Twenty-Seven years (1994-present) Experiences with Detectors at Particle Colliders

LHC: CMS / ATLAS

HERA: ZEUS

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for
Workshop at Isfahan University Technology

Hardware activities

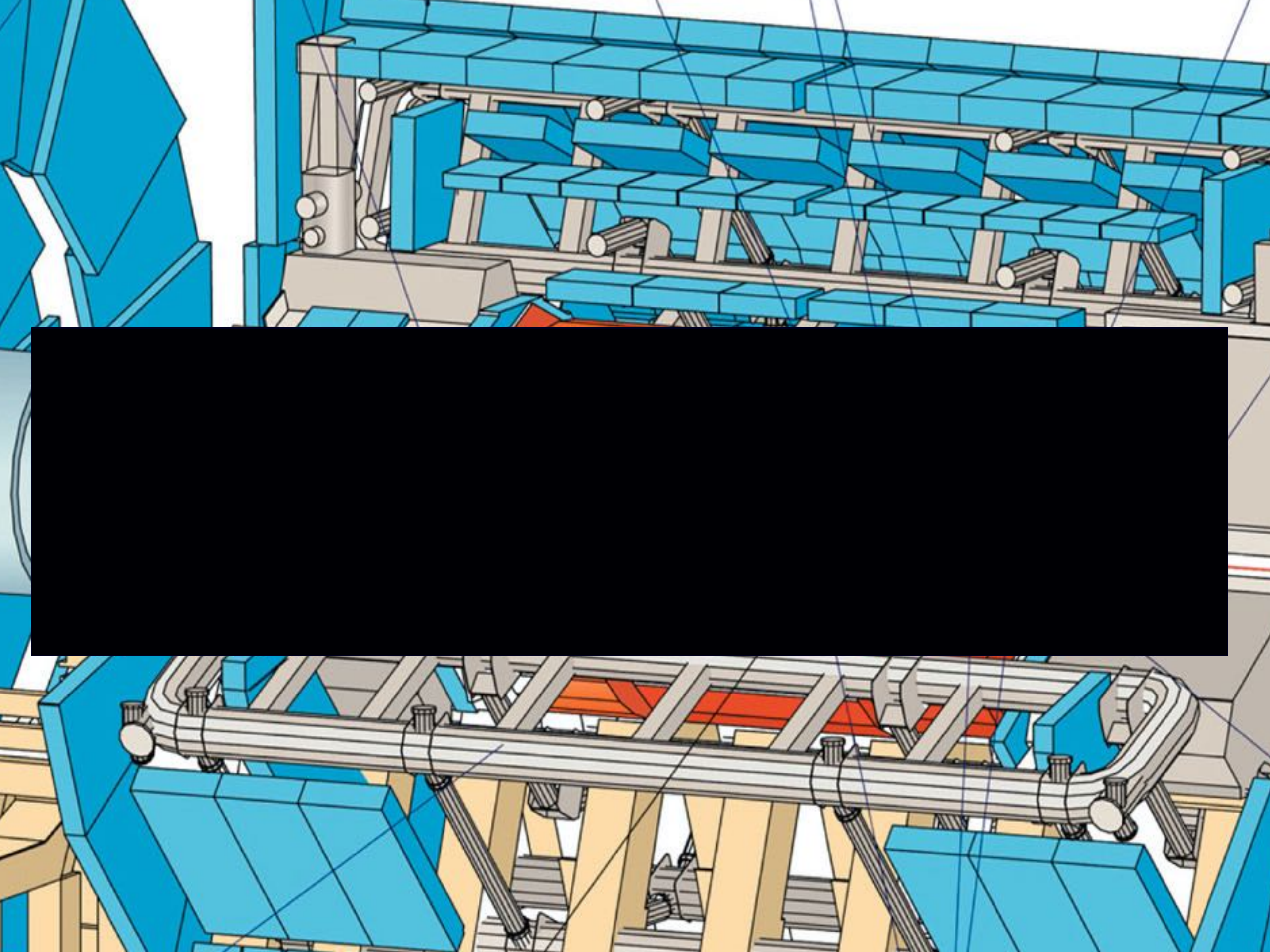
(1) Introduction to detectors

(2) CMS Hardware contribution

(3) Larak activities

(4) ATLAS collaboration

(5) DESY activities



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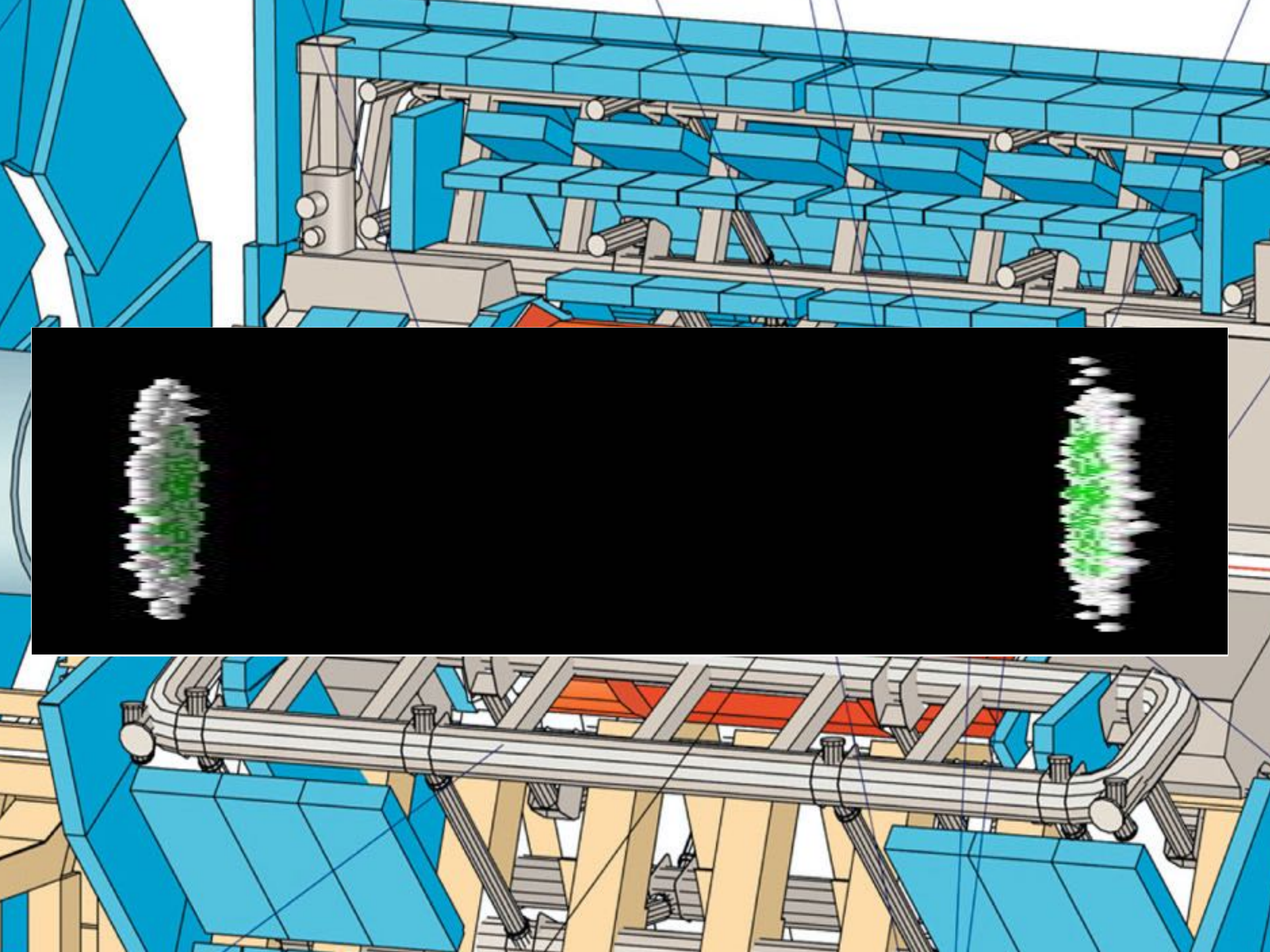
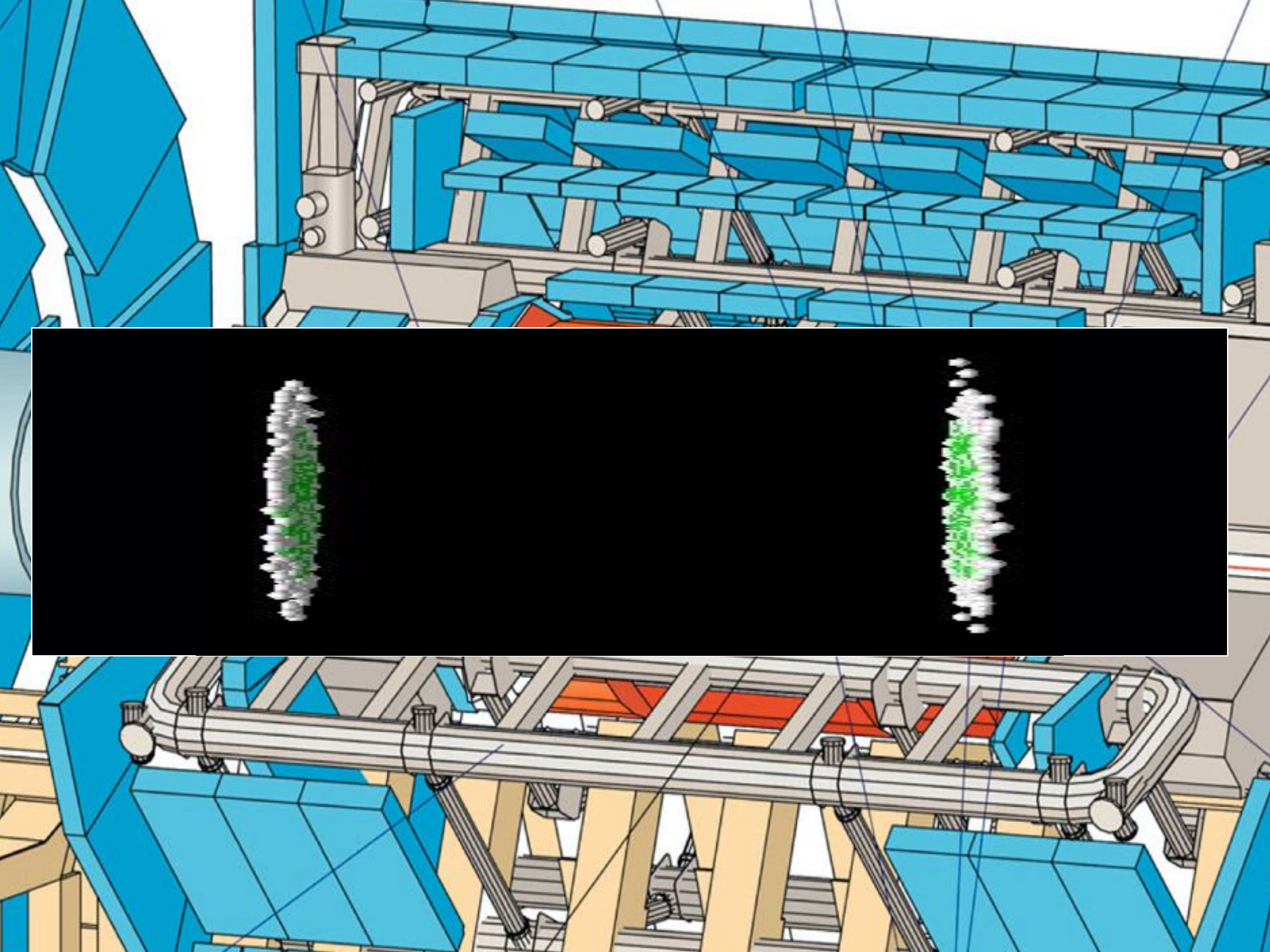
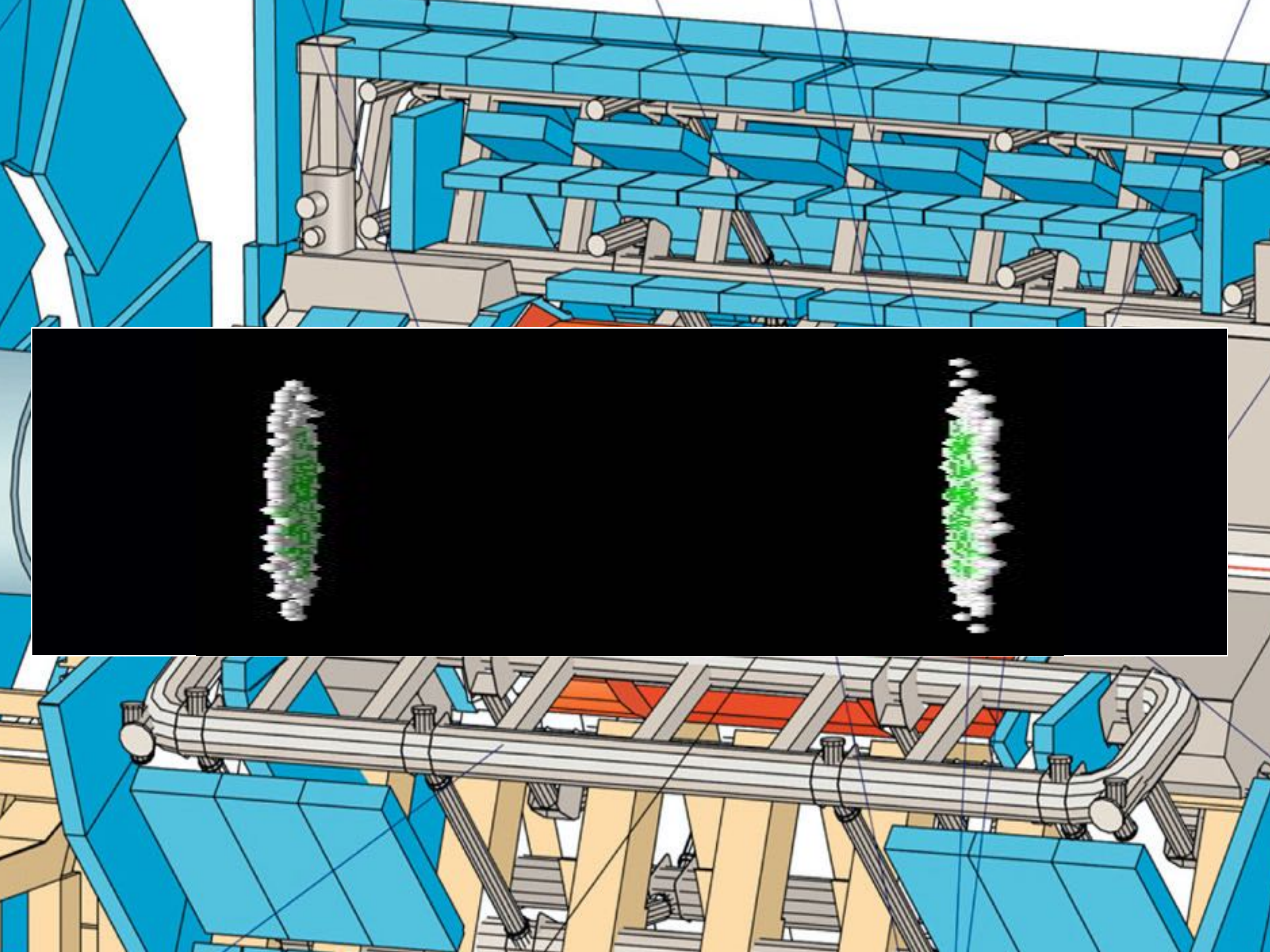
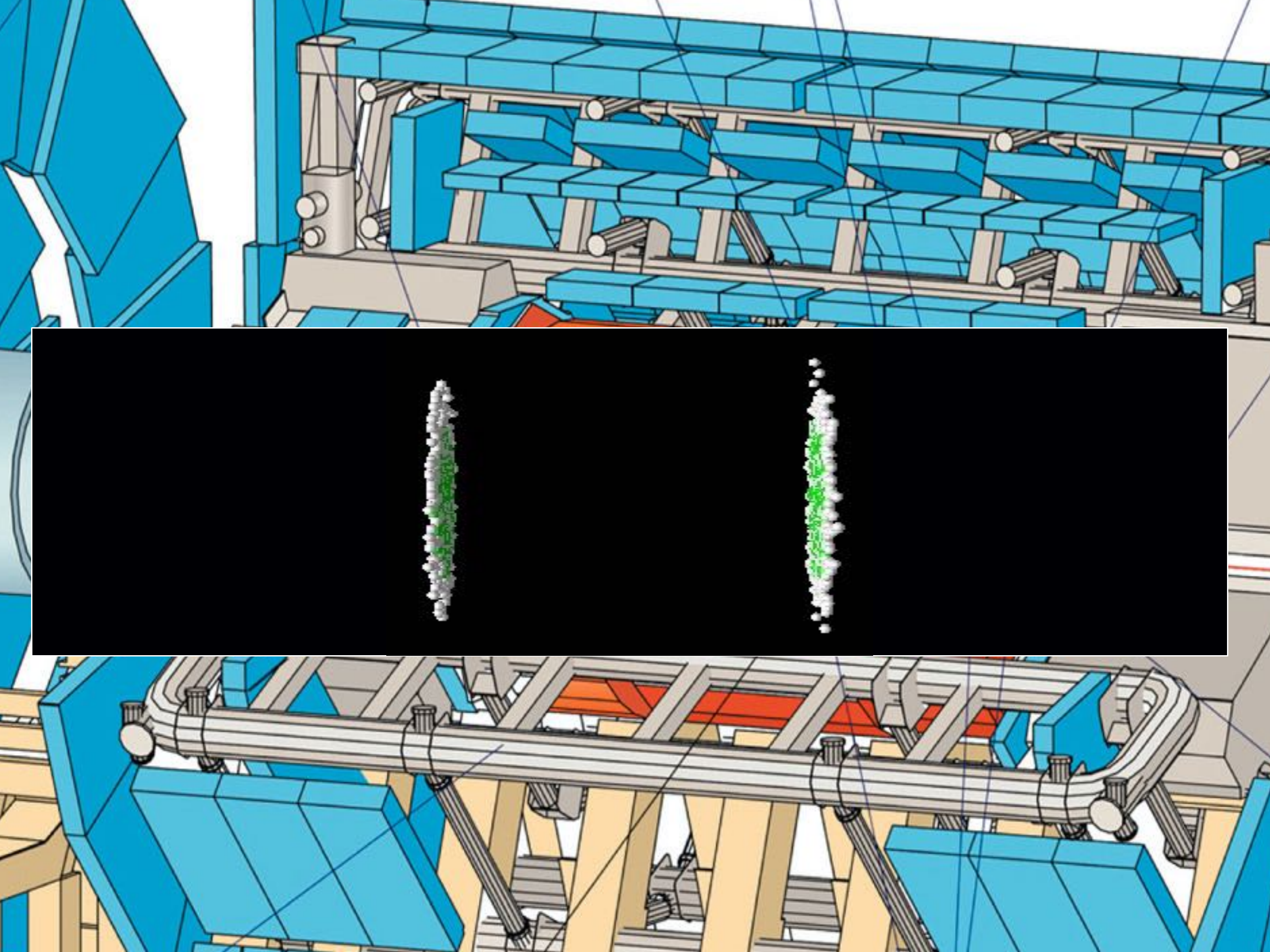
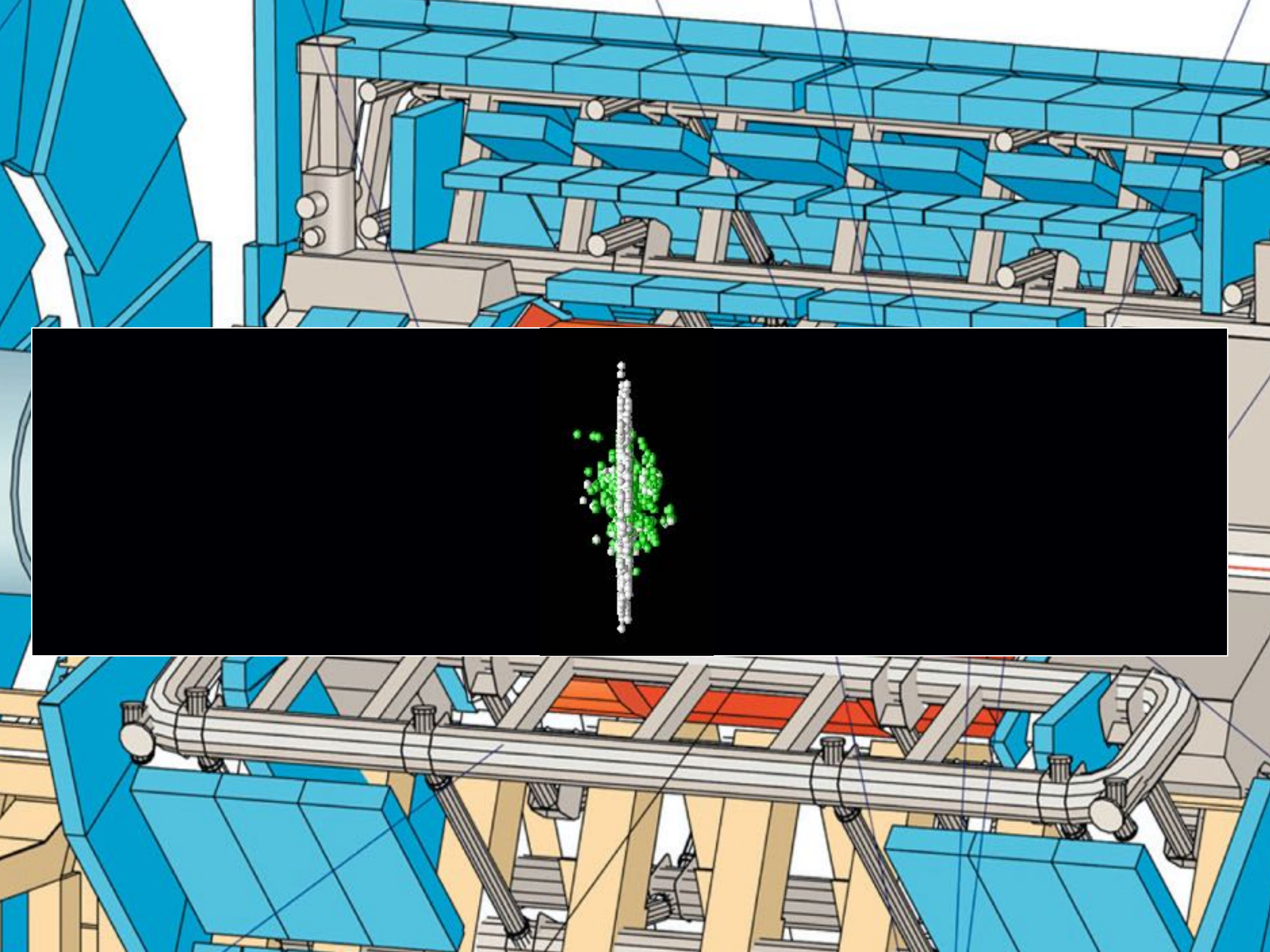
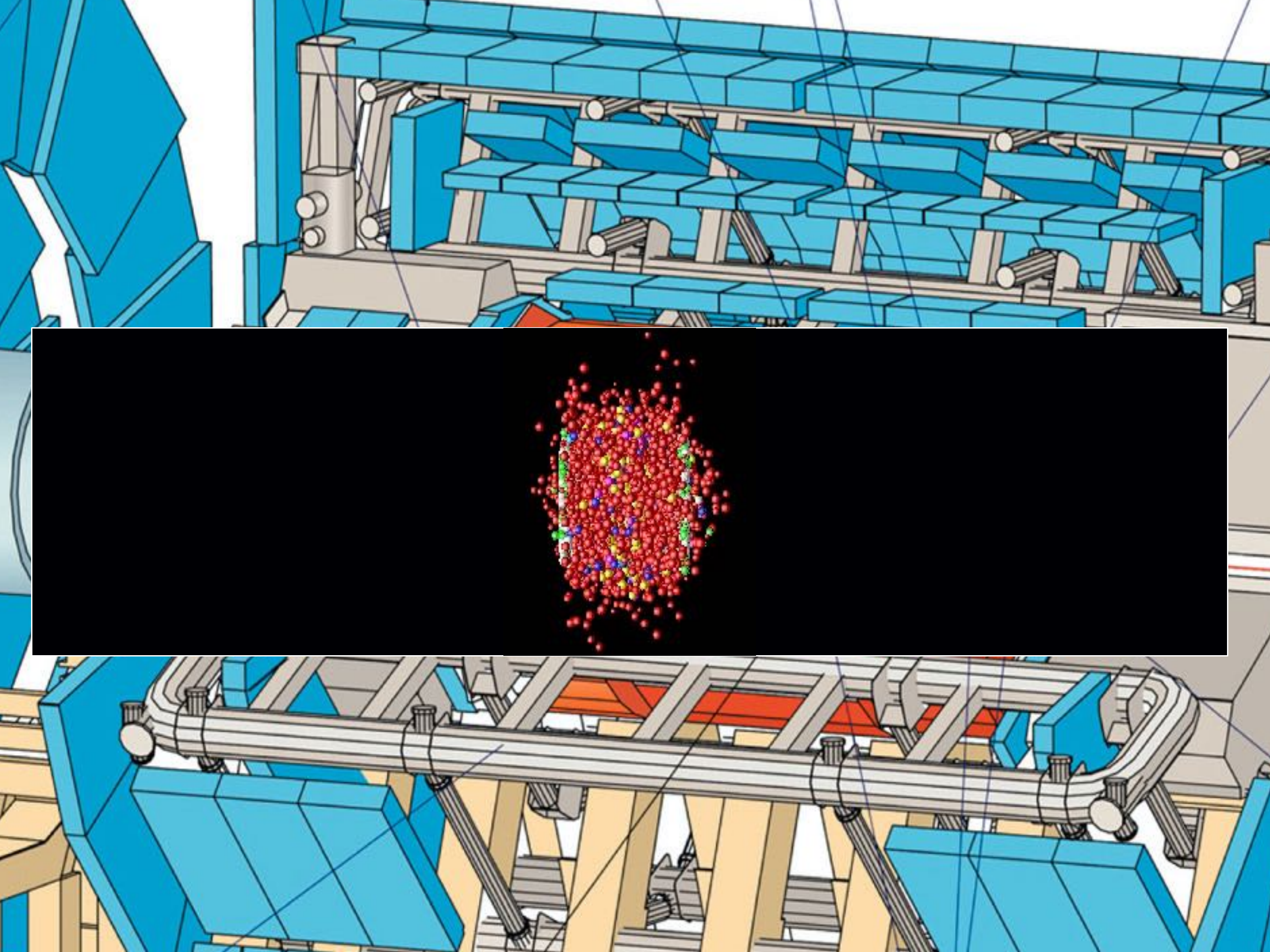


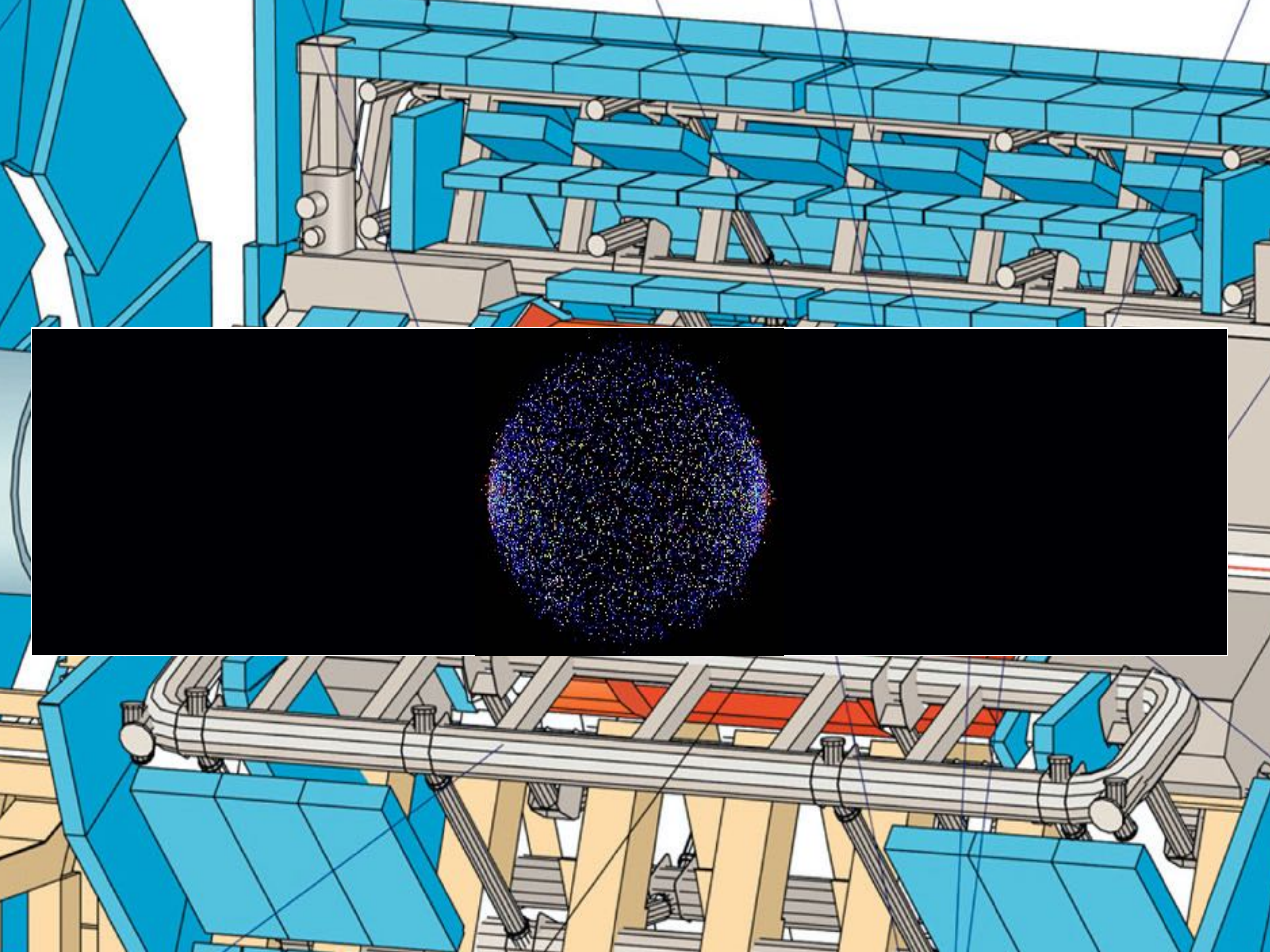




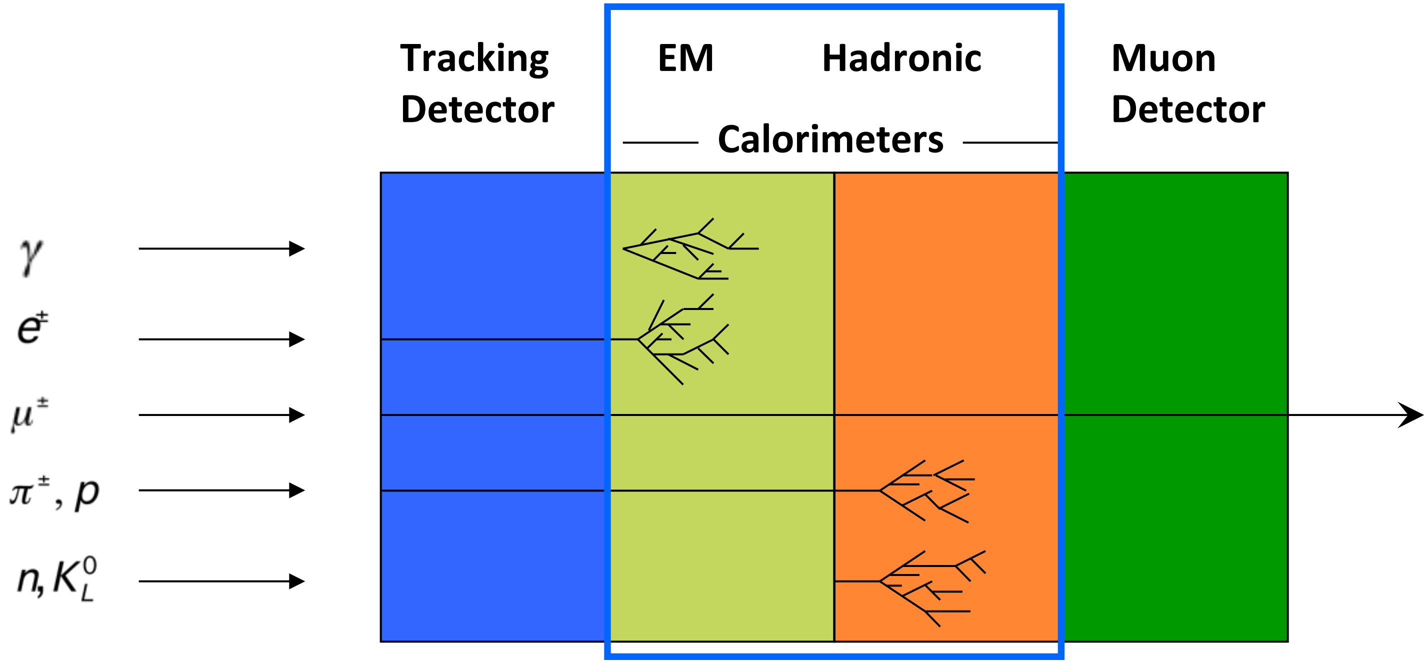




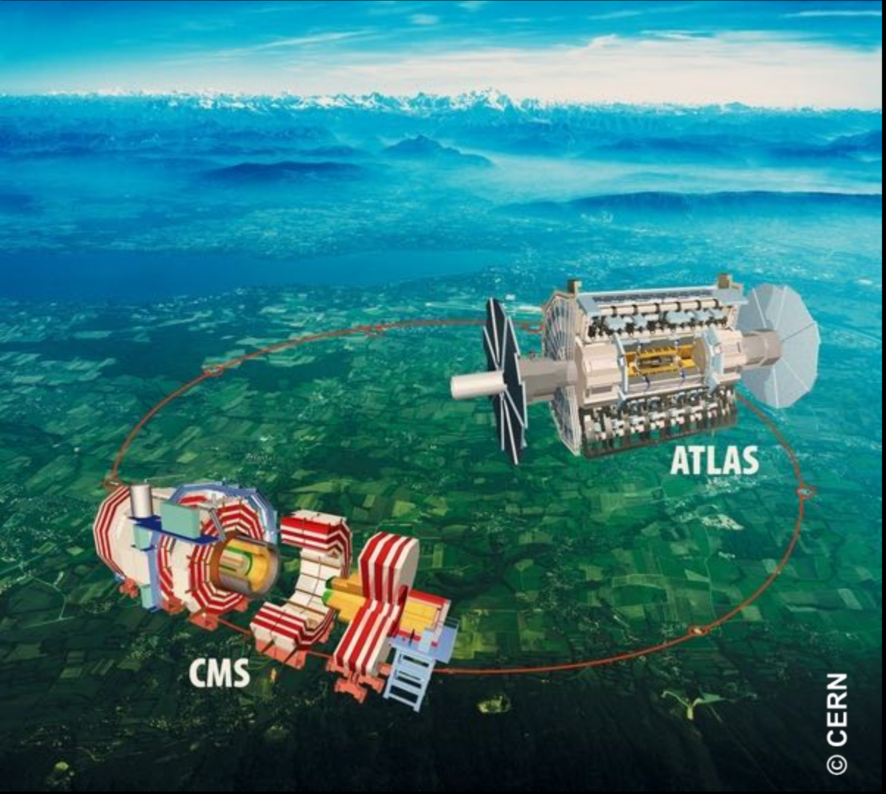




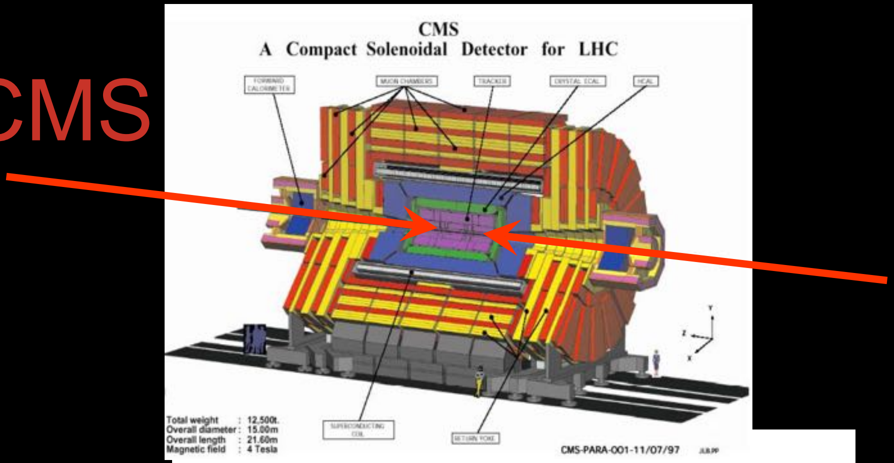
Collider Detectors



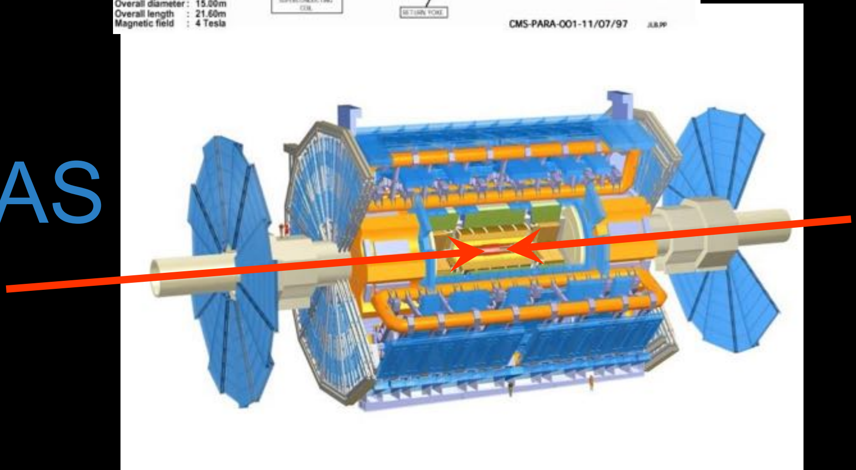
Counter-circulating beams collide at heart of detectors:



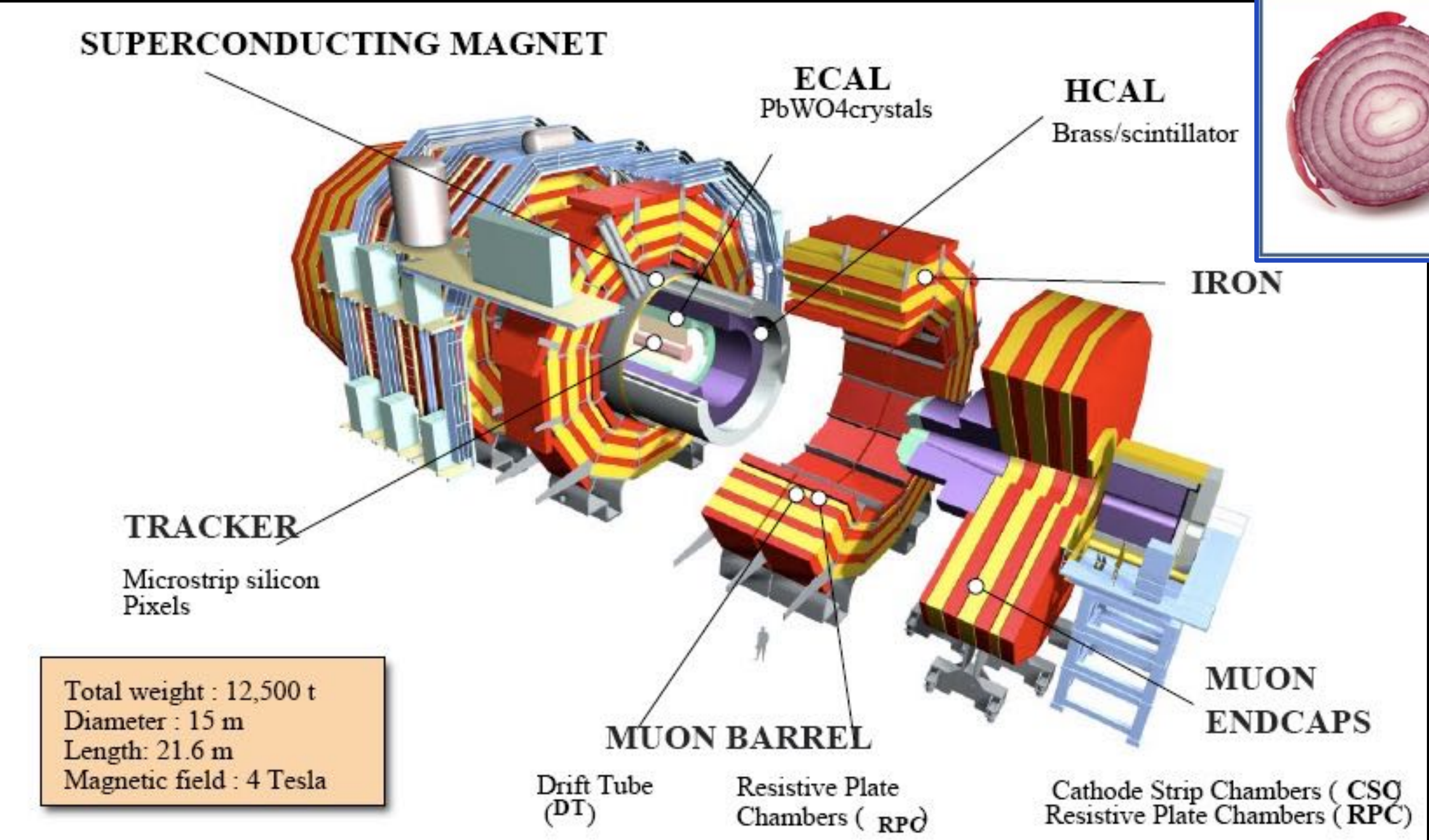
CMS



ATLAS



CMS (Compact Muon Solenoid)



Total weight : 12,500 t
Diameter : 15 m
Length: 21.6 m
Magnetic field : 4 Tesla

ATLAS (A Toroidal LHC ApparatuS)

Three main sub-systems:

1) Inner Tracking System

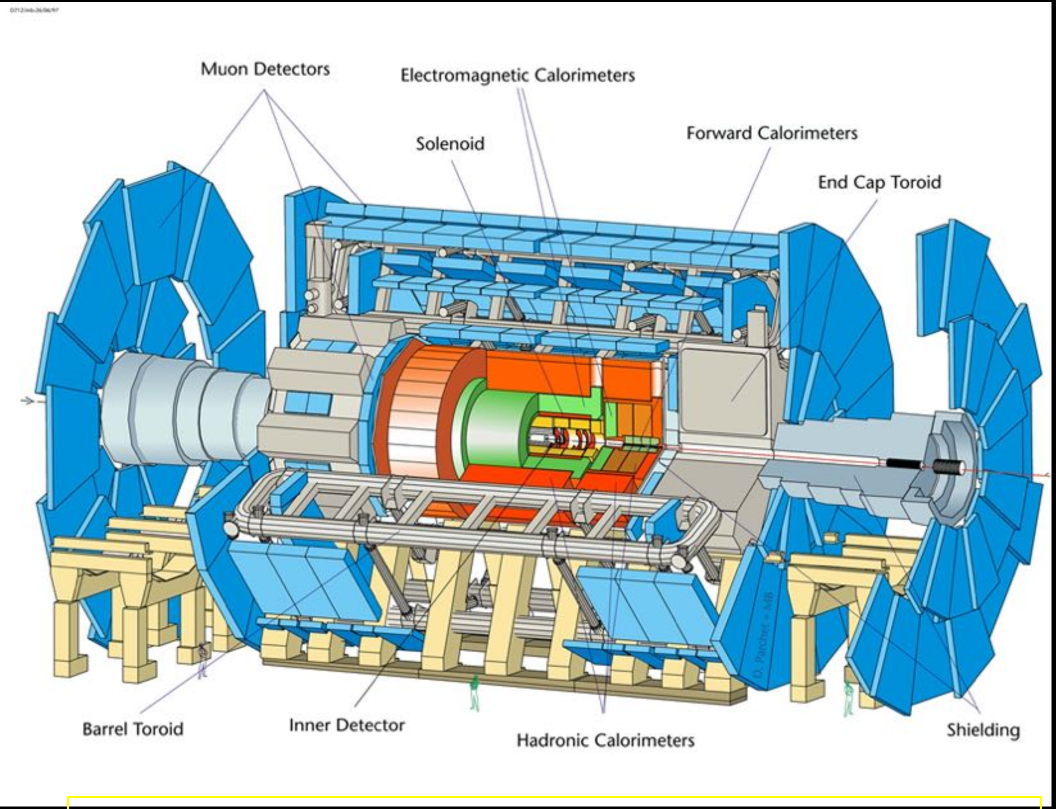
- Pixel Detector
- Semiconductor Tracker
- Transition Radiation Tracker

2) Calorimeter

- Barrel Carlorimeter
  - Liquid Argon Electromagnetic
  - Hadronic (Tile-Calorimeter)
- 2 Liquid Argon End Caps
  - Electromagnetic (Pb)
  - Hadronic (Cu)
  - Forward Calorimeter (Cu,W)

3) Muon Spectrometer

- Large Air-core toroid (0.5 T)
- Monitored Drift Tubes and CSC
- Trigger: TGC and RPC

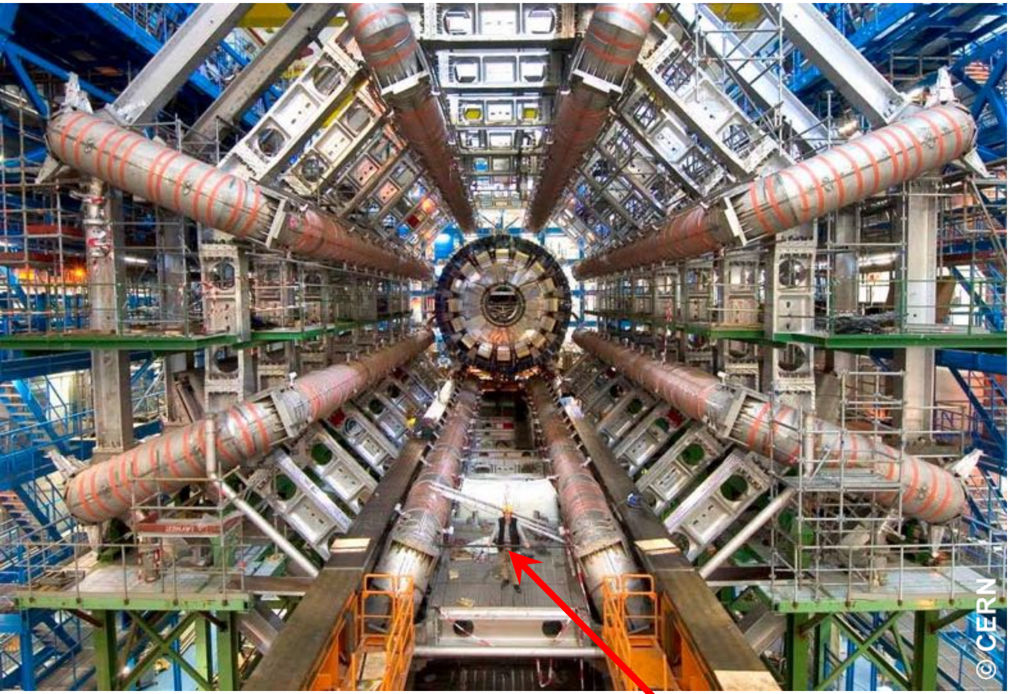


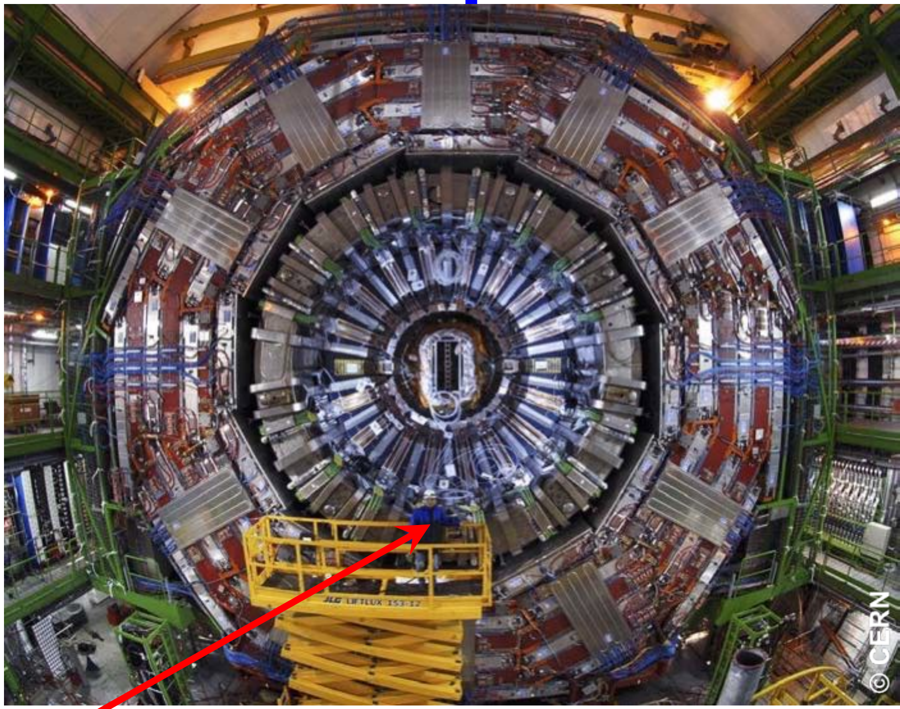
Diameter	*25 m*
Barrel toroid length	*26 m*
Overall length	*46 m*
Overall weight	*7000 Tons*

IT'S ~~LARGE~~ HUGE!

Largest, most complex detectors ever built

Study tiniest particles with incredible precision





(people)

Contributions to CMS
at
CERN
(2009-present)

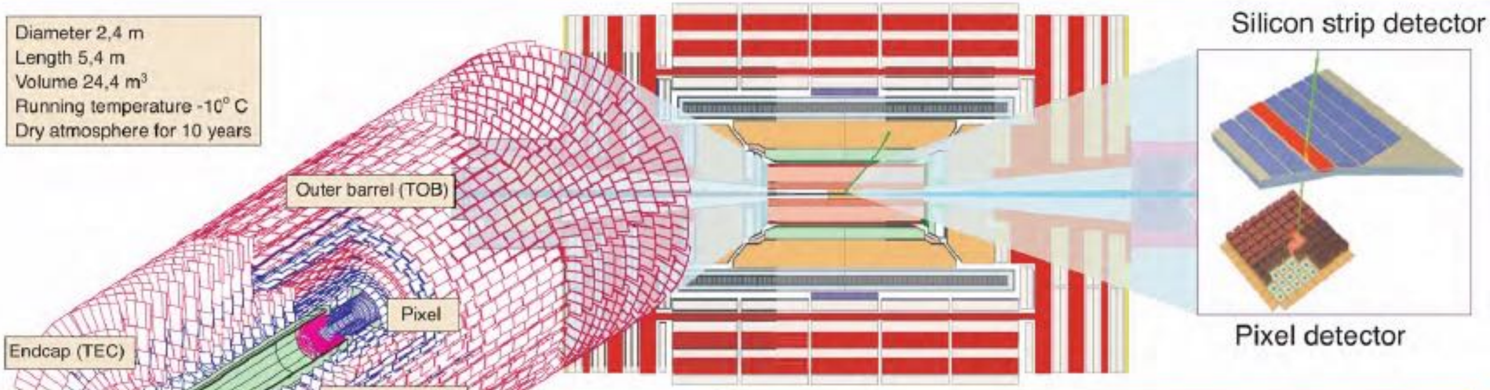
Hardware Activities

- **Tracker: Silicon Strip (2012-2014)**
- **Forward Detector (2010 - present)**

CMS Tracker Upgrade for HL-LHC (Sensors R&D)

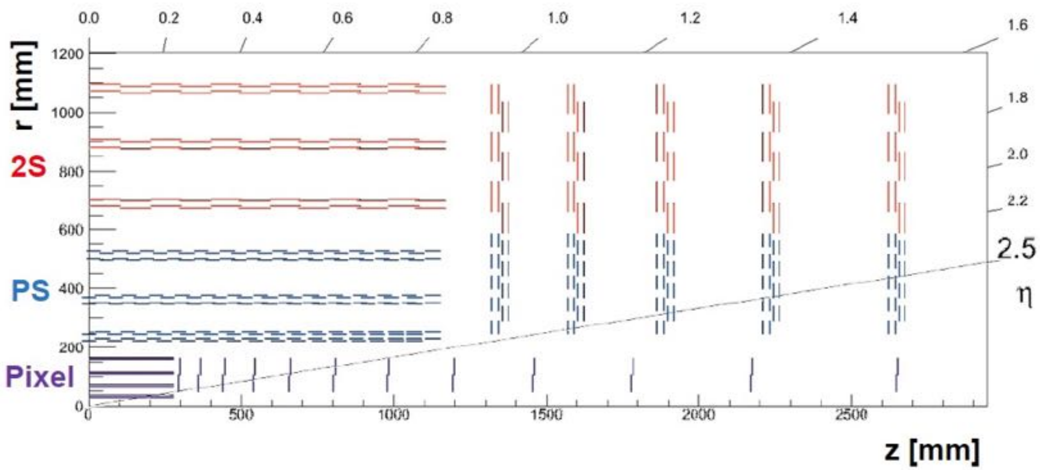
Collaboration: 2012-2014

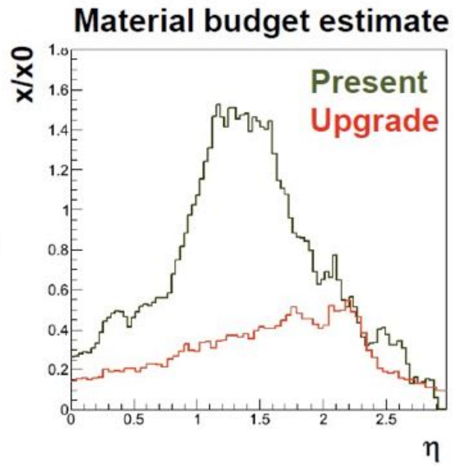
CMS tracker detector upgrade



Survive $\int L.dt = 3000\ fb^{-1}$ **conditions**	**Sensor radiation hardness** **Operating at** -20°C
Deal with **<μ>=140 → 200**	**Increase granularity** (shorter strips)
No maintenance	**Robustness**
enhance tracking efficiency at **high pT**	**Increase granularity** (smaller pitch)
enhance tracking efficiency at **low pT** Reduce secondary interactions	**Reduce material budget**
enhance CMS trigger decision	**usage of tracking to Level-1**

Tracker Layout

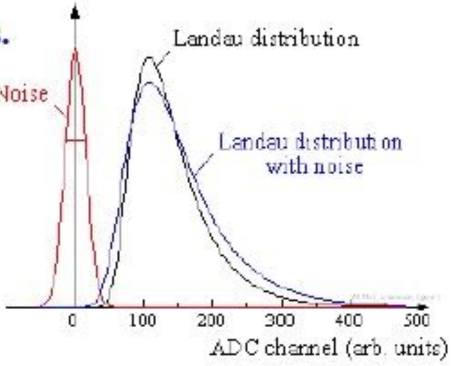




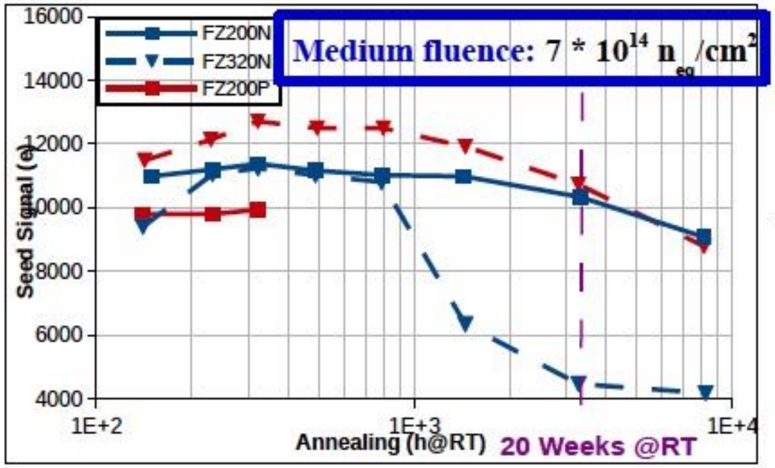
- **Baseline layout is a classical barrel + endcap layout with 5 disks**
  - Better performance at lower power, material & cost than a long barrel geometry
  - 15 348 modules, 58kW of front-end power (today: 15 148 modules, 33kW)
  - Option to extend pixel coverage to $\eta \approx 4$ is under consideration (baseline: $\eta < 2.5$)
- Two basic module types in outer tracker:
  - Modules with 2 strip sensors back-to-back (“2S p_T-modules“)
  - Modules with 1 pixel and 1 strip sensor back-to-back (“PS p_T-modules“)

Charge collection comparison (I)

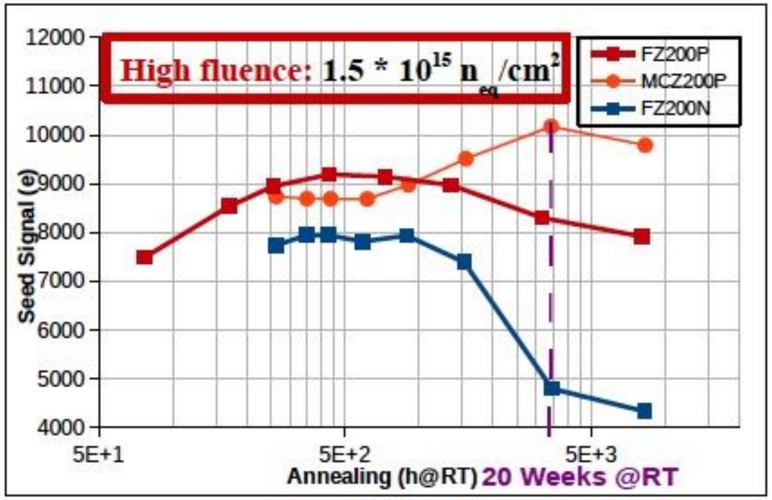
Measure charge collection with ^{90}Sr at -20 °C after different irradiations.



- **Study annealing functionality of seed signal at fixed fluences for different material and thickness.**



- **All thin p-type samples work well and show seed signals > 8 ke⁻ until above 20 w @ RT.**
- **Signal on n-bulk sensor decreases after a few weeks @ RT to a low level.**



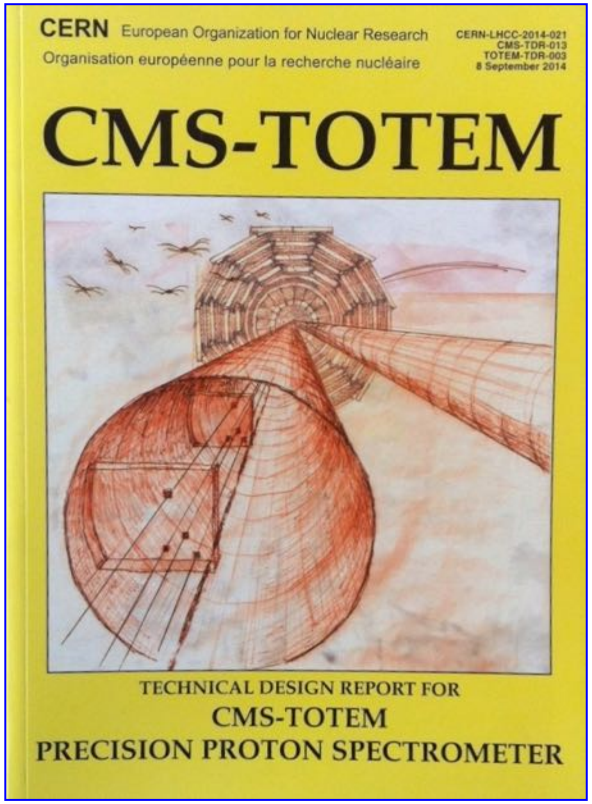
Forward Detector

- CT-PPS project
- Physics Motivation
- Timing Detector

~~CT~~-PPS project

CMS-TOTEM Precision Proton Spectrometer:

A new tool to investigate many phenomena, including precise measurements of protons as they emerge at small angle (*1μrad*) in the forward direction.



CMS-TOTEM Memorandum of Understanding:

CMS and TOTEM jointly undertake the PPS project

CT-PPS project approval:

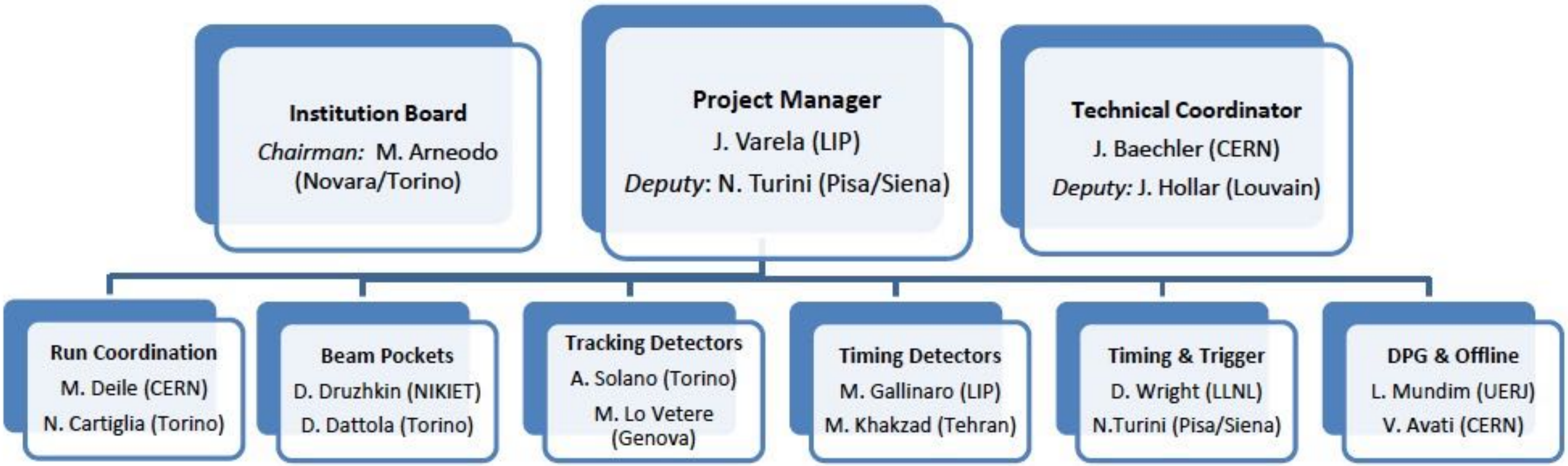
CERN Research Board, December 2014

Institutes and Responsibilities

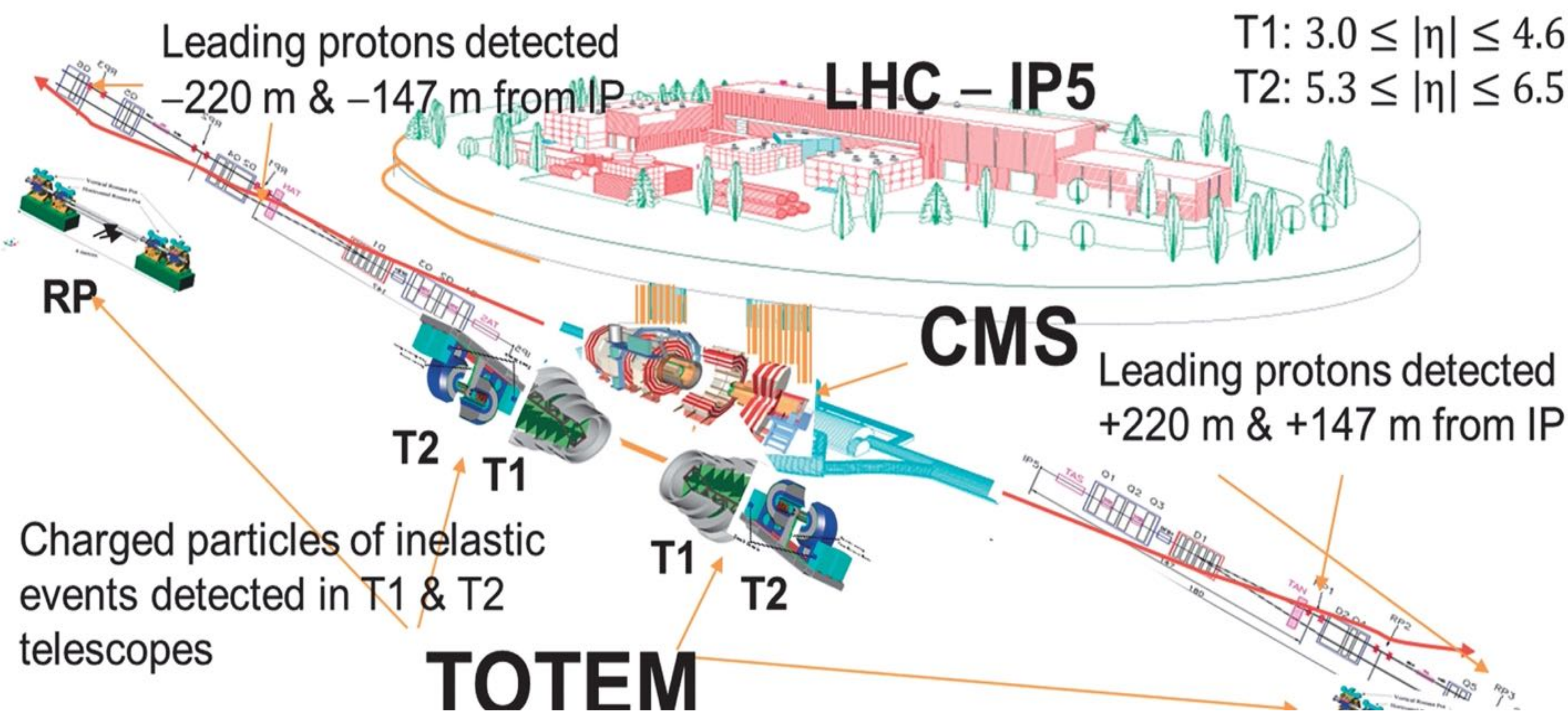
	Infrastructure	RP	MBP	Tracking sensors	Tracking readout	Timing sensors	Timing readout	Trigger & timing	Offline SW
CMS									
Belgium									
Louvain			x			x			x
Brazil									
UERJ					x		x		x
CBPF									x
CERN									
CMS TC group	x	x	x						
Italy									
Torino			x	x	x	x			
Genova				x	x				x
Iran									
Tehran			x				x		x
Portugal									
LIP						x	x	x	x
Russia									
IHEP Protvino						x			x
US									
Fermilab						x			
Livermore								x	
Kansas									
Iowa						x	x		
Rockefeller									x
TOTEM									
CERN	x	x	x			x		x	x
Czech Republic									
Prague	x	x							
Pilsen						x		x	
Finland									
Helsinki						x			x
Italy (INFN)									
Bari	x					x		x	x
Pisa/Siena	x					x		x	x
Collaboration									
CommonFund	x								

10 countries
20 institutes
93 people

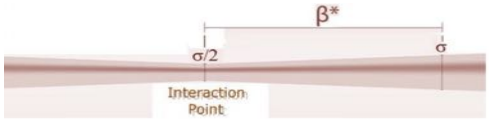
CT-PPS Organization chart



Beam line region …



- Rap gaps & Fwd particle flows: T1 & T2 spectrometers
- Fwd energy flows: Castor & ZDC
- Veto counters at: ±60m & ±140m?

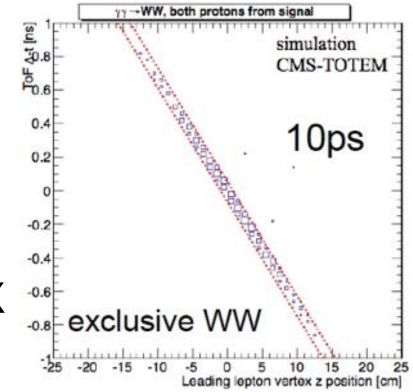


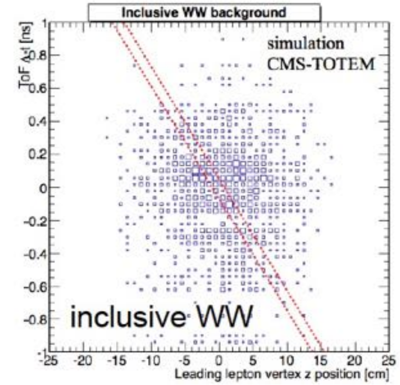
Detector concept

CT-PPS concept:

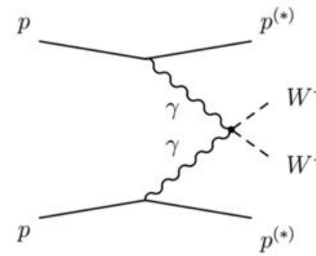
1) Proton spectrometer making use of machine magnets
2) Two tracking stations with 3D pixel detectors
3) One stations with 10 ps timing detectors

ToF vs. z vertex



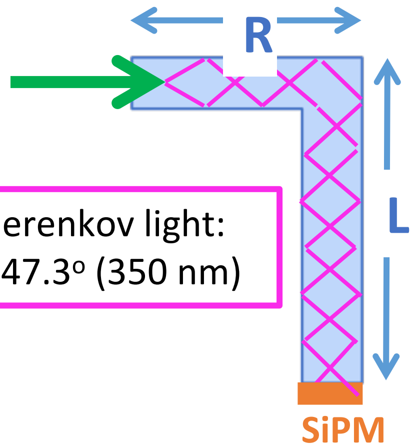


Use timing to reject pileup background



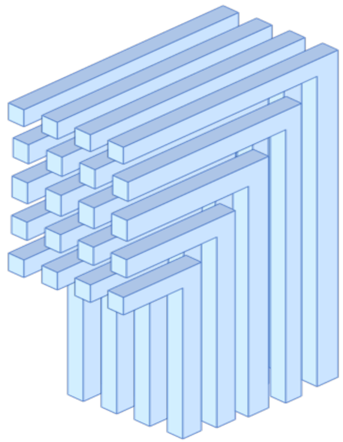
Forward Cherenkov Detector (FCD) Module

Quartz L-Bar



Cherenkov light:
θ=47.3° (350 nm)

QUARTIC Array



SiPMs = S-12572-050-P
Qualified for 10^{12} n/cm²
$V_{OP} = V_{BR} + 2.6$ V

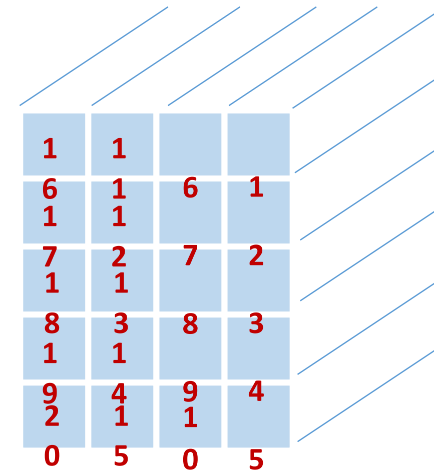
$n = 1.475$ (350nm)
$\rho = 2.20$ g·cm^{-3}
$\lambda_{Int} = 44.5$ cm

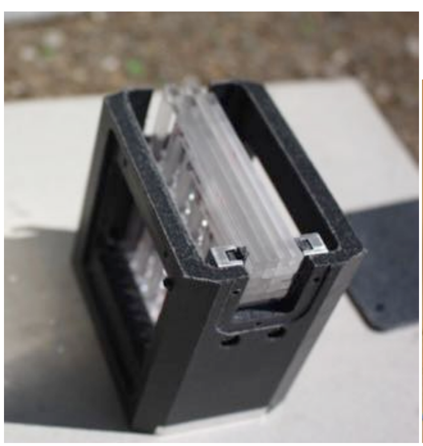
Q2 channel	R (mm)	L (mm)	R+L (mm)
1	63	71,2	134,2
2	53	68,1	121,1
3	43	65	108
4	33	61,9	94,9
5	23	58,8	81,8
6	58	71,2	129,2
7	48	68,1	116,1
8	38	65	103
9	28	61,9	89,9
10	18	58,8	76,8
11	63	71,2	134,2
12	53	68,1	121,1
13	43	65	108
14	33	61,9	94,9
15	23	58,8	81,8
16	58	71,2	129,2
17	48	68,1	116,1
18	38	65	103
19	28	61,9	89,9
20	18	58,8	76,8

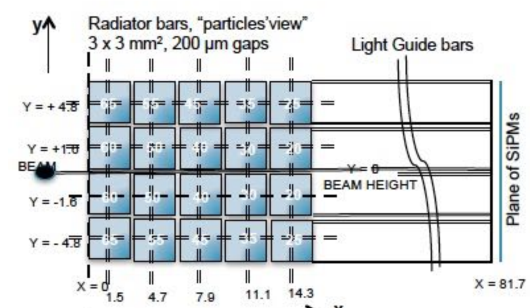
4x5=20 3x3 mm² bars
100 µm separatinion

Active area
12.6 x 15.8 mm²

QUARTIC Mapping

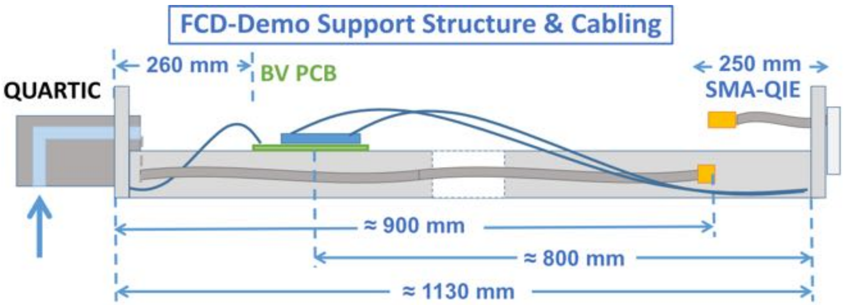


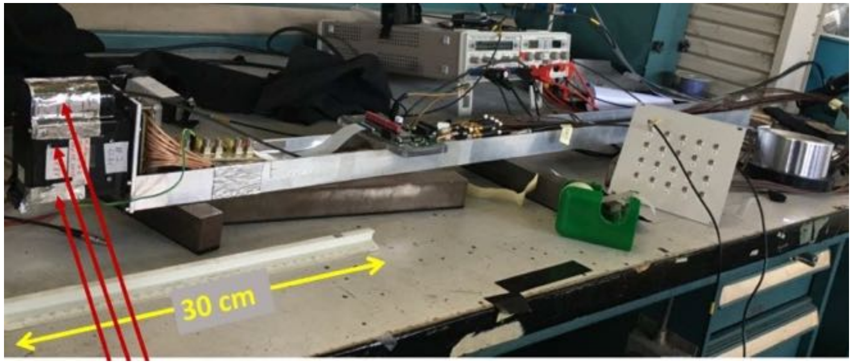


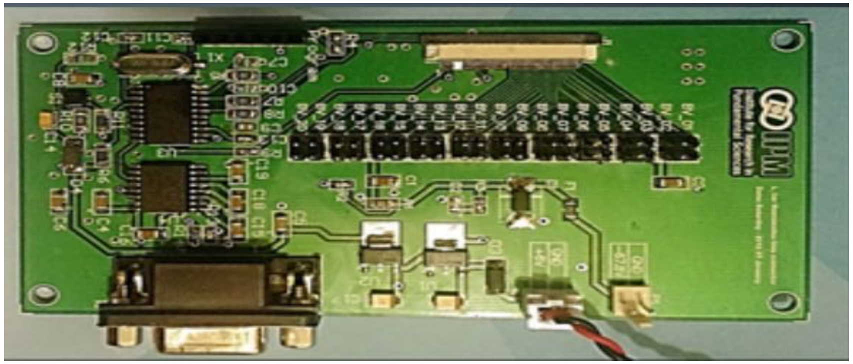


FCD Tests and Commissioning

- **Bld. 226 Tests**
  - Q2 Module test and Mapping
  - LED Tests
- **H8 beam: Prototype(s) tested**
  - L-bars, Straight bars
  - Quartz, Sapphire (radiators)
  - PMT, MCP, SiPM (photodetectors)
- **Bld. 904 Tests**
  - QIE-10 HFM readout (ADC + TDC)
- **UXC: CASTOR Table (minus side)**
  - Performance of FCD module
  - High radiation environment
  - High particle rates (timing)





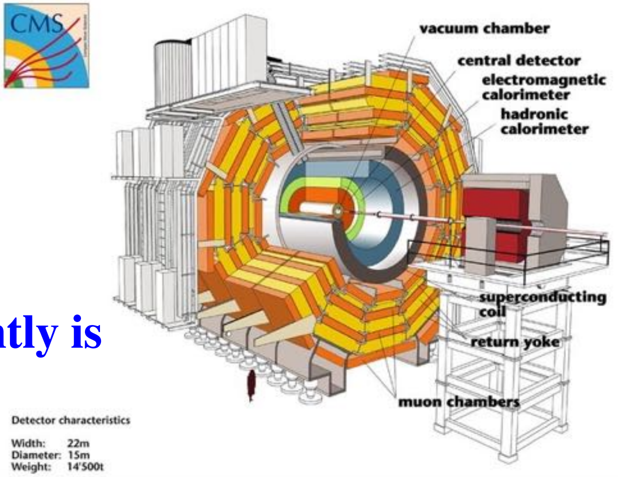


Work done at Larak

Hardware: Upgrade phase

- ECAL upgrade II
- R&D on Timing detector
- Cosmic Ray measurement

ECAL upgrade

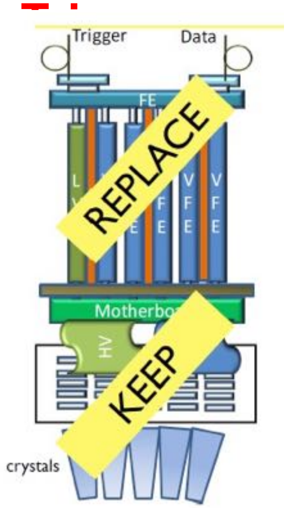


At the HL-LHC, there would be 10 times more data.

To remove the noise accompanying the signal online (currently is done offline).

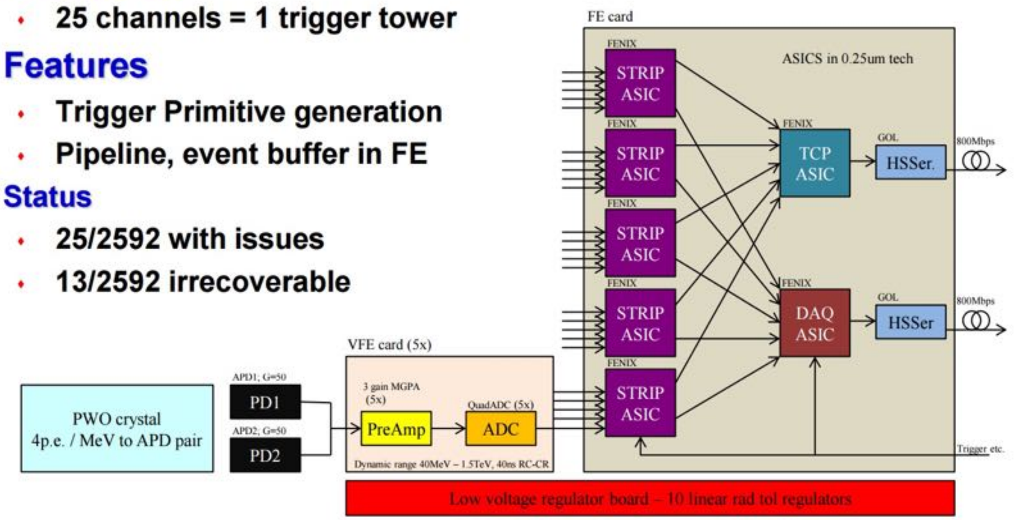
DAQ ASIC will be used as main data readout part

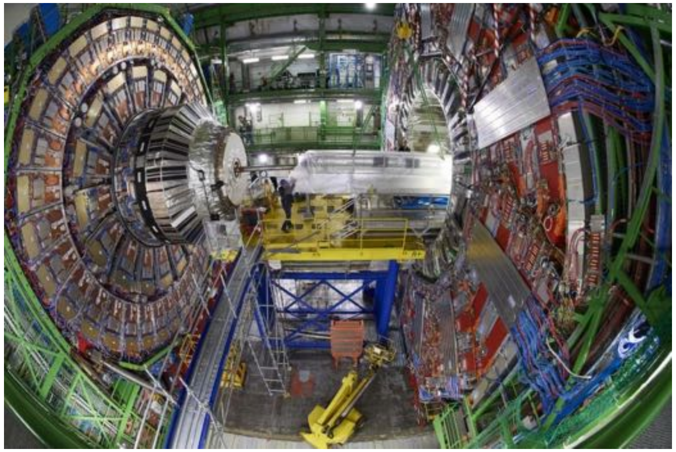
Hardware



ECAL barrel trigger tower

- **Modularity**
  - 25 channels = 1 trigger tower
- **Features**
  - Trigger Primitive generation
  - Pipeline, event buffer in FE
- **Status**
  - 25/2592 with issues
  - 13/2592 irrecoverable





The effects of temperature on FPGA for the CMS ECAL upgrade

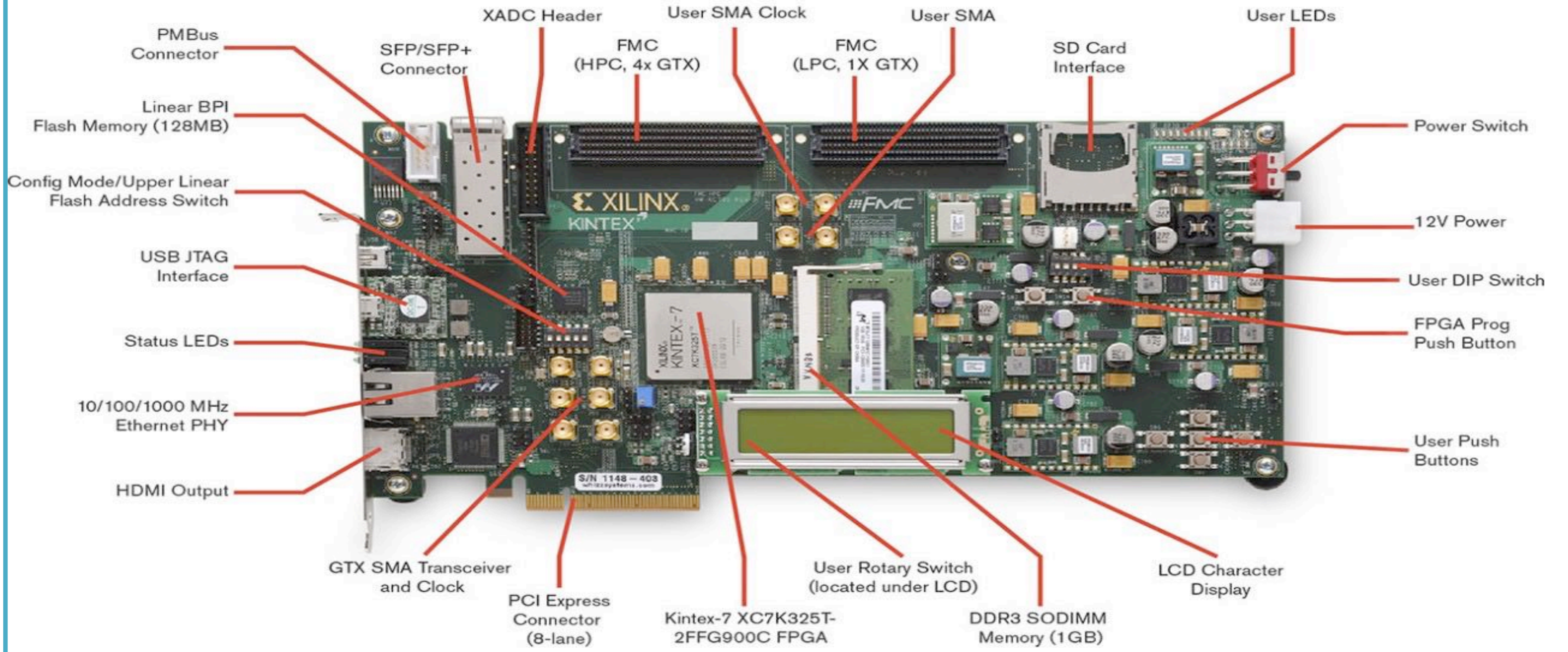
M.Khakzad, S.Jamili

School of Particles and Accelerators, IPM

Introduction

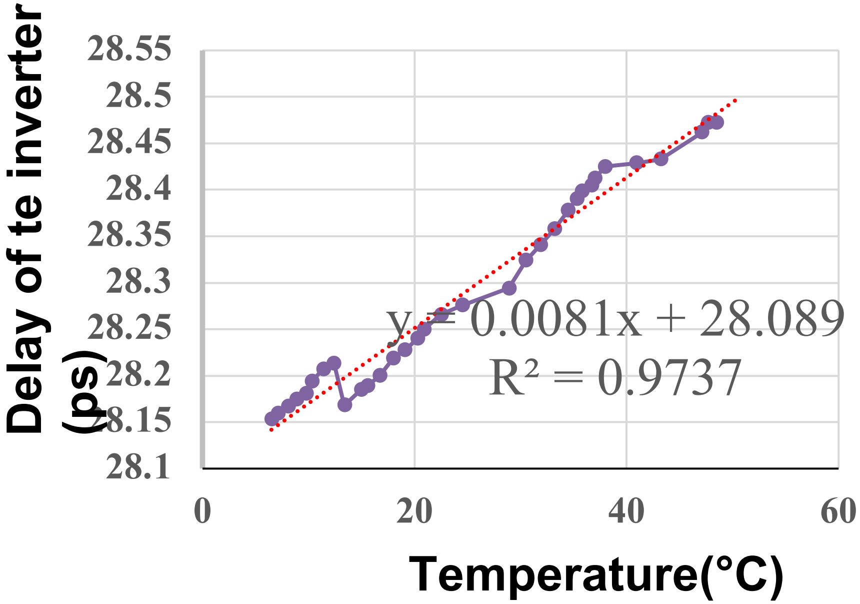
Using Field Programmable Gate Arrays (FPGAs) for critical applications are very popular because they provide high logic density and high performance capability. Investigating the temperature effects are important to increase reliability and safe operation. In this analysis, we investigate the effect of temperature on the Xilinx KC705.

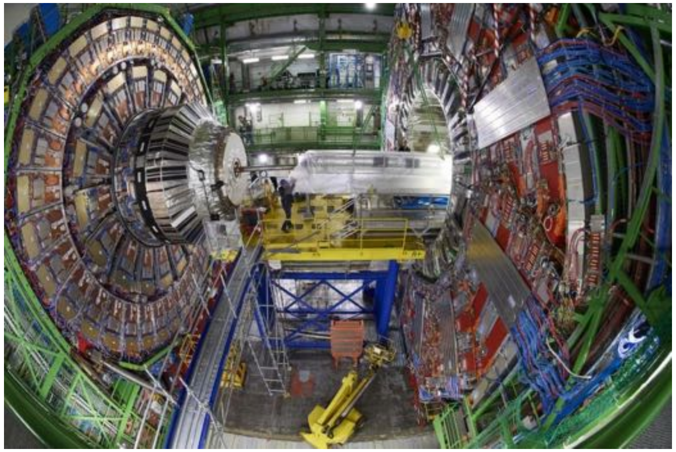
KC705 Evaluation Board for the Kintex-7 FPGA



Results

- The graph shows the average delay of the inverter versus the temperature in a ring oscillator
- As it can be seen, by increasing the temperature, the intrinsic delay gets bigger.





Quartic Timing Detector: Si-PM readout

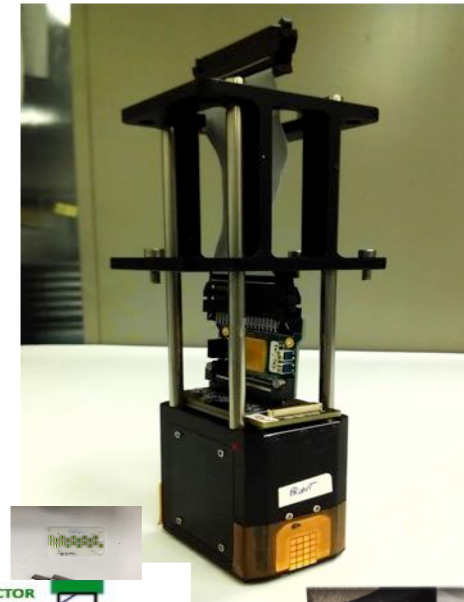
(Design and Construction)

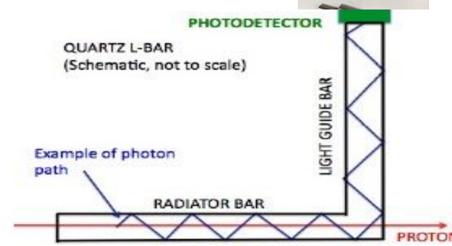
Timing detector

Quartz detector:

- Detector is a 4 x 5 array of quartz bars, 3 x 3mm^2, SiPM light detection.
- Radiator bars separated by 100 mm for total internal reflection

SiPM -> Single DAQ readout





QUARTIC SiPM

The board includes two main sections:

1. Bias Voltage Connector

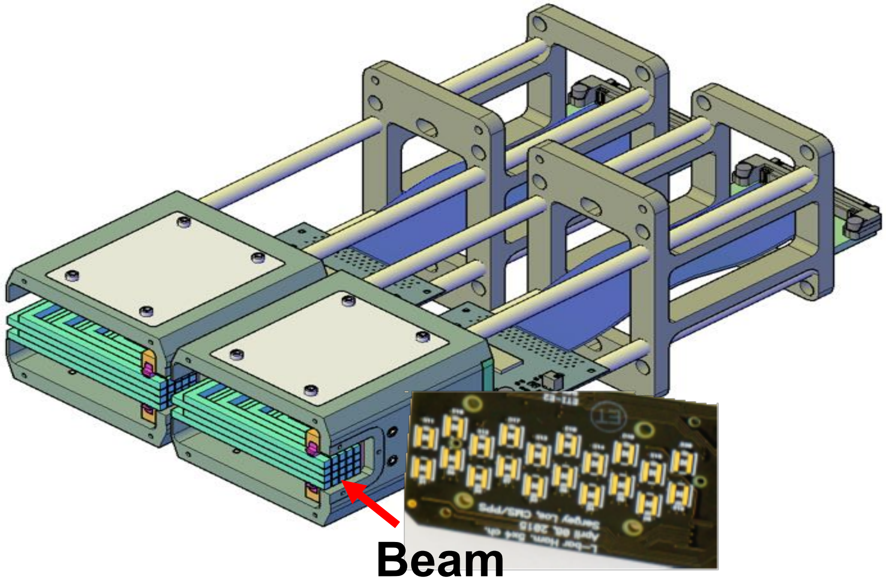
The QUARTIC SiPM has 20 sensors. It has a ribbon cable for connecting HV Bias, so we have many pins that require a connection to HV supply and it's better to have the ability for selected sensors for testing purposes.

2. Temperature and Humidity Data Logger

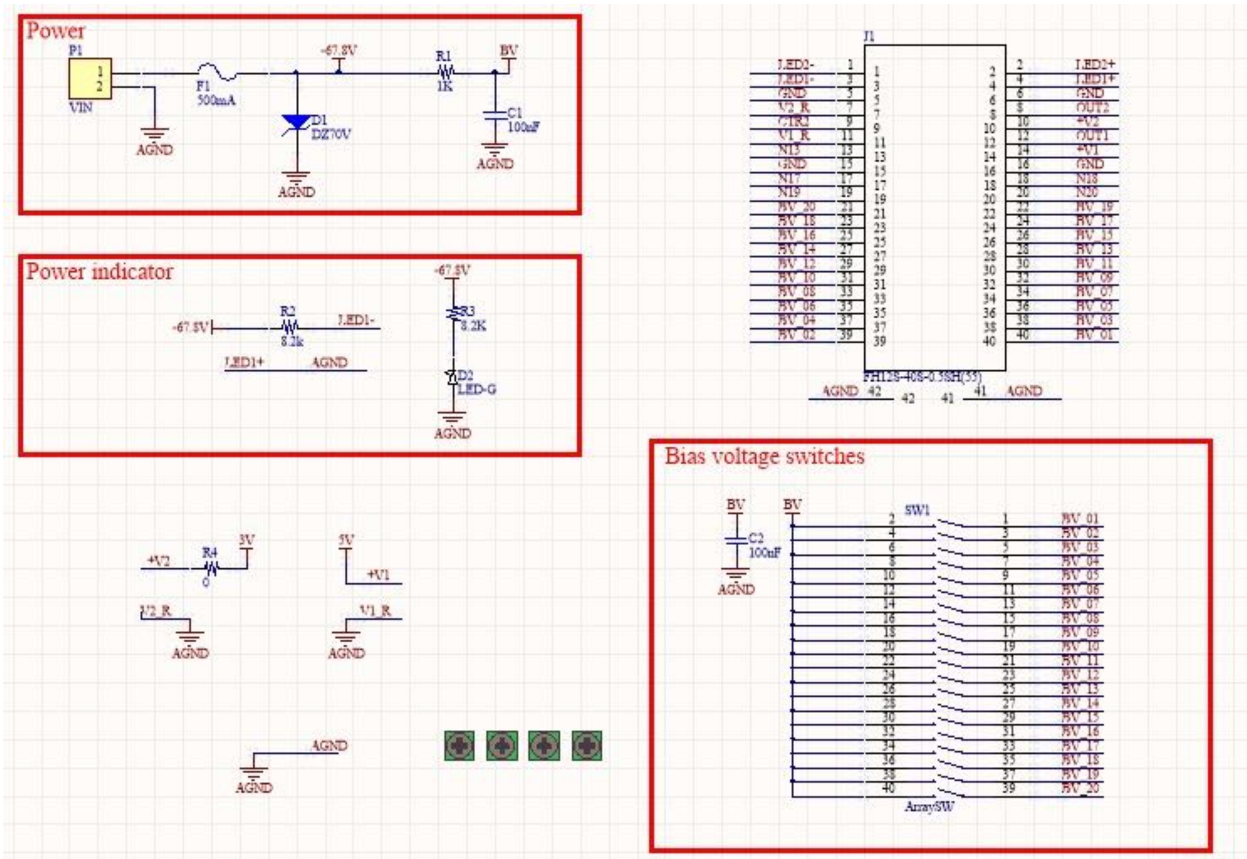
The QUARTIC SiP M has a temperature and humidity sensor and a unique Readout System which is designed exclusively. This sensor is not assembled on QUARTIC SiP M board.

We put a sensor on this Readout System in order to prevent the board from modifying.

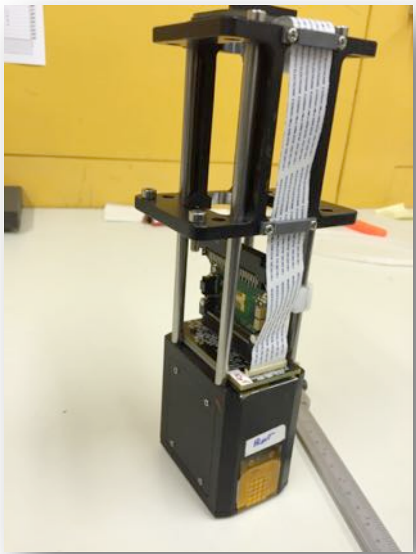
So It's working dependently.

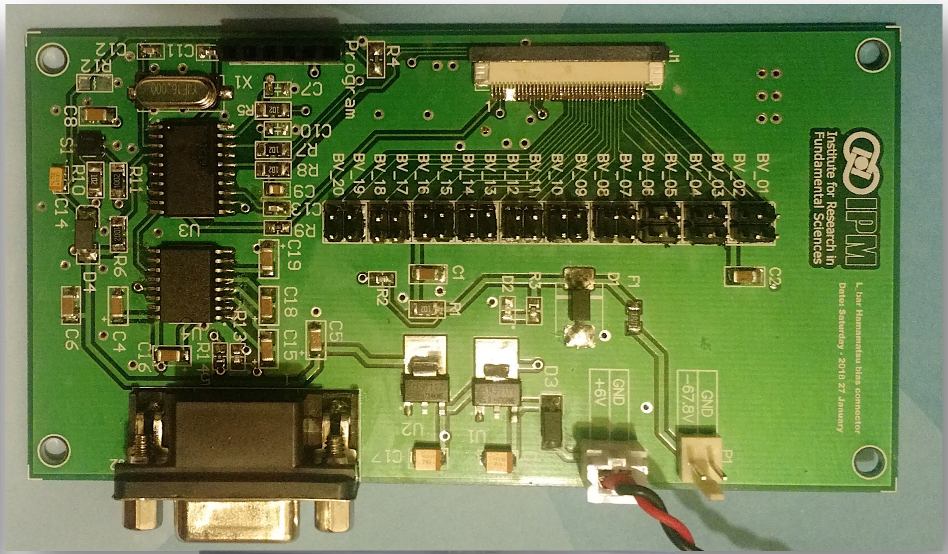


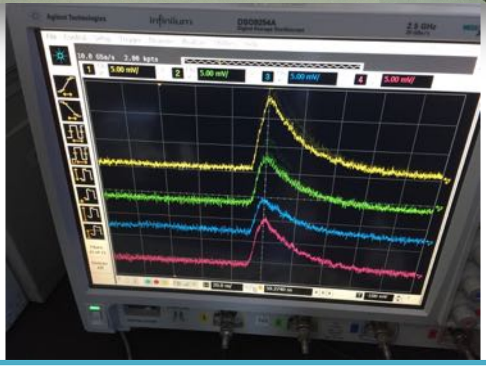
QUARTIC SiPM

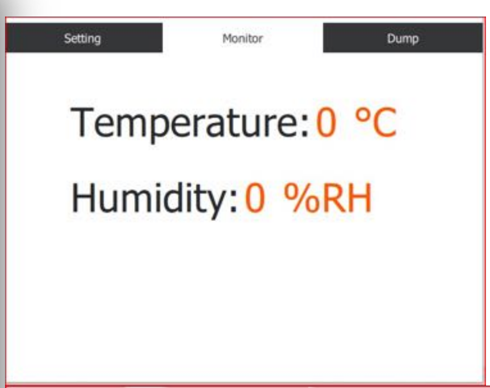


QUARTIC SiPM Bias Voltage Connector and Temperature and Humidity data logger





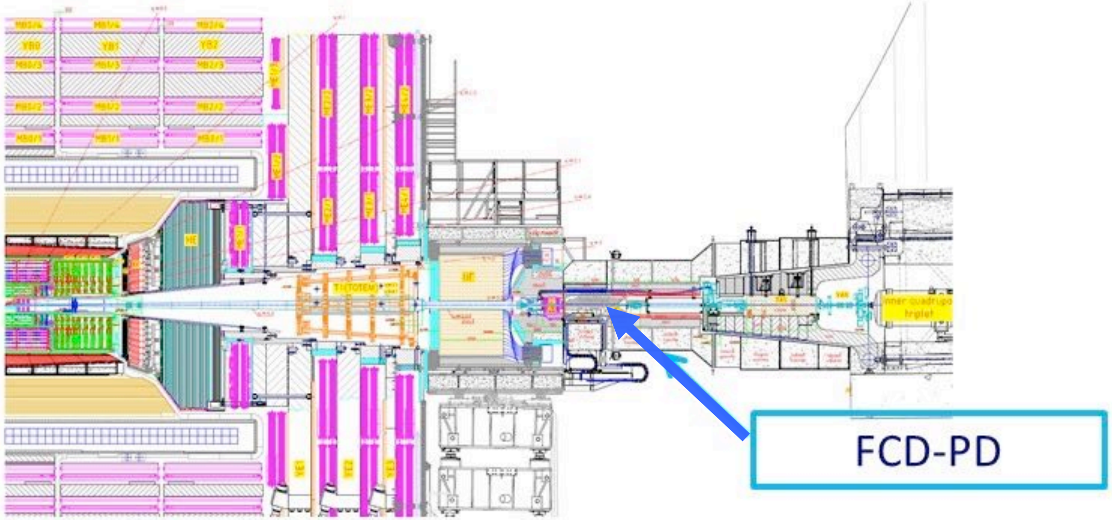




A	B	C	D
H:/13_40_27.csv			
Time	Temperature	Humidity	
0	26	19	
1	26	19	
2	26	19	
3	26	18	
4	26	18	
5	26	19	
6	26	19	

Installation in LHC tunnel

FCD-PD INSTALLATION TO UXC



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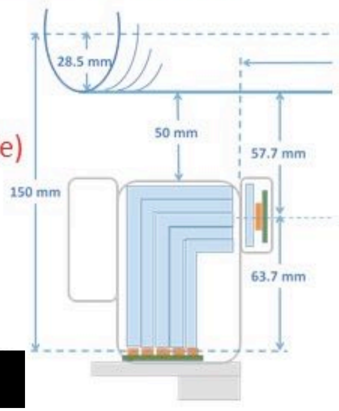

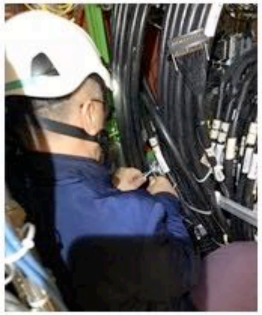

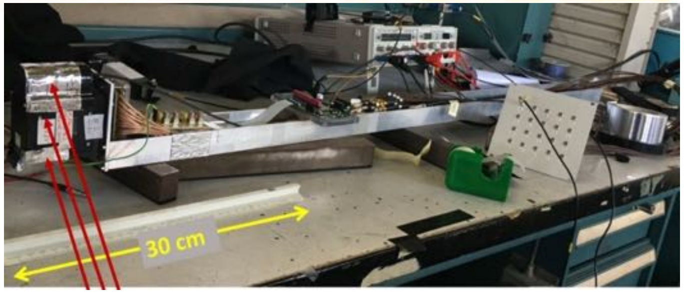

Available on CMS information server

CMS CR -2020/169

The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

11 October 2020

A Study of a Quartz Bar Detector in the Forward Region of the CMS Experiment at LHC

M. Khakzad, V. Samoylenko, J. Baechler, A. Baud, D. Druzhkin, B. Kaynak, R. Stefanovitch, M. J. Wagner, O. Atakisi, M. Kaya, S. Cerci, S. Ozkorucuklu, C. Simsek, D. Sunar Cerci, A. Mestvirishvili, A. Penzo

Abstract

In high rapidity regions of experiments at colliders (e.g. Large Hadron Collider LHC), along the direction of the interacting beams, the conditions are particularly challenging and the detectors need to have excellent time resolution, spatial resolution, high-rate capability and radiation resistance. Among various detector schemes proposed for these applications, combinations of Cherenkov radiators (quartz, sapphire, etc.) with fast photodetectors (e.g Micro Channel Plate PMT (MCP PMT), Silicon PM (SiPM)) have been studied. Quartz-based calorimeters are already employed at CMS (Compact Muon Solenoid) experiment in the forward direction. Quartz bar array detectors were initially proposed as timing elements for the CT-PPS (CMS-TOTEM Precise Proton Spectrometer) project. We report here on the performance of one of these QUARTIC (QUARtz TIming Cherenkov) detectors, which was installed in 2018 (as test prototype) in the CMS Forward Zone near the CMS beam pipe.

Presented at *3rd International Iran-Turkey Joint Conference on LHC Physics*

Cosmic rays muon detection on the earth surface

M. Khakzad, M. Ghahremani

School of Particles and Accelerators, IPM

مجلهٔ پژوهش فیزیک ایران، جلد ۲۰، شمارهٔ ۳، پاییز ۱۳۹۹
DOI: 10.47176/ijpr.20.3.51053

آشکارسازی میون‌های ناشی از تابش‌های کیهانی با استفاده آشکارساز سوسوزن پلاستیک

مریم قهرمانی‌گل و محسن خاکزاد

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(دریافت مقاله: ۱۳۹۹/۲/۱۷ ؛ دریافت نسخهٔ نهایی: ۱۳۹۹/۶/۲)

چکیده

در این تحقیق به آشکارسازی میون‌های ناشی از تابش‌های کیهانی در پژوهشکدهٔ ذرات و شتابگر، پژوهشگاه دانش‌های بنیادی، پرداخته شده است. اندازه‌گیری سرعت و طول عمر میون‌ها توسط آشکارساز سوسوزن پلاستیک و لامپ تکثیرکنندهٔ نوری انجام شده است. در این تحقیق از دستگاه دیجیتال، به دلیل مزایایی همچون قابلیت اطمینان و سرعت عملکرد بالا، حجم کوچک و پاسخ دقیق‌تر، نسبت به دستگاه آنالوگ، به منظور داده‌برداری استفاده شده است. بر اساس نتایج تجربی حاصل از این تحقیق، میانگین سرعت میون‌ها حدوداً 10^{8} × (۰/۰۳۹۴ ± ۲/۸۳۱) متر بر ثانیه (β = ۰/۹۴۴ ± ۰/۰۱۳۱) و طول عمر میون حدود (۰/۱۷۷ ± ۲/۰۳۳) میکروثانیه به دست آمده که با نتایج مطالعات تئوری منطبق است. در این مطالعه از تجهیزات موجود در پژوهشکدهٔ ذرات و شتابگرها در پژوهشگاه دانش‌های بنیادی استفاده شده است.

واژه‌های کلیدی: تابش‌های کیهانی، آشکارساز سوسوزن پلاستیک، لامپ تکثیر کنندهٔ فوتونی، سرعت و طول عمر میون

Nuclear Inst. and Methods in Physics Research, A 957 (2020) 163401

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

Technical notes

PMT glass window sensitivity to gamma-rays: A digital signal processing approach

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ARTICLE INFO

Keywords:
Photomultiplier tube (PMT)
Scintillation detector
Time response
Digital pulse processing

ABSTRACT

A digital data acquisition system together with MATLAB software for data analysis were utilised to measure the pulse specification of the scintillation detector assembly. Besides, the sensitivity of a photomultiplier tube (PMT) window to gamma-rays was studied to discriminate the signals produced as a result of gamma-ray interactions inside the glass window from those originating from the scintillator cell. The result showed that an algorithm based on the time features was capable to evaluate the contributions of these two different signals.

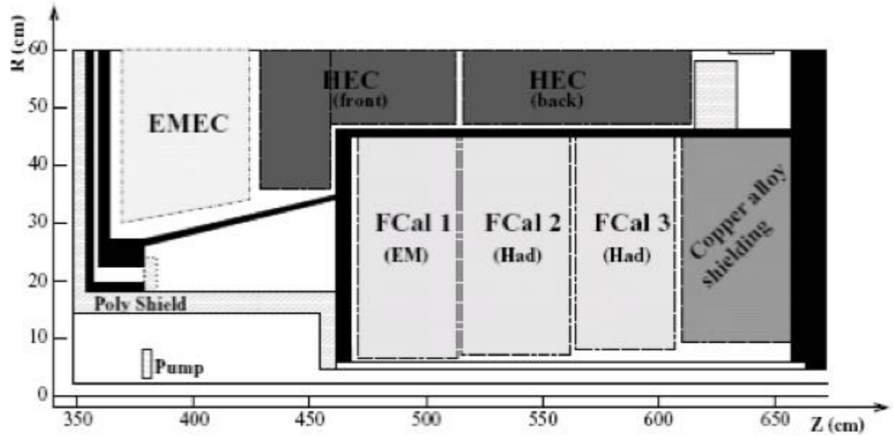
Contributions to ATLAS
at
CERN
(1999-2009)

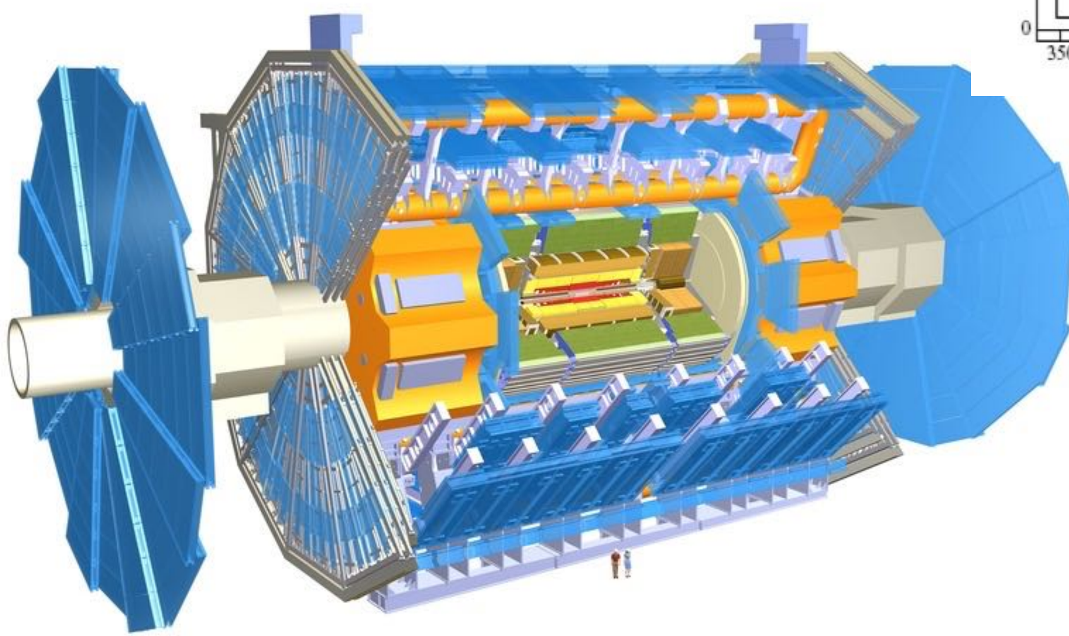
Liquid Argon Forward Calorimeter (LAr FCal)

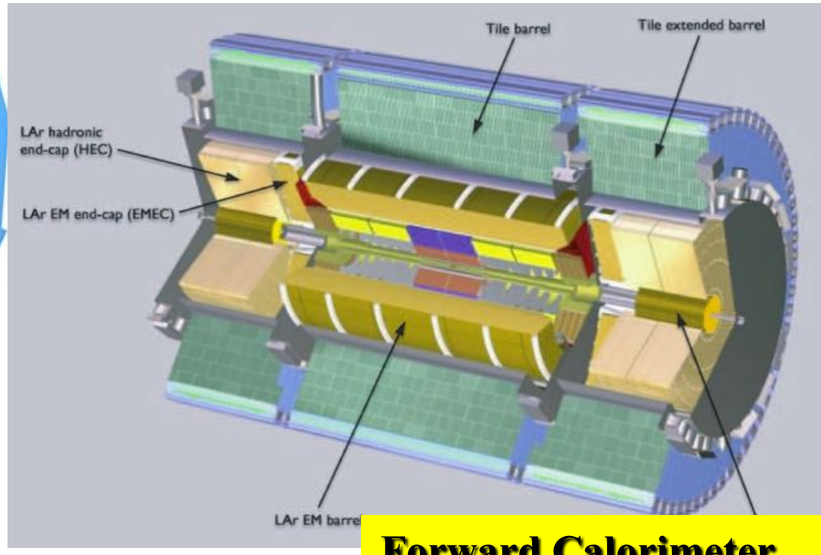
Tow Modules:

ATLAS Forward Calorimeter

Each costing: $1m and weighting of 4 Tones

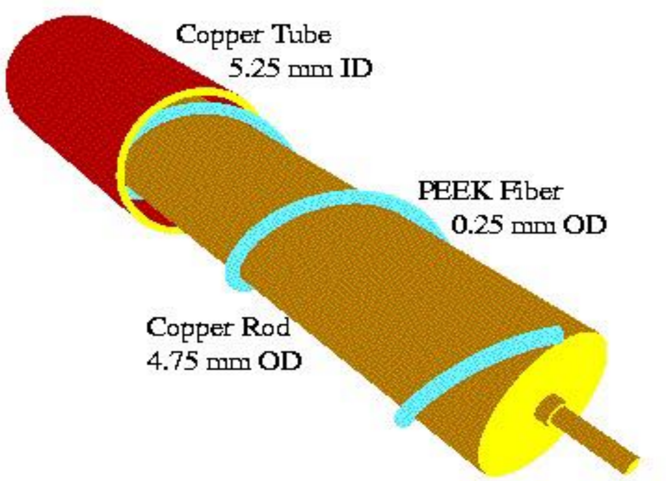






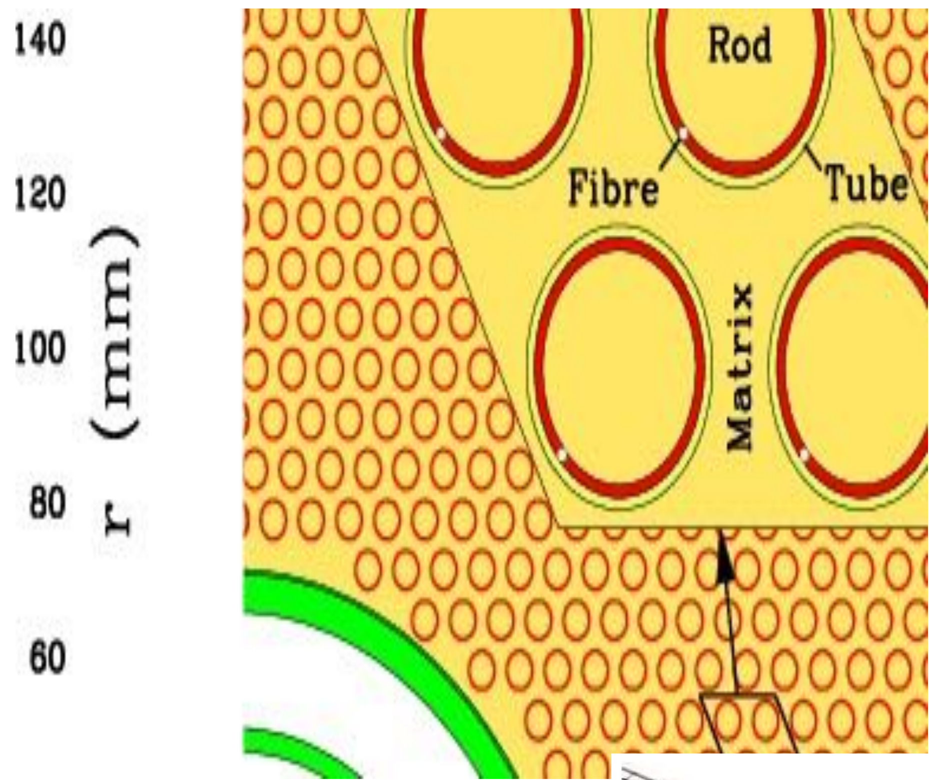
FCal Read-out Scheme

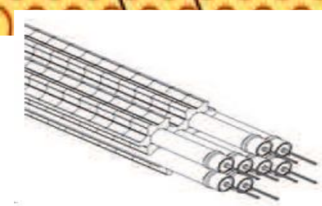
- The electrodes consist of a rod (Cu or W) inside an outer tube with liquid Ar in between (250 to 500 μm)



- The matrix is made of Cu (FCAL1) or W (FCAL2 and FCAL3)
- Ion build-up should not be a problem because of the very small gaps

FCAL End View





Liquid Argon gap

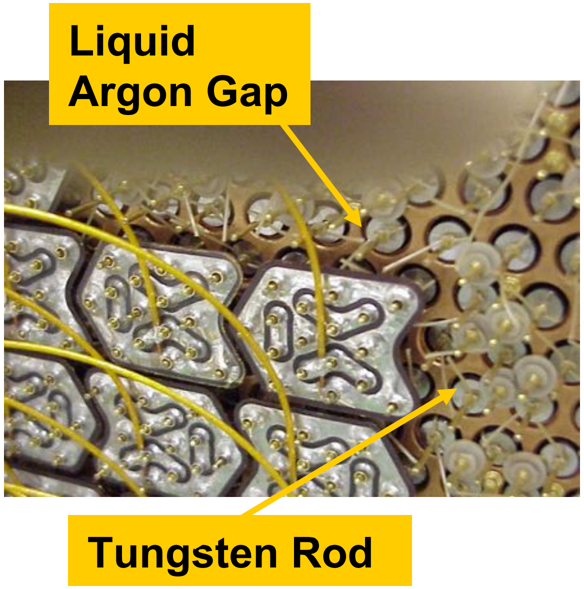
- 250 / 375 / 500 μm

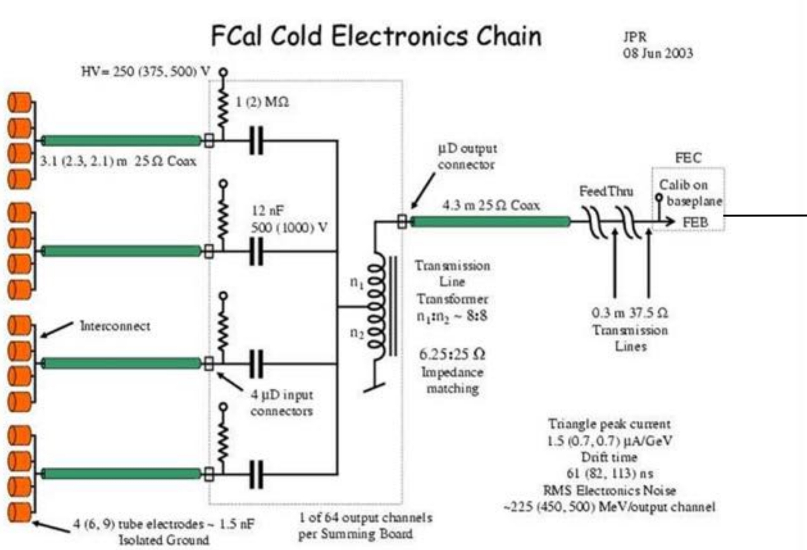
FCal Readout

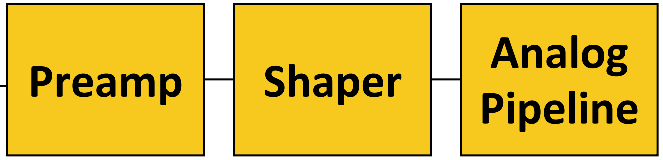
Electrodes ganged together at module face: 4, 6, and 9 for FCal 1, 2 and 3

Four (adjacent) groups are summed in the cold:

- **Provides adequate readout granularity**
- **Reduces need for feedthrough channels**

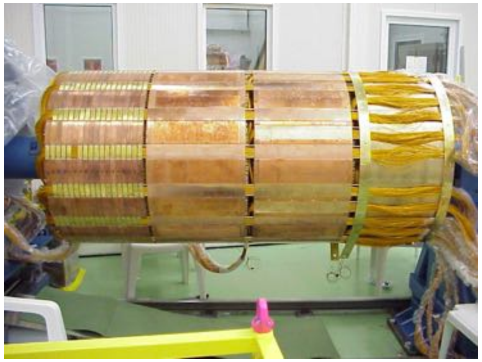


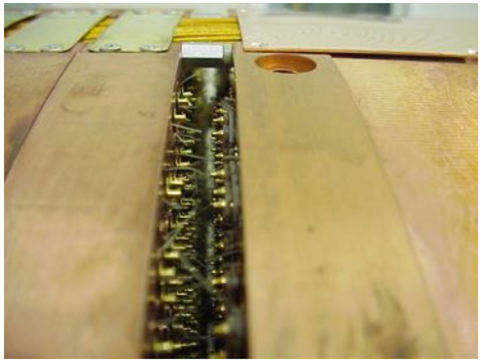




Module Alignment During FCal Assembly







FCal1, 2 interface

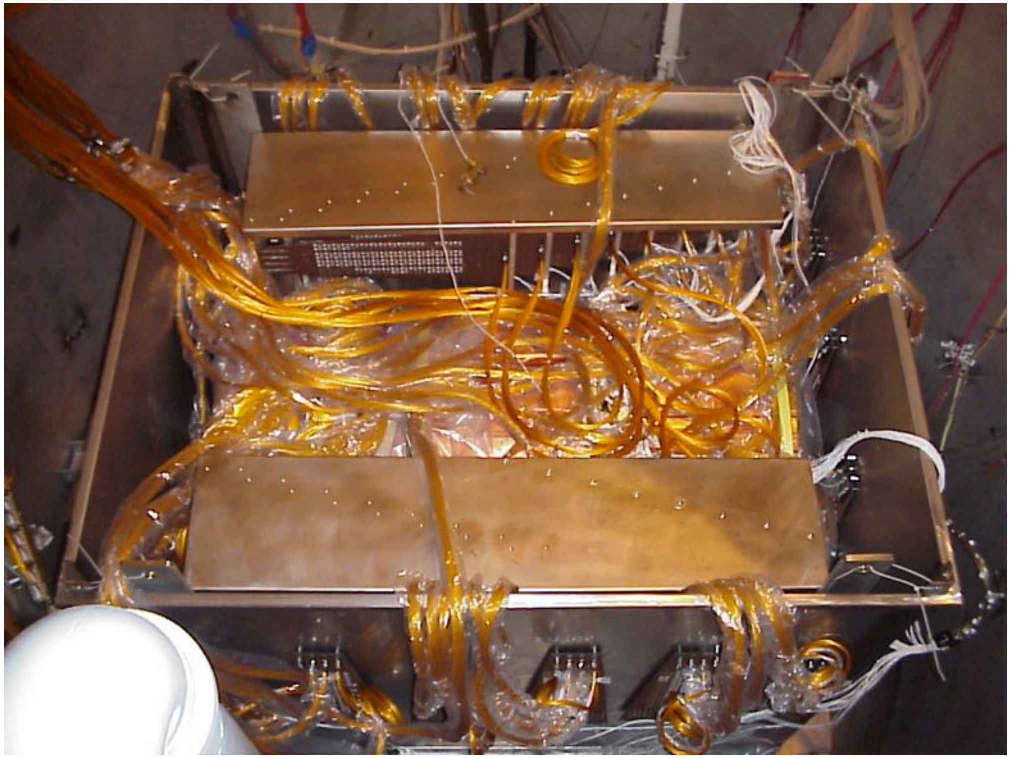
FCalC Cable Dressing

Insertion into Cold Tube

LAr Forward Calorimeters

The three modules for the first end-cap side were shipped in 2002 to CERN and cold-tested, they were tested for a beam calibration on June 2003

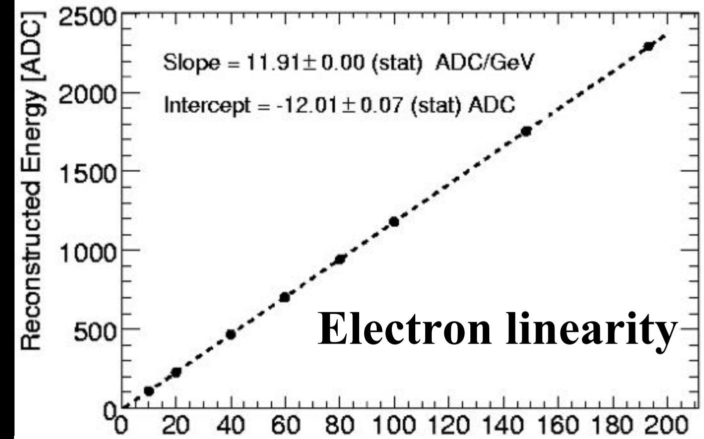
FCAL module during insertion of ICB

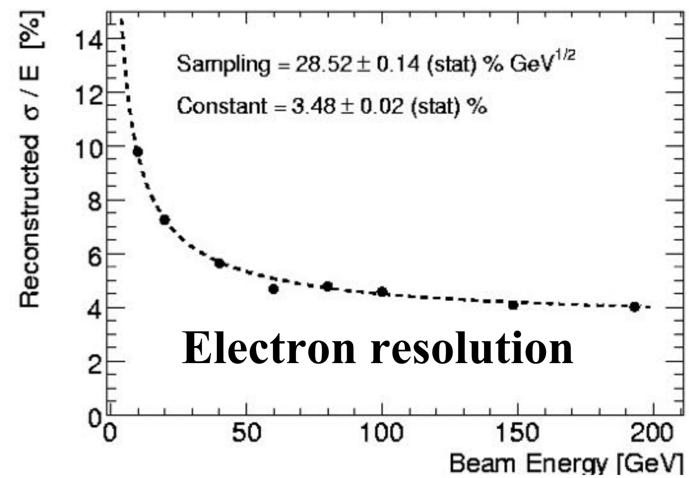


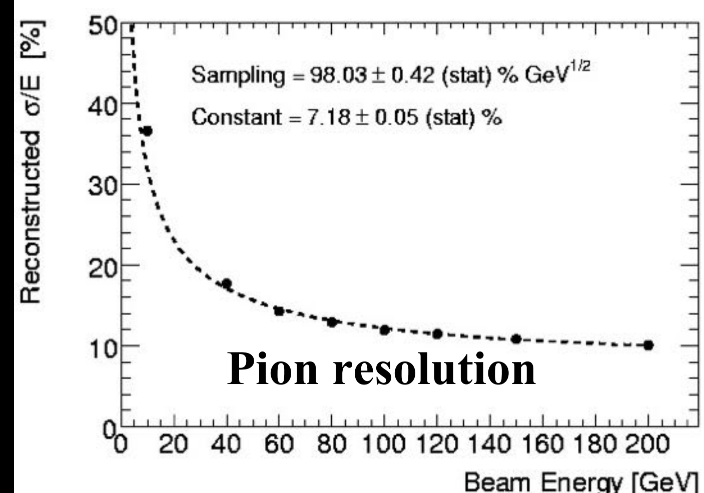
Cold test of the three FCal modules for the first side

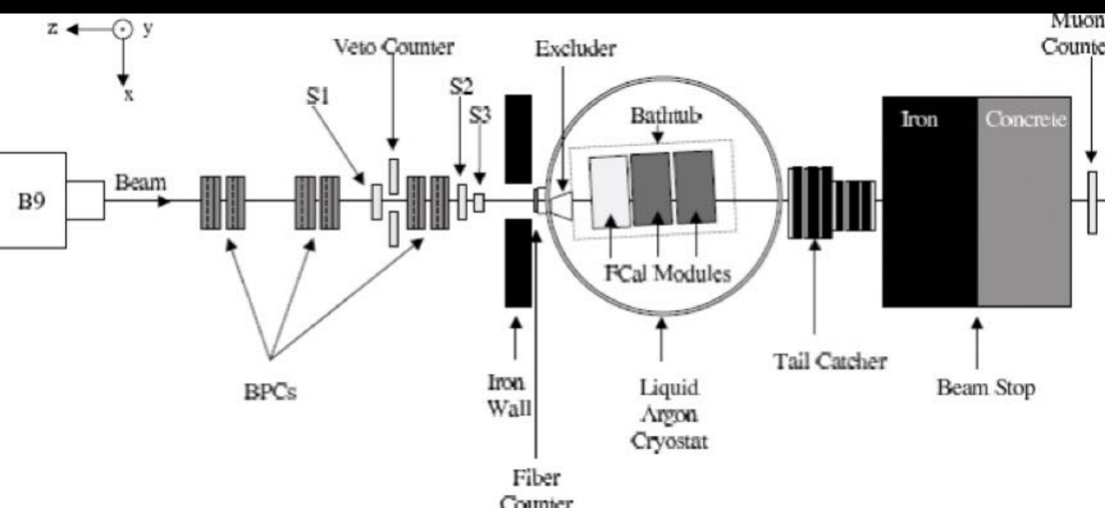
Detector calibration: FCal 2003 Test Beam

- FCal production modules in a testbeam at CERN
- Exposed to pions and electrons from 10 - 200 GeV
- Calibrate the detector response
- Linearity
- Electron resolution →
- Pion Resolution →







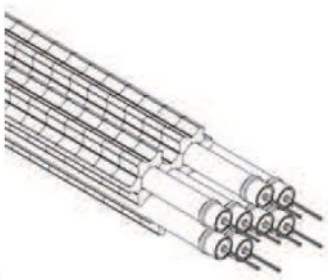


Forward Calorimeter (Fcal)

Two detector modules to measure the energy of particles.

Each module was 1m in diameter and weighed 4 tons.

Both modules completed, shipped and installed at CERN



Construction

Shipping to CERN

Contributions to ZEUS at DESY (1994-1999)

HERA

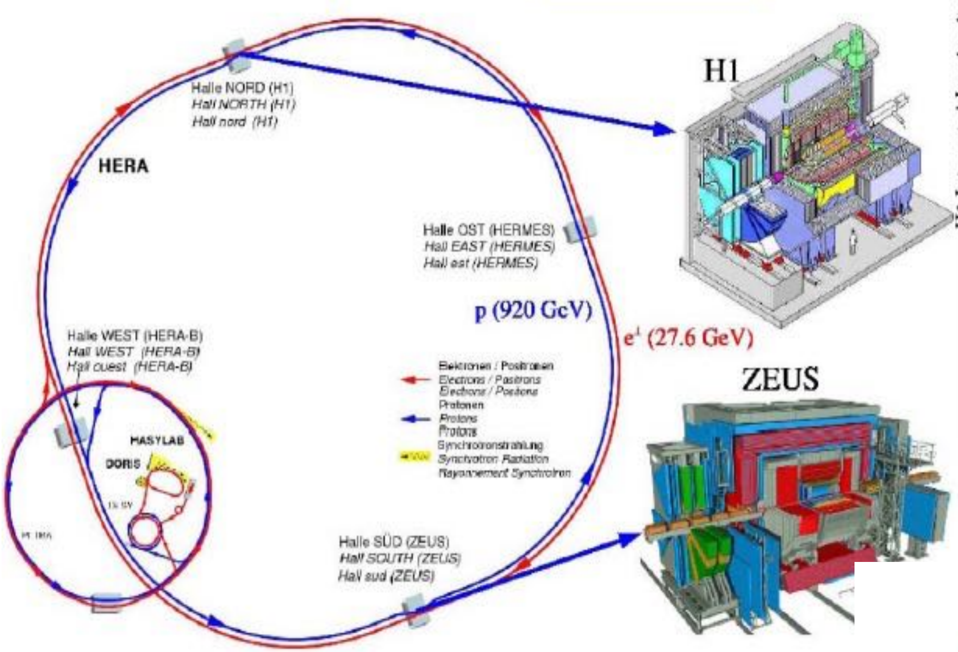
The first electron-proton collider at DESY Hamburg (1992-2007)

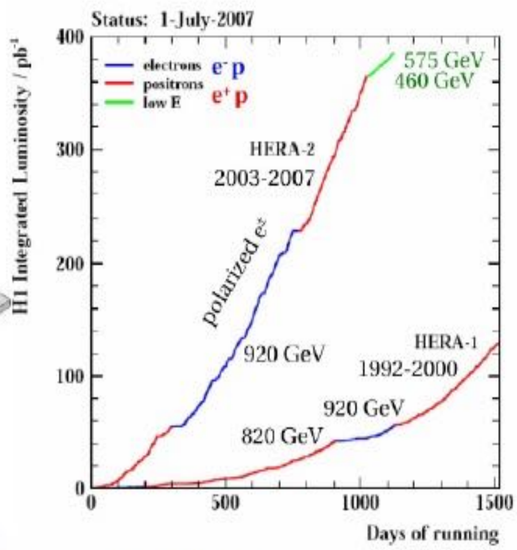
$E_{e\pm}$ = 27.6 GeV E_p = 920 GeV

Total centre-of-mass energy of collision up to $\sqrt{s} \approx 320$ GeV

(equivalent to $5 \cdot 10^{13}$eV photon on a stationary proton target)

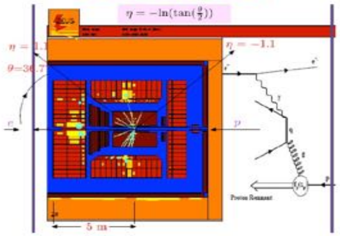
Two collider experiments: H1 and ZEUS





total lumi:
0.5 fb^{-1} per experiment

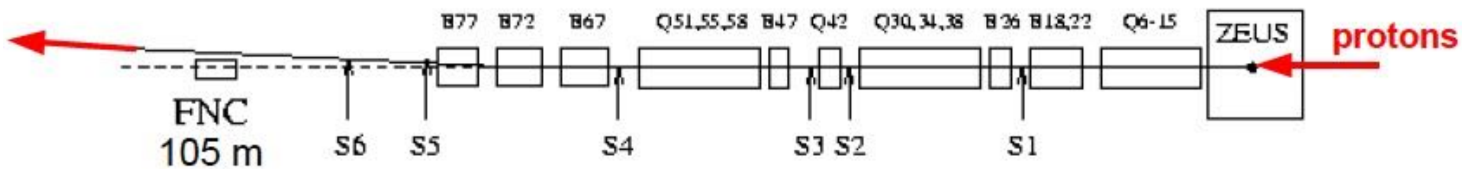
ZEUS Detector

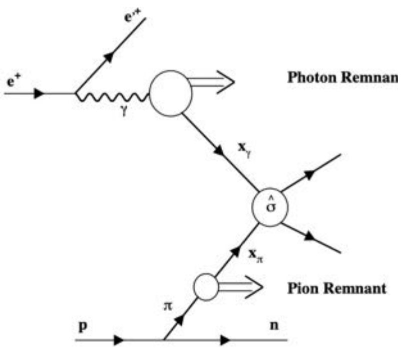


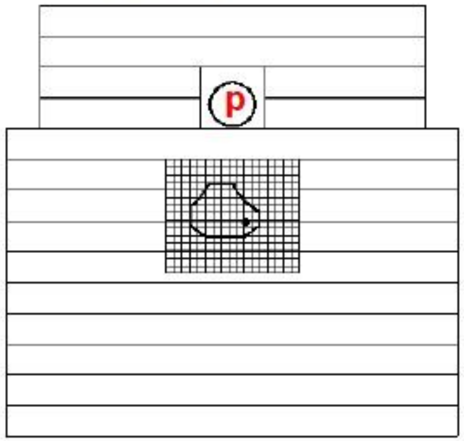
LB Detectors:

<u>HERA beamline in *p* direction from ZEUS:</u> Vertical dipole acts as

- Analyzing magnet for Leading <u>Proton</u> Spectrometer (LPS) for LP
- Sweeping magnet for Forward <u>Neutron</u> Calorimeter (FNC) for LN

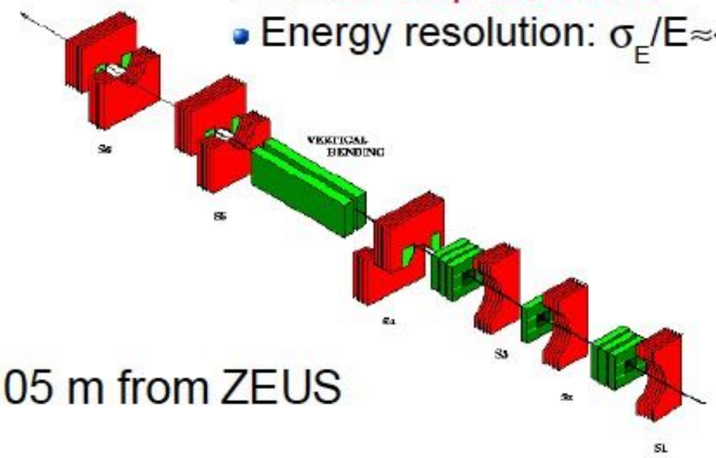






<u>LPS:</u> Si-strip detectors

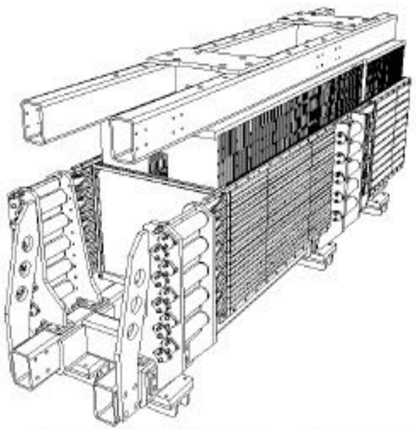
- Energy resolution: $\sigma_E/E \approx <1\%$



<u>FNC:</u> Pb-Sci calorimeter @ 0° 105 m from ZEUS

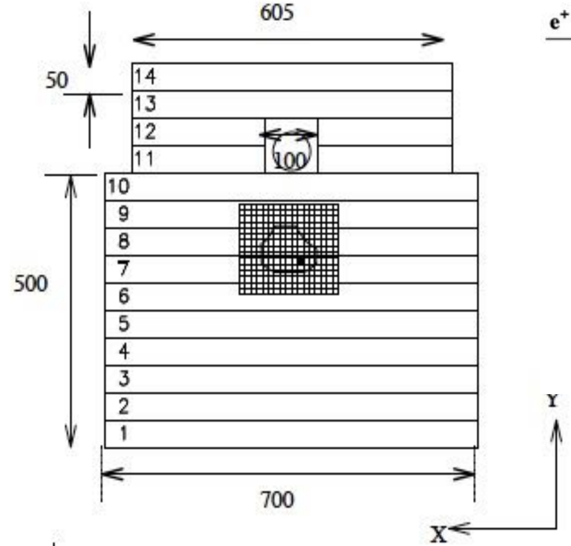
- Energy resolution: $\sigma_E/E \approx 0.7/\sqrt{E}$
- Sci-hodoscope position detector $1\lambda_I$ into FNC

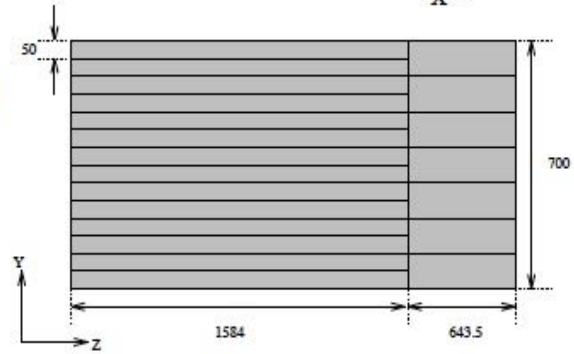
The General view of ZEUS-FNC detector

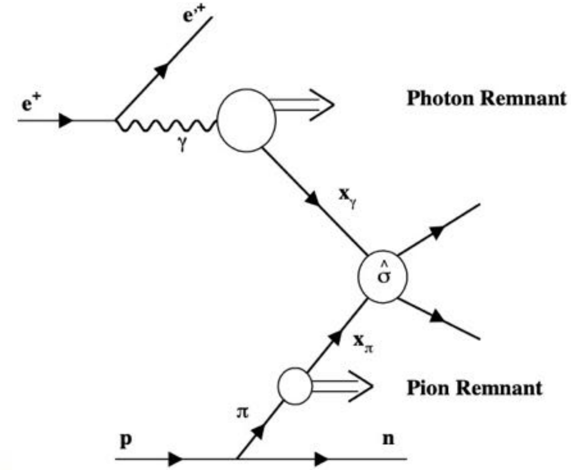


- S.Bhadra et al., *NIM A394 (1997) 121*
- sampling calorimeter, $e/h \sim 0.96$
- 134 layers 1.25cm Pb and 0.26cm scintillator, readout by WLS from both sides,
- front section (7λ) -14 towers, rear section 3λ,
- e/h separation using transverse width of shower
- $\sigma_E/E = 0.65\%/\sqrt{E\ [GeV]}$

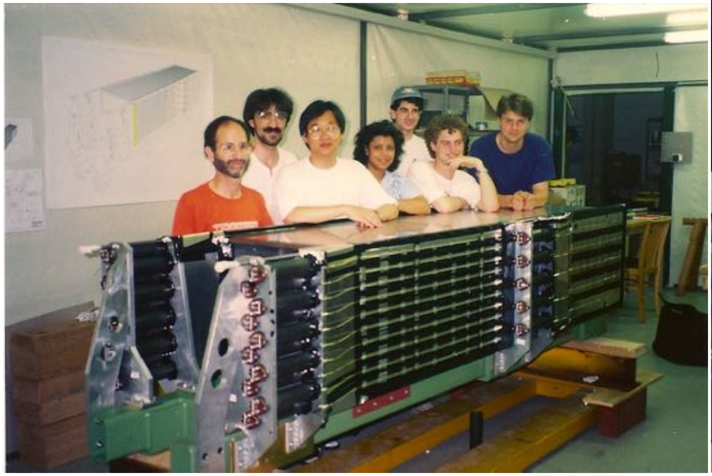
–Forward Neutron Tracker (since 1998)
17$\times$15 X-Y strips, 1.2cm each,
installed 1λ inside the calorimeter
position resolution 0.23cm







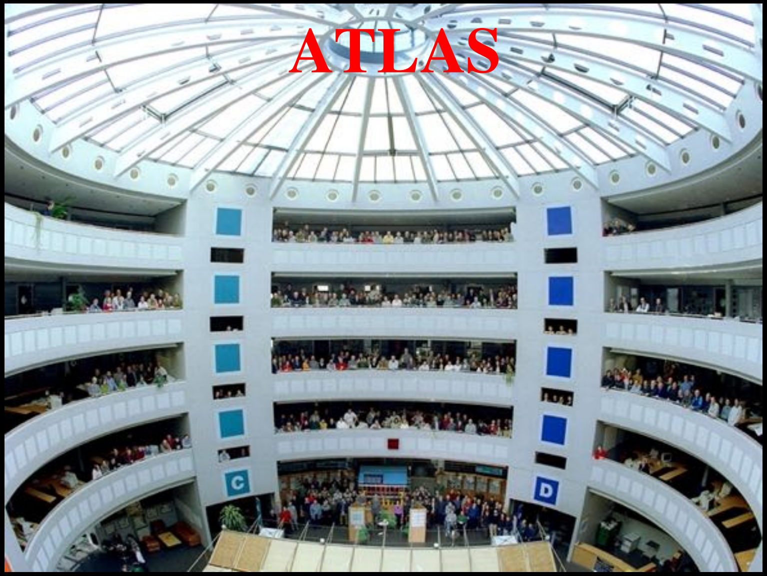
Forward Neutron Calorimeter (FNC)



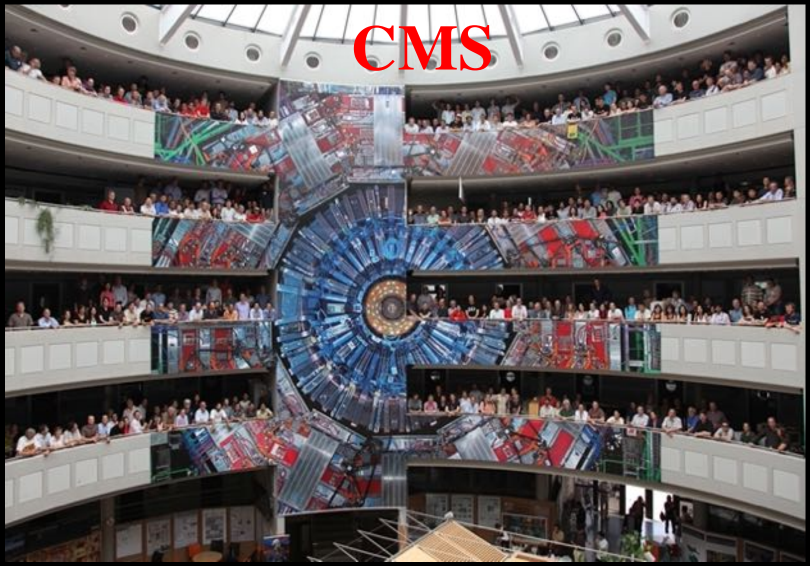
Summary (1994-present)

(1994-1999)

(1999-2009)



(2009-present)



Information

For more information see:

CERN - http://public.web.cern.ch/public/

CMS - http://cms.cern.ch/

IPM - http://particles.ipm. ir/

Thank you