Timing Trigger at CMS

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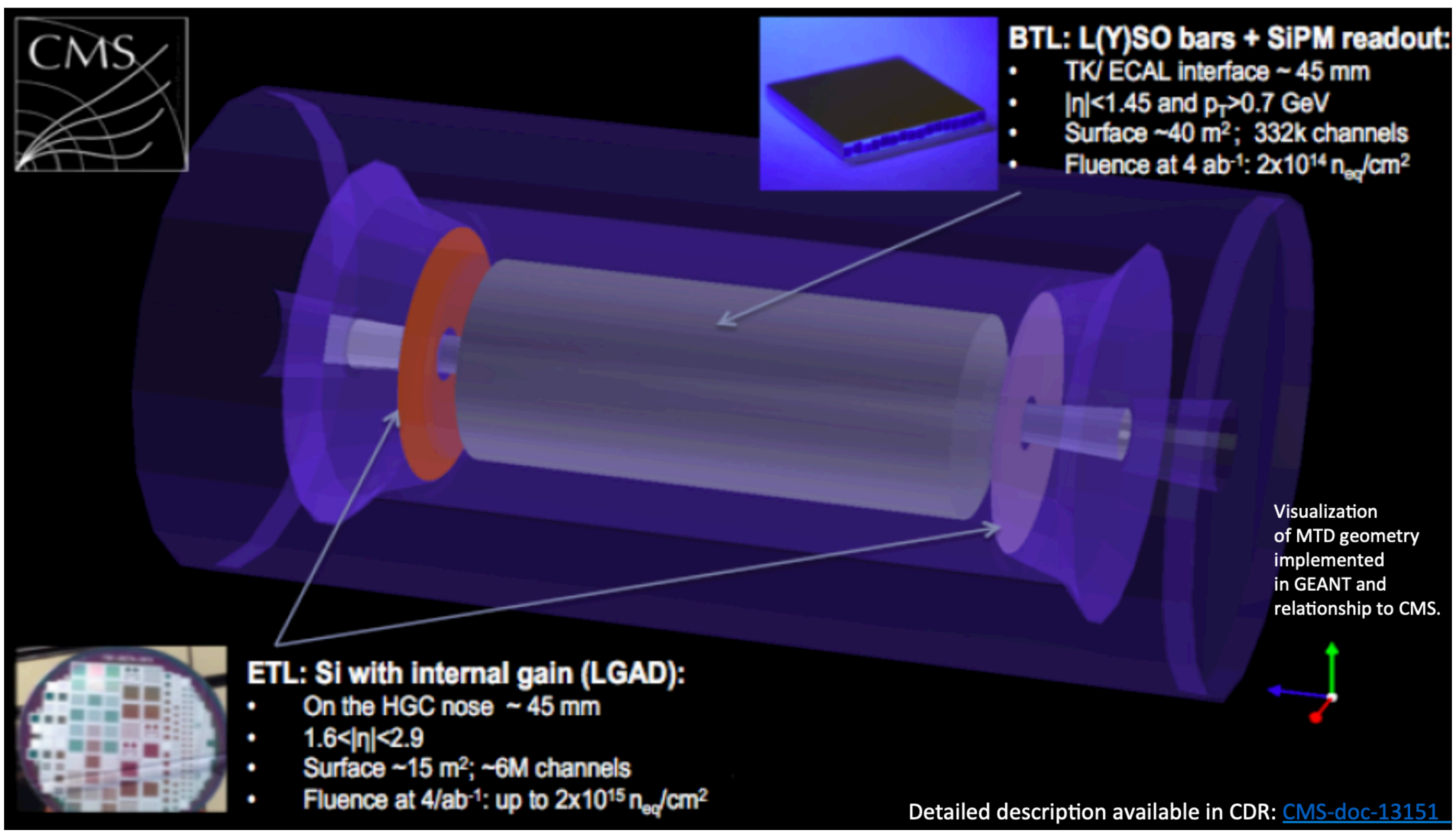
L1 MTD Design Options Nov 8, 2019

Precision Timing

Many detectors at CMS have timing capabilities:
ECAL, HCAL, RPC, HGCAL

What is “Precision Timing”?

- Timing that allows for distinguishing the production time of an individual particle across a bunch crossing (< 180 ps)



Overview of L1 MTD

The **MIP Timing Detector** is a **completely new detector at CMS** for HL-LHC
- It is capable of measuring the precise time (30ps) of MIPs

The option to include the MIP Timing Detector (MTD) at Level-1 has been considered for CMS

- **Physics Gains Identified: Long Lived** (Exotic) **Particle** Identification (from the **pheno community**), Pile Up contamination reduction, 4D vertex reconstruction (3D space + time)

- **Difficulties Identified:** Baseline DAQ bandwidth needs to be doubled, even with this, an ROI would be needed to reduce the readout to ~ 1 MHz

- Report to be published

Precision Timing MTD

BTL:

LYSO:CE bars + SiPM readout:

- Fast and bright crystal
- Radiation tolerant
- **Well-understood**

Modules and Readout Units are assembled onto cooling trays

- operated at ~ -30°C

TOFHIR for readout

- Zero suppressed

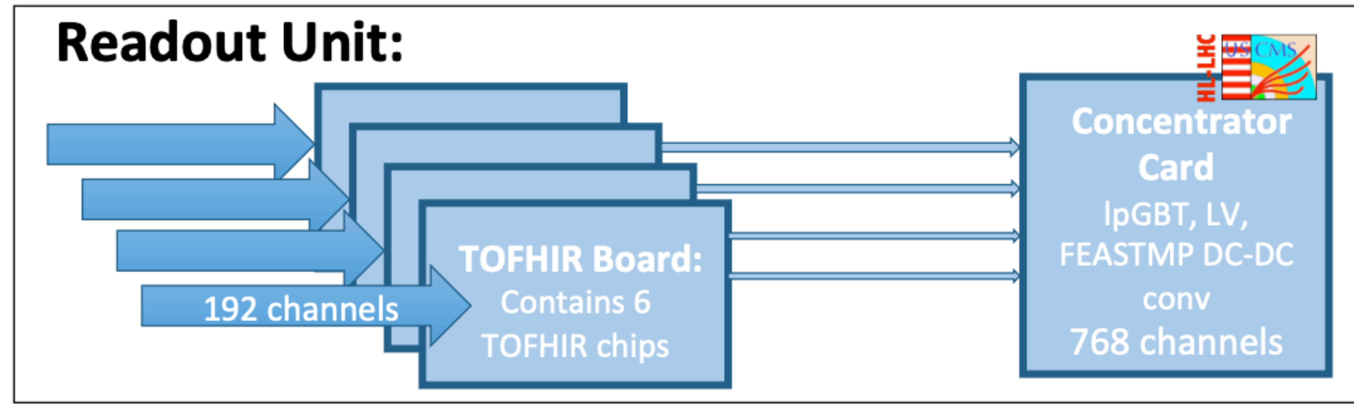
ETL:

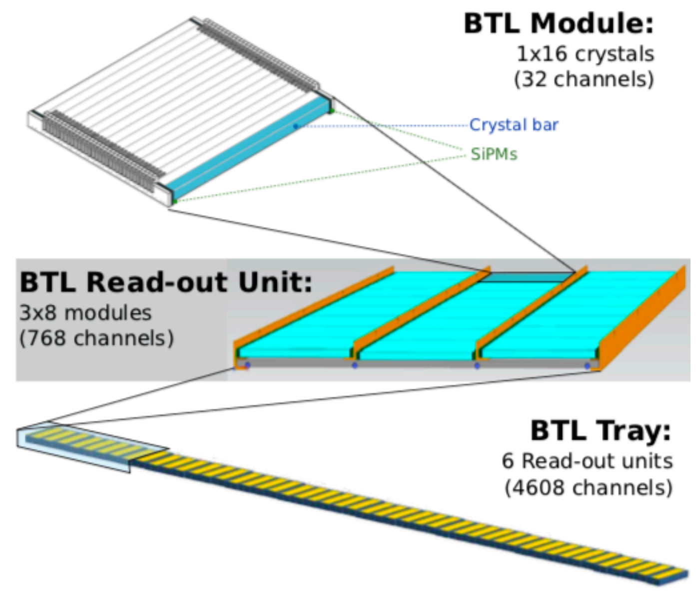
LGAD sensor - dual layer

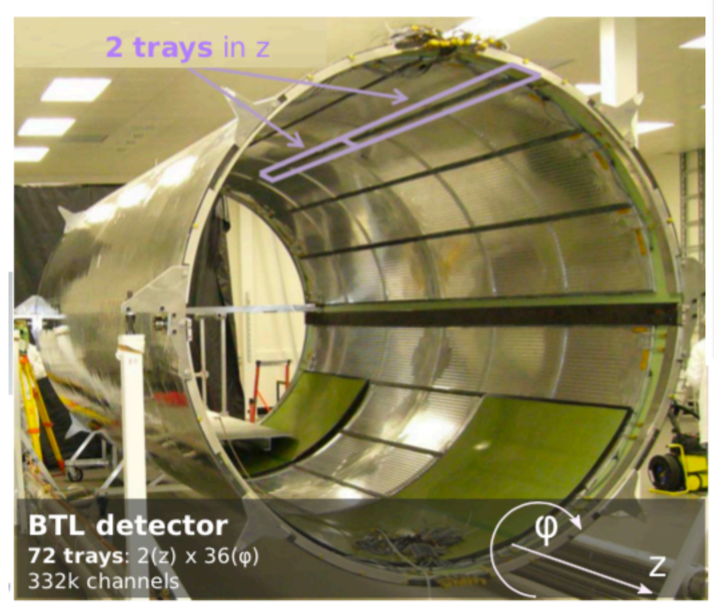
- Small(er) size
- Operable at high dose rate

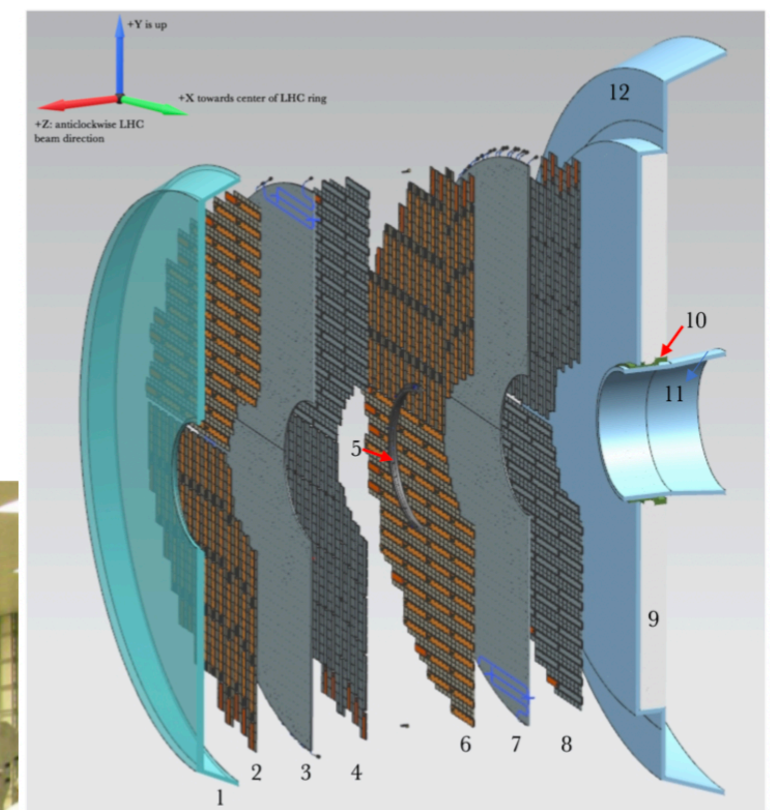
ETROC for readout

- Zero suppressed









Opportunities

Challenge: Make precision timing information available for use in the Level-1 Trigger system

- Requires more readout bandwidth (*similar needs to pixel triggering*)

Next Generation Tracking:
MTD is a “final-layer” of tracking with precision timing information

- **Allows for 4D vertexing and pile-up track removal**

If all tracking layers had precision timing then **track reconstruction combinatorics would be reduced** in high pile up environments

- For the current HL-LHC scenarios, one would expect a reduction by 4x (200PU to 50 PU)
- **Track reconstruction is the most resource intensive process in offline** computing, grows exponentially with Pile Up
- **Similar gains would be seen in online track reconstruction**

R&D Areas

ROI Architectures

- Perhaps this can still be considered an option

Radiation-hard high-speed low-power links

- Reliant on 10 Gbps lpGBT
- Next generation links needed
  - Higher bandwidth
  - Low power
  - Radiation Hard

Next-generation (low-power) ASICs

- As a reference: current limitation for ETROC is 1 W/chip
- On detector clustering to reduce bandwidth

Fast detector technologies

- Operable at higher temperatures

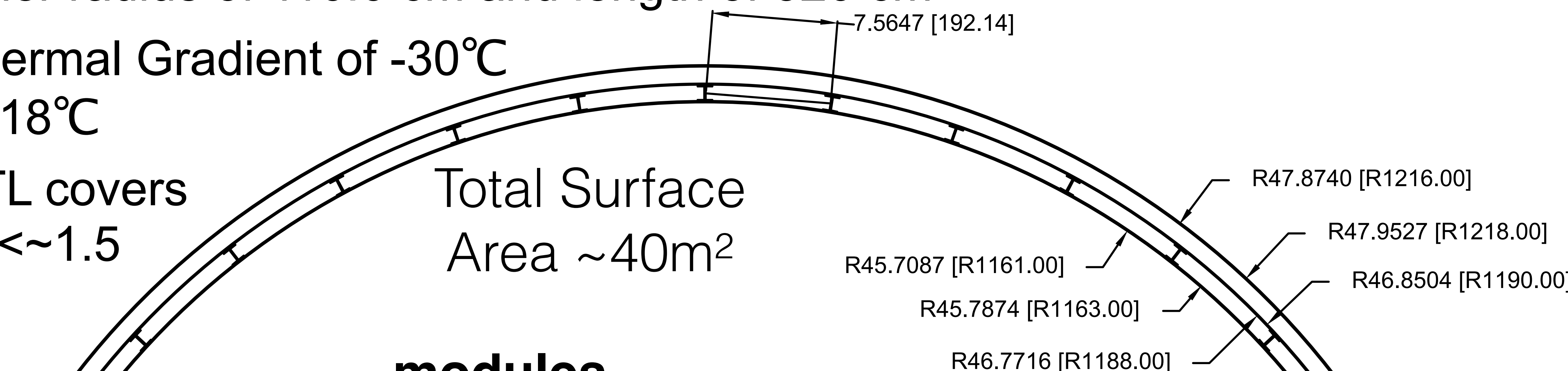
BackUp

Mechanical Structure (Barrel Timing Layer)

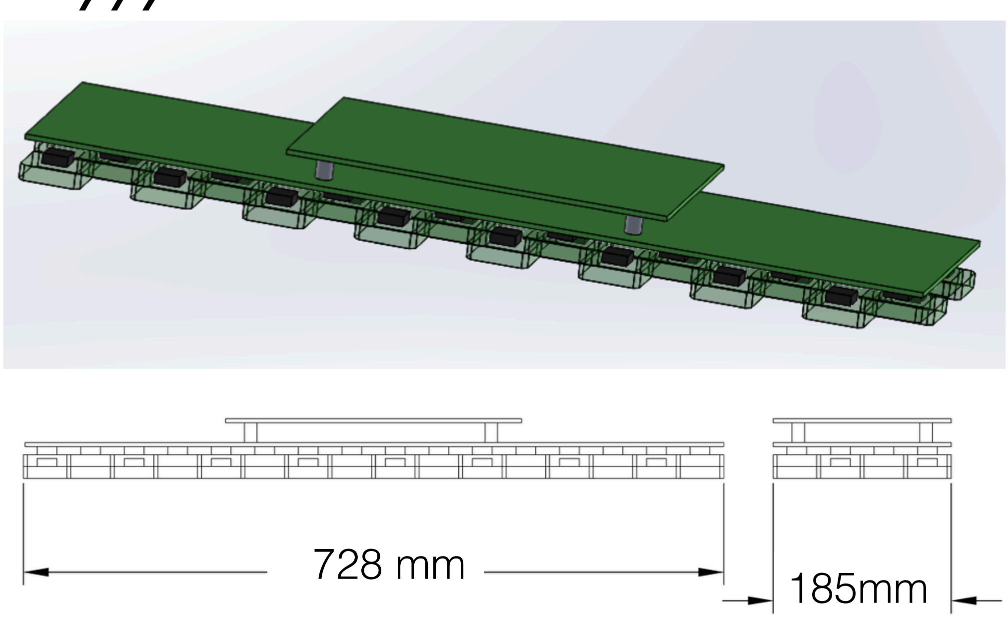
Designed to **minimally affect the existing Physics program at CMS**

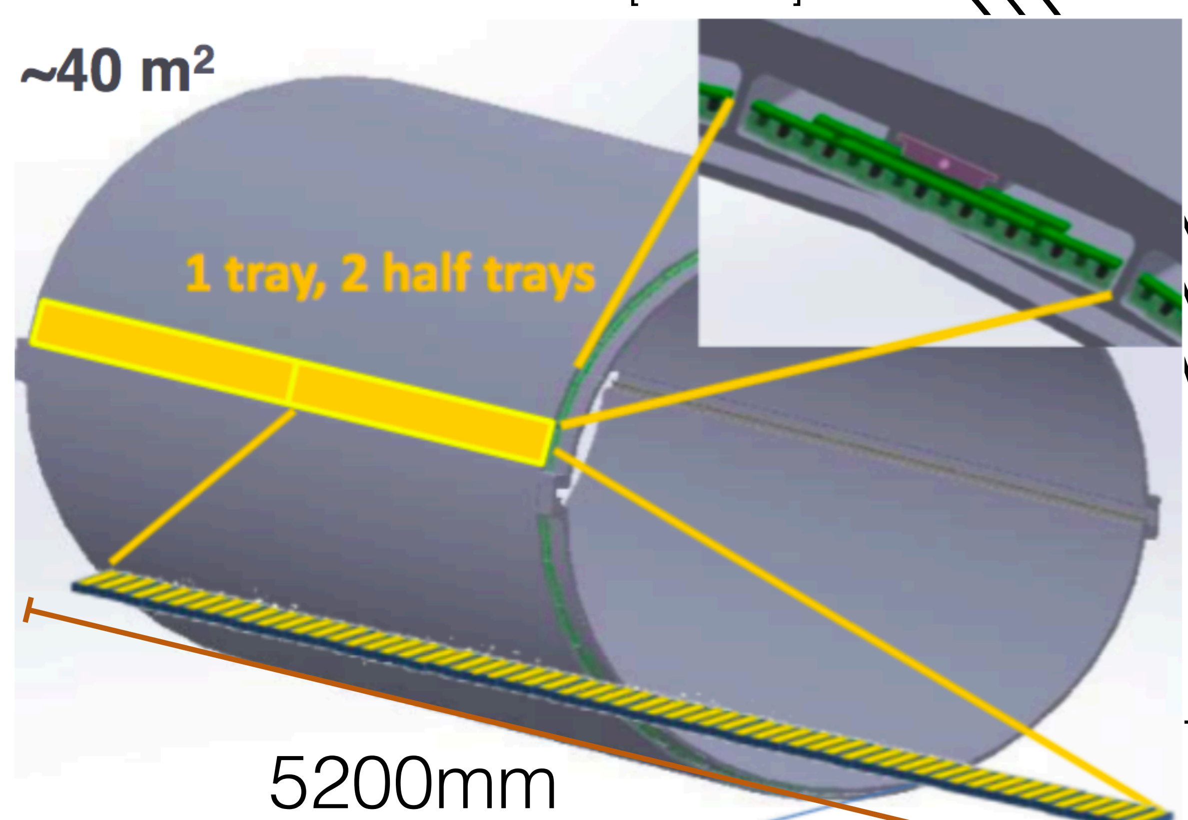
- Crystals + SiPM attached to the **Tracker Support Tube**
- Inner radius of 116.6 cm and length of 520 cm
- Thermal Gradient of -30℃ to 18℃
- BTL covers $|\eta|<\sim1.5$

Total Surface Area ~40m²



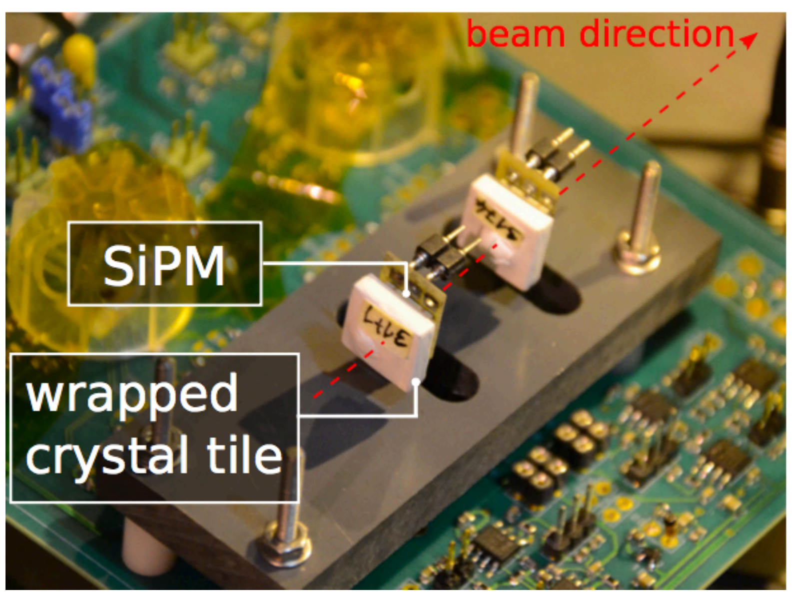
modules (16x4 crystals+SiPM)

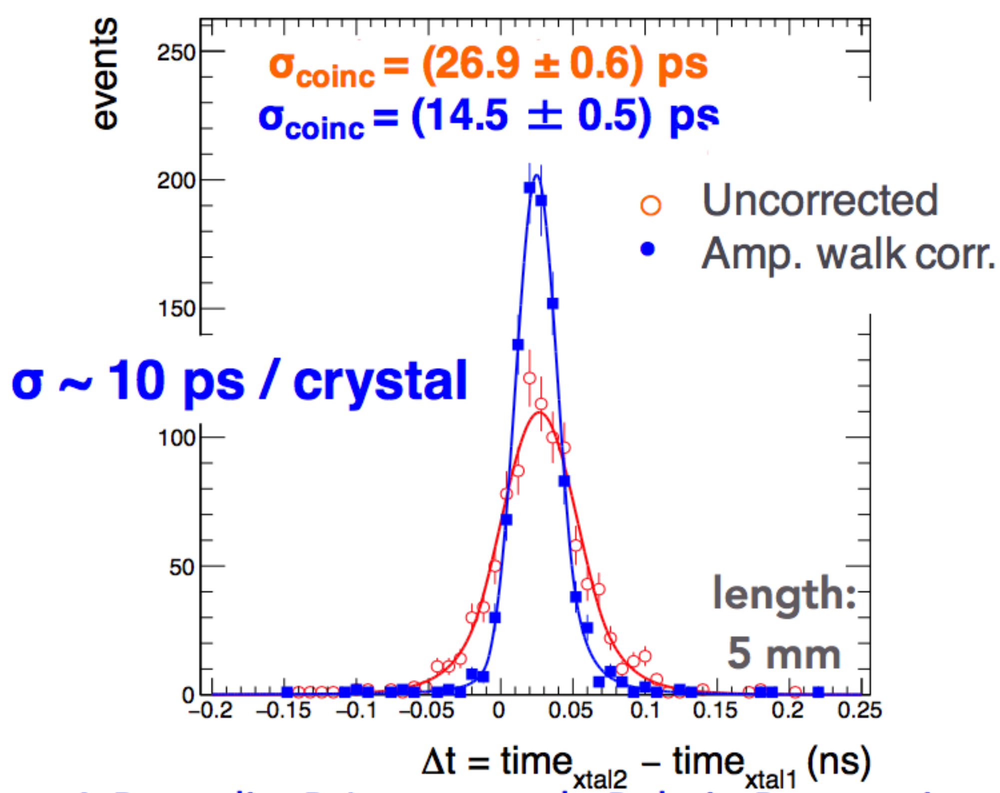




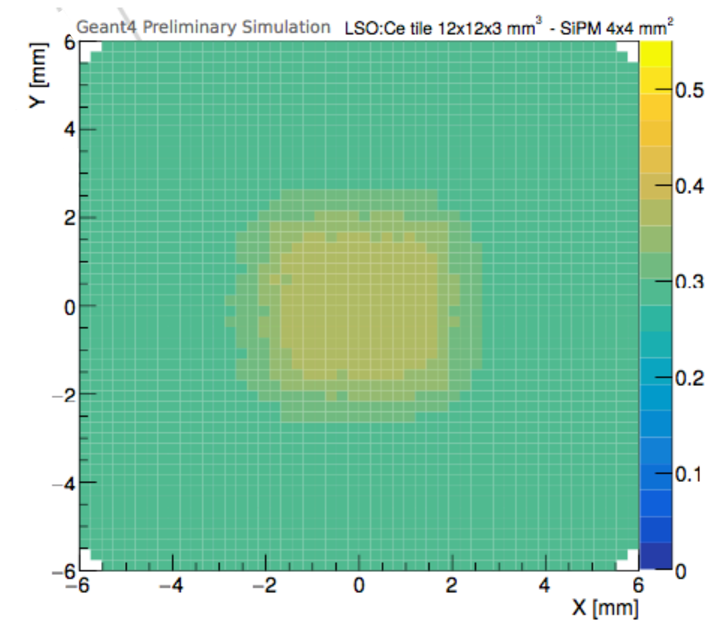
Fast Scintillating Crystals for Precision Timing

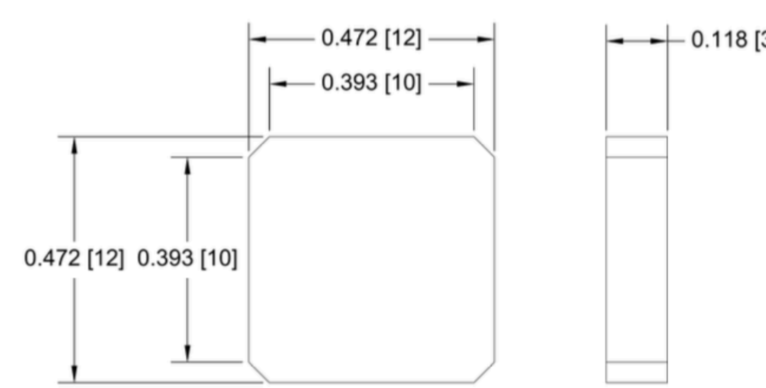
- **LYSO:CE crystals**
  - short decay time, high light output, excellent Scintillator
- In Test Beams, sensors with similar geometry as for the BTL have been proven capable of achieving MIP Timing **resolution better than 30ps**
  - In these devices a **MIP was detected with 100% efficiency**
  - Capable of withstanding 100MRad with minimal transparency loss
- **Overall, performance is simulated well**





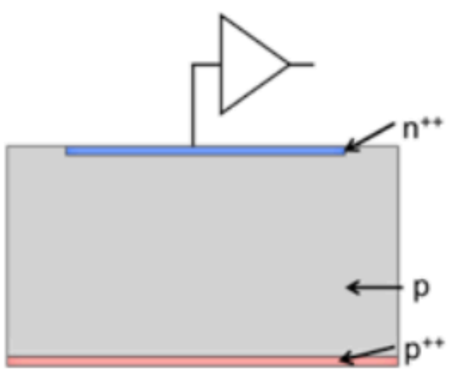
A.Benaglia, P. Lecoq, et al., Pub. in Preparation
On the Properties of Crystal Timing in LYSO



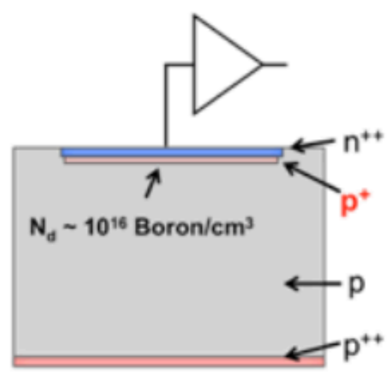


Low Gain Avalanche Devices (LGADs)

- Ultra Fast Silicon Detectors
- Optimize silicon sensor to increase dV/dt (gain), reduce shot noise, decrease landau fluctuations (thinning to 50 um)
- < 30ps resolution achieved up to a fluence of 3e14 n. eq.



Traditional silicon detector



Low gain avalanche detectors