Compact Muon Solenoid Detector (CMS) & The Token Bit Manager (TBM)

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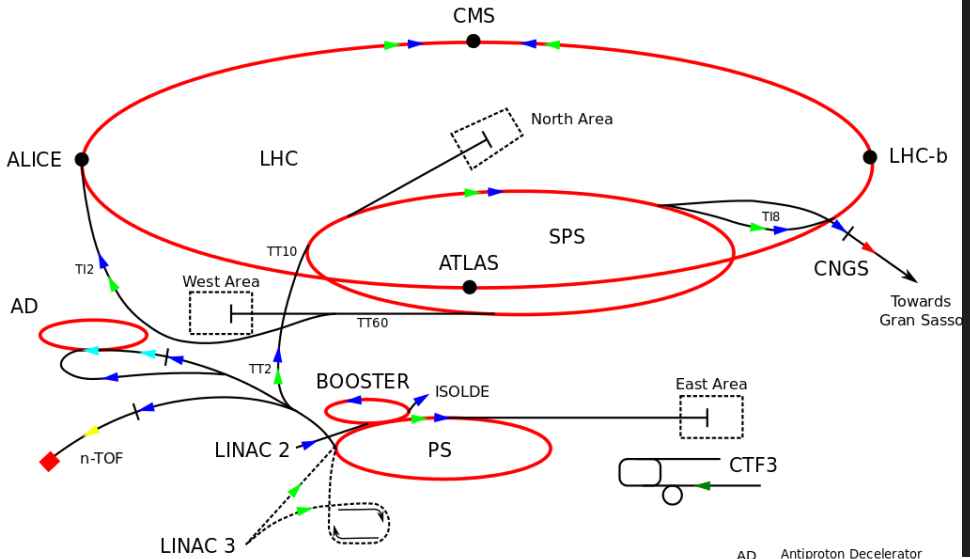
Mentor: Dr. Andrew Ivanov

CERN

Conseil Européen pour la Recherche Nucléaire (European Council for Nuclear Research) (1952)



ACCELERATORS

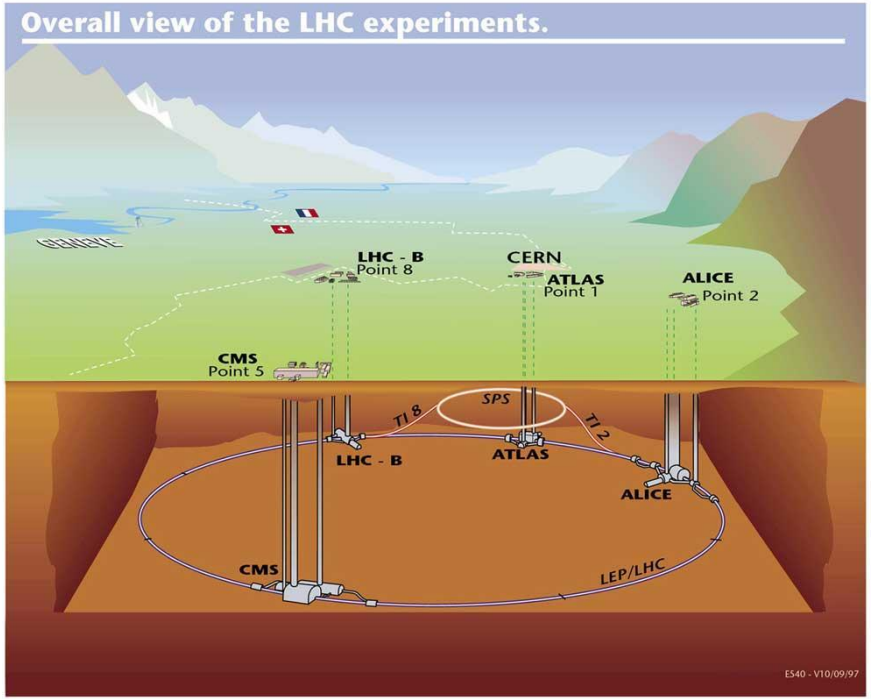
- The Antiproton Decelerator
- The Large Hadron Collider
- The Proton Synchrotron
- The Super Proton Synchrotron
- CERN Neutrinos to Gran Sasso

EXPERIMENTS

ACE	COMPASS
AEGIS	DIRAC
ALICE	ISOLDE
ALPHA	LHCb
AMS	LHCf
ASACUSA	MOEDAL
ATLAS	NA61/SHINE
ATRAP	NA62
AWAKE	nTOF
CAST	OSQAR
CLOUD	TOTEM
CMS	UA9

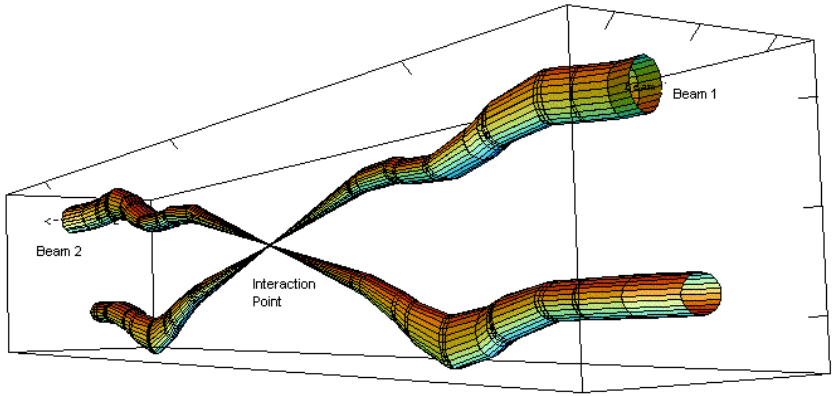
CERN -> LHC

Large Hadron Collider (2008)



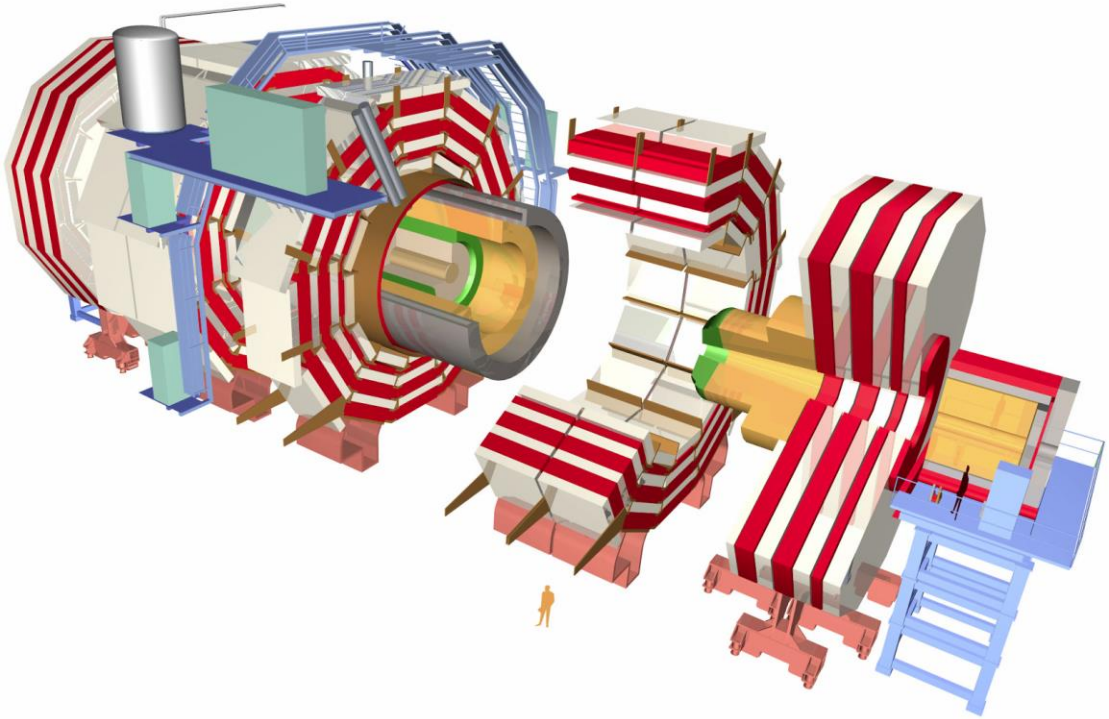
Two proton beams travel in opposite directions until collision in detectors

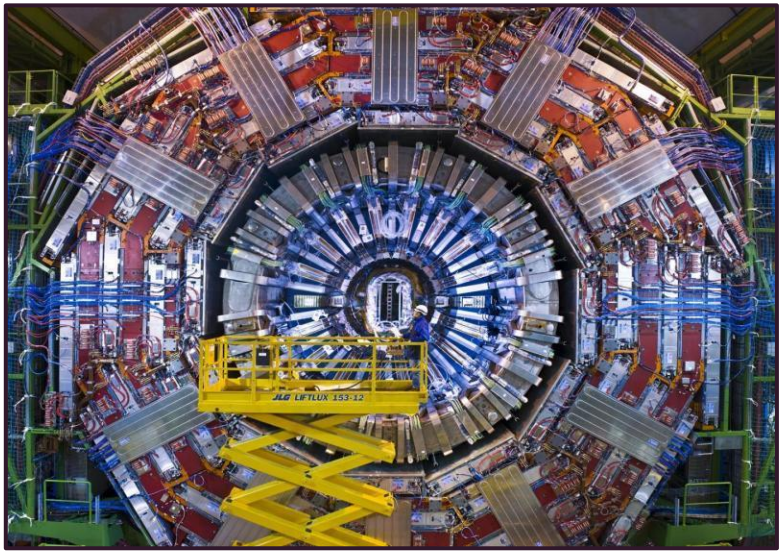
1) ATLAS
2) ALICE
3) LHCb
4) CMS



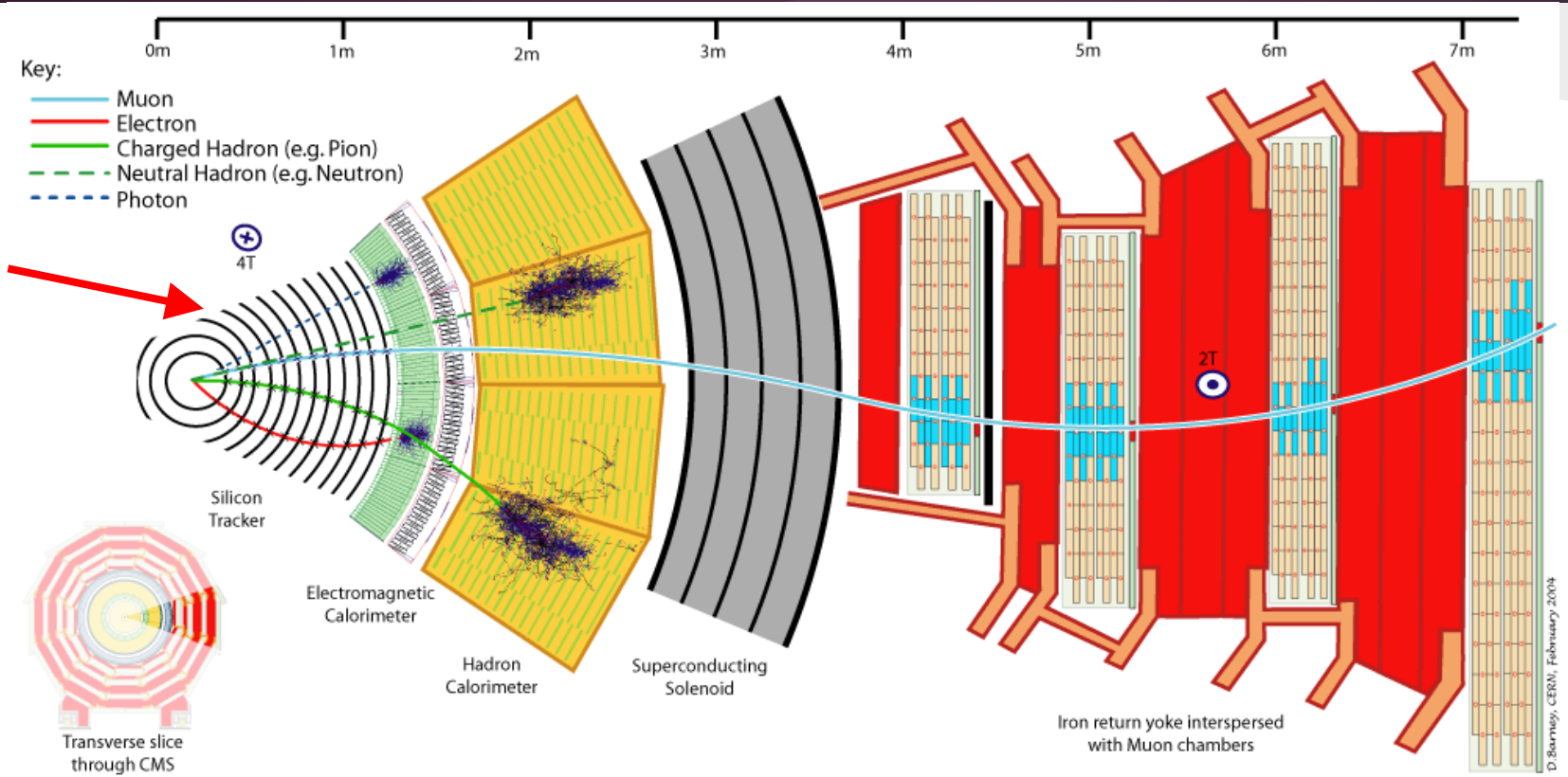
CERN -> LHC -> CMS

Compact Muon Solenoid (2008)

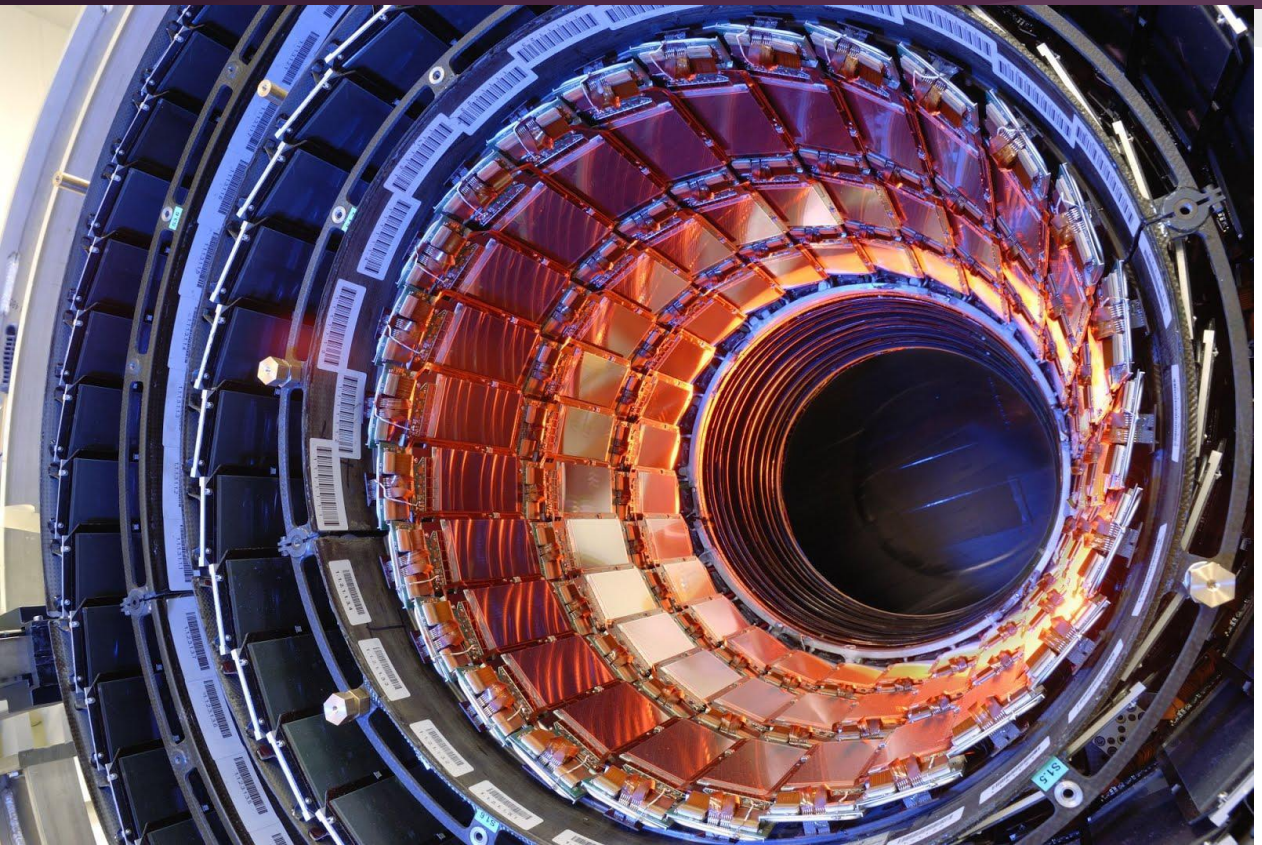




CMS Detector System

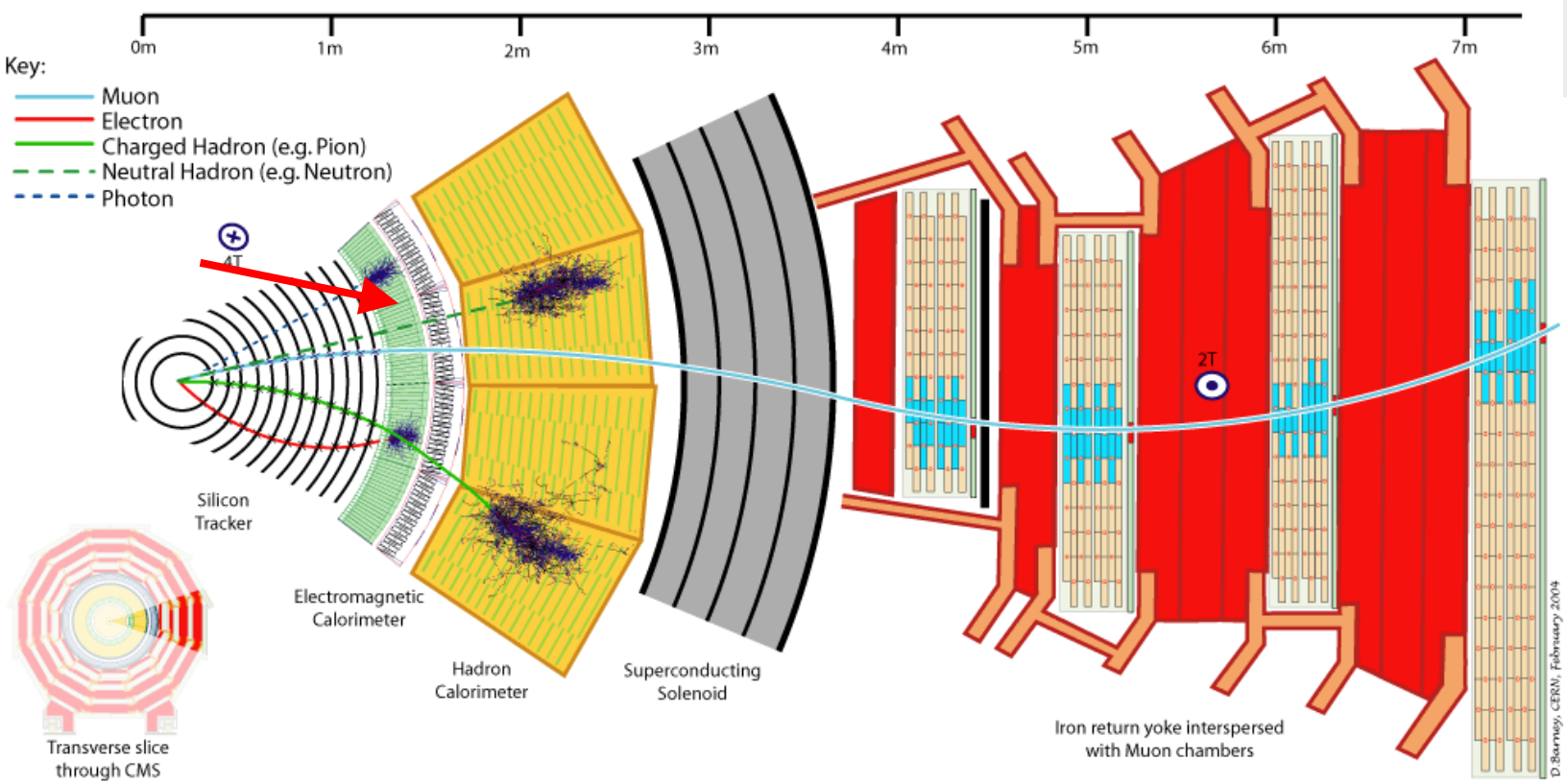


Inner Detectors



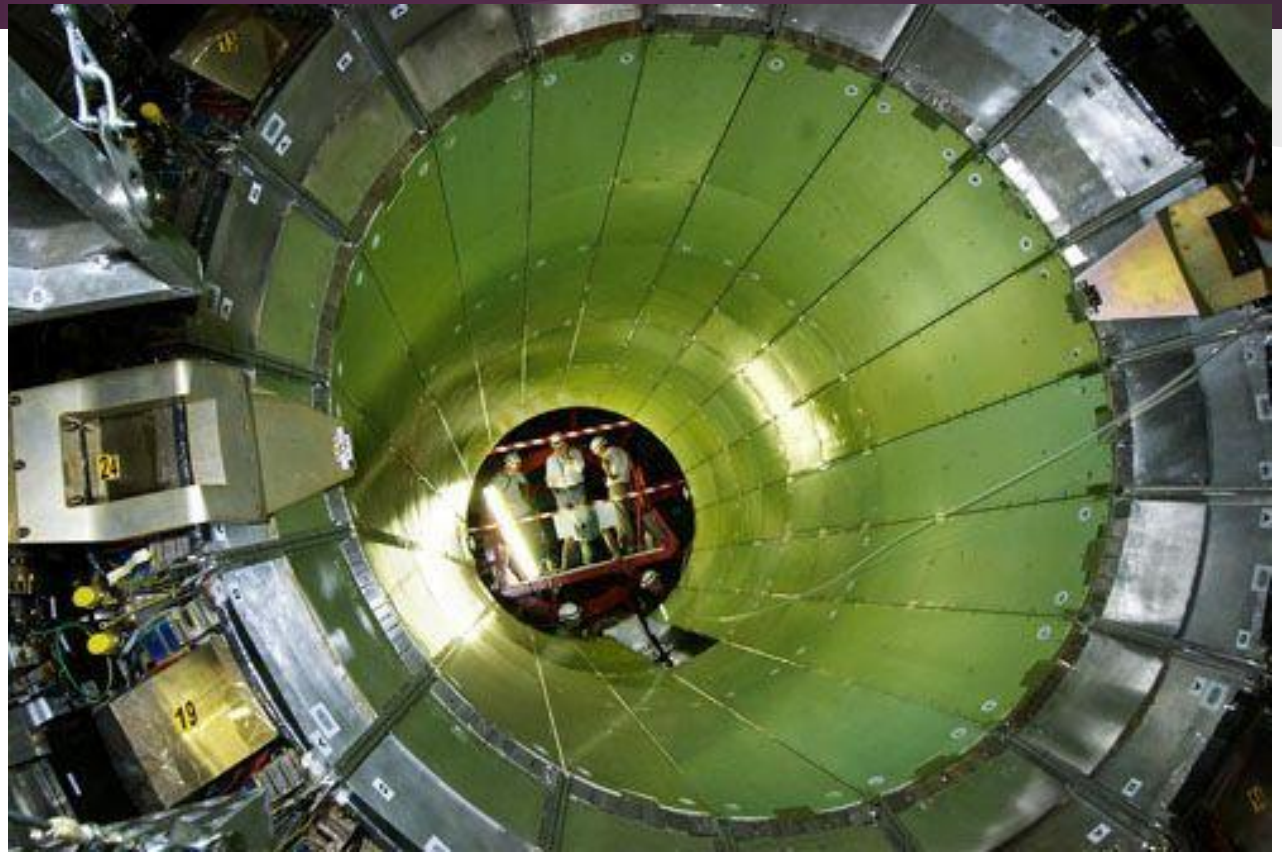
Silicon strip detectors in the inner tracking system detect position of particles at a given time

CMS Detector System

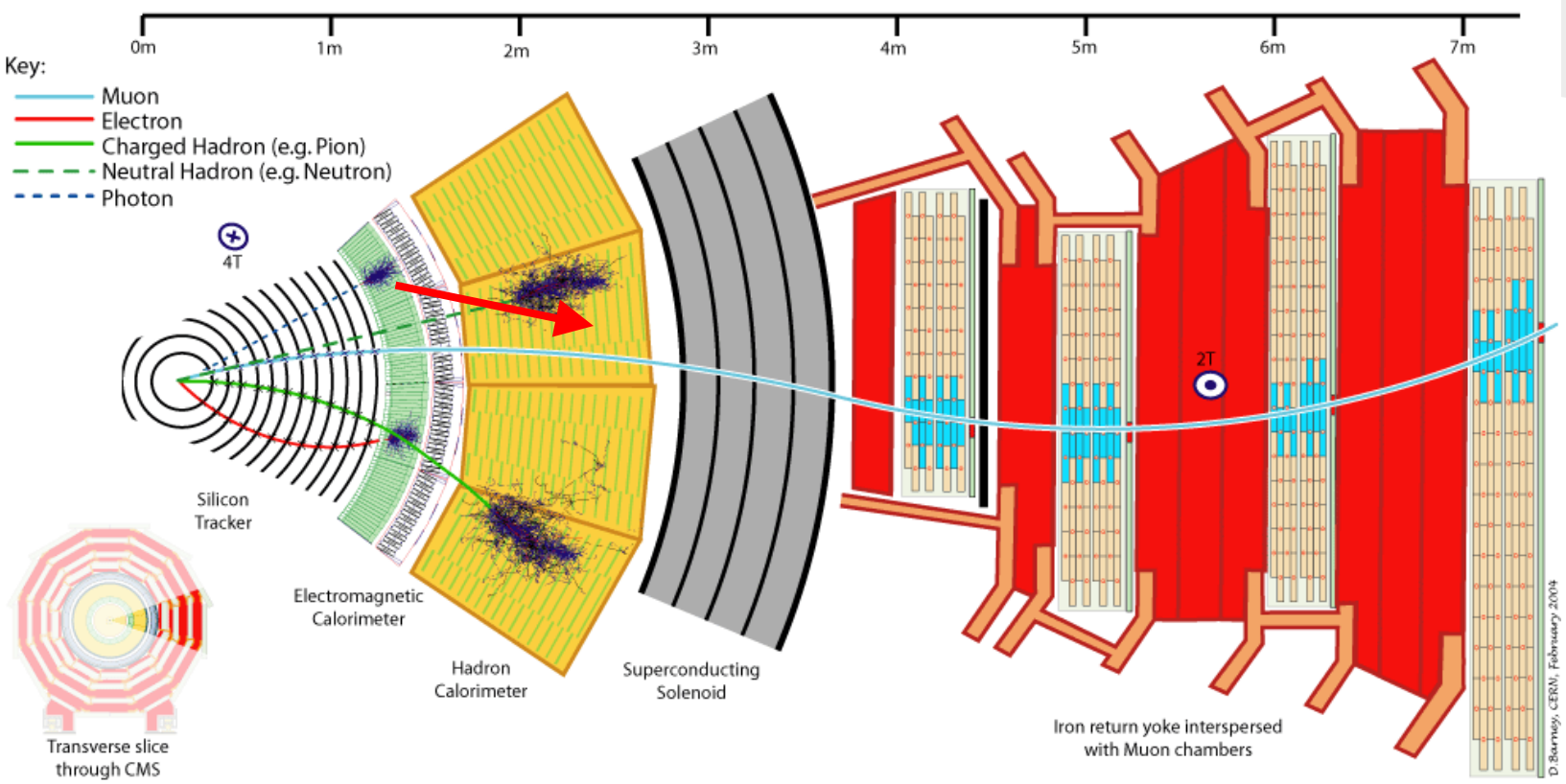


Electromagnetic Calorimeter (ECAL)

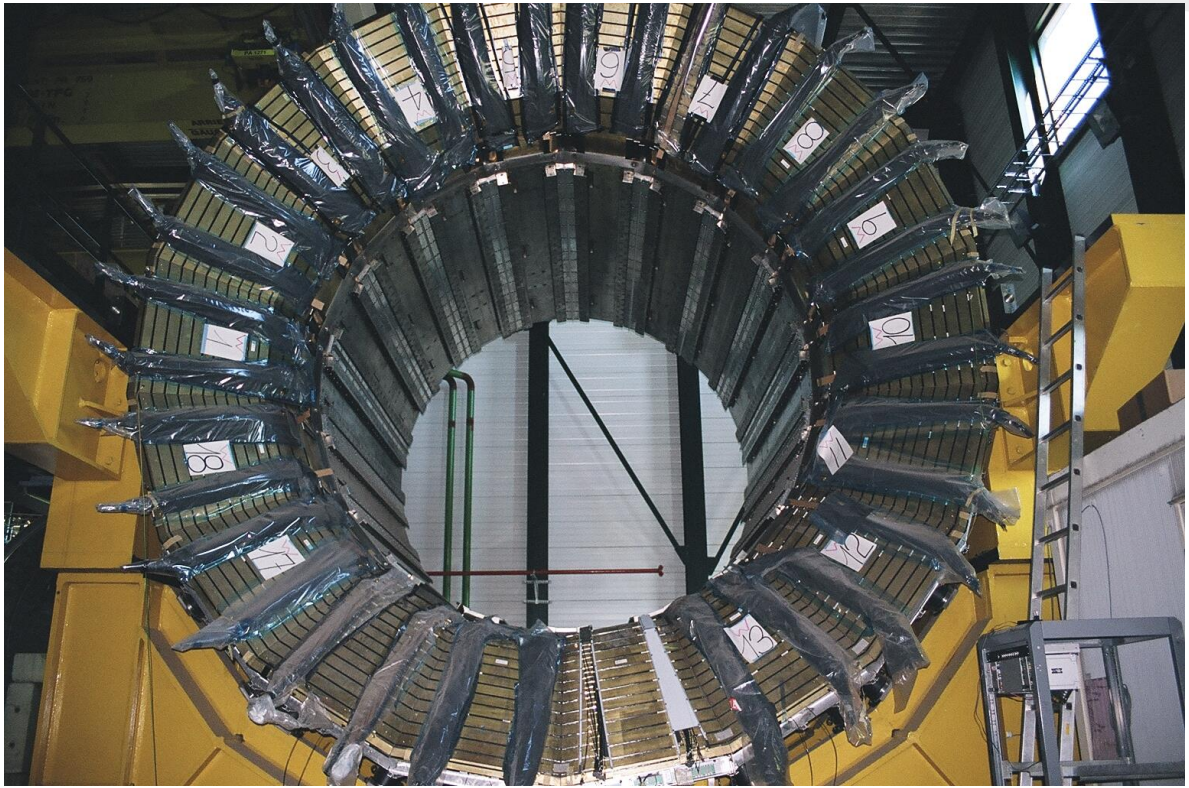
Lead tungstate crystals formed into supermodules measure energy of electrons and photons



CMS Detector System

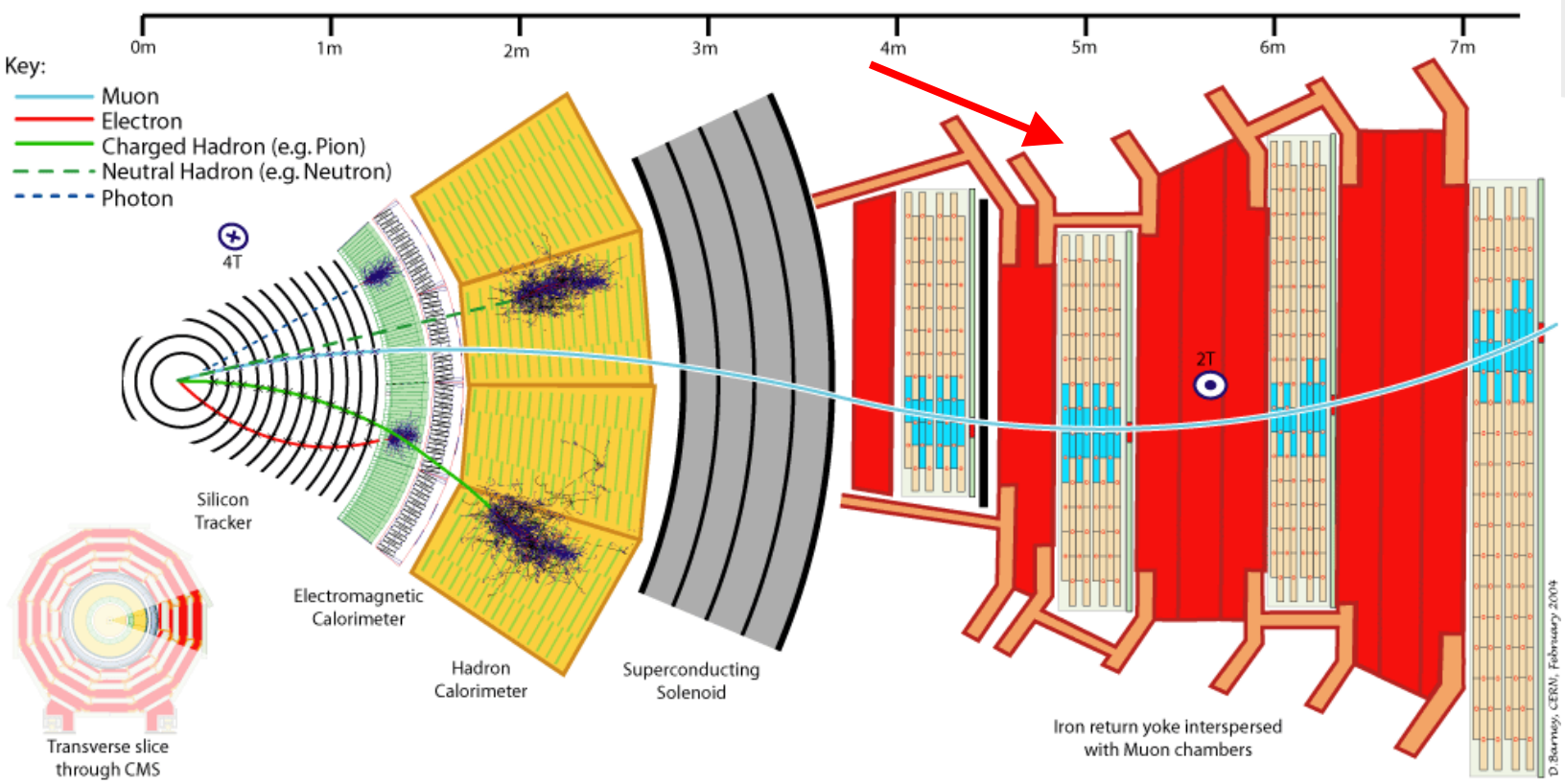


Hadron Calorimeter



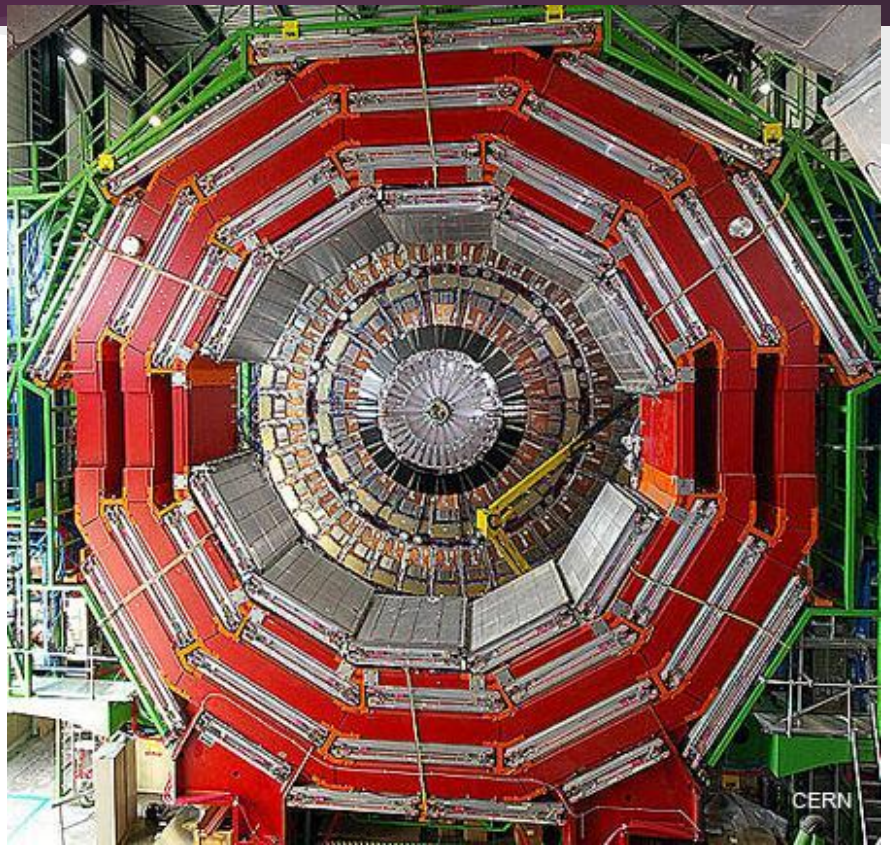
Repeated layers of absorber plates (brass and steel) and active scintillating material detect neutral and charged hadrons

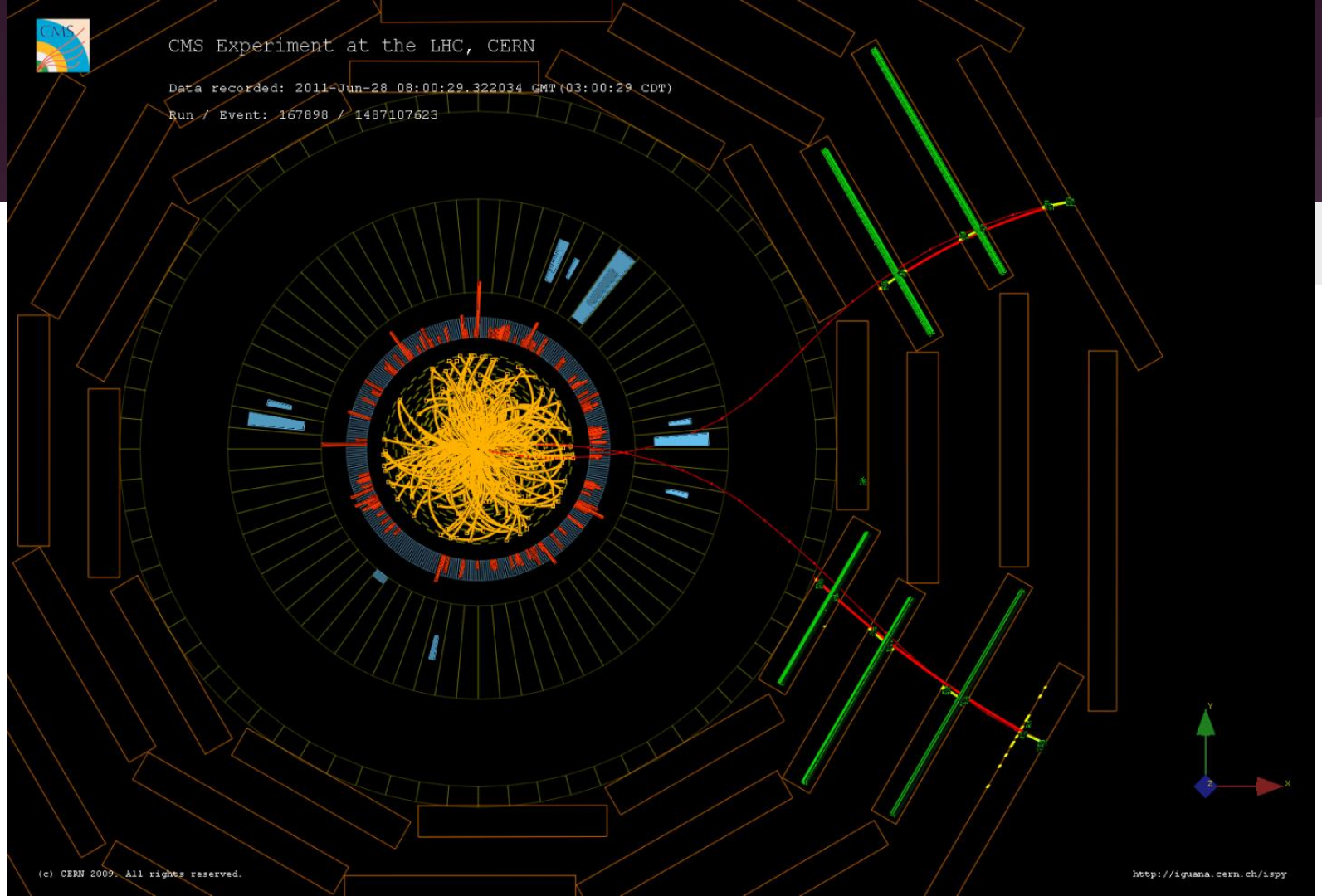
CMS Detector System

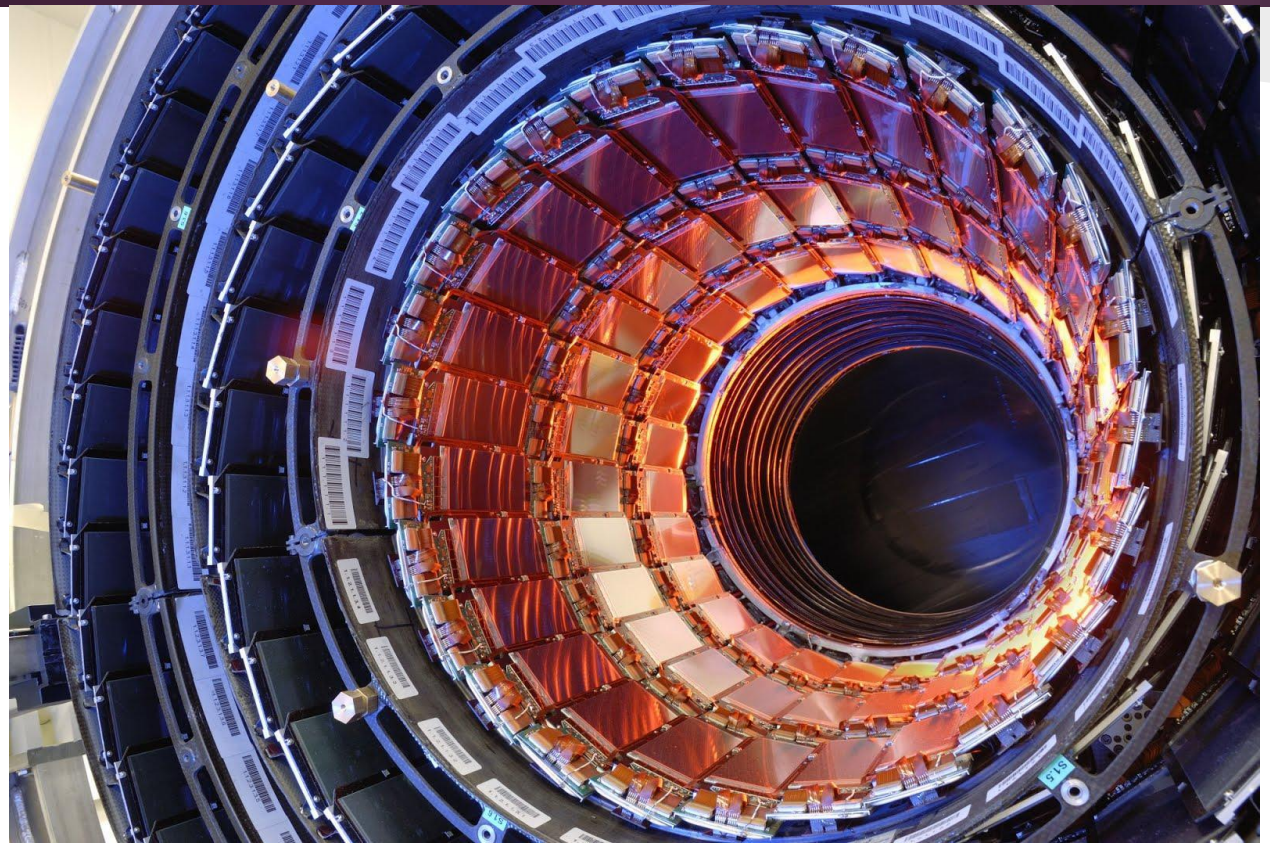


Muon Chambers

4 layers of muon detection stations interspersed with iron “return yoke” plates detect muons



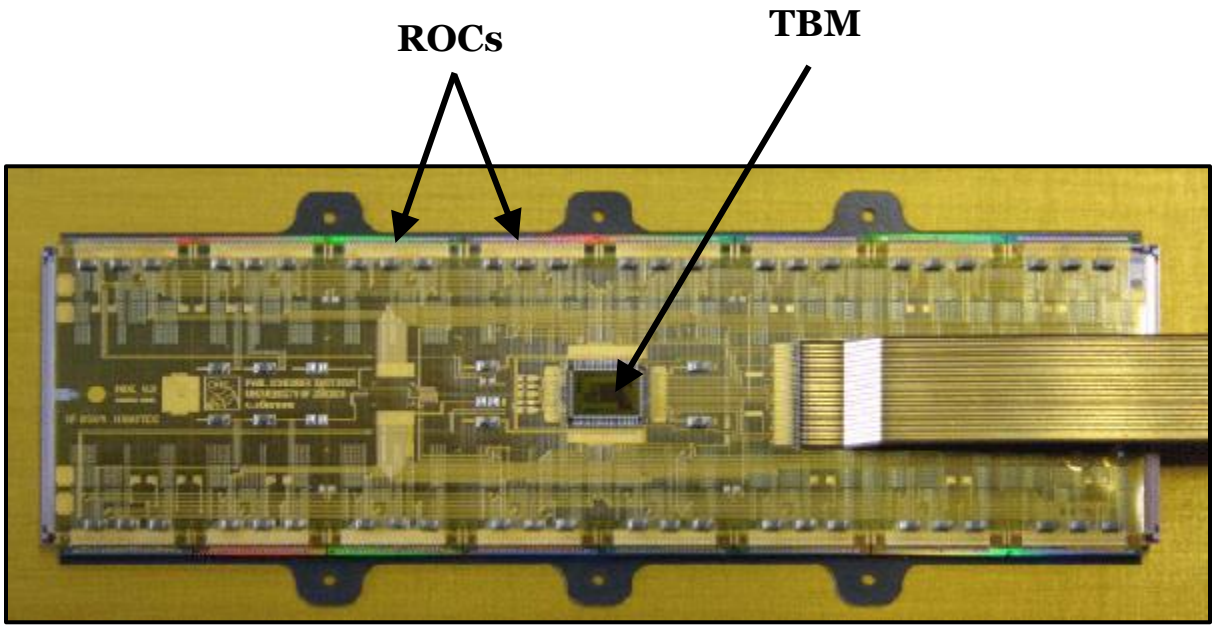

CMS Experiment at the LHC, CERN
Data recorded: 2011-Jun-28 08:00:29.322034 GMT(03:00:29 CDT)
Run / Event: 167898 / 1487107623
(c) CERN 2009. All rights reserved.
http://iguana.cern.ch/ispy



Inner Tracking System

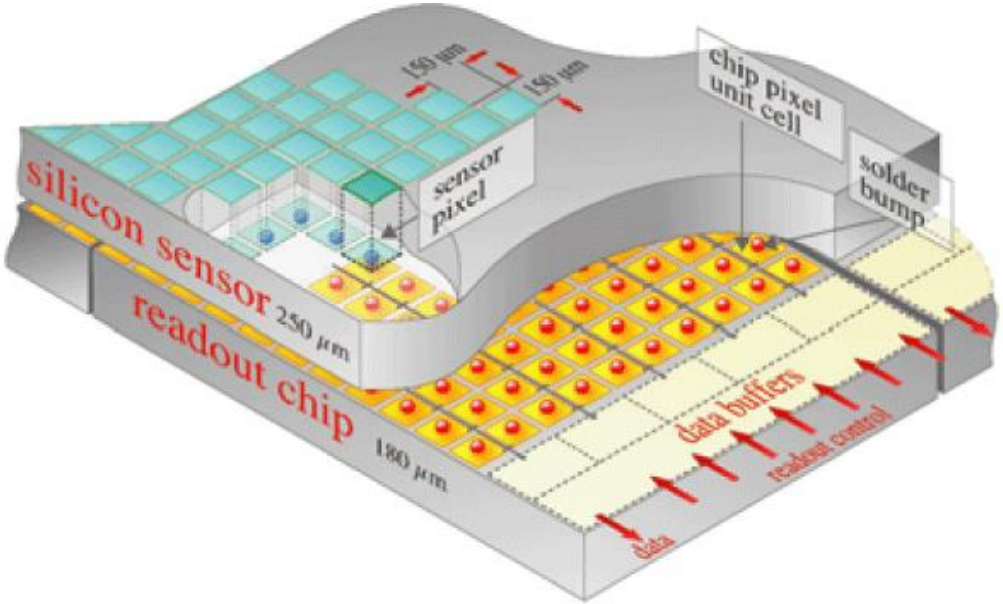
- Consists of 3 barrels of pixel detectors that amounts to a 4.4-10.2 cm radius tube

- [This picture displays a TBM connected to 16 ROC (read out chips)]

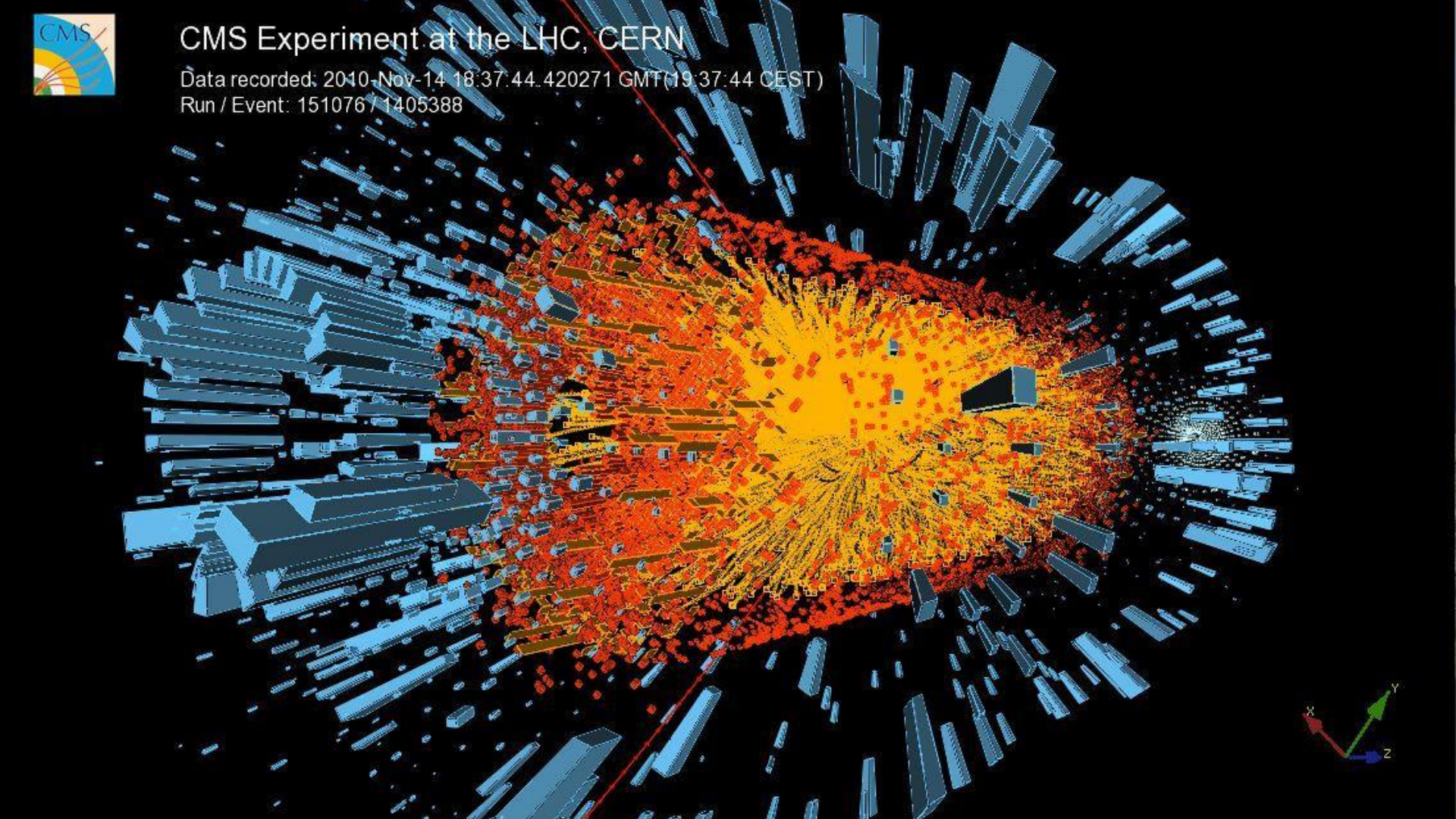


More Inner Tracking

- The Inner Tracking Detector has 66 million pixels
- The whole system is cooled to -20° C
- Each silicon sensor is only 150 x 100 μm (about 2 hair widths)



Problems

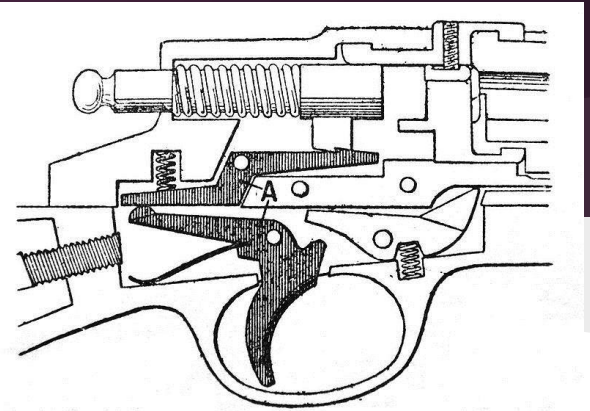

CMS Experiment at the LHC, CERN
Data recorded: 2010-Nov-14 18:37:44.420271 GMT(19:37:44 CEST)
Run / Event: 151076 / 1405388
Y
X
Z

Problems

1) SO MUCH DATA! - 40 terabytes/second
    a. Level 1 Trigger System - L1T (3500ns latency)
    b. Higher level trigger - HLT

2) High Collision Rate - 40 MHz (25ns gap)
    a. Buffer zones in ROCs and high time resolution

Level 1 Trigger

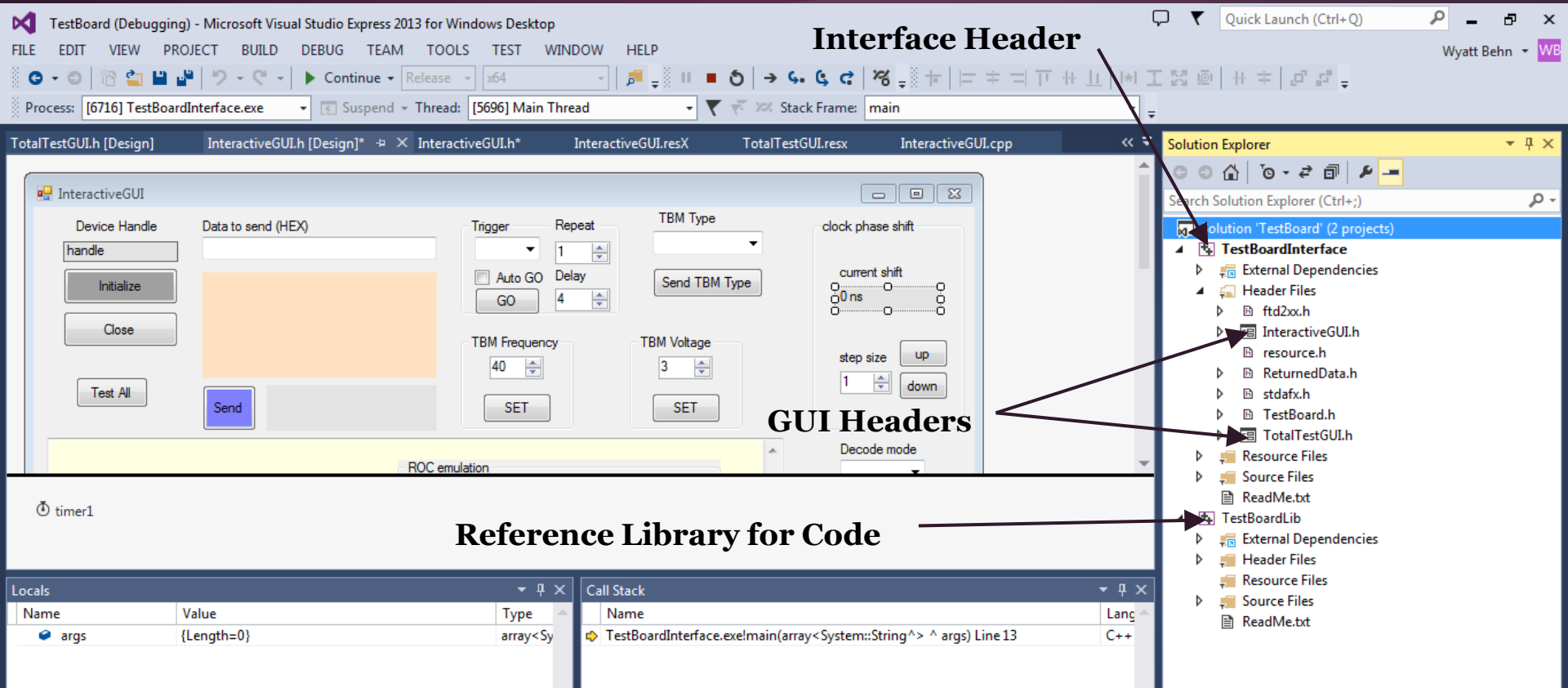


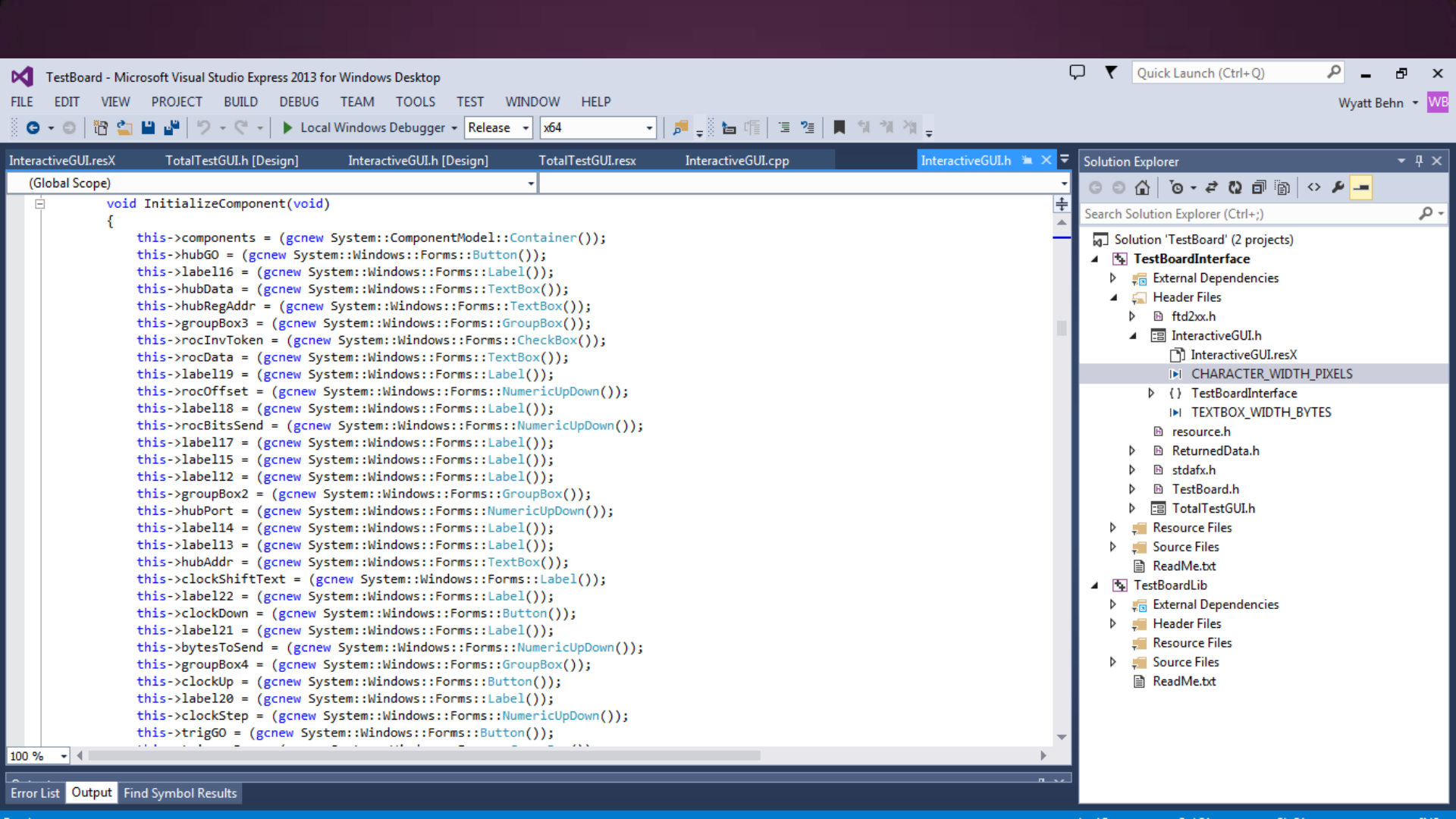
- Completely Automatic - No Software
- Selects ~1/10,000 hits
- The whole system is the trigger
  1) Detection by Calorimeter and Muon Chambers
  2) Hardware analysis selects desirable events
  3) Acceptance/rejection message sent to **TBM**
  4) **TBM** sends message to ROC to collect or discard
  5) Collected messages are sent downstream

What We're Doing/Specifics

- Presently, working on understanding the code used for testing the TBM chips (VC++)
- Using Cascade software for controlling the testing station
- Understanding how the TBM interacts and functions as part of the detector system

The Testing Software/Code

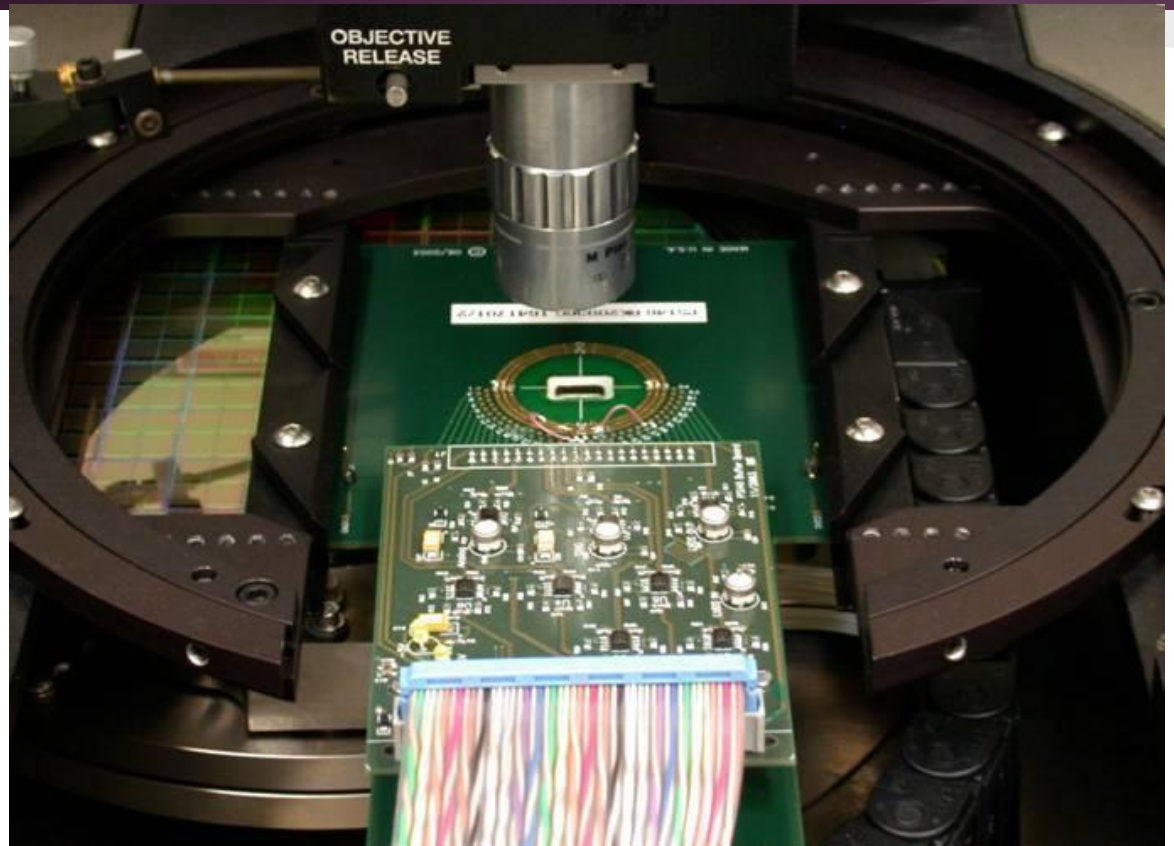



TestBoard - Microsoft Visual Studio Express 2013 for Windows Desktop
Quick Launch (Ctrl+Q)
FILE EDIT VIEW PROJECT BUILD DEBUG TEAM TOOLS TEST WINDOW HELP
Wyatt Behn
Local Windows Debugger
Release
x64
InteractiveGUI.resX
TotalTestGUI.h [Design]
InteractiveGUI.h [Design]
TotalTestGUI.resx
InteractiveGUI.cpp
InteractiveGUI.h
(Global Scope)
void InitializeComponent(void)
{
this->components = (gcnew System::ComponentModel::Container());
this->hubGO = (gcnew System::Windows::Forms::Button());
this->label16 = (gcnew System::Windows::Forms::Label());
this->hubData = (gcnew System::Windows::Forms::TextBox());
this->hubRegAddr = (gcnew System::Windows::Forms::TextBox());
this->groupBox3 = (gcnew System::Windows::Forms::GroupBox());
this->rocInvToken = (gcnew System::Windows::Forms::CheckBox());
this->rocData = (gcnew System::Windows::Forms::TextBox());
this->label19 = (gcnew System::Windows::Forms::Label());
this->rocOffset = (gcnew System::Windows::Forms::NumericUpDown());
this->label18 = (gcnew System::Windows::Forms::Label());
this->rocBitsSend = (gcnew System::Windows::Forms::NumericUpDown());
this->label17 = (gcnew System::Windows::Forms::Label());
this->label15 = (gcnew System::Windows::Forms::Label());
this->label12 = (gcnew System::Windows::Forms::Label());
this->groupBox2 = (gcnew System::Windows::Forms::GroupBox());
this->hubPort = (gcnew System::Windows::Forms::NumericUpDown());
this->label14 = (gcnew System::Windows::Forms::Label());
this->label13 = (gcnew System::Windows::Forms::Label());
this->hubAddr = (gcnew System::Windows::Forms::TextBox());
this->clockShiftText = (gcnew System::Windows::Forms::Label());
this->label22 = (gcnew System::Windows::Forms::Label());
this->clockDown = (gcnew System::Windows::Forms::Button());
this->label21 = (gcnew System::Windows::Forms::Label());
this->bytesToSend = (gcnew System::Windows::Forms::NumericUpDown());
this->groupBox4 = (gcnew System::Windows::Forms::GroupBox());
this->clockUp = (gcnew System::Windows::Forms::Button());
this->label20 = (gcnew System::Windows::Forms::Label());
this->clockStep = (gcnew System::Windows::Forms::NumericUpDown());
this->trigGO = (gcnew System::Windows::Forms::Button());
100 %
Error List
Output
Find Symbol Results
Solution Explorer
Search Solution Explorer (Ctrl+;)
Solution 'TestBoard' (2 projects)
TestBoardInterface
External Dependencies
Header Files
ftd2xx.h
InteractiveGUI.h
InteractiveGUI.resX
CHARACTER_WIDTH_PIXELS
TestBoardInterface
TEXTBOX_WIDTH_BYTES
resource.h
ReturnedData.h
stdafx.h
TestBoard.h
TotalTestGUI.h
Resource Files
Source Files
ReadMe.txt
TestBoardLib
External Dependencies
Header Files
Resource Files
Source Files
ReadMe.txt

Hardware & Calibration

- Using Cascade Probe Station and Nucleus 3.2 Interactive Software
- The stage (or chuck) moves freely beneath a stationary testing board that contains a probing zone
- The wafer is placed on the chuck and raised up to the board to make a connection and run tests (Note: Only 50 μm of freeplay are allowed when making connection)
- Some issues with the chuck being unbalanced could lead to crashing the probe

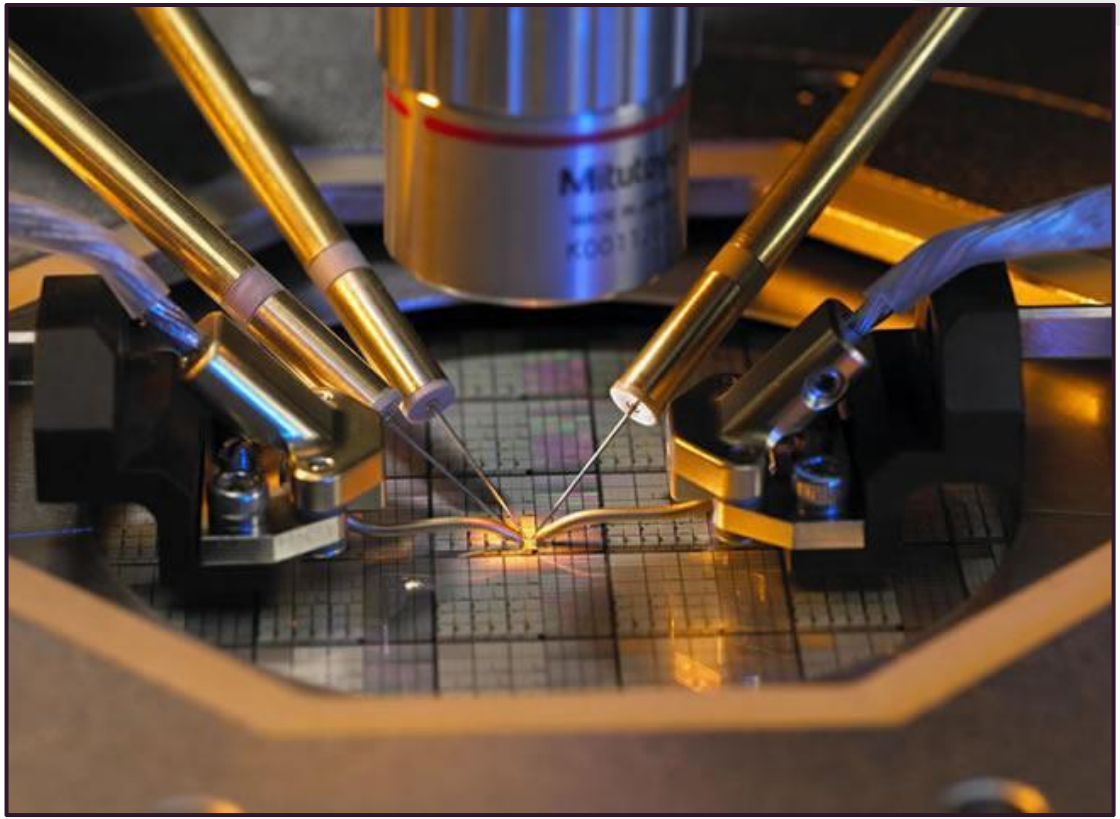
The Probing Station



The test board floats above a free moving stage.

The microscope is placed above for navigation.

Current Group Problem



Unstable electronic connection between TBM chip and probe

Our Endgame

- Have a fully automated way of testing each wafer, and each unique version of TBM chip, with an automatic data output (pass/fail) identifying individual TBMs

- Alternatively, an efficient way to test all TBMs on each wafer so we at least know if they work as designed

Why CMS is Important

- CMS is one of the proposals for a more powerful detector at the Large Hadron Collider (LHC)

- It will be able to handle higher-energy collisions (greater luminosity) with more accuracy and be able to reduce the data stream to a manageable load

Wyatt's Quandaries

- How do the calorimeters and other detectors work in tandem with the TBM to reduce the data?
- Theoretically, what are we interested in seeing? More particles, or reinforcement? More about the particles and interactions in question.
- Using ROOT to analyze actual data/making pretty graphs.

Alex's Goals of Understanding

- The testing code
- TBM Chip design
- ROOT
- Top Quark Research