The CMS experiment at IIHE

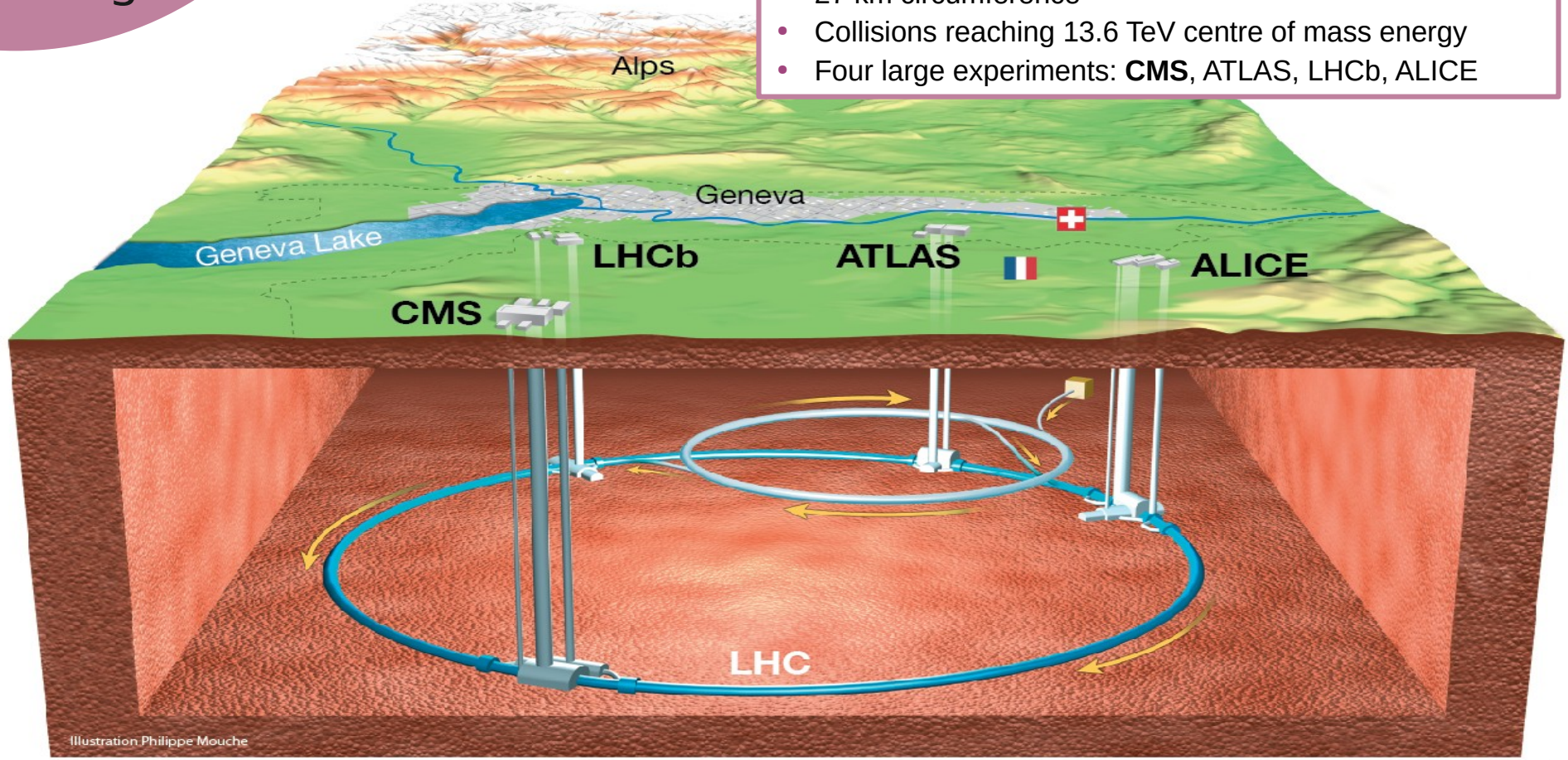
IIHE annual meeting

Ilia Kalaitzidou
On behalf of the IIHE CMS groups

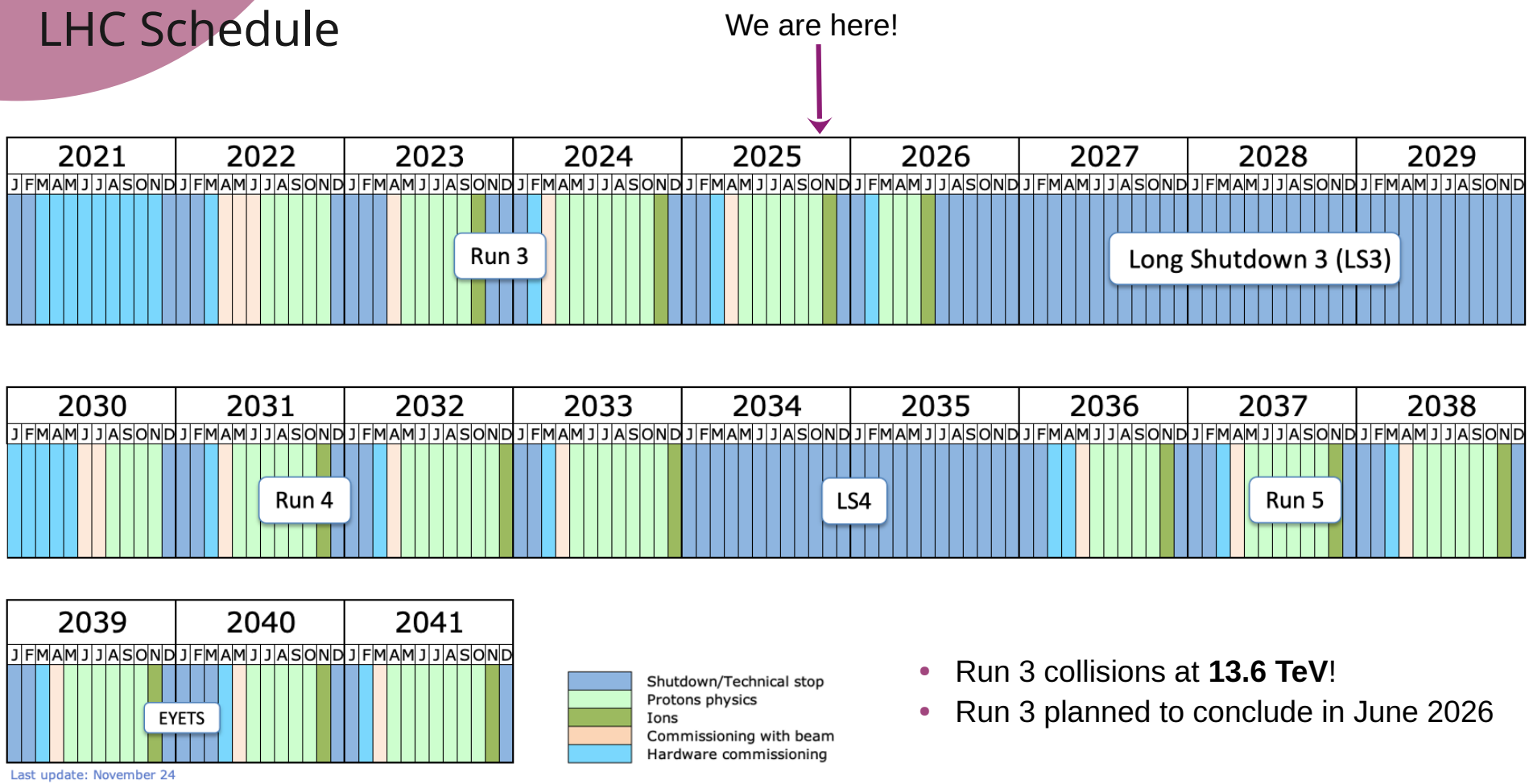
November 10, 2025

Large Hadron Collider

- Accelerates protons (mostly) and heavy ions
- 27 km circumference
- Collisions reaching 13.6 TeV centre of mass energy
- Four large experiments: **CMS**, ATLAS, LHCb, ALICE



LHC Schedule



- Run 3 collisions at **13.6 TeV**!
- Run 3 planned to conclude in June 2026

Phase-2 Upgrades

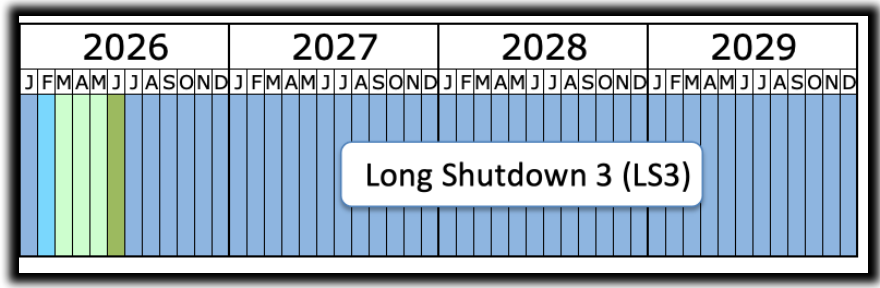
- **Major detector upgrades** planned for Long Shutdown 3 (Phase 2 upgrade) in preparation for High-Luminosity LHC Run!
  - New **Tracker** (silicon pixel + strip detectors)

    Brussels group: **strong involvement in Tracker construction** and QA, operating clean-room facilities for module assembly and testing

    Will be covered in detail in the Aloke's talk
  - **Muon system** upgrades (new GEM and improved RPC chambers)

    Brussels group: participation in **GEM detector R&D** and commissioning

    Will be covered in Yanwen's talk



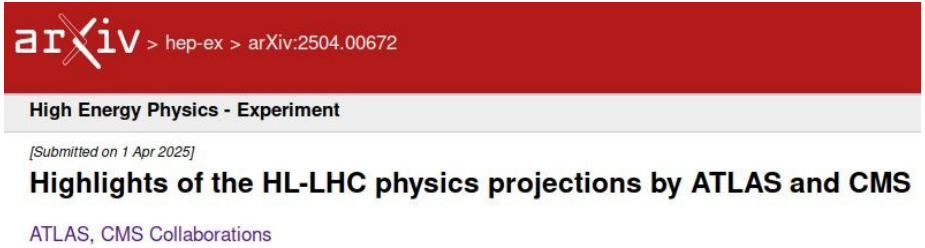
European Strategy Update

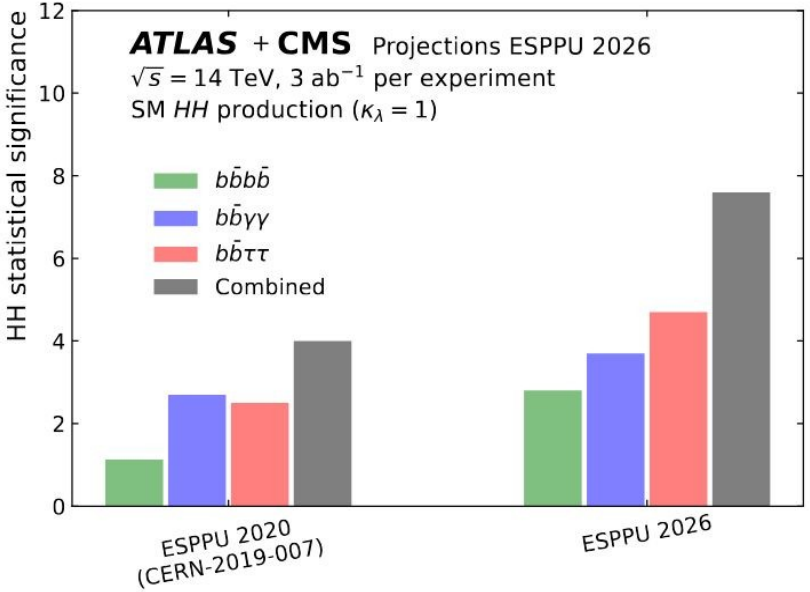
Steven

- **2026 European Strategy for Particle Physics Update**

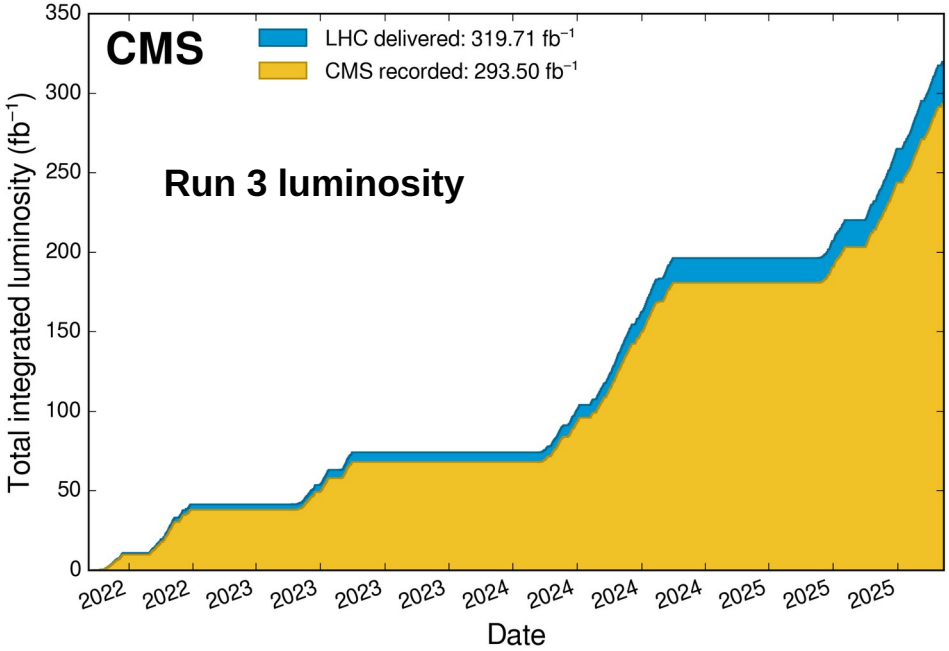
  Process started in Summer ‘24, physics inputs by March ‘25
- CMS + ATLAS updated projections for key HL-LHC measurements
  - Single Higgs precision
  - Higgs self-coupling from double-Higgs discovery
  - Electroweak potential shape and stability

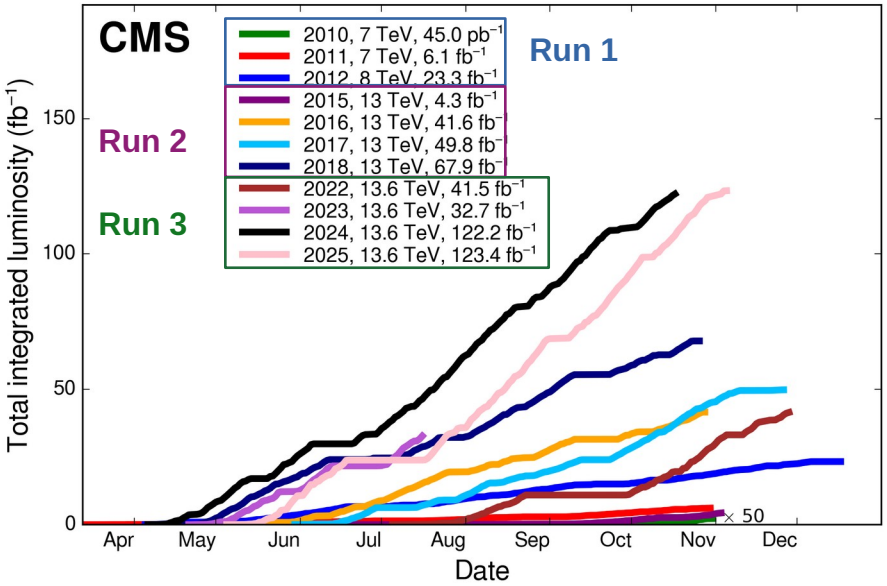
Steven Lowette co-coordinated as **2024-2025 Physics Officer**





Luminosity





- CMS has recorded ~ 300 fb^{-1} in Run 3 and goes on!
- Already recorded more than double the luminosity compared to Run 2

CMS Shifts

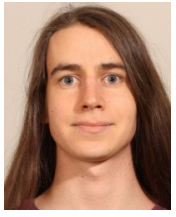
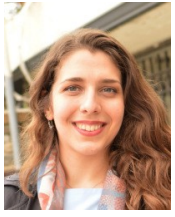
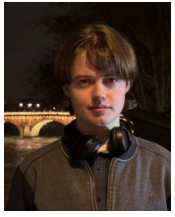
- We need shifters to assure high data quality and data-taking stability!
  - Actively contributing in various P5 central shifts (CMS control room)
  - Several GEM, RPC, L1, Tracker DOC (experts on-call)

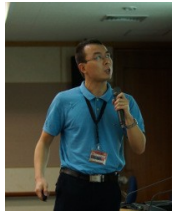










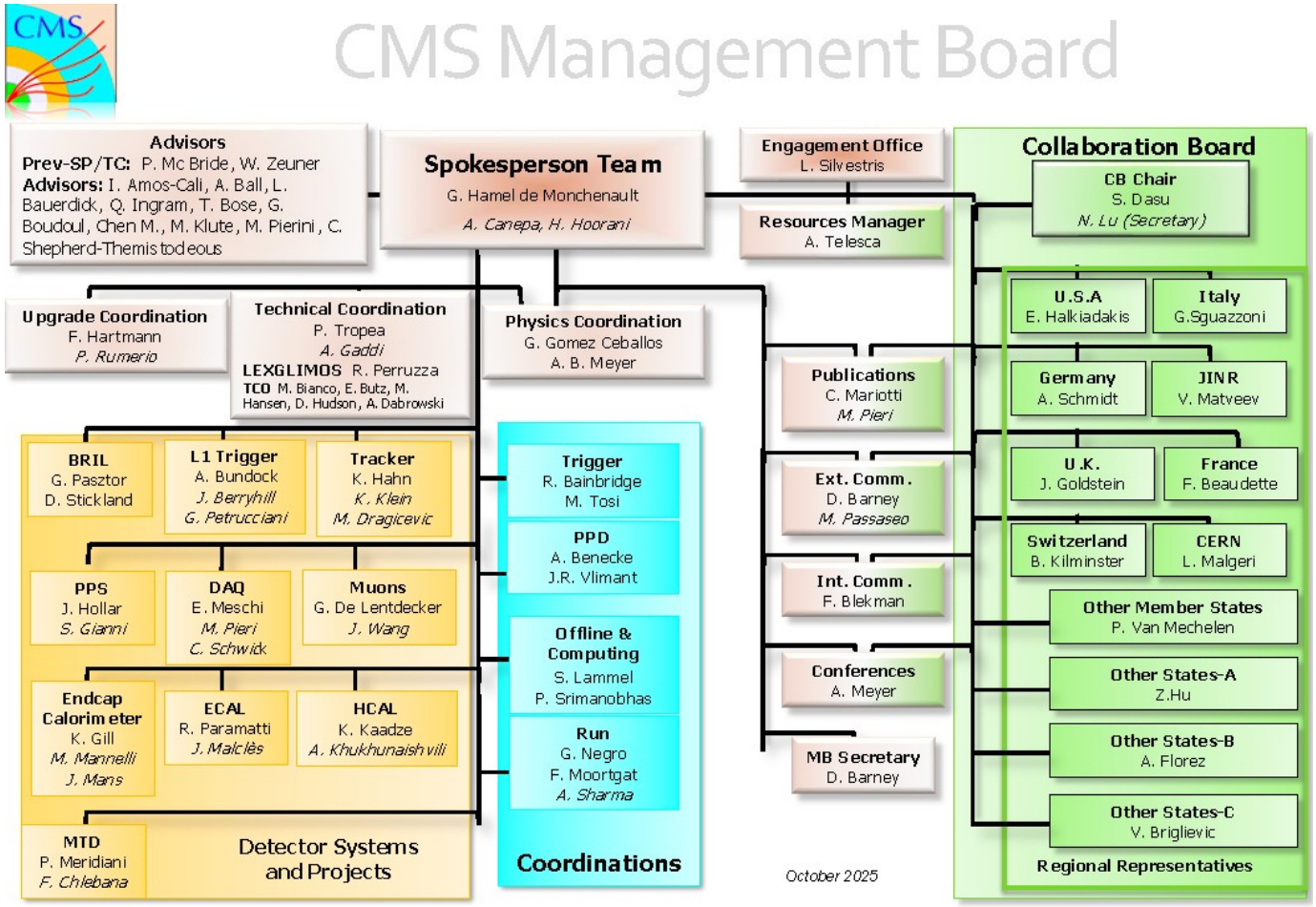


CMS Shifts

Congratulations to Itana who received a well-deserved award:

"For her deep competence and exemplary commitment in consistently undertaking DAQ shifts every year of Run 3"

How IIHE Fits into the CMS Puzzle



How IIHE Fits into the CMS Puzzle

Martin

Current L2 convener in Tracker DPG

Laurent

Former L2 convener in L1 Trigger DPG

Gilles

Project manager of the CMS muon system

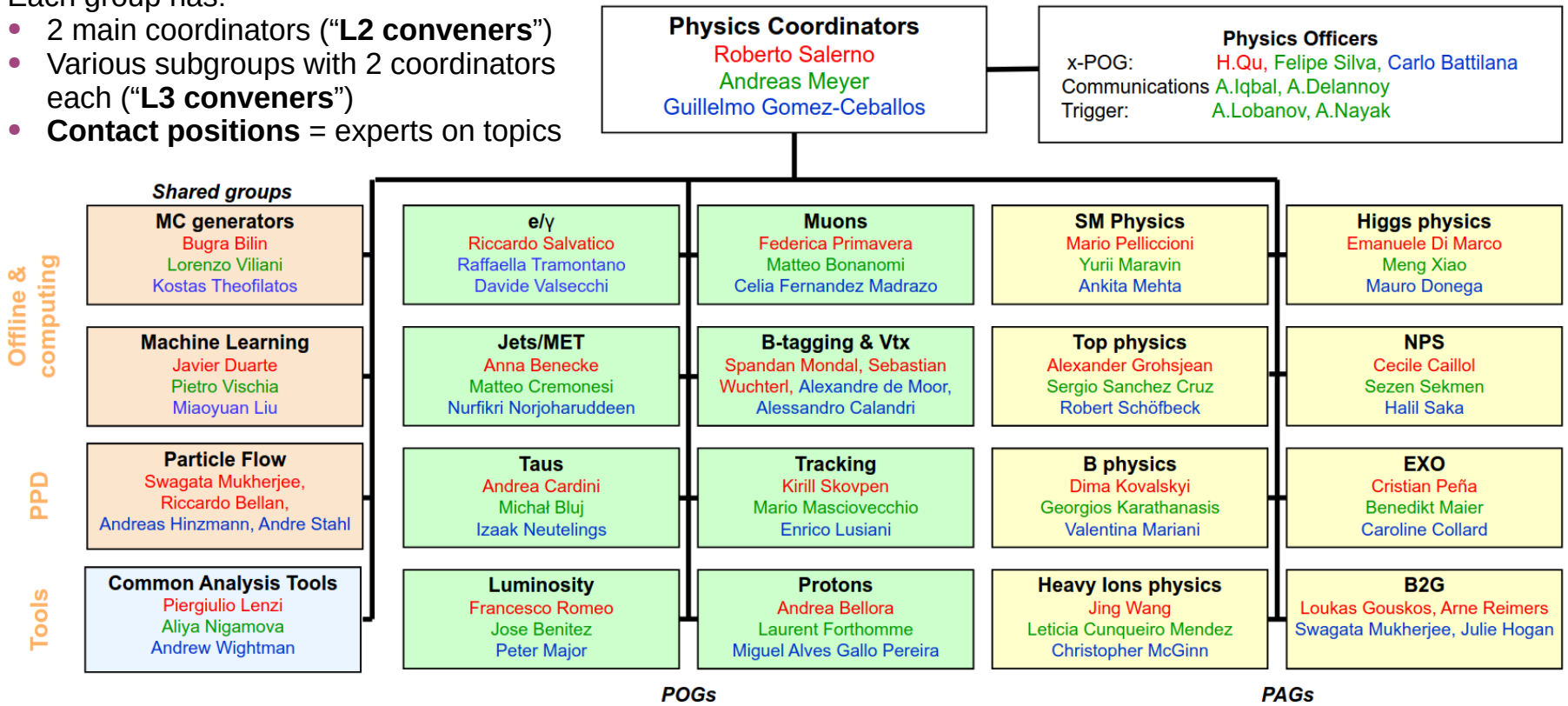
How IIHE Fits into the CMS Puzzle

CMS physics organization (2025-2026)

Outgoing
Continuing
Incoming

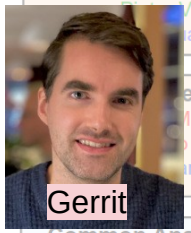
Each group has:

- 2 main coordinators (“**L2 conveners**”)
- Various subgroups with 2 coordinators each (“**L3 conveners**”)
- **Contact positions** = experts on topics



How IIHE Fits into the CMS Puzzle

Former L2



Current L3 in generator tuning

CMS physics organization (2025-2026)

Physics Coordinators
Roberto Salerno
Andreas Meyer
Guillelmo Gomez-Ceballos

Physics Officers
x-POG: H.Qu, Felipe Silva, Carlo Battilana
Communications: A.Iqbal, A.Delannoy
Trigger: A.Lobanov, A.Nayak

Offline & computing

MC generators
Bugra Bilin
Lorenzo Viliani
Kostas Theofilatos

Machine Learning
Javier Duarte
Vischia
an Liu

PPD

e Flow
Mukherjee,
Bellan,
nn, Andre Stahl

Common Analysis Tools
nzi
ova
man

e/γ
Riccardo Salvatico
Raffaella Tramontano
Davide Valsecchi

Muons
Federica Primavera
Matteo Bonanomi
Celia Fernandez Madrazo

SM Physics
Mario Pelliccioni
Yurii Maravin
Ankita Mehta

Higgs physics
Emanuele Di Marco
Meng Xiao
Mauro Donega

Jets/MET
Anna Benecke
Matteo Cremonesi
Nurfikri Norjoharuddeen

B-tagging & Vtx
Spandan Mondal, Sebastian Wuchterl, Alexandre de Moor, Alessandro Calandri

Top physics
Alexander Grohsjean
Sergio Sanchez Cruz
Robert Schöfbeck

NPS
Cecile Caillol
Sezen Sekmen
Halil Saka

Taus
Andrea Cardini
Michał Bluj
Izaak Neutelings

Tracking
Kirill Skovpen
Mario Masciovecchio
Enrico Lusiani

B physics
Dima Kovalskyi
Georgios Karathanasis
Valentina Mariani

EXO
Cristian Peña
Benedikt Maier
Caroline Collard

Luminosity
Francesco Romeo
Jose Benitez
Peter Major

Protons
Andrea Bellora
Laurent Forthomme
Miguel Alves Gallo Pereira

Heavy Ions physics
Jing Wang
Leticia Cunqueiro Mendez
Christopher McGinn

B2G
Loukas Gouskos, Arne Reimers
Swagata Mukherjee, Julie Hogan

POGs

PAGs

How IIHE Fits into the CMS Puzzle

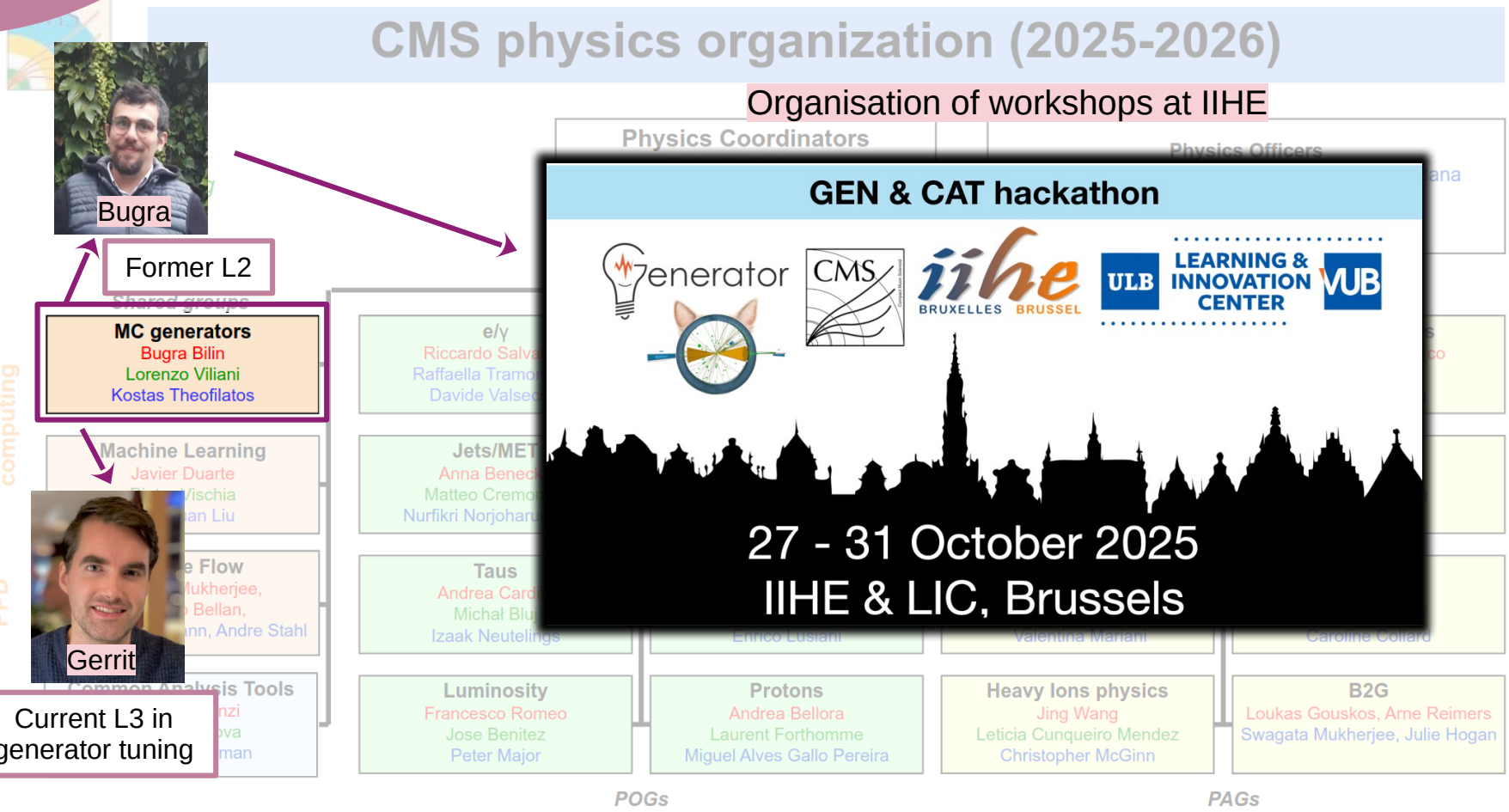
Bugra

Former L2

Organisation of workshops at IIHE

Gerrit

Current L3 in generator tuning



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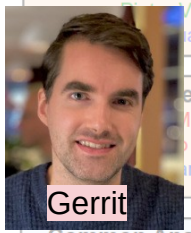
Former L2



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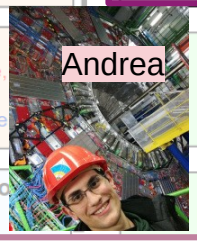

Former L3 in JERC

Former L2

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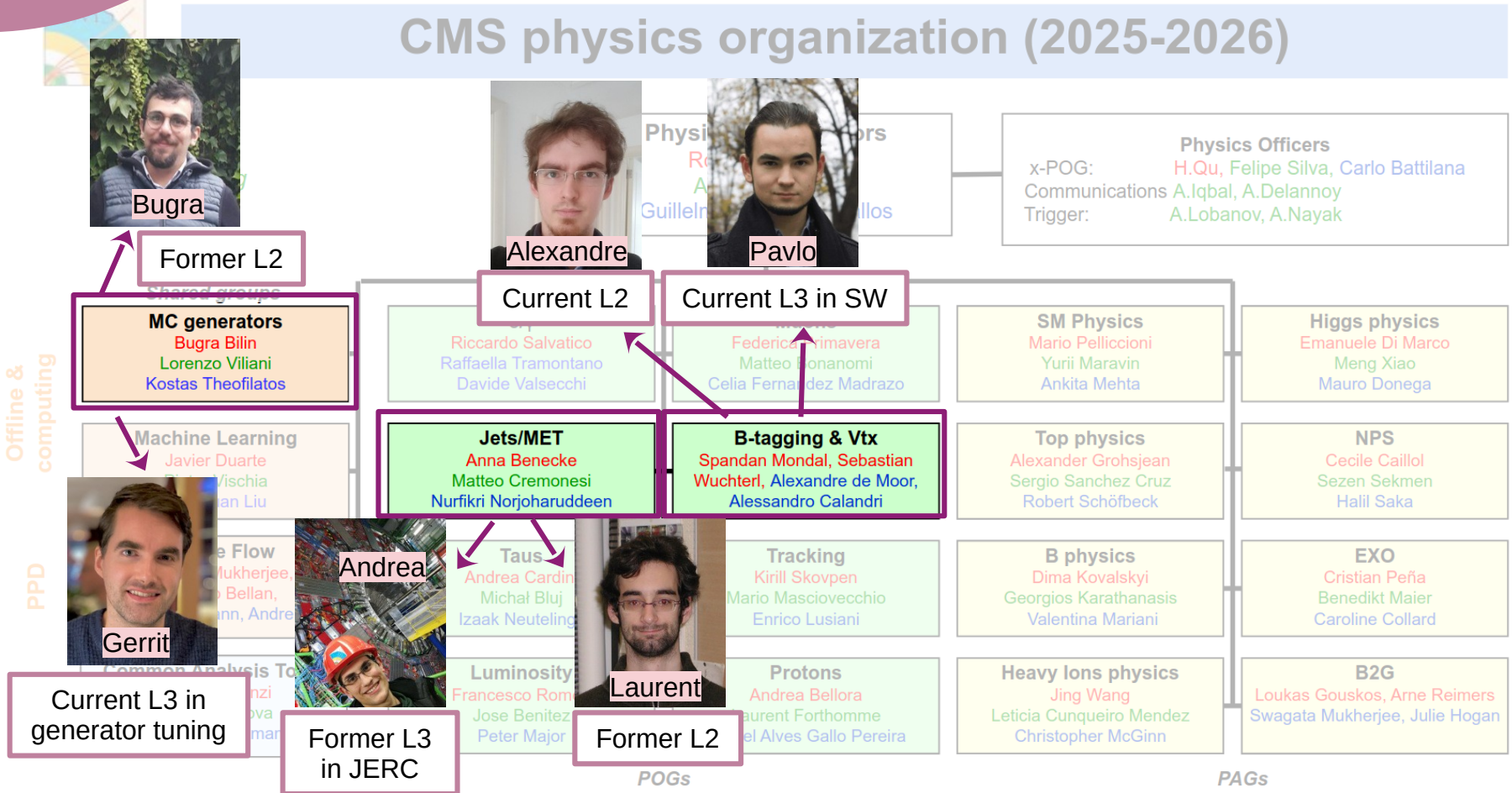
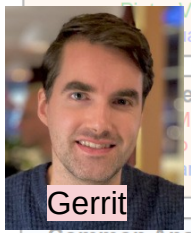


How IIHE Fits into the CMS Puzzle

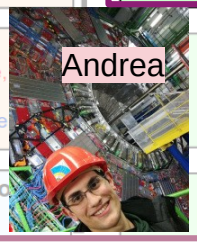
Former L2

Current L2

Current L3 in SW

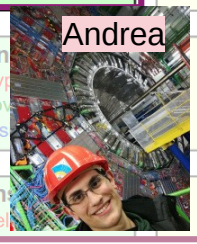


Current L3 in generator tuning



Former L3 in JERC

Former L2



Former L3 in diboson resonances

Former L3 in very heavy fermions

How IIHE Fits into the CMS Puzzle

Former L2

Current L2

Current L3 in SW

Current Trigger coordinator contact

MC generators
Bugra Bilin
Lorenzo Viliani
Kostas Theofilatos

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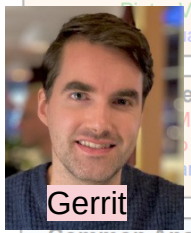
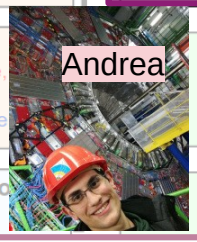
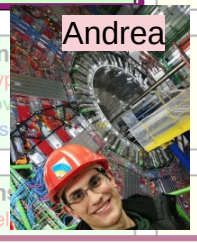


Current L3 in generator tuning



Former L3 in JERC

Former L2



Former L3 in diboson resonances

B2G
Loukas Gouskos, Arne Reimers
Swagata Mukherjee, Julie Hogan

How IIHE Fits into the CMS Puzzle


Bugra

Former L2


Alexandre

Current L2


Pavlo

Current L3 in SW


Max

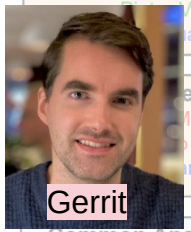
Current Trigger coordinator contact


Steven

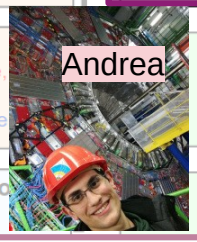
Former L2


Ilia

Current electron contact


Gerrit

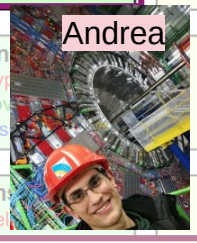
Current L3 in generator tuning


Andrea

Former L3 in JERC


Laurent

Former L2

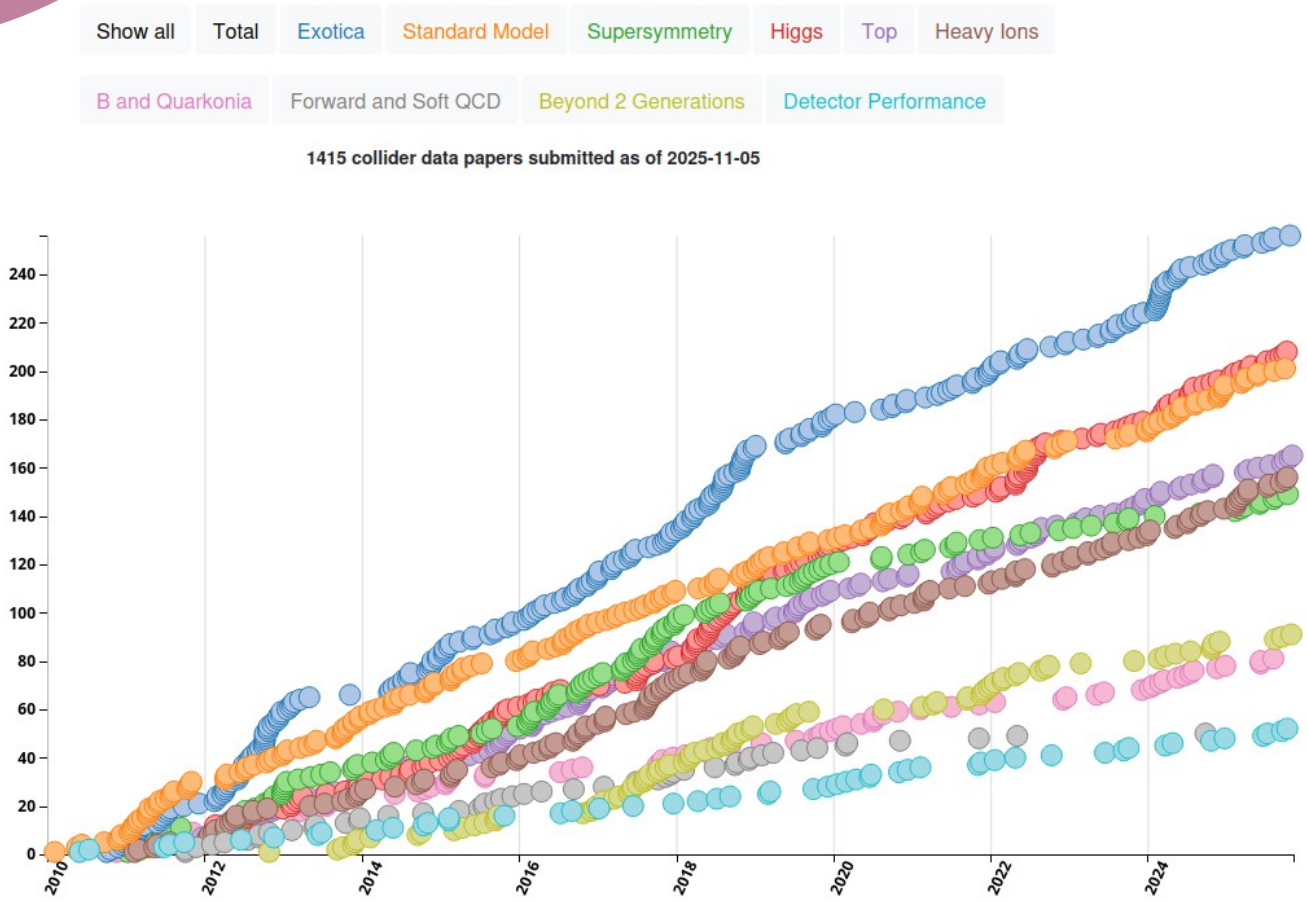

Andrea

Former L3 in diboson resonances


Gerrit

Former L3 in very heavy fermions

Physics analyses in CMS

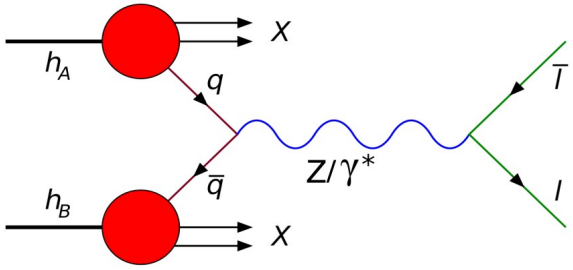


Searches

Precision measurements

The Drell-Yan chronicles

International collaboration with Korea, Lithuania and US groups



- Main physics analysis:

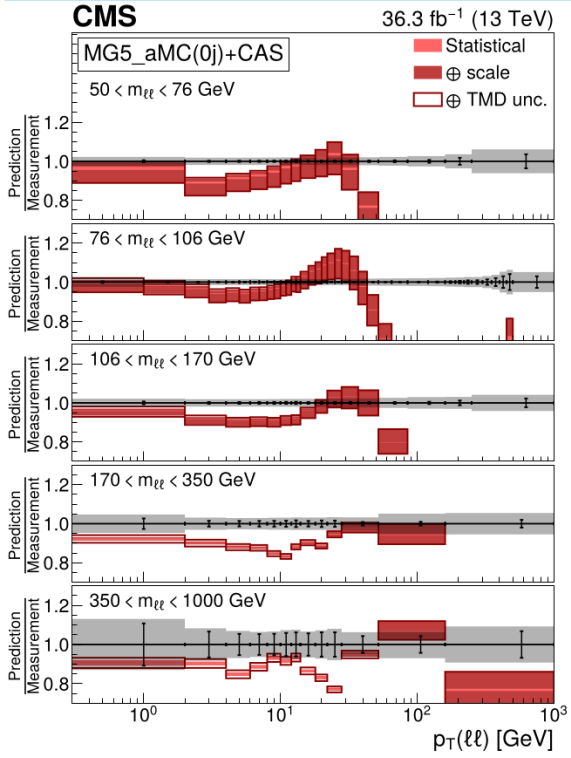
  Differential DY cross section measurement as a function of dilepton variables (mass, p_T, rapidity)

  - **Precise test** of the standard model
  - Constraint of **parton distribution functions (PDF)** and **multiple gluon resummation treatment**

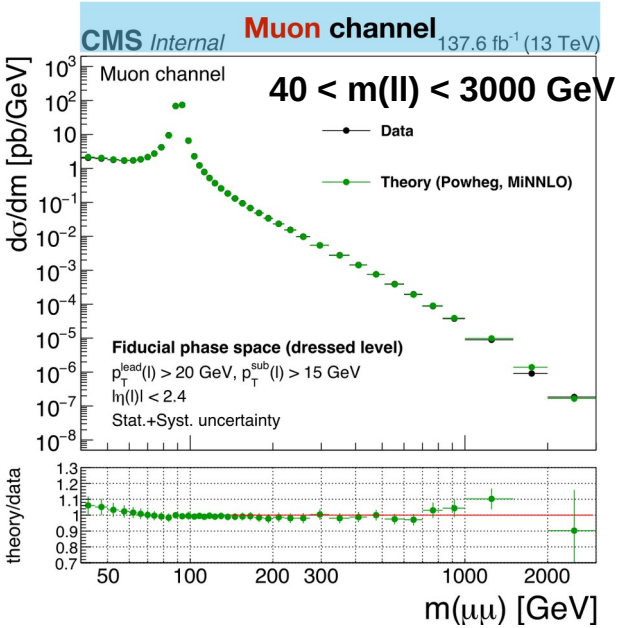
Recent publication with 2016 data

$d^2\sigma/dm dp_T$ @ 13 TeV

(Eur. Phys. J. C 83, 628 (2023))

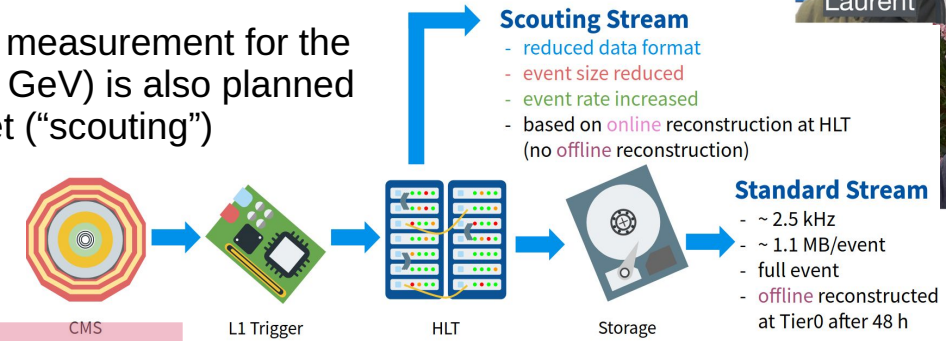


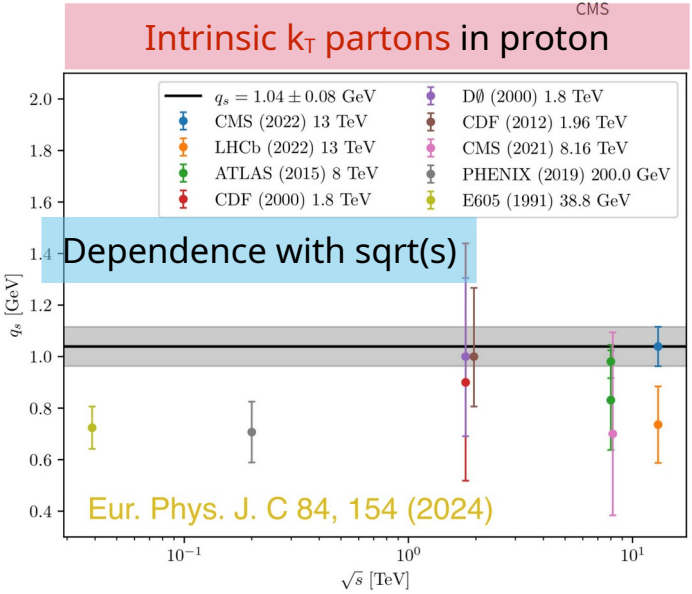
On-going effort with full Run 2 data



The Drell-Yan chronicles

- **Scouting data**: Additional measurement for the **low mass** (10 < m(ll) < 40 GeV) is also planned using a specialised dataset (“scouting”)





- Intrinsic transverse momentum is tuned in MC with a non-physical energy dependence
- k_T measured on low-p_T Drell-Yan events → No strong dependence on centre-of-mass energy observed

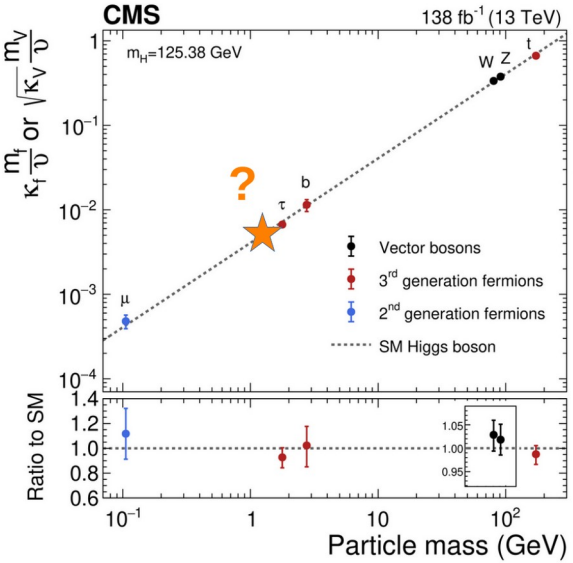
A charming future
Probing the Higgs-charm coupling

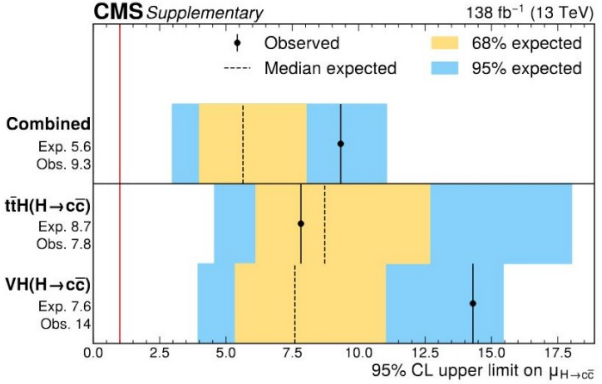

Michael

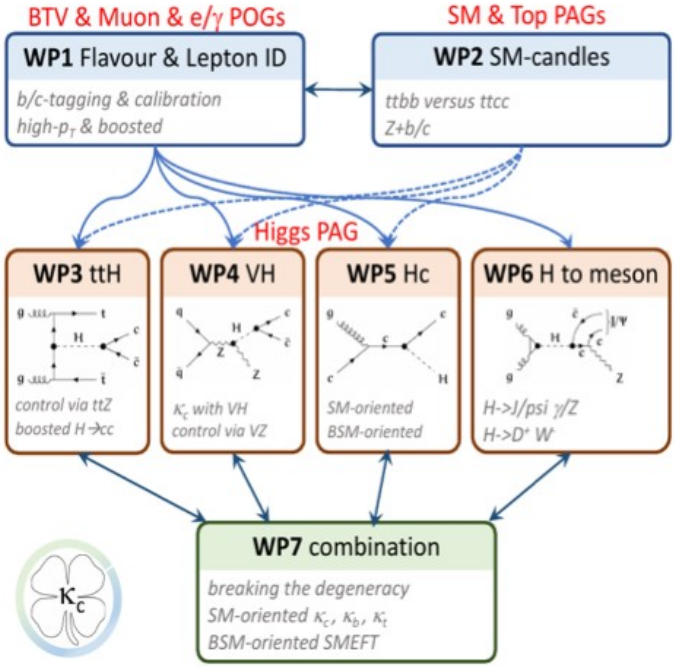

Steven

- charm-Higgs coupling y_c **next milestone at LHC** → Currently only limits on y_c
- Large inter-university project **iBOF** (VUB + UGent + UAntwerp) → Probe various processes sensitive to y_c and combine for ultimate precision

Nature 607 (2022) 60-68

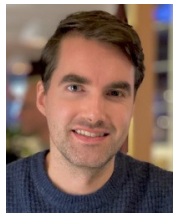


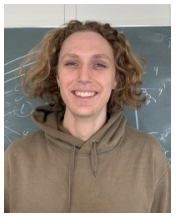




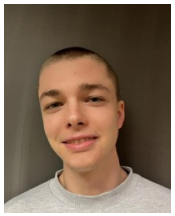
A charming future
H + c process

H+c with H → ZZ* → 4ℓ

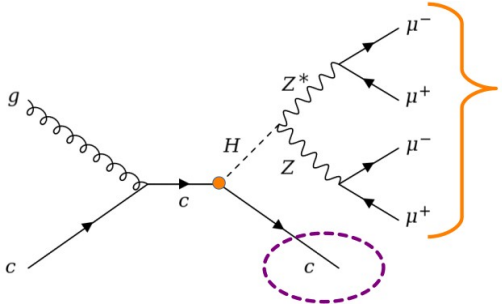

Gerrit


Felix


Nordin

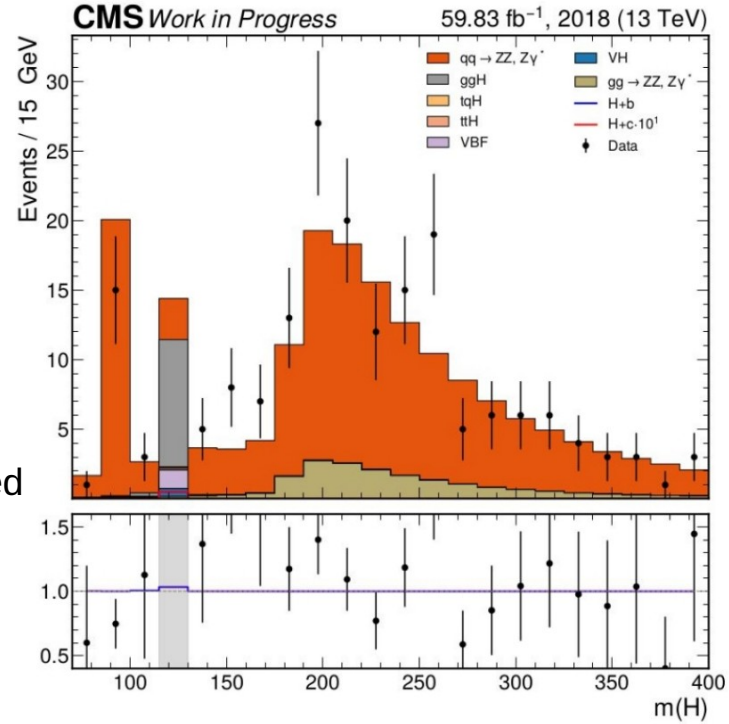

Stef


Saranya



Higgs boson candidate reconstruction from 4 muons

Challenge: picking the "good" jet
→ Via likelihood ratio using kinematic properties



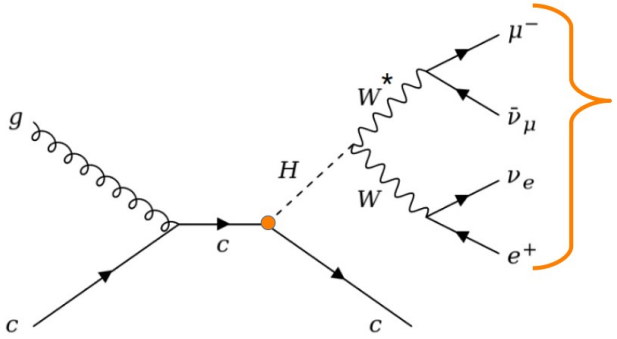
Invariant mass of H candidate

- **Run 2** dataset (2018 data): Set limit on y_c by fitting jet c-tag discriminator shapes
- **Run 3** dataset: Joined SM-oriented effort, focus on BSM-oriented approach on longer term

Collaboration within CMS with Antwerp, Athens, Brown groups

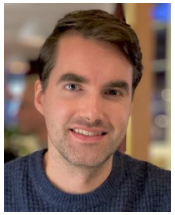
A charming future
H + c process

H+c with H → WW* → 2ℓ2ν



Challenge: H candidate reconstruction involves missing transverse momentum

- **Run 3** dataset: Joined SM-oriented effort, explore BSM interpretation (with Saranya)


Gerrit


Chirayu

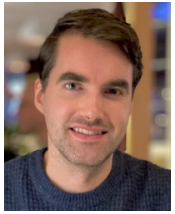
Collaboration within CMS with Antwerp group

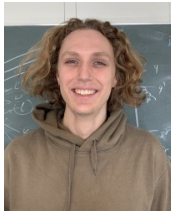
Constraints on new physics in H+c using EFT

$$\mathscr{L}_{\mathrm{SMEFT}} = \mathscr{L}_{\mathrm{SM}} + \frac{1}{\Lambda^2}\sum_i C_i \mathcal{O}_i^{(6)}$$

Pheno paper in preparation: target draft end of year

- Identified EFT operators relevant in H+c events
- Checked validity regimes of Wilson Coefficients C_i
- Approximating systematic uncertainties & derive expected constraints on C_i

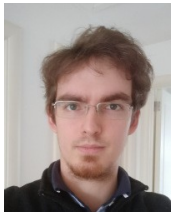

Gerrit

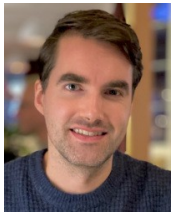

Felix


Nordin

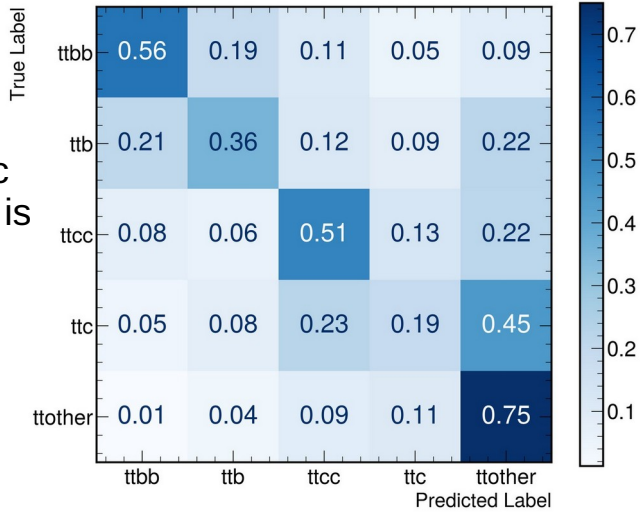
A charming future
tt+cc cross section


Juhee

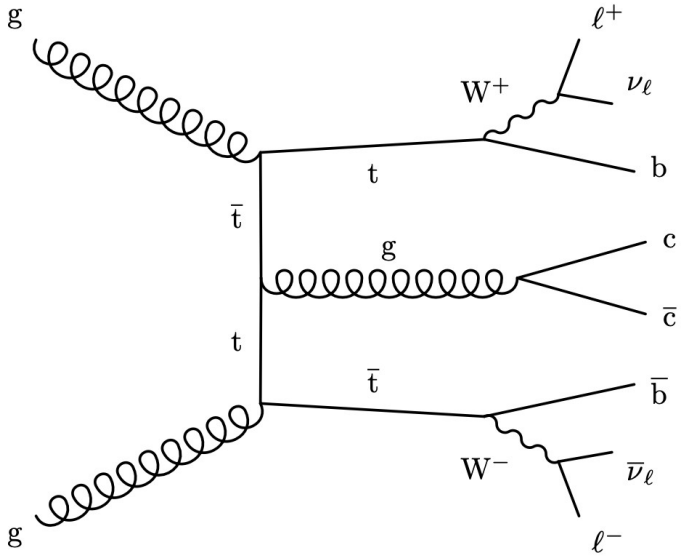

Alexandre


Gerrit

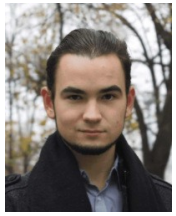
- **Aim**: Measurement of **tt+cc inclusive cross section**
- tt+heavy flavour is an irreducible background in many analyses including ttH
- Full Run 2 dataset
- Use deep learning architecture for event classification

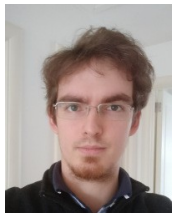


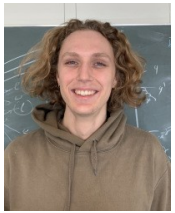
Classification performance: ttcc shows 51% accuracy, while ttc is more challenging



A charming future
Jet flavour identification


Pavlo

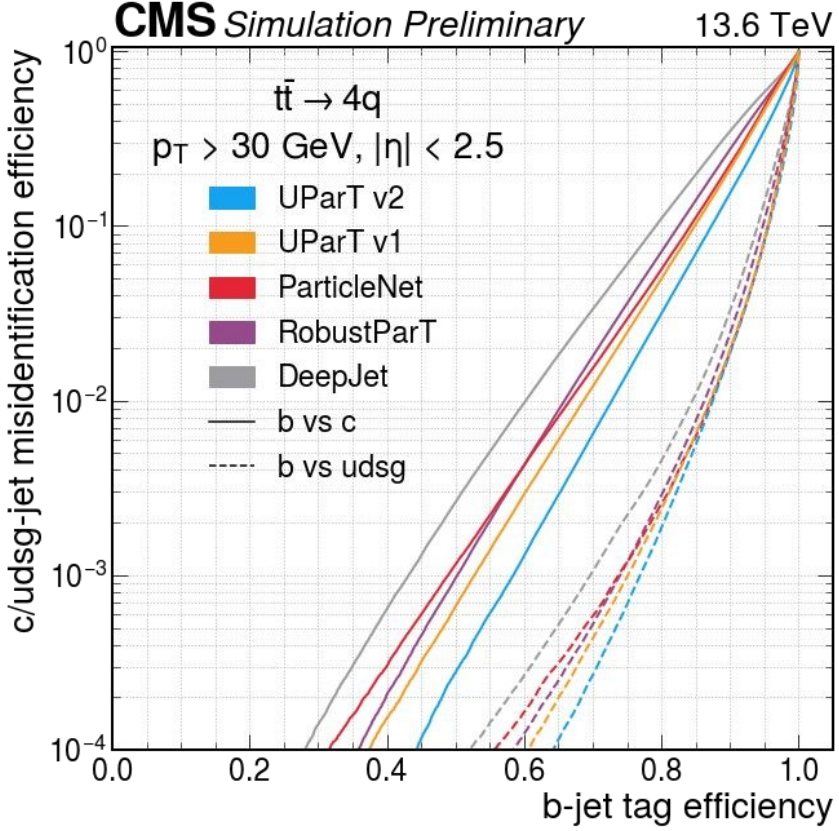

Alexandre


Felix


Juhee


Saranya

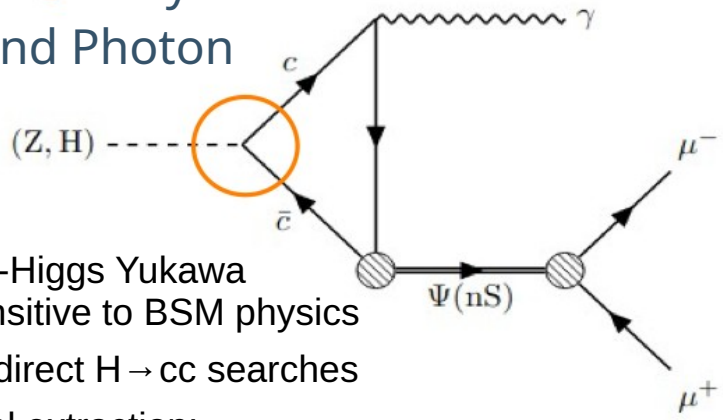

Chirayu



- **Jet flavour identification** is crucial for all the previous analyses
- Major involvement in **BTV POG**
- Milestone of 2025, **UParTv2**: New state-of-the-art flavour tagging (faster, optimised, larger model and dataset size)
- Continuous work ongoing for **UParTv3**
- Phase-II developments: Study on HLT and Offline / Software contributions

A charming future
Rare Higgs decays

Higgs/Z-boson decay to Psi Meson and Photon

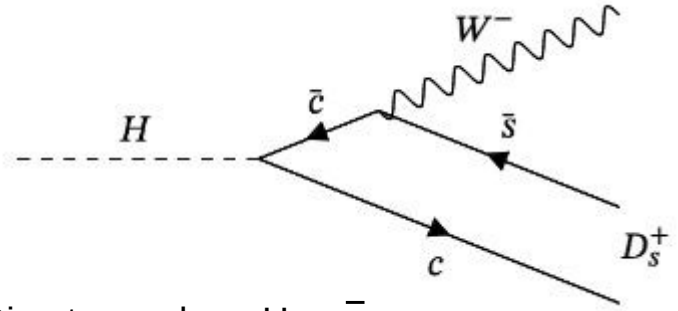


- Probes charm-Higgs Yukawa coupling + sensitive to BSM physics
- Alternative to direct H→cc searches
- 2D-fit for signal extraction: Simultaneous fit in $m_{\mu\mu}$ and $m_{\mu\mu\gamma}$

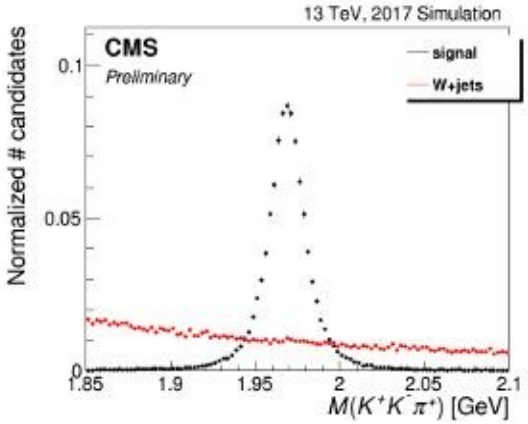
Jas

Collaborative effort

Higgs decay Ds meson and W boson

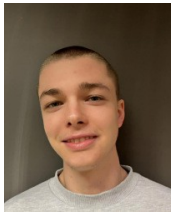


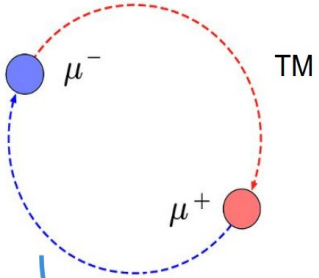
- Direct search on H→$c\bar{c}$



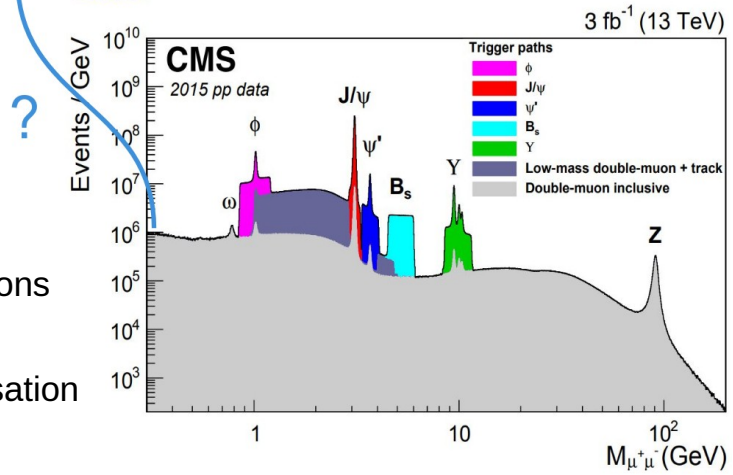
Kai

In Pursuit of the True Muonium


Stef



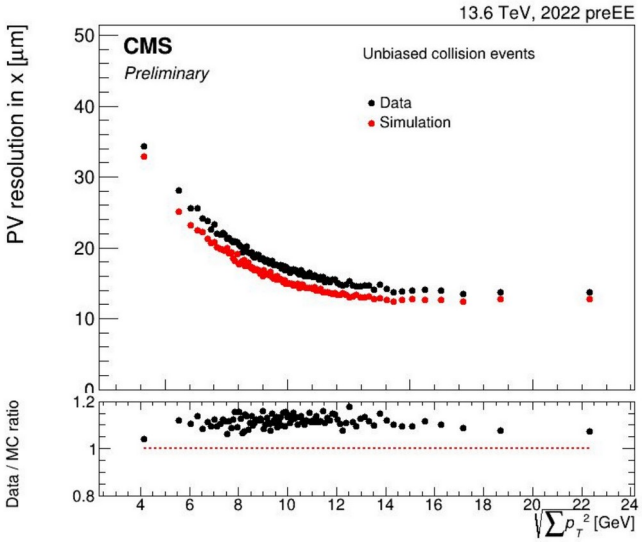
- **True Muonium (TM)** is an unobserved QED bound state of ***μ***+***μ***-
  - m ~ 210 MeV, cτ ~ .5mm → predicted by the SM
  - Serves as precision test of QED + sensitive to BSM physics
- Look at dissociated muons from TM after material interactions
- **Current work**: first background estimations from photon conversions and hadron decays in the form of displaced muon pairs
- **Future work**: Signal simulation and background reduction optimisation



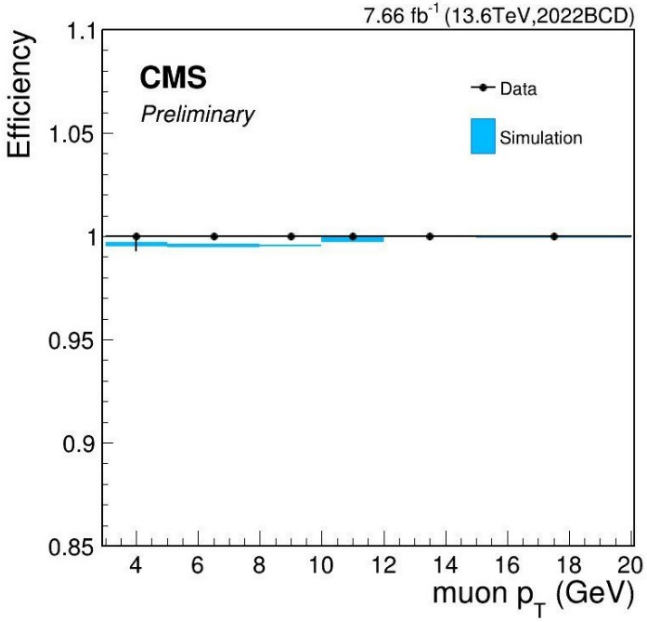
On the Right Track

Kai

- For all the above analyses precise tracking is crucial!



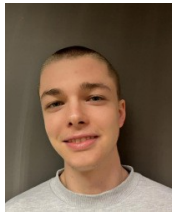
- Run-3 primary vertex and track impact parameter resolution calibrations



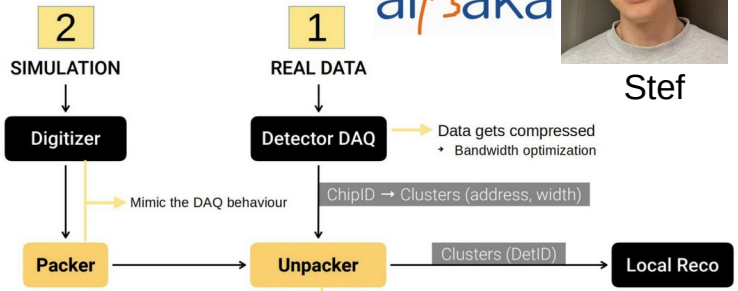
Jas

- Run-3 tracking efficiency at low p_T with J/ψ→μμ decays
- Run-3 displaced vertexing calibrations

- Software development for Phase-2 Outer Tracker



Stef



Higgs Gone Exotic

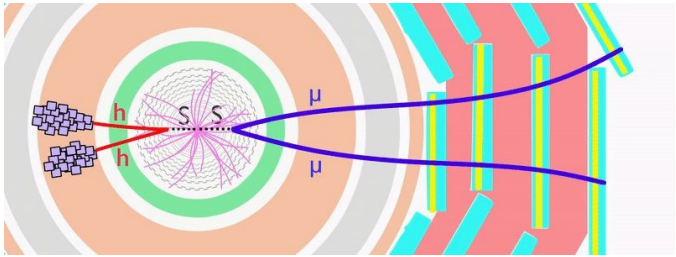

Soumya

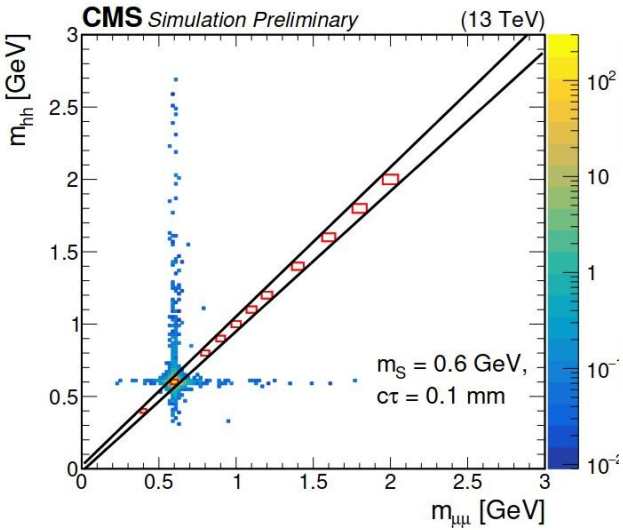

Jas

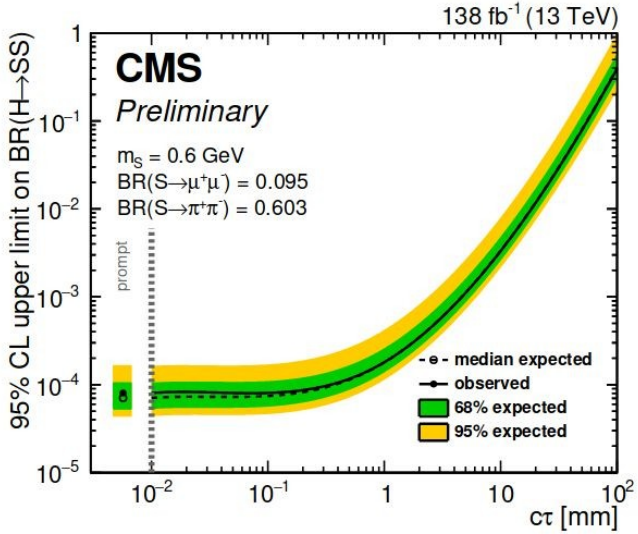

Barbara


Steven

- **First search** ever for exotic Higgs decay H → SS → 2μ + 2K/2π
- When S low mass → dominant decay to pair of kaons or pions
- Nearly background free using m(S1) = m(S2)
- Considered prompt as well as displaced decay
- Unique sensitivity at low mass, down to below 10^{-4}!





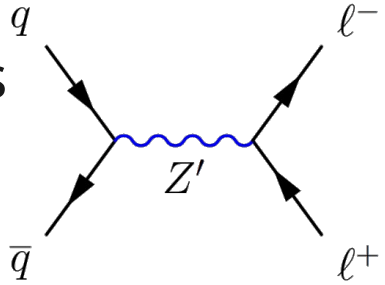


Public:

CMS-PAS-EXO-24-034

CMS physics briefing

Chasing Heavy Resonances



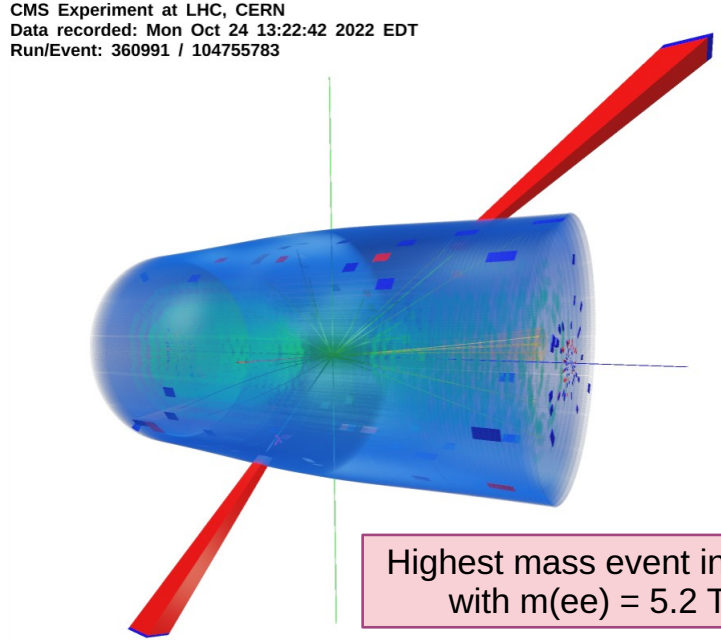

Laurent


Franco

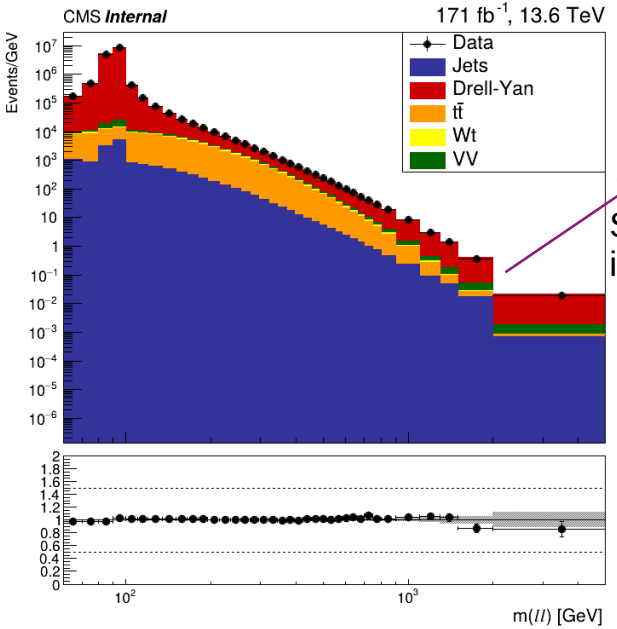

Ilia

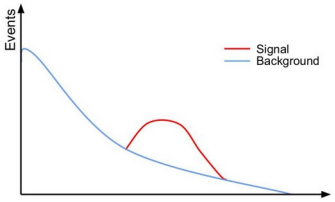

Barbara

- **Current work:** Inclusive search for high mass dilepton resonances (Run 2 + partial Run 3 data)
- **Future plan:** Sophisticated analysis strategy with exclusive categories (Full Run 2 and Run 3 data)



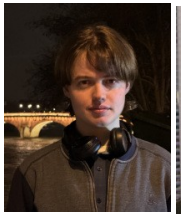
Highest mass event in Run 3 with m(ee) = 5.2 TeV!





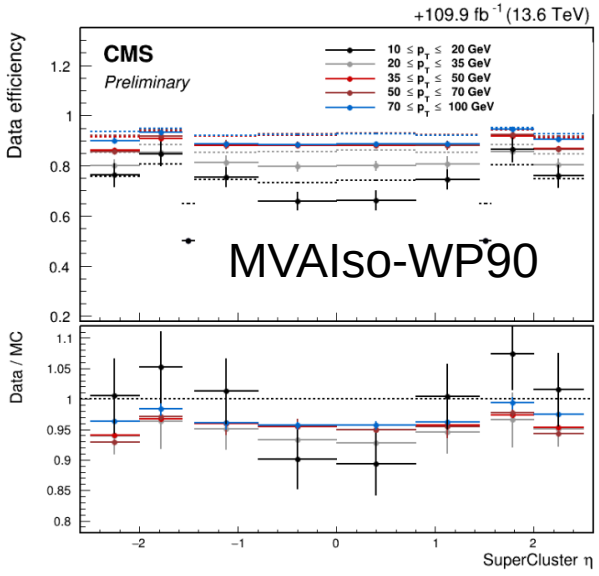
Search for resonances in m(*ll*) distribution tail

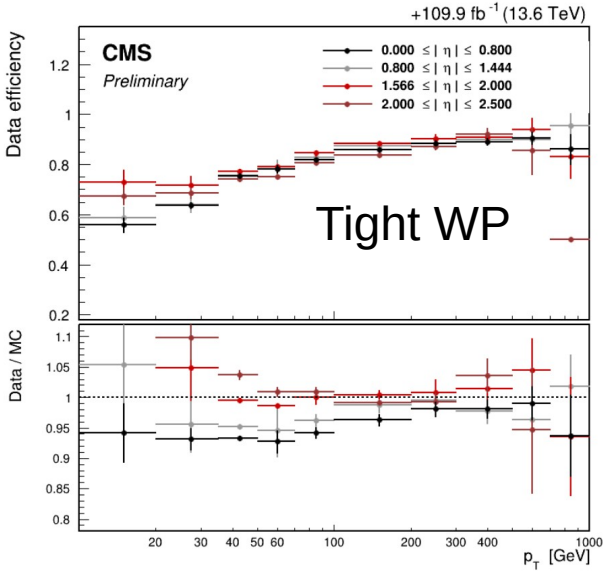
Spotting the Electrons

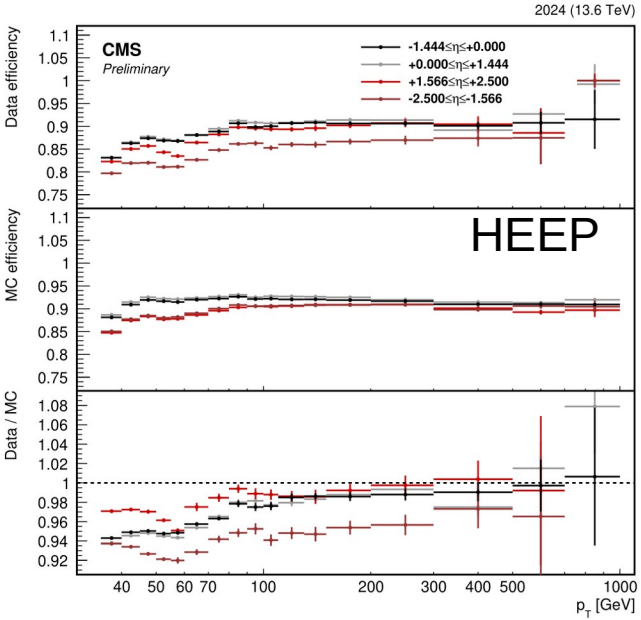




Aamir Franco Laurent

- For such analyses measuring the electron identification efficiency is crucial
- Derived Run 3 electron ID scale factors

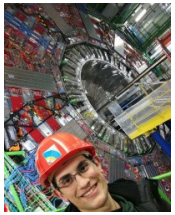


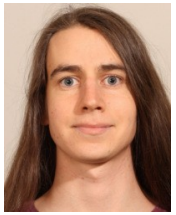




p_t bins: 10-100 GeV

Higgs Undercover


Andrea


Hugues

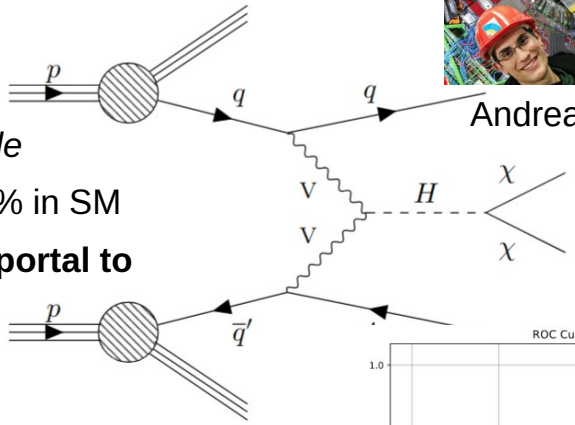

Aamir

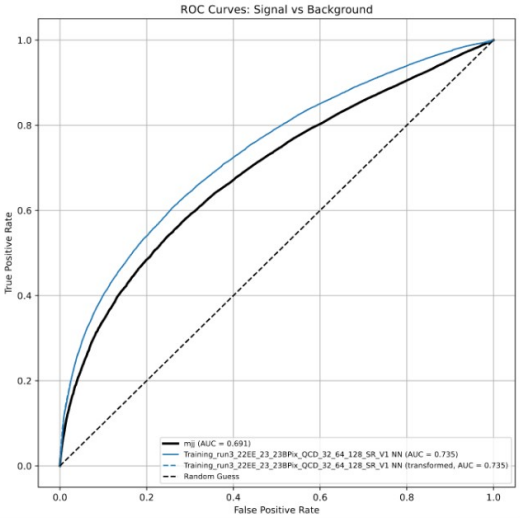

Chaochen


Laurent


Pascal

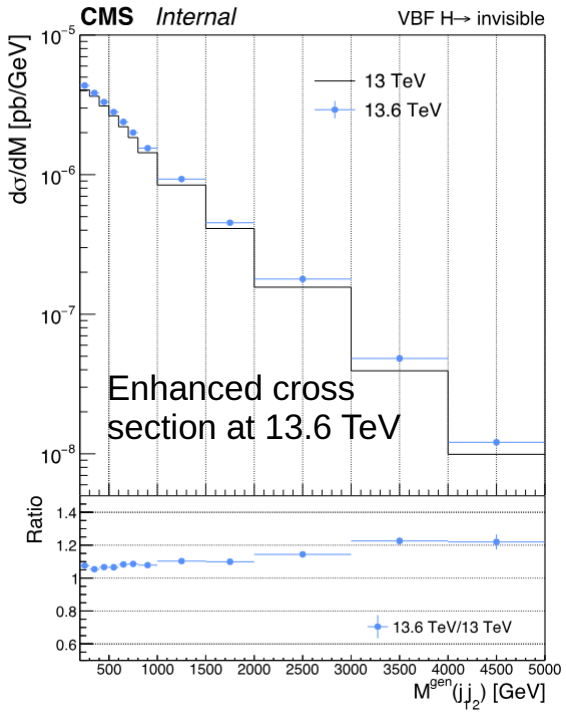
- Search for *H → invisible*
  - B(H → inv) ≃ 0.1% in SM
  - Higgs could be a **portal to dark matter**



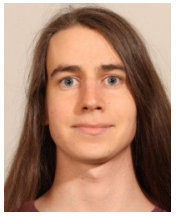


- Long standing effort for Higgs to *invisible*
  - Worked on full Run 2 analysis
  - **Current work**: Run 3 analysis focusing on vector boson fusion production mode

    Tagging production mode with machine learning techniques



Higgs Undercover

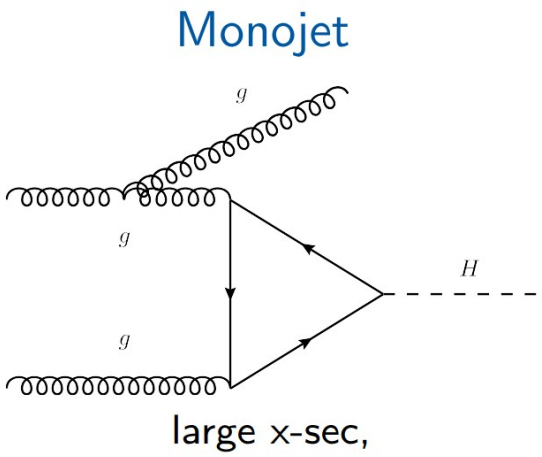



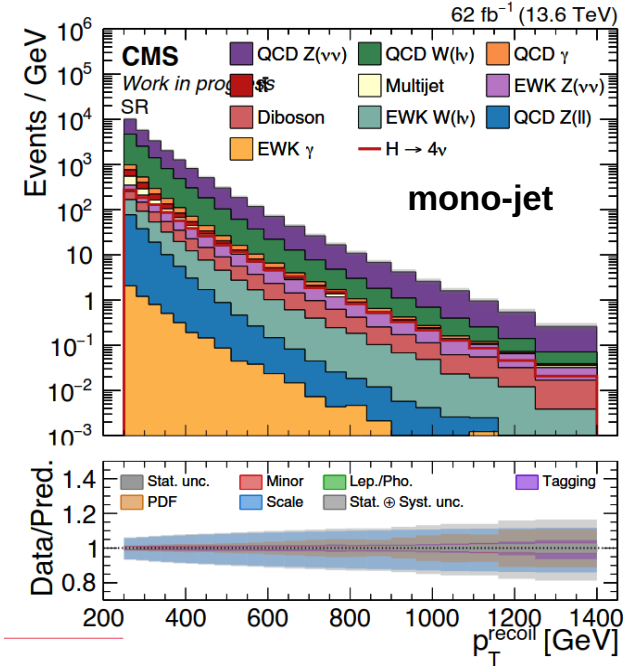


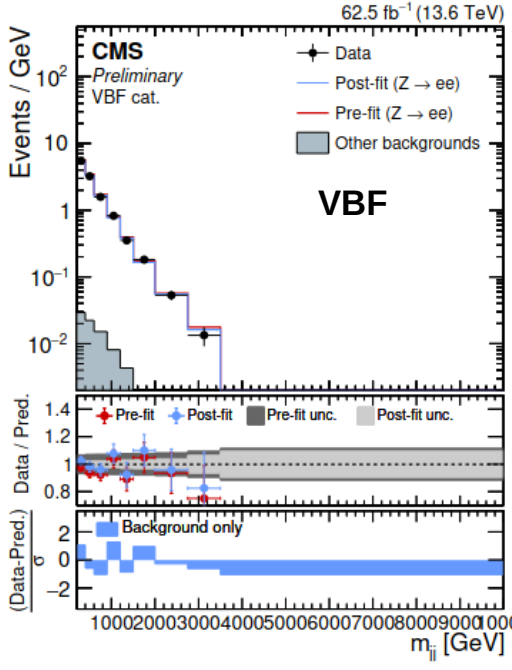
Andrea Hugues Aamir Chaochen Laurent Pascal

International collaboration with Boston university

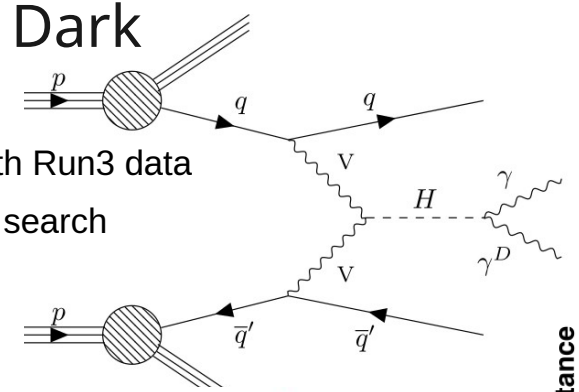
- Team also involved in mono-jet analysis
- Results from VBF and mono-jet categories will be combined







$H \to \gamma\, \gamma^D$: Light Meets Dark

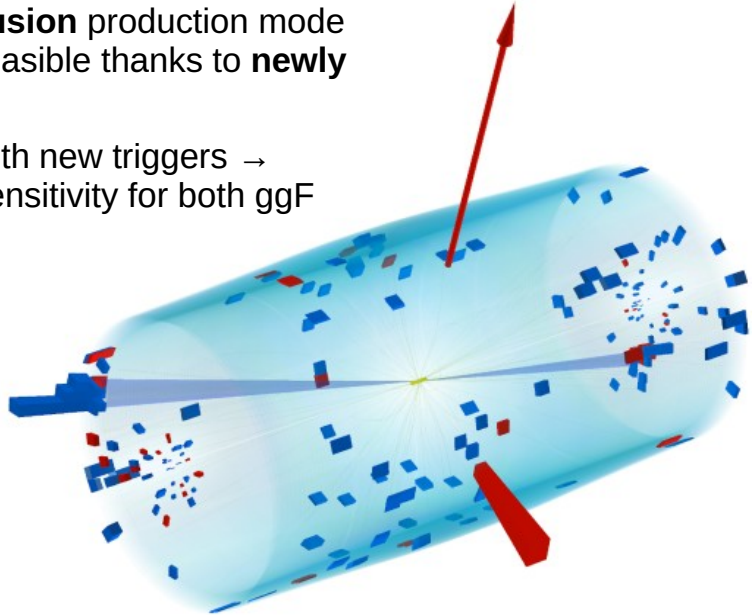


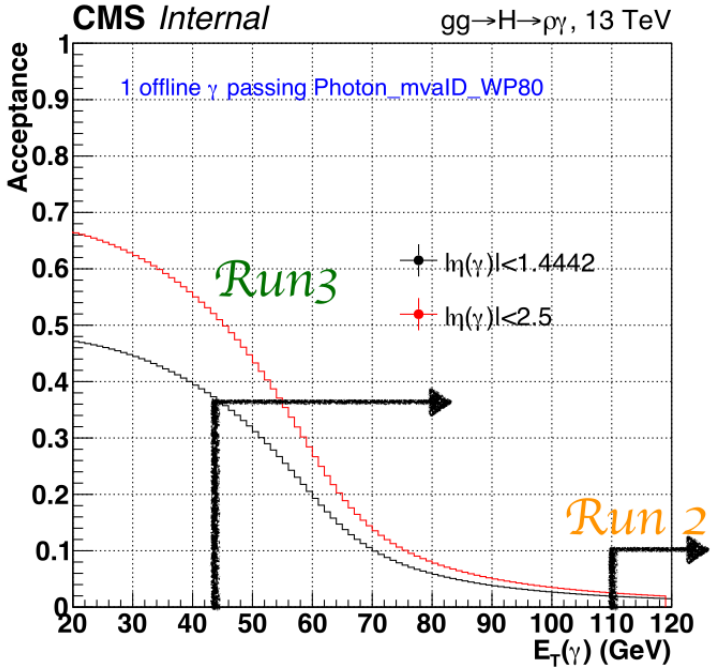



Andrea Longsheng Laurent Pascal

- Search for **photon + dark-photon** with Run3 data
  - Complementary to *H → invisible* search

- Investigating **gluon fusion** production mode too for the first time feasible thanks to **newly developed triggers**
- Preliminary studies with new triggers → expected improved sensitivity for both ggF and VBF



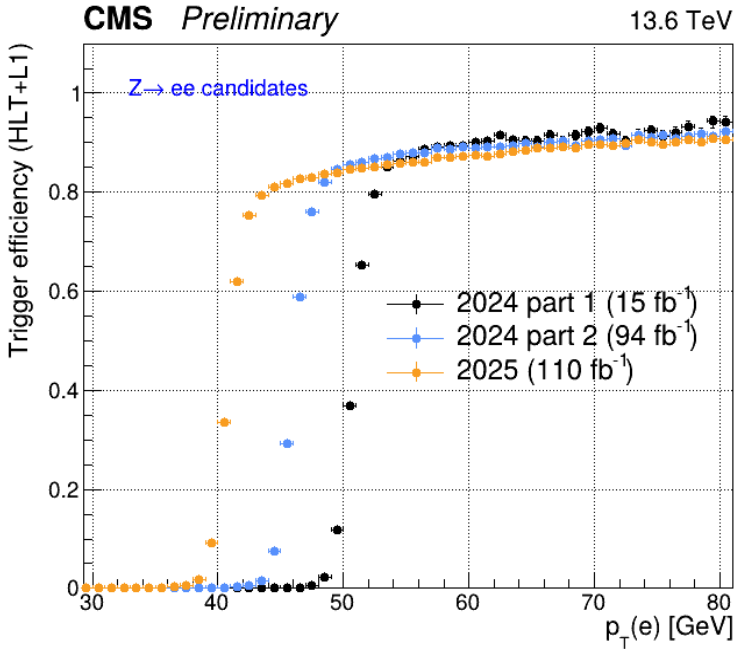


Triggering the Future

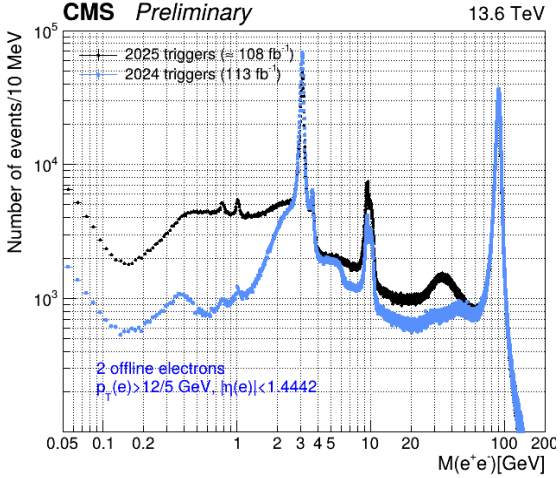
Laurent

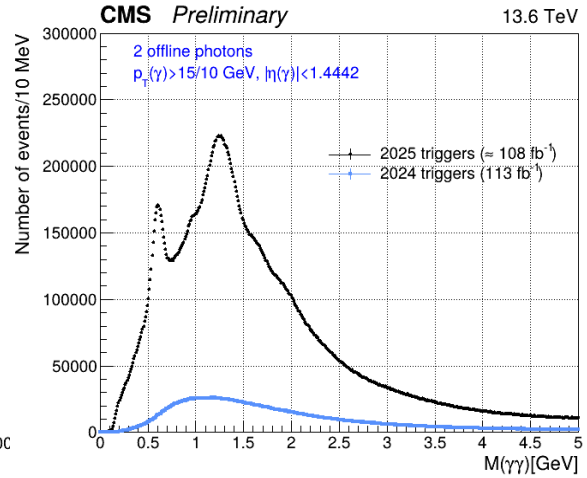
- Development of **new triggers** is crucial for all searches

New **low p_T single-photon trigger** running since 24

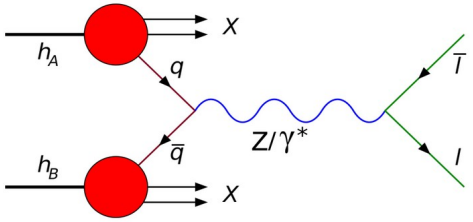


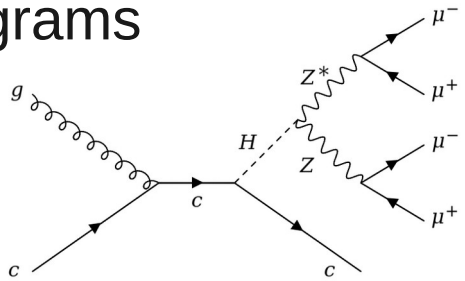
New triggers targeting **low mass dielectron/diphoton resonances** running since 25

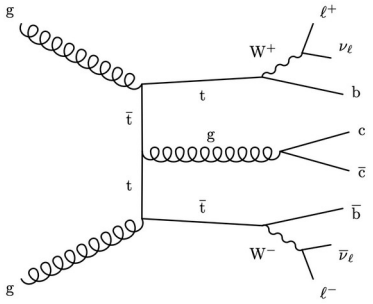


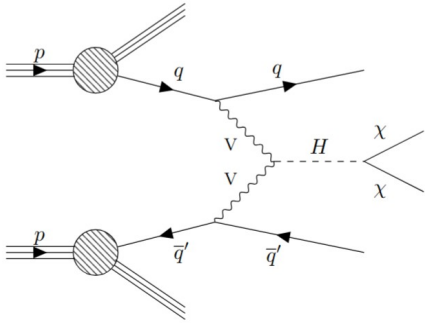


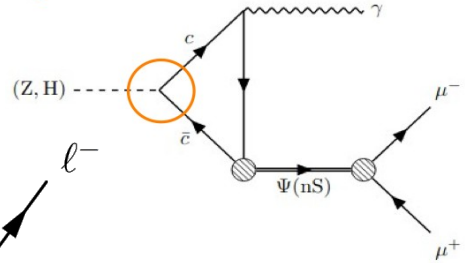
A Summary in Diagrams

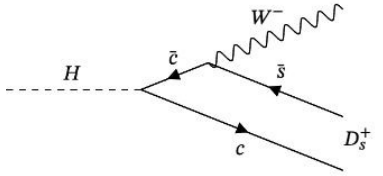


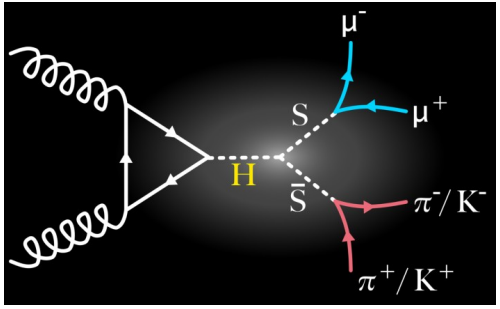


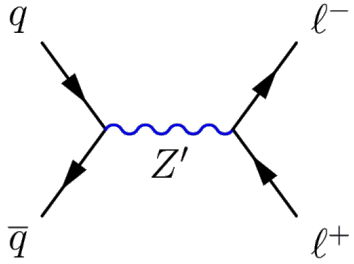


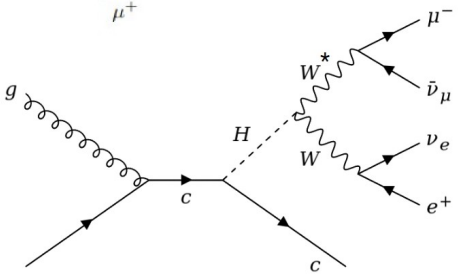


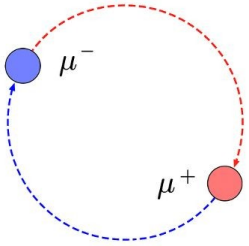


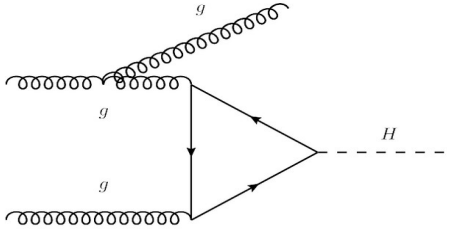


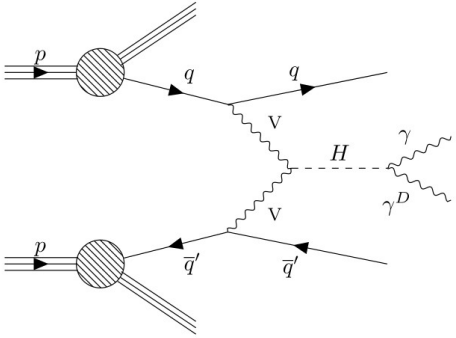








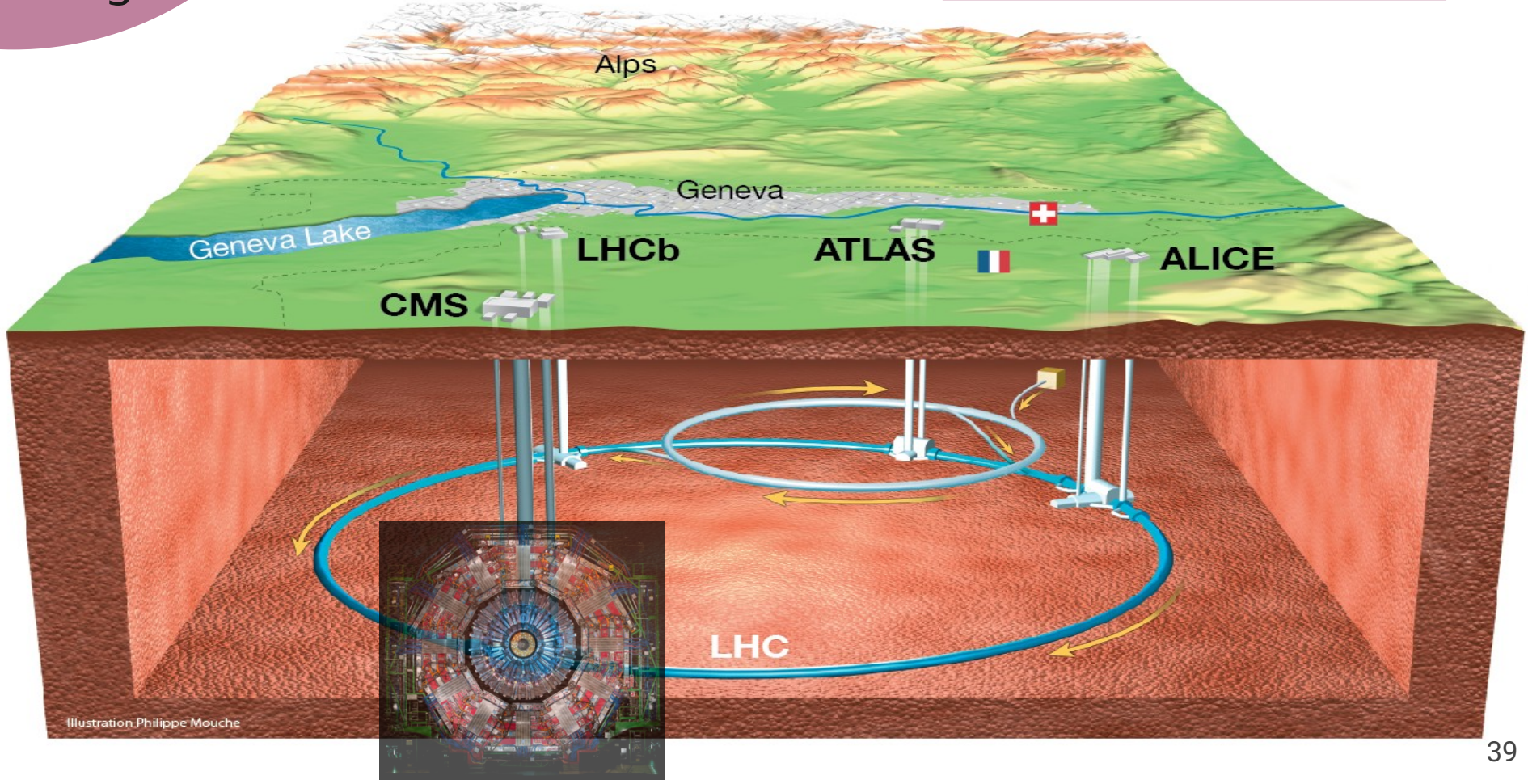




Back-up slides

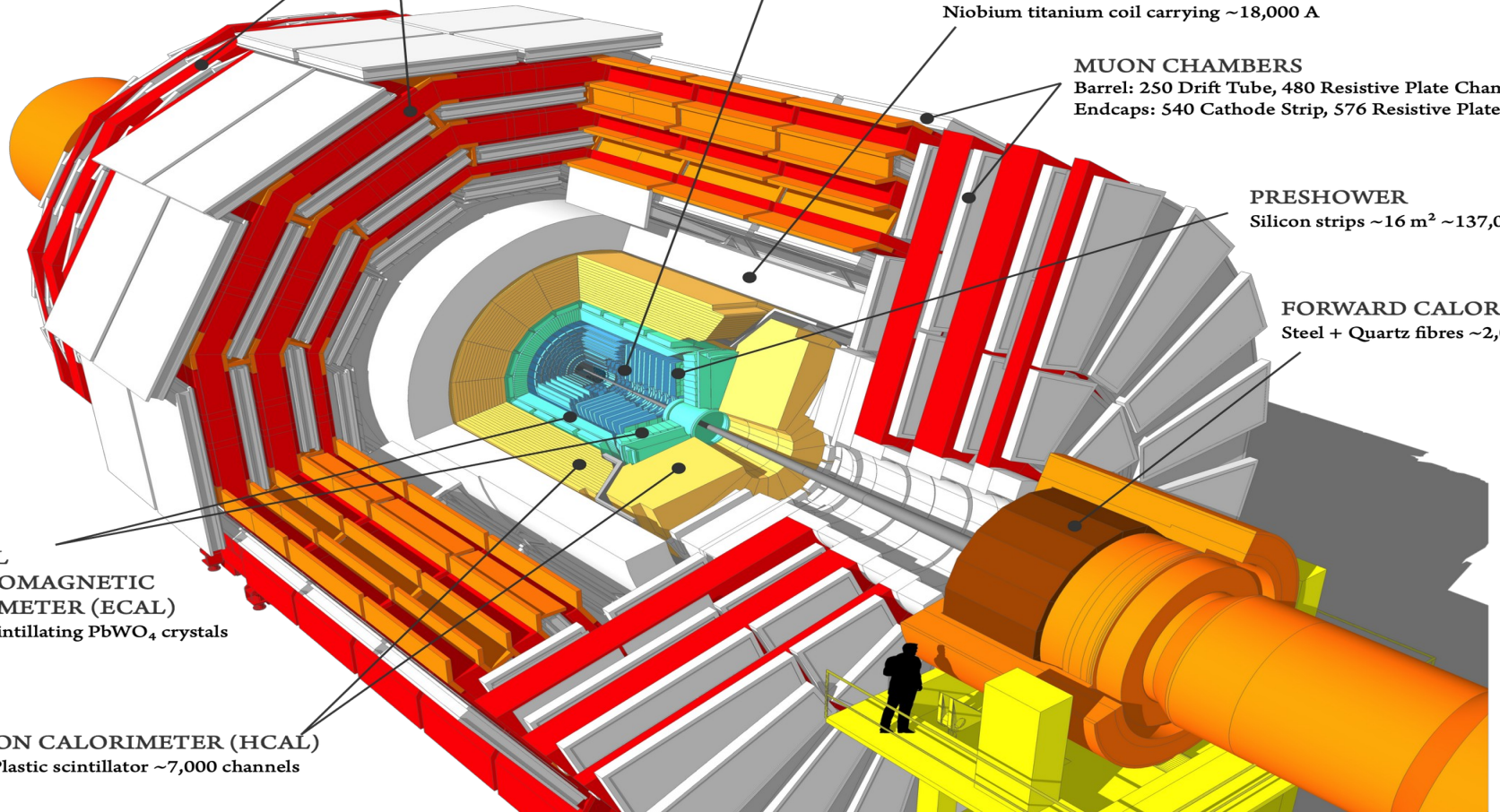
Large Hadron Collider

Let's have a look at the CMS detector



CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T



STEEL RETURN YOKE
12,500 tonnes

SILICON TRACKERS
Pixel (100x150 μm²) ~1.9 m² ~124M channels
Microstrips (80–180 μm) ~200 m² ~9.6M channels

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000 A

MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

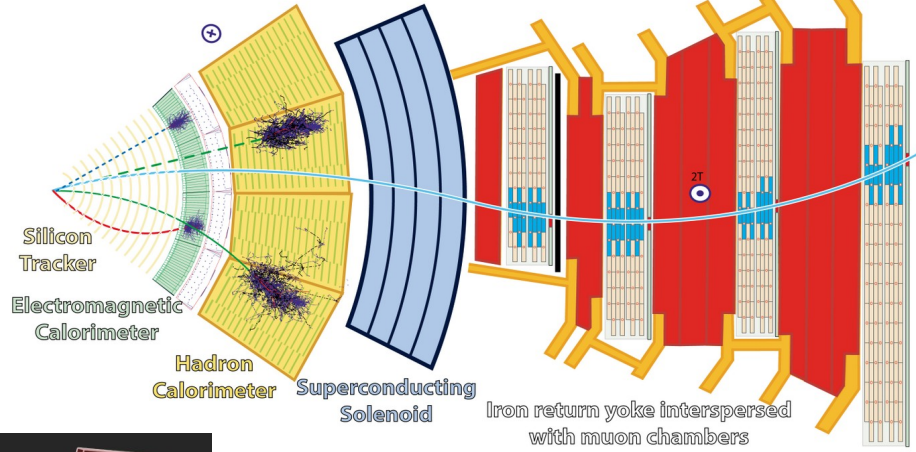
PRESHOWER
Silicon strips ~16 m² ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

CMS detector



high-pileup fill of last month