Alexandre.Samochkine @ cern.ch

CLIC TWO-BEAM MODULE

DESIGN & INTEGRATION

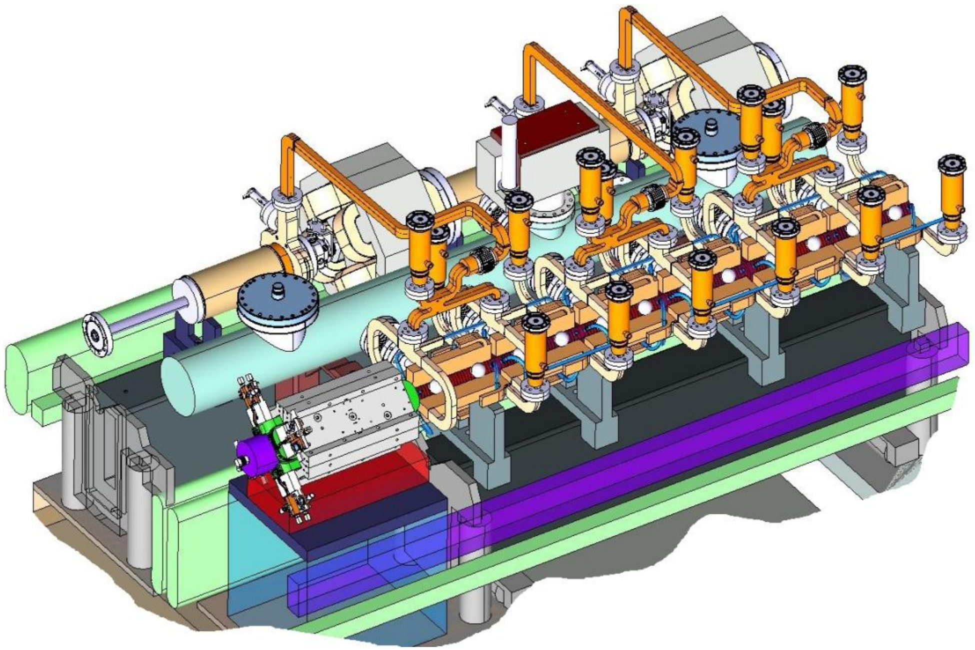
Alexandre.Samochkine @ cern.ch

Module design is based on two-beam acceleration concept currently developed at CERN. The RF power is generated by a high current electron-beam called Drive Beam (DB), running parallel to the Main Beam (MB). The DB is decelerated in dedicated power extraction structures (PETS) and the generated RF power is transferred via waveguides to the accelerating structures (AS).

The module design and integration has to cope with challenging requirements from different technical systems.

The baseline solutions were defined for each component of the technical system and being developed.

Many issues appear often during integration !



COLLABORATORS:

CEA/Saclay
CIEMAT
Dubna/JINR
UH/VTT
LAPP
NTUA
Pakistan, NCP
PSI
UPPSALA
University of Manchester
…

CLIC TWO-BEAM MODULE SYSTEMS

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R F

AS shape tolerance ± 2.5 µm

MAGNET AND POWERING

DB 81.2-8.12 T/m, current density: 4.8 A/mm2, MB 200 T/m

INSTRUMENTATION

BPM resolution: MB - 50 nm, DB – 2 µm, temporal - 10 ns (MB & DB),

PRE-ALIGNMENT AND STABILIZATION

active pre-alignment ± 10 µm at 3σ, MB Q stabilization 1 nm >1Hz

SUPPORTING

Max. vertical & lateral deformation of the girders in loaded condition 10µm

VACUUM

Baseline 10^{-9} mbar

COOLING

400 W per AS

ASSEMBLY, TRANSPORT, INSTALLATION

clear interconnection plane

MODULE TYPES

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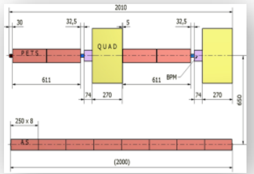
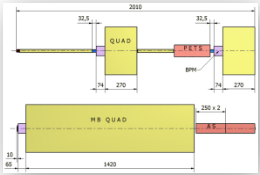
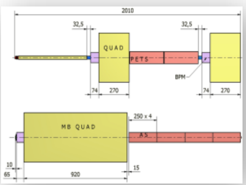


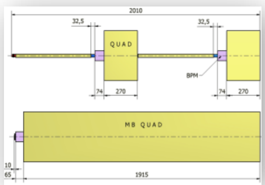
Standard Module
8374 per Linac



Module Type 3
477 per Linac



Module Type 2
634 per Linac



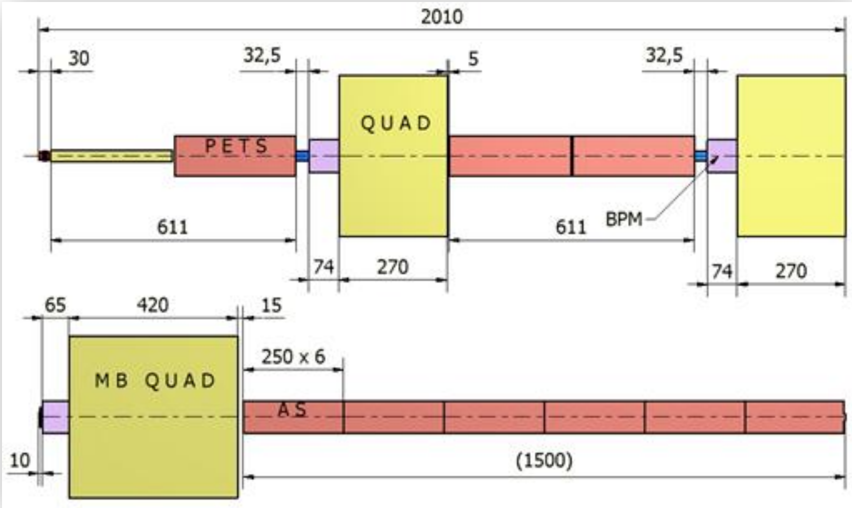
Module Type 4
731 per Linac

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
154 per Linac

1 pair of AS replaced by MB Quadrupole



+
special modules
(damping region,
modules with instrumentation
and/or vacuum equipment)

CLIC MODULE TYPE 1

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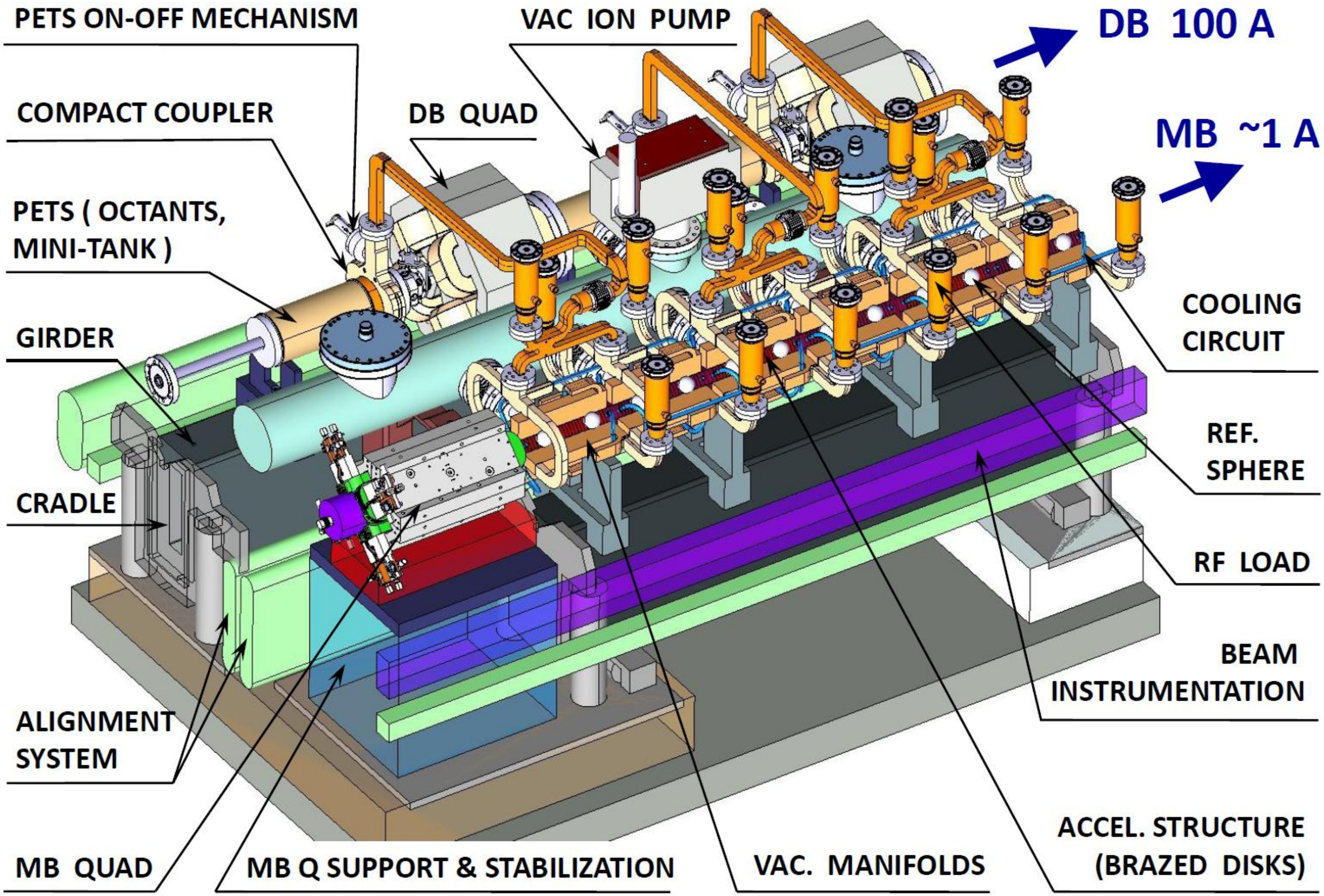

RF SYSTEM

RF NETWORK LAYOUT

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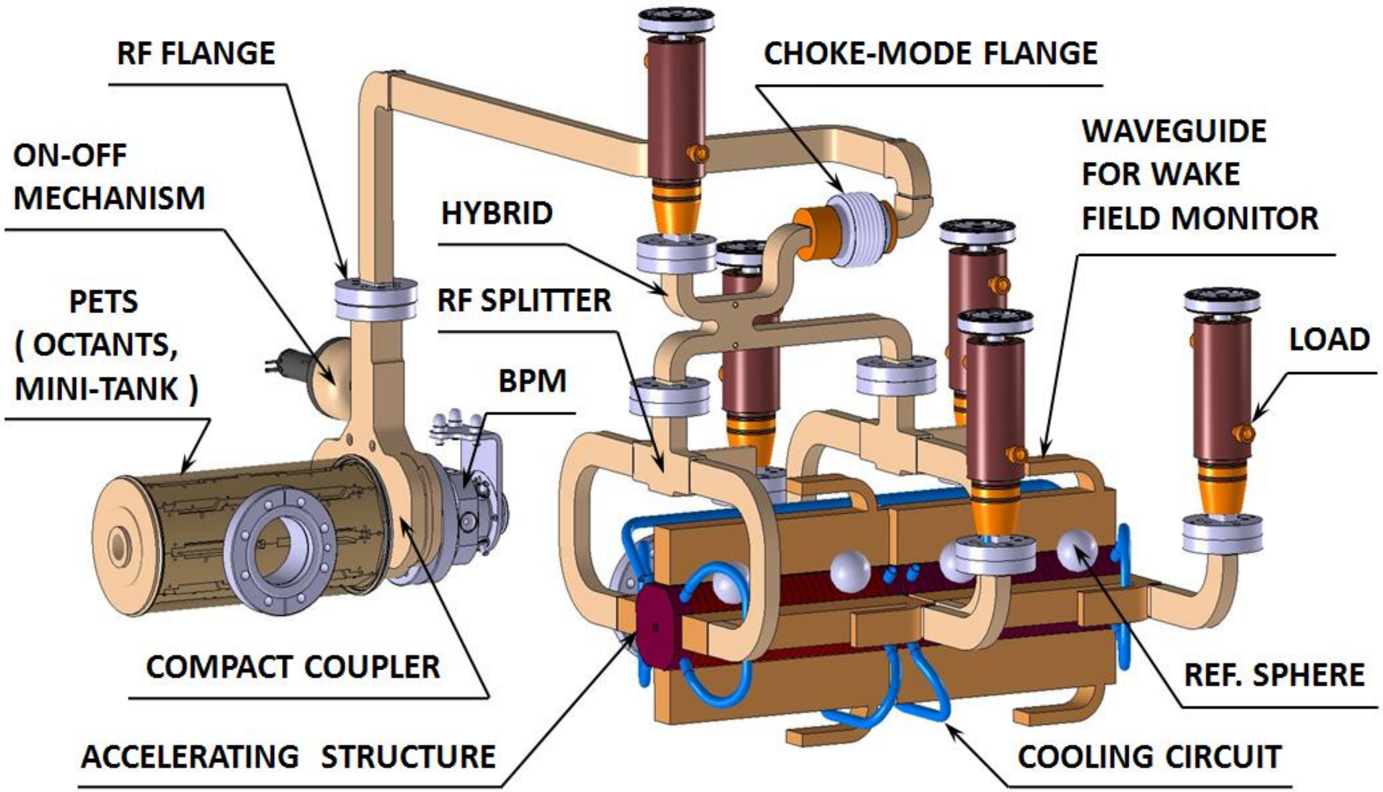
tolerance on RF phase change between DB and MB: ± 0.12 deg



The CLIC two-beam RF network includes the standard X-band rectangular waveguides connecting PETS, AS and other supplementary devices such as choke-mode flange (CMF), Hybrid, high power load, splitter and WFM.

ACCELERATING STRUCTURE

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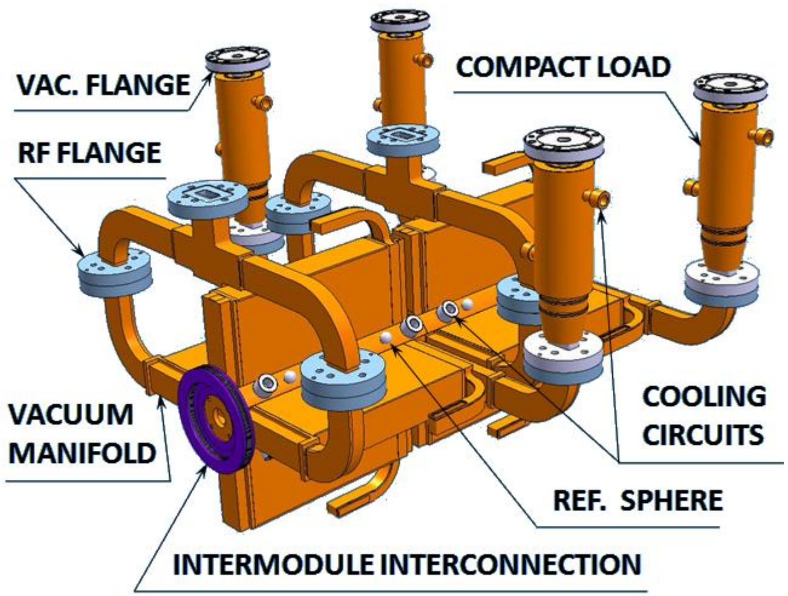
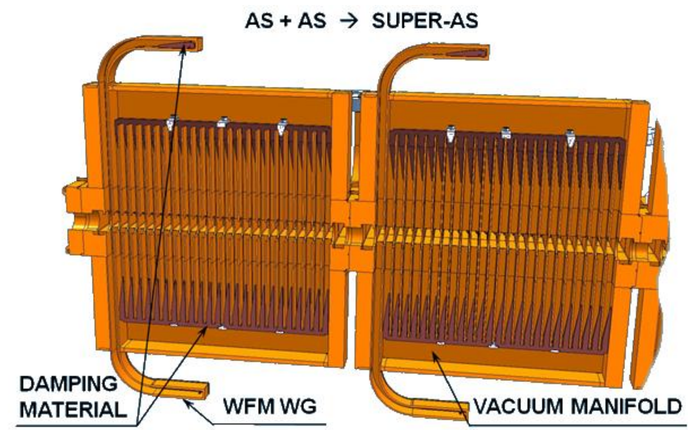
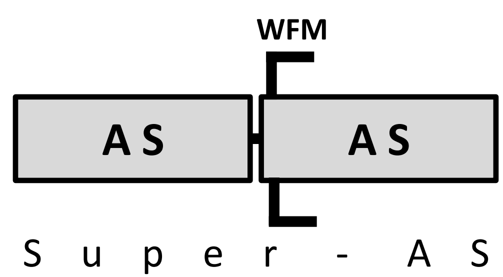
The design of AS is driven by extreme performance requirements. The assembly accuracy is 5 µm. Many features of different systems, such as vacuum, cooling, wake field monitor as well as damping waveguide absorbers are incorporated into design.





Longitudinal cut of Super-AS



Schematic layout of Super-AS implemented in test module

COMPLEXITY

Brazed disks with “compact” coupler & vacuum system (10^{-9} mbar),
micro-precision assembly, cooling circuits (400 W per AS)
wakefield monitor (1 WFM per SAS), interconnection to MB Q (stabilization!)
structure support (alignment), output WG with RF components (e.g. loads)
RF distribution (WGs & splitters)

Detailed design under way

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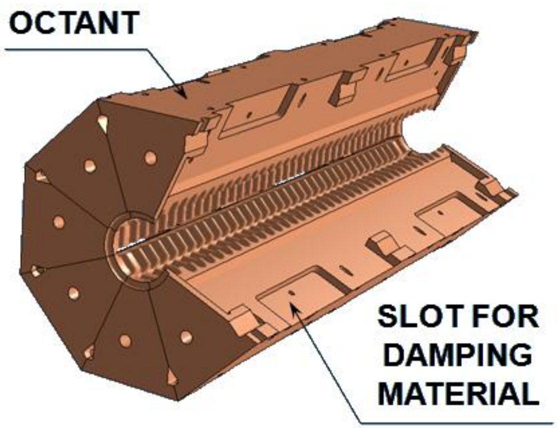
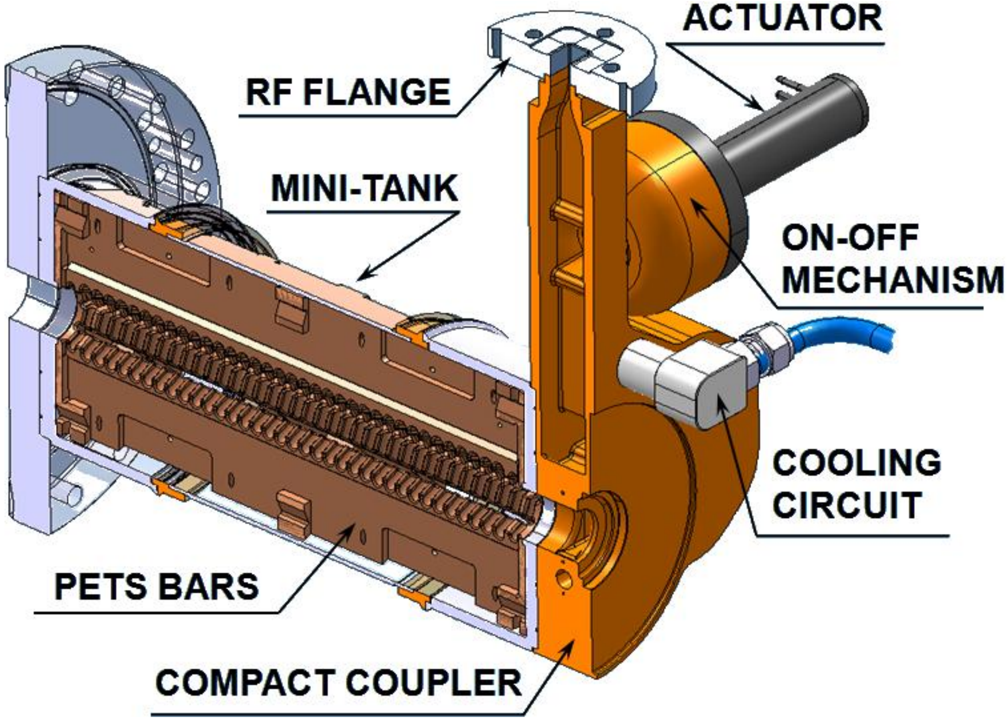


The PETS are composed of eight bars milled with 0.015 mm shape accuracy. The octants assembly, mini-tank, "ON-OFF" mechanism combined with compact coupler, vacuum system, cooling circuits and interconnection are the subject for integration study.



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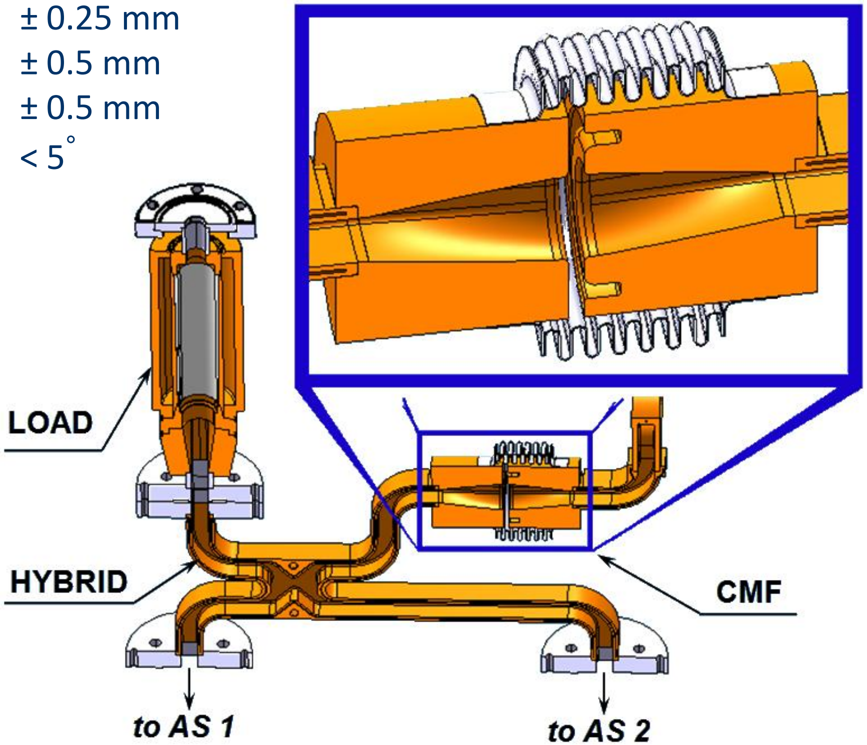
Requirements:

WG interconnections between PETS and AS via CMF:

X – shift: ± 0.25 mm
Y – shift: ± 0.5 mm
Z – shift: ± 0.5 mm
Twist: < 5°



RF Design of CMF, Hybrid and Load by I. Syratchev & A. Cappelletti

The power transmission without electrical contact between two beams, and also MB and DB independent alignment is getting possible with CMF. The Hybrid provides the power to two adjacent AS. The RF load is attached to one of the hybrid ports to avoid the RF reflection to the corresponding PETS. The RF splitters are used to equally feed the AS.

Waveguide length optimization is based on losses, phase advance and RF to beam timing considerations.

INSTRUMENTATION

BEAM POSITION & WAKE FIELD MONITORS

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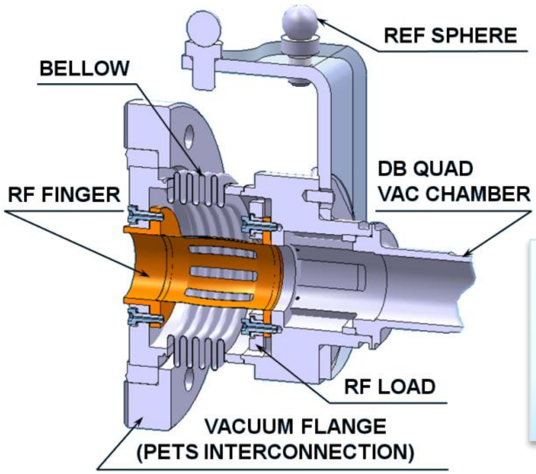
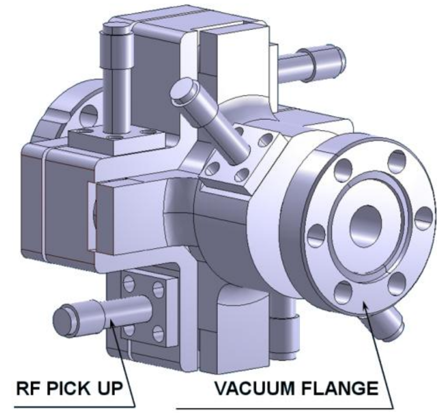
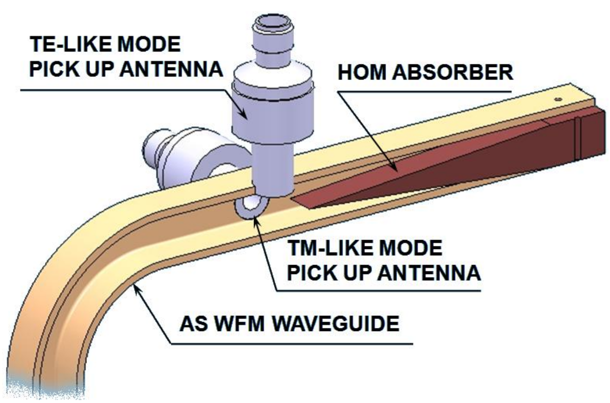
Limited space for BPM integration and interconnection, 1 BPM per Quad, 1 WFM per SAS (RMS position error 5 µm)
Qty: DB: ~47000; MB: ~151000 units



DB BPM
resolution requirement: 2 µm, 10 ns
design: RF - S. Smith (SLAC),
mechanical - D. Gudkov (JINR)

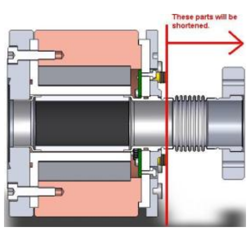


MB BPM
resolution requirement: 2 µm, 10 ns
choke type, mech. design of prototype is done. Optimization for CLIC module layout is under way.



WFM
Design:
RF - F. Peauger (CEA-Saclay),
Mechanical - A. Solodko (JINR)

AS with WFM → end of 2010
Validation in CLEX (2011)



alternative: DB BPS (IFIC)

MAGNET SYSTEM

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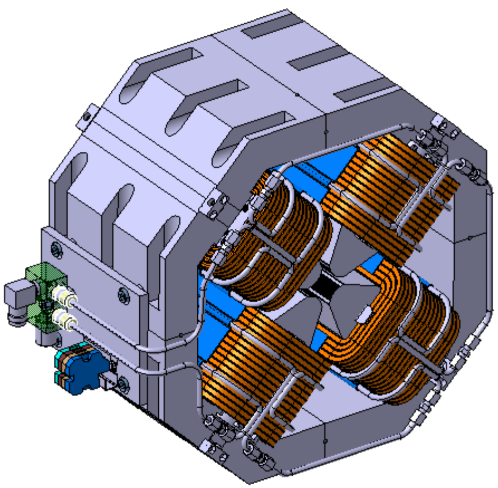
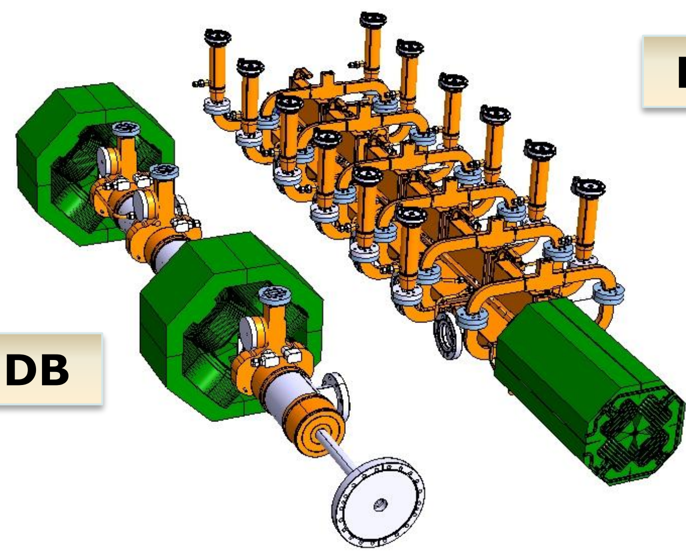
Baseline: classical electro-magnetic design

MB: The magnets are needed in four different magnetic lengths (350, 850, 1350 & 1850mm).
- the beam pipe is attached to the magnet and must be aligned to the magnetic centre of the Quad with an accuracy better than 30 μm; transverse tolerance for pre-alignment 17 μm at 1σ; stabilization: 1nm >1Hz in vertical & 5nm >1Hz in horizontal direction at 1σ.

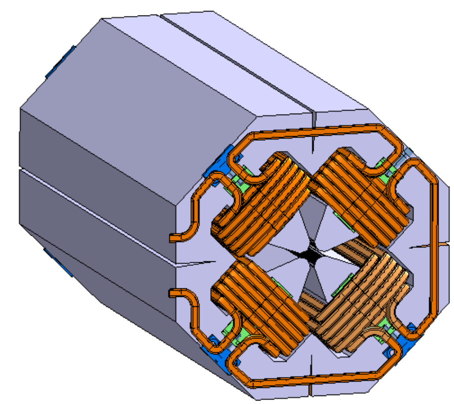
DB: The active length specified is 150 mm. The total number of quads required for both linacs is ~42000. In current module design the DB Quad vertical size drives the beam height.





MB

DB



Drive Beam Quadrupole
working gradient: 81.2-8.12 T/m,
current density: 4.8 A/mm^2
magnet aperture: Ø23mm

Main Beam Quadrupole
Nominal Gradient: 200 T/m
Magnet aperture: Ø10 mm

alternative: DB tuneable permanent magnet solution is under investigation (Cockcroft Institute)

Details → talk of M. Modena

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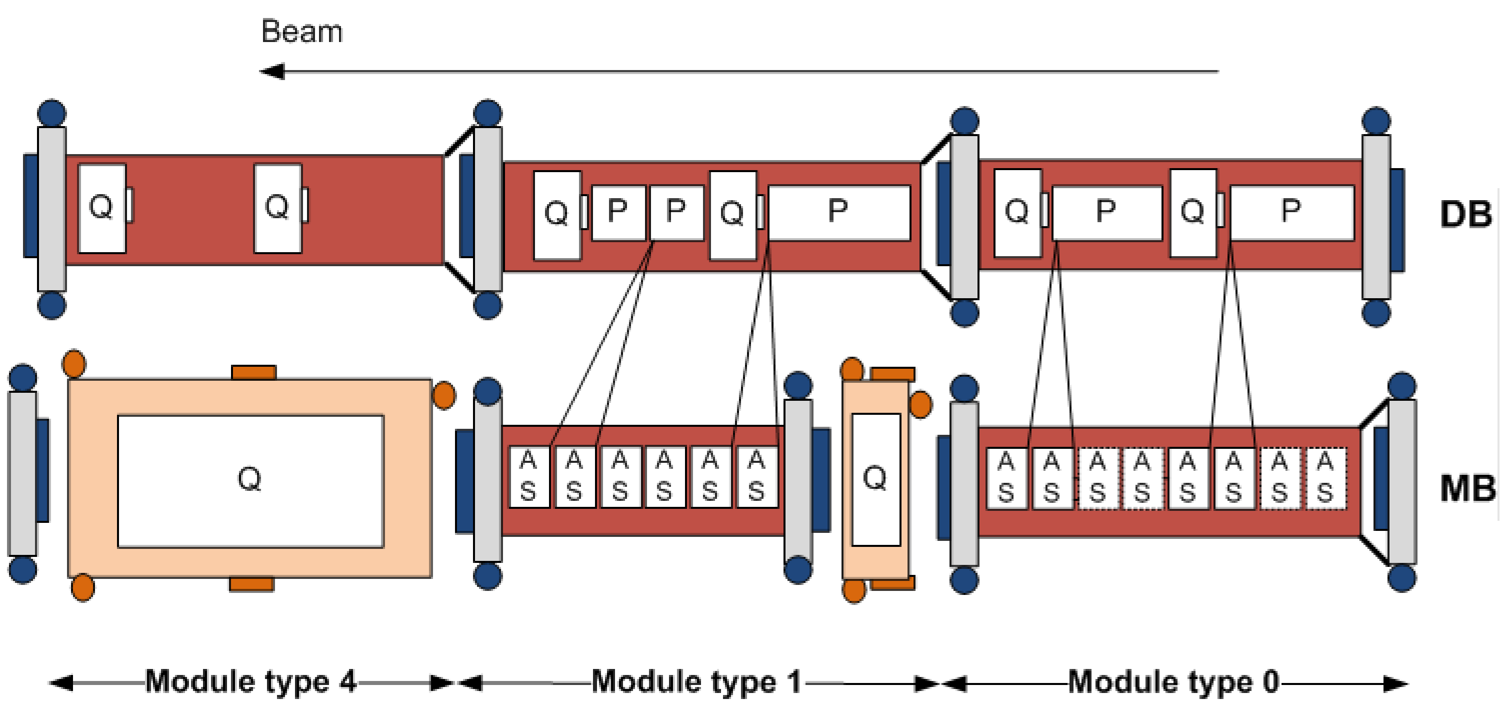
SUPPORTING SYSTEM

Alexandre.Samochkine @ cern.ch

BASELINE:
- interconnected girders form a “snake system”
- MB girders are not of the same length
- MB Q support interrupts the MB girder
- MB Q beam pipe and AS are connected by bellows



CLIC MODULE SUPPORTING SYSTEM

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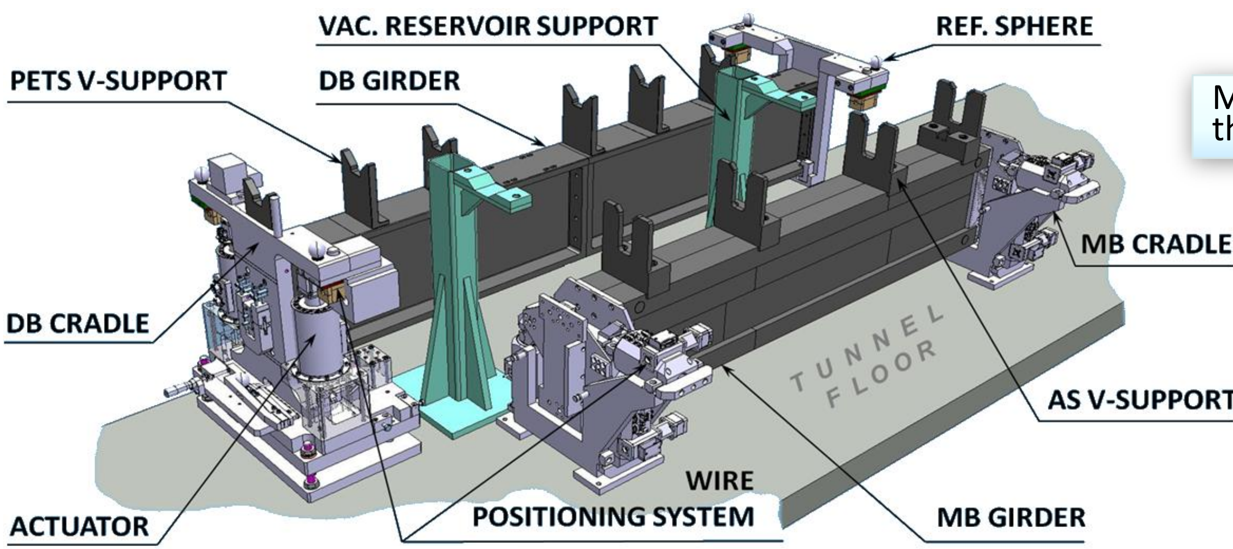
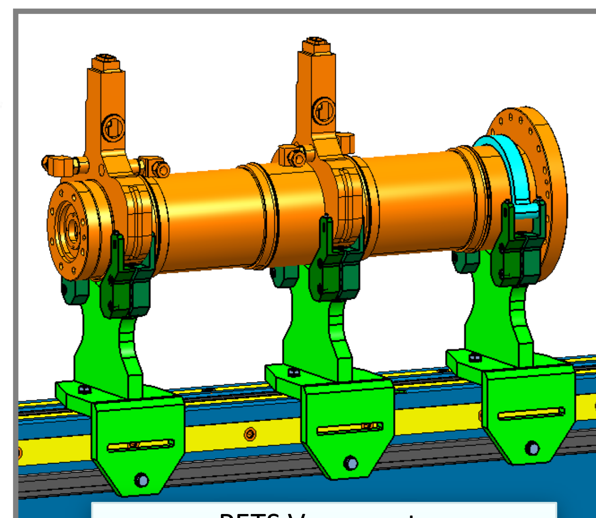
The main components of both beams are supported on rectangular shaped girders linked to one chain all along the linac. The MB focusing magnet is an exception due to stringent position requirements. It has its own support and stabilization unit, which will be integrated in a later phase.
The sensors of Wire Positioning System (WPS) are reading the transversal and vertical distances to one of the wires stretched between two beams for forming a straight reference line all along the linac.



Max. vertical & lateral deformation of the girders in loaded condition - 10µm

requirement : yellow reference surfaces precision - 2 µm



PETS V-supports
mech. design – J. Huopana (HIP)

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VACUUM SYSTEM

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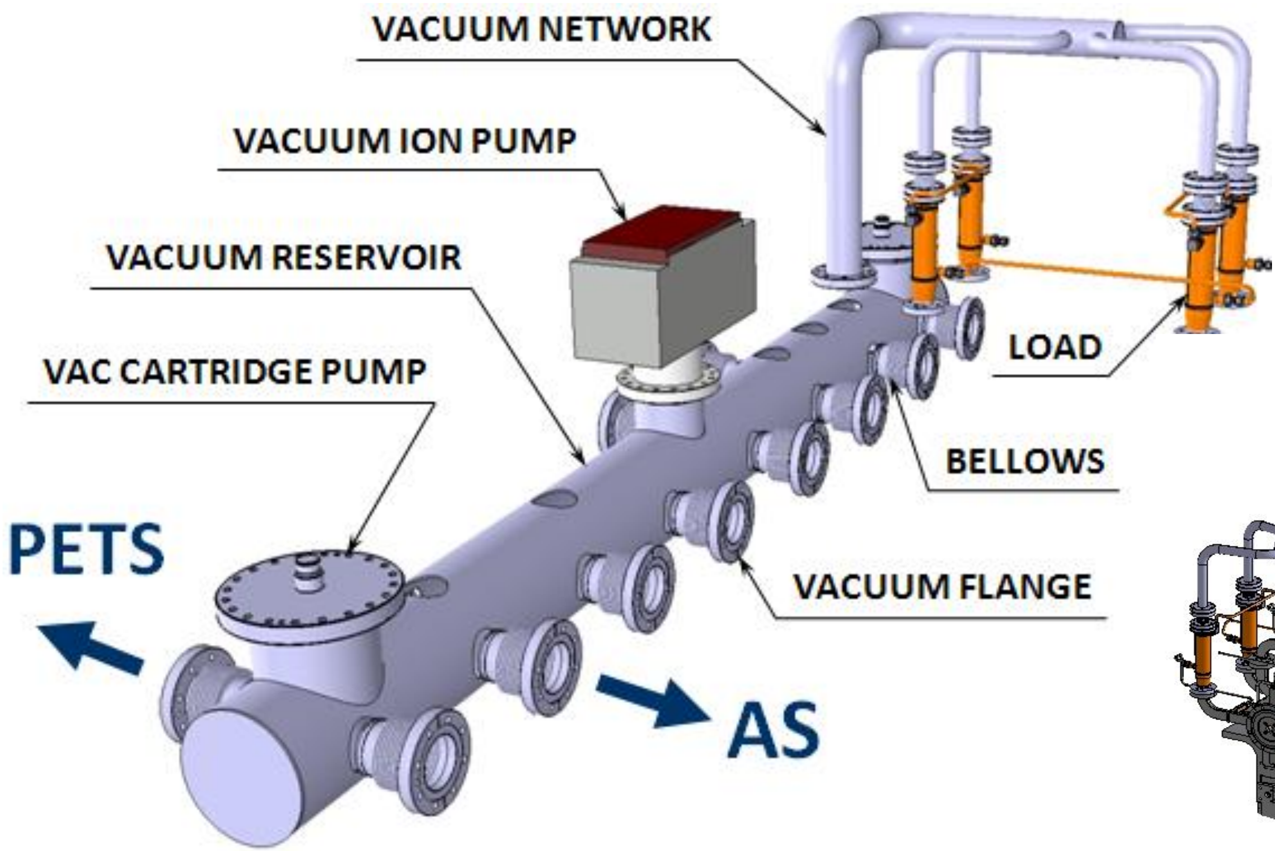
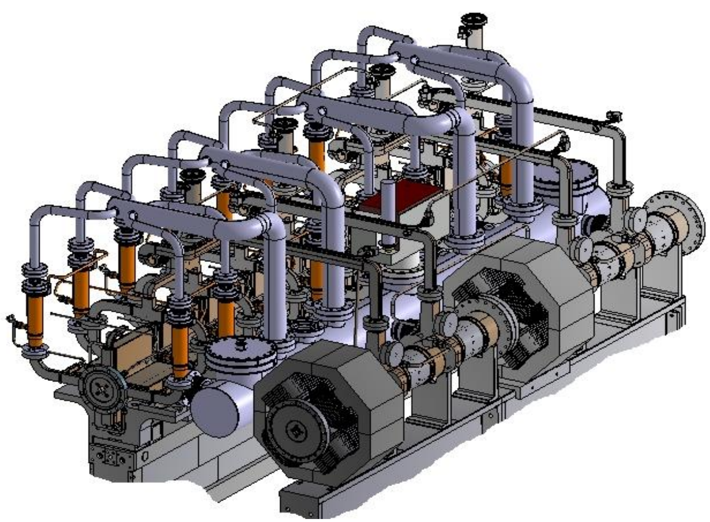
A low pressure level (10^{-9} mbar) is needed for keeping the good beam quality. The interconnections between main components should sustain the vacuum forces, provide an adequate electrical continuity with low impedance and remain flexible not to restrict the alignment.





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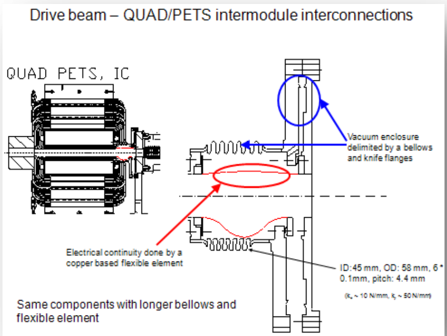
The MB and DB vacuum coupled via the common manifold and WG

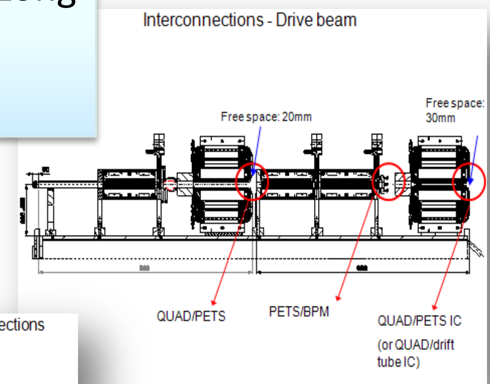


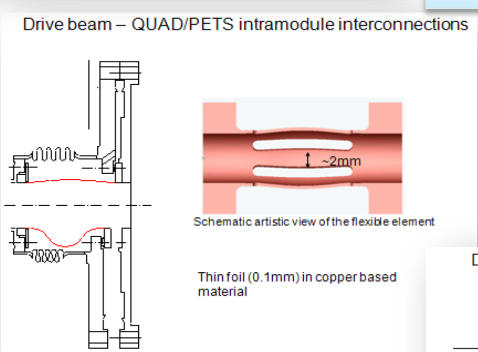
<u>The vacuum interconnections (intra-/inter-module):</u>

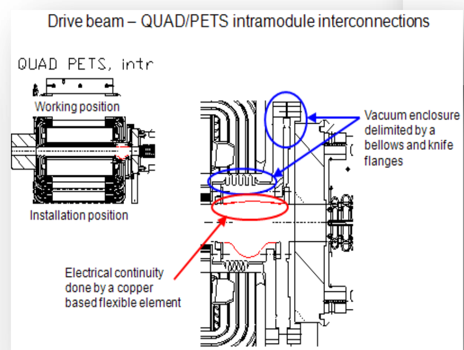
MB: non-contacting interconnects acceptable. Short range wake-fields essentially equal to an iris. Long range wake-fields need damping.

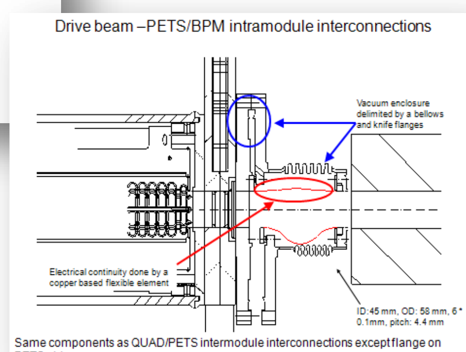
DB: good contact is necessary due to high current.

BASELINE:
10^{-9} mbar









Design by C. Garion

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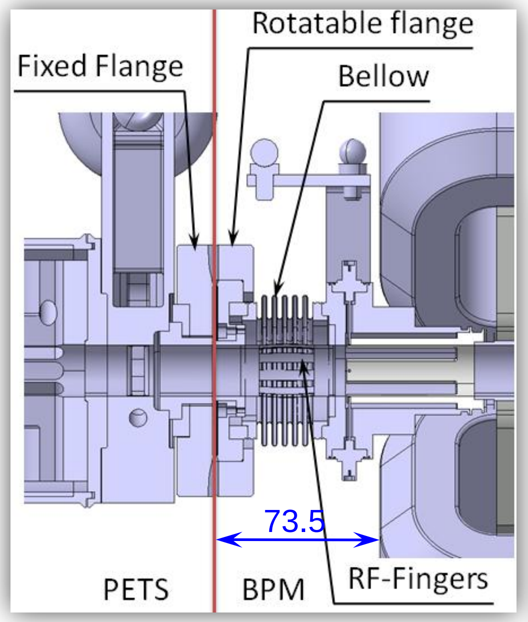

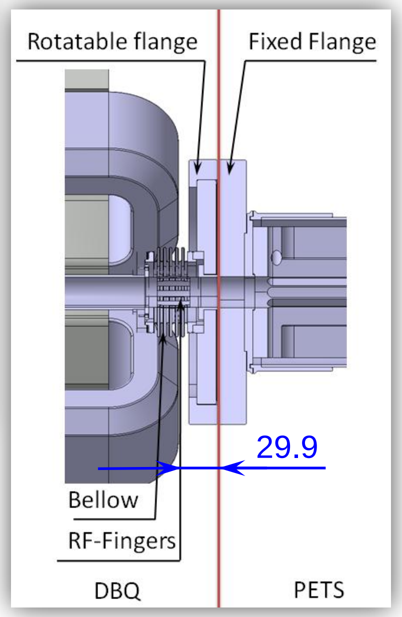

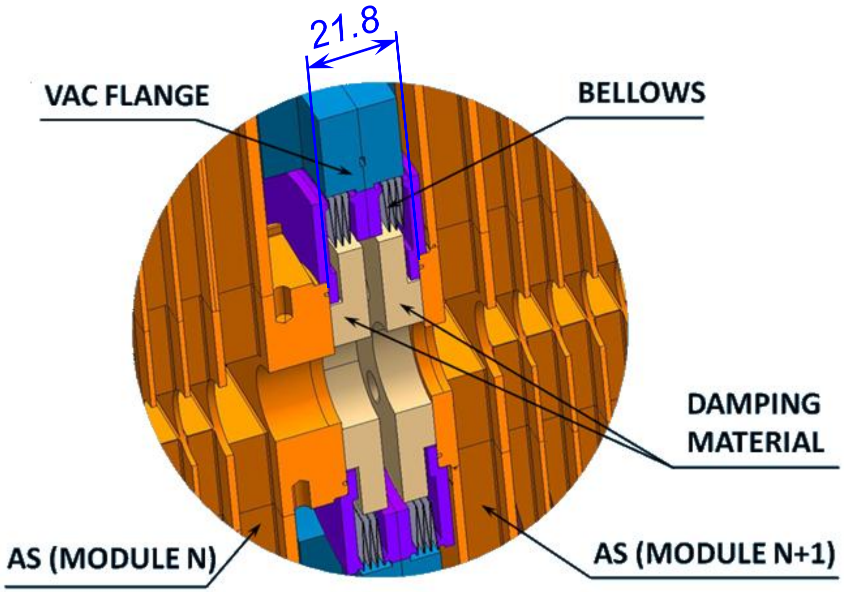

MB AS-AS interconnections

DB Quad vacuum chamber – PETS interconnections
(mech. design D. Gudkov, JINR)

Details → talk of C. Garion

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PRE - ALIGNMENT & STABILIZATION SYSTEM

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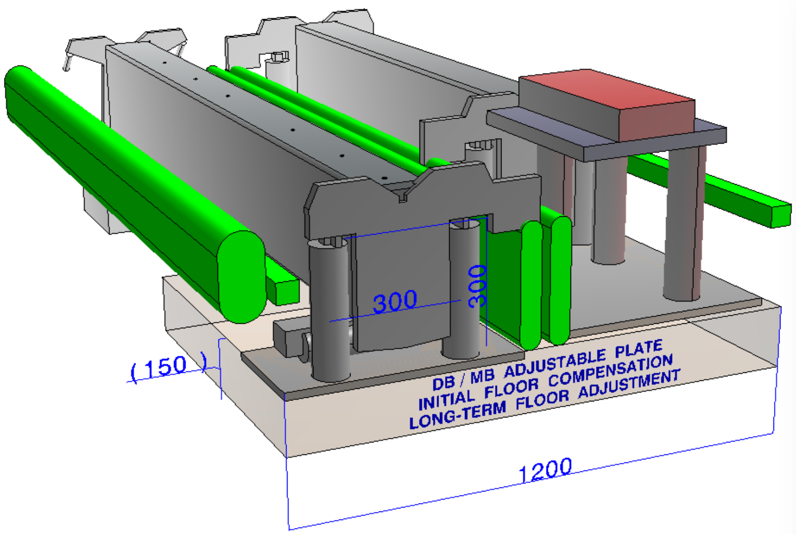
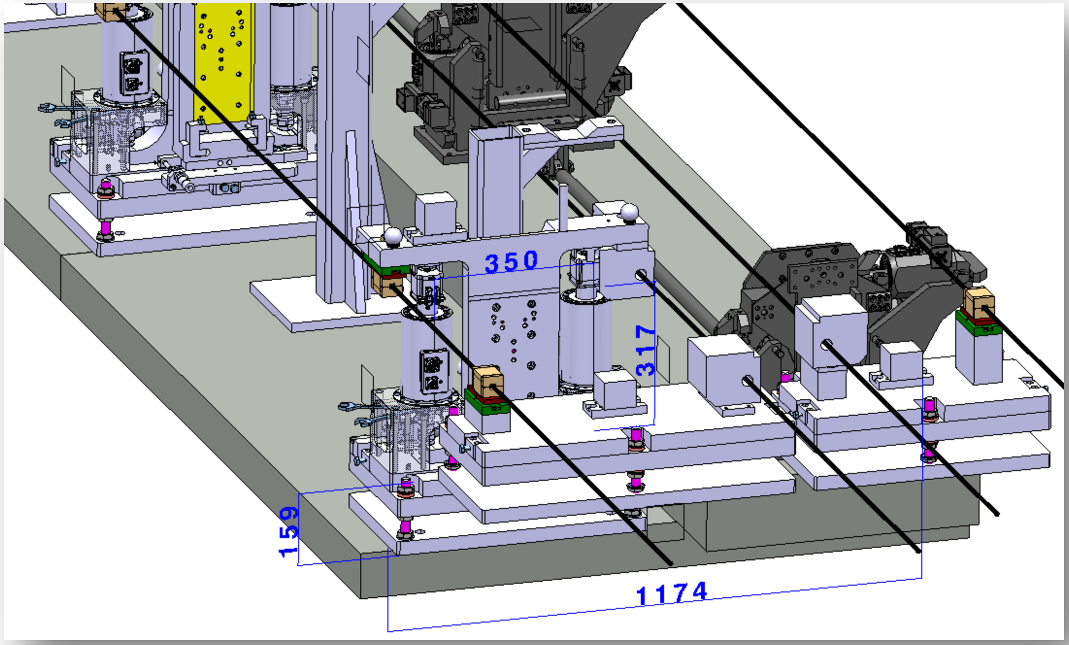
Mechanical pre-alignment within ±0.1 mm (1σ) → active pre-alignment: within ± 10 µm (3σ)

Concept: «snake system», straight alignment reference over 20 km based on overlapping stretched wires, AS and PETS pre-aligned on independent girders, MB Quad pre-aligned independently.



Space reservation for the alignment equipment



3D model of the WPS

STABILIZATION

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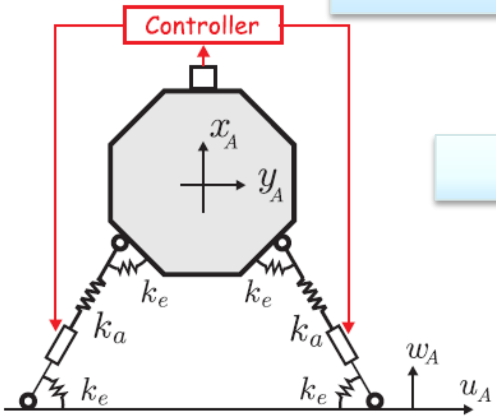
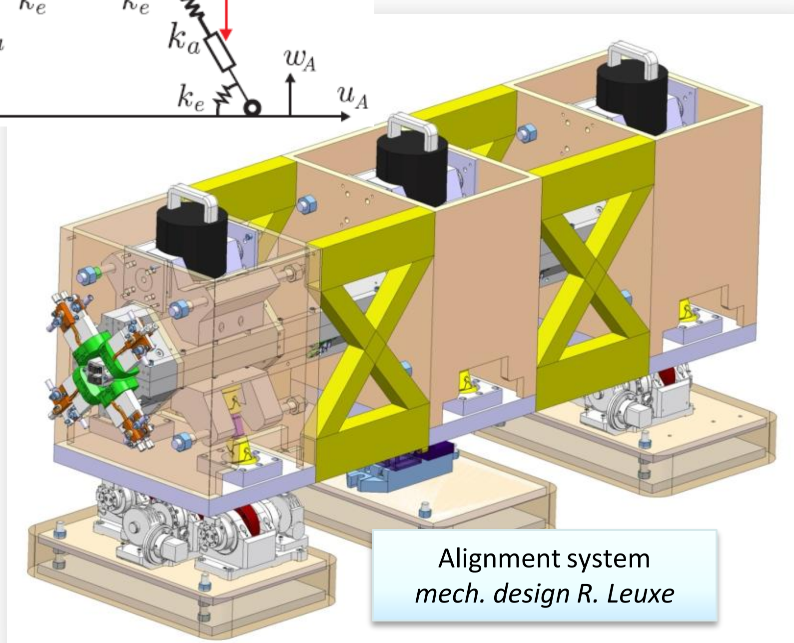
Stabilization **requirement** for the MB Quad (vertical tolerance: 1 nm >1 Hz)
Compatibility of stabilization and pre-alignment systems to be considered
<u>TWO OPTIONS:</u>
CERN: rigid (active stabilization + fast nano-positioning)
LAVISTA: soft support

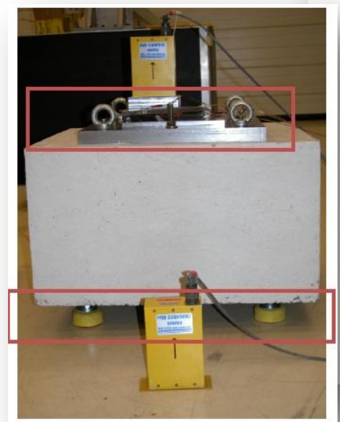


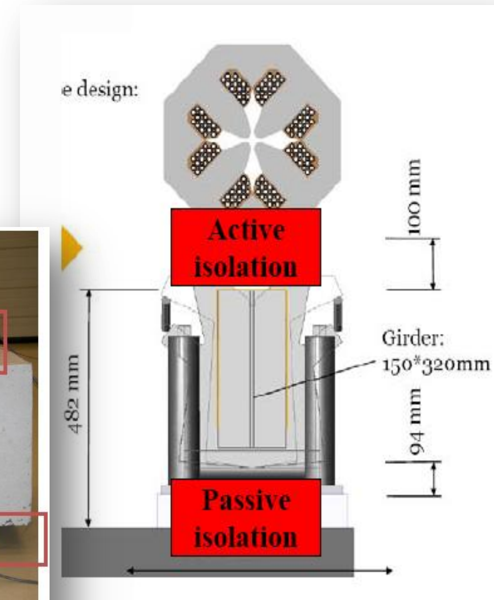
CERN



Alignment system
mech. design R. Leuxe

LAVISTA





Details → talks of K. Artoos & C. Collette

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COOLING SYSTEM

MODULE (TYPE 1) COOLING LAYOUT

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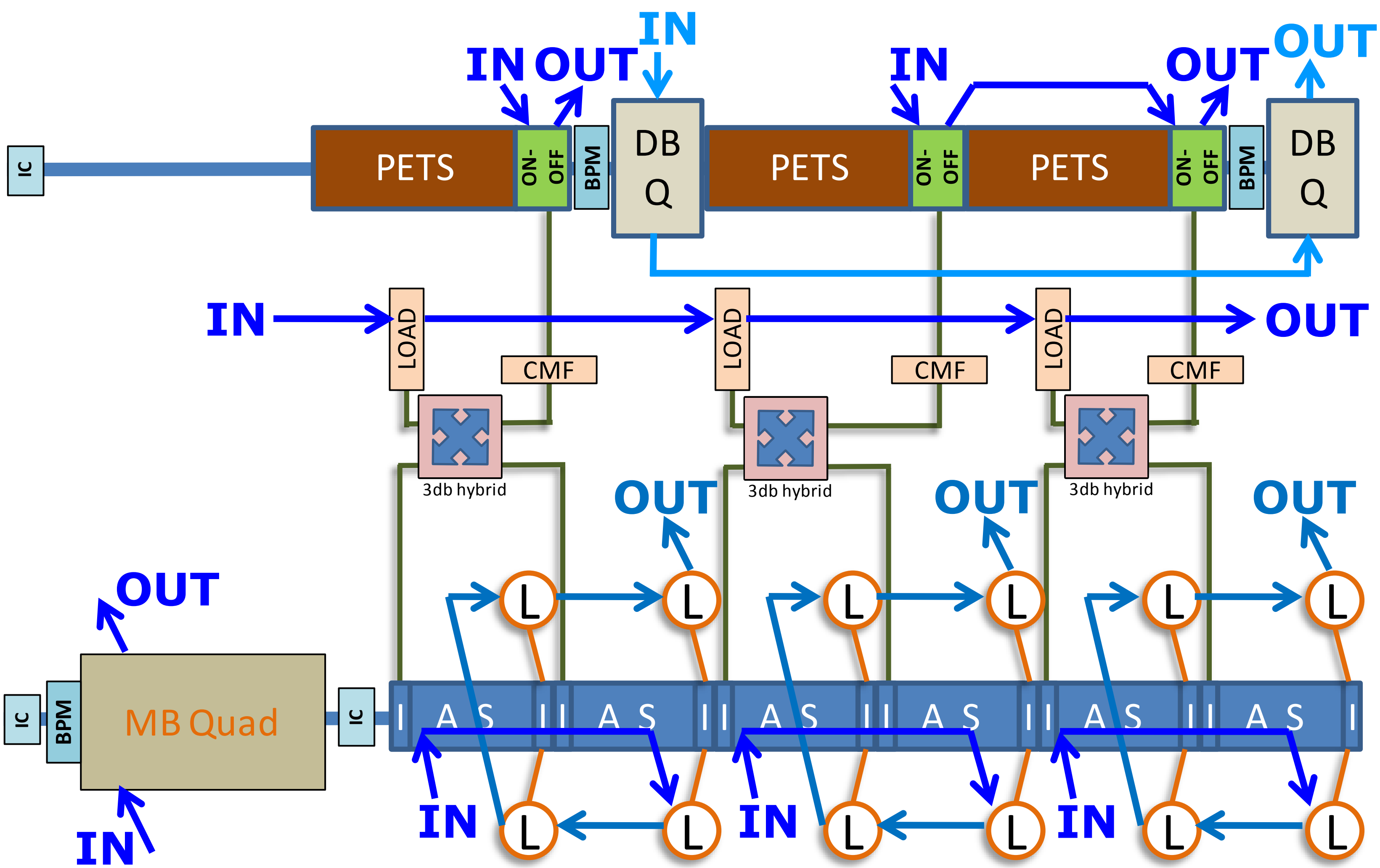

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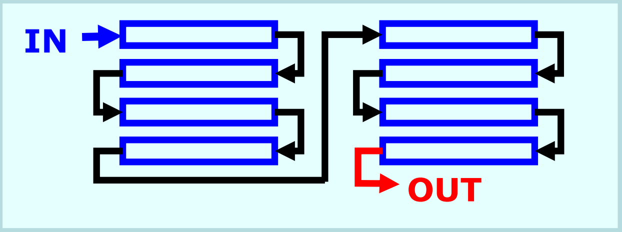
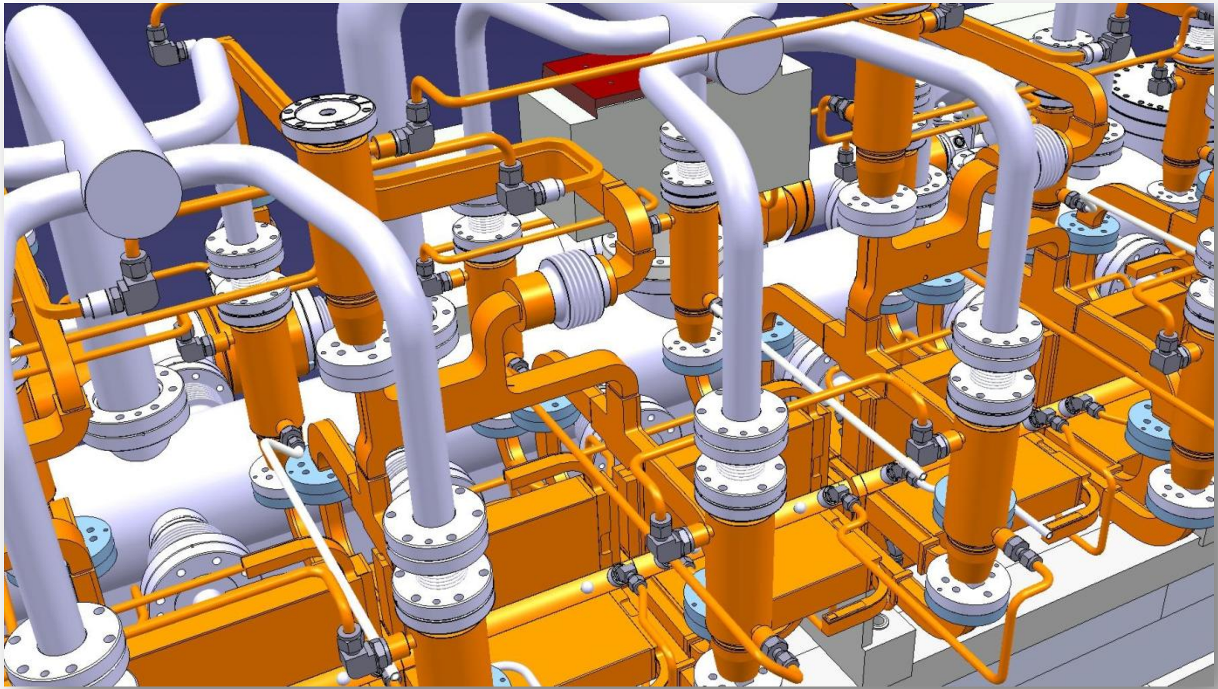


Baseline cooling scheme (Super-AS)

- **MB** - AS in series, loads in series, Quad – in parallel
- **DB** - PETS in series, Quads in series

The water circuits have a common inlet and outlet. Loads dimensions are adapted to the current module configuration and do not exceed 150 mm in length and Ø 50 mm.

The RF structures and magnets are water cooled due to high power dissipation .
RF network must maintain its correct electrical length and the WGs are also water cooled .



Cooling circuits layout

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ASSEMBLY, TRANSPORT & INSTALLATION

MODULE TRANSPORT & INSTALLATION

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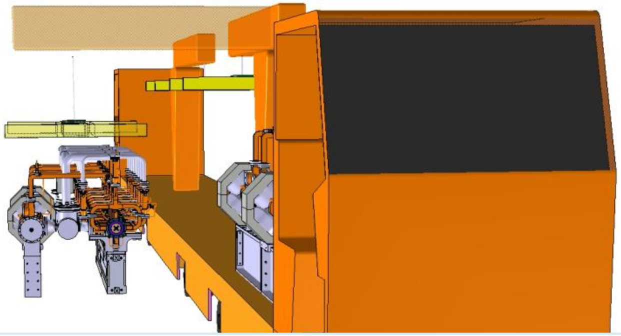
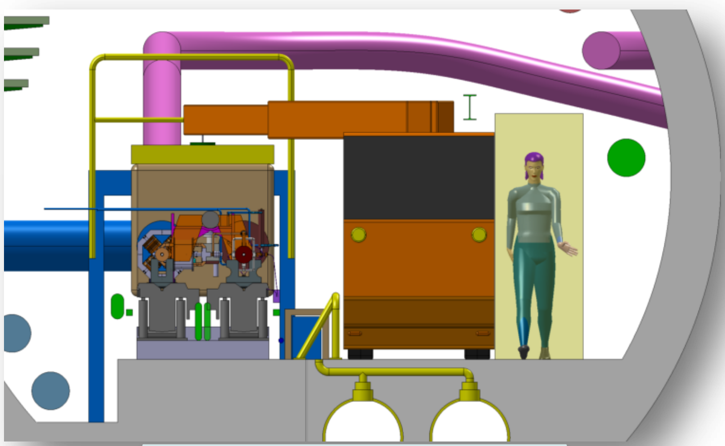


3-D View of conceptual design of module transport and installation vehicle (lifts module from above)

The module assembly will be done on the surface. Each module has the cradles only on one end => a temporary support is needed. A suggested strategy is based on overhead lifting with spread beam. The two beams must be rigidly bound in order to maintain the alignment during transport (our concern – dedicated test in girder mock-up). Strategy for Quadrupole modules to be finalized. The aim is to transport already interconnected modules.

Transport and installation considerations in module design

- Ensure clear interconnection plane (allow installation and removal of one module at a time).
- Include lifting and support points (lifting beams) and transport restraints in design process.
- Test modules should be used to design for and test installation issues e.g. with overhead crane or hoist. (be able to lift assembled module and place it on supports).
- Consider how MB Quadrupoles transported and installed.
- Consider whole installation sequence during module design including installation of supports, survey equipment, interfaces between girders and their supports (Full sequence starts with assembly of modules).



Courtesy of A. Kosmicki (CERN)

Installation of module onto supports in tunnel.
(need to pass over pre-installed survey equipment).

CONCLUSIONS

Alexandre.Samochkine @ cern.ch

- Baseline for all systems defined and frozen by May 2010.
- Detailed design for the main systems is mostly done but the optimization is needed.
- Tests in the lab must reveal the critical points. (Details → talk of G. Riddone)
- AS layout is under way. Integration conditions are specified. The system is very challenging for design and integration due to necessity to have many systems attached to AS.
- RF network is well advanced.
- PETS design is done including the ON-OFF mechanism.
- The detailed design for supporting system is under final optimization.
- This is valid for the alignment and stabilization systems' components as well.
- The vacuum parts are defined, but the neighboring components might give some restrictions. The optimization will be continued also for other types of the module.
- The instrumentation components design would require additional iteration(s).
- Transport and installation features would require more attention.

Design for CDR by Mar-2011

CLIC modules in the lab from 2010

Test modules in CLEX from 2011

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I am very much obliged

to each system responsible

and our collaborators

for their contribution & cooperation !

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THANKS

FOR

YOUR

ATTENTION !