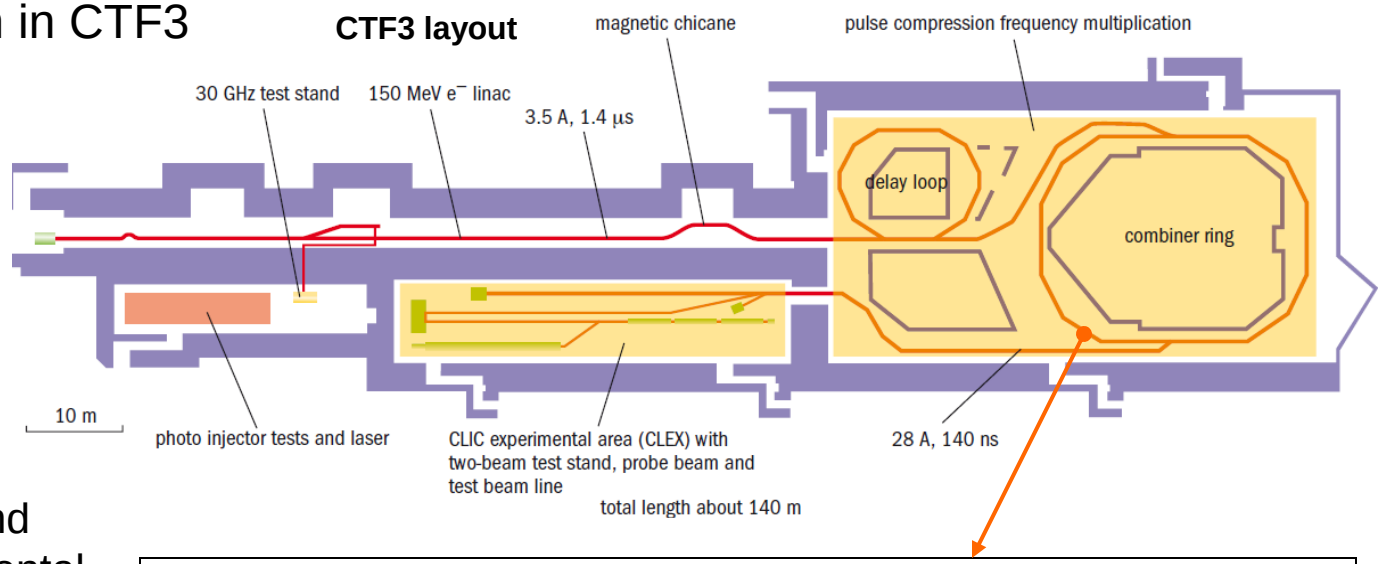
Report from Two Beam Test Stand

I. Syratchev for CLIC/CTF3 collaboration

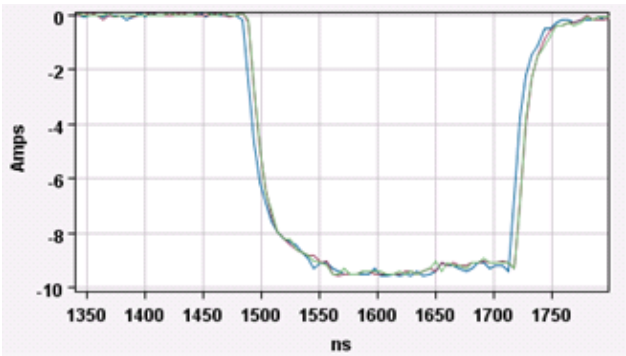
Two-beam Test Stand Prospects

- Unique and versatile facility for demonstrating the CLIC two beam accelerating technology
  - two-beam operation
    - high power drive-beam [~110 MeV, ~30A]
    - high quality probe-beam [~140 MeV, ~0.5A]
  - excellent beam diagnostics
  - easy access & flexibility for future upgrades
- Excellent test possibilities
  - power production & accelerating structures
    - beam kick
    - beam dynamics effects
  - full CLIC module
    - beam-based alignment

Drive beam generation in CTF3

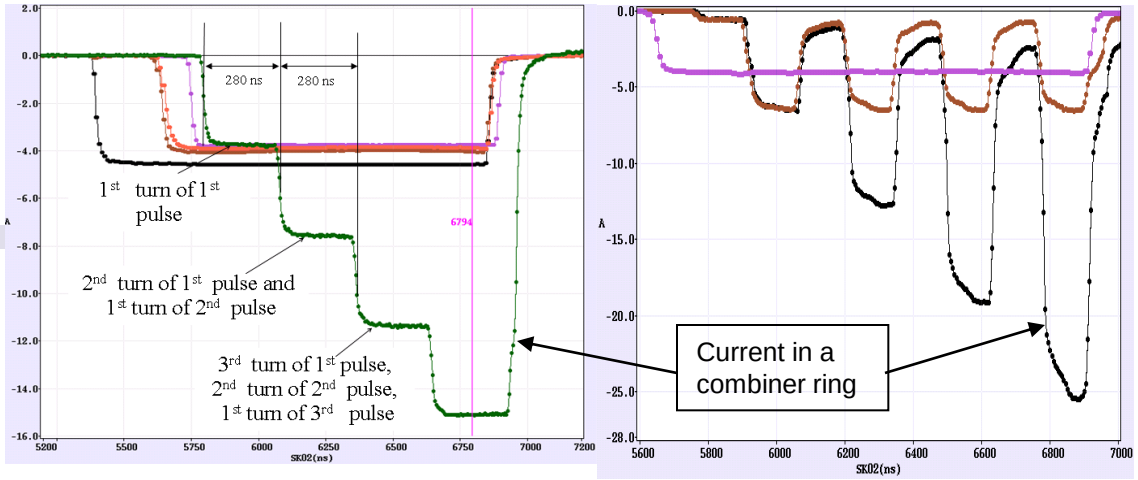


CTF3 drive beam generation complex reliably produces and delivers to the CLIC experimental area up to 12 A x 240 ns beam (without DL).

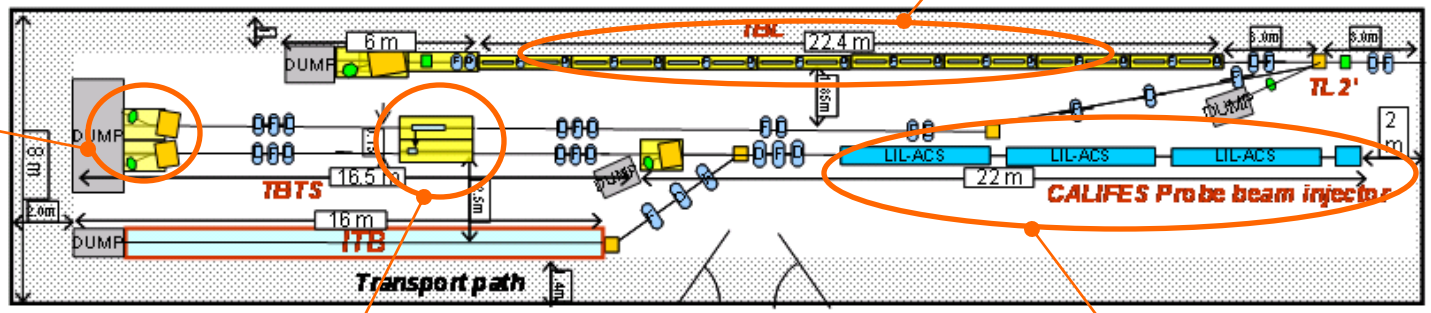


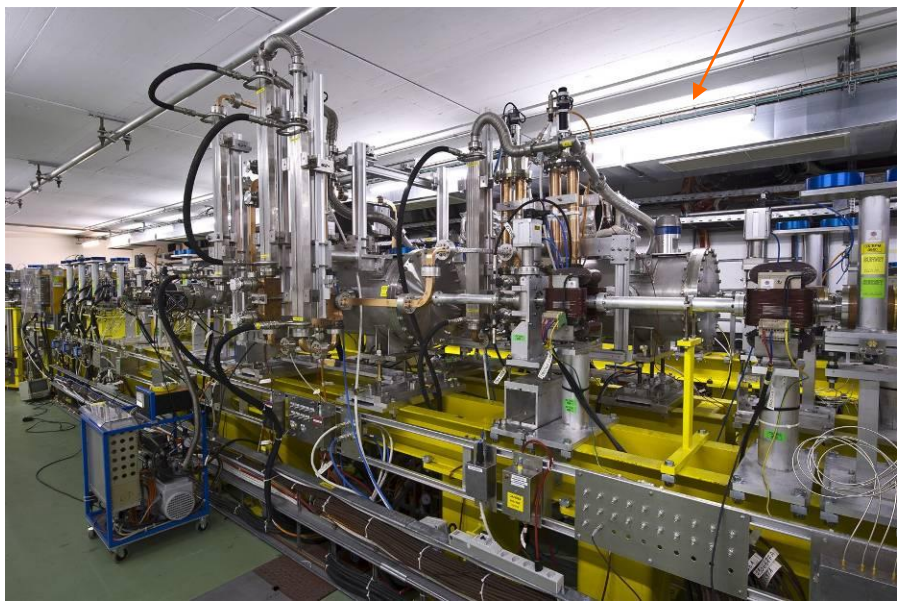
Routinely factor 4 combination achieved with 15 A, 280 ns (without DL) and current stability 0.25%

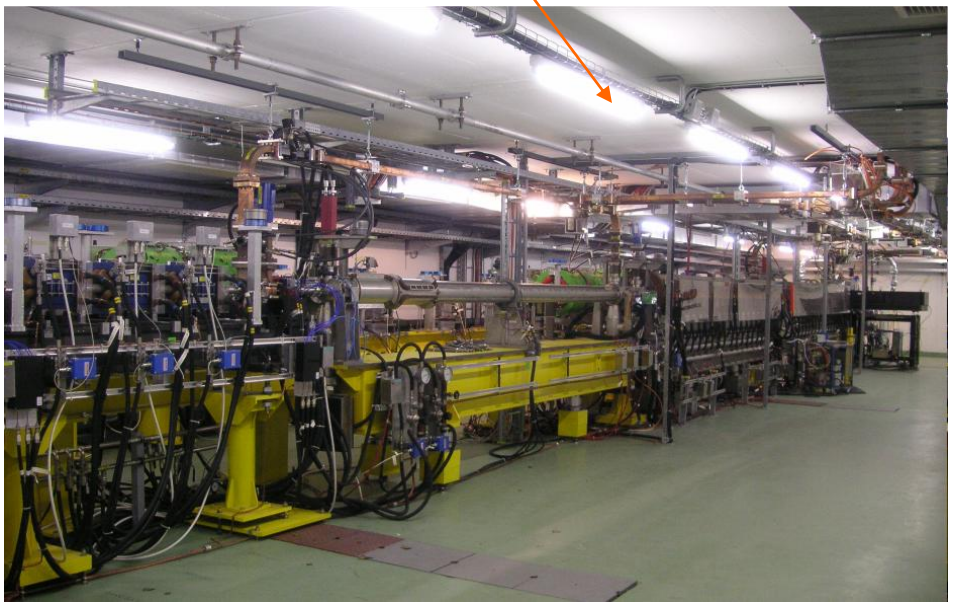
28 A combined achieved, nominal 140 ns pulse and current stability 1%



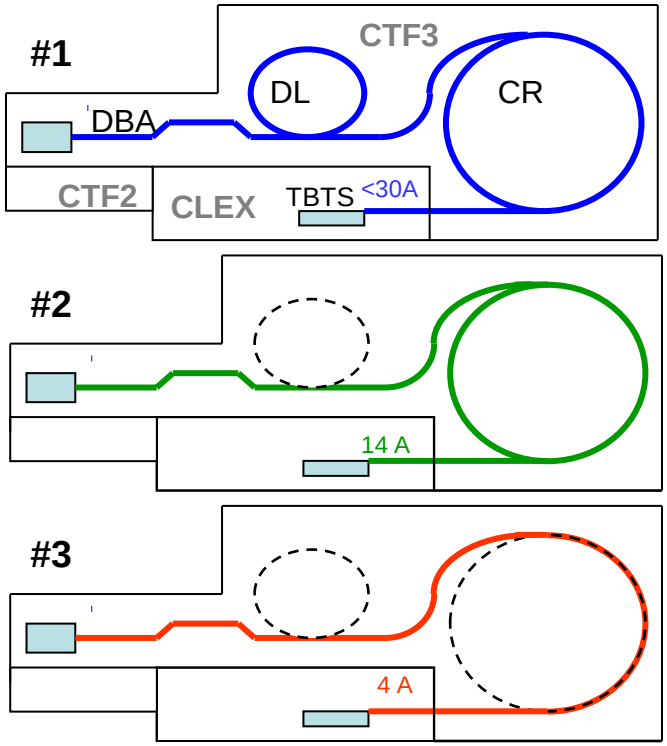
TBTS is the test area in CLEX, where feasibility of the CLIC two beam acceleration scheme is…already demonstrated (not yet at a nominal 100 MV/m accelerating gradient).







Different scenarios of the drive beam generation in the CTF3

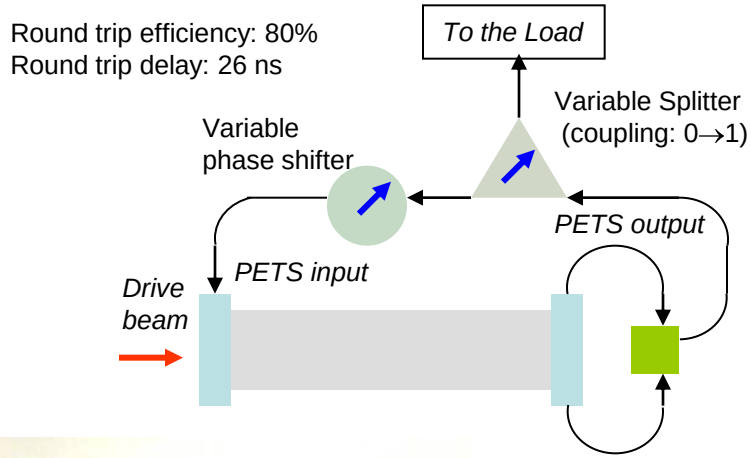


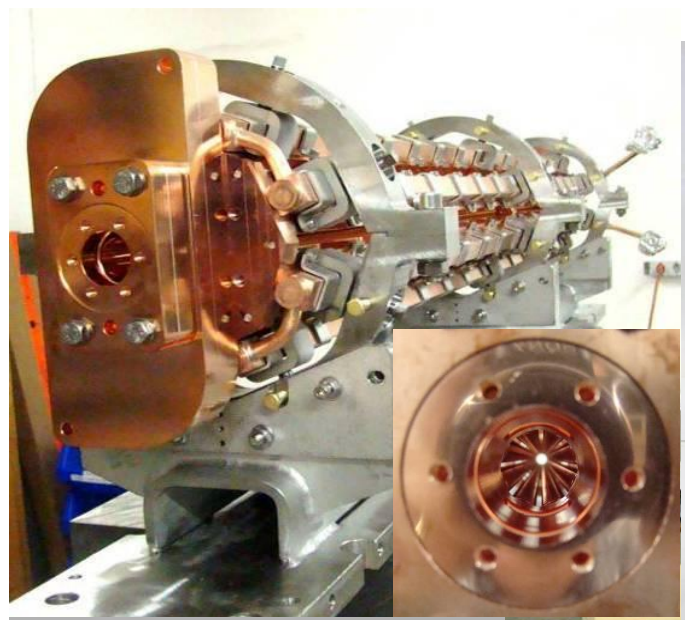
• To compensate for the lack of current, the active TBTS PETS length was significantly increased: from the original 0.215 m to 1 m.

Operation mode	#1	#2	#3	CLIC
Current, A	<30	14	4	101
Pulse length, ns	140	<240	<1200	240
Bunch Frequency, GHz	12	12	3	12
PETS power (12 GHz), MW	<280	61	5	135

RF power production with re-circulation

• In order to demonstrate the nominal CLIC power level and pulse length and yet low current, it was decided to implement a different PETS configuration – PETS with external re-circulation.





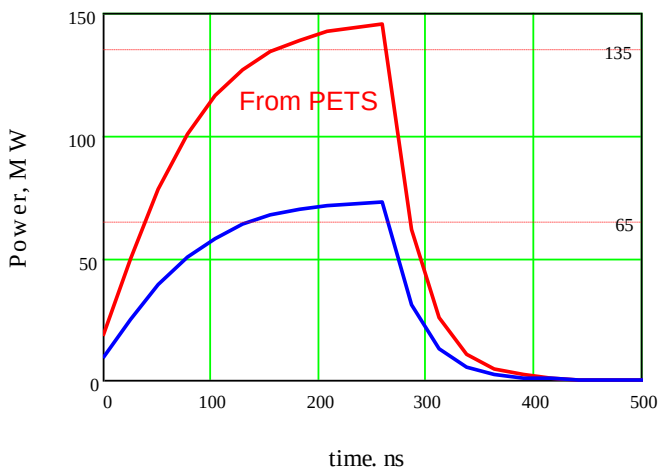
Fully equipped 1 m long TBTS PETS

Variable RF phase shifter and splitter

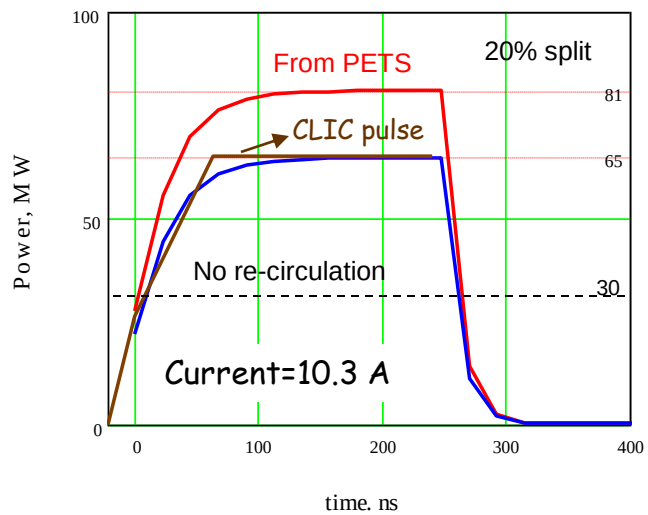
- With re-circulation, PETS operates in the amplification mode, similar to that in classical resonant rings. The only difference is that now we have a beam as an internal source of the RF power. Ultimately, peak RF of GW level can be generated with moderate (10 A) drive beam current.

CTF3 mode#2 of operation (240 ns)

With 8A drive beam and 50% power split, PETS will generate and deliver to single structure nominal CLIC pulses.



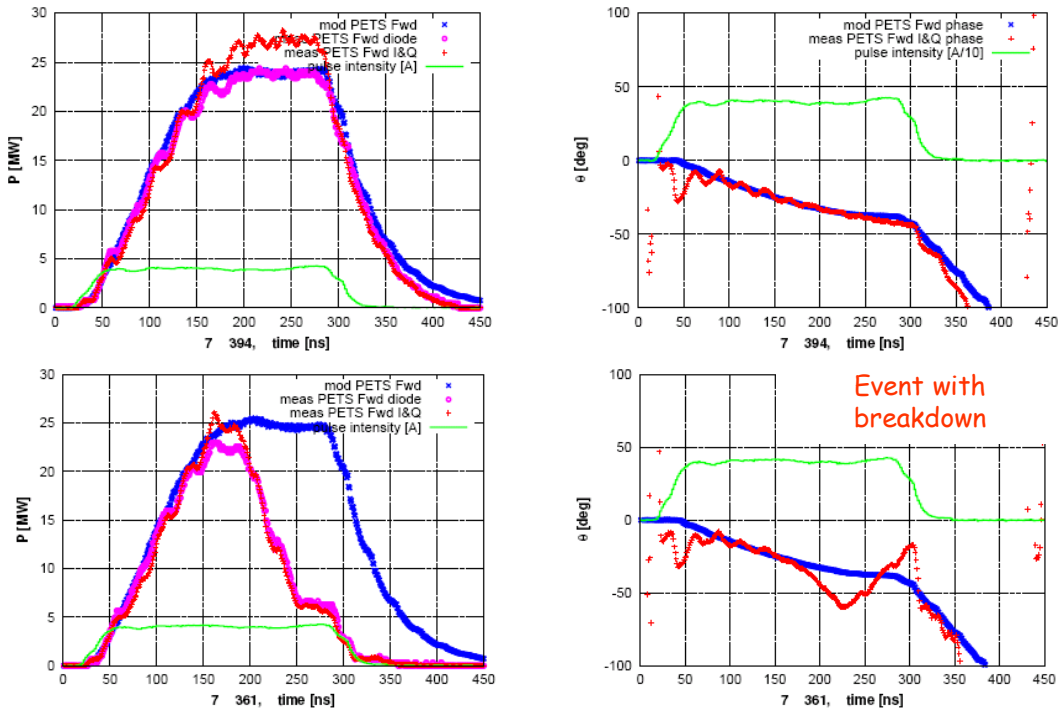
We can generate RF pulses which mimic the CLIC pulse.



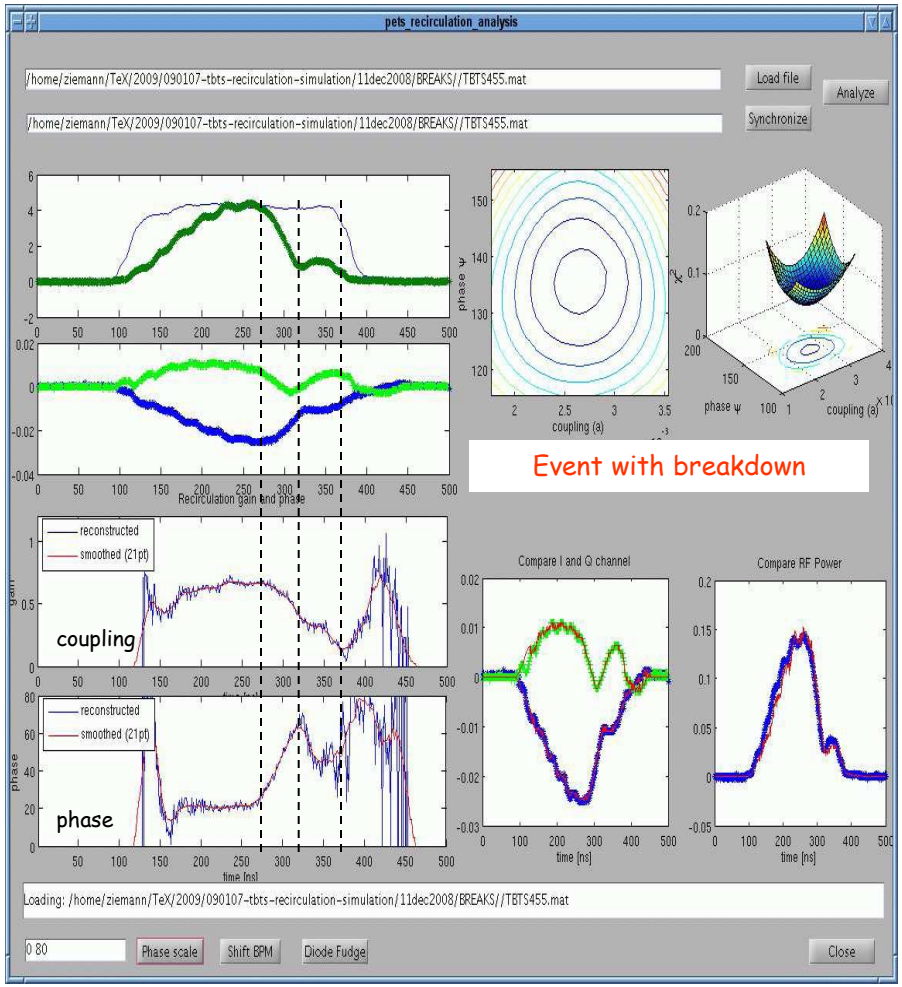
15 A will be needed to produce the same pulses without re-circulation. That moves CTF3 into operation mode #1 with short pulses.

- In itself, re-circulation provides additional opportunity for the complimentary beam diagnostic and potentially for the RF breakdown characterization.
- Normally, the breakdown event de-synchronize the re-circulation conditions and thus quench the power production protecting the structure.

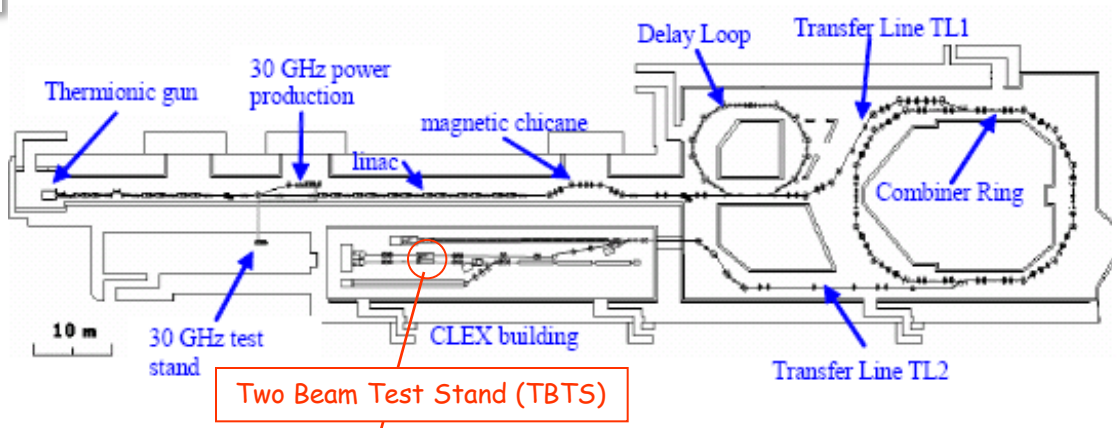
Model with constant coupling and phase (E. Adli)



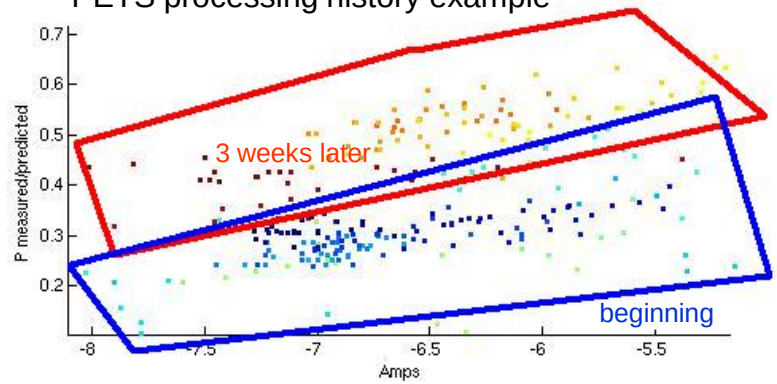
Model with time variable coupling and phase (V. Ziemann)

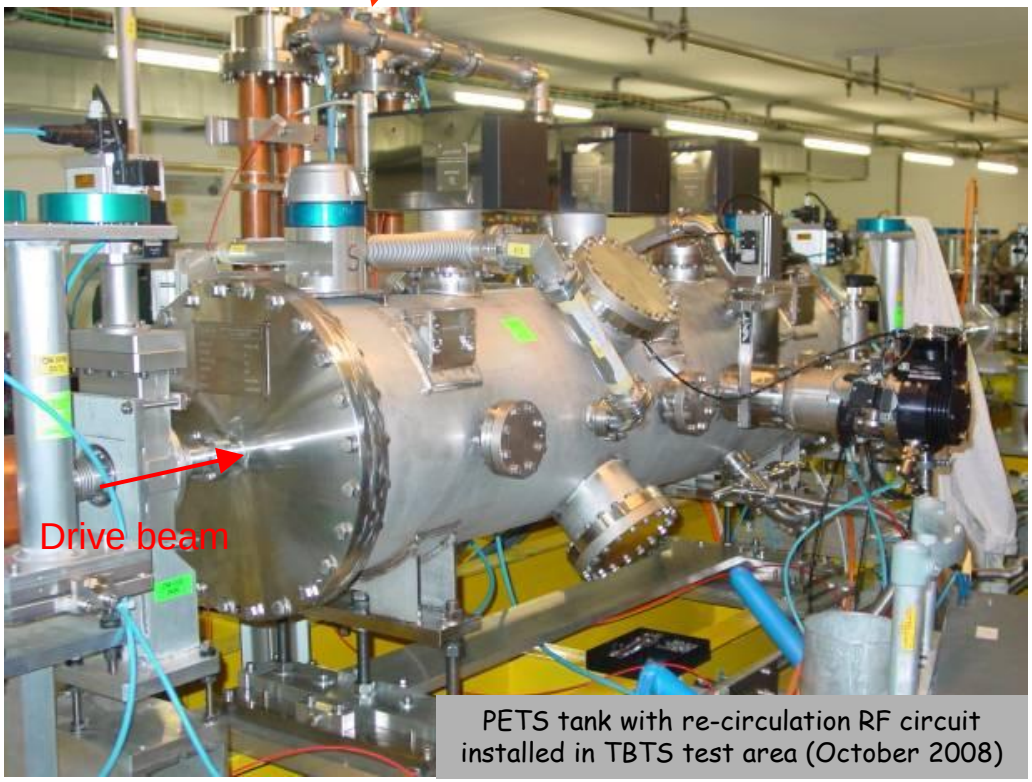


TBTS tests in 2009

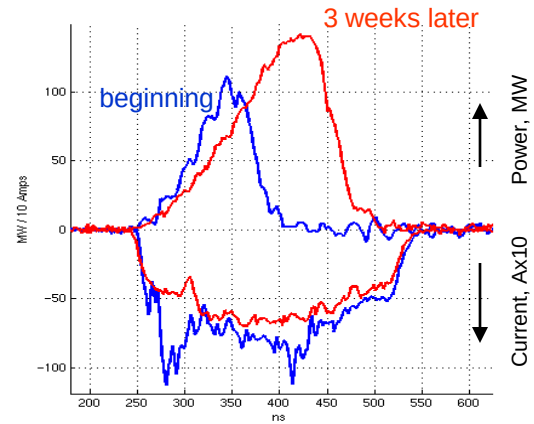


PETS processing history example

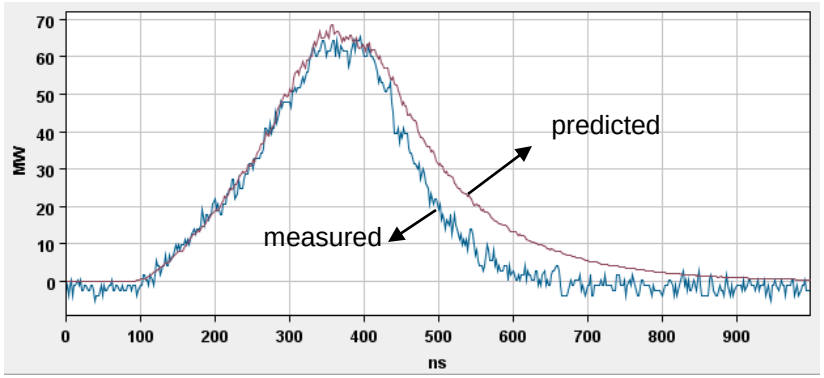




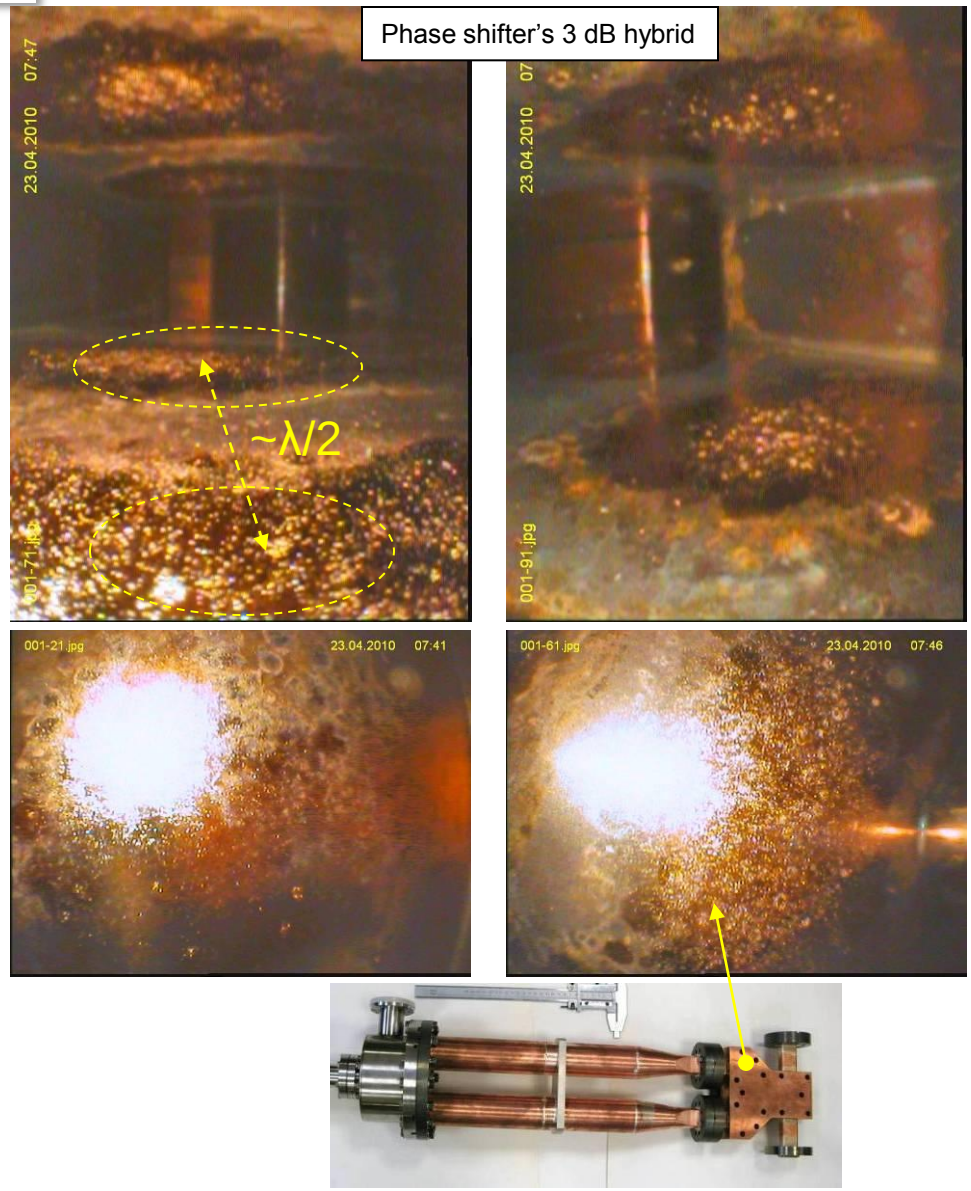
PETS tank with re-circulation RF circuit installed in TBTS test area (October 2008)



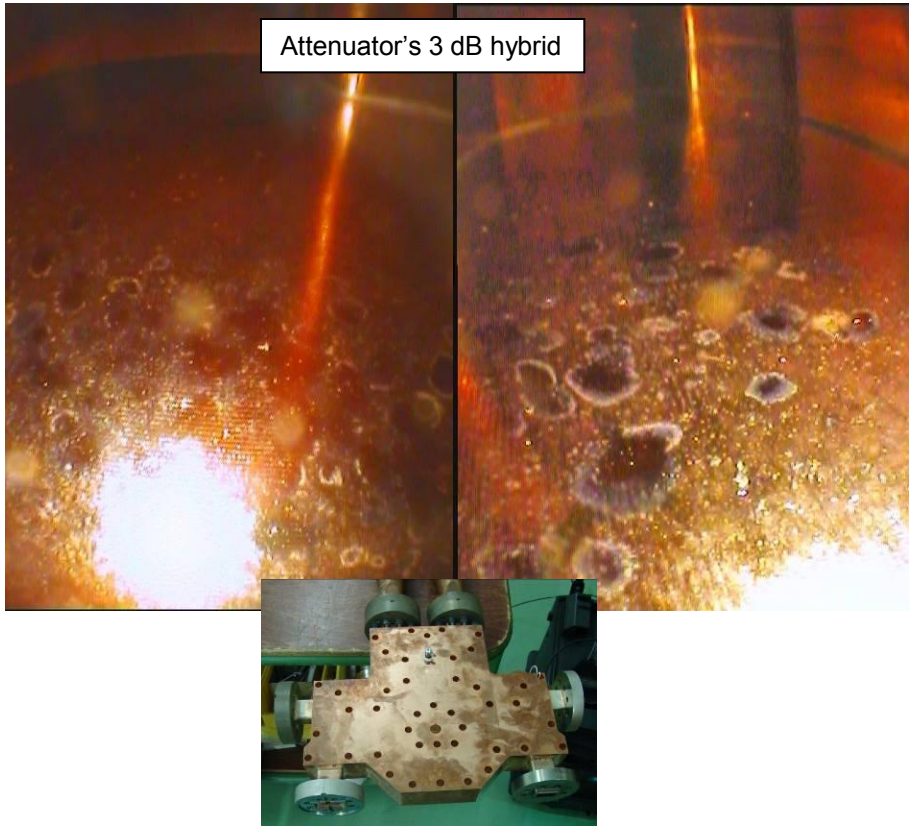
At the end of 2009, the PETS was reliably producing ~60/70 MW



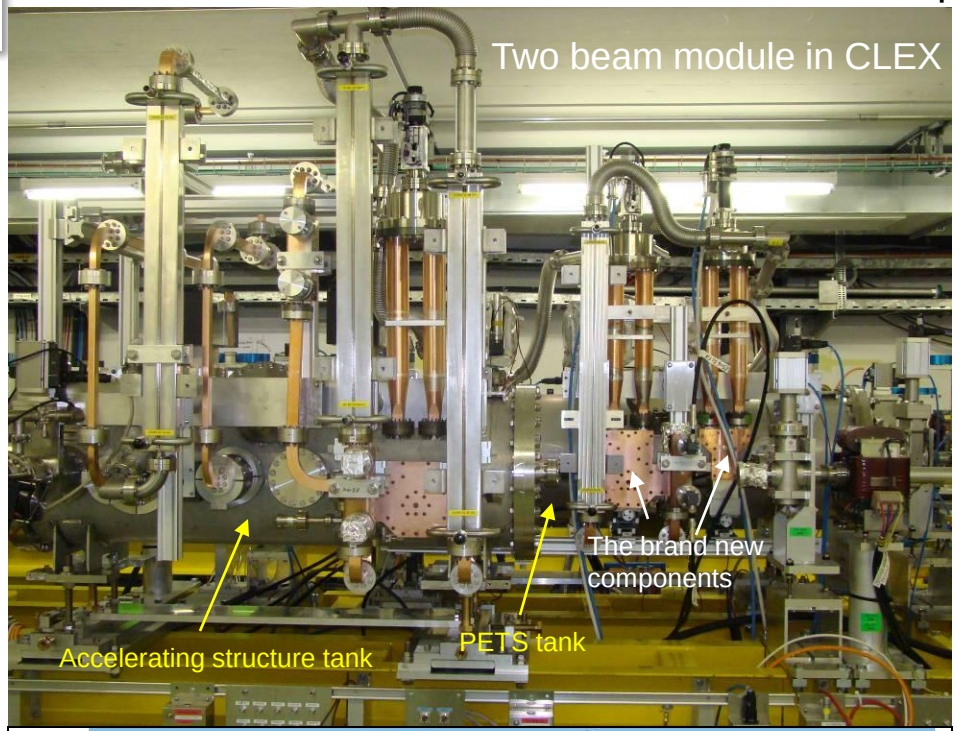
TBTS in 2009



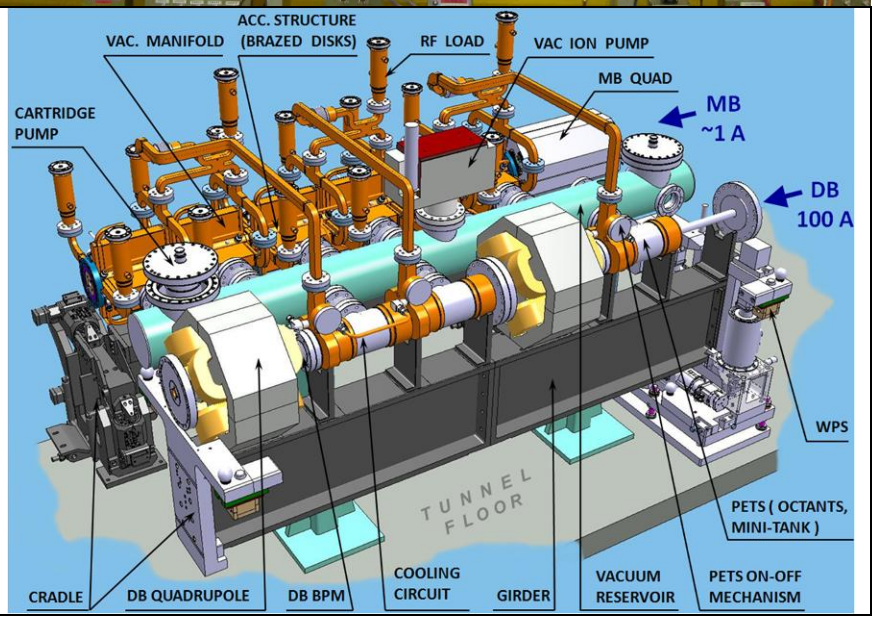
The RF signal analysis indicated that in most of the cases breakdown activity was associated with feedback loop and not the PETS itself. Visual inspection of the attenuator's and phase shifter's hybrid bodies showed serious breakdown damages and confirmed that these devices were limiting the power production performance.



TBTS hardware upgrade earlier in 2010



Two beam module in CLIC

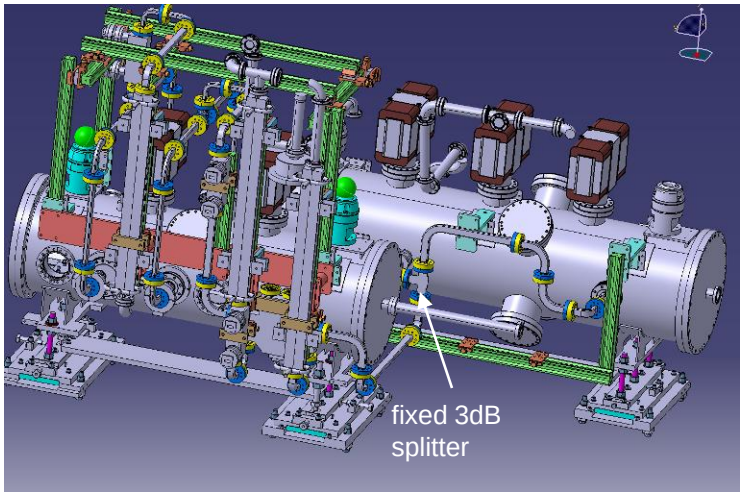


1. The brand new waveguide components made by GYCOM (Russia) went through the complete cleaning procedure:
- Chemical
- Hydrogen firing
- Vacuum firing

and were installed into the PETS re-circulation loop.

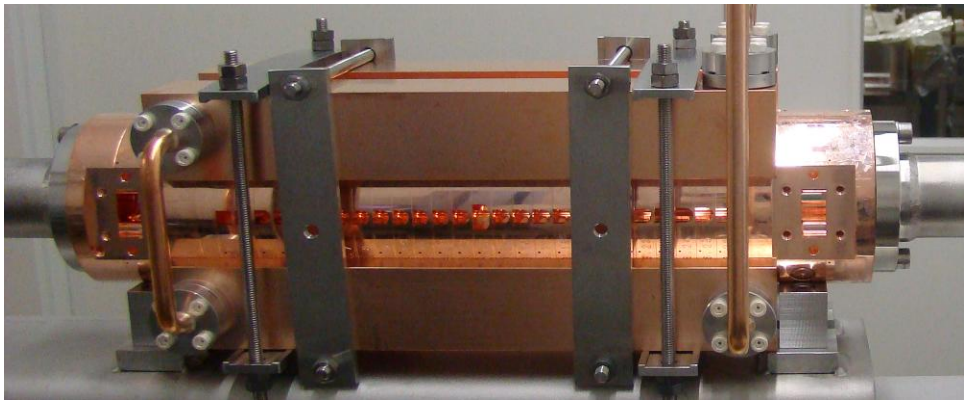
2. The TD24 accelerating structure tank was installed into TBTS area. <u>Ready for the 2-beam operation.</u>

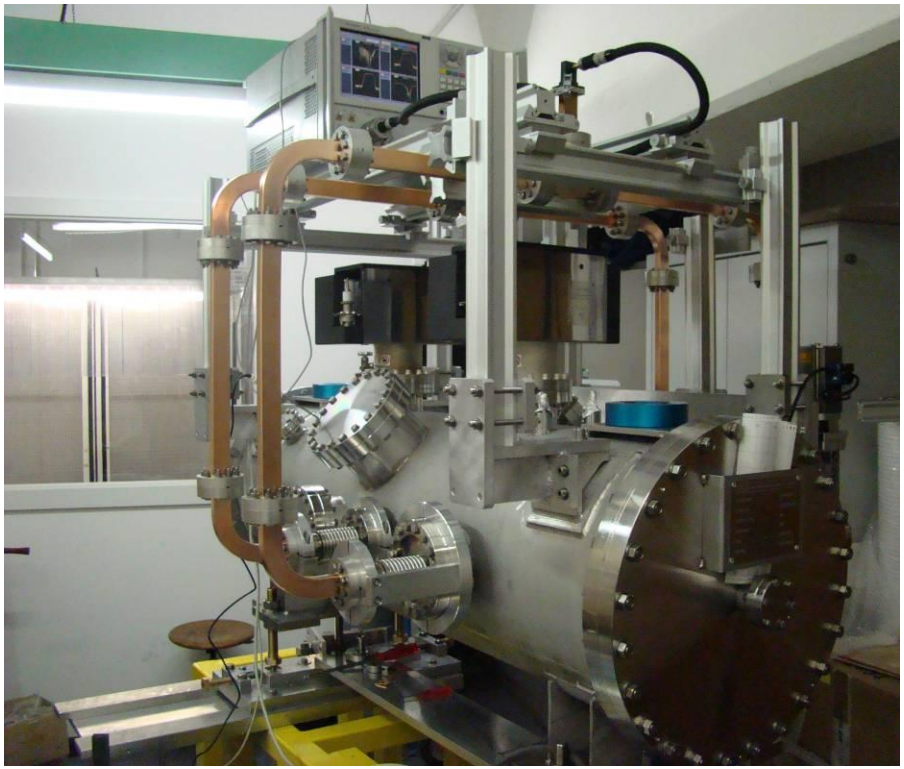
If any problem with attenuator and phase shifter in a future, we have prepared back-up solution with a fixed 3dB splitter.



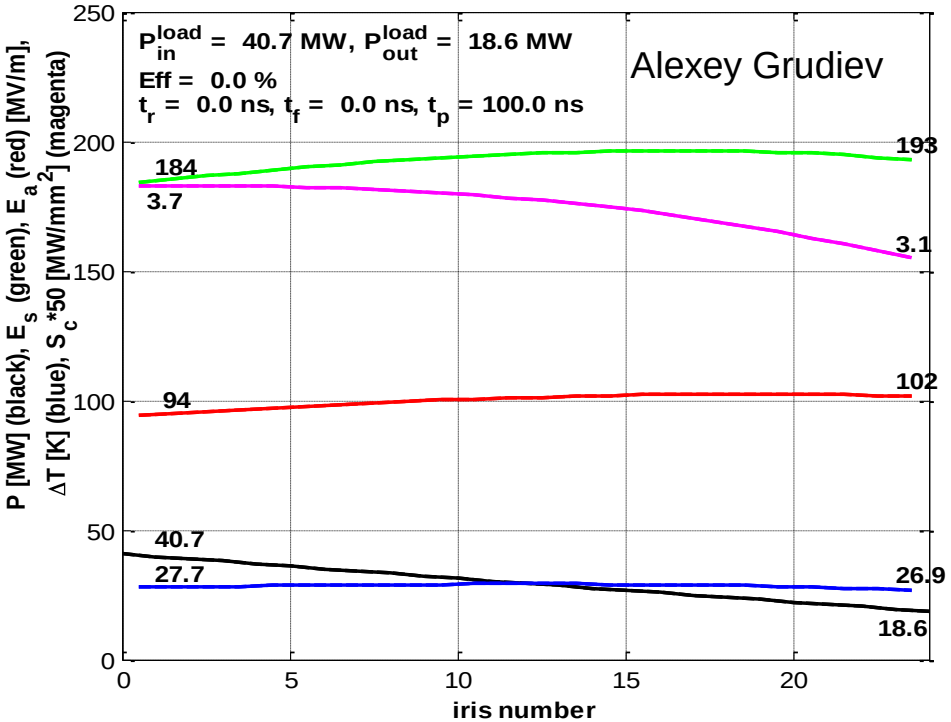
TD24_vg1.8_disk accelerating structure in TBTS

- 24 regular + 2 coupler cells with damping features
- L_{acc} = 200.0 mm (regular cells)
- filling time = 65 ns
- 42 MW input power for 100 MV/m (unloaded) (57 MW loaded)

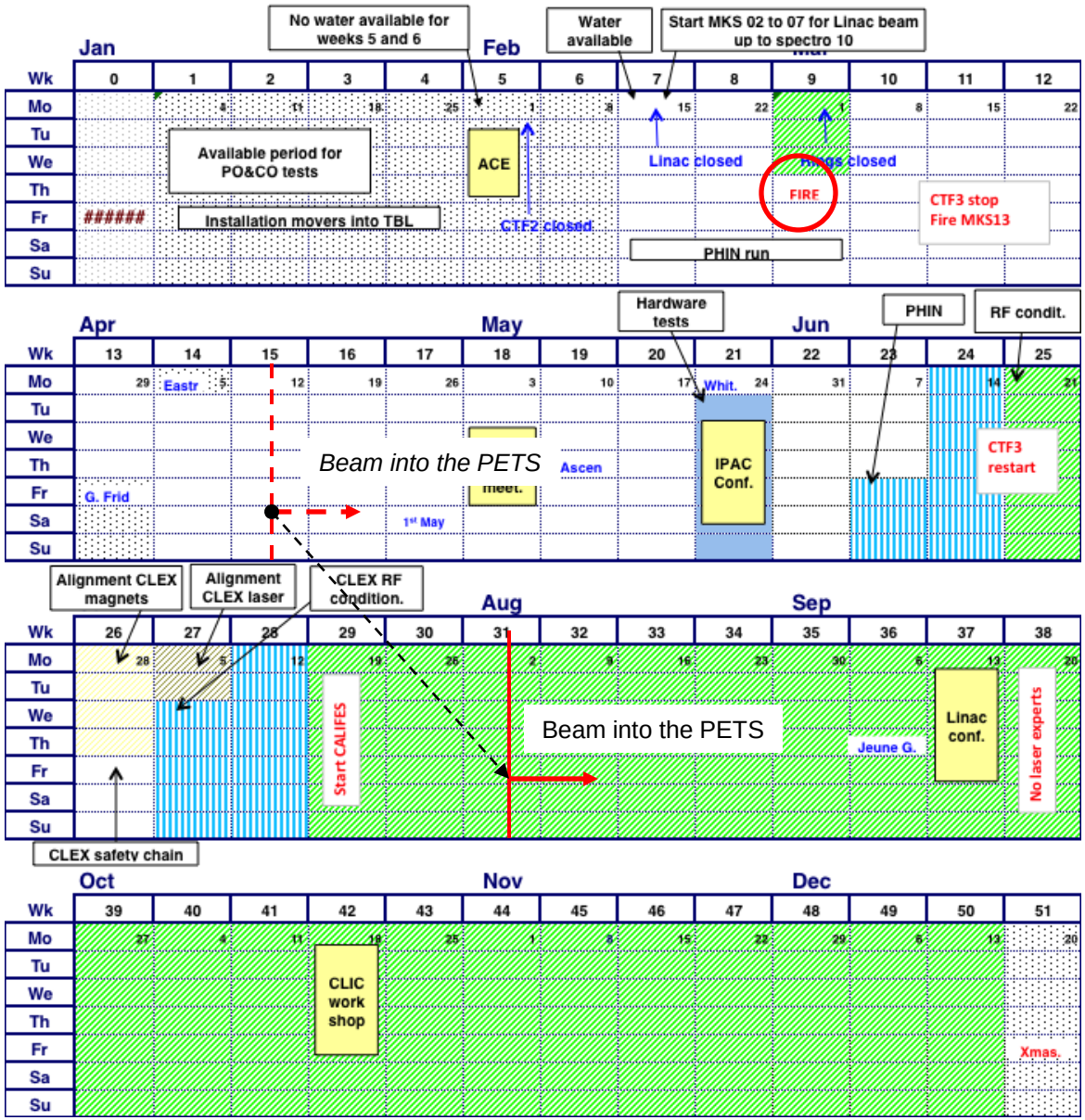




Average unloaded gradient of 100 MV/m



2010 CTF3 schedule

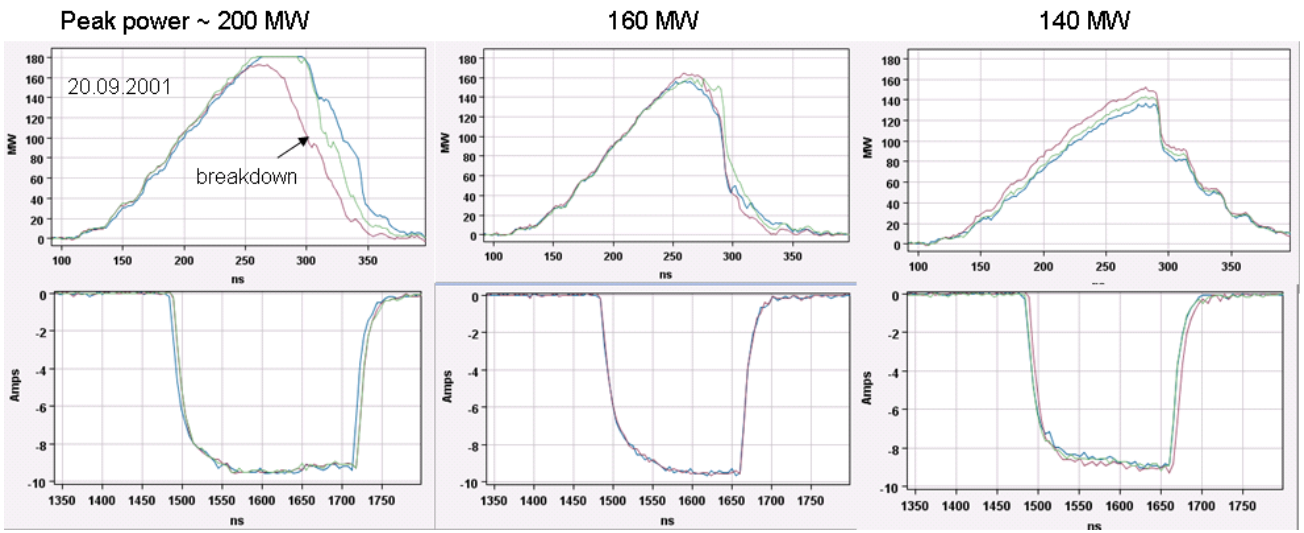


The fire accident with klystron modulator#13 brought about 3 months delay into CTF3 operational schedule.

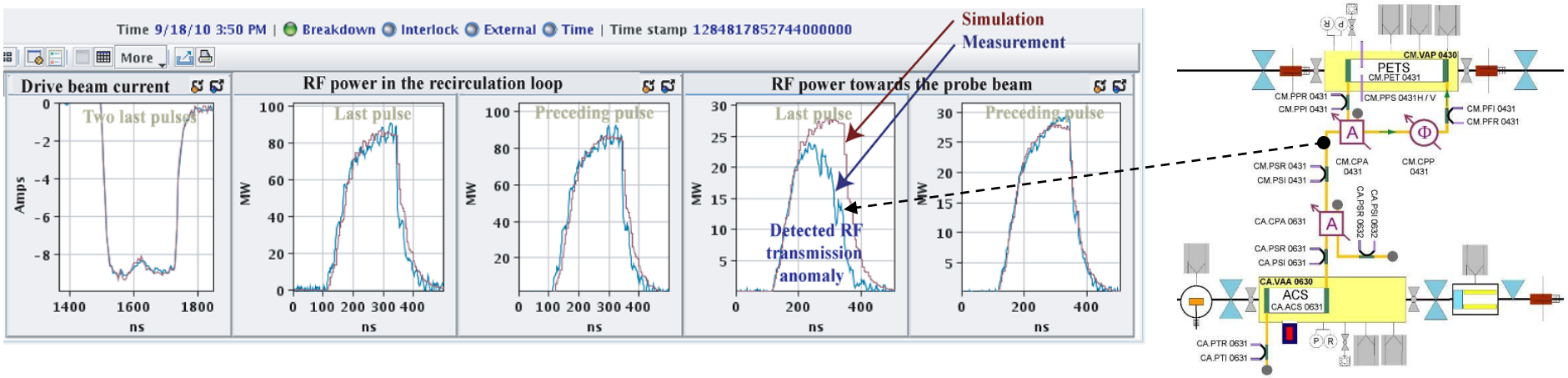
Pulse Forming Network after fire

The first drive beam arrived to TBTS in early August 2010.

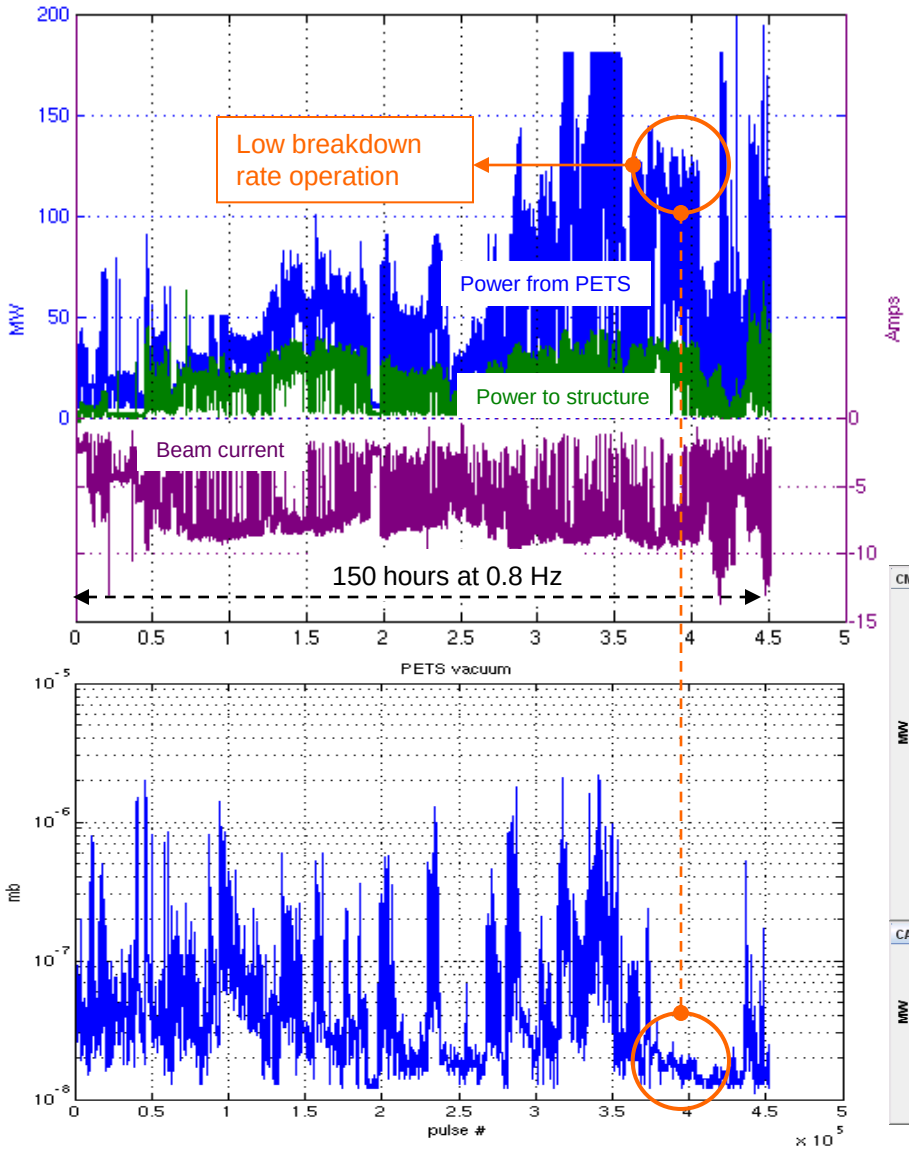
PETS rapidly (~ $3x10^5$ pulses) reached record 200 MW peak RF power level, providing reliably pulses up to 130 MW peak (CLIC nominal). This is enough for demonstration of 100 MV/m acceleration in a two beam experiment with TD24_vg1.8_disk structure.



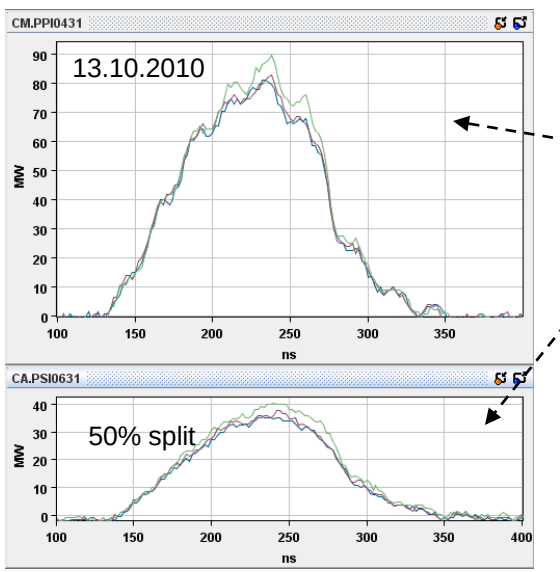
The whole waveguide network also requires certain processing.

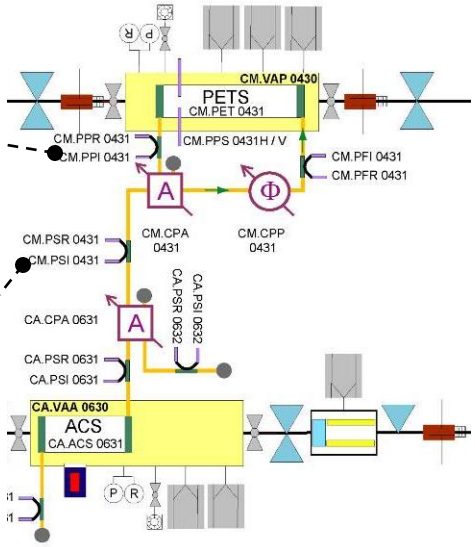


Power production history in TBTS



PETS consistently produces required RF power for the accelerating structure processing and the two beam acceleration experiments.





First two-beam acceleration in CTF3

The 11 MeV probe beam energy gain was measured after acceleration over 0.2 m structure, demonstrating 55 MV/m accelerating gradient.