Building ATLAS with LEGO

A new model for the HL-LHC Era

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On behalf of the ATLAS Collaboration

EPS-HEP 2025, Marseille

7-11 July 2025

LEGO

- A highly versatile system of interlocking plastic bricks
- Evolved from a toy into a global cultural phenomenon

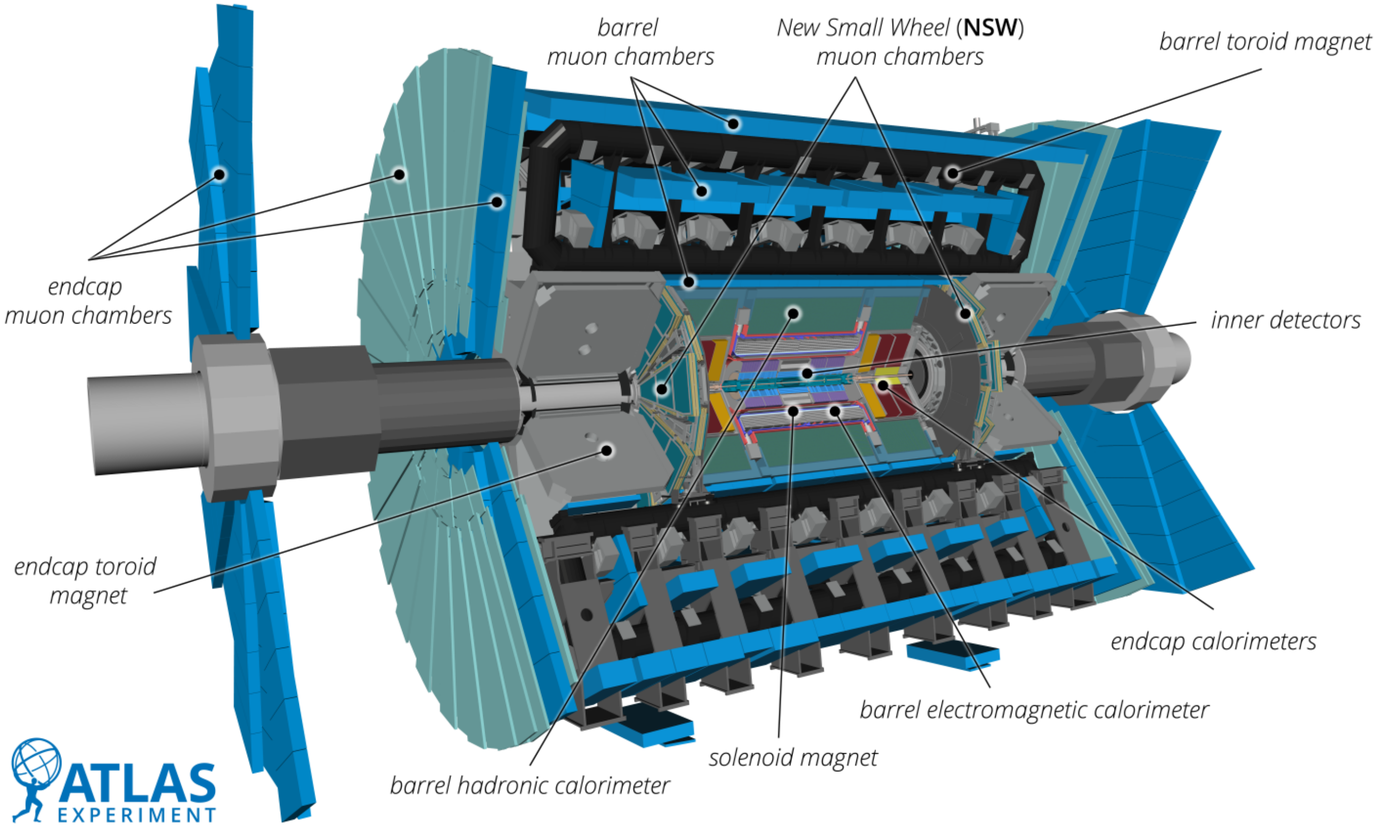
- A powerful tool for creativity and innovation:
  - Fosters complex model building, engineering, and problem solving
  - Intuitive nature and broad appeal engage diverse audiences
  - Offers a tangible, accessible way to explain complex scientific concepts

An exceptional tool for
public engagement & science communication!

https://www.lego.com/en-gb/product/lego-creative-bricks-10692

The ATLAS Experiment

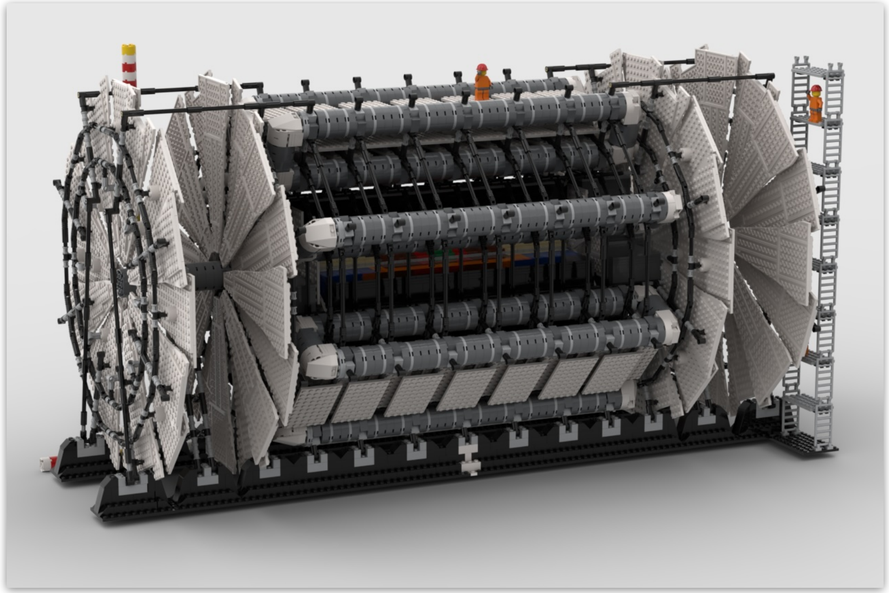
- A general purpose particle physics experiment at the LHC
- Extensive upgrades are in progress so it can thrive in the harsh radiation environment of the upcoming High-Luminosity LHC

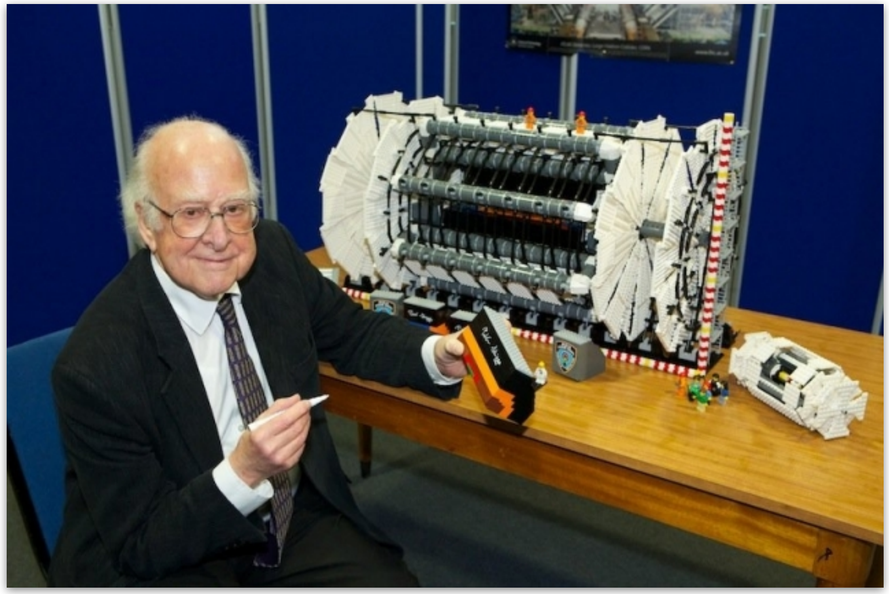


The Original LEGO ATLAS

- Original LEGO ATLAS designed in fall 2011
  - Designer: Sascha Mehlhase (Munich)
  - Uses ~9,500 Lego bricks
  - Approximately 1:50 scale

- Over 60 exist at institutes around the world!
  - CERN (Geneva, Switzerland)
  - LAPP (Annecy, France)
  - LPSC (Grenoble, France)
  - Sheffield (UK)
  - …



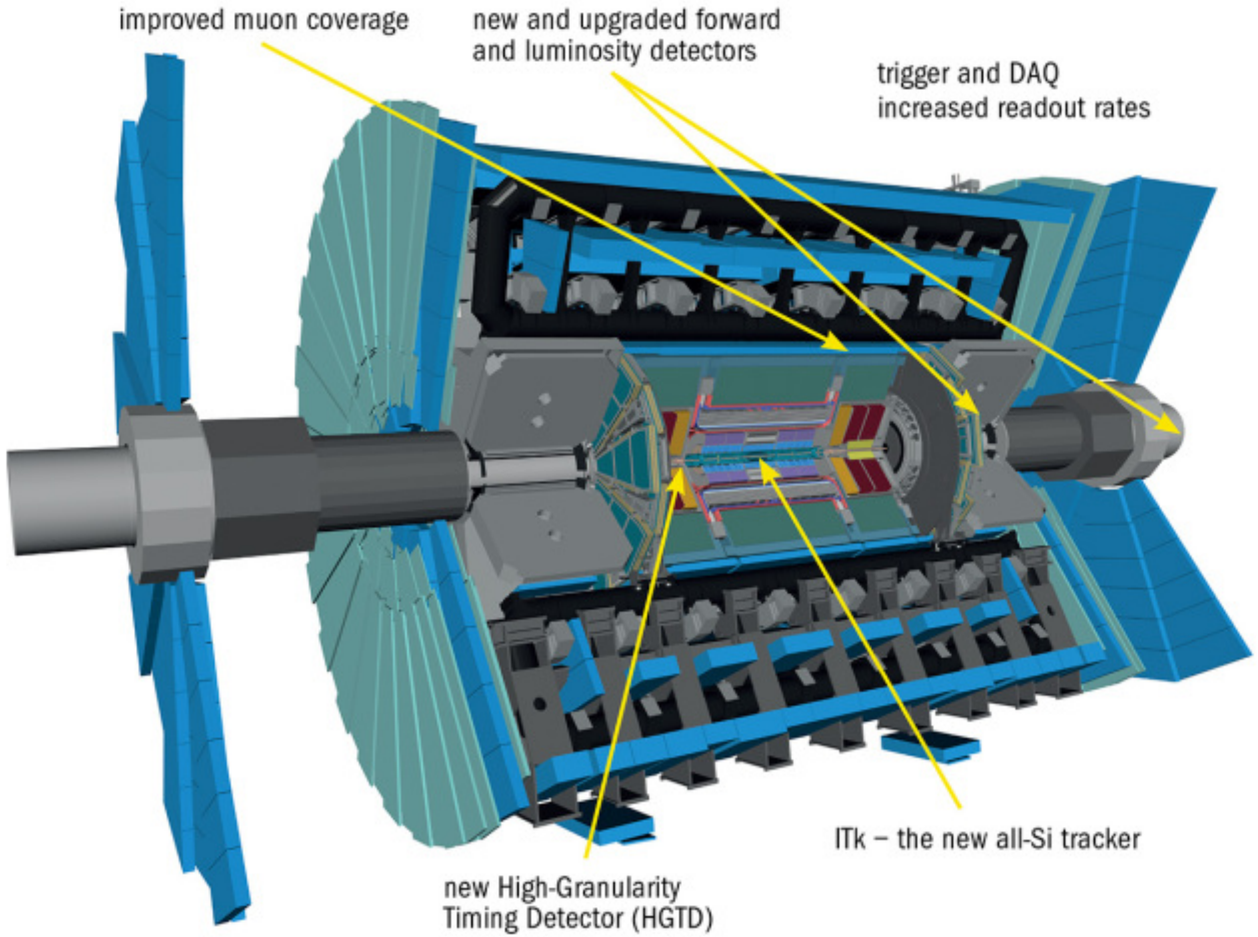


ATLAS-PHO-COLLAB-2014-004

Why build a new one?

- ATLAS has been getting upgrades for the HL-LHC
  - New detector components not depicted by the original model

- Components include:
  - New Small Wheels: New Muon detectors
  - Inner Tracker (ITk) - Upcoming replacement for existing inner detector
  - High Granularity Timing Detector (HGTD) - new detector to improve time resolution



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Why build a new one?

- The original model is beautiful but fragile
  - Tends to collapse in transport
  - In February 2023, Sheffield displayed this at UK National Videogame Museum:

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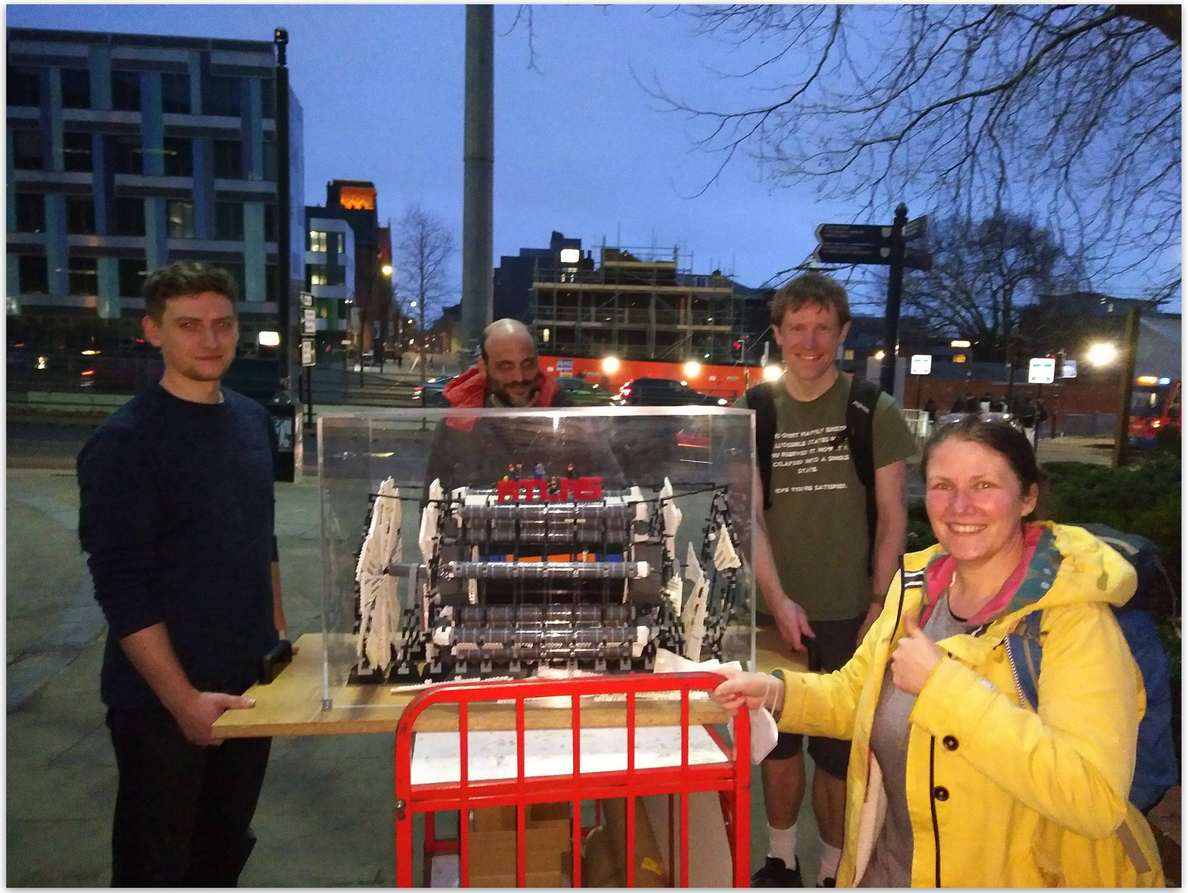

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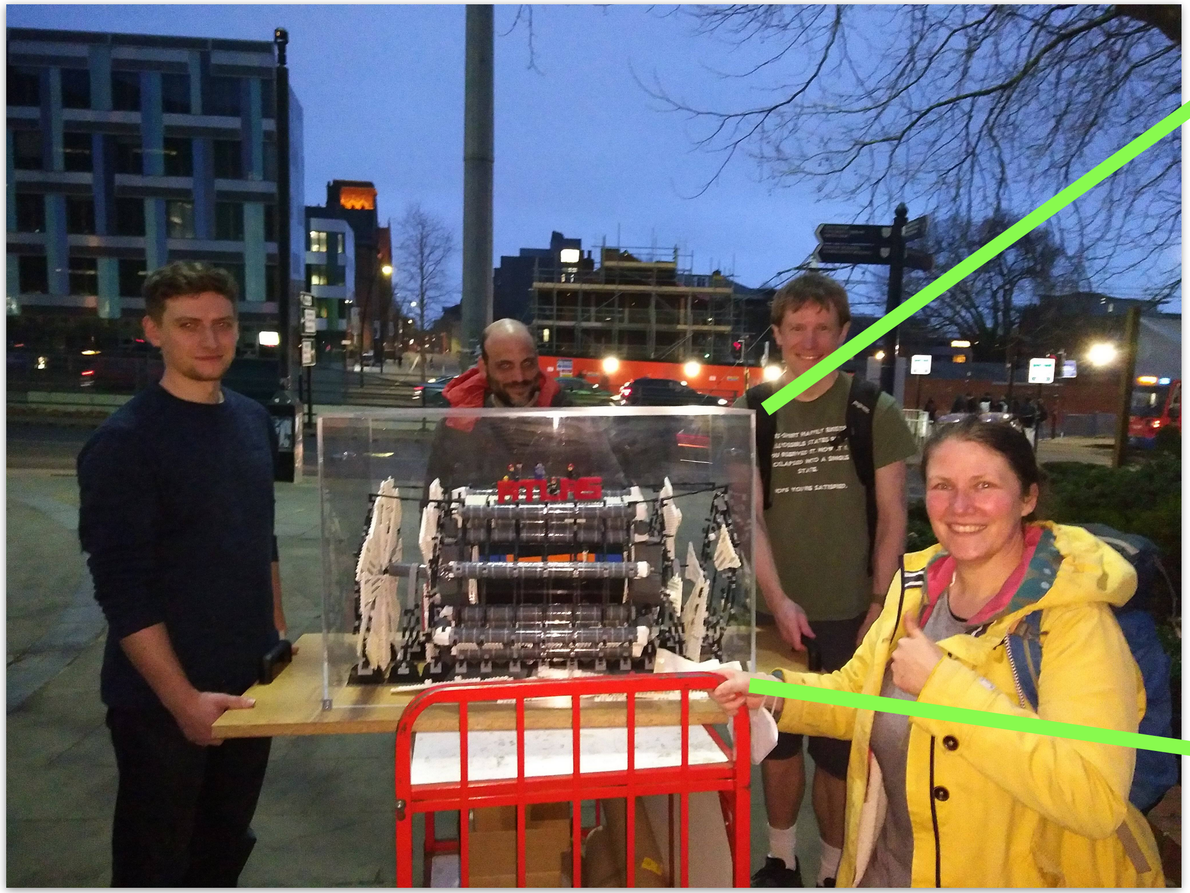
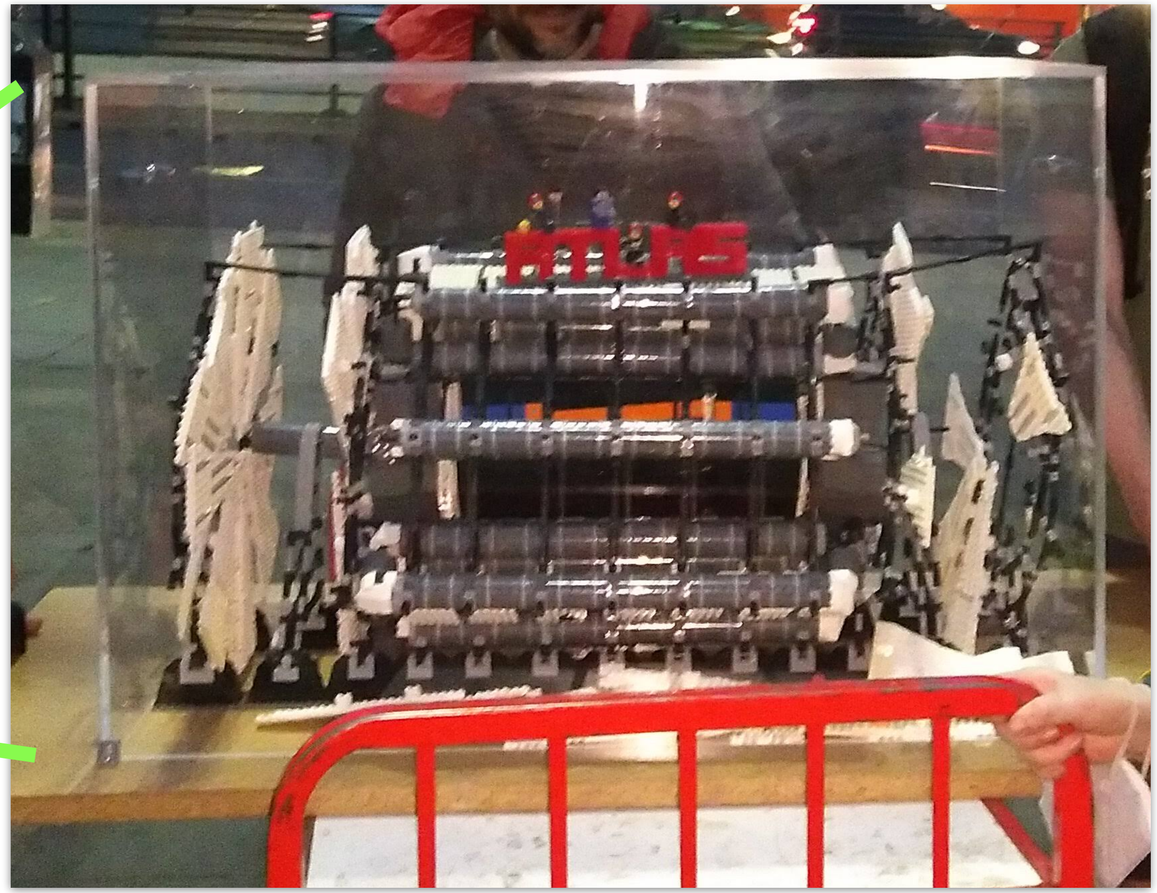
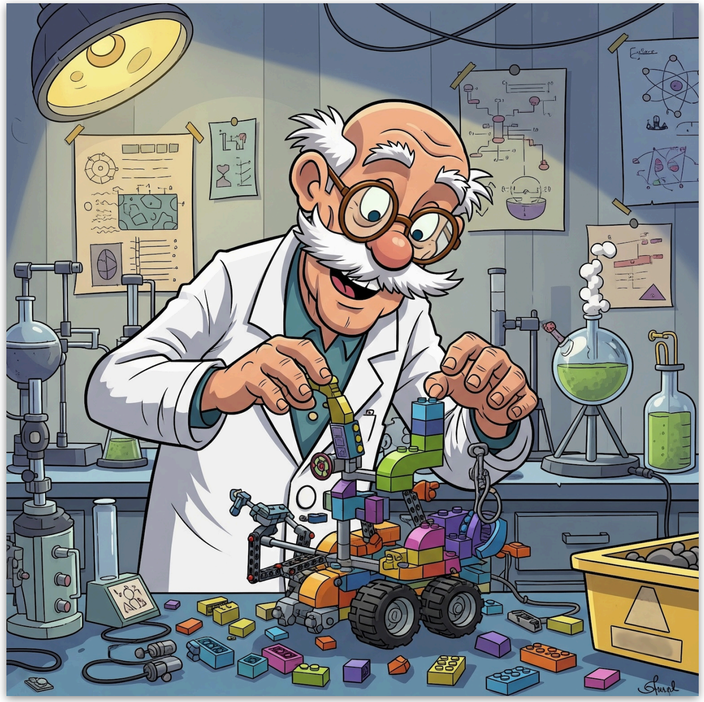
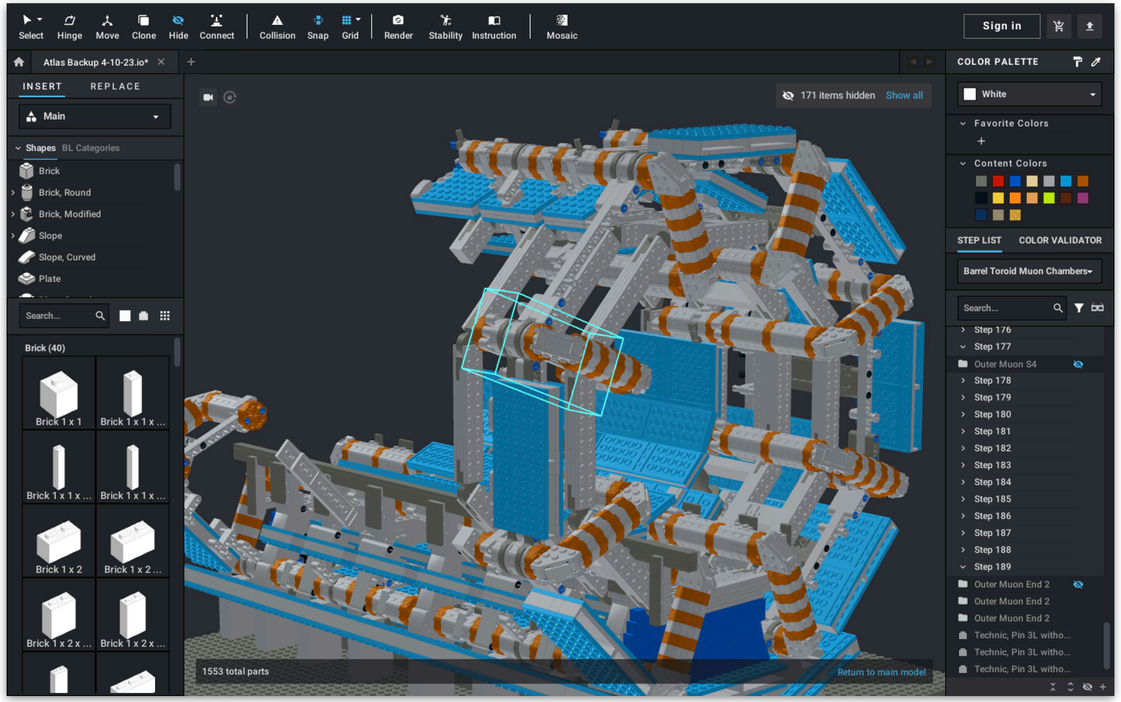




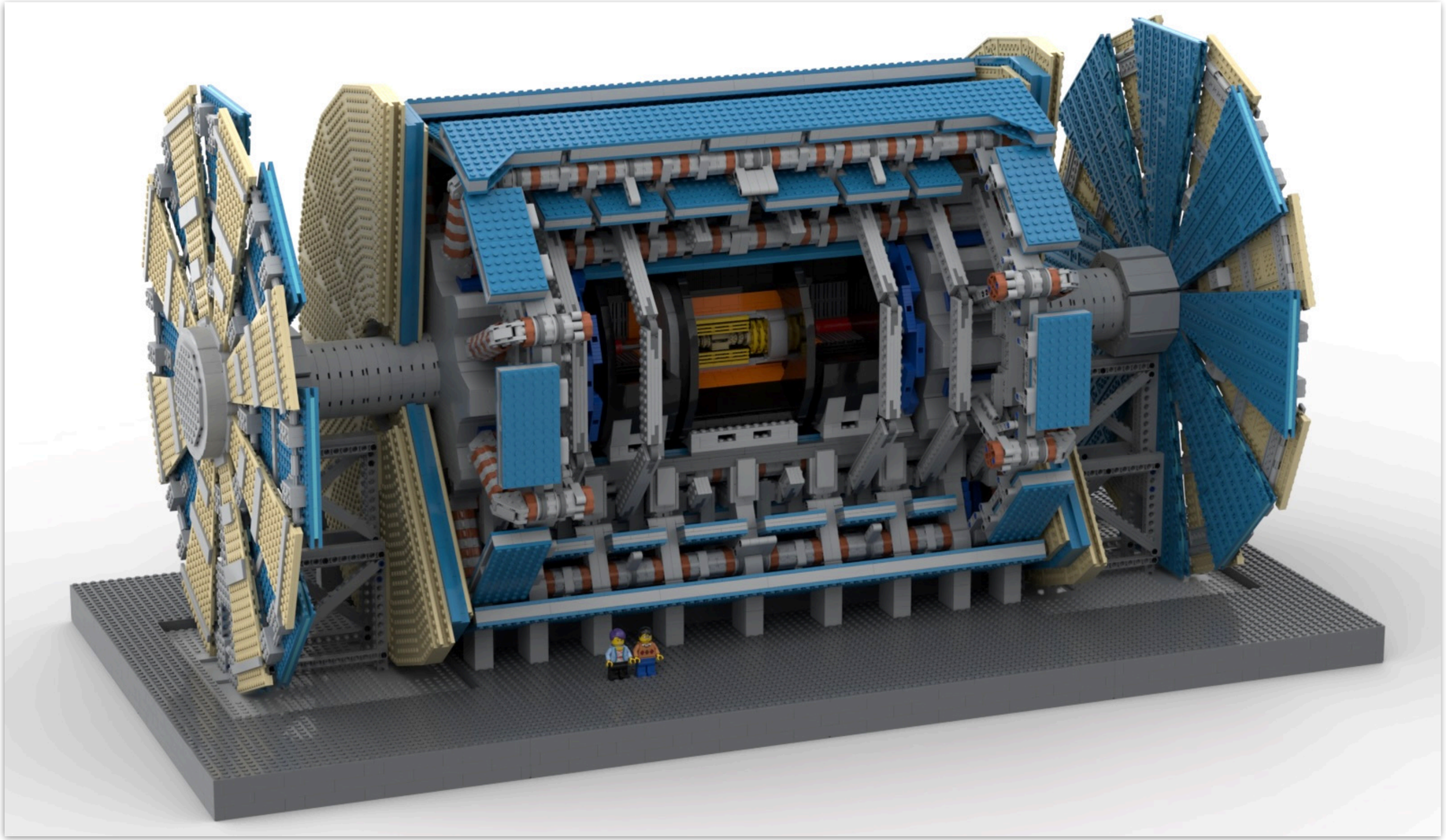
Designing a New Model

- Originally planned to refine existing design with newer LEGO elements
  - This approach **replaced** by a **completely new design**
- Work began in March 2023 and required **~1,000 hours**
  - Model designed digitally using specialist LEGO CAD software
  - Extensively researched using ATLAS technical reports and engineering drawings
- Model presented a **significant engineering challenge**





LEGO ATLAS for the HL-LHC



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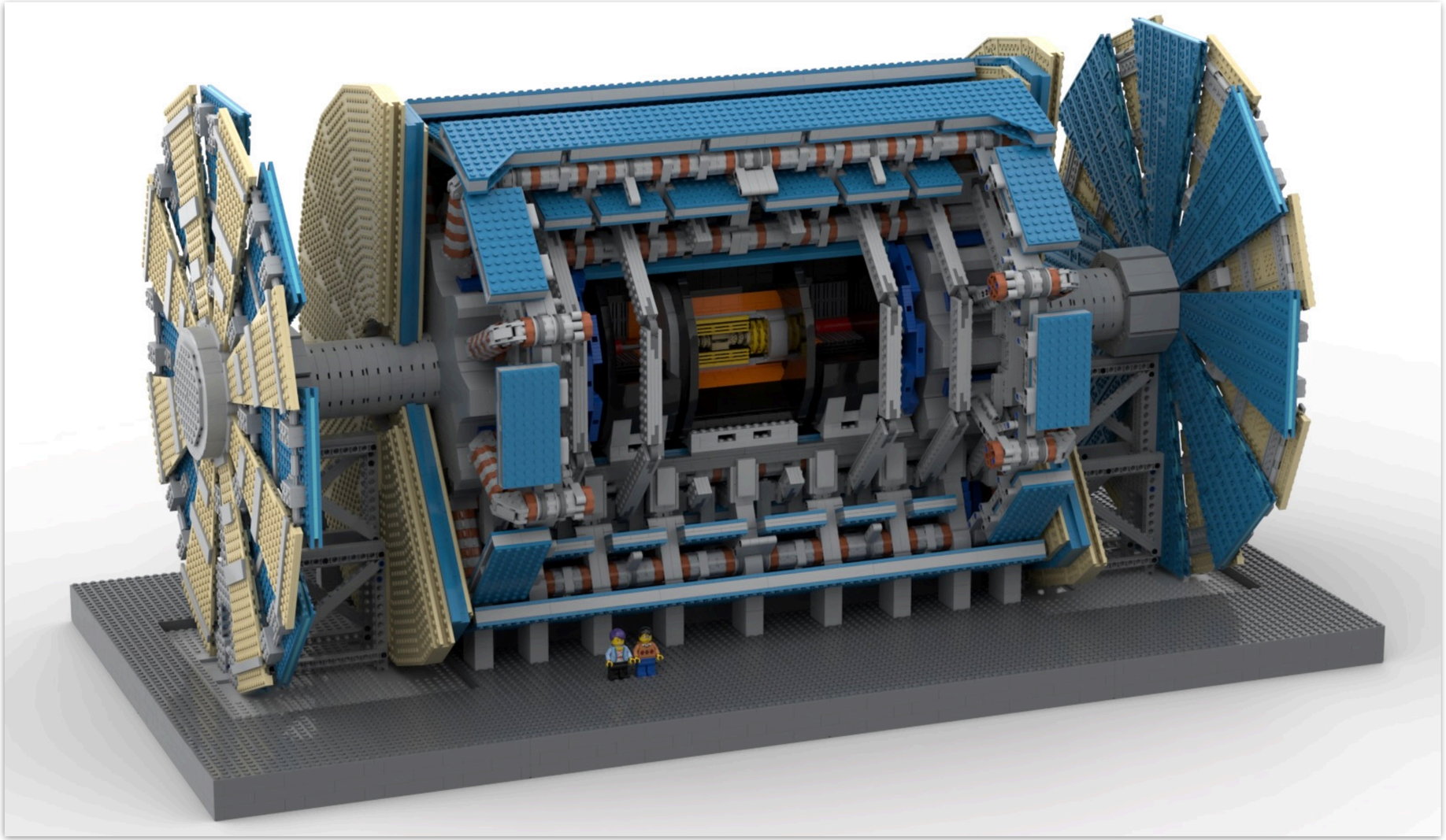

- Over 21,400 pieces!
- Weighs over 30.2 kg!
- Hyper-accurate 1:50 scale!
- Measure over 100 cm long!
- Measures over 50 cm wide!
- All standard LEGO pieces!

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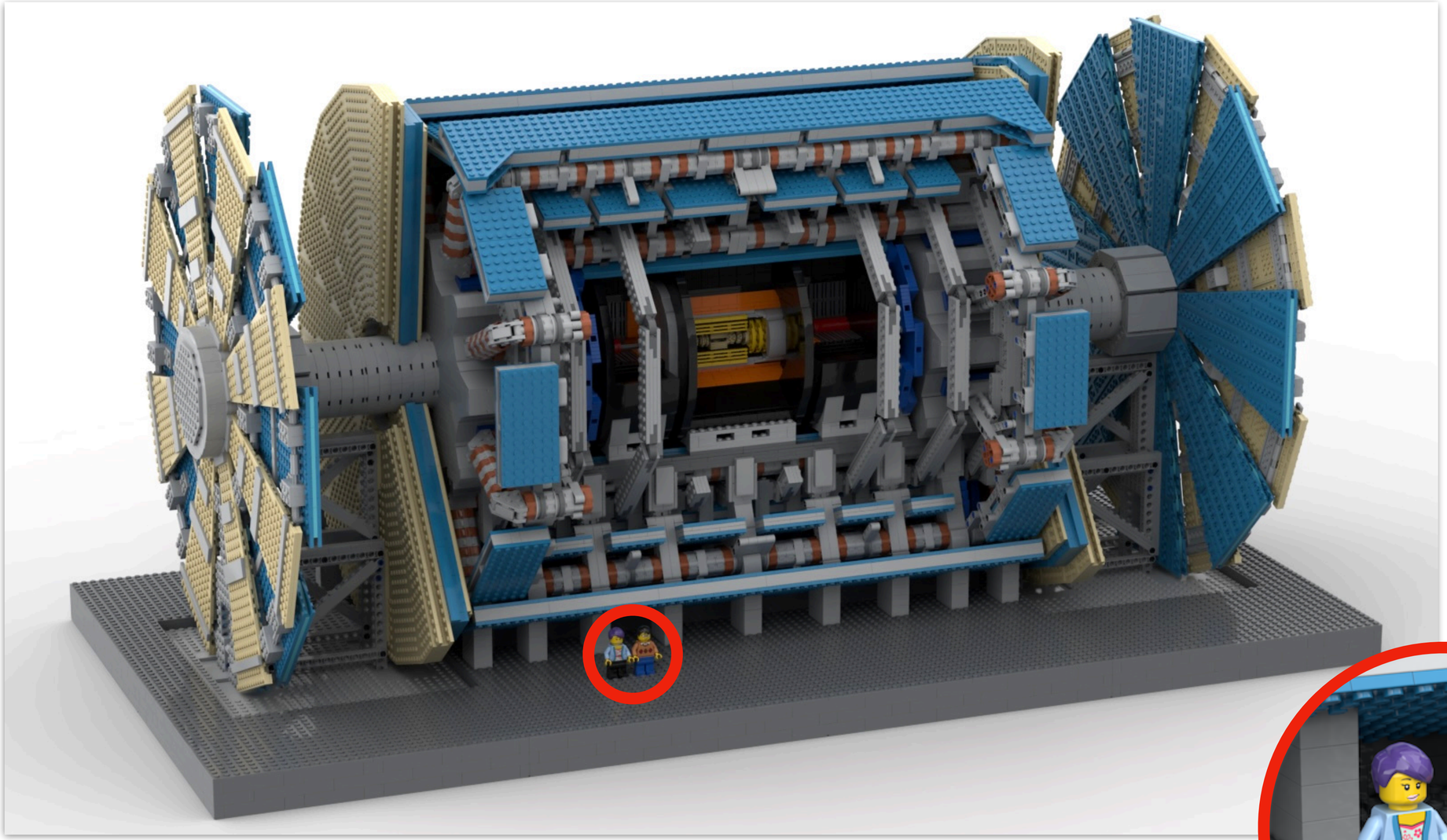

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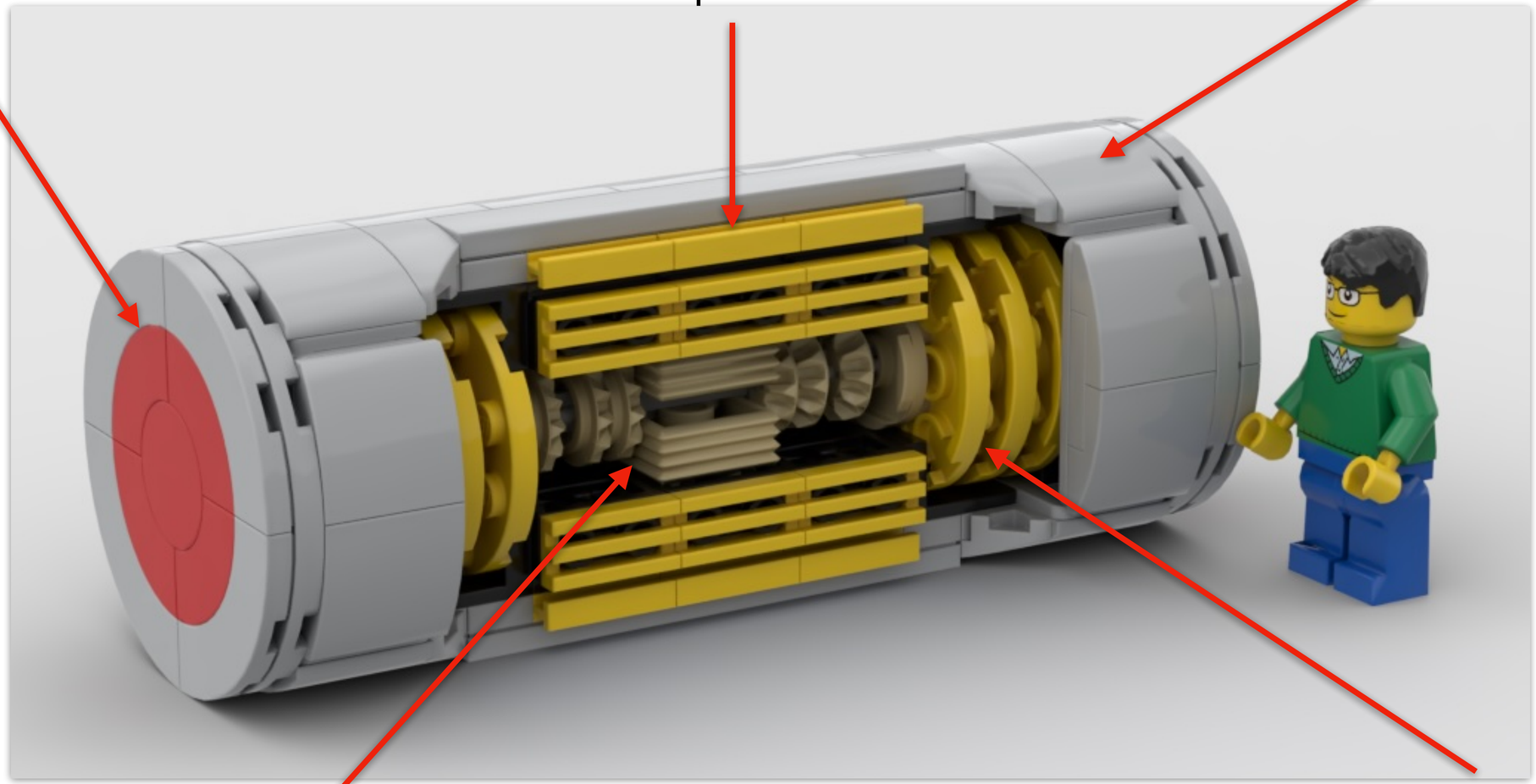
Upgrade: Inner Tracker (ITk)

Red circle represents HGTD

Four horizontal bands represent the four layers of Strip modules

Grey cylinder represents barrel solenoid



Grooved Lego brick shows 4 layers, approximating the 5 pixel barrel layers

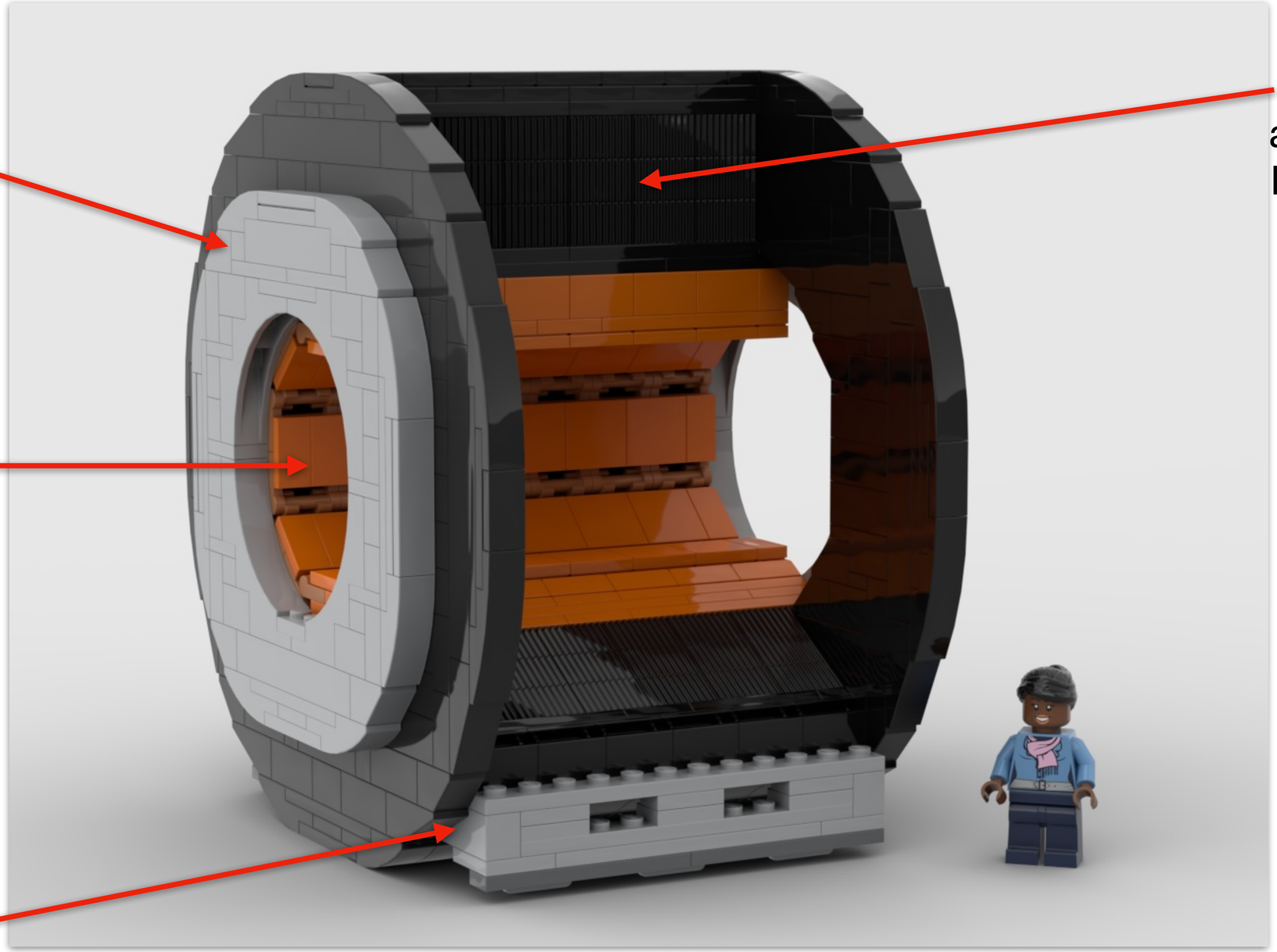
Alternating tan and yellow round components to represent pixel and strip module end-caps

Upgrade: Central Calorimeter

LAr Calorimeter Cryostat

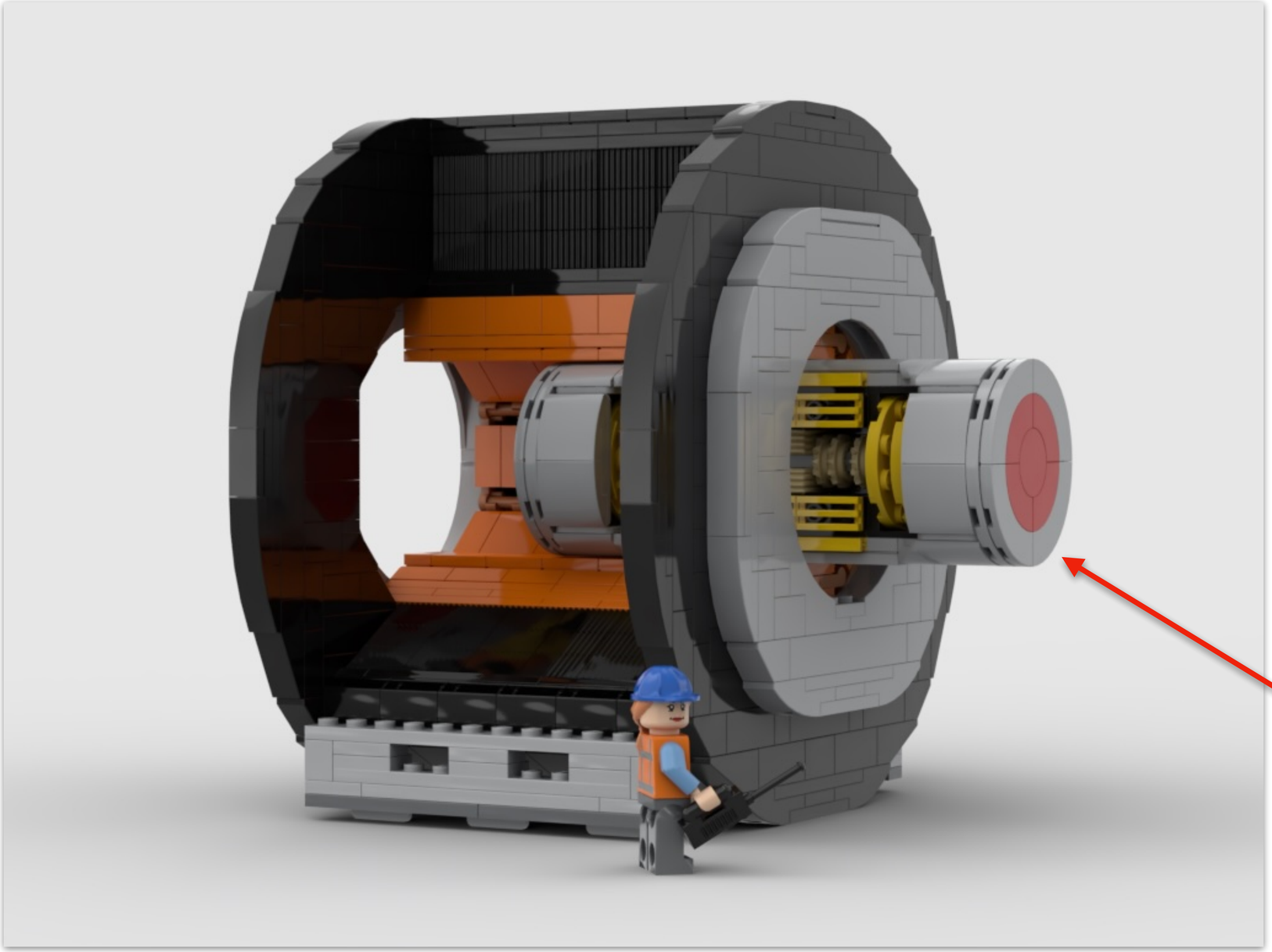
Liquid Argon (LAr) Calorimeter

Integrated sled



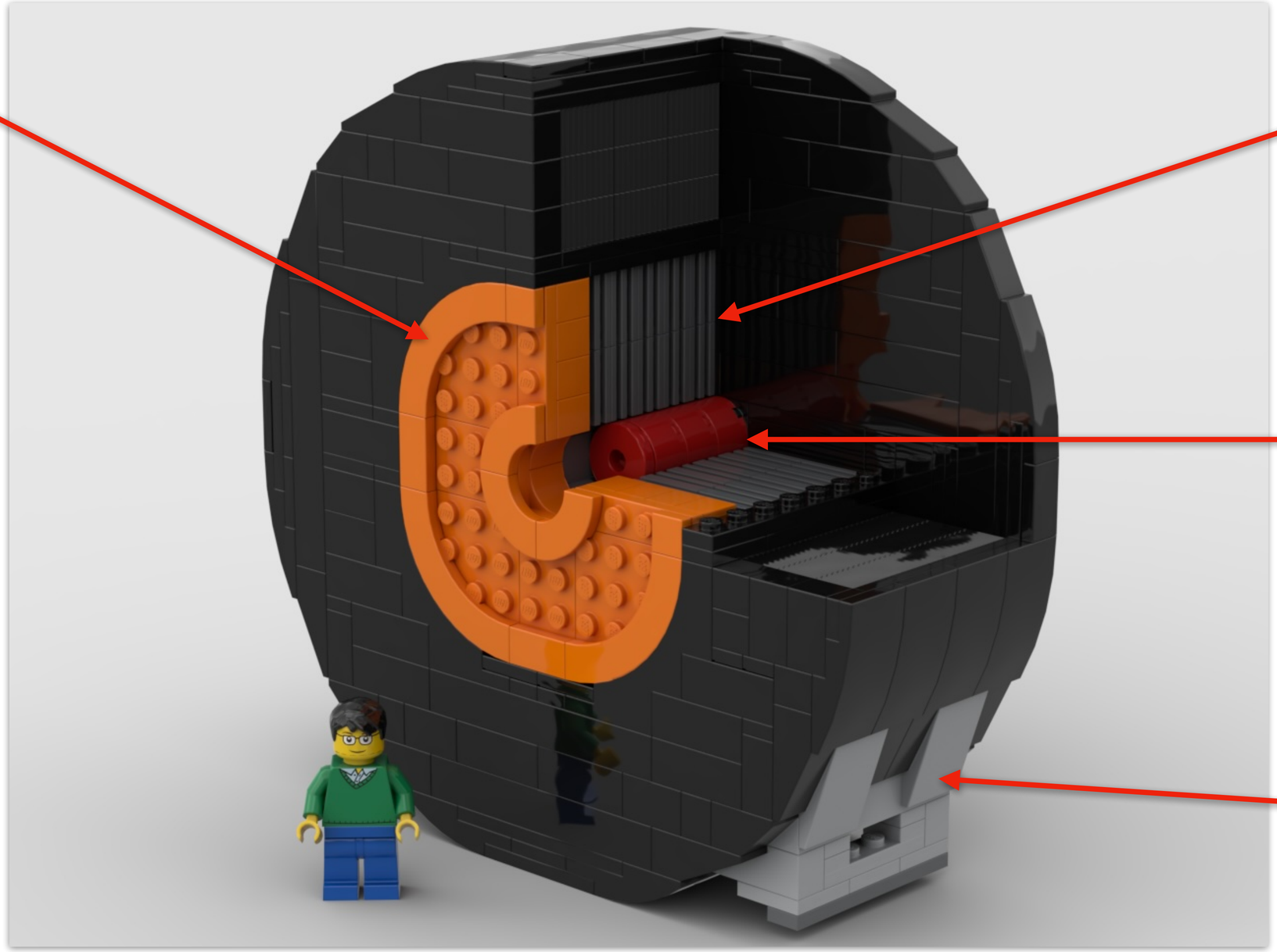
Grooved bricks representing the alternating layers of lead and scintillator

Upgrade: Central Calorimeter with ITk



ITk slides inside calorimeter: ITk is **removable**

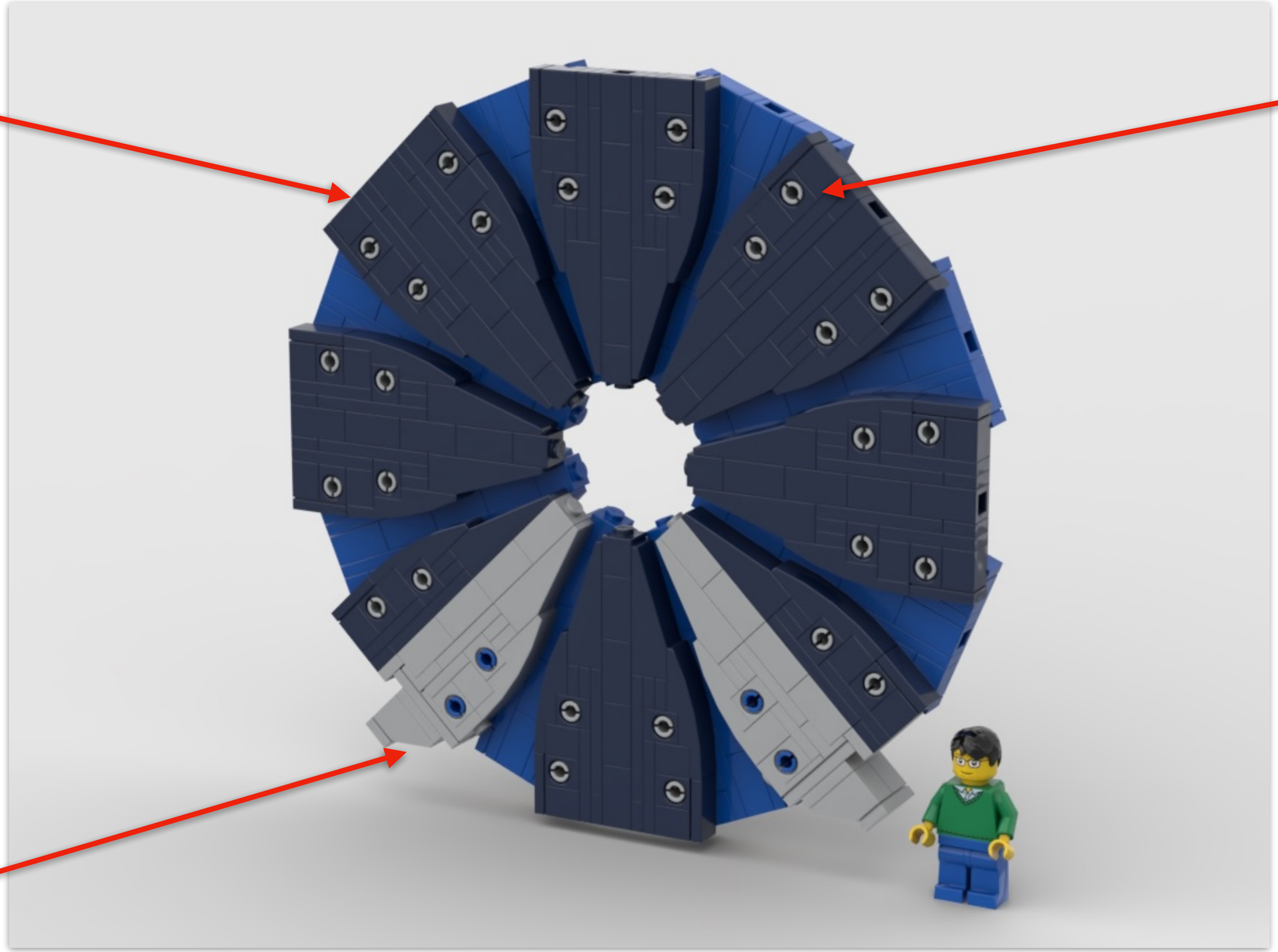
Upgrade: End-cap Calorimeter



New Small Wheel

Completely new detector component

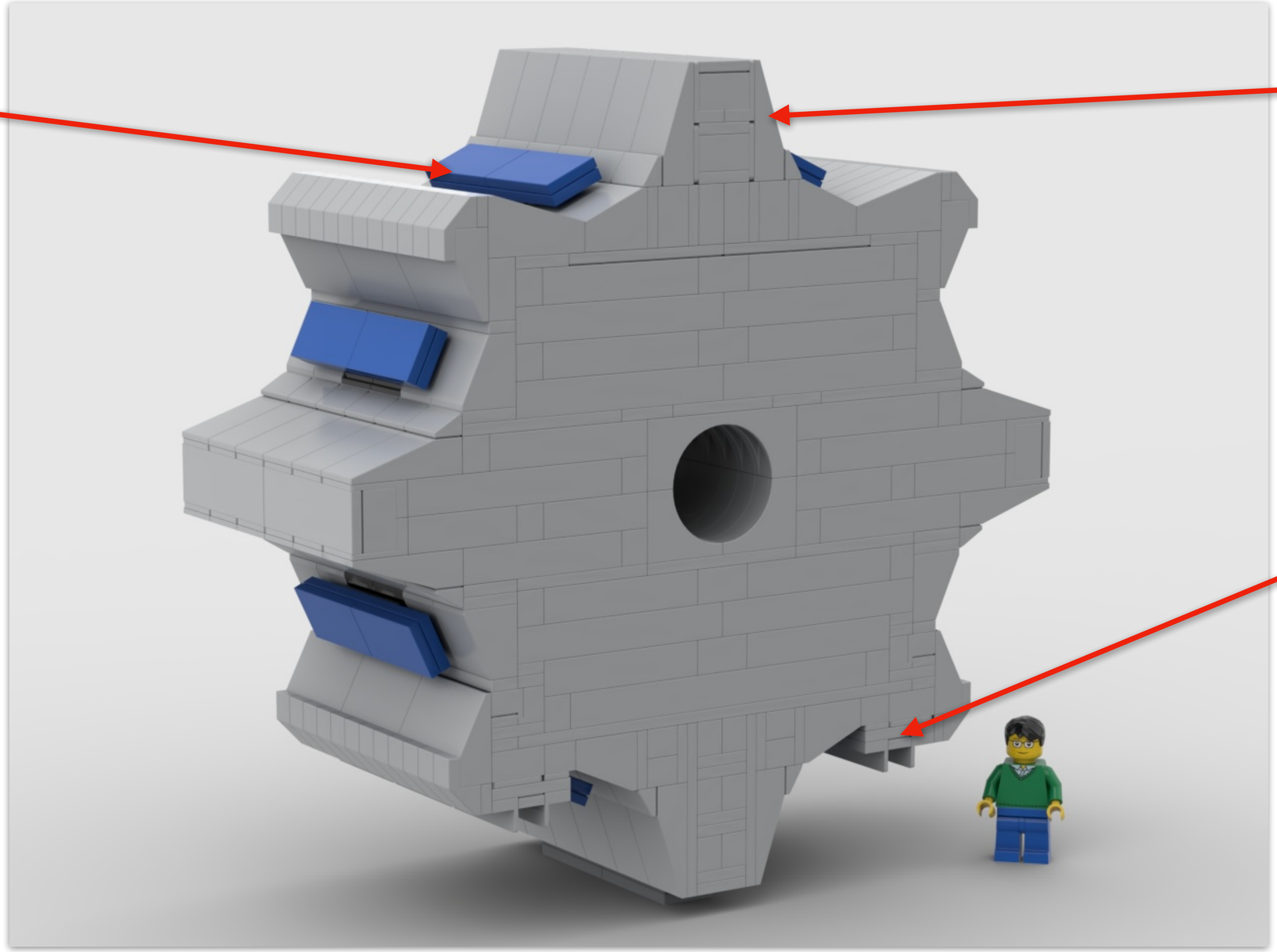
Pins hold 16 alternating petals together



Novel foot design

Endcap Toroid

Integrated muon chambers



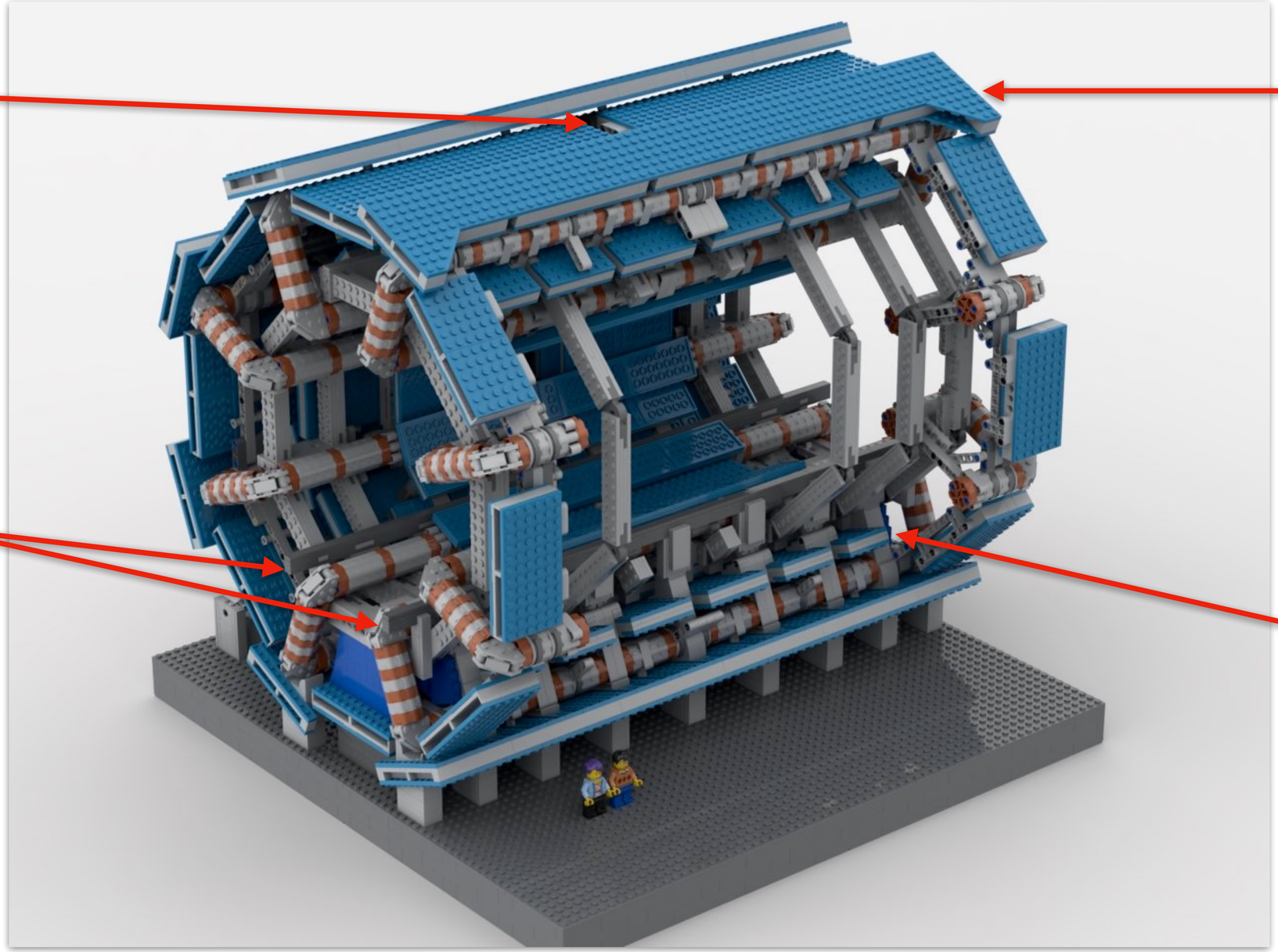
Accurate 8-point star shape

Integrated rail mount

Barrel Muon Chambers and Toroid

Crack region modelled

Model includes outer muon chambers

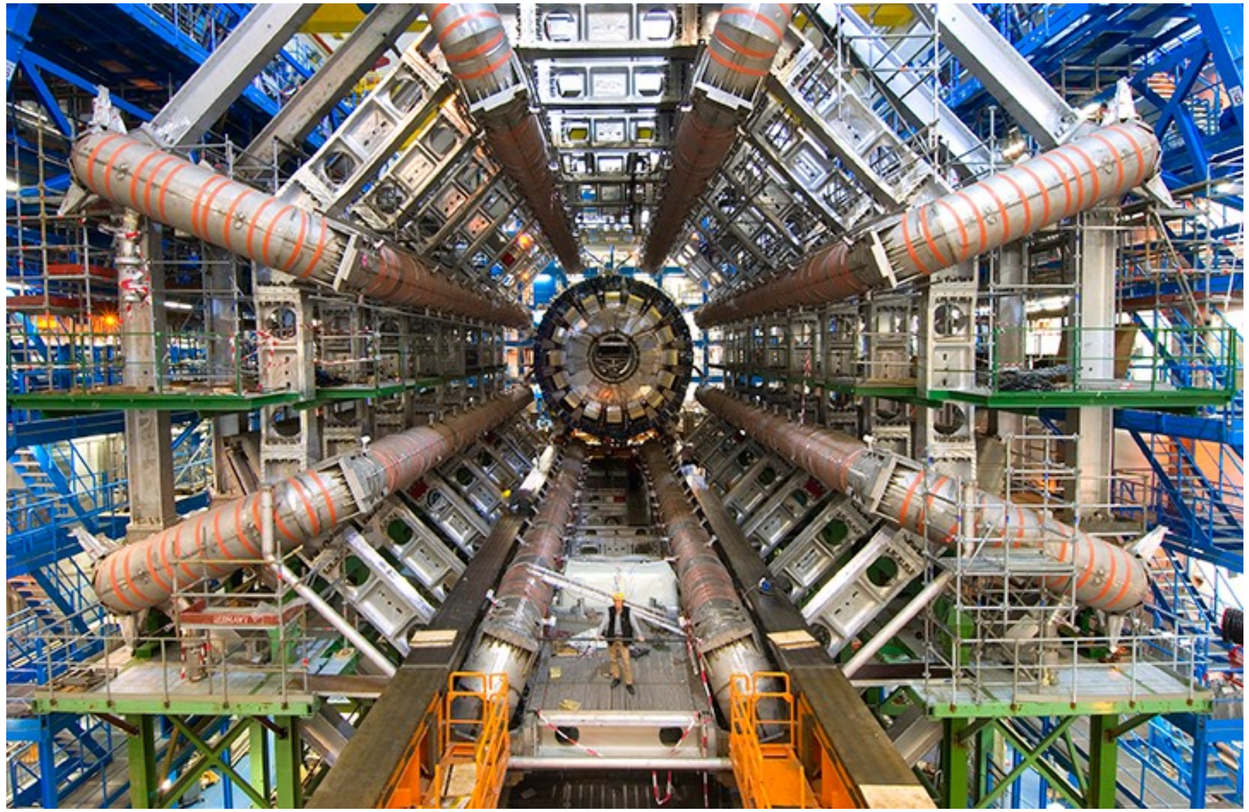


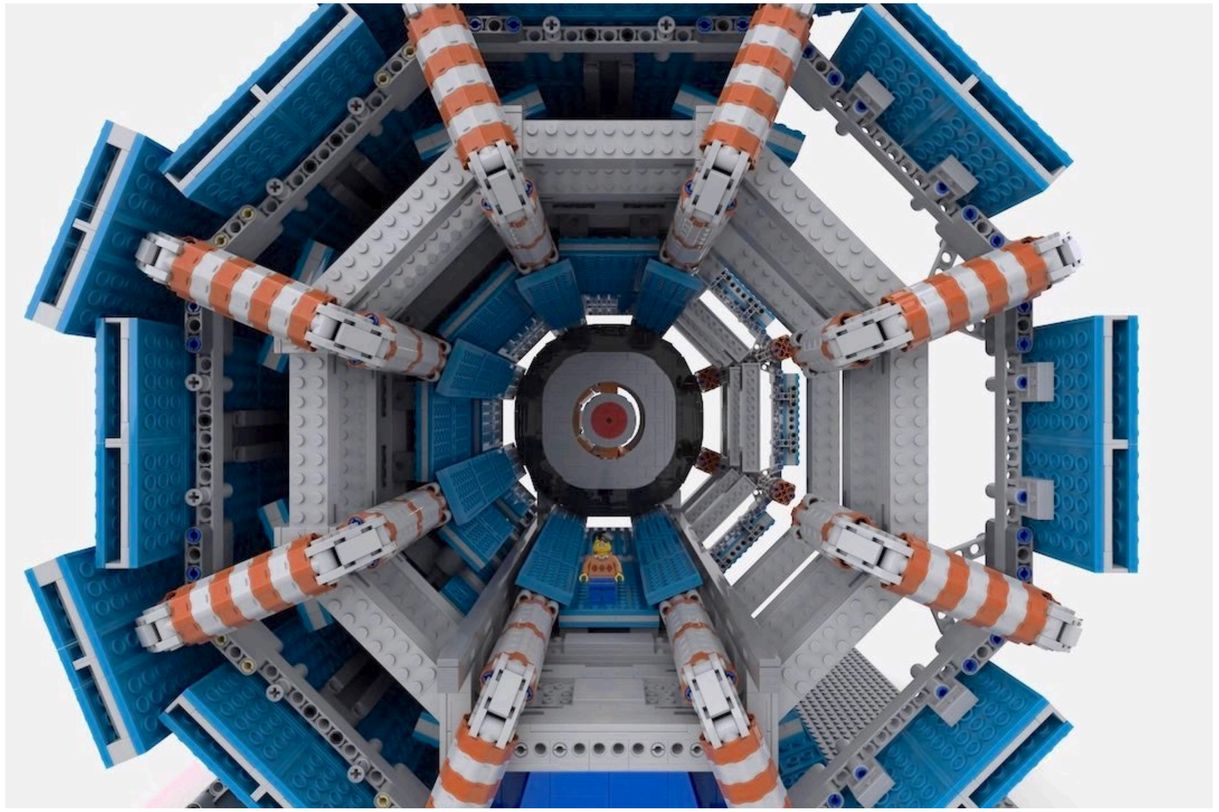
Rails

Muon chambers suspended between toroid coils

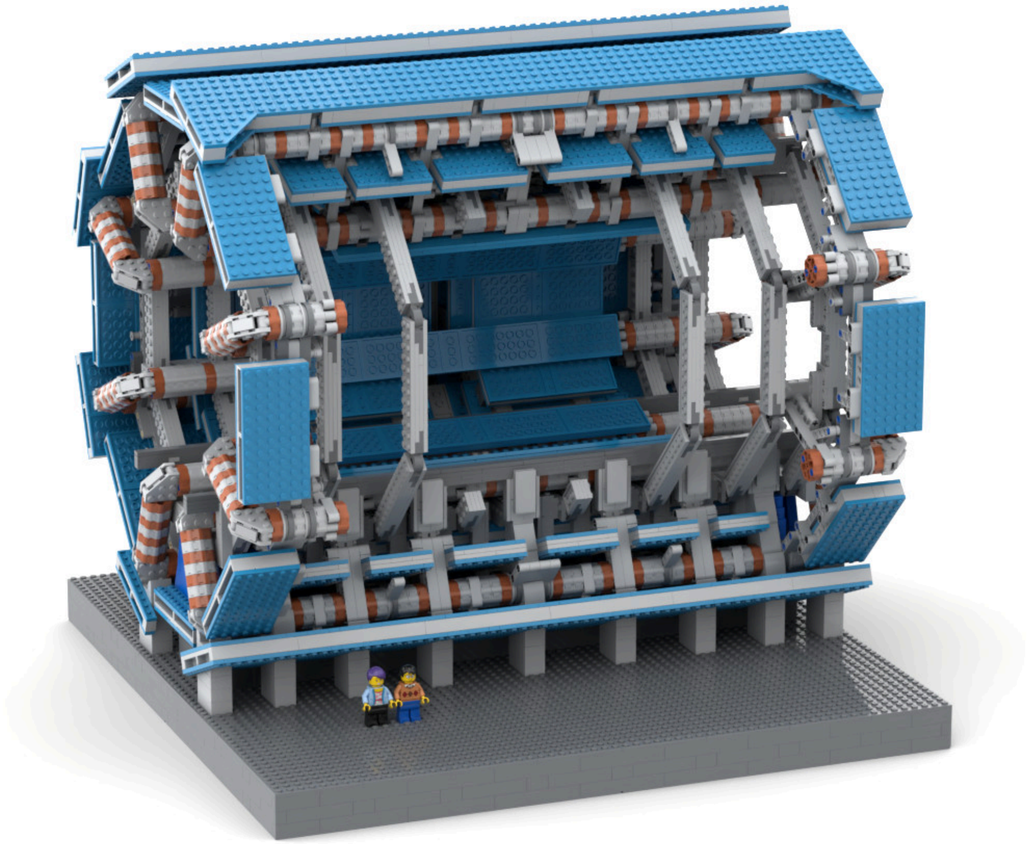
Free-standing, self-supporting structure

The Barrel Muon Toroid System





Putting It All Together



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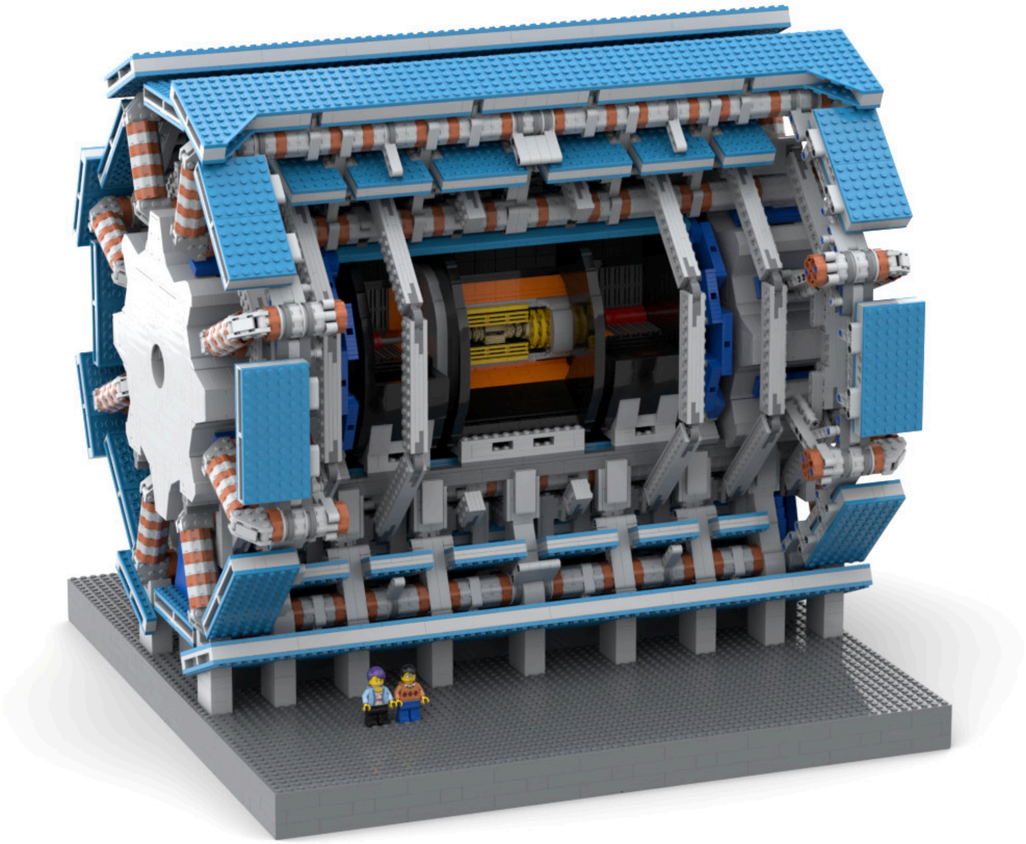
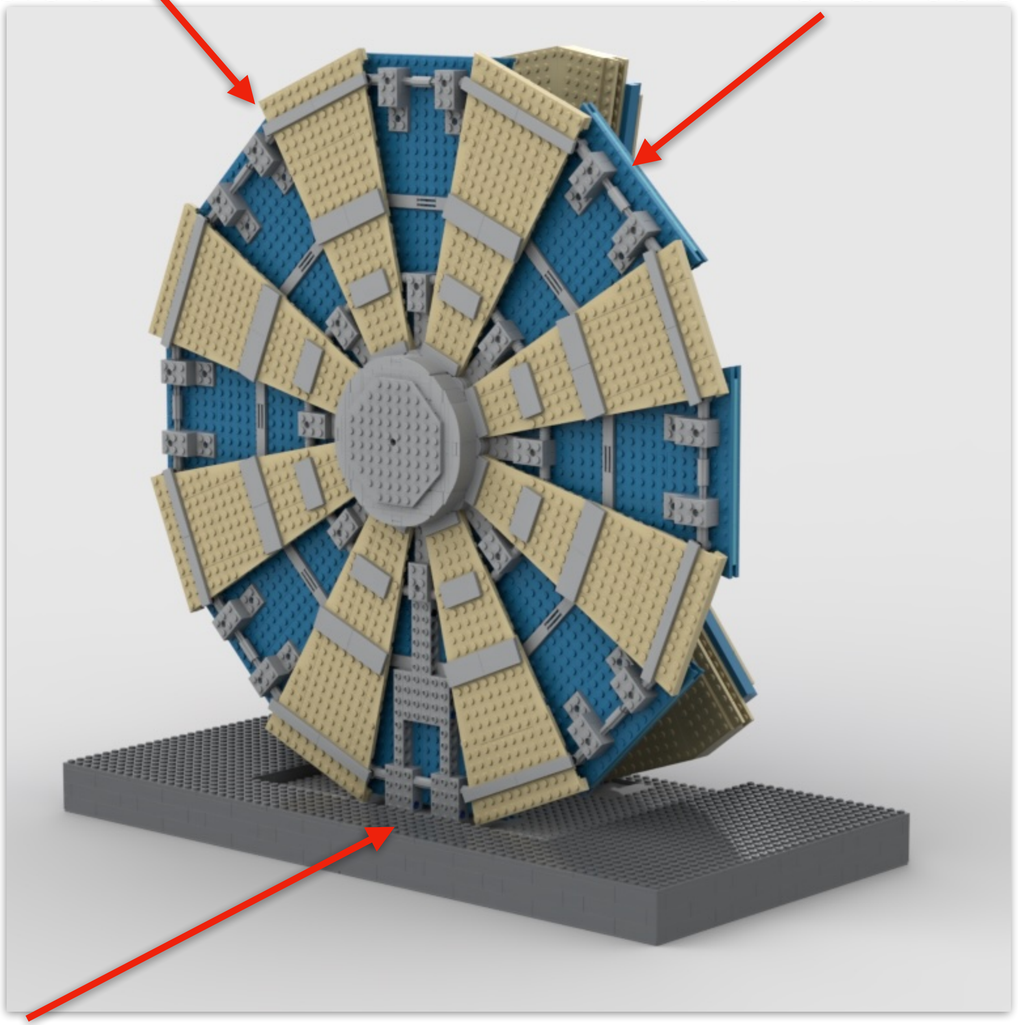


Muon End-Caps

Large and small sectors

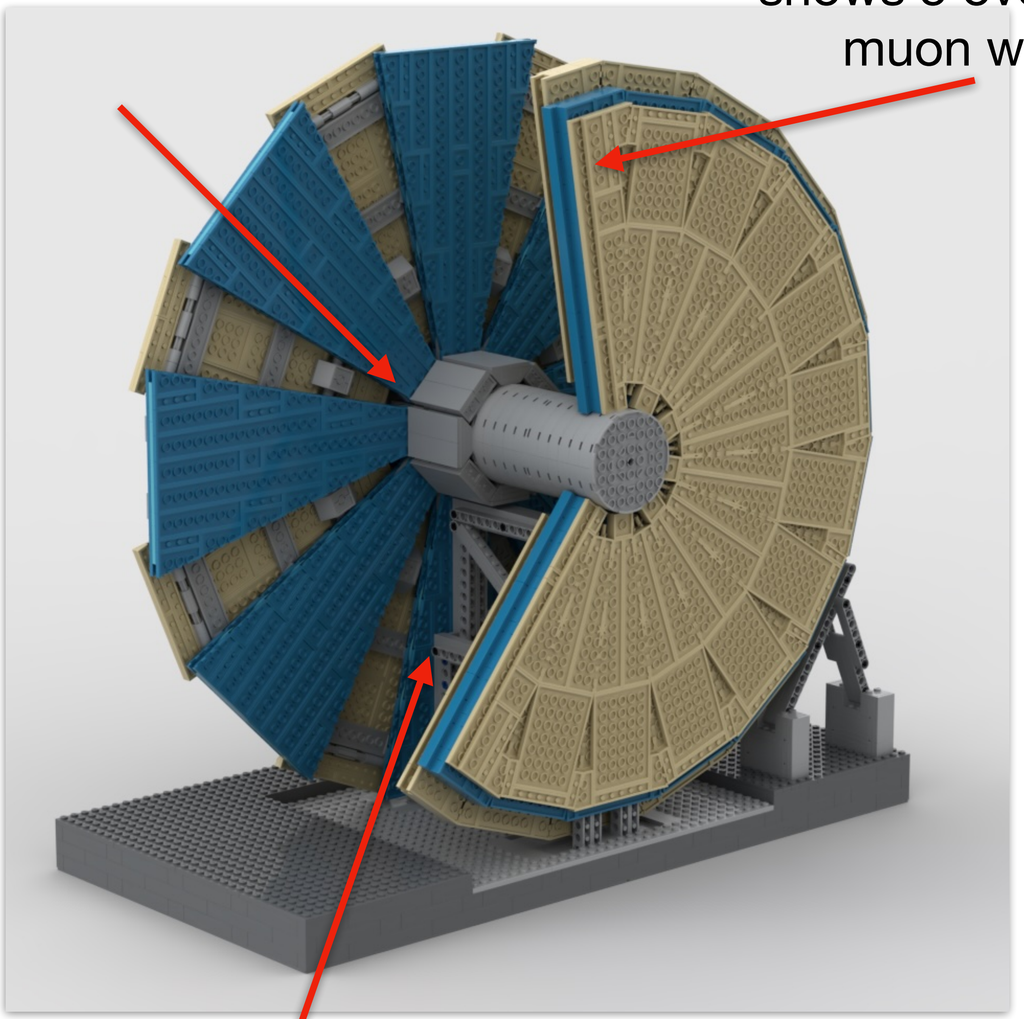
16 overlapping muon chambers



Support struts integrated into display base

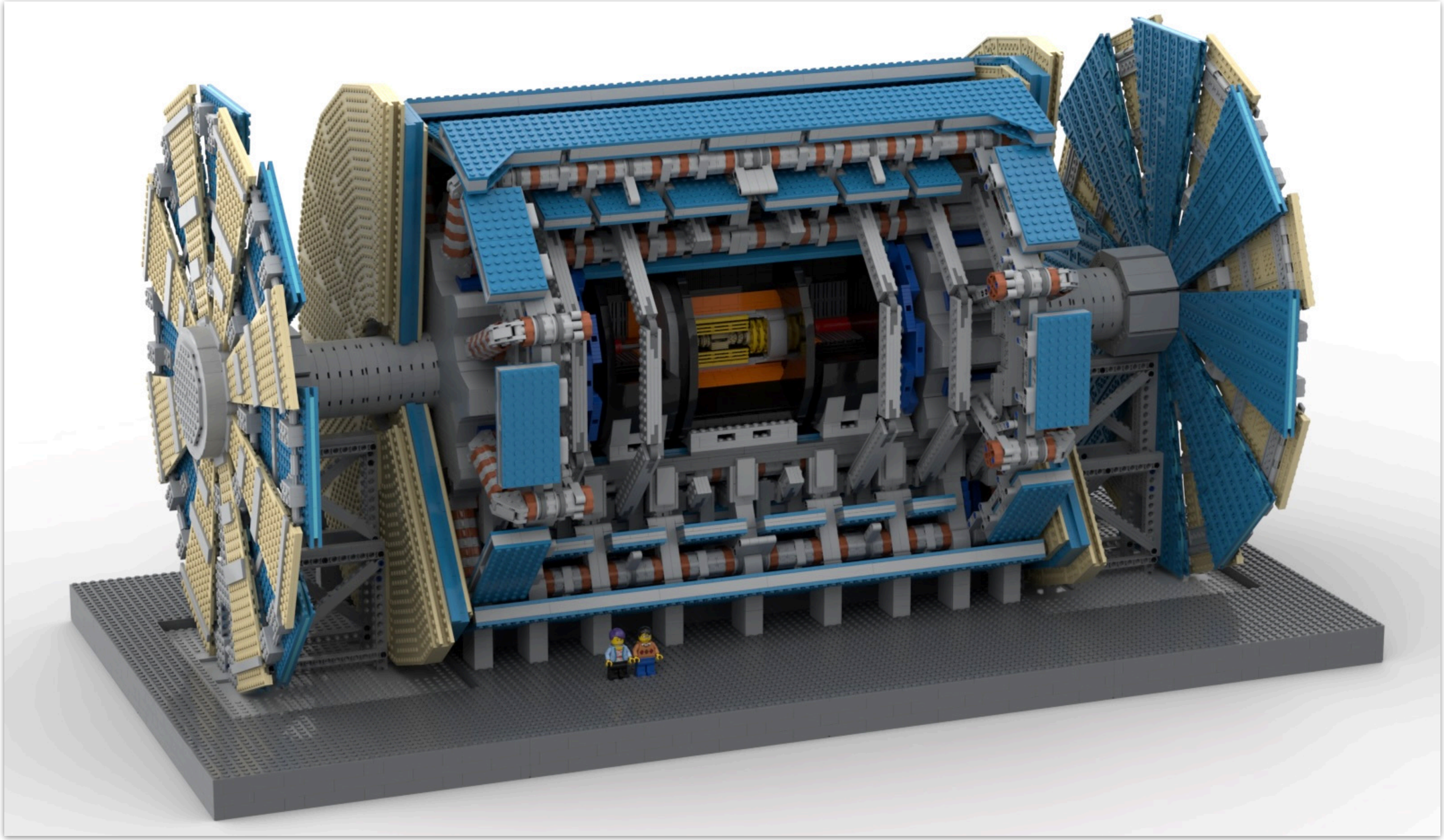
Shielding

Cutaway segment shows 5 overlapping muon wheels



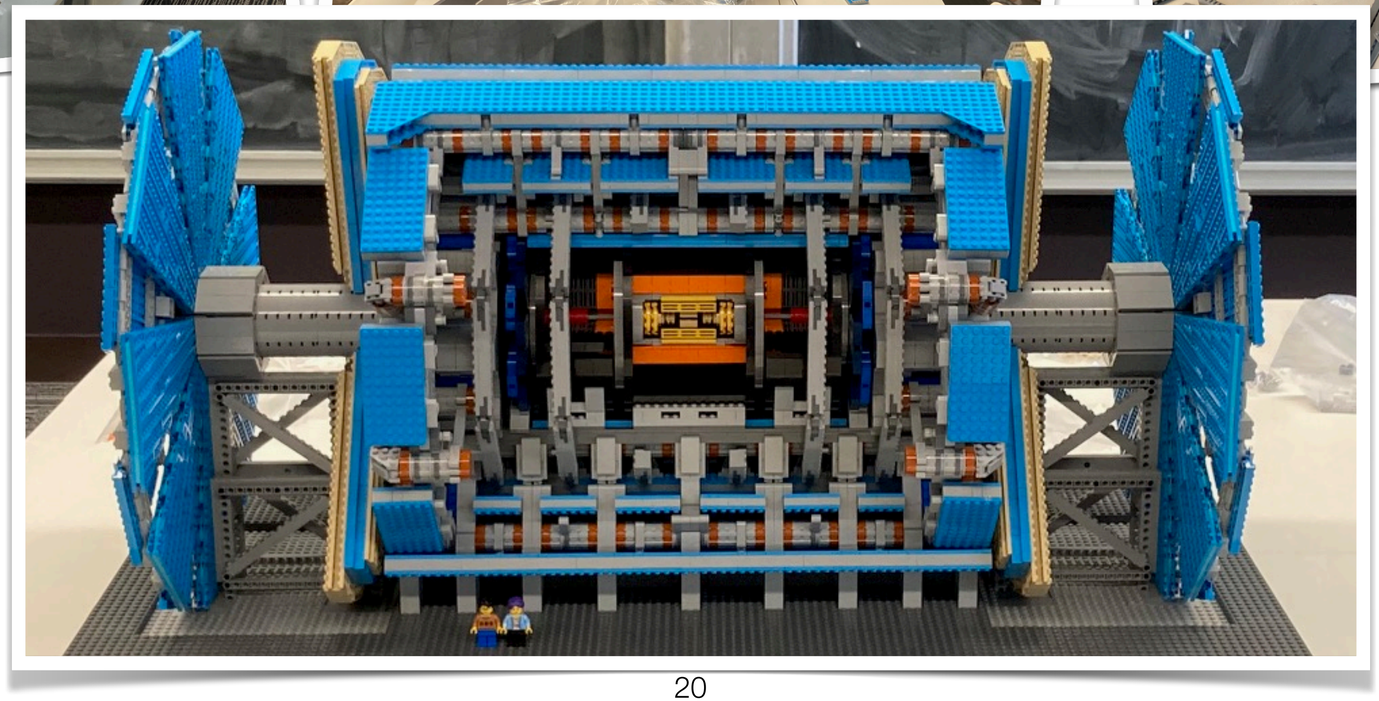
Support structure not accurately modelled but vital for structural integrity

The Final Model



Building in Real Life

- Build event hosted at Sheffield in June 2024: ~15 people building for 3 days!



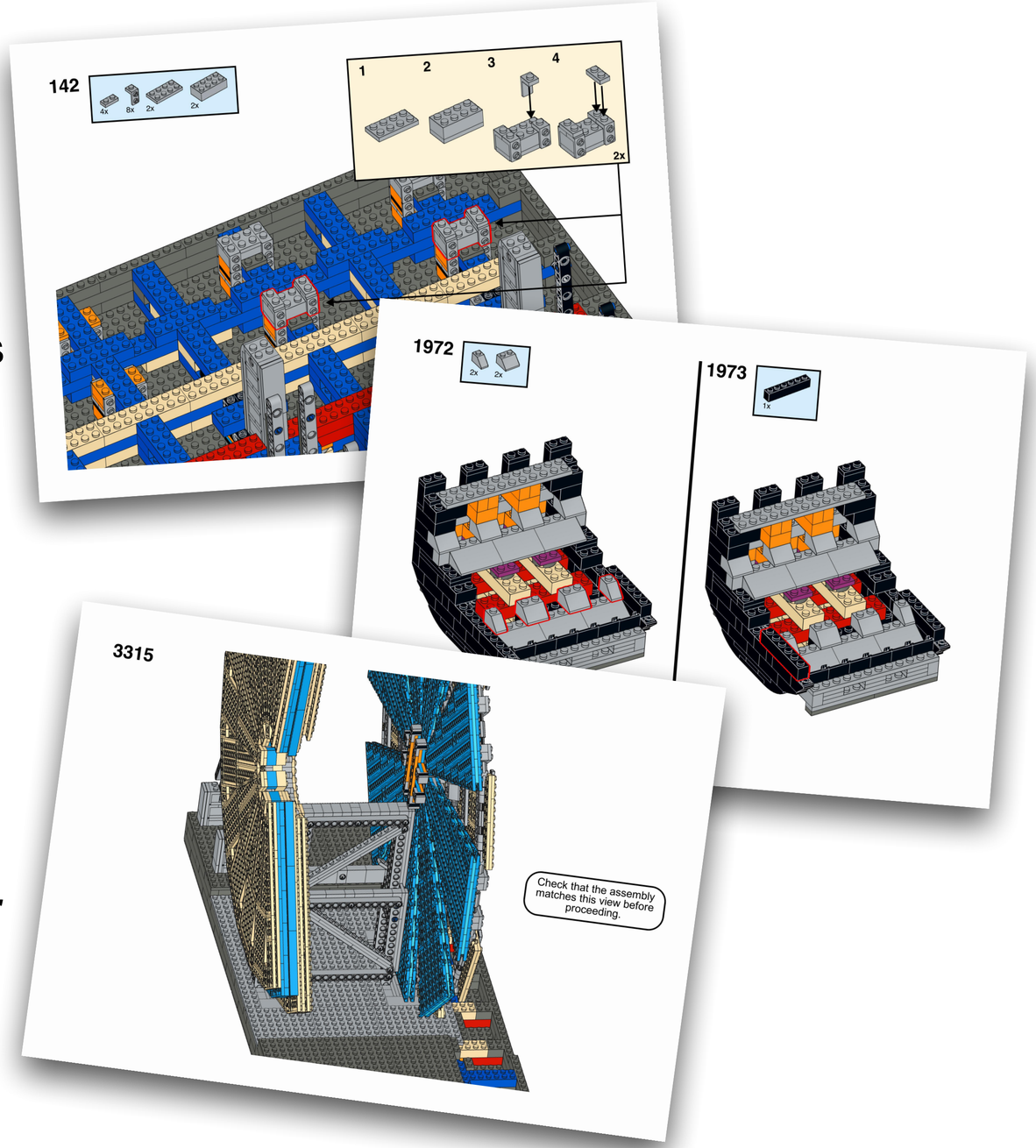
The Book of Instructions

- A model has no value if others cannot recreate it

- A detailed **step-by-step guide** has been prepared
  - Model was rebuilt digitally, with the bricks being painstakingly organised into steps and sub-assemblies

- Final manual follows style of official LEGO sets
  - Over **700 hours** work!
  - Over **4,000 steps** on **2,300 pages**!
  - **1.5 GB** download!

- ***Special thanks to the ATLAS Outreach Team for their support in this endeavour!***



Building Your Own!

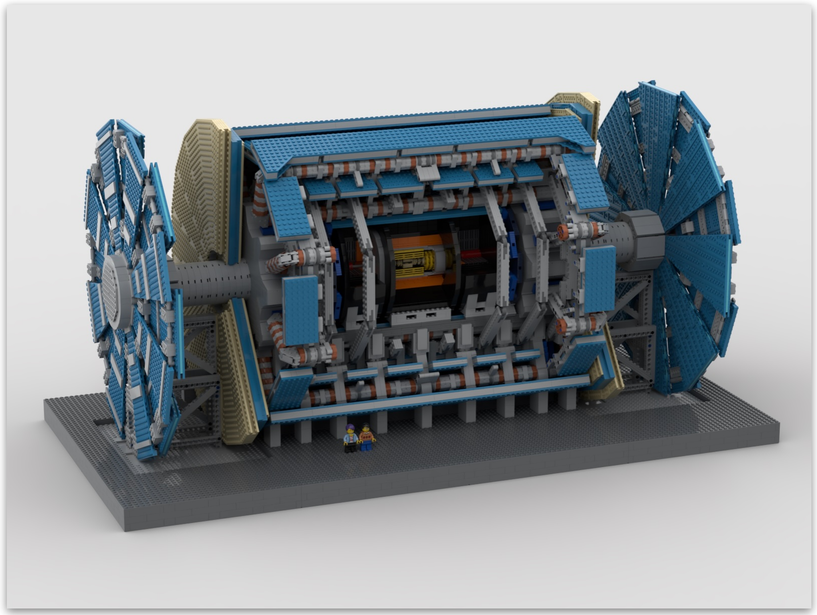
- Everything you need to build your own is available here:
  - https://build-your-own-particle-detector.org/models/atlas-run-4-model/

- You can download for free:
  - Digital model
  - Complete parts list
  - 2,300 page step-by-step building guide

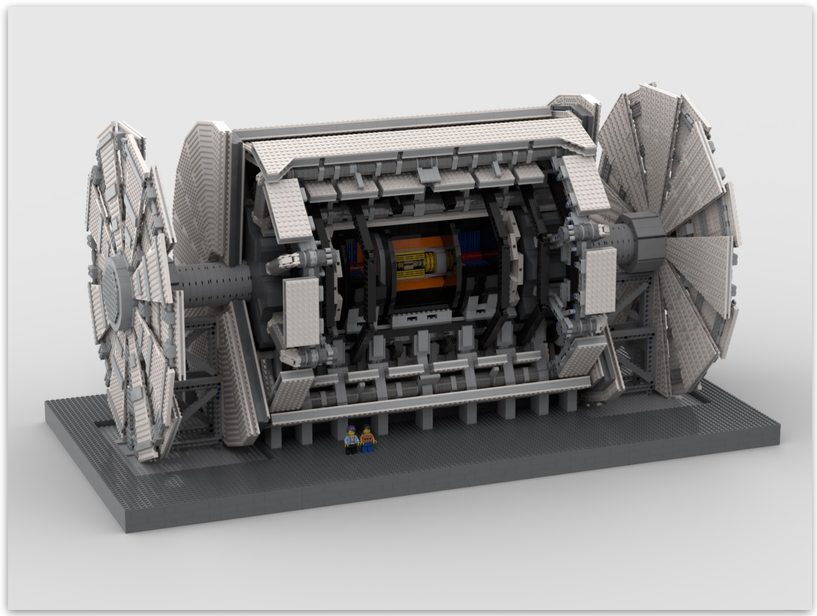
- Parts cost:
  - 4,000 EUR direct from Lego
  - ~2,500 EUR using 3rd party sellers (Bricklink)

Alternate Colour Schemes

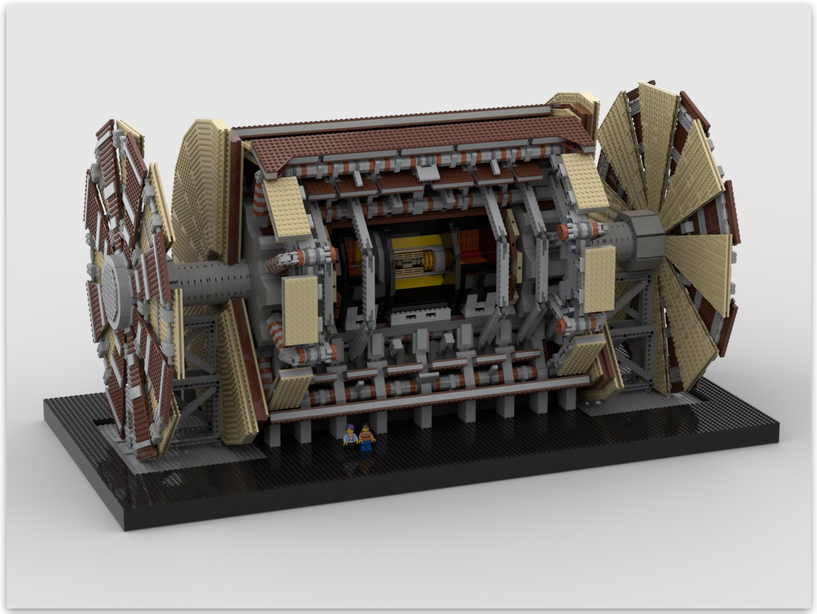
- LEGO periodically revise set of available elements
- To maximise model shelf-life, various alternative colour schemes are available
- PDF manual and parts lists will need exporting from CAD model file



The Artist’s Concept

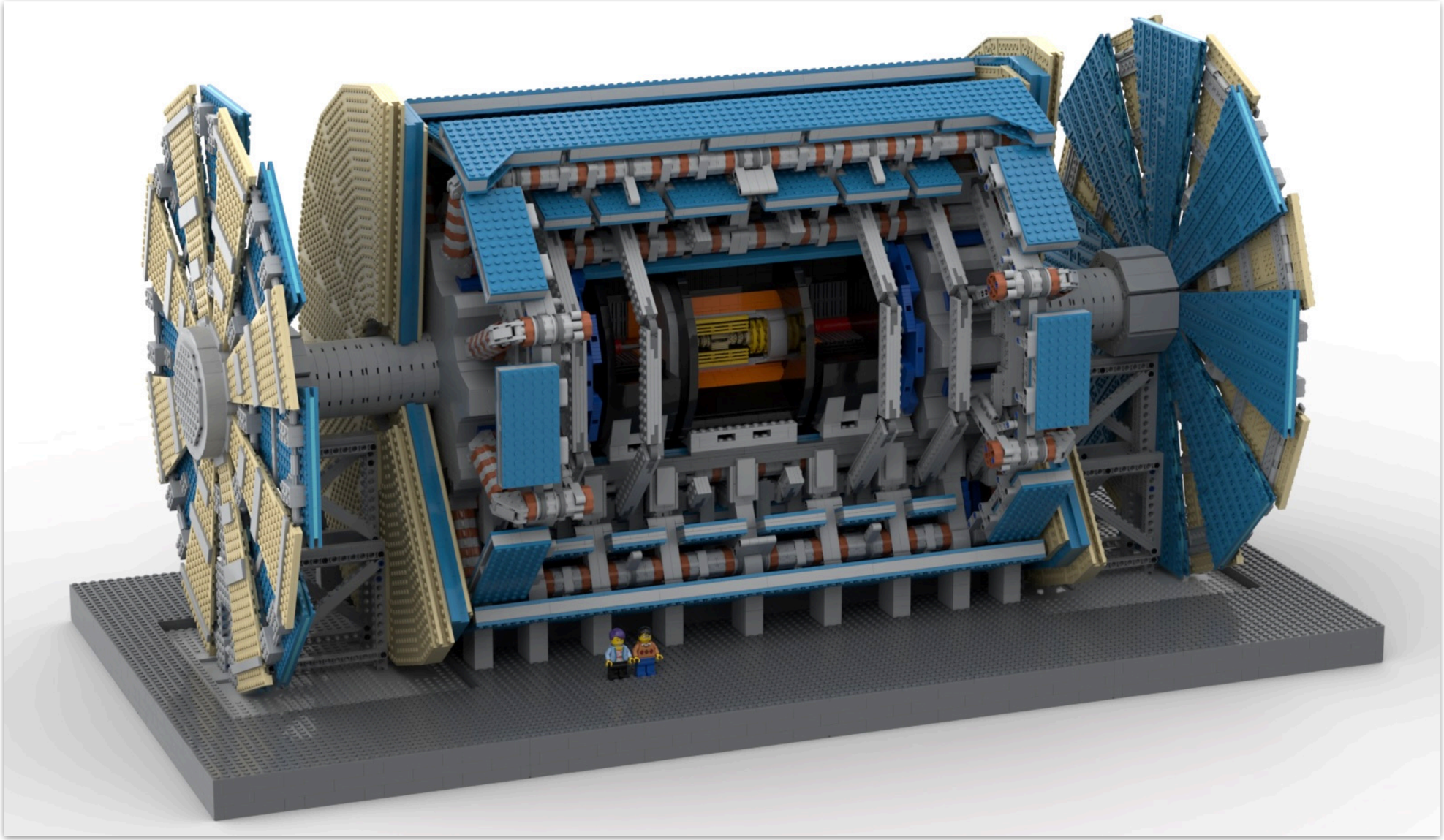


The Mehlhase



The Woodworker

Happy Building!



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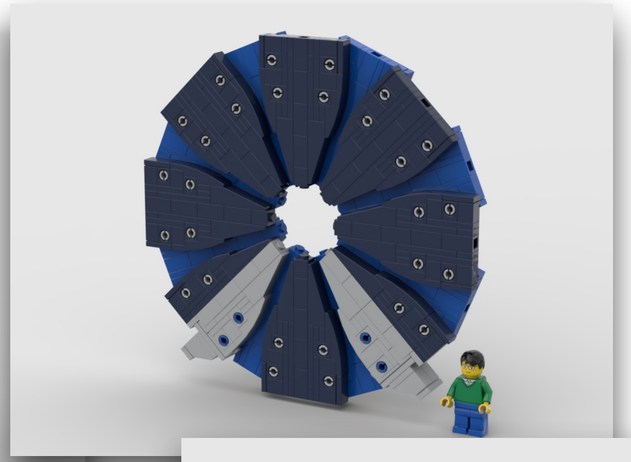
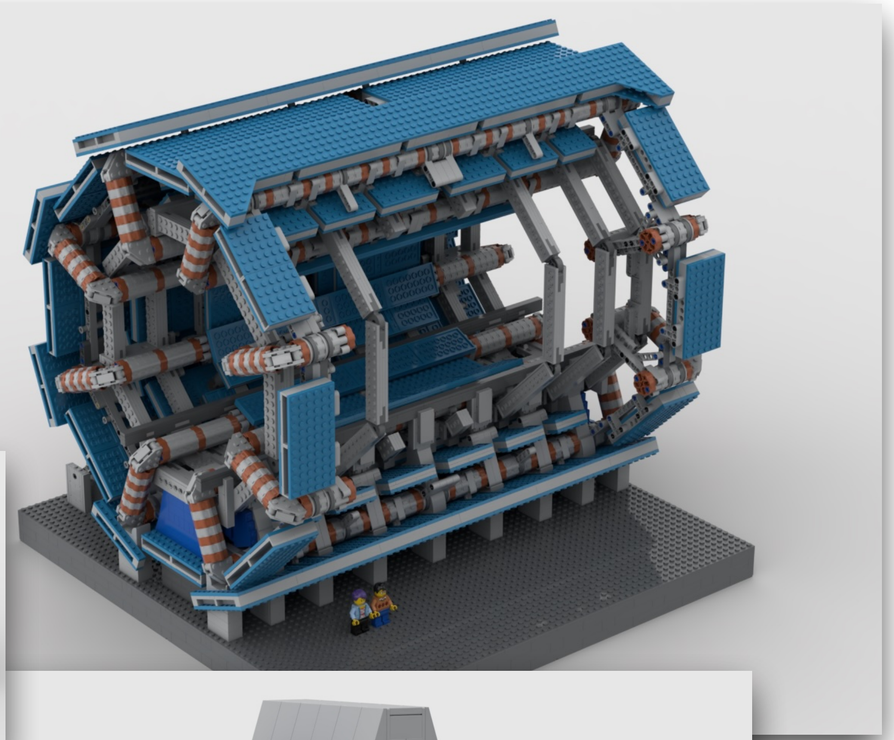
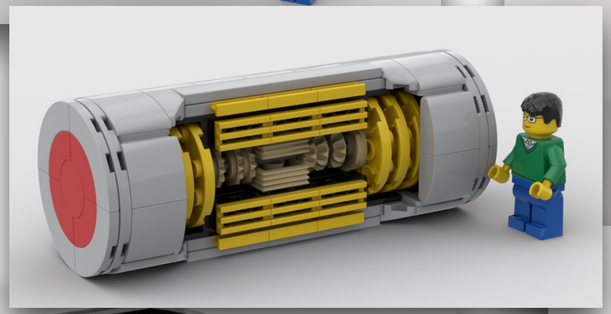
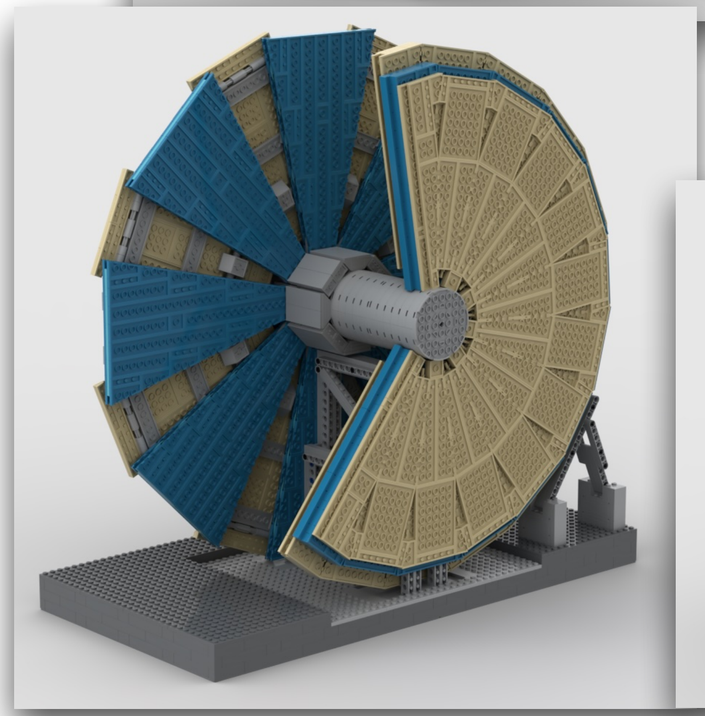
Backup

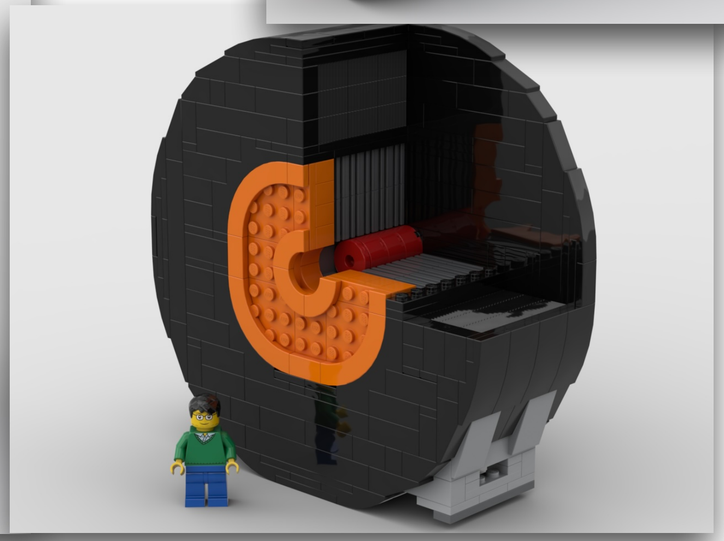
Modular Breakdown

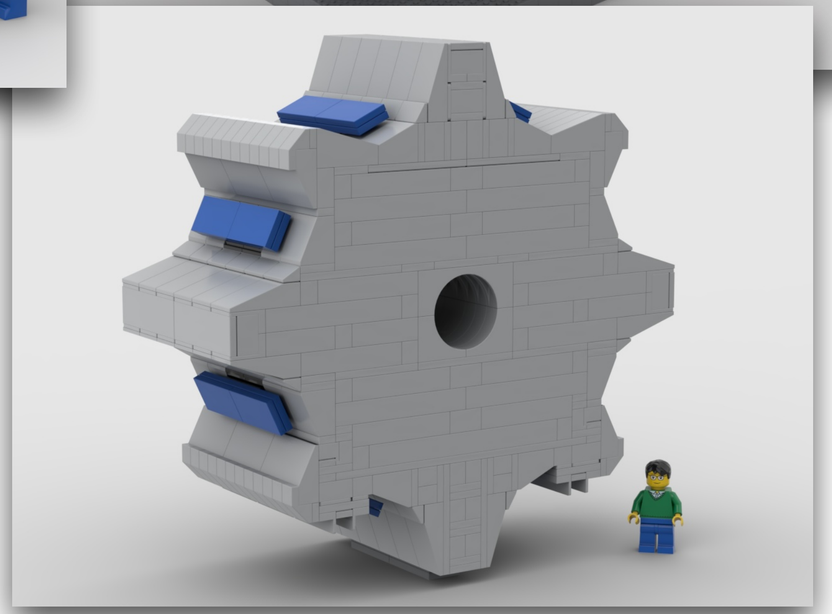




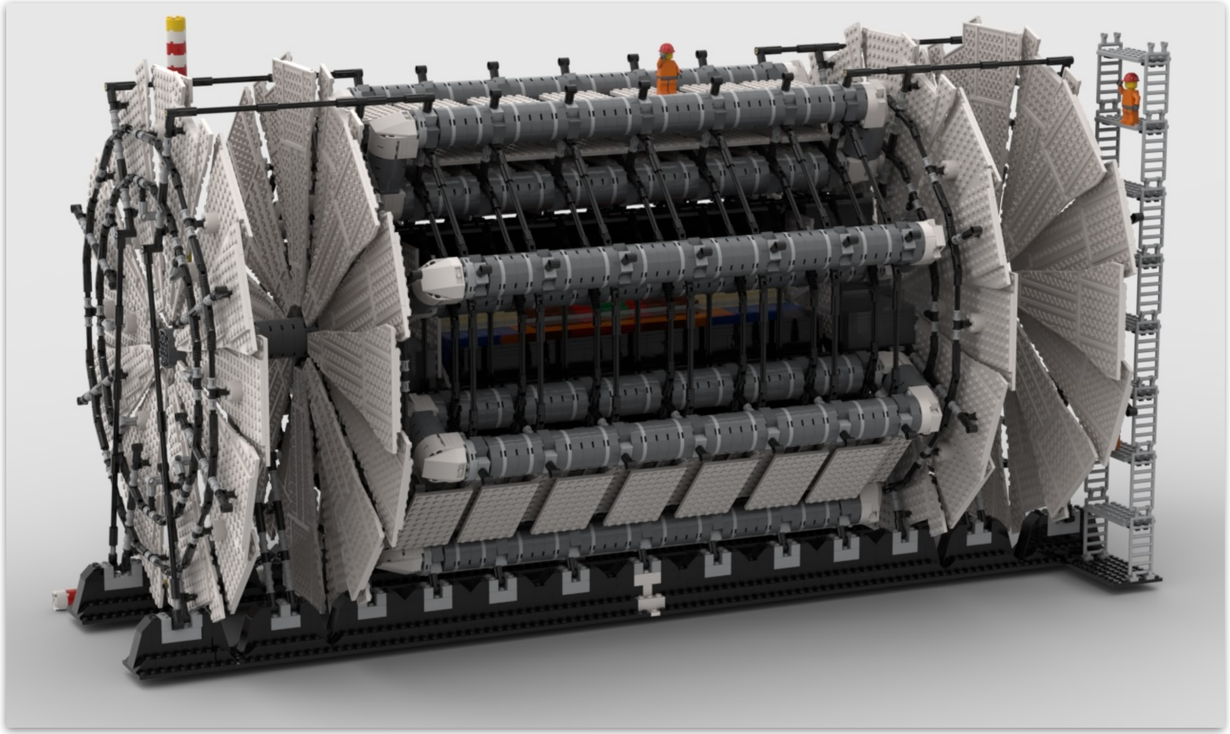


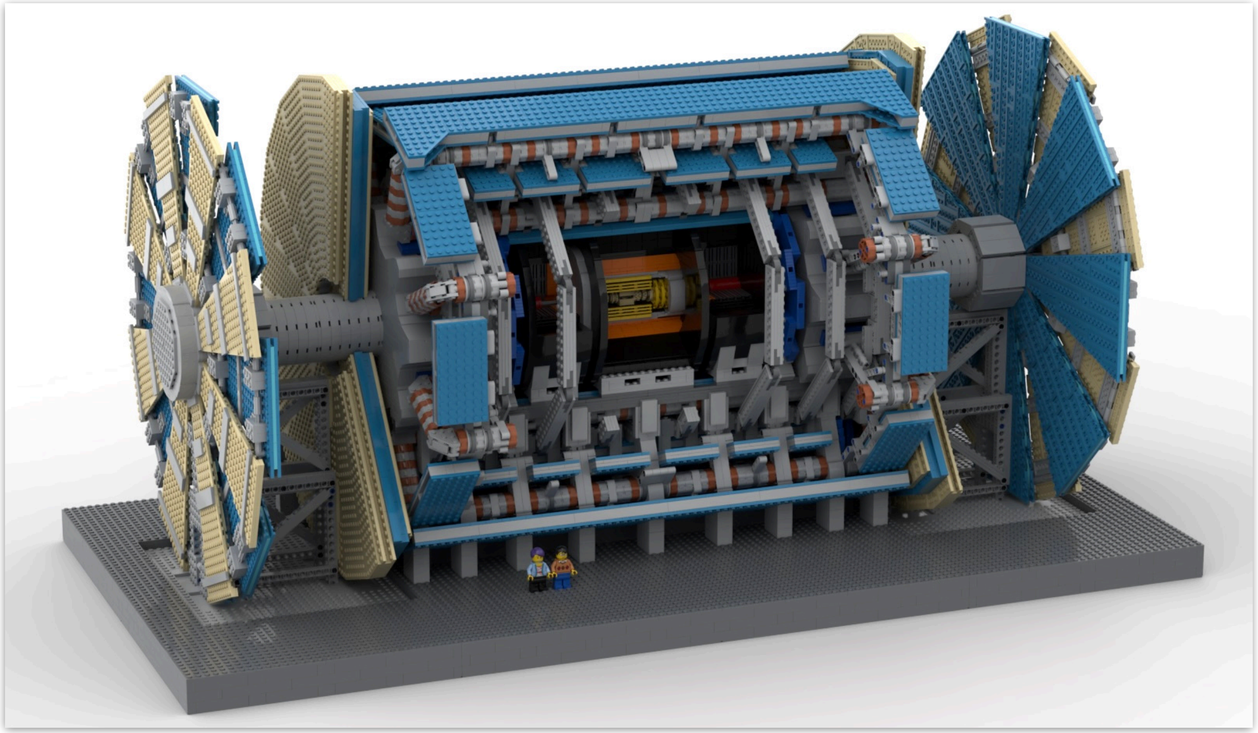




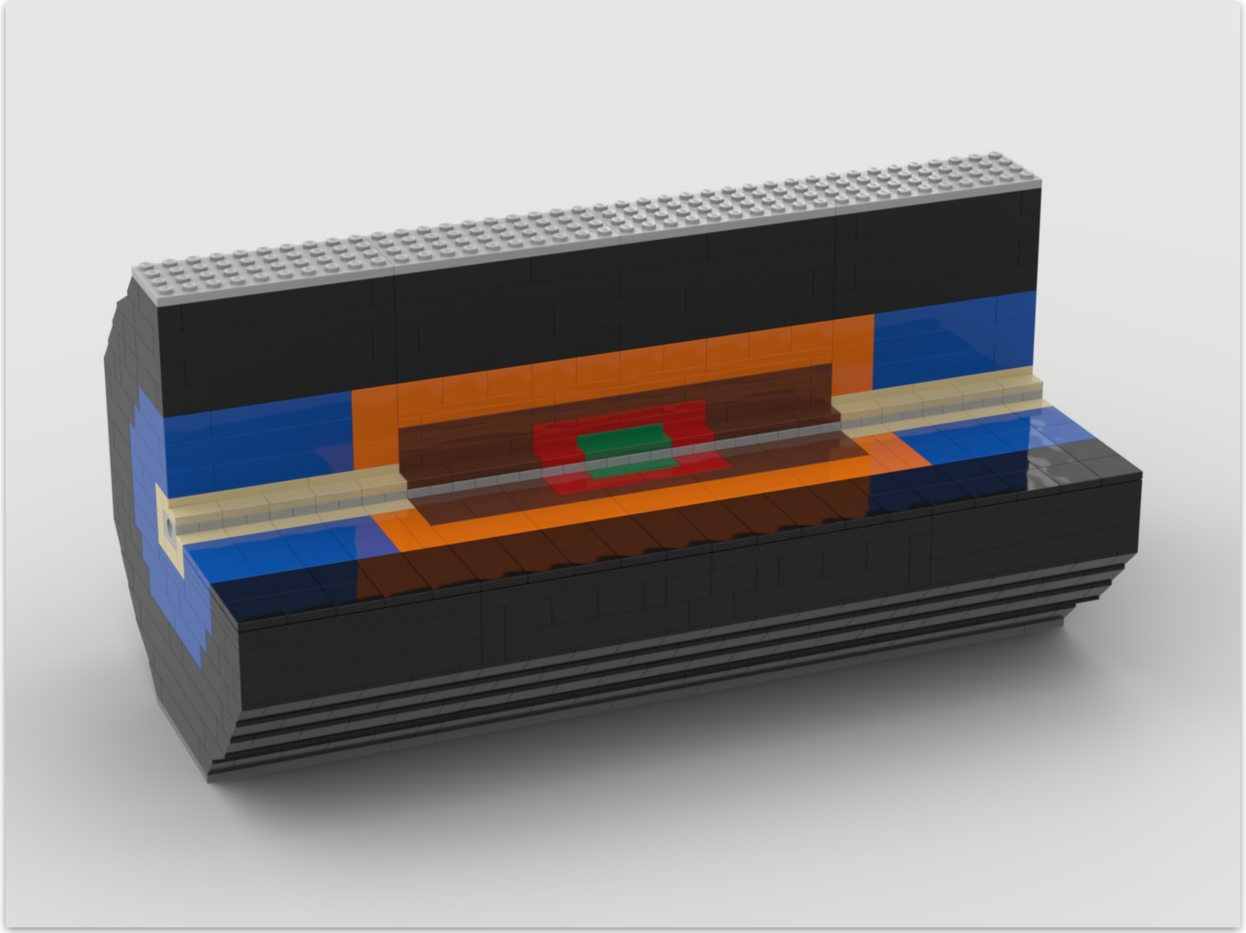


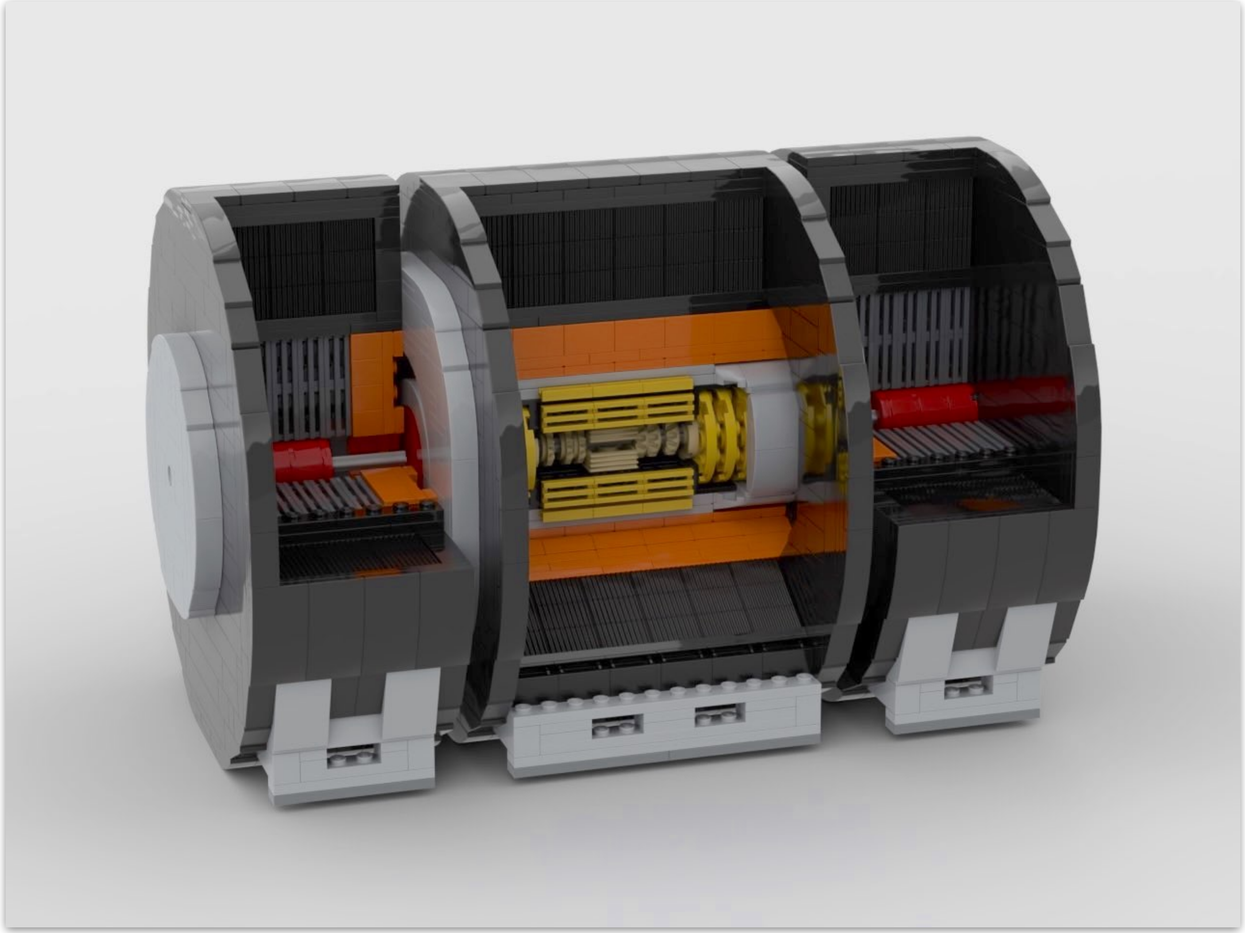
Original vs New



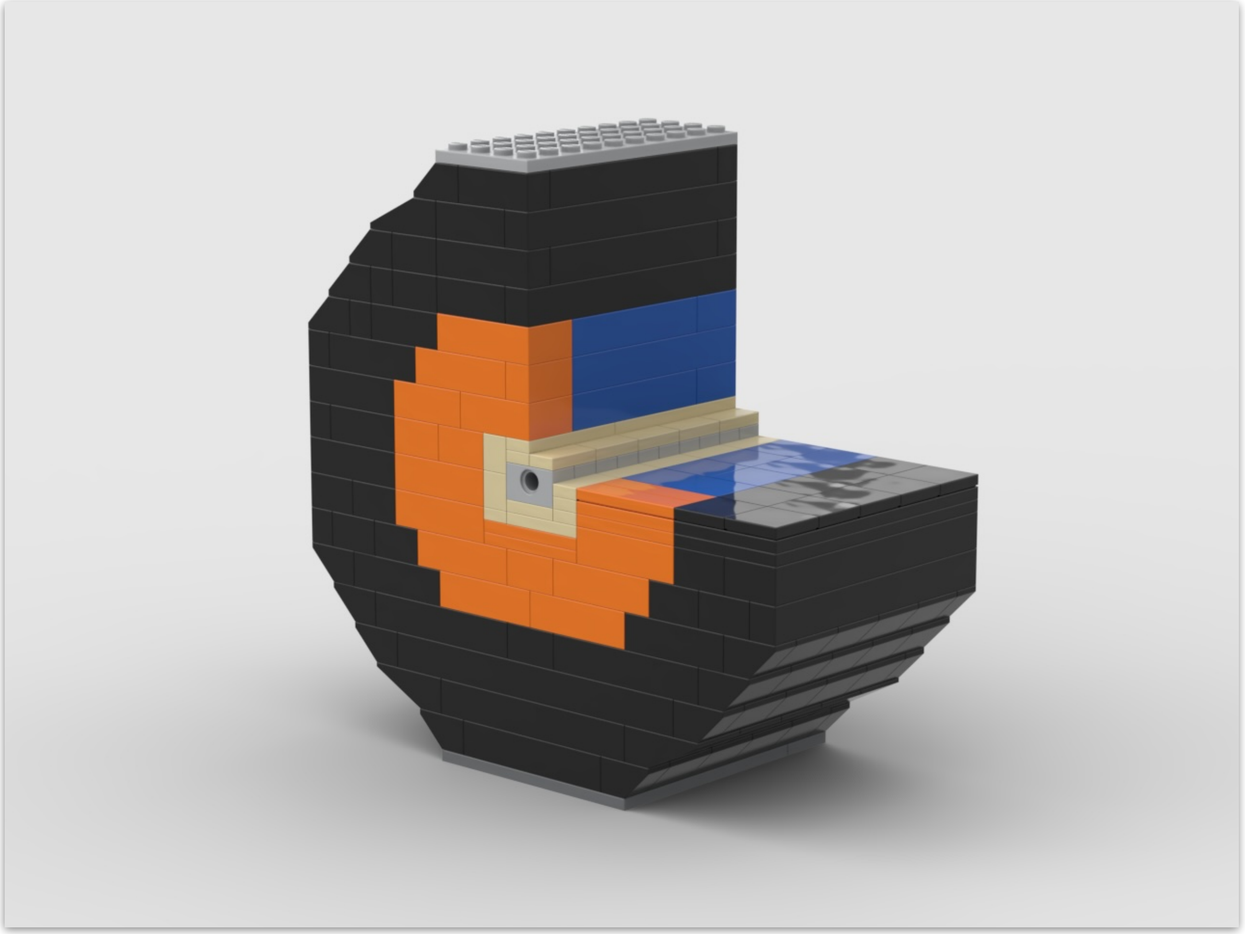


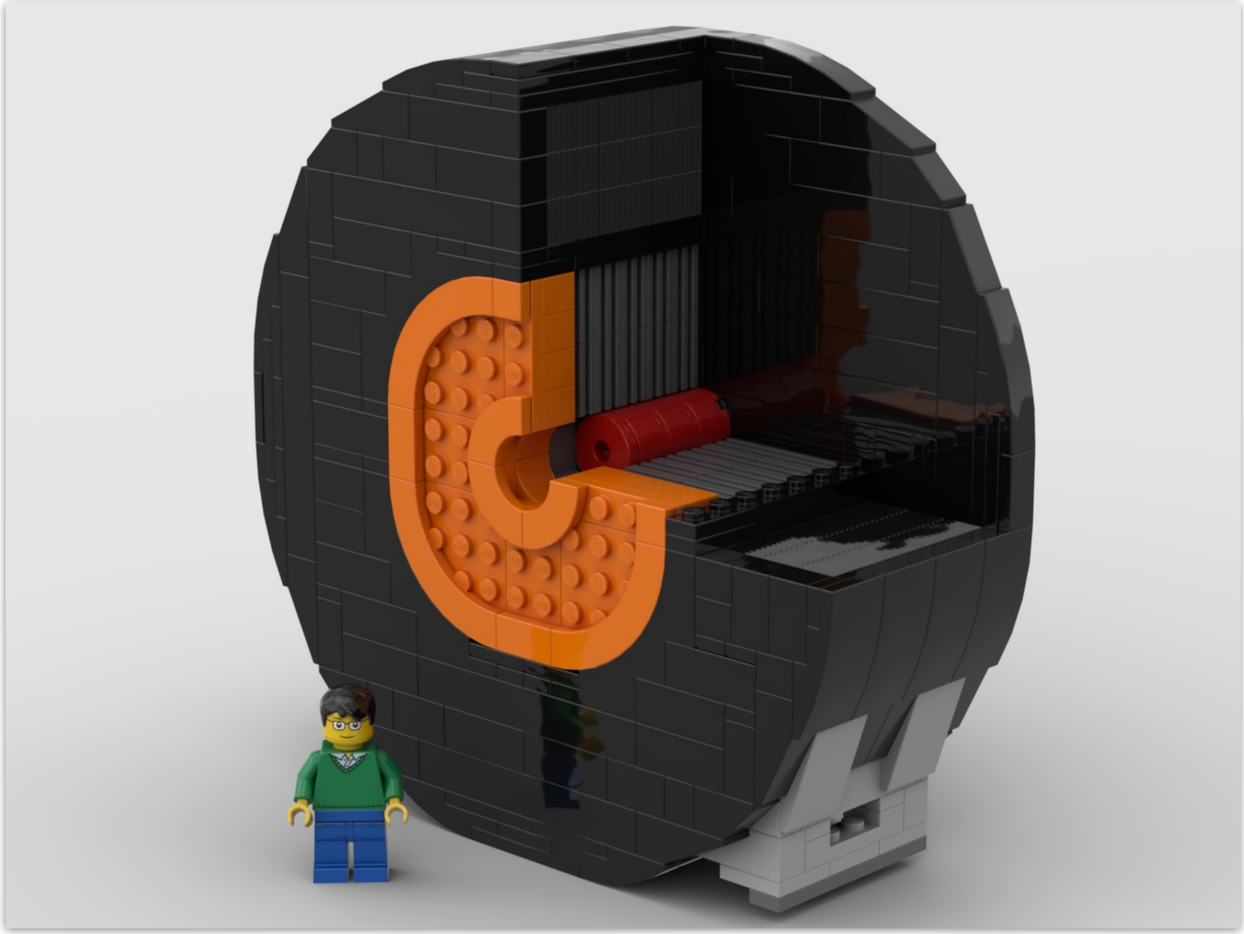
Original vs New: Calorimeters





Original vs New: Endcap Calorimeters





Original vs New: EC Toroid