# Testing Infrastructure, Program and Milestones

- Test Facilities
- Testing Program for 2008
- Milestones

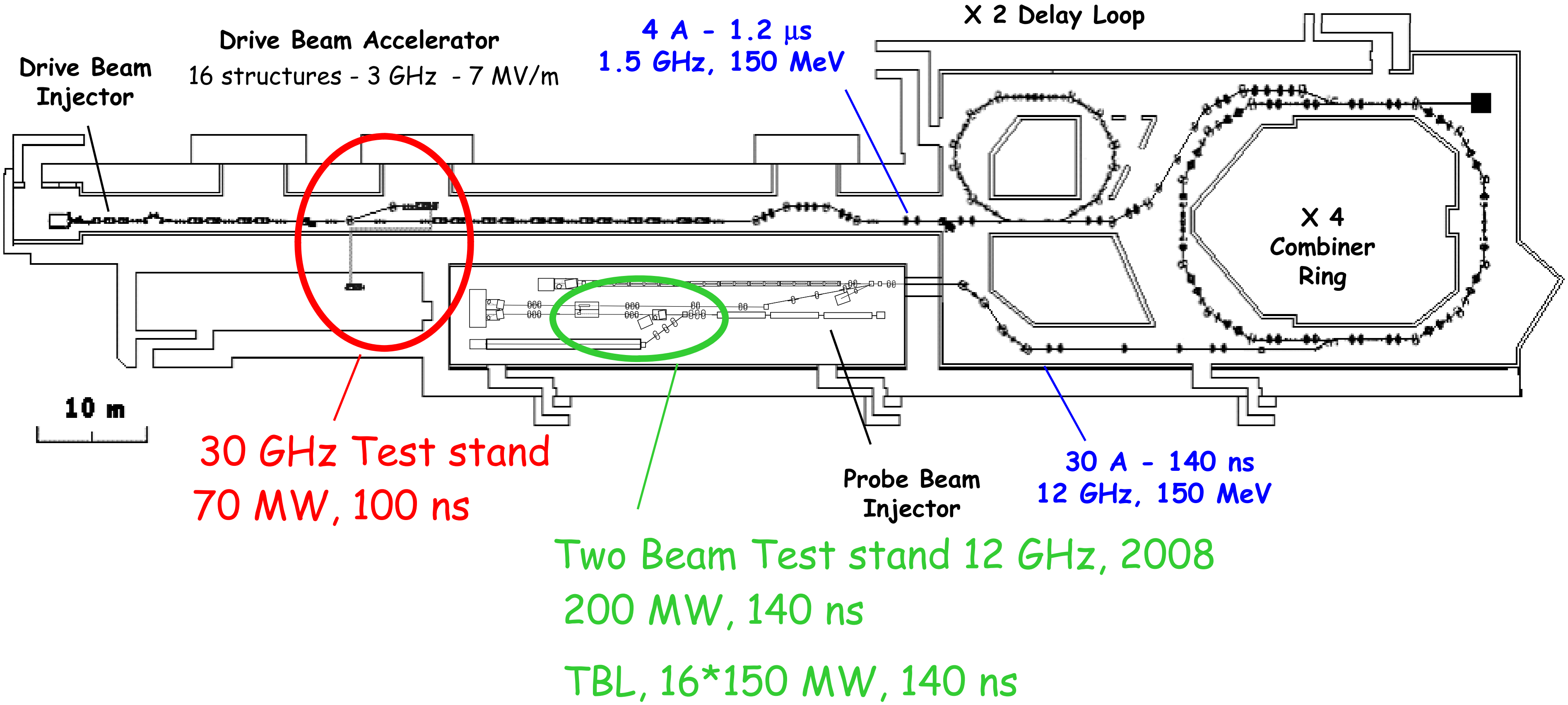
# X-band High Power test facilities

- KEK: NEXTEF; 2x50 MW, 400 ns, 24/7 operation
  single klystron test stand
- SLAC: NLCTA; 3* 2x50 MW into SLED (300 MW), 240-400 ns
  ASTA; 2x50 MW into SLED, multiple pulse length
  single klystron test stands
- CERN: stand alone test stand, 50 MW into SLED
  (150 MW, 300ns) at 12 GHz → planned for 2009

  two beam test stand: 200 MW, 140 ns at 12 GHz

# High Power test facilities at CERN

## Rf power production with CTF3




Automatic conditioning system controlling the experiments and the accelerator

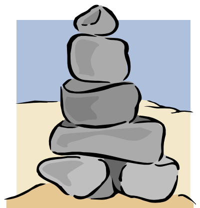
# Structure Program Philosophy

1. <u>Accelerator Prototype program (highest priority):</u>
   Demonstrate a CLIC prototype structure:
   (100 MV/m,200-300ns, 11-12 GHz, damping,
   $10^{-7}$ BD-rate)

2. <u>General high gradient R&D (high priority):</u>
   Find the universal breakdown theory,
   Sc, pulsed heating, phase advance, materials
   Try to do that with simple and clear experiments
   (single cells and short structures)

3. <u>Fabrication technology (high priority):</u>
   Disks, slots, quadrants, surface treatment, procedures
   Start with simple structures and experiments
   (single cells, DC-spark),
   eventually we need to go to full structures
   would be good to fix the structure geometry first

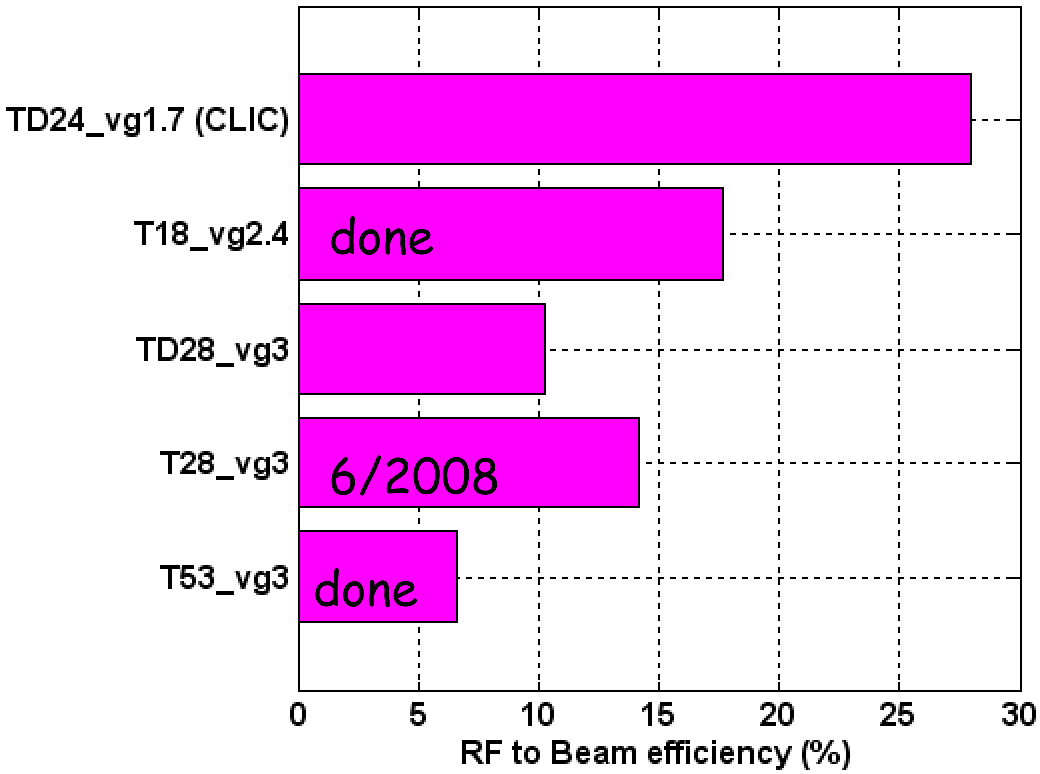
# Mile stones and decision points



- 100 MV/m average gradient for CLIC pulse length with good breakdown rate and acceptable efficiency > 10 %
- Similar performance with damping
- Similar performance, damping, better efficiency 'CLIC prototype structure'
- Fully featured structure HOM loads and s-BPM's integrated (ASSET test ?)

- 07/2008: Review manufacturing technology, optimization strategy, baseline geometry, rf parameters
- 12/2008: Review damping options and parameter optimization

# Efficiency milestones




P = 64 MW; 241 ns ⇔ nb = 312

P = 64 MW; 268 ns ⇔ nb = 312

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*$10^9$,
6-8 rf period bunch spacing, P*pl/C = 18 Wue

# 30 GHz flow chart

2007

HDS4_vg2.6_thick (negative test result)

NDS4_vg2.5_thick (negative test result)

C30_vg4.7_quad (not useable)

Input for x-band

2008

~~Quads or slot are not a problem~~

~~P/C ok~~

~~HDS11_vg2~~

~~HDS4_vg2.6_thick_clean~~

~~NDS4_vg3.6_thin~~

Quads or slot are a problem

C30_vg2.6

C30_vg8.2

New ideas if needed

C30_vg4.7_sb

C30_vg2_TM02

# 11 GHz CLIC structure program

11.4 GHz: List of planned experiments

- TD18_vg2.4_quad (CERN (VDL), KEK (Japanese industry)) [2x]
  (test of P/C, damping, quadrant technology)

- T28_vg2.9 (done by SLAC)
  (conservative approach)

- T18_vg2.4_disk (SLAC,KEK) [2-4]
  {1 CERN, 2 SLAC/KEK (test 1 at SLAC and 1 at KEK), 1 KEK}

  (test of P/C in conservative technology, technology comparison)

Decision point, see flow chart

- T18_vg2.4_quad (CERN) → on hold
  (test of P/C, quadrant technology)

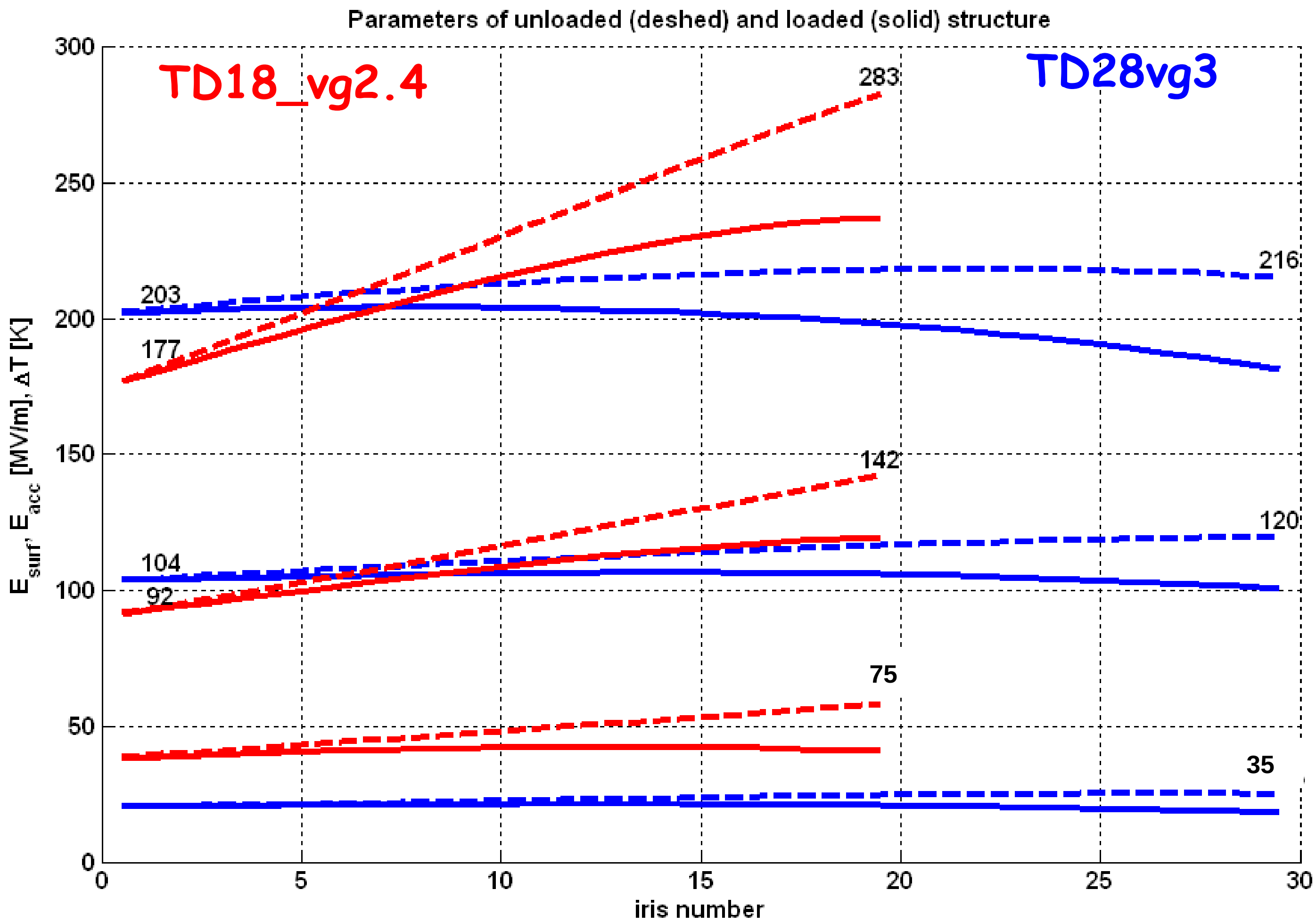
- TD18_vg2.4_disk (CERN) [2x]
  {CERN, KEK?} (mainly test of damping)

- TD28_vg2.9 (CERN) → on hold
  (back up test of damping if others are not successful)

- T24vg1.7 (CERN); detailed design started
  (CLIC reference structure)

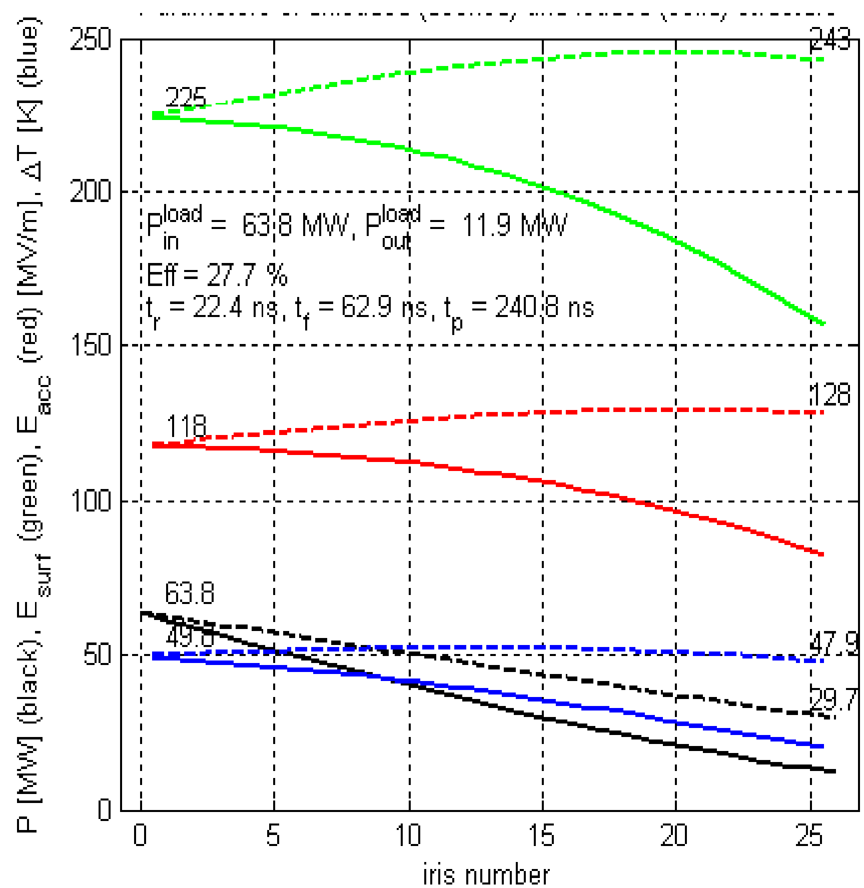
# Parameters along the structures

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



# Parameters of new structure TD24vg1.7

| Structure | TD24vg1.7 |
|---|---|
| Frequency: $f$ [GHz] | 12 |
| Average iris radius/wavelength: $\langle a \rangle/\lambda$ | 0.11 |
| Input/Output iris radii: $a_{1,2}$ [mm] | 3.15, 2.35 |
| Input/Output iris thickness: $d_{1,2}$ [mm] | 1.67, 1.00 |
| N. of reg. cells, str. length: $N_c$, $l$ [mm] | 24, 229 |
| Bunch separation: $N_s$ [rf cycles] | 6 |
| Luminosity per bunch X-ing: $L_{bx}$ [m$^{-2}$] | $1.22\times10^{34}$ |
| Bunch population: $N$ | $3.72\times10^{9}$ |
| Number of bunches in a train: $N_b$ | 312 |
| Filling time, rise time: $\tau_f$, $\tau_r$ [ns] | 62.9, 22.4 |
| Pulse length: $\tau_p$ [ns] | 240.8 |
| Input power: $P_{in}$ [MW] | 63.8 |
| $P_{in}/C t^P_p{}^{1/3}$ [MW/mm ns$^{1/3}$] | 18 |
| Max. surface field: $E_{surf}^{max}$ [MV/m] | 245 |
| Max. temperature rise: $\Delta T^{max}$ [K] | 53 |
| Efficiency: $\eta$ [%] | 27.7 |
| Figure of merit: $\eta L_{bx}/N$ [a.u.] | 9.1 |




We recently decided to prepare a T24_vg1.7 at 11.4 GHz

# 11 GHz flow chart

2008

TD18_vg2.4_quad
T28_vg2.9
T18_vg2.4_disk (great result, but limited at the end)

CLICvg1
geometry OK

CLICvg1
geometry not OK

Disks OK

Quads OK
+Damp

TD18_vg2.4_disk
(T18_vg2.4_quad)

TD28_vg2.9
T24_vg1.7

Damping
Not OK

2009

Input from break down R&D

CLIC prototype quads damped

?

CLIC prototype disks damped

CLIC prototype TD24 like

2010

Go towards more extreme structures

# 11 GHz breakdown R&D program with short structures

Probing different apertures, iris thickness, structure length and transition between SW and TW regime

Breakdown R&D

- C10_vg1.3 (close to old CLIC vg1.1) [2x]
- C10_vg0.7 [2x]
- C10_vg3.3 (T53 input cell) [2x]
- C10_vg2.2_thick [2x]
- New C10 –type structure with waveguide damping, geometry to be determined

Structures made by SLAC with reusable coupler,

The program is nicely complementing SLAC's efforts focusing on single cells

# ‘The Plan’

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2008 | | | | | | | | | | |
| | | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dez |
| Facility | Structure | | | | | | | | | | | |
| CTF3 30 GHz | HDS4_vg2.5_thick | | | | | | | | | | | |
| | C30_vg2.6 | | | | | | | | | | | |
| | C30_vg2_TM02 | | | | | | | | | | | |
| | HDS11_vg2 | | | | | | | | | | | |
| | C30_vg4.7_sb | | | | | | | | | | | |
| | | | | | | | | | | | | |
| CLEX 12 GHz | Pets 12 GHz | | | | | | | | | | | |
| | T18_vg2.4_disk | | | | | | | | | | | |
| | | | | | | | | | | | | |
| NEXTEF 11.4 GHz | KX03 | | | | | | | | | | | |
| | Old CLIC vg1.1 | | | | | | | | | | | |
| | T18_vg2.4_disk[2] | | | | | | | | | | | |
| | T18_vg2.4_disk[3] | | | | | | | | | | | |
| | TD18_vg2.4_quad[2] | | | | | | | | | | | |
| | TD18_vg2.4_disk[2] | | | | | | | | | | | |
| | | | | | | | | | | | | |
| SLAC Station 1 | TD18_vg2.4_quad[1] | | | | | | | | | | | |
| 11.4 GHz | C10vg0.7[1] | | | | | | | | | | | |
| | C10vg1.3[1] | | | | | | | | | | | |
| | C10vg3.3[1] | | | | | | | | | | | |
| | C10vg2.2_thick[1] | | | | | | | | | | | |
| | T24vg1.7_disk | | | | | | | | | | | |
| | | | | | | | | | | | | |
| SLAC Station 2 | T28_vg2.9 | | | | | | | | | | | |
| | C10vg0.7[2] | | | | | | | | | | | |
| | C10vg1.3[2] | | | | | | | | | | | |
| | C10vg3.3[2] | | | | | | | | | | | |
| | C10vg2.2_thick[2] | | | | | | | | | | | |
| | T53vg3MC | | | | | | | | | | | |
| | | | | | | | | | | | | |
| SLAC Station 3 | T18_vg2.4_disk[1] | | | | | | | | | | | |
| | T18_vg2.4_disk[4] | | | | | | | | | | | |
| | PETS 11.4 GHz | | | | | | | | | | | |
| | TD18_vg2.4_disk[1] | | | | | | | | | | | |
| | | | | | | | | | | | | |

# Conclusions

- First promising data points are existing (close to or first goal)
- Damping is the next big milestone
- We have set up a coherent testing program with well defined and realistic goals
- The program is constraint by the availability of testing slots
- We (CLIC) have to rely heavily on our collaborations to succeed
- but having this powerful international collaboration makes us very confident that together we can succeed

# Discussion Points

- How do we coordinate testing, data analysis, data sharing
- Standardization of testing and results
- Should we align different programs ?
- Should we continue with T18vg2.4 or switch to T24vg1.7
- List of new ideas
- How can we support each other ?

The end, reserve slides following

## Testing procedure for CLIC prototype structures

Conditioning:

- 50 ns, 100 ns, 150 ns, 200 ns square pulses conditioning to ~30% excess power than nominal at each pulse length if possible limit breakdown rate $< 10^{-3}$ using an automated system
- Recovery after each breakdown, ramp in pulse length and power from about 50 % of current target parameters

Measurements:

- Try to run at nominal power and pulse length and get initial data point if the conditioning was successful (BDR $< 10^{-4}$)
- Measure initial slope BDR vs Gradient
- Determine maximum flat top pulse length obtainable for a breakdown rate of $10^{-7}$
- Measure dark current and $\beta$-value if possible, absolute dark current value relevant at nominal working point
- Take breakdown position data
- Breakdown rate with design pulse shape in case of success

*Depending on results and individual structure behavior*

- Getting more statistics or reprocess
- Additional measurements (pulse length dependence)

Desirable data acquisition and control:

- Input, Transmitted and Reflected Power Integral pulse to pulse, evaluation of missing energy to trigger events (stop rf and save data) and to record conditioning history
  F-Cup or reflected power could also be used for breakdown triggering
- Input Power calibrated
- Power waveforms for breakdown events
- Dark current detector, F-Cup or current monitor
- Vacuum in the $10^{-8}$ mbar range, with interlocks
- Automatic conditioning system, breakdown rate counter

# 30 GHz break down R&D program in CTF3

List of planned experiments

- HDS4_vg2.6_thick (iris thickness, phase advance, P/C) Finished !
- NDS4_vg2.5_thick (Effect of slots and quadrants) Finished !
- C30_vg4.7_quad (clear experiment for fab. Tech.) not useable

Decision point, see flow chart !

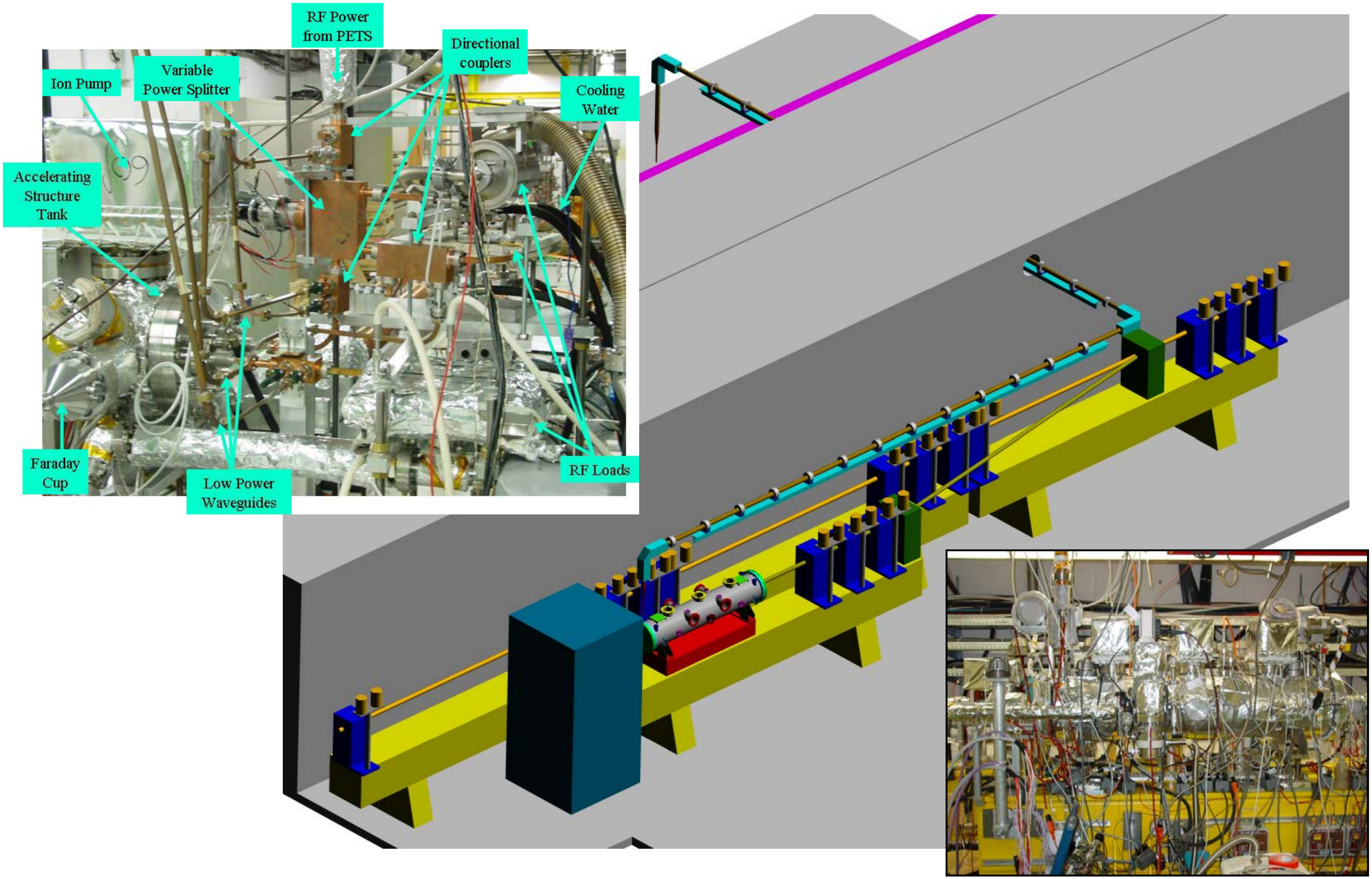
- HDS11_vg2 (clear P/C experiment without other changes)
- HDS4_vg2.6_thick_clean (compares cleaning with previous)
- NDS4_vg3.6_thin (iris thickness in comparison with NDS4_thick)
- C30_vg2.6 (P/C)
- C30_vg8.2 (P/C)
- C30_vg4.7_sb (speed bump)
- C30_vg2_TM02 (vg)
- HDS 11 copper/molybdenum (for better statistics)

# Iris diameter and thickness scaling

test geometrical variation of gradient

| d [mm]<br>a [mm] | 2.66 | 2.13 | 2.00 | 1.66 | 1.37 | 1.25 |
|---|---|---|---|---|---|---|
| 2.53 | | | | Vg 0.7 | | CLIC _vg1 output 1.0% |
| 2.85 | | | | T53 output 1.0% | | |
| 3.0 | | | CERN-X 1.1% | Vg 1.3 | | |
| 3.87<br>3.89* | CLIC _vg1 Input 2.2% | 30 GHz 2π/3 ≈2.6% | | T53 input* 3.3% | | |
| 4.38 | | 30 GHz 2π/3 4.7% | | | | |
| 5.00 | | 30 GHz π/2 7.4% | | | 30 GHz 2π/3 8.2% | |

# 30 GHz test stand in CTF3



# Automatic conditioning using CTF3


Check out the online results: http://cern.ch/project-clic-rfcond30/