Documentation process of the test of PS & 2S modules

Reception tests for CMS Phase-2 Outer Tracker at IP2I

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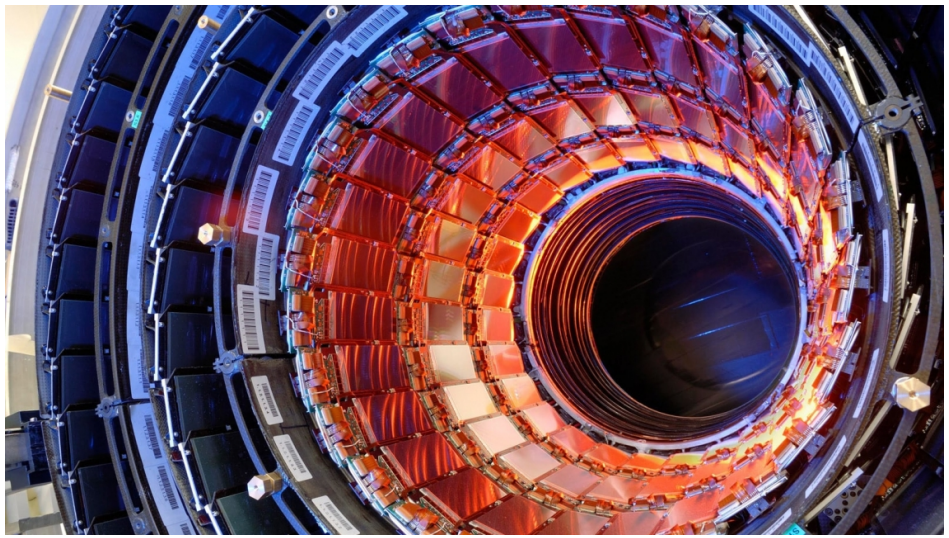
Institut de Physique des 2 Infinis
Université Claude Bernard - Lyon 1

Monday, July 6^{th}

Scientific context - HL-LHC



Present Phase-1 Tracker in CMS: in use since 2008.
Phase 1 upgrade (2016): pixel detector replaced

Tracker specificities

- High efficiency for P.U ~ 30 collisions per bunch crossing
- Instantaneous luminosity of $1.0 \times 10^{34} cm^{-2} s^{-1}$
- up to an integrated luminosity of $500 fb^{-1}$

Scientific context - HL-LHC

HL-LHC physics

- P.U $\sim$ 150 collisions per bunch crossing
- Inst. luminosity of $7.5 \times 10^{34} cm^{-2} s^{-1}$
- Int. lumi of 3000 fb^{-1}

$\Rightarrow$ Studies of accumulated damage from HL-LHC radiation:

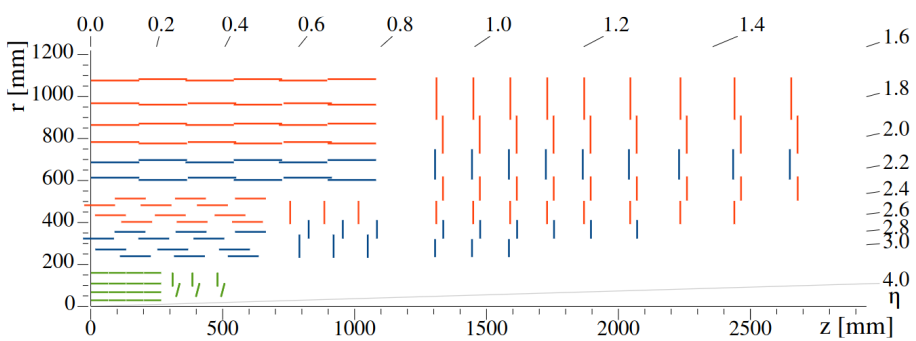
- Pixel sensors: reduces charge collection efficiency, deteriorated spatial resolution: leads to reduced hit efficiency.
- Strip tracker: increase of sensor depletion voltage and leakage current.

$\Rightarrow$ Damage mitigated by cooling, but after 1000 fb^{-1}, "unnaceptable degradation": **tracker change is needed.**

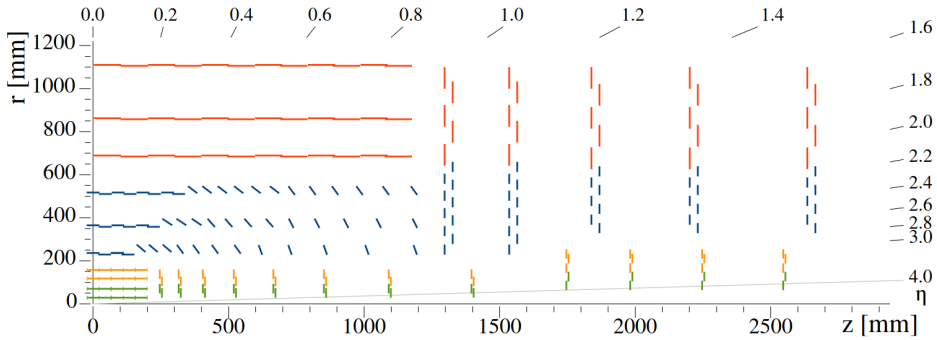
Phase-2 Tracker

Phase-2 CMS Tracker: Inner Tracker (IT) based on silicon pixel modules, & Outer Tracker (OT) made from silicon modules.
Main requirements for the tracker upgrade :

- Radiation tolerance (up to 3000 fb^{-1})
- Increased granularity (to accommodate high P.U)
- Improved track separation
- Level-1 trigger
- Extended tracking acceptance

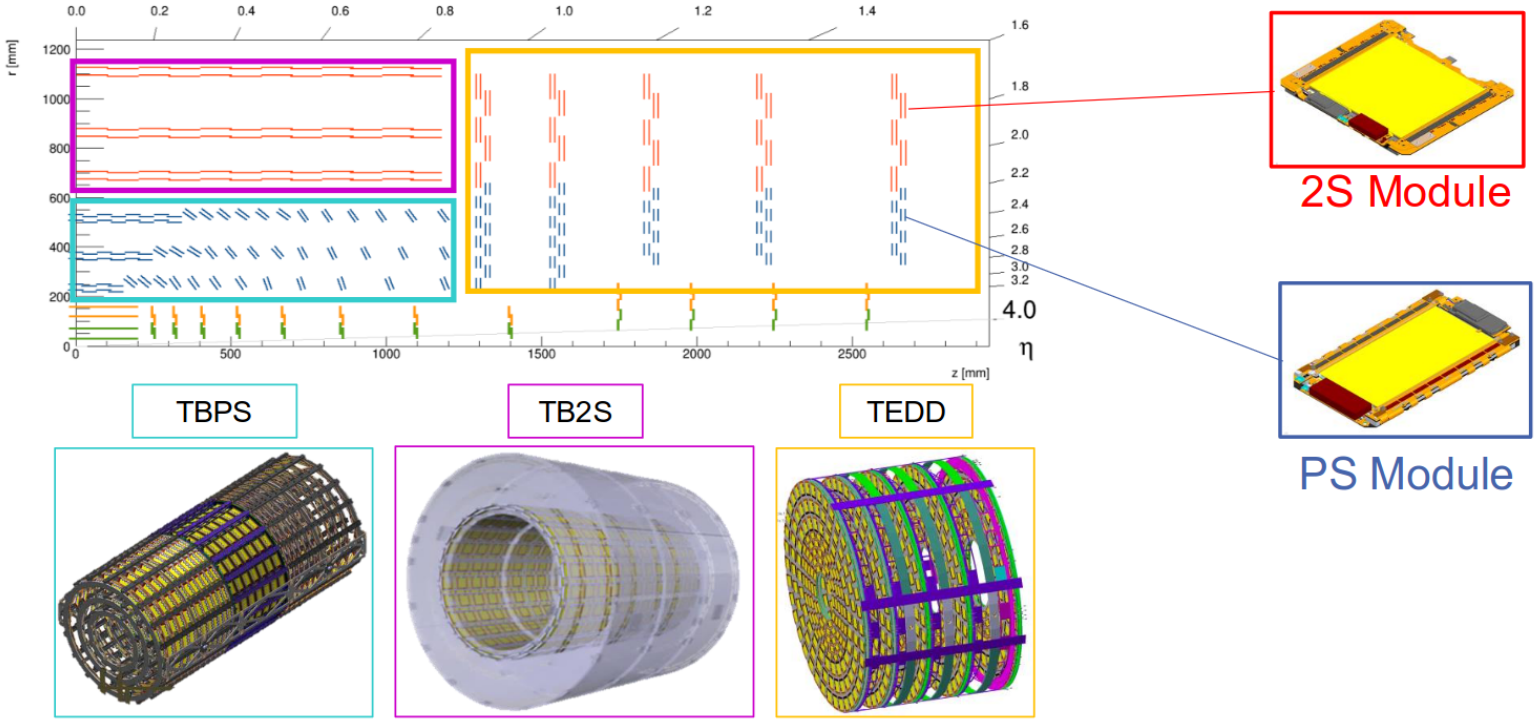


Phase-1 Tracker



Phase-2 Tracker

Phase-2 Outer Tracker



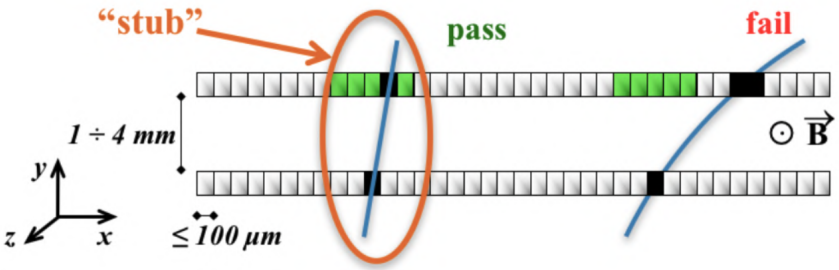
213M readout channels (for 9.3M Phase-1)
New "tilted" geometry
Participation in L1 trigger.
6 cylindrical "barrels" covering $|z| < 1200$ mm, + 5 "endcap" double discs on each side for $1200 < |z| < 2700$ mm.

L1 trigger

HL-LHC challenges

- Increased P.U (200 vs 50)
- Strong increase in fake/soft objects

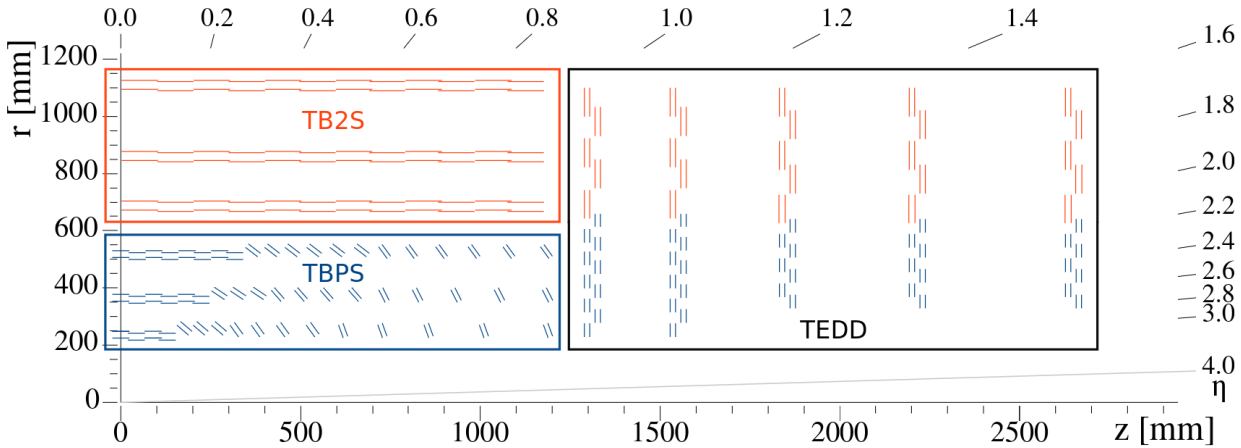
$\Rightarrow$ L1 trigger!

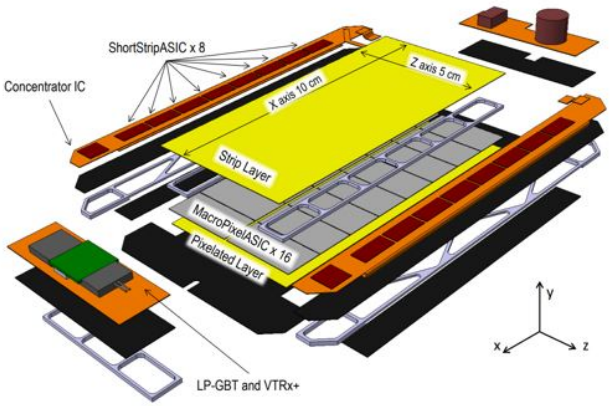


L1 trigger: tracker **self-select info** for every bunch crossing: design of "p_T modules".

"p_T **modules**": 2 single-sided closely spaced-sensors. Tracks from charged particles are bent with angle depending on particle p_T: modules can select **hit pairs** with chosen p_T threshold.

L1 trigger: modules

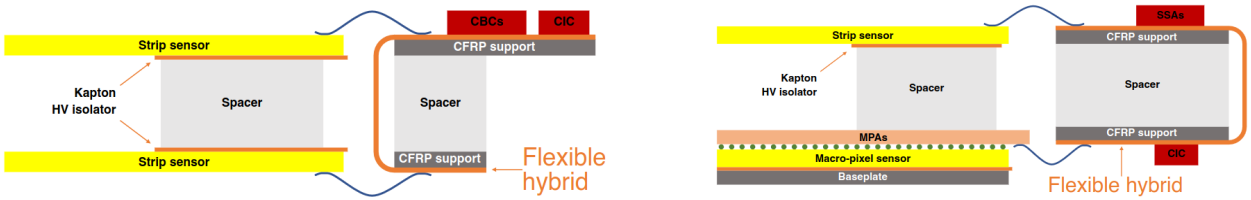




A deconstructed PS module.

L1 trigger requires complex module design.
2 types only:
PS (inner radii) = "pixel-strip"
2S (outer radii) = "strip-strip",
with spacing sub-variants

L1 trigger: modules



2S module (left) and PS module (right).

2S modules: 2×90 cm^2 active area.

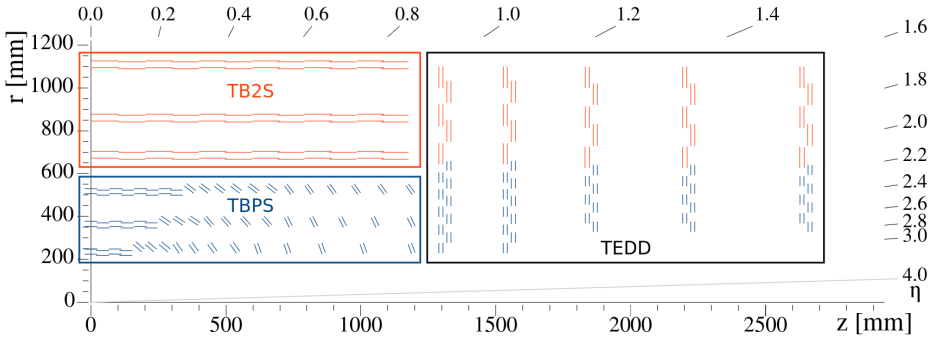
- Coarse z coordinate
- Easier cooling
- Reduced occupancy

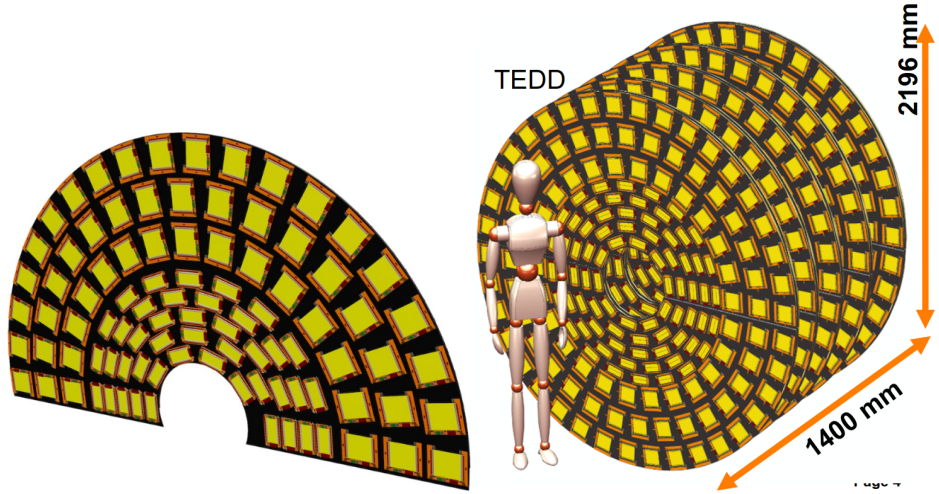
PS modules: 2×45 cm^2 active area.

- Accurate z coordinate
- Shorter strips: good for higher track density in inner regions

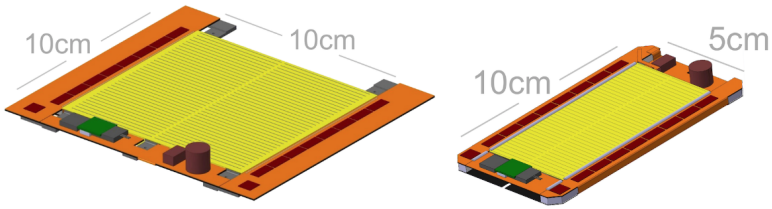
p_T modules: top & bottom sensors read **independantly** by front-end electronics to select a **stub**.
2GeV selection: data volume reduction by one order of magnitude

Phase-2 Outer Tracker Endcaps

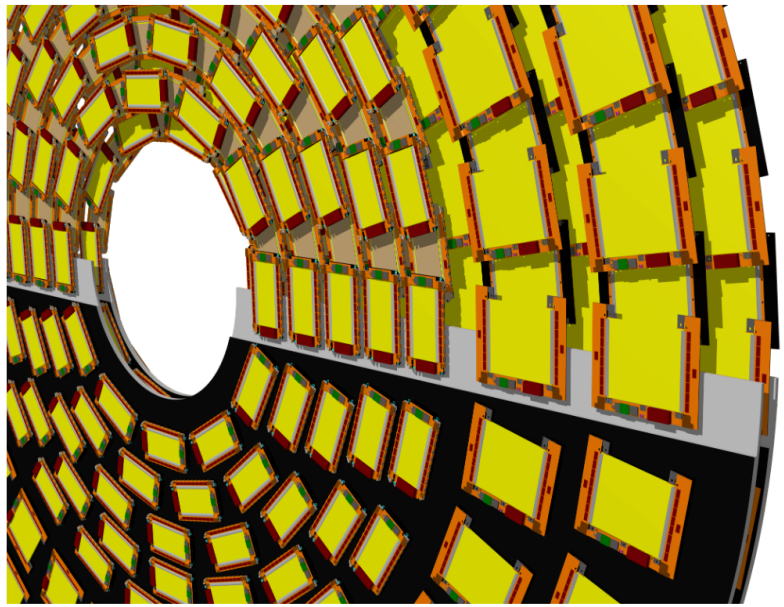




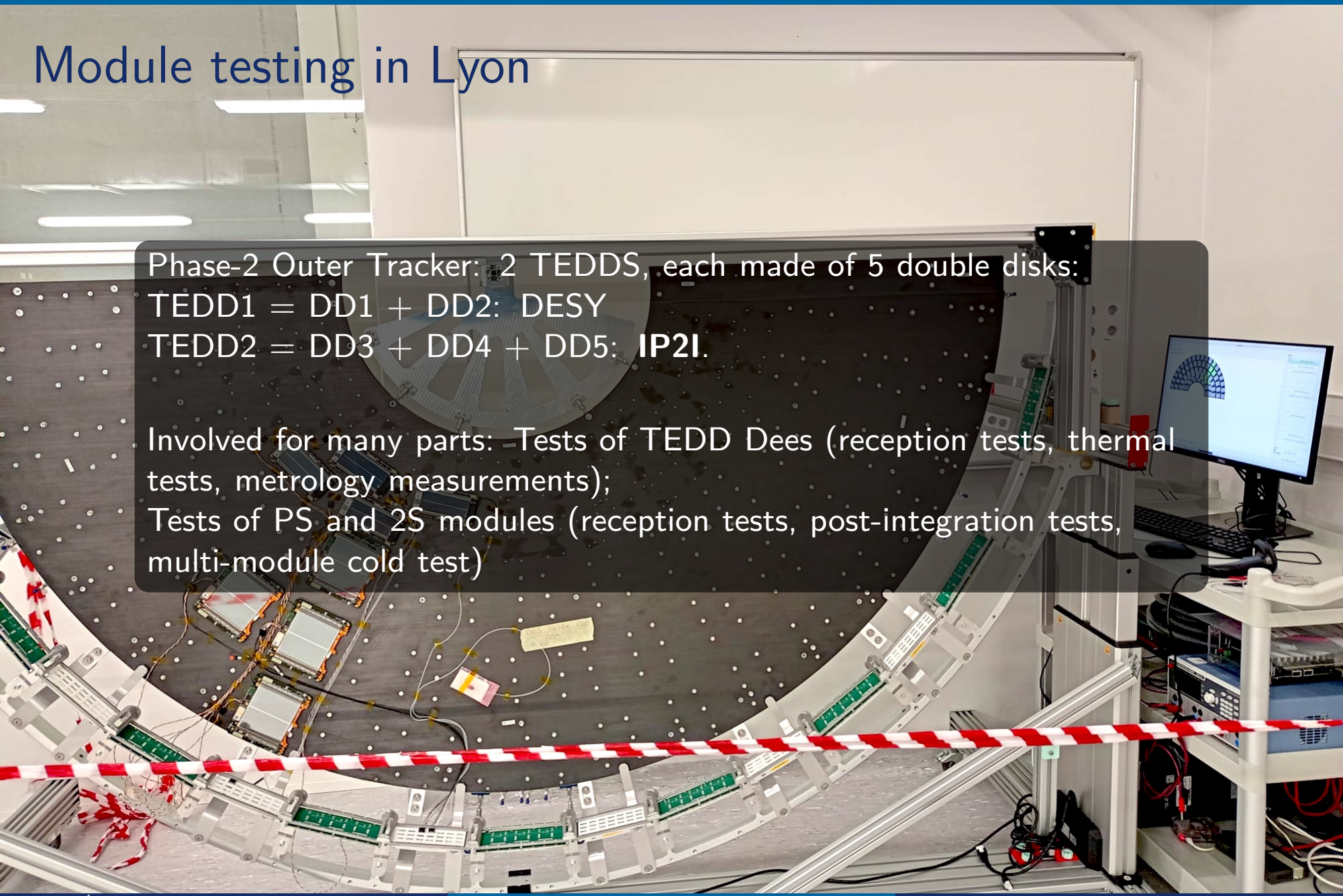
"TEDD": Tracker End Cap Double-Disks.



2S & PS modules Assembled on a "dee"
2 "dees" make up a "disk": Each TEDD is 5 double disks.



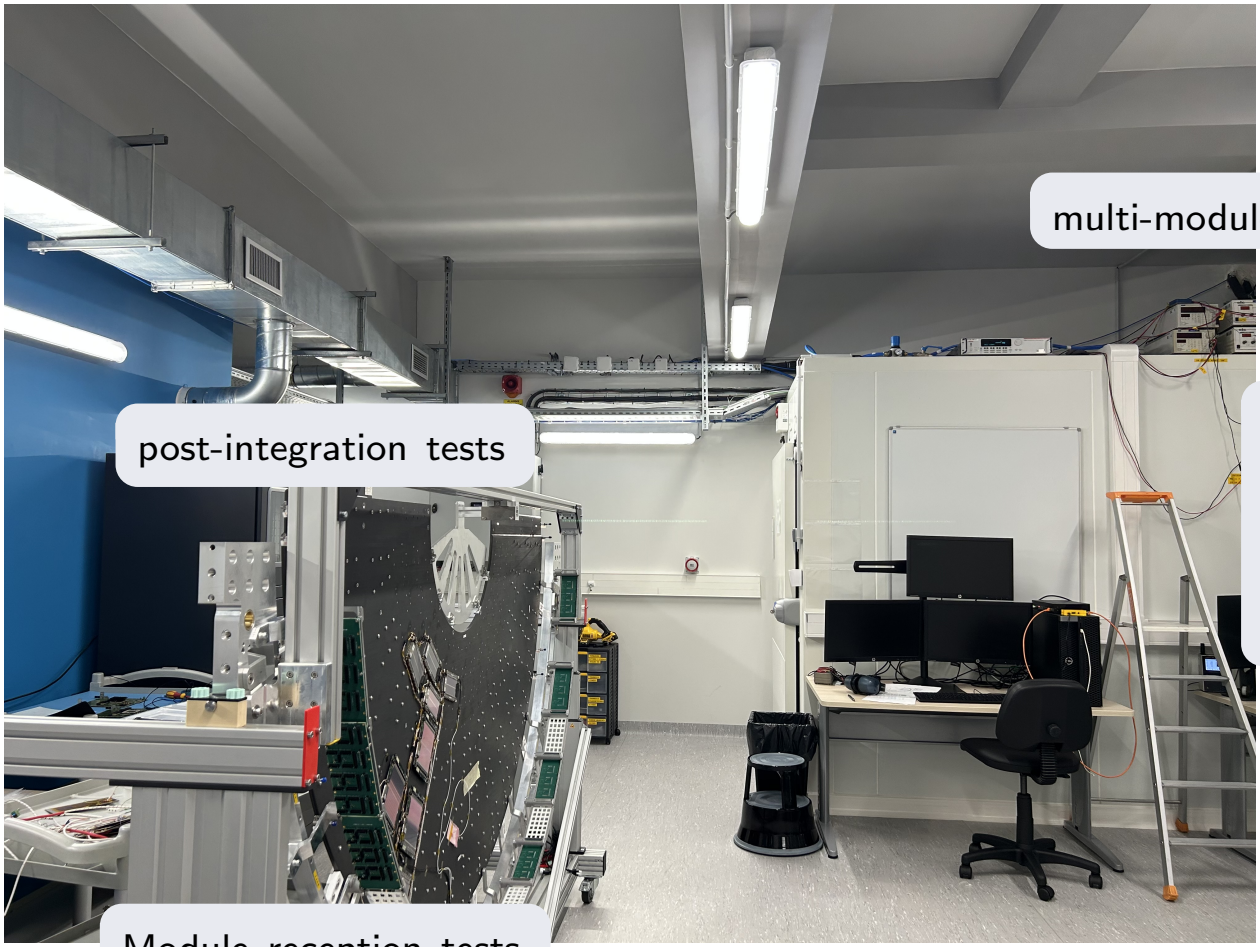
Module testing in Lyon



Phase-2 Outer Tracker: 2 TEDDS, each made of 5 double disks:
TEDD1 = DD1 + DD2: DESY
TEDD2 = DD3 + DD4 + DD5: **IP2I**.

Involved for many parts: Tests of TEDD Dees (reception tests, thermal tests, metrology measurements);
Tests of PS and 2S modules (reception tests, post-integration tests, multi-module cold test)

CMS Clean Room



multi-module cold tests

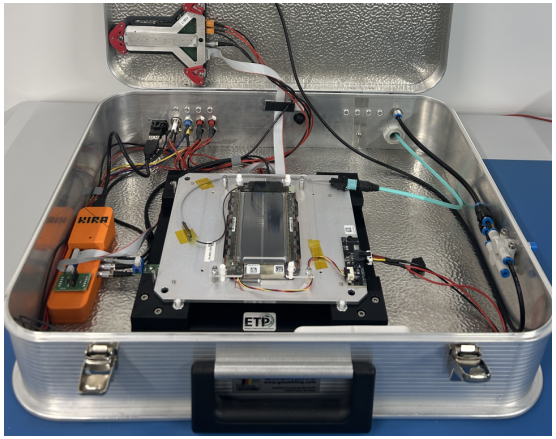
post-integration tests

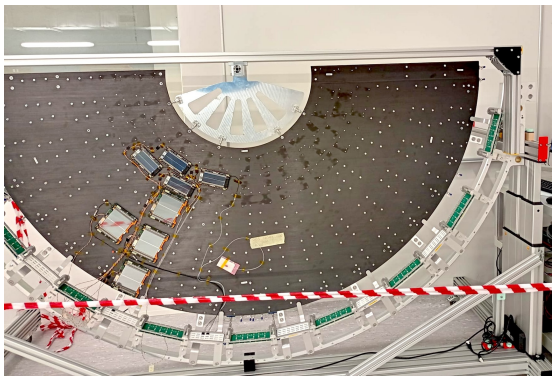
Module reception tests

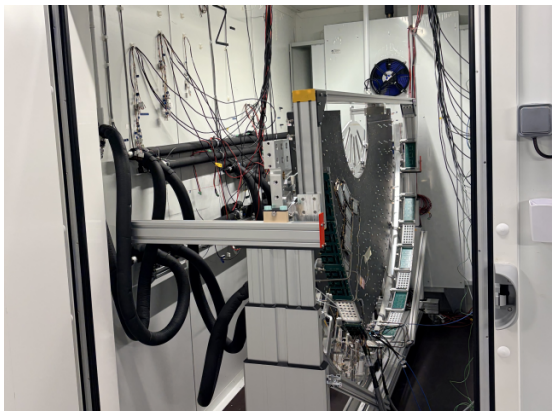
Van de Graaf building.
2 stories: 1^{st} floor for test of modules and integration on the dee.

Module reception tests

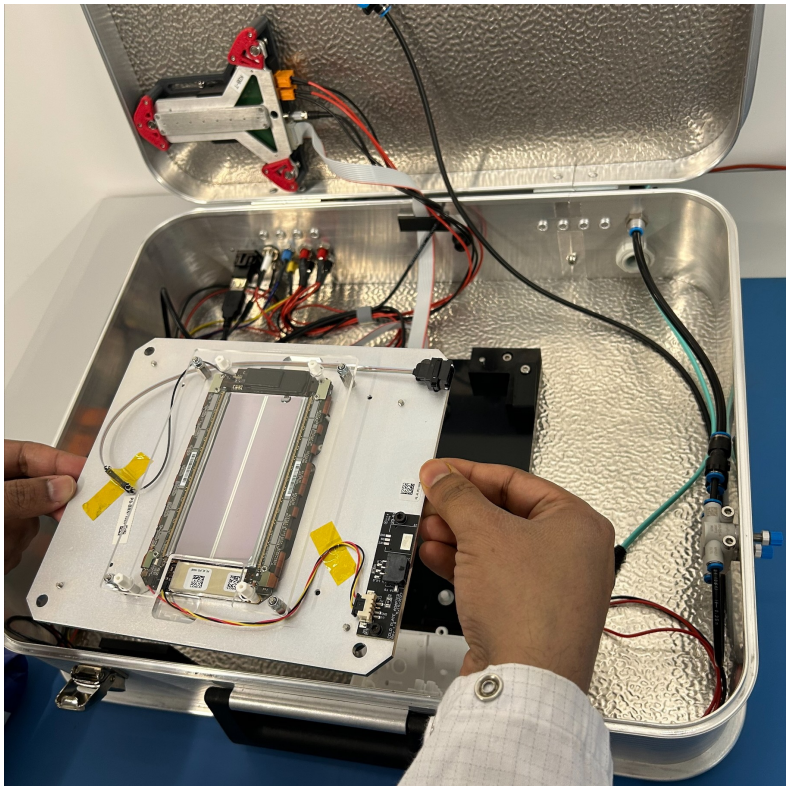
1. **Module reception test**
   functionality tests of modules
2. **Post-integration test**
   Module tests after integration on dee
3. **Multi-module cold test**
   dee tested at -18°C







Module reception tests in Lyon



Modules received

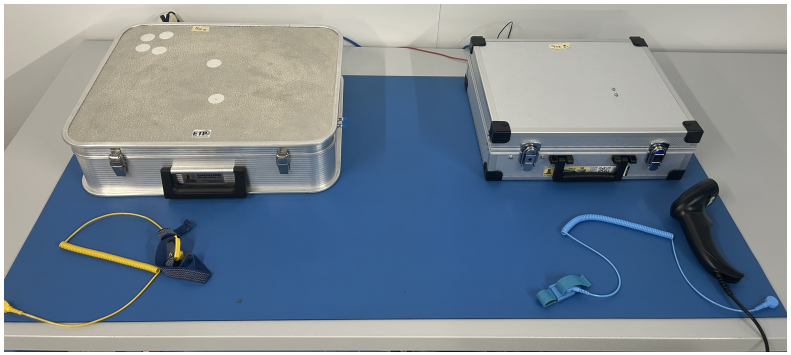
5 PS + 5 2S prototype modules to test:

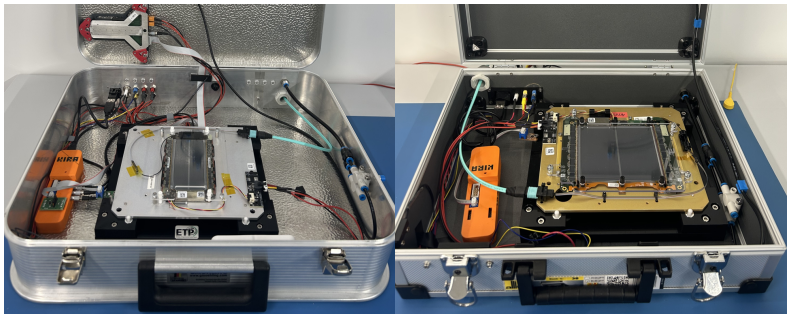
- 5 PS modules from Perugia
- 5 2S modules from KIT

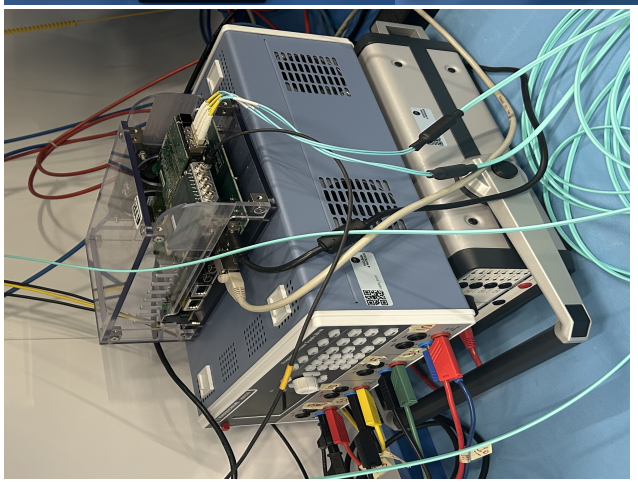
Many labs test Phase-2 OT modules: unified module test stations from KIT & associated software.

"Reception test": measurement of **noise** & **IV behaviour**.
Modules get a **grade**, depending on performance.

Reception test: Hardware



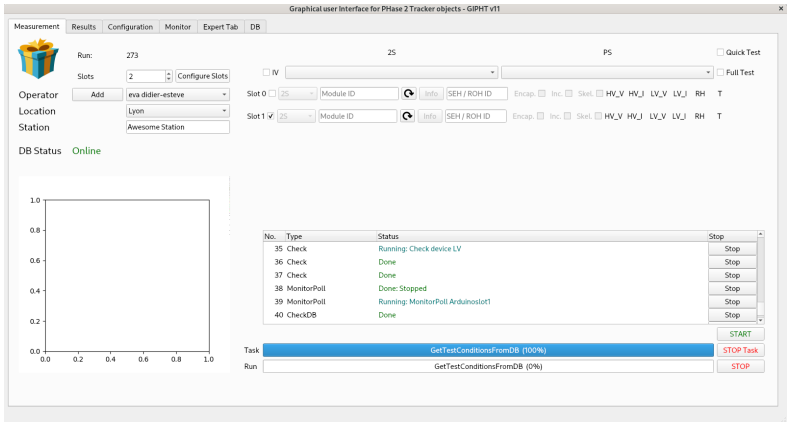


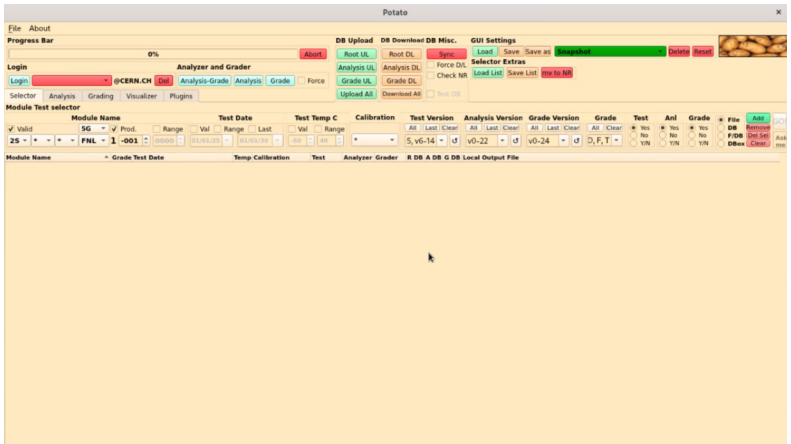


Standardized test stations developed at KIT (Germany):

- "Test boxes" from KIT. Aluminium, hosts 1 module, connected to LV, HV, dry air, optical cable.
- KIRA: signal injector
- Arduino: controls KIRA system, monitors temperature & humidity

Reception test: Software





GIPHT (Graphical user Interface for PHase-2 Tracker objects): software associated to standardized KIT test stations.
From GIPHT, control of test conditions & current applied to modules:

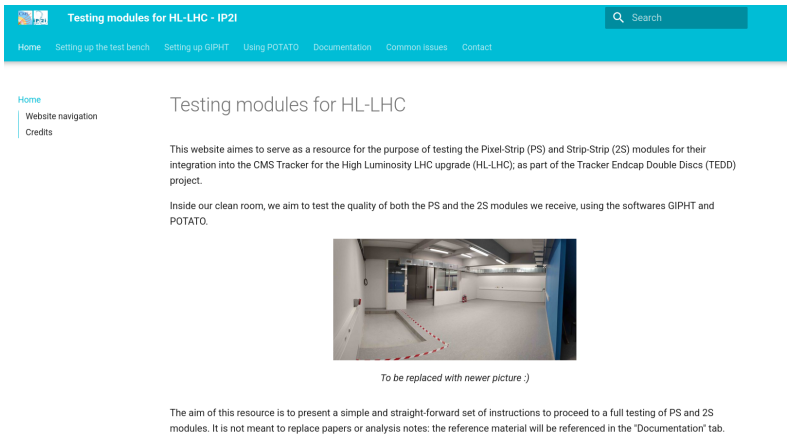
- Measure of noise at room temperature for -350V bias
- Measure of IV behaviour: sensor leakage current vs. bias voltage (up to -800V)

POTATO (Phase-2 Outer Tracker Analyzer of Test Outputs) analyzes GIPHT output to grade different modules, from A (best) to D (worst).

Documentation of module reception tests

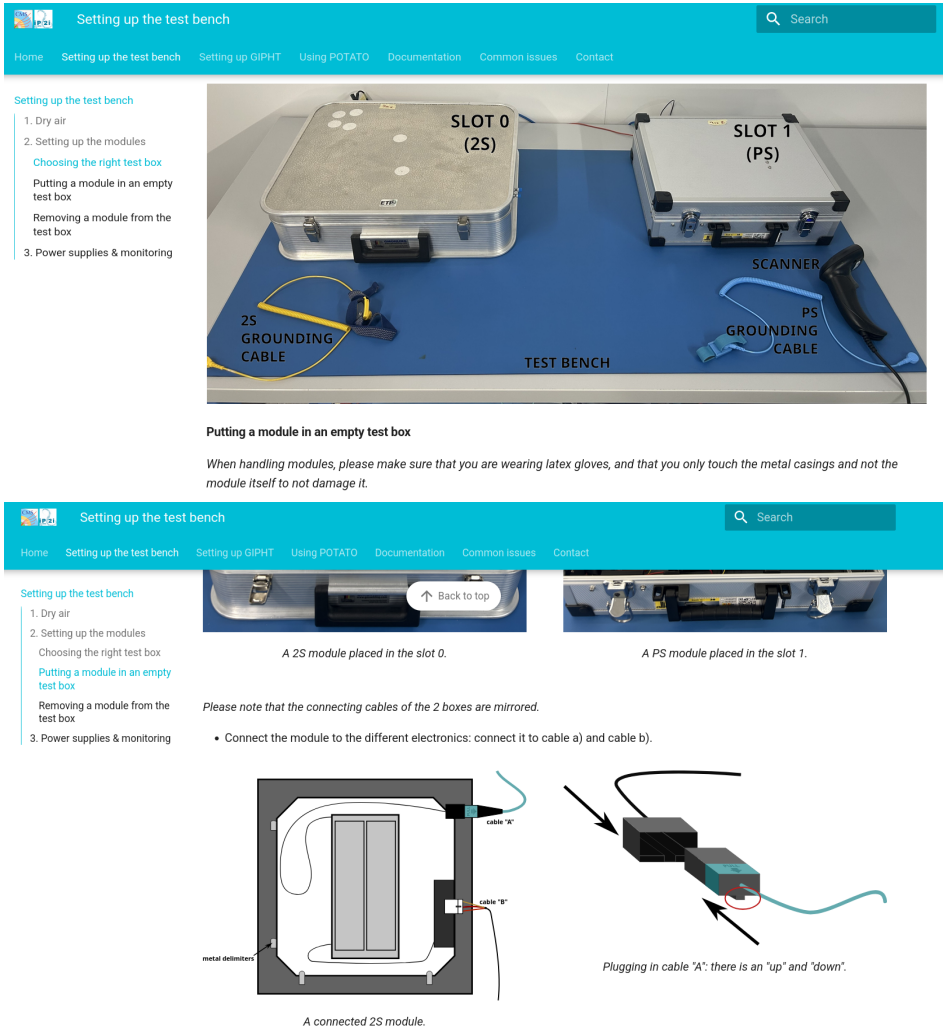
- Lots of hardware + software
- Still in development: updates are regular
- Modules are fragile & costly

$\Rightarrow$ Need to have clear + precise + up-to-date documentation for the whole testing process.



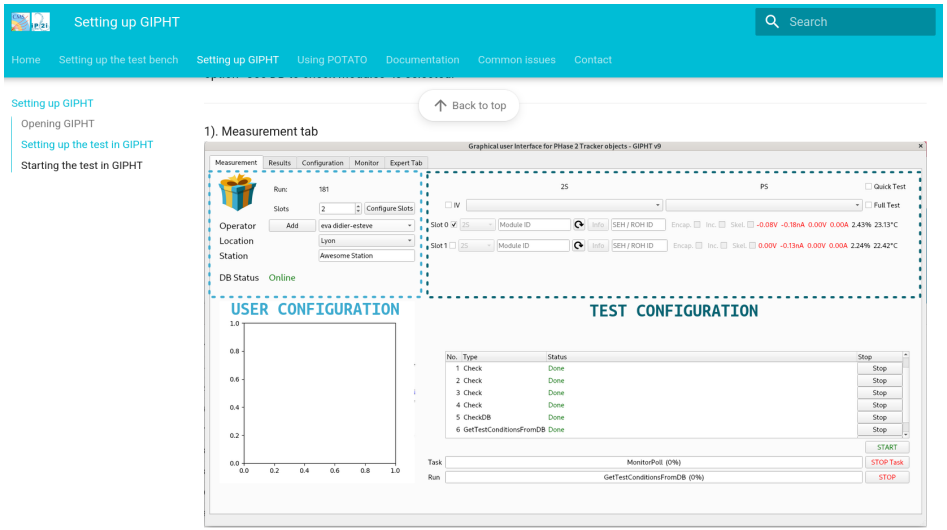
Development of a website containing instructions for a module reception test,accessible by all IN2P3

Setting up the test



- Tutorial to set up the KIT test bench to test 2S and PS modules, from beginning to end:
- Turn on dry air & fetch from dry cabinet
- Set up & plug in all electrical components for the different modules
- Handling the modules for testing & storing.

Testing in GIPHT



This step is essential to ensure the good function and safety of both you and the modules.

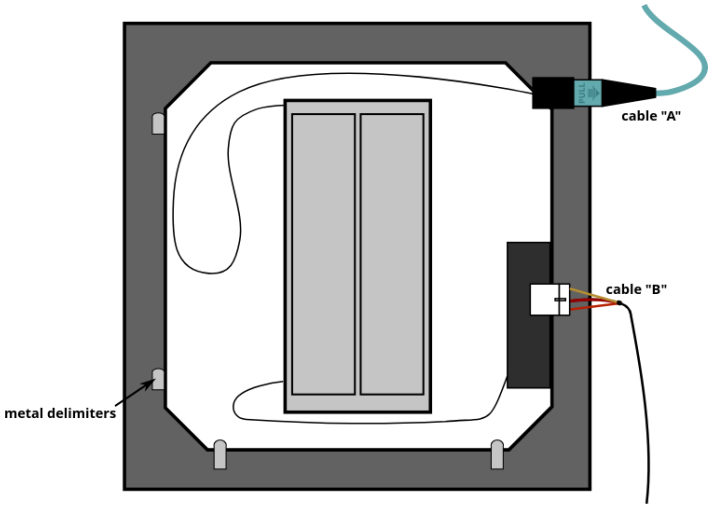
Documentation of the whole process of setting up the module tests in GIPHT:

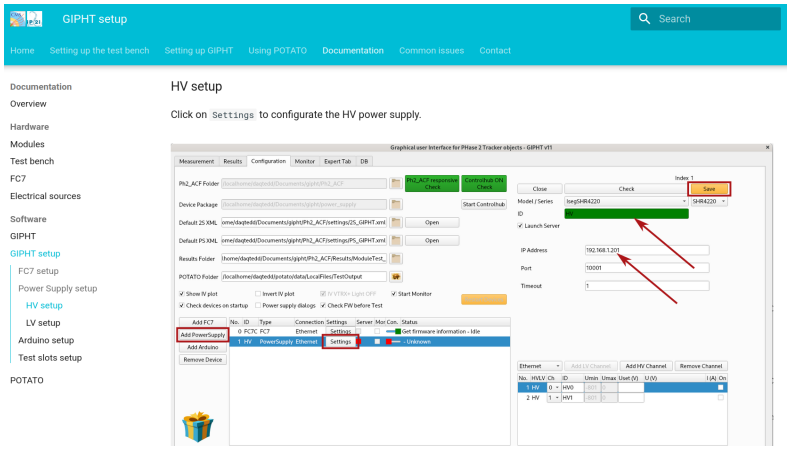
- Monitoring temperature, humidity and dewpoint
- Setting up the hardware & software elements
- Connecting to database to store results

⇒ Complete tutorial to do a FullTest of PS and 2S modules.

More information

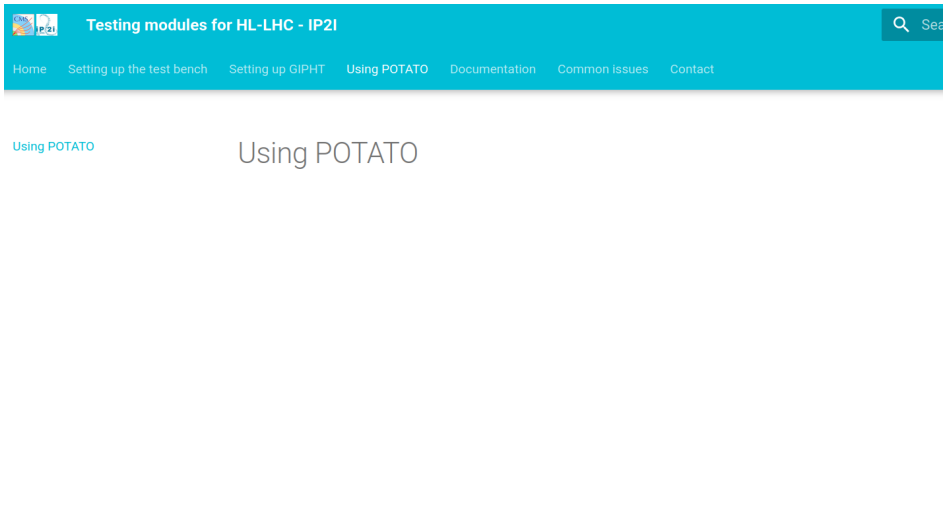
Modules

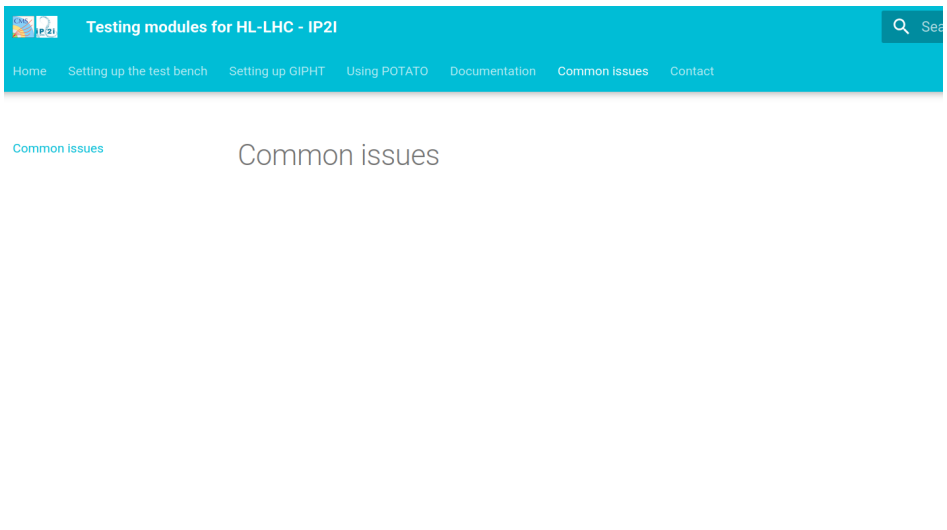




- Recording of common issues about hardware and software
- Links to software distros
- Complete tutorials to set up the test bench from the beginning
- Illustrations of modules, hardware, software... for clarity
- ...

Next steps





- "`POTATO`" section
- "Common issues" section (go through months of recorded issues)
- User-friendly corrections (feedback: more pictures!)
- Complete tutorials to set up the software from the beginning
- Update continuously to take care of software updates (the `GIPHT` section is 2 months old but already out-of-date)

Conclusion

CERN-LHCC-2017-009
CMS-TDR-014
1 July 2017

The Phase-2 Upgrade

of the CMS Tracker

Technical Design Report

CMS Collaboration

LHCC-2017-009 / CMS-TDR-014
018

Conclusion

WYDZIAŁ FIZYKI
UNIWERSYTET WARSZAWSKI

PS Module Testing for the HL-LHC CMS Outer Tracker Upgrade

Marianna Głażewska, Faculty of Physics, University of Warsaw, Poland

Supervisors: Andreas Nürnberg, Younes Otarid, Daniil Rastorguev

19^{th} July- 8^{th} September 2022

Abstract

The High Luminosity LHC (HL-LHC) is expected to commence operations in 2029, and will mark the start of Phase-2 at CERN. In the best case scenario, the upgrade will lead to a peak luminosity of 7.5×10^{34} cm^{-2} s^{-1} - five times higher than the current value. In preparation for this increase, the CMS experiment upgrade must take into consideration the increase in radiation that will be inflicted onto the

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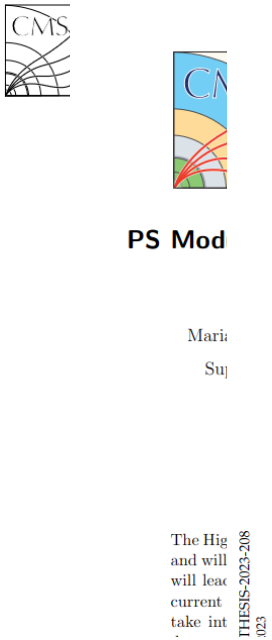
Conclusion



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Pixel-Strip Modules for the CMS Tracker Phase-2 Upgrade

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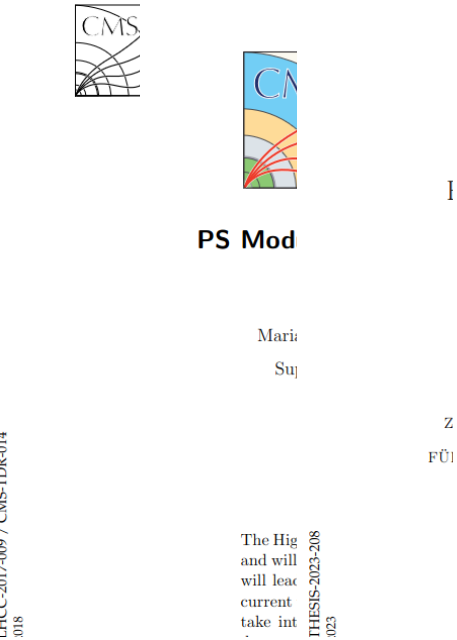
From DAQ test system development to module assembly and qualification

DISSERTATION

ZUR ERLANGUNG DES DOKTORGRADES AN DER FAKULTÄT
FÜR MATHEMATIK, INFORMATIK UND NATURWISSENSCHAFTEN
FACHBEREICH PHYSIK
DER UNIVERSITÄT HAMBURG

Conclusion



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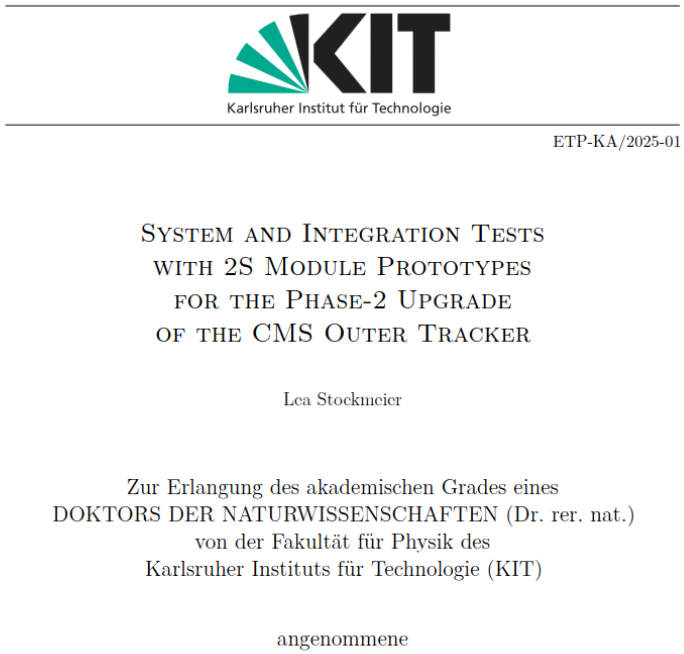


Karlsruher Institut für Technologie

ETP-KA/2025-01

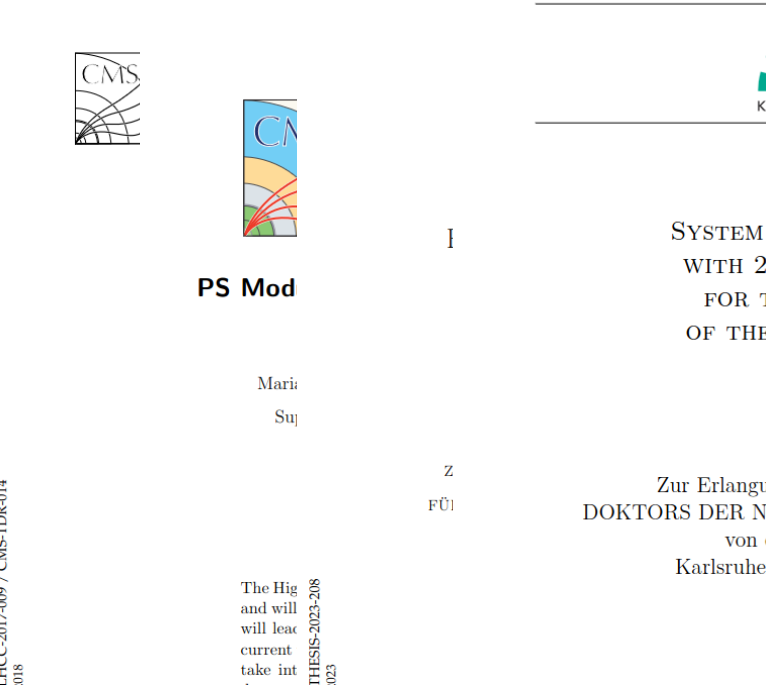
System and Integration Tests
with 2S Module Prototypes
for the Phase-2 Upgrade
of the CMS Outer Tracker

Lea Stockmeier

Zur Erlangung des akademischen Grades eines
DOKTORS DER NATURWISSENSCHAFTEN (Dr. rer. nat.)
von der Fakultät für Physik des
Karlsruher Instituts für Technologie (KIT)

angenommene

Conclusion



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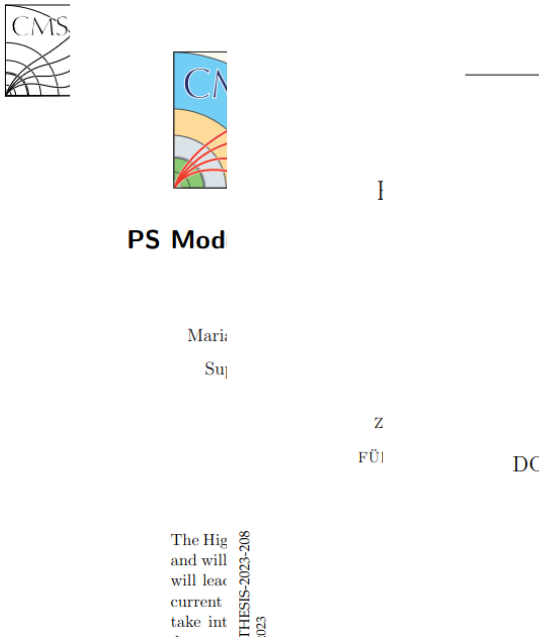
MANUAL
OT Module Test Bench and Readout GUI (GIPHT)

Stefan Maier (& Roland Koppenhöfer)

s.maier@kit.edu
Karlsruhe
November 13, 2024

v4.0

Conclusion



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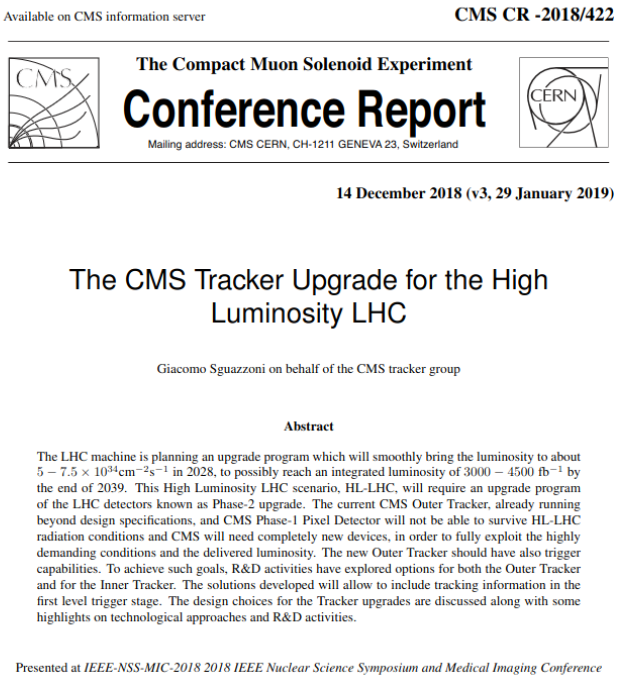


Available on CMS information server

CMS CR -2018/422

The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

14 December 2018 (v3, 29 January 2019)

The CMS Tracker Upgrade for the High Luminosity LHC

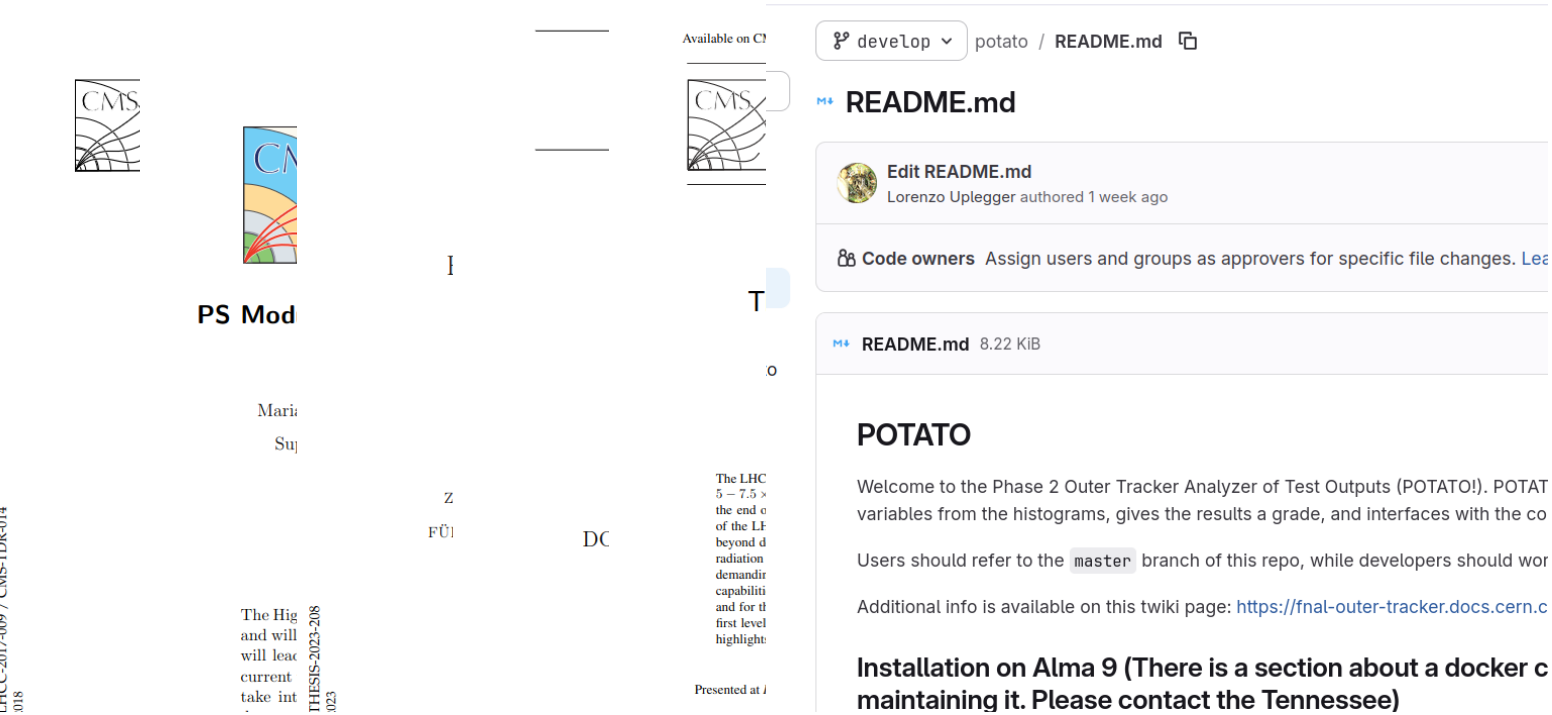
Giacomo Sguazzoni on behalf of the CMS tracker group

Abstract

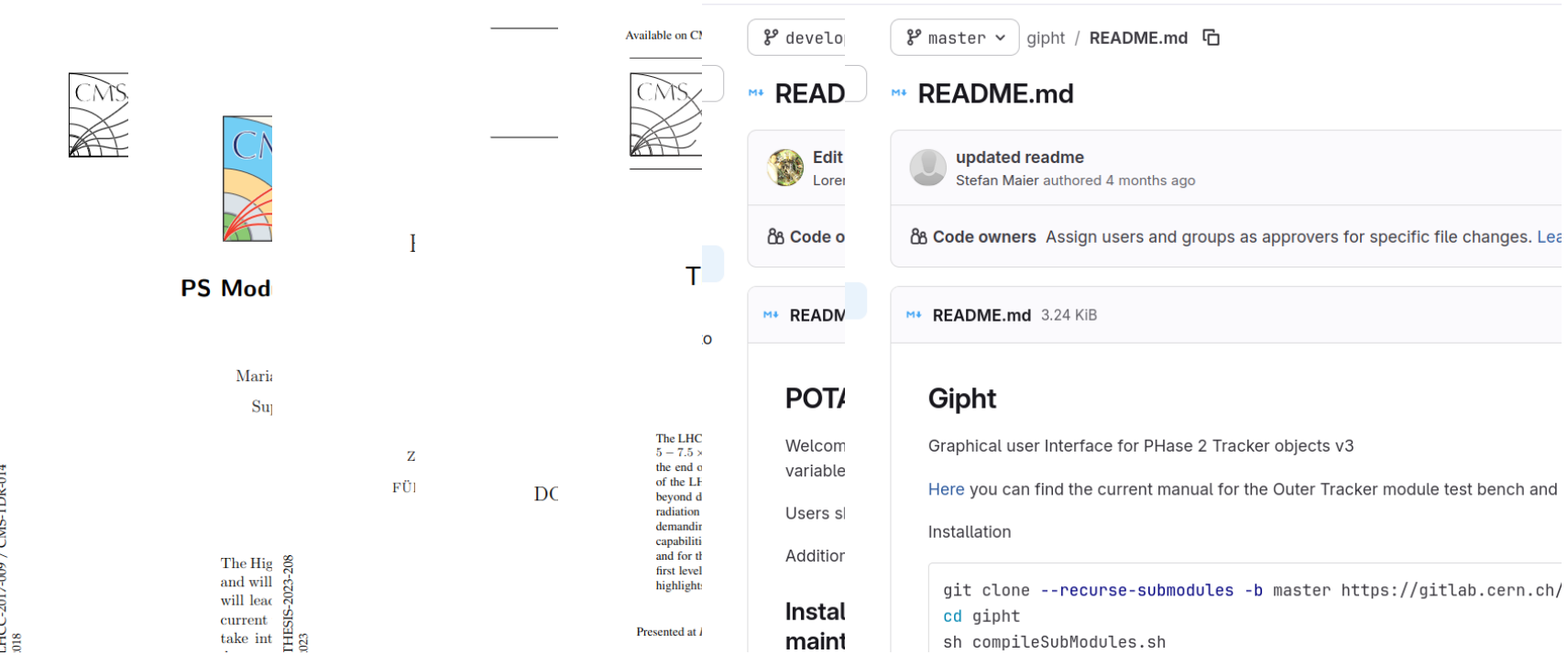
The LHC machine is planning an upgrade program which will smoothly bring the luminosity to about $5 - 7.5 \times 10^{34}\text{cm}^{-2}\text{s}^{-1}$ in 2028, to possibly reach an integrated luminosity of $3000 - 4500\ \text{fb}^{-1}$ by the end of 2039. This High Luminosity LHC scenario, HL-LHC, will require an upgrade program of the LHC detectors known as Phase-2 upgrade. The current CMS Outer Tracker, already running beyond design specifications, and CMS Phase-1 Pixel Detector will not be able to survive HL-LHC radiation conditions and CMS will need completely new devices, in order to fully exploit the highly demanding conditions and the delivered luminosity. The new Outer Tracker should have also trigger capabilities. To achieve such goals, R&D activities have explored options for both the Outer Tracker and for the Inner Tracker. The solutions developed will allow to include tracking information in the first level trigger stage. The design choices for the Tracker upgrades are discussed along with some highlights on technological approaches and R&D activities.

Presented at *IEEE-NSS-MIC-2018 2018 IEEE Nuclear Science Symposium and Medical Imaging Conference*

Conclusion


develop
potato / README.md
README.md
Edit README.md
Lorenzo Uplegger authored 1 week ago
Code owners Assign users and groups as approvers for specific file changes.
README.md 8.22 KiB
POTATO
Welcome to the Phase 2 Outer Tracker Analyzer of Test Outputs (POTATO!). POTAT
variables from the histograms, gives the results a grade, and interfaces with the co
Users should refer to the master branch of this repo, while developers should wor
Additional info is available on this twiki page: https://fnal-outer-tracker.docs.cern.c
Installation on Alma 9 (There is a section about a docker c
maintaining it. Please contact the Tennessee)

Conclusion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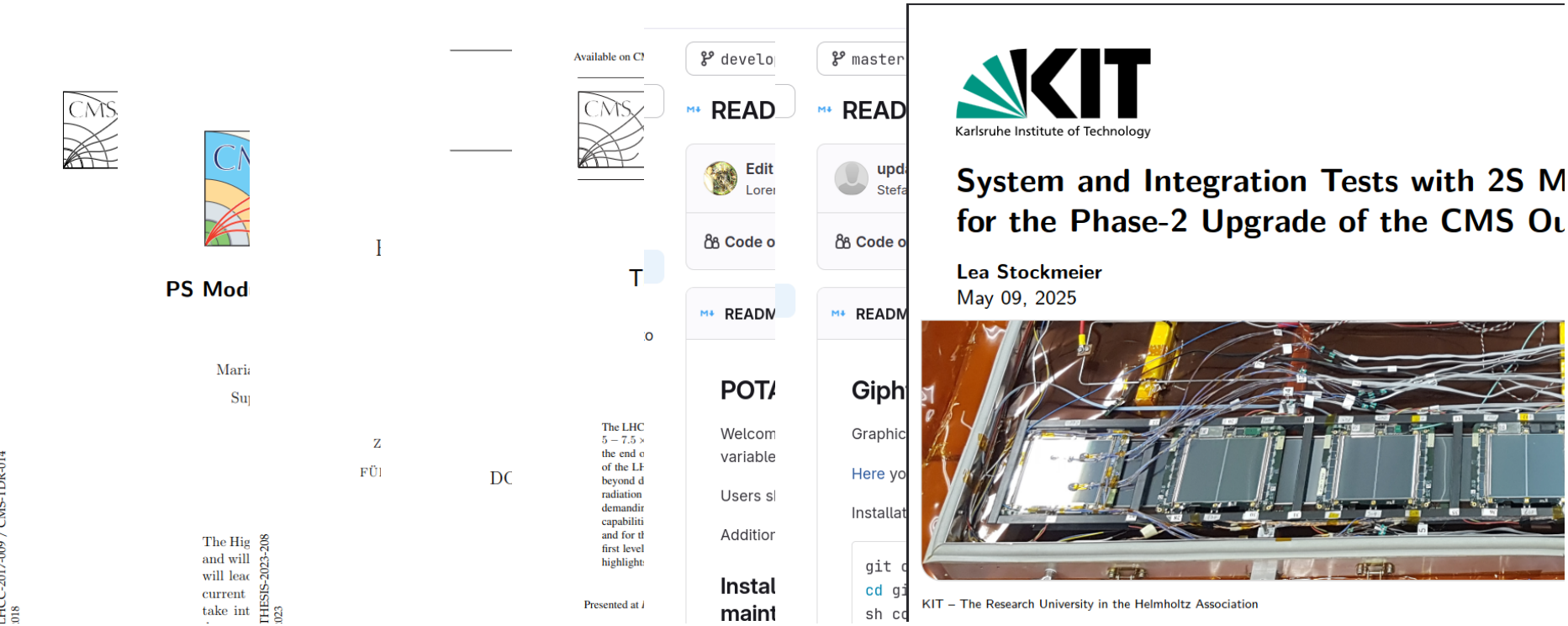
Conclusion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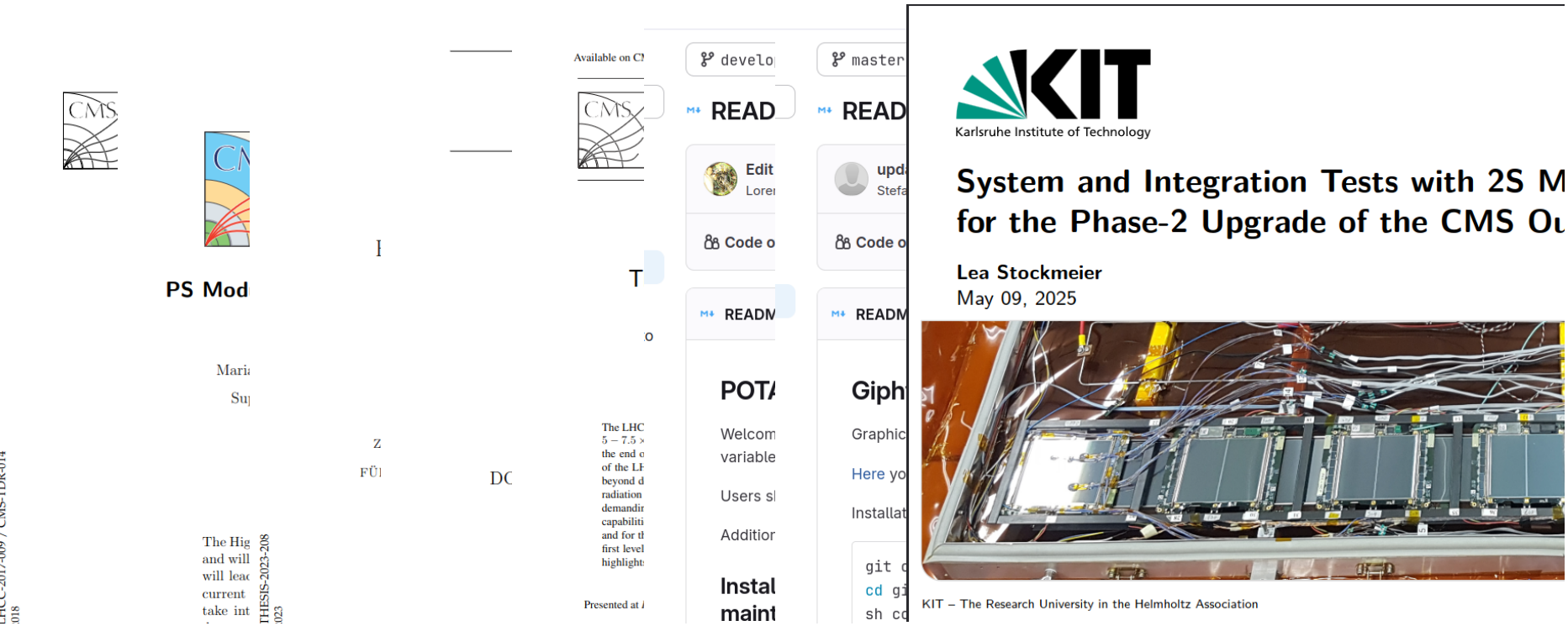
System and Integration Tests with 2S M
for the Phase-2 Upgrade of the CMS Ou
Lea Stockmeier
May 09, 2025
KIT – The Research University in the Helmholtz Association

Conclusion



For now: 5+5 modules to test. In the future: reception of 100s of modules in Lyon: need to have testing framework **ready & efficient**, & knowledge easily accessible.