High-performance timing detector for the HL-LHC Upgrade of the CMS experiment at CERN

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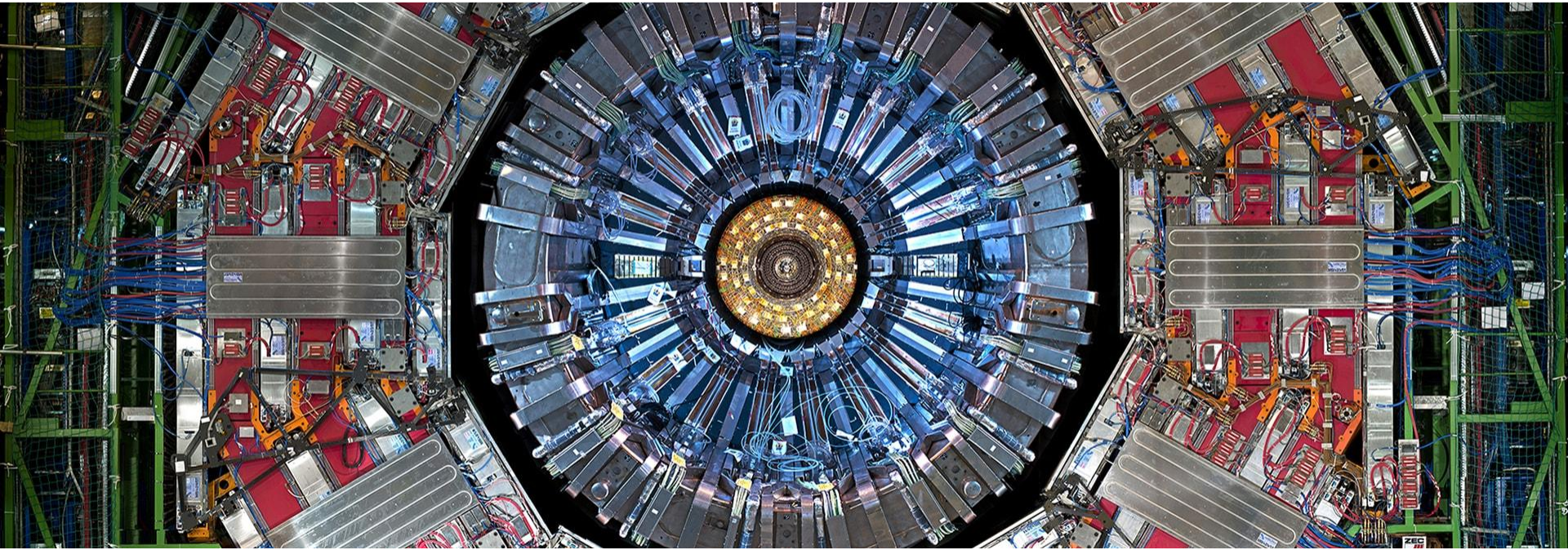
FCT Fundação para a Ciência e a Tecnologia

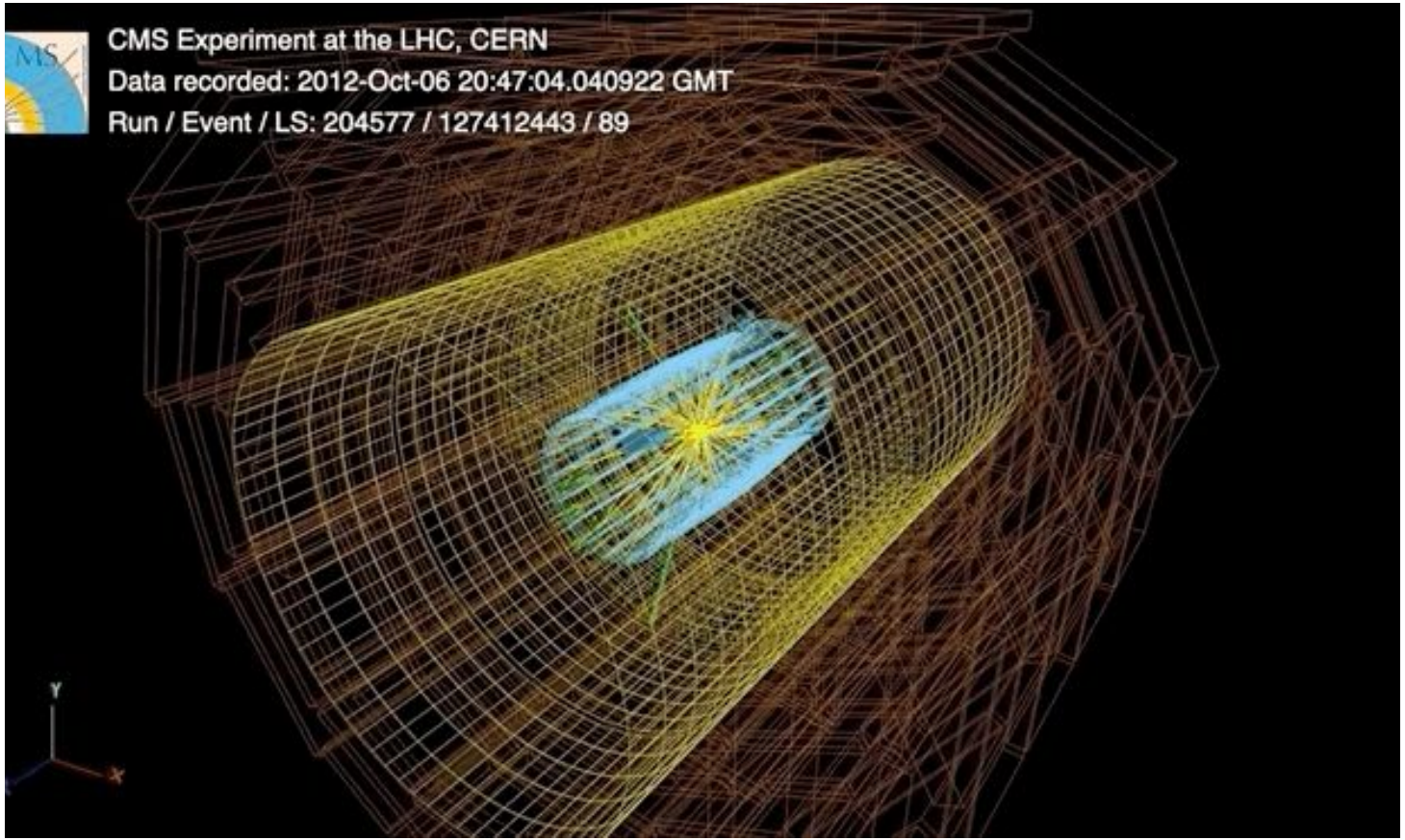
LIP LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS

*"**CMS** acts as a giant, high-speed camera, taking 3D **"photographs"** of **particle collisions** from all directions up to 40 million times each second."*



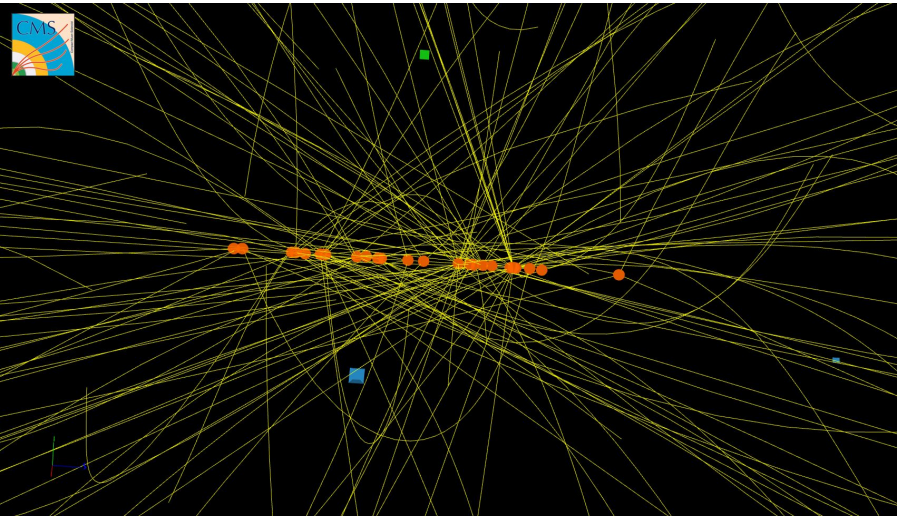
14000-tonne detector situated underground in 1 of the 4 collision locations of the Large Hadron Collider at **CERN**

How the **CMS detector** sees a **pp collision**



RunII

2015-2018

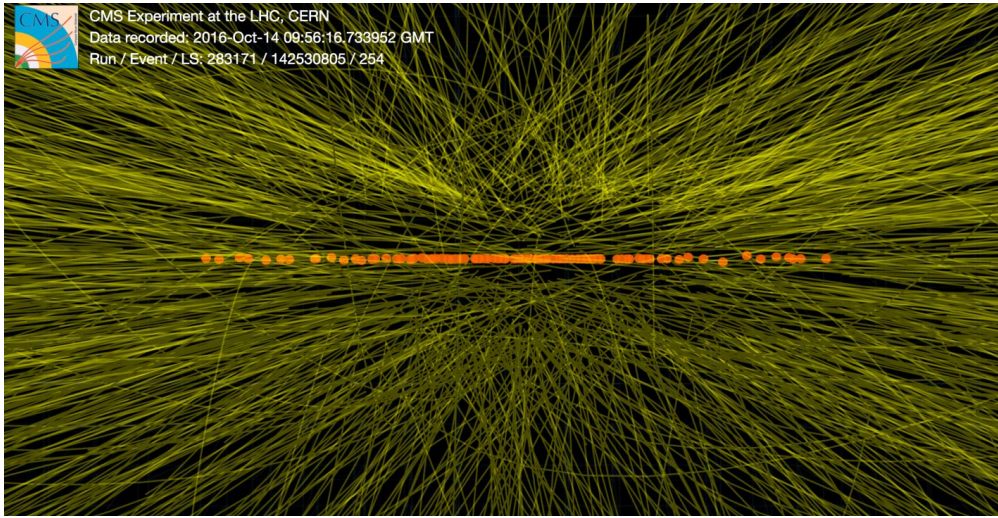


~34 Interaction points

Accumulated Luminosity: **150 fb^{-1}**

High-Luminosity LHC

2025-2035



~140 Interaction points

Accumulated Luminosity: **3000 fb^{-1}**

The much **higher collision** rates **far exceed** the **CMS detector** current capabilities → Needs to be **upgraded**

We **build a new** detector: **MTD**
Minimum ionizing particles **T**iming **D**etector

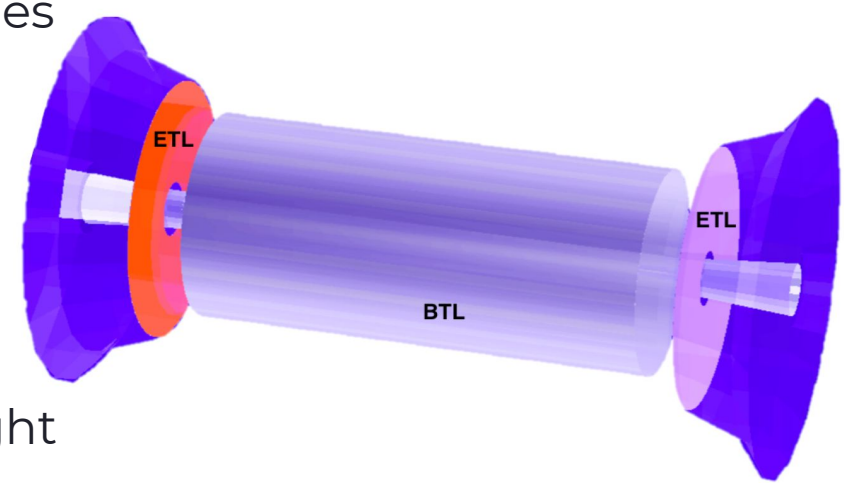
Assign **charged tracks** to the **correct interaction vertices** by exploiting the fact that the individual interactions **do not** all **occur at** precisely the **same time** but over time with an rms of 180–200 ps

➔ Preserve data quality at high luminosities

➔ Built between Tracker and ECAL

➔ Provide **timing information** for MIPs with resolution of **30-40 ps**

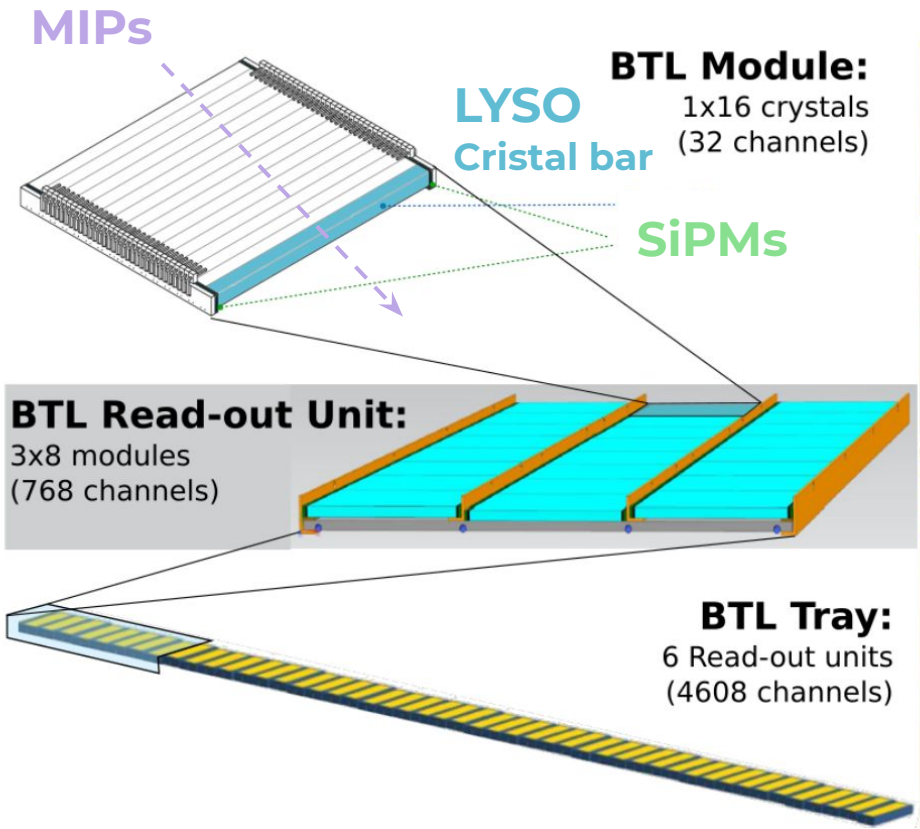
➔ New capabilities to CMS: identification of charged hadrons based on time-of-flight Heavy Ion physics and for QCD studies

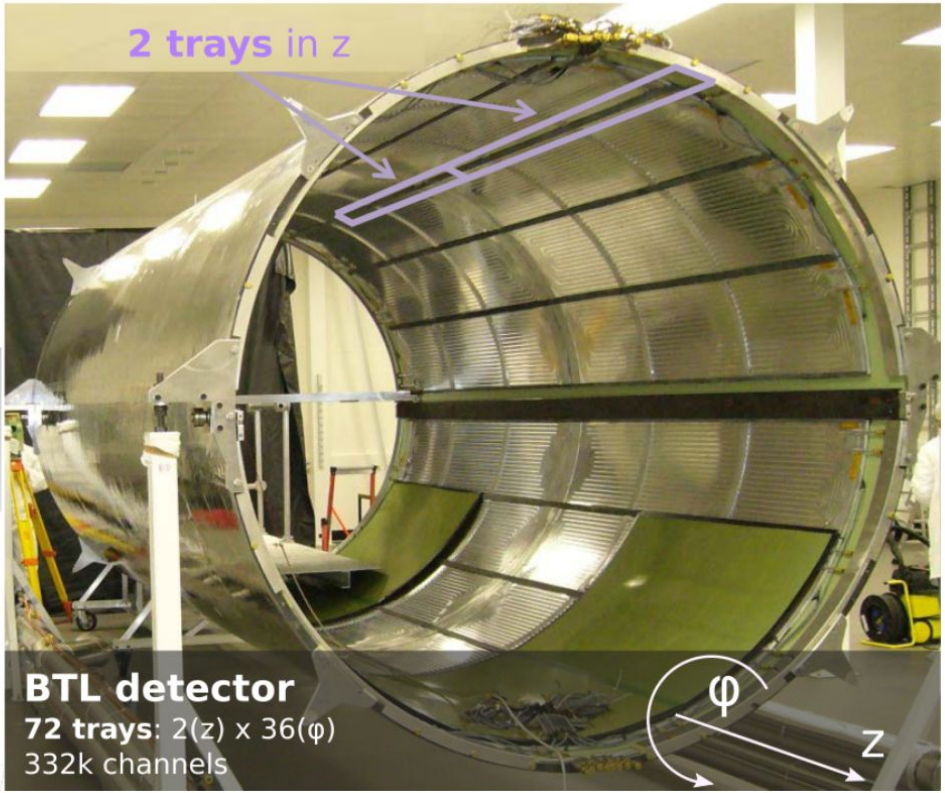


Expected **scientific** impact of **MTD**

Signal	Physics measurement	MTD impact
H → γγ H → 4 leptons	+ 15-25 % stats precision on cross-section → Improve coupling measurements	Isolation Vertex identification
VBF → H → ττ	+ 30 % stats precision on cross-section → Improve coupling measurements	Isolation VBF tagging, p_T^{miss}
HH	+ 20 % gain in signal yield → Consolidate searches	Isolation b-tagging
EWK SUSY	+ 40 % background reduction → 150 GeV increase in mass reach	MET b-tagging
Long-lived particles	Peaking mass reconstruction → Unique discovery potencial	β_{LLP} from timing of displaced vertices

Overview of the Barrel Timing Layer

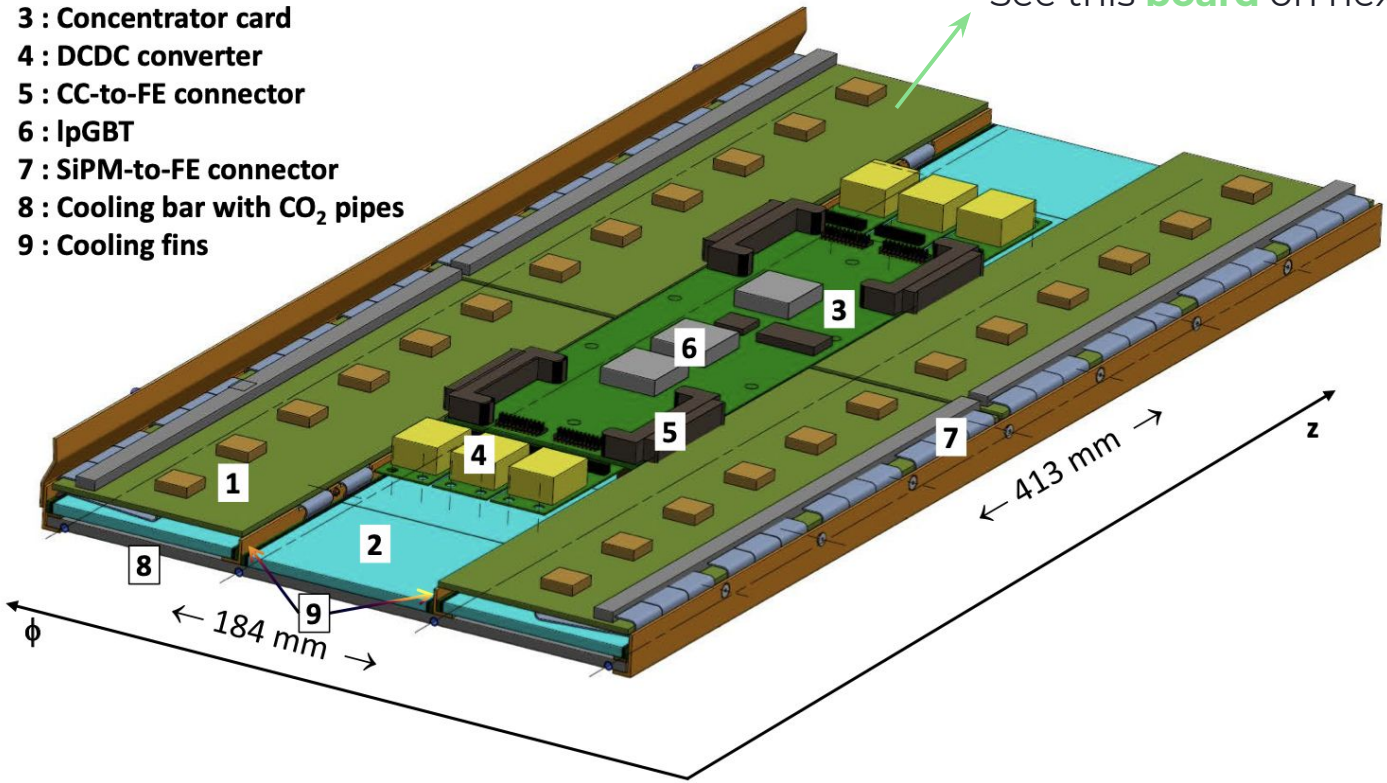




Representation of a **Readout** Unit

1 : TOFHIR board with 6 ASICs
2 : LYSO array with 16 LYSO bars, bars oriented in ϕ
3 : Concentrator card
4 : DCDC converter
5 : CC-to-FE connector
6 : lpGBT
7 : SiPM-to-FE connector
8 : Cooling bar with CO_2 pipes
9 : Cooling fins

See this **board** on next slide



TOFHIR ASIC requirements

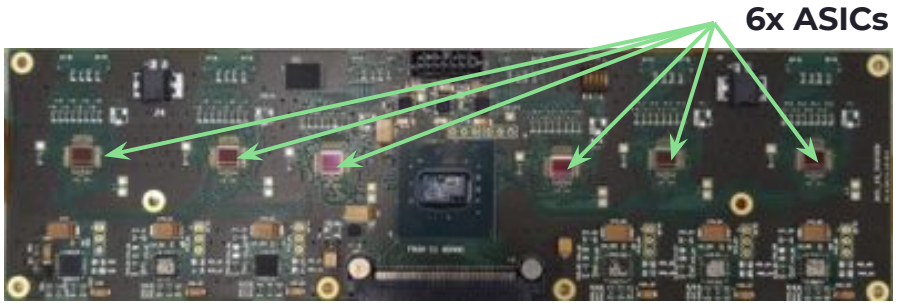
Time-Of-Flight, HIgh Rate

Used for **acquisition** and **digitization** of the photo-sensor signals. In particular the circuit must:

- Perform the digitization of time and energy of the passing MIPs
- Reject lower energy particles, mainly photons from the ECAL
- Provide links for data transmission, fast and slow control
- Comply with radiation tolerance, power and operation temperature
- Integrate test features

It's **LIP-CMS** task to deliver this!

My **EPR work** has been focused on **testing** TOFHIR FEB



TOFHIR Front-end-board

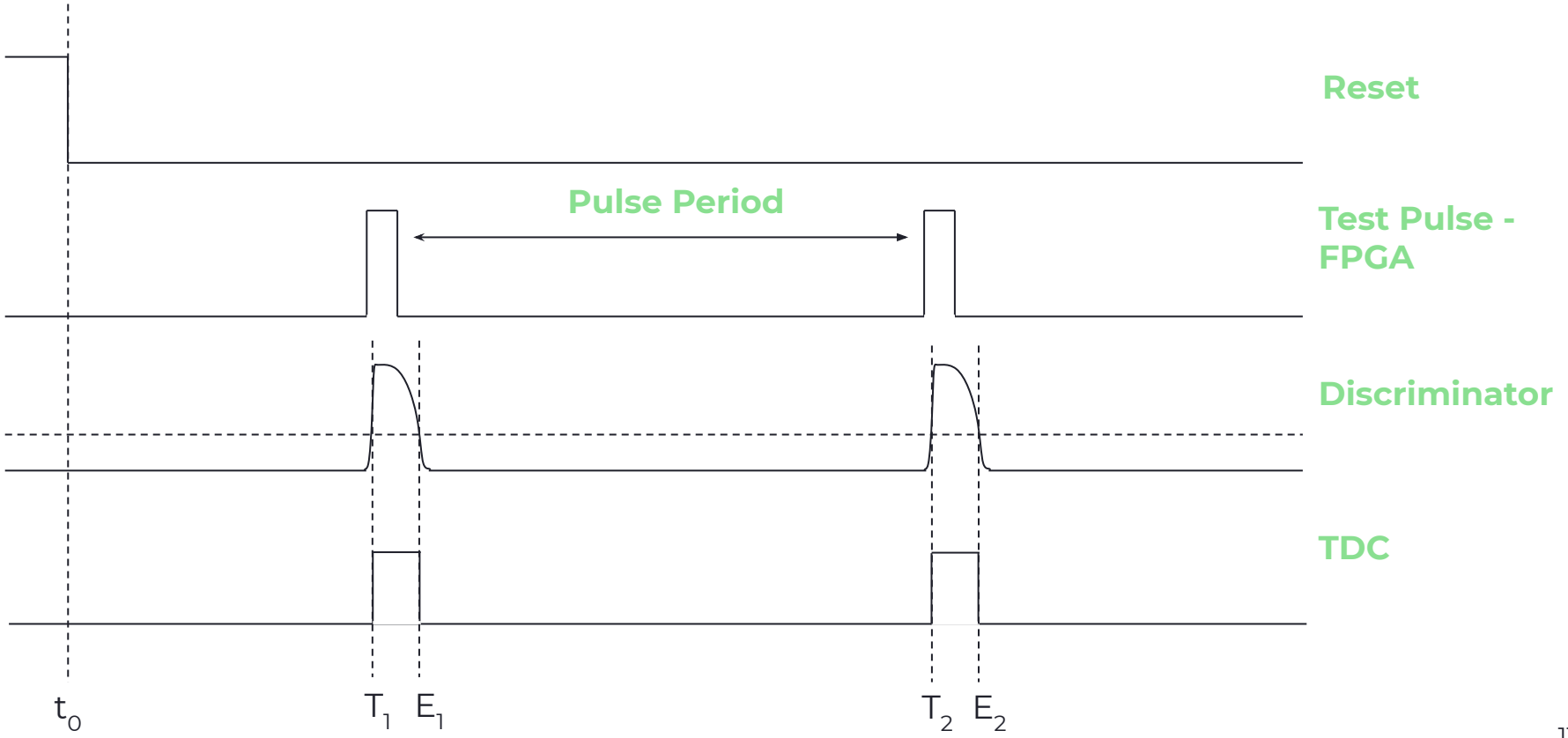
Measuring the **time resolution** FEB's ASICs

MTD's Goal: time resolution of 30-40 ps

FEB testing strategy:

1. Use FPGA's test pulse
2. Calibrate Time-to-digital converter (TDC)
3. Perform two channel coincidences (CTR)
4. $TDC_{res} = \frac{CTR}{\sqrt{2}}$
5. Is TDC_{res} within MTD's goal?

Front-end test pulse



Two Channel Coincidences

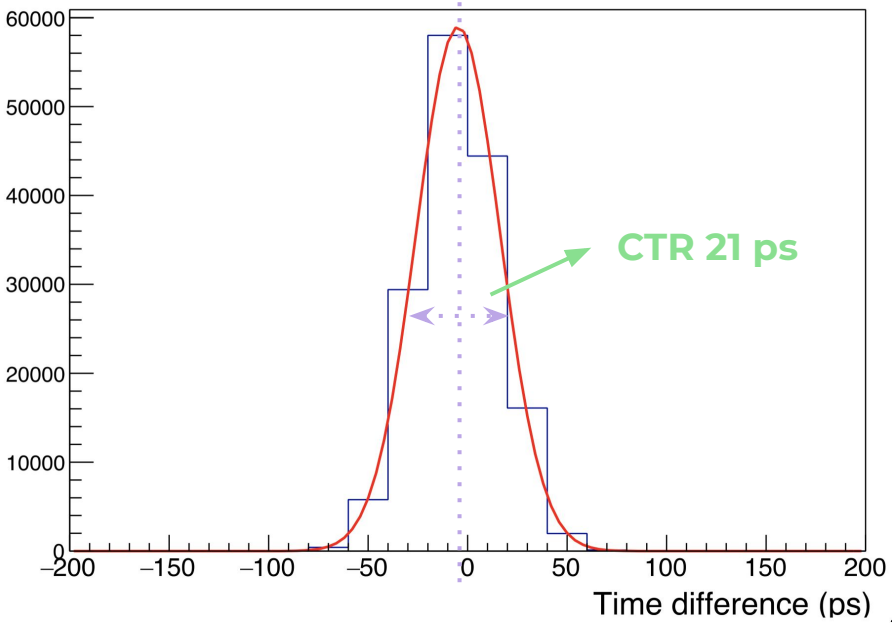
Jitter is introduced from FPGA test pulse, cables, FEB board...

Part of it is common to all channels

1. Inject **fixed phase** test pulse in any two channels of the ASICs
2. Measure TDC time on both channels
3. Compute the difference
4. Distribution of difference → **time resolution**

Coincidences on test boards vs FEB

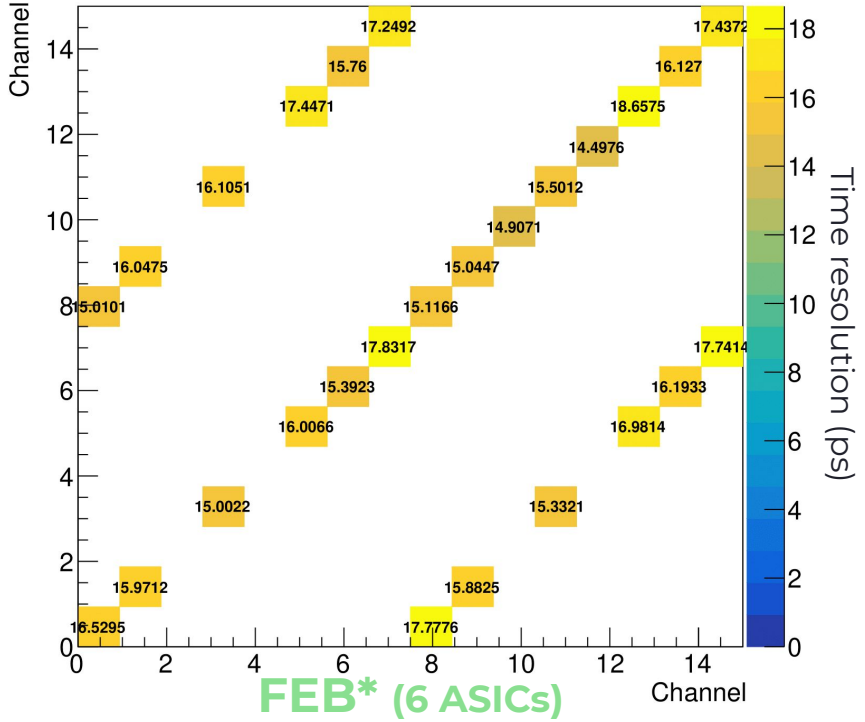
Time difference between two channels



TOFHIR1 TEST BOARD

(1 ASIC)

Sigma dt, ps: ASIC 5 vs ASIC 3



FEB* **(6 ASICs)**

*Preliminary results

Summary

- The new MTD upgrade to CMS detector answers the challenge of the increased expected pile-up
- Current testing gives promising results
- More tests to TOFHIR are still taking place: such as laser pulse, single SiPM and beam tests