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A milestone on the road to CLIC

Testing the two-beam acceleration scheme in the Two-beam test stand at CERN

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Overview

- An accelerator beyond LHC
- Compact Linear Collider CLIC
  - the subsystems
  - the critical issues
- The CLIC test facility CTF3 at CERN
- The Two-Beam Test Stand
  - recent results
  - the milestone
- What's next?

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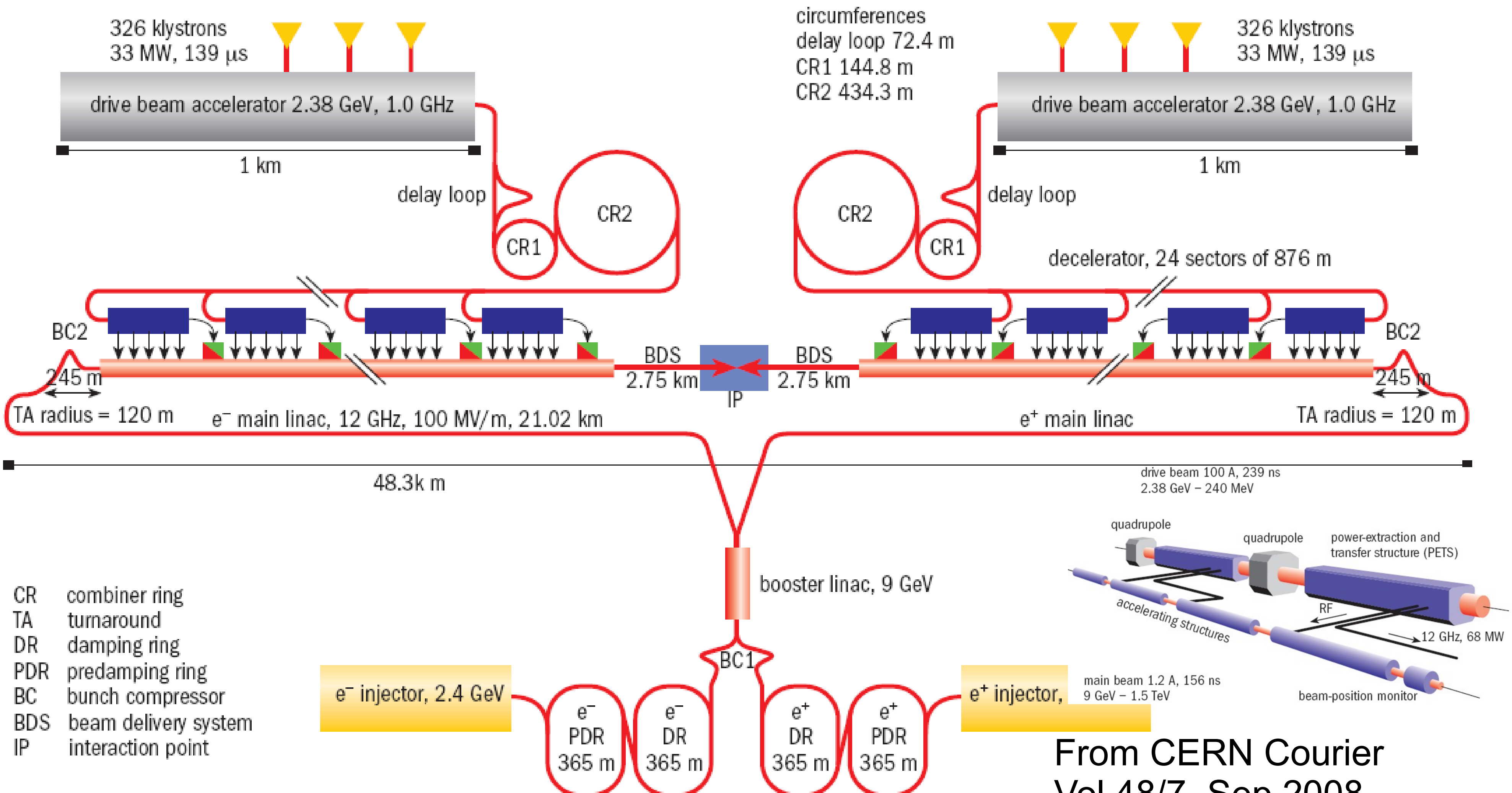
Accelerator Meta-sequencing

- An example from the past generation
  - First came theory (Elektroweak model)
  - Then came the discovery machine
    - SPS, 400 GeV protons and anti-protons, 7 km
    - high energy, but difficult reaction kinematics with many quarks and glouns participating in a single collision
  - Then came the precision machine
    - LEP, 55 → 100 GeV electrons and positrons, 27 km
    - roughly the same energy per colliding particle, but simpler kinematics with only two initial point-like leptons

The next generation

- Theory: Missing Higgs in the standard model and 'beyond standard model' extensions
- The Discovery Machine
  - LHC, 7 TeV protons on protons, 27 km
  - Reach as high energies as technically possible
- The Precision Machine
  - 1: ILC, 250 → 500 GeV/beam electron-positron collider, super-conducting RF, ~30 km, 2ms
  - 2: **CLIC**, up to 1.5 TeV/beam electron-positron collider, normal-conducting RF, ~50 km, 240 ns

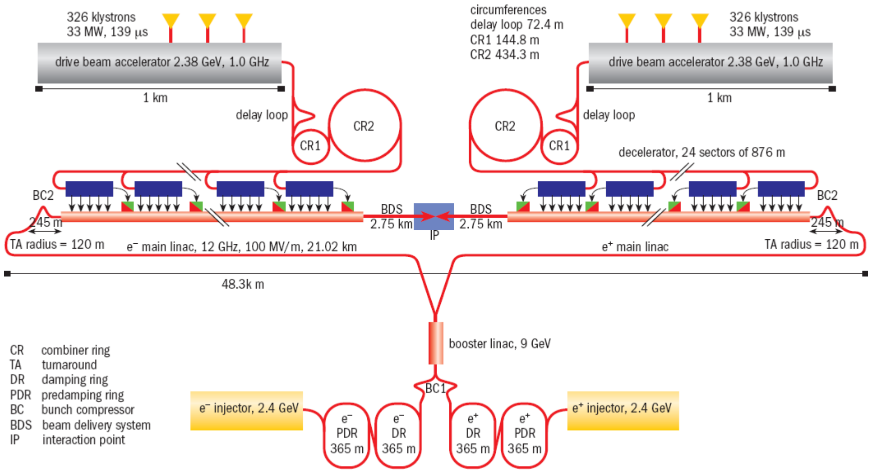
CLIC



From CERN Courier
Vol 48/7, Sep 2008

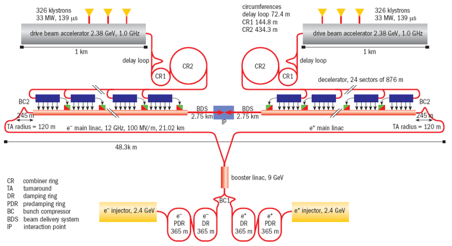
Technical challenges

- Small spots 100 x 1 nm
- Making small emittances
  - damping ring design
- Making short bunches
  - damping ring plus bunch compressor in RTL
- Extreme alignment tolerances on and below the nm level
- Getting rid of the bunches after collision
  - post-collision line



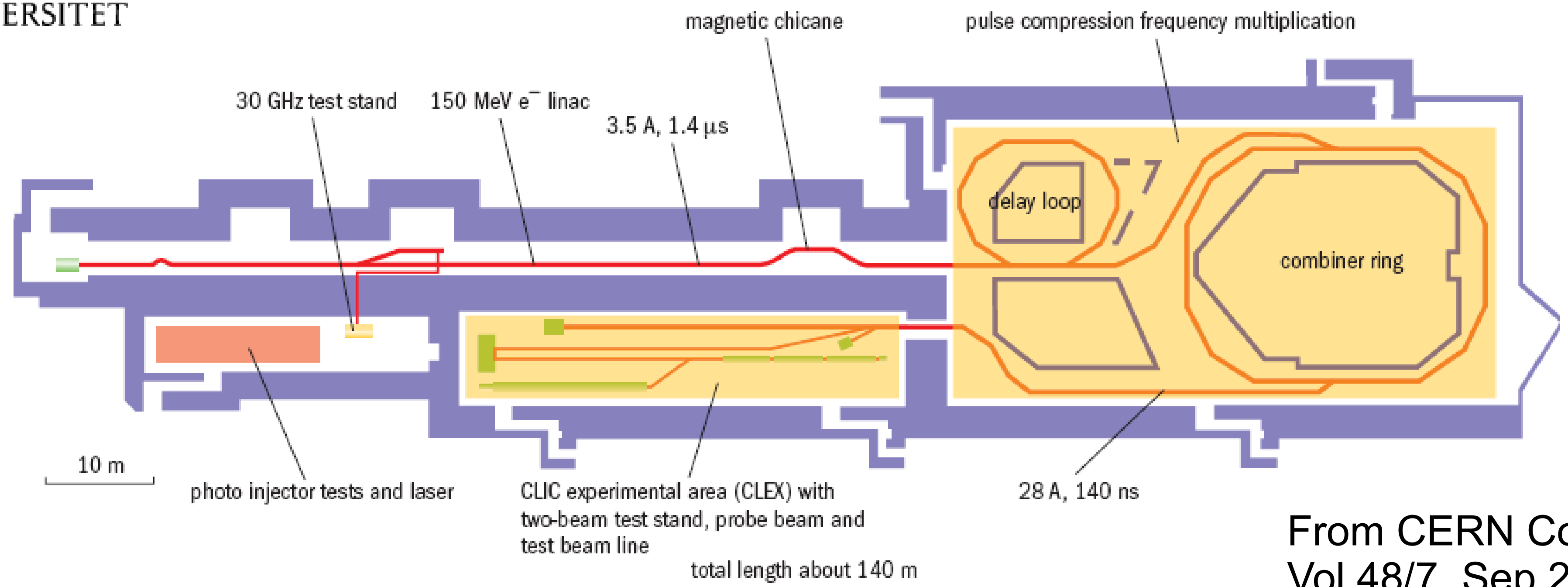
Challenges addressed in CTF3

- High acceleration gradient to keep the length within reasonable bounds ('compact')
  - 100 MV/m, material science inside the RF structures determines limits.
  - Reliability, 140000 structures, breakdown rate < 10^{-7}
- Distribution of power to the 140000 acceleration structures



  - Many, many klystrons
  - Use a 'distributed klystron', the drive beam
- Energy efficiency, optimize the wall-plug power

CTF3

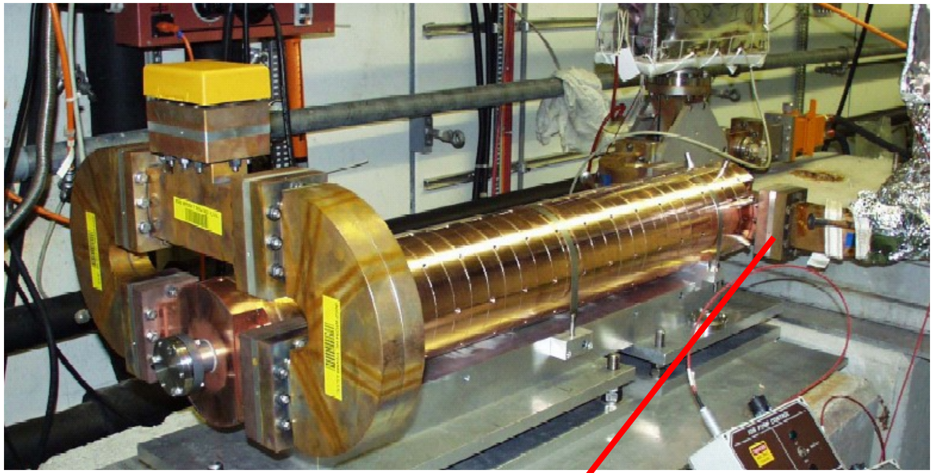


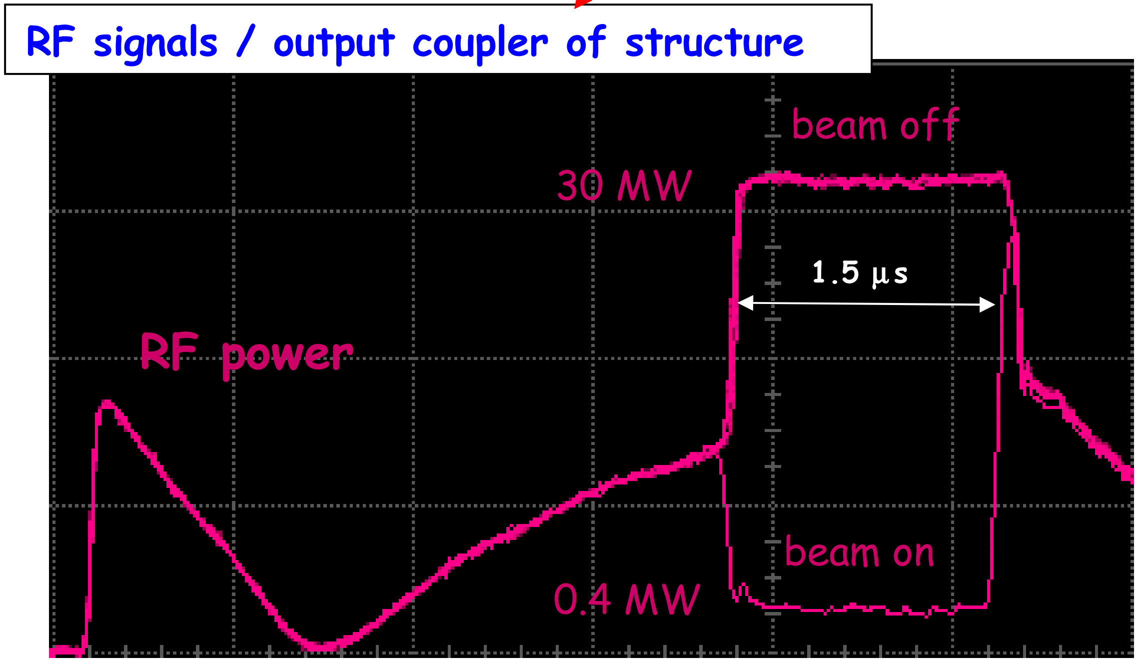
From CERN Courier Vol 48/7, Sep 2008

- Efficiency: Fully-loaded operation
- Distributed klystron: Drive beam complex
- Two-beam acceleration: CALIFES and the Two-beam test stand

Fully loaded operation

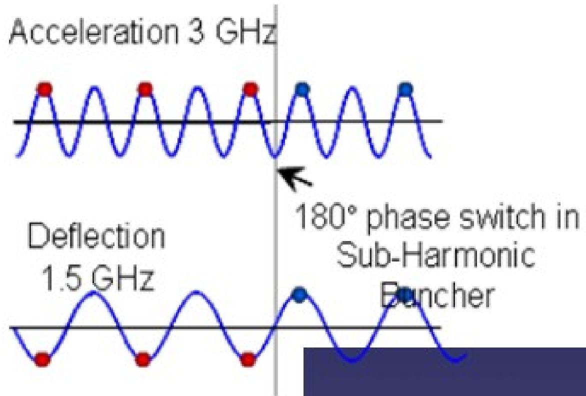
- Efficient transfer of RF in accelerating structure to the beam
- maximum beam loading
- 94% transfer efficiency

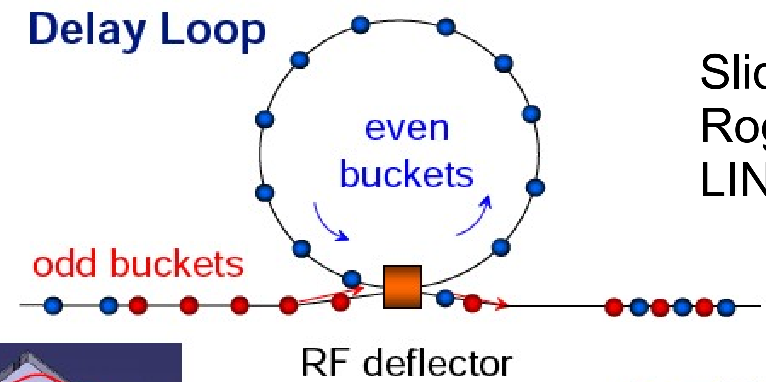




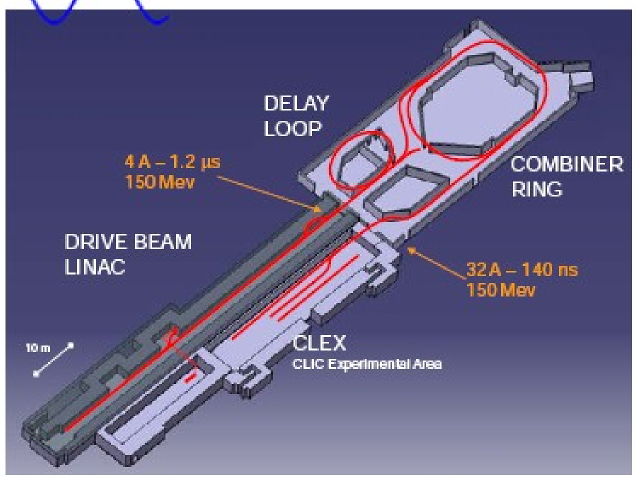
From F. Tecker
CLIC ACE June 2007

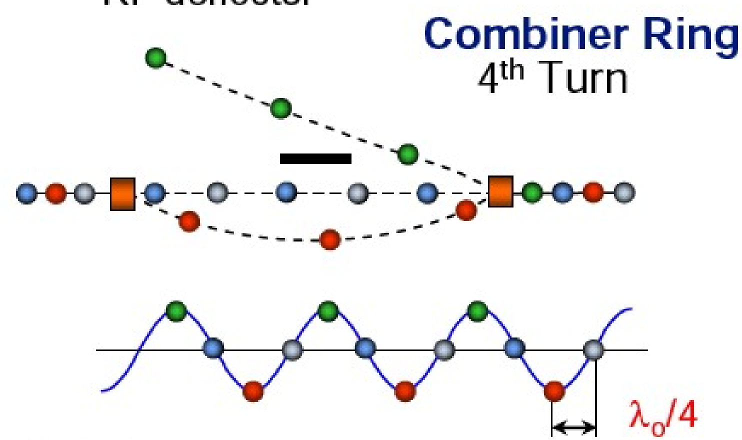
Recombination

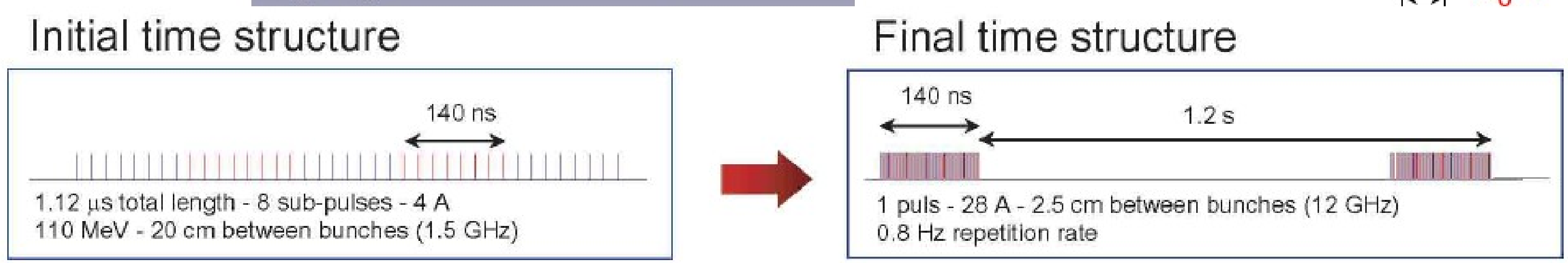




Slide prepared by Roger Ruber, UU LINAC10, MO303

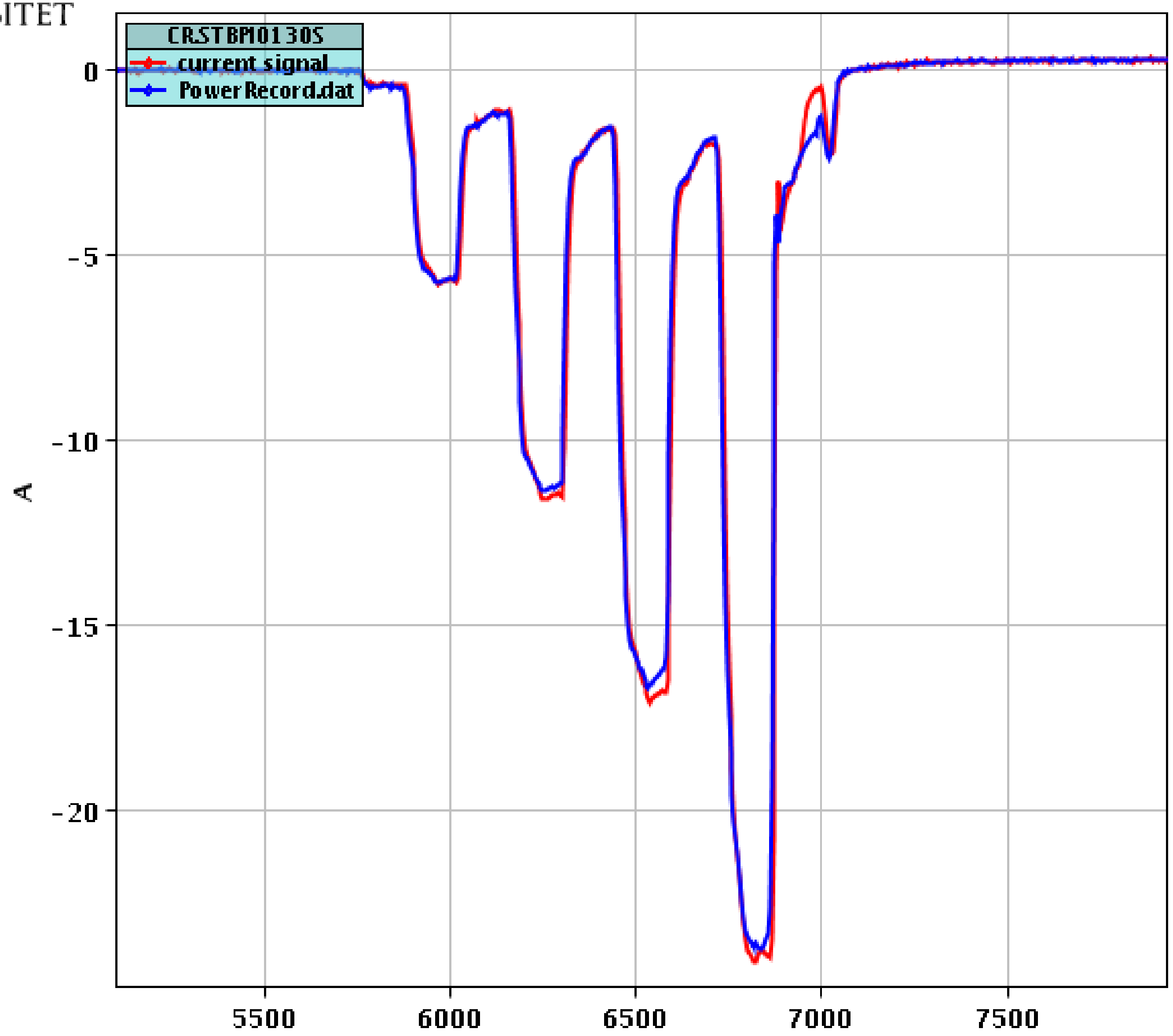






Show Alexandra Andersson's Lemmings movie

Bunch recombination



From R. Corsini
CLIC ACE, Feb 2011

Two-Beam Acceleration a section along the CLIC linac

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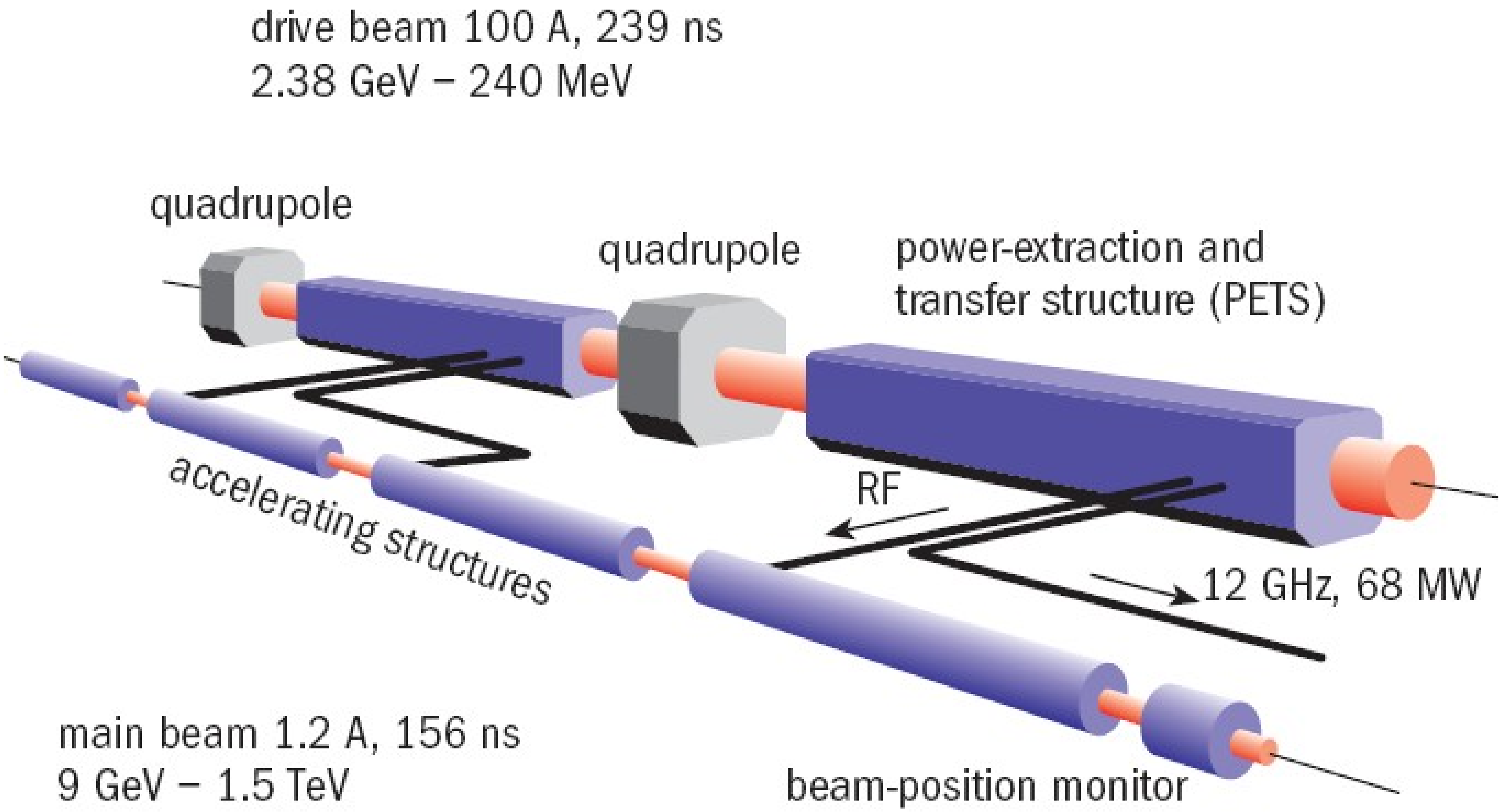
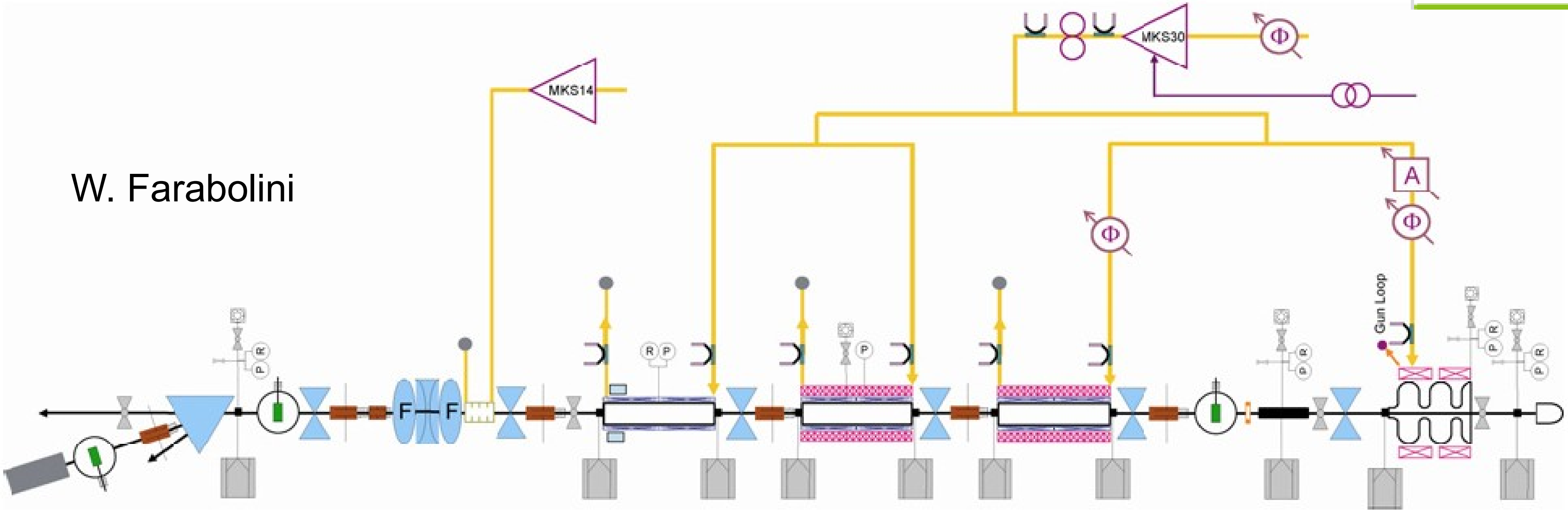


From CERN Courier
Vol 48/7, Sep 2008

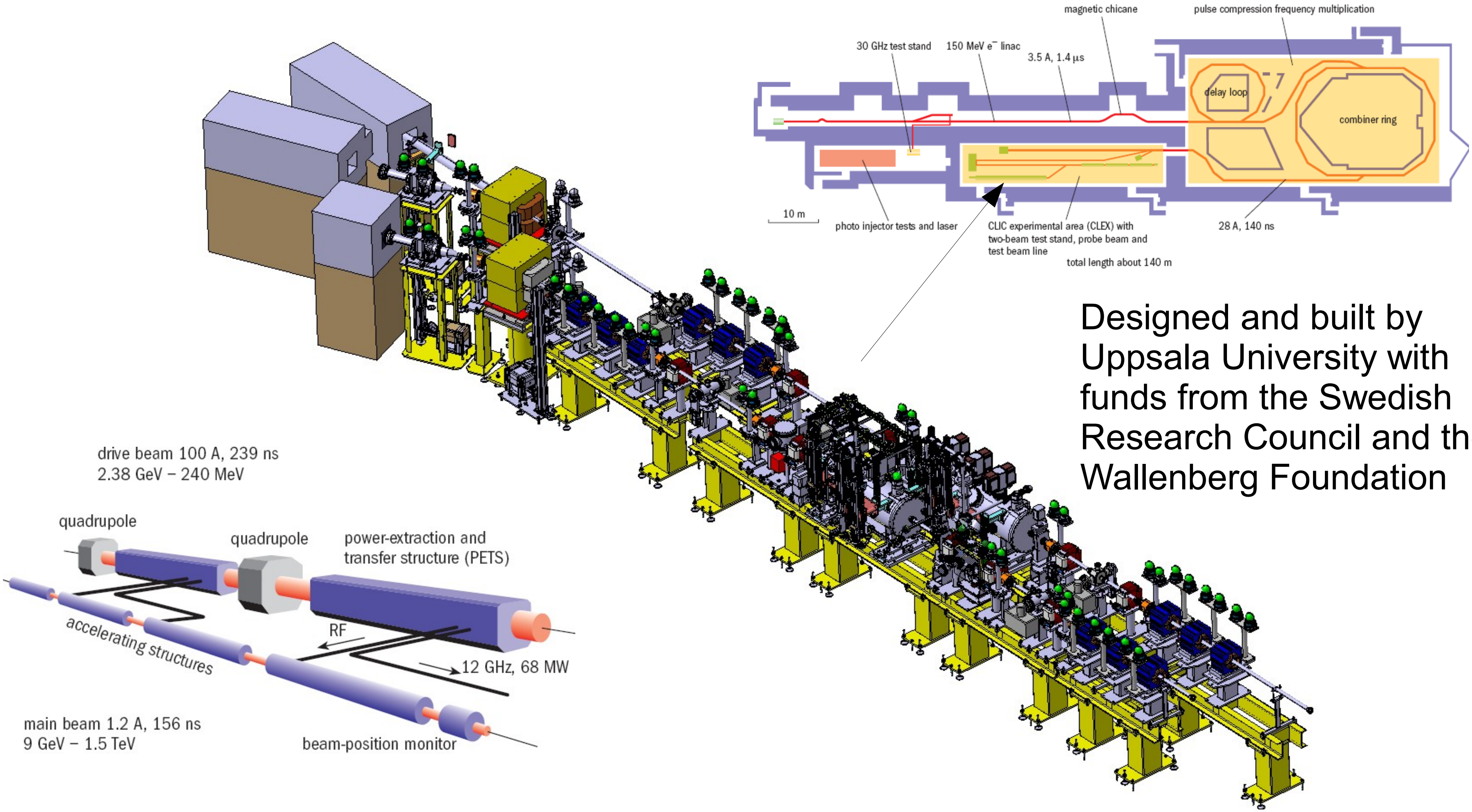
The second beam: CALIFES

W. Farabolini



- Model of the CLIC main beam (to be accelerated)
- Normal conducting 3 GHz structures, up to 180 MeV
- RF photo gun, 666 ps bunch spacing, 0.3 nC/bunch

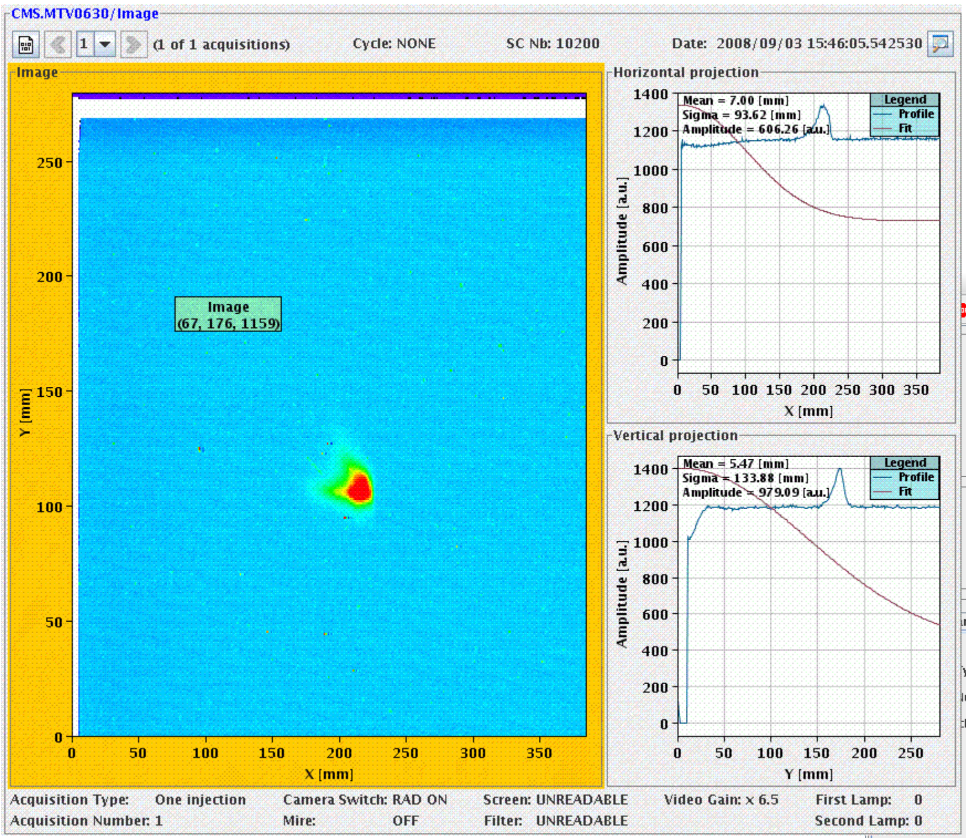
Two-Beam Test Stand



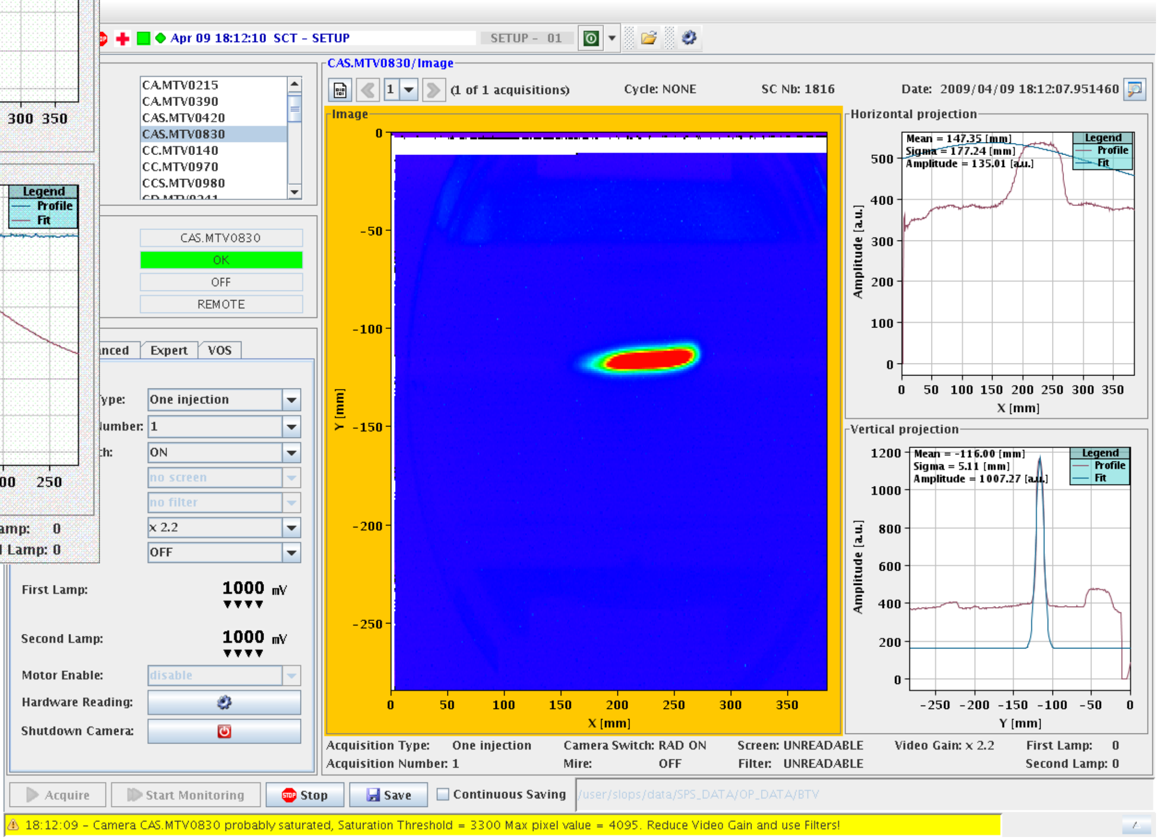
Designed and built by Uppsala University with funds from the Swedish Research Council and the Wallenberg Foundation

The real thing

First beams



Drive beam on Sept 3, 2008



Probe beam on April 9, 2009

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What do we do with it?

- Power production in the PETS structures
  - with recirculation to increase the power level
- Accelerating the probe beam
  - timing, 1^0 at 12GHz corresponds to 230 fs
  - the acceleration gradient
- Investigating what happens to the beam in case of an RF breakdown during conditioning
  - energy loss, transverse kick,
  - ejected electron and ions, Flashbox

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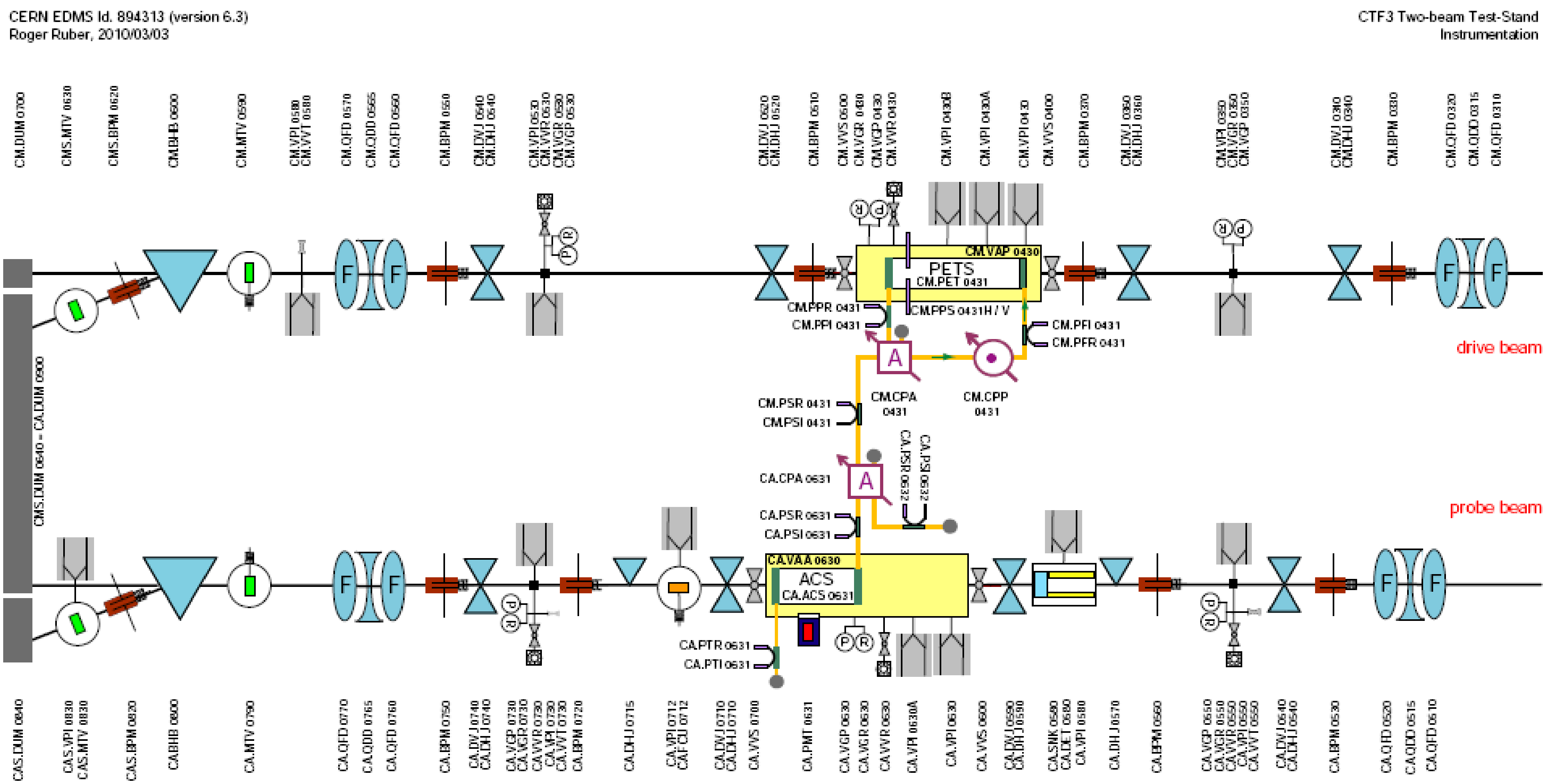
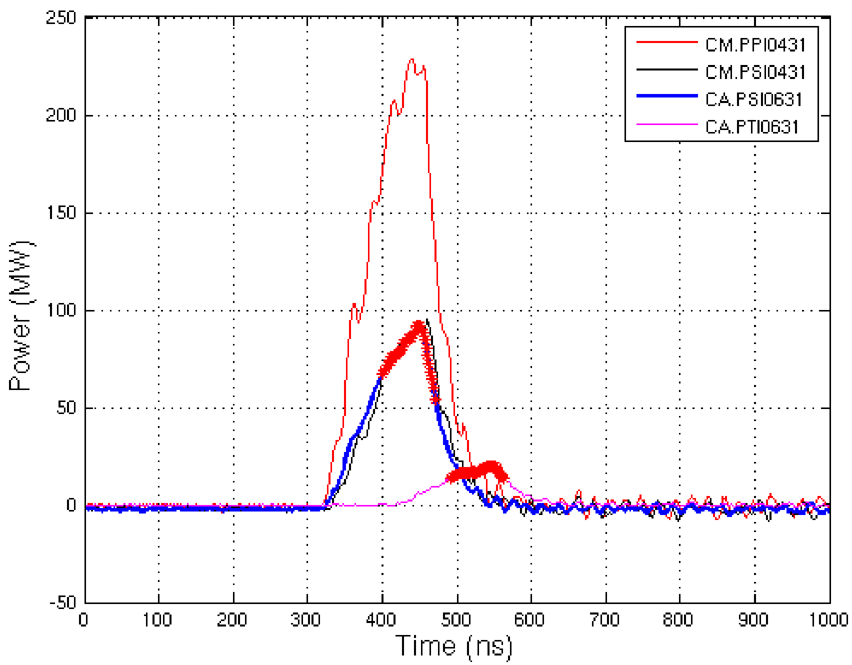
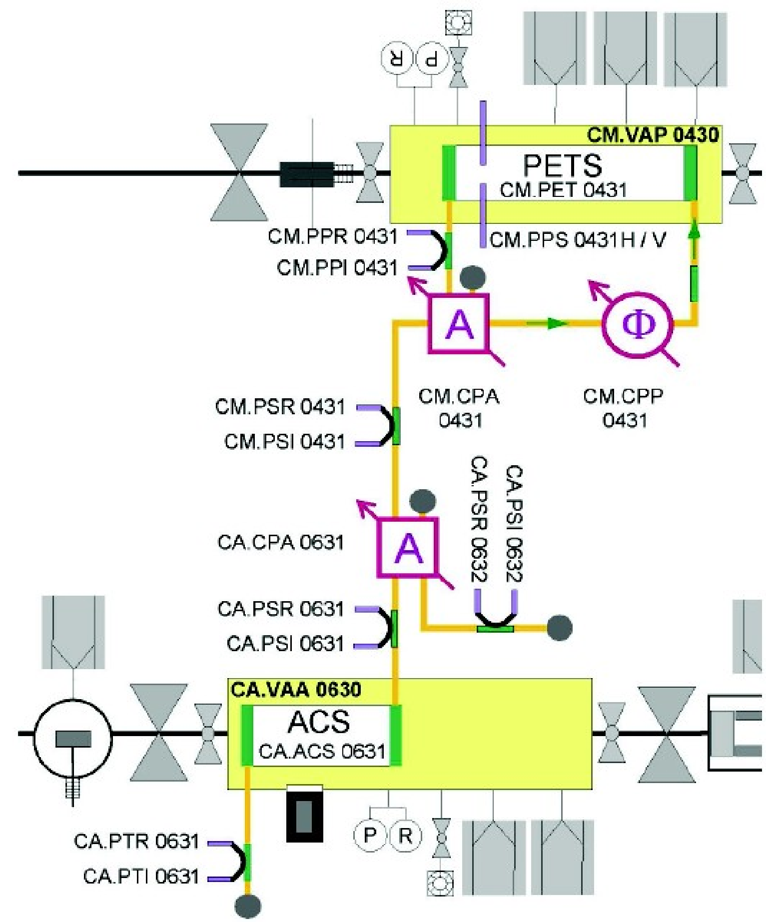
How do we do it? TBTS Instrumentation



Power production in PETS

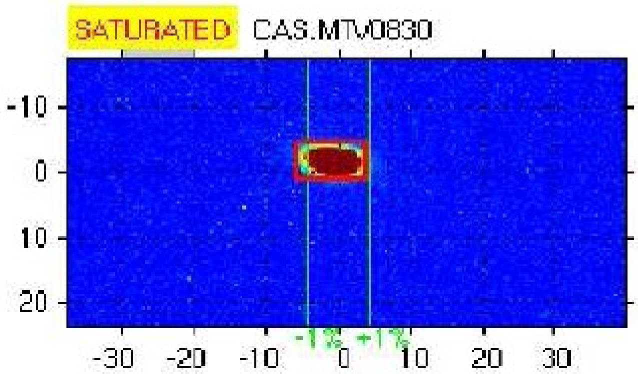
- Get 200 MW in recirculation mode inside PETS
- and 100 MW in acceleration structure



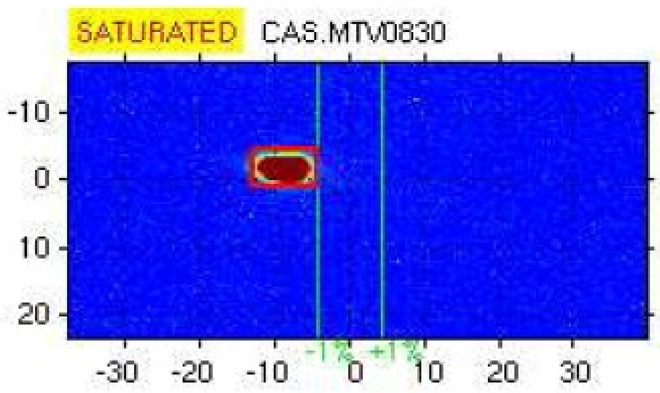


 From R. Ruber

Accelerating the Probe Beam

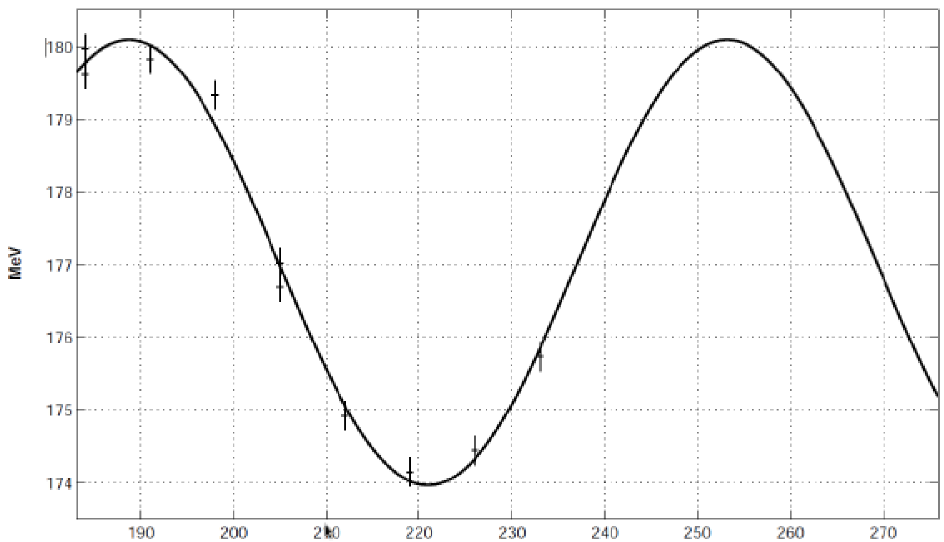


174.6 MeV (RF on - drive beam on)



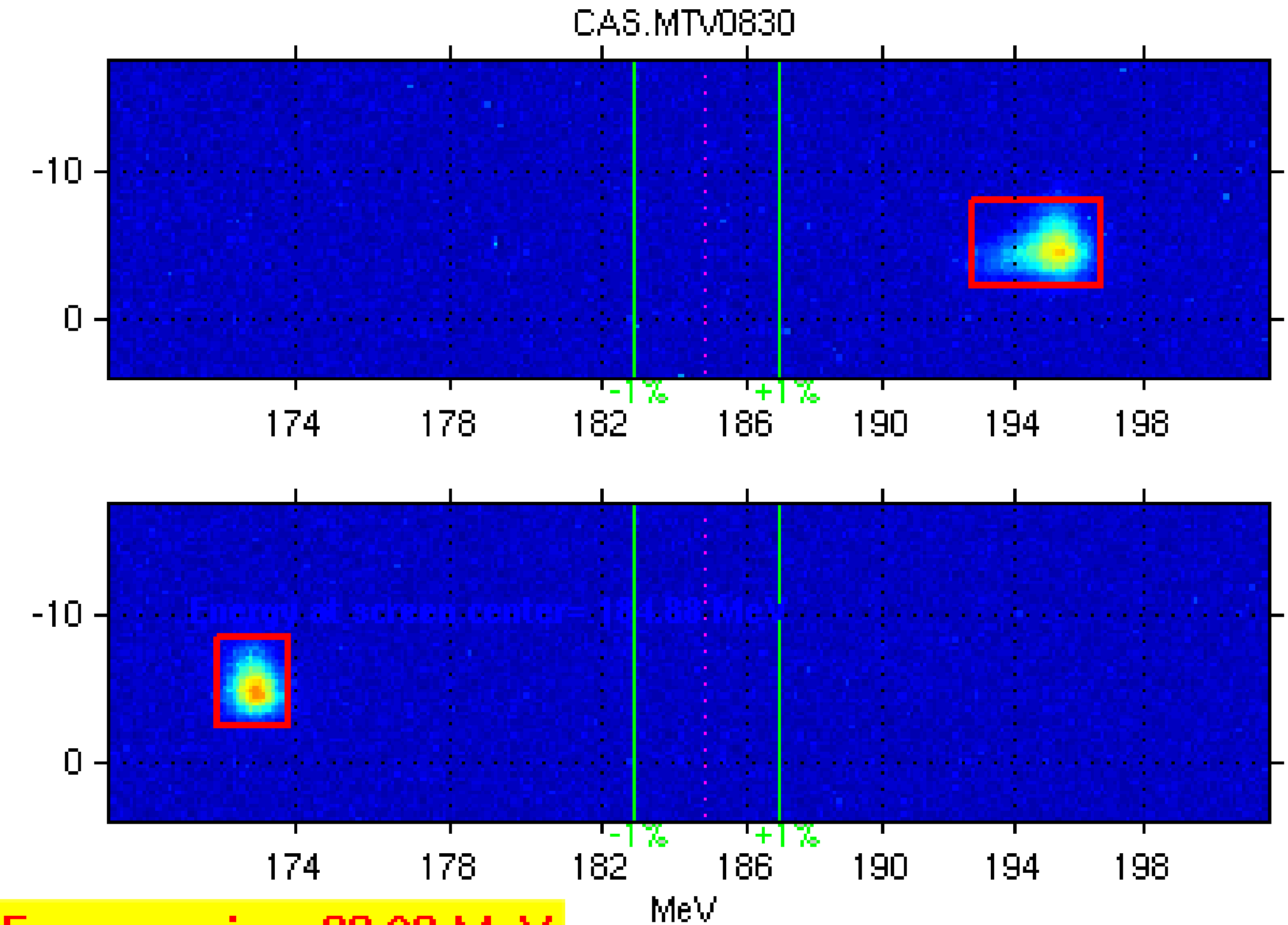
170.9 MeV (RF off - no drive beam)

- Observe beam spot on screen in spectrometer line
- Turn drive beam on and off
- Vary the RF phase of Califes



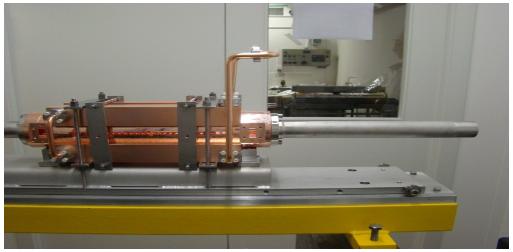
From A. Palaia, ILWC2010, data from 19.August 2010

106 MeV/m



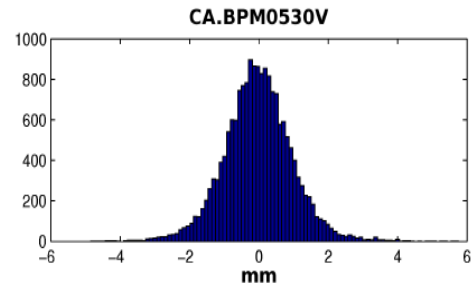
Energy gain = 23.08 MeV

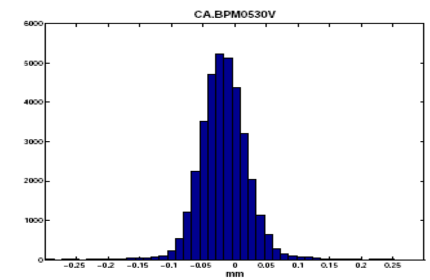
From R. Corsini, 6th CLIC ACE

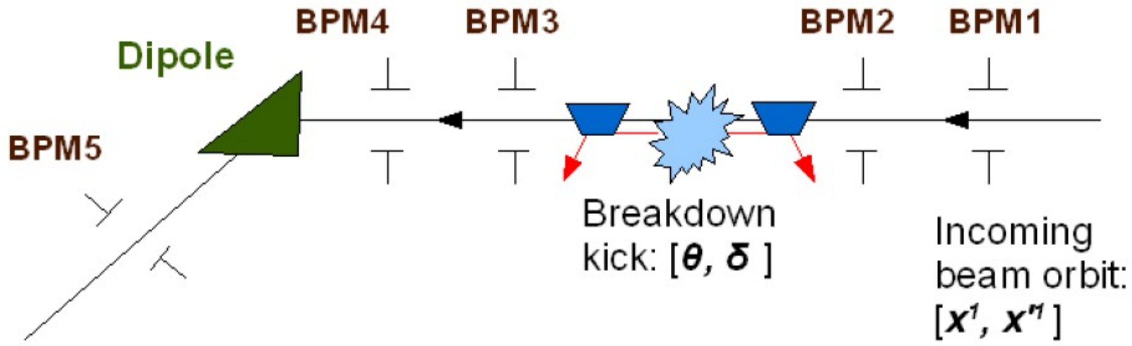


What's next?

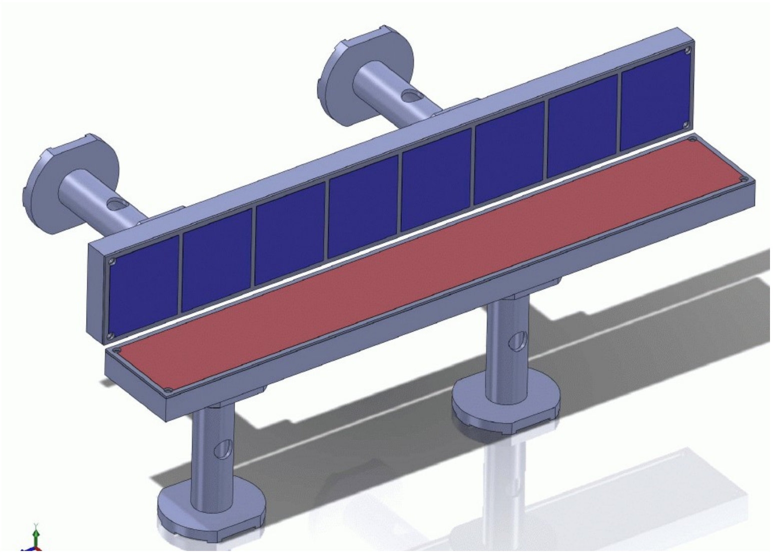
- Need to debug the system much more
  - Calibration
  - BPM resolution
  - Beam optics
- Beam kicks from breakdown

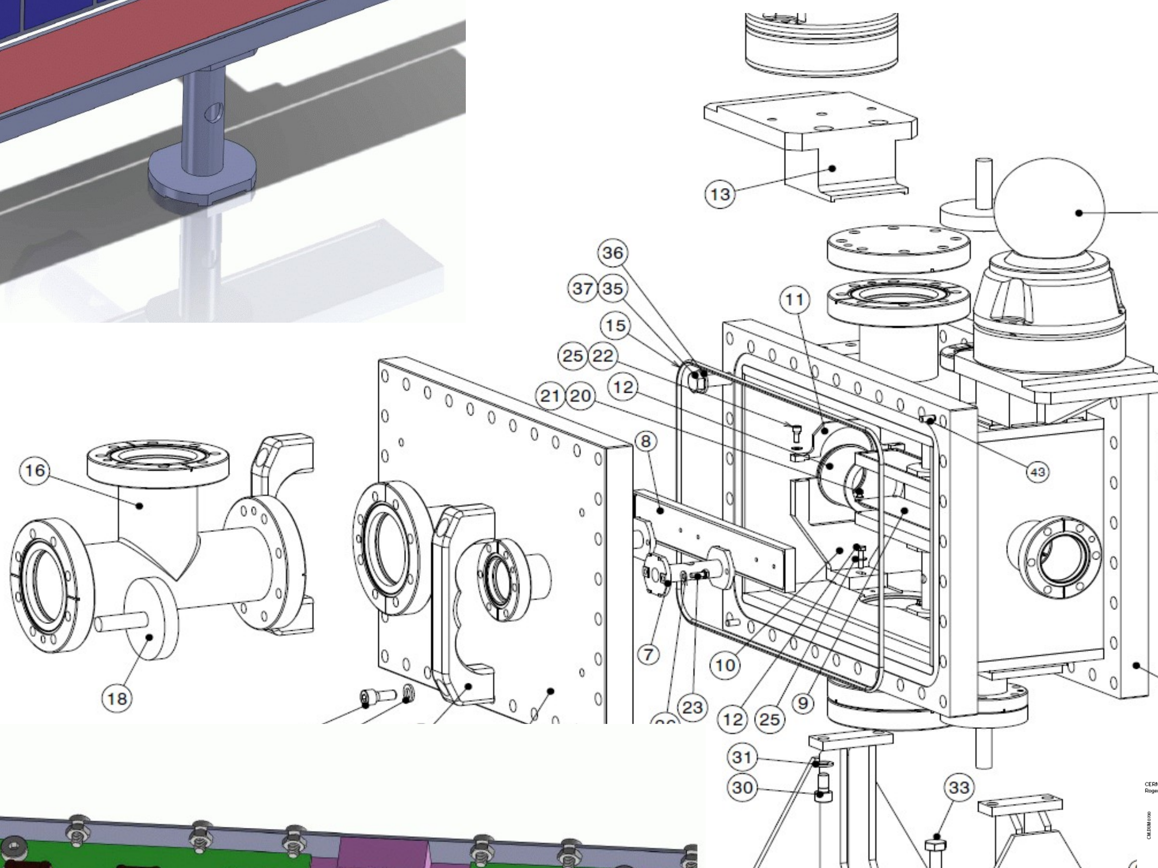


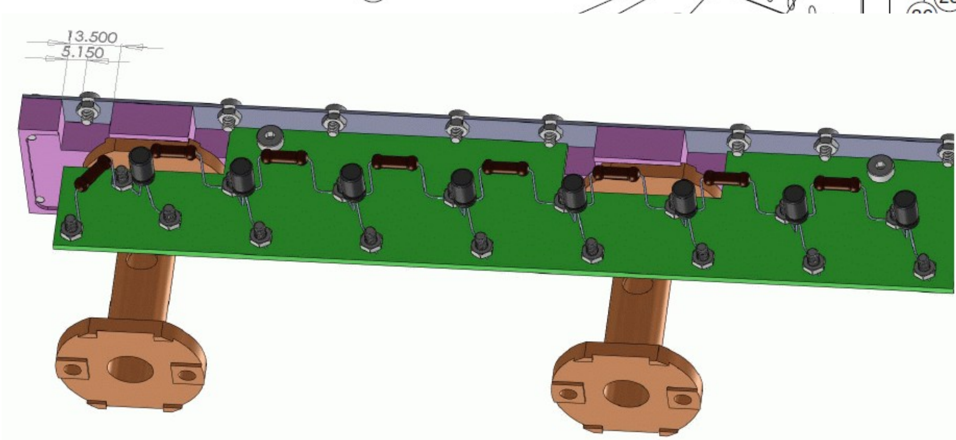


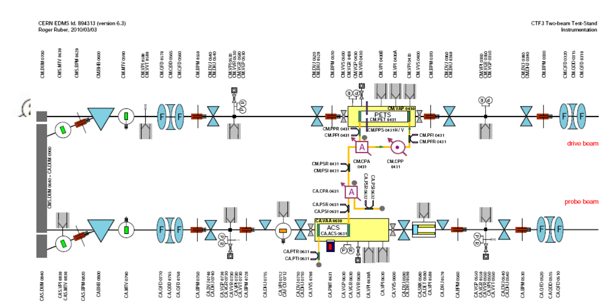


Flashbox



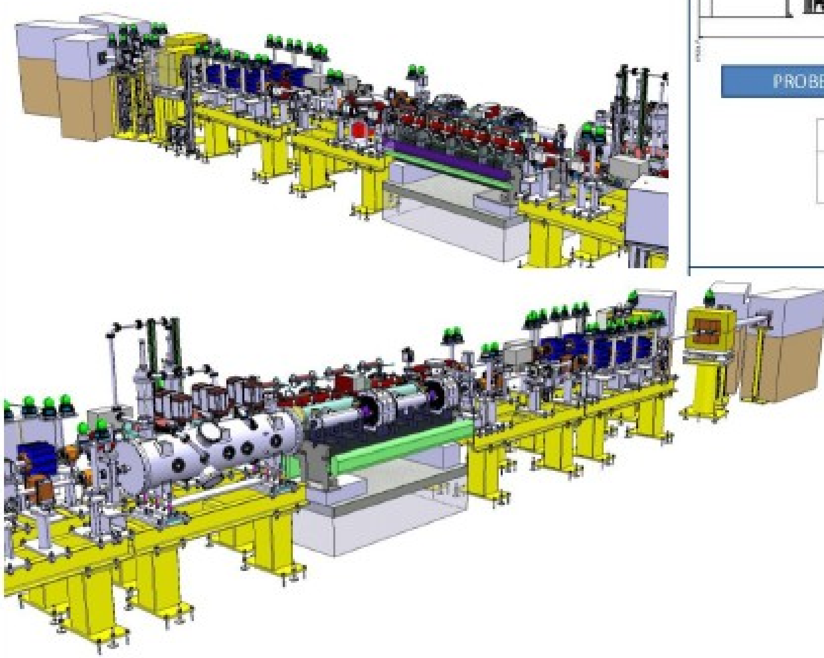


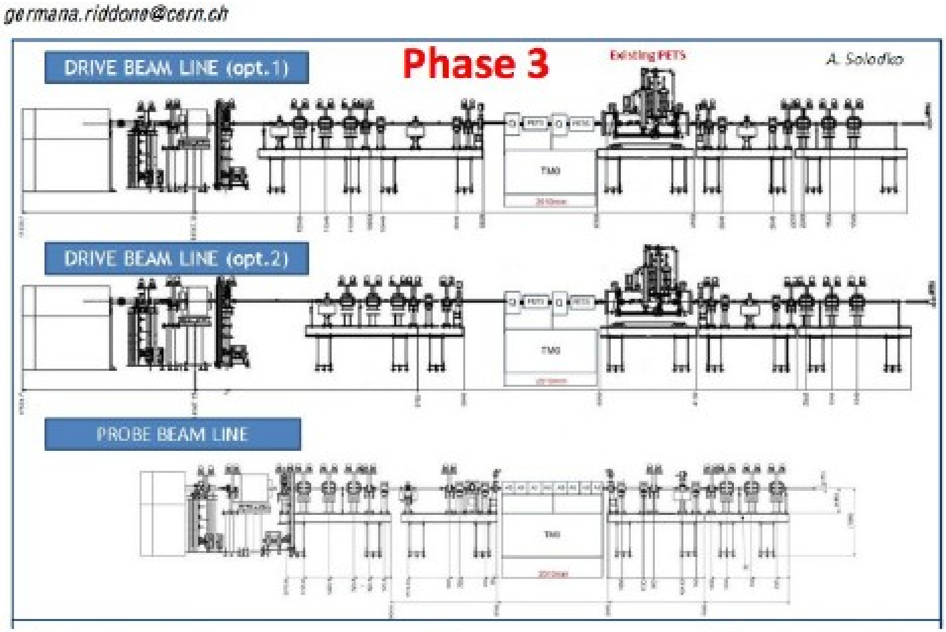


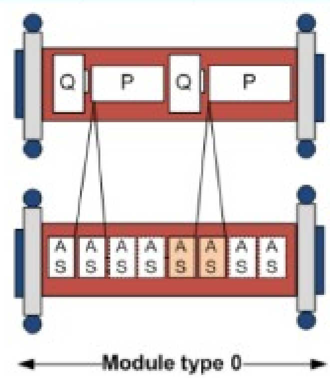


CLIC Module Tests (2012 or so)

- Module type 0
  - double length PETS
  - 8 ACS (4 powered)







Roger Ruber (Uppsala University) - Two-beam Test Stand   CTF3 Committee Meeting (19-Aug-2010)   5

Other CLIC-related Activities at Uppsala University

- Norduclic
  - joint venture with Helsinki, Oslo, Århus
  - ACS design, manufacture and testing
  - focussed on the 12 GHz standalone test-stand
  - Fast vacuum measurements
- FP7-EuCARD
  - HV breakdown inside scanning electron microscope
  - Upgrade of TBTS (Flashbox)

Conclusions

- Motivated some of the R&D issues for CLIC and how the Two-beam Test Stand plays a central role in that context.
- Recently achieved the design gradient for the acceleration structures of 100 MV/m.
- There's fun ahead for us
  - beam kicks and flashbox (and 12TS)
- It's a pleasure to be here. Thanks for the opportunity to talk about our work.