CLIC WORKSHOP October 2009

CLIC MODULE INTEGRATION ISSUES

A. Samoshkin
14-Oct-2009

WG 5 «TECHNICAL SYSTEMS»

Alexandre.Samochkine @ cern.ch

CLIC SYSTEMS

R F	MAGNET
INSTRUMENTATION	COORDINATE
SUPPORTING	ALIGNMENT AND STABILIZATION
BEAM FEEDBACK	VACUUM
COOLING	ASSEMBLY, TRANSPORT, INSTALLATION

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CLIC MODULE

Module design is based on two-beam acceleration idea, where the RF power is generated by a high current e-beam (DB) running parallel to the MB. This drive beam is decelerated in special power extraction structures (PETS) and the generated RF power is transferred to the main beam (AS).

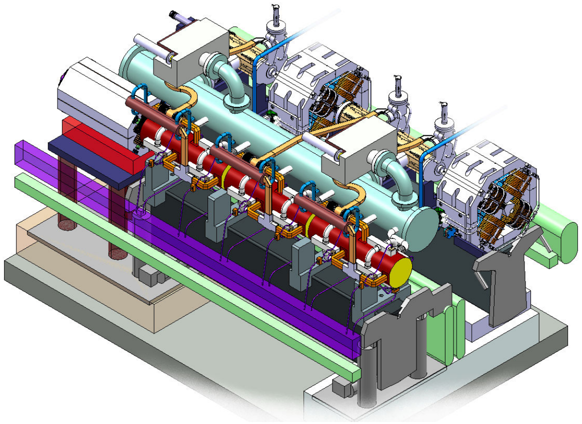
Each system must be compatible with others, which makes both, the design and integration complex & challenging.

Baseline and alternative solution/s are being studied for each component of the technical system.

Many issues appear often during integration

THE MAIN TASKS OF INTEGRATION:

- overall layout,
- space reservation,
- number of components and their exact position and dimension
- system integration; interfaces between components, interference of components
- layout of special regions (i.e. DB turn-around loops)



COLLABORATORS:

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

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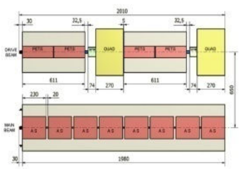
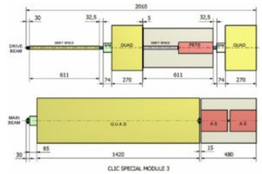
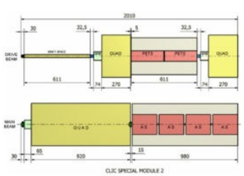
MODULE TYPES



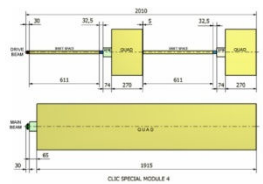
Standard Module
8374 per Linac



Module Type 3
477 per Linac



Module Type 2
634 per Linac



Module Type 4
731 per Linac

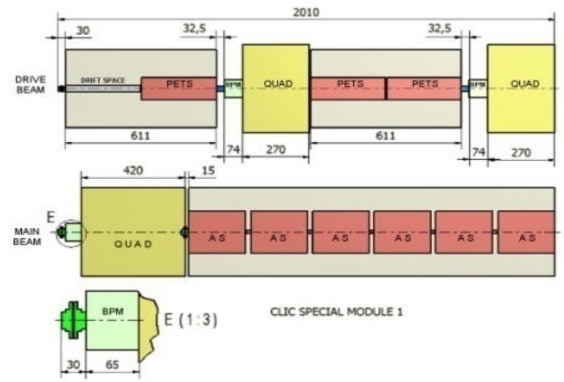
DB (100 A)
4 PETS, 2 Quads with BPM
Each PETS feeds 2 AS

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

CLIC Module Type1
154 per Linac

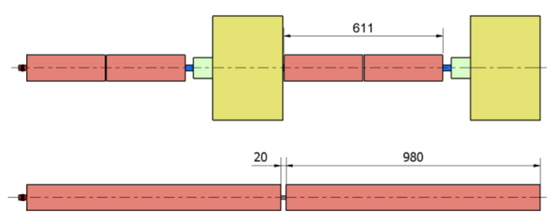
2 configurations under study

Tank Version



Sealed Version

current baseline



AS: based on CLIC "G" disk damped (sealed version) (250 mm including 20 mm for interconnection)

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

CLIC MODULES T0, T1 & T4

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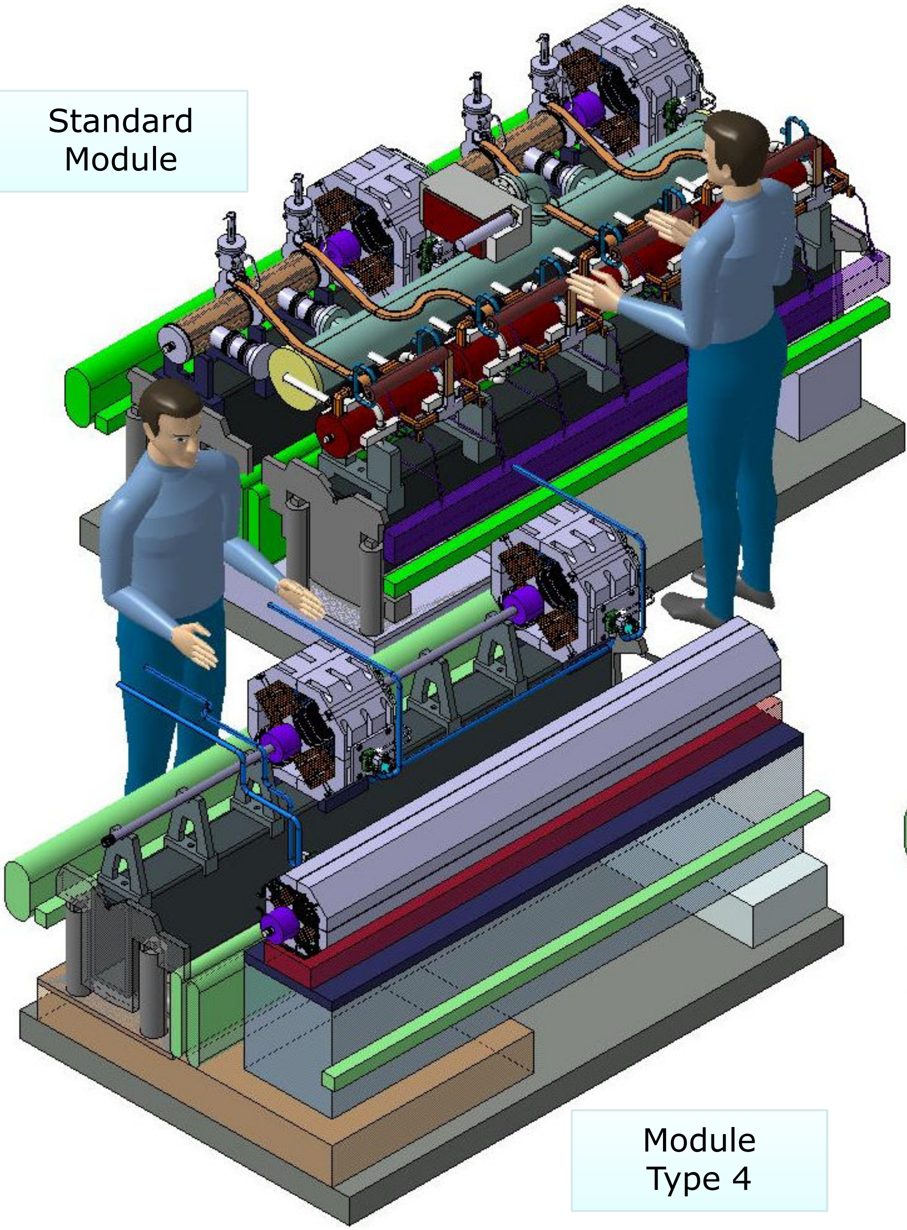
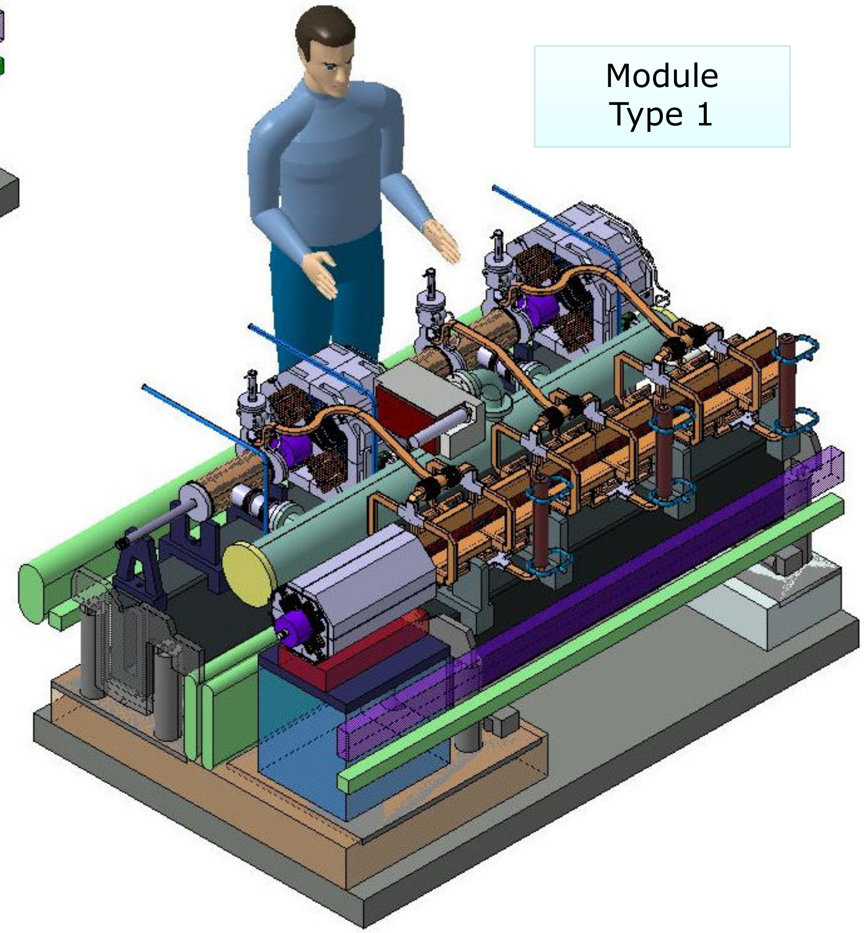
Standard Module



Module Type 4

Module Type 1



CLIC MODULE TYPE 1

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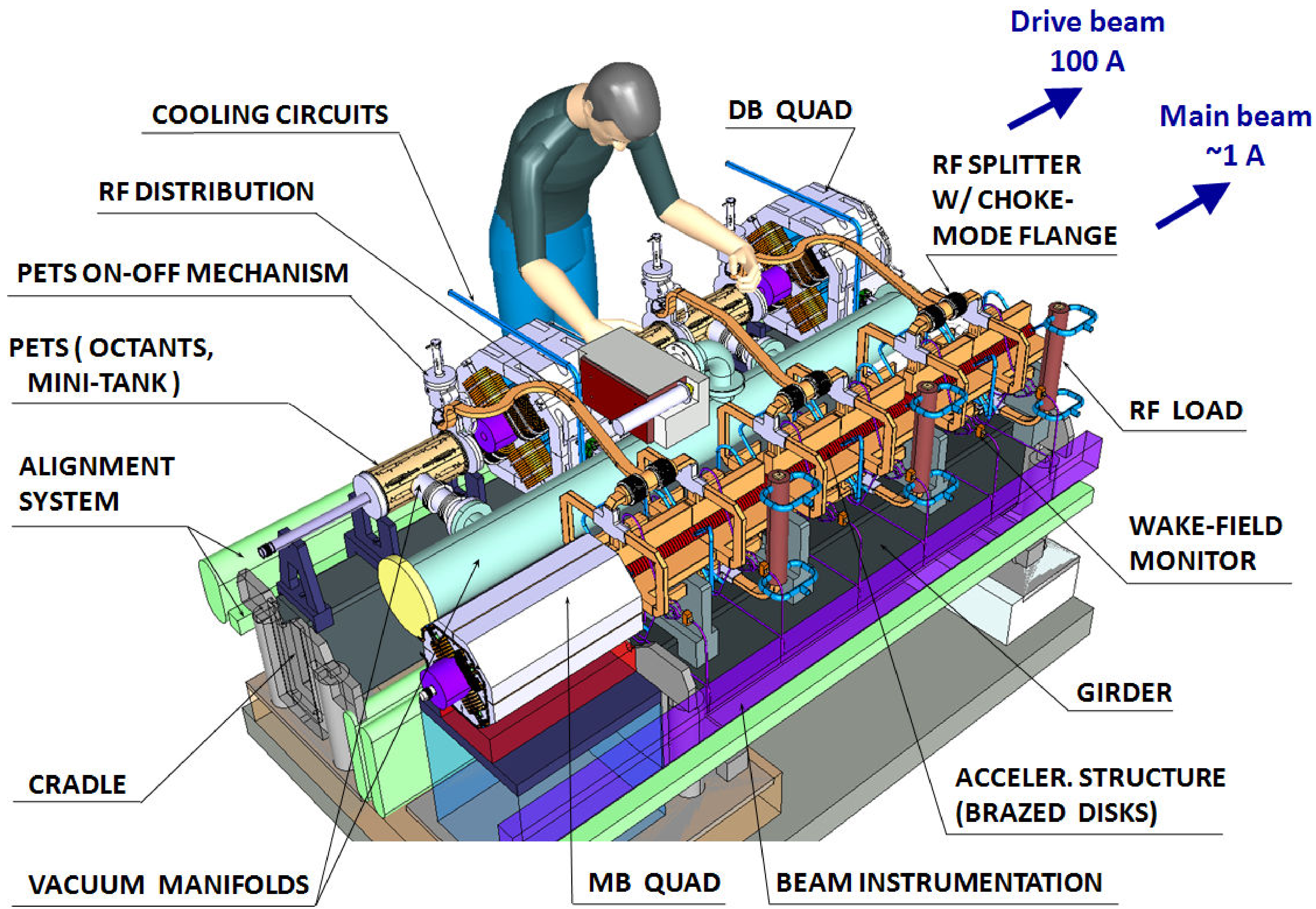

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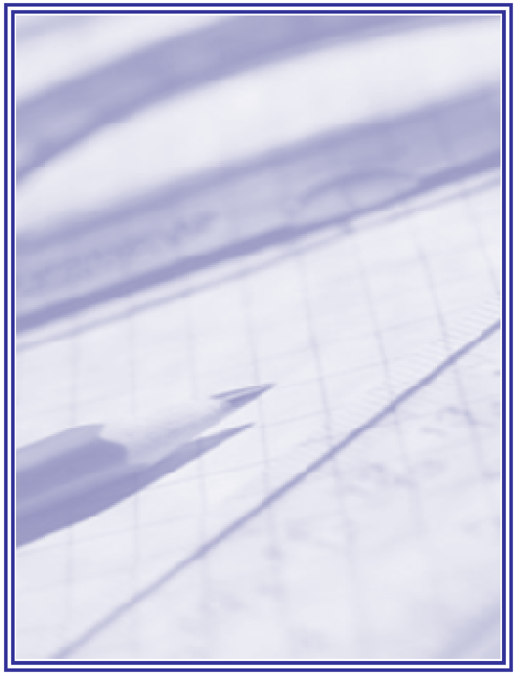

RF SYSTEM

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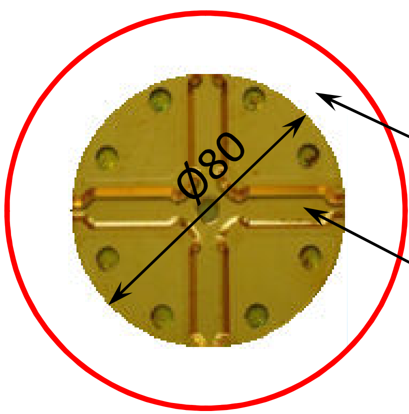
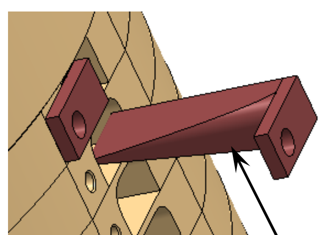
AS INTEGRATION

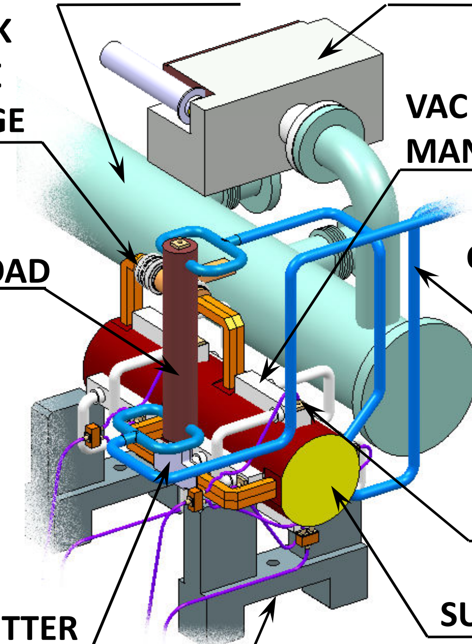
The design of the AS is driven by extreme performance requirements. The shape accuracy is relatively high (0.005 mm).

Several features of different systems, such as vacuum, cooling, WFM have to be incorporated into design. The damping waveguide loads are in between of them.

Two AS forming one Super-Structure
(Ø 140 mm, L=2*230+20=480 mm)







Detailed design under way

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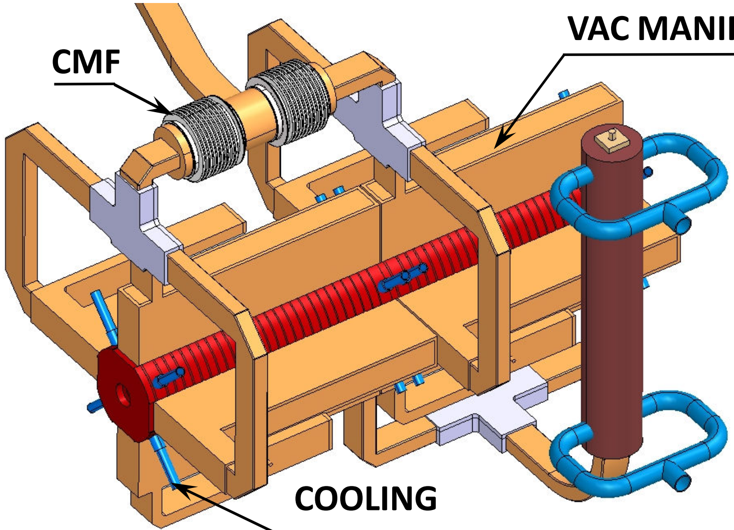
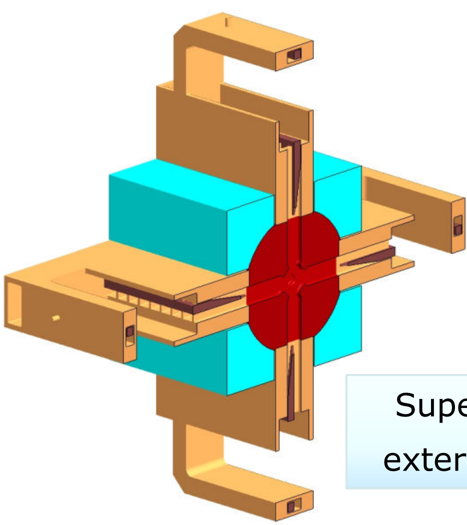
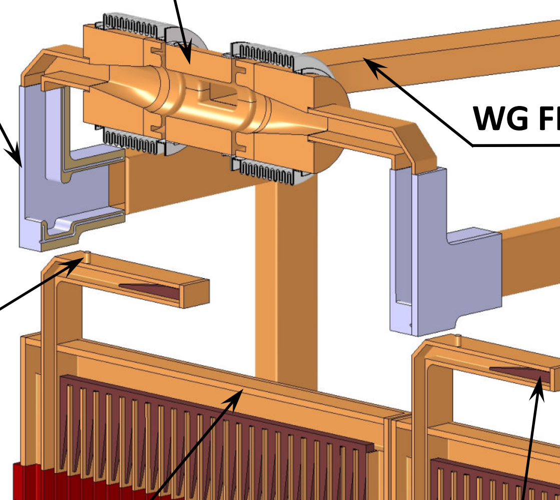
AS INTEGRATION



Super-AS with internal cooling



Super-AS with external cooling



COMPLEXITY

- Brazed disks with "compact" coupler
- Micro-precision assembly
- Cooling circuits (400 W per AS)
- Wakefield monitor (1 WFM per AS)
- Vacuum system (10-8 mbar)
- Interconnection to MB Q (stabilization!)
- Structure support (alignment)
- Output WG with RF components (e.g. loads)
- RF distribution (CMRS w/CMF)

Many systems to be integrated around the "Super-AS"

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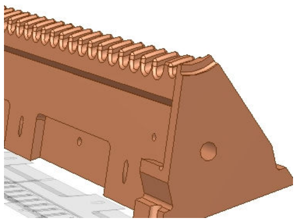
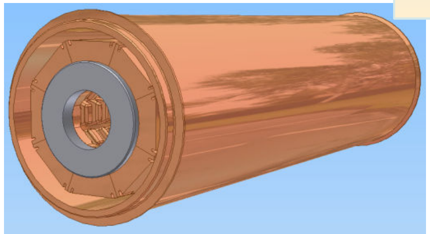
PETS INTEGRATION

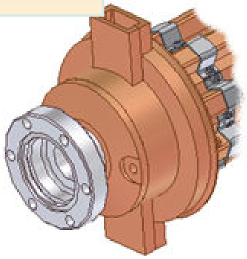
OLD

PETS octant (single bar)



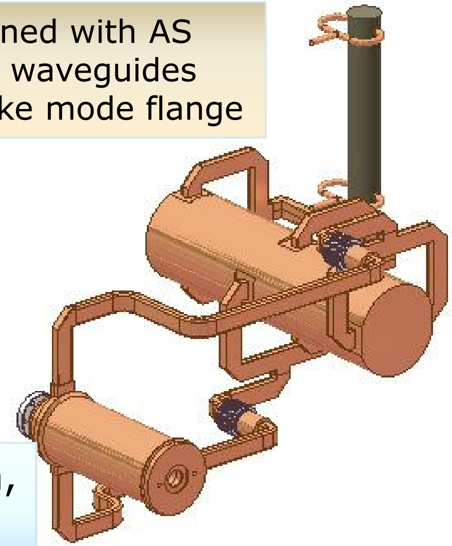


Assembled in mini-tank

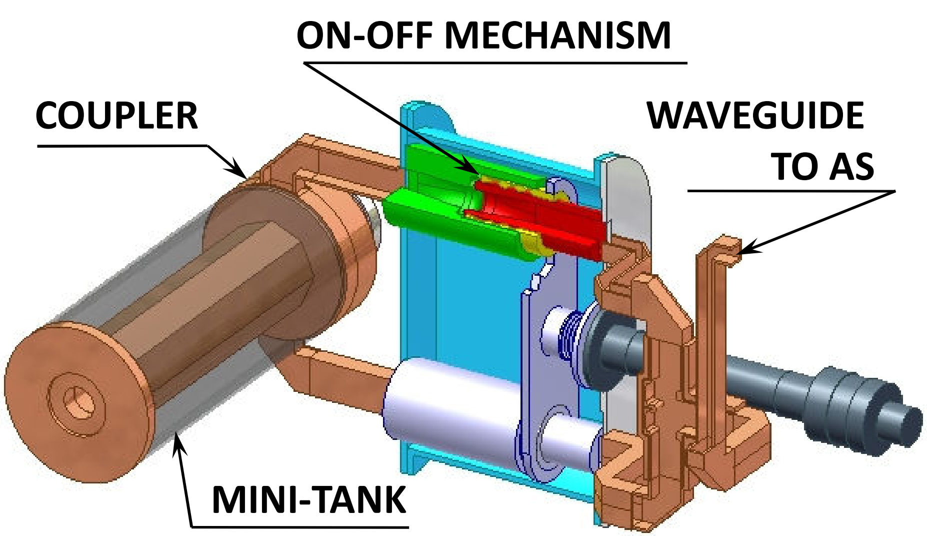


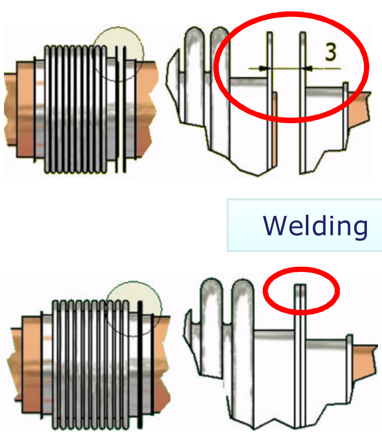
Equipped with couplers

Joined with AS via waveguides & choke mode flange

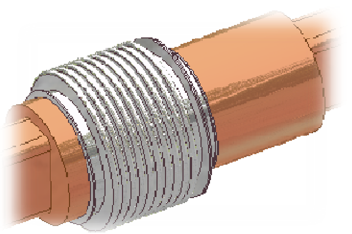


The octants assembly, mini-tank, on-off mechanism, vacuum system, cooling circuits, interconnection & supports are the subjects for integration





Welding



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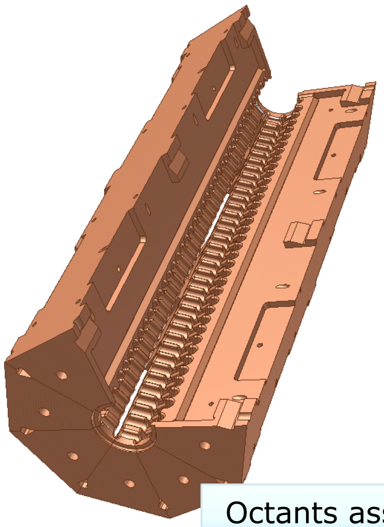
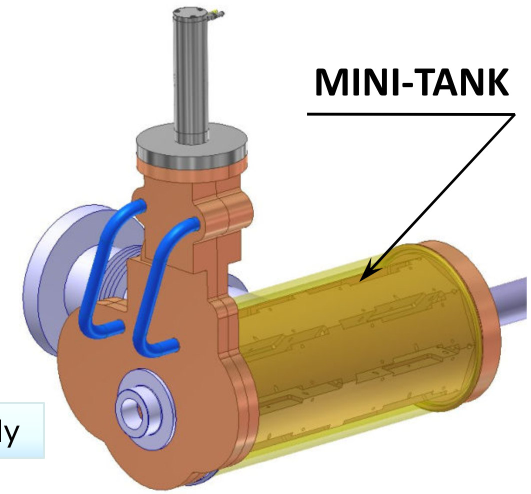
PETS INTEGRATION

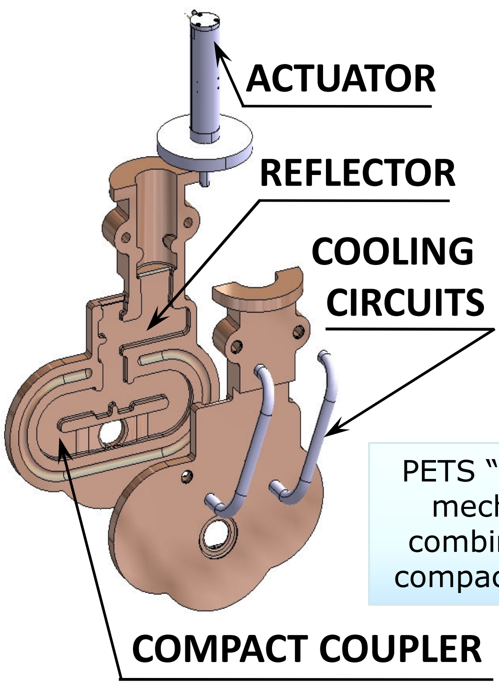
NEW



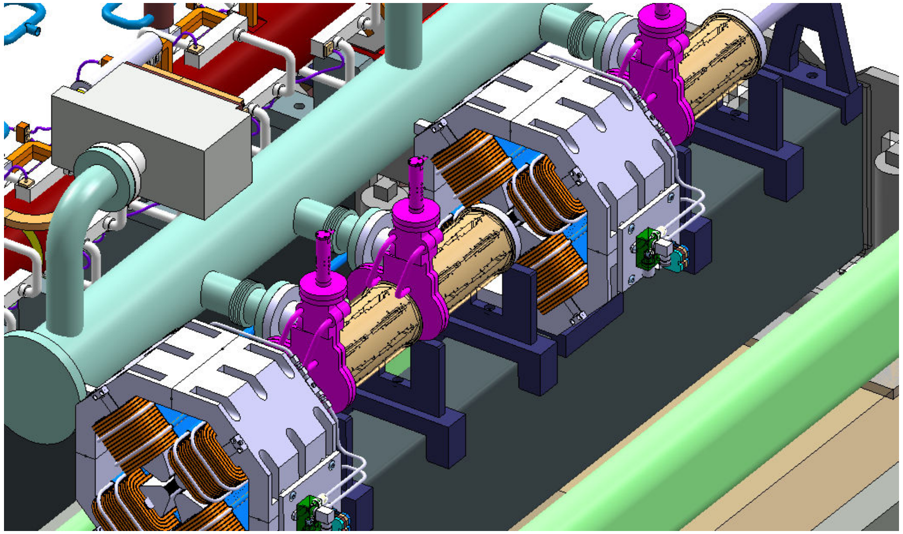
Octants assembly



- Structure (8 octants) with "compact" couplers
- Mini-tank for structure
- On-off mechanism (t «off» → 20 ms)
- Cooling circuits (size for 0.5% beam loss, couplers water-cooled, bars cooled by conduction)
- RF distribution to AS
- Vacuum system
- Interconnection to BPM
- Mini-tank support (fiducialisation)



PETS "ON-OFF" mechanism combined with compact coupler



RF SPLITTER WITH CMF

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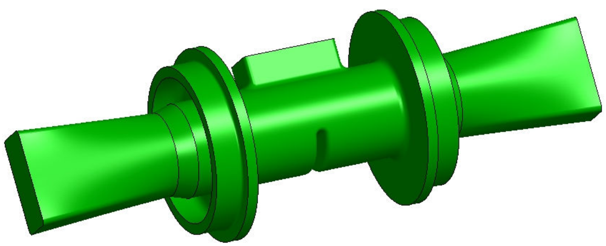
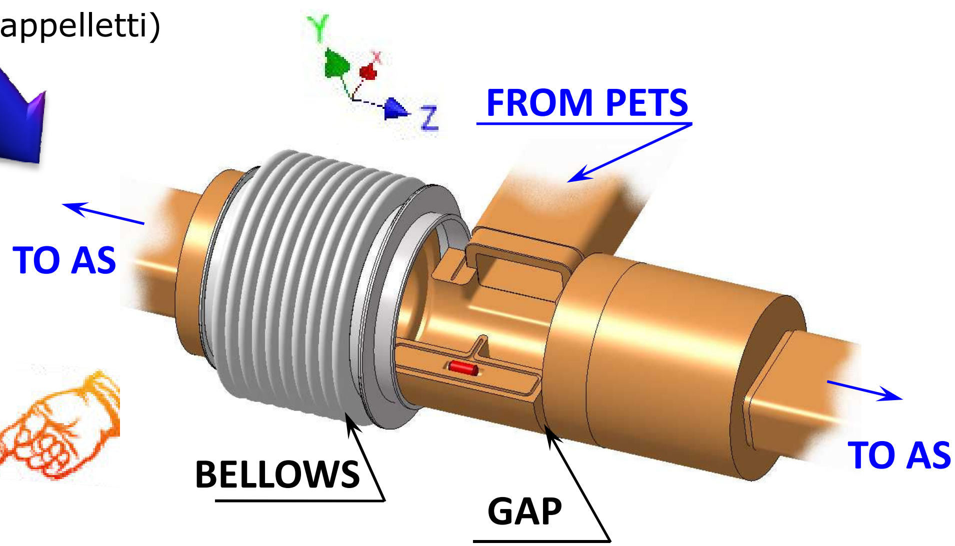
PETS **(A)** and AS **(B)** are connected via waveguides and RF splitter with choke mode flanges (CMF). CMF allows the power transmission without electrical contact between waveguides. This device should be flexible in order to permit independent alignment of two waveguides.



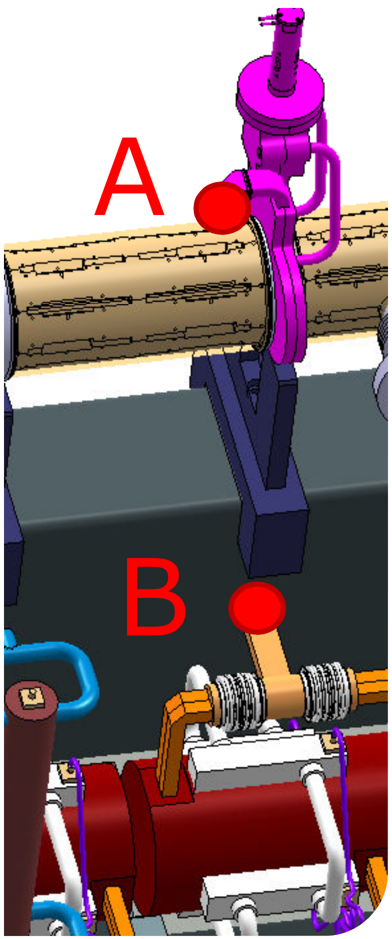
RF Design of CMRS
(I. Syratchev & A. Cappelletti)

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 splitter with **C**hoke **M**ode **F**langes



Hi Alexandre,

it works even better than the one I sent you (input reflection is -54dB instead of -50dB).

Best regards,
Alessandro.

RF NETWORK DESIGN

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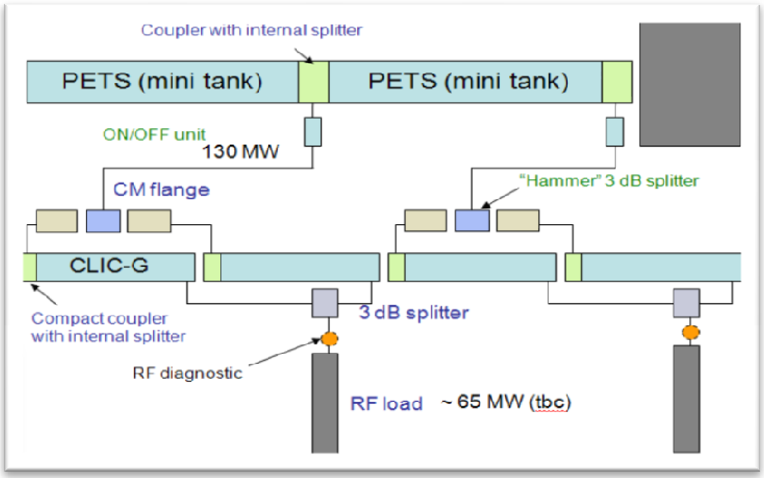
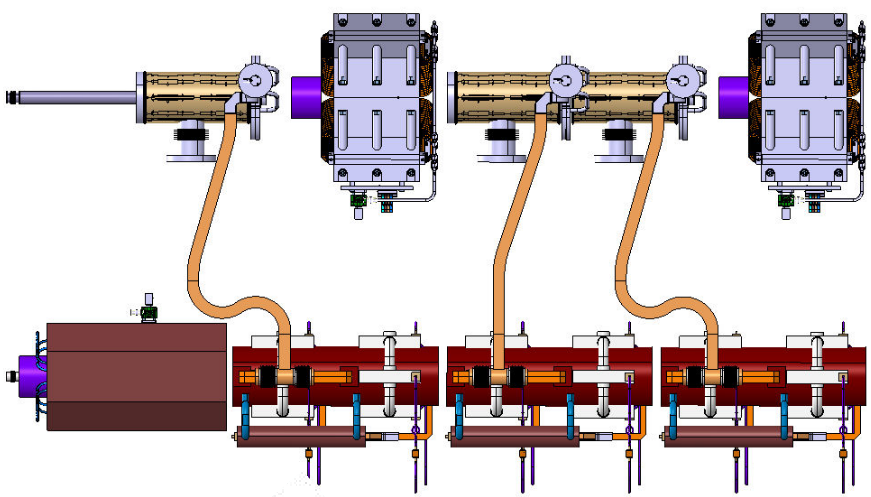
Waveguide length optimization is based on losses, phase advance and RF to beam timing considerations.





	A	B	C	D	E	F	G
1		WAVEGUIDE					
2		a		2.29E-02	m		
3		c		2.998E+08	m/s	Speed of Light	
4		f		1.1994E+10	Hz	CLIC frequency	
5		λ_0		2.50E-02	m	CLIC wavelength (c/f)	
6		λ_{cutoff}		0.04572	m	= 2 x a	
7							
8		WAVELENGTH					
9		λ_{wg}		2.985110E-02	m	$\lambda_{wg} = \frac{c}{f} \times \frac{1}{\sqrt{1-\left(\frac{c}{2a \cdot f}\right)^2}}$	
10							
11							
12		GROUP VELOCITY					
13		vg		2.51E+08	m/s	$vg = c \times \sqrt{1-\left(\frac{c}{2a \cdot f}\right)^2}$	
14		vg/c		8.37328E-01			
15							
16							
17		WAVEGUIDE LENGTH					
18		Las		0.25	m	AS Length	
19		Las x vg/c		2.09E-01	m		
20		Delay		8.339E-01	ns	$\frac{Las}{c} \times 10^9$	
21		$L_2 - L_1$	=Las x vg/c	2.09E-01	m	= n x λ_{wg}	
22		n		7.0125E+00			
23		n real		7.0000E+00			
24		$L_2 - L_1$ corr		2.089577E-01	m	208.957	mm
25			ERROR	-1.490973E-03	ns		

442.541	1st waveguide length			
$L1_1$ =	442.541	1	PETS 1	wg1
$L2_1$ =	651.498	2		wg2
$L1_2$ =	592.512	1	PETS 2	wg3
$L2_2$ =	801.469	2		wg4
$L1_3$ =	442.541	1	PETS 3	wg5
$L2_3$ =	651.498	2		wg6
$L1_4$ =	592.512	1	PETS 4	wg7
$L2_4$ =	801.469	2		wg8

The breakdown detectors must be integrated

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INSTRUMENTATION

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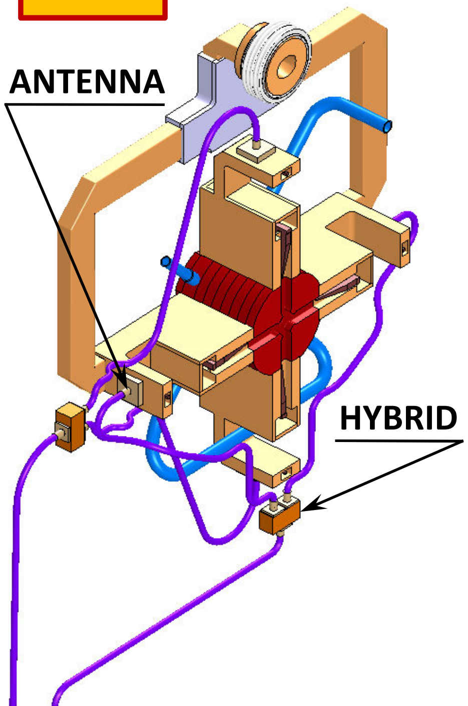
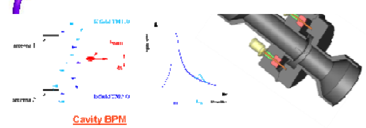
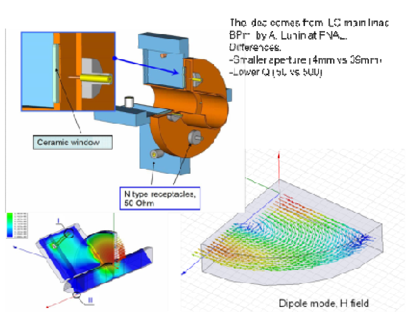
BEAM POSITION & WAKE FIELD MONITORS

WFM







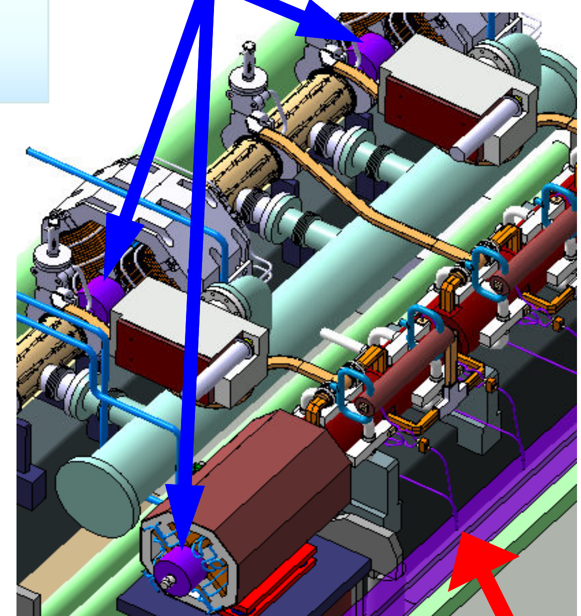
Limited space for BPM integration:
60-100 mm, 1 BPM per Quad,
1 WFM per AS (RMS position error 5 µm)
Qty: DB: ~47000; MB: ~151000 units

MB BPM
Choke BPM: RF design made, mechanical design to be done (possible collaboration with RHUL)
FNAL Low-Q cavity BPM: wakefield calculation must be done very soon

DB BPM
Design will start in 2010 (collaboration with SLAC)

WFM: Mechanical design under way (collaboration with CEA-Saclay).
AS with WFM → in 2010

BPM



50x100 mm space on the side along the module has been reserved for the electronics placement.

Detailed design is needed

Q-BPM interconnection must be studied

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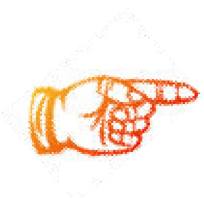
EDMS № 1009474

22-Jul-2009 AS, CG, GR, HMD, IS, KA, LS **EDMS № 1009474**

Summary on CLIC Module (Type 1) instrumentation cables.

System	Number of signals	Qty of cables per module	Signal frequency	Frequency of read-out
Beam Instrumentation	25	6		
RF components	6	6		
Cooling	72	2		
Alignment	47	21		
Stabilization	20	30		
Vacuum	20	2		
Sum	**190**	**?**		

BACK TO CONTENTS



The signal and read-out frequencies still must be clarified and collected to the document.

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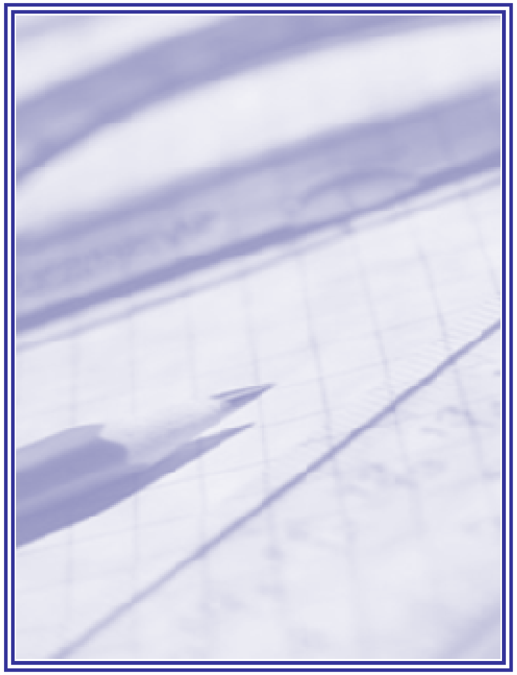

MAGNET SYSTEM

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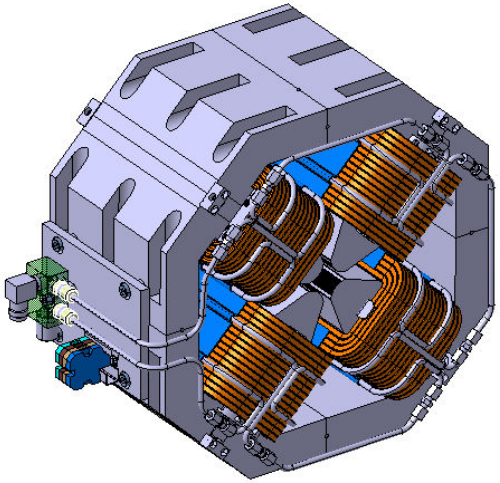
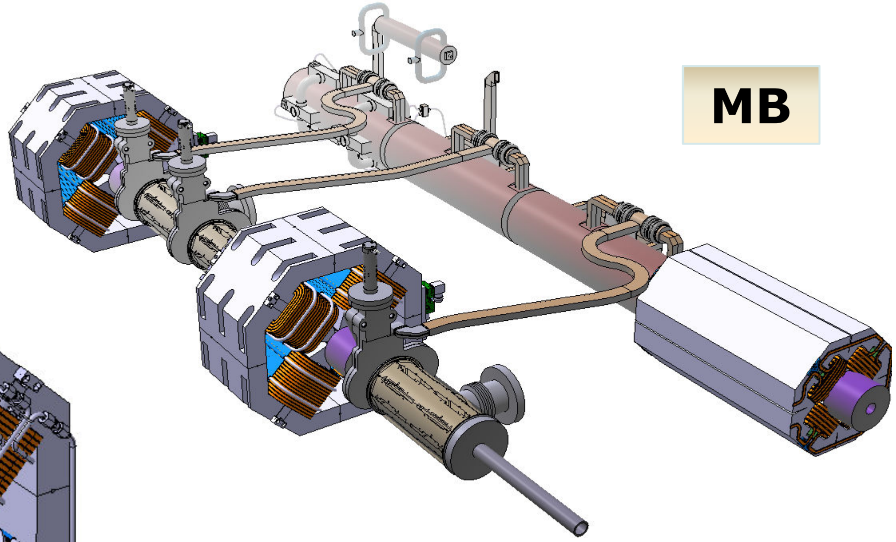
QUADRUPOLES

MB: The magnets are needed in four different magnetic lengths (350, 850, 1350 & 1850mm).
Baseline: the beam pipe is attached to the magnet. The beam pipe centre needs to be aligned to the magnetic centre of the quad with an accuracy better than 30 μm. Transverse tolerance for pre-align. 17 μm at 1s, Stabilization: 1nm >1Hz in vertical & 5nm >1Hz in horizontal direction at 1s.

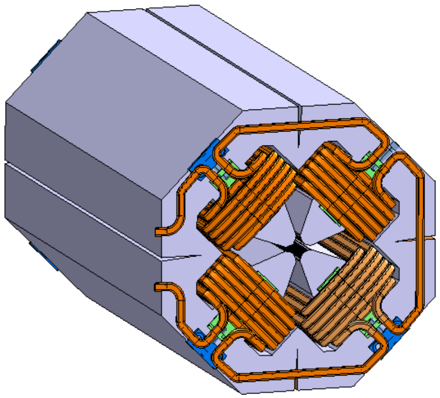
DB: The active length specified is 150 mm. The total number of quads required for both linacs is ~42000. In current module design the DB Quad vertical size drives the beam height.

DB





MB



Main Beam Quadrupole
Nominal Gradient: 200 T/m
Magnet bore Ø: 10 mm

Drive Beam Quadrupole
Nominal Gradient: 67 T/m
Magnet bore: Ø23mm

Final 3D models for magnets needed
→ to be compatible with space allocation

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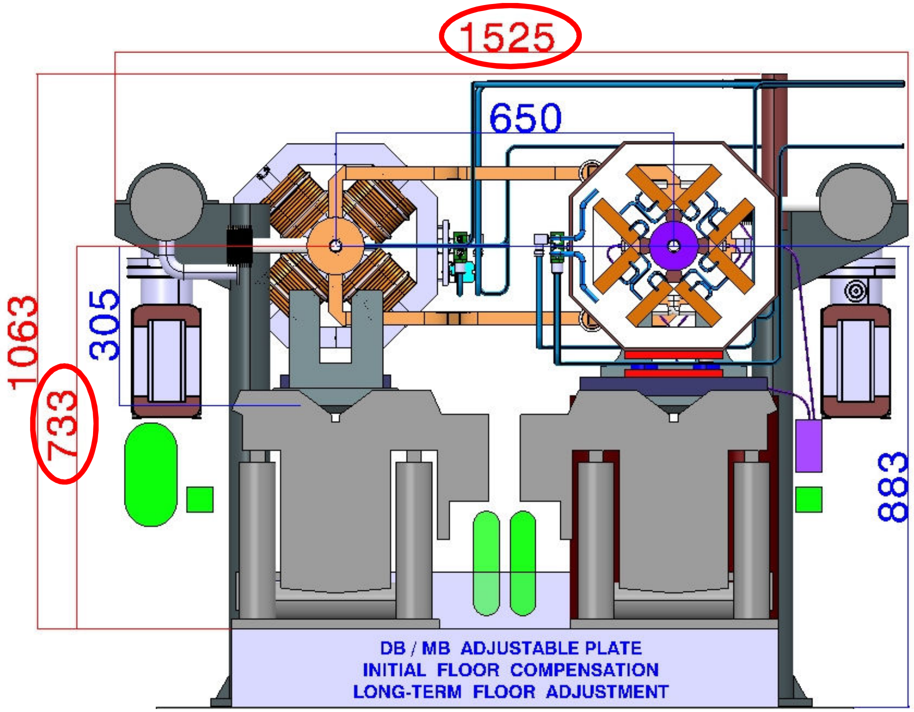
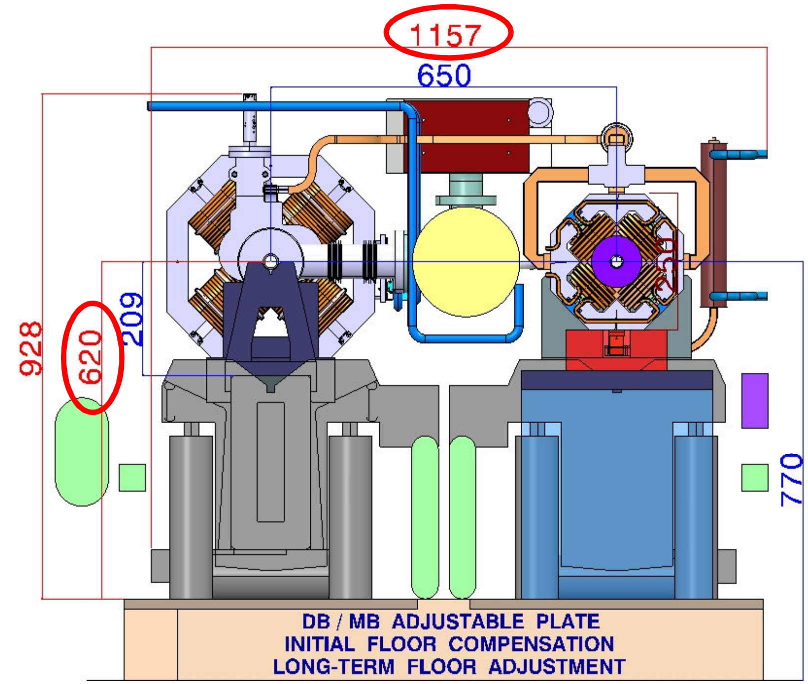
MODULE OVERALL DIMENSIONS



Nov-2008



Oct-2009

WIDTH: **1160** vs **1525**
BEAM HEIGHT: **620** vs **730**

Direct influence on alignment, stability, transport and installation

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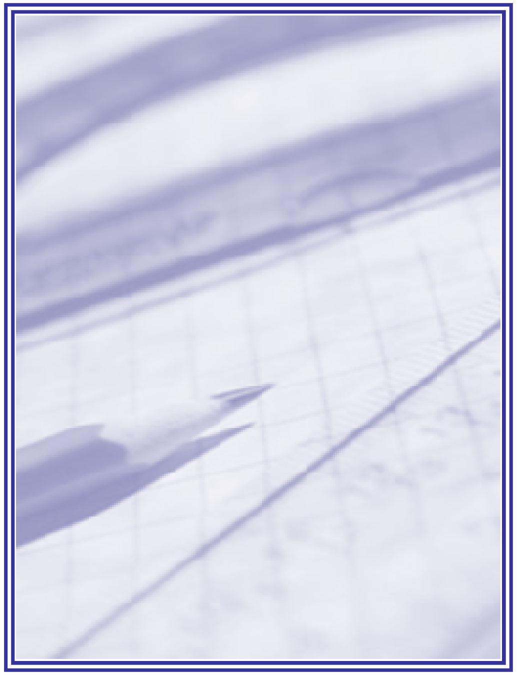

SUPPORTING SYSTEM

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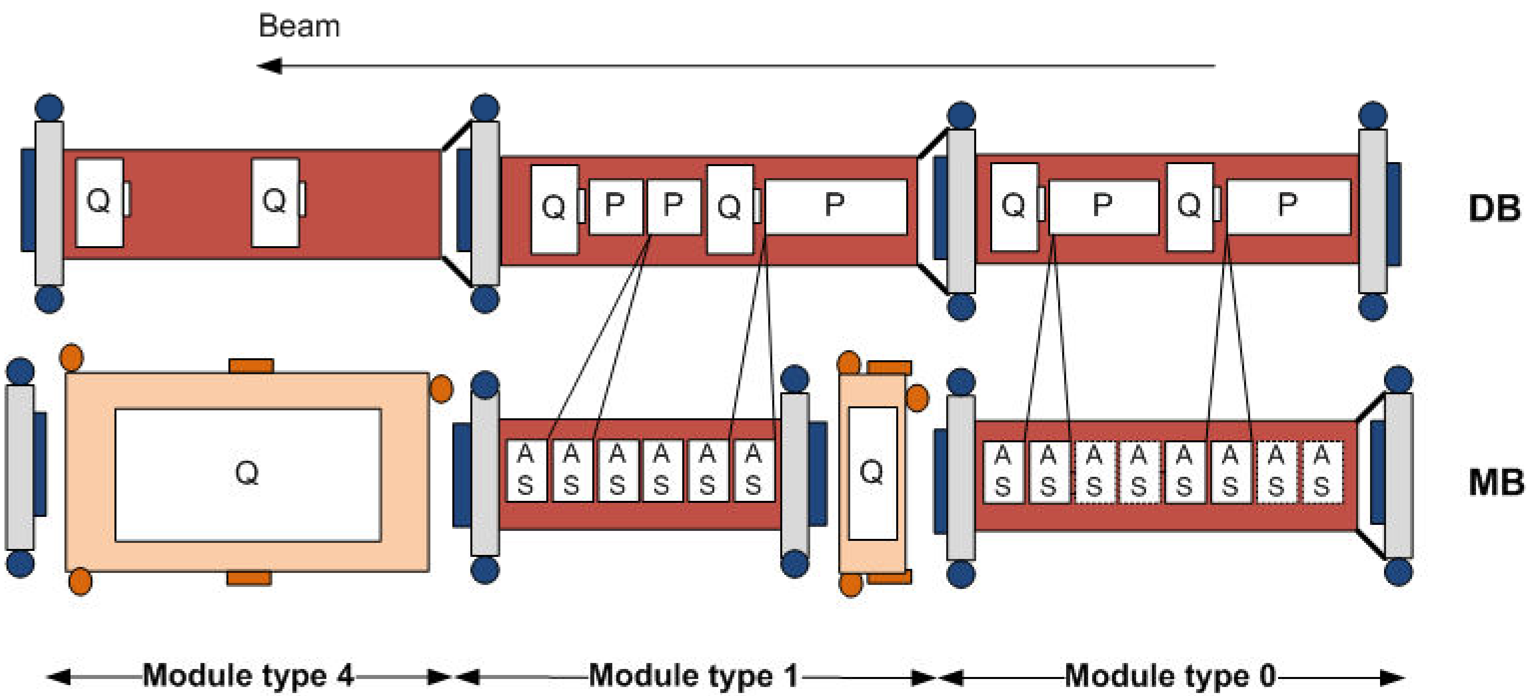
SUPPORTING SYSTEM

BASELINE:

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



All AS are with WFM

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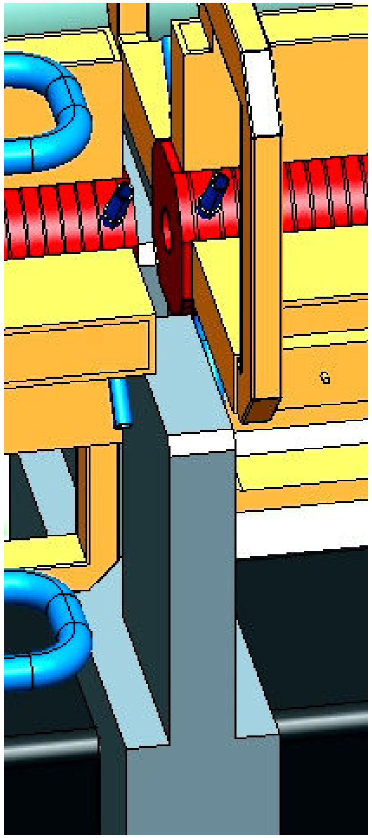
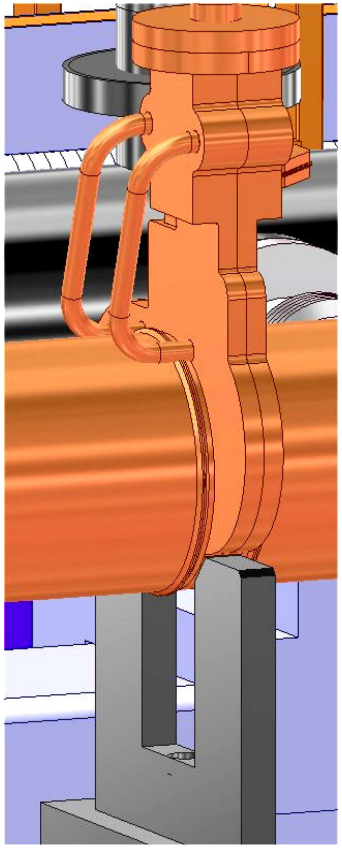
SUPPORTING SYSTEM

Current baseline is to support the AS and PETS with V-support connected to the SiC girder with rectangular cross-section.



AS support



PETS support

Different shape configurations of the girders are considered. The girder material properties must provide a compromise between damping and stiffness (under investigation in a contact with several companies).

Supports must be compatible with thermal loads. The structures must stay within longitudinal and transversal tolerances under variable beam-loading conditions.

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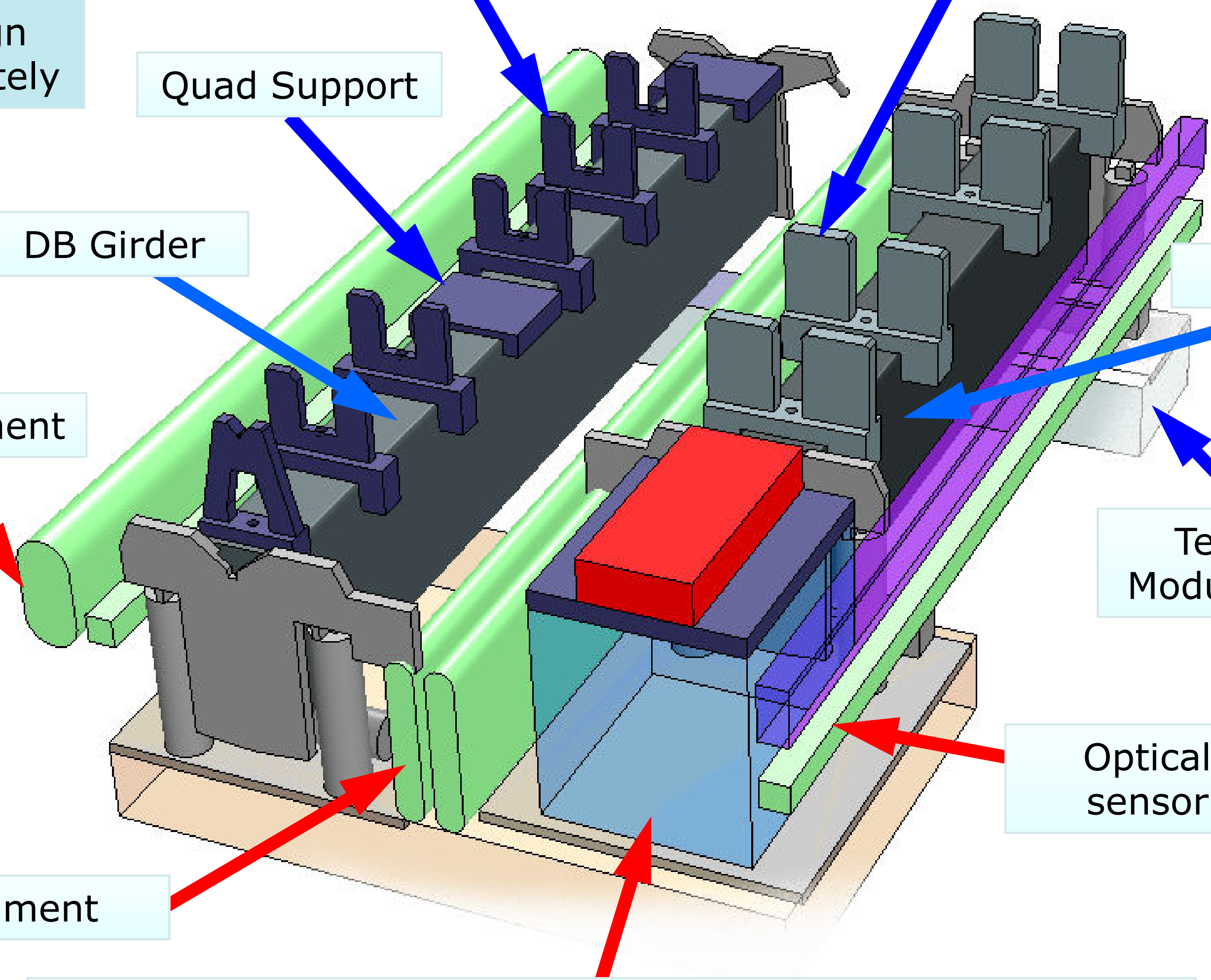
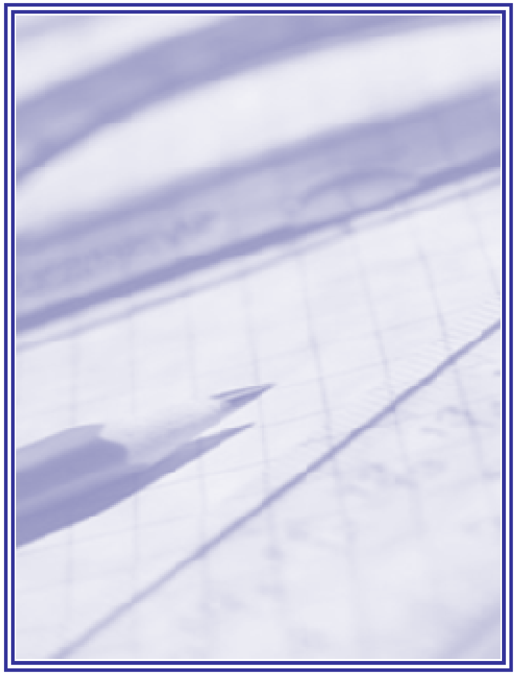
SUPPORTING SYSTEM

Requirement:
possibility to align MB & DB separately



Space is reserved for MB Quad support (including alignment/stabilization/support) and alignment system



VACUUM SYSTEM

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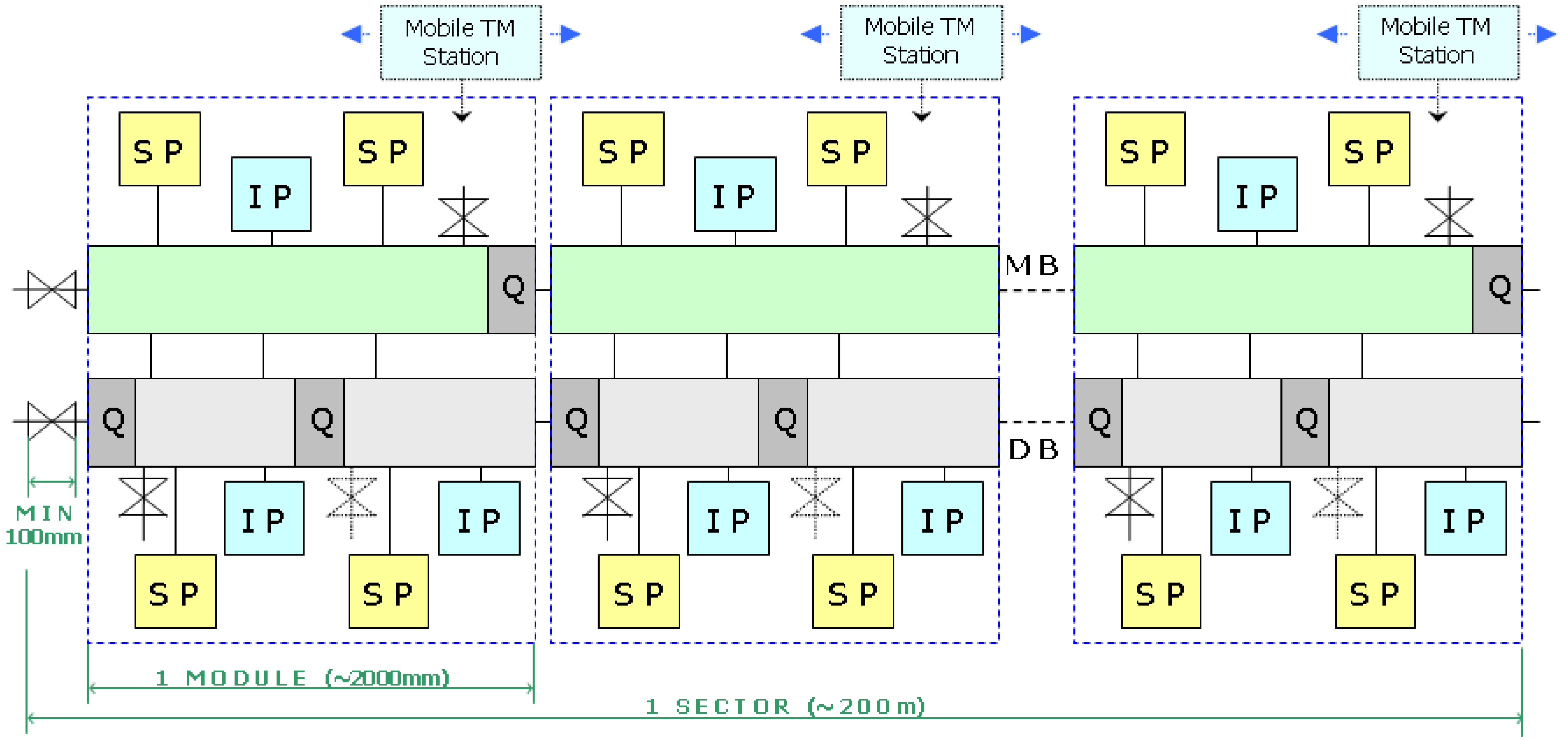
VACUUM LAYOUT

Consideration on the quantity and overall dimensions of devices needed for creation and maintaining vacuum for the experiment is shown schematically.

BASELINE: 10^{-8} mbar



Sectoring valves must be integrated

LEGEND	OBJECT	QUANTITY	SIZE (mm)	WEIGHT
Q	Quadrupole			
Mobile TM Station	Mobile Turbo Molecular Station	3-6 stations/sector, 40 in total	500x500x900	
S P	Sublimation Pump	4/module [MB-2, DB-2]		
I P	Ion Pump	3/module [MB-1, DB-1 or 2*]	152x310x240	20 kg
	Manual Valve	3/module [MB-1, DB-1 or 2*]		

** - depends on Quad Vacuum Chamber cross section*

Noel Hilleret, Alexandre Samochkine 11-Dec-2007

VACUUM

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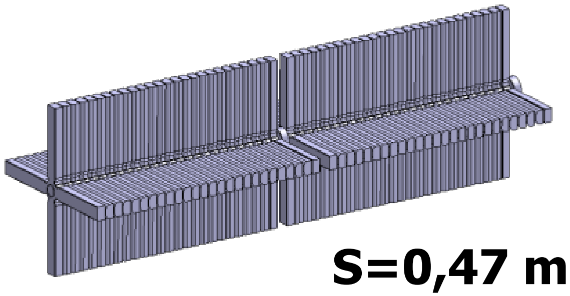
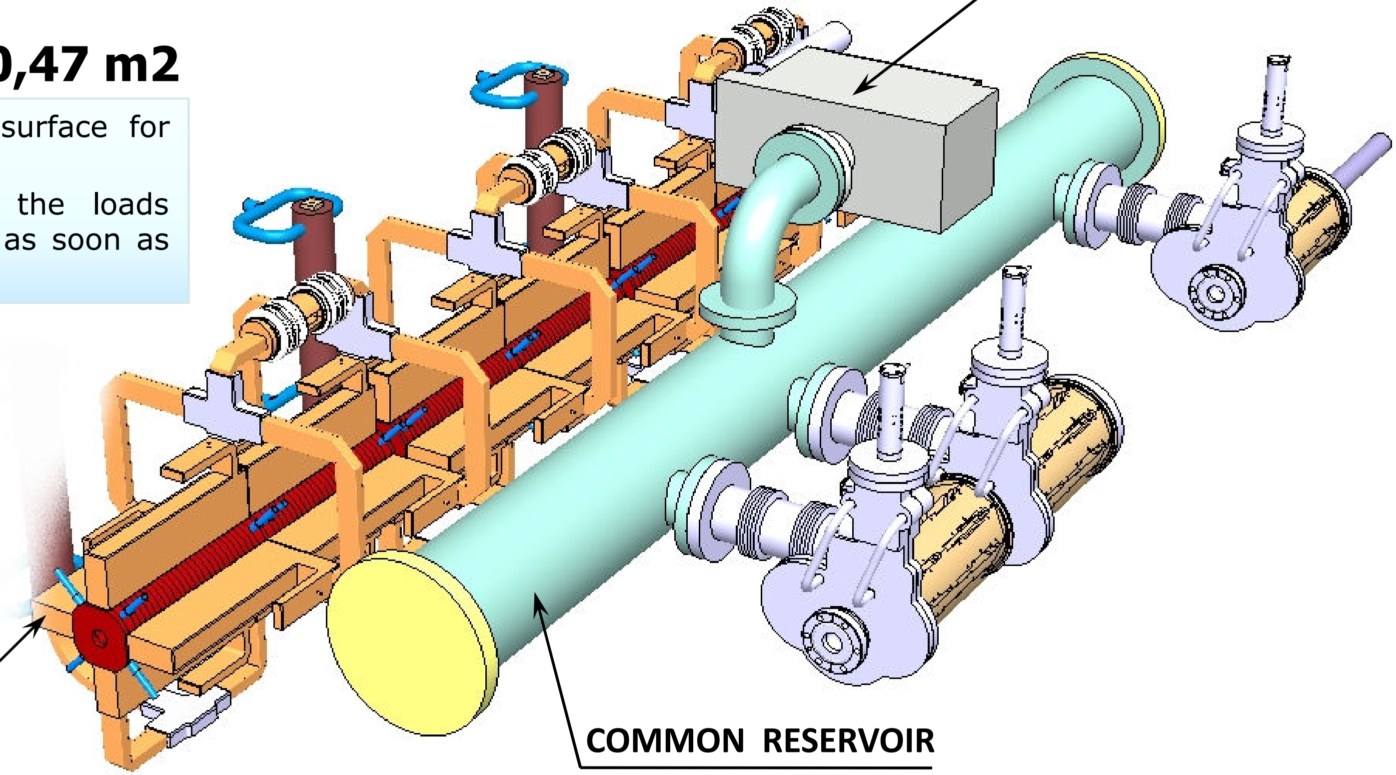


S=0,47 m2

Rough calculation of AS surface for pumping is done.
The more precise (with the loads surface) must be finished as soon as the AS design done.

Vacuum system is under optimization



The Quad vacuum chamber must be integrated.
Vacuum components supporting, decoupling from AS & PETS are our current challenging tasks.

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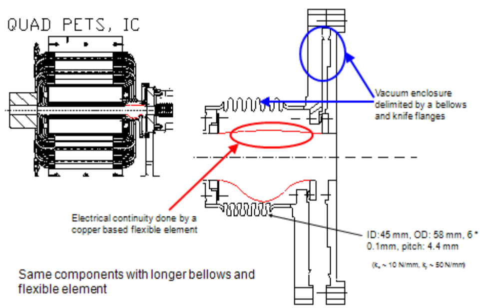
VACUUM INTERCONNECTIONS

Drive beam – QUAD/PETS intermodule interconnections



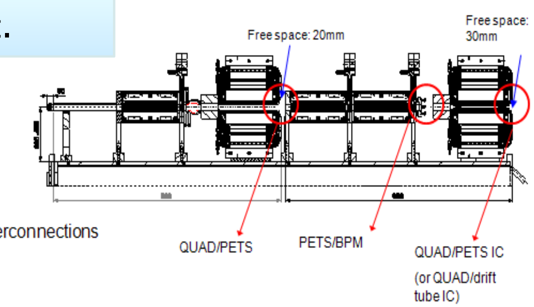
The MB and DB vacuum coupled via the common manifold and WG

The vacuum interconnections (intra-/inter-module):

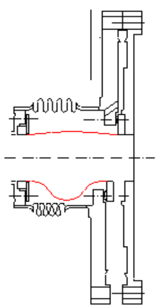
MB: non-contacting interconnects acceptable. Short range wake-fields essentially equal to an iris. Long range wake-fields need damping. (under optimization)

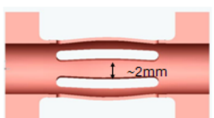
DB: good contact is necessary due to high current.

Interconnections - Drive beam



Drive beam – QUAD/PETS intramodule interconnections

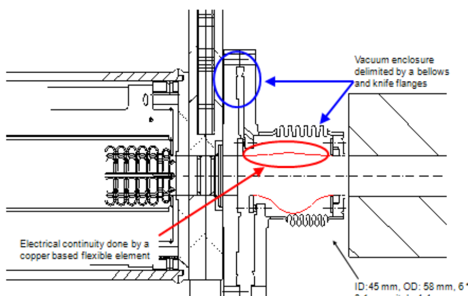




Schematic artistic view of the flexible element

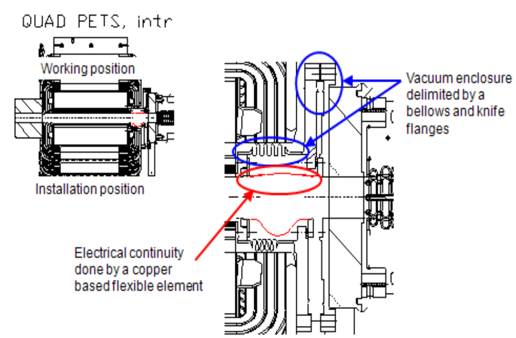
Thin foil (0.1mm) in copper based material

Drive beam –PETS/BPM intramodule interconnections

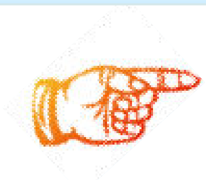


Same components as QUAD/PETS intermodule interconnections except flange on PETS side

Drive beam – QUAD/PETS intramodule interconnections



Concepts by C. Garion ready for detailed mechanical design study and implementation in the modules.



To be integrated ASAP

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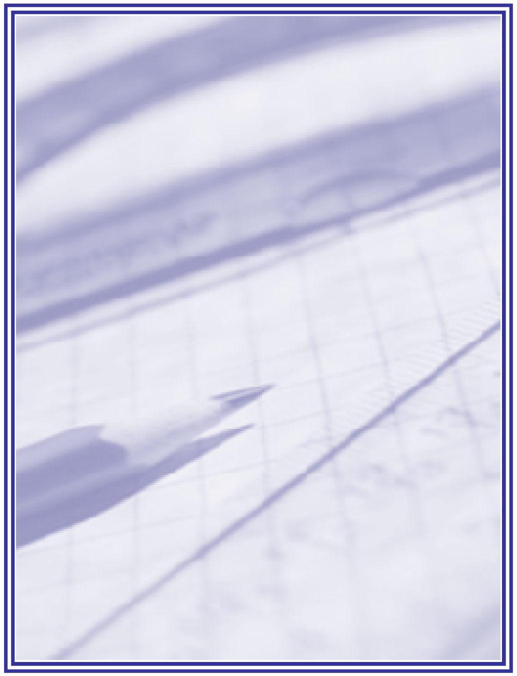

ALIGNMENT & STABILIZATION SYSTEM

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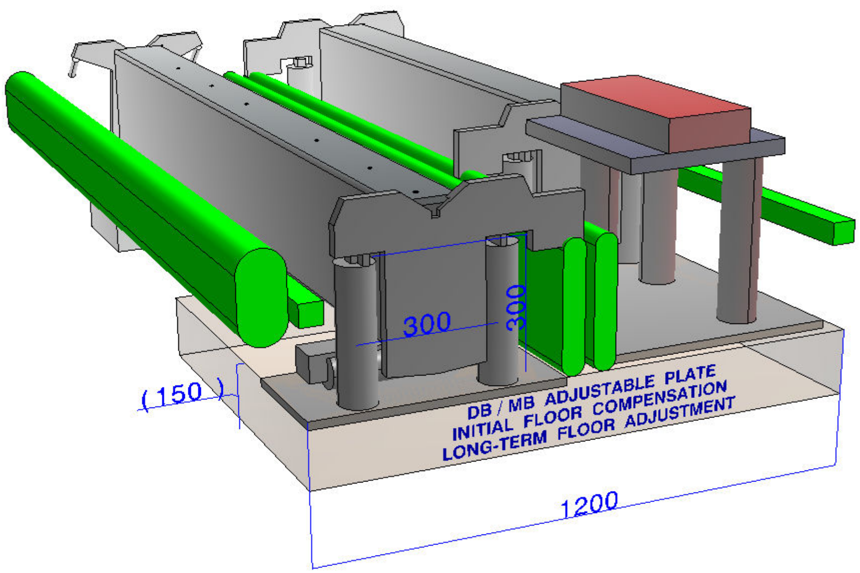
ALIGNMENT

Mechanical pre-alignment within ±0.1 mm (1s) → Active pre-alignment: within ± 10 µm (3s)
Concept: straight alignment reference over 20 km based on overlapping references

- AS and PETS pre-aligned on independent girders (mono-girder alternative is also considered)
- «Snake system», validated in CTF2. (Scaling needed due to higher load)
- MB Quad pre-aligned independently.

To be considered in integration:

- Integration of the pre-alignment system/s in the modules, ⇨ transport and installation
- Fiducialisation (design and tests)



Space reservation for the alignment equipment

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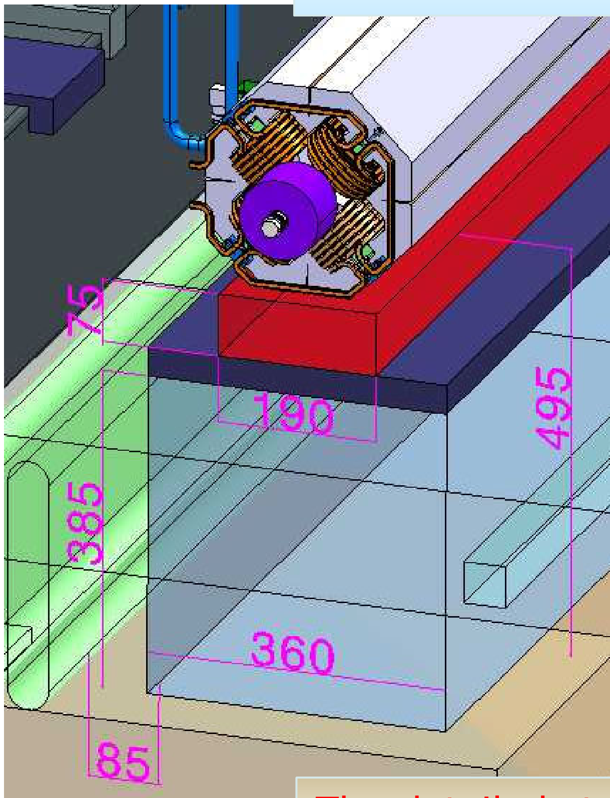
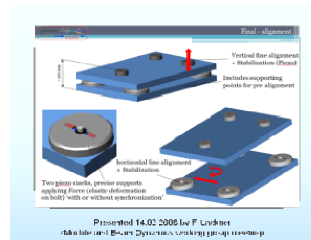
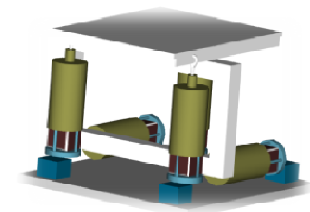
STABILIZATION

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







A proposal for the MB Quad fine alignment and stabilization has been suggested previously. Space is reserved accordingly. The problem is under study.

The detailed study of vibration from different kind of sources as well as the components modal behaviour must be accomplished before integration of the MB Quad stabilisation system in the module .

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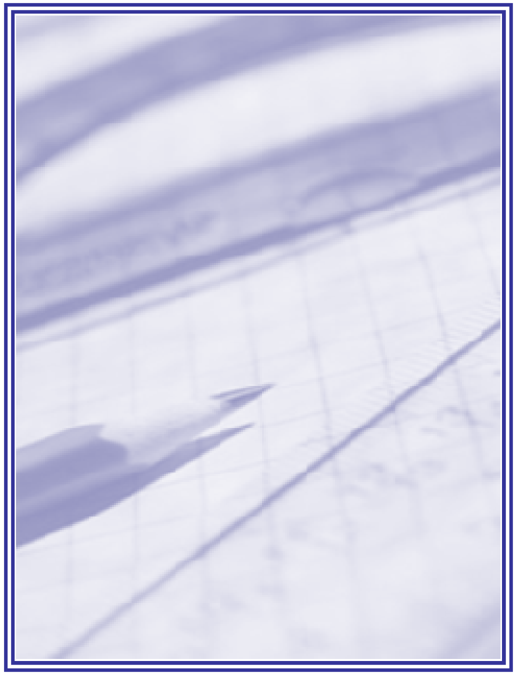

COOLING SYSTEM

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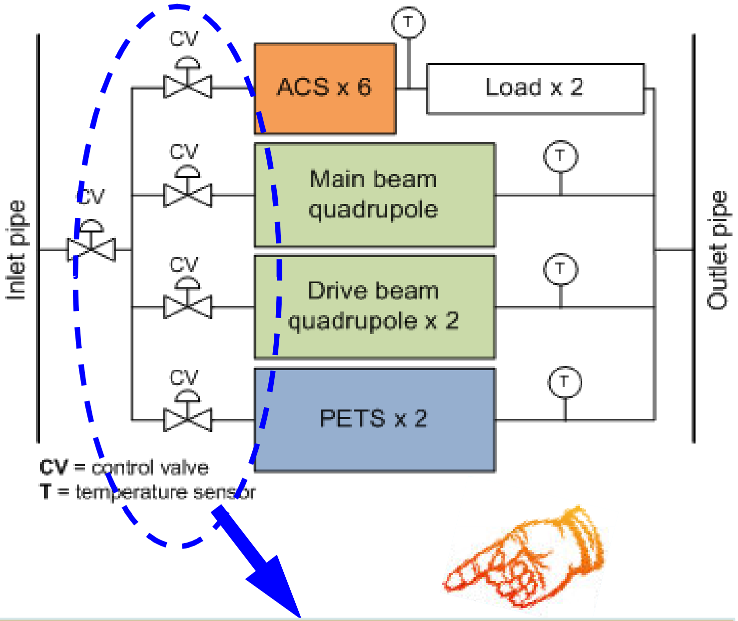
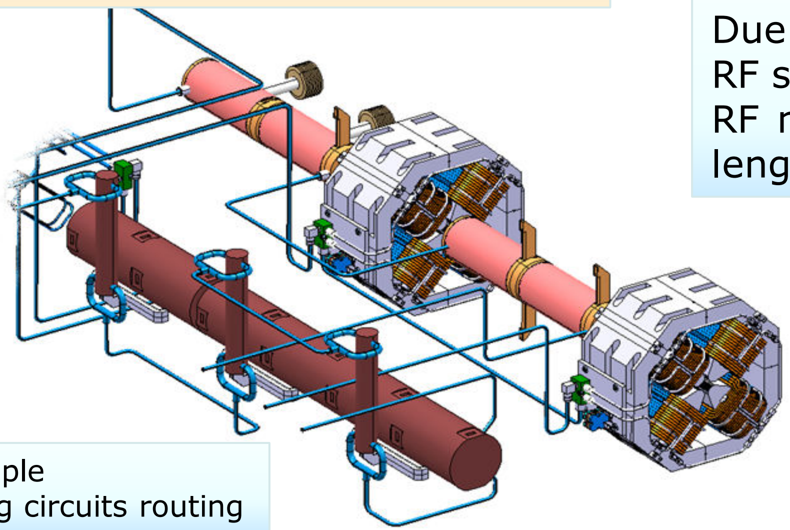
MODULE COOLING LAYOUT



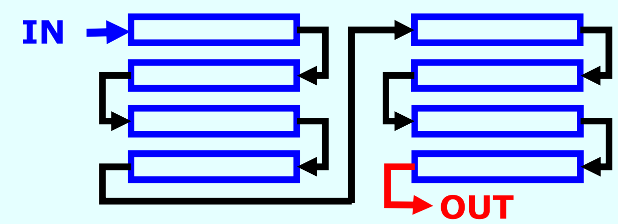
Valves still have to be integrated



An example of cooling circuits routing

- **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 300mm in length and Ø 50mm.



Baseline cooling scheme (Super-AS)

Due to high power dissipation:
RF structures and magnets are water cooled.
RF network must maintain its correct electrical length.

(RF network cooling to be confirmed)

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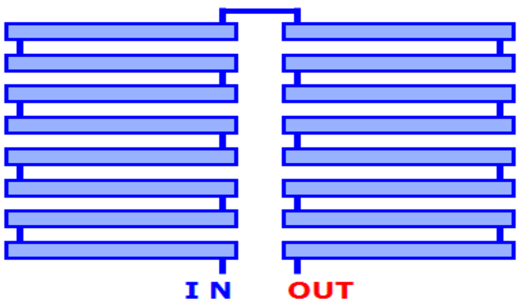
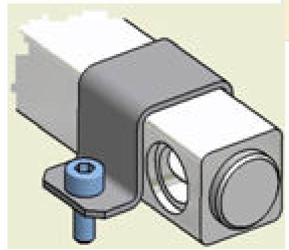
PETS COOLING

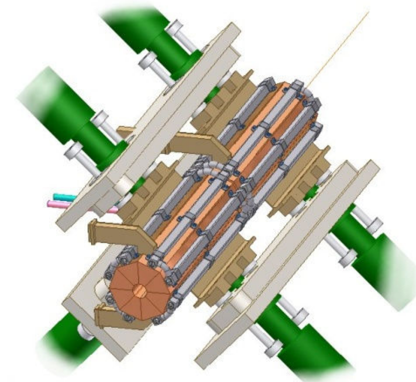
Baseline:
- cooling circuits external to PETS
- cooling of PETS in series

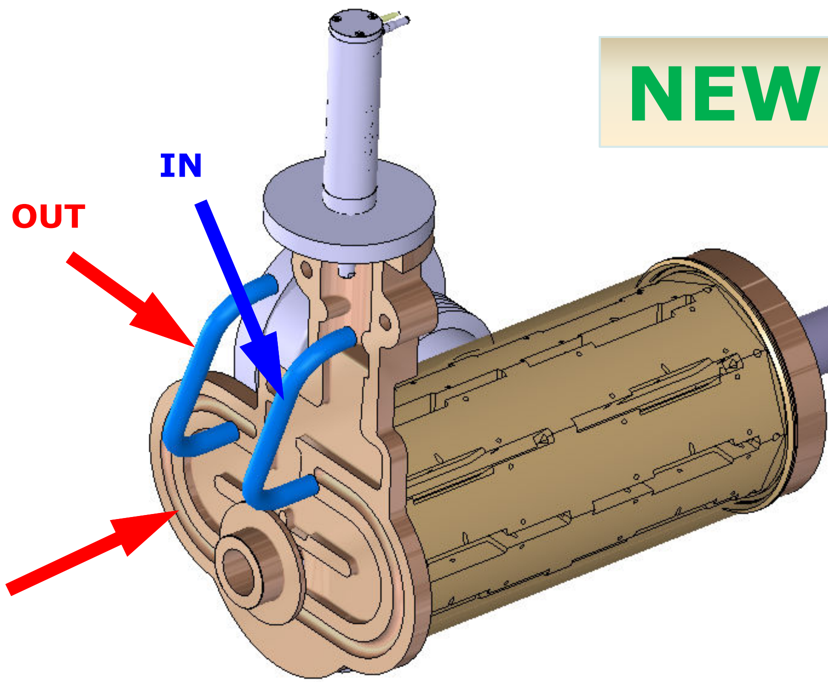




OLD

Forced convection cooling – circuits inside the vacuum tank, outside the octants





NEW

New cooling configuration

Cooling channel and tubes integrated into compact coupler.

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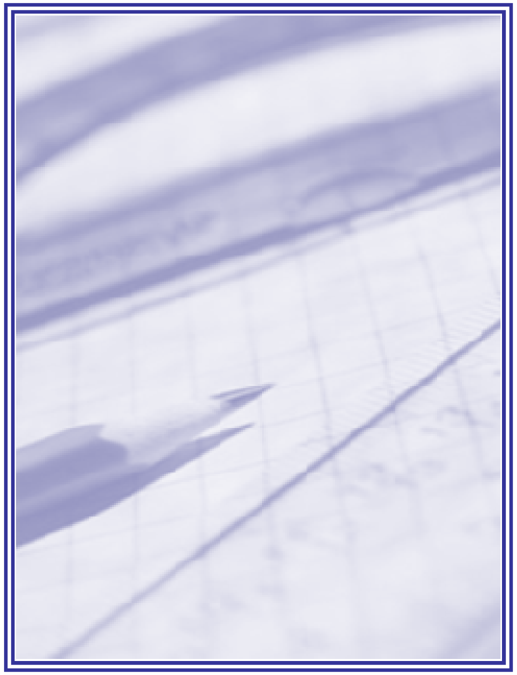

ASSEMBLY, TRANSPORT, INSTALLATION

MODULE TRANSPORT & INSTALLATION

The module assembly will be done on the surface. Each module has the cradles only on one end => the temporary support is needed. Strategy for Q modules to be agreed with SWG.

An agreed strategy (with CES WG) 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). The aim is to transport already interconnected modules.

The vertical interconnection plane between adjacent modules is included in integration requirements. (inter-girder connection: 30 mm)

The required space has been reserved for the alignment system. And we have to cross these zones during installation.

The lifting points still must be defined.

- The transport solution needs to be in compliance with systems' components.
- The test area must be compatible with transport and installation tests requirements.
- The transport and installation issues must be studied at the current design phase.

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CONCLUSIONS

- Integration of different systems in terms of space reservation has been finished.
- Detailed design started for the main systems.
- PETS concept is well advanced including the On-Off mechanism.
- AS layout is under way. Integration conditions are specified. The system is very complex for design and integration. This is due to necessity to have many systems attached to AS.
- Magnets dimensions should be confirmed soon.
- RF network is well advanced.
- PETS concept is well advanced including the On-Off mechanism.
- The detailed design for supporting system is needed for better understanding of integration issues.
- This is valid for the alignment and stabilization systems' components as well.
- The vacuum parts are defined, but the neighboring components give some restrictions. The optimization will be continued.
- The instrumentation components design would require more attention.
- Transport features to be studied and implemented.

Overview of the module systems now. Review in the nearest future (by Dec-2009).

Module baseline design definition by the end of Mar-2010.

CLIC modules in the lab from 2010

Test modules in CLEX from 2011

GRATITUDE

I am very much obliged
to each system responsible
and all collaborators
for their contribution & cooperation !

THANK

YOU !

THE END

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EXTRA SLIDES

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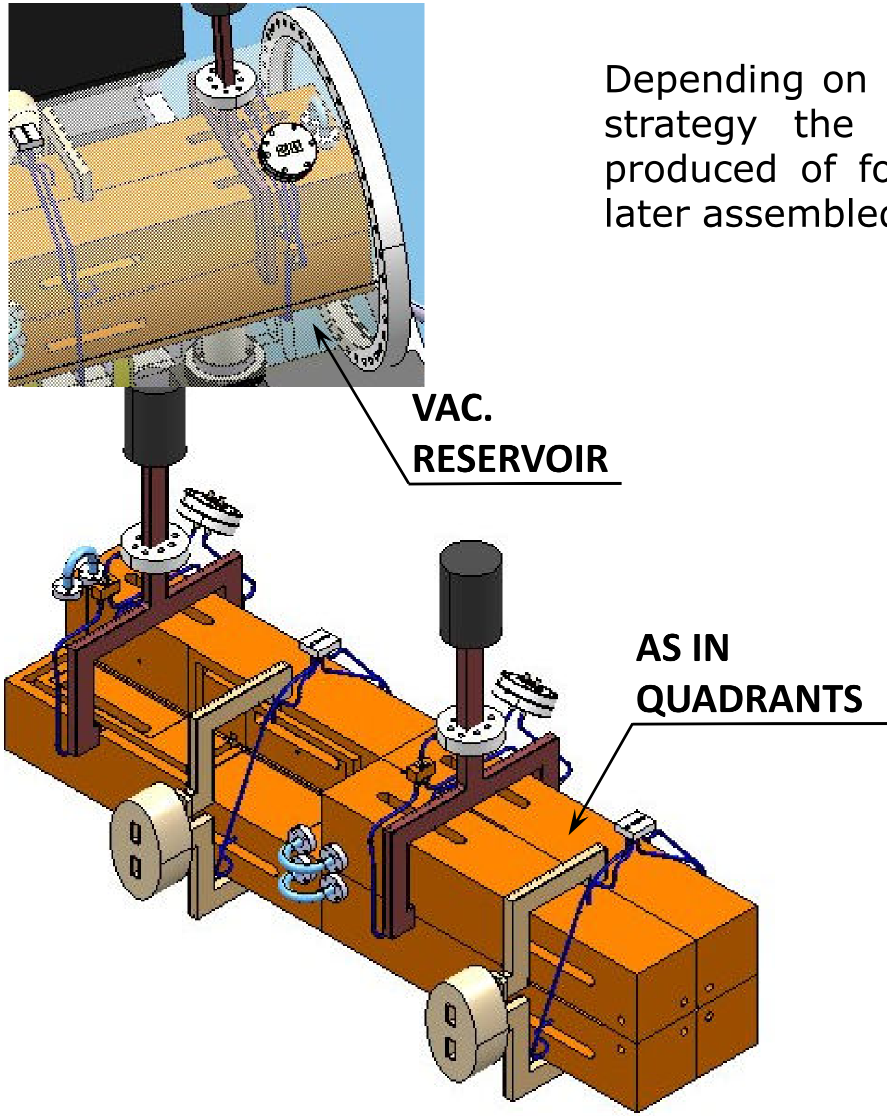
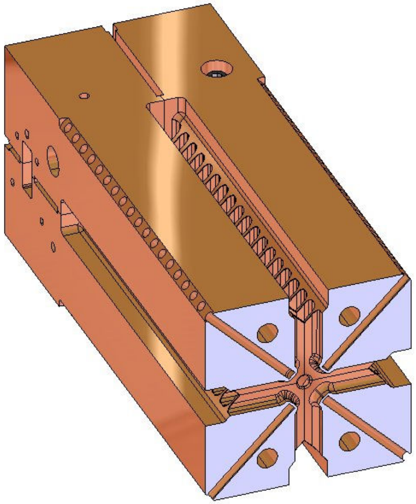
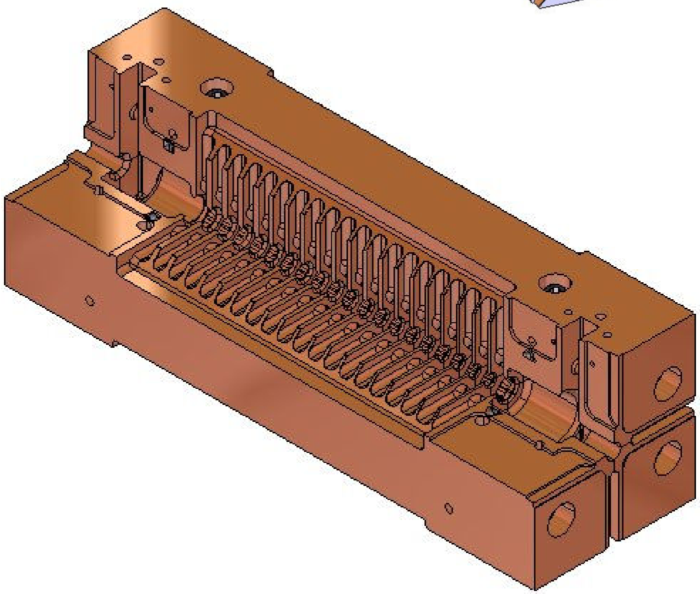
AS (ALTERNATIVE)



Depending on manufacturing strategy the AS could be produced of four quadrants, later assembled together.





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TEST MODULES INTEGRATION STUDY