



Heavy stable particles, dark corner of modern physics

Maxime Gouzevitch

IP2I, Lyon, France

- 1) iRPC project for HL-LHC
- 2) FEB design
- 3) FEB certification, calibration and production

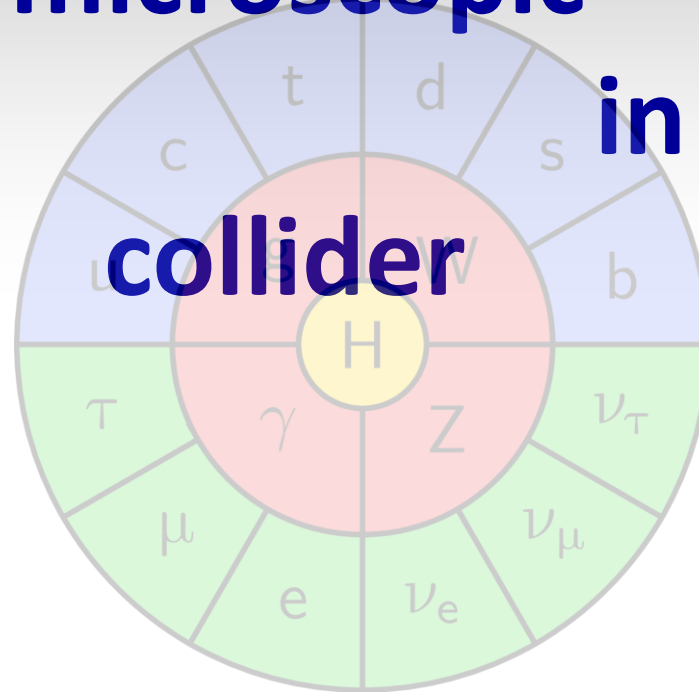


1) How do we look for

microscopic

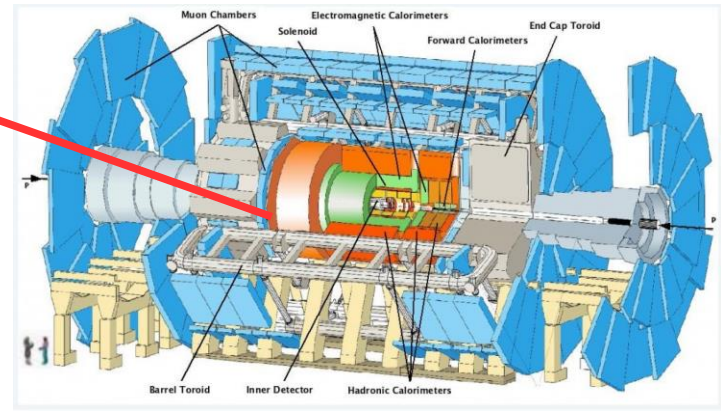
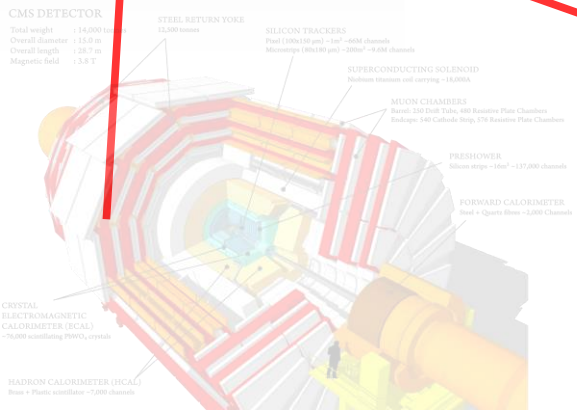
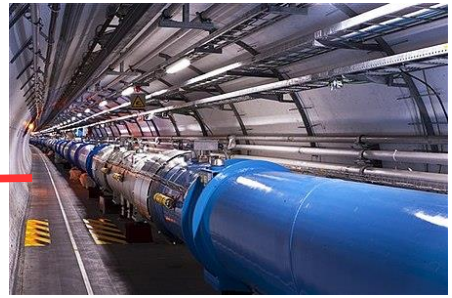
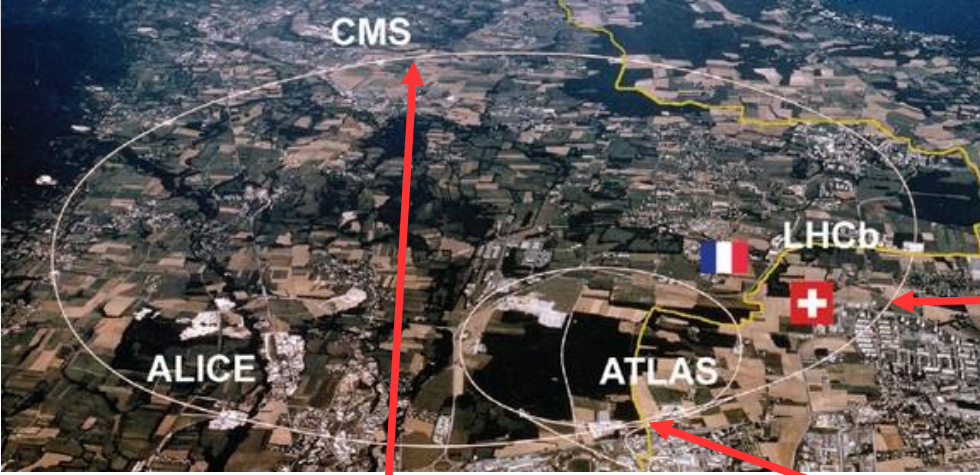
physics

in a giant



LHC

Proton beam parameters	LHC Design	2012 LHC	Early 2015 LHC
# bunches/beam	2808	1374	3 - 458
Bunch spacing [ns]	25	50	25 and 50
Mean bunch length [ns]	1.3	1.2	1.2
Bunch intensity [10^{11} p]	1.15	1.1 - 1.7	1.0 - 1.2
Emittance at injection [μm]	3.5	1.5 - 2.0	1.5 - 3.0
Collision energy/beam [TeV]	7	4	6.5
Emittance at collision [μm]	3.75	2.4	1.5 - 4.0
β^* at ATLAS/CMS [m]	0.55	0.6	0.8



Collisions

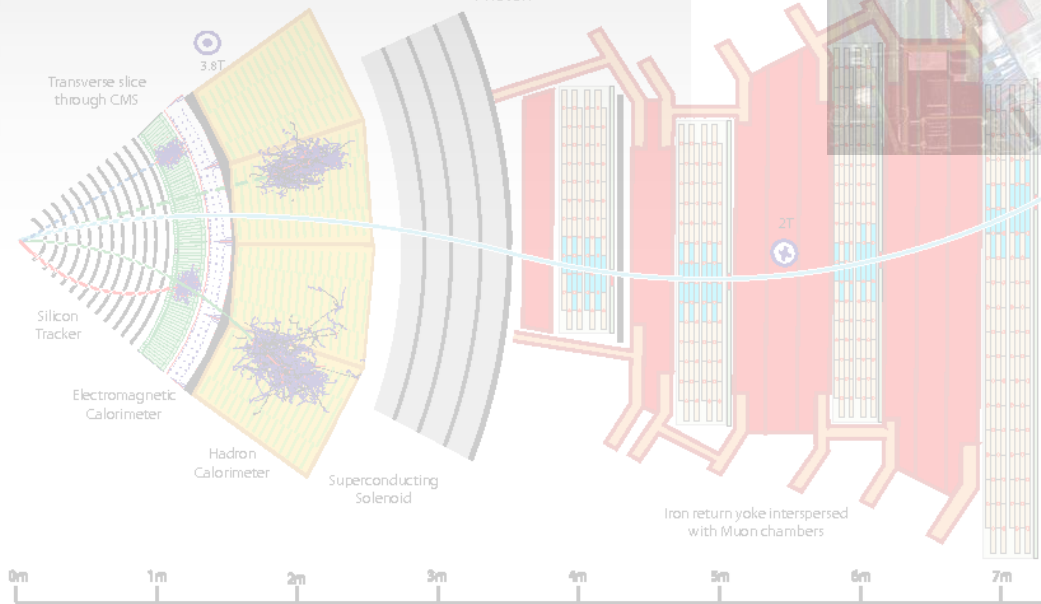


Particles identification

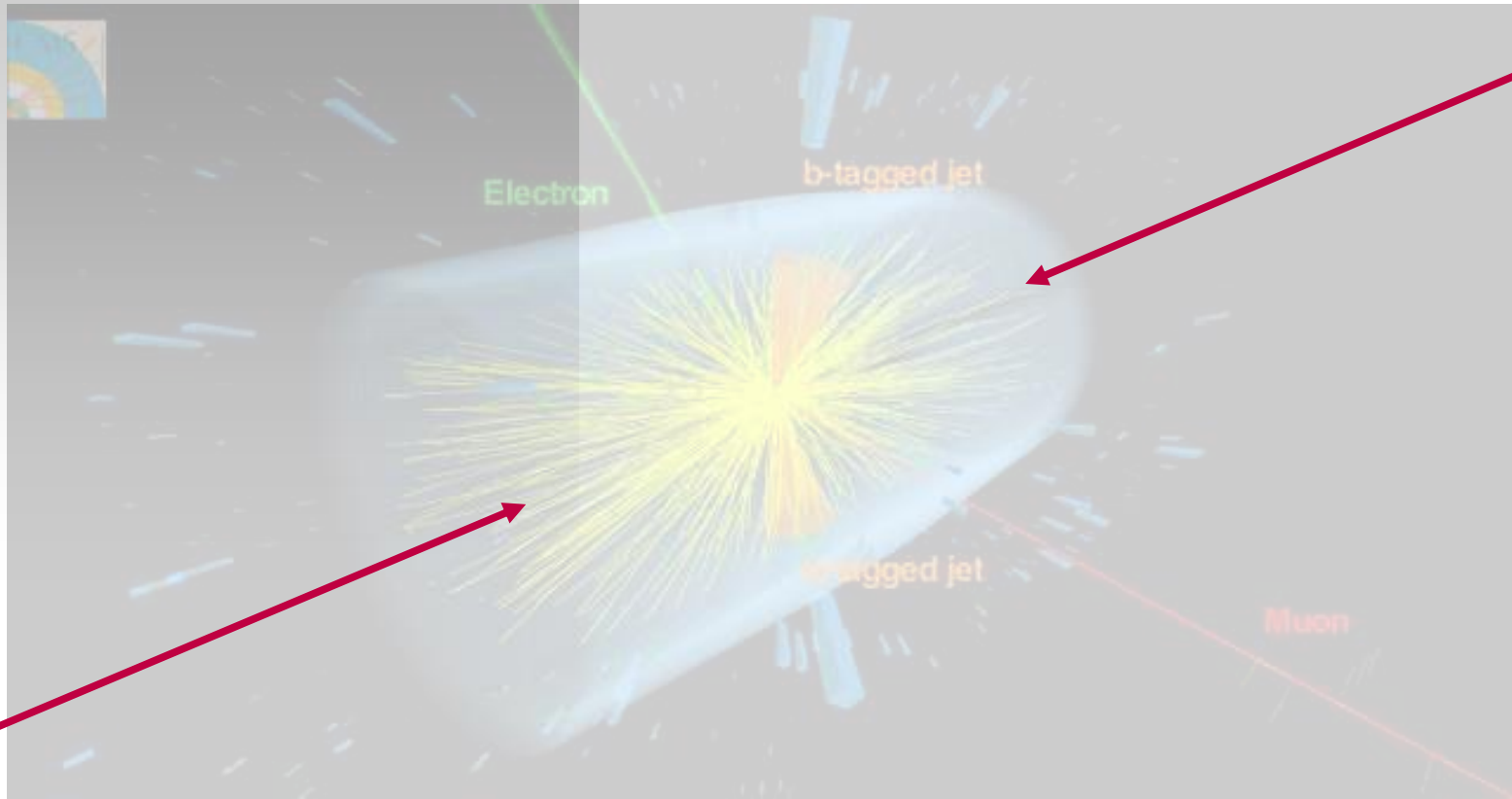
Particle Flow paper

Key:

- Muon
- Electron
- Charged Hadron (e.g. Pion)
- Neutral Hadron (e.g. Neutron)
- Photon

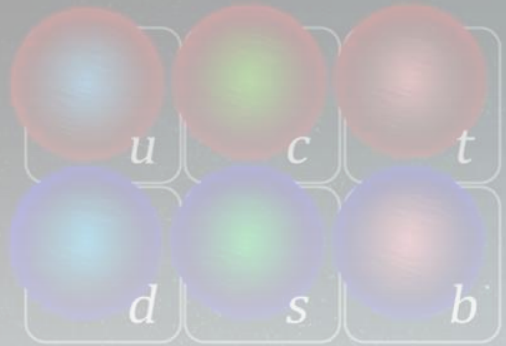


Collisions again



Higgs boson example

1.2) Collisions



Quarks



Leptons

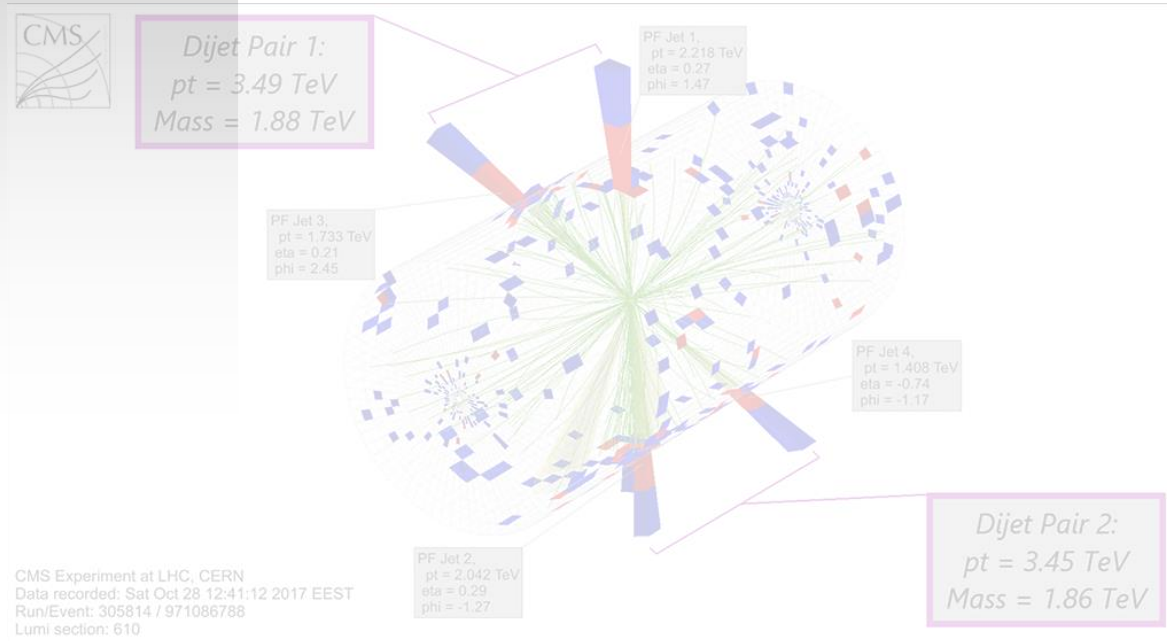


Higgs boson



Forces

1.2) New physics program of the LHC



1.2) HL-LHC upgrade

CMS HL-LHC Upgrade: Scope



Technical proposal CERN-LHCC-2015-010 <https://cds.cern.ch/record/2020886>
Scope Document CERN-LHCC-2015-019 <https://cds.cern.ch/record/2055167/files/LHCC-G-165.pdf>

Complete replacement**

L1-Trigger/HLT/DAQ**

<https://cds.cern.ch/record/2283192>
<https://cds.cern.ch/record/2283193>

- Tracks in L1-Trigger at 40 MHz
- PFlow-like selection 750 kHz output
- HLT output 7.5 kHz

Calorimeter Endcap**

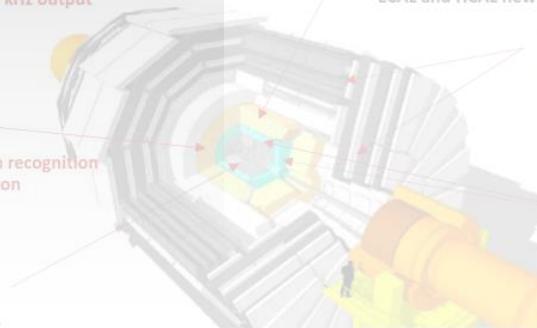
<https://cds.cern.ch/record/2293646>

- 3D showers imaging for pattern recognition
- Precision timing for PU mitigation
- Si, Scint+SiPM in Pb/W-SS

Tracker**

<https://cds.cern.ch/record/2272264>

- P_t module design for tracking in L1-Trigger
- Extended coverage to $\eta \approx 3.8$
- Much reduced material budget
- Si-Strip and Pixels increased granularity



Barrel Calorimeters*

<https://cds.cern.ch/record/2283187>

- ECAL crystal granularity readout at 40 MHz
- Precision timing for e/ γ at 30 GeV, for vertex localization ($H \rightarrow \gamma\gamma$)
- ECAL and HCAL new Back-End boards

Major Electronics Upgrade/ Consolidation*

Muon systems* ***

<https://cds.cern.ch/record/2283189>

- Extended GEM coverage to $\eta \approx 3$
- DT & CSC new FE/BE readout
- RPC back-end electronics
- New GEM/RPC $1.6 < \eta < 2.4$

MIP Timing Detector***

<https://cds.cern.ch/record/2296612>

- Precision timing for PU mitigation
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

New Detector System***

Beam Radiation Instr. and Luminosity
Common Systems and Infrastructure
<https://cds.cern.ch/record/2020886>

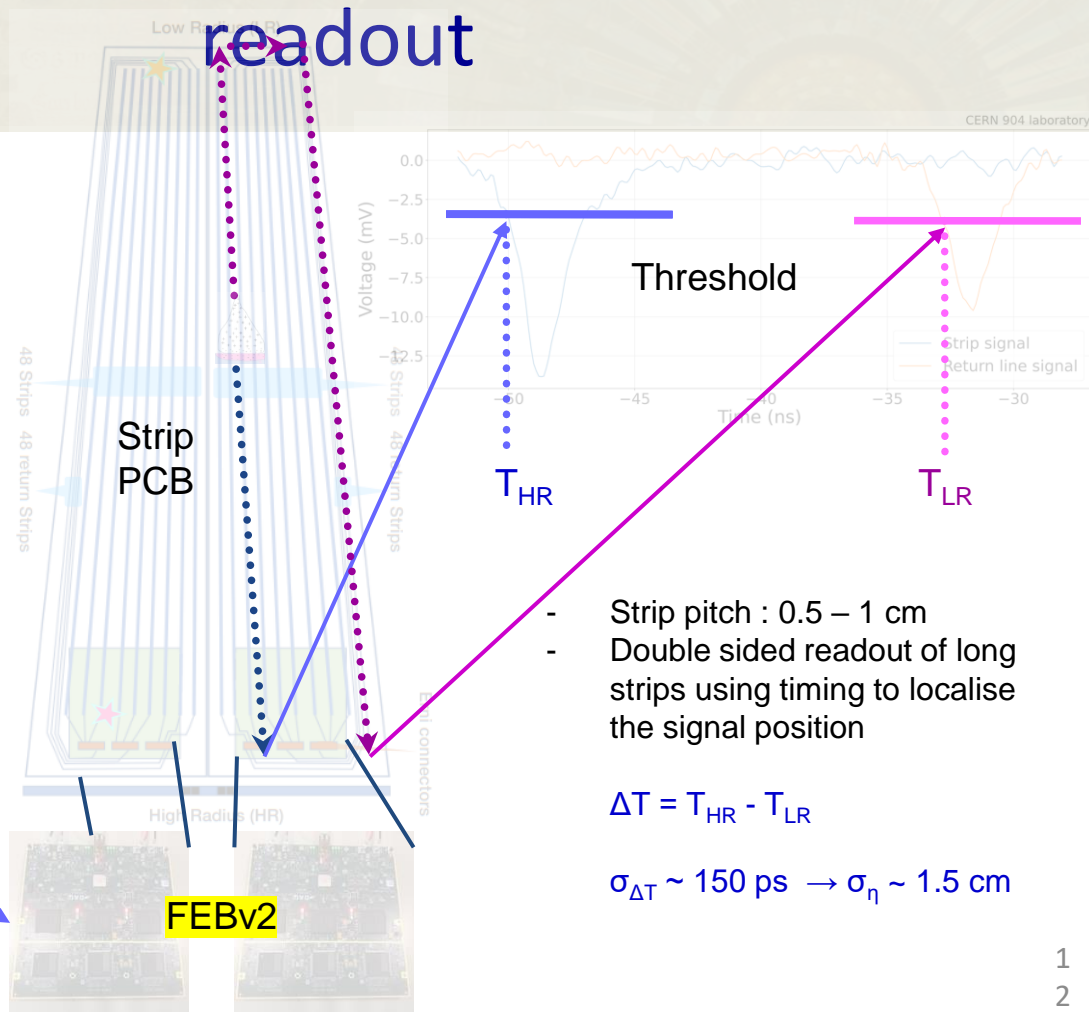
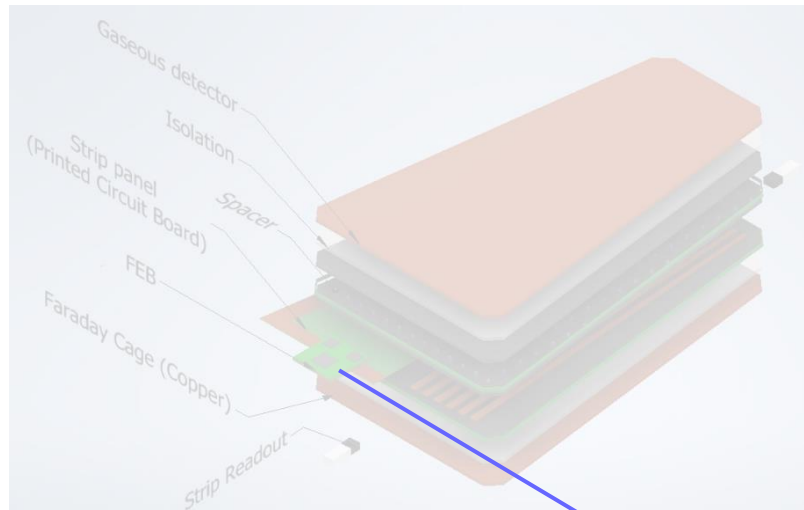
New paradigms for a HEP experiment to meet the unprecedented challenges
and fully exploit the HL-LHC luminosity and physics potential

- High precision timing detectors : Timing layer between tracker and calorimeter
- High precision timing for Muon chambers : 1.5 – 0.5 ns time resolution
- New tracker with high rate fast transmission



1.3) iRPC

readout



- Strip pitch : 0.5 – 1 cm
- Double sided readout of long strips using timing to localise the signal position

$$\Delta T = T_{HR} - T_{LR}$$

$$\sigma_{\Delta T} \sim 150 \text{ ps} \rightarrow \sigma_{\eta} \sim 1.5 \text{ cm}$$