CLIC two-beam module development

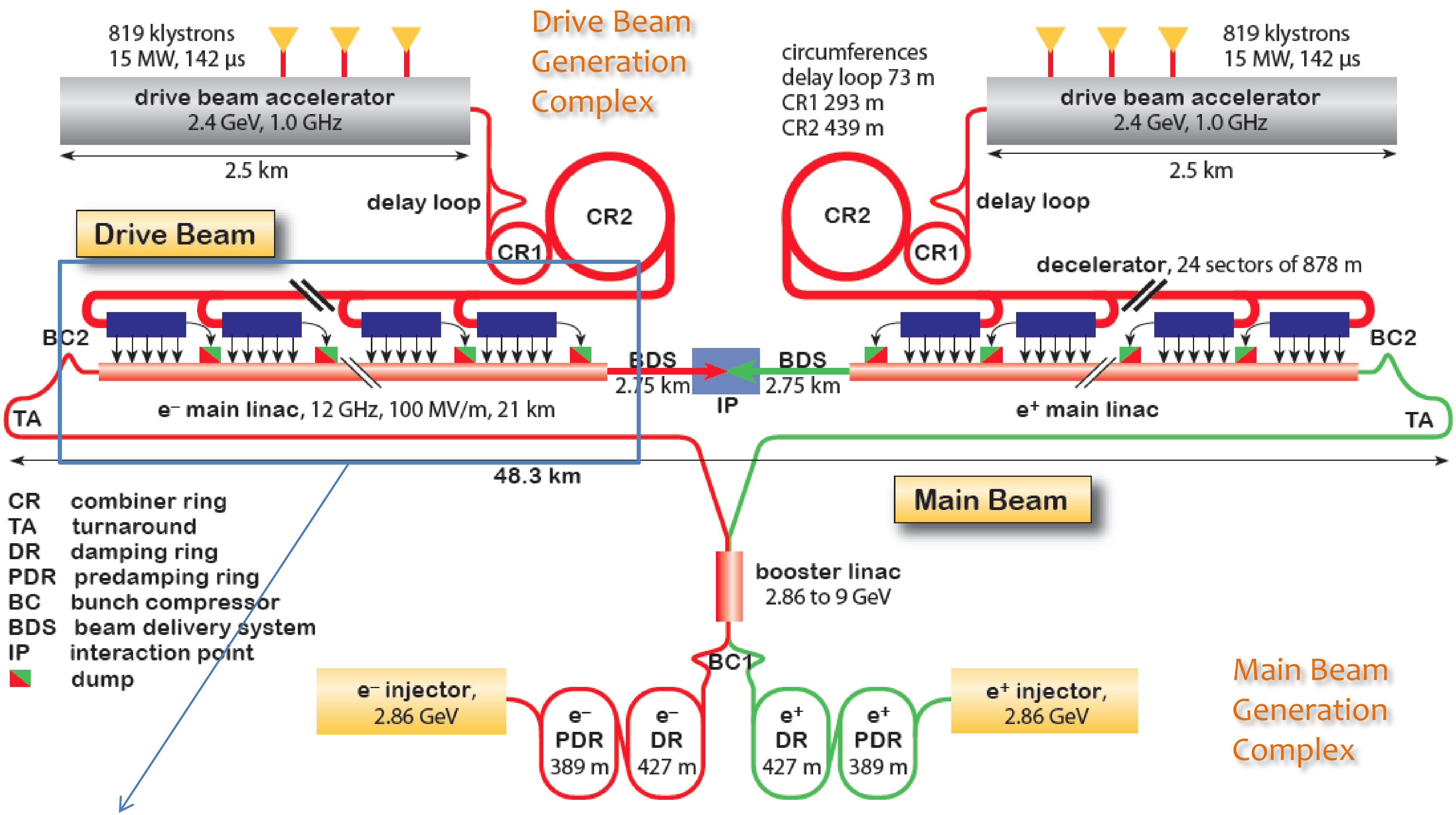
Status and future plans

G. Riddone

Outlook

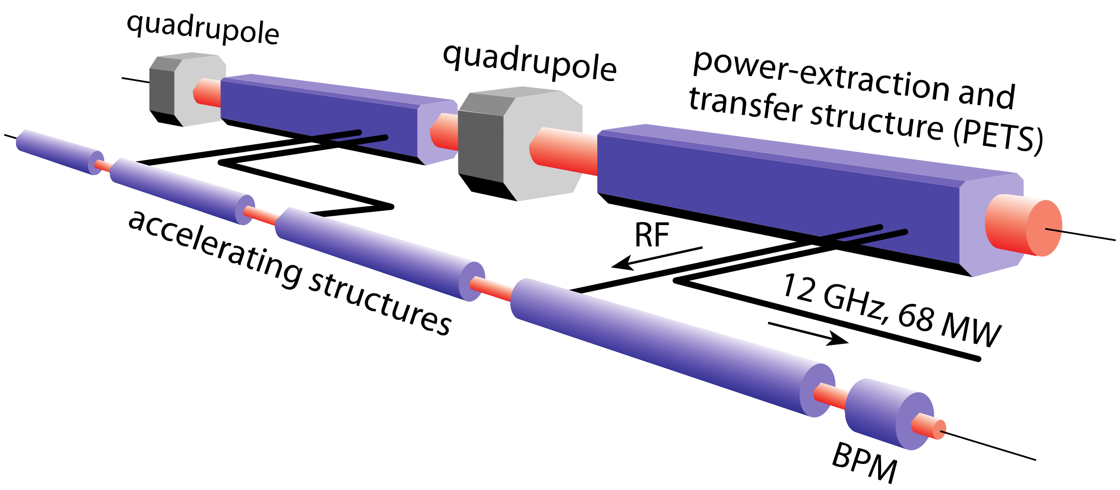
- Short introduction
- CLIC Module
- Validation program
- Future steps

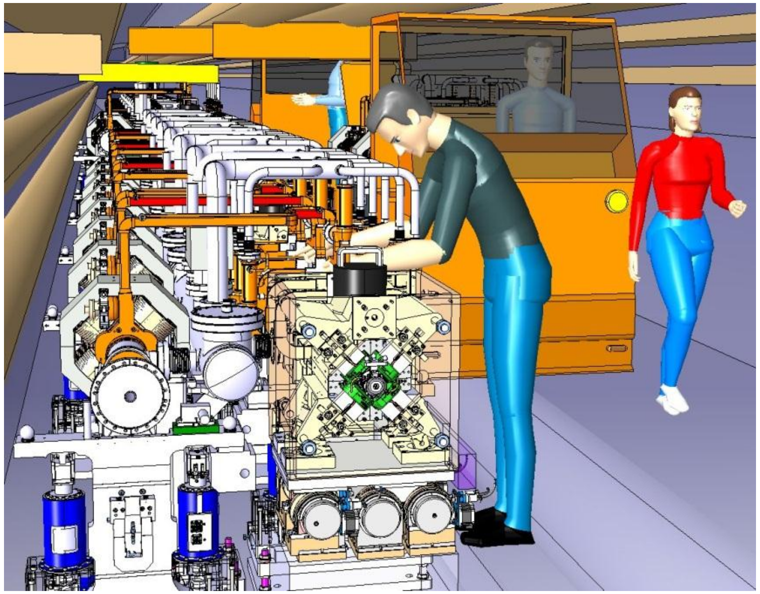
CLIC Layout at 3 TeV



Main LINAC ➔ two-beam modules

Two-beam acceleration - two-beam modules





Energy	500 Gev A	500 GeV B	1.5 TeV	3 TeV
No. of sectors	10	8	24	48
No. of modules	4232	3726	10726	21452

Program

CLIC Modules (boundary conditions, technical system design and integration)

- CDR modules
- Prototypes
  - Laboratory
  - CLEX

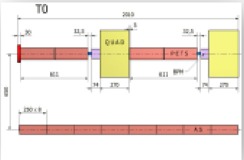
Stringent technical requirements:

- Accelerating structure iris shape tolerance: 5 μm
- Active pre-alignment: ±10 μm @ 1σ
- Vacuum: 10^{-9} mbar
- Power dissipation: ~ 7.7 kW/module

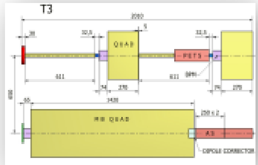
In addition:

- Compact design to optimize the filling form
- Technology to lower the overall cost

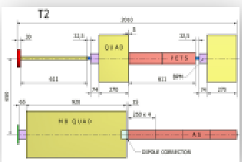
CDR modules



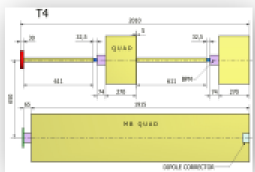
Standard Module
73 %



Module Type 3
9 %



Module Type 2
12 %



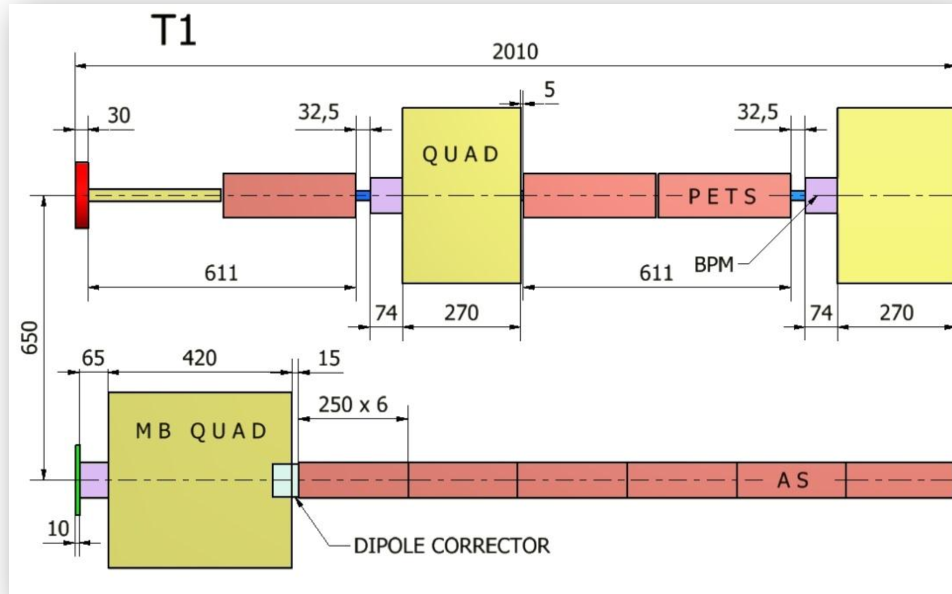
Module Type 4
3 %

Standard Module (L = 2010 mm)
DB (100 A)
4 PETS, 2 Quads with BPM
Each PETS feeds 2 AS

MB (1 A)
8 acc. structures
MB filling factor: 91%

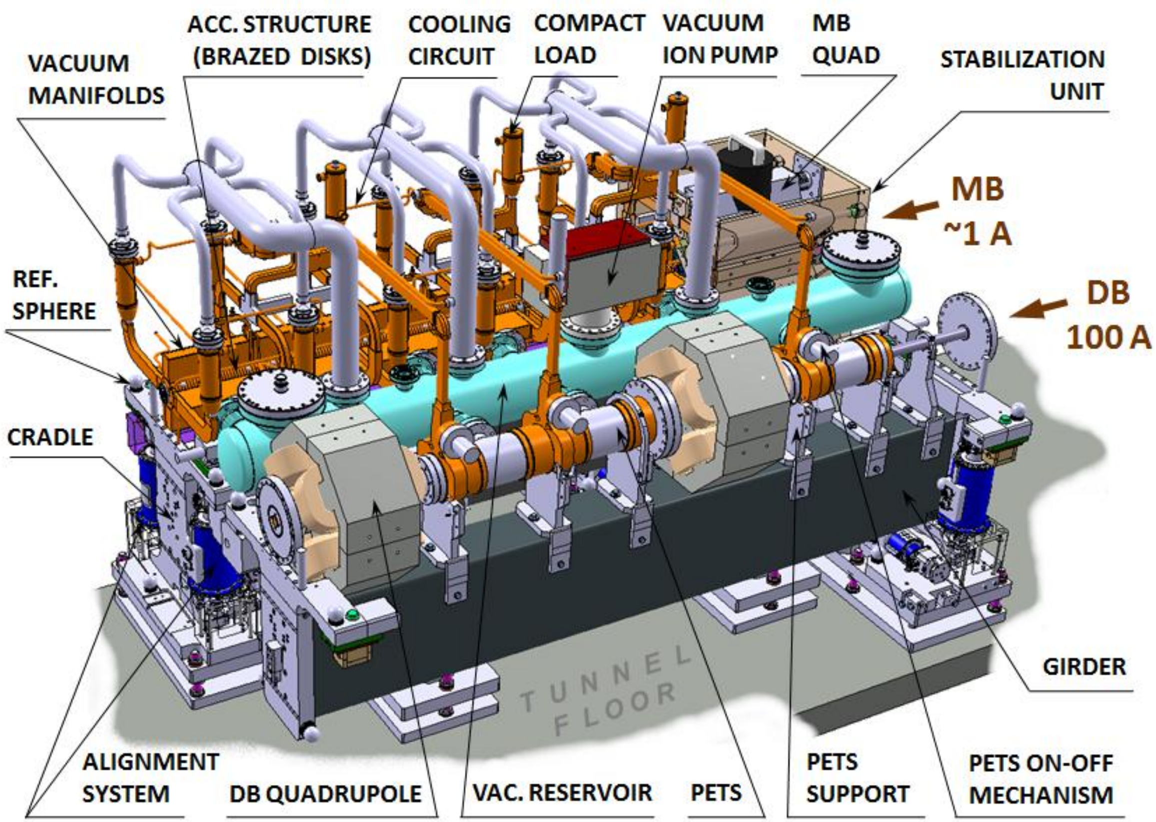
CLIC Module Type1
3 %

1 pair of AS replaced by MB Quadrupole



\+ special modules (damping region, modules with instrumentation and/or vacuum equipment) to be studied in TDR phase

CDR modules (Type 1)



Energy	500 Gev A	500 GeV B	1.5 TeV	3 TeV
No. of AS	26950	23826	71536	143072
No. of PETS	13475	11913	35768	71536

Prototypes

2010-2016

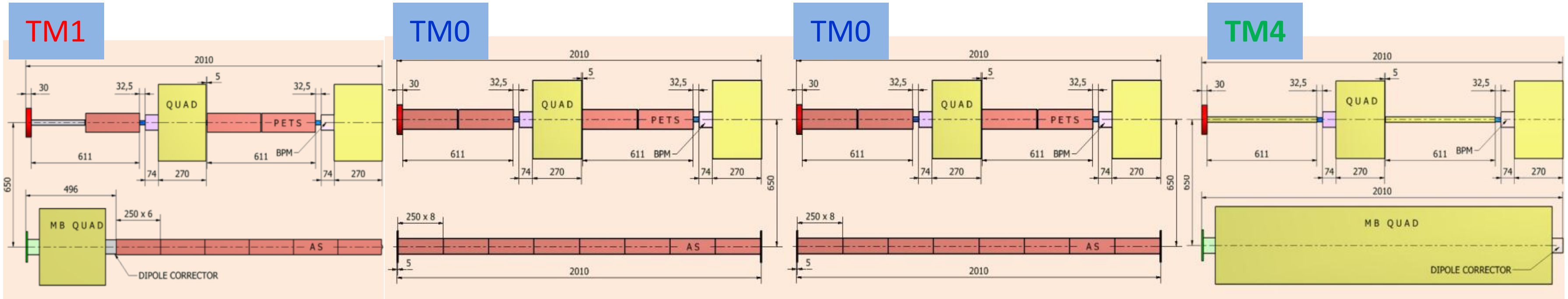
- **LAB version**
  - **4 modules, 2 sequences foreseen**
    - **Type 1, Type 0, Type 0, Type 4**
    - **Type 0, Type 1. Type 0, Type 4**

Demonstration of the two-beam module design (from single technical system to complete modules)
This implies the assembly and integration of all components and technical systems, such as RF, magnet, vacuum, alignment and stabilization, in the very compact 2-m long two-beam module

- **CLEX version**
  - **3 modules**
    - **Type 0, Type 0, Type 1**

Demonstration of the two-beam acceleration with beam and RF with real modules
Address other feasibility issues in an integrated approach

Prototypes – Laboratory version



1) Currently under assembly and installation

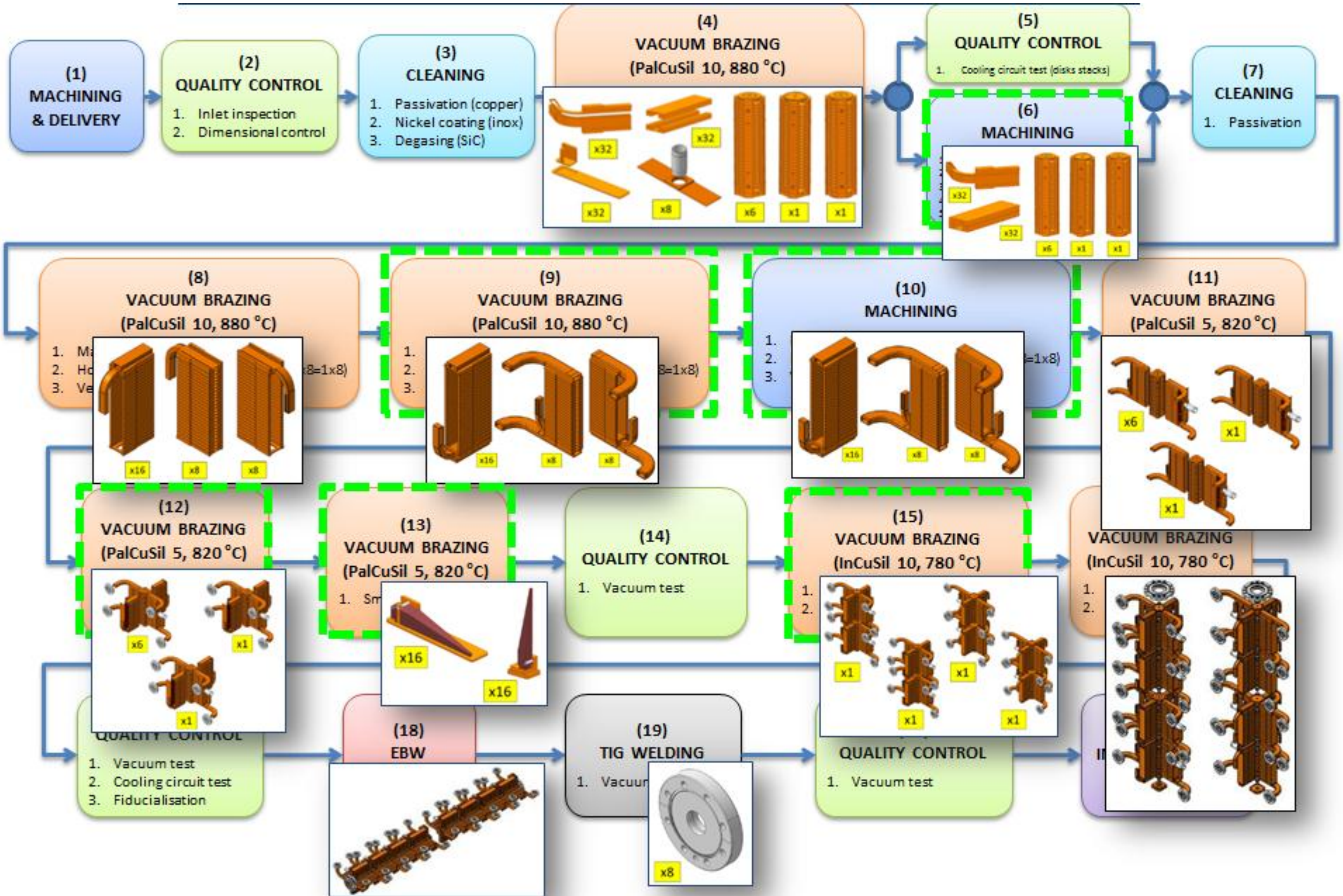
Essential learning process, so far:

- Fabrication procedure of the different technical systems
- Assembly procedures (e.g acc. structure)
- Integration of systems (few improvements already injected for next modules)
- Girders (different design and material) and actuator behavior

2) Main components under procurement

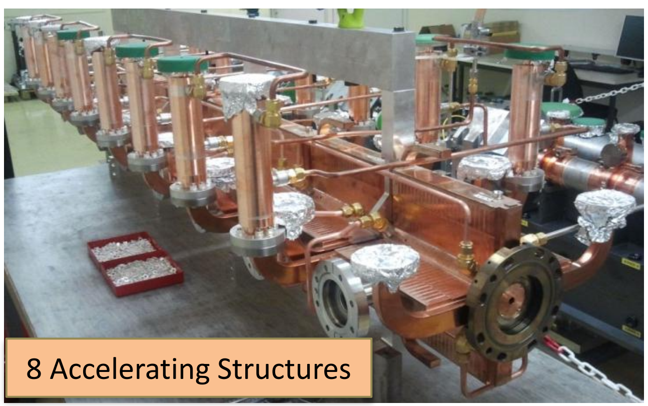
3) Last module

Accelerating structure workflow



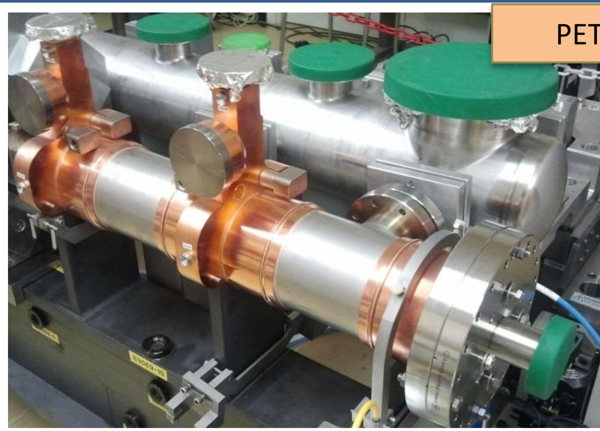
Prototype module fabrication: RF system

Disk stack **alignment** → few tens of μm



8 Accelerating Structures

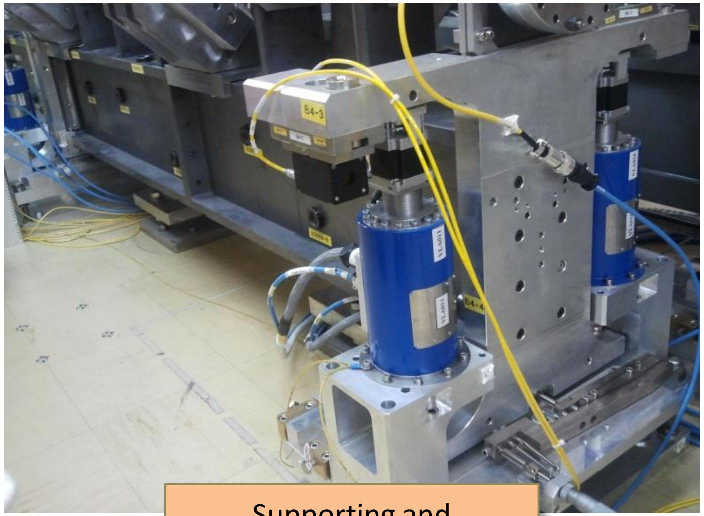
RF network



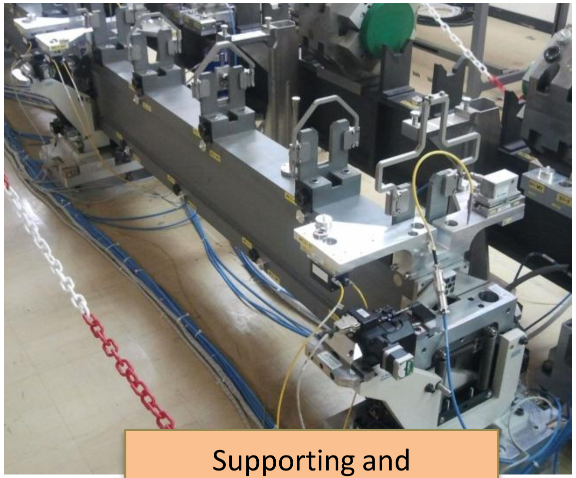
PETS

Prototype module fabrication: supporting/alignment

Girder: deformation under load ≤ 10 μm according to specification



Actuators: rangeability, backslash, hysteresis, resolution measured → meet specification (From +/- 1 mm to +/- 3 mm, ≤ 1 μm, ≤ 0.5 μm, ≤ 1 μm)

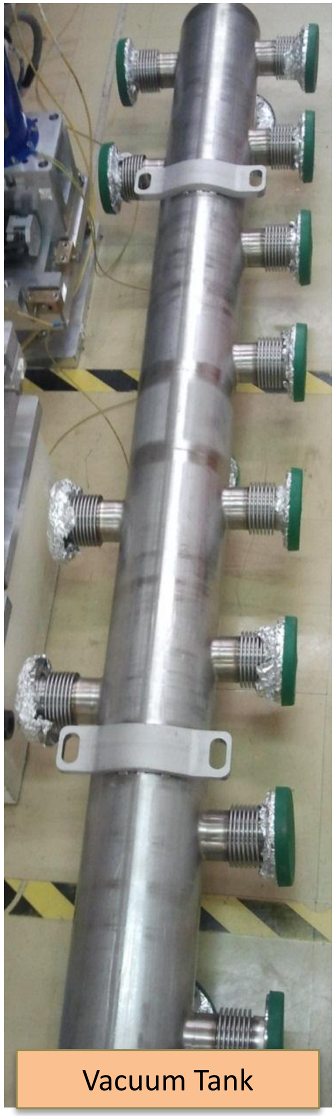


Alignment bench with sensors

Supporting and positioning system (DB)

Supporting and positioning system (MB)

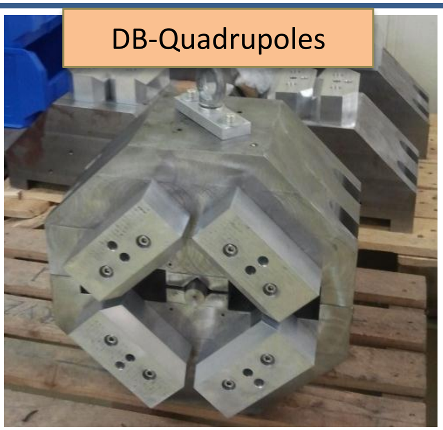
Prototype module fabrication: Vacuum/Magnets



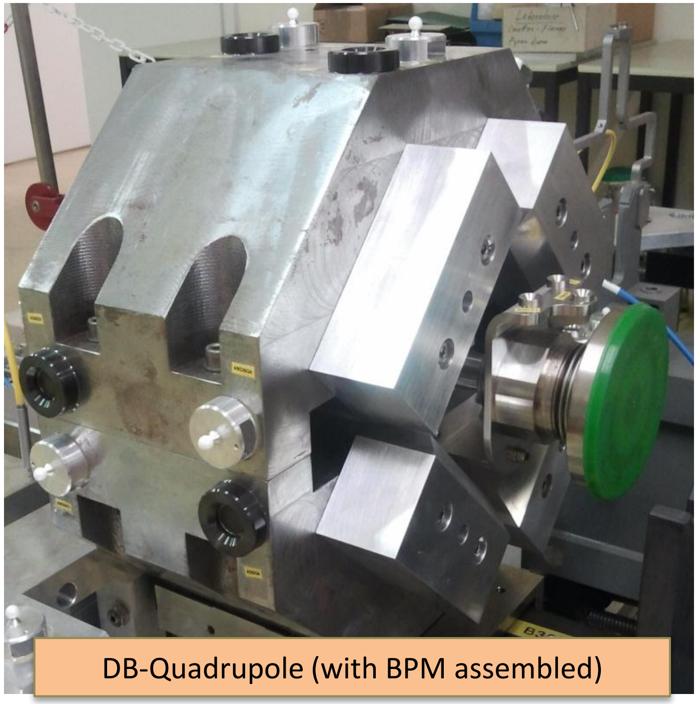
Vacuum Tank

Vacuum Manifolds

Extremity supports

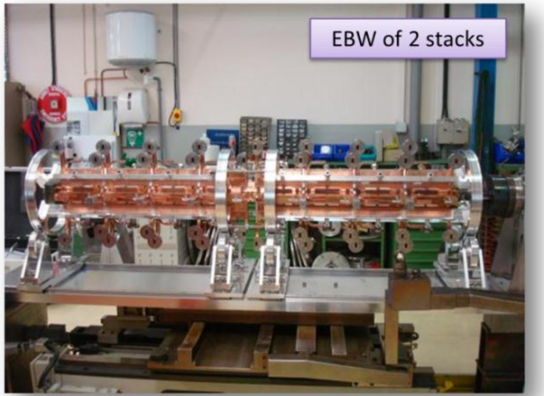


DB-Quadrupoles



DB-Quadrupole (with BPM assembled)

Prototype modules - Status



- **First prototype Type 0 - Lab:**
  - First 2-m accelerating structure stack completed
  - RF network installation completed
  - Under final leak test
  - During assembly, validation of girders and supporting system ➔ several alignment/positioning tests successfully performed
  - **Next main steps:**
    - **Thermo-mechanical tests together with alignment verification and vibration measurements**
    - **Transport test and alignment verification**

- **First prototype Type 0 - CLEX**
  - First double length from CIEMAT fully assembled
  - Integrated supporting system (including girder, positioning system and Rf structure supports) under fabrication (ZTS-Boostec)
  - Accelerating structures under machining at VDL

Thermo-mechanical tests

STEP 0 – Alignment tests

ENVIRONMENT

T_{amb} = 20 & 40 °C

MEASUREMENTS

a. Comparison between laser tracker and WPS measurements (no movements of girders)

b. Alignment tests by moving girders via actuators and comparison between laser tracker and WPS measurements

STEP 1 – Heating environment

ENVIRONMENT

T_{amb} = 20 - 40 °C

in steady-state conditions and by steps of 5 °C

HEATING

No active heating in RF structures

COOLING

No active cooling in RF structures

MEASUREMENTS

1. Temperature
2. Alignment
   - Laser tracker
   - Romer arm
   - WPS
   - Micro-Triangulation system

STEP 2 – Heating only PETS

ENVIRONMENT

T_{amb} = 20 °C

in steady-state conditions

HEATING

PETS

by steps up to 110 W/unit

COOLING

PETS

< max calculated T

MEASUREMENTS

1. Temperature
2. Volumetric flow rate
3. Alignment
   - Laser tracker
   - Romer arm
   - WPS
   - Micro-Triangulation system

STEP 3 – Heating only AS

ENVIRONMENT

T_{amb} = 20 °C

in steady-state conditions

HEATING

AS

by steps up to 400 W/unit

COOLING

AS

< max calculated T

MEASUREMENTS

1. Temperature
2. Volumetric flow rate
3. Alignment
   - Laser tracker
   - Romer arm
   - WPS
   - Micro-Triangulation system

STEP 4 – Heating all module

ENVIRONMENT

T_{amb} = 20 - 40 °C

in steady-state conditions and by steps of 5 °C

HEATING

AS + PETS + DBQ

by steps up to max power/unit

COOLING

AS + PETS + DBQ

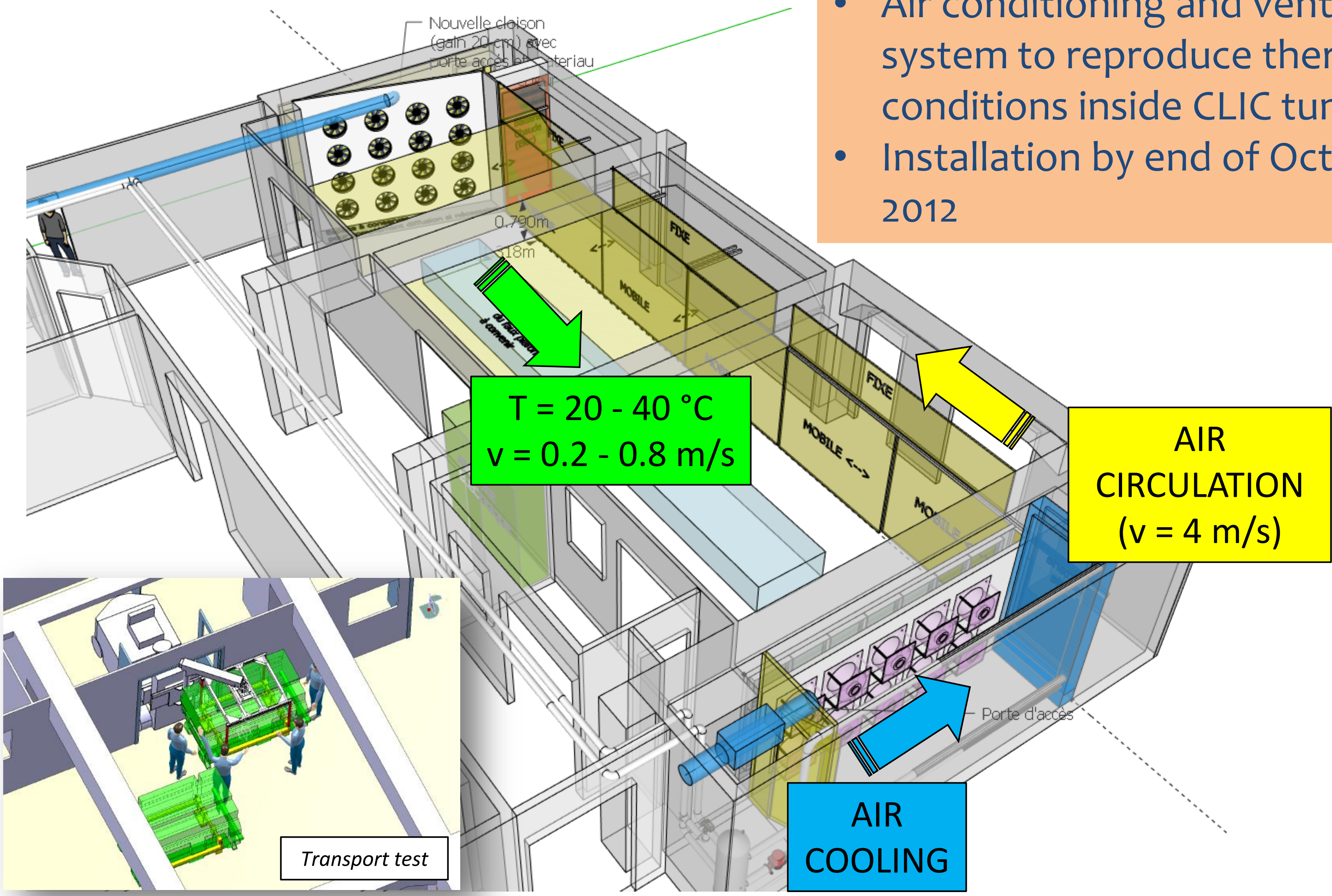
< max calculated T

MEASUREMENTS

1. Temperature
2. Volumetric flow rate
3. Alignment
   - Laser tracker
   - Romer arm
   - WPS
   - Micro-Triangulation system

Simulating tunnel conditions

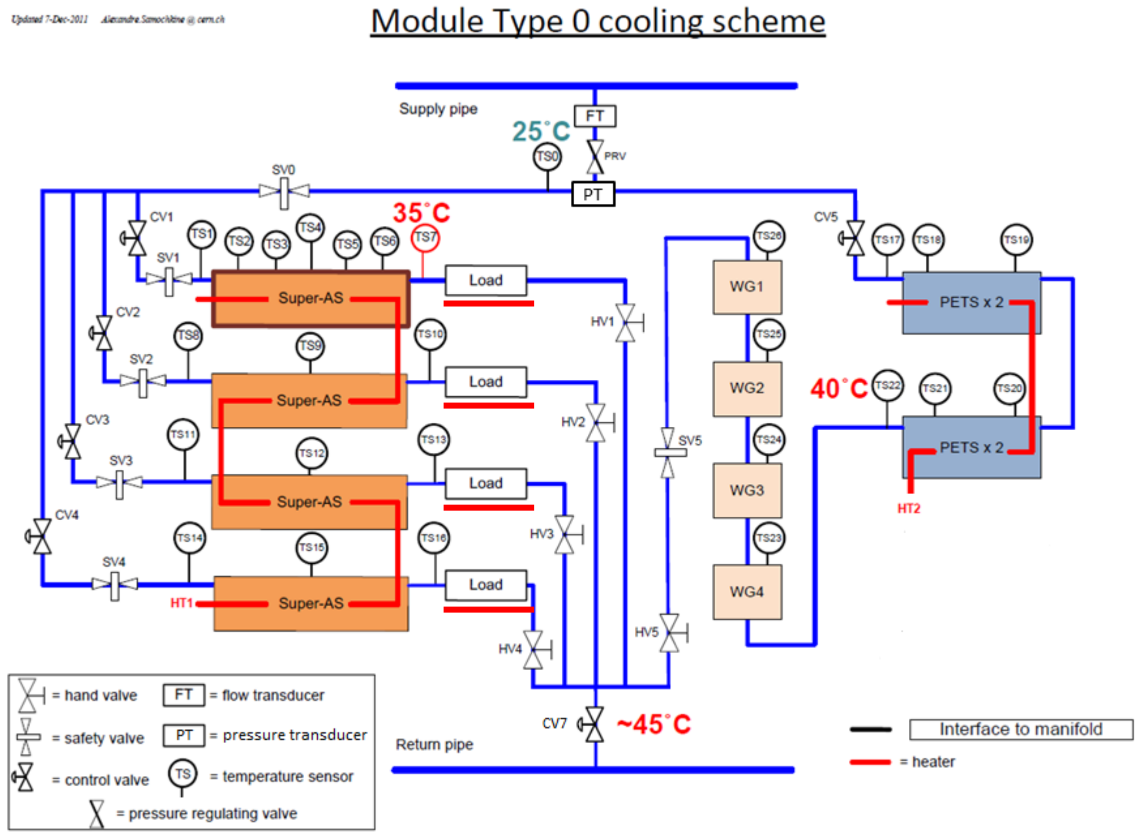
- Air conditioning and ventilation system to reproduce thermal conditions inside CLIC tunnel
- Installation by end of October 2012



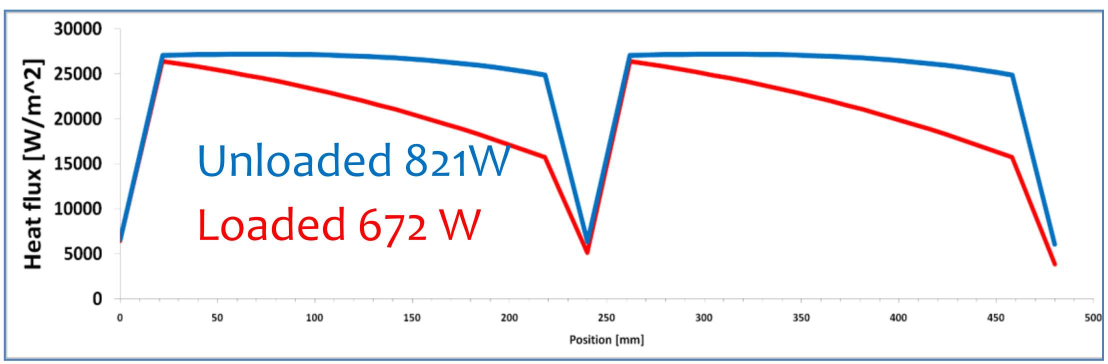
Transport test

Module cooling system

- Nominal volumetric flow rate: 0.36 m^3/h
- Water inlet temperature: 25 °C
- Water outlet temperature: 45 °C
- Power dissipation: 7.7 kW



Distribution of heat flux over 2 AS



FEA analysis

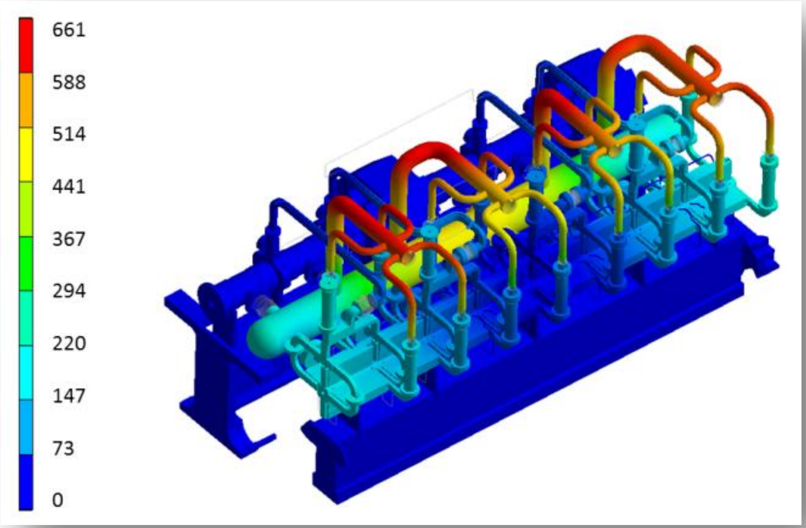
Resulting temperatures inside the modules

Temperature [°C]	Prototype type 0
Max temp. of module	43
Water output temp. MB	35
Water output temp. DB	30

Resulting displacements on the DB and MB lines due to thermal, vacuum and gravity loads

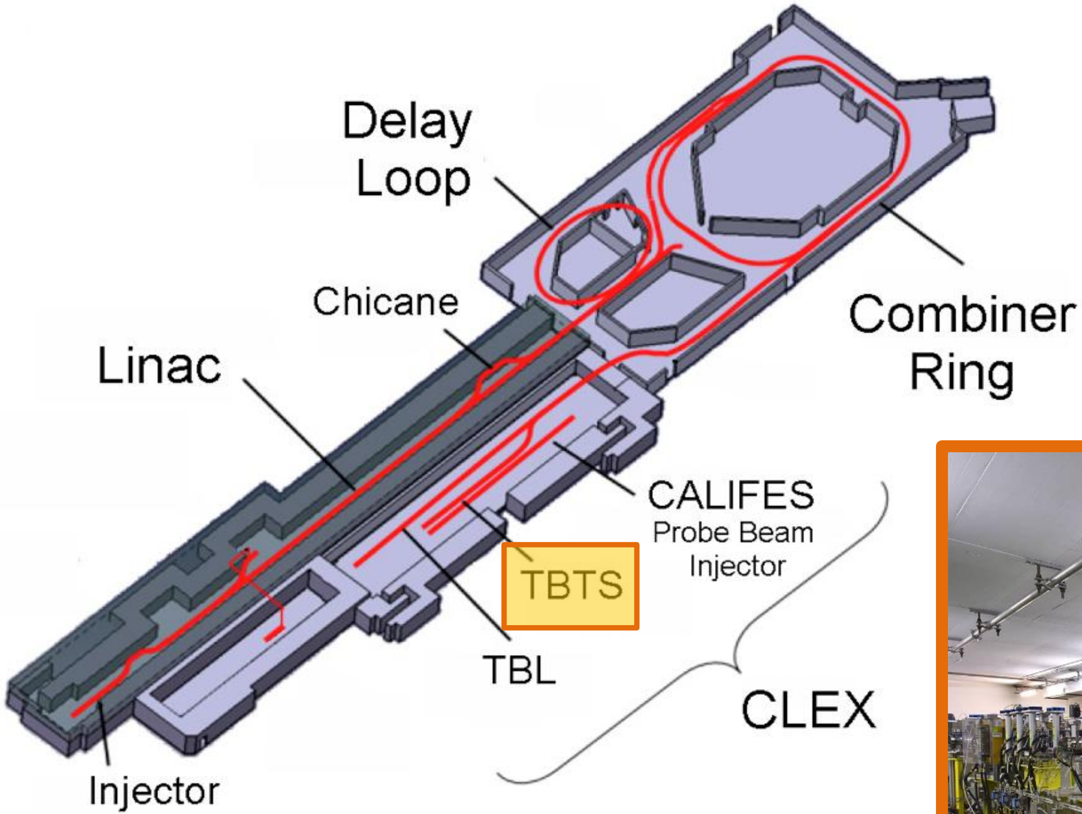
Displacements [μm] (location and load type)	Prototype type 0
MB (RF load)	183
DB (RF load)	47
MB (vacuum load)	30
DB (vacuum load)	131
MB (gravity load)	27
DB (gravity load)	40

Deformed shape of prototype module type 0 due to applied thermal RF loads (values in μm)



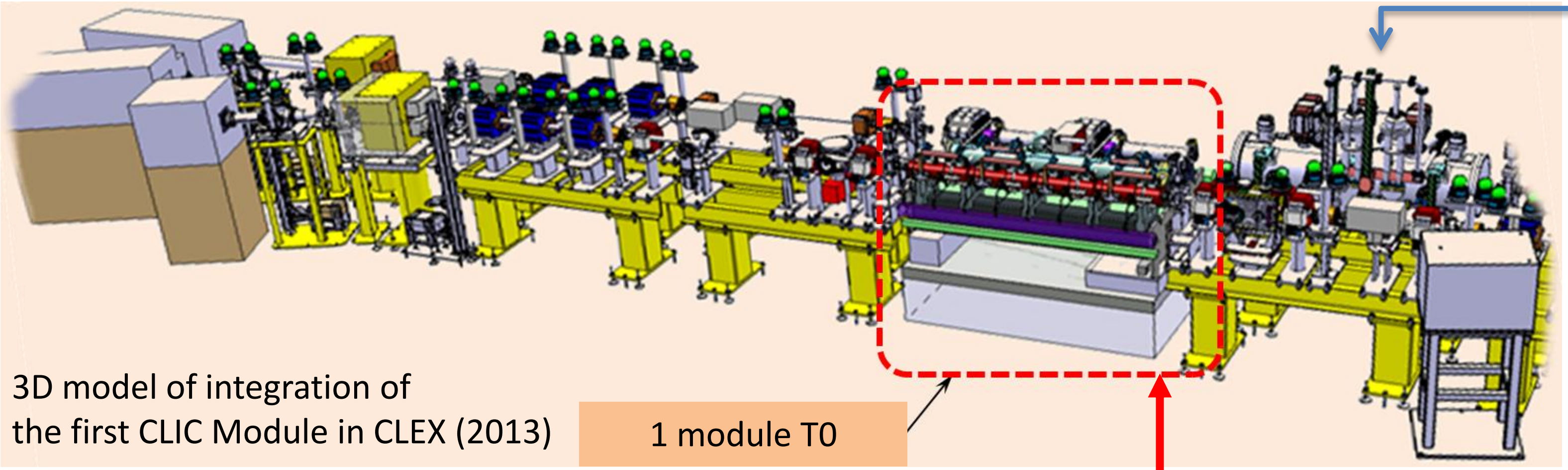
(2 AS = 820 W, PETS unit = 78 W, T_{amb} = 25 °C 8 AS mechanical connected as one rigid unit)

CLIC Test Facility (CTF3)



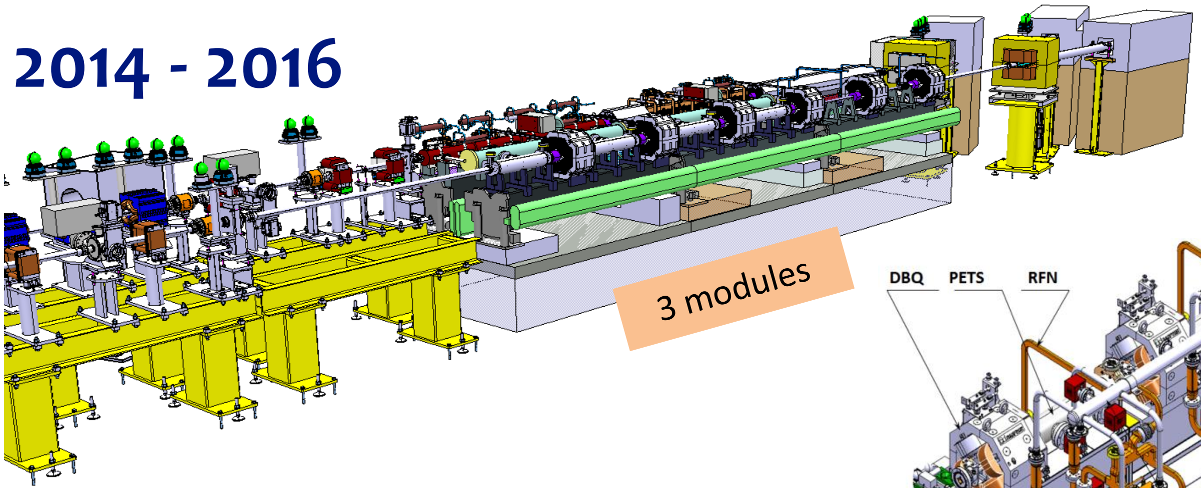
Prototype modules in CLEX

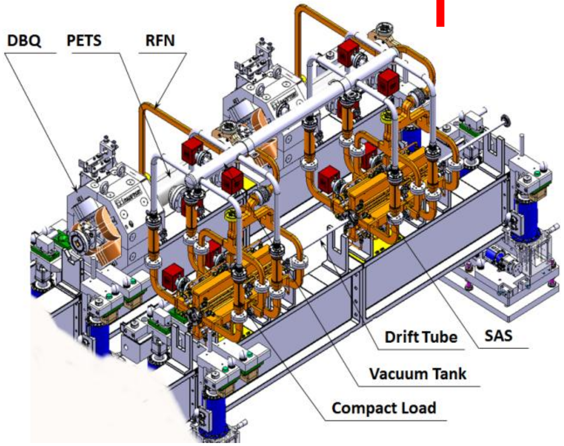
2013



3D model of integration of
the first CLIC Module in CLEX (2013)

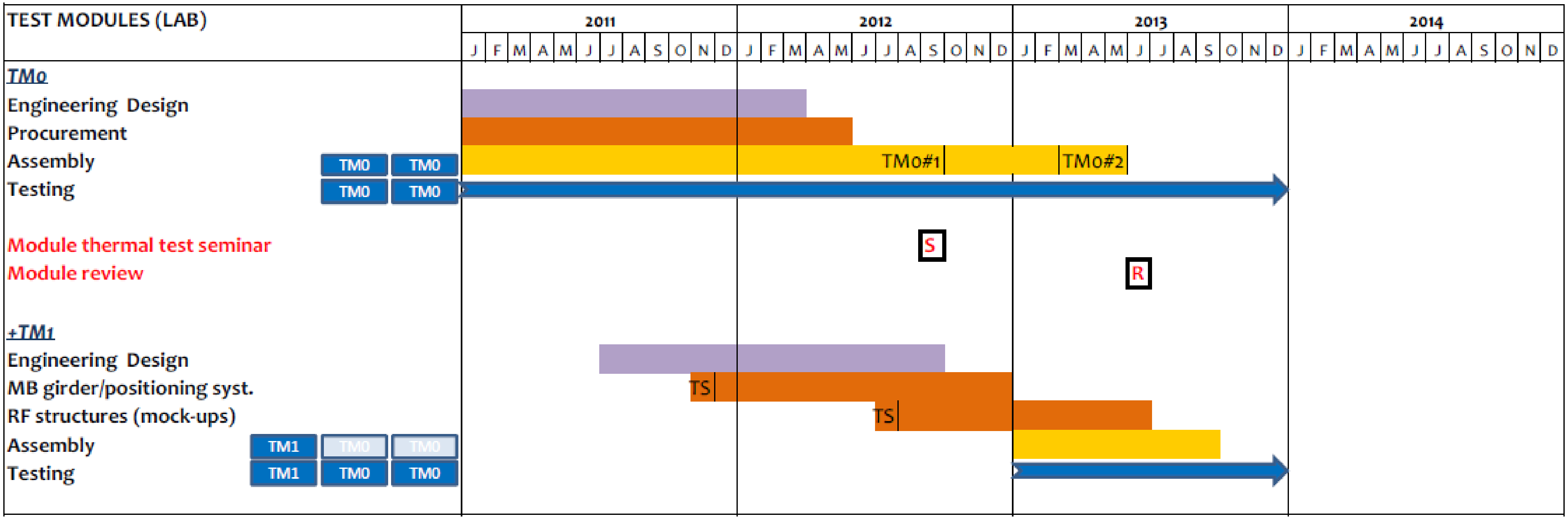
2014 - 2016

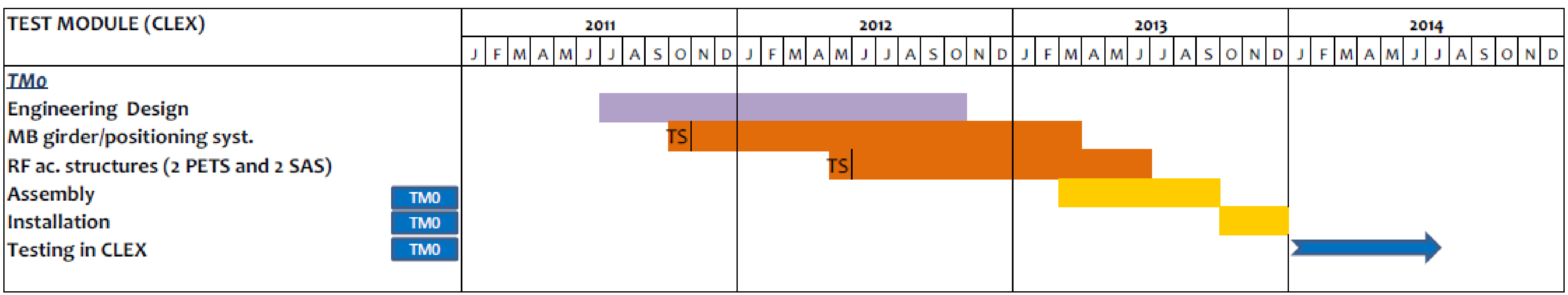




TBTS PETS tank

SCHEDULE


TEST MODULES (LAB)
2011
2012
2013
2014
J F M A M J J A S O N D
TM0
Engineering Design
Procurement
Assembly
Testing
TM0
TM0#1
TM0#2
Module thermal test seminar
Module review
S
R
+TM1
Engineering Design
MB girder/positioning syst.
RF structures (mock-ups)
Assembly
Testing
TM1
TS


TEST MODULE (CLEX)
2011
2012
2013
2014
J F M A M J J A S O N D
TM0
Engineering Design
MB girder/positioning syst.
RF ac. structures (2 PETS and 2 SAS)
Assembly
Installation
Testing in CLEX
TS

Conclusions

- Design an and integration of the two-beam module completed for CDR : compact design taking into account several stringent technical requirements but no cost optimization yet

- Program to validate design and main technical choices defined up to 2016:
  - 4 modules for thermo-mechanical tests in laboratory:
    - First module assembly completed
  - 3 fully fledged modules for tests in CLEX
    - First module installation during shut-down 2013-2014

- From assembly and testing of the first module
  - Supporting/alignment/positioning system according to the specifications
  - A lot of experience gained in the assembly of the RF structures, as well as on bonding and brazing processes
  - Few technical alternatives are already considered for the following ones: mini-pumps directly connected to RF structures

- Next steps:
  - Module system integration and cost optimization in collaboration with industrial companies (e.g RF structures, new technology and/or more compact design towards multi-featured disks)
  - Follow re-baselining evolution: one-beam design for 500 GeV klystron based configuration

Acknowledgement to the module WG members and several CLIC collaborators

A. Samochkine, D. Gudkov, N. Gazis and F. Rossi highly contributed to the preparation of this talk

EXTRA

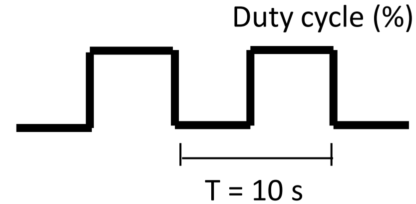
Actuator results

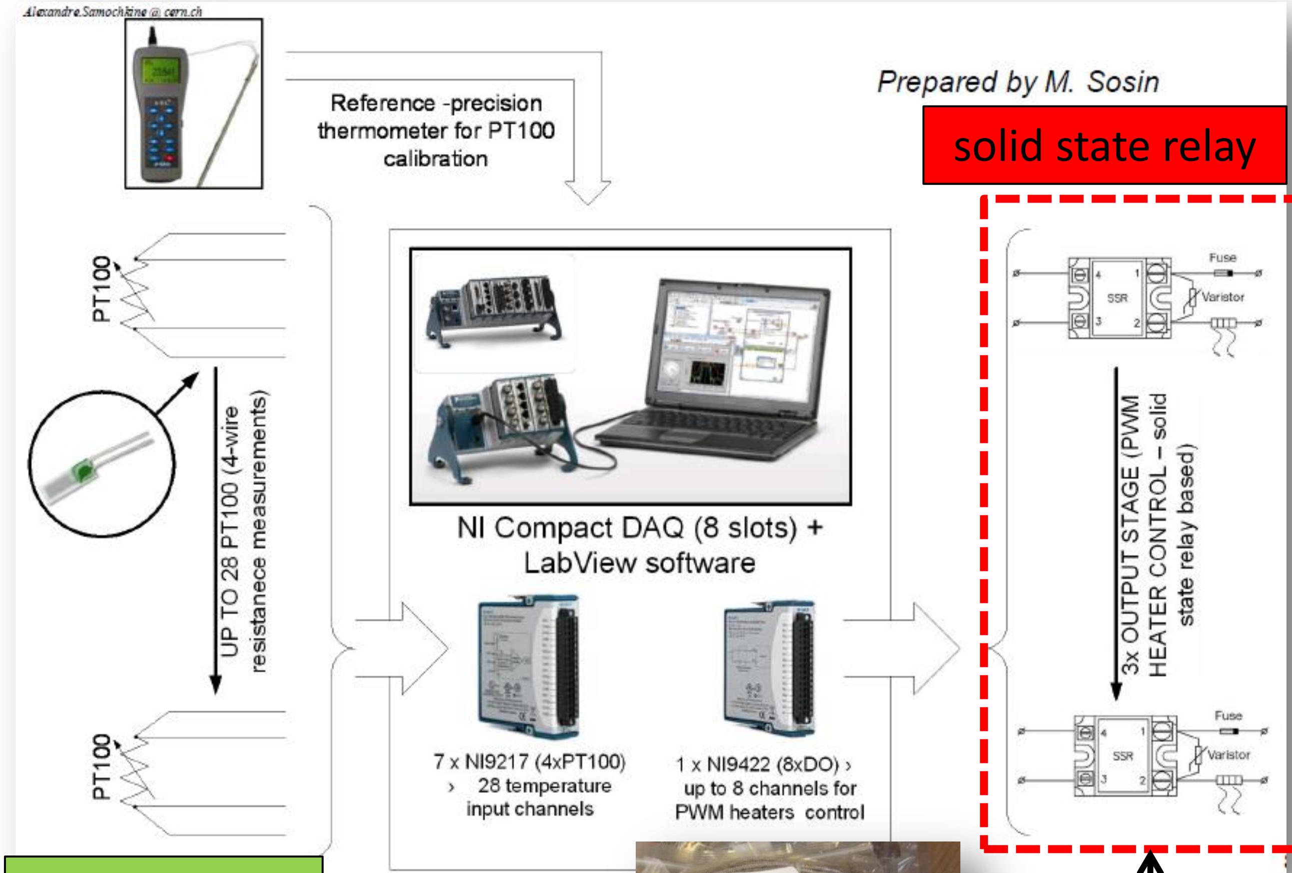
Vivien Rude, EDMS 1158356

Specifications			Boostec		Micro-Contrôle	
			Vertical	Horizontal	Vertical	Horizontal
Limite	**From +/- 1 mm to +/- 3 mm**	Limite	+ / - 2 mm	+ / - 3 mm	+ / - 1 mm	+ / - 1 mm
Backlash	**≤ 1 µm**	Backlash	[-1 µm, 1 µm]	[-2 µm, 2 µm] **Backlash à partir de 500 microns de déplacement pour RLA003**	[-1 µm, 1 µm]	[-1 µm, 1 µm]
		Répétabilité	limite à 2h30	40 cycles sans problème	50 cycles sans problème	50 cycles sans problème
		Linéarité (cas classique)	σ=1 micron	σ=1 micron pour RLA001 σ=3 microns pour RLA002 σ=10 microns pour RLA003	σ=3 microns	σ=2 microns
Hystérésis	**≤ 1 µm**	Hystérésis	[-1 µm, 1 µm]	[-1 µm, 1 µm] Problème quelques fois pour RLA003	[-1 µm, 1 µm]	[-1 µm, 1 µm]
Résolution	**≤ 0.5 µm**	Résolution	0.17647 µm	0.2 µm	<0.1 µm	<0.1 µm

Temperature sensors

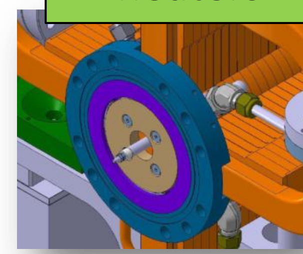
PWM signal for controlling the heaters





solid state relay

heaters



1 DOF for each heating sub-system (AS, PETS and DBQ)

temperature sensors

IL

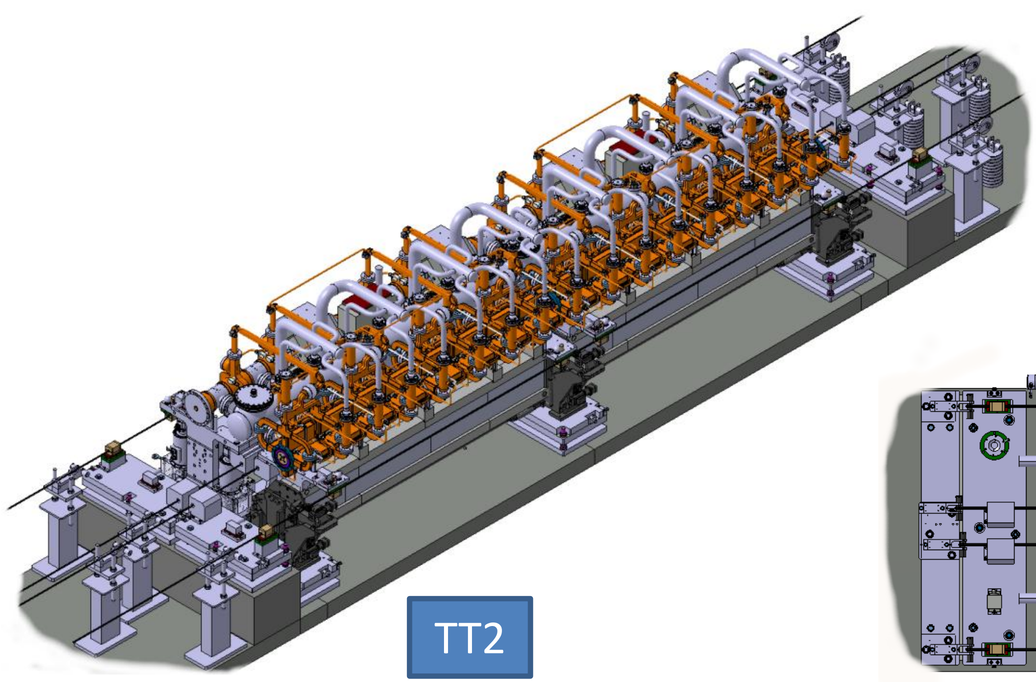
max. temp. limit: 50 °C

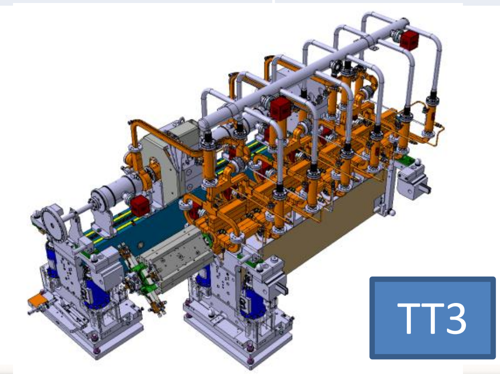
Hardware thermal interlock (2 for AS, 1 for each PETS and DBQ)

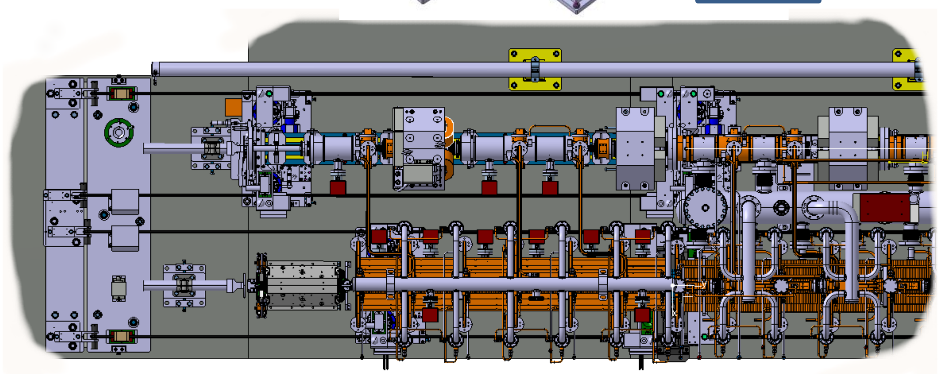
All temperature sensors are currently stored in the lab

Thermo-mechanical test sequence

NAME	LAB CONFIGURATION	PARAMETERS		
		Heating	Cooling	Vacuum
TT1	TM0	V	V	X
TT2	TM0 + TM0	V	V	X
TT3	TM1 + TM0	V	V	V







Thermo-mechanical test: alignment verification

Measuring arm Romer Multi Gage

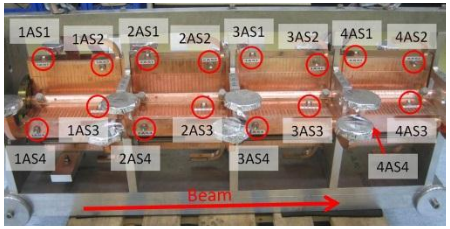
- With a length of 60 cm, this kind of portable CMM allows to measure fiducials by probing or by one point. According to Romer, the maximum permissible error is less than 18 µm.

Micro-Triangulation system

- The principle of Micro-Triangulation is to use the full potential of a theodolite by substituting a CCD camera instead of the eye of an operator.
- This method has clearly demonstrated its high precision capability on the 2 m long mock-up where a precision about 10 µm along each axis has been obtained in the determination of the illuminated fiducials locations.

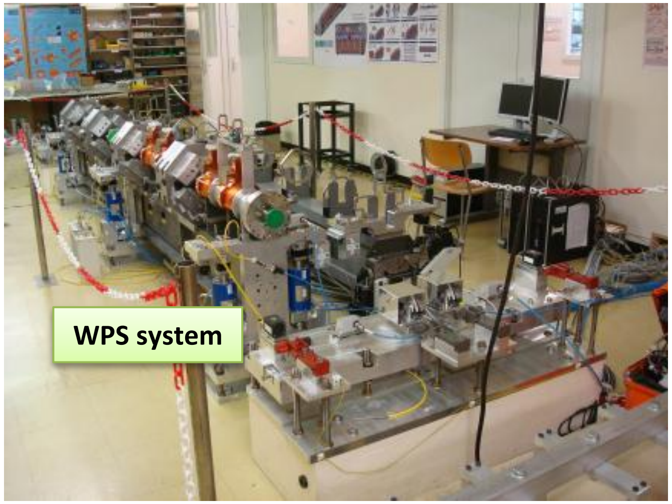
Laser tracker Leica AT401

- According to simulation calculations, the expected accuracy of AT401 measurements on a girder and its components is about 5 µm rms (up to 40 °C).
- Fiducials are measured with respect to a fixed reference system.
- Measurements taken from different stations can be elaborated and combined together.
- The measuring device must be at the same temperature of the parts to be measured.



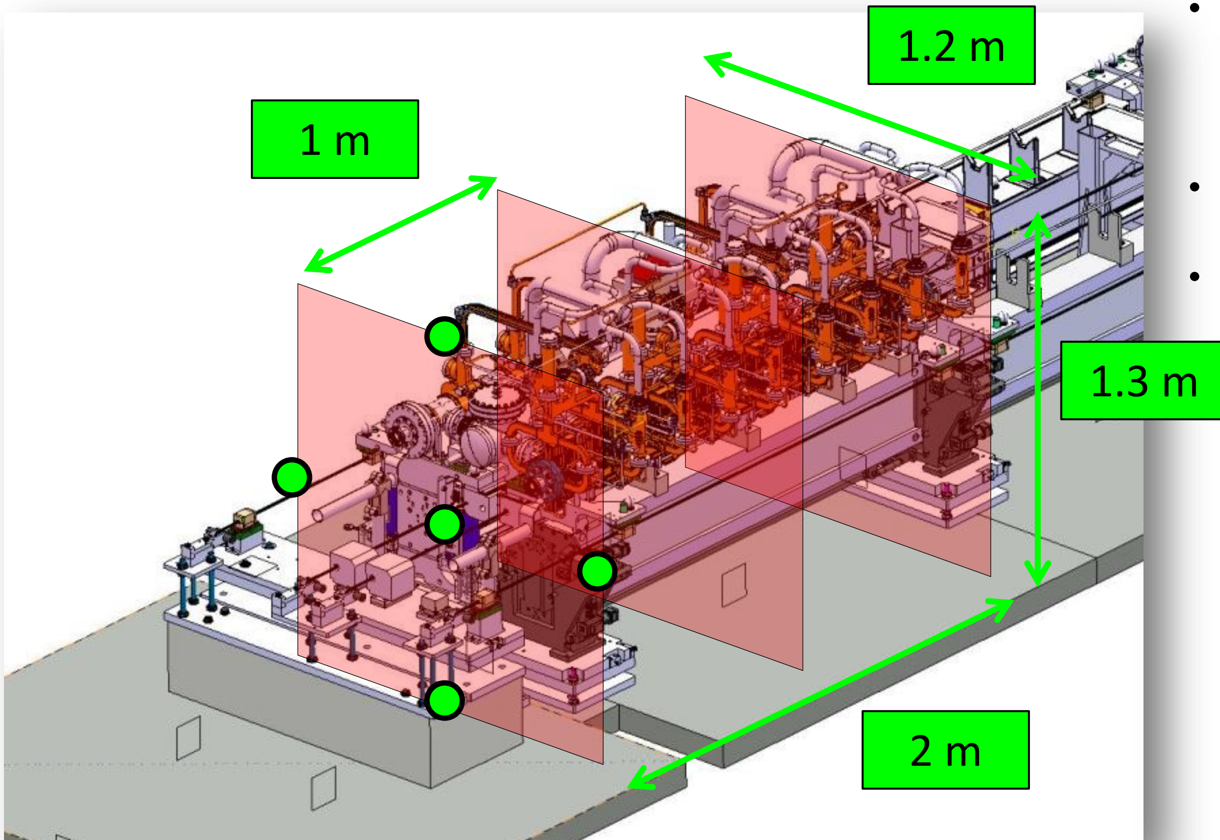
<u>Fiducials dedicated to Micro-triangulation</u>

The aluminium main part of this fiducial (made in CERN) is equipped with a breakthrough ceramic ball with a diameter of 8 mm, a removable drawer which contain a LED allows to illuminate the accurate ball.



S. Griffet et al.

Tunnel simulation: temperature profile



- 5 thermocouples for each section
    - Thermocouple type T (± 0.5 °C)
- 15 thermocouples in total
- Continuous acquisition during tests

NI 9214
16-Channel Isothermal Thermocouple Input Module

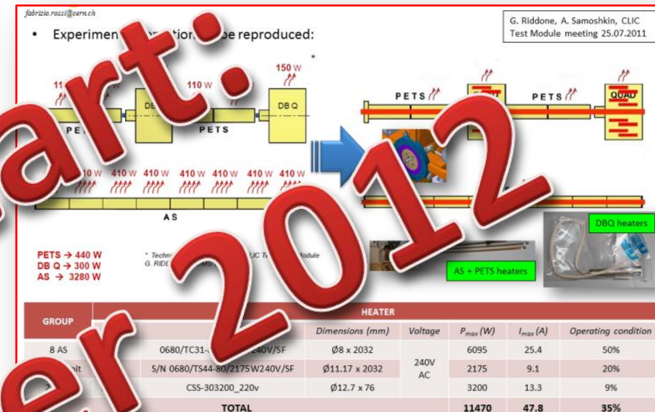
Thermo-mechanical test: preparation

LAB ENVIRONMENT

- Air conditioning and ventilation system: end of October
  - Main work for HVAC installation should start W42
  - Some smaller work should be done before with limited impact for the lab (move the compressed air supply, remove the sink/ fridge and furniture, move some lighting fixtures)

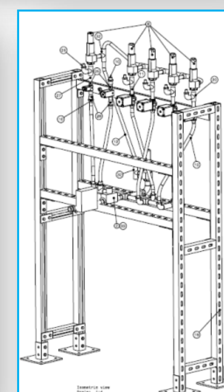
HEATING SYSTEM

- Heaters: DELIVERED
- T[illegible]rs: DELIVERED
- [illegible]dware: DELIVERED
- Thermocouples + DAQ card: DELIVERED
- Electric scheme (IL, SSR, etc.): COMPLETED



COOLING SYSTEM

- Water supply: DELIVERED
- Hydraulic parts (pipes, elbows, etc.): DELIVERED
- Control valves: DELIVERED
- Measuring devices (pressure transducer, flow rate transducer, etc.): DELIVERED
- PRV: DELIVERED
- Safety valves: DELIVERED
- Supporting frames (beams, ladders, etc.): end of September
- Electric scheme: COMPLETED



Preliminary thermal tests start: November 2012