TTC backbone upgrade

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EP-ESE/SY-BI Collaboration Seminar

TTC backbone: Introduction

A bit of history

Current status

TTC backbone

Optical fiber networks in charge of LHC signal transmission from Machine to Experiments

TTC backbone:

RF -> Experiments

- 2xBunch Clocks (40.078MHz clock),
- 2xOrbits (5ns pulse at 11kHz)

- No encoding, the signals are converted into Optics and transmitted over the fibers

BST network:

BI -> experiment

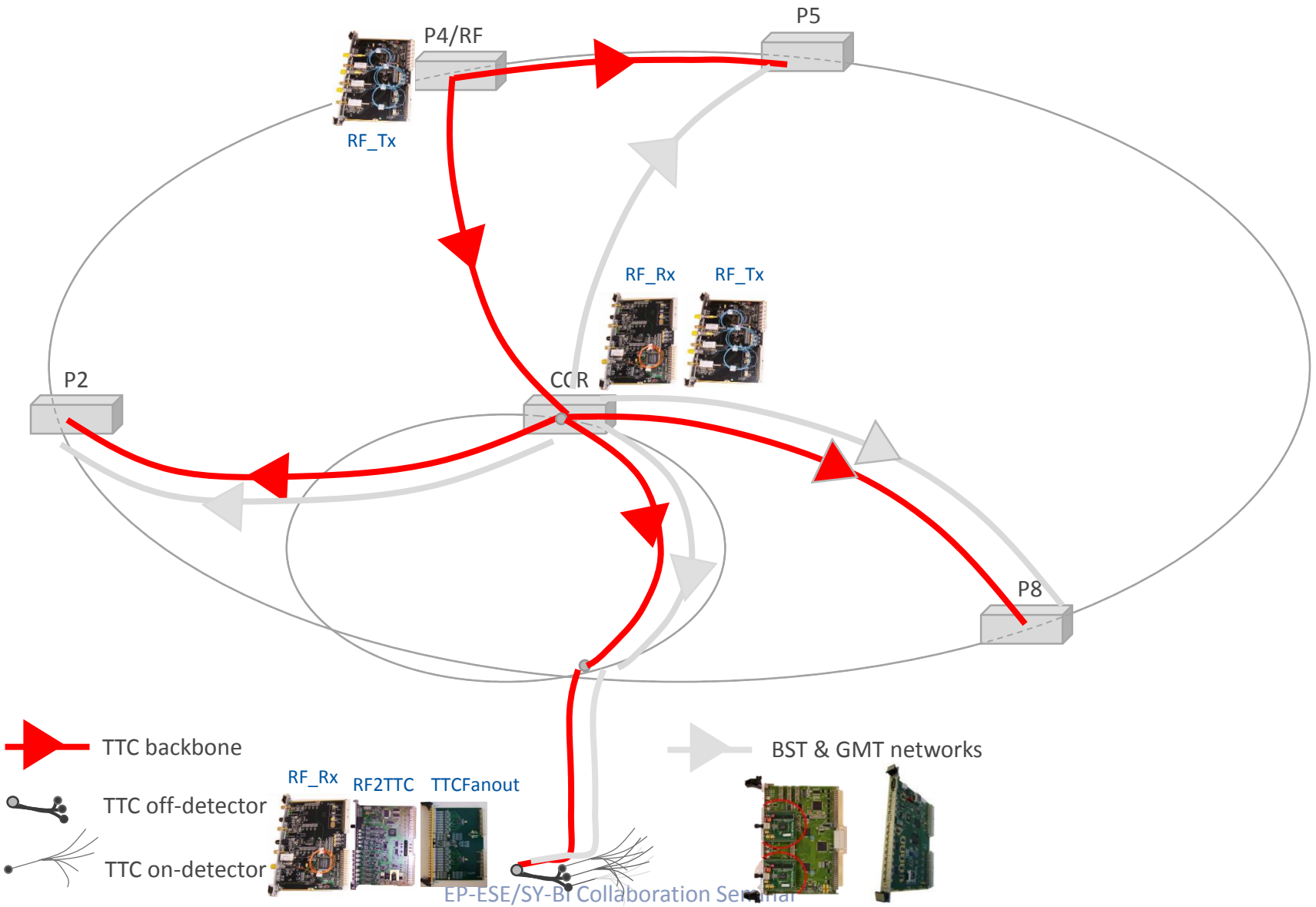
- Beam Synchronous Timing: LHC synchronous data:
  - machine mode,
  - Beam type, energy,
  - bunch structure,
  - timing events,
  - low precision BC and Orbit)
- Based on TTC legacy electronics (TTCex, TTCrm)
  - The serial frame is synchronous to the LHC frequency

GMT network:

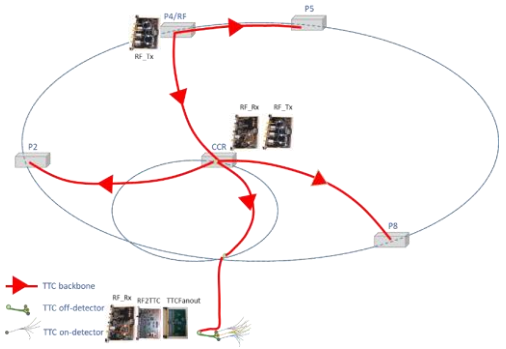
CO -> experiments

- General Machine Timing: LHC telegram:
  - Telegrams,
  - LHC events,
  - 40MHz
  - 1kHz, pps,
  - UTC time…
- Ethernet frame locked to a cesium clock
  - asynchronous wrt LHC

TTC Backbone network



TTC backbone system



- Signals distributed to all experiments via optical network
  - Source at point 4 (RF system location)
  - Passive splitters at Point4 and in CCR

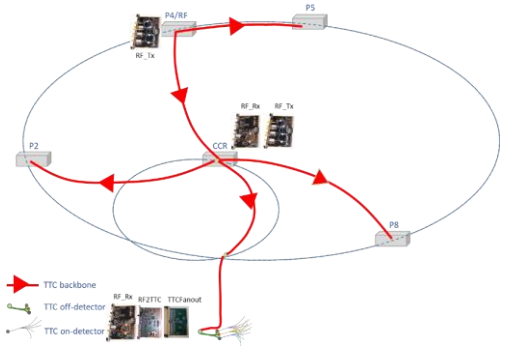
- Common hardware for LHC RF system and TTC backbone
  - Initially designed by PH/ESS to replace initial TTC system (2005)
  - Tx and Rx were then adopted and tuned by RF team
    - Used by RF in their own systems (Point4, CCR, BA3…)
    - 100s were produced and installed on many locations

RF_Tx

RF_Rx

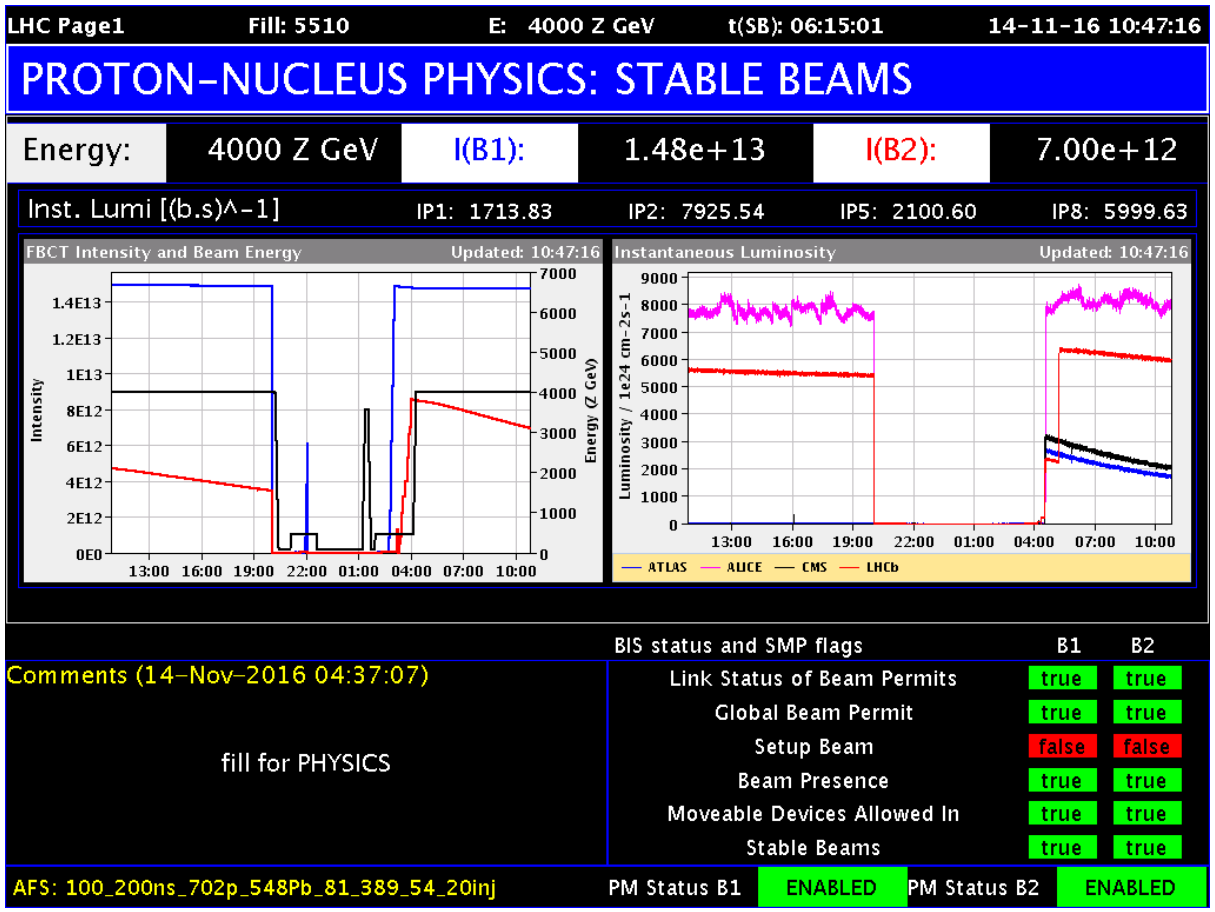
- Support
  - Level1: Spares handled by experiments
  - Level2: RF piquet service
  - Monitoring via DIP and Vistar

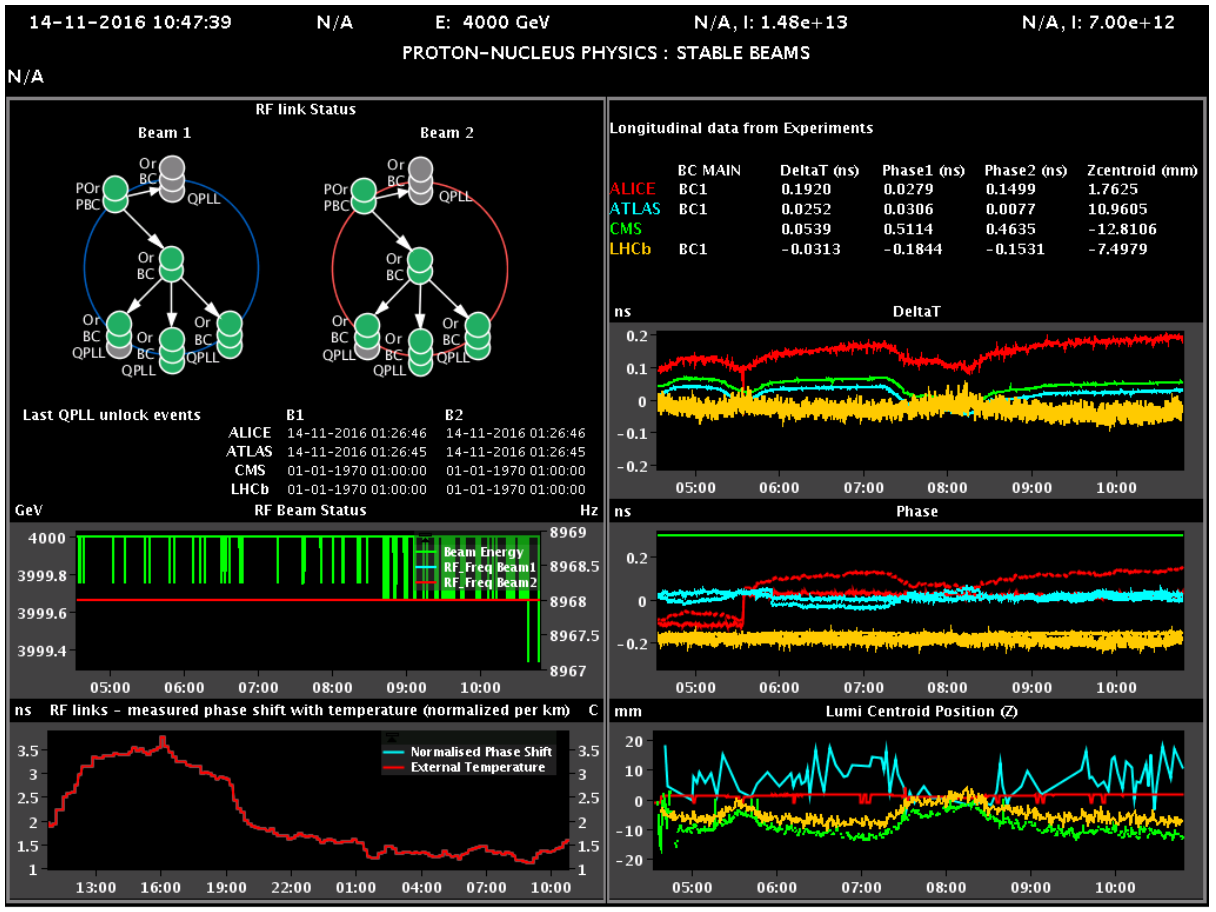
RF-TTC backbone Vistar Page



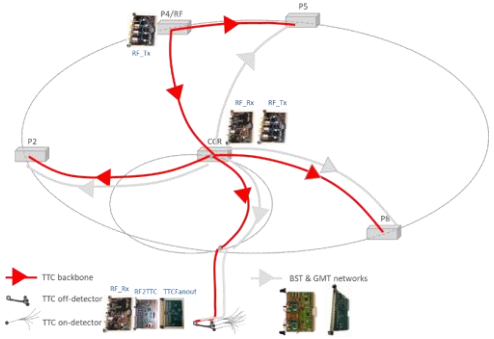
https://op-webtools.web.cern.ch/vistar/vistars.php?usr=LHC1

https://op-webtools.web.cern.ch/vistar/vistars.php?usr=LHCRFTiming





TTC backbone status



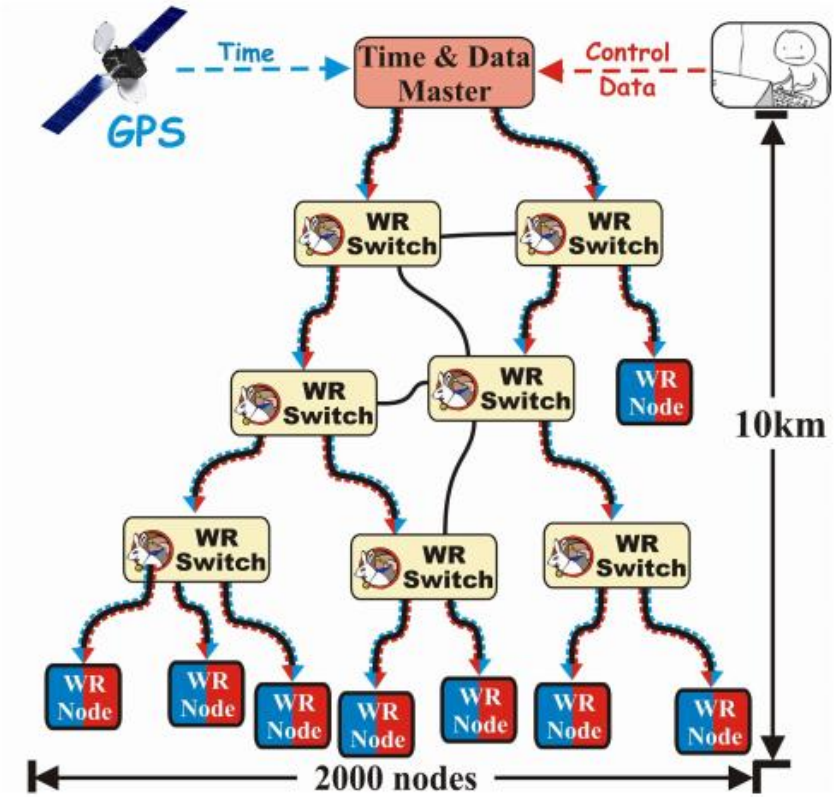
- Ageing system
  - Spares handled by Experiments, RF and ESE
  - Not possible to produce additional boards
- TTC backbone future is not so clear
  - Not a clear mandate for ESE
    - But historically was handled by EP-ESS/ESE (support excepted)
  - Technology is tightly linked to HL-LHC RF plans
    - Especially if we want to keep the pragmatic approach taken last time
    - Currently not the priority of the RF group (SPS restart, crab cavities control…)
    - The RF will not design a system for us, so if we want it to match experiments needs, we should start to think about it
  - When ? LS3? LS4?
    - What we know is that LS4 may be far too late
  - No specs (except that the new system should behave as or better than the current one)

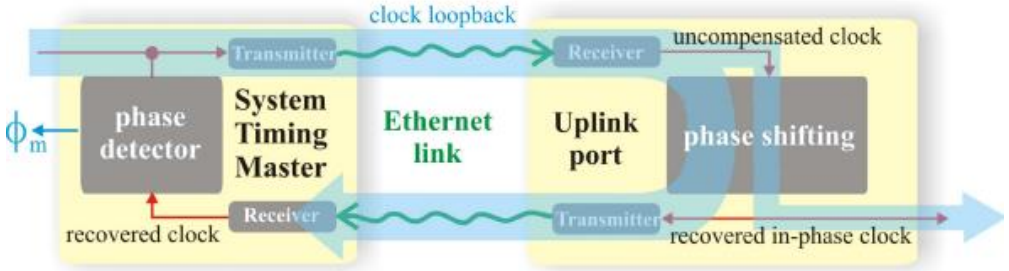
TTC backbone: Towards LS3

The White Rabbit

RF upgrade plans

White Rabbit at a Glance





- Designed by CERN BE/CO (now BE-CEM) team to replace the GMT
- Now an official variant of the IEEE1588 PTP SyncE standard
  - IEEE1588-2019 extension as «High-Accuracy»
  - https://ohwr.org/project/wr-std/wikis/home
- Ethernet network fully synchronised to **GPS time** with **fixed and deterministic latency** ensured by precise **phase monitoring and compensation**
  - **Sub-ns precision**
  - **Longuest path latency** is set to all nodes
  - Nodes have the **same absolute time reference**
  - All nodes receive **commands at the same time**

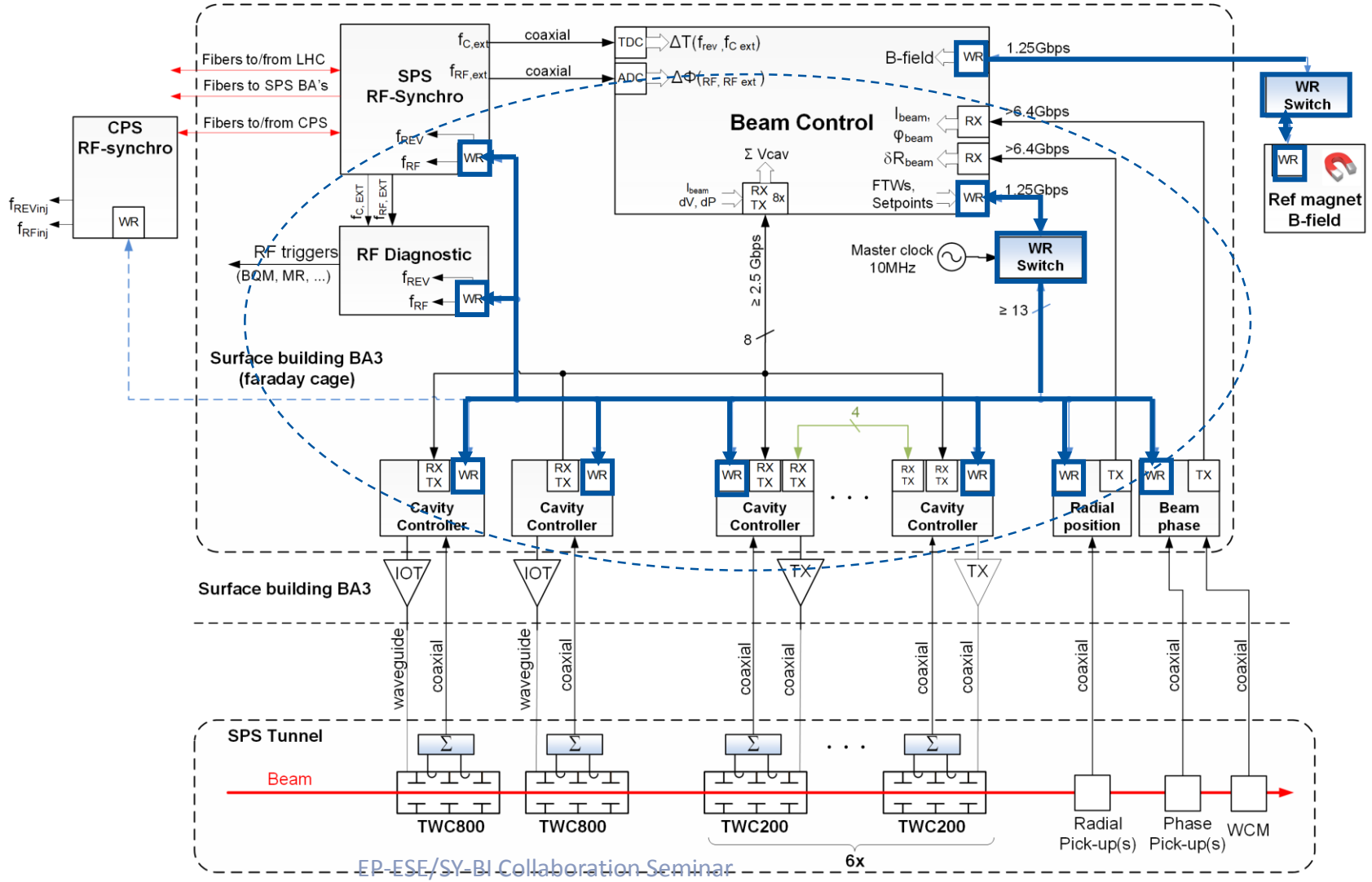
Good to control accelerator instrumentation

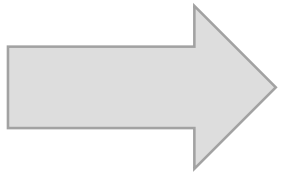
…and to control cavities…

- The values of the RF **frequency** and **phase** are continuously transmitted to all nodes as a **numerical words**, using WR deterministic network
  - All cavity controllers receive the information at the same time
  - The RF is then locally reconstructed (in phase and frequency) at each node via a DDS and a PLL
  - The carrier frequency of the serial link is not moving with frequency ramp (ie no loss of lock of the CDR)
- Proof of concept demonstrated by BE/CO
  - Now implemented for SPS beam control system

WR2RF for SPS: ongoing upgrade

- White Rabbit is currently being commissioned in BA3 for the Low-Level RF of the SPS





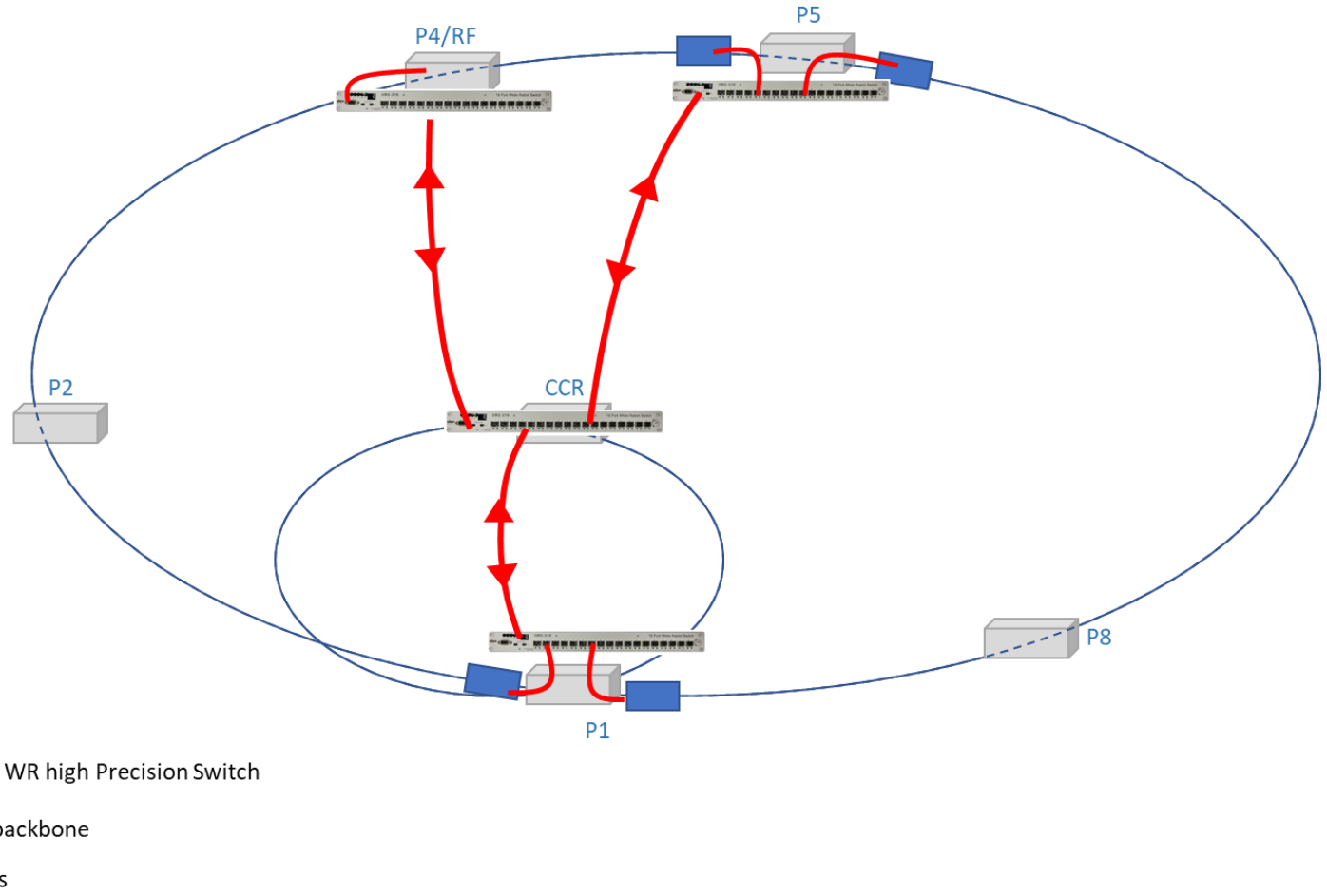
Good solution for RF cavity control …

or for Bunch Clock
distribution to the experiments!

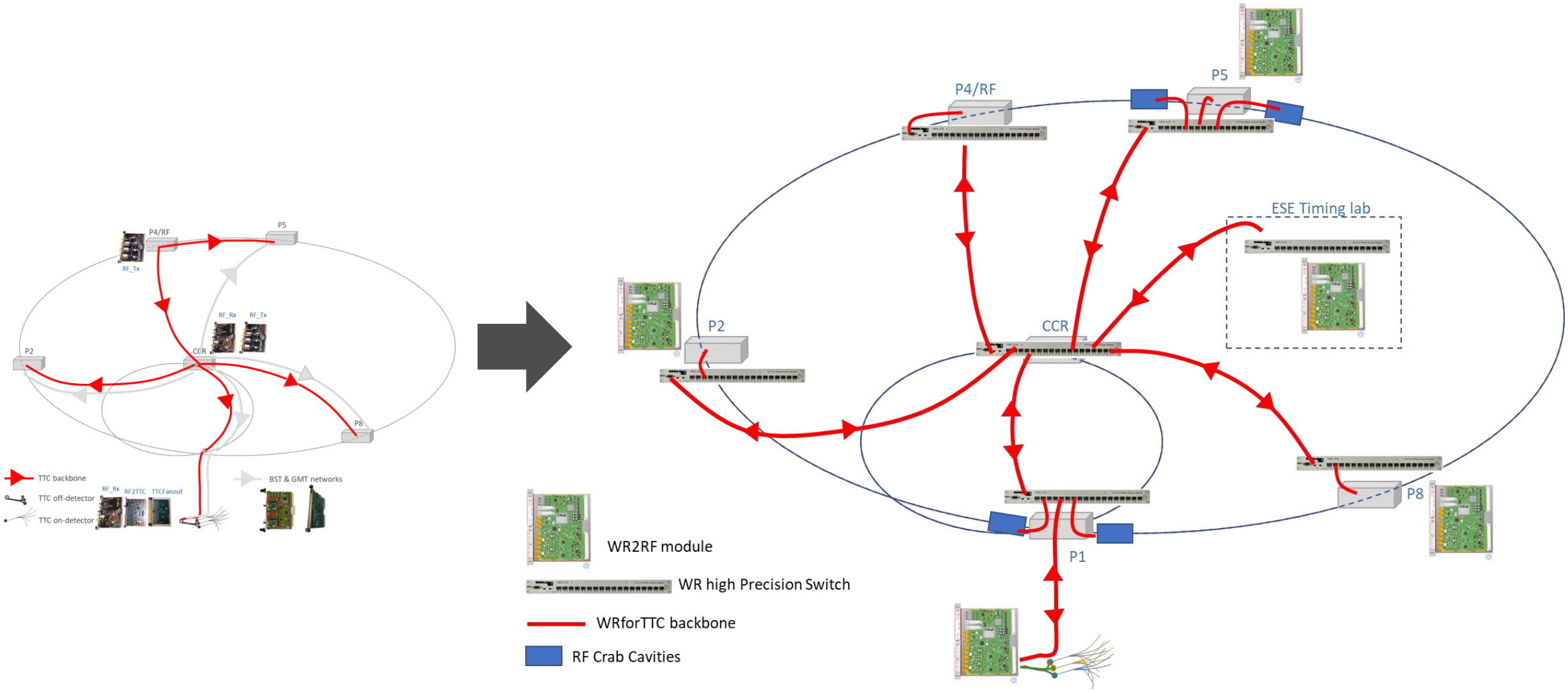
TTC Backbone Upgrade

Proof of Concept - Proposal

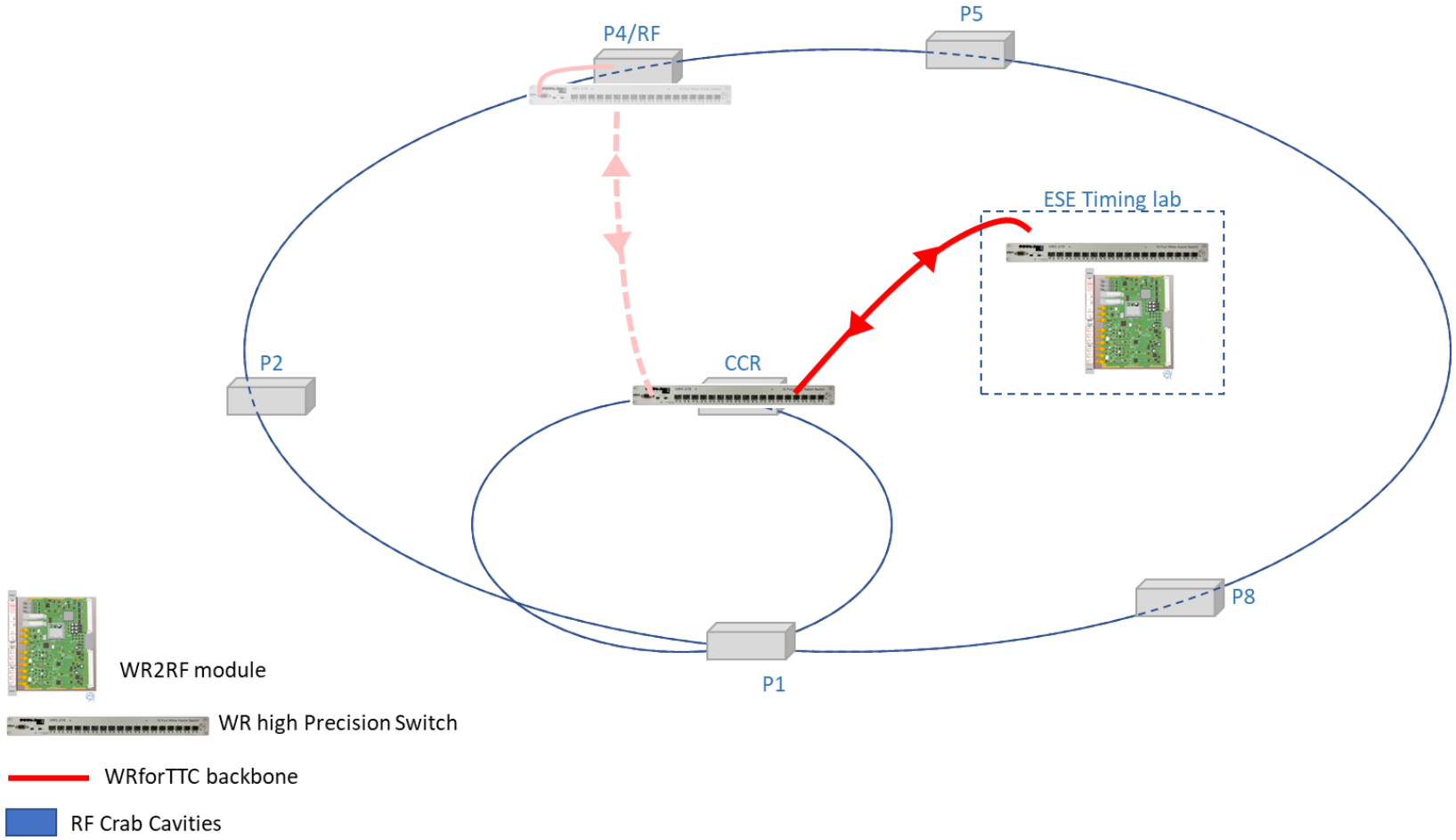
RF (very) preliminary plans for Crab Cavities control



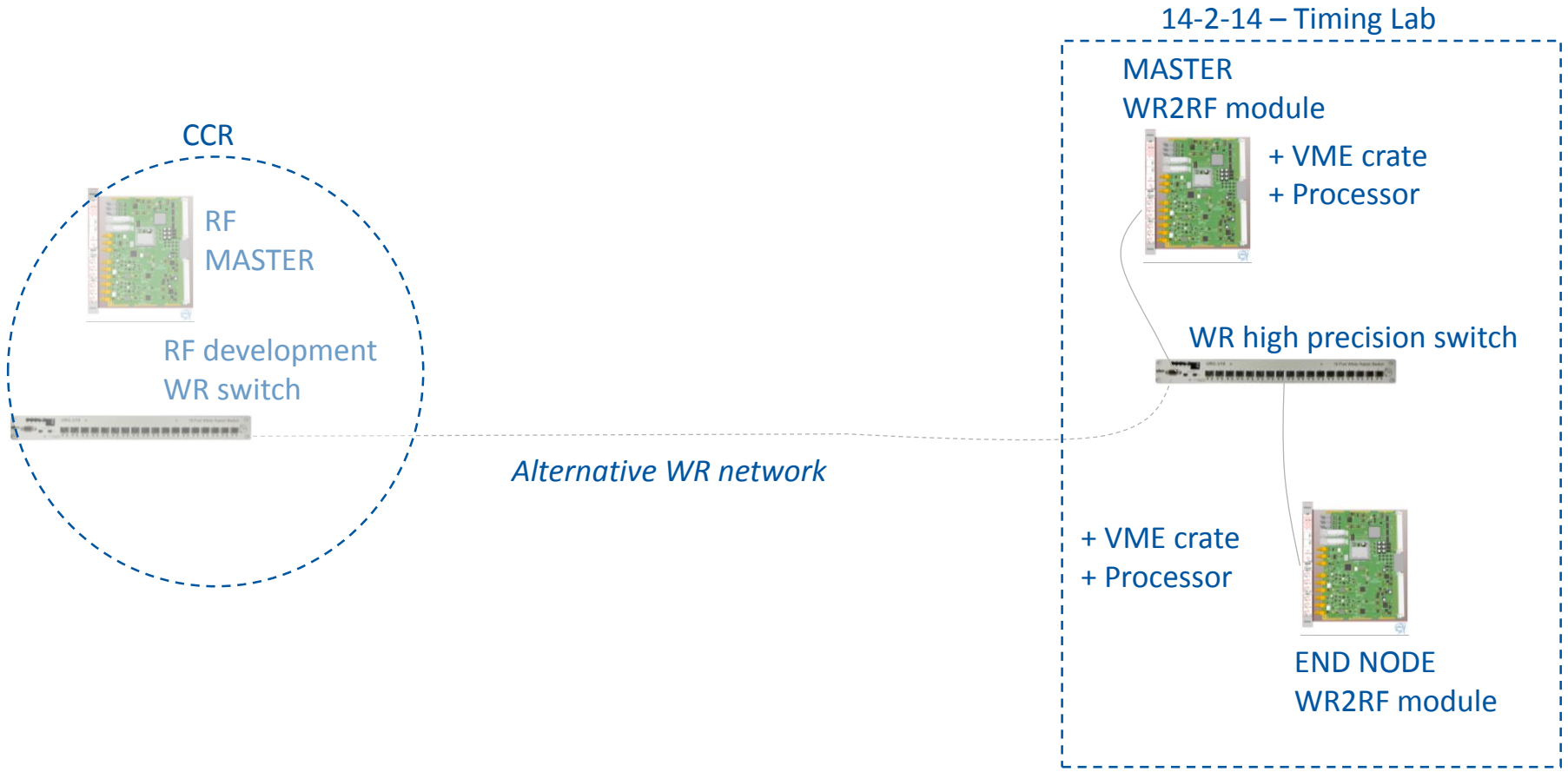
The proposal



To start with…

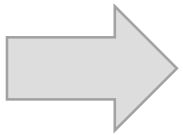


Starting soon…



Starting soon…

- In close collaboration with BE-CEM (and SY-RF)
- Implementation of a simple WR network with 2 WR2RF boards and one switch (in the timing lab)
  - Thanks to the financial participation of the 4 main LHC experiments
  - Assess the WR2RF boards as a initial example of RF receiver in experiments (gracefully lend by John, Javier and Co)
    - This could be an excellent start
  - Reconstruct ‘BC & Orbit like’ signals over the network
    - Investigate an RF over ethernet protocol: https://ohwr.org/project/roe-protocol/wikis
    - Characterize the obtained quality
  - Connect as end-nodes to the BE-CEM and SY-RF White Rabbit development networks
- Exploratory project
  - Just starting
  - To be steered by a working group



Could this
- replace somehow the BST transmitted to the experiments?
- be merged with the future BST system?

THANKS…

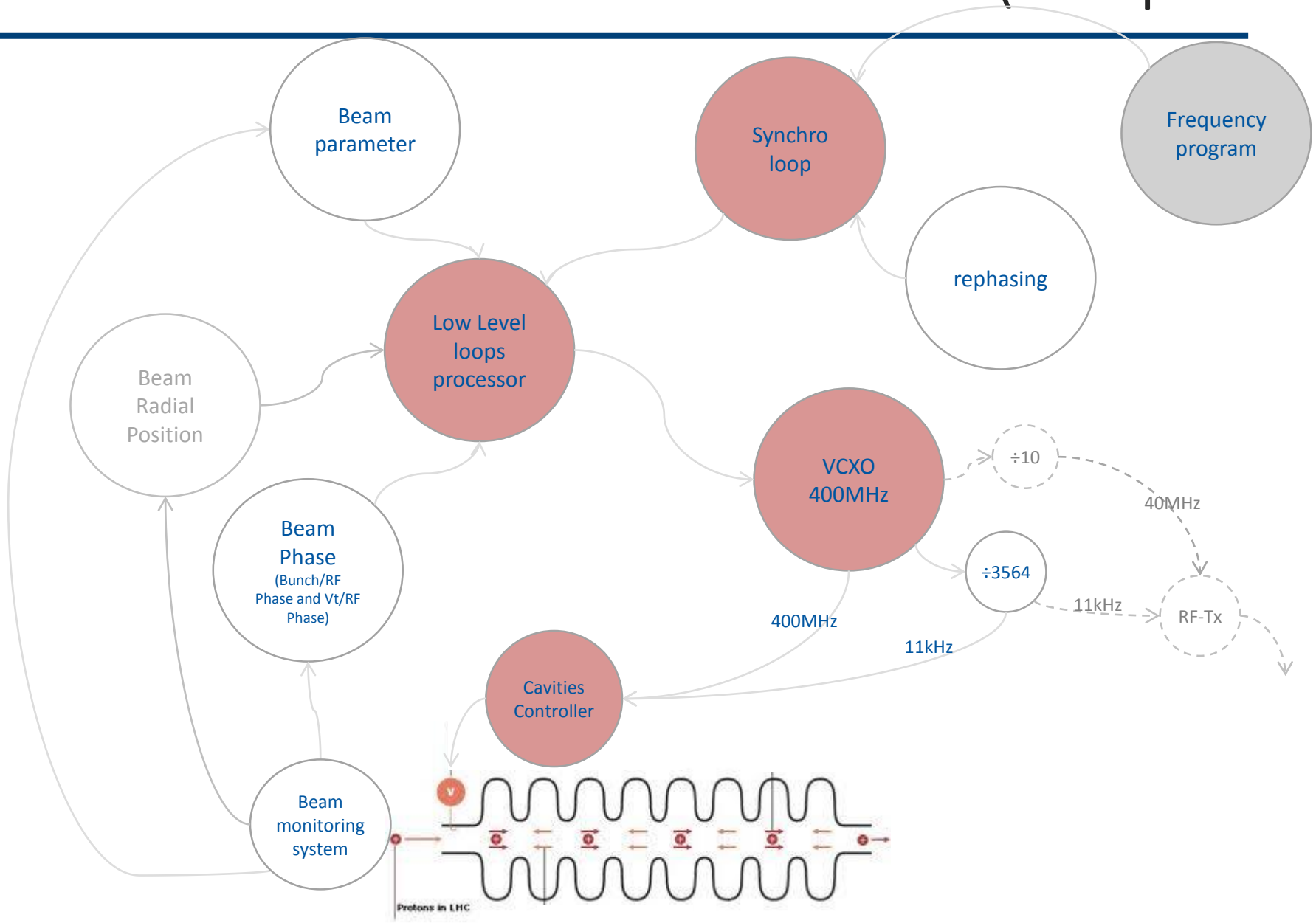
Questions?

Spare Slides

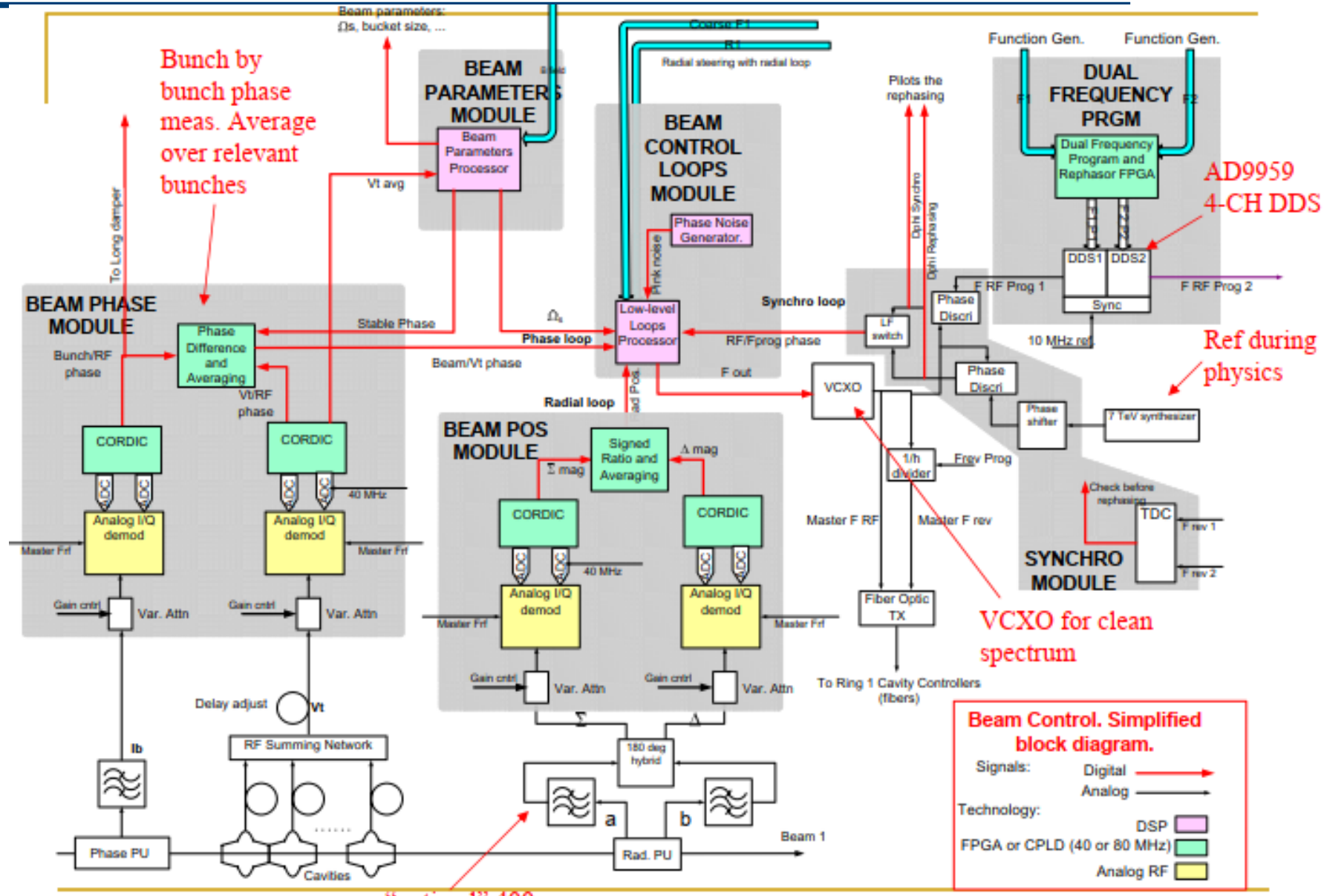
References

- Agreement between PH/AB/EN for current TTC backbone:
  - Signature list: https://edms.cern.ch/ui/#!master/navigator/document?D:1041861675:1041861675:approvalAndComments
  - Final document: https://edms.cern.ch/document/628545/2
- BST System: https://indico.cern.ch/event/391439/contributions/935727/attachments/783431/1073995/BST_hardware.pdf
- BOBR specs: http://ttc.web.cern.ch/BOBRspec.pdf
- GMT/CTRV presentation: https://indico.cern.ch/event/20321/sessions/131591/attachments/306761/428332/LeadLHC.pdf
- CTRV board specs: https://twiki.cern.ch/twiki/bin/view/Sandbox/CTRV_board
- BE/CO control systems 2019: https://be-dep-co.web.cern.ch/sites/be-dep-co.web.cern.ch/files/Introduction_to_the_BE-CO_Control_System.pdf
- The new SPS LLRF, P. Baudrenghien OP shutdown lecture, Oct 2020, https://indico.cern.ch/event/895500/
- The SPS RF-train over White-rabbit, A. Spierer https://wikis.cern.ch/x/n__3BQ
- RFNCO specification (IP core), A. Spierer, https://edms.cern.ch/document/2061209
- White Rabbit page: https://ohwr.org/project/white-rabbit
- White Rabbit IEEE standardization: https://ohwr.org/project/wr-std
- WR2RF, OHWR, D. Lampridis, M. Rizzi, https://ohwr.org/project/wr2rf-vme
- WR2RF diagram, G. Hagmann, https://gitlab.cern.ch/ghagmann/wr2rf
- WR2RF specification, D. Lampridis, https://edms.cern.ch/document/2260001
- WR2RF gitlab: https://gitlab.cern.ch/ghagmann/wr2rf
- eRTM14/15 modules updates in HPTD meetings: https://indico.cern.ch/event/837613/contributions/3558468/attachments/1914001/3163681/ep_ese_timing_sep24.pdf
- RF Signal Distribution over WR, J. Gill, Nov. 2019, BE seminar https://indico.cern.ch/event/865008/attachments/1949767/3236439/BE_seminar_WR_Applications-RFoWR.pdf
- THE CERN SPS LOW LEVEL RF UPGRADE PROJECT, G. Hagmann et al. IPAC19, https://ref.ipac19.org/reference/show/90696
- RF over EThernet – a protocol https://ohwr.org/project/roe-protocol/wikis
- Crab Cavities: https://indico.cern.ch/event/326148/contributions/1711480/attachments/633065/871253/HiLumi_KEK_Burt_add.pptx

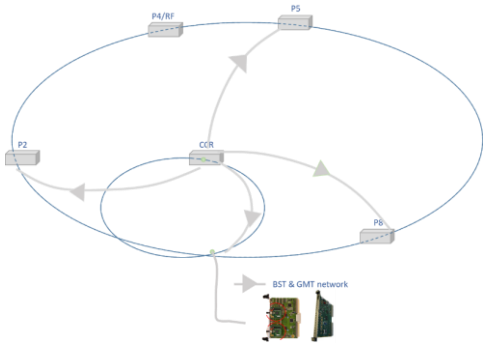
LHC LLRF Beam Control In SR4 (simplified)



LHC LLRF Beam Control In SR4



BST & GMT systems

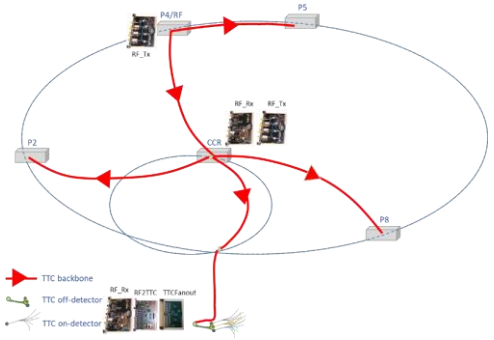


- Each experiment is equiped with at least one module of BST & GMT
  - BOBR (2001) for the BST,
  - CTRV or CTRP (2003) for the GMT
  - Used in experiments for:
    - One unique source of General Timing for all systems (very useful for timestamping events, post mortem or global management tasks)
    - Beam mode and LHC timing events

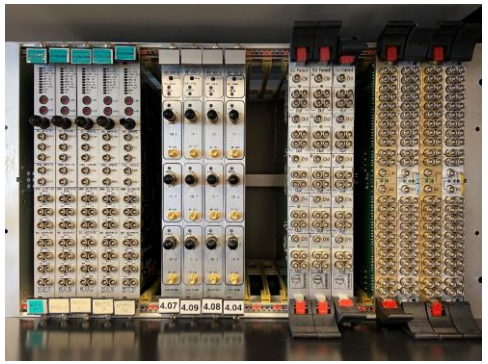
- Support:
  - Modules are now obsolete
  - best effort basis but expertise is disappearing

- Expected Upgrades
  - GMT (BE/CO) to be replaced by White Rabbit (see following slides)
  - BST (BE/BI) will probably join the effort and the 2 systems will probably be merged

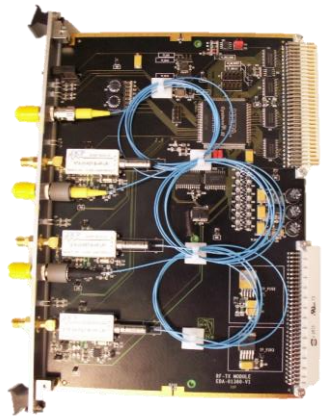
RF-TTC backbone current status



- Spares handled by experiments, RF and ESE



- Ageing hardware (2007)
  - Last production of RF-Rx took 2 years (!)



RF-Tx

RF-Rx

RF2TTC

FANOUT