First Year of Operation at the Two-beam Test Stand

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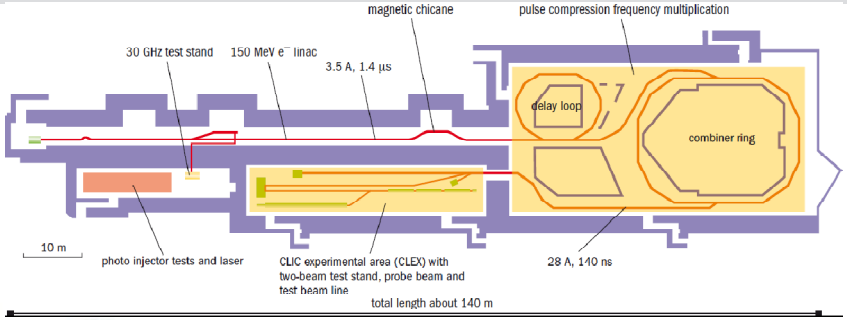
for the TBTS Team

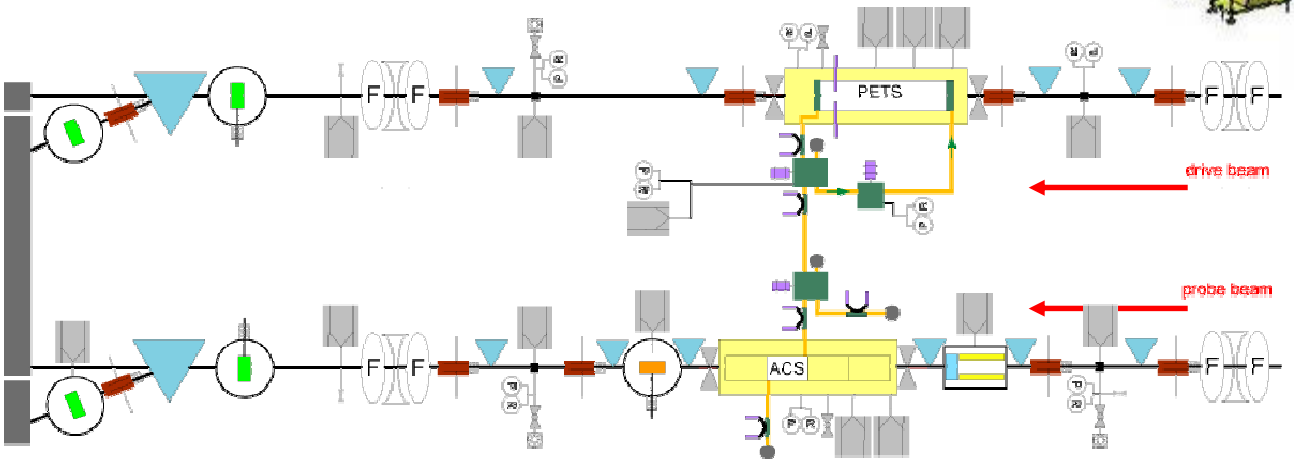
CLIC09 Workshop

13 October 2009

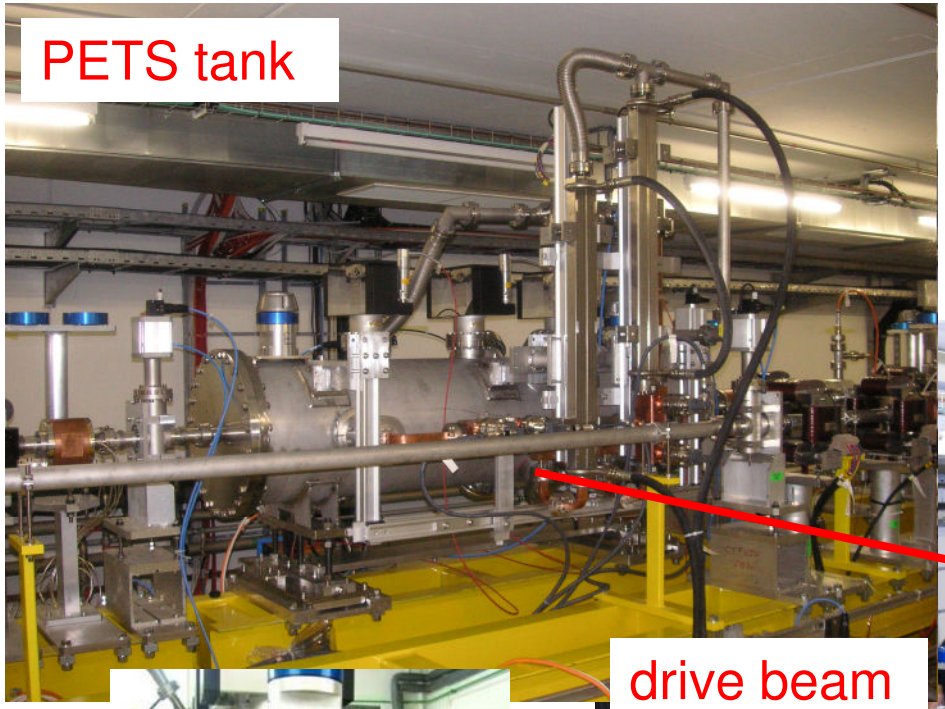
Two-beam Test Stand Layout

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

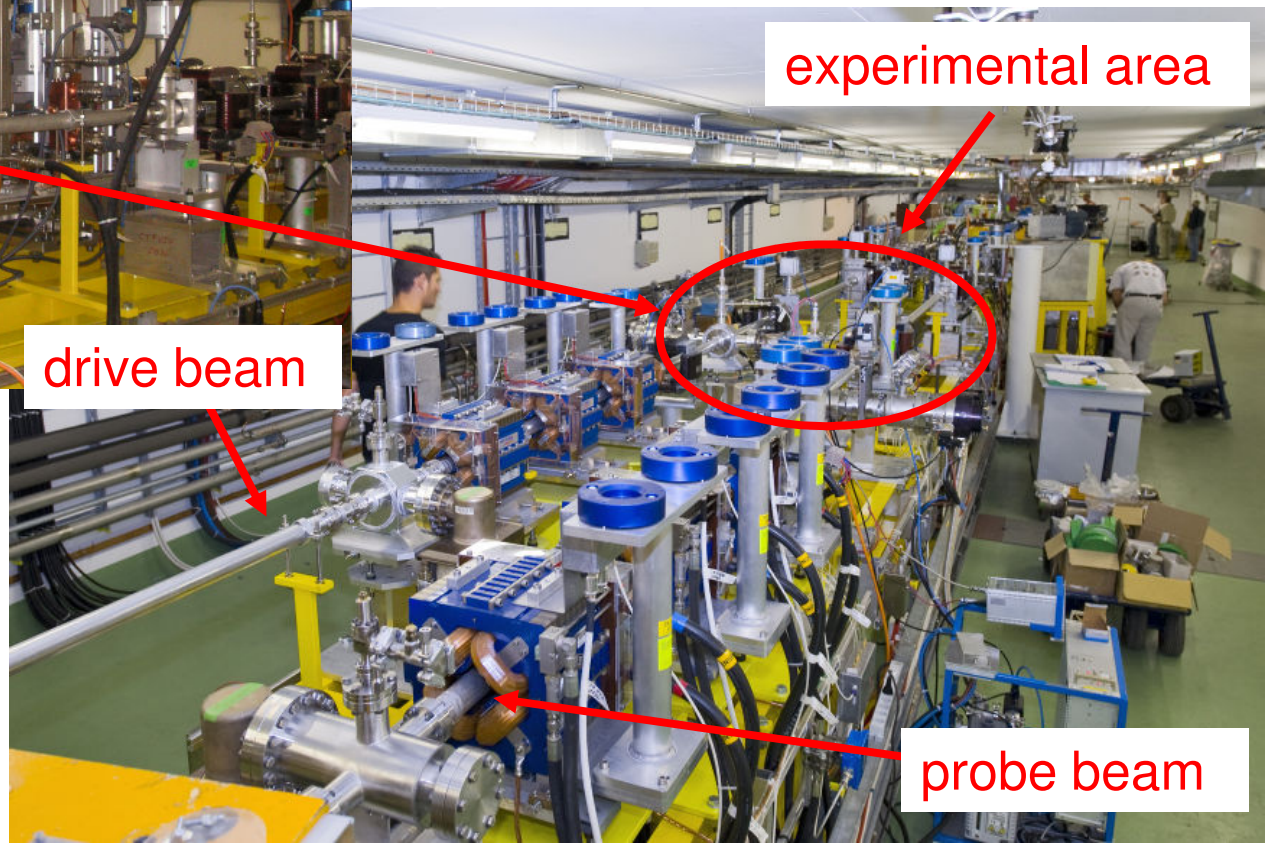




Drive Beam Line Commissioning

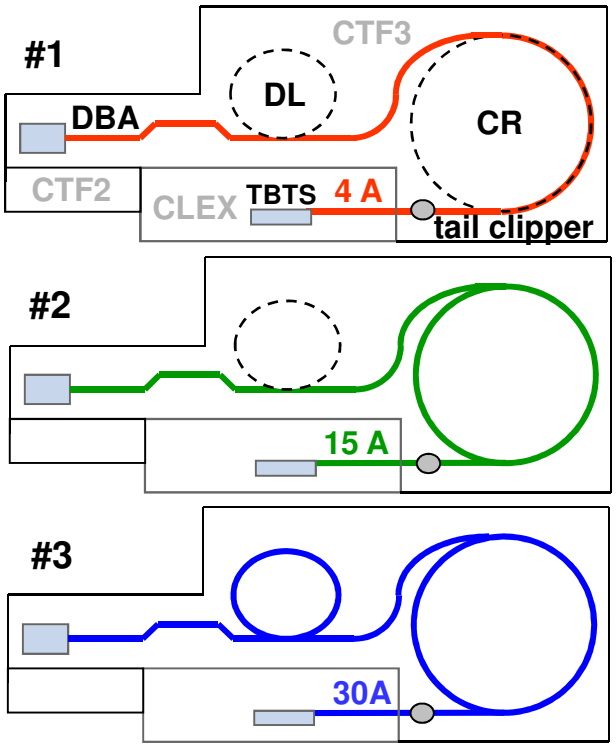


- First beam on 3rd Sep. 2008
- PETS installed October
- First beam in PETS 14 Nov.



Drive Beam Generation

	Mode	#1	#2	#3
Recombination		-	x4	x8
Current	[A]	4	14	28
Pulse length	[ns]	500	240	140
Frequency Linac	[GHz]	3	3	1.5
TBTS	[GHz]	3	12	12
PETS power	[MW]	5	61	280



NOTE:

- PETS length 1 m (0.215 m in CLIC)
- To adjust the pulse length,
  a tail clipper is installed between CR and TBTS
- To increase power at low current long pulse length,
  PETS equipped with RF recirculation loop

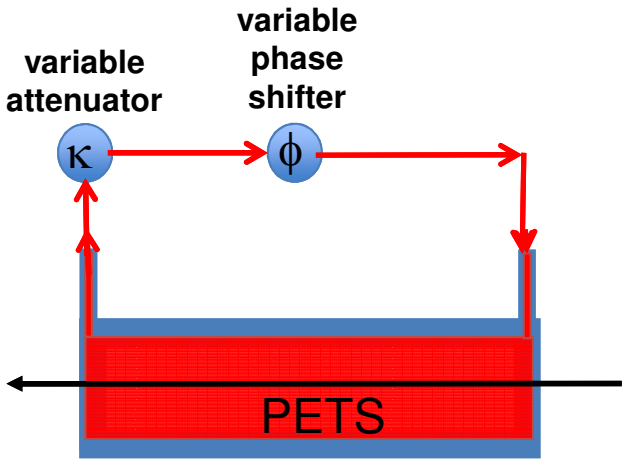
PETS Power Recirculation

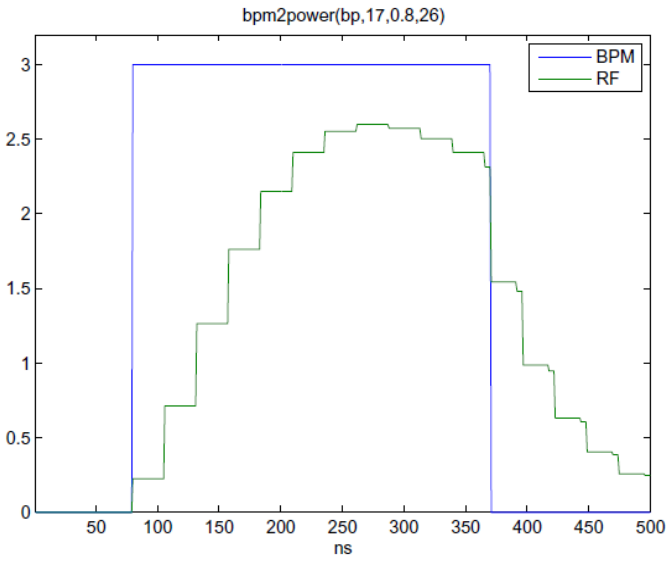
- Electron bunch generates field burst
- Field burst returns after
  - roundtrip time $t_r = 26$ ns
  - attenuation $g = e^{-\alpha}$
  - phase φ
- Output after n+1 turns $P \propto c_{cal}^2 E^2$

$$E_{n+1} = E_n g e^{i\varphi} + c_{I2E} I$$

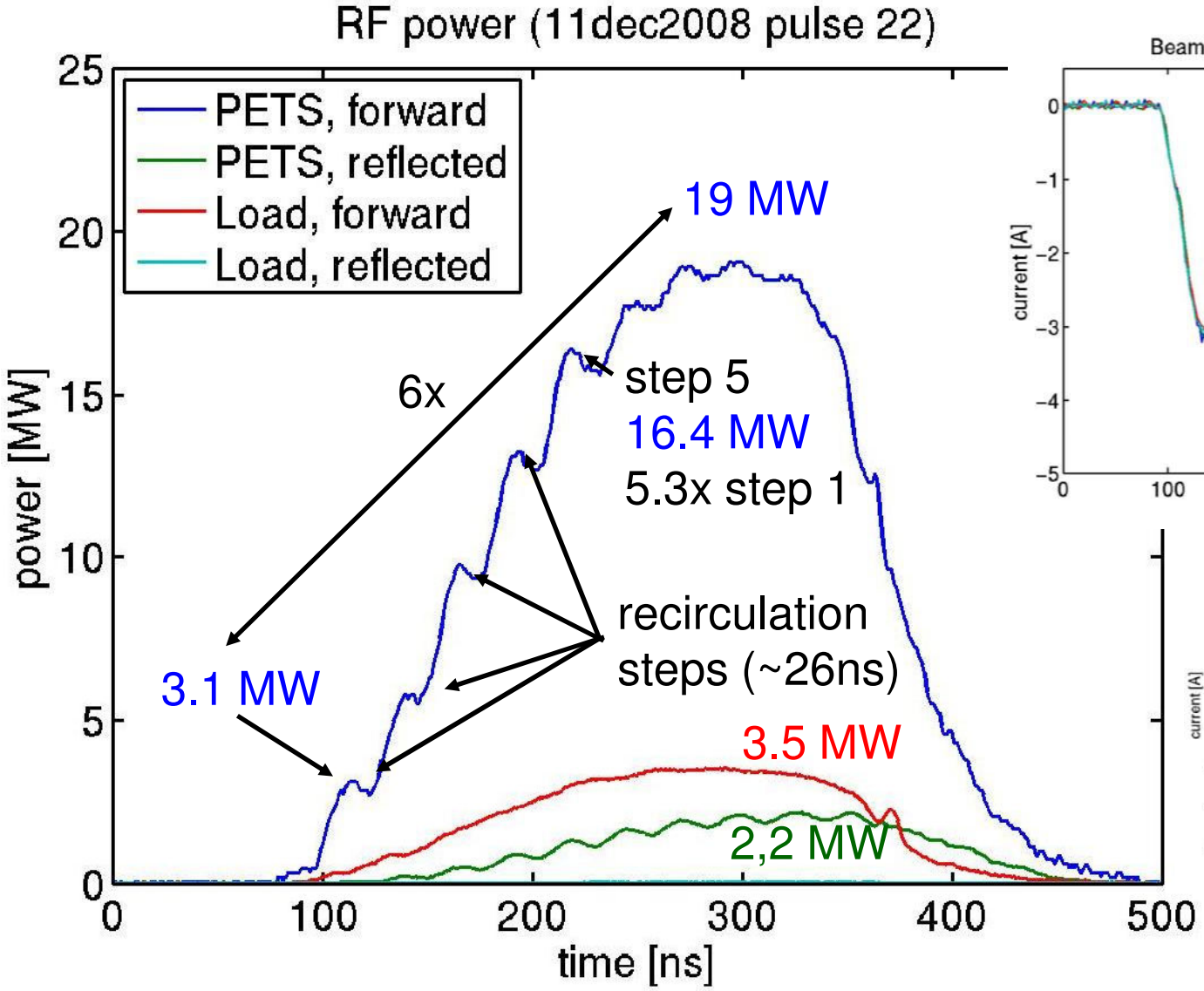
$$E_n = E_0 g^n e^{in\varphi}$$

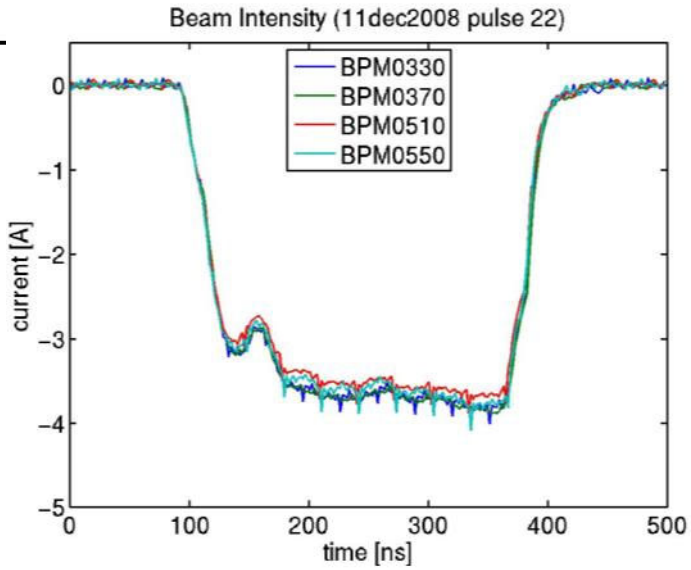
- Accurate prediction generated power
- c_{cal} from bunch length, coupling, ohmic efficiency → data fit
- 180° phase shift kills recirculation

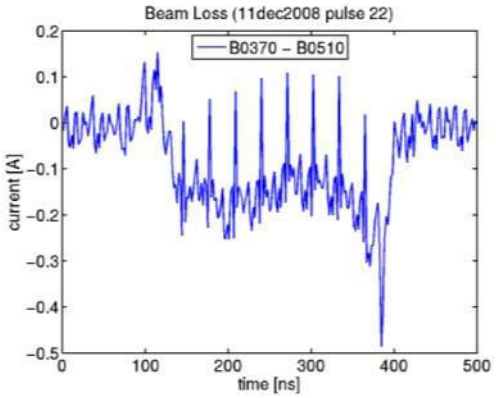




Power Production with Recirculation



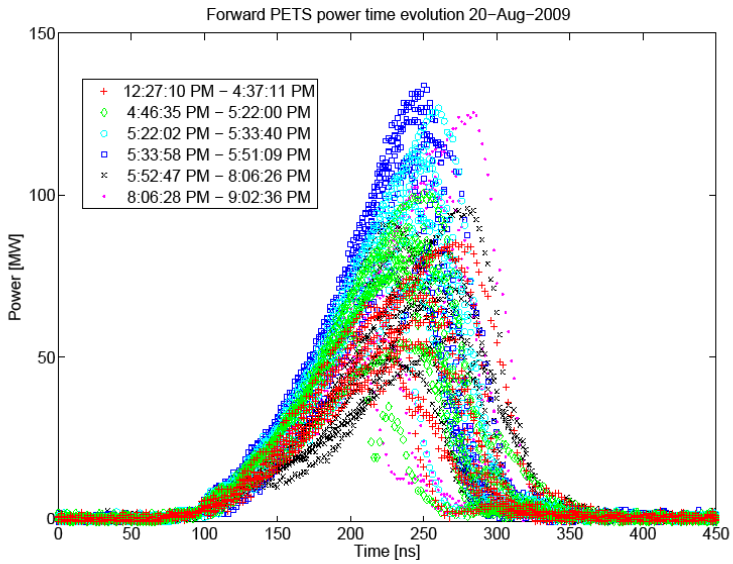


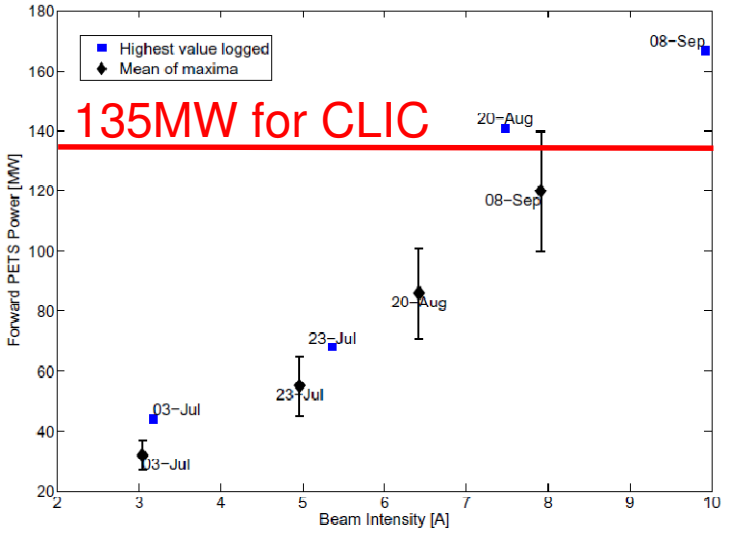


12GHz PETS Conditioning

- Run 0
  November/December 2008:
  - ~28 h beam time
  - Mode 1: 1.8 A, 5.2 MW
  - Mode 2, 2xCR: 5.3 A, ~30 MW
- Run 1
  July/August/September 2009:
  - ~60 h beam time, 2x10^5 pulses
  - Mode 2, 4xCR: ~10 A, >170 MW

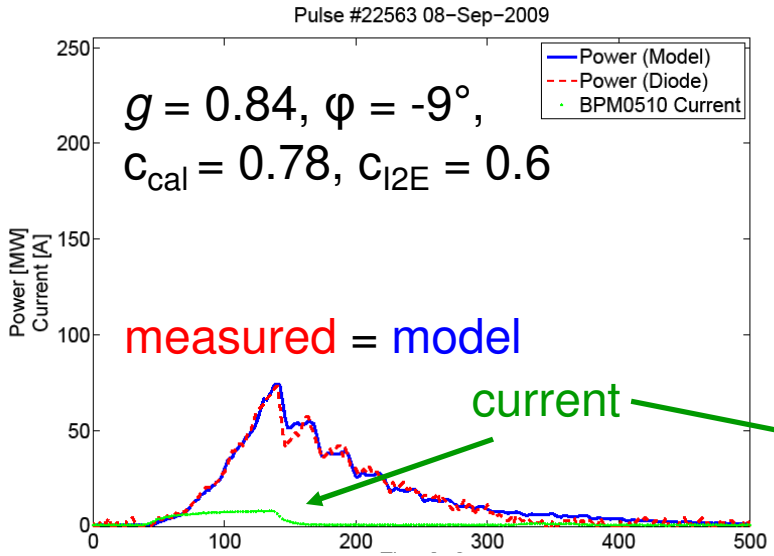
→ **reached CLIC nominal power**

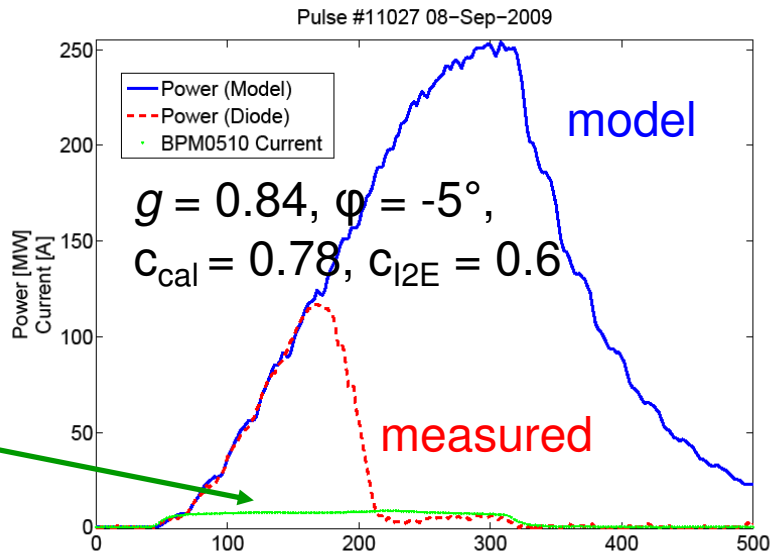




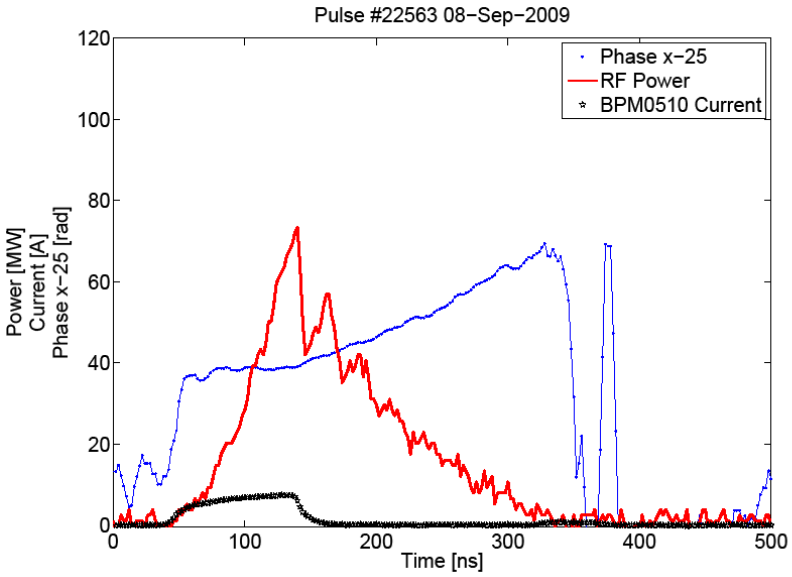
Details Thursday 09:50 (WG4: RF structures)

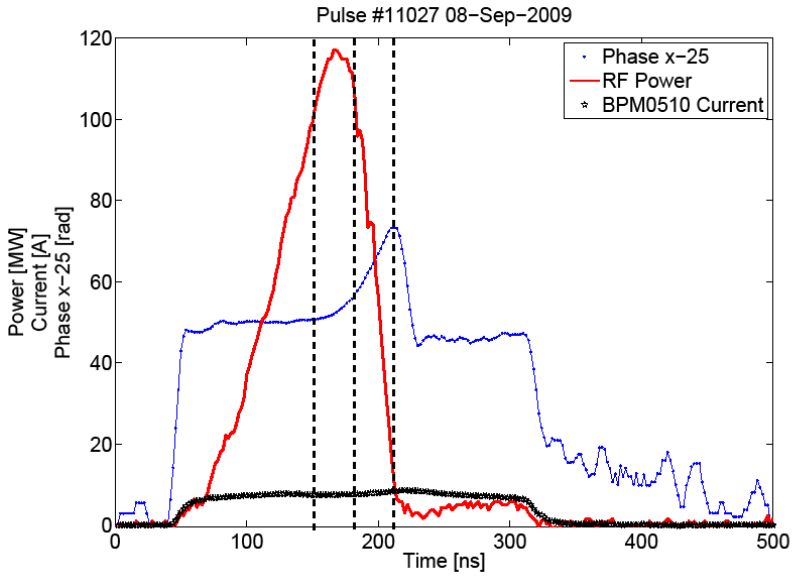
Power and Phase as Breakdown Indicators





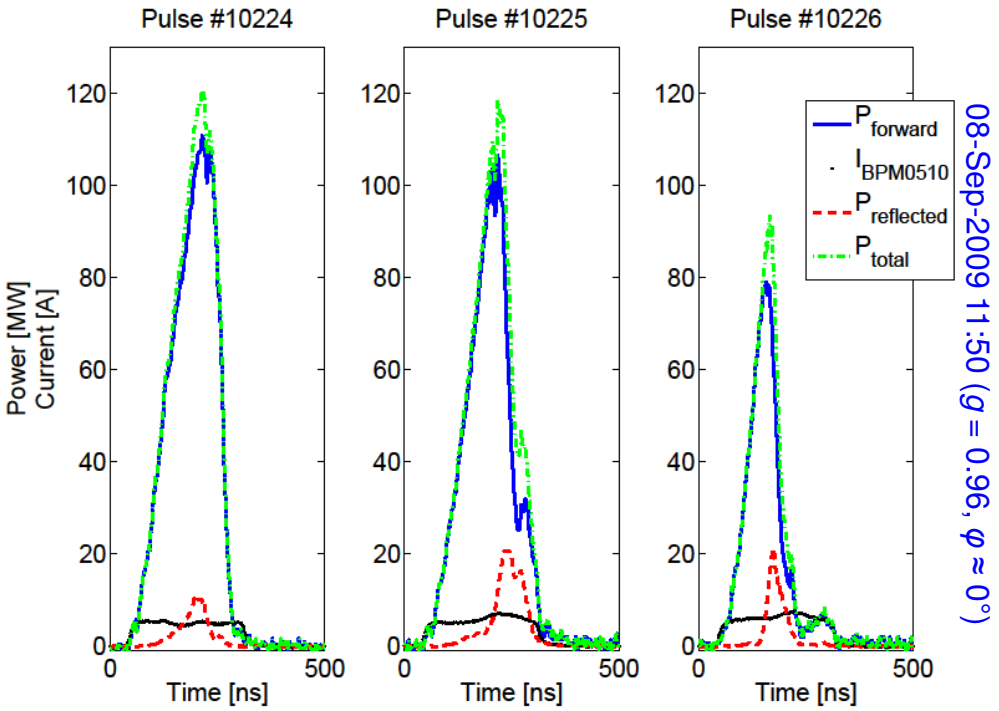
current

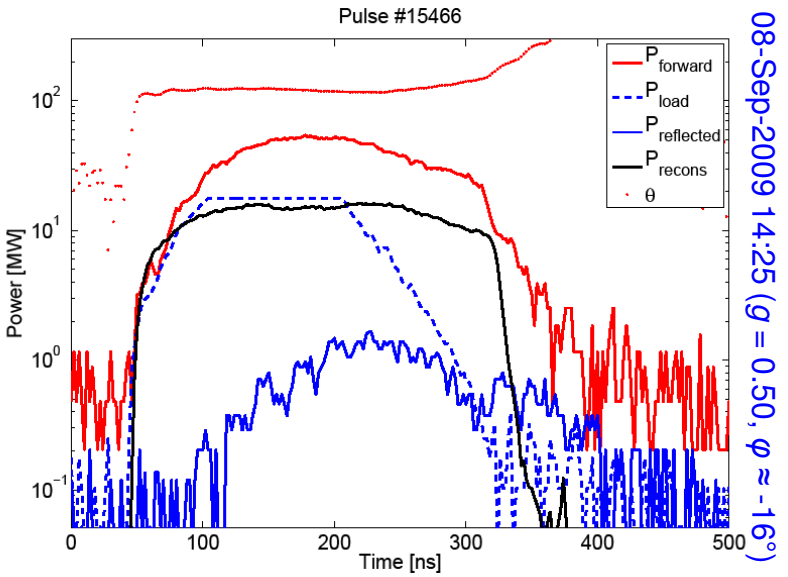


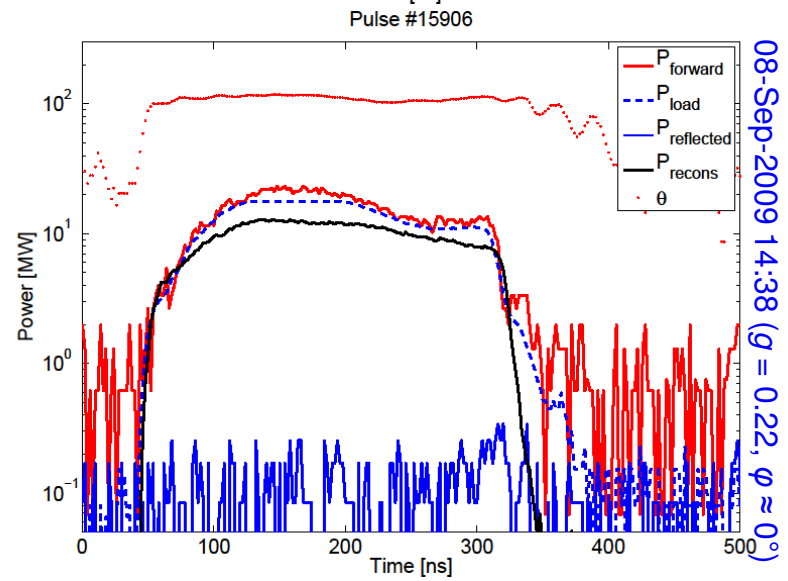


Behaviour Reflected and Load Power

- $P_{refl,output}$ not linear with P_{forw}
- P_{load} not linear with P_{forw}
- suspect variable attenuator
  → replaced by waveguide







Beam Kick Measurements

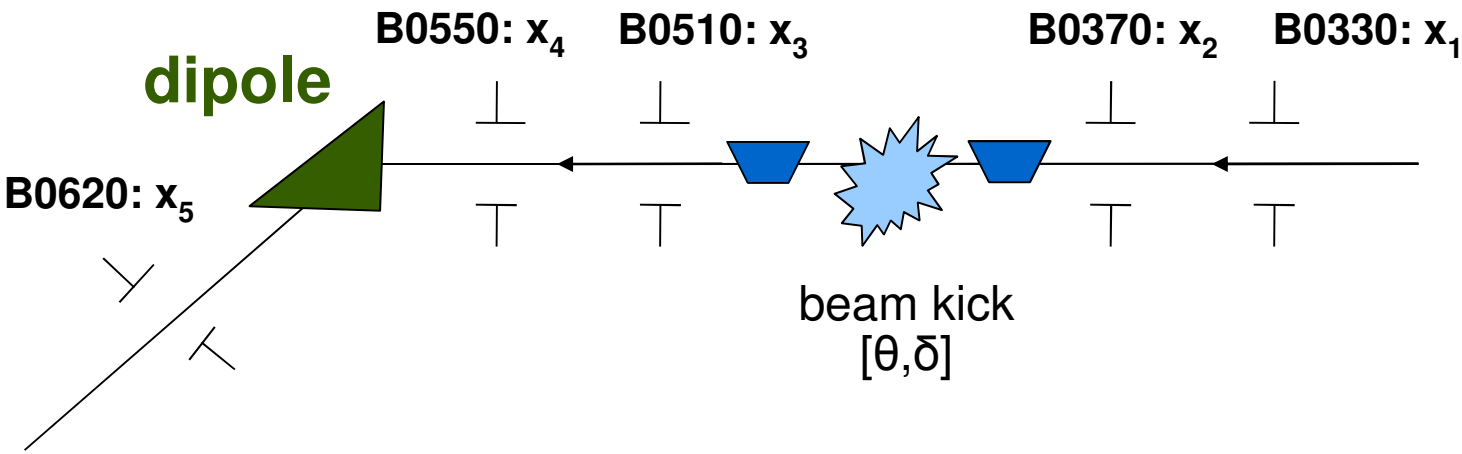
- 4 BPMs for incoming angle & offset, kick angle
- dipole + BPM5 for energy measurement

$$\vec{x} = A\vec{\theta}$$

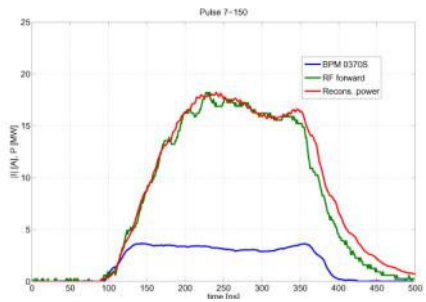
$$\vec{\theta} = (A^t A)^{-1} A^t \vec{x}$$

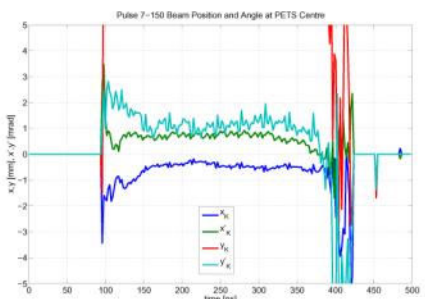
$$\begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ R_{11}^{12} & R_{12}^{12} & 0 & 0 \\ R_{11}^{13} & R_{12}^{13} & R_{12}^{c3} & 0 \\ R_{11}^{14} & R_{12}^{14} & R_{12}^{c4} & 0 \\ R_{11}^{15} & R_{12}^{15} & R_{12}^{c5} & D^5 \end{pmatrix} \begin{pmatrix} x_1 \\ x_1' \\ \theta \\ dp/p \end{pmatrix}$$

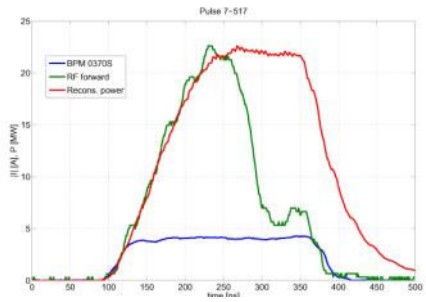
- PETS beam kick estimate: $\theta / x_P = 2 \frac{L_{\mathrm{PETS}}}{E_{tot}} e \frac{I}{f_{\mathrm{bunch}}} k_1' = 27 \mu\mathrm{rad/mm}$

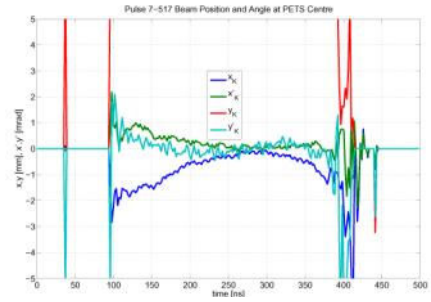


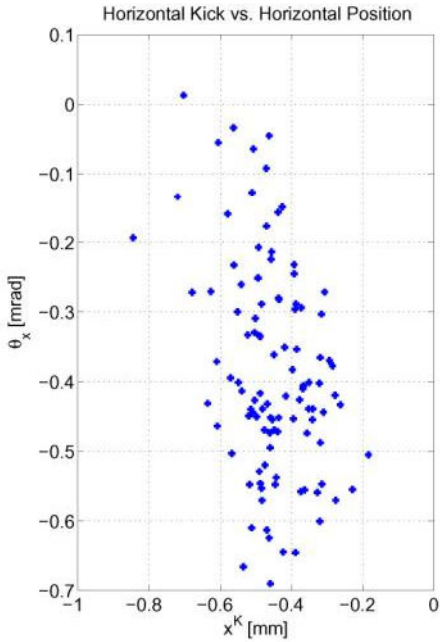
Beam Kick Measurements

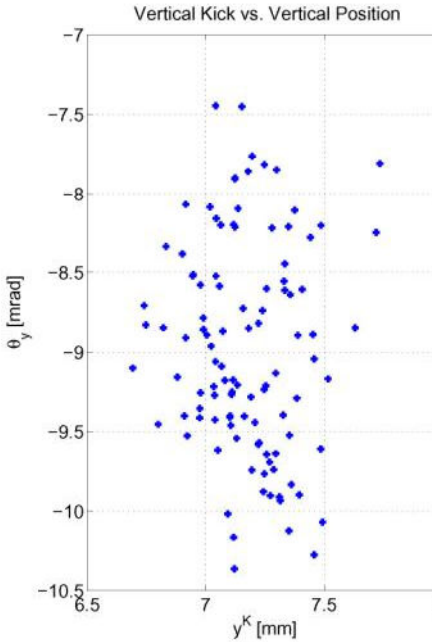


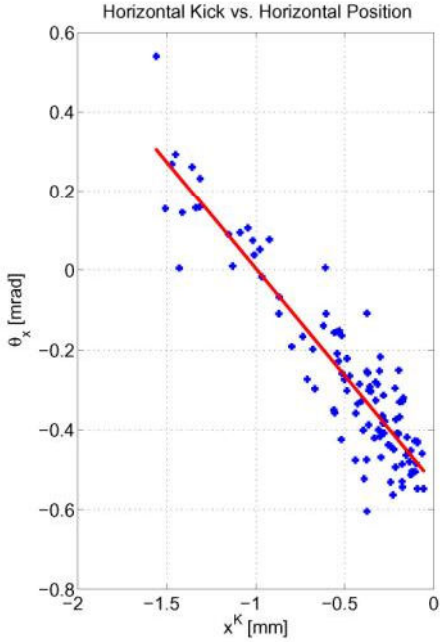


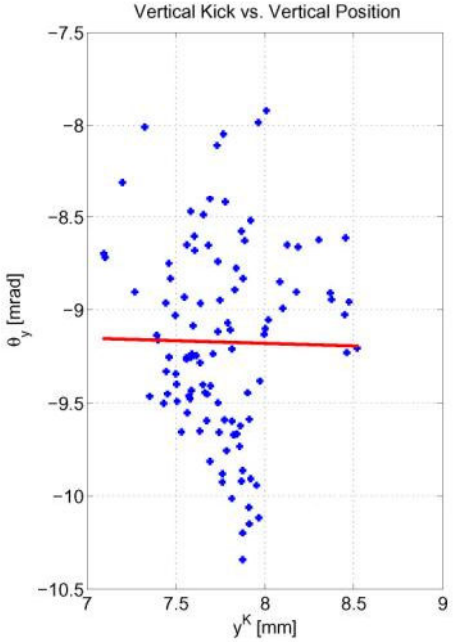












No clear correlation b/w kick and position

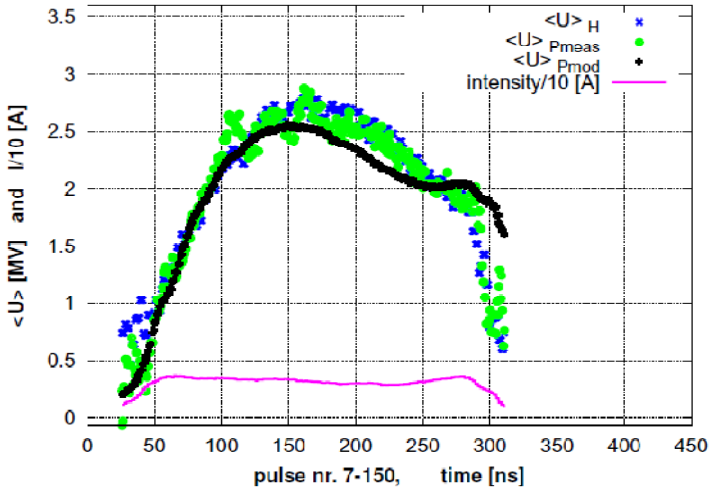
Horizontal kick vs. position: -0.54mrad/mm → 20x prediction

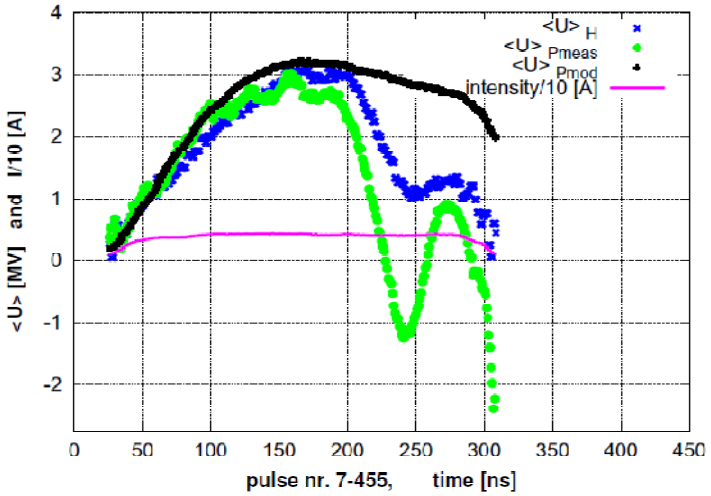
Beam Energy Loss Measurements

Energy loss estimation based on (same example pulses)

- BPM position measurements (blue)
- Beam intensity and PETS output power (green)
- Beam intensity only (black)

→ suspect energy variation incoming beam



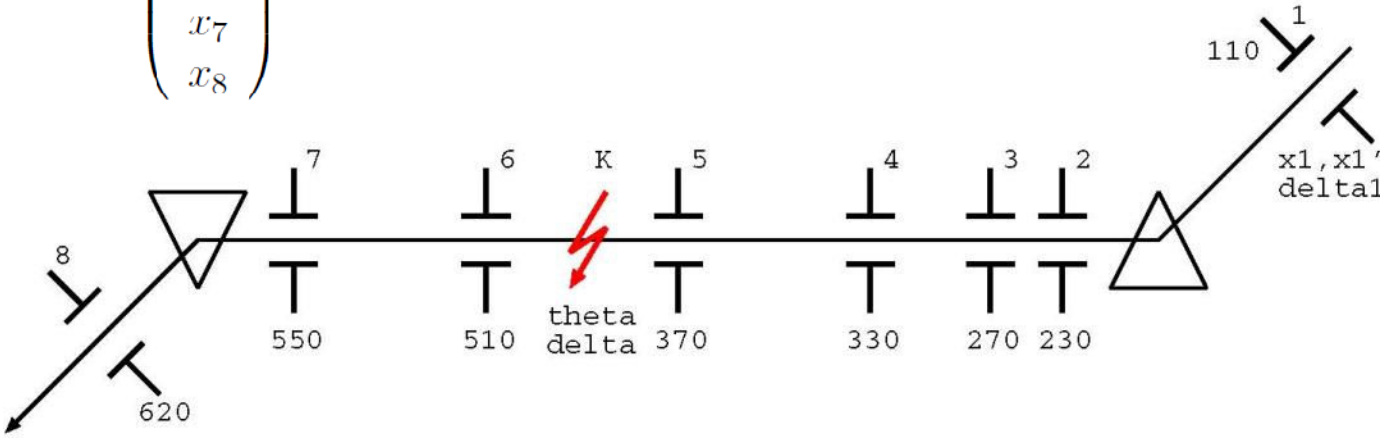


Kick Determination with Initial Energy Variation

To adjust for incoming beam energy variation:

- Add incoming beam energy: δ_1
- Now included in measurements, data to be analyzed

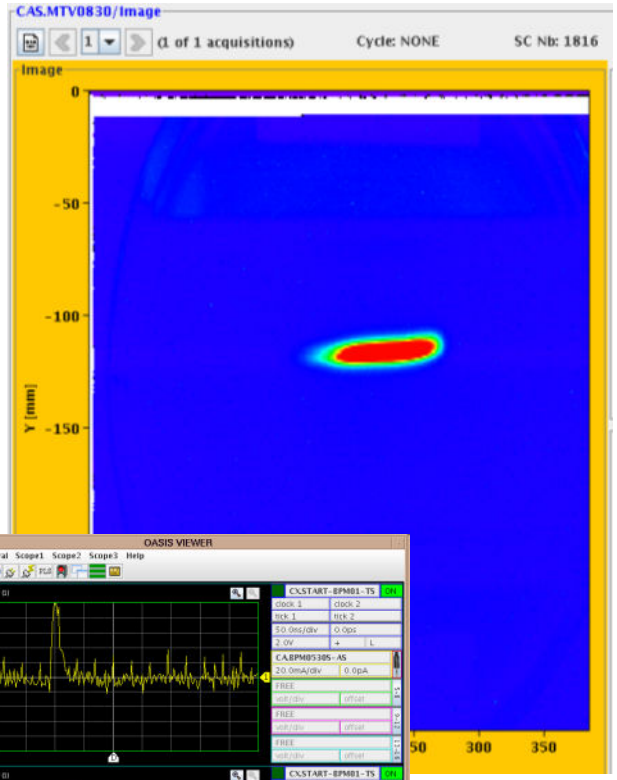
$$\begin{pmatrix} x_1 \\ x_1' \\ \delta_1 \\ \theta \\ \delta \end{pmatrix} = (\Lambda^t \Lambda)^{-1} \Lambda^t \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \\ x_7 \\ x_8 \end{pmatrix}$$

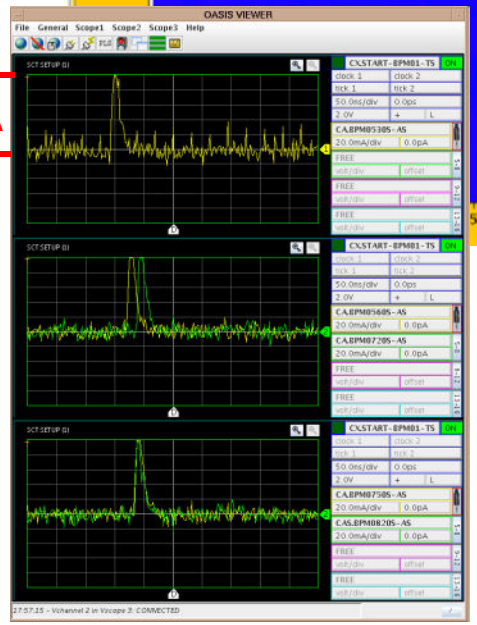


Probe Beam Line Commissioning

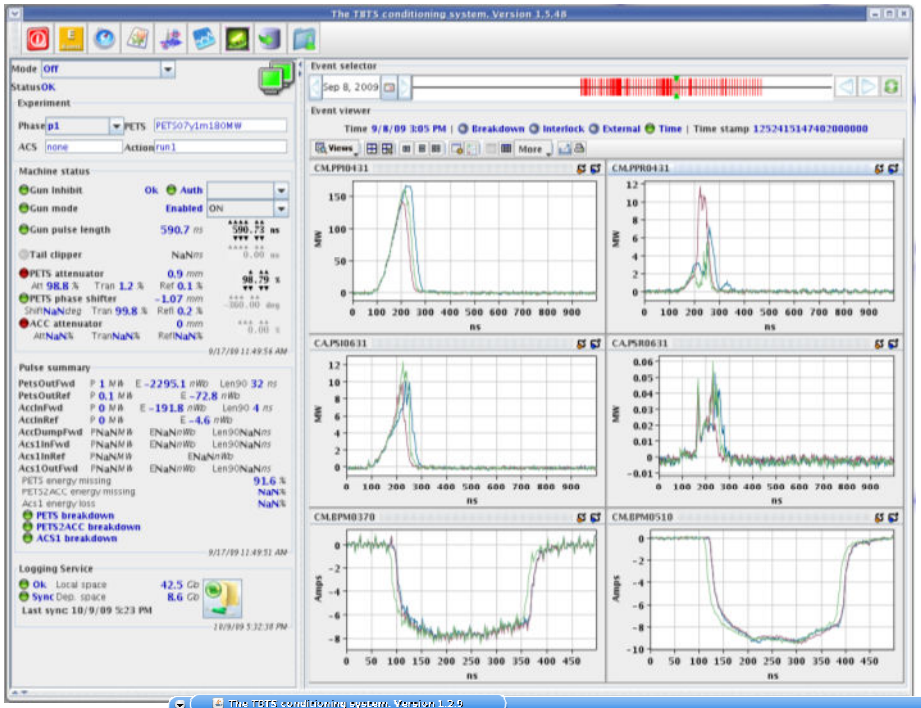
- First beam end of line on 9th April
- Excellent integration with CALIFES:
  August restart: emittance measurement, set quads → immediate full transmission
- Installed extra MTV last week
- Recalibration BPMs for lower current

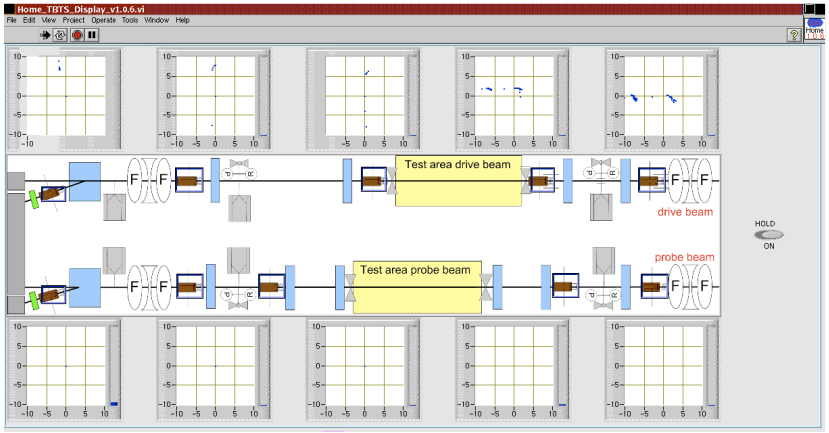
Details in the next talk by Wilfrid.

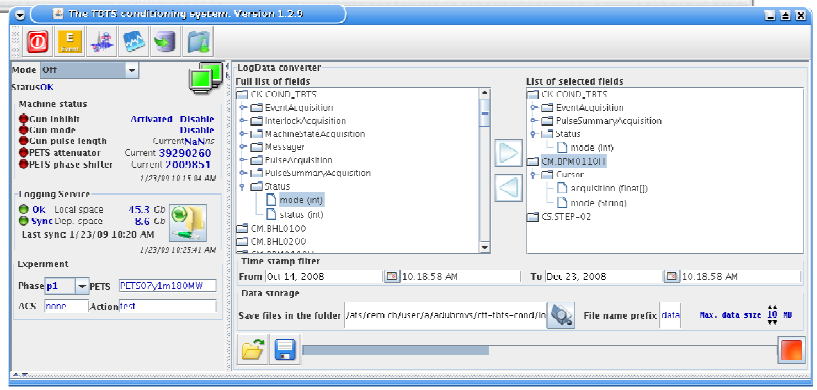


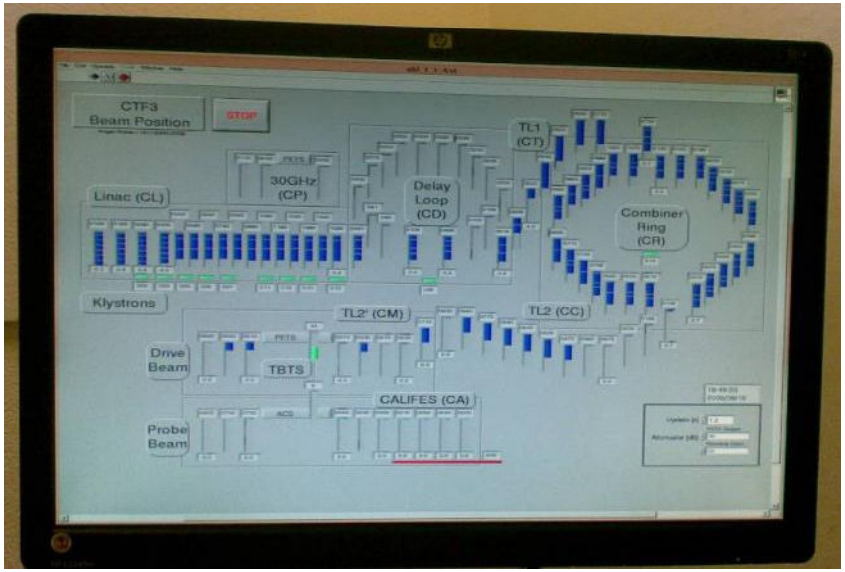


Improved Data Acquisition & Monitoring









Conclusions

- Two-beam Test Stand up & running!
- Promising results,
  - started to study details of power production, beam kick and beam dynamics
- During winter shutdown, installation
  - accelerating structure
  - additional beam & breakdown diagnostics
- Keep an eye on our web site http://cern.ch/ctf3-tbts

- Thanks to all colleagues
  especially maintenance, operation & control teams!