

Particle physics at accelerators

Agni Bethani

on behalf of the experimental particle physics team at IRMP/CP3

The logo for IRMP (Institut de Recherche en Physique de Mons) features the letters 'IRMP' in a blue serif font. The letters are partially obscured by a blue, multi-pointed starburst or particle track effect.The logo for UCLouvain consists of a blue square icon with a white vertical bar on the left side, followed by the text 'UCLouvain' in a bold, blue, sans-serif font.

Particle physics at accelerators: activities

- CMS at the LHC (CERN)
 - Physics data analysis
 - Tracker Phase 2 Upgrade
- NA62 experiment at CERN
- Muography
 - Techniques that originated in high energy physics are used for muon imaging, in a wide range of applications

Technical staff, physicists, engineers and computer scientists

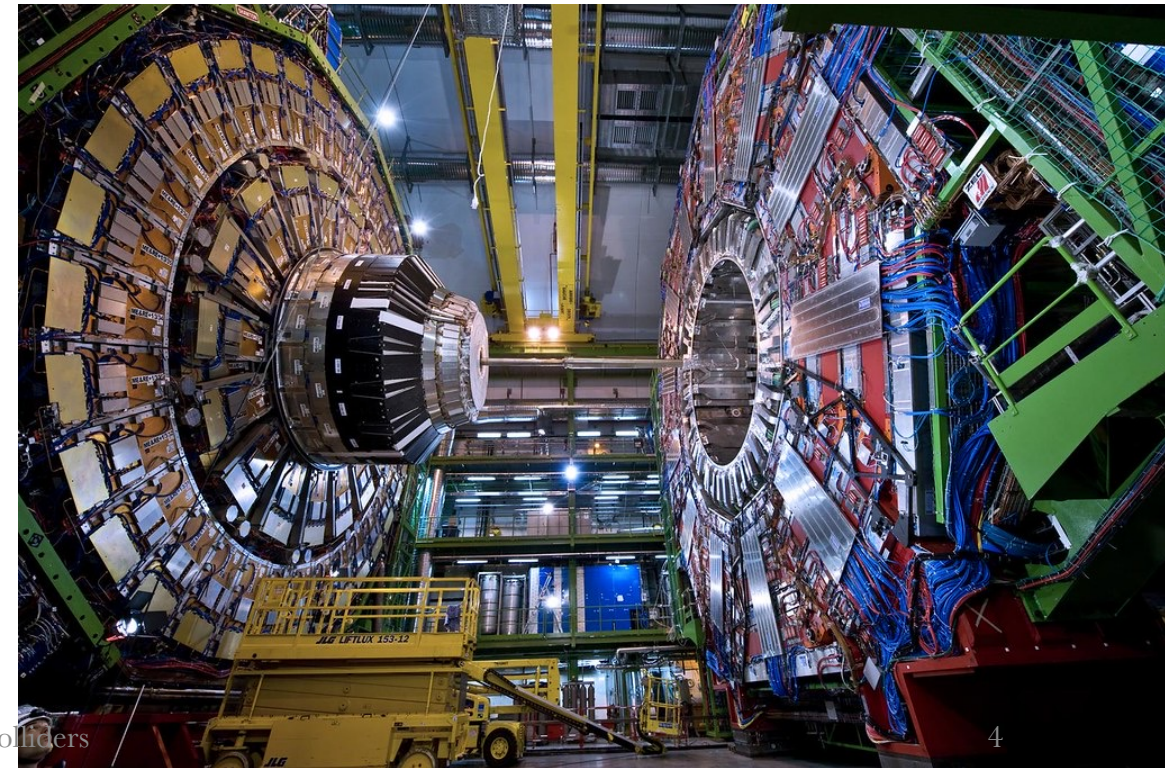
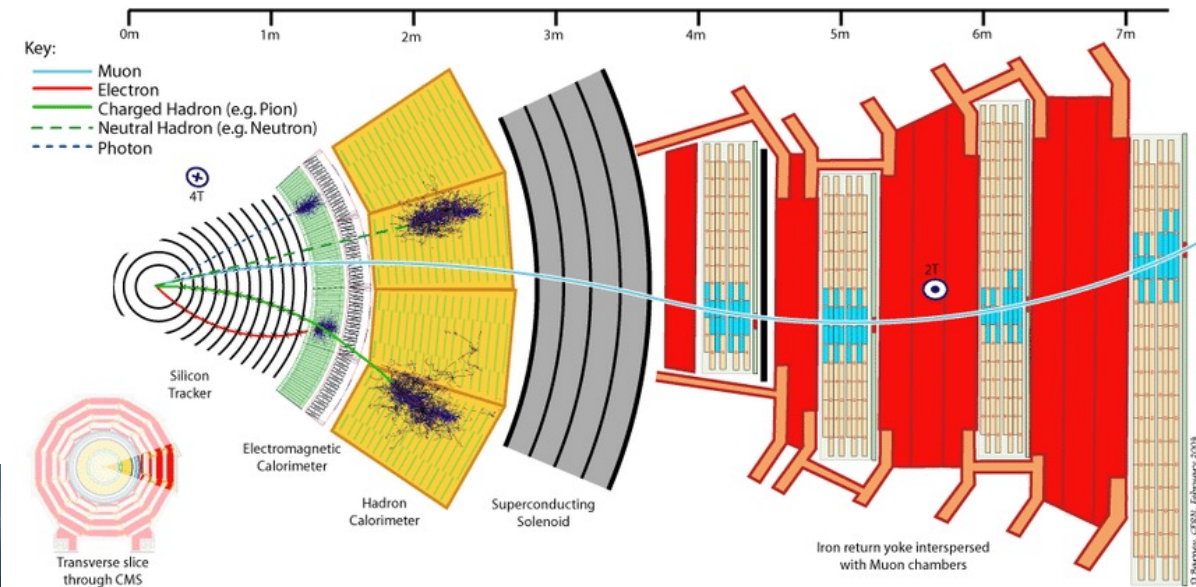
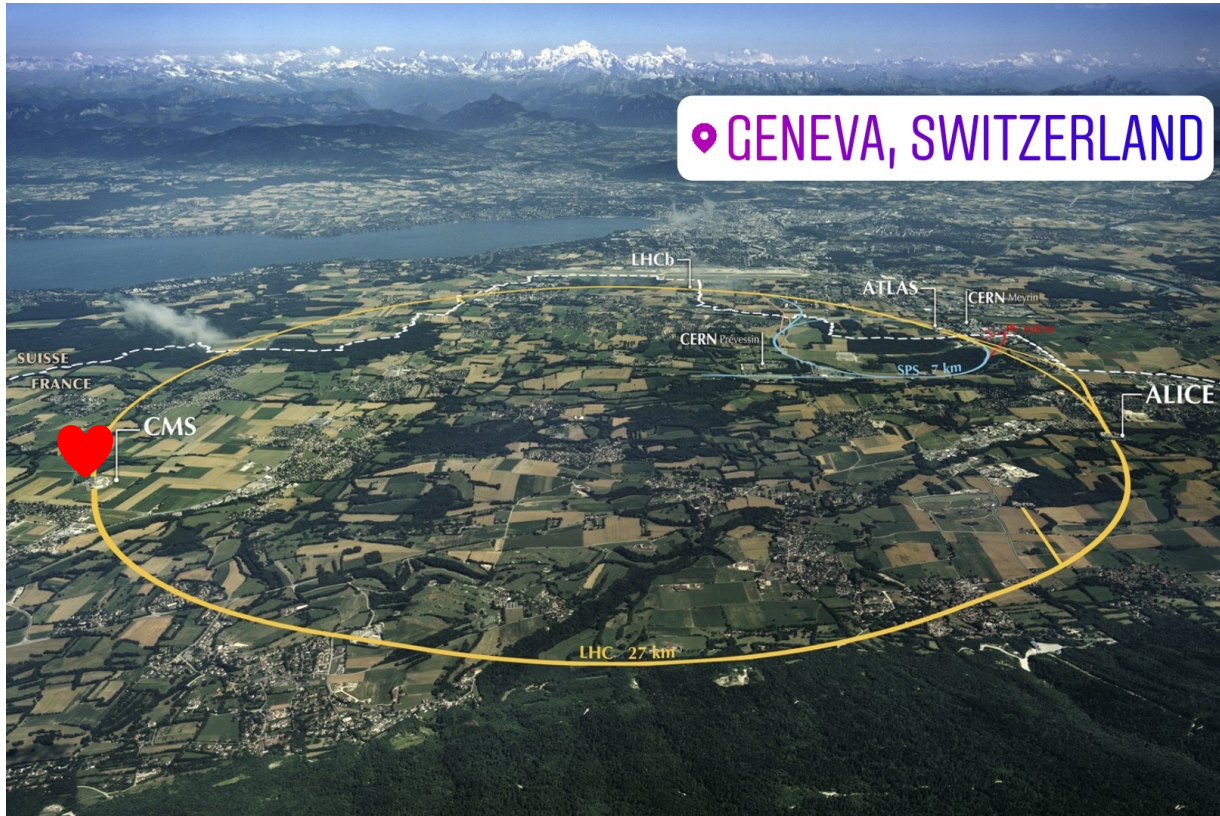
Technical staff

- Nicolas Szilasi
- Raphaël Indot
- Quentin de Smedt

Physicists, engineers and computer scientists

- Pavel Demin
- Andres Tanasijczuk

The CMS experiment



CMS team

PhD students

- Oguz Güzel
- Paola Mastrapasqua
- Francisco Casalinho

Research scientists

- Jérôme de Favereau
- Andrea Giammanco

Post-docs

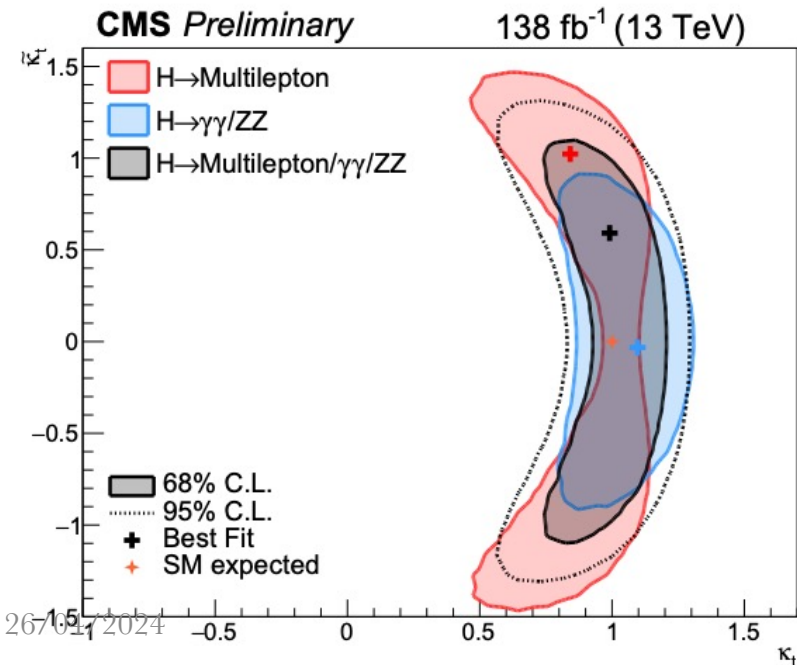
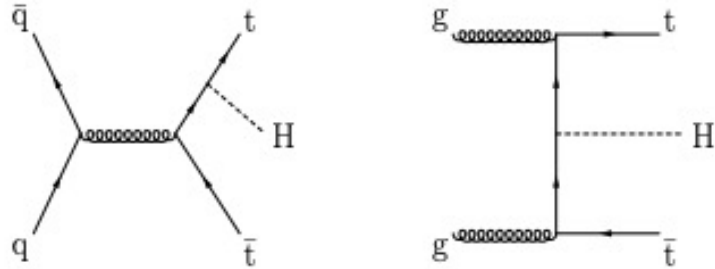
- Anna Benecke
- Jindrich Lidrych
- Paul Malek
- Semra Turkcapar
(joining soon)
- Zak Lawrence
(joining soon)
- +1 (joining soon)

Academic staff

- Agni Bethani
- Christophe Delaere
- Vincent Lemaitre
- Giacomo Bruno (10⁰%)

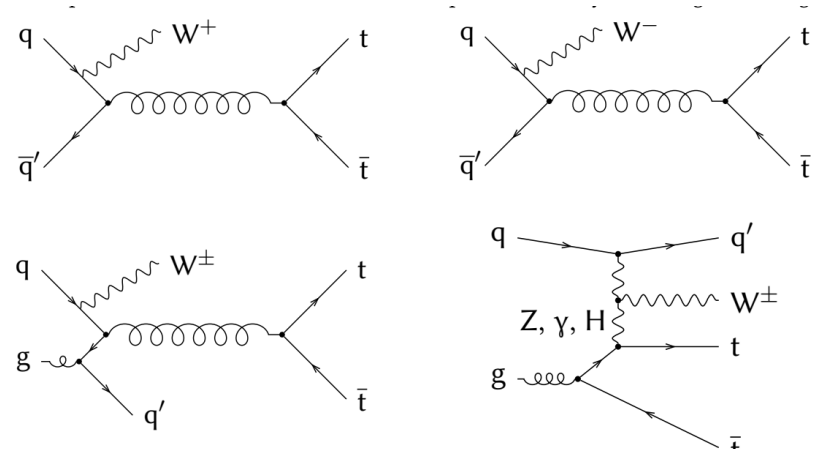
CMS physics analysis

Search for CP violation in ttH and tH production

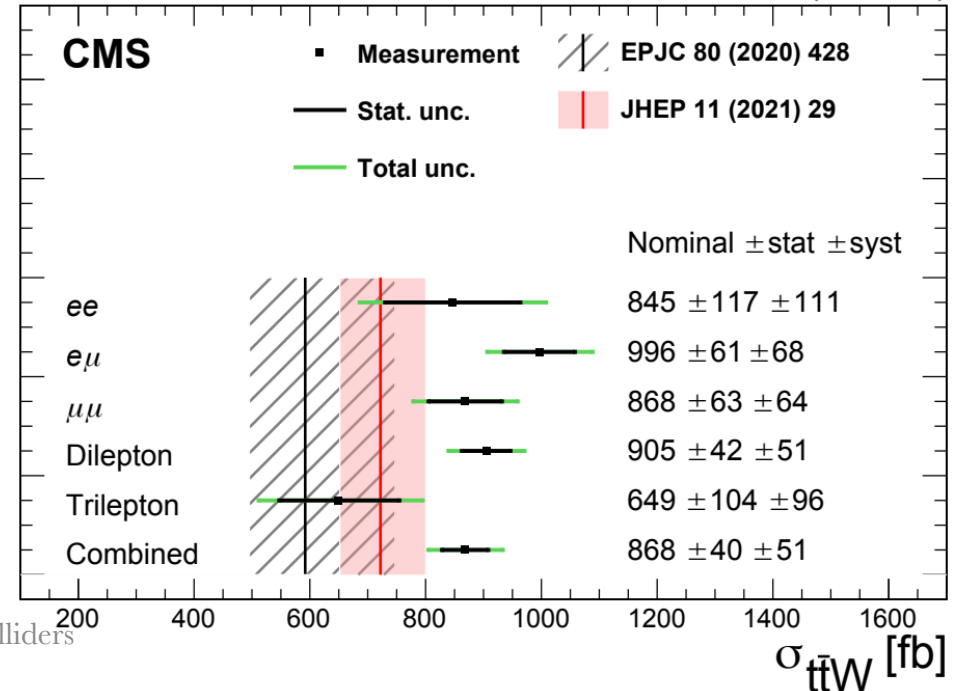


<https://cds.cern.ch/record/2803420/files/HIG-21-006-pas.pdf>

Measurement of the cross section ttW



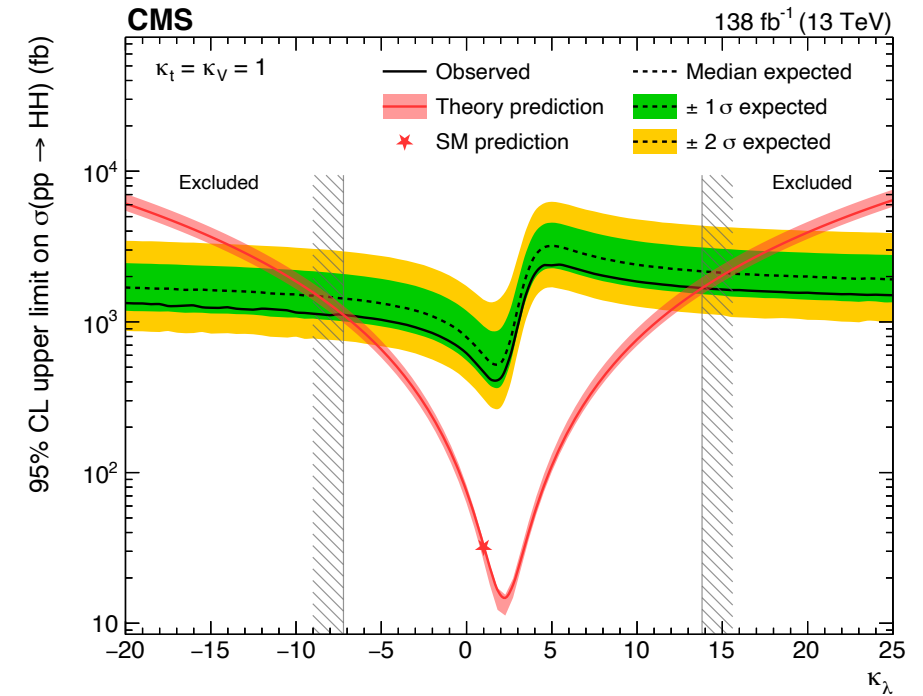
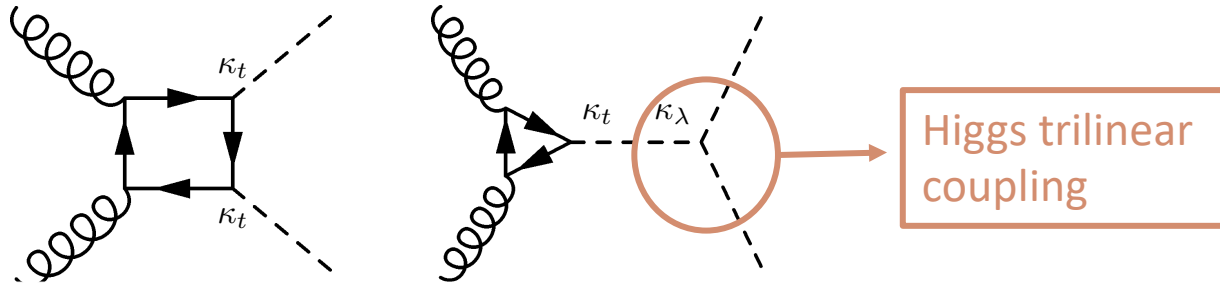
138 fb^{-1} (13 TeV)



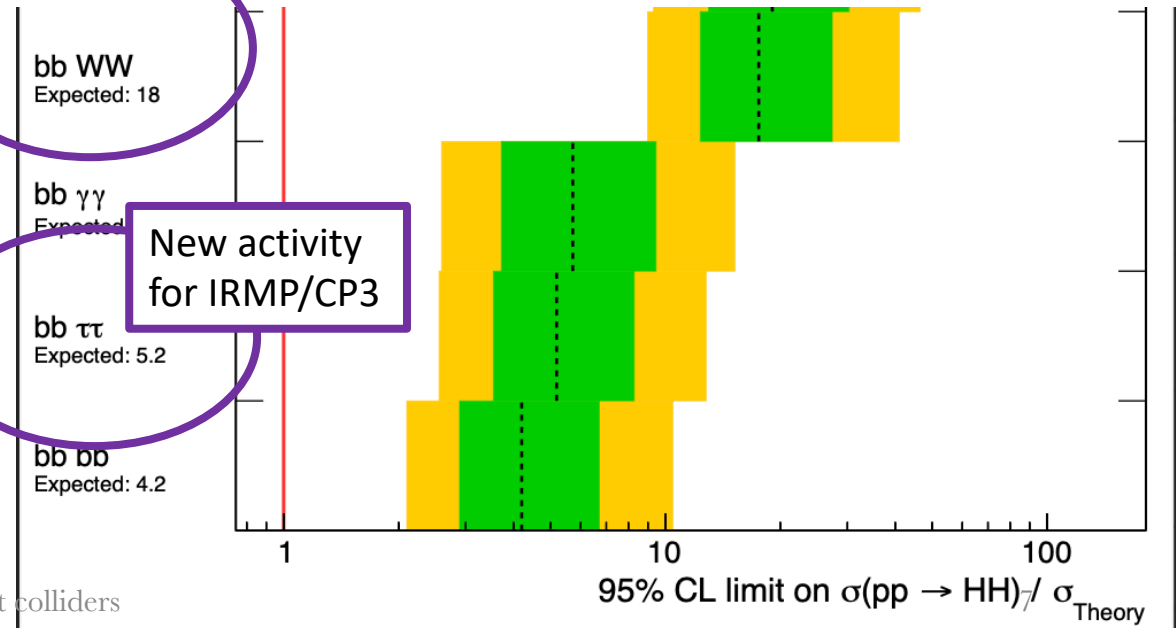
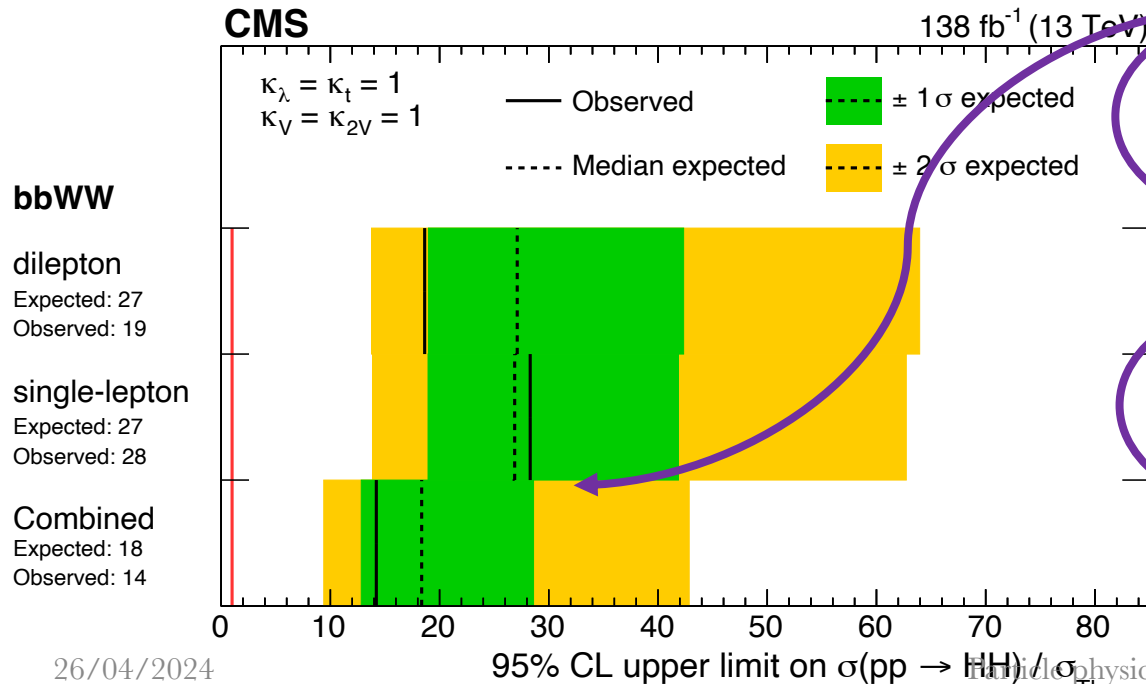
<https://arxiv.org/pdf/2208.06485.pdf>

CMS physics analysis

Search for HH production in the bbWW channel



<https://arxiv.org/abs/2403.09430>

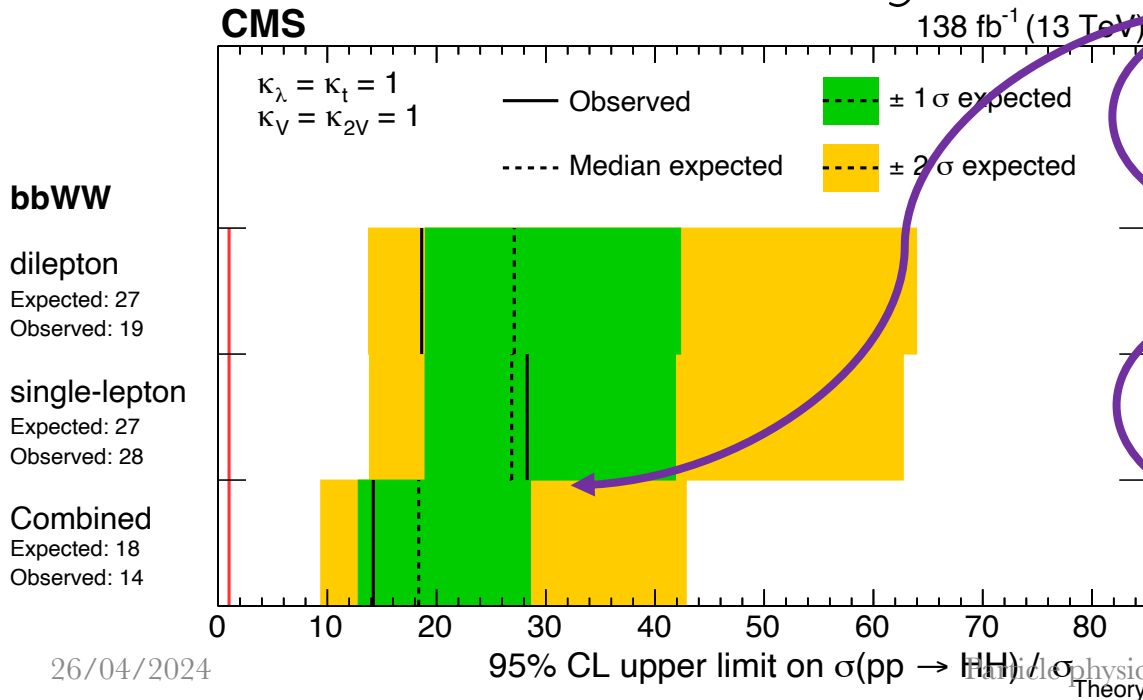
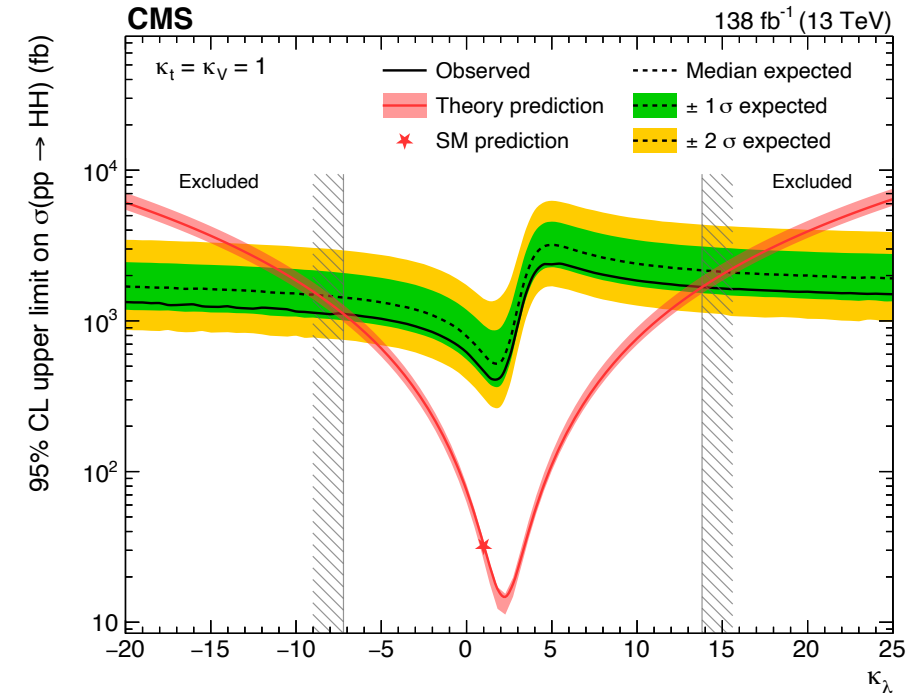


CMS physics analysis

Search for HH production in the bbWW channel



<https://arxiv.org/abs/2403.09430>

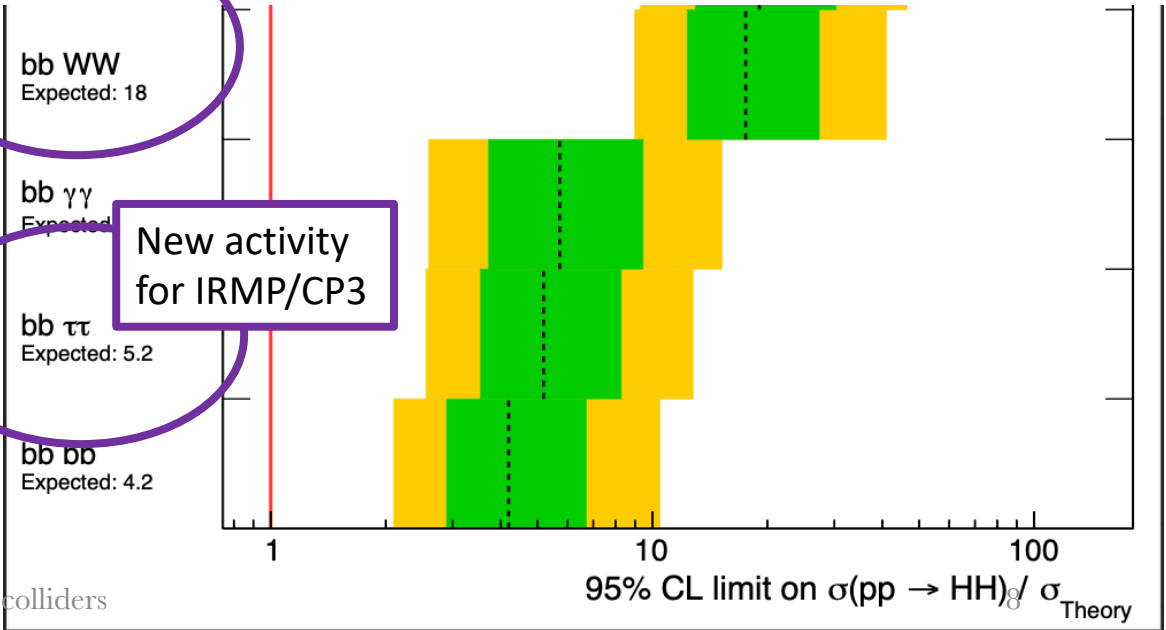


bbWW

dilepton
Expected: 27
Observed: 19

single-lepton
Expected: 27
Observed: 28

Combined
Expected: 18
Observed: 14

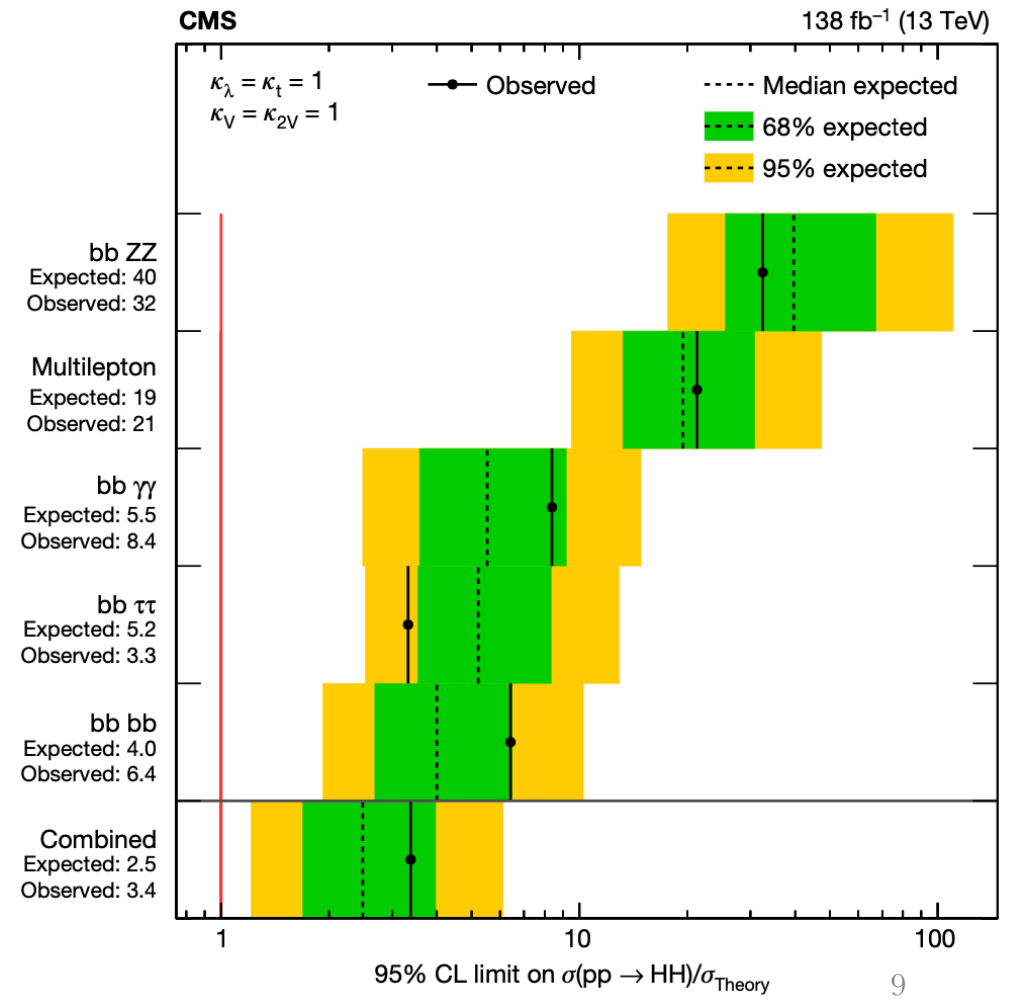
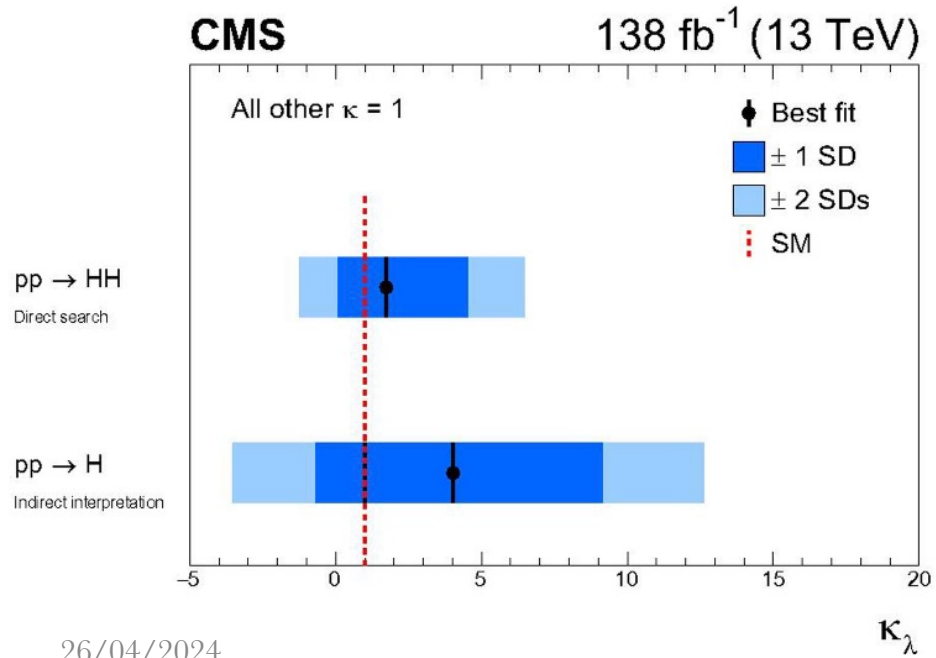
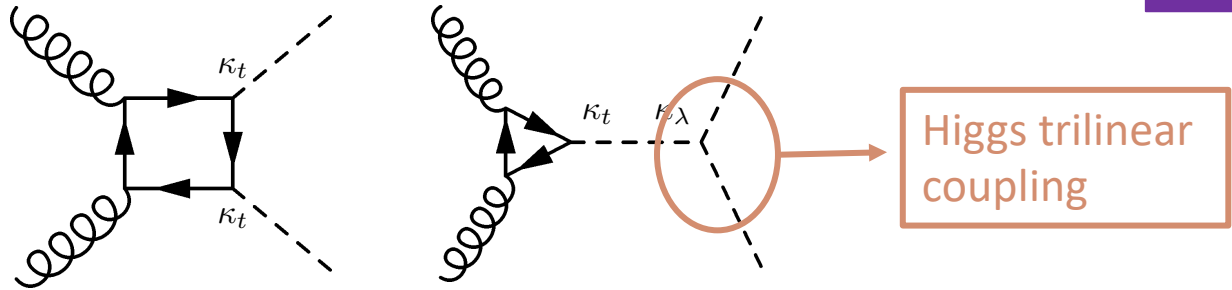


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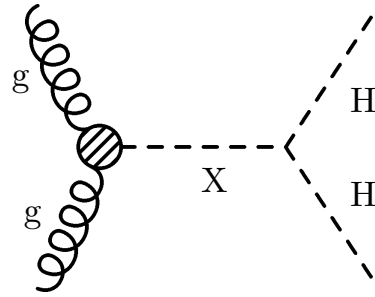
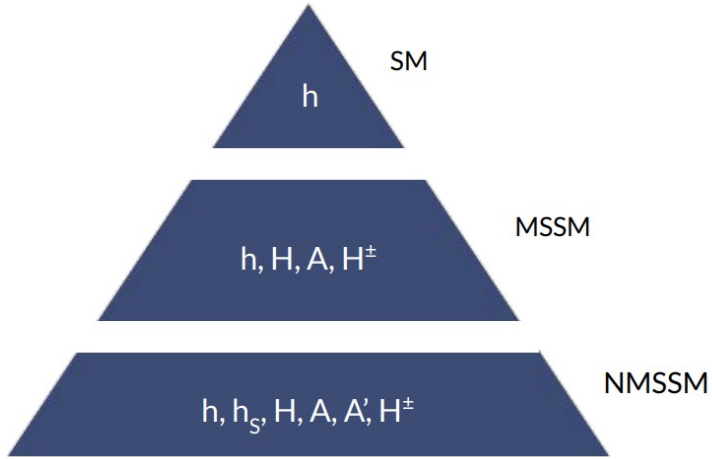
particle physics at colliders

CMS physics analysis

HH combination
 Published in Nature!
<https://www.nature.com/articles/s41586-022-04892-x>

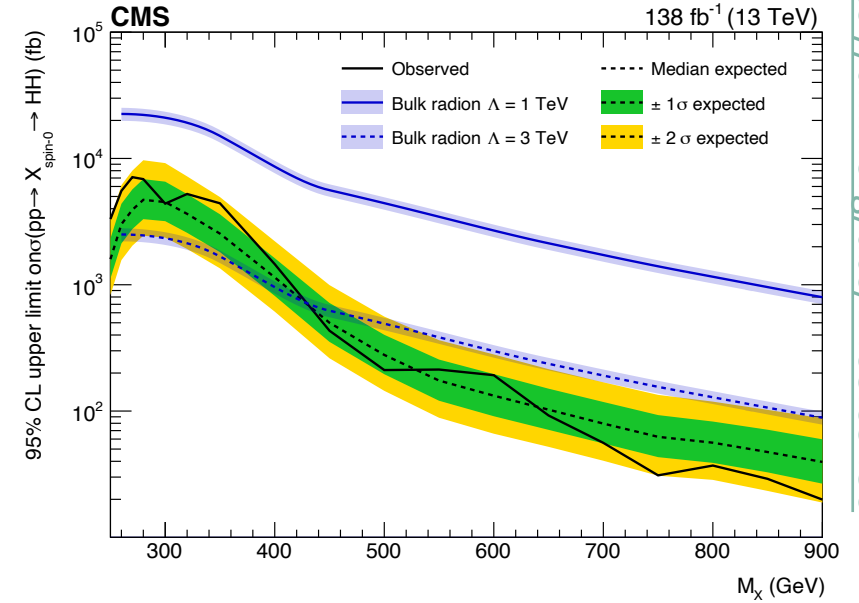


New physics searches

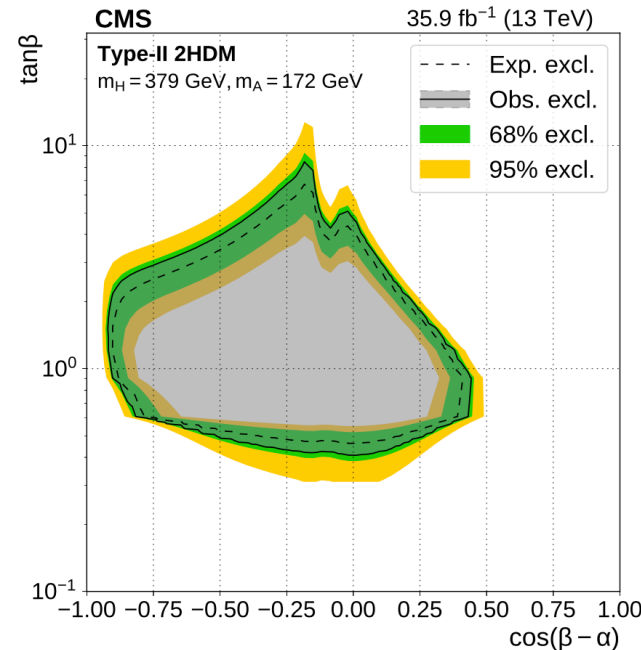
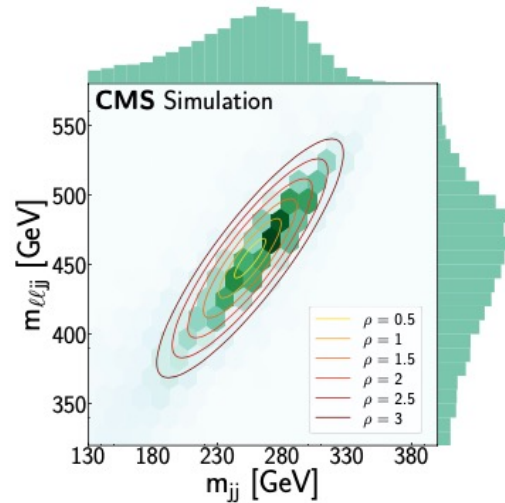
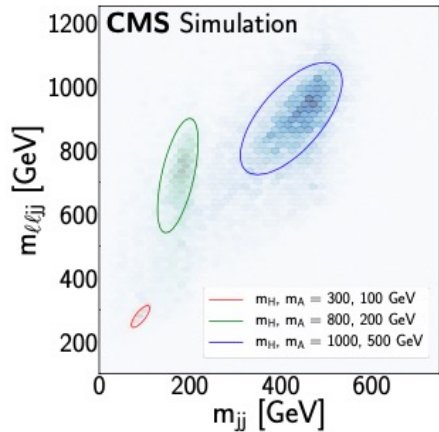


H/A → ZA / H → bbll final state

X → HH → bbWW



<https://arxiv.org/abs/2403.09430>



New ongoing activity:
H/A → ZA / H → ττll

[https://link.springer.com/article/10.1007/JHEP03\(2020\)055](https://link.springer.com/article/10.1007/JHEP03(2020)055)

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Software development

- **DELPHES**
 - software for fast simulation of generic detector
 - multiple application in collider experiments, current and future
- **BAMBOO**
 - Software for analysing LHC data
 - Used by several teams in CMS globally
- **MoMEMta**
 - software for calculating matrix elements, compatible for workflows in LHC experiments



DELPHES
fast simulation



Current roles of responsibility in CMS

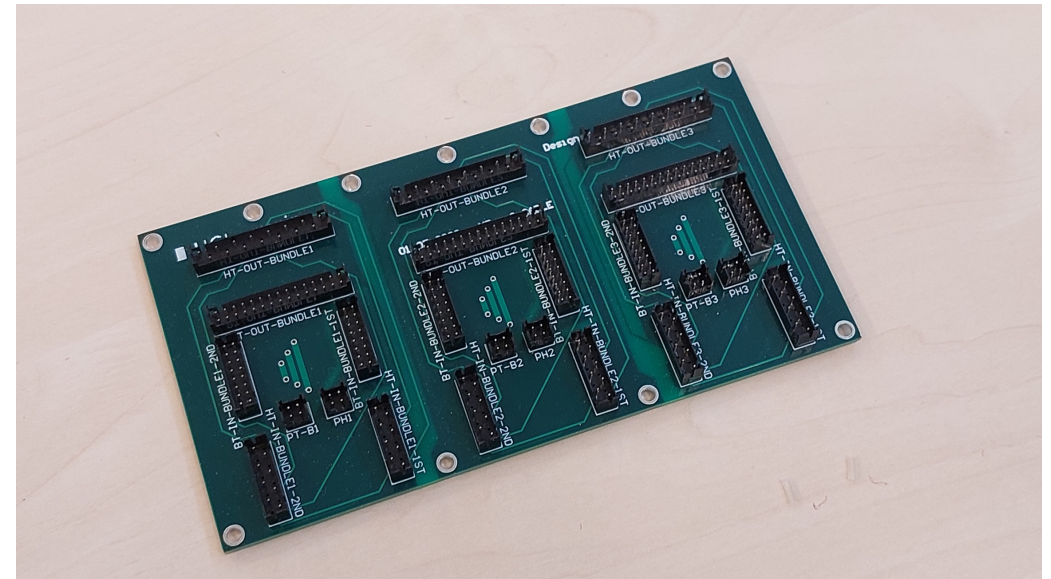
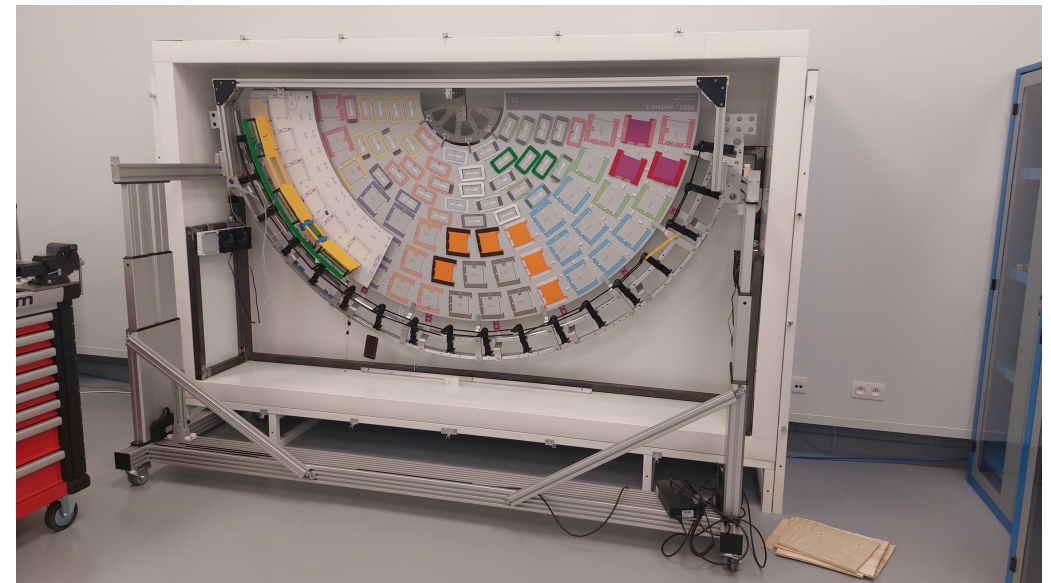
- Jet and Missing Transverse Energy convener
 - Anna Benecke
- Tau Calibration-Quality-Monitoring convener
 - Paola Mastrapasqua
- Di-boson Searches (including di-Higgs) convener
 - Agni Bethani
- Outer Tracker Upgrade Coordinator
 - Christophe Delaere

Outer tracker upgrade

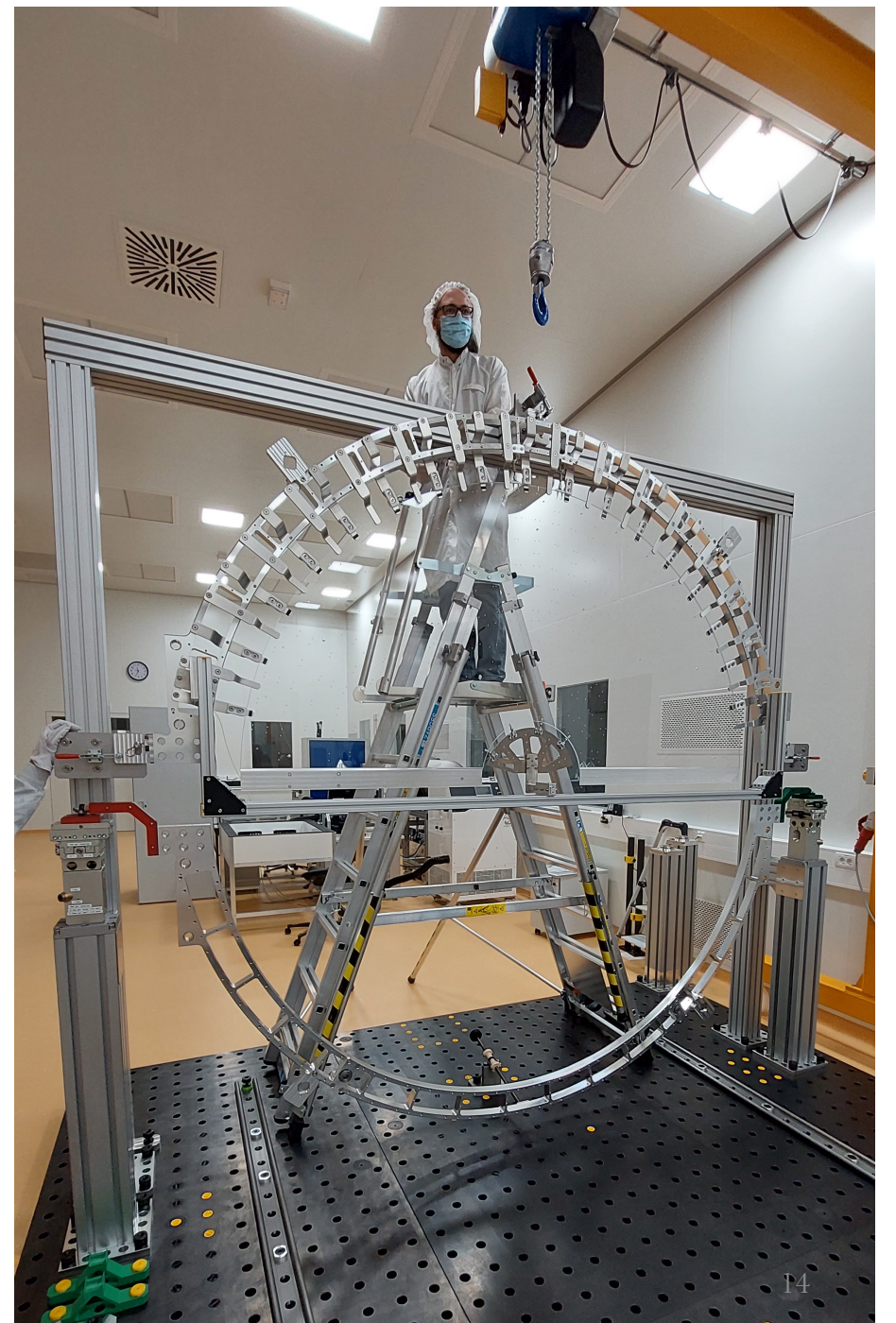
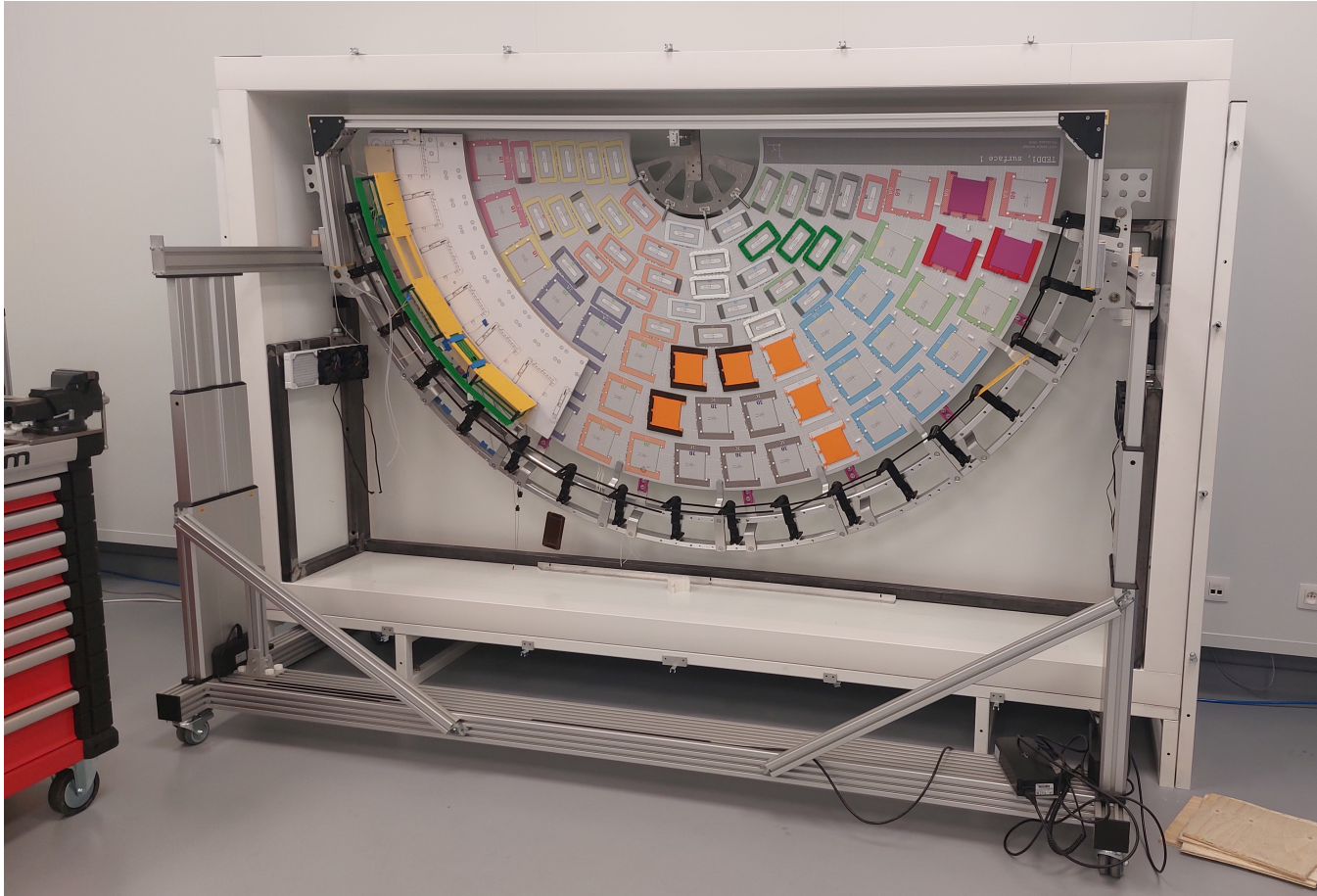
Responsibilities in construction and testing the Phase-II upgrade of the outer tracker

- Integration of 5 double disks, making one endcap.
- In charge of the design of services (power, optics, cooling).
- Burn-in of modules assembled in Brussels.

<https://doi.org/10.1016/j.nima.2022.166795>



Outer tracker upgrade



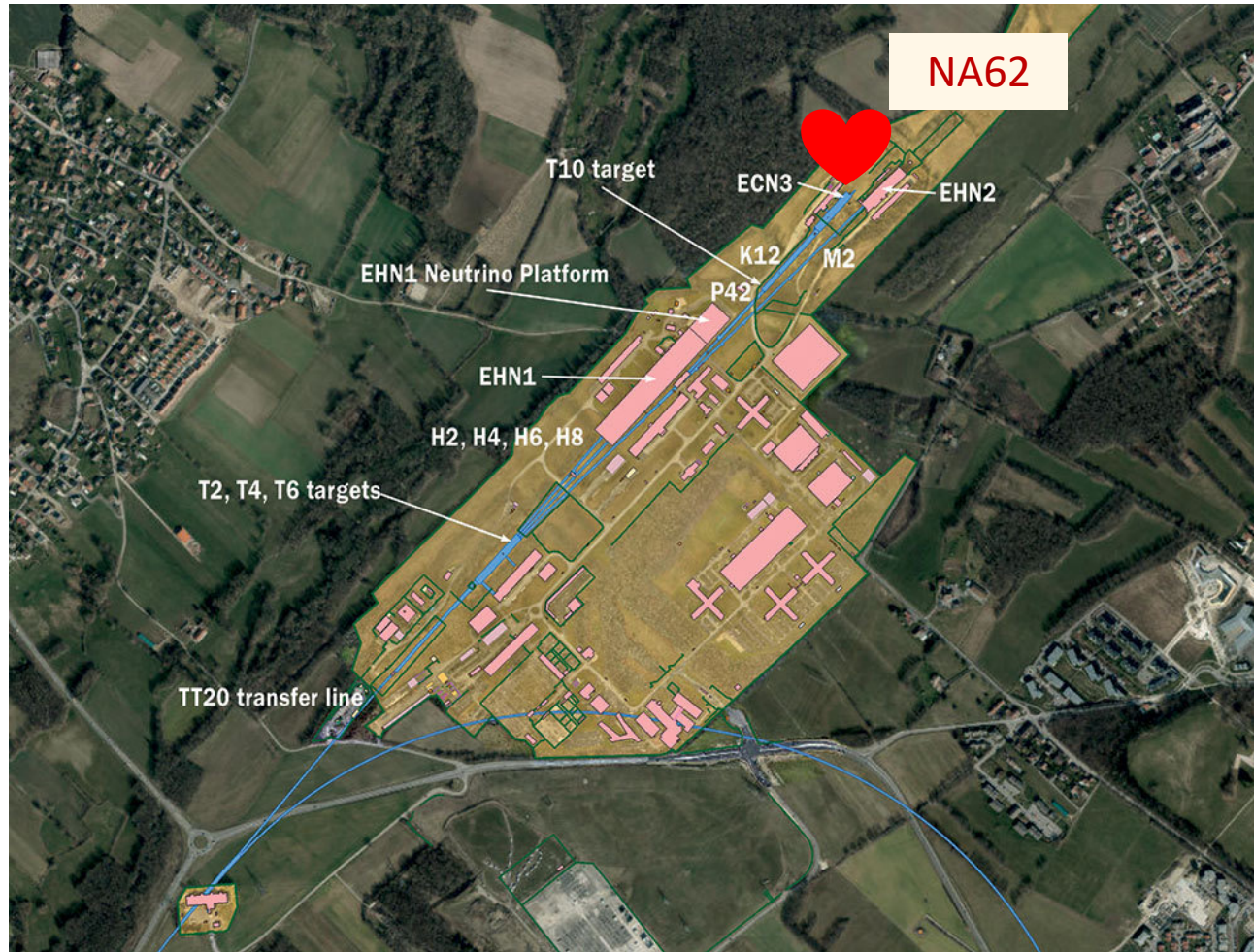
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Particle physics at colliders

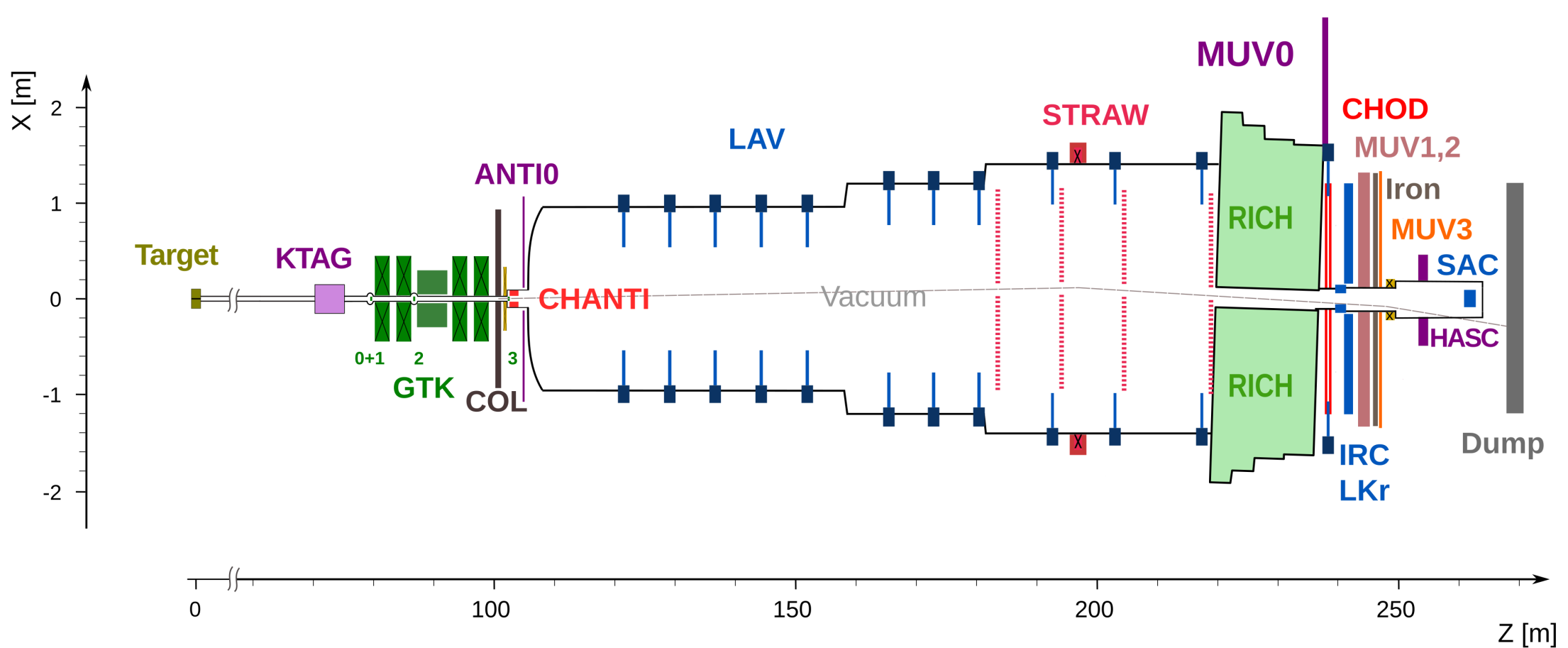
CMS theses since 2019

- First measurements of the tt cross section in LHC pp and pPb collisions at 5.02 and 8.16 TeV and determination of the absolute luminosity in the CMS experiment
Author: Georgios Konstantinos Krintiras
Advisor: Andrea Giammanco
Defence: Jan 10, 2019
- Search for an extended scalar sector through the $H \rightarrow ZA \rightarrow l+l-bb$ process in pp collisions at $\sqrt{s}=13$ TeV
Author: Alessia Saggio
Advisor: Christophe Delaere
Defence: Dec 16, 2019
- Development of a new tracker for the CMS upgrade phase 2 and study of the HL-LHC physics reach
Author: Martin Delcourt
Advisor: Christophe Delaere
Defence: Sep 10, 2020
- Constraining the Higgs and heavy neutral lepton sectors with the CMS detector
Author: Angela Taliercio
Advisor: Giacomo Bruno
Defence: Jul 6, 2022
- Application of deep learning techniques in CMS : from matrix element regression to the search for Higgs boson pair production
Author: Florian Bury
Advisor: Christophe Delaere
Defense: Dec 16, 2022
- CMS endcap tracker for the High-Luminosity LHC and search for Higgs pair production
Author: Suat Donertas
Advisor: Christophe Delaere
Defence: Sep 15, 2023
- Search for 2HDM neutral Higgs bosons through llbb final states at CMS in run 2 LHC data.
Author: Khawla Jaffel
Advisor: Christophe Delaere
Defence: Sep 8, 2023
- A study of top quark pairs production in association with a W boson
Author: Tu Thong Tran
Advisors: Andrea Giammanco and Didar Dobur
Defence: Dec 13, 2023

NA62 experiment



NA62 experiment



NA62 experiment

- NA62 is a fixed target experiment at CERN
 - Main objective: Measurement of the very rare kaon decay $K^+ \rightarrow \pi^+ \nu \bar{\nu}$ (BR $\sim 10^{-11}$) at 10% level
 - Largest sample of K^+ decays in the world ($\sim 10^{13}$ K^+ decays) allowing the detailed study of other rare decays:
 - LNV/LFV
 - Search for new physics in rare K^+ decays
- Use of the experiment in a beam dump configuration:
 - Search of long-live-particles: $X \rightarrow ll, \text{hadrons}$

NA62 team

Academic staff

- Eduardo Cortina Gil

Postdocs

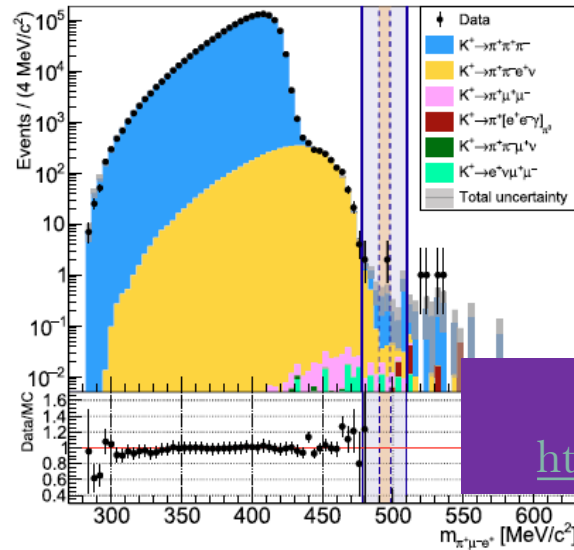
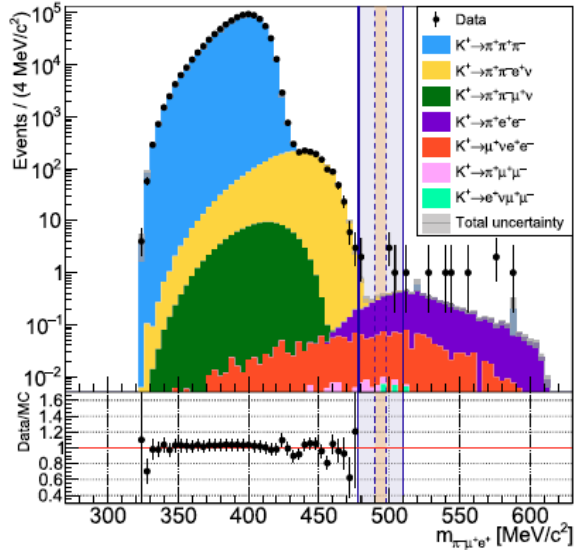
- Muhammad Usman Ashraf

Achievements

- Scientific output since 2009
 - 5 PhD thesis
 - 24 peer review
- Since last review (2019)
 - 3 PhD thesis:
 - Elisa Minucci (2018)
Search for Lepton Number and Flavor violations in Kaon decays at the NA62 experiment
 - Alina Kleimenova (2021)
Study of GigaTracker performance and a search for Axion-Like Particles at the NA62 experiment
 - Jan Jerhot (2023)
Hidden sector searches with fixed target experiments
 - 19 peer review articles (Phys. Lett. B, JHEP, Phys. Rev. Lett.)
 - 4 of them main author from Louvain

Results

Search for Lepton Number and Flavor Violation in K^+ and π^0 Decays
 Phys. Rev. Lett. 127, 131802



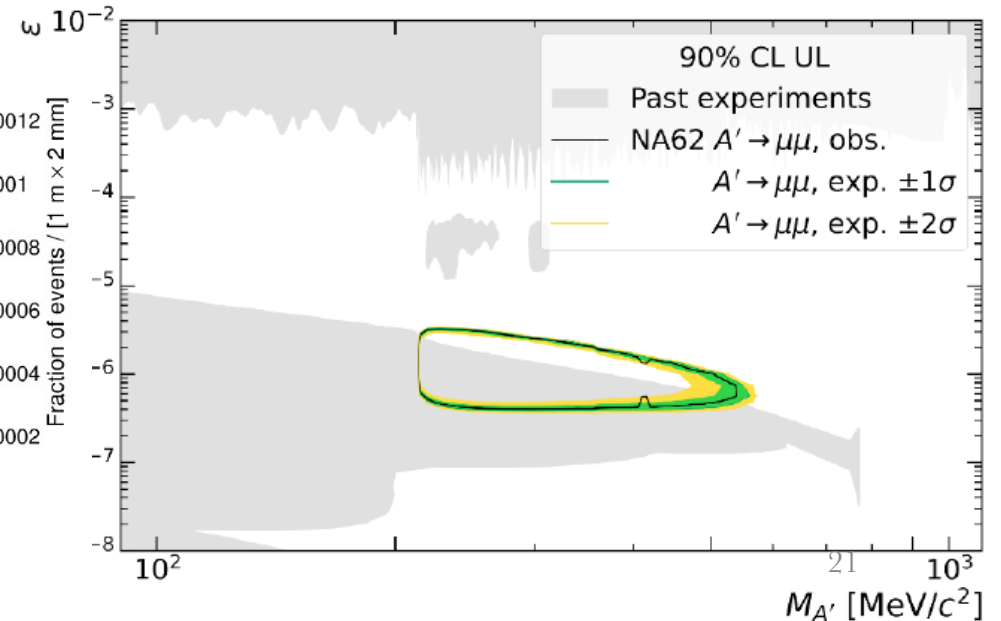
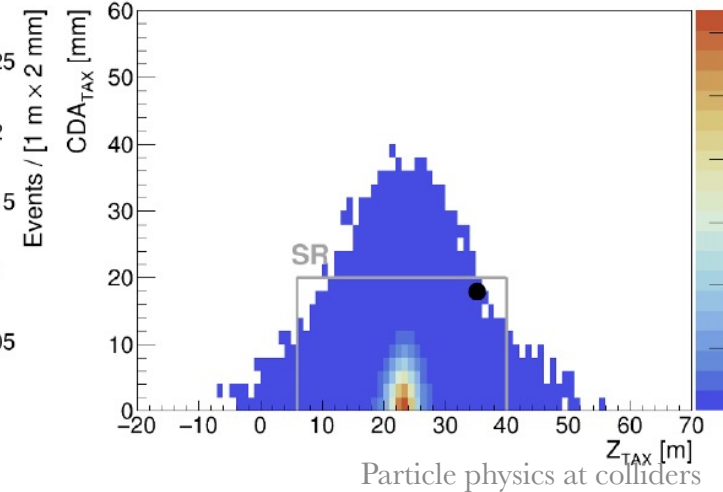
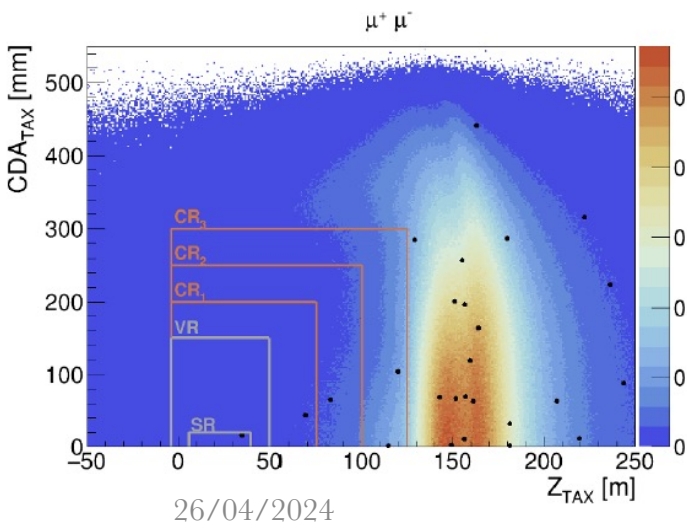
$$B(K^+ \rightarrow \pi^- \mu^+ e^+) < 4.2 \times 10^{-11};$$

$$B(K^+ \rightarrow \pi^+ \mu^- e^+) < 6.6 \times 10^{-11};$$

$$B(\pi^0 \rightarrow \mu^- e^+) < 3.2 \times 10^{-10}.$$

Search for dark photon A'

[https://link.springer.com/article/10.1007/JHEP09\(2023\)035](https://link.springer.com/article/10.1007/JHEP09(2023)035)

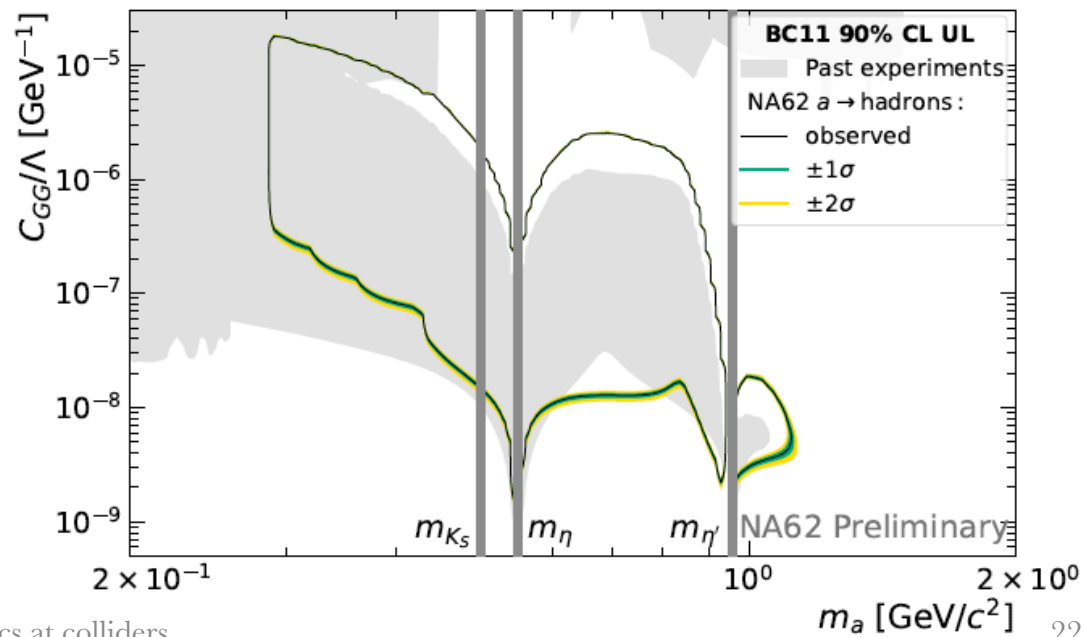
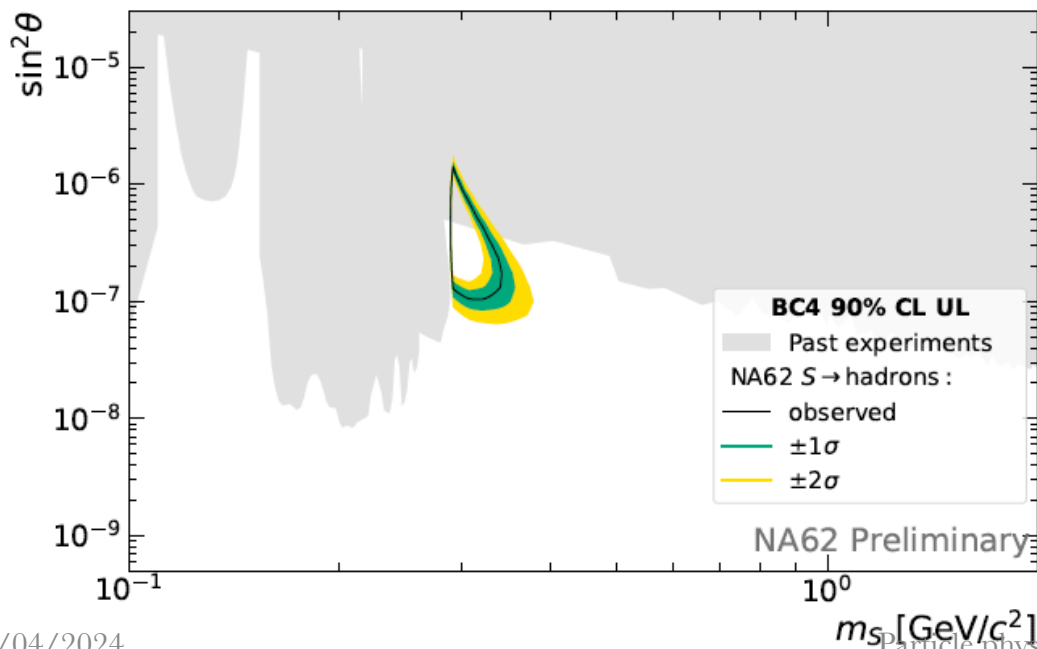


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Results

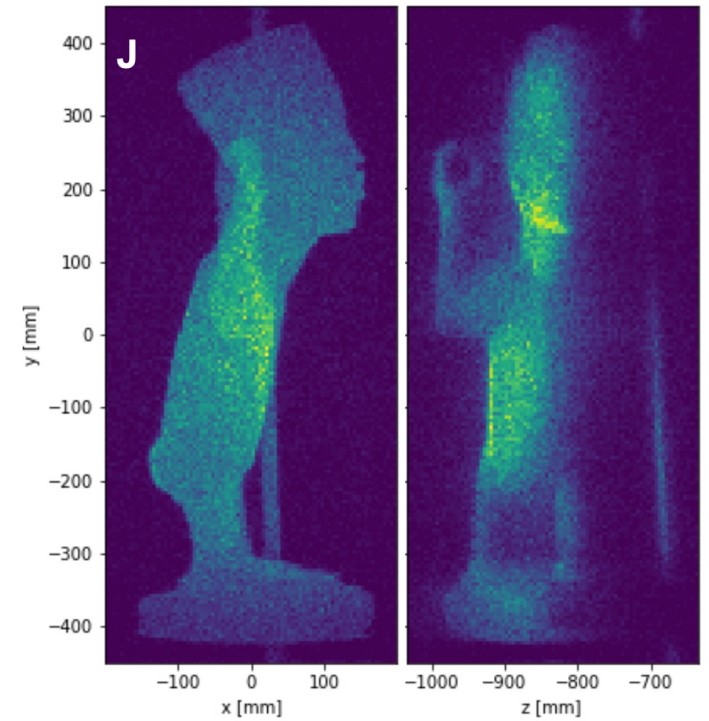
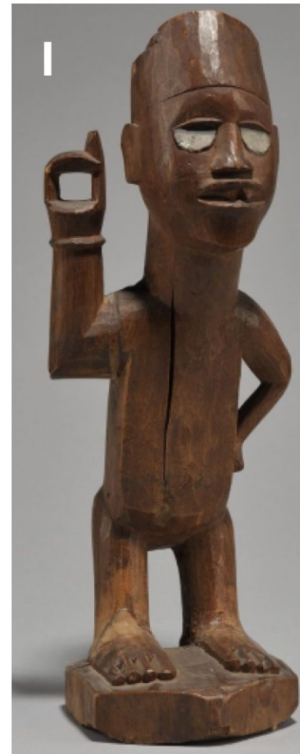
DP	DS	ALP
$\pi^+\pi^-$	$\pi^+\pi^-$	$\pi^+\pi^-\gamma$
$\pi^+\pi^-\pi^0$		$\pi^+\pi^-\pi^0$
$\pi^+\pi^-\pi^0\pi^0$	$\pi^+\pi^-\pi^0\pi^0$	$\pi^+\pi^-\pi^0\pi^0$
		$\pi^+\pi^-\eta$
K^+K^-	K^+K^-	
$K^+K^-\pi^0$		$K^+K^-\pi^0$

- ALP: Primakoff (on-, off-shell), mixing with $P = \{\pi^0, \eta, \eta'\}$, $B^{\pm,0} \rightarrow K^{\pm,0,(\star)} a$
- DP: Bremsstrahlung, $P \rightarrow A'\gamma$, $V \rightarrow A'P$ ($V = \{\rho, \omega, \phi\}$)
- DS: $B^{\pm,0} \rightarrow K^{\pm,0,(\star)} S$

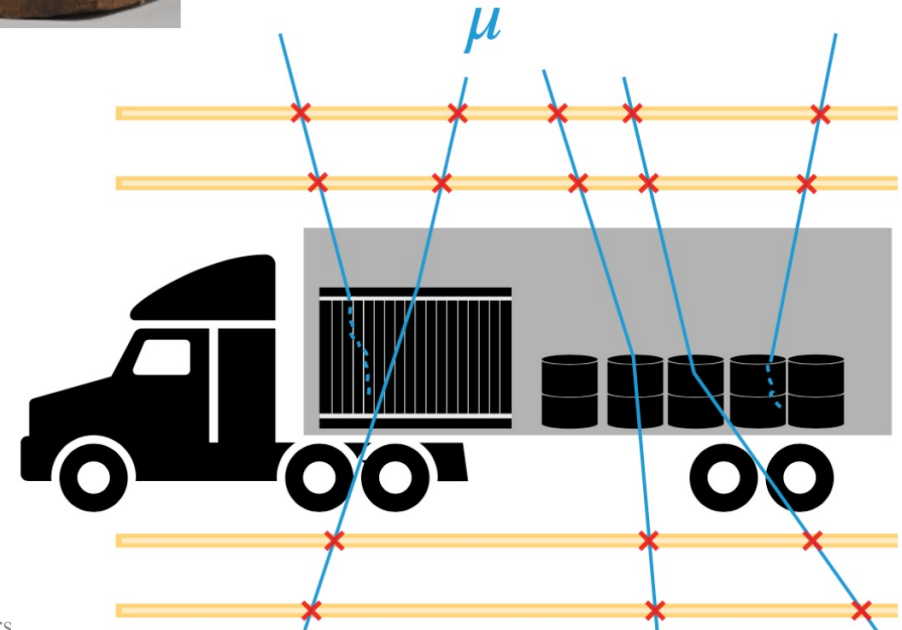


Muography

- Development of portable RPCs for muography applications.
- Light-weight, low electrical power consumption and autonomous operation
- Image the interior of large objects via the absorption or diffusion of cosmic rays.
- Silent border project
 - EU-funded project for cargo scanning at border controls.
 - In collaboration with Gscan (Estonia)



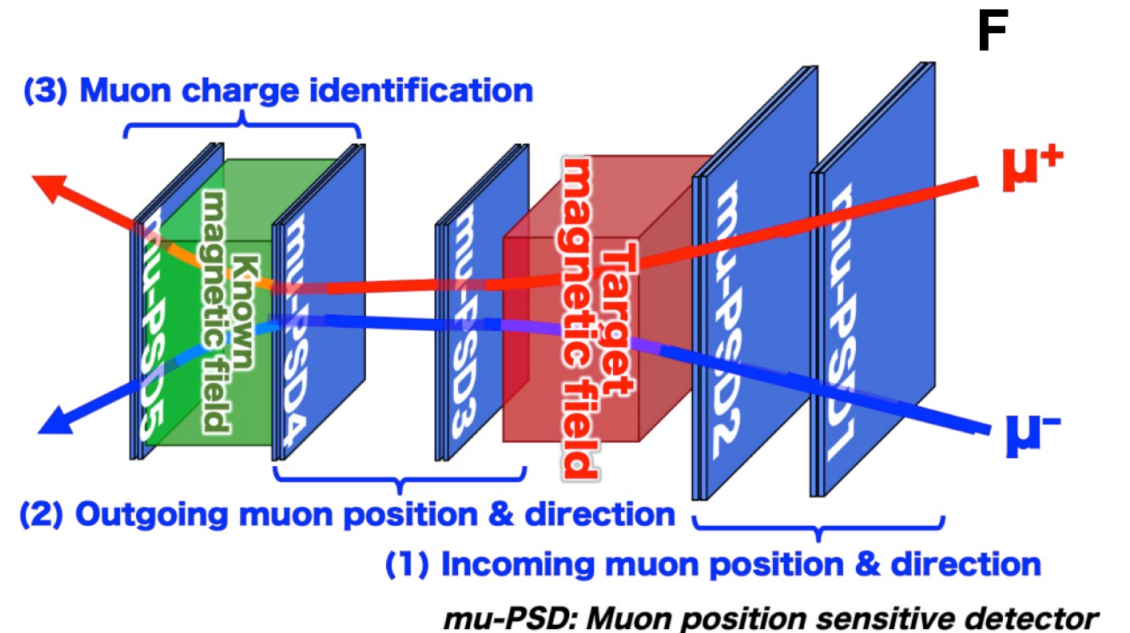
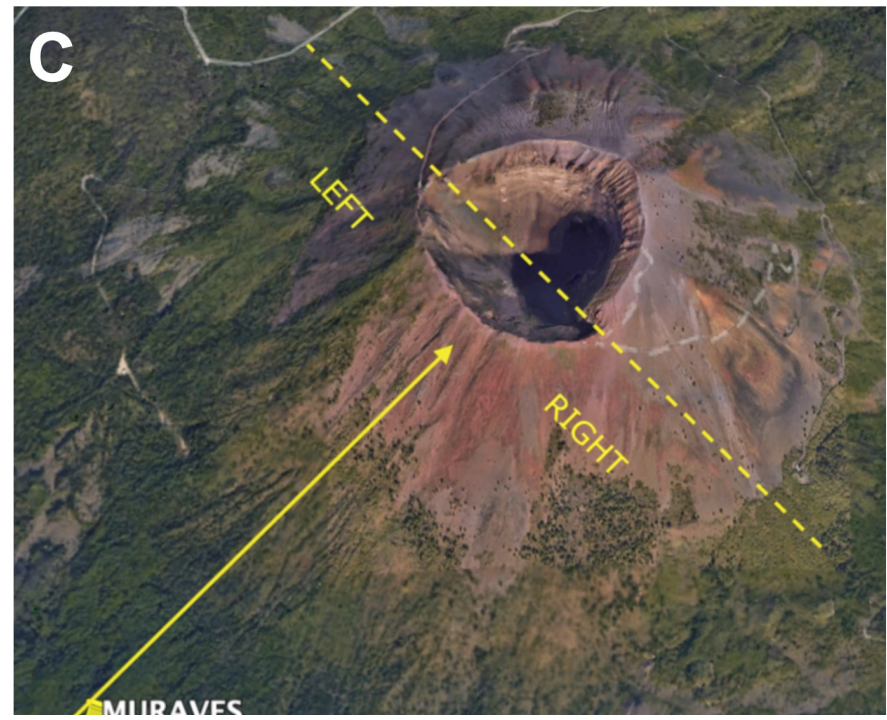
Cultural heritage



Silent border project

Muography

- MURAVES experiment
 - Studying the volcanic activity of mount Vesuvio
 - In collaboration with INGV (national research institute for volcanology) and INFN (national institute for nuclear and particle physics).
- Magic- μ
 - Magnetic field Imaging Cosmic-ray Muons.
 - Applications include monitoring plasma in nuclear fusion reactors and accelerators
 - In collaboration with Kyushu University
- TomOpt
 - software package, developed to optimise layout and specifications of detectors for muography



Muography team

PhD students

- Sumaira Ikram
- Samip Basnet
- Zahraa Daher
- Maxime Lagrange
- Khalil El Achi

Post-docs

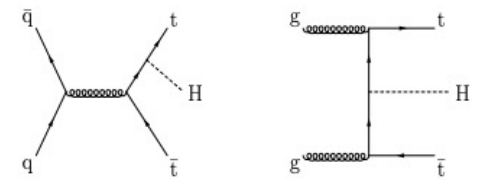
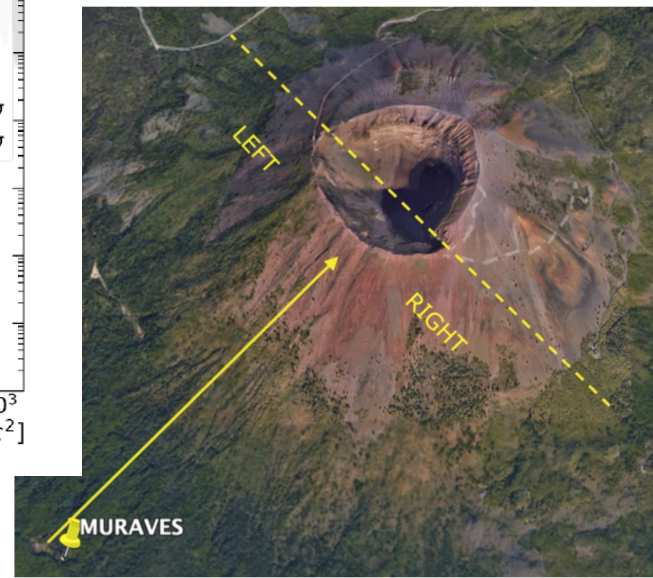
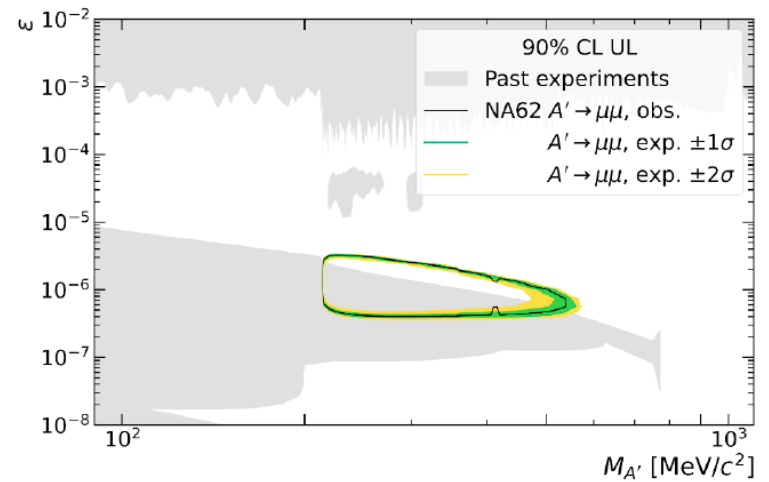
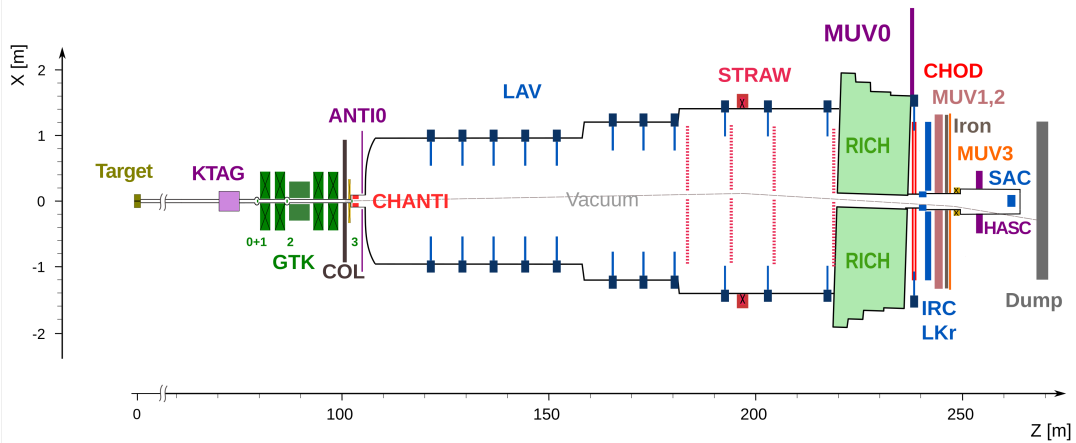
- Marwa Al Moussawi
- Vishal Kumar

Academic and research staff

- Eduardo Cortina Gil
- Andrea Giamanco

PhD theses in muography since 2019

- Muography: using cosmic rays as an imaging tool for volcanology and cultural heritage applications
 - Author: Marwa Al Moussawi,
 - Advisors: Andrea Giammanco and Eduardo Cortina Gil
 - Defence: Jan 26, 2024
- Development of single gap resistive plate chamber detectors for muography
 - Author: Ishan Darshana
 - Advisors: Andrea Giammanco and Eduardo Cortina Gil
 - Defence: Sep 18, 2023



Thank you for your attention!

