CMS Experiment Highlights: IIHE Contributions and Achievements

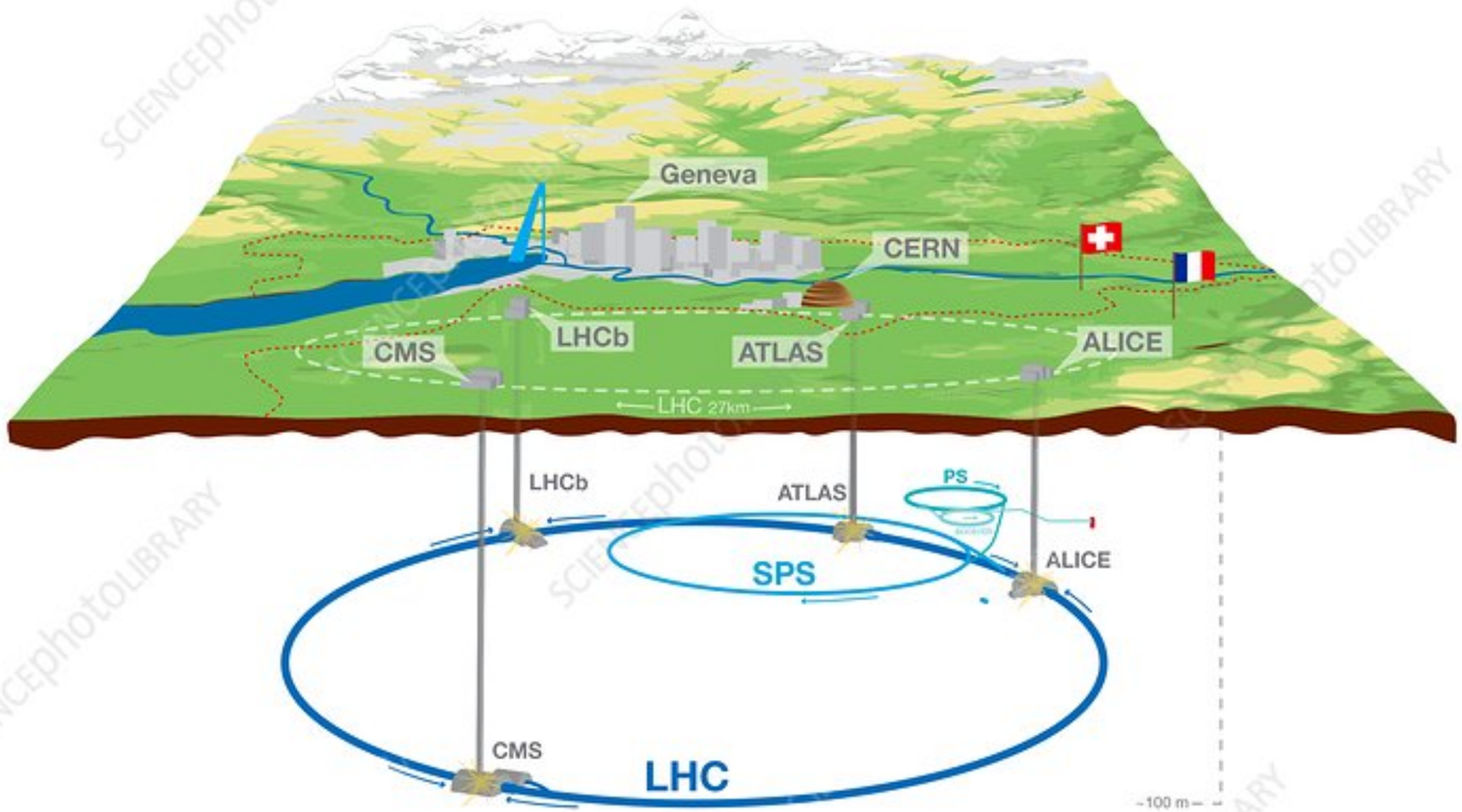
Andrea Malara

Université Libre de Bruxelles

28 November 2024

Experimental setup: LHC

- Proton & heavy ions collider
  - 27 km circumference
  - Up to 13.6 TeV of energy available at $\sqrt{s}$
- Host of 4 large experiments
  (+ several others)
  - ATLAS
  - CMS
  - LHCb
  - ALICE



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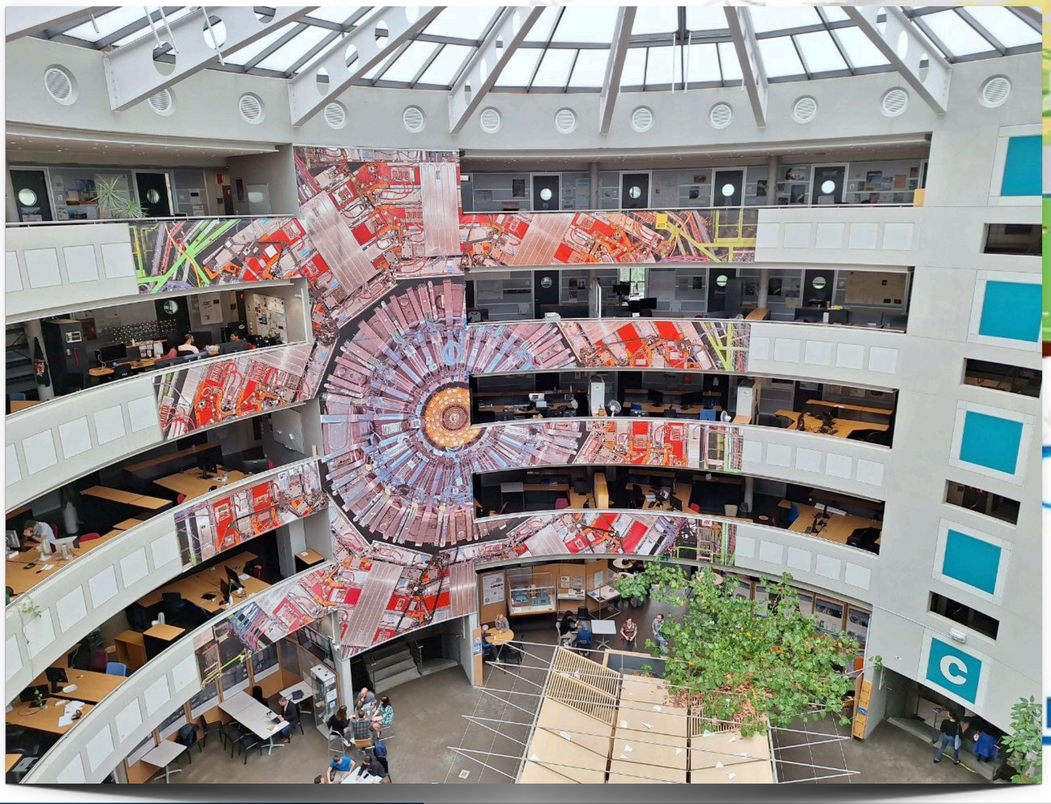

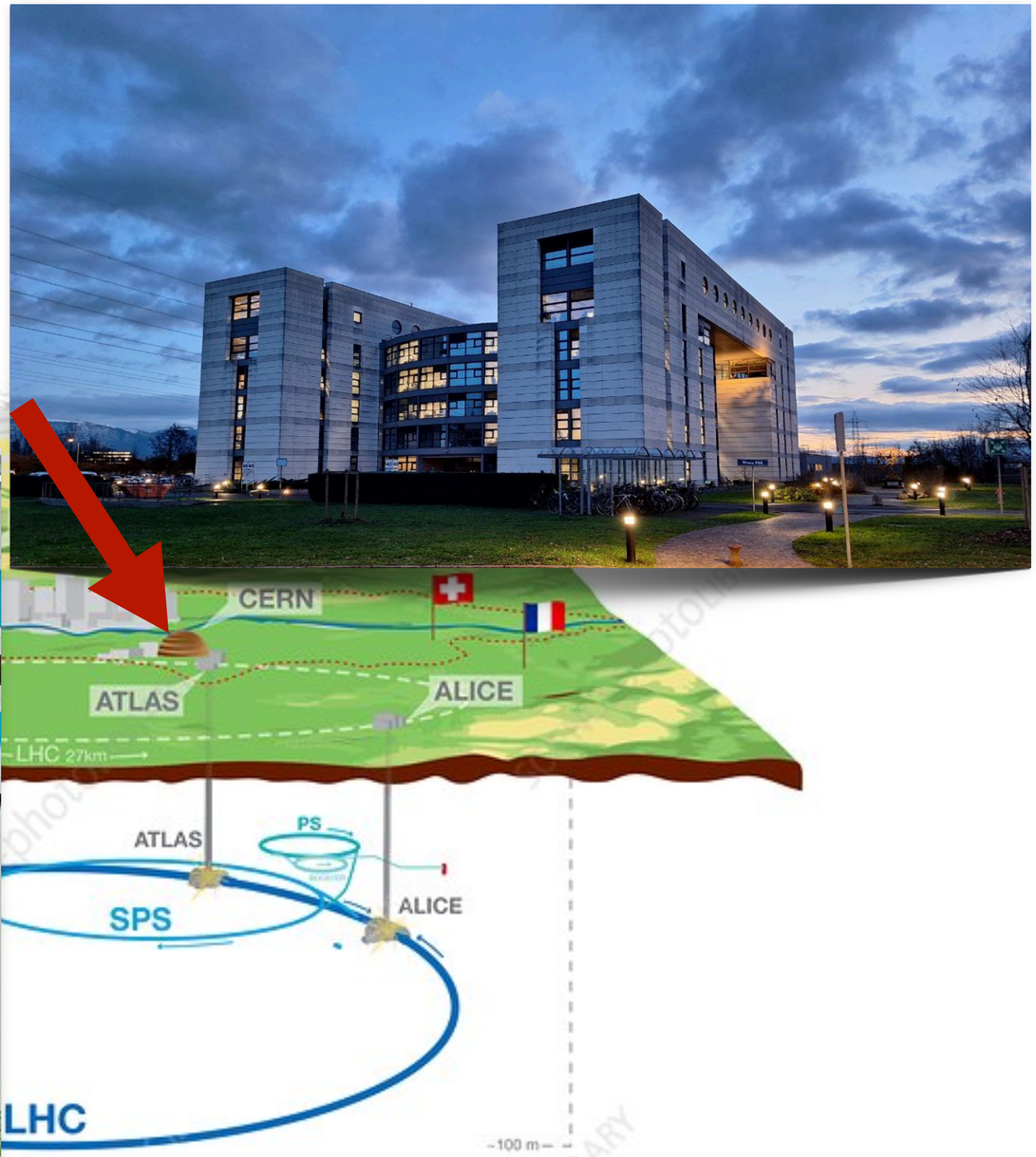

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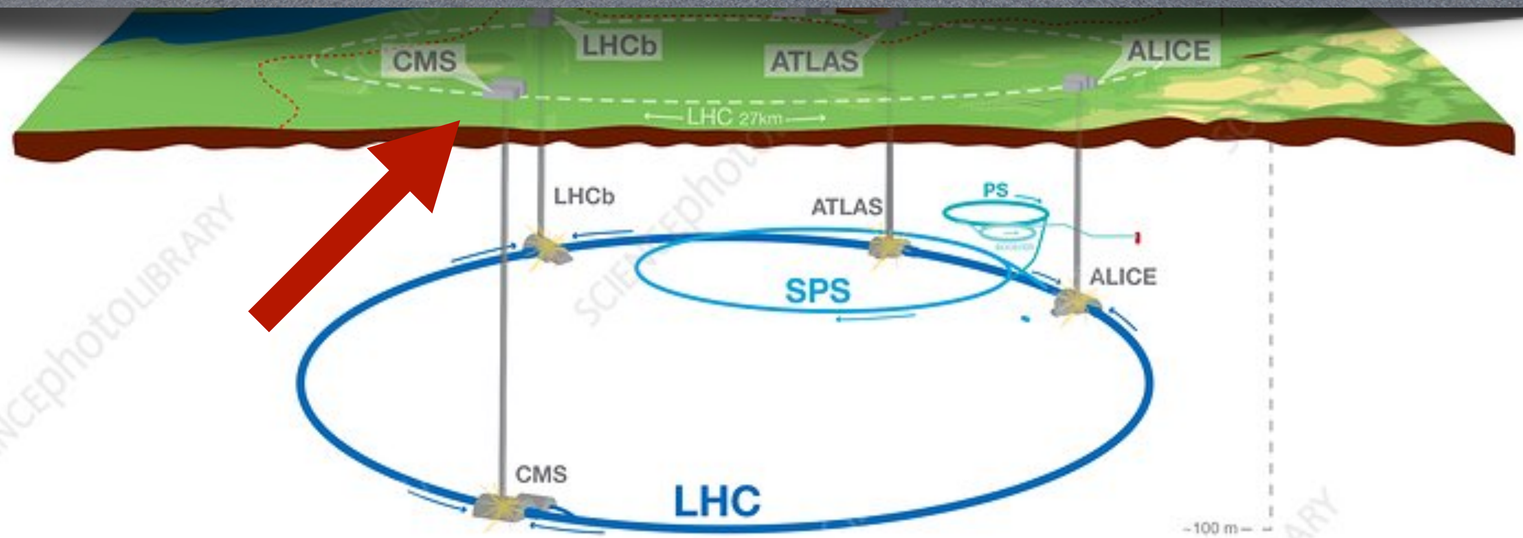

Experimental setup: LHC

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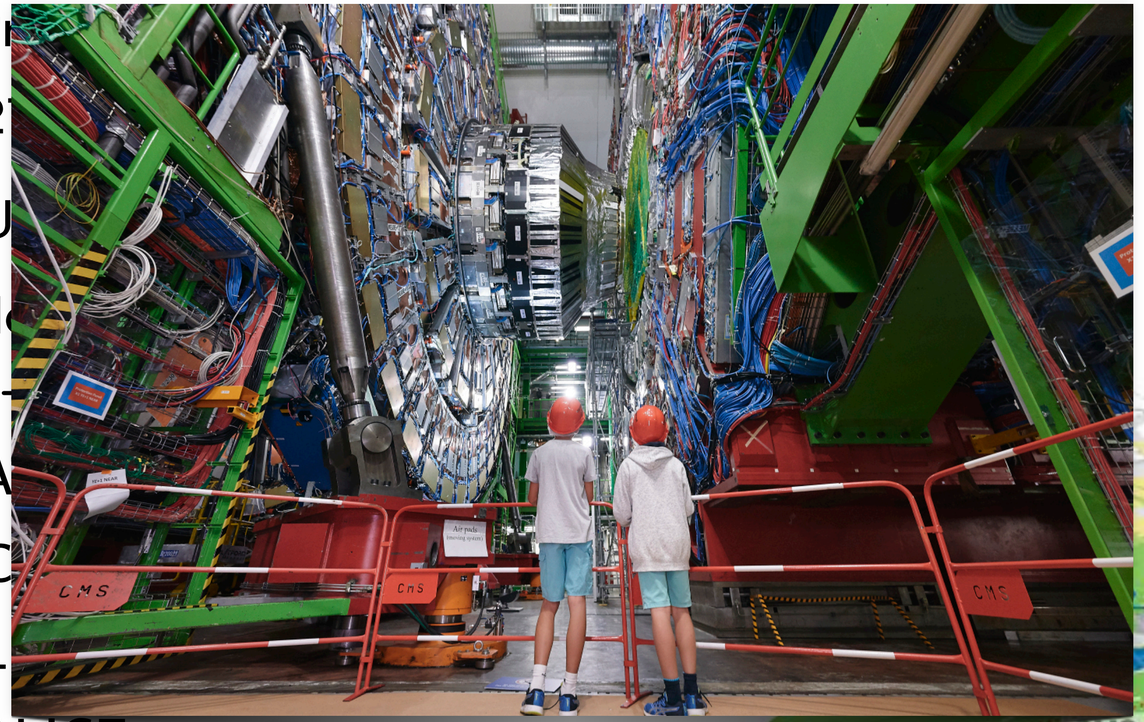
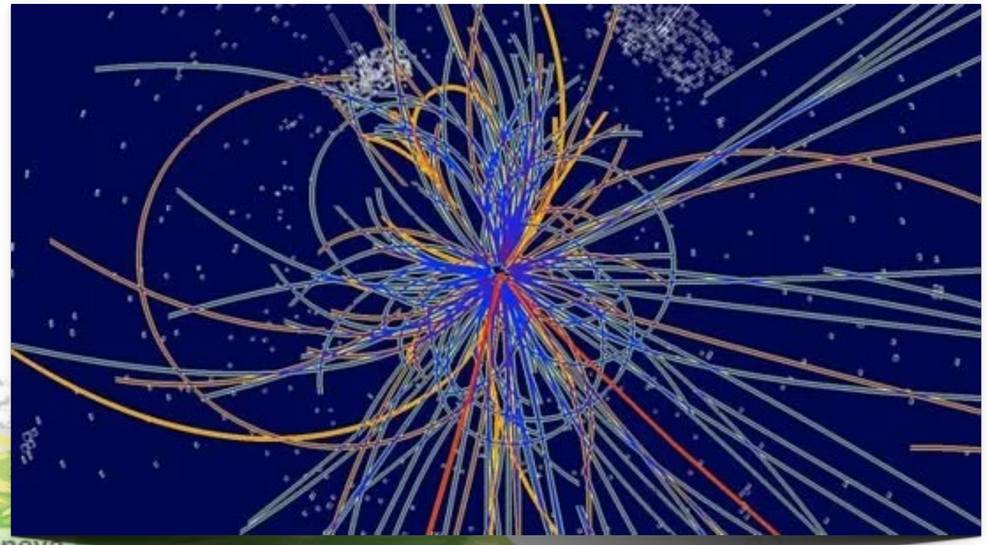
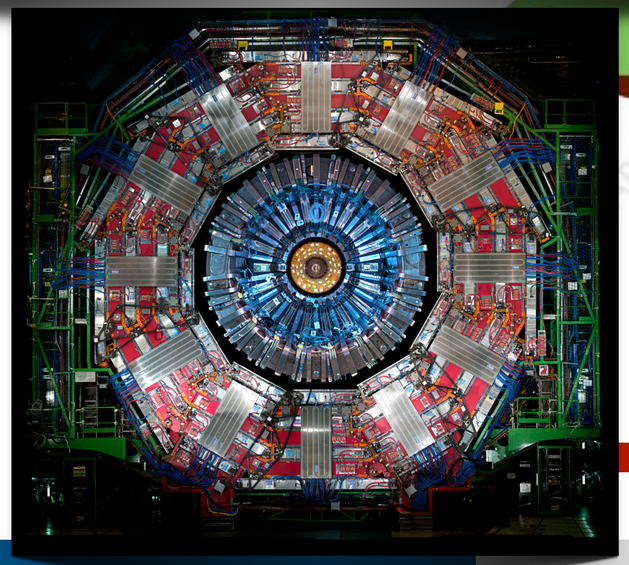
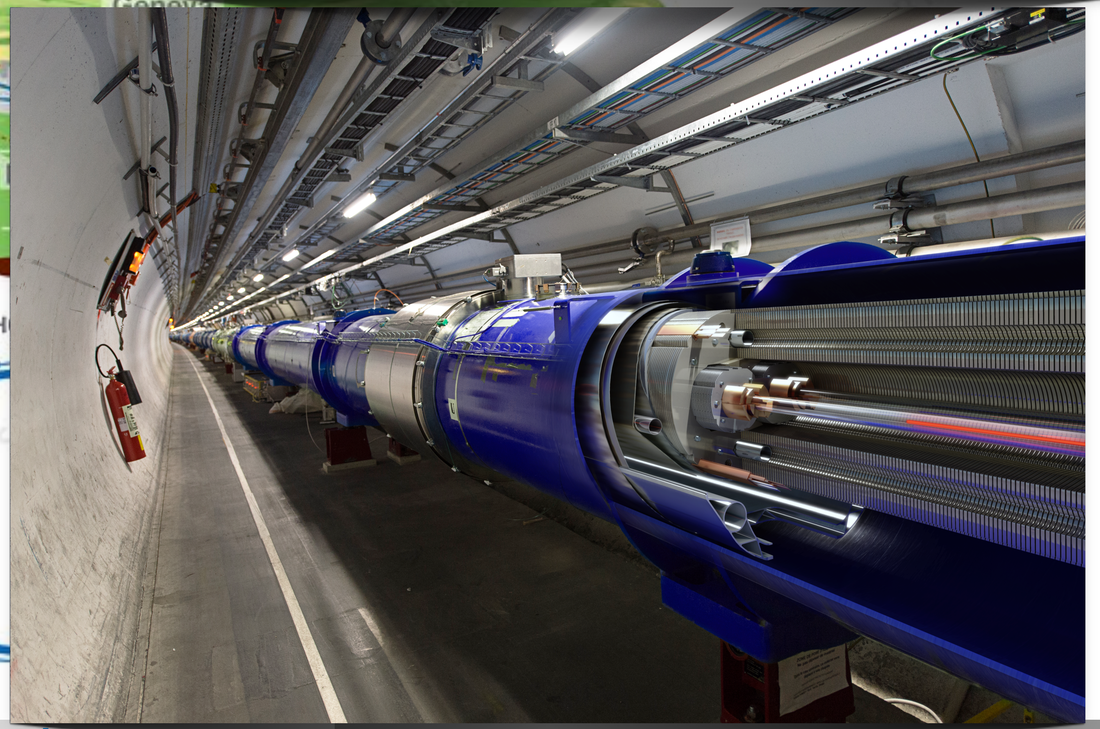
- ALICE



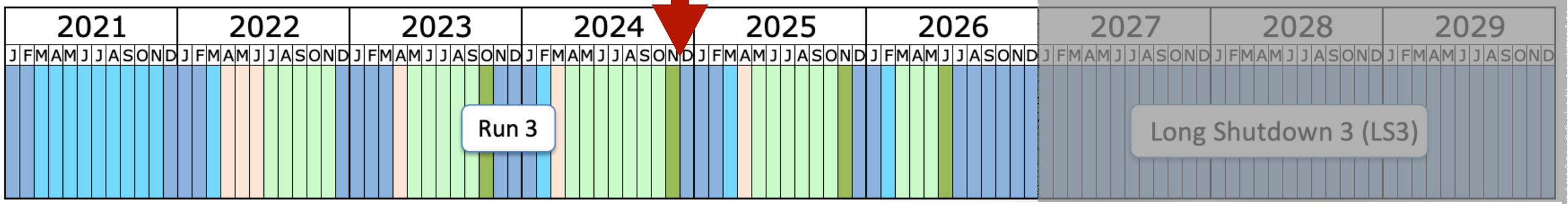


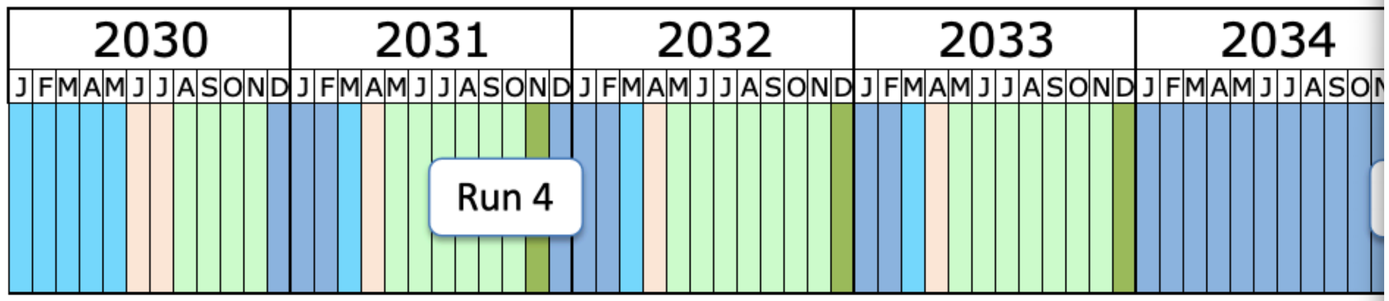


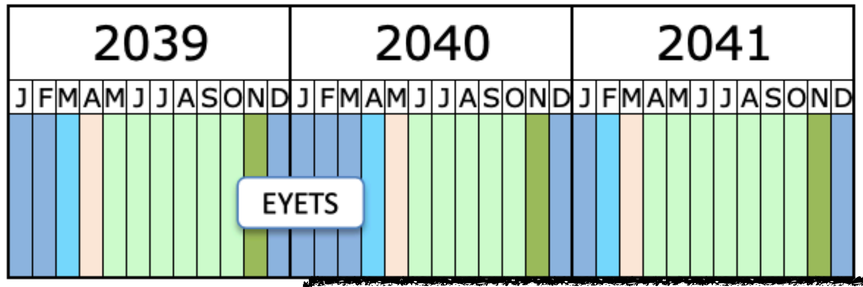


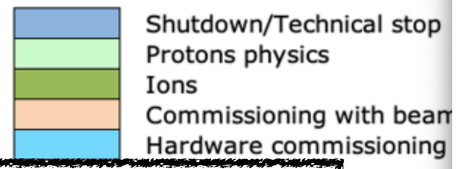
LHC and CMS

We are here



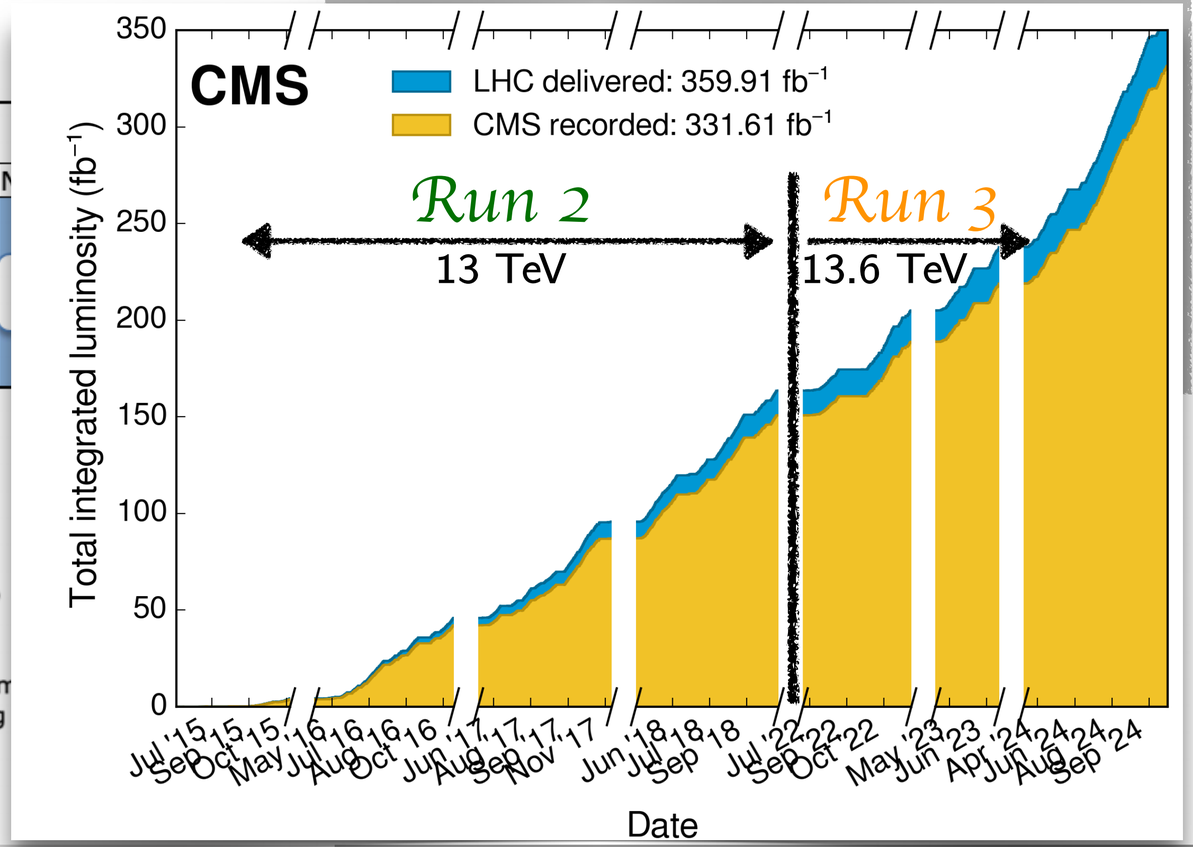






Last update: November 24

See next talks for more info on the upgrade for HL-LHC



CMS mission

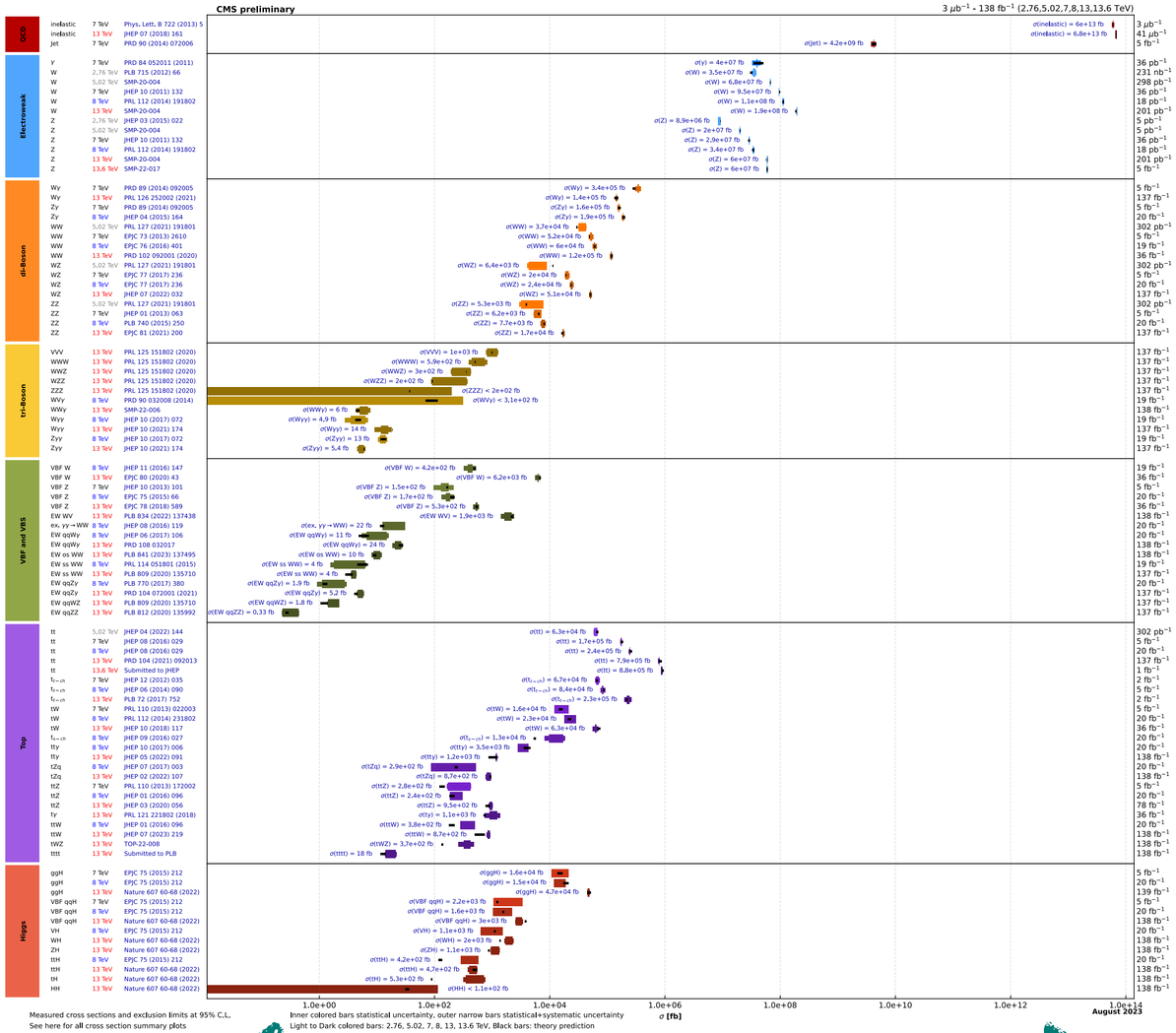
Recipe for the universe: Exploring the fundamental structure of things!!

Taken from Symmetry

CMS mission

- CMS is many experiments at once

Overview of CMS cross section results



Measured cross sections and exclusion limits at 95% C.L.
See here for all cross section summary plots

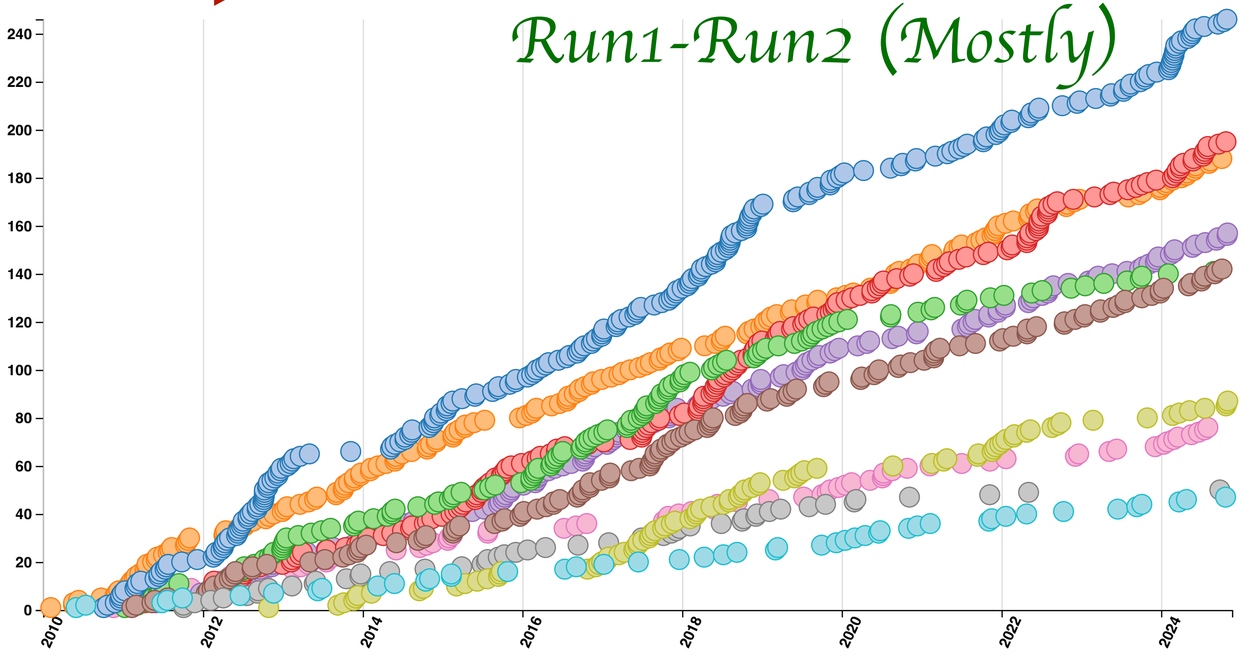
Inner colored bars statistical uncertainty, outer narrow bars statistical+systematic uncertainty
Light to Dark colored bars: 2.76, 5.02, 7, 8, 13, 13.6 TeV, Black bars: theory prediction

10^{-1} 10^{14}

Show all | Total | Exotica | Standard Model | Supersymmetry | Higgs | Top | Heavy Ions

B and Quarkonia | Forward and Soft QCD | Beyond 2 Generations | Detector Performance

1332 collider data papers submitted as of 2024-11-05



CMS mission

- CMS is many experiments at once
  - Span over 15 orders of cross-sections
  - Versatile for various physics analyses
  - Exceeded projections and expectations
  - Competitive among experiments
  - Precision physics
    - Standard Model physics
    - Top and B quark physics
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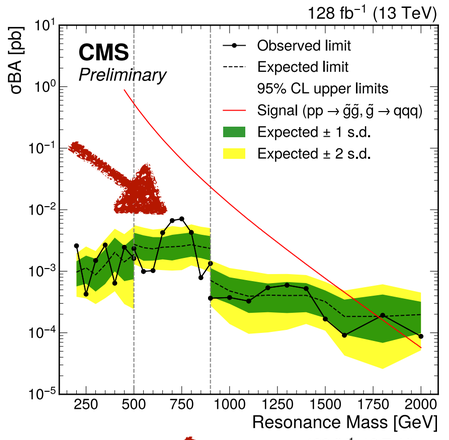
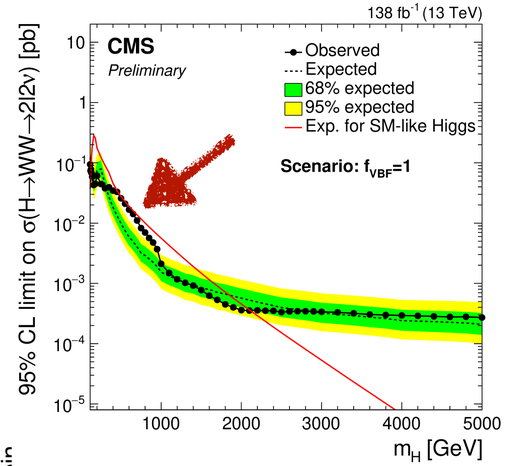
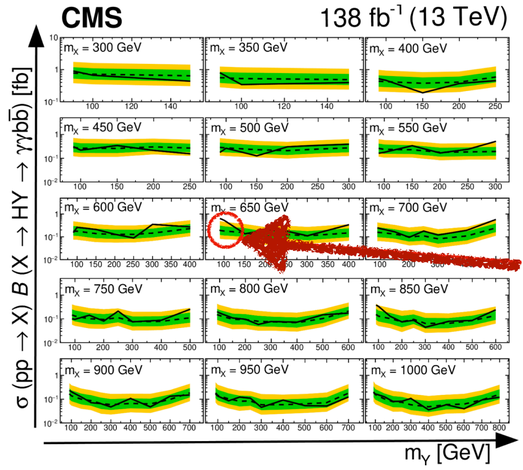
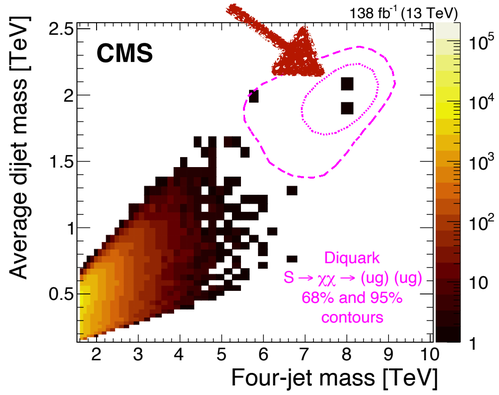
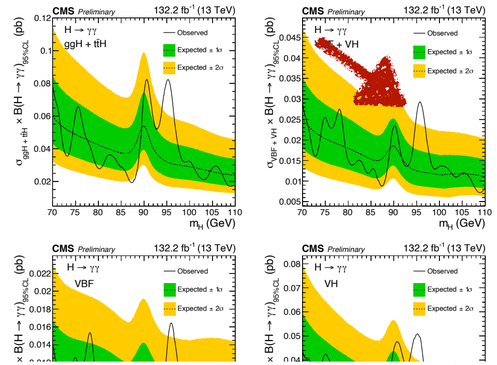
    - Heavy resonances
    - Exotica -> dark-sectors, new signatures, ...

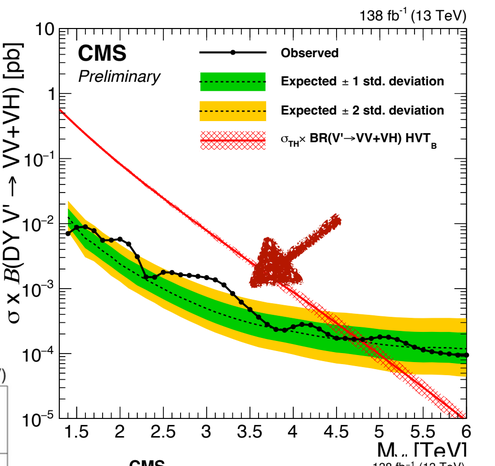


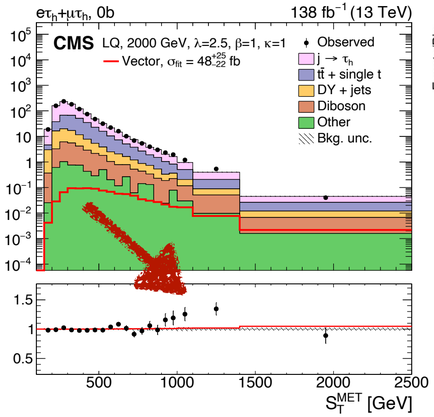


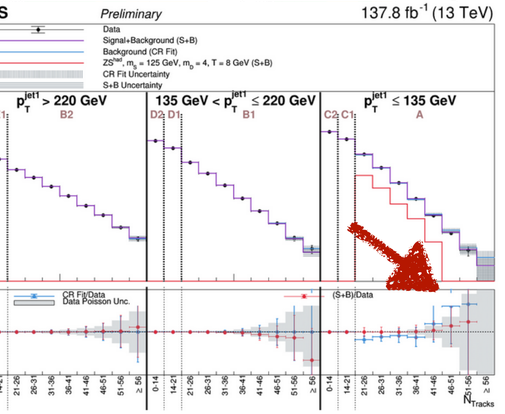


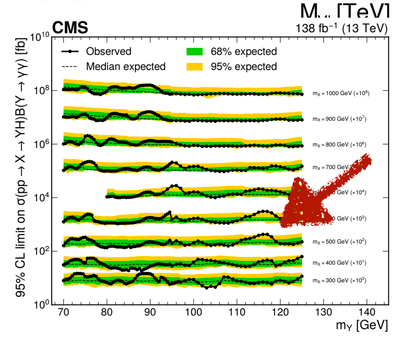












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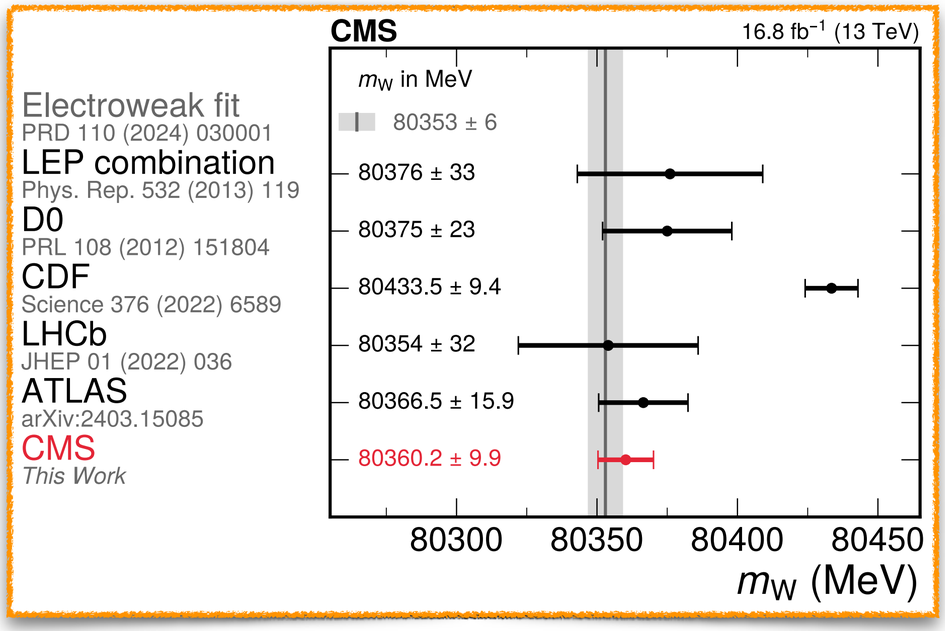
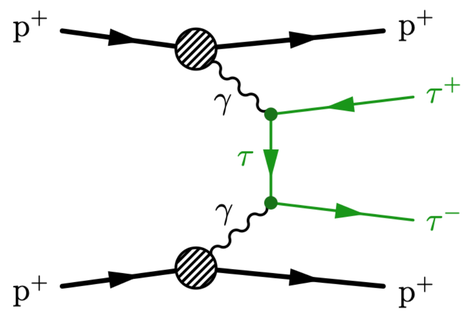
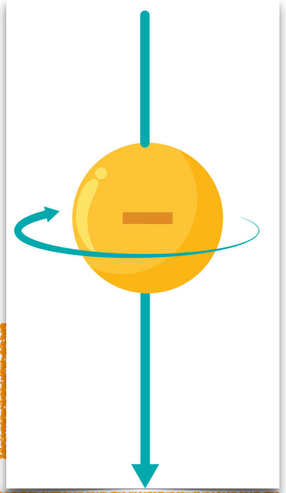
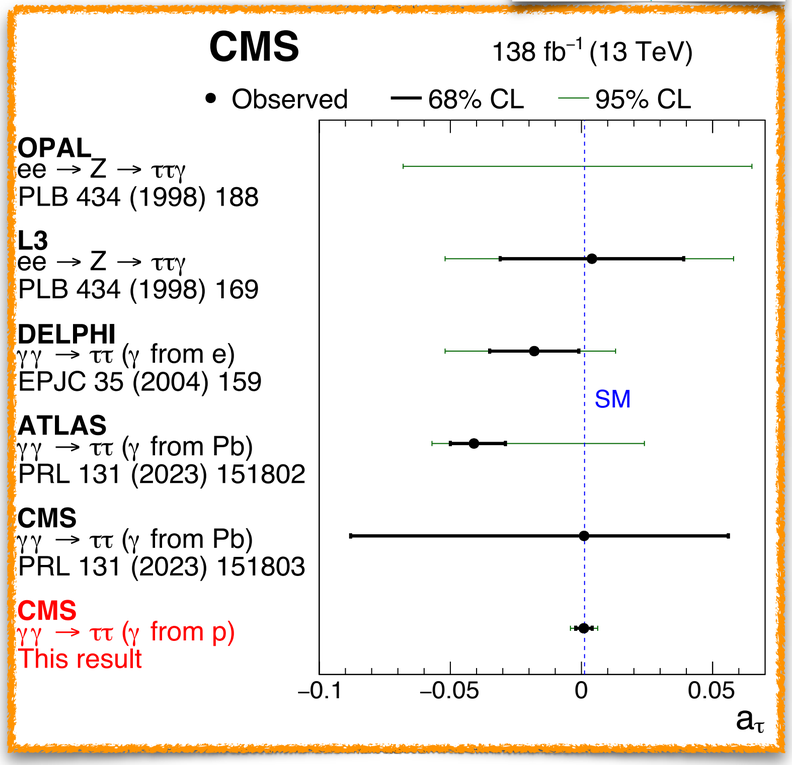
W boson mass





Tau g-2





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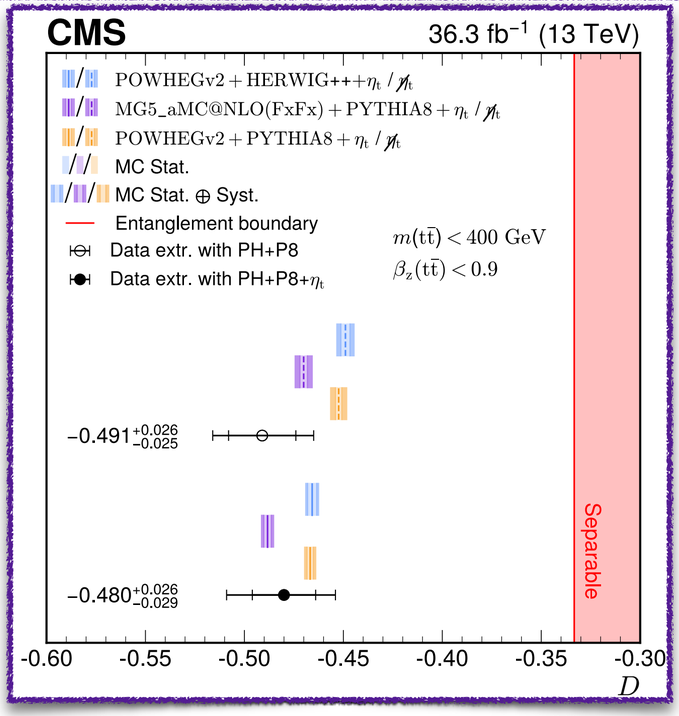
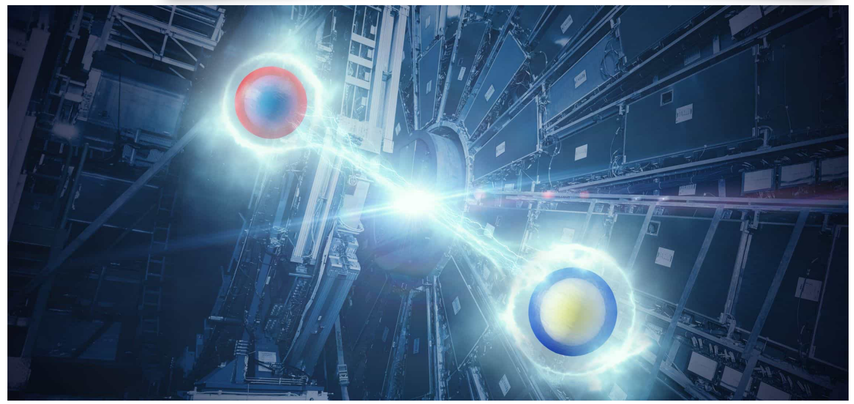
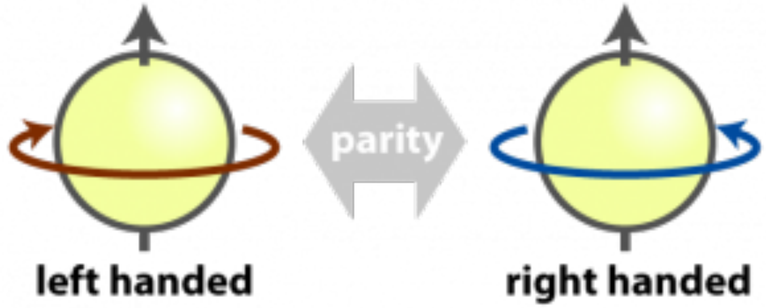
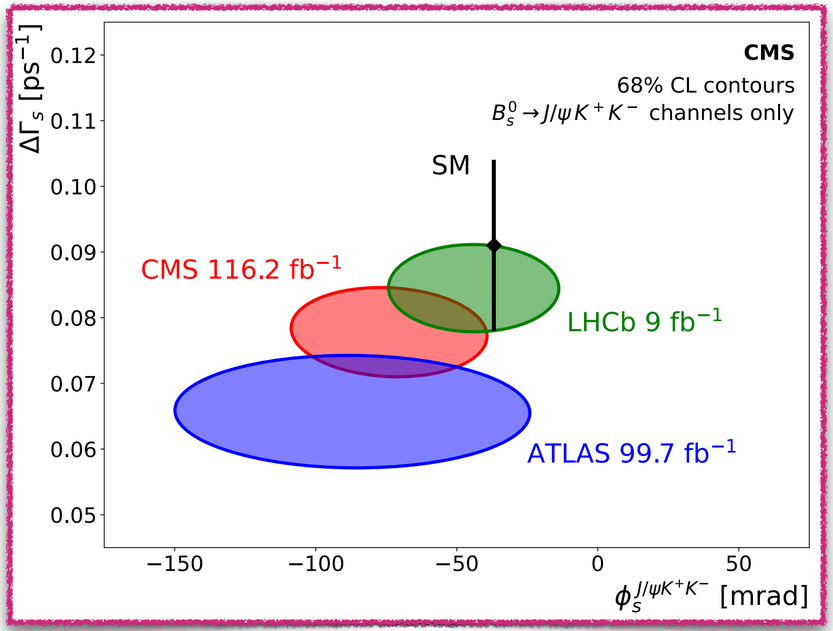
Top quantum entanglement







CP violation in B_s



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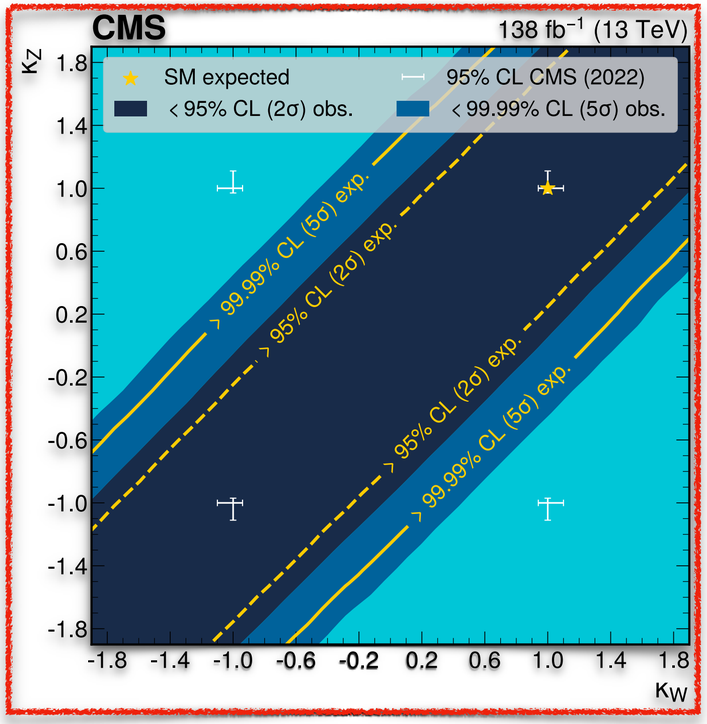
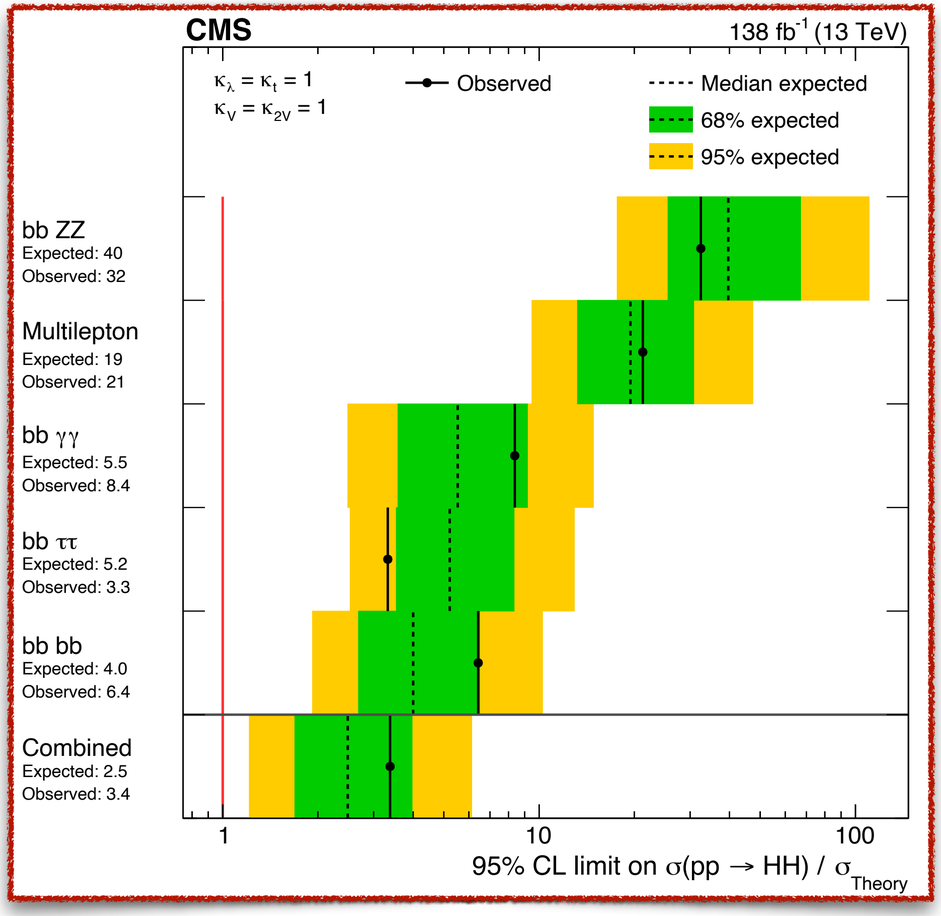
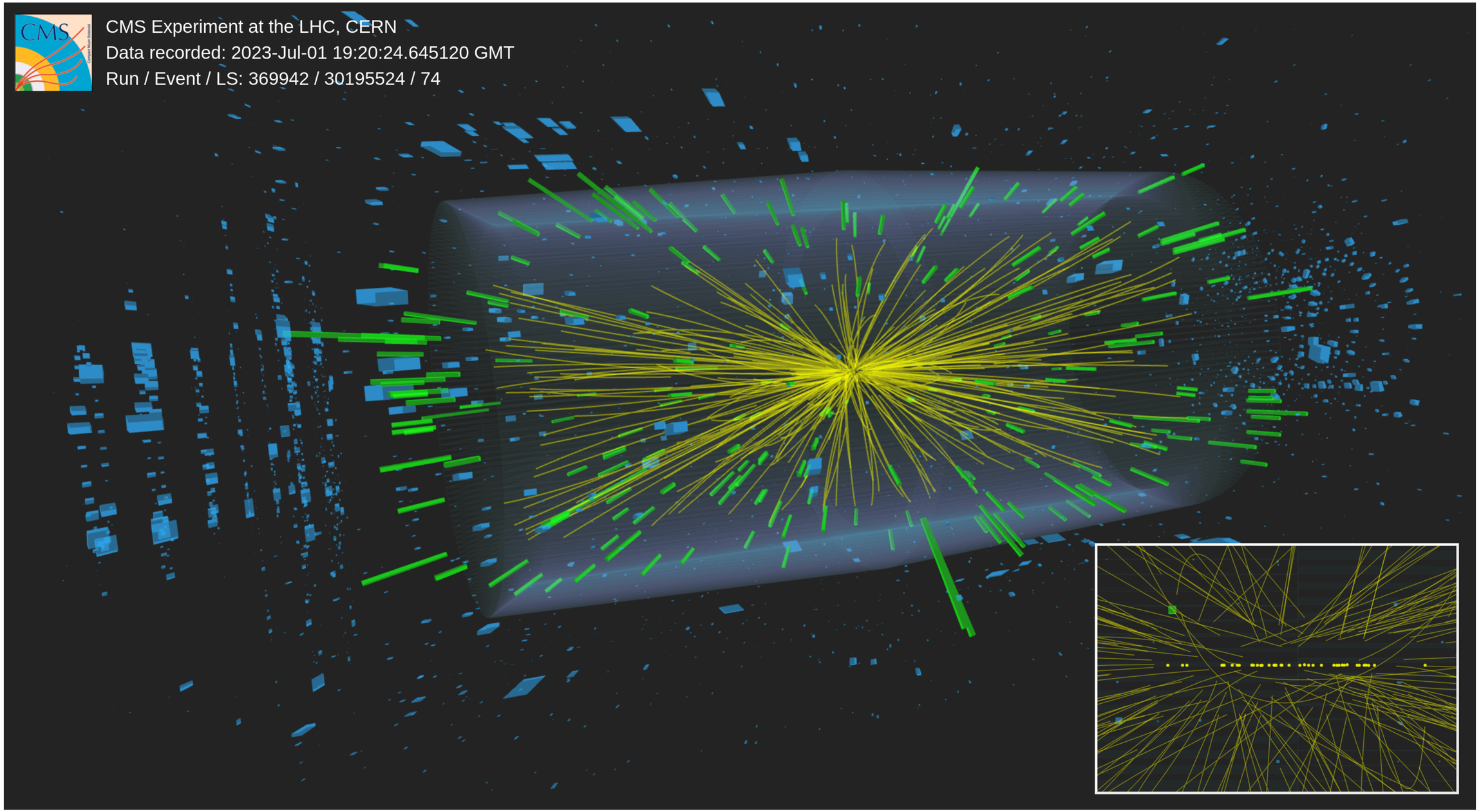
H coupling to vector bosons



H self-coupling

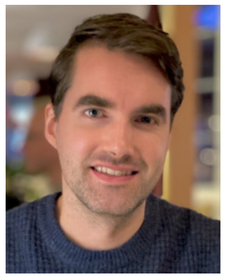


How to extract physics from collisions



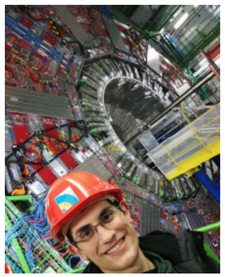
IIHE responsibilities in CMS

Shifters and Detector responsibilities


Gerrit


Nordin


Hugues


Andrea


Aamir

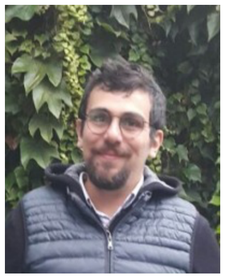

Juhee


Yanwen


Itana

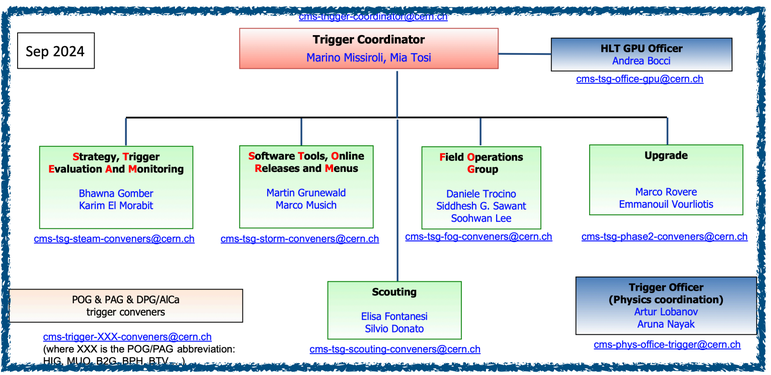

Max


Eliott


Bugra

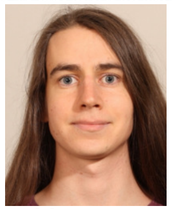
IIHE responsibilities in CMS

DPS = Detector performance summary



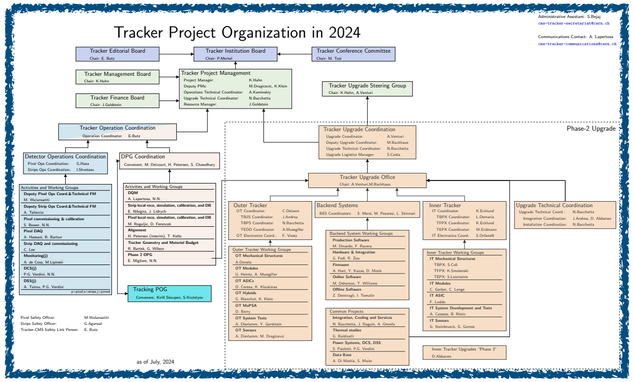
Laurent

Trigger



Hugues

Former L2 coordinator



Martin

Tracker

Nordin

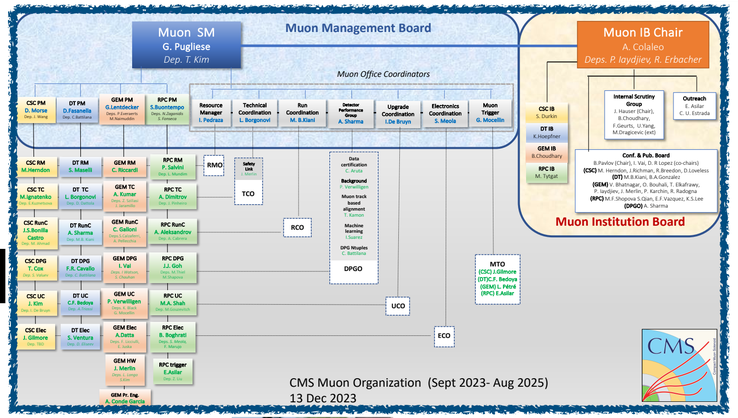
L2 coordinator

Michael

Former Muon-RPC IB Chair

Isabelle

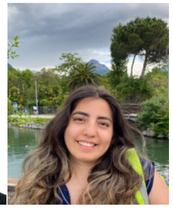
Former Muon Upgrade Coordinator



Gilles

Yanwen

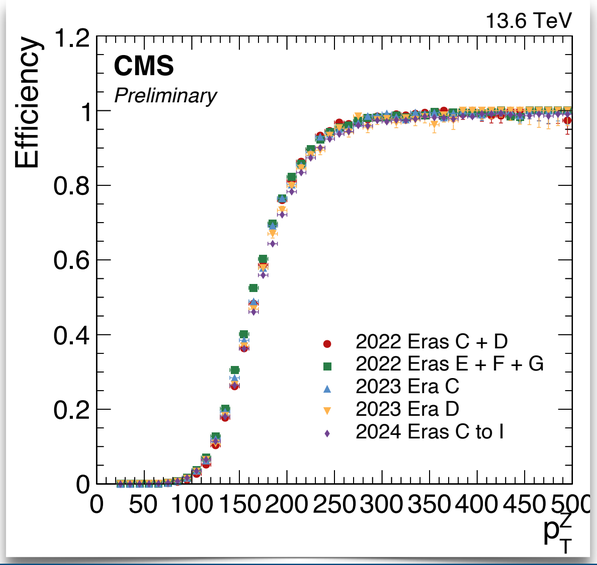
Juhee



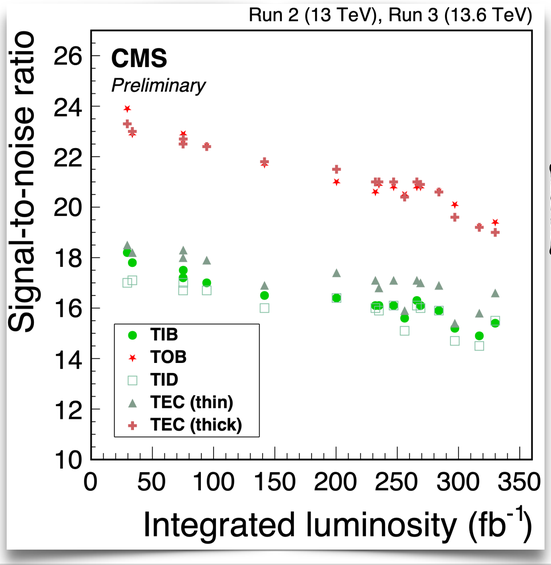
Donya

GEM

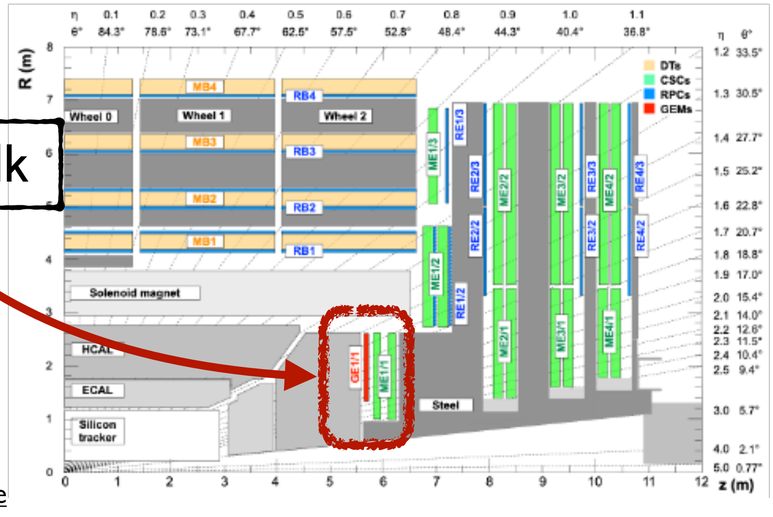
RPC



DPS on
- L1 trigger
- MET trigger



See Gilles's talk

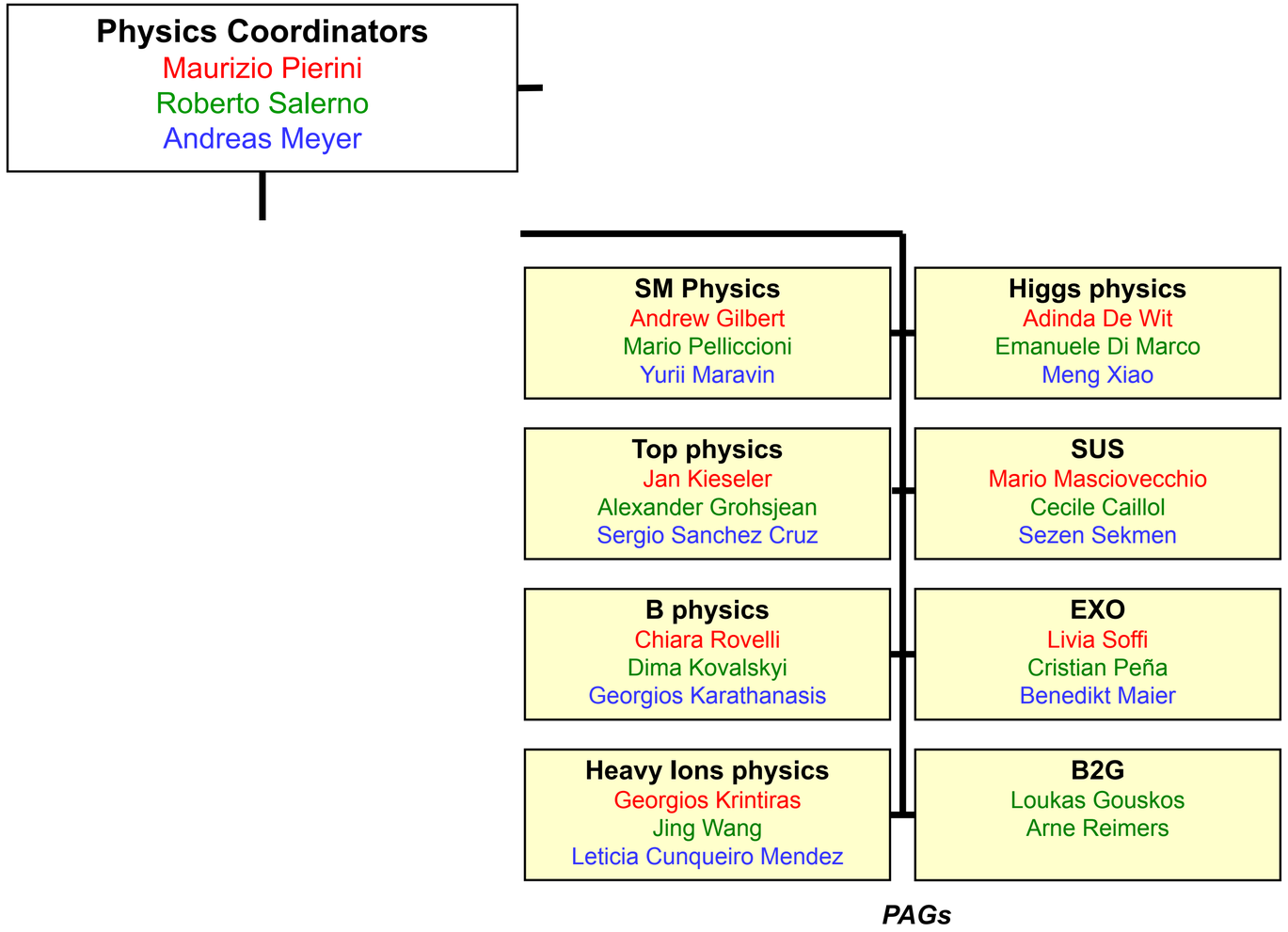


DPS on tracker performance

IIHE responsibilities in CMS

CMS physics organization (2024-2025)

Outgoing
Continuing
Incoming



IIHE responsibilities in CMS

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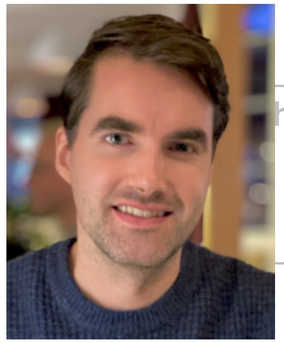
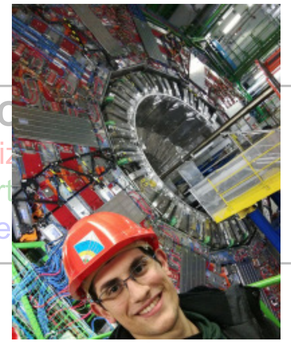
Former



Gerrit

Current



Andrea

Outgoing
Continuing
Incoming

L3 coordinators

Steven

Former
L2 coordinator

SM Physics
Andrew Gilbert
Mario Pelliccioni
Yurii Maravin

Top physics
Jan Kieseler
Alexander Grohsjean
Sergio Sanchez Cruz

B physics
Chiara Rovelli
Dima Kovalskyi
Georgios Karathanasis

Heavy Ions physics
Georgios Krintiras
Jing Wang
Leticia Cunqueiro Mendez

SUS
Mario Masciovecchio
Cécile Caillol
Sezen Sekmen

EXO
Livia Soffi
Cristian Peña
Benedikt Maier

B2G
Loukas Gouskos
Arne Reimers

PAGs

Strong involvement in 3 review papers

IIHE responsibilities in CMS

CMS physics organization (2024-2025)

Outgoing
Continuing
Incoming

Physics Coordinators
Maurizio Pierini
Roberto Salerno
Andreas Meyer

Physics Officers
x-POG: H.Qu, J.R. Vlimant, Felipe Silva
Phys Comm: C.Lourenco, A.Jafari, A.Iqbal, A.Delannoy
Trigger: M.Tosi, J.Alimena, A.Lobanov, A.Nayak

	Shared groups	*POGs*		*PAGs*	
Offline & computing	**MC generators** Meng Lu Bugra Bilin Lorenzo Viliani	**e/γ** Anshul Kapoor Riccardo Salvatico Afiq Anuar	**Muons** Jan Frederik Schulte Federica Primavera Matteo Bonanomi	**SM Physics** Andrew Gilbert Mario Pelliccioni Yurii Maravin	**Higgs physics** Adinda De Wit Emanuele Di Marco Meng Xiao
Offline & computing	**Machine Learning** Jennifer Ngadiuba Javier Duarte Pietro Vischia	**Jets/MET** Alexis Kalogeropoulos Anna Benecke Matteo Cremonesi	**B-tagging & Vtx** Spandan Mondal Sebastian Wuchterl	**Top physics** Jan Kieseler Alexander Grohsjean Sergio Sanchez Cruz	**SUS** Mario Masciovecchio Cecile Caillol Sezen Sekmen
PPD	**Particle Flow** Swagata Mukherjee Riccardo Bellan	**Taus** Daniel Winterbottom Andrea Cardini Michał Bluj	**Tracking** Slava Krutelyov Kirill Skovpen Mario Masciovecchio	**B physics** Chiara Rovelli Dima Kovalskyi Georgios Karathanasis	**EXO** Livia Soffi Cristian Peña Benedikt Maier
Tools	**Common Analysis Tools** Clemens Lange Piergiulio Lenzi Aliya Nigamova	**Luminosity** Anton Babaev Francesco Romeo Jose Benitez	**Protons** G. Gil da Silveira Andrea Bellora Laurent Forthomme	**Heavy Ions physics** Georgios Krintiras Jing Wang Leticia Cunqueiro Mendez	**B2G** Loukas Gouskos Arne Reimers

IIHE responsibilities in CMS

CMS physics organization (2024-2025)

Outgoing
Continuing
Incoming

Physics Coordinators
Maurizio Pierini
Roberto Salerno
Andreas Meyer

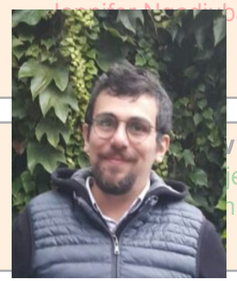
Physics Officers
x-POG: H.Qu, J.R. Vlimant, Felipe Silva
Phys Comm: C.Lourenco, A.Jafari, A.Iqbal, A.Delannoy
Trigger: M.Tosi, J.Alimena, A.Lobanov, A.Nayak

Shared groups

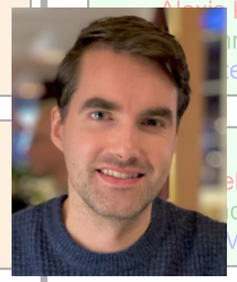
MC generators
Meng Lu
Bugra Bilin
Lorenzo Viliani

L2 coordinator

L3 coordinator



Bugra



Gerrit

Offline & computing

PPD

Tools

e/γ
Anshul Kapoor
Riccardo Salvatico
Afiq Anuar

Muons
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Federica Primavera
Matteo Bonanomi

SM Physics
Andrew Gilbert
Mario Pelliccioni
Yurii Maravin

Higgs physics
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Emanuele Di Marco
Meng Xiao

MET
Alexia Kalogeropoulos
[illegible] Benecke
[illegible] Cremonesi

B-tagging & Vtx
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Sebastian Wuchterl

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Common Analysis Tools
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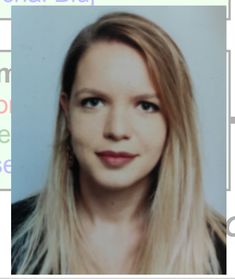
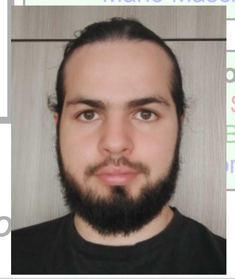
Aliya Nigamova

Lum[illegible]
Anto[illegible]
France[illegible]
Jose[illegible]



Itana



Eliott

[illegible]ons
[illegible] Silveira
[illegible] Bellora
[illegible]rthomme

Heavy Ions physics
Georgios Krintiras
Jing Wang
Leticia Cunqueiro Mendez

B2G
Loukas Gouskos
Arne Reimers

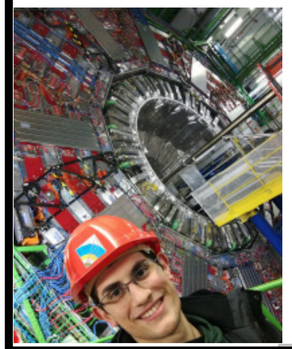
PAGs

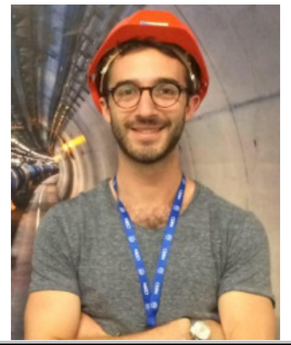
IIHE responsibilities in CMS

DPS = Detector performance summary

CMS physics organization (2024-2025)

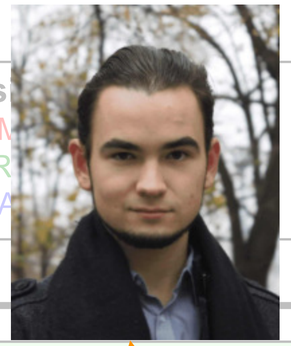
Former L3 coordinators


Andrea


David


Denise


Alexandre


Pavlo

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Swagata Mukherjee

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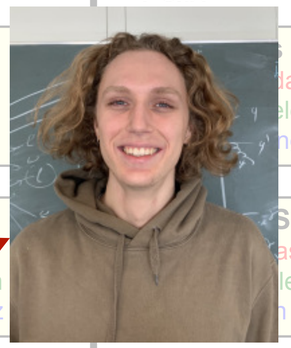
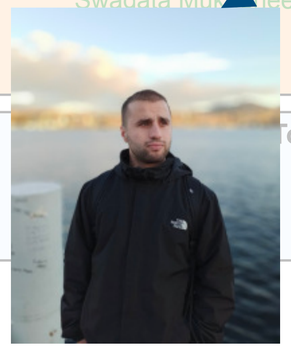
Felix




Soumya

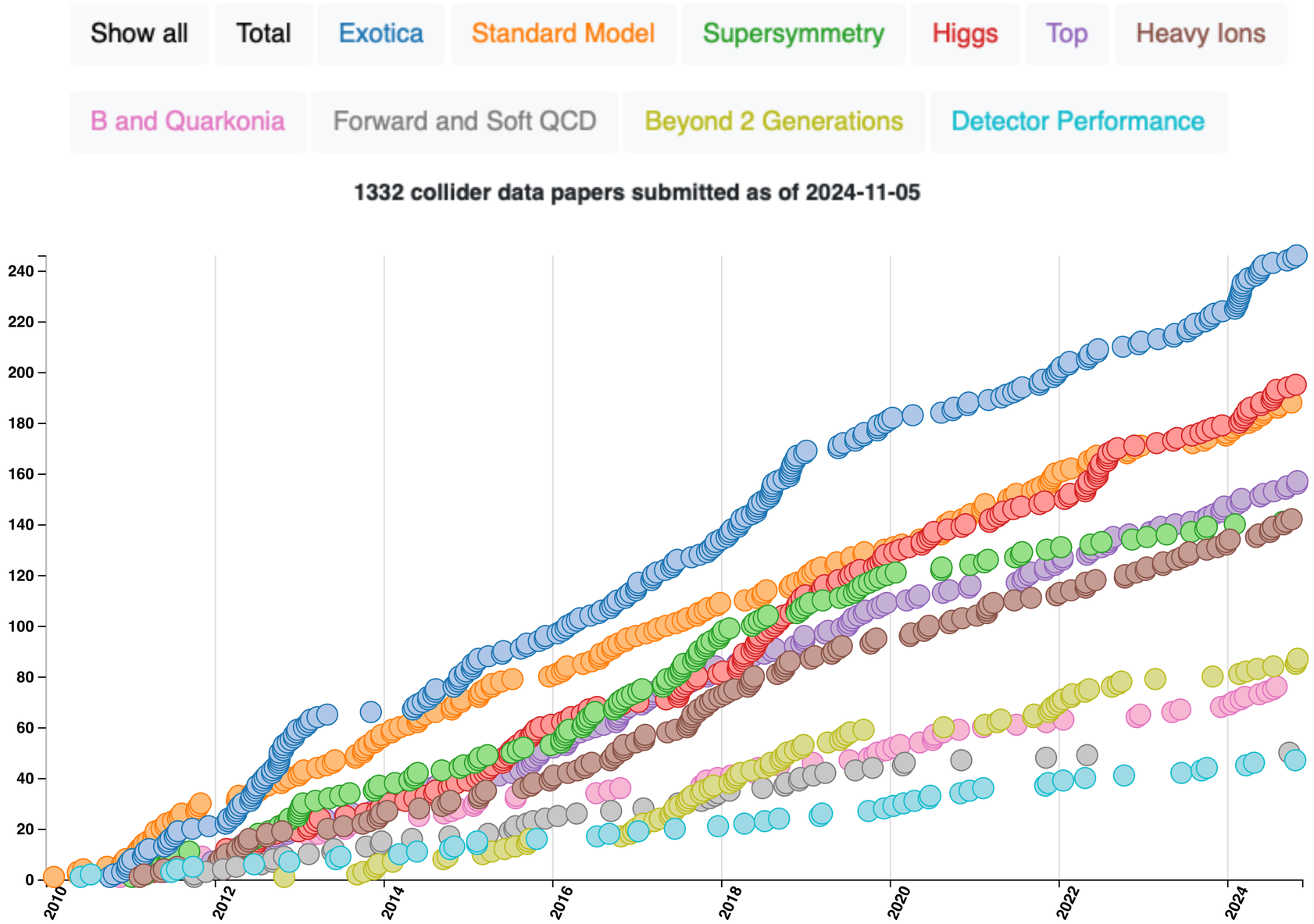

Paris


Jas

5 DPS on jet perfomance
3 DPS on b-tagging performance

POGs *PAGs*

IIHE physics contributions in CMS



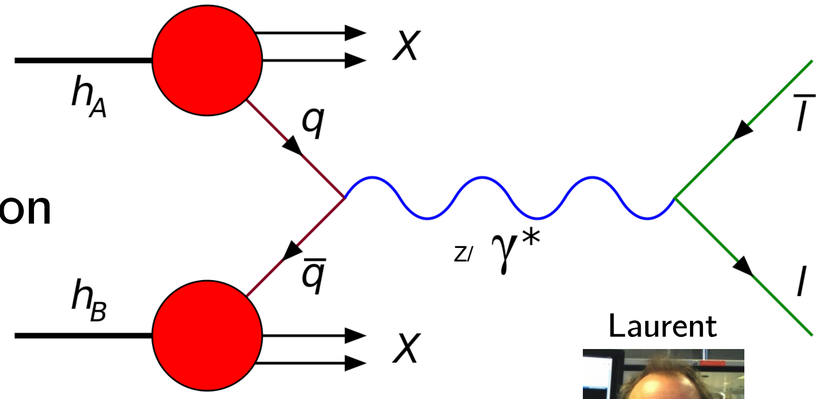
Searches

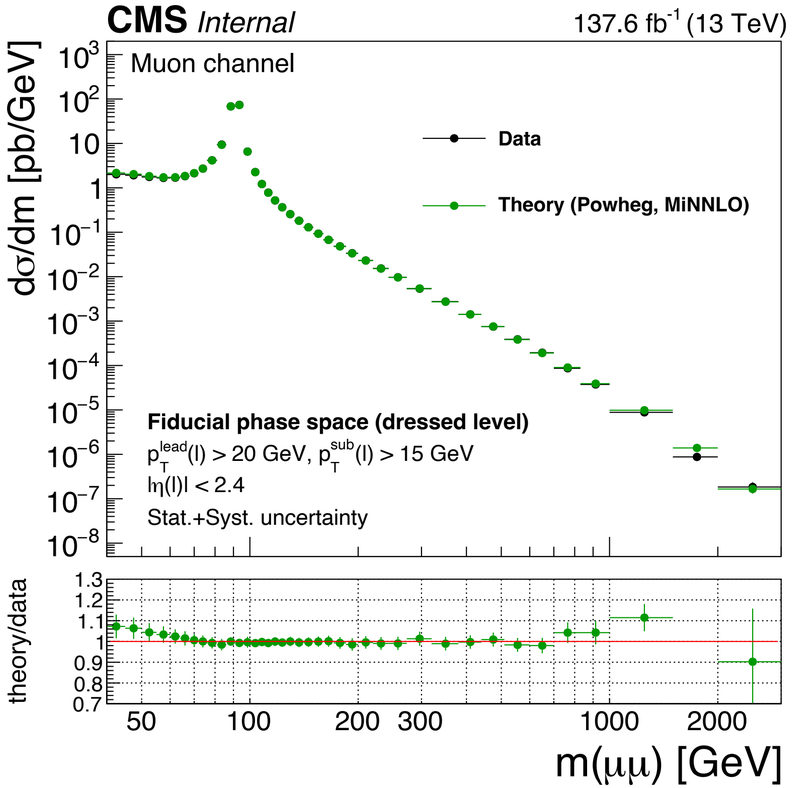
Precision measurements

IIHE physics contributions in CMS

Charting the Drell-Yan process: differential cross section measurement

- Precise test of the standard model
  - Important input to parton distribution functions and gluon resummation
  - Recent publication with 2016 data ($\sim 36\, fb^{-1}$) Eur. Phys. J. C 83, 628 (2023)
- Ongoing efforts:
  - Full Run2 data
  - Scouting data (Run2 + Run3)
  - Single -> multi-dimensional fit





Standard data stream:
~ 1 kHz, ~ 1000 MB/s

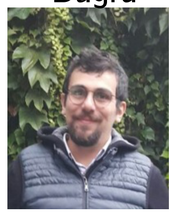
Prompt offline reconstruction

Scouting data stream:
~ 5 kHz, ~ 40 MB/s

No offline reconstruction

Laurent

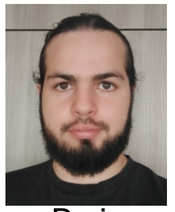
Bugra



Max

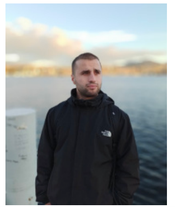
Itana

Eliott



Kyeongpil

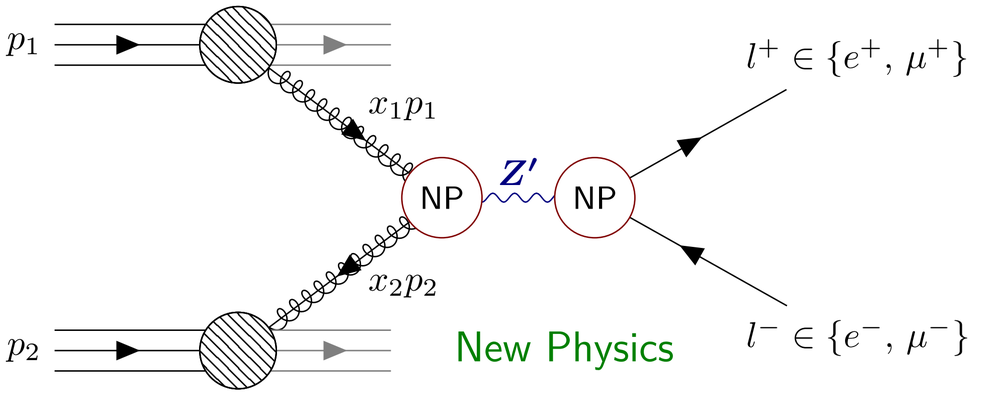
Paris

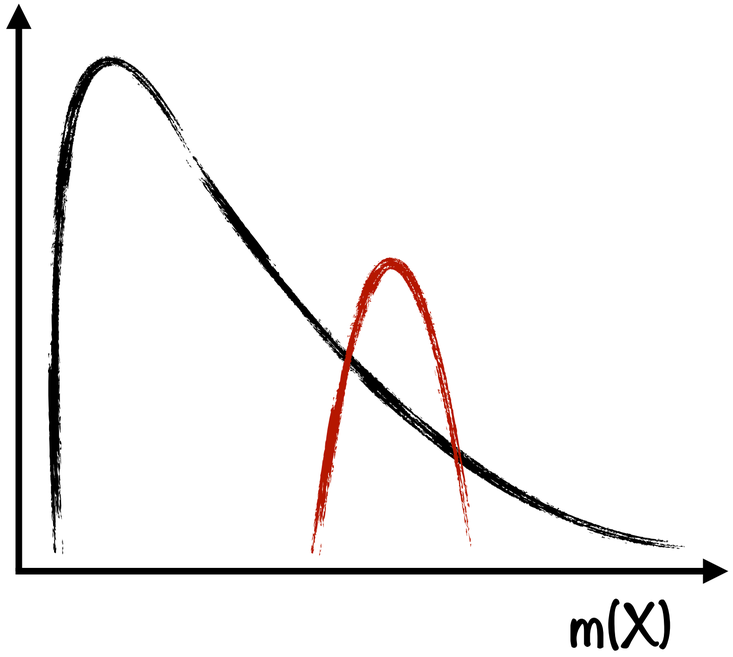


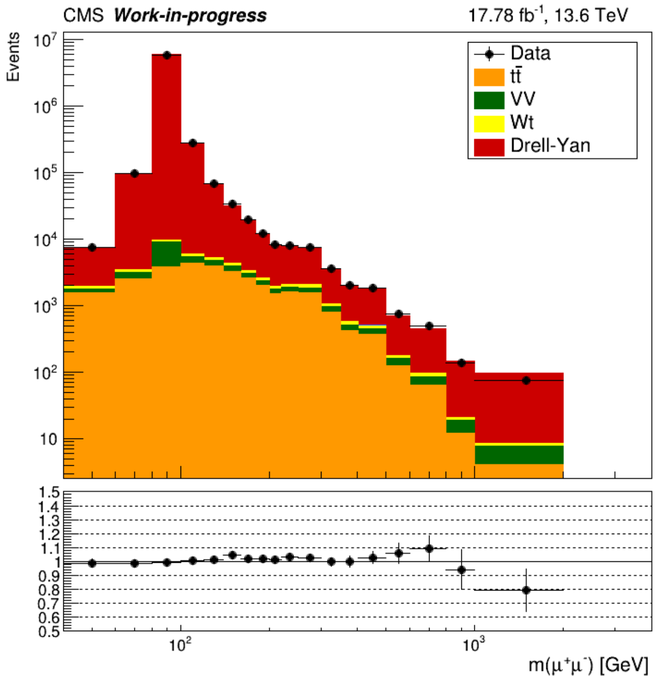
IIHE physics contributions in CMS

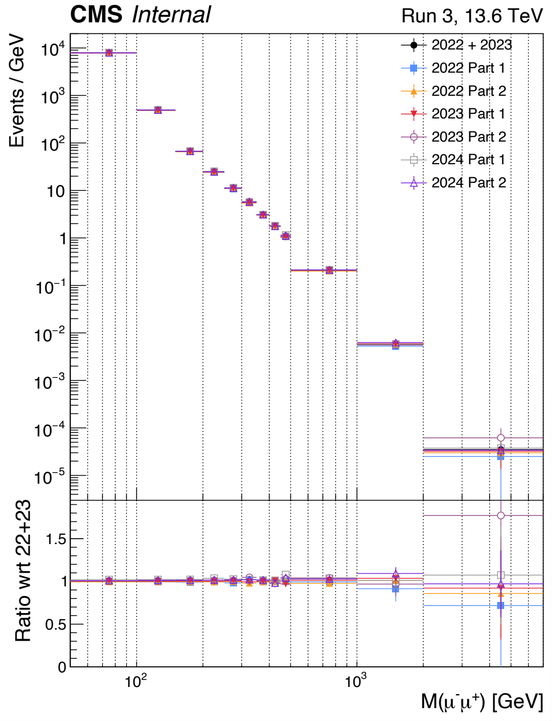
The tale of two leptons

- Looking for new particles in the tail of DY process
  - Bump hunt search
- Ongoing efforts:
  - Focus on new Run3 data
  - Improve sensitivity with new targeted categories









Ilia

Franco

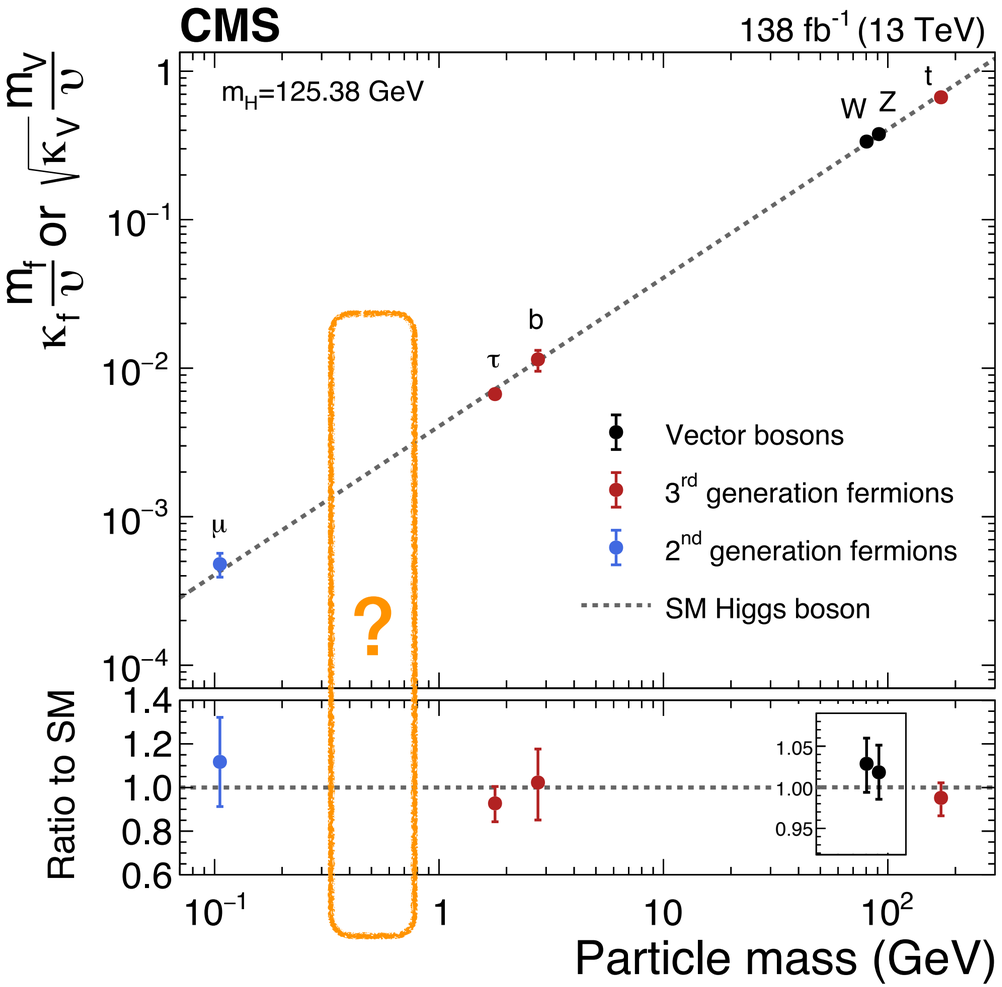
Laurent

Barbara

IIHE physics contributions in CMS

Exploring the Charm-Higgs Coupling

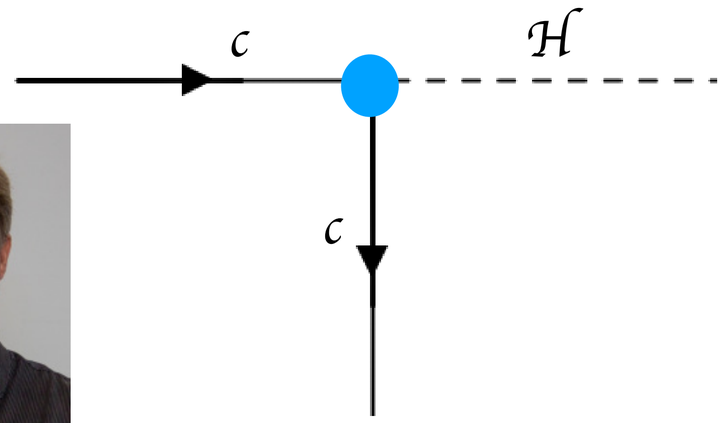
- Large inter-university project (iBOF)
  - VUB/UGent/UAntwerp

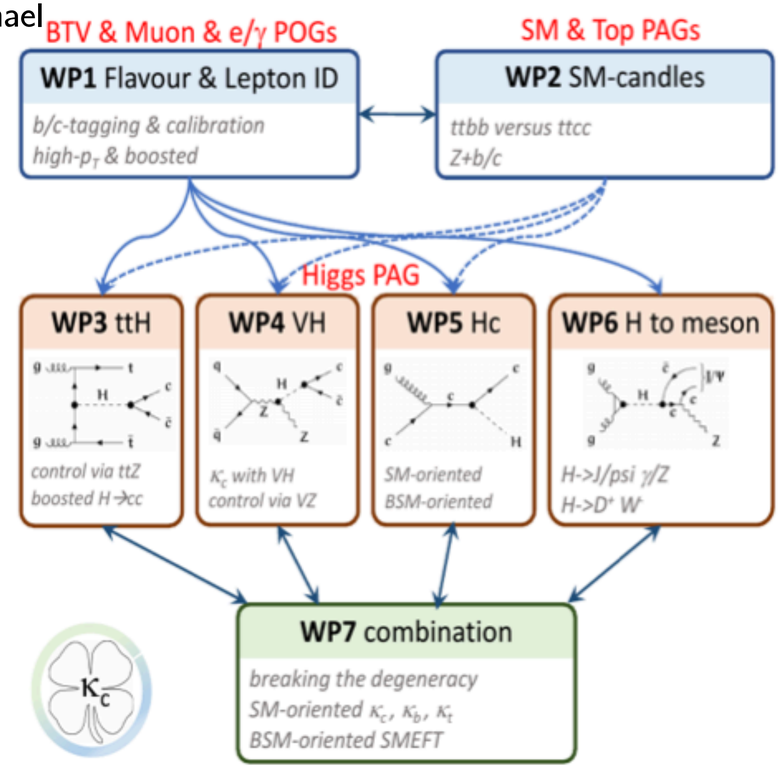



Steven


Jorgen


Michael





IIHE physics contributions in CMS

Exploring the Charm-Higgs Coupling

- Large inter-university project (iBOF)
  - VUB/UGent/UAntwerp
- Several analyses sensitive to this vertex
  - $t\bar{t} + c\bar{c}$
  - $H \rightarrow mesons$
  - $H + c$

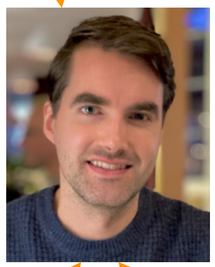
Felix

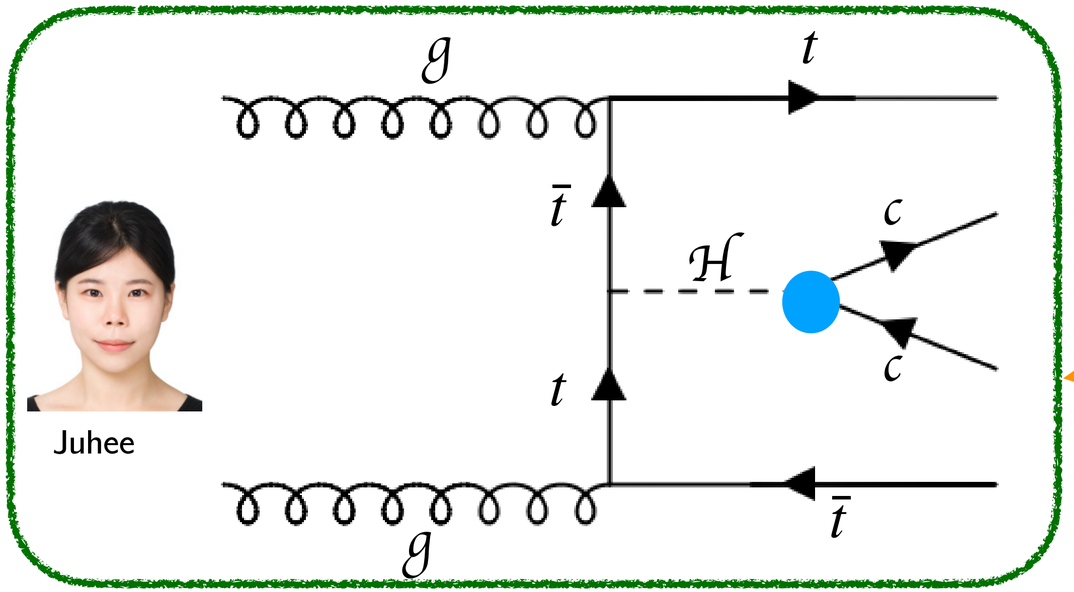
Nordin

Saranya

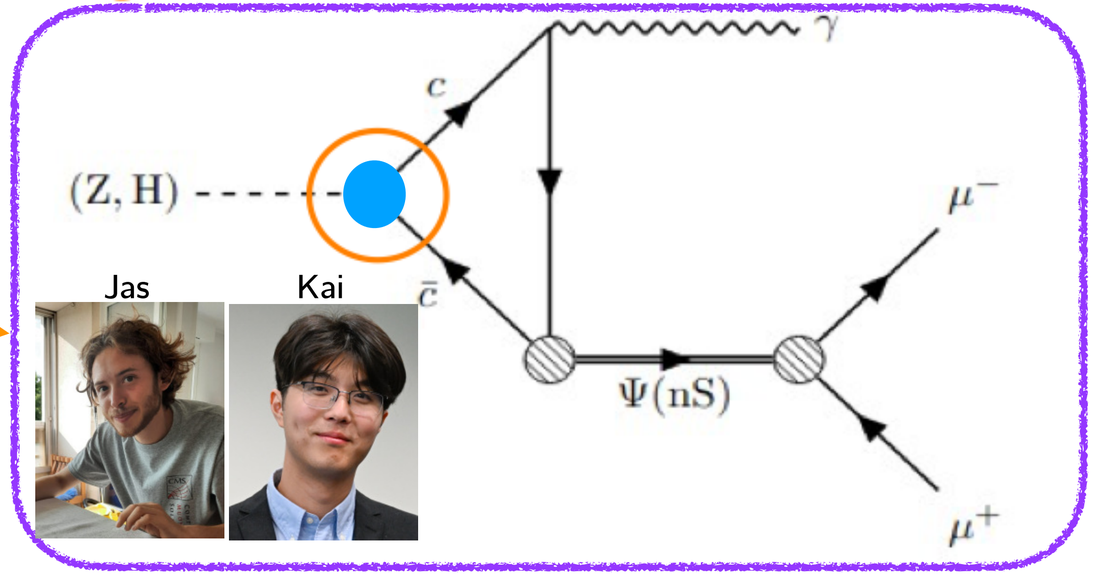
Chirayu

Gerrit





Juhee



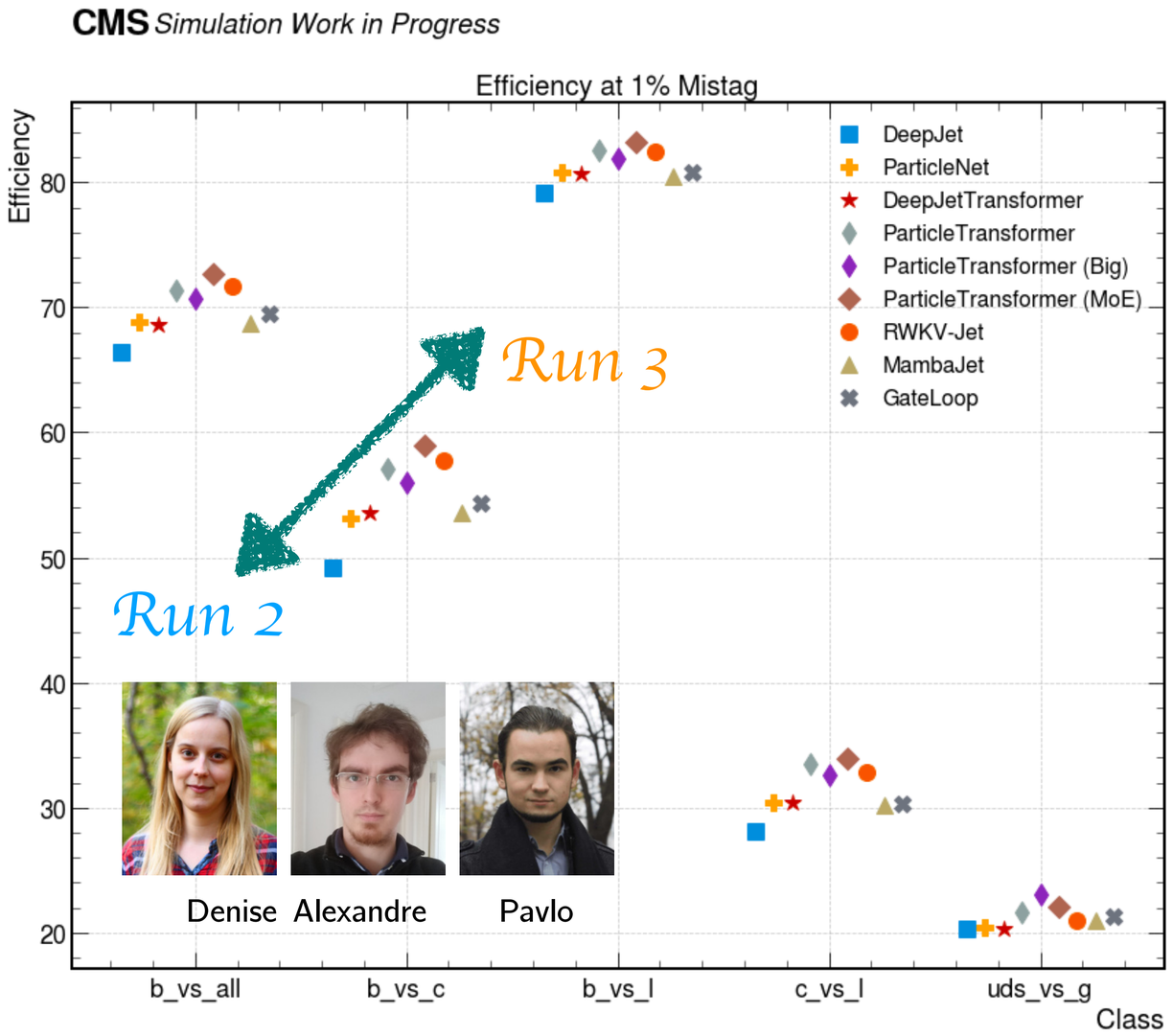
Jas

Kai

IIHE physics contributions in CMS

Exploring the Charm-Higgs Coupling

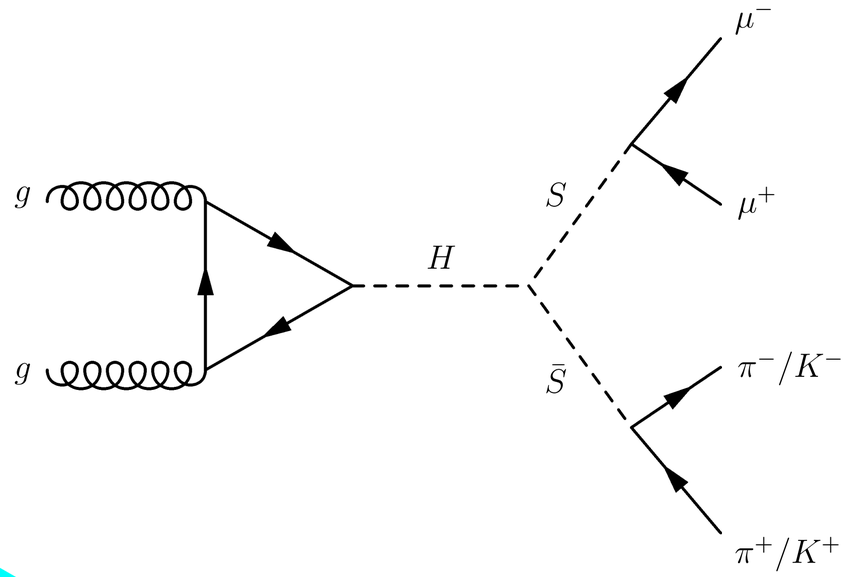
- Large inter-university project (iBOF)
  - VUB/UGent/UAntwerp
- Several analyses sensitive to this vertex
  - $t\bar{t} + c\bar{c}$
  - $H \rightarrow mesons$
  - $H + c$
- Measurements ↔ searches
  - SM/BSM/EFT
- ML as common thread
  - Improved techniques
  - Crucial aspect of the project
  - IIHE has a key role in ML development

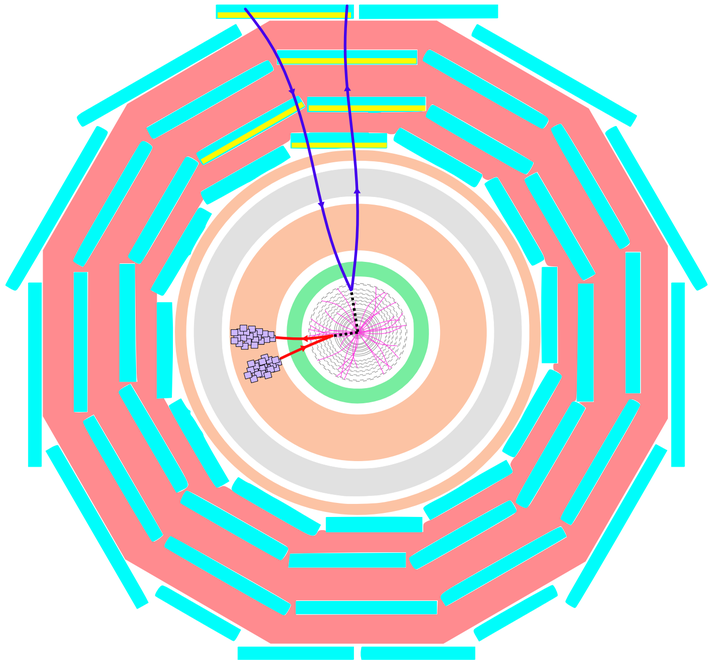


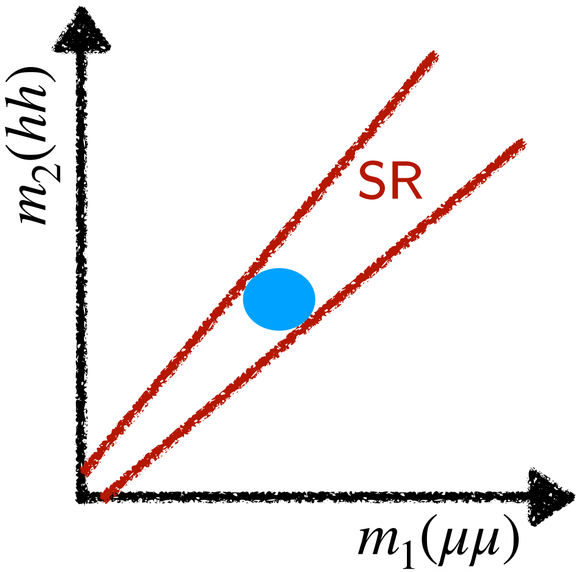
IIHE physics contributions in CMS

Exotic Higgs decays

- Higgs boson in the Standard Model
  - good compatibility between observations and predictions
  - upper bound on Higgs boson decays to new particles is $\mathcal{O}(10\%)$
  - ... still room for exotic Higgs decays
- $H \to SS$
  - Decay to a pair of muons and hadrons
  - Excellent mass resolution
  - Looking at displaced and prompt signatures





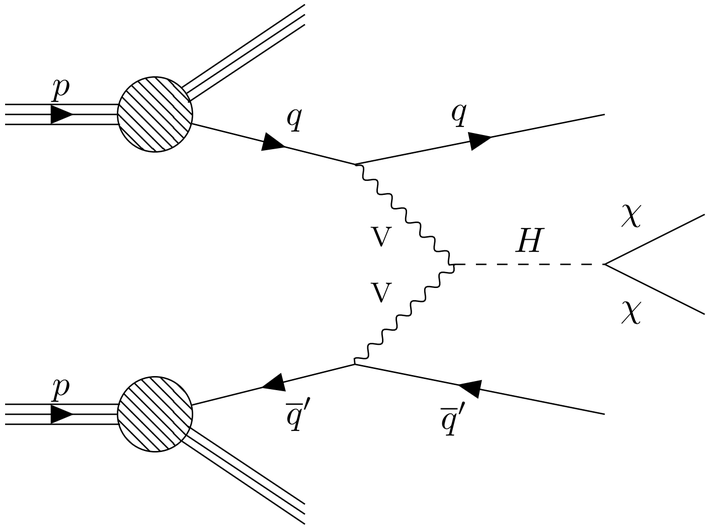


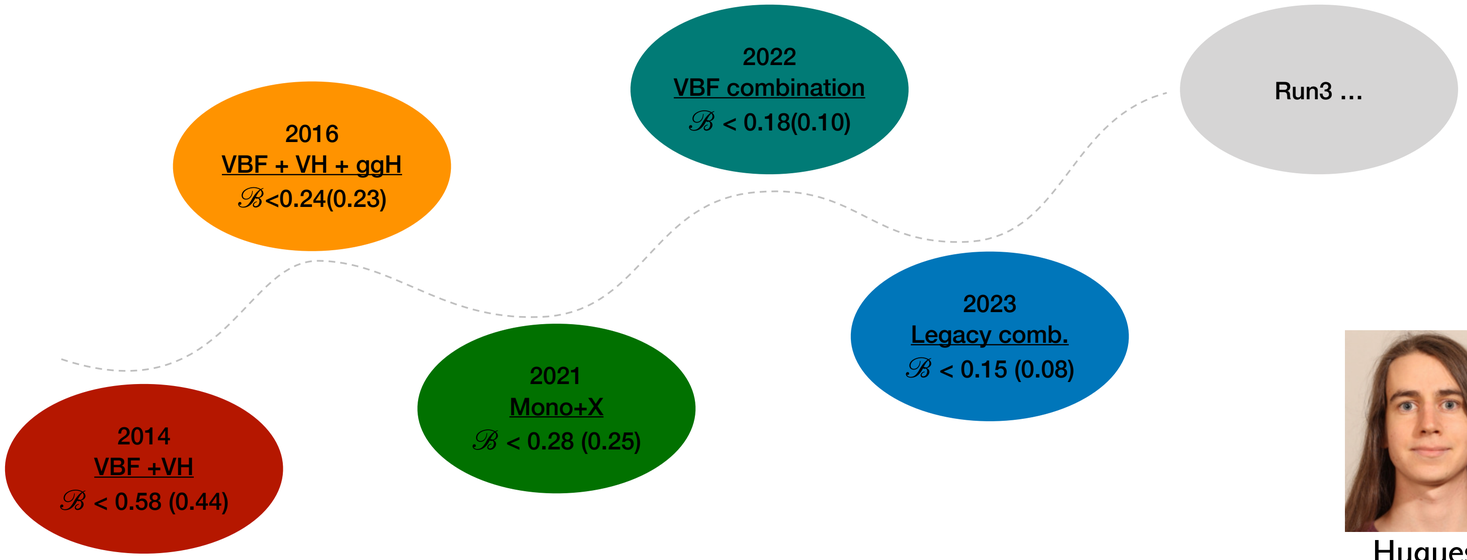
Jas Soumya David Steven Barbara

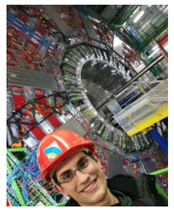
IIHE physics contributions in CMS

VBF signatures and how to find them

- Long-standing effort for $H \rightarrow invisible$
  - Worked on full Run2-data until 2y ago
  - Already analysing Run3 data
  - Focus on VBF production mode






Andrea


Pascal

Hugues

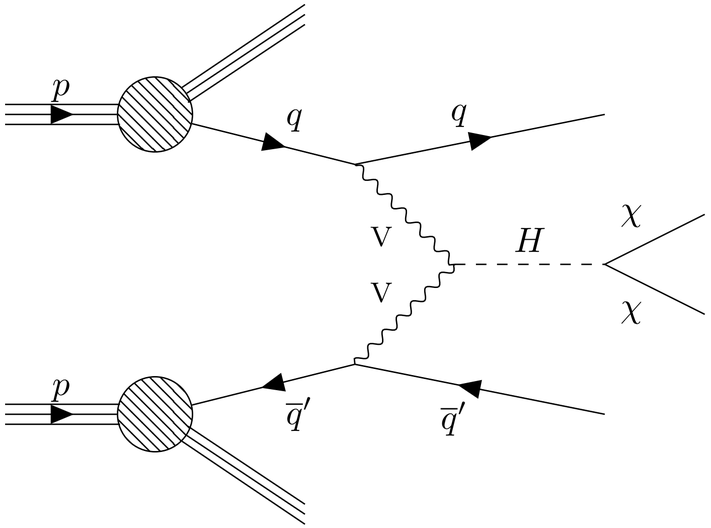

Aamir

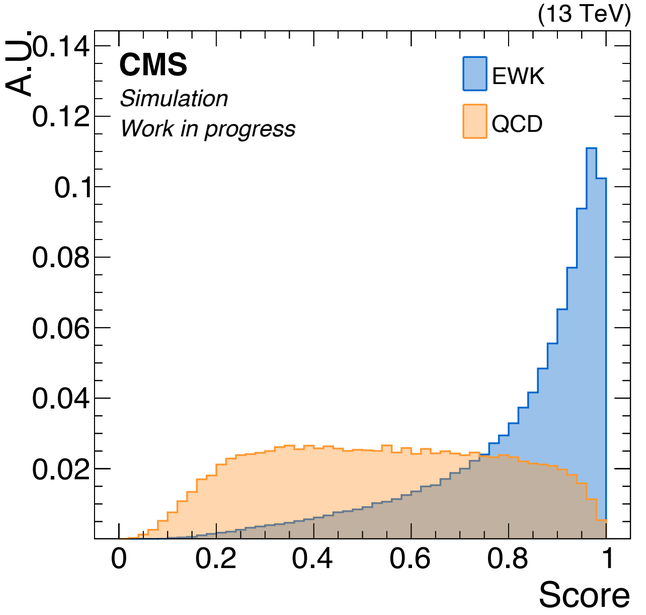

Laurent

IIHE physics contributions in CMS

VBF signatures and how to find them

- Long-standing effort for $H \rightarrow invisible$
  - Worked on full Run2-data until 2y ago
  - Already analysing Run3 data
  - Focus on VBF production mode
- Development with ML
  - Tagging production mode (first time in CMS)
  - Strong synergy between ULB and VUB





2016
VBF + VH + ggH
$\mathcal{B}$<0.24(0.23)

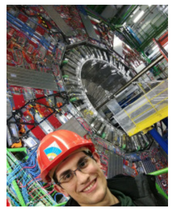
2022
VBF combination
$\mathcal{B}$ < 0.18(0.10)

Run3 ...

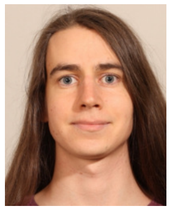
2023
Legacy comb.
$\mathcal{B}$ < 0.15 (0.08)

2021
Mono+X
$\mathcal{B}$ < 0.28 (0.25)

2014
VBF +VH
$\mathcal{B}$ < 0.58 (0.44)

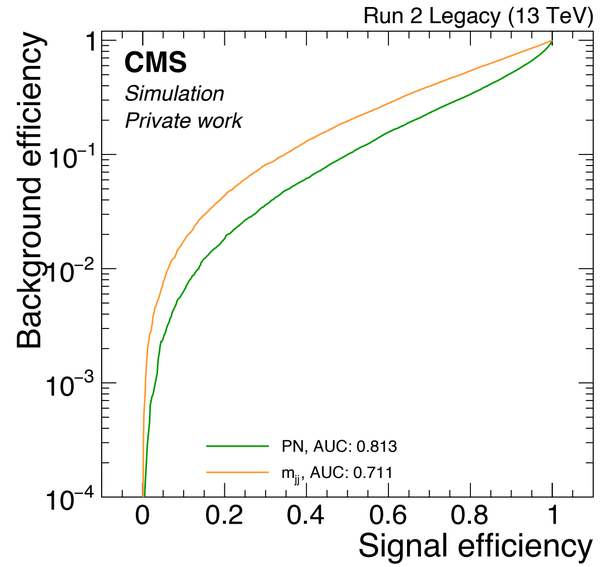

Andrea


Pascal


Hugues


Aamir

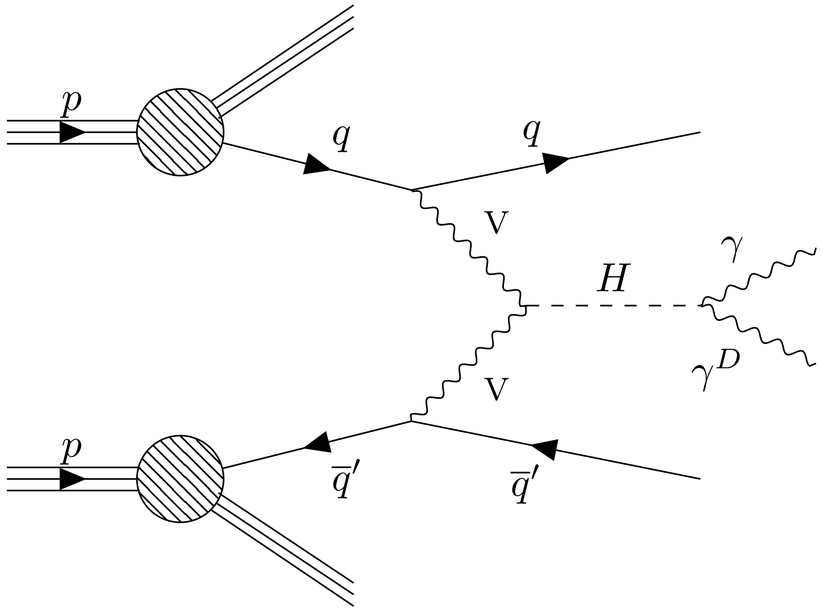

Laurent

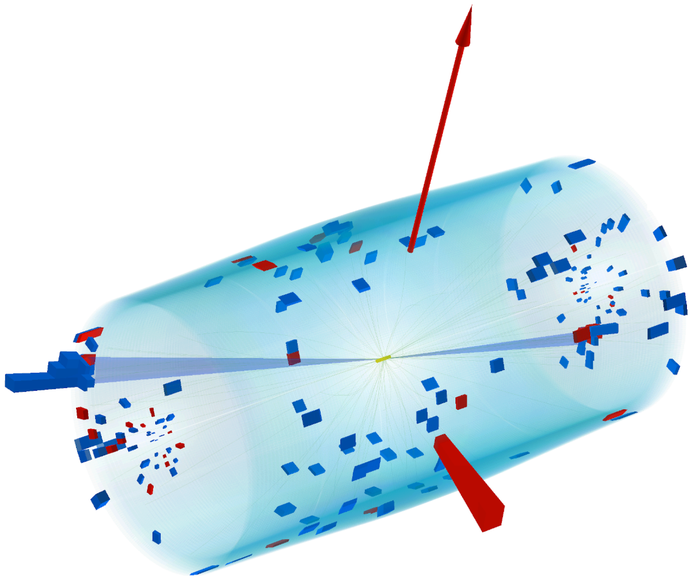


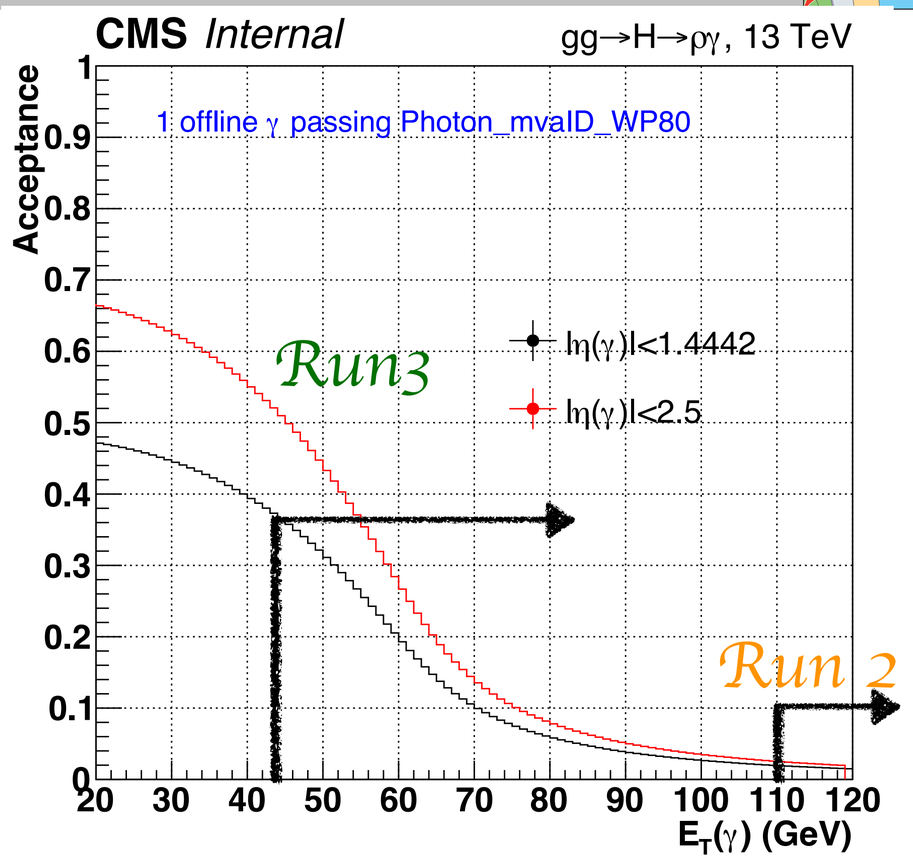
IIHE physics contributions in CMS

VBF signatures and how to find them

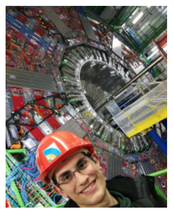
- Search for photon + dark-photon
  - Focus on Run3 data
  - Complementary to $H \rightarrow invisible$ search
- Investigating ggF production too
  - First time at LHC
  - Potentially feasible thanks to newly developed triggers







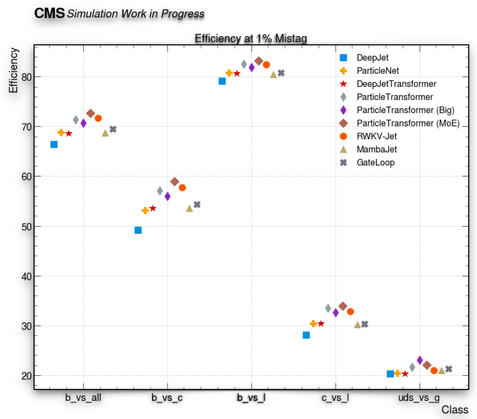

Longsheng

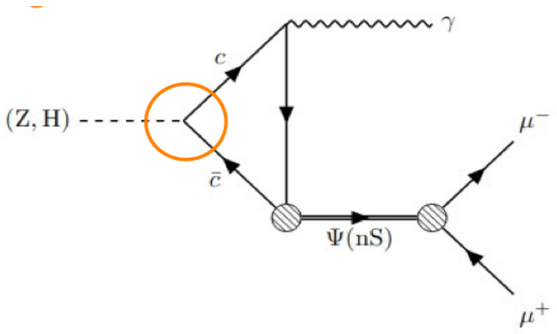

Andrea

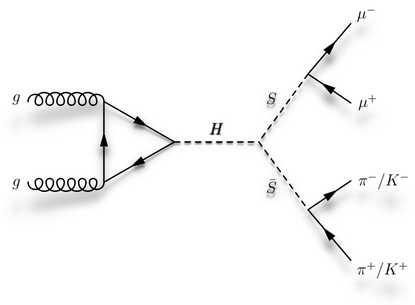

Pascal

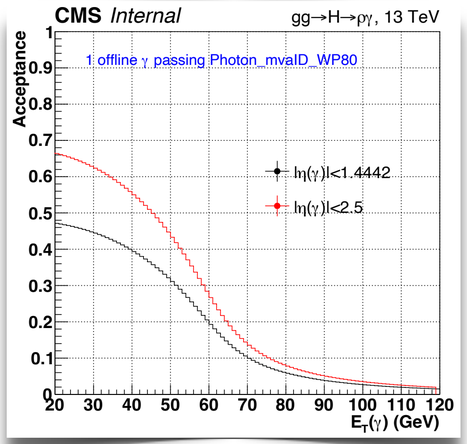

Laurent

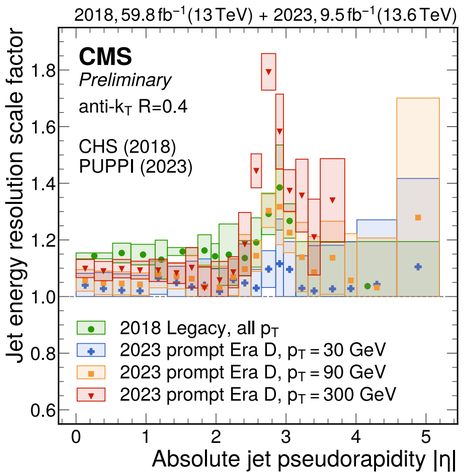
Summary

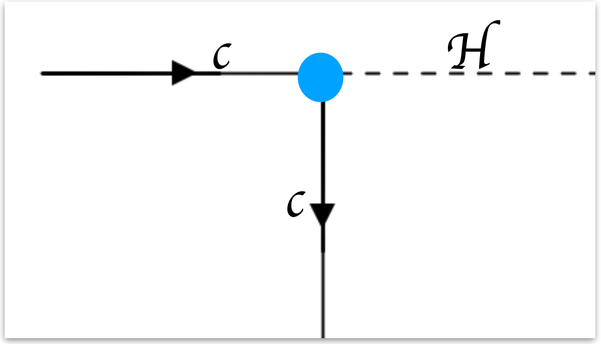




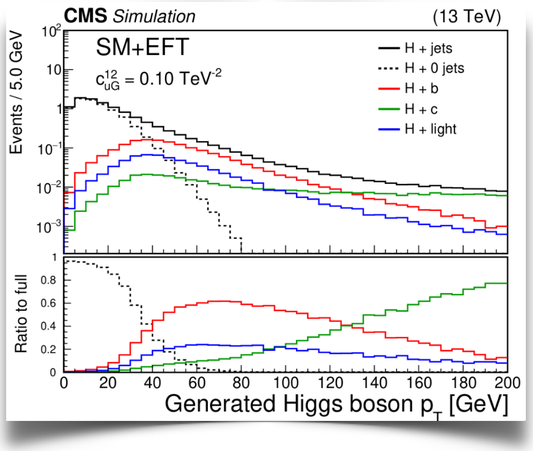


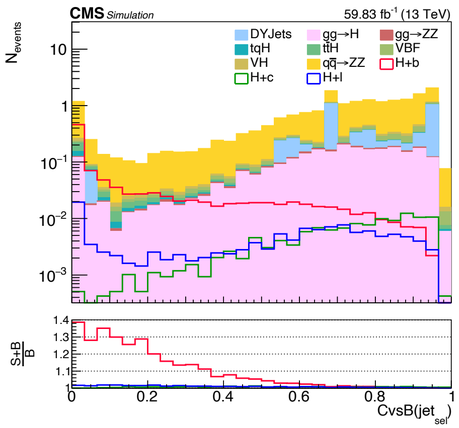


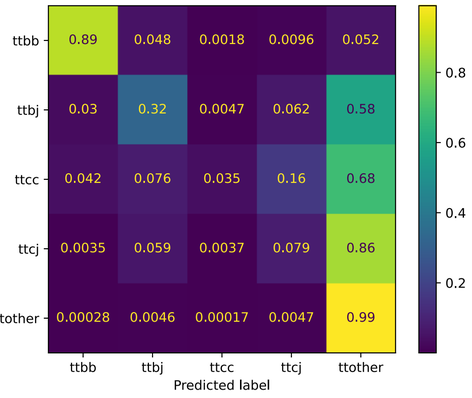


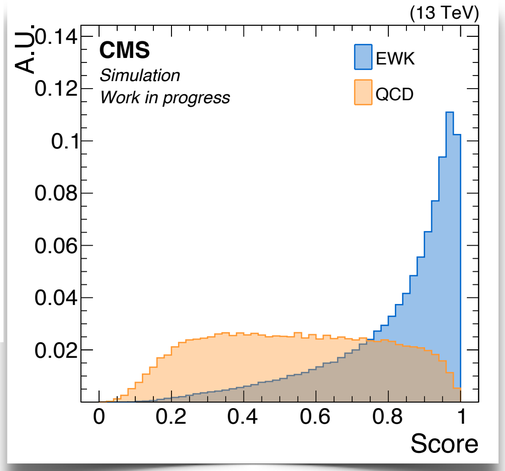


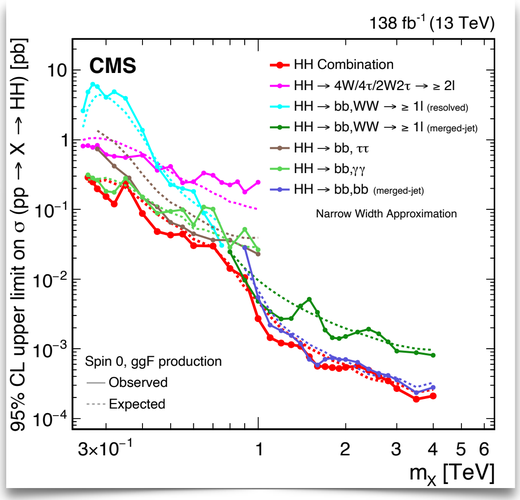
A glimpse of IIHE's impactful contributions to CMS









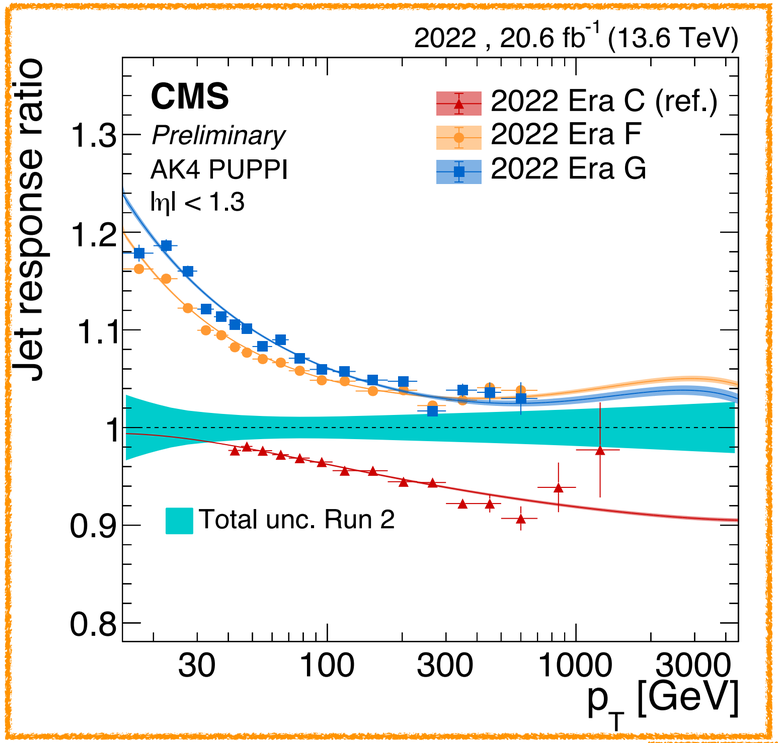


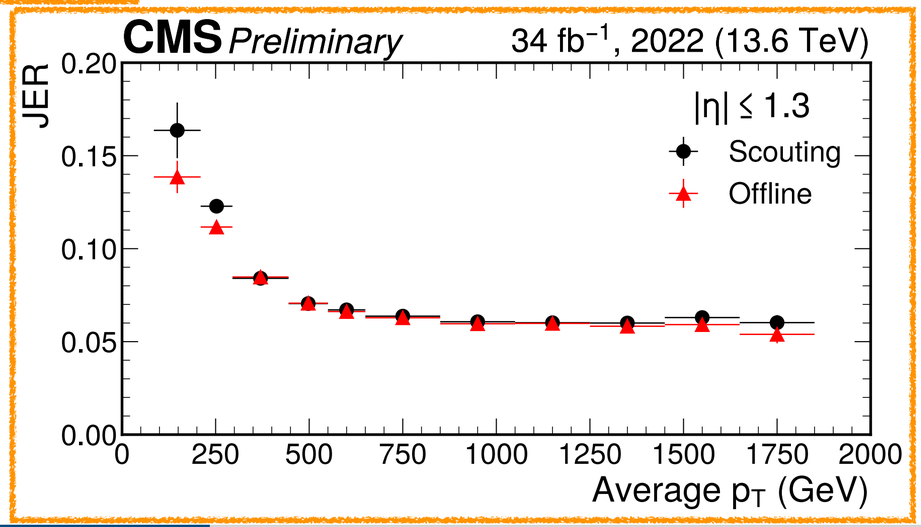
Backup

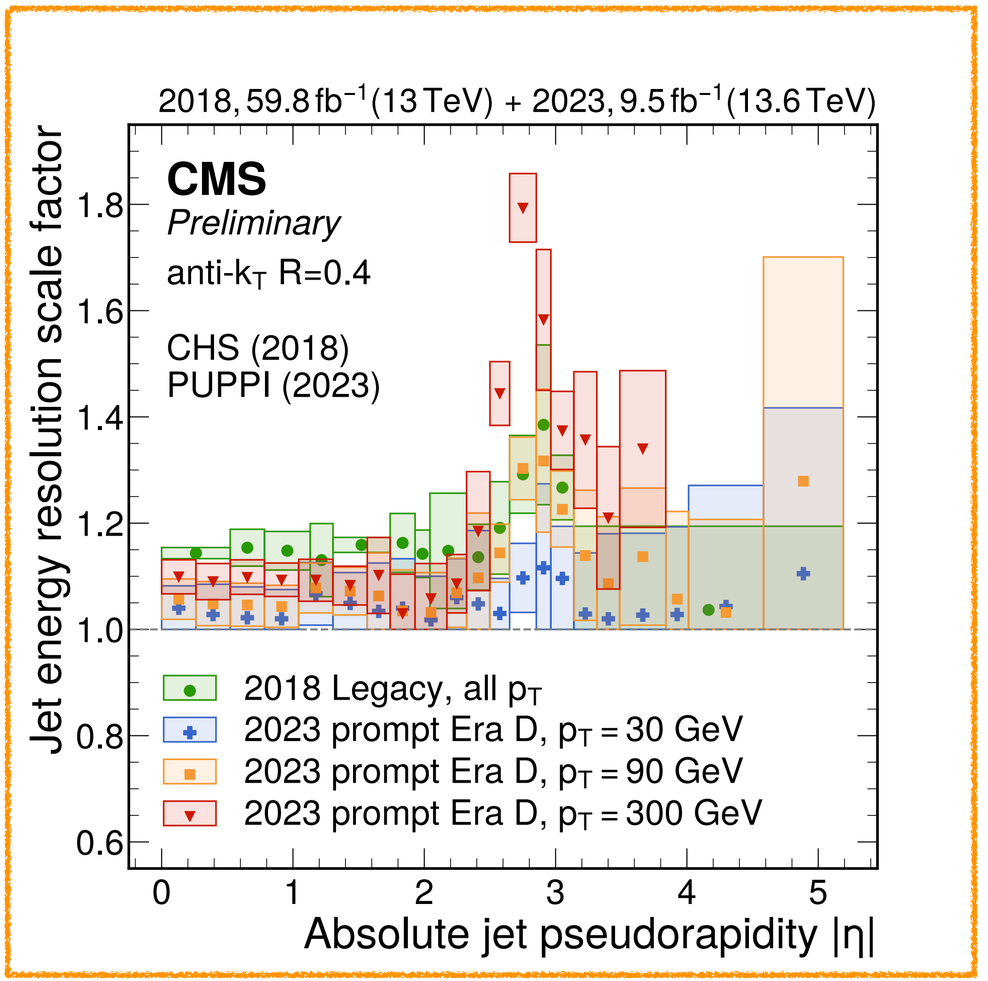
~~~ Additional Material ~~~

IIHE responsibilities in CMS

DPS = Detector performance summary







IIHE responsibilities in CMS

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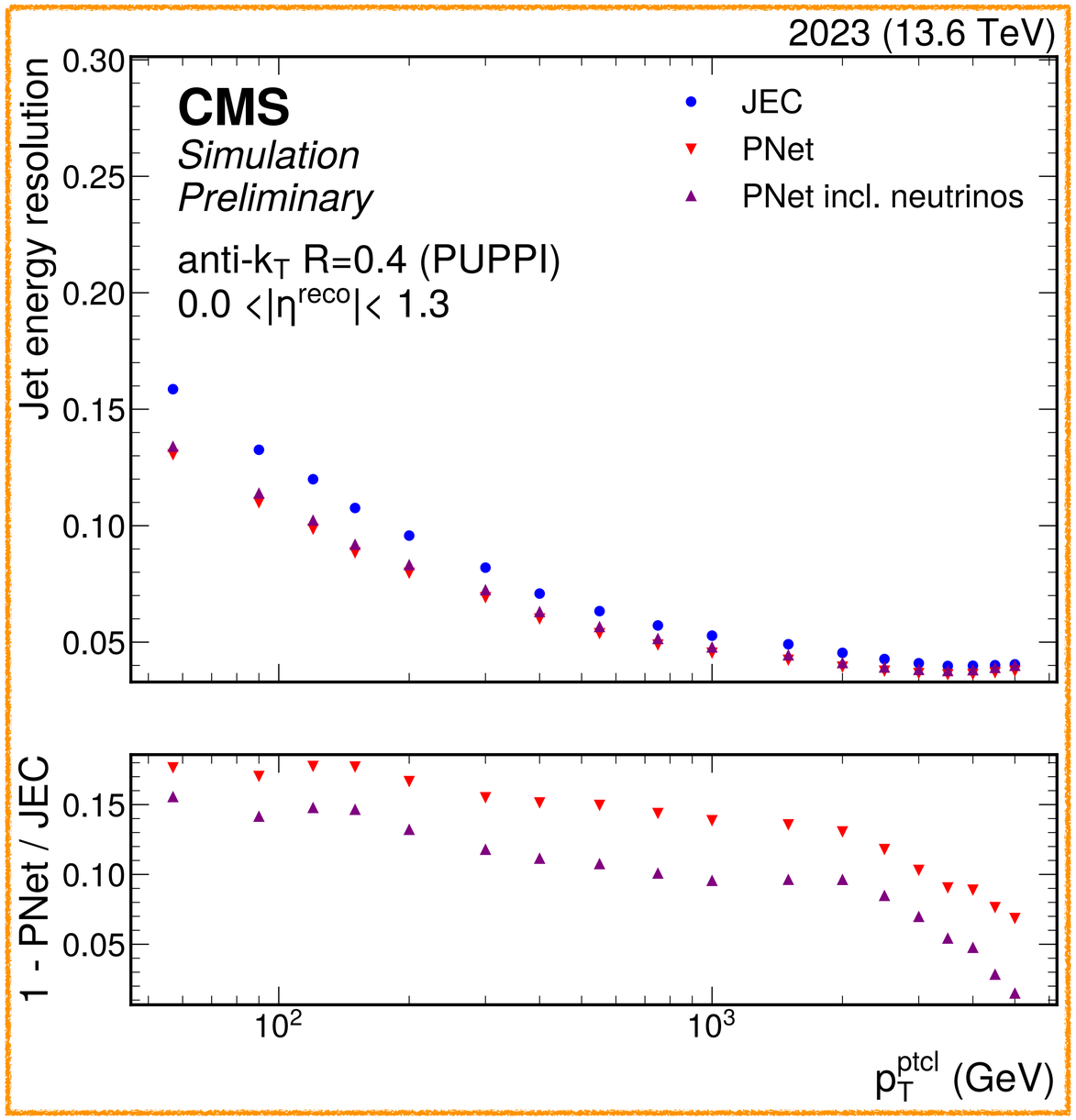
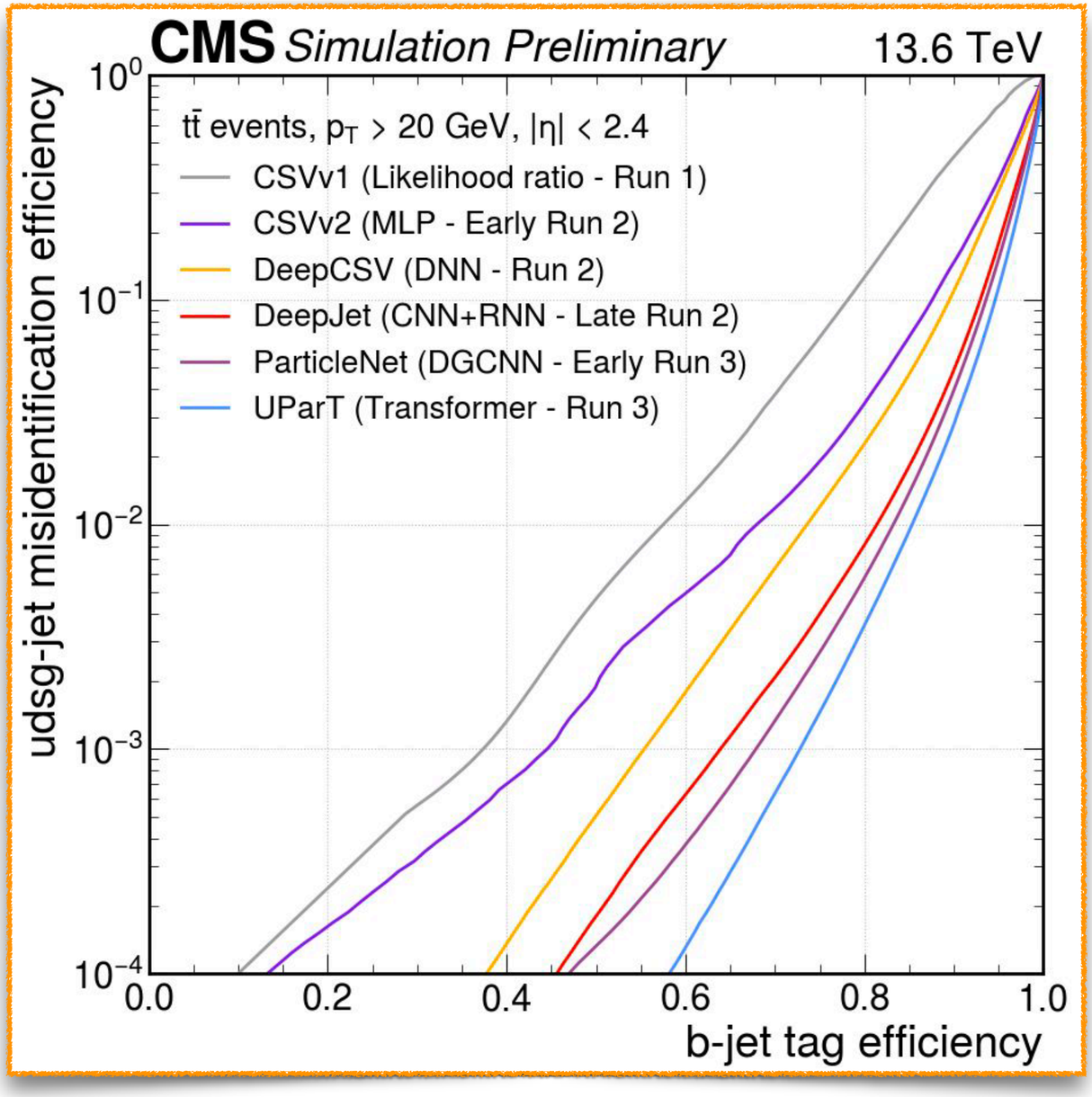
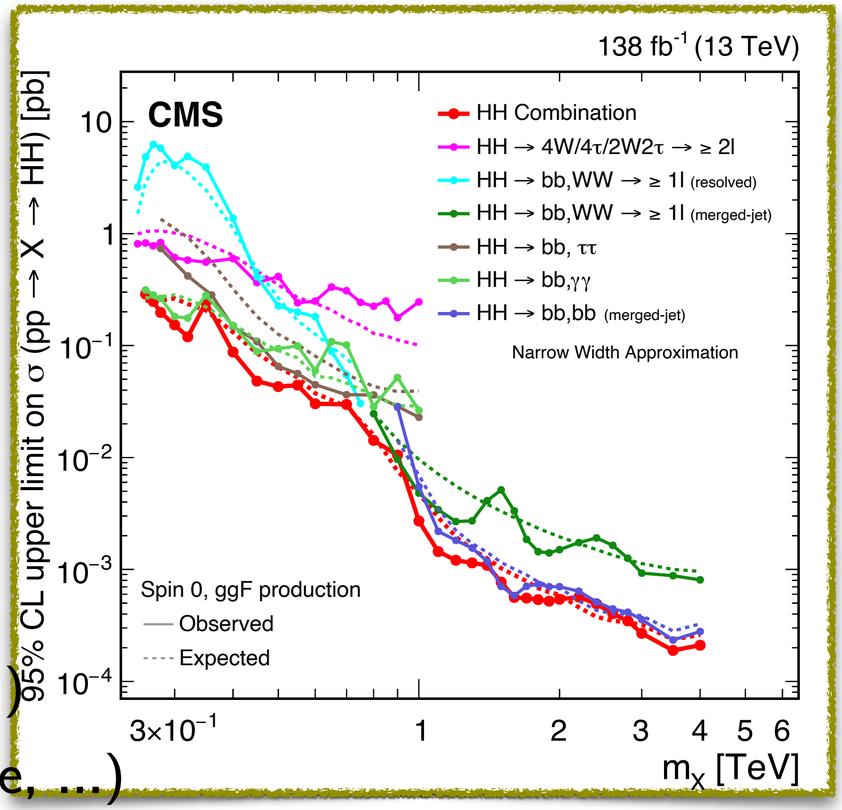




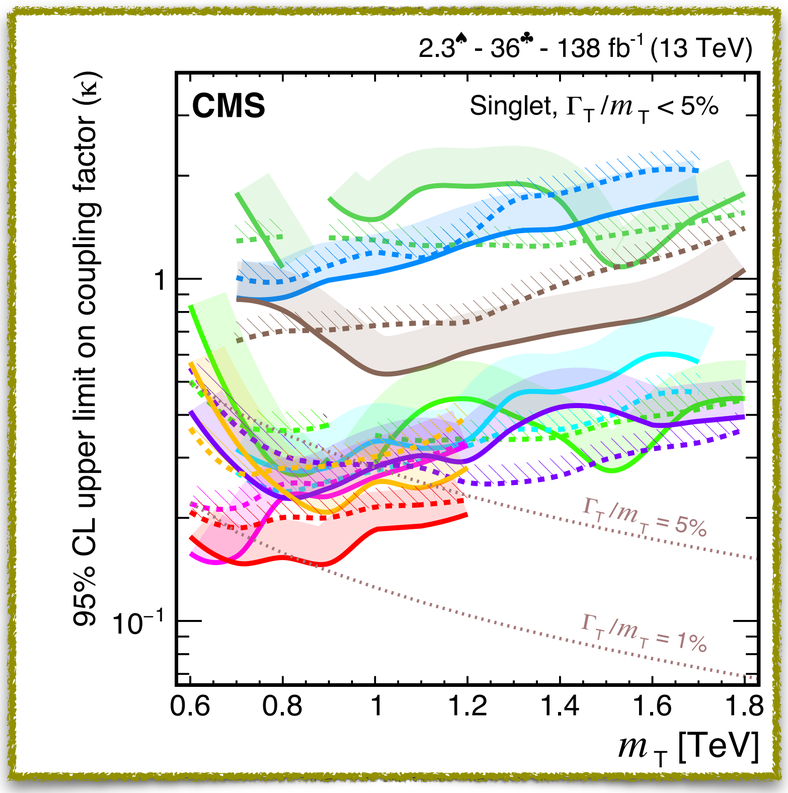
CMS mission

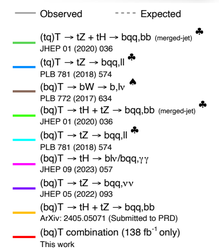
- CMS is many experiments at once
  - Precision physics
    - Standard Model physics
    - Top and B quark physics
    - Higgs physics
  - BSM physics
    - Heavy resonances
    - Exotica -> dark-sectors, new signatures, ...
  - Competitive among experiments
    - Previous colliders (LEP, Tevatron)
    - At the LHC (ATLAS, LHCb, Alice, ...)
  - Complementary to many others
    - B-factories (Belle II, Babar)
    - Dark matter and neutrino experiments

HH resonant production



Vector-like quark





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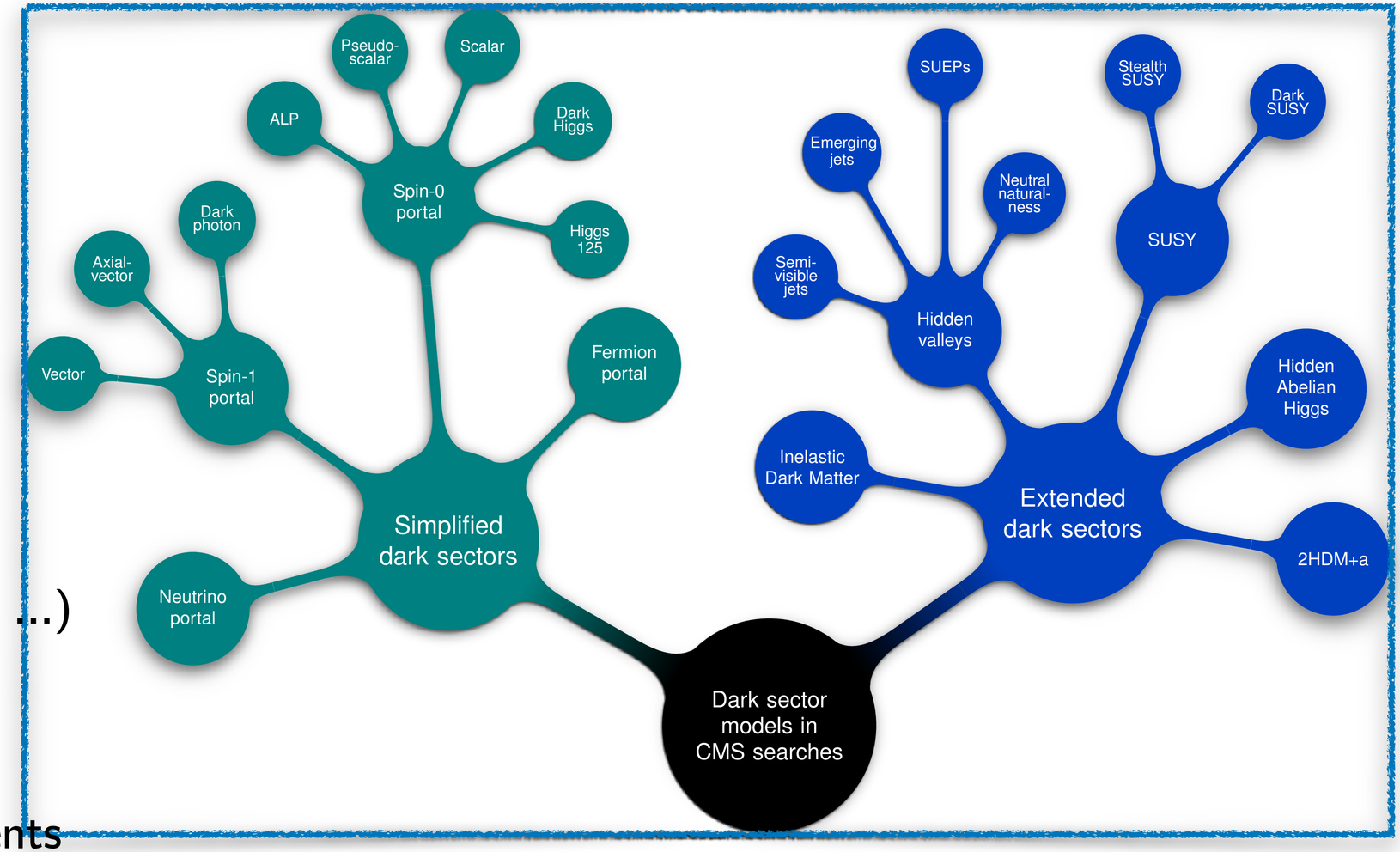
Dark sector searches



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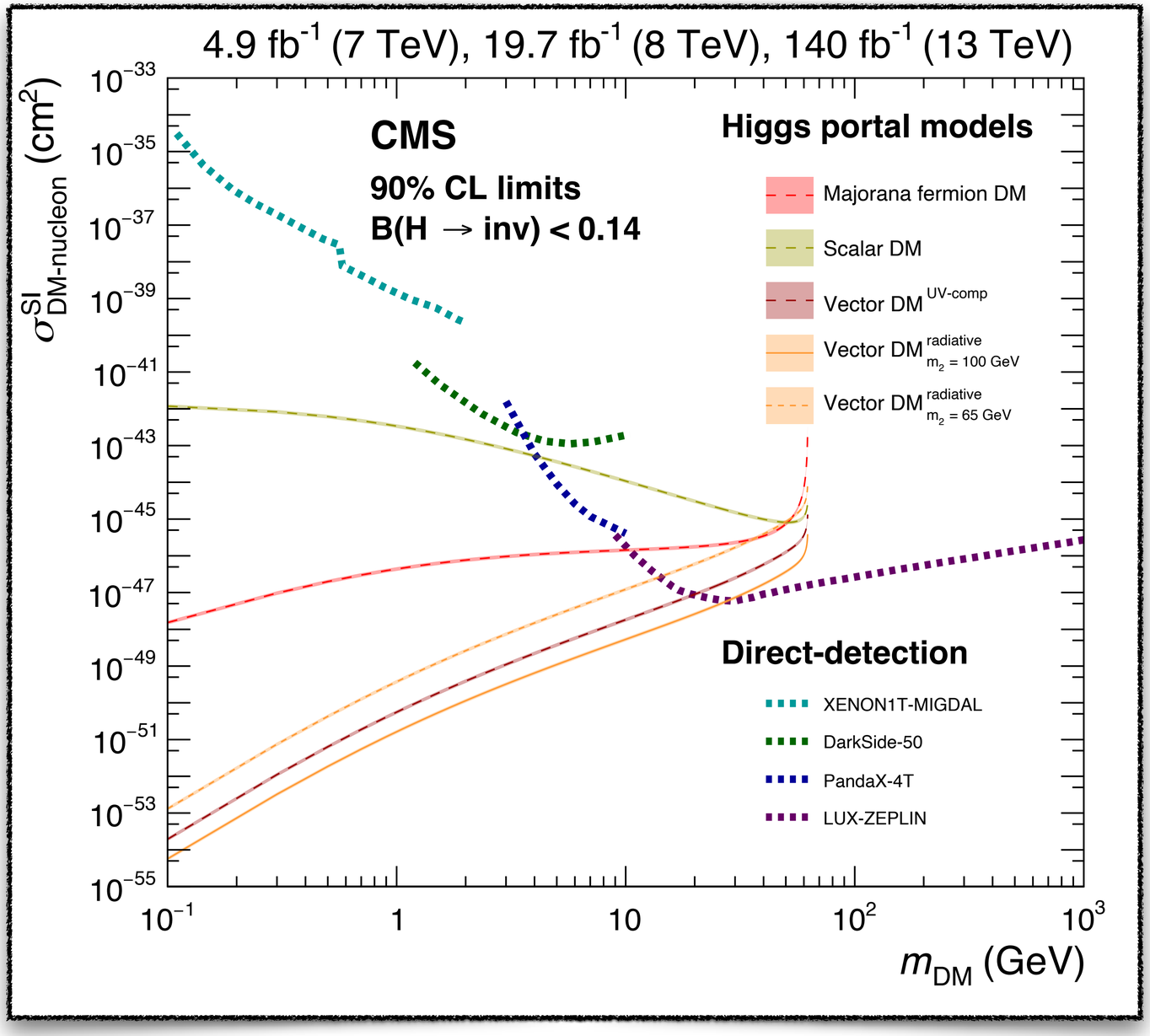
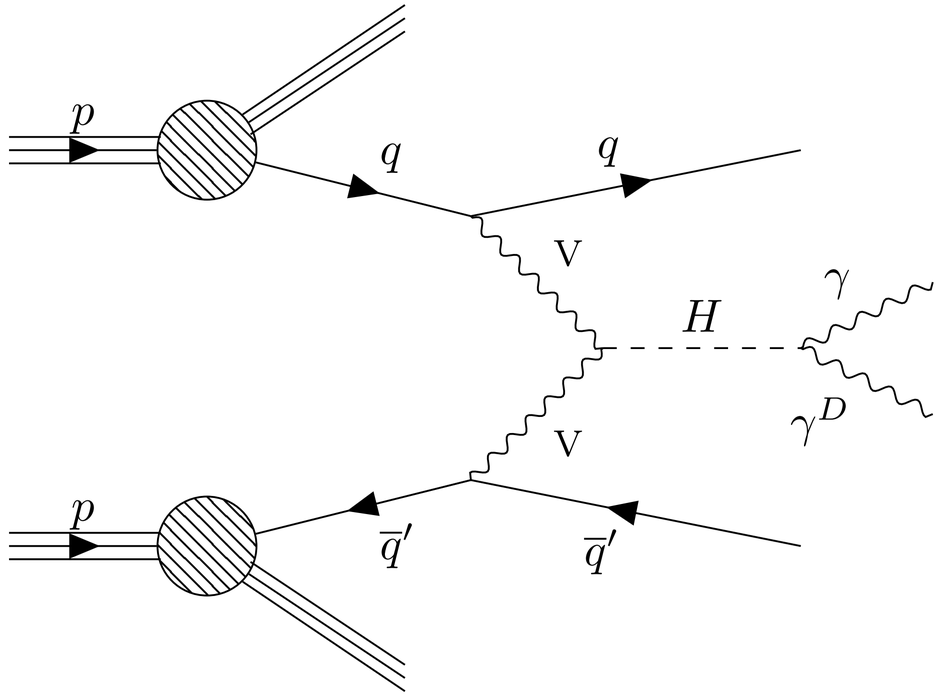
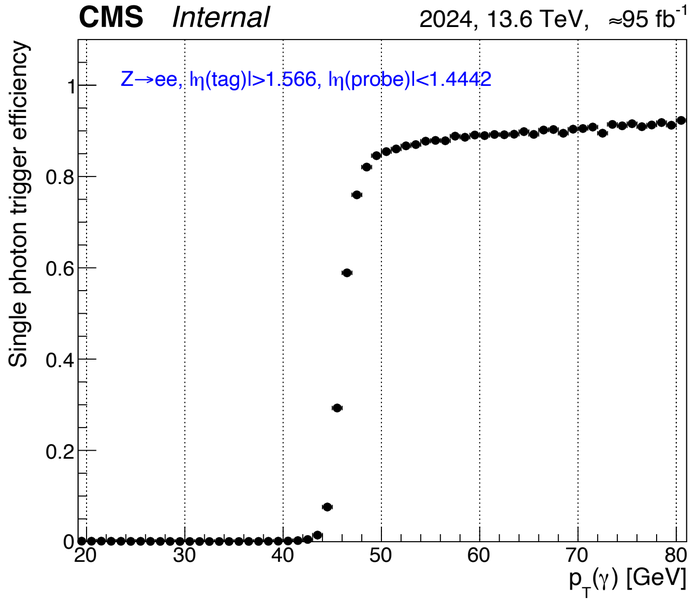


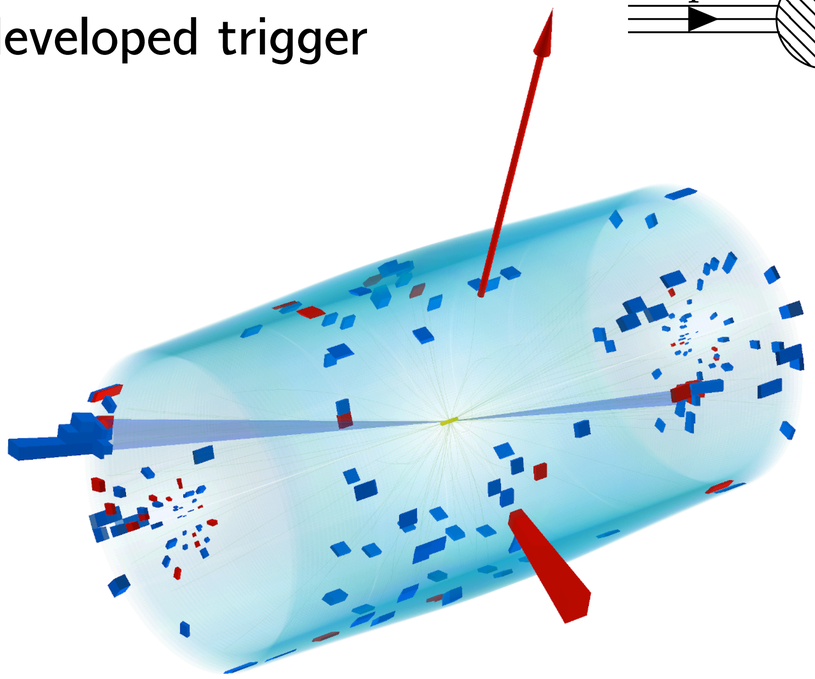
IIHE physics contributions in CMS

VBF signatures and how to find them

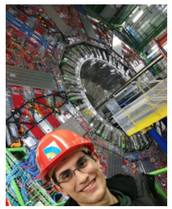
- Search for photon + dark-photon
  - Focus on Run3 data
  - Complementary to $H \rightarrow invisible$ search
- Investigating ggF production too
  - First time at LHC
  - Potentially feasible thanks to newly developed trigger












IIHE physics contributions in CMS

Exploring the Charm-Higgs Coupling

- Large inter-university project (iBOF)
  - VUB/UGent/UAntwerp
- Several analyses sensitive to this vertex
  - $t\bar{t} + c\bar{c}$
  - $H \rightarrow mesons$
  - $H + c$
- Measurements ↔ searches
  - SM/BSM/EFT
- ML as common thread
  - Improved techniques
  - Crucial aspect of the project
  - IIHE has a key role in ML development