CLICWEEK2019
Compact Linear Collider Workshop
January 21 - 25, 2019 @ CERN

CLIC MODULE DESIGN

C. Rossi on behalf of the CLIC Module team

CLIC Module Activity in 2018

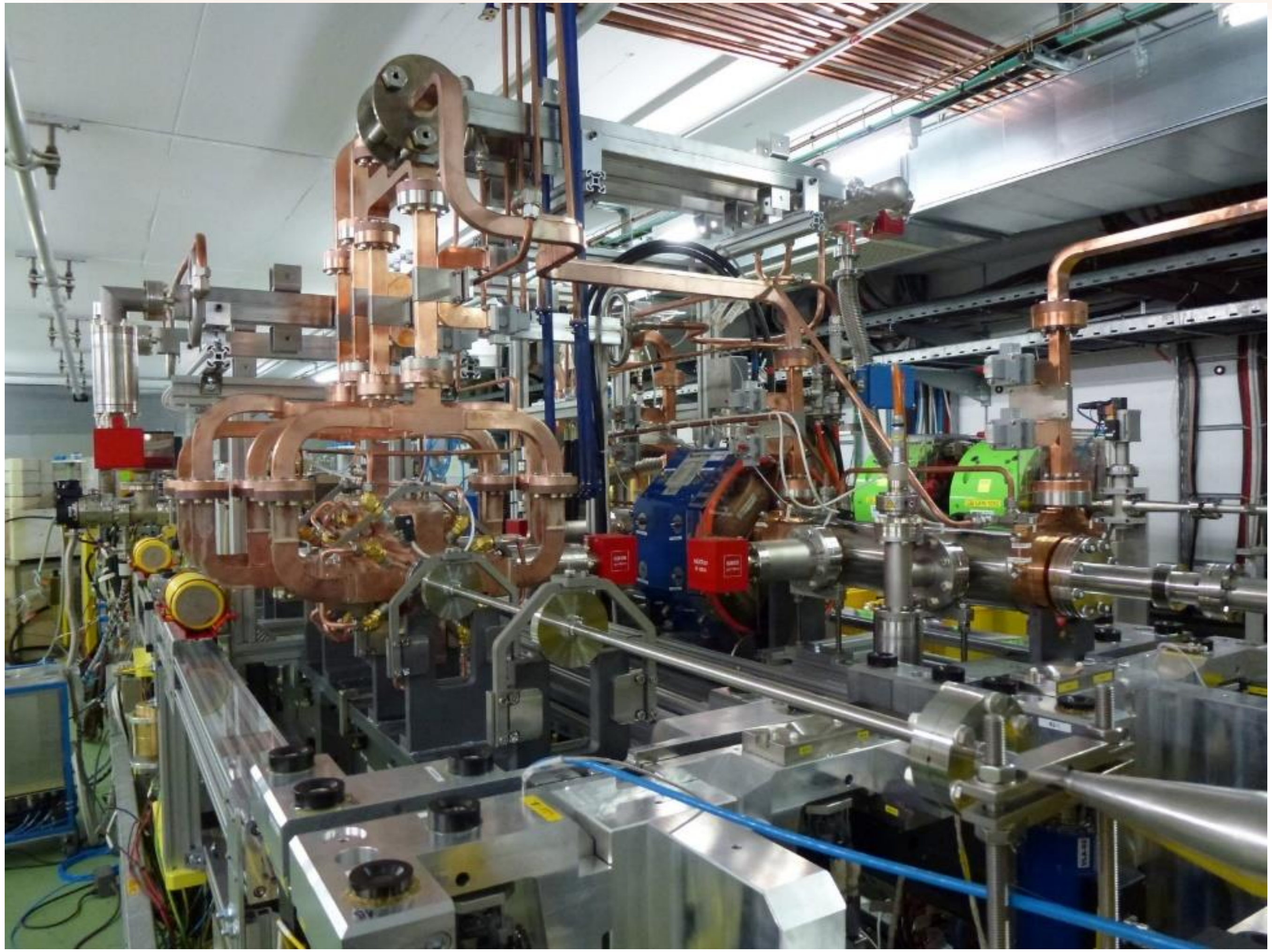
The main effort in 2018 was oriented to the PiP completion and to the preparation of the CLIC cost review

- Complete the Design and Integration of the CLIC Module in the Drive Beam and Klystron-based versions.
  Provided input to the Civil Engineering and Infrastructure studies

- Progress with the CLIC Module thermo-mechanical studies.
  Actively participated into the Cooling and Ventilation studies

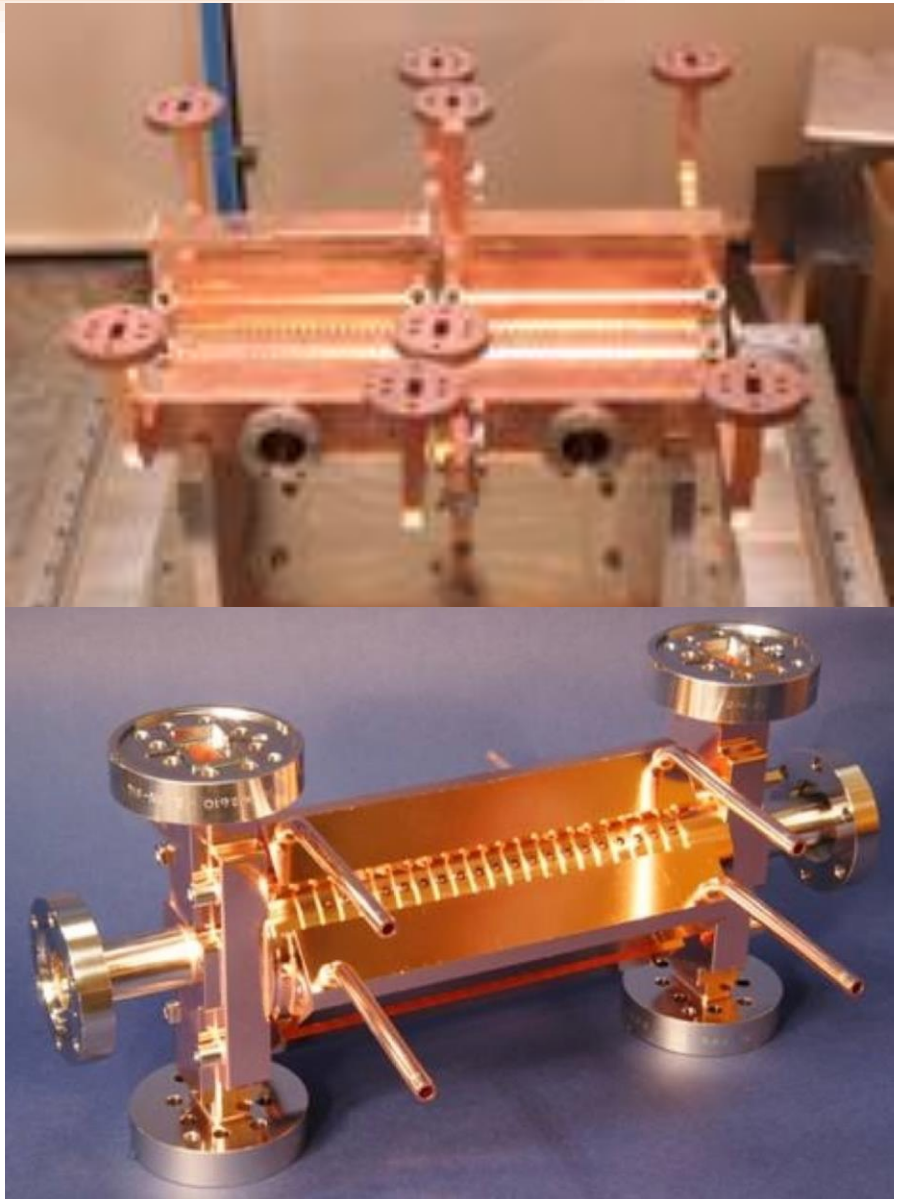
- Environmental studies.

CLIC Module Layout



AS are assembled in what we call the CLIC Modules (each Module length is about 2 m).

RF Accelerating Structures (AS).

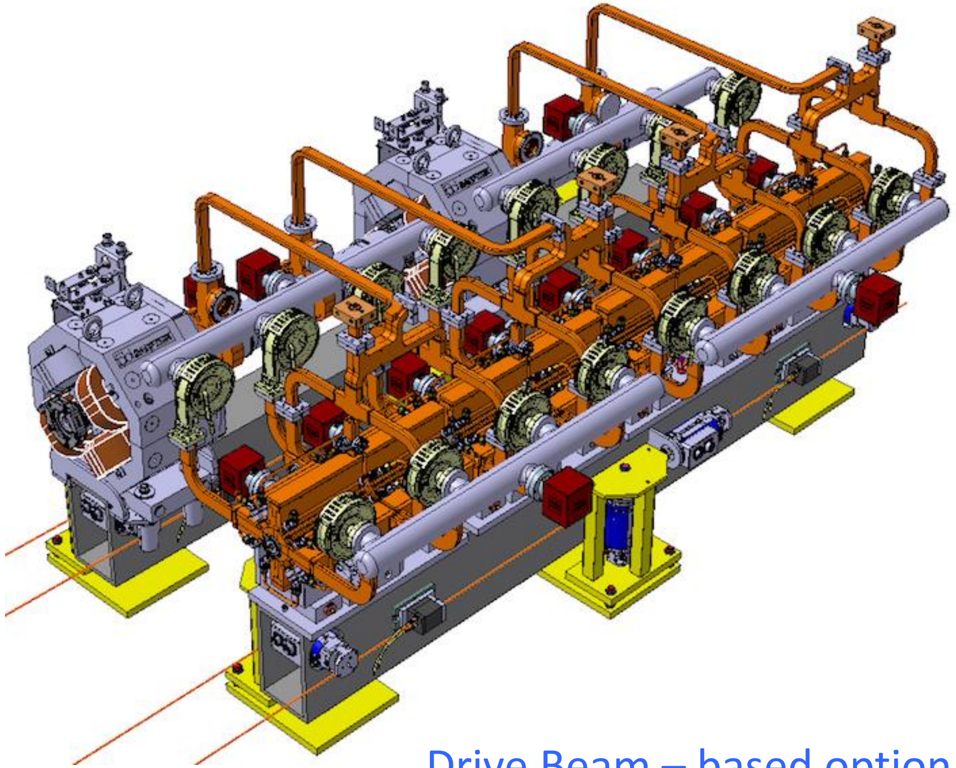


Courtesy N. Catalan and A. Solodko

CLIC Module Layout

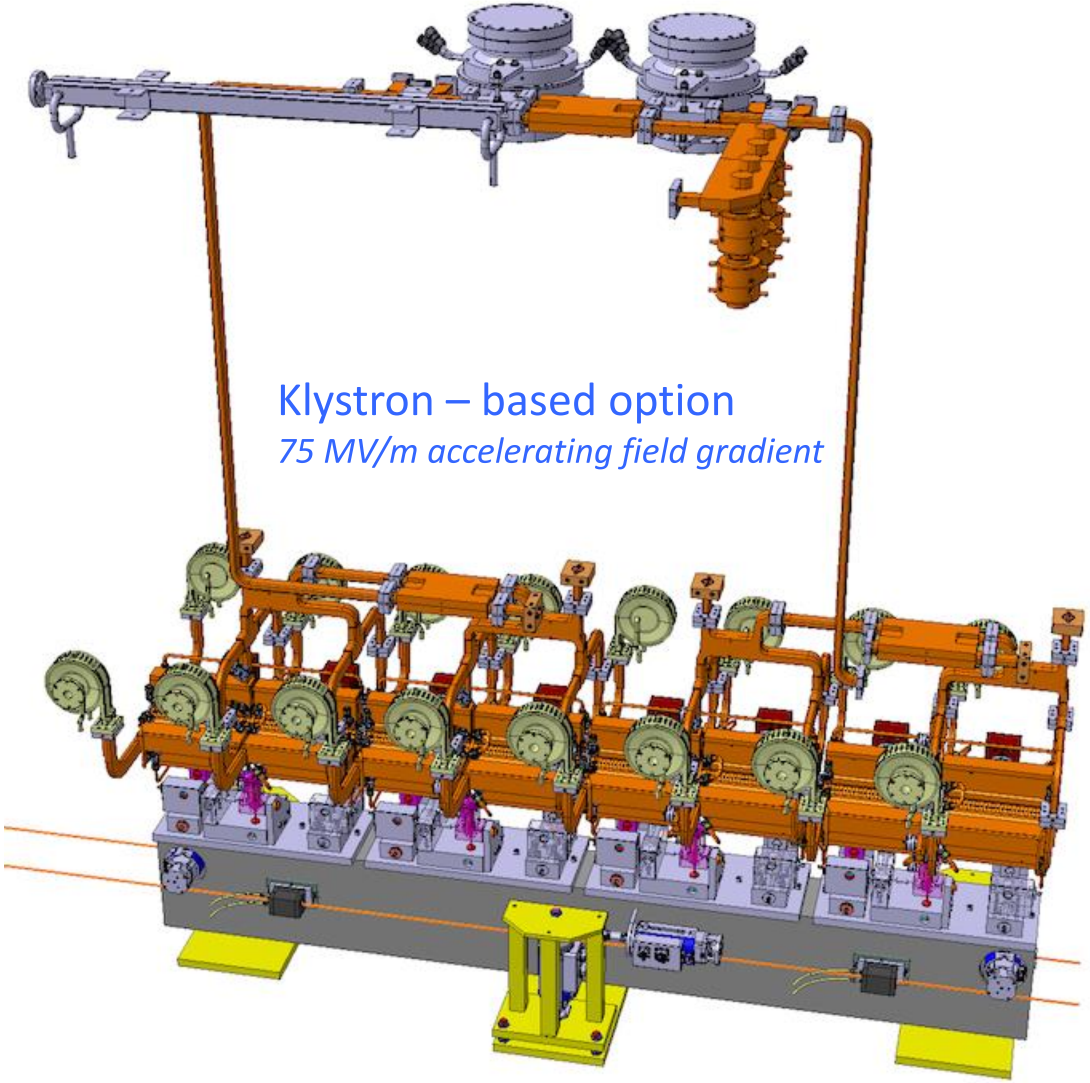
The rebaselining exercise has produced two distinct optional layouts at the energy stage of 380 GeV for the CLIC Module.

For Module rebaselining see: [Main Linac HW Baselining *in CLIC WS2018*]



Drive Beam – based option

72 MV/m accelerating field gradient

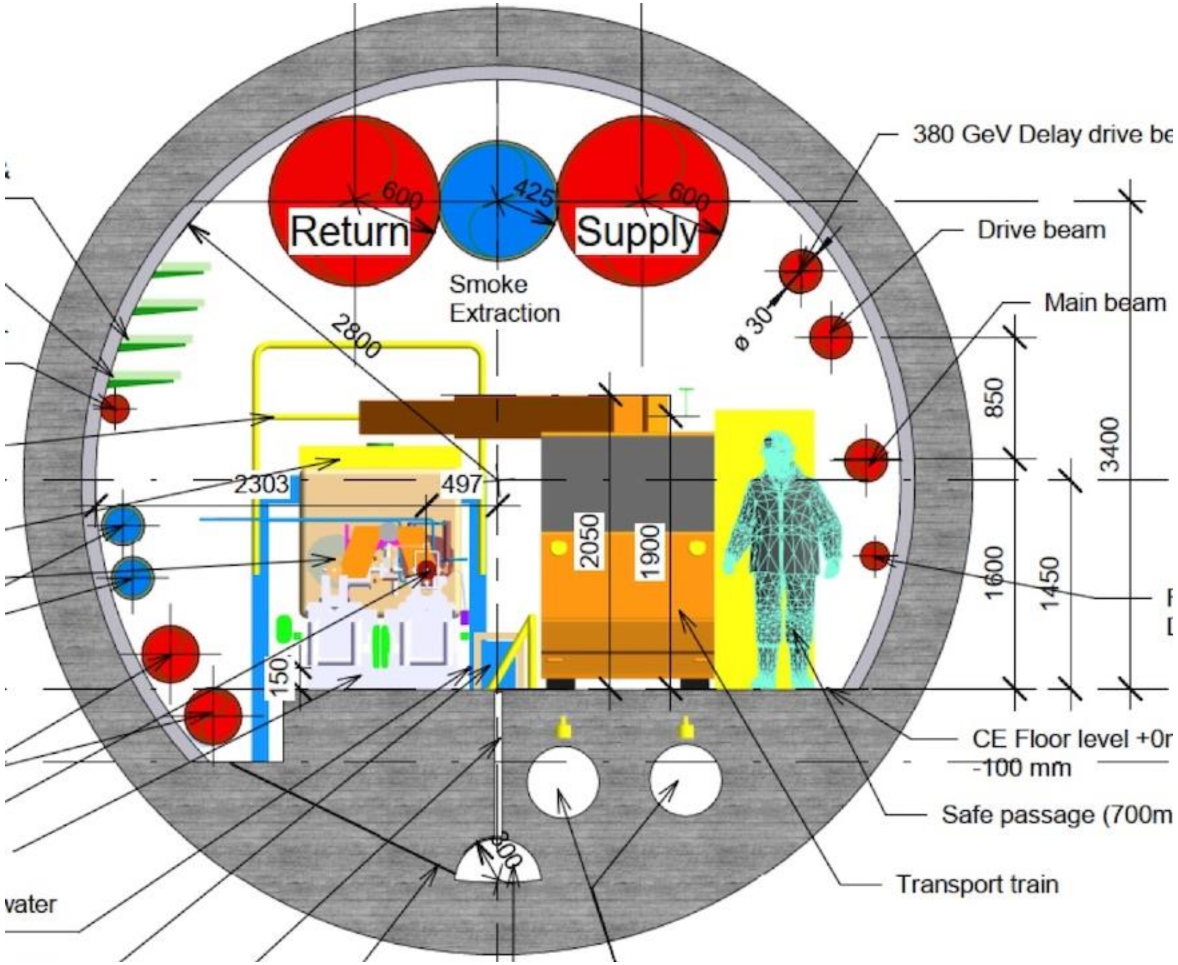


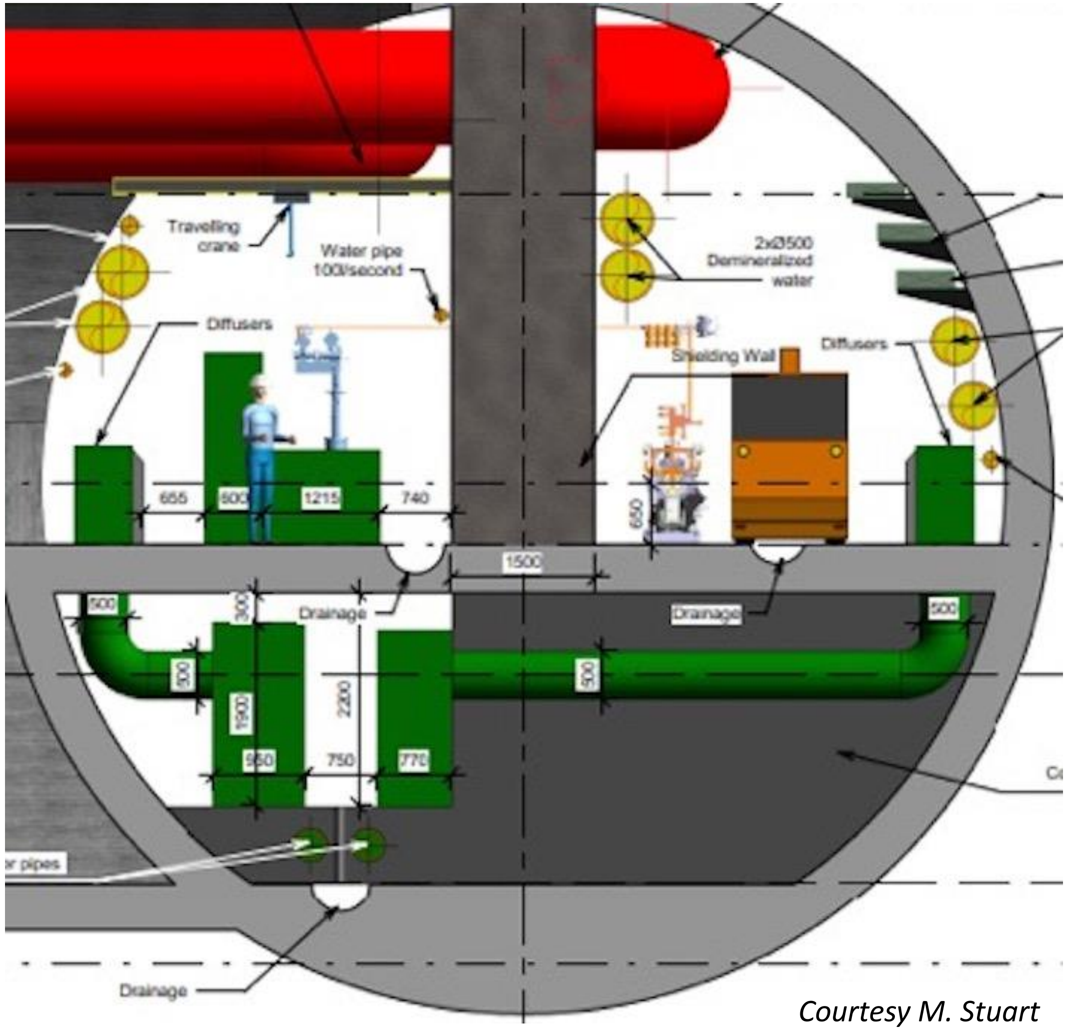
Klystron – based option

75 MV/m accelerating field gradient

CLIC Module Integration in the Main Linac tunnel

Tunnel integration for the DB and K options, PiP version.

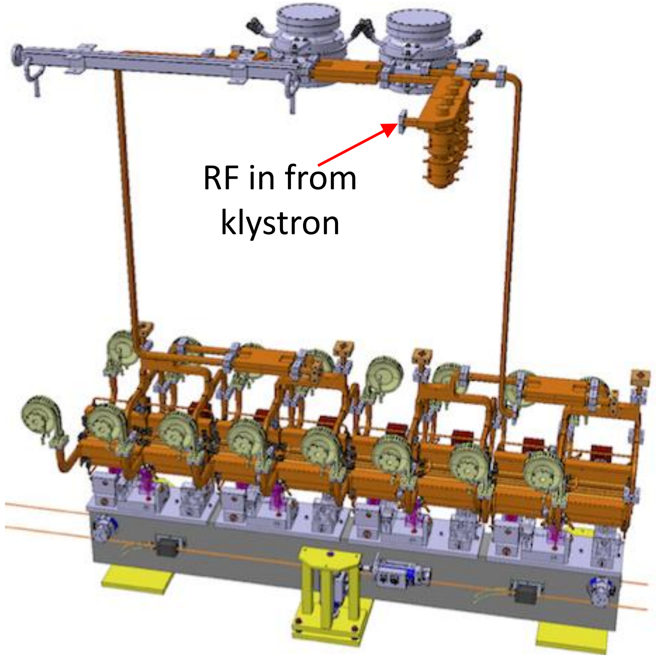




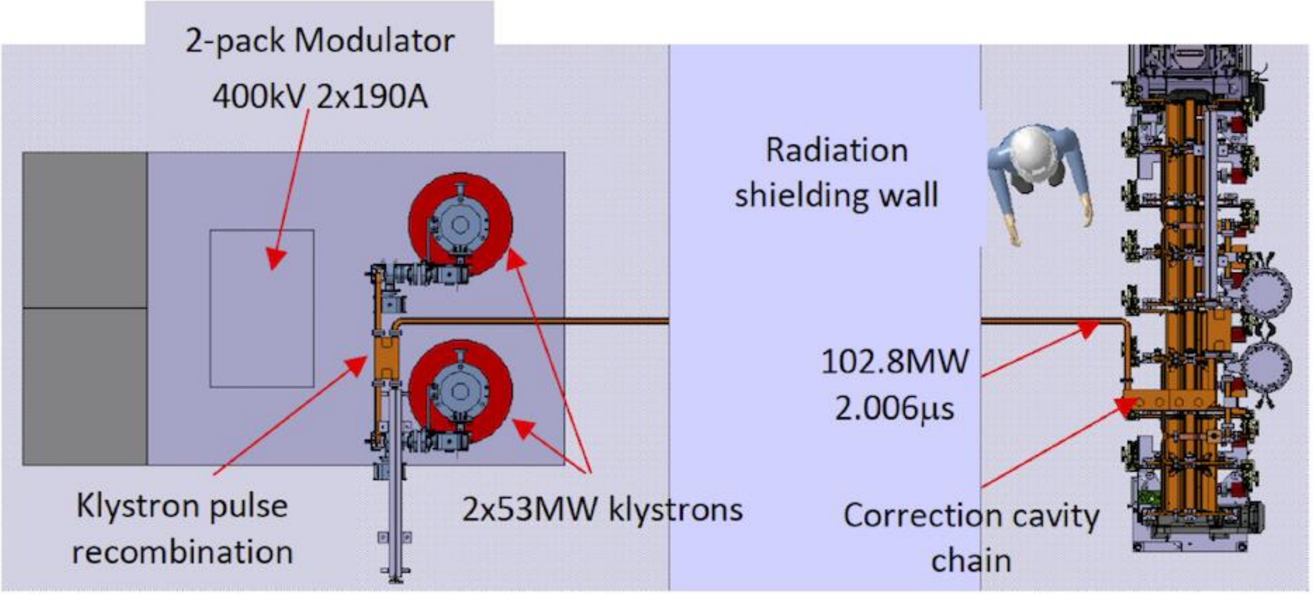
Courtesy M. Stuart

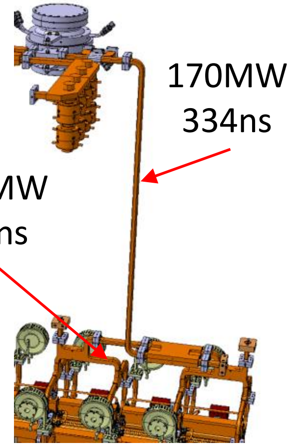
CLIC Power distribution in the K Module

The klystron-based Main Linac requires a total of 2912 Modules, each equipped with 4 RF superstructures 0.46 m long, which are fed by 5824 klystrons.



Klystron – based option





Power management in the CLIC Module

The power dissipation in the CLIC Module is something critical for the machine stability and performance.

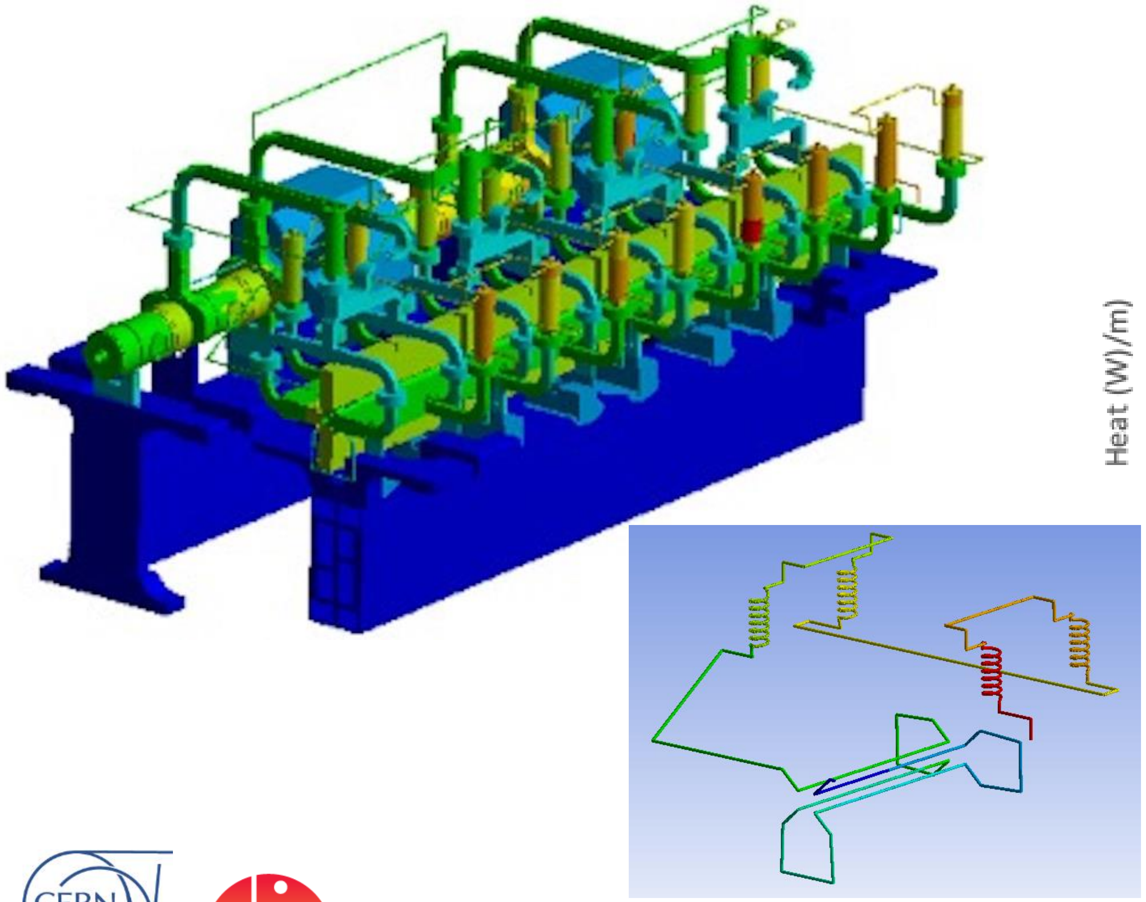
Drive Beam Module		**Unloaded conditions**	
Module component	Number	Item Dissipation [W]	Total Dissipation [W]
SAS	4	772	3088
PETS	4	10.5	42.1
SAS RF Loads	16	168	2690
Waveguides	4	60.2	241
DBQs	2	171	342
Total Dissipation / Module			6403

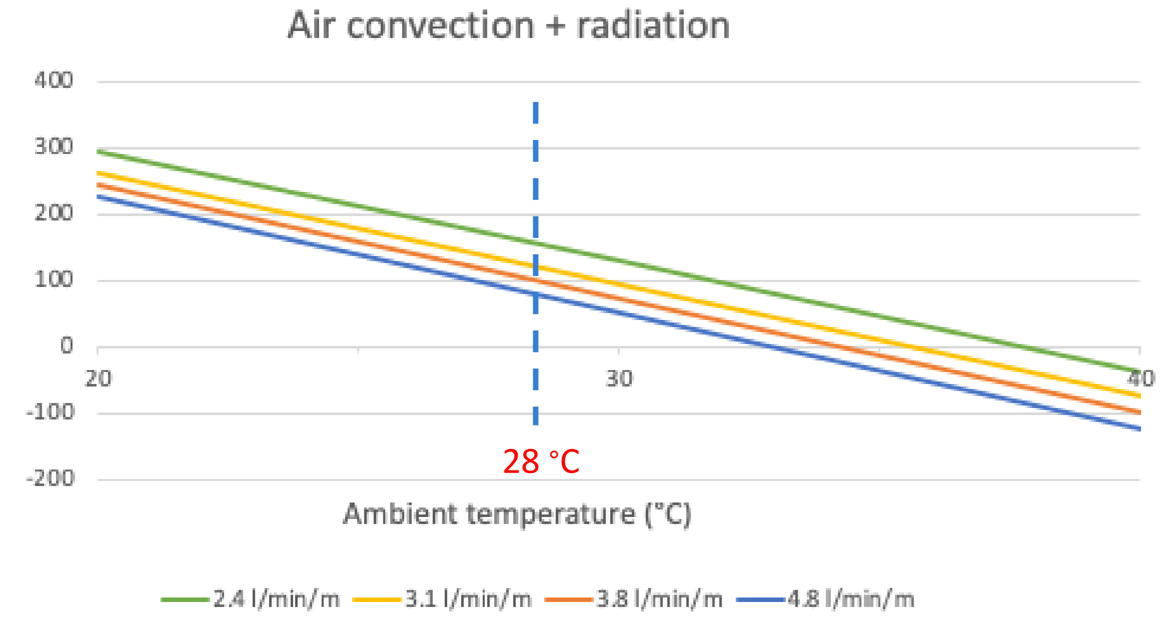
Klystron – based Module		**Loaded conditions**	
Module component	Number	Item Dissipation [W]	Total Dissipation [W]
SAS	4	1100	4400
SAS RF Loads	16	178	2842
Waveguides and RF Pulse compression	1	1034	1034
Total Dissipation / Module			8276

With unloaded conditions, the klystron – based Module would dissipate 10388 W.

Power management in the CLIC Module

The temperature stabilization is under study to minimize the heat-to-air load and provide the required operational stability. Case of the DB Main Linac.

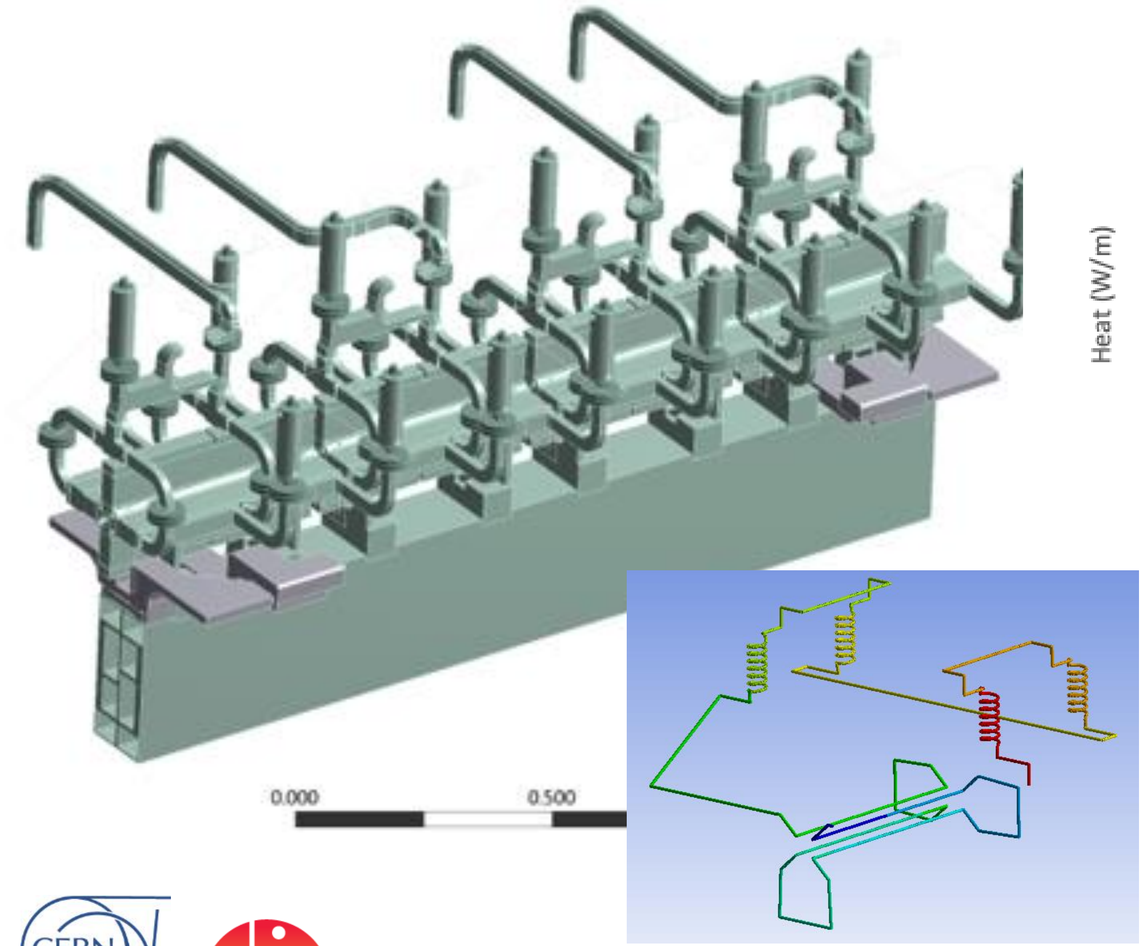


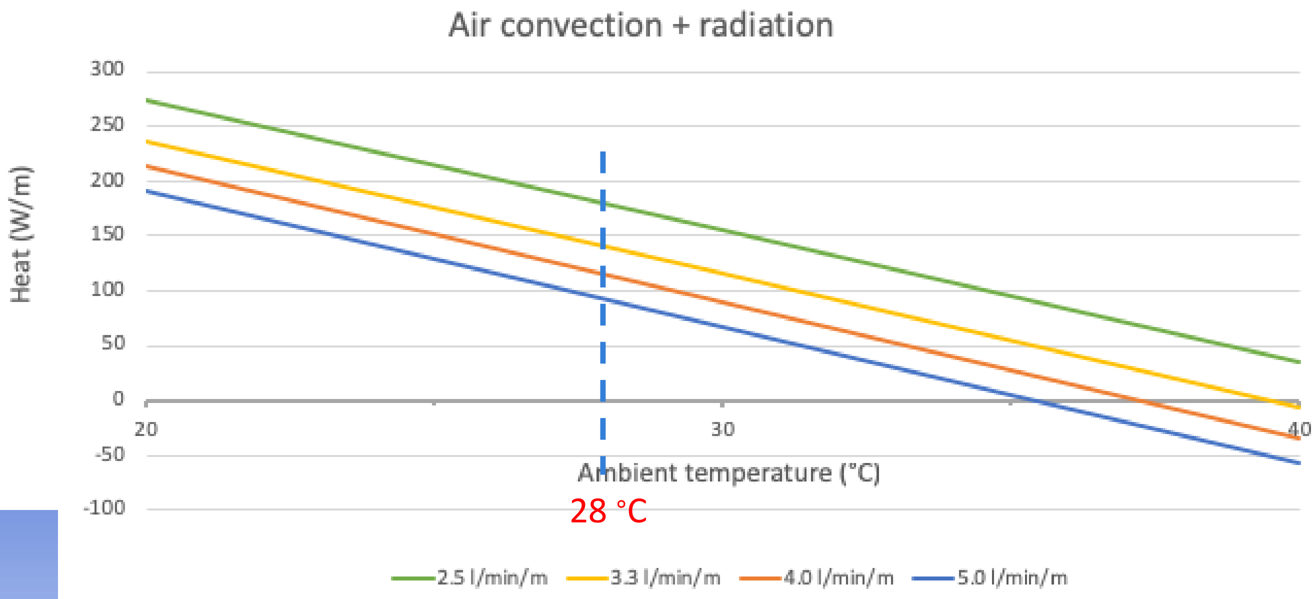


SAS and Compact Loads connected in series

Power management in the CLIC Module

A simplified case of the klystron – based Linac has been studied; the case requires further optimization.





SAS and Compact Loads connected in series

… and heat transfer to the environment

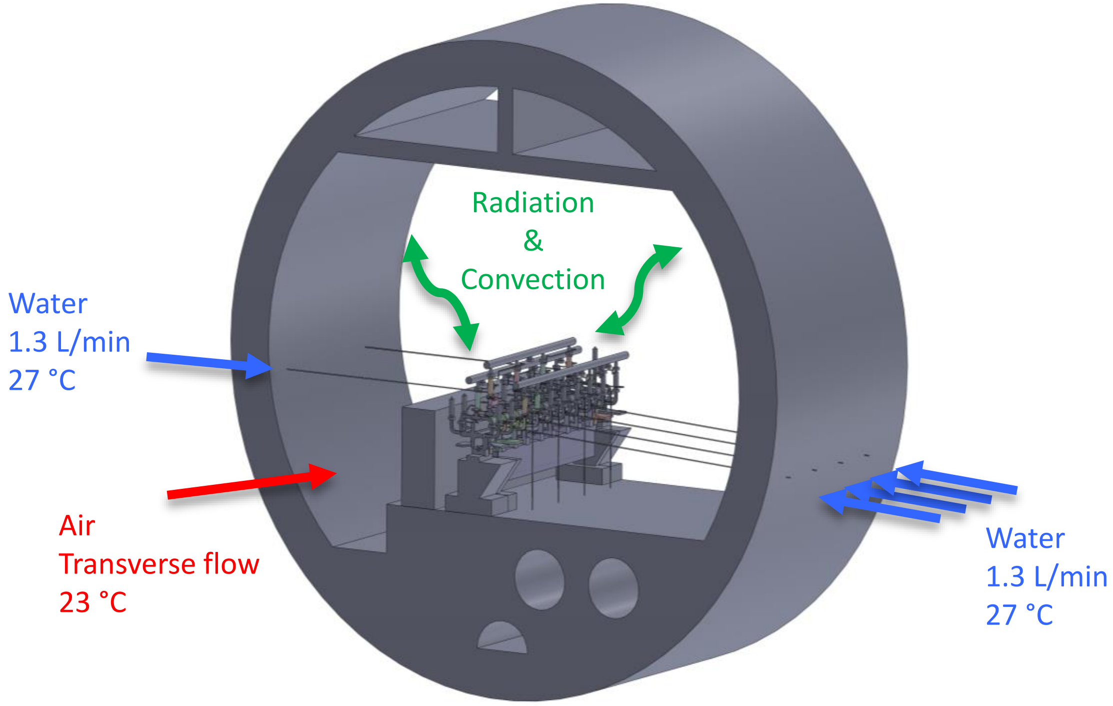
CFD simulations have been set up, need to progress further, exchange from tunnel to soil seems not relevant.

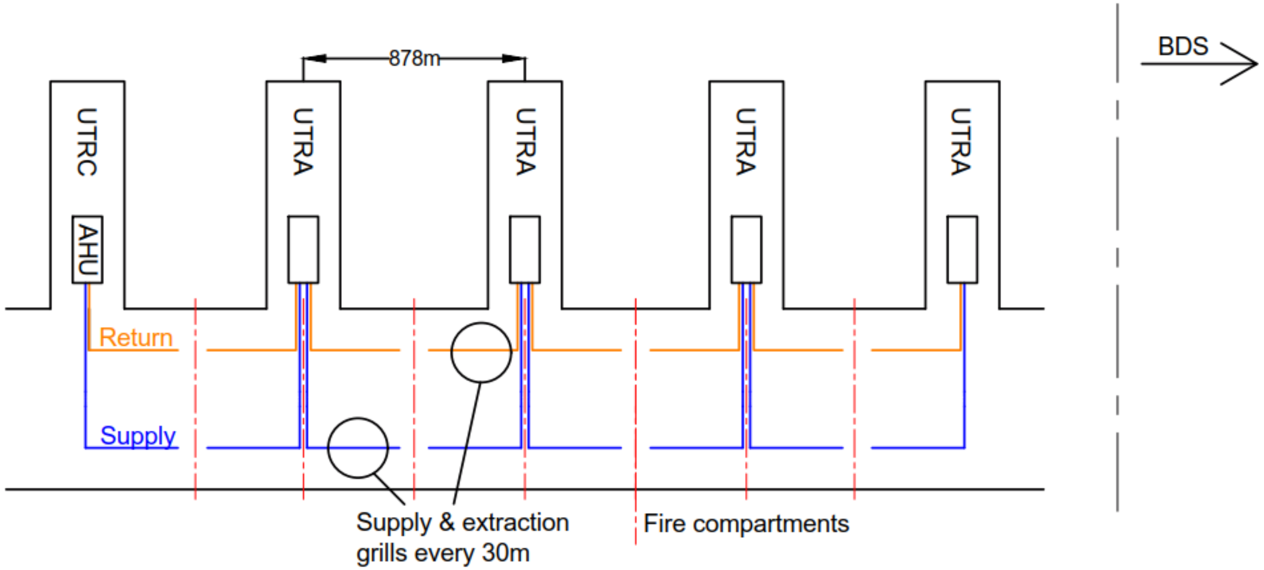
The ambient temperature has been set at 28 °C;

Supply temperature has been set at 23 °C;

ΔT = 5 °C;

Supply and extraction ducts extend within each sector.

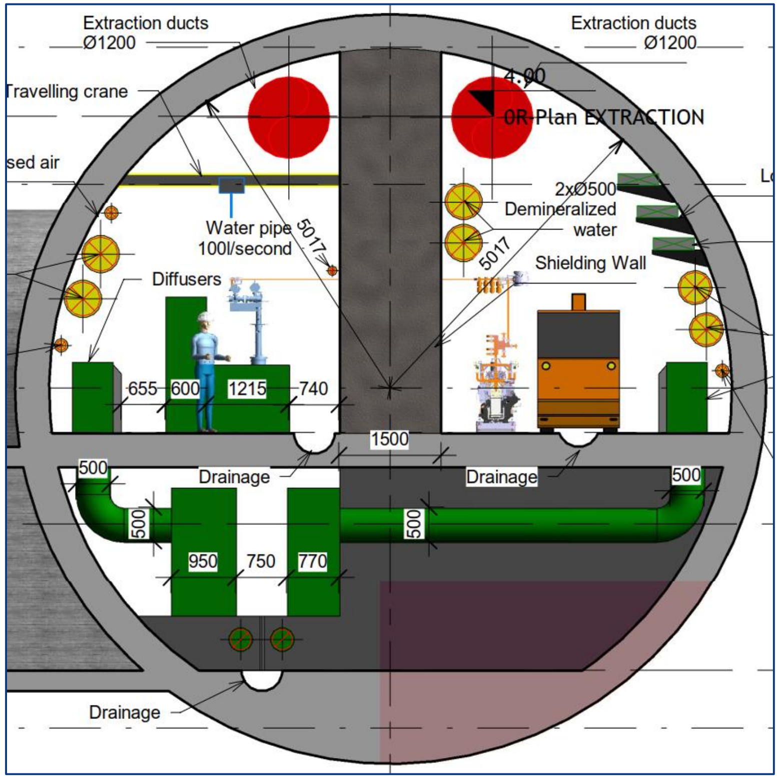




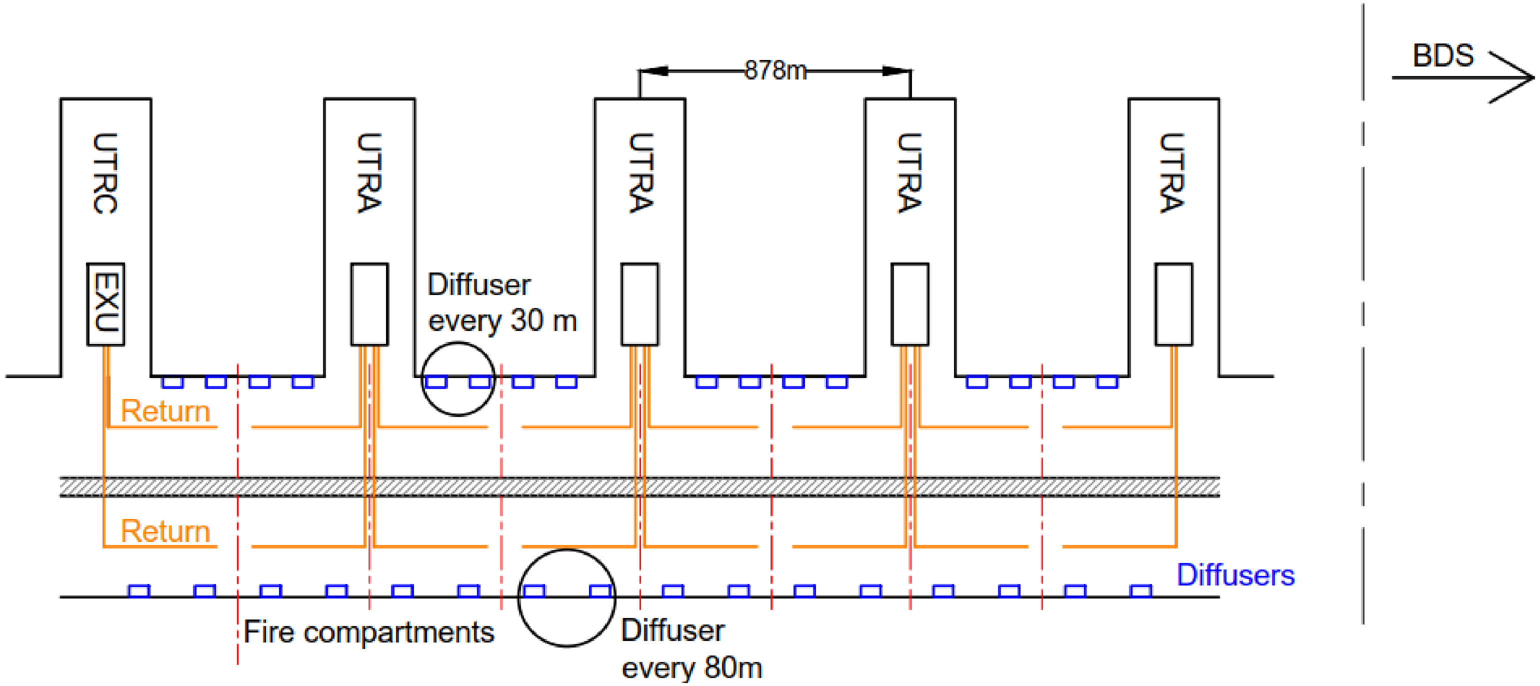
Case of the DB Main Linac

… and heat transfer to the environment

Air supply diffusers are distributed along the sector (at floor level) as well as extraction ducts (on ceiling);



For both DB and K cases temperature distribution needs to be computed and transient effects studied.

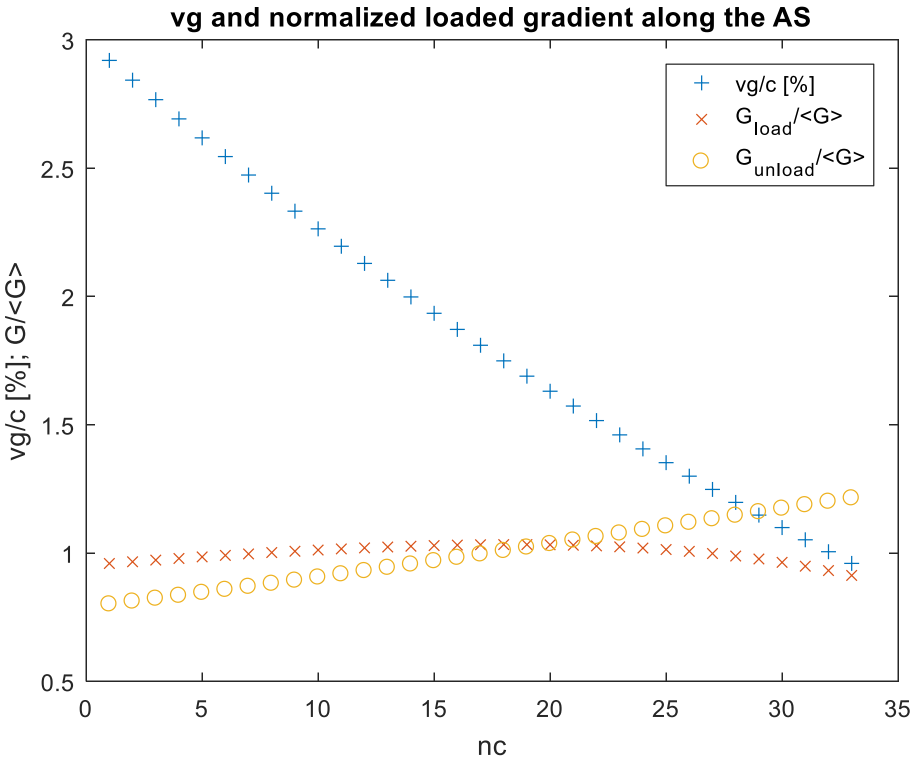


Case of the klystron-based Main Linac

… and heat transfer to the environment

Temperature stability within modules is essential to achieve the expected luminosity target.

If temperature errors could be anticipated along the Linac this could contribute in relaxing the tolerances.

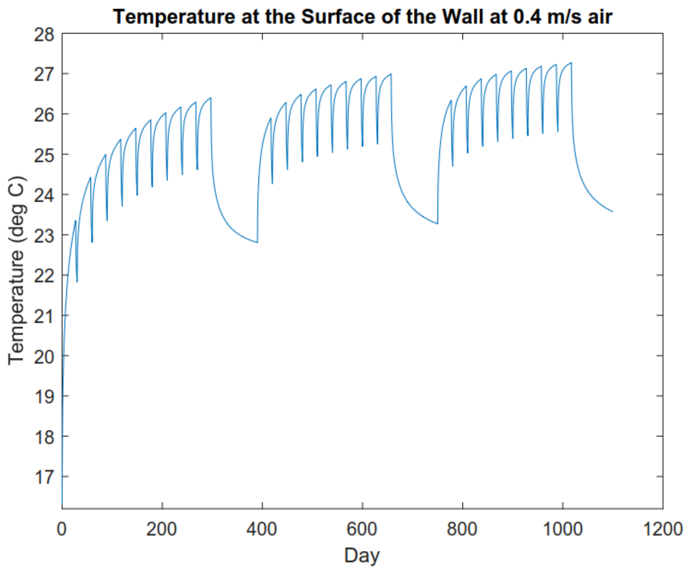


Courtesy A. Grudiev

Synchronous phase: $\varphi_0 = 30^o$
dV/V < 1%
Loaded case: dT < 0.55 K
Unloaded case: dT < 0.5 K

Synchronous phase: $\varphi_0 = 12^o$
dV/V < 1%
Loaded case: dT < 1.3 K
Unloaded case: dT < 1.2 K

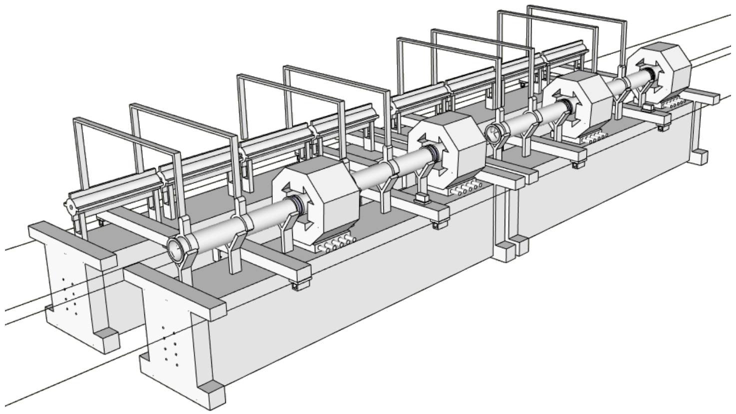
Transition states should be limited in amplitude and duration.



Acceptable voltage error AS-to-AS < ± 1%.

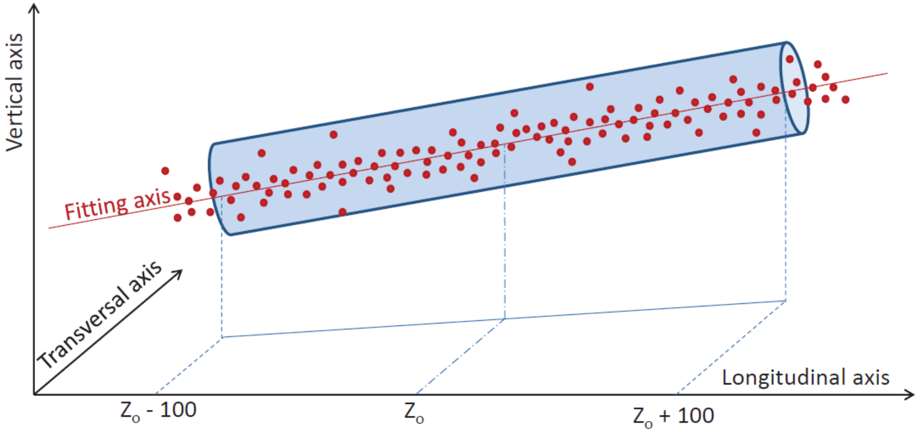
CLIC Alignment requirements

The alignment strategy is based on stretched wires and position sensors, providing information to the active movers supporting the CLIC Module.



Courtesy H. Mainaud-Durand

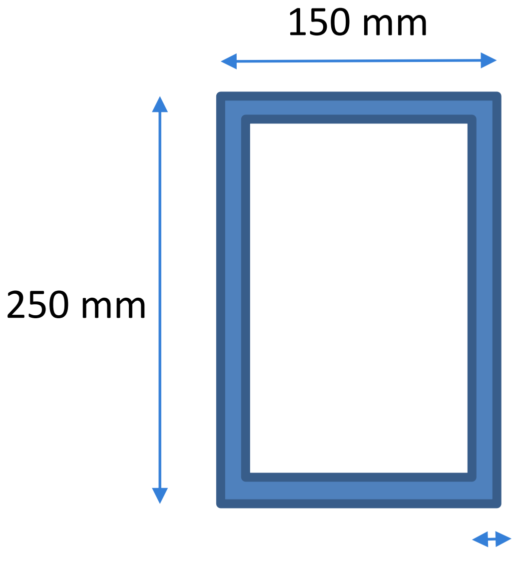
± 14µm must be assured over a 200m sliding window, by an active alignment system.



			$\Delta\epsilon_y$ [nm]		
Imperfection	With respect to	Value	1-2-1	DFS	RF
Girder end point	Wire reference	12 μm	11.37	11.31	0.07
Girder end point	Articulation point	5 μm	1.45	1.45	0.02
Quadrupole roll	Longitudinal axis	100 μrad	0.04	0.04	0.04
BPM offset	Wire reference	14 μm	154.54	14.01	0.10
Cavity offset	Girder axis	14 μm	5.51	5.50	0.04
Cavity tilt	Girder axis	141 μrad	0.10	0.47	0.25
BPM resolution		0.1 μm	0.01	1.03	0.02
Wake monitor	Structure centre	3.5 μm	0.01	0.01	0.40
All			176.68	32.72	0.84

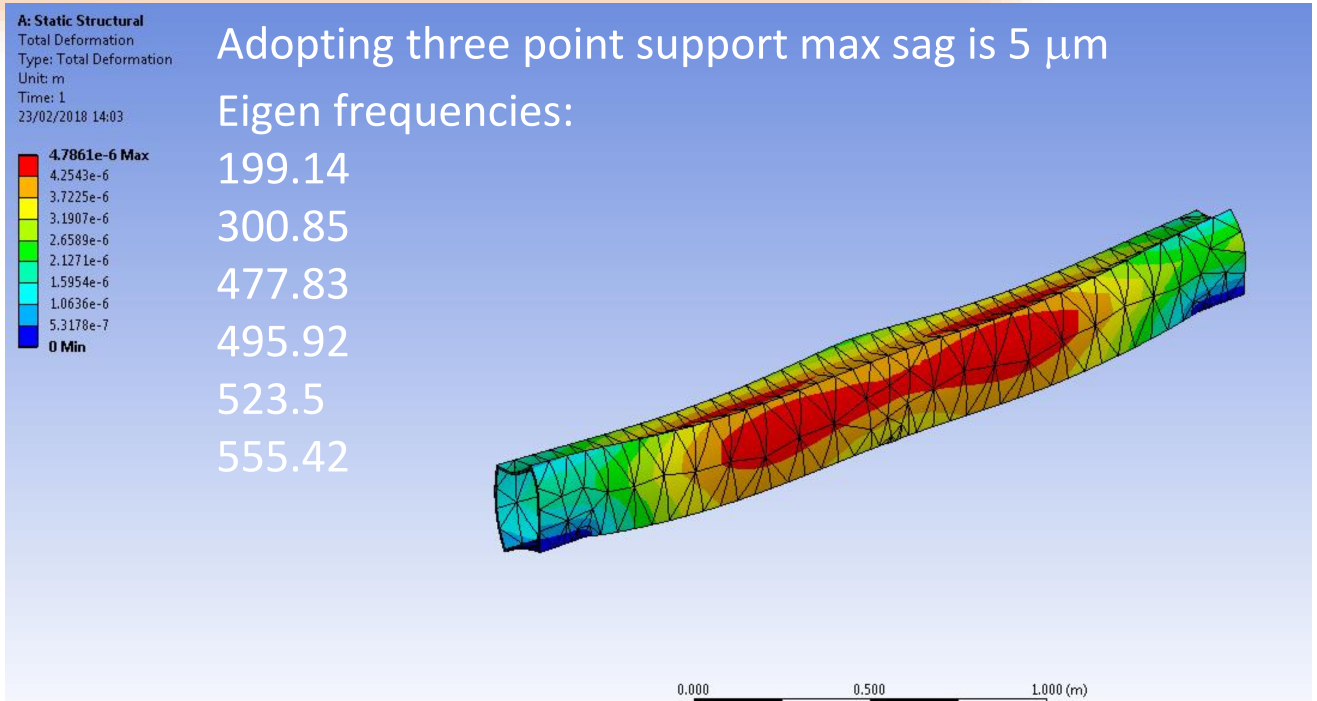
CLIC Module mechanical pre - alignment

New mechanical design of the girder and of the support and adjustment system.



Steel structure

Weight is 100kg for 2m.



Adopting three point support max sag is 5 µm

Eigen frequencies:

199.14

300.85

477.83

495.92

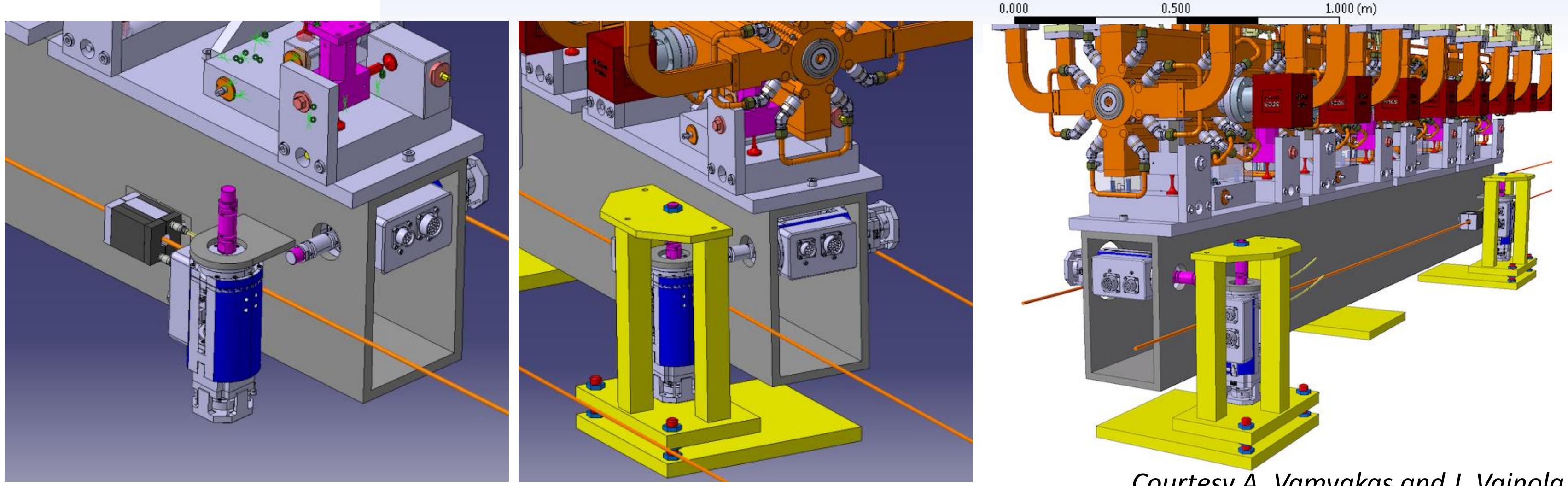
523.5

555.42

Movers integrated in the girder

Flexure based joints

WPS directly attached to the girder

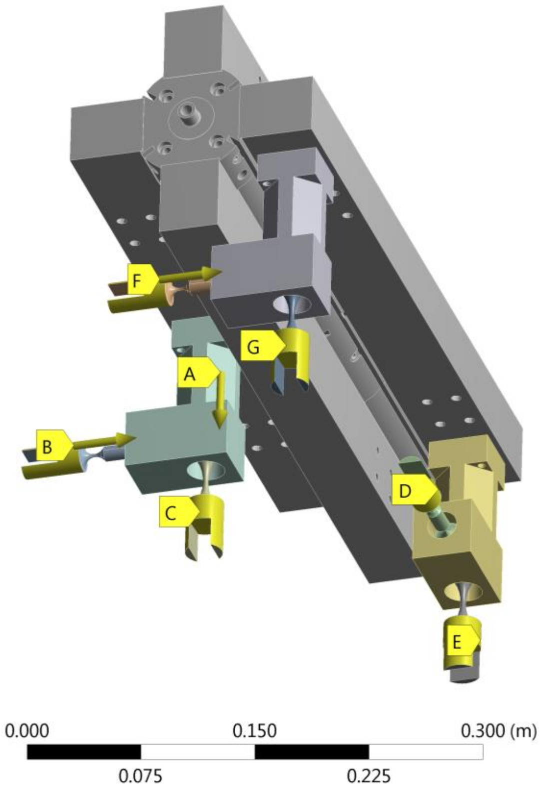


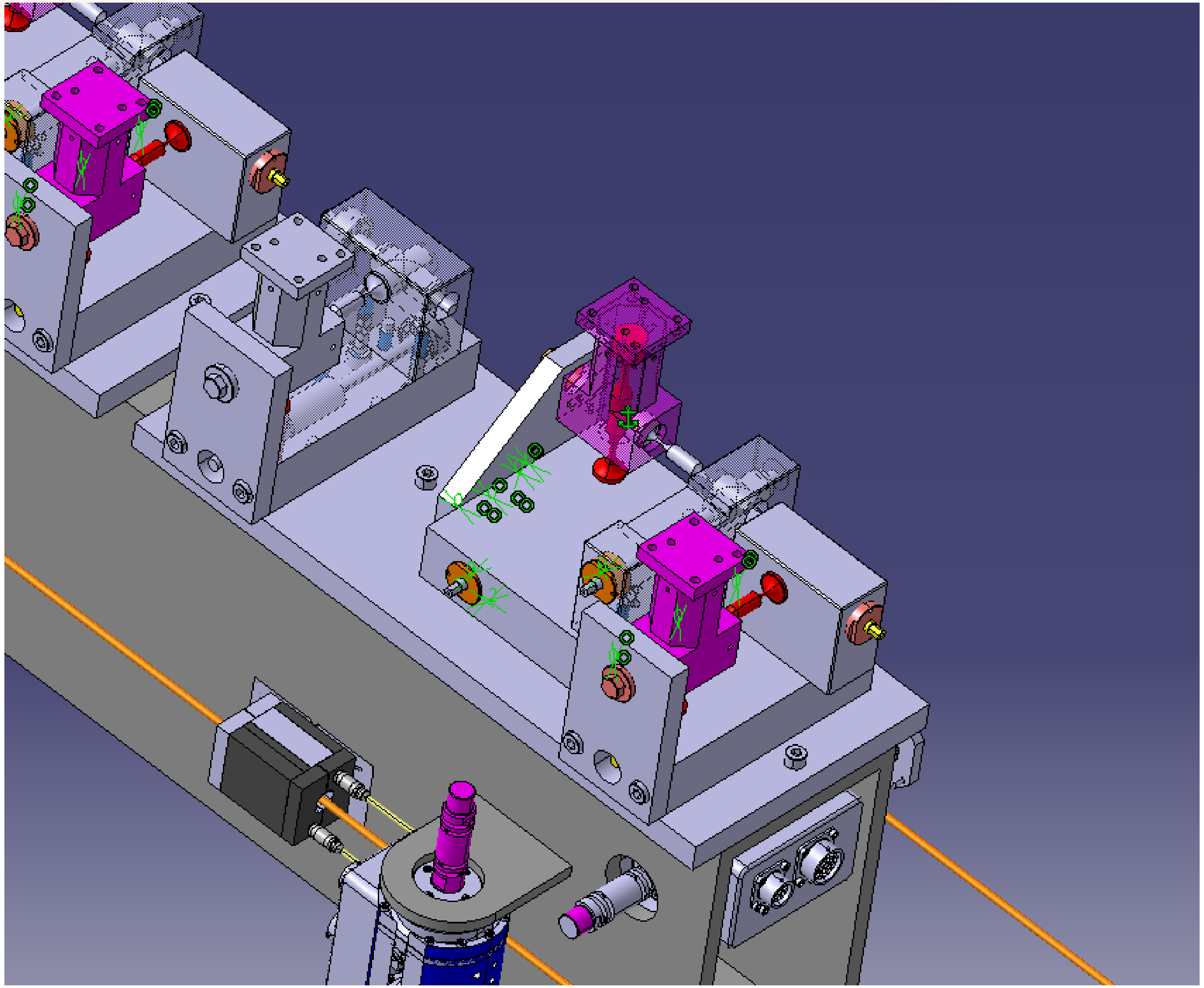
Courtesy A. Vamvakas and J. Vainola

CLIC Module mechanical pre - alignment

New adjustable supports based on flexures and wedges.

Can be motorized for fast adjustment.

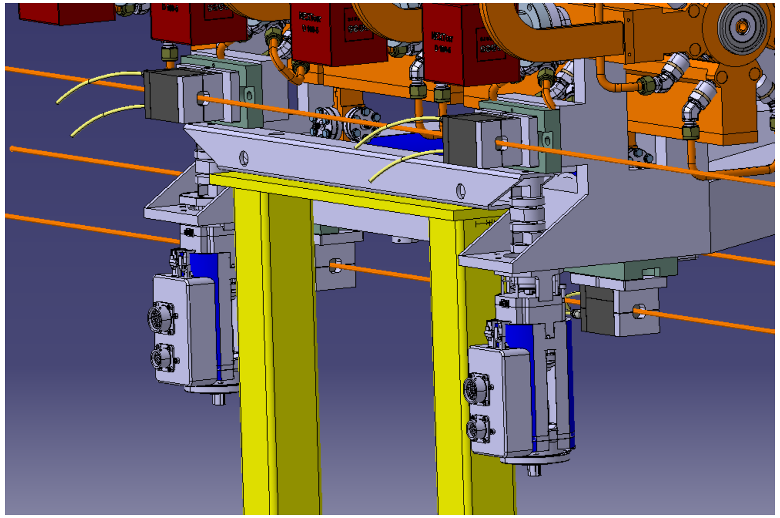




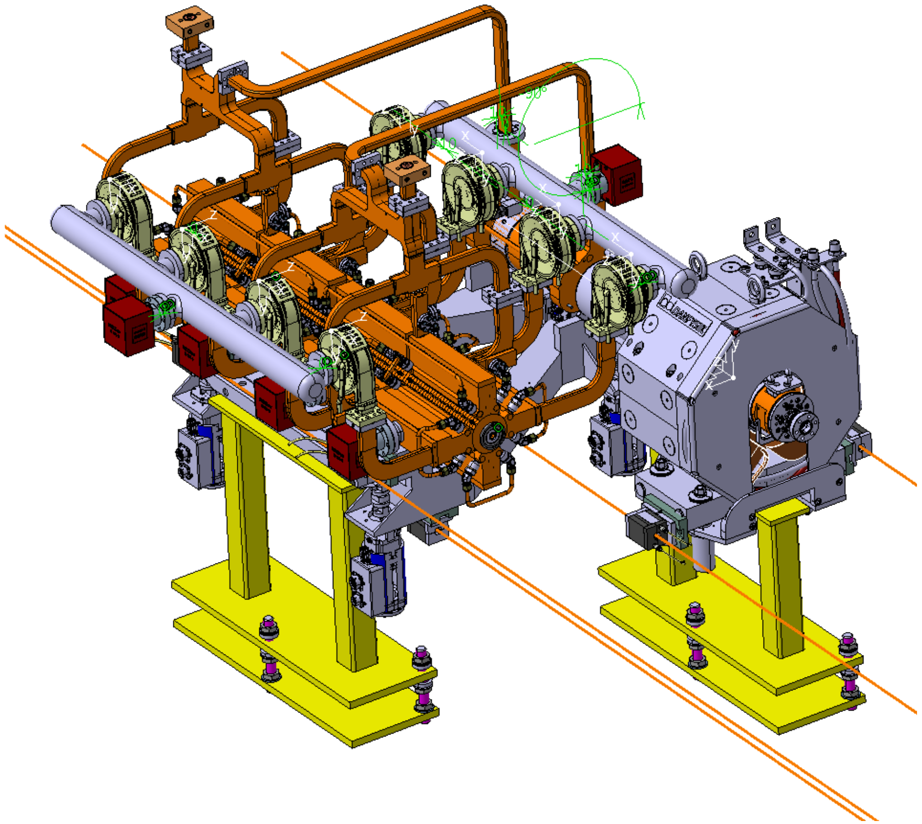
Courtesy A. Vamvakas and J. Vainola

Common girder for an RF Unit

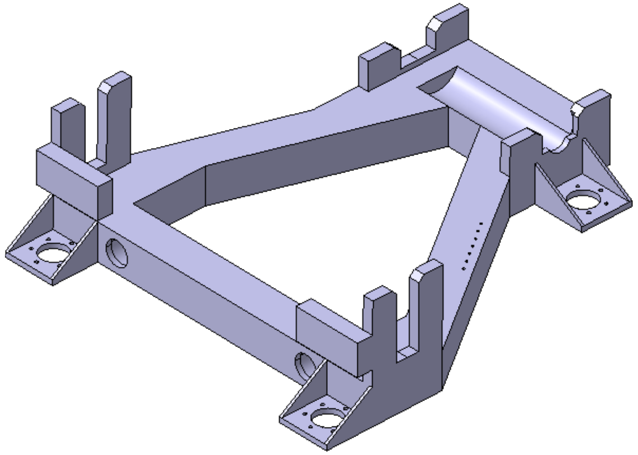
- WPS close to the beam line;
- The whole assembly can be extracted vertically;
- DBQ on motorized support

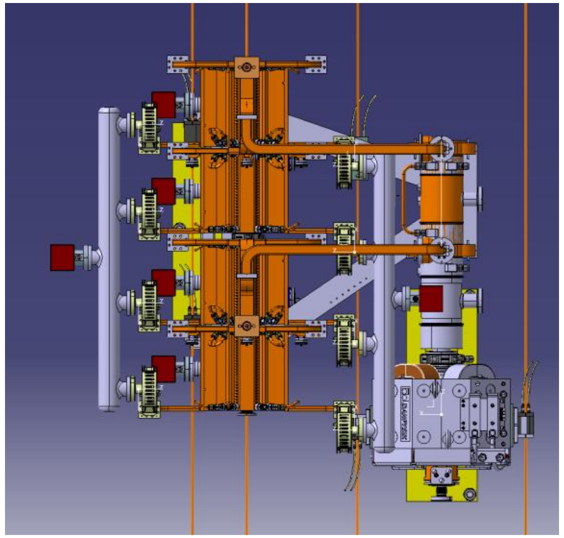


SAS, PETS, actuators pre-assembled on light girder.



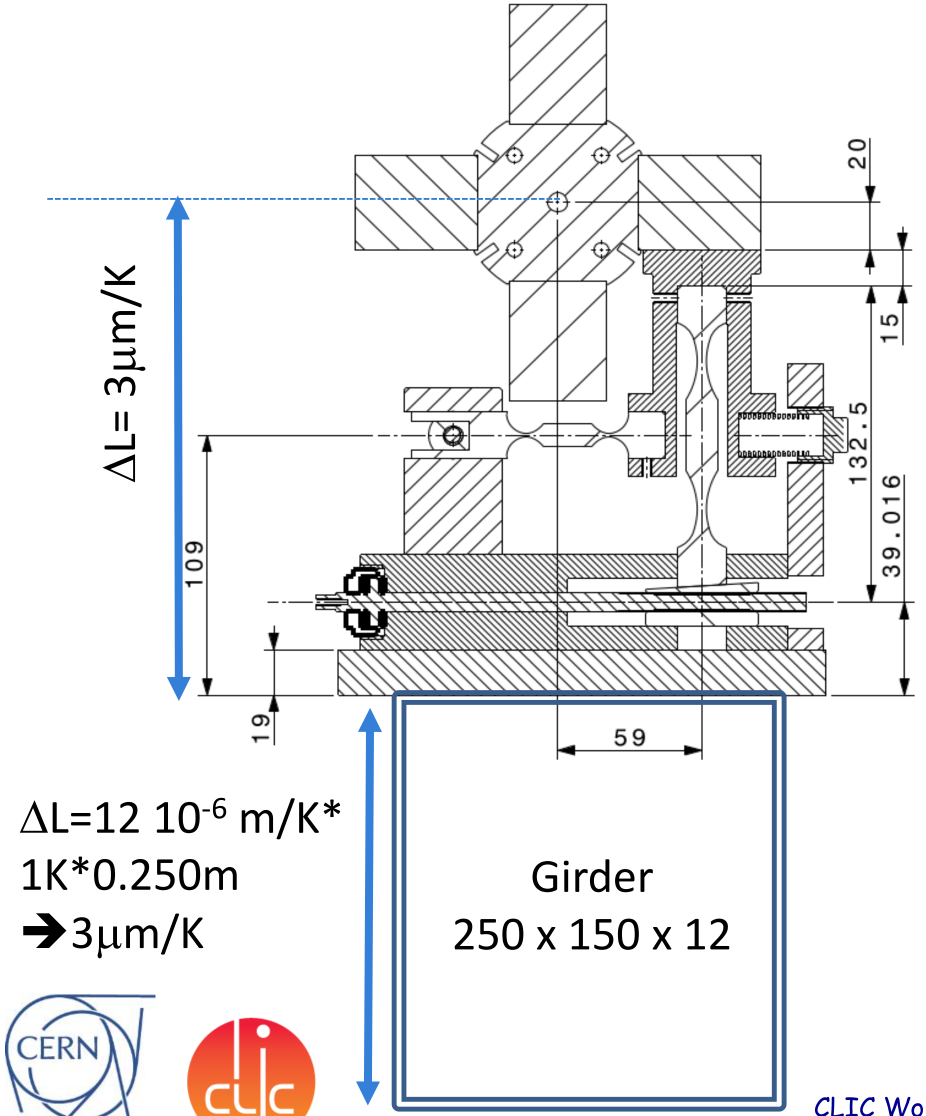
Courtesy A. Vamvakas and J. Vainola



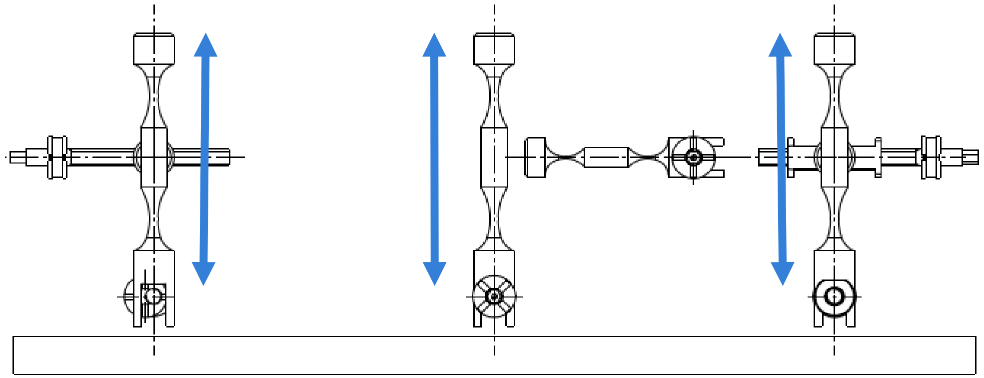


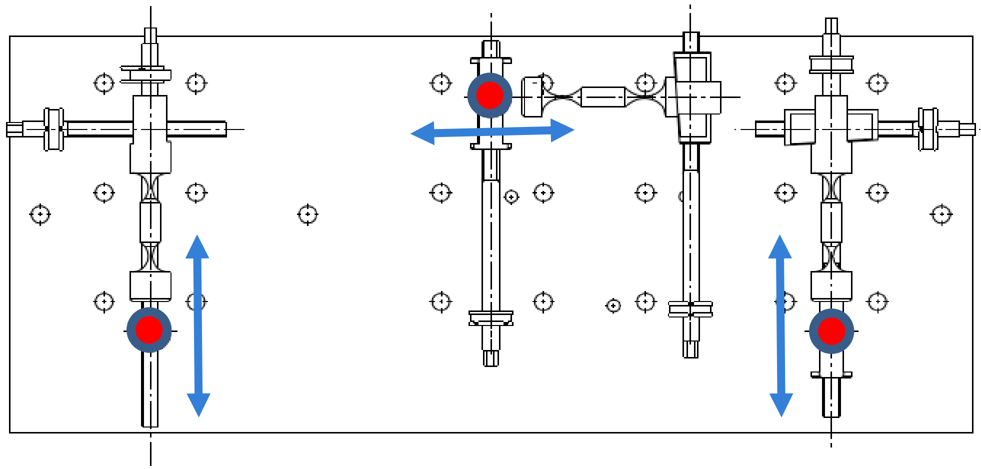
Effects of temperature and vacuum

Preliminary studies on the effects of temperature on the adjustable supports.



$\Delta L = 12\ 10^{-6}$ m/K*
1K*0.250m
➔3μm/K

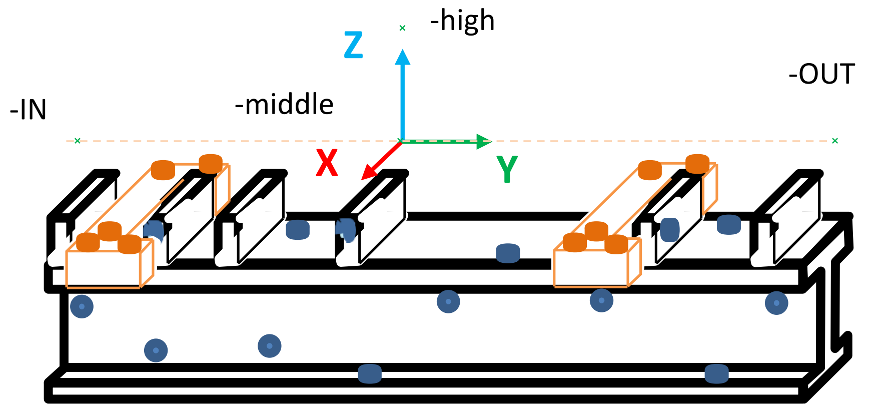




Courtesy J. Vainola

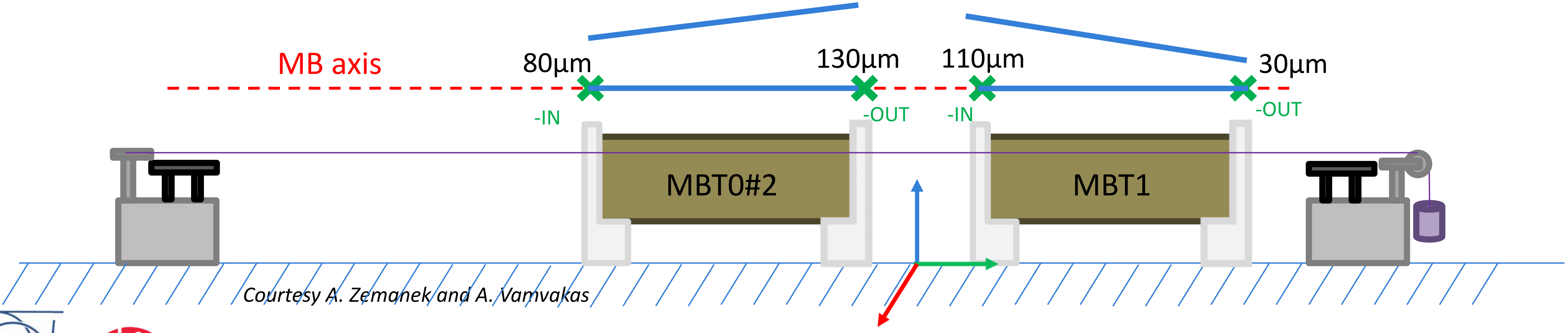
Effects of temperature and vacuum

Measurement campaign completed in the Module Lab with old girders and supports. Will be our reference for the updated design.



Three measurement sessions going from 20 °C ambient temperature up to 30 °C and back to 20 °C.

In each session girders and SAS were cycled with water and heaters.



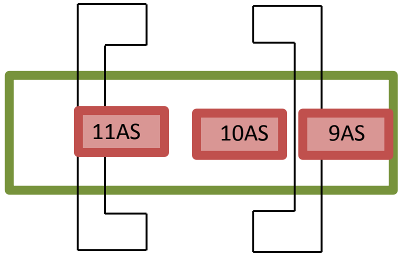
Courtesy A. Zemanek and A. Vamvakas

Effects of temperature and vacuum

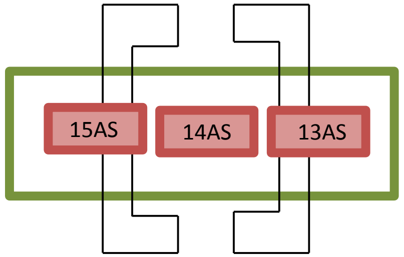
The displacement of each AS has been also monitored

Precision for translation ~± 10 µm, for roll~± 60 µrad, dtemp~± 1.5°C

	10AS	11AS	13AS	14AS	15AS
Ambient 20°C, water 27°C	-	-	-	-	-
Ambient 20°C, water 27°C + heaters	OK	OK	OK	OK	OK
Ambient 20°C, water 27°C + heaters (one off)	OK	OK	OK	OK	OK
Ambient 20°C, water 27°C	OK	OK	OK	OK	OK
Ambient 30°C, water 27°C	OK	OK	Ry=250 µrad	OK	OK
Ambient 30°C, water 27°C + heaters	OK	OK	OK	OK	OK
Ambient 30°C, water 27°C	OK	OK	OK	OK	OK
Ambient 20°C, water 27°C	OK	OK	OK	OK	Ry=180 µrad Ty=45µm
Ambient 20°C, no water	OK	OK	OK	OK	Ty=-45µm



T0 #2



T1

Effects of temperature and vacuum

The displacement of Main and Drive Beam girders with vacuum conditions, with mini-pumps, and of AS vs girder reference frame.

Initial – vacuum

	wires	
	dX [mm]	dZ [mm]
DBT0#2-in	0.039	0.001
DBT0#2-out	0.037	0.004
DBT1-in	0.028	0.009
DBT1-out	-0.006	-0.002

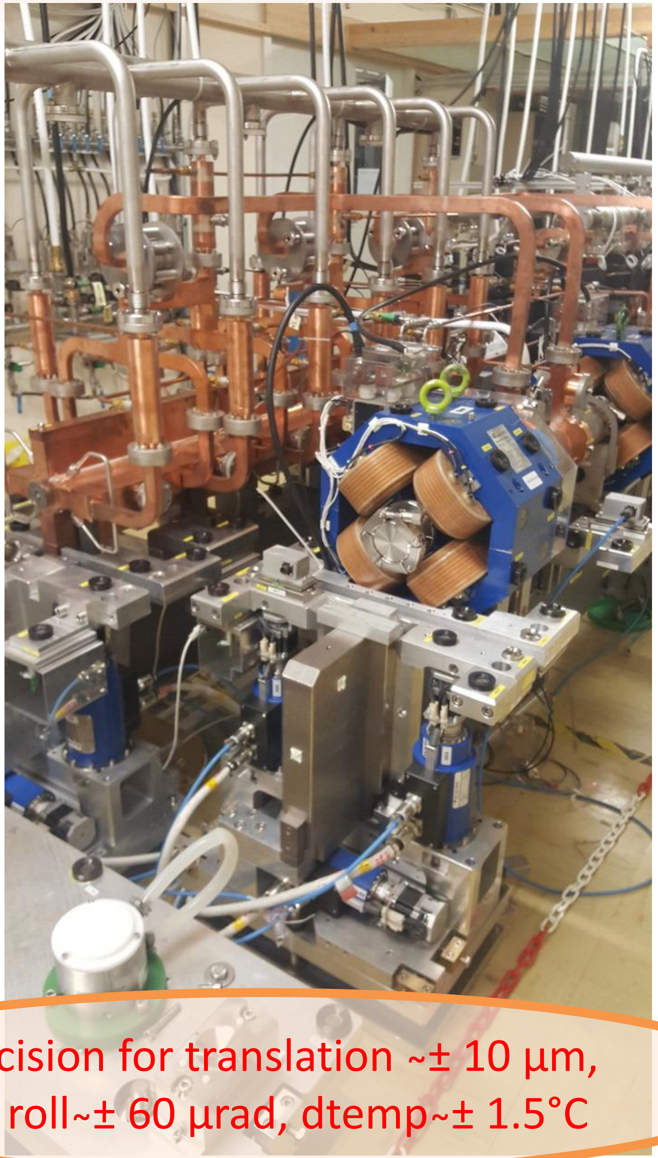
MBT0#2-in	0.010	-0.005
MBT0#2-out	-0.012	-0.004
MBT1-in	-0.002	-0.001
MBT1-out	-0.008	0.000

Initial – back to no vacuum

	wires	
	dX [mm]	dZ [mm]
DBT0#2-in	0.006	-0.001
DBT0#2-out	-0.001	0.001
DBT1-in	0.003	0.000
DBT1-out	-0.004	0.000

MBT0#2-in	0.011	-0.007
MBT0#2-out	0.005	-0.005
MBT1-in	0.001	-0.002
MBT1-out	-0.001	-0.003

Structure	Vacuum	Back to no vacuum
10AS	No impact	Back at initial
11AS	No impact	Back at initial
13AS	No impact	Back at initial
14AS	Ry = 170 µrad	Back at initial
15AS	No impact	Back at initial

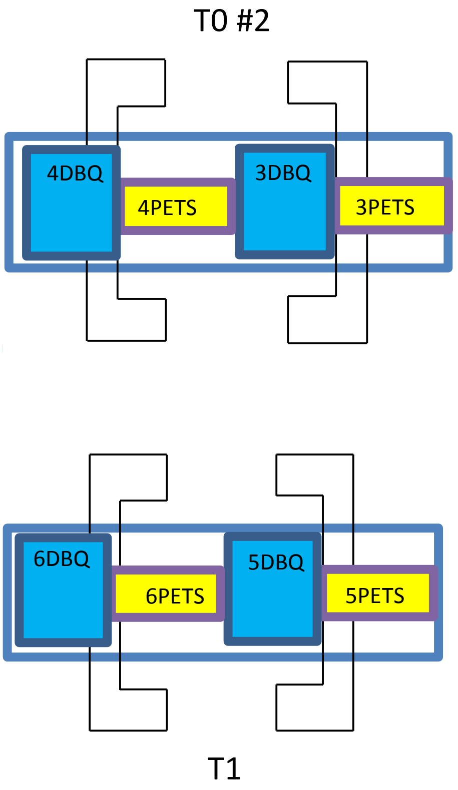


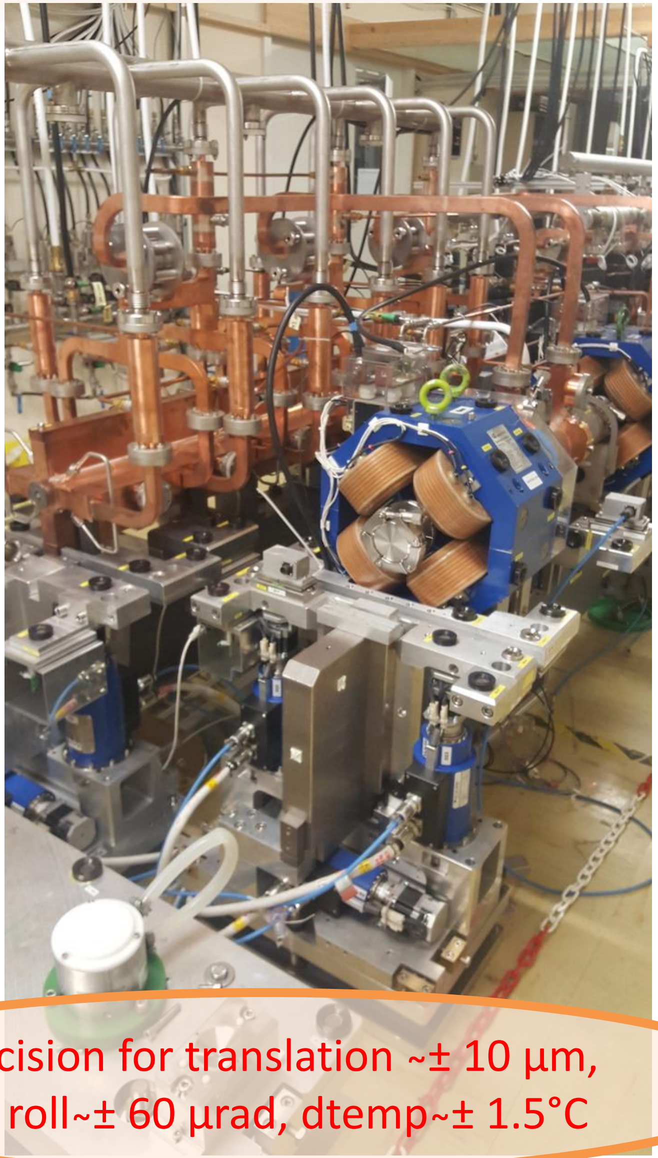
Precision for translation ~± 10 µm, for roll~± 60 µrad, dtemp~± 1.5°C

Effects of temperature and vacuum

Surprisingly, elements on the Drive Beam girder report more important movements with respect to the girder reference frame.

Structure	Vacuum
3PETS	No impact
3DBQ	No impact
4PETS	No impact
4DBQ	No impact
5PETS	Tx = 36 µm Ty = 25 µm
5DBQ	Tx = 36 µm Rx = 120 µrad Ry = 150 µrad
6PETS	Ty = -25 µm Tz = 48 µm
6DBQ	Ty = 23 µm Tz = -25 µm



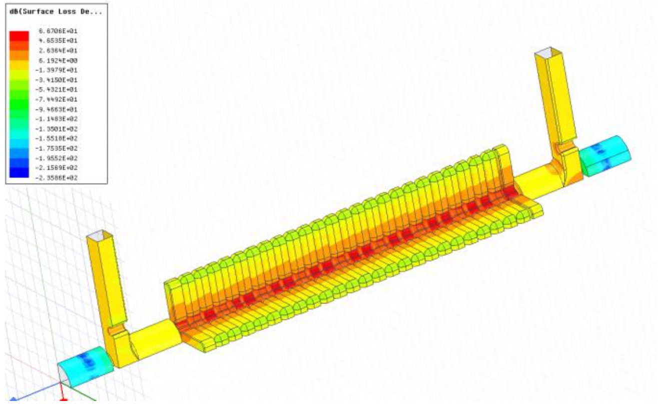


Precision for translation ~± 10 µm, for roll~± 60 µrad, dtemp~± 1.5°C

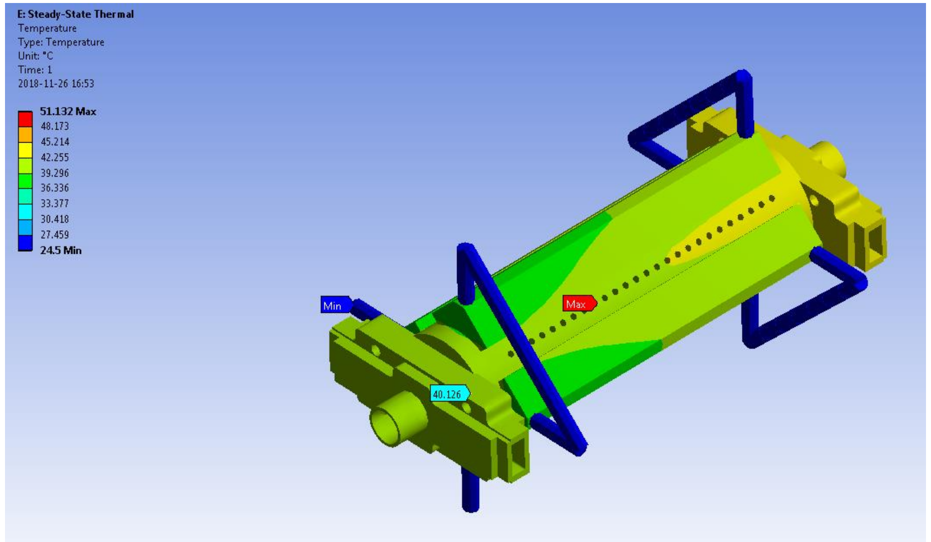
Effects of temperature and vacuum

In the effort of better modeling the heat transfer from the CLIC Module to its environment and overall thermal stability, deeper studies are ongoing in synergy with the Xbox test program.

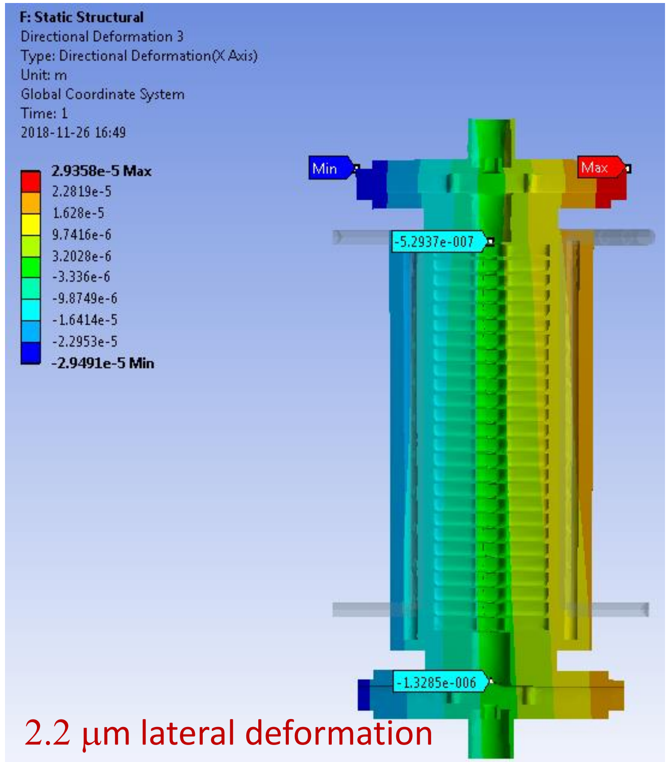
All details in the presentation by A. Vamvakas on Tuesday at 14:50 in room 30-7-018: ***Thermo-mechanical simulations and measurements of CLIC accelerating structures***



Power dissipation from RF field from HFSS



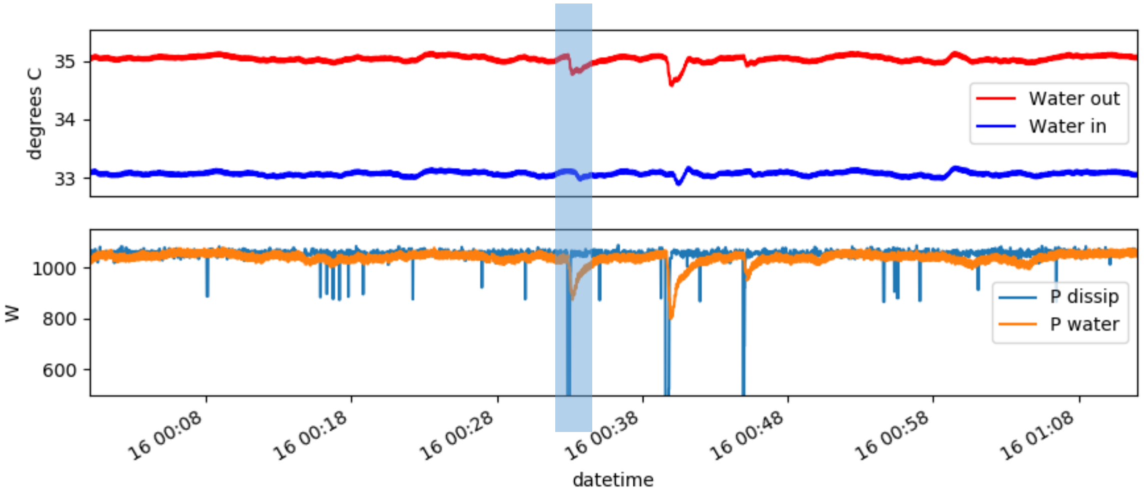
Cooling water flow simulated with linear elements and mechanical deformation obtained from ANSYS



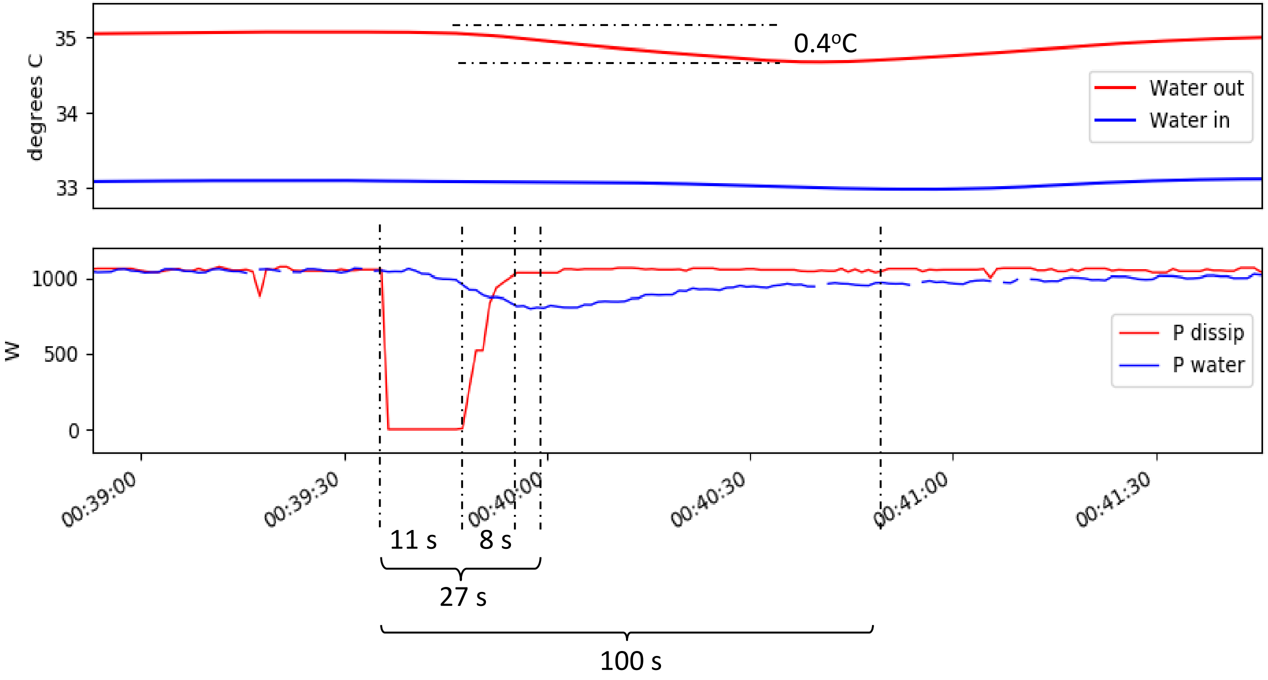
2.2 µm lateral deformation expected in free standing AS under nominal conditions

Effects of temperature and vacuum

Parasitic data taking from AS conditioning is used for building a process to predict heat load to air and mechanical displacement of structures under different operational conditions, as well as structure detuning due to temperature variations.



Sequence of events can be analyzed and also transitions between different operational states studied.



Comparison of Xbox and simulated results show good agreement on preliminary results.

CONCLUSIONS

A considerable effort has been made in 2018 to complete the studies that were needed as an input to the CLIC PiP.

The complete costing of the Main Linac has been reviewed in 2018 and estimates of the main cost drivers have been provided.

Some preliminary and very interesting results from thermo-mechanical studies have been achieved and we will further concentrate our efforts on this aspects of the CLIC Module design in 2019.

In the short term, our goal is to build models and benchmark processes to become capable of predicting the Module thermo-mechanical behavior and its interaction with the environment in the different operational scenarios.

The preparation of the CLIC TDR should be our next milestone.