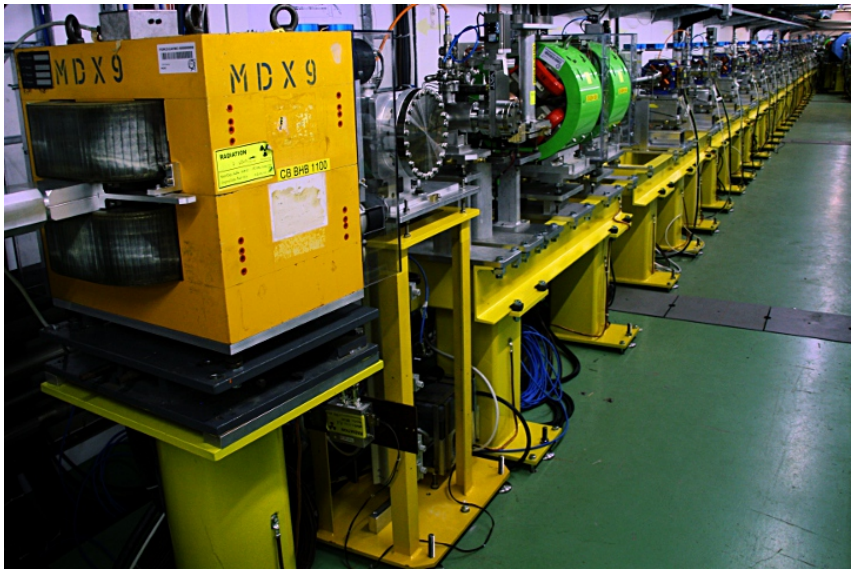
The Test Beam Line of the CTF3

Reidar Lunde Lillestøl
with Erik Adli, Steffen Döbert, Maja Olvegård and Anne Dabrowski

CERN / NTNU

IWLC 2010

Motivation - feasibility



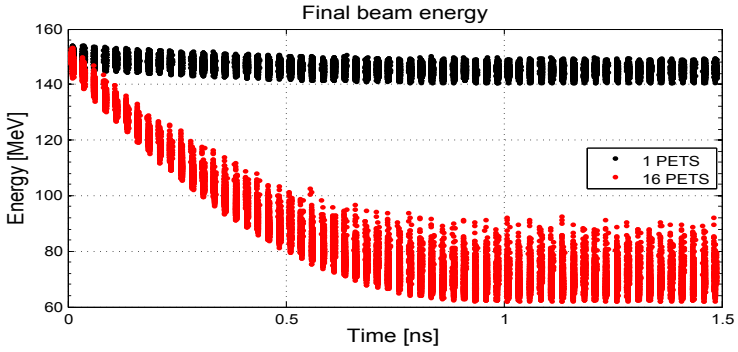
- First prototype of the CLIC decelerator
- Demonstration of stable beam transport for a heavily decelerated beam
- Will have 16 PETS at nominal operation, extracting 55 % of the energy

Power production experiments

- The fundamental mode for power production (monopole, 12 GHz) is by definition independent of beam position offset. Higher-order modes depend on the beam position offset, and can give perturbations on the measured field.
- Correlation studies between beam position offset and power production

Beam physics

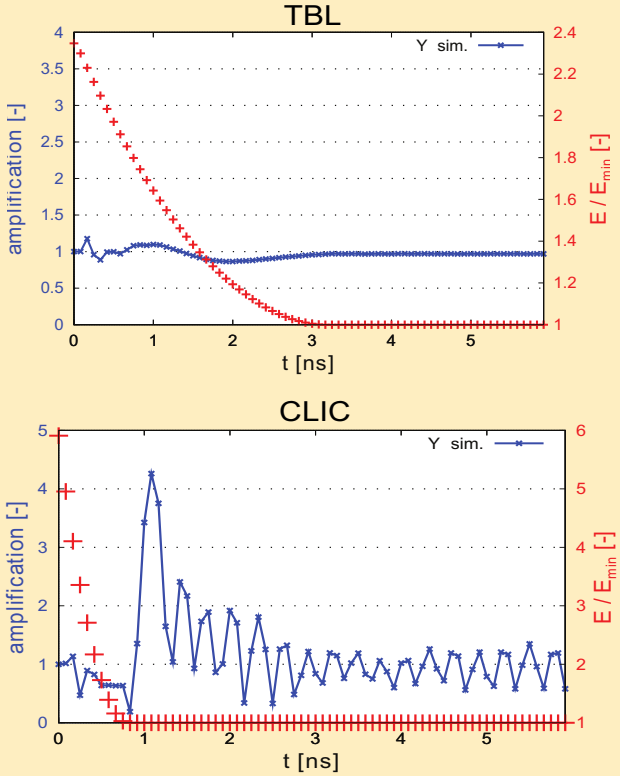
- Mean energy loss of 5.2 MeV per PETS at nominal current (28 A)
- Large energy spread – lattice must be scaled to the most decelerated particles



- Adiabatic undamping will increase the average particle action by a factor 2.2
- Envelope growth: $r = 7.6$ mm at the end, filling 2/3 of the aperture (perfect machine and injection)

Dipole wakes

Wake growth factors for pointlike bunches shown for TBL and CLIC. Much smaller amplification in TBL.

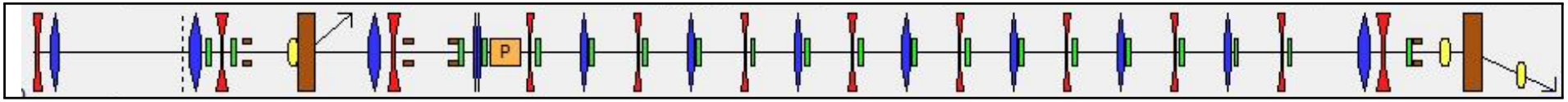


TBL parameters

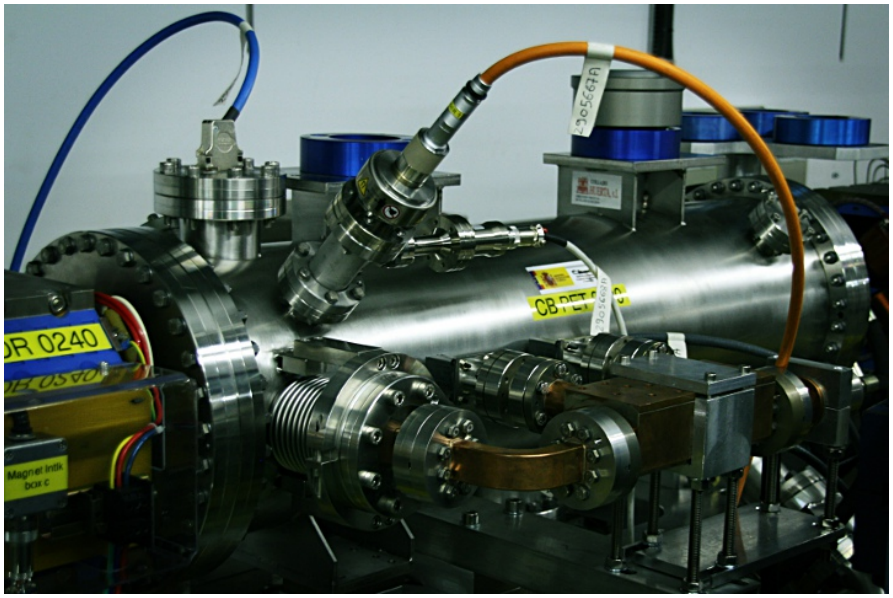
Nominal parameters for the TBL and CLIC:

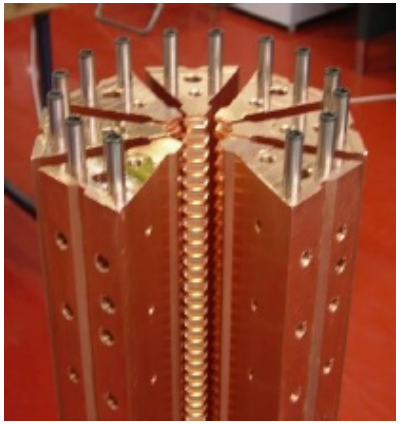
Parameter	TBL	CLIC	Unit
Initial energy	150	2,370	MeV/c
Power production per PETS	139	135	MW
Energy loss per PETS	5.2	1.4	MeV
Number of PETS	16	1,491	-
Length of PETS	0.8	0.2	m
Energy extraction efficiency	55	90	%
Average current in pulse	28	101	A
Pulse length	140	240	ns
Bunch form factor	0.97	0.97	-
Repetition rate	1	50	Hz
Normalised emittance	150	150	μm

Current TBL lattice extracted from the MAD-X model:



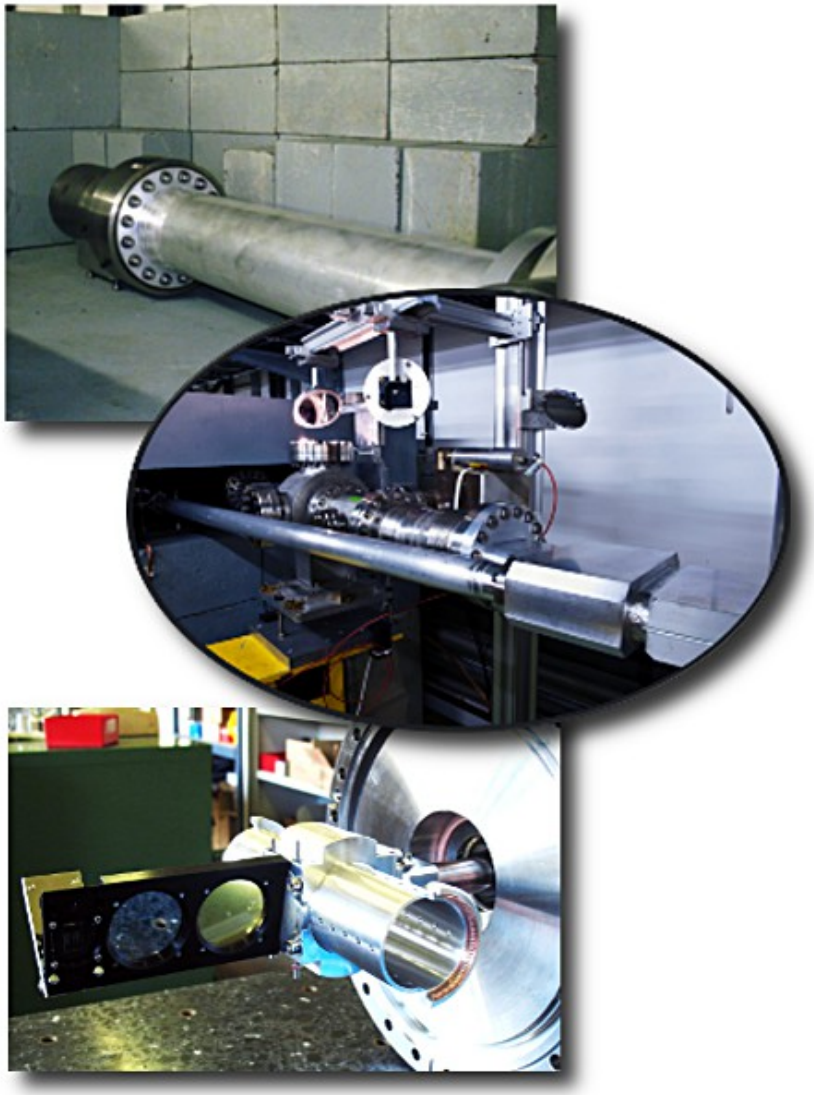
Installed PETS





- First PETS produced by CIEMAT, Spain
- Two output arms allow for measurements of asymmetric fields produced by wakes
- Forward power measured with an IQ demodulator. Reflected power measured with diodes
- PETS field is coupled out and the signal is attenuated by ∼95 dB before the electronics
- Future PETS will have one arm each as only the power amplitude is interesting in transport studies

Installed diagnostics

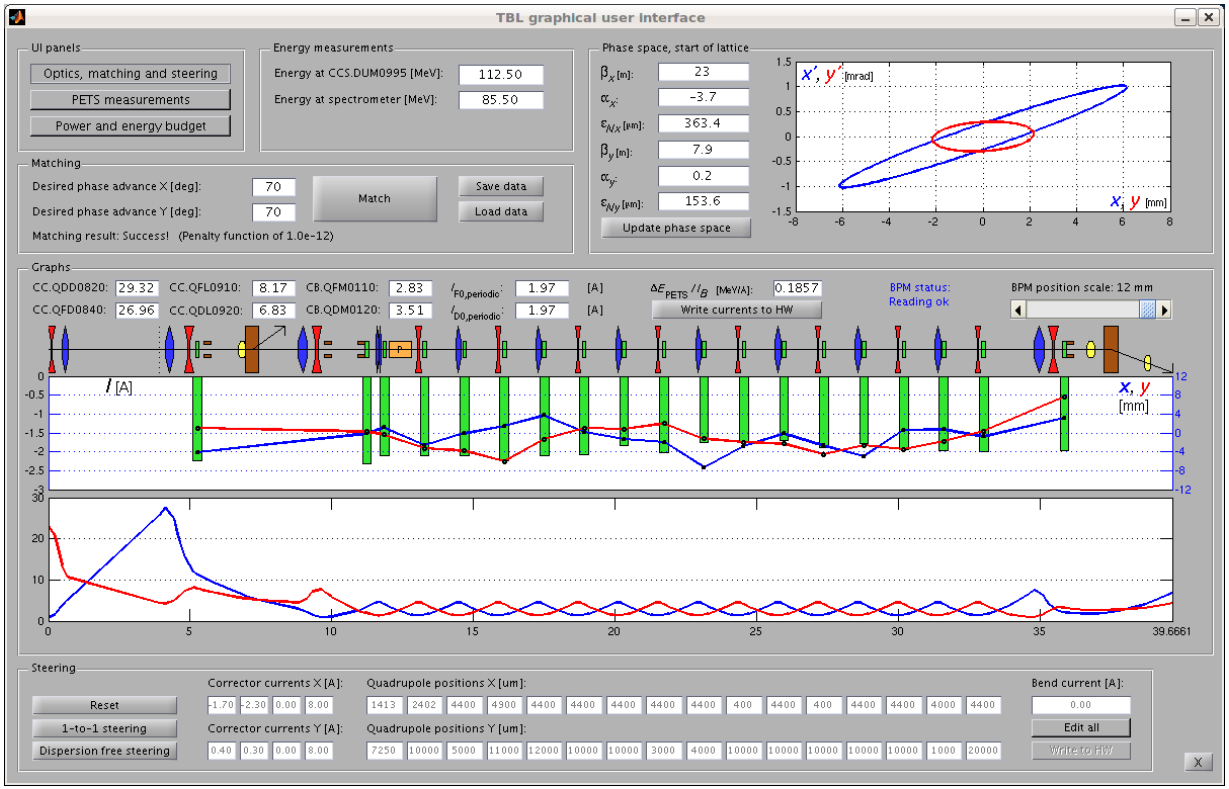


- 17 BPMs
- 2 OTR screens for transverse profile/emittance measurements (start and end of the line)
- 2 OTR screens for high resolution spectrometry (start and end of the line)
- Slit dump for time resolved spectrometry at the end of the line

See talk

A. Dabrowski: *CTF3 Instrumentation*
Wednesday 16:10 (WG 6)

TBL Graphical user interface



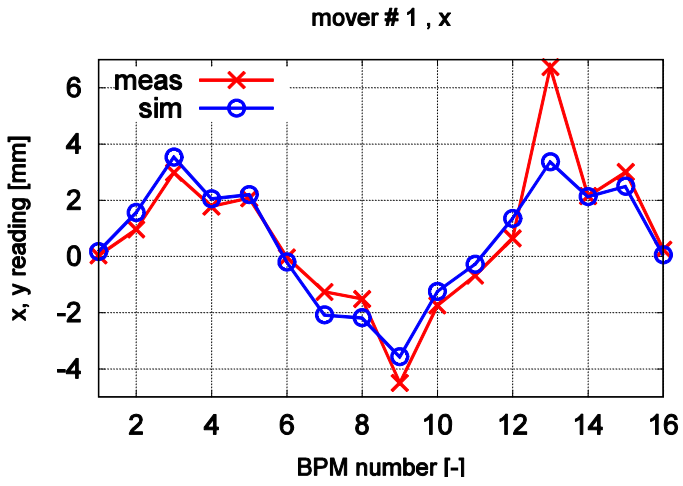
- Commissioning: Orbit, phase space plot
- Matching: Interface to MAD-X, can automatically set the quadrupoles
- Steering: Reads and writes to all correctors and quadrupole movers; automatic steering interface with Placet (not yet implemented)

TBL running this year

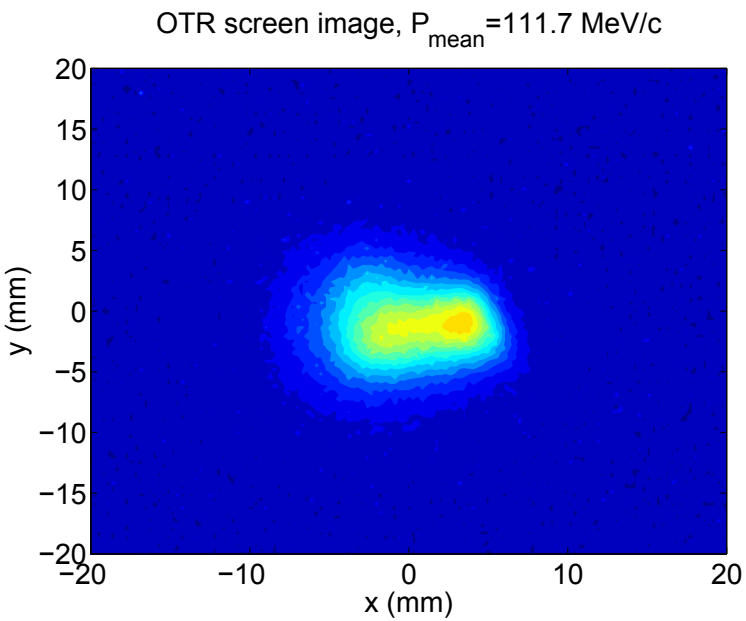
- 6 dedicated TBL days
- However, TBL has been used more than this for conditioning the machine (indirect measurement of the form factor, phase variation seen from PETS rf signals)

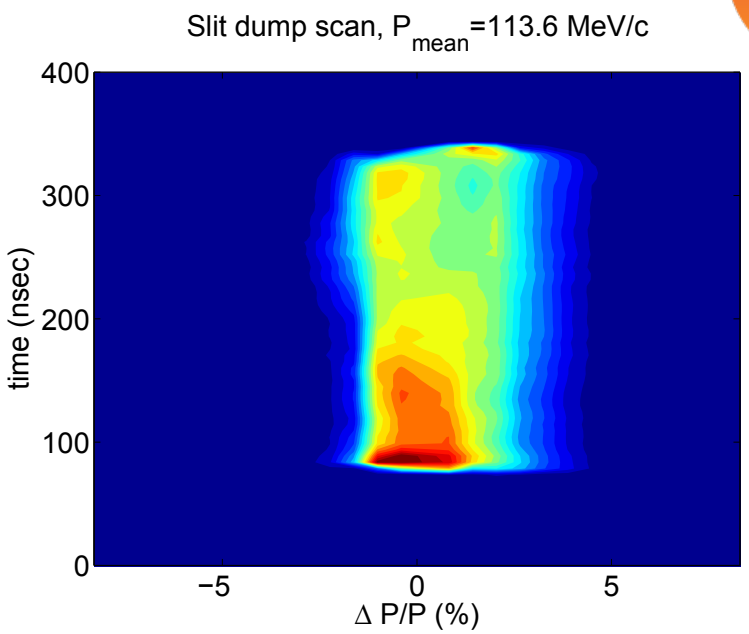
- Mainly either uncombined or factor 4 combined beam
- Beam current of 2.5 to 9 A
- Power production experiments with 1 to 16 MW produced

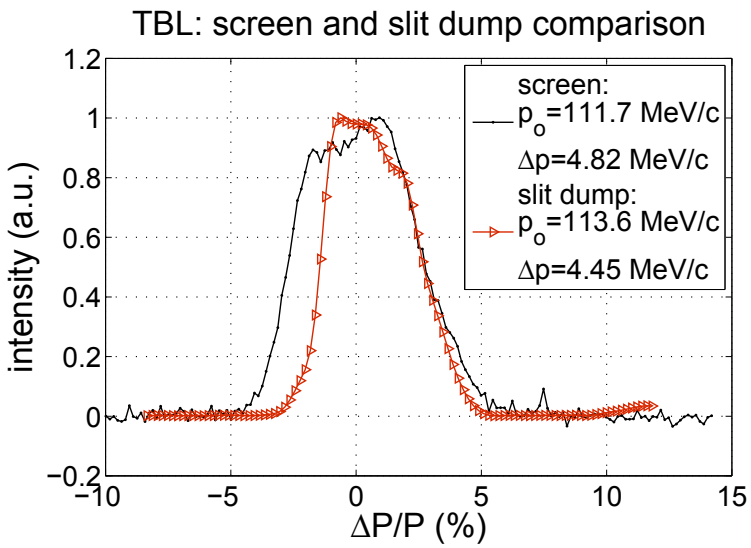
- Kick measurement:
  - 16 quadrupoles mounted on movers
  - First quadrupole moved by 0.5 mm in the horizontal direction
  - Good agreement between measured trajectory and the theoretical optics model



Diagnostics



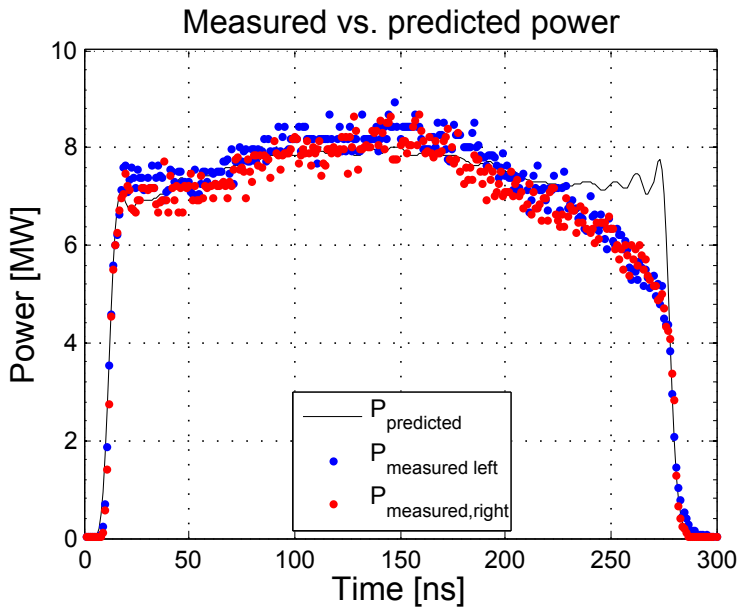


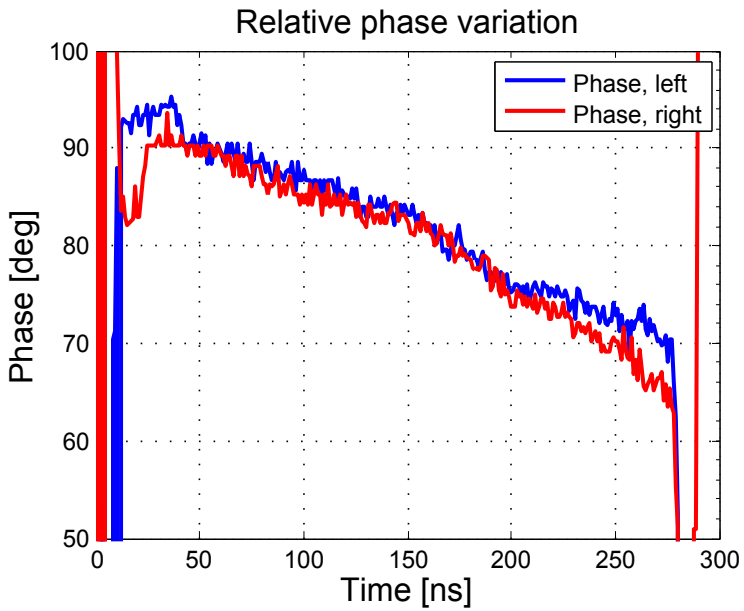


- Measurements from 23/09/10
- Factor 4 combined beam with 8.5 A current
- Quite good consistency between the two measurements

M. Olvegård

Power production





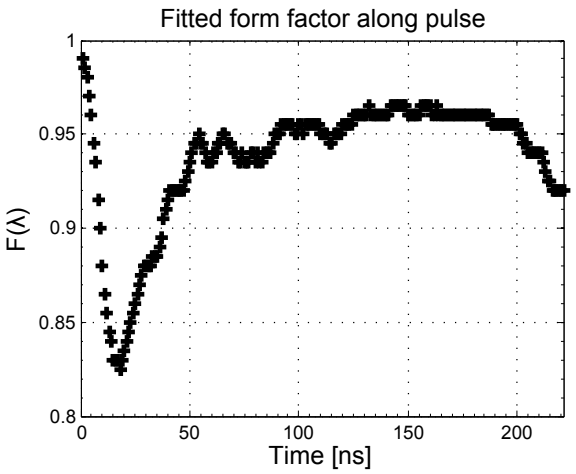
- Measurements from 23/09/10
- Factor 4 combined beam with 8.5 A current
- Total power for both PETS arms is around 16 MW
- IQ demodulator used for power measurements
- Linear phase change of 20°

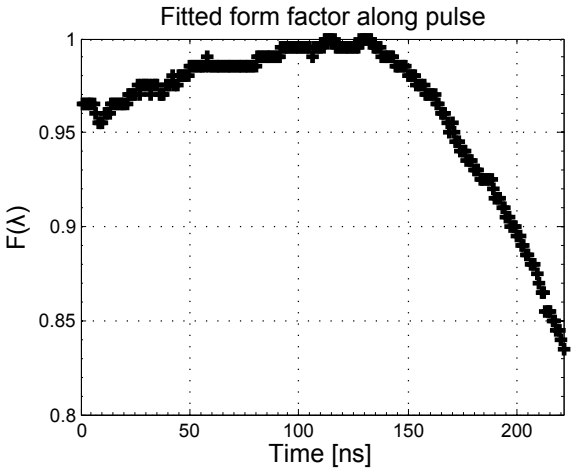
Prediction

$$P = \frac{1}{4}(R'/Q)\frac{\omega_{\mathrm{rf}}}{v_g}L^2_{\mathrm{PETS}}I^2F^2\eta^2_{\Omega,\mathrm{PETS}}$$

Curve fitted with $F = 0.97$. Generally very large form factor, maybe because of calibration errors

Form factor variation along the pulse





Measurements from 01/09/10

- Around 7 A current (factor 4 combination)
- 14 MW rf power produced
- For each sample a form factor is fitted over 300 pulses by minimizing the error between predicted and measured power

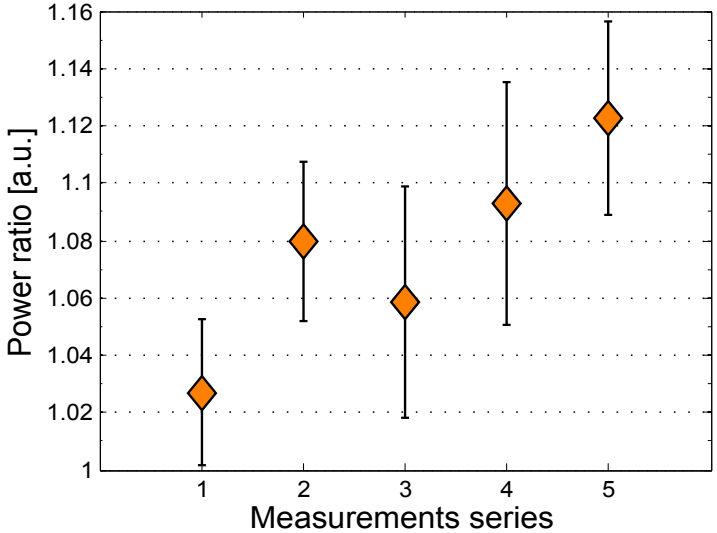
Measurements from 23/09/10

- 8.5 A current (factor 4 combination)
- 16 MW rf power produced
- Highest current and power this year (no beam time with good factor 8 combination)

By looking at the fitted form factor and the IQ demodulator phase, the available TBL PETS has also been used to condition the rest of the machine

Power production vs. beam position offset

- 5 measurements series with different offsets from the axis, with 300 pulses in each
- Ratio taken between left and right arm for each sample, then averaged for each pulse

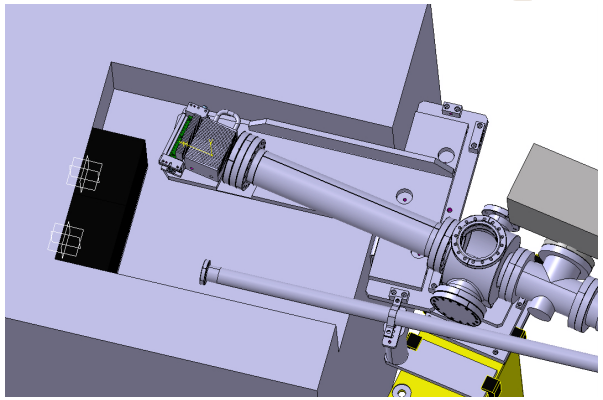


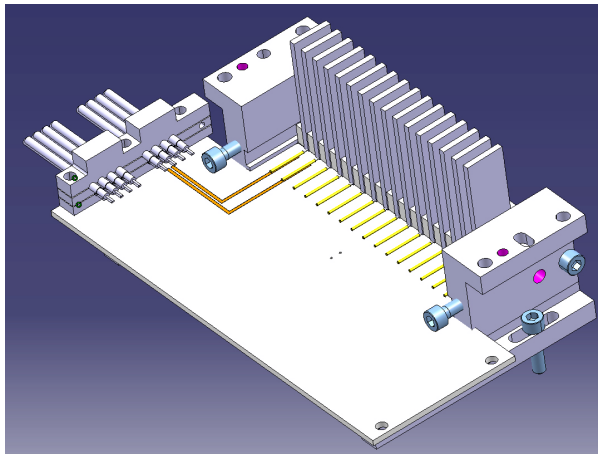
1. −5 mm H
2. −3 mm V
3. 0 mm
4. +2 mm V
5. +5 mm H

- Horizontal position (1, 3 and 5) appears to have an effect
- Need more data to conclude on this

New diagnostics

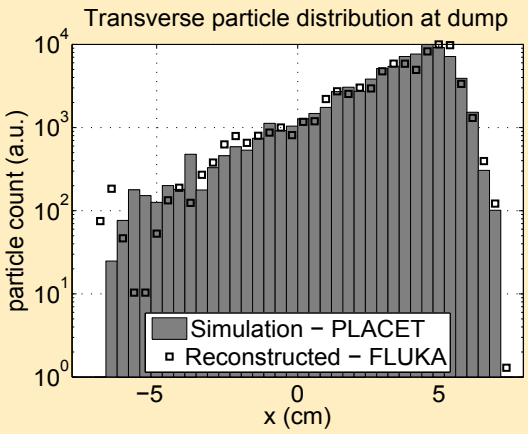
- Novel segmented beam dump for single-shot time resolved spectrometry
- Optical line and streak camera for bunch length measurements
- Beam loss monitors (hopefully)





M. Olvegård

Segmented dump specifications



- 32 channels, 32 tungsten segments
- Single-shot measurements for up to 6 PETS
- Time resolution: ∼5 ns
- Energy resolution: ∼2 %
- Energy precision: ∼5 %

Near-future plans

- Increasing beam current and improving the form factor
- 1 PETS installed in November
- Segmented dump installed in January
- A total of 4 PETS in January, then a total of 8 in summer 2011
- New streak measurements in CLEX in February
- 8 last PETS in 2012
- 12 GHz power production for structure conditioning
- Upgrade to a test facility relevant for CLIC TDR work

See talk

S. Döbert: *Report from TBL*
Wednesday 11:40 (WG 4)

See talk

R. Corsini: *Future Work and Upgrade of CTF3*
Thursday 16:40 (WG 6)

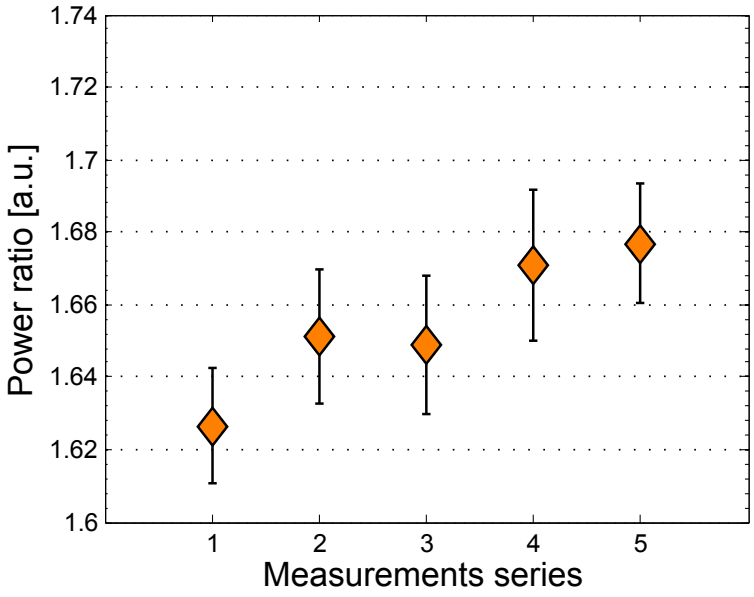
Conclusion

- Conditioning in progress – work with power production, beam transport, diagnostics
- A milestone for deceleration studies with 8 PETS (25 % deceleration)
- Feasibility demonstration can be started in 2011 and improved in 2012 with all 16 PETS
- Form factor fitted along the pulse but is generally not constant
- TBL can also be used to condition the rest of the CTF3 machine
- Seems to be a correlation between horizontal position and power in each PETS arm, need more data to conclude
- Nominal parameters (beam current of 28 A and a constant field form factor of 0.97) needed to produce 135 MW
- Looking forward to a good factor 8 combined beam!

Extra slides

Power production vs. beam position offset (ii)

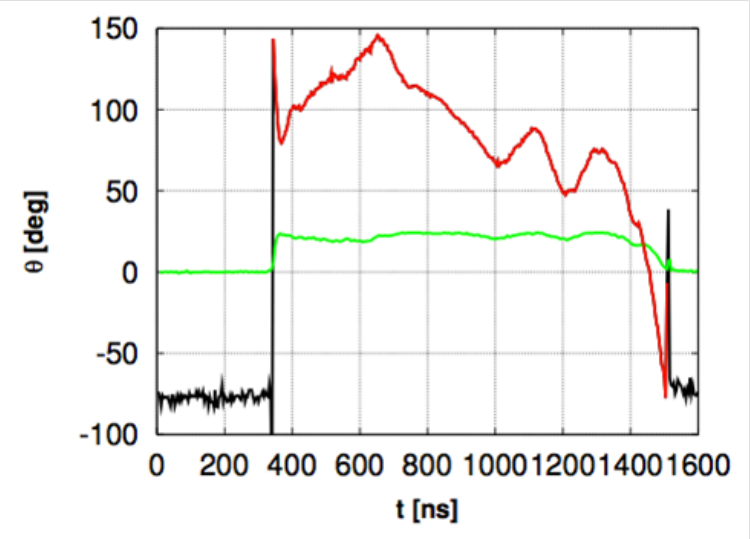
- Same calculation done for 01/09/10 (another day with old calibration factors)
- Difference in the horizontal plane here as well
- Smaller difference (3 %) here compared to the other series (10 %), but this is consistent with smaller offsets from this day

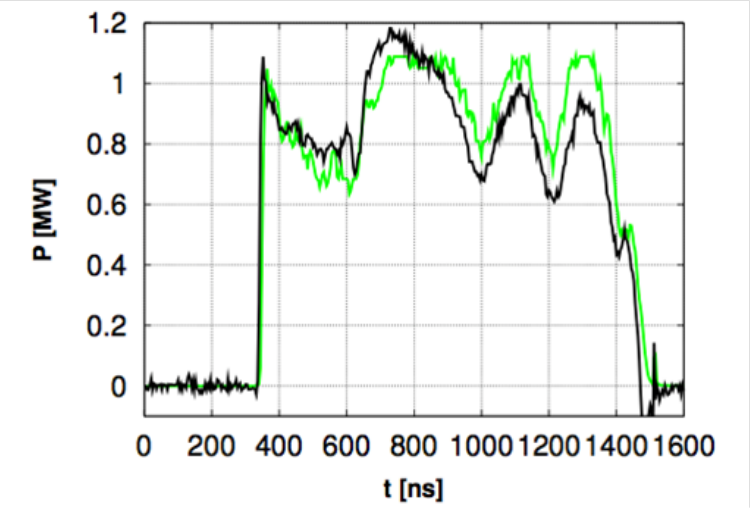


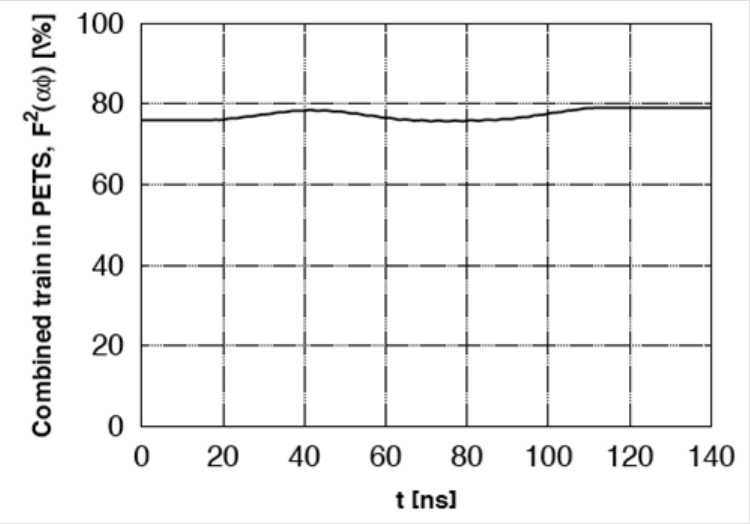
1. −2 mm H
2. −2 mm V
3. 0 mm
4. +2 mm V
5. +2 mm H

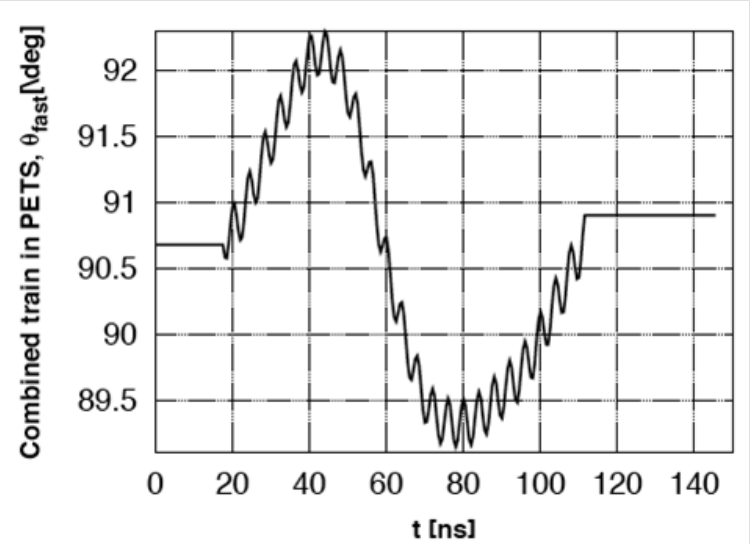
Some observations from CTF3 (i)

Example before operator optimization (end of September 2010)



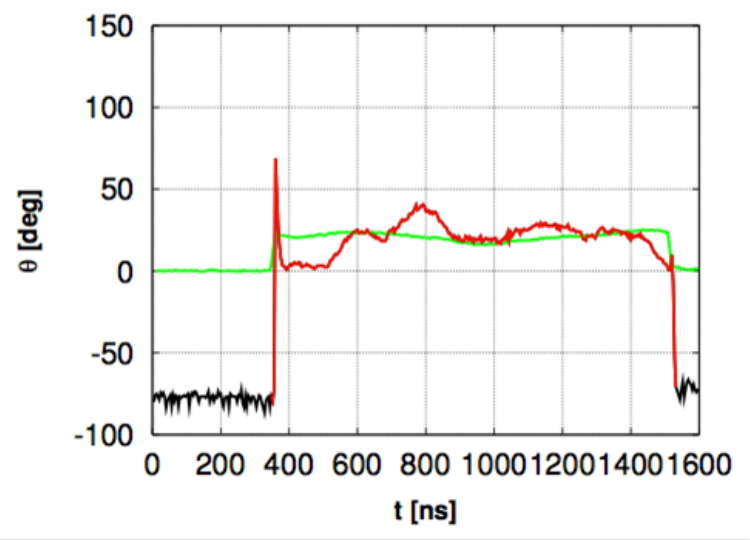


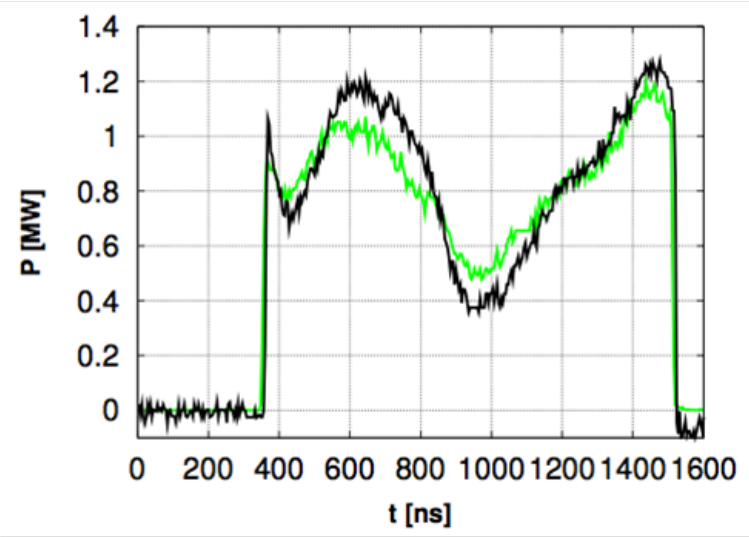


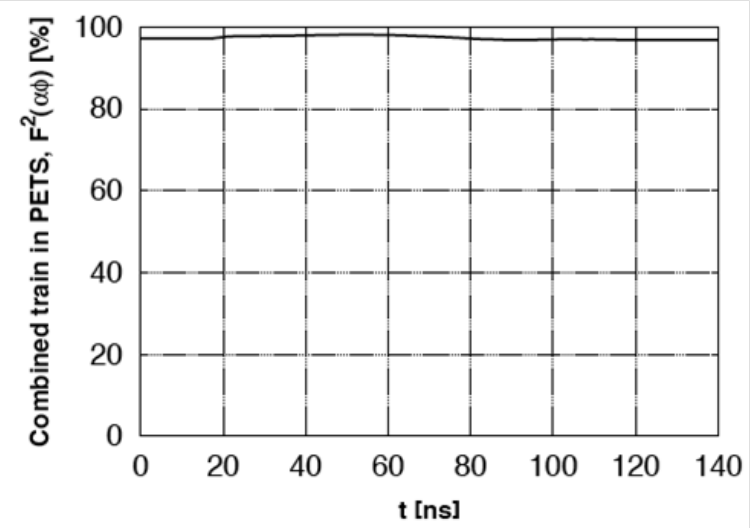


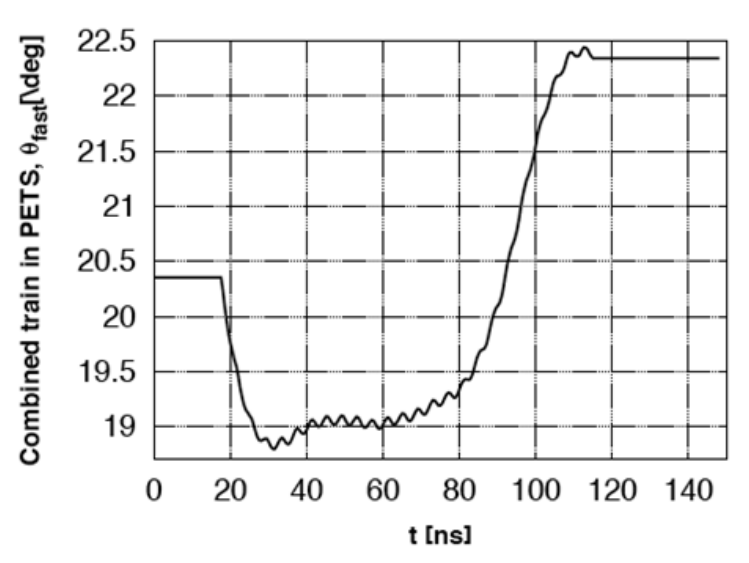
Some observations from CTF3 (ii)

Example after operator optimization (October 7, 2010)



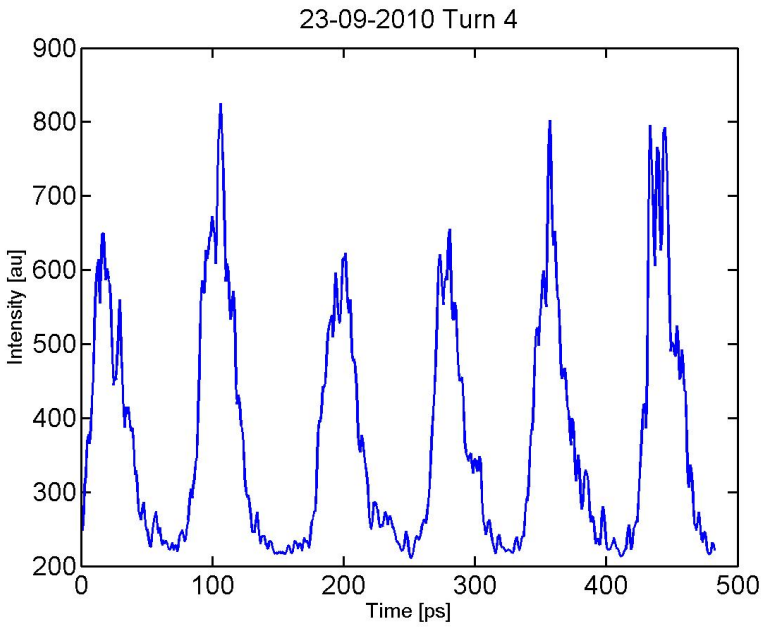






Streak measurements

Measurements from 23/09/10, from turn 4 in the combiner ring



Anne Dabrowski