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CLIC Feasibility Demonstration at CTF3

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for the CLIC/CTF3 Collaboration

http://cern.ch/clic-study

LINAC’10 – MO303
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The Key to CLIC Efficiency

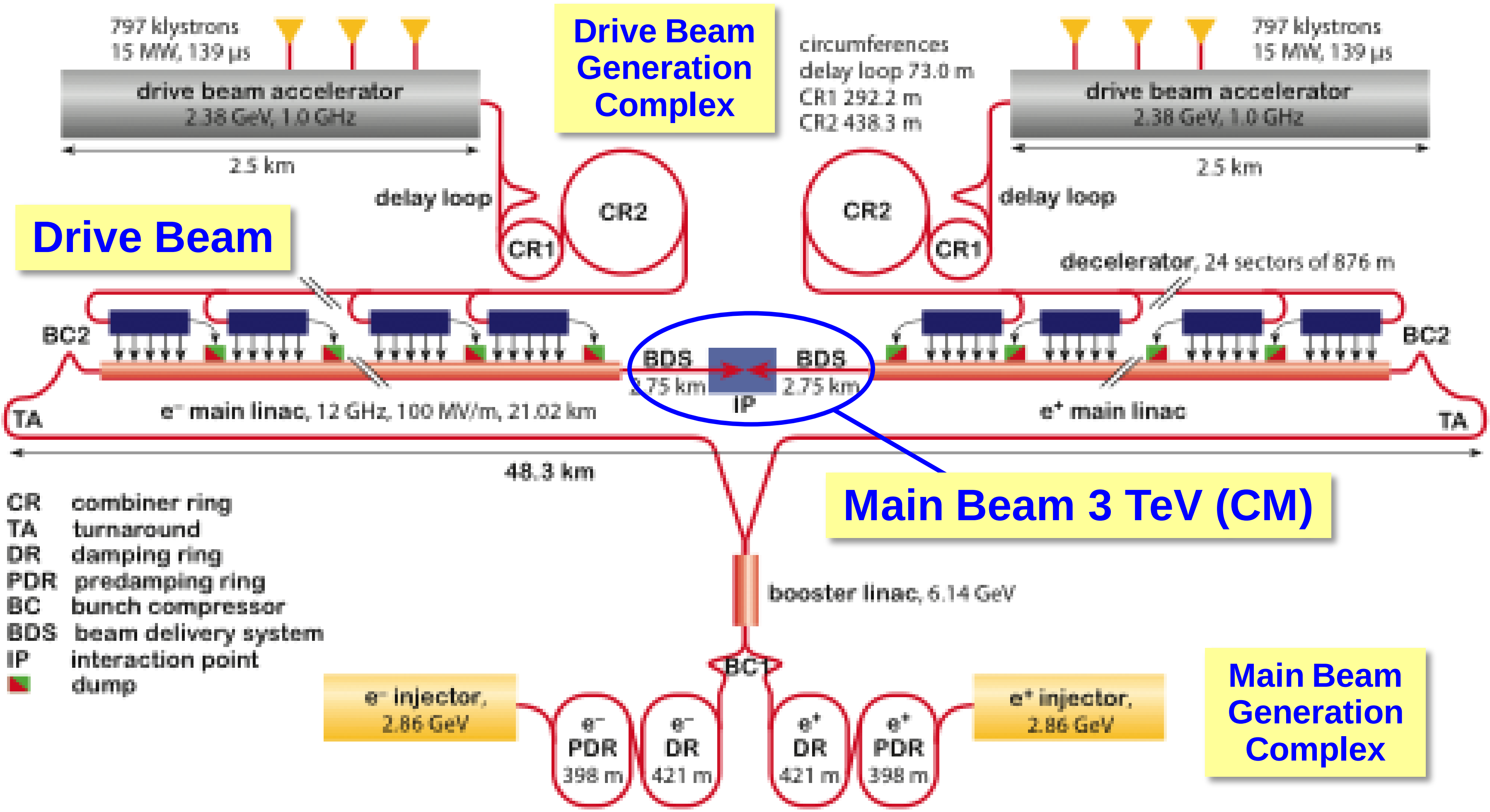
- NC Linac for 1.5 TeV/beam
  - accelerating gradient: **100 MV/m**
  - RF frequency: **12 GHz**
- Total active length for 1.5 TeV: **15 km**
  - ➔ individual klystrons not realistic
- **Two-beam acceleration scheme**

Main Linac	
C.M. Energy	3 TeV
Peak luminosity	2×10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	50 Hz
Pulse time duration	156 ns
Average gradient	100 MV/m
# cavities	2 x 71,548

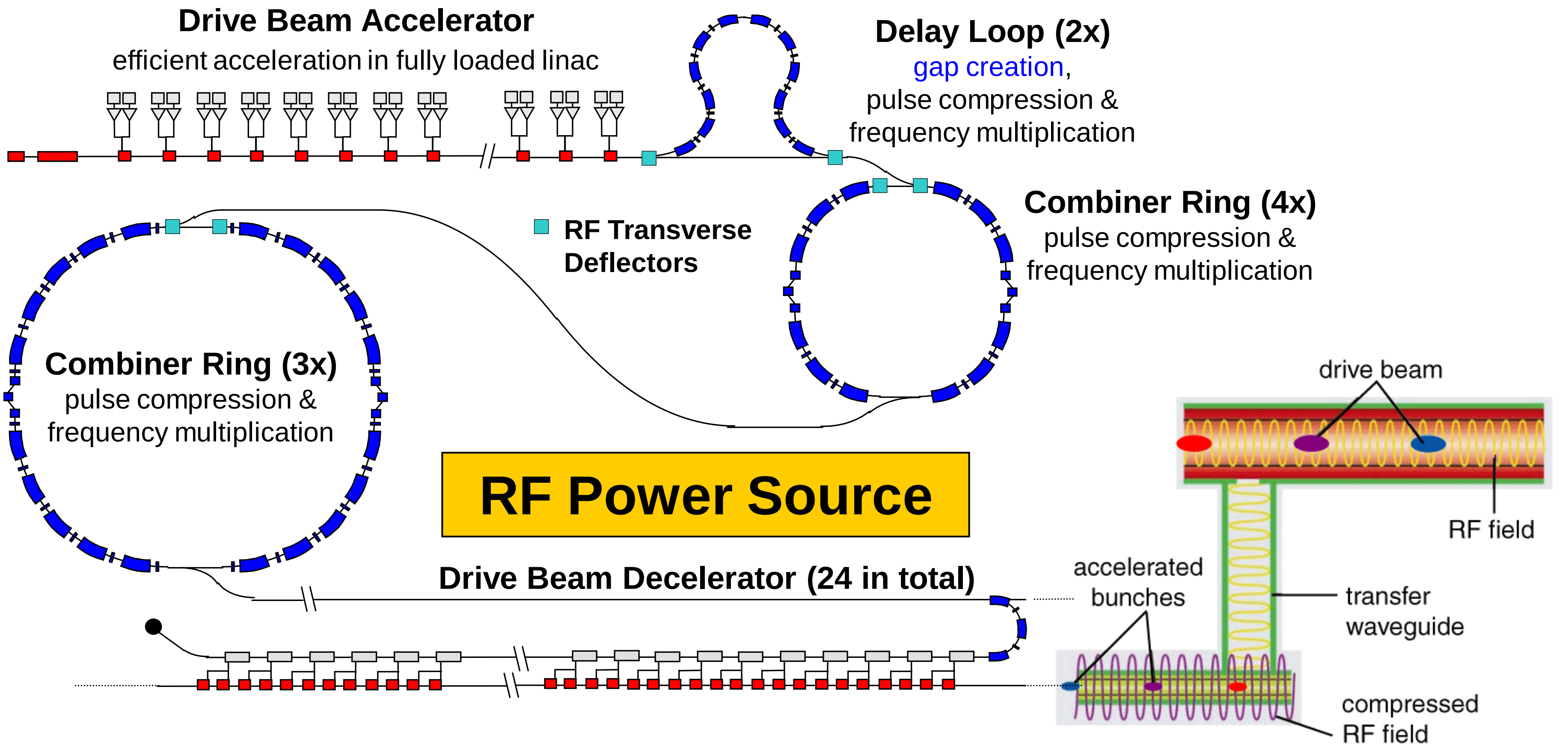
- Luminosity of 2×10^{34} $cm^{-2}s^{-1}$
  - short pulse (156ns)
  - high rep-rate (50Hz)
  - very small beam size (1x100nm)

- 64 MW RF power / accelerating structure of 0.233m active length
  - ➔ 275 MW/m
- Estimated wall power **415 MW** at 7% efficiency

CLIC Layout

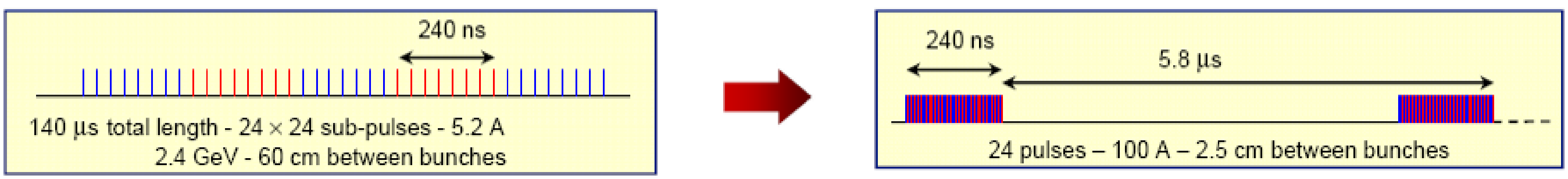

797 klystrons
15 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
2.5 km
Drive Beam
Generation
Complex
circumferences
delay loop 73.0 m
CR1 292.2 m
CR2 438.3 m
797 klystrons
15 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
2.5 km
delay loop
CR2
CR1
CR2
CR1
delay loop
Drive Beam
decelerator, 24 sectors of 876 m
BC2
BDS
2.75 km
IP
BDS
2.75 km
BC2
TA
e⁻ main linac, 12 GHz, 100 MV/m, 21.02 km
e⁺ main linac
TA
48.3 km
Main Beam 3 TeV (CM)
CR combiner ring
TA turnaround
DR damping ring
PDR predamping ring
BC bunch compressor
BDS beam delivery system
IP interaction point
dump
booster linac, 6.14 GeV
BC1
e⁻ injector, 2.86 GeV
e⁻ PDR 398 m
e⁻ DR 421 m
e⁺ DR 421 m
e⁺ PDR 398 m
e⁺ injector, 2.86 GeV
Main Beam
Generation
Complex

CLIC Two-beam Acceleration Scheme



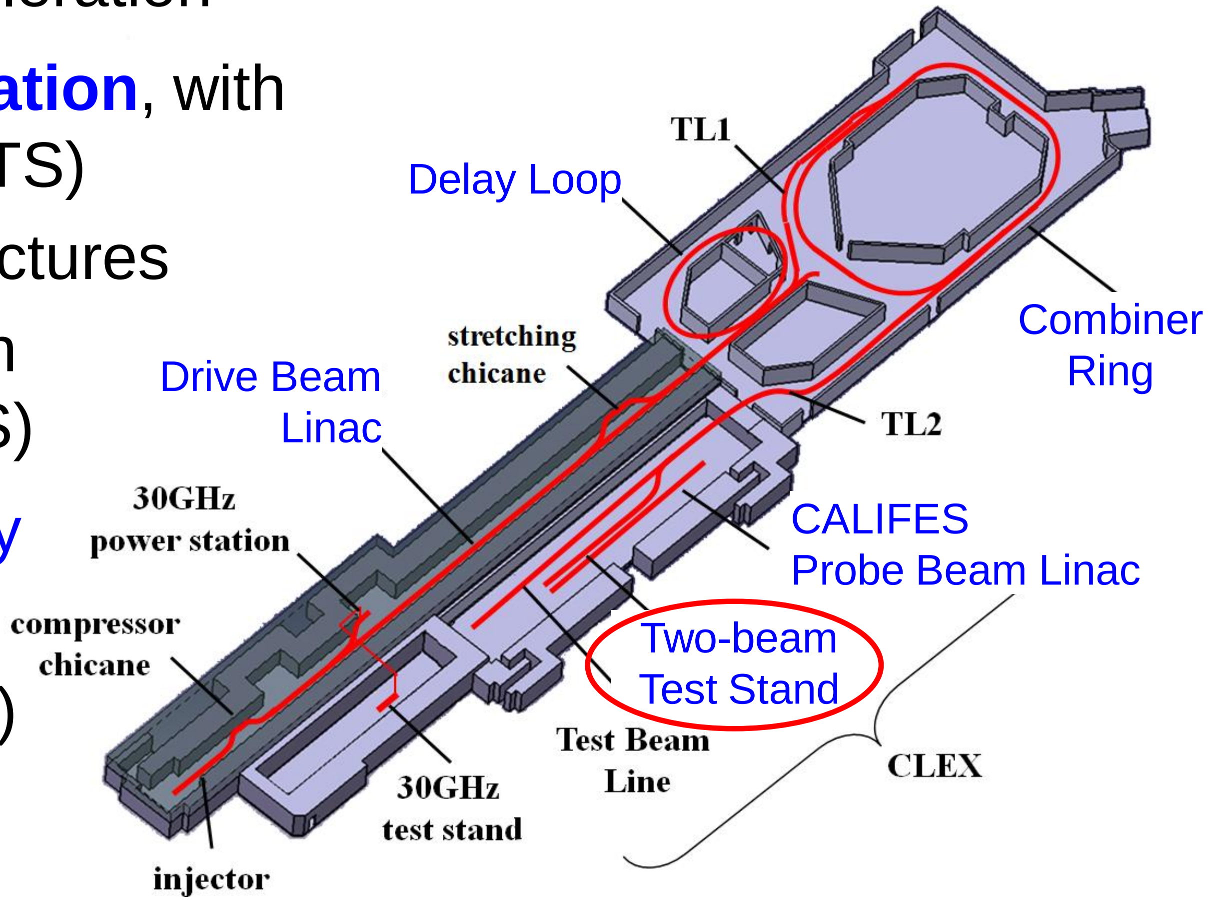
Drive beam time structure - initial

Drive beam time structure - final

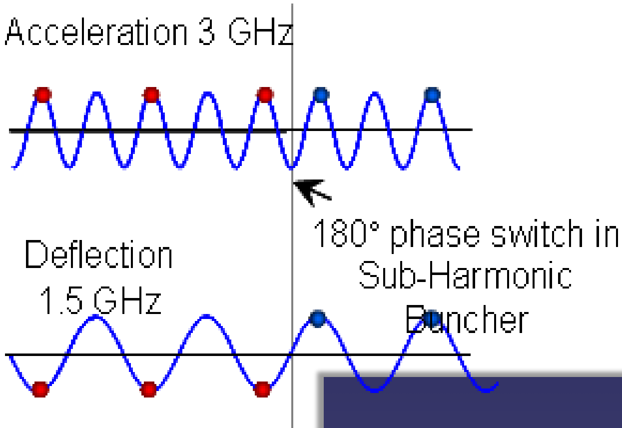


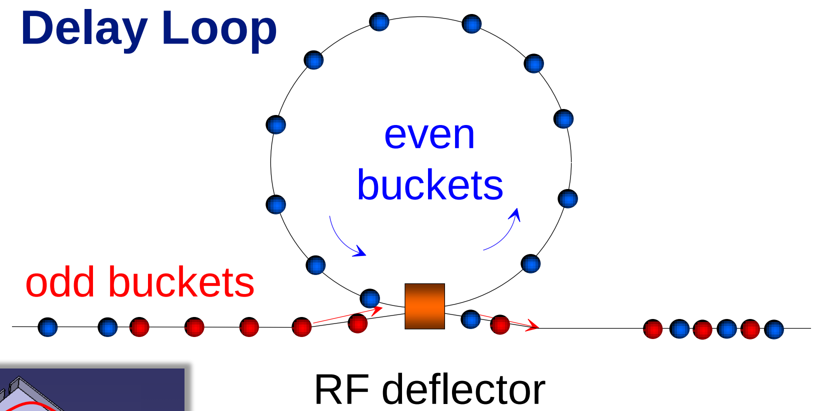
CLIC Test Facility CTF3

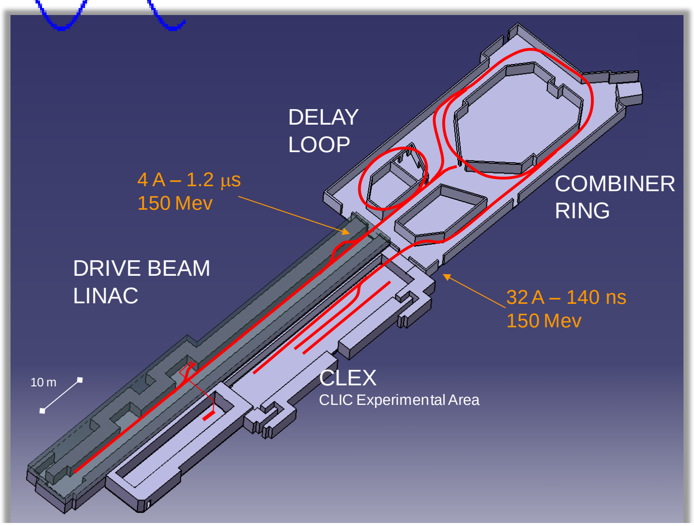
- **Drive beam generation**, with
  - appropriate time structure, and
  - fully loaded acceleration
- **Two-beam acceleration**, with CLIC prototype (TBTS)
  - accelerating structures
  - power production structures (PETS)
- Deceleration stability (TBL)
- Photoinjector (PHIN)

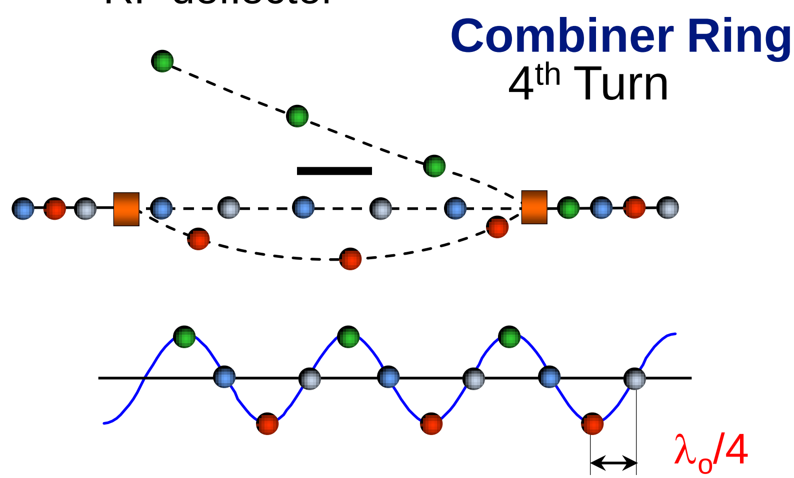


Recombination Principle

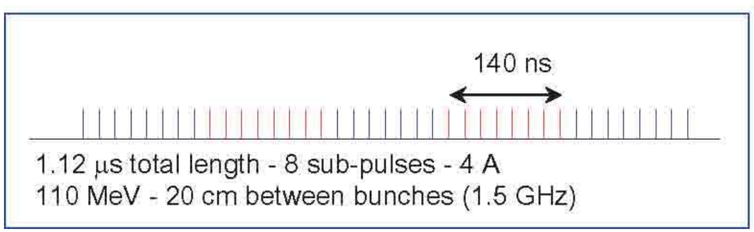




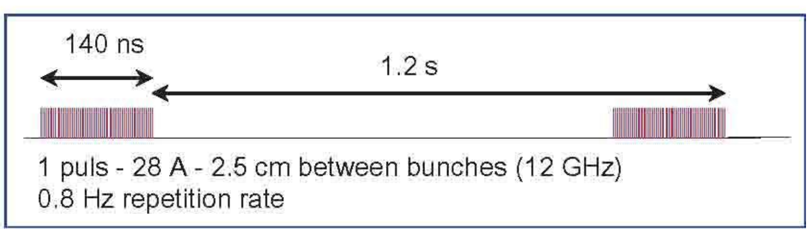




Initial time structure

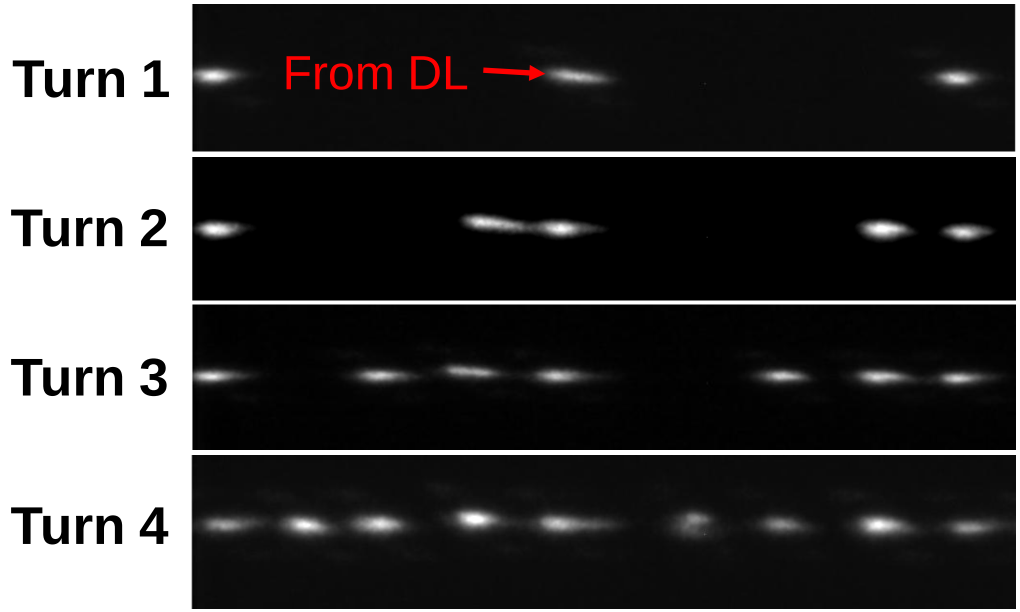


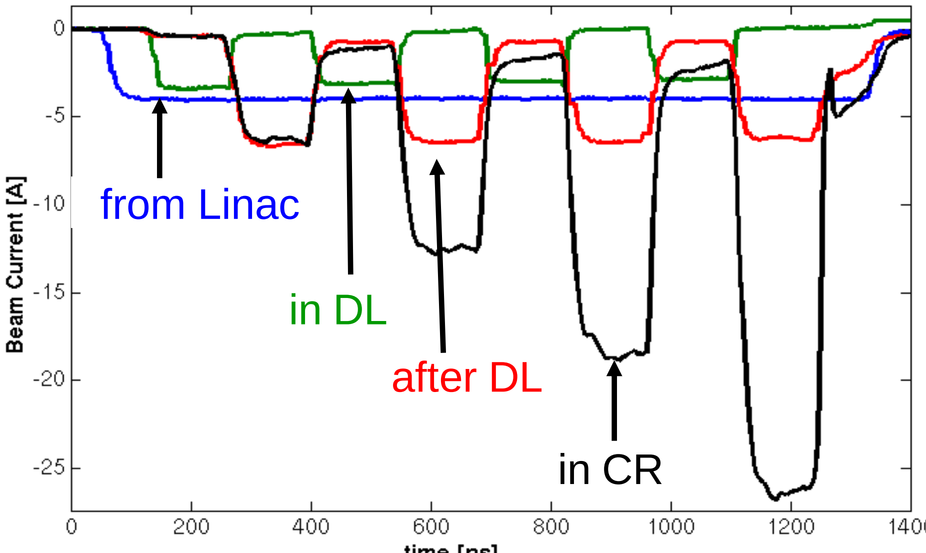
Final time structure



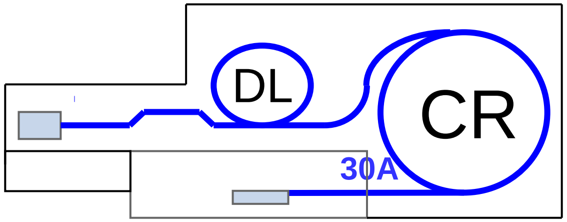
Bunch Re-combination DL + CR

- **Streak camera images from CR**
- bunch spacing:
  - 666 ps initial
  - 83 ps final
- circulation time correction by wiggler adjustment





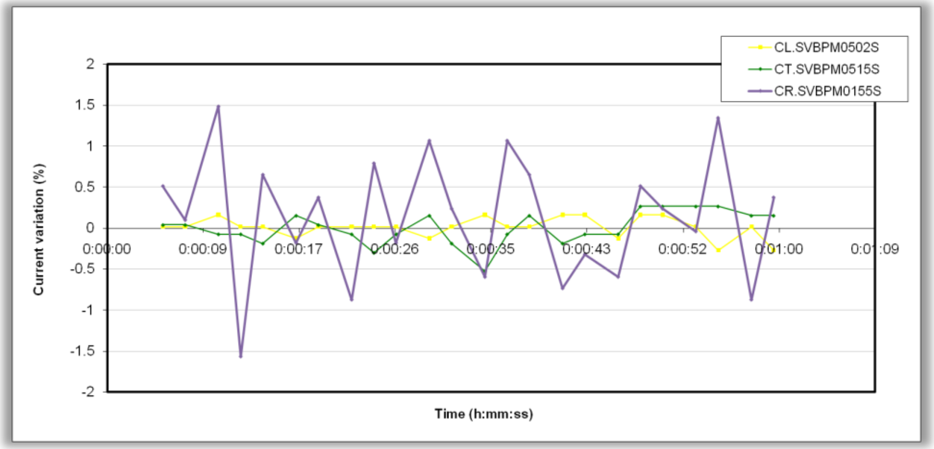
- **Signal from BPMs**



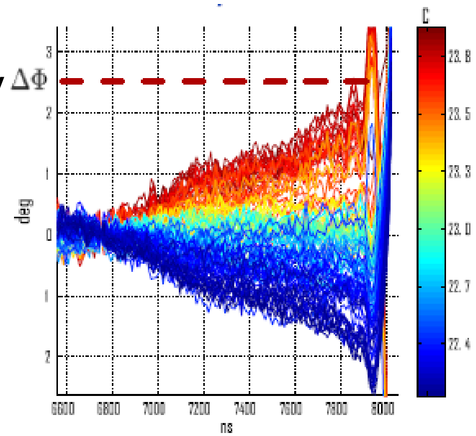
Ongoing Work

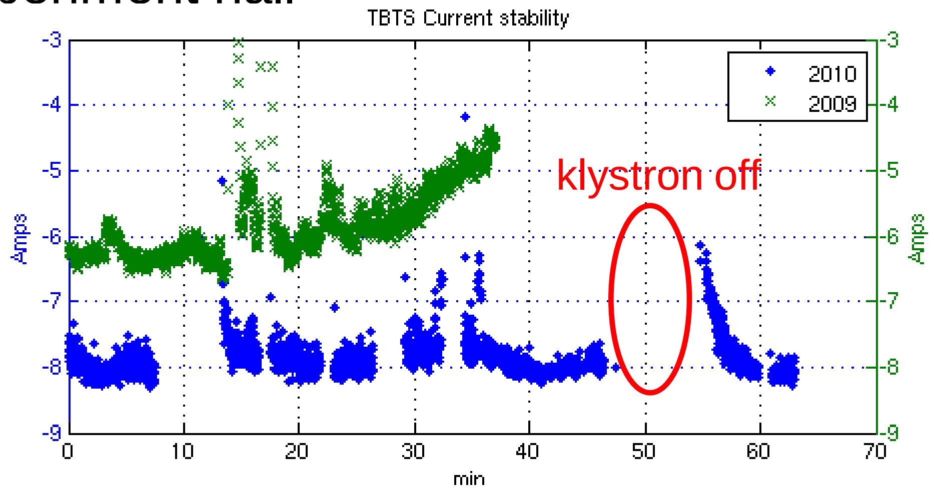
- **Beam current stabilization**
  - CLIC requires stability at 0.075% level
  - ok from linac and DL
    need improvement in CR
- **Phase stabilization**
  - temperature stabilization
    pulse compressor cavity
- **Transfer line commissioning**
  - transport losses from CR to experiment hall

	LINAC	DL	CR
Variation	0.13%	0.20%	1.01%



RF phase stability along pulse (for different ambient temperatures)





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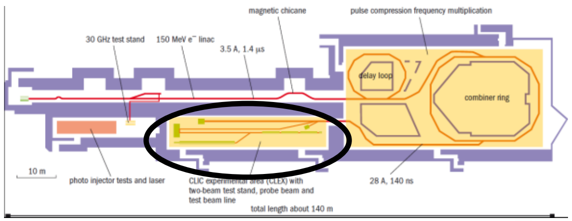
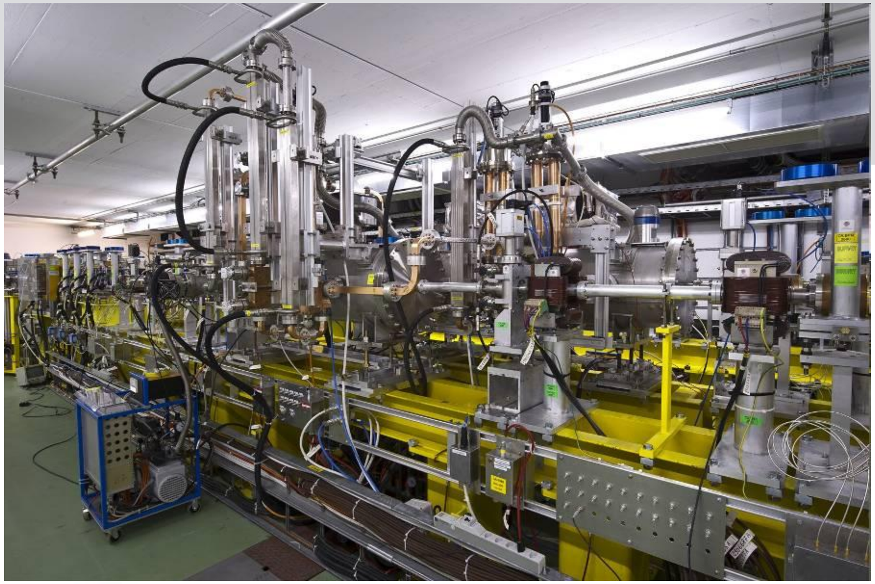
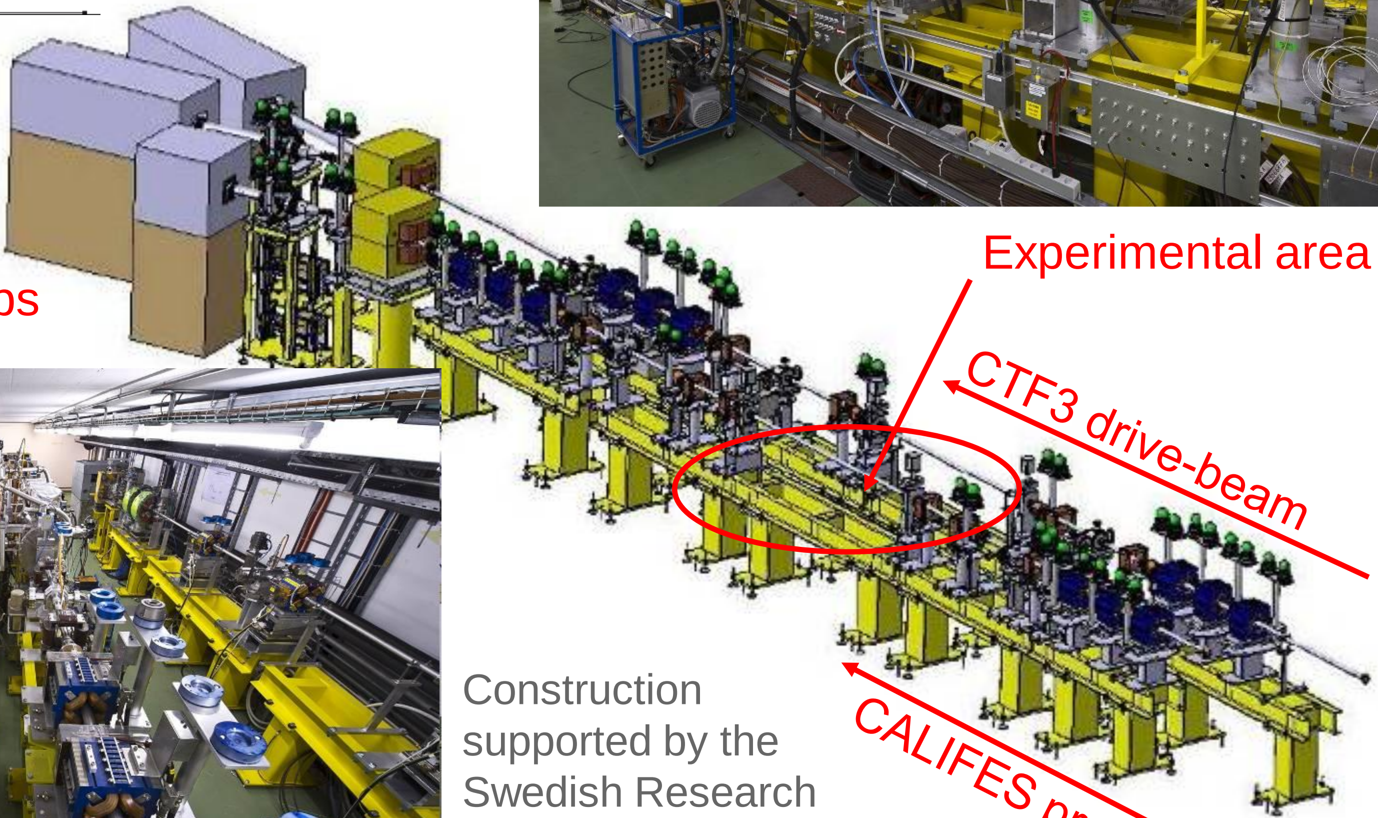
Two-beam Test Stand





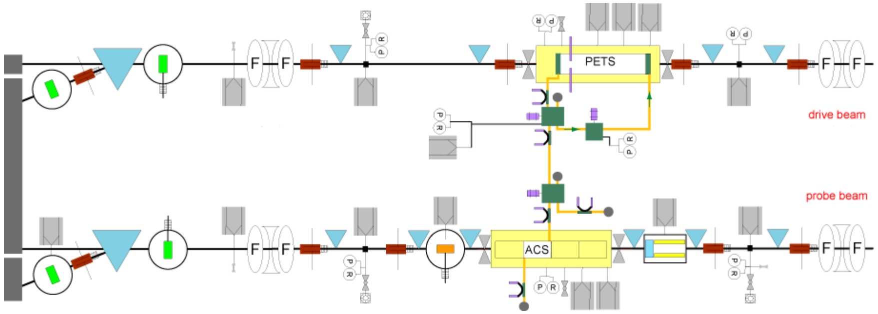


Construction supported by the Swedish Research Council and the Knut and Alice Wallenberg Foundation

Two-beam Test Stand Prospects

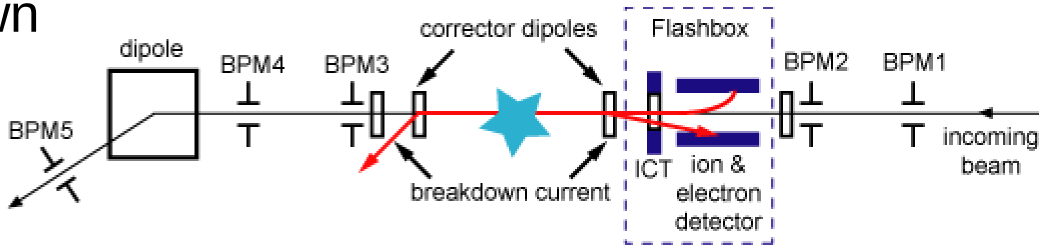
Versatile facility

- two-beam operation
  - 28A drive beam [100A at CLIC]
  - 1A probe beam [like CLIC]
- excellent beam diagnostics, long lever arms
- easy access & flexibility for future upgrades



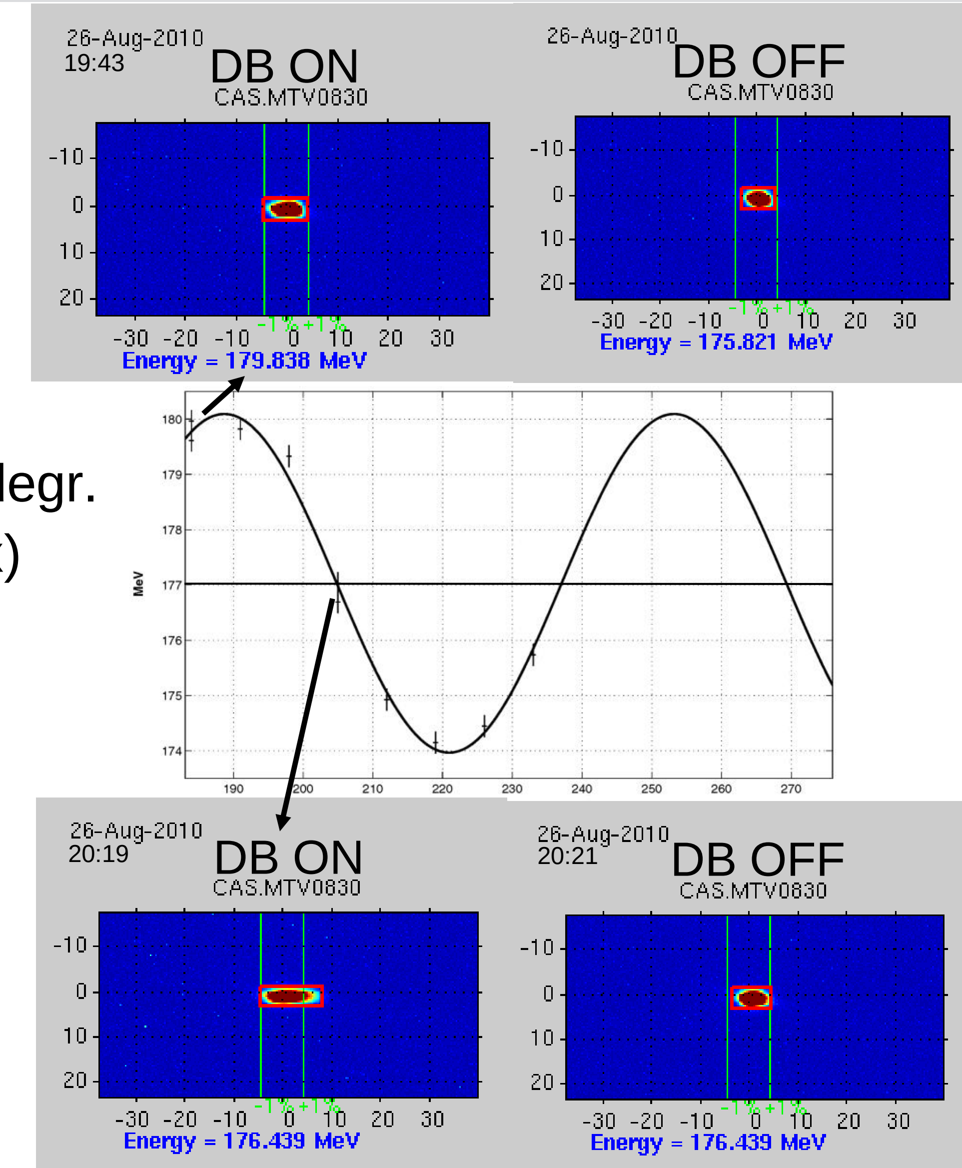
Unique test possibilities

- power production in prototype CLIC PETS
- two-beam acceleration and full CLIC module
- studies of
  - beam kick & RF breakdown
  - beam dynamics effects
  - beam-based alignment

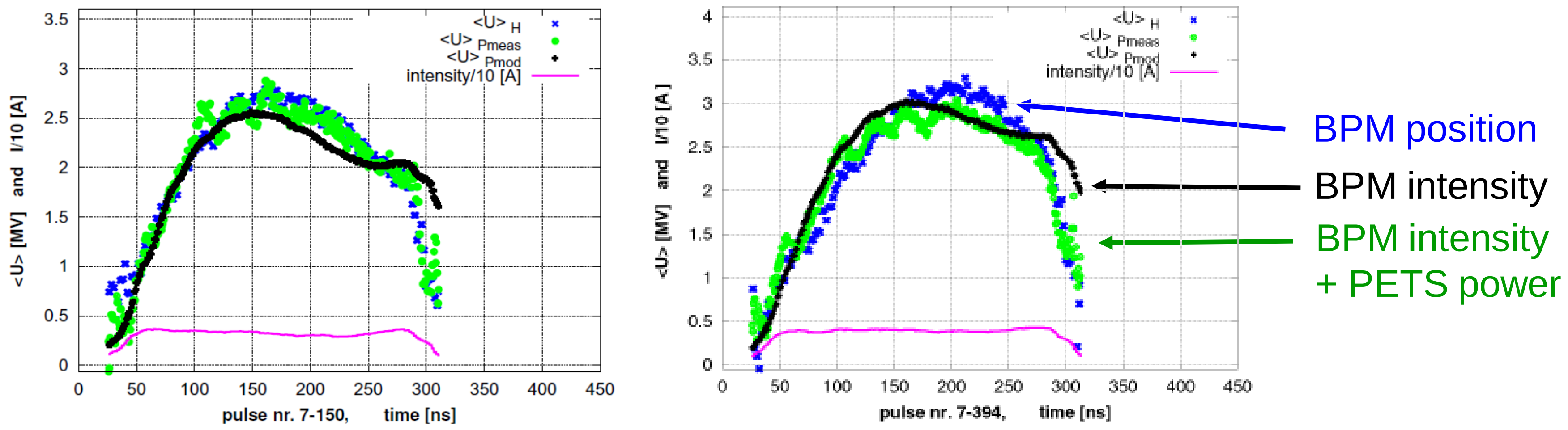


First Trial Probe Beam Acceleration

- Fine tuning DB↔PB timing
  - **3GHz phase scan klystron**
  - coherent with 1.5GHz laser timing signal
- **~6 MeV peak-to-peak**
  - zero crossing: 177 MeV, 205 degr.
  - phase scaling: 5.58 (expect 4x)
- optimize
  - PB energy spread & bunching
  - klystron pulse compression
  - coherency klystron and laser
  - low input power (ACS not conditioned)



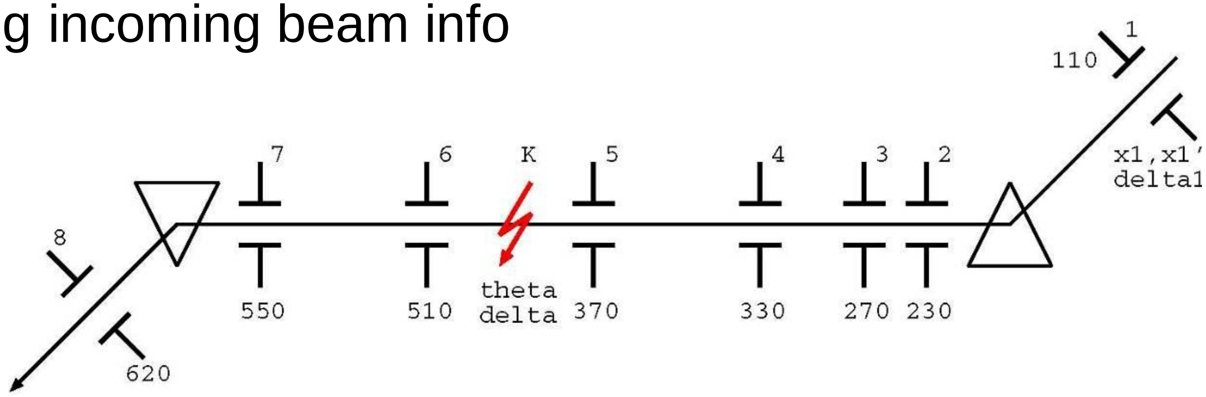
Drive Beam Deceleration



Energy loss estimation

→ mismatch black-green due to phase variation along pulse

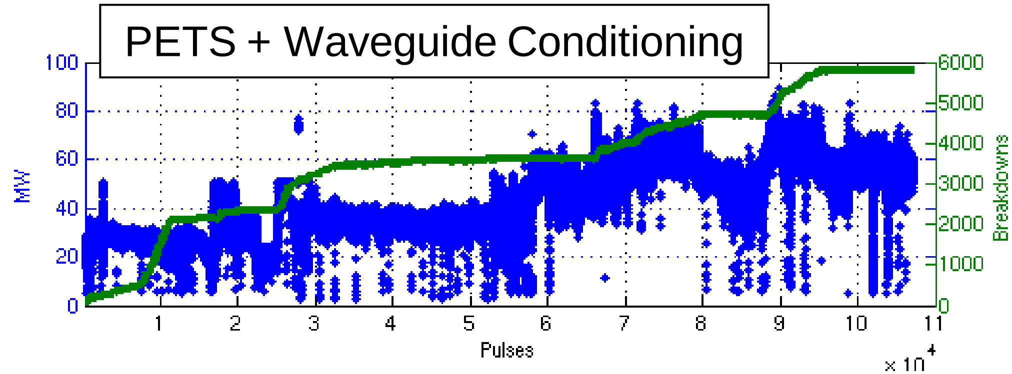
Improve by incorporating incoming beam info

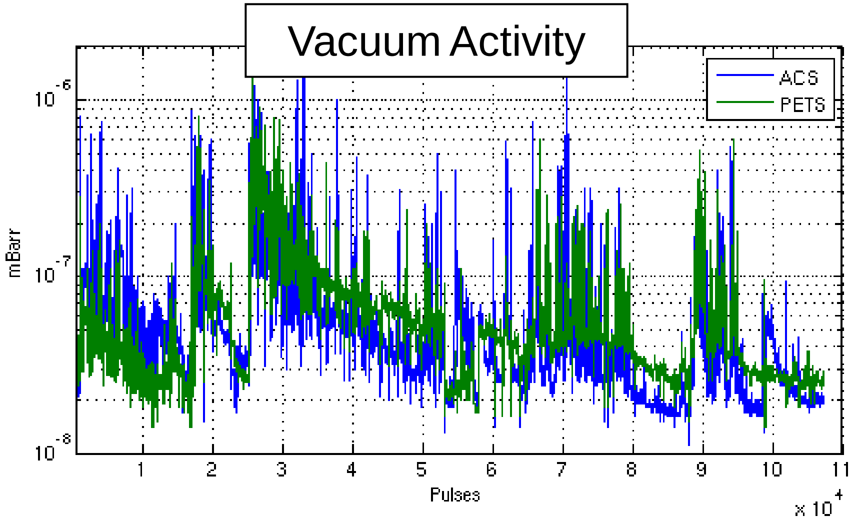


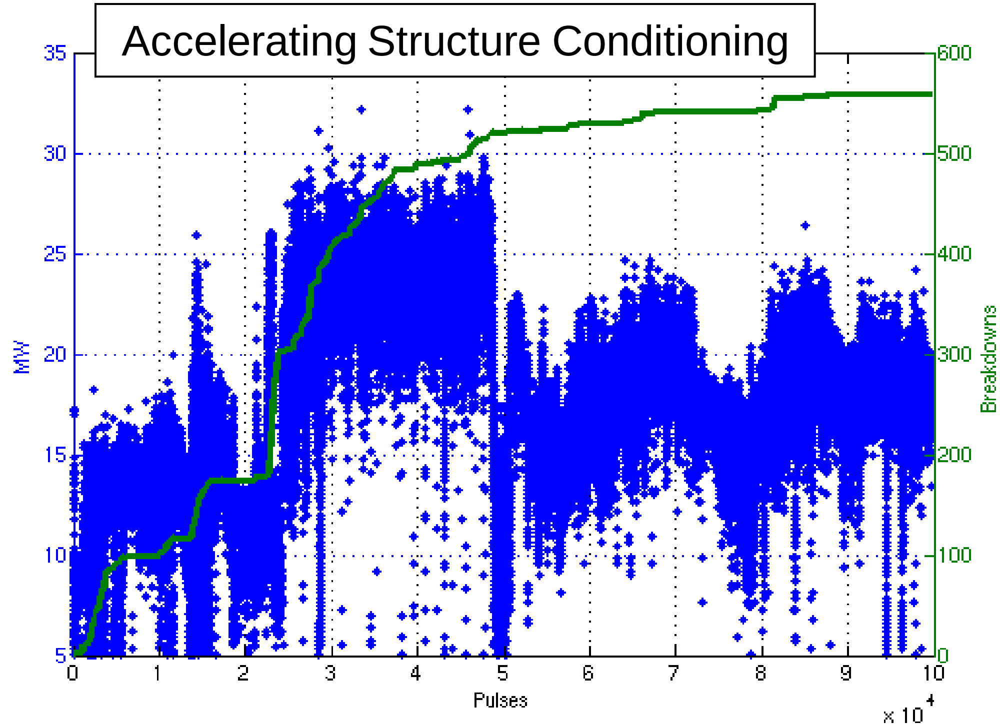
Conditioning Process

Present stable level:

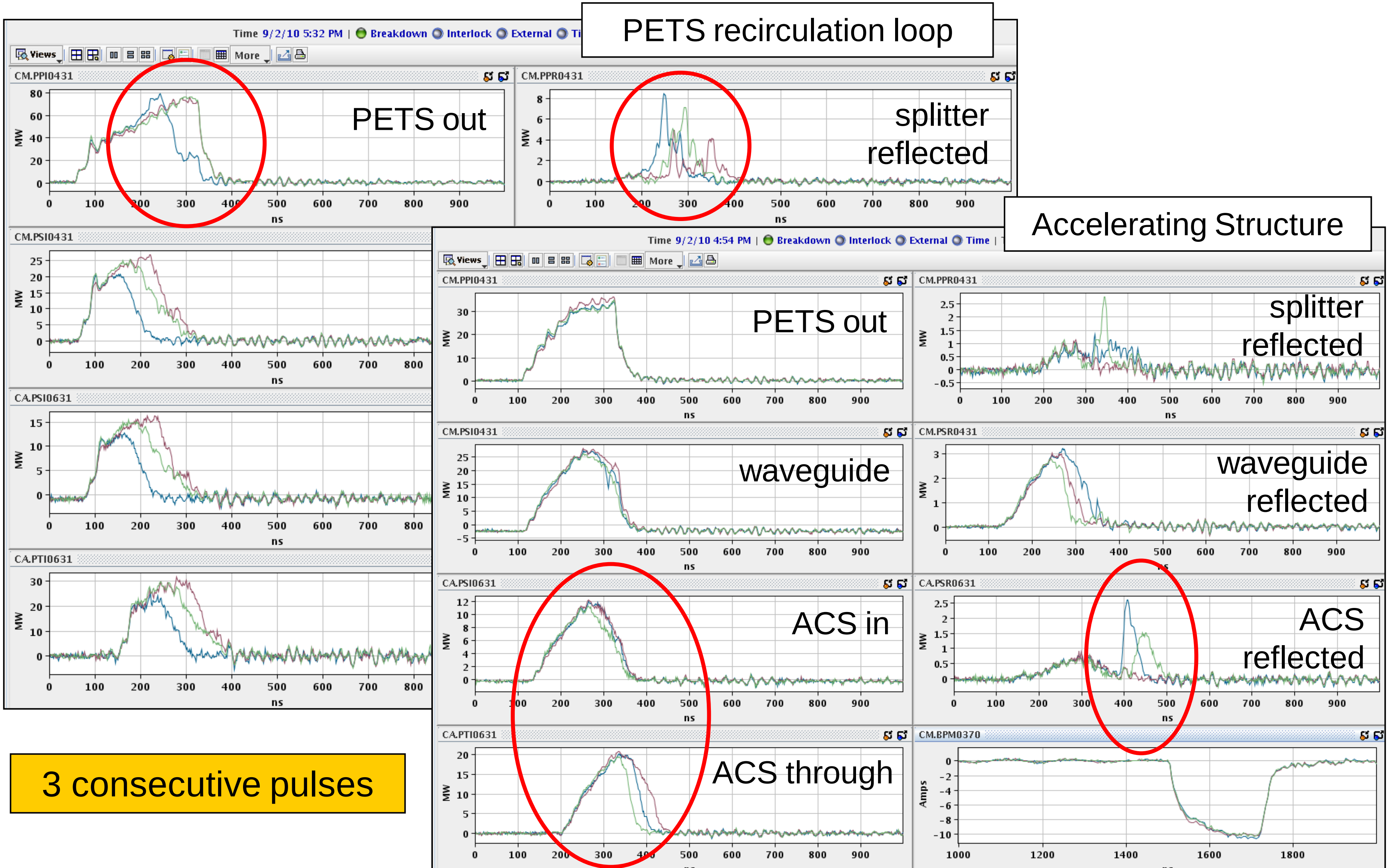
- PETS + recirculation loop
  - ~70 MW peak power,
  - ~200 ns pulse
- Accelerating structure
  - ~23 MW peak power







Example RF Breakdowns



3 consecutive pulses

CTF3 Experimental Program

- Two-beam acceleration
  - conditioning and test PETS and accelerating structures
  - breakdown kicks of beam
  - dark (electron) current accompanied by ions
  - install 1, then 3, two-beam modules
- Drive beam generation
  - phase feed forward for phase stability
  - increase to 5 Hz repetition rate
  - coherent diffraction radiation experiments
- Drive beam deceleration
  - extend TBL to 8 then 16 PETS
  - high power production + test stand
- 12GHz klystron powered test stand
  - power testing structures w/o beam
  - significantly higher repetition rate (50 Hz)

TBTS is the only place available to investigate effects of RF breakdown on the beam

Conclusions

- Reached first milestones:
  - Drive beam generation with appropriate time structure and fully loaded acceleration.
  - Two-beam acceleration with CLIC prototype structures.
- Continued operation:
  - Optimize beam and two-beam acceleration.
  - Investigate RF breakdown effects on beam.
- Planned enhancements:
  - 12 GHz klystron powered test stand
  - Install full two-beam test modules.

Many thanks to all colleagues, their work and their suggestions!