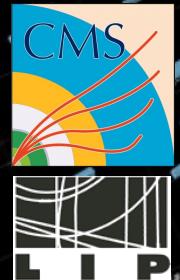


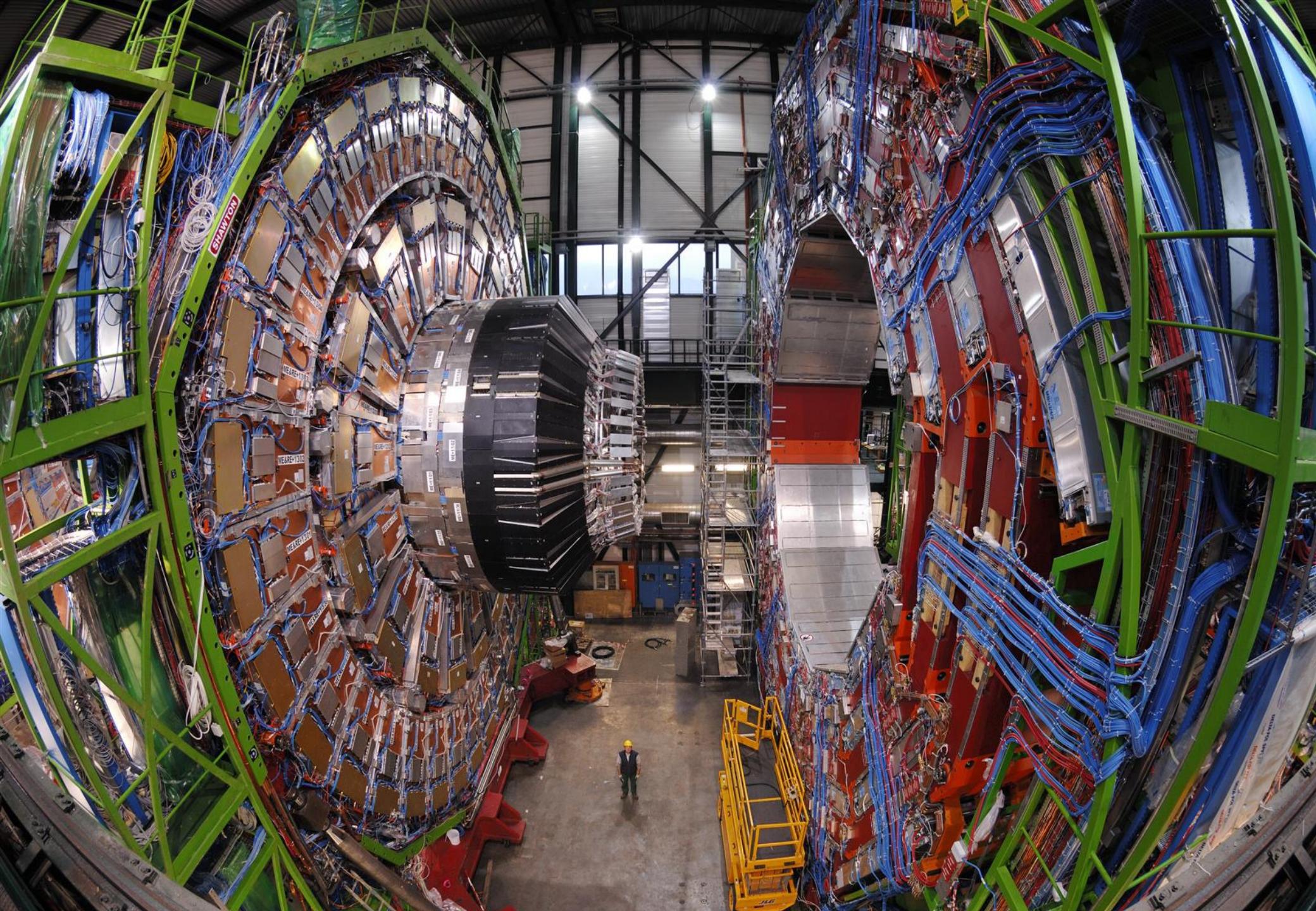
Probing the SM at LHC: The Higgs boson and beyond

Michele Gallinaro

Oeiras, May 13, 2022

michgall@cern.ch

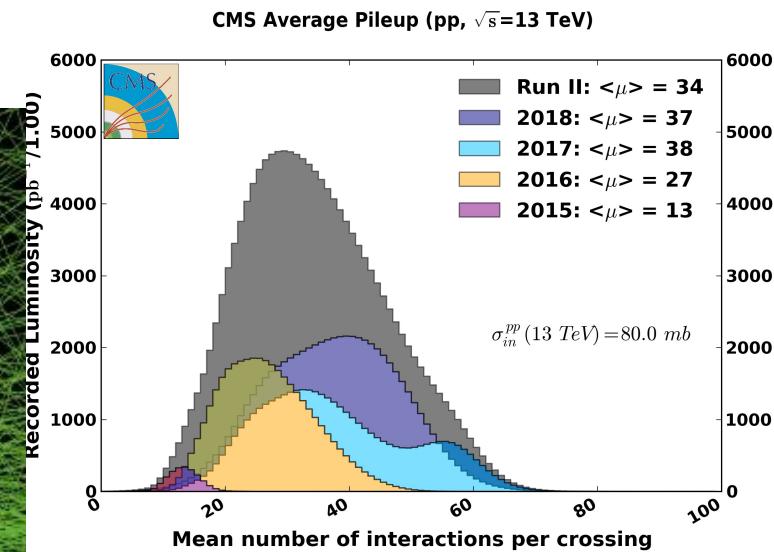




...in a challenging environment

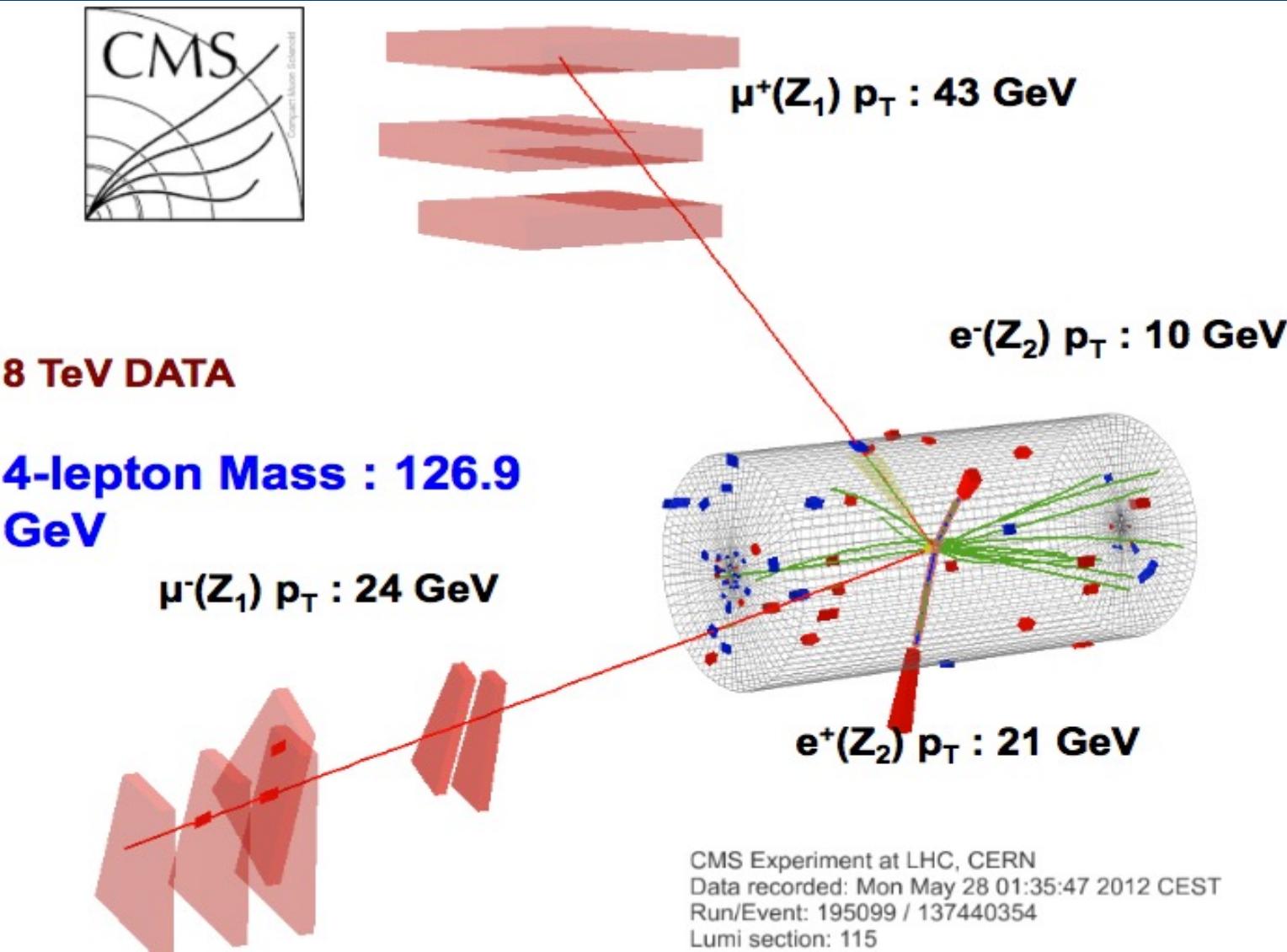


CMS Experiment at LHC, CERN
Data recorded: Fri Oct 26 09:06:57 2018 CEST
Run/Event: 325309 / 244518
Lumi section: 1
Orbit/Crossing: 121529 / 1650



136 vertices !

Higgs candidate event



Tests of the Standard Model

M. Araújo, P. Bargassa, D. Bastos, A. Boletti, C. Beirao, R. Bugalho, P. Faccioli, M. Gallinaro, J. Hollar, H. Legoinha, N. Leonardo, T. Niknejad, M. Pisano, J. Seixas, P. Silva, J. Silva, J. Varela, J. Wulff

At the LHC we will continue testing the SM through **precise measurements** and **rare decays** studies:

- Lepton Flavor Universality: top- and b-quark physics

JHEP 02(2020)191

- Forward physics w/ proton tagging: excl. processes

JHEP 07(2018)153, TOP-21-007, SMP-21-014, MSc thesis, IST (2019)

- Heavy ion collisions: heavy flavor

PLB 829(2022)137062, MSc thesis, IST (2019)

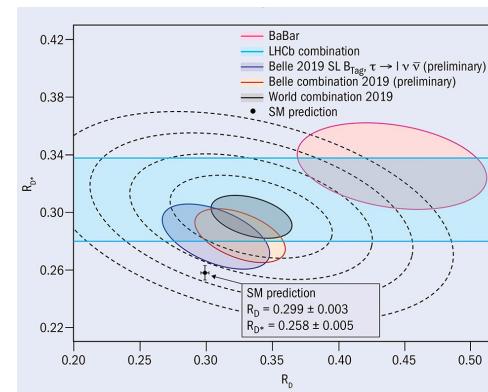
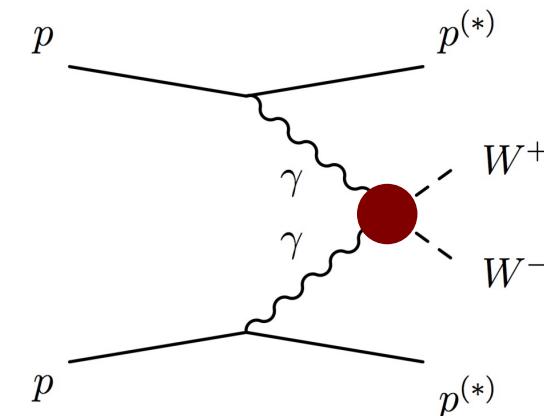
- Rare decays: $B \rightarrow \mu\mu$, $B \rightarrow K^*\mu\mu$

JHEP 04(2020)188, arXiv:1812.07638

- Quarkonia: polarization studies

PRL 124(2020)16, 162002

QUARKS		LEPTONS		GAUGE BOSONS	
$\sim 2.3 \text{ MeV}/c^2$	$2/3$	$\sim 4.8 \text{ MeV}/c^2$	$-1/3$	$\sim 95 \text{ MeV}/c^2$	0
up	$1/2$	down	$-1/3$	strange	$1/2$
charm	$1/2$	bottom	$-1/3$	tau	$1/2$
top	$2/3$	electron	-1	muon	-1
gluon	0	neutrino	0	Z boson	$91.2 \text{ GeV}/c^2$
Higgs boson	$\sim 126 \text{ GeV}/c^2$	neutrino	$1/2$	W boson	$80.4 \text{ GeV}/c^2$



The Higgs boson and beyond

M. Araújo, P. Bargassa, D. Bastos, A. Boletti, C. Beirao, R. Bugalho, P. Faccioli, M. Gallinaro, J. Hollar, H. Legoinha, N. Leonardo, T. Niknejad, M. Pisano, J. Seixas, P. Silva, J. Silva, J. Varela, J. Wulff

The Higgs boson was discovered in 2012 and it is still a largely unknown particle. A detailed study of its properties may provide hints to the EWSB mechanism and possibly to New Physics.

Our studies in this area cover:

- **Higgs discovery & couplings: diphoton final state**

PLB 716(2012)30, JHEP 08(2016)045

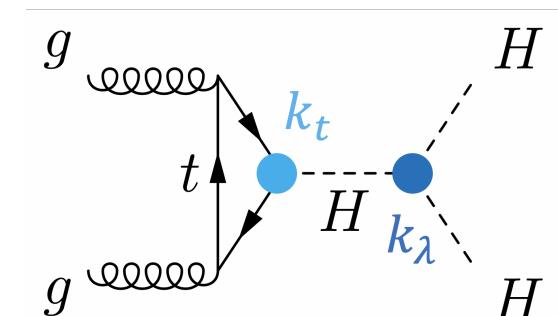
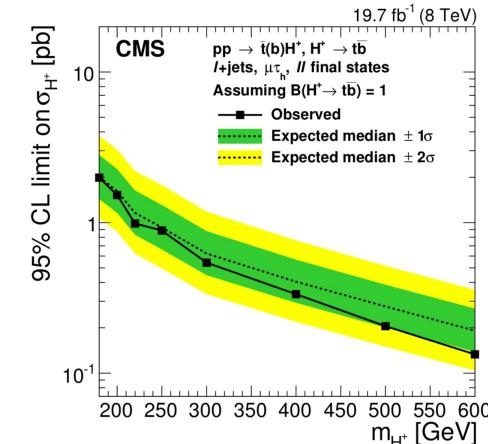
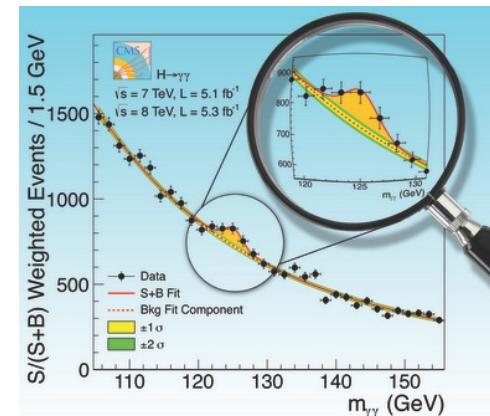
- **Charged Higgs: if present, it would be unequivocal presence of BSM physics**

JHEP 07(2012)143, JHEP 11(2015)018

- **Higgs Pairs:** allows measurement of self-coupling parameters (k_λ) with Machine Learning tools

PLB 778(2018)101, arXiv:1902.00134, CMS-HIG-20-010, CMS-TDR-020

- **Higgs rare decays:** couplings to light generations



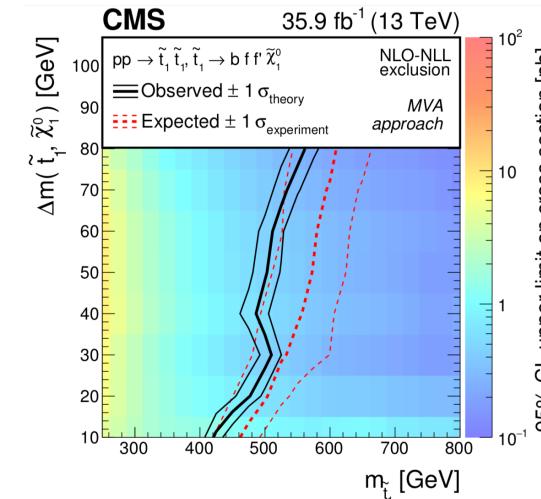
Beyond the SM

M. Araújo, P. Bargassa, D. Bastos, A. Boletti, C. Beirao, R. Bugalho, P. Faccioli, M. Gallinaro, J. Hollar, H. Legoinha, N. Leonardo, T. Niknejad, M. Pisano, J. Seixas, P. Silva, J. Silva, J. Varela, J. Wulff

The SM has no apparent major problem. However, there are compelling reasons to believe the SM is an incomplete theory of Nature.

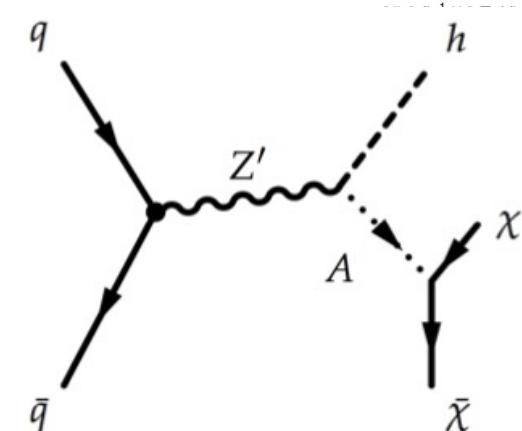
- **Supersymmetry:** exploring a compressed spectrum where mass difference btw stop and LSP is smaller than W boson mass

JHEP 09 (2018) 065



- **Dark Matter:** produced in association with the Higgs boson, only a few events, large MET

JHEP 03 (2020) 025



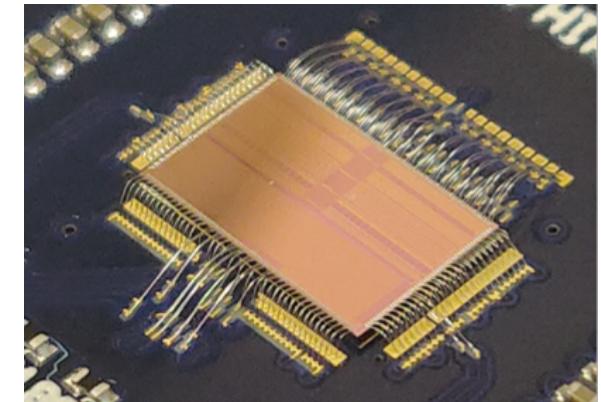
Detector Upgrades

M. Araújo, P. Bargassa, D. Bastos, A. Boletti, C. Beirao, R. Bugalho, P. Faccioli, M. Gallinaro, J. Hollar, H. Legoinha, N. Leonardo, T. Niknejad, M. Pisano, J. Seixas, P. Silva, J. Silva, J. Varela, J. Wulff

MIP Timing Detector (MTD):

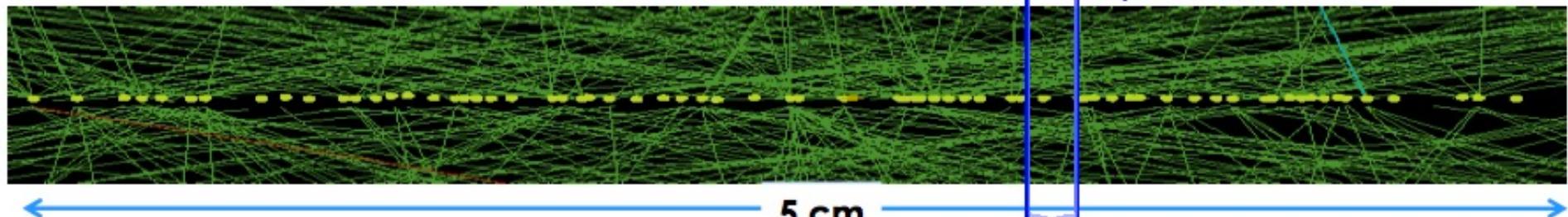
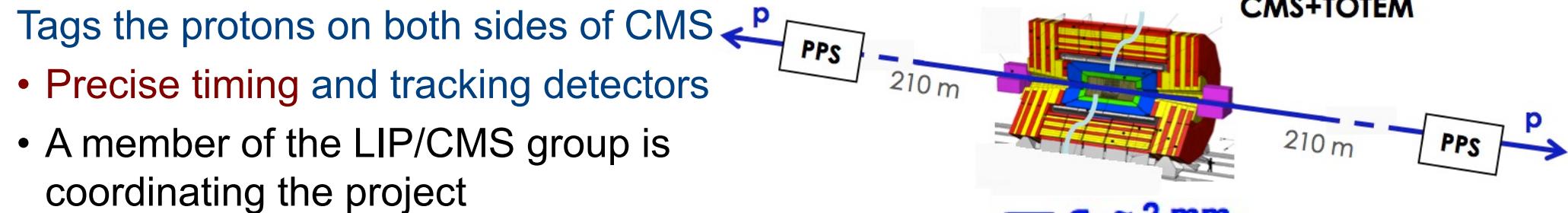
Precise time measurement of charged particles

- LIP/CMS group responsible for BTL readout electronics



Precision Proton Spectrometer (PPS):

Tags the protons on both sides of CMS

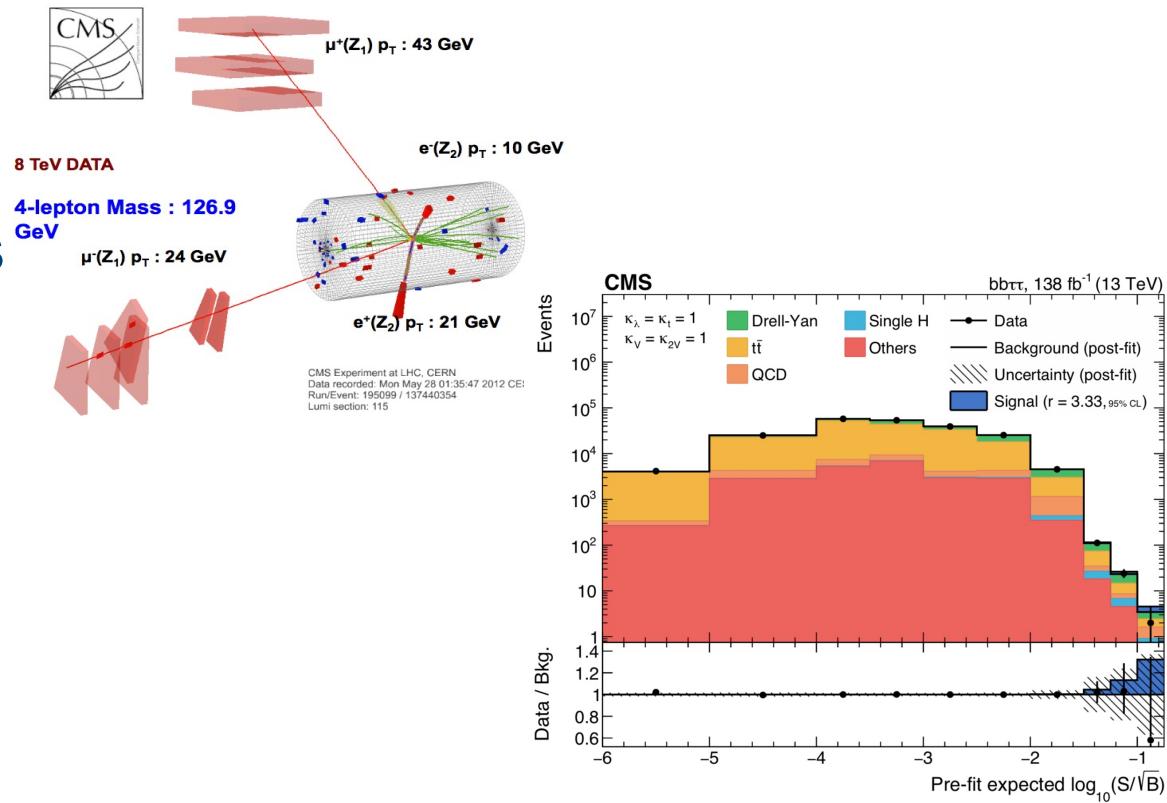


The Higgs boson and beyond...

M. Araújo, P. Bargassa, D. Bastos, A. Boletti, C. Beirao, R. Bugalho, P. Faccioli, M. Gallinaro, J. Hollar, H. Legoinha, N. Leonardo, T. Niknejad, M. Pisano, J. Seixas, P. Silva, J. Silva, J. Varela , J. Wulff

...we are in uncharted territory

- Data analysis
 - Tests of the SM, Higgs boson studies, BSM searches
- R&D and detector upgrades
 - PPS and Timing detector
- Involvement in running of the experiment
 - understanding, operation, direct involvement



⇒ There is a lot to learn & contribute

Recent MSc and PhD theses

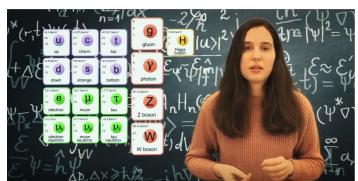


Measurement of b-quark fragmentation fraction ratios at the CMS experiment: a key ingredient for the $B_s^0 \rightarrow \mu^+ \mu^-$ rare decay analysis

[CERN-THESIS-2018-274](#), May 2018

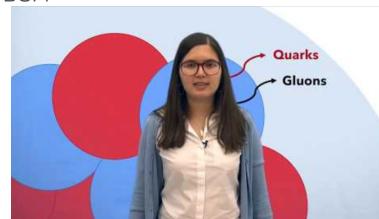
Now at LLR, Paris

Bruno Afonso Fontana Santos Alves



Probing the quark gluon plasma medium through B meson production measurements in PbPb collisions at the LHC

Júlia Manuela Cardoso Silva

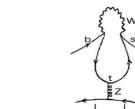


Search for exclusively produced top quark pairs at the LHC

[CERN-THESIS-2019-280](#), Dec. 2020

Now at DESY, Hamburg

Beatriz Ribeiro Lopes



Investigating the flavour anomalies through the rare beauty decay $B^0 \rightarrow K^{*0} \mu^+ \mu^-$

Maria Carolina Feliciano Faria

[CERN-THESIS-2021-220](#), Oct. 2021

Now at EPFL, Lausanne



UNIVERSIDADE DE LISBOA
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DEEP LEARNING METHODS
APPLIED TO HIGGS PHYSICS AT THE LHC

Giles Chatham Strong

[CERN-THESIS-2021-211](#)

arXiv:1902.00134, Mach. Learn. Sci. Techn. 1 045006, Dec. 2020
Now at U. Padova, Italy



Universidade de Lisboa
Instituto Superior Técnico



Top quark physics and search for physics beyond the Standard Model at the Large Hadron Collider

Author: Oleksii Toldaiev

[CERN-THESIS-2020-203](#)

JHEP 02 (2020) 191, Oct. 2020
Now at Cern with U. Indiana, USA

Thank you!



If you want to know more:
Course on Physics at the LHC

- Interesting analysis topics available
- Strong involvement of students
- Master and PhD thesis projects

⇒ Join, your contribution will make
the difference!



Citing the report of the recent Institutional Evaluation performed by an international review panel nominated by FCT: "The LIP-CMS group, while small in size, is really outstanding and world-class".