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Leptons



Quarks charm top down bottom strange



Leptons



The Higgs boson plays a fundamental role explaining the masses of all the particles.

The Higgs sector is special

The Higgs boson is a fundamental^(*) scalar particle and its theory is unlike anything else we have seen in Nature

A gauge interaction

much like what we have seen before. It generates the masses of the vector bosons (W, Z⁰ bosons).





A Yukawa interaction

unlike anything we have probed before. It provides naturally mass terms to the fermion.

A potential V(ϕ)~- $\mu^2(\phi\phi^{\dagger})$ + $\lambda(\phi\phi^{\dagger})^2$

the keystone of the Higgs mechanism and SM, <u>never probed</u>

(*) maybe composite?









The experimental apparatus

LHC the world's largest and most powerful particle accelerator





14000-tonne weight

21 metres long, 15 metres wide and 15 metres high 4 Tesla field (~100,000 times the magnetic field of the Earth)

Performance

Pixel tracker 10 μ m in (r, ϕ) plane / 20 μ m in z direction Electromagnetic resolution down to 0.3%



within the Higgs boson landscape



Pre-LHC : we made discovery potential studies

Future colliders

Nowadays : we study the complete Higgs Boson profile

We were key players of the Higgs boson discovery





Key example : $H \rightarrow ZZ \rightarrow 4I$ channel



Nobel Prize in Physics (2013)

Clean signature: narrow resonance of four primary and isolated leptons.



"Inca world leader"

From the discovery towards the complete study of the strength and tensor structure of the Higgs-boson







Key example : $H \rightarrow ZZ \rightarrow 4I$ channel



Nobel Prize in Physics (2013)

Clean signature: narrow resonance of four primary and isolated leptons.







Groupe CMS au LLR Expérience CMS: Prix EPS HEP 2013, Mention pour l'attribution du Prix Nobel 2013 C'est un grand bonheur po physiciens, ingénieurs et tech du LLR d'avoir été associés d'au à la découverte du boson de explicitement citée par le comité

Intermezzo : awards

Our collective work contributed to 2013 Nobel Prize. We were awarded of the High Energy and Particle Physics Prize 2013. Last but not least, our students are regularly awarded !

- the construction of the CMS electromagnetic calorimeter" of CMS Thesis award^(*)
- H to WW(*) to $2e2v^{"}$ OMS Thesis award^(*)
- 2013 L. Bianchini "Search for the Standard Model <u>Higgs boson</u> decaying to tau leptons with the CMS experiment at LHC" ⁶ CMS Thesis award^(*)
- 2015 L. Mastrolorenzo "Search for the <u>Higgs boson</u> decaying into T lepton pairs with the Matrix Element
- 2017 T. Strebler "Probing the <u>Higgs</u> coupling to the top quark at the LHC in the CMS experiment" **École Doctorale Thesis award**
- at the LHC" OCMS Thesis award(*)



In the group there are a CNRS silver medalist and French Academy of Sciences Prize winner.

• 2001 I. Puljak "CMS discovery potential for the <u>Higgs boson</u> in the H to ZZ* to 4e decay channel. Contribution to

• 2005 C. Rovelli "The CMS electromagnetic calorimeter and the search for the <u>Higgs boson</u> in the decay channel

Method and t trigger optimization in the CMS experiment at the LHC " of École Polytechnique Thesis award

• 2017 L. Cadamuro "Search for <u>Higgs boson pair</u> production in the bbit decay channel with the CMS detector

(*) O(100) completed PhD Theses/year inside the CMS collaboration

Towards Higgs boson self-coupling

Essential in EWSB, need to measure the Higgs boson trilinear coupling (λ_{HHH}) via

double Higgs boson production



Production cross section <1/1000 signal Higgs boson production

The shape of the potential is linked to many open questions of particle physics and cosmology

Its modification makes the EW vacuum metastable

Its stability at high energy has an impact on the role of the Higgs as an inflation in the primordial Universe



Upgrade of LHC : High Luminosity LHC →10 higher collision rate



The upgrade of CMS detector for HL-LHC

Involved in one of the most challenging projects for HL-LHC

Endcap calorimeters





Future colliders

pp collider: towards high energy

FCC-hh

16 T magnets for 100 TeV collisions 100-Km tunnel



Strong synergy at Unc from concept to prototypes towards physics

ee collider : towards high precision

Linear collider

super-conductive RF cavities staged, $\sqrt{s} = 250$ GeV - 1 TeV, L ~ 1-3 ab-1

FCC-ee

same tunnel as FCC-hh $\sqrt{s} = 180 - 380$ GeV, L = 150 - 1.5 ab-1

