CLIC09 WORKSHOP

Status and progress of the module studies

G. Riddone on behalf of the CLIC Module WG, 13.10.2009

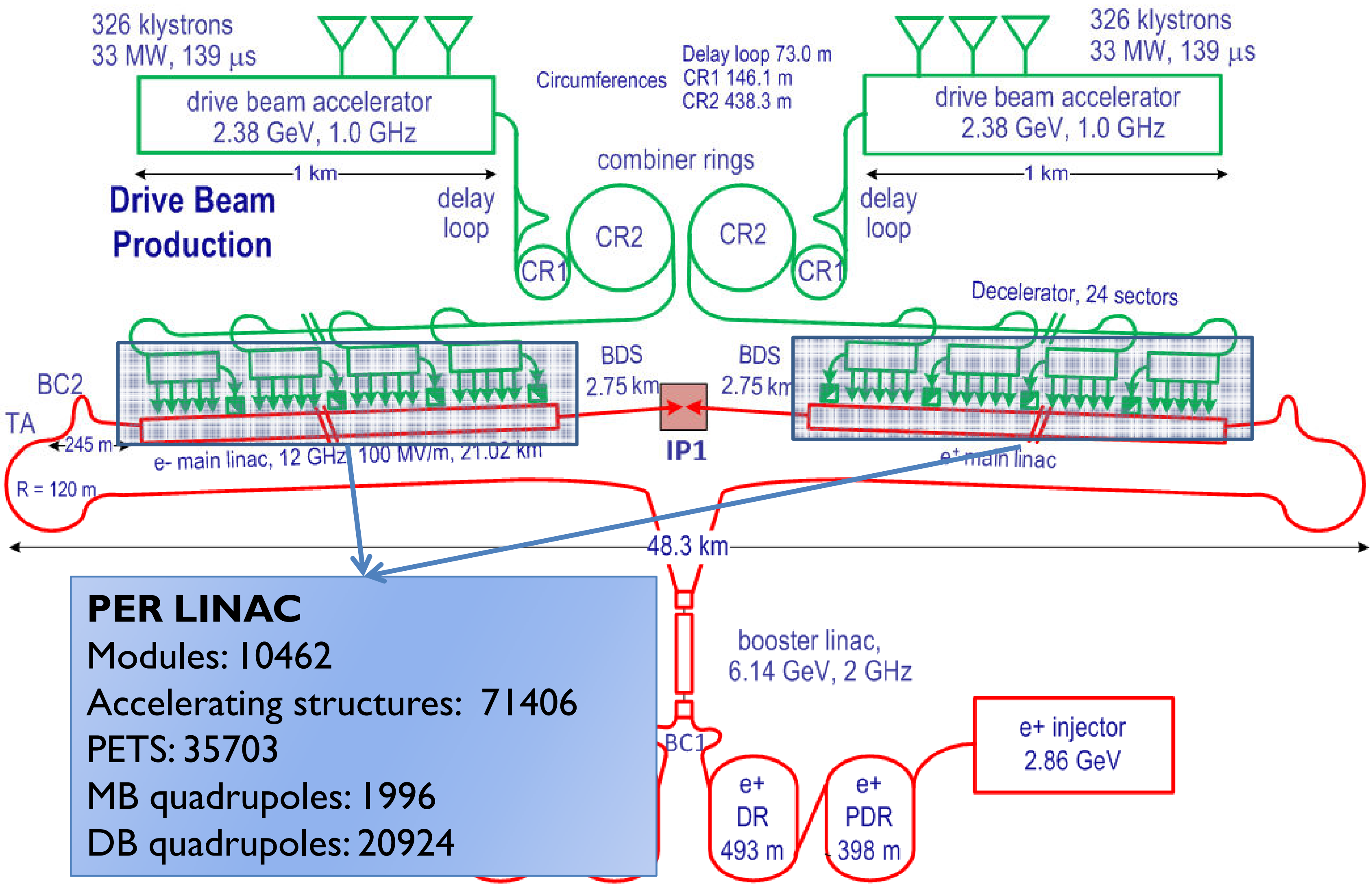
Outline

- Introduction and motivation
- Module types
- **Systems/components: design status and studies**
- **Module integration: design status and studies**
- Conclusions

Dedicated talks on module baseline, test program, integration and overall simulations in the WG5 on Wed 14.10

INTRODUCTION AND MOTIVATION

CLIC overall layout – 3 TeV



PER LINAC

Modules: 10462

Accelerating structures: 71406

PETS: 35703

MB quadrupoles: 1996

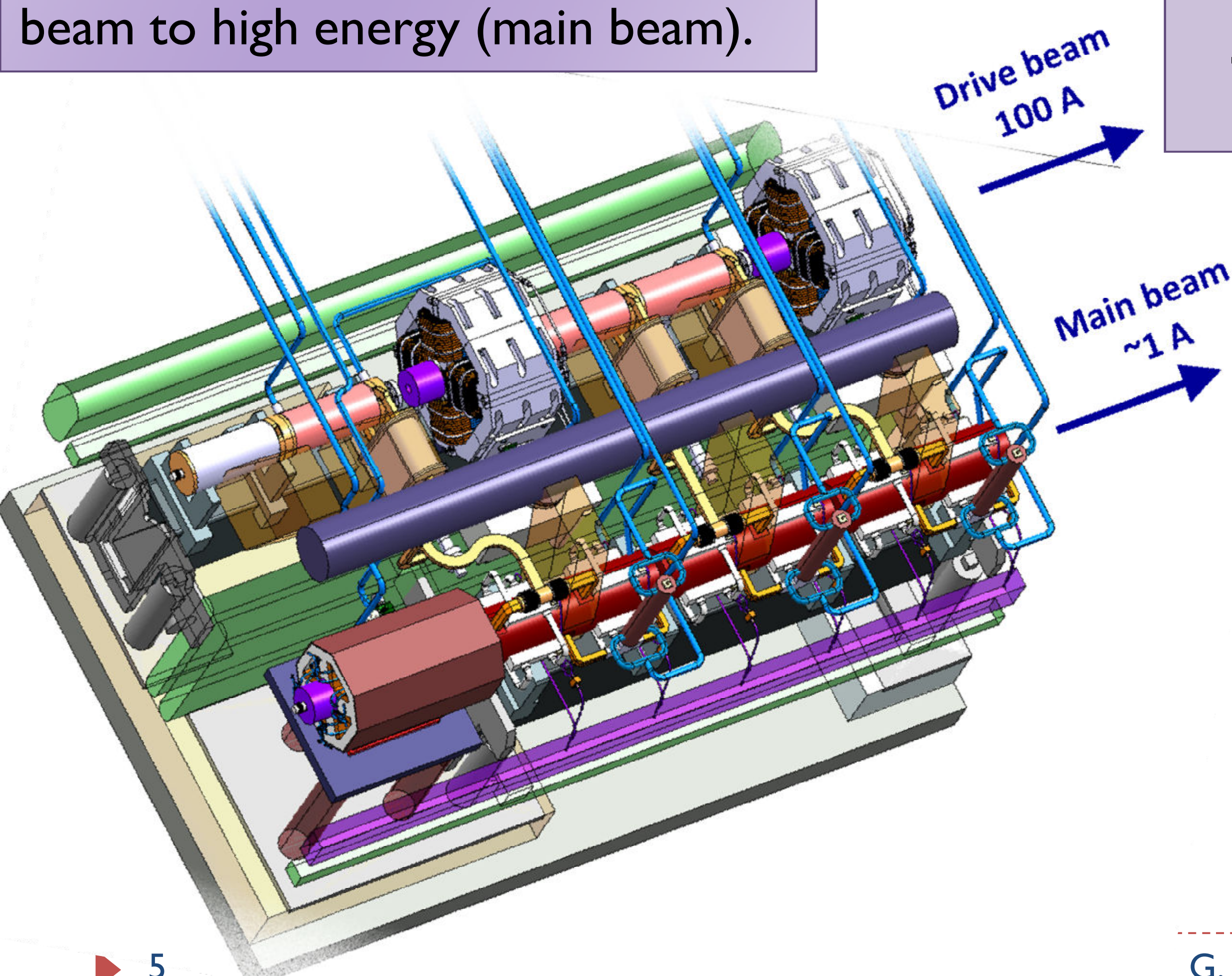
DB quadrupoles: 20924

A fundamental element of the CLIC concept is two-beam acceleration, where RF power is extracted from a high-current and low-energy beam (drive beam) in order to accelerate the low-current main beam to high energy (main beam).

10 CLIC Feasibility Issues

- Two Beam Acceleration:
  - Drive beam generation
  - Beam Driven RF power generation
  - Two Beam Module

CLIC specific



PETS
-6.5 MV/m, 136 MW, 213 mm

Accelerating structure
+100 MV/m, 64 MW, 229 mm

Two-beam module

Current activities

BASELINE DESIGN for CDR

- Definition of overall layout (space reservation, number of components and their exact position and dimension)
- **Definition of boundary conditions and design constraints to the CLIC technical systems**
- **Detailed study and mechanical design of the module,** as well as integration and fabrication issues [*WG5*]
- Definition of layout of special regions (drive beam turn-around loops)

- Module integration in the tunnel, including module transport and installation in collaboration with CES WG *[WG5]*
- Design and construction of the so called "Test Modules" [*WG5*]
- Cost estimate
- Provide feedback for other areas of the study

Organization

Working group
with link persons for main
technical systems and interfaces

↔

Collaborators

Technical systems

- RF: I. Syratchev, W. Wuensch, R. Zennaro,
- RF instrumentation: F. Peauger, R. Zennaro
- Beam instrumentation: L. Soby
- Vacuum: C. Garion
- Magnet: M. Modena
- Pre-alignment:. F. Lackner, H. Mainaud-Durand, T. Touzé
- Stabilization: K. Artoos, A. Jeremie
- Structure supports: N. Gazis J. Huopana, R. Nousiainen
- Beam feedback: H. Schmickler
- Integration: A. Samoshkin D. Gudkov;
- Tunnel and Transport: J. Osborne, K. Kershaw

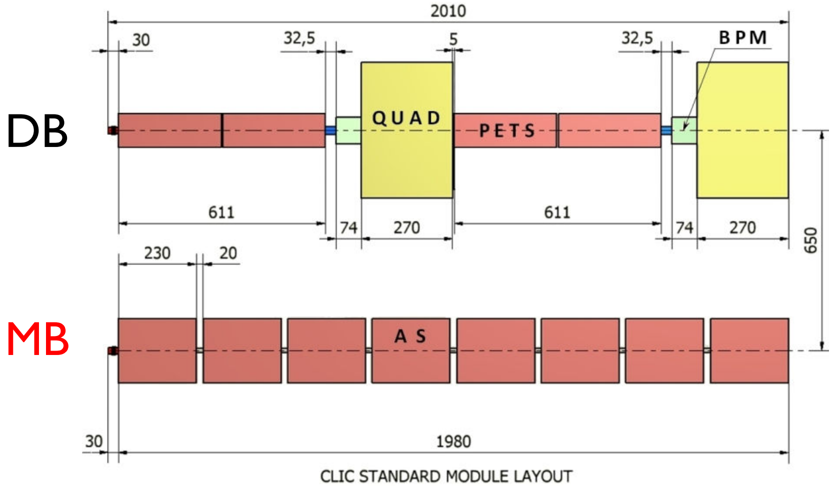
Interface to

Beam physics: D. Schulte
Transfer lines: B. Jeanneret
Radiation issues: S. Mallows

CEA/Saclay
CIEMAT
DUBNA/JINR
UH/VTT
LAPP
NTUA
NCP (Pakistan)
PSI
UPPSALA
University of Manchester
….

MODULE TYPES

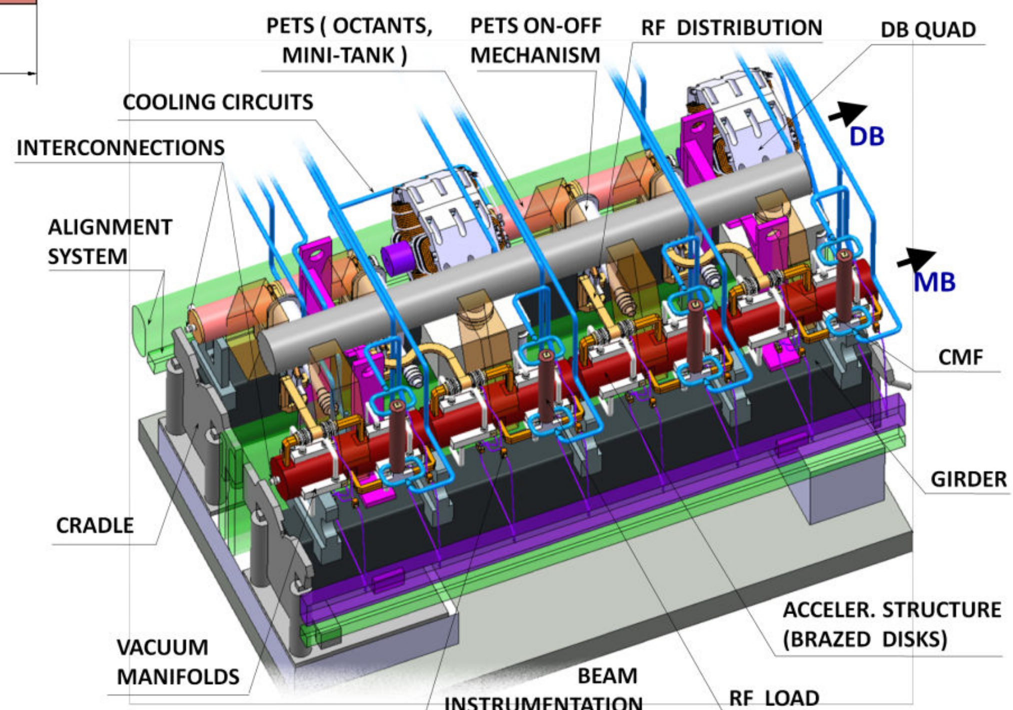
Module type 0



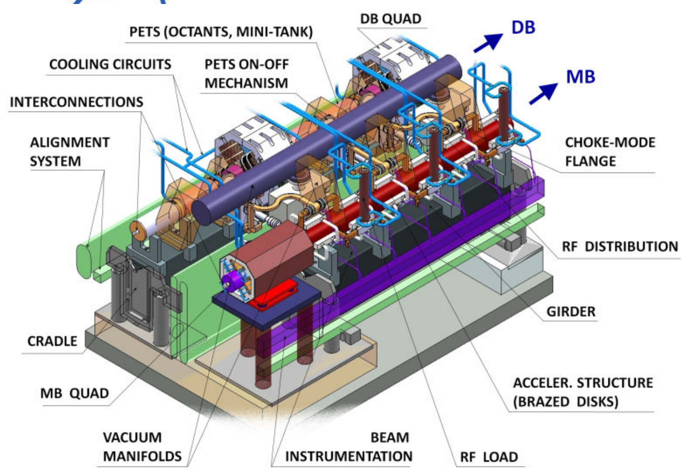
8 accelerating structures
8 wakefield monitors

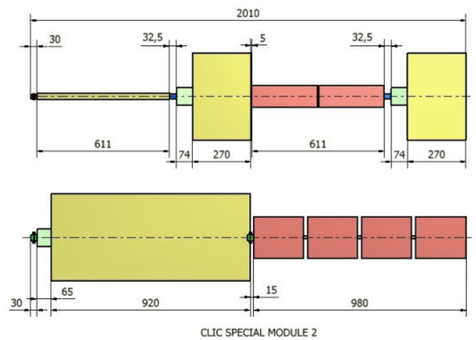
4 PETS
2 DB quadrupoles
2 DB BPM

Total per linac (3 TeV)
8374 standard modules



Other module types





Type 2

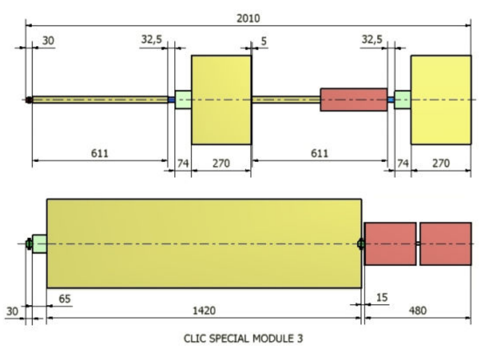
Total per linac (3 TeV)

type 1: **154** type 2: **634**

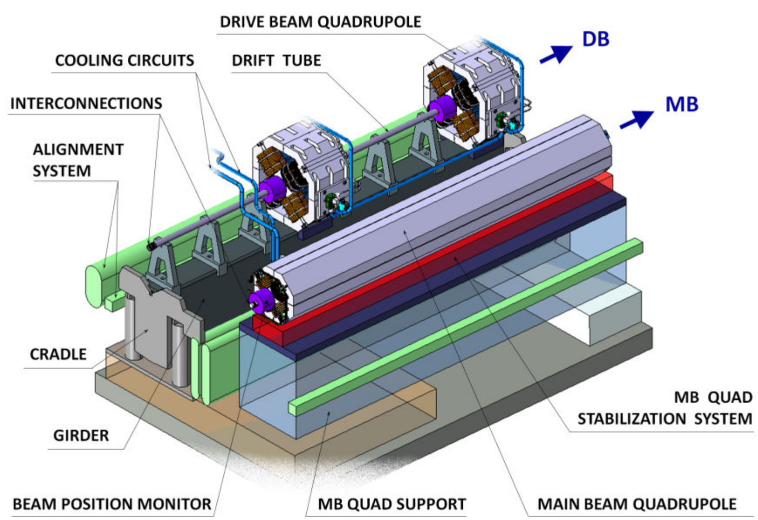
type 3: **477** type 4: **731**

Other modules

- modules in the damping region (no structures)
- modules with dedicated instrumentation
- modules with dedicated vacuum equipment …



Type 3

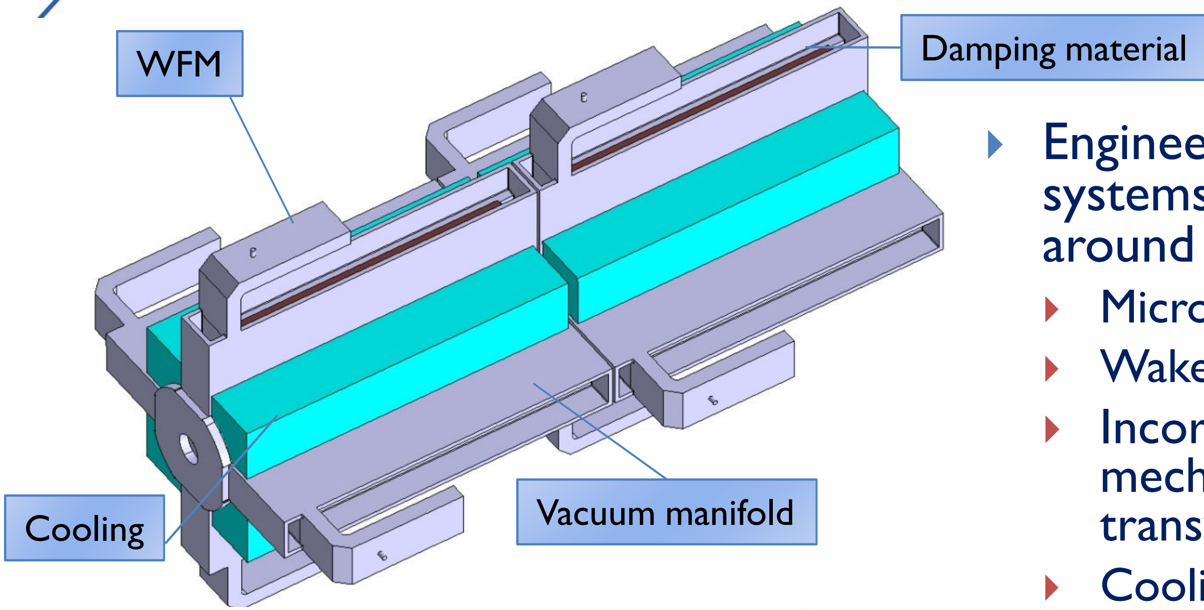


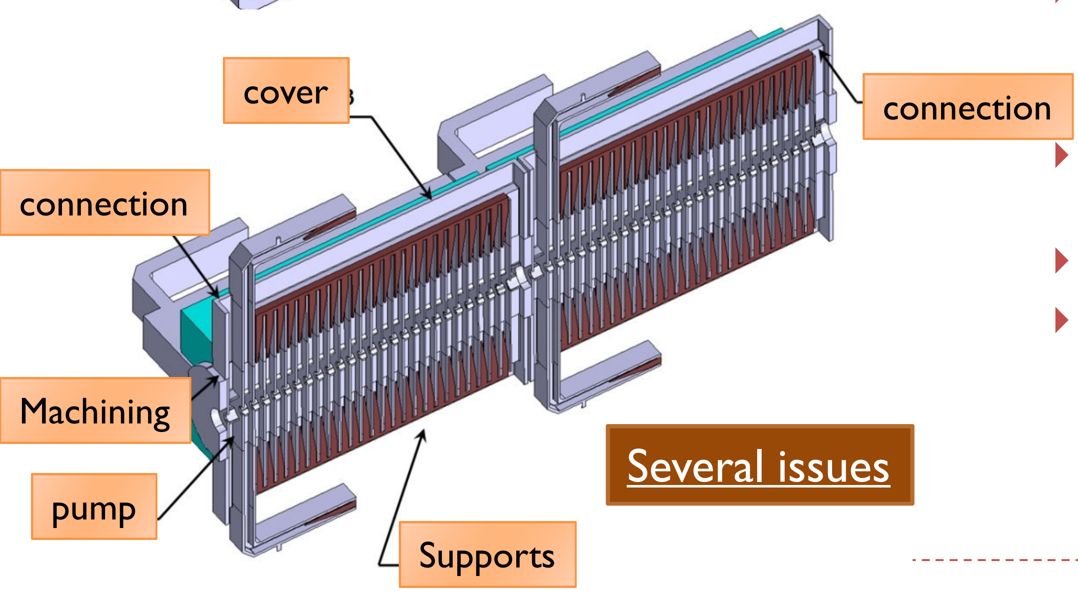
- ✓ RF system (Accelerating Structures [AS], PETS, RF distribution)
- ✓ Magnet system
- ✓ Pre-alignment, stabilization, supporting systems
- ✓ Beam instrumentation
- ✓ Cooling, vacuum systems

SYSTEMS/COMPONENTS – DESIGN STATUS AND ISSUES

Accelerating structures

A. Grudiev, D. Gudkov, j. Huopana, A. Samoshkin

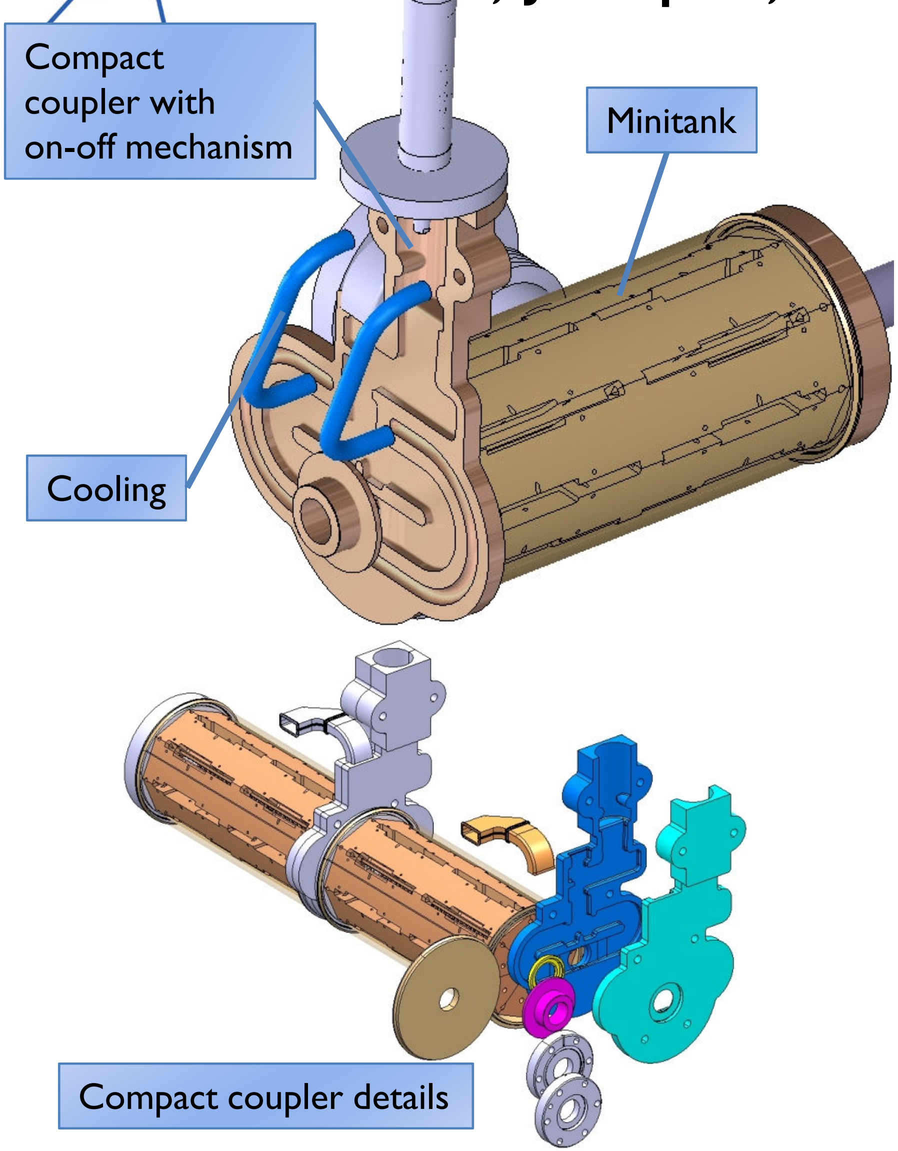




- Engineering design under way. Many systems to be designed & integrated around the "super-structure"
  - Micro-precision assembly (5 um)
  - Wakefield monitor (1 per AS)
  - Incorporating damping is mechanically complex and requires transverse space.
  - Cooling circuits (400 W per AS) – internal/external under study
  - Vacuum system (10^{-8} mbar)
  - Interconnection to MB Q (stabilization!)
  - Structure support (alignment)
  - Connection to RF distribution (flexibility)

PETS

D. Gudkov, J. Huopana, A. Samoshkin, I. Syratchev



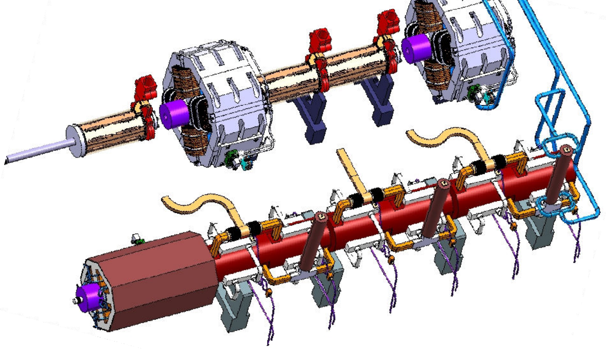
Engineering design well advanced

- 8 octants with "compact" couplers and integrated on-off mechanism
- Minitank for octants
- Cooling circuits (size for 0.5% beam loss) – couplers water cooled, bars conduction cooled
- RF distribution to AS
- Vacuum system (sizing of mini-tank)
- Interconnection to BPM (limited space – few tens of mm)
- Minitank support (fiducialisation)

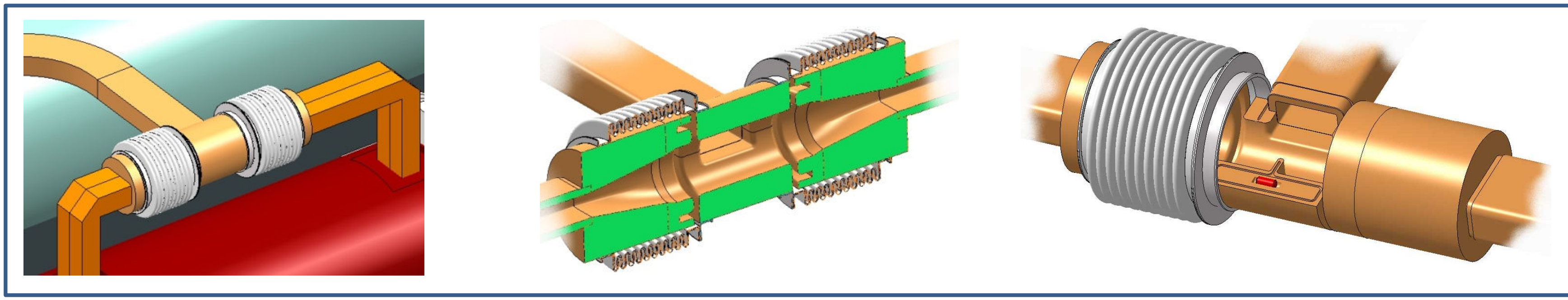
RF distribution

D. Gudkov, A. Samoshkin, I. Syratchev

Beam inter-axis – **650 mm** ONLY



- Study of compact 3-dB RF splitter with choke mode flange, including assembly and alignment features
- Study of waveguide routing
- Study of HP loads at the outlet of the AS with integrated RF diagnostic devices



The **compact 3-dB splitter** is an adapter from a rectangular (H10) to two circular (H11) waveguides with two integrated choke mode flanges (CMF). CMF allows the power transmission without electrical contact between waveguides.

Dynamic range for the accepted performance (S11< –45 dB):

- x – shift: ± 0.25 mm
- y – shift: ± 0.5 mm
- z – shift: ± 0.5 mm
- Twist: < 5°

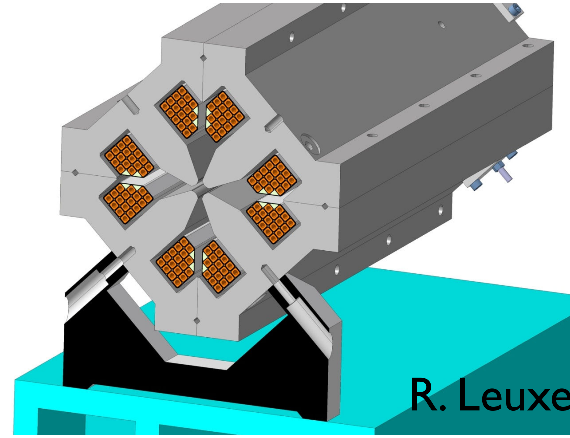
Magnets

M. Modena

MAIN BEAM

✓Four different magnetic lengths, namely 0.35, 0.85, 1.35 and 1.85m (weight 400 kg).

✓Beam pipe supported by the magnet. *The beam pipe centre needs to be aligned to the magnetic centre of the quad with an accuracy better than 30 µm.* ➔ design at CERN, prototype under tendering



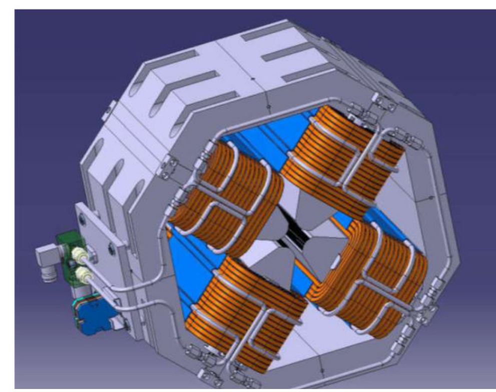
Nominal Gradient: ***200 T/m***
Magnet bore Ø: ***10 mm***

✓For the beam-based feedback, a 1-cm long magnet in front of each quadrupole (decouple BBF and stabilisation) **[under study]**

DRIVE BEAM

✓The quadrupole active length is 0.15 m.

✓Total number of quadrupoles is about 42000 (on series production, optimisation on going together with Cockcroft institute)



Nominal Gradient: ***81.2 -8.12 T/m***
Magnet bore Ø: ***23 mm***

Powering of magnets to be optimized to limit power dissipation

Pre-alignment

H. Mainaud-Durand and SU team See talks WG5

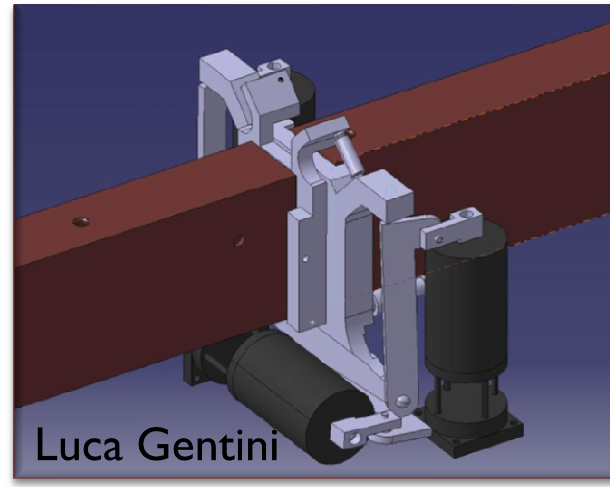
Mechanical pre-alignment within +/- 0.1 mm (1σ) → Active pre-alignment: within +/- 10 um (3σ)

Concept: straight alignment reference over 20 km based on overlapping references

- Accelerating structures and PETS pre-aligned on independent girders [mono-girder alternative also under study]
- "Snake system/articulation point" adopted for girder pre-alignment ➔ "CTF2 concept", validated in CTF2, with beam.
- MB quad pre-aligned independently

To be considered in the pre-align. system study:

- Integration of the pre-alignment systems in the modules ➔ transport and installation
- Fiducialisation (design and tests – stability during time, impact of thermal variations)



CTF2 validation, but:

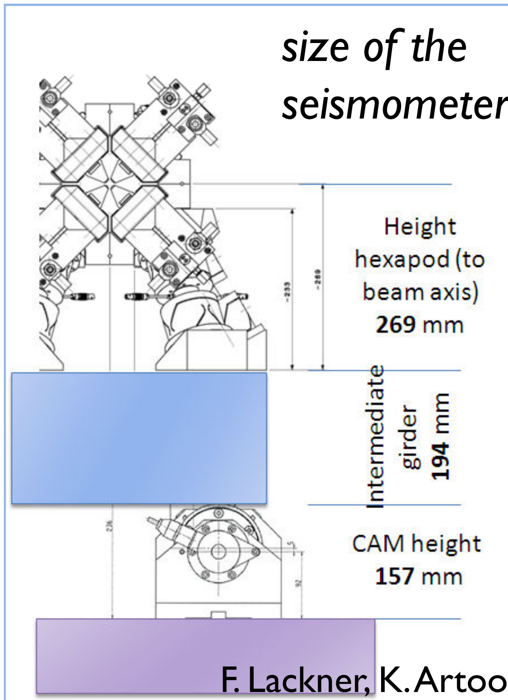
- Resizing needed (higher loads)
- Actuators not on the shelf (alternative study-cam system)
- Stability with AS requirements
- Kinematics (14 bearings)

Stabilization

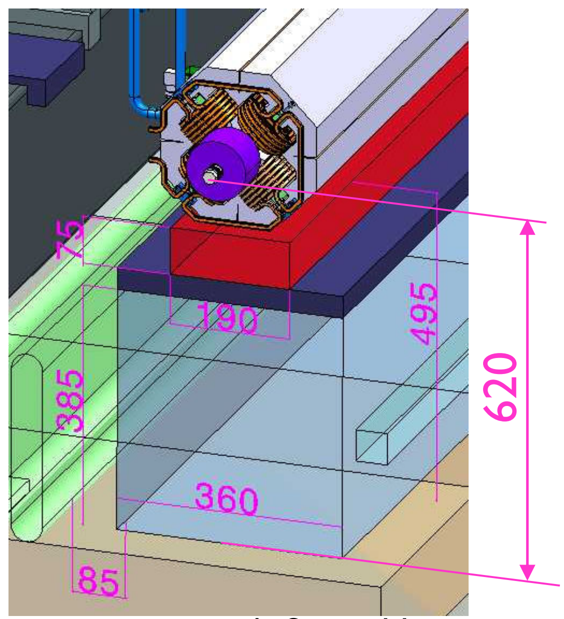
K. Artoos   A. Jeremie and SWG   See talks plenary+WG5

Stabilization needed for the MB quadrupole (vertical tolerance: 1 nm > 1 Hz)
Compatibility stabilization and pre-alignment
Under study

1. CERN option: rigid (active stabilisation + fast nano-positioning with a Hexapod)
2. LAVISTA option: soft support



F. Lackner, K. Artoos



A. Samoshkin

For the integration of the MB quadrupole stabilisation system in the module an inventory of modal behaviour and rigidities of components is needed, as well as an inventory of vibration sources

Girder/structure supports

J. Huopana/HIP – N. Gazis/NTUA

- RF structures (accelerating structures and PETS) on dedicated supports which are connected to the SiC girder
- For the girder, SiC material chosen as best compromise for damping to stiffness ratio (2 m long girder seems to be feasible – contacts with several companies under way)
  - Other material (such as steel) are not abandoned
  - Different shape configurations are under study

- Supports shall be compatible
  - with thermal loads (sizing in parallel with cooling system design)
  - with pre-alignment design and "fiducialisation"
  - with stabilisation requirements

Study on the MB & DB Girder

Weight estimation for the structures of the CLIC-Module

MAIN BEAM
MB-magnet Support
Cradles
Integral "V" Support (StSt)
Vacuum Manifold (StSt)
Pumps
Vacuum Reservoir (StSt)
Accelarating Structure (Cu)
Loads (StSt)
Waveguides from CMF to ACS (Cu)
Splitter (Cu)
Cooling Blocks (Cu)
Girder Weight (SiC)

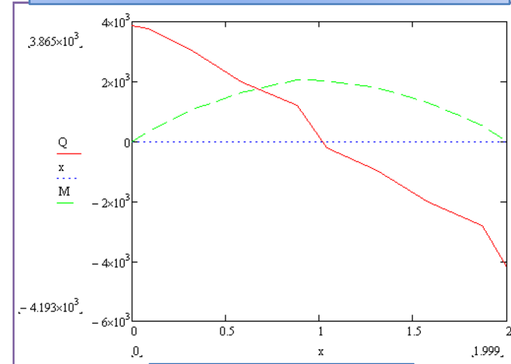
DRIVE BEAM
DB Magnets
Cradles
Integral "V" Support (StSt)
Vacuum Manifold (StSt)
Pumps
Vacuum Reservoir (StSt)
PETS (Cu)
Mini-Tank (Cu)
DB Drift Tube (StSt)
RF Distribution (Cu)
Cooling Blocks (Cu)
Girder Weight (SiC)

Type	Total Weight [MB+DB] (kg)
0	1800
1	1600
2	160[illegible]
3	[illegible]
4	[illegible]

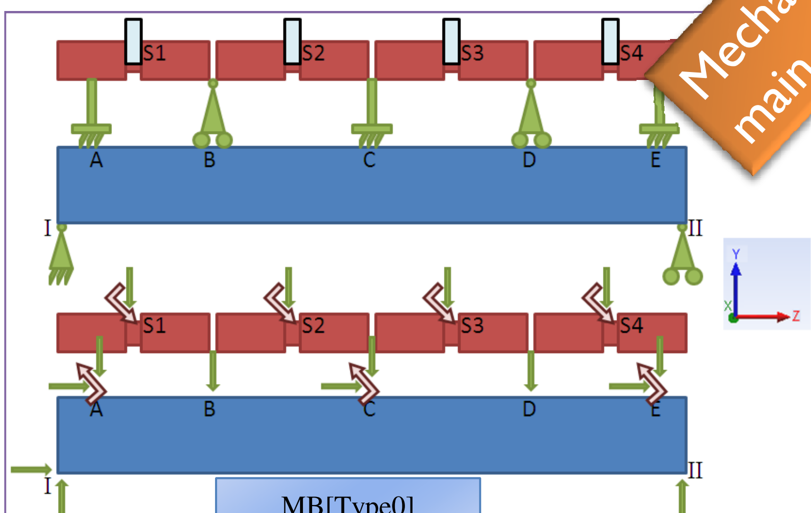
W... est... ...es and ... ...posed on ... ...hrough the ... the structures, ...e evaluated.

Mechanical analysis done for main and drive beam girders

Q (force), M (momentum) reaction on the the girder.

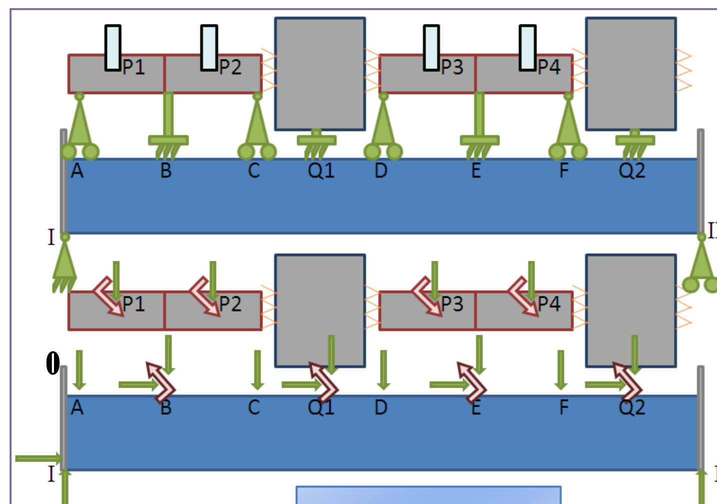


MB[Type0]



MB[Type0]

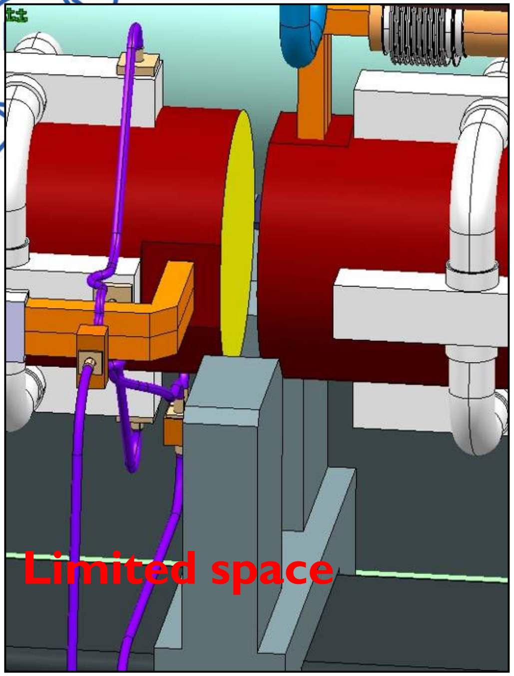
Layout for the forces & the momenta imposed on the Girder.

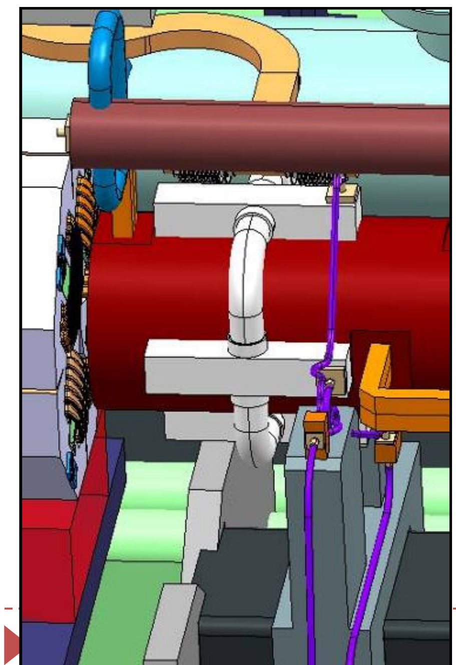


DB[Type0]

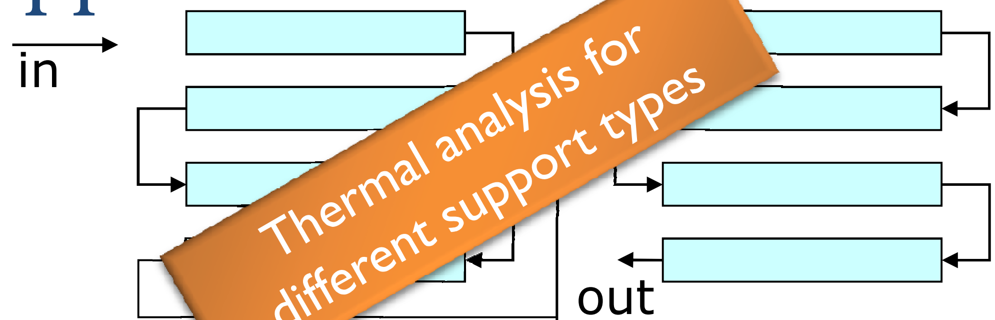
G. Riddone, CLIC Workshop, 13/10/2009

Structure supports



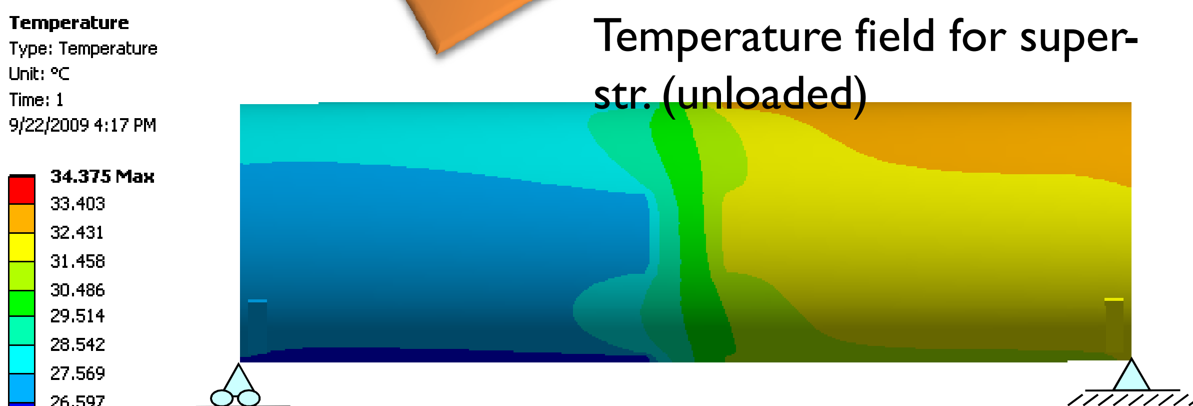


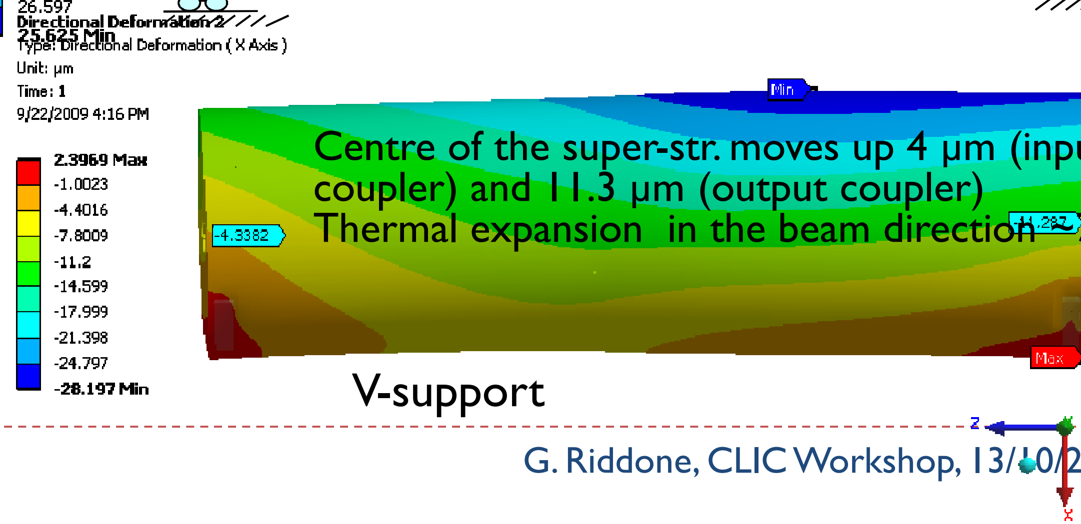
Used cooling scheme



Thermal analysis for different support types

Temperature field for super-str. (unloaded)





Centre of the super-str. moves up 4 µm (input coupler) and 11.3 µm (output coupler)

Thermal expansion in the beam direction ~75 µm

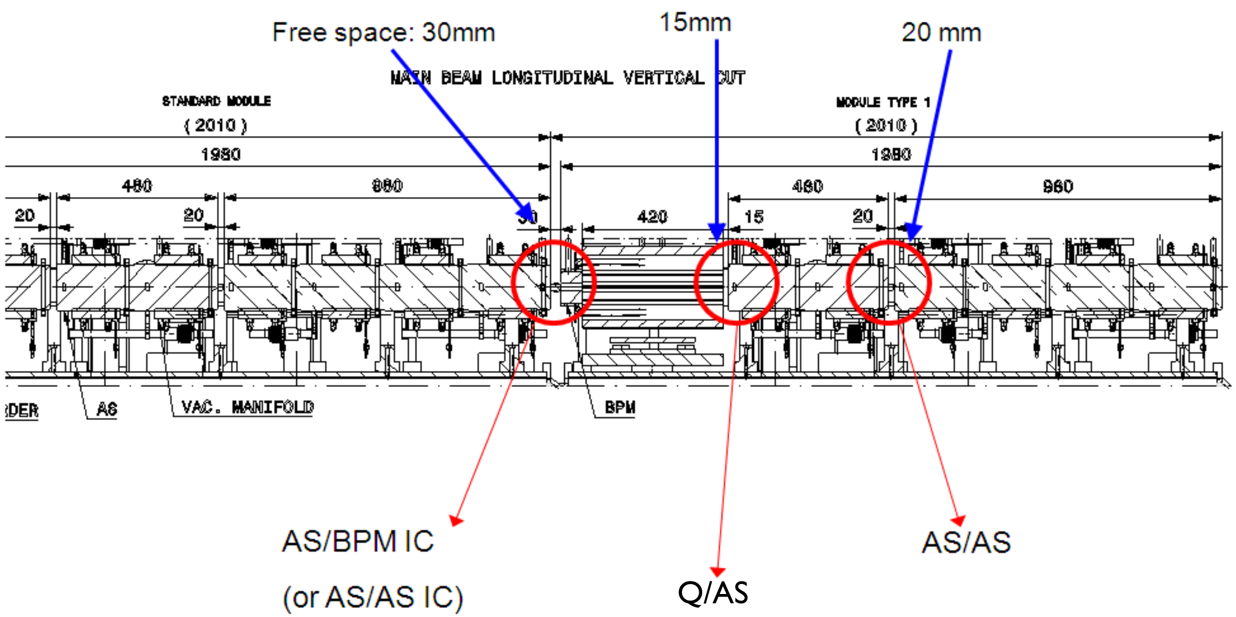
V-support

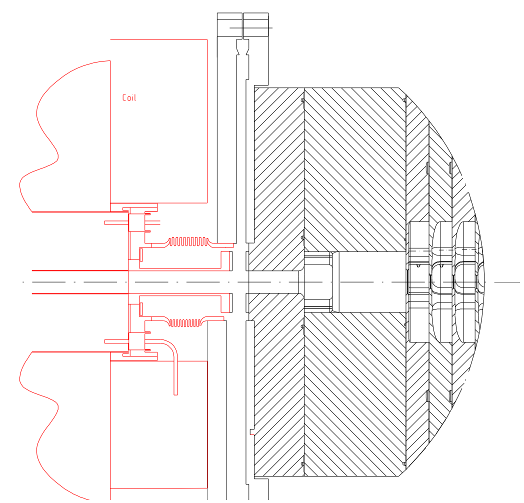
Vacuum

C. Garion, R. Zennaro See also talks in WG4

Detailed studies under way:

- Pumping system (MB and DB vacuum coupled via the common manifold and the waveguides)
- Quadrupole vacuum chamber with NEG films integrated
- Interconnections (intra-module and inter-module)
  - Main beam – Non-contacting interconnects acceptable. Short range wakefields essentially equal to an iris. Long range wakefields need damping
  - Drive beam – contacting interconnect necessary for baseline design due to the high drive beam current.





Solution with a gap and damping material (solution found for RF design)

Cooling

R. Nousiainen HIP/VTT

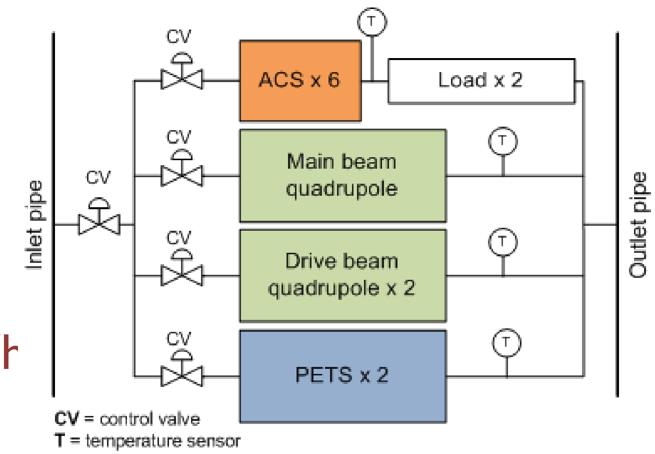
Detailed study under way:

-The structure must maintain its longitudinal and transverse tolerances during operation with varying beam-loading conditions. Power factors of roughly two in the downstream end of structure.

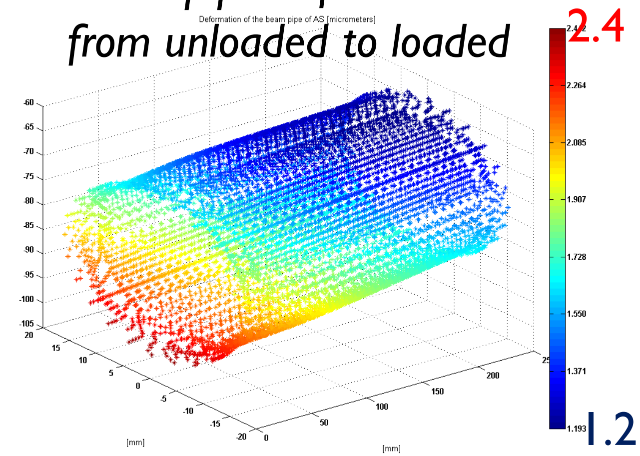
-RF network cooling - The rf network must maintain its correct electrical length, expansion is 0.2° phase/(°C*meter of group delay).

AS ~ 412 W
PETS ~ 110 W

Linac ~ 65000 kW
Module ~ 7.7 kW
Flow / Linac: 3100 m^3/h
Flow / Module: ~340 m^3/h



Beam pipe deformation: from unloaded to loaded



$\Delta T_{linac} = \Delta T_{module} = 17.5$ K

High power dissipation: RF structure and magnets are water cooled (RF network to be confirmed)

Beam instrumentation

L. Søby

- Limited space for BPM integration: 60 to 100 mm
- 1 BPM per Q, 1 WFM per AS
- DB: ~ 47000 devices; MB: ~151000 devices
- BPM rigidly connected to the quadrupole

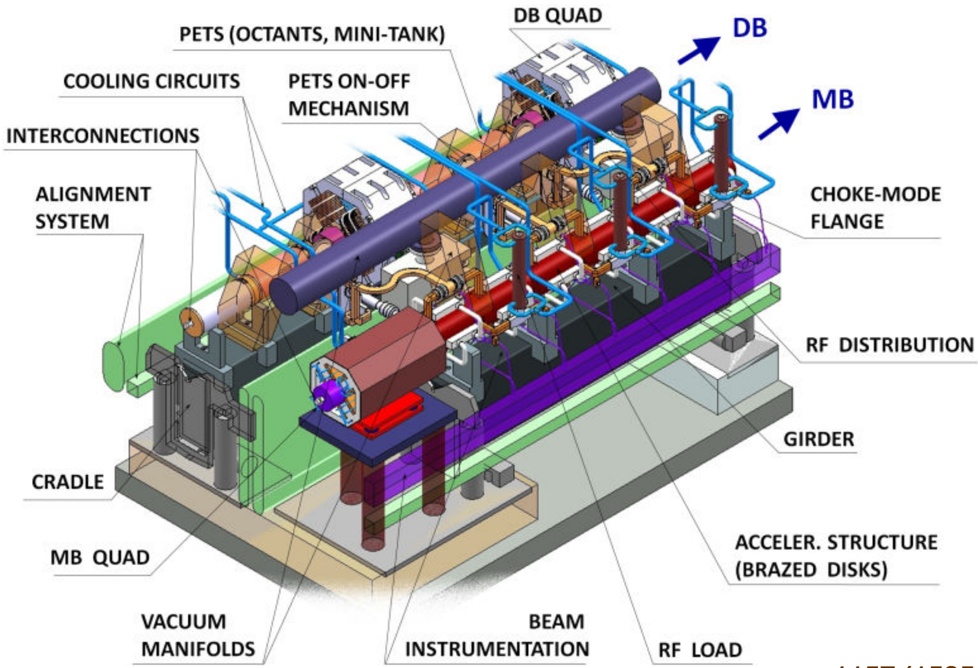
- MB BPM
  - Choke BPM: RF design made, mechanical design to be done (possible collaboration with RHUL)
  - FNAL Low-Q cavity BPM: wakefield calculation coming in few weeks
- DB BPM
  - Design will start next year - collaboration with SLAC

- WFM: Mechanical design under way – collaboration with CEA-Saclay (accelerating structure with WFM in 2010)

MODULE INTEGRATION: DESIGN STATUS AND STUDIES

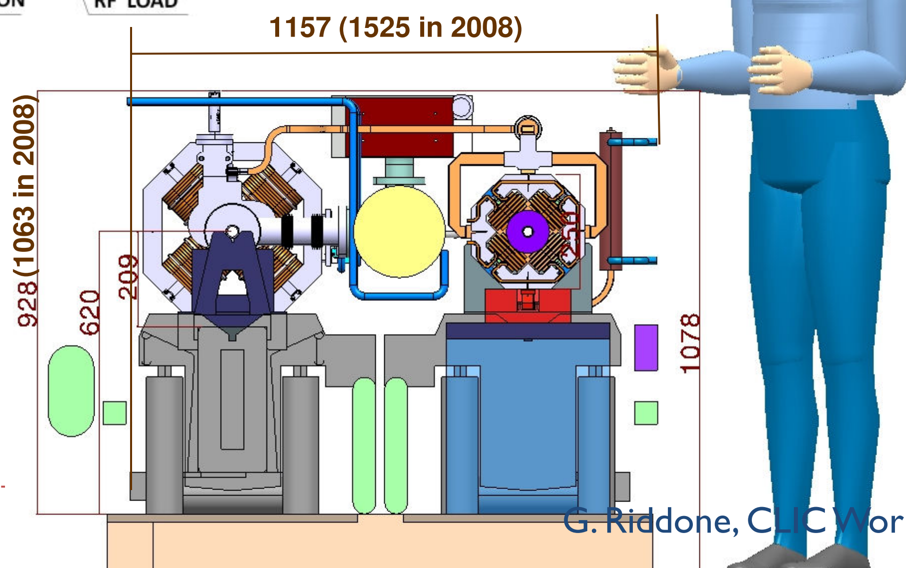
System integration

A. Samoshkin DUBNA/JINR



Integration of technical systems is very challenging
- ➔Module gives the boundary conditions and design constraints
- ➔ space reservation and conceptual to detailed design for most of the systems
- ➔Module detail design evolving in parallel to the definition of the technical systems
- ➔ high number of instruments: ~190 signals per module

Effort on space reduction:
- longitudinal compactness gives gradient and efficiency.
- transverse compactness for tunnel integration



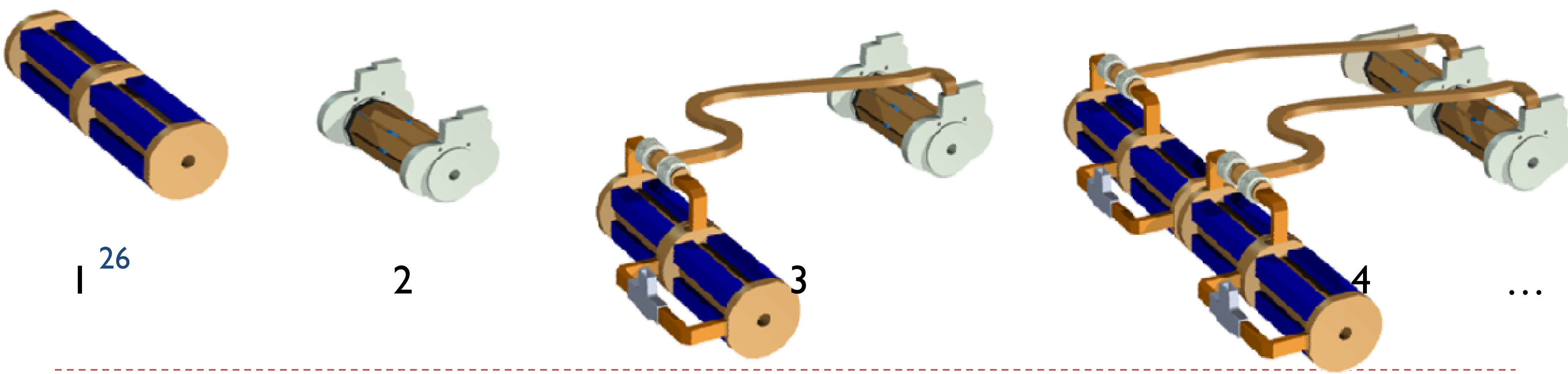
Thermo-mechanical simulation of the module

R. Nousiainen UH/VTT See Talk WG5

- ANSYS model capable to simulate the thermal-mechanical behaviour of the entire module under all operation modes
  - incrementally starting from RF structures – started now as in parallel to detailed design (feedback to technical systems)

First steps integrated

1. Transient thermal behaviour of the RF-structures coupled with cooling
2. Operation modes' relation to RF-structure movement, thermal / structural behaviour
3. Induced effect from coupling of beams, dilatations & forces
4. Mechanical response of interconnections in thermal cycle, dilatations & forces



Conclusions

- More than 20000 modules in the two linacs (~140000 accelerating structures) ➔ two beam acceleration is one of the feasibility issues
- Module design evolves in parallel to the system design
- Detailed design for several systems (e.g. vacuum, pre-alignment,…) started in 2009 and now well advanced → must be frozen by Q1-2010
- Several studies are driven by the module (e.g. engineering design of RF structures with all systems around, power dissipation and cooling ,…)
- Several CERN people and collaborators are involved in the module studies (warm acknowledgement to all of them)
- Test modules will be built in the lab and in CLEX in the coming years (2010-2013)