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# Two-beam acceleration: two-beam prototype validation program

G. Riddone in collaboration with N. Gazis, D. Gudkov, A. Solodko
(input from CLIC Module WG members)

**OUTLINE**

- Two beam acceleration feasibility issue
- Prototypes modules to be tested without RF and beam: design and procurement status, objectives, schedule
- Prototypes modules to be tested with RF and beam: design and procurement status, objectives, schedule

# CLIC FEASIBILITY ISSUES

| System | Item | Feasibility Issue | Unit | Nominal |
|---|---|---|---|---|
| Two Beam Acceleration | Drive beam generation | Fully loaded accel effic | % | 97 |
| | | Freq&Current multipl | - | 2*3*4 |
| | | 12 GHz beam current | A | 4.5*24=100 |
| | | 12 GHz pulse length | nsec | 240 |
| | | Intensity stability | 1.E-03 | 0.75 |
| | | Drive beam linac RF phase stability | Deg (1GHZ) | 0.05 |
| | Beam Driven RF power generation | PETS RF Power | MW | 130 |
| | | PETS Pulse length | ns | 170 |
| | | PETS Breakdown rate | /m | < 1·10-7 |
| | | PETS ON/OFF | - | @ 50Hz |
| | | Drive beam to RF efficiency | % | 90% |
| | | RF pulse shape control | % | < 0.1% |
| | Accelerating Structures (CAS) | Structure Acc field | MV/m | 100 |
| | | Structure Pulse length | ns | 240 |
| | | Structure Breakdown rate | /m MV/m.ns | < 3·10-7 |
| | Two Beam Acceleration | Power producton and probe beam acceleration in Two beam module | MV/m - ns | 100 - 240 |
| | | Drive to main beam timing stability | psec | 0.05 |
| | | Main to main beam timing stability | psec | 0.07 |
| Ultra low beam emittance & sizes | Ultra low Emittances | Emitttance generation H/V | nm | 500/5 |
| | | Emittance preservation: Blow-up | nm | 160/15 |
| | Alignment | Main Linac components | microns | 15 |
| | | Final-Doublet | microns | 2 to 8 |
| | Vertical stabilisation | Quad Main Linac | nm>1 Hz | 1.5 |
| | | Final Doublet (assuming feedbacks) | nm>4 Hz | 0.2 |
| Operation and Machine Protection System (MPS) | | 72MW@2.4GeV | | |
| | | main beam power of 13MW@1.5TeV | | |

Demonstration of novel scheme of two beam acceleration in compact modules integrating all technical systems for RF production, beam measurement and acceleration including alignment, stabilisation and vacuum at their nominal parameters.

# CLIC TWO-BEAM MODULES

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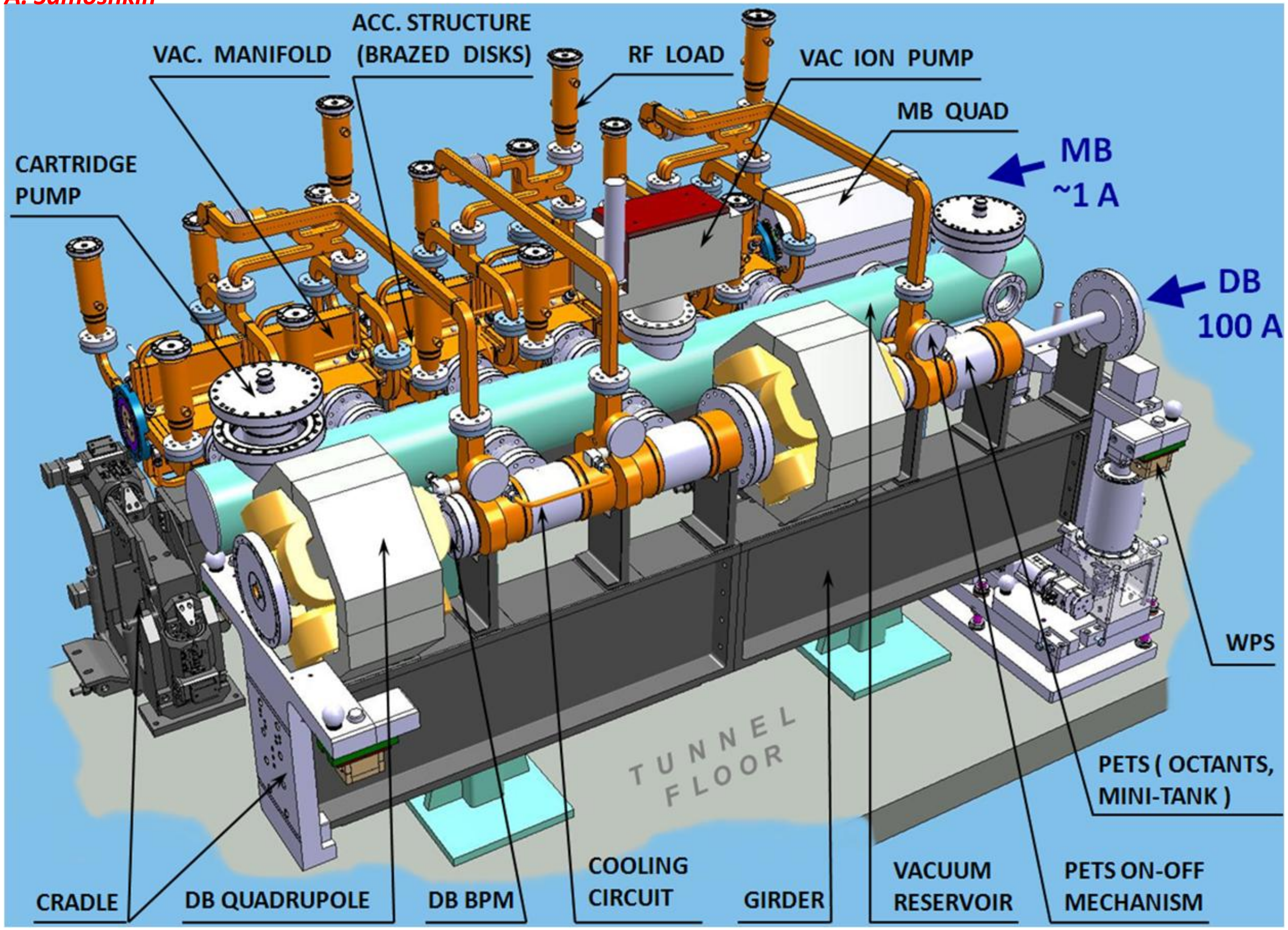
*A. Samoshkin*




**Prototype modules → as close as possible to CLIC modules**

# STEPS TOWARDS TWO-BEAM ACCELERATION MODULES

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## 2009-2011

Two-beam test stand (PETS and ac. structures)

→ Demonstration of the two-beam acceleration with one PETS and one accelerating structure at nominal parameters in CLEX

## 2010-2013

Prototype modules in LAB

→ Demonstration of the two-beam module design

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

Prototype modules in CLEX

→ Demonstration of the two-beam acceleration with two-beam modules in CLEX

Address other feasibility issues in an integrated approach

Industrialization and mass production study

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# PROTOTYPE TWO-BEAM MODULES IN THE LAB

# PROTOTYPE MODULES TO BE TESTED IN A LAB

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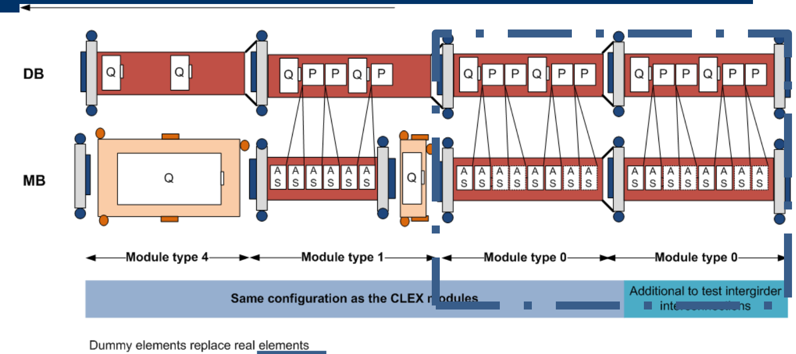
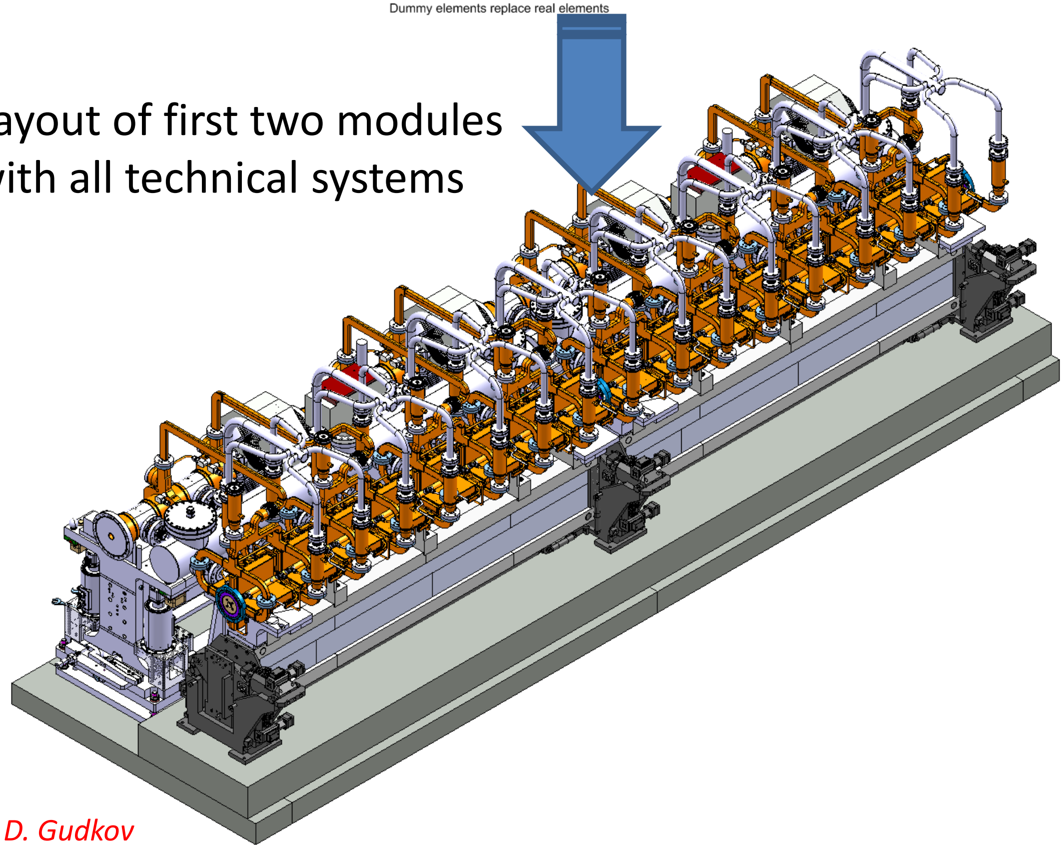
4 modules representative of all CLIC module types
First two modules under procurements
Reception at factory of girders started on 20 October




SiC girder before final
Grinding at Boostec

Layout of first two modules
with all technical systems



*D. Gudkov*

# PROTOTYPE MODULES IN THE LAB: OBJECTIVES

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- Integration of all technical systems (dummy RF structures and quadrupoles can be used – real dead weight and interfaces to other systems)
- Validation of different types of girders and movers
- Pre-alignment of girders/quadrupoles in the module environment, including fiducialisation
- Full metrology of the module components
- Validation of interconnections under different simulated thermal loads
- Stabilization of main beam quad in the module environment
- Vibration study of all systems and identification of vibration sources
- Measurement of resonant frequencies (both in lab and in the tunnel/underground area)
- Simulation of several thermal cycles: measurements of thermal transients (e.g. how long it takes to achieve a new equilibrium state), fiducialisation verification
- Transport of the module and verification of alignment

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# PROTOTYPE MODULES IN THE LAB: TEST PROGRAM

**Phase 00a**

- Overall integration and full metrology
- Pre-alignment validation with dummy elements
- Interconnections - pumping (static conditions)
- Repositioning
- Thermal cycles
- Measurements of resonant frequencies

**CDR**

**Phase 00b**

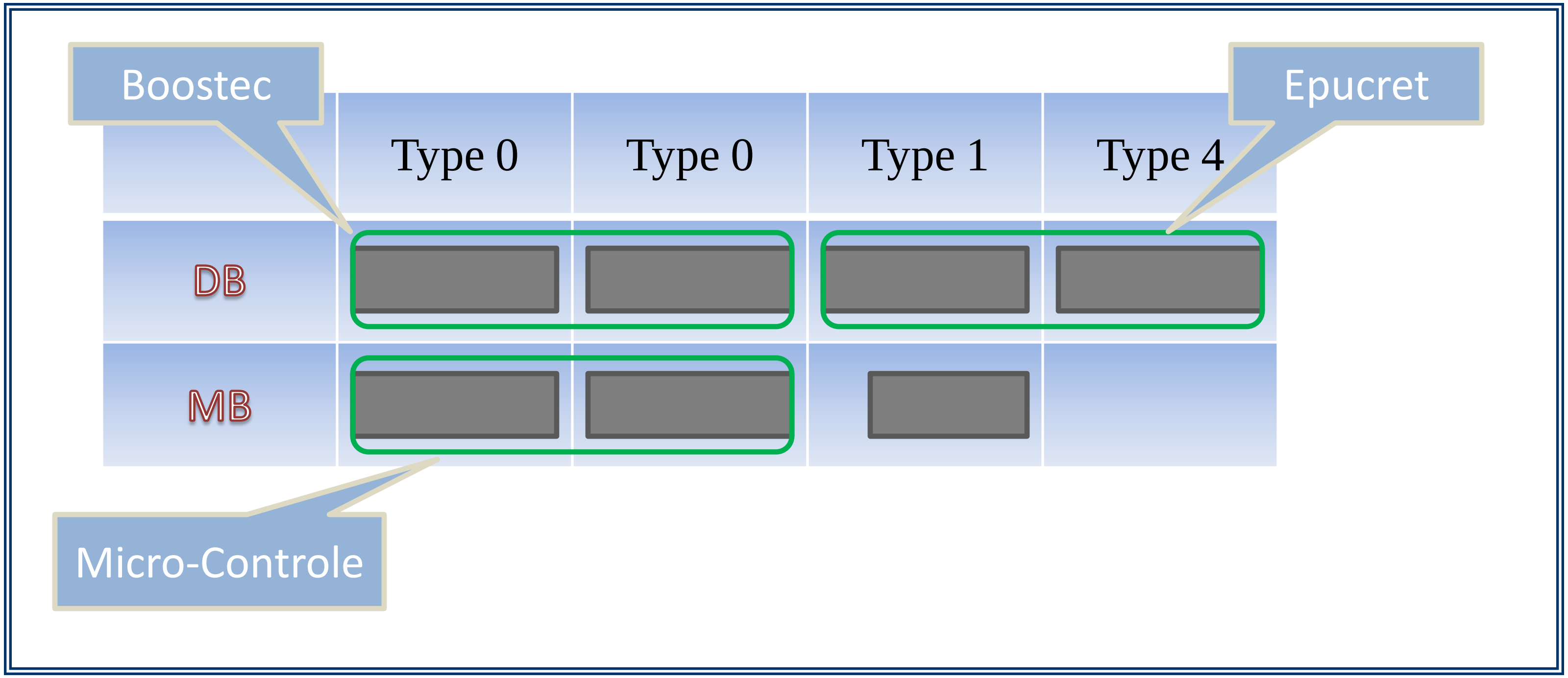
- Transport and thermal cycles
- Vibration study of all system and vibration sources
- Measurements of resonant frequencies

**Phase 001a**

- Stabilization (Q) and pre-alignment compatibility
- Vibration study of all system and vibration sources

# PROTOTYPE GIRDERS

*N. Gazis*

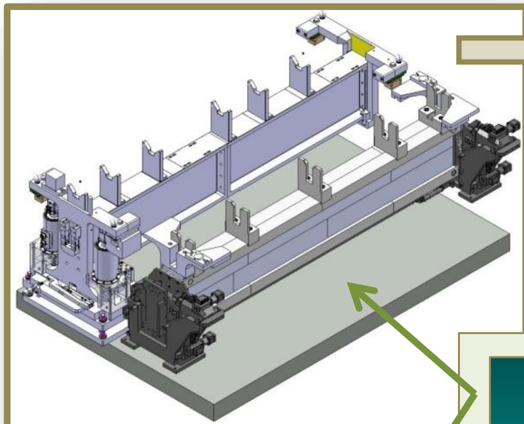



<u>3 companies</u> with three different strategies:

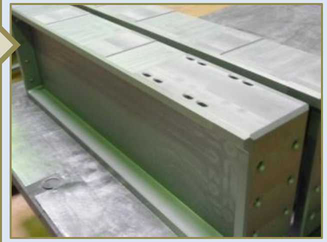
- **Bootsec**: supply of 2 SiC girders with V-shaped supports [Nov 2010]
- **Microcontrole**: supply of 2 SiC girders with V-shapes supports, and positioning system [Dec 2010]
- **Epucret**: supply of 2 Mineral cast girders [Nov 2010]

# PROTOTYPE GIRDERS

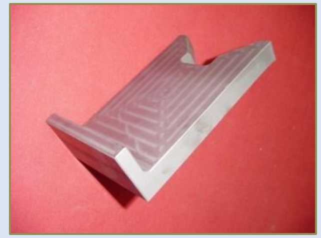
*N. Gazis*



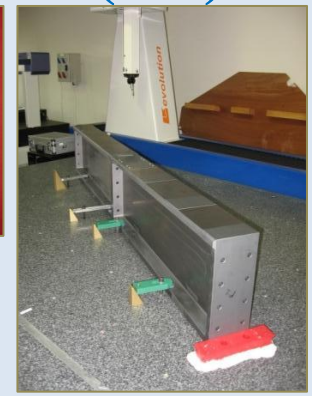
## Boostec (SiC)



SiC Girder Half

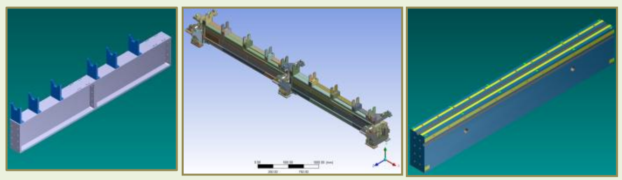


SiC V-support

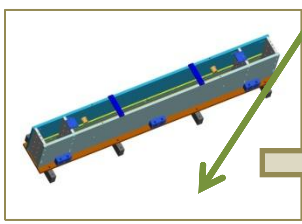


SiC Girder Brazed

SiC Girder before V-support brazing

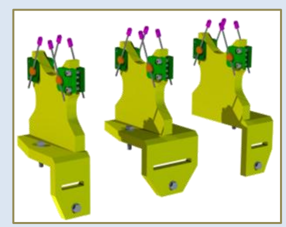


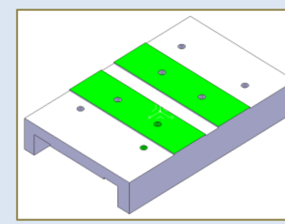
Conceptual Design Feb – Jul 2010



## Epucret (Mineral Cast Material)

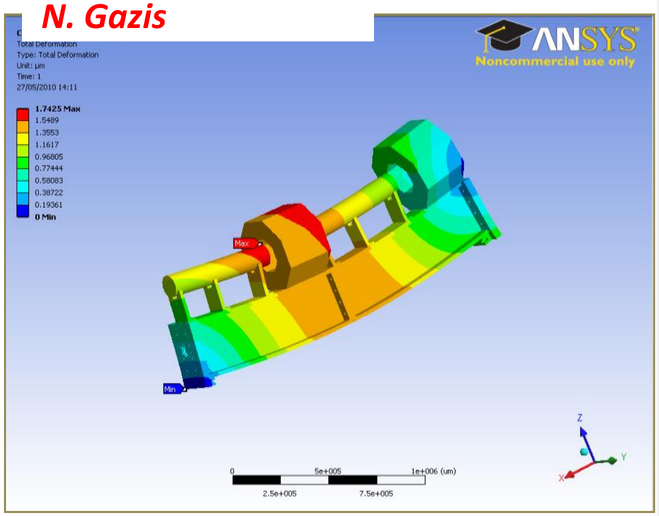
Girder Mould fabrication

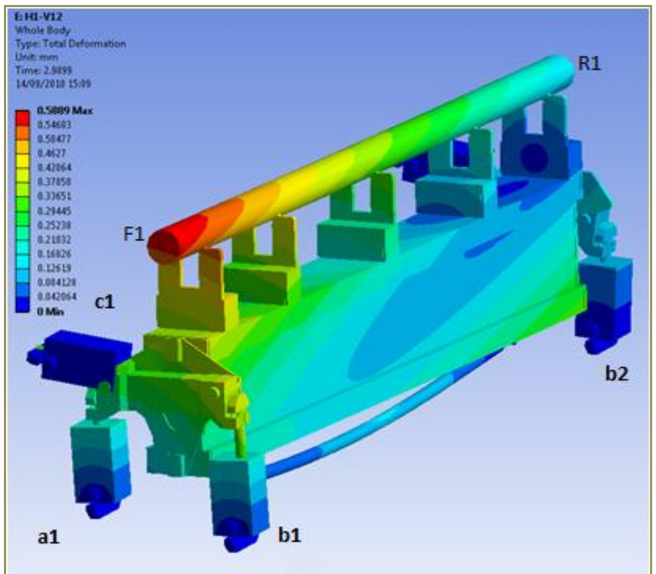




Metal V-supports, U-clamps
DB-quad support plate

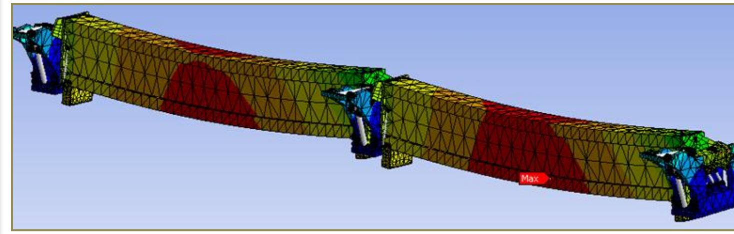
*N. Gazis*

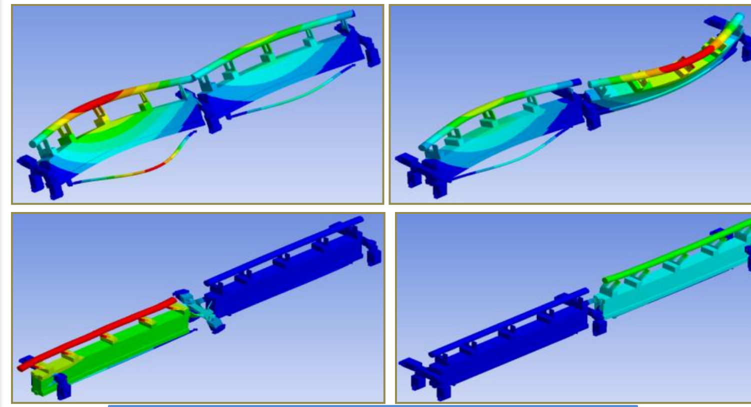


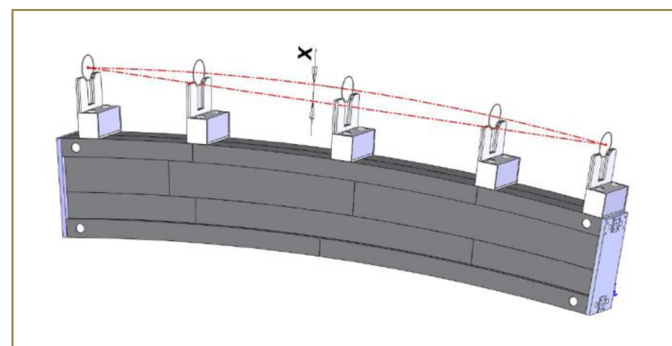

- **Modal Analyses for all CLIC Two-Beam Module Girder prototype configurations: <u>Eigenfrequencies (f) ≥ 35 Hz</u>**
- **Static Analyses of loaded CLIC Two-Beam Module Girder prototype configurations: <u>80 μm ≥ Deformations (ε) ≥ 10 μm</u>**

Pre-stressed girders, according to the simulated RF component loads, with precision machining after the integration of the V-shaped supports.





Modal Analysis



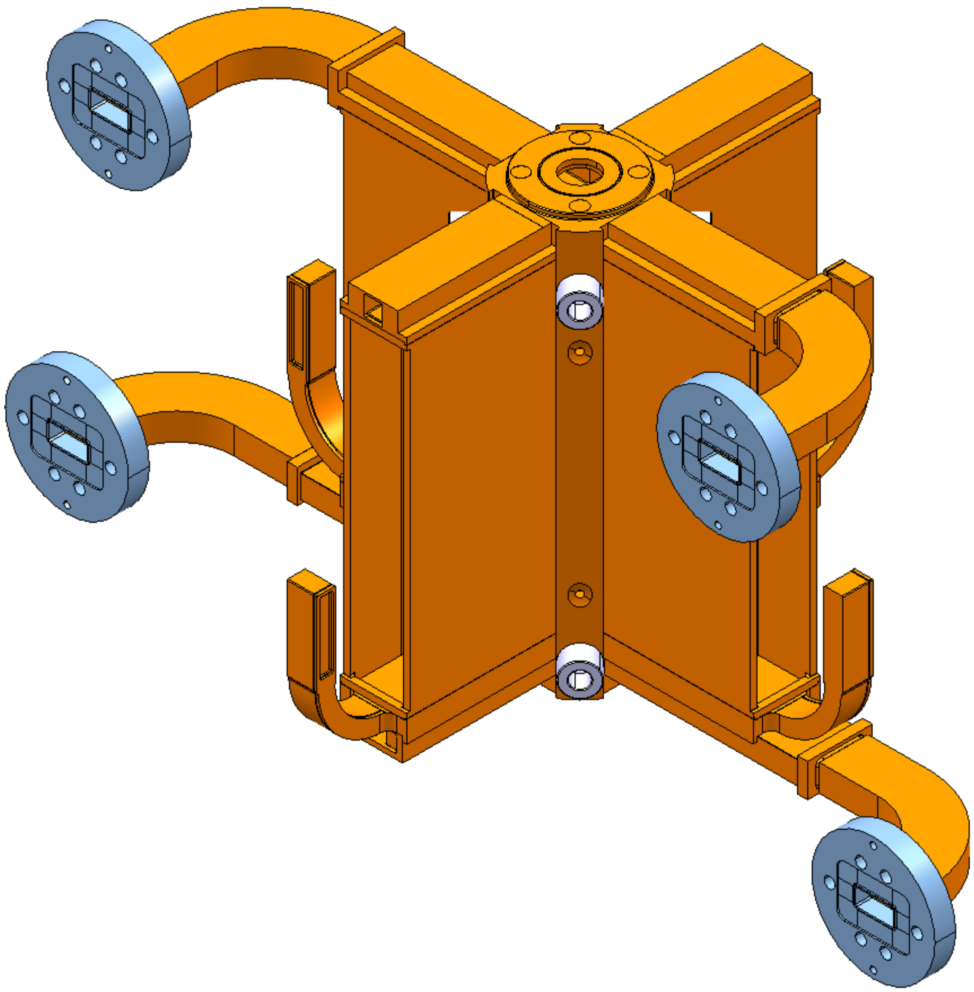
Pre-stressed solution

# MAIN BEAM AS ASSEMBLY SEQUENCE (1/4)

*D. Gudkov*

1. Brazing of the manifolds (preliminary brazed);

2. Brazing of plugs and cooling fittings adapters;

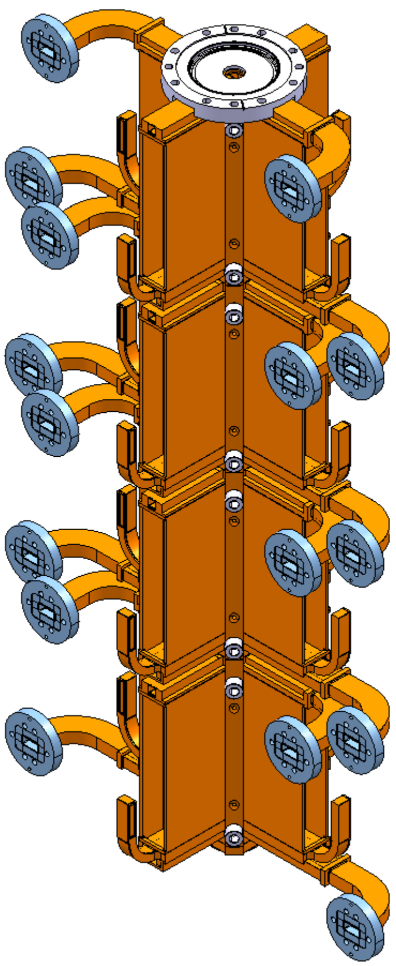


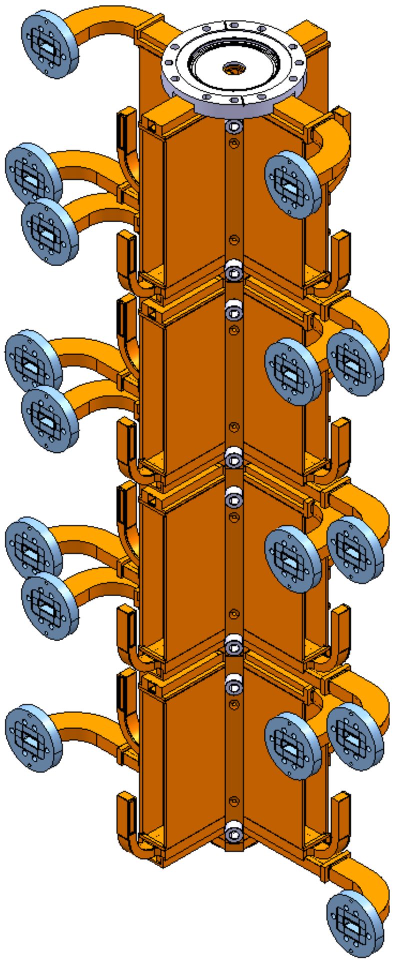
# MAIN BEAM AS ASSEMBLY SEQUENCE (2/4)

*D. Gudkov*

3. Brazing of 2 stacks 1005 mm long each:
Includes:
4 AS with manifolds;
Interconnection MB-MB;

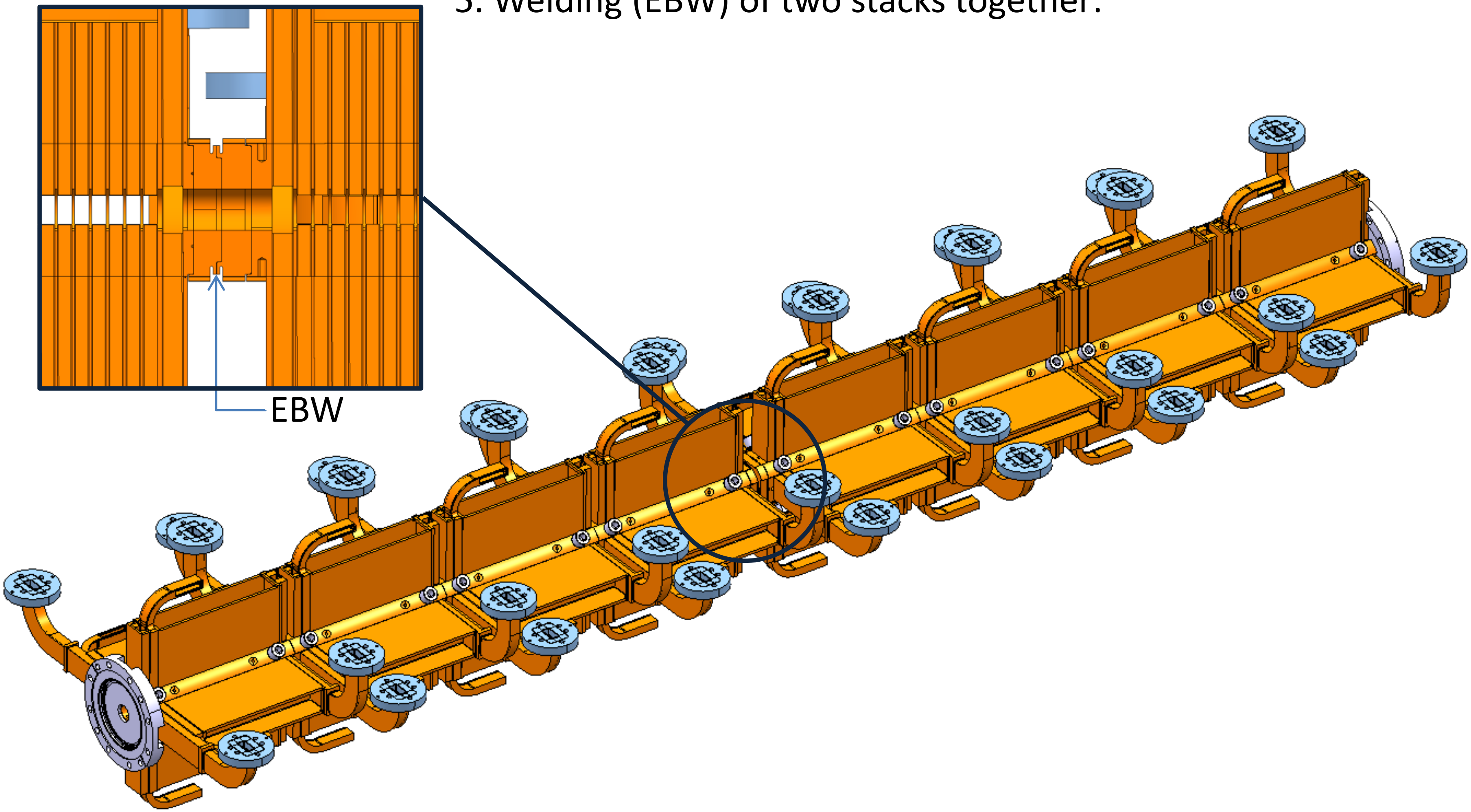
4. Installation of the damping material and EB welding of covers





*D. Gudkov*

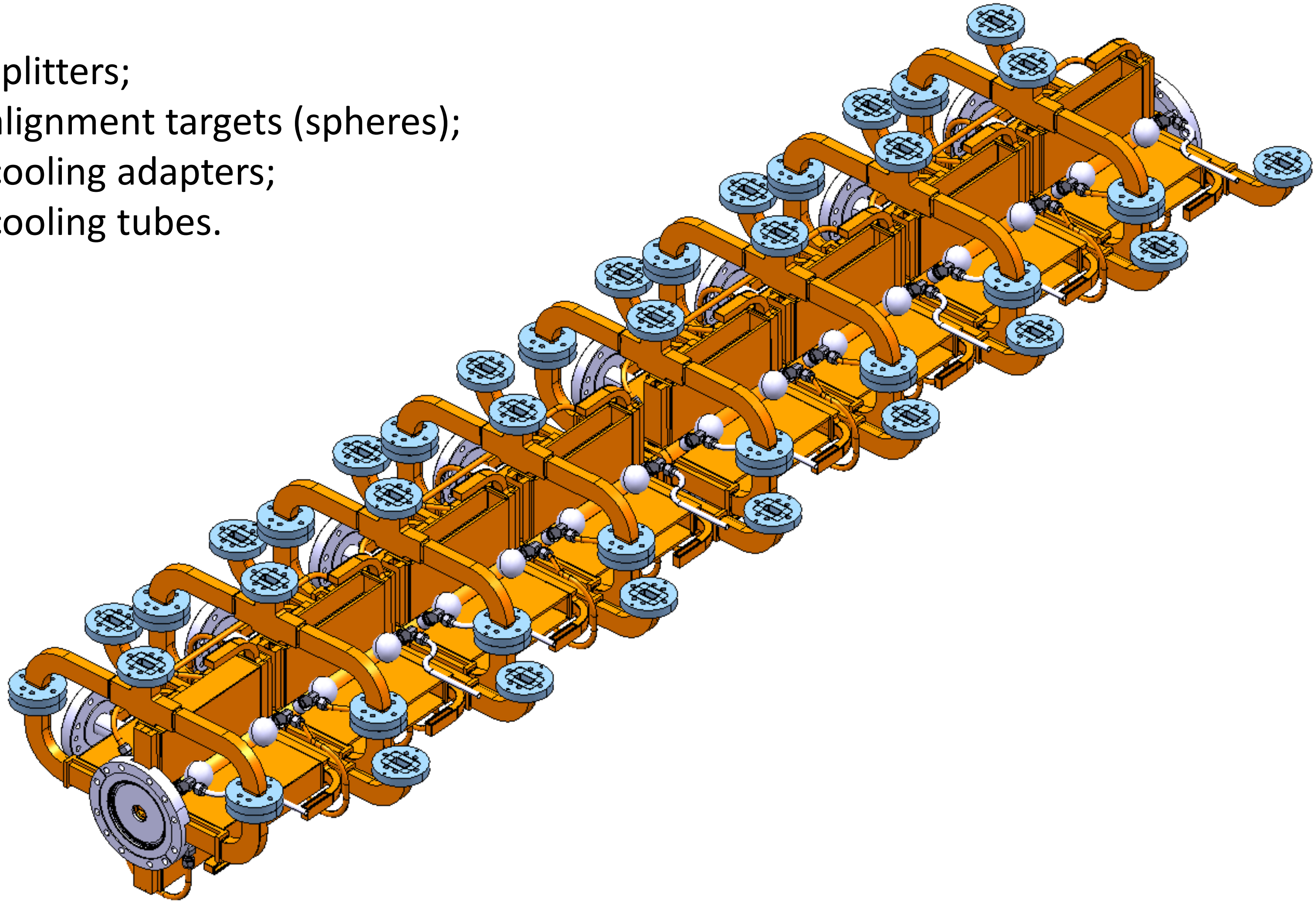
5. Welding (EBW) of two stacks together:



# MAIN BEAM AS ASSEMBLY SEQUENCE (4/4)

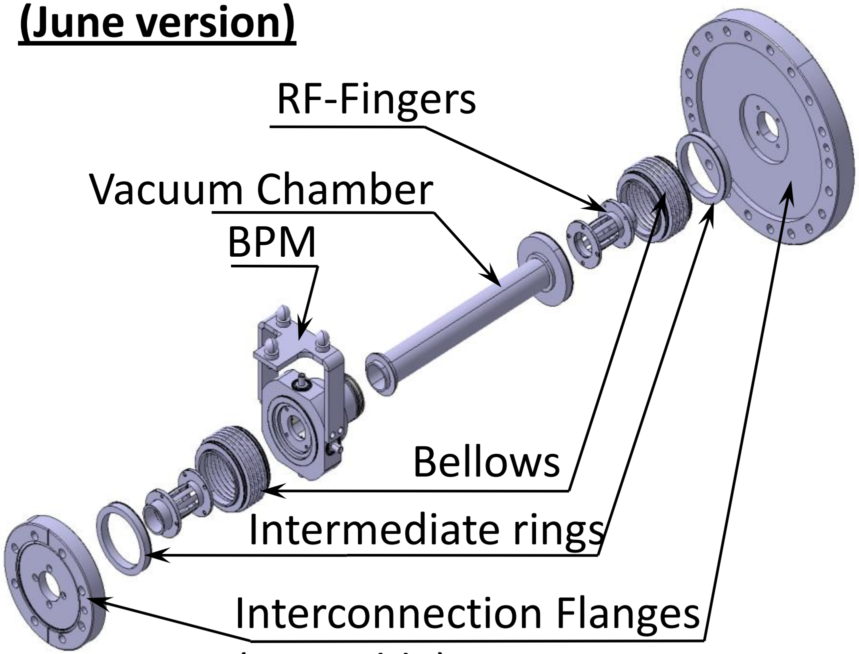
*D. Gudkov*

6. Installation of splitters;
7. Installation of alignment targets (spheres);
8. Installation of cooling adapters;
9. Installation of cooling tubes.

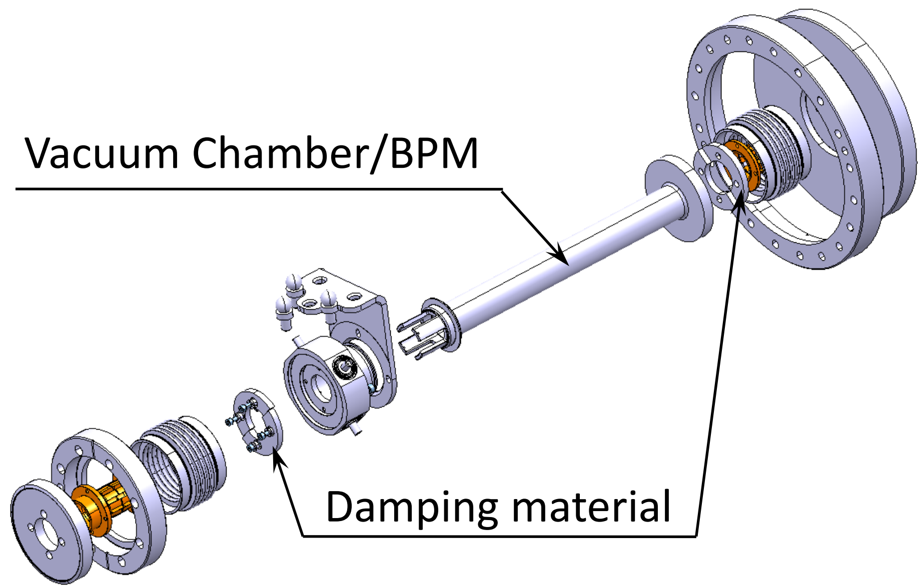


*D. Gudkov*

**DB BPM – Vacuum chamber ASSEMBLY (June version)**




**DB BPM – Vacuum chamber ASSEMBLY (July version)**

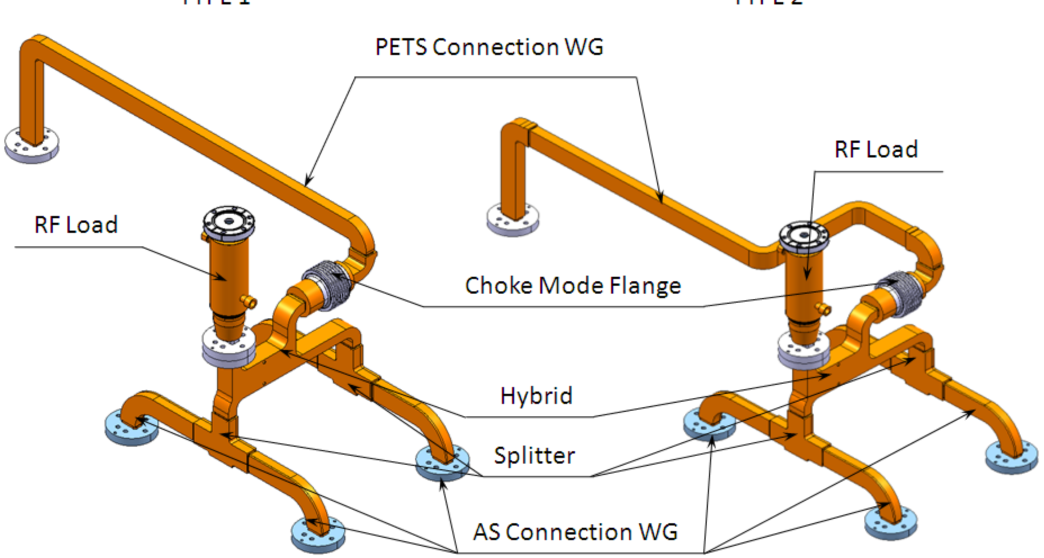



1. Vacuum chamber and BPM are joined as one part to increase the precision;
2. Damping material added;
3. Alignment frame is finalized;
4. Production drawings: CLIATLBI0009

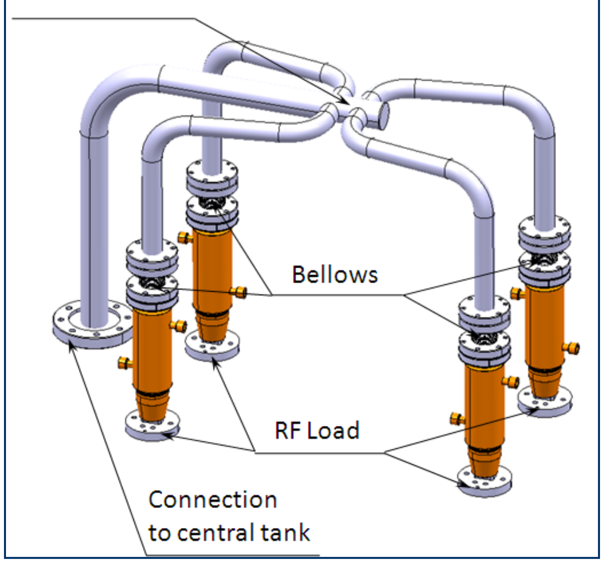
# RF AND VACUUM NETWORKS

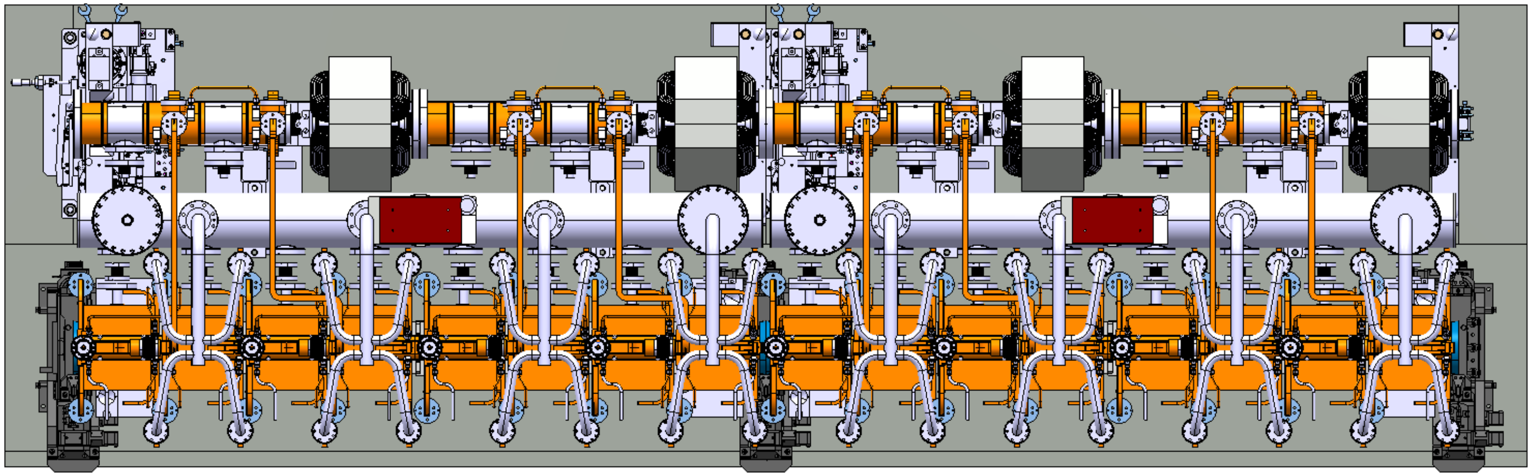
*D. Gudkov*

**RF NETWORK**




**VACUUM NETWORK**



# PRTOTOTYPE MODULES – LAB: SCHEDULE

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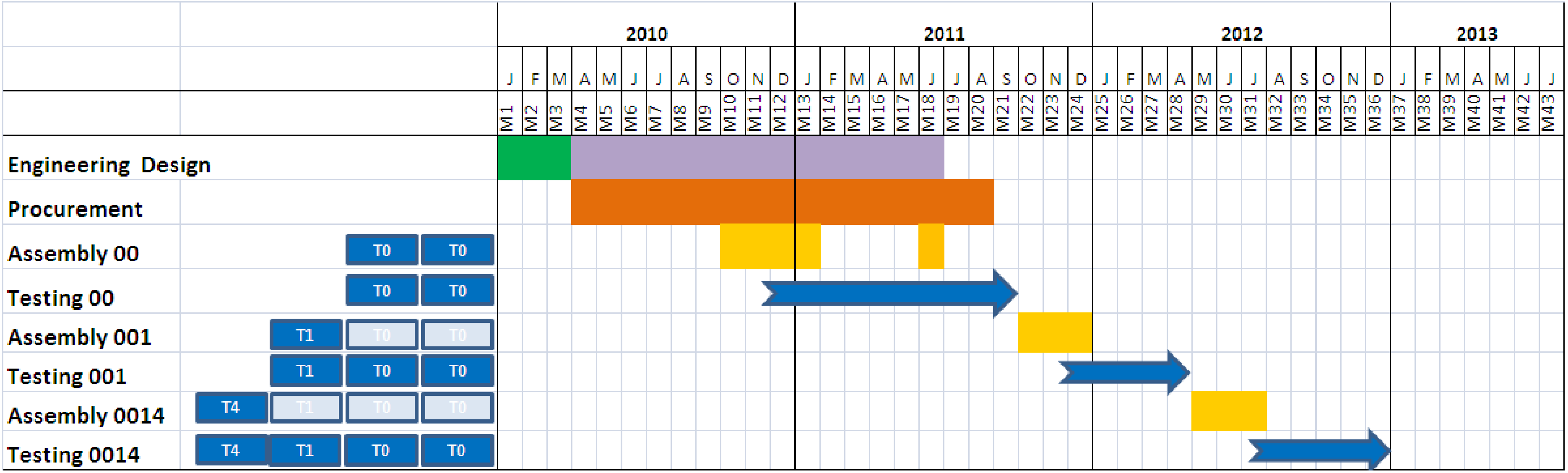


Actuators/sensors under fabrication

MB T1 and T4 at CERN

Girders under fabrication

Under tendering: vacuum system , beam instrumentation and RF system

**For details, see**
EDMS number: 1076281

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# PROTOTYPE TWO-BEAM MODULES IN CLEX

# TEST MODULES - CLEX: OBJECTIVES

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- Two-beam acceleration in compact modules integrating all technical systems for RF production, beam measurement and acceleration including alignment, stabilisation and vacuum at their nominal parameters.

- Accelerating structure alignment on girder using probe beam
- Wakefield monitor (WFM) performance in low and high power conditions, and after a breakdown
- Investigation of the breakdown effect on the beam

- Alignment and stabilization systems in a dynamic accelerator environment
- RF network phase stability especially independent alignment of linacs
- Vacuum system performance, both static and dynamics with rf
- Cooling system, especially dynamics due to beam loss and power flow changes

- Validation of assembly, transport, activation, maintenance etc.

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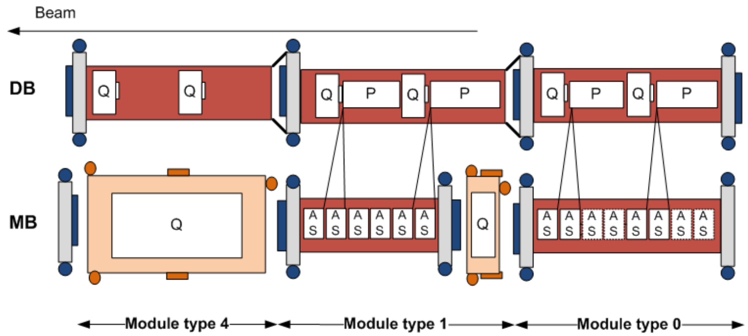
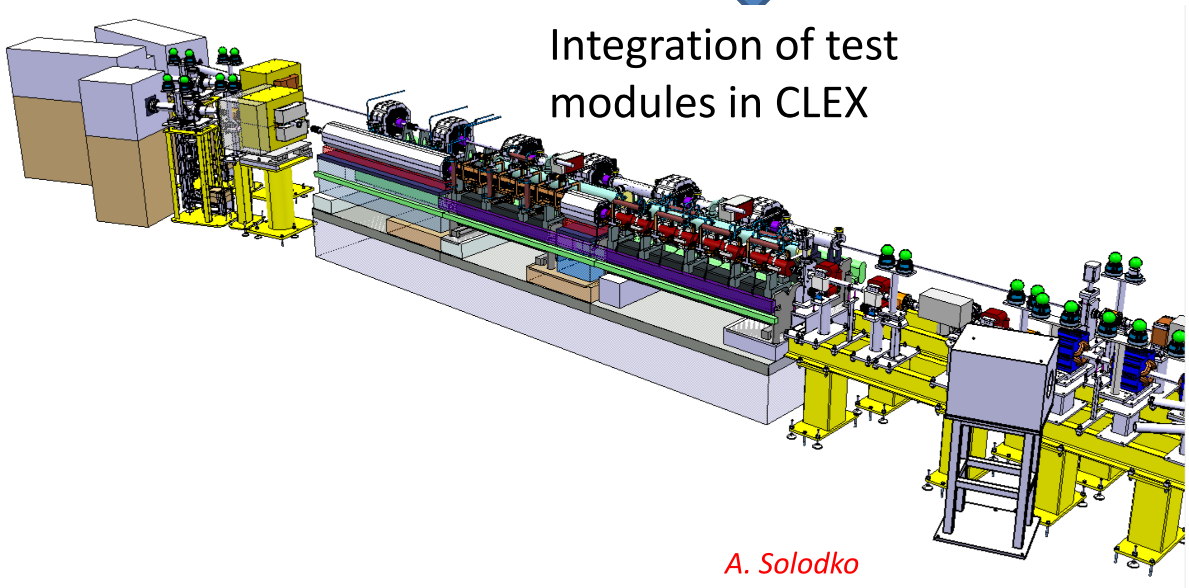
# PROTOTYPE MODULES TO BE TESTED IN CLEX




- 3 modules to be tested with beam and RF
- module layout compatible with CLEX requirements:
    - double length PETS feeding two accelerating structures
    - accelerating structures with all technical systems and damping features

- First module to be ready by end of 2011

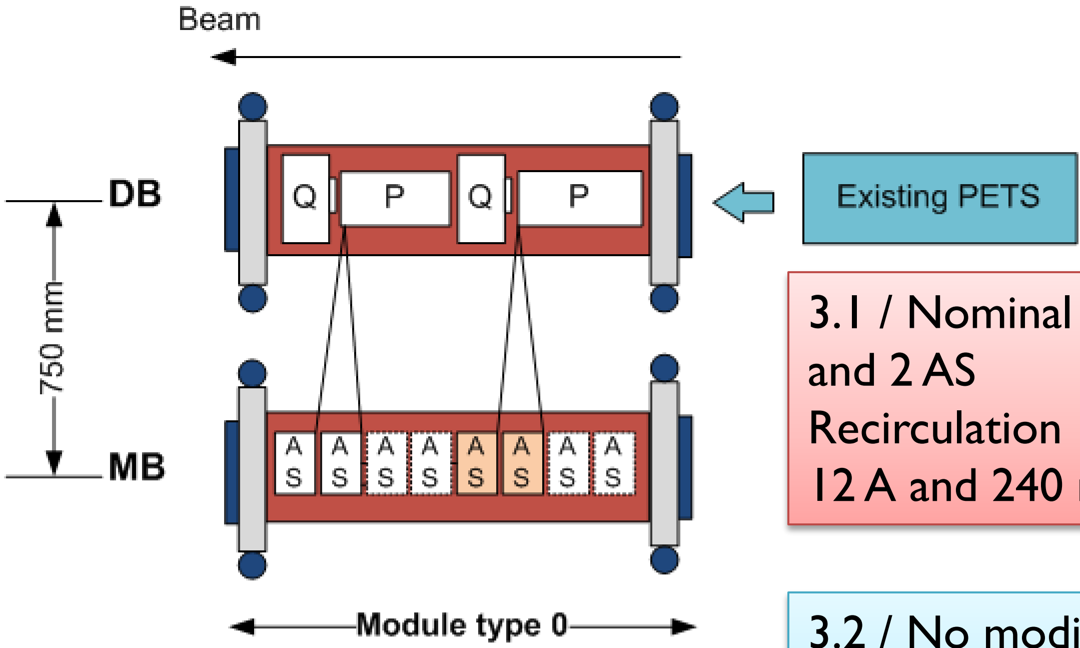
Integration of test modules in CLEX



*A. Solodko*

# PROTOTYPE MODULE - CLEX: PHASE 3

Phase 3 foresees the installation and testing of 1 module type 0: AS equipped with WFM (5 um accuracy / few WFM in the 1st powered AS)




3.1 / Nominal power and pulse length for 1 PETS and 2 AS
Recirculation
12 A and 240 ns

3.2 / No modifications on the module type 0 HW
No Recirculation
Current increase from 12 A to 19.2 A
Pulse length reduced from 240 ns to 140 ns

# PROTOTYPE MODULE - CLEX: PHASE 4

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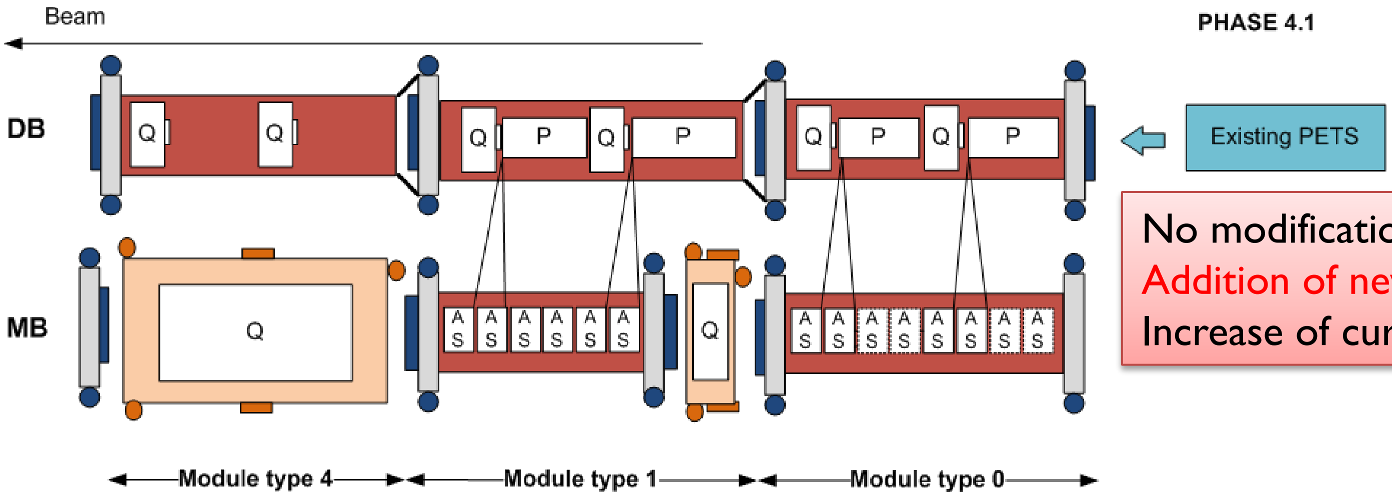
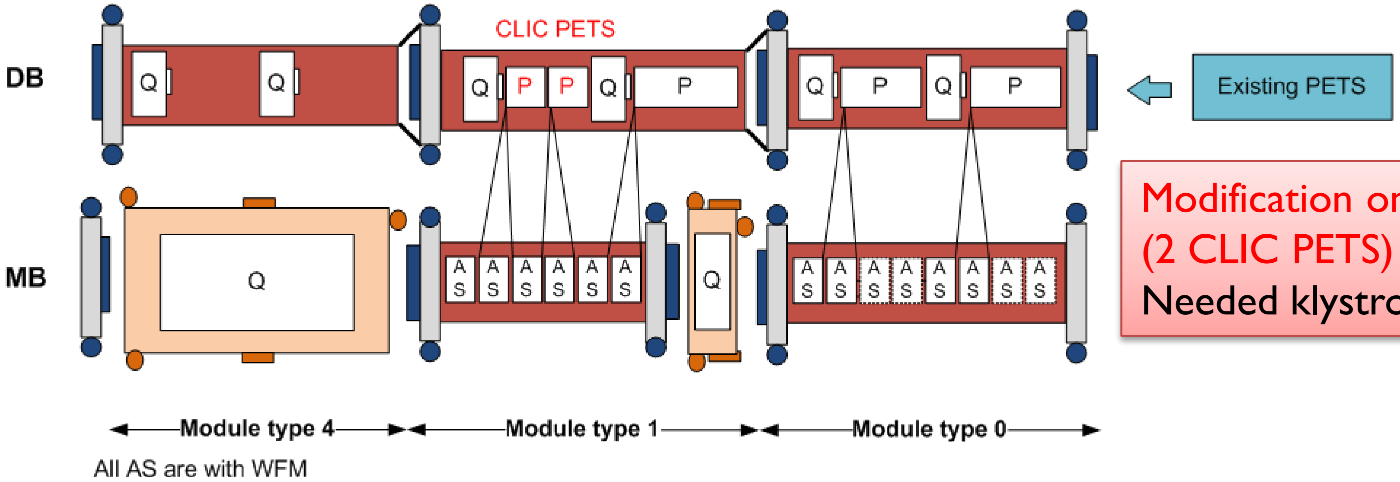
PHASE 4.1




No modifications on the module type 0
Addition of new modules - type 1 and 4
Increase of current from 19.2 A to 22 A

PHASE 4.2




Modification on the module type 1 (2 CLIC PETS)
Needed klystrons and PC

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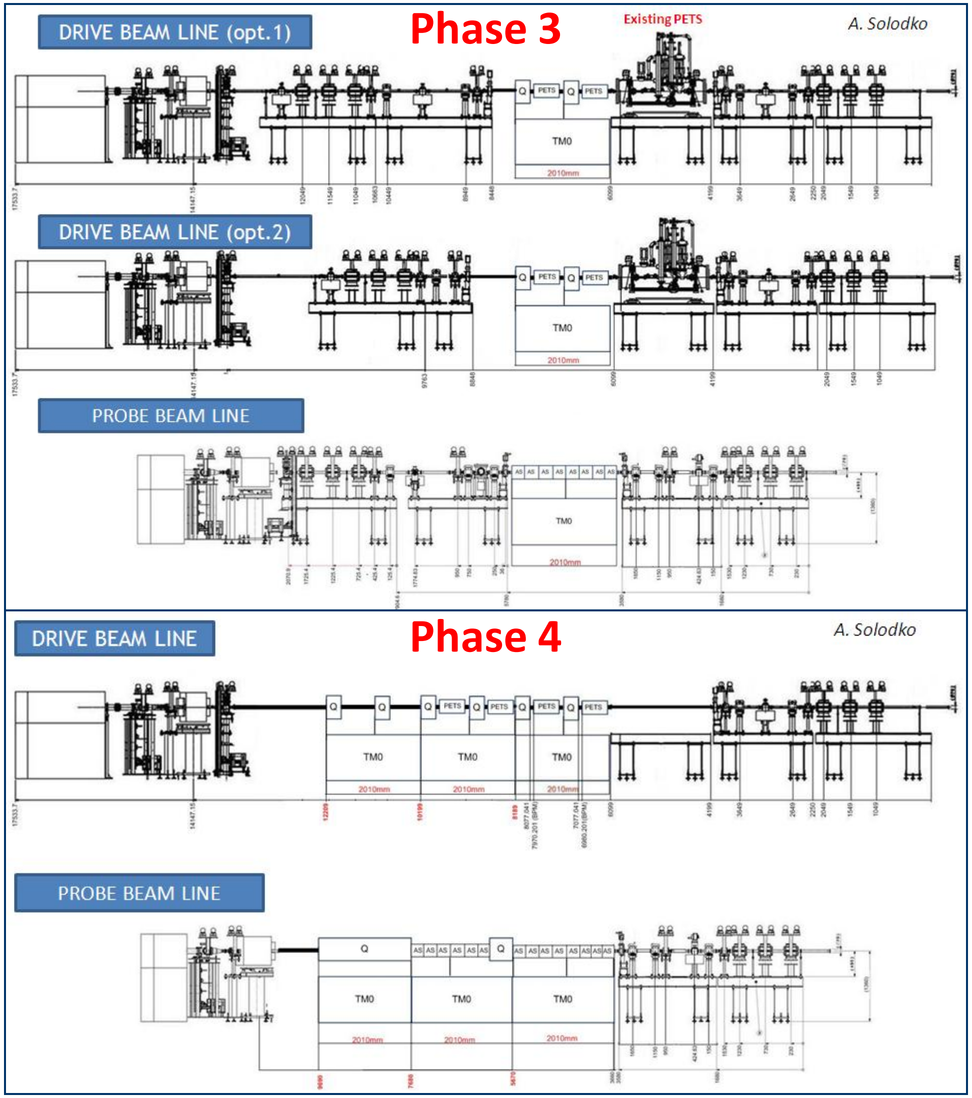


**Phase 3:**

-Existing PETS (currently under test) will be reused

- It will be moved to allow for Type 0 module installation

**Phase 4:**

-Instrumentation downstream the type 0 module will be removed

- Installation of type 1 and 4 without displacing type 0

# PRTOTOTYPE MODULES – CLEX: SCHEDULE

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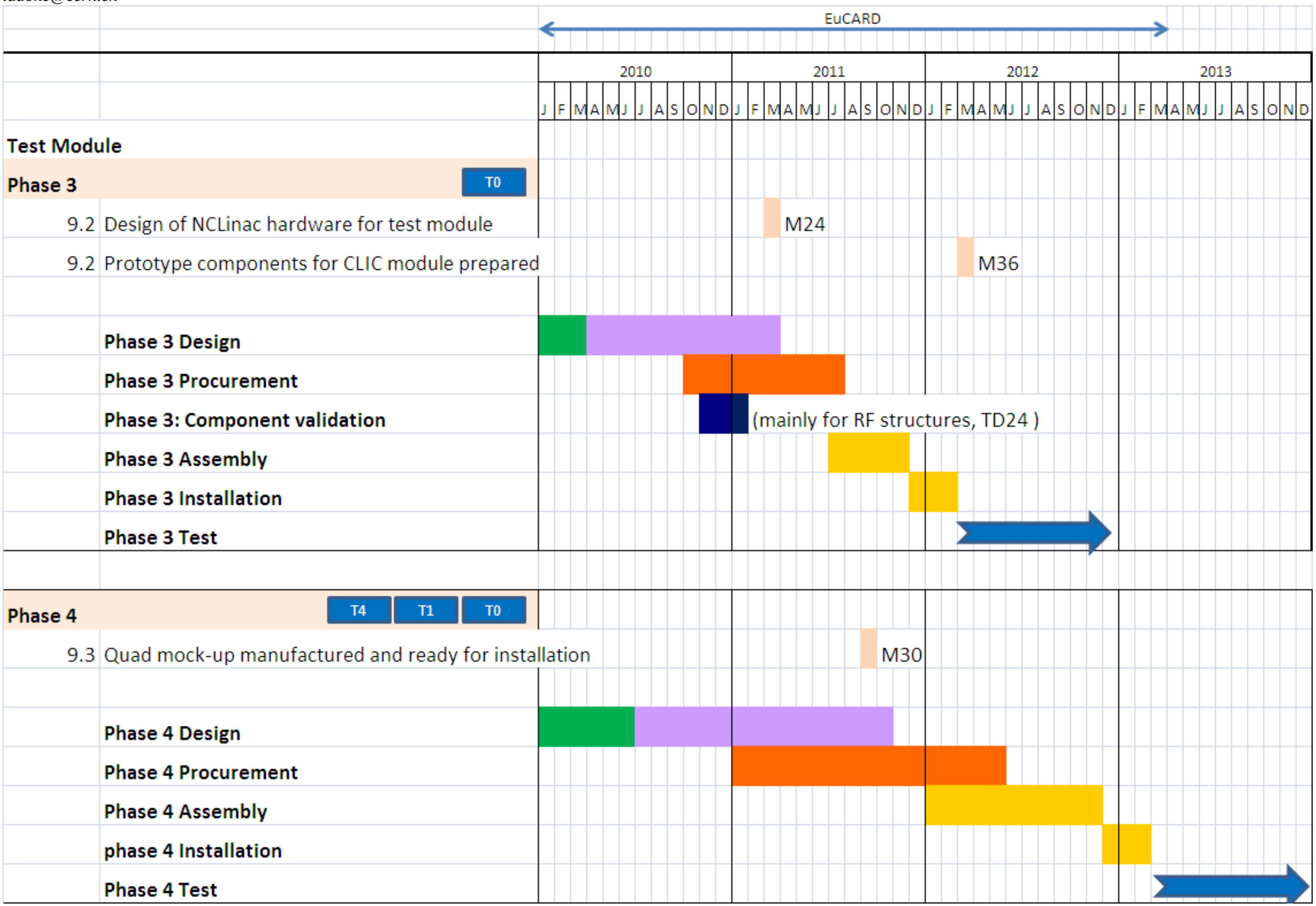

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# CONCLUSIONS

- Two-beam module is part of the CLIC feasibility program
- At the end of 2009 the prototype module project has been approved: 7 modules
- Prototype Module project very challenging:
  - Non standard procurement, several iterations needed with firms
  - First girders in Nov 2010 for type 0 test modules in the lab, although reception at factory already started
  - Eucard WP 9.2 NC linac – NC accelerating cavities is part of test modules in CLEX ➔ several collaborators highly contributing
- Next months will be very busy with the assembly of the first two modules: metrology and thermal cycles tests are expected to be finished before CDR

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**EXTRA SLIDES**

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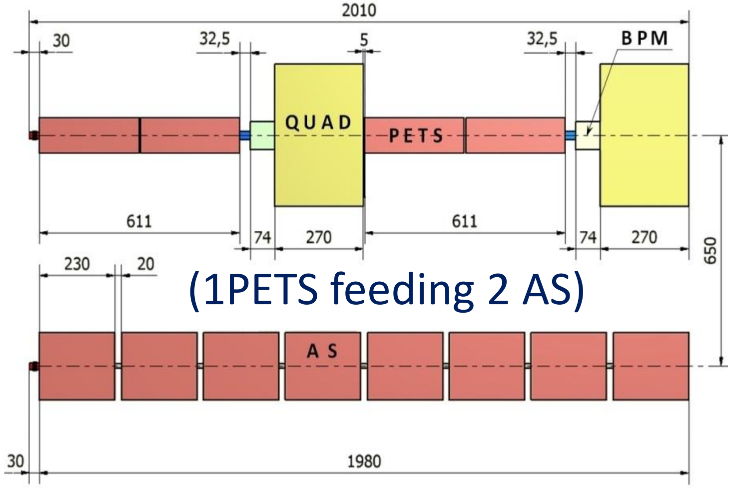
## CLIC module type 0




CLIC STANDARD MODULE LAYOUT

| Parameters | CTF3 | CLIC |
|---|---|---|
| Energy | 0.150 GeV | 2.4 GeV |
| Pulse length | 1.2 μs | 140 μs |
| Multiplication factor | 2 x 4 = 8 | 2 x 3 x 4 = 24 |
| Linac current | 3.75 A | 4.2 A |
| DB final current | 30 A | 100 A |
| RF frequency | 3 GHz | 1 GHz |
| Repetition rate | up to 5 Hz | 50 Hz |
| Energy per beam pulse | 0.7 kJ | 1400 kJ |
| Average DB power | 3.4 kW | 70 MW |

## CLEX module type 0

Double length PETS