BCT for protection

LHC Machine Protection Review
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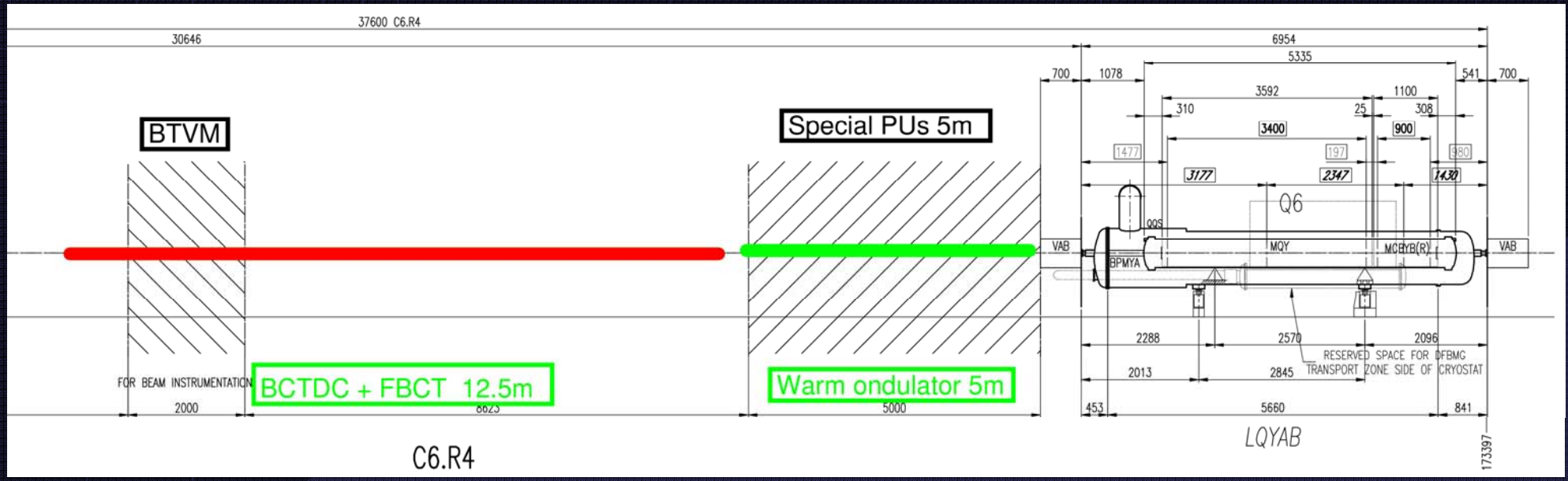
Contents

- General overview
- FBCT specifications
- Requirements for MPS
- Actual design philosophy
- HW changes needed for MPS
- Timetable
- Conclusion

General Overview

- 4 BCTFRs installed in IP4, 4 BCTFDs in IP6
- 2 FBCTs per vacuum pipe
- BCTFRs at right side, between Q5 and Q6
- Electronics in gallery (UA47)



Note: this is to be issued as an engineering request soon

General Overview

- BCTDC and BCTFR are installed nearby
- Having DC and fast transformers together ensures higher security margin:
  - Possibility to cross-check the intensity measurement with multiple instruments when available$_{(FF)}$
  - Possible to cross calibrate the equipment$_{(FF)}$

FBCT specification

LHC-BCT-ES-0001
from 17.1.2005

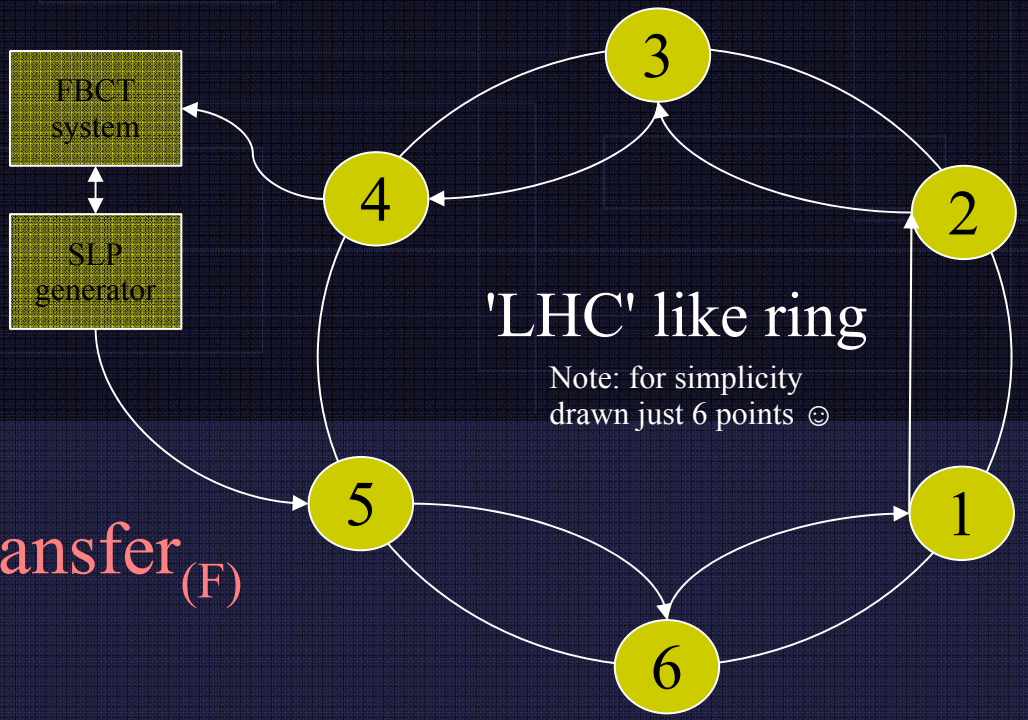
- Accuracy / Resolution
  - Single pass (injection)
    - Pilot bunch ±20%/±20% i.e. $\pm 10^9/\pm 10^9$ protons
    - Nominal bunch ±3%/±1% i.e. $\pm 3 \cdot 10^9/\pm 10^9$ protons
  - Circulating beam (normal mode, > 2.10^2 bunches)
    - Pilot bunch ±10%/±10% i.e. $\pm 0.5 \cdot 10^9/\pm 0.5 \cdot 10^9$ protons
    - Nominal bunch ±1%/±1% i.e. $\pm 10^9/\pm 10^9$ protons
  - Lifetime measurement
    - Pilot bunch 10% accuracy (10h/1min), $8.4 \cdot 10^5$ p/min
    - Nominal bunch 10% accuracy (30h/10sec), $1.1 \cdot 10^6$ p/10s

FBCT specification

- Desired parameters for machine protection
  - Safe beam flag
    - High accuracy not required (10% is fine)
  - Beam loss rate
    - Sensitivity 0.1-0.2% of total nominal intensity ($3\text{-}6\cdot10^{11}$p) in single turn for fast losses$_{(FFF)}$ (you can get $3\cdot10^{12}$)
    - Propagation delay of information less than machine turn (~90μs, no problem)
    - Improvement by averaging (factor of √n) may not help – other sources of errors (for example presence of particles in abort gap)
    - Requirement exceeds the sensitivity available by order of magnitude

FBCT specification

- Discussed scheme for MP:
  - Need info about intensity on hardware level$_{(F)}$
  - Data for machine protection system are sent by optics without SW intervention
  - The same data should be received when propagated through LHC$_{(F)}$
  - Feedback should assure correct data transfer$_{(F)}$



From discussions with B. Puccio & P. Nouchi

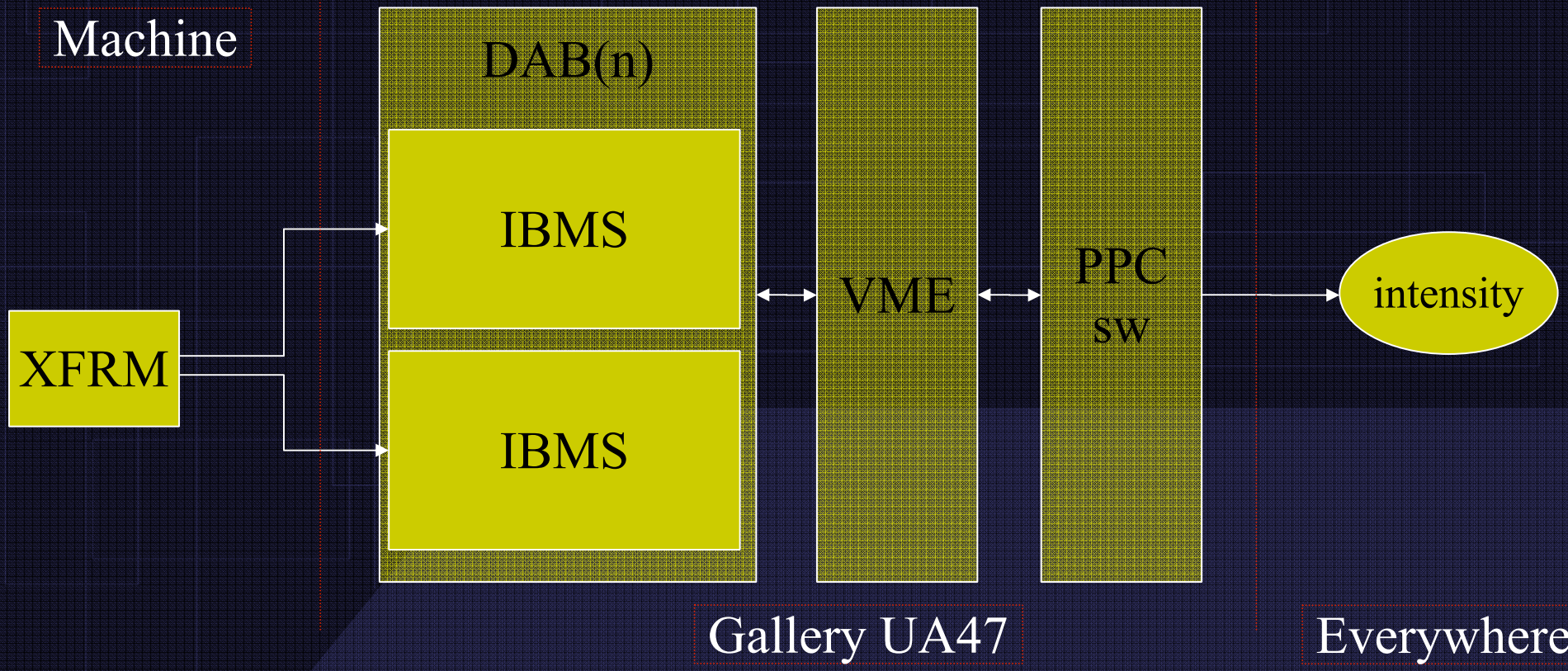
FBCT specification

- Discussed scheme for MP – SLP communication
  - 1ms is the needed rate for the intensity information
  - Packet is sent twice with the same information, spaced about 250μs (ie. ~500μs average rate)
  - 32bits total to be sent, 18bits of intensity maximum (format still not defined, just ideas). **Note:** intensity is defined as the sum of all bunches over one turn, averaged over 8 turns
  - AGREEMENT: FBCT system will only give one intensity information per ring(info about beam safe flag is not generated at our side)

From discussions with B. Puccio & P. Nouchi

Actual Design Philosophy

- Approach – copy working system of SPS
  - Based on the DAB(n) card from TRIUMPH Canada



Actual Design Philosophy

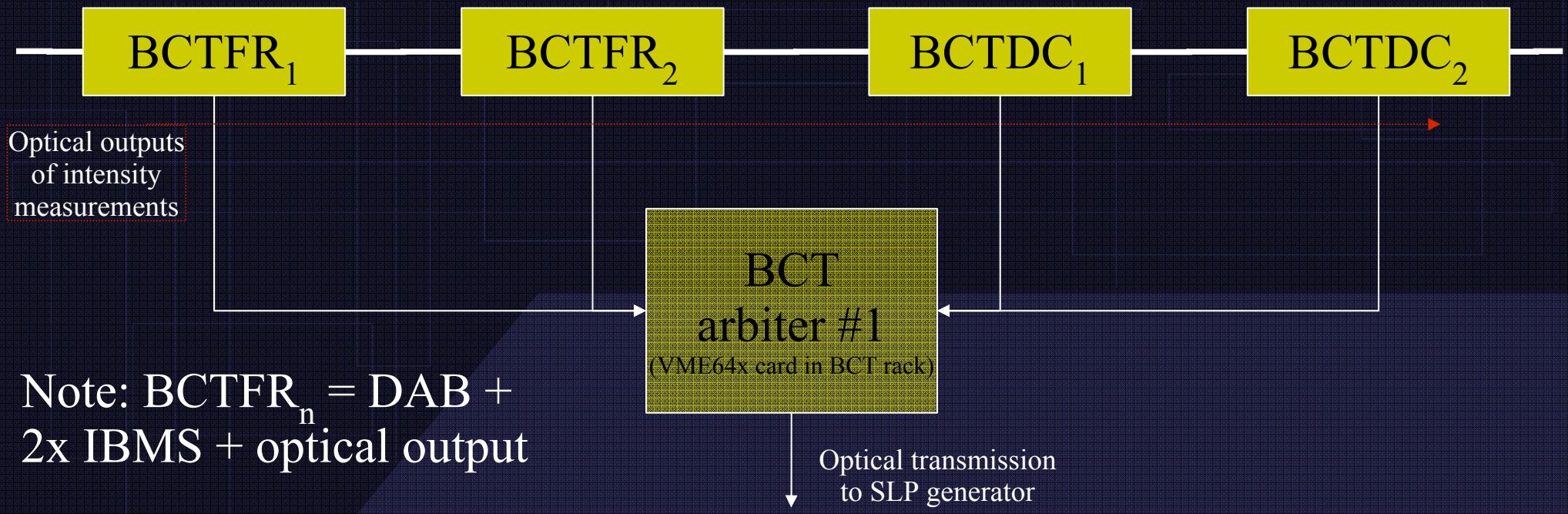
- Approach – copy working system of SPS
  - IBMS does integration (based on Clermont-Ferrand integrator chip) + A/D conversion (14 bits)
  - DAB is the storage and processing card (including post mortem) → FPGA + MEM + VME64x interface
  - DC restoration, intensity calculation and information distribution is done in software
  - DC restoration: clean 3μs abort gap permits calculation of the DC component of the intensity measurement. The value calculated is 'added' in next turn to the result of integration → intensity

Actual Design Philosophy

- Suitability of this solution for MPS - Yes and No:
  - ✔ Beam safe flag and beam presence flag you can get by RTT software
  - ✔ Slow losses and slow current decay measurements you can also get by software
  - ✗ Fast losses require hardware processing
  - ✗ Transmission of the information is required by separate channel (i.e. not the standard VME/Ethernet connection)
  - ✗ Also for security reasons all processing must be separated from control system – no software involved (question: can DAB card be recognized as safe equipment?)
- So...

HW changes needed for $MP_{(F)}$

- DAB has possibility to add third mezzanine (i.e. 2x IBMS + optical output)
- Need to change the implementation scheme:



Note: $BCTFR_n$ = DAB + 2x IBMS + optical output

What we can do for start-up

- We are able to provide you with very basic functions:
  - Intensity measurements calculated and generated by software
  - Eventually send this information via optical link from one transformer only (needs to add some HW)
- This means – in terms of propagation delay†:
  - ~50-100ms when we send information via dedicated link (i.e. PPC takes care about calculation and HW sends via optics)
  - > 100-150ms when treated completely by software and sent over 'standard' route (vme crate/eth)

† Estimated values

What we can do for start-up

- This should be sufficient for
  - Beam safe flag
  - Beam presence flag
  - Slow losses (theory, within 1s?, precision?)
- Is not sufficient for
  - Fast losses, especially in terms of propagation delays and precision of the instrument

Time table

- For start-up just basic functions
- If (money)&&(manpower)
  - We can do further steps with arbiter + hardware calculus
  - Improvement of measurement to get desired precision
- Did you notice small (FF) comments†?
  - It gives you rough estimation foreseen for the task
    - F = future
    - FF = far future
    - FFF = far far future **(note: this is maximum amount of future)**

† As you can see it is not very defining → too many unknown factors

Conclusion

- You can get 'almost' everything, but not now
- You can get SW calculated intensity sent via optical link, with rate of change ~100ms
- For the future it is foreseen to implement measurement on HW level
- Most problematic seems to be precision requested for fast losses
- Also some study must be done concerning suitability of the DAB card for machine protection

THANK YOU FOR ATTENTION