# Hungarian activities in CMS hardware development and detector performance studies

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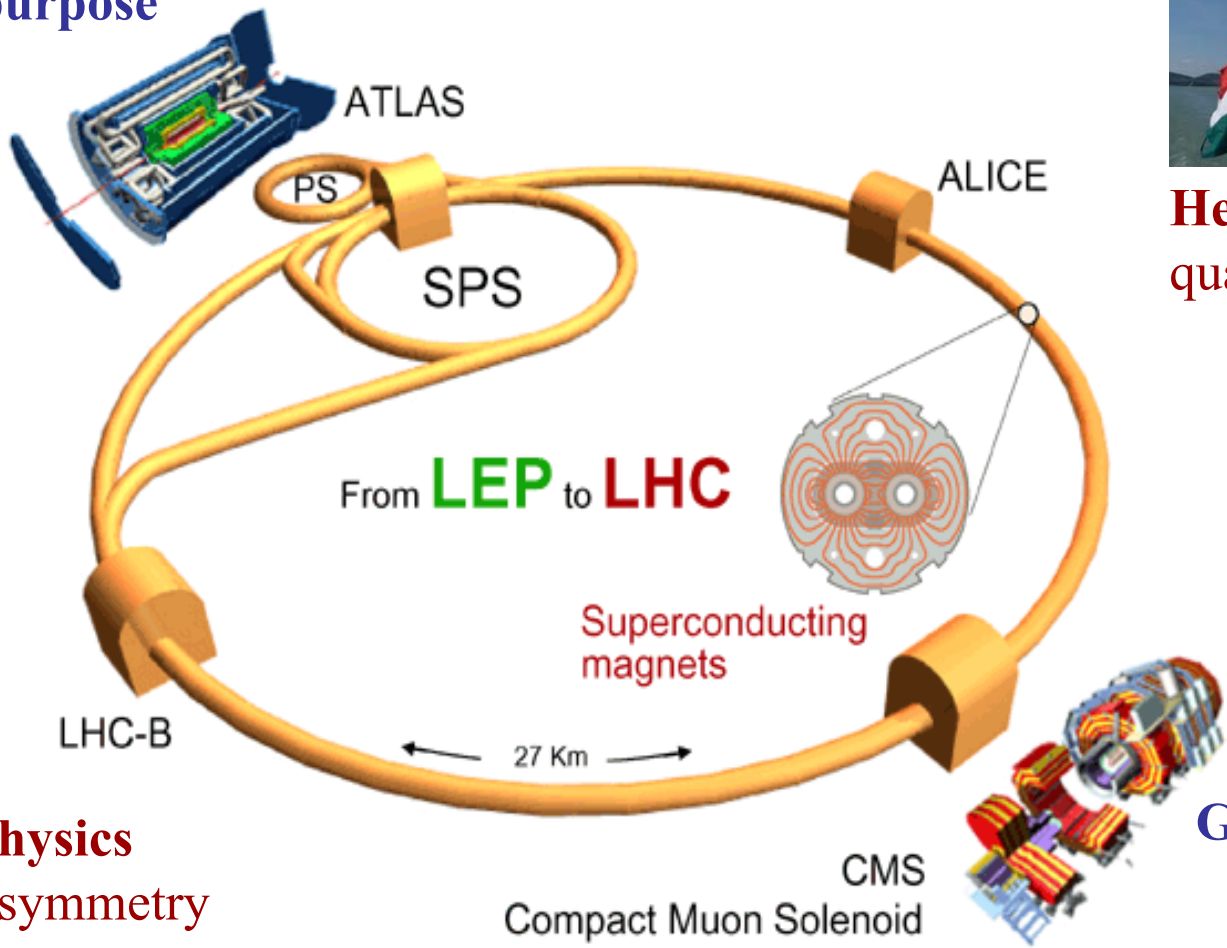
**Wigner Research Centre for Physics**

**RECFA visit to Hungary, October 4-5, 2013**

# Detectors at the LHC

**General purpose**
Higgs
SUSY
??



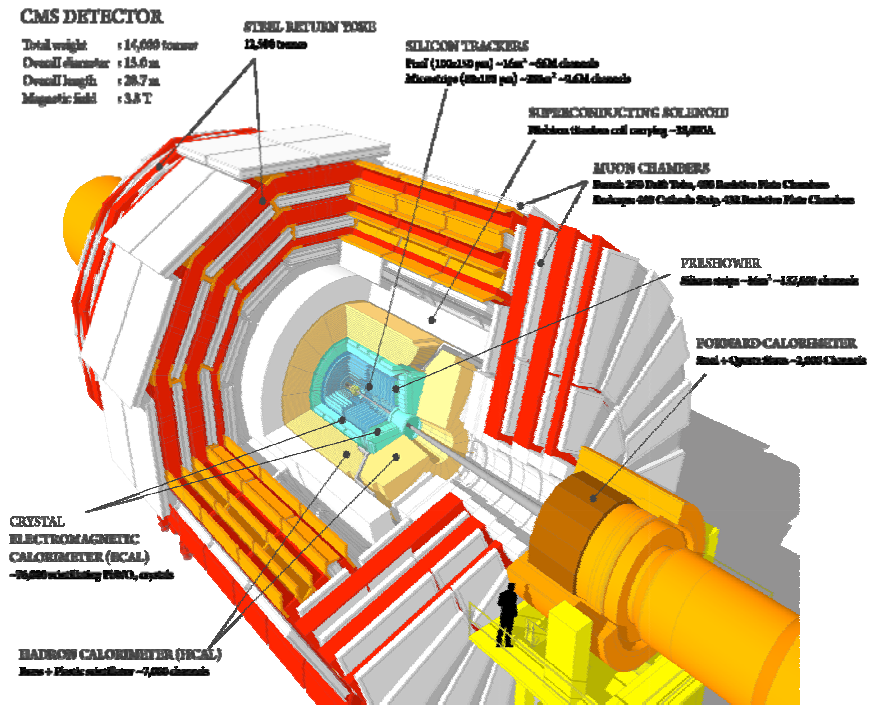

**Heavy Ion Physics**
quark-gluon plasma

**B physics**
CP symmetry

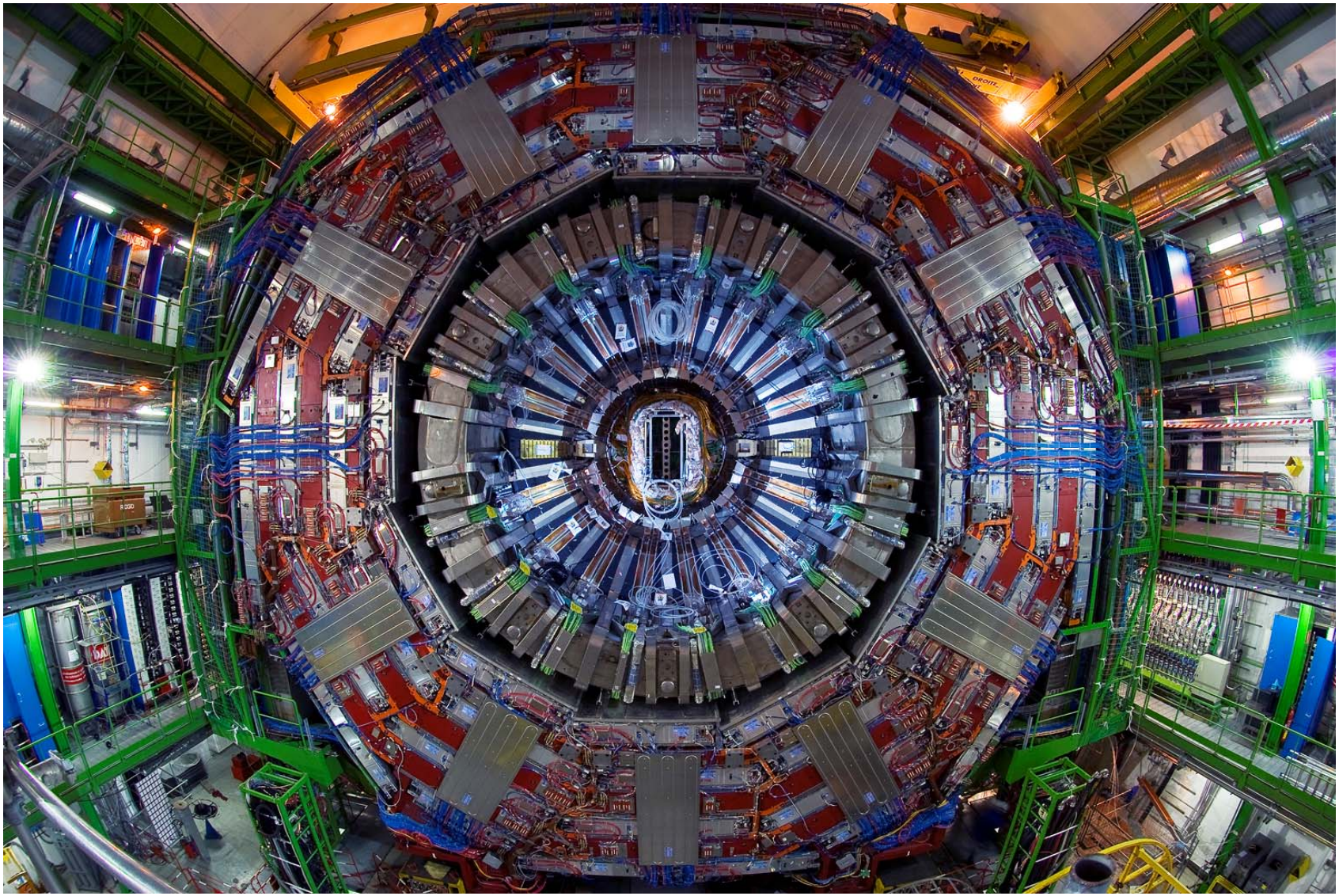
**General purpose:**
Higgs
SUSY
??

# The Hungarian CMS group

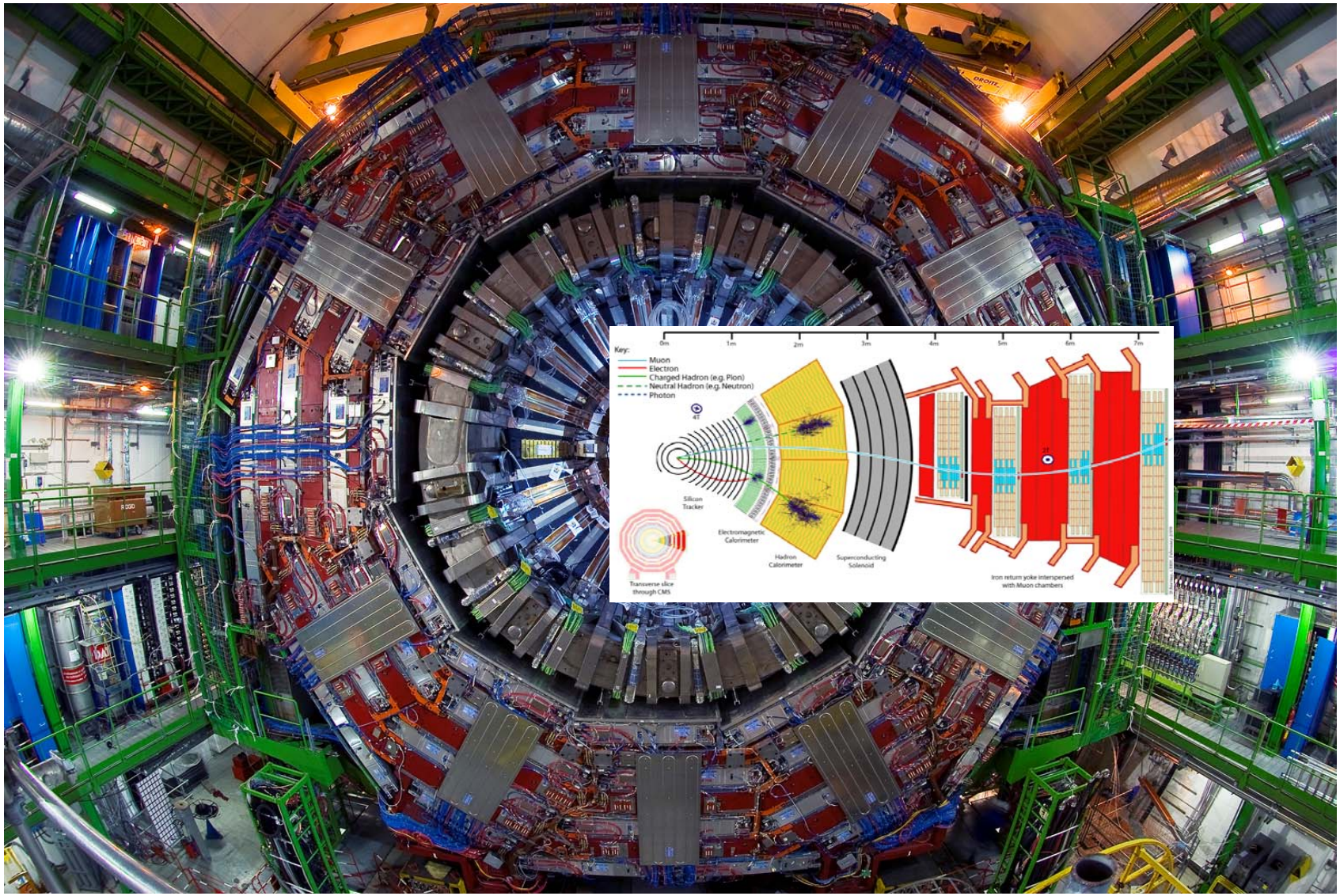
- The Hungarian CMS group is composed of 3 institutes
- Overall 25-30 Hungarian participant. With right to access data:
  - Wigner Research Centre for Physics, Budapest: 12 persons (8 authors)
  - Institute of Nuclear Research, Debrecen: 5 persons (5 authors)
  - Institute of Experimental Physics at University of Debrecen: 5 persons (4 authors)
- Participation in the following areas:
  - Run coordination
  - Heavy Ion runs
  - Offline software maintenance
  - Computing infrastructure (GRID)
  - Physics analyses
  - Detector development, maintenance, and upgrade



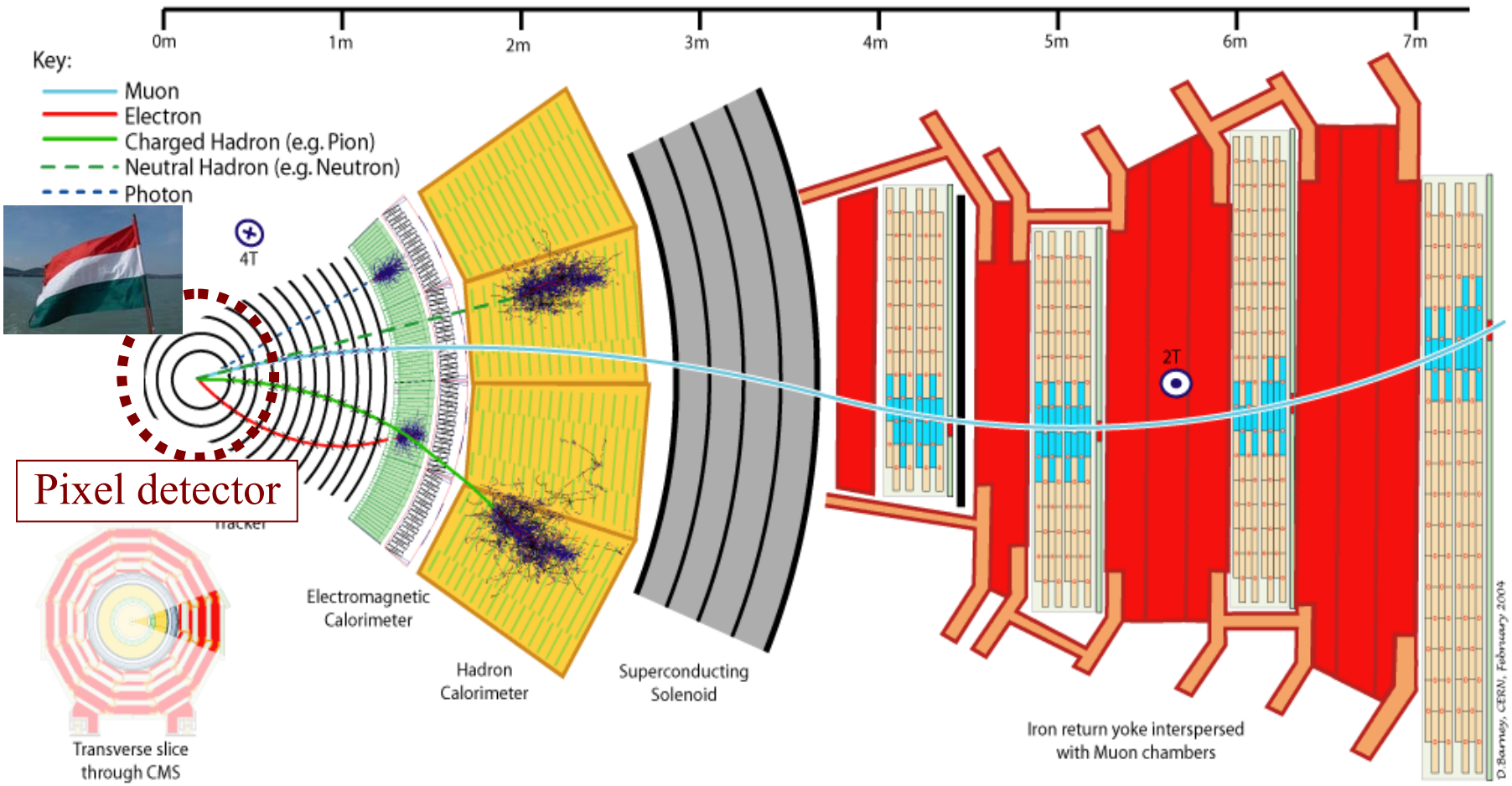
# Cross-section of CMS



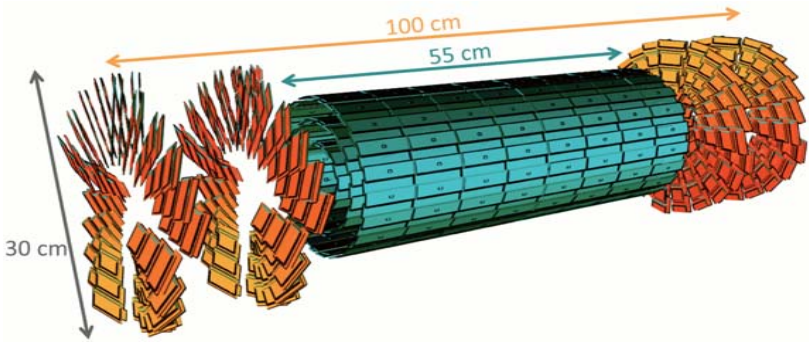
# Cross-section of CMS



# A slice of the CMS detector: the Pixel detector

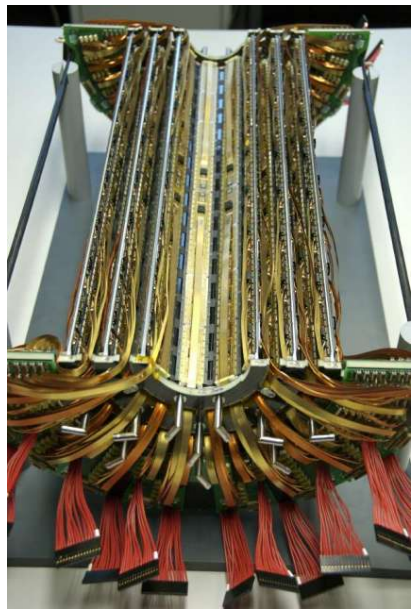


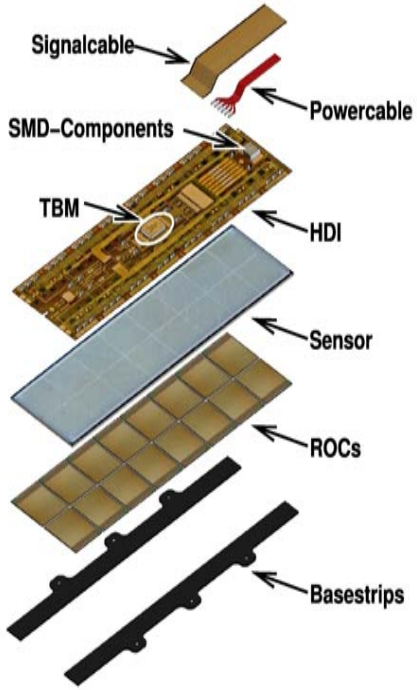
# The pixel detector

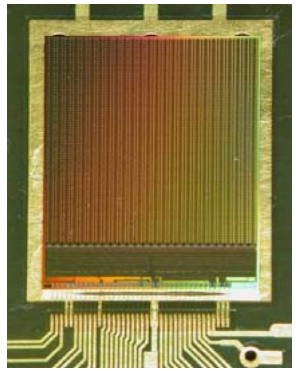



- Barrel:
  - 3 tracking layers
  - R=4.3 cm, 7.2 cm, 11 cm
- Endcap:
  - 2 disks on each side
  - Z=34.5 cm and 46.5 cm

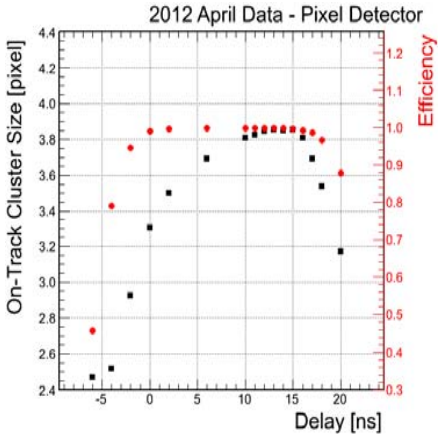
- N+-in-n sensor, 66 M pixels
- Pixel size: 100 μm x 150 μm x 285 μm
- Data sparsification of 52x80 pixels by Read Out Chip
- 15840 ROCs in 1312 read-out links



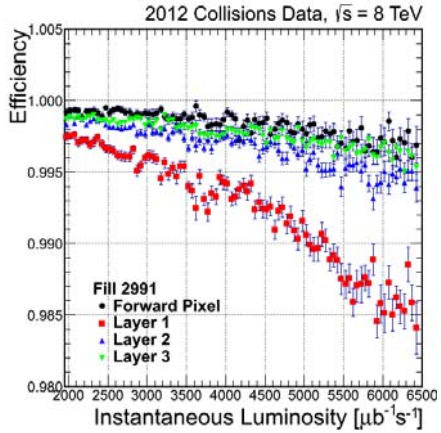


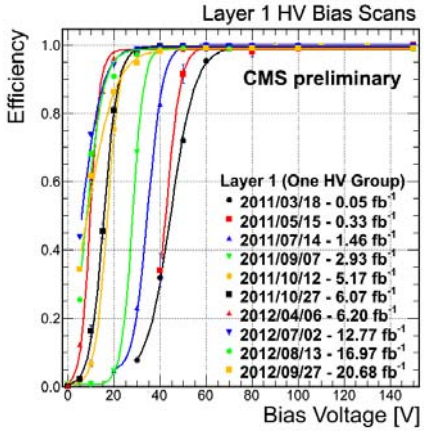
# CMS: Pixel Calibration and Simulation

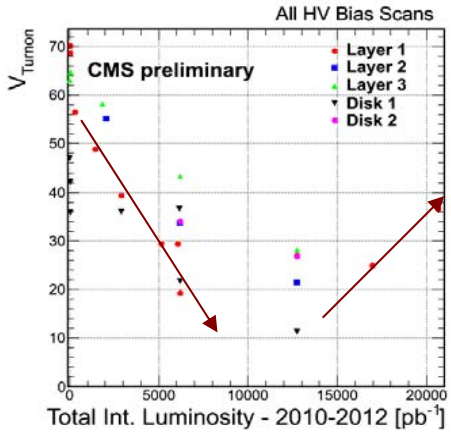



- Online operation, DAQ software development
- Optimizing the alignment of the pixel exposition time to the LHC collisions



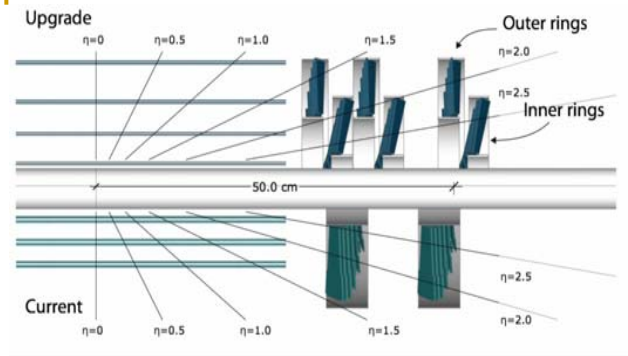

- Pixel hit efficiency vs collision rate. Adjusting simulation to reproduce the effect

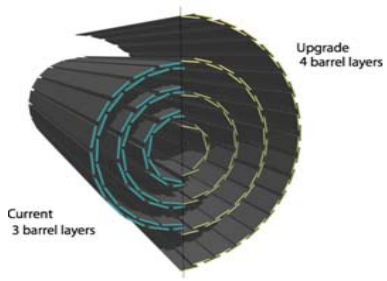


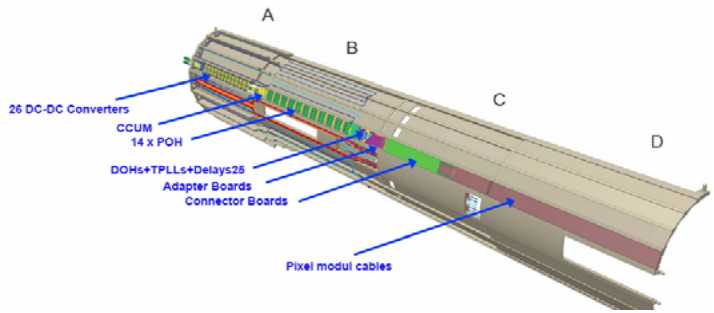




- Radiation causes effective doping of the pixels to change. Monitoring bias voltage required for fully efficient running

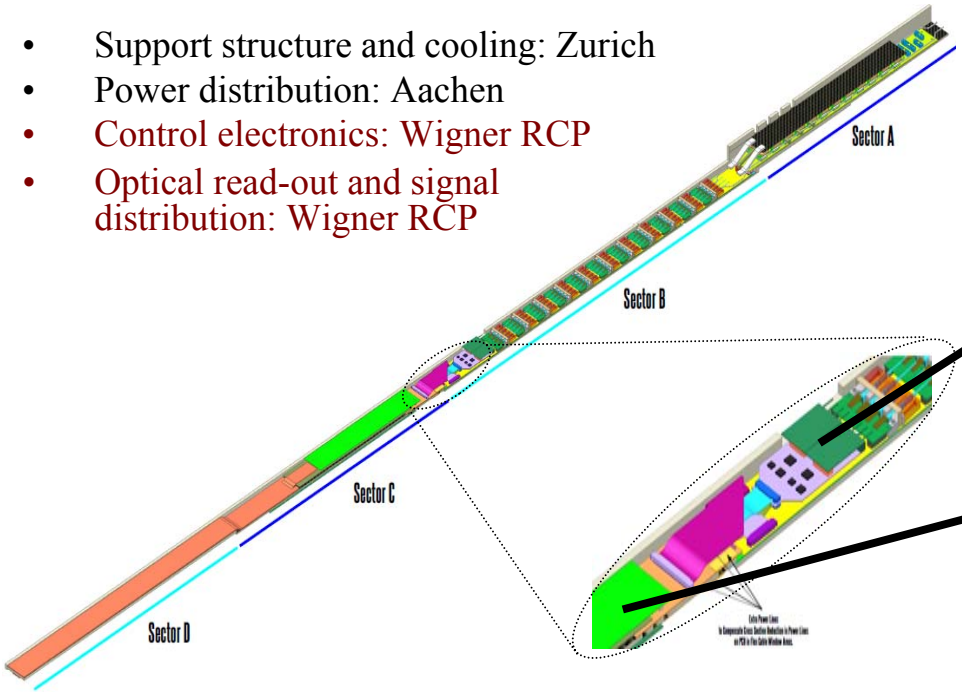
# CMS: Pixel Detector Upgrade



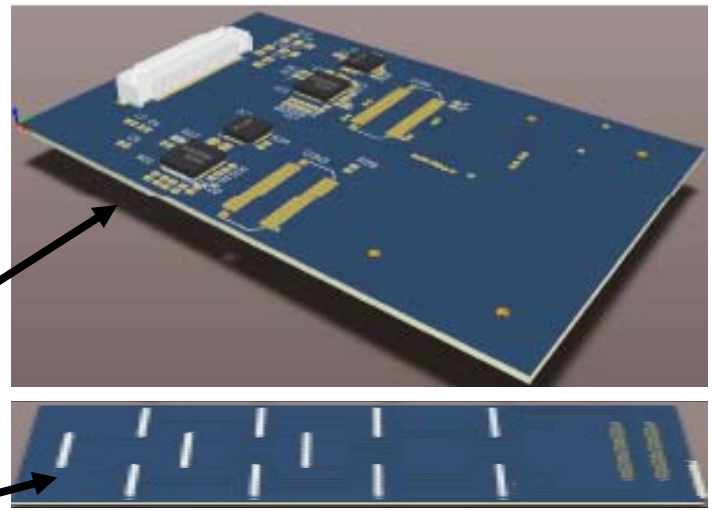




- Improvements in the upgraded pixel detector: measurement in one more layer, reduced material budget
- Support structure and cooling: Zurich
- Power distribution: Aachen
- Control electronics: Wigner RCP
- Optical read-out and signal distribution: Wigner RCP

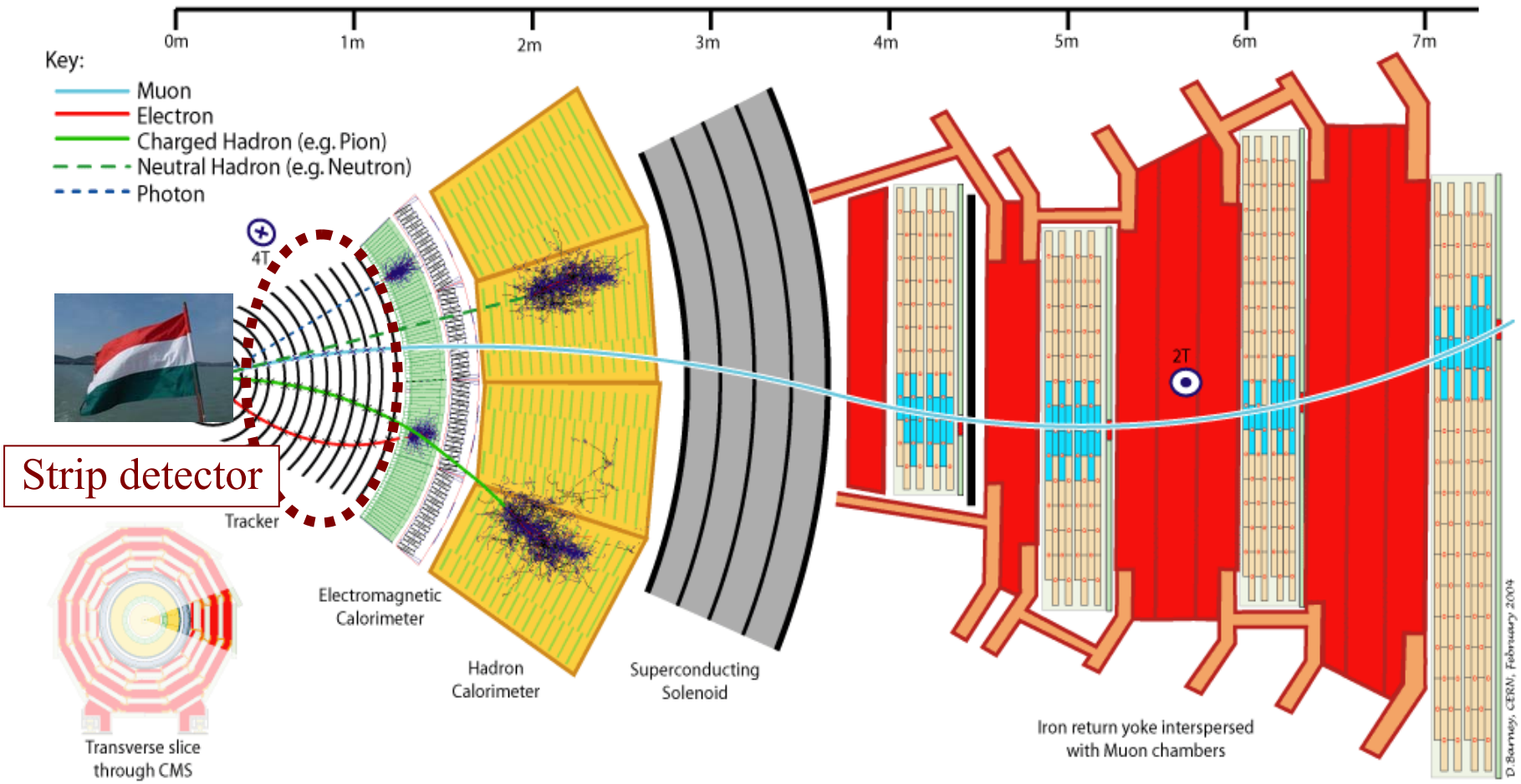



- Supply tube at the two ends of the sensor barrel: controls, programs, and reads out the detector

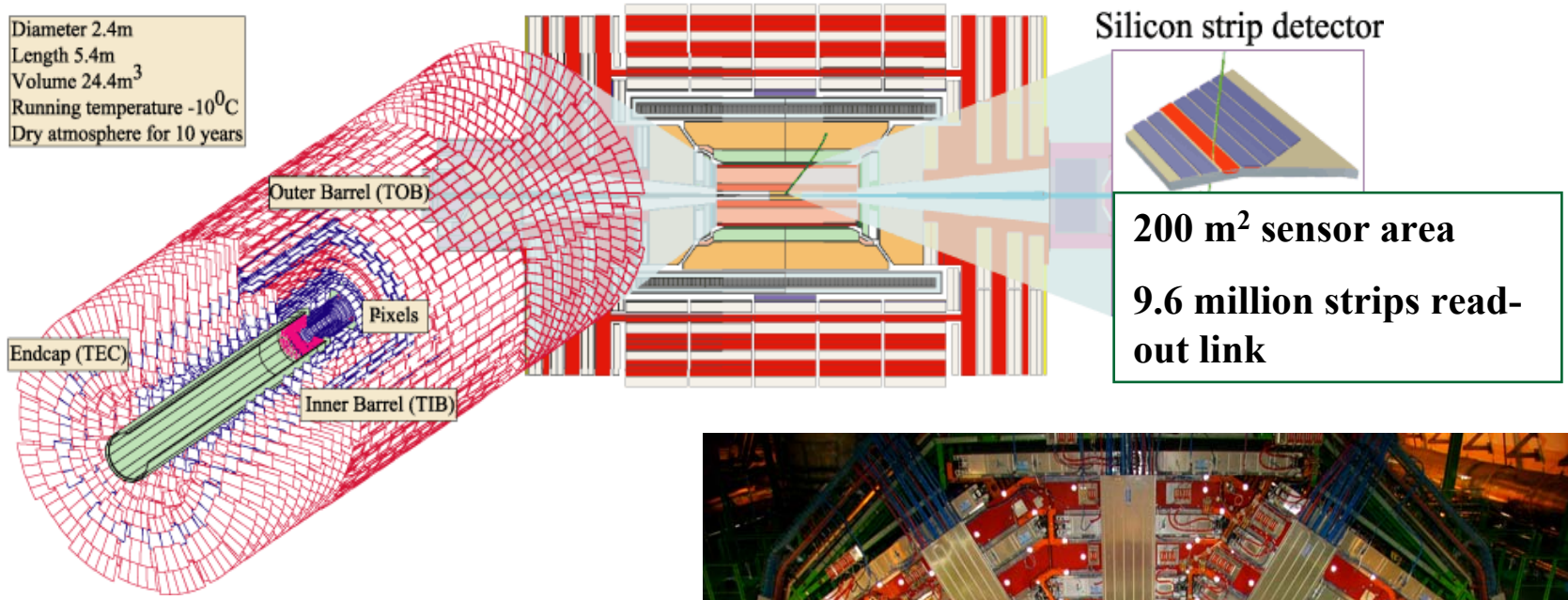


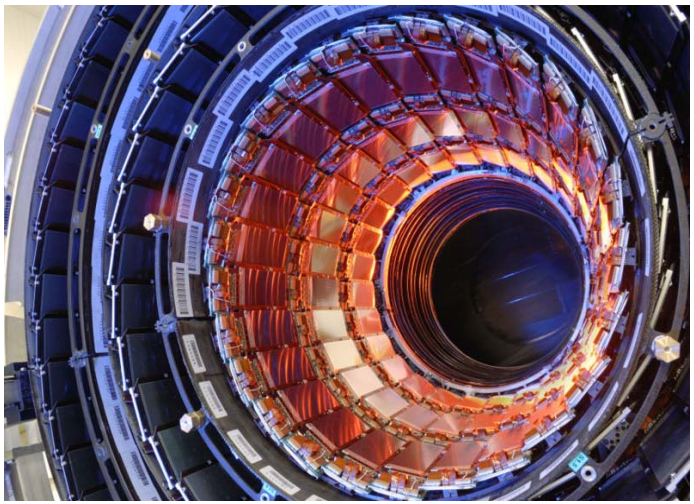
- Control electronics with fiber optic communication devices
- Connector board for pixel modules

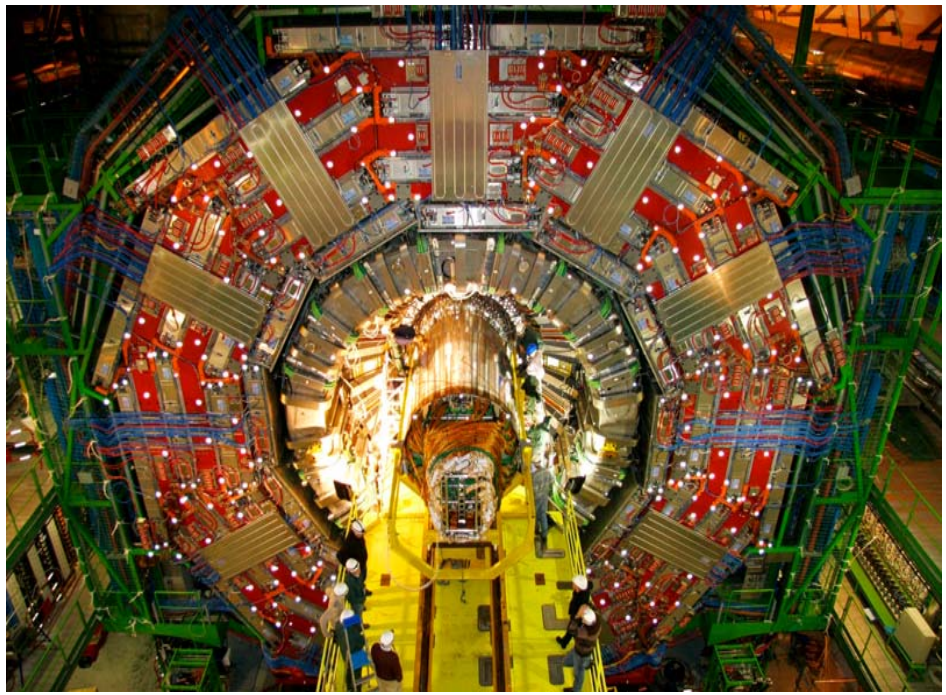
# A slice of the CMS detector: the Pixel detector



# The Strip tracker detector



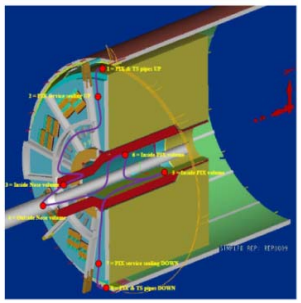


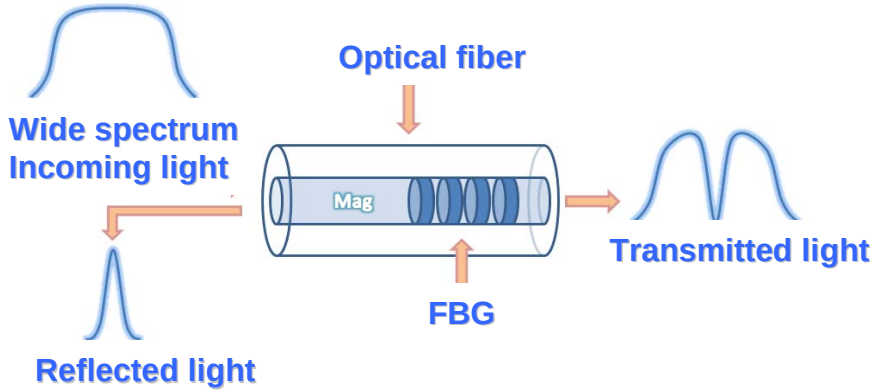
# Relative humidity measurement in the CMS Tracker

- Desired coolant temperature of -25 Co
- Requires low dew point inside tracker volume
- Need instrumentation for precise monitoring

Calibration in two independent climate chambers

• Overall 80 sensors in CMS
• 16 FOS in the pixels

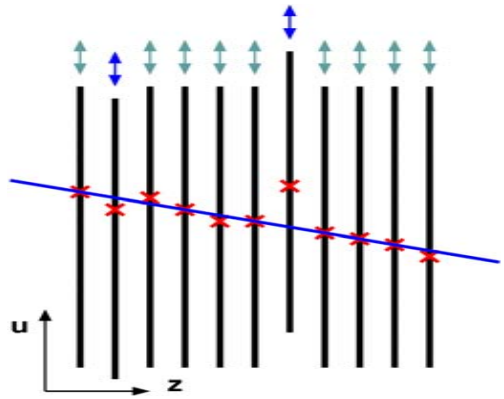




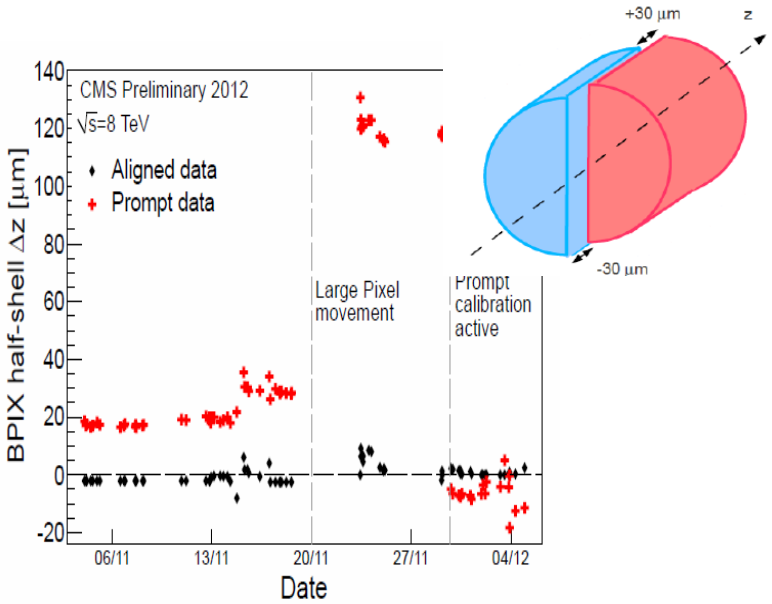

- **Humidity** and **temperature measurement**
  - Wide range of temperature
  - Small contribution to material budget
  - Insensitivity to strong magnetic field
  - Large radiation resistivity
- Fiber Bragg Grating sensors: the wavelength reflected in the core of the fiber optic cable gets shifted by mechanical tension
- The tension is created by the poliimid coating induced by a change in humidity

# Alignment of the Tracker layers

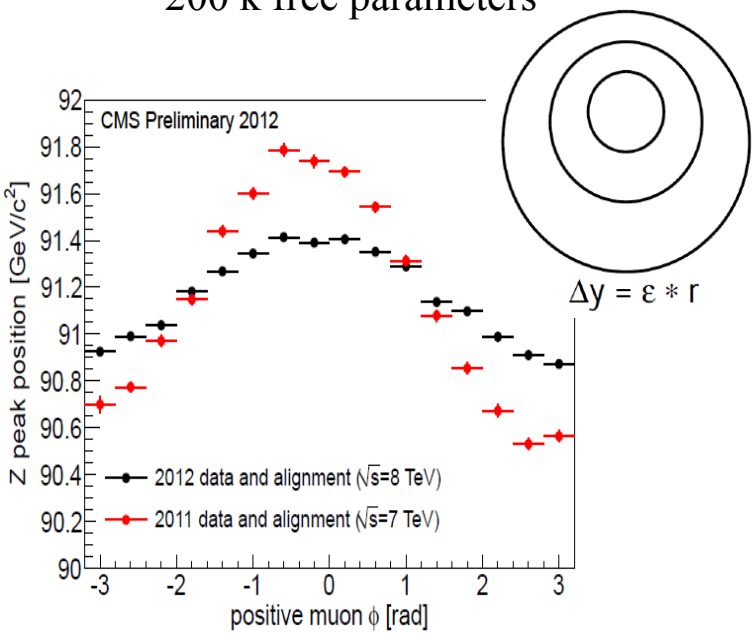
- Individual module movements and bows are tracked
- Calibration parameters are determined in multi-dimensional fits and fed back to reconstruction
  - Our group significantly contributes in the Pixel alignment




200 k free parameters

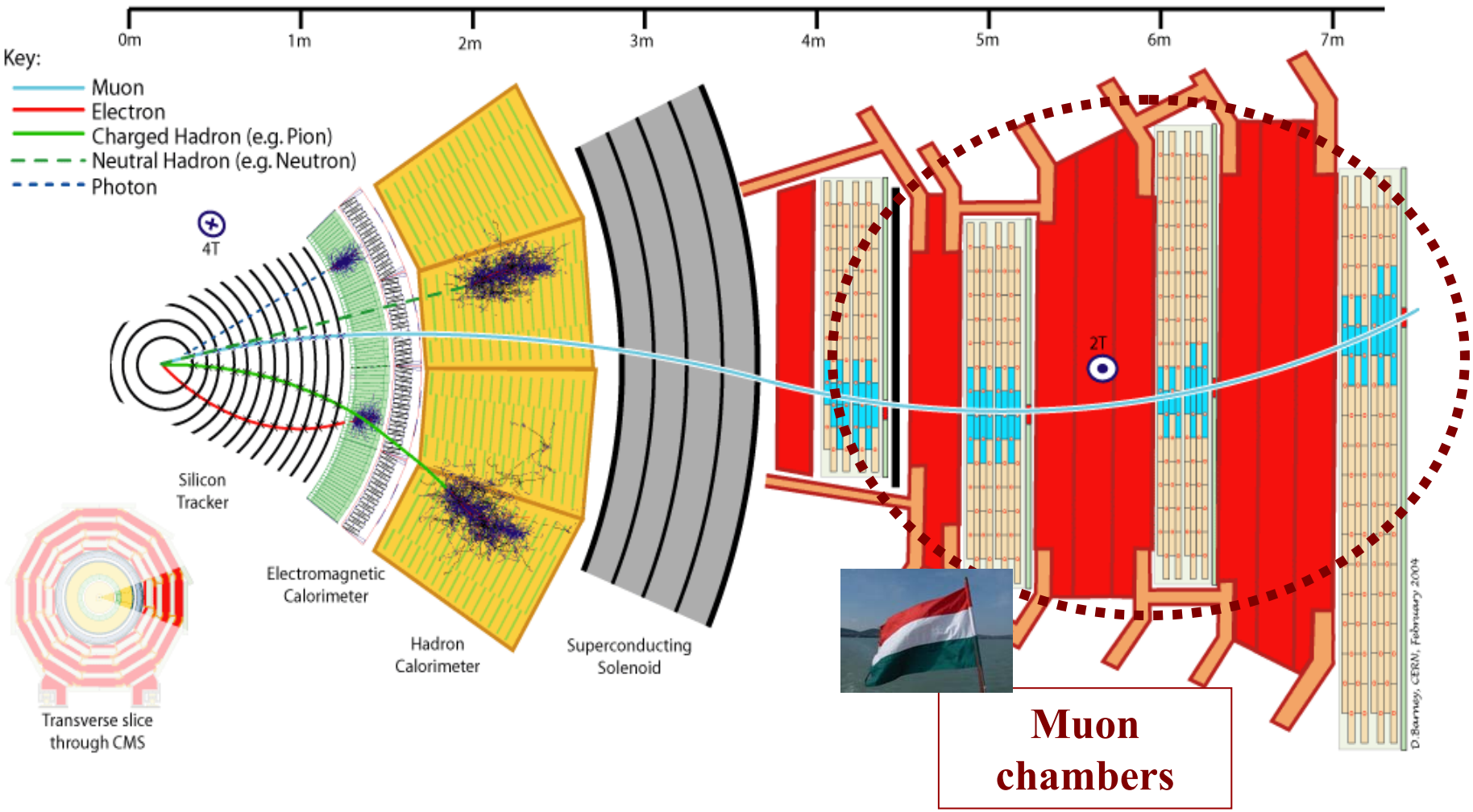



Thermal cycling on Nov 22

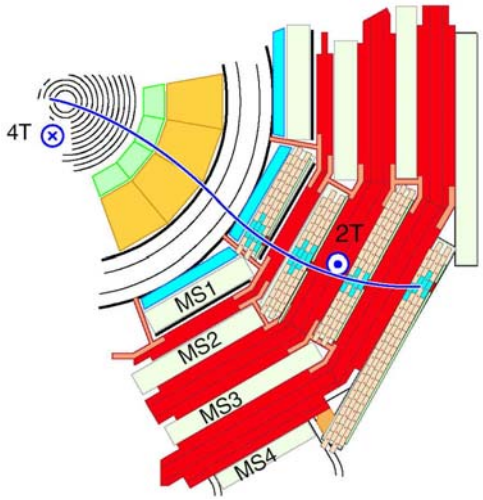


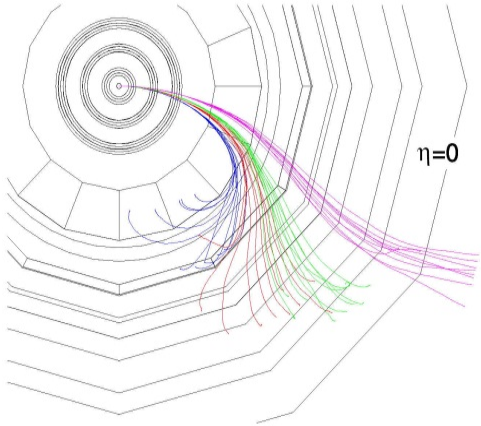

Azimuthal dependence of reconstructed Z-mass (not a physics analysis result)

# A slice of the CMS detector: the Pixel detector



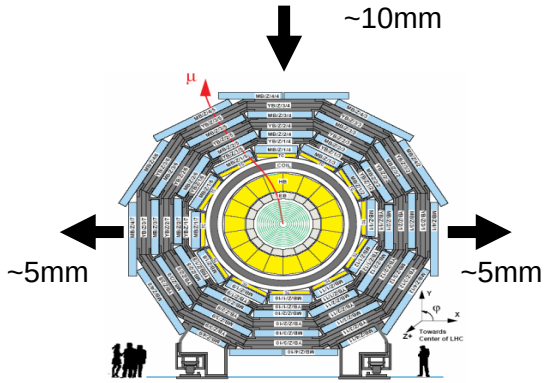
# Movements of the Muon chambers

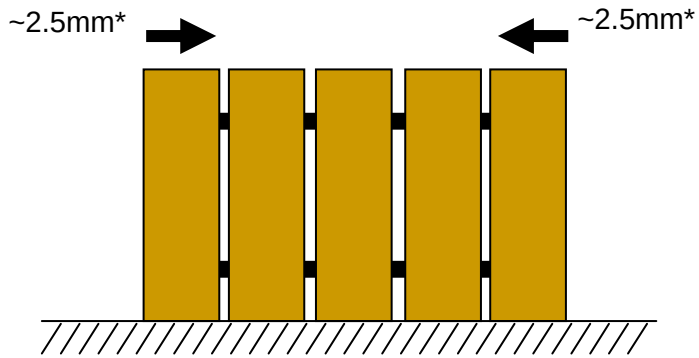



$p_t$ = 3.5, 4.0, 4.5, 6.0 GeV

- The curvature of the muon trajectories strongly depends on the transverse momentum, important to know the positions of the chambers in their reconstruction



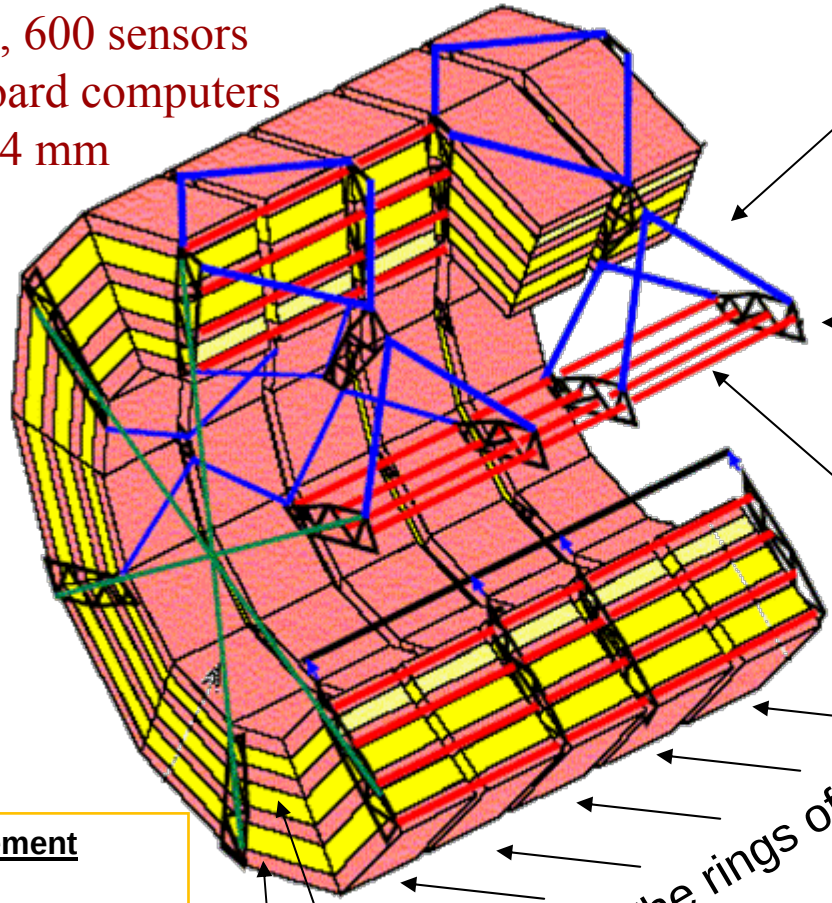



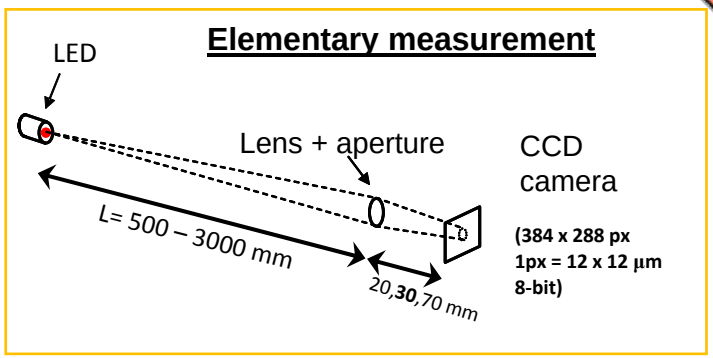

- The cylindrical shape of the muon system can get distorted under its own weight, during opening and closing its segments, and in cycling the magnetic field

# The Muon Alignment system

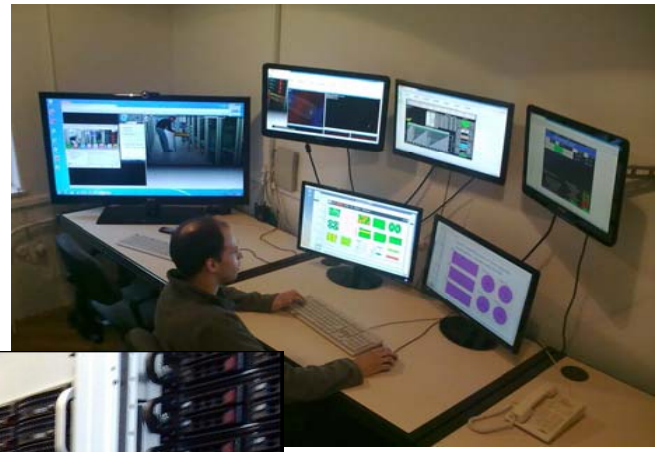
250 chambers, 9000 LED, 600 sensors
Parallel processing in 36 board computers
Precision of 0.2-0.4 mm

**Flagship project of Debrecen with contributions from Budapest**



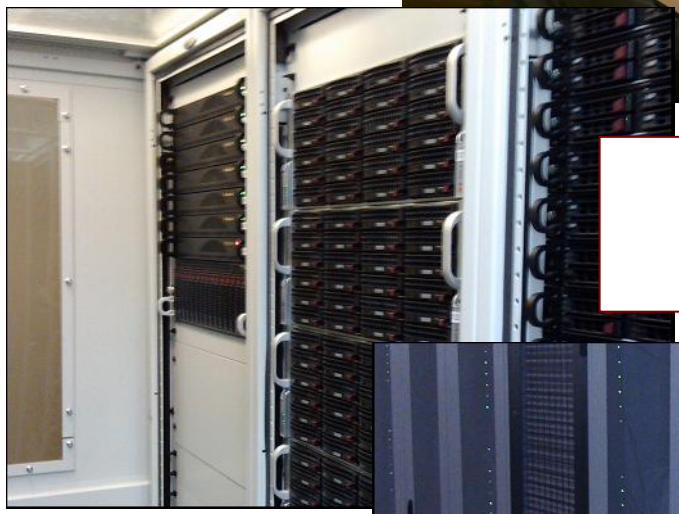



# Computing Infrastructure: CMS Centre and Tier-2 Site



CMS Centre

- Data Quality Monitoring shifts for the CMS Tracker Collaboration (60 days)
- Adjustment of Pixel calibration parameters within the 48 hour reconstruction delay window

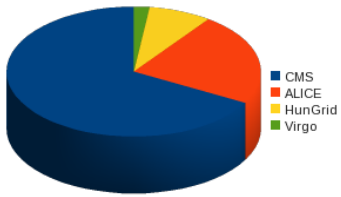


Grid Tier-2 Site:

- Hardware statistics:
  - CPU: ~500 cores
  - Storage: ~300 TB
- Infrastructure developments (this year):
  - Renewal of the grid server room
  - Cooling systems, safety systems etc.
  - New worker nodes, one new UI machine

Job statistics
Submitted: ~1 million/year
Site availability: 99%, reliability: 100%

Users:
CMS – 67%
ALICE – 23%
HunGrid – 8%
Virgo – 2%



# Summary

- Hungarian participants constitute ~1 % of CMS
- Relatively wide range of activities from online operations, detector development and maintenance, to offline software maintenance and analysis
- Major efforts in hardware
  - Pixel operation
  - Pixel detector performance studies
  - Pixel upgrade
  - Tracker alignment and data quality check
  - Construction of the muon chambers
  - Muon alignment hardware and software
  - Computing infrastructure