The TOTEM precision clock distribution system

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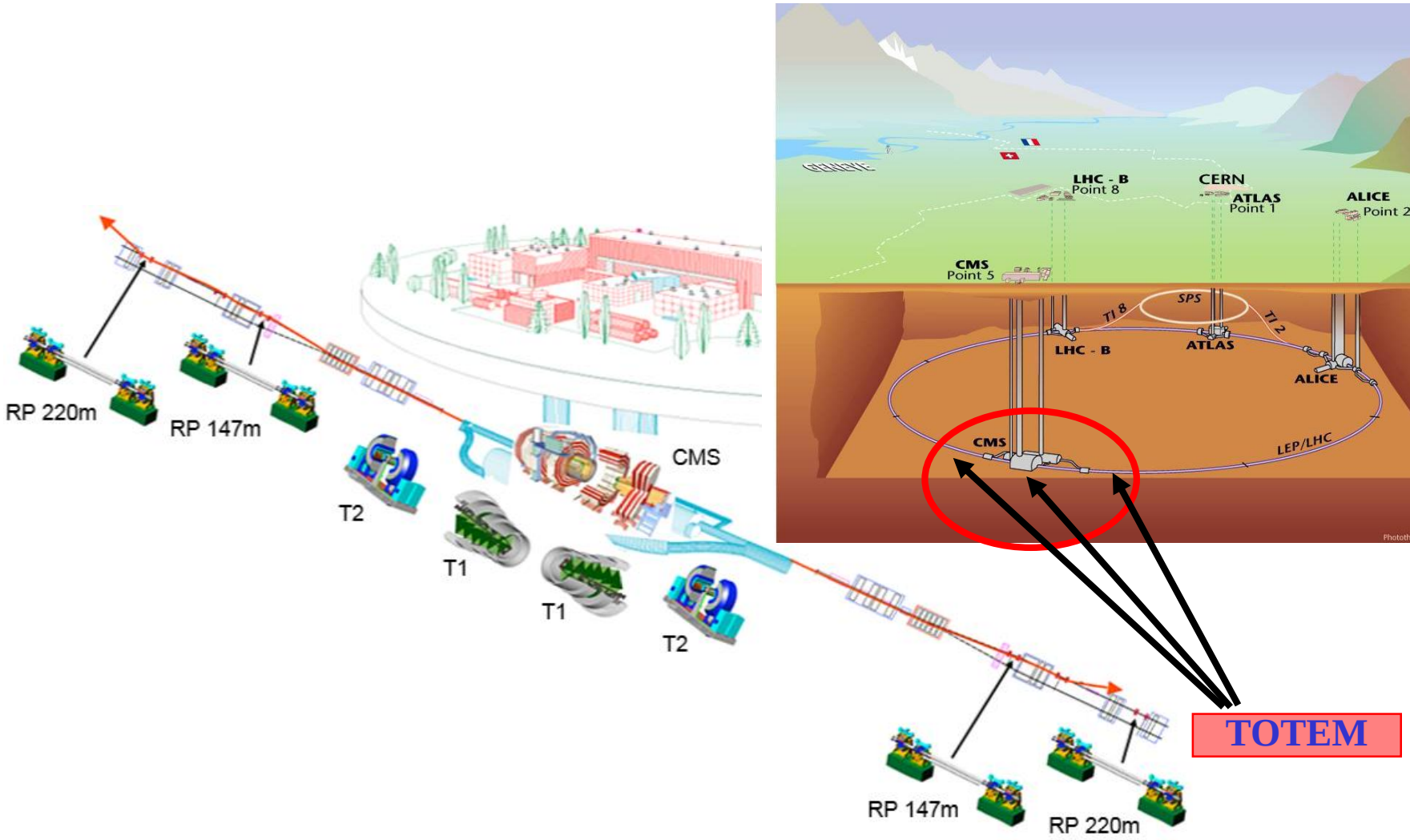
On behalf of TOTEM Collaboration

Contents

- The TOTEM Experiment at the LHC
- The upgrade program for Run II
- The TOTEM precision timing distribution system
  - Full system overview
  - System simulations
  - First set-up and results
- Conclusions

TOTEM Experiment - Run I



TOTEM Physics goals

- TOTEM (TOTal cross section, Elastic scattering and diffraction dissociation Measurement at the LHC)
  - σ_{TOT}^{pp} with a precision ~1-2%, luminosity independent method (optical theorem) simultaneously measuring:

    - N_{el} down to -t ~10^{-3} GeV^2
    - N_{inel} with losses < 3%

    $$\sigma_{tot} = \frac{16\pi}{1+\rho^2}\frac{(dN_{el}/dt)_{t=0}}{(N_{el}+N_{inel})}$$

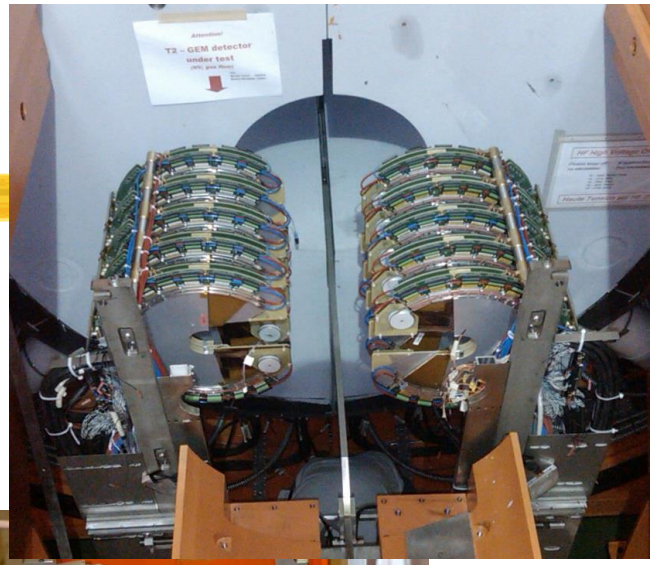
    - Elastic pp scattering in the range 10^{-3}
    - Soft diffraction (SD and DPE)
    - Particle flow in the forward region

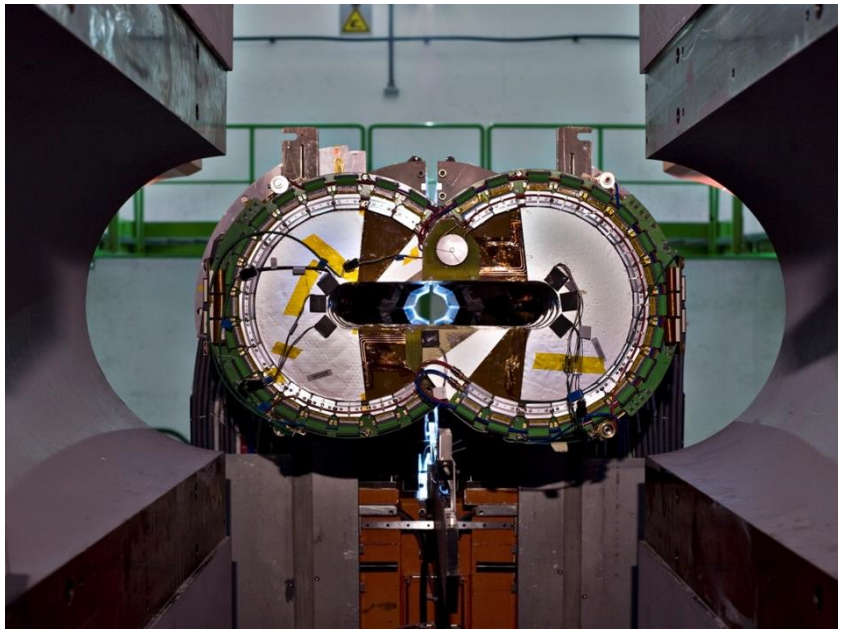
    $$\sigma_{tot}^2 = \frac{16\pi}{1+\rho^2}\frac{d\sigma_{el}}{dt}|_{t=0},\ \ \sigma_{inel} = \sigma_{tot} - \sigma_{el}.$$

- TOTEM & CMS
  - Soft and hard diffraction in SD and DPE (production of jets, bosons, h.f.)
  - Central exclusive particle production
  - Low-x physics
  - Particle and energy flow in the forward region

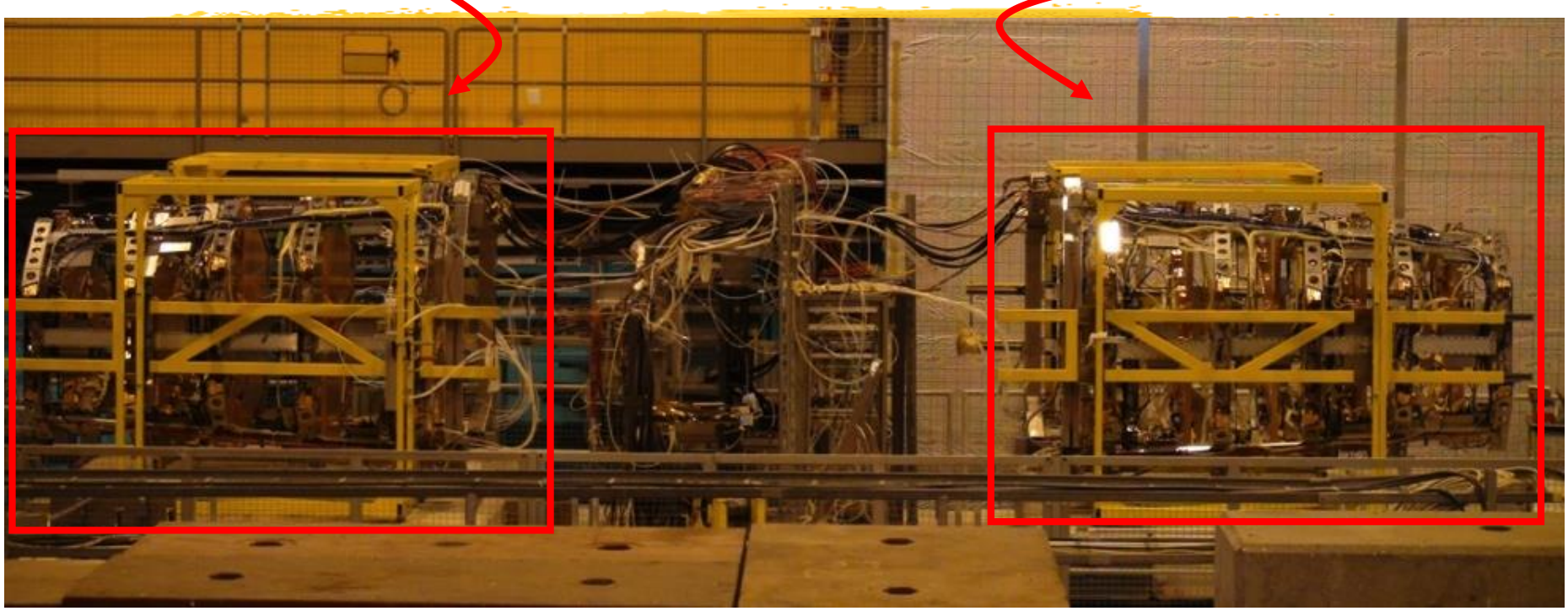
T2 Detector

- T2 telescope is based on GEM chambers.





T1 detector

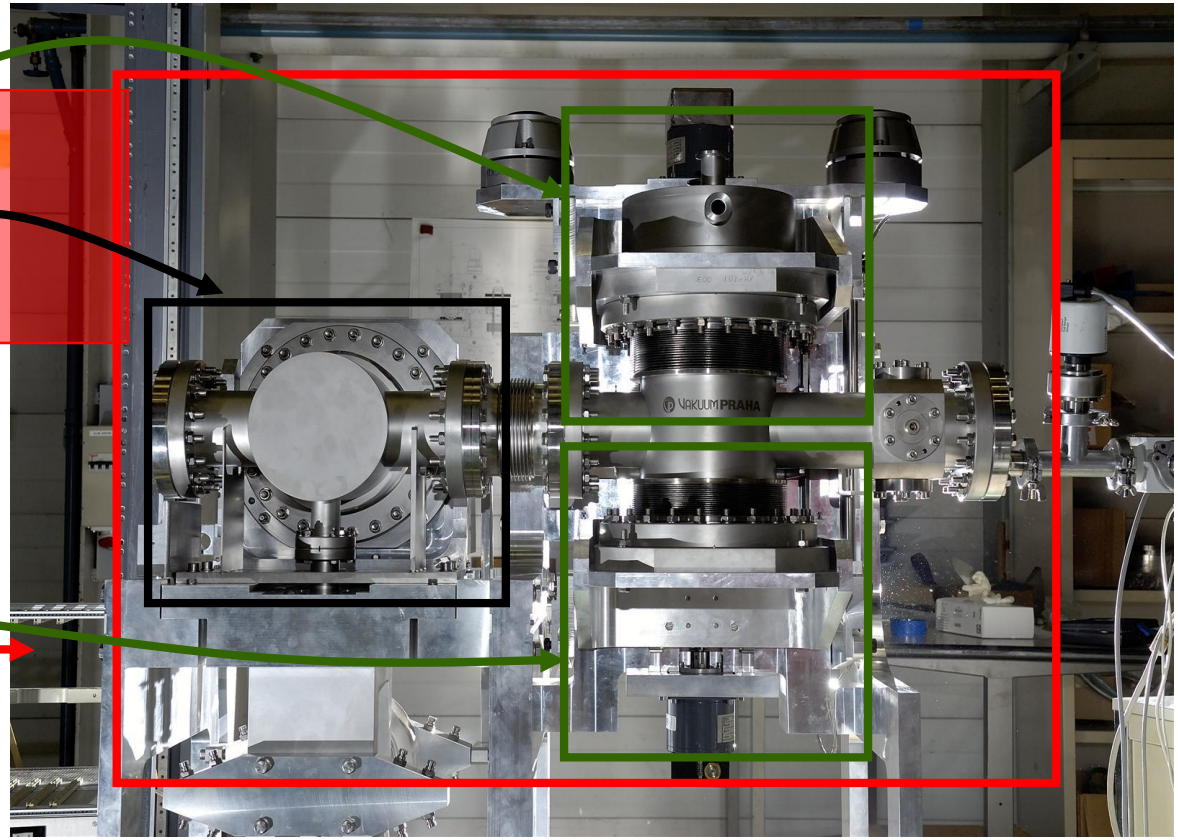


- T1 telescope uses cathode strip chambers (CSC)

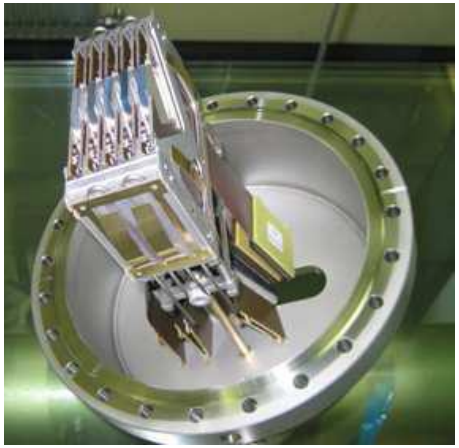
Roman pots

One RP station:
- **2 units**

One unit:
- **2 vertical pots**
- **1 horizontal pot**



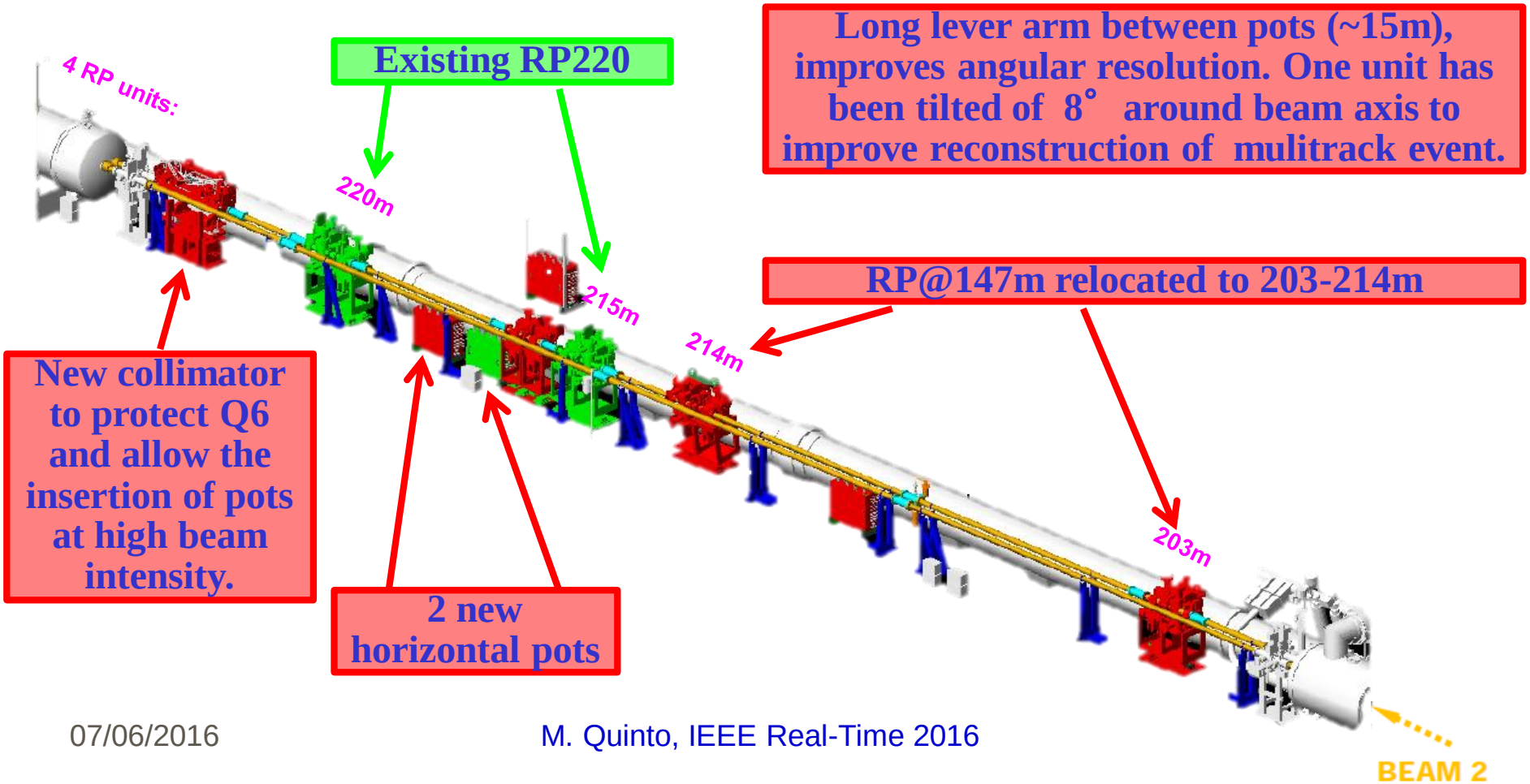
- Each RP is equipped with a stack of 10 silicon strip detectors, designed with the specific objective of reducing the insensitive area at the edge facing the beam to only a few tens of mm.
- During LHC Run I, 24 Roman pots were distributed in 4 stations at ±220 and ±147 m.



Contents

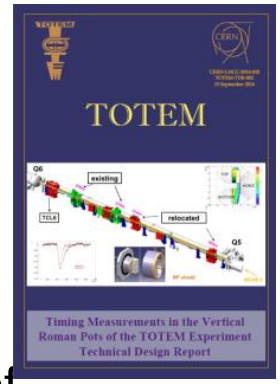
TOTEM Program for RUN II

- **Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment** (CERN-LHCC-2014-020 ; TOTEM-TDR-002; https://cds.cern.ch/record/1753189/);
- **CMS-TOTEM Precision Proton Spectrometer** (CERN-LHCC-2014-021 ; TOTEM-TDR-003 ; CMS-TDR-13; https://cds.cern.ch/record/1753795?ln=en);



The TOTEM timing upgrade

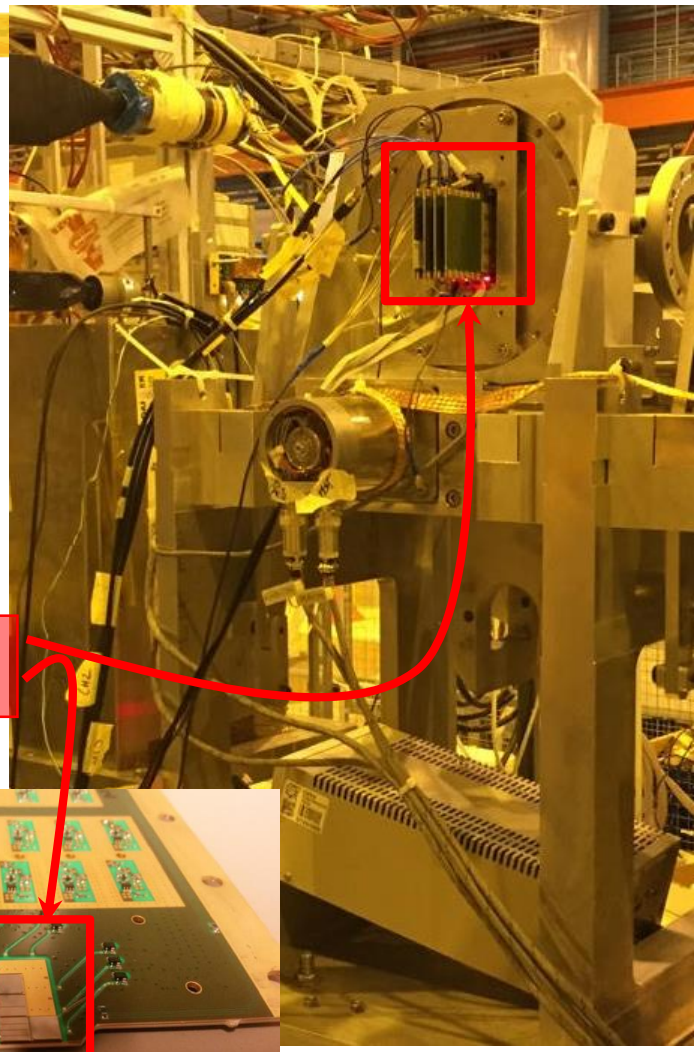
- **Timing Measurements in the Vertical Roman Pots of the TOTEM Experiment**
  - **High beta* (90 m), special runs, low luminosity**
  - All **vertical RPs** with one equipped with timing detectors (TOTEM R&D)
  - Integrated Luminosity of the order of 1-100 pb^{-1}
  - CMS and TOTEM common data taking
  - The integrated luminosities, required by the cross-sections of the processes, imply a pileup from ~10% up to ~50%
  - **TIMING detectors are needed above 15% pileup**

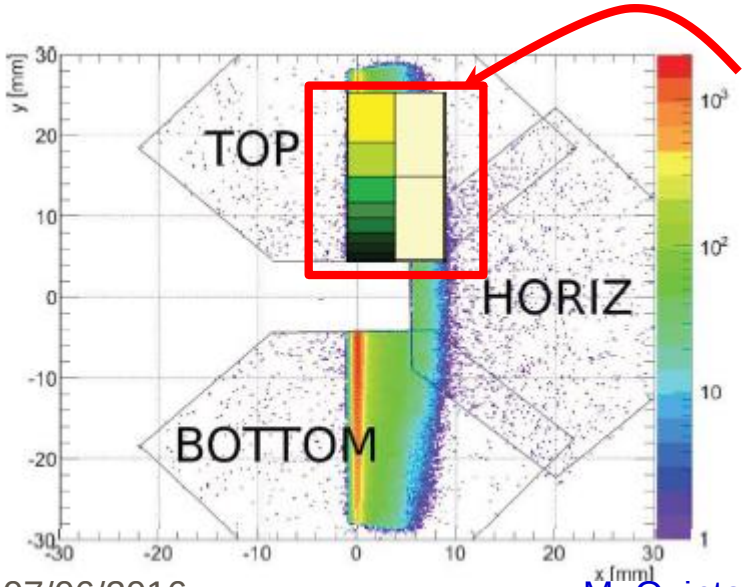


- **Scientific objectives**:
  - Exclusive central diffraction;
  - Low mass resonances and glueball states;
  - Exclusive charmonium state;
  - Search for missing mass and momentum candidates;
  - Exclusive jet production.

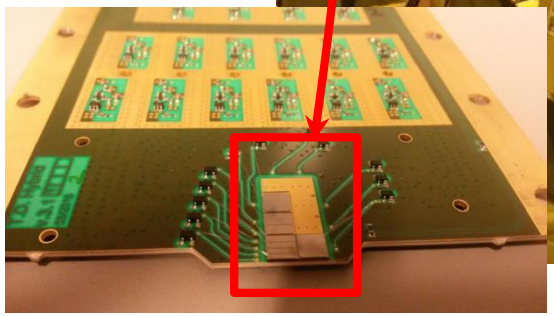
The TOTEM timing upgrade

- Timing detectors in the relocated vertical RPs:
  - Limited space available -> Solid State Detectors: Diamond
  - Time resolution & performances: 50ps per pot (~100ps per detector), reduce pile-up by a factor 4 (50% ->~ 12%).





Diamond detectors



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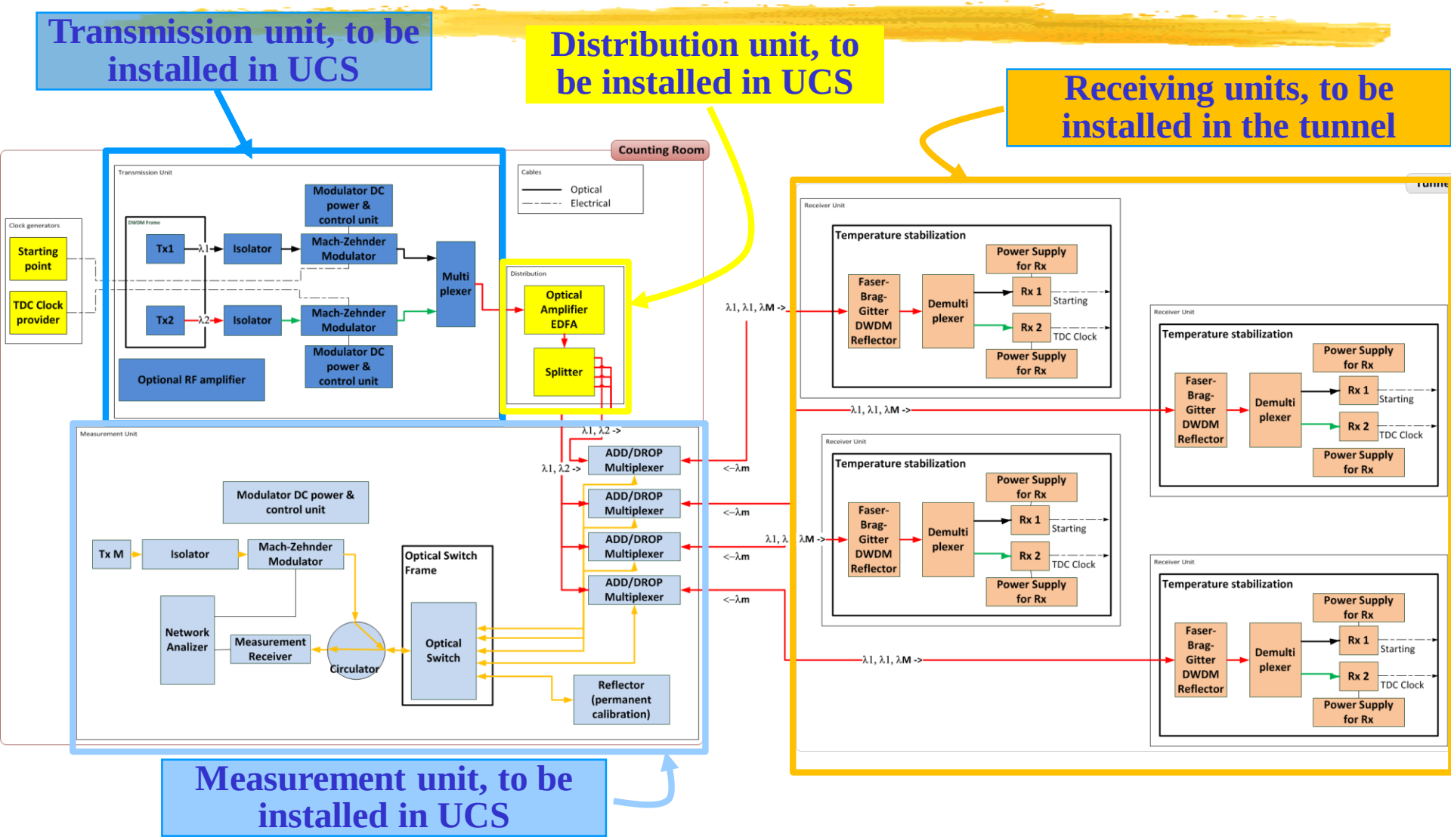
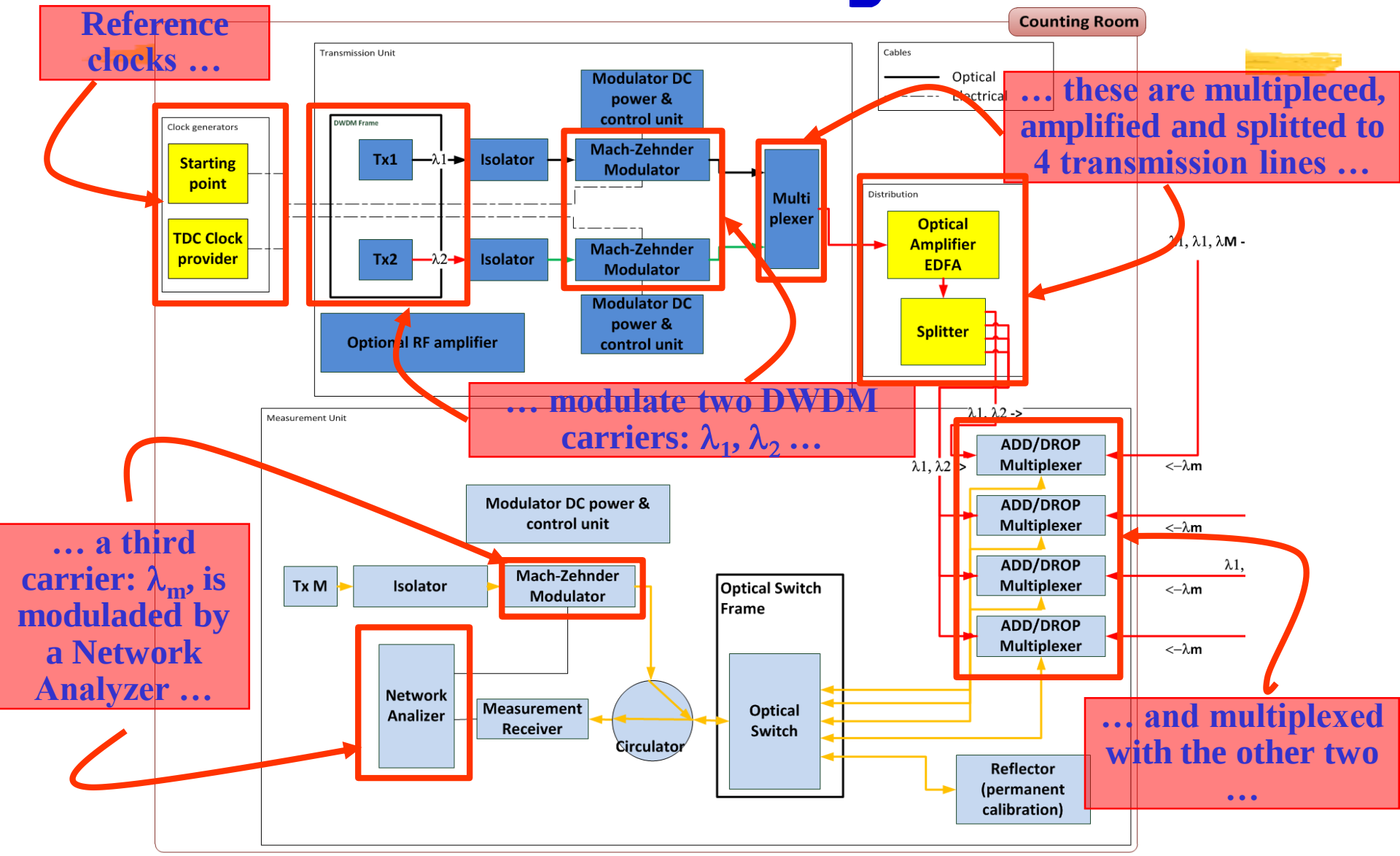
The clock distribution

- A precise, low jitter, clock distribution over long distance, is mandatory
- Implementation based on the "*Universal Picosecond Timing System*", developed for FAIR at GSI by M. Bousonville.
  - M. Bousonville and J. Rausch. *Universal picosecond timing system for the Facilityfor Antiproton and Ion Research*. Phys. Rev. ST Accel. Beams, 12 (2009), p. 042801 (http://link.aps.org/doi/10.1103/PhysRevSTAB.12.042801).
  - P. Moritz and B. Zipfel. *Recent Progress on the Technical Realization of the Bunch Phase Timing System BuTiS*. Conf.Proc., C110904 (2011), pp. 418-420.
- System strengths:
  - **Scalability**: up to 128 signals can be transmitted on a single transmission medium.
  - **Robustness**: based on DWDM (*Dense Wavelength Division Multiplexing*) industrial standards for telecommunications over optical fibers
  - The system can be constantly monitored (i.e. temperature drift)
  - **Low jitter** contribution **~0.4ps**.

The full system view



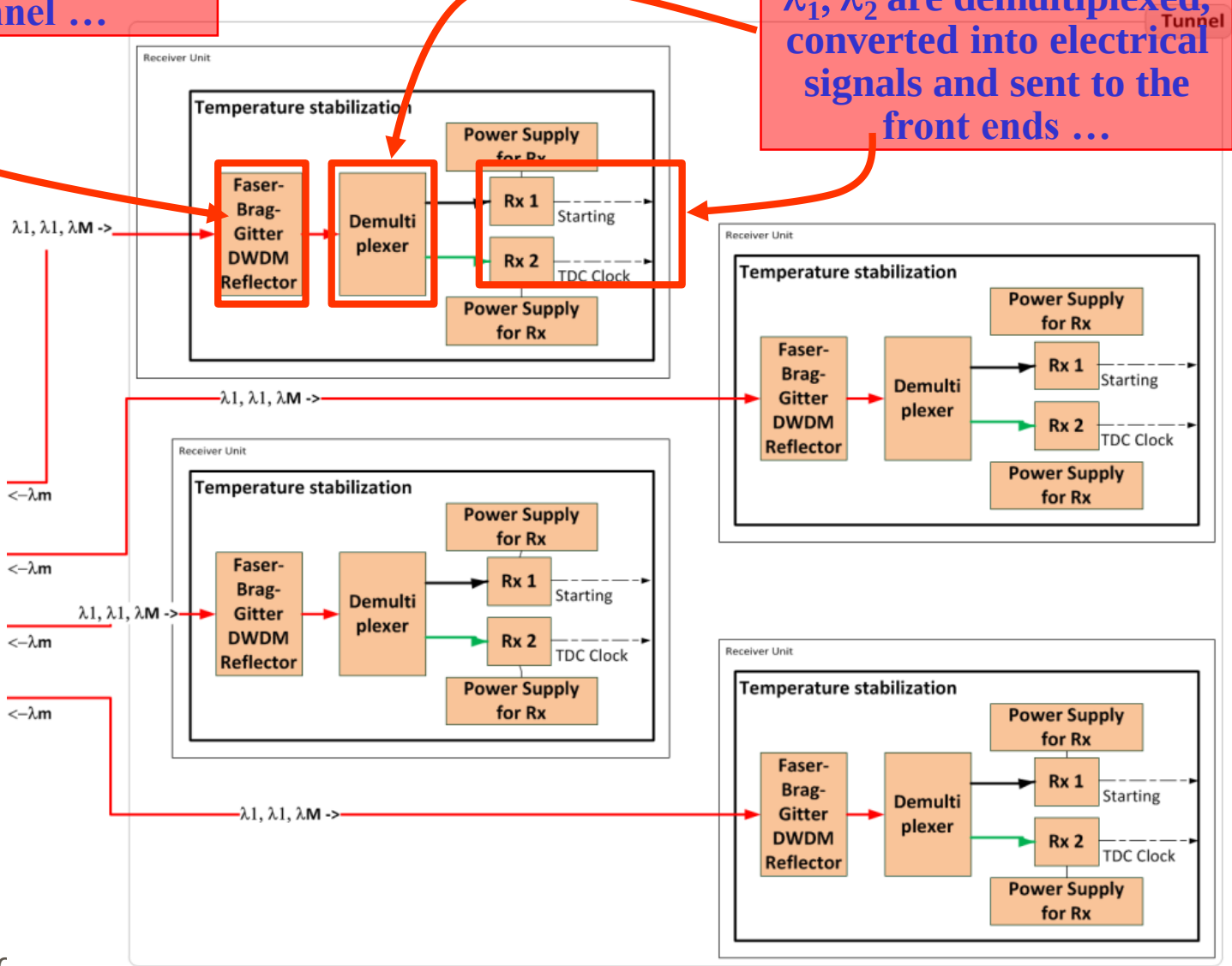
Transmitting



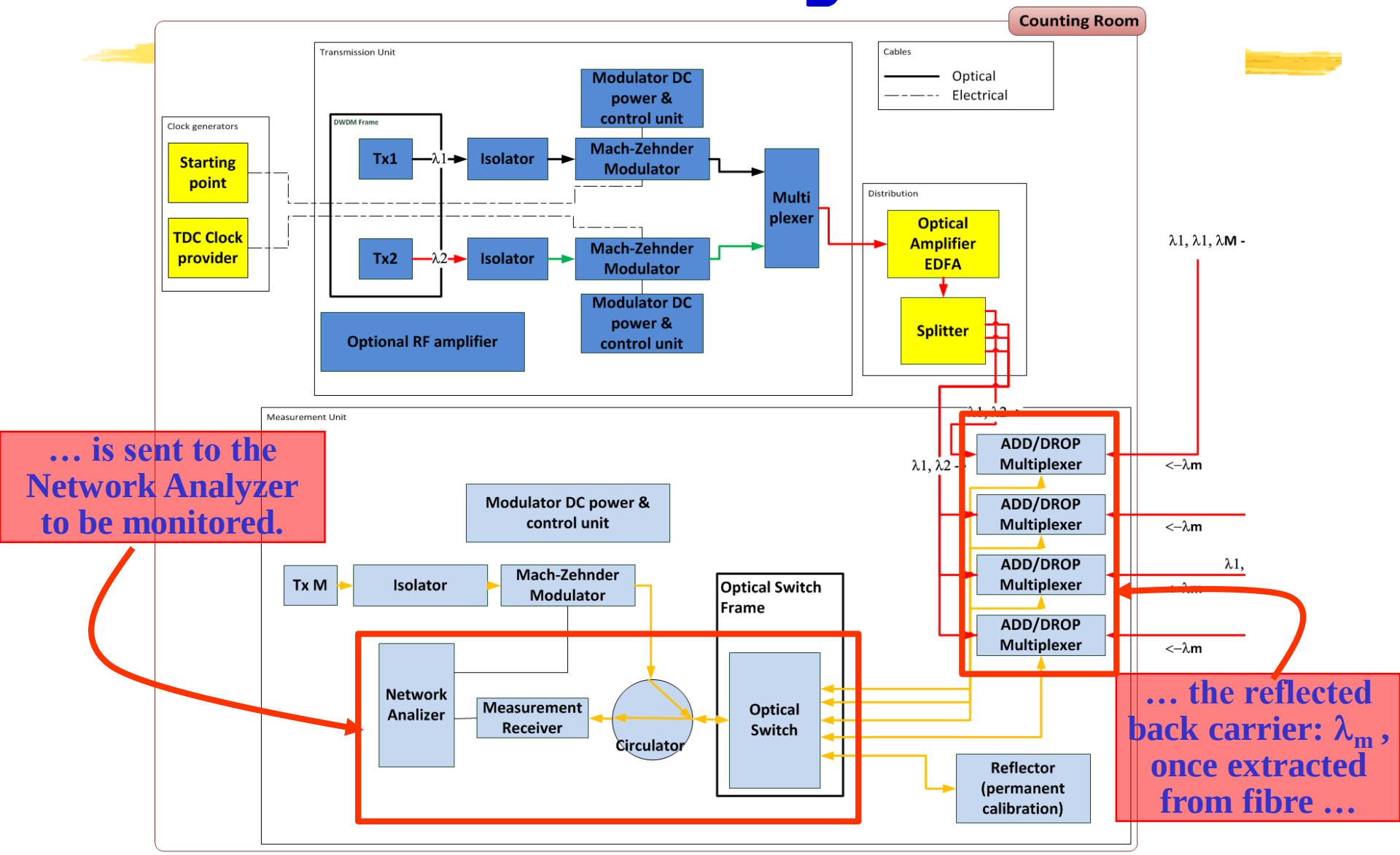
Receiving

… the third carrier: λ_m , is reflected back once in the tunnel …

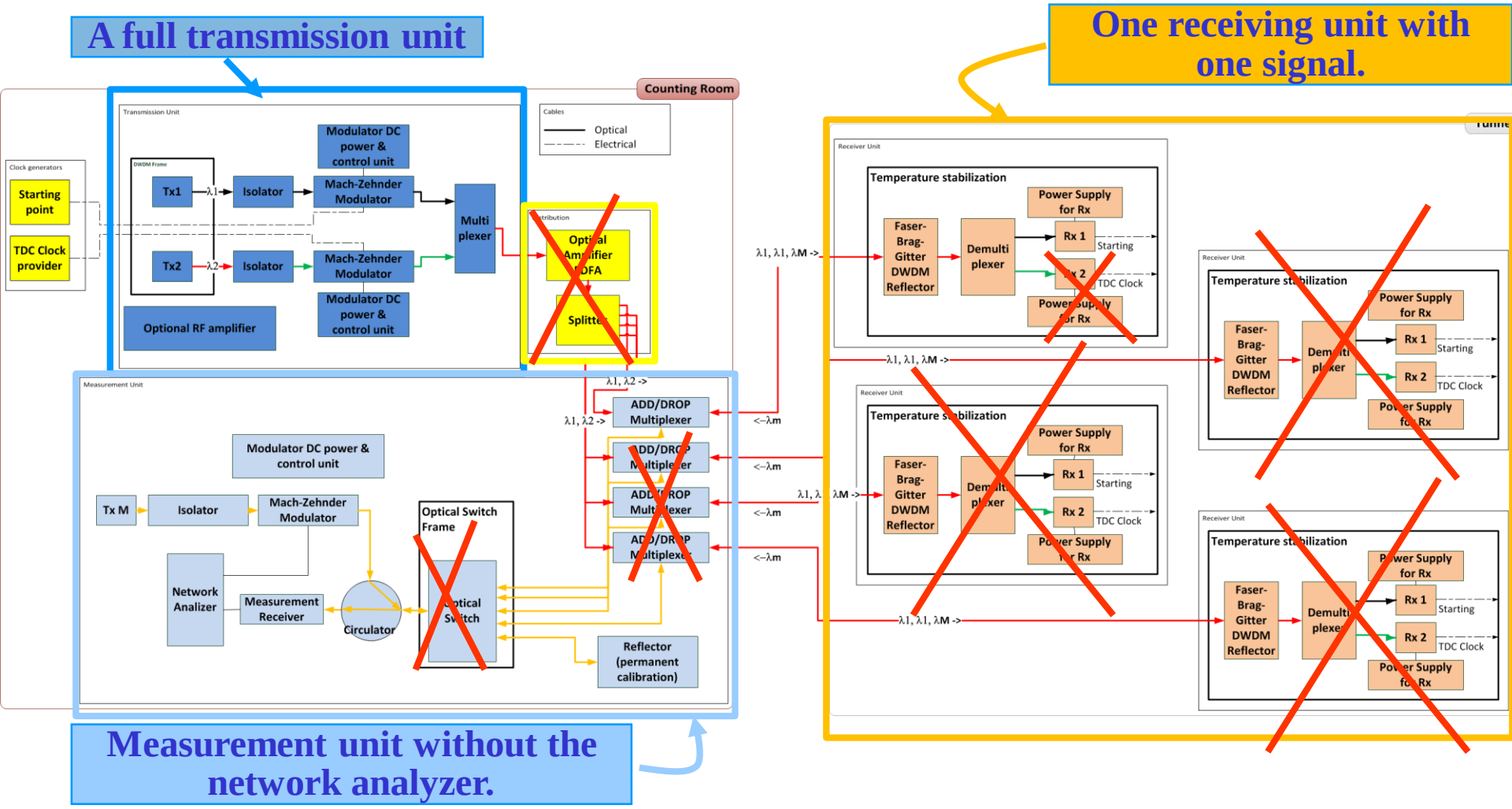
… the two first carrires: λ_1, λ_2 are demultiplexed, converted into electrical signals and sent to the front ends …



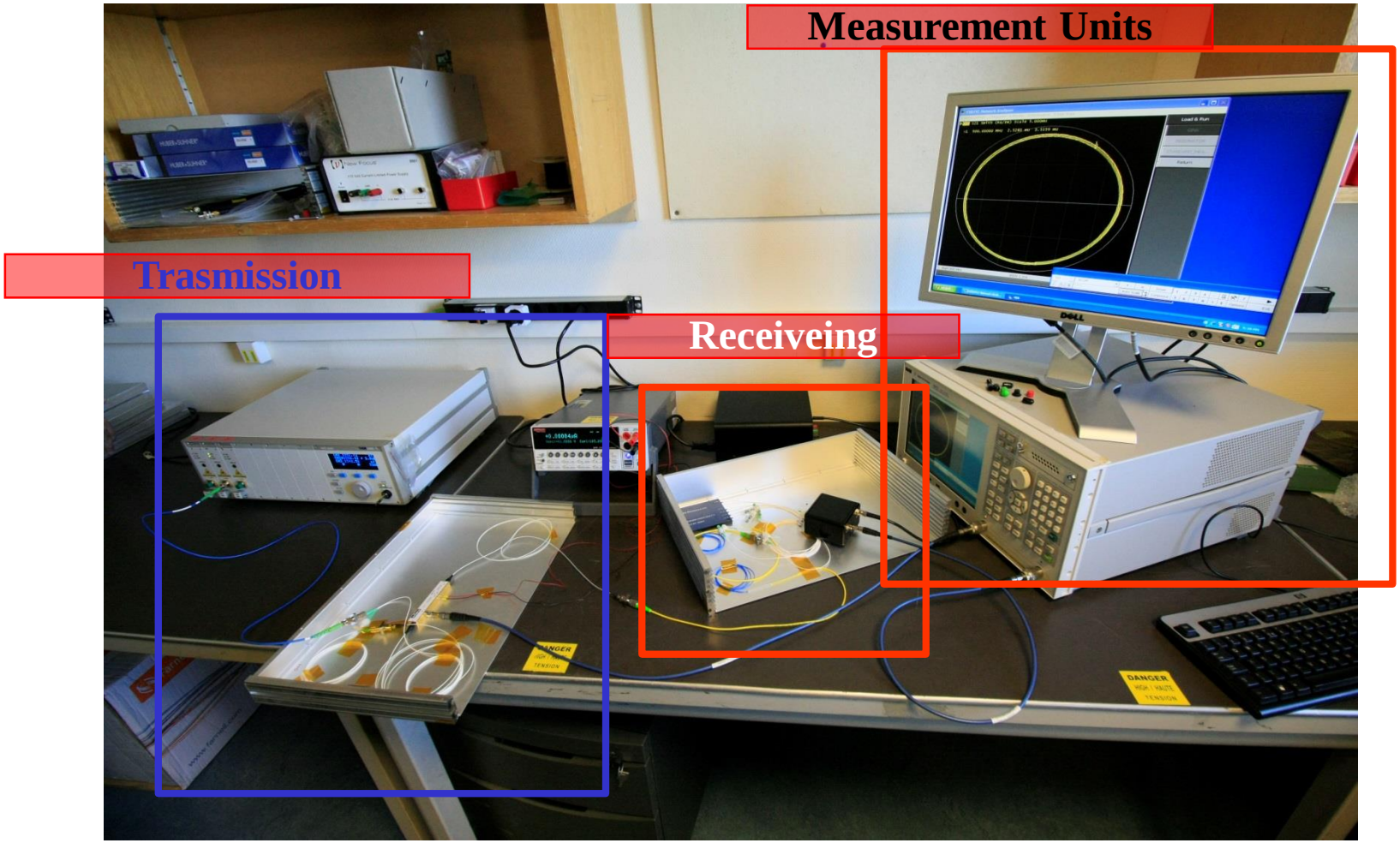
Measuring


Counting Room
Transmission Unit
Cables
Optical
Electrical
Clock generators
Starting point
TDC Clock provider
DWDM Frame
Tx1
λ1
Isolator
Modulator DC power & control unit
Mach-Zehnder Modulator
Tx2
λ2
Isolator
Mach-Zehnder Modulator
Modulator DC power & control unit
Optional RF amplifier
Multi plexer
Distribution
Optical Amplifier EDFA
Splitter
λ1, λ1, λM -
λ1, λ2 -
ADD/DROP Multiplexer
ADD/DROP Multiplexer
ADD/DROP Multiplexer
ADD/DROP Multiplexer
<–λm
<–λm
λ1,
<–λm
Measurement Unit
Modulator DC power & control unit
Tx M
Isolator
Mach-Zehnder Modulator
Optical Switch Frame
Network Analizer
Measurement Receiver
Circulator
Optical Switch
Reflector (permanent calibration)
… is sent to the Network Analyzer to be monitored.
… the reflected back carrier: λm , once extracted from fibre …

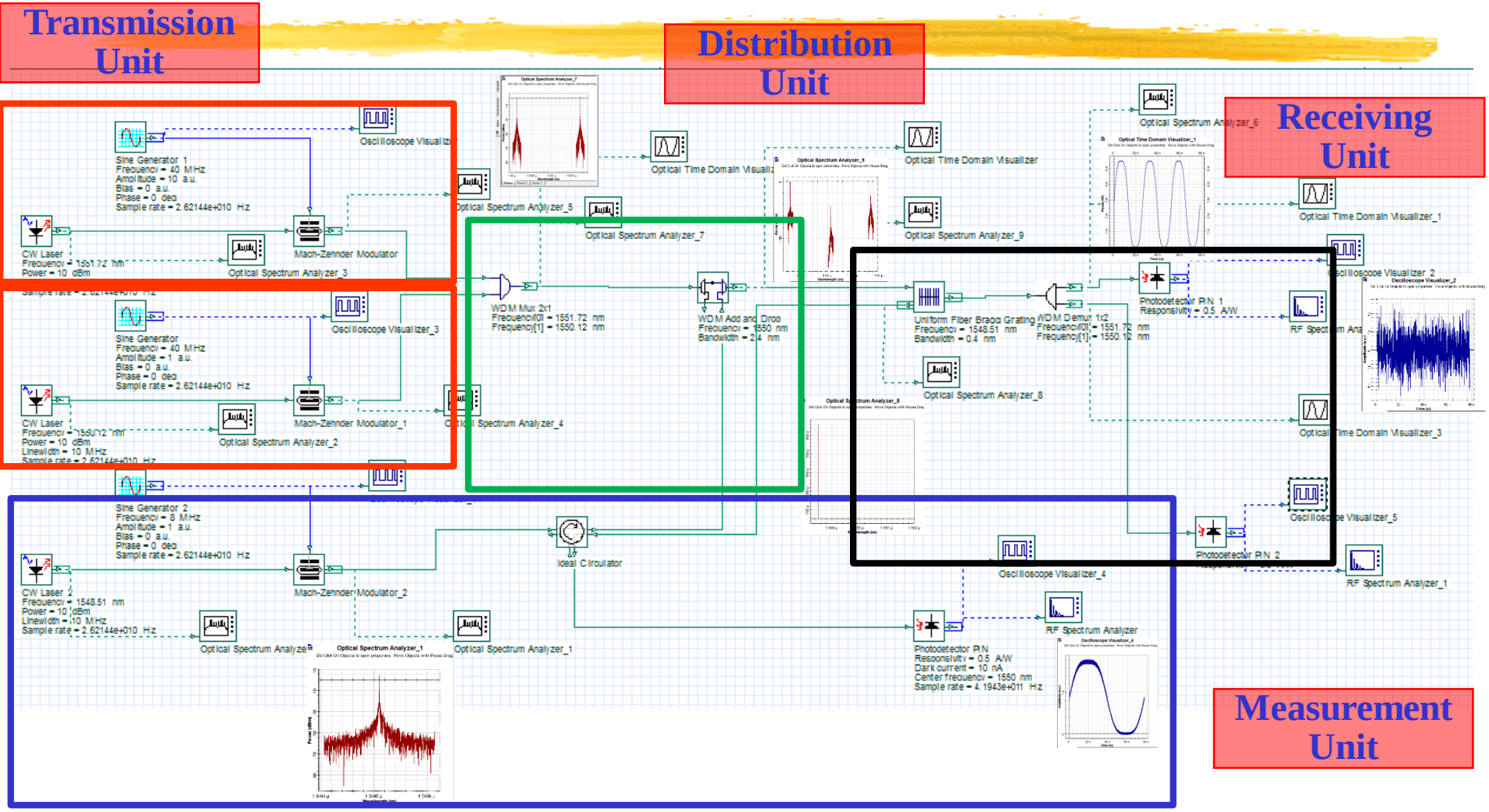
The first test configuration



First test Setup



Full system simulation



Full system simulation using Optisystem

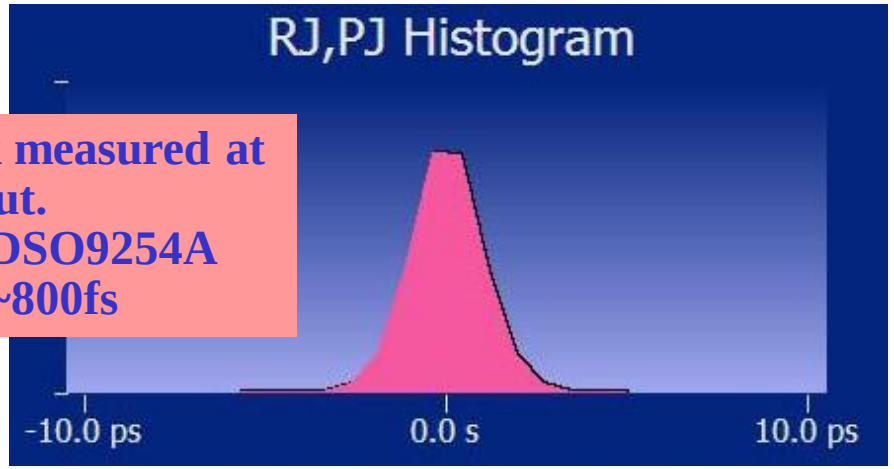
DIPARTIMENTO DI INGEGNERIA ELETTRICA E DELL'INFORMAZIONE

PHOTONICS RESEARCH GROUP

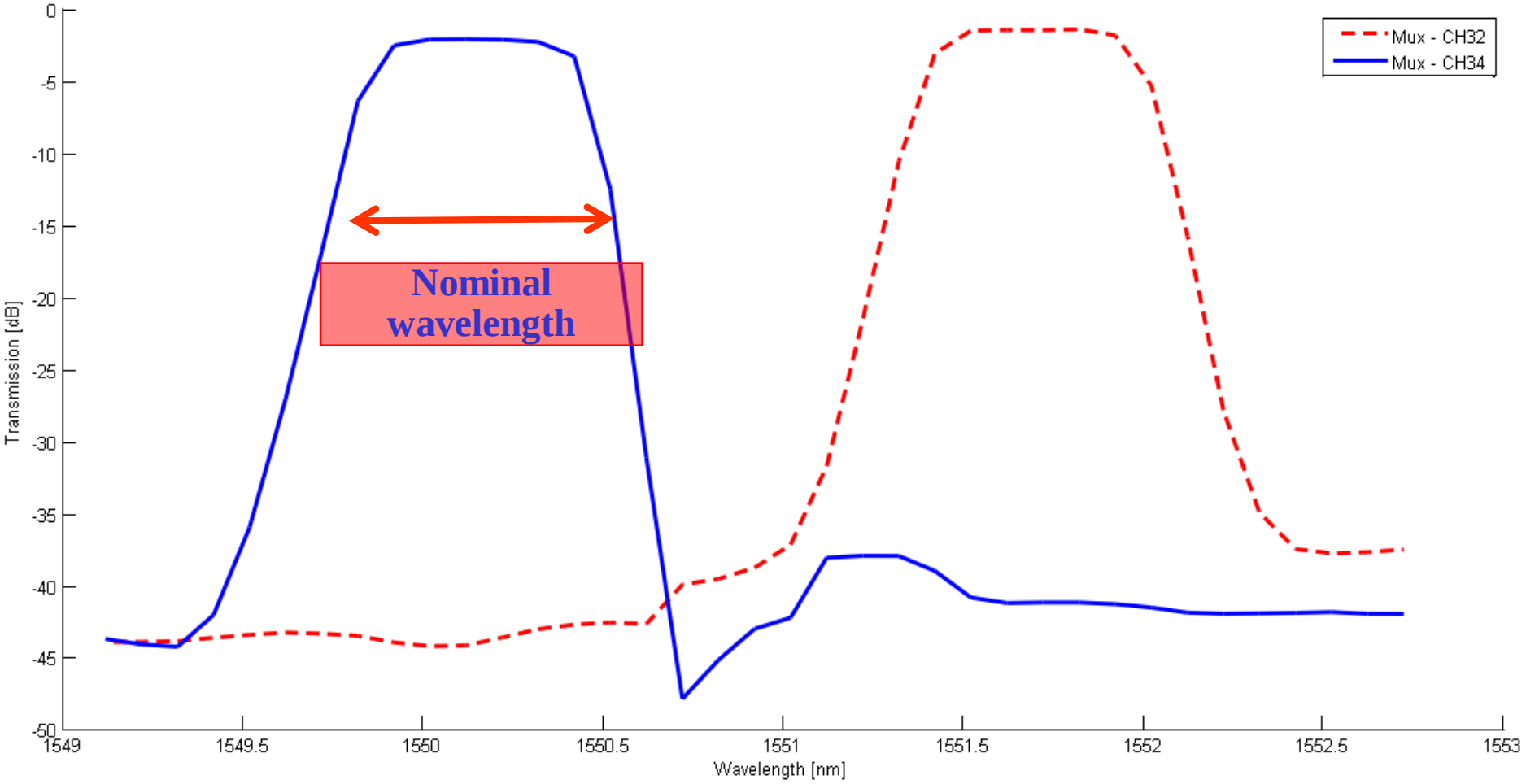
Clock source

- Clock source based on TI CDCM6208 chip able to work both as a clock source and as a jitter cleaner
- The jitter level is:
  - <300fs in clock synth mode
  - ~1ps in jitter cleaner mode

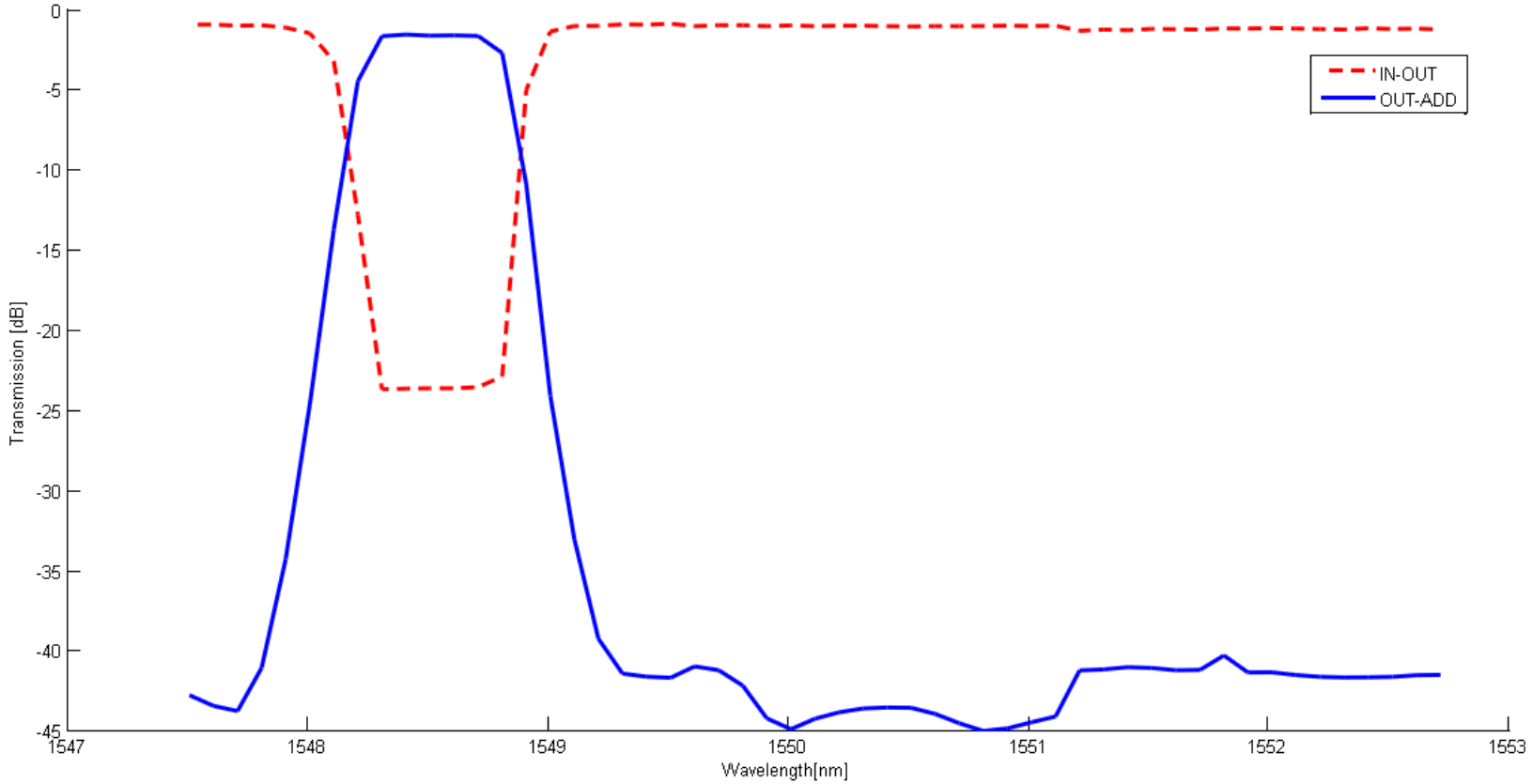
Synthetized clock measured at CDCM6208 output.
RealTime Scope DSO9254A
Random jitter = ~800fs



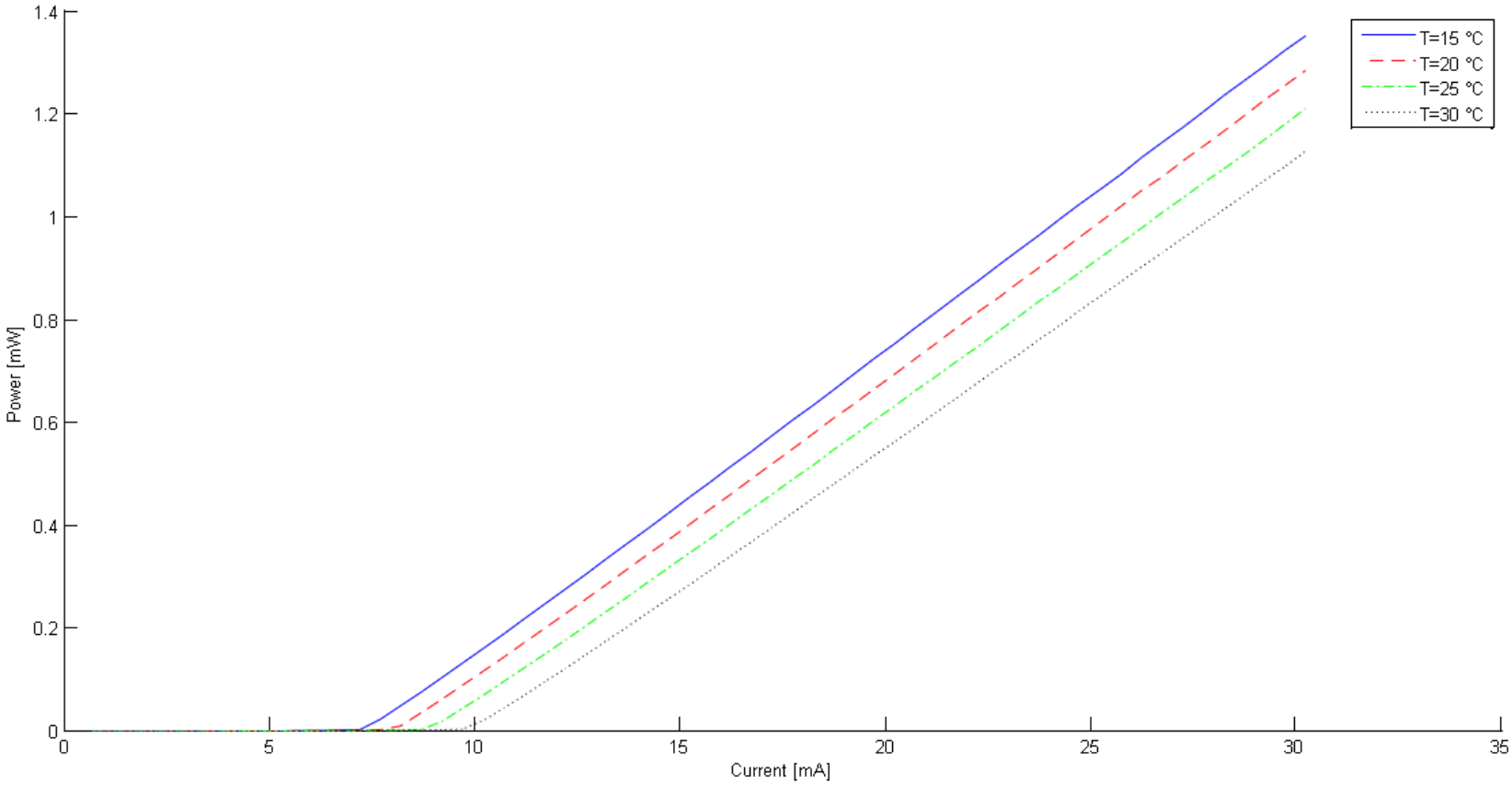
Characterization of the optical MUX



… the optical ADD/DROP

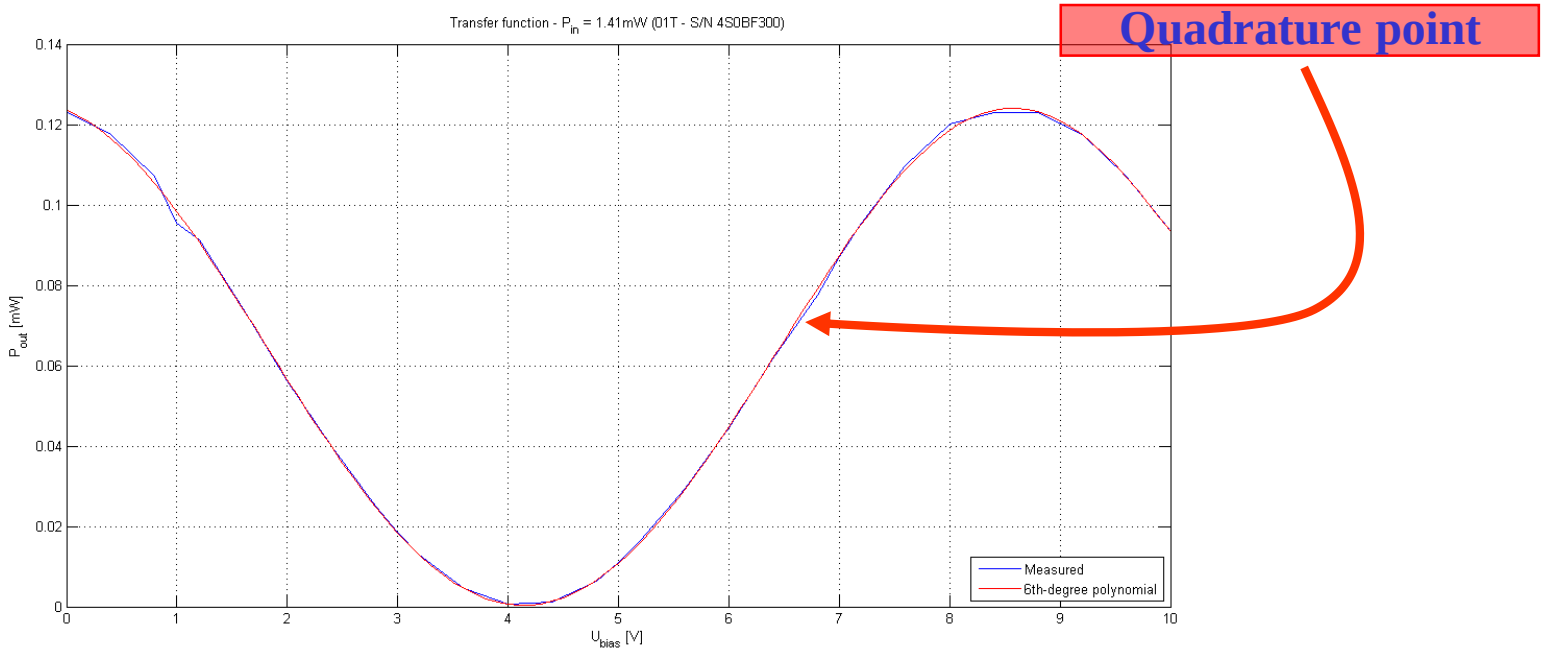


… the laser source

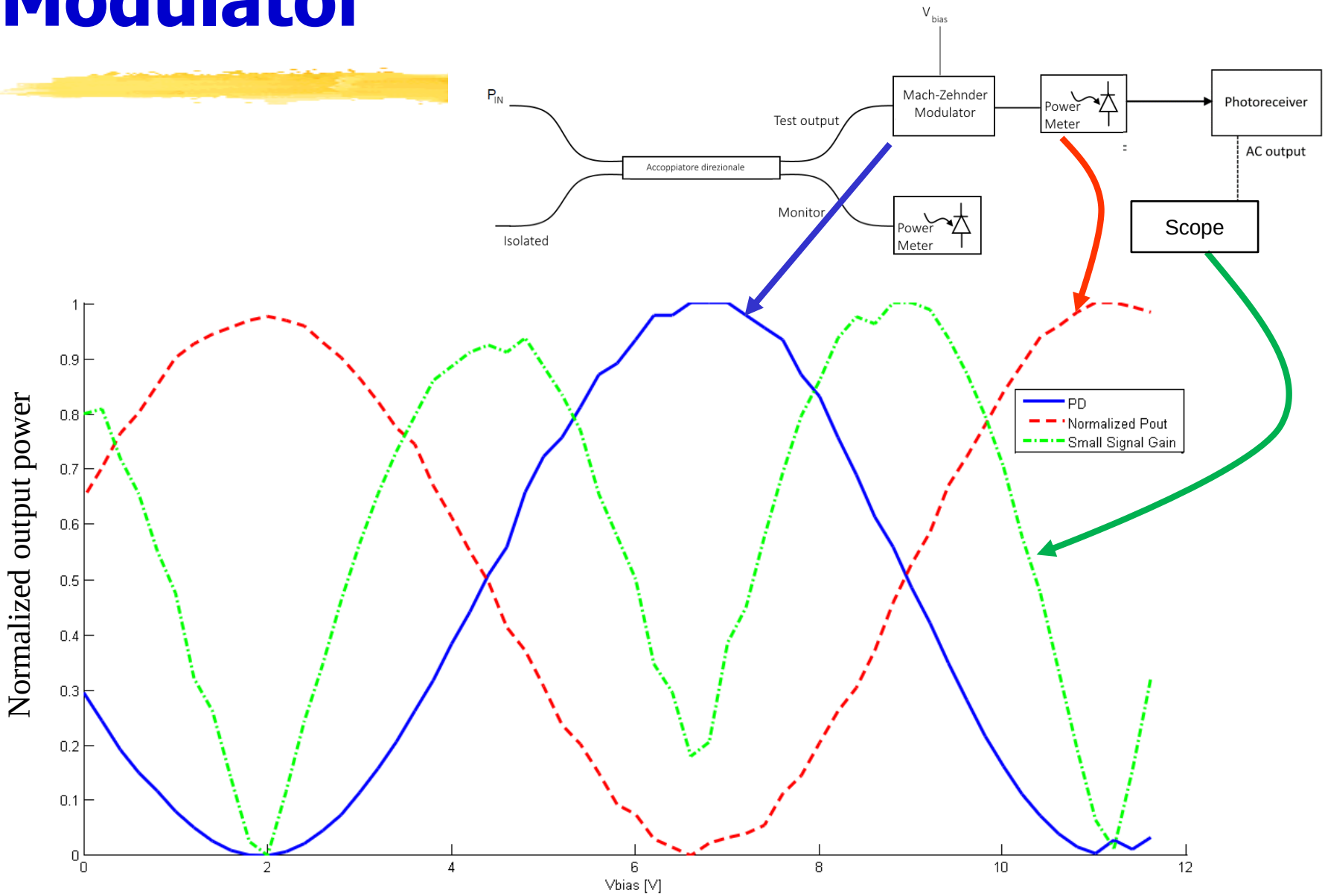


… the optical modulator

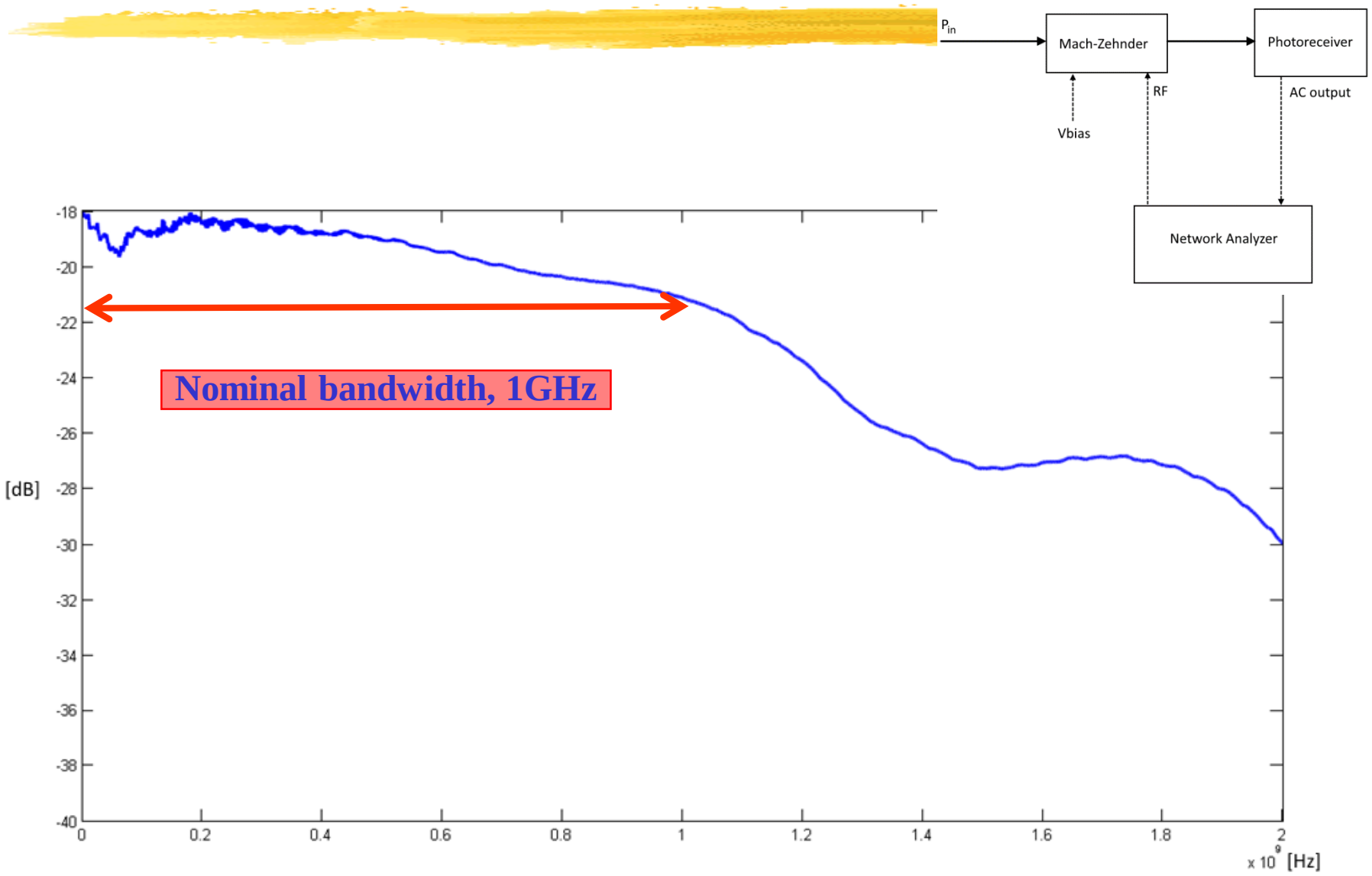
- Characterization of the optical modulator
  - Biasing at quadrature point
  - Bias point drift observed
  - Stabilization is important



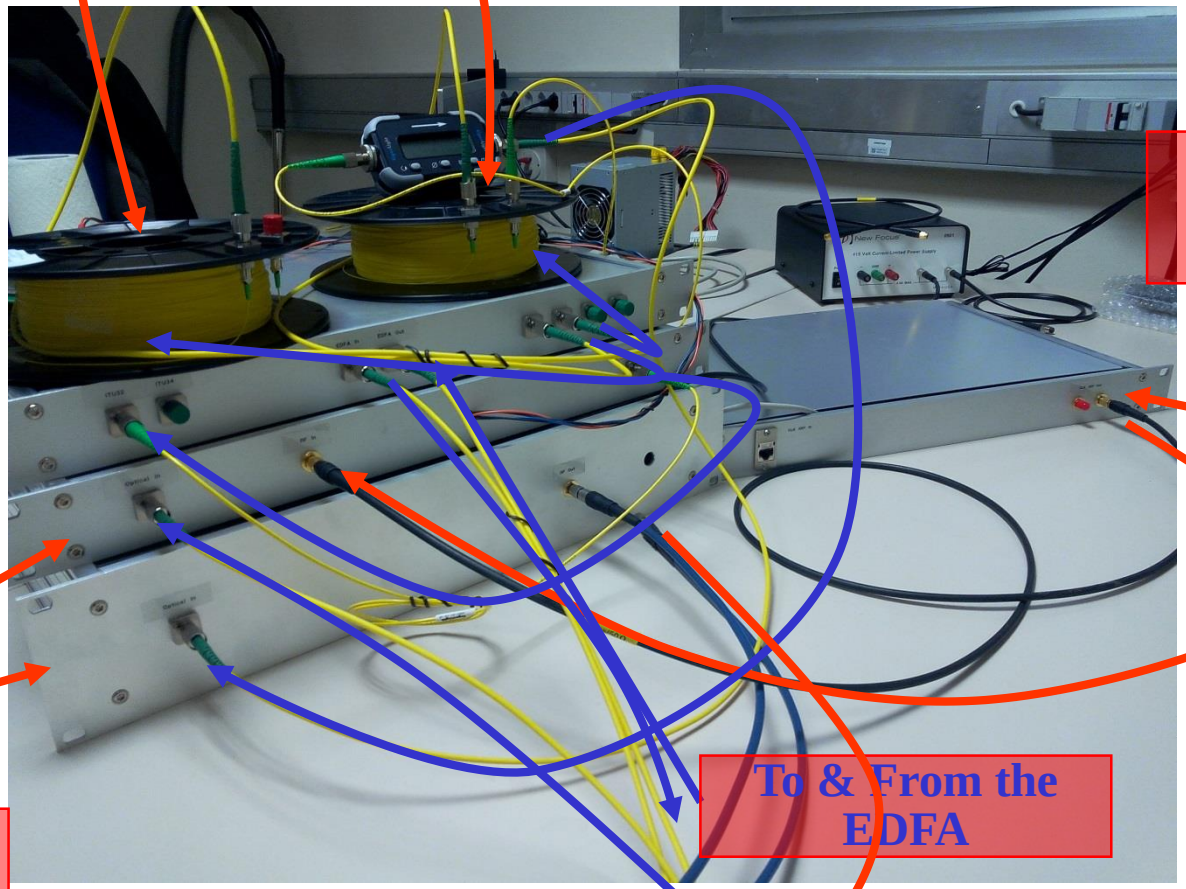
Modulator


V bias
P IN
Test output
Mach-Zehnder Modulator
Power Meter
Photoreceiver
AC output
Accoppiatore direzionale
Monitor
Isolated
Power Meter
Scope
Normalized output power
Vbias [V]
PD
Normalized Pout
Small Signal Gain

… the photoreceiver



The lab. setup



Conclusions

- In the framework of the TOTEM timing detectors upgrade a precise, low jitter clock distribution is needed to transmit the reference timing information over long distances (~300m).
- The system "*Universal Picosecond Timing System*", developed for FAIR at GSI by M. Bousonville has been adopted.
- Fiber infrastructure has been already deployed.
- A first test set-up has been used to characterize optical components and a full tunnel emulator has been set-up to further test and characterize the system.
- The receiving units will be possibly installed during this week LHC technical stop.

THANKS!!