

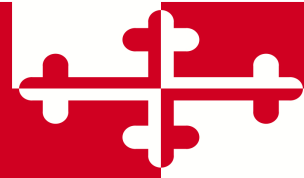
# Creating a LEGO® model of CMS

Jeff  
Temple,  
Marguerite  
Tonjes,  
Jaime  
Gomez



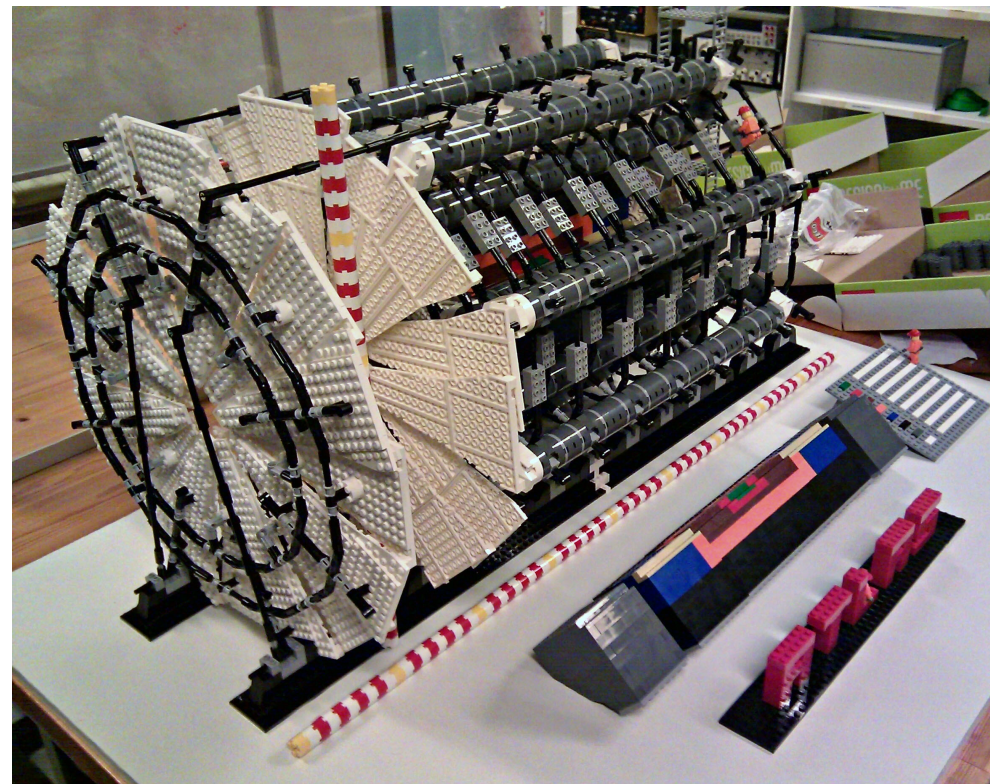
University of  
Maryland

Depts. of  
Physics/Nuclear  
Chemistry

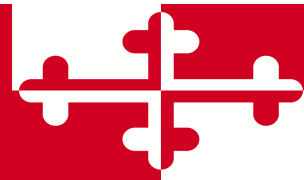


# Why?

- Inspired by ATLAS model built by Sascha Mehlhase at the Neils Bohr Institute ( <http://sascha.mehlhase.info/physics.php> )
- Why let ATLAS have all the cool toys?



Anything ATLAS can do, CMS can do ... ~~better~~  
... ~~later~~  
... with more mass  
in a smaller volume!

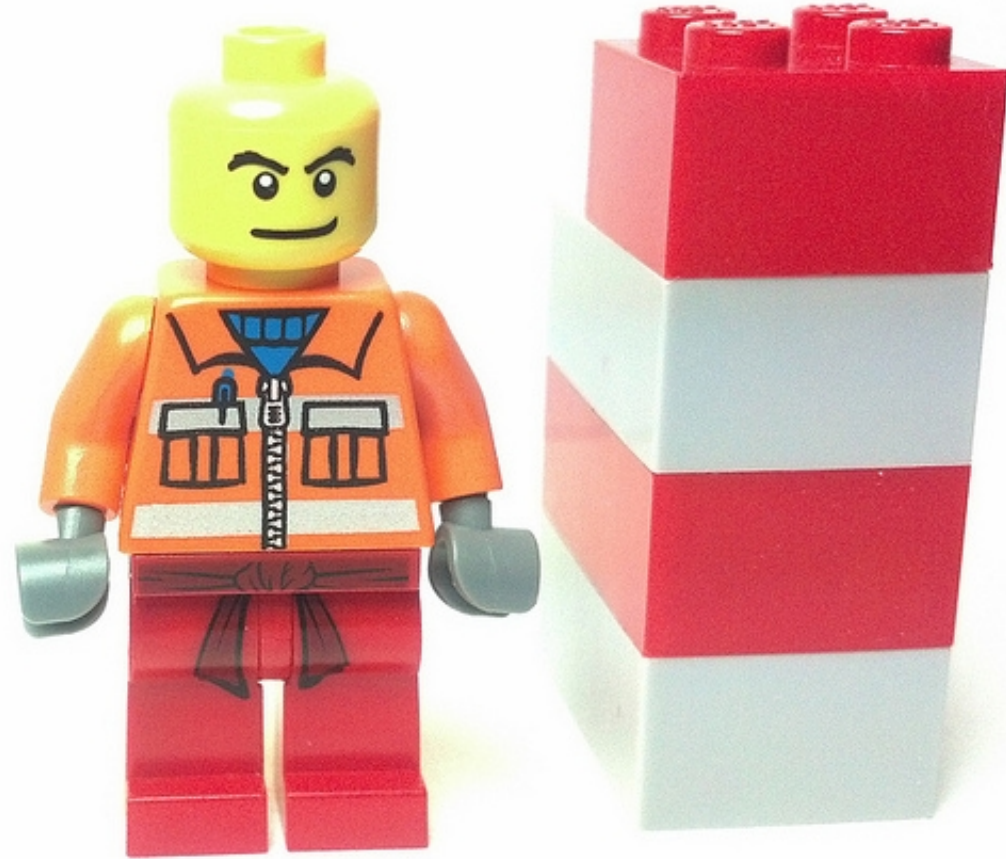




# LEGO® dimensions

Scale model to LEGO®  
“minifig” dimensions

- Roughly a **1:48** scale
- 1 LEGO® brick = 0.461 m high
- 1 LEGO® stud = 0.382 m wide

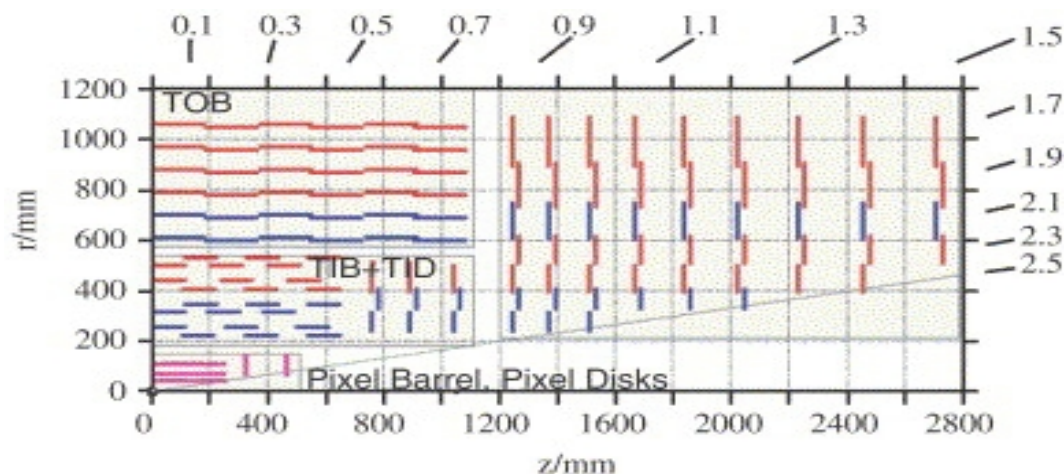


Standard Minifig is  
4 bricks (1.84 m) tall

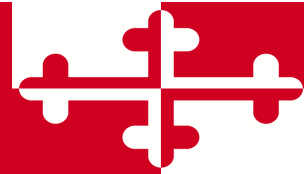


# CMS Silicon Tracker

- ~5.6 m long (z)
- diameter ~ 2.4 m
- Comprises:

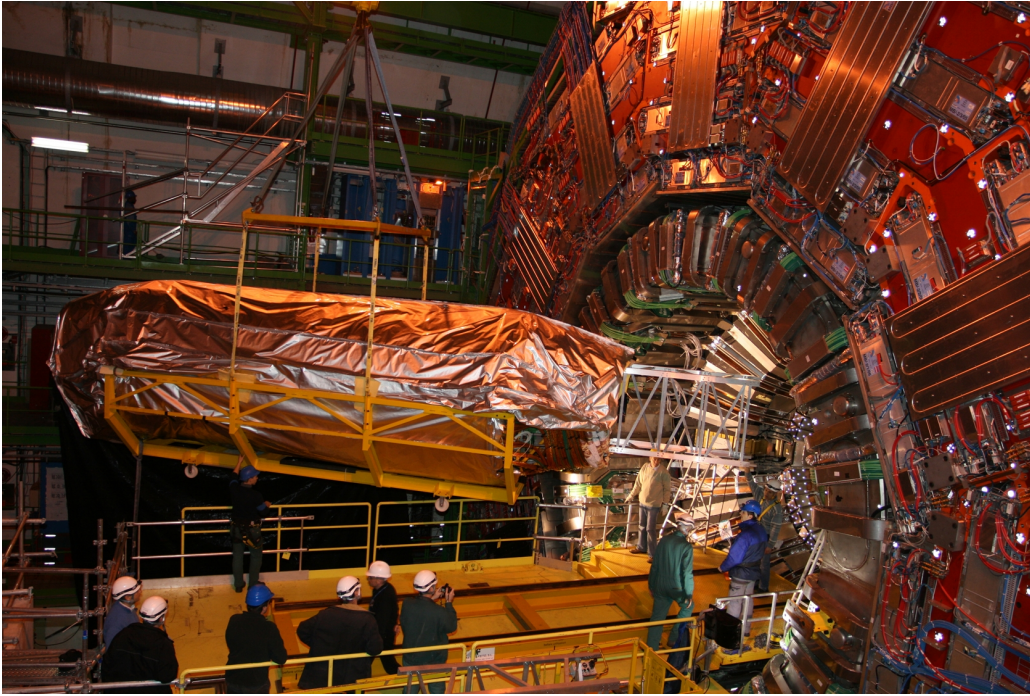


- Tracker Inner Barrel & Tracker Inner Disk (TIB/TID):  
 $r < 0.5$  m,  $z < 1.2$  m
- Tracker Outer Barrel (TOB): extends to  $r = 1.2$  m
- Tracker End Cap (TEC): extends to  $|z| = 2.8$  m
- Pixel tracker outer radius is 10.2 cm; too small to have a LEGO<sup>®</sup> counterpart





# CMS Silicon Tracker Images



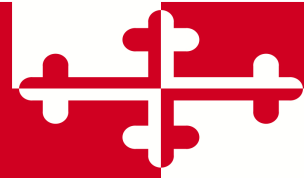
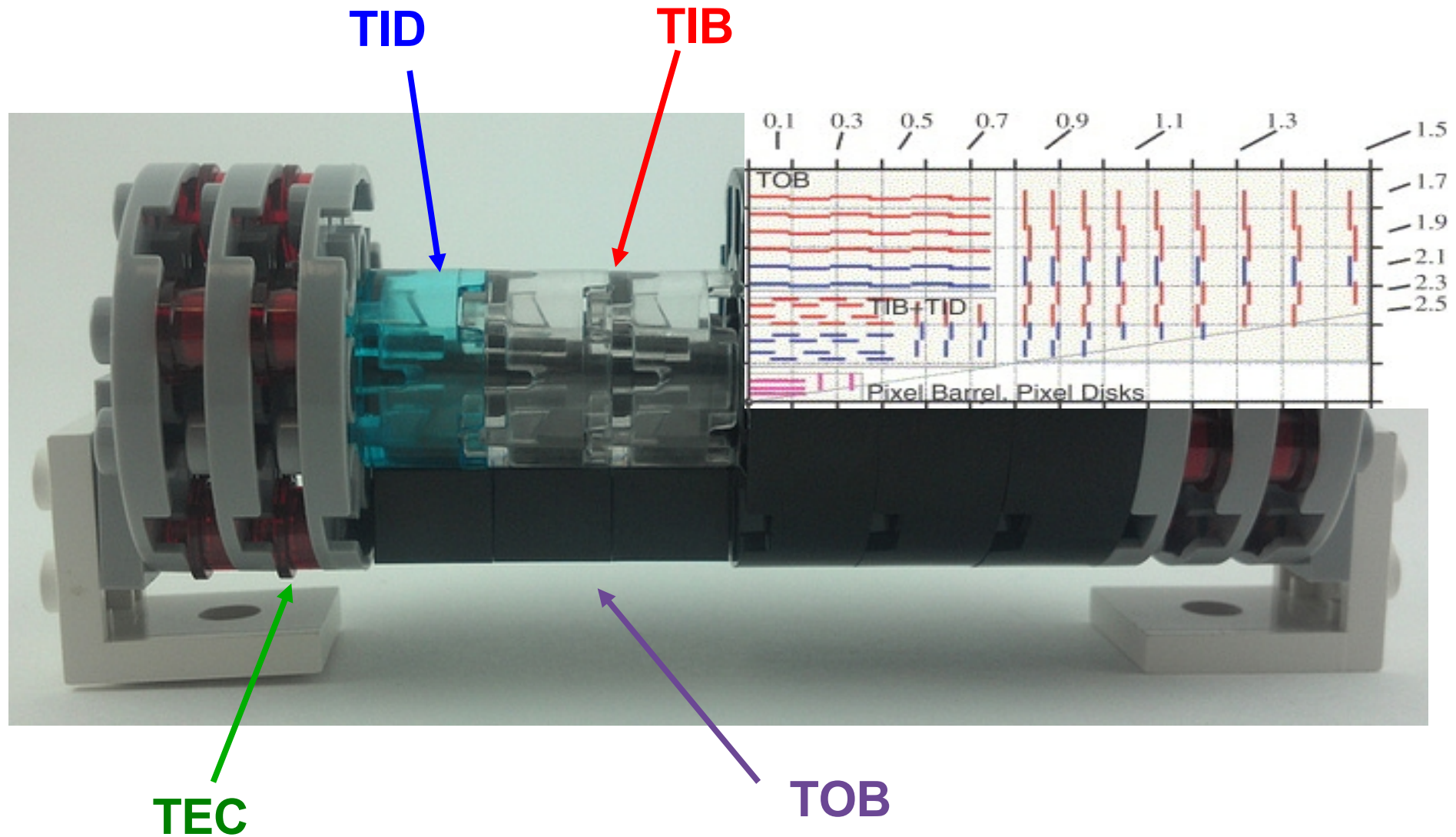
*Insertion into CMS*



*View of Tracker End Cap*

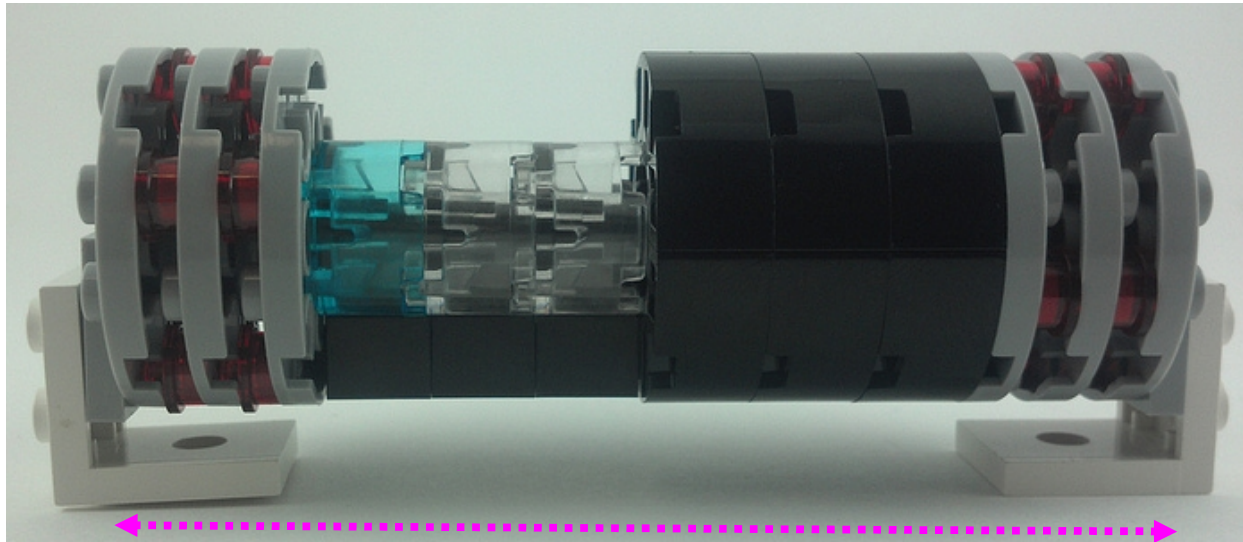


# CMS Silicon Tracker: LEGO® Model





# CMS Silicon Tracker: Comparing Dimensions

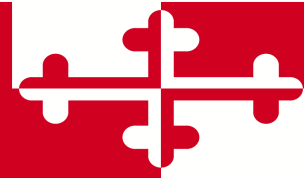
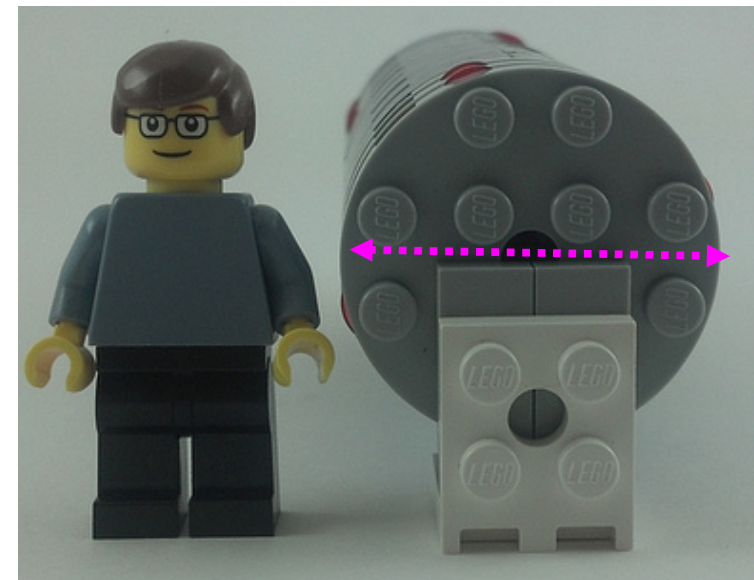


Length: 9.3 bricks  
(4.3 meters)

- Also smaller than actual tracker, but proportionally consistent with radius
- Tracker holding apparatus extends overall length to 10.6 bricks (4.9 m)

Diameter: 4 studs  
(1.5 meters)

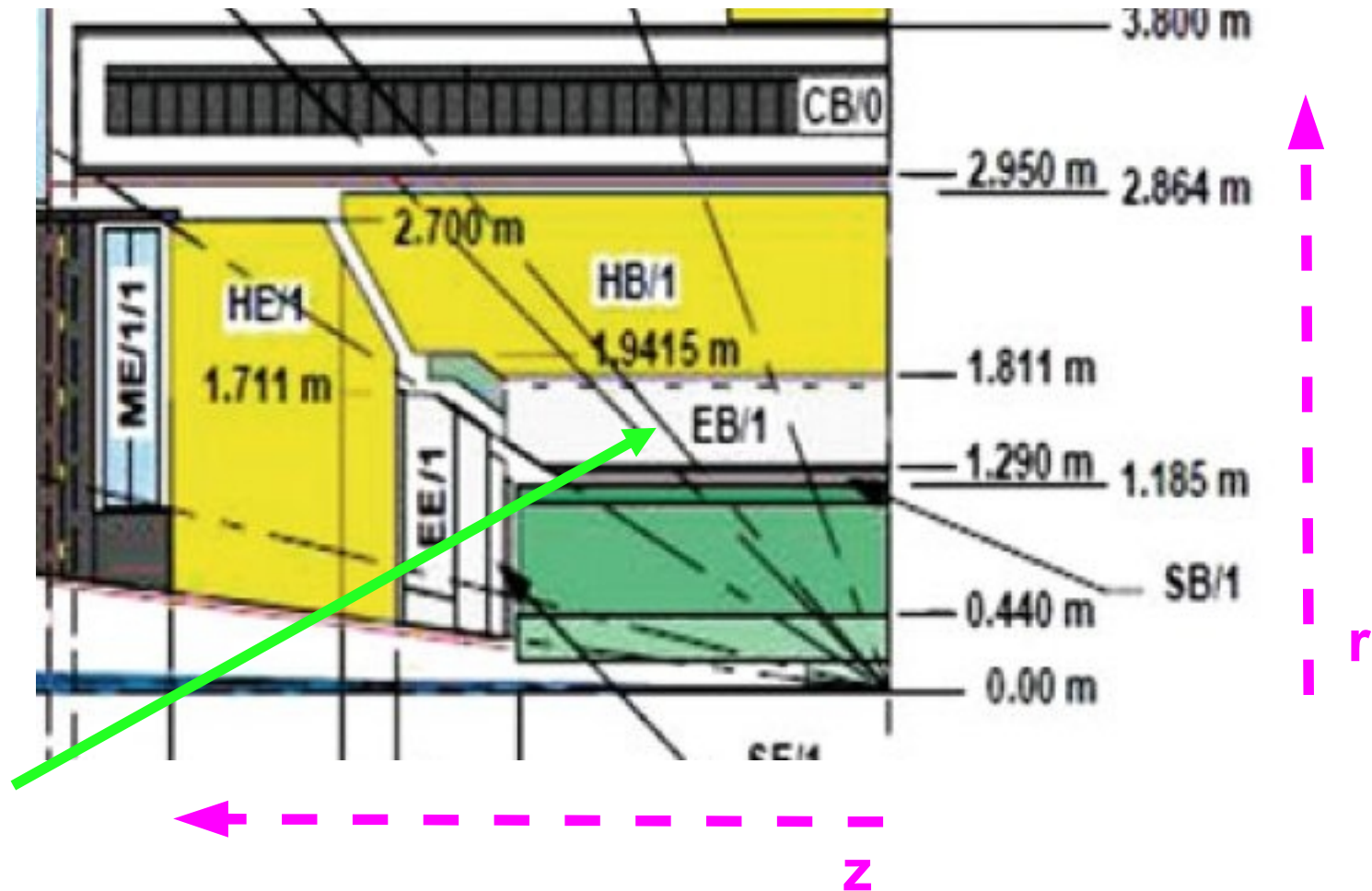
A bit smaller than the actual tracker, but we're limited by availability of round LEGO® pieces



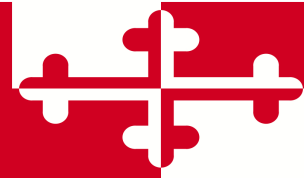


# Electromagnetic Calorimeter (ECAL)

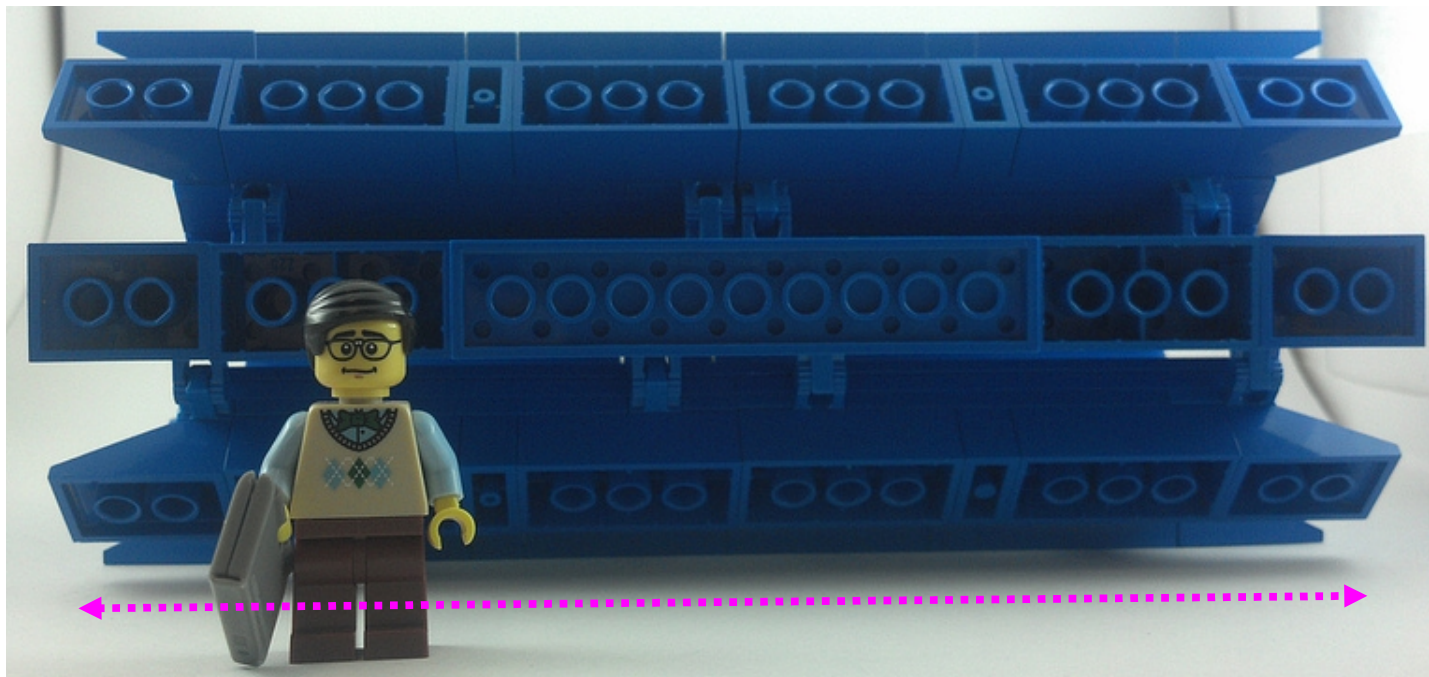
- A Lead Tungstate barrel calorimeter (EB) extends from  $r=1.3$  m to  $r=1.8$  m, and to  $|z|=2.9$  m in a pseudo-projective geometry



ECAL Barrel

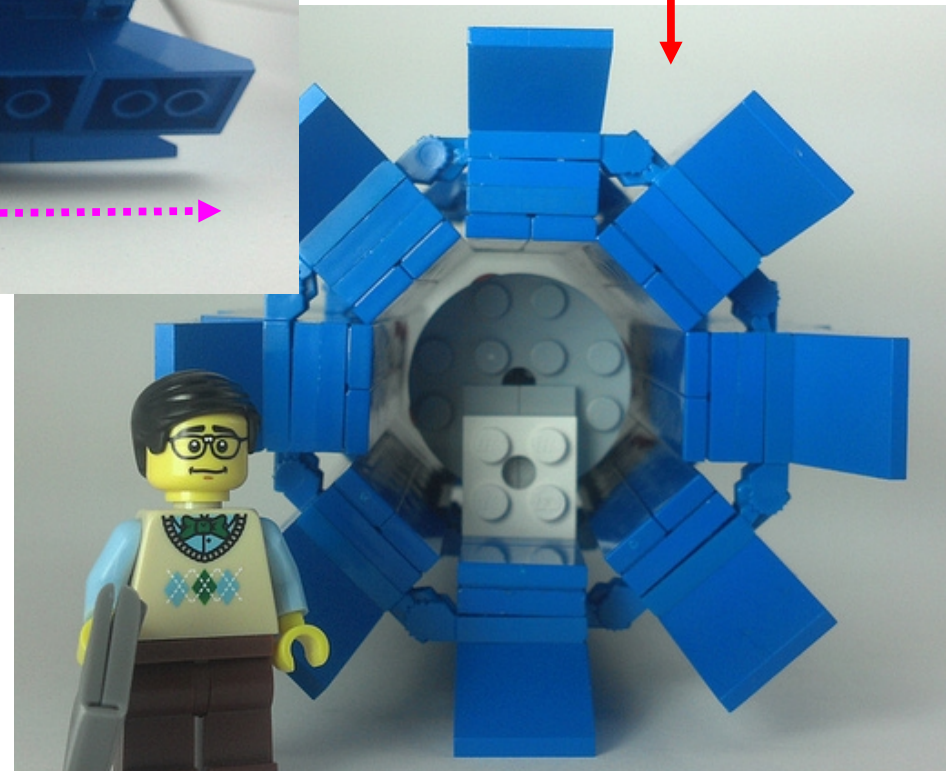


# LEGO® ECAL

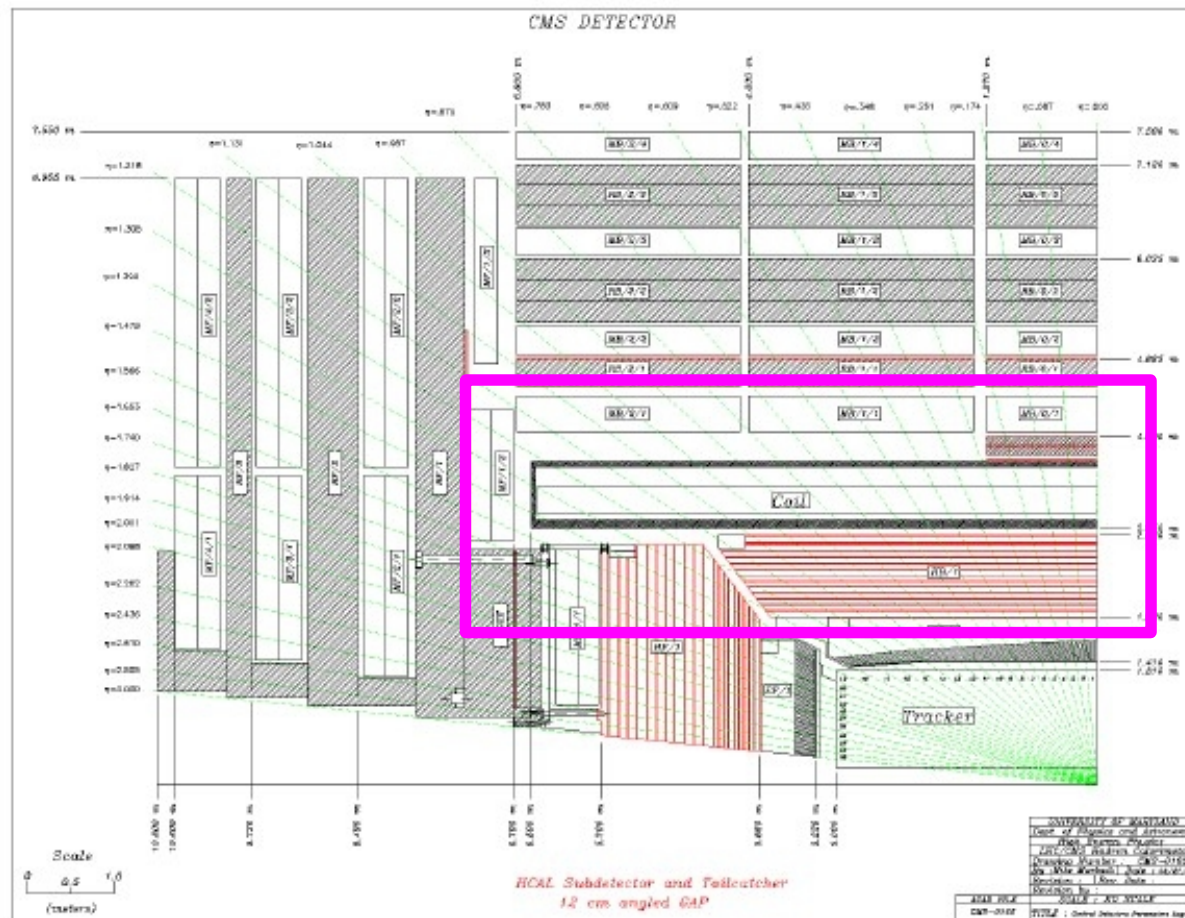


Main body of ECAL is 20 studs ( 7.7 m) long, with angled pieces at ends to suggest projective geometry

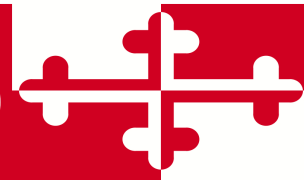
Tracker fits snugly within ECAL!



# CMS Hadron Calorimeter (HCAL) and Solenoid



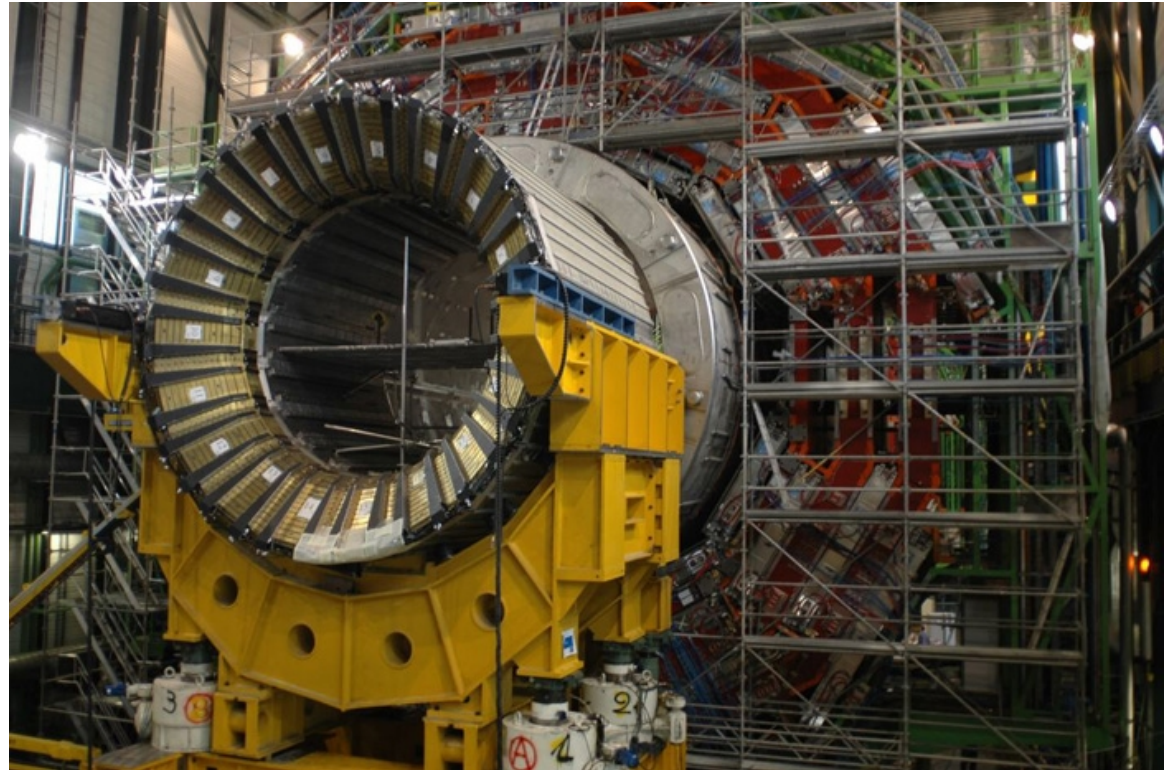
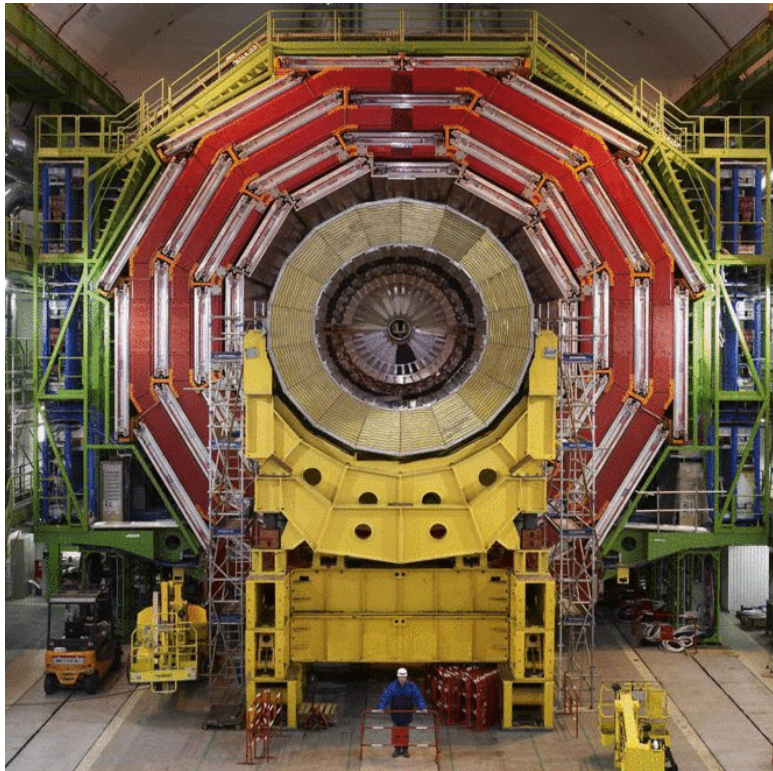
- HCAL barrel is a brass-scintillator sampling calorimeter
  - made up of 18 20-degree wedges within solenoid coil
    - Each wedge ranges from  $r=2$  m to  $r=3$  m
  - HCAL barrel is 9 m long
- Solenoid is  $\sim 1$  m thick in radius, 12.5 m long



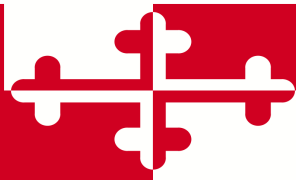


# HCAL/Solenoid images

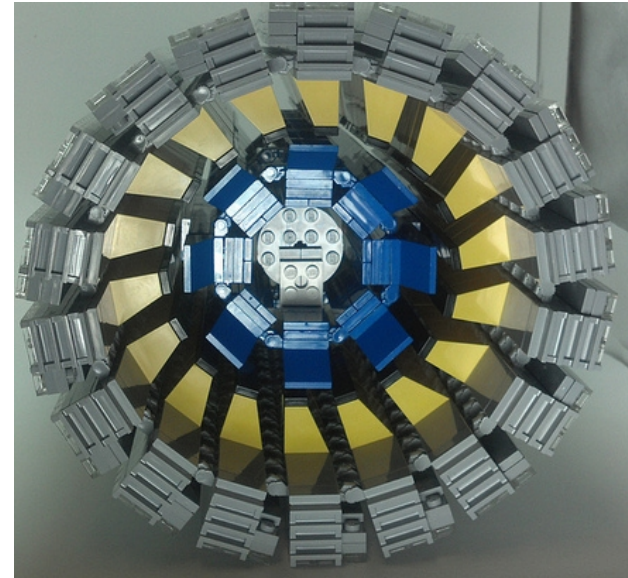
*below: HCAL barrel  
(without solenoid) inside the  
muon rings*



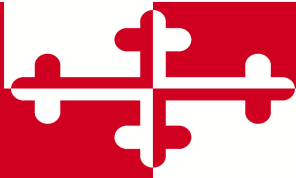
*above: HCAL being inserted into solenoid*



# Lego® HCAL/Solenoid:



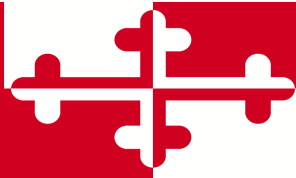
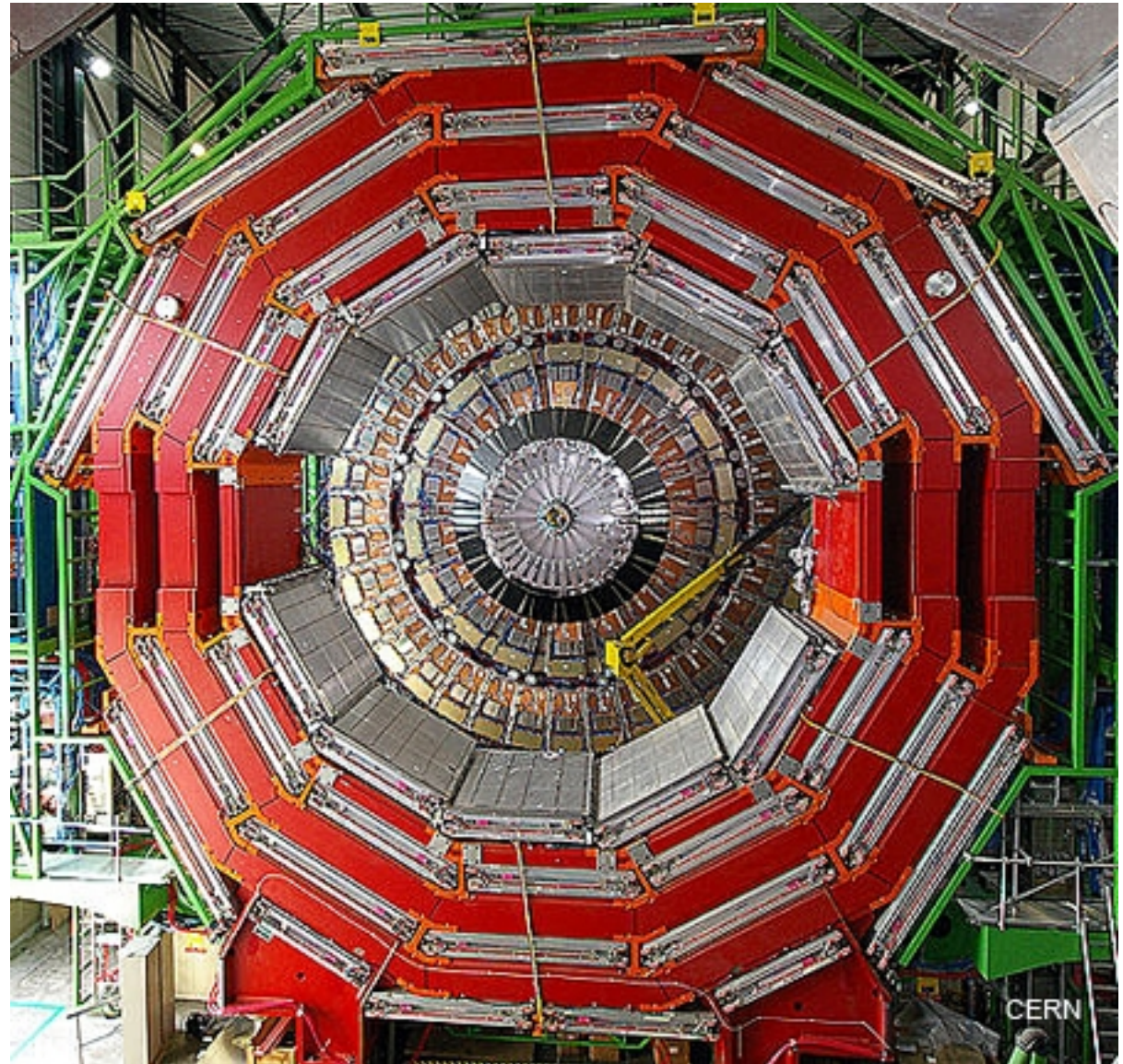
- Solenoid (grey) is 34 studs (13.1 m) long
- HCAL (yellow) is 24 studs (9.2 m) long
- Solenoid diameter:  $\sim 16$  bricks (7.4 m)
- Transparent studs on outer layer of solenoid represent HO (Hcal Outer detector)





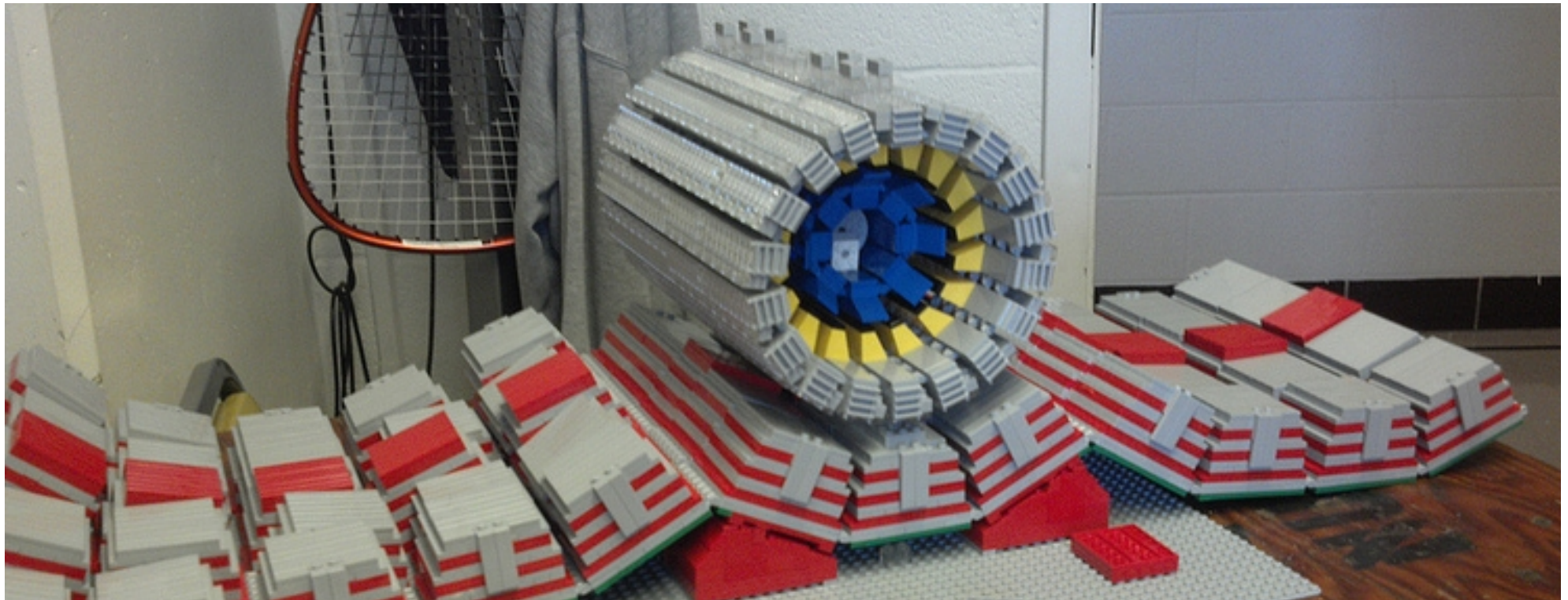
# CMS Muon Rings

- 5 Muon rings
- Each ring contains 4 layers of drift tubes (DTs) and resistive plate chambers (RPCs) interspersed within magnet return yoke
- 12 different phi positions (30-degree segmentation) in each ring
- Central ring (ring 0) contains an additional “tail-catcher” inner layer





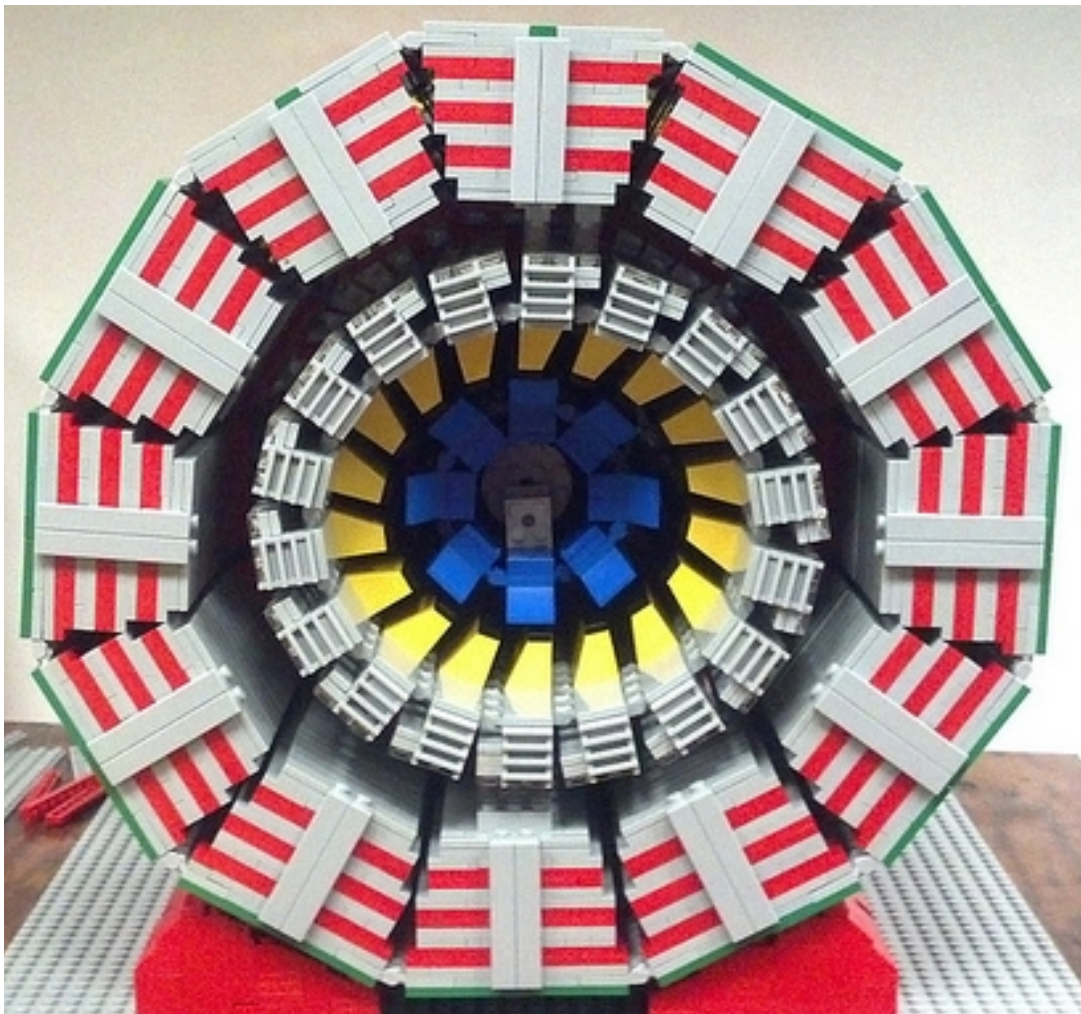
# LEGO® Muon Rings



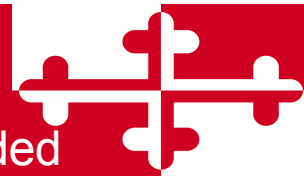
- Solenoid and inner detectors sitting on (disassembled) muon rings.
- Center muon ring has additional red “tail-catcher” layer



# CMS Barrel Detector



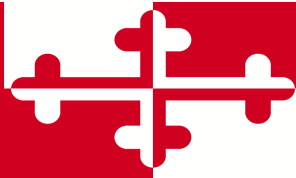
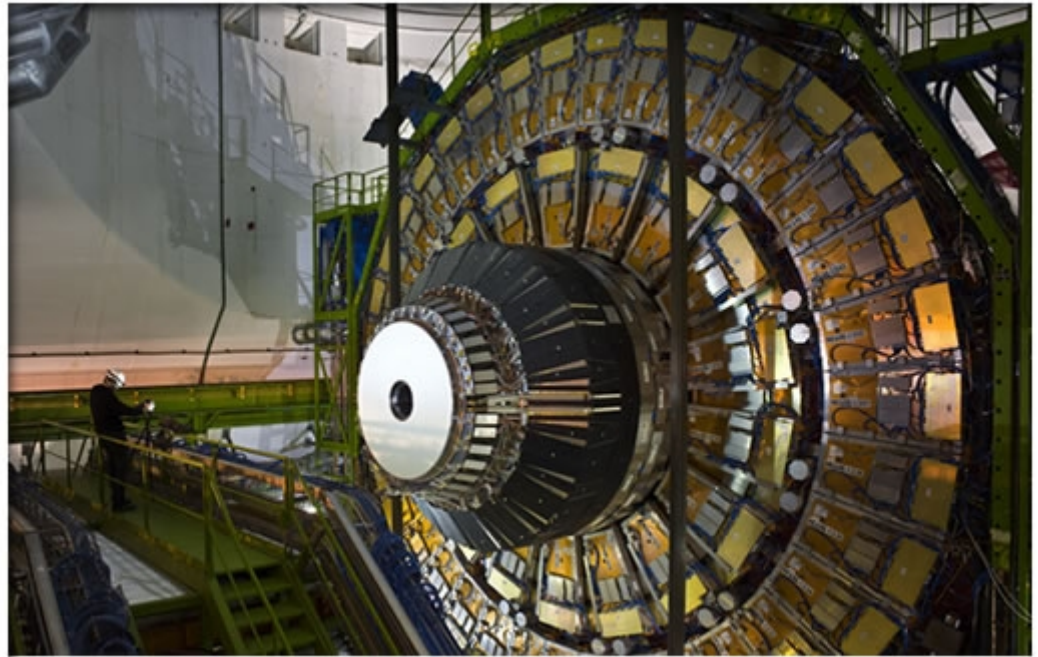
- Hinged muon rings surround solenoid
- Spacer pieces on solenoid maintain muon ring shape
- Green outer plates provide support, match CMS support structure\*





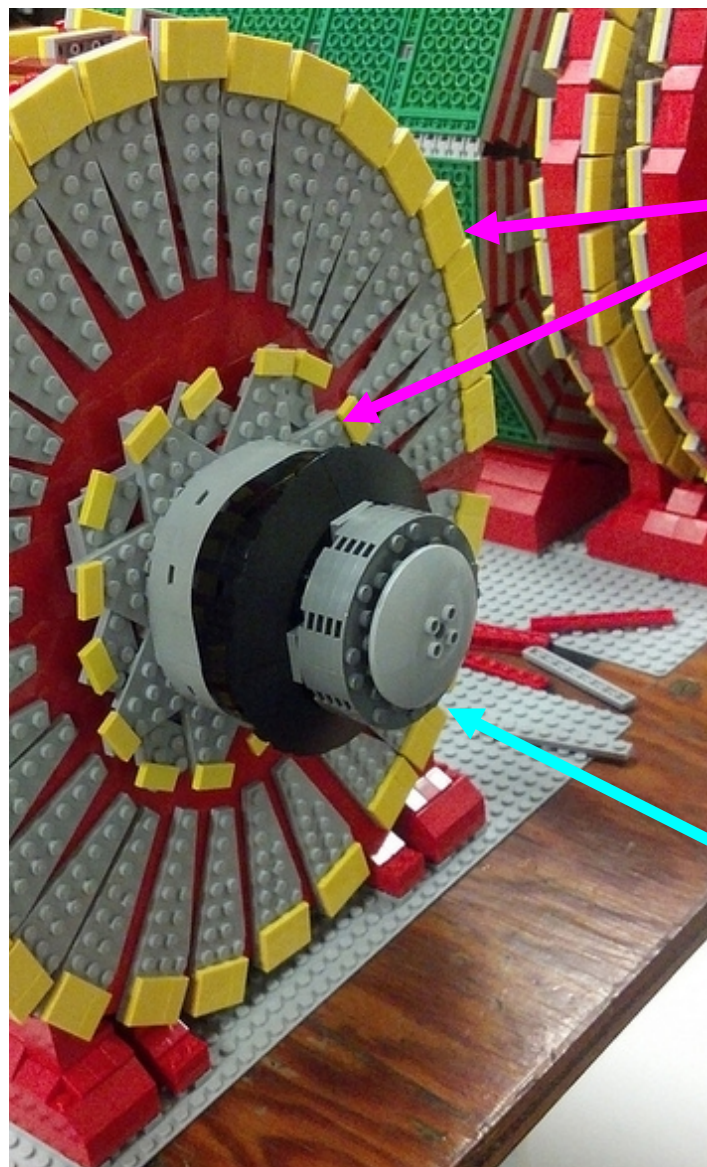
# CMS Endcaps

- Endcaps contain:
  - Preshower detector
  - ECAL endcap
  - HCAL endcap
  - Muon endcaps
    - 4 layers of muon chambers



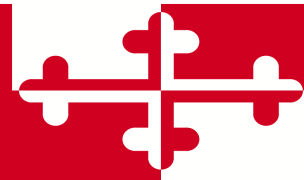
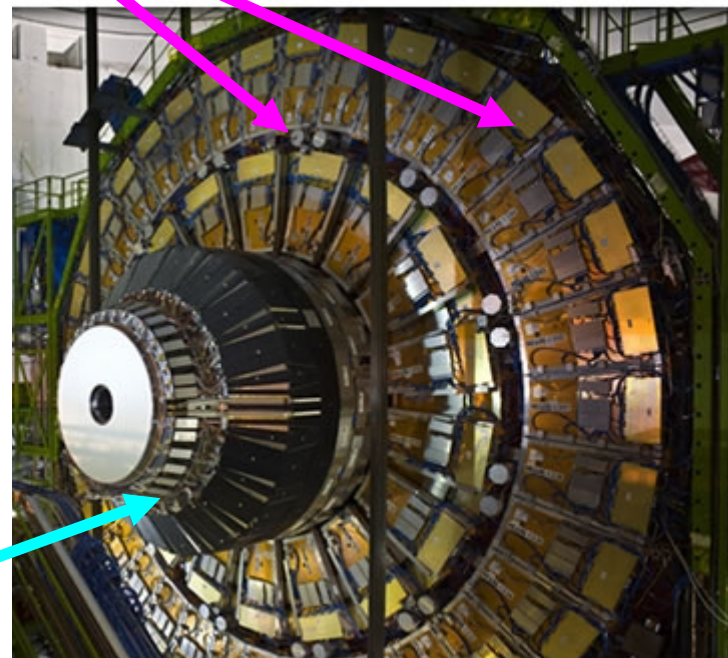


# LEGO® Endcaps



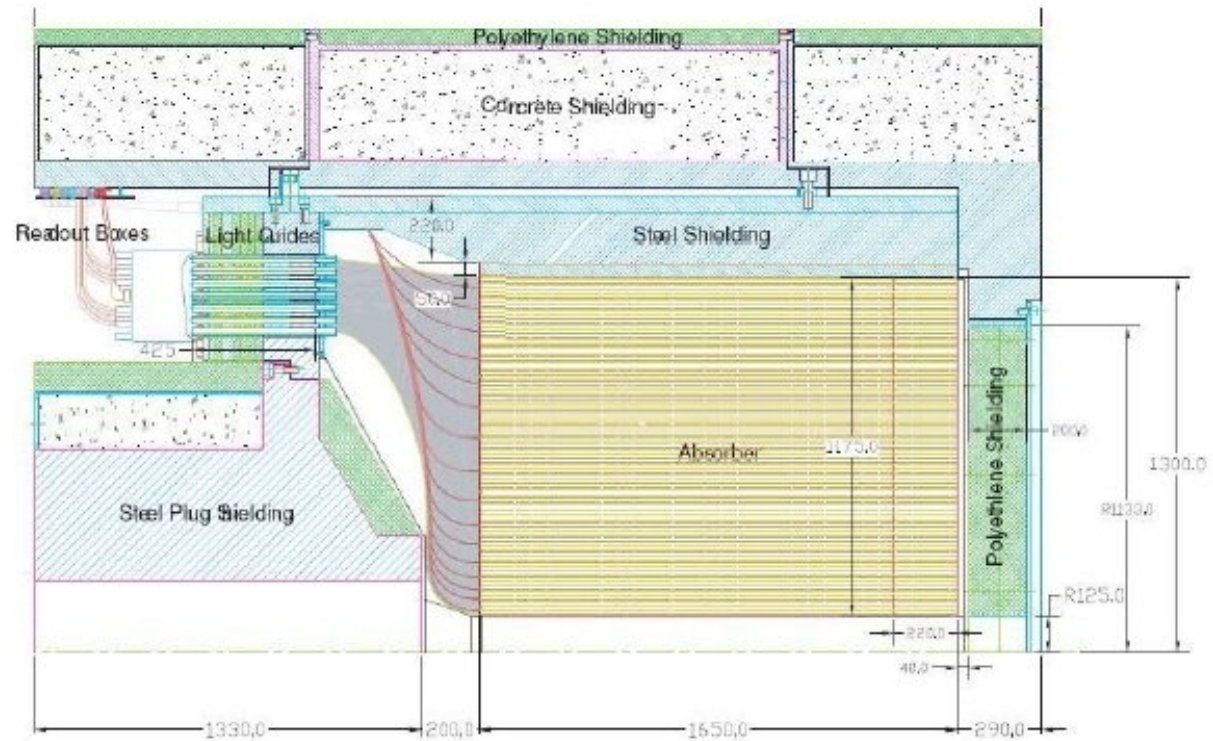
muon chambers

Endcap  
Calorimeters

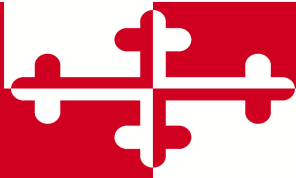


# LEGO<sup>®</sup> HF and CASTOR

- HF and CASTOR provide forward calorimetry information
- Sit behind last muon station
- HF:
  - quartz fibers extend a distance of 1.65m
  - light guides to PMTs from 1.65 to 3.47 m
  - concrete shielding around HF, plug behind HF



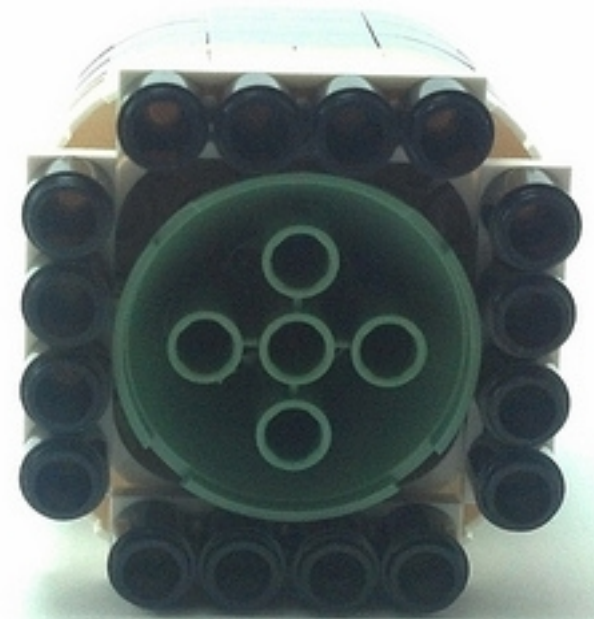
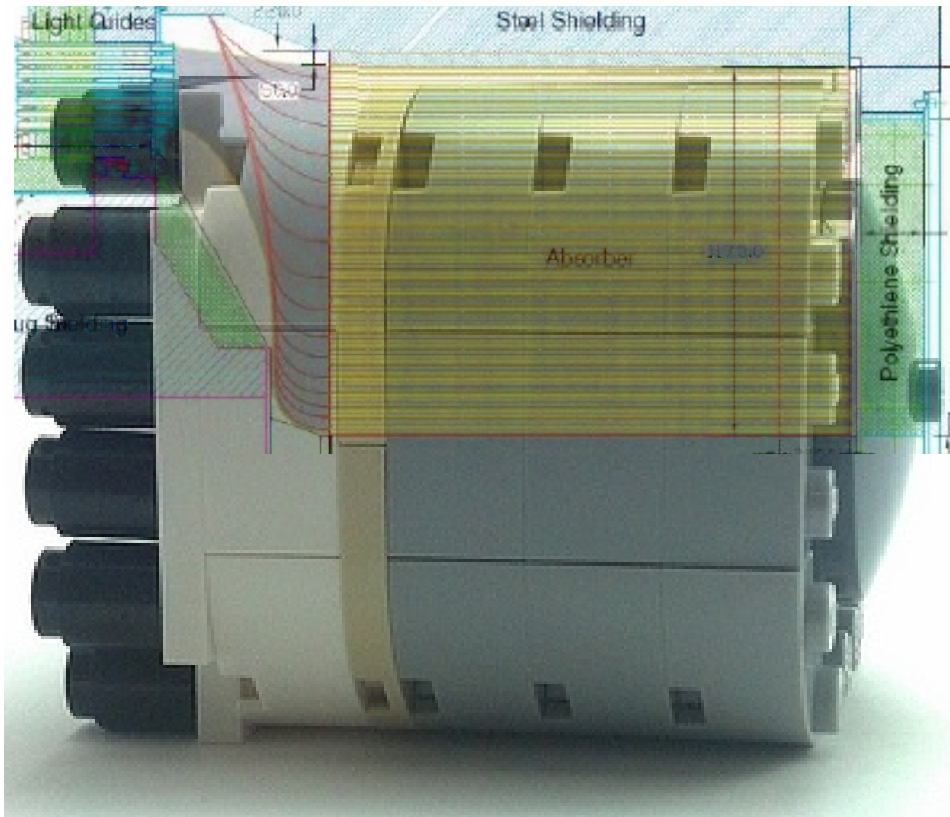
- CASTOR:
  - 0.6m wide, 1.6m long, behind HF-







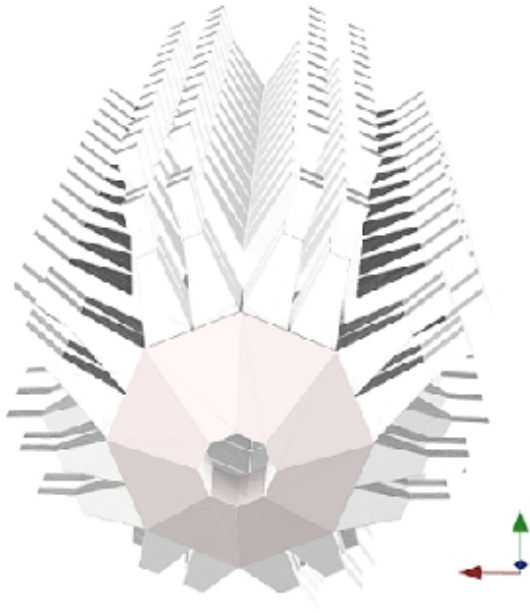
# LEGO<sup>®</sup> HF



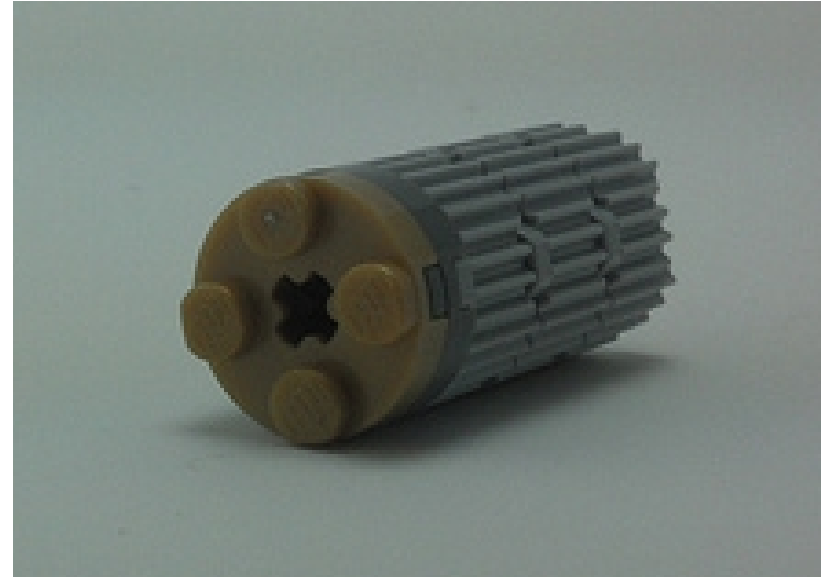
Top left: Side view  
Top right: Front view  
Bottom right: Back view  
(with plug installed)



# LEGO<sup>®</sup> CASTOR



CASTOR  
(schematic)



CASTOR  
(Lego scale)



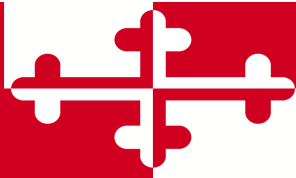




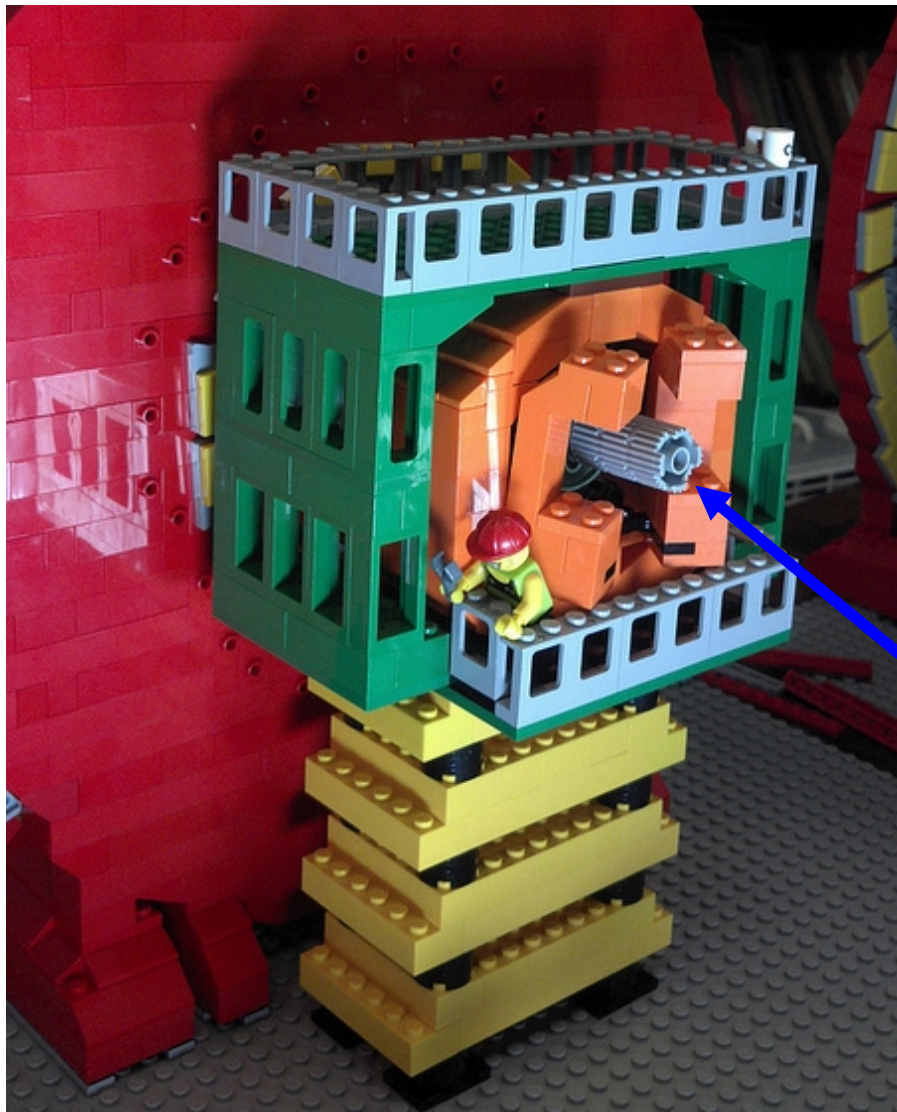
# LEGO® HF+



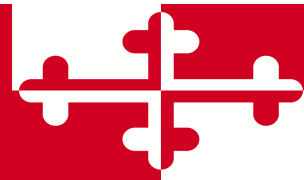
Final HF+ (including shielding and support stand) behind muon endcap



# LEGO® HF- and CASTOR

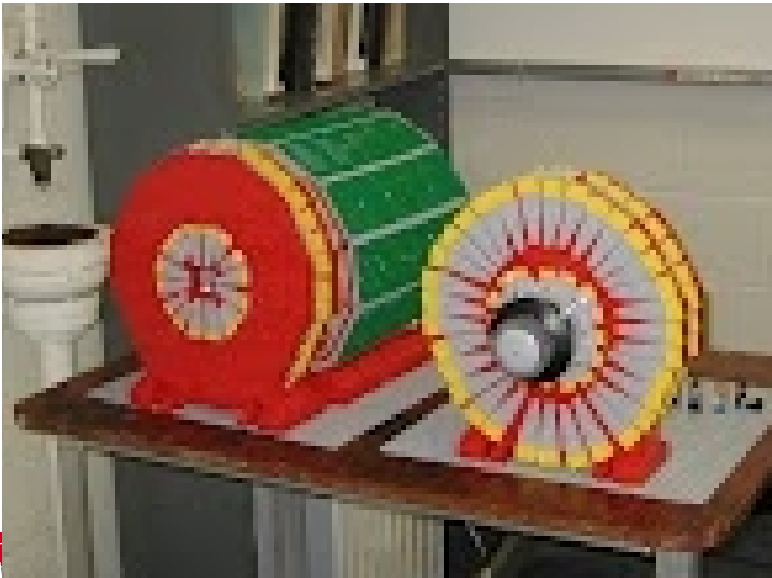


CASTOR



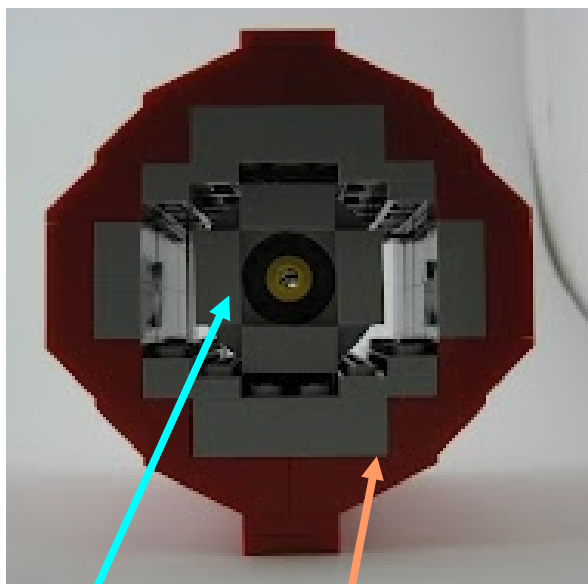


# Completed Detector



# Mini CMS model

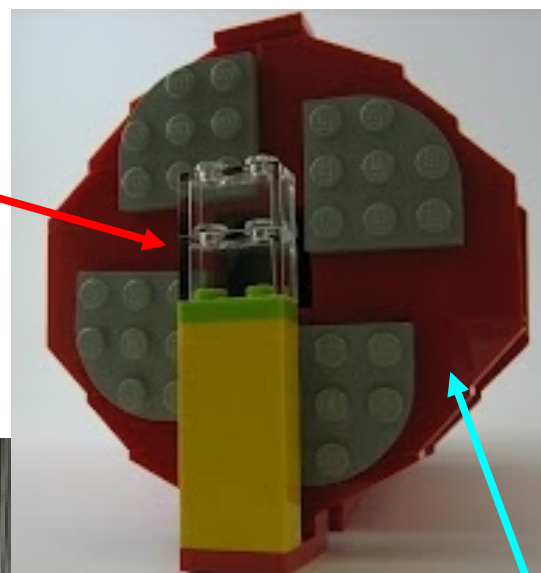
- 1:200 scale



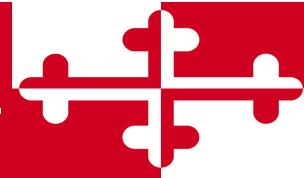
Solenoid

Muon ring

HF



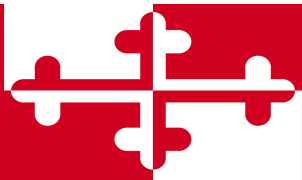
Muon Endcap







# Logos



# Final Specs

- Total pieces: ~ 14,000
- Total cost: ~ \$2300.00
  - (mini-CMS model, CMS logo, and CERN logo each cost between \$50-\$100)
- Total person-hours: Hmm... more than there should've been, probably.







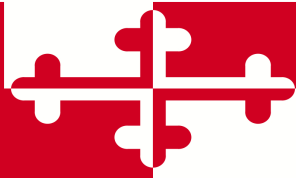
# Thanks to:

- The Build Team:
  - Kevin Pedro, Ellie & Kevin Twedt, Jaime Gomez, Marguerite & Wayne Tonjes, Sarah Eno, Ernie Buchanan, Fred Buchanan, and Charlie Dawson
- Drew Baden and Nick Hammer for funding & encouragement
- Nick Hadley, Andris Skuja, and Dick Kellogg for likeness rights
- [shop.lego.com](http://shop.lego.com) for its “pick a brick” service
- Many sellers at [bricklink.com](http://bricklink.com)



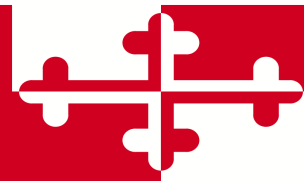
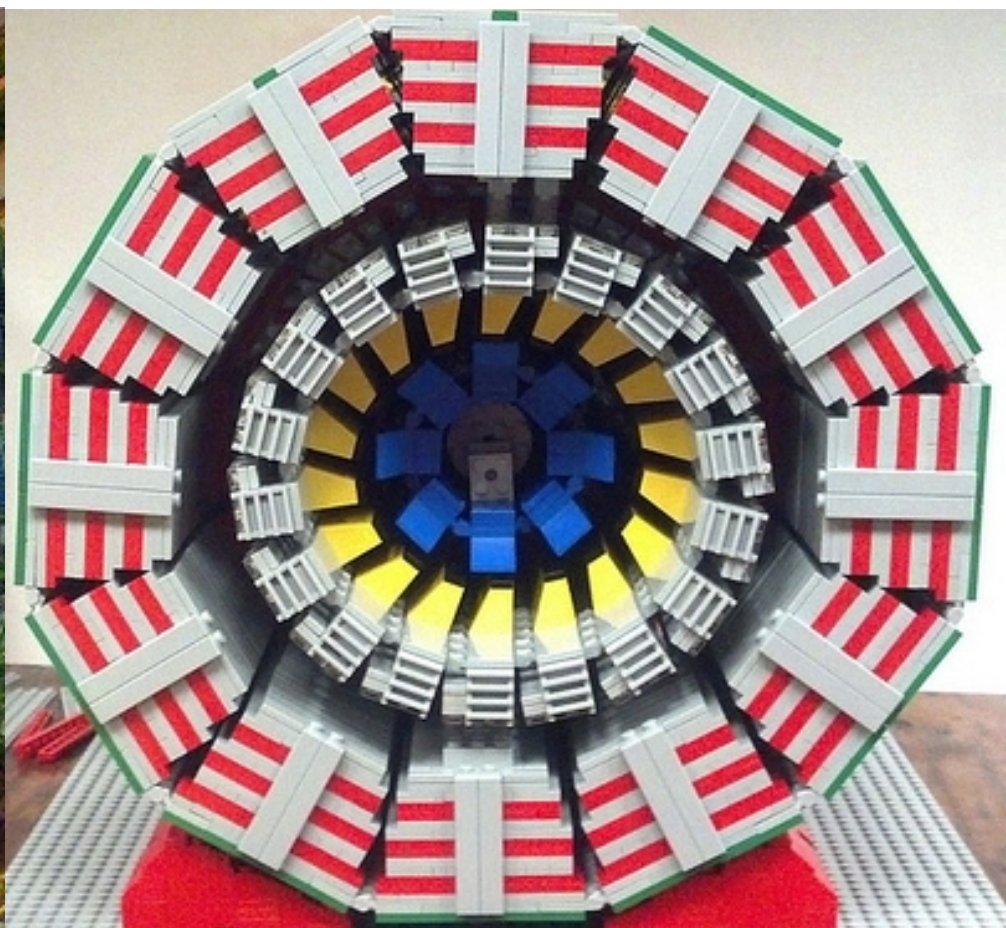
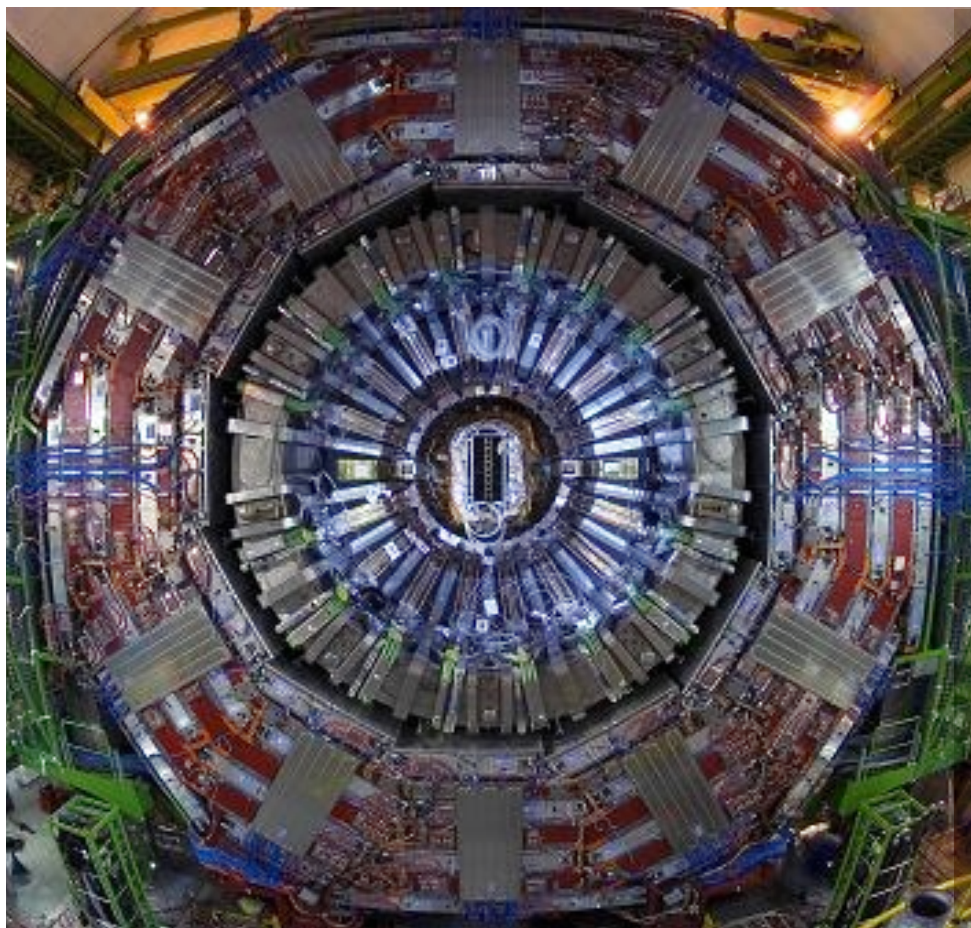


# Backup Slides





# Side-by-side comparison





# List of BrickLink Suppliers

4 Fun Bricks & More  
ACE: Blacktron Surplus LLC  
Alaska Brick Movers  
BAY AREA BRICKWERKS!  
Bay Area Brick Yard  
Bombcar Heavy Bricks  
Brick Ideas  
Brock's Bricks  
Builder's Universe - Sale!  
Cincinnati Bricks, LLC  
CreativeFury  
Dad's AFOL Supplies  
Dumbo's Mother  
Grandma's Attic  
Japhy's Bricks  
Joes Brick Depot

Johnny's Bricks  
Missing Brick  
Plastic Bricks Direct  
Play Well USA  
Queen Creek Bricks  
Rens Brick Room  
Spyder's Brick Stores  
Tanner's Bricks  
TOLEDO Bricks, LLC  
The Brick Layers  
TheBrickGuys  
Toy Brick Brigade  
ToyBurg  
ViroColor Productions  
We-Like-It Bricks & Studs

