EDMS# 849681

Two Beam Module Design

G. Riddone
on behalf of the CLIC Module working group

08.06.2007

Content

- Introduction
- Layout
  - Longitudinal dimensions
  - Transverse dimensions
- System integration
- Alignment tolerances
- Tunnel integration

Mandate

- Develop the general layout, system integration, space hindrance, number of components and their position
- Specify the alignment/supporting system
- Specify the cooling system
- Specify the vacuum system
- Study the tunnel integration
- Identify critical points
- Cost estimate

Activities/Domains

- Layout and integration
- Alignment and supporting system
- Vacuum system
- Cooling system
- Beam instrumentation
- Beam dynamics
- Tunnel integration, transport and handling
- Radiation constraints and safety
- Assembly, installation, maintenance

Members

• Paolo Chiggiato	TS/MME	Vacuum system
• Pedro Costa Pinto	TS/MME	Vacuum system
• Noel Hilleret	AT/VAC	Vacuum system
• Raphael Leuxe	TS/MME	Mechanics
• Alexej Grudiev	AB/RF	RF design
• Helene Mainaud-Durand	TS/SU	Alignment system
• Bertrand Nicquevert	TS/MME	Mechanics
• Thomas Sahner	TS/MME	Mechanics
• Daniel Schulte	AB/ABP	Beam dynamics
• Igor Syratchev	AB/RF	RF design
• Lars Søby	AB/BI	Beam instrumentation
• Mauro Taborelli	TS/MME	Mechanics
• Walter Wuensch	AB/RF	System integration
• Carlo Wyss	DSU/HEP	Tunnel integration, cost estimate
• Thomas Zickler	AT/MEL	Quadrupole design

Layout

- Main input for module length:
  - Accelerating structure length
  - PETS length

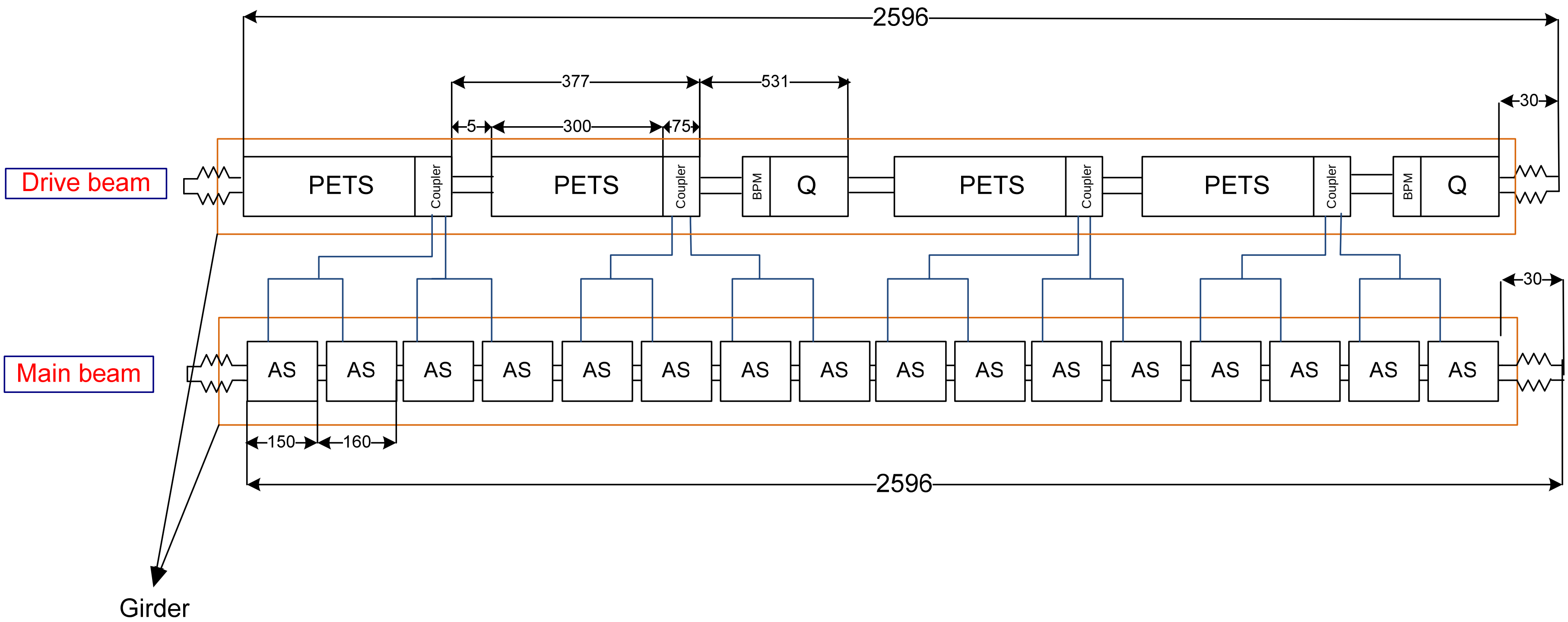
- The module length defines the drive beam quadrupole length (+ BPM) and the main beam quadrupole lengths (+BPM)
  - Feasibility of the quadrupoles is then to be verified

SINCE Jan 2007

- 1st Layout @ 12 GHz, 100 MV/m following change of parameters at the end of 2006 (January-April 2007)

- Updated layout from mid of April 2007
  - standard module (from April 2007)
  - special modules: pairs of accelerating structures replaced by quadrupole (from June 2007)

Standard module layout – Jan 2007



Accelerating structures

CLIC

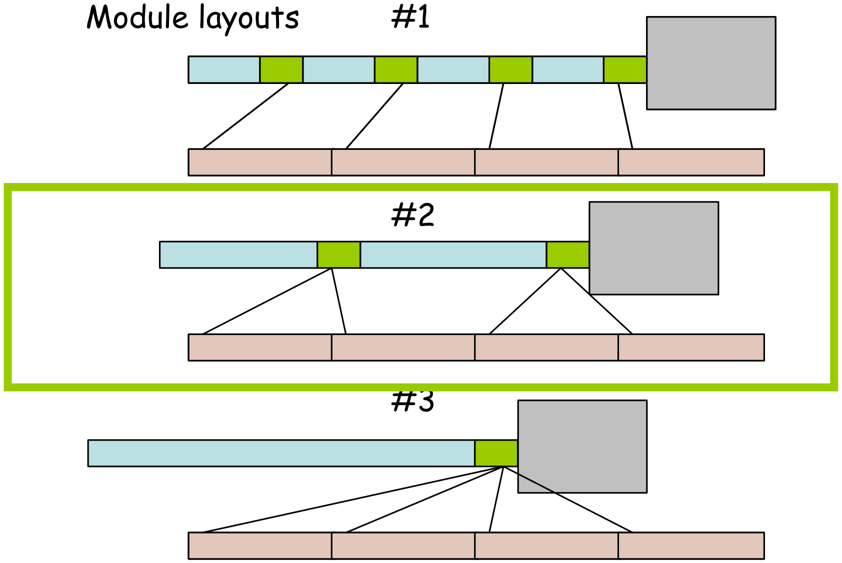
Parameters of WDS120 for CLIC @ 18Wu

Structure	old	new
RF phase advance per cell: $\Delta\varphi$ [°]	120	120
Average iris radius/wavelength: $\langle a\rangle/\lambda$	0.12	0.12
Input/Output iris radii: $a_{1,2}$ [mm]	3.87, 2.13	3.87, 2.13
Input/Output iris thickness: $d_{1,2}$ [mm]	2.66, 0.83	2.66, 0.83
Group velocity: $v_g^{(1,2)}/c$ [%]	2.39, 0.65	2.39, 0.65
N. of reg. cells, str. length: N_c, l [mm]	24, 229	24, 229
Bunch separation: N_s [rf cycles]	7	8
Number of bunches in a train: N_b	265	311
Pulse length, rise time: τ_p, τ_r [ns]	244, 30	297, 30
Input power: P_{in} [MW]	76	69
Max. surface field: E_{surf}^{max} [MV/m]	323	309
Max. temperature rise: ΔT^{max} [K]	57	60
Efficiency: η [%]	31.0	28.8
Luminosity per bunch X-ing: $L_{b\times}$ [m^{-2}]	2.6×10^{34}	2.4×10^{34}
Bunch population: N	5.8×10^{9}	5.2×10^{9}
Figure of merit: $\eta L_{b\times}/N$ [a.u.]	13.7	13.3

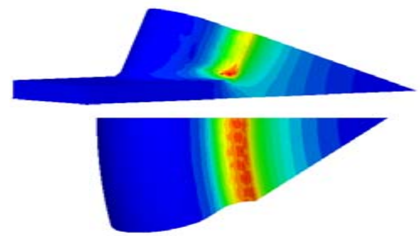
A. Grudiev, 28.03.2007,
update 17.04.2007

PETS

Fixed input parameters for the CLIC 12 GHz PETS design:
- Power production:
  - Power/WDS = 76 MW
  - WDS length (physical)=0.246 m
  - Power limit/PETS ~ WDS ?
  - Drive beam frequency = 12 GHz (first harmonic)
- Module layout:
  - Quad + BPM length = 0.35 m
- PETS specific:
  - Extractor length = 0.075 m
- Drive beam energy < 2.5 GeV
- Beam stability: Quad spacing ≈ 1 m



PETS slotted configuration bring ~ 30% Wu enchantment.



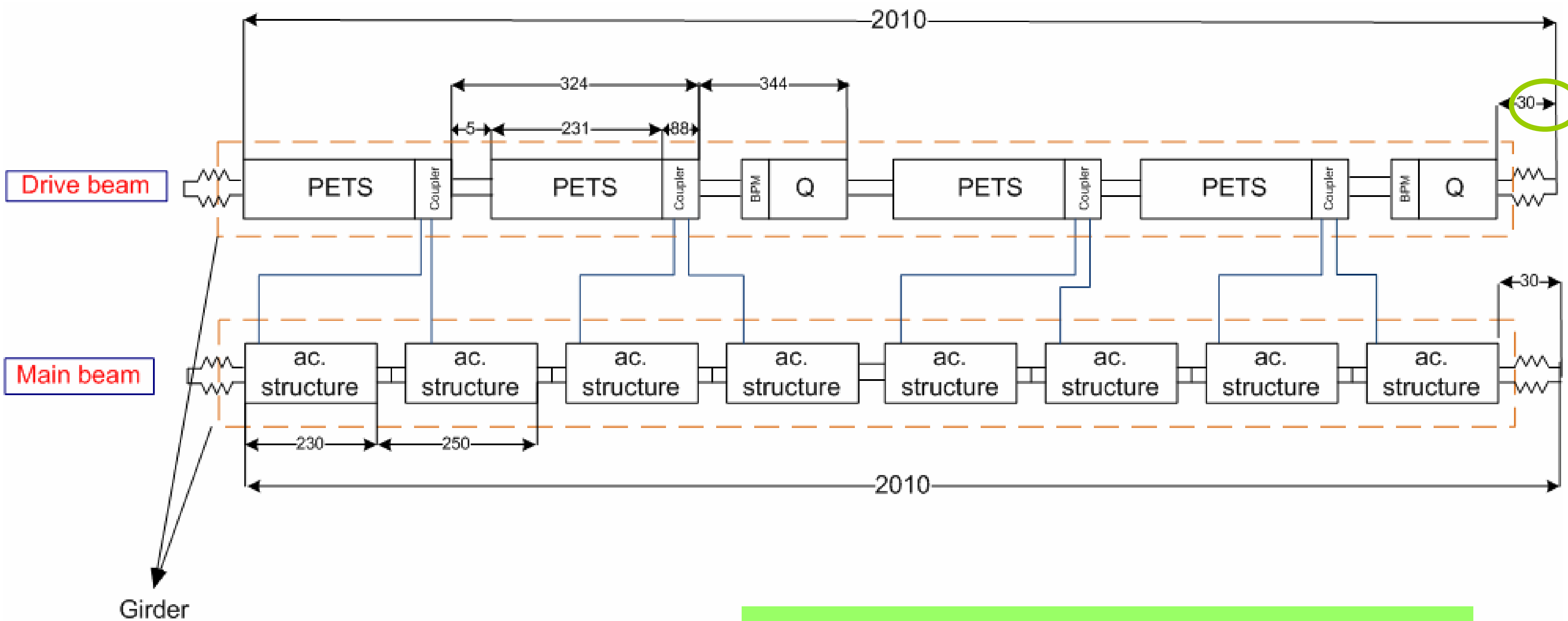
About 10% can be played back with optimizing the iris profile

Module layouts	#1	#2	#3
Unit length, m		1.0	
Drive beam, GeV		2.25	
Drive beam , A		93	
Aperture, mm	15.7	23	30.8
Length, m	0.10	23	56.4
Power/PETS,MW	79	160	317
Wu/WDS (slotted)	0.46	1.0	1.37
Wt (norm./23mm)	3.1	1.0	0.42
QT (norm./23 mm)	1.65	1.0	0.8

Layout #2 is the best compromise in terms of power production, beam stability and cost

I. Syratchev, 17.04.07

Standard Module – Apr 2007




Value to be confirmed

# of standard modules: 16748

 # PETS: 66992

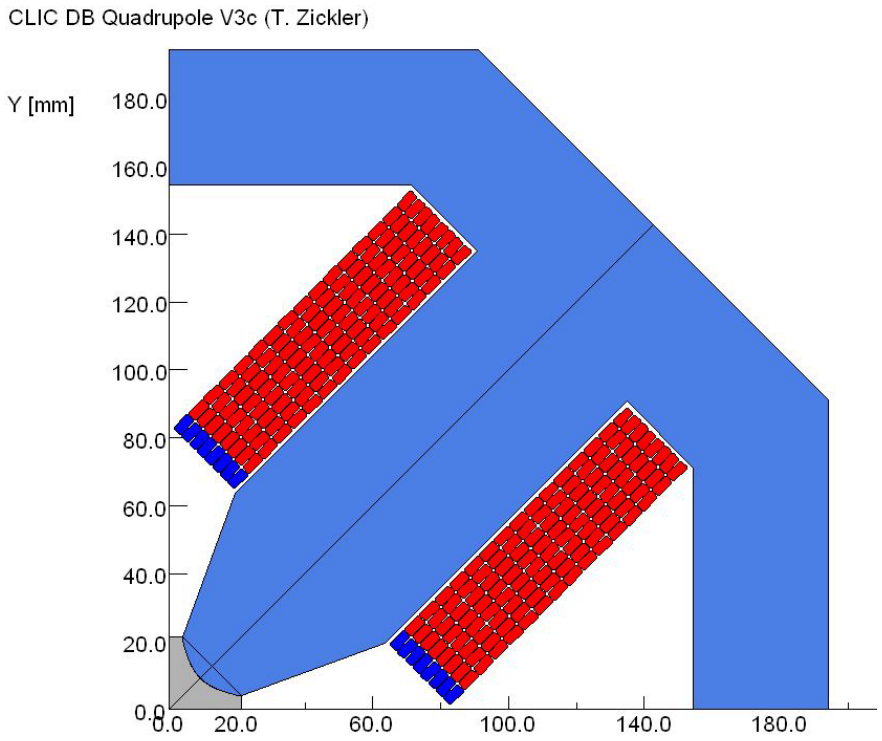
 # AS: 133984

Longitudinal dimensions and quantities

Longitudinal dimensions and quantities							
					number	unit length [mm]	total length [mm]
	Main linac						
		Standard module					
			Accelerating structure length including couplers		8	230	
			accelerating structure interconnection including cutoff pipe		7	20.0	
			inter girder connection		1	30.0	
			Total		girder	2010.0	
					filling factor	0.92	

Drive linac						
	Standard module					
		PETS effective active length		4	231	(6.253x37)
		Coupler + matching cell + space to stop the slot		4	88.0	
		Interconnection		3	5.0	
		PETS effective active length + coupler			319	
		PETS effective active length + coupler + interconnection			324	
		quadrupole + BPM		2	344	
		intergirder PETS /quadrupole interconnection		1	30.0	
		Total			2010	

Proposed Main Beam Quadrupole Layout



2.5 GeV nominal beam energy	
Aperture radius:	13.0 mm
Integrated gradient:	14.3 Tm/m
Nominal gradient:	67.1 T/m
Iron length:	200 mm
Magnetic length:	213 mm
Total length:	270 mm
Magnet width:	390 mm
Magnet weight:	180 kg

Distance between opposite coils: 118 mm

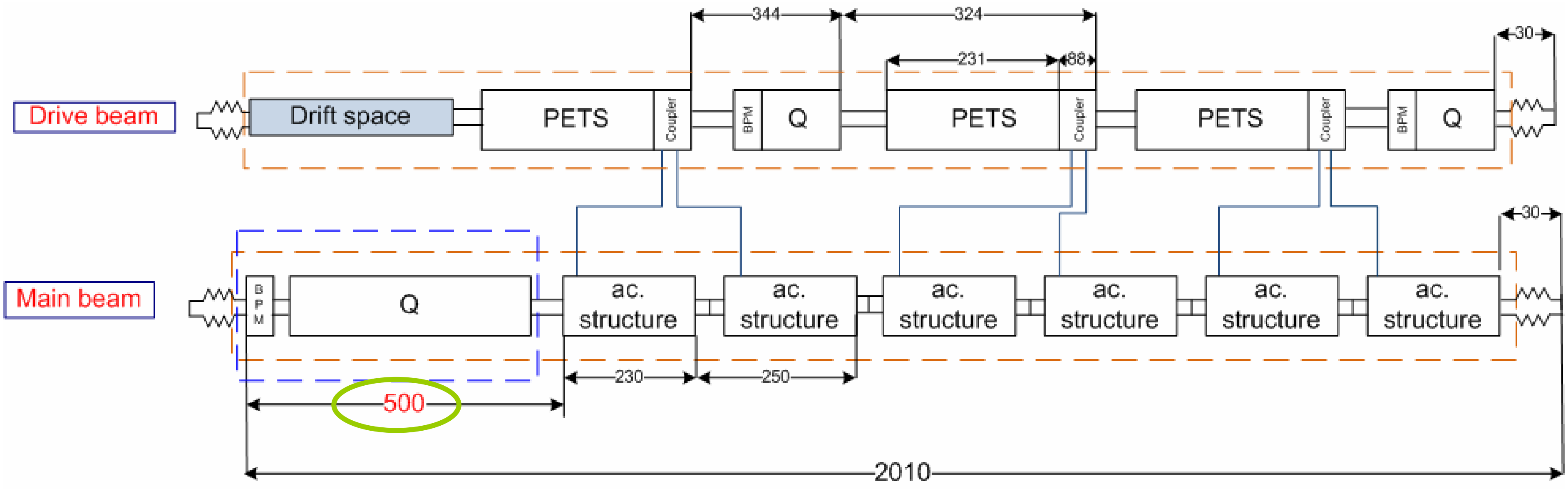
Space available for BPM: 109 mm

Number of turns: 128

Air cooling

T. Zickler, 21.05.2007

Module layout – special #1
Single length quadrupole



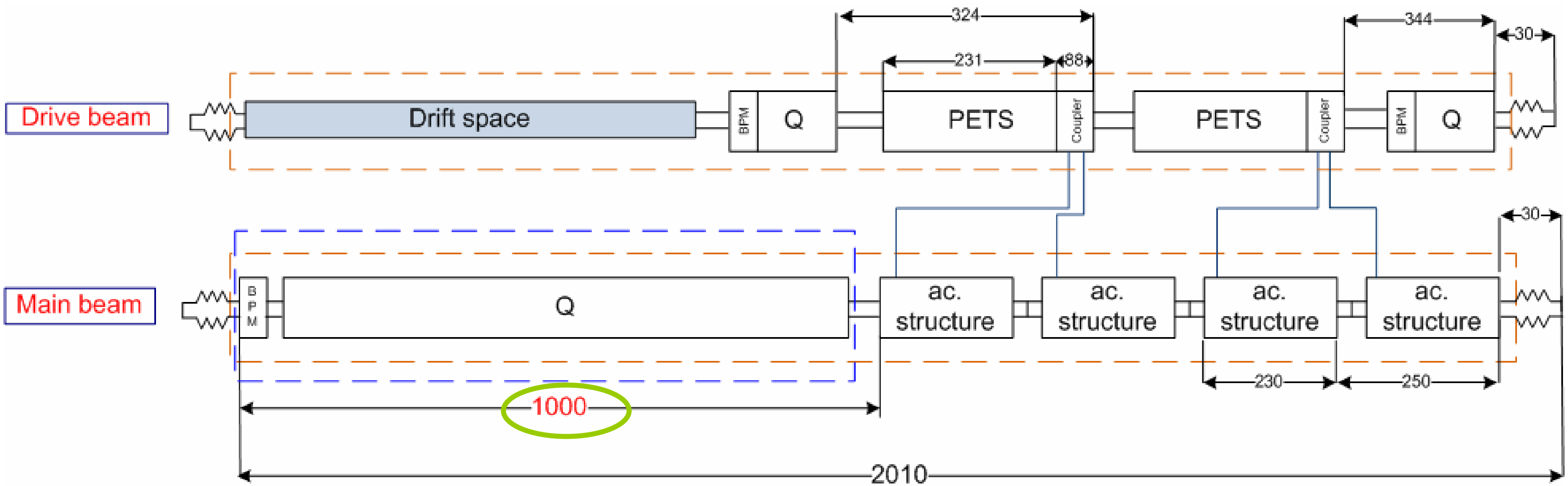
Value to be confirmed

# of special modules 1: 288

 # PETS: 864

 # AS: 1728

Module layout – special #2
Double length quadrupole



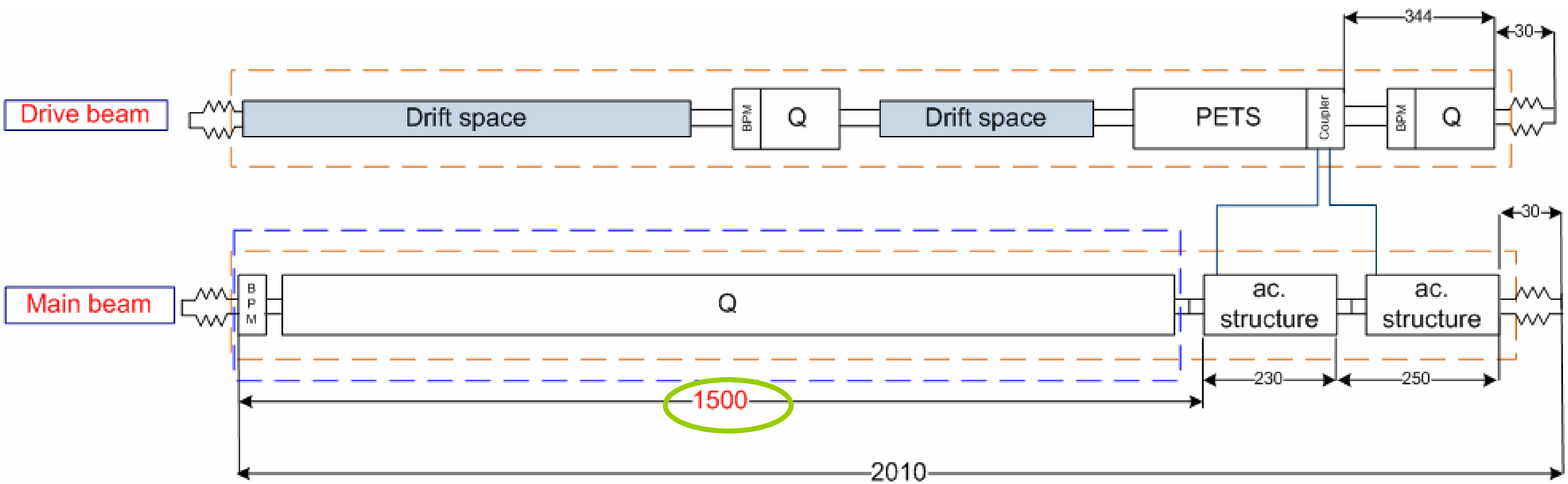
Value to be confirmed

# of special modules 2: 1328

 # PETS: 2656

 # AS: 5312

Module layout – special #3
Triple length quadrupole



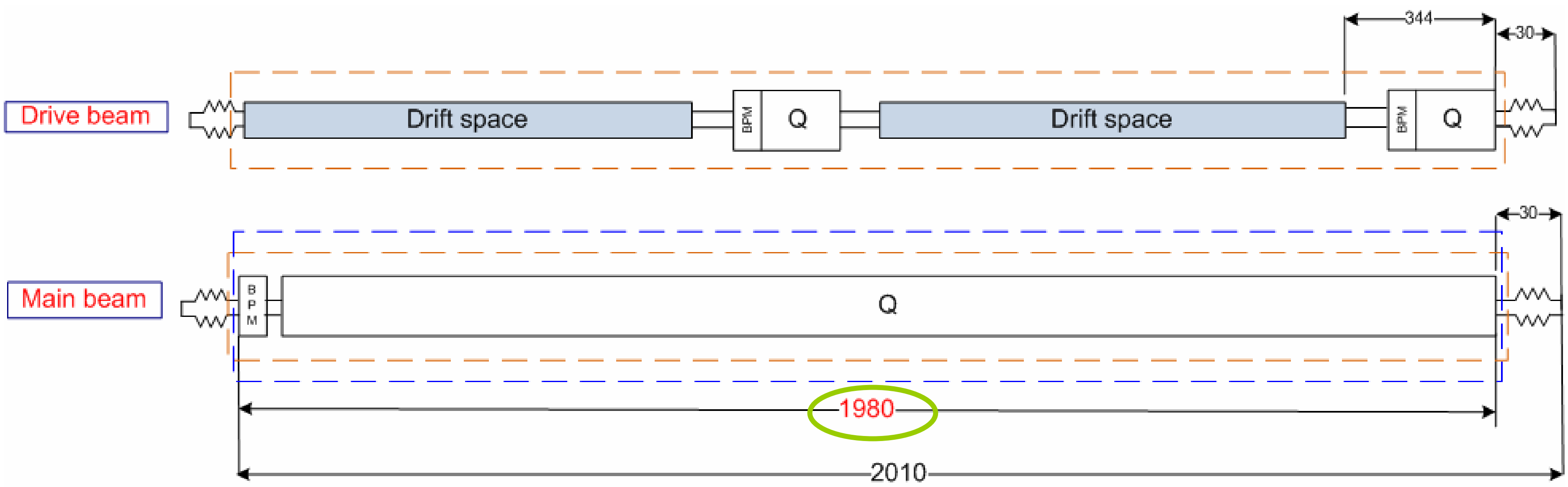
Value to be confirmed

# of special modules 3: 948

 # PETS: 948

 # AS: 1896

Module layout – special #4
Full length quadrupole



Value to be confirmed

# of special modules 4: 1448

 # PETS: 0

 # AS: 0

Longitudinal dimensions and quantities

		Number	Unit length [mm]
Special module (- 2 Acc. Structures) - single length quadrupole			
	Accelerating structure length including couplers	6	230
	accelerating structure interconnection including cutoff pipe	5	20.0
	inter girder connection	1	30.0
	Quad + BPM	1	500.0
	Total	girder	2010.0
Special module (- 4 Acc. Structures) - double length quadrupole			
	Accelerating structure length including couplers	4	230
	accelerating structure interconnection including cutoff pipe	3	20.0
	inter girder connection	1	30.0
	Quad + BPM	1	1000.0
	Total	girder	2010.0
Special module (- 6 Acc. Structures) - triple length quadrupole			
	Accelerating structure length including couplers	2	230
	accelerating structure interconnection including cutoff pipe	1	20.0
	inter girder connection	1	30.0
	BPM(s) from structure damping waveguides	2	0.0
	separate BPMs fixed to accelerating structures	0	0.0
	Quad + BPM	1	1500.0
	Total	girder	2010.0
Special module (- all Acc. Structures) - full length quadrupole			
	Accelerating structure length including couplers	0	230
	accelerating structure interconnection including cutoff pipe	0	20.0
	inter girder connection	1	30.0
	BPM(s) from structure damping waveguides	0	0.0
	separate BPMs fixed to accelerating structures	0	0.0
	Quad + BPM	1	1980.0
	Total	girder	2010.0

Transverse dimensions inside quadrupoles

Transverse dimensions inside quadrupoles			
Main linac			
beam pipe inner radius	2.13	mm	to be confirmed by T. Zickler
beam pipe thickness including stiffening and pumping if necessary	1	mm	to be confirmed by T. Zickler
radial play for alignment	1.5	mm	to be confirmed by T. Zickler
quadrupole inner radius	5	mm	
gradient	216	T/m	
Drive linac			
beam pipe inner radius	11.5	mm	confirmation T. Zickler at the CMWG on 21.05.2007
beam pipe thickness	0.5	mm	
radial play for alignment	1	mm	
quadrupole inner radius	13	mm	
Nominal gradient	67.1	T/m	
Iron length	200.0	mm	
Magnetic length	213.0	mm	
Total length	270.0	mm	

System integration

- Decision to work in parallel to input definition
- Baseline approach:

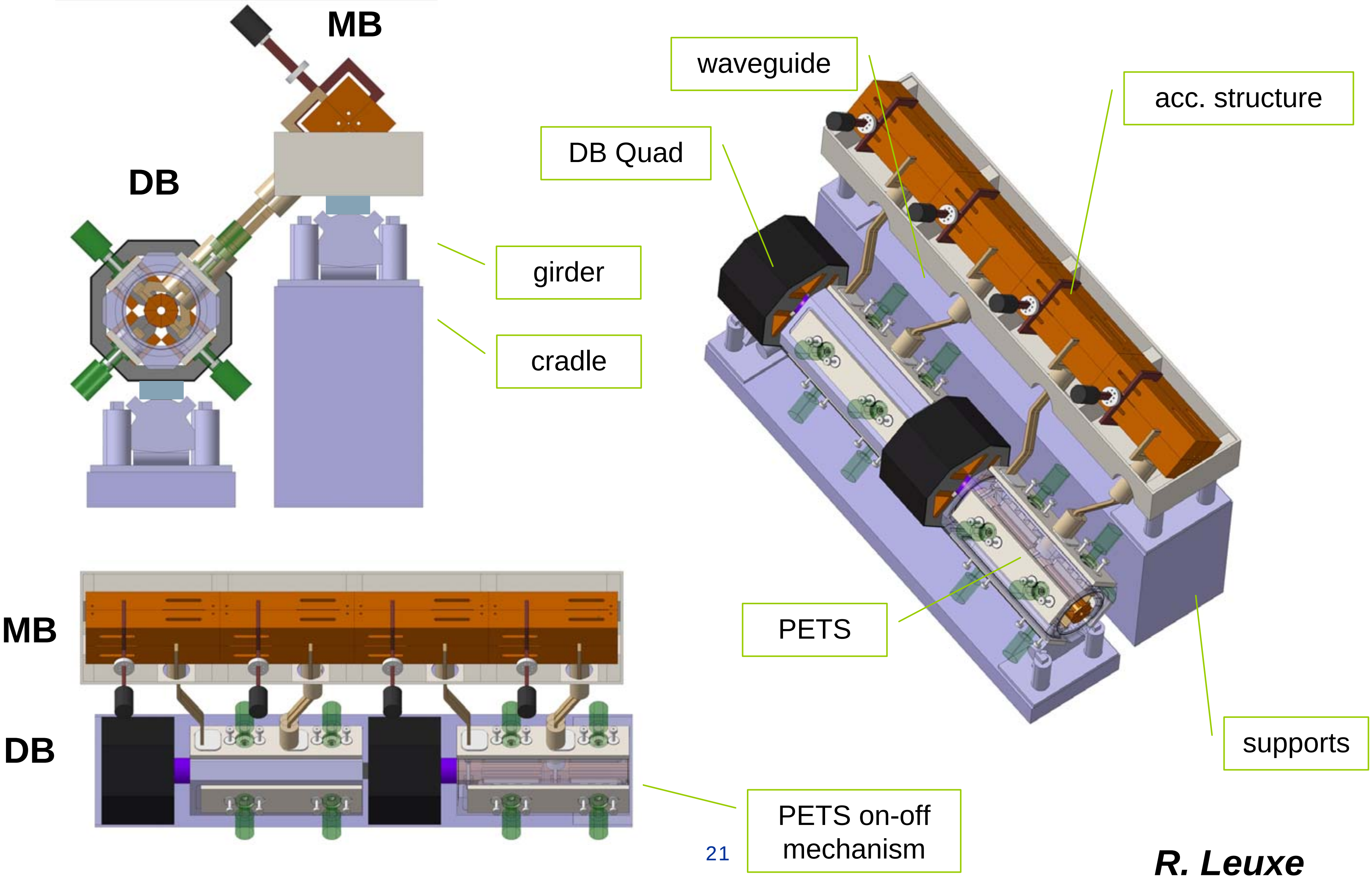
1. Identification of the requirements for the main components (PETS, acc. structures,...) and systems (cooling, vacuum alignment, beam instrumentation, beam dynamics ...)
2. “quasi-detailed study” for the main components: acc. structures, PETS
3. Space reservation for the main systems: alignment/supporting system, ...
4. Detailed study of each system

System integration

- Main boundary conditions (in addition to input on accelerating structures and PETS)
  - PETS-accelerating structure inter-axis: 750 mm
  - Acc. structures: quadrants
  - Tank for PETS and tank for acc. structures
  - PETS and accelerating structures with common vacuum
  - Separate PETS and accelerating structure girders

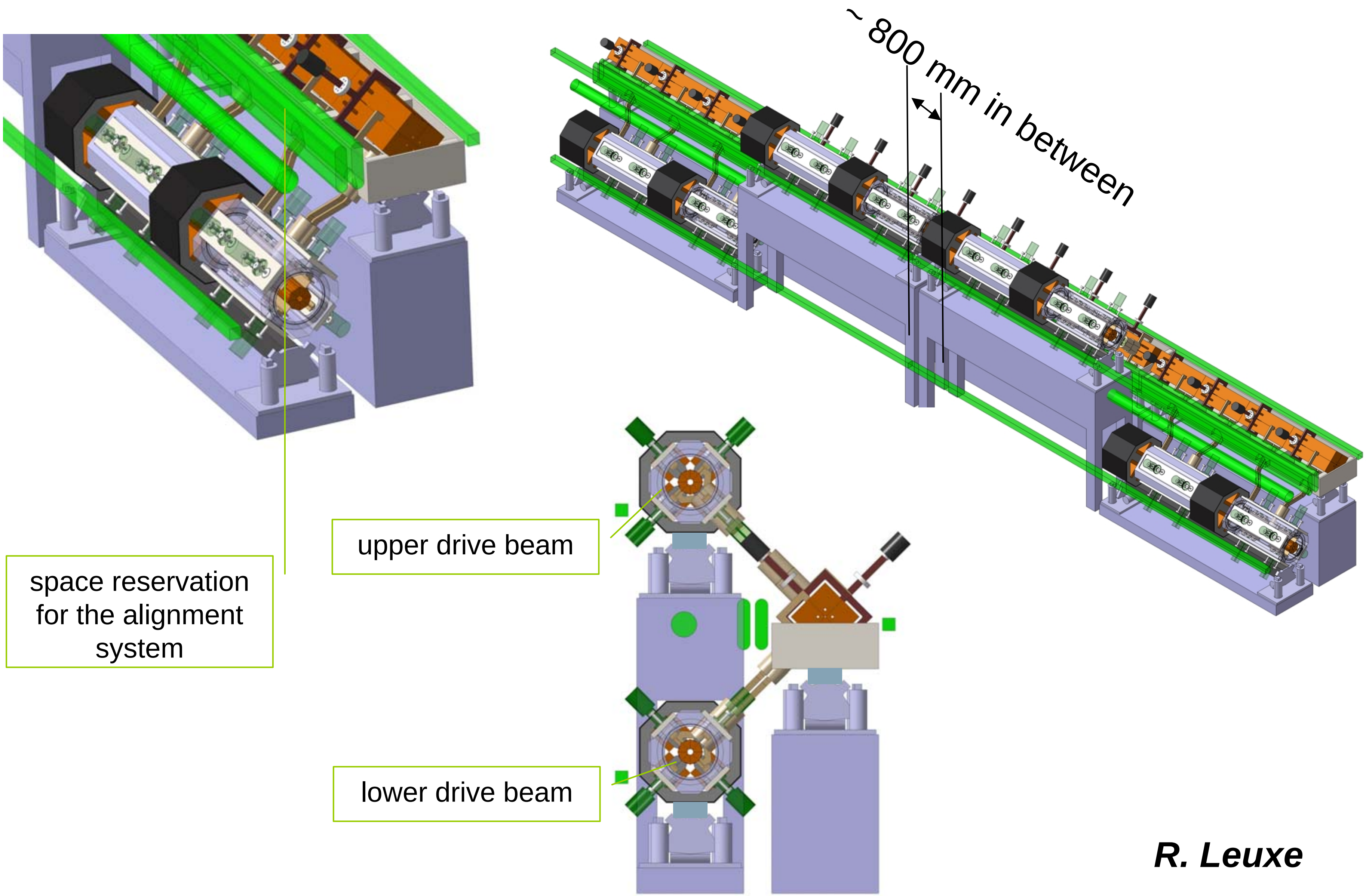
  - BPM attached to drive beam quadrupoles
  - Separate BPM and main beam quadrupoles
  - BPM attached to each accelerating structures

Standard module



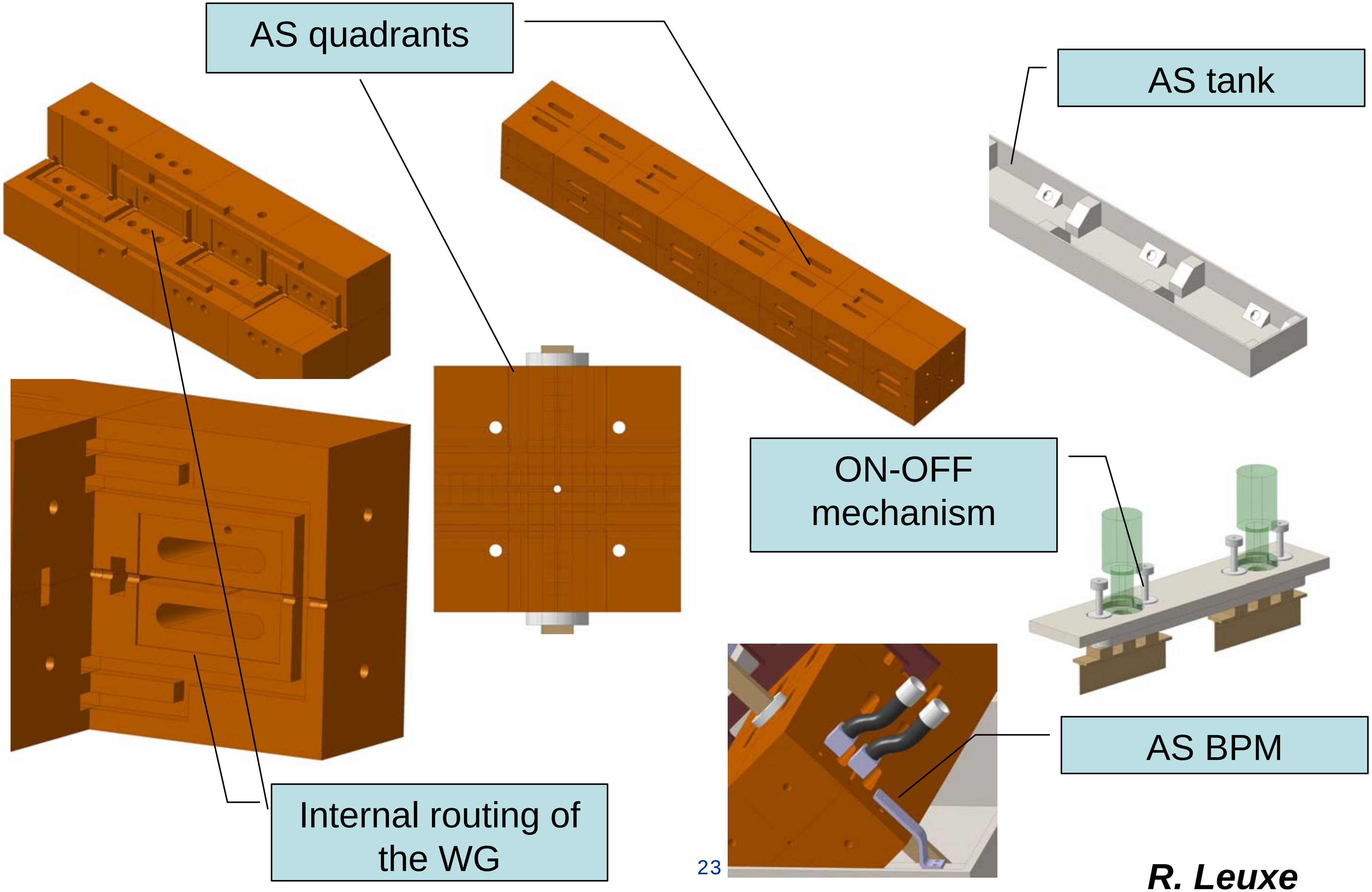
R. Leuxe

Standard module



R. Leuxe

Standard module - Details



R. Leuxe

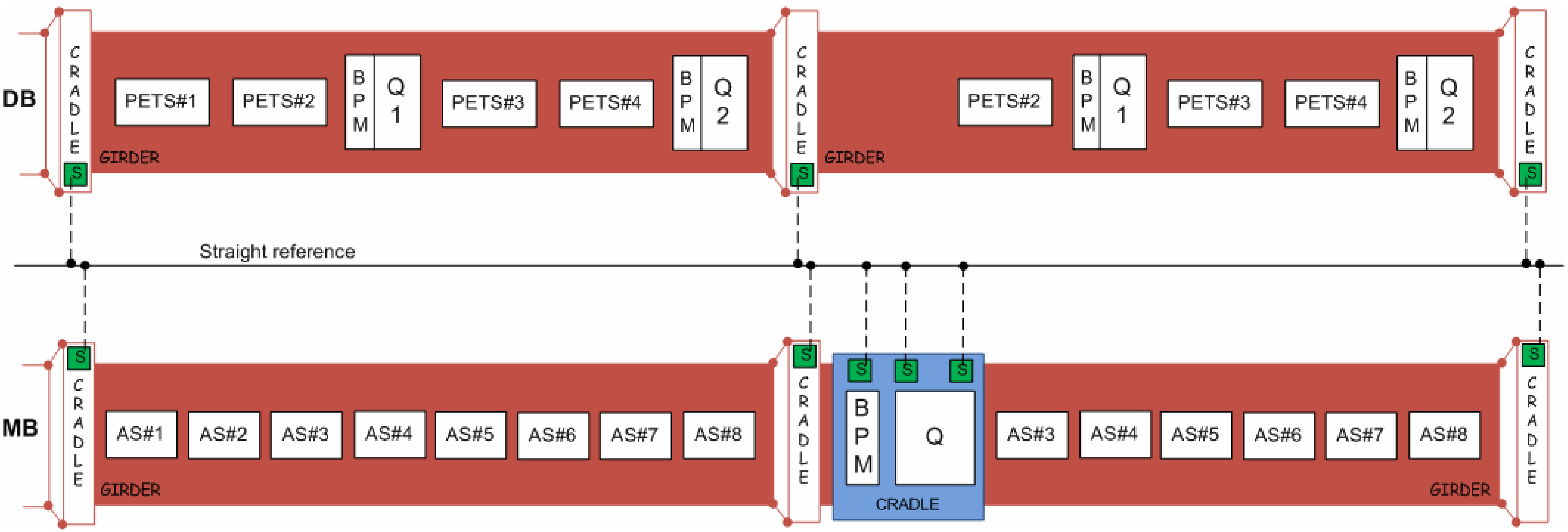
Alignment tolerances

- Dedicated study in collaboration with D. Schulte and H. Mainaud-Durand
- Alignment error identification:
  - Mechanical errors
  - Positioning errors
- Tolerances for:
  - Pre-alignment: before pilot beam
  - Alignment: beam-based alignment
- Main cases:
  - Accelerating structures (1) and PETS (4)
  - Main linac quadrupoles (2)
  - Main linac quadrupole BPM (3)

Definitions for the errors

- Identification of the r.m.s value for each independent and random error "E"
- The quadratic sum of all the individual errors (r.m.s) gives the r.m.s value of the process
- The tolerance (maximum acceptable error) of the process is <u>3 times</u> the r.m.s error of the process

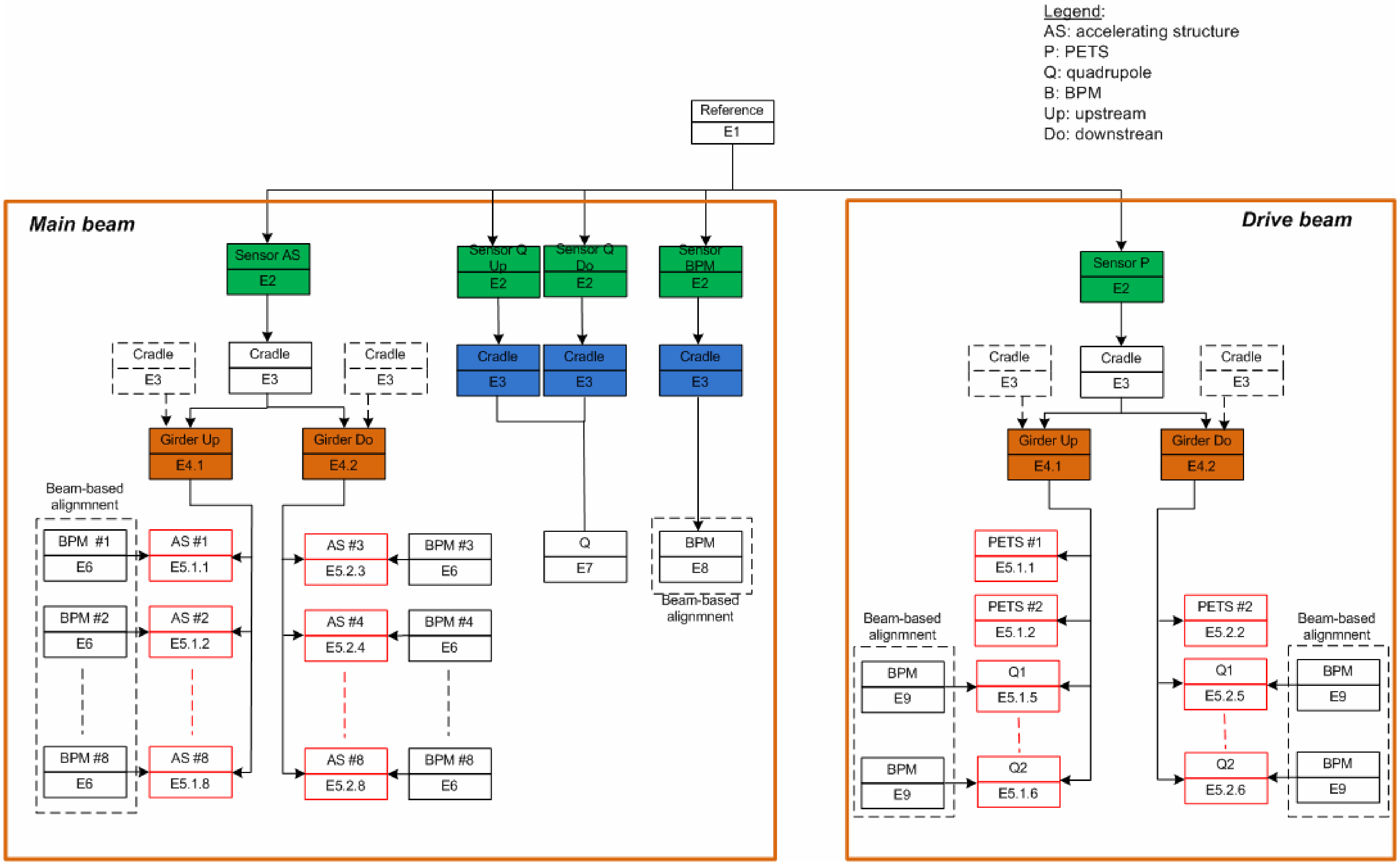
Module layout with sensor position



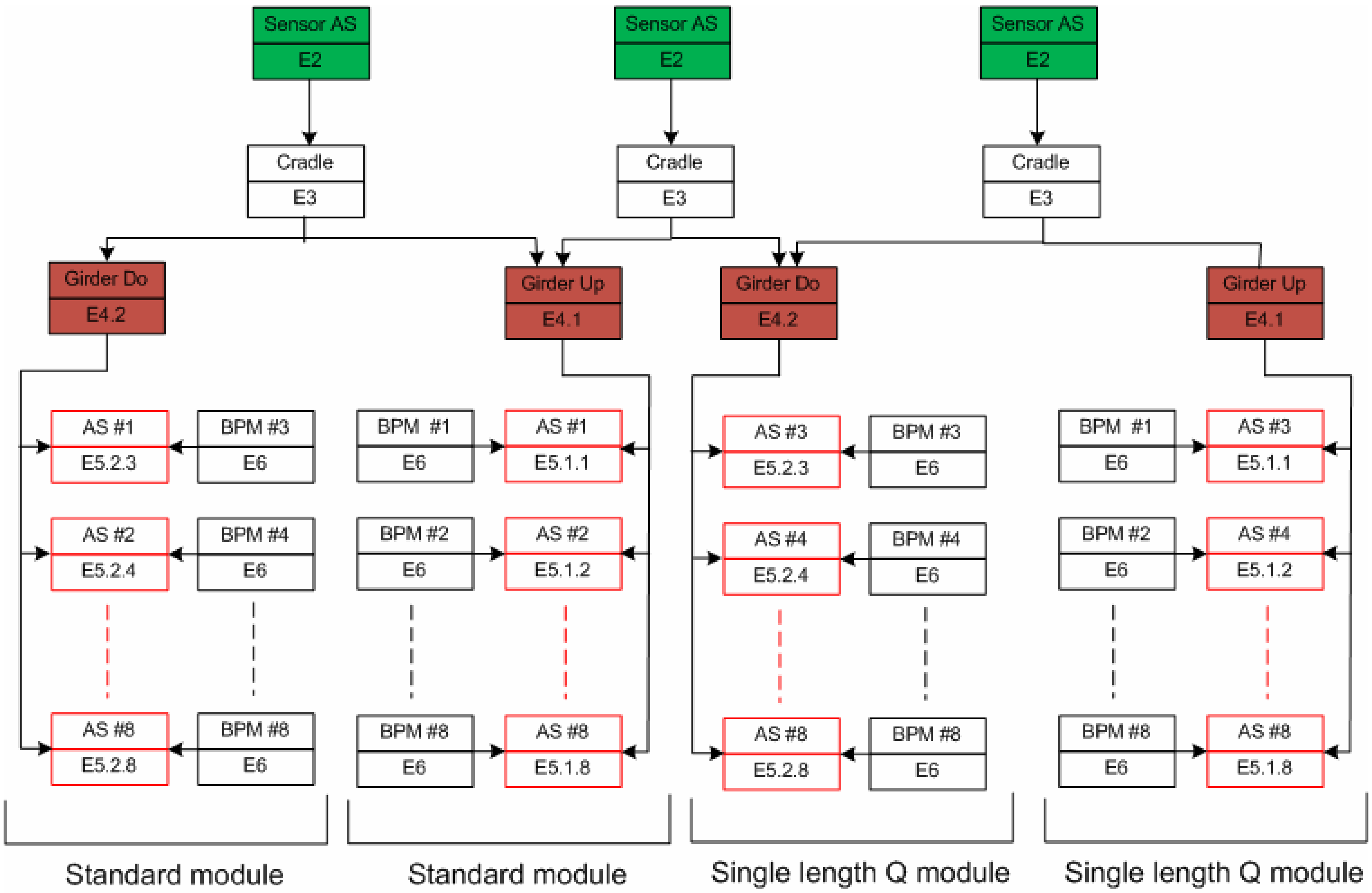
Standard module

Special module

Pre-alignment and beam based alignment process



Pre-alignment and beam based alignment process



Tolerance for accelerating structure

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 Tolerance	14 μm 40 μm	1σ 3σ

BEAM-BASED ALIGNMENT

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

Detailed error description

Case 1: accelerating structure

Link	Errors description	Origin
E1*: Link "local" reference / straight reference line	Error on the "reconstruction" of the straight line using overlapping references	Positioning
	- Link between the 2 reference points of the straight line and the local references.	
E2: Link sensor / "local" reference	Error on the reference surface of the sensor support w.r.t. the "local" reference	positioning
	- stability of the reference	
	- interchangeability of the sensor	
	- uncertainty of the measurement of the sensor	
E3: Link sensor/cradle	Error on the reference surface of the sensor support wrto the reference surface of the cradle	mechanical
	- connection between sensor reference plate and cradle	
E4: Link cradle/girder	Error on the mechanical references position of the girder wrto the 2 adjoining articulation points	mechanical
	- connection between the cradle and the girder (default at the level of the articulation point) on one side	
E5a: Link girder/acc. structure	Error on the mean axis of the accelerating structure wrto the mech. reference of the girder	mechanical
	- positioning of the accelerating structures on girder	
	- BPM measurement	
E5b: Inherent precision of structure	Error on accelerating structure position wrto the mean axis of the accelerating structures	mechanical
	- geometry of the accelerating structure	

Some remarks:

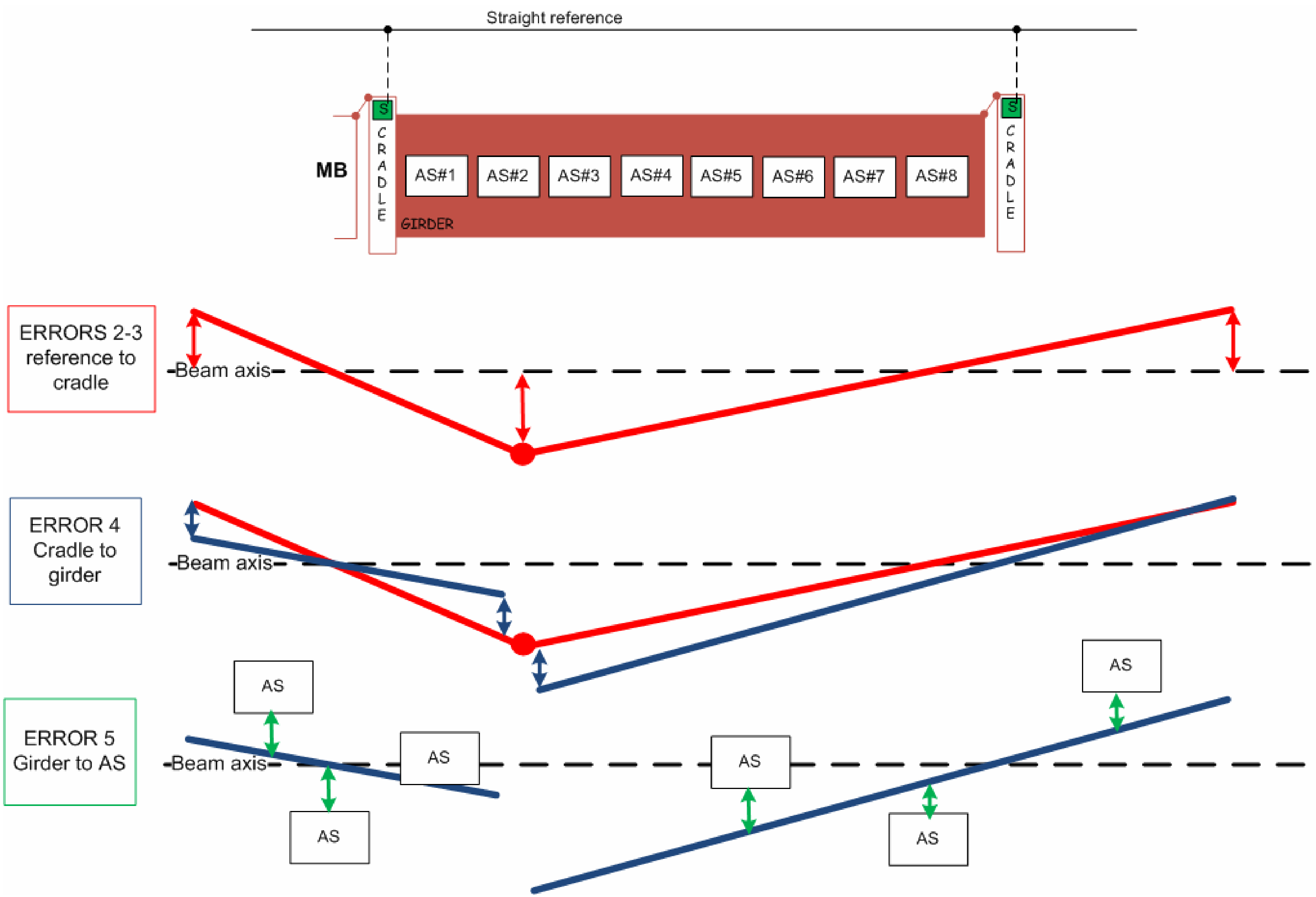
E1*: it includes E1 which is the error due to the link between two adjacent girders

E5a, E4, E3: are the steps of the fiducialisation

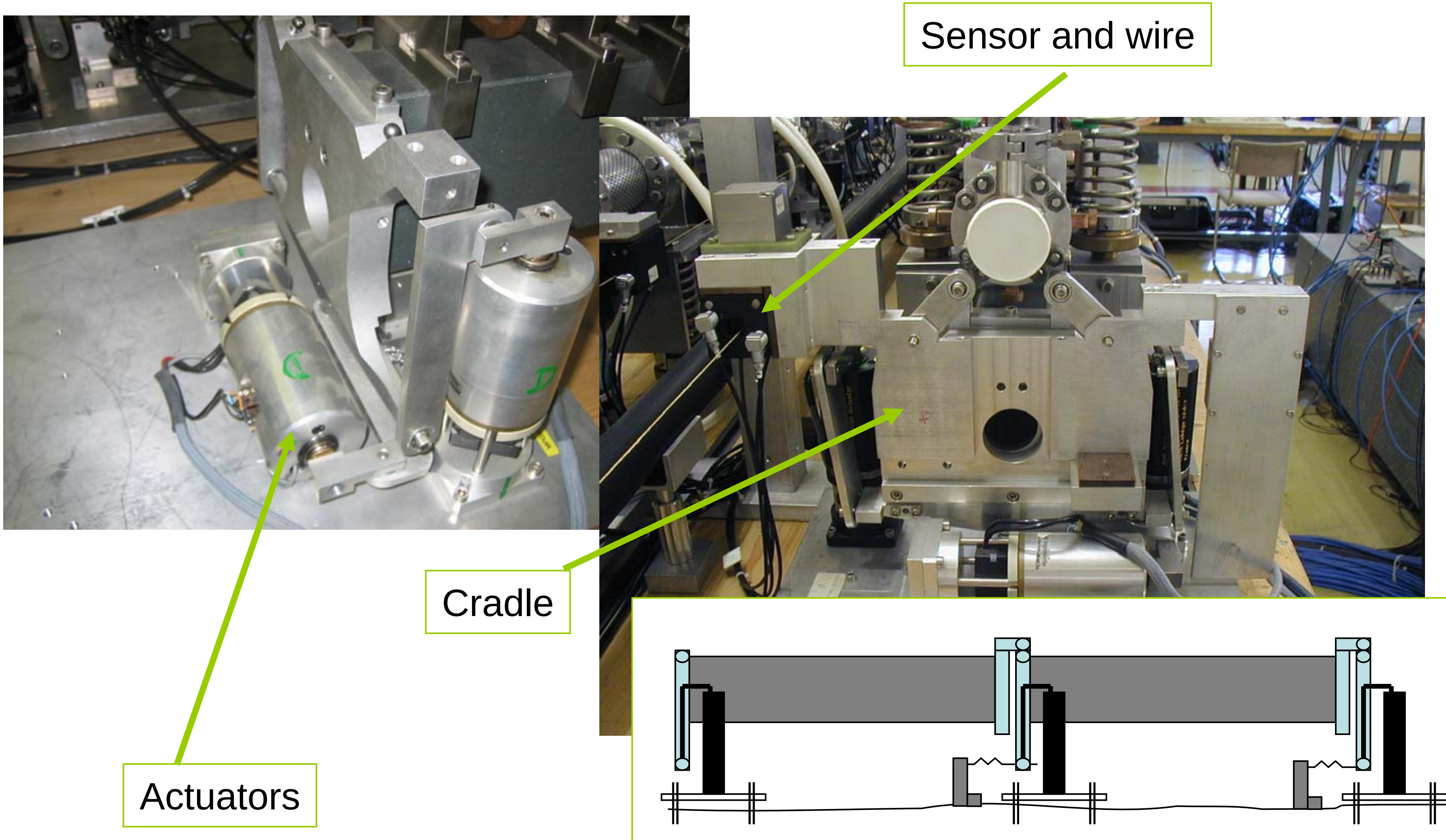
What we want to align according to the readings of the sensors is the articulation point.

E5a: mean axis : is this the mechanical reference of the first and last accelerating structures on the girders or the <u>beam reference of the first and last accelerating structures?</u>

Schematic representation of the errors



Girders and cradles – Example CTF2



Tolerance for main linac quadrupole

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

Tolerance for quadrupole BPM

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

Tolerance for PETS

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 Tolerance	31 μm 93 μm	1σ 3σ

Error feasibility and dedicated development

Case 1: accelerating structure

	Link	In case of overlapping reference =wire, "local" reference = wire				In case of overlapping reference =wire, "local" reference = RASNIK			
		Budget error (feasible)	**Error origin on 200m**	**Error on 200m**	**Error on correction**	**Budget error (feasible)**	**Error origin**	**Error on 200m**	**Error on correction**
	E1*: Link "local" reference / straight reference line	TBD	Gravity	+/- 15 microns	TBD	TBD	Gravity	+/- 15 microns	TBD
			Modelization	+/- 10 microns	TBD		Modelization	+/- 10 microns	TBD
	E2: Link sensor / "local" reference	+/- 5 microns on 20m				TBD on 20m	RASNIK: no more than 20m (otherweise under vacuum)		
			Gravity	+/- 15 microns	TBD		No Gravity influence		
			Modelization	+/- 10 microns	TBD		No modlization		
			"coriolis" type	+/- 30 microns	TBD		No "coriolis" type		
Fiducialisation	**E3: Link sensor/cradle**	+/- 5 microns according to CTF2							
Fiducialisation	**E4: Link cradle/girder**								
Fiducialisation	**E5a: Link girder/acc. structure**								
	E5b: Inherent precision of structure	+/- 10 microns							

Some remarks:

E1*: it includes E1 which is the error due to the link between two adjacent girders

E5a, E4, E3: are the steps of the fiducialisation

What we want to align according to the readings of the sensors is the articulation point.

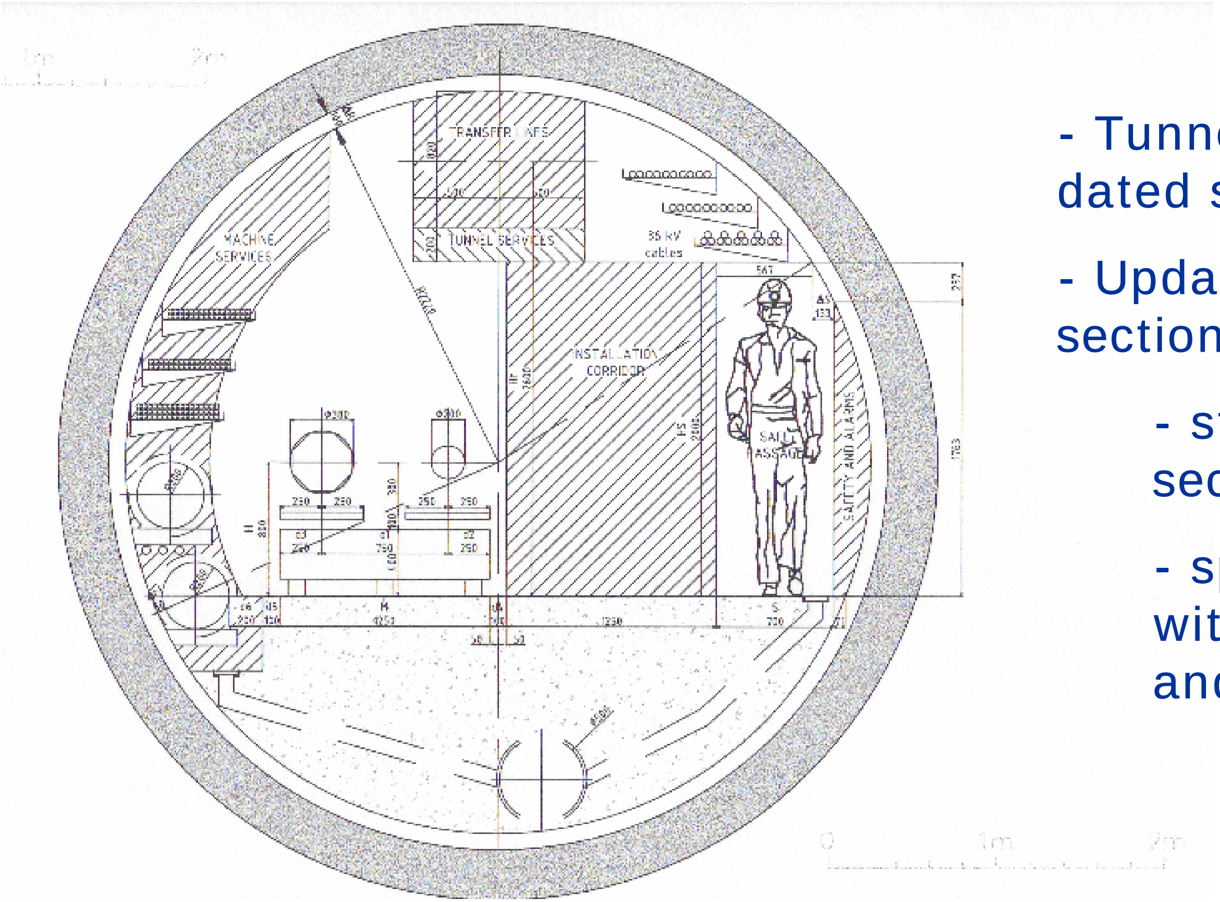
E5a: mean axis : is this the mechanical reference of the first and last accelerating structures on the girders or the beam reference of the first and last accelerating structures?

H. Mainaud-Durand

Other systems - status

- Cooling system
  - Calculation of the dissipated power
    - AS: average dissipated power 530 W
    - PETS: beam losses 1500 W/m2 – surface current: 1850 W/m2
  - Next step: sizing of the cooling system
- Vacuum system
  - Calculation of the surfaces to be pumped:
    - MB: 8.3 m²
    - DB: 2.3 x2 = 4.6 m²
    - Waveguides = 0.2 m²
  - Next step: sizing of the vacuum system
- Alignment/supporting system
  - Detailed work will start in July 2007

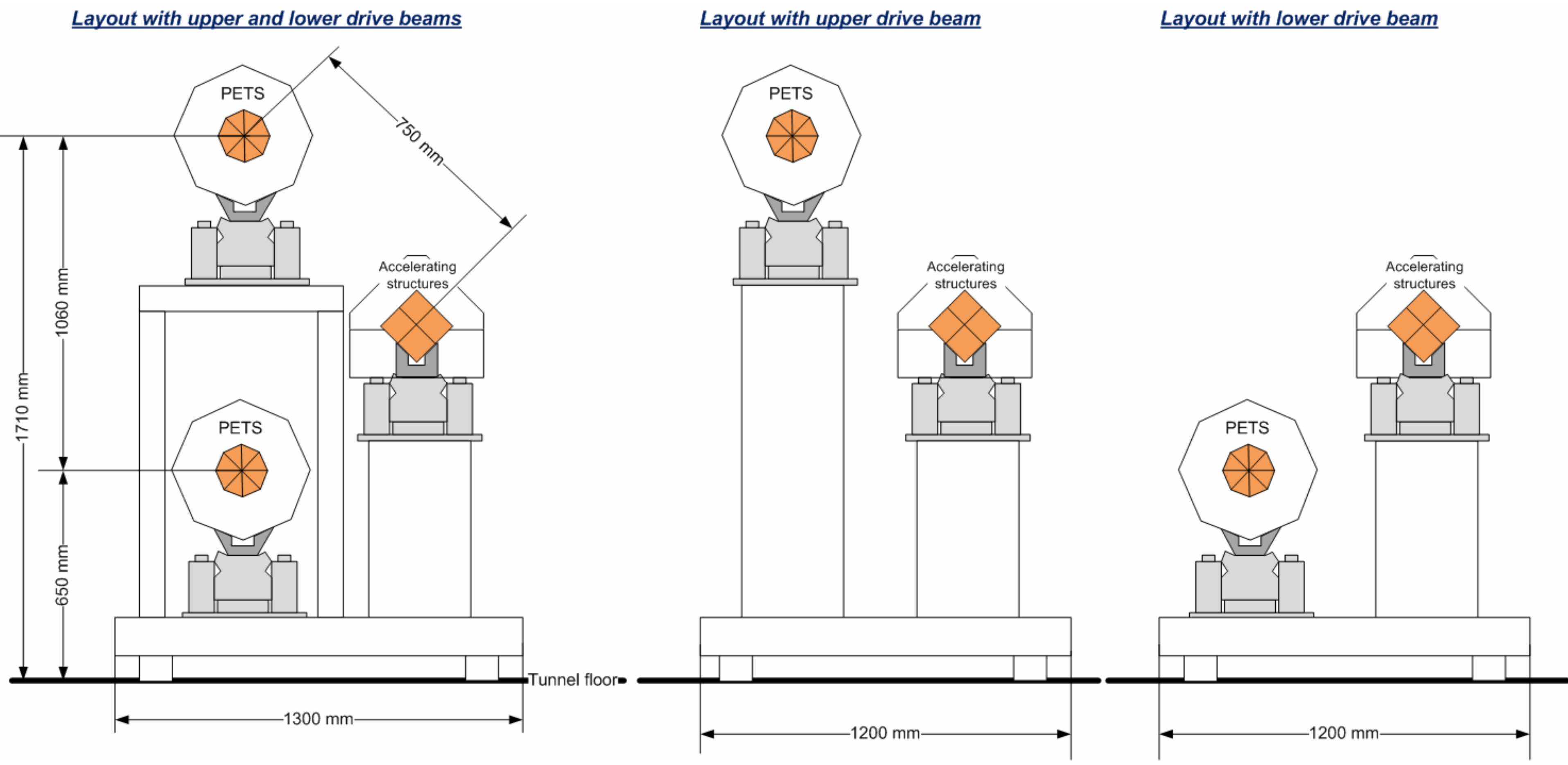
Tunnel integration



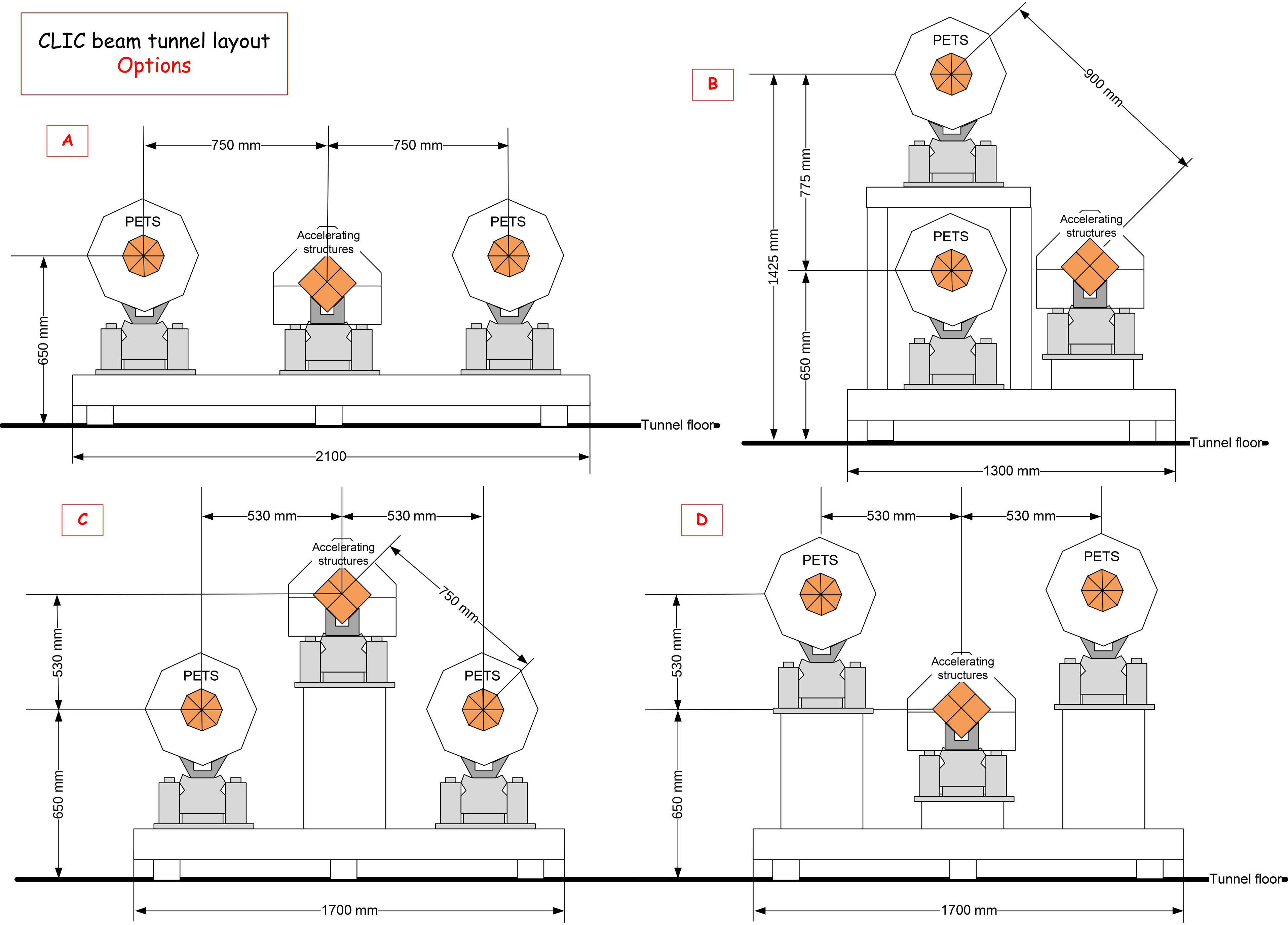
- Tunnel cross-section dated sept 2006
- Update of the cross-section from summer 2007
  - standard cross-section
  - special cross-sections with drive beam “in” and drive beam “out”

CLIC beam layout

Baseline configuration

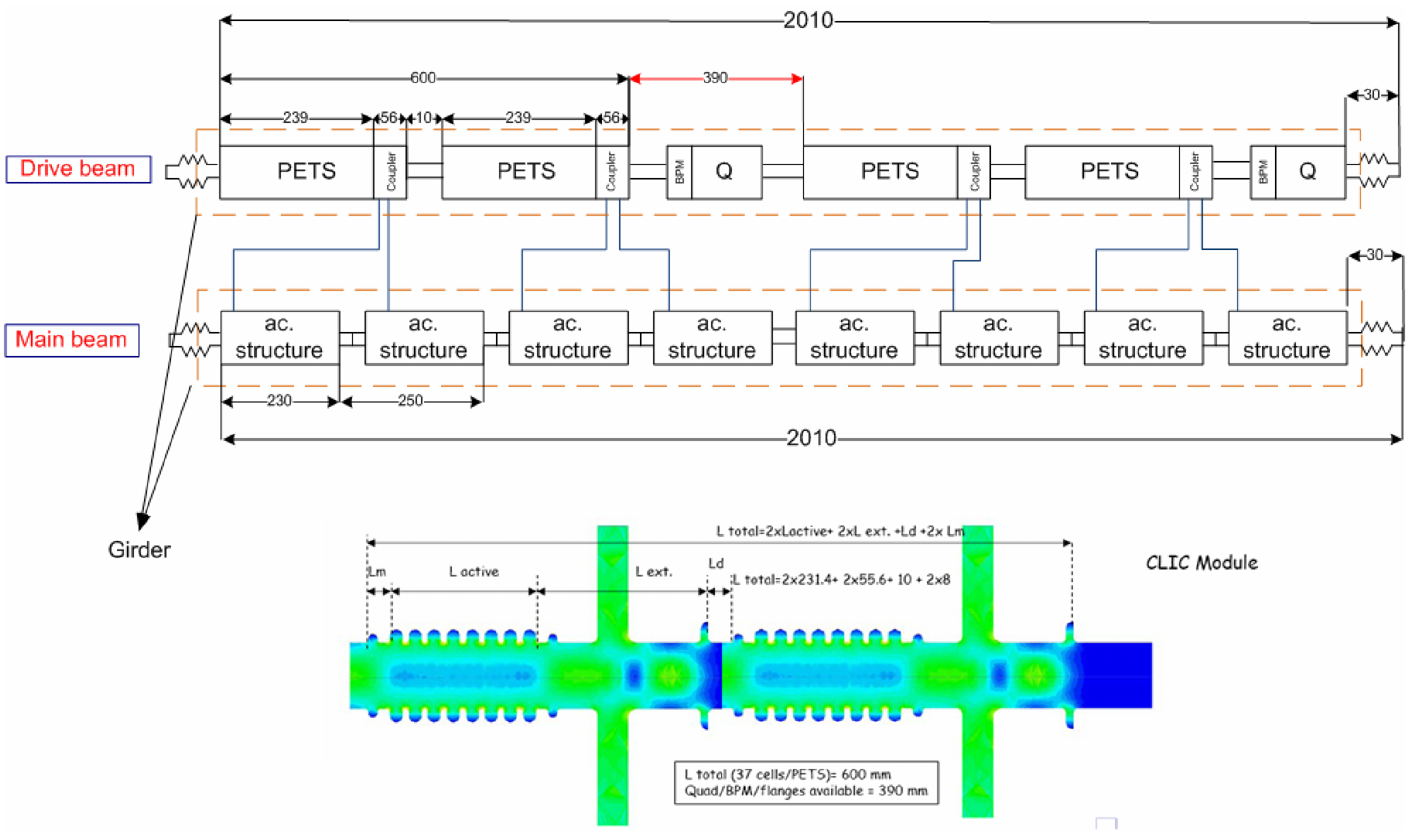


CLIC beam tunnel layout
Options



Changes in the pipeline

- Shorter PETS interconnection length ➔ additional space for drive beam quadrupoles and BPM



Future work

- Finish first round of system integration for standard module ➔ June 2007
- Start first round of system integration for special modules ➔ June 2007
- Initiate next level of design for standard and special modules ➔ Summer 2007
- Main beam quadrupole design ➔ summer 2007
- Continue study on alignment, cooling and vacuum systems
- Supporting system and tunnel integration ➔ summer 2007

Documentation available in EDMS structure

- CLIC Module
  - General
  - Meetings
  - Technical Specification
  - Technical Notes
  - Procedures
  - Reports
  - Components
    - Quadrupoles
    - Accelerating Structures
    - PETS
    - BPM
    - Waveguides
    - RF Components
    - Alignment-supporting System
    - Vacuum System
    - Cooling System
  - Layout
  - Drawings
  - Tunnel Integration
  - Schedule