PROCEEDINGS OF SCIENCE

Building ATLAS with LEGO

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A new LEGO model of the ATLAS detector has been developed to aid and enhance educational outreach. Comprising over 21,000 LEGO elements and measuring over 1 m in length, this accurate 1/50 scale model depicts ATLAS as it will appear in the High-Luminosity LHC era. Cutaway walls clearly reveal every component of the real detector, from the muon chambers to the ITk Strip Detector and Pixel Sensors at the very heart of ATLAS. A fully modular structure facilitates group building events and the exploration of individual detector components. The accompanying CAD model, parts list, and detailed step-by-step instructions will allow this engaging and accurate LEGO representation to serve as a powerful tool for demystifying particle physics at CERN and inspiring future generations.

The European Physical Society Conference on High Energy Physics (EPS-HEP2025)
7-11 July 2025
Marseille, France

*Speaker

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PoS(EPS-HEP2025)604

1. Introduction

The ATLAS detector [1] is one of the largest and most sophisticated scientific experiments ever constructed. However, the inherent complexity of the detector can make it feel remote and inaccessible to the general public. To address this, extensive outreach programmes have been developed to raise awareness and make the physics concepts more tangible. These programmes are often facilitated through the use of models, for which the LEGO brick is a natural and effective tool.

LEGO is a versatile system of colourful interlocking plastic bricks that was first introduced in the 1950s [2]. Originally developed as a children's toy, it has grown in popularity and become a global cultural phenomenon. The system's universal appeal and intuitive nature have cemented its use as a powerful educational tool. It fosters complex model building, engineering, and problem solving, while offering a tangible and accessible way to explain complex scientific concepts.

These proceedings detail the design and construction of a new large-scale LEGO model of the ATLAS detector. This new LEGO model addresses structural and transportability flaws of an earlier design, providing an exceptional tool for public engagement and science communication.

2. The first LEGO ATLAS detector model

The first LEGO model of the ATLAS detector was designed in Autumn 2011 [3]. The model comprised 9,500 pieces, measured over 1 m in length, and was built to an approximately 1/50th scale. The original prototype cost approximately 2,000 EUR and was funded by the high energy physics group at the Niels Bohr Institute (Copenhagen, Denmark). Over 68 copies of the model have since been built at various institutes worldwide. The model has been effectively leveraged for particle physics communication across countless successful outreach events. A computer generated image of this original model is shown in Figure 1.

Although a striking display piece that has admirably fulfilled its purpose, the model suffers from numerous issues. Several large components (most notably the "petals" on the big muon wheels) are attached by only a handful of LEGO studs and easily fall off. More seriously, each of the vertices of the 16-sided polygonal shapes forming the internal skeleton of the model are built using semi-flexible hinge pieces, meaning that the model can easily deform and distort out of shape. Furthermore, this interior skeleton largely obscures the major internal components of ATLAS, such as the calorimeters or inner detectors. Such flaws are relatively trivial if the model is built and maintained *in situ*, but moving the model risks complete structural failure. A more significant concern was the increasing obsolescence of the model.

The ATLAS detector has evolved over the years, and continues to be upgraded as it transitions into the era of the High Luminosity LHC (HL-LHC). For instance, ATLAS has already been fitted with new systems, such as the New Small Wheel [4], that are not depicted on the existing LEGO model. Further upgrades are also planned, such as the all-silicon Inner Tracker (ITk) [5, 6] and the High Granularity Timing Detector (HGTD) [7]. This made a compelling case for the creation of a new LEGO model of the ATLAS detector.

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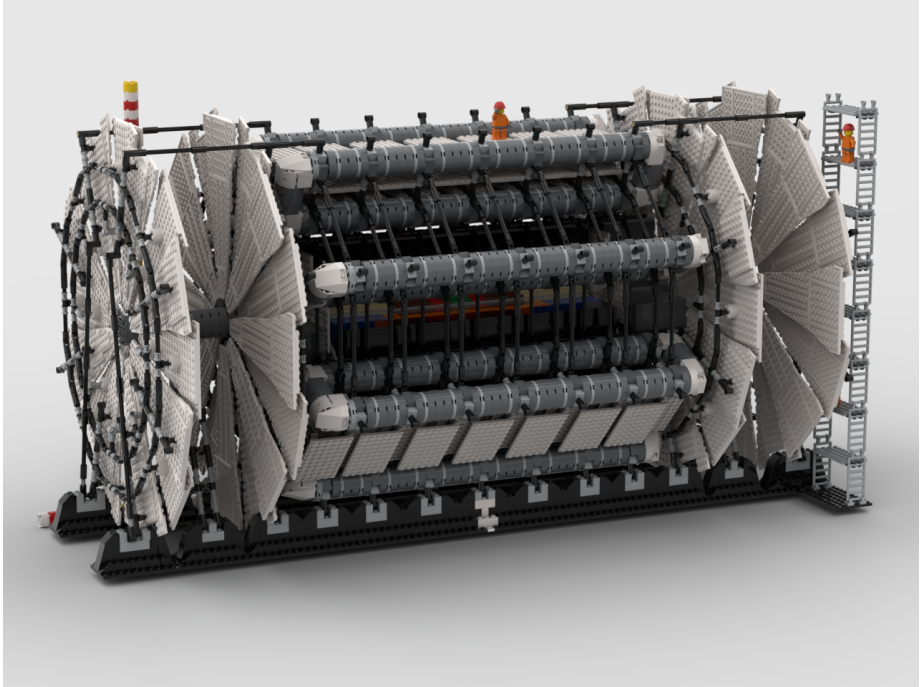

Figure 1: First LEGO ATLAS detector model, designed in 2011.

3. A LEGO model of the ATLAS detector for the HL-LHC era

The new LEGO model of the ATLAS detector is shown in Figure 2. It comprises over 21,400 pieces, weighs approximately 30.2 kg, and is over 1 m in length. While the overall size is comparable to the original model, it exhibits significant differences due to having been built to an exacting 1/50th scale. This high degree of accuracy has been achieved through detailed study of Technical Design Reports for the various detector subsystems [5–10] and non-public engineering drawings. The new design is the result of over 1,000 hours of work, the vast majority of which has been undertaken in the designer's personal time. All parts are standard LEGO elements that are readily available (at time of writing), at a cost of just under 4,000 EUR, and can be assembled without the need for any adhesives.

The model has been designed digitally using Bricklink's Stud.io software [11], a free CAD-like editor that allows users to build with virtual LEGO bricks. Although the virtual LEGO elements connect together just like their real-world counterparts, it is important to note that gravity and other forces cannot be simulated. Consequently, the digital models must be carefully assessed and, where possible, physically built to validate their strength and stability. This, coupled with the constraints that physical LEGO pieces were unobtainable until design completion, and that initial assembly would take place at a public event, contributed significantly to the protracted development. The editor also includes tools to facilitate the creation of step-by-step assembly guides.

The new model is modular and highly robust, in order to facilitate outreach demonstrations and safe transport. The entire structure rests on a substantial and fully integrated brick-built display base, which splits into three main segments: the central barrel and two end-cap sections. The end-

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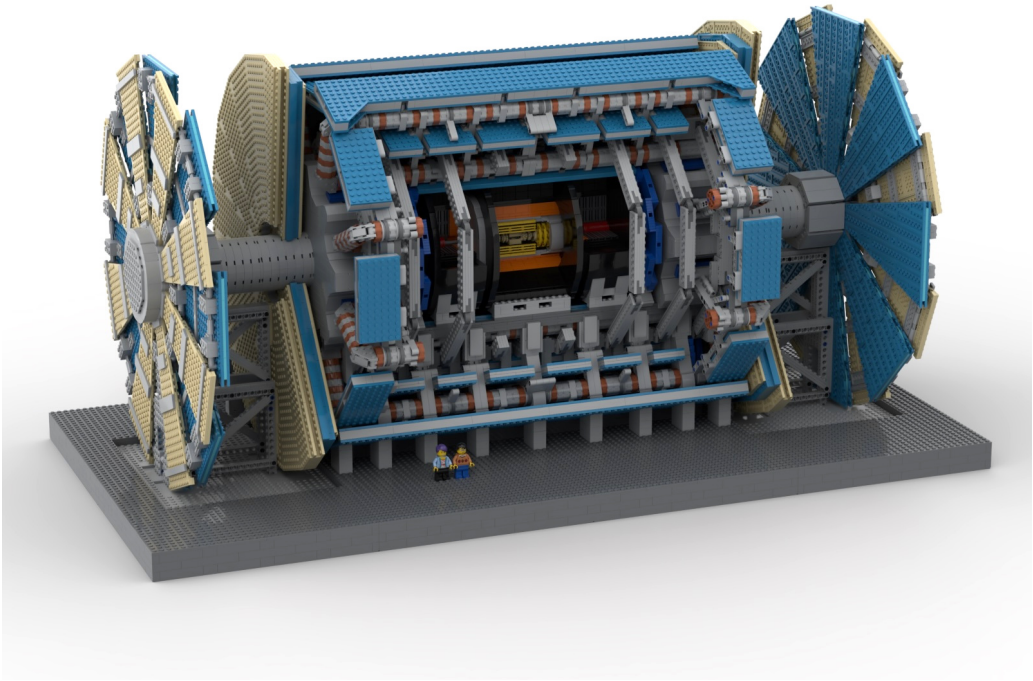

Figure 2: New LEGO ATLAS Detector model, designed 2023-2025.

cap sections each depict massive muon wheels constructed from overlapping large and small sector "petals", and are an impressive structural achievement. The central barrel unit is a masterpiece of geometry and engineering, being free-standing, self-supporting, self-bracing, and not reliant on any interior components for structural support. It accurately depicts the iconic toroid coils that give ATLAS its distinctive shape, and includes three layers of concentric muon chambers. New to this design is the inclusion of muon chambers suspended from the toroid coils, demonstrating how ATLAS achieves almost complete coverage. The model is so accurate that even the crack regions - gaps in the muon chambers to accommodate the detector services - are modelled. Two rails run the length of the barrel to support the inner detector systems.

The calorimeters are represented by three separate units (barrel and end-caps). Orange bricks are used to depict the Liquid Argon calorimeters, while black bricks depict the Hadronic Tile Calorimeter. The units each have integrated sleds so they can slide precisely into position in the barrel, mimicking their installation in the real detector and facilitating outreach demonstrations. The ITk is a standalone module that uses colour-coded bricks to distinguish the Pixel detectors, Strip detectors, and the HGTD. It is designed to slide into the barrel calorimeter. The end-cap toroid is accurately depicted as an eight-point star shape, featuring integrated muon chambers and an integrated sled for mounting on the barrel rails. The model also incorporates the New Small Wheel, which features a novel design for the overlapping muon chambers. A selection of detail views of these components is shown in Figure 3.

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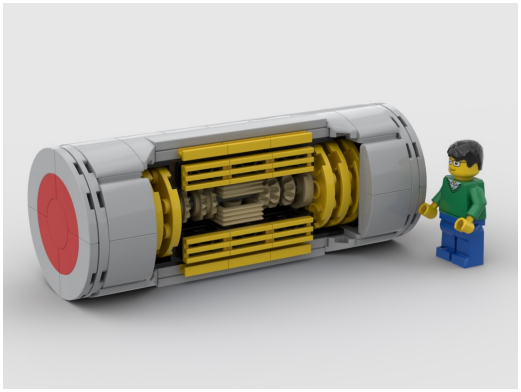
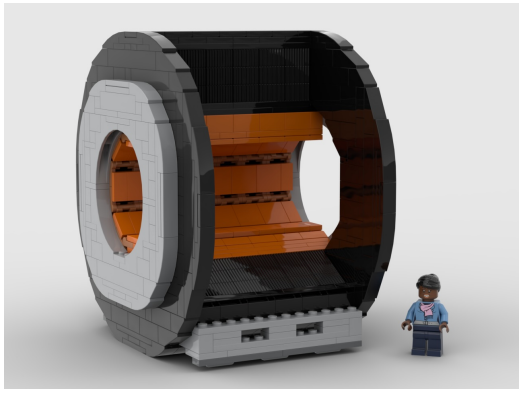
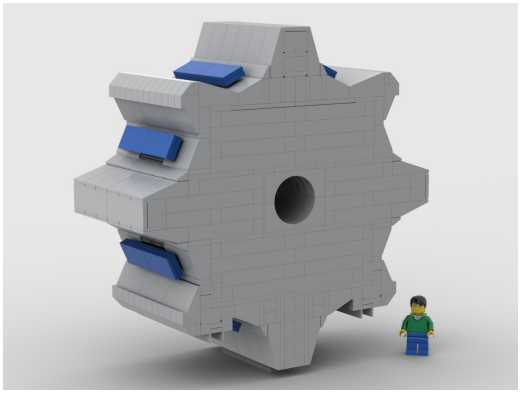


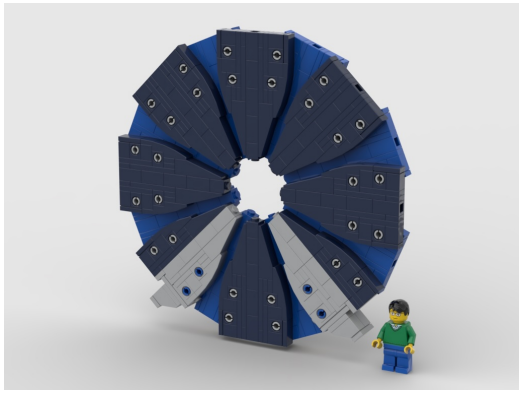
(a) The Inner Tracker



(b) The Barrel Calorimeter



(c) Endcap Toroid



(d) New Small Wheel

Figure 3: Detail views of a selection of components from the new LEGO model of the ATLAS detector.

The prototype model was built in Sheffield in June 2024 by a group of approximately 15 people working for three days. The designer then invested a further 700 hours in the creation of a definitive, detailed step-by-step assembly guide. All project materials have been made available at Ref. [12] for free public download.

4. Conclusion

A new, accurate, and large-scale LEGO model of the ATLAS detector has been designed. This model depicts ATLAS in the HL-LHC era, representing a significant improvement on the original through its more modular and robust design. All project materials, including a detailed step-by-step assembly guide, are publicly available at Ref. [12].

Acknowledgments

The designer gratefully acknowledges the support of the staff at the University of Sheffield and the members of the ATLAS Outreach Group for their assistance in the completion of this project.

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