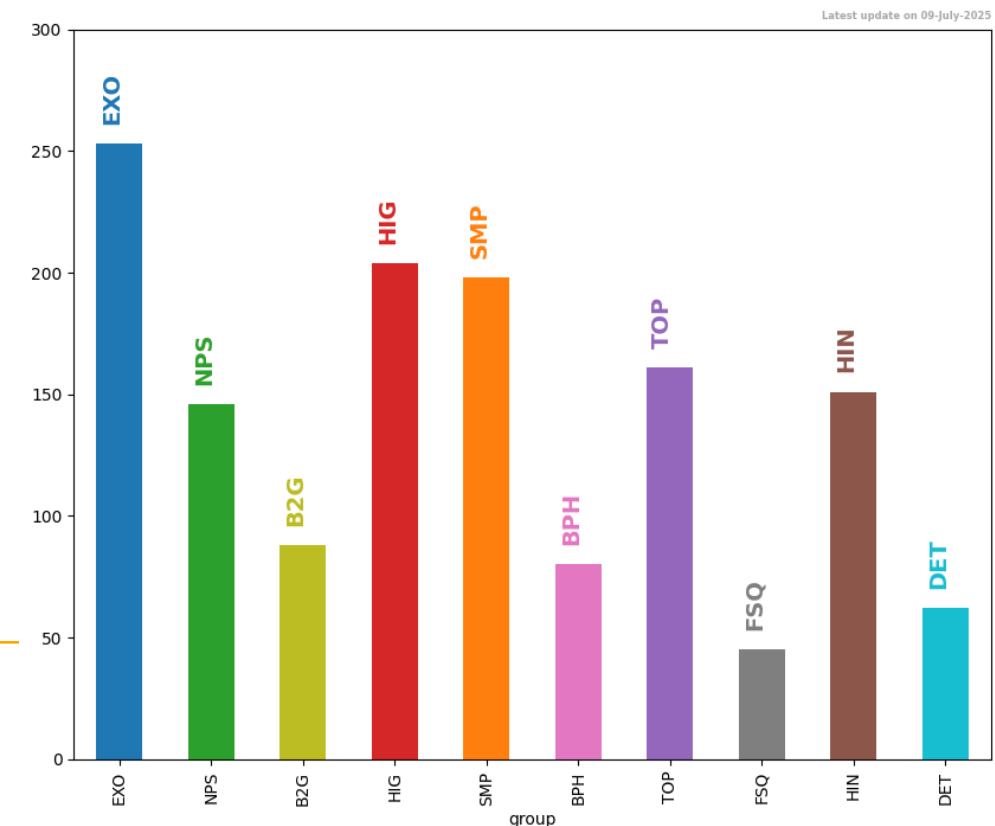

CMS Status report

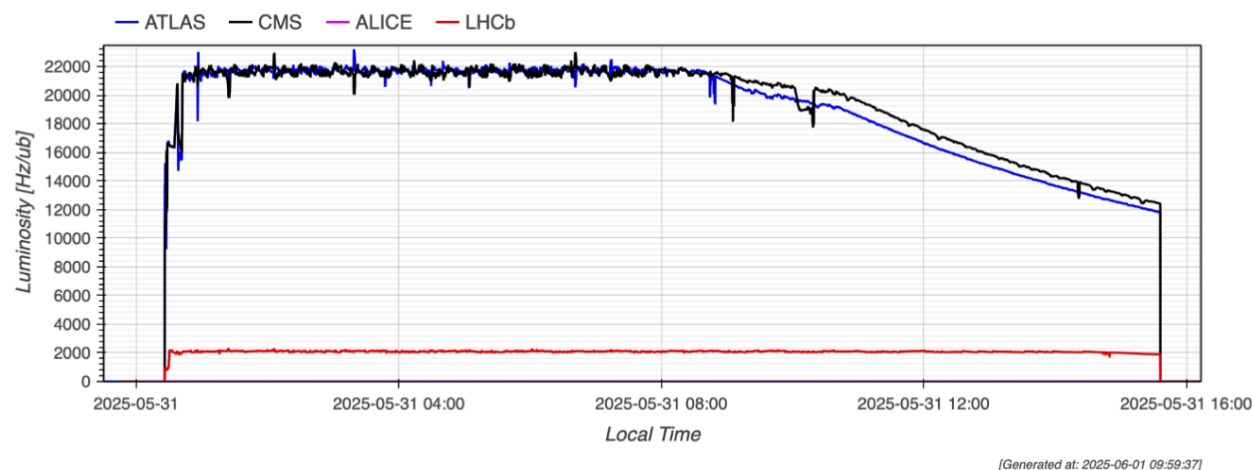
2025 in a nutshell

- Gautier Hamel de Monchenault CMS SP appointed as the Director for Research and Computing at CERN, effective January 1, 2026!
- The 4 LHC experiments have been awarded with 2025 Breakthrough prize in fundamental Physics
 - “For pushing the boundaries of fundamental physics to unprecedented limits”
- Last full year of data taking before LS3
 - In 2026 we will run only up to June
 - Detector is aging but still manageable
 - No major data loss, so far, due to HW failures but physics starts to be affected by ECAL, ES, and pixel detector loss of performance
- Lots of interesting physics results
 - First papers using Run3 dataset (2022->) @13.6 TeV are out.
 - Observation of a Top antiTop quasi-bound state
 - For the first time LHC delivered Oxygen-Oxygen and also Neon-Neon collisions
- Switching gears towards Phase-2

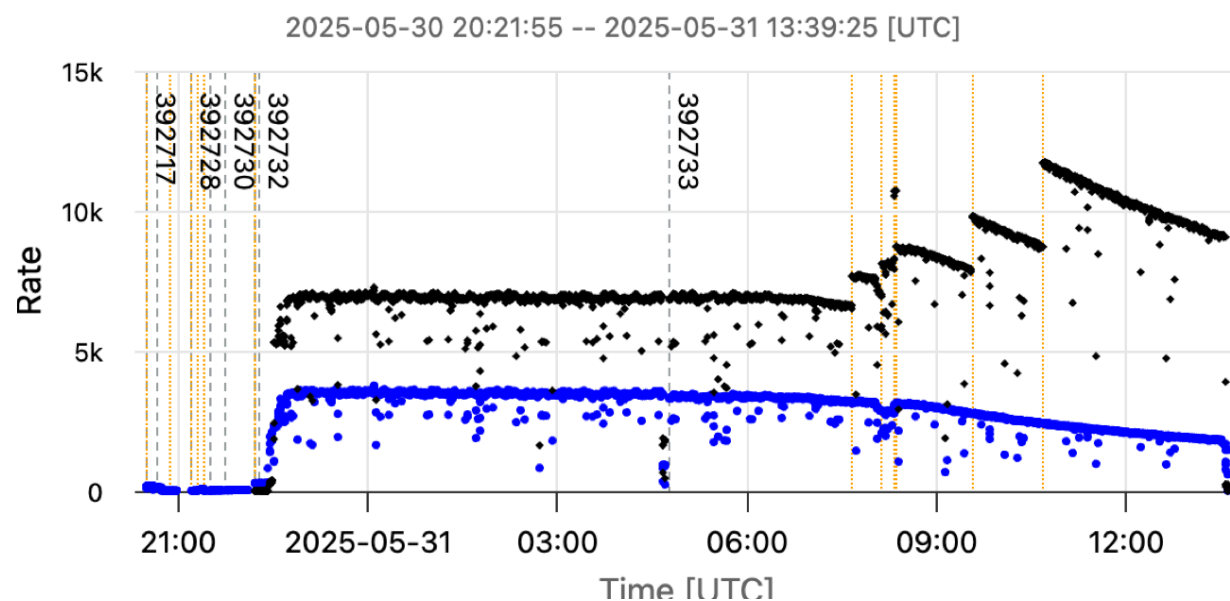


2025 pp Data taking

May 31: CMS is entering the “more than 1 fb⁻¹ of data” per fill



HLT rate

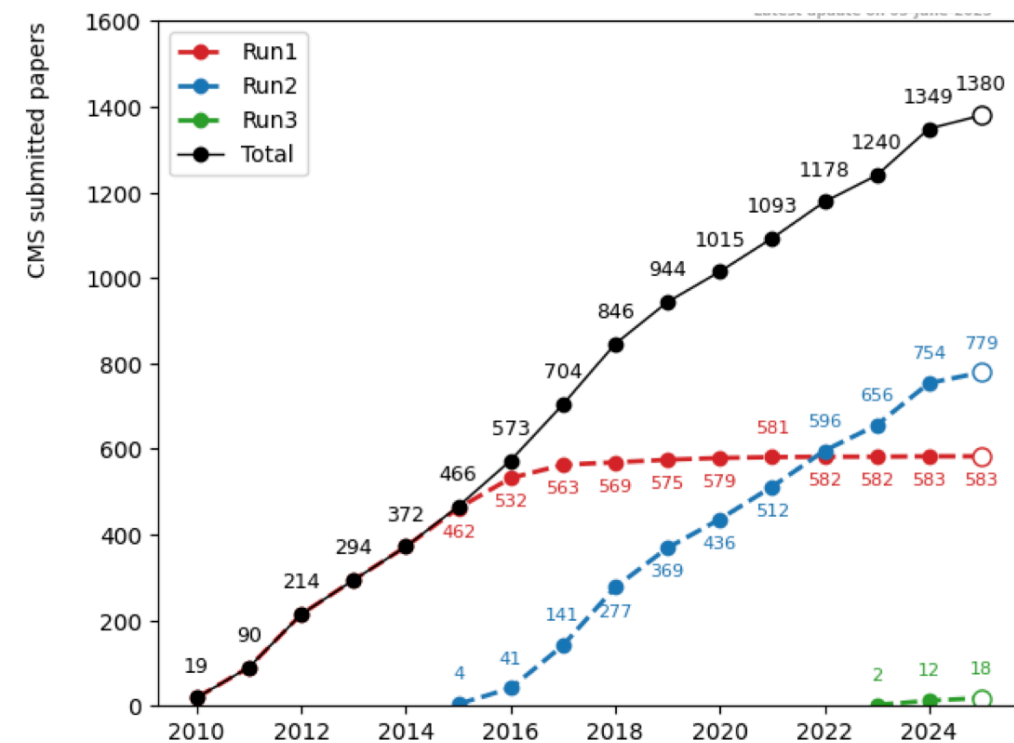
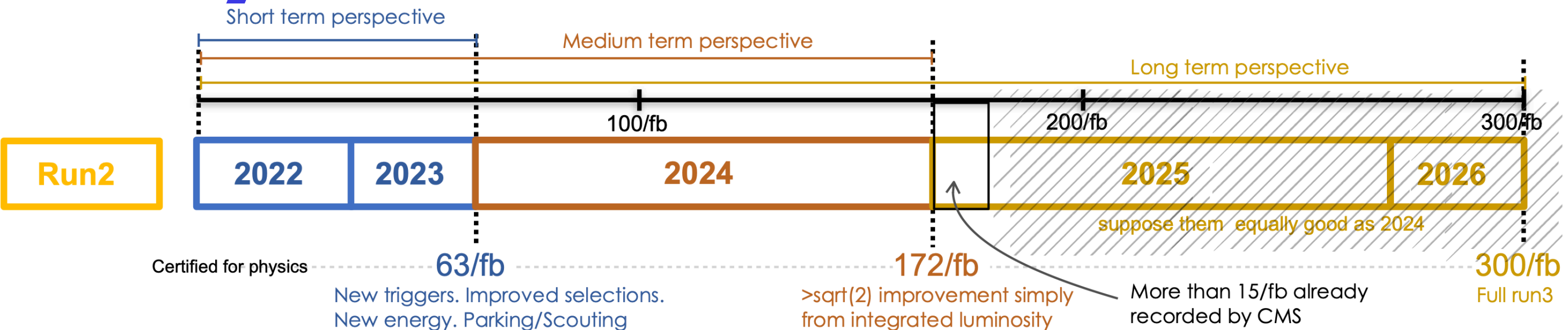


First fill with more than 1 fb⁻¹ of data recorded

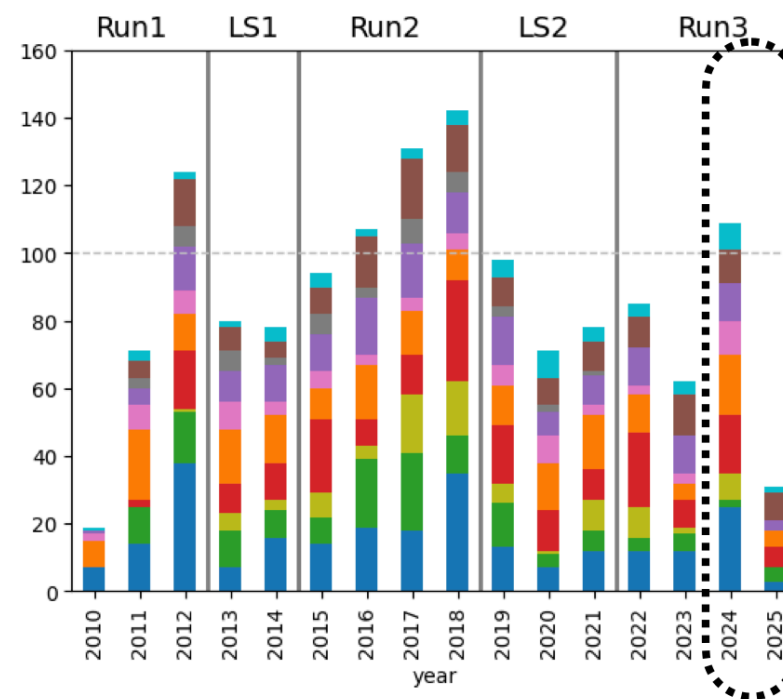
- Fill: 10676
- Date: May 31, 2025
- Duration (Stable Beams): 15.5 hours
- Delivered: 1.06 fb⁻¹
- Recorded: 1.01 fb⁻¹
- Efficiency: 95%
- Levelling at PU63
- L1 rate: 110/105 kHz
- Deadtime: 3-4%
- Levelling: 3.5 kHz (Physics stream) → 7 kHz total

Up to today: 12 fills with more than 800 pb⁻¹

Physics!



Publication rate is steady



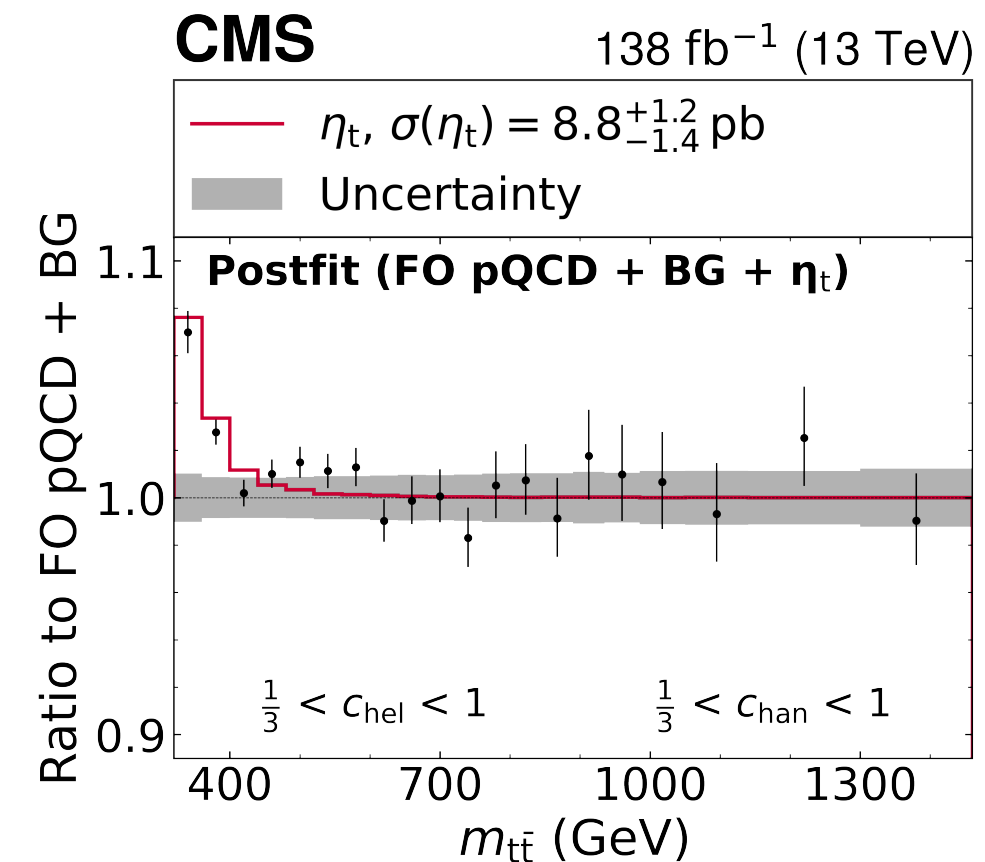
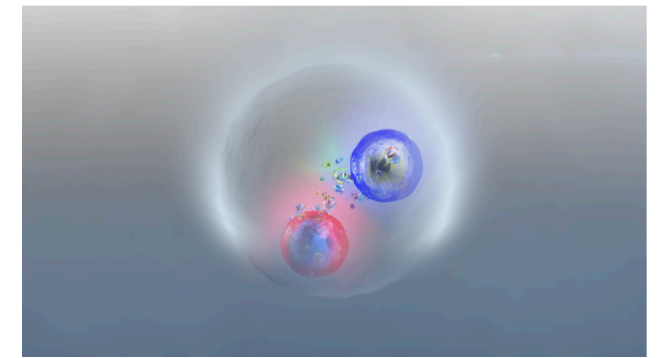
2024 : 109 submitted papers

2025 : 31 submitted papers

4 ready to be submitted

Toponium (?!?)

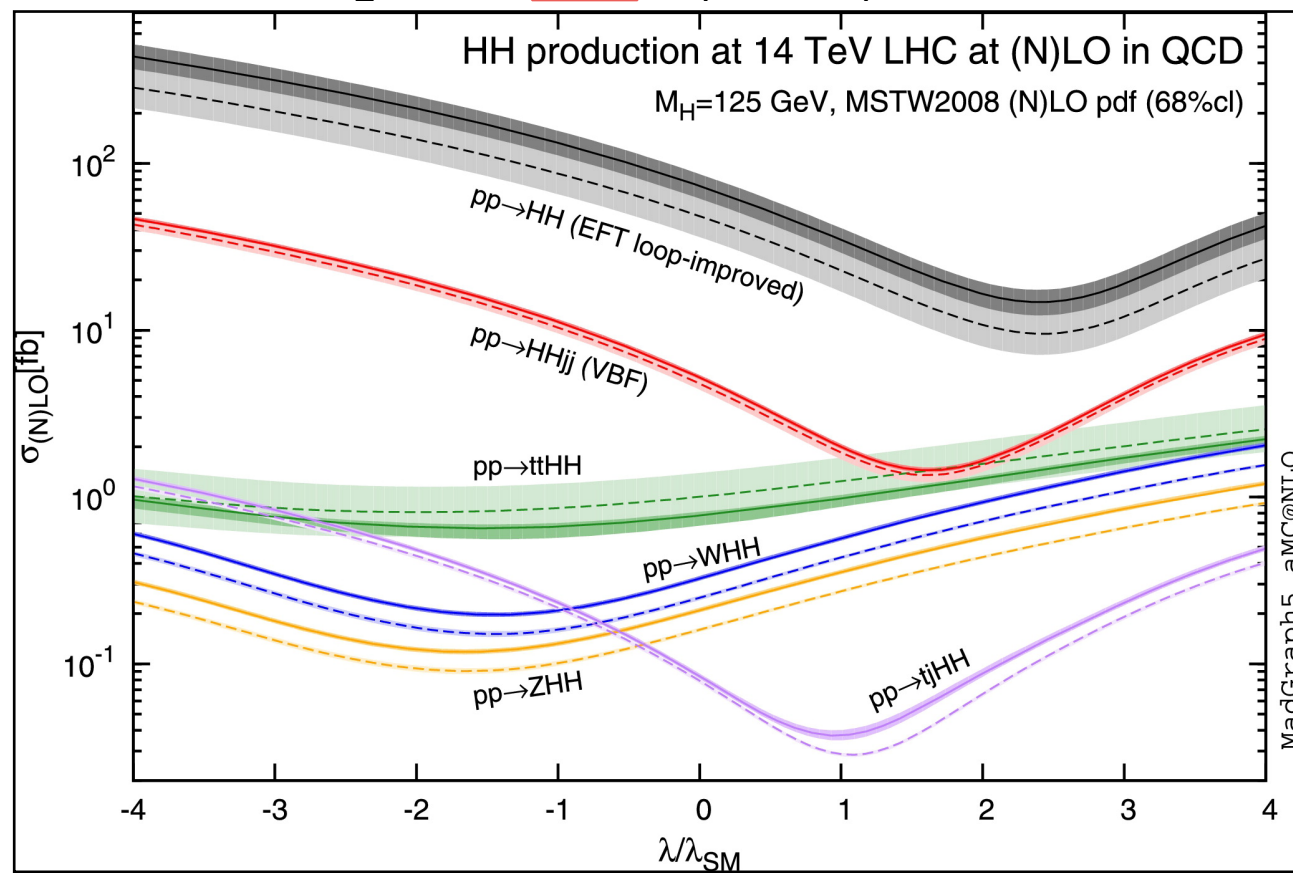
- CMS measured the cross section for the top quark–antiquark excess to be 8.8 picobarns (pb) with an uncertainty of about 1.3 pb.
- Now also ATLAS has found the same excess!
- N.B. this process has always been considered too small to be seen at a hadron collider!
- CMS Collaboration 2024 [TOP-24-007](#)
- ATLAS Collaboration 2025 [ATLAS-CONF-2025-008](#)



Higgs boson self-coupling

- Goal: probe the shape of Higgs boson potential around the minimum by studying Higgs-boson self-interactions
 - N.B. HH production cross-section is ~1000 times smaller than single Higgs one!
- We are involved in two out of three “golden” channels : 4b and bbtatau
 - For the 4b final state we are looking at Run3 data for non-resonant analysis.
 - For bbtatau we are working on both resonant (Run2 data) and non-resonant (Run3 data) analysis.

$$V(H) = \frac{1}{2}m_H^2 H^2 + \boxed{\lambda v H^3} + \frac{1}{4}\lambda H^4 - \frac{\lambda}{4}v^4$$



$W^+W^-\gamma\gamma$
 Obs. (Exp.): 95 (54)

$b\bar{b}ZZ, 4l$
 Obs. (Exp.): 33 (41)

$\gamma\gamma\tau^+\tau^-$
 Obs. (Exp.): 31 (26)

Multilepton
 Obs. (Exp.): 22 (20)

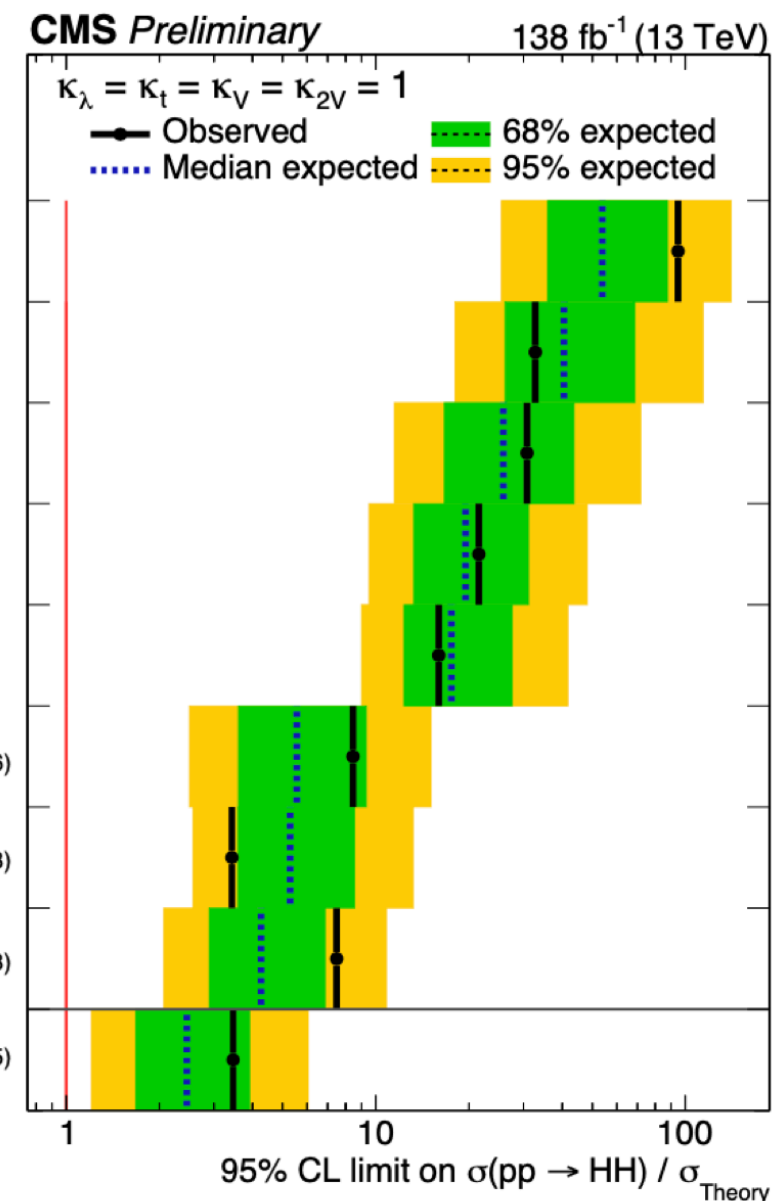
$b\bar{b}W^+W^-$
 Obs. (Exp.): 16 (18)

$b\bar{b}\gamma\gamma$
 Obs. (Exp.): 8.4 (5.6)

$b\bar{b}\tau^+\tau^-$
 Obs. (Exp.): 3.4 (5.3)

$b\bar{b}b\bar{b}$
 Obs. (Exp.): 7.5 (4.3)

Combined
 Obs. (Exp.): 3.5 (2.5)



Higgs boson self-coupling

HH→4b

- Analysis based on “early” Run3 data collected in 22+23
- **Two regimes:** resolved jet topology and fully merged one
- **Several novelties developed in preparation for the analysis since 2022:** (1) new triggers dedicated to HH→4b, (2) improvements to b-tagging and jet p_T regression, (3) dedicate calibration and uncertainties of AK4 p_T regressed jets, (4) dedicated calibration of merged $X \rightarrow bb$ taggers via boosted $Z \rightarrow bb$
- **Several novelties introduced in the analysis:** (1) transformer for signal-to-bkg separation (2) background estimation methods revamped (3) increased number of background validation and closure tests (4) completely new analysis in the merged topology

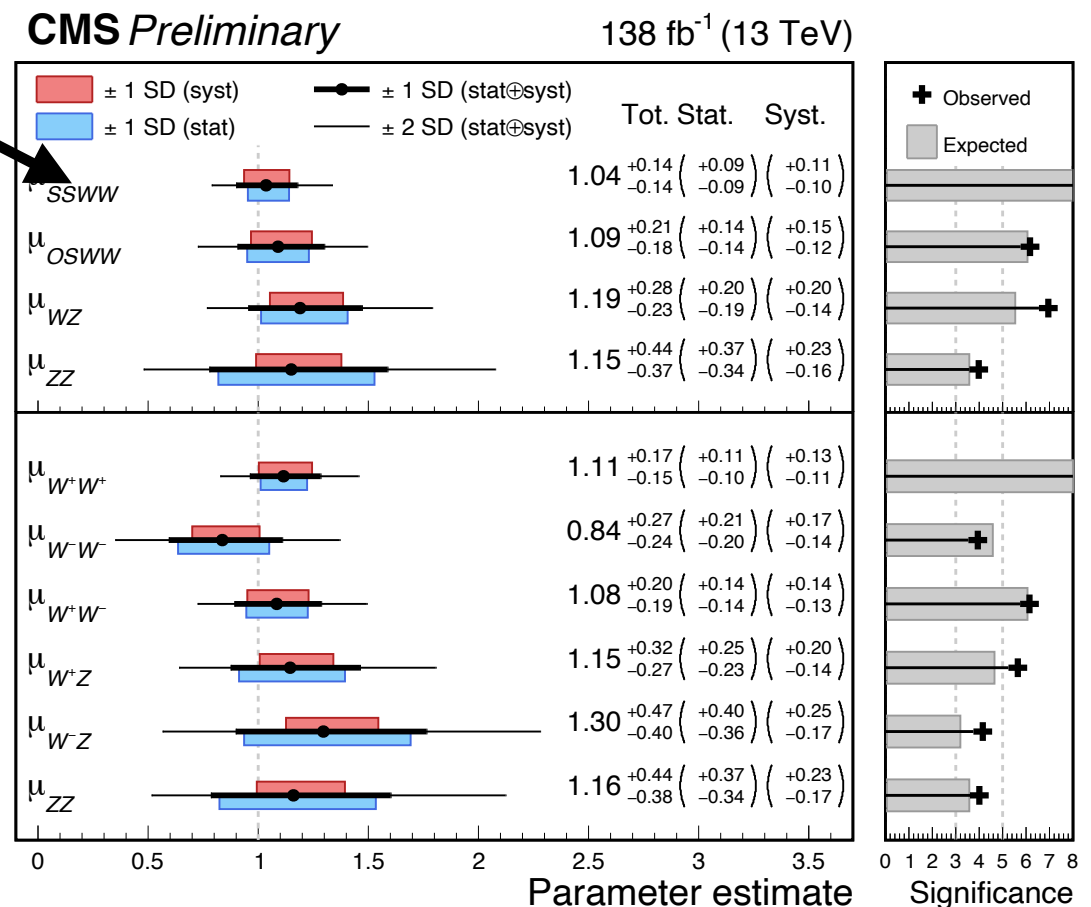
HH→bbττ

- Analysis based on “early” Run3 data collected in 22+23
- **Three regimes:** resolved topology, $H \rightarrow \tau\tau$ with boosted tau reconstruction, and merged $H \rightarrow bb$
- **Several novelties developed:** (1) new triggers lowering τ thresholds exploring the di-jet system (2) improvements in τ identification (2) boosted analysis optimised (3) dedicated VBF-HH analysis under development
- **Several novelties developed:** (1) new triggers lowering τ thresholds exploring the di-jet system (2) improvements in τ identification (2) boosted analysis optimised (3) dedicated VBF-HH analysis under development

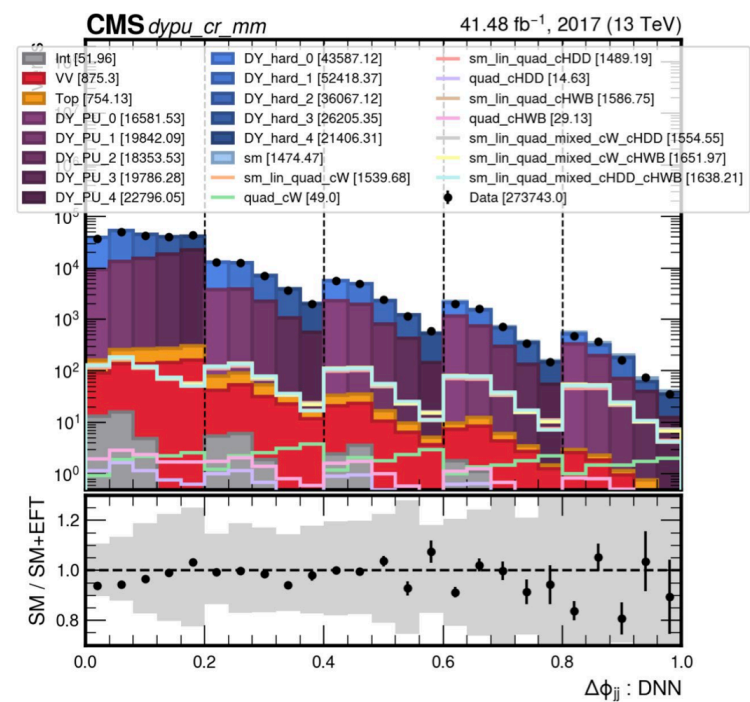
Vector Boson Scattering

Very nice article on the cern courier this month: [decoding-the-higgs-mechanism-with-vector-bosons](#)

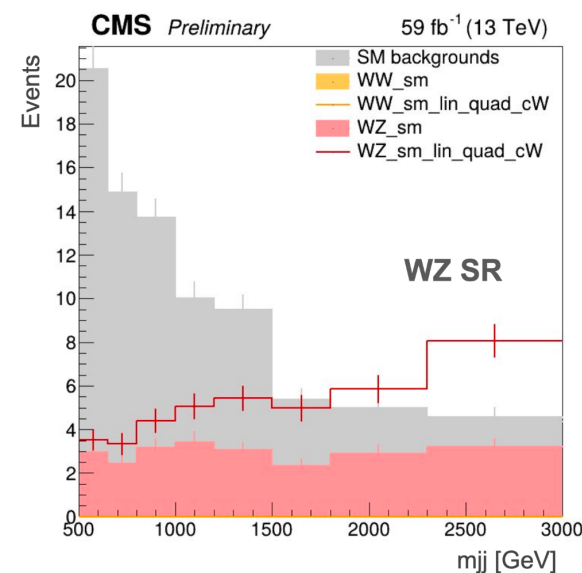
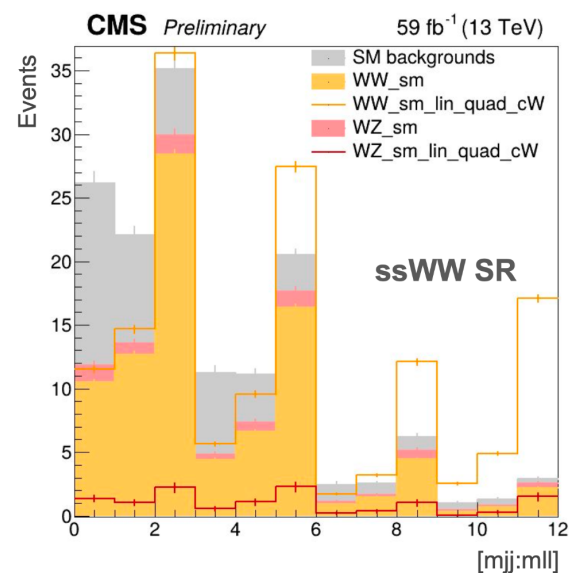
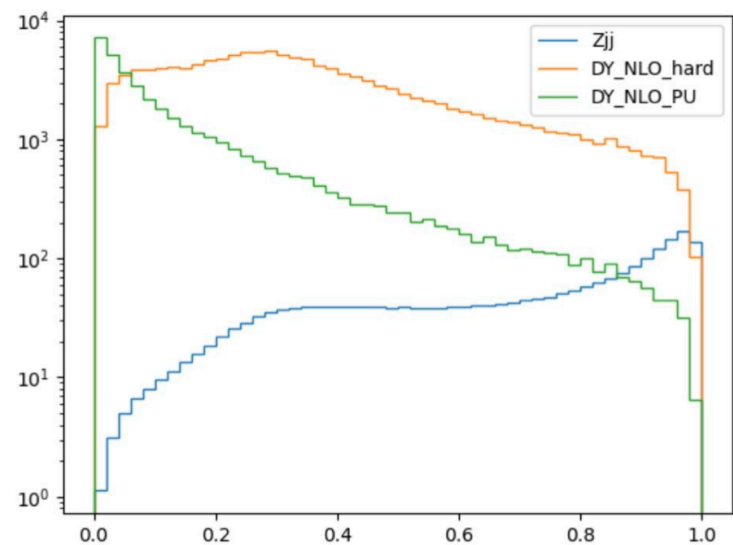
- MIB group has a leading role in VBS physics since several years and contributed to create a Italian network of institutes working on VBS physics.
 - This network comprises MIB, Perugia, Turin, Florence, and Padova
- VBS analyses conducted at MIB with Run2 data: WW scattering OS [Link] and WW+WZ semi-leptonic scattering [Link]
- Leading role in the VBS Run2 cross section combination
- Deeply involved in EFT interpretations of Run2 VBS analyses: channels on which we are working on are OS WW, WW+WZ semi-leptonic, and same-sign WW scattering.
- Run3 prospects: focus on the most important VBS process in terms of sensitivity i.e. same-sign WW scattering. Goal is to (1) release a first set of unfolded differential cross section measurements and (2) measurement of polarised scattering amplitudes by improving the methodology used in Run2
- Nota bene: the group is also active in EFT interpretations and differential cross section measurements of other rare electroweak processes like VBF-Z and VBF-W production



VBF Z e SSWW



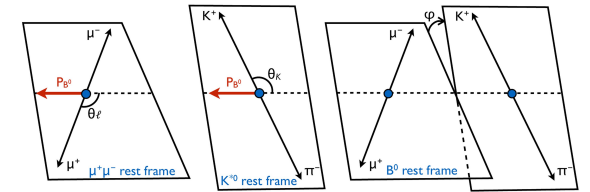
DNN output



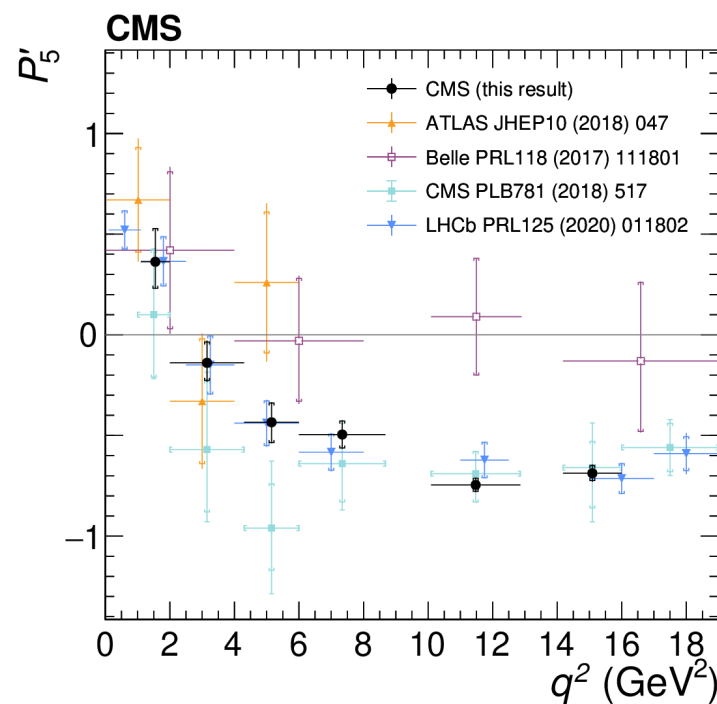
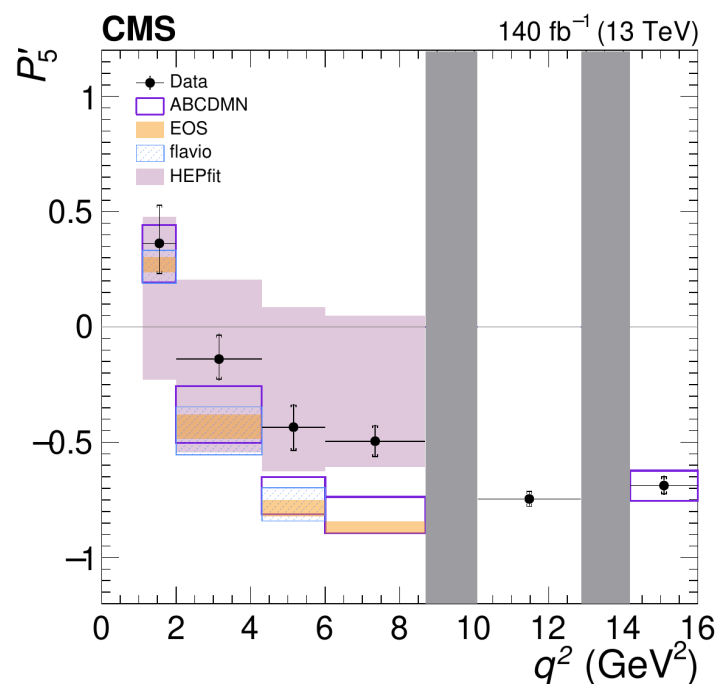
	cW	cHW	cHWB	cHDD	cHB	cHbox
VBS SSWW (e, μ)	✓	✓	✓	✓		✓
VBS SSWW τ had	✓	✓	✓	✓		✓
VBS WZ	✓	✓	✓	✓		✓
VBS WV semilep	✓	✓	✓		✓	✓
VBS ZV semilep	✓	✓	✓		✓	✓
VBF-Z	✓		✓	✓		
VBF-W	✓		✓	✓		
VBF- γ	✓		✓			
WW	✓		✓	✓		
VV	✓	✓	✓	✓	✓	✓

$B^0 \rightarrow K^*(892)^0 \mu^+ \mu^-$ angular analysis

- $B^0 \rightarrow K^*(892)^0 (\rightarrow K^+ \pi^-) \mu^+ \mu^-$ FCNC process forbidden at tree level & CKM disfavoured:



- CP-average angular decay rate can be fully described by θ_K, θ_l, ϕ and the dimuon mass² (q^2).
 - PDF parametrized by 8 “clean” observables: i.e. their prediction are affected by reduced theoretical uncertainties.
- Run 2 Analysis ($\sqrt{s}=13, 140 \text{ fb}^{-1}$) published in 2025: DOI : 10.1016/j.physletb.2025.139406 (presented at LHCP2025).
 - First analysis in CMS that exploited the entire set of 8 observables, though 4-dimensional UML fits (mass, 3 angles) on all q^2 bins.



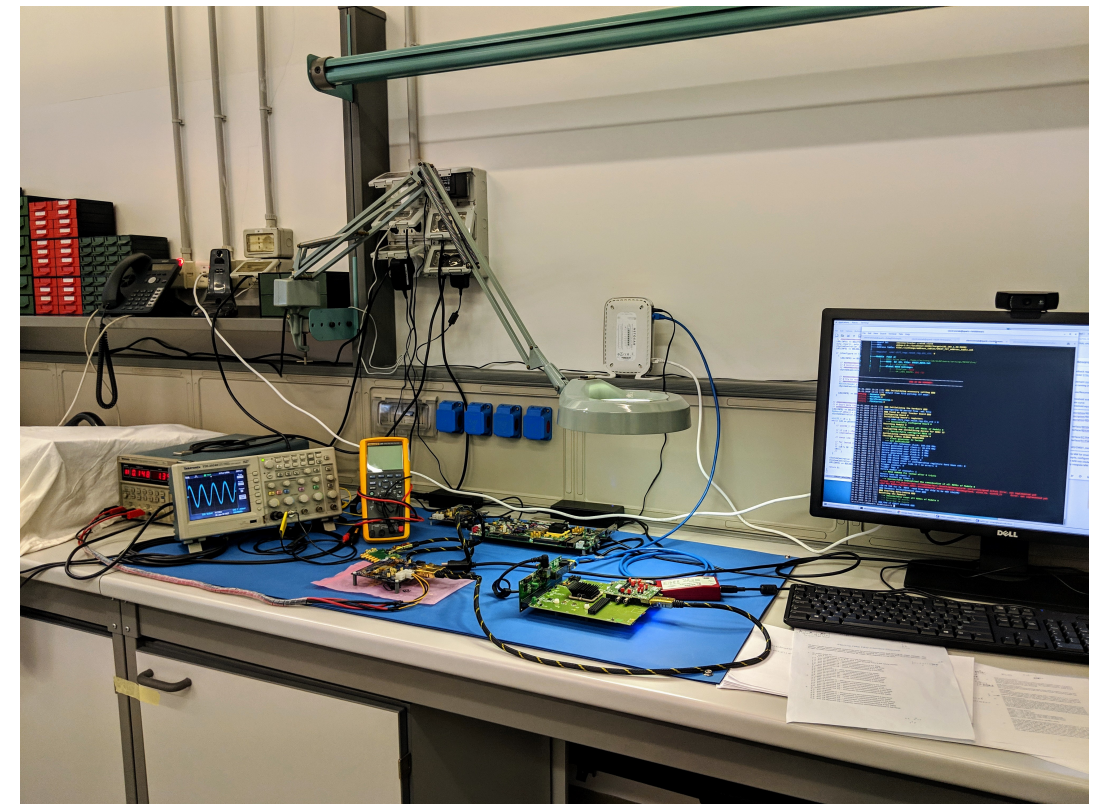
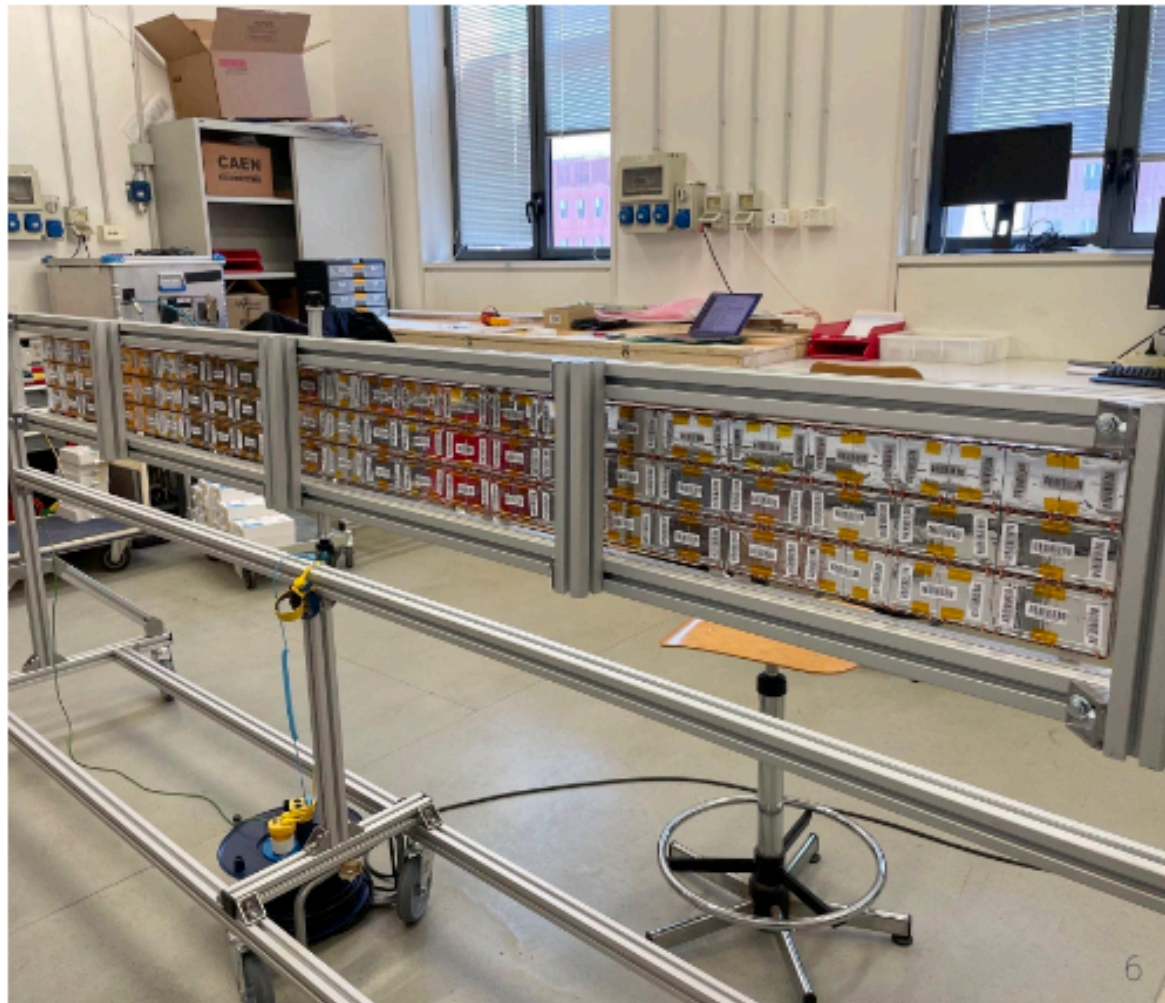
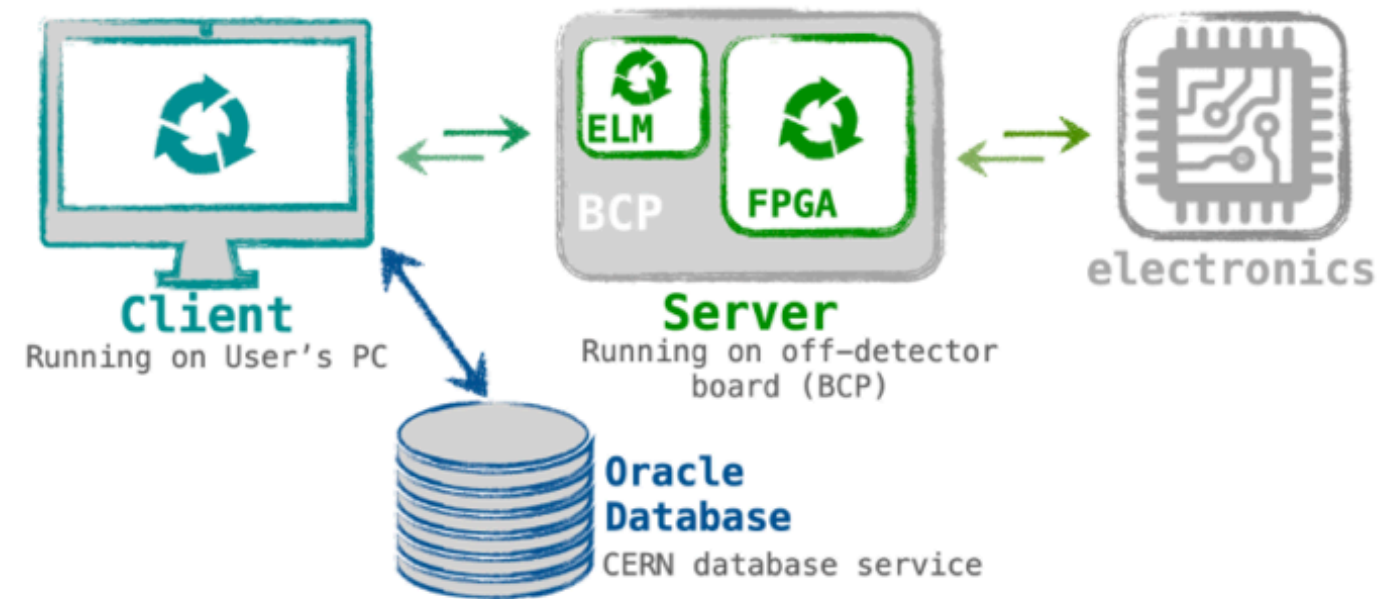
Contribution to “European Strategy for Particle Physics Update” for the projections of this measure @HL-LHC (ESPPU-24-001).

Run 3: still no plan but the analysis team members agree to restart the analysis’ effort. They are looking for new manpower.

$P'5$ the most interesting observable for NP, with tensions wrt some SM predictions.

CMS precisions are quite comparable with that of LHCb. So far, it’s the only experiment able to compete on this measure.

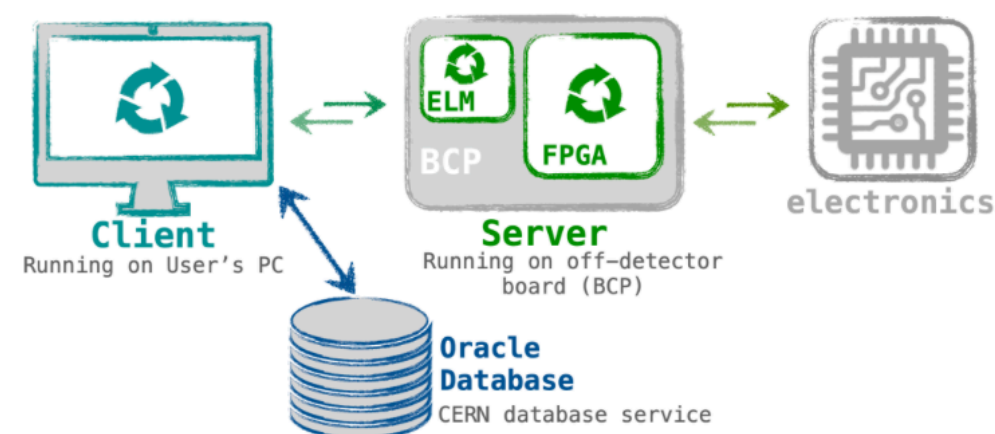
Phase2



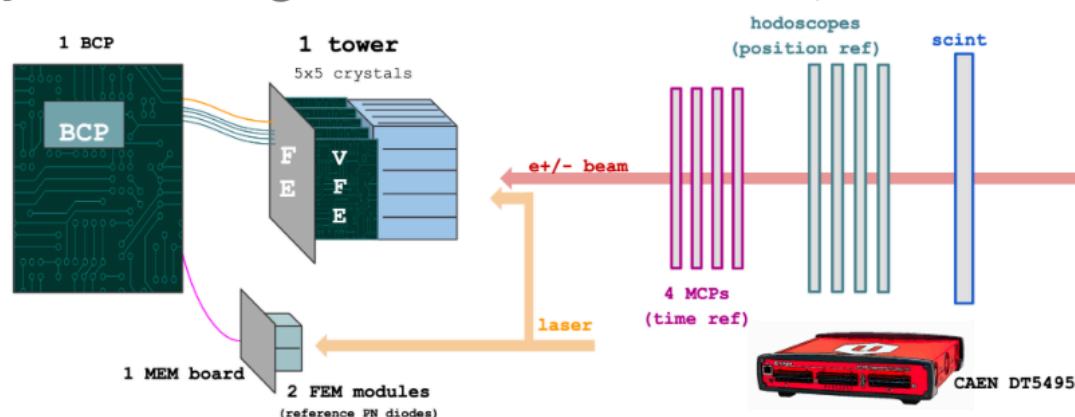
ECAL upgrade DAQ SW

Contribution to the **development of DAQ software for ECAL Phase 2 Upgrade:**

- Joined the development of C++/Python software (now successfully **configures electronics** and **acquires data** with latest prototypes available)
 - integration with XDAQ tools ongoing
- Worked on **database** for configuration data
- **Monitoring tools** under development



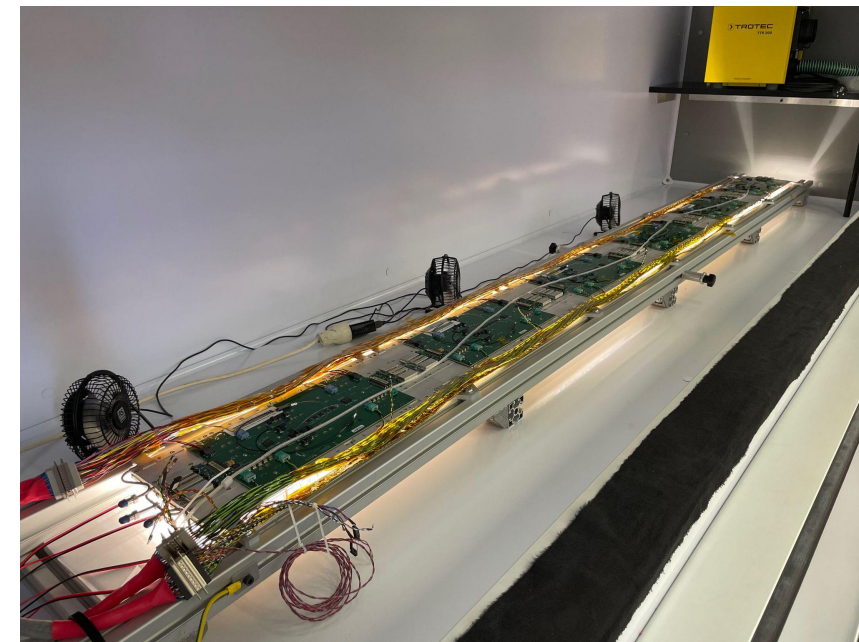
System testing: **contributions to 2023,2024 and 2025 beam test campaigns @CERN SPS facility**



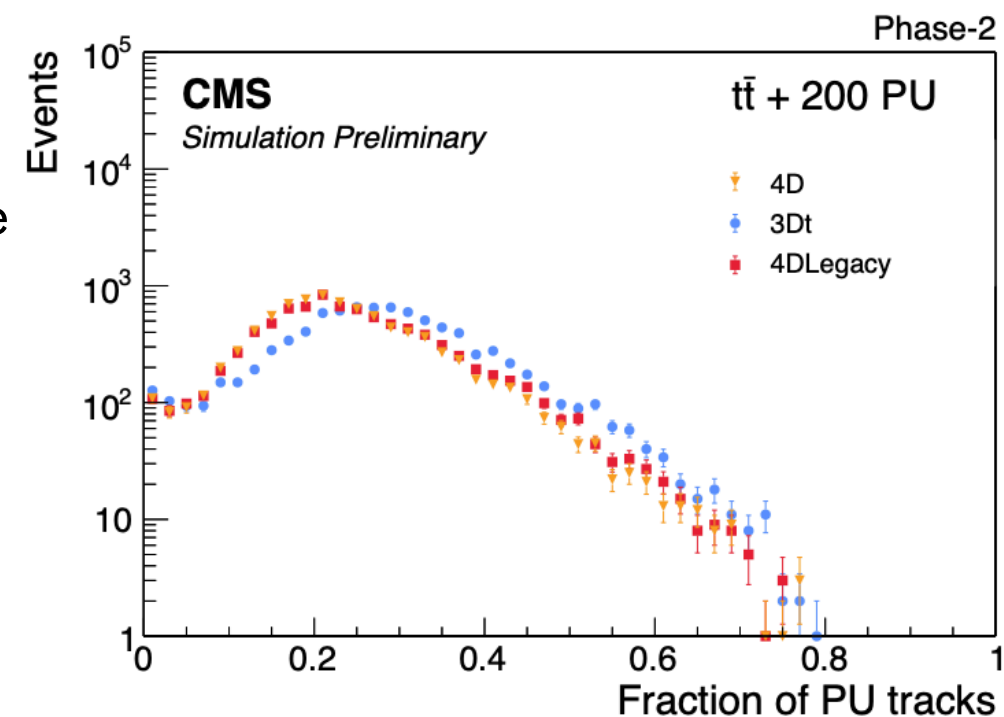
- Worked on the **installation and operation of the setup in 2023 and 2024**
 - full ECAL readout chain in place
- Currently **developing SW for 2025 TB** (october)
 - largest scale TB so far: about **20 readout units**, **2 off-detector boards**, latest prototypes

MTD-BTL

- Assemblaggio dei moduli e dei segmenti
 - 70% dei moduli assemblati
 - Assemblaggio remoto dei tray in corso (4 su 18)
- Sviluppo del DAQ per il readout di BTL per gli Assembly Centers
- DPG: update della simulazione e uso del timing nella ricostruzione



- Paper pubblicati nell'ultimo anno:
 - “Optimization of LYSO crystals and SiPM parameters for the CMS MIP timing detector” [JINST 19 (2024) 12, P12020]
 - “The CMS Barrel Timing Layer: test beam confirmation of module timing performance” [accept. by NIM]



The Compact Muon Solenoid Collaboration
confers on

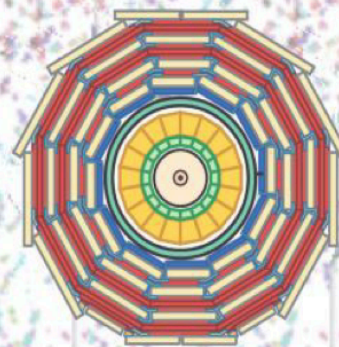
Simona Palluotto
Università Degli Studi Milano-Bicocca – Italy

CMS 2024 Award

**For outstanding contributions to the optimization and performance validation
of MTD Barrel Timing Layer sensors**

The Collaboration Board Chairperson
(Elisabetta Gallo)

Elisabetta Gallo



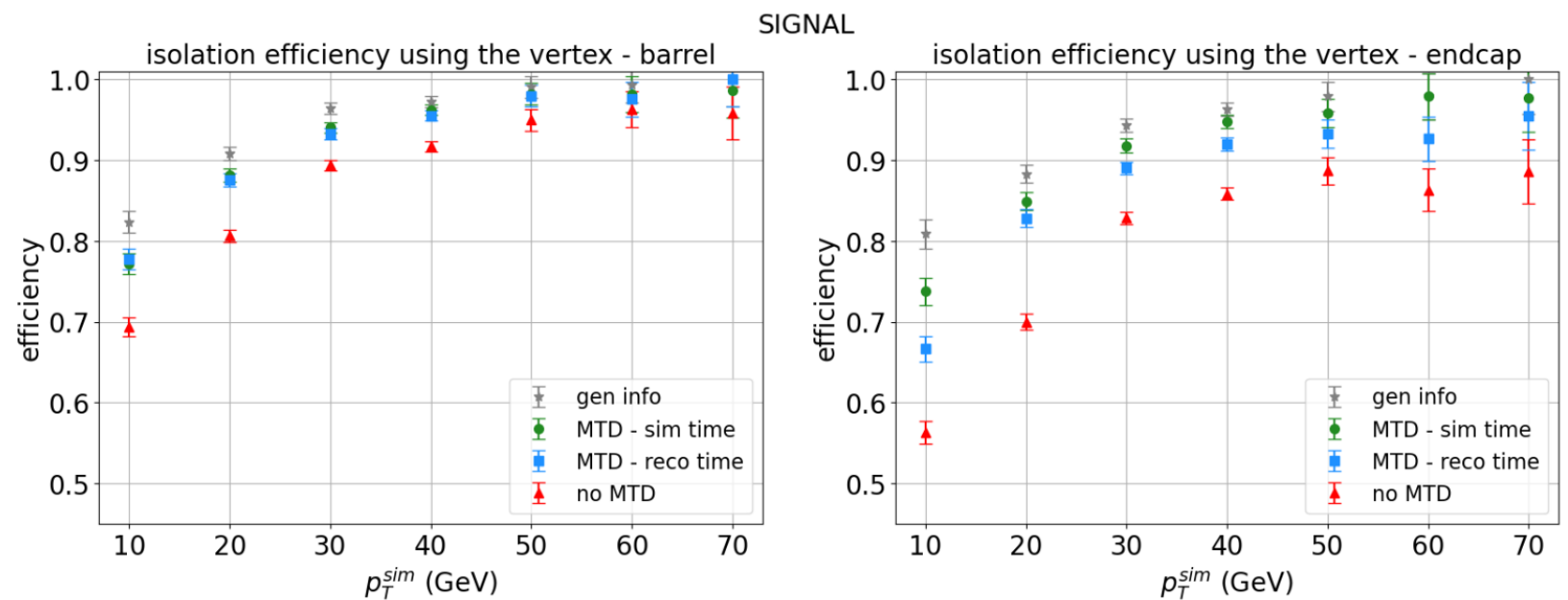
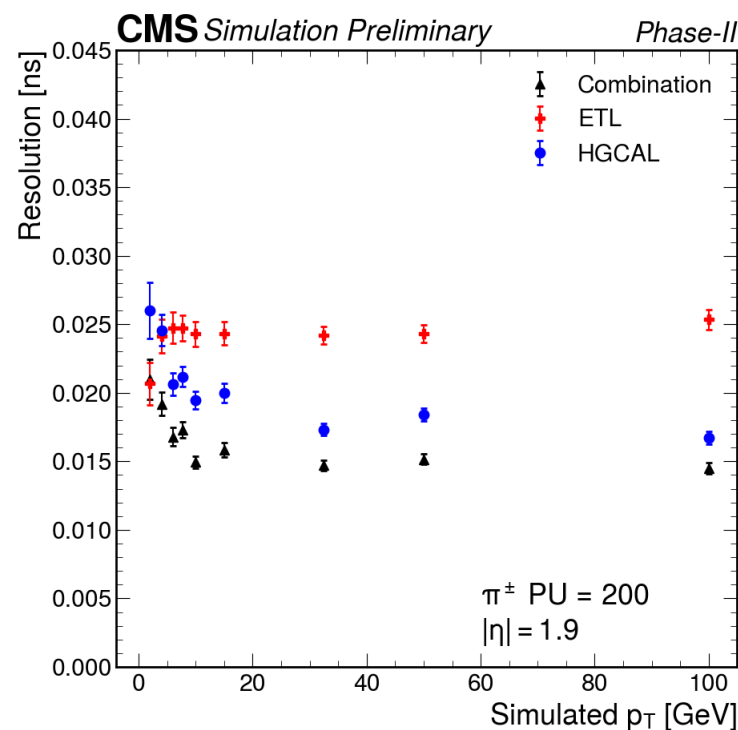
June 11th, 2025

The Experiment Spokesperson
(Gautier Hamel de Monchenault)

Gautier Hamel de Monchenault

Reconstruction and isolation with MTD

- Time compatibility when linking tracks with energy deposits in HGICAL
 - compare the time of the track from MTD and the cluster time from HGICAL and reject the link if they are not compatible
- Combination of MTD and HGICAL information for the final time assignment to the Particle Flow candidates
 - improves the time resolution
- Electron isolation in PU200 using MTD information
 - track around the electron are not used for the isolation computation if their time and the electron time at the vertex are not compatible

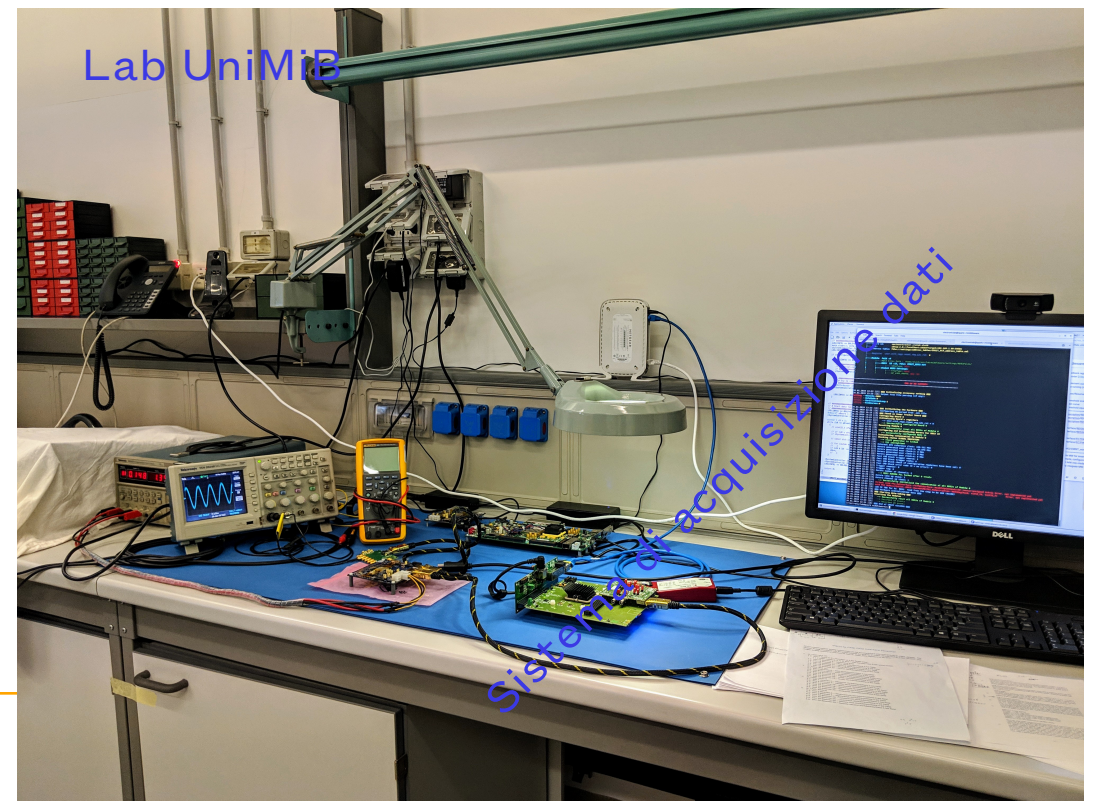
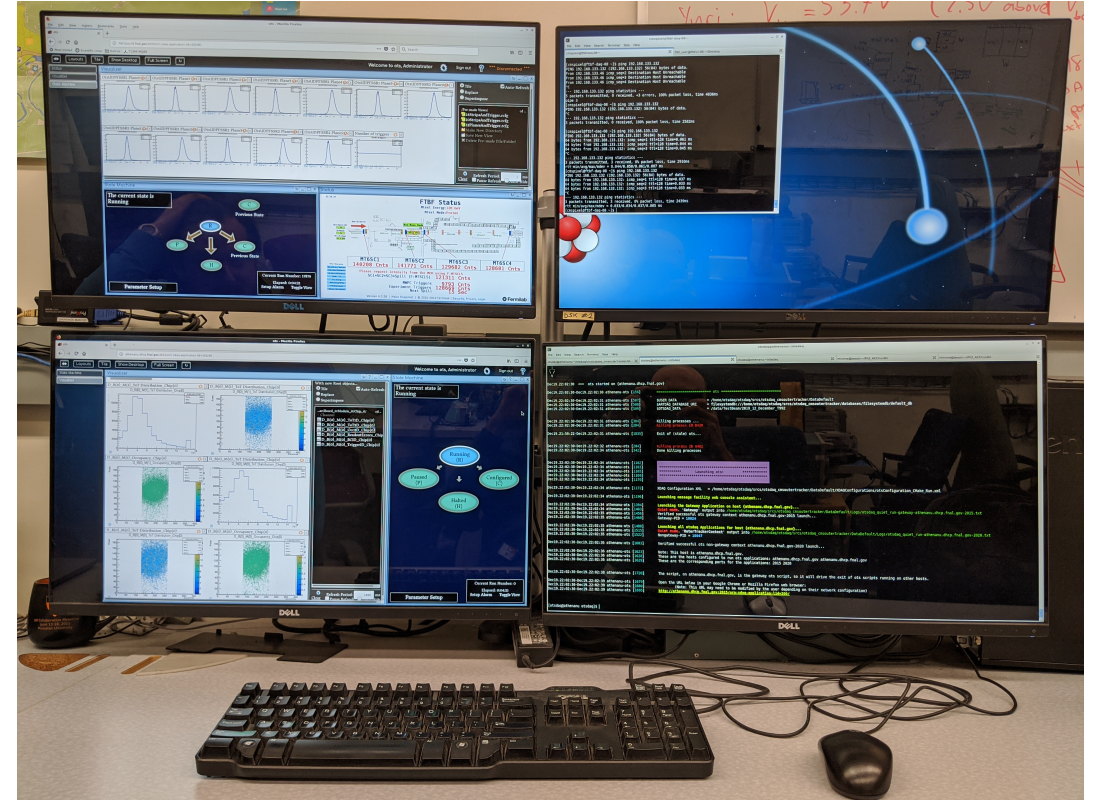


$Z \rightarrow e^+e^-$, PU = 200

Attività Tracker

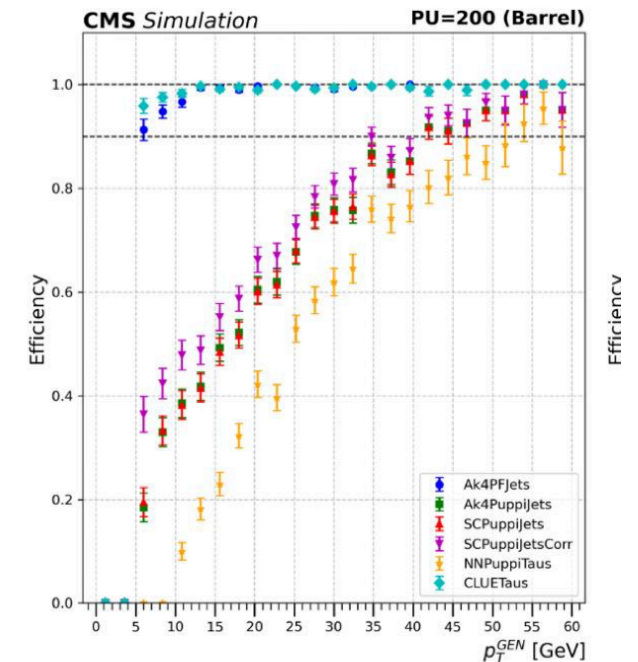
- The $\sim 2 \times 10^9$ pixels of the final detector need to be calibrated and monitored for the greatest data quality. We developed the software that handles the detector in all its aspects on test bench, and on beam test experiments
- We are responsible for the Production Quality Assurance (PQA) of pixel modules within the CMS collaboration → There will be an ongoing work to address the needs for PQA
- Article:
 - We wrote an article on the Data Acquisition Software for the PQA, and we are currently in the process of addressing the comments of the internal CMS review
 - Performance of the 3D silicon pixels in internal review

Slowly moving towards final system for integration at CERN

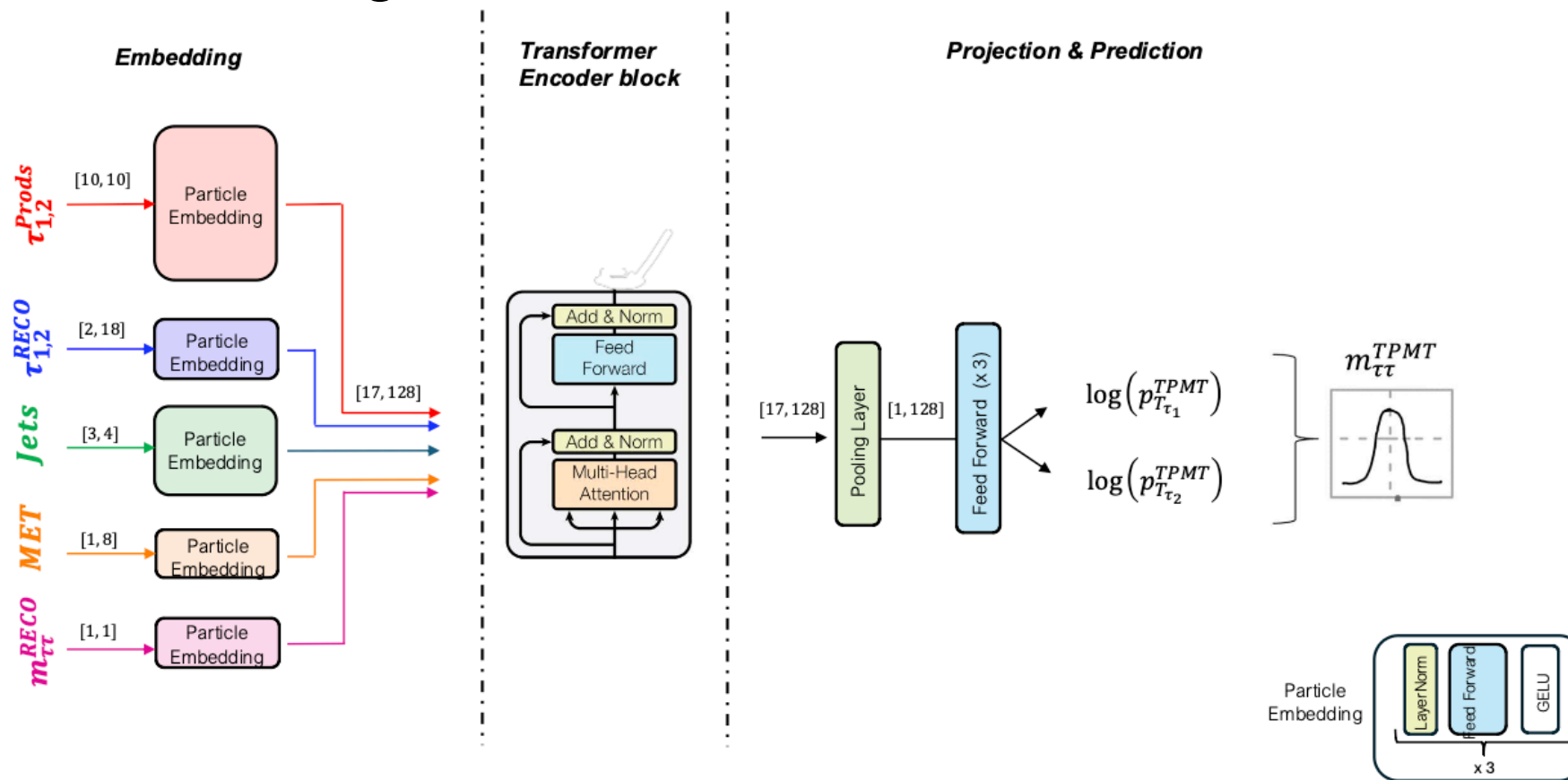
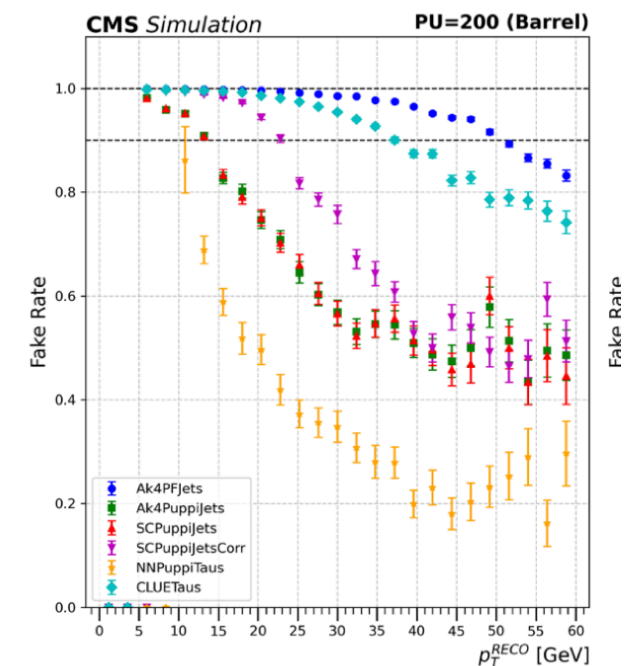


Scouting analysis

- In congiunzione con un progetto finanziato da Terabit con fondi PNRR (aka FPGA cluster) abbiamo iniziato a lavorare su metodi alternativi per le analisi dati a HL-LHC, sfruttando la cosiddetta stream di scouting.
- Abbiamo due benchmark analisi
 - W->3 pion
 - Low pT taus da low mass resonances
- Entrambi i progetti prevedono l'utilizzo di FPGA per parte dell'analisi e l'uso di ML on edge devices



Fake



Conclusions

- The group has several commitments in analysis and HW development and is playing a major role in MTD and in the tracker DAQ for upgrade
- 3 out of 5 PhD have a doctoral contract at cern while the other 2 spent there 1 year thanks for the CSN1 contracts (once known as Simil Fellow)
- CMS is aging fast, but we should arrive to the end of Run3 with limited impact in the physics program
- Phase-2 activities are becoming more and more demanding the more we approach the start of LS3

Back up

Responsabilità

Nome/Cognome	Progetto	Descrizione	Livello
Andrea Massironi	CMS	Run Coordinator	1
Luca Guzzi	FISICA	HLT Tracking contact	3
Andrea Benaglia	MTD	MTD BTL system	3
Martina Malberti	MTD	DPG convener	2
Mauro Emanuele Dinardo	TRACKER	BES Production SW	3
Simone Gennai	TRACKER	FB italian representative	3
Marco Toliman Lucchini	MTD	MTD BTL Sensor	3
Flavia Cetorelli	MTD	BTL Test Beam Analysis coordinator	3
Marco Paganoni	MTD	Resource Manager MTD	2
Paolo Dini	CALCOLO	DR computing	3
Luca Guzzi	TRACKER	Responsabile beam spot	3
Federico Deguio	MTD	BTL DAQ Contact	3

2025 Breakthrough Prize in Fundamental Physics

For detailed measurements of Higgs boson properties confirming the symmetry-breaking mechanism of mass generation, the discovery of new strongly interacting particles, the study of rare processes and matter-antimatter asymmetry, and the exploration of nature at the shortest distances and most extreme conditions at CERN's Large Hadron Collider.

Patricia McBride (Fermilab, spokesperson 2022 to 2024) accepted the prize on behalf of the collaboration. The \$1 million (of the \$3 million prize) allocated to CMS was donated to the CERN & Society Foundation for grants to doctoral students from member institutes to spend research time at CERN.

[Prize Laureate are all authors up to July 2024](#)

The LHC
experiments
represented by

- Marco Van Leeuwen
- Andreas H \ddot{o} cker
- Patricia McBride
- Vincenzo Vagnoni



Tautau Mass reconstruction

