Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

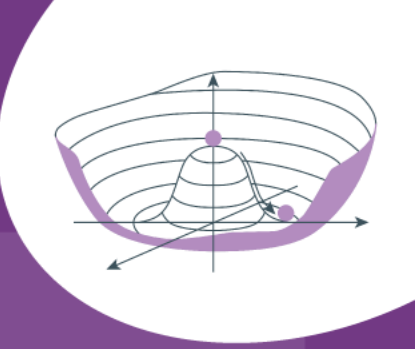
Quantum Universe Attract.Workshop

QU- Activities in Higgs and DM (part 2)

Johannes Haller

November 24, 2025, Hamburg

The Higgs boson is …



… a very special particle

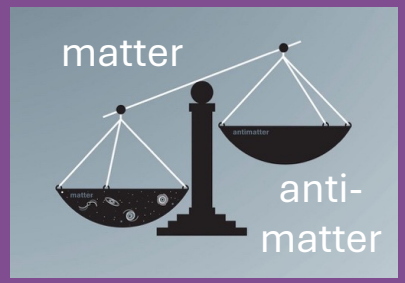
- central piece of the Standard Model
- coupling to mass !

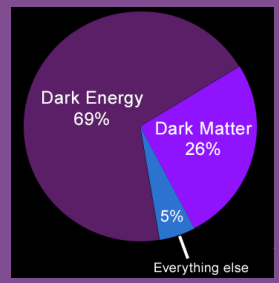
  → intimate connection to mass and gravity

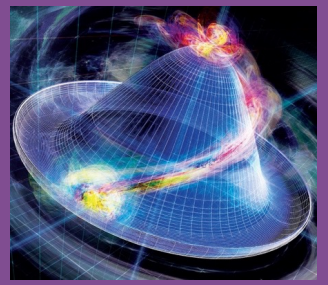
… the key to a deeper understanding of the big questions in physics

- matter-antimatter asymmetry
- dark matter and dark energy
- the structure of the vacuum

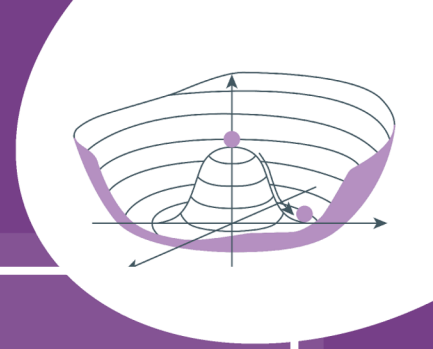
…. and their intimate connections







Hamburg: the place for Higgs+DM



a unique
'Higgs collaboration'

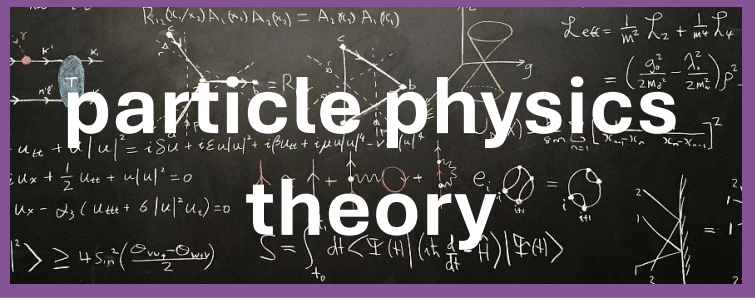
Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

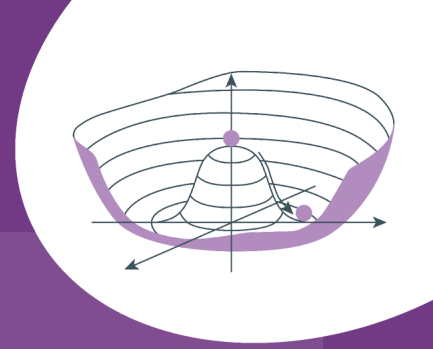
CMS

ATLAS EXPERIMENT



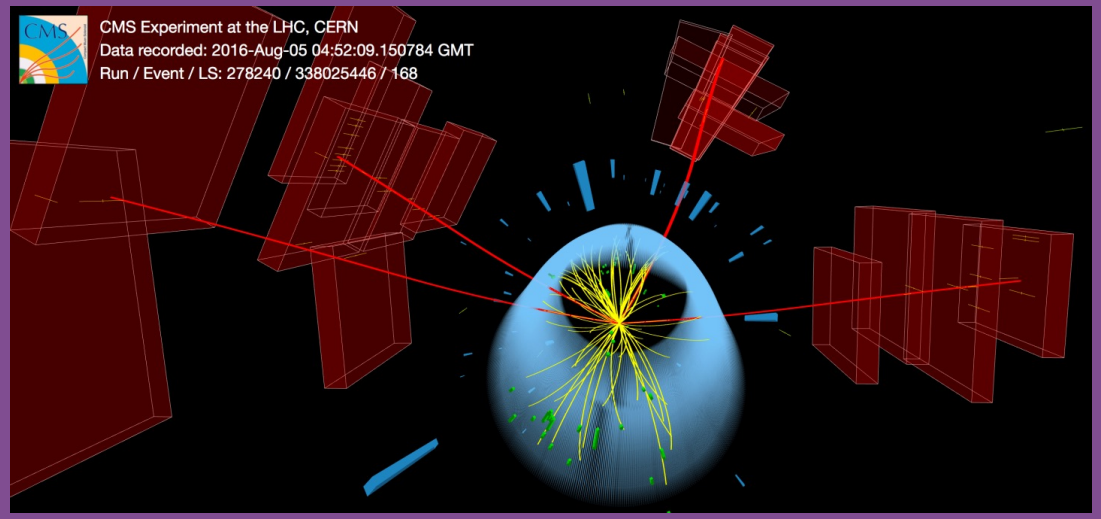
with world-leading Higgs researchers

studying the Higgs boson

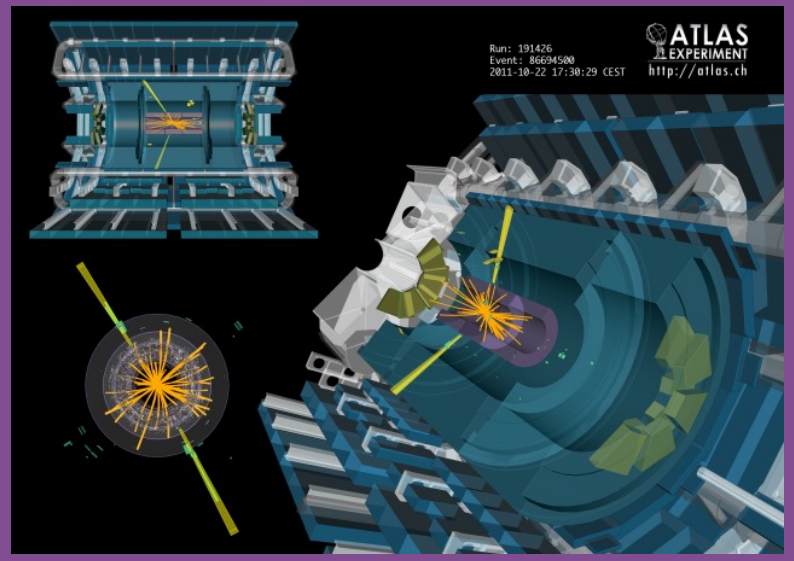


only two experiments have access to the Higgs boson:
ATLAS and CMS at CERN's LHC

CMS covered in this talk !

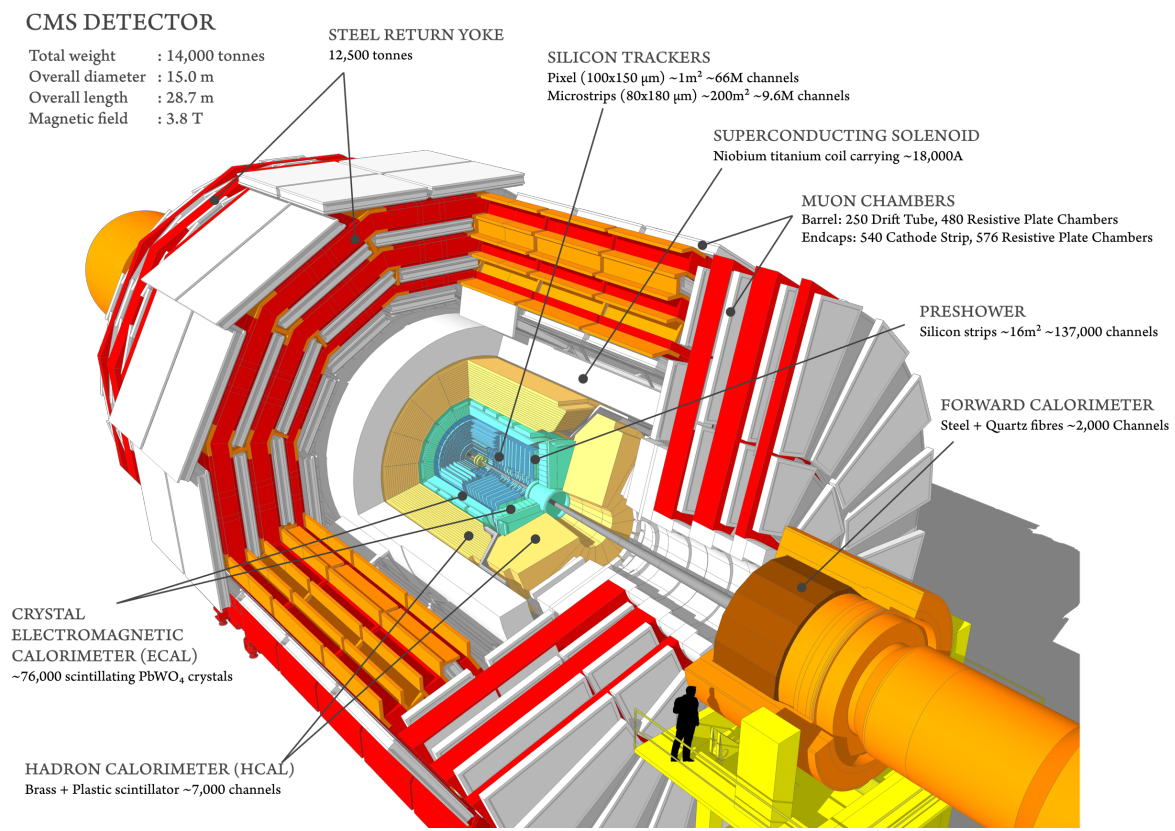


ATLAS covered in talk by K. Behr

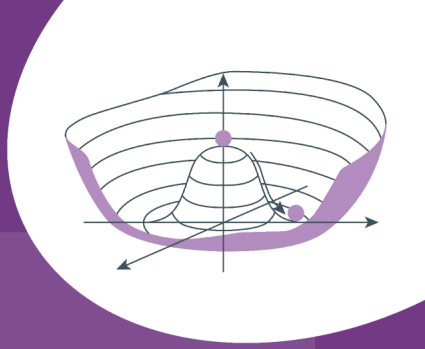


CMS experiment in Hamburg

- **UHH and DESY have large groups working in CMS**
  - O(200) people on campus
  - largest site outside CERN
- **major contributions to all aspects of the experiment**
  - operation
  - computing
  - analysis
  - building subdetectors
  - management
  - ...



Higgs/DM: CMS people in QU



Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

CLUSTER OF EXCELLENCE
QUANTUM UNIVERSE

DESY.

Dr. Philip Gadow

Prof. Gregor Kasieczka

Prof. Peter Schleper

Prof. Kostas Nikolopoulos

Prof. Christian Schwanenberger

Prof. Elisabetta Gallo

Dr. Andreas Meyer

Dr. Roman Kogler

Dr. Alexander Grohsjean

Dr. Matthias Schröder

Prof. Johannes Haller

expertise in all relevant areas!

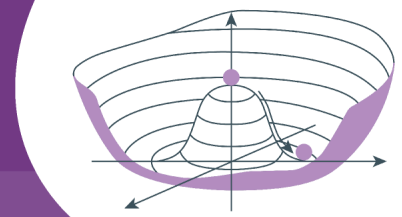
- please contact these people in case of interest in a certain topic
- even if no position is available currently, this might be the case at a later stage

Prof. Freya Blekman

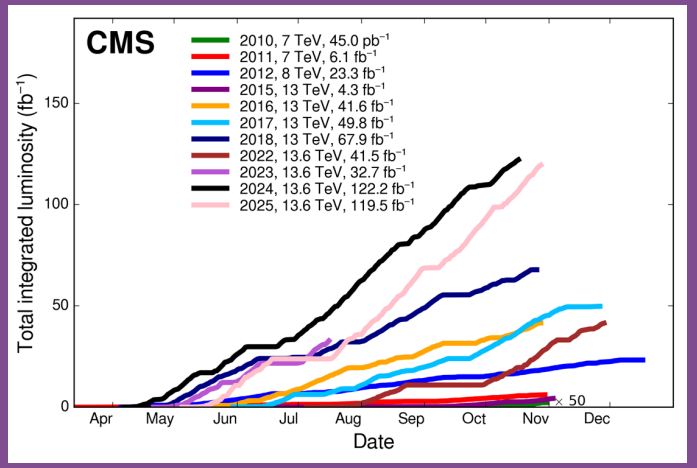
Dr. Julliette Alimena

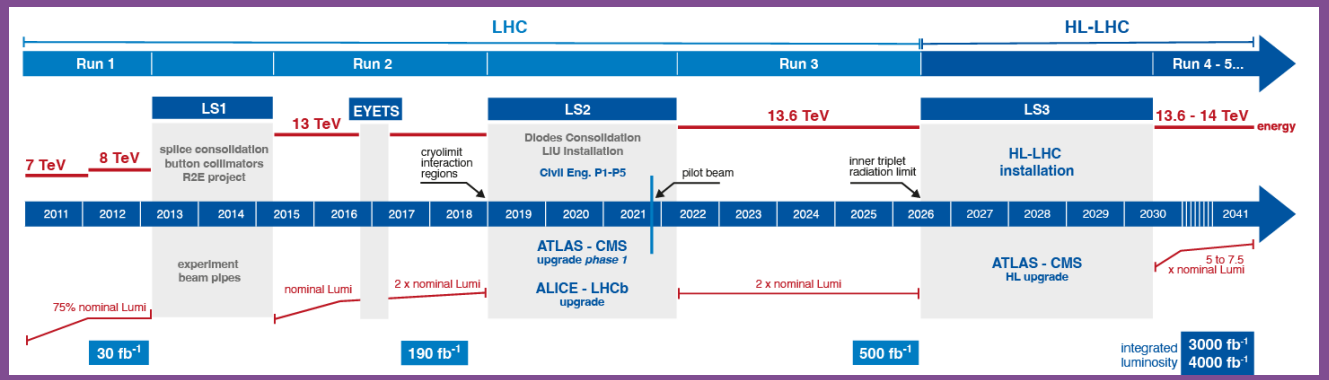
Dr. Andreas Hinzmann

available datasets and schedule



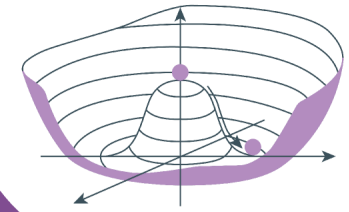
- run3 data-taking ongoing until summer 2026
- large datasets available already
- with a start in 2026 one can analyse the complete run3 data.





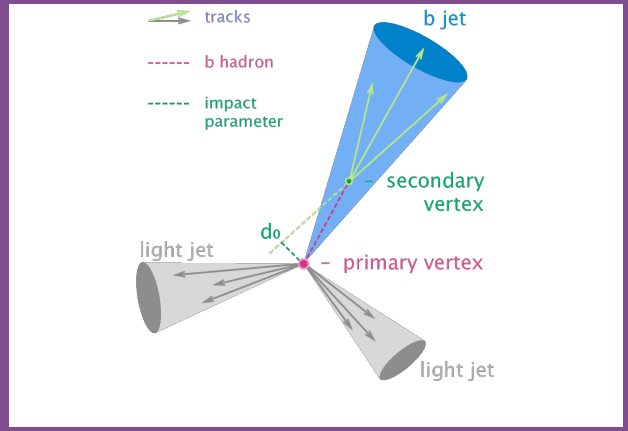
- major contribution to HL-LHC from Hamburg
  - construction of tracker
  - start of data-taking scheduled for 2030

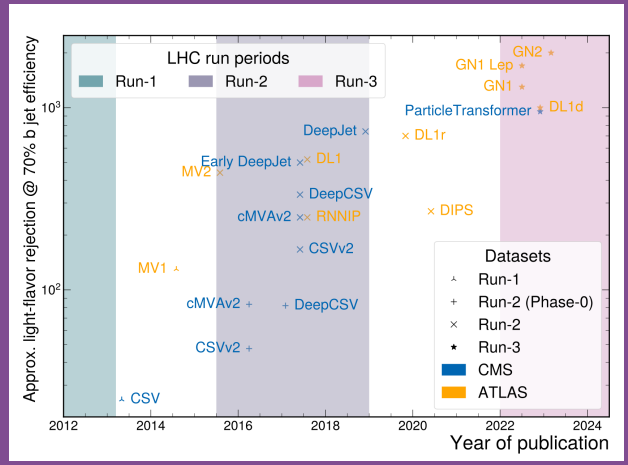
Higgs/DM with CMS: general aspects



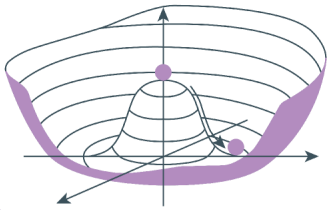
- **CMS Higgs/DM projects in QU:**
  - data analysis of run3 datasets
  - improvement of algorithms
- **focus:**
  - AI related tools
  - interface with theory
- **QU projects:**
  - H.1 ‘Higgs potential’
  - H.2 ‘Higgs and the origin of matter’
  - H.3 ‘Tools and new facilities’
  - DM.3 ‘Dark sector searches at colliders’

e.g. AI progress in b-tagging



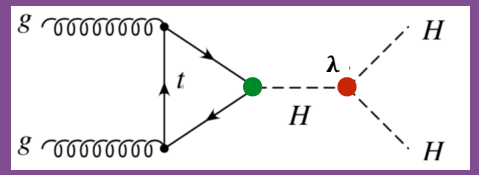


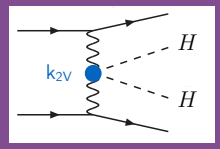
H.1 Higgs potential



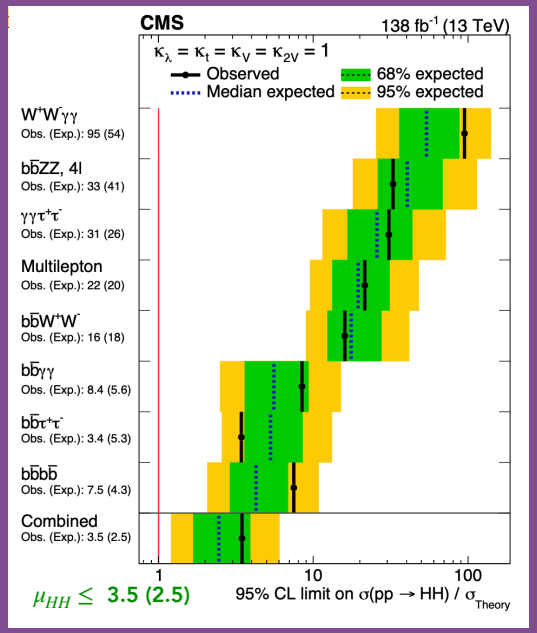
shape of Higgs potential can be measured in Di-Higgs-Production

- very small cross-section at LHC
- very broad program in CMS, many channels

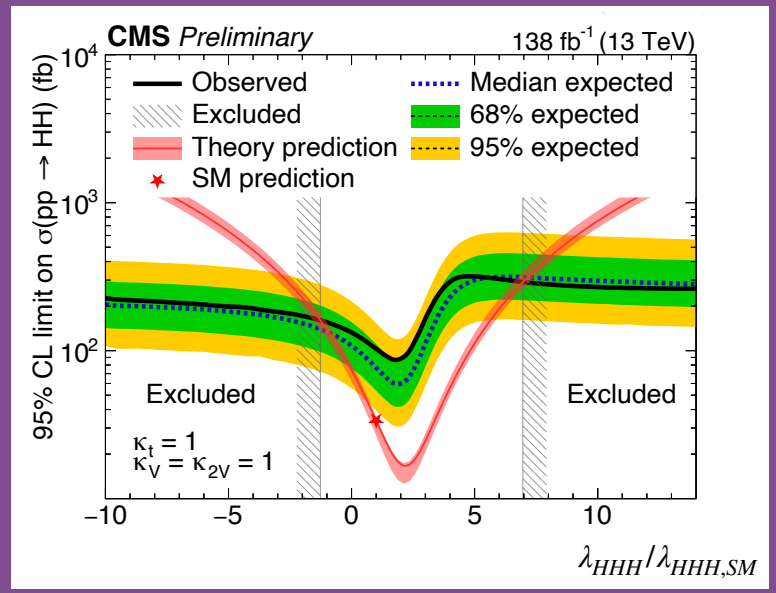




run2 result



run2 result

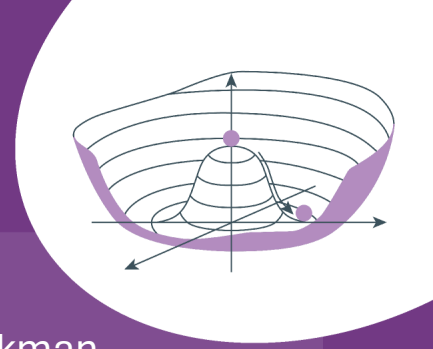


CMS people involved in H.1: E. Gallo, J. Haller, K. Nikolopoulos, P. Schleper, M. Schröder

huge progress expected for run3 and HL-LHC

exploratory study of tri-Higgs-Production

H.2 Higgs and the origin of matter



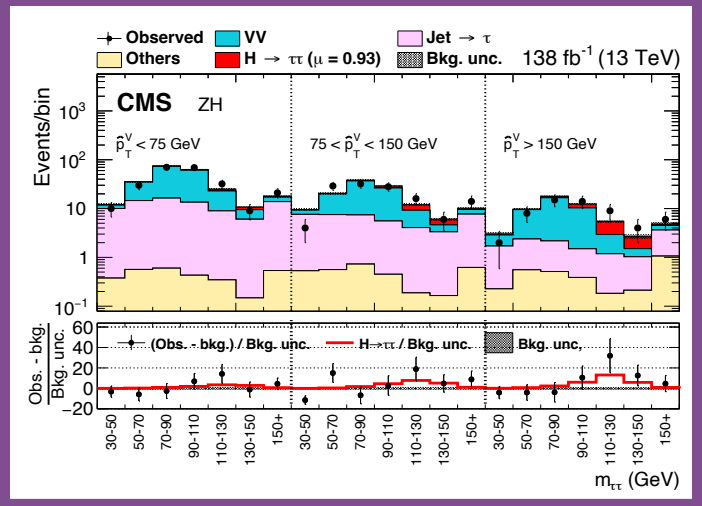
new physics in the Higgs sector?

- DM contribution ?
- CP violation ?
- extended Higgs sectors ?

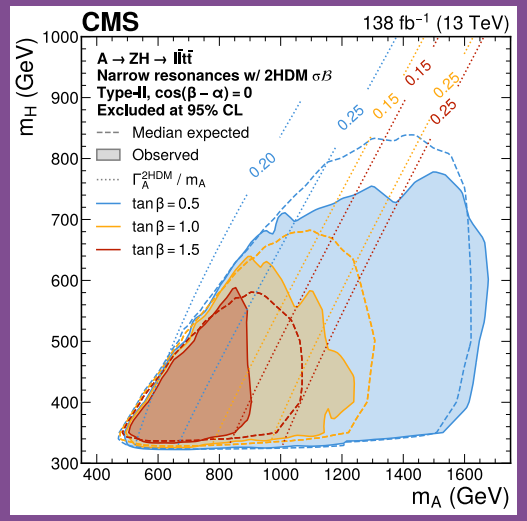
several experimental approaches

CMS people involved in H2.: F. Blekman, E. Gallo, A. Grohsjean, J. Haller, M. Schröder, C. Schwanenberger

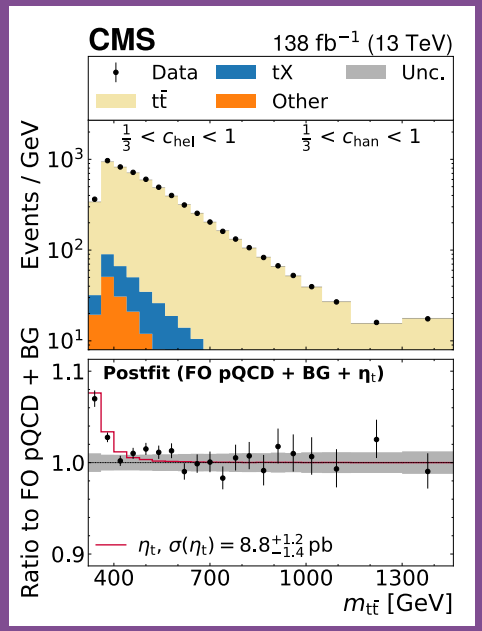
e.g. differential distributions in $H \to \tau\tau$



e.g. search for heavy Higgs

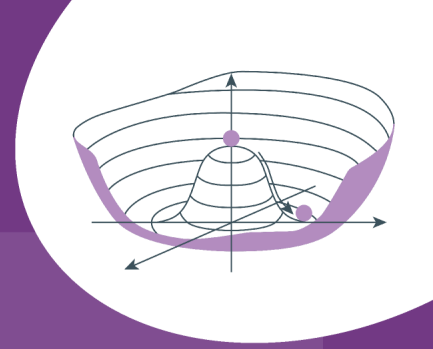


e.g. observation of a new 'particle' decaying to $t\bar{t}$



very interesting options for run3!

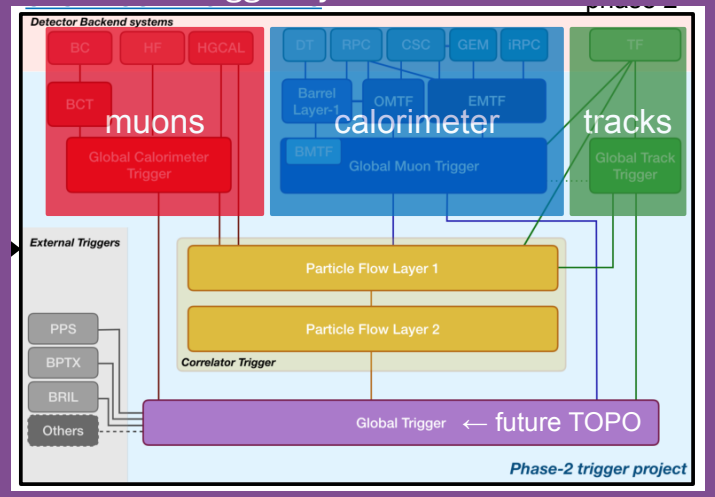
H.3 Tools for Higgs studies



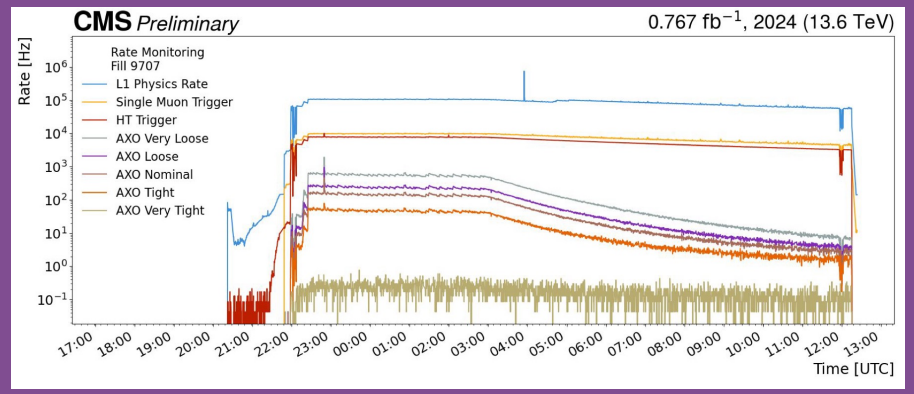
- **CMS L1 Trigger built in FPGA electronics**
- **latest generation: usage of AI based algorithms**
- **test algorithms in run3**
- **huge potential for HL-LHC**

CMS people involved in H.3: F. Blekman, E. Gallo, J. Haller, G. Kasieczka, P. Schleper, M. Schröder

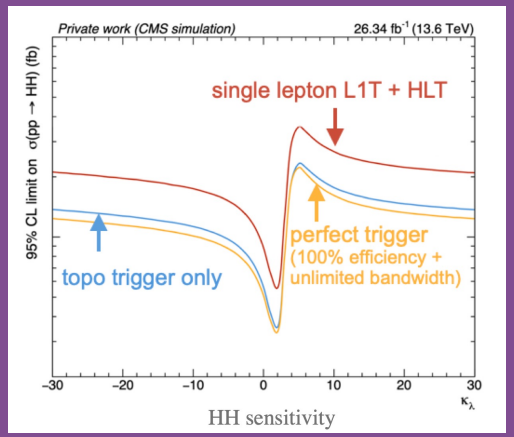
CMS L1 trigger system in HL-LHC



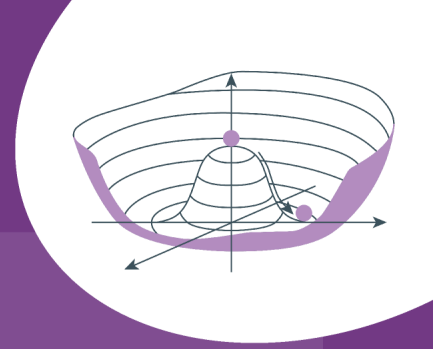
trigger rates of tests in run3 data-taking



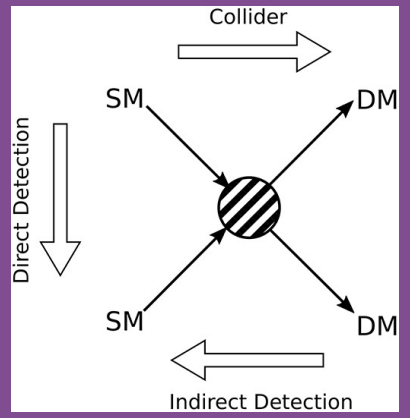
HL-LHC: improved sensitivity by new ML-based triggers



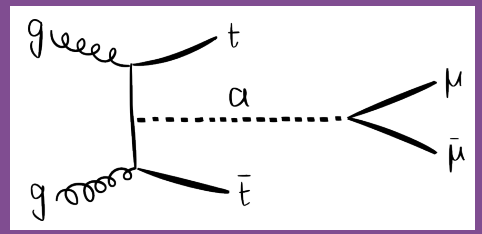
DM. 3 Dark sector searches at colliders



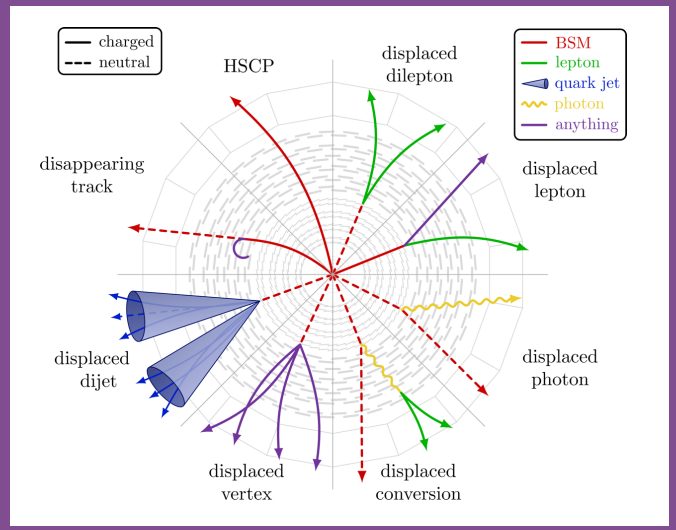
- **DM could be produced at colliders**
- **QU focus:**
  - ALP DM
  - long-lived particles
- **non-standard reconstruction**

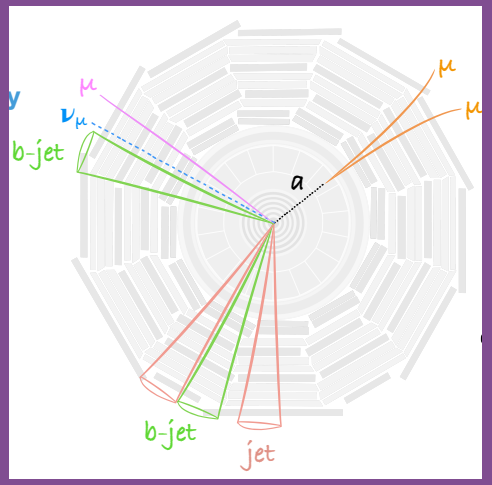


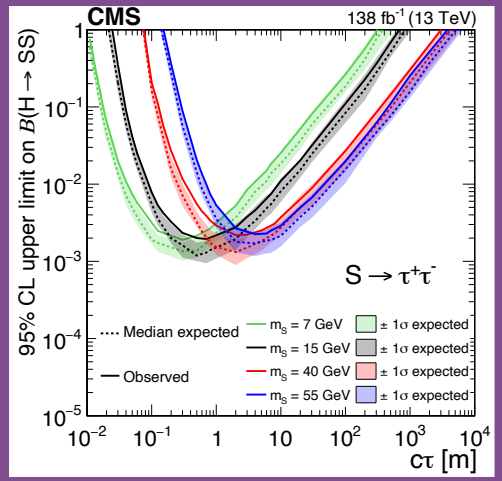
e.g. ALP production in association with $t\bar{t}$



source: tikZ

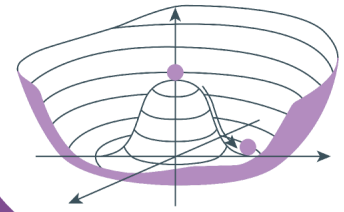




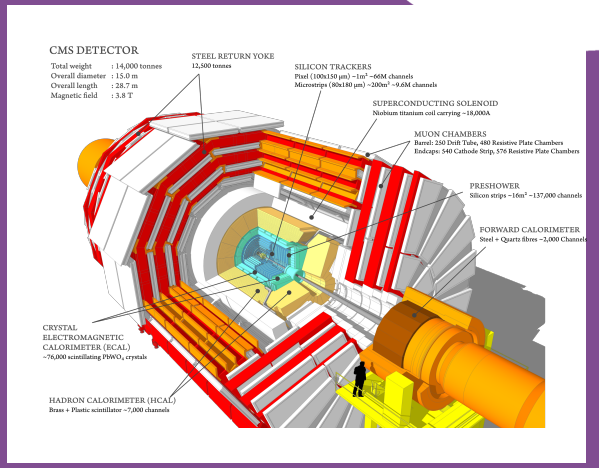


CMS people involved in DM.3: J. Alimena, F. Blekman, A. Grohsejan, J. Haller, G. Kasieczka, K. Nikolopoulos, P. Schleper, C. Schwanenberger

Summary

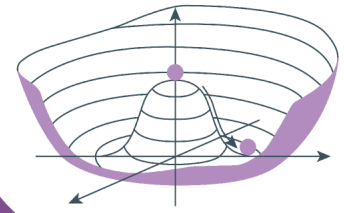


- **CMS expertise on campus is excellent**
- **strong involvement in Higgs and DM physics**
  - broad spectrum of topics in QU
  - datasets with highest sensitivity available now



- **In case of interest: please contact the involved researchers**
  - even if no position is open currently, as this might change quickly

list of open CMS positions in Higgs and DM



project	topic	contact person	level
H.1	**Trilinear Higgs Coupling**	**E. Gallo**	**postdoc**
H.2	**Higgs + DM**	**C. Schwanenberger**	**PhD student**
H.3	**AI for Higgs**	**P. Schleper**	**postdoc**
DM.3	**prompt ALPs**	**C. Schwanenberger**	**PhD student**
DM.3	**long-lived particles**	**G. Kasieczka**	**PhD student**
SMART.2	**signature based triggers**	**J. Haller**	**PhD student**

more positions from other funds might be available within the groups