Current TTC Systems and TTC-PON Upgrade

TTC PON

E. Mendes
on behalf of the TTC-PON team
(S. Baron, E. Mendes, A. Lippiello, C. Soos, F. Vasey)

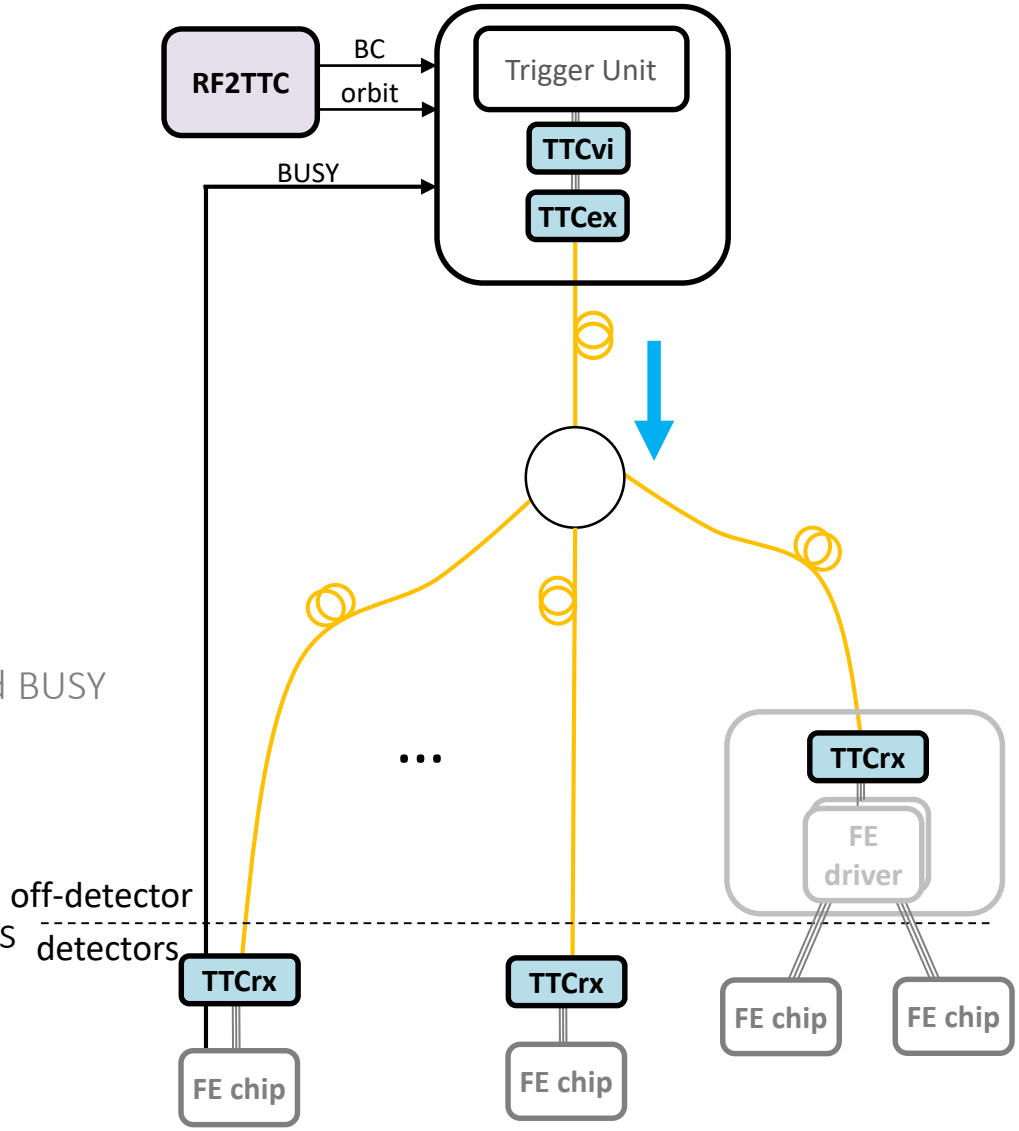
CERN

Outline

- Current TTC systems
- TTC-PON project
- Next generation TTC-PON: TTC-PON+
- Summary

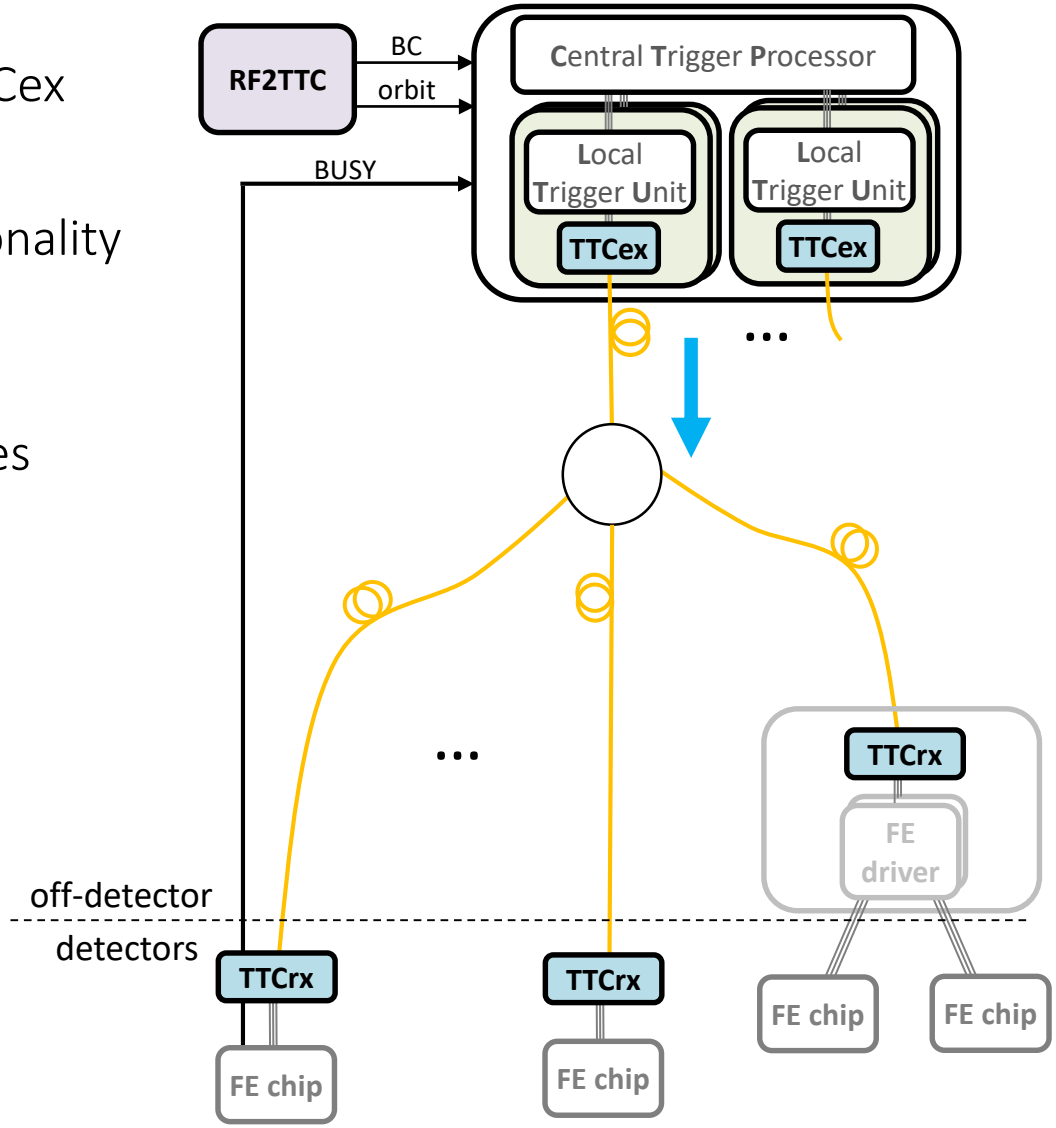
Current TTC system

- TTC: Timing, Trigger and Control
  - Implemented early 2000's
- Main Features
  - Point-to-Multipoint
    - Max split-ratio: 1x32
  - Low bandwidth
    - 40Mb/s per channel (A and B)
  - Unidirectional (optical)
    - Separate electrical link to send BUSY information
- CERN common-project
  - Adopted by all LHC experiments
  - Common set of VME modules



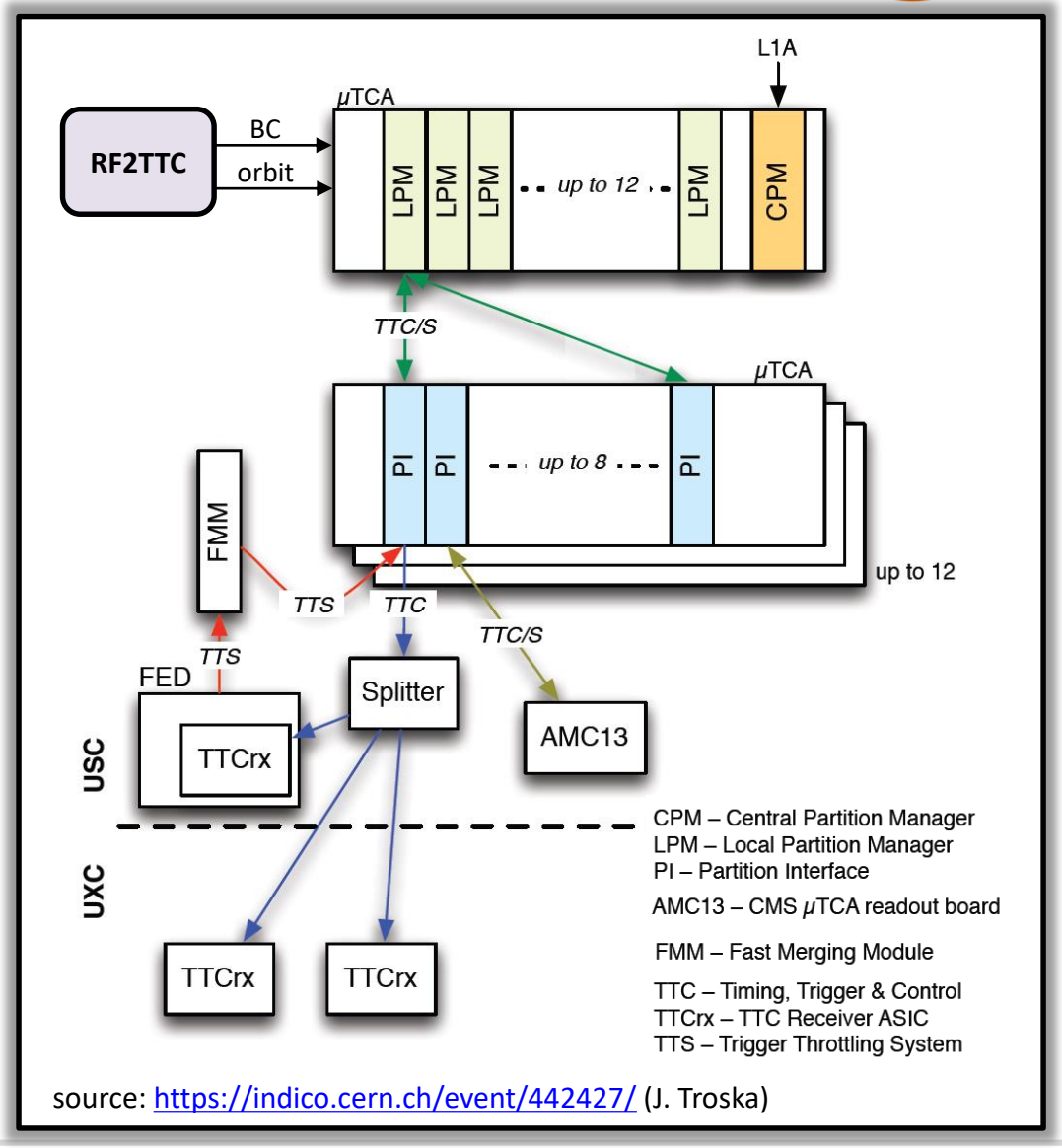
Current TTC system in ALICE experiment

- TTC-partition with LTU and TTCex
- LTU incorporates TTCvi functionality
  - No TTCvi boards
- TTC upgrade: phase-1 upgrades
  - TTC-PON
- Thanks to Marian Krivda



Current TTC system in CMS experiment

- TCDS (Timing and Control Distribution System)
  - Upgraded end of LS1
- µTCA system based on modern FPGAs (7 series)
- Thanks to Jan Troska



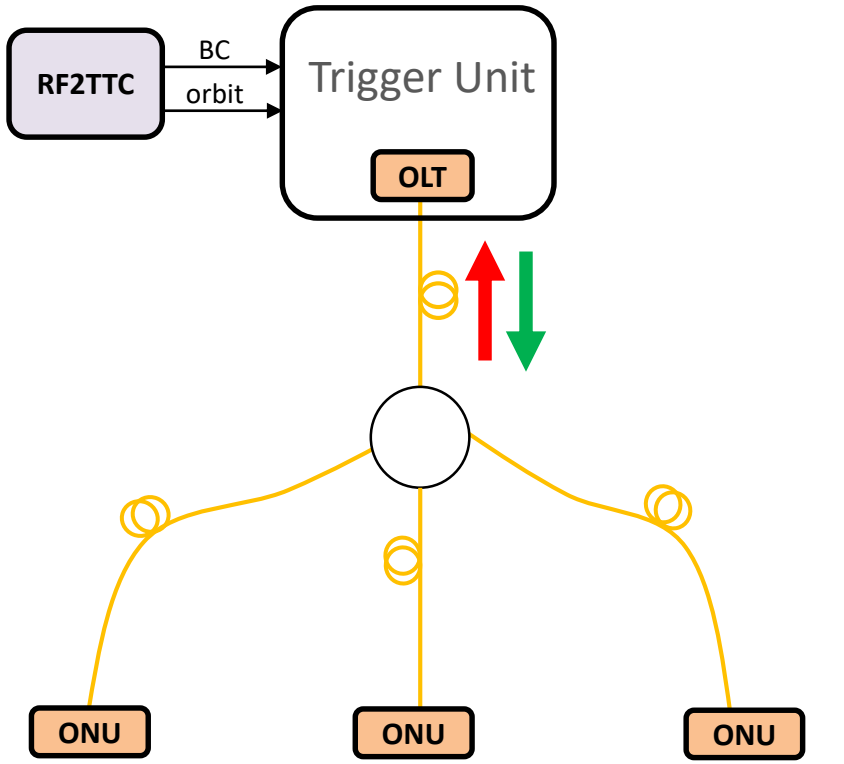
source: https://indico.cern.ch/event/442427/ (J. Troska)

Outline

- Current TTC systems
- **TTC-PON project**
- Next generation TTC-PON: TTC-PON+
- Summary

TTC-PON: Concept

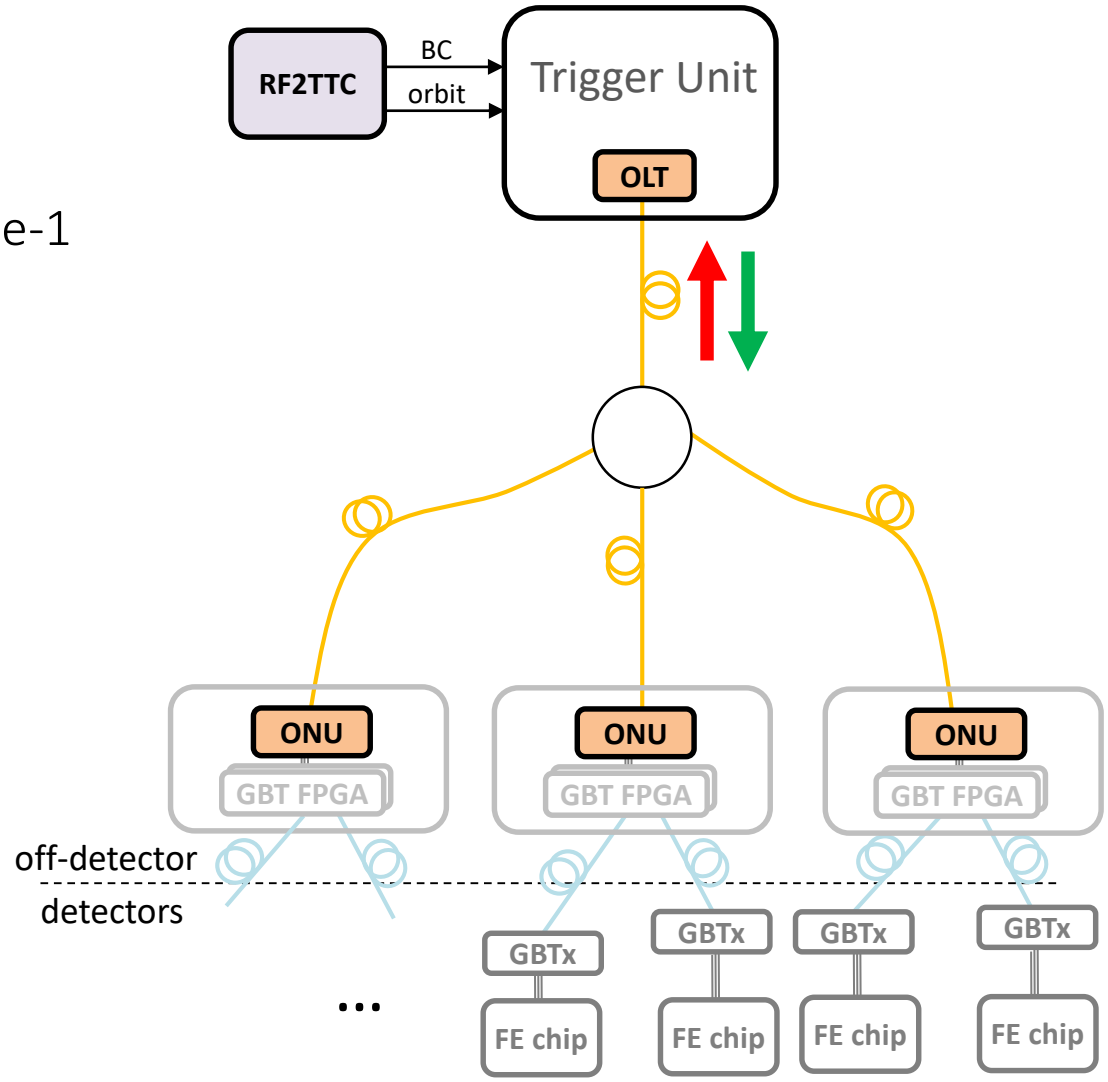
- PON (Passive Optical Networks)
  - Point-to-Multipoint
    - Up to 1x64 split-ratio with ~4dB optical margin
  - High bandwidth
  - Bidirectional (single fibre)
    - Downstream (OLT → ONUs)
    - Upstream (ONUs → OLT)
  - XG-PON technology
    - + custom protocol
- CERN common-project
  - Target: phase-1/2 upgrades



OLT: Optical Line Terminal / ONU: Optical Network Unit

TTC-PON: Concept

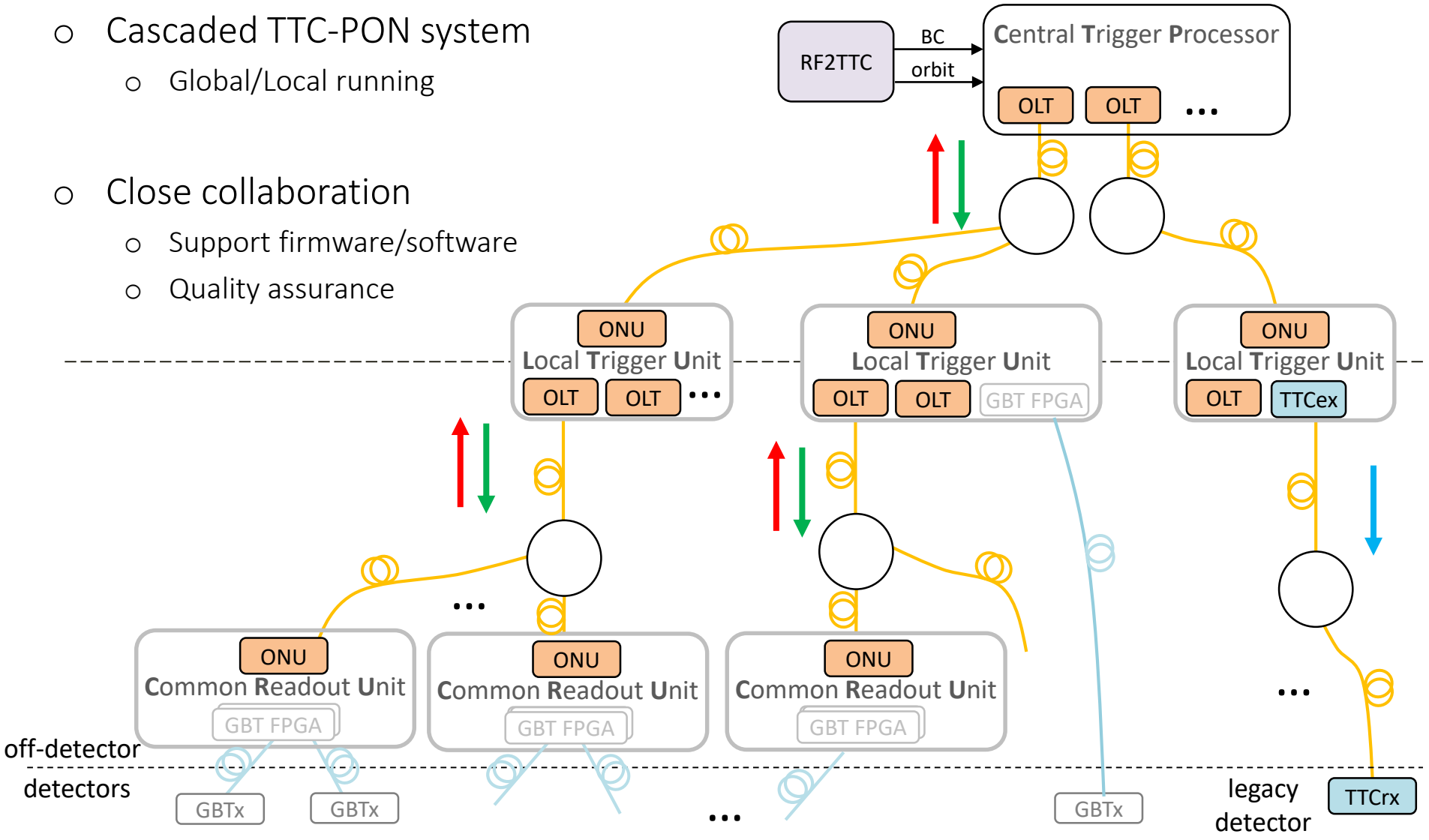
- CERN common-project
  - Target: phase-1/2 upgrades
- Being commissioned for phase-1 ALICE upgrades



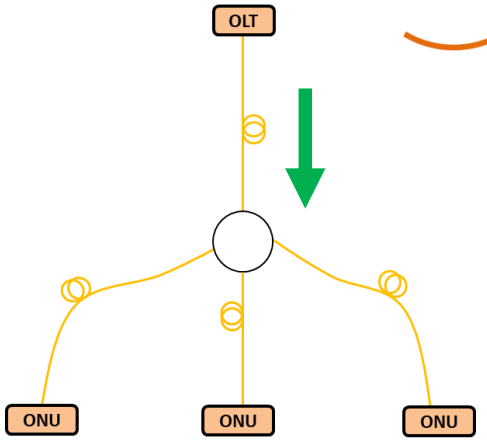
OLT: Optical Line Terminal / ONU: Optical Network Unit

TTC-PON / ALICE phase-1 flavour

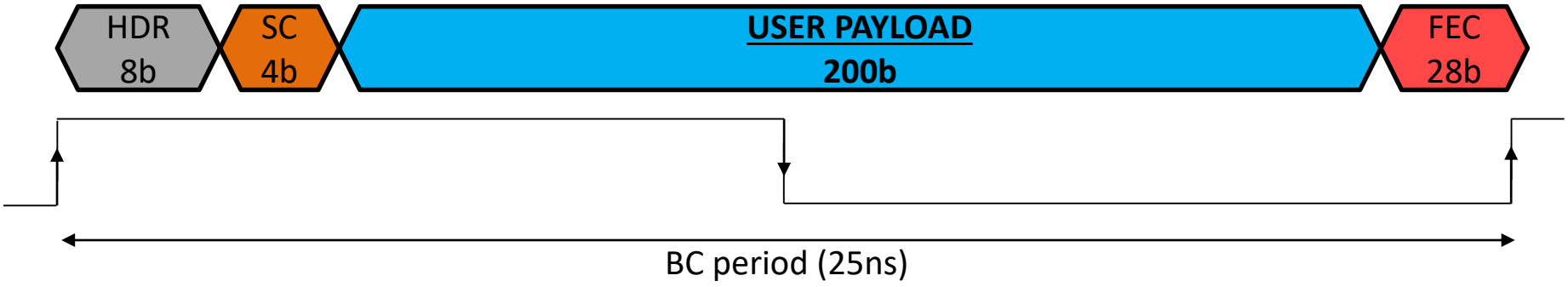
- Cascaded TTC-PON system
  - Global/Local running
- Close collaboration
  - Support firmware/software
  - Quality assurance



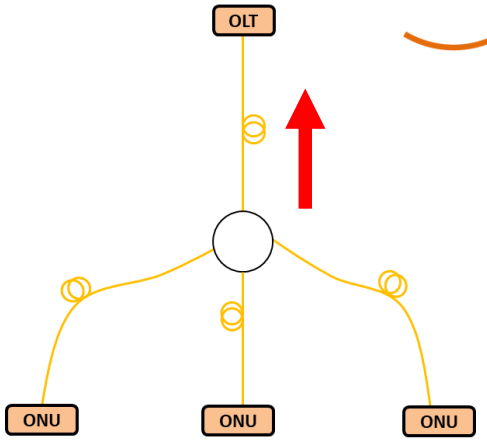
TTC-PON: downstream



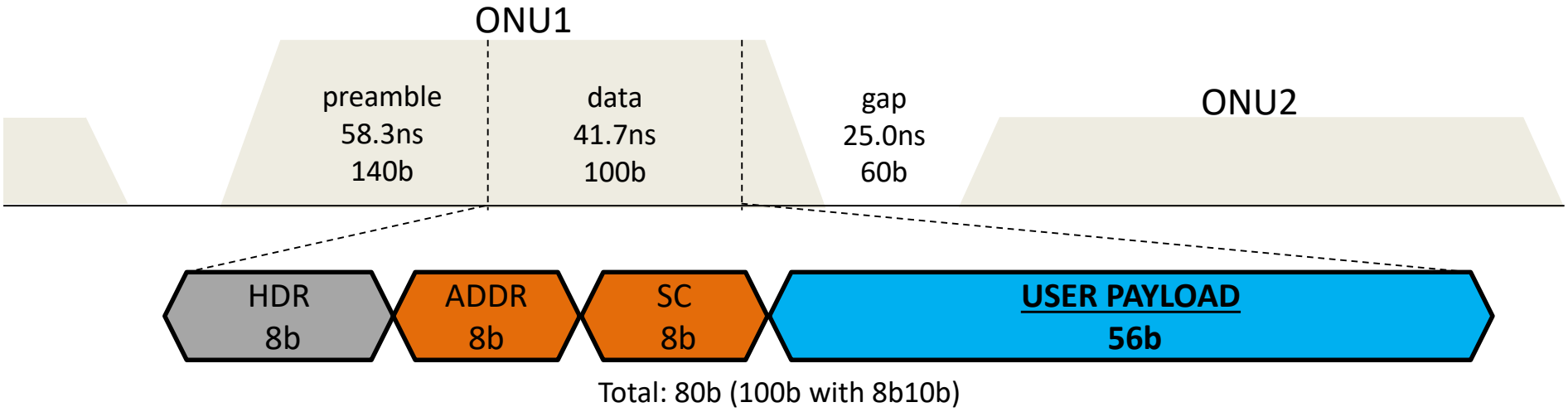
- OLT → ONUs (broadcast)
- 9.6Gb/s line-rate (1577nm)
- Low and fixed latency
- FEC (forward error correction)
  - 2x BCH(120,106) – double random error correcting code
  - 88.3% efficiency, ~3dB coding gain
- SC (slow control)
  - System control/monitoring (FEC and CRC-7 protected)
- **High User Bandwidth (200b per BC – 8Gb/s)**



TTC-PON: upstream



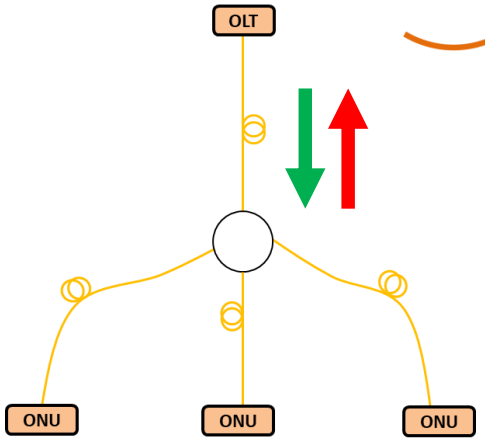
- ONUs → OLT (TDMA)
- 2.4Gb/s line-rate (1270nm)
- Synchronized to downstream
- 8b10b encoded
- Total burst length: 125ns (100ns burst + 25ns gap)
- **Waiting time (BUSY latency): 125ns x Number ONUs (8us for 64 ONUs)**
- **User bandwidth: 448Mb/s x (1 / Number ONUs)**

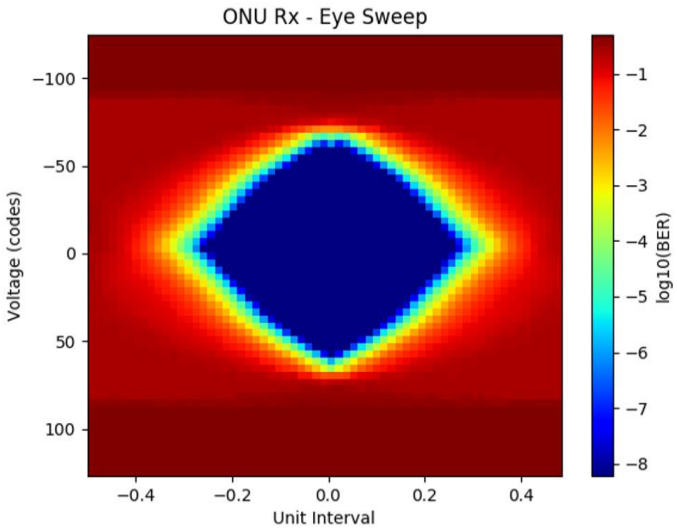


TTC-PON: system features

- Examples of **online** features:
  - Downstream Error Monitoring
    - FEC single error correction
    - FEC double error correction
    - SC-CRC error detection
  - Downstream Eye Scan
    - So far for Xilinx (Kintex7, Kintex Ultrascale)
  - Upstream Error Monitoring
    - 8b10b error detection
  - Among others (see https://indico.cern.ch/event/608587/contributions/2614195/)

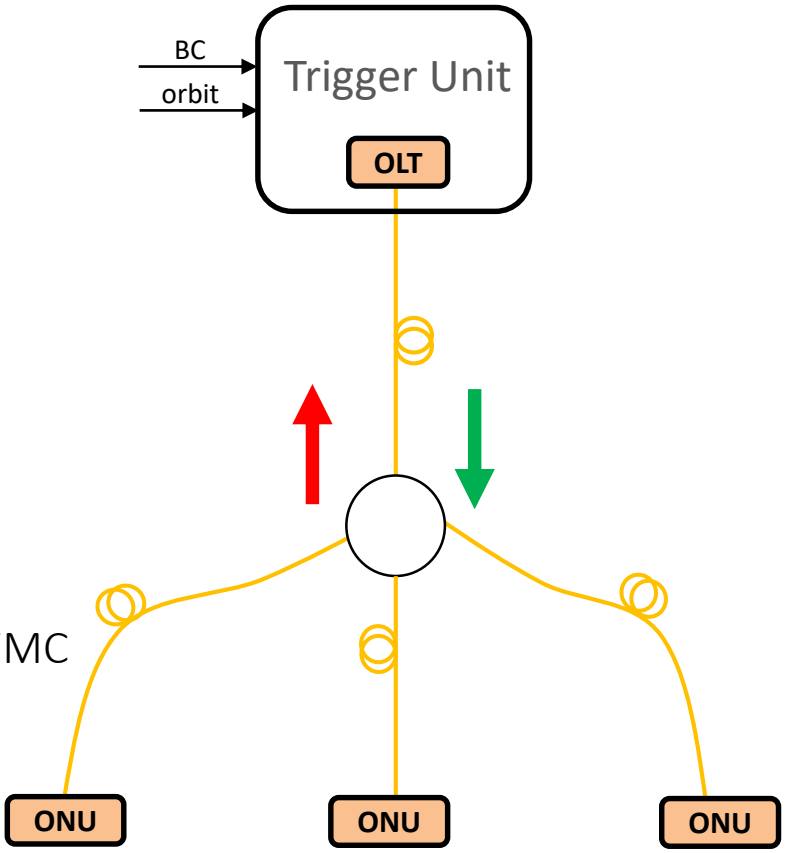
severity





TTC-PON: getting started

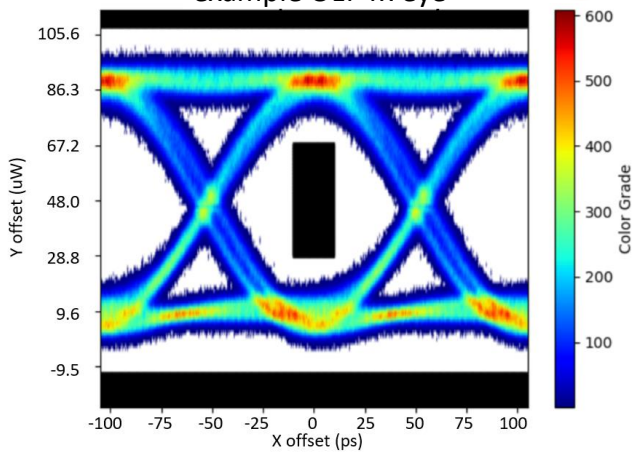
- Software (PC – soft/hard processor)
  - Full system control and monitoring from OLT
  - Python-based
- Firmware
  - OLT core: Kintex Ultrascale
  - ONU core: Kintex7, Kintex Ultrascale, Arria10
- Hardware
  - Various FPGA evaluation boards + TTC-PON FMC
  - PON components
- Support
  - User guide
  - Quick start guide for example designs
  - https://gitlab.cern.ch/TTC-PON - access on request

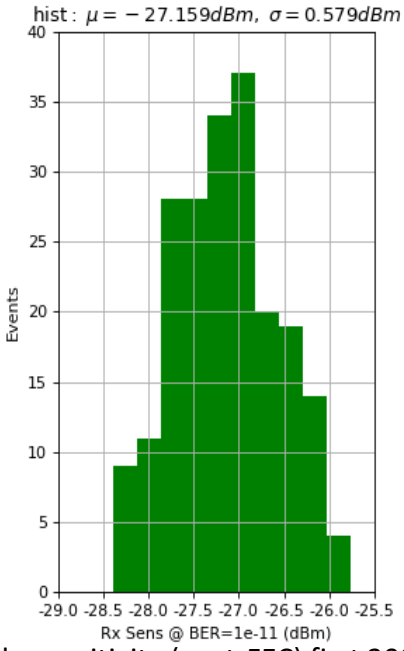


TTC-PON: production for phase-1

- Common price enquiry for OLT/ONU modules
  - ALICE
  - LHCb
  - ~1000 ONU and ~100 OLT modules
    - ONU ~ 100 USD
    - OLT ~ 600 USD
- Quality assurance
  - Specifications based on XG-PON protocol + some additional CERN requirements
  - Components are tested against the specs. defined in the price enquiry for transmitter/receiver

example OLT Tx eye





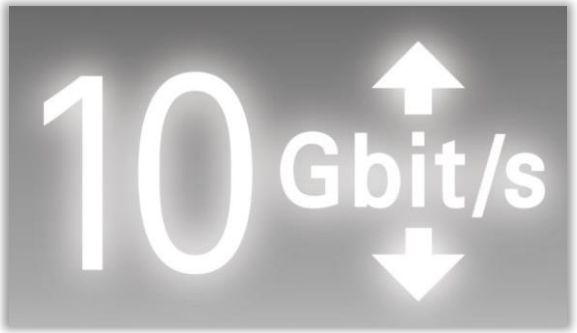
example sensitivity (post-FEC) first 200 ONU lot

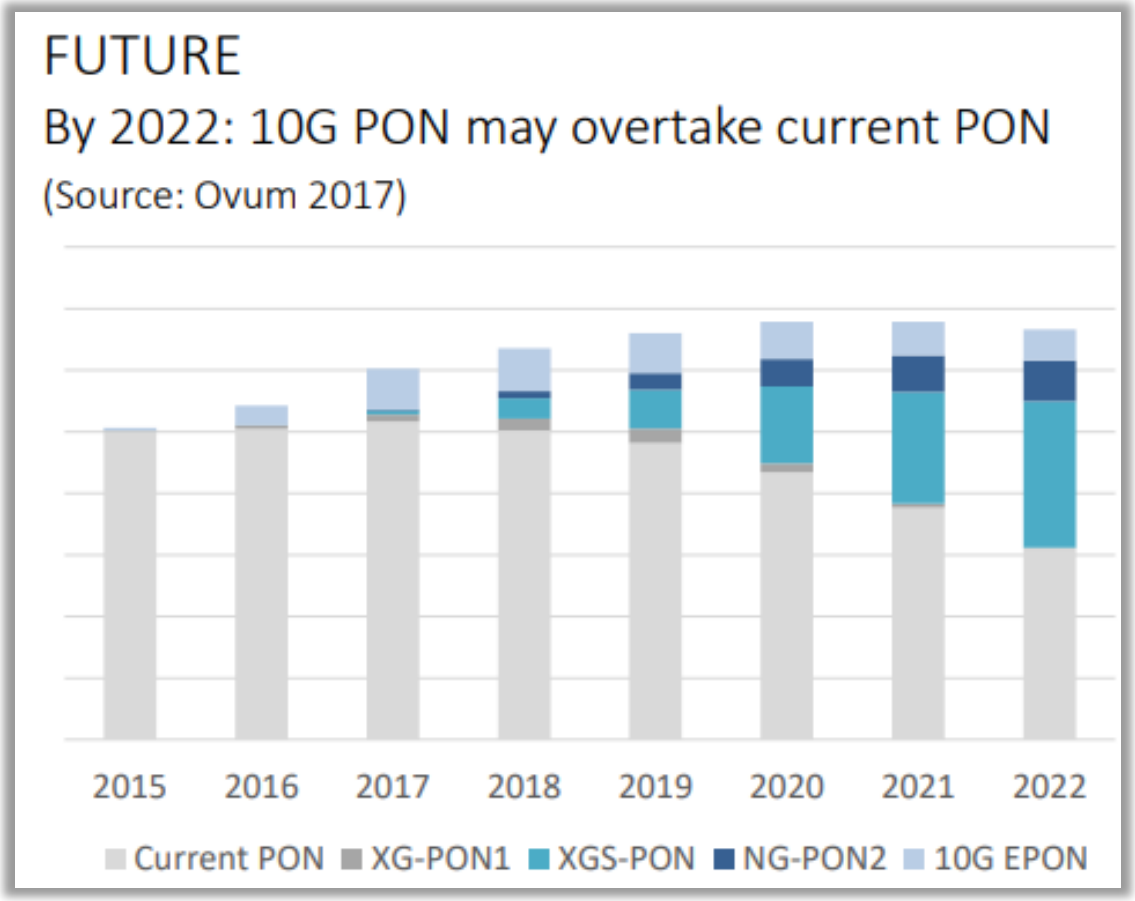
Outline

- Current TTC systems
- TTC-PON project
- **Next generation TTC-PON: TTC-PON+**
- Summary

TTC-PON+: XGS-PON

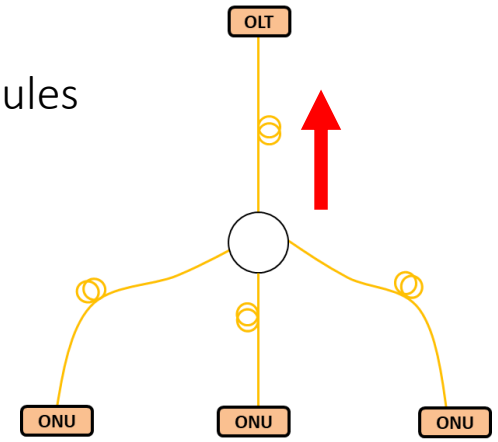
- Target: phase-2 upgrades
- **XGS-PON technology**
  - 10Gb/s symmetrical
  - SALT: 1st offer worldwide in Switzerland





TTC-PON+: XGS-PON challenges

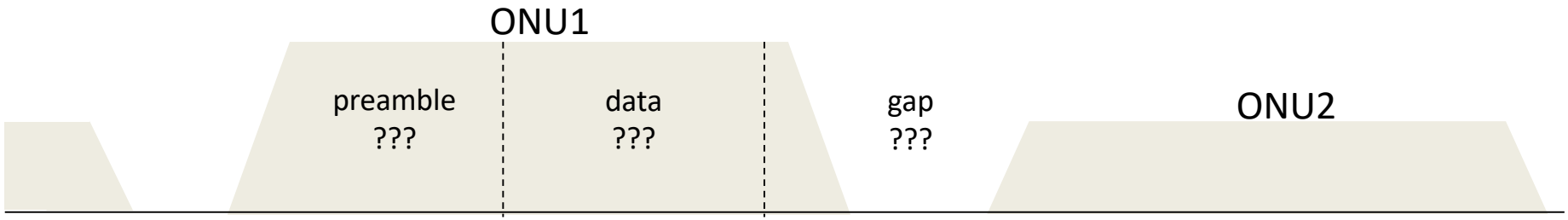
- Physical layer
  - Test and investigate the limits of commercial optical modules (in progress)



- 10Gb/s upstream burst-mode data reception in FPGA
  - Not natively supported by FPGA transceivers
  - Simple oversampling might not be possible
    - 5 x 10Gb/s → 50Gb/s
  - We are working on different concepts

TTC-PON+: XGS-PON design choices

- Protocol
  - Bandwidth, upstream waiting time?
  - Upstream flexibility: user tunable payload?
  - Split-ratio (FEC also upstream?)



- High Precision Timing
  - Improve phase stability following HPTD (Sophie's talk) studies
  - Fine phase monitoring?

- Plan to have a first proof-of-concept by the end of the year

- **User feedback is very welcome in design stage**

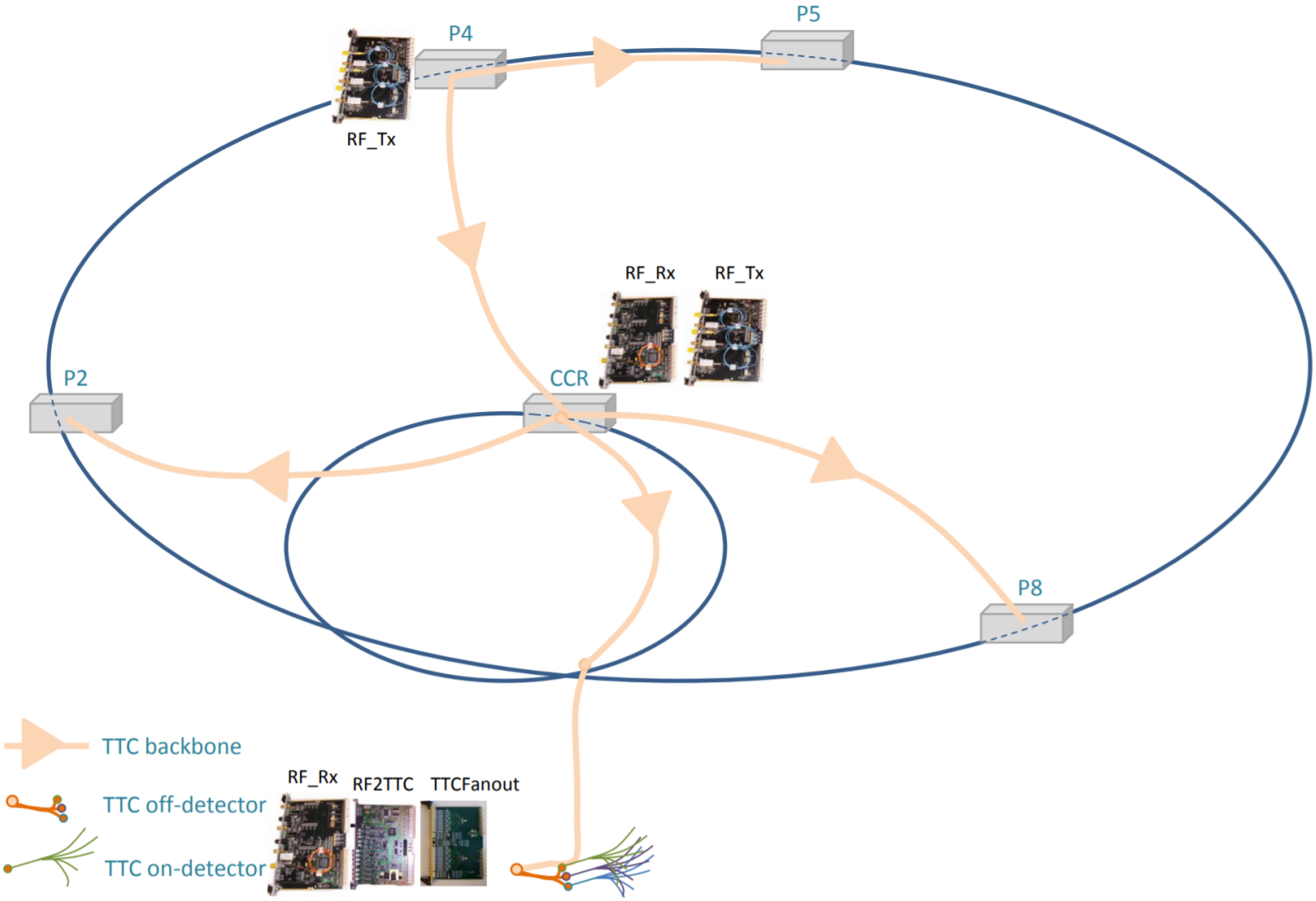
Summary

- Current TTC system in experiments have different flavours and are progressively being replaced by other solutions
- TTC-PON production for phase-1 has started and optical modules are being received and tested (~1000 ONUs, ~100 OLTs)
  - Each experiment adopts it in its own way
- Next generation TTC-PON is under study based on XGS-PON technology
- **Do not hesitate to contact our team in case you would like to evaluate TTC-PON for your own application**

Thank you

Spare slides

RF-TTC distribution



source: https://indico.cern.ch/event/202454/attachments/304791/425754/TTCClockdistribution6.pdf

TTC-PON: optical power margin

Device	Attenuation
Splitter - 1:32 Splitter - 1:64	17 dB 20.5dB
Splitter 1:2	3.7 dB
Fiber (200m, 0.5dB/km)	0.1 dB
Connectors (4 units, 0.5dB/unit)	2.0dB
Total attenuation 1:64 **Total attenuation 1:128**	**22.8dB** **26.3dB**

Specification - Downstream	Power
Min OLT Tx Power (OMA)	+5.68 dBm
Max ONU Rx Sensitivity (OMA) – 1e-12	-21 dBm
FEC coding gain	3 dB
Total power budget	**29.68 dB**
Margin 1:64 **Margin 1:128**	**6.88 dB** **3.38 dB**

Specification – Upstream	Power
Min ONU Tx Power (OMA)	+3.68 dBm
Max OLT Rx Sensitivity (OMA) – 1e-11	-23 dBm
Total power budget	**26.68 dB**
Margin 1:64 **Margin 1:128**	**3.88 dB** **0.38 dB**