2025

Physics analyses at the LHC. – A search analysis for scalar top quark (stop) production in a supersymmetric extension of the Standard Model (SUSY) that assumes a compressed mass spectrum – a small difference between the masses of the stop and the neutralino, the lightest supersymmetric particle (LSP) – is being pursued in collaboration with the MTA-ELTE Lendület CMS group. The analysis focuses on long-lifetime stop decays in the kinematically most plausible, four-body decay scenario with the expectation to improve the exclusion limits of the previous analysis (shown in Fig. 1). In 2025, the reconstruction and particle identification efficiency ratio of data and simulation for the prompt electrons has been evaluated. This calculation for electrons in the displaced region, and for muons overall is in progress. The analysis is expected to be completed and the publication process started in 2026.

The final status report of the search in the gauge-mediated SUSY breaking model – in which low-mass gravitinos are assumed to be the LSP and neutralinos the next-to-lightest supersymmetric particles – has recently been prepared, concluding our efforts in this analysis channel. The pre-approval is expected to take place in early 2026.

The analysis searching for supersymmetry in hadronic and leptonic final states with highly Lorentz-boosted objects using razor variables was finally approved in 2025. The Physics Analysis Summary has been released [1], and the publication of the results is under preparation.

Detector operation and construction. – We participated in the operation of the CMS Tracker and in the performance studies of the pixel detector: analyzed the high voltage bias scans taken through the year, and monitored the radiation damage of the silicon sensors. Based on these analyses, the high voltage settings of the different detector layers were increased several times during the year to keep the detection efficiency optimal.

The mass production of the CMS Phase-2 Outer Tracker hybrid electronics ramped up at the manufacturer in 2025. After the successful training of a new team, we started to effectively participate in the visual inspection, and tested ~3700 module components for the future tracker detector. We also photographed all of the electronics arrived to Wigner by the large area optical scanner, and performed linear measurements and automatic checks (e.g. to find contaminated bond pads, or incorrectly soldered components). The automatic checks employed a newly developed, AI-based algorithm.

The CMS BRIL Project (Beam Radiation, Instrumentation and Luminosity) is developing two new detectors for HL-LHC to fulfill the increased luminosity determination requirements: the Fast Beam Condition Monitor (FBCM), which is a standalone detector with unique timing capabilities, and the Tracker Endcap Pixel (TEPX) detector that implements FPGA-based, real-time cluster reconstruction. The prototype detectors were tested in several beam tests at CERN. We contributed to the analysis of the 2024 beam test data, and to the software development. Some aspect of the work has been presented in a poster [2], and the full results published in paper [3].

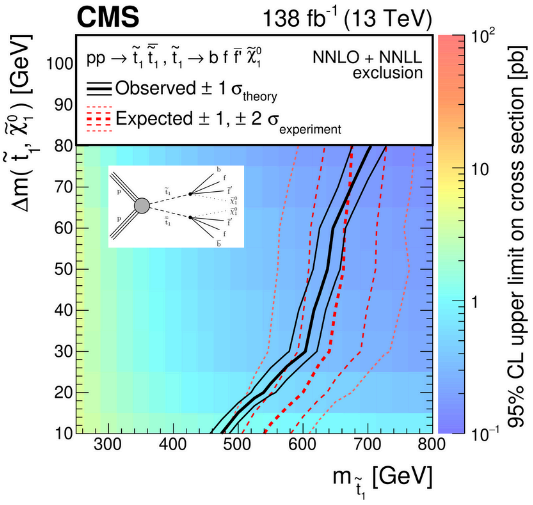

Figure 1: Exclusion limits for the stop mass and mass difference between the stop and the LSP from the Run-2 prompt analysis (JHEP 06 (2023) 060).

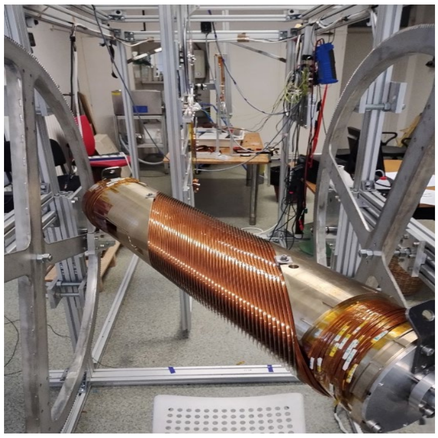

Figure 2: Outer former during the winding process.

Superconducting magnet development. – In the framework of the I.FAST European project, we have successfully designed and manufactured a high-temperature superconductor (HTS)-based Canted Cosine Theta (CCT) magnet, achieving the complete assembly of the 4 Tesla prototype. This collaborative project marks a significant milestone in advancing HTS magnet technology, and the closure of the project in our research group.

The magnet’s development required innovative solutions to handle the unique properties of the REBCO HTS tape, which is sensitive and can only be bent in its "easy" direction. To this end, a dedicated C++ design library was created to calculate the precise 3D winding pattern that achieves the required field quality while respecting the conductor's mechanical constraints.

A crucial achievement was the design and construction of a winding machine. This system fabricates a composite cable in-situ by sandwiching two HTS tapes between two copper stabilizer tapes, all insulated with a Kapton wrap. The machine synchronizes the rotation of a tilted mandrel with the 3D movement of the tape spools, enabling the accurate and repeatable creation of the complex CCT geometry.

The magnet's assembly was a two-stage, international effort:

Winding and Mechanical Assembly at Wigner RCP**:** Using the bespoke winding machine and infrastructure developed on-site, our team successfully wound both the inner and outer superconducting layers onto their respective formers. The complete mechanical assembly of the magnet structure was also performed here. Winding of the outer former is shown in Fig. 2.

Soldering and Impregnation at Elytt Energy (Spain): The assembled magnet was then transferred to our industrial partner, Elytt Energy. There, the critical process of heating the magnet to 140°C for soldering the current leads and joints was performed, followed by wax impregnation to secure the windings.

Progress on this magnet, including the design, machine development, and initial manufacturing stages, has been documented in a peer-reviewed publication in the IEEE Transactions on Applied Superconductivity: "Development of a 4 T HTS Canted Cosine Theta Magnet for I.FAST" [4]. The successful completion of the full construction phase demonstrates a viable manufacturing pathway for high-field HTS CCT magnets and provides a strong foundation for future developments in the field.

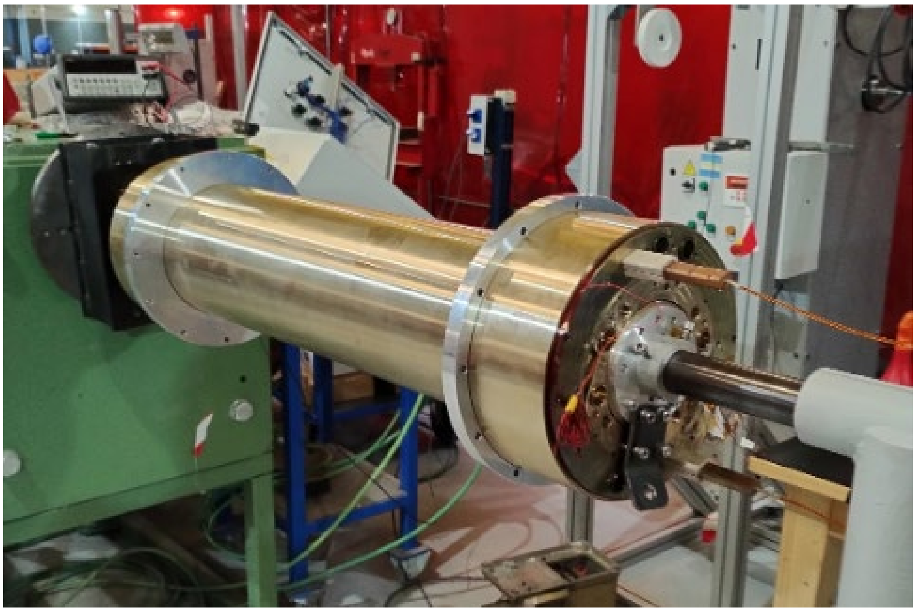

Figure 3: Final assembled magnet.

References

[1] CMS-PAS-SUS-23-014, https://cds.cern.ch/record/2932486

[2] G. Auzinger *et al* 2025 *JINST* **20** P11008 https://doi.org/10.1088/1748-0221/20/11/P11008

[3] https://doi.org/10.1016/j.nima.2025.170663

[4] DOI: https://doi.org/10.1109/TASC.2025.3622552