Concepts and Challenges for CW Diagnostics

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HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

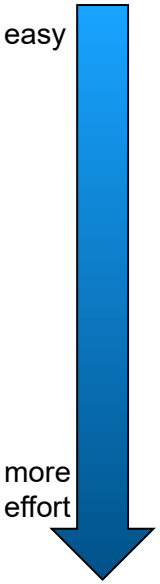
European XFEL

DESY.

Content

No longitudinal diagnostics

- Standard diagnostics
- Change to Ultimate burst mode or CW
- Dosimetry + Screen
- BLM + BHM
- Wire scanner
- Toroid
- Dark Current Monitor
- BPM
- (IBFB)
- Summary



Standard diagnostics installed at Eu-XFEL

System	Subsystem	Gun	Injector [XTIN]	XTL	XTDs
Dosimetry	RadFets				
Screens	Simple	3			
~ 70	Complete		7	26	18
	Dump		1	4	5
	Compressor			3	
Loss monitors	BLM	1	18	230	240
~ 490	BHM		1	1	2
Wire scanners				6	8
14					
Charge	FCUP	4			
~ 50	DaMon	1	1	7	
	Toroid	1	3	16	15
BPM system	Button	3	7	164	131
~ 460	Cavity Ø 10 mm				107
	Cavity Ø 40.5 mm		3	18	2
	Reentrant		1	23	
	Button Compressor			3	

Change to Ultimate burst mode or CW

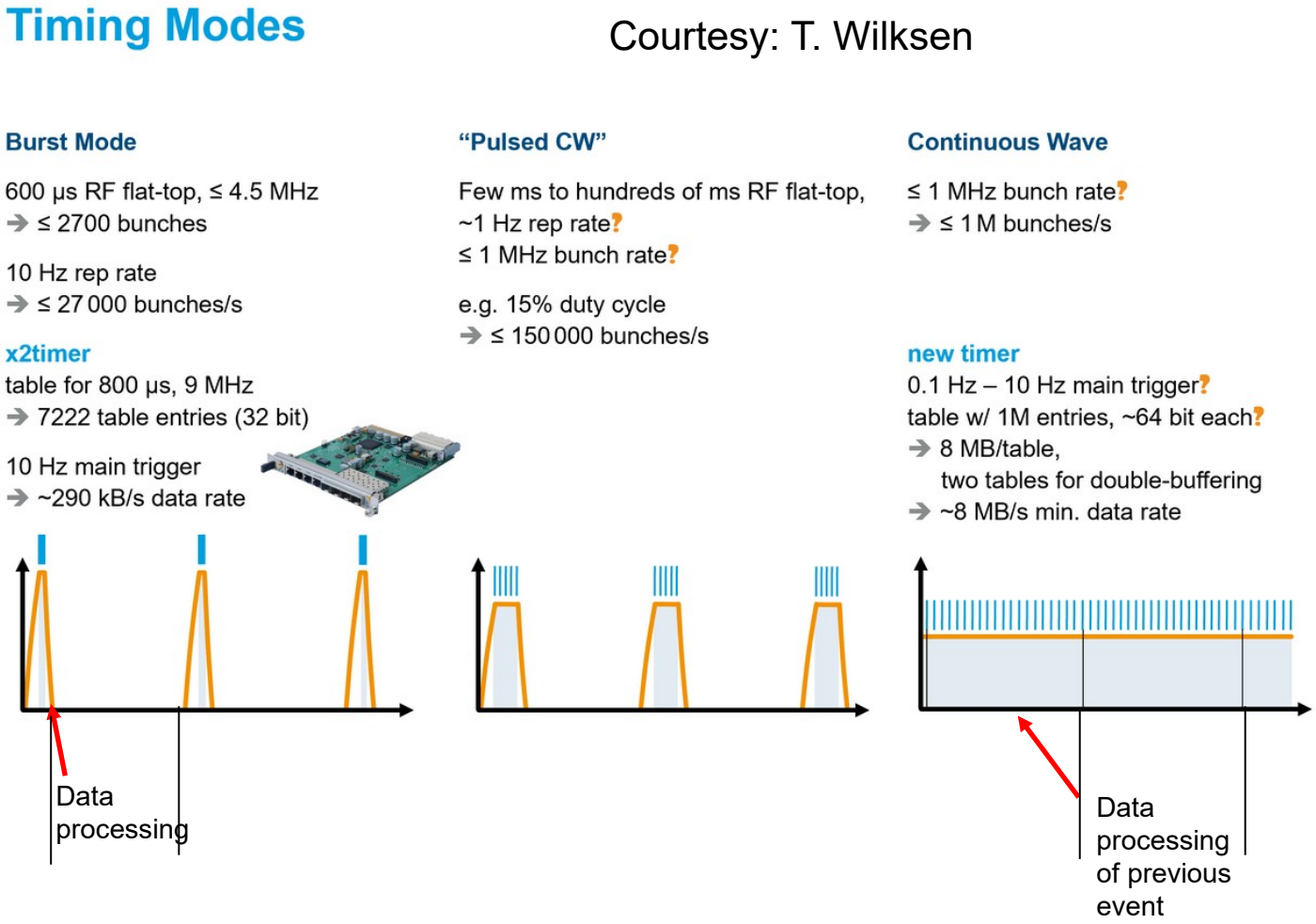
Ultimate burst mode with max. 3 ms bunch train length or CW

Need to distinguish between

- Ultimate burst mode and
- CW

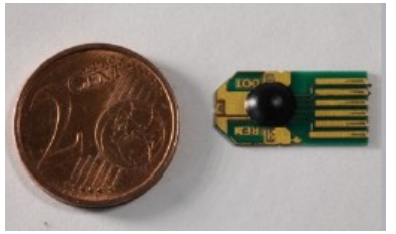
Ultimate burst mode for single bunch diagnostics need longer sampling range

CW needs new timing concept



Dosimetry + Screen

No Problem

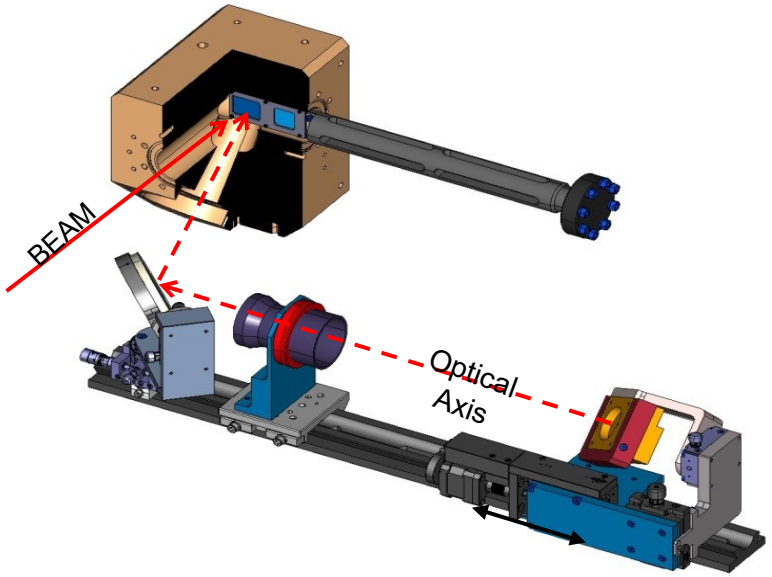


RadFet Sensor

Dosimetry: read-out continuously during current timing concept

Screen:

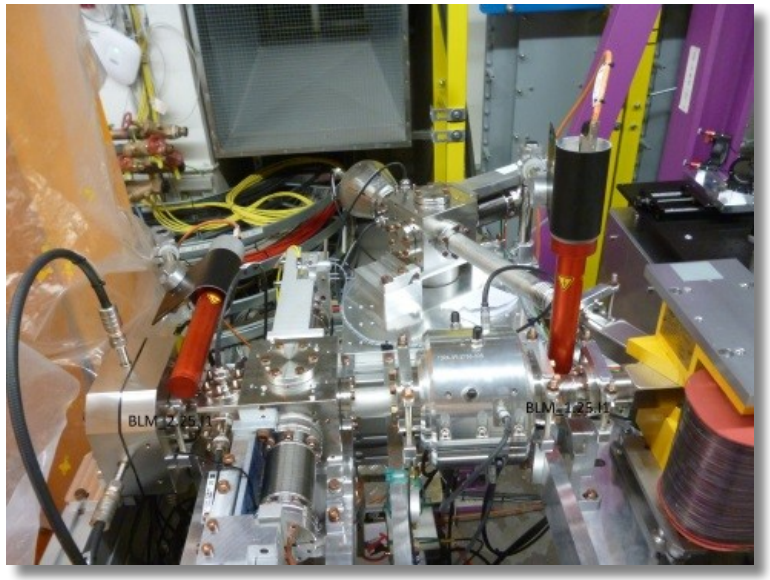
- On-Axis screen: currently reduce number of bunches per train when in use
- Off-Axis screen: kick a single bunch out of axis, for CW the kicker system needs to be adapted to the new timing system
- **Higher dissipated power on bellows**

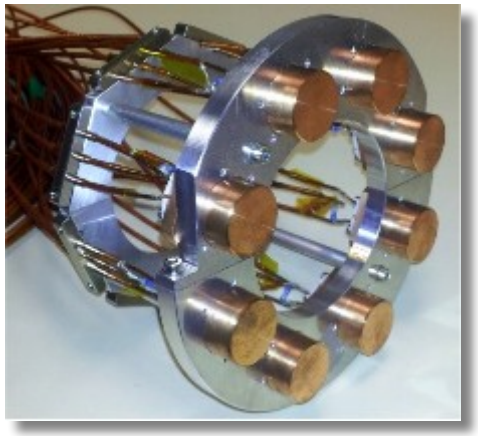


Screen station design

BLM + BHM

- Scintillators with photomultipliers
- Single bunch resolution
- On board HV generation
- Single, multiple bunch and integration alarms to MPS
- Readout by µTCA board with rear transition module, digital interface to MPS system for interlock
- Keep hardware for new timing concepts
- **For Ultimate burst mode: adapt FW and SW**
- **For CW:**
  - **Interlock: change FW multi alarm and integral alarm with moving window**
  - **Pre-requisite event ID from timing system with DMA tandem and data processing in following event.**
  - **Rebuild Firmware and Software**
  - **Test at Ts4i**

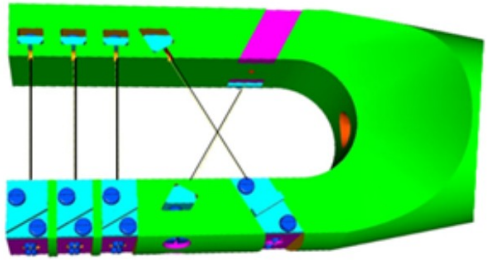




Wire scanner

Integrated into screen station

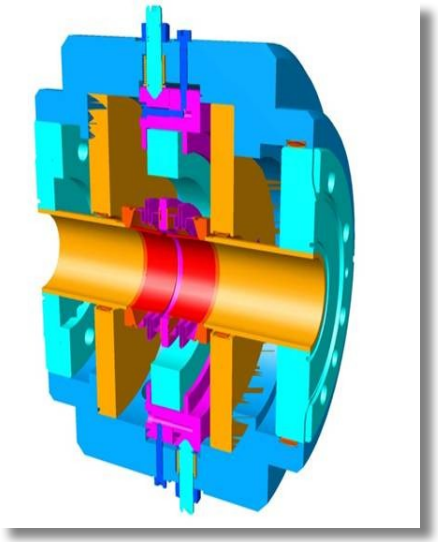
- Can move slow for scan several trains or fast to scan within train
- Read-Out with BLMs and special loss monitors
- Keep hardware for new timing concept
- **For Ultimate burst mode and CW:**
  - **masking BLM when wire IN and read-out accordingly**
  - **For slow scan reduced bunch repetition rate, maybe one bunch per event ID**
  - Fast scan is not affected
  - **higher heating due to dissipated power to wires and bellows**
  - **Need modification of FW and SW**

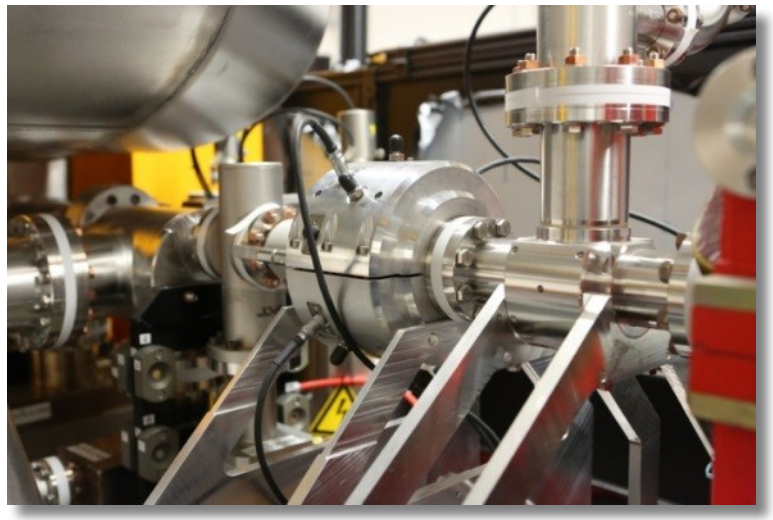


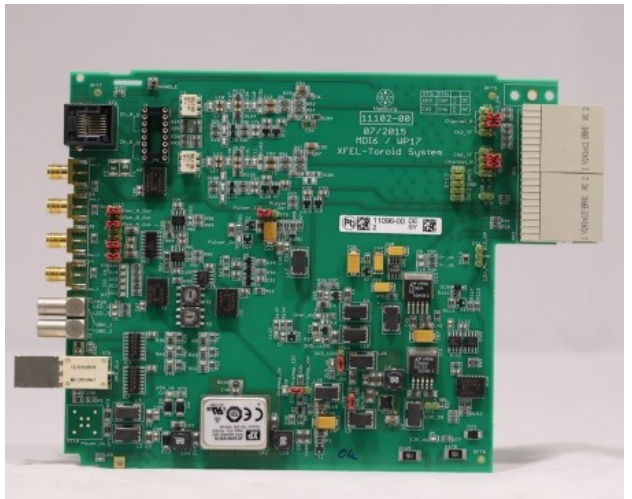
Fork with wires

Toroid

- provide differential signal from RFFE processed in µTCA;
- Test-winding for calibration and self-test;
- Connection to MPS for transmission Interlock
- Keep hardware for new timing concept
- **For Ultimate burst mode: DMA buffer elongate, FW and SW modification,** no alarm modification
- **For CW:**
  - **Check dissipated power**
  - **multi- and Integral alarm with moving window**
  - **Pre-requisite event ID with DMA tandem**
  - **FW and SW modification (9 to 4.5 MHz raster)**
  - **Test at Ts4i**

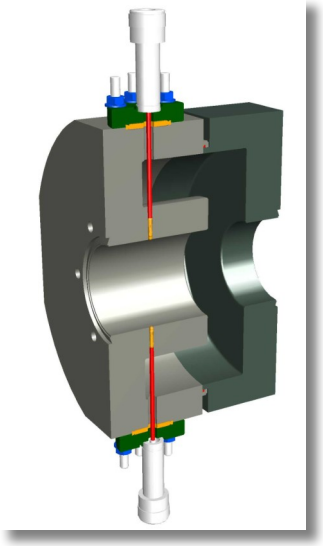


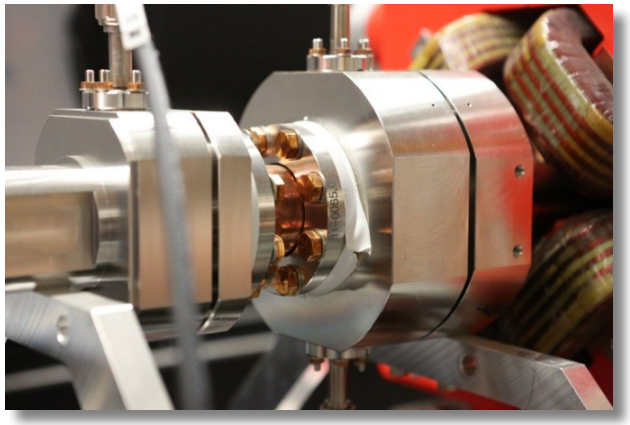




Dark Current Monitor

- RFFE free running with triggered µTCA ADC
- Provide dark current within HF pulse
- Provide bunch charge within train
- Keep hardware for new timing concept; but new RTM in development
- **For Ultimate burst mode: elongate read-out ADC range (similar to BLM)**
- **For CW (similar to BLM):**
  - **Check dissipated power**
  - **need event ID and data processing in following event**
  - **Rebuild Firmware and Software**
  - **Test at Ts4i**





BPM

- Button, re-entrant and cavity BPMs
- Read-out by Modular BPM Unit (MBU) connected to DAMC02 in µTCA via fiber; **In-Kind contribution from PSI**
- Provide beam position, charge and fast signals for IBFB and beam loading
- Keep vacuum components with new timing concept
- **For Ultimate burst mode (PSI answer):**
  - **would need 5x more RAM on the board for beam data waveforms**
  - **firmware/software effort needs to be investigated**

For vacuum components: Check heating due to dissipated power

BPM

CW

Keep MBUs, answer PSI:

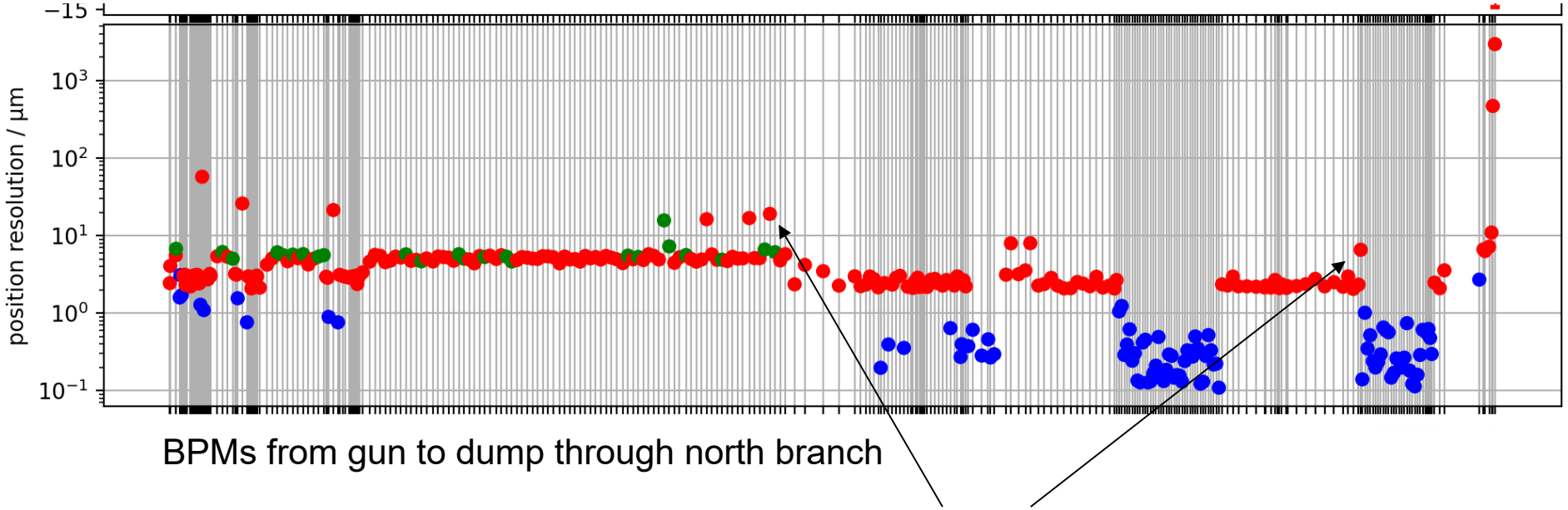
- be beneficial to transfer the BPM & other data not in huge packets with 1 Hz but smaller packets with at least 50-100 Hz transfer rate.
- This would also make the data packet size similar to the 3 ms pulsed mode, but it may require even more RAM on the board, since you may want to fill one RAM buffer while you transfer a 2nd RAM buffer every 10-20 ms to DOOCS alternatingly.
- Alternatively, one could also transfer data in smaller packets much more often (maybe with 10 kHz packet rate), to use the network more effectively.
- you may consider transferring and storing only decimated/averaged BPM data from MBU to DOOCS, plus RMS values etc, similar to what many storage rings are doing because 128 MByte/s (1.28 GBaud) per MBU is at the limit of the fiber link (when using 2.5 GBaud),
- when single bunch necessary one could consider using more than one fiber link from MBU to DOOCs for data transfer (about 3 k€ [DAMC card] x 40 = 120 k€ + cabling)
- storing bunch-by-bunch data at 1 MHz CW bunch rep rate only on local board memory (until it is full), and read this data only on demand
- Replace GPAC with up-to date FPGA possible: 160 x 5 k€ = 800 k€
- Effort for changing Firmware and Software is high by PSI

BPM

PSI and DESY electronics comparison

red: buttons
green: reentrants
blue: cavities

Install MDI new electronics with new FW and SW: hardware cost about 150 k€ (buttons) + 160 k€ (cavity + reentrant) + 150 x 2HE crates 14 k€/crate = 2.4 M€



BPMs from gun to dump through north branch

MDI

Keep MBU: better resolution, need to pay PSI **or**
New MDI electronics: up to date with µTCA, no dependency to other institute, need to replace all BPM electronics, small µTCA crates necessary at each MBU position

At Ts4i: will start with MDI solution and invite PSI with MBU

Intra-Bunch Feedback System (IBFB)

Hard connected between MBU and IBFB control; In-Kind contribution from PSI, answer PSI

Tomco amplifiers were specified to have max. 1ms pulse length and 3% duty cycle.
For 3 ms RF pulse length,

- need to replace them, or
- Tomco if they could be modified to run at longer pulse length, maybe with reduced max RF power

Intra-Bunch Feedback System (IBFB)

Hard connected between MBU and IBFB control; In-Kind contribution from PSI, answer PSI

For CW operation, the Tomco amplifiers probably must be replaced.

- One could either use amps that run CW (-> more power dissipation & cooling, and/or less power and kick strength), or
- amps that can be enabled/disabled very quickly.
- The terminations for the amplifiers at the kicker output ports would also see more RF power, and thus bigger terminations with more cooling would be needed.
- you may consider having fast "normal" corrector magnets upstream of the IBFB and upstream of the undulators, in addition to the bunch-by-bunch IBFB kicker magnets.
- With a thin beam pipe, the correctors could have a bandwidth of >> 1 kHz, and you could run a continuous orbit feedback with 20+ kSPS correction rate.
- Then only need the IBFB kickers to correct orbit perturbations that are above the bandwidth of the normal corrector magnets, and thus may need less RF power for the kicker power amplifiers, running them in CW mode at 100% duty cycle.
- Typically, CW power amplifiers with 250W and 400 MHz bandwidth cost around 25 kCHF/piece maybe less for the IBFB that only needs ~100 MHz kicker BW.
- When need more kick strength, you could also consider using two kickers in series, thus doubling the kicker length (2x longer kickers are equivalent to 4x more kicker amp power).

Summary

- Modifications of standard beam diagnostics for Ultimate burst mode or CW are necessary
- No aparend changes needed for screens and dosimetry yet, check HOM
- Modifications of FW and SW for BLM, BHM, Wirescanner, DaMon and Toroid necessary
- BPM:
  - need decision to keep PSI In-Kind contribution with updated hardware and FW and SW or
  - New hardware DESY solution
- (IBFB needs to be modified)

Contact

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