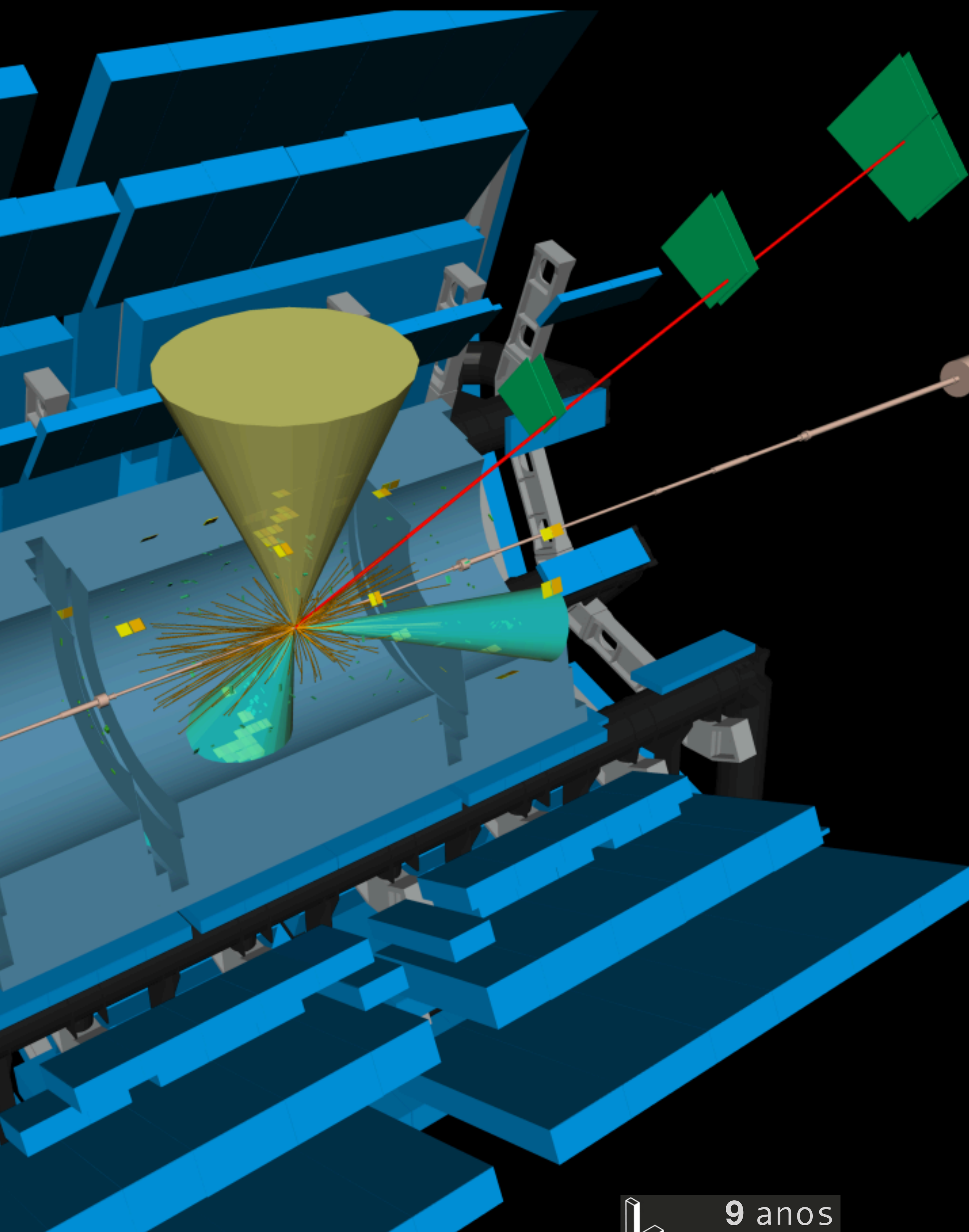
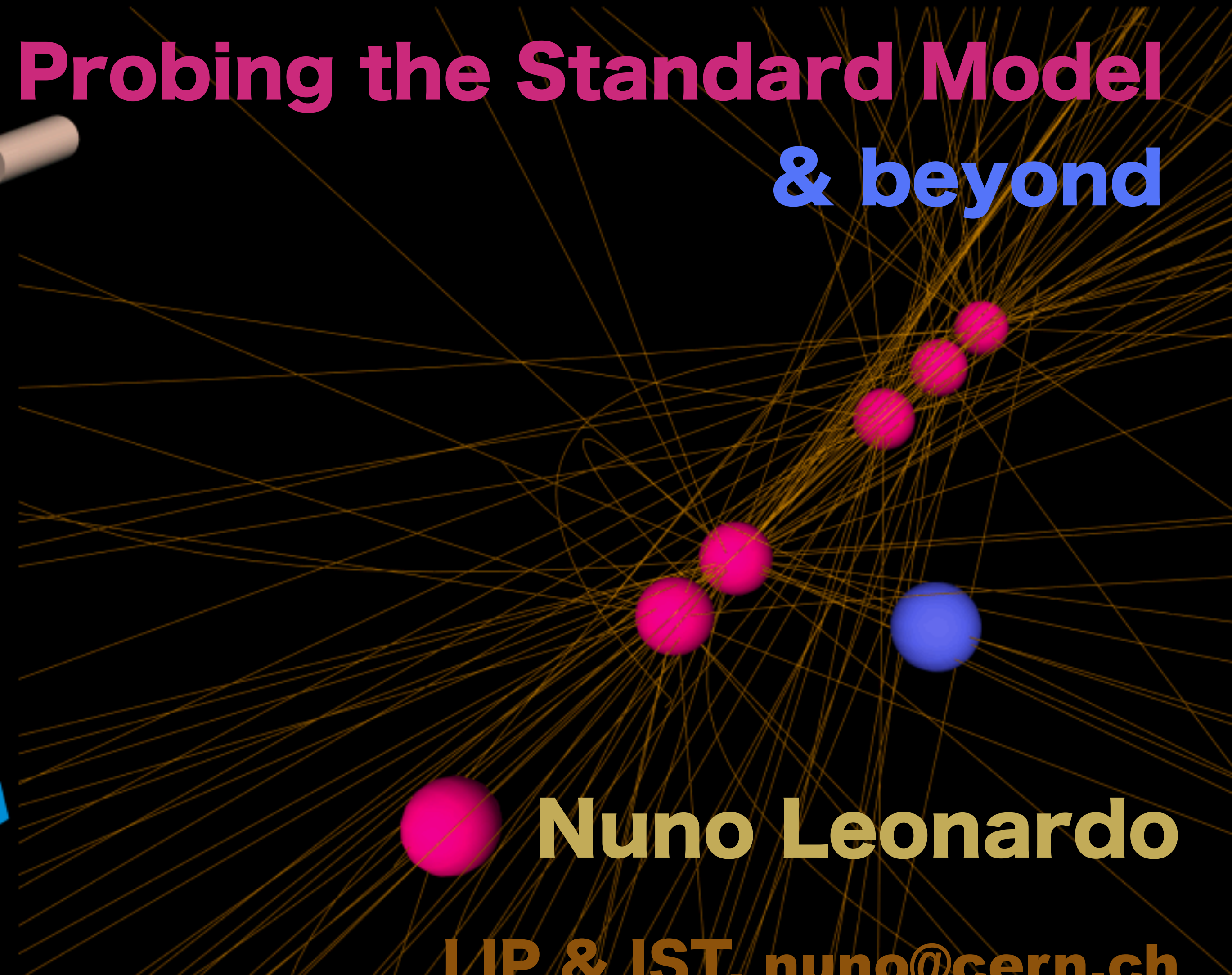


Physics @ LHC

Probing the Standard Model & beyond



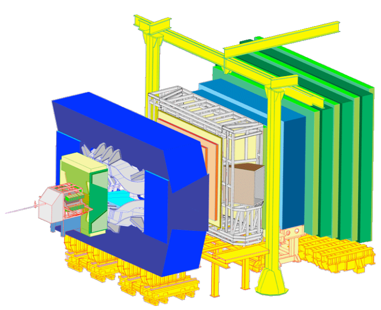
Nuno Leonardo

LIP & IST, nuno@cern.ch

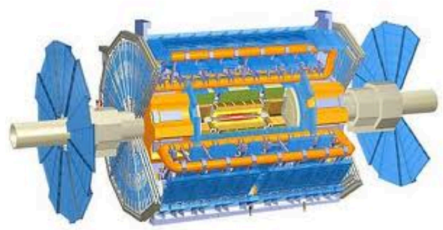
LIP Internship Lectures, June 18th, 2025

Physics @ LHC

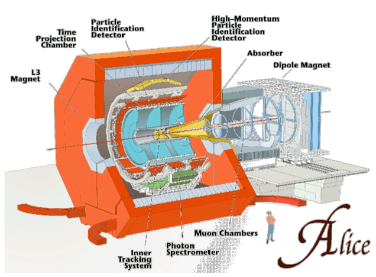
LHCb



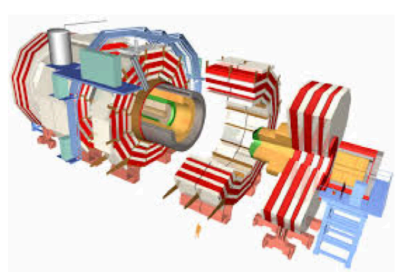
ATLAS



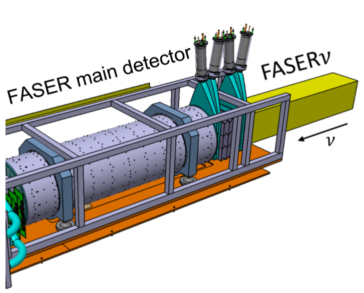
ALICE



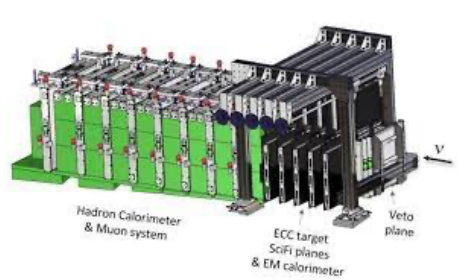
CMS



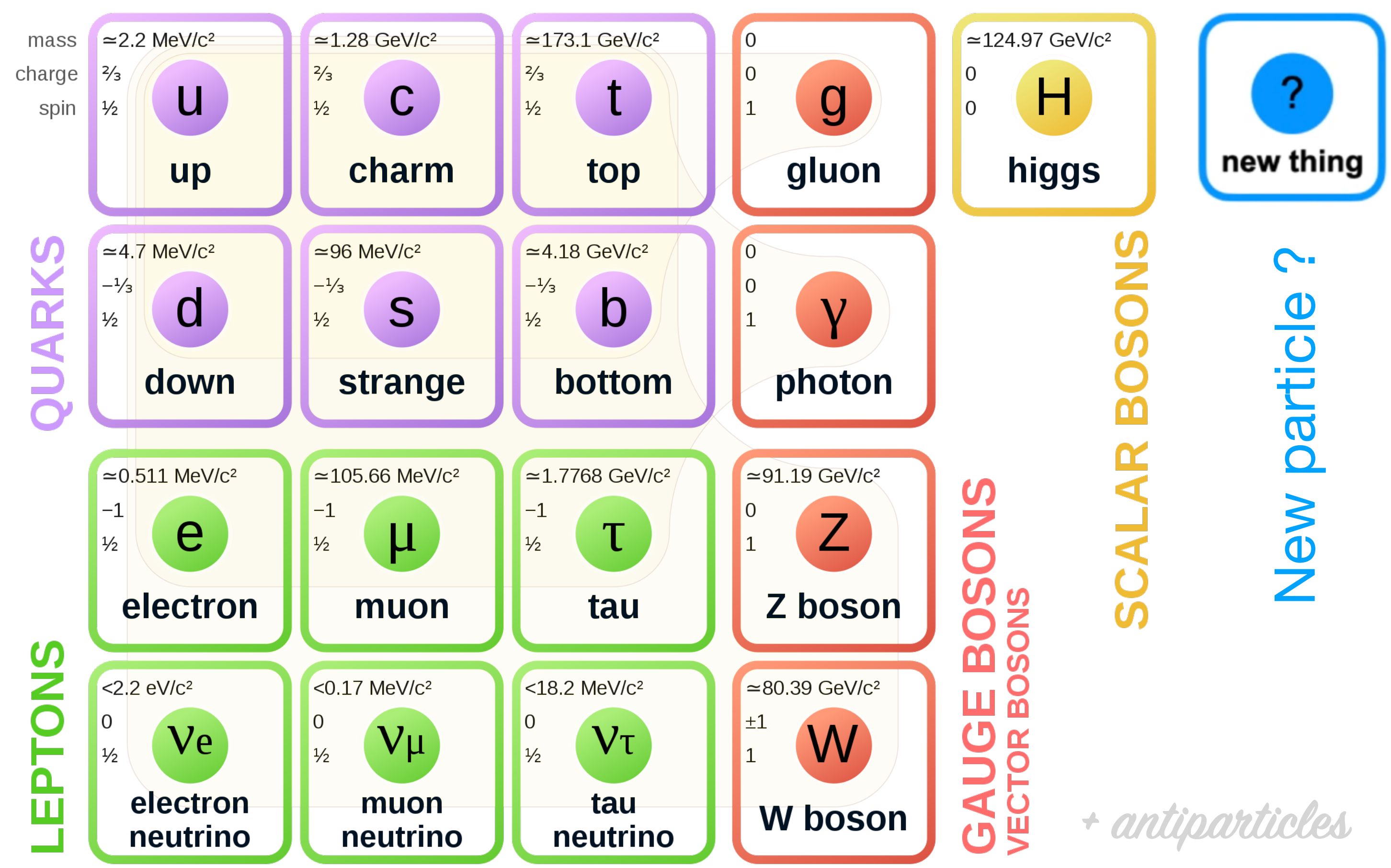
FASERν



SND@LHC

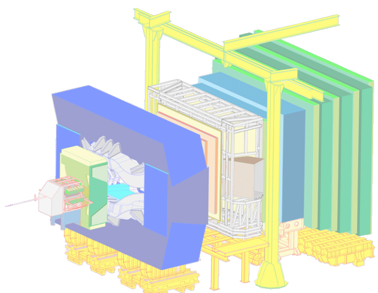


- Study *all* SM particles +interactions
  - ➡ *Precision SM measurements*
- Look for *new* particles +interactions
  - ➡ *Searches for beyond-SM phenomena*



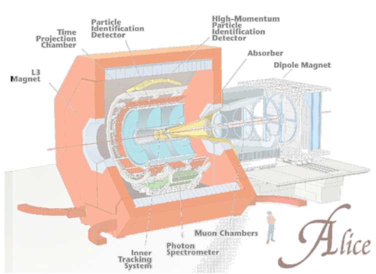
Physics @ LHC

LHCb

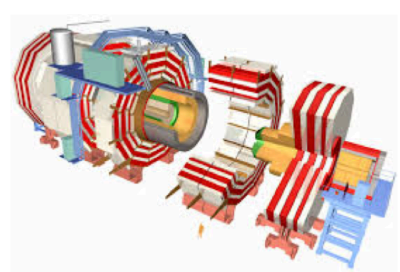


ATLAS

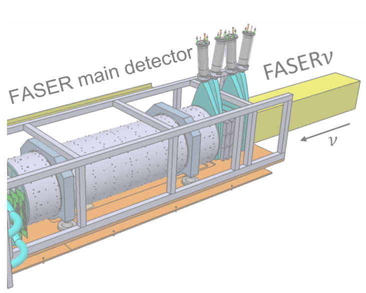
ALICE



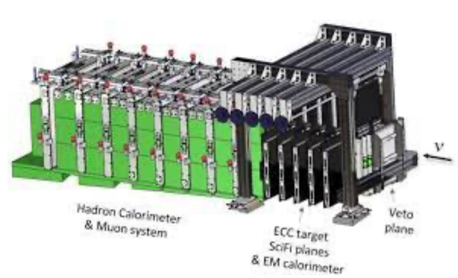
CMS



FASERν



SND@LHC



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  - ➡ *Precision SM measurements*
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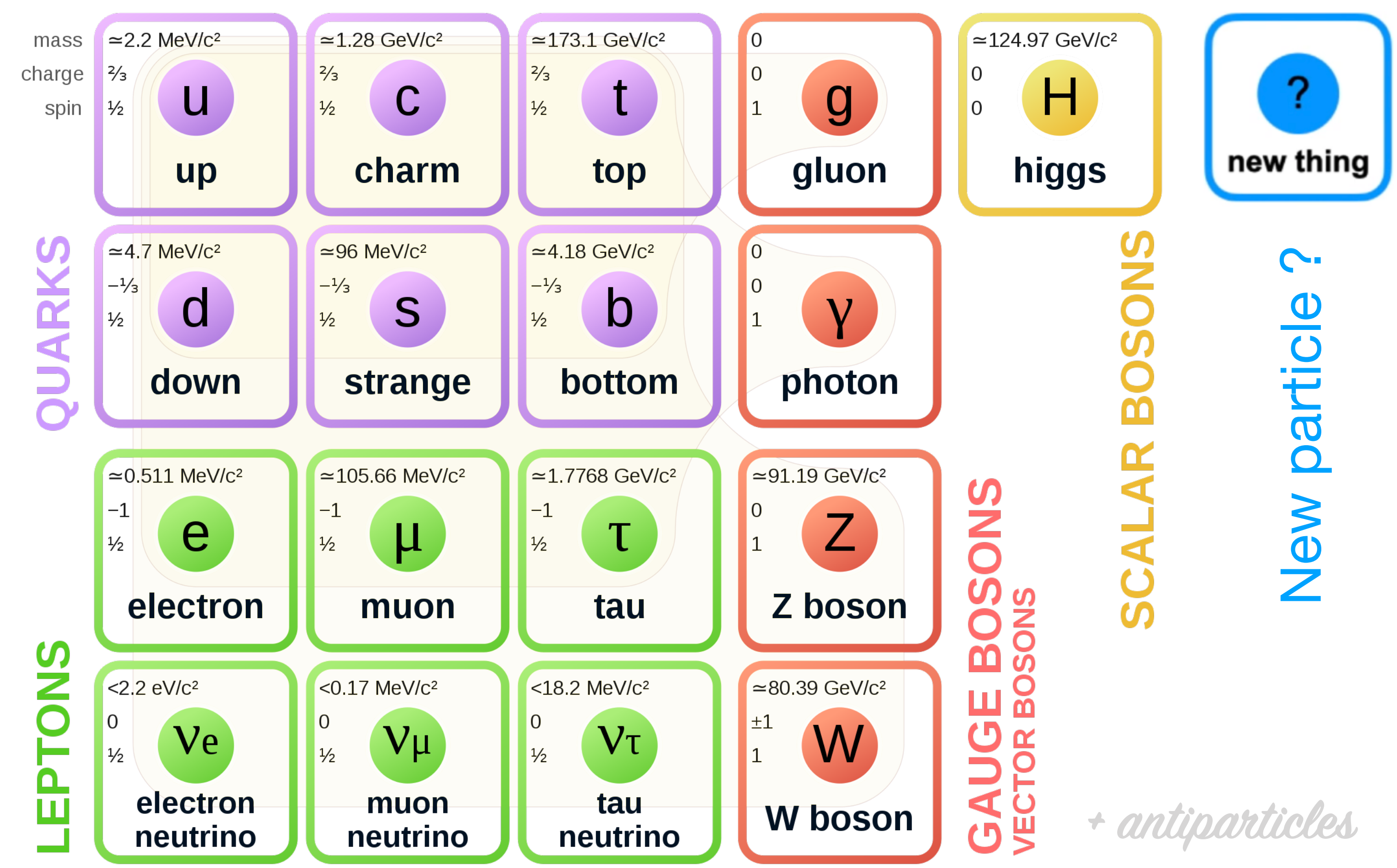
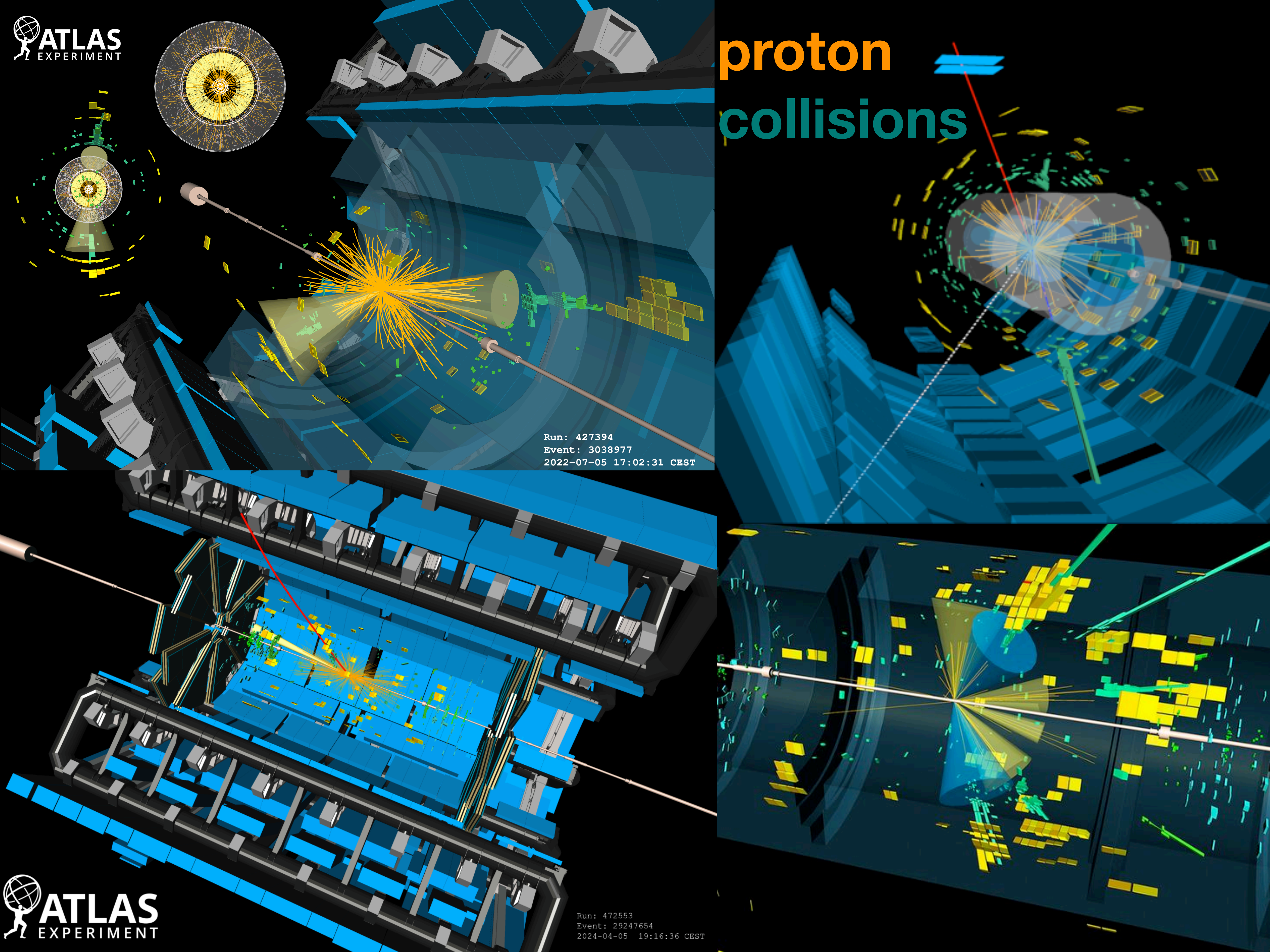
  - ➡ *Searches for beyond-SM phenomena*



(with LIP Portuguese participation — LIP)


ATLAS
EXPERIMENT
proton
collisions
Run: 427394
Event: 3038977
2022-07-05 17:02:31 CEST
ATLAS
EXPERIMENT
Run: 472553
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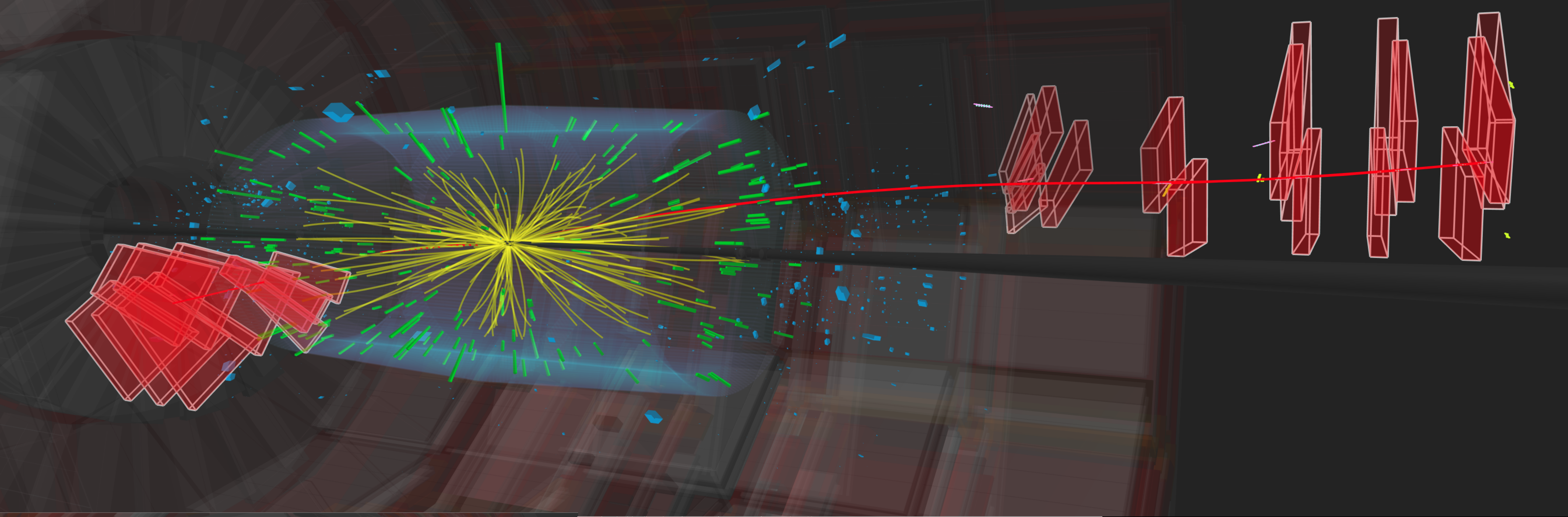
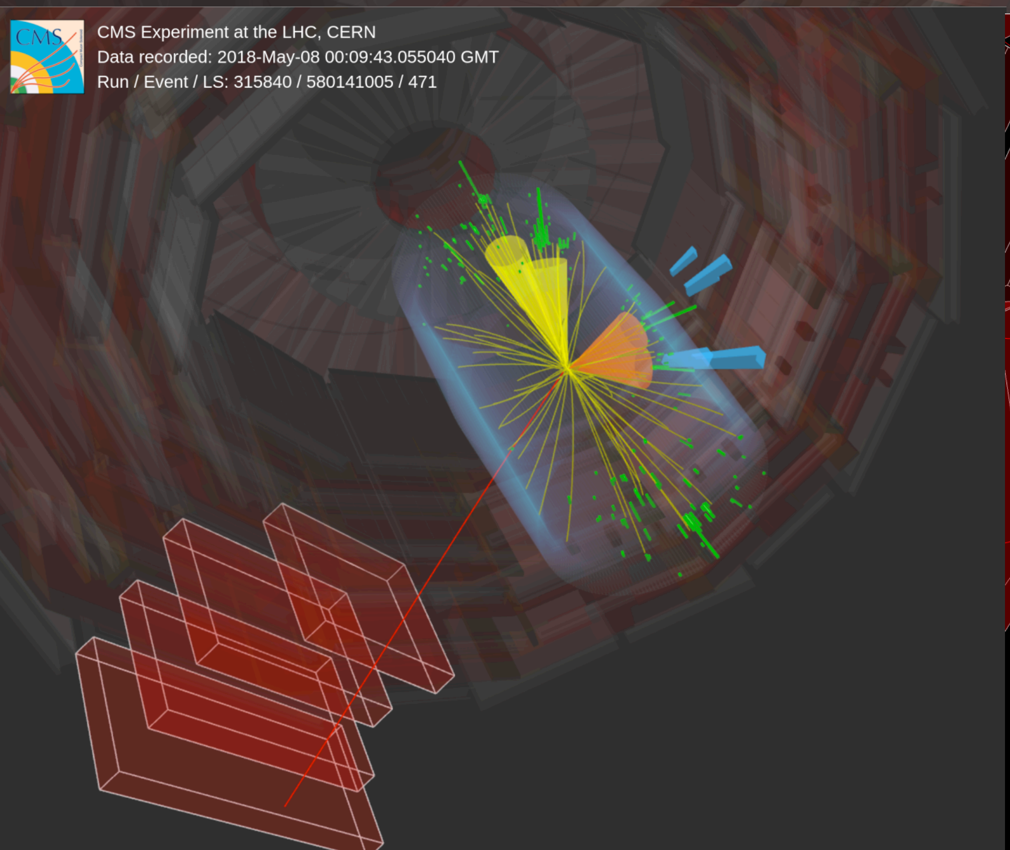
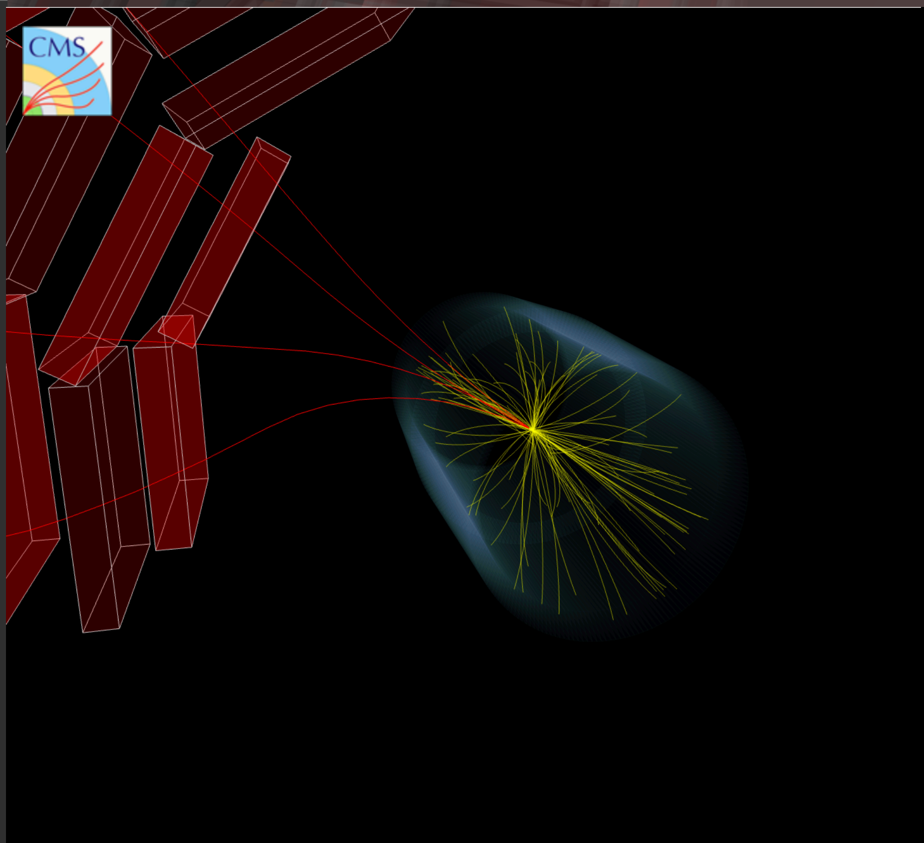
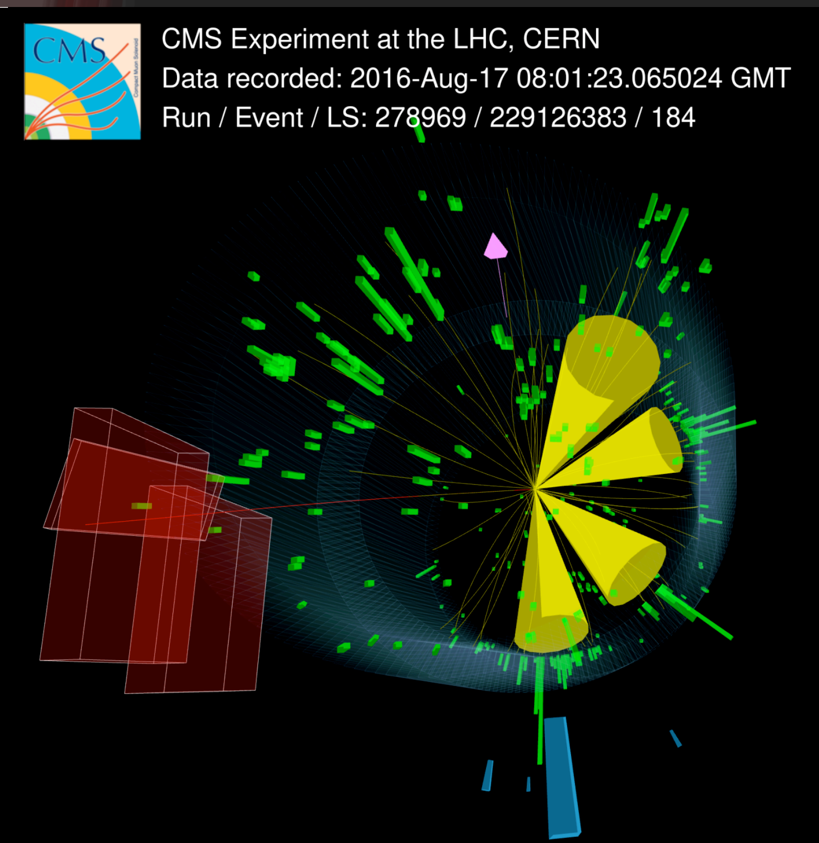
2024-04-05 19:16:36 CEST

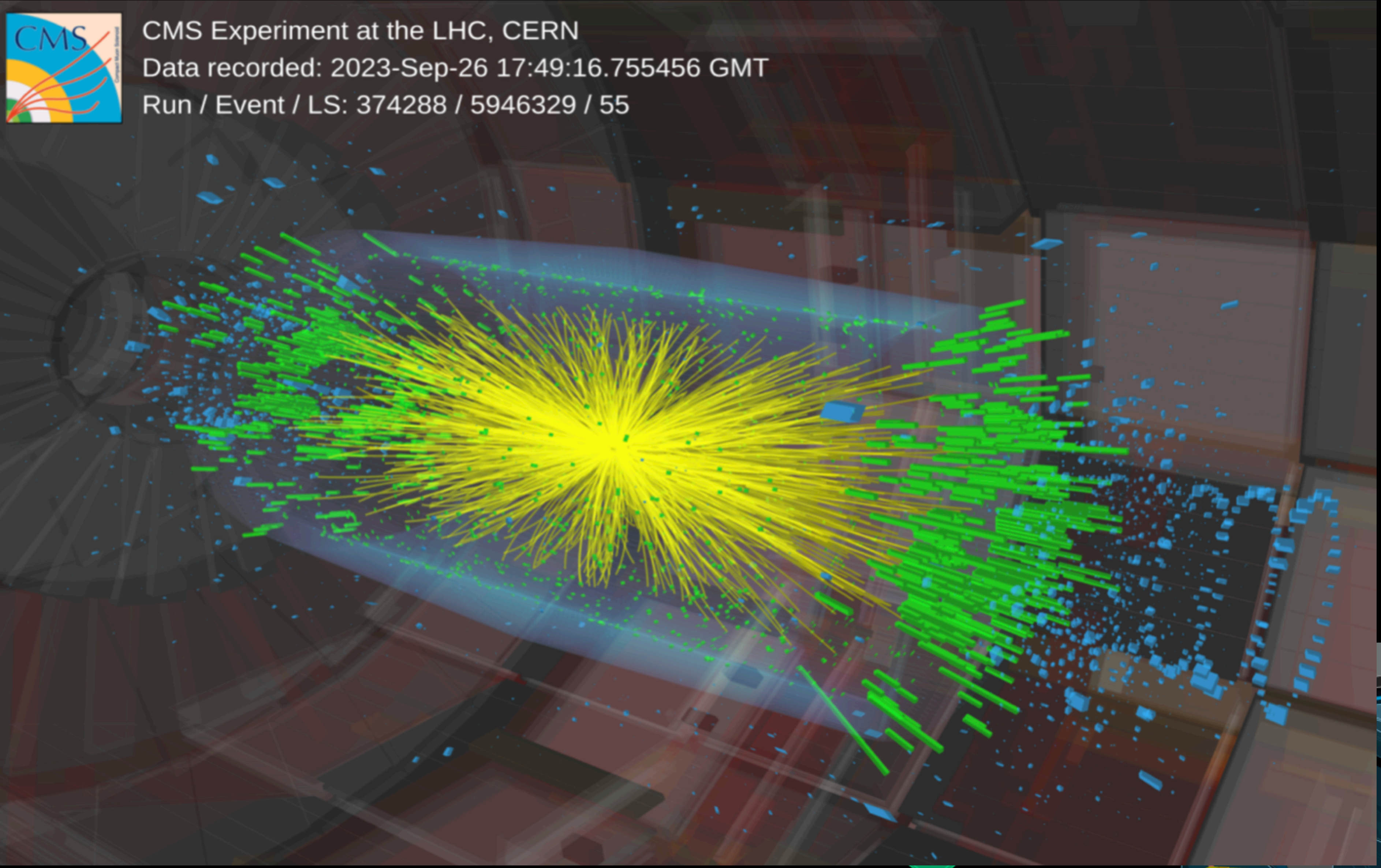
proton collisions





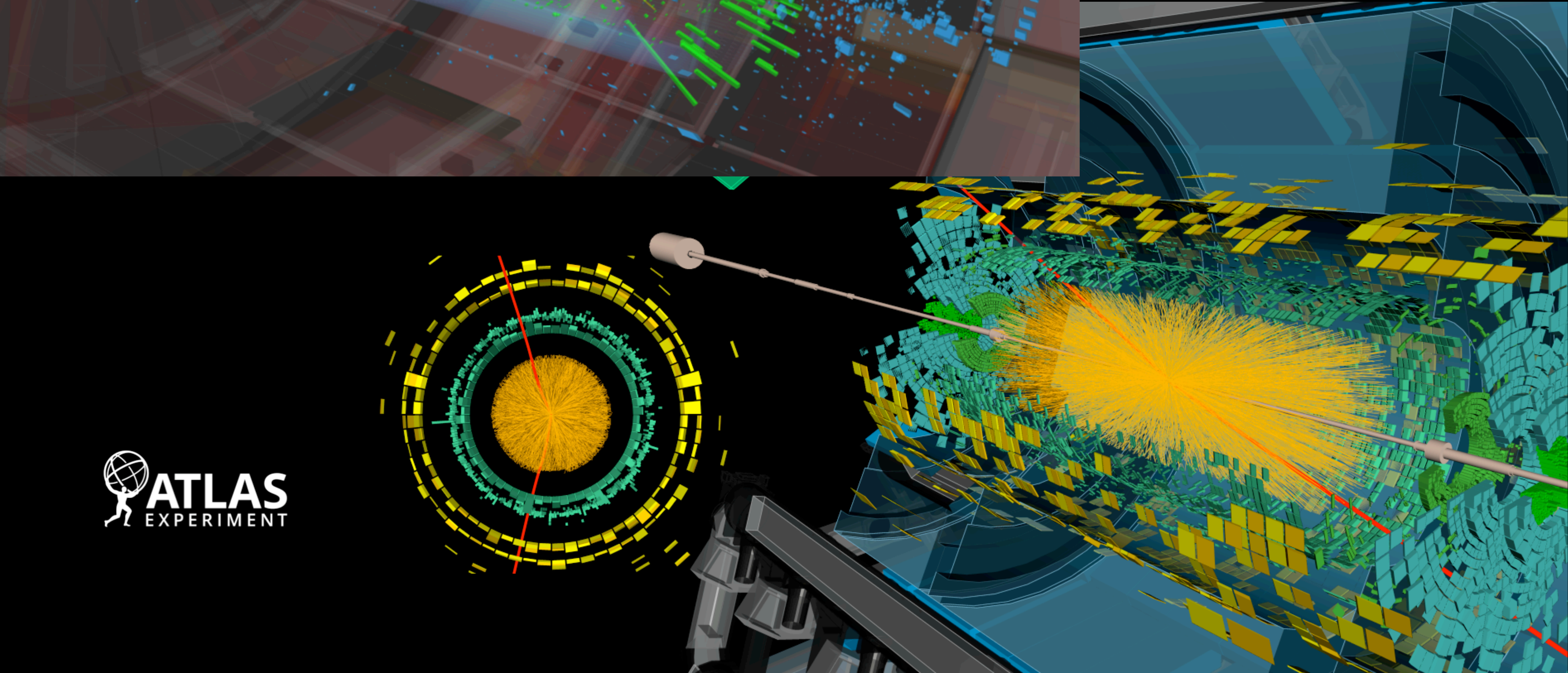




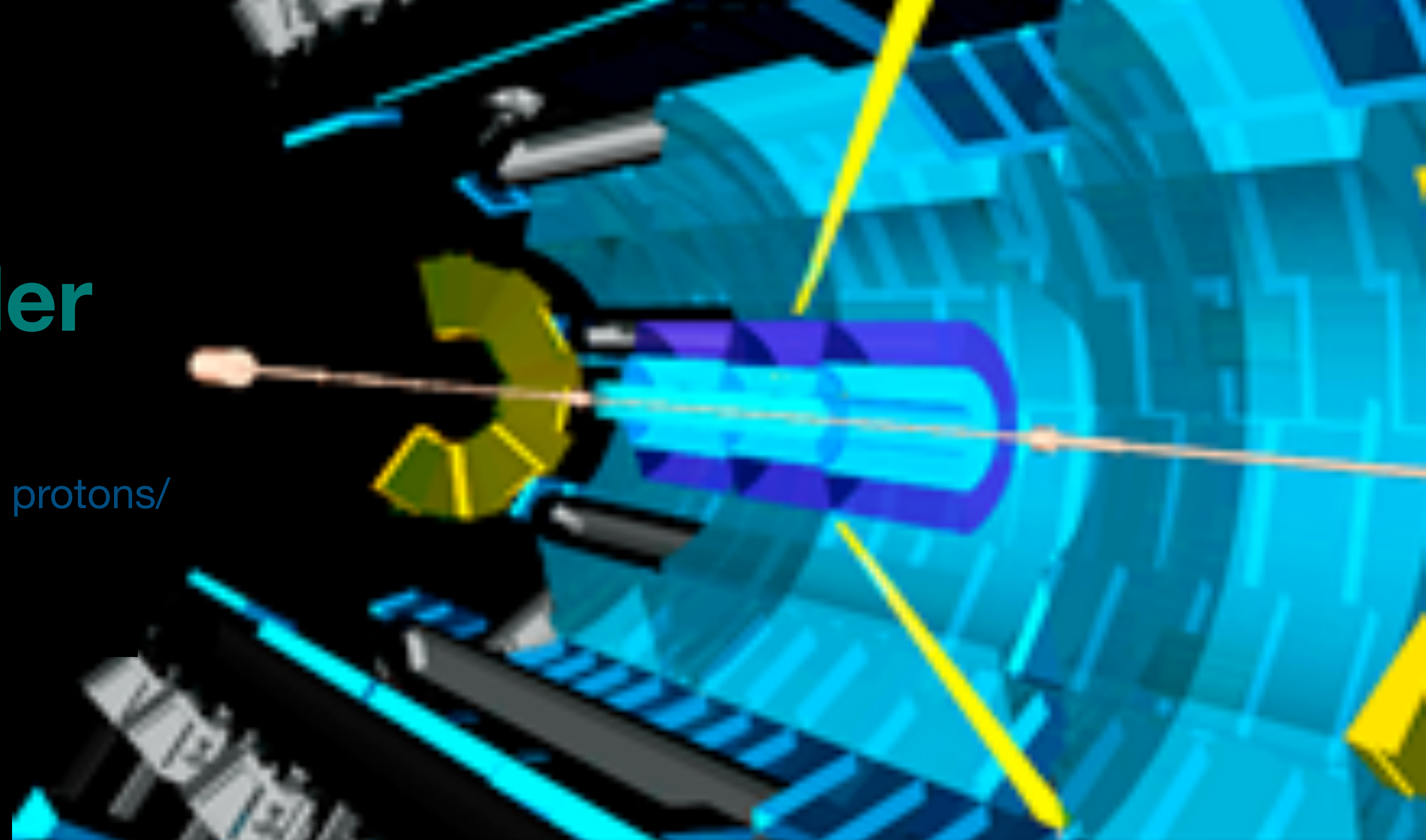


heavy ion collisions

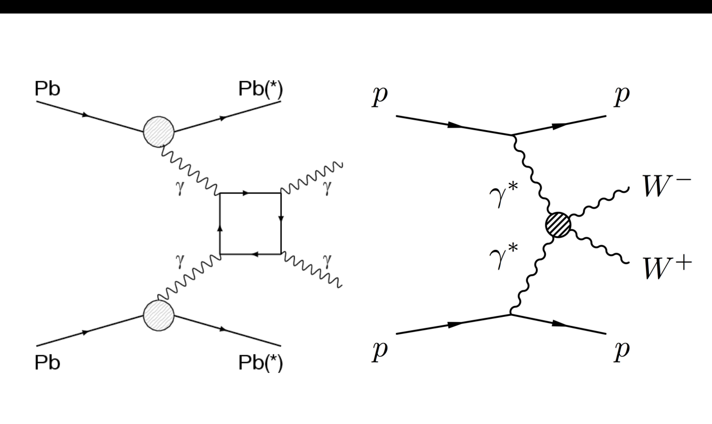
1 month per year the LHC collides ions (eg PbPb)



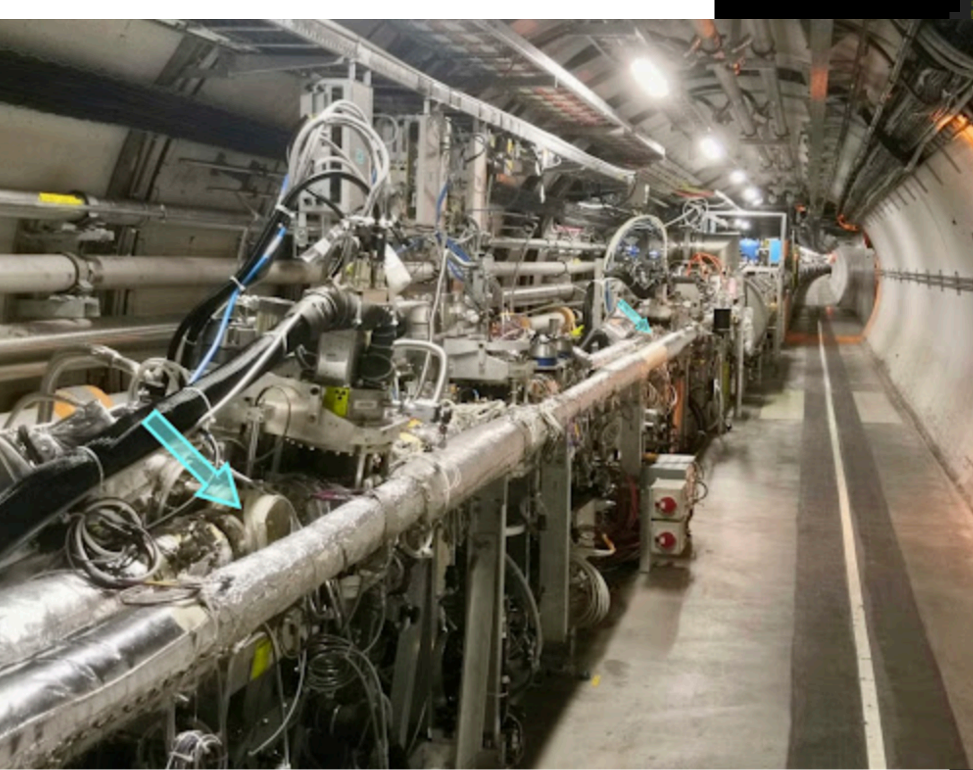
LHC as a photon collider

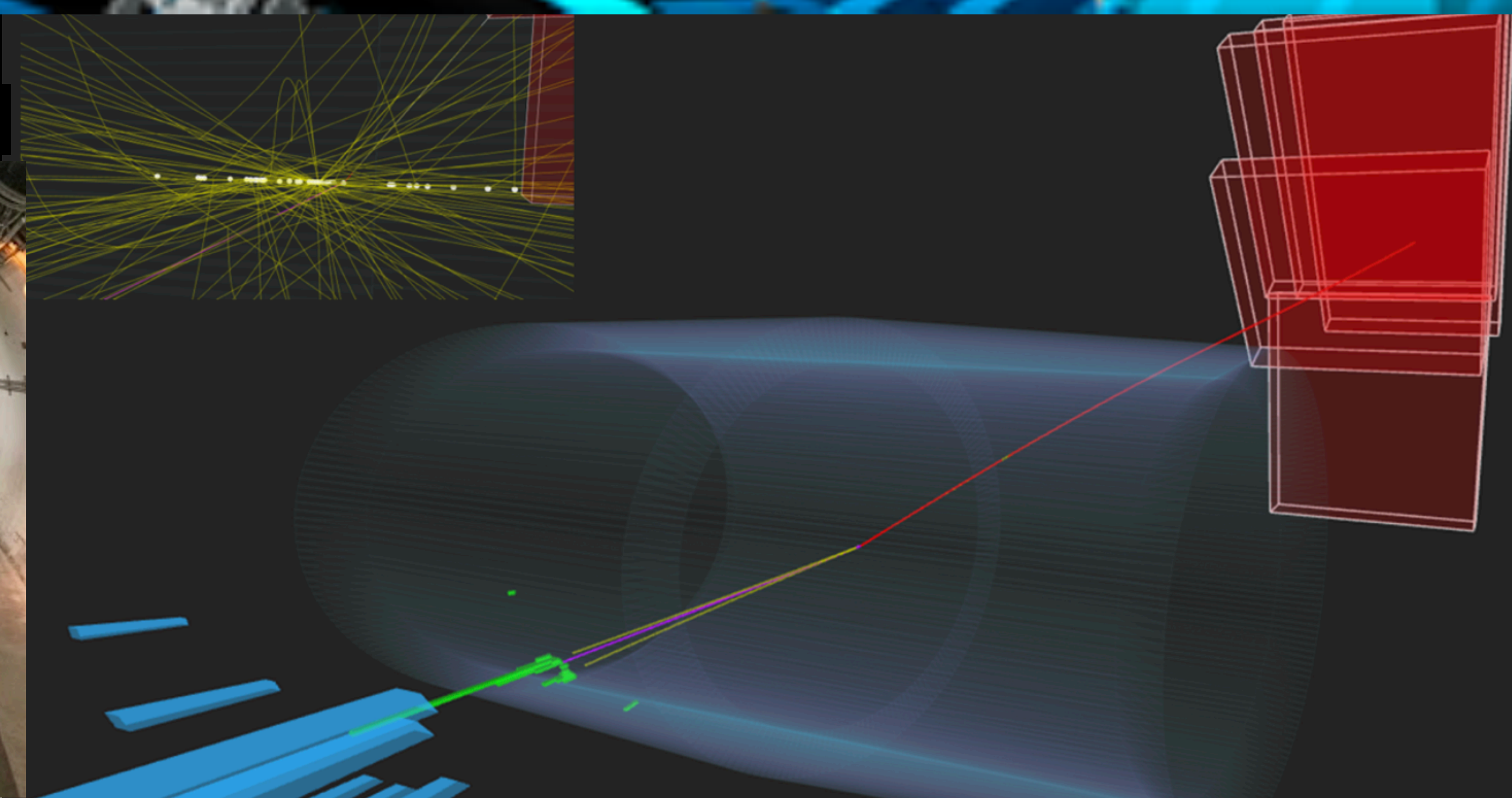


photons radiated from colliding protons/ ions can themselves collide
➥ dedicated detectors

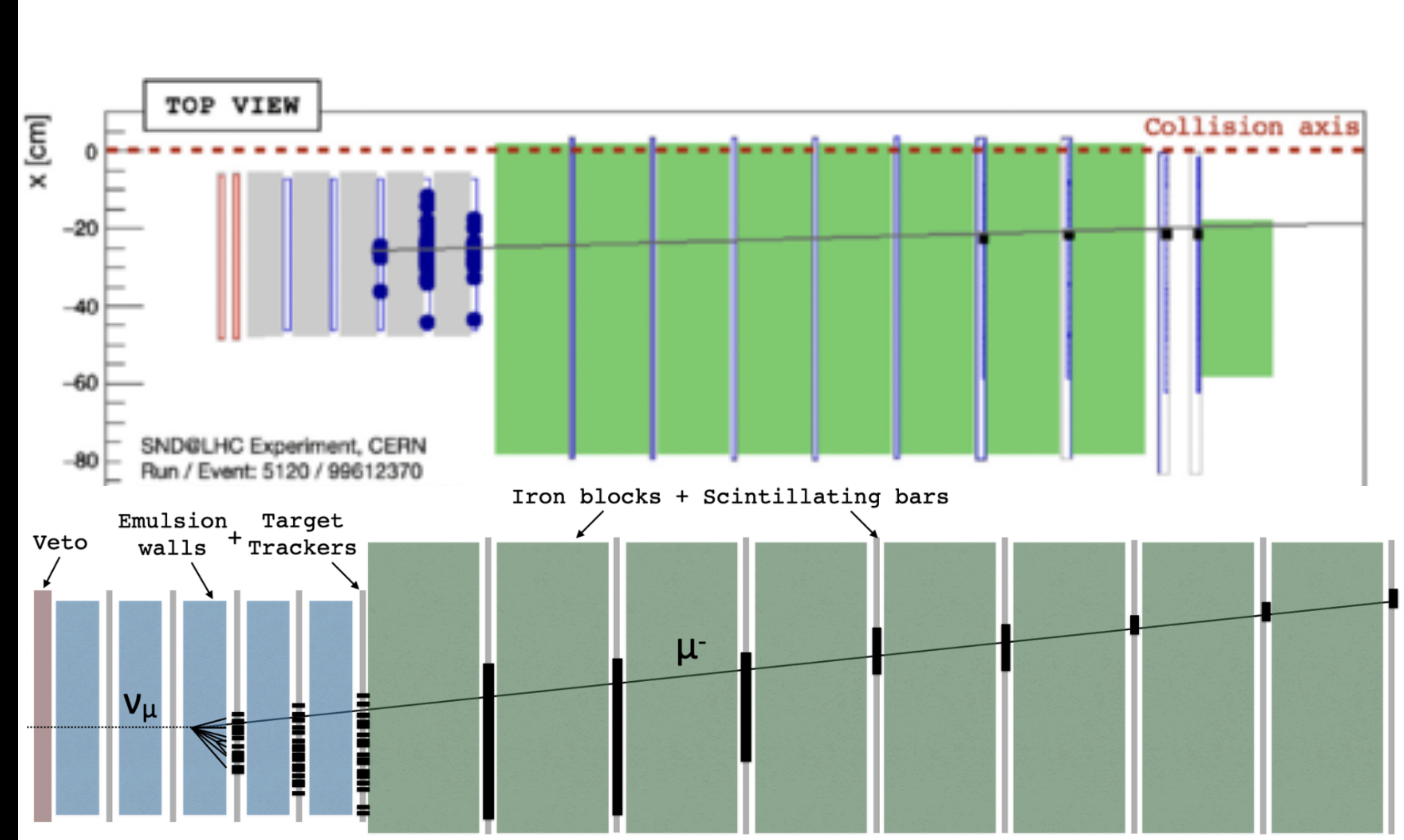


AFP, PPS

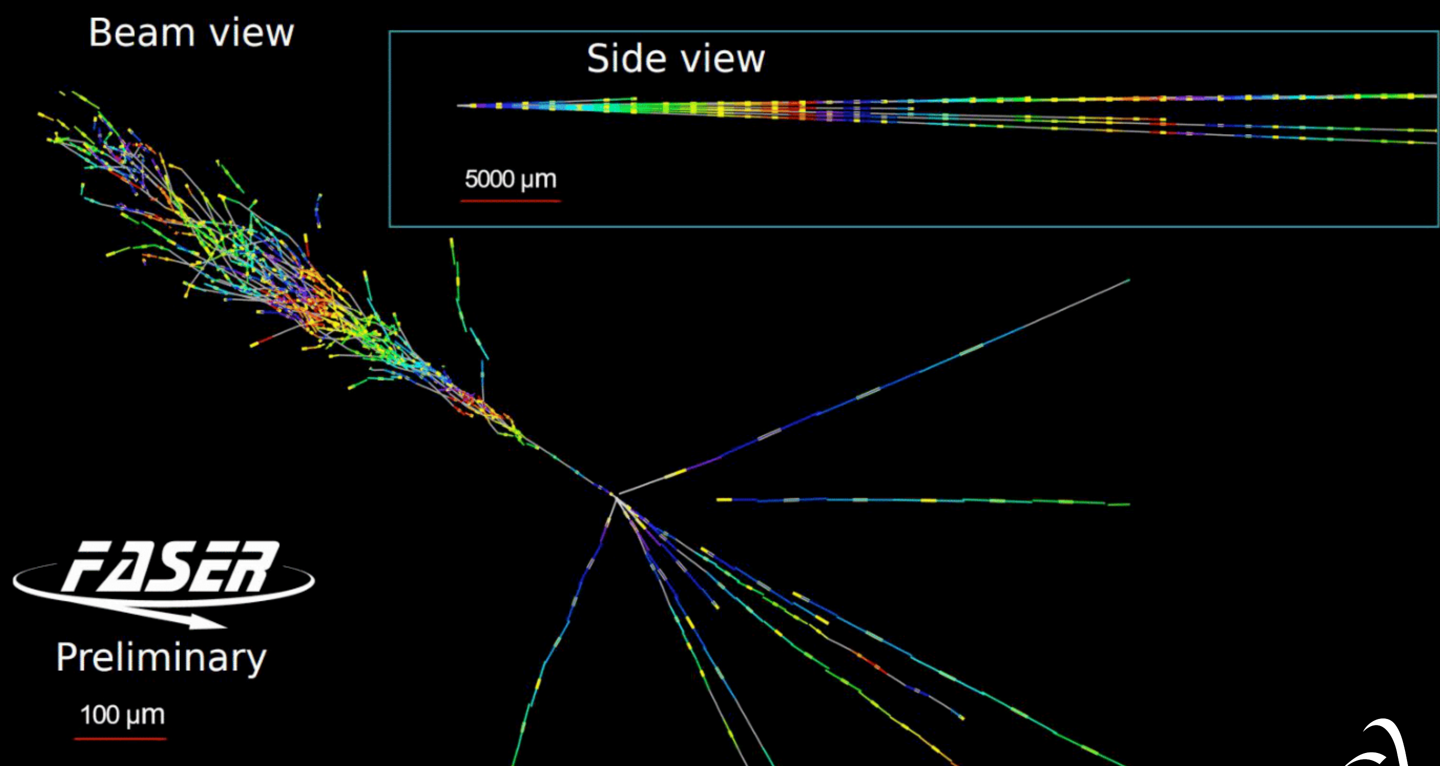




first neutrino interactions @LHC



detection of neutrino interactions @LHC
➥ required novel, dedicated detectors (Run3)



SND@LHC

LHC
Scattering and Neutrino Detector at the LHC

LHC — mission & legacy

- **energy** frontier — search program at the TeV scale
- **intensity** frontier — precision electroweak measurements
- lifetime/**coupling** frontier — search for long-lived beyond-SM signatures
- heavy **flavour** — explore heavy quarks and leptons: t, b, τ (aka the 3rd family)
- heavy **ions** — ultra-relativistic nuclear collisions, deconfined QCD medium
- **photon** collider — ultra-peripheral collisions and proton tagging
- collider **neutrinos** — direct measurements of all neutrino flavours

↪ replaces+extends previous machines: Tevatron, BaBar/Belle, RHIC, LEP…

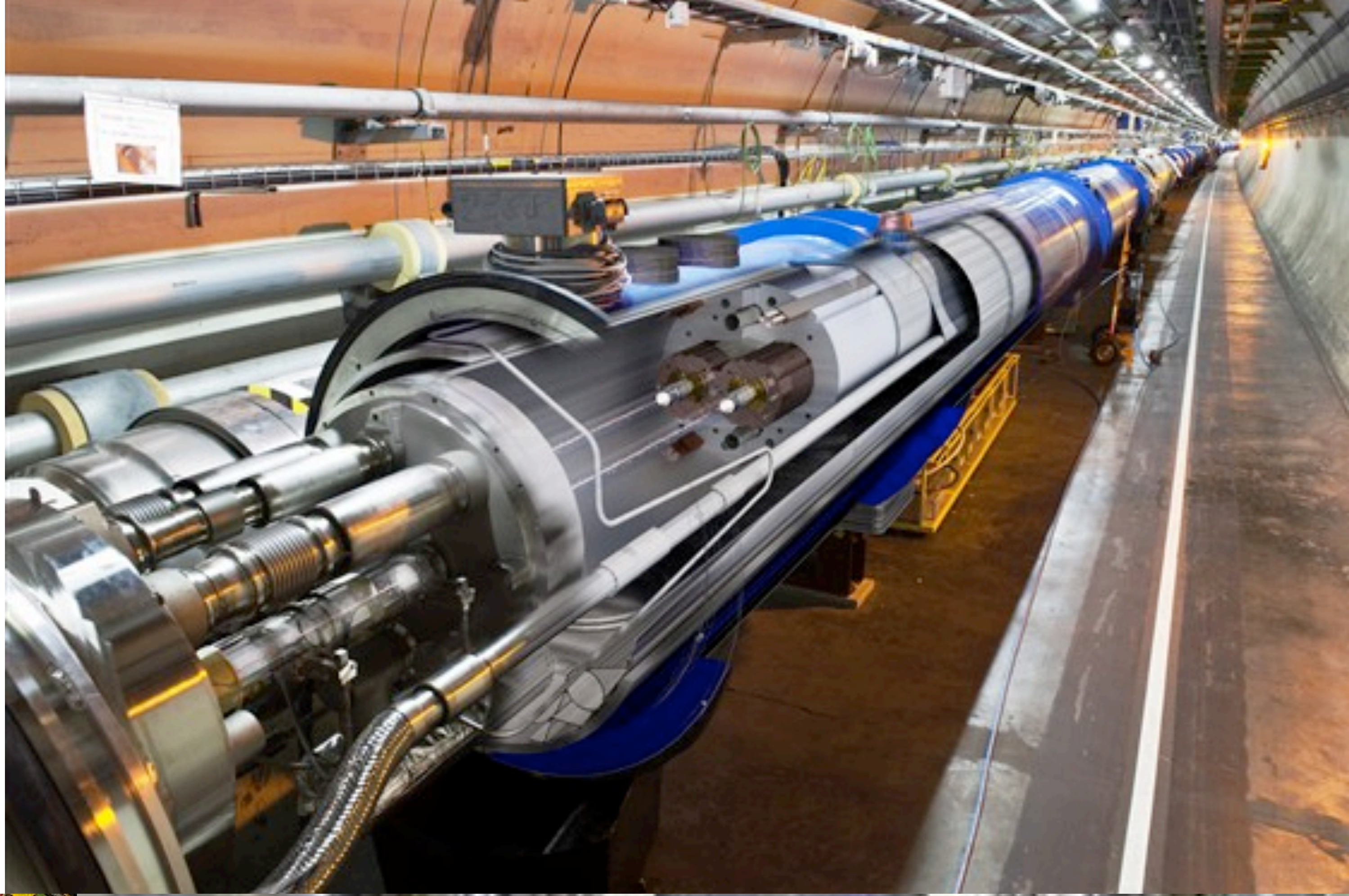
The accelerator

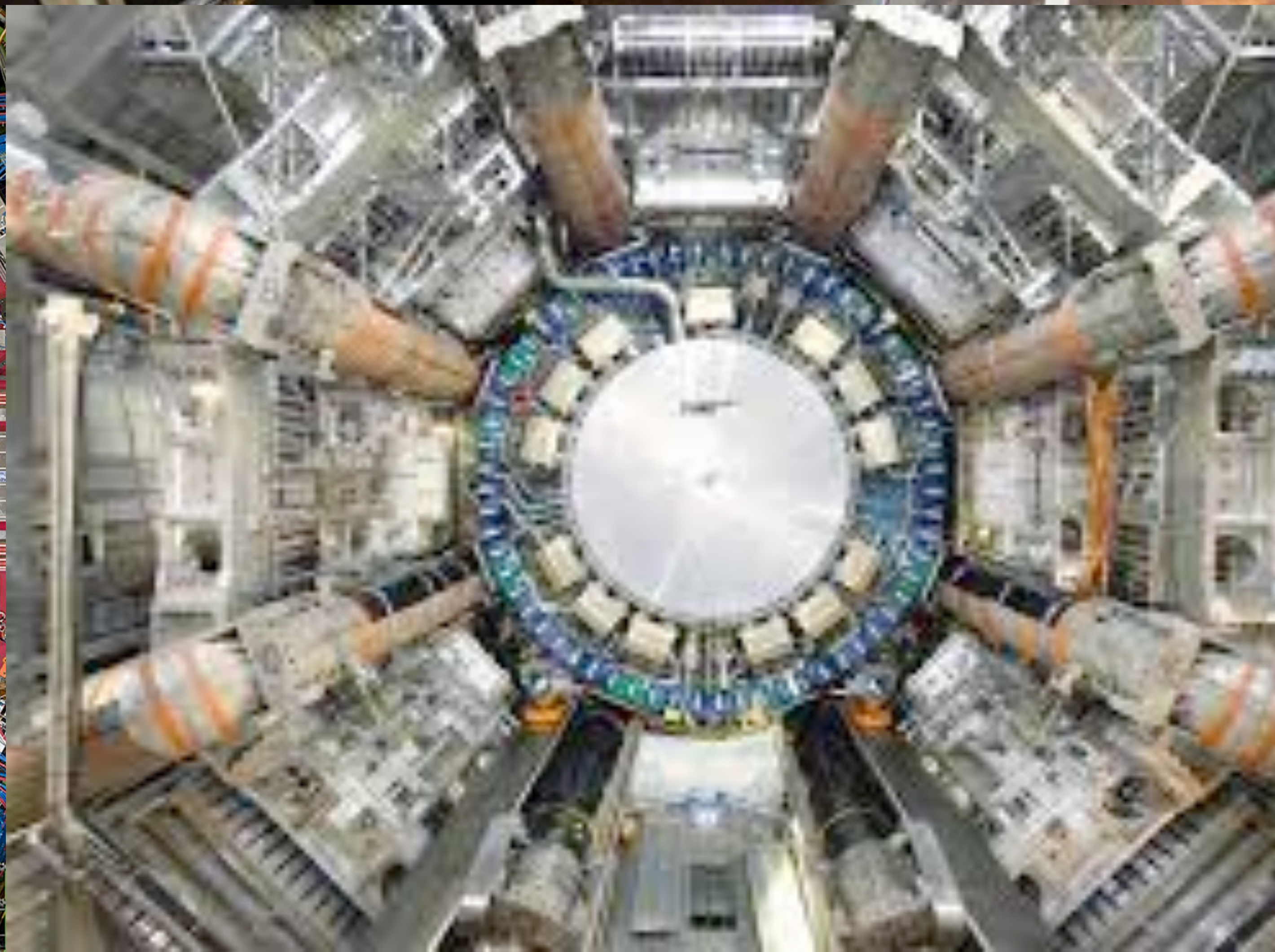
The LHC is the **world-leading** particle accelerator & collider

Delivering **unprecedented** energies and intensities

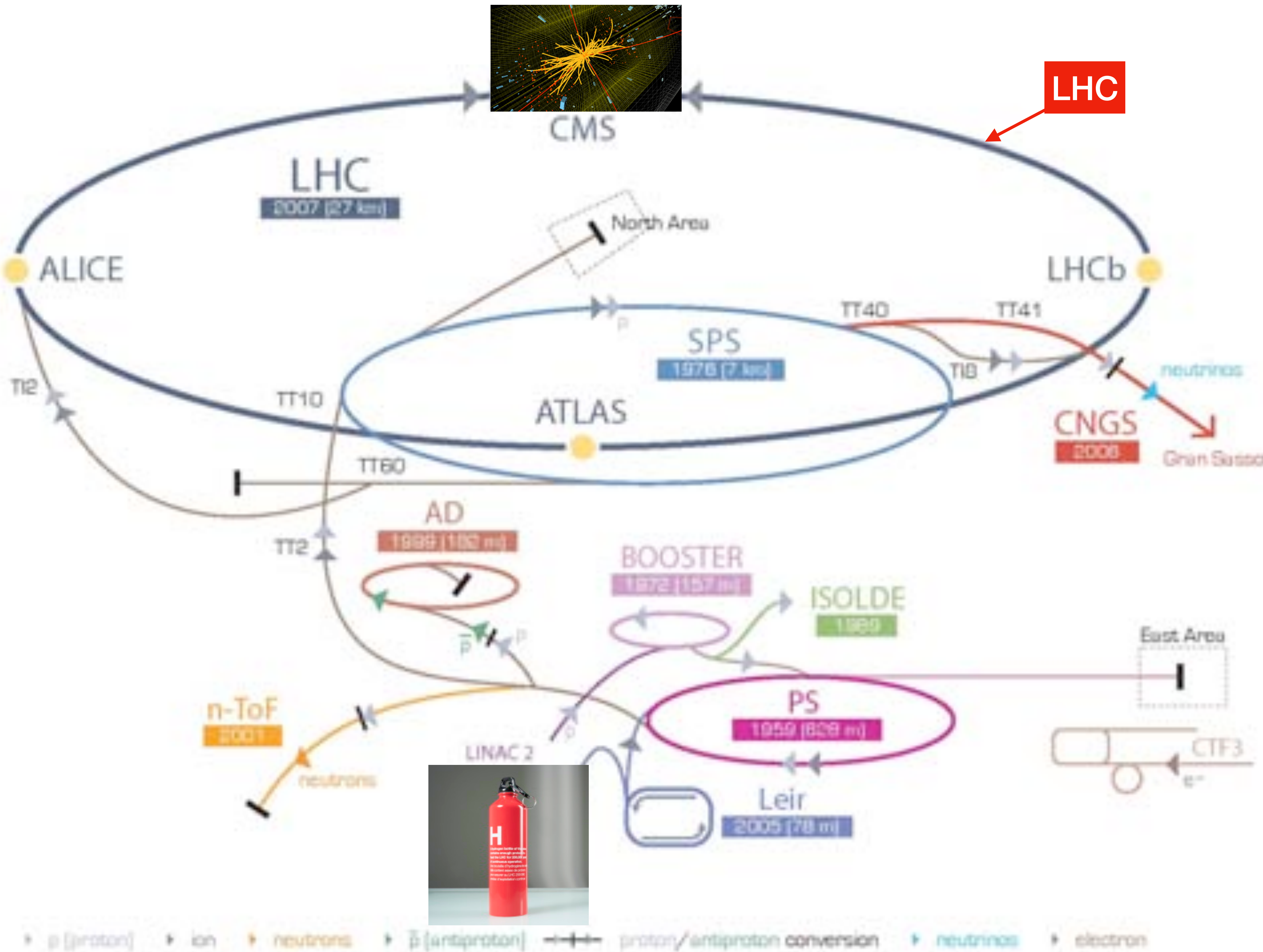
The LHC detectors are the most **sophisticated** scientific tools yet

Machine and detectors not static, systematically improved/**upgraded**





the CERN accelerator complex

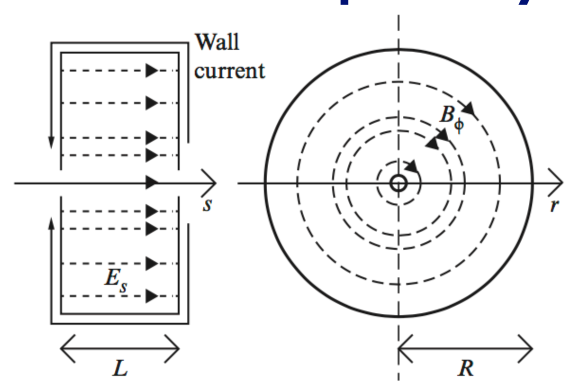


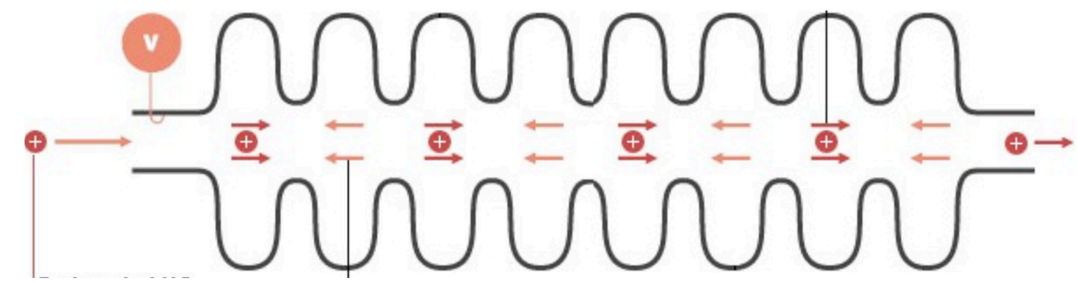
accelerate, bend, focus …

- only charged particles can be accelerated: p, $\bar{p}$, e$^{\pm}$, ($\mu^{\pm}$), ions
  - e.g. **LHC** (**p+p**, p+Pb, Pb+Pb); Tevatron (p$\bar{p}$); LEP, PEP, KEKB (e$^+$e$^-$); RHIC (ions); FAIR (p-ions)
- acceleration by radiofrequency

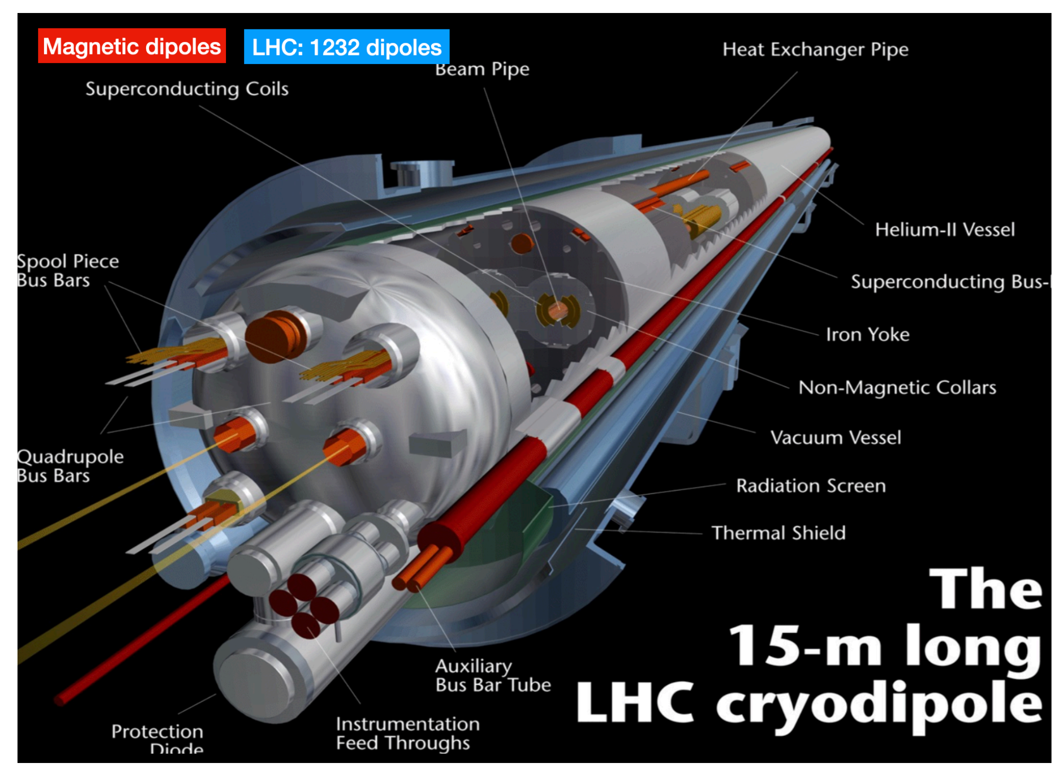
$$\mathbf{F} = q(\mathcal{E} + \mathbf{v} \times \mathbf{B})$$

$$\mathbf{E} = -\nabla\varphi - \frac{\partial \mathbf{A}}{\partial t}$$

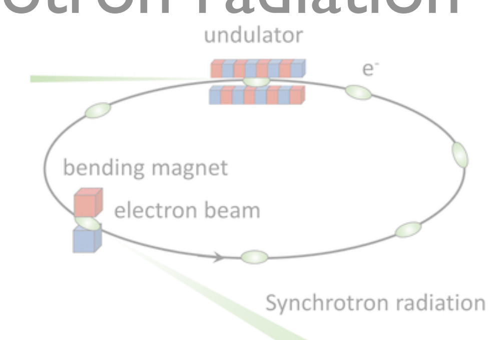


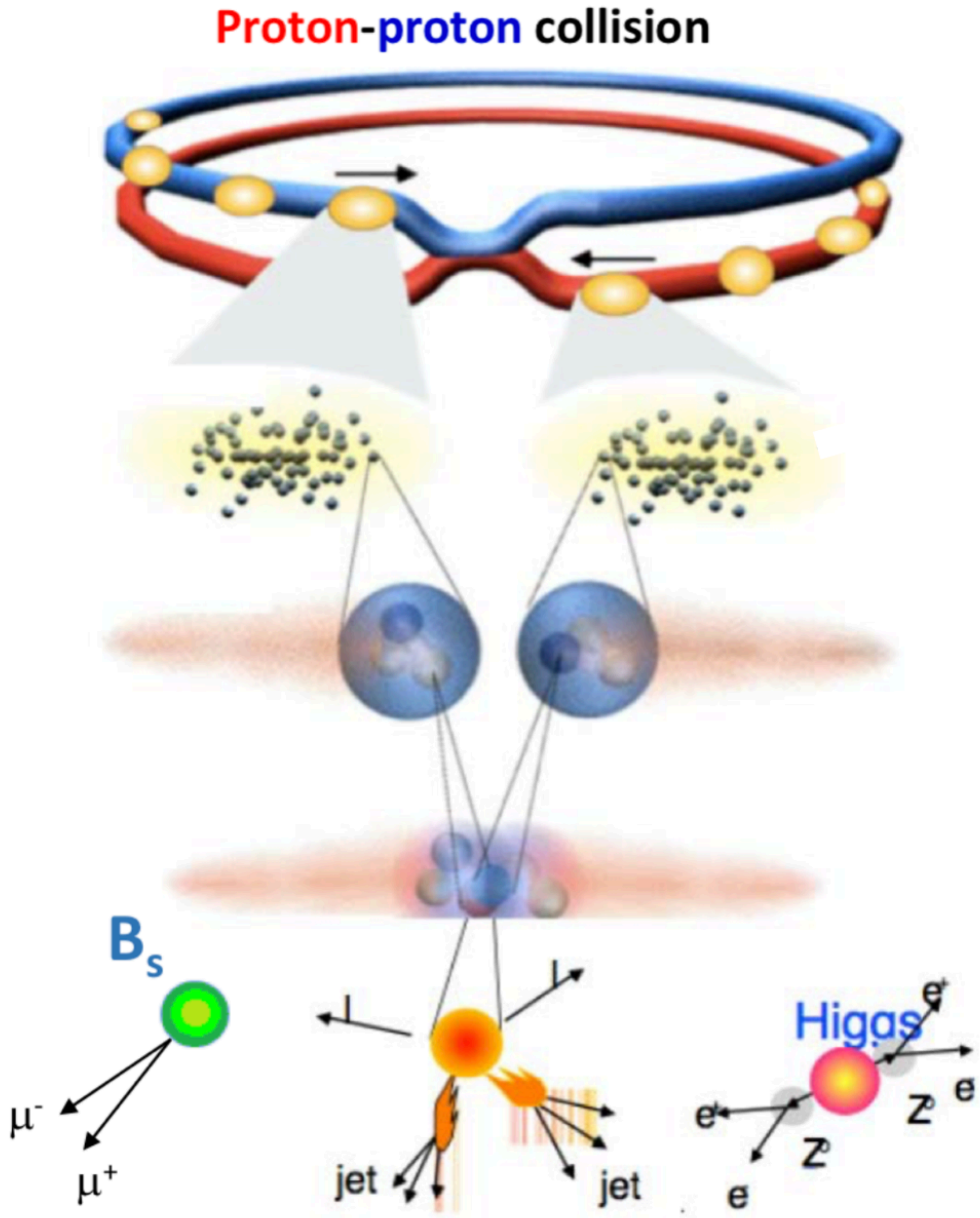


- trajectory bending via dipoles
- beam focusing via quadrupoles



- accelerating particles radiate
  - synchrotron radiation





Some specs:

Beam structure

circumference: 27 km
bunches: 3564 + 3564
protons / bunch: 10^{11}

Bunch Crossing $4\ 10^{7}$ Hz

Proton Collisions 10^{9} Hz

Parton Collisions

4000 $W^{\pm}$ s / sec

1200 Z^{0} s / sec

17 $t\bar{t}$ s / sec

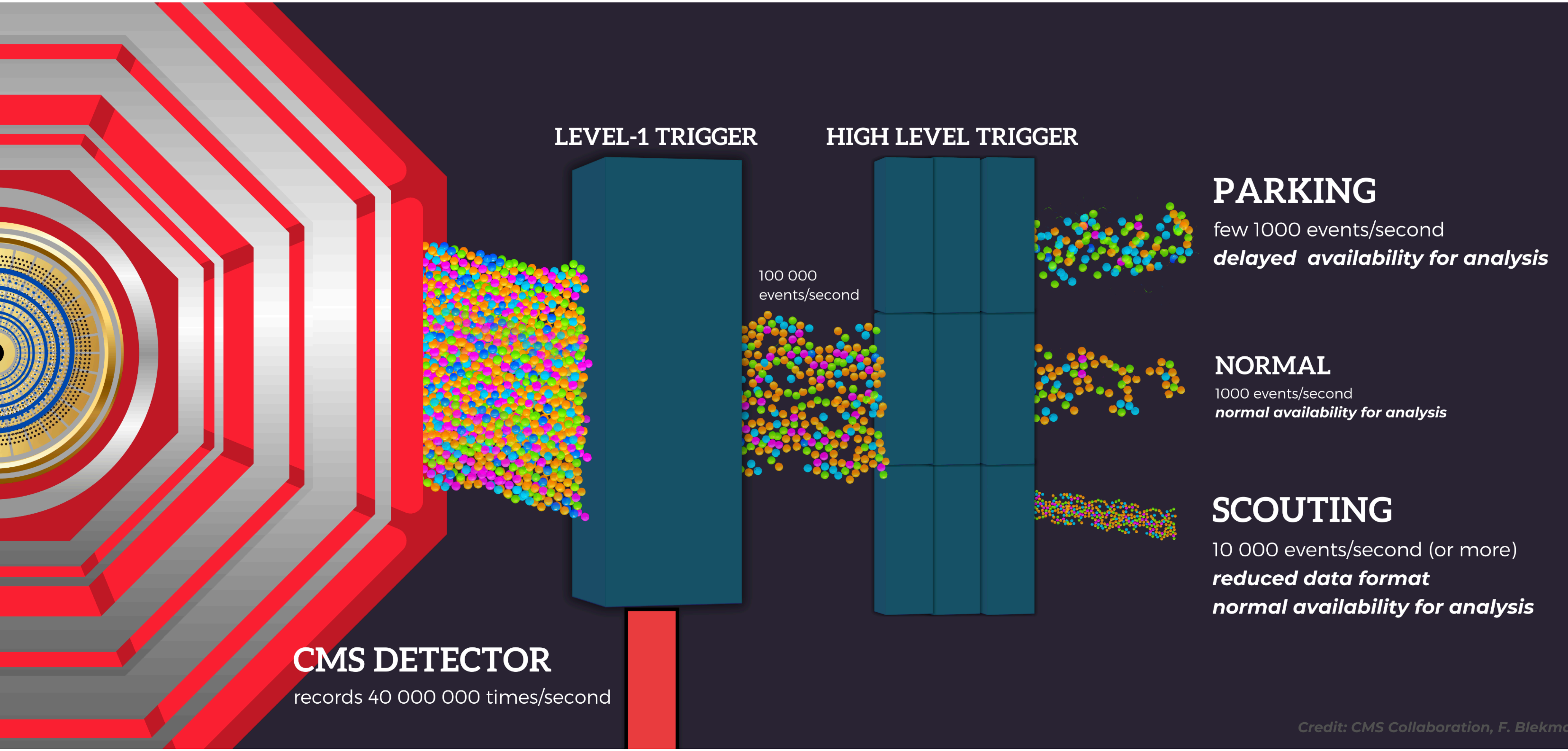
1 h^{0} s / sec

New Particle Production 10^{-5} Hz

We're interested in **rare** events

➥ Real-time filtering: **Trigger**

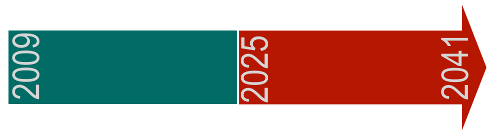
Filtering collision events



novel data-taking paradigms
Run3 & HL-LHC

enhance physics sensitivity

LHC — schedule ("half-time")



↪ we're at the middle of the LHC journey

- Accumulate larger datasets
  ↪ precision measurements, rarer processes
- **Enhance apparatuses**
  ↪ improved detectors needed for HL environment
- **Extend physics** scope
  ↪ enhance acceptance for SM & BSM, new detectors

Physics sensitivity

Observed in the data | Driven by the machine | Driven by the detector

maximize sensitivity

stat. ∝ √N

$$\mathcal{N} = \sigma \times \mathcal{L} \times \mathcal{A} \times \epsilon$$

Cross section

for a given physics process
∝ collision energy, √s

rare processes = small σ
↪ require large Lumi. + Eff

Luminosity

Integrated:
increases ~linearly with time
challenge: manage large datasets

Instantaneous:
increases with upgraded machine
challenge: manage pileup

Acceptance

Geometric:
Extend detector coverage

Kinematic:
Extend sensitivity to low p_T

Improve with upgraded detector and data acquisition

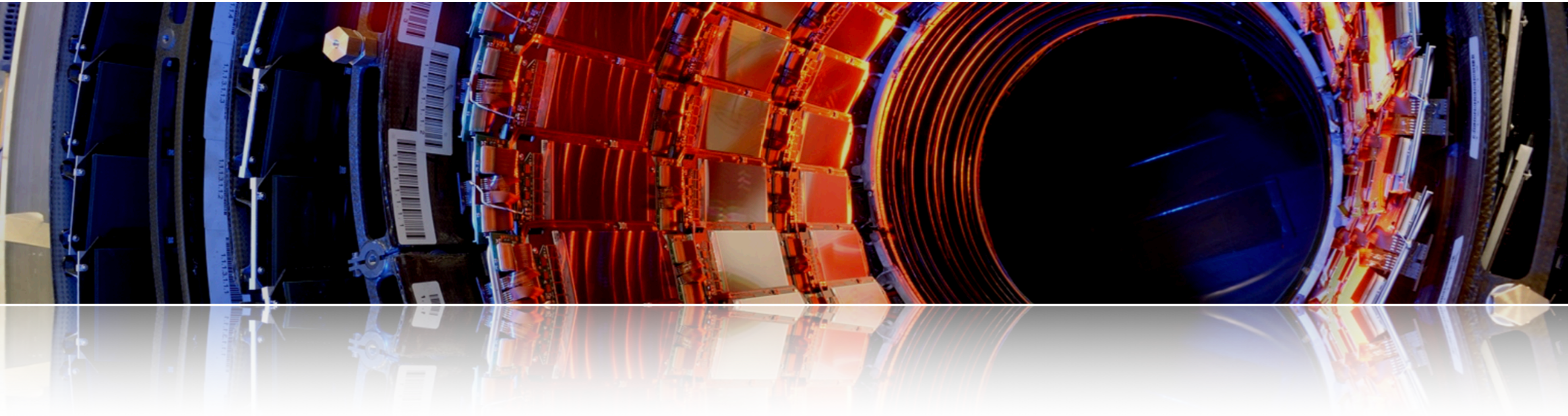
Efficiency

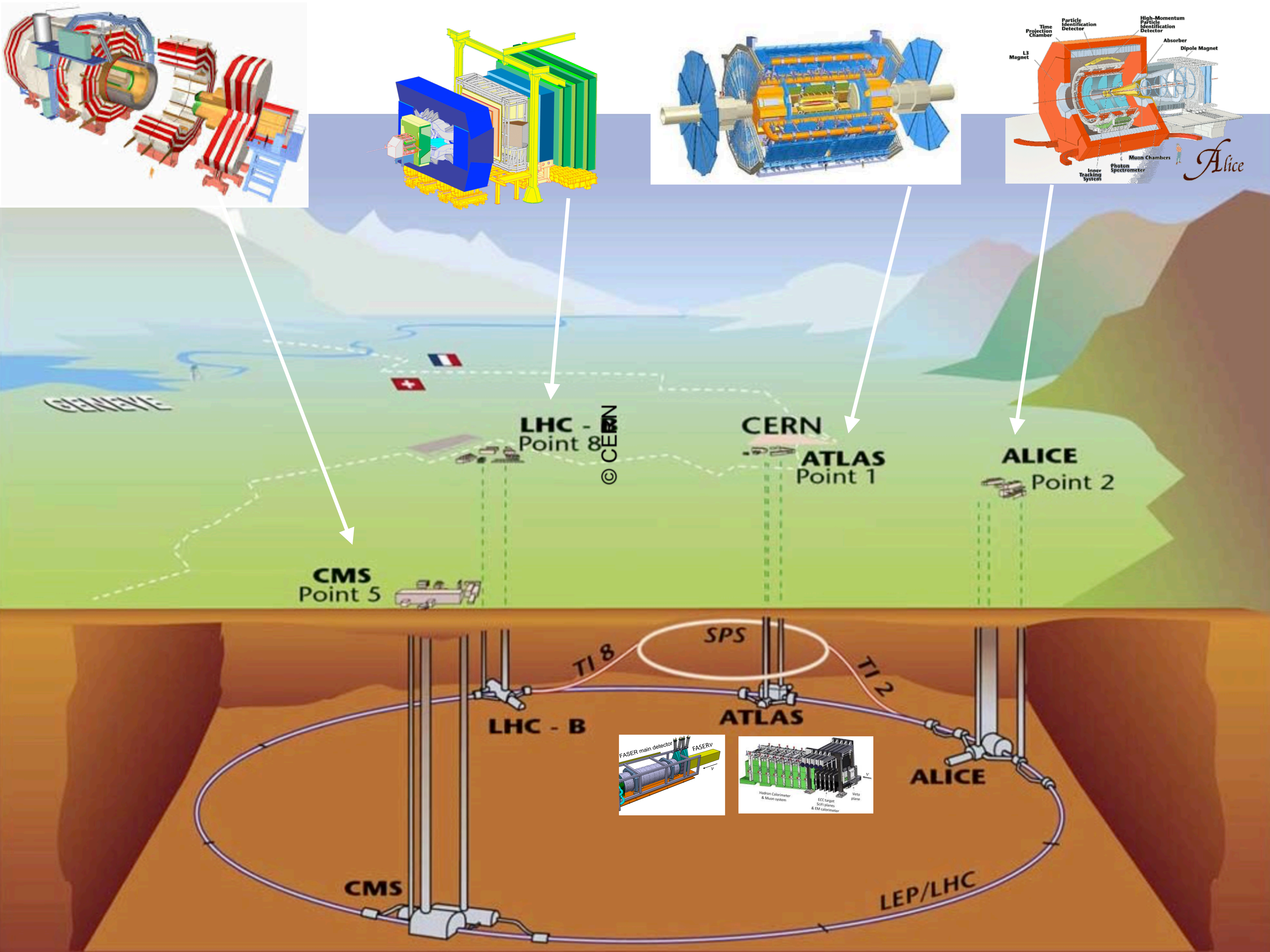
Trigger / DAQ
Physics object Reco. & ID
Background rejection

Improve with upgraded detector and analysis methods (ML)

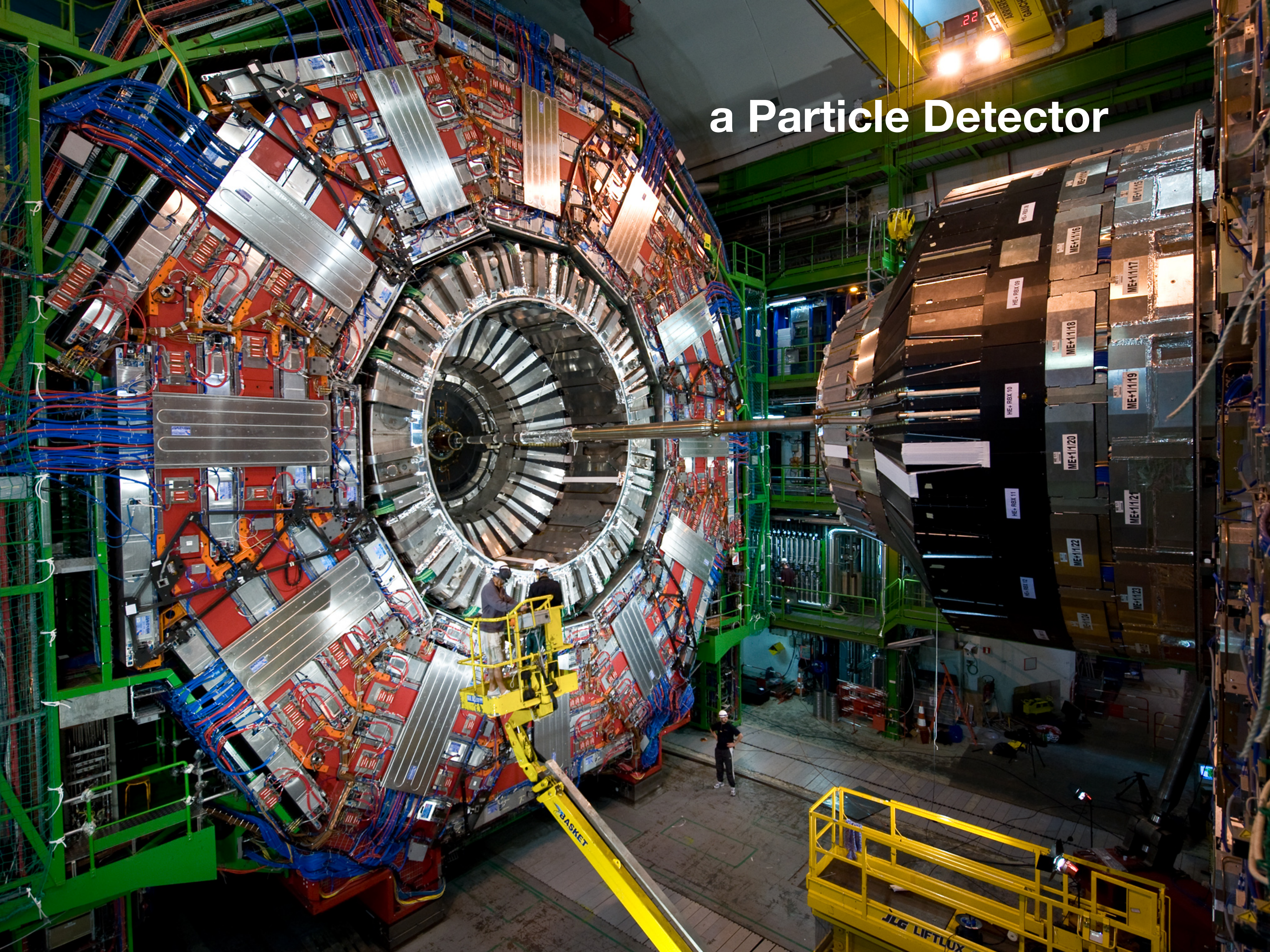
- physics reach determined by:
  - Collision **energy** (√s) — how deep can we probe matter
  - **Luminosity** (L) — quantifies the collision rate (increase!)
  - Detector **acceptance** and efficiency (improve/upgrade!)

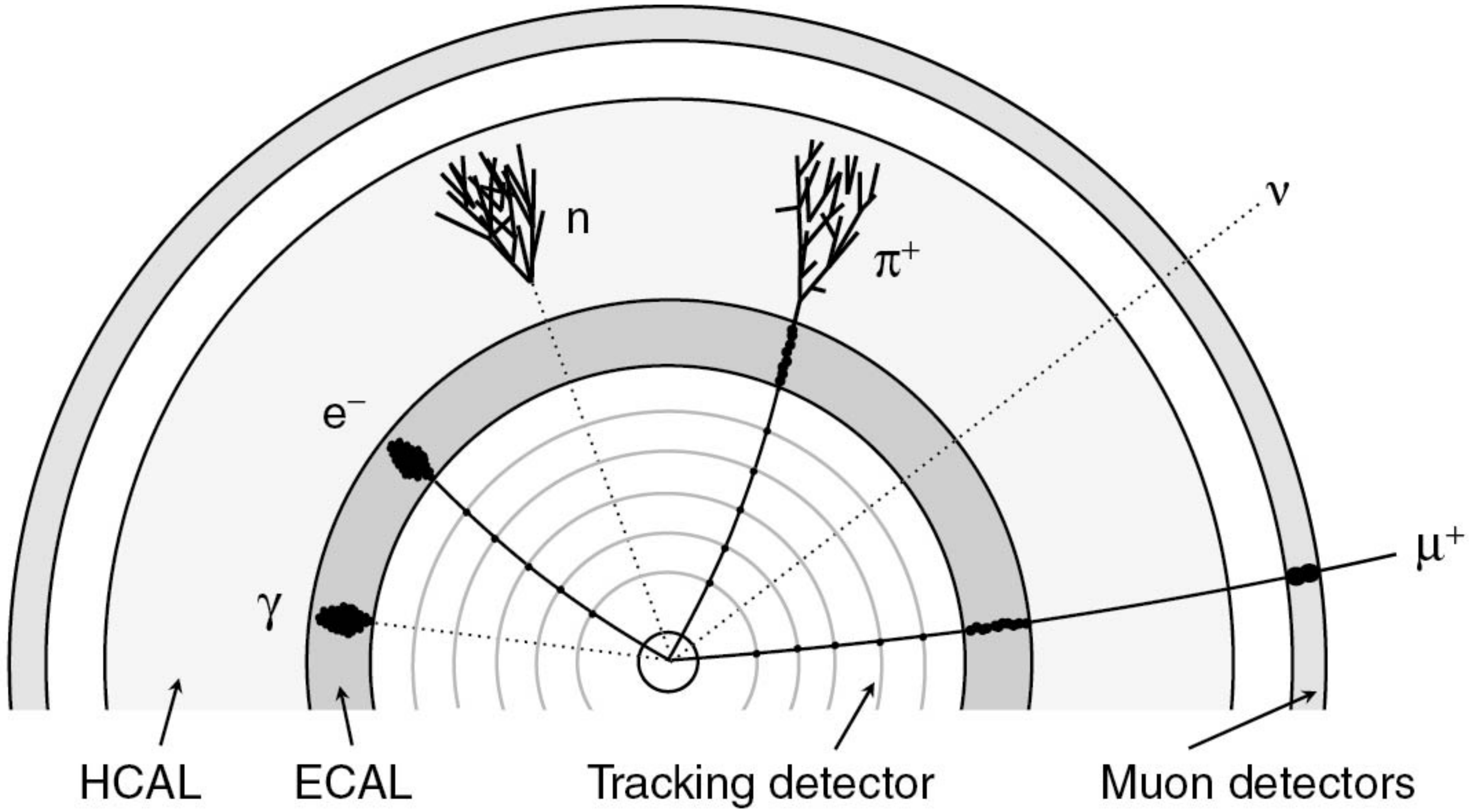
The detectors





Time Projection Chamber
Particle Identification Detector
High-Momentum Particle Identification Detector
L3 Magnet
Absorber
Dipole Magnet
Muon Chambers
Inner Tracking System
Photon Spectrometer
Alice
GENEVE
LHC - B
Point 8
© CERN
CERN
ATLAS
Point 1
ALICE
Point 2
CMS
Point 5
SPS
TI 8
TI 2
LHC - B
ATLAS
ALICE
CMS
LEP/LHC
FASER main detector
FASERν

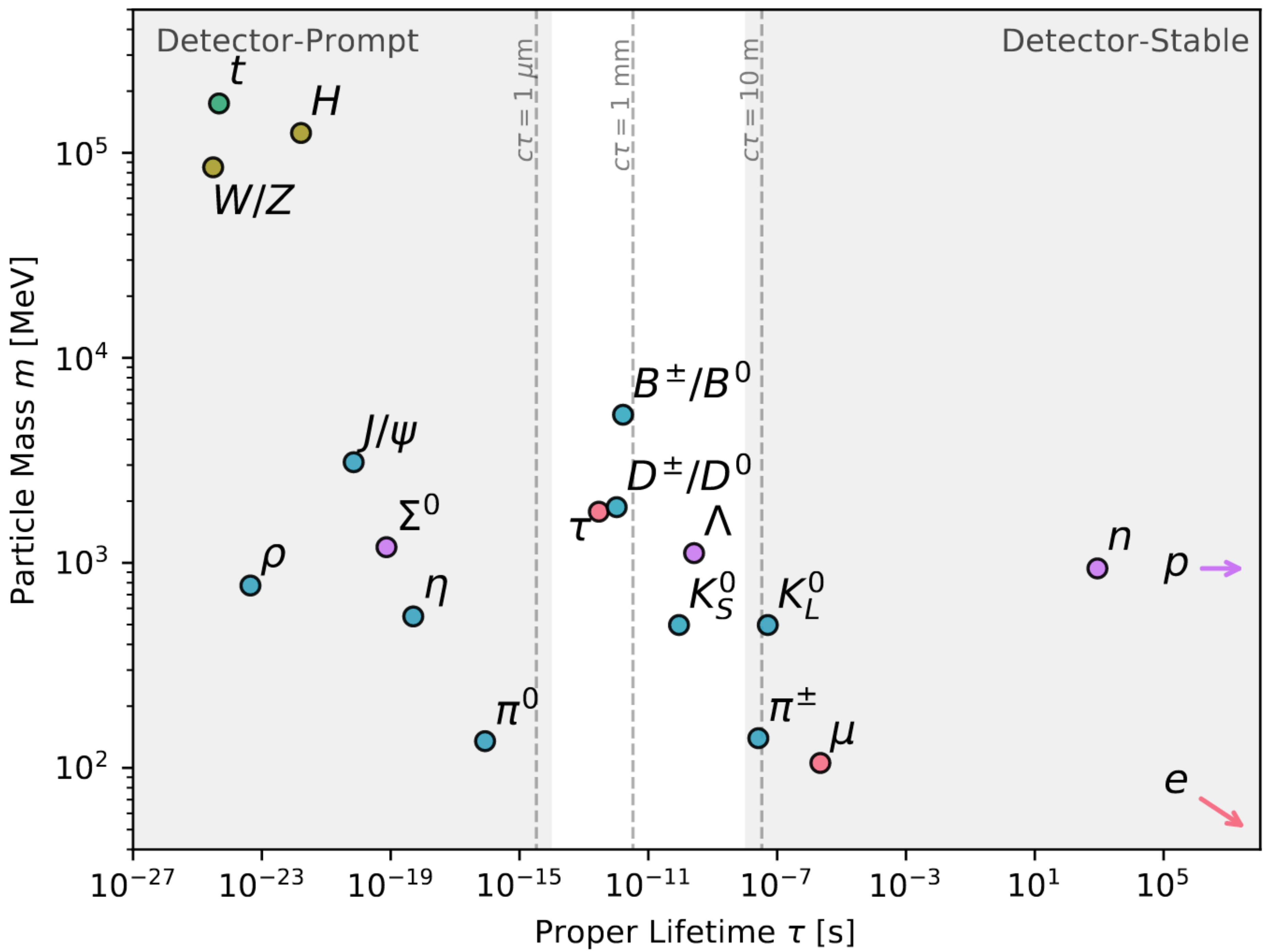

a Particle Detector
BASKET
JLG LIFTLUX



calorimeters:
measure particle's
energy by absorbing it

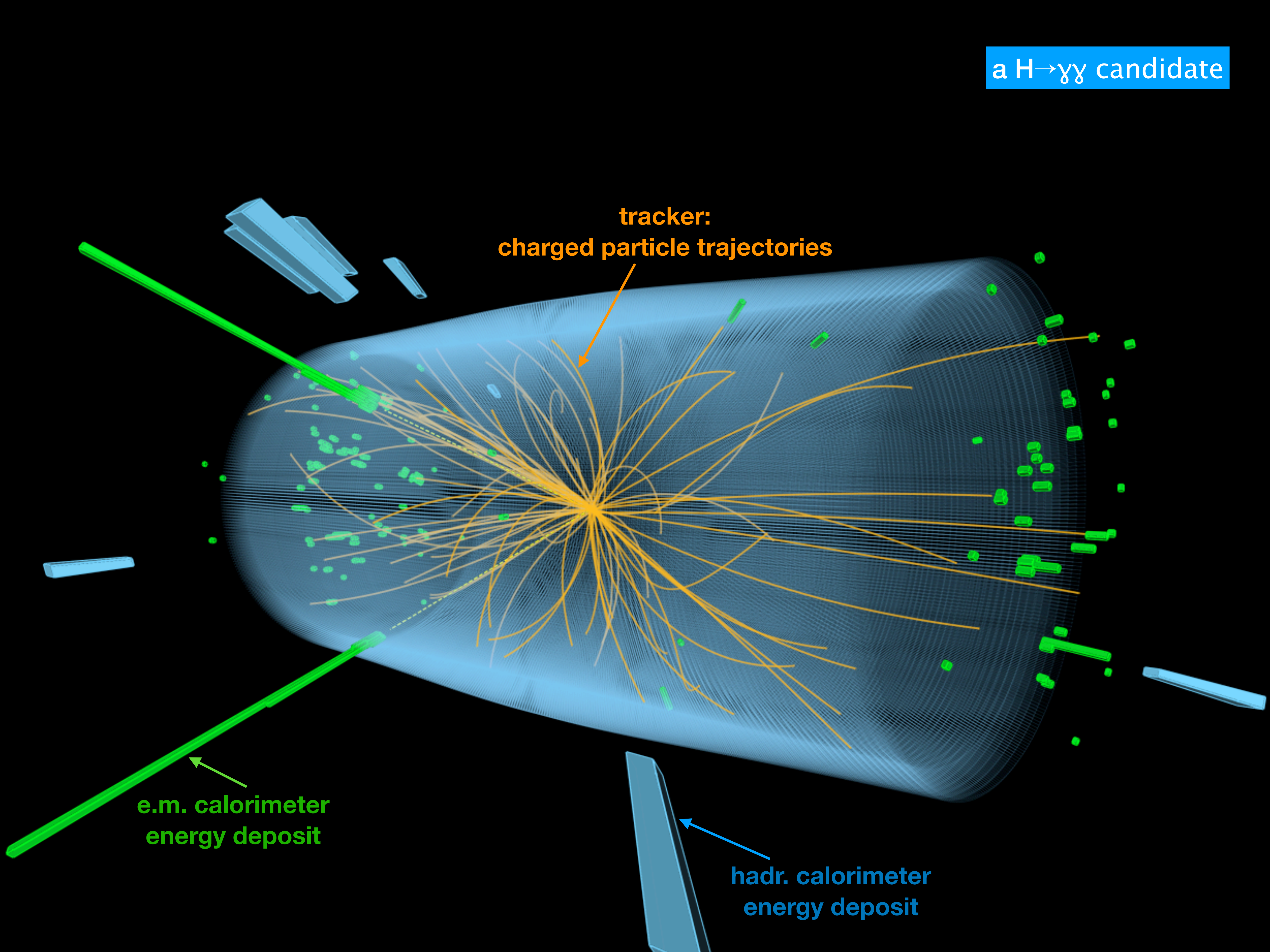
trackers:
detect trajectory
of charged particles

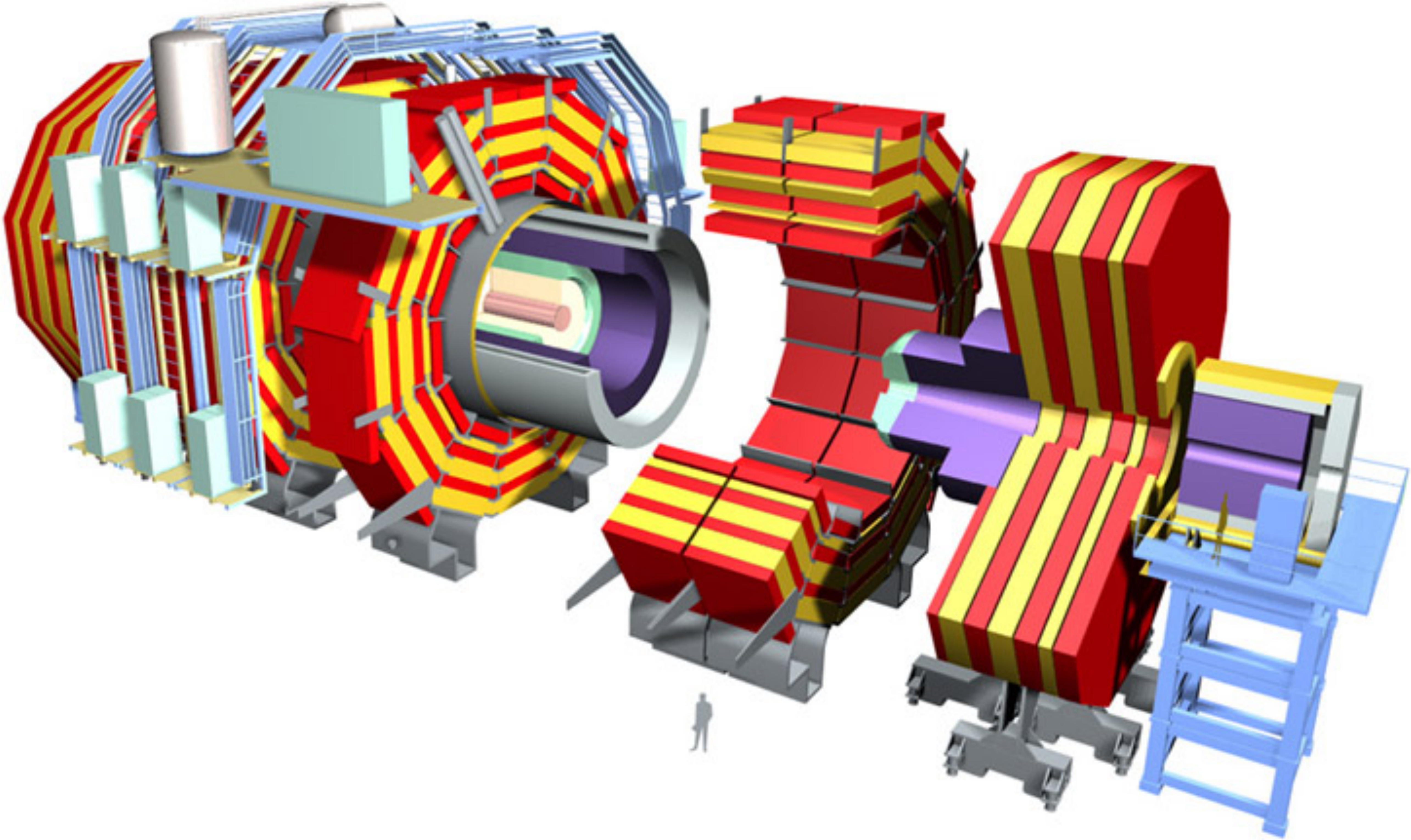
muon chambers:
muons reach outer
detector layers

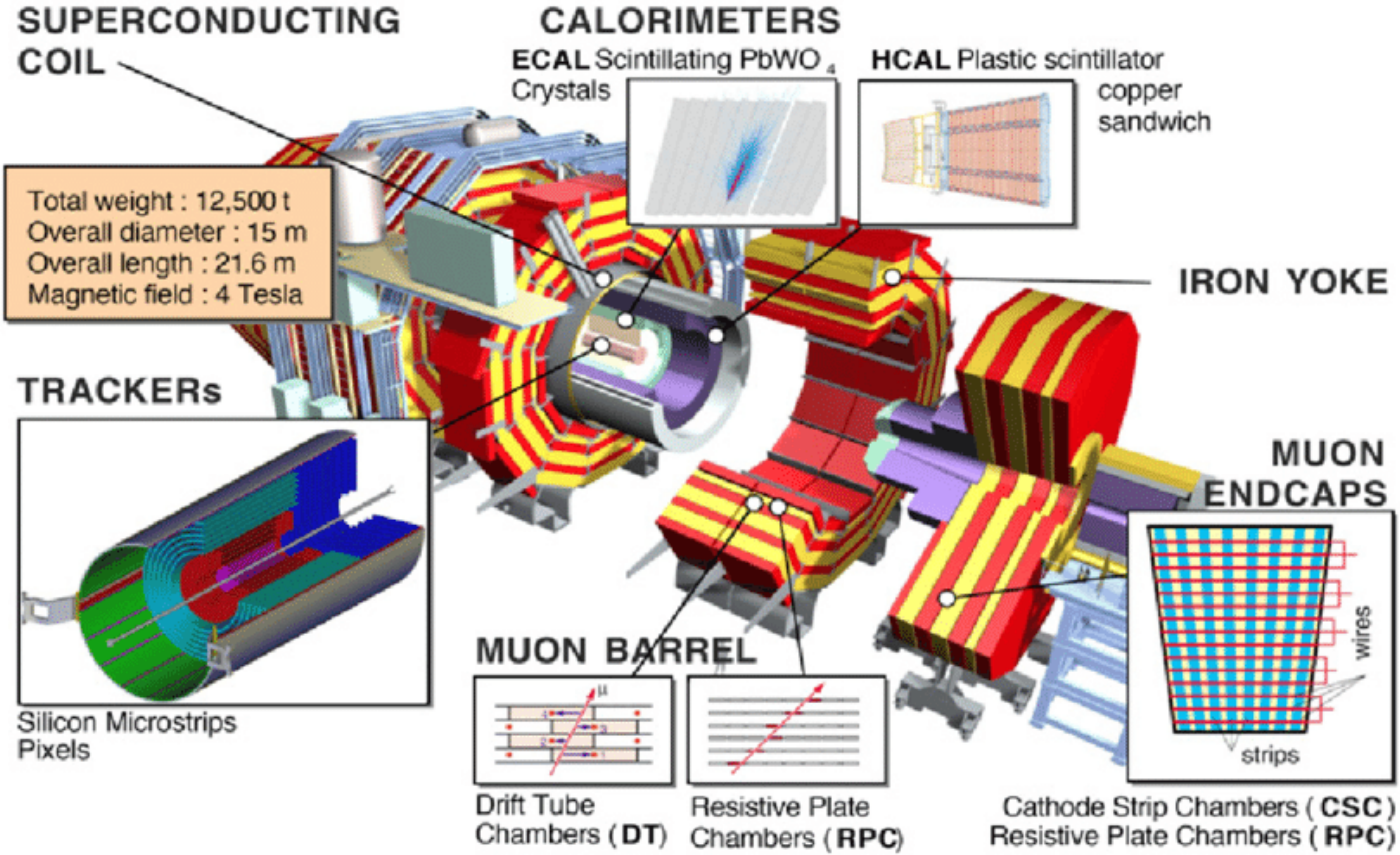


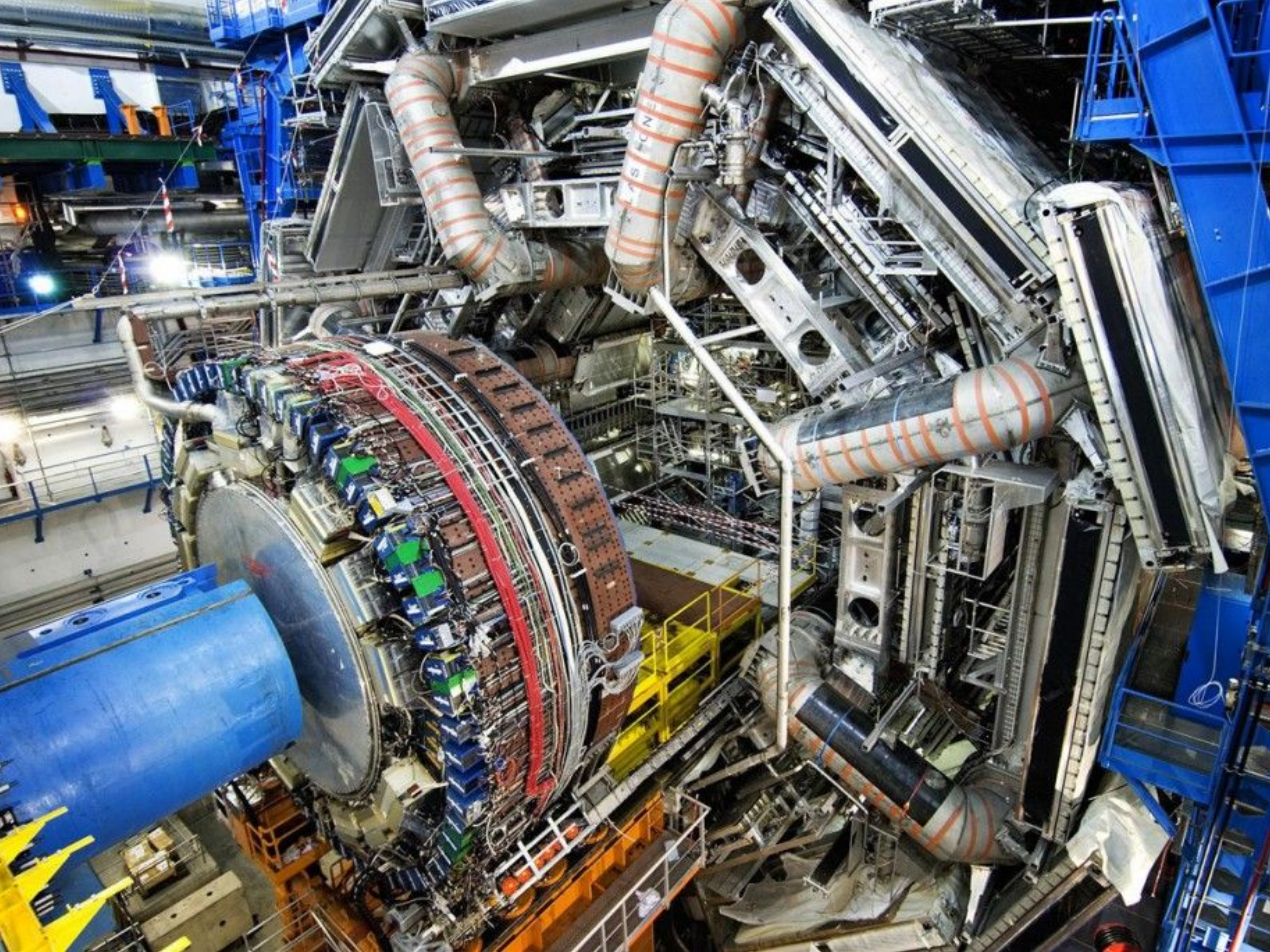
Only *quasi*-sable particles are directly detectable: e, μ, γ, π, K, p, n

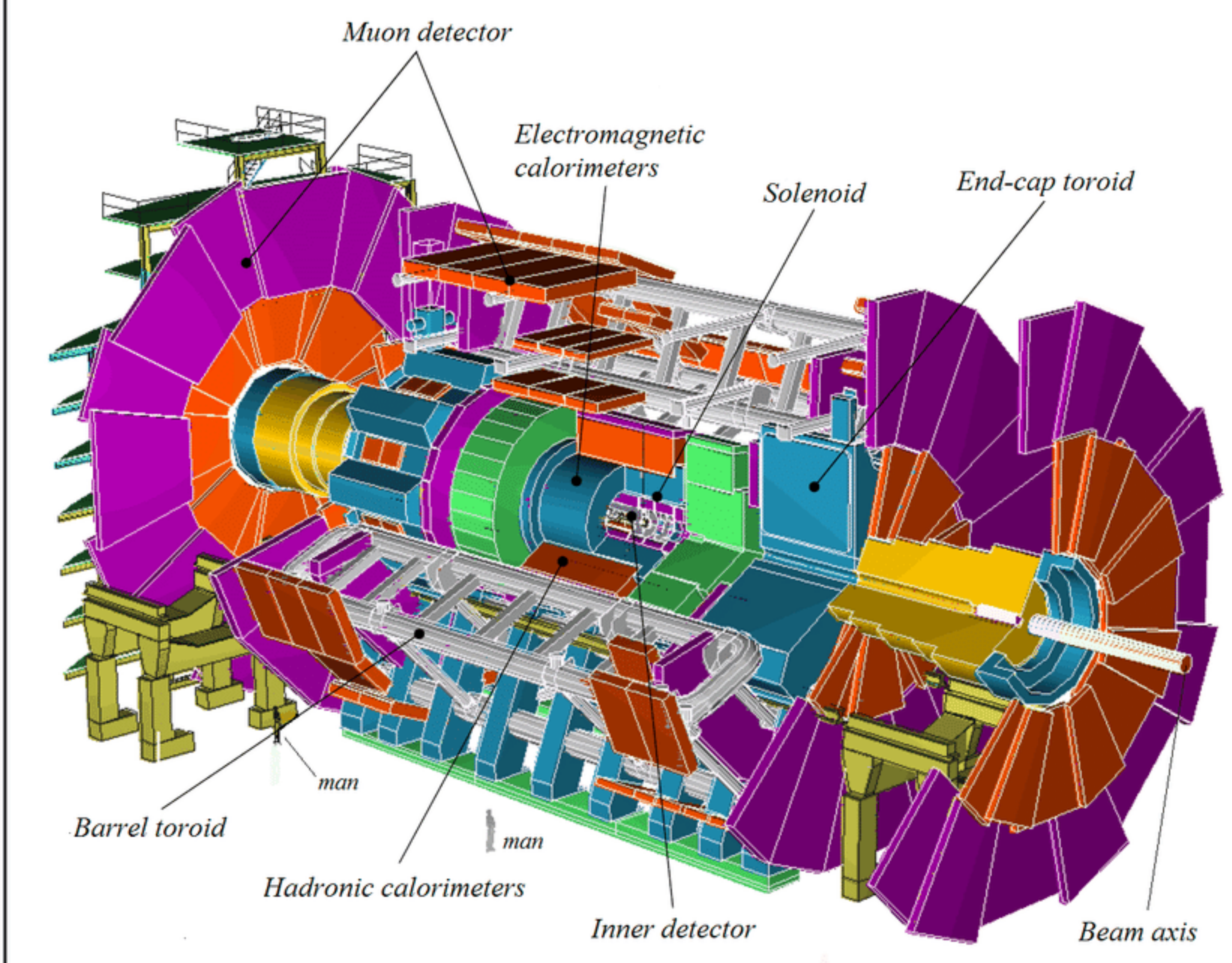
All other, unstable particles decay, and their (stable) final states are detected.


a H→γγ candidate
tracker:
charged particle trajectories
e.m. calorimeter
energy deposit
hadr. calorimeter
energy deposit



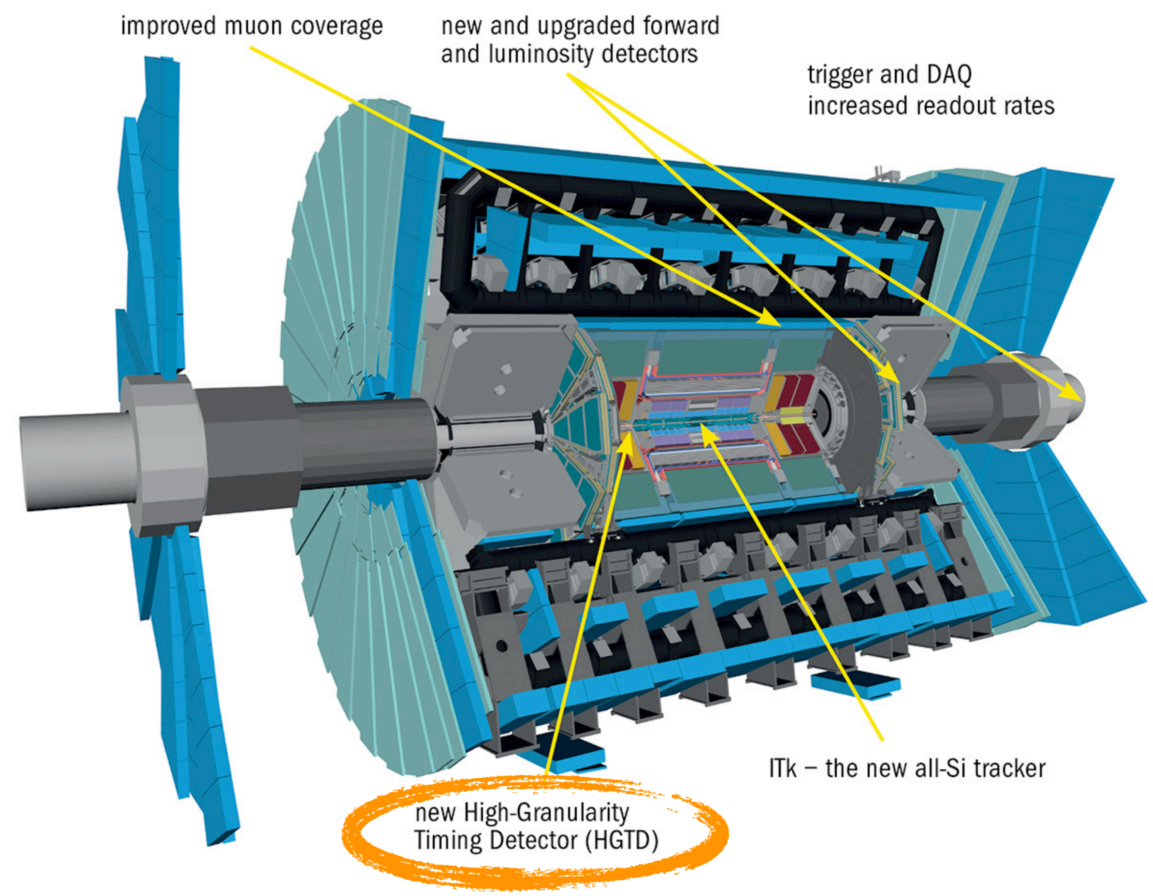

SUPERCONDUCTING COIL
CALORIMETERS
ECAL Scintillating PbWO4 Crystals
HCAL Plastic scintillator copper sandwich
Total weight : 12,500 t
Overall diameter : 15 m
Overall length : 21.6 m
Magnetic field : 4 Tesla
IRON YOKE
TRACKERs
Silicon Microstrips
Pixels
MUON ENDCAPS
MUON BARREL
wires
strips
Drift Tube Chambers (DT)
Resistive Plate Chambers (RPC)
Cathode Strip Chambers (CSC)
Resistive Plate Chambers (RPC)

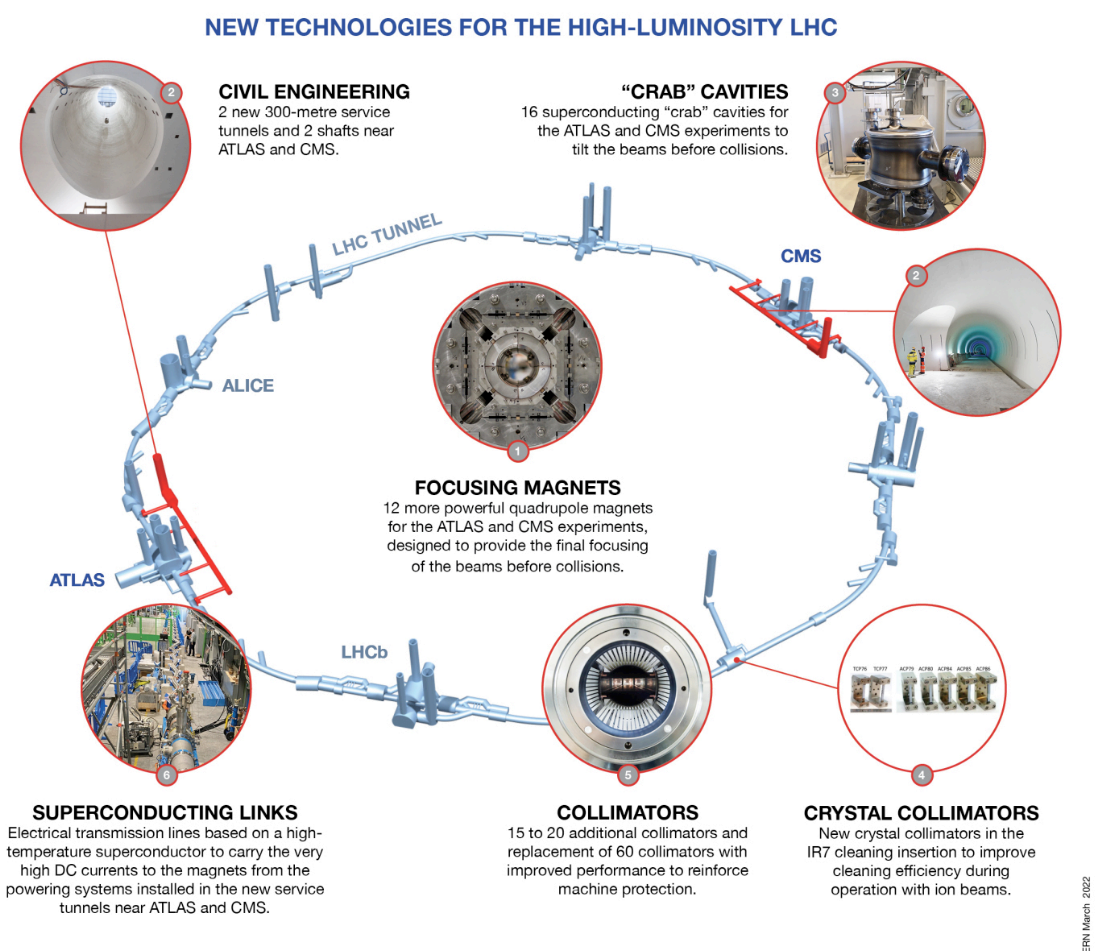


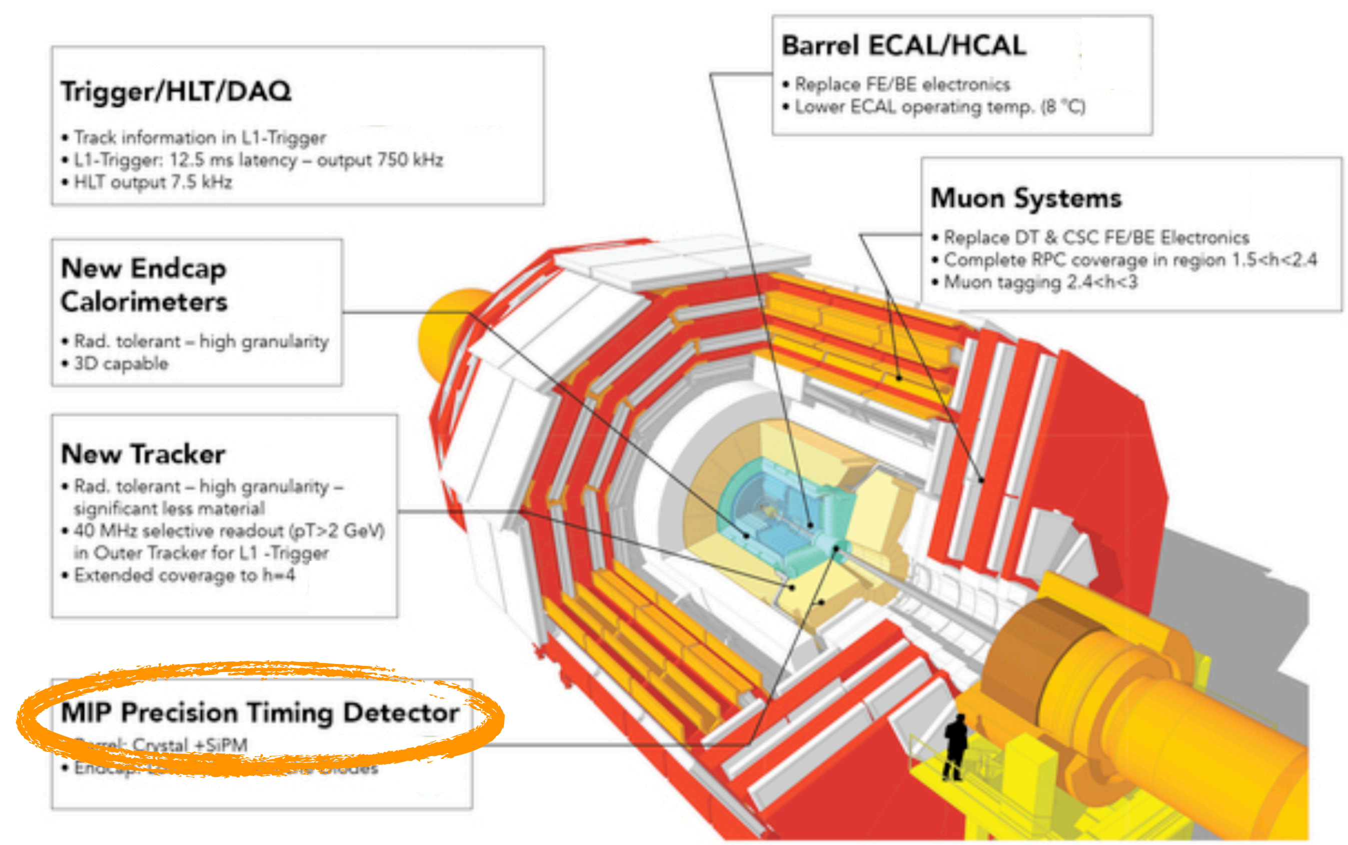

Muon detector
Electromagnetic calorimeters
Solenoid
End-cap toroid
man
Barrel toroid
man
Hadronic calorimeters
Inner detector
Beam axis

High-Luminosity LHC

- an *new*, more intense LHC
- require refurbished detectors!
- upgrade with state-of-the-art technologies
- novel or redesigned detector components
- being advanced now



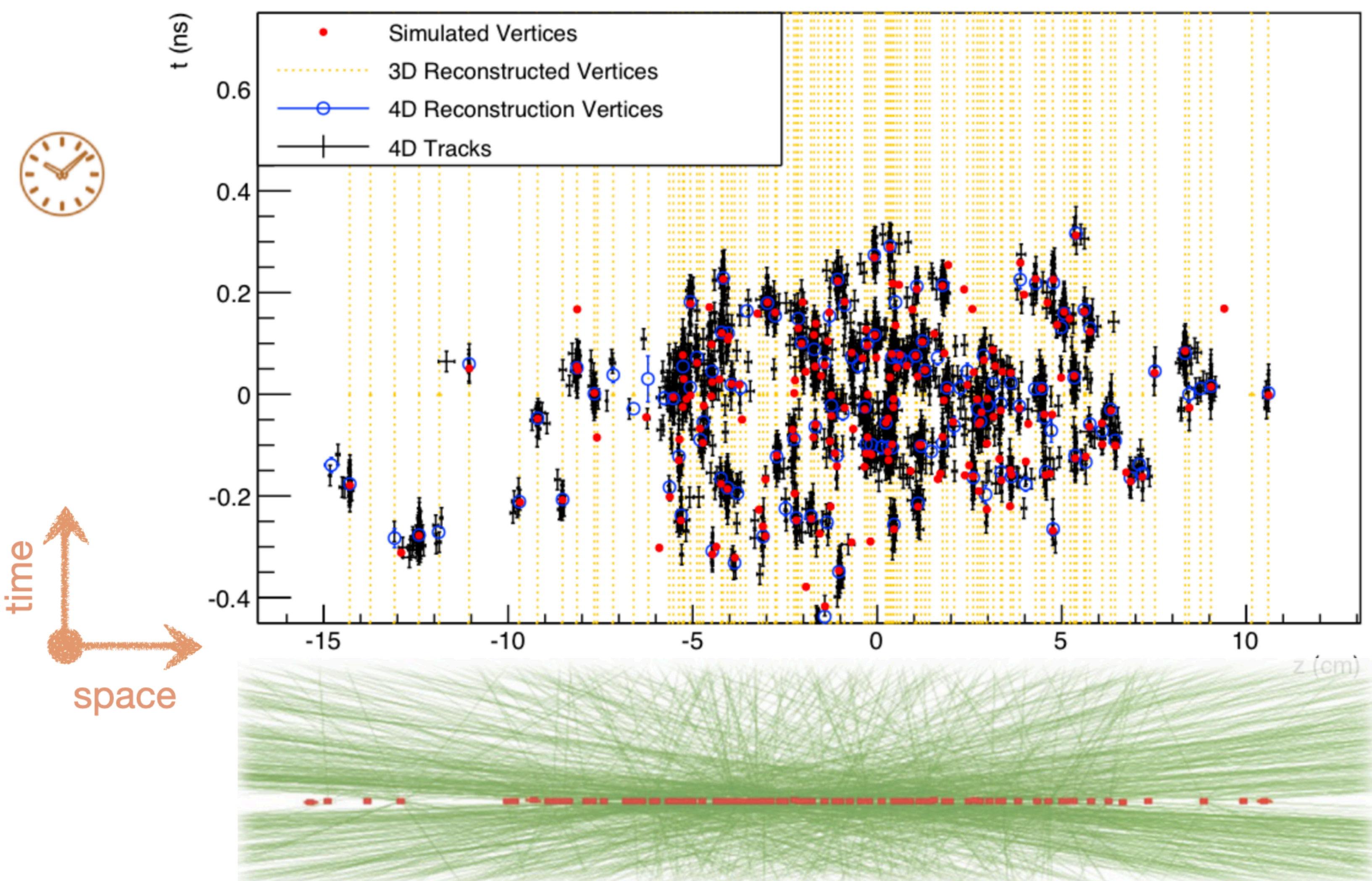


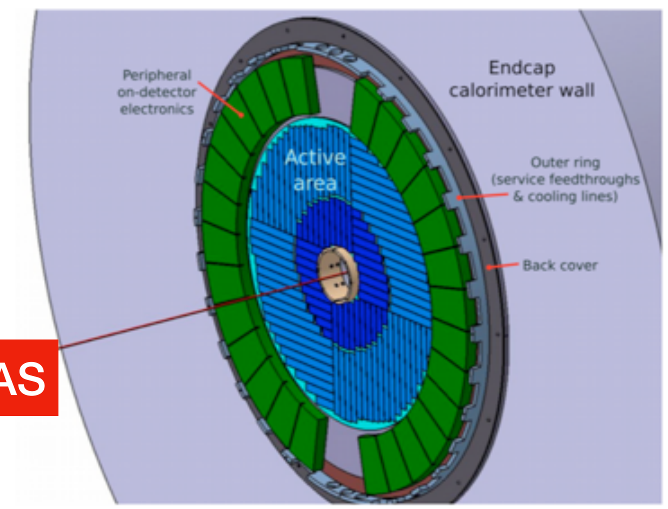


HL-LHC: adding precision timing detectors

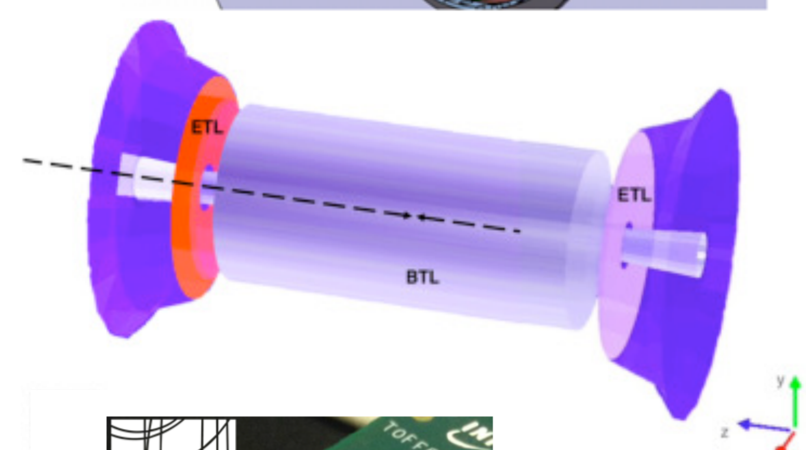
Example challenge for the high-luminosity LHC phase: **pile-up**

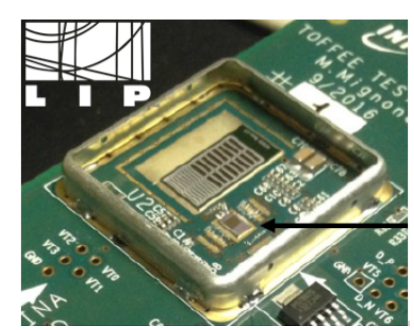
- can expect up to 200 simultaneous collisions per bunch crossing
- detectors do not have the spacial resolution to distinguish resulting vertices
- solution: add time dimension, i.e. develop novel precision timing detectors





ATLAS

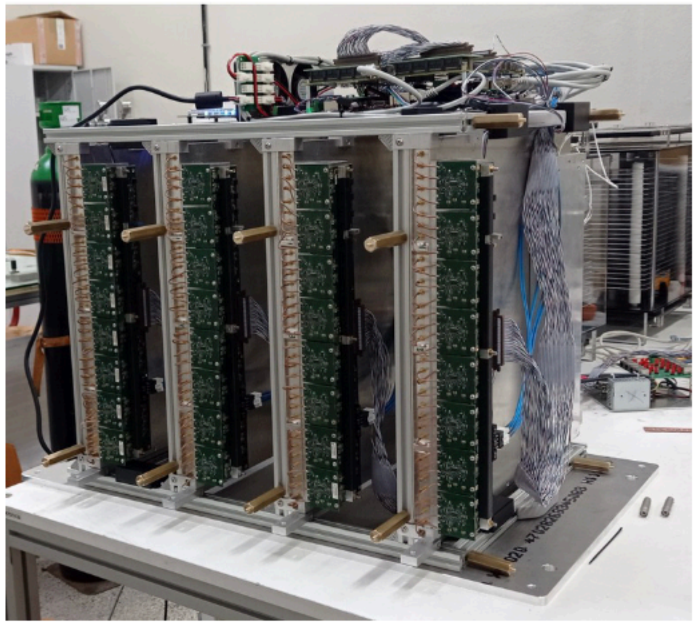


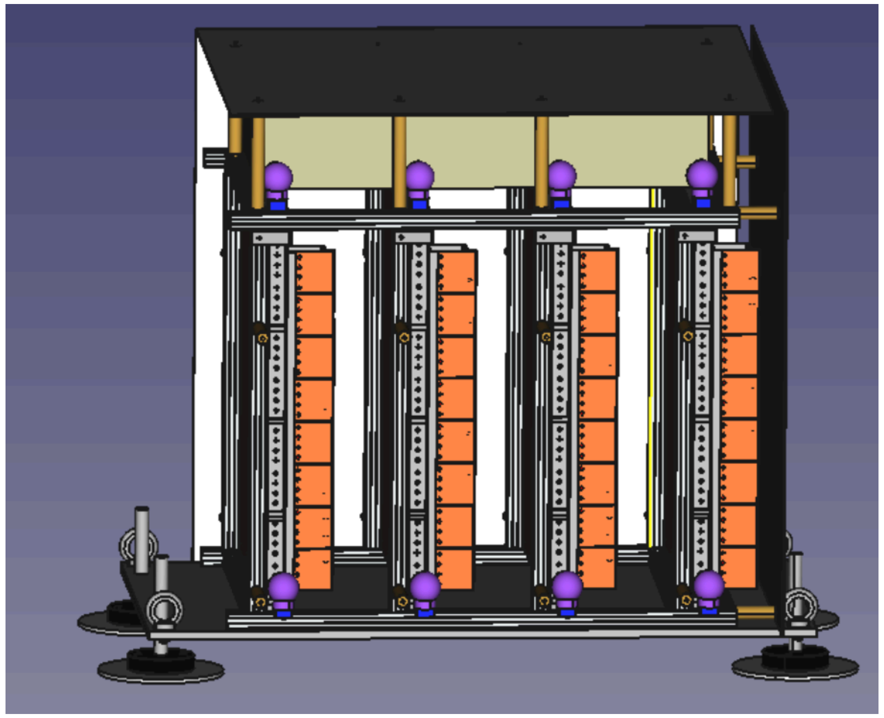


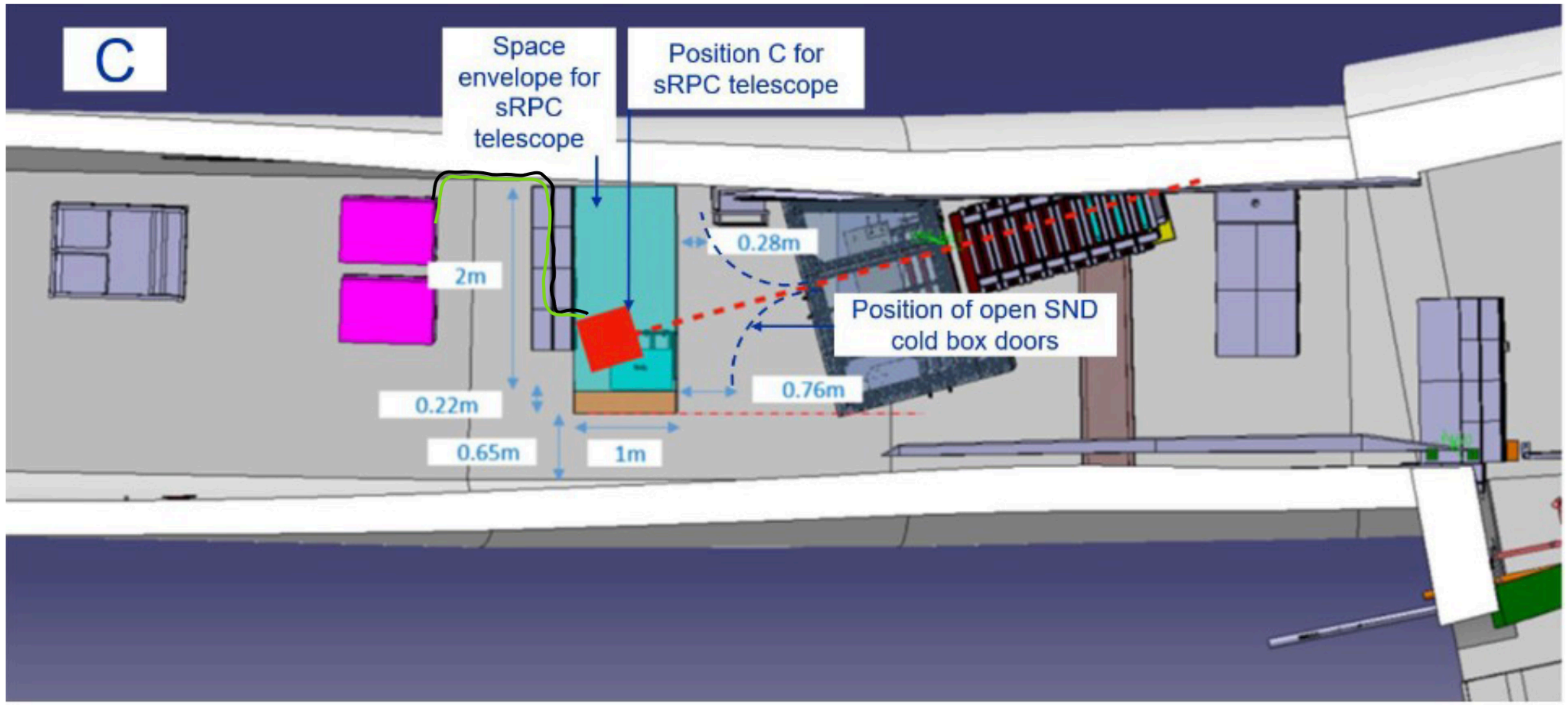
CMS

Run 3: a muon telescope @LHC *(made by LIP)*

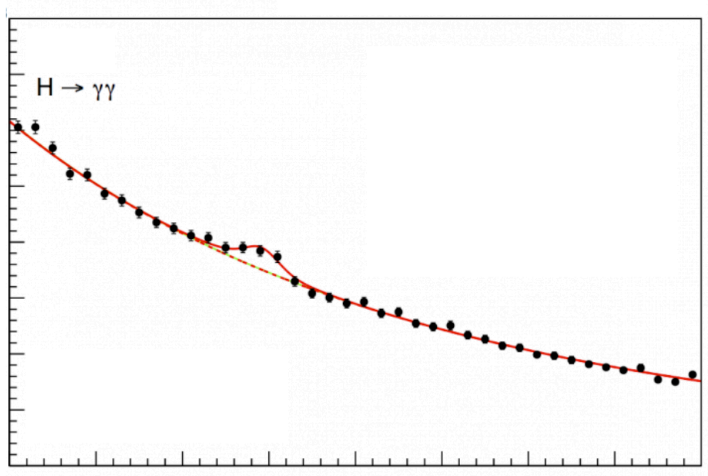
- (Example)
- new detector for measuring **muon flux** at LHC
- establish innovative technology (sRPC), designed and built @LIP, deploying in LHC environment
- being installed in the SND@LHC tunnel this week
- additional uses requested by community, beyond physics measurement (environment, upgrades)



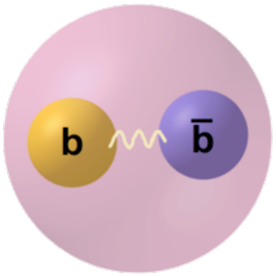




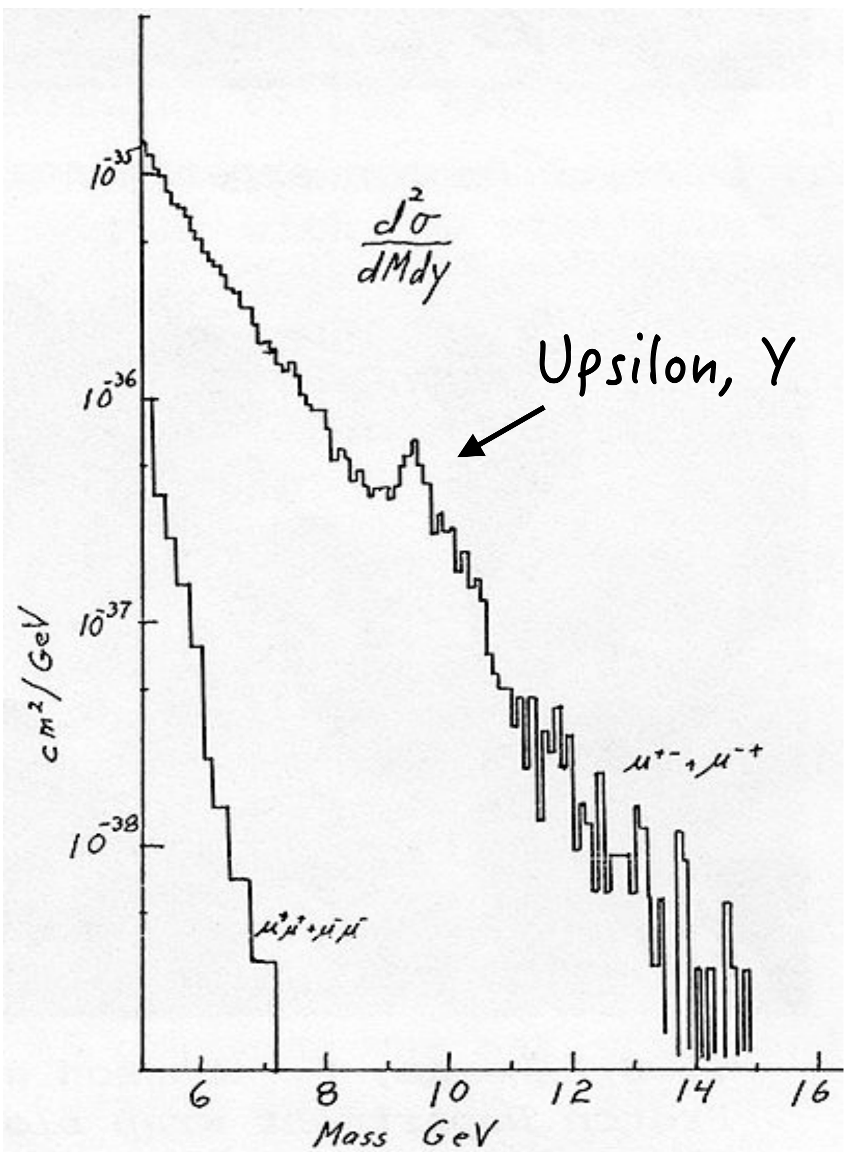
How do we ‘see’ particles?



the SM discovery



1977

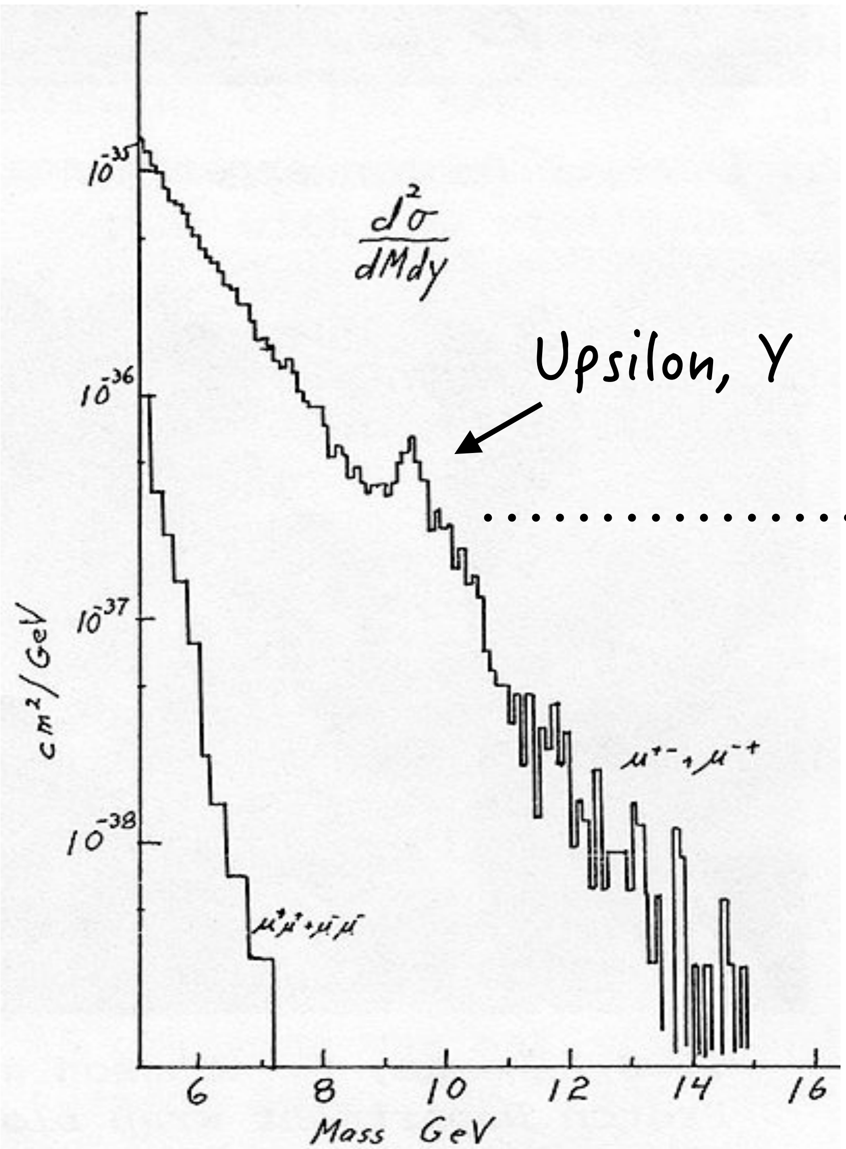


the discovery of the
b quark

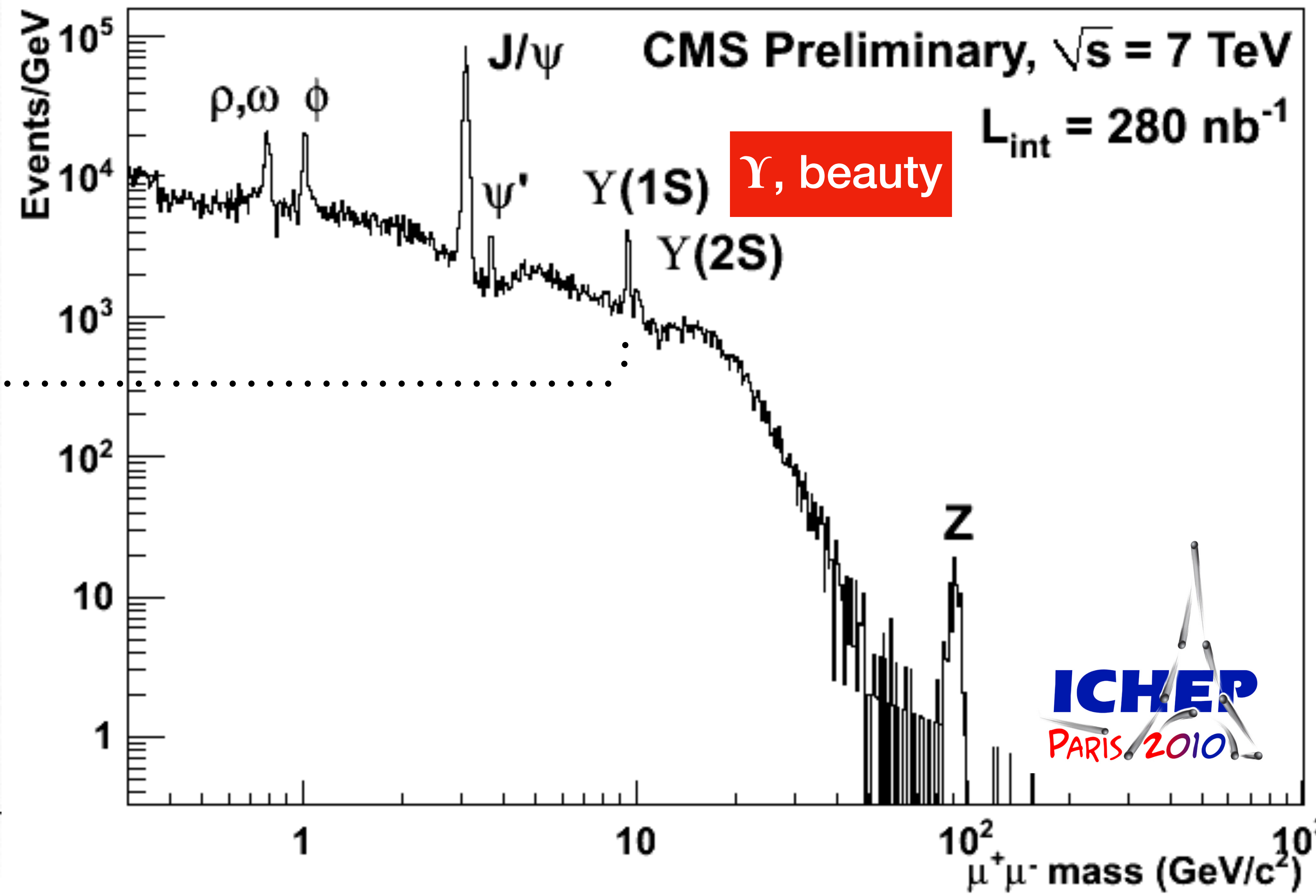
Υ, beauty

the SM *re-*discovery @ LHC

1977

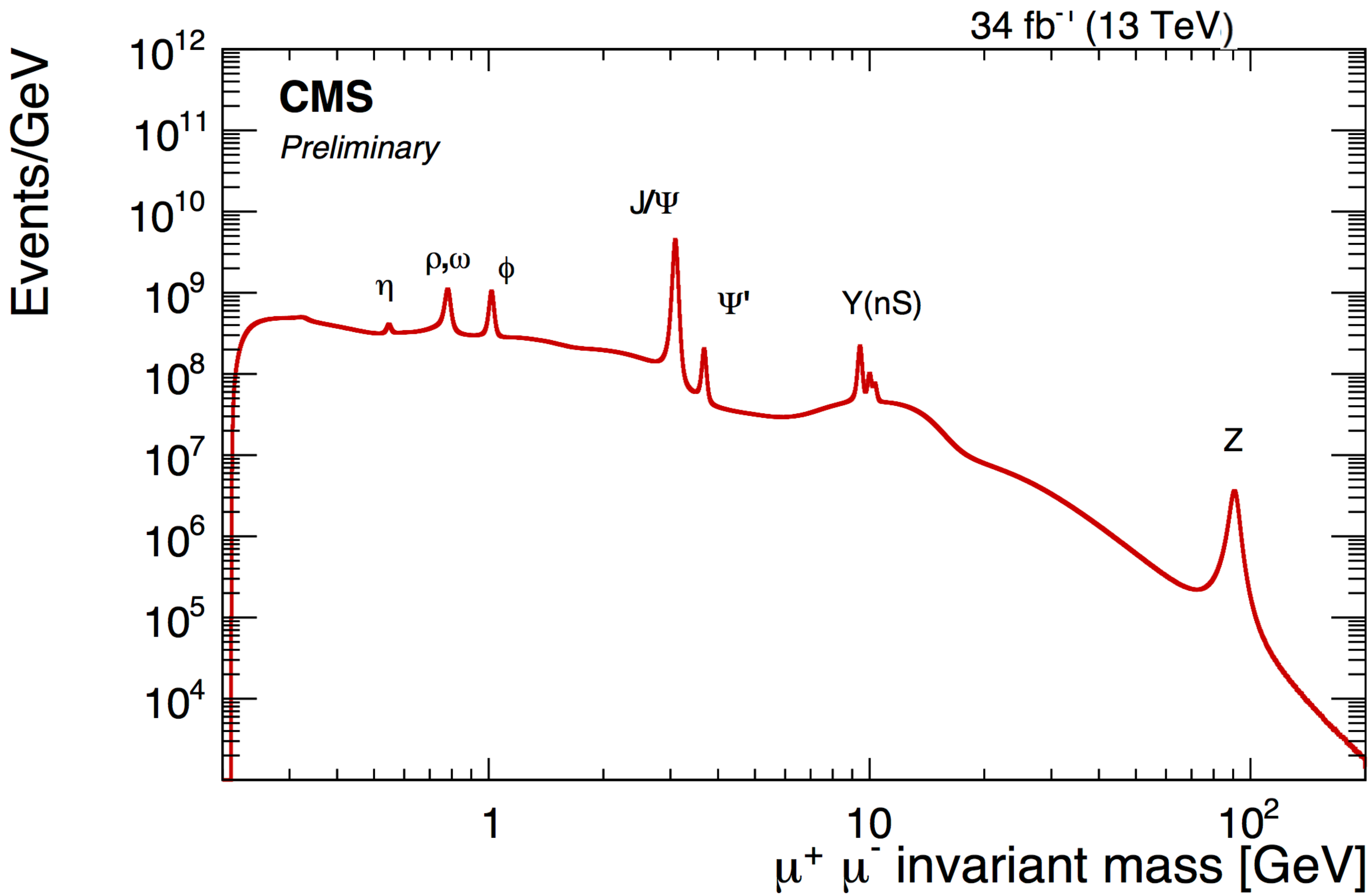


2010

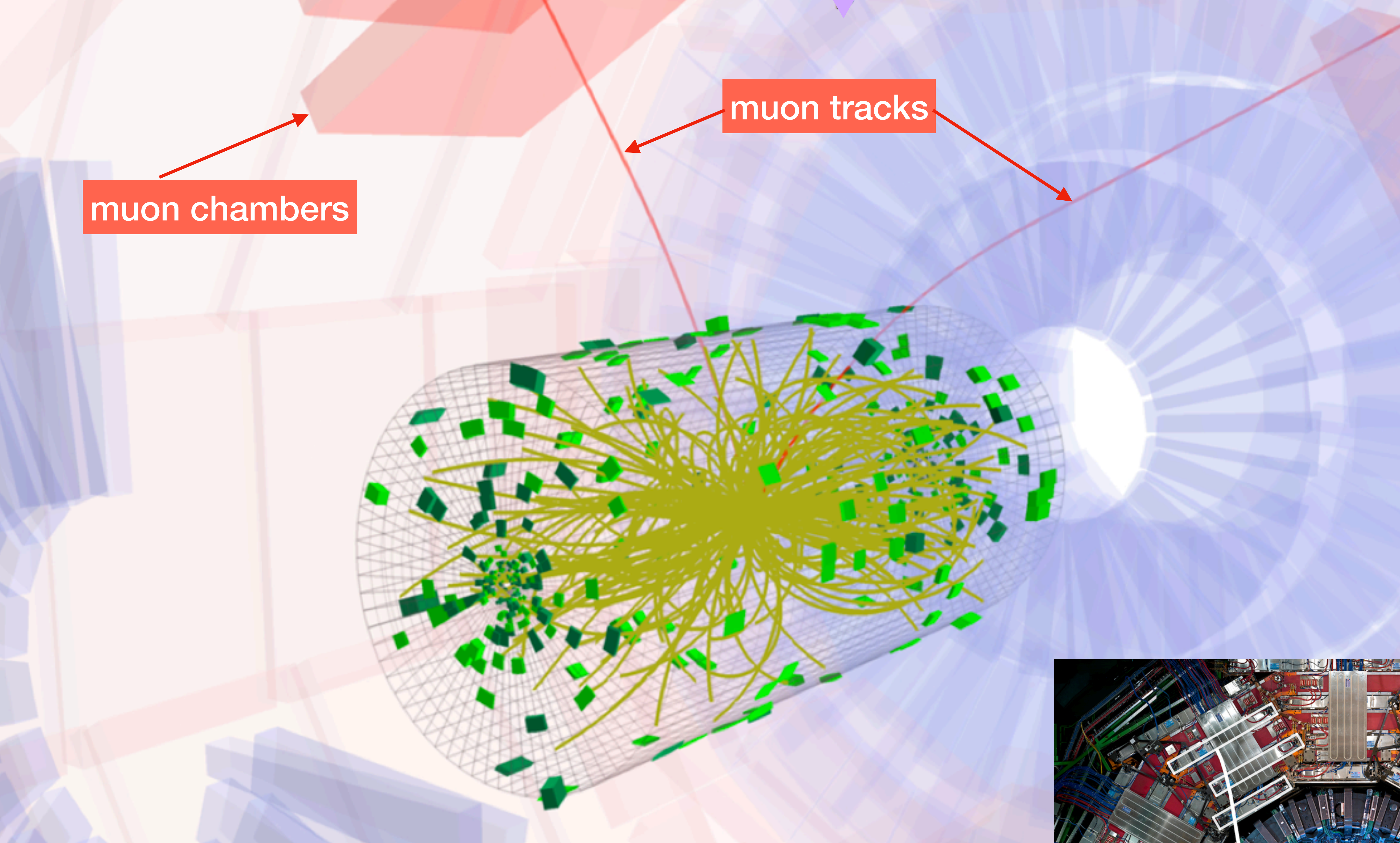


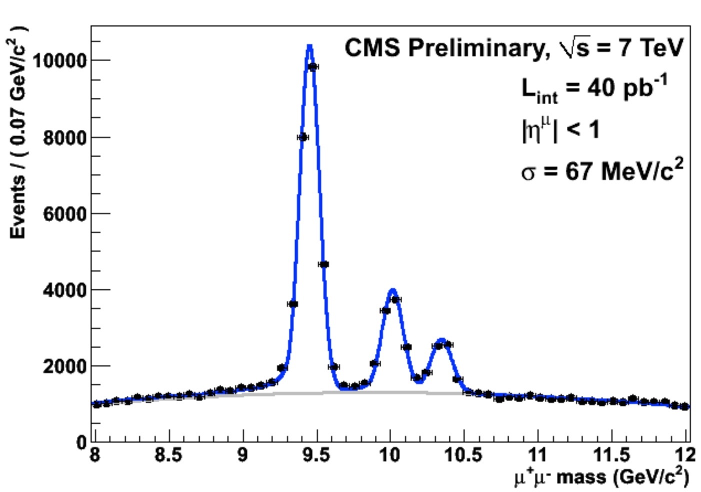
the discovery of the
b quark

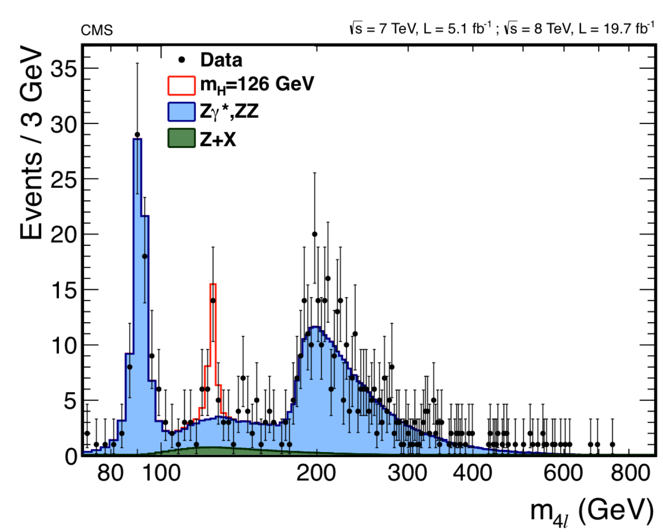
the SM re-discovery @ LHC

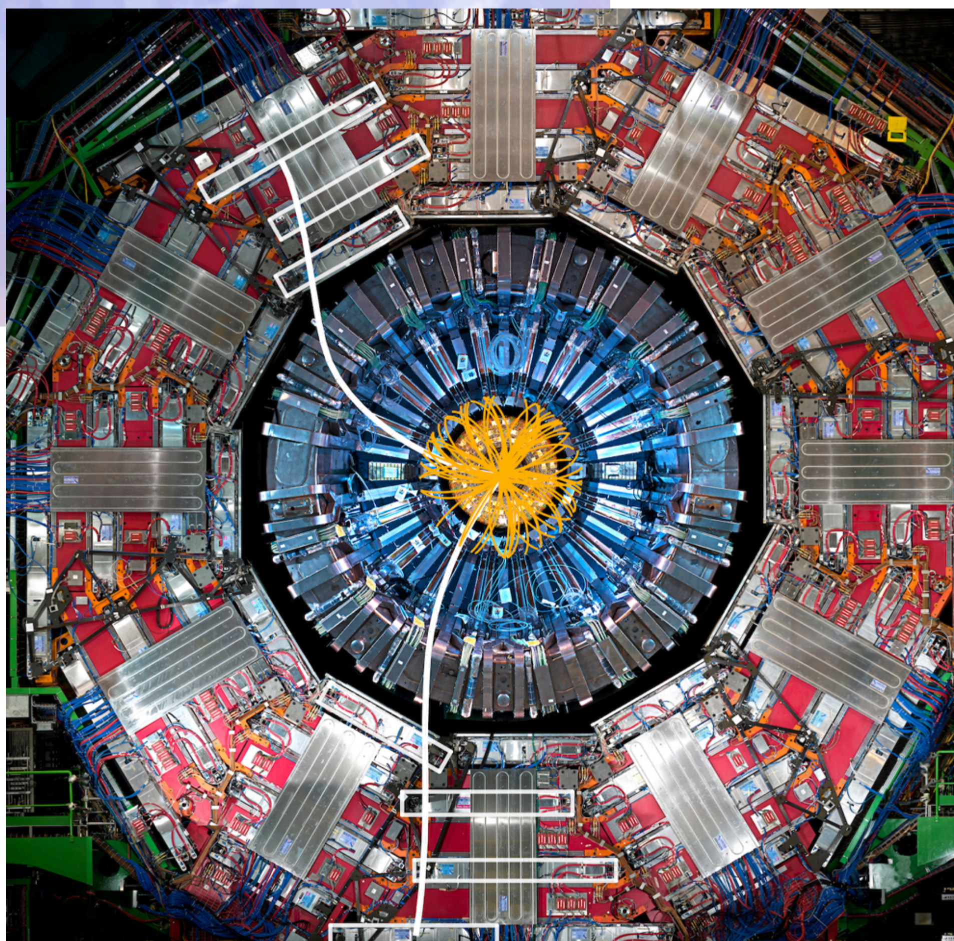


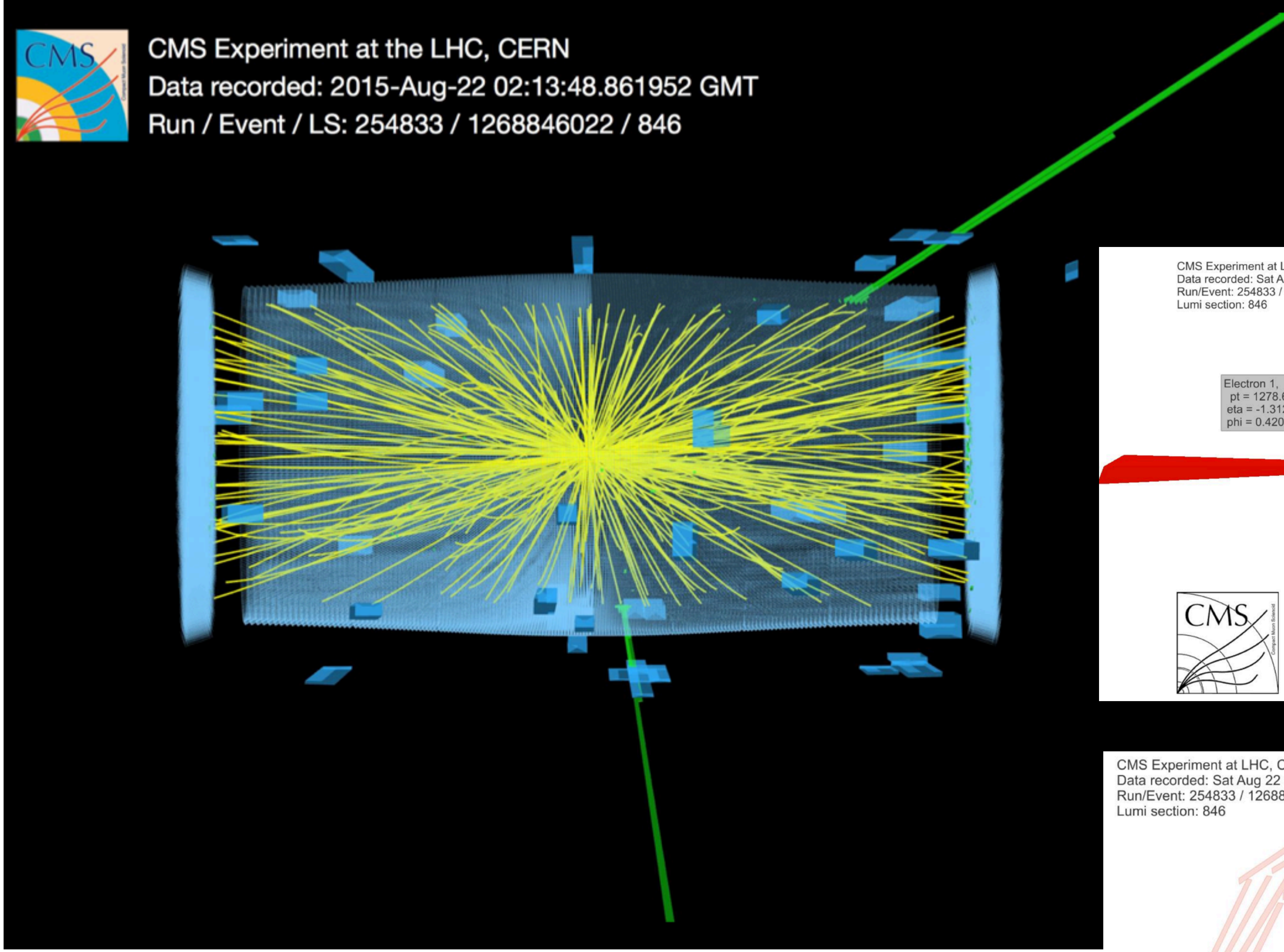
Decades worth of particle physics discovery … in a single plot!

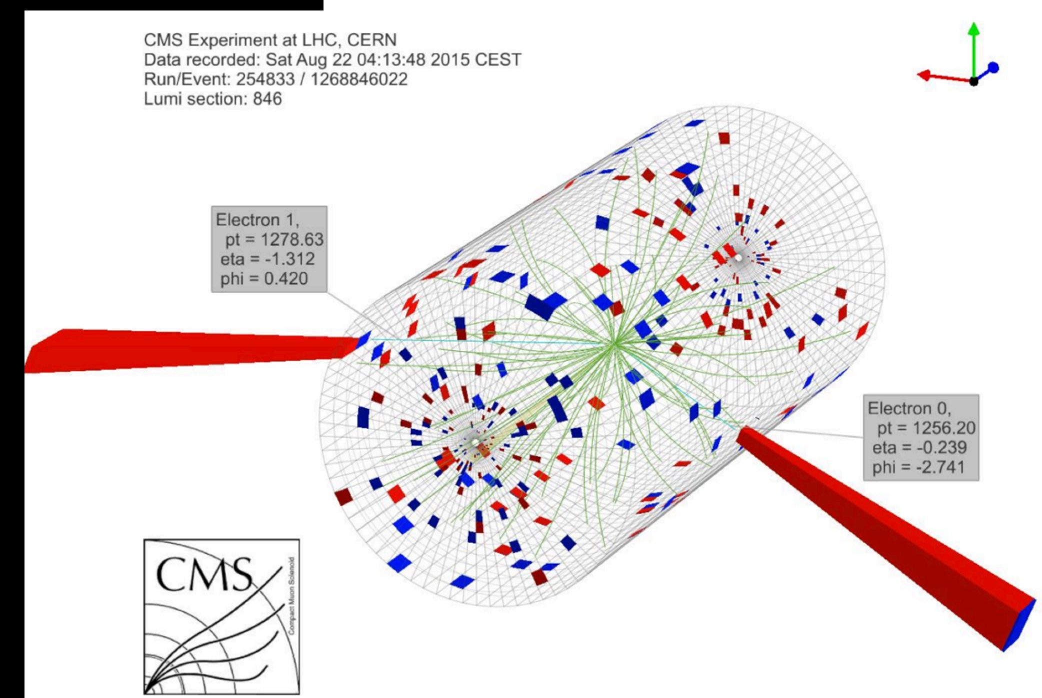

muon tracks
muon chambers

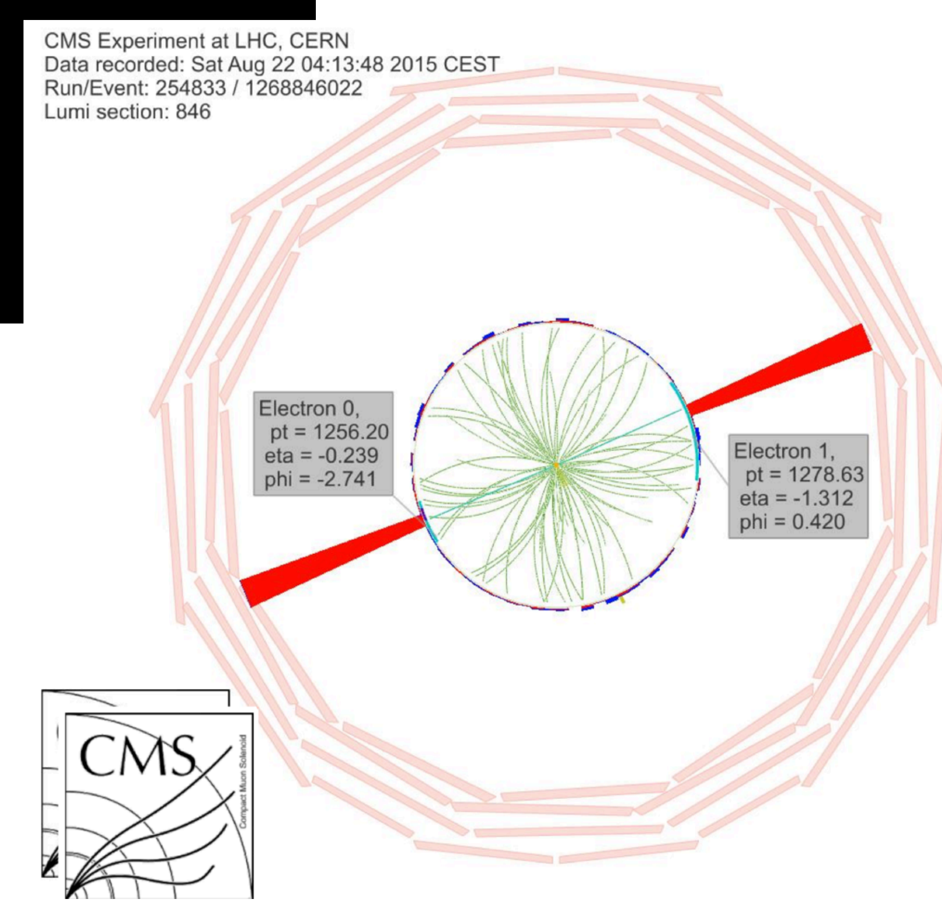

CMS Preliminary, $\sqrt{s}$ = 7 TeV
L_{int} = 40 pb^{-1}
$|\eta^{\mu}| < 1$
σ = 67 MeV/c^2
Events / (0.07 GeV/c^2)
$\mu^+\mu^-$ mass (GeV/c^2)


CMS
$\sqrt{s}$ = 7 TeV, L = 5.1 fb^{-1} ; $\sqrt{s}$ = 8 TeV, L = 19.7 fb^{-1}
Data
m_H=126 GeV
$Z\gamma^*$,ZZ
Z+X
Events / 3 GeV
m_{4l} (GeV)




CMS Experiment at the LHC, CERN
Data recorded: 2015-Aug-22 02:13:48.861952 GMT
Run / Event / LS: 254833 / 1268846022 / 846


CMS Experiment at LHC, CERN
Data recorded: Sat Aug 22 04:13:48 2015 CEST
Run/Event: 254833 / 1268846022
Lumi section: 846
Electron 1,
pt = 1278.63
eta = -1.312
phi = 0.420
Electron 0,
pt = 1256.20
eta = -0.239
phi = -2.741
CMS


CMS Experiment at LHC, CERN
Data recorded: Sat Aug 22 04:13:48 2015 CEST
Run/Event: 254833 / 1268846022
Lumi section: 846
Electron 0,
pt = 1256.20
eta = -0.239
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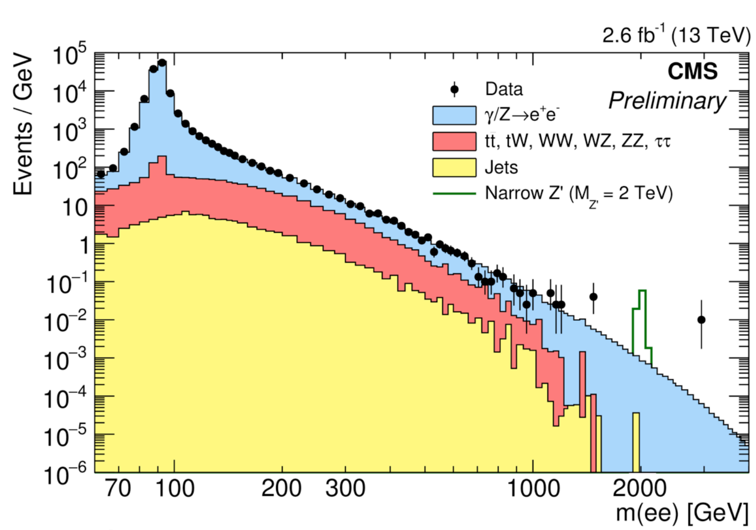
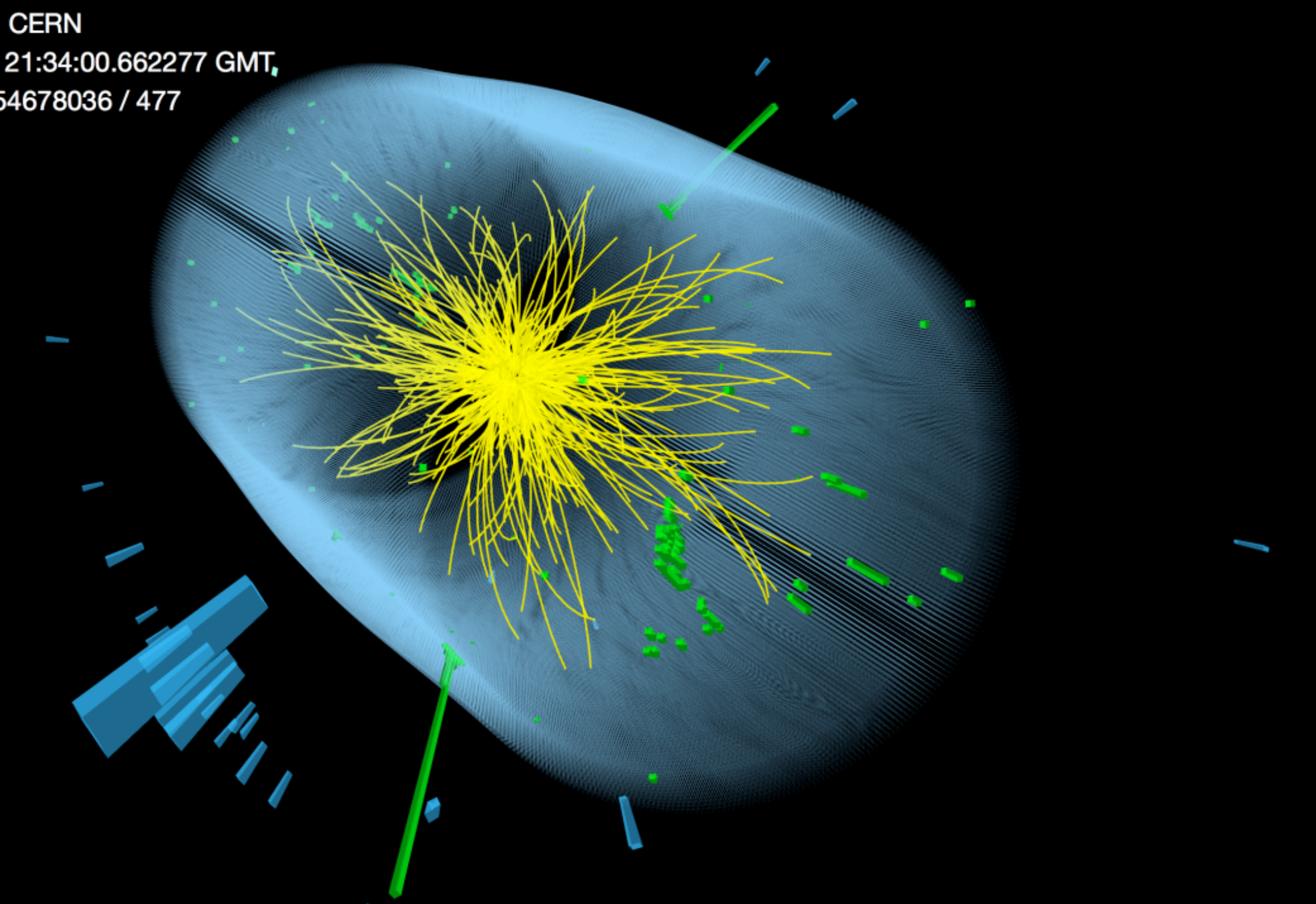
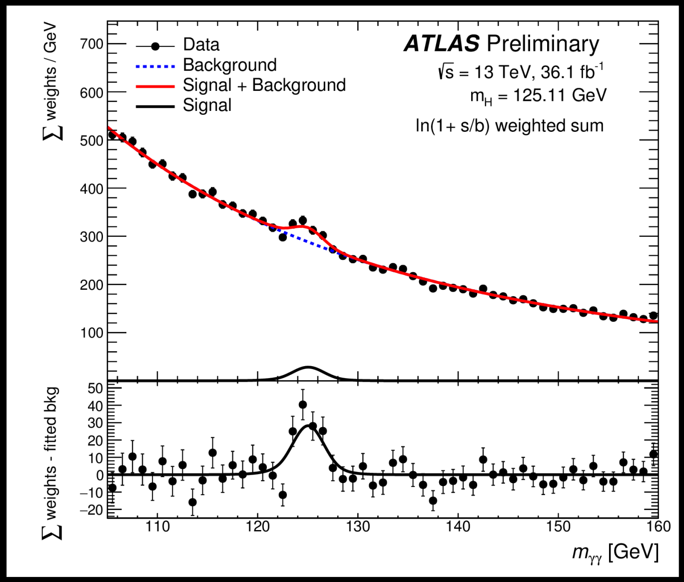
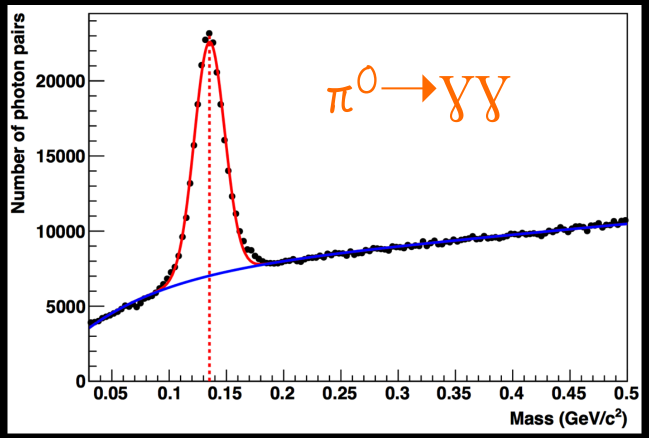
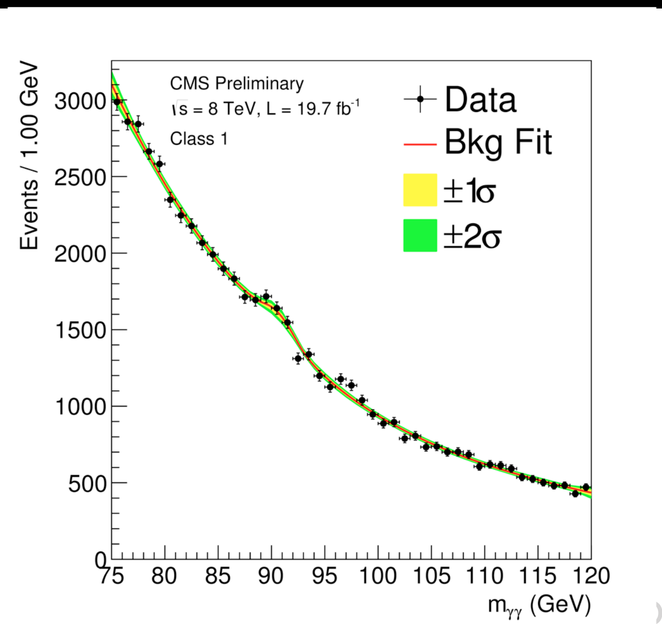
eta = -1.312
phi = 0.420
CMS

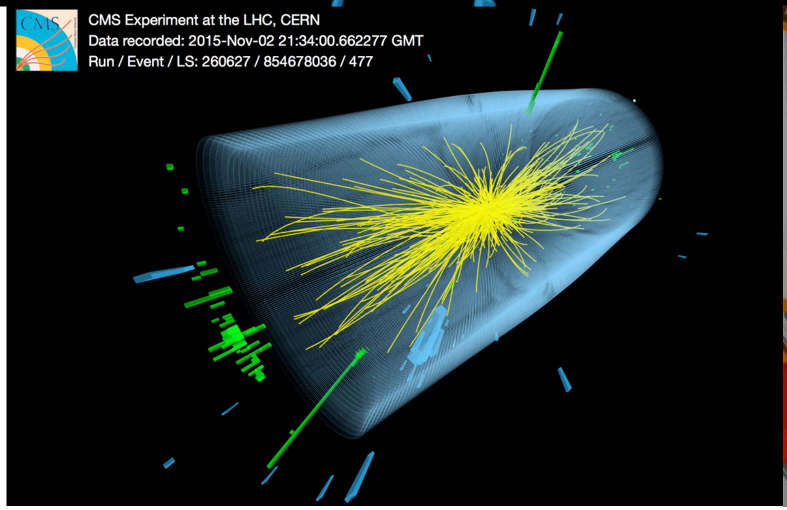

2.6 fb-1 (13 TeV)
CMS
Preliminary
Data
γ/Z→e+e-
tt, tW, WW, WZ, ZZ, ττ
Jets
Narrow Z' (MZ' = 2 TeV)
Events / GeV
m(ee) [GeV]

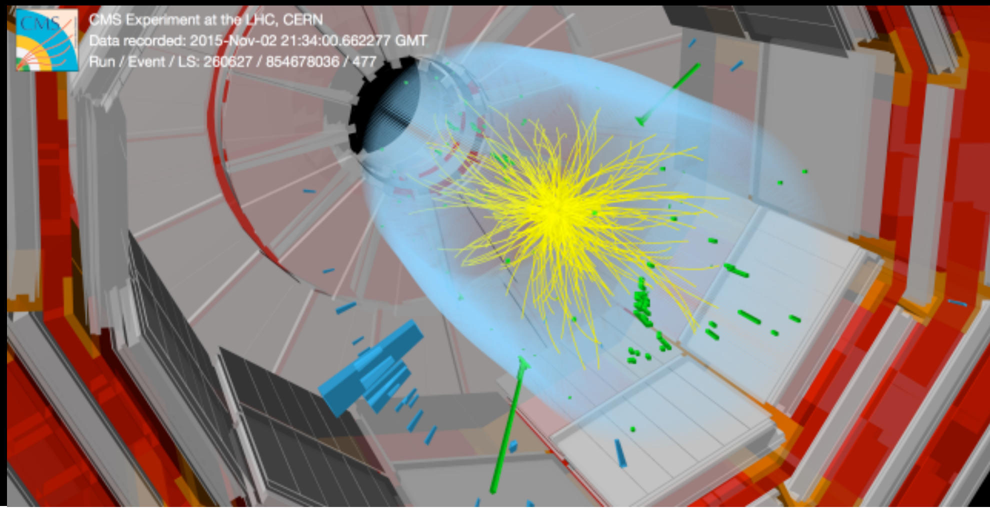

CMS Experiment at the LHC, CERN
Data recorded: 2015-Nov-02 21:34:00.662277 GMT
Run / Event / LS: 260627 / 854678036 / 477

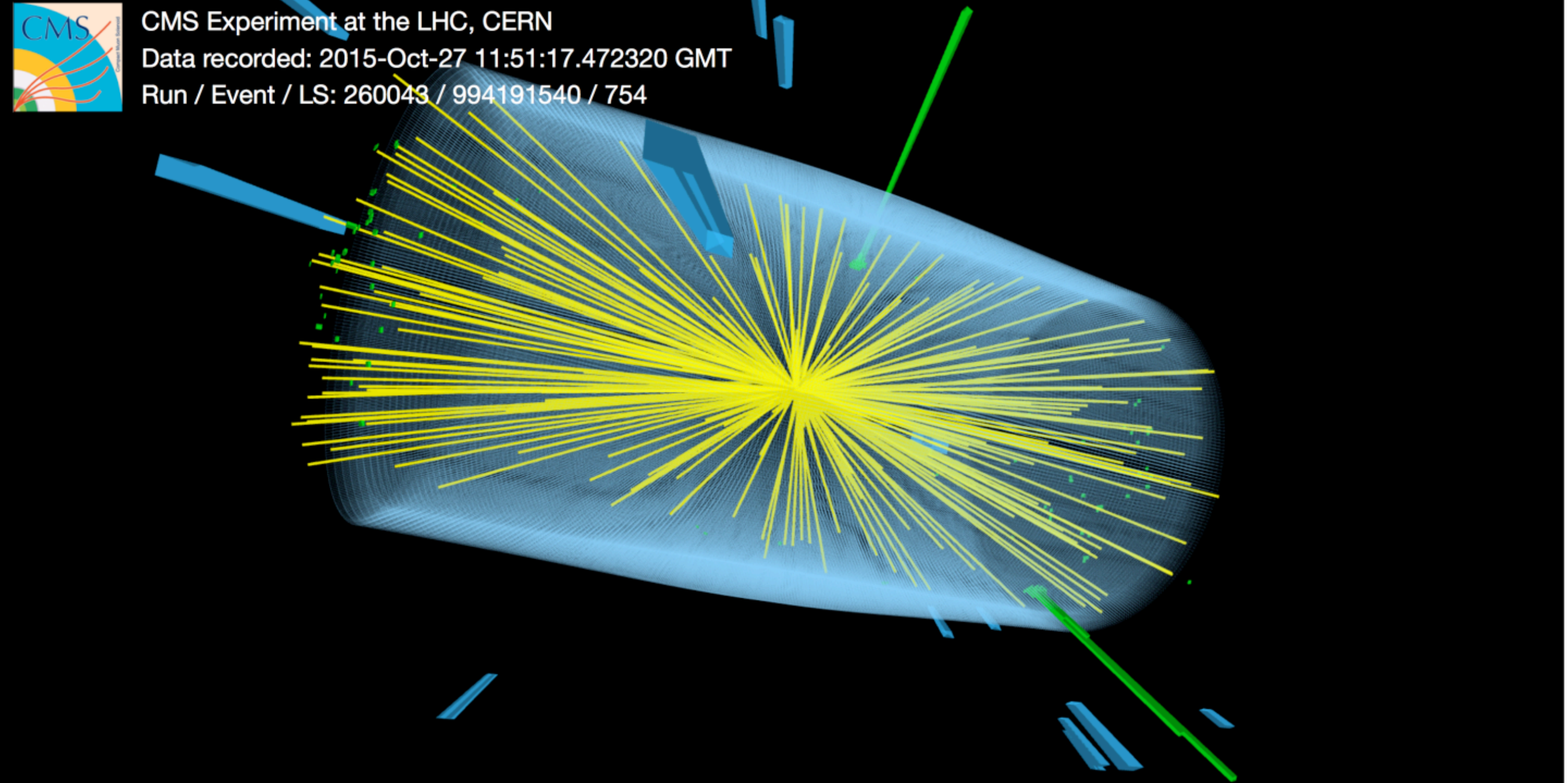

ATLAS Preliminary
$\sqrt{s}$ = 13 TeV, 36.1 fb^{-1}
m_H = 125.11 GeV
ln(1+ s/b) weighted sum
Data
Background
Signal + Background
Signal
$\sum$ weights / GeV
$\sum$ weights - fitted bkg
$m_{\gamma\gamma}$ [GeV]

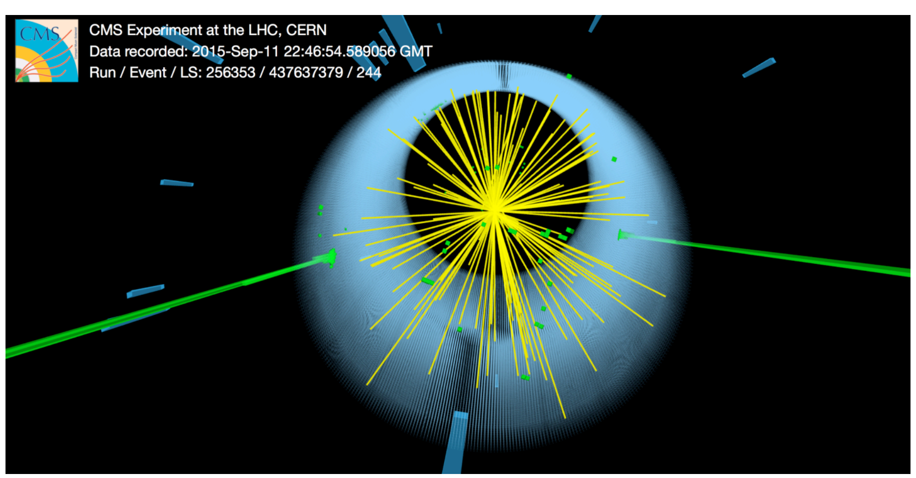

$\pi^0 \to \gamma\gamma$
Number of photon pairs
Mass (GeV/c^2)

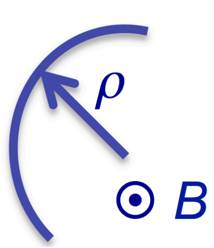

CMS Preliminary
$\sqrt{s}$ = 8 TeV, L = 19.7 fb^{-1}
Class 1
Data
Bkg Fit
$\pm 1\sigma$
$\pm 2\sigma$
Events / 1.00 GeV
$m_{\gamma\gamma}$ (GeV)


CMS Experiment at the LHC, CERN
Data recorded: 2015-Nov-02 21:34:00.662277 GMT
Run / Event / LS: 260627 / 854678036 / 477

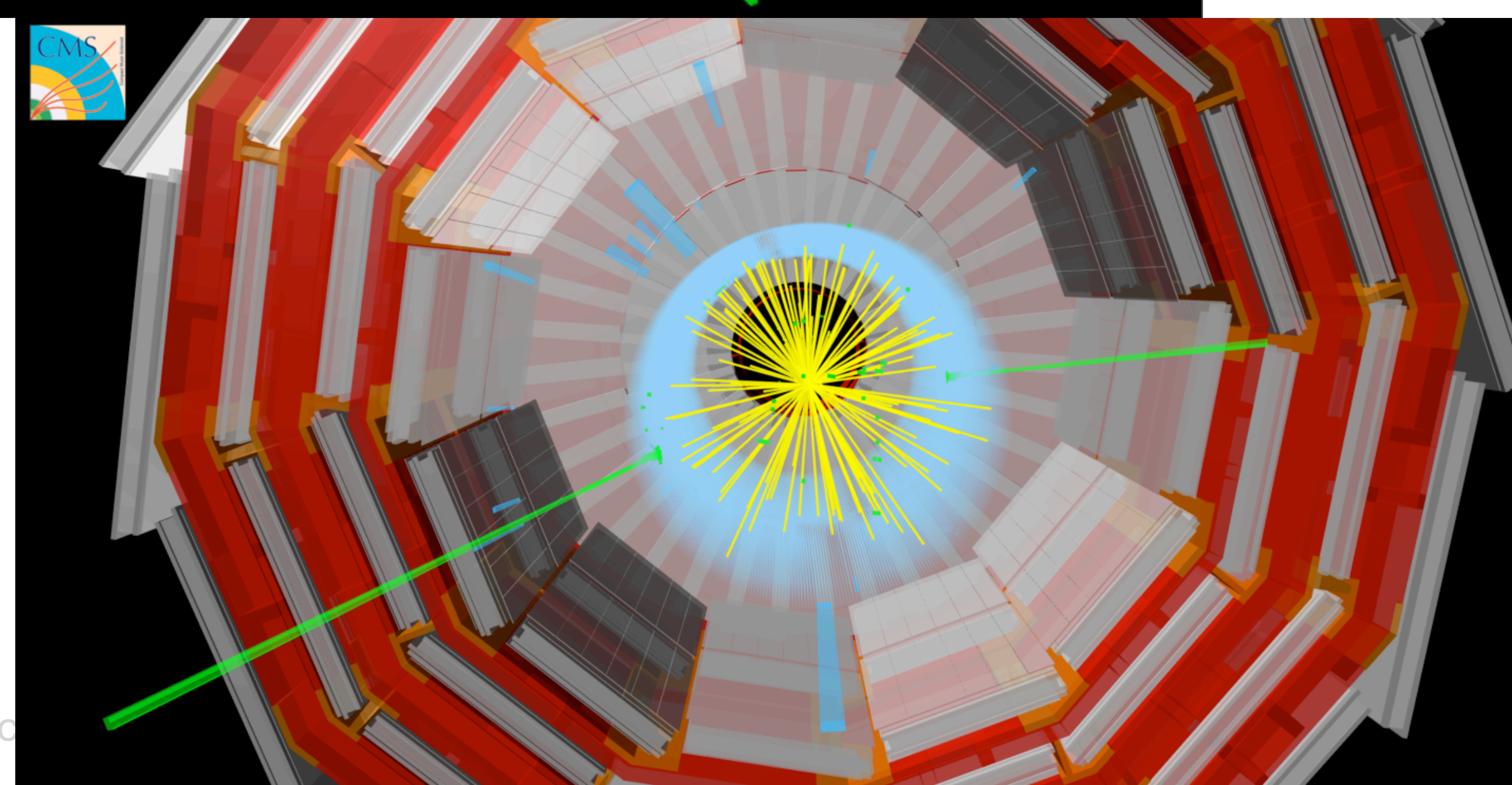

CMS Experiment at the LHC, CERN
Data recorded: 2015-Nov-02 21:34:00.662277 GMT
Run / Event / LS: 260627 / 854678036 / 477

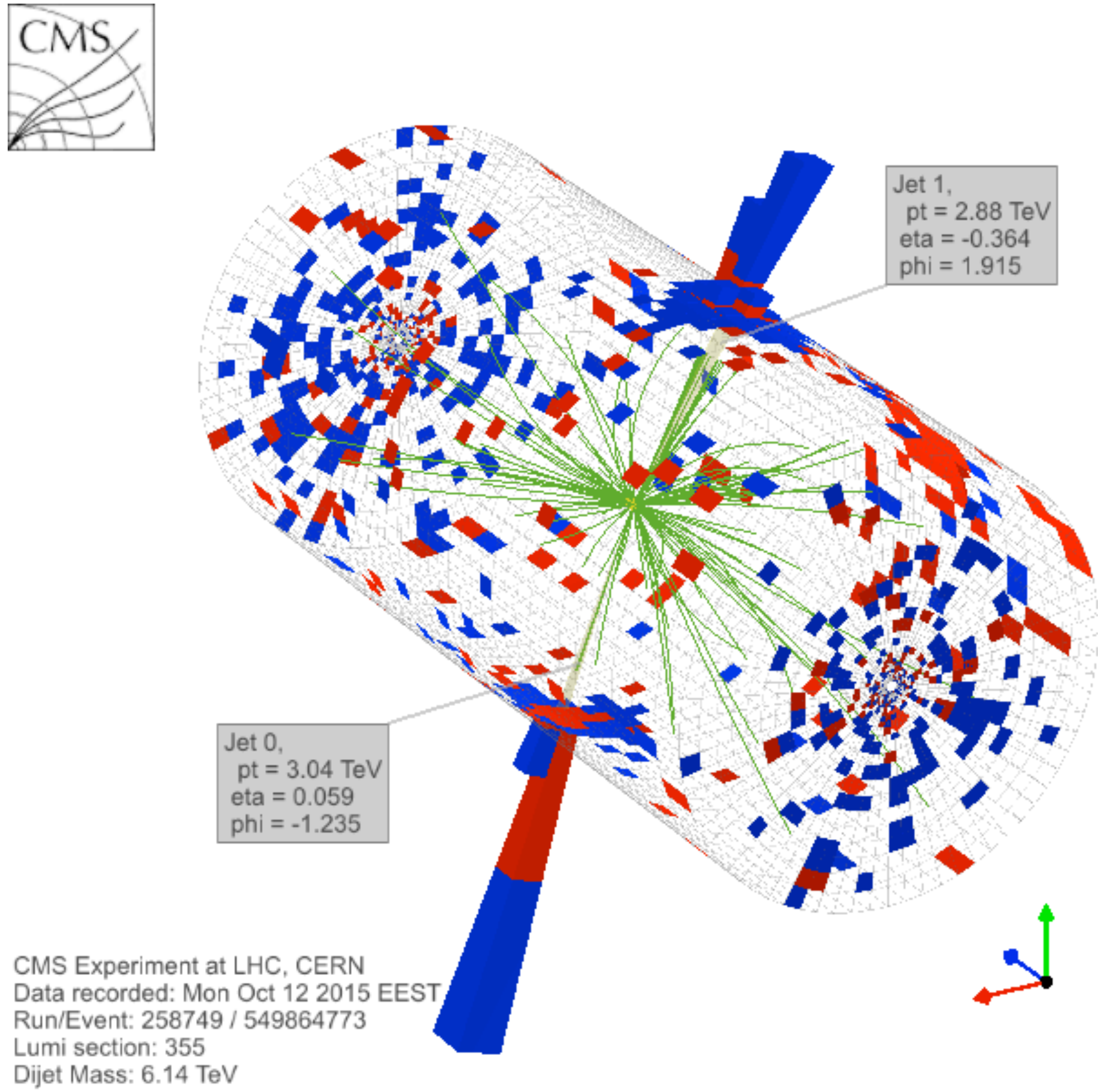


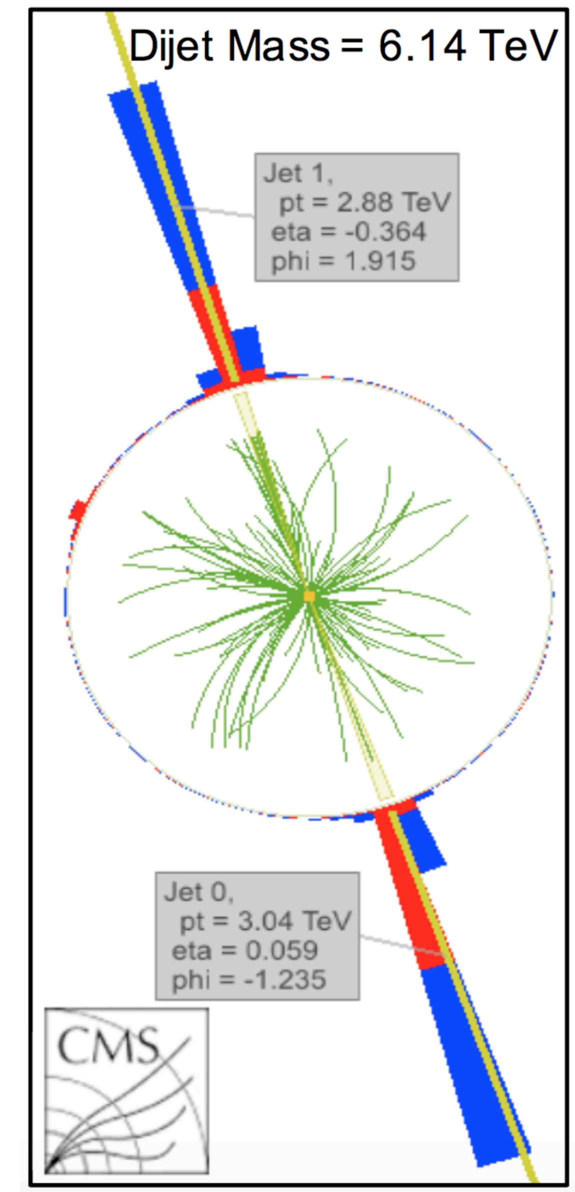


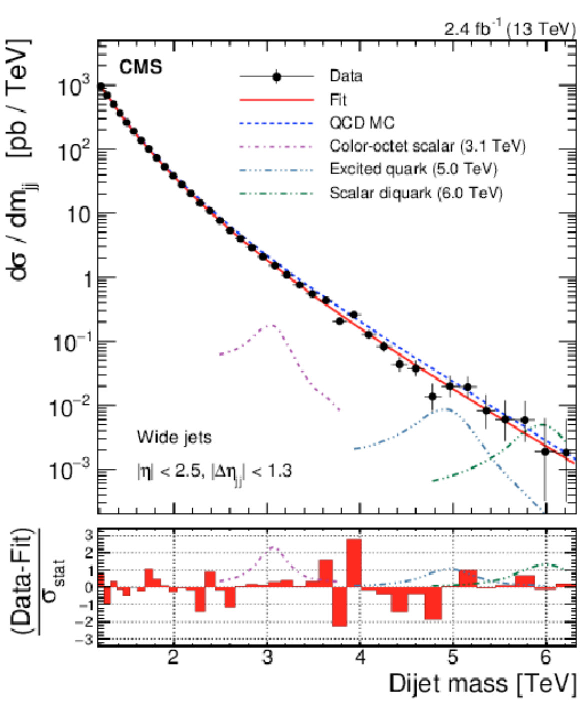


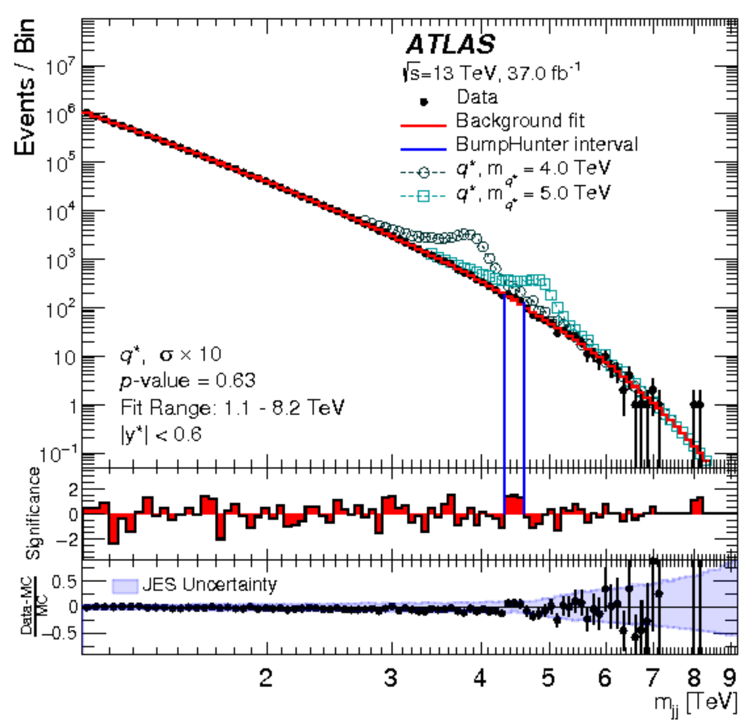
$$\rho = \frac{p}{ZeB}$$

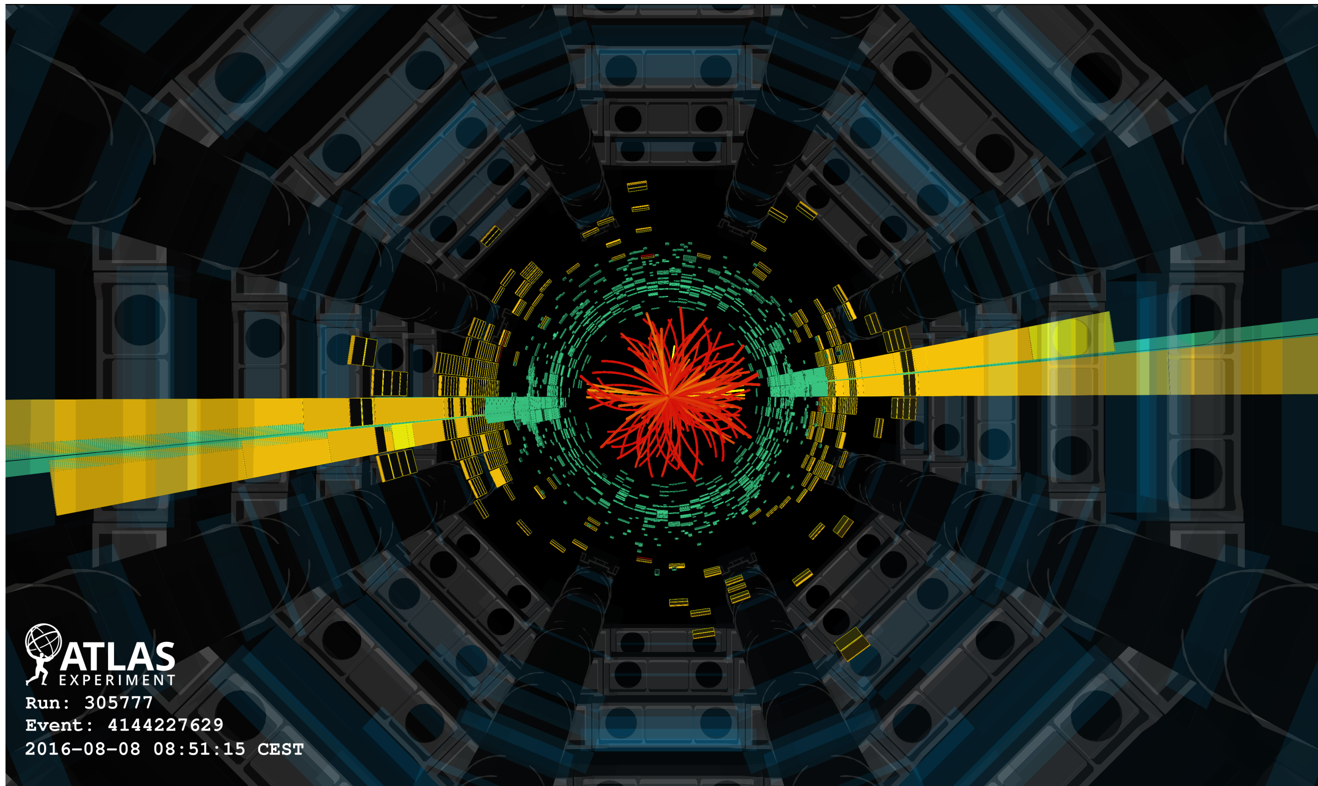


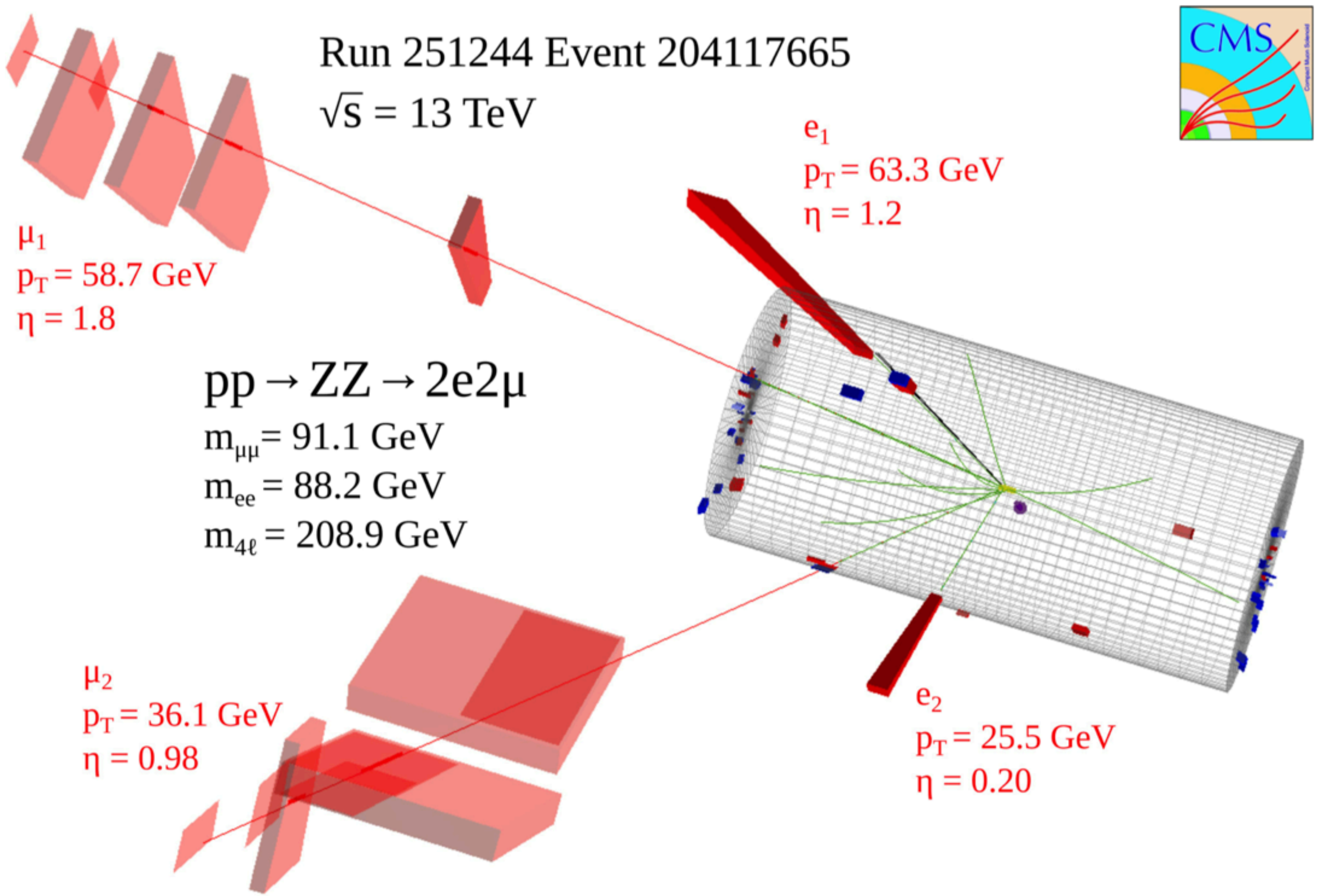

CMS
Jet 1,
pt = 2.88 TeV
eta = -0.364
phi = 1.915
Jet 0,
pt = 3.04 TeV
eta = 0.059
phi = -1.235
CMS Experiment at LHC, CERN
Data recorded: Mon Oct 12 2015 EEST
Run/Event: 258749 / 549864773
Lumi section: 355
Dijet Mass: 6.14 TeV

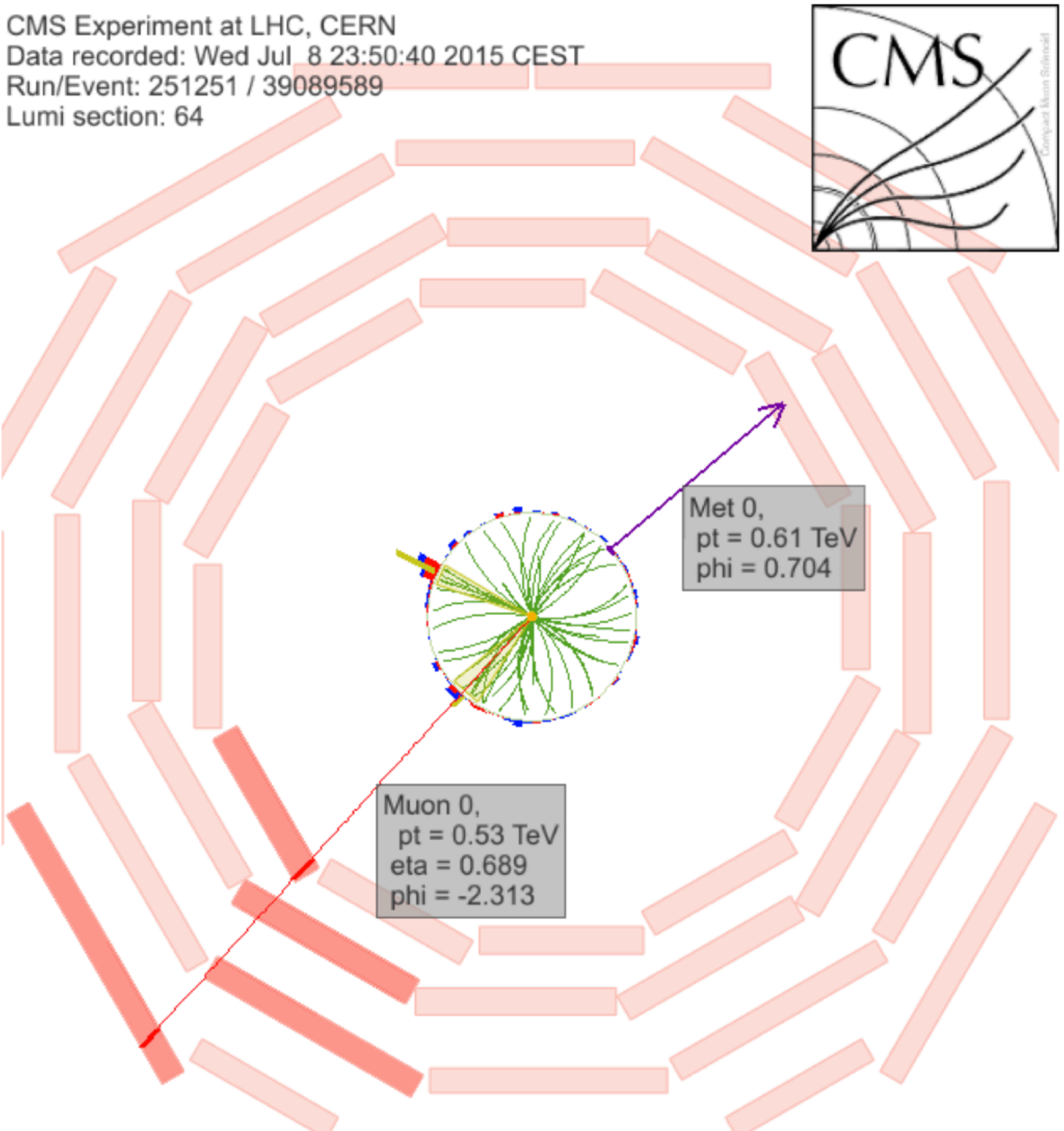

Dijet Mass = 6.14 TeV
Jet 1,
pt = 2.88 TeV
eta = -0.364
phi = 1.915
Jet 0,
pt = 3.04 TeV
eta = 0.059
phi = -1.235
CMS


2.4 fb-1 (13 TeV)
CMS
Data
Fit
QCD MC
Color-octet scalar (3.1 TeV)
Excited quark (5.0 TeV)
Scalar diquark (6.0 TeV)
Wide jets
|η| < 2.5, |Δη_jj| < 1.3
dσ / dm_jj [pb / TeV]
(Data-Fit) / σ_stat
Dijet mass [TeV]

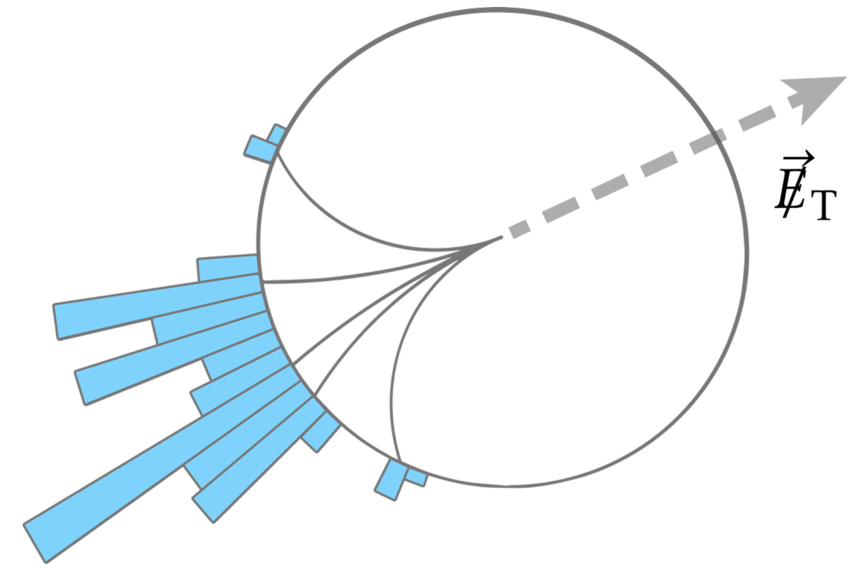

ATLAS
√s=13 TeV, 37.0 fb-1
Data
Background fit
BumpHunter interval
q*, m_q* = 4.0 TeV
q*, m_q* = 5.0 TeV
q*, σ × 10
p-value = 0.63
Fit Range: 1.1 - 8.2 TeV
|y*| < 0.6
Events / Bin
Significance
JES Uncertainty
Data-MC / MC
m_jj [TeV]

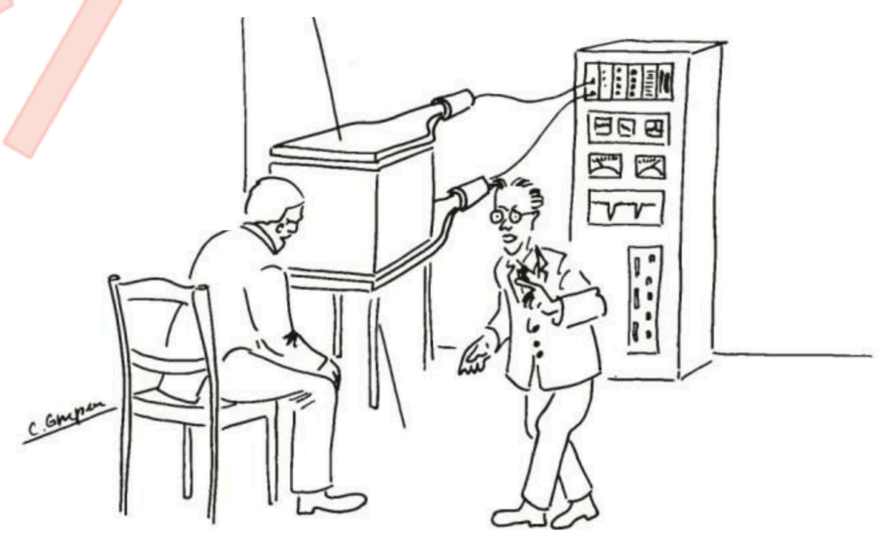

ATLAS
EXPERIMENT
Run: 305777
Event: 4144227629
2016-08-08 08:51:15 CEST


Run 251244 Event 204117665
$\sqrt{s}$ = 13 TeV
CMS
e_1
p_T = 63.3 GeV
η = 1.2
μ_1
p_T = 58.7 GeV
η = 1.8
$pp \rightarrow ZZ \rightarrow 2e2\mu$
$m_{\mu\mu}$ = 91.1 GeV
m_{ee} = 88.2 GeV
$m_{4\ell}$ = 208.9 GeV
μ_2
p_T = 36.1 GeV
η = 0.98
e_2
p_T = 25.5 GeV
η = 0.20



Missing momentum

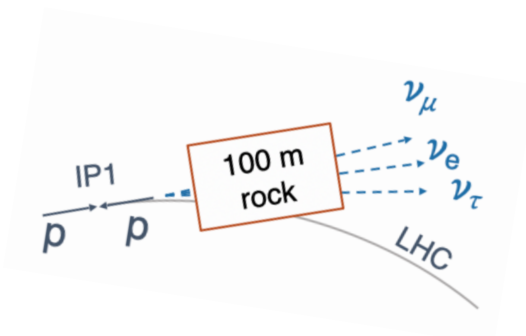


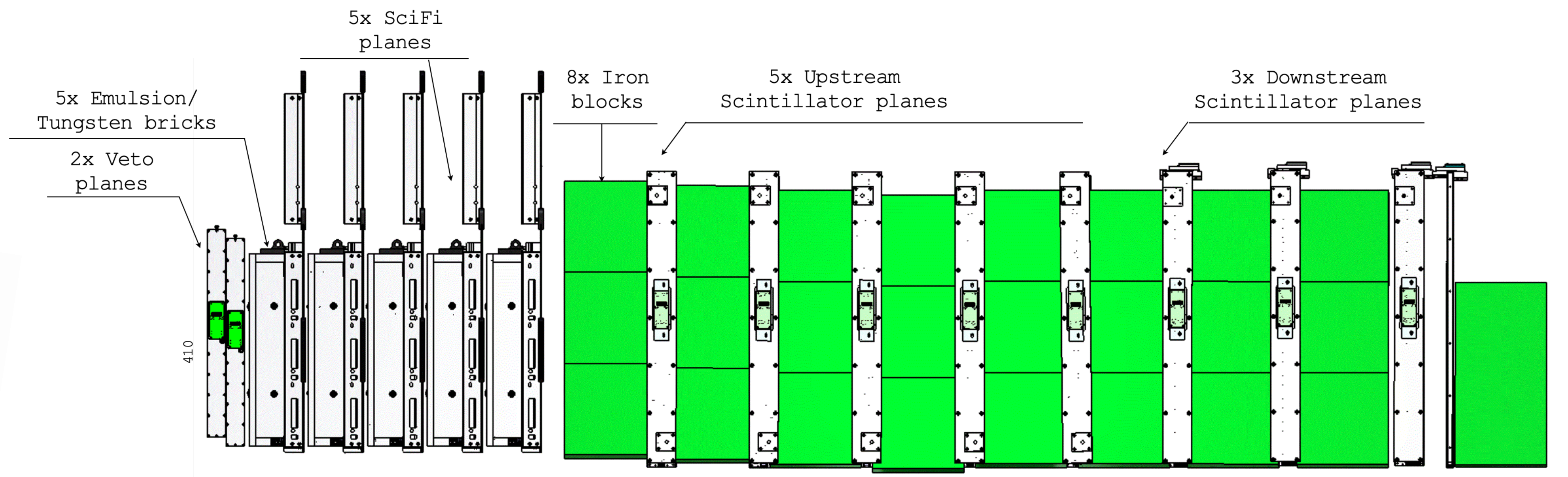


"Did you see it?"
"No nothing."
"Then it was a neutrino!"

Neutrinos cannot be detected at the LHC! … or can they

The Dawn of Collider Neutrino Physics @LHC

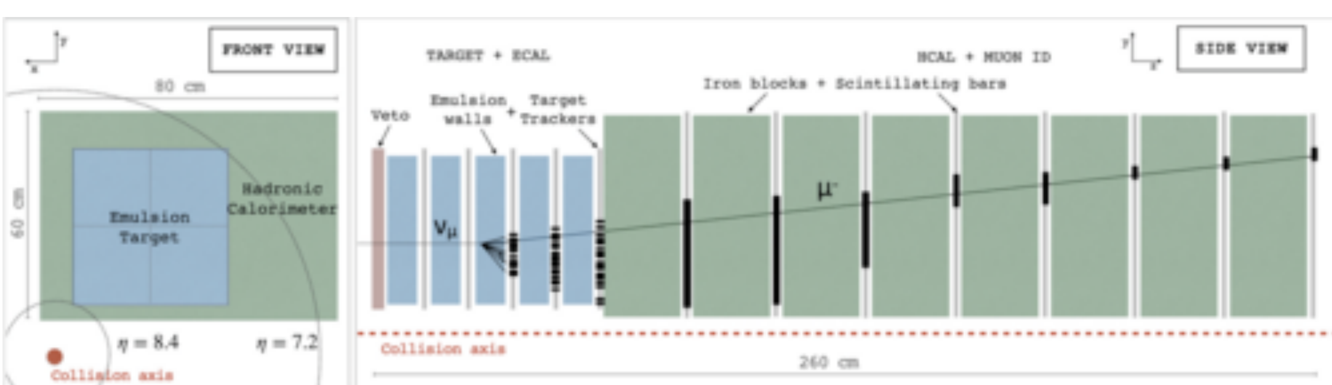


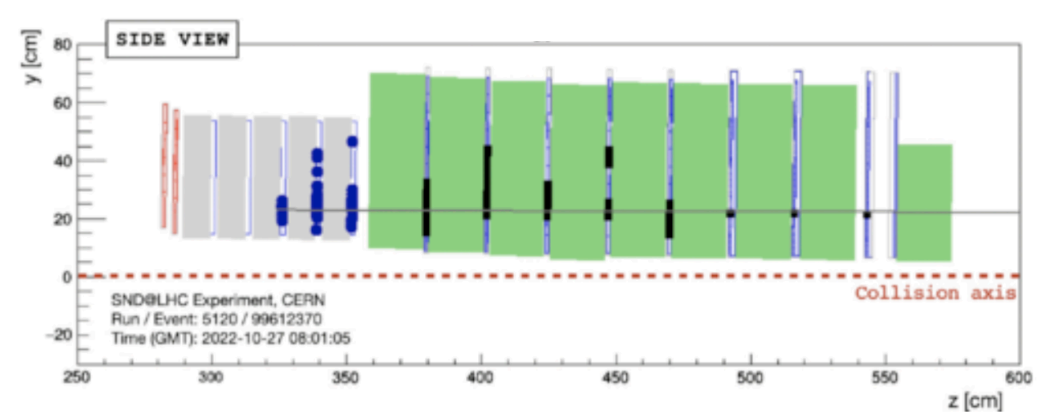


target/
tracker

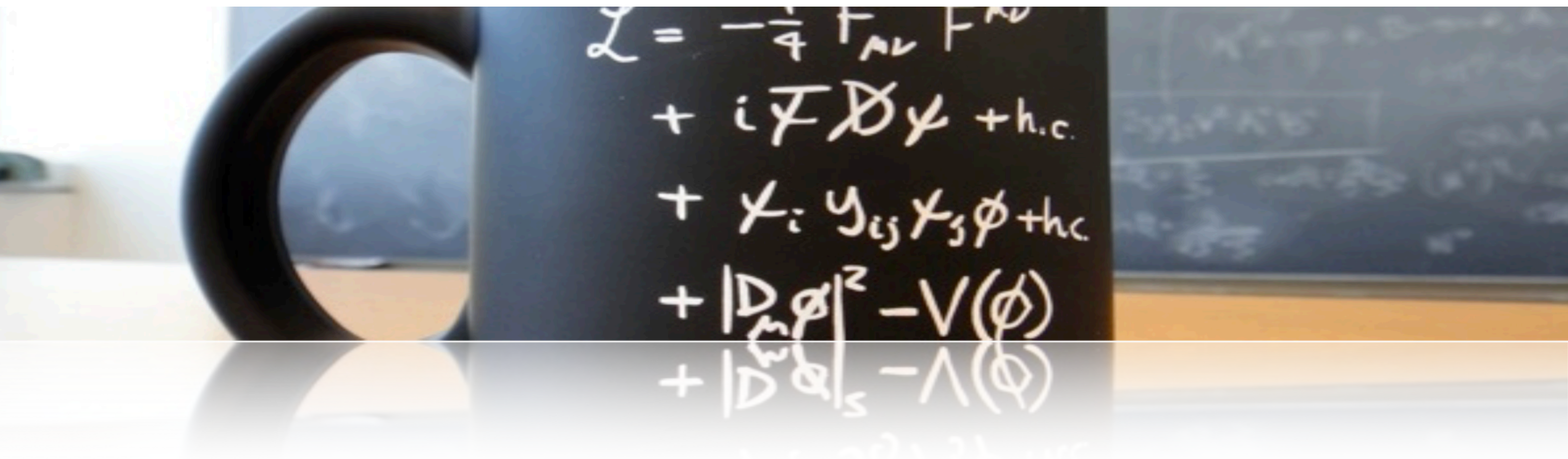
had.
calorimeter

muon
chambers

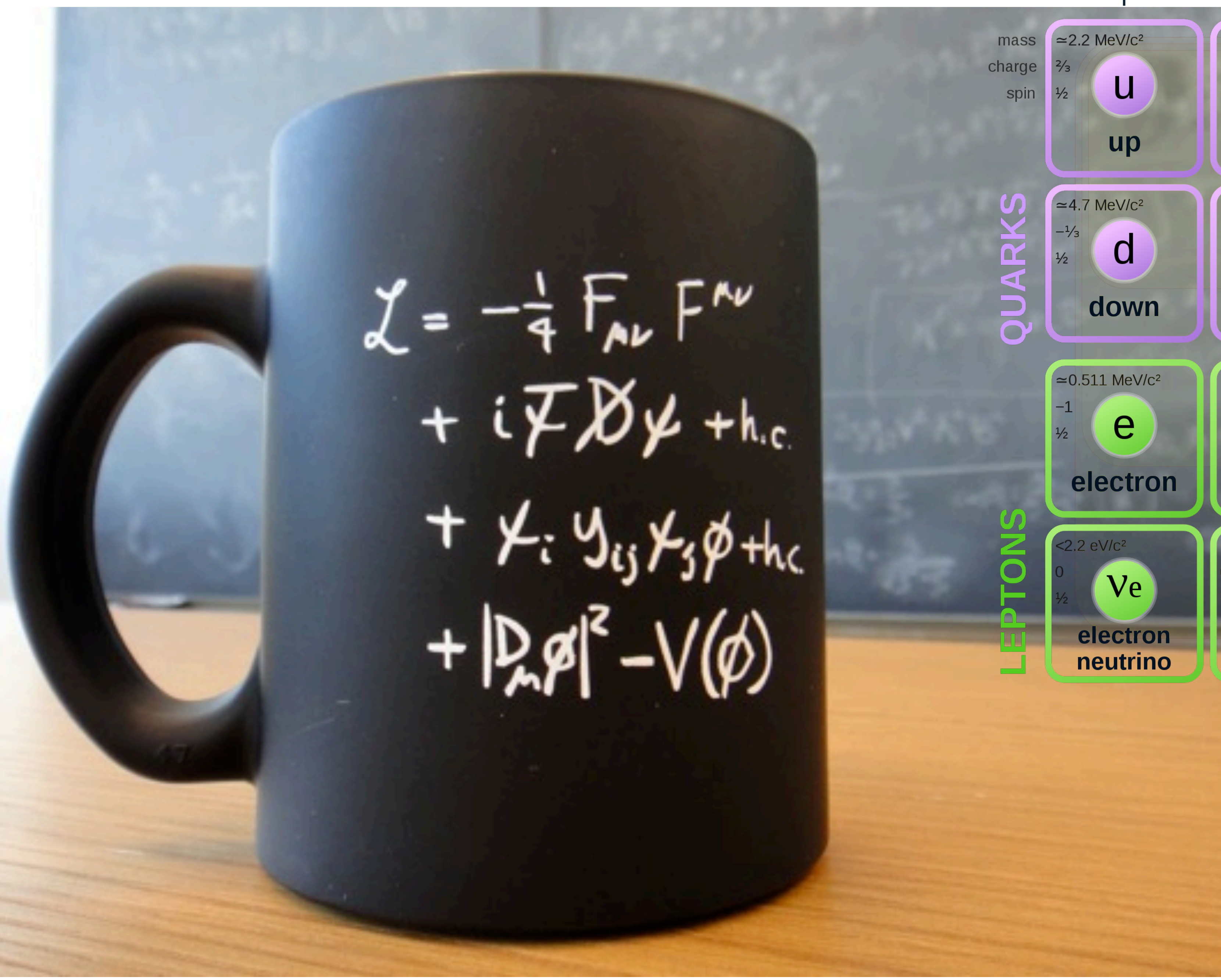


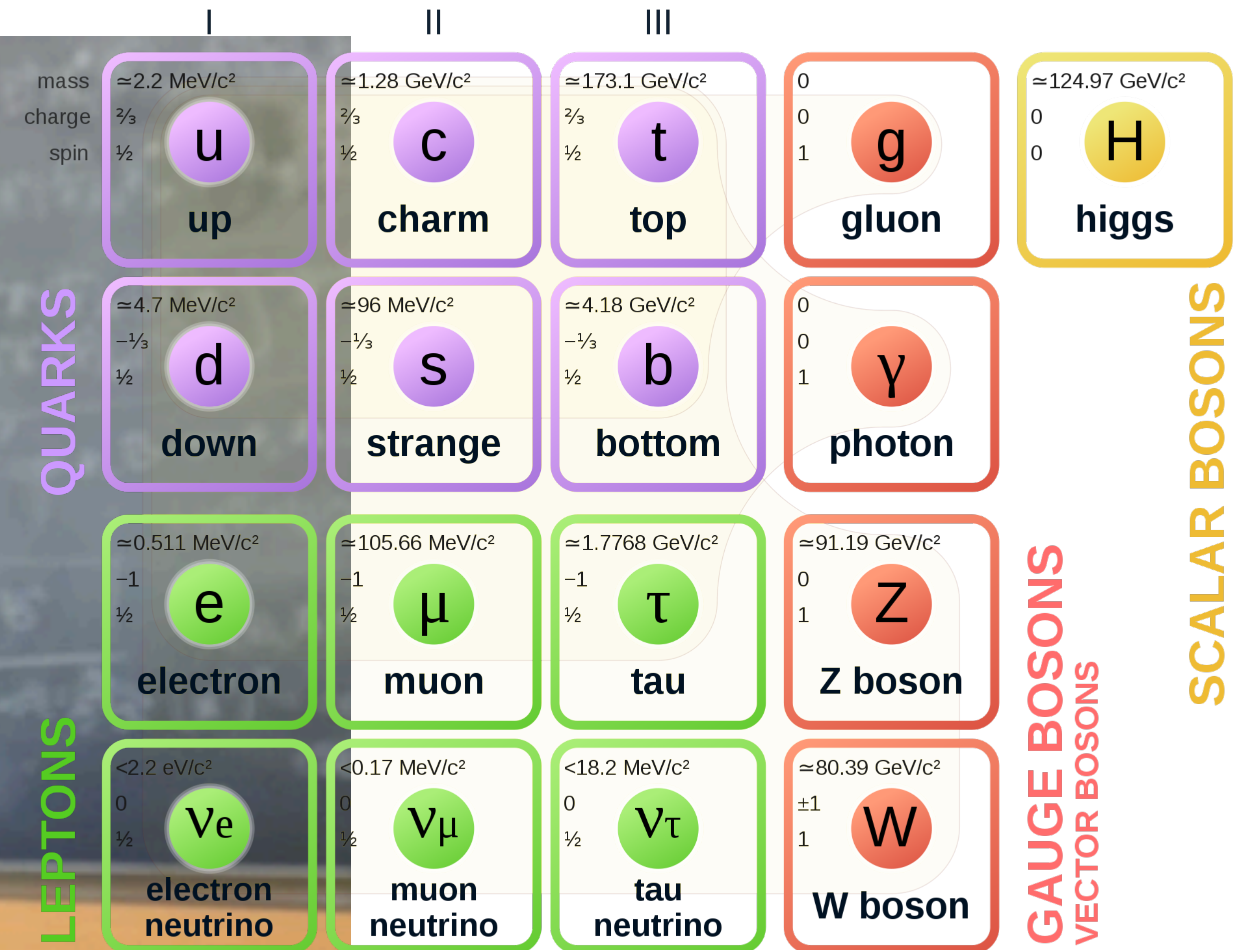


Physics



The Standard Model of Particle Physics





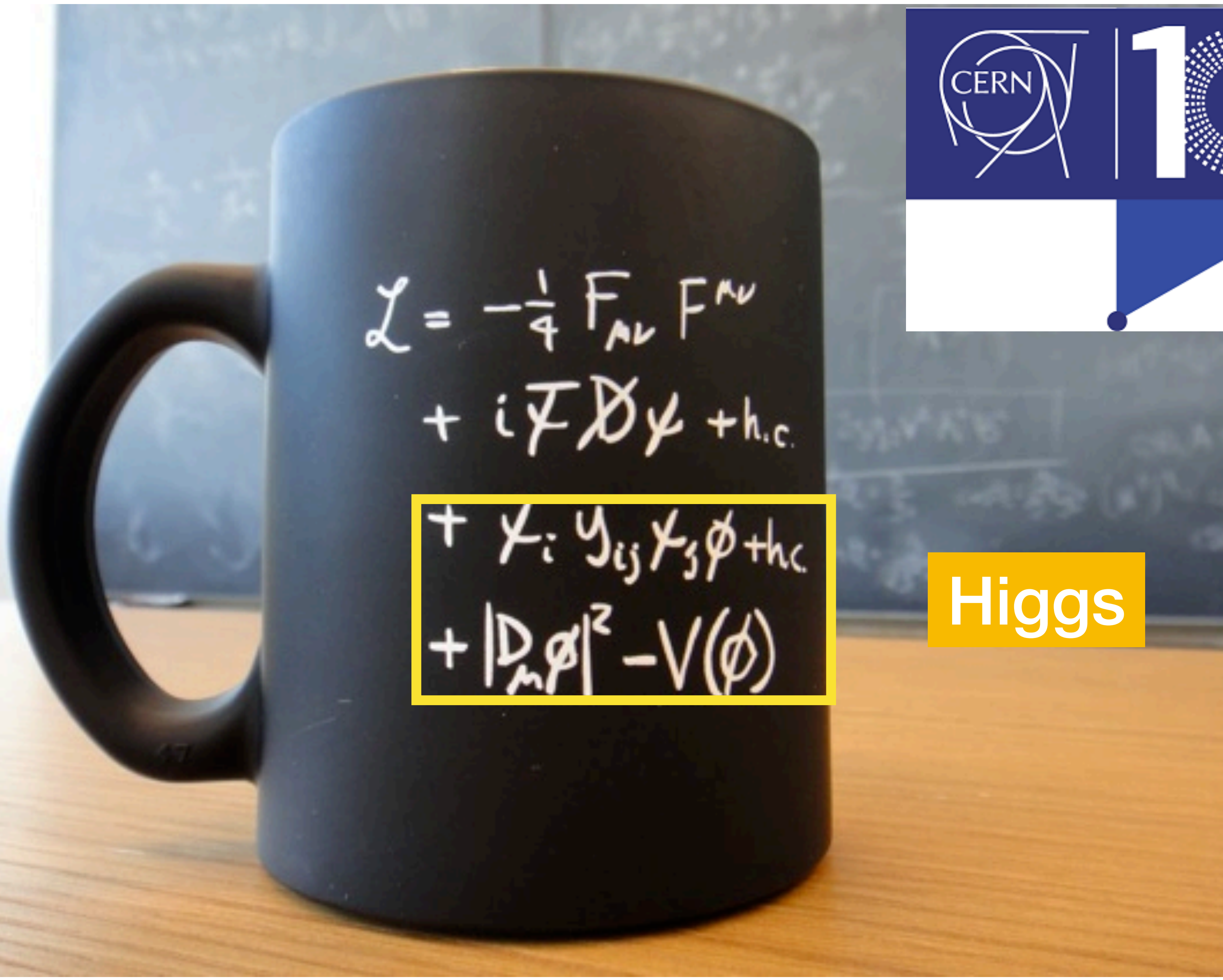
SM **predictions** can be **tested** against experimental data

Standard Model = **Quantum mechanics + Special relativity** (+fields+symmetries)

Outcome of **theory** + **experiment** interplay & discovery

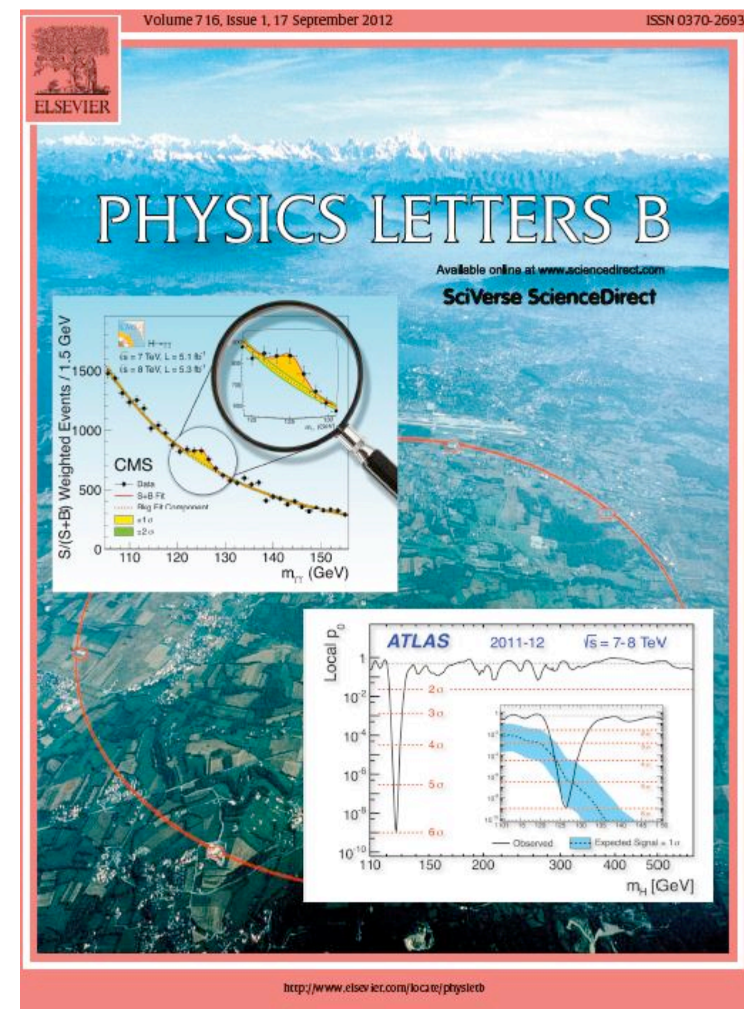
One of the great achievements of 20$_{th}$ century science.

The Higgs boson



Higgs

CERN 10 years HIGGS boson discovery



Standard Model = **Quantum mechanics + Special relativity** (+fields+symmetries)

Outcome of **theory** + **experiment** interplay & discovery

One of the great achievements of 20_{th} century science.

The Higgs boson (discovery) turns 13

The Higgs boson, ten years after its discovery

The landmark discovery of the Higgs boson at the Large Hadron Collider exactly ten years ago, and the progress made since then to determine its properties, have allowed physicists to make tremendous steps forward in our understanding of the universe

4 JULY, 2022

Read the celebratory CMS & ATLAS papers

Research Articles

A detailed map of Higgs boson interactions by the ATLAS experiment ten years after the discovery

Ten years after the discovery of the Higgs boson, the ATLAS experiment at CERN probes its kinematic properties with a significantly larger dataset from 2015–2018 and provides further insights on its interaction with other known particles.

The ATLAS Collaboration

Article | Open Access | 4 Jul 2022 | Nature

A portrait of the Higgs boson by the CMS experiment ten years after the discovery

The most up-to-date combination of results on the properties of the Higgs boson is reported, which indicate that its properties are consistent with the standard model predictions, within the precision achieved to date.

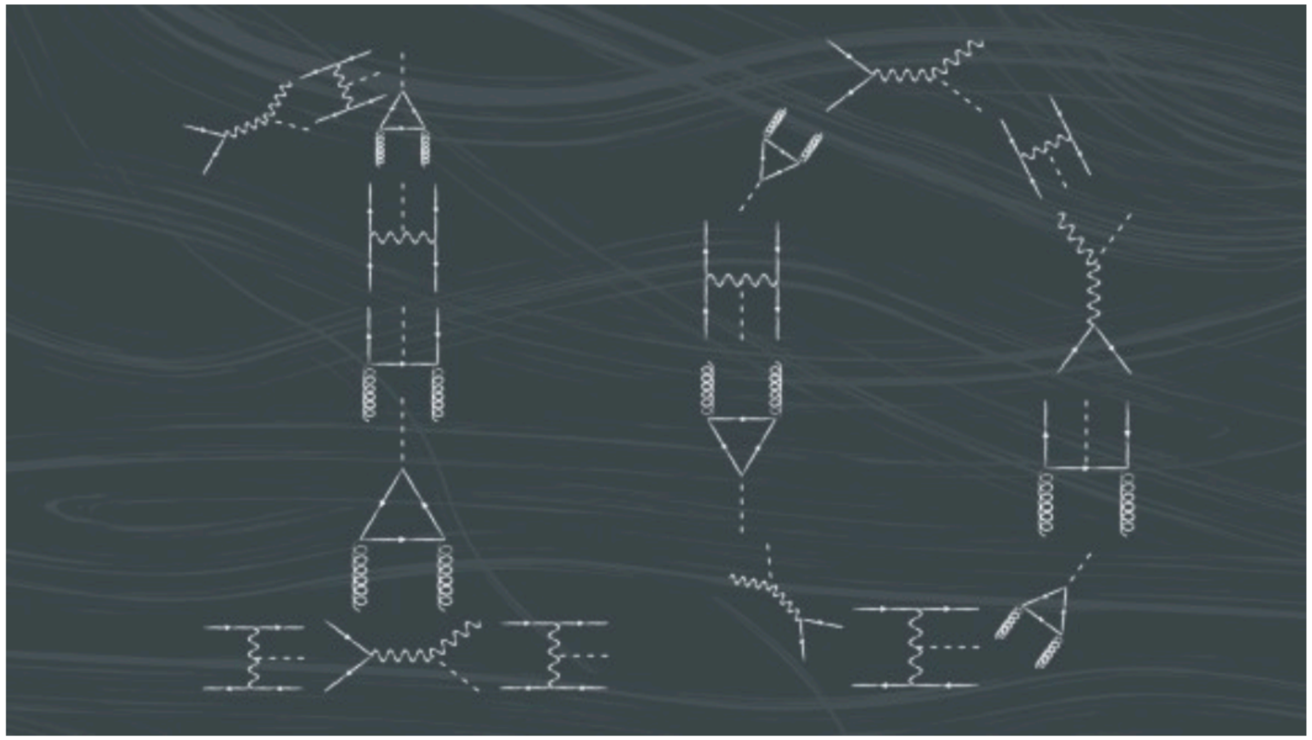
The CMS Collaboration

Article | Open Access | 4 Jul 2022 | Nature

Collection | **04 July 2022**

The Higgs boson discovery turns ten

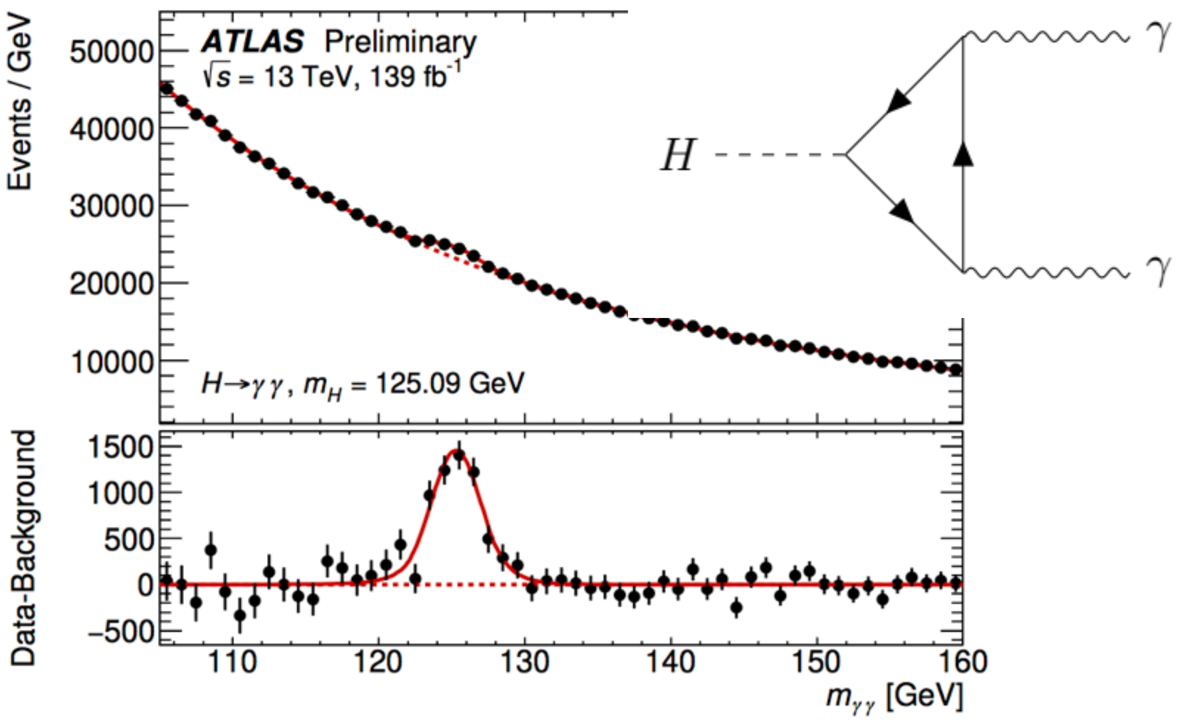
The discovery of the Higgs boson was announced ten years ago on the 4th of July 2012 — an event that substantially advanced our understanding of the origin of elementary particles' masses. In this collection of articles from *Nature, Nature Physics* and *Nature Reviews Physics* we celebrate this groundbreaking discovery and reflect on what we have learned about the Higgs boson over the intervening years.

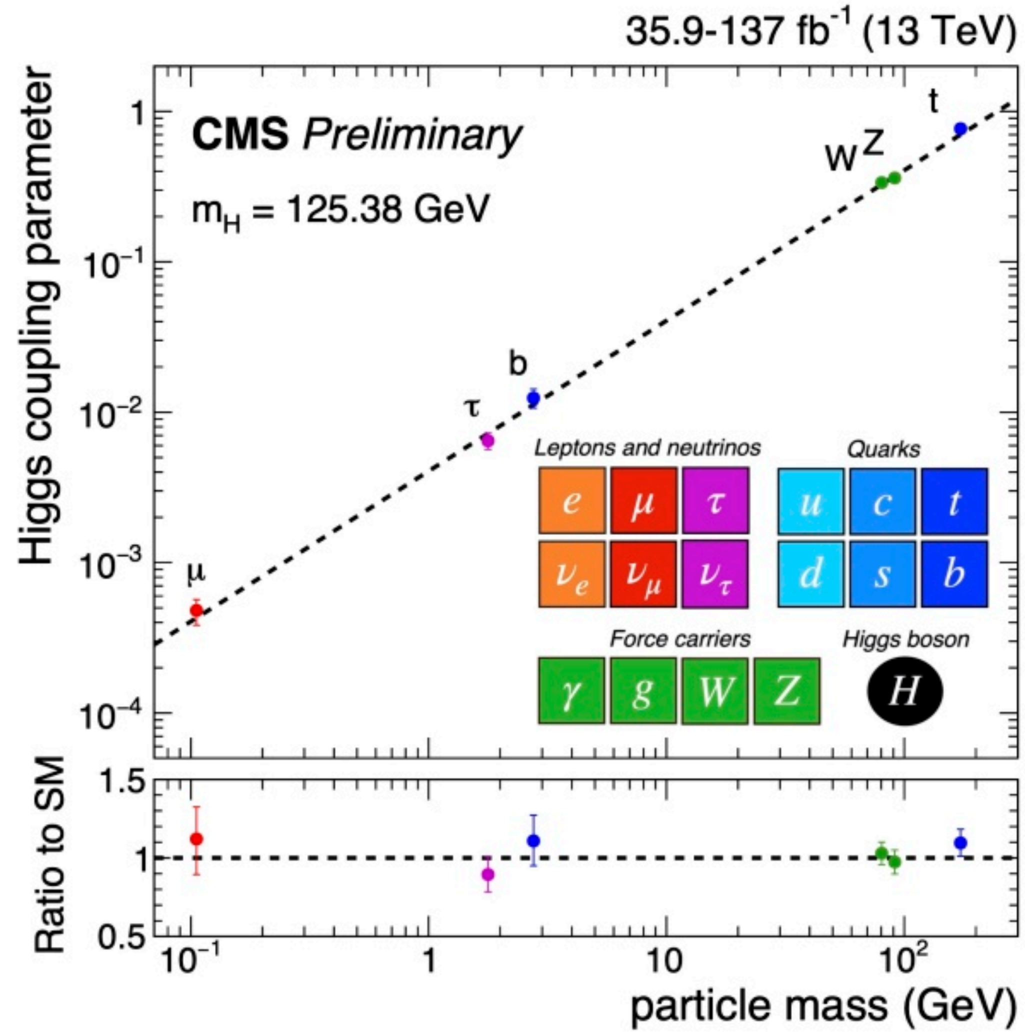


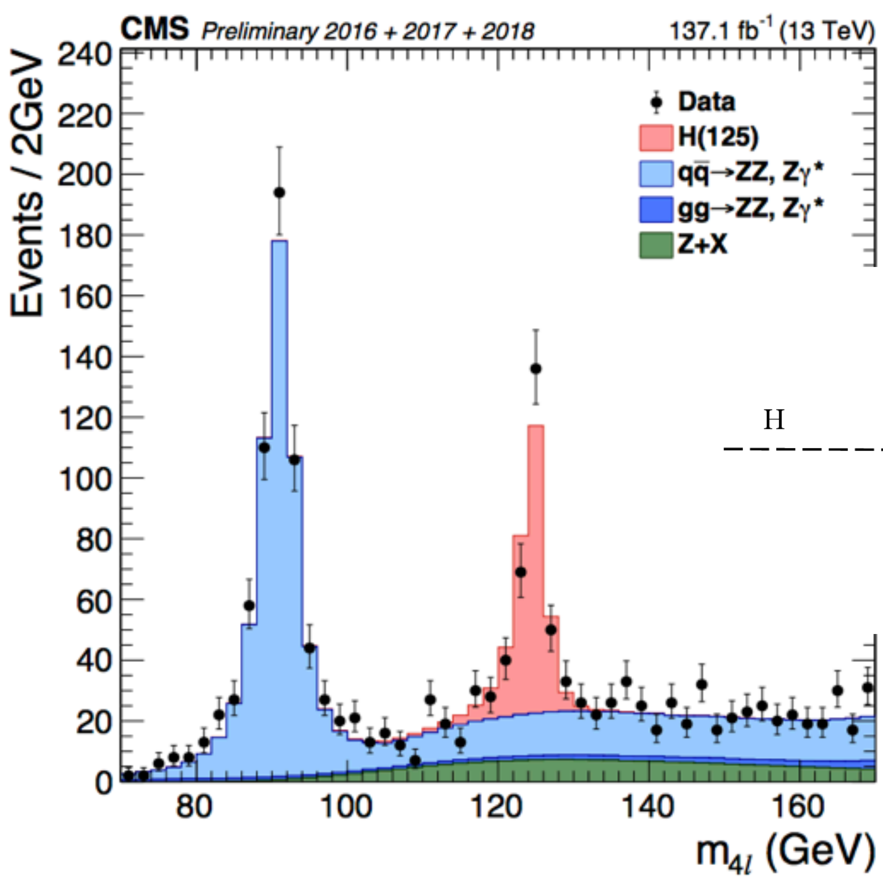
https://home.cern/news/press-release/physics/higgs-boson-ten-years-after-its-discovery

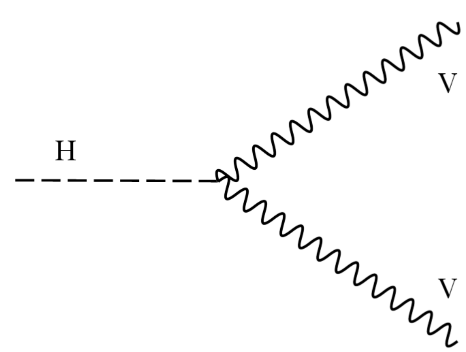
https://www.nature.com/collections/gbfhieacie

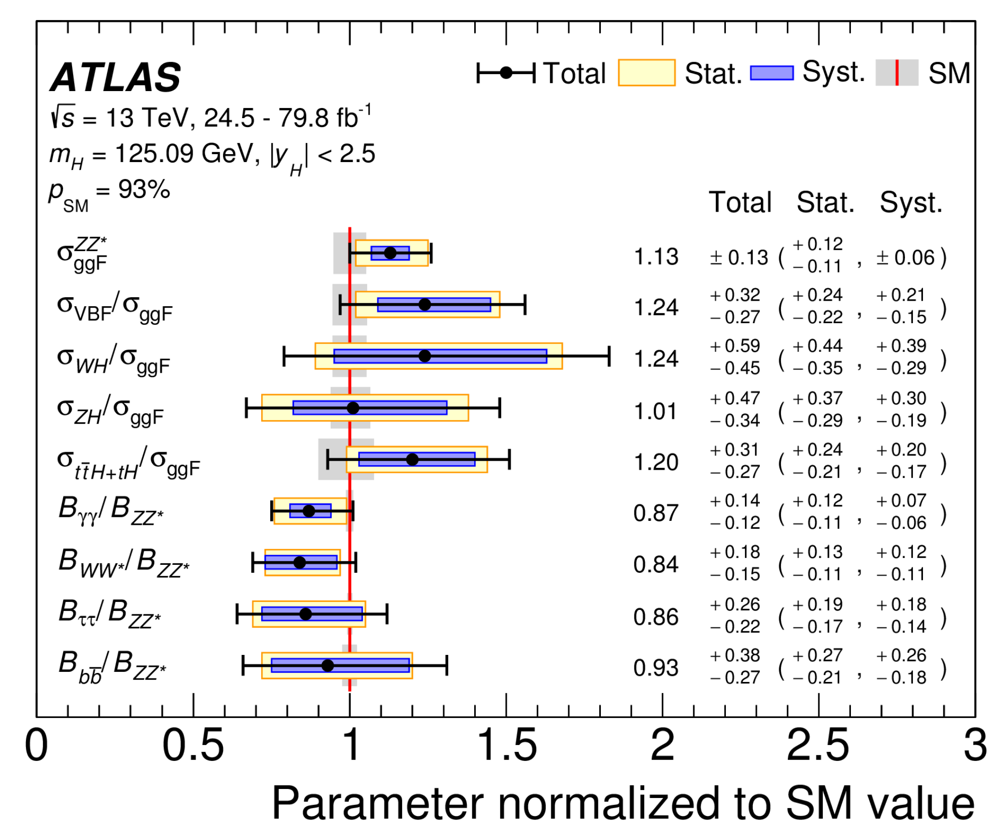
Status of the scalar





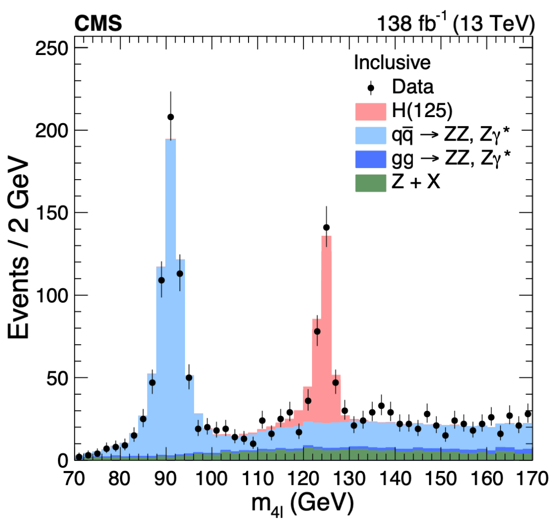




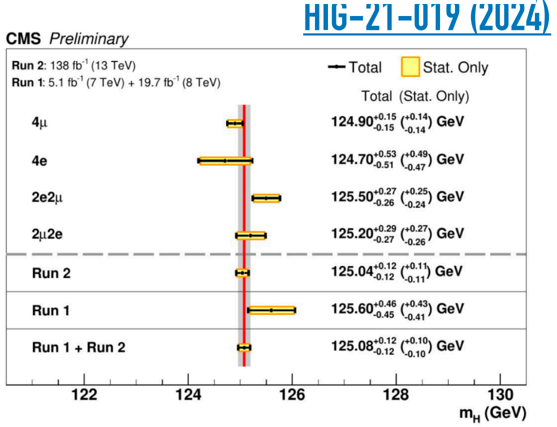


Higgs properties and rare processes

mass

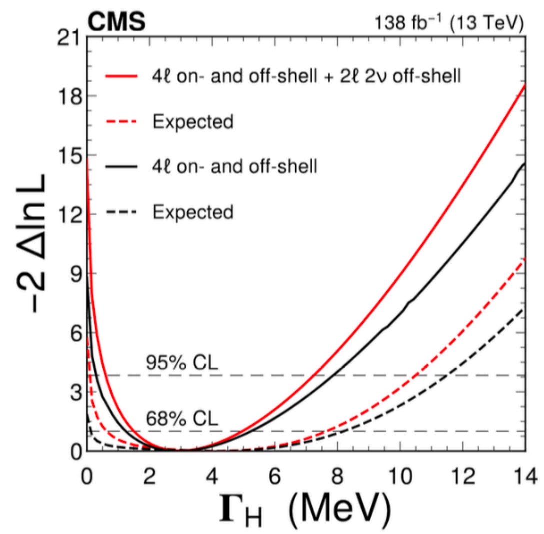


HIG-21-019 (2024)



- most precise m_H from single channel to date

width



$$\Gamma_H = 3.0^{+2.0}_{-1.5}\ \text{MeV}$$

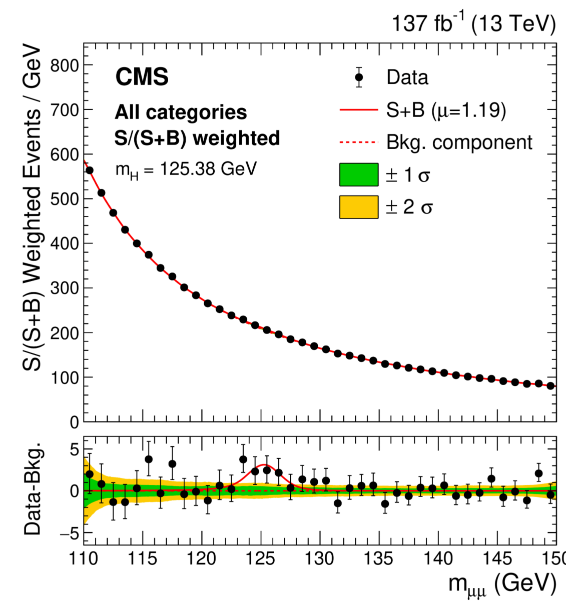
- on- vs off-shell

$$\sigma^{\text{on-shell}} \propto \mu^{\text{on-shell}}$$

$$\sigma^{\text{off-shell}} \propto \mu^{\text{on-shell}}\,\Gamma_H$$

- plus interference with ZZ continuum
- best bound on Γ_H to date

rare decay: H→μμ



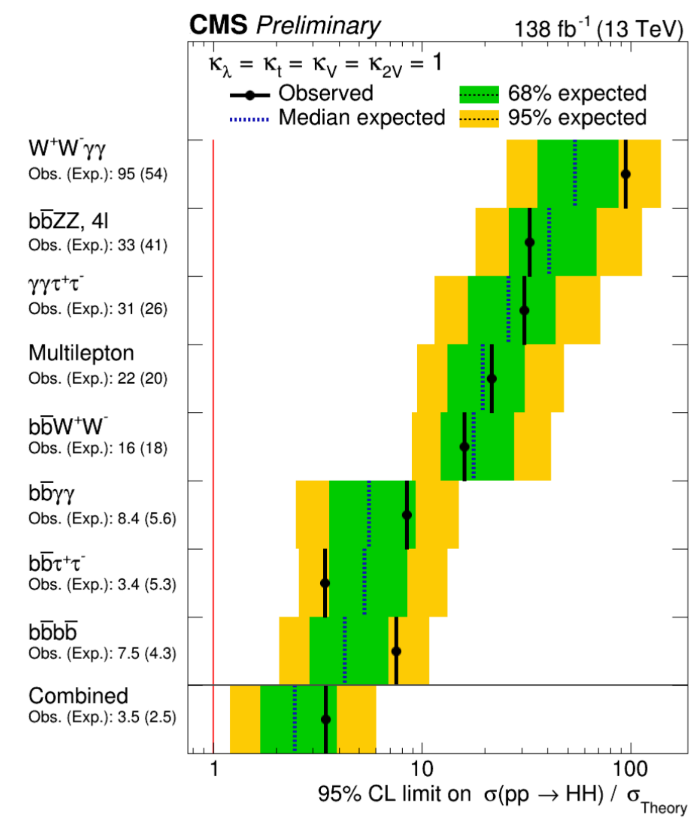
CMS-HIG-19-006

- most precise H to μ coupling measurement

$$\mu = 1.19^{+0.40}_{-0.39}\ (\text{stat})^{+0.15}_{-0.14}\ (\text{syst})$$

- first evidence (3σ) for Yukawa couplings to the second generation

rare production (HH)

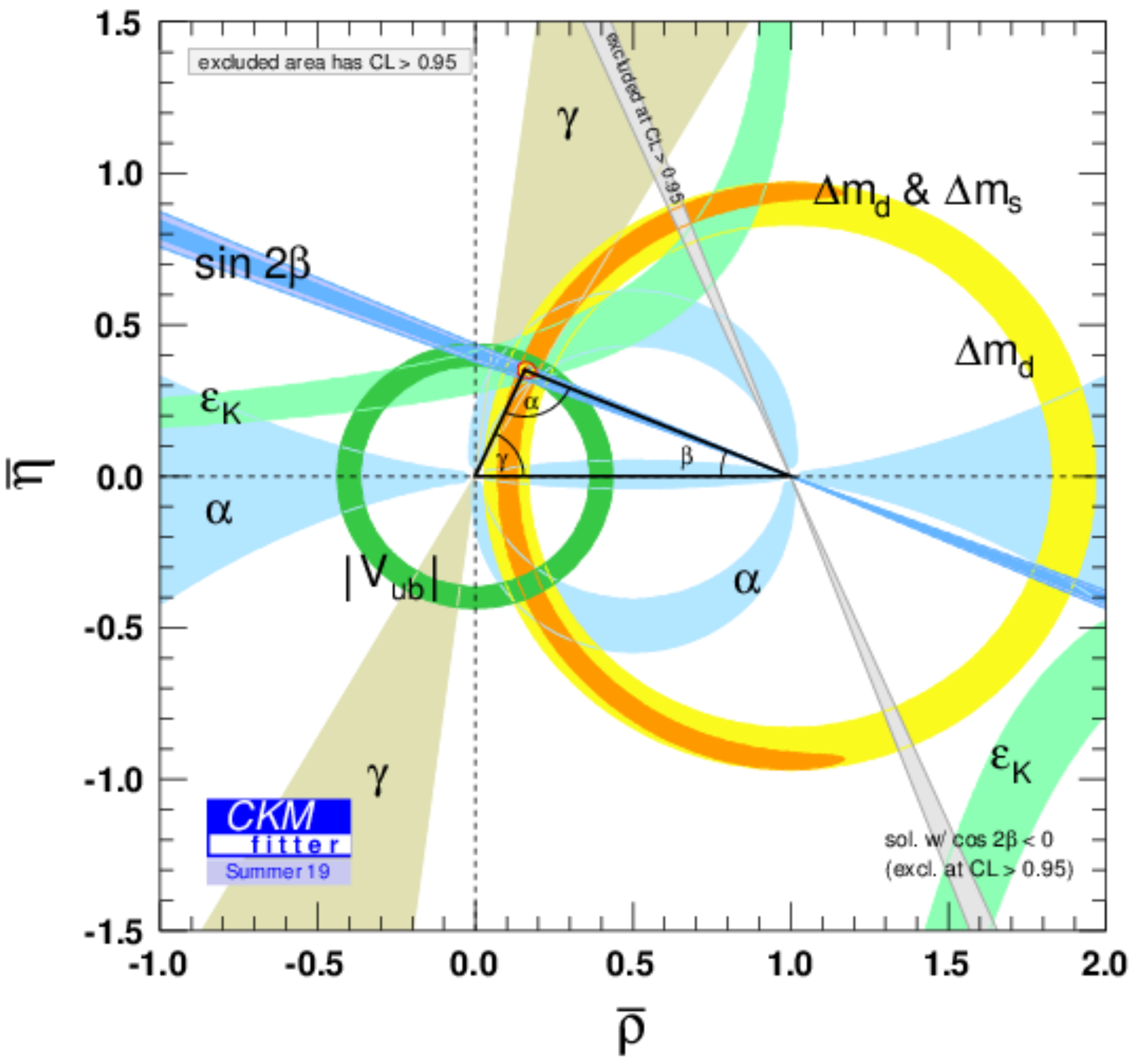


HIG-20-011 (2024)

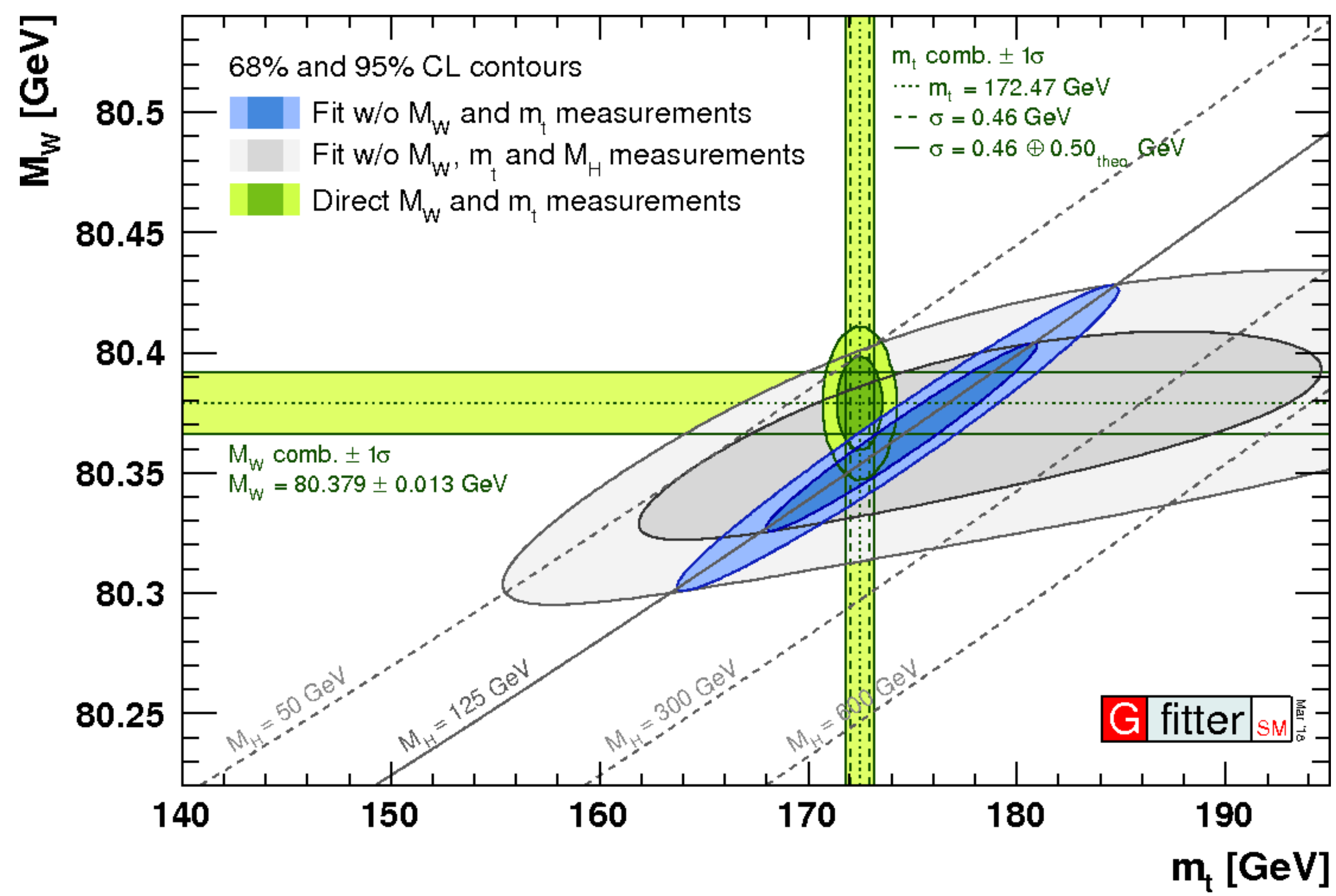
- limit 3.5 (2.5) times SM
- evidence extrapolated to be reached with 2000/fb

The Standard Model: precision measurements

quarks



H vs W vs t

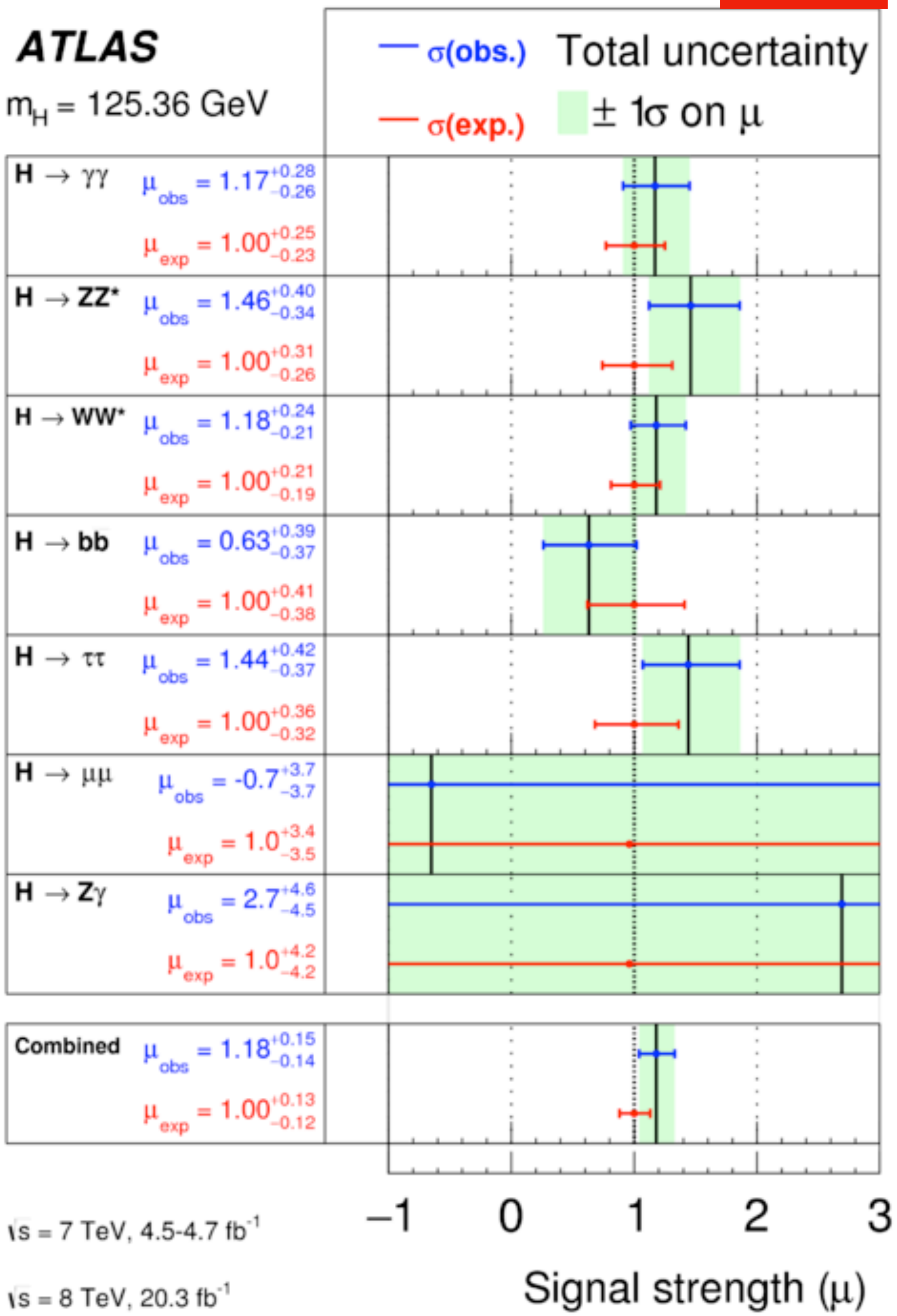


The SM describes all (*) experimental data !

SM = Precision

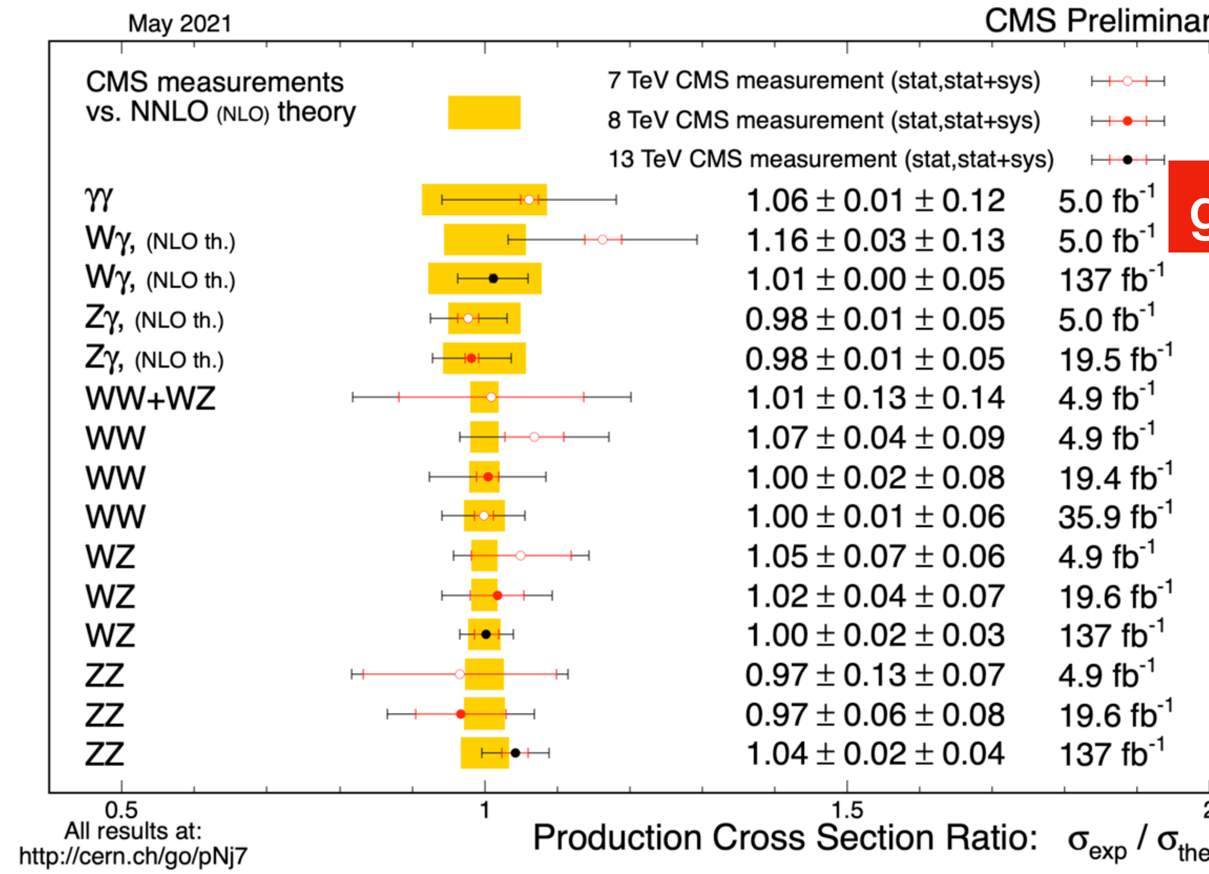
data vs theory

higgs

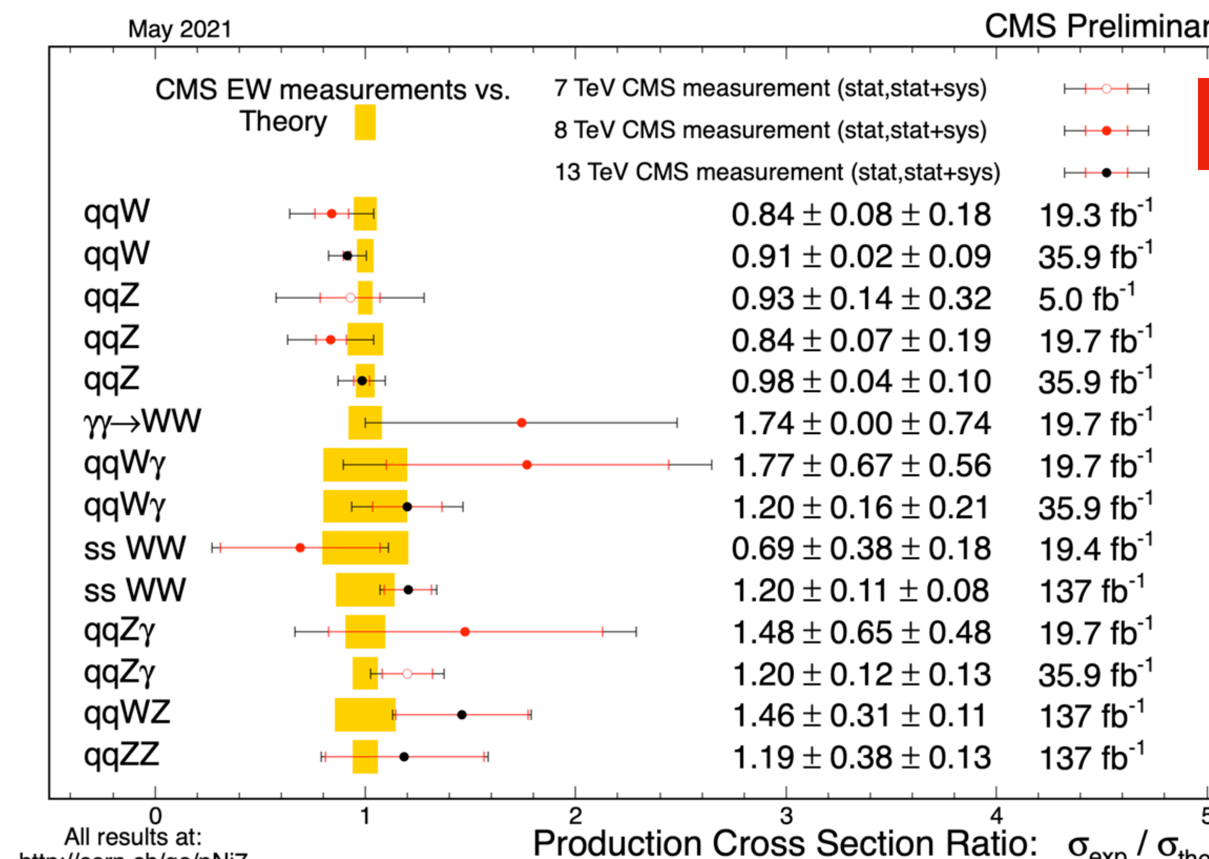


μ = data/SM

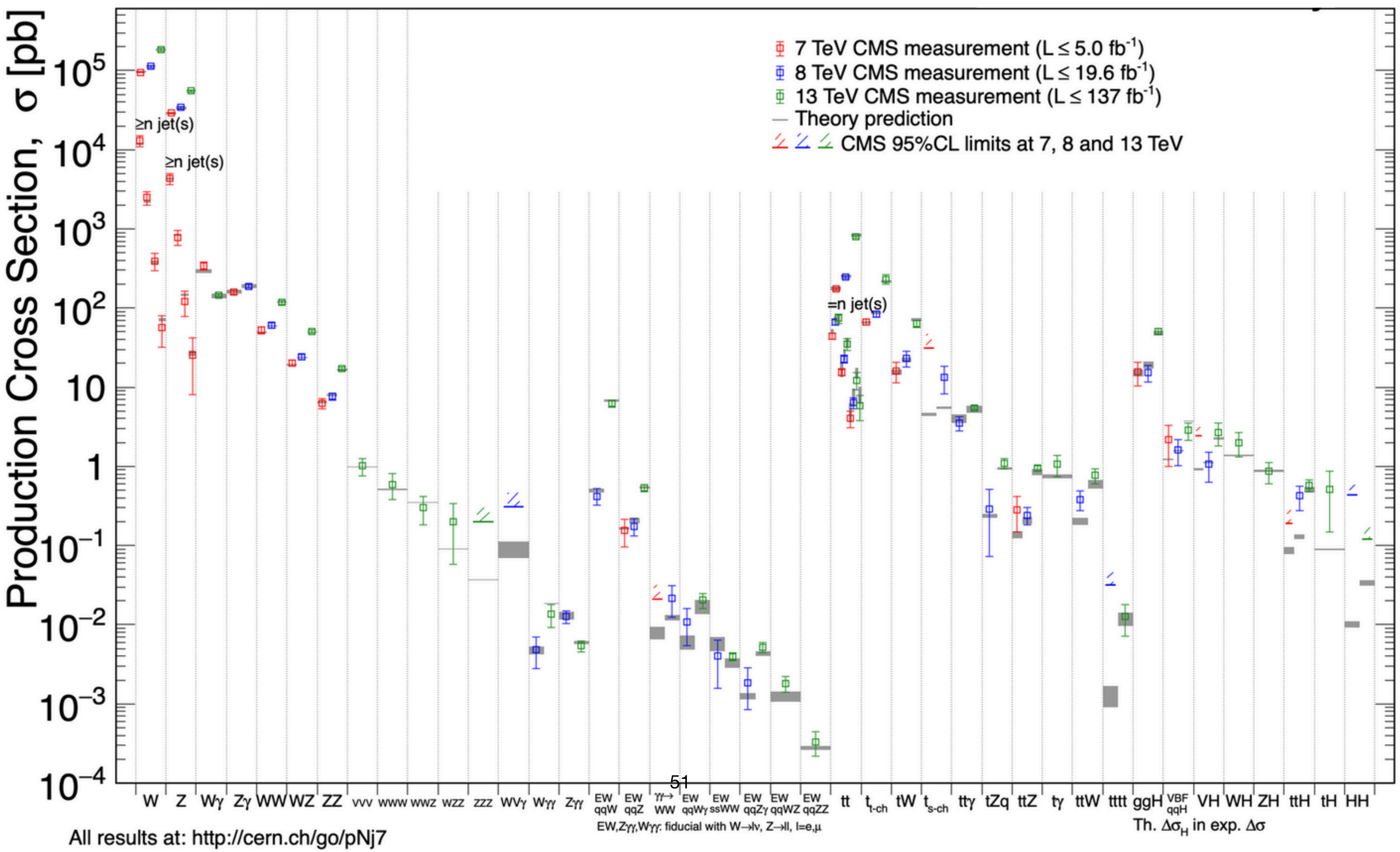
gauge

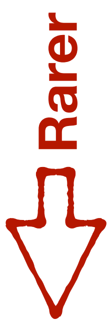


ewk



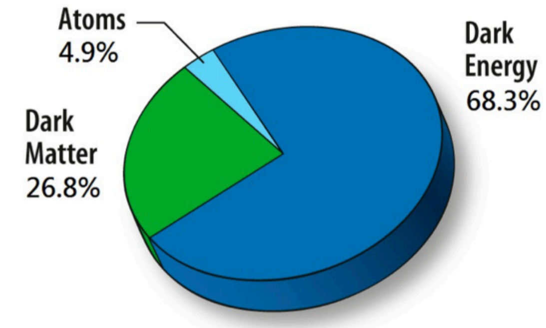
Probing multiple final states

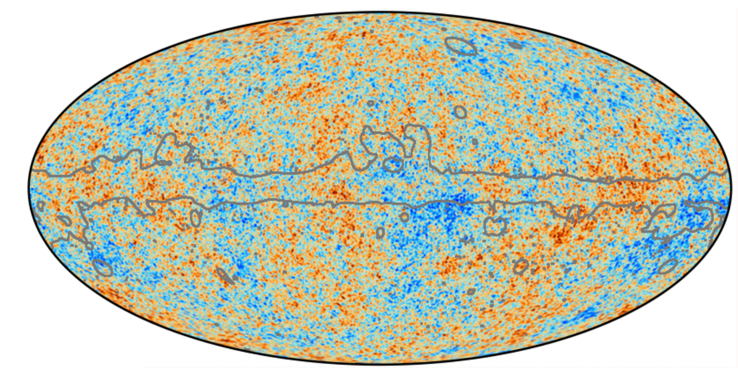




So. The SM is great. Why do we want to go beyond?

SM + gravity ≠ cosmos

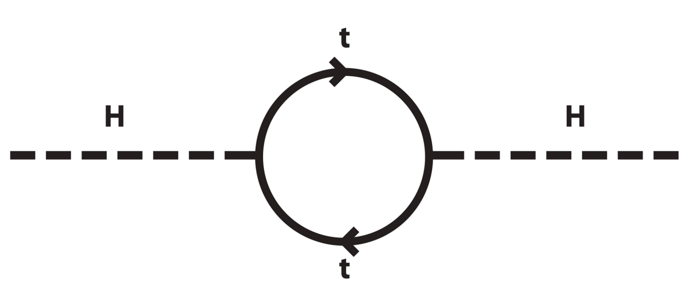




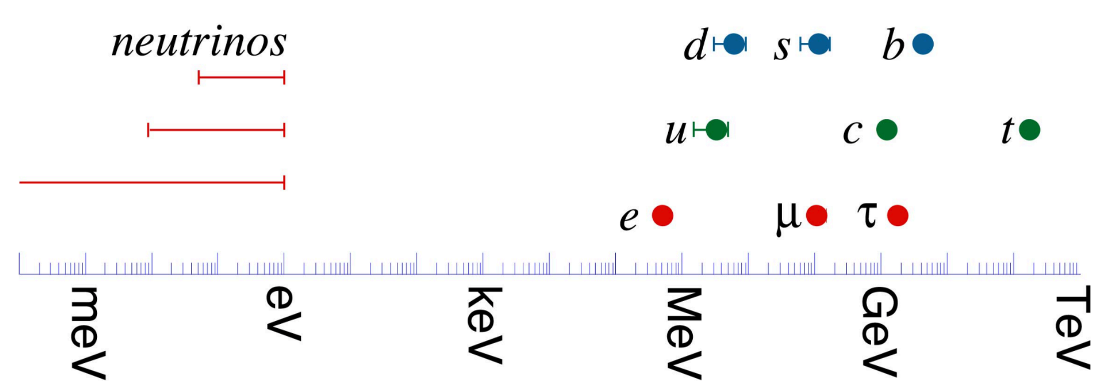
<u>Dados</u> que *decididamente* não conseguimos explicar:

assimetria matéria-antimatéria (CPV?…) — massa dos neutrinos — matéria escura (WIMPs, ALPs, HNLs,…)

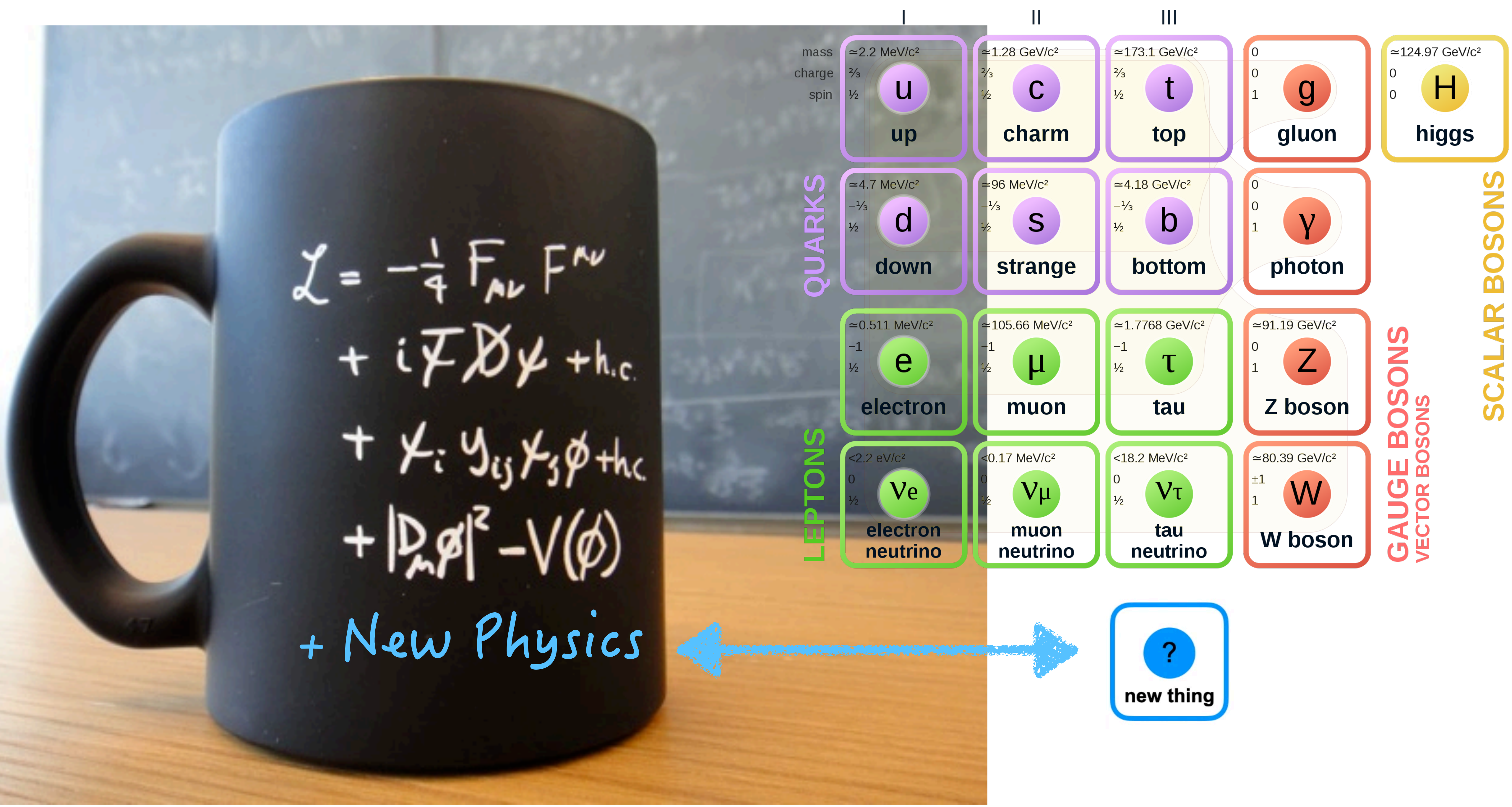
- **Hierarquia electrofraca**
- Fraca/Gravidade ~10^{24}
- EWK << Planck (Deserto?)
- Instabilidade da massa do Higgs
- Fine tuning
- Naturalness



- **Hierarquia de sabor**
- Porquê tantos parâmetros (19+)?
- Porquê 3 famílias ('Who ordered that?')
- Porquê $\theta_{QCD}<10^{-9}$ (Strong CP problem)
- Porquê hierarquias enormes nas massas e acoplamentos dos fermiões?



Going beyond the Standard Model



Physics goals at the LHC?

- Test the Standard Model (SM)
  - Precision measurements + rare processes
- Find physics beyond the Standard Model (BSM)
  - Direct and indirect searches for new particles

Produce BSM particles in the collisions + detect their decay products

Infer presence of BSM particles through their effect on properties of SM particles

ie "a la Higgs"

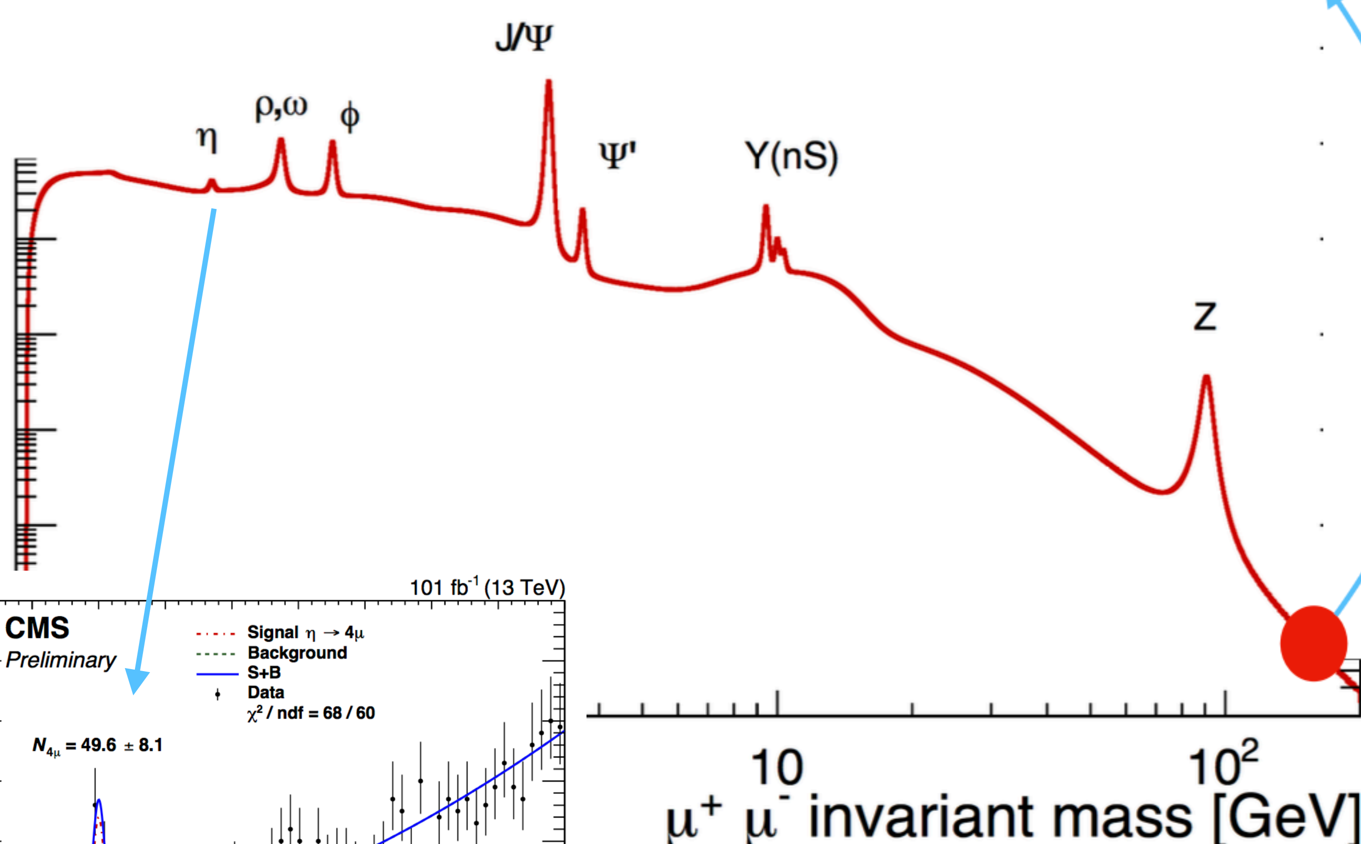
New particles discovered at LHC?

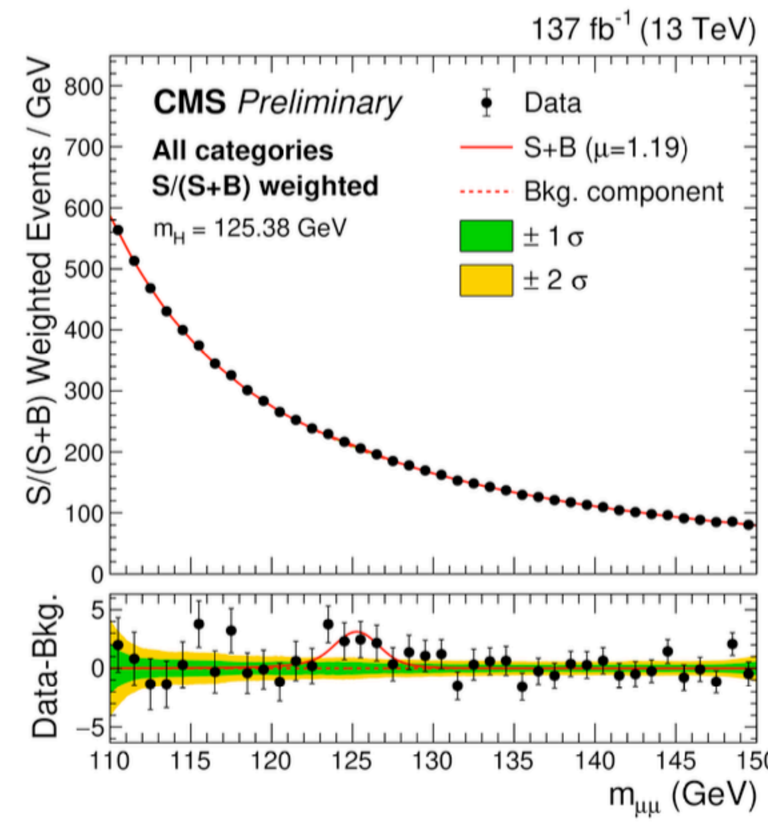
New ~~particles~~ discovered at LHC?
interactions

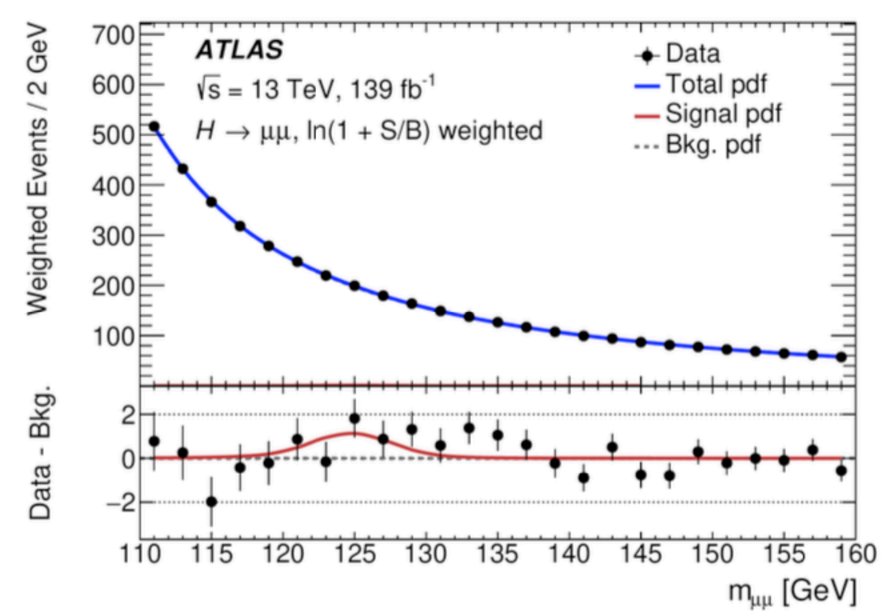
thorough exploration across the spectrum

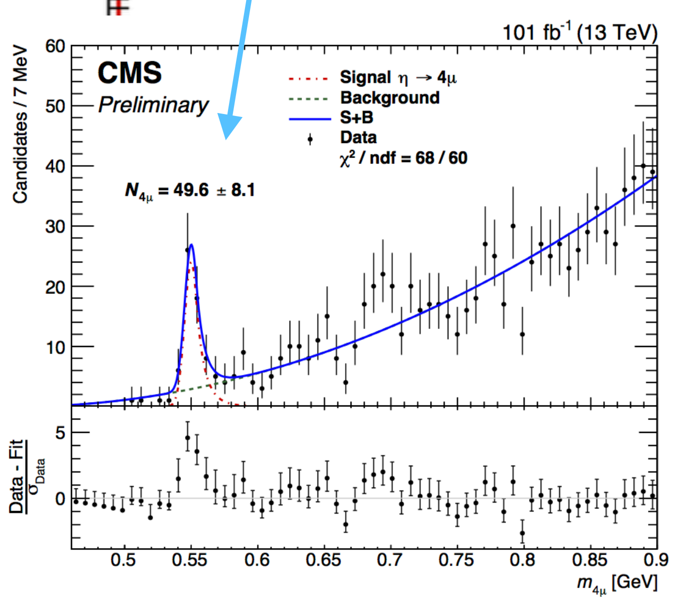
evidence for

H→μμ





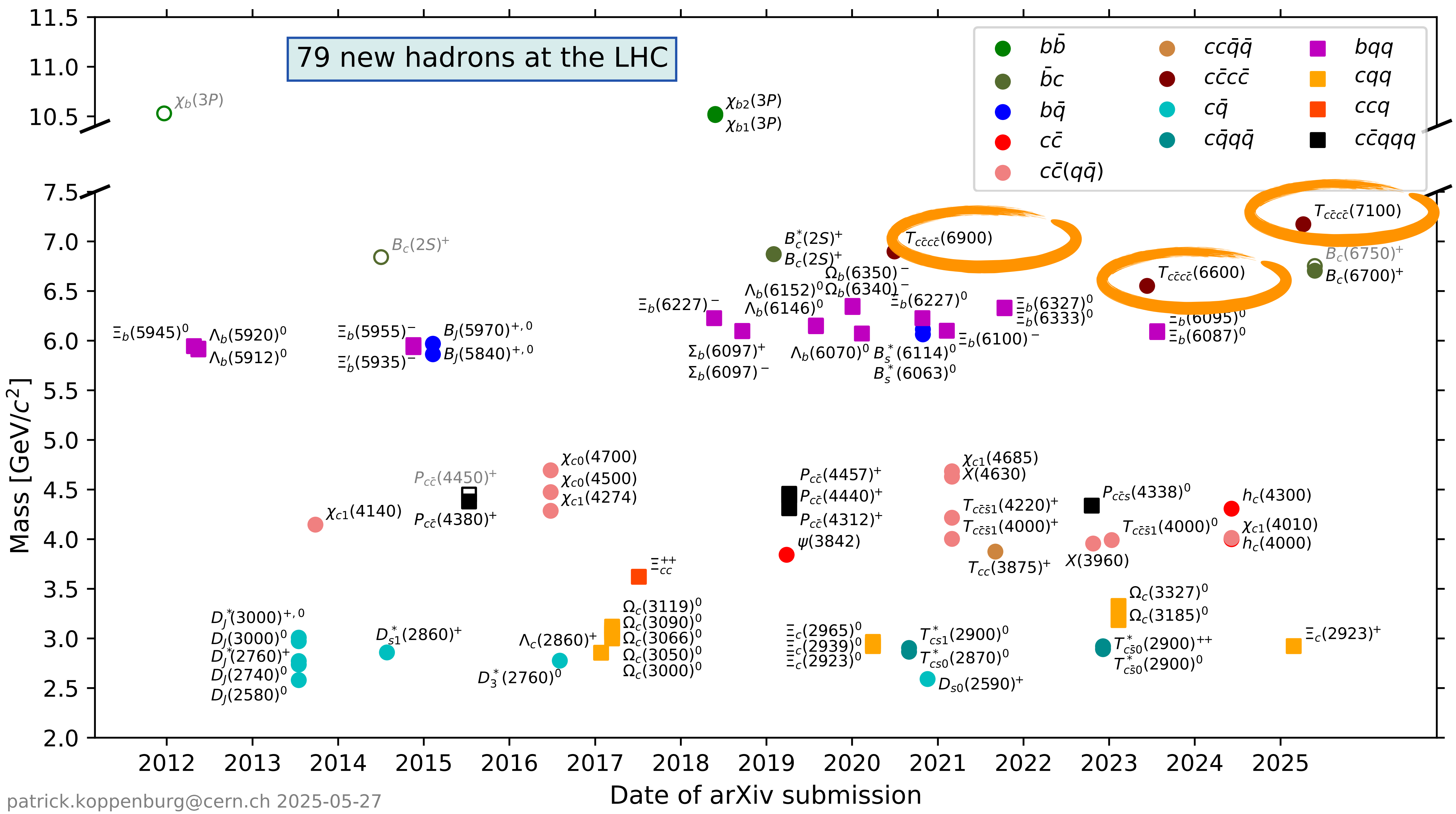




η→μμμμ

observation of new low-mass rare decay (with data scouting!)

New particles discovered at LHC?

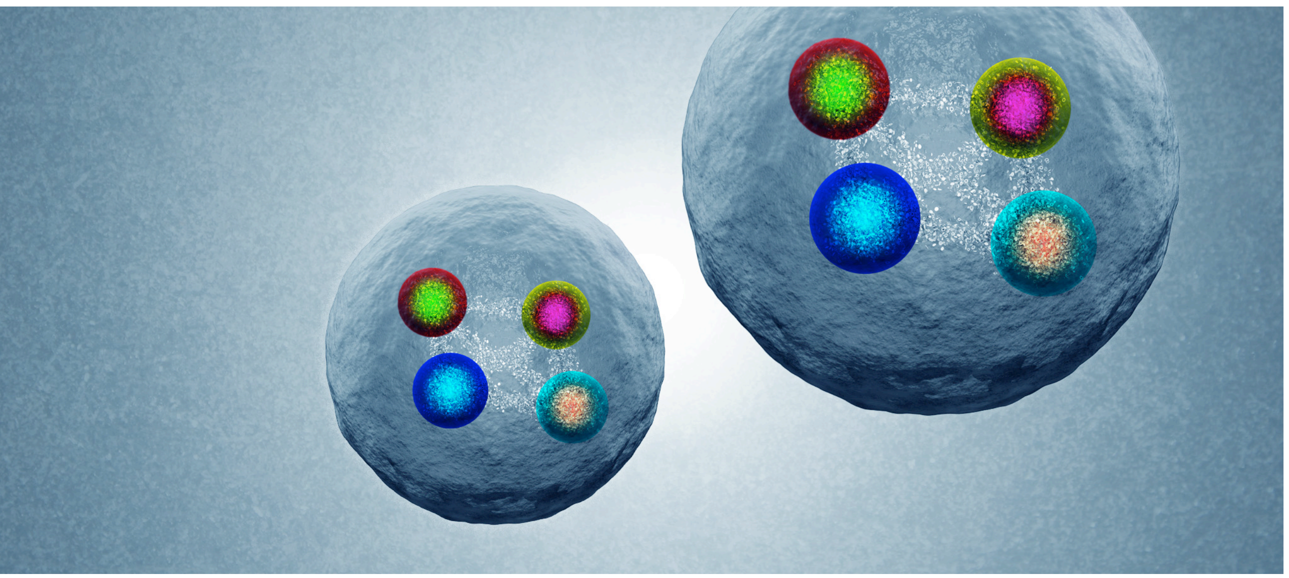


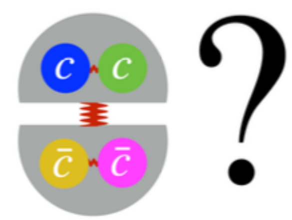
79+1 new particles already discovered — and more awaiting to be discovered !

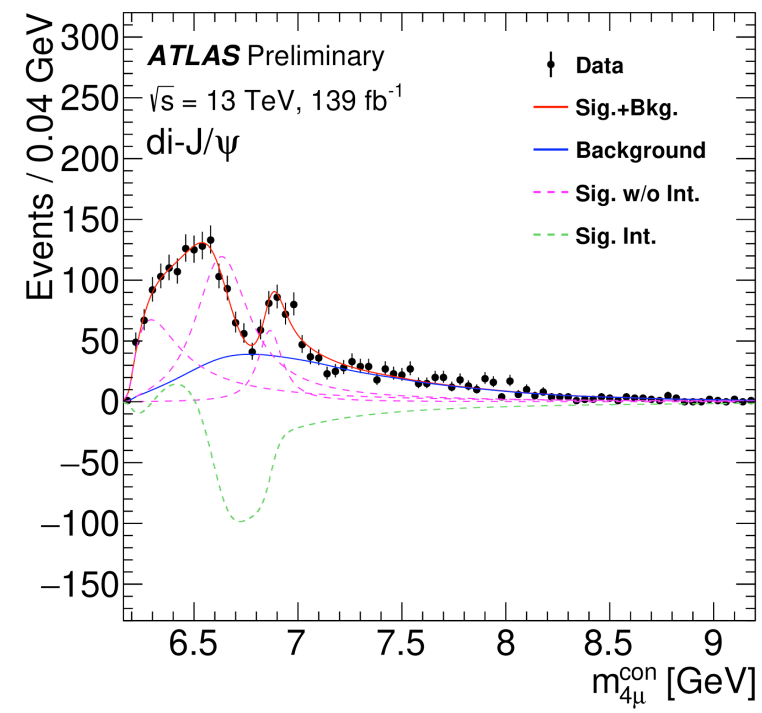
https://www.nikhef.nl/~pkoppenb/particles.html

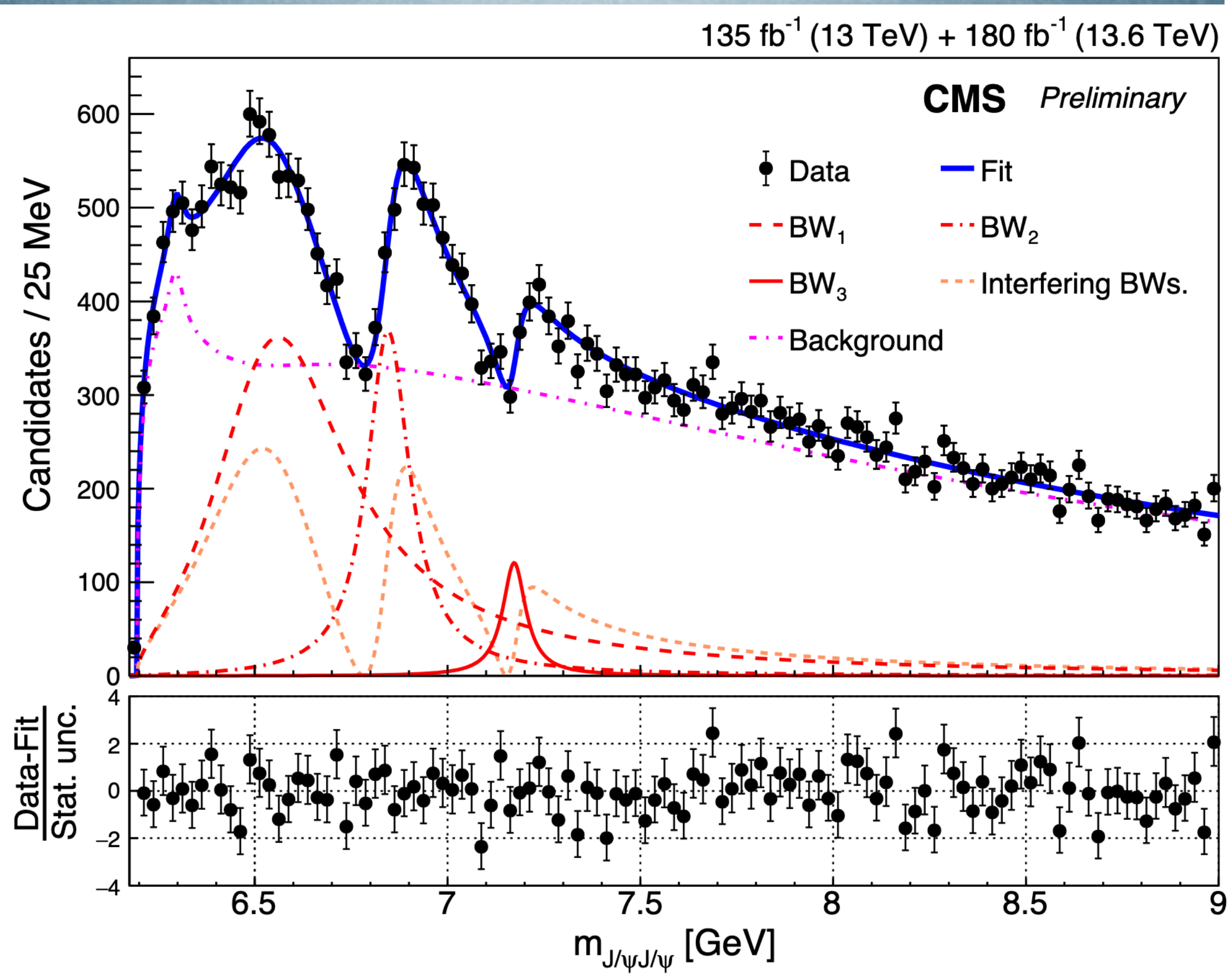
New particles discovered at LHC?

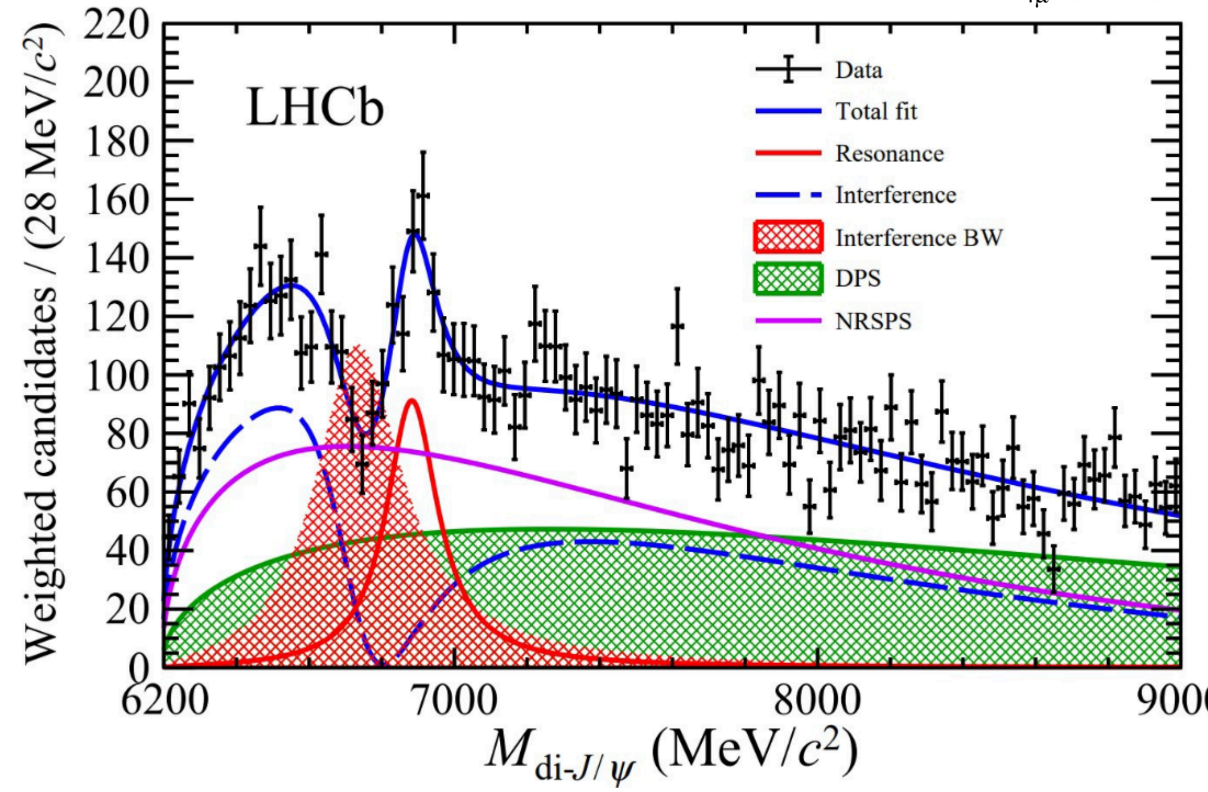
an all-charm tetraquark (candidates)



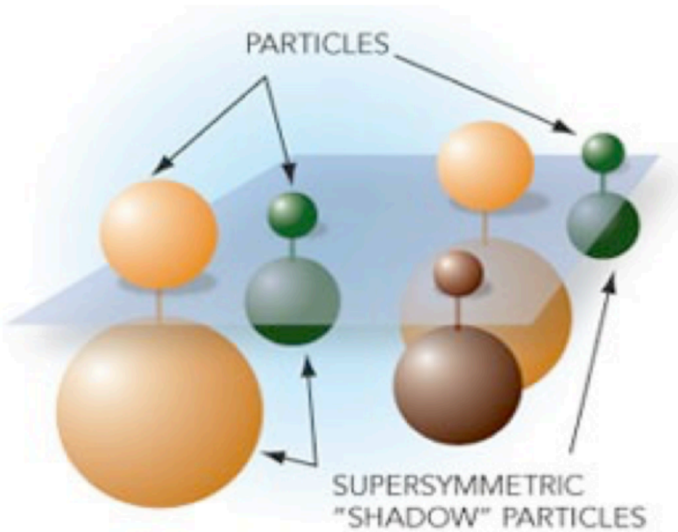


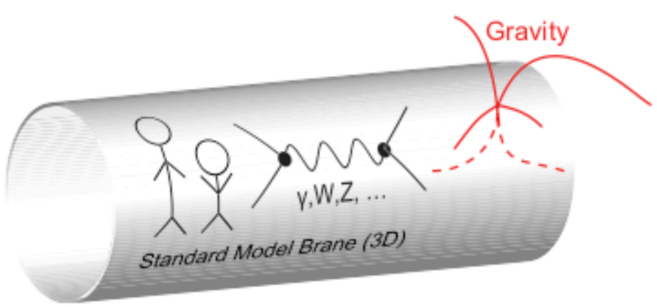


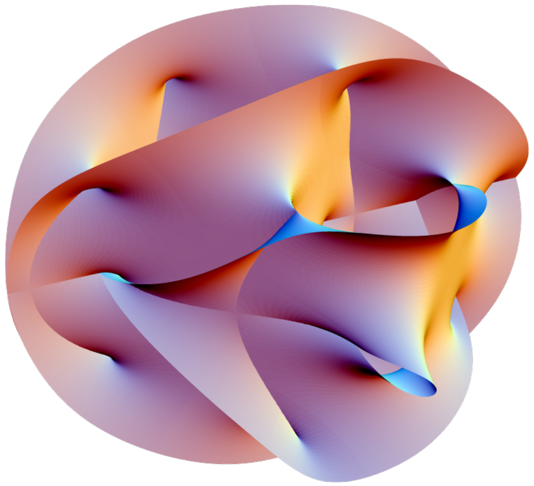




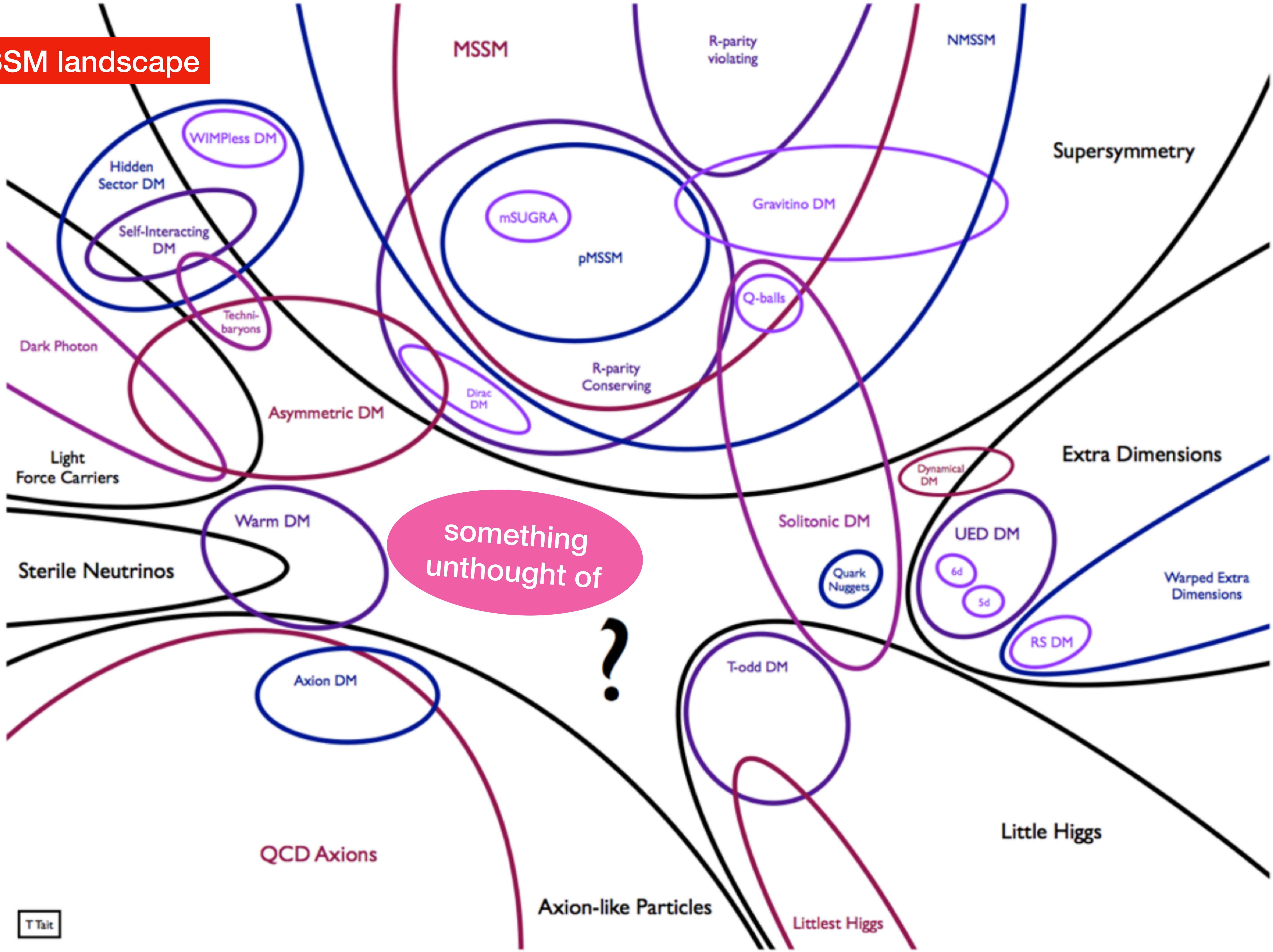
Probing beyond the SM





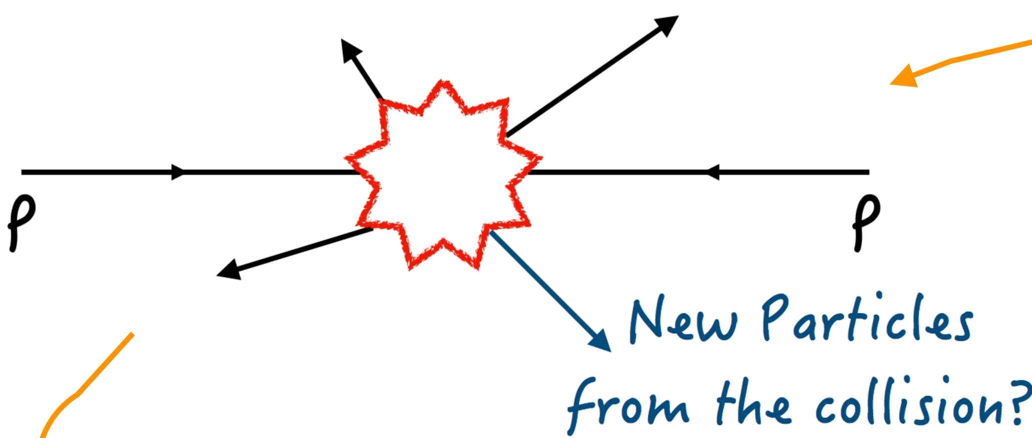


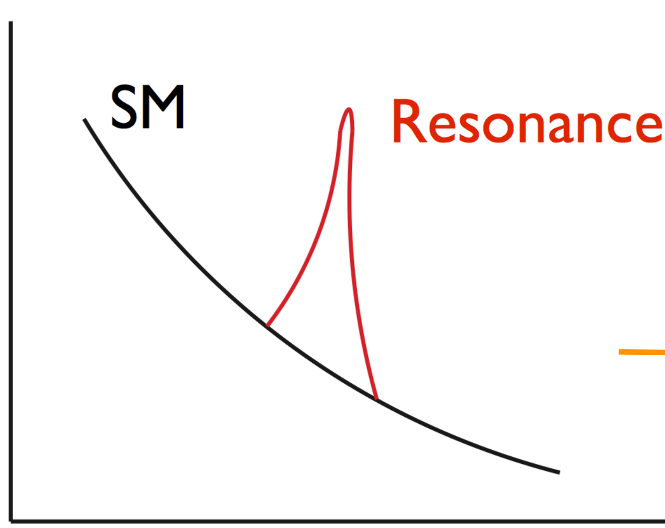
BSM landscape

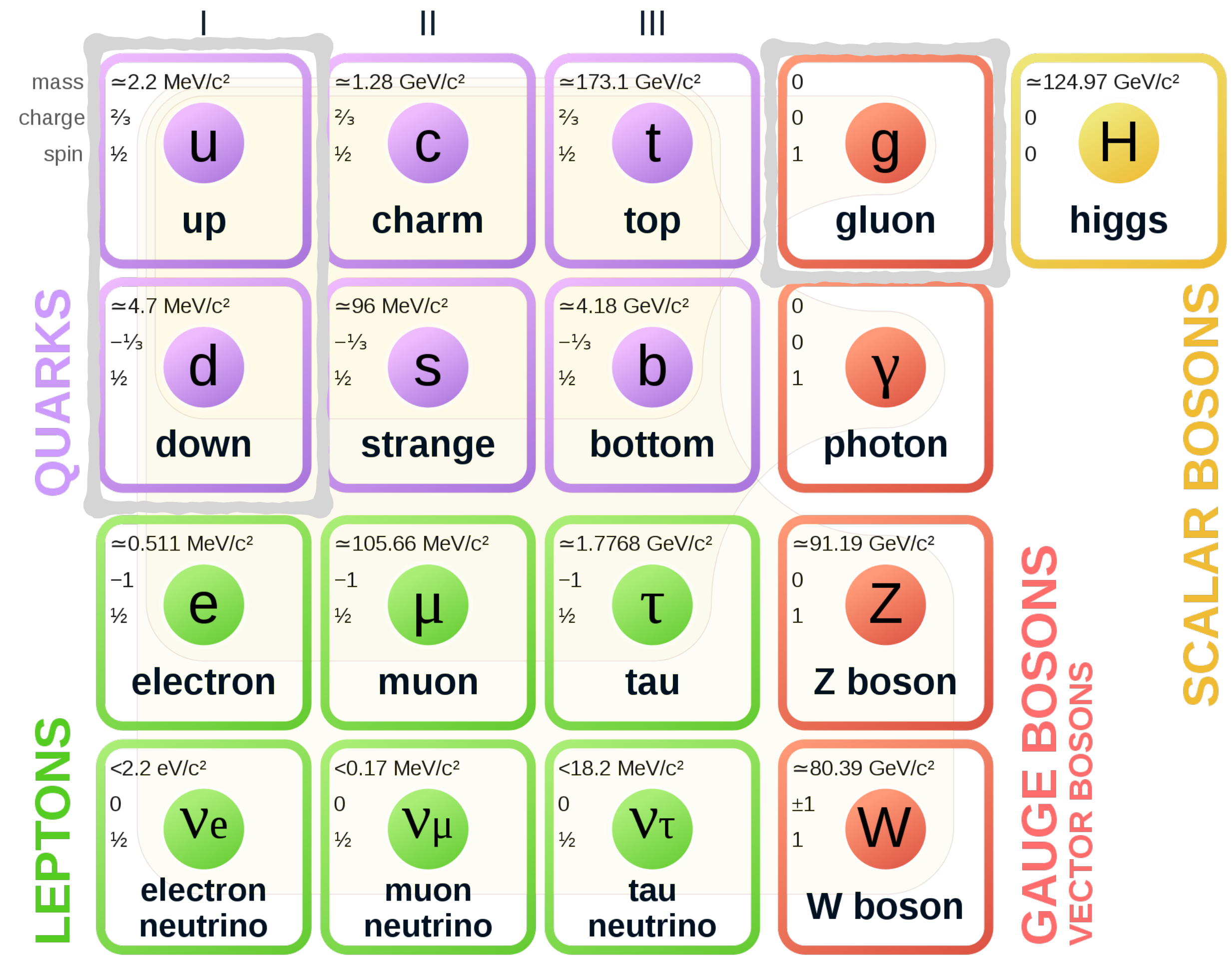


Going beyond the Standard Model

1) the easy way: direct discovery

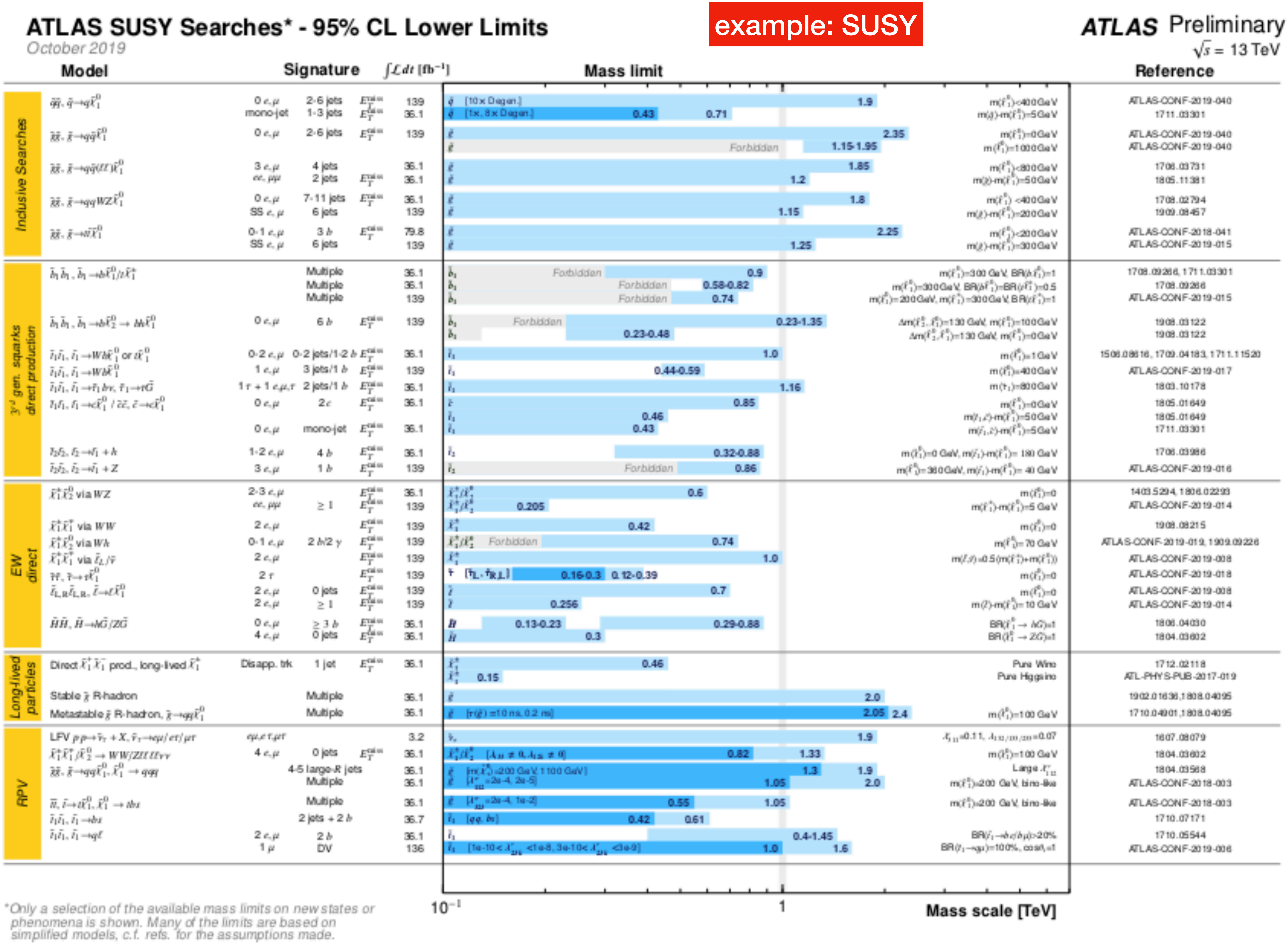






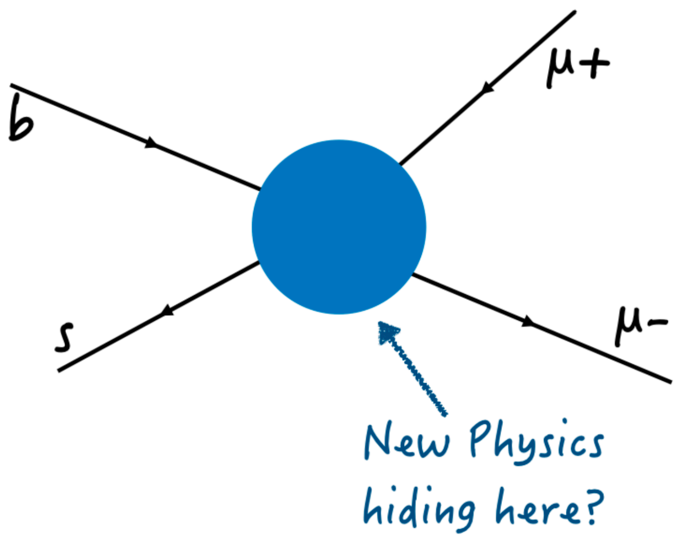
Energy frontier

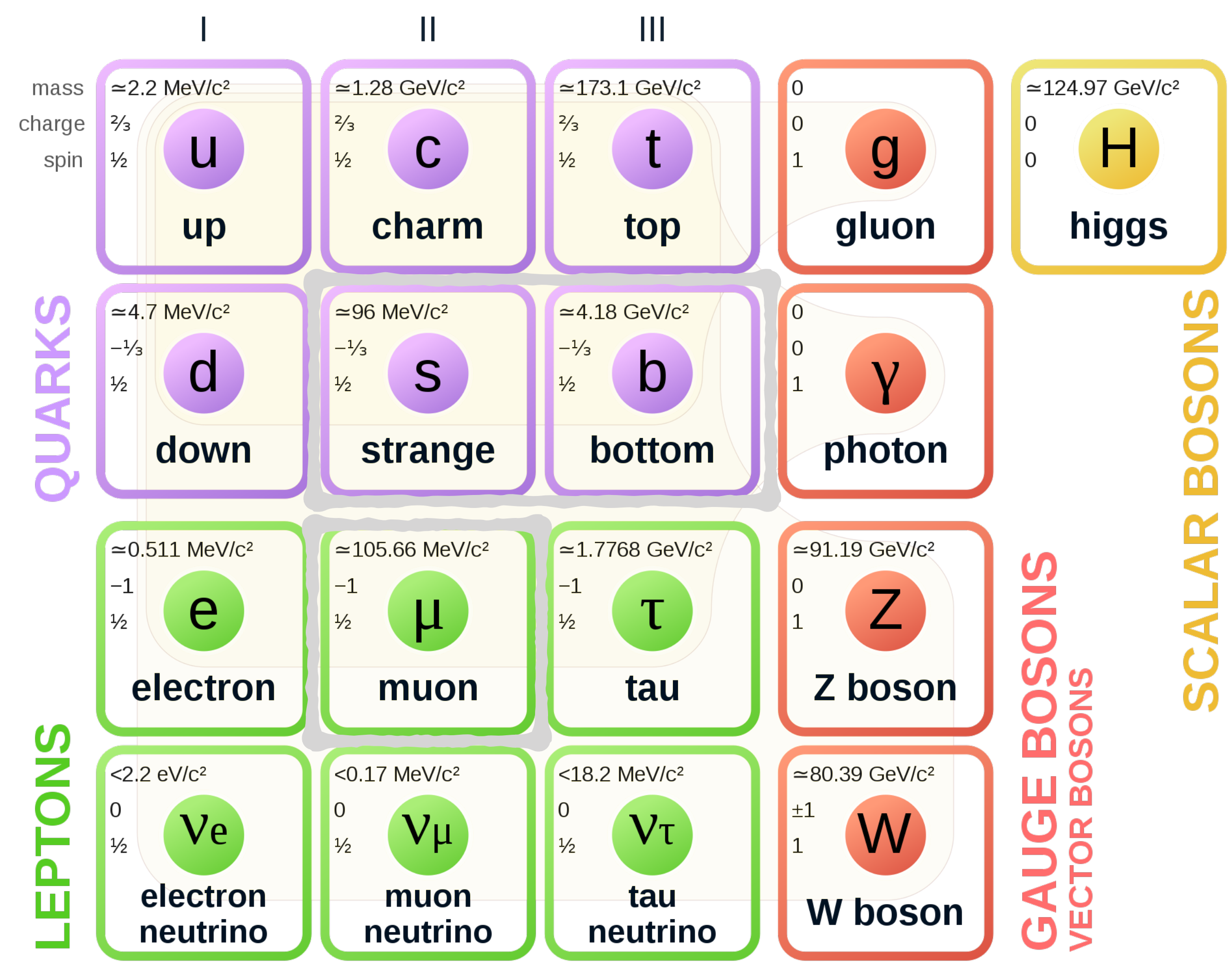
example: SUSY

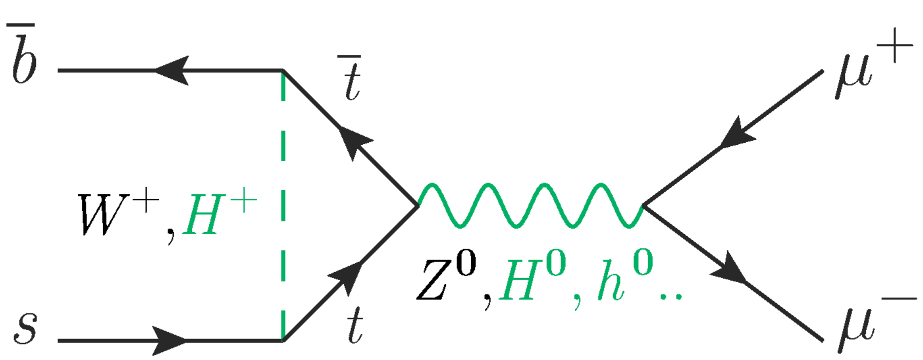


Going beyond the Standard Model

2) the not-so-easy way: *indirect* discovery





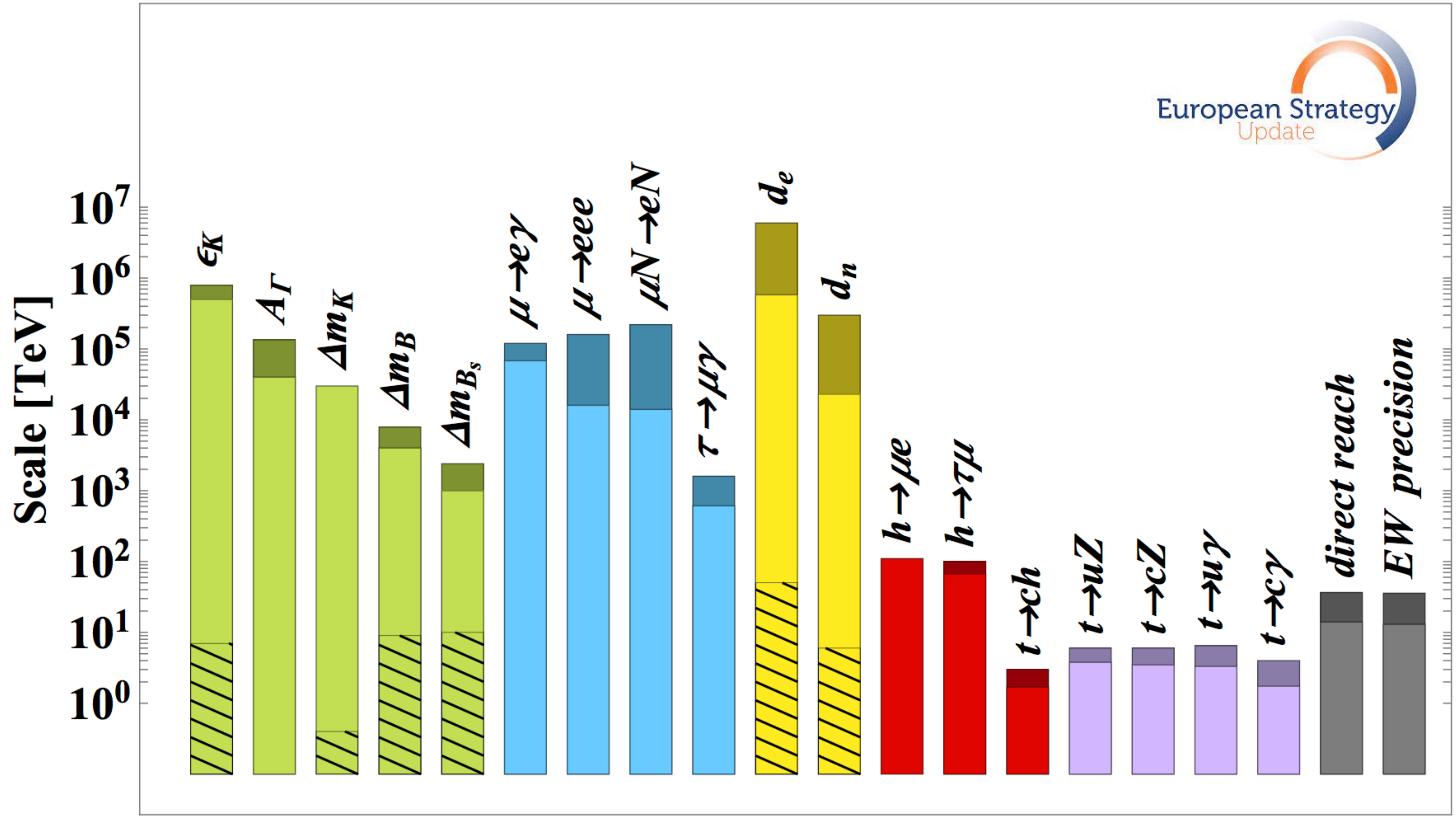


fuelled by Quantum Mechanics

Intensity frontier

Going beyond the Standard Model

Indirect searches: fuelled by Quantum Mechanics



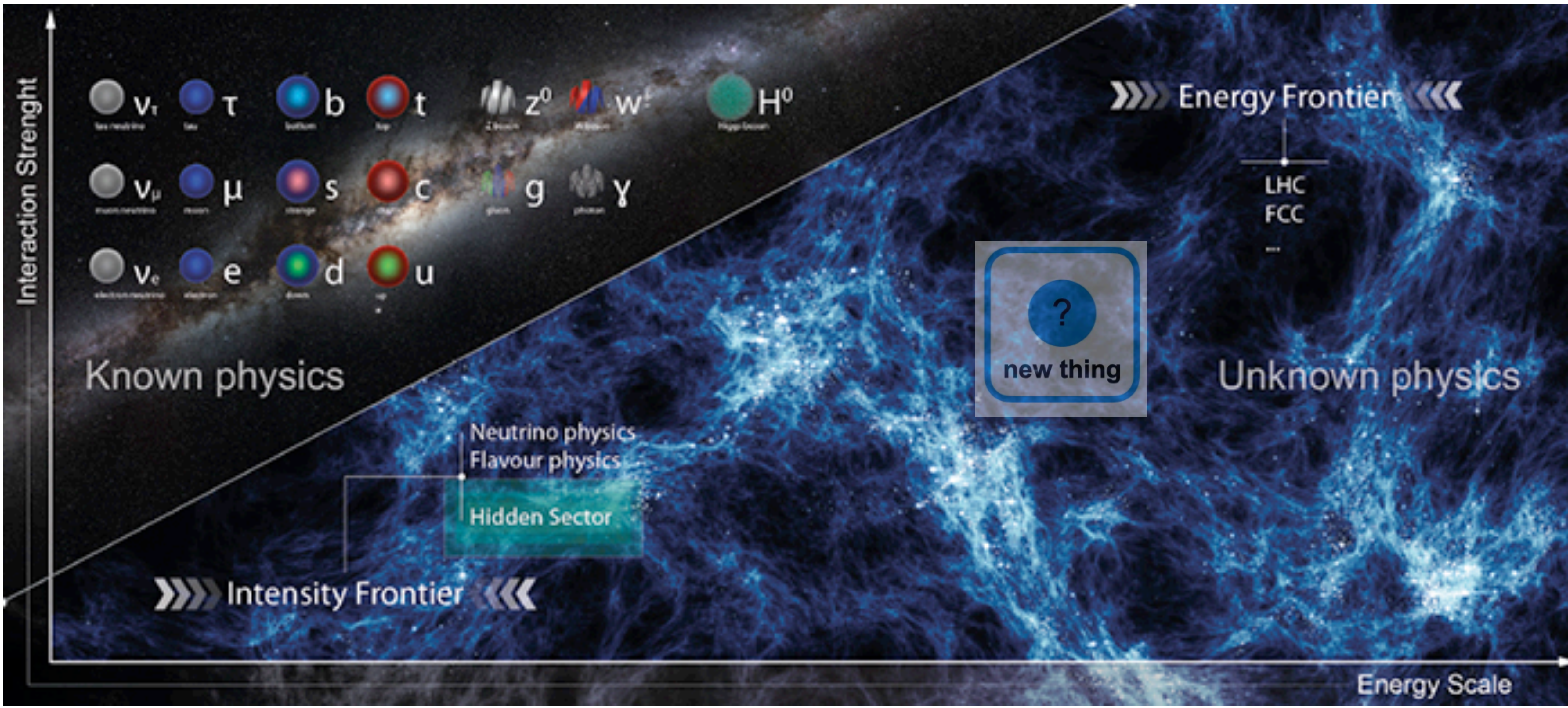
May access to NP scales well beyond collision energy !

Going beyond the Standard Model

LHC — explore both energy and intensity frontiers

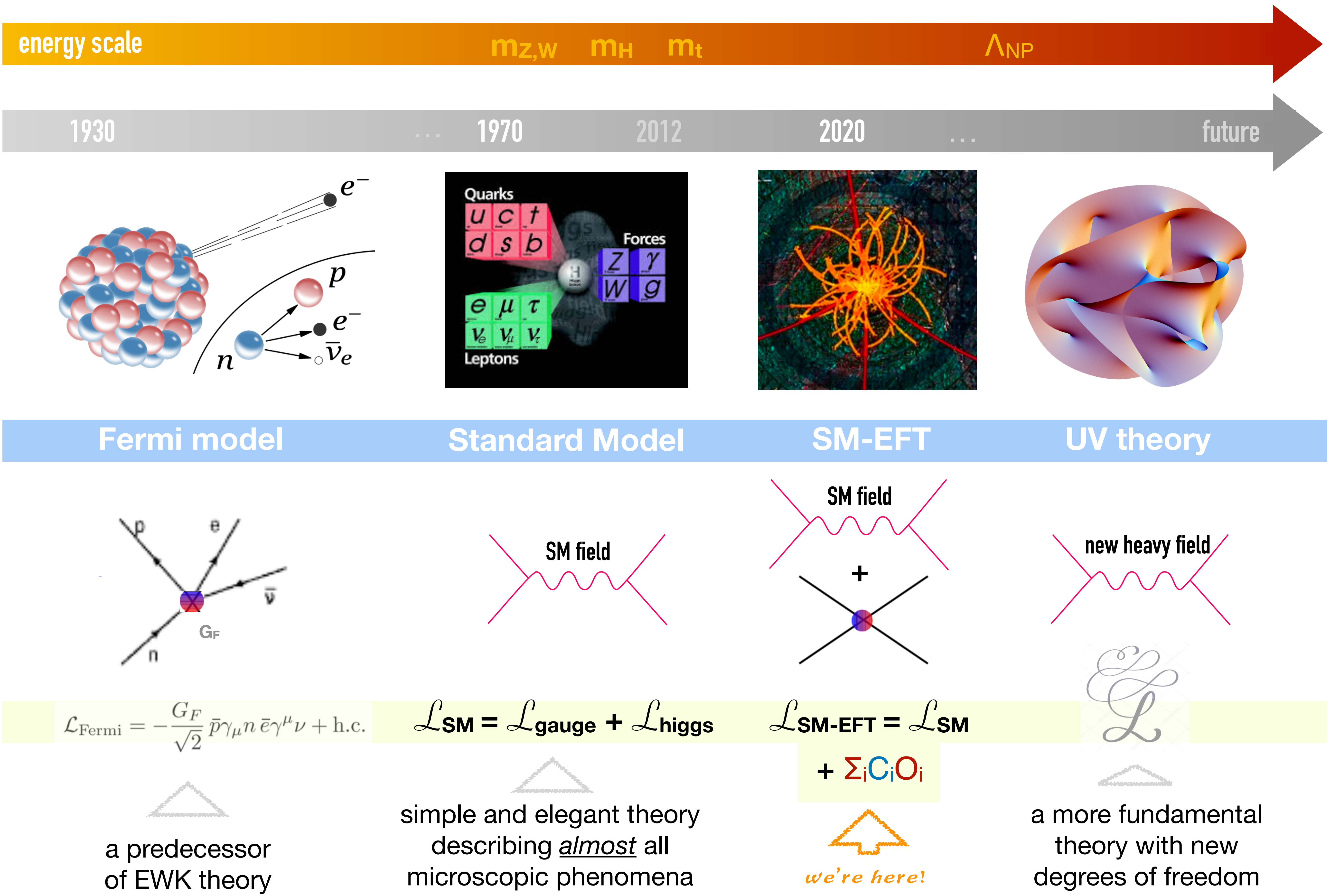
energy frontier

intensity frontier



Beam intensity: high luminosity

Beam energy: √s



energy scale
$m_{Z,W}$ m_H m_t Λ_{NP}
1930 ... 1970 2012 2020 ... future
e^-
p
e^-
n
$\bar{\nu}_e$
Quarks
u c t
d s b
Forces
Z γ
W g
e μ τ
ν_e ν_μ ν_τ
Leptons
Fermi model
Standard Model
SM-EFT
UV theory
p e
$\bar{\nu}$
G_F
n
SM field
SM field
+
new heavy field
$\mathcal{L}_{\text{Fermi}} = -\frac{G_F}{\sqrt{2}}\bar{p}\gamma_\mu n\,\bar{e}\gamma^\mu\nu + \text{h.c.}$
$\mathcal{L}_{\text{SM}} = \mathcal{L}_{\text{gauge}} + \mathcal{L}_{\text{higgs}}$
$\mathcal{L}_{\text{SM-EFT}} = \mathcal{L}_{\text{SM}}$
$+ \Sigma_i C_i O_i$
$\mathcal{L}$
a predecessor of EWK theory
simple and elegant theory describing *almost* all microscopic phenomena
we're here!
a more fundamental theory with new degrees of freedom

Happy internship projects!

a selection of [LHC-related] reports by your colleagues from last year's edition https://indico.lip.pt/event/1771/

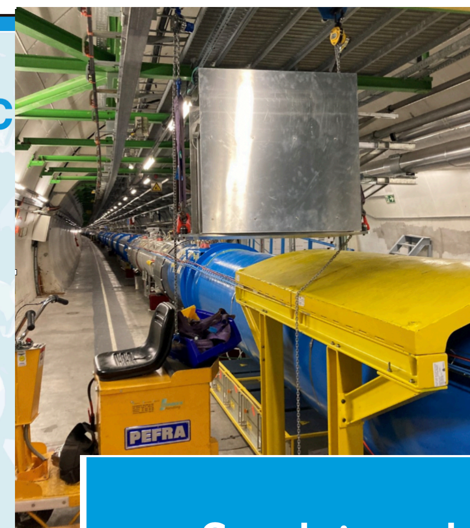
Study of quark hadronization at the LHC

Pythia exploration

Manuel Bidarra

Prof. Dr. Nuno Leonardo
Prof. Henrique Legoinha

LIP Internship Program, Final Workshop, 5/9/2024



Tracking muons from ongoing LHC Collisions

6th September 2024, LIP Summer Internship, Final Workshop

Alexandre Mendonça
Tristan Barlerin

LIP Internship Program | 2024 Edition

Investigating the Flavour Anomalies with Machine Learning at LHC

Final Workshop

05/09/2024

Authors: Diogo Pereira, Gonçalo Marujo
Supervisors: Alessio Boletti, Nuno Leonardo

Studying the Primordial Fluid with Deep Learning

Martim Pinto (IST)
Supervised by João A. Gonçalves (LIP)

[1] LIP / Laboratório de Instrumentação e Física Experimental de Partículas
[2] IST/ Instituto Superior Técnico

Probing Quark Hadronization with B mesons

Ye Jinghao

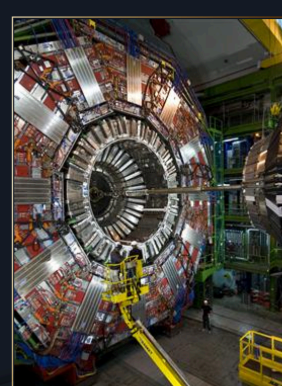
Prof. Dr. Nuno Leonardo
Prof. Henrique Legoinha

LIP Internship Program, Final Workshop, 5/9/24

Timing performance of the CMS Precision Proton Spectrometer in LHC Run3 data

Ana Sofia Roque Gomes

Project supervisors: Giovanni Marozzo, Jonathan Hollar



Expanding the ATLAS Physics reach with anomaly detection at trigger leve

Ana Rita Ferreira Carvalho
Supervisor: Inês Ochoa

Program – 5th September 2024

Upgrade of the ATLAS Tile Calorimeter High Voltage System

LIP Summer Internship 2024

Carolina Antunes & David Encarnação

Supervisors:
Agostinho Gomes, Luis Gurriana & Guiomar Evans

Laboratory of Instrumentation and Experimental Particle Physics

6th September 2024

Construction of a Particle Accelerator

Ana Armada, José Martins
Supervisor : Henrique Carvalho