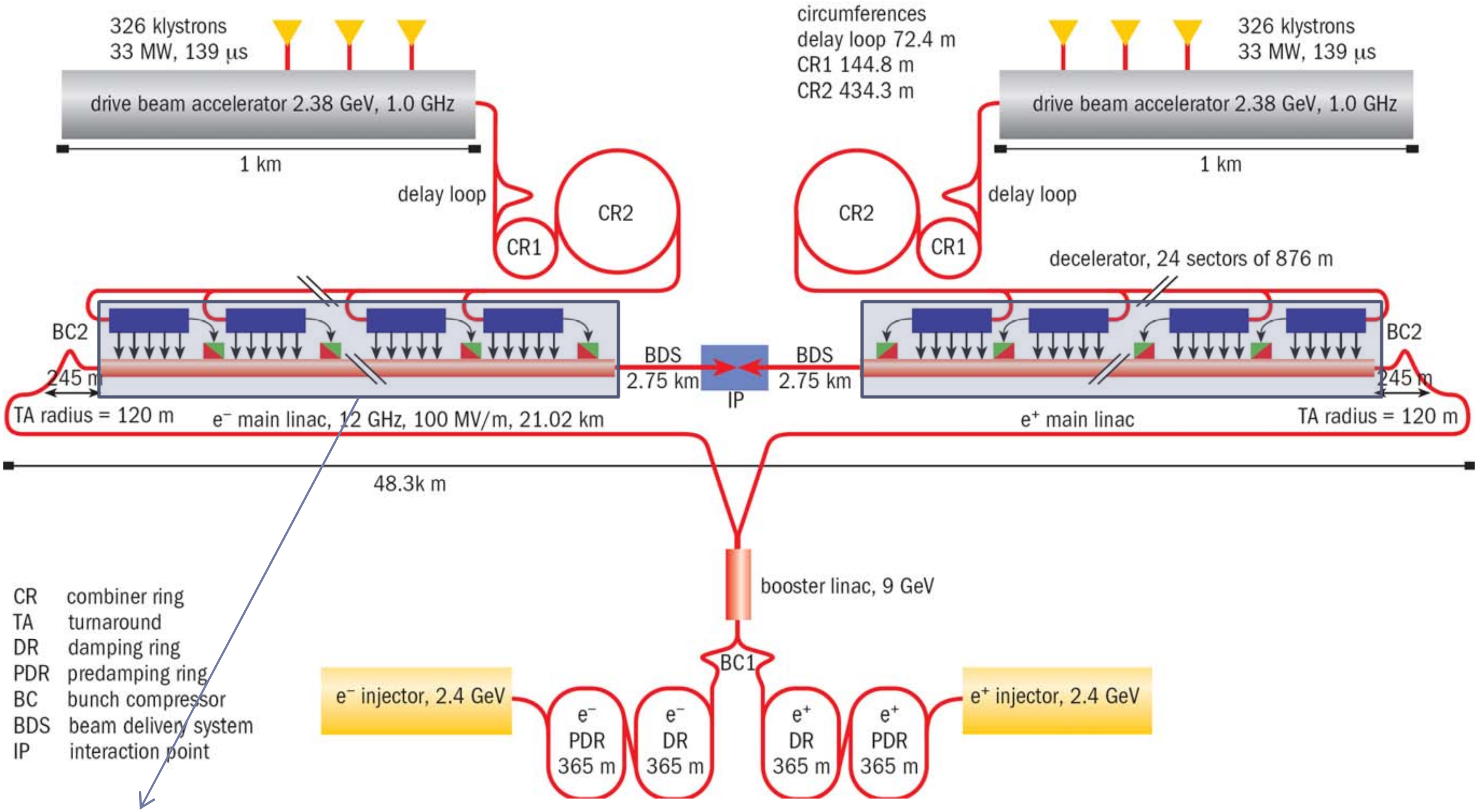
4th CLIC Advisory Committee (CLIC-ACE), May 26-28, 2009

CLIC two-beam module integration issues

G. Riddone on behalf of the CMWG, 27.05.2009

Content

CLIC Layout @ 3TeV



CR	combiner ring
TA	turnaround
DR	damping ring
PDR	predamping ring
BC	bunch compressor
BDS	beam delivery system
IP	interaction point

Per linac:

Module: 10460

Accelerating structures: 71406

PETS: 35703

MB quadrupoles: 1996

DB quadrupoles: 20920

What is the two-beam module?

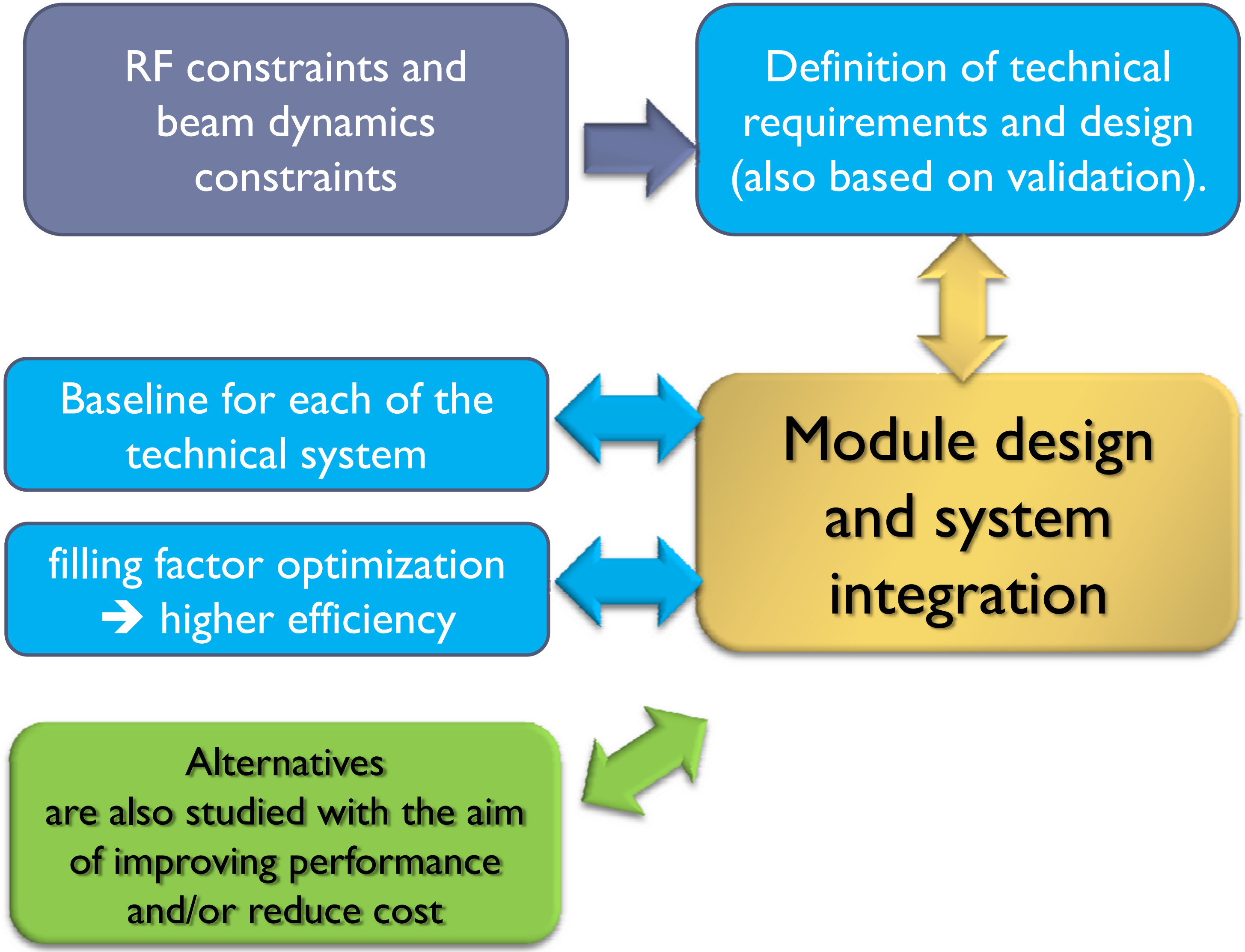
Two-beam module (main + drive beams)

- RF system
  - Accelerating structures
  - PETS
- Vacuum system
- Beam instrumentation system
  - BPM
  - WFM
- Cooling system
- Magnet system
  - MB quadrupoles
  - DB quadrupoles
- Magnet power system
- Supporting system
- Alignment system
- Stabilization system
- Beam feedback system
- Assembly , Transport and Installation

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

Strong interaction with:
- Beam physics WG (stabilization/alignment)
- CES WG (tunnel integration)
- MPO WG (cooling system)
- C&S WG (major cost driver)

Module Baseline Definition



RF constraints and beam dynamics constraints

Definition of technical requirements and design (also based on validation).

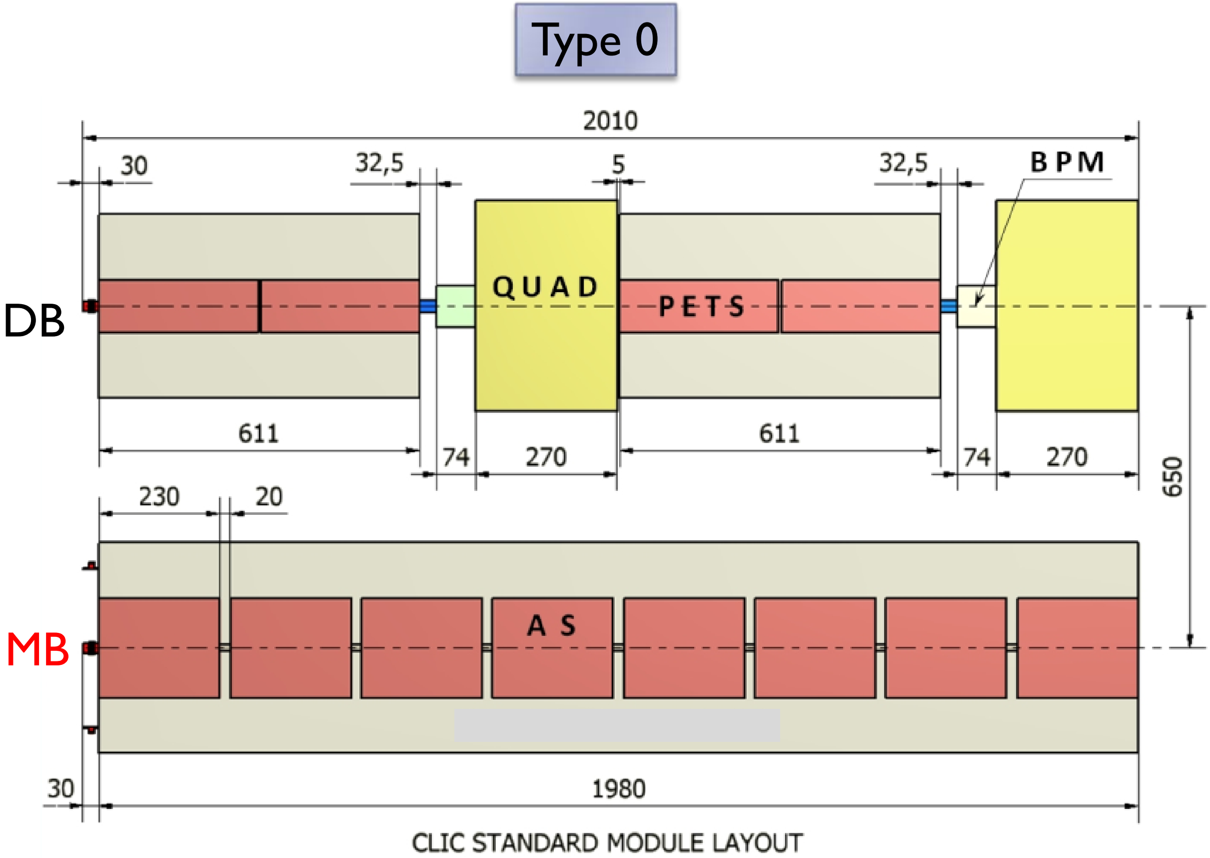
Baseline for each of the technical system

filling factor optimization → higher efficiency

Module design and system integration

Alternatives are also studied with the aim of improving performance and/or reduce cost

Module types and numbers



CLIC STANDARD MODULE LAYOUT

Total per module

8 accelerating structures

8 wakefield monitors

4 PETS

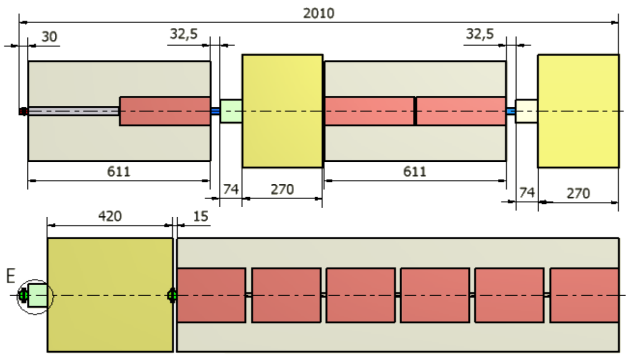
2 DB quadrupoles

2 DB BPM

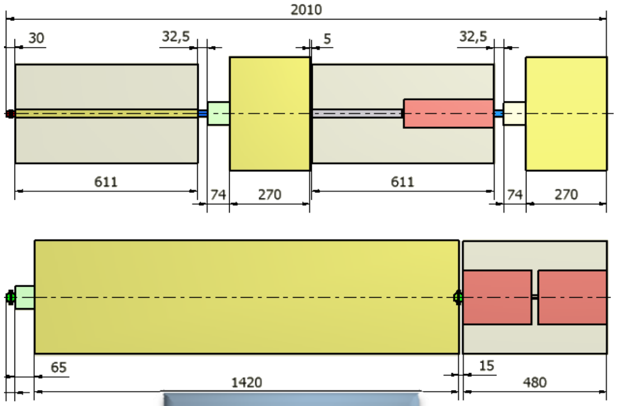
Total per linac

8374 standard modules

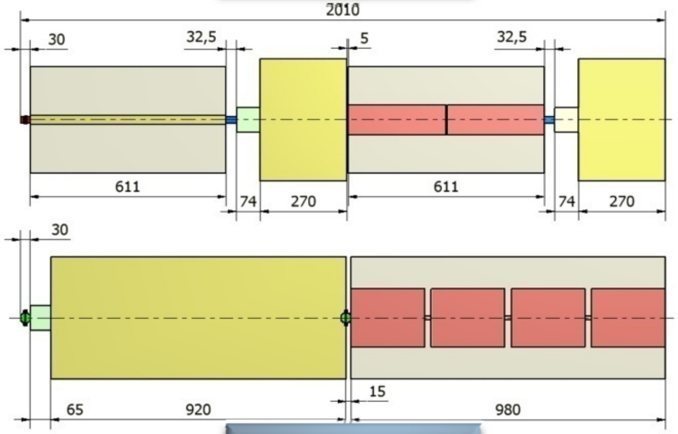
Module types and numbers



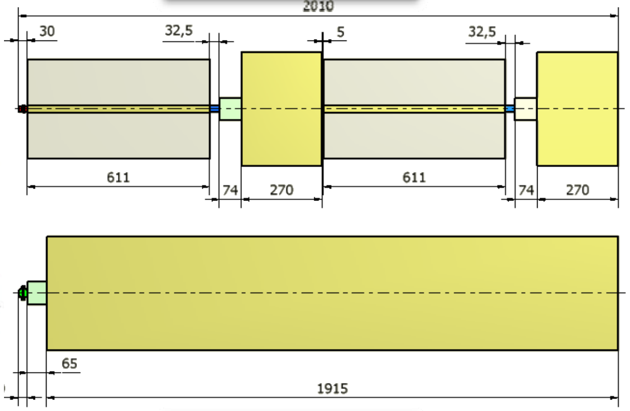
Type 1



Type 3



Type 2



Type 4

Total per linac

Quadrupole type 1: 154

Quadrupole type 2: 634

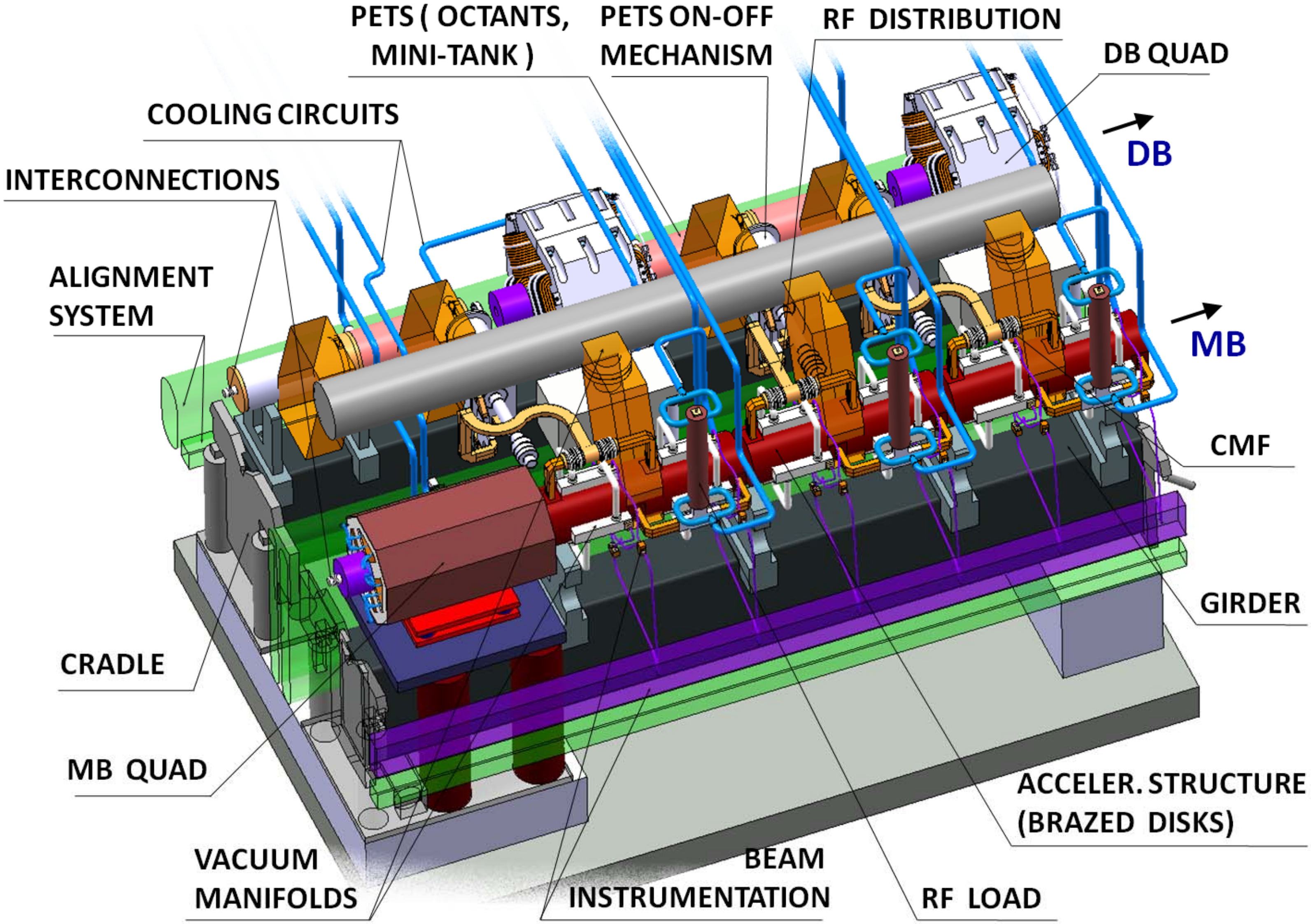
Quadrupole type 3: 477

Quadrupole type 4: 731

Other modules

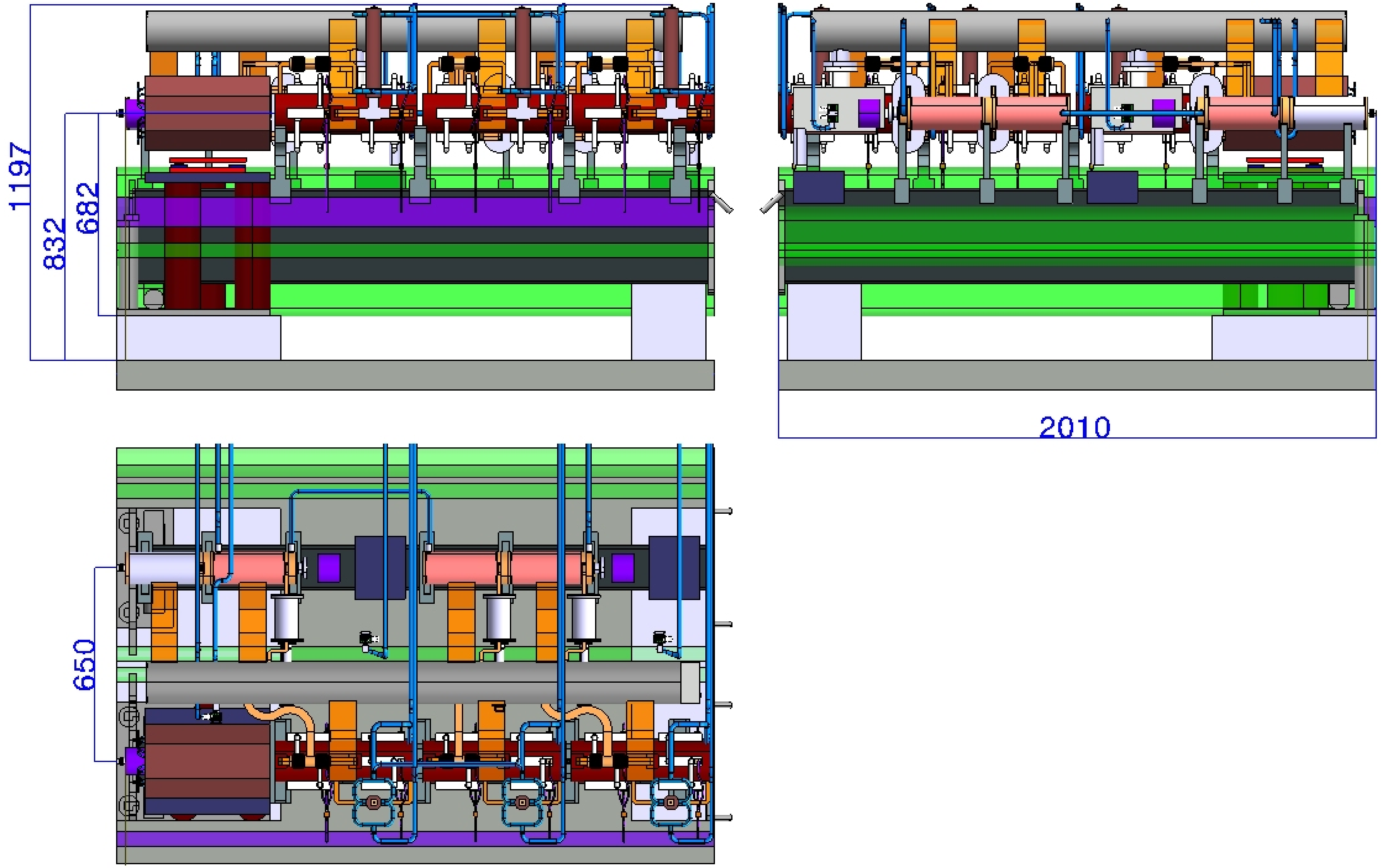
- modules in the damping region (no structures)
- modules with dedicated instrumentation
- modules with dedicated vacuum equipment
- …

Module type 1



All 3D models made by A. Samoshkin

Module type 1 views



Requirements and baseline

Some requirements

- accelerating structure pre-alignment transverse tolerance 14 um at 1σ
  (shape accuracy for acc. structures: 5 um)
- PETS pre-alignment transverse tolerance 30 um at 1σ
  (shape accuracy for PETS: 15 um)
- Main beam quadrupole:
  - Pre-alignment transverse tolerance 17 um at 1σ
  - Stabilization (values at 1σ):
    - 1 nm > 1 Hz in vertical direction
    - 5 nm > 1 Hz in horizontal direction

Temperature stabilization for any operation mode is an important issue

- Module power dissipation : 7.7 kW (average)
  (~ 600 W per ac. structure)
- Vacuum requirement: few nTorr

Requirements and baseline

Baseline

- Accelerating structure: CLIC G (100 mV/m, L = 230 mm, aperture ~ 5 mm)
- PETS: CLIC note 764 (6.5 MV/m, L=310 mm, aperture 23 mm)
- 1 PETS powering 2 accelerating structures

- Accelerating structures and PETS + DB Q on girders
- Girder end supports ➔ cradles mechanically attached to a girder and linked by rods to the adjacent one: **snake-system adopted** (*DB: 100 A, MB: minimization of wakefields,* validation at 30 GHz in CTF2)
- Separate girders for main and drive beam ➔ possibility to align DB quadrupole separate from accelerating structures
- Separate support for MB Q and its BPM
- MB Q and BPM rigidly mechanically connected
- Common actuators/devices for stabilization and beam-based feedback systems

Interaction among technical systems

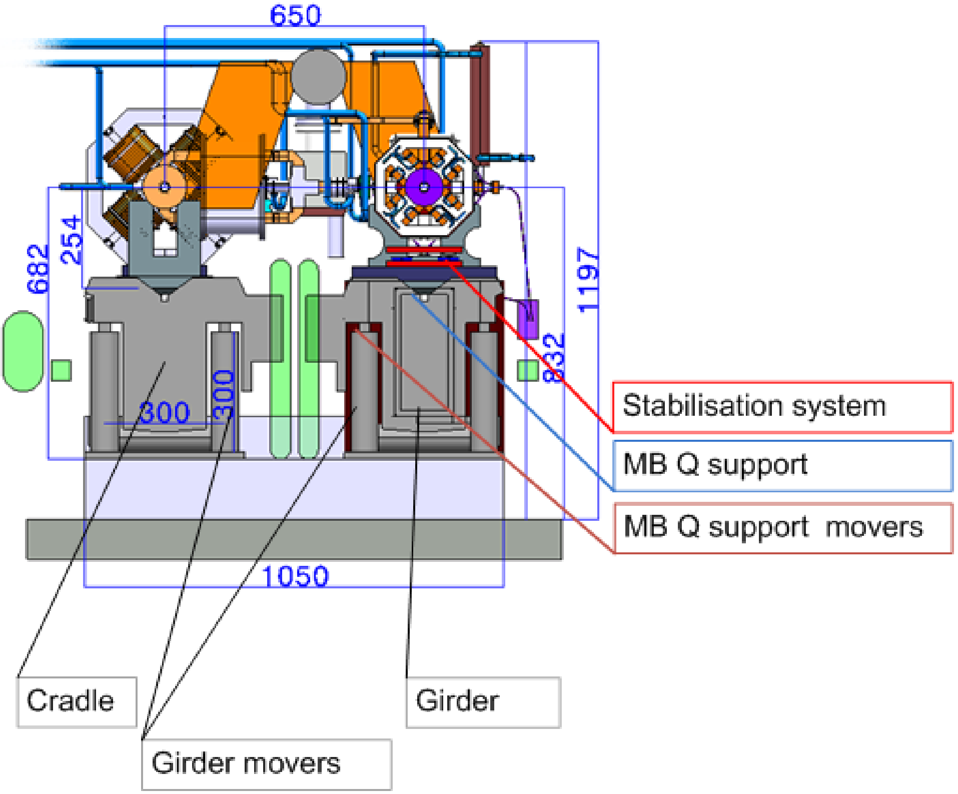
- Technical system design is not an isolated activity, as boundary conditions shall be defined together with other systems and module integration

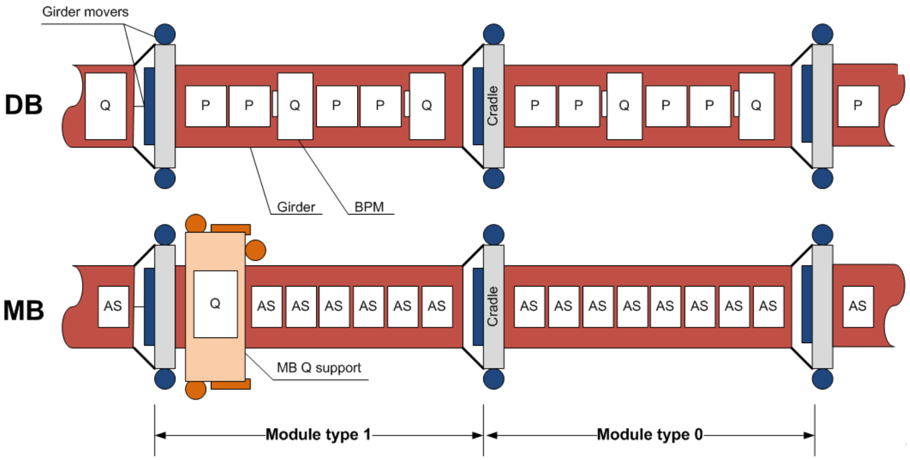
Some examples

- supporting system ⇒ to be compatible with cooling, alignment and stabilization systems
  - compatibility of MB Q supporting system design with stabilization and alignment ⇒ coupling between girders, coupling of stabilization with beam-based feedback,…
- quadrupople design ⇒ to be compatible with stabilization system (stabilization of the magnetic axis) and BPM design
- cooling system ⇒ to be compatible with RF requirements as well as supporting and stabilization system (cooling induced vibrations)
- vacuum system ⇒ to be compatible with RF requirements

Integration of supporting, alignment and stabilization

CTF2





Continuity between girders

All MB girders have the same length

MB Q support passes over the MB girder

MB Q beam pipe and AS beam pipe are coupled via bellows

Quadrupole support (alternative)

No full continuity between MB girders (increasing of align. cost)

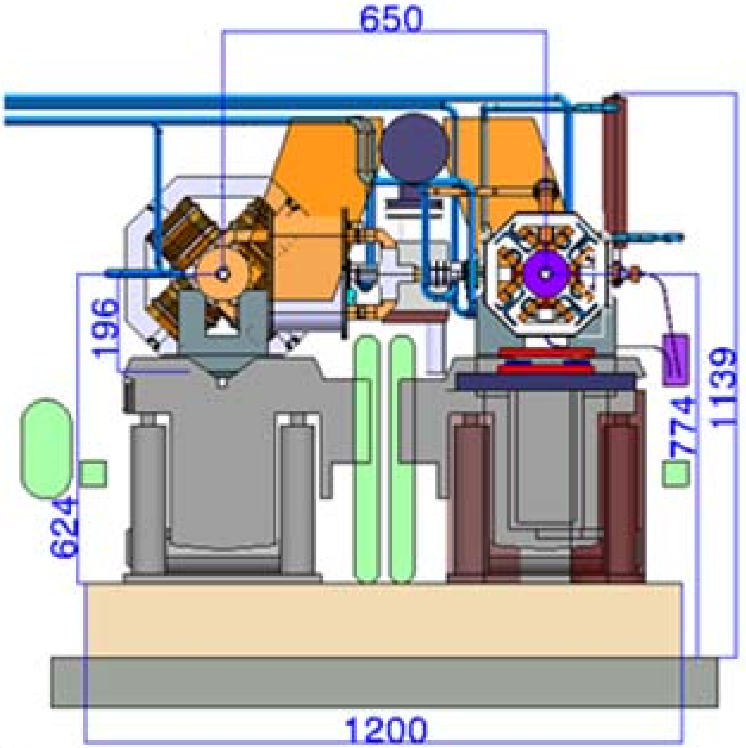
MB girder length changes as function of module type

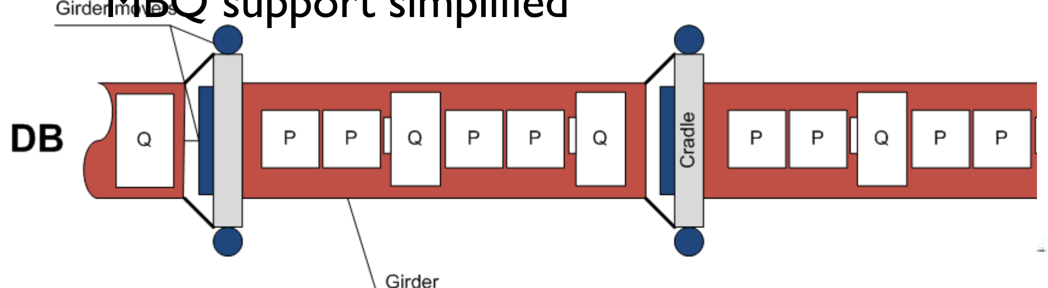
Beam height lowered

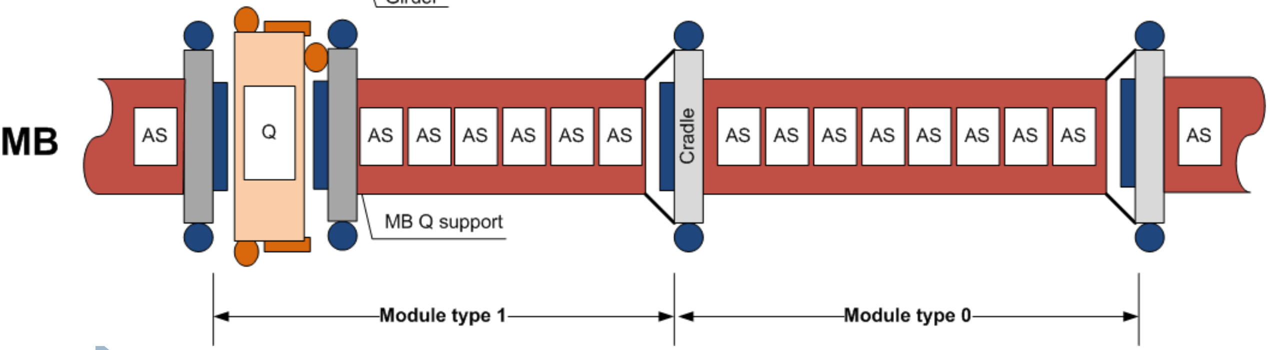
MB Q beam pipe and AS beam pipe are coupled via bellows

No girder underneath MB Q

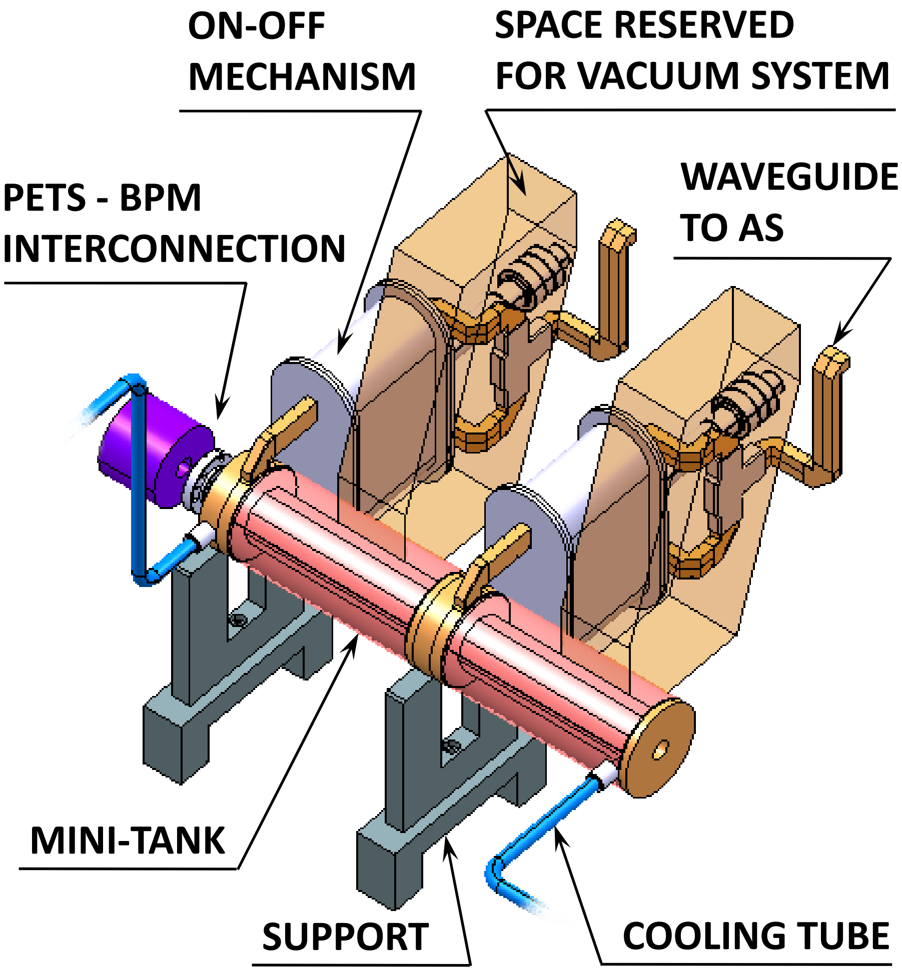
MBQ support simplified





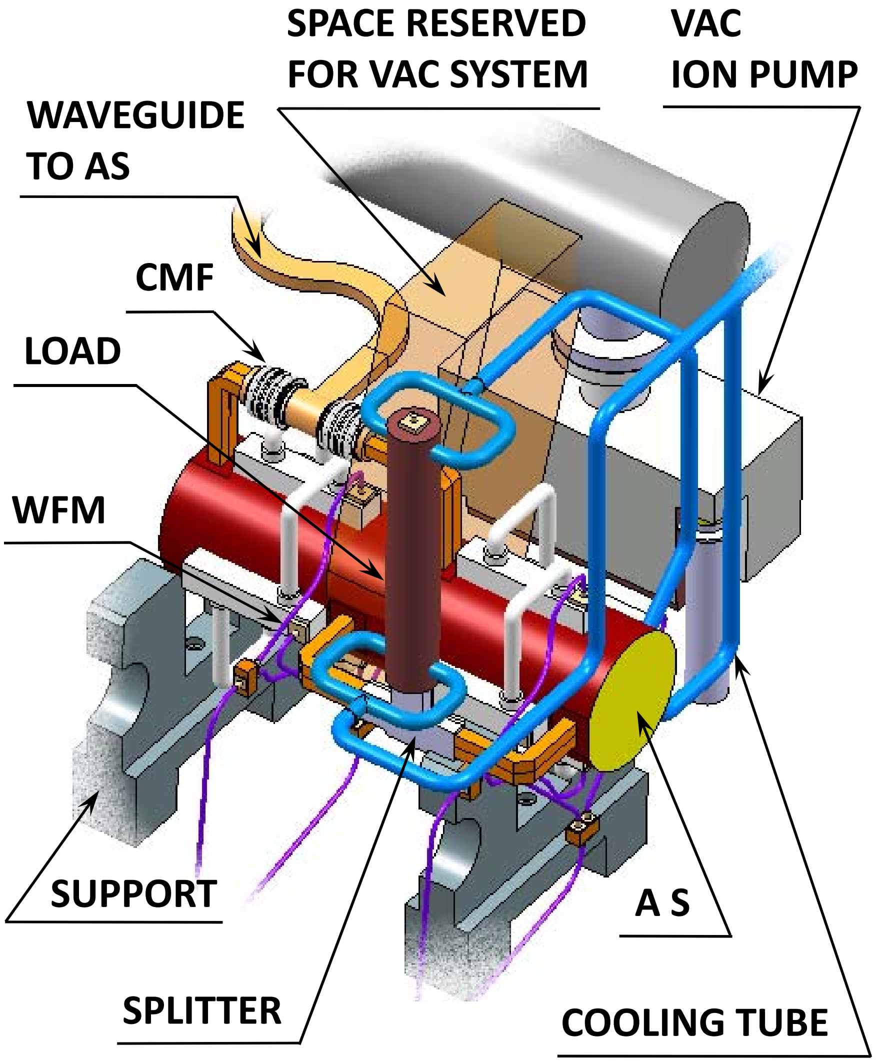


PETS and accelerating structures



- PETS (CLIC note 764)
  - Structure (8 octants) with "compact" couplers
  - Minitank for structure
  - On-off mechanism (20 msec OFF, 20 sec ON)
  - Cooling circuits (size for 1% beam loss)
  - Vacuum system
  - Interconnection to BPM
  - Minitank support

PETS and accelerating structures

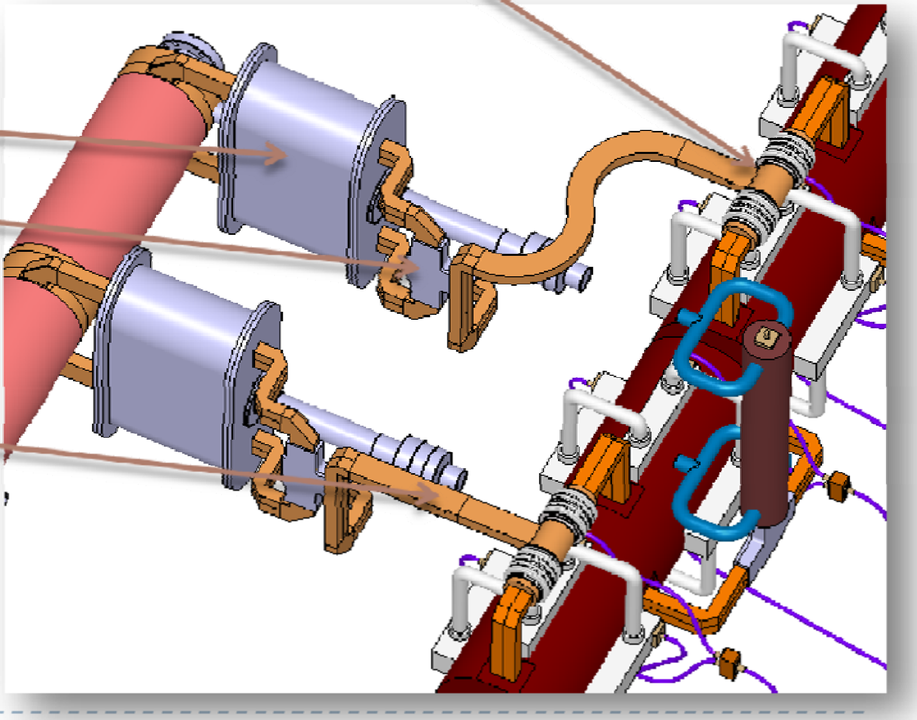


- Acc. structure (CLIC G, D: 140 mm)
  - Structure (brazed disks) with “compact” coupler
  - Wakefield monitor (1 per AS)
  - Cooling circuits
  - Vacuum system
  - Interconnection to MB Q
  - Structure support
  - Output waveguide with RF components (eg. loads)

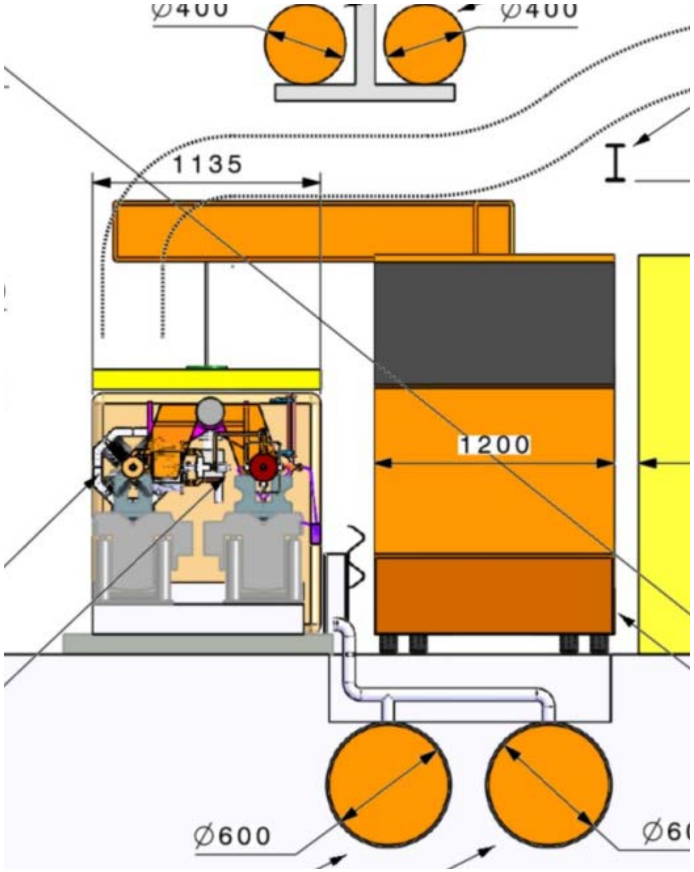
RF distribution network (from PETS to AS)

- Beam axis: 650 mm

- PETS and accelerating structures are connected via waveguides and choke mode flanges to guarantee flexibility ➔ choke mode flanges allows the power transmission without electrical contact between waveguides. This device shall be flexible in order to permit independent alignment of two waveguides.
- PETS on-off mechanism and RF components to be integrated
- Waveguide length optimization and routing based on losses, phase advance and RF to beam timing considerations



Tunnel integration



Study in collaboration with CES WG

Module design has a strong impact on tunnel dimensions

Transport and installation have to be considered in the early stage of the design

The principle of overhead lifting and vertical lowering fits with the tunnel integration (including survey space reservation)

Clear interconnection plane requirement is being included in module integration design work ➔ space for inter-girder connection: 30 mm

Transport restraints and lift points have started to be considered in module integration design work

Some milestones

- Module review scheduled in sep 2009:
  - Present the integration issues
  - Review the baseline design for technical systems
  - Stimulate work on alternative design for selected technical systems
  - Identify the necessary R&D and engineering efforts for the completion of the CDR possibly prepare milestone, cost estimate, manpower requirements
- CLIC workshop (oct 2009): recommendations from the module review will be reported together with the action plan
- Module baseline design: ready for CDR (mid 2010)

- Test modules in CLEX (2009-2013) [includes FP7 activities]: design, procurement and testing of "quasi" CLIC Modules: first module ready in 2011

Conclusions

- The Module WG is a forum where technical experts meet and exchange their requirements and technical solutions
- Interaction with several other working groups is mandatory (such as beam physics, CES, cost and schedule)

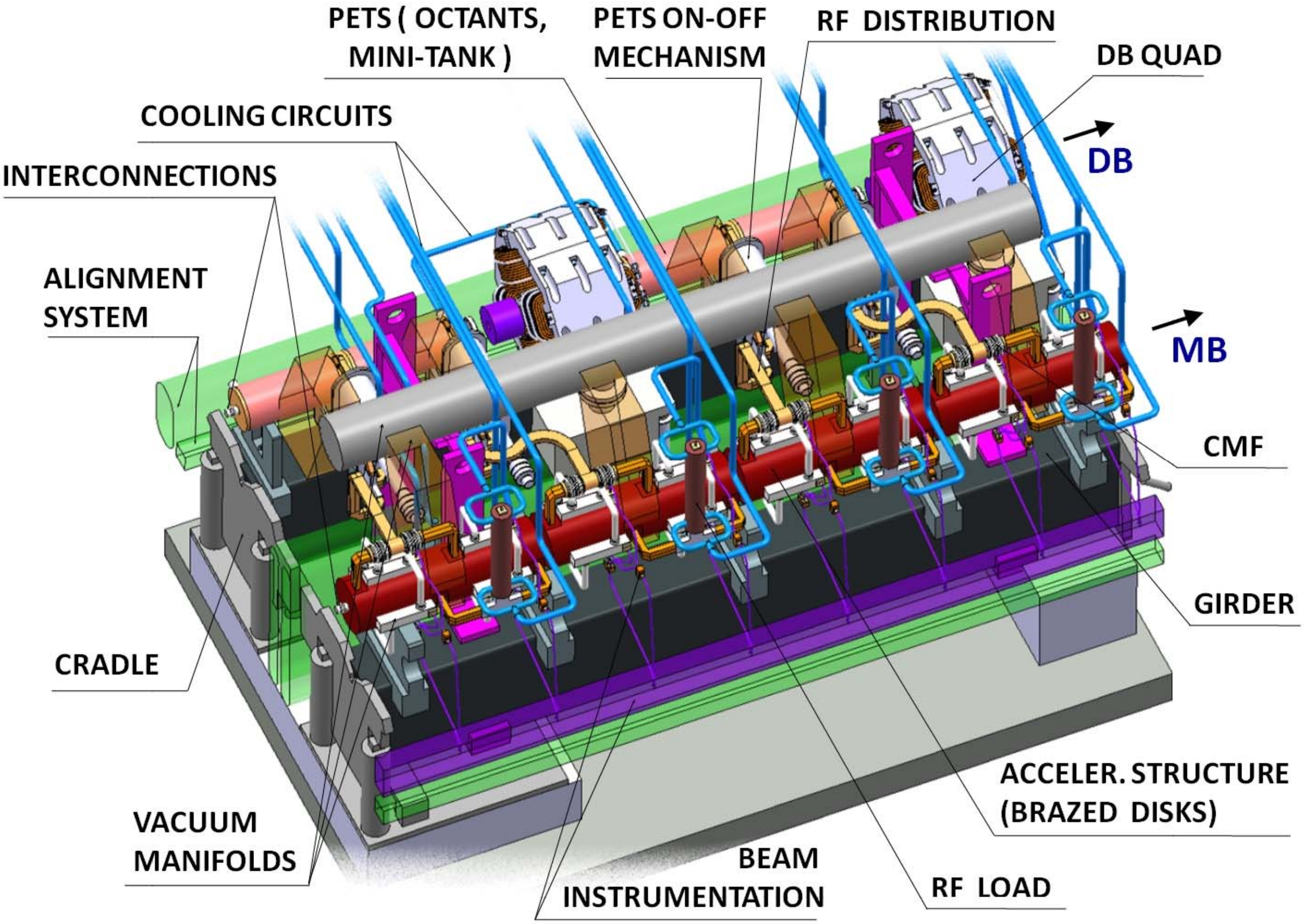
- Module design and integration evolves in parallel to the definition of technical system (some of them being part of the list of critical items, such as high-power rf structure) and specifies their boundary conditions and some of basic parameters
- The Module allows for identifying areas needing dedicated study and design

- For each technical system, a baseline is being defined and will be reviewed at the module review.
- Some integration issues:
  - Supporting/alignment/stabilisation systems
  - Structures with all technical systems
  - Interconnections (beam-beam, inter-girder, intra-girder)
- Module thermo-mechanical behavior under all operation conditions has to be simulated (expected first results for the module review)
  -
- 21 km x 2 are filled with modules ➔ major cost driver

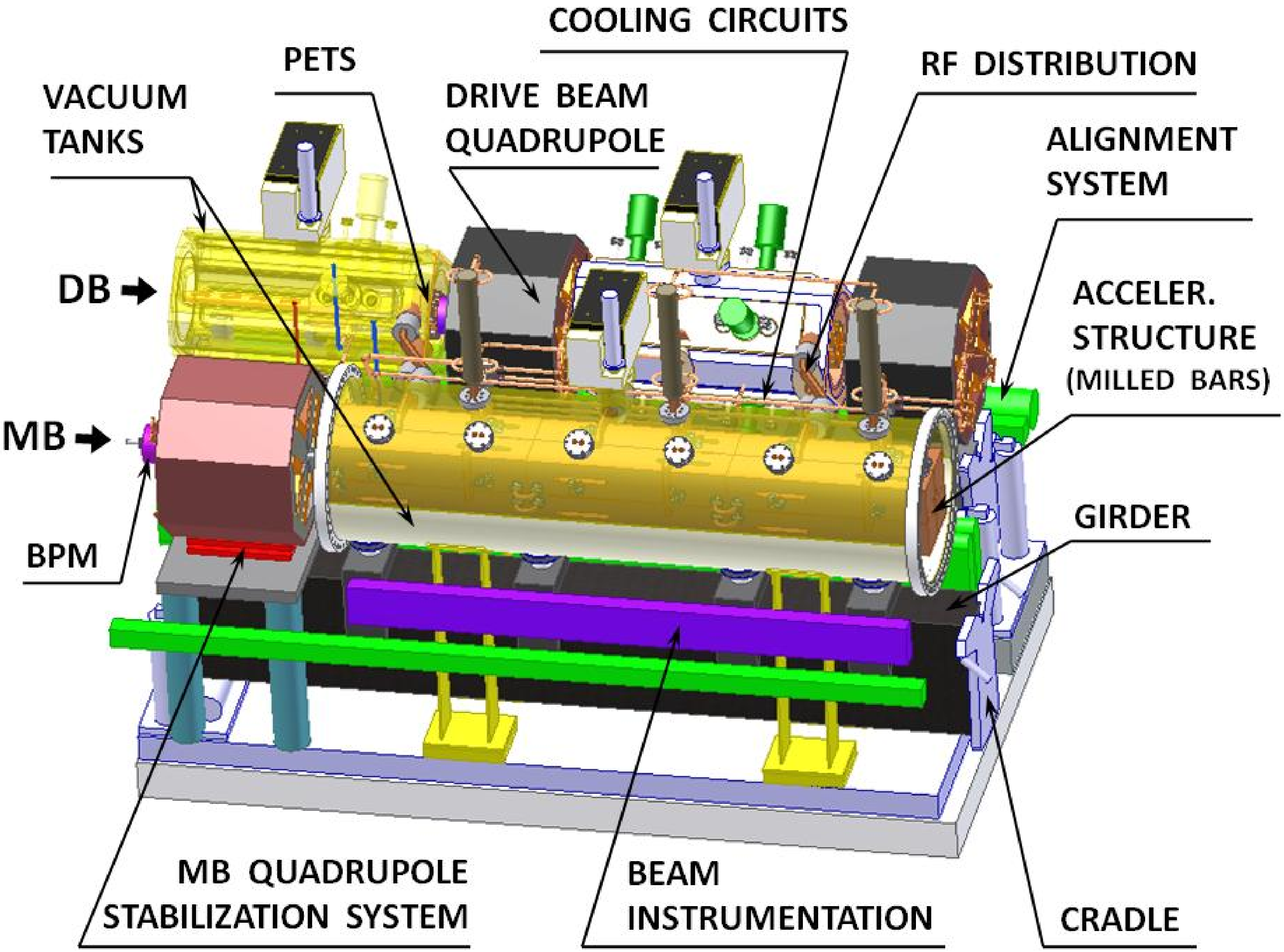
- We are really confident we will have the baseline module design ready or the CDR

EXTRA SLIDES

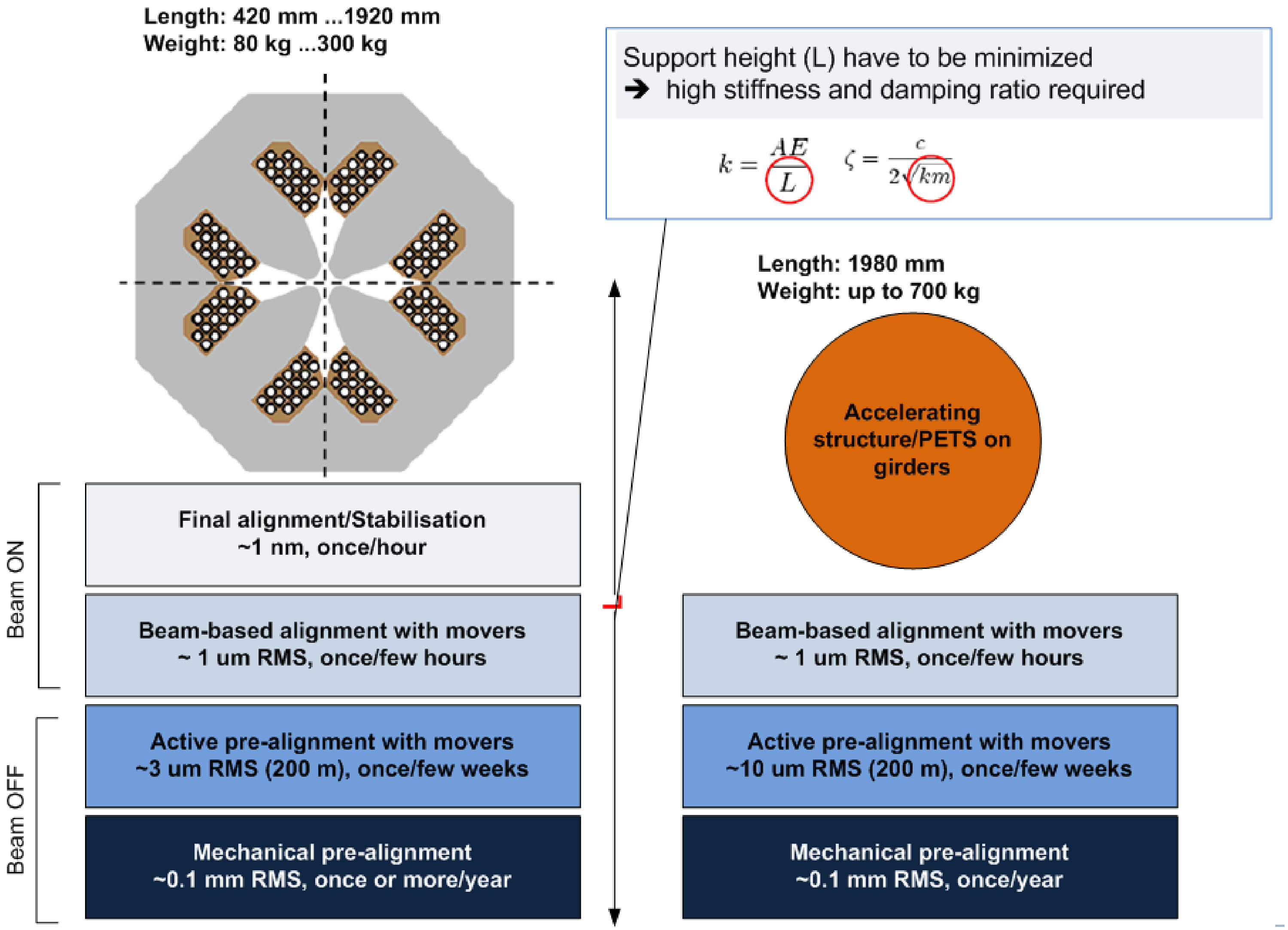
Module type 0



Module with tank configuration



Integration of alignment, stabilisation and feedback systems



Length: 420 mm ...1920 mm
Weight: 80 kg ...300 kg

Support height (L) have to be minimized
➔ high stiffness and damping ratio required

$$k = \frac{AE}{L} \qquad \zeta = \frac{c}{2\sqrt{km}}$$

Length: 1980 mm
Weight: up to 700 kg

Accelerating structure/PETS on girders

Final alignment/Stabilisation
~1 nm, once/hour

Beam-based alignment with movers
~ 1 um RMS, once/few hours

Active pre-alignment with movers
~3 um RMS (200 m), once/few weeks

Mechanical pre-alignment
~0.1 mm RMS, once or more/year

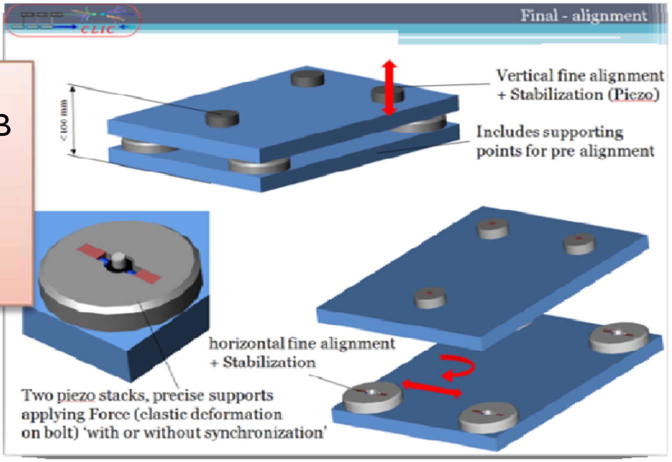
Beam-based alignment with movers
~ 1 um RMS, once/few hours

Active pre-alignment with movers
~10 um RMS (200 m), once/few weeks

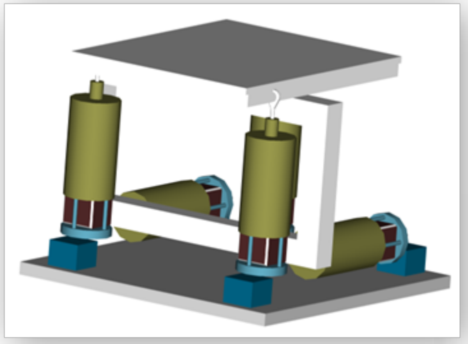
Mechanical pre-alignment
~0.1 mm RMS, once/year

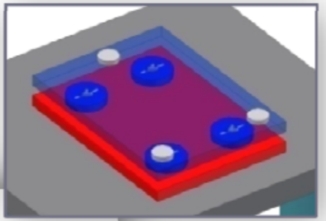
Stabilization (present config.)

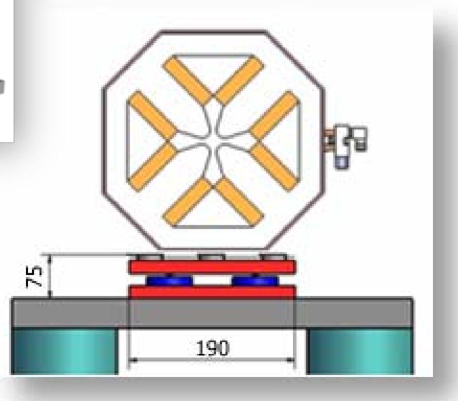
A possible solution for MB quad fine alignment and stabilization.



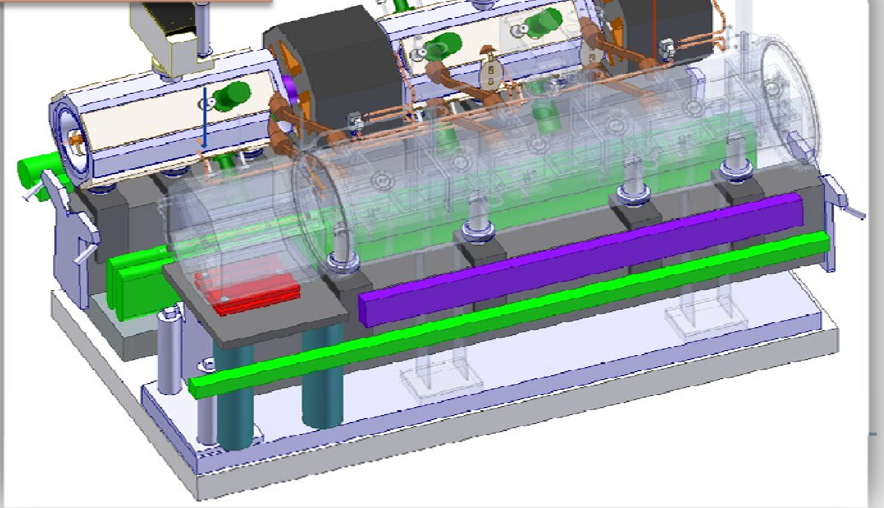
Presented 14.02.2008 by F. Lackner
(Module and Beam Dynamics working group meeting)

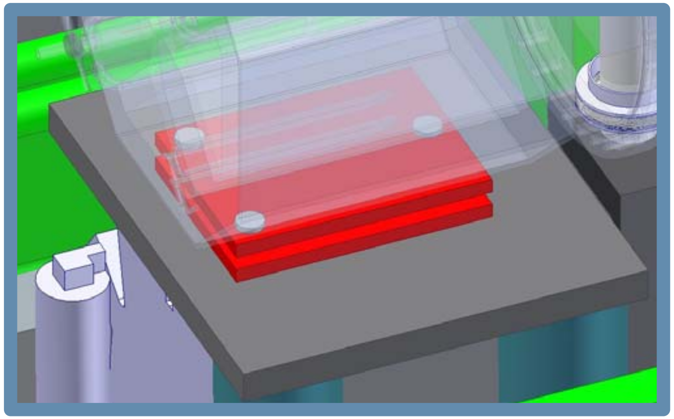






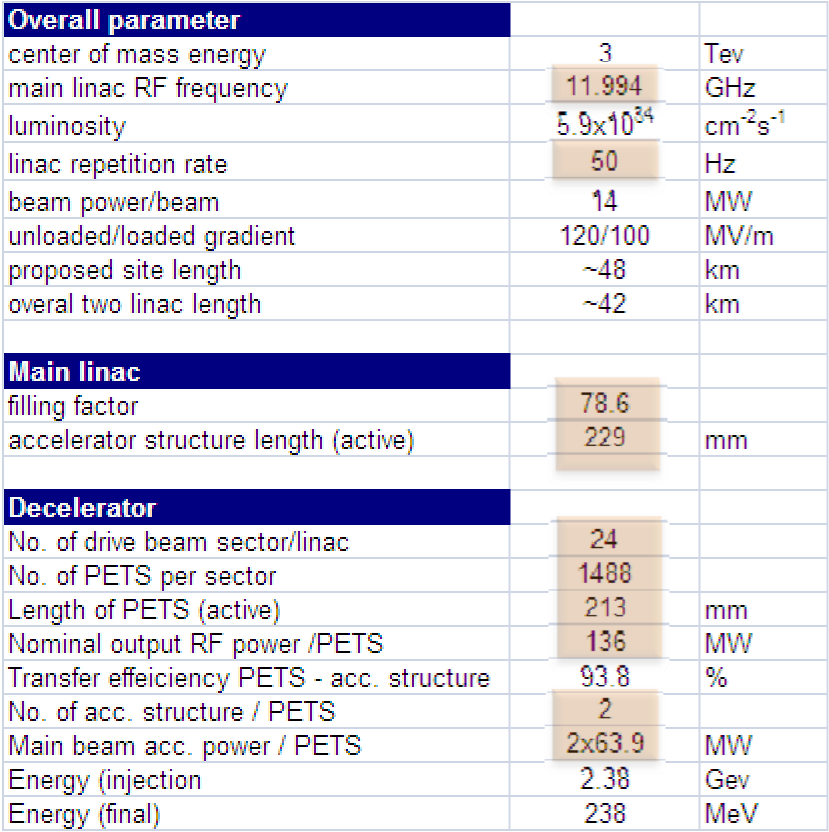
Integration of MB Quad support.





CLIC module relevant parameters

Module design based on latest CLIC parameters



Overall parameter		
center of mass energy	3	Tev
main linac RF frequency	11.994	GHz
luminosity	$5.9x10^{34}$	cm^{-2}s^{-1}
linac repetition rate	50	Hz
beam power/beam	14	MW
unloaded/loaded gradient	120/100	MV/m
proposed site length	~48	km
overal two linac length	~42	km
Main linac		
filling factor	78.6	
accelerator structure length (active)	229	mm
Decelerator		
No. of drive beam sector/linac	24	
No. of PETS per sector	1488	
Length of PETS (active)	213	mm
Nominal output RF power /PETS	136	MW
Transfer effeiciency PETS - acc. structure	93.8	%
No. of acc. structure / PETS	2	
Main beam acc. power / PETS	2x63.9	MW
Energy (injection	2.38	Gev
Energy (final)	238	MeV

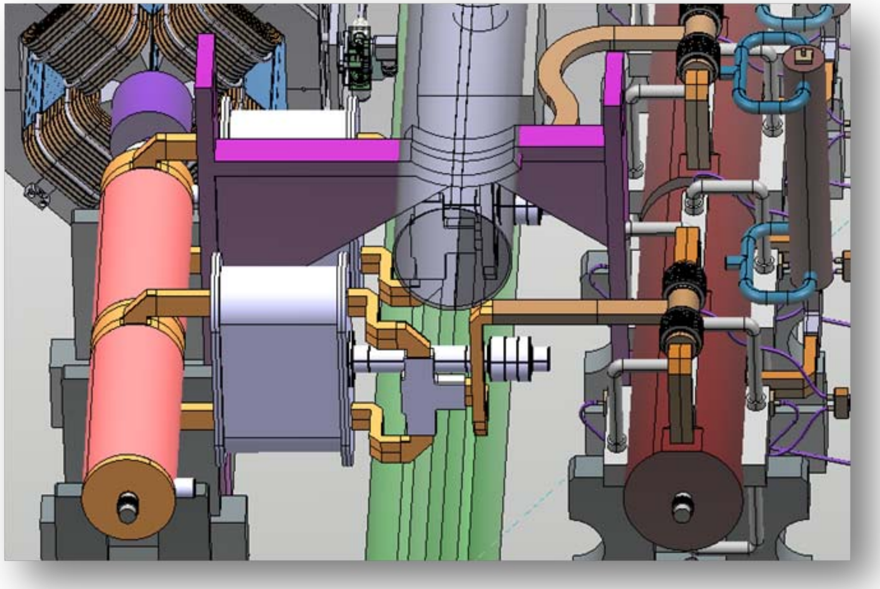
Total per linac

Modules: 10460
Accelerating structures: 71406
PETS: 35703
MB quadrupoles: 1996
DB quadrupoles: 20920

BPM: 22916
WFM: 71406

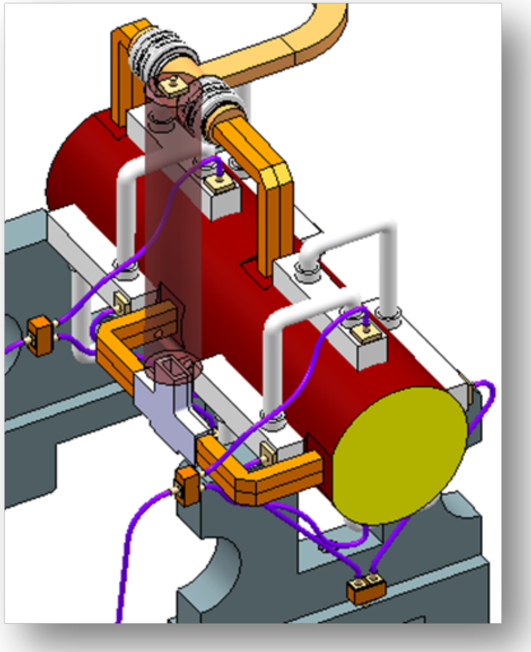
Vacuum system

Requirements: $5 \cdot 10^{-9}$ mbar



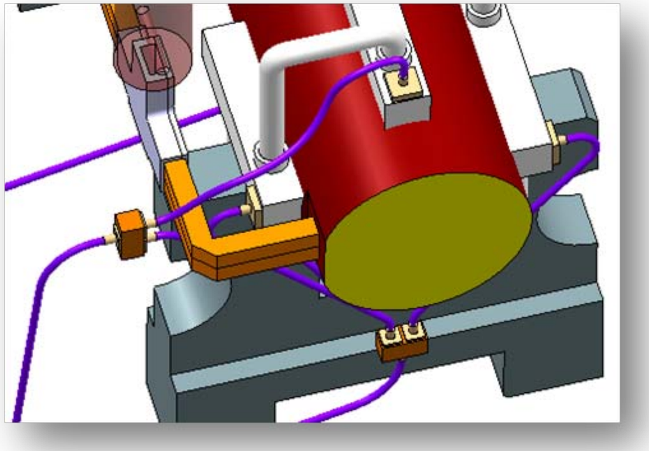
- Several configurations have been studied depending on structure technologies and design
  - Accelerating structures made in quadrant or in disks
  - Structure sealed or mounted inside a vacuum tank
- Two configurations have been studied
  - In configuration #2, the ACS are made of discs all brazed together forming a sealed structure, and the PETS are made of octants and "mini-tanks" around the bars ➔ adopted as baseline
  - In configuration #1, the accelerating structures are formed by four high-speed milled bars which are then clamped together, and the PETS bars and couplers are all clamped and housed in a vacuum tank.➔ alternative

WFM



WFM integrated in acc. structure:
RMS position error 5 µm

(~142000 WFM)



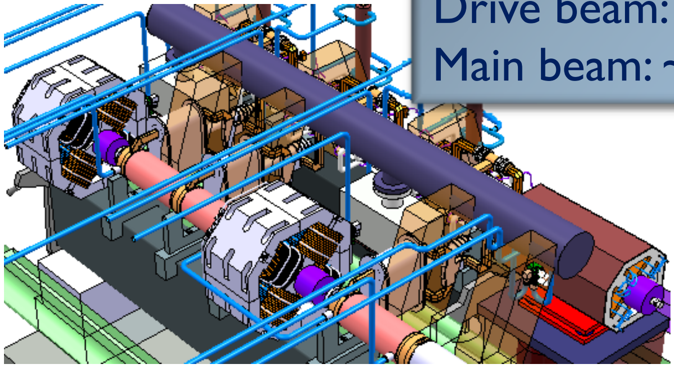
BPM

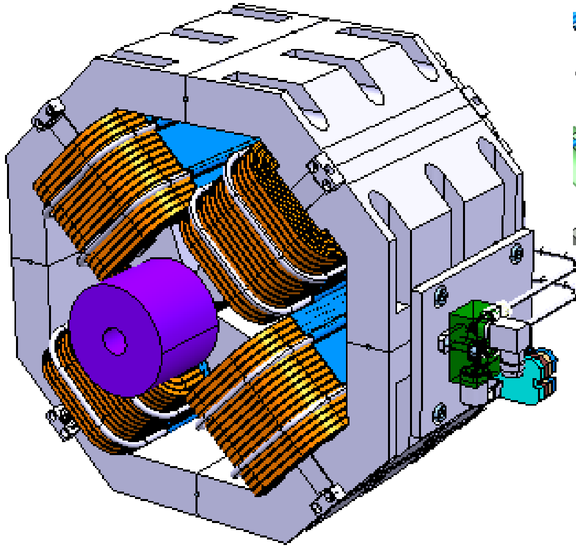
Limited space for BPM integration: 60 to 100 mm

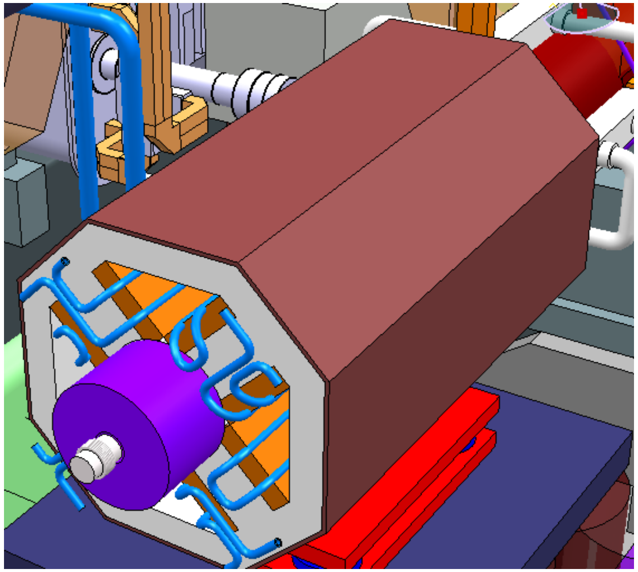
-1 BPM per Q

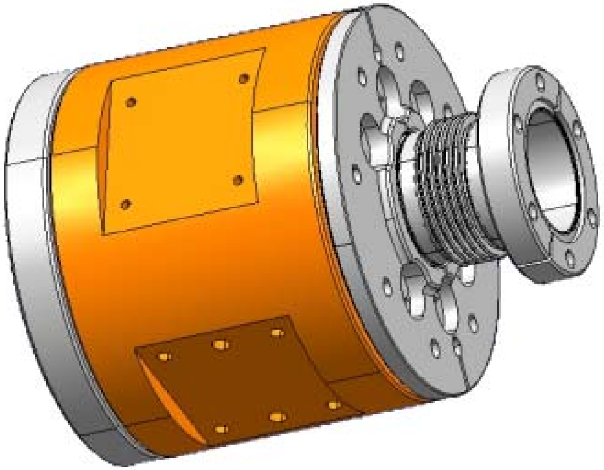
Drive beam: ~ 47000 devices

Main beam: ~151000 devices









Main objectives of the test module

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

- Integration of different sub-systems: , i.e. to simultaneously satisfy requirements of highest possible gradient, power handling, tight mechanical tolerances and heavy HOM damping

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

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

Task 2: Normal Conducting High Gradient Cavities

- Building on the success of CTF3 and complementing it, the goal of this task is to optimize CTF3 and its use towards
  - cost- and performance optimized accelerating structures and their integration in CLIC modules. Together with all subsystems (vacuum, cooling, alignment,..). This also requires
  - better modeling of breakdown and
  - better suppression of HOM's,
  - experimental verification
- Partners: CIEMAT, University of Manchester (CI), HIP/University Helsinki, Uppsala University, CERN (coordination)
- Estimated total: 2.45 M€, 22 FTE

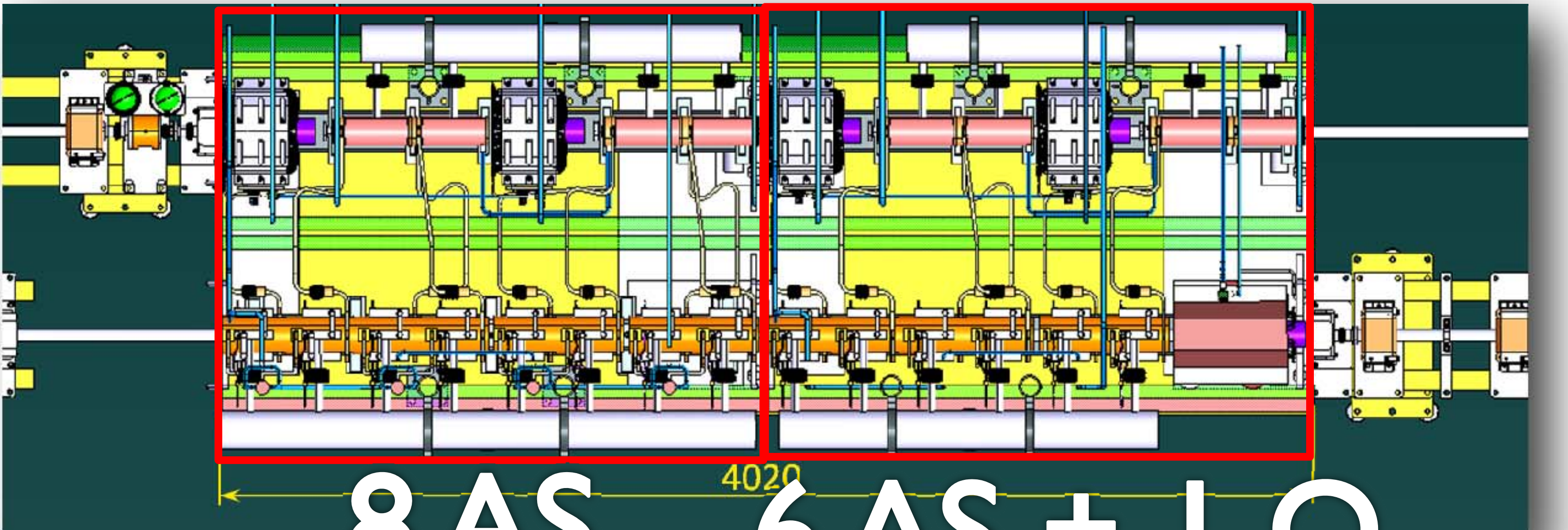
- This task is complementary to the "module implementation" which is financed 100% by CERN (and other collaborators) and not part of this proposal
- Also note that the CLIC main beam accelerator structures are not explicitly part of this program.

Ph.3: Type 0

Ph.4 : TYPE 1

DB

MB



8 AS

6 AS + 1 Q

STANDARD & TYPE 1 CLIC MODULES IN CLEX

(2010 mm + 2010 mm = 4020 mm)