CLIC workshop
”Two beam hardware and integration” working group

Module layout and main requirement

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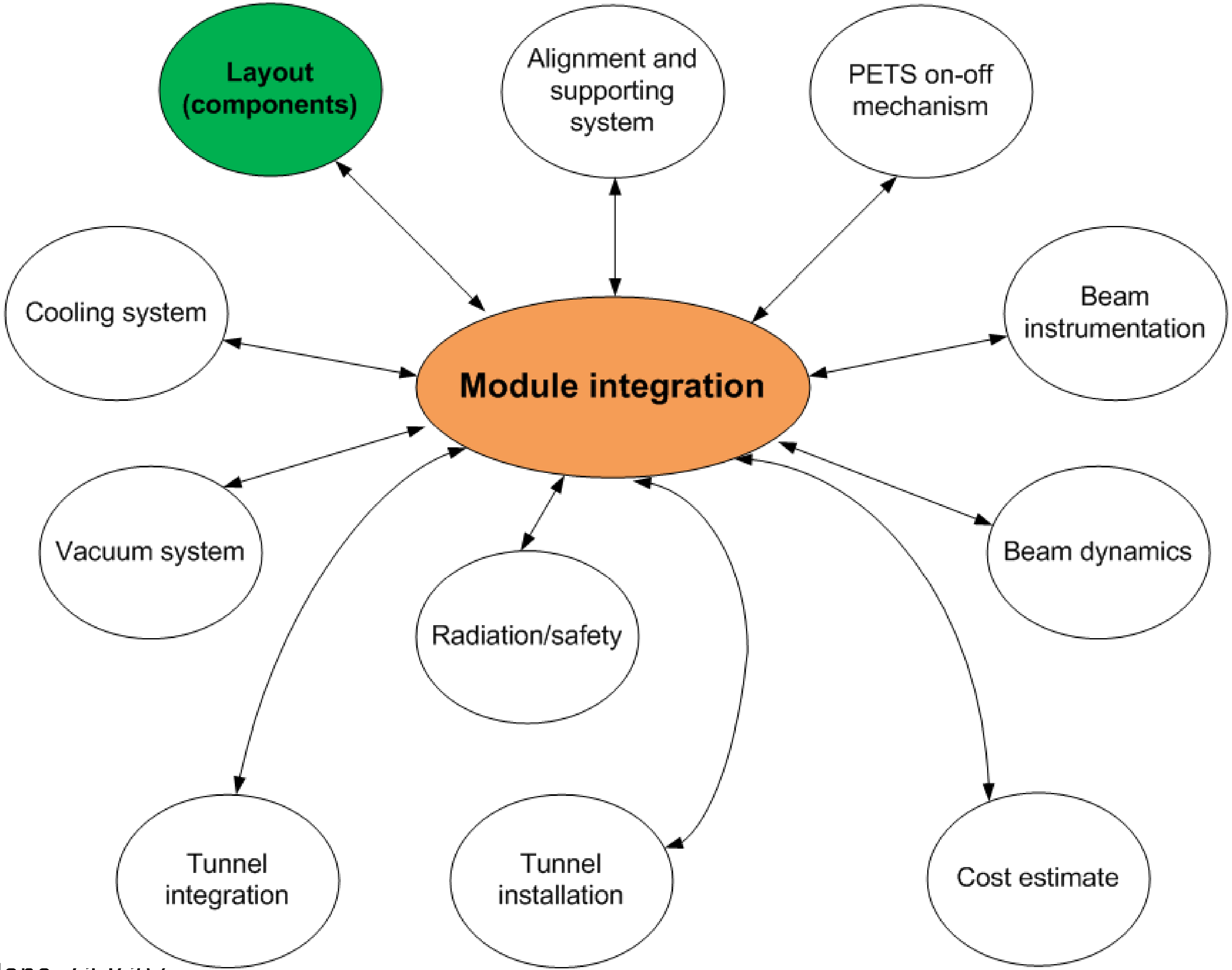
17.10.2007

Content

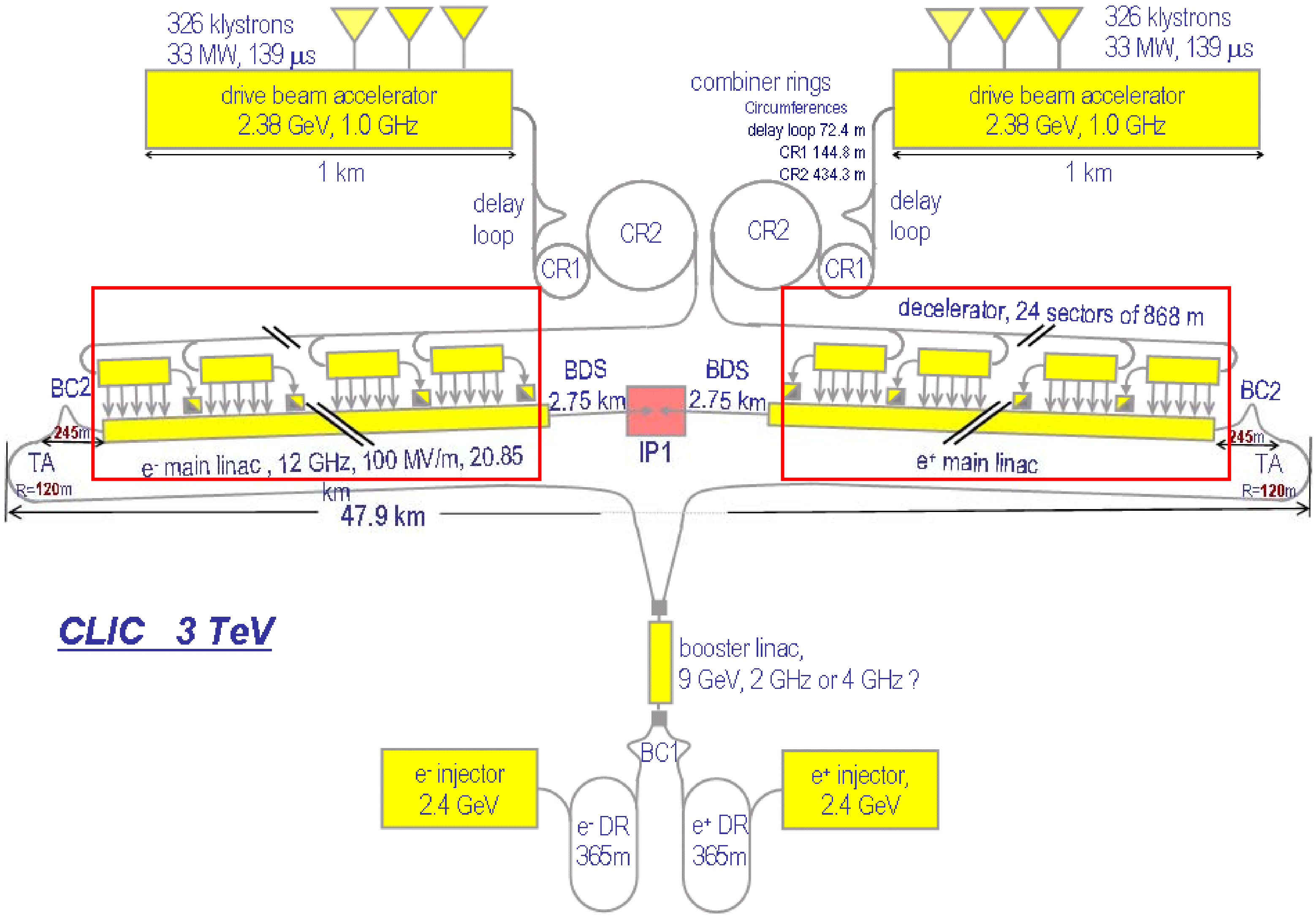
- Introduction and general CLIC parameters
- Layout
- Main system requirement
- Tunnel integration
- Conclusions

Introduction

Several activity domains



CLIC layout



326 klystrons
33 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
1 km
delay
loop
CR1
CR2
combiner rings
Circumferences
delay loop 72.4 m
CR1 144.8 m
CR2 434.3 m
CR2
CR1
delay
loop
326 klystrons
33 MW, 139 μs
drive beam accelerator
2.38 GeV, 1.0 GHz
1 km
decelerator, 24 sectors of 868 m
BC2
245m
TA
R=120m
e- main linac , 12 GHz, 100 MV/m, 20.85 km
BDS
2.75 km
IP1
BDS
2.75 km
e+ main linac
BC2
245m
TA
R=120m
47.9 km
CLIC 3 TeV
booster linac,
9 GeV, 2 GHz or 4 GHz ?
BC1
e- injector
2.4 GeV
e- DR
365m
e+ DR
365m
e+ injector,
2.4 GeV

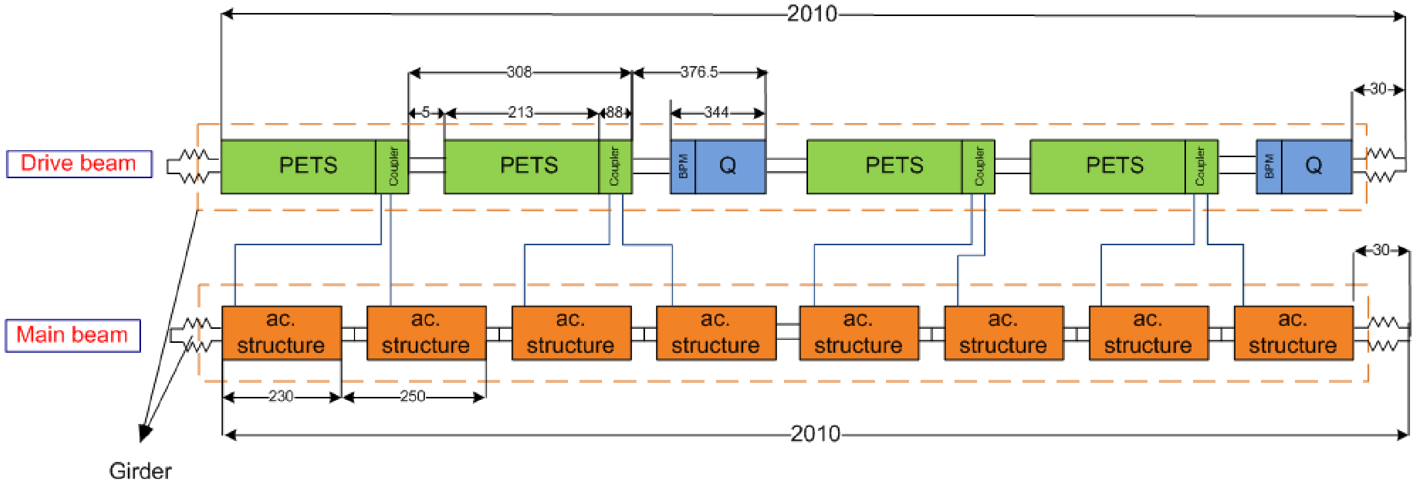
Main parameters

Overall parameter		
center of mass energy	3	Tev
main linac RF frequency	11.994	GHz
luminosity	5.9×10^{34}	$cm^{-2}s^{-1}$
unloaded/loaded gradient	120/100	MV/m
proposed site length	47.9	km
overal two linac length	41.7	km
Main linac		
filling factor	78.6	
accelerator structure length	229	mm
Decelerator		
No. of drive beam sector/linac	24	
Drive beam sector length	868	m
No. of PETS per sector	1491	
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

Module		
No. of module per sector	428	
No. of module per linac	10275	
No. of modules (2 linacs)	20549	
	Acc. structure	**PETS**
No. per sector	2982	1491
No. per linac	71568	35784
No. (2 linacs)	143136	71568
Modules	**Standard**	
No. per linac	8274	
No. (2 linacs)	16547	
Modules	**type 1**	**type 2**
No. per linac	143	664
No. (2 linacs)	286	1328
Modules	**type 3**	**type 4**
No. per linac	474	720
No. (2 linacs)	948	1440

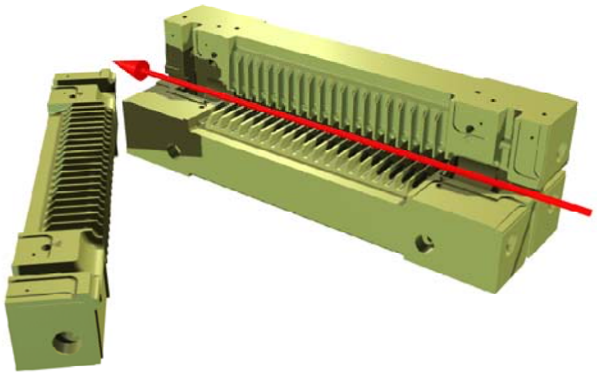
Layout

Standard module

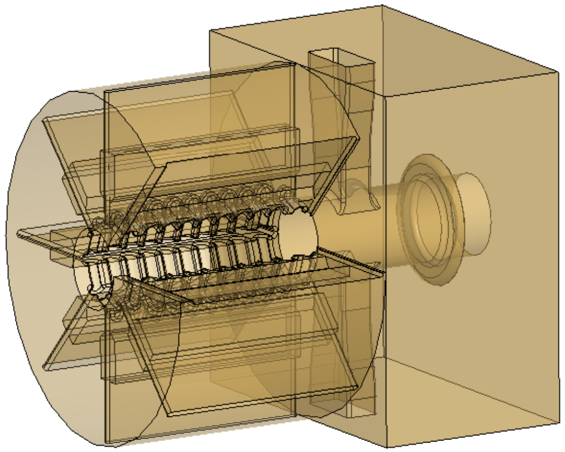


x 16547

Accelerating structures:
x 143000

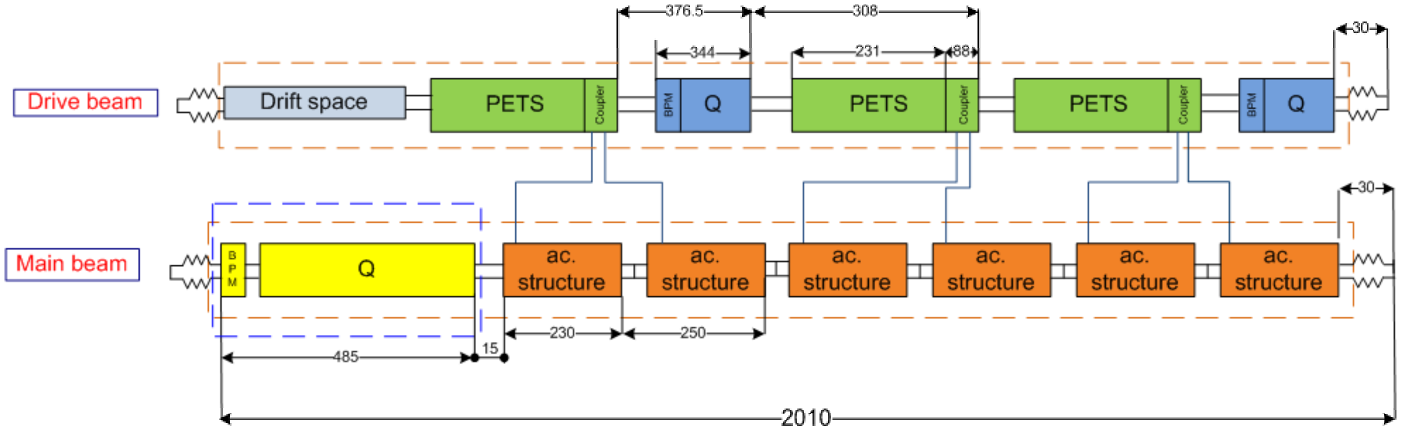


Power extraction and transfer energy PETS: x 71500

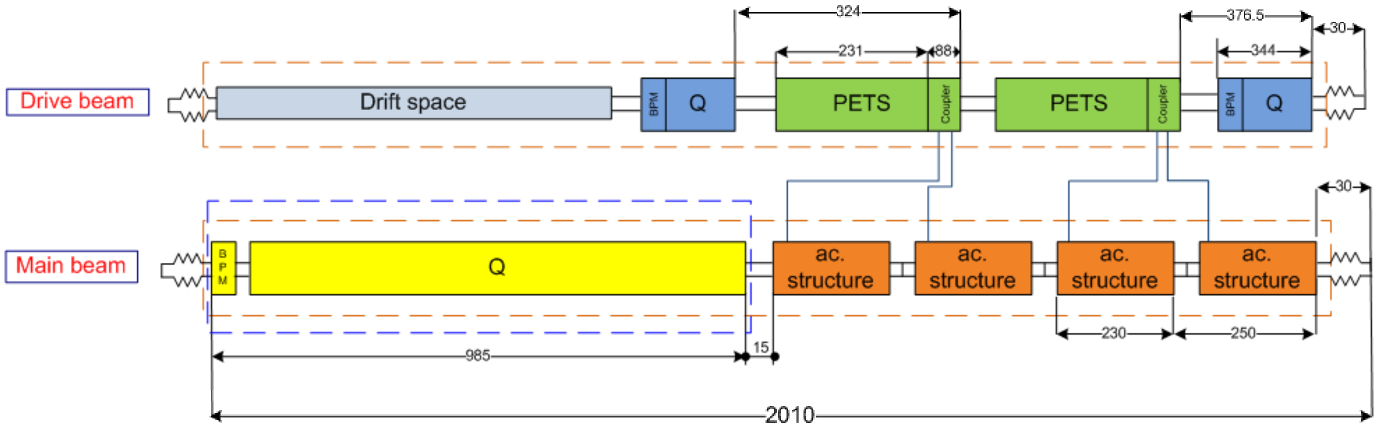


Quadrupole type modules

Type 1 (x 286)

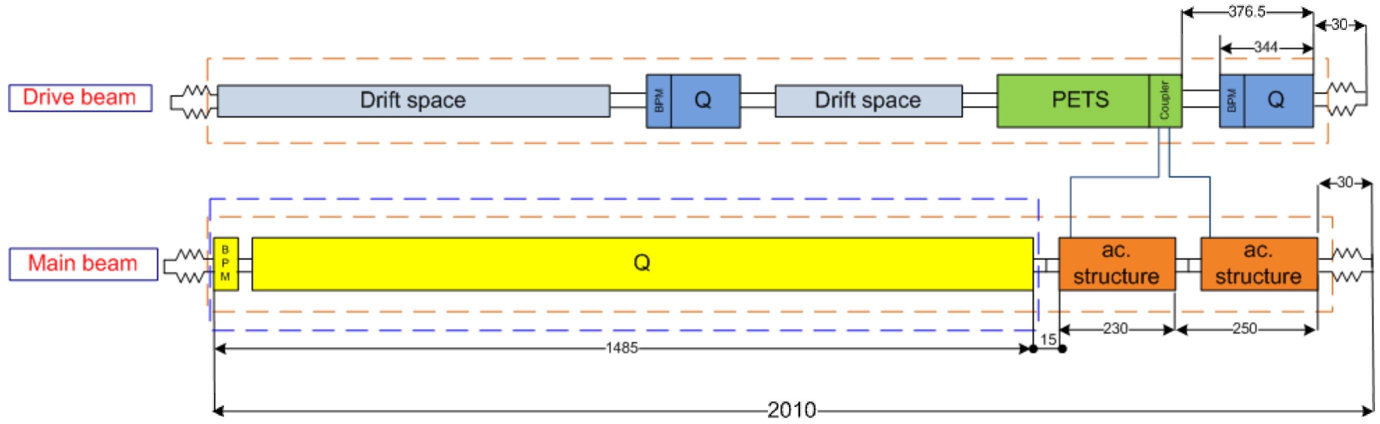


Type 2 (x 1328)

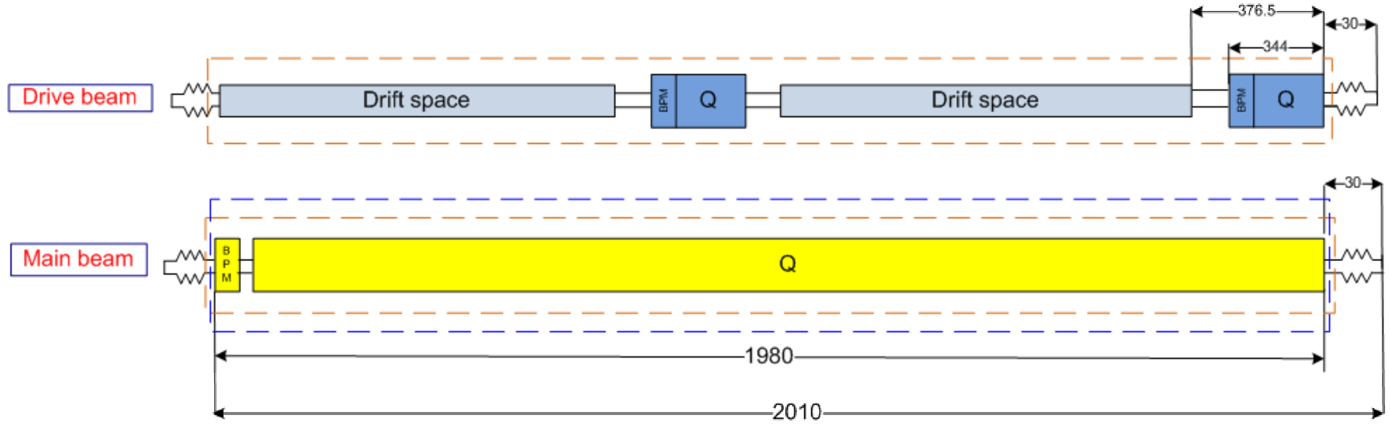


Quadrupole type modules

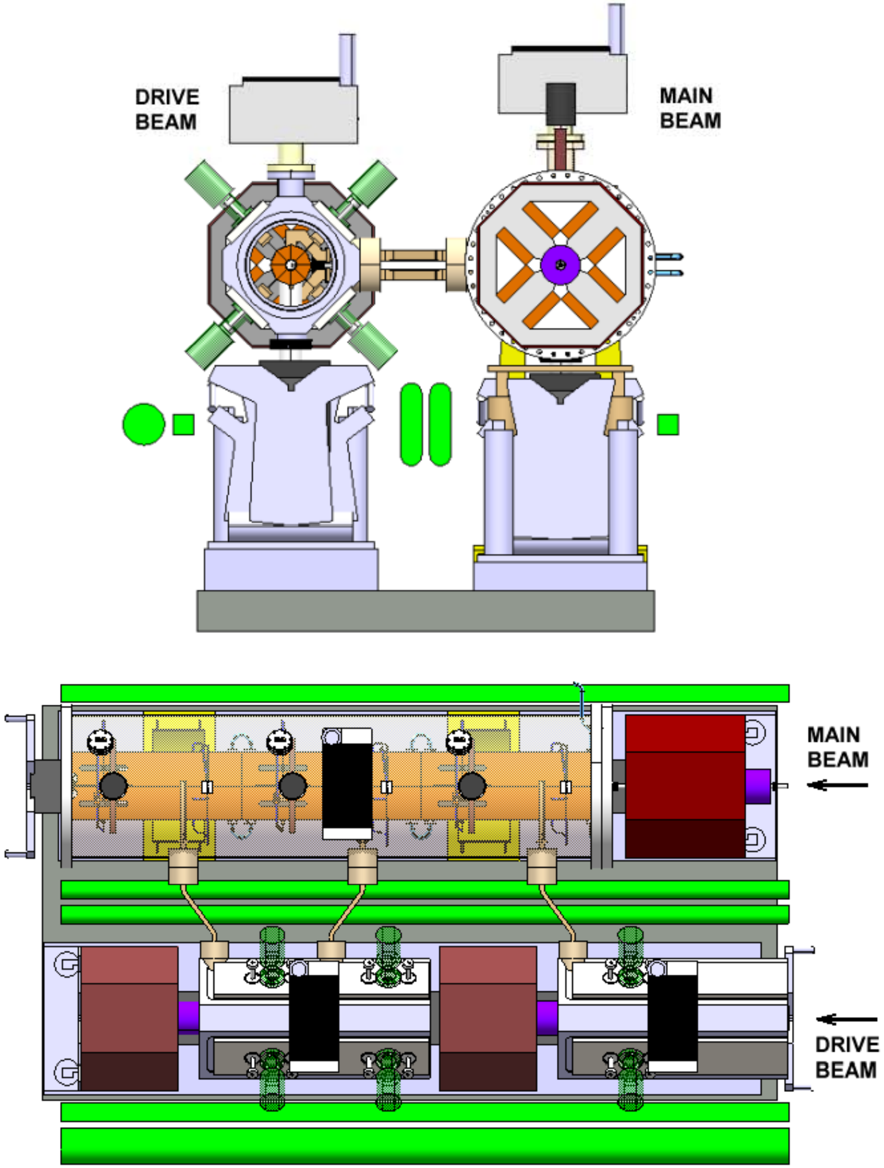
Type 3 (x 948)



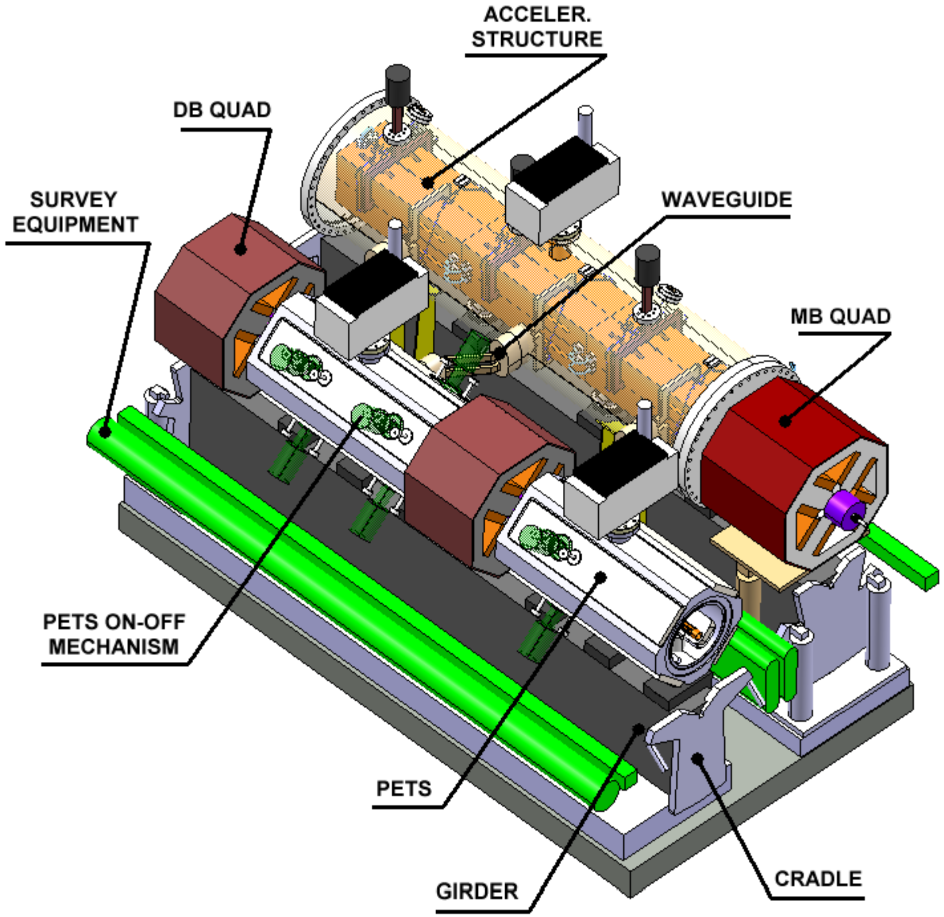
Type 4 (x 1440)



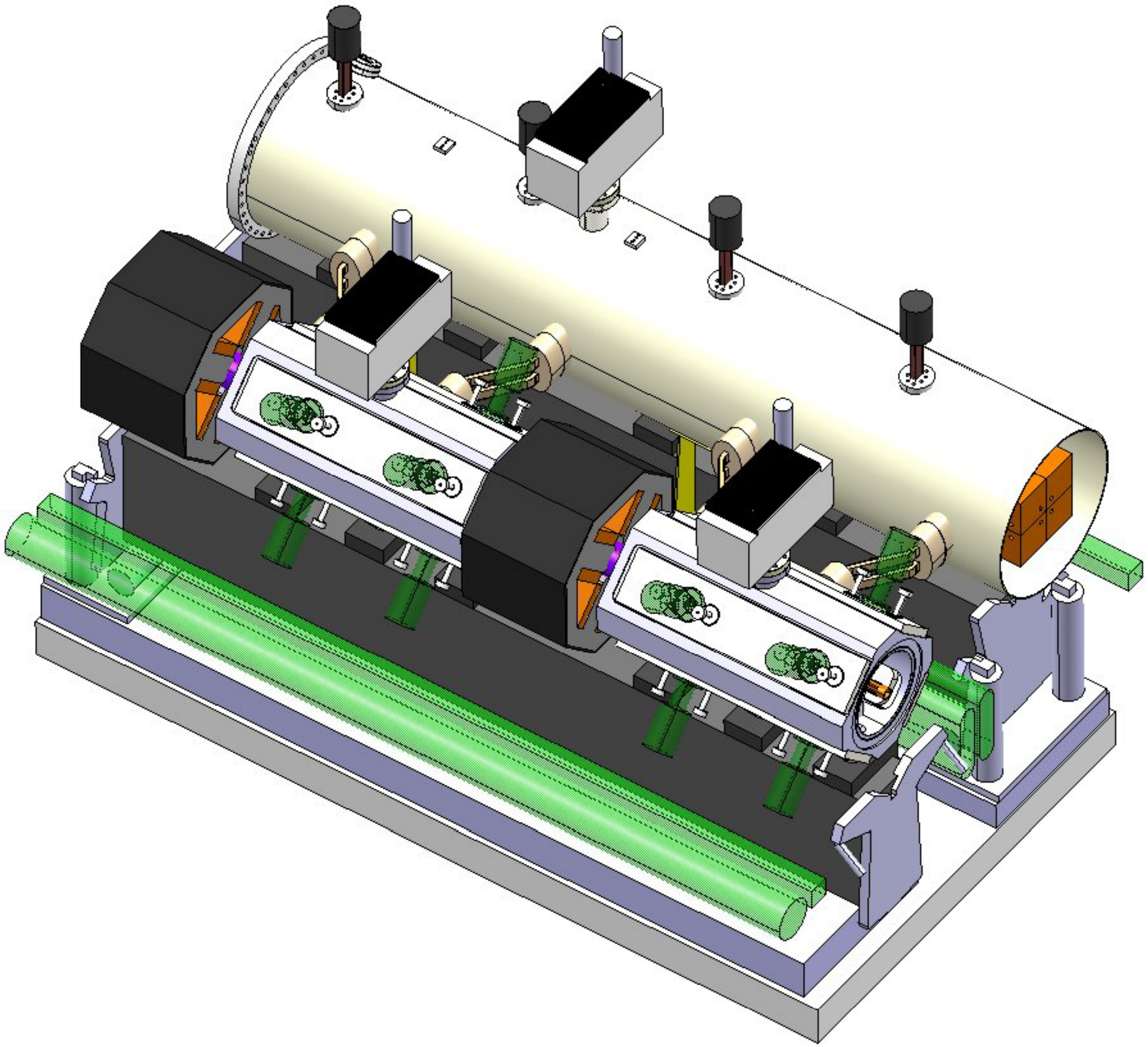
CLIC module



Type 1 quadrupole module



Standard module



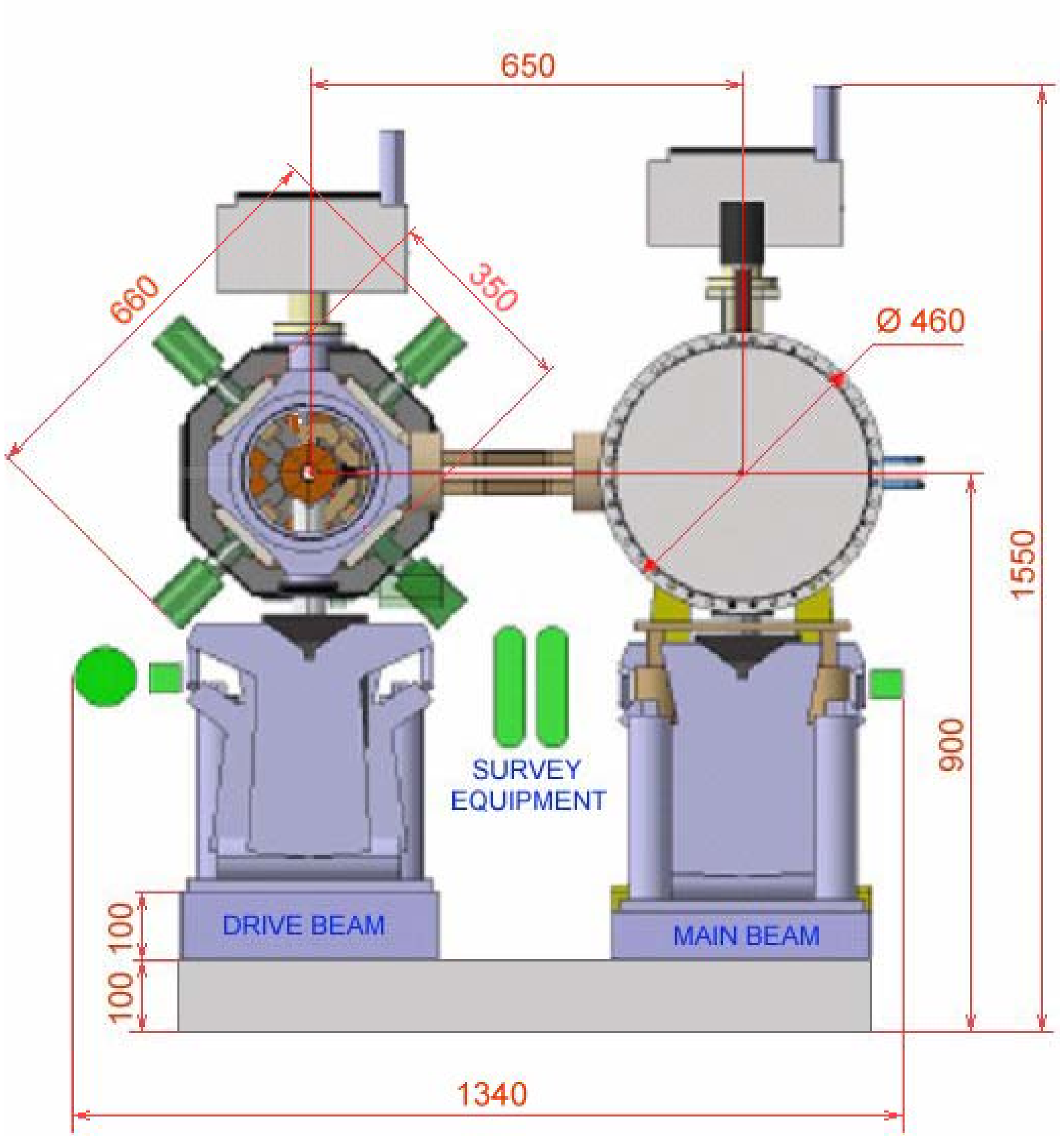
Main beam

8 accelerating structures

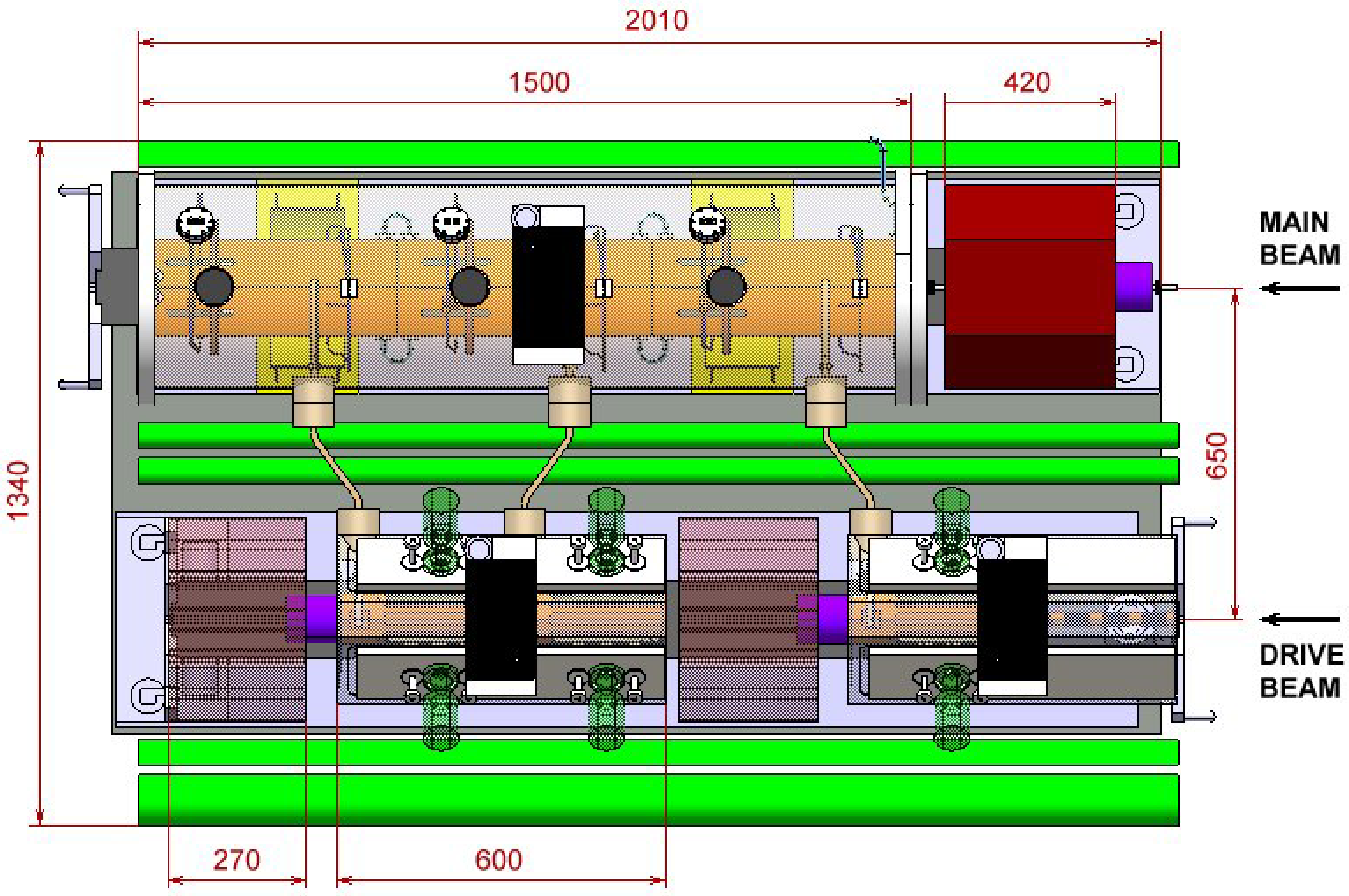
Drive beam

4 PETS (1x 2 acc. str.)
2 quadrupoles

Module cross-section



Module top-view

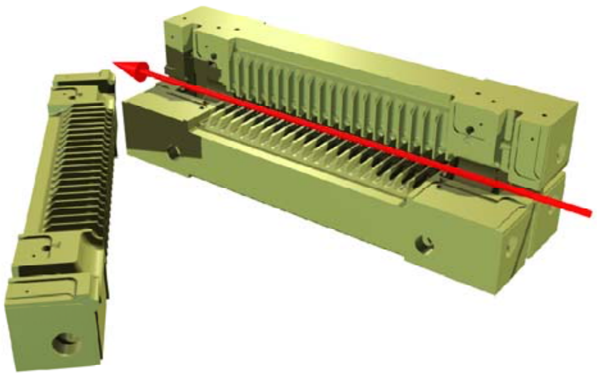


Main components

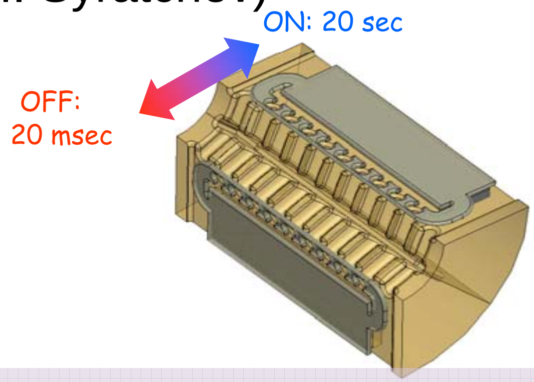
Main components: structures

Accelerating structure (A. Grudiev)

Structure	CLIC_G
Frequency: f [GHz]	12
Average iris radius/wavelength: $\langle a\rangle/\lambda$	0.11
Input/Output iris radii: $a_{1,2}$ [mm]	3.15, 2.35
Input/Output iris thickness: $d_{1,2}$ [mm]	1.67, 1.00
N. of reg. cells, str. length: N_c, l [mm]	24, 229
Bunch separation: N_s [rf cycles]	6
Luminosity per bunch X-ing: $L_{b\times}$ [m^{-2}]	1.22×10^{34}
Bunch population: N	3.72×10^{9}
Number of bunches in a train: N_b	312
Filling time, rise time: τ_f, τ_r [ns]	62.9, 22.4
Pulse length: τ_p [ns]	240.8
Input power: P_{in} [MW]	63.8
$P_{in}/C\tau_p^{1/3}$ [MW/mm ns$^{1/3}$]	18
Max. surface field: E_{surf}^{max} [MV/m]	245
Max. temperature rise: ΔT^{max} [K]	53
Efficiency: η [%]	27.7
Figure of merit: $\eta L_{b\times}/N$ [a.u.]	9.1



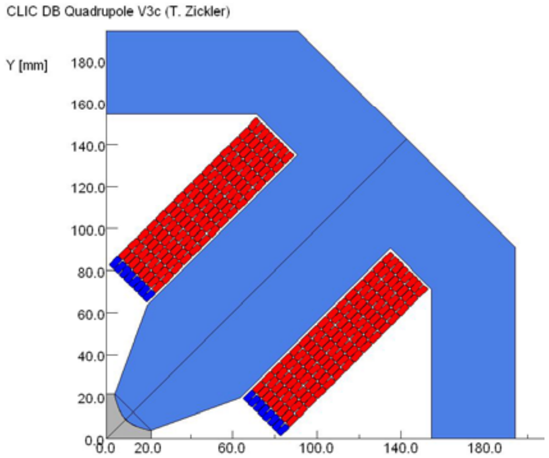
PETS (I. Syratchev)



PETS parameters:
- Aperture = 23 mm
- Period = 6.253 mm (90^0/cell)
- Iris thickness = 2 mm
- R/Q = 2258 Ω
- V group= 0.453
- Q = 7200
- P/C = 13.4
- E surf. (135 MW)= 56 MV/m
- H surf. (135 MW) = 0.08 MA/m
  (ΔT max (240 ns, Cu) = 1.8 C^0)

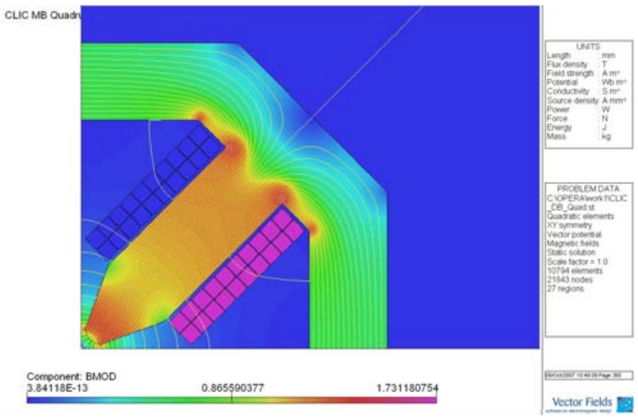
Main components: Quadrupoles

Drive beam



Aperture radius: 13.0 mm
Integrated gradient: 14.3 Tm/m
Nominal gradient: 67.1 T/m
Total length: 270 mm
Magnet width: 390 mm
Magnet weight: 180 kg
Distance between opposite coils: 118 mm
Water cooling

Main beam

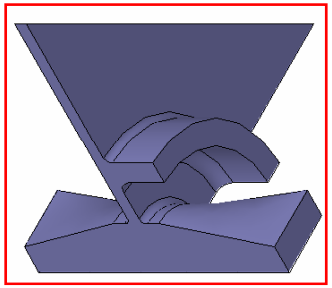


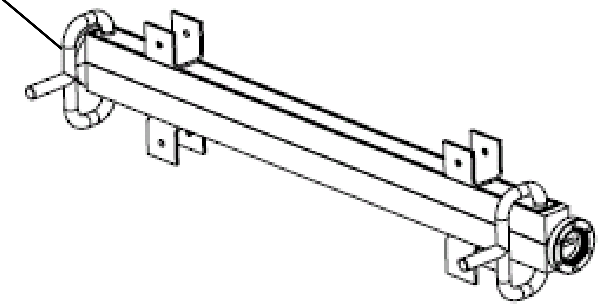
Aperture radius: 4.00 mm
Integrated gradient: 70 (170, 270, 370) Tm/m
Nominal gradient: 200 T/m
Total length: 420 (920, 1420, 1920) mm
Magnet width: < 200 mm
Magnet height: < 200 mm
Magnet weight: ~ 75 (110, 135, 270) kg
Water cooling

See talk T. Zickler

Main components

- Waveguide connection between PETS and accelerating structures:
  - Choke mode flanges (see talk D. Carrillo)
- High power loads
- Waveguides
- External supports
- Vacuum equipment
- Alignment equipment





Systems

System specification

– Structure fabrication and assembly
– RF network definition
– Alignment/supporting system (close collaboration with beam dynamics working group)
– Stabilization system
– Vacuum system
– Cooling system
– BPM definition and beam instrumentation

These activities have to be developed in close collaboration with integration study

➔ tunnel integration, transport and installation

Tolerances

Tolerances of the structures:

4 kinds of tolerances:

Machining (Δx, Δy, Δz) (see talk of M. Taborelli)
Assembly (Δx, Δy, Δz)
Alignment (Δx, Δy, Δz)
Operation [Cooling] (ΔT (t) water in, ΔT (z))

Predictable: operational temperature, longitudinal elongation, transverse elongation

Unpredictable: water temperature instability, RF power variation

3 kinds of problems

Alignment (wakefield effects)
Bookshelf (transverse kick)
RF matching (reflected power, phase errors)

Alignment system

Transverse tolerances

PRE-ALIGNMENT

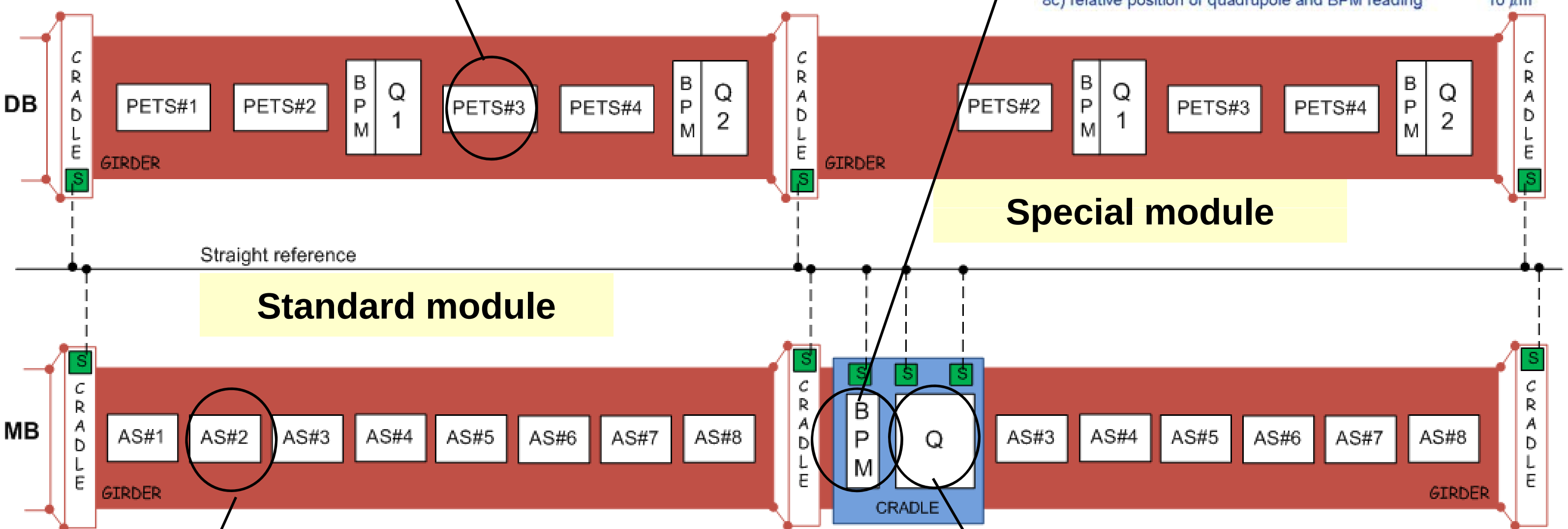
Ref.	1	Inherent accuracy of reference (link between two adjacent girders)	10 μm	1σ
Ref. to cradle	2	Link "local" reference/sensor	20 μm	1σ
	3	Link sensor/cradle	5 μm	1σ
Cradle to girder	4	Link cradle/girder	5 μm	1σ
Girder to PETS	5a 5b	Link girder/PETS Inherent precision of PETS	20 μm	1σ
		TOTAL	31 μm	1σ
		Tolerance	93 μm	3σ

PRE-ALIGNMENT

Ref.	1	Inherent accuracy of reference	10 μm	1σ
Ref. to cradle	2	Link "local" reference/sensor	5 μm	1σ
	3	Link sensor/cradle	5 μm	1σ
Cradle to BPM	8a	Link cradle/quadrupole BPM axis	5 μm	1σ
BPM	8b	Inherent precision of quadrupole BPM axis	5 μm	1σ
		TOTAL	14 μm	1σ
		Tolerance	40 μm	3σ

BEAM-BASED ALIGNMENT:

8c) relative position of quadrupole and BPM reading	10 μm	1σ



PRE-ALIGNMENT

Ref.	1	Inherent accuracy of reference (link between two adjacent girders)	10 μm	1σ
Ref. to cradle	2	Link "local" reference/sensor	5 μm	1σ
	3	Link sensor/cradle	5 μm	1σ
Cradle to girder	4	Link cradle/girder	5 μm	1σ
Girder to AS	5a 5b	Link girder/acc. structure Inherent precision of structure	5 μm	1σ
		TOTAL	14 μm	1σ
		Tolerance	40 μm	3σ

BEAM-BASED ALIGNMENT

6) relative position of structure and BPM reading	5 μm	1σ

PRE-ALIGNMENT

Ref.	1	Inherent accuracy of reference	10 μm	1σ
Ref. to cradle	2	Link "local" reference/sensor	5 μm	1σ
	3	Link sensor/cradle	5 μm	1σ
Cradle to quad.	7a	Link cradle/quadrupole	5 μm	1σ
Quad.	7b	Inherent precision of quadrupole	10 μm	1σ
		TOTAL	17 μm	1σ
		Tolerance	50 μm	3σ

See talk of H. Mainaud-Durand

Stabilisation system

- Performance will be limited by vibration of the focusing quadrupoles
- More stringent requirement in vertical direction (CLIC note 530)

Stability requirements (> 4 Hz) for a 2% loss in luminosity

Magnet	Ix	Iy
Linac (2600 quads)	14 nm	1.3 nm
Final Focus (2 quads)	4 nm	0.2 nm

➔ Need active damping of vibrations

- Resistive quadrupoles ➔ they incorporate water cooling circuits, which will increase the vibration level of the quadrupoles ➔ cooling induced vibration
  - preliminary promising tests done (**CLIC NOTE 578)**
  - But detailed study and dedicated development required

CERN vibration test stand

See talk of A. Jeremie

Vacuum system

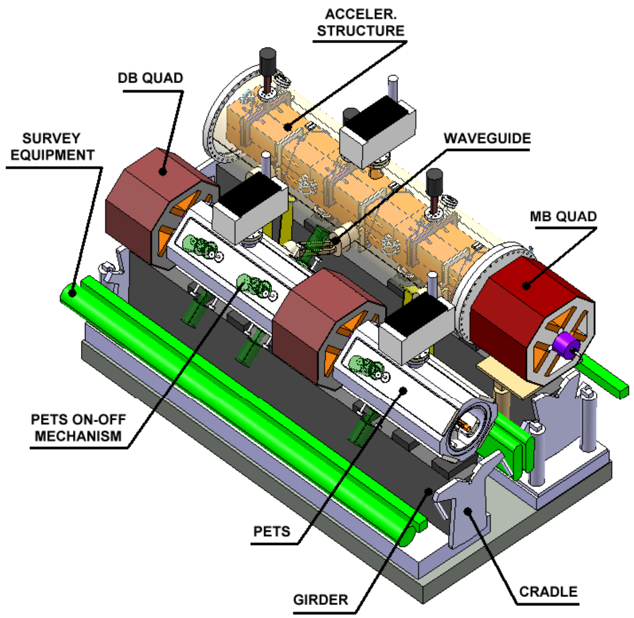
- Main beam and drive beam: same vacuum ➔ via waveguide interconnections
- Requirement dictated by beam dynamics
  - 10^{-10} mbar for transfer lines
  - 10^{-8} mbar could be accepted for main beam
- Pumping
  - during nominal operation
  - during breakdown
  - P recovery between breakdowns (main beam 8 m^2 surface to pumped)
- Pre-evacuation: Mobile TM stations (access needed)
- Holding pumps: Ion+ Sublimation pumps

- Sectorisation ➔ length of sector determined by
  - Operation: in case of failure or modification all the length vented=> reconditionning. Failure rate?
  - Additional space required (~ 20 cm)
  - Additional cost

See talks of N. Hilleret, A. Latina, P. Costa-Pinto

Supporting system

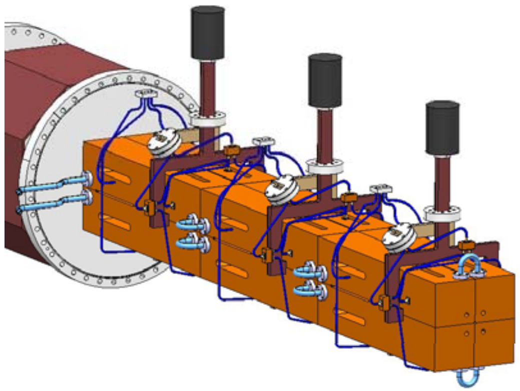
- Mechanical and thermal stability required
- Main beam
  - Accelerating structures on girders
    - Girder attached to cradles at the two extremities
    - Alignment system integration (pre- and beam based alignment)
  - Main beam quadrupole on dedicated supports
    - Stabilisation and alignment system integration
- Drive beam
  - PETS and quadrupoles on the same girders
  - Pre-alignment system integration
- Cradles mechanically attached to a girder and linked by rods to the adjacent one



See talk of R. Nousiainen, F. Toral

Cooling system

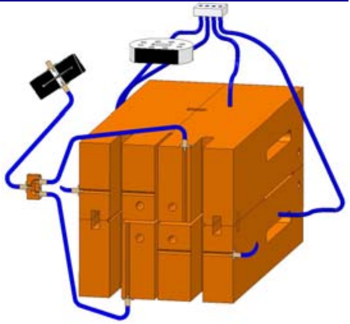
- Water cooling for accelerating structures, quadrupoles and loads
- Water cooling for PETS to be confirmed
- Different operation modes to be taken into account
- More stringent requirement: cooling of the acc. structures (~ 600 W/as)
  - Different cooling configurations according to under study ➔ consequence on the needed volumetric flow
- Temperature stabilisation +/- 0.1 K
- Temperature drop across acc. structure: 1.5 K



See talks of J. Inigo-Golfin, R. Nousiainen

Beam instrumentation

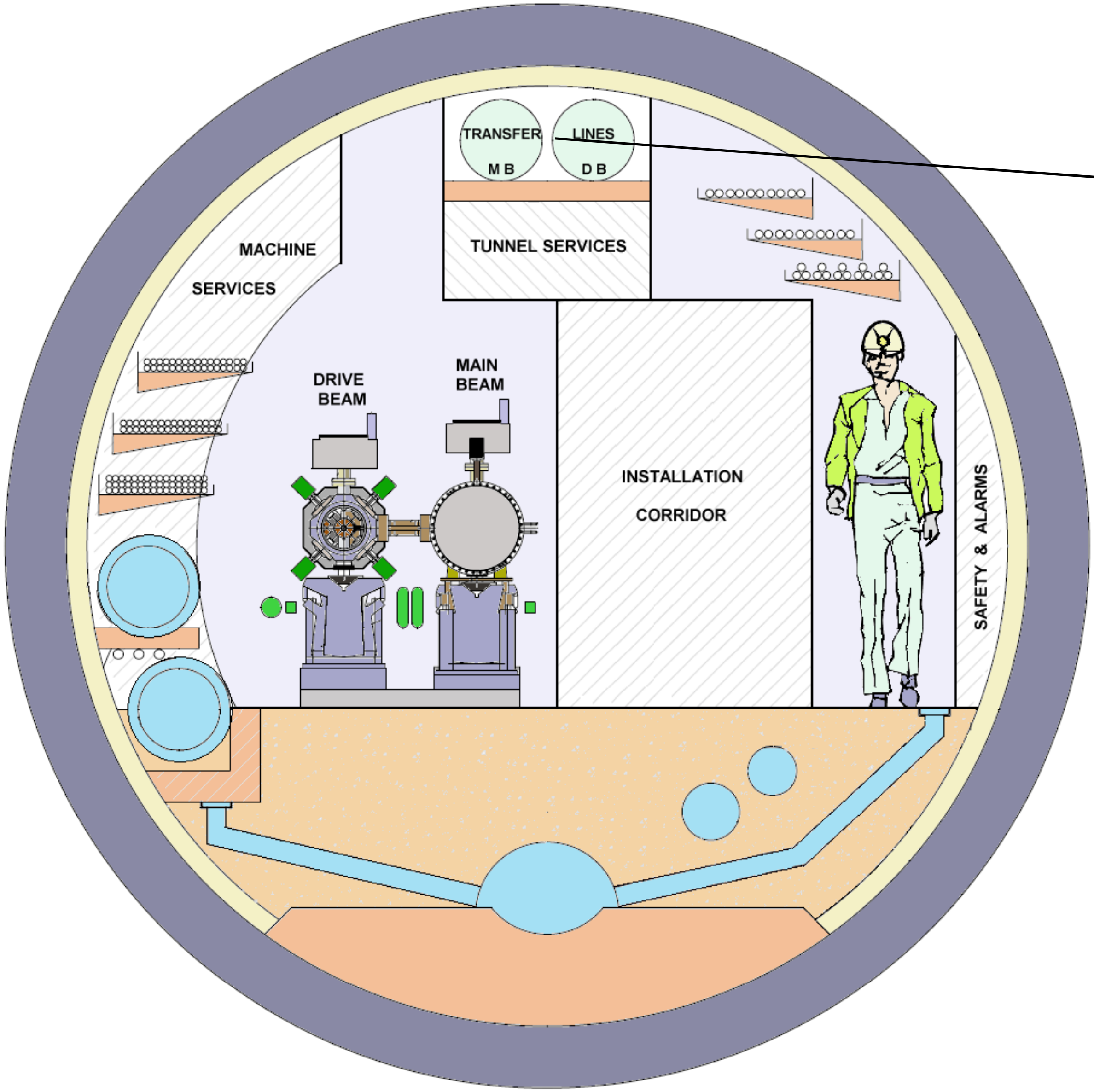
	Main beam		Drive beam
	Wakefield Monitor	Quadrupole	Quadrupole
Where	Center	Before	Before
How many	4	0 or 1	2
Type	Damped cavity	Damped cavity, Re-entrant cavity, Inductive, ?	Damped cavity, Re-entrant cavity, Inductive, ?
Bunch frequency	1.5GHz	1.5GHz	12GHz
Meas. frequency	16GHz	DC or N*1.5GHz	DC or 12GHz
Max Q_L (Wakefield)	10	~10*nb of cells?	1?
Max Q_L (Time res.)	500	500	500
Requirements	Time resolution: 10ns Resolution: 1um Precision: 10um Aperture: 6.0mm	Time resolution: 10ns Resolution: 100nm Precision: 10um Aperture: 4.16mm	Time resolution: 10ns Resolution: 1um Precision: 10um Aperture: 23.0mm
Available length	..-..	80 (60)mm??	109mm / 79mm
Electronics	**Hybrid very close. Mixers + in alcove**	**Inductive**: Active hybrid very close to avoid errors due to cables	



See talks of L. Soby, G. Montoro

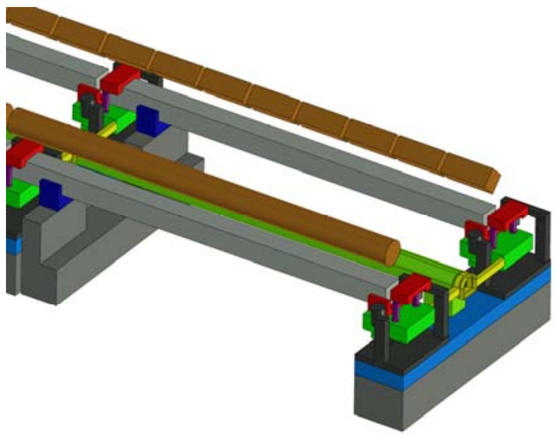
Tunnel integration

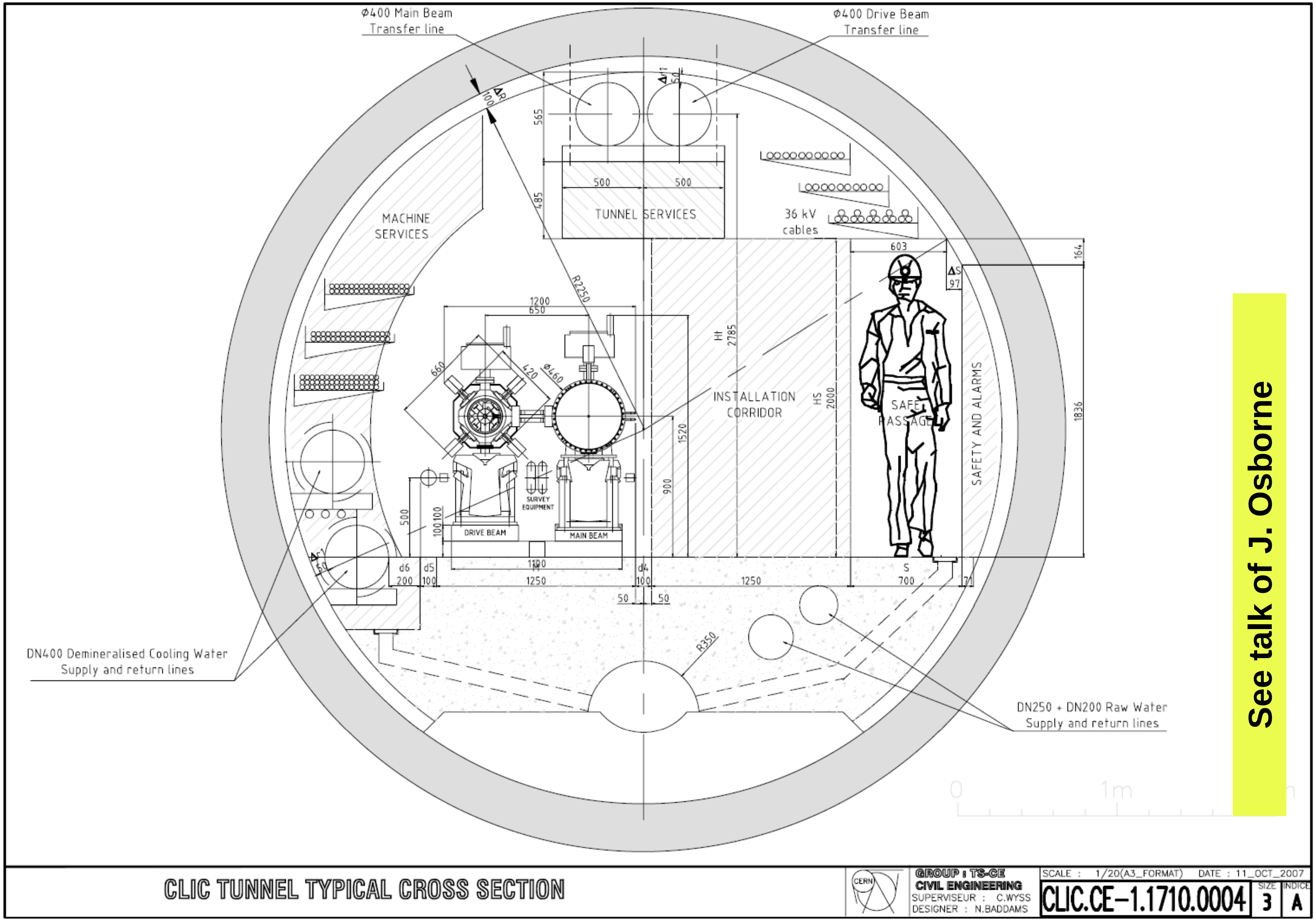
CLIC tunnel cross section



See talks of
B. Jeanneret and
L. Rinolfi

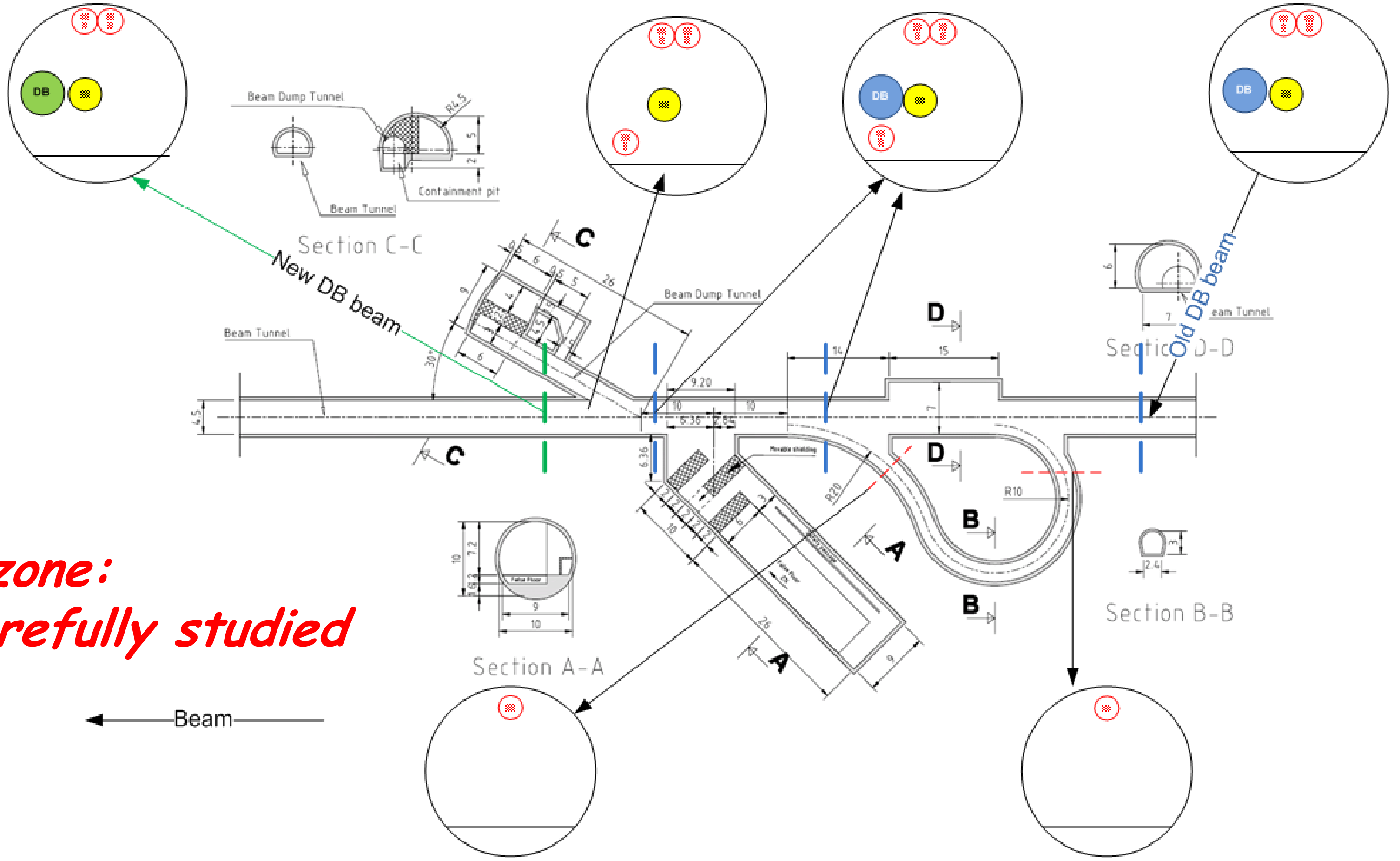
Transport:
see talk of
K. Kershaw





See talk of J. Osborne

Drive beam return loop



Special zone:
to be carefully studied

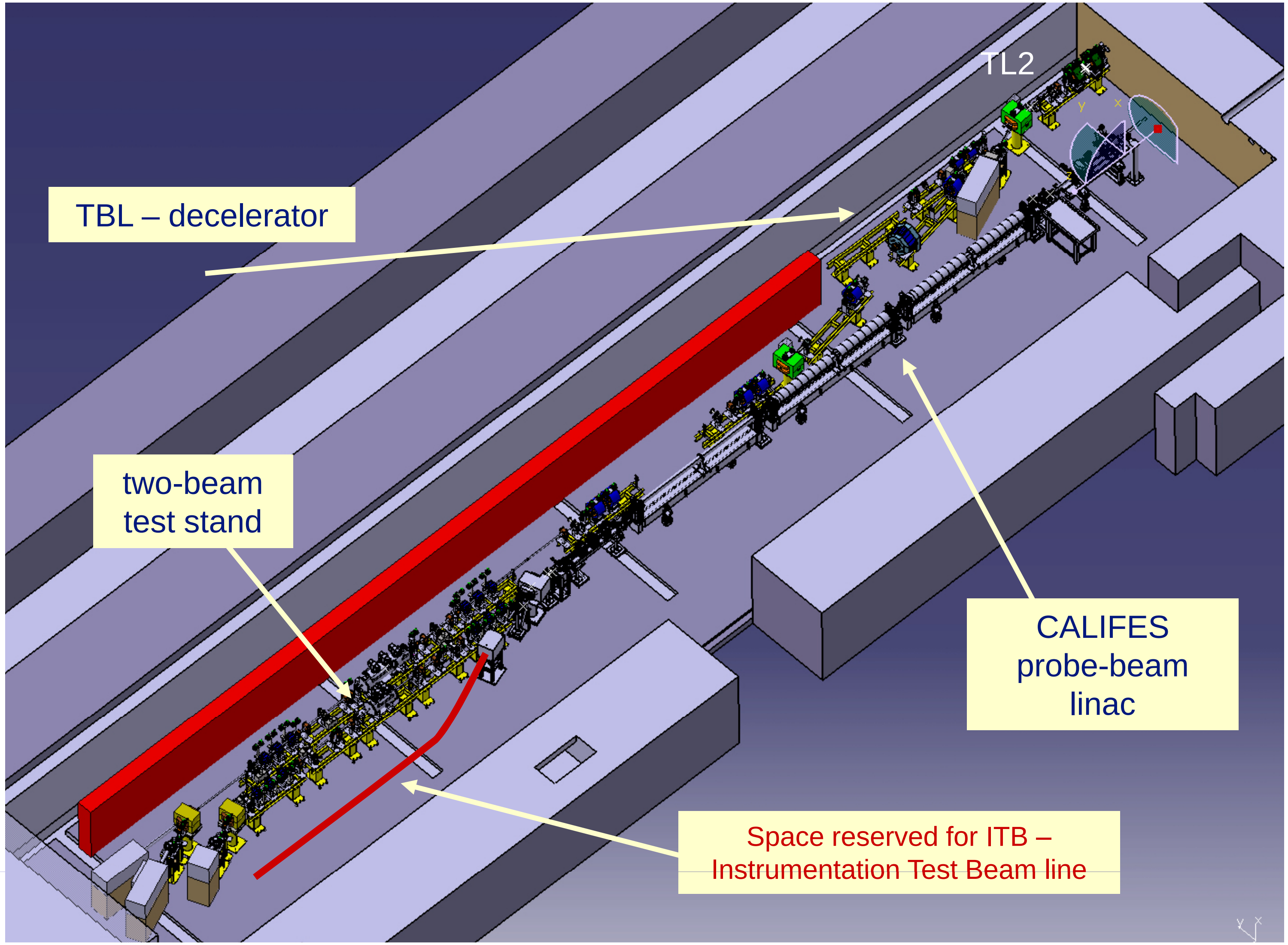
Beam

CLIC – Drive beam loop and beam dump

Conclusions

- Dedicated development programs of systems including, micron precision pre-alignment, nanometer stabilization, cooling, vacuum, beam instrumentation, active alignment and beam dynamics, etc. are needed
- An important issue is the integration of these various systems into the CLIC module which will be repeated over twenty thousand times along the length of CLIC ➔ optimization, reliability, scheduling (see talk of M. Gastal) and cost
- The module study raises feasibility issues, identifies areas needing study and design, addresses important aspects of cost and provides basic parameters for other areas of the study
- Test module in CLEX from 2008 (see talks of K. Alam and F. Toral [TBL]):
  - System integration
  - Alignment system
  - Stabilization system

CLEX layout



TL2
TBL – decelerator
two-beam test stand
CALIFES probe-beam linac
Space reserved for ITB – Instrumentation Test Beam line

Acknowledgment to the members of the CLIC module working group

Layout
- W. Wuensch
- I. Syratchev: PETS
- A. Grudiev: accelerating structures
- T. Zickler: Quadrupoles
- Transfer lines: B. Jeanneret, L. Rinolfi

Module integration
- A. Samoshkin, R. Leuxe
- T. Sahner - M. Taborelli
- W. Wuensch

Vacuum system
- P. Costa-Pinto - P. Chiggiato
- N. Hilleret

Alignment/supporting system
- H. Mainaud-Durand – T. Touzet (survey/alignment)
- R. Nousiainen (supports)
- J. Huopana (structure assembly)

Cooling system
- J. Inigo-Golfin, R. Nousiainen

Beam dynamics and stabilisation
- D. Schulte

Beam instrumentation
- L. Søby

PETS on-off mechanism
- B. Nicquevert

Tunnel integration, installation
- J. Osborne
- G. Riddone, A. Samoshkin

Radiation
- H. Vincke

Cost estimate
- G. Riddone