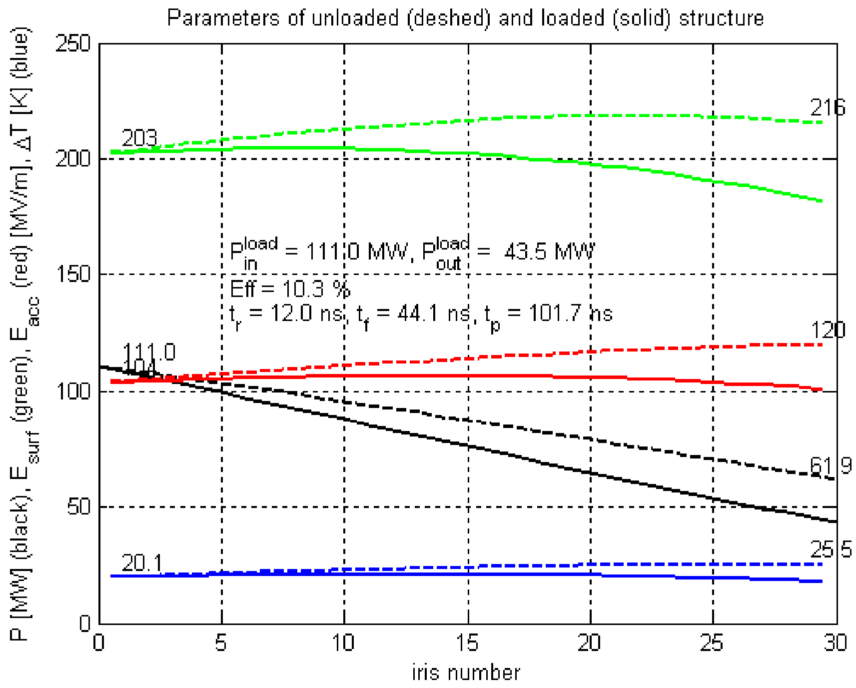
Parameters along the structures

CLIC_vg3/1 is more extreme in maximum surface field, pulsed heating and lowest group velocity

CLIC_vg3/1

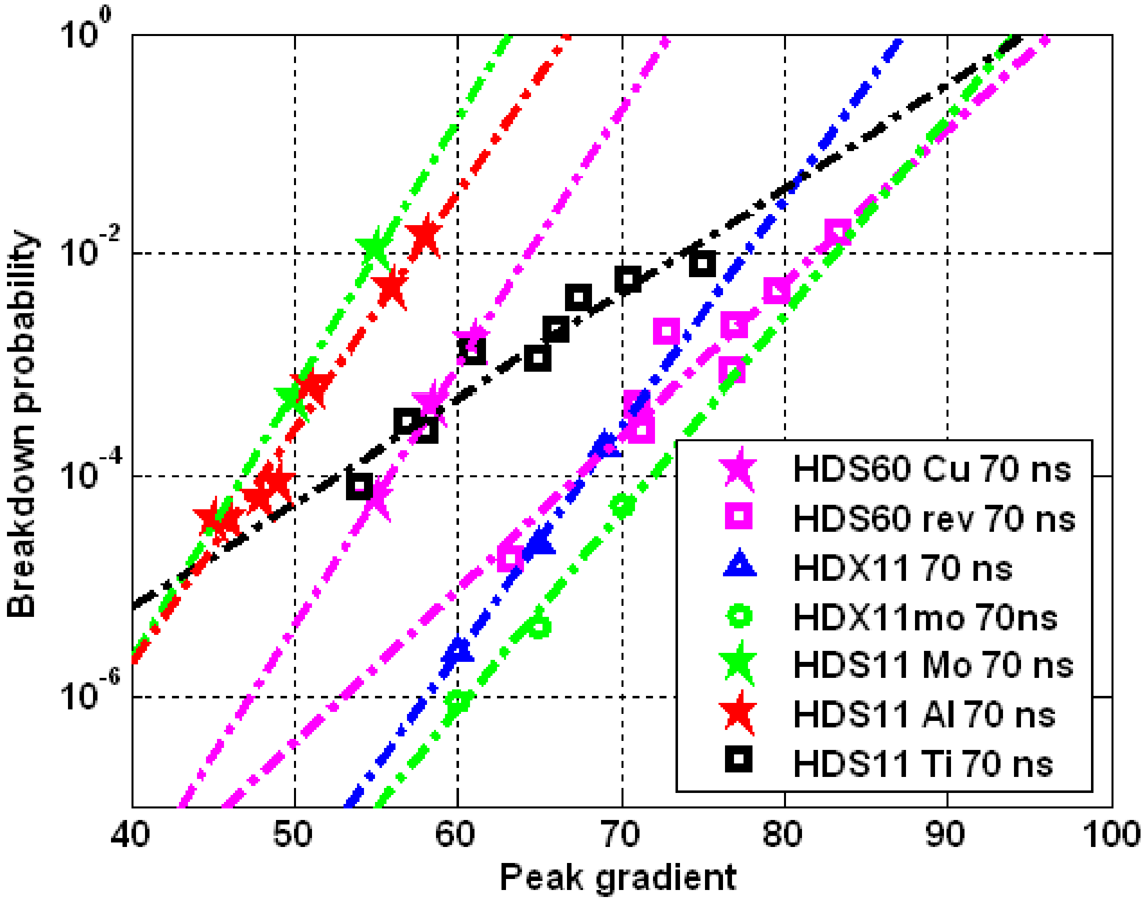


T26vg3_D



Even More Breakdown Rates

All HDS-type structures tested so far



HDS performs consistently worse than round structures
No significant improvement for other materials over Copper

Typical Conditioning history