Introduction to CLIC

Walter Wuensch
KVI, Groningen
25 March 2011

Outline

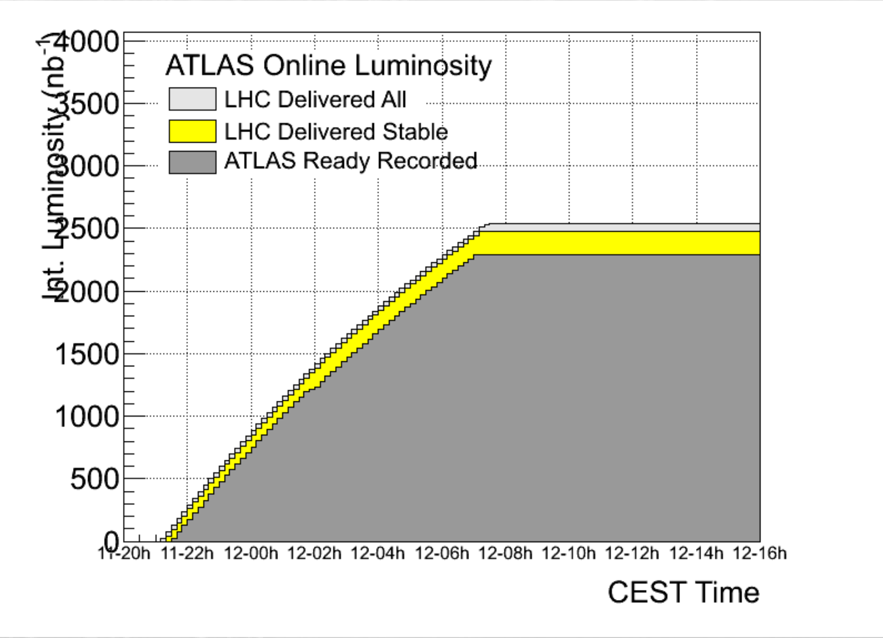
- The linear collider landscape
- The CLIC machine
- High-gradient rf development

State-of-the-art in TeV facilities

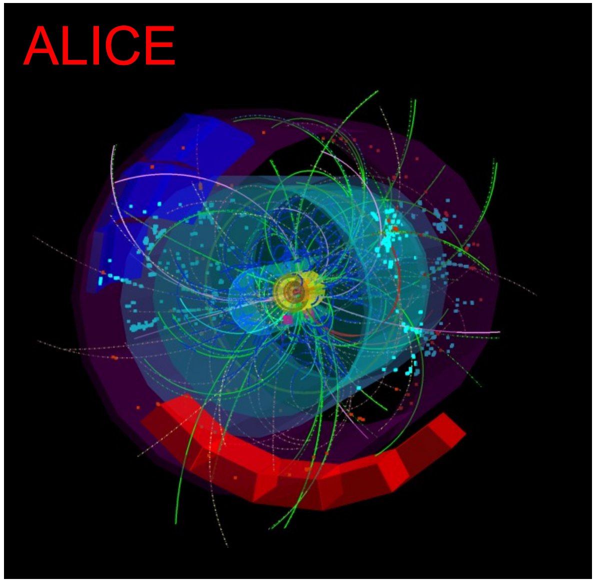
The LHC at CERN, has just started its second year of operation at a 7 TeV center of mass energy with proton-proton collisions.

The energy will be increased to the design specification of 14 TeV in the coming years.

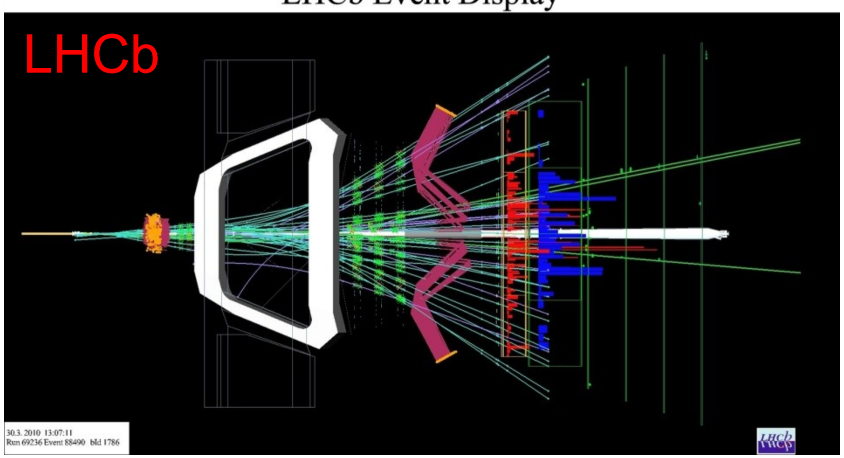
Upgrades in luminosity and/or energy are already being discussed.

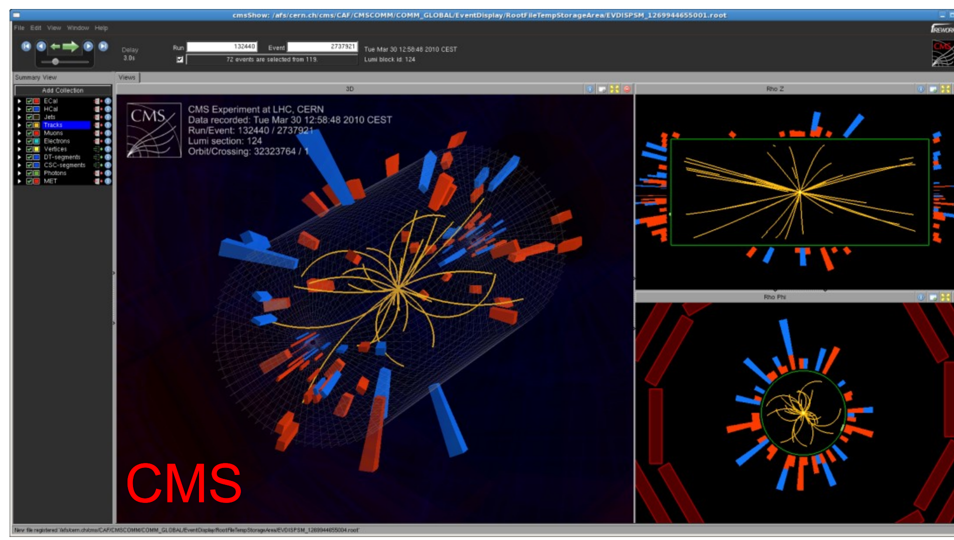


LHC: First collisions at 7 TeV on 30 March 2010



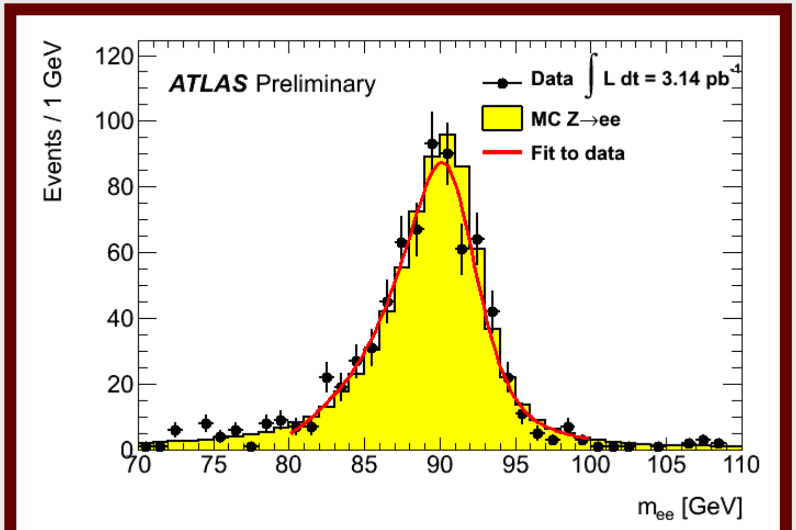
LHCb Event Display



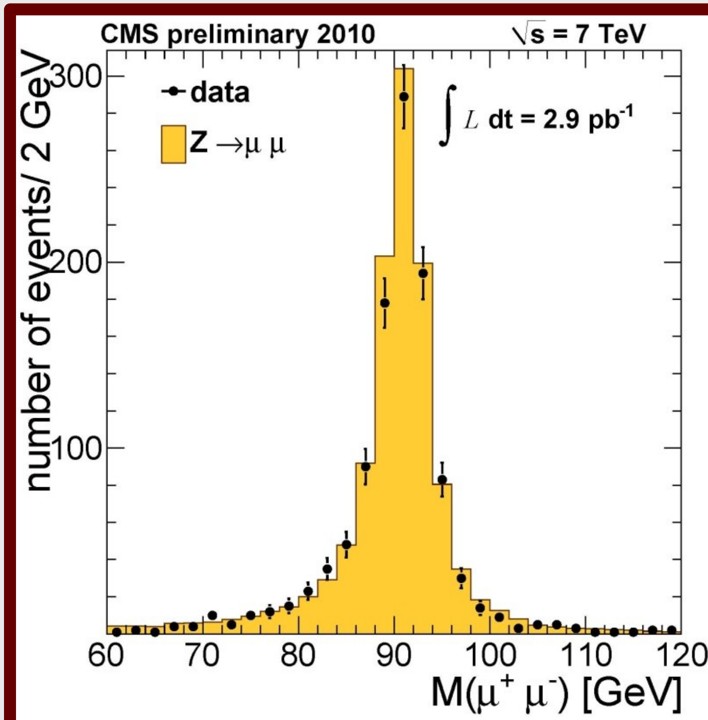


What's new since Beijing

- Experiments are performing very well



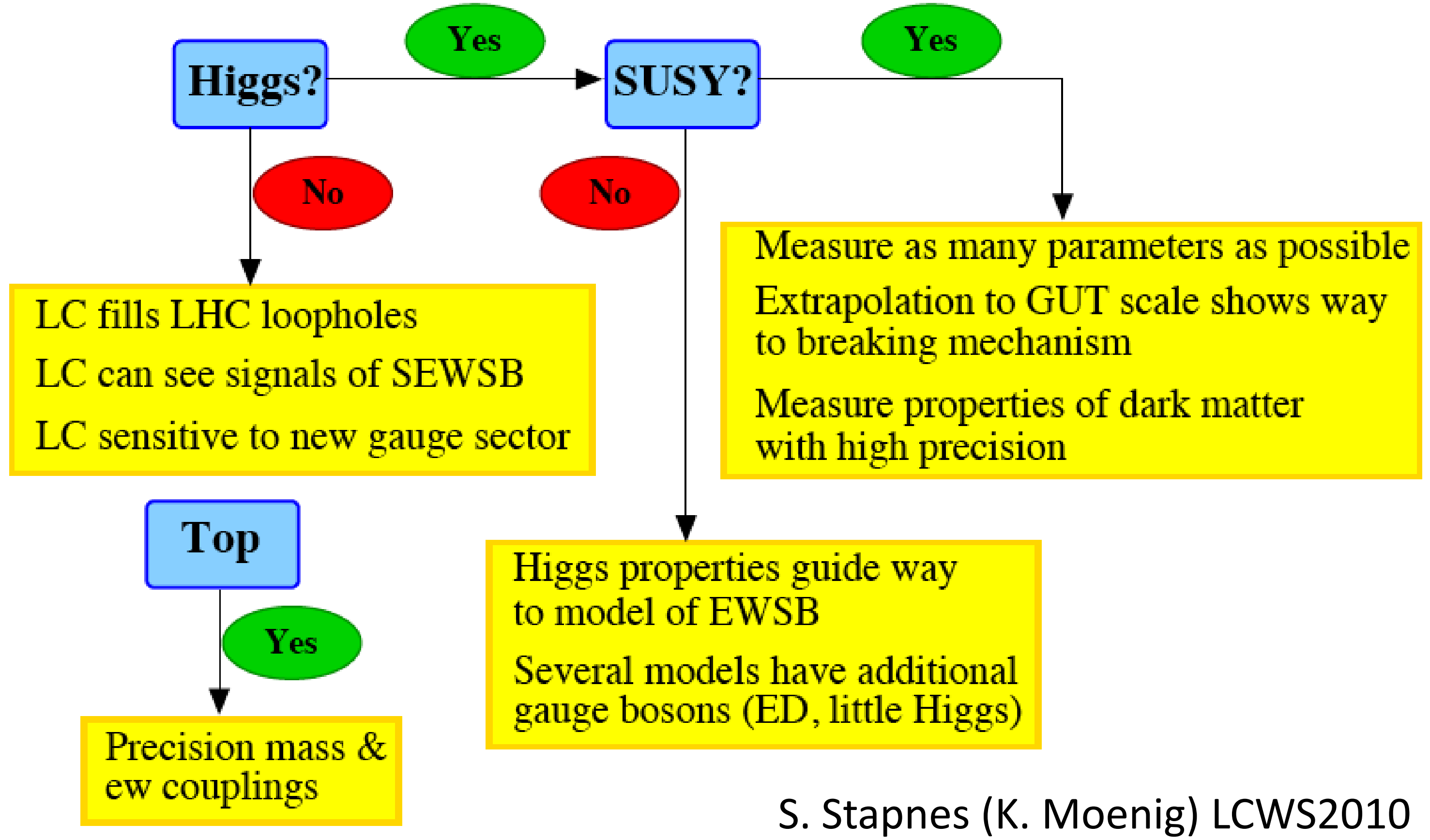
EM energy scale known to 1-3%
Resolution approaching MC value



Muon scale known to ~ 1% (or better) in Z-region
Resolution approaching MC value

TeV dreams

Many new physics discoveries are hoped for from the LHC - Higgs, super symmetry, dark matter. Many of these new particles could then be better studied in detail using the simpler experimental environment of **lepton** collisions.



S. Stapnes (K. Moenig) LCWS2010

e^+e^- linear colliders

Electron-positron linear colliders operating in the range of 0.5 to 3 TeV to complement the LHC are under active study.

The energy of a future linear collider is expected to be determined more precisely from the physics results produced by the LHC in the next two years or so.

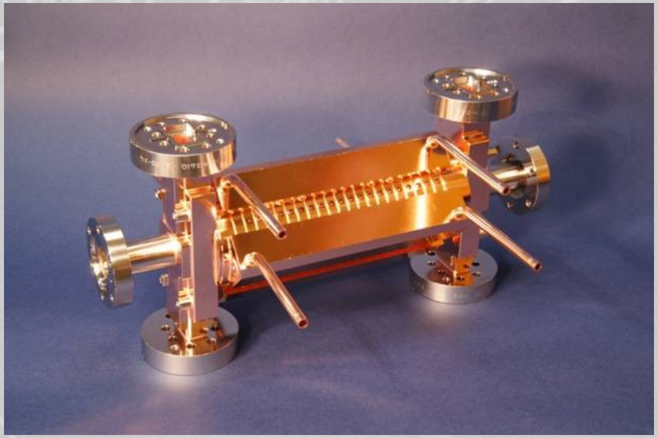
(The lower energy compared to the LHC is that only the energy of individual constituent quarks and gluons of the protons, six in total, that actually contribute to the relevant interaction.)

ILC and CLIC

There are two main approaches currently formalized as projects: ILC and CLIC

- The ILC is superconducting with a gradient of 31.5 MV/m
- CLIC is normal conducting with an accelerating gradient of 100 MV/m.

		CLIC	CLIC	ILC
E_{cms}	[TeV]	0.5	3.0	0.5
f_{rep}	[Hz]	50	50	5
f_{RF}	[GHz]	12	12	1.3
G_{RF}	[MV/m]	80	100	31.5
n_b		354	312	2625
Δt	[ns]	0.5	0.5	369
N	$[10^9]$	6.8	3.7	20
σ_x	[nm]	202	40	655
σ_y	[nm]	2.26	1	5.7
ϵ_x	[μm]	2.4	0.66	10
ϵ_y	[nm]	25	20	40
$\mathcal{L}_{total}$	$[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	2.3	5.9	2.0
$\mathcal{L}_{0.01}$	$[10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}]$	1.4	2.0	1.45



The early days of multi-TeV linear colliders

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN-LEP-RF/86-06

and

CLIC NOTE 13
13.2.86

A TWO-STAGE RF LINEAR COLLIDER
USING A SUPERCONDUCTING DRIVE LINAC

W. Schnell

Abstract

The efficiency from RF input to beam power of a normal conducting travelling-wave linac can be raised above 5% albeit at the price of a very short power pulse and an appreciable but probably correctible energy spread. Compensated multibunch operation may yield 30% efficiency but higher order wakefield problems have to be solved and a suitable final focus system must be found. The worst remaining problem seems to be the economic and efficient generation of peak RF power. The solution proposed here consists of a limited number of CW UHF klystrons, a superconducting UHF drive linac and a tightly bunched drive beam of several GeV average energy, transferring energy from the superconducting linac to the main linac via short sections of transfer structures. The power balance of this scheme is analysed and it is found that overall efficiency can be very high. Very dense drive bunches are required. Present-day performance of superconducting cavities is already sufficient to make the scheme viable at main linac accelerating gradients approaching 100 MV/m.

Geneva, Switzerland
February 1986

CLIC Note 38
(May, 1987)

ORGANISATION EUROPÉENNE POUR LA RECHERCHE NUCLÉAIRE
CERN EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

REPORT FROM THE ADVISORY PANEL ON THE PROSPECTS
FOR e^+e^- LINEAR COLLIDERS IN THE TeV RANGE

GENEVA
1987

The years of many linear collider studies

MPI-PhE/93-14
ECFA 93-154
Vol. 1
June 1993

LC92

ECFA WORKSHOP ON e^+e^- LINEAR COLLIDERS

GARMISCH PARTENKIRCHEN

25 July - 2 August 1992

PROCEEDINGS
VOL. 1

EDITOR: Ron Settles

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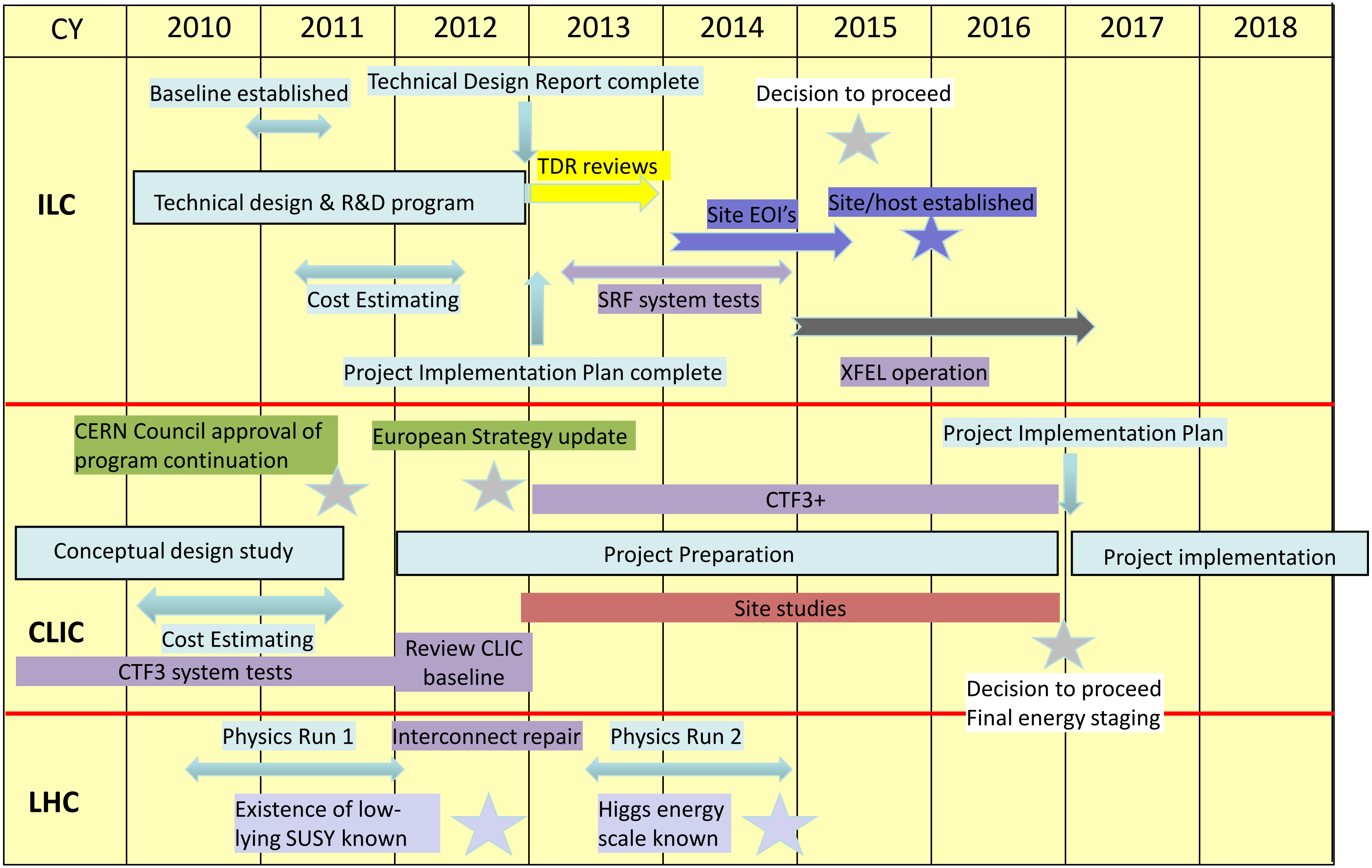
Volume I. Introductory Session

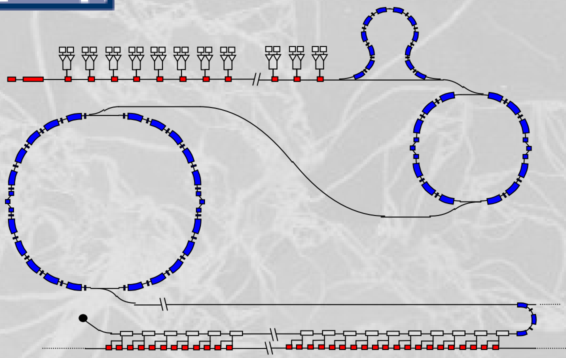
CLIC & ILC roadmaps



P. Lebrun LCWS2010

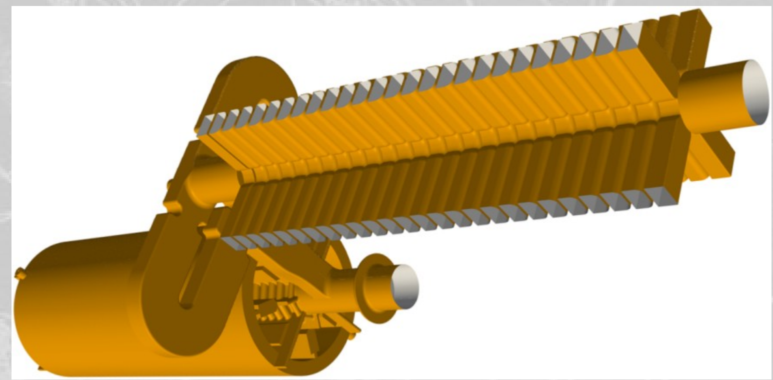
The CLIC machine

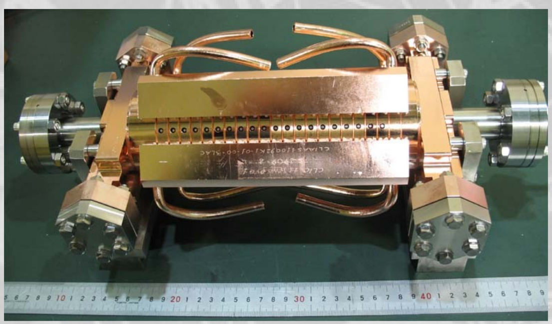
CLIC - fundamental features



Beam-based pulse compression

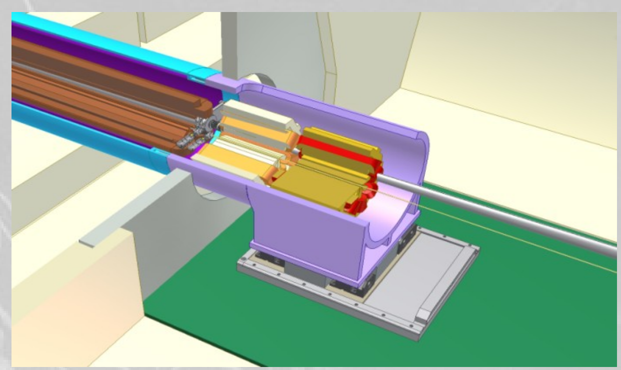
Two-beam acceleration





High-gradient rf acceleration

Low emittance beams
(not covered today)



Beam-based pulse compression

The total peak 12 GHz power required to feed the whole CLIC linac for 3 TeV center of mass energy and 100 MV/m acceleration is around of 8 TW with a total rf pulse energy of around 8 MJ.

Consequently CLIC, like most linacs, is a pulsed machine. The CLIC duty cycle is very low, around 10^{-5}.

CLIC has a beam-based scheme for storing energy and then compressing it, a logical approach for a laboratory specialized in particle beams.

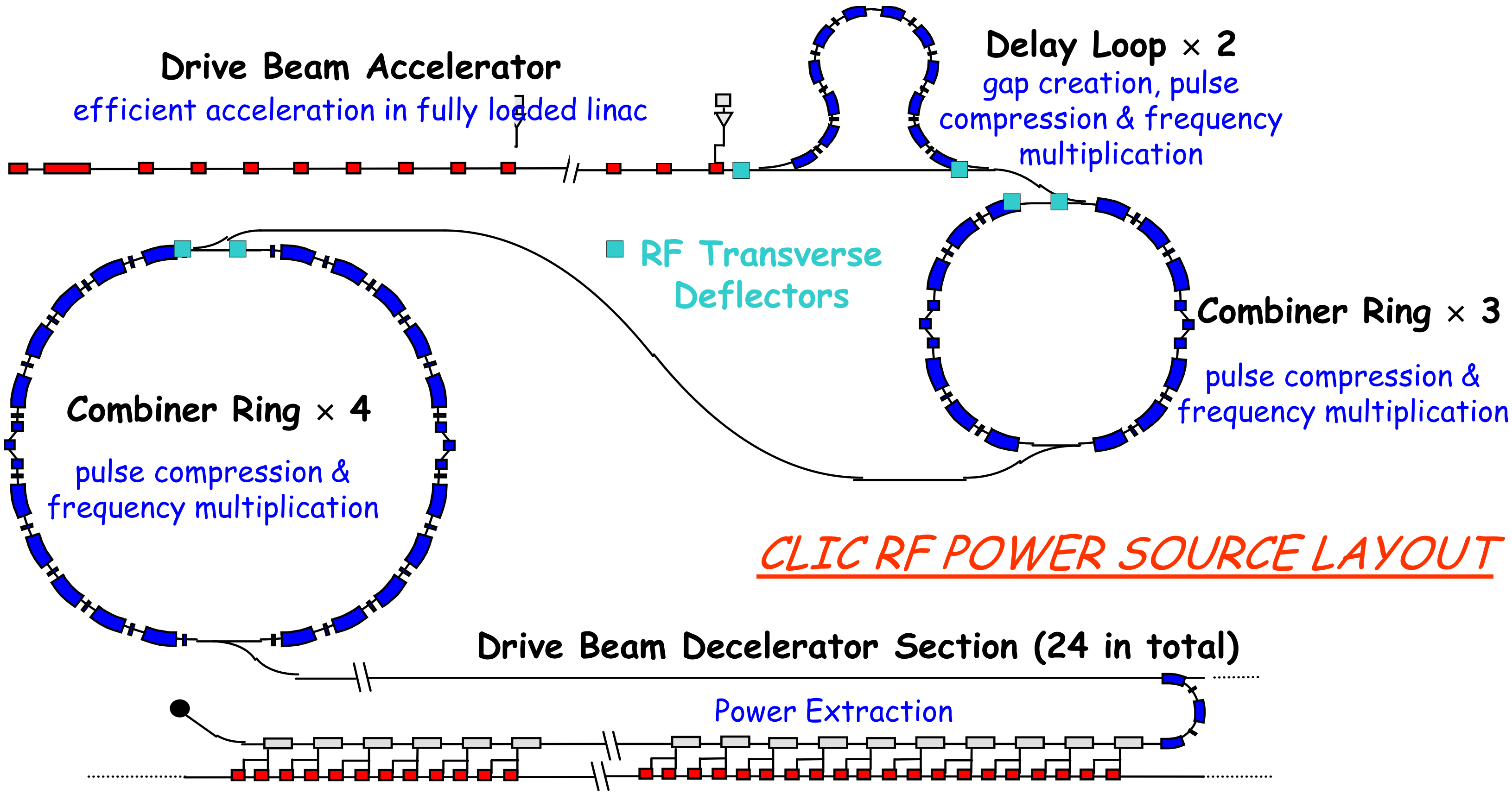
Beam-based pulse compression

Step 1: Energy transferred from mains to 100 A, 2.4 GeV and 140 μs drive beam via fully loaded 1 GHz linac fed by long pulse klystron/modulator. Factor 143.

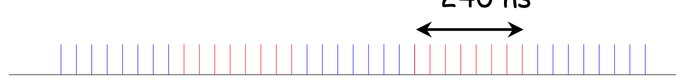
Step 2: Beam compression delaying loops and rings. This is an active pulse compressor based on rf deflection. Factor 24.

Step 3: Counter-flowing drive and main beam. Factor 24.

CLIC Drive Beam generation

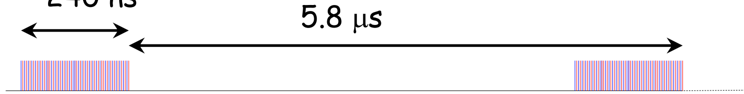


Drive beam time structure - initial



140 μs train length - 24 × 24 sub-pulses
4.2 A - 2.4 GeV - 60 cm between bunches

Drive beam time structure - final



24 pulses - 100 A - 2.5 cm between bunches

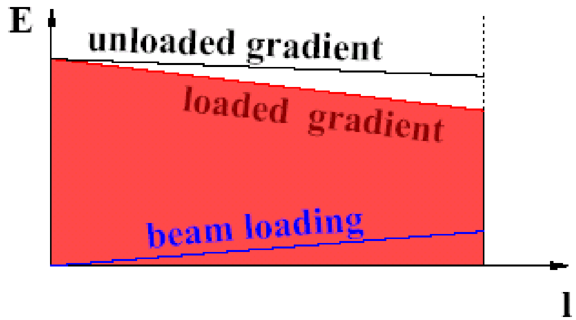
Let’s follow the power

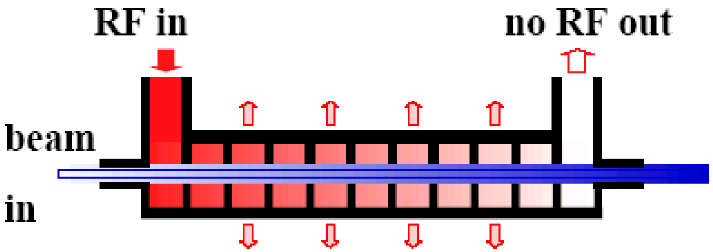
Fully loaded operation

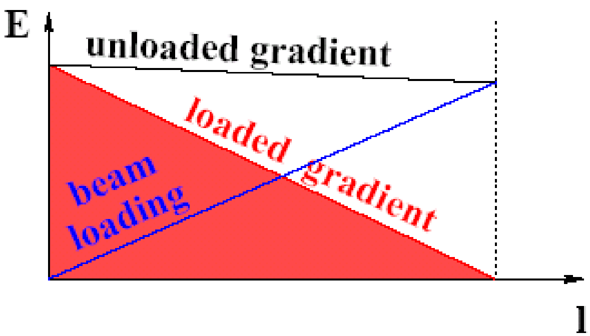
- efficient power transfer from RF to the beam needed

"Standard" situation:

- small beam loading
- power at structure exit lost in load



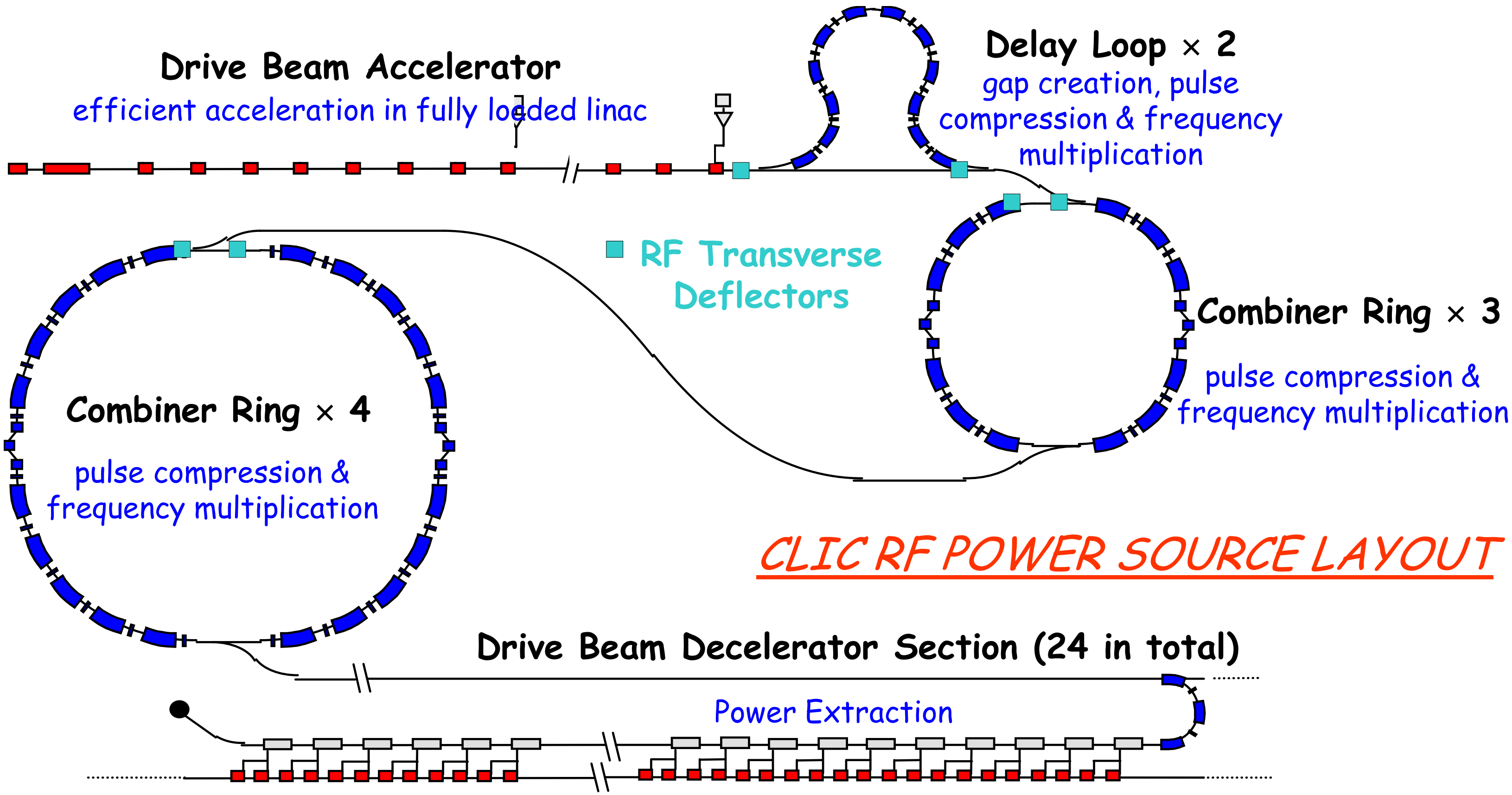




"Efficient" situation:

- high beam current
- high beam loading
- no power flows into load
- $V_{ACC} \approx 1/2\ V_{unloaded}$

CLIC Drive Beam generation



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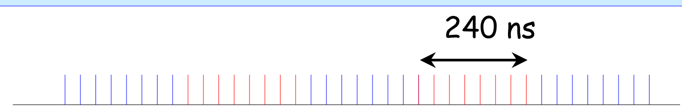
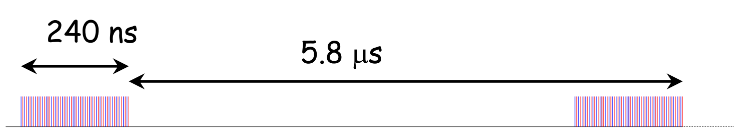
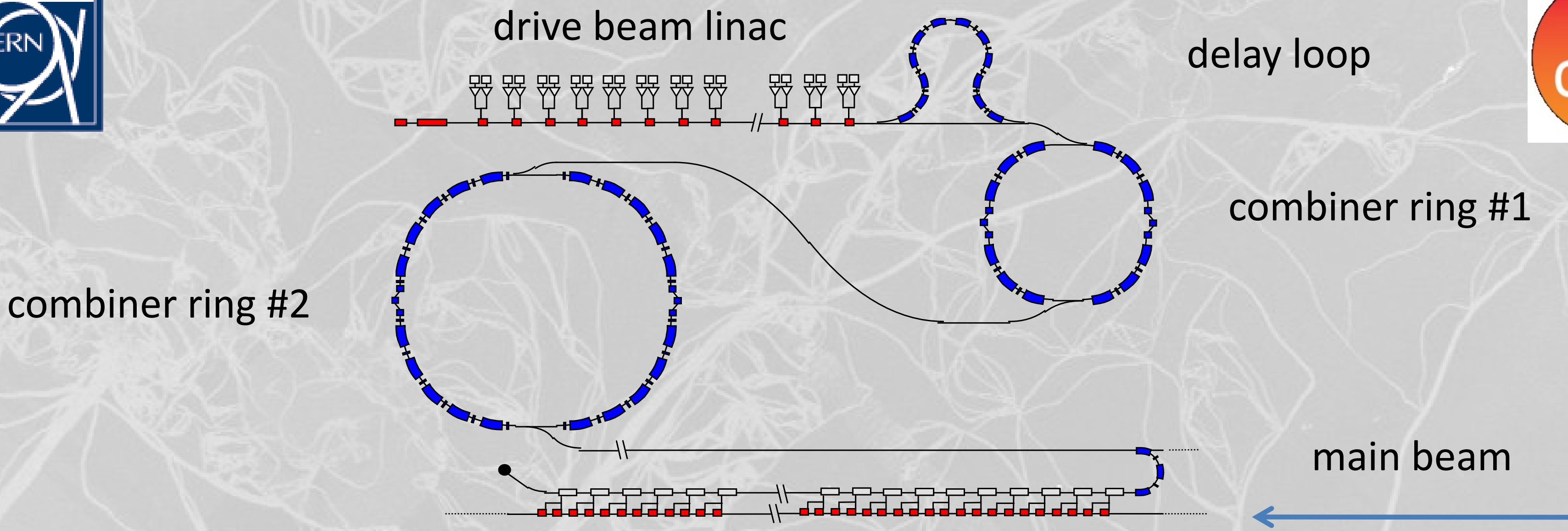


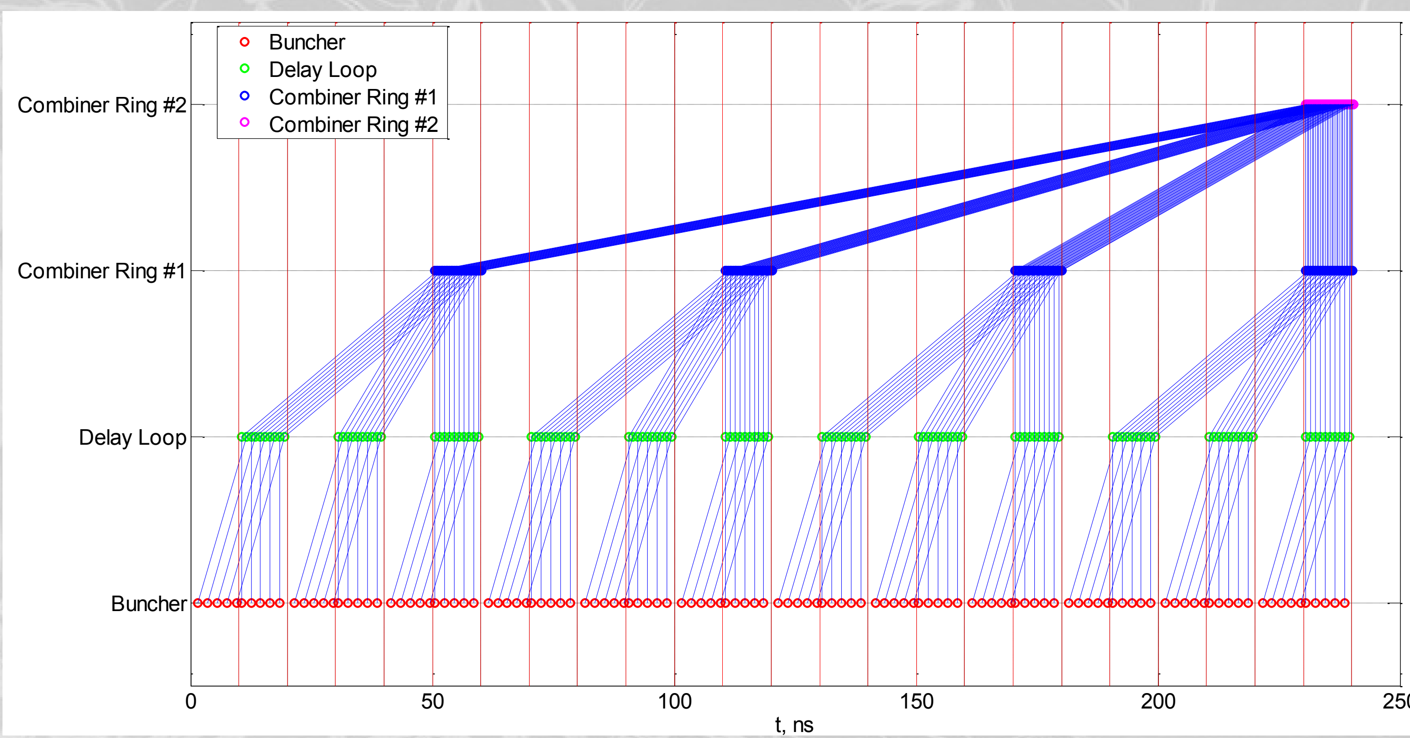
140 μs train length - 24 × 24 sub-pulses
4.2 A - 2.4 GeV - 60 cm between bunches

Drive beam time structure - final



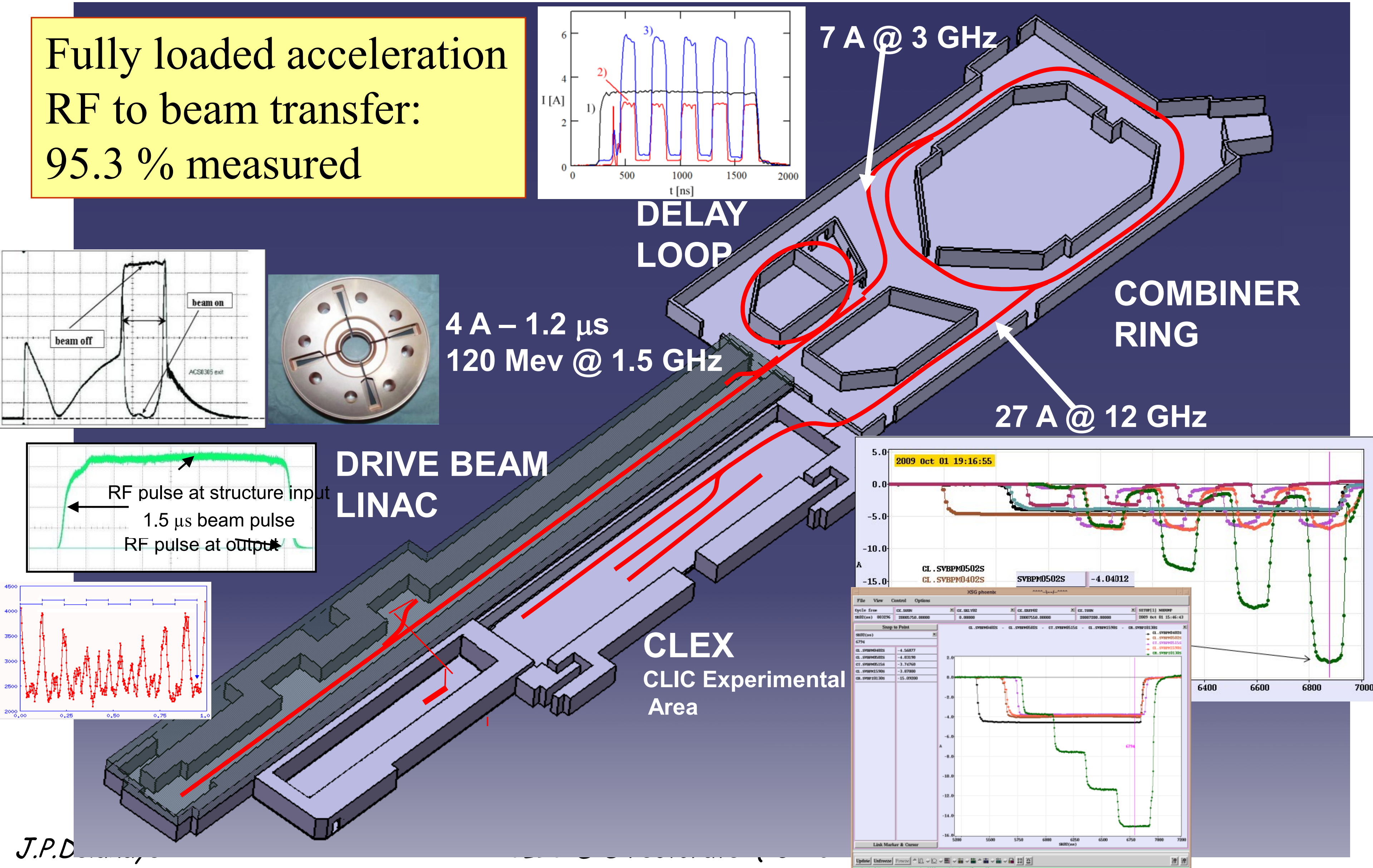
24 pulses – 100 A – 2.5 cm between bunches


drive beam linac
delay loop
combiner ring #1
combiner ring #2
main beam


Buncher
Delay Loop
Combiner Ring #1
Combiner Ring #2
Combiner Ring #2
Combiner Ring #1
Delay Loop
Buncher
0
50
100
150
200
250
t, ns

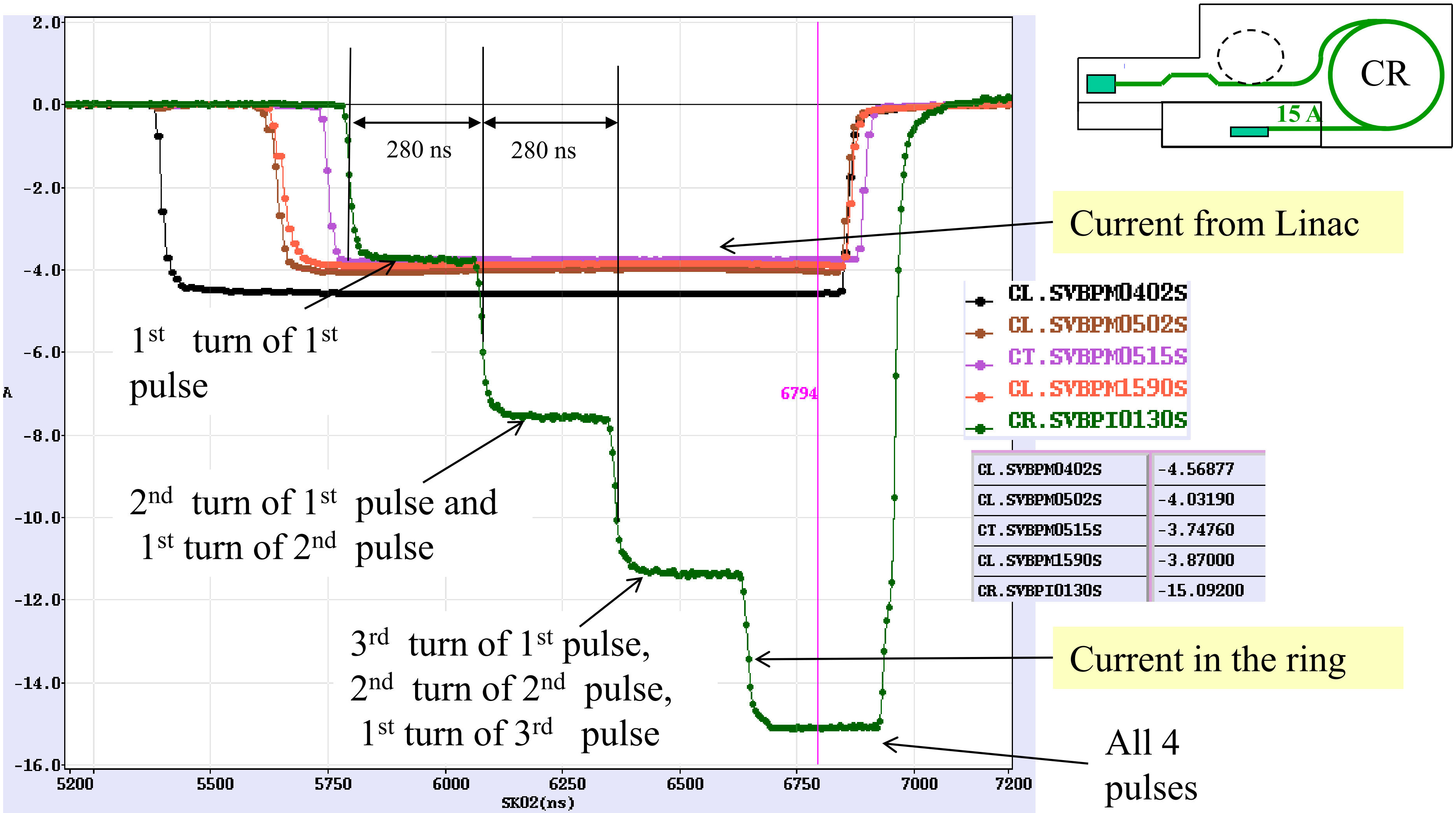
CTF3 completed, operating 10 months/year, under commissioning:Drive Beam Generation demonstrated

Fully loaded acceleration RF to beam transfer: 95.3 % measured

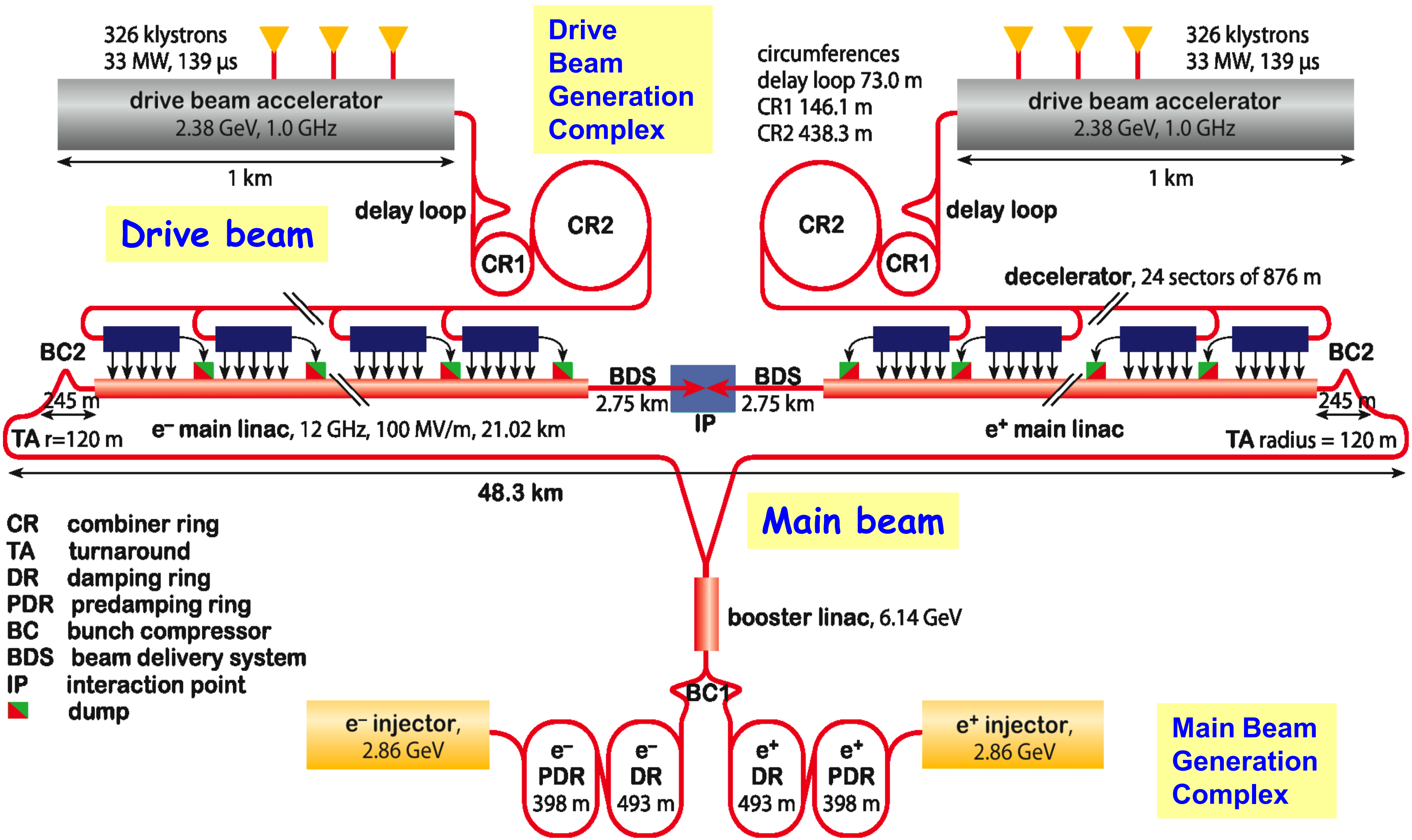


Combiner ring status

- factor 4 combination achieved with 15 A, 280 ns (without Delay Loop)



CLIC – overall layout – 3 TeV

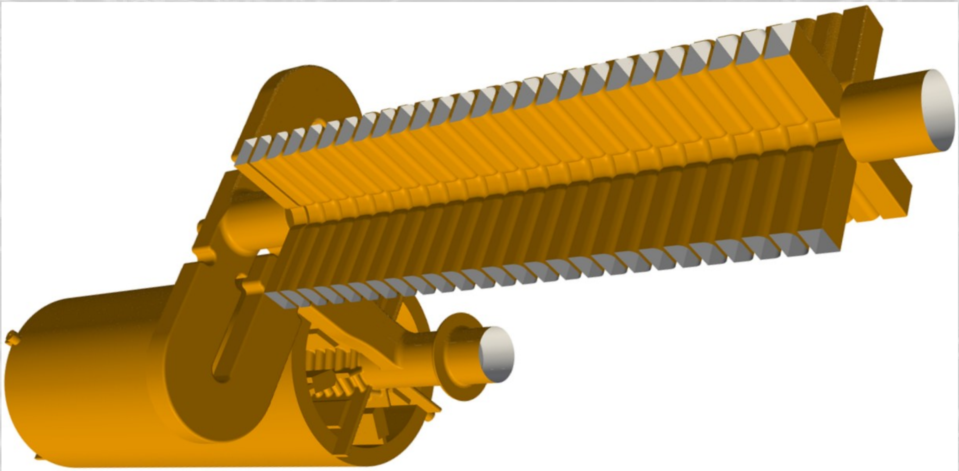


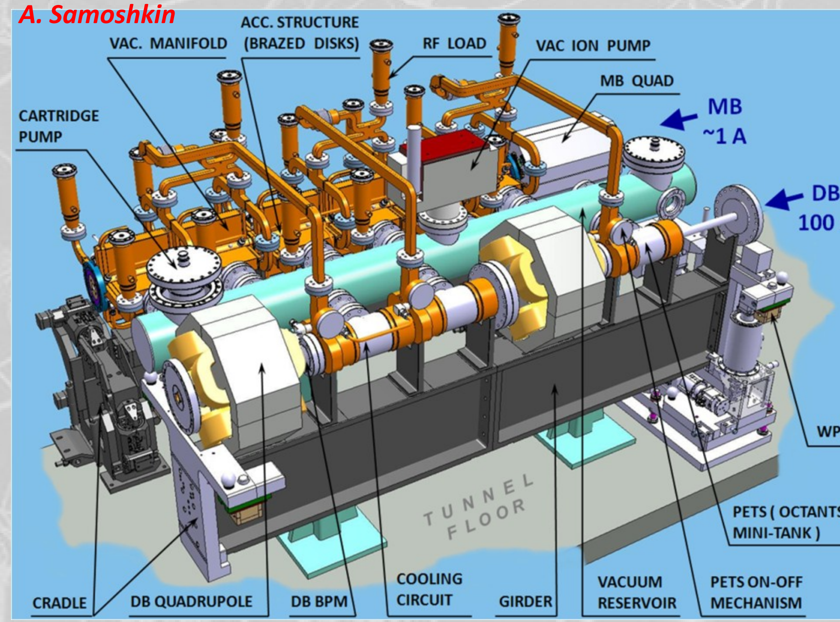
Two-beam acceleration

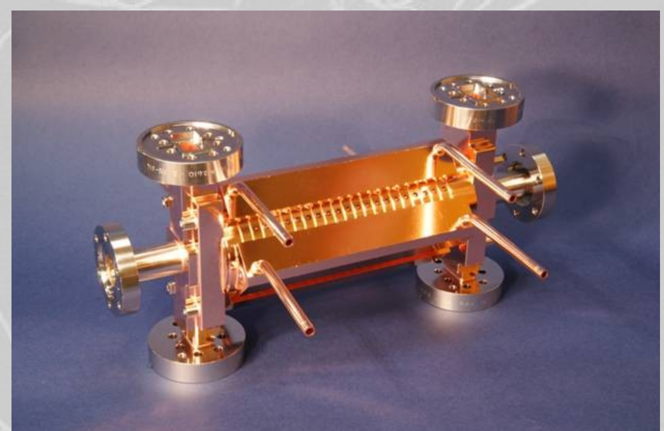
The next trick is transfer the kinetic energy of the 100 A drive beam to the 1A main beam via a two-beam "rf transformer"

Here the so-called PETS (Power extraction and transfer structure) decelerate the drive beam with a gradient of – 5.7 V/m to produce 135 MW of power in order to feed two accelerating structures with a gradient of 100 MV/m.

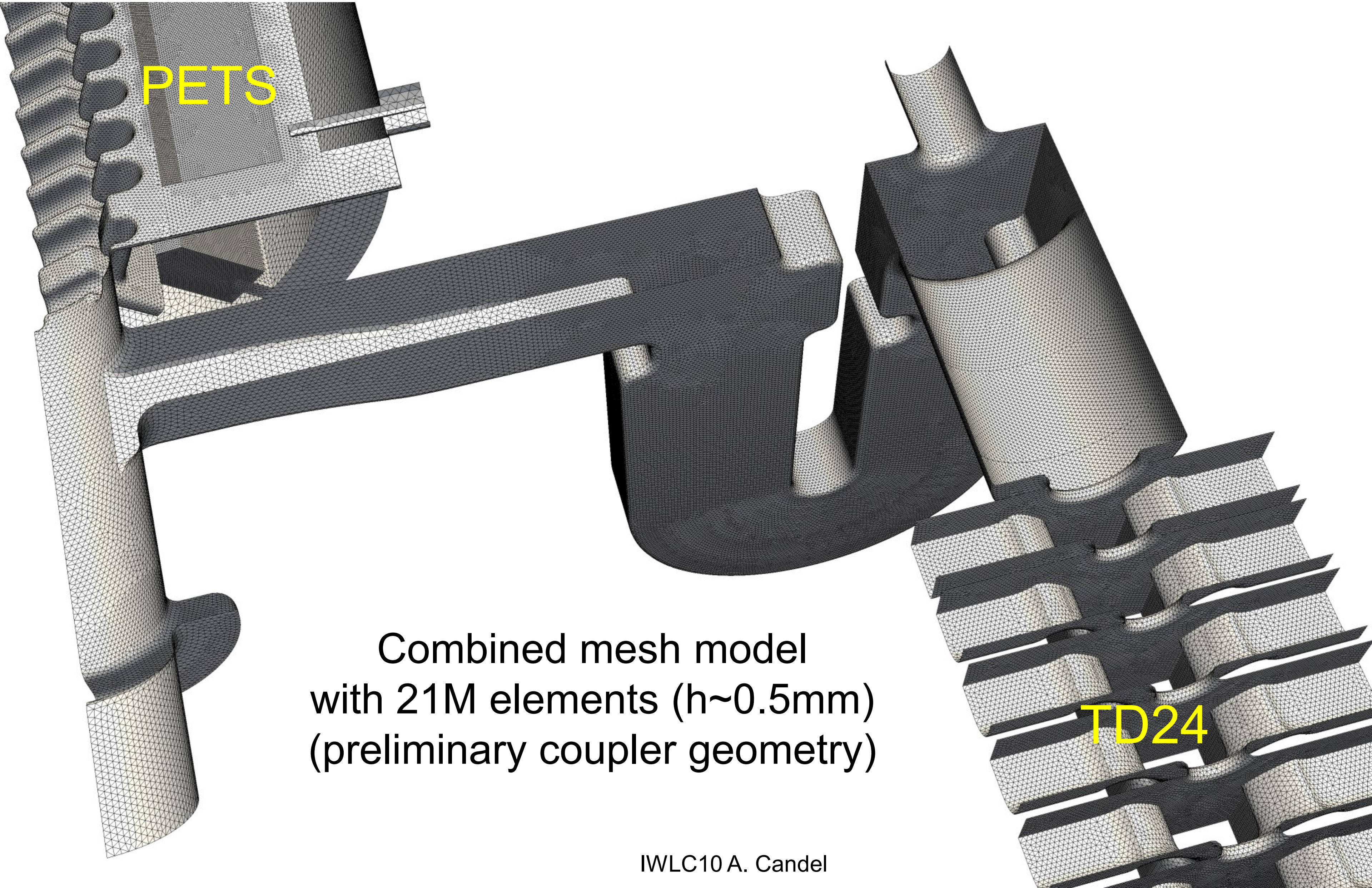
Elements of CLIC two-beam





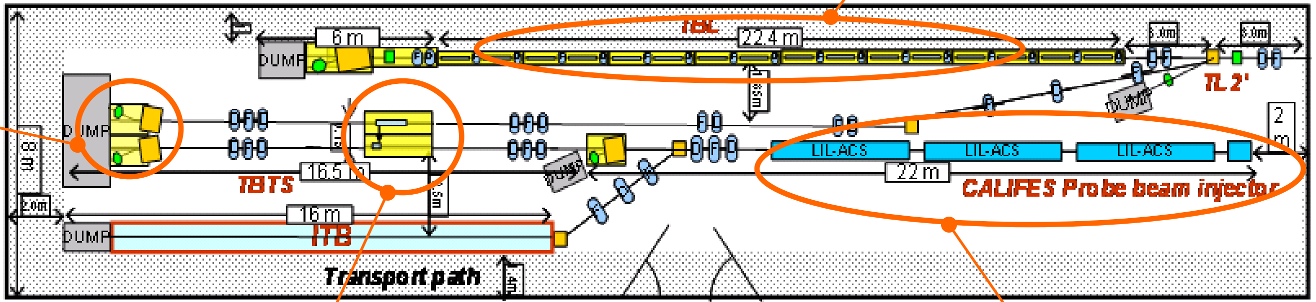


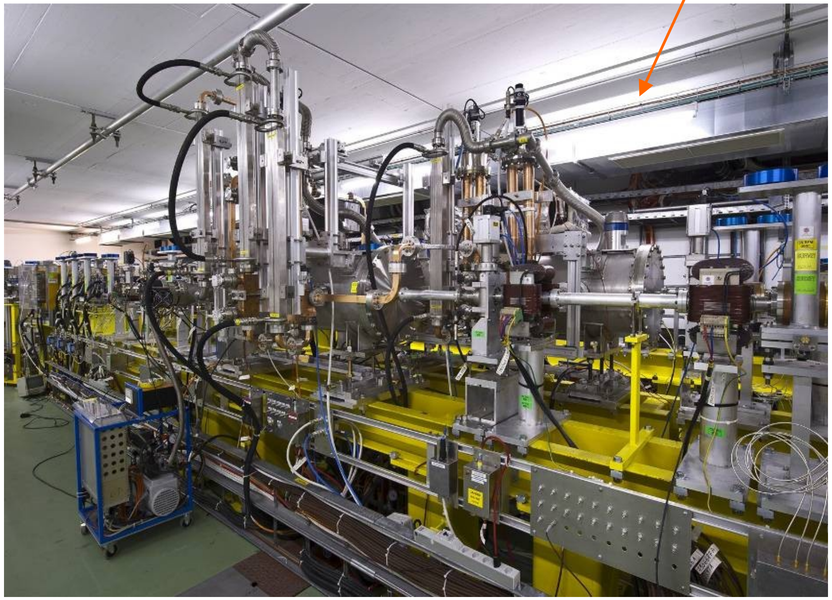
T3P: Wakefield Coupling PETS <-> TD24

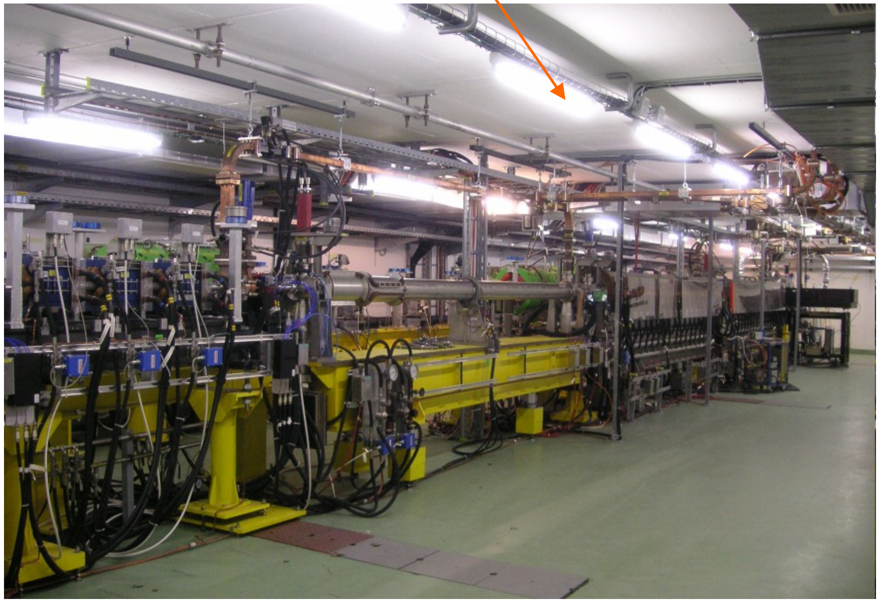


Combined mesh model
with 21M elements (h~0.5mm)
(preliminary coupler geometry)

TBTS is the test area in CLEX, where feasibility of the CLIC two beam acceleration scheme is…already demonstrated (not yet at a nominal 100 MV/m accelerating gradient).



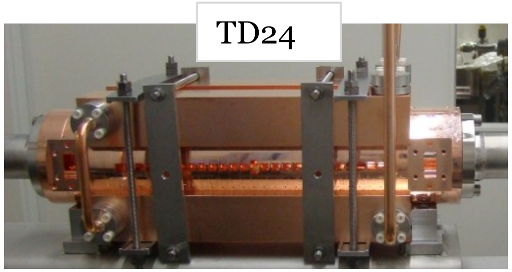


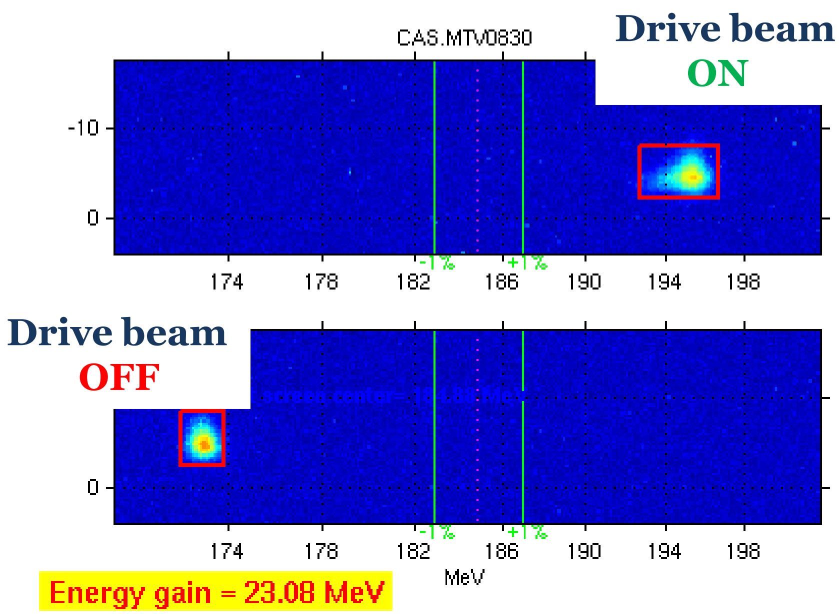


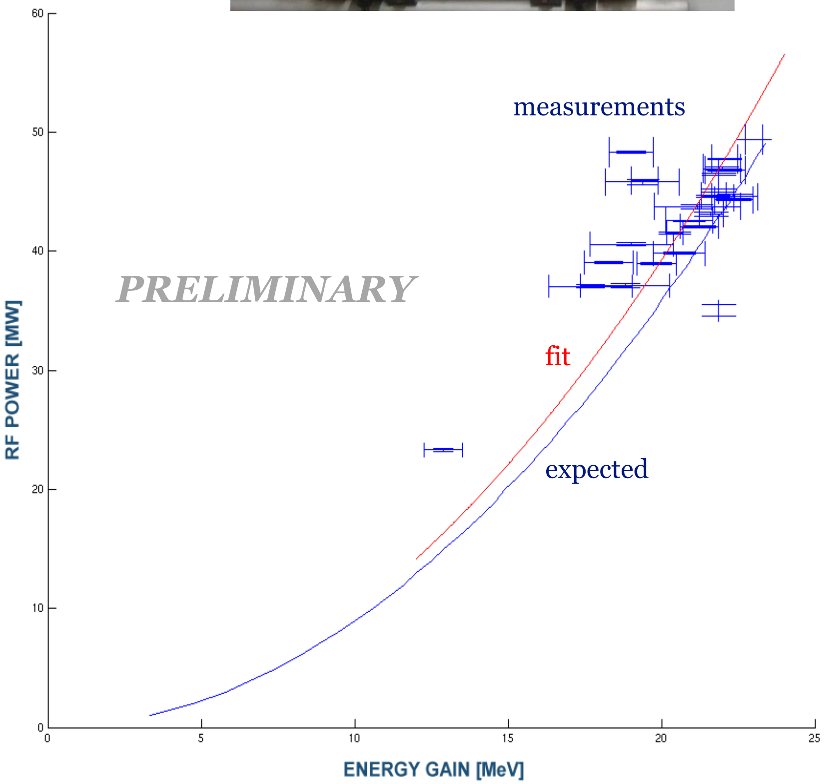
Two-Beam Acceleration demonstration in CTF3 Two-Beam Test Stand

Maximum probe beam acceleration of 23 MeV measured

⇒ Corresponding to a gradient of **106 MV/m**







Development of high-power and high-gradient rf structures

because

The energy reach of a linear collider is largely determined by the accelerating gradient.

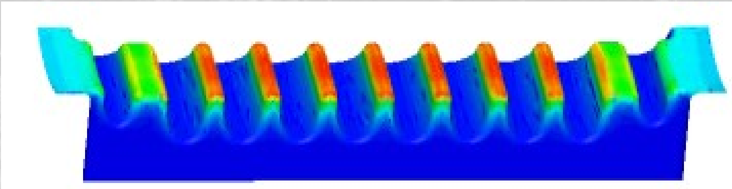
We follow the power again

PETS – specifications

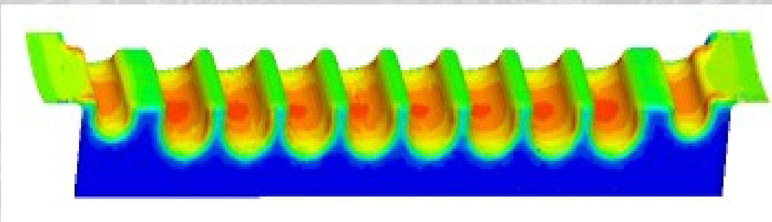
High-power:
1. 135 MW output power
2. 170 (flat top)/240 (full) ns pulse length
3. <2×10^{-7} 1/pulse/m breakdown rate

Beam dynamics:
1. Fundamental mode: gives 23 mm diameter aperture which corresponds to a/λ=0.46 and v_g/c=0.49 to give 2.2 kΩ/m, longitudinal impedance
2. Single bunch transverse wake: < 8 V/pC/mm/m
3. Long-range transverse wakefield with effective suppression of main HOMs by $Q_n(1-\beta_n)<8$ each

PETS – fundamental mode characteristics



Surface electric field



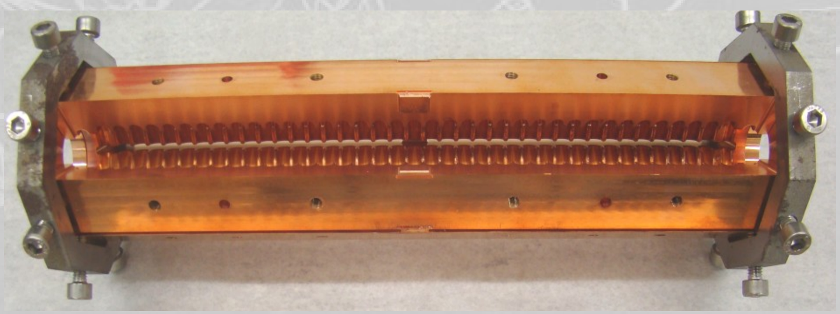
Surface magnetic field

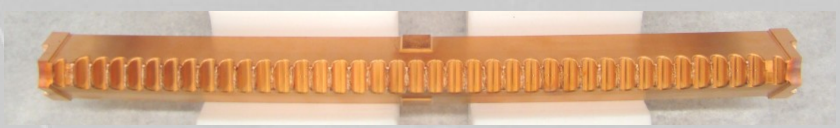
Beam-driven structure so power rises quadratically with current and length,

- 135 MW for 100 A beam
- 213 mm active length

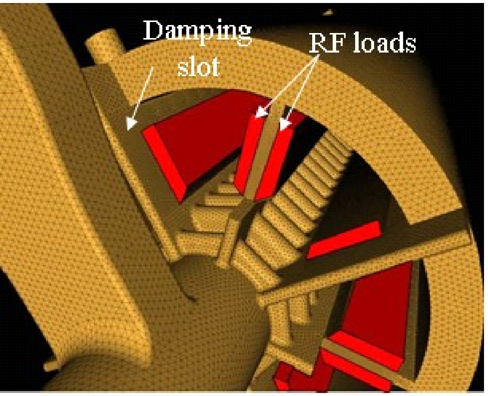
Maximum fields at output with values,

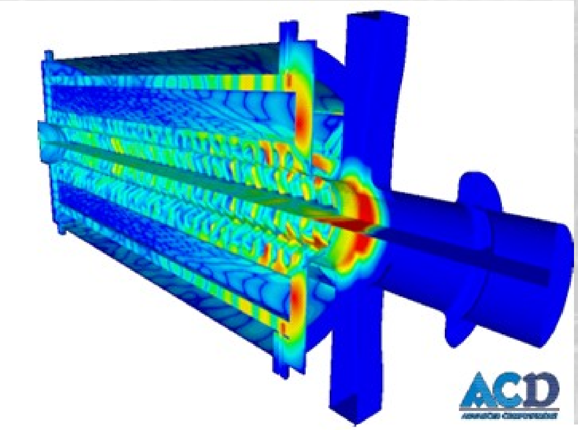
- E_{surf}=56 MV/m
- ΔT=1.8 (H_{surf}=0.08 MA/m)
- S_c=1.2 MW/mm^2





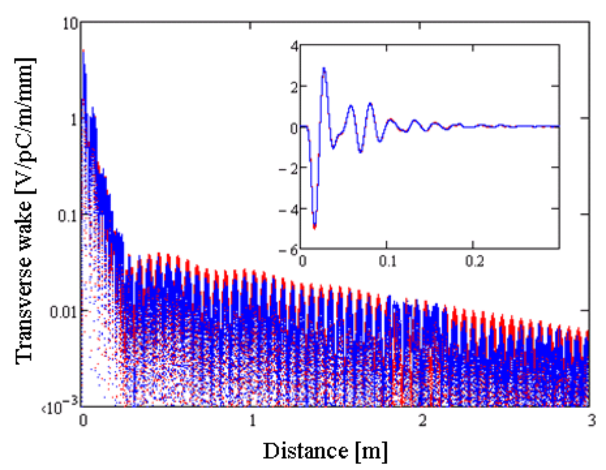
PETS – HOM suppression features

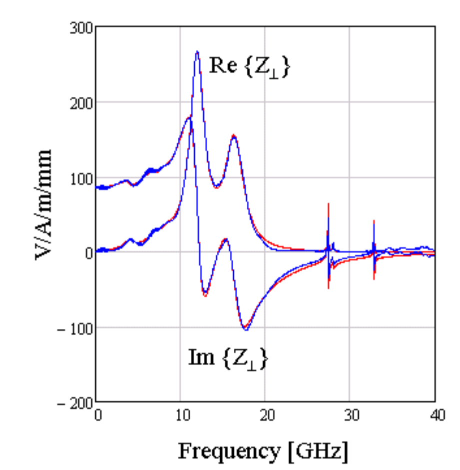


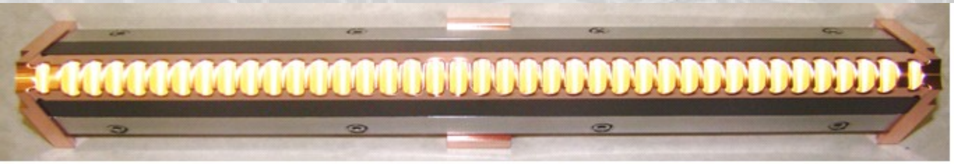


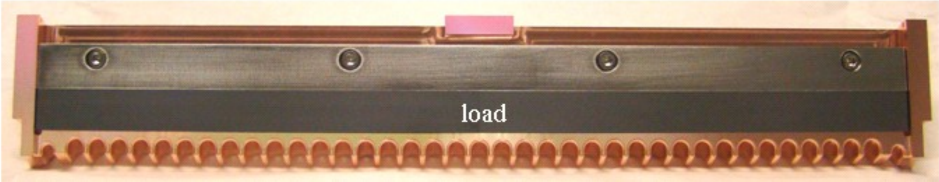
ACE3P analysis of HOM properties

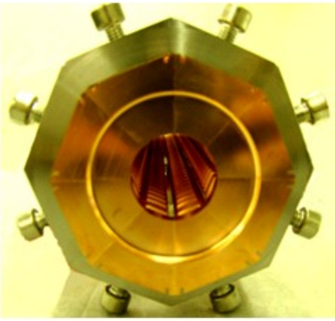
GdfidL and ACE3P benchmarking with analysis of PETS HOM properties











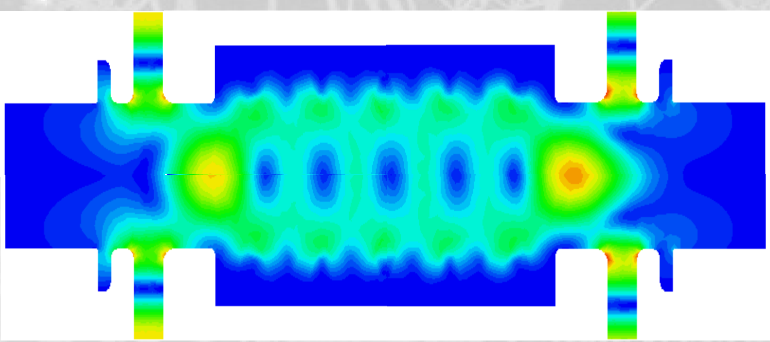
PETS for high-power testing **with SiC absorbers installed.**

PETS – the high-power testing challenge

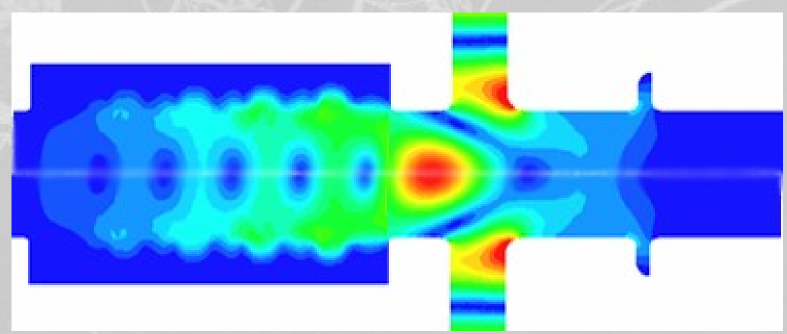
To high-power test the PETS in nominal conditions would require a 100 A driving beam.

“Waveguide” test with klystron/pulse compressor
- not many 135+ MW X-band power sources – ASTA at SLAC
- much harder to run, full fields at input

Beam-based tests with CTF3 4-30 A beam.
- 1000 mm long PETS
- Connect output to input – beam-driven rf resonant ring for lower, <10 A, current



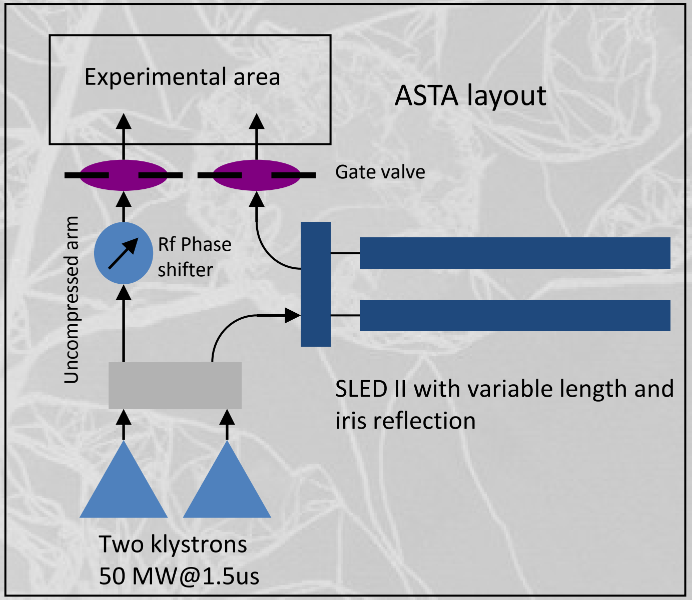
Fields in klystron and recirculation tests

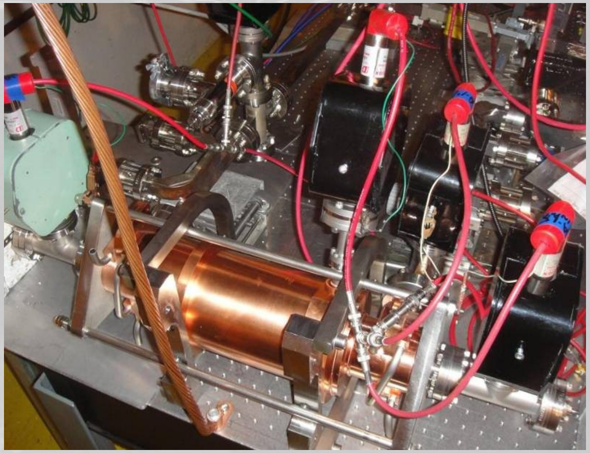


Fields in CLIC and CTF3 at high current

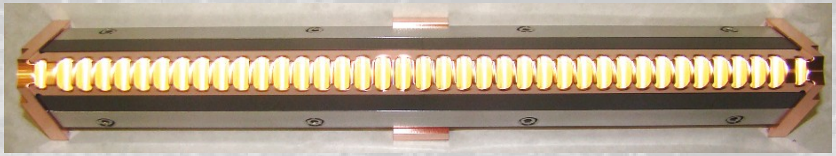
PETS testing in ASTA

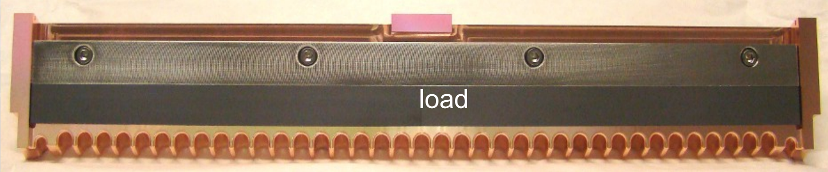
PETS waveguide-mode PETS testing is being done at ASTA in SLAC an impressive facility but testing a single object with 135+ MW power is very challenging. The results you will see are a mixture of conditioning of the PETS and ASTA…

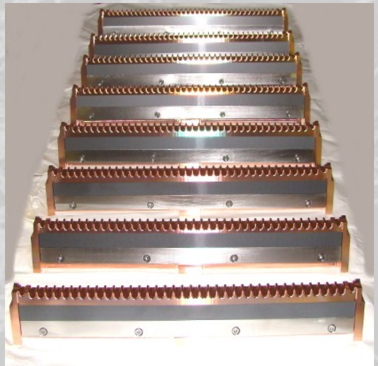


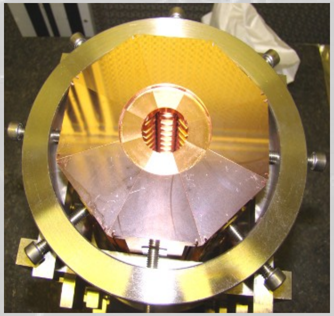


ASTA test PETS version with damping slots and **damping material (SiC)**

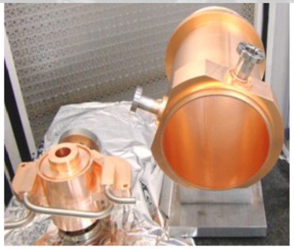


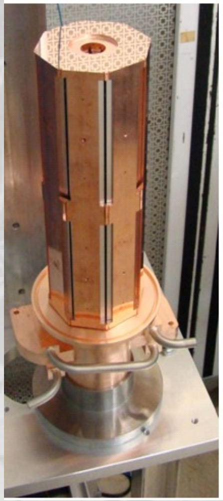




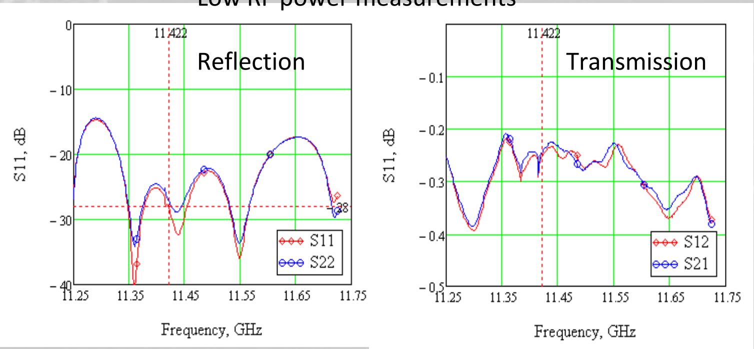


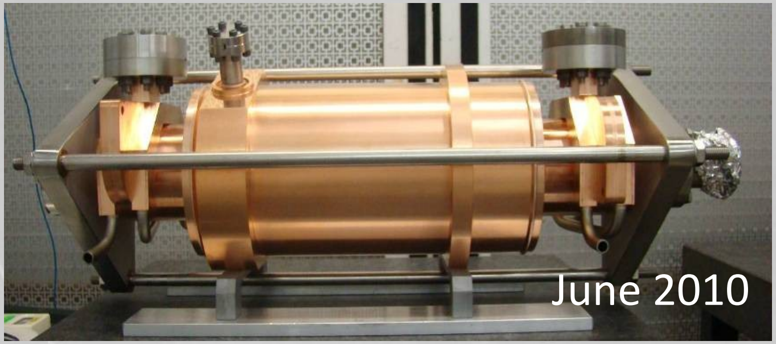
PETS preparation for the EB welding of the RF couplers and the mini-tank





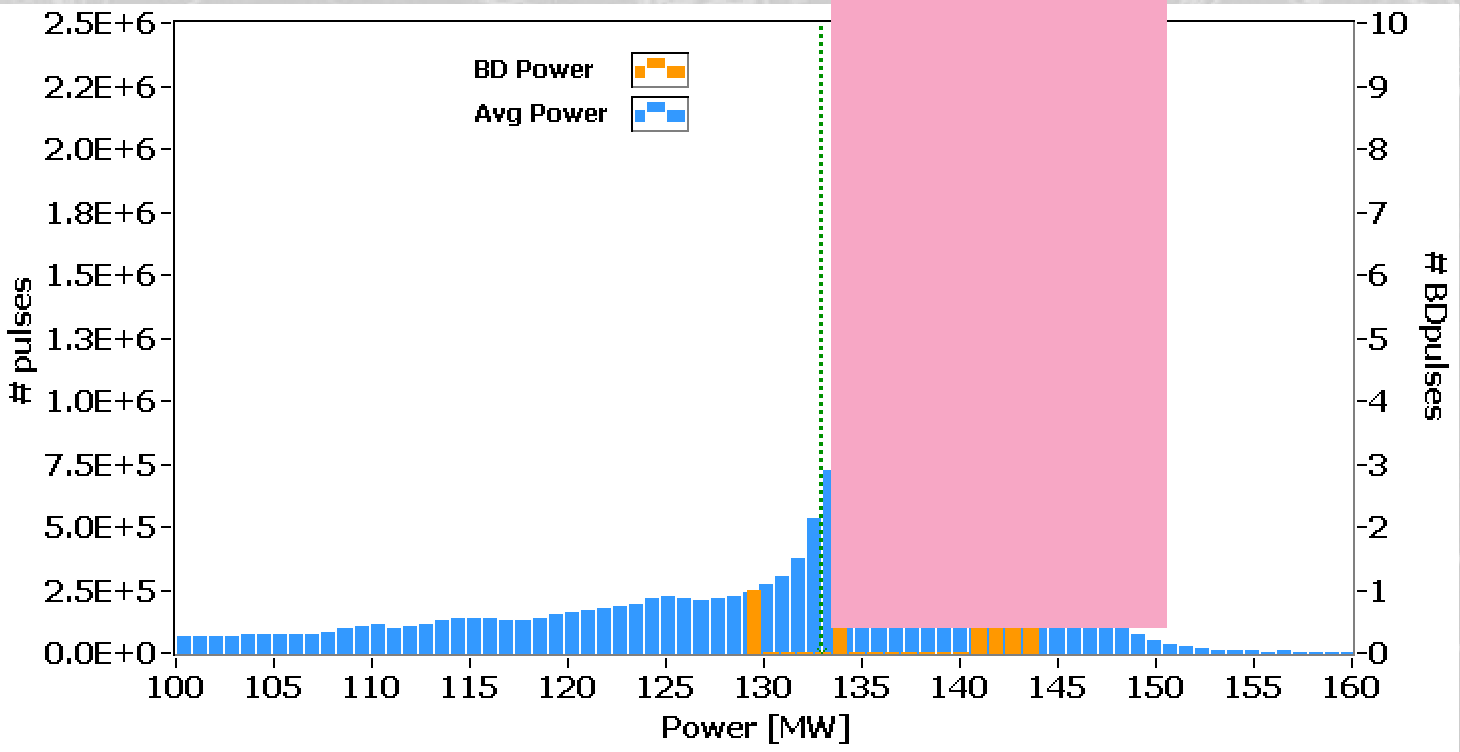
Low RF power measurements





Extraction of PETS breakdown trip rate

Part of the statistical distribution → 1.55×10^7 pulses



- 1.55×10^7 pulses were accumulated in a 125 hour run.
- 8 PETS breakdowns were identified giving a breakdown rate of **5.3×10^{-7}/pulse**.
- Most of the breakdowns were located in the upper tail of the distribution, which makes BDR estimate rather conservative.
- During the last 80 hours no breakdowns were registered giving a BDR **$<1.2 \times 10^{-7}$/pulse**.

Accelerating structures – specifications

High-gradient:

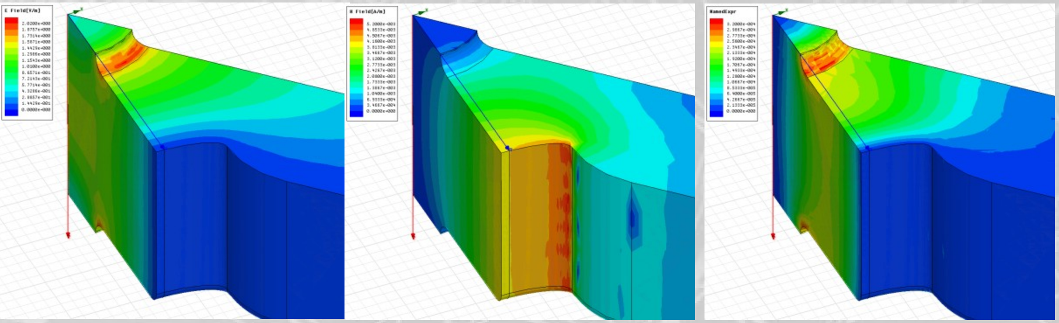
1. 100 MV/m loaded gradient
2. 170 (flat top)/240 (full) ns pulse length
3. $<4x10^{-7}$ /pulse/m breakdown rate

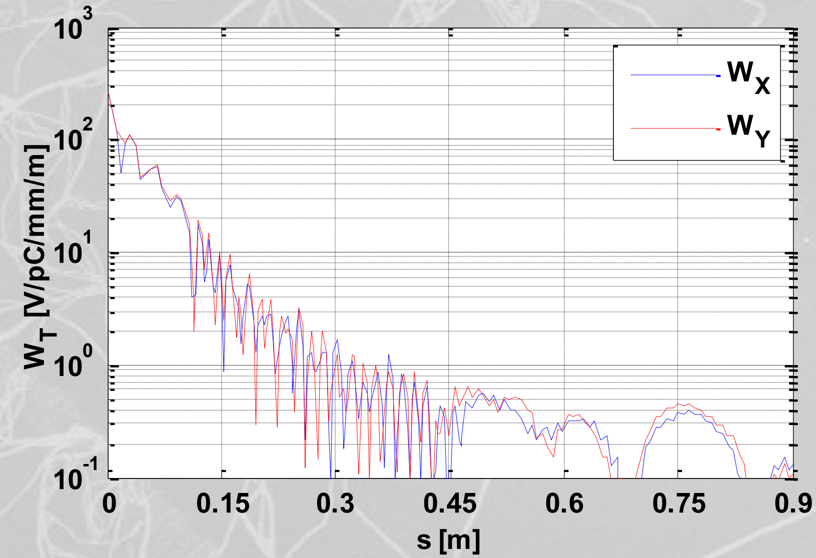
Beam dynamics:

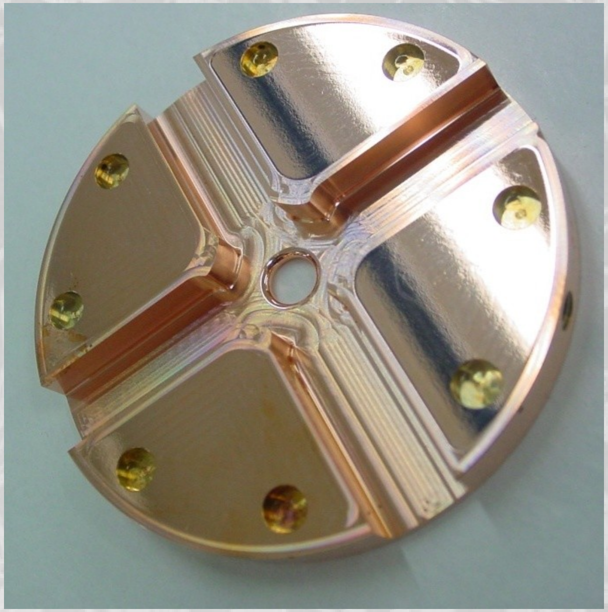
1. 5.8 mm diameter minimum average aperture (short range transverse wake)
2. < 1 V/pC/mm/m long-range transverse wakefield at second bunch (approximately x50 suppression).

Accelerating structures – features

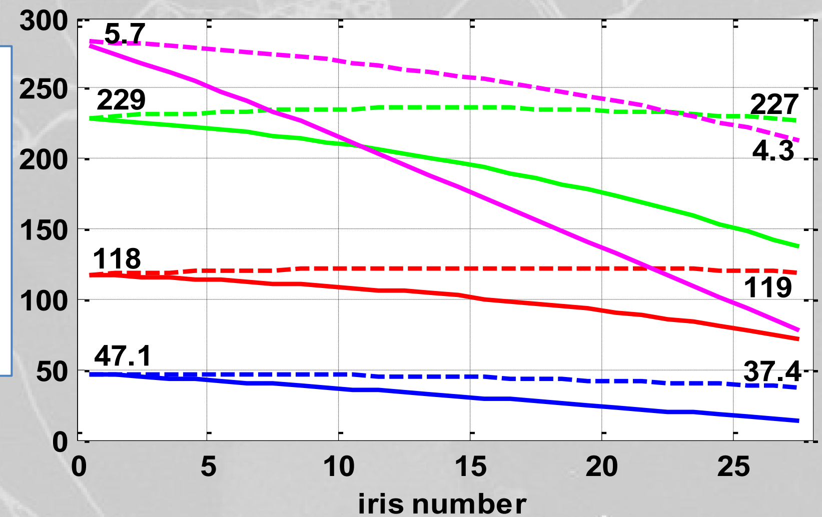
E_s/E_a H_s/E_a S_c/E_a^2



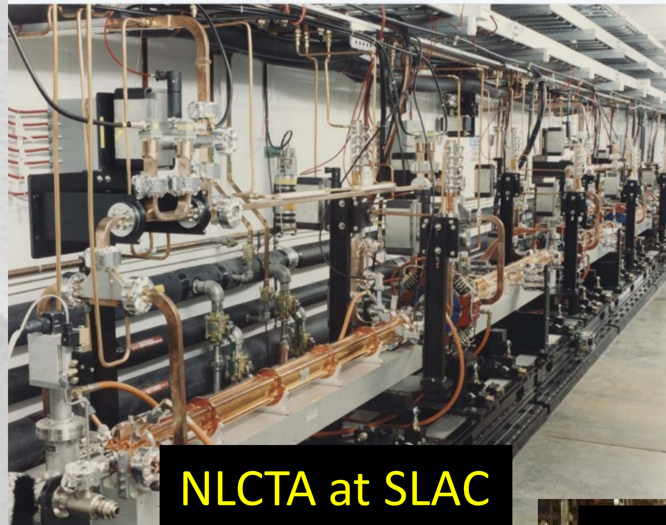




$S_c^{1/2}$ [MW/mm^2]
E_s max [MV/m]
E_{acc} [MV/m]
ΔT [°C]
dashed – unloaded
solid – loaded



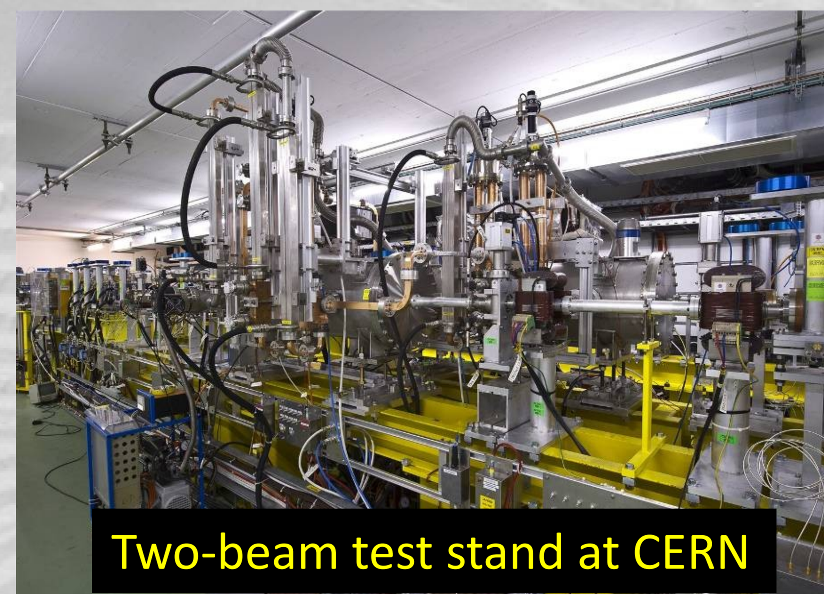
Prototype accelerating structure test areas


NLCTA at SLAC

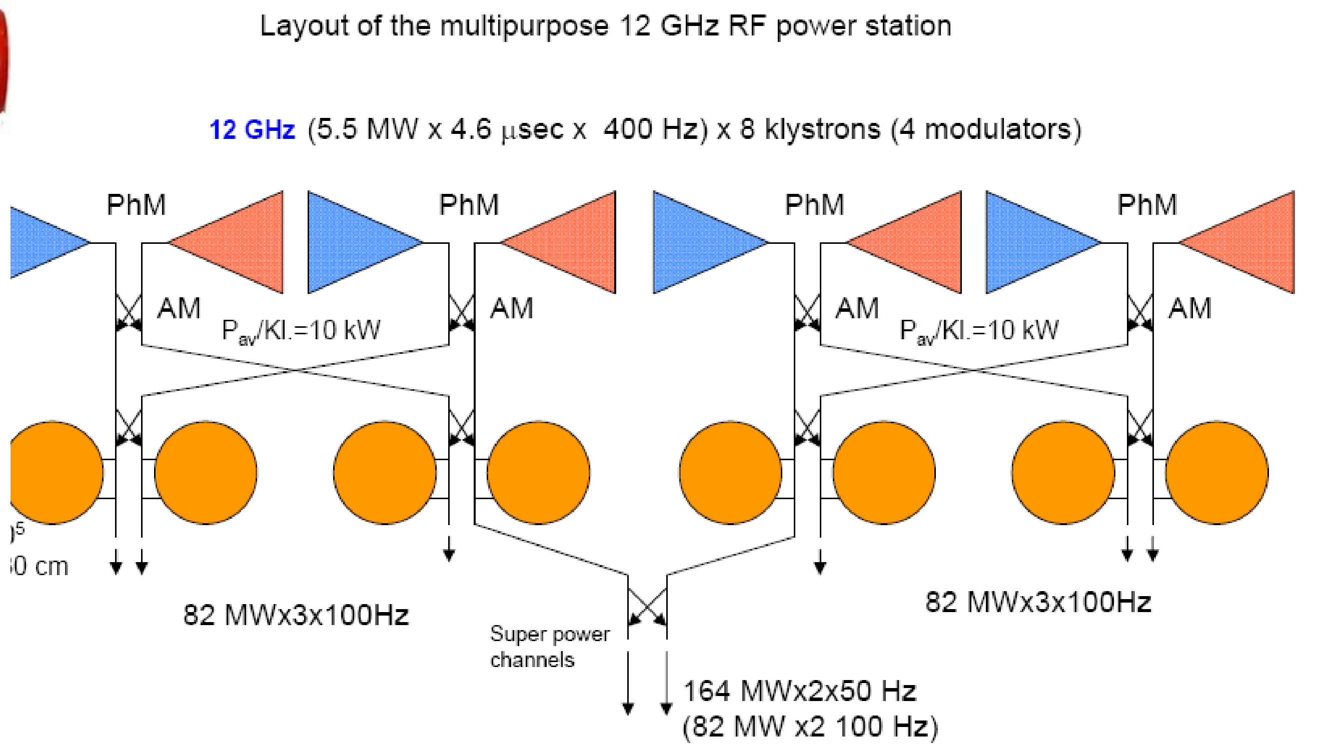

Nextef at KEK


New klystron at CERN

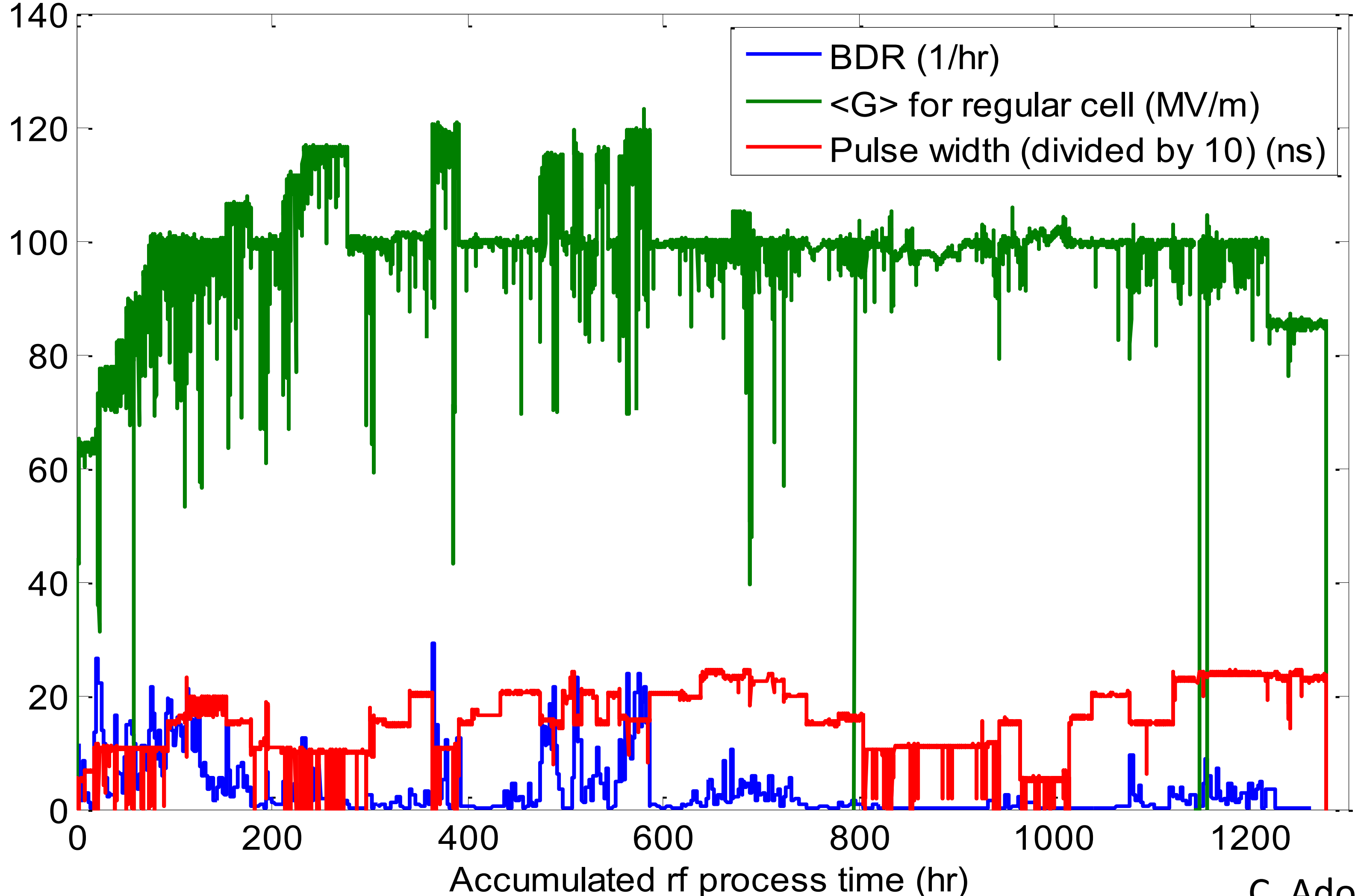

ASTA at SLAC


Two-beam test stand at CERN

A better way to expand testing capability?



High Power Operation History



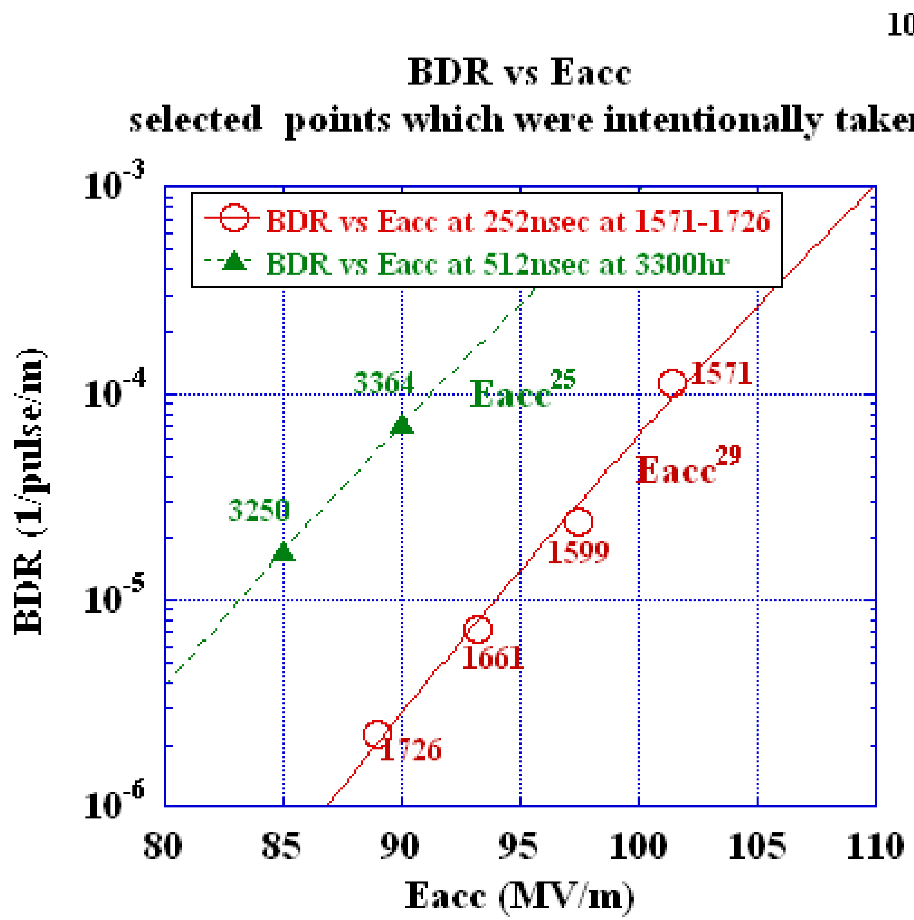
Final Run at 230 ns: 94 hrs at 100 MV/m w BDR = 7.6e-5

60 hrs at 85 MV/m w BDR = 2.4e-6

TD18

C. Adolphsen
F. Wang
SLAC

Relevant data points of BDR vs Eacc

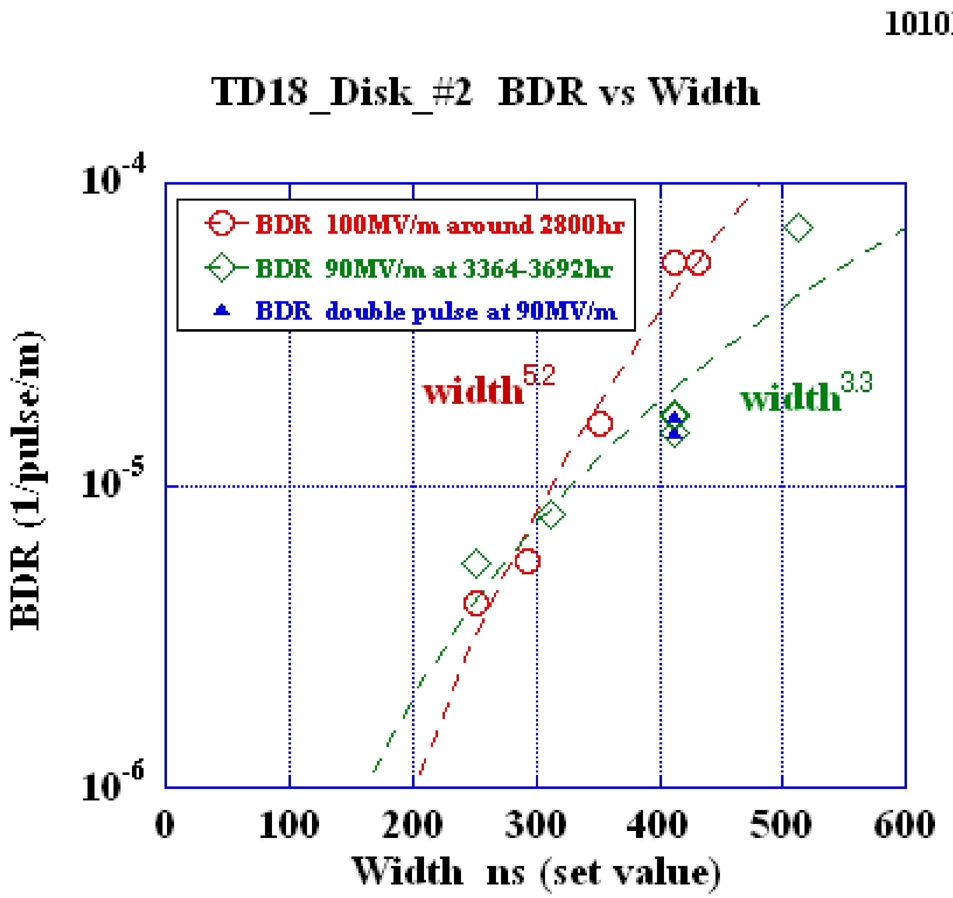


TD18

Steep rise as Eacc, 10 times per 10 MV/m, less steep than T18

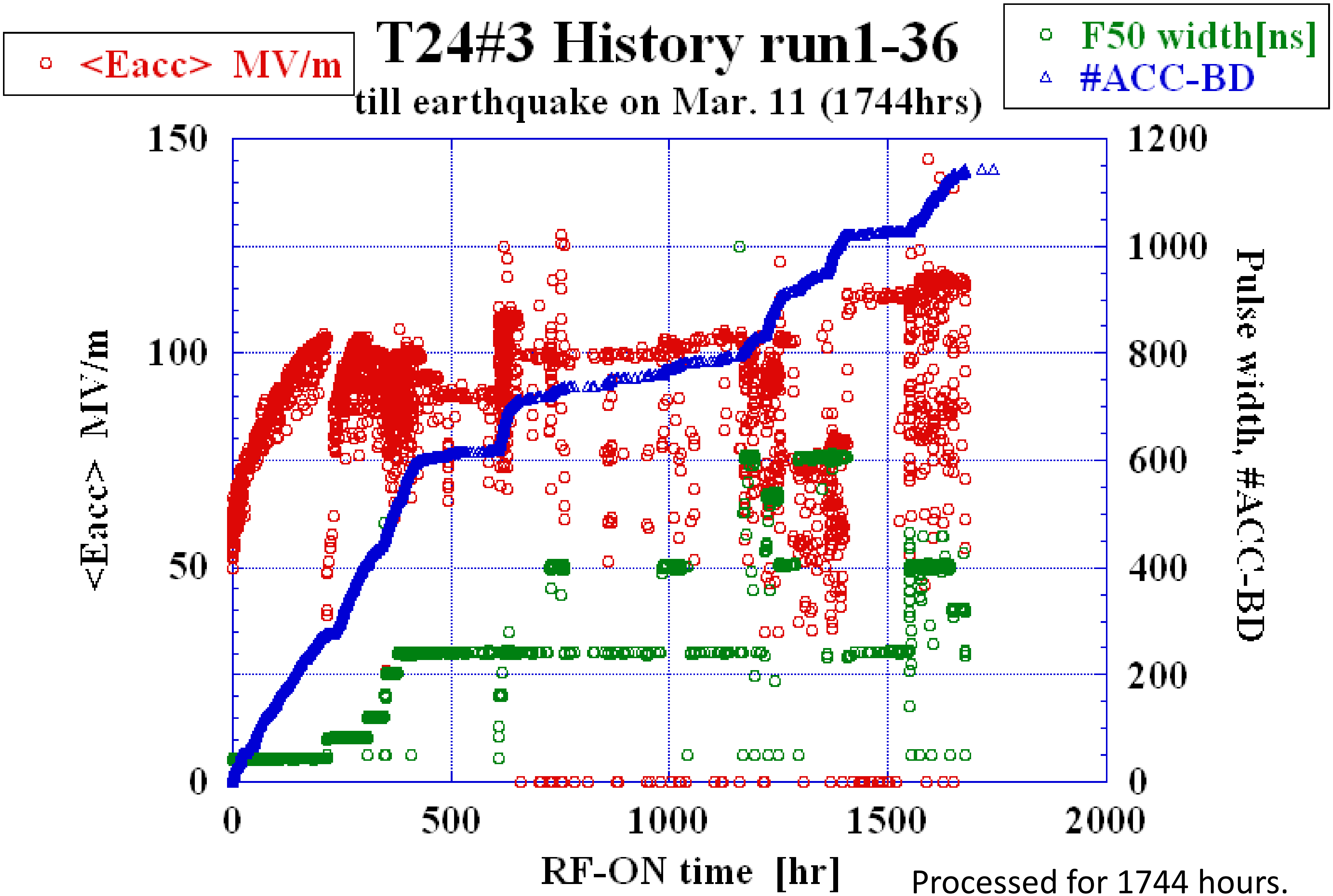
TD18_#2 BDR versus width

at 100MV/m around 2800hr and at 90MV/m around 3500hr



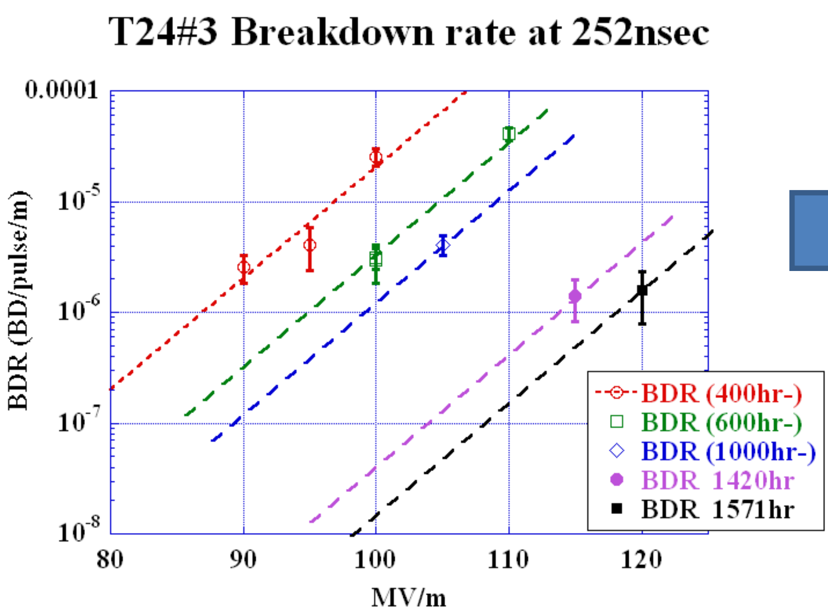
TD18

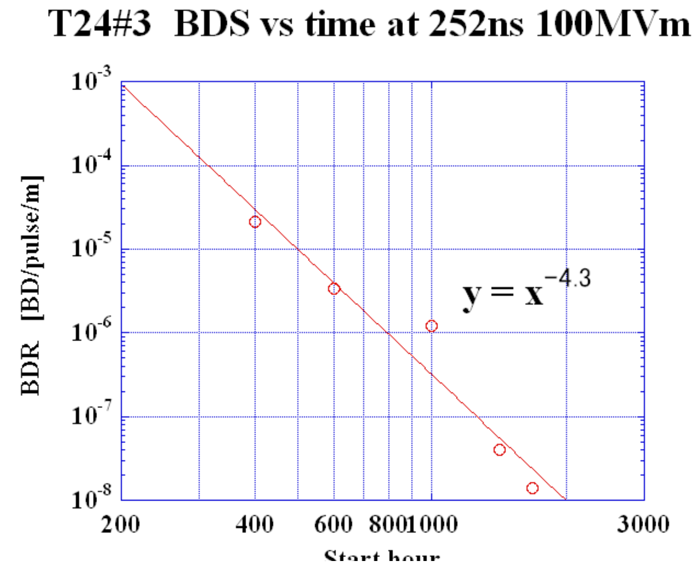
Similar dependence at 90 and 100 if take usual single pulse?

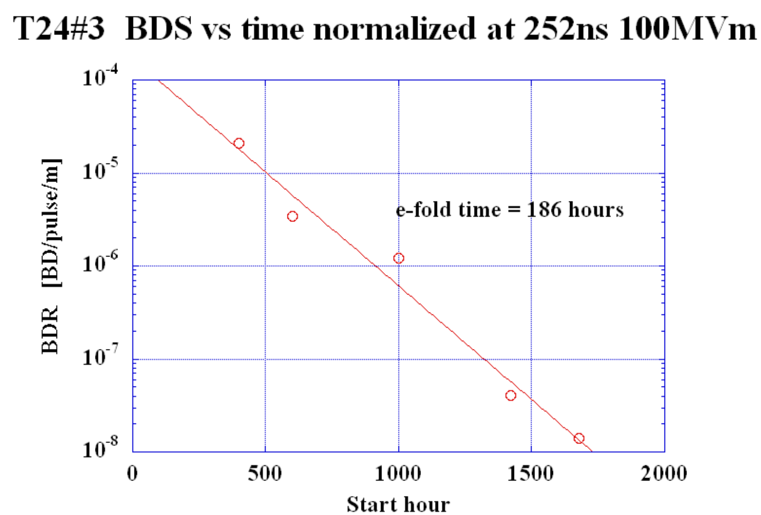


Processed for 1744 hours.

T24#3
BDR evolution at 252ns normalized 100MV/m



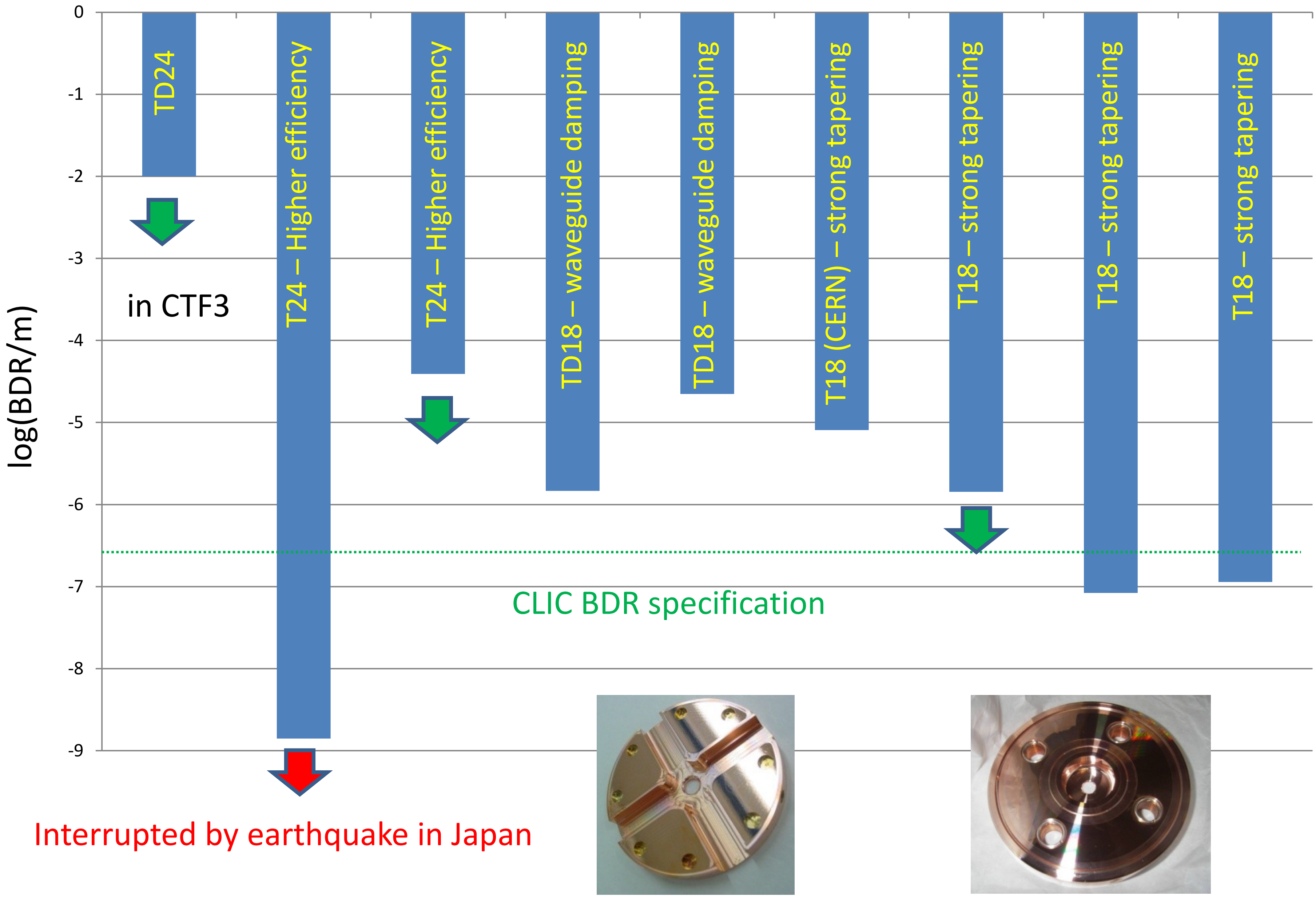




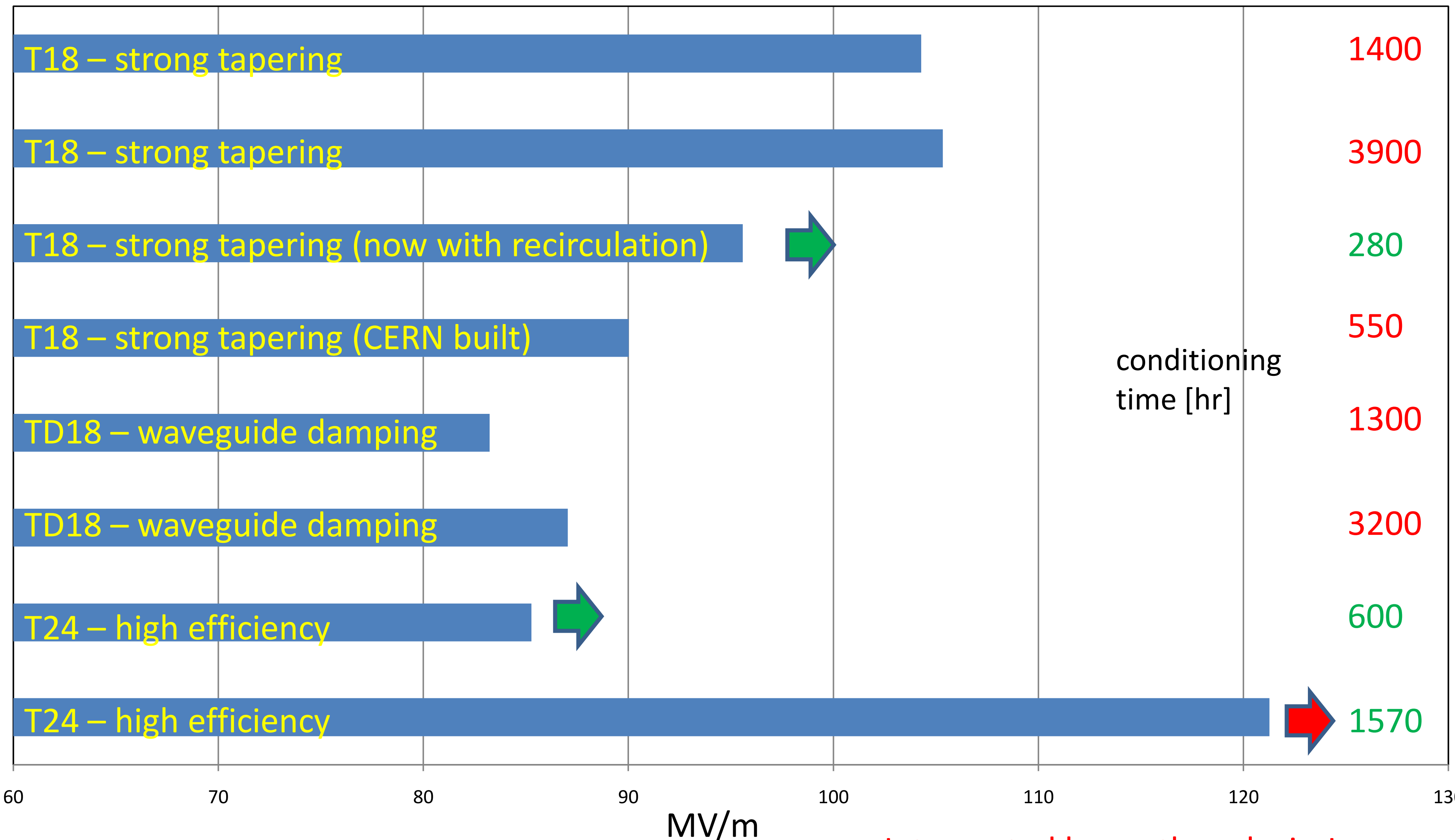
Assuming the same exponential slope as that at 400hr

We understand the BDR has been kept decreasing.

Breakdown rate at 100 MV/m (unloaded) accelerating gradient and scaled to 180 ns pulse length

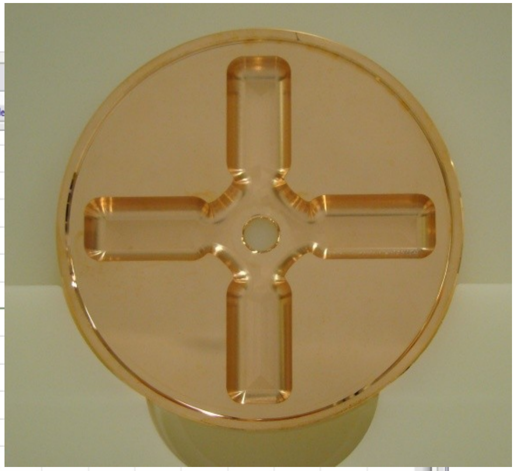


Unloaded gradient at CLIC $4*10^{-7}$ BDR and 180 ns pulse length



Interrupted by earthquake in Japan

DETUNED DAMPED DISK FROM VDL (TD24)



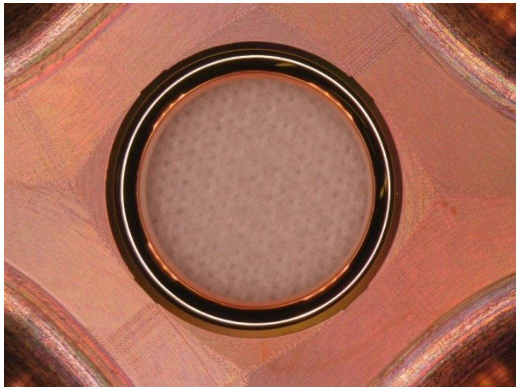
Enabling Technologies Group — **Inspection Report**

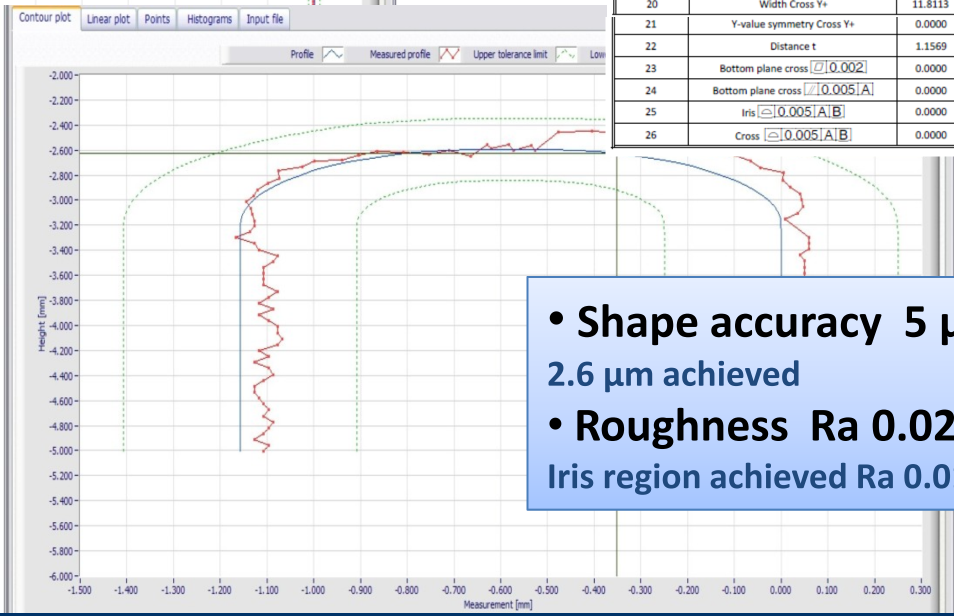
Drawing no.	CLIAAS110337 Standard Cell Disk 21	Prod. Nr.
Description	11 WDSDVG1.8KEK Standard cell	

Dimensions

Measurand	Description	Nominal	Upper	Lower	Actual	Deviation	Pass √	Fail √
1	Ref A ▱ 0.002	0.0000	0.0020	0.0000	0.0011	0.0011	√	
2	Outer diameter Ref B	74.0000	0.0025	-0.0025	74.0015	0.0015	√	
3	⌭ 0.002	0.0000	0.0020	0.0000	0.0009	0.0009	√	
4	⊥ 0.002 A	0.0000	0.0020	0.0000	0.0006	0.0006	√	
5	ø 70	70.0000	0.0000	-0.0100	69.9957	-0.0043	√	
6	ø70 ◎ 0.005 B	0.0000	0.0050	0.0000	0.0010	0.0010	√	
7	Diameter 2xa	5.1901	0.0025	-0.0025	5.1900	-0.0001	√	
8	Distance d	8.7327	0.0020	-0.0020	8.7334	0.0007	√	
9	Plane at distance d ▱ 0.002	0.0000	0.0020	0.0000	0.0020	0.0020	√	
10	ø 70	70.0000	0.0150	0.0100	70.0133	0.0133	√	
11	ø70 ◎ 0.005 B	0.0000	0.0050	0.0000	0.0007	0.0007	√	
12	Distance t	1.1569	0.0025	-0.0025	1.1562	-0.0007	√	
13	Distance g	7.5758	0.0025	-0.0025	7.5765	0.0007	√	
14	Width Cross Z+	11.8113	0.0025	-0.0025	11.8131	0.0019	√	
15	Y-value symmetry Cross Z+	0.0000	0.0025	-0.0025	0.0002	0.0002	√	
16	Width Cross Z-	11.8113	0.0025	-0.0025	11.8134	0.0022	√	
17	Y-value symmetry Cross Z-	0.0000	0.0025	-0.0025	0.0002	0.0002	√	
18	Width Cross Y-	11.8113	0.0025	-0.0025	11.8122	0.0009	√	
19	Y-value symmetry Cross Y-	0.0000	0.0025	-0.0025	0.0012	0.0011	√	
20	Width Cross Y+	11.8113	0.0025	-0.0025	11.8120	0.0007	√	
21	Y-value symmetry Cross Y+	0.0000	0.0025	-0.0025	0.0003	0.0003	√	
22	Distance t	1.1569	0.0025	-0.0025	1.1563	-0.0006	√	
23	Bottom plane cross ▱ 0.002	0.0000	0.0050	0.0000	0.0005	0.0005	√	
24	Bottom plane cross ∥ 0.005 A	0.0000	0.0025	-0.0025	0.0014	0.0014	√	
25	Iris ⌓ 0.005 A B	0.0000	0.0050	0.0000	0.0026	0.0026	√	
26	Cross ⌓ 0.005 A B	0.0000	0.0050	0.0000	0.0027	0.0027	√	

Zeiss CMM, free state measurement





- **Shape accuracy 5 µm**

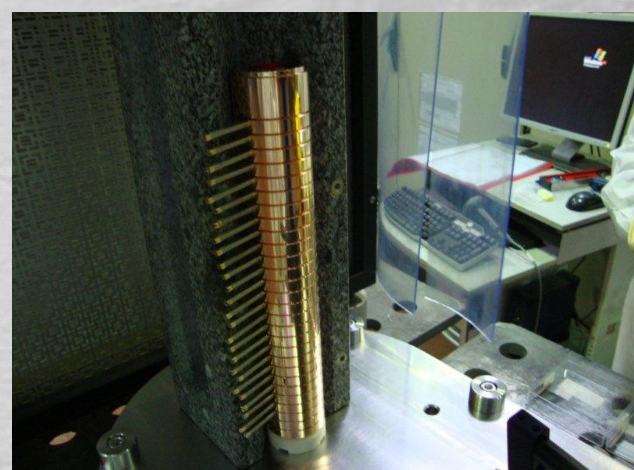
  2.6 µm achieved
- **Roughness Ra 0.025**

  Iris region achieved Ra 0.016

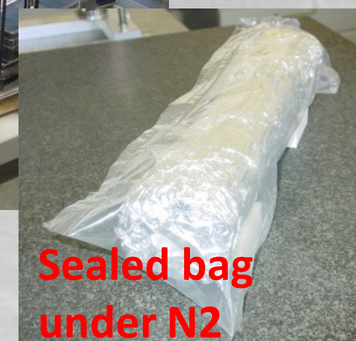
A new level of care for CERN-built structures

Individual inspection

Operation done under laminar flow



Boxes under N2



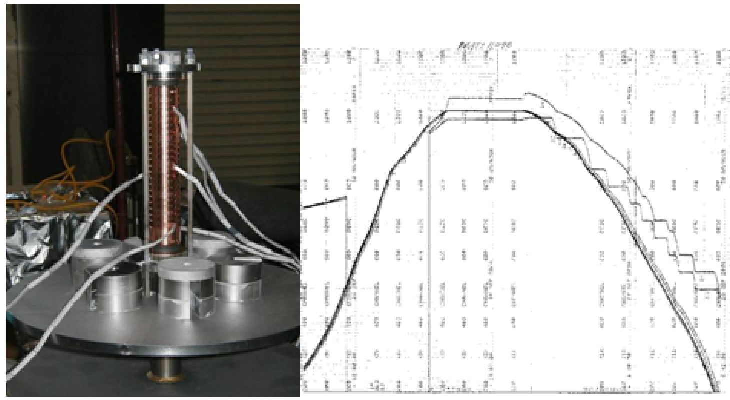
Sealed bag under N2

RF measurement

Accelerating structures – manufacture

Stacking disks

Diffusion Bonding of T18_vg2.4_DISC

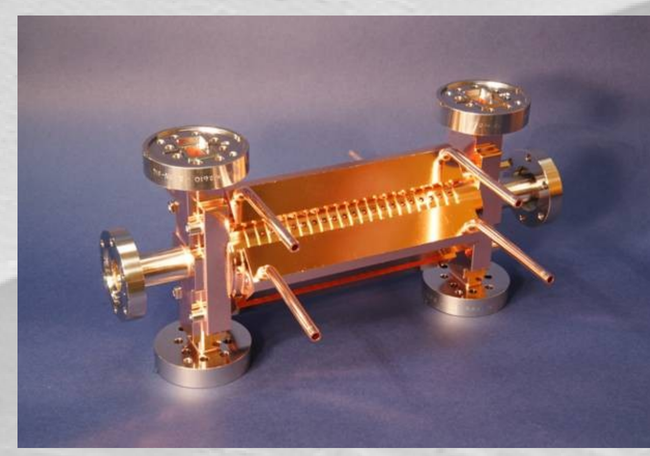


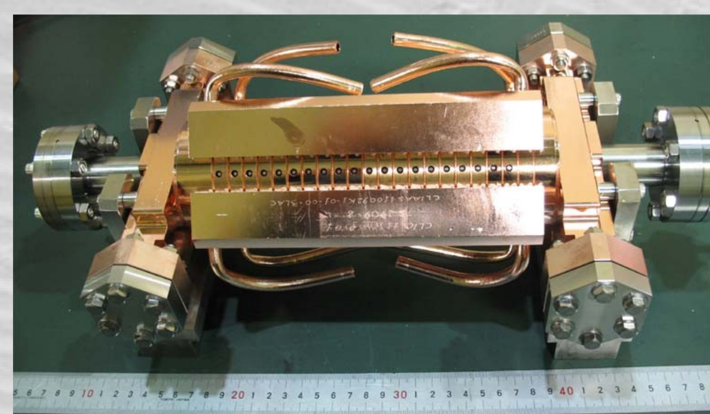
Pressure: 60 PSI (60 LB for this structure disks)
Holding for 1 hour at 1020° C

Vacuum Baking of T18_vg2.4_DISC

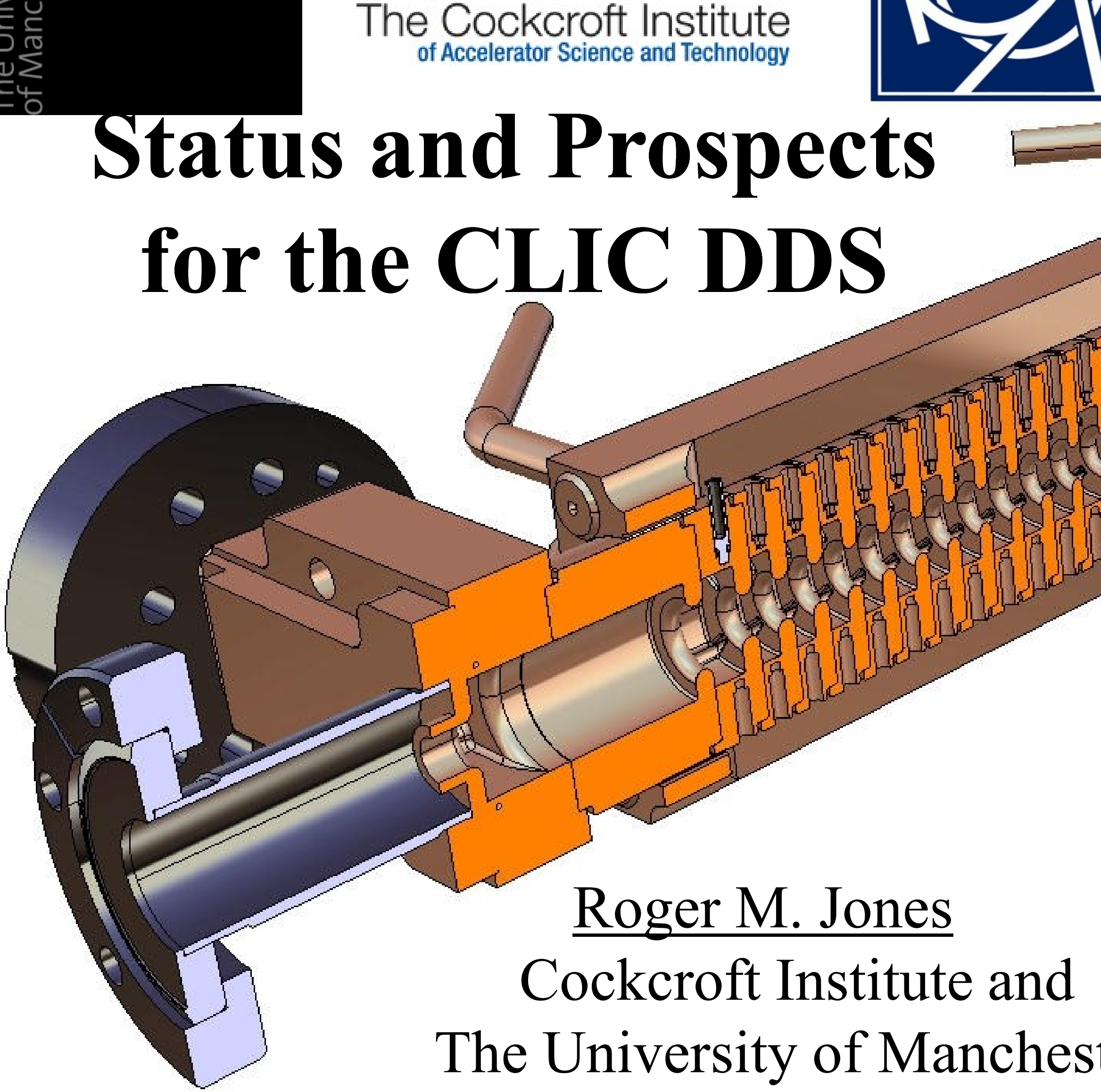
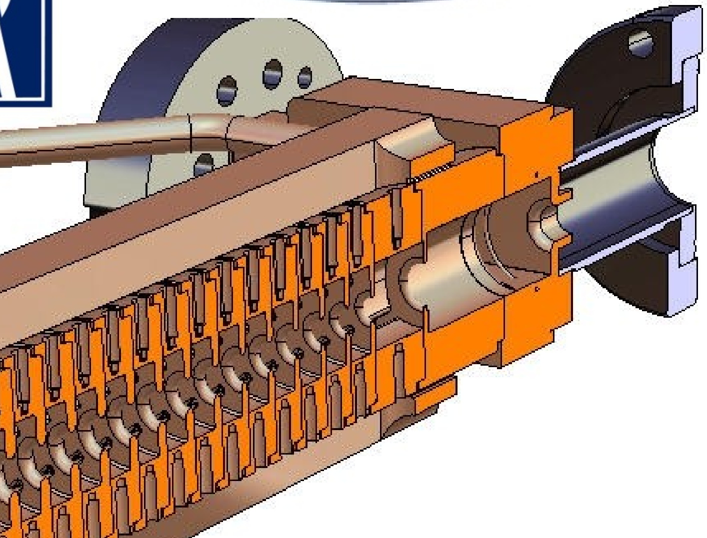
650° C
10 days

Temperature treatment for high-gradient

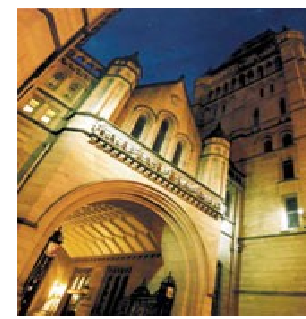




Structures ready for test

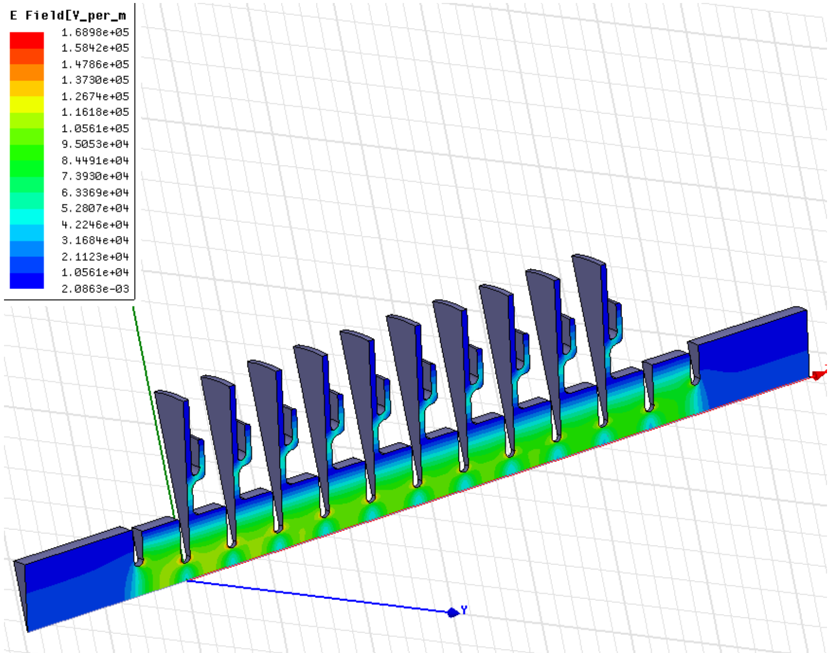



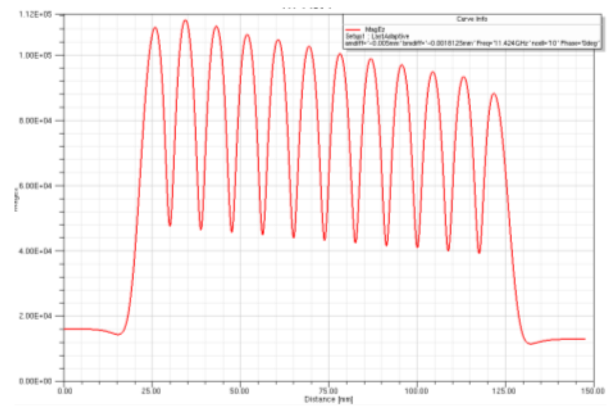
Status and Prospects for the CLIC DDS

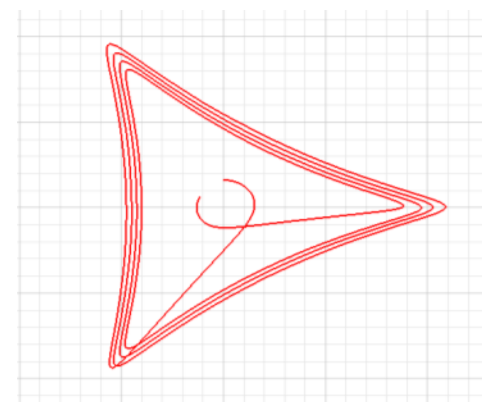


Roger M. Jones
Cockcroft Institute and
The University of Manchester

Design of CD-10-Choke



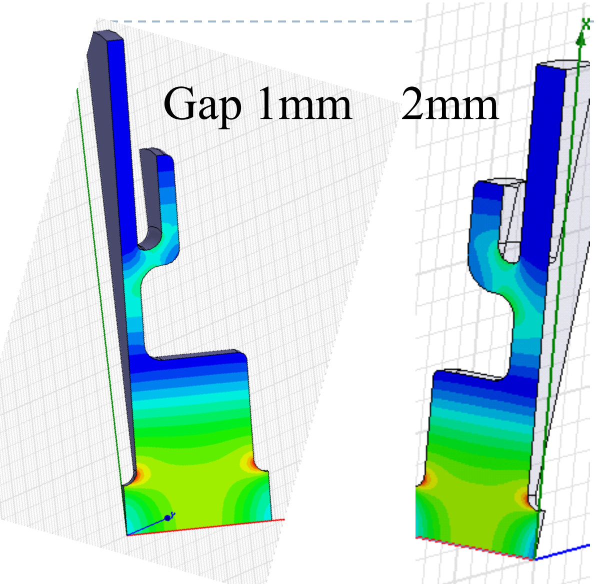




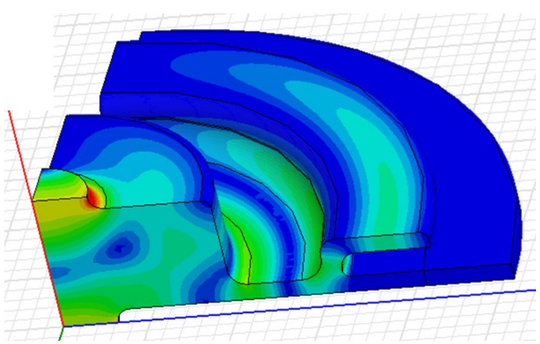
120 Degree

- CD10-Choke for demonstration
  - RF Design for Gap 1mm, 1.5mm, 2mm
  - Mechanical Design finished for 1mm-gap
  - Qualification disks and bonding test
- To the production pipeline and High Power testing

Damping simulation with Gdfidl/HFSS



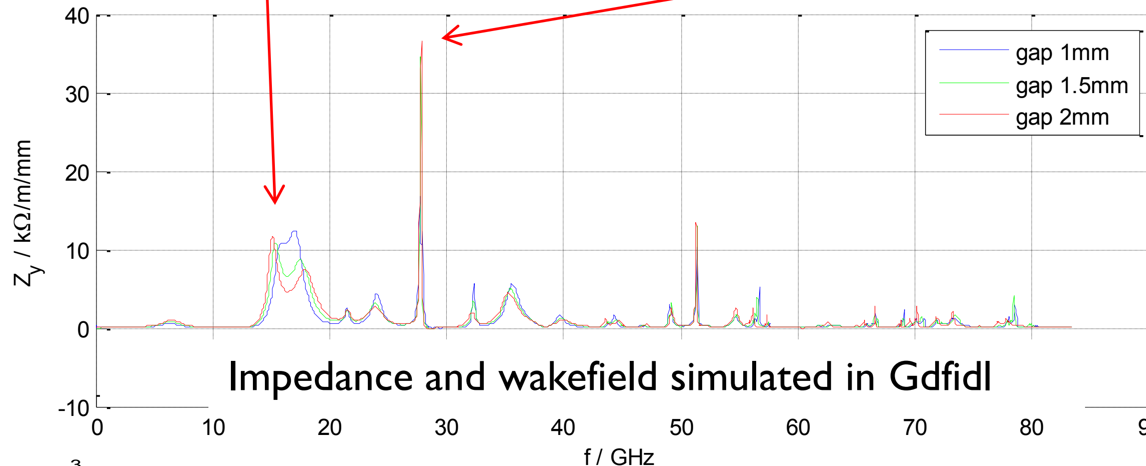
E field, fundamental mode



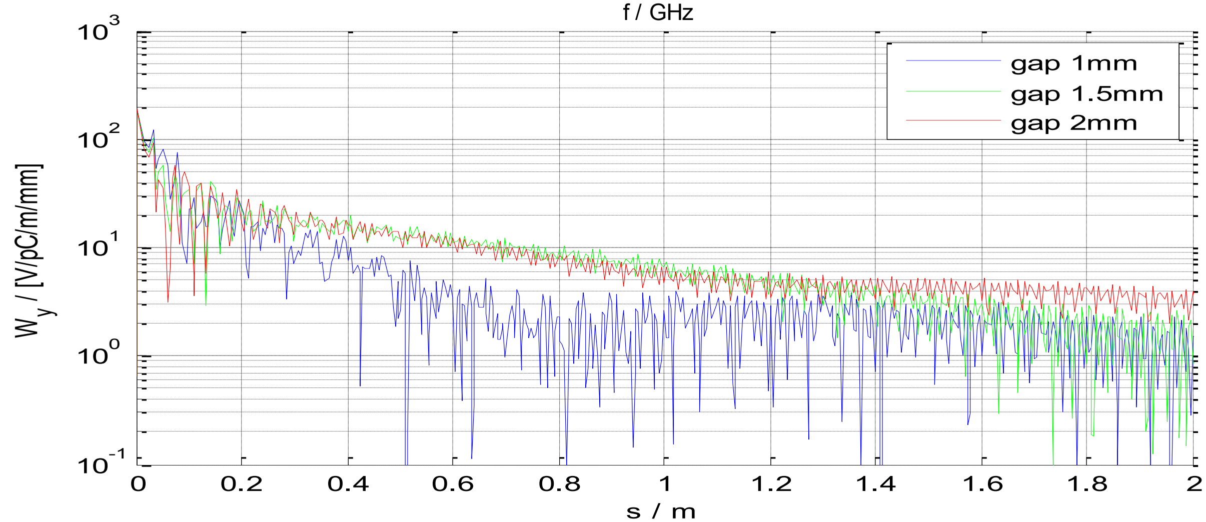
E field of a dipole mode that is reflected by the choke

Good damping for first dipole

Mode reflected by the choke, to be studied…



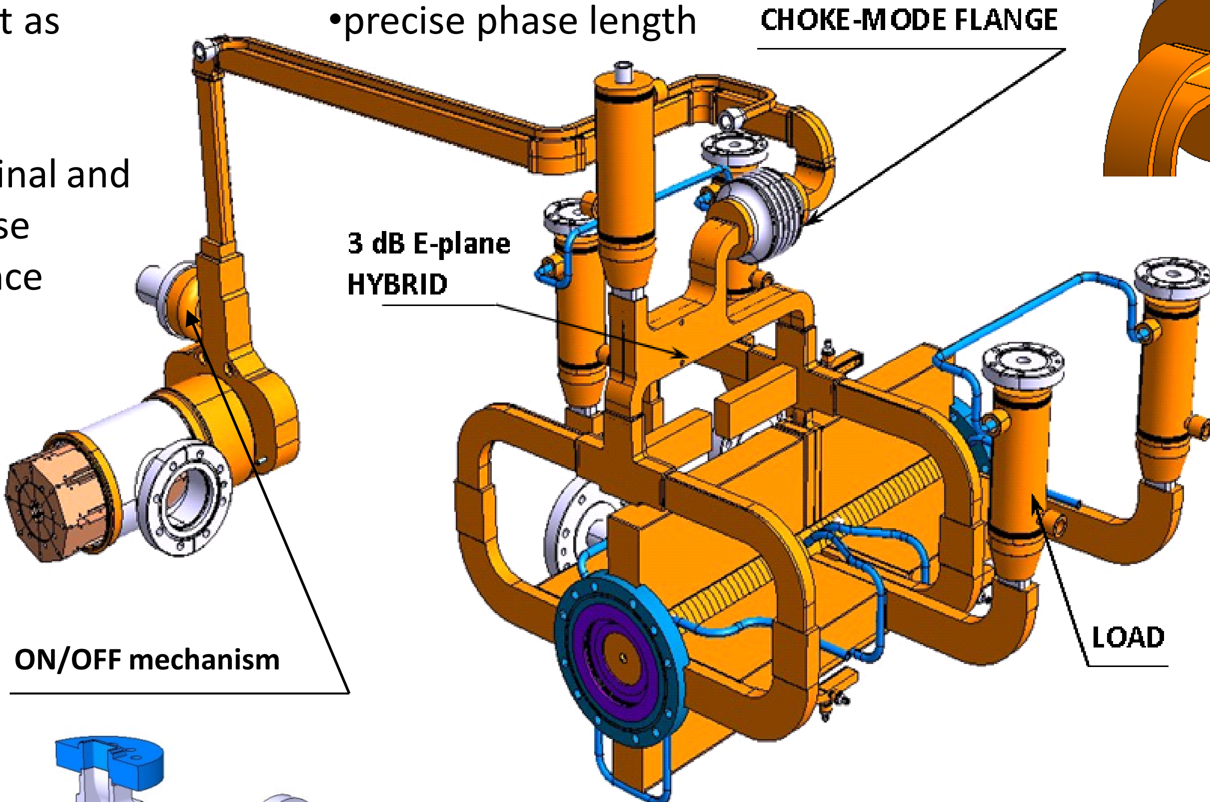
Impedance and wakefield simulated in Gdfidl

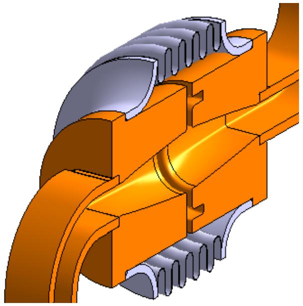


CLIC main linac rf network

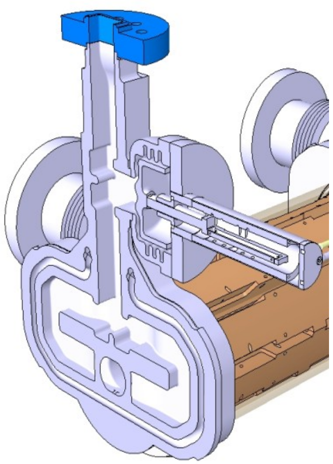
PETS
- high-power
- as short as possible
- low longitudinal and transverse impedance

Waveguide network
- high power
- precise phase length



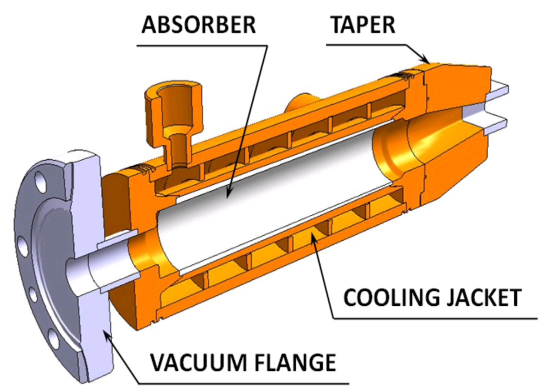


Choke mode flange
- independent alignment of main and drive beam



On/ramp/off
- necessary (?) to react to breakdown and/or failure

Accelerating structure
- high-gradient
- as long as possible
- micron precision
- transverse wakefield suppression



High-power design criteria

We have developed a set of high-power scaling laws to describe the observed dependence which are supported by plausible physical arguments:

$$\frac{P}{C} \propto \text{const}$$

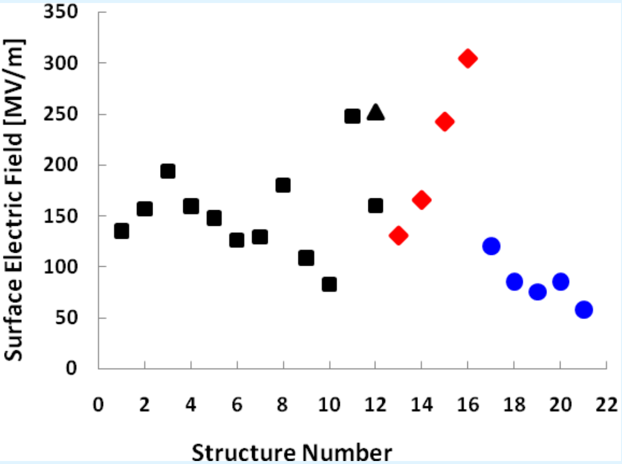
global power flow

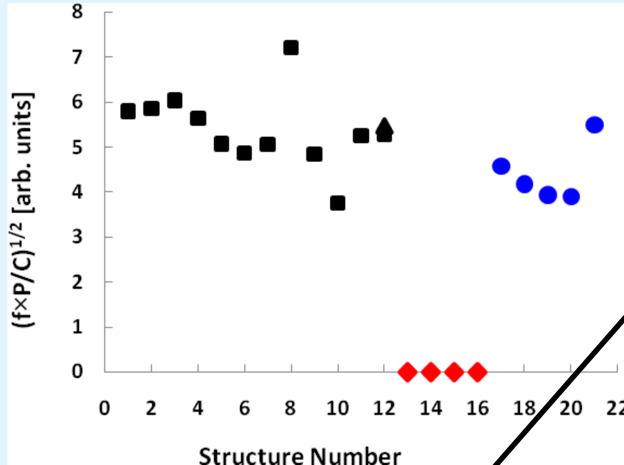
$$S_c = \mathrm{Re}(\mathbf{S}) + 6\,\mathrm{Im}(\mathbf{S})$$

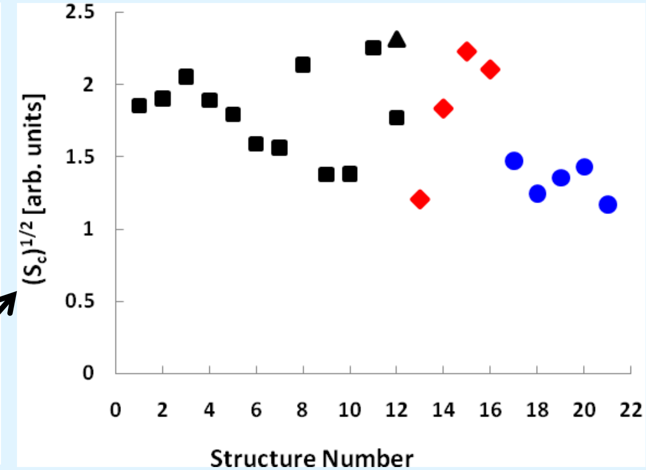
local complex power flow

These are now standard design criteria used throughout the CLIC structure program. We are actively pursuing checking their validity over a wider range of parameters and putting them on a more solid footing – fundamental breakdown studies later in this talk.

S_c: high-power design parameter





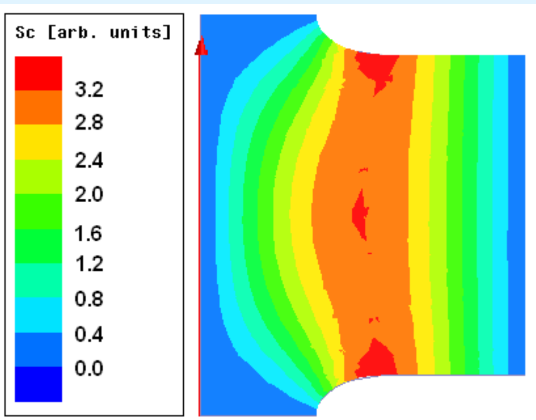


X-band and 30 GHz, pulses of the order of 100 ns.
Travelling and standing wave

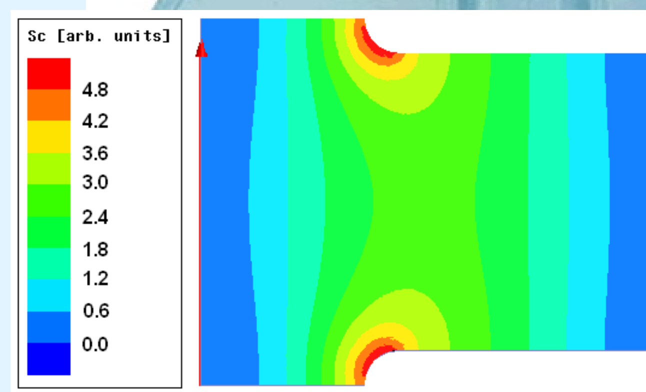
Related to the complex Poynting vector:

$$S_c = \Re\{\overline{S}\} + g_c \cdot \Im\{\overline{S}\}$$

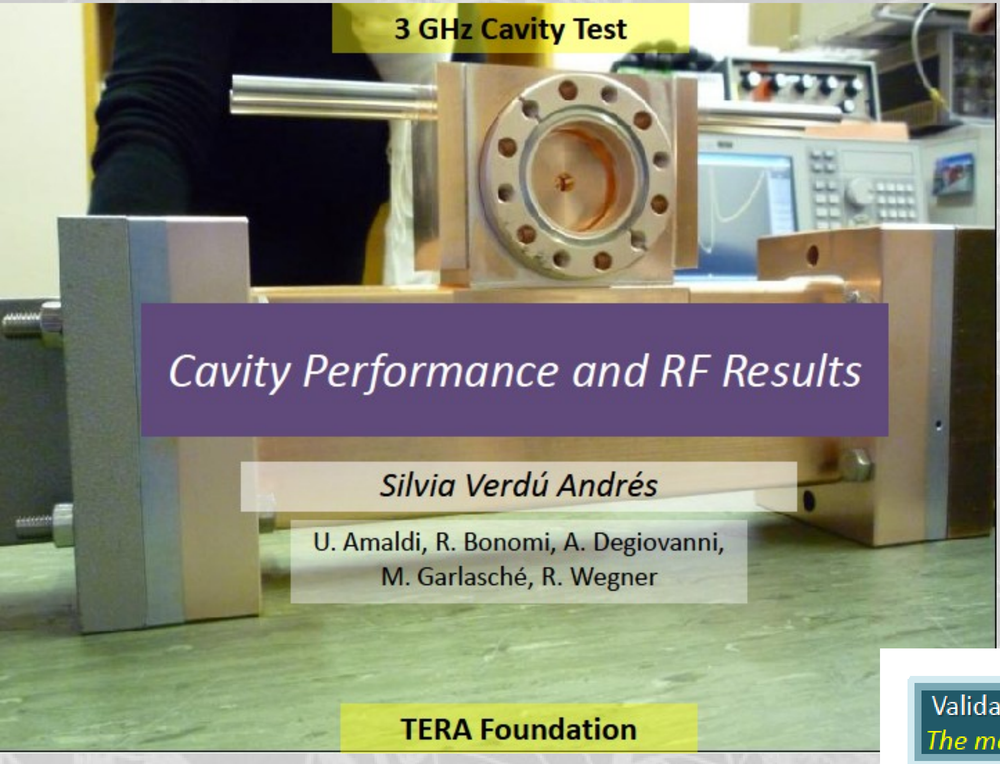
Travelling wave



Standing wave



W. Wuensch



Do our high-gradient limits extend all the way down to S-band and microsecond pulses?

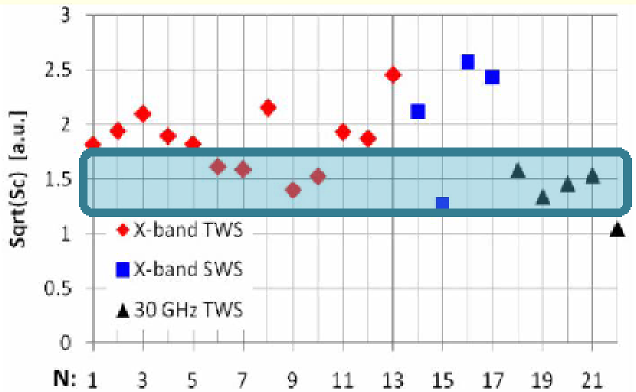
PRELIMINARY RESULTS!

Validation of CLIC observations:
The modified Poynting vector as a RF constraint to high gradient performance

The square root of S_C has been scaled to t_{pulse} =**200 ns** and BDR=**10^{-6} bbp/m**

$$\sqrt{S_C^{equiv}} = \sqrt{S_C}\cdot\left(\frac{t_{pulse}}{t_{pulse}^{ref}}\right)^{\frac{1}{6}}\cdot\left(\frac{BDR^{ref}}{BDR}\right)^{\frac{1}{30}}$$

"A New Local Field Quantity Describing the High Gradient Limit of Accelerating Structures", A.Grudiev et al., Phys.Rev.ST Accel. Beams (2009) 102001

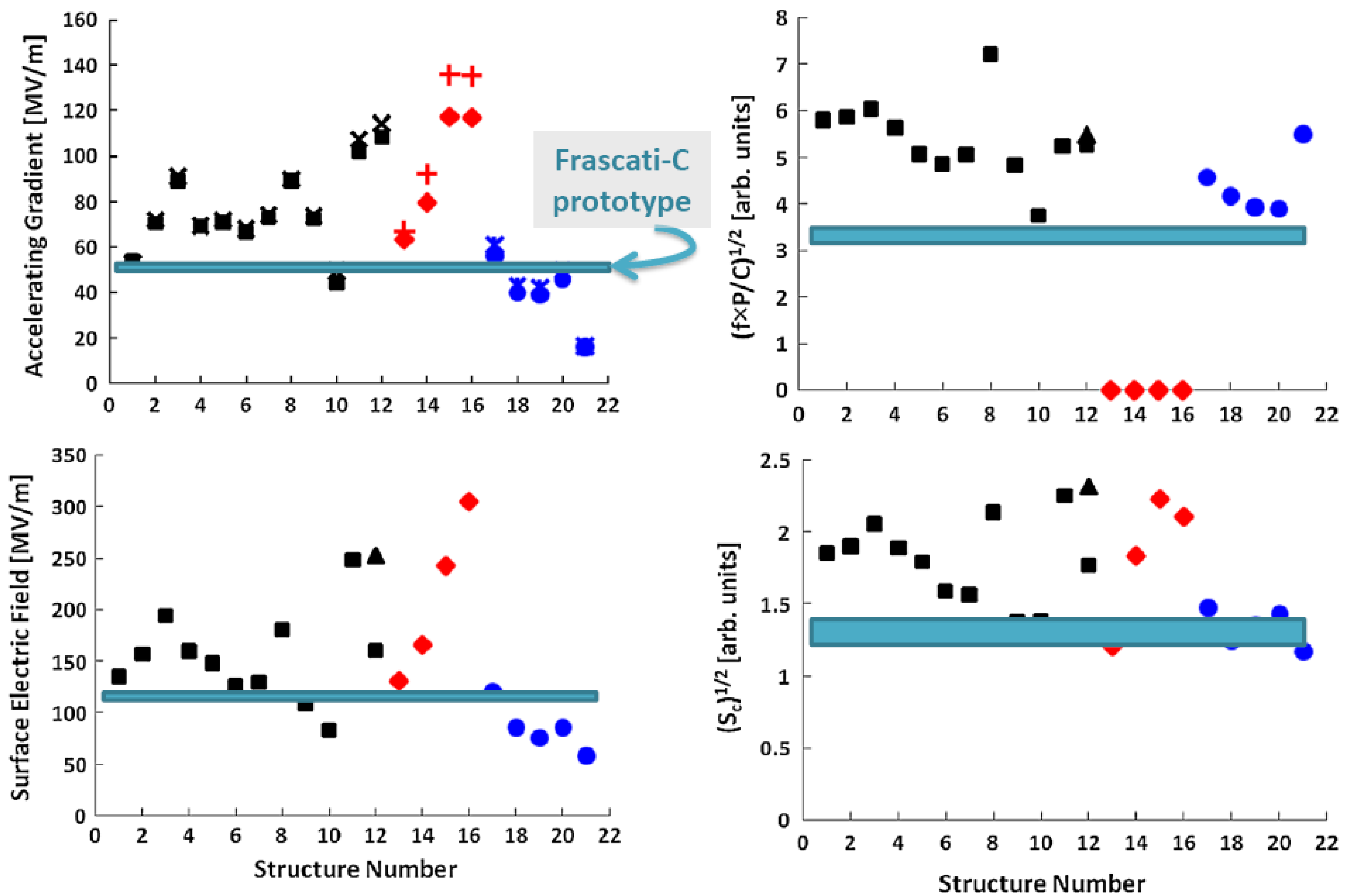


TERA
Sqrt(S_c) ϵ [1.3-1.6]

C-band test of Frascati C-band structure at KEK

Silvia Verdu-Andres

Results: *limit to high-gradient performance???*



- great accordance with data for E_0 and E_S plots; lower accordance for P and S plots

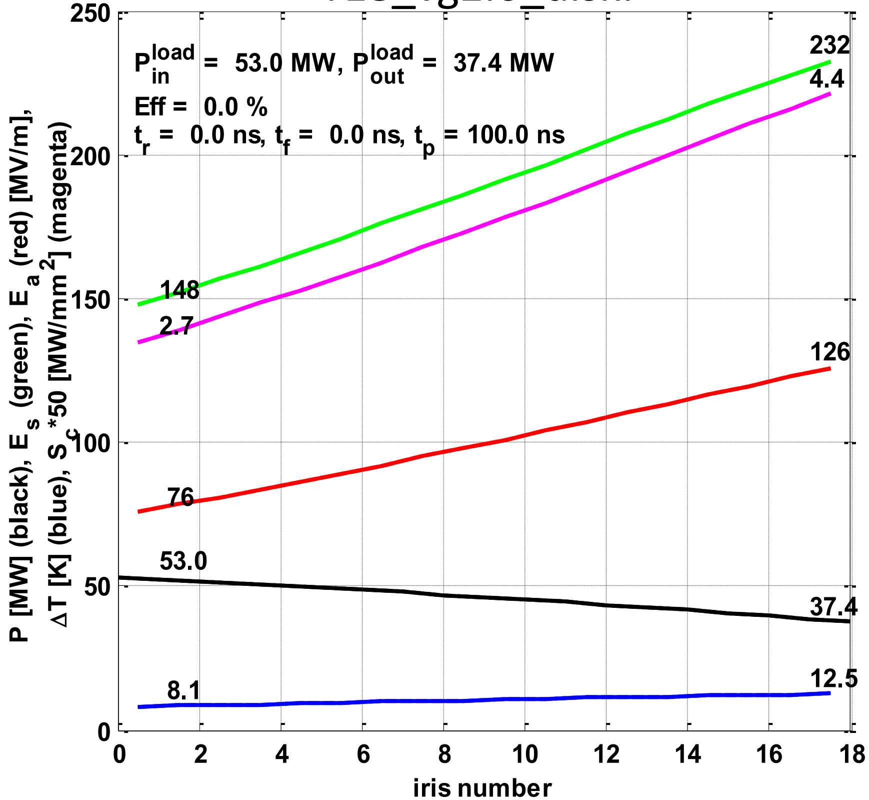
"New Local Field Quantity Describing the High Grad Limit of Acc. Structures", *A. Grudiev, S. Calatroni and W. Wuensch.* Phys. Rev. ST Accel. Beams 12/10, 102001 (2009).

1st generation of CLIC X-band test structure prototypes T18/TD18

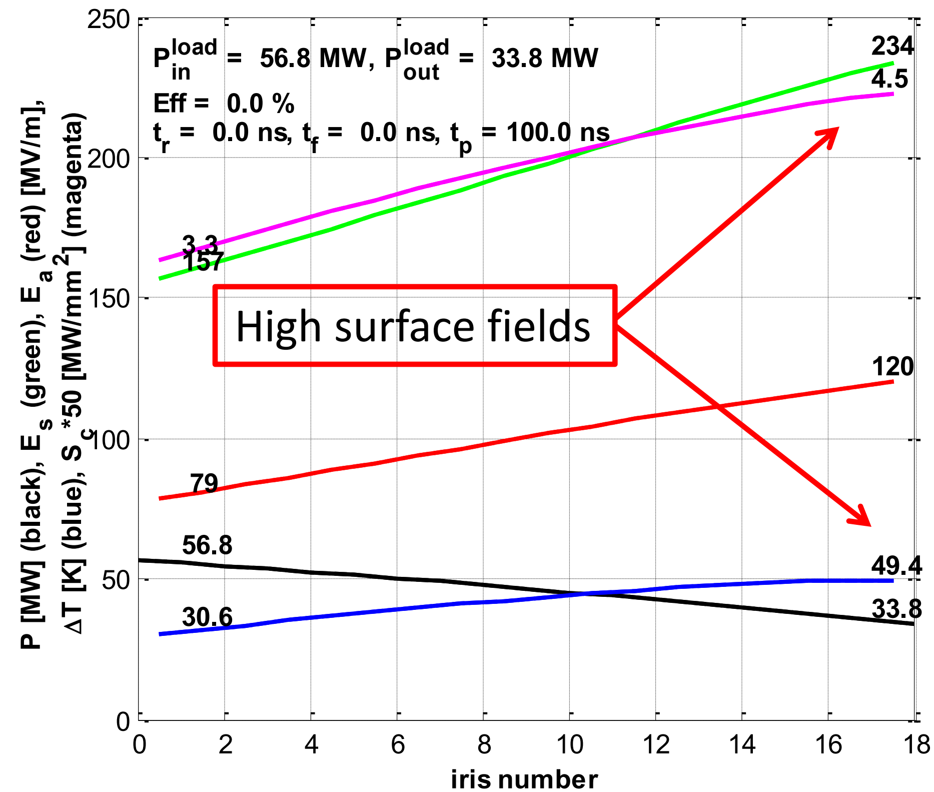
2007

Parameters at tp=100 ns, <Ea>=100 MV/m

T18_vg2.6_disk:



TD18_vg2.4_disk:



Very strong tapering inspired by the idea of having constant P/C along the structure

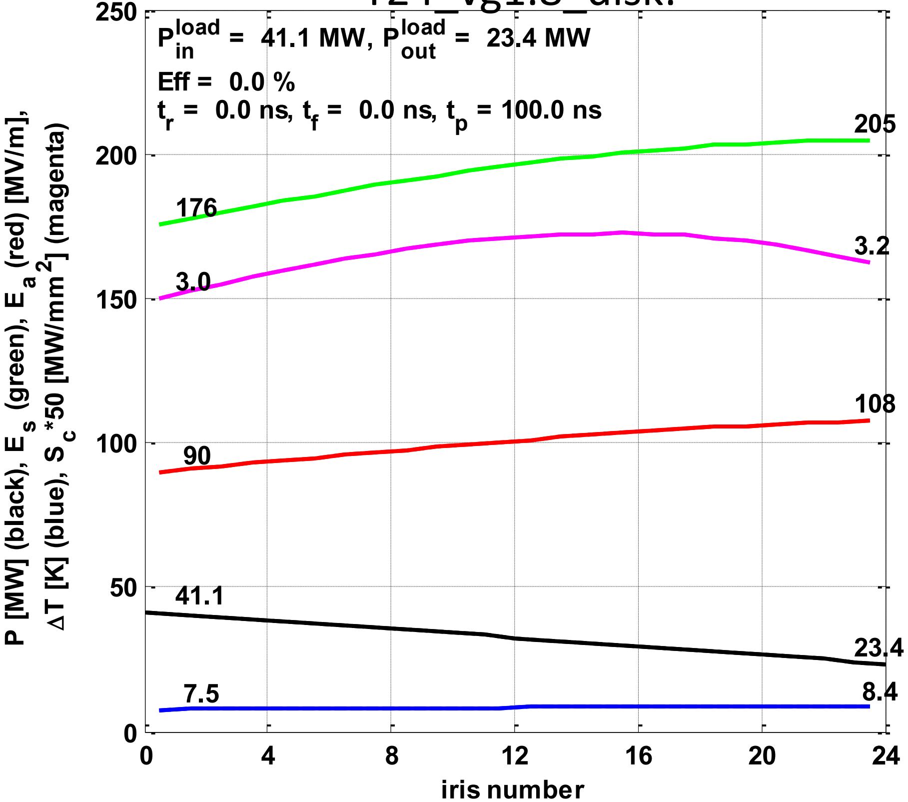
In TD18, all quantities are close to T18 at the same average gradient, except for the pulsed surface heating temperature rise which is factor 5 higher in the last cell.

A. Grudiev, IWLC2010

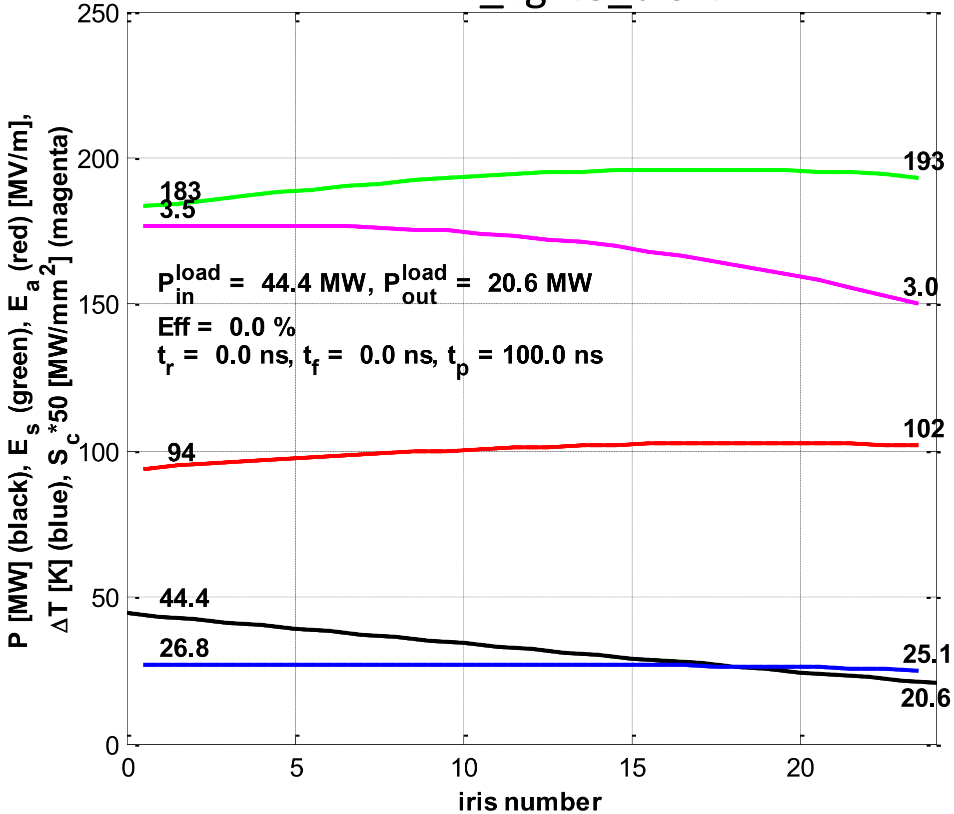
2nd generation of CLIC X-band test structure prototypes T24/TD24

2007 Parameters at tp=100 ns, <Ea>=100 MV/m

T24_vg1.8_disk:



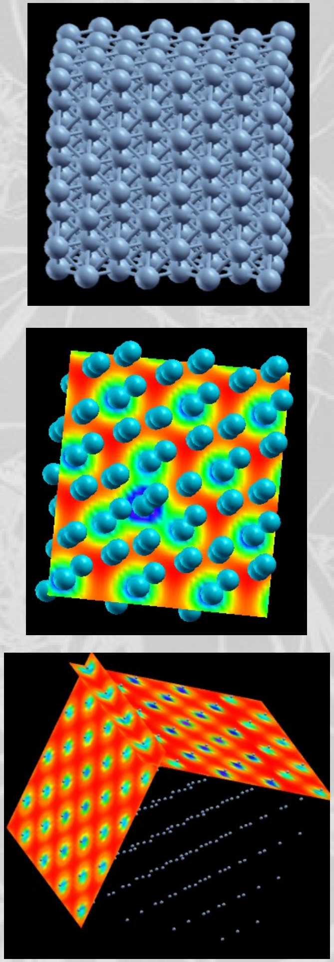
TD24_vg1.8_disk:



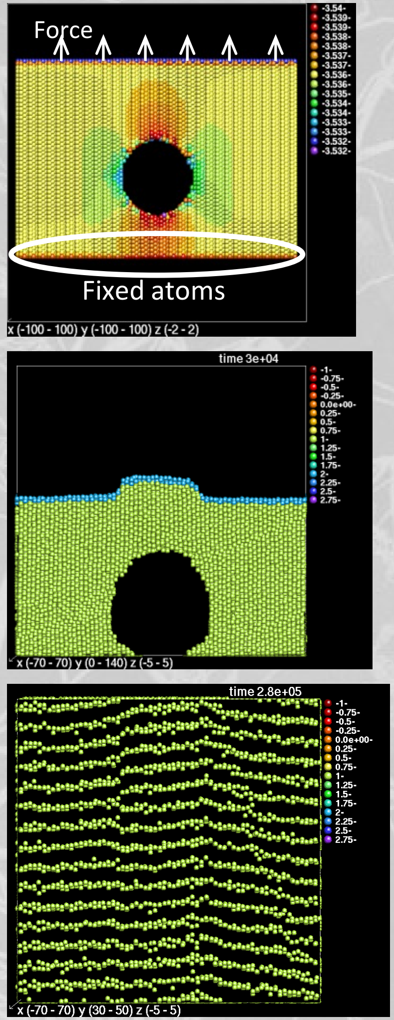
Weaker tapering (quasi const gradient) together with smaller aperture (11% instead of 12.8%) reduce surface fields significantly compared to T18/TD18.

In TD24, all quantities are lower than in TD18 at the same average gradient.
In particular pulsed surface heating temperature rise reduced by factor 2.

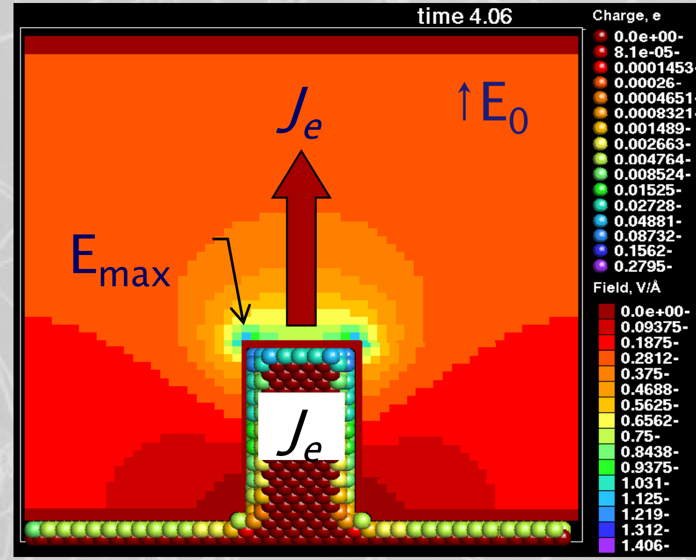
Multi-scale simulation of breakdown developed by the Helsinki Institute of Physics

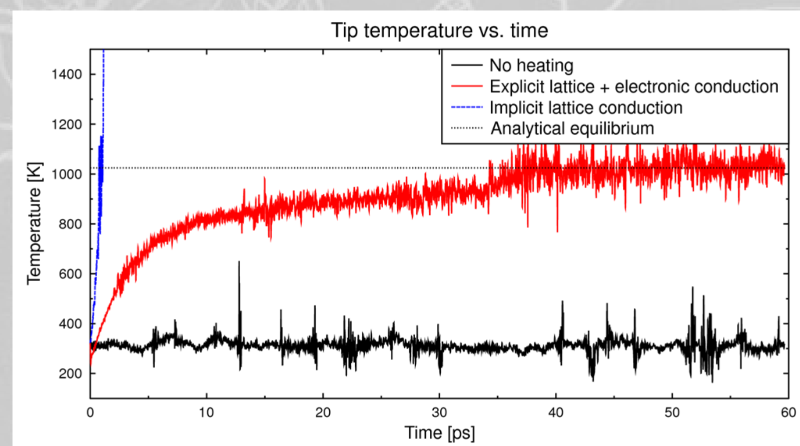


1. Calculation of charge distribution in crystal



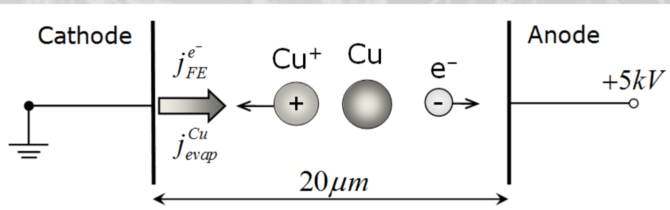
2. Emission site formation – breakdown rate

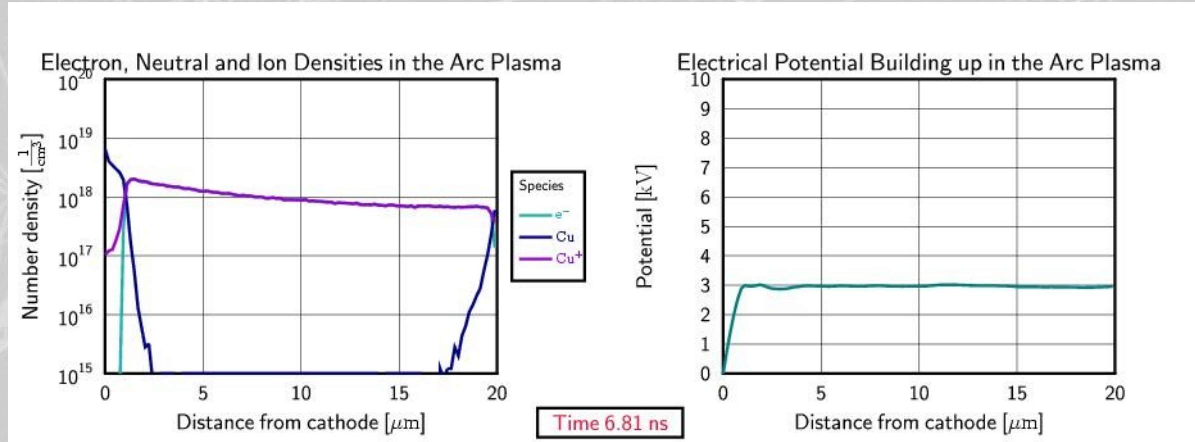




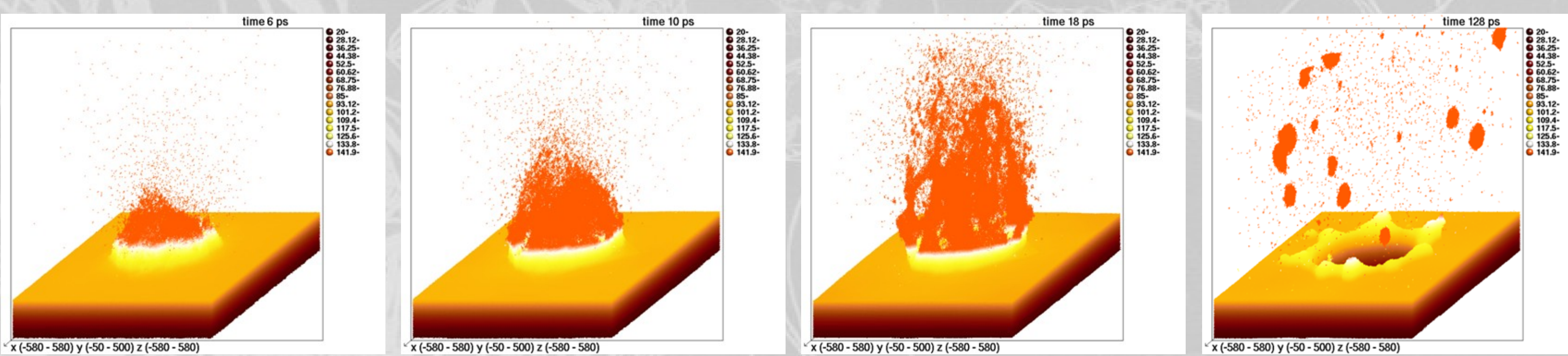
3. Field emission to breakdown trigger, including thermal effects

Multi-scale simulation of breakdown developed by the Helsinki Institute of Physics



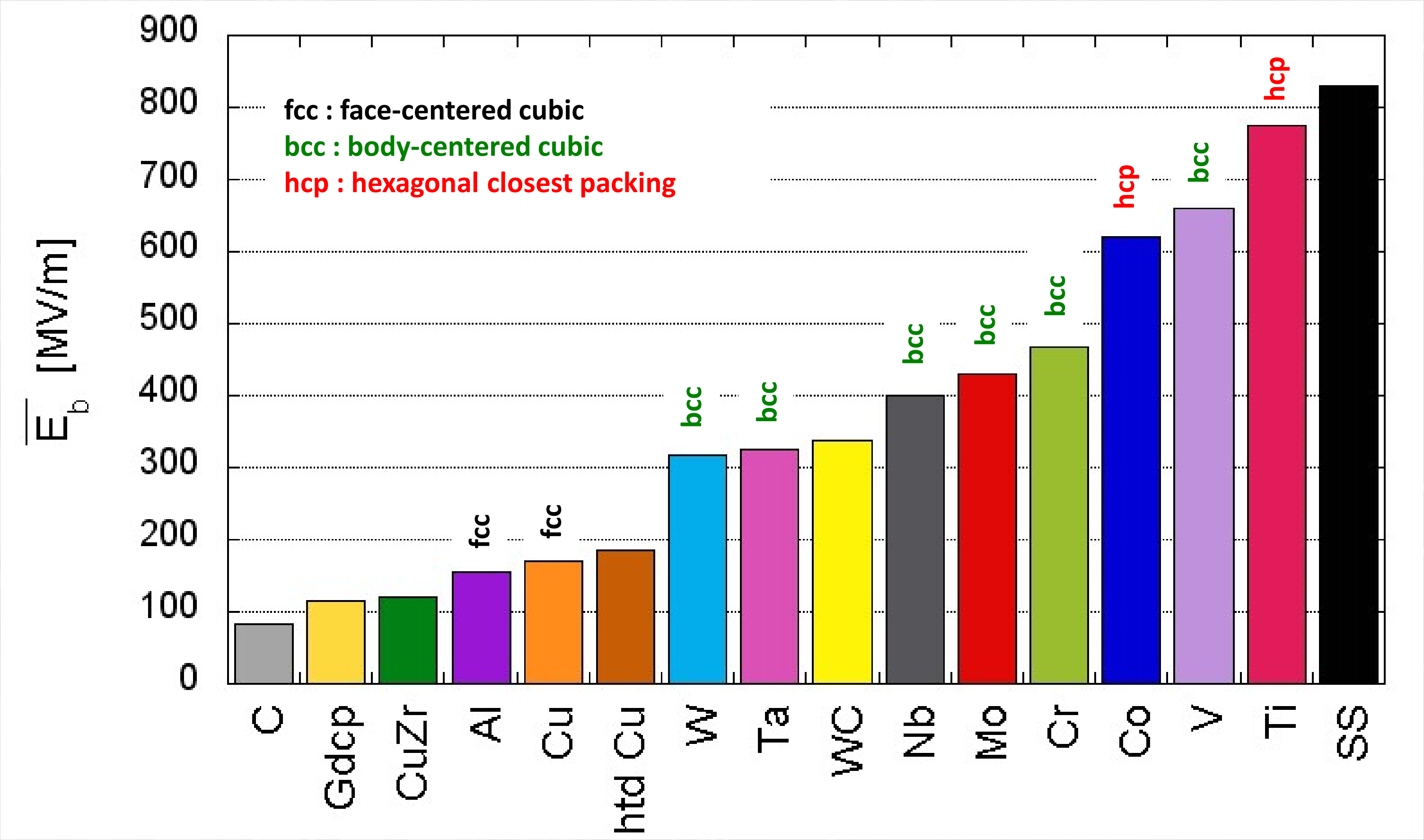


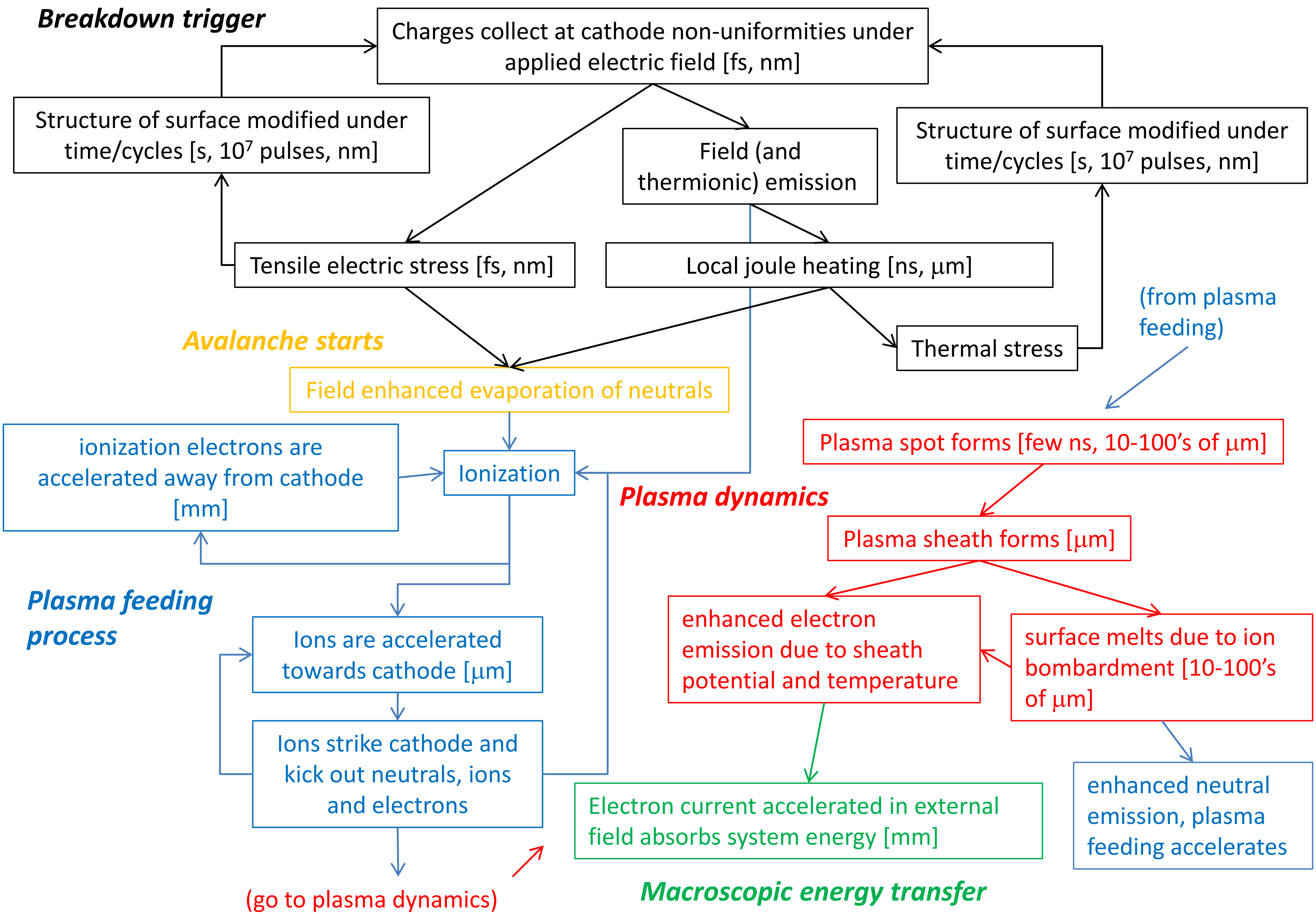
4. Breakdown ignition and plasma formation

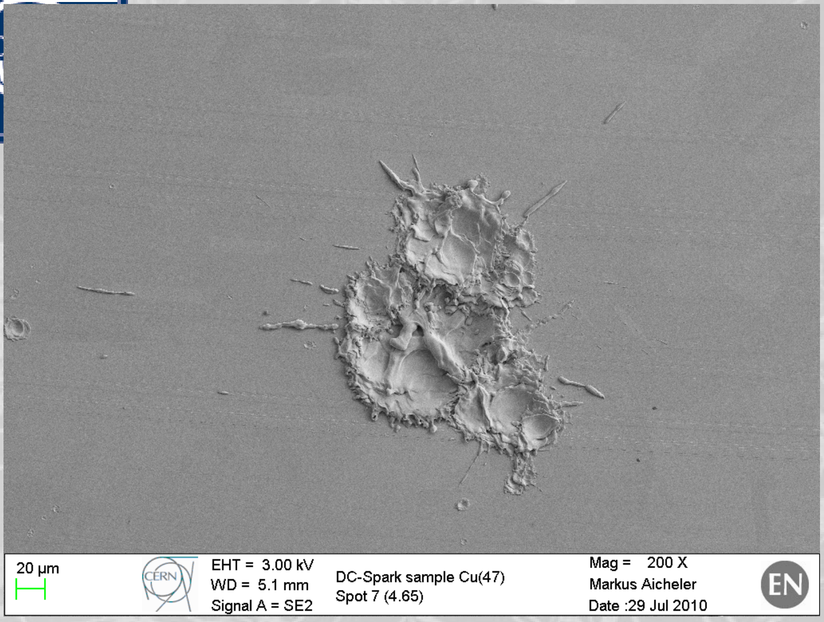


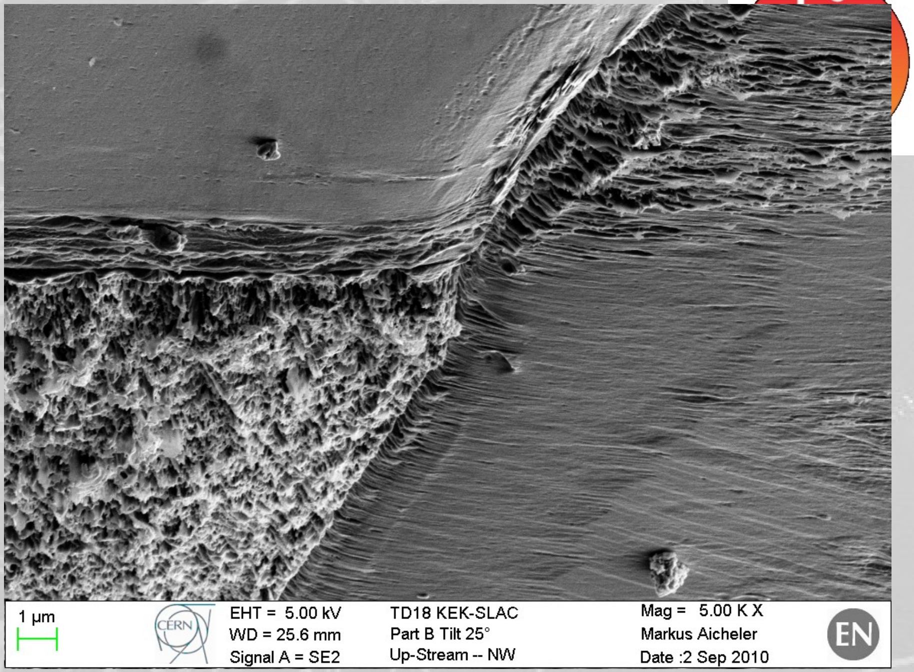
5. Surface damage mechanism

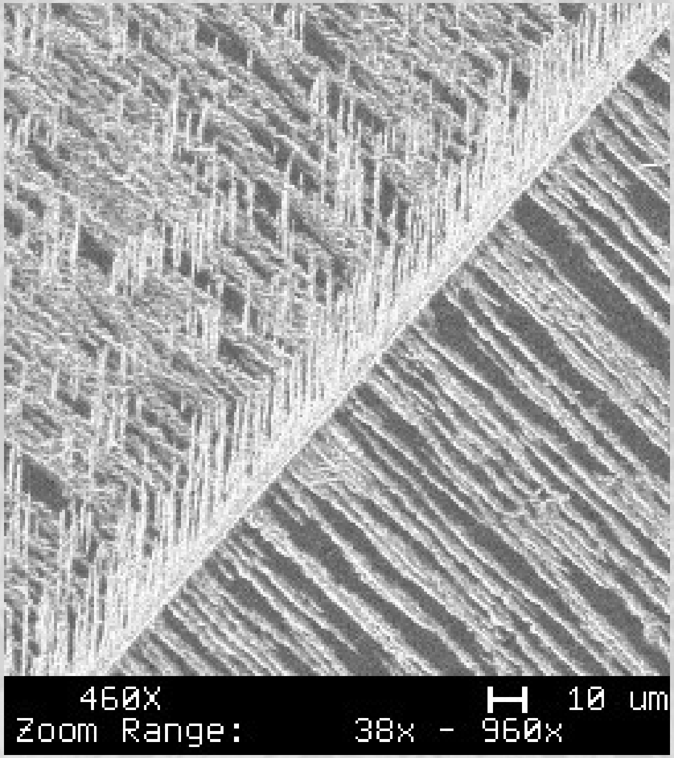
Hints for higher performance

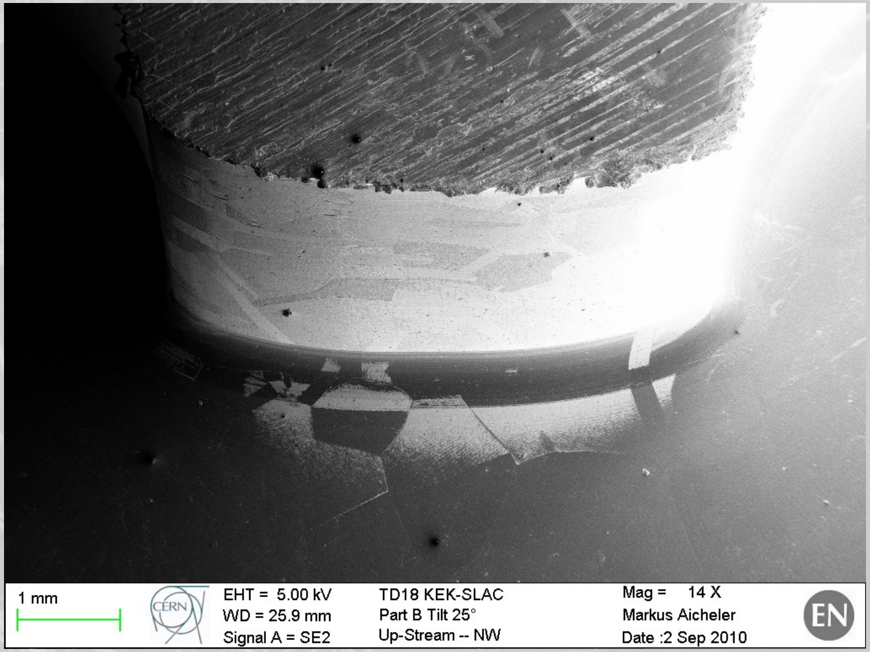



Breakdown trigger
Charges collect at cathode non-uniformities under applied electric field [fs, nm]
Structure of surface modified under time/cycles [s, 10^7 pulses, nm]
Field (and thermionic) emission
Structure of surface modified under time/cycles [s, 10^7 pulses, nm]
Tensile electric stress [fs, nm]
Local joule heating [ns, μm]
(from plasma feeding)
Avalanche starts
Thermal stress
Field enhanced evaporation of neutrals
Plasma spot forms [few ns, 10-100's of μm]
ionization electrons are accelerated away from cathode [mm]
Ionization
Plasma dynamics
Plasma sheath forms [μm]
Plasma feeding process
enhanced electron emission due to sheath potential and temperature
surface melts due to ion bombardment [10-100's of μm]
Ions are accelerated towards cathode [μm]
Ions strike cathode and kick out neutrals, ions and electrons
Electron current accelerated in external field absorbs system energy [mm]
enhanced neutral emission, plasma feeding accelerates
(go to plasma dynamics)
Macroscopic energy transfer

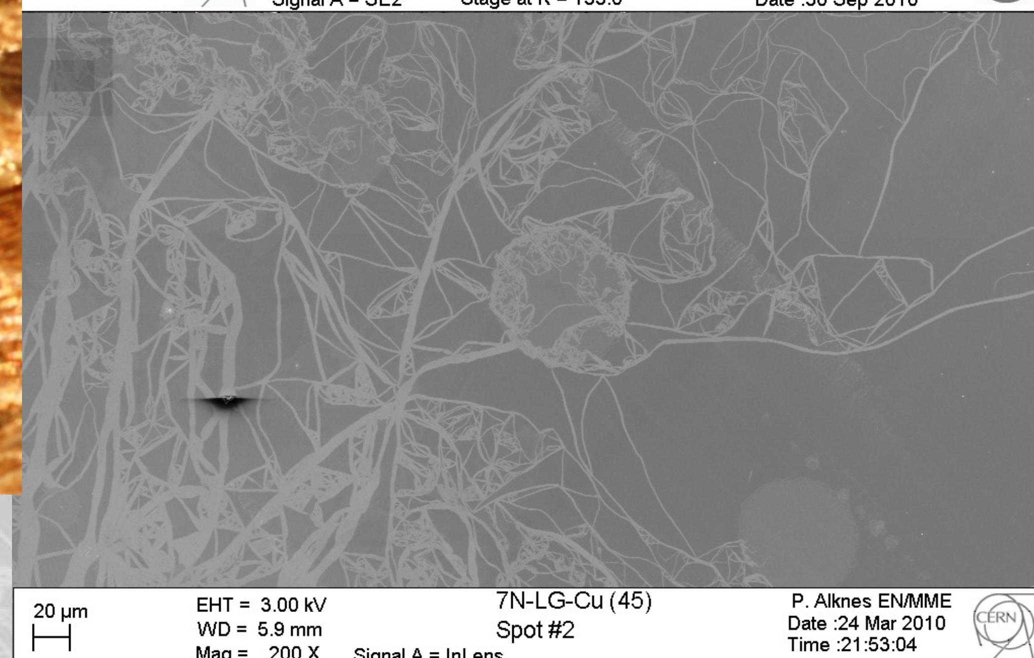

20 µm
EHT = 3.00 kV
WD = 5.1 mm
Signal A = SE2
DC-Spark sample Cu(47)
Spot 7 (4.65)
Mag = 200 X
Markus Aicheler
Date :29 Jul 2010
EN


1 µm
EHT = 5.00 kV
WD = 25.6 mm
Signal A = SE2
TD18 KEK-SLAC
Part B Tilt 25°
Up-Stream -- NW
Mag = 5.00 K X
Markus Aicheler
Date :2 Sep 2010
EN


460X
10 um
Zoom Range: 38x - 960x


1 mm
EHT = 5.00 kV
WD = 25.9 mm
Signal A = SE2
TD18 KEK-SLAC
Part B Tilt 25°
Up-Stream -- NW
Mag = 14 X
Markus Aicheler
Date :2 Sep 2010
EN


20 µm
EHT = 5.00 kV
WD = 15.4 mm
Signal A = SE2
TD18 KEK-SLAC Part C Tilt 30°
Down-Stream -- Cell Wall S-W
Stage at R = 135.0 °
Mag = 200 X
Markus Aicheler
Date :30 Sep 2010
EN


20 µm
EHT = 3.00 kV
WD = 5.9 mm
Mag = 200 X
7N-LG-Cu (45)
Spot #2
Signal A = InLens
P. Alknes EN/MME
Date :24 Mar 2010
Time :21:53:04

Fundamental design dependencies

There is a deep interrelation between achievable accelerating gradient, efficiency, beam dynamics and luminosity through the accelerating structure geometry.

L_{bx}/N