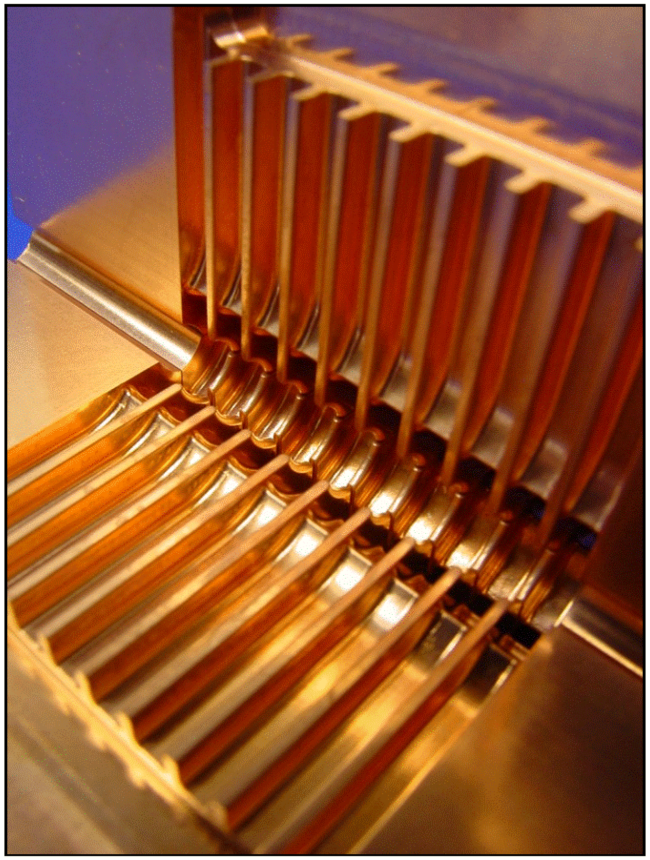
# Technological challenges of CLIC

*A short summary and some (very personal) comments*

R. Corsini



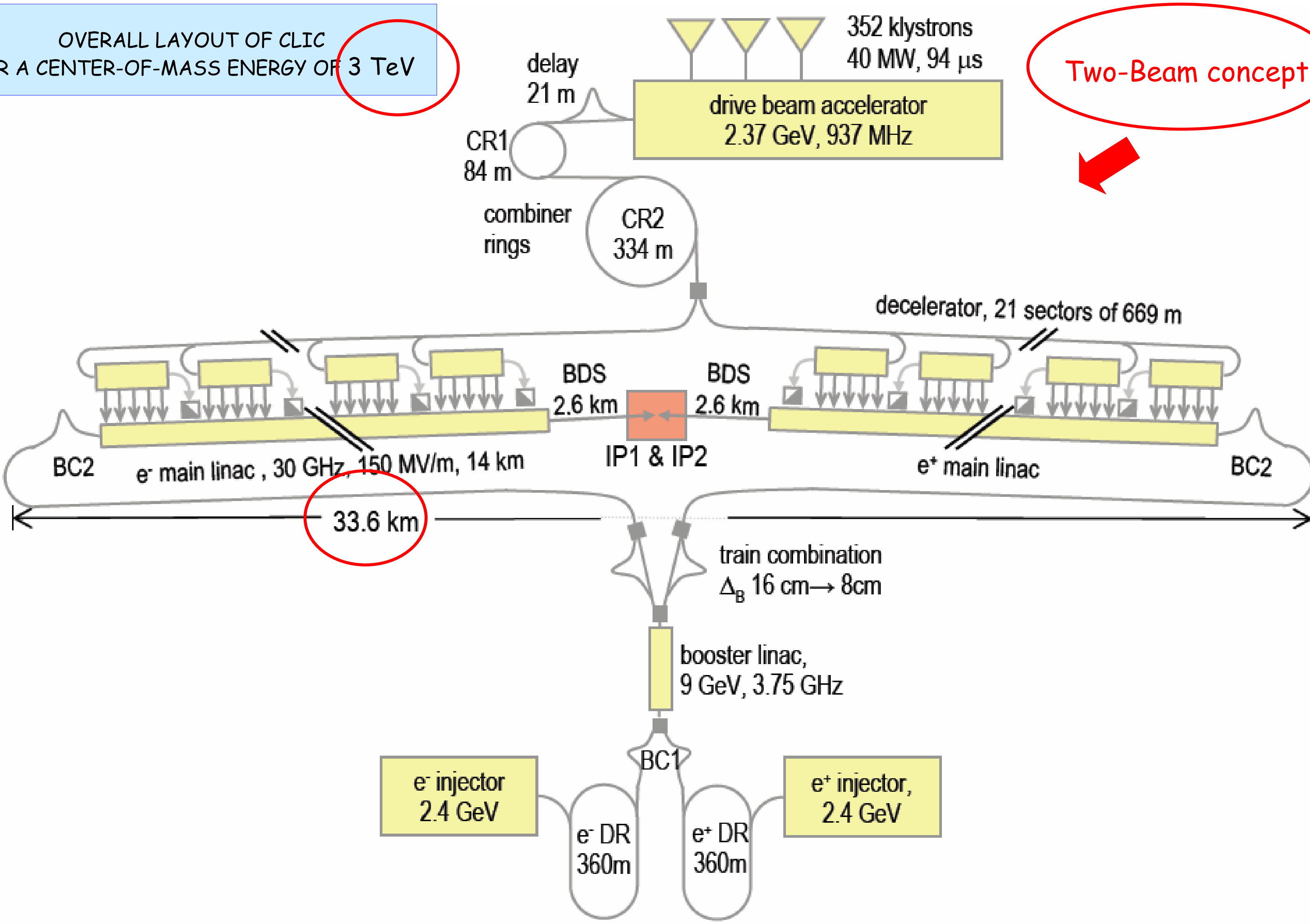
http://clic-study.web.cern.ch/CLIC-Study/

# TECHNOLOGICAL CHALLENGES OF CLIC

| | | |
|---|---|---|
| 12 June | Motivation, general description, test facilities | R. Corsini |
| 13 June | RF power generation and high gradient issues | S. Döbert |
| 14 June | Materials for accelerating structures | G. Arnau-Izquierdo |
| 15 June | Components alignment and stability | H. Mainaud, S. Redaelli |
| 16 June | Beam diagnostics equipment | T. Lefevre |

OVERALL LAYOUT OF CLIC
FOR A CENTER-OF-MASS ENERGY OF 3 TeV

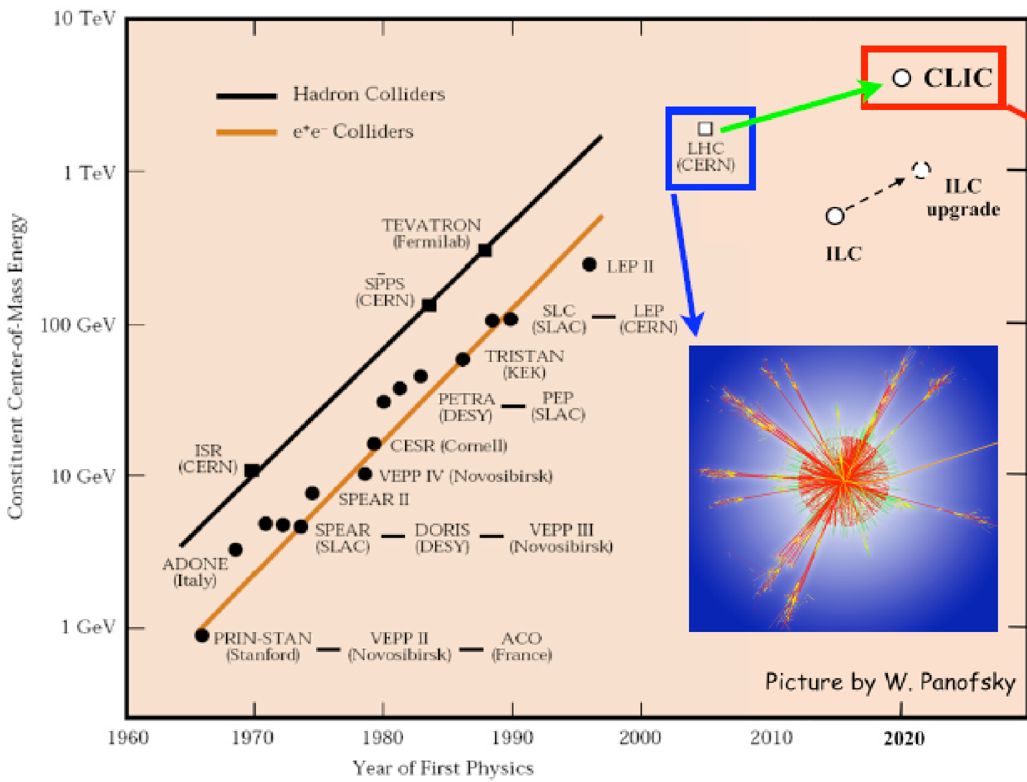
Two-Beam concept



*Challenge for accelerator physicists:* build machines that produce higher energy beams and deliver higher luminosities!

1) **ENERGY ($E_b$)** Discovery reach → $E = mc^2$

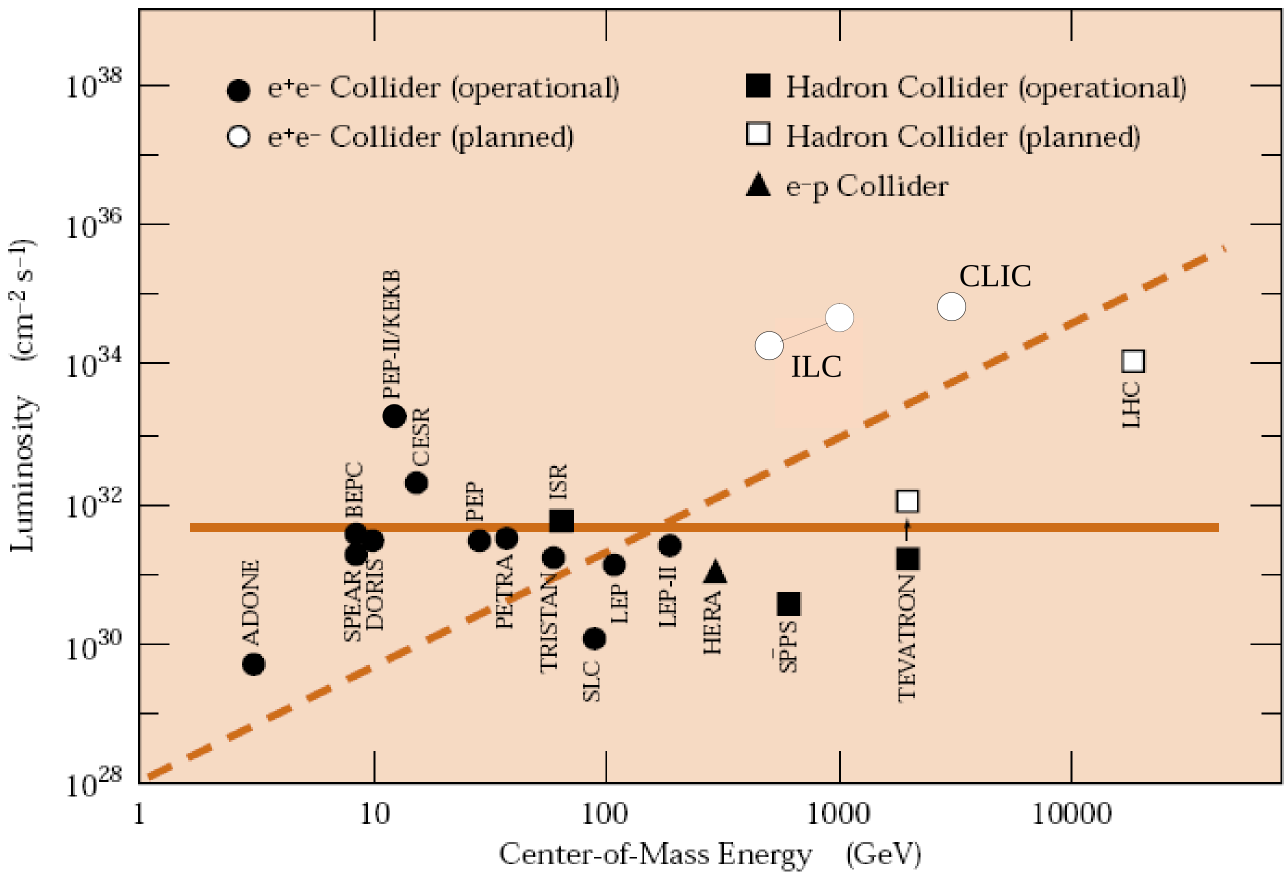
2) **LUMINOSITY ($L$)** Event rate → $N_{\mathrm{Event}} = \sigma \times \mathcal{L}$




*The Compact LInear Collider (CLIC) can make our dreams true!*

*Stefano Redaelli*

Luminosity plot (adapted from W. Panofsky)



What do we need for a multi-TeV linear collider?

Energy reach

$$E_{cm} = 2\,F_{fill}\,L_{linac}\,G_{RF}$$

- High gradient

Special material requirements

Luminosity

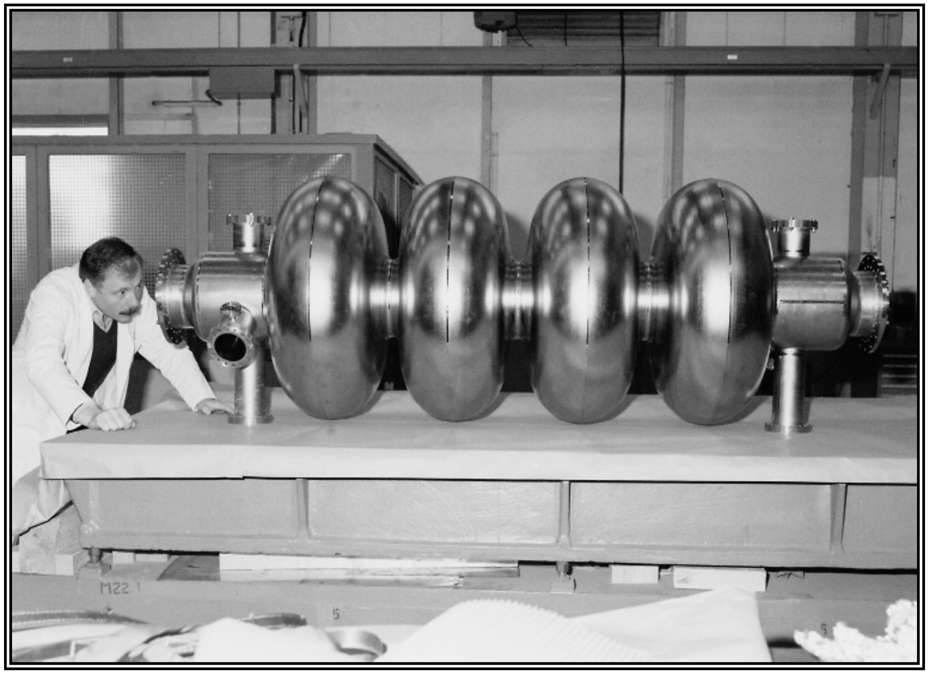
$$L = \frac{n_b N^2 f_{rep}}{4\pi\sigma_x^*\sigma_y^*} \times H_D \propto \frac{\eta_{beam}^{AC}\,P_{AC}}{\varepsilon_y^{1/2}}\,\frac{\delta_{BS}^{1/2}}{E_{cm}}$$

- Acceleration efficiency — high frequency, two-beam scheme
- Generation of small emittance — damping rings
- Conservation of small emittance — wake-fields, alignment, stability
- Extremely small beam spot at Interaction Point — beam delivery system, stability

Sophisticated beam diagnostics

# Why very high frequency ?

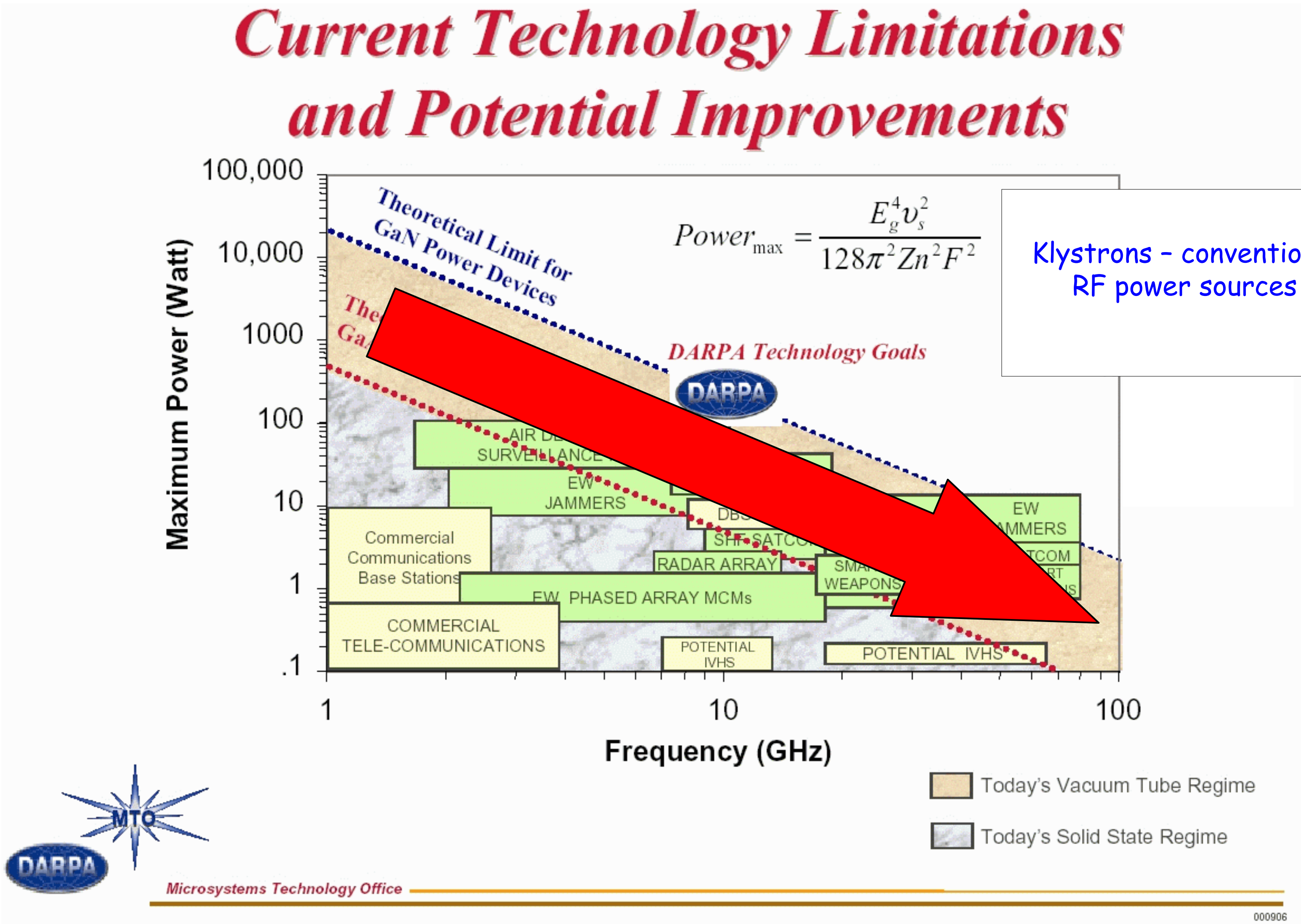
**LEP-Cavity 350 MHz**



**CLIC-Cavity 30 GHz**

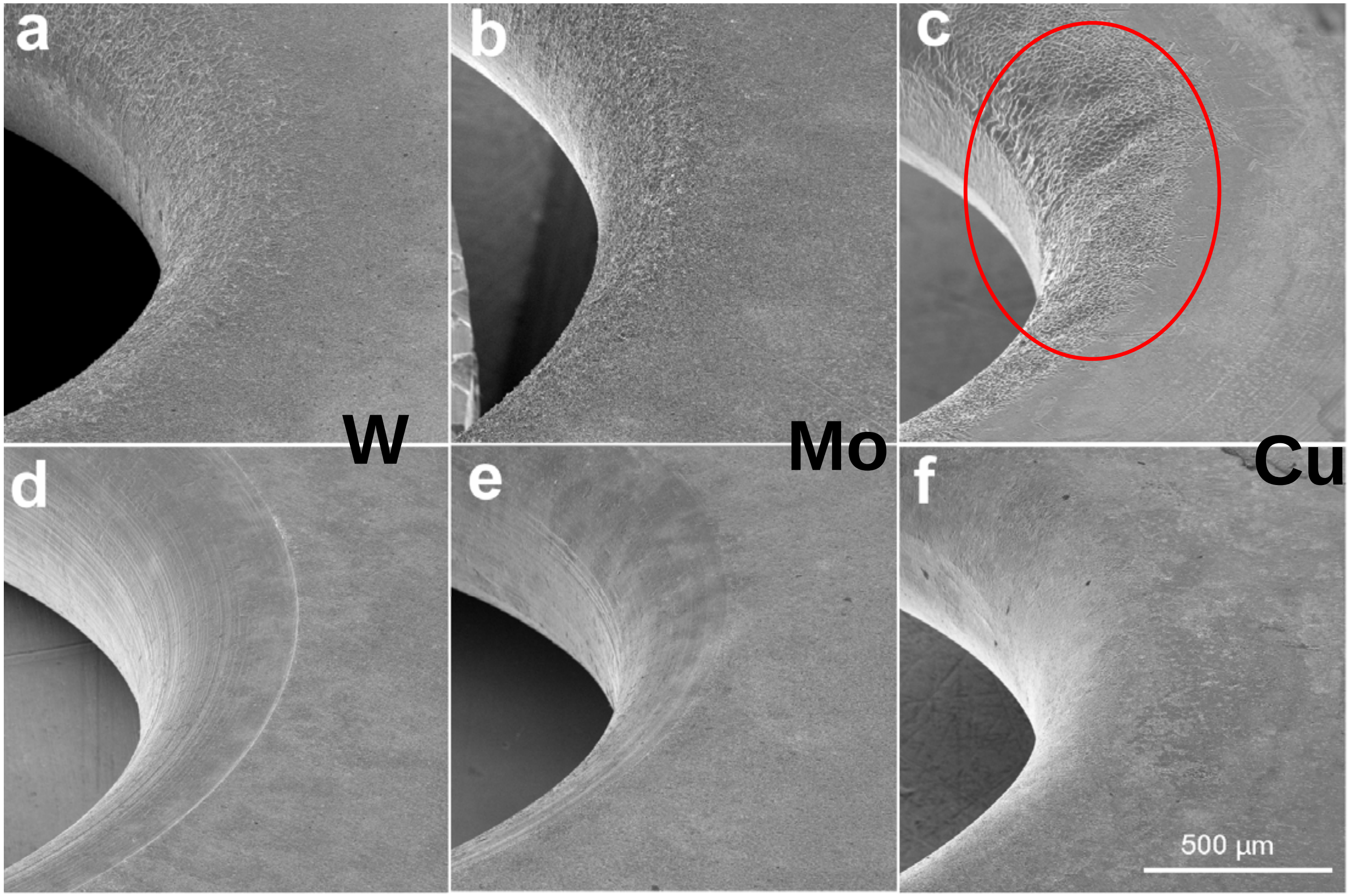
*Steffen Döbert*

# Why Two-Beam scheme ?




Klystrons – conventional RF power sources

## Limitation to high gradient: damage




Damage on iris after runs of the 30-cell clamped structures of previous example tested in CTF2.
First (a, b and c) and generic irises (d, e and f) of W ,Mo and Cu structures respectively.

*Gonzalo Arnau-Izquierdo*

# 30 GHz results so far

## Power Production (642 MW, 70 ns):

280 MW (350 peak) for 16 ns (CTF II)

100 MW for 70 ns (CTF3)

600 MW for 400 ns (NLCTA, SLAC, 11 GHz)

## Accelerating structure (150 MV/m, 70 ns):

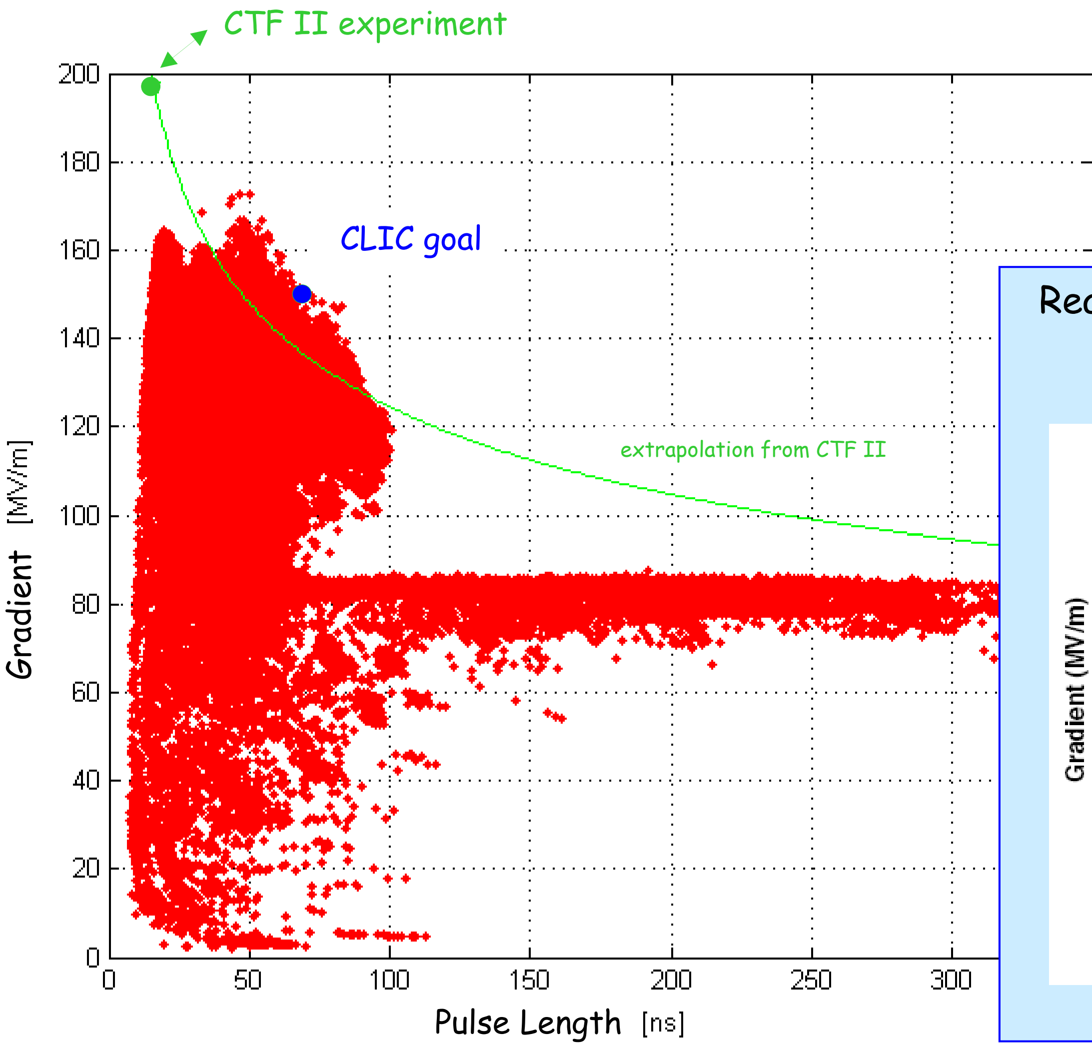
150 MV/m (193 peak) for 16 ns (CTF II)

150 MV/m peak for ~ 70 ns (CTF3, Dec 2005)
(but the breakdown rate is too high, surface erosion)

Two Beam acceleration demonstrated at low Power in CTFII

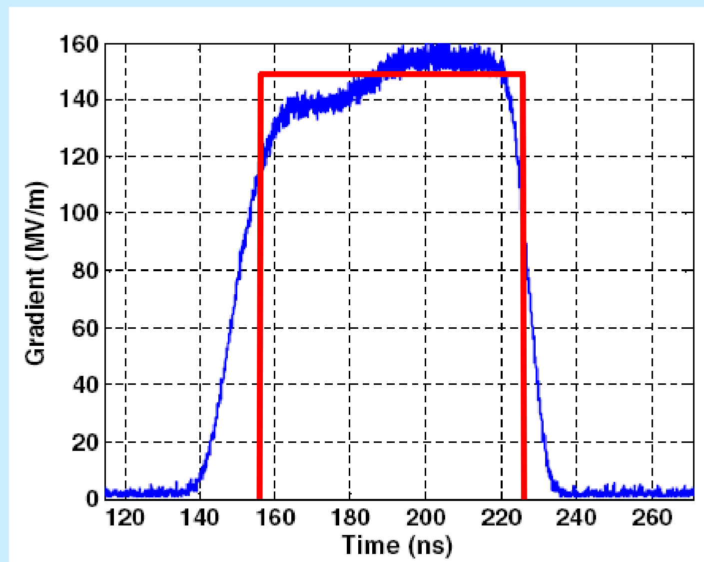
*Steffen Döbert*

# Molybdenum Structure Conditioning

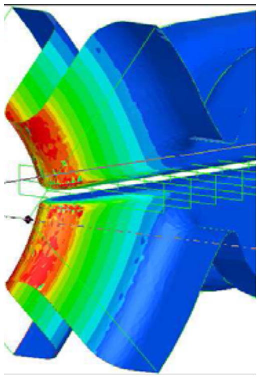



Reached nominal CLIC values :

150 MV/m 70 ns

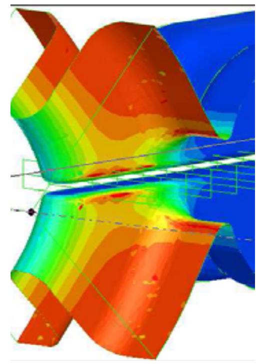



*Steffen Döbert*



E-field (breakdown)

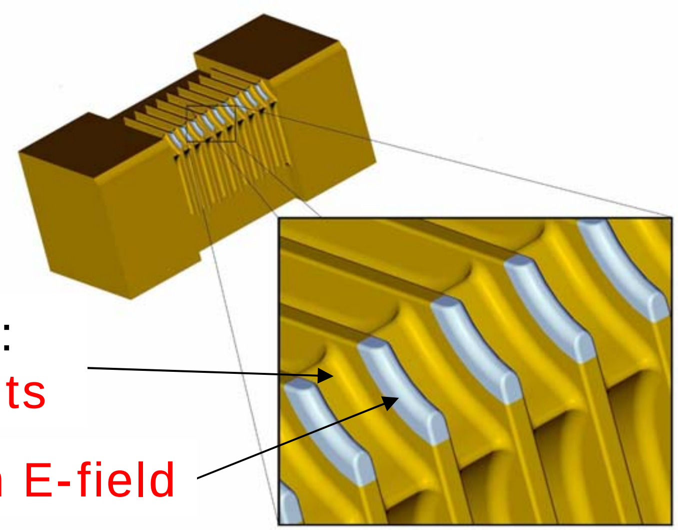
⇨use of **Mo**, or alternative refractory metal.



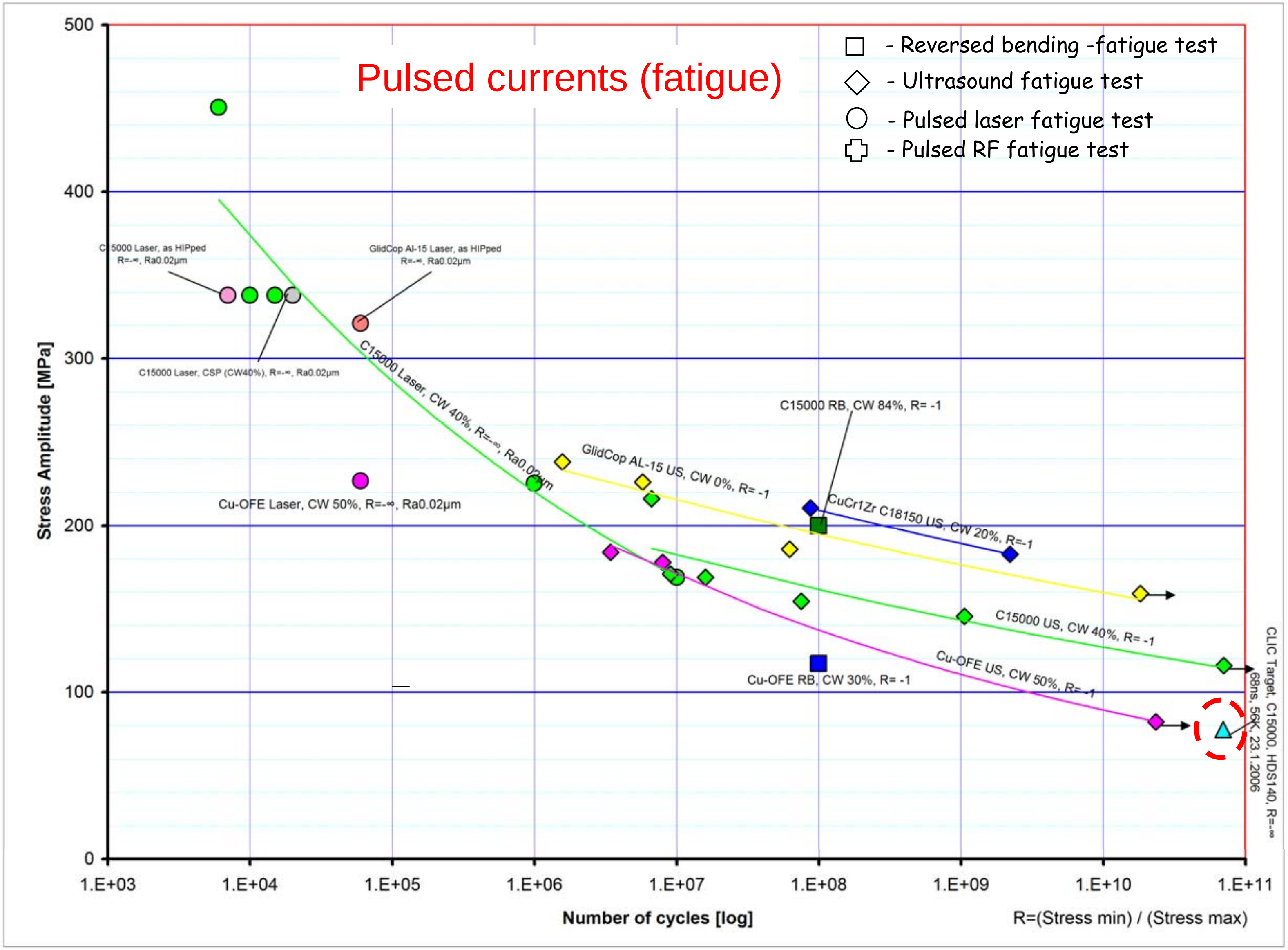
Pulsed currents (fatigue)

⇨ use of **CuZr**, or improved mechanical strength high conductivity alloy.

⇨Use bi-metallic



# Pulsed currents (fatigue)




Gonzalo Arnau-Izquierdo

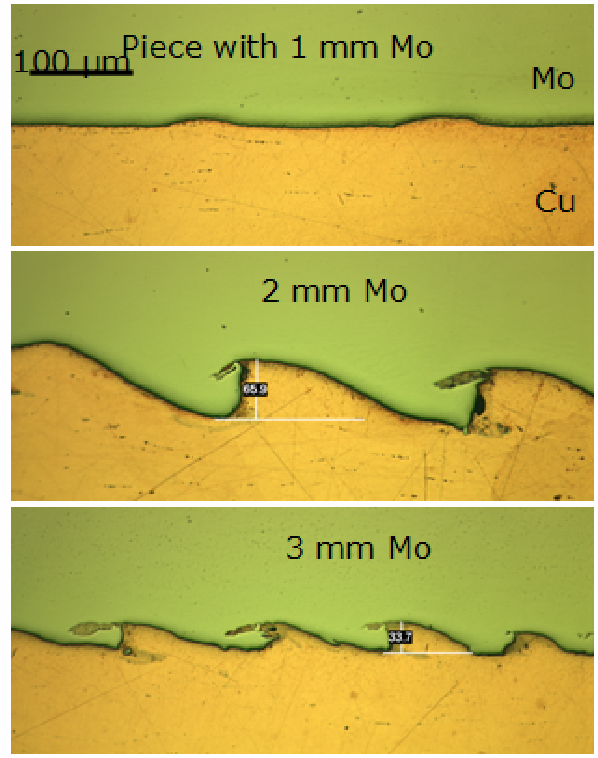
# Bimetals by explosion bonding

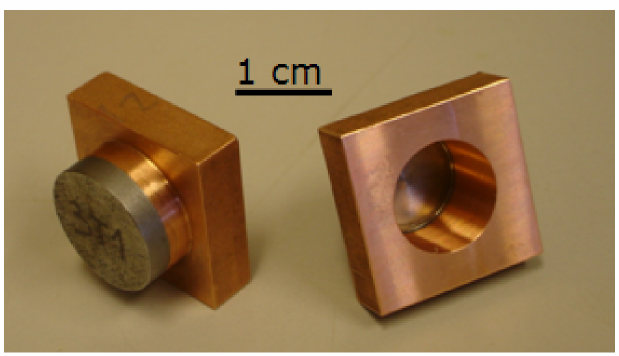
RESULTS

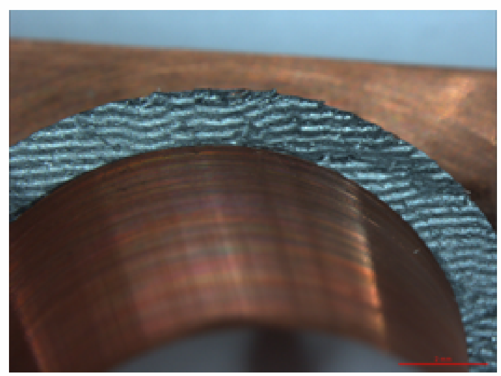
- Bond soundness
  - Good strength and absence of interface voids
- Possible fragilisation of the Mo in a layer close to the interface

PERSPECTIVES

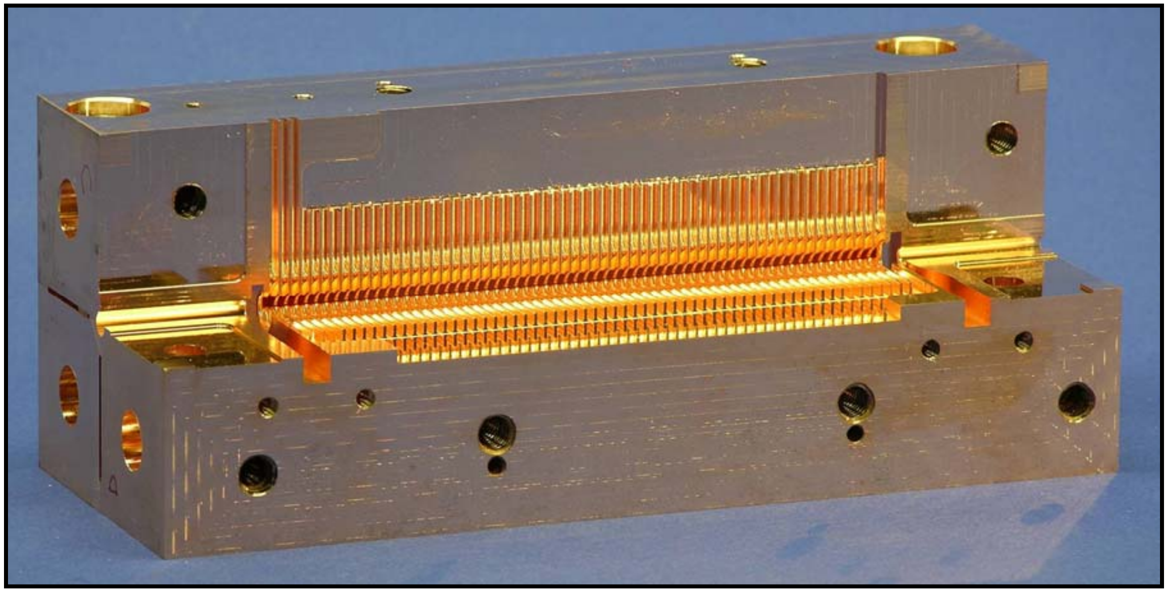
- Production of pieces for machining HDS prototype is underway
- Study possible curved configuration to better adapt to the geometry of the HDS structure

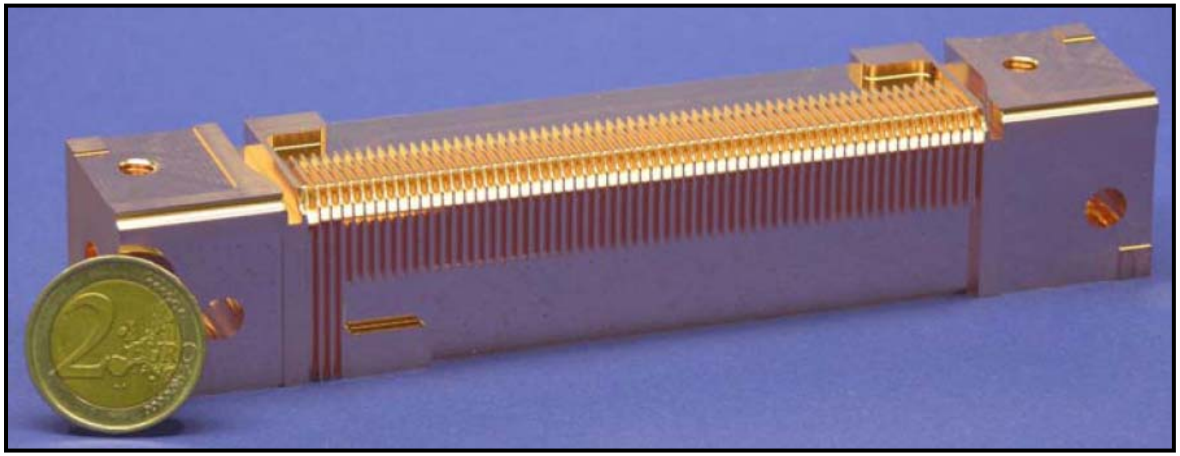


# New Ideas from CLIC

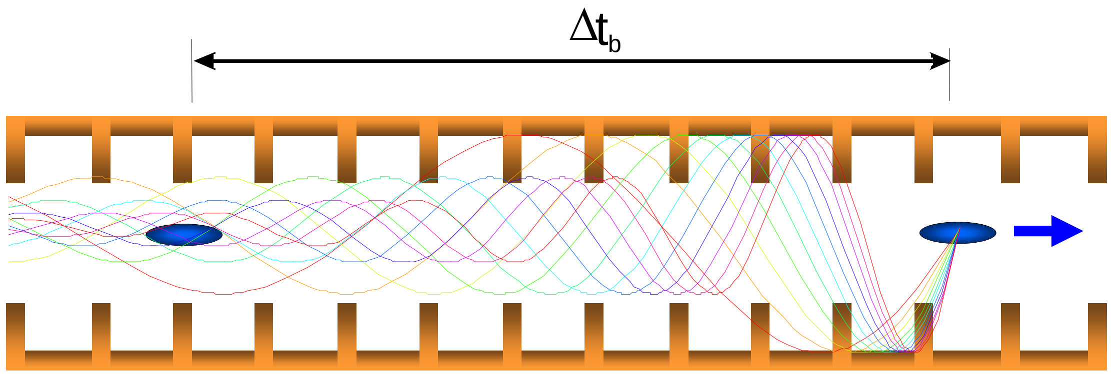




Currently being installed for testing !

Steffen Döbert

## Wake-fields

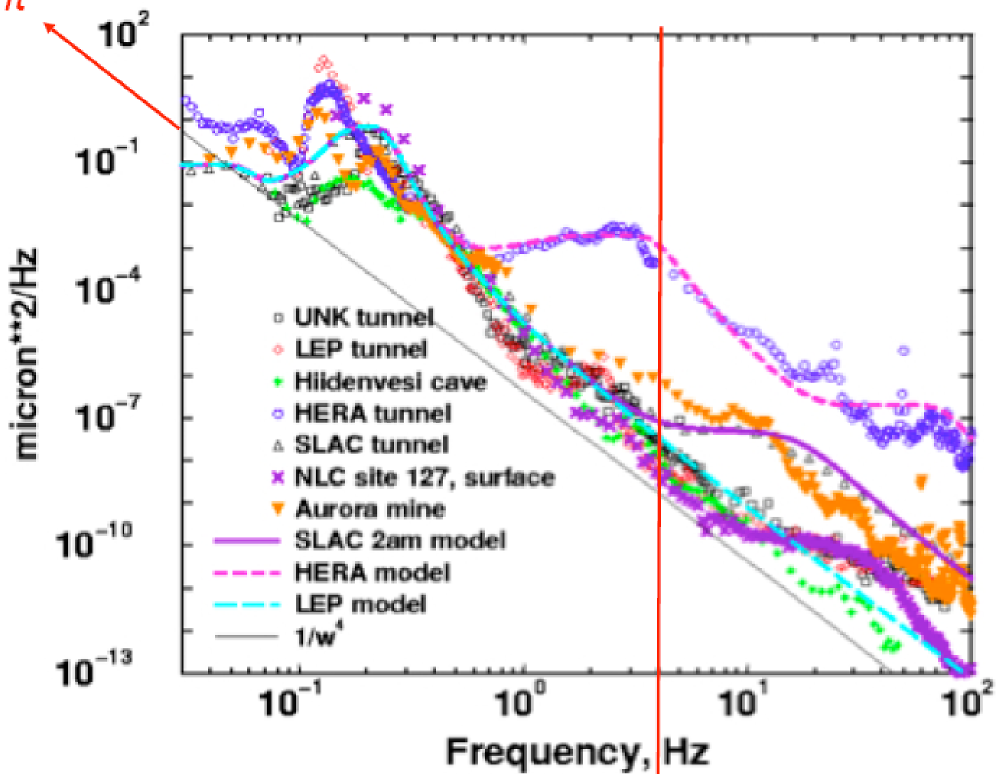



- Bunches traveling in accelerating structures induce fields which perturbs later bunches
- Bunches passing off-centre excite transverse higher order modes (HOM)
- Later bunches are kicked transversely

beam break-up ⇒ Emittance growth !!!

Pre-alignment

- Active !
- Sufficient to send a pilot beam




Courtesy of A. Seryi

Correction with beam based feedbacks

Limited by $f_{rep}$

Slow motion

Fast motion

Mechanical stability of magnets

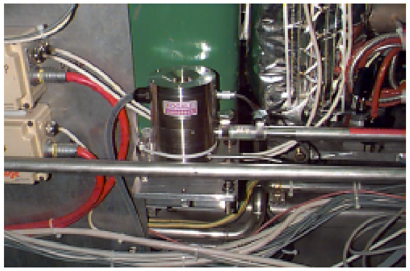
$f_{cut} \approx f_{rep} / 25 = 4$ Hz

## ALIGNMENT SYSTEMS

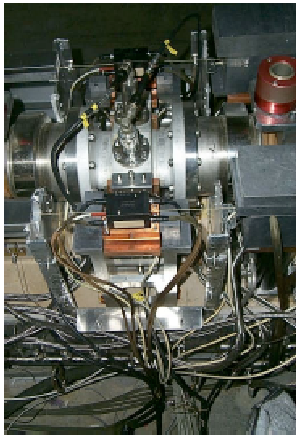
Tolerance of CLIC prealignment: ± 10 μm over 200m

→ need for alignment systems with the following characteristics:

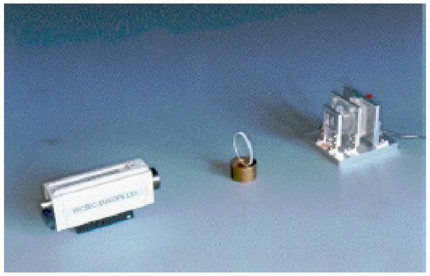
- high resolution
- continuous measurements
- working in severe environment (strong electro-magnetic fields and radiations)



Hydrostatic Levelling System (HLS)



Wire Positioning System (WPS)



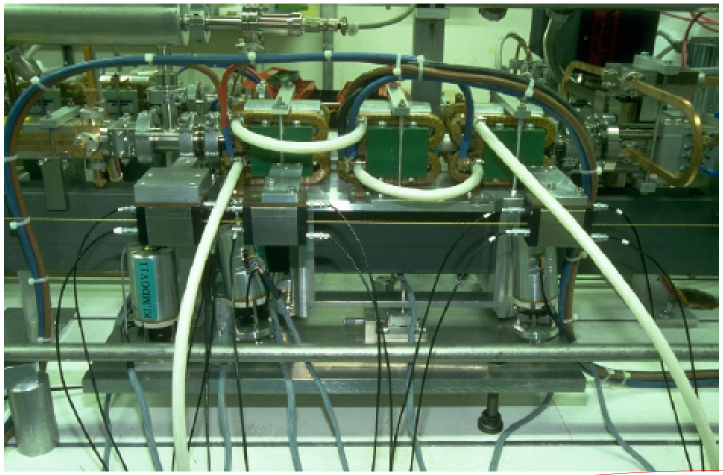
Red Alignment System from NIKHEF (RASNIK)

Helene Mainaud

# ALIGNMENT SYSTEMS : PREVIOUS APPLICATIONS

All these alignment systems have already been used sucessfully :

- ✓ L3 detector for RASNIK system
- ✓ LEP low beta quadrupoles for HLS system
- ✓ LEP spectrometer for WPS system
- ✓ WPS + HLS tested on CTF2



In a closed loop, the elements were maintained w.r.t wire within a $\pm$ 5 $\mu$m window and operated reliably in a high radiation environment

For CLIC: a new parameter … the dimension

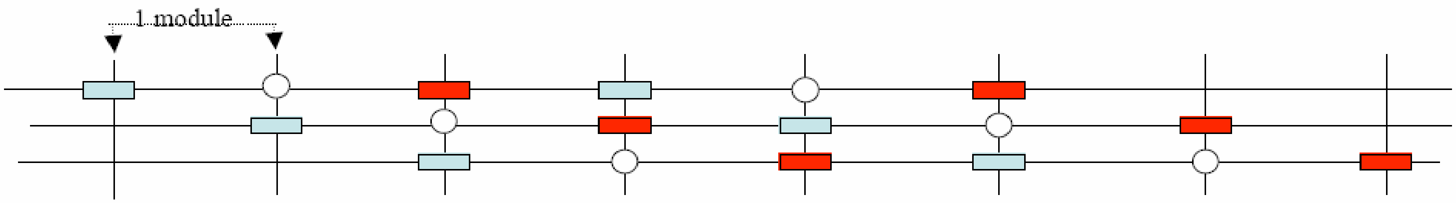
Perturbation of gravity and its consequences

*Helene Mainaud*

# A SOLUTION FOR THE CLIC PREALIGNMENT

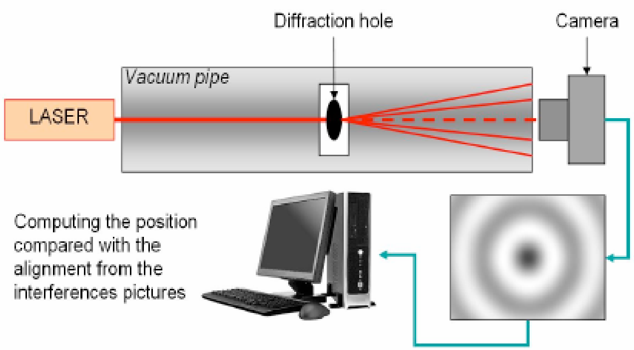
Two solutions are explored regarding the metrological networks:

✓ In both cases: proximity network = RASNIK




✓ Regarding the propagation network:

- Solution 1: WPS system: overlapping stretched wires (100 m)
- Solution 2: optical system named « RASCLIC », under collaboration frame with NIKHEF



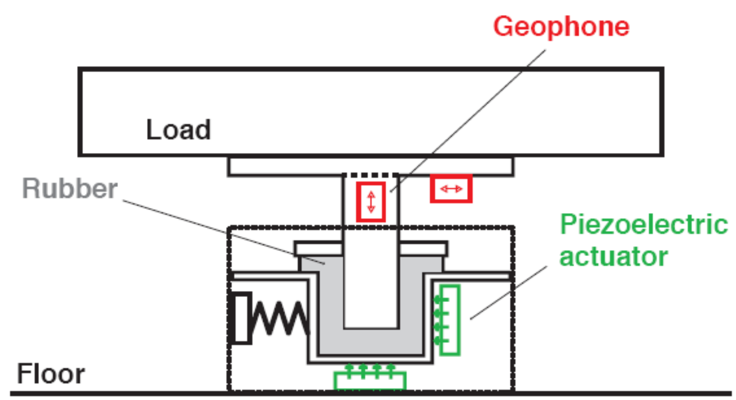

**Results:**

✓ According to the configuration, articulation points prealigned with a standard deviation comprised between ± 8 and 14 μm on a sliding window of 200m.

✓ Hypotheses to be confirmed with a mock up under installation

*Helene Mainaud*





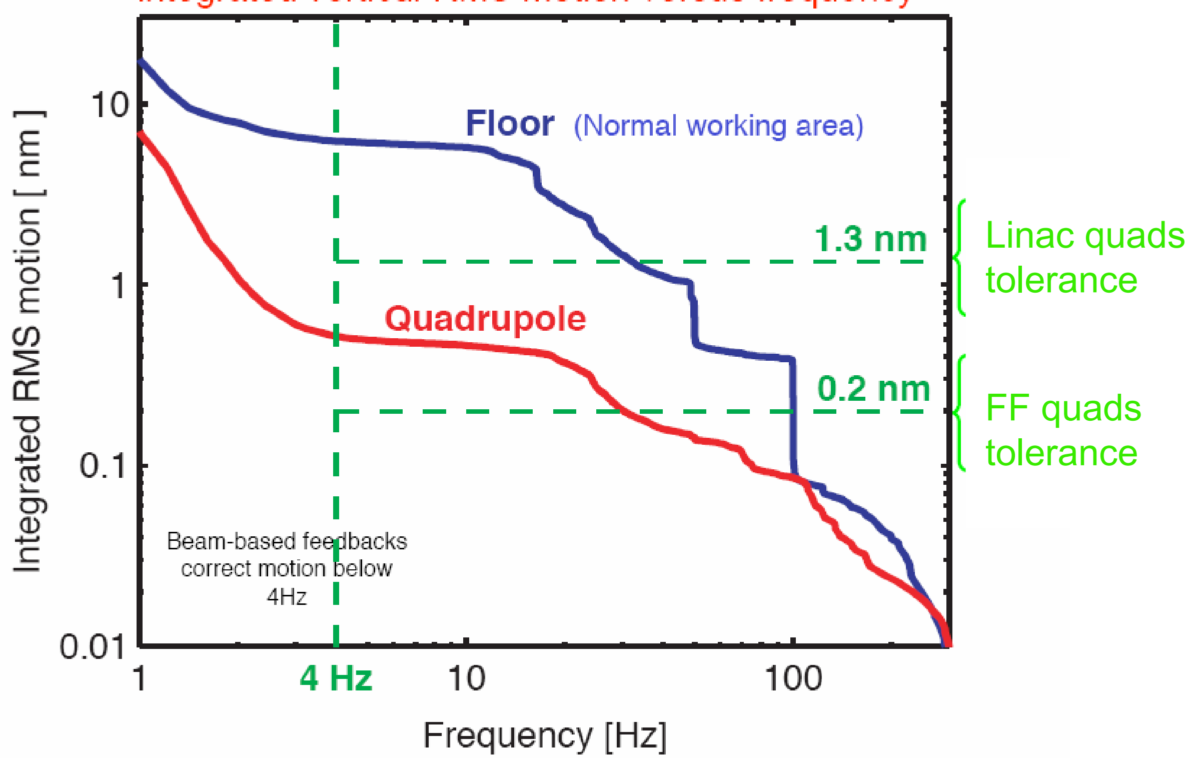

*Stefano Redaelli*

## CERN vibration test stand results

**RMS vibrations above 4 Hz**

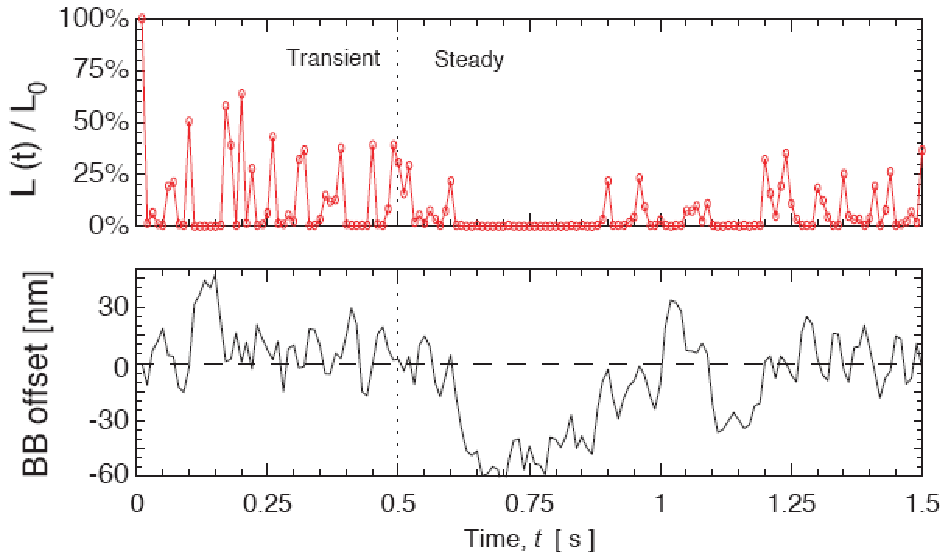
| | Quad [nm] | Ground [nm] |
|---|---|---|
| Vertical | **0.43** | **6.20** |
| Horizontal | **0.79** | **3.04** |
| Longitud. | 4.29 | 4.32 |

Integrated *vertical* RMS motion versus frequency




**CLIC prototype magnets stabilized to the sub-nanometre level !!**

***Above 4Hz:*** **0.43 nm** on the quadrupole instead of **6.20 nm** on the ground.

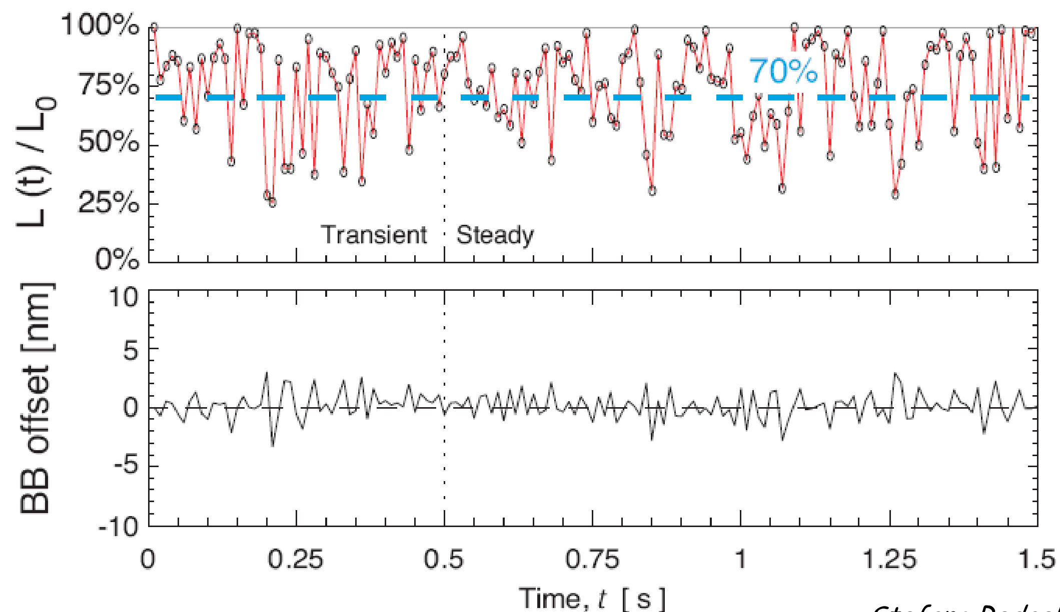



Without stabilization (ground):

No significant luminosity is produced!

With stabilization:

**~ 70 % of the luminosity is steadily maintained!**



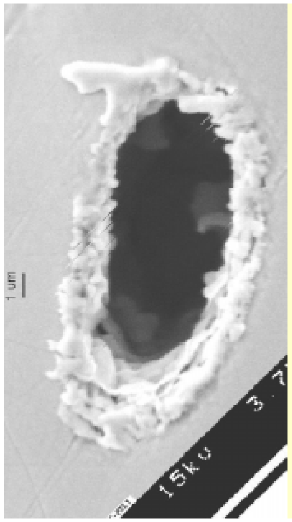

*Stefano Redaelli*

# 'Measuring small beam size'

- In linac → $\sigma \sim 1\mu m$
- In Final Focus → $\sigma \sim 1nm$

Small beam size means high charge density
*$10^{9}$ - $10^{12}$ nC/cm$^2$*

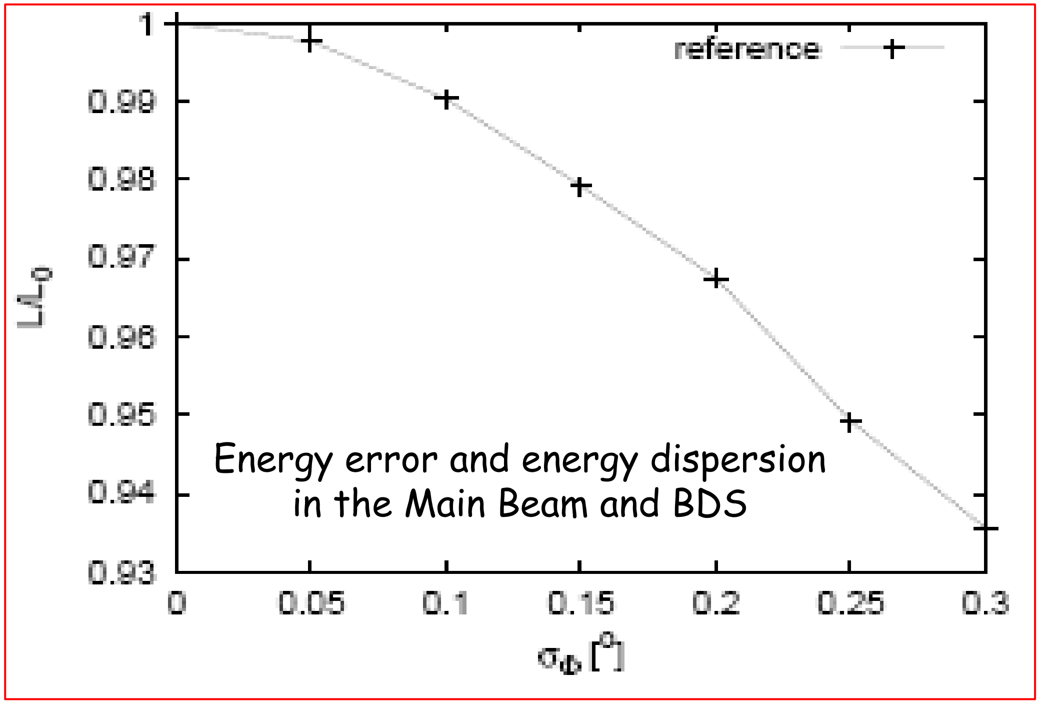
*The thermal limit for 'best' material (C, Be, SiC) is ~ 1 $10^{6}$ nC/cm$^2$*



High resolution non intercepting beam size monitor

*Thibaut Lefevre*

# Phase stability of the Drive Beam



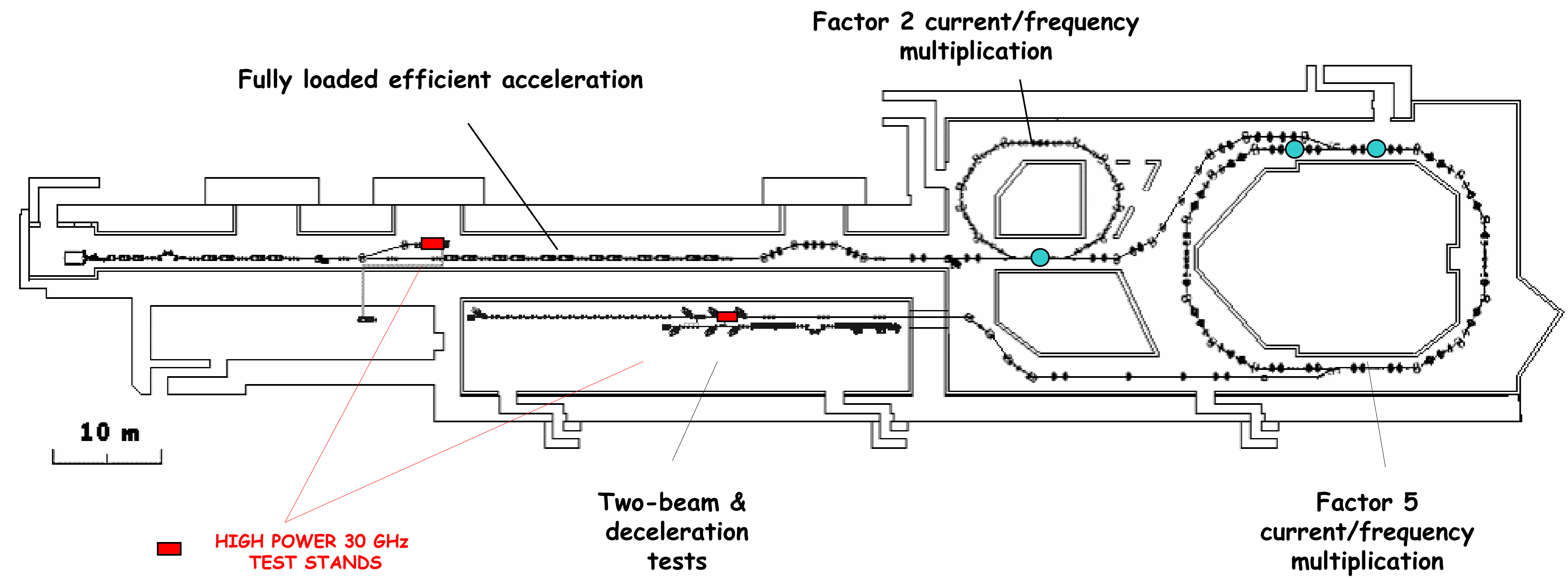

' 4% luminosity reduction'

➡ Average gradient error over the linac $\sigma_\phi$ = 0.225°

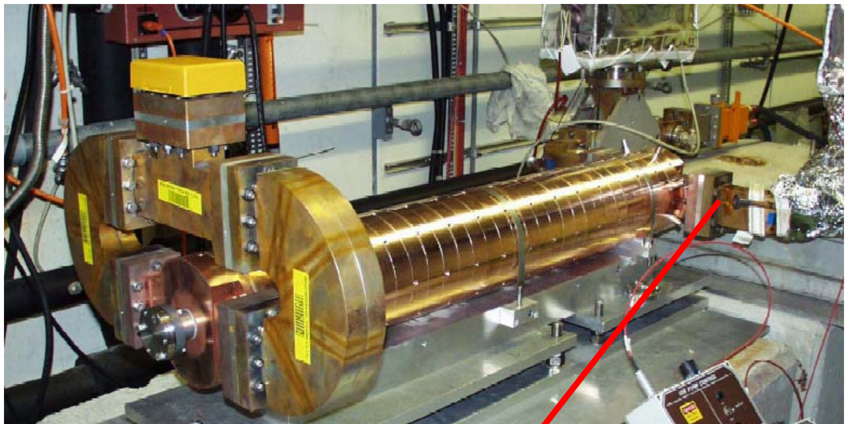
➡
- Longitudinal Drive beam tolerance $\Delta_z$ = 6μm
- Feedback/feedforward for optimization

## CTF3 COLLABORATION

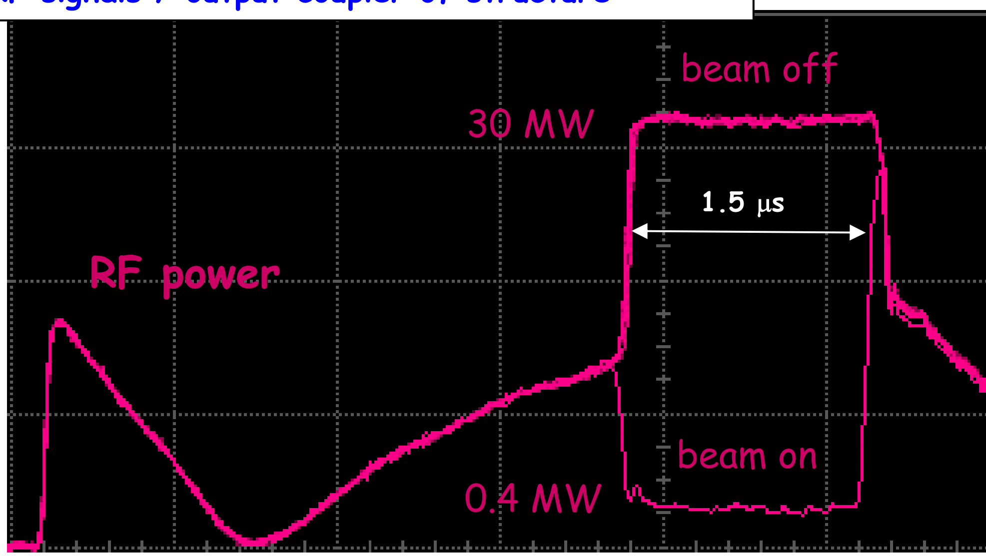
| | | |
|---|---|---|
| Ankara University , (Turkey) | HIP, Helsinki (Finland) | Northwestern University, (USA) |
| BINP, Russia | IAP, (Russia) | RAL, (England) |
| CIEMAT, (Spain) | INFN , Frascati (Italy) | SLAC , San Francisco (USA) |
| CERN, Geneva (Switzerland) | LAL , Orsay (France) | Svedberg Lab. (Sweden) |
| DAPNIA, Saclay (France) | LAPP, Annecy (France) | Uppsala University , (Sweden) |



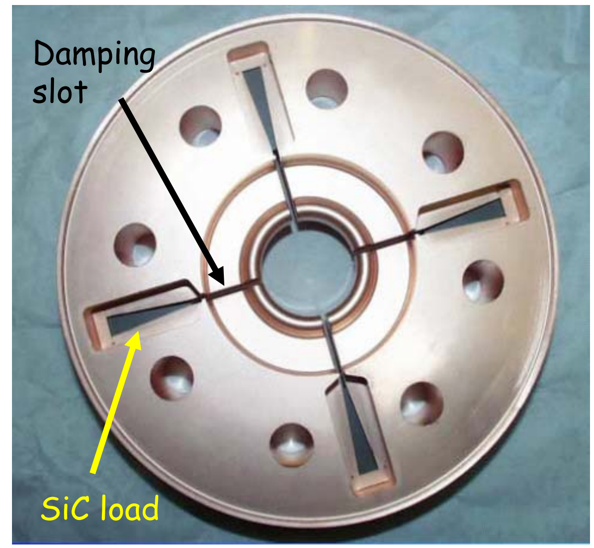
# First "full beam loading" operation in CTF3



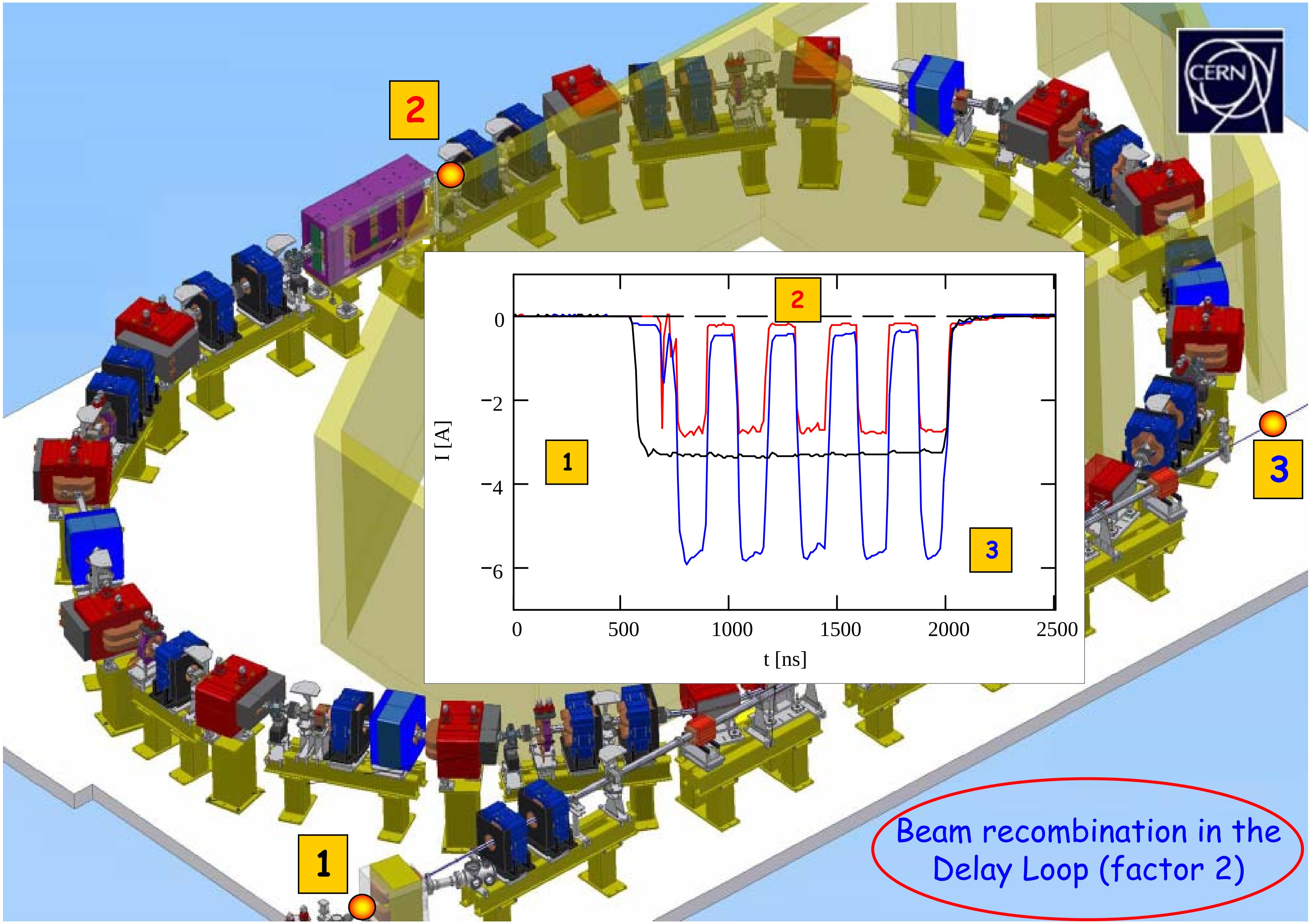
**RF signals / output coupler of structure**




Dipole modes suppressed by slotted iris damping (first dipole's Q factor < 20) and HOM frequency detuning

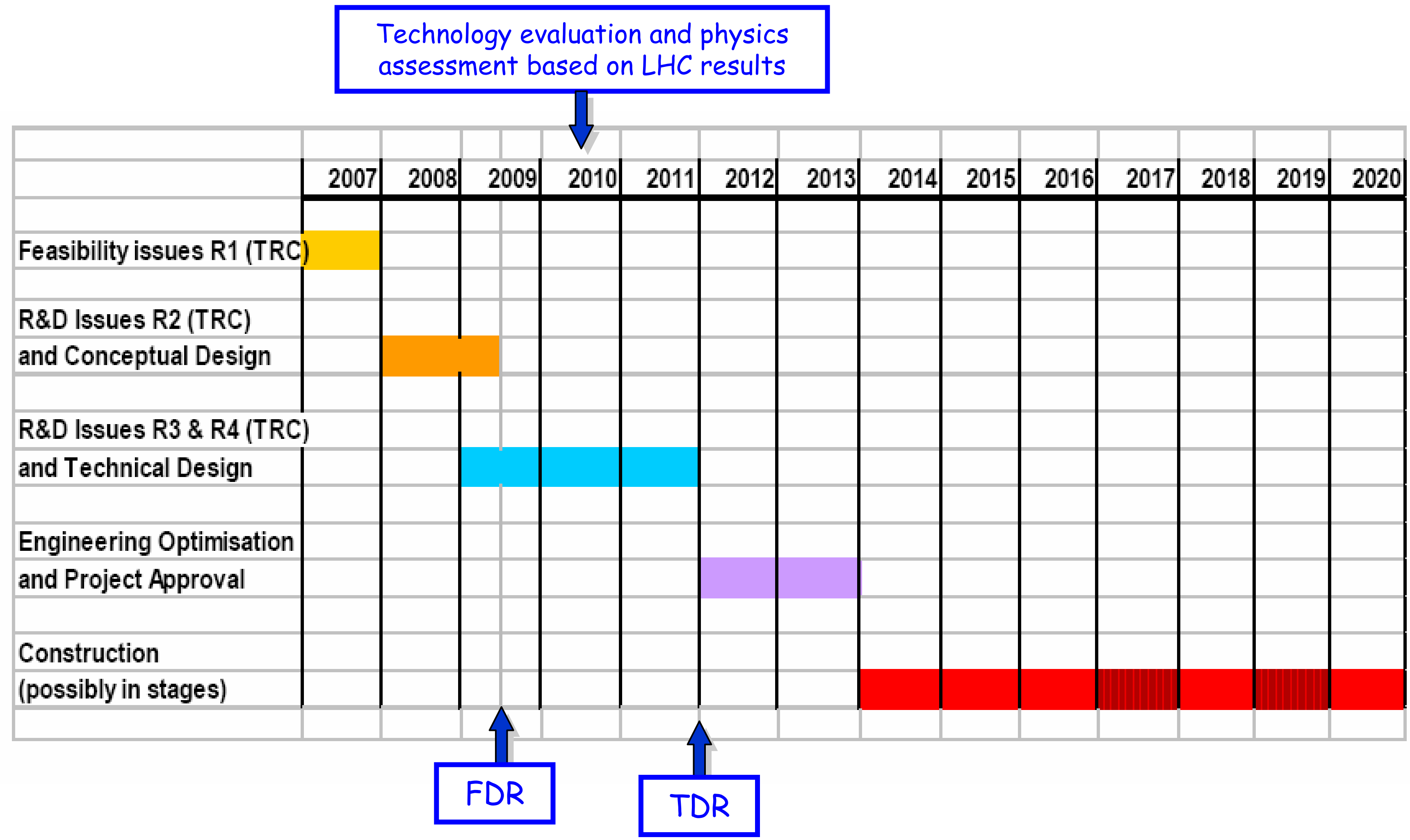


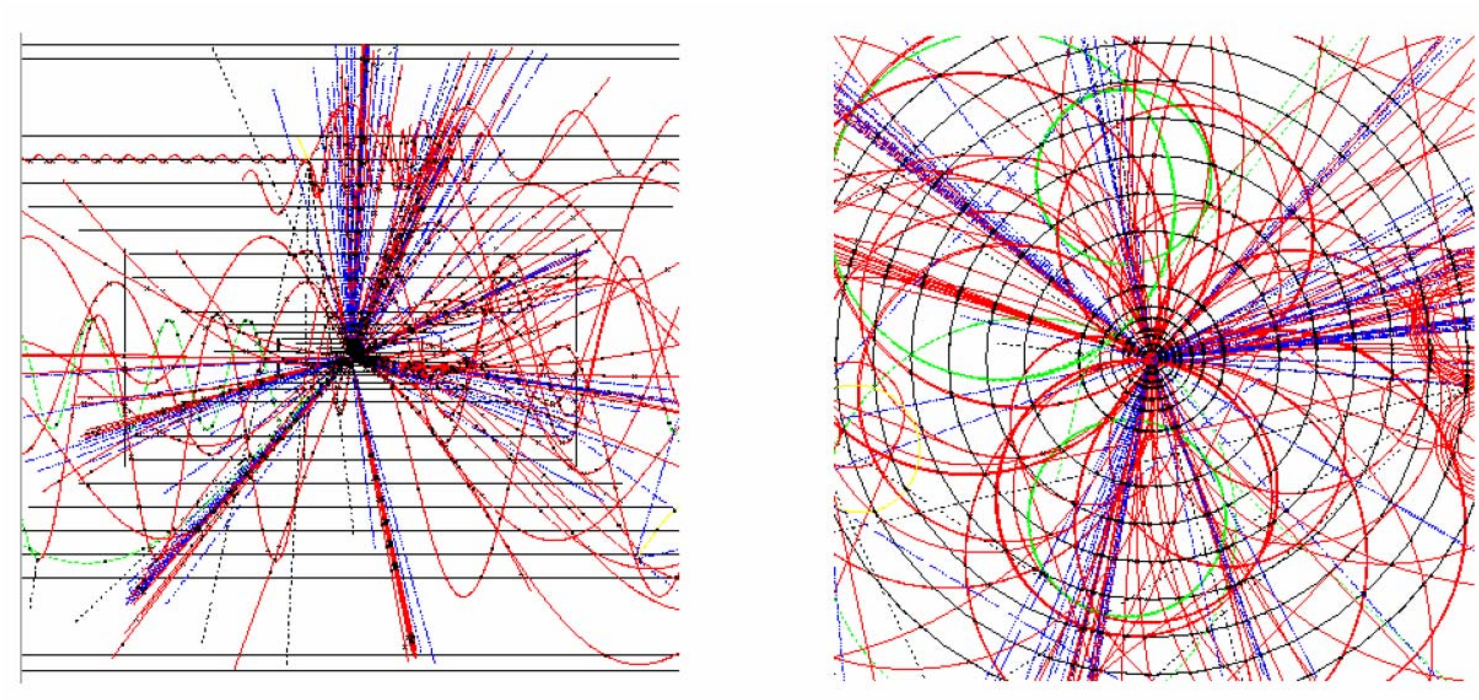

| | |
|---|---|
| Beam current | 4 A |
| Beam pulse lenght | 1.5 μs |
| Power input/structure | 35 MW |
| Ohmic losses (beam on) | 1.6 MW |
| RF power to load (beam on) | 0.4 MW |
| RF-to-beam efficiency | ~ 94% |


2
1
3
I [A]
0
−2
−4
−6
0
500
1000
1500
2000
2500
t [ns]
Beam recombination in the Delay Loop (factor 2)

# TENTATIVE LONG-TERM CLIC SCENARIO

(success oriented)





…experiments at CLIC will be able to exploit fully its high centre-of-mass energy for tests of the Standard Model as well as unique probes of ideas for new physics beyond the Standard Model.

CLIC will take physics at the energy frontier to a new scale and level of accuracy.