Physics and Data Analysis

Florencia Canelli, Andrea Rizzi

Induction Course, September 20th, 2021

University of Zurich[UZH]

Istituto Nazionale di Fisica Nucleare

UNIVERSITÀ DI PISA

Outline

- What do we do
  - Measure the products of the LHC collisions
  - Several frontier physics domains
- Organization
  - Physics coordination
  - POGs: Physics Object Groups
  - PAGs: Physics Analysis Groups
  - Shared groups with other Coordination areas
- Analysis: from idea to publication
  - Steps of a physics analysis, from collisions to journal submission
  - Publication Committee
- Getting started with physics analysis

What do we do within Physics Coordination?

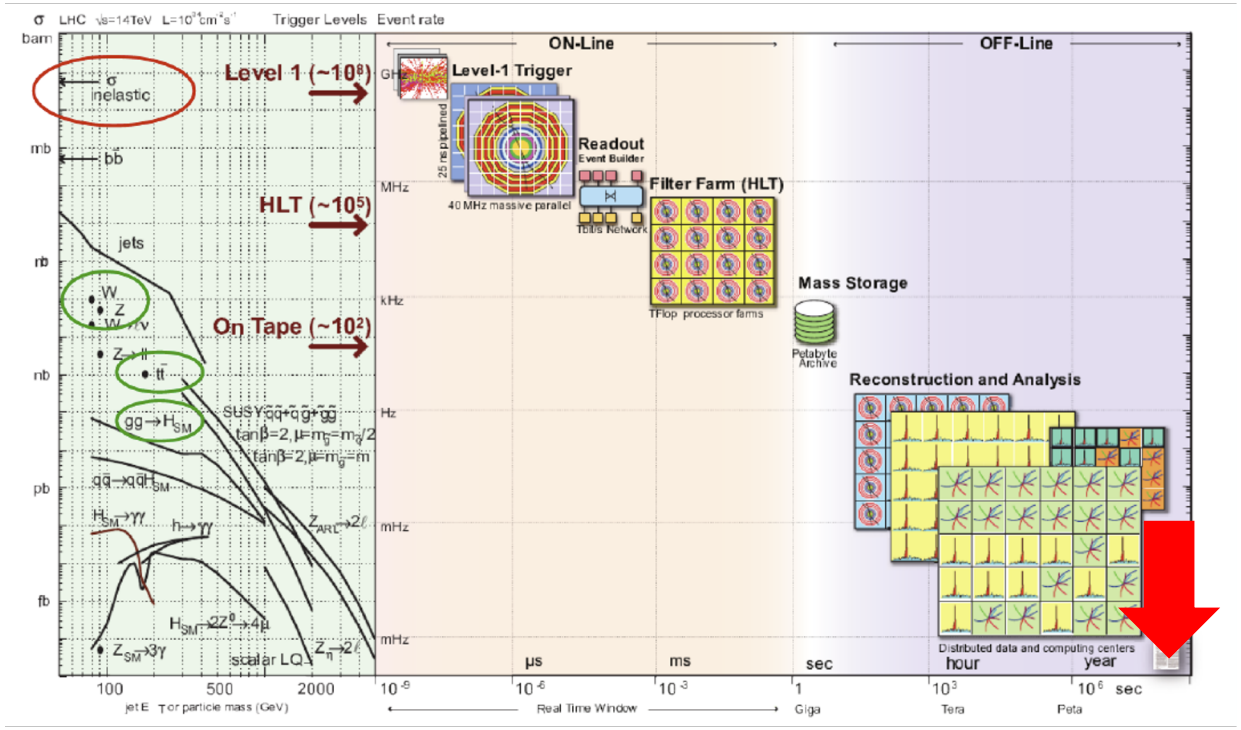
Physics Coordination in CMS

Task: obtain **top level physics results** from the LHC collisions

- Make sure that that the necessary inputs and resources are available (with the other coordination areas)
- Study and optimize the measurement and identification of the products of the collisions
- Cover the essential elements of our physics program, avoiding duplications
- Organize the internal review process

"Physics analysis" is the last step in the chain towards publication:

- The previous steps in the chain are as important or more than this final step, no good physics results without:
  - good detectors,
  - good trigger,
  - and good monitoring and reconstruction,
  - good calibrations

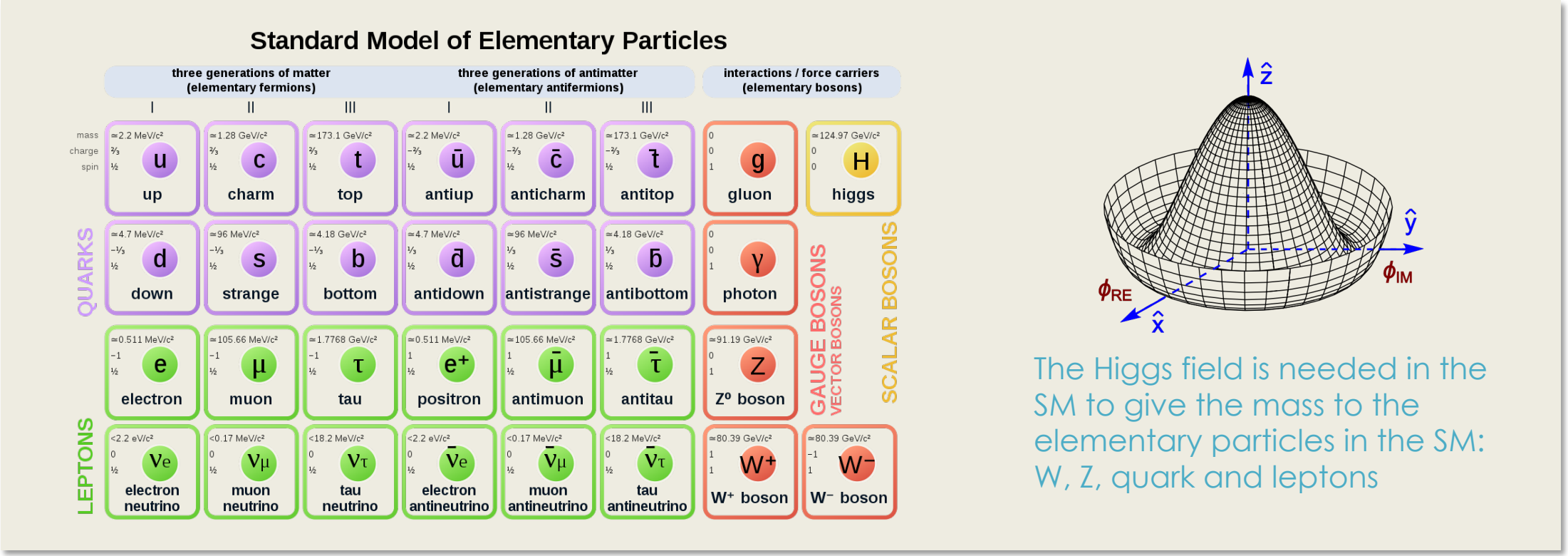


The open questions

The standard model of particle physics

A quantum field theory based on the symmetry $SU(3)\times SU(2)_L\times U(1)$ representing the three fundamental interactions:

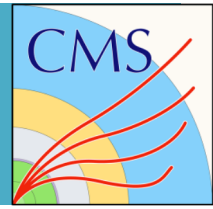
- $SU(3)$: strong Interactions, $SU(2)_L$: weak Interaction, $U(1)$: electromagnetism



The Higgs field is needed in the SM to give the mass to the elementary particles in the SM: W, Z, quark and leptons

- Experimentally tested with superb agreement: the last piece of the standard model (SM) is the Higgs boson, discovered at ATLAS and CMS in 2012

(some) Open questions in particle physics



- SM does not include neutrino masses
- SM does not explain gravitation *(Why is gravity such a weak force?)*
- SM does not accommodate dark matter *(What is dark matter?)*
- SM does not predict many parameters *(Why is the Higgs boson mass 125 GeV?)*
- SM does not explain the unbalance matter in the Universe *(What happened to the antimatter after the big bang?)*
- SM has a peculiar pattern of particles *(Why are there three generations of quarks and leptons with such a different mass scale?)*
- *Do the quarks or leptons have any substructure, or are they truly elementary particles? Is there more exotic physics waiting to be discovered at higher energies? Are there more Higgs bosons? Do we understand the Higgs boson that gives particles mass? …*

The LHC physics program

The LHC physics program aims to answer some of these questions :

- either by direct discovery of new particles
- or with deviations from the SM predictions

Test the SM by making precise measurements of expected parameters and search for new particles and forces that can appear in the collisions

Standard Model

- Ultimate precision measurements and constraints

Higgs boson

- Precise determination of the Higgs boson properties
- Search for new phenomena in the Higgs sector

Direct searches for new physics

- Supersymmetry
- Long-lived particles
- Dark Matter
- Heavy Resonances

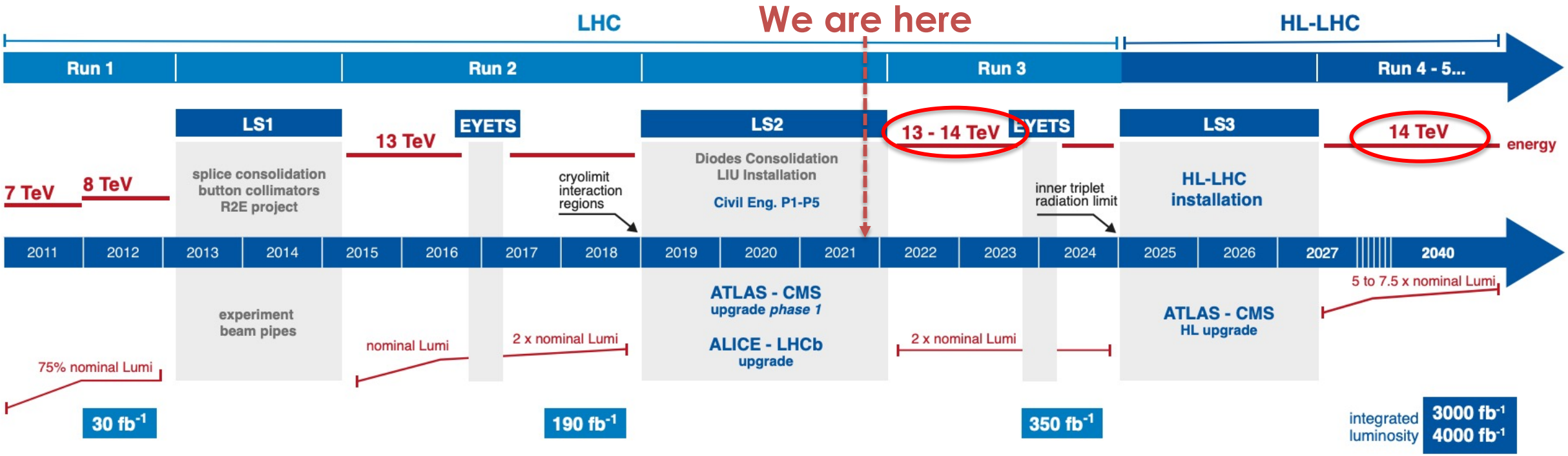
Flavor

- CKM metrology and QCD spectroscopy
- Rare decays

Heavy ions

- Precision study of material properties of QCD media
- Study HI-like behavior in small systems (pp and pA)

LHC luminosity plans



- We are ending a long shutdown (LS2) after a very successful pp run at 13 TeV
- We will have another run at 13-14 TeV starting in early 2022, where at least x2 luminosity
- Then, after a shutdown for major upgrades, in 2026 LHC will start the high-luminosity run (HL-LHC) where the luminosity will increase x10
- **So far LHC has delivered 5% or less of the total planned integrated luminosity!**

Physics Coordination

Physics Coordination

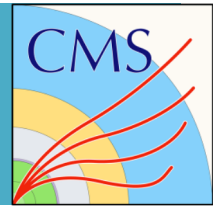
Physics Coordination is managed by 2 co-coordinators (L1)

The organization is comprised of different areas

- **Physics Object Groups (POGs)** in charge of of reconstruction and ID of physics objects
- **Physics Analysis Groups (PAGs)** focused on some specific area of interest
- **Shared groups (SG)** with other coordination areas in charge of reconstruction, simulation, and algorithms
- **Physics office** that support physics coordination in cross-POG coordination, physics communication, and trigger

Cross coordination among PAGs, POGs, and SG relies on **liason or contact people** who represent a given group. The specific mandate depends on the groups. For the POG contacts in PAGs they also review the use objects in the different analyses done in the PAGs

Work Organization in POGs and PAGs



All groups have sub-groups (L3 groups)

- In POG's they mostly address specific areas: Identification, Reconstruction, HLT, etc.
- In PAG's they mostly address specific signatures common to many analyses or needs: leptonic, hadronic, mass, properties, MC production, Trigger, etc.
- They are also the first entry for analysis proposals and follow analyses up to pre-approval stage (see later for more details)
- Groups and subgroups have Hypernews (HN) forums: https://hypernews.cern.ch/HyperNews/CMS/top.pl

All groups have meeting structure (in the CERN afternoon in most cases):

- POG general meetings on Monday every two weeks
- PAG general meeting on Tuesday every two weeks
- **Weekly plenaries** on Thursday: PPD (Physics Performance and Datasets) and WGM (Weekly General Meeting)
- Parallel working group meetings all afternoons, except Thursdays

Have a look at the scheduled meetings in Indico: https://indico.cern.ch/category/6803/overview?period=day
and pay attention to the groups' HN announcements / Twikis

Organization (2021/2022)

Continuing
Incoming

Physics Coordinators
A. Rizzi
F. Canelli

Physics Officers
x-POG: M. d'Alfonso, L. Gouskos
Phys Comm: F. Blekman, K. Mazumdar
Trigger: S. Gennai

MC generators G. Singh Chahal S. Bhattacharya	**e/γ** L. Finco S. Mukherjee	**Muons** S. Sanchez Cruz G. Karathanasis	**SM Physics** G. Gomez Ceballos P. Govoni	**Higgs** N. Wardle J. Steggemann
Machine Learning G. Kasieczka J.-R. Vlimant	**Jets/MET** H. Kirschenmann C. McLean	**B-tagging & Vtx** S. Mitra J. Allison	**Top** A. Jung K-F. Chen	**SUSY** M. Peruzzi V. Dutta
Particle Flow K. Long J. Pekkanen	**Taus** K. Androsov A.C. Le Bihan	**Tracking** V. Mariani M. Musich	**B physics** S. Polikarpov R. Manzoni	**Exotica** S. Lowette Z. Demiragli
UPSG (until end of Snowmass) A. Savin S. Sekmen	**Luminosity** C. Schwick J. Knolle	**Protons** K. Shchelina M. Pitt	**Heavy Ions** Y. Kim A. Stahl	**Beyond 2 Gen.** A. Hinzmann D. Pinna

Offline & computing

PPD

Upgrade

Shared groups ***POGs*** ***PAGs***

Organization (2021/2022)

Florencia Canelli
(U. Zurich)

Andrea Rizzi
(Pisa & INFN)

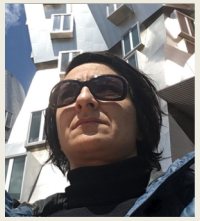
Contact: cms-physics-coordinator@cern.ch
More information: Webpage
Announcements: Hypernews

Physics Coordinators
A. Rizzi
F. Canelli

Physics Officers

x-POG:	M. d'Alfonso, L. Gouskos
Phys Comm:	F. Blekman, K. Mazumdar
Trigger:	S. Gennai

X_POG office



Mariarosaria D'Alfonso
(MIT, US)

Loukas Gouskos
(CERN)

Physics communication office

Freya Blekman
(DESY &Hamburg, DE)

Kajari Mazumdar
(TIFR Mumbai, IN)

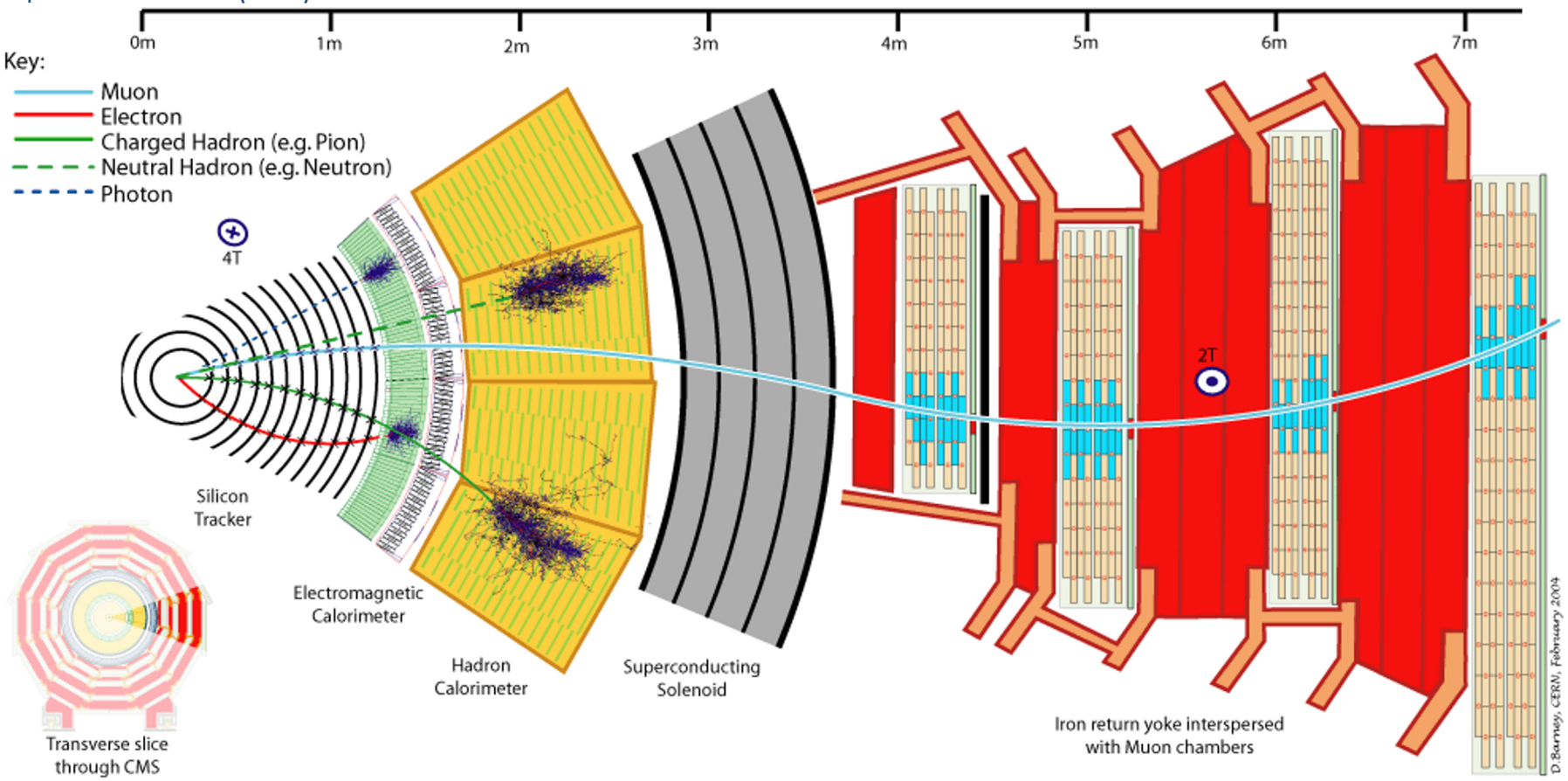
Trigger office

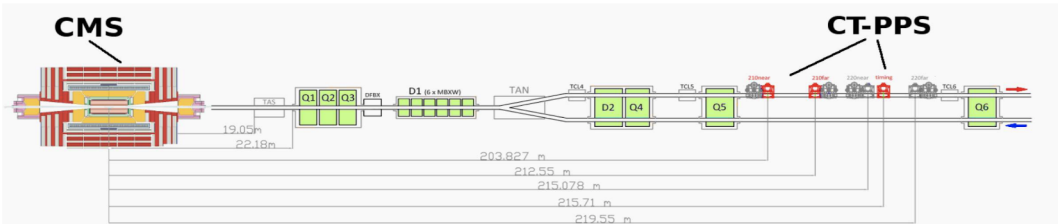
Simone Gennai (Milano, IT)

Physics Objects Groups

Physics Object Groups (POGs)

Most particles are directly detected, identified and their four vector is measured, including forward protons in the Precision Proton Spectrometer (PPS)





POGs are in charge of reconstruction and ID of physics objects **(e/γ, μ, τ, jet/MET, b/c-jets, tracks, luminosity, protons)** – **8 POGs**

- Work closely with Trigger, Offline, PPD and Detector Performance Groups (DPG)
- Study, develop, characterize and validate the tools to identify and reconstruct objects using all the information available from the CMS detector, both for the offline analysis and for the online event selection
- Provide official recipes and recommendations on how to optimally use our objects

Calibrations and scale factors

There are many needed **alignment and calibrations**:

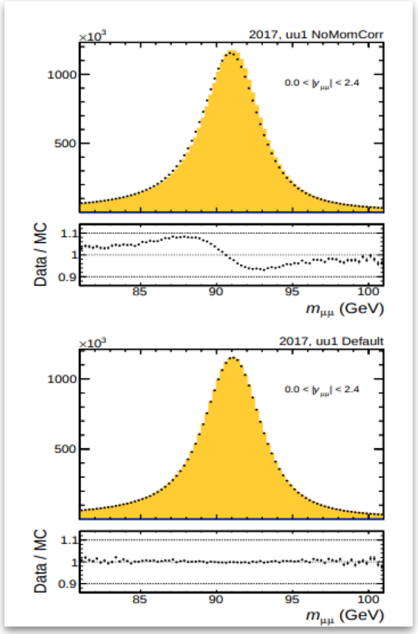
- at detector level (e.g. tk aligment, ecal transparency correction)
- at physics object level (e.g. Jet Energy Scale, muon momentum scale)

Scale Factors (SF) and/or efficiencies are computed to correct MC wrt data

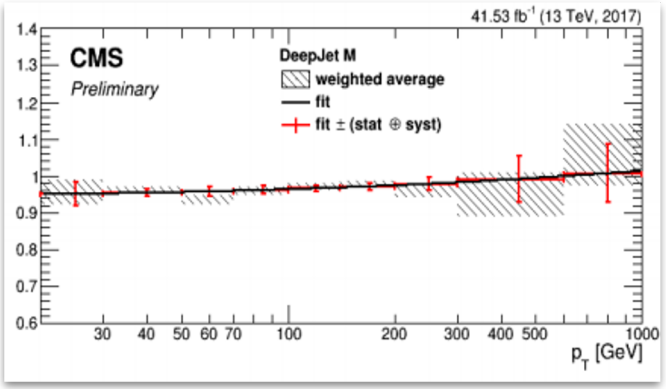
- ID/Tag efficiency, trigger eff, resolutions

Most CMS physics analyses rely on POGs to obtain them

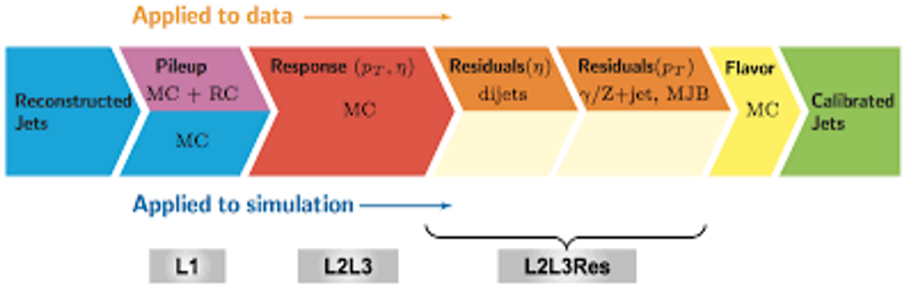
Muon Scale

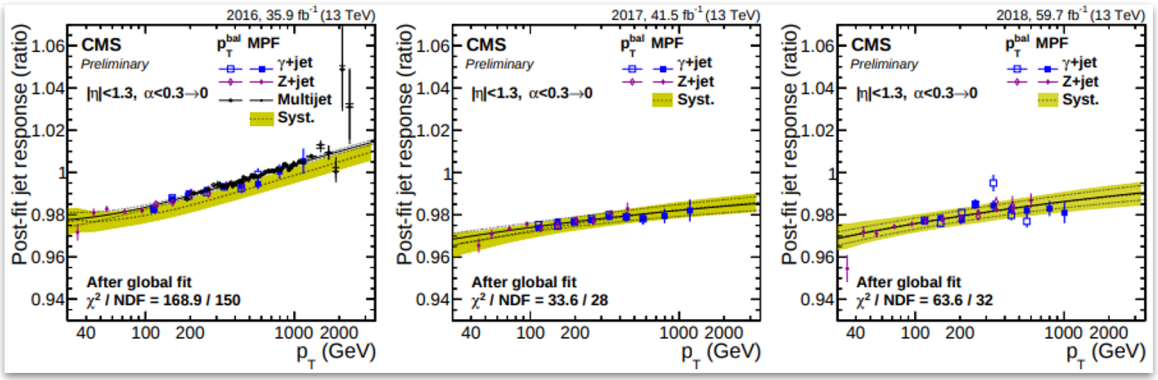


b-tag Data/MC Scale Factor



Jet Energy Scale





EGM POG, electrons and photons

The E/gamma POG coordinates the work on the development of:

- **reconstruction algorithms for electron and photon** objects starting from standalone ECAL reconstructed objects (e.g. SuperClusters)
- standardized tools **for electron and photon identification**
- algorithms to distinguish photons from pi-zeros
- **HLT algorithms for electrons and photons**, and the optimization of trigger paths, rates and efficiencies
- techniques to measure **trigger and reconstruction efficiencies** using data

Meetings: ODD weeks Monday, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/1305/
Subgroups: HLT, ID, RECO
Information: Twiki, hypernews, mattermost
Contact: cms-phys-conveners-egm@cern.ch

Conveners (2021/22)

Swagata Mukherjee (Aachen, DE)

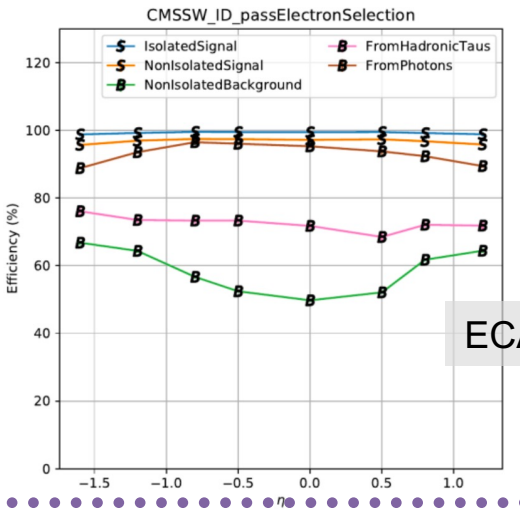
Linda Finco (Nebraska, US)

EXAMPLE

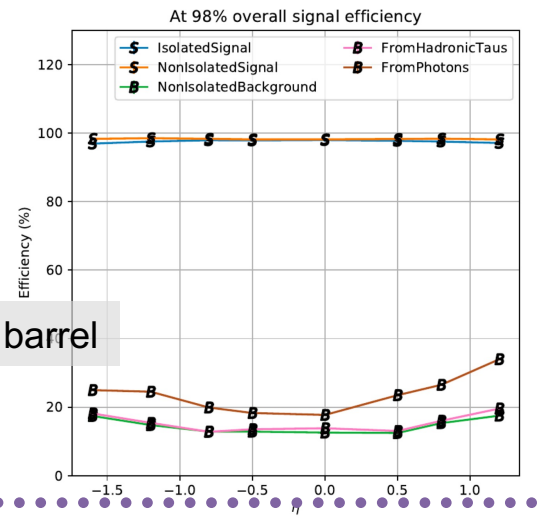
Particle flow e/gamma ID:
Current Trained during Run 1 – not optimal for Run 3

Significant improvement with new DNN based technique.
Similar improvement in the endcaps

Run 2 approach



DNN-based approach for Run 3



ECAL barrel

Many open tasks available in each of the subgroups for newcomers

MUO POG, muons

The charge of the MUO POG includes

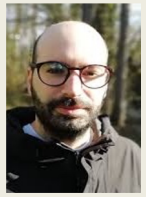
- Improvement of the **muon reconstruction** efficiency
- Optimizing the **muon selection**
- Calibrating muon momentum and **efficiency** and derive **corrections**
- Reviewing the correct usage of muon object in CMS
- Data certification (on the periods with beams) and MC validation
- **HLT muon reconstruction** and related measurements

Meetings: EVEN weeks Monday, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/1306/
Subgroups: HLT, Calibration/Commissioning, Offline RECO
Offline DQM, Data certification and Validation
Information: Twiki, hypernews
Contact: cms-phys-conveners-muo@cern.ch

Conveners (2021/22)

Georgios Karathanasis (Boulder, US)

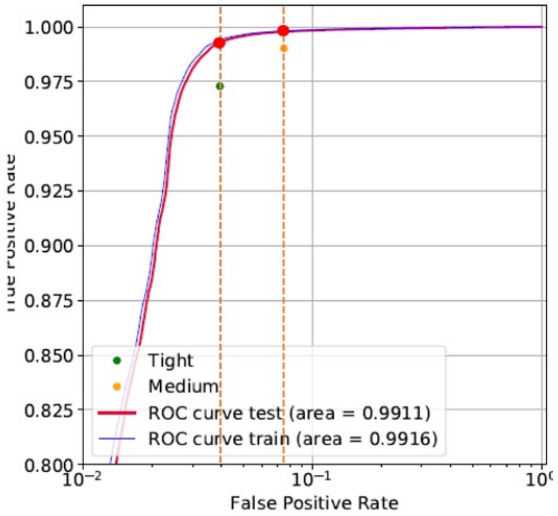
Sergio Sanchez Cruz (U. Zurich, CH)

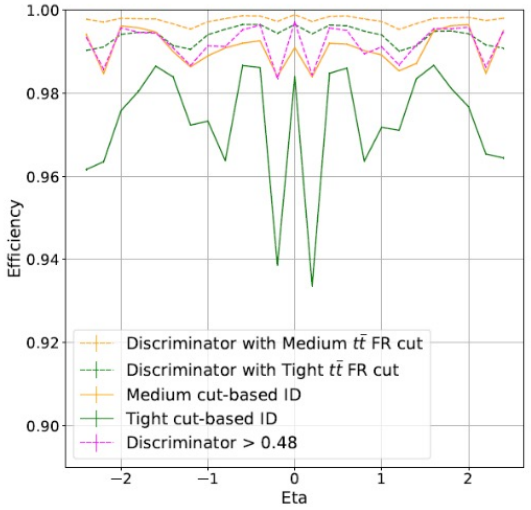


EXAMPLE

New MVA IDs are being developed for Run 3 to replace cut-based IDs

Remarkable performance gain, up to 2% efficiency gain for the same fake-rate





Many open projects for newcomers

- Machine Learning in DQM
- Implementation of fast validation code
- Reconstruction of displaced muons
- Improvement of PF muon selection
- Scale Factors for Run 3 ID and HLT
- NanoAOD code development
- Studies on automation of fits
- Displaced muon resolution
- Multidimensional efficiency measurements

….

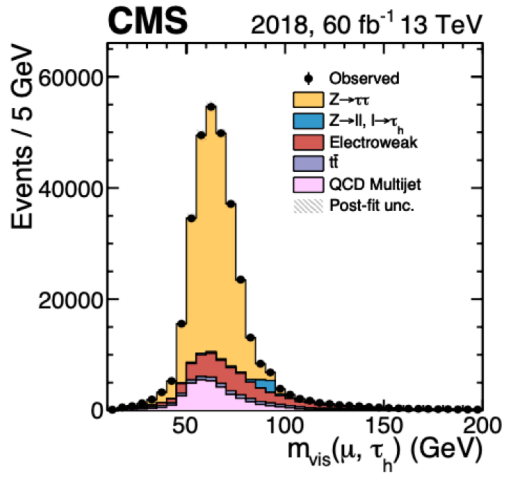
TAU POG, tau leptons

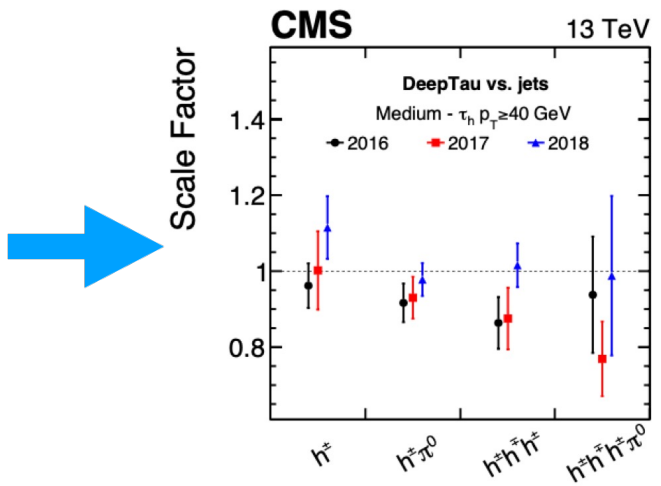
The Tau POG is responsible for studying, developing and validating tau reconstruction and identification algorithms, both offline and online (HLT) and for developing tools for these purposes

Major tasks are:

- Offline tau **reconstruction and identification**
- Tau reconstruction in the **HLT and Tau L1 trigger**
- Strategies for **efficiency, energy scale, and resolution** measurements using data and MC
- Tau DQM, run certification, and release validation

EXAMPLE





Meetings: ODD weeks Monday, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/6330
Subgroups: ID, Trigger, Validation, Validation HLT, Reco/AT, Phase II, MC
Information: Twiki, hypernews
Contact: cms-phys-conveners-tau@cern.ch

Conveners (2021/22)

Anne-Catherine Le Bihan (Strasbourg, FR)

Konstantin Androsov (ETHZ, CH)

Current available activities

- ML-based offline tau id for Run 3 and Phase 2 for resolved and boosted tau topologies
- ML-based reconstruction for prompt and displaced tau decays
- Introduction of ML techniques for online tau ID at various HLT stages
- Measurements of identification scale factors (genuine τ_h, jets, electrons, muons) and τ_h energy scale from $Z \rightarrow \tau_h\tau_h \rightarrow \tau_h\mu$ and $W^* \rightarrow \tau_h\nu$ events
- Data driven $Z \rightarrow \tau\tau$ events, from embedded $Z \rightarrow \mu\mu$ events → better description of jets, pile-up, as well as detector noise and resolution effects

TRK POG, tracking

The TRK POG develops, validates, and maintain the general tools to reconstruct trajectories of charged particles. Some of the group mandate:

- Develop software for **offline and HLT tracking reconstruction**
- Develop tools for track finding, fitting, and optimization of tracking efficiencies and fake rates
- Determine tracking **efficiency, momentum scale and resolution** on parameters of charged-particle tracks from real data
- Define **selection of tracks** and guidelines to be used in other POGs/PAGs
- Reconstruct **primary vertices** (shared with BTV POG), **beam-spot**, **V0 reconstruction** and **online primary vertex finding**

Important opportunities to collaborate with the TRK POG

- **DeepCore** -> tracking inside Jets. Activity already started, validation and further developments are needed
- **Data / MC comparison** -> in view of Run3 a systematic and solid workflow will be crucial

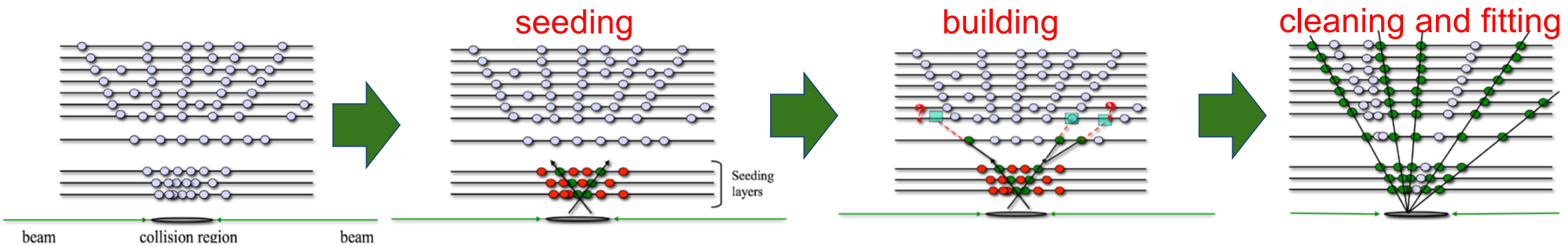
Meetings: ODD weeks Monday, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/2029/
Subgroups: Offline and reconstruction, software validation (SIM), software validation (Data), Tracking data certification, HLT
Information: Twiki, hypernews
Contact: cms-phys-conveners-trk@cern.ch

Conveners (2021/22)

Marco Musich
(Nebraska, US)

Valentina Mariani
(Perugia, IT)

Tracking is one of the hardest tasks in the reconstruction software



JME POG, jets and MET

The JME (or JetMEt) is responsible for coordinating

- the development of algorithms for **jet reconstruction**, **jet substructure, and pile-up subtraction for jets and MET**
- the derivation of **jet energy and MET scale and resolution corrections** to bring agreement between MC and associated systematic uncertainties data
- the **software application tools** related to jet and MET objects
- the effort to promptly **monitor the jet and MET** objects during data taking providing run certification results
- the reconstruction, calibration of the jets and MET in the **HLT**, as well as the validation of their performance

Meetings: EVEN weeks Monday, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/1308/
Subgroups: JMAR, JERC, MET, JetMet DQM, JetMet Trigger
Information: Twiki, hypernews, Mattermost
Contact: cms-phys-conveners-jetmet@cern.ch

Conveners (2021/22)

Christine McLean
(Buffalo, US)

Henning
Kirschenmann
(Helsinki, FI)

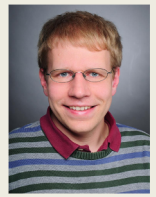
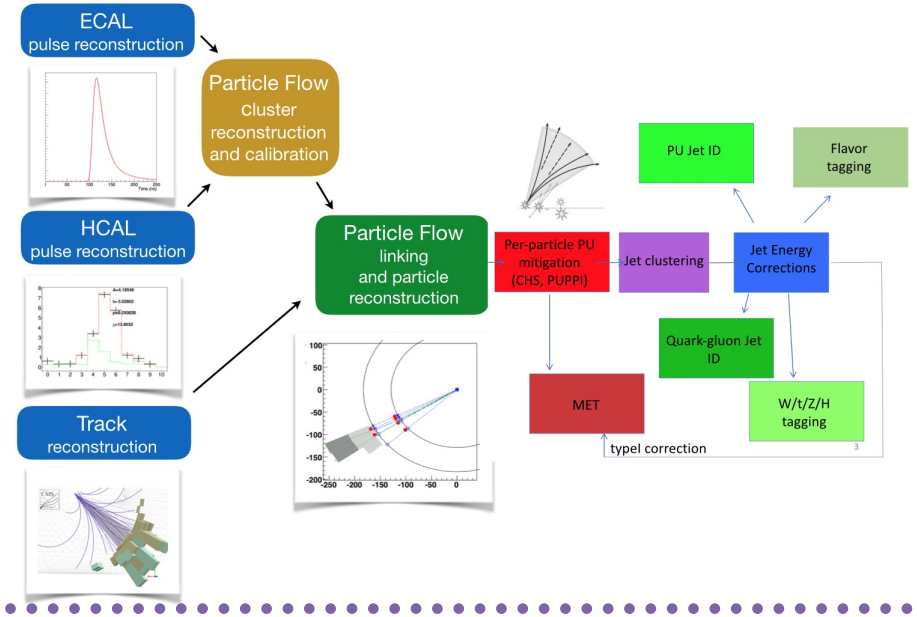


Diagram of jet and met ID, reconstruction, and corrections



Many open tasks needing person-power

JERC (Jet Energy Resolution and Corrections)
Jet energy resolution scale factors in Z+jets events; Jet energy corrections for HEM mitigation; R&D for JERC workflow automation with coffea (columnar analysis framework)

JMAR (JetMET Algorithms and Reconstruction)
Pileup Jet ID - used for pileup mitigation; Train the BDT/NN on top of PUPPI for Run 3; Improve existing techniques for Phase-2; include timing information; Quark-gluon tagging; Train the likelihood for Run 3; Contribute to the quark-gluon paper efforts

MET
MET Significance; Overall upkeep of the MET significance tool is needed. Unclustered energy uncertainty component of the algorithm needs to be revisited. Validate significance for PF and Puppi MET; Unclustered Energy Uncertainty; Update variations related to unclustered energy on individual PF candidates (update of resolution functions, full validation, code development); Uncertainty correlation study; Detailed studies of correlation between years, mostly focusing on unclustered energy, but also the propagation of the sub components of JEC uncertainties.

BTV POG, b-tagging and vertex

This group is responsible for all aspects of b tagging, including

- **algorithm** development
- **performance** measurement with data
- **HLT** and the corresponding online and offline DQM tasks

It is also responsible for **vertex fitting and secondary vertex finding**. It shares responsibility for offline primary vertex finding with the TRK POG.

Meetings: ODD weeks Monday, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/1309/
Subgroups: Algorithms and software, Performance measurement, commissioning and validation, btag@HLT
Information: Twiki, hypernews
Contact: cms-phys-conveners-btag@cern.ch

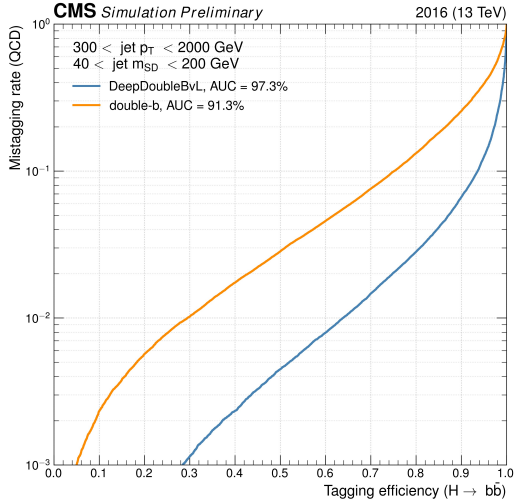
Conveners (2021/22)

John Allison
(Carnegie-Mellon, US)

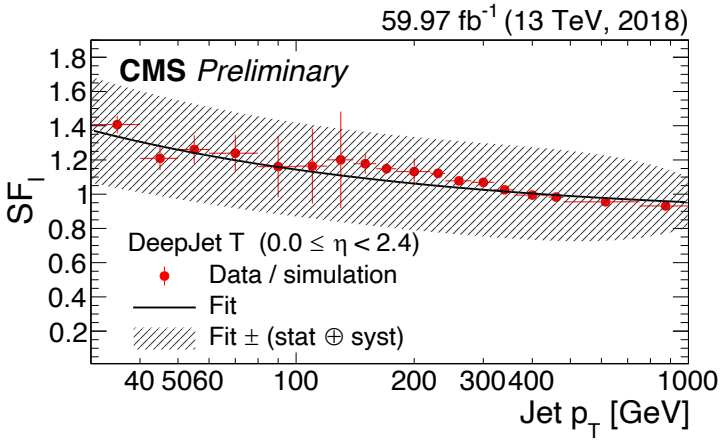
Soureek Mitra
(Karlsruhe, DE)

EXAMPLE

Algorithms to distinguish bb, cc, and light jets use different deep tagging techniques



Calibration scale factors between data and simulation are evaluated for each data period and different b-taggers



LUM POG, luminosity

The LUM POG is in charge of measuring precisely the integrated luminosity

- Important input for all physics analyses: largest uncertainty in many inclusive cross sections
- Precision ~2.5% in Run 1 and Run 2
  - Now improved to 1.2 % for 2016 (other years in progress)

Difficult enterprise. No availably physics process with precisely known cross section to compare measurement and theory to extract luminosity (counting Z-bosons is used as a crosss-check)

Method: measure beam properties and then calculate the luminosity

- Special Van de Meer runs are used to measure the shape of the beams. This run is used to calibrate the counting rates of various detectors to the luminosity
- Then extrapolate the calibration to normal data taking conditions… far from trivial

Meetings: EVEN weeks Tuesday, 16:00-17:00 CET
Meeting agendas: https://indico.cern.ch/category/1482/
Information: Twiki, hypernews (hn-operations)
Contact: cms-phys-conveners-lum@cern.ch

Conveners (2021/22)

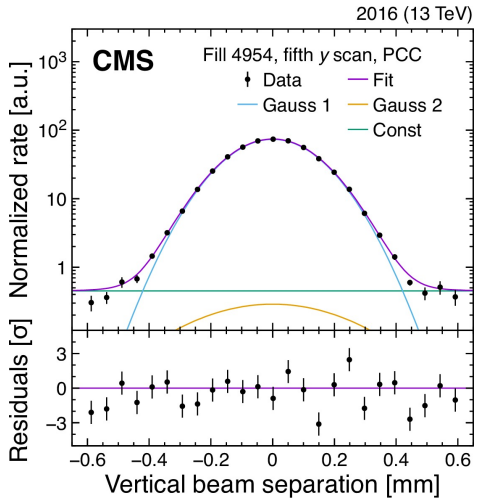
Joscha Knolle (Ghent, BE)

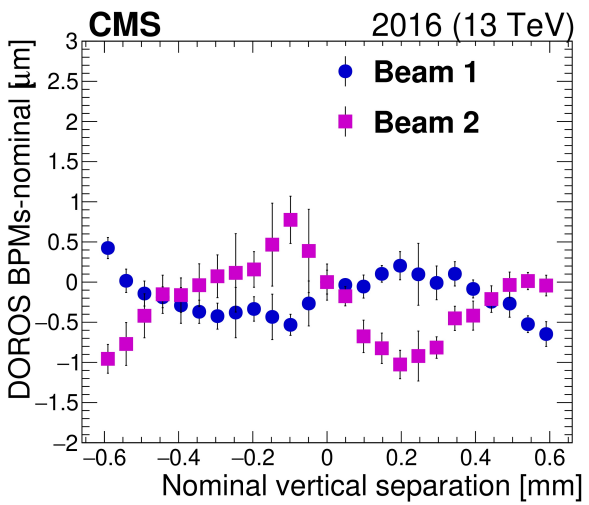
Christoph Schwick (CERN)

EXAMPLE

Measurement of the luminosity recorded by the CMS detector at √=s= 13 TeV during in 2015 and 2016 improved the uncertainty by ~2X

Eur. Phys. J. C 81 (2021) 800





Many interesting open activities where you can learn about

- the beams in the accelerator: the foundation of your physics analysis
- Instruments to measure the beam properties in the LHC
- Many CMS systemats used to measure luminosity

PRO, tagged protons

The aim of the group is to develop and maintain the required tools and algorithms for the **reconstruction and identification of protons detected with the PPS system**, study their performance and review their usage across different analyses and PAGs

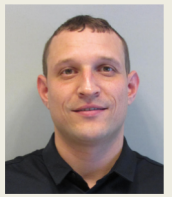
Summary of tasks:

- Proton reconstruction
- RP and beam position alignment
- Optics modelling & calibration
- Proton efficiencies
- Proton timing
- Protons in HLT
- MC development

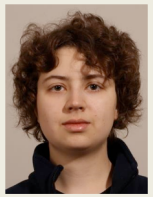
Meetings: ODD weeks Tuesdays, 16:00-17:00 CET
Meeting agendas: https://indico.cern.ch/category/10977
Information: Twiki, hypernews
Contact: cms-phys-conveners-egm@cern.ch

Conveners (2021/22)

Michael Pitt
(CERN)



Ksenia Shchelina
(Torino, IT)



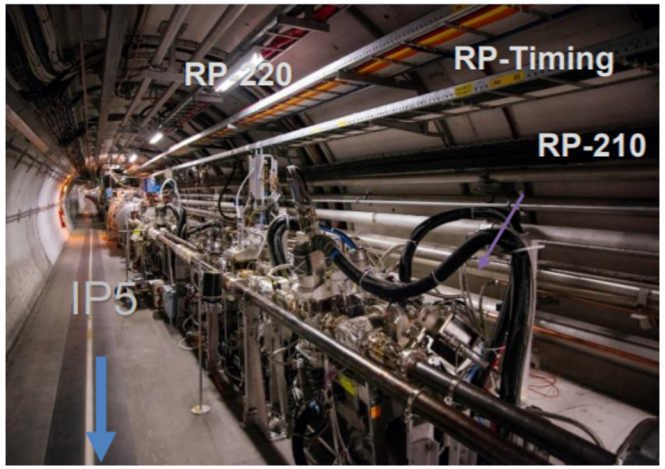
Precision Proton Spectrometer (PPS) – a new CMS sub-detector since 2016

Located in LHC tunnel ±200m from the Interaction Point (IP)

Comprises tracking and timing detectors

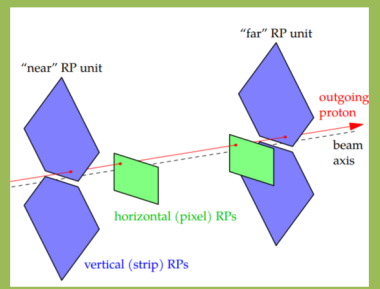
- While PPS is the farthest detector from the IP, it is the nearest detector to the LHC beam (~2mm), operated inside the LHC vacuum at high irradiation rates

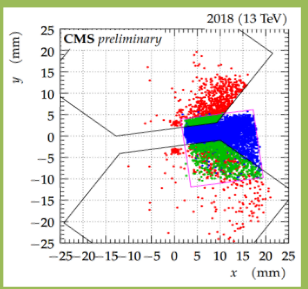
- Reconstruct protons with p_T between 5.5TeV to 6.3TeV(!)



Many opportunities within the PRO POG:
Alignment, estimation of radiation damage, simulation using LHC optics…

Alignment is done using special LHC fills





XPOG, cross physics objects office

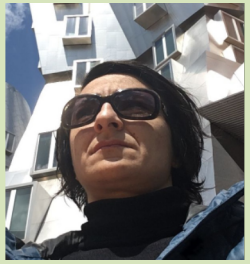
The XPOG is a forum where the the activities relevant for the development, maintenance and use of analysis data-formats are discussed allowing different POGs and PAGs to keep up to date with major changes in other groups. The activities overseen by the Cross-POG Forum include:

- Coordinating the integration and prioritization of new features from the output of the local reconstruction to the final quantities provided to the PAGs in MiniAOD/nanoAOD format
- Propagate "recipes" for object identification, isolation and calibration in a coherent way to all possible data tiers
- Prioritize the preparation of re-reco, re-miniaod and nanoAOD campaigns
- Define the MiniAOD/nanoAOD content balance point;
- Keep track and document the feature set and changes of each MiniAOD/nanoAOD campaign
- Interact with PPD and Offline/Computing projects in defining the "must have features" /"analyses needs" for processing campaigns and prompt reco deployments (this includes providing physics inputs for defining schedules, validation and releases strategies with PPD and Offline based on the PC inputs)

Meetings: Wednesdays every 3 weeks, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/5517/
Information: Twiki, hypernews
Contact: cms-phys-officers-xpog@cern.ch

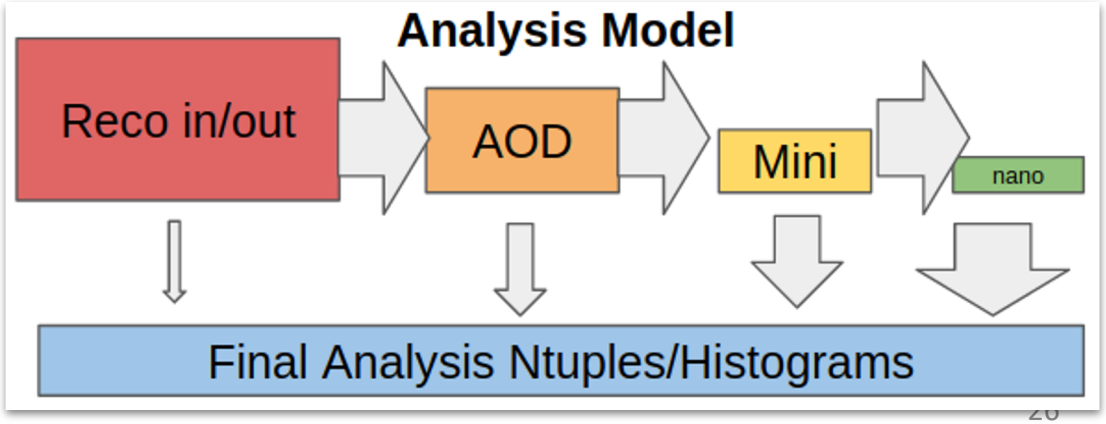
Officers (2021/22)

Mariarosaria D'Alfonso (MIT, US)



Loukas Gouskos (CERN)

Data Tier for analysis: AOD, MiniAOD, NanoAOD



Physics Analysis Groups

Physics Analysis Groups (PAGs)

There are **8 PAGs** in order to cover the large CMS physics program

In each specific area, the goals of the PAGs include

- Coordinate physics analysis
- Follow and review analyses
  - Make sure all (POG, SG, StatComm, etc.) recommendations are applied and participate in forming them (through object expert contacts)
- Help defining Trigger strategies and Monte Carlo needs for pursuing analyses
  - Provide, together with POGs, the person-power to propose and implement the High Level Triggers
- Approve all public output in the group: conference reports, PAS, twiki pages

Standard Model: SMP and TOP

- Ultimate precision measurements and new physics constraints
- Establish SM processes

Higgs boson: HIG PAG

- Precise determination of the Higgs boson properties
- Search for new phenomena in the Higgs sector

Direct searches for new physics: SUS, EXO, B2G PAGs

- Supersymmetry
- Long-lived particles
- Dark Matter
- Heavy Resonances

Flavor: BPH PAG

- CKM metrology and QCD spectroscopy
- Rare decays

Heavy ions: HIN PAG

- Precision study of material properties of QCD media
- Study HI-like behavior in small systems (pp and pA)

SMP PAG, standard model physics

The SMP PAG studies different standard model processes with the goals of **extracting properties** such as masses and couplings of known particles with **high precision**. The group performs detailed comparisons of the data with respect to the **QCD and EWK theory predictions**. The SMP PAG aims to improve the understanding and characterization of mundane processes like the underlying events of all collisions and also to measure rarely produced SM processes. The group also studies soft QCD and small-x physics and diffraction & exclusive processes

Meetings: ODD week Tuesdays, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/3886/
Subgroups: SMP-V, SMP-VV, SMP-VJ, SMP-HAD
Information: Twiki, hypernews
Contact: cms-phys-conveners-SMP@cern.ch

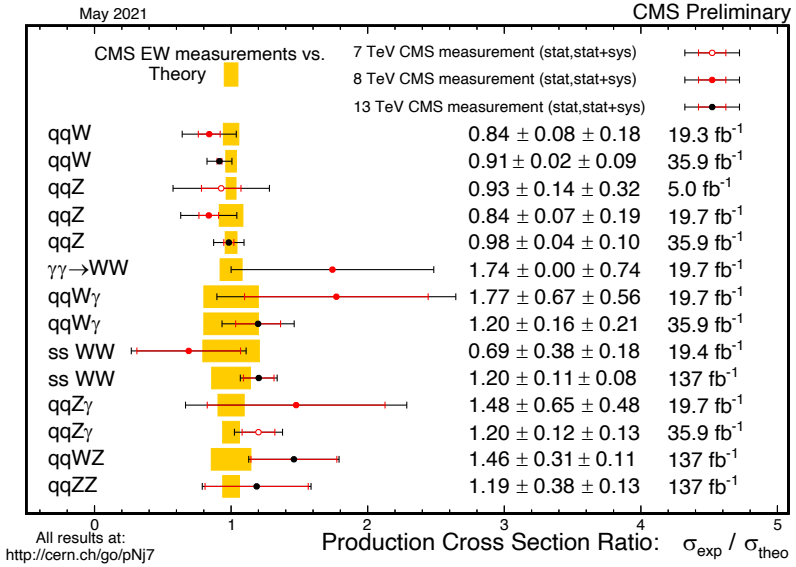
Conveners (2021/22)

Guillelmo Gomez Ceballos (MIT, US)

Pietro Govoni (Milano, IT)

EXAMPLE

Summary of the cross sections of pure Electroweak (EWK) interactions among the gauge bosons presented as a ratio compared to theory.



List of open analyses in different SMP subgroups include a variety of different channels, measurements and methods – and also with early Run 3 data

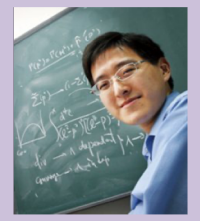
TOP PAG, top quark physics

The TOP PAG is responsible for **precision measurements of the properties of the top quark**, the heaviest particle in the SM. The top-quark mass is one of the most important properties as it is a key parameter for calculations in the standard model. The top group also aims to establish measurements of **rare production modes** of the top quark in association with other particles, and **search for new couplings** of the top quark. TOP also aims to improve our understanding of top quark production and decay processes in order to **improve background predictions for physics searches** beyond the SM

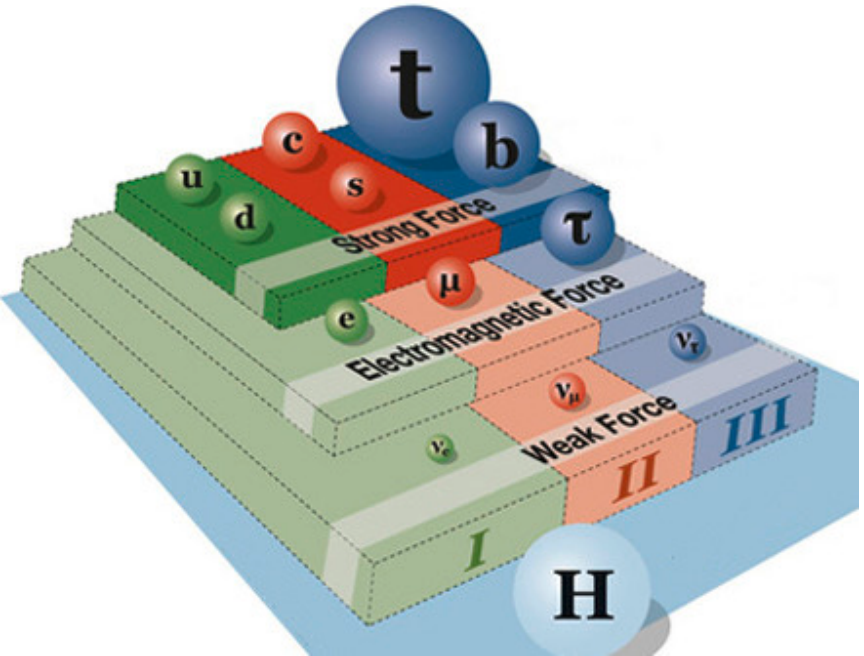
Meetings: EVEN week Tuesdays, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/4628/
Subgroups: Mass&Properties, EFT, EMG, ttX, tX
Information: Twiki, hypernews
Contact: cms-phys-conveners-TOP@cern.ch

Conveners (2021/22)

Jack Chen
(Taipei, TW)



AndyJung
(Purdue, US)



Early Run-3 analyses
Perform the inclusive cross section measurements for standard top quark pair and single top quark production at the new collision energy

- inclusive dilepton ttbar x-sec
- inclusive lepton+jets ttbar x-sec
- inclusive ttW x-sec
- inclusive single top t-channel x-sec
- inclusive tW x-sec

These topics are suitable for newcomers!

HIG PAG, Higgs boson physics

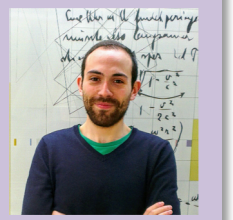
The HIG PAG main goal is to provide a **precise characterization** of the newly discovered Higgs boson, by measuring its mass and couplings to different SM particles, including itself via the production of **diHiggs boson** events. In addition, the HIG PAG searches for **additional Higgs bosons** (charged or neutral) in extended Higgs sectors, and for Higgs boson **rare and exotic Higgs boson** decays

Meetings: EVEN week Tuesdays, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/26/
Subgroups: Extended Higgs, Rare/Exotic Higgs, Hphotons, Combination/EFT, HWW, H2tau, Hbb, HZZ, Future
Information: Twiki, hypernews
Contact: cms-phys-conveners-HIG@cern.ch

Conveners (2021/22)

Jan Steggemann
(ETHZ, CH)

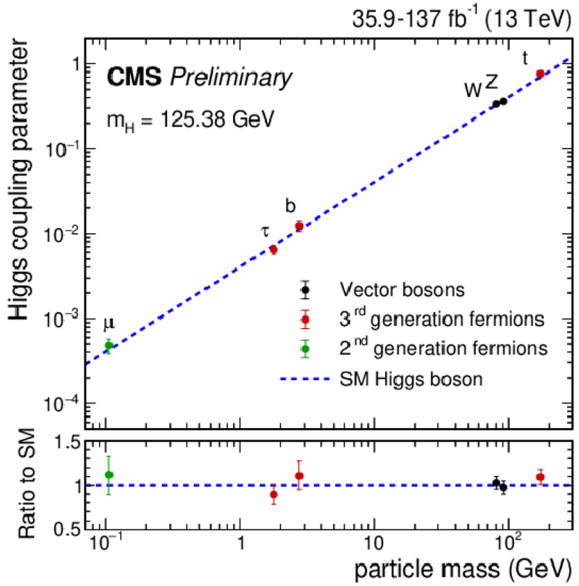
Nick Wardle
(IC London, UK)



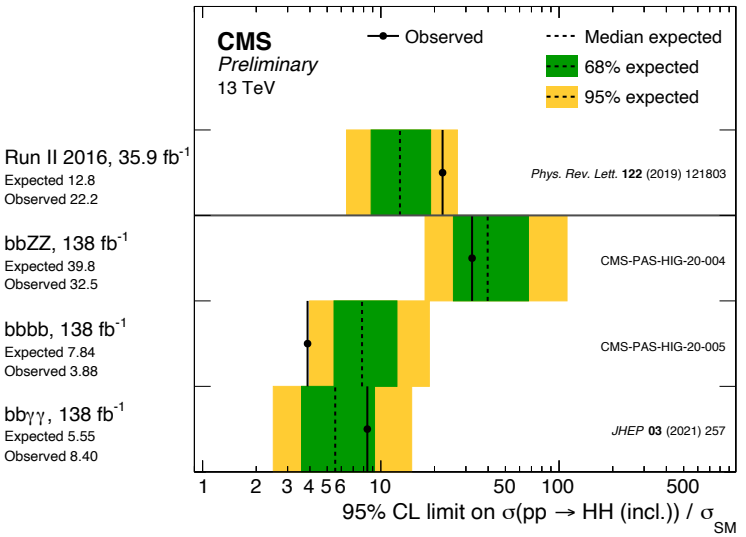
EXAMPLE

Working on all full Run 2 data, some analyses already completed

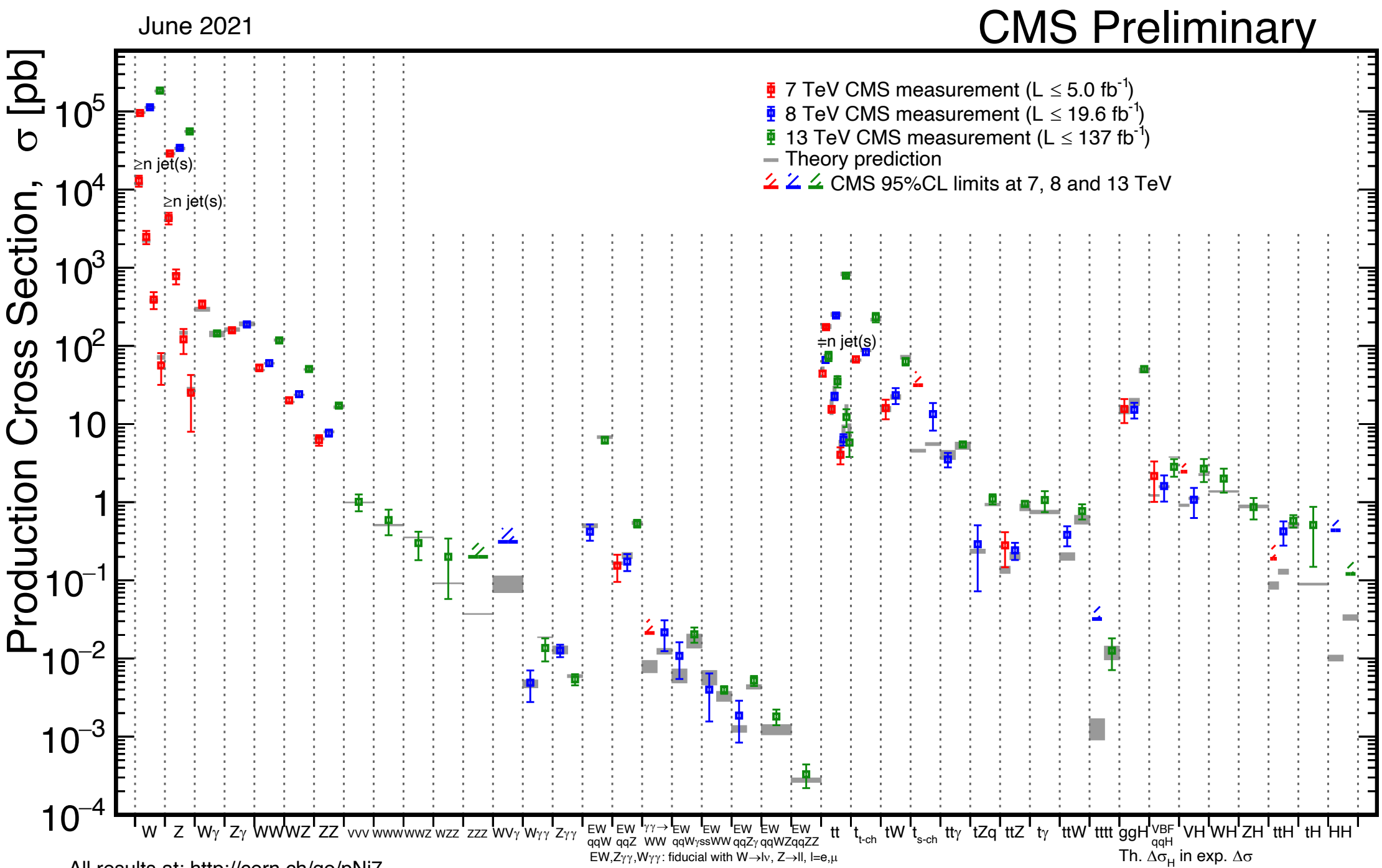
Recent first evidence of Higgs decay to pairs of muons



Improving reach to diHiggs production

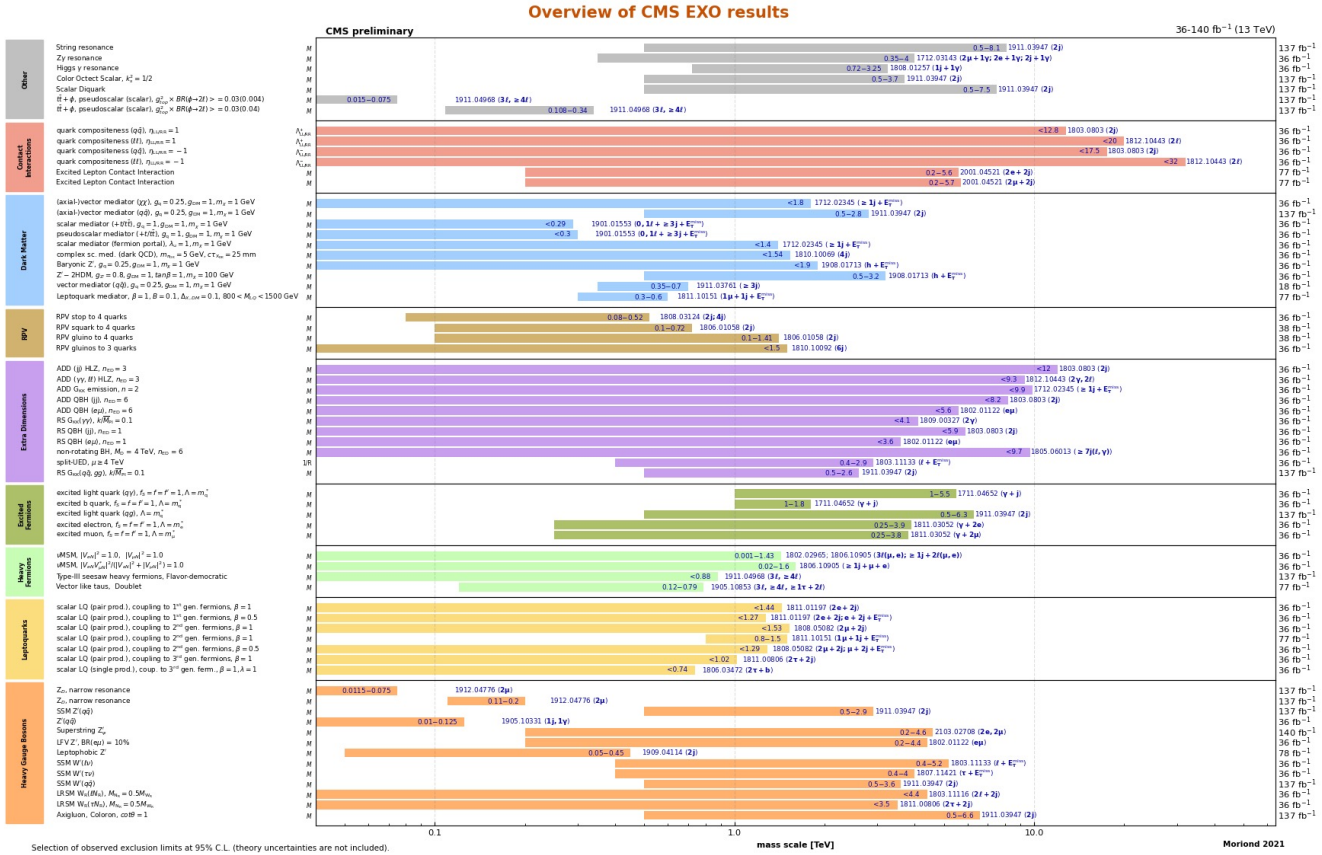


New ideas and smart use of data can make a difference in the search for diHiggs production


June 2021
CMS Preliminary
Production Cross Section, σ [pb]
7 TeV CMS measurement (L ≤ 5.0 fb-1)
8 TeV CMS measurement (L ≤ 19.6 fb-1)
13 TeV CMS measurement (L ≤ 137 fb-1)
Theory prediction
CMS 95%CL limits at 7, 8 and 13 TeV
≥n jet(s)
≥n jet(s)
=n jet(s)
W Z Wγ Zγ WWWZ ZZ VVV WWWWWZ WZZ ZZZ WVγ Wγγ Zγγ EW qqW EW qqZ γγ→WW EW qqWγssWW EW qqZγ EW qqWZ EW qqZZ tt t t-ch tW t s-ch ttγ tZq ttZ tγ ttW tttt ggH VBF qqH VH WH ZH ttH tH HH
EW,Zγγ,Wγγ: fiducial with W→lν, Z→ll, l=e,μ
Th. Δσ_H in exp. Δσ
All results at: http://cern.ch/go/pNj7

EXO PAG, search for exotica

The EXO PAG oversees **generic searches for physics beyond the standard model**. The search program of EXO covers a wide variety of possible signatures, and focuses on a large set of new physics models



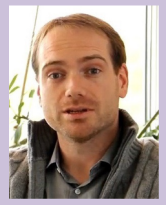
Selection of observed exclusion limits at 95% C.L. (theory uncertainties are not included).

[Figure with clickable link]

Meetings: ODD week Tuesdays, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/1682/
Subgroups: Non-hadronic, Jets+X, MET+X, LLP, MC-interpretations
Information: Twiki, hypernews
Contact: cms-phys-conveners-EXO@cern.ch

Conveners (2021/22)

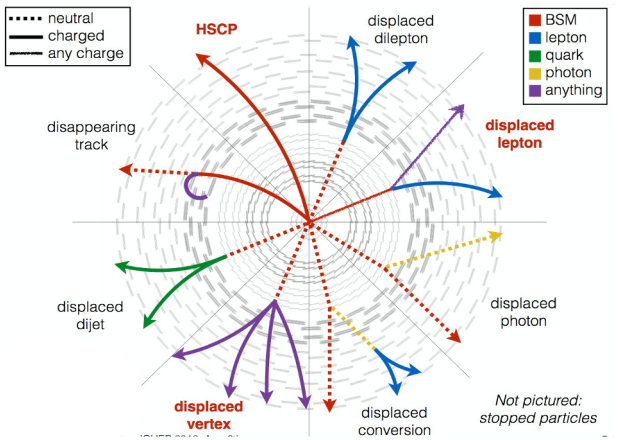
Zeynep Demiragli
(Boston U., US)



Steven Lowette
(Brussels VUB)

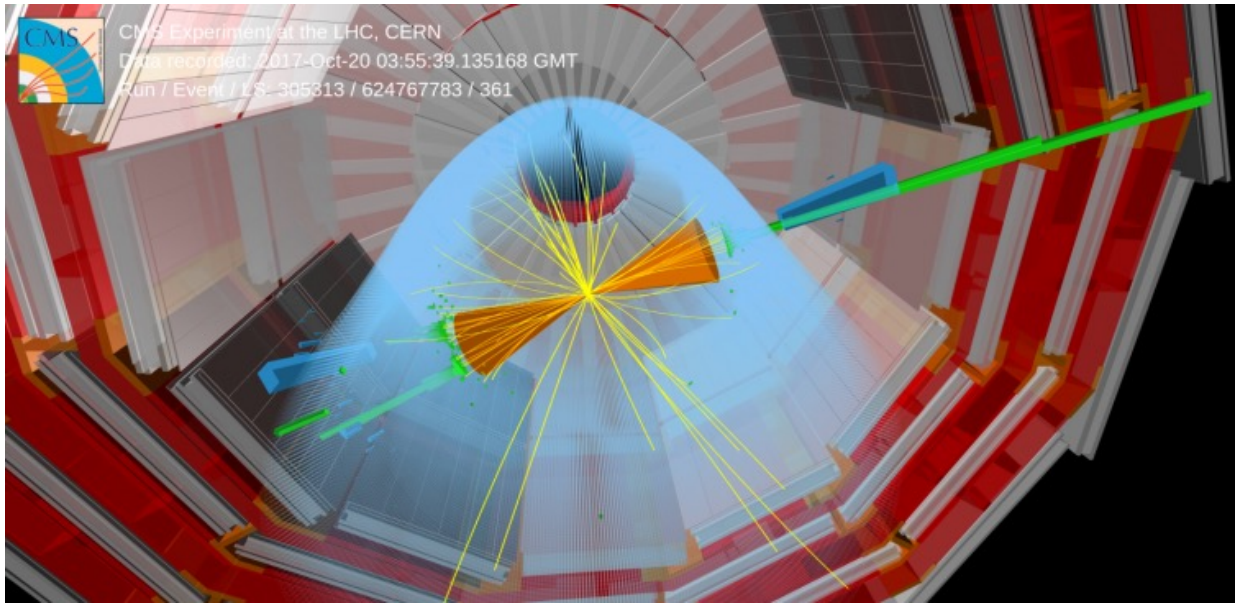
New non-traditional signatures are being explored

Improvements for Run-3 could be implemented at trigger level to increase the acceptance of unconventional signatures



B2G PAG, search for exotica

The B2G PAG covers models of **new physics featuring heavy standard model particles** in the final state. This includes searches for diboson resonances, heavy partners of the top quark with vector-like properties as well as heavy resonances, such as W' and Z' resonances. In many of these searches the final state particles can have significant Lorentz boosts, so that their individual decay products often overlap and merge. Such **boosted topologies** are exploited with dedicated reconstruction algorithms that were developed and are continuously being improved



Meetings: EVEN week Tuesdays, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/4277/
Subgroups: Resonances, Very Heavy Fermions, Dibosons
Information: Twiki, hypernews
Contact: cms-phys-conveners-B2G@cern.ch

Conveners (2021/22)

Andreas Hinzmann (Hamburg, DE)

Deborah Pinna (Wisconsin, US)

Many available analysis topics for Run 2 and Run 3 organized by subgroups can be found in this recorded meeting https://indico.cern.ch/event/1072915/

SUS PAG, search for exotica

The primary goal of the SUS PAG is to **search for physics signatures involving large missing transverse momentum**, together with other features such as jets, muons, electrons, taus, photons, and b-jets. If we discover such signatures with yields significantly in excess of standard model backgrounds, our goal will be to characterize the event samples as fully as possible.

In the first phase of our physics program, we have performed a broad set of searches with relatively simple signatures. These analyses relied on development of robust, data-driven procedures for estimating backgrounds. In addition, **more narrowly targeted searches** for particularly difficult production modes such as 3rd generation squarks and models with compressed spectra have increasingly become a focus of the group

Meetings: EVEN week Tuesdays, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/1685/
Subgroups: Inclusive and RPV, Leptonic and TBT, MC-interpretations, Trigger and new analysis strategies
Information: Twiki, hypernews
Contact: cms-phys-conveners-SUS@cern.ch

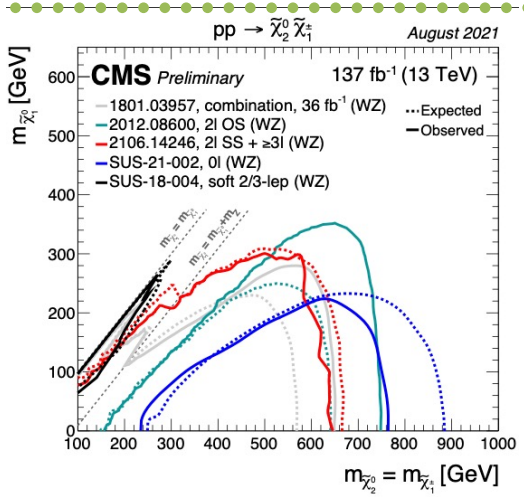
Conveners (2021/22)

Valentina Dutta (UCSB, US)

Marco Peruzzi (CERN)

EXAMPLE

New summary of limits of electroweak production of supersymmetric particles



New efforts and person power needed in analyses, specially

to join the Run 2 photon+lepton+MET SUSY search (updated version of SUS-17-012)

to spearhead new efforts in RPV SUSY searches, since this is a part of the program that will be expanded heading into Run 3

BPH PAG, b-flavor physics

The BPH PAG is responsible for heavy flavor (**beauty** and **charm**, but not top) studies. Its activities involve **precision measurements** of heavy-quark hadron **production, decay and properties**, and the **search for associated new and rare processes**

Meetings: EVEN week Tuesdays, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/7486/
Subgroups: Production and properties, Exotica and Rare decays, Violation of Fundamental Symmetries
Information: Twiki, hypernews
Contact: cms-phys-conveners-BPH@cern.ch

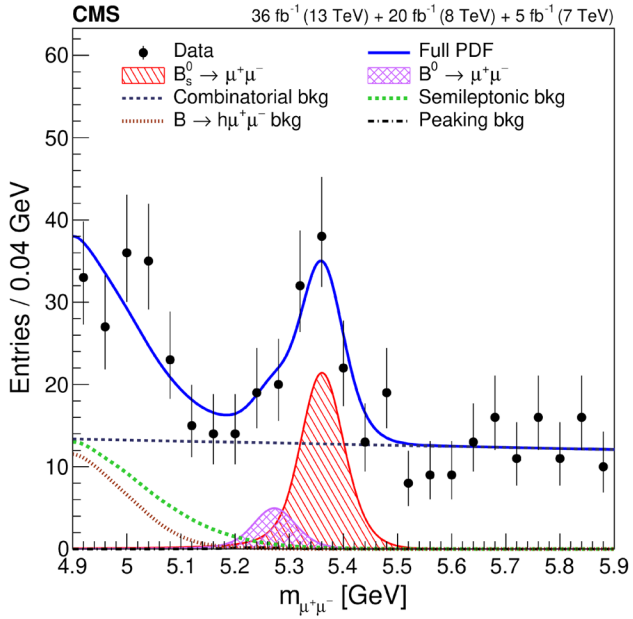
Conveners (2021/22)

Riccardo Manzoni (ETHZ, CH)

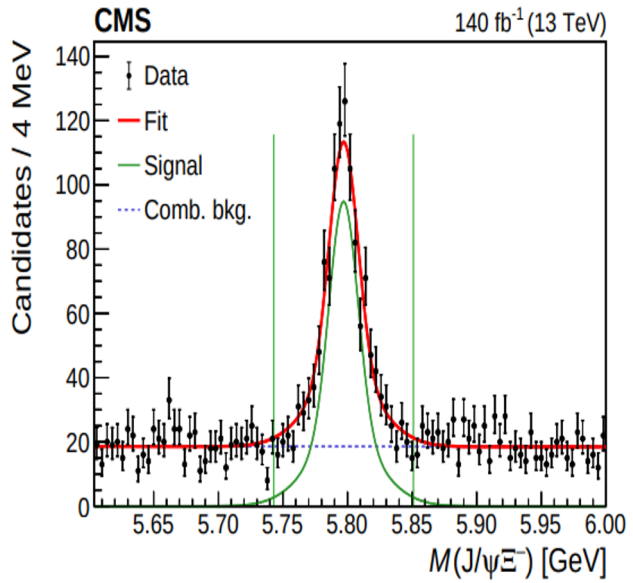
Sergey Polikarpov (MEPHI, RU)

EXAMPLE

Exploring rare B decays that are very sensitive to new physics



Spectroscopy, properties of B hadrons



Competitive program thanks to the high cross sections at LHC, the huge luminosity collected and dedicated triggers selecting J/Ψ, Υ and B-hadron decays

We also collected in 2018 a 10 billion sample of unbiased B-hadron decays which can be exploited for several analyses. Many available analyses to join or to start!

HIN PAG, heavy ions physics

The HIN PAG studies **the characteristic of the hadronic medium at the highest temperatures and densities**, as well as the interaction of all kind of particles/probes with this medium

Meetings: EVEN week Tuesdays, 16:00-18:00 CET
Meeting agendas: https://indico.cern.ch/category/29/
Subgroups: Production and properties, Exotica and Rare decays, Violation of Fundamental Symmetries
Information: Twiki, hypernews
Contact: cms-phys-conveners-HIN@cern.ch

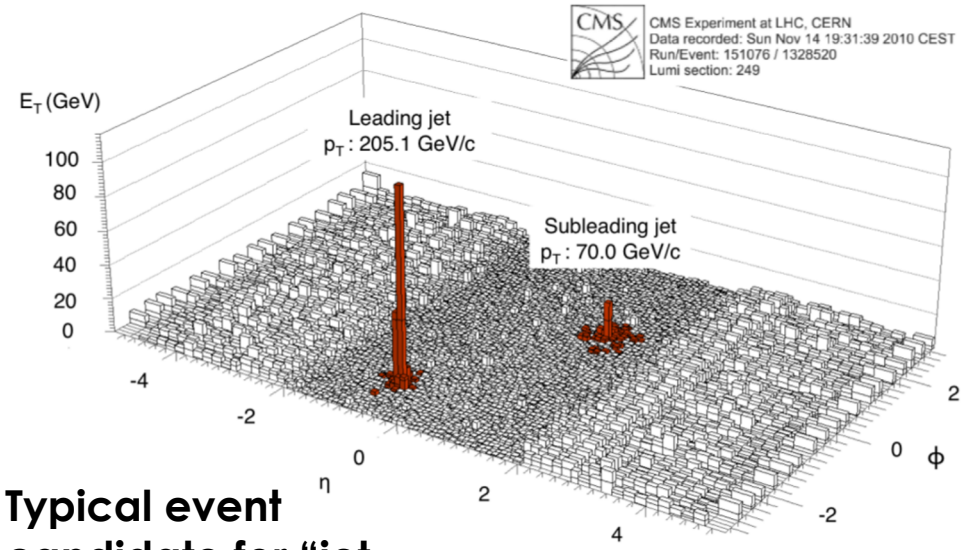
Conveners (2021/22)

Andre Stahl
(Rice, US)

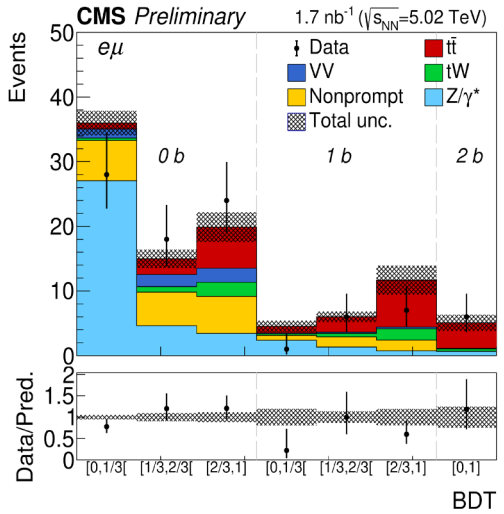
Yongsun Kim
(Seoul Sejong, KR)

EXAMPLE

Heavy Ion collisions in CMS (Pb-Pb, p-Pb, Xe-Xe)



Typical event candidate for "jet quenching"



First evidence for top quark pair production in PbPb

Shared Groups

GEN SG, generators

The GEN SG, is a shared responsibility with **Offline & Computing Coordination**. Its main goal is to collect our expertise on physics generators (the first stage of our simulation). Some of the tasks are

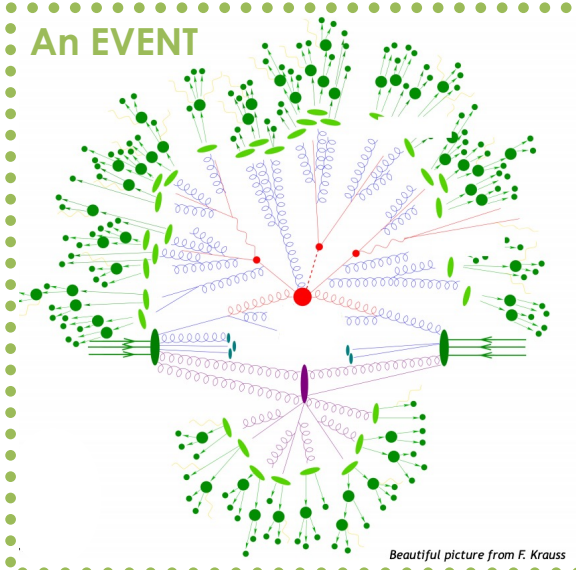
- Choice of versions & settings of different generators
- Validation and tuning of the MC by comparisons with data
- Preparation of different generators and simulation campaigns

Meetings: Every Mondays, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/548/
Subgroups: Physics comparisons and Generator Tunes, Matrix Element and Future Generators, Generator Integration, Generator Validation
Information: Twiki, hypernews
Contact: cms-phys-conveners-GEN@cern.ch

Conveners (2021/22)

Saptaparna Bhattacharya (Northwestern, US)

Gurpreet Singh Chahal (IC London, UK)



Hard Scattering = processes with large momentum transfer (Q^2)
Represents only a tiny fraction of the total inelastic pp cross section (~ 70-80 mb)

eg. $\sigma(pp \rightarrow W+X) \sim 150$ nb $\sim 2 \cdot 10^{-6}\, \sigma_{tot}(pp)$

It is typically the process we want to study (direct link to lagrangians)

Factorization = assume we can describe the overall interaction as the product of phenomena that can be handled independently (it is an approximation) - Hard Scattering, PDF, Underlying Event, Initial State Radiation, Parton Shower and Final State Radiation

PF SG, particle flow

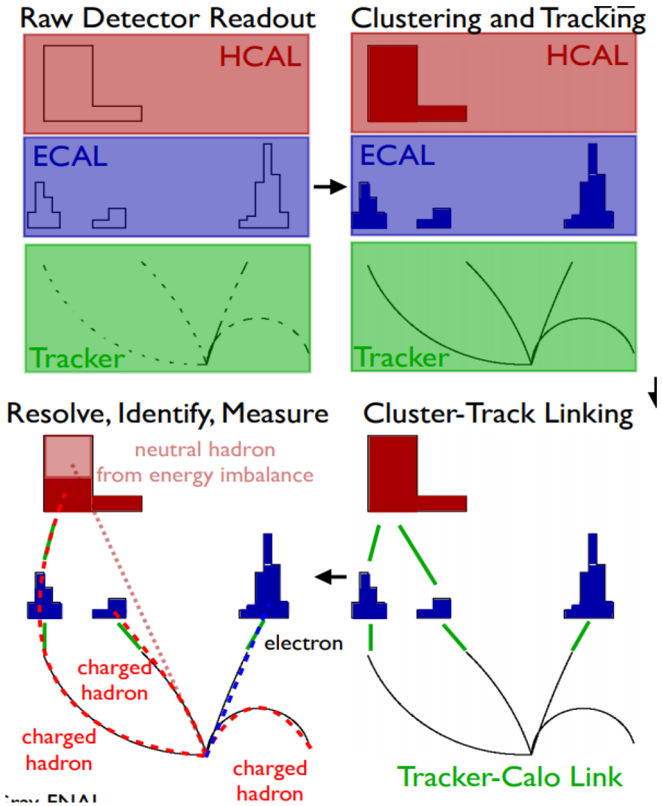
The PF SG is a share responsibility with **Physics Performance Dataset Coordination**. It provides a centralized overview of PF reconstruction and all PF related modules & products used offline and at L1/HLT, as well as the core PF reconstruction development & support.

Meetings: EVEN week Fridays, 14:00-17:00 CET
Meeting agendas: https://indico.cern.ch/category/11266/
Information: Twiki, hypernews
Contact: cms-conveners-particleflow@cern.ch

Conveners (2021/22)

Kenneth Long (CERN)

Juska Pekkanen (Buffalo, US)



THE PARTICLE FLOW ALGORITHM

Combination of information from multiple detectors improves reconstruction (not just for electrons or muons)

- Identify charged hadron footprints in calorimeters
- Assign excess energy to neutral hadrons

Algorithm:

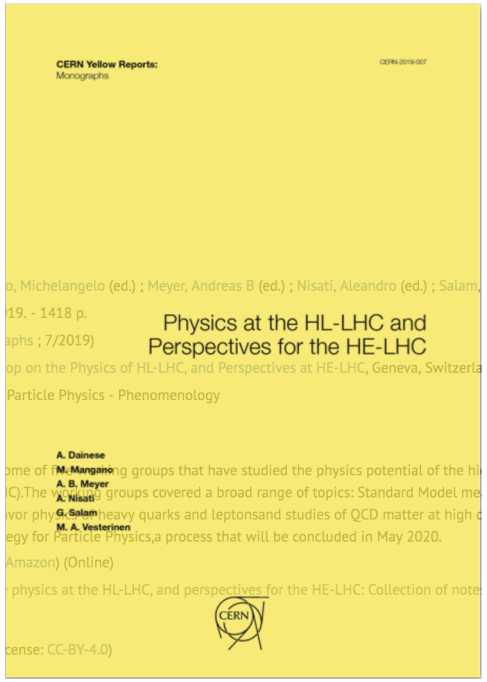
- Start by linking footprints in different detector
- Identify and subtract starting from the particles that have a clearer signature
- Continues until everything is assigned to some "PF Candidate"

UPSG SG, upgrade performance studies

The UPSG is a common group under **Upgrade Coordination** and Physics Coordination. The oversees studies of physics cases relevant for the remaining Phase II Technical Design Reports and provide input for any design optimizations. The group

- Defines physics benchmarks to evaluate the performance of the specific upgrade elements and for Snowmass 21 process within CMS
- Oversees software developments with the goal to achieve a full Phase II reconstruction in the CMS software framework

December 2018:
Yellow reports on physics at the HL-(and HE-)LHC



Meetings: Every Wednesday, 14:00-16:00 CET
Meeting agendas: https://indico.cern.ch/category/5353/
Information: Twiki, hypernews
Contact: cms-phys-conveners-UPG@cern.ch

Conveners (2021/22)

Alexander Savin
(Wisconsin, US)

Sezen Sekmen
(Kyungpook, KR)

How will your analysis look in the future?

ML SG, machine learning

The ML SG is a responsibility between **Offline & Computing** and Physics Coordination. The group takes care of implementing benchmarks and validation tools of the technical performance of ML methods, and monitor the usage of ML within CMS. In addition it provides consulting role to the CMS members, coordinating training examples, and fostering R&D into ML approaches for future challenges.

Machine Learning is **widely used in CMS**

- In most analysis: signal categorization, background subtraction, regression, training on data, anomaly searches
- In physics objects application: jet-tagging, tau identification, MET improvements, b-jet energy regression
- In operation: data quality monitoring, computing operation

Growing effort and good progress with using ML

- in event reconstruction : calorimeter clustering, track reconstruction, vertexing, particle-flow, end-2-end ID/regression
- in simulation : shower simulation, analysis-level, particle-level

New ML techniques: Deep Learning, Graph Networks are being implemented

Meetings: EVEN Wednesday, 16:00-17:00 CET
Meeting agendas: https://indico.cern.ch/category/9376/
Subgroups: Knowledge, Production, Innovation
Information: Twiki, hypernews
Contact: cms-conveners-ML@cern.ch

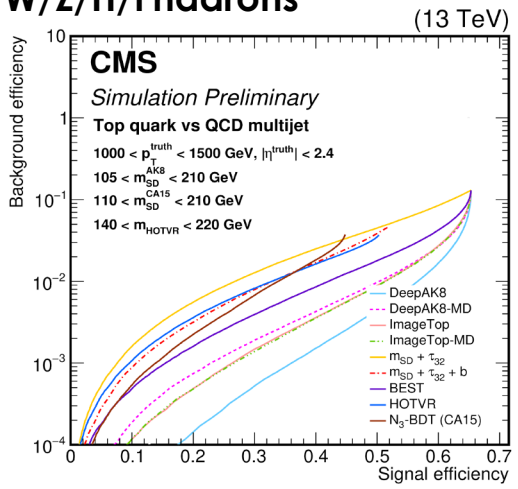
Conveners (2021/22)

Jean-Roch Vlimant (CALTECH, US)

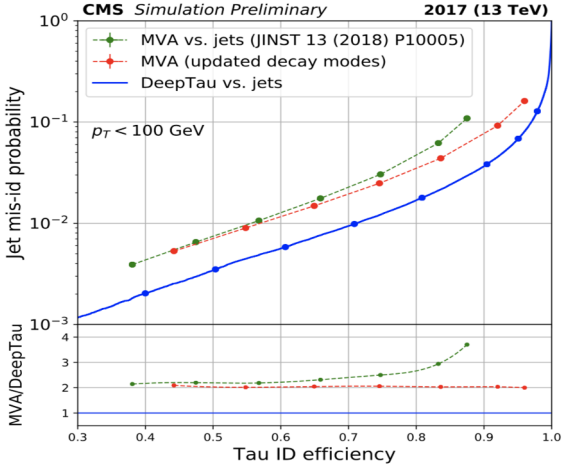
Gregor Kasieczka (Hamburg, DE)

EXAMPLE

ML taggers for highly boosted W/Z/H/t hadrons



Tau and jet identification and energy measurement



Analysis to Publication

Public documents released by CMS

5 types of public documents:

- **Journal Publications**: they appear on refereed journals and are signed by the whole CMS Collaboration
- **Physics Analysis Summaries** (PAS): summary documents usually in preparation for a paper or a conference contribution. More than one PAS can be "concentrated" in a single paper.
- **Detector Performance Summaries** (DPS): equivalent of PAS for performance plots and detector related analyses. They are managed jointly by Physics Coordination, Run Coordination and PPD.
- **Conference Reports** (CR): proceedings to be submitted to conferences.
- **CMS Notes**: used only in special cases like generator-based studies, combination procedures, statistical interpretations, ... of interest to the external physics community. They are citable in our papers.

Please note:

- Apart CR, all physics documents are signed by the whole CMS Collaboration
- All public documents must pass an internal review

Rules for limited authorship papers are currently being re-discussed in the Collaboration Board

Internal (private) documents

3 types of internal documents

- **Analysis notes** (AN): they are usually in support of PAS/CMS Notes, with detailed documentation on analysis single step. They are used in the internal review of analyses and should be kept up-to-date.

- **Detector Performance Notes** (DP): it is the private version of a DPS. Usually contains more material and explanation w.r.t. a DPS to help CMS speakers in conferences.

- **Detector Notes** (DN): focused on technical aspects of the detectors and managed usually internally in every single project.

Please note:

- All private documents have explicit reference to the authors
- The private documents are not reviewed (CMS only checks that the contents are not inappropriate) but they are used in the review process of the public documents

Doing physics analysis in CMS

Step 1: **Think and Act**

- You have an idea
- You don't have an idea, but you would like to contribute

Select a group and talk directly to group/sub-group conveners

Step2: **Attend the POG, PAG & subgroup meetings, subscribe to HNs, become active in the group**

- Do you need a particular MC sample? → Help becoming a MC production expert
- Do you need a particular object? → Work in the POG in order to get it as performant as you need it (& for CMS)
- Do you need a particular workflow? → Develop it and propose it to PPD
- Do you need a special trigger? → Work in L1 and HLT in order to set it up in your analysis (& for CMS)

How can you help the group? -> ask the conveners and volunteer!

Step 3: **Present your work**

- Start presenting your analysis (or your team's analysis) in the pertinent working group/sub-group meetings
- When conveners find the analysis mature, a CADI line is open and a hypernews forum is created, all discussion during the review process is posted here.
- A twiki page with all the documentation and Q&A during the review should be linked from the CADI.
- When the analysis is at a state that is judged sufficient to call a pre-approval presentation (the sub-group L3 conveners decide in consultation with the L2 conveners)
  - (Some groups require a full-status presentations before pre-approval)

Doing physics analysis in CMS

Step 4: **Pre-approval**

- Presentation it **is usually held inside a PAG/POG meeting or subgroup meeting**, and it is called by the PAG/POG conveners 15 days in advance. This is also the time when an **Analysis Review Committee (ARC)** is appointed and starts to follow your analysis.
- At pre-approval you will need a draft of a public document & detailed internal documentation. Involve a language editor (CCLE) early in the process! (List of CCLE here)
  - Some analyses get greenlight for data unblinding, and only get pre-approved post showing results in the hn or another presentation.

Step 5: **ARC review and approval**

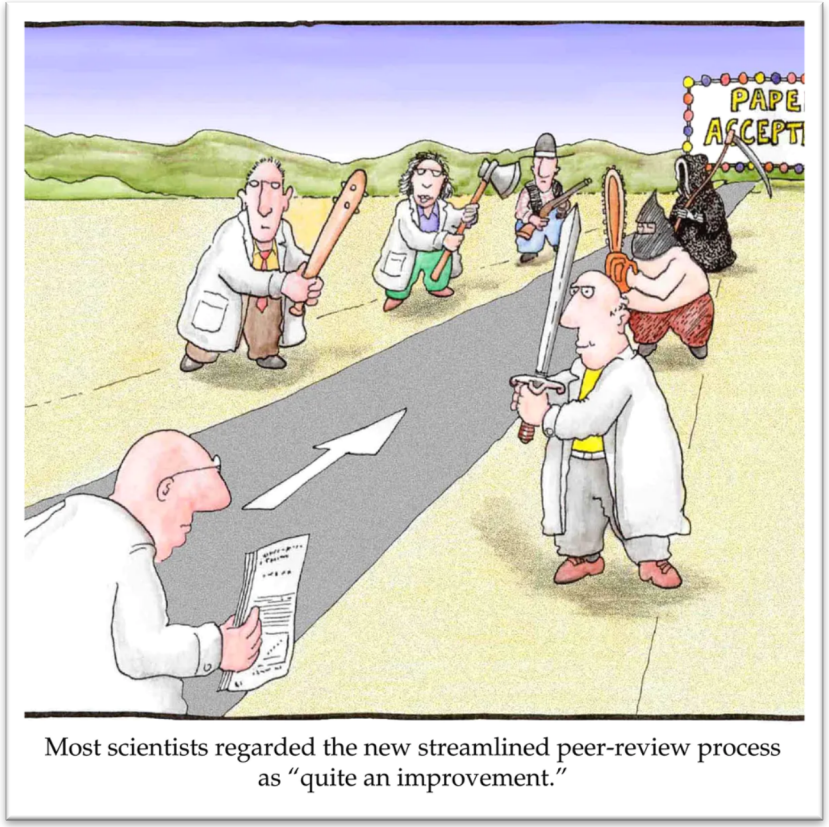
- After pre-approval the ARC scrutinizes the analysis in detail. When the analysis is considered to meet the CMS standards, the ARC gives the greenlight for approval. The approval is usually held inside a general group meeting called by the POG/PAG conveners unless it is declared to be "central" in CMS (called by Physics Coordinators).
  - Before the main steps of the review the documentation has to be "frozen" a week in advance to allow the collaboration to send comments

Unless decided differently from the start, the main target of an analysis is a physics publication. After approval in many cases a PAS document is produced to show preliminary results at conferences while the final paper is being prepared. Typically, a Collaboration wide review (CWR) -ready paper draft is required before releasing a PAS.

Doing physics analysis in CMS

Step 6: **Collaboration Wide Review (CWR)**

- Everybody in the collaboration is asked to comment on the paper and a few institutes are explicitly asked to review the paper
- This step is coordinated by the Publication Committee
- Authors receive comments, address the comments on a new version and post their answers



Most scientists regarded the new streamlined peer-review process as "quite an improvement."

Step 7: **Final Reading (FR) and submission to a journal**

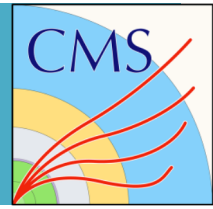
- The ARC and the Publication Committee evaluate the comments from CWR and the FR is scheduled to wrap it up before submission. Submission is handled centrally

Step 8: **Journal review and final submission**

Journal will send comments from peer reviewers, authors address the comments by making the necessary changes to the paper and writing a response letter

ARC and the Publication Committee evaluate the responses and changes. The final version of the paper is submitted, also centrally

Interpretation and statistical analysis



Statistics Committee twiki and hyperforum

The statistical treatment of the physics analyses is quite complex.
The CMS **Statistics Committee (StatComm)** supports individual analyses from early to late stages in matters like:

- Multivariate discriminants
- Data fitting
- Searches and Limits
- Unfolding
- Systematics
- Presentation of final results and derived quantities
- Histogramming issues

You are welcome to contact the StatComm with questions about your analysis

The statistics committee also follows ex-officio all CADI entries, and you should fill a statistical questionnaire for each analysis before pre-approval: https://cern.ch/cms-stat-questionnaire

- For each CMS Physics Analysis Group (PAG) one or two Statistics Committee members act local contact persons

Finding information on all analyses

Analysis information CADI pages, iCMS toolkit

We have a single database that stores all info:

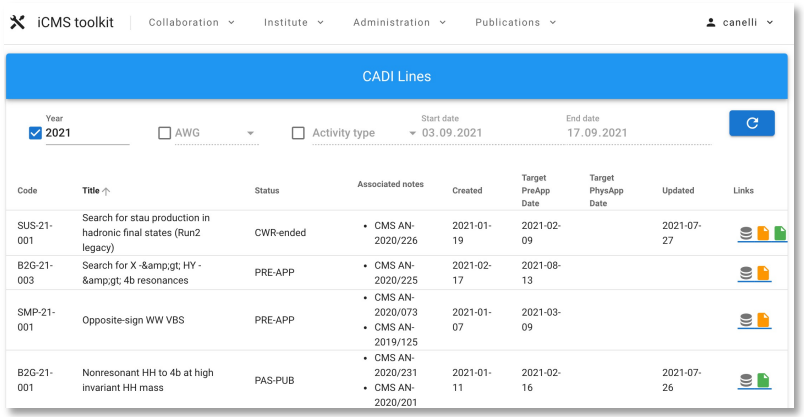
- CADI (CMS Analysis Database Interface)

AWGs | Notes | ARCs | IRCs | Misc | show Analysis papers | Admin ToDo list | Analysis Management »

switch to EDIT mode | set FULL Info | show Analyses any in any with Status (after) any

Code	Name	Status	PAS	PAPER	ARC
B2G-12-001 » | show	Search for t' pair production in the dilepton channel	Free			NO ARC
B2G-12-002 » | show	Search for baryon-number violating top decays into 2 jets and 1 lepton	PAS-PUB	P		Jorgen D'Hondt (BRUSSEL-VUB)
B2G-12-003 » | show	Search for a heavy partner of the top quark with charge 5/3	PAS-PUB	P		Sridhara Rao Dasu (WISCONSIN)
B2G-12-004 » | show | CDS | JHEP	Search for b' pair production in the lepton + jets channel	PUB			Andrea Giammanco (LOUVAIN)
B2G-12-005 » | show	Search for ttbar resonances in boosted all-hadronic final state	PAS-only-PUB	P		Vyacheslav Krutelyov (UCSB)
B2G-12-006 » | show	Search for ttbar resonances in semileptonic final state	PAS-only-PUB	P		Kevin Patrick Lannon (NOTRE_DAME)
B2G-12-007 » | show	Search for ttbar resonances in dileptonic final state	PRE-APP			Kevin Patrick Lannon (NOTRE_DAME)

- They can also be found via the iCMS toolkit

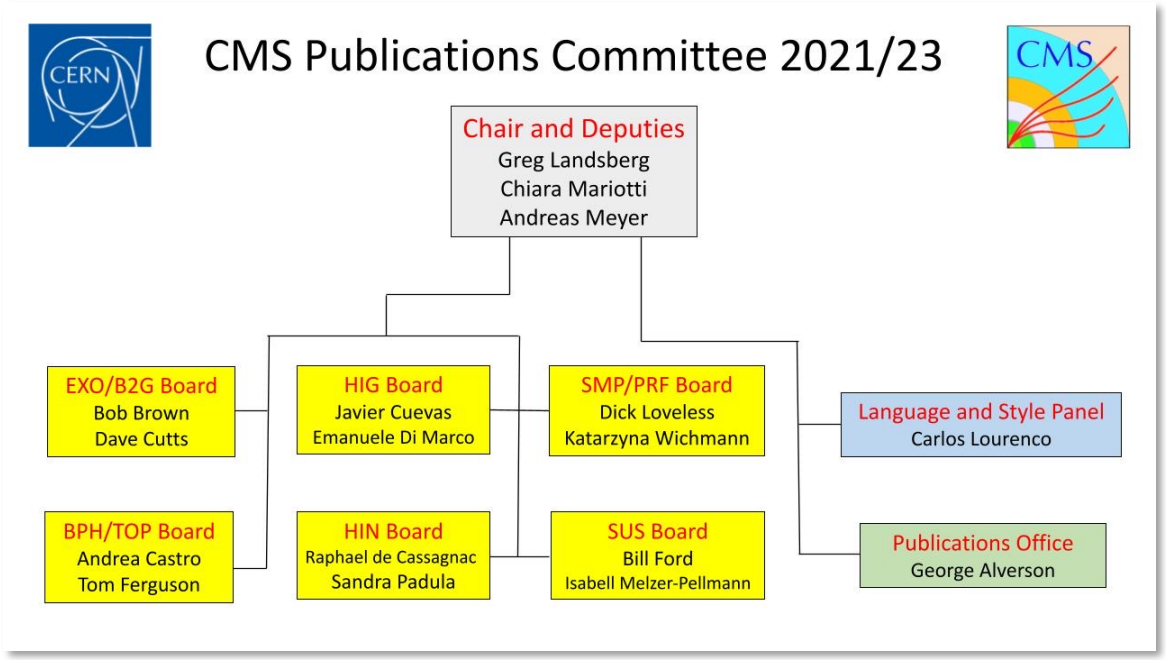


Publication committee

The **CMS Publications Committee (PubComm)** is responsible for the high editorial quality of all CMS publications and public documents

The PubComm defines the CMS standards for detector descriptions, figures, formats, styles, symbols, etc.

Publication Committee webpage, twiki



The PubComm is organized in six Editorial Boards (EB), associated to one or more physics groups

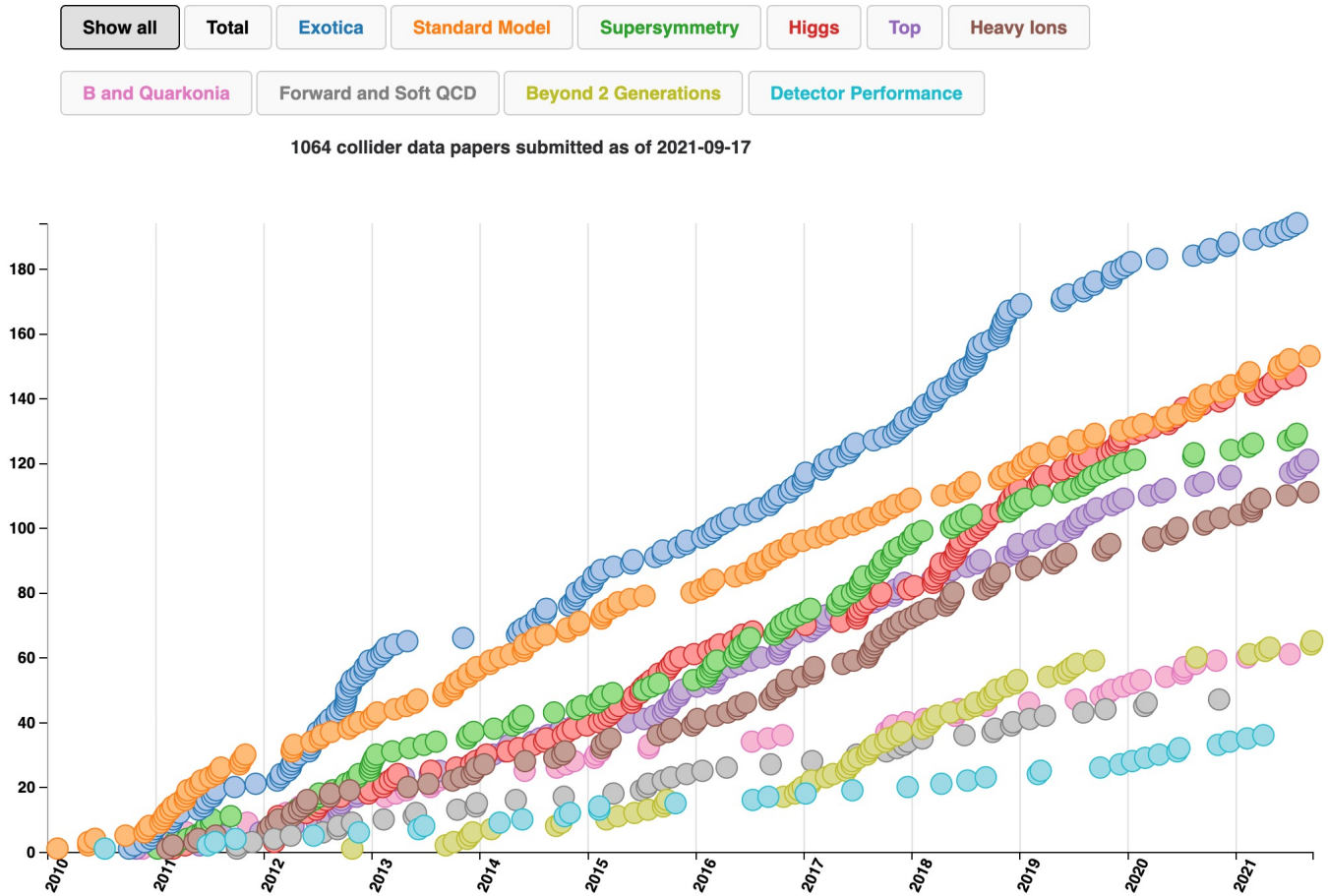
The EB chairs form the PubComm Steering Board

Publication guidelines

- The CMS procedures for the writing of papers and for the publication process are described here.
- A graphical summary of the various steps and responsibilities throughout the paper scrutiny up to the FR is given in this PDF file.
- The CMS Publication Committee style guidelines are here.
- Inputs for the description of the detector and physics object reconstruction are here.
- The guidelines for figures are here.
- The role of a CMS certified language editor (CCLE), the procedure to qualify as one, and the list of CCLEs is here.
- The role of the journal submission experts (JSE) and their list is here.
- The instructions on how to prepare a paper for submission (formatting issues) are here.
- The rules for what can be cited in a CMS journal publication are here.
- The rules for non-CMS publications by individual CMS members can be found here

Publication statistics

Publication timeline (this plot)http://cms-results.web.cern.ch/cms-results/public-results/publications-vs-time/

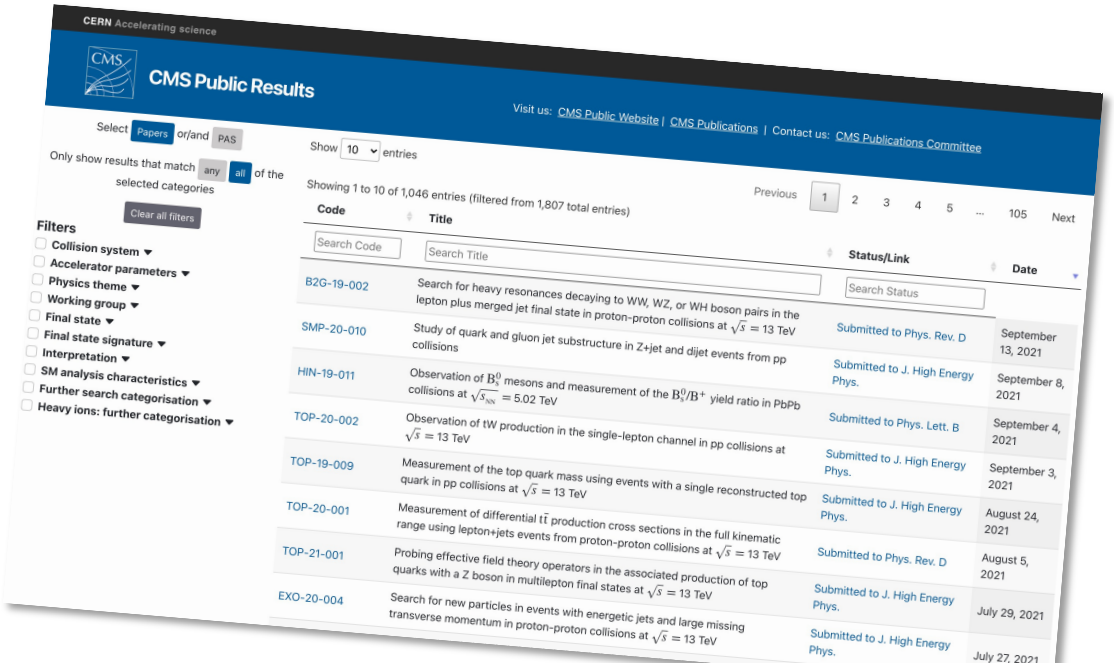


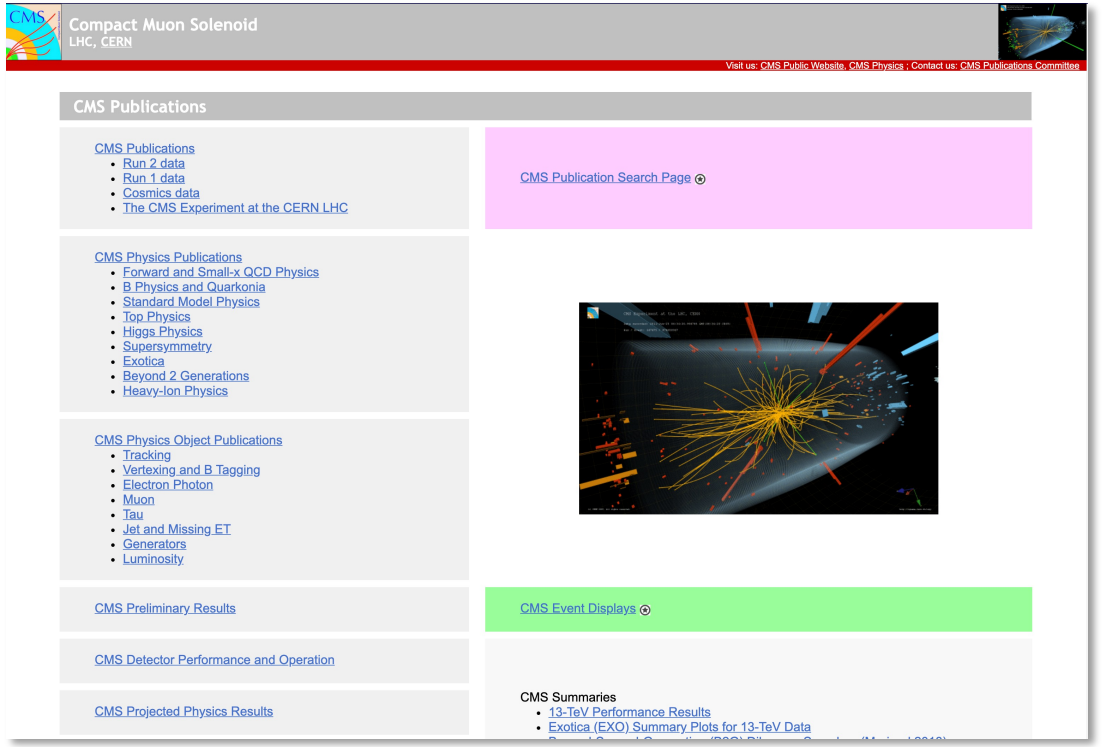
CMS results public pages

Public entry point for CMS public results

CMS public results published, preliminary
Searchable webpage

- Organized by topic / physics group
- Individual pages include (references to) preprint, paper, figures, additional material
- Includes also lists of preliminary public results (Physics Analysis Summaries, PAS)





New! Searchable page: many different ways to find CMS results

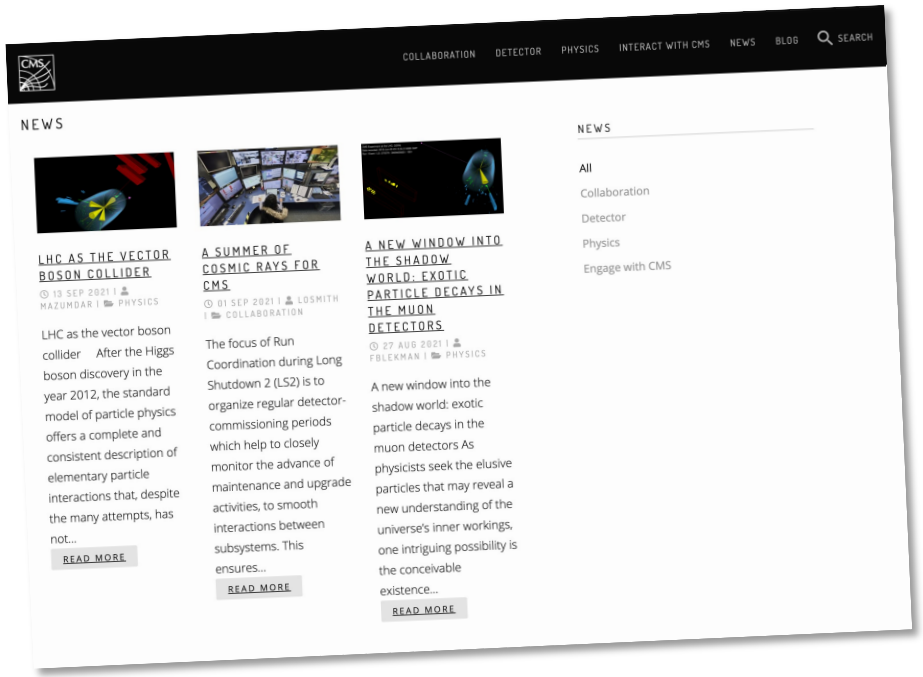
Physics briefings

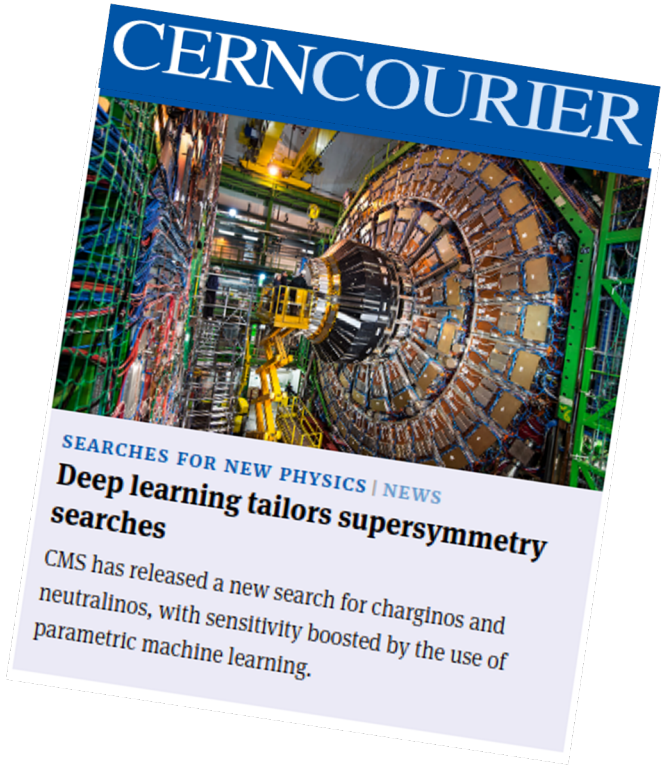
The CMS Communications Office works withing PC to prepare content for the dissemination of CMS physics results of new CMS results and to sustain communication to the wider HEP community.

Physics Communications Office twiki

Plain briefings are plain english summaries aimed to the science-interested general public, including policy makers and (non-HEP) scientists which are published on the main CMS webpage

- all authors are encouraged to write these!





In addition, we have other ways to communicate what we do

facebook
twitter
instagram
youtube
web page
google alert

Conferences

All past and available conferences are stored in the CMS Information on Conferences (CINCO)

Conference Committee: webpage twiki
Announcements: hypernews
Talks available: CINCO

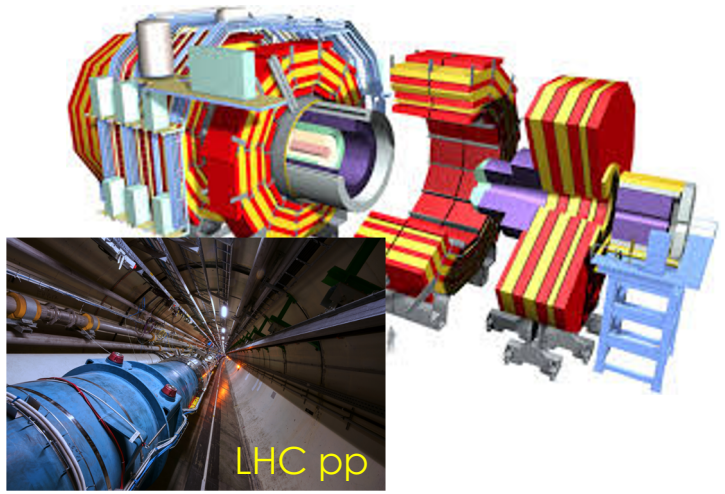
Presenting results at conferences

- Find an available talk and nominate yourself or another candidate via CINCO
- If you are interested in submitting an abstract to a specific conference, contact the L2 approving your work
- Guidelines from the Conference Committee are here

Keep your profile in CINCO up to date, it helps the CMS Conference Committee in the selection of candidates

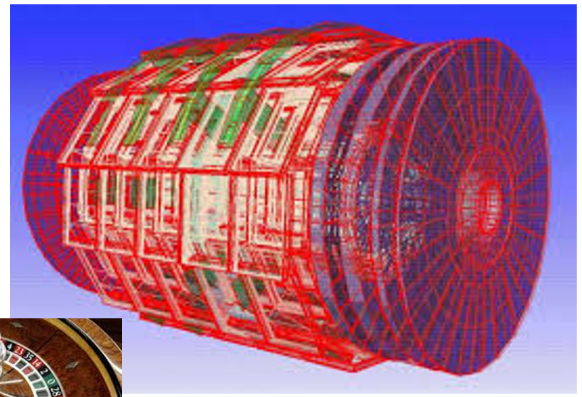
How do you get the data to do an analysis?

Reconstruction and simulation software

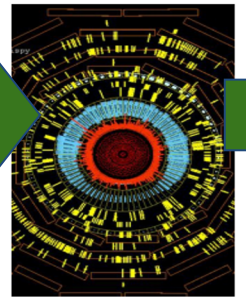


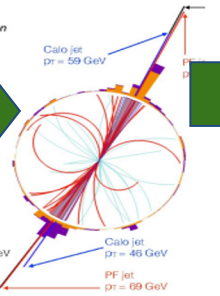
Real world

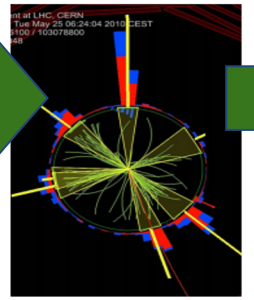
Simulation

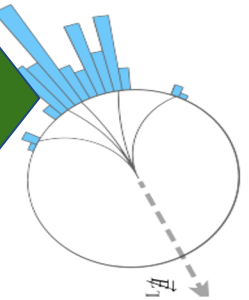


Detector Data → Local reconstruction → Particle representation → Jet Clustering → High level features



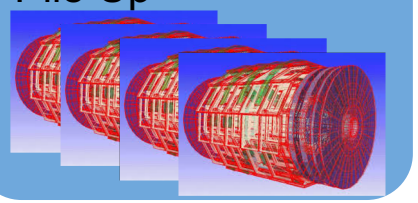






Corrections and Calibrations

Pile Up

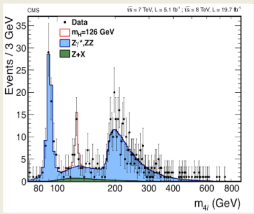


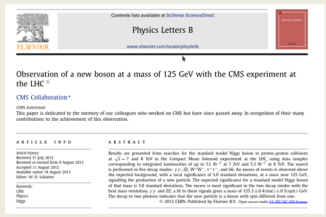
Sensor and Electronics sim

Geant4 propagation and interactions

MC generation

Analyses and papers

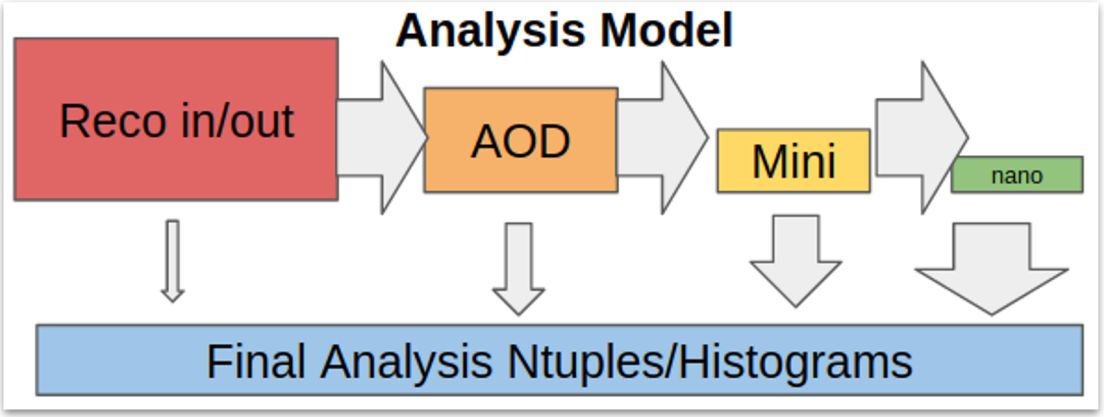




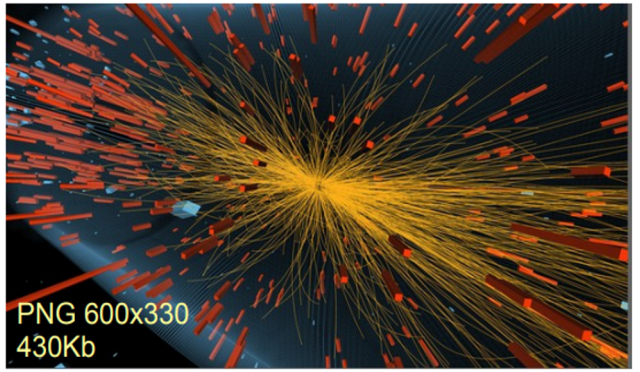
Datasets / Data Tiers

Data taking for (e.g.) 2018:

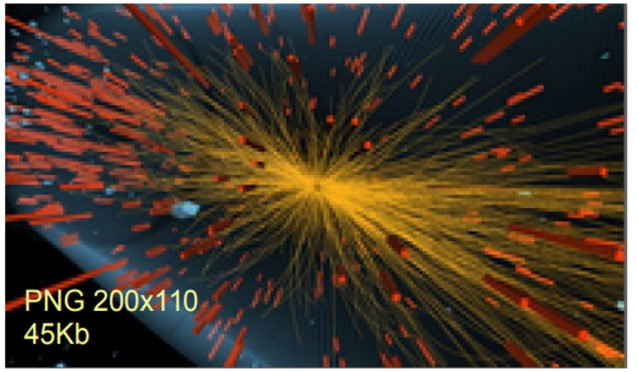
- Data taking @ 1 kHz HLT + 2 kHz parked → 3 kHz of events, 6 months per year
  - ~ 20B events/y
  - Each event ~ 1 MB => ~20 PB x2 (custodial copies) RAW
  - For each data event, 1 to 2 MC events to process (~40 sec/ev)
  - Processing RAW → RECO/AOD ~ 30 sec/ev
  - Processing AOD → MiniAOD ~ 1-2 sec/ev
  - Processing MiniAOD → NanoAOD ~ 0.1 sec/ev
- Multiple formats ("Data Tiers") for the data and MC
  - For analysis: AOD, MiniAOD, NanoAOD
  - Different use cases => different data tier
  - All datasets can be found in DAS: https://cmsweb.cern.ch/das/



AOD 450kb/ev



MiniAOD 50kb/ev



NanoAOD 1-2kb/ev

Getting started: a few “first steps”

The overall collection of software, referred to as CMSSW (CMS SoftWare), is built around Framework, an Event Data Model, and Services needed by the simulation, calibration and alignment, and reconstruction modules that process event data so that physicists can perform analysis

Where to get help and find info

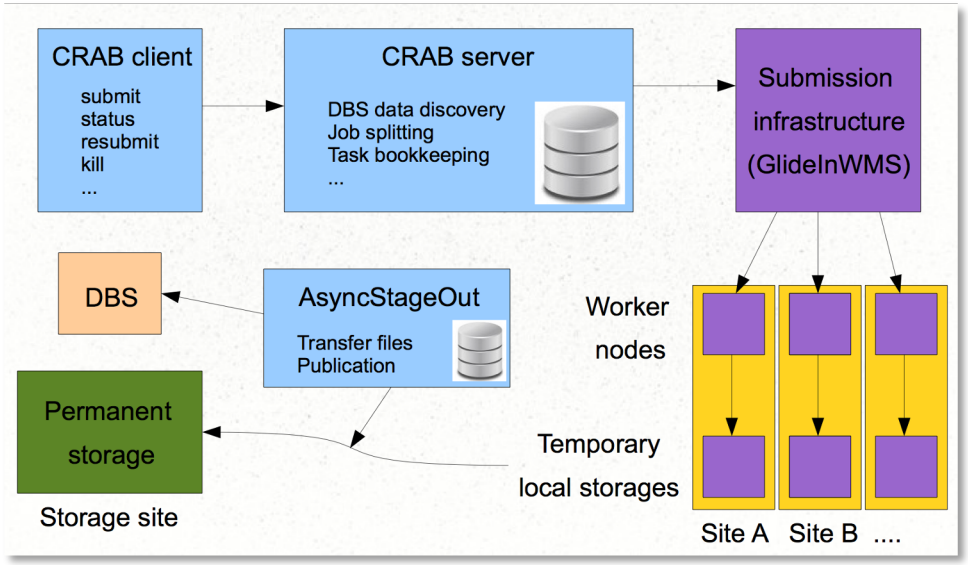
- Get familiar with the CMSSW WorkBook
- Participate in the CMS **D**ata **A**nalysis **S**chools (CMS DAS)

How do you access full datasets on the GRID?

CRAB (CMS Remote Analysis Builder) is software & hardware infrastructure used by CMS to submit analysis jobs to the LHC Computing Grid.

- Access CMS data and Monte-Carlo which are distributed to CMS aligned centres worldwide
- Exploit the CPU and storage resources at CMS aligned centres

We are now in its third major release (CRAB3) and this is the ONLY one supported for Run2 (CRAB3 tutorial)



Which analysis releases and datasets to use

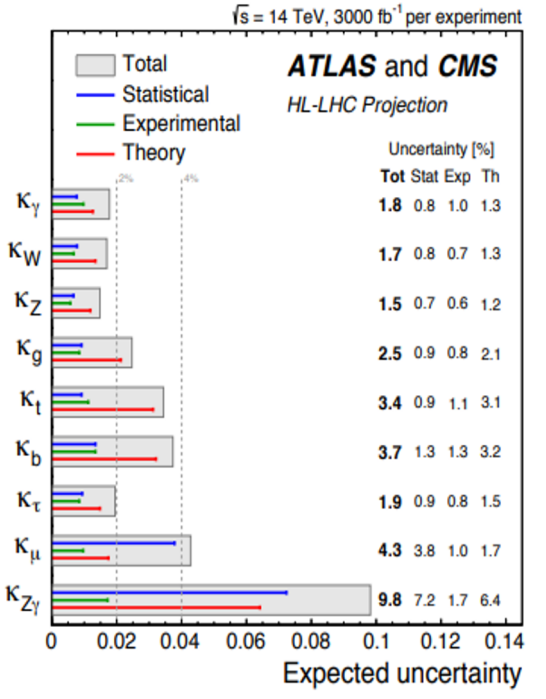
- Current and past analysis recipes
- Monte Carlo production tutorial

Analyses to come

CMS has published more than a 1000 papers, this is a HUGE success

- Many searches produced null outcome, but
  - Run 3 will provide (little) more energy to scan further the new physics phase space
  - We only looked in some signatures, the more classical- model driven ones
- Many analyses are systematic uncertainty dominated, but we can
  - reduce the source of systematic uncertainties
  - improve treatment of systematics in the analysis (e.g. in-situ)
- Many measurements have not been done, but
  - SM parameters can be sensitive to new physics
  - many have only done with partial datasets

- Analysis tools are becoming very sophisticated, and new tools are being explored aiming at gaining sensitivity in measurements and searches
  - most results are showing to be better than expectation



Summary

This is just a really limited overview of the activities in the Physics Coordination area

- Hopefully you can find here at least a hook from where you can find your way through the maze
- Please feel free to contact anybody you have seen named in these slides for any doubt or question you might have

Useful sources of information:

- **First entry point in CMS:** https://cms.cern/ (see link at the bottom Entry to CMS members)
  We are transitioning to this page https://cms-info.web.cern.ch/
- **Physics Coordination** (dropdown menu in Coordination Areas)
  https://cms-info.web.cern.ch/cms-internal/coordination/physics/
- **Twiki pages, especially the WorkBook:**
  https://cern.ch/twiki/bin/view/CMSPublic/WorkBook
- **Tutorials, CMSDAS schools:**
  https://indico.cern.ch/category/2063/
- **Hypernews:**
  https://hypernews.cern.ch/HyperNews/CMS/cindex (subscribe to forums)
  WARNING: in transition to CMS talk https://cms-talk.web.cern.ch/pub/cms-talk-user-guide

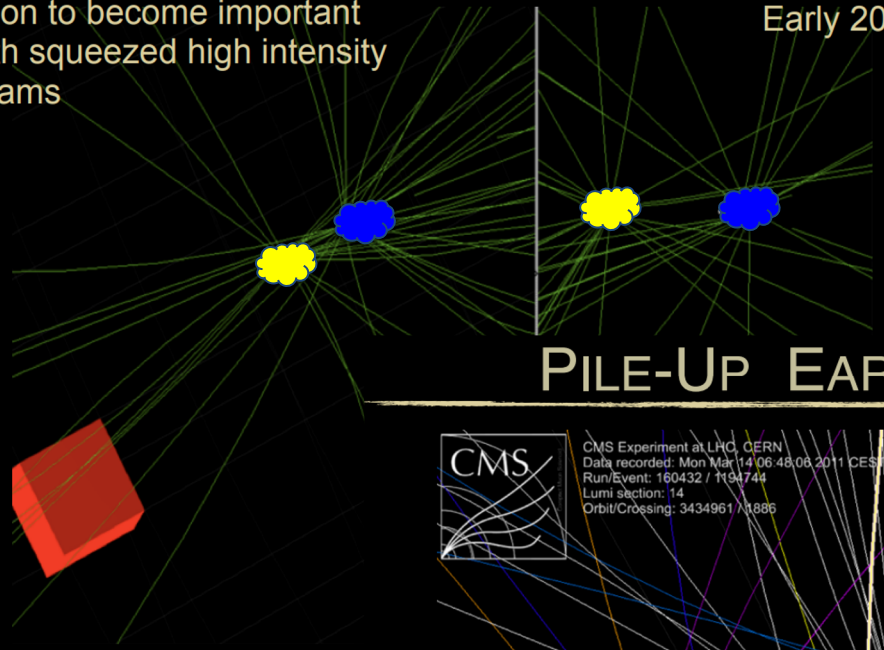
Extra material

Pile-up: more luminosity comes at a price

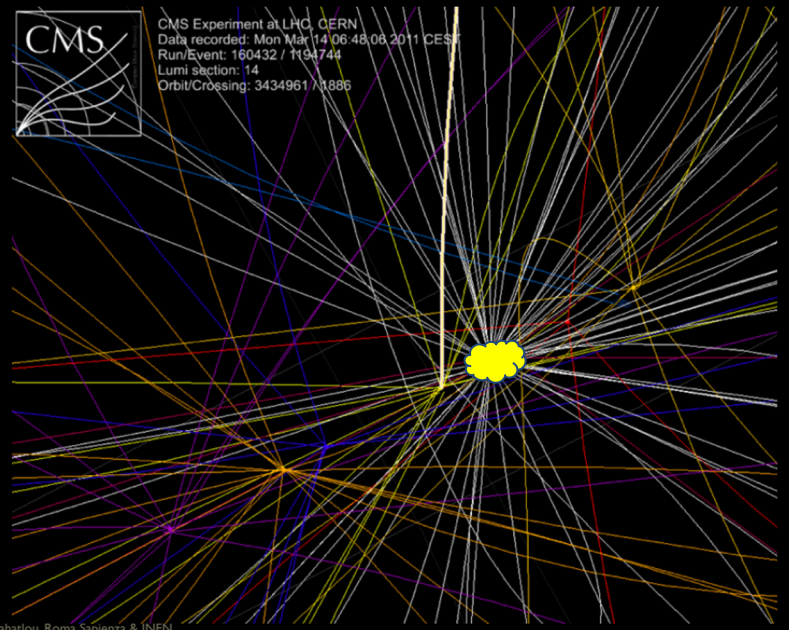
PILE-UP AT LOW LUMINOSITY

Soon to become important with squeezed high intensity beams

Early 2010

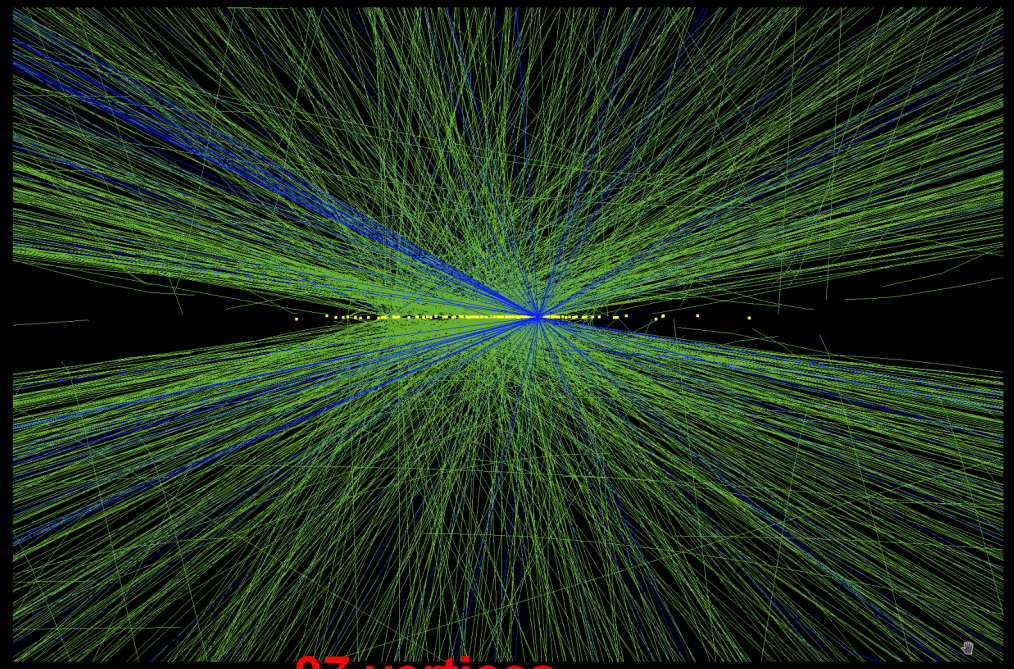


PILE-UP EARLY 2011

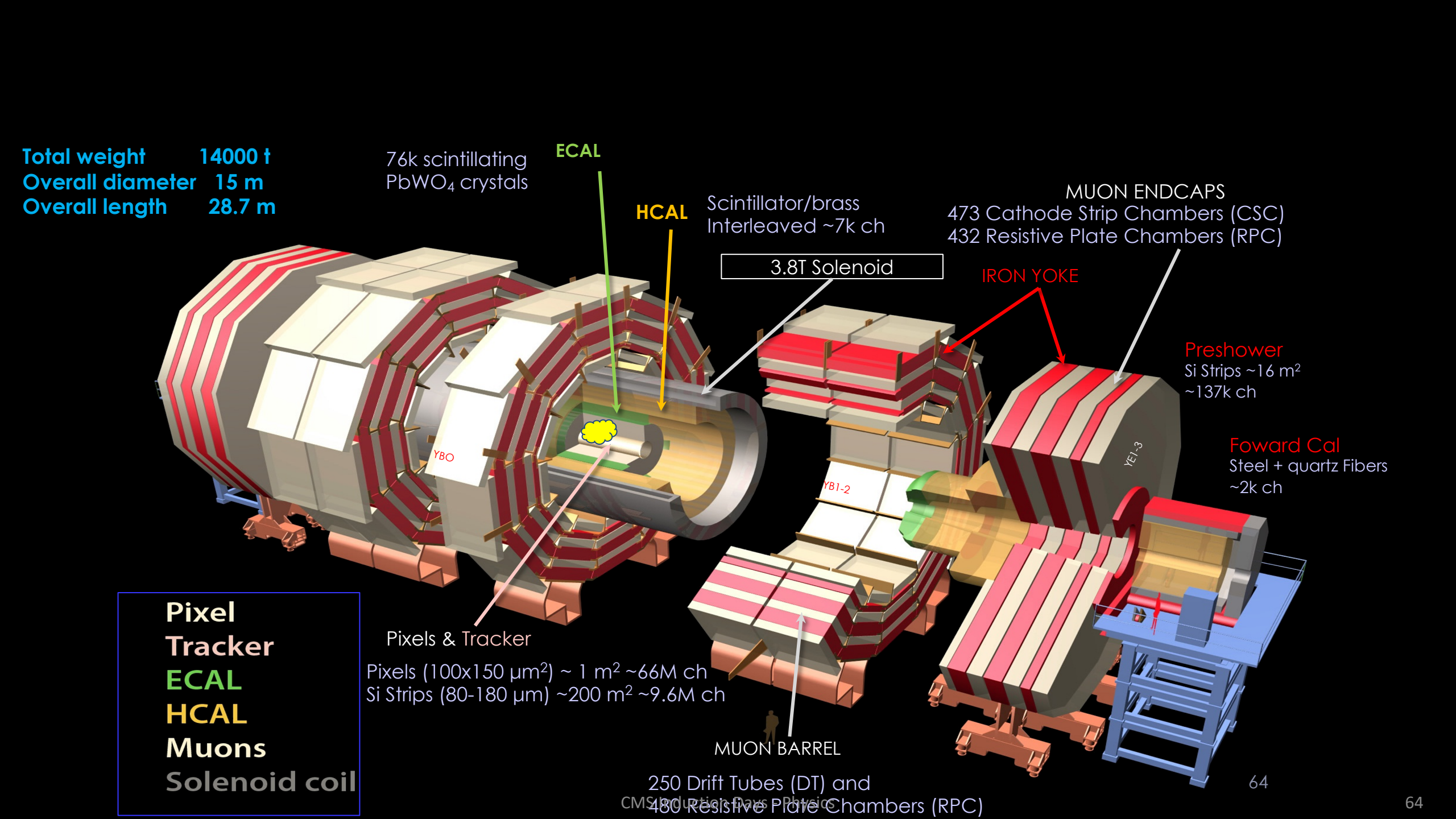


Shahram Rahatlou, Roma Sapienza & INFN

PILE-UP IN 2018



97 vertices


Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m
76k scintillating PbWO4 crystals
ECAL
HCAL
Scintillator/brass Interleaved ~7k ch
3.8T Solenoid
MUON ENDCAPS
473 Cathode Strip Chambers (CSC)
432 Resistive Plate Chambers (RPC)
IRON YOKE
Preshower
Si Strips ~16 m2
~137k ch
Foward Cal
Steel + quartz Fibers
~2k ch
YBO
YB1-2
YE1-3
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil
Pixels & Tracker
Pixels (100x150 μm2) ~ 1 m2 ~66M ch
Si Strips (80-180 μm) ~200 m2 ~9.6M ch
MUON BARREL
250 Drift Tubes (DT) and
480 Resistive Plate Chambers (RPC)

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