Design and measurements of the CTF3 TBTS accelerating structure Wake-Field Monitors

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Accelerating Structures and WFMs

- Wakefield monitors were installed on the central cell of each accelerating structure.
- The HOM waveguides were extended by a waveguide terminated with a SiC absorber.

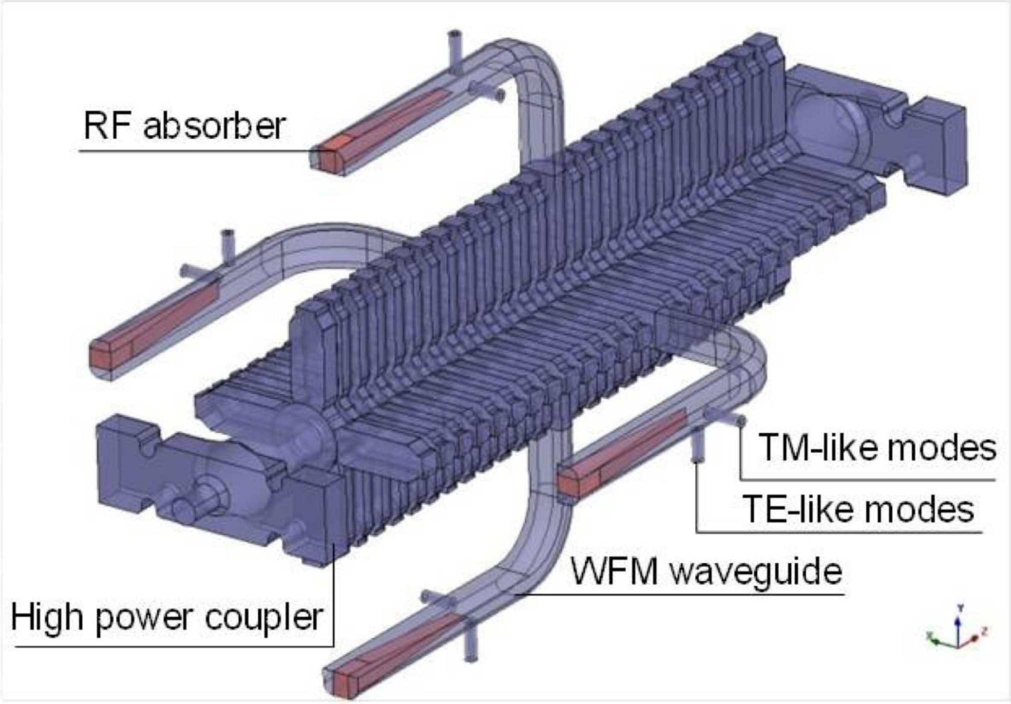
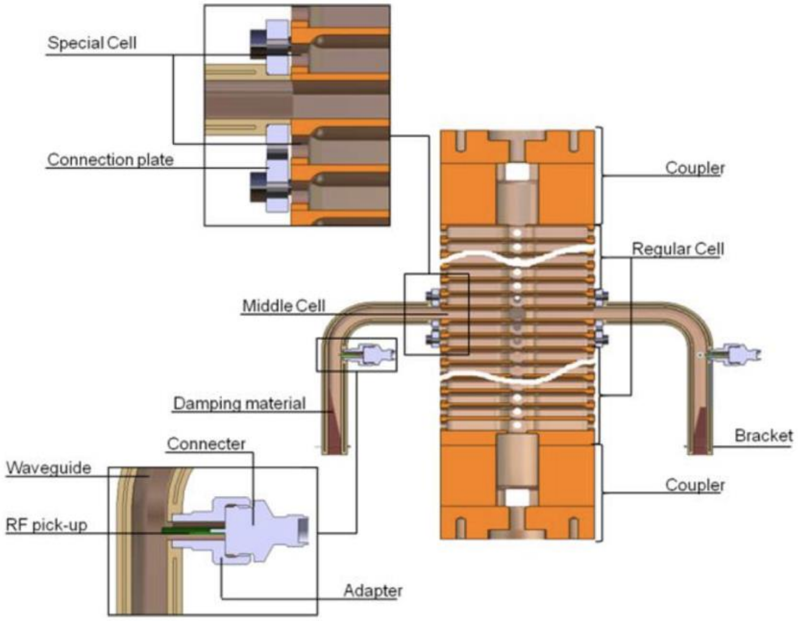


Table 1: Wakefield Monitor Specifications

Parameters	CLIC commissioning	CLIC operation	CTF3
Charge / bunch (nC)	0.06	0.6	0.6
Number of bunches	1-312	312	1-226
Bunch length (μm)	45-70	45-70	400
Train length (ns)	156	156	150
Bunch Spacing (ns)	0.5	0.5	0.66
Accuracy (μm)	5	5	
Resolution (μm)	5	< 5	
Range (mm)	± 2	± 0.1	± 2
Beam Aperture (mm)	~5.5	~5.5	~5.5

F. Peauger et al.,“Wakefield Monitor Development for CLIC Accelerating Structure“, Conf. Proc.: LINAC2010, Tsukuba, Japan (TUP098).

ACSs and WFMs design



The basic design of the CLIC accelerating structures consists of 24 tapered and weakly coupled cells working on the 2□/3 mode at 12 GHz, with a mean aperture of 5.5 mm.

Each cell has four orthogonal waveguides and rf absorbers in order to damp strongly the higher order modes (HOM) induced by the beam.

The dipole modes, usually used for the offset detection are above 16 GHz with a Q factor below 10.

F. Peauger et al.,"Wakefield Monitor Development for CLIC Accelerating Structure", Conf. Proc.: LINAC2010, Tsukuba, Japan (TUP098).

The WFM consists of a bent waveguide extending the damping waveguide with the same section.

There are four waveguides per structure which are 90° bent for size reasons and connected to the middle cell to have the mean offset of the structure.

Two coaxial rf pick-ups are implemented on the WFM waveguide: one on the large side to extract the TM-like modes and the other one on the small side to extract the TE-like modes.

WFMs modes

The TM-like and TE-like modes are hybrid electromagnetic (HEM) dipole modes in the cavity.

They are coupled to the damping waveguides and propagate with the TE10 mode in the bent waveguide on respectively the vertical (cut-off frequency Fc=13.3 GHz) and horizontal (Fc = 21.2 GHz) polarization.

The internal conductor of the pick-up is inserted 1 mm inside the waveguide giving a coupling factor of -10 dB while keeping the reflection level to the cell below -20 dB.

In a first step, the structure does not include the SiC absorbers, except for the middle cell where the WFM is implemented.

F. Peauger et al.,"Wakefield Monitor Development for CLIC Accelerating Structure", Conf. Proc.: LINAC2010, Tsukuba, Japan (TUP098).

TM-like

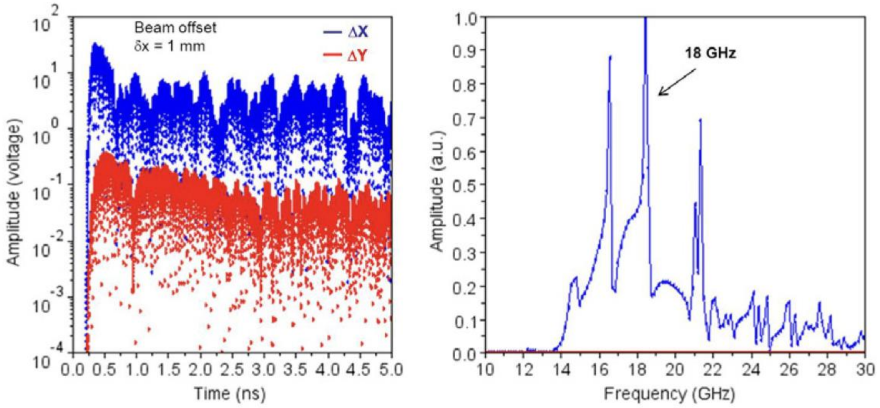


Figure 2: Horizontal (blue) and vertical (red) port signal amplitude of the TM-like modes after 180° recombination in time (left) and frequency (right) domain for a beam offset of 1 mm on the horizontal plane.

In time domain, the horizontal recombined signal (blue curve) is a factor of 100 higher than the vertical one (red curve). This means that the intrinsic resolution is about 10 μm, assuming a perfect geometry of the structure, a hybrid coupler with infinite isolation and no thermal noise.

On the frequency spectrum, one can see that the 12 GHz fundamental mode is well rejected and that the lowest dipole-band mode around 18 GHz is predominant.

The resolution will be very well dependant to the 180°hybrid coupler which has a typical isolation of 15 dB.

TE-like

WFMs modes

The difference in amplitude between the vertical (magenta curve) and the horizontal (cyan curve) signals is a factor of 100 to 250.

Assuming a perfect geometry of the cells and no thermal noise, a theoretical resolution of 4 μm may be achieved.

The involved modes have resonant frequencies going from 22 to 28 GHz, with a significant amount of signal at 24 GHz.

For the TE-like modes, no recombination is needed since the rejection of the fundamental mode is very good.

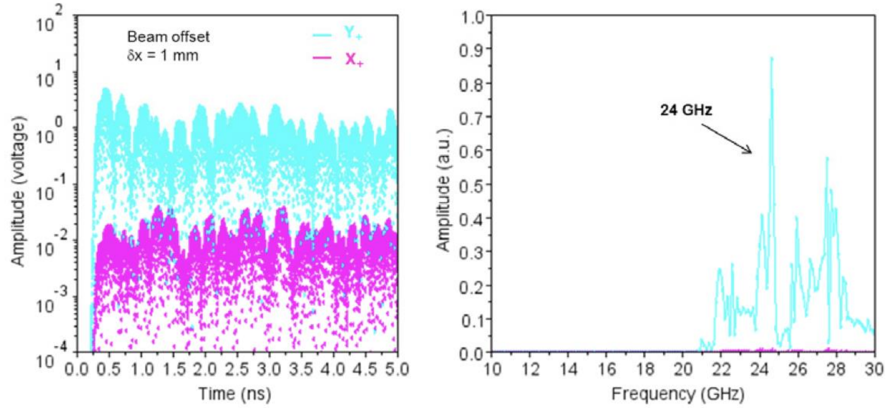
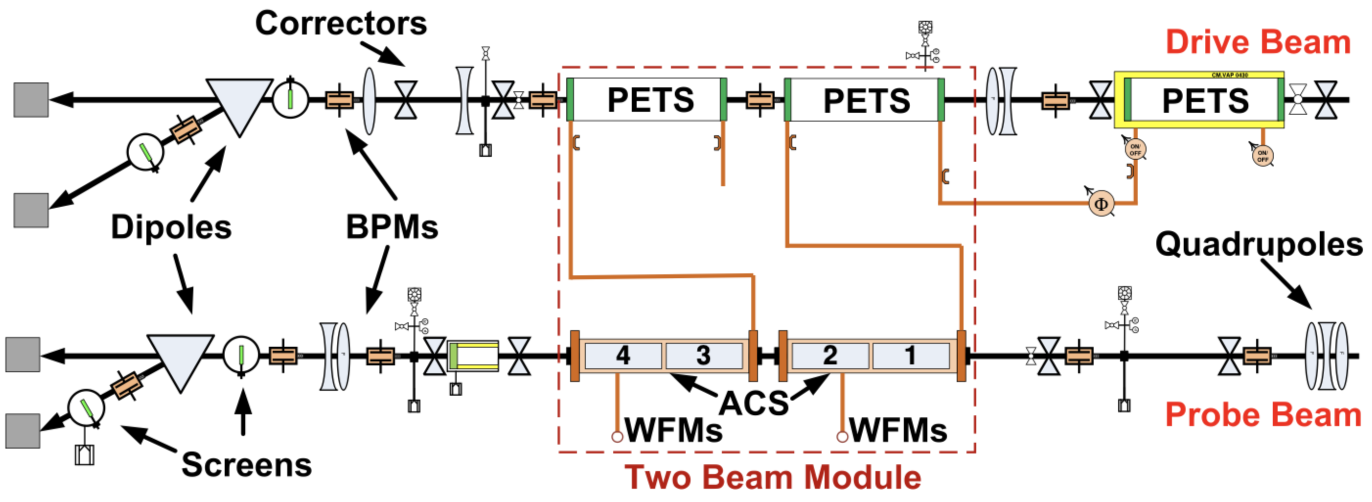


Figure 3: Horizontal (cyan) and vertical (magenta) port signal amplitude of the TE-like modes in time (left) and frequency (right) domain for a beam offset of 1 mm on the horizontal plane.

F. Peauger et al.,"Wakefield Monitor Development for CLIC Accelerating Structure", Conf. Proc.: LINAC2010, Tsukuba, Japan (TUP098).

Installation & procedure

- Two dipolar modes were sampled by 50 dBm logarithmic detectors, a TM-like 18 GHz and a TE-like 24 GHz
- The beam position inside the ACS was scanned using vertical and horizontal correctors upstream the ACSs.
- An absolute calibration of beam position vs WFMs was done using a screen located downstream the ACSs.



J.L. Navarro Quirante, et al., CALIFES: A multi-purpose electron beam for accelerator technology tests, in: Proceedings of the 27th Linear Accelerator Conference, LINAC2014, Geneva, 2014, paper MOPP030.

Main Results I

The independent measurements provided by the two ACSs were used to determine the resolution in beam position of the WFMs by fitting the calibrated beam offset of one ACS against the other and correcting for longitudinal displacement

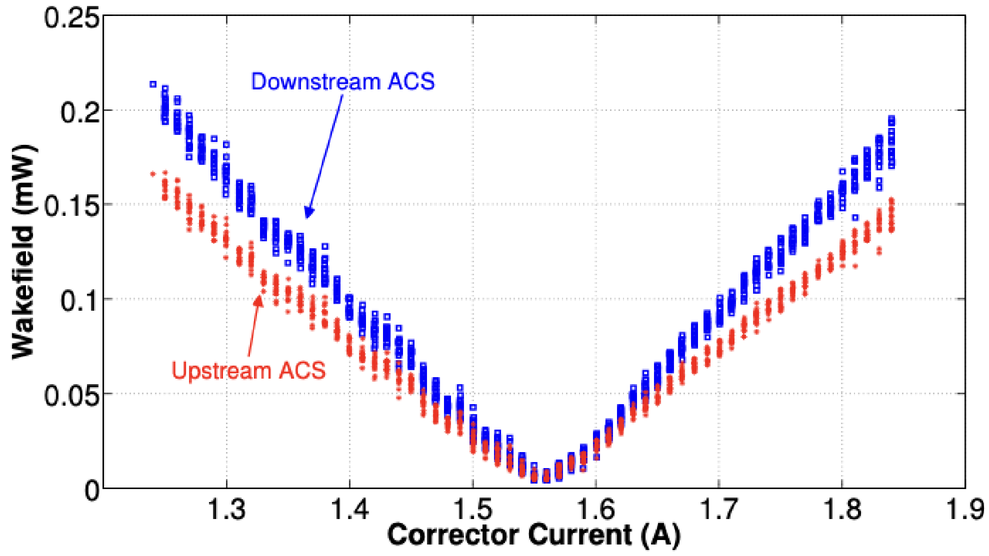


Figure 5: TE-like 24 GHz wakefield excited as function of the upstream vertical corrector current for the upstream (red) and downstream (blue) ACSs installed in TBTS.

J.L. Navarro Quirante, et al., CALIFES: A multi-purpose electron beam for accelerator technology tests, in: Proceedings of the 27th Linear Accelerator Conference, LINAC2014, Geneva, 2014, paper MOPP030.

Main Results II

The resolution defined as the standard deviation of the measurements to the fitted dependency is <10 μm for 1 mm beam offset improving to <5 μm for beam offsets <0.4 mm.

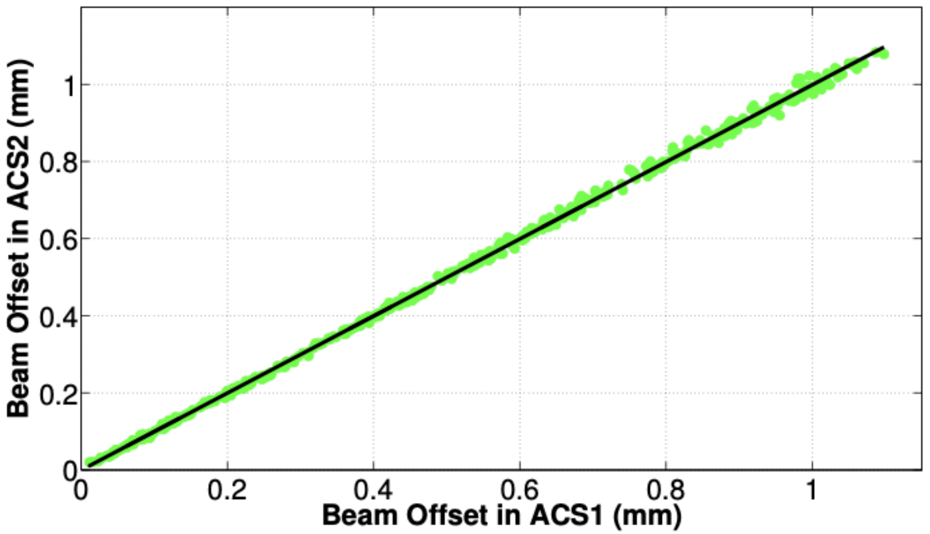


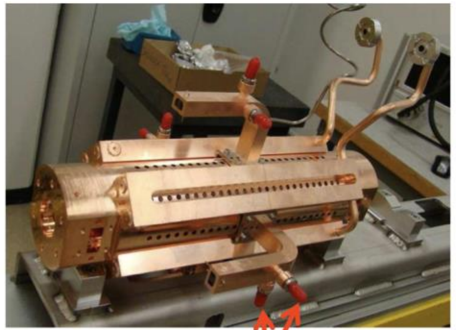
Figure 6: Correlation of measured beam position from 24 GHz excited wakefields (green dots) in downstream ACS with respect to position measured in upstream ACS and the expected lineal behaviour (black line).

J.L. Navarro Quirante, et al., CALIFES: A multi-purpose electron beam for accelerator technology tests, in: Proceedings of the 27th Linear Accelerator Conference, LINAC2014, Geneva, 2014, paper MOPP030.

Some additional measurements

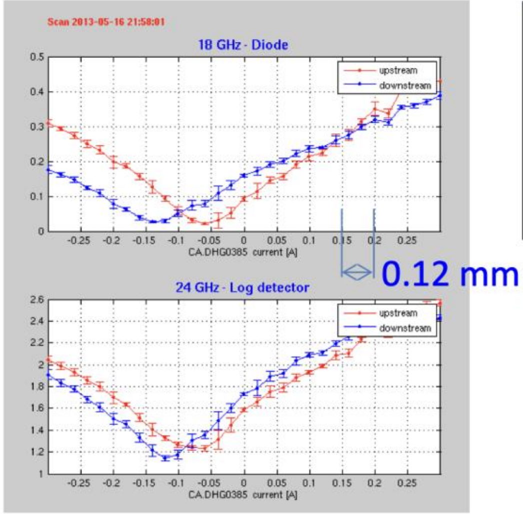
N.B.: 0.1 A ~ 240 um

The first results obtained by scanning the beam positions with correctors have shown a vertical misalignment of the two ACS as regard to the rest of the line elements (Fig. 10). This misalignment has been corrected resulting in a much easier beam transport.

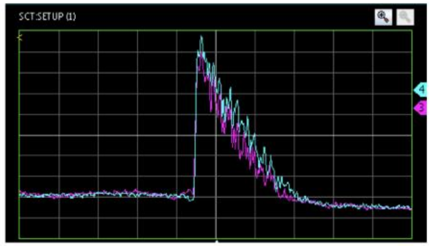


ACS with WFM

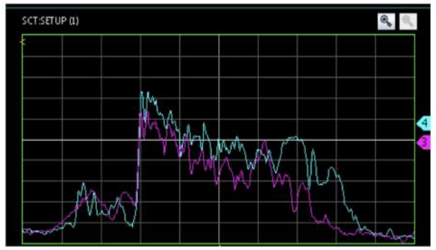
F. Peauger



Position scan
with corrector



Without RF power



With RF power

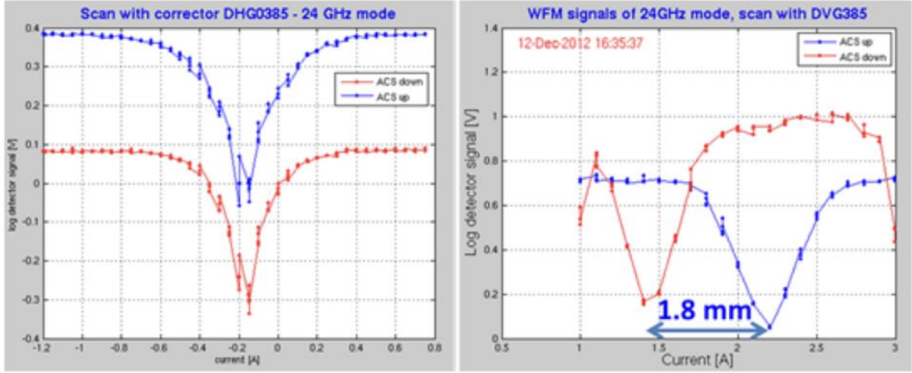


Figure 10: WFM response of the 2 ACS for a horizontal beam position scan (left) and a vertical scan (right). The ACSs were vertically misaligned.

W.Farabolini et al.,“RecentResultsfromCTF3TwoBeam Test Stand“, Conf. Proc.: IPAC2014, June 2014.

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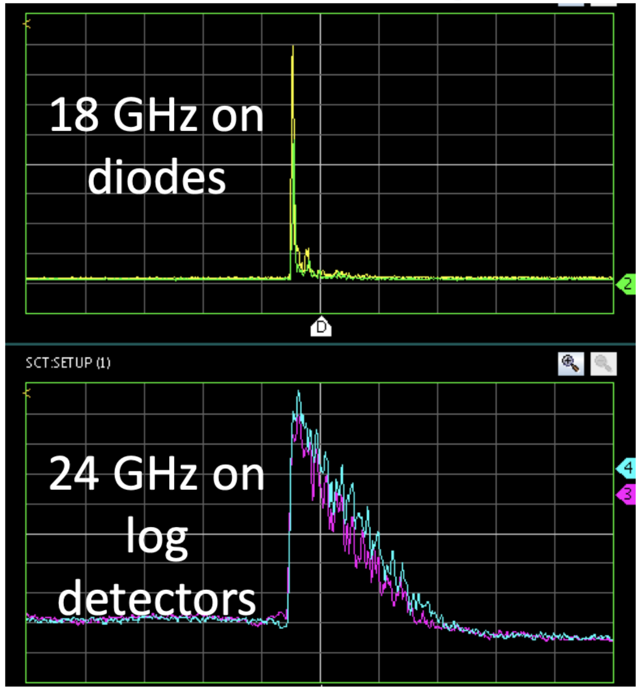
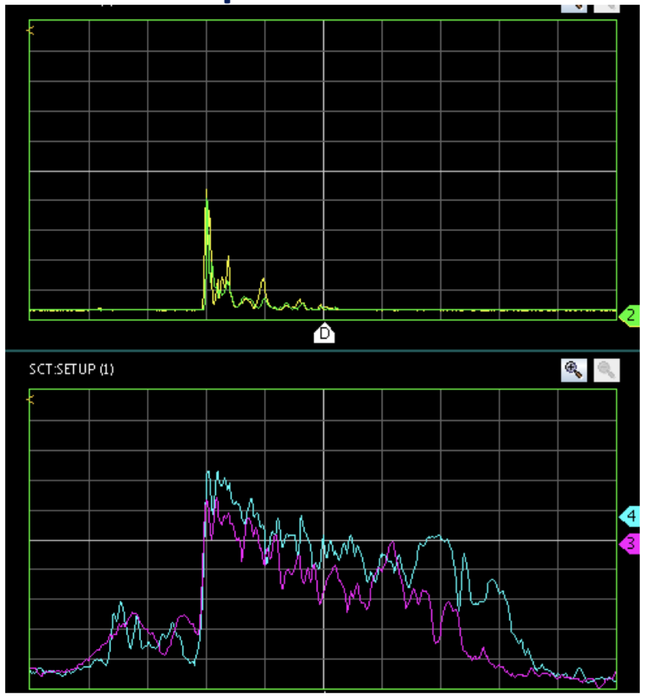
Some additional measurements

WFM signals from a PB pulse





WFM signals without 12 GHz RF power

WFM signals with RF power

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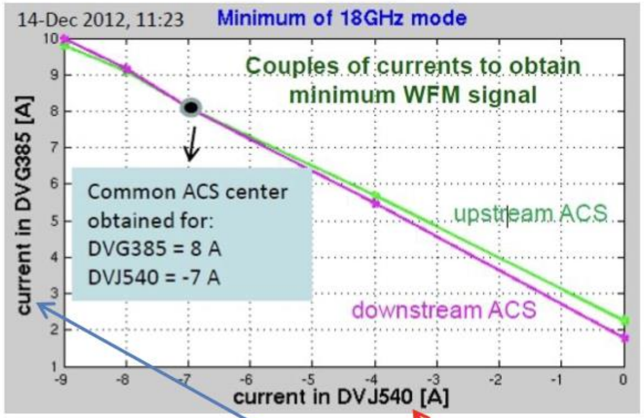
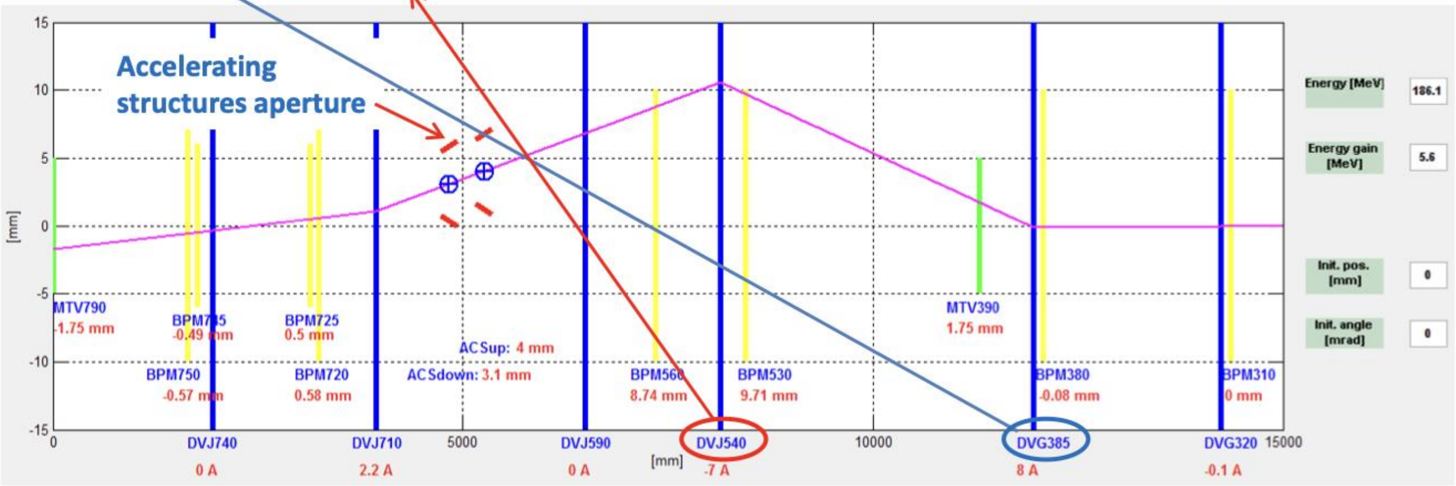
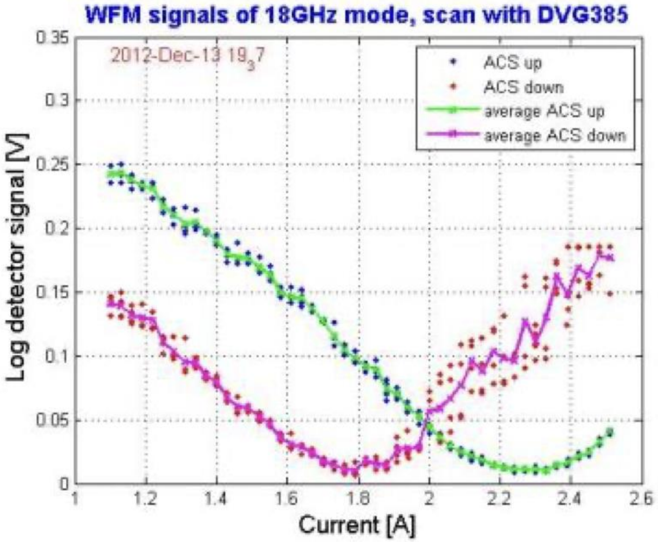
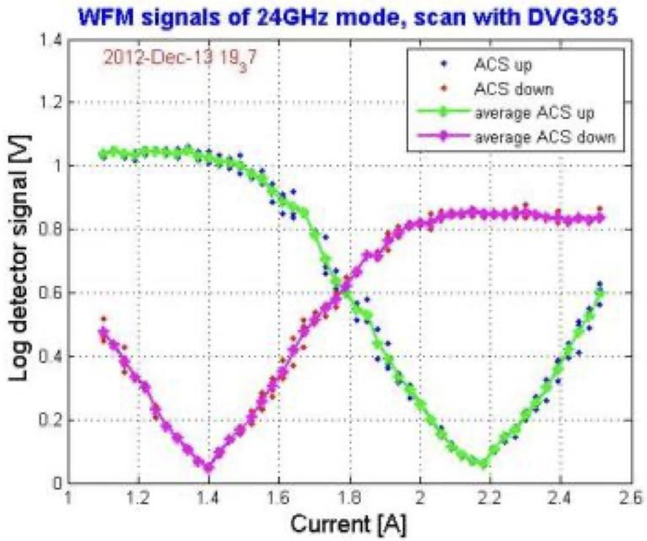
Some additional measurements



First successful results: realignment of the ACSs tank according to the position delivered by the WFM.
Using corrector is now no longer required to transport the beam through TBTS line.







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