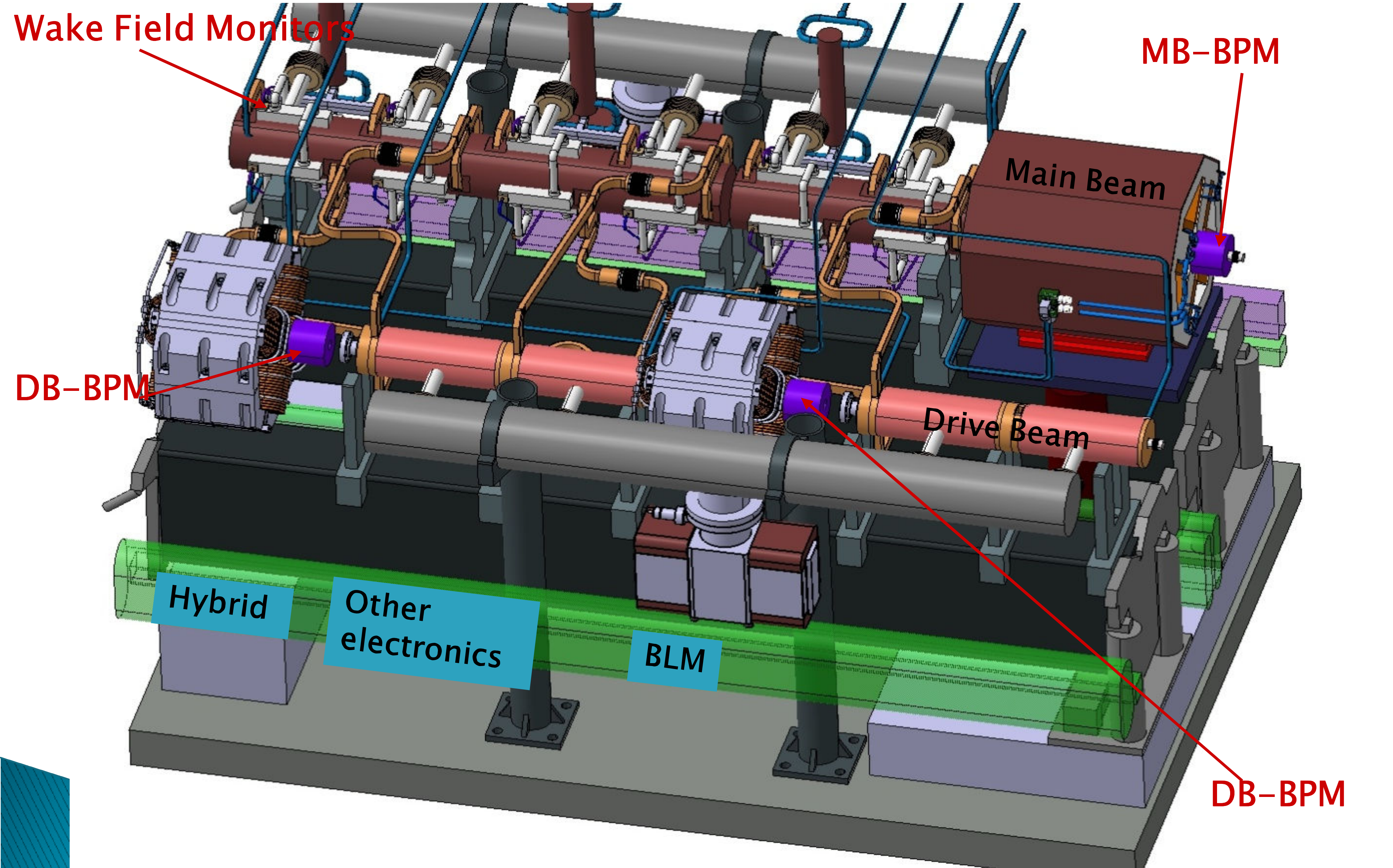
CLIC module instrumentation

- **Module beam instrumentation**
  1. BPM's
  2. Wakefield monitors
  3. BLMs
  4. Acquisition system

- **Sector beam instrumentation**
  1. Transverse profile monitors
  2. Current measurement
  3. Bunch form / length
  4. Beam phase

CLIC module, Type 1



BPM collaborations

	Main beam BPM	Main beam BPM	Drive beam BPM	WFM	FE electronics
Institute	FNAL	RHUL	SLAC	CEA	LAPP
Contact	M. Wendt	G. Blair	S. Smith	F. Peauger	S. Vilalte
Deliverable	3D design Cavity BPM Acq. system	3D design Choke BPM, Lab tests Beam tests?	1 year at CERN. 3D design. Lab tests	Design, build and test in CTF3	Design and test of standard acquisition module.
CERN	Mechanical design. Build 3 (4) proto types Lab tests	Mechanical design. Build proto type.	Mechanical design. Build 1 (3) proto types	?	Write specifications Test in CTF3
MOU	Unofficial	Not yet	Yes	Yes	Not yet

BPM and WFM specifications

Main beam

Nominal beam parameters: Charges/bunch :$3.7*10^9$, Nb of Bunches: 312, Bunch length: 45µm-70µm, Train length: 156ns

	Accuracy	Resolution	Stability	Range	Bandwidth	Beam tube aperture	Available length	Intercepting device?	How many?	Used in RT Feedback?	Machine protection Item?	Comments	Ref
BPM	5µm	50nm	100nm		35MHz	8.0mm	95/65mm	No	4176	Yes	Yes	Choke BPM? Inductive BPM	CLIC note 764
WFM	5µm	<5µm	?		35MHz	8.0mm?	"-"	No	142812	Yes	No	TM01~16GHz	CLIC note 764

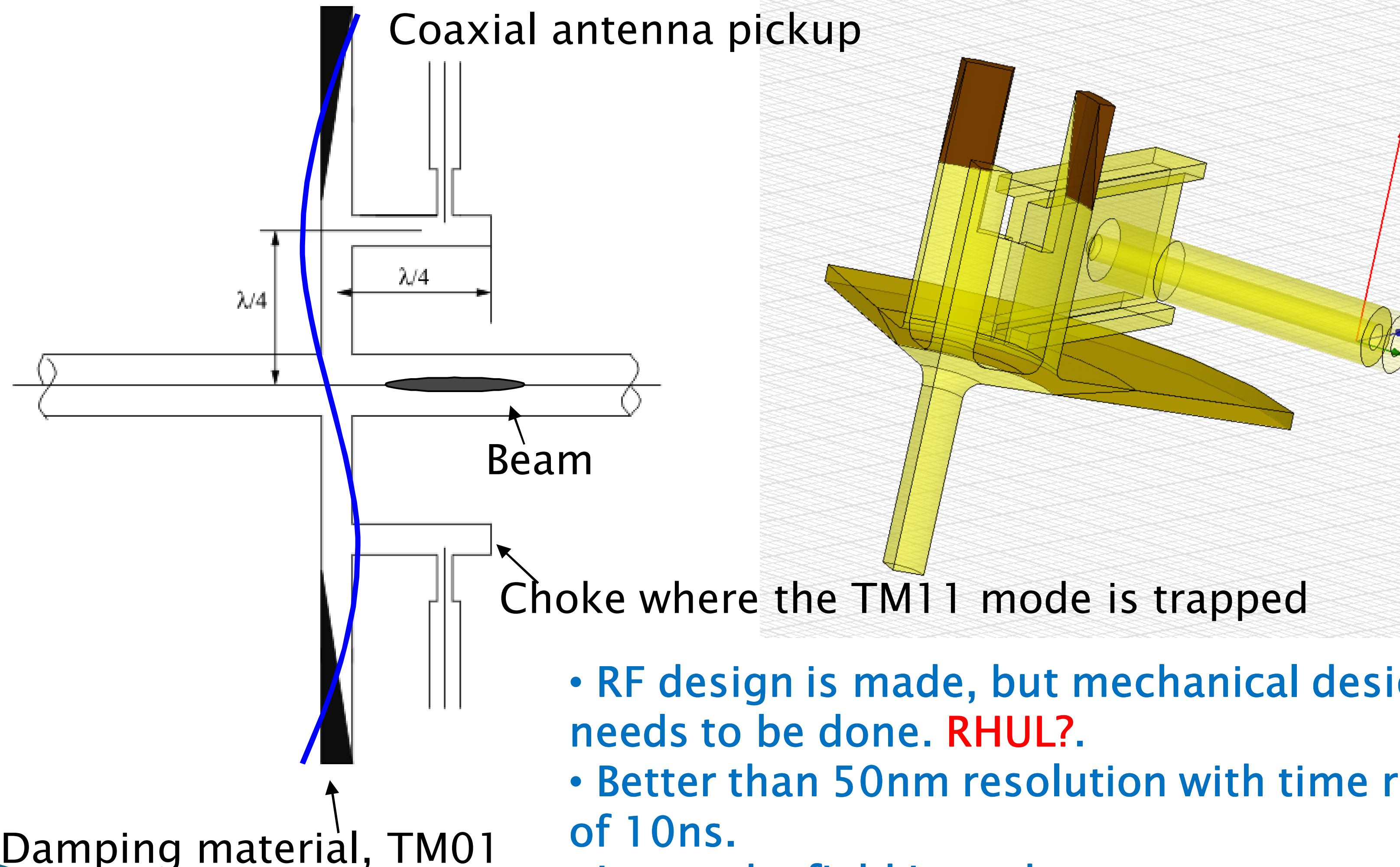
Drive beam

Nominal beam parameters: Charges/bunch :$5.2*10^{10}$, Nb of Bunches: 2922, Bunch length: 1mm, Train length: 243.7ns

	Accuracy	Resolution	Stability	Range	Bandwidth	Beam tube aperture	Available length	Intercepting device?	How many?	Used in RT Feedback?	Machine protection Item?	Comments	Ref
BPM	20µm	2µm	?	<5mm	35MHz	23mm	104/74mm	No	41480	Yes	Yes	Inductive ? Strip line ?	CLIC note 764

Main beam choke BPM

Developed by R. Fandos and I. Syrachev's



- RF design is made, but mechanical design still needs to be done. RHUL?.
- Better than 50nm resolution with time resolution of 10ns.
- Low wake field impedances.

Main beam BPM: FNAL

Cavity BPM design steps

✓1

1. General idea:
   - low Q-factors
   - monopole modes decoupling

✓1

Cavity spectrum calculations:
- Frequency
- R/Q, Q
- TM11 output voltage

✓1

BPM parameters:
- Cavity length
- Waveguide dimensions
- Coupling slot
- Coaxial transition

✓1

3. Parasitic signals:
   - monopole modes
   - quadruple modes

loop

loop

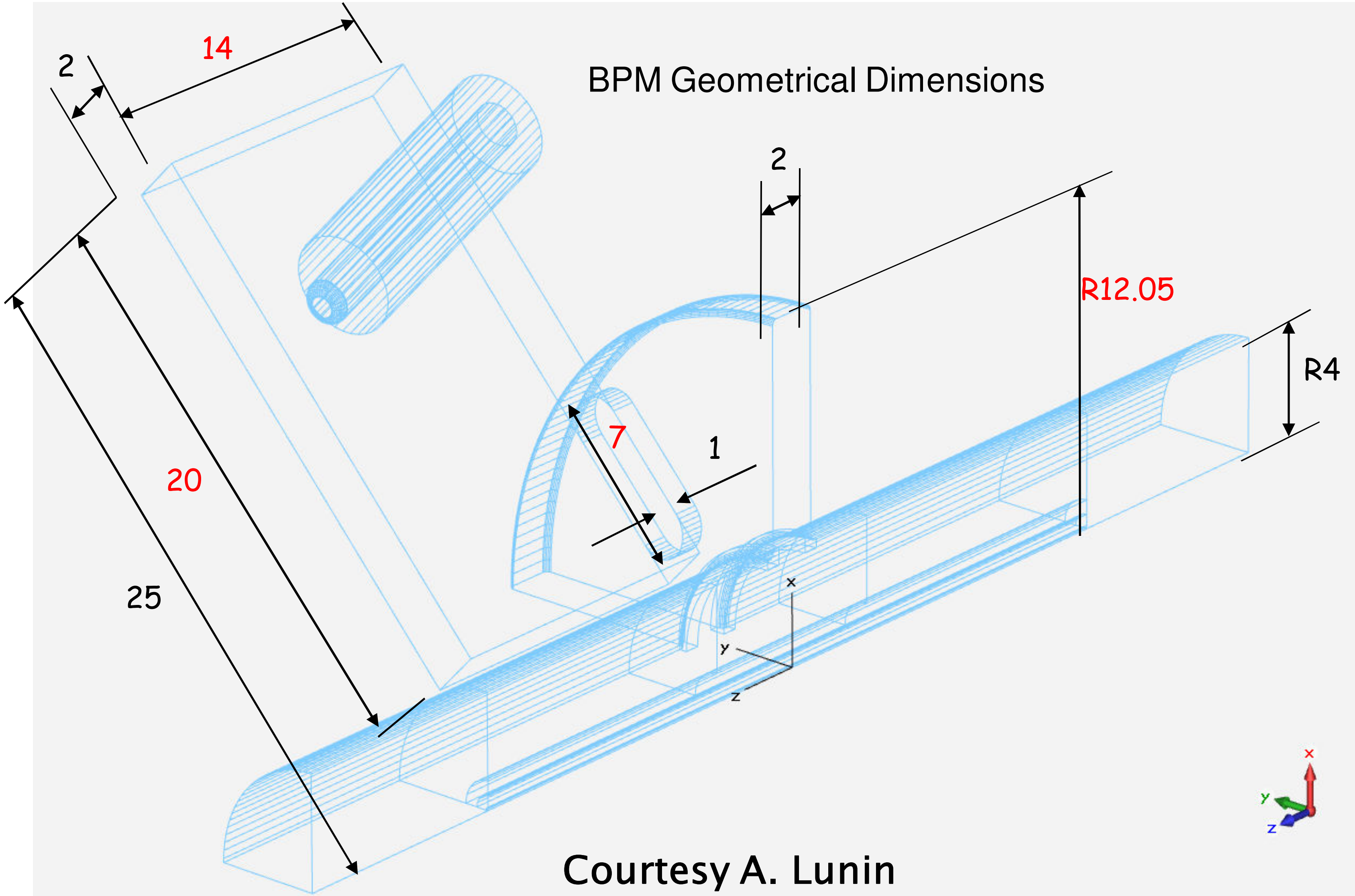
4. Cross coupling:
   - waveguide tuning
   - 2 ports vs 4 ports

✓1

5. Tolerances calculation:
   - coupling slots
   - waveguide to cavity
   - cavity to pipe

Courtesy A. Lunin

Main beam BPM: FNAL



Courtesy A. Lunin

Main beam BPM: FNAL

Cavity BPM spectrum calculation

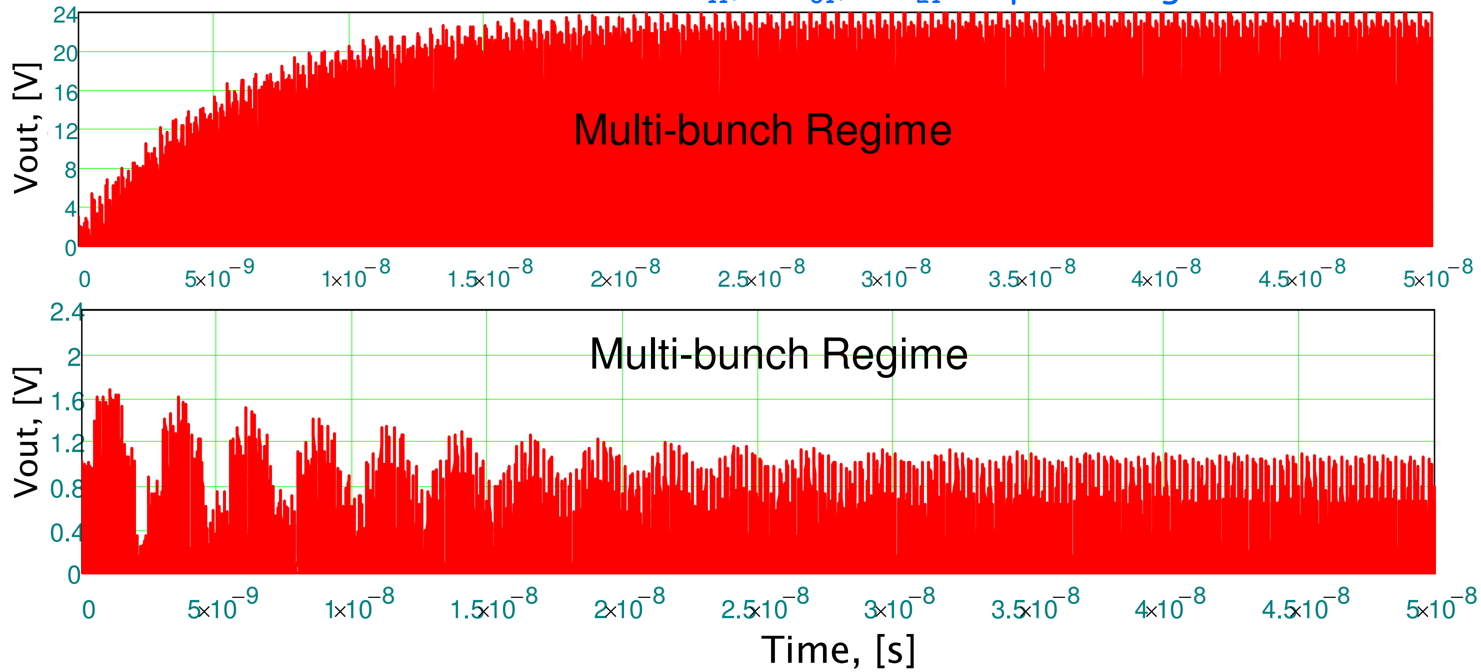
Mode Type		Freq., [GHz]	Qtot[1]	R/Q[2], [Ohm], [Ohm/mm]	Output Voltage[2,3], [V], [V/mm]	Frequency Filter Rejection	Phase Filter Rejection	Multi-bunch Regime Rejection
TM01		10.385	380	45	< 0.001	0.005	0.1	0.1
TM11		13.999	250	3	11.5	-	-	-
TM21		18.465	80	0.05	5	0.025	0.1	0.1
TM02		24.300	680	12	< 0.001	0.001	0.1	0.05
WG1	TM11	12.285	6	-	3	-	-	-
	TM21	12.285	6	-	0.3	-	0.1	-
WG2	TM11	15.878	4	-	5	-	-	-
	TM21	15.880	4	-	1.2	-	0.1	-
WG3	TM21	21.610	7	-	-	-	-	-

[1] – Stainless steel material was used
[2] – Dipole and quadruple modes values were normalized to 1mm off axis shift
[3] – Signals are from a single coaxial output at resonance frequency.

Courtesy A. Lunin

Main beam BPM: FNAL

The sum of TM_{11}, TM_{01}, TM_{21} output voltages



100 µm off-axis beam shift

0.1 µm off-axis beam shift

Mode Type	Freq., [GHz]	Qtot[1]	Beam Shift, [µm]	Maximum Output Voltage[2], [V]	Total Estimated Rejection	BPM Resolution (Limited by TM_{01}&TM_{21} Modes Leakage), [nm]
TM01	10.385	380	0.1	< 1	5E-4	~ 2
TM11	13.999	250	100	24	-	-
TM21	18.465	80	100	< 0.1	2.5E-3	~ 1

1 – Stainless steel material was used
2 – Sum of the signals from two opposite coaxial outputs at resonance frequency.

Courtesy A. Lunin

Main beam BPM

FNAL Low-Q cavity BPM

- Developed by A Lunin
- Wake field calculations coming within a few weeks
- M. Wendt and A. Lunin will come to CERN beginning of November
- FNAL will also develop acquisition system
- Beam tests to be discussed in November
- Fabrication drawing costs and production to be covered by CERN.
- Four proto types to be build

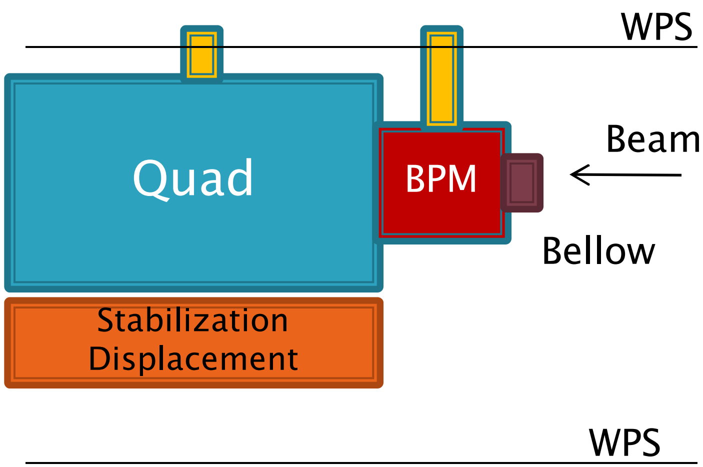
Choke BPM

- Developed by Raquel and Igor
- Possible collaboration with RHUL to build proto type

Main beam BPM

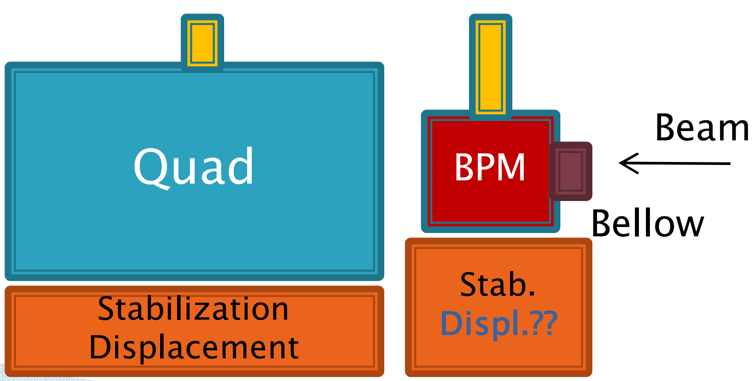
The main beam BPMs are mounted before the quadrupoles and on the same vibration damped support as the quadrupoles. They are fixed to the quadrupole and cannot be aligned separately, and must be connected to the Wire Position System. The BPM should include a connection to the quadrupole chamber (different length according to module type), and a bellow at the other end, for inter module connection.

Base line scenario



- Is WPS necessary on BPM?
- Rigid connection. Study vibration resonances, $<$ 50nm.
- Beam in BPM center. Offset varying (50Hz) and must be read back and corrected for. Study vibration resonances, bellow.

Alternative scenario

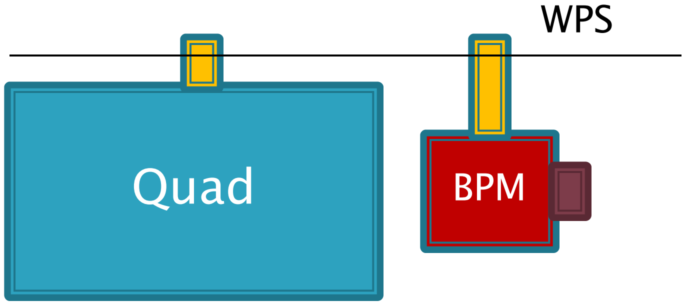


- Beam in BPM center?. If NO, real beam position and NO BPM displacement.
- Space on girder?

Drive beam BPM

The drive beam quadrupole and BPM are mounted on the drive beam girders. BPMs cannot be moved independently of the PETS, the quadrupoles will either be on movers, or equipped with dipole corrector coils. The BPMs are mounted before quadrupoles. The acceptable level of wake field needs to be determined.

Base line scenario



Drive beam BPM studies will start January 2010!

Wakefield Monitors (1/2)

One WFM per accelerating structure needed (up to 8 per girder), the mean of the WFM's on one girder computed

Main specifications:

- Accuracy : 5µm
- Resolution: 5 µm
- Single bunch to long train operation
- No available length ⇒ WFM integrated in the structure

⇓

The four damping waveguides of the middle cell are used to measure the beam position inside the accelerating structures

Courtesy F. Peauger

R&D phase ⇒ development plan:

1) Detailed design of WFM and procurement of a prototype for integration in a CERN accelerating structure and test on the Two Beam Test Stand with CALIFES probe beam (2009 – 2010)

2) Design and procurement of complete accelerating structures including WFM (2010)

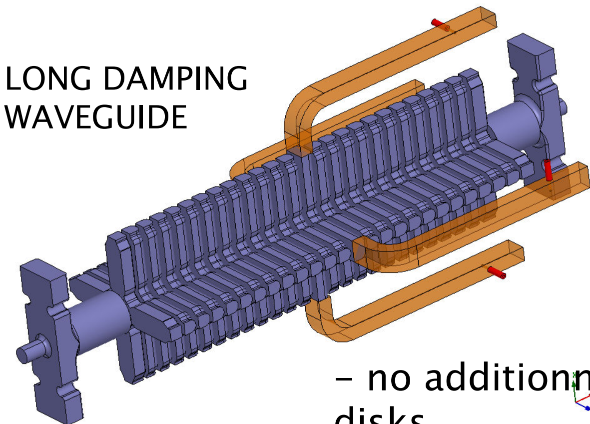
Wakefield Monitors (2/2)

Design:

• Mode: Baseline = TM11 at ~18 GHz, alternative = TE11 at 23 GHz

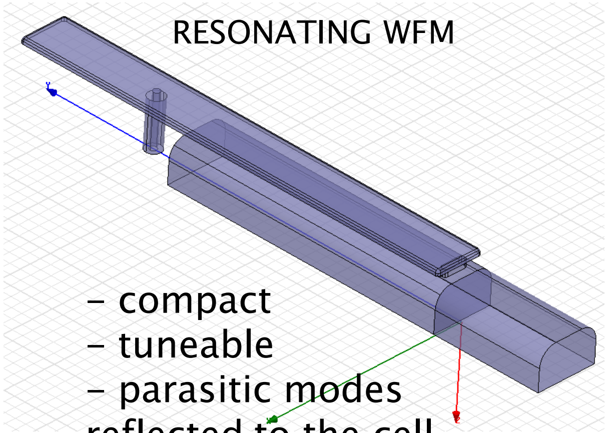
• Transition: several design under study, must attenuate fundamental to ~160 dB

LONG DAMPING WAVEGUIDE



- no additionnal machining of the disks
- wideband
- may be difficult to integrate in the module

RESONATING WFM



- compact
- tuneable
- parasitic modes reflected to the cell

!! needs support and additional time to converge to a solution

• Opposite port recombination by external 180° hybrid coupler (only if TM11 used)

• Electronic not studied -> needs maybe additional ressources

Courtesy F. Peauger

BLM schedule

1	Loss locations in standard operation	MPWG; Jean Bernard Jeanneret ? + Barbara Holzer ?	Nov '09
2a	List 'all' failure scenarios and identify most critical ones	MPWG; Jean Bernard Jeanneret + Michel Jonker	Nov '09
2b	Simulation of the 2-3 most critical ones	MPWG; Daniel Schulte (team)	Q2 '10
3a	Limiting equipment for loss (standard and failure)	MPWG (determine limiting condition); Daniel Schulte (team), equipments experts	Q4 '09
3b	Limits for steady state beam loss (radiation)	MPWG; Thomas Otto	Q2 '10
3c	Simplified (geometry) model simulations (particle showers) of the 2-3 most critical failure scenarios	BLM; Mariusz Sapinski (SCR: Sophie Mallows -FLUKA)	Q3 '10
4a	Choice of measurable (BLM, BPM, etc); establish required SIL (damage protection and availability) levels, estimate SIL levels of various protection systems, determine redundant systems when needed.	MPWG; ?? for BLM: Mariusz Sapinski	Q1 '10
4b, 4c	Choice of BLM system; simulations for the most critical loss scenarios and estimation of monitor response (accuracy ~ factor 10)	BLM; Mariusz Sapinski	Q3 '10

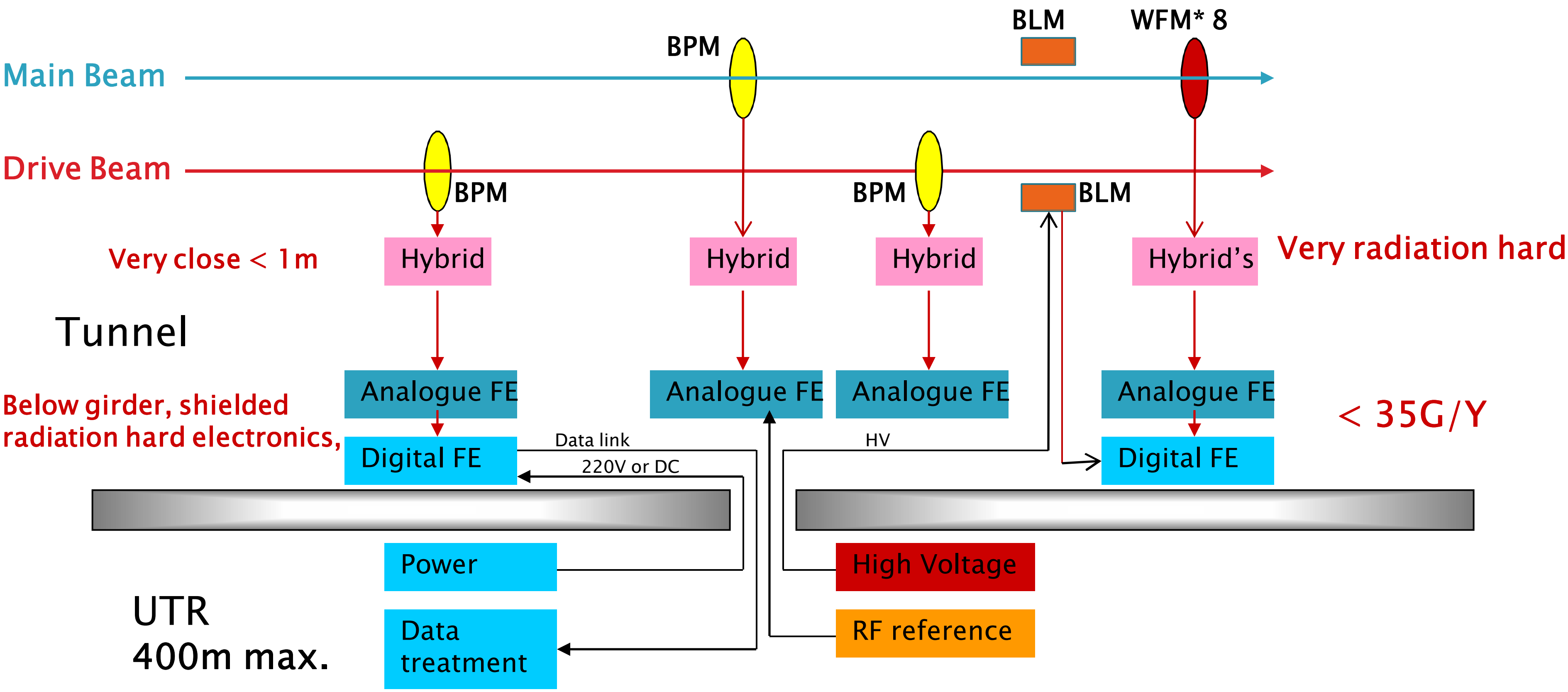
Courtesy B. Holzer

Additional CLIC BLM tasks

BLM system specs for fiber studies (Liverpool collaborators)	Nov'09
Investigate existing solutions for the CLIC components; document cost and number of monitors; identify costly and tech. difficult parts	Jan '10
Investigate and document the radiation sources in tunnel (other than beam loss)	Nov'09
Investigate and document loss locations in standard operation (item 1)	Nov09
Prepare list of questions for failure scenarios (item 2)	Oct '09
Investigate and document limiting equipment for loss (item 3a)	Nov'09
Collection of requirements for BLM system from BD group	Q1 '10
Functional specs	Q4 '10
Cost estimate	Q4 '10

Courtesy B. Holzer

Module acquisition systems



Analogue FE = Down converters, Signal conditioning, Calibration units

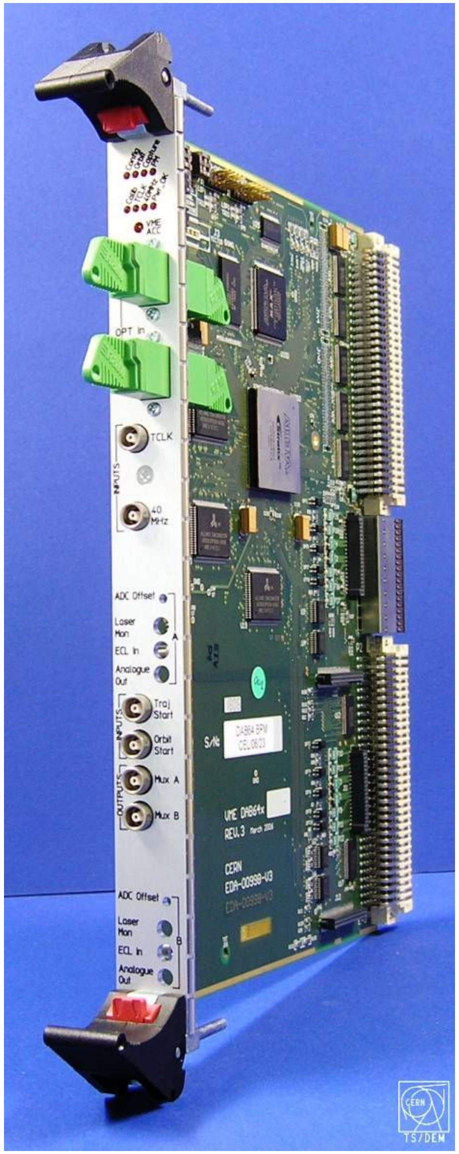
Digital FE = Digitizers and control

OBS: Only 4 cables per module

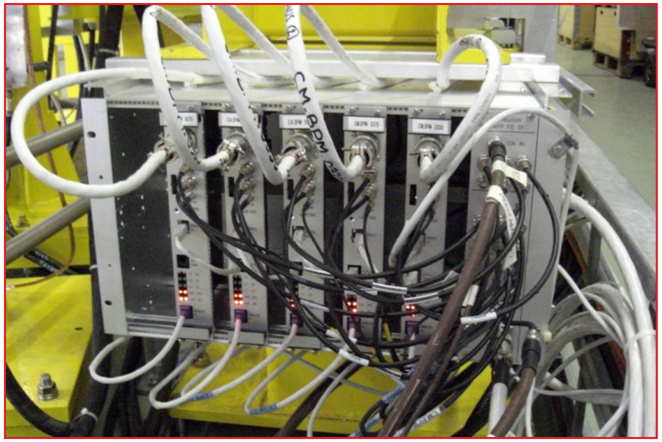
But could be further reduced!

Numbers of devices

- Electronic Standardisation
  - Single type of digital electronics acquisition card used for the majority of LHC instruments
    - Disadvantages
      - Needs from many users have to be assimilated
      - Design more complicated
      - Small changes affect many systems
    - Advantages
      - More efficient & cheaper production runs
      - Faults easier to find as many users test a single product
      - Software development much faster



LAPP BPM Read-out electronics



From CTF3 – to the development of a larger infrastructure as for CLIC

Rare acces fr … ***dartisation…***

Most im

- *Pov*
- *Loc*
- *Net*
- *Acqu*
- ***FPGA processing:*** *raw data, processed data…*
- ***Radiation hardness ?***
- ***Timing/clock and connection via synchronous ethernet (White Rabbit)***

• Prototype in 2010 to be tested in CTF3 for radiation hardness

• Specifications to be written by CERN (channel per girder, ADC's Bandwidth,…)

S. Vilalte, J. Jacquemier, Y. Karyotakis, J. Nappa, P. Poulier, J. Tassan

Specifications of sector instruments

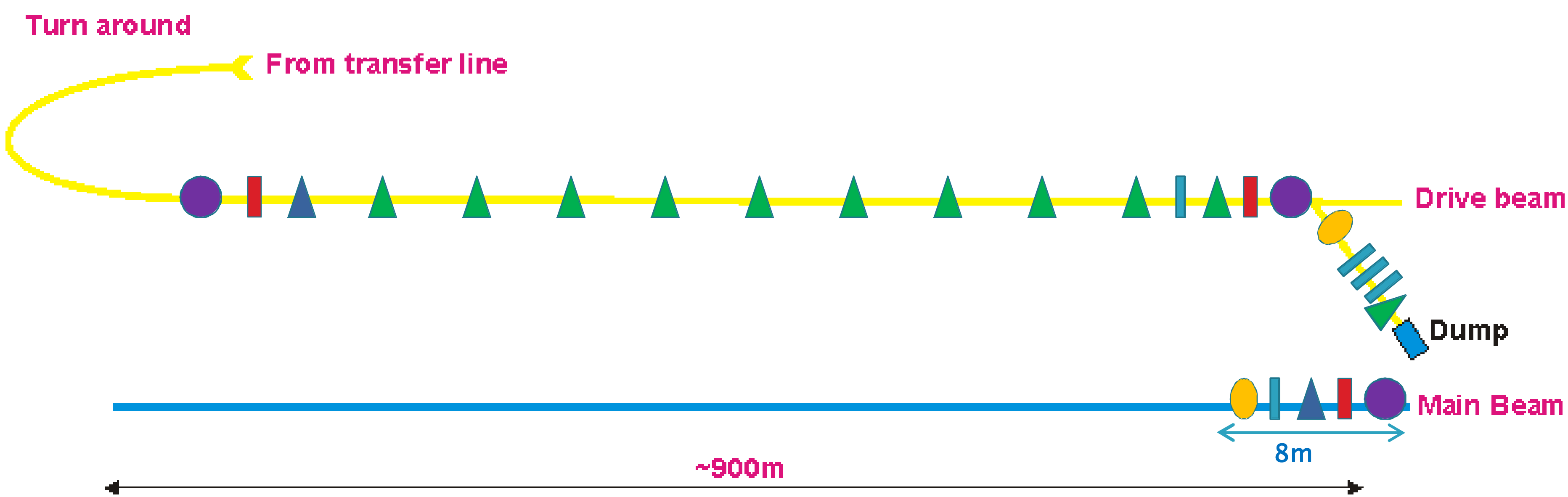
Main beam

	Accuracy	Resolution	Bandwidth	Beam tube aperture	Stability	Non-intercepting device?	How many?	Used in RT Feedback?	Machine protection Item ?	Comments	Ref
Intensity	0.1%						48	No	Yes		
Beam Size / Emittance	10%	2%				yes	48	No	No		
Energy	0.10%					yes	48	Yes			
Energy Spread								?			
Bunch Length							48			single shot	
Beam Phase		0.1°					48	Yes	No		

Drive beam

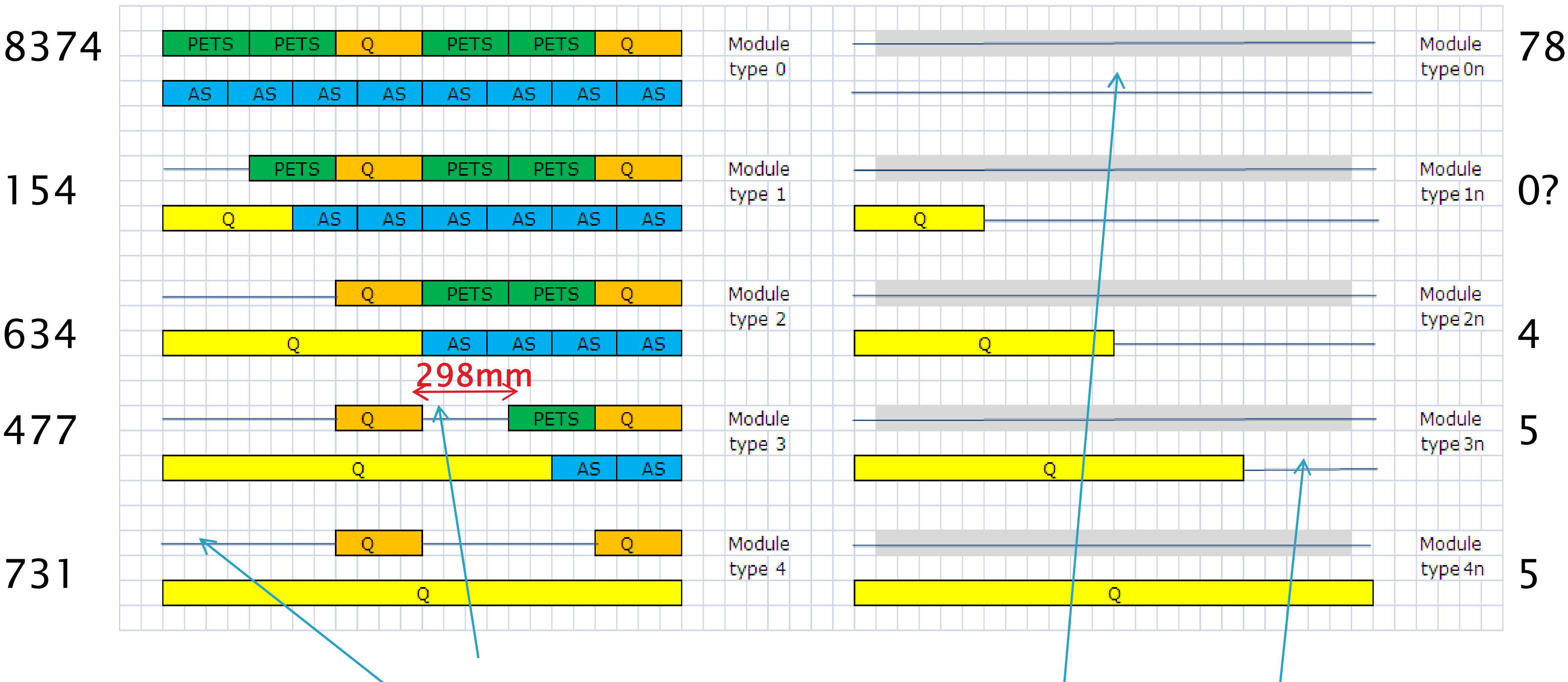
	Accuracy	Resolution	Range	Bandwidth	Beam tube aperture	Stability	Non-intercepting device?	How many?	Used in RT Feedback?	Machine protection Item ?	Comments	Ref
Intensity	0.1%			20MHz	23mm		Yes	48	No	Yes		
Intensity	1%			20MHZ	23mm		Yes	~864	No	Yes	Still Valid?	
Beam Size / Emittance	50um				23mm		No	288	No	No		
Energy	10um		10mm	12GHz	?			48	No	No		
Energy Spread					?							
Bunch Length	1%				23mm			24	No	No	single shot	
Beam Phase					23mm			96				

Sector instrumentation



- Transverse profile monitors, L~300mm
- Fast (12GHz) BPM, L~100mm, Energy
- Form factor, Fast bunch shape measurement,L~500mm
- Slow current measurement, L~150mm, 1%
- Slow current measurement, L~150mm, 0.1%
- Beam Phase
- Segmented dump, Energy

Module types



Use “empty” space for “sector” beam instrumentation

Module length: 2.010 m

~4 type “xn” per sector at extraction

Summery

- Dedicated studies and designs of main beam BPM's and WFM 's are well advanced.
- Drive beam BPM studies will start as from 1st of January.
- BLM design schedule well established
- A digital standard FE will be developed by LAPP and will significantly reduce the cable costs.
- Space must be foreseen for electronics on the module and in a radiation shielded location within a few meters, i.e. in the floor.
- Dive beam SECTOR instruments should be designed for type 1-4 modules.
- Main beam SECTOR instruments can only be foreseen close to extraction region on module types 0n-3n.