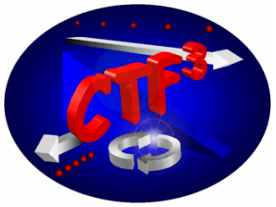


Two-beam Acceleration at the Two-beam Test Stand*

Andrea Palaia

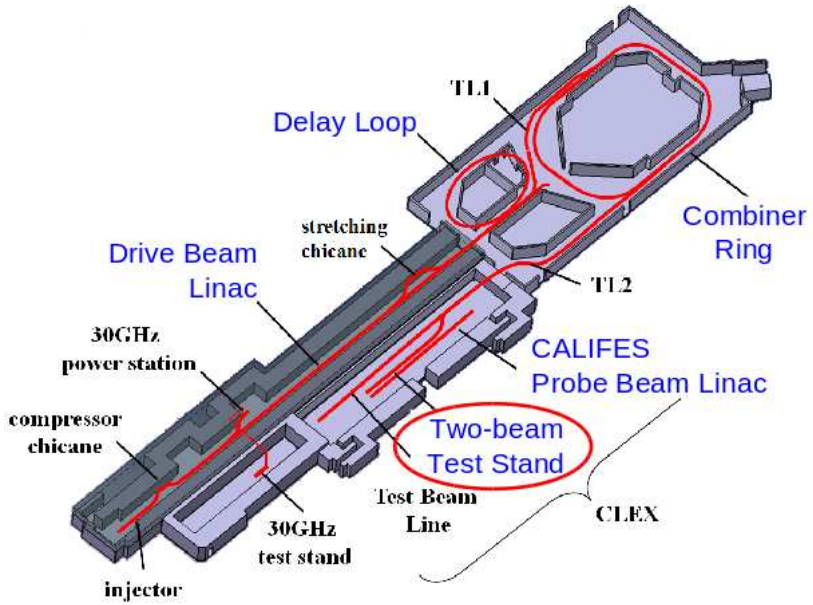
Uppsala University
(on behalf of the CTF3 team)

IWLC2010
21 October 2010

* Supported by the 7th European Framework program EuCARD under grant number 227579

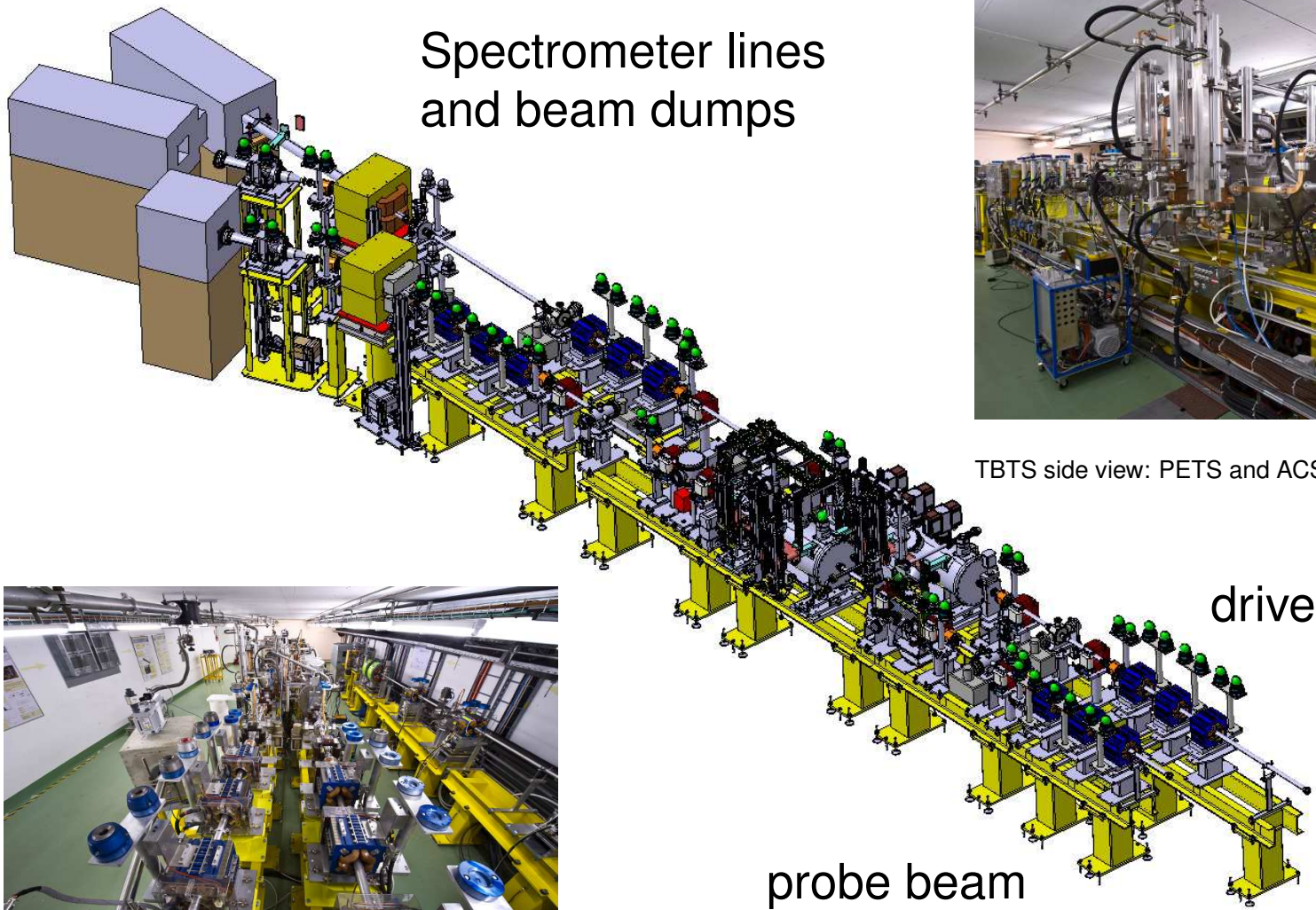
Two-beam Test Stand

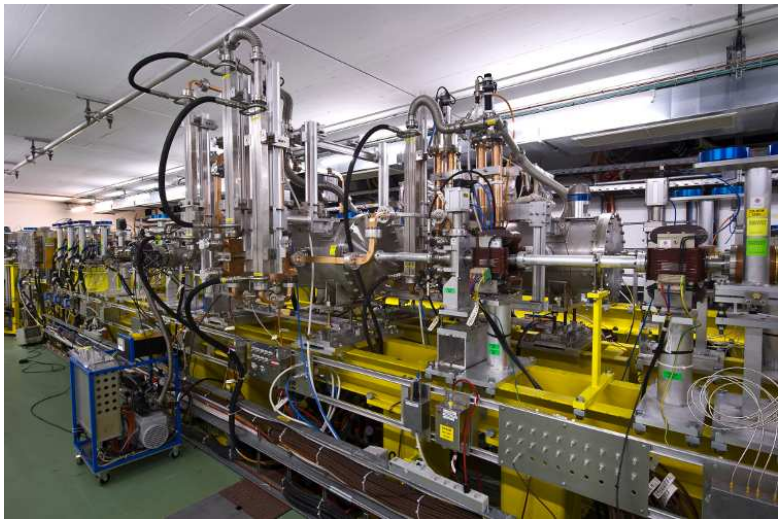
the only facility where CLIC structures (PETS and ACS) can be tested with beam



- power production in the PETS
- two-beam acceleration with CLIC prototype structures
- high order modes (HOM): effects and beam based alignment
- RF breakdown in presence of beam
- beam kick measurements in the PETS and in the ACS (indirect study of HOM and RF breakdowns)
- relative timing between drive and probe beam
- full two-beam module behaviour, intra-girder alignment

TBTS experimental area

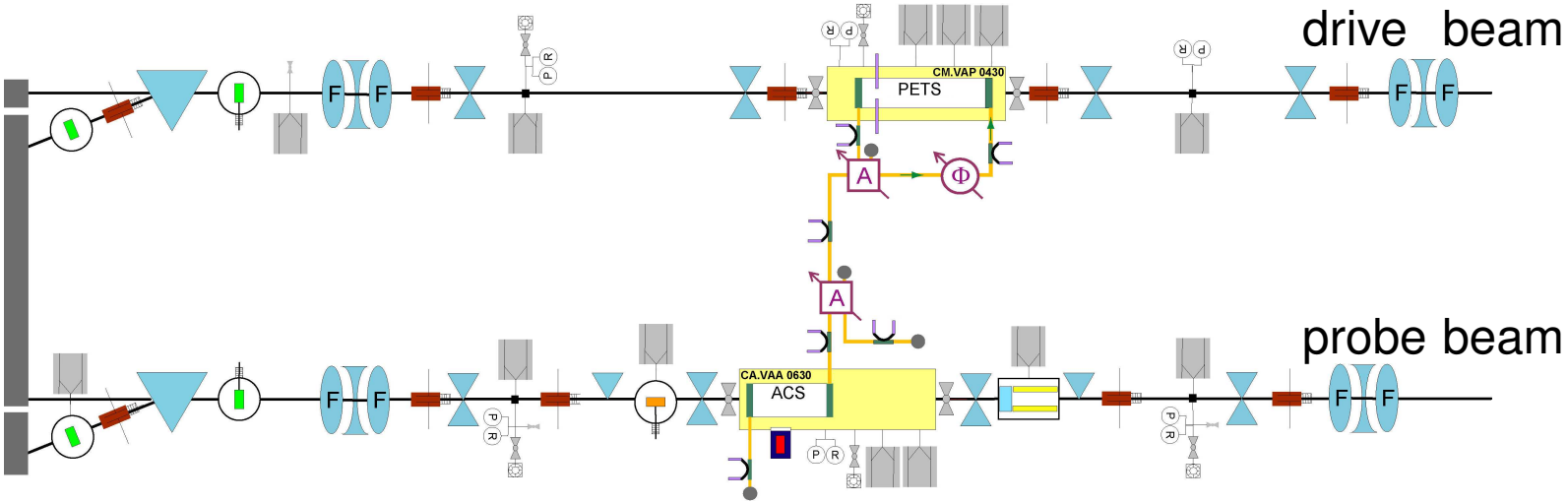




TBTS side view: PETS and ACS tanks

TBTS top view

TBTS instrumentation

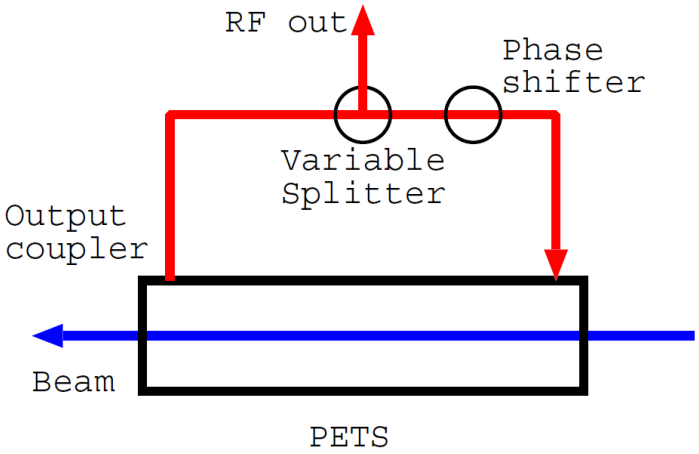


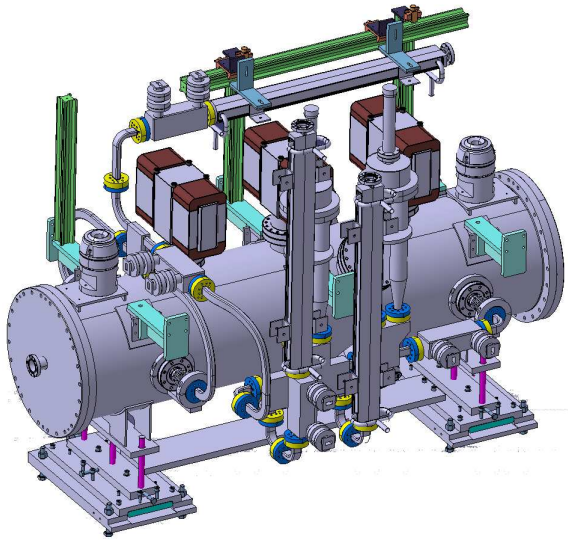
Beams specs

	Drive beam	*Probe beam*
Energy	120 MeV	180 MeV
Energy spread (RMS)	2%	1%
Pulse length	140–1100 ns	0.6–150 ns
Bunch frequency	1.5–15 GHz	1.5 GHz
Bunch charge	up to 3 nC	0.085–0.6 nC
Intensity		
- short pulse	28 A	1 A
- long pulse	4 A	0.13 A
Repetition rate	0.8–5 Hz	0.8–5 Hz

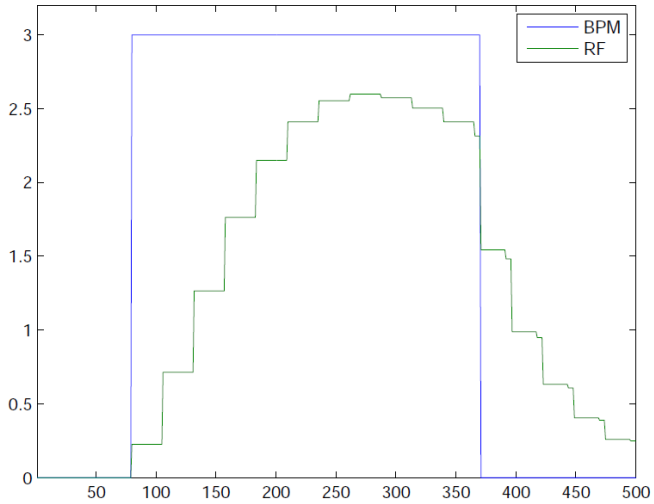
- two beam lines;
- two spectrometer lines;
- 5 BPMs per beam line (expected resolution 10 μm);
- two screens per beam line;
- 1 PETS and 1 ACS.

PETS recirculation loop



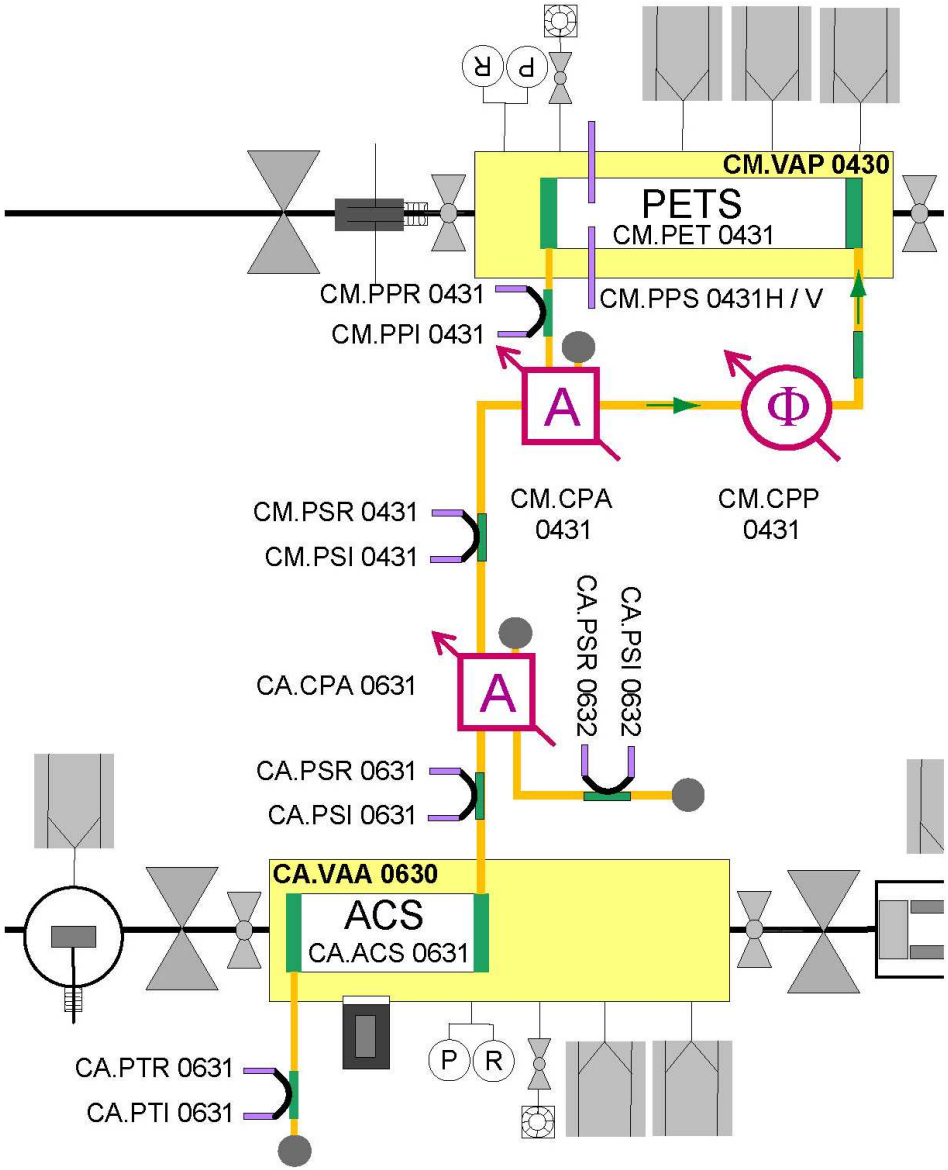


- 1 m long 12 GHz PETS
- external recirculation loop (26 ns) to increase the power inside the PETS
- phase shifter to optimize power recirculation
- variable splitter to send power to the ACS

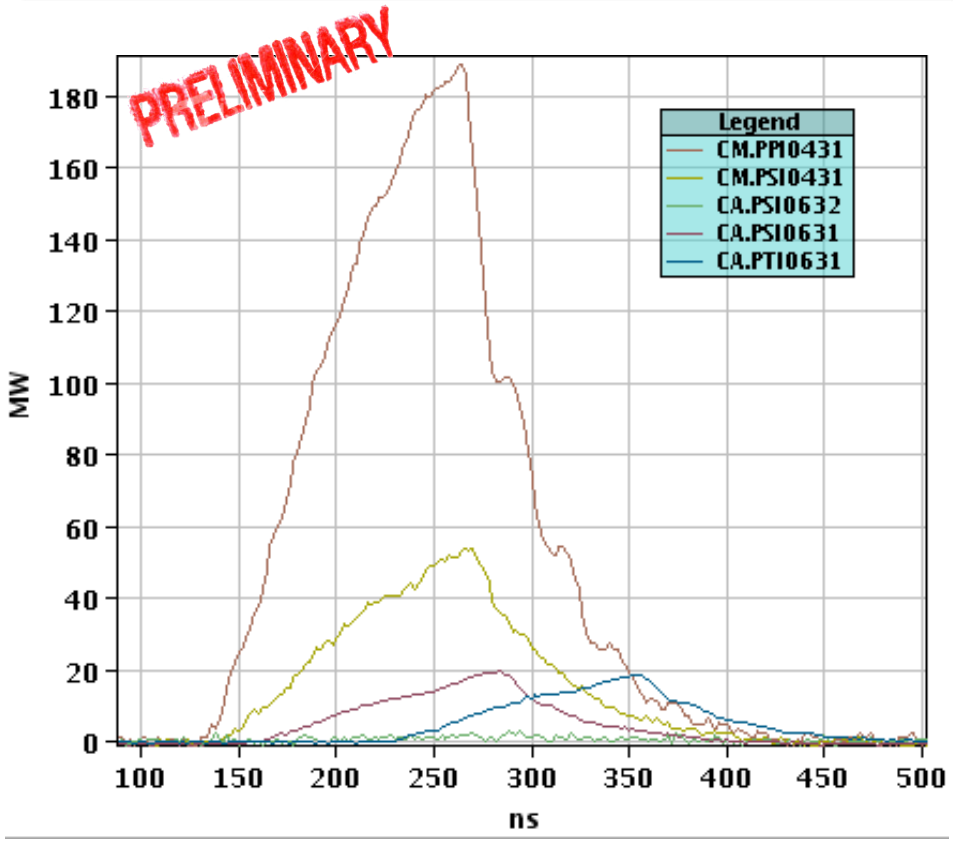


Simulated recirculating power for a square current pulse (CTF3-Note-092)

PETS power



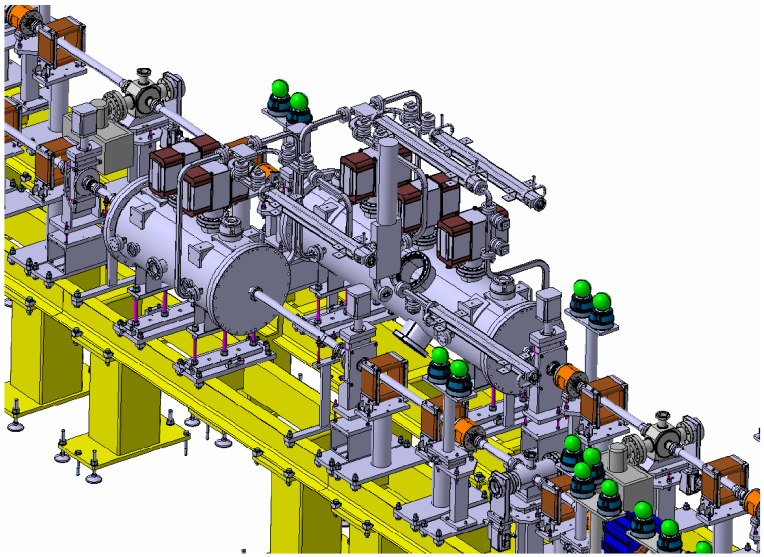
power amplification in the PETS: recirculation time is 26 ns



about 12 A, peak power is 190 MW

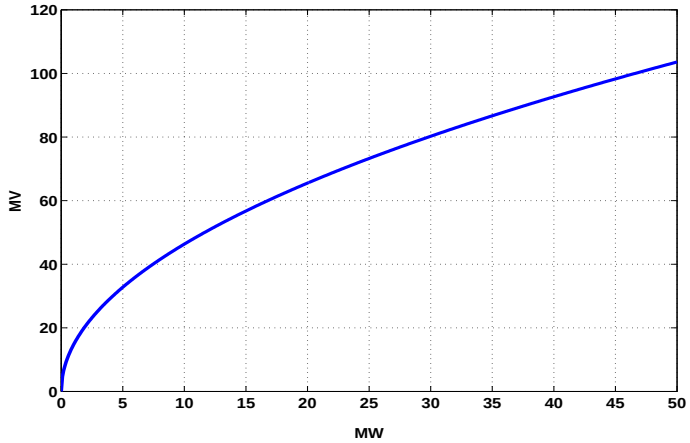
Power sent to the ACS

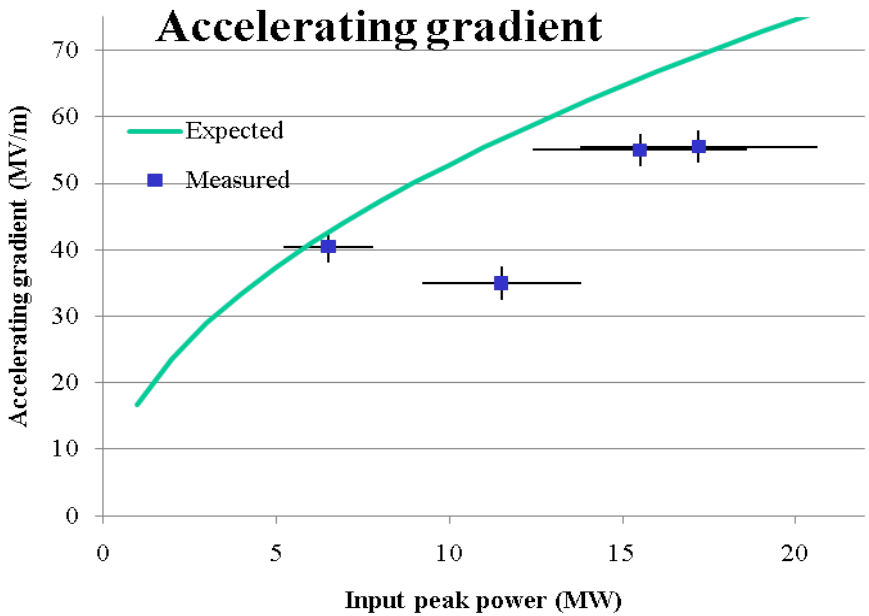
- 22.77 cm, 24 regular cell + 2 matching cells ACS*
- variable splitter to regulate input power
- 46.5 MW to reach CLIC nominal 100 MVm^{-1} *



* Alexej Grudiev (EDMS 1070498)

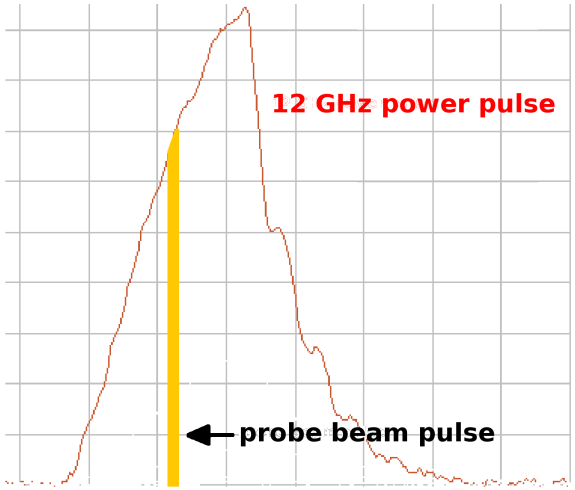
expected ACS performance (TD24_vg1.8_disk, unloaded)



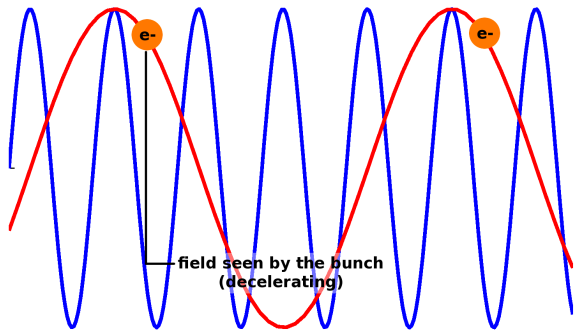


12 GHz phase scan

For a given power in the ACS we need to tune the maximum acceleration



macro timing not optimized to match rf maximum power



micro timing not optimized to maximum energy gain

- macro timing in steps of 52 ns (klystron) / down to 10 ps (laser)

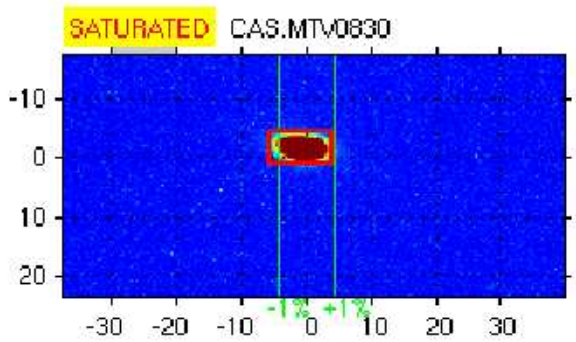
  2 different knobs → relative phase have to be adjusted at each step
- micro timing by varying the 3 GHz klystron phase (together with the 1.5 GHz laser phase)

1 ° at 1.5 GHz = 2 ° at 3 GHz = 8 ° at 12 GHz

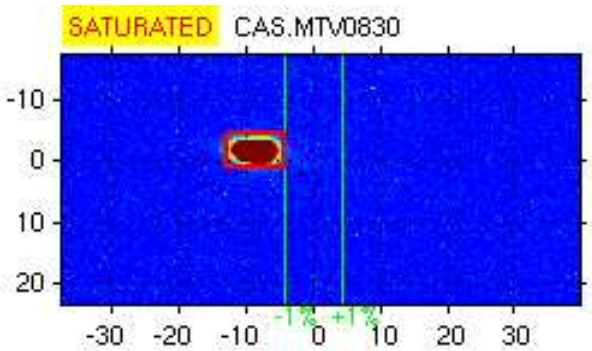
1 ° at 12 GHz = 231 fs = 69 μm at the speed of light

First Two-beam Acceleration - 19 Aug 2010

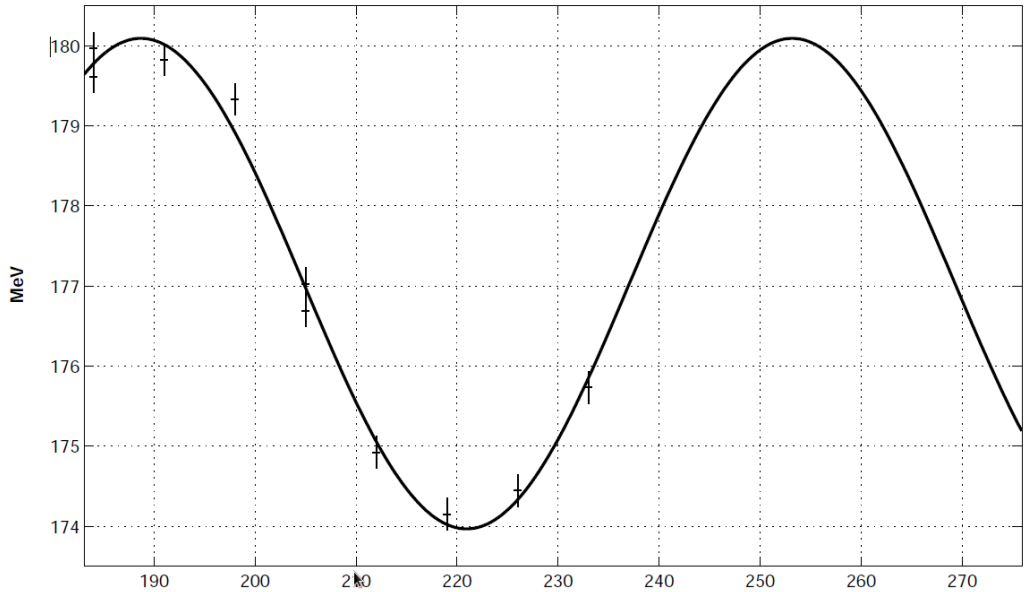
from CALIFES online monitor spectrometer line screen



174.6 MeV (RF on - drive beam on)



170.9 MeV (RF off - no drive beam)

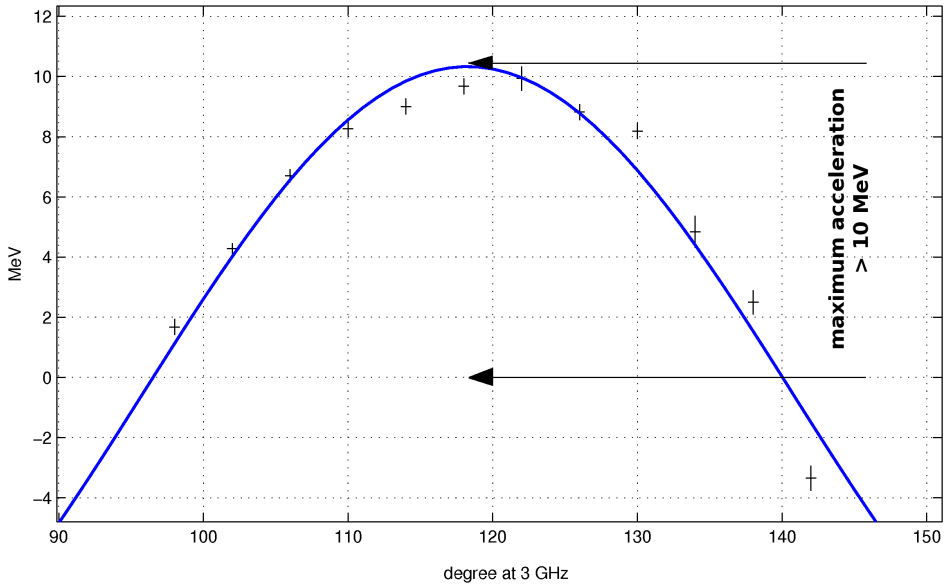


- phase scan over 50° (3 GHz phase)
- observed different incoming beam energies for different klystron phases

(details by W. Farabolini, WG6, Thu 14.20)

Maximum acceleration up to now

22 September 2010



20 MW peak power in ACS

Model Fit

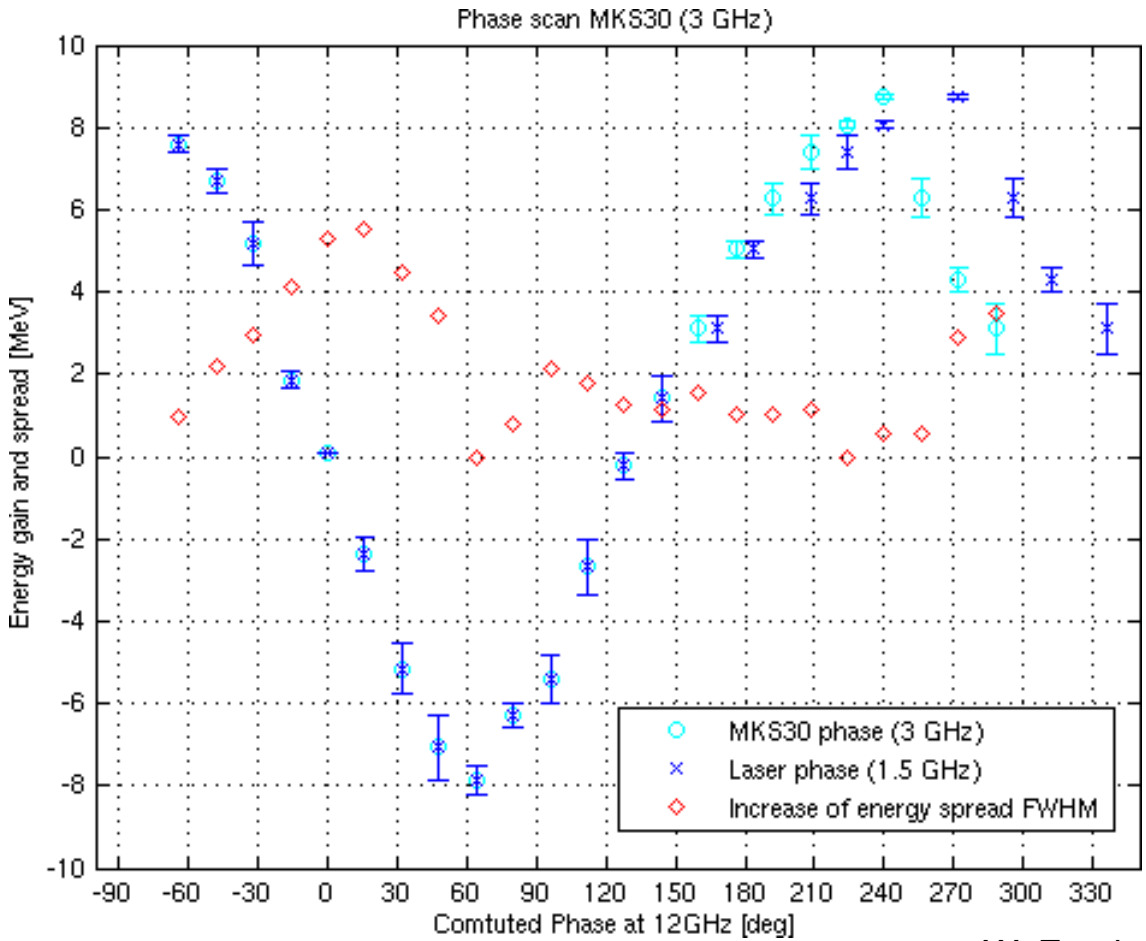
$$f(x) = a + b\left[\sin\left(x - c\right)\frac{\pi}{180}\cdot 4\right]$$
$$a = 0.57 \pm 0.33$$
$$b = 10.9 \pm 0.1$$
$$c = -39.2 \pm 0.2$$
$$\chi^2/dof = 8$$

- phase scan over 44° (3 GHz phase)
- energy measured using the screen in the spectrometer line
- differential measurements (with and without 12 GHz RF for each point) to exclude incoming beam energy changes

Complete phase scan

13 October 2010

Range identified where klystron compressed pulse is stable over 90° (360° at 12 GHz)



W. Farabolini

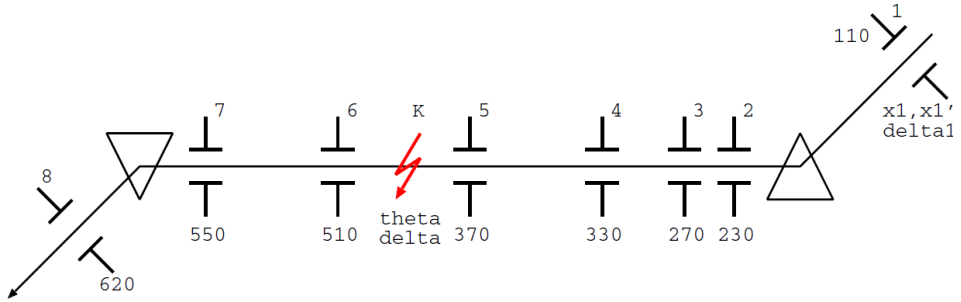
Beam kick and RF breakdown studies

- Measurements of beam kick due to HOM and RF breakdowns both on the drive beam and on the probe beam

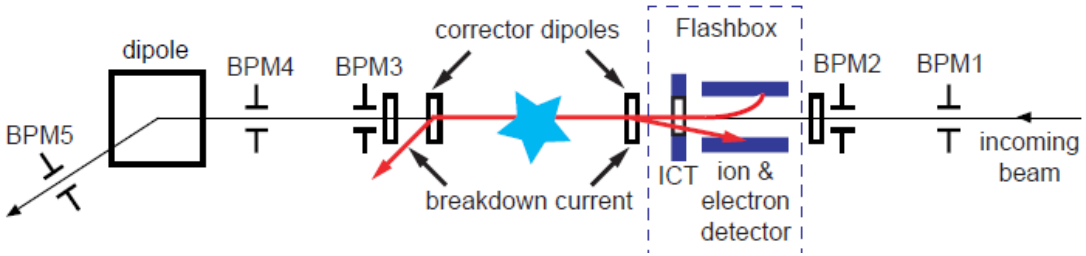
  (10 μm BPMs resolution for 10 mrad angular resolution)

already in 2009 for the drive beam without considering incoming energy variation

(CTF3-Note-098)

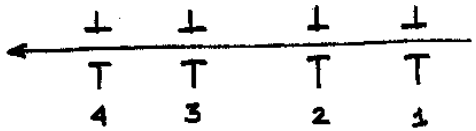


- better understanding of the breakdown process with:
  - indirect RF measurements (reflection during breakdowns);
  - direct measurements of emitted electrons and ions (flashbox).

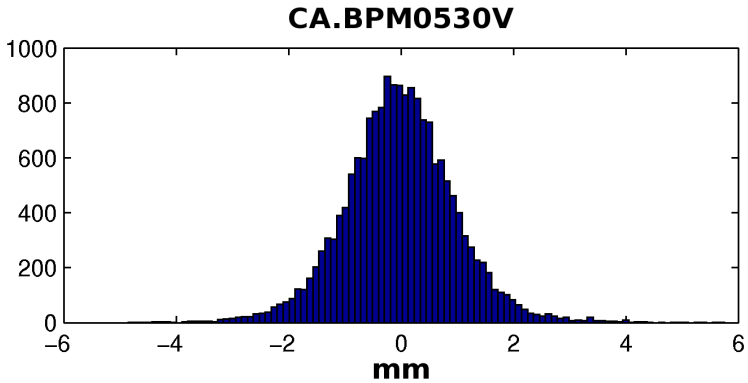


BPMs resolution measurement

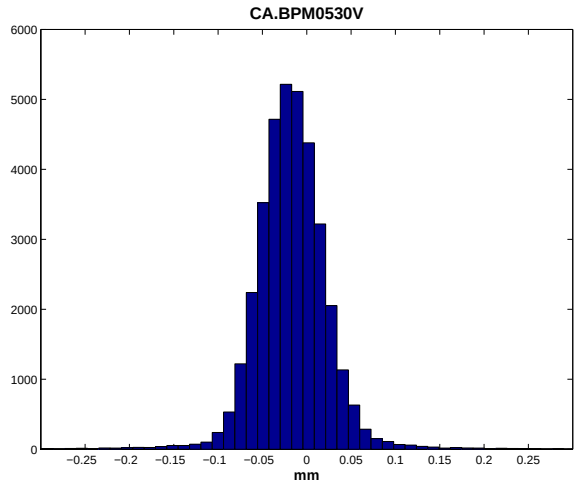
Expected BPMs resolution is 10 μm (by design)



Three out of four BPM readings used to calculated the expected reading at the fourth BPM. The width of the distribution of (expected - measured) position is assumed as resolution for each BPM.



Resolution is 1 mm (too low) signals' amplitude in order of ADC resolution



BPMs signals amplified (+10 dB)
10 bit ADC at +/-2 V
Measured resolution is 45 to 70 μm.

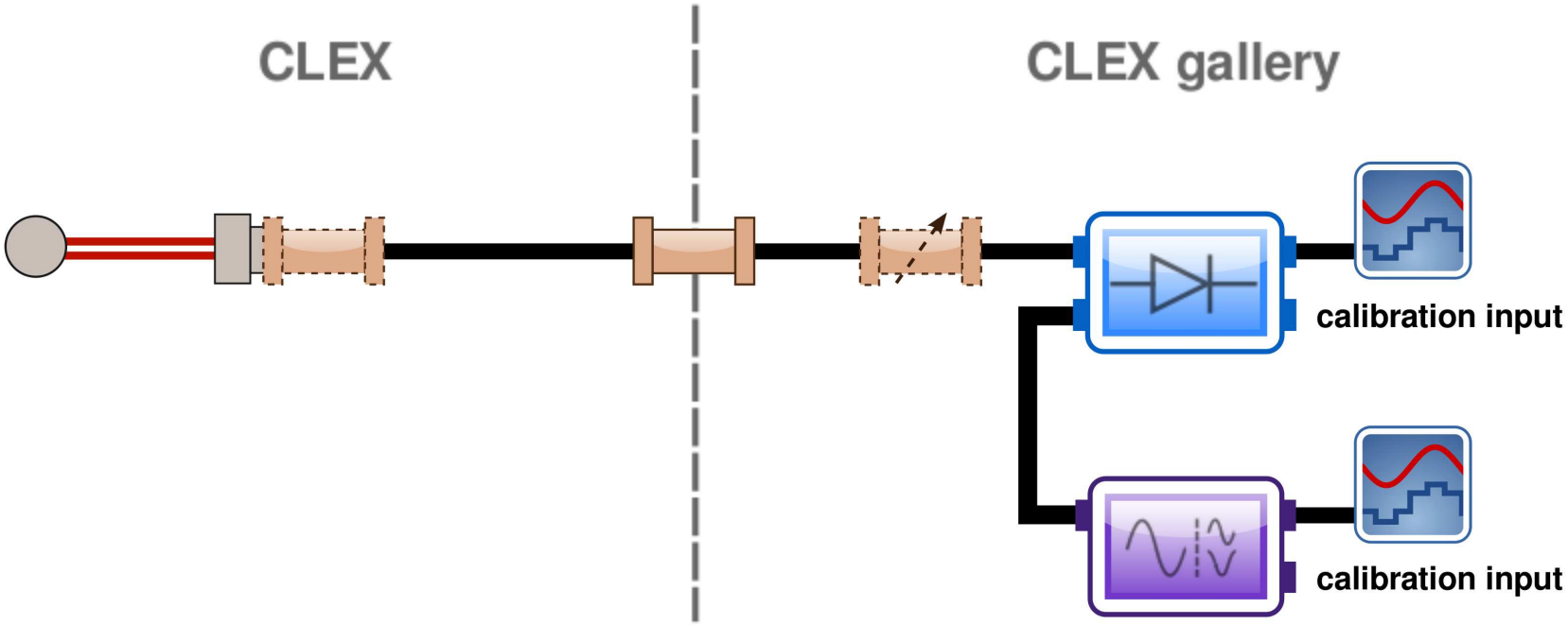
Summary

- PETS power > 180 MW(CLIC nominal is 135 MW)
- first two-beam acceleration (3.5 MeV) on 19 August 2010
- measured 11 MeV acceleration (55 $\mathrm{MVm^{-1}}$) at 20 MW measured ACS power (22 September 2010)
- BPM resolution measured for four BPMs (probe beam side, below 100 $\mu\mathrm{m}$) close to the one expected (10 $\mu\mathrm{m}$)

Next steps

- improvement of power measurements - (ongoing)
  - measurement of 100 $\mathrm{MeVm^{-1}}$ gradient (expected at 46.6 MW ACS power)
- optimization of BPMs signals and resolution measurements (all BPMs, vertical and horizontal) - (ongoing, LAPP)
  - kick measurements (HOM and RF breakdowns)
  - deceleration measurements
- RF breakdowns studies (Flashbox) - (ongoing, assembling hardware)

12 GHz RF diagnostics layout



Attenuator
Variable attenuator
Directional coupler
ADC
IQ demodulator crate
Diode detector crate
Coaxial cable
Waveguide
Waveguide to coax transformer

TBTS probe beam BPMs resolution

TBTS probe beam line, BPMs vertical signals: