CMS Overview

LHCP 2019 - Puebla (Mexico)

Luca Malgeri on behalf of the CMS Collaboration

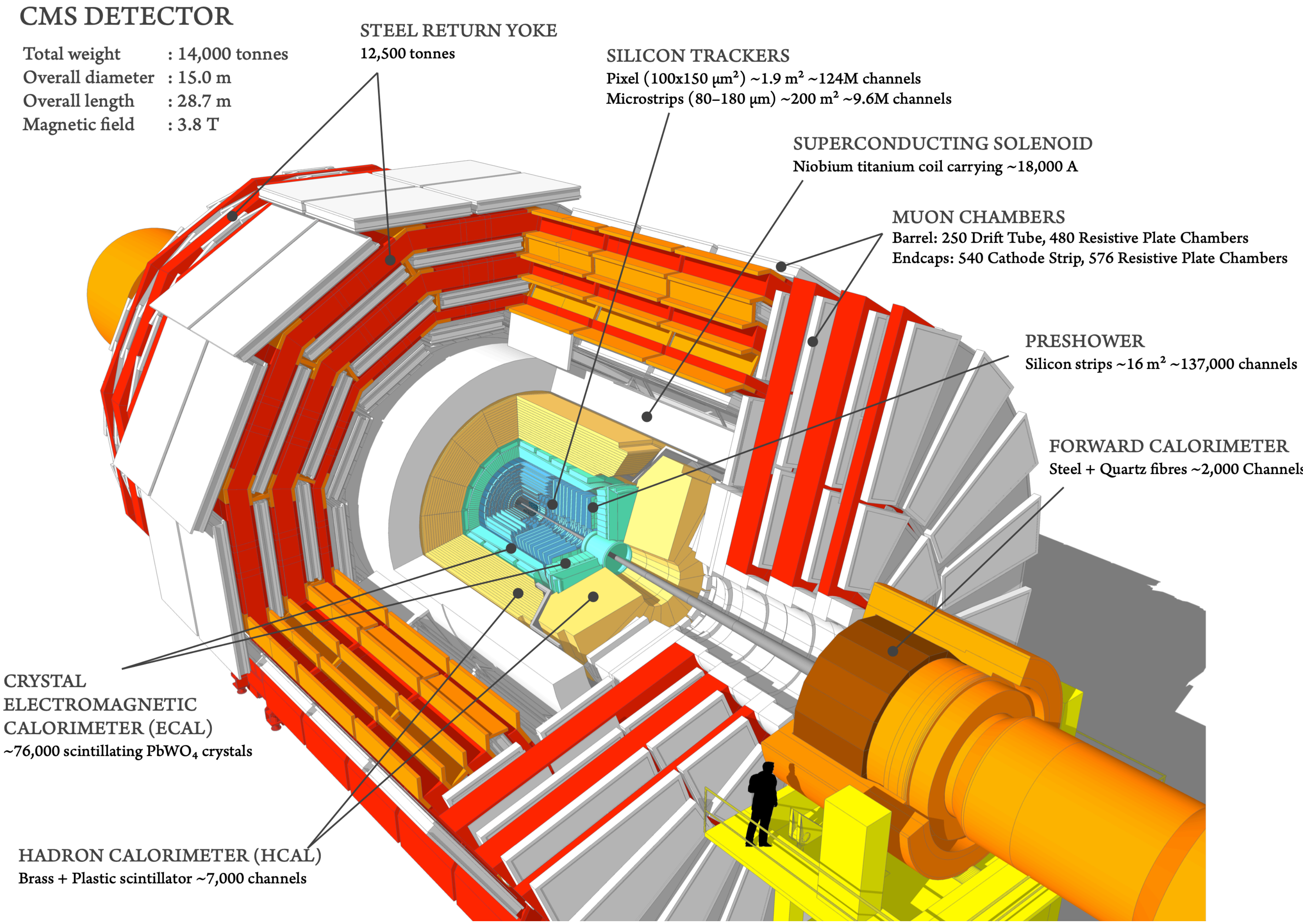
with many thanks to the organizing committees for this wonderful place and conference

Outline

CMS: a truly global collaboration

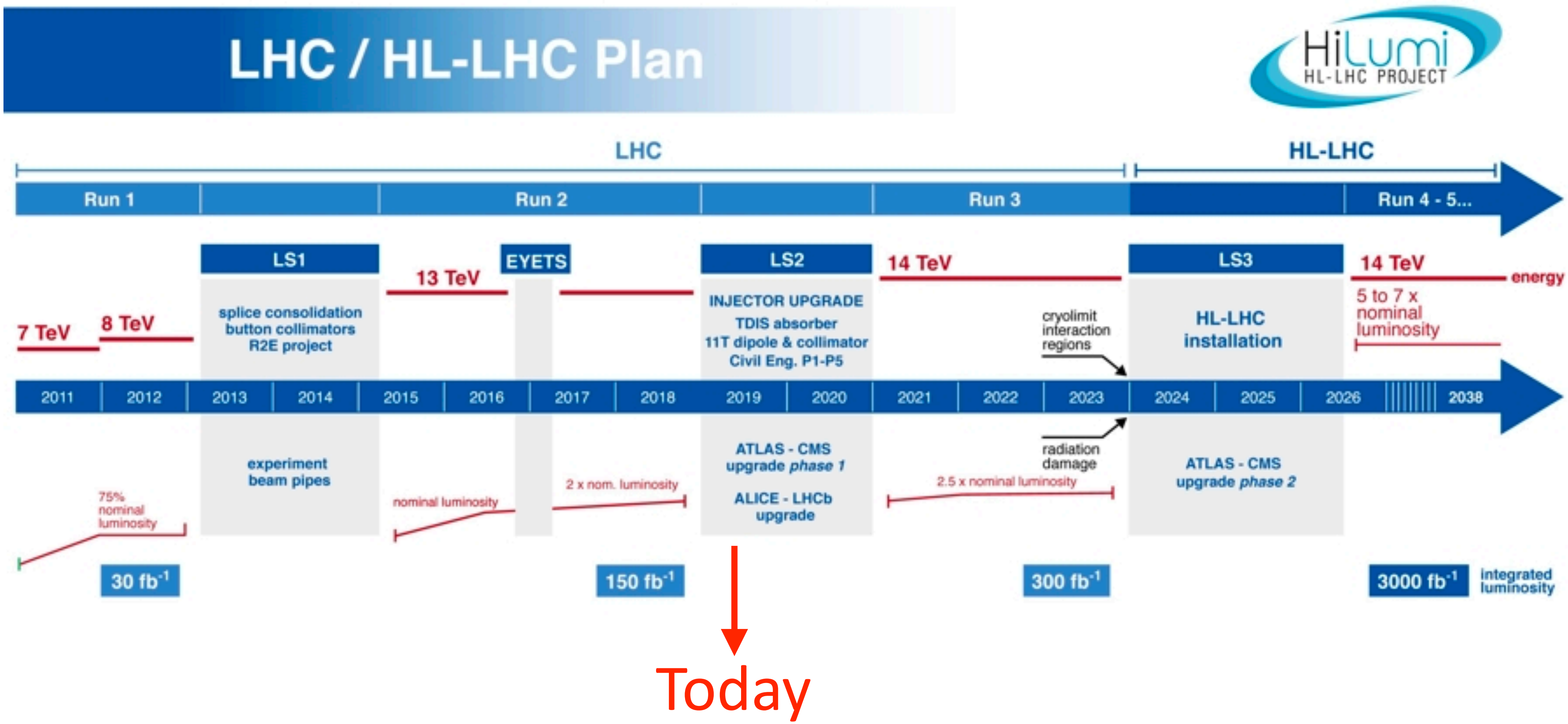
- **Status of CMS**
- **Recent physics highlights**
- **Preparation for Run3**
- **Longer term upgrades (Phase-2)**

CMS status



CMS DETECTOR
Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T
STEEL RETURN YOKE
12,500 tonnes
SILICON TRACKERS
Pixel (100x150 μm²) ~1.9 m² ~124M channels
Microstrips (80–180 μm) ~200 m² ~9.6M channels
SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000 A
MUON CHAMBERS
Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers
PRESHOWER
Silicon strips ~16 m² ~137,000 channels
FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels
CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO4 crystals
HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

LHC plan



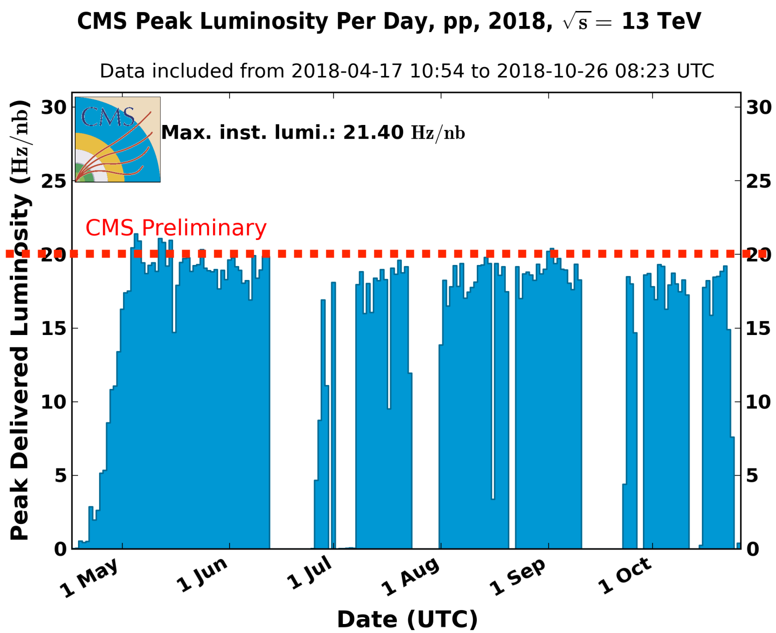
Run 2
$<\mu>$~37
L up to 2.0E34 Hz/cm²

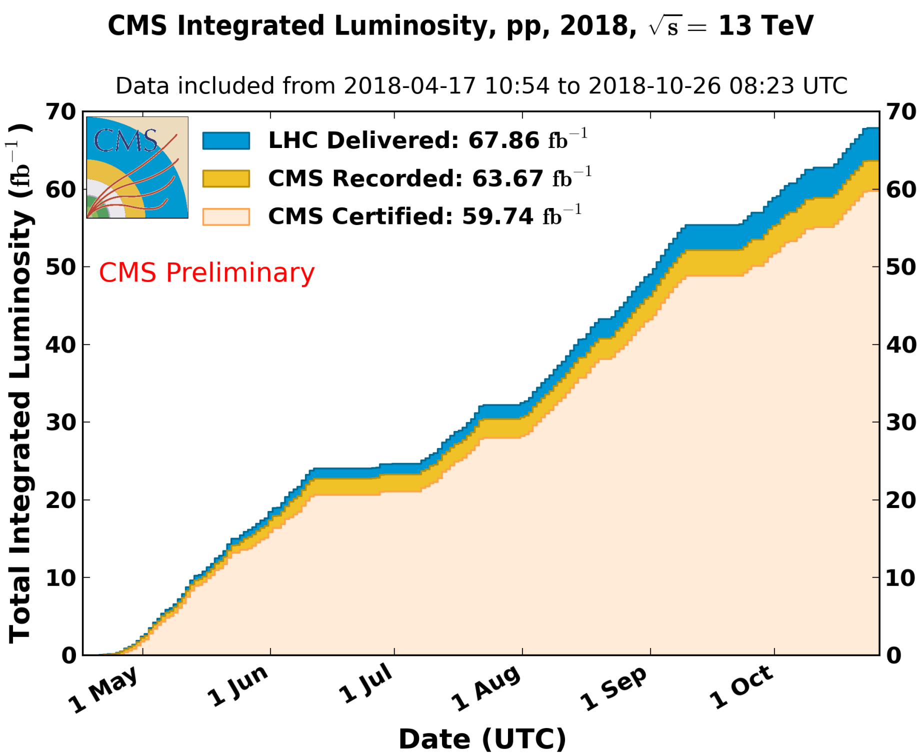
Run 3
$<\mu>$~55
L up to 2.0E34

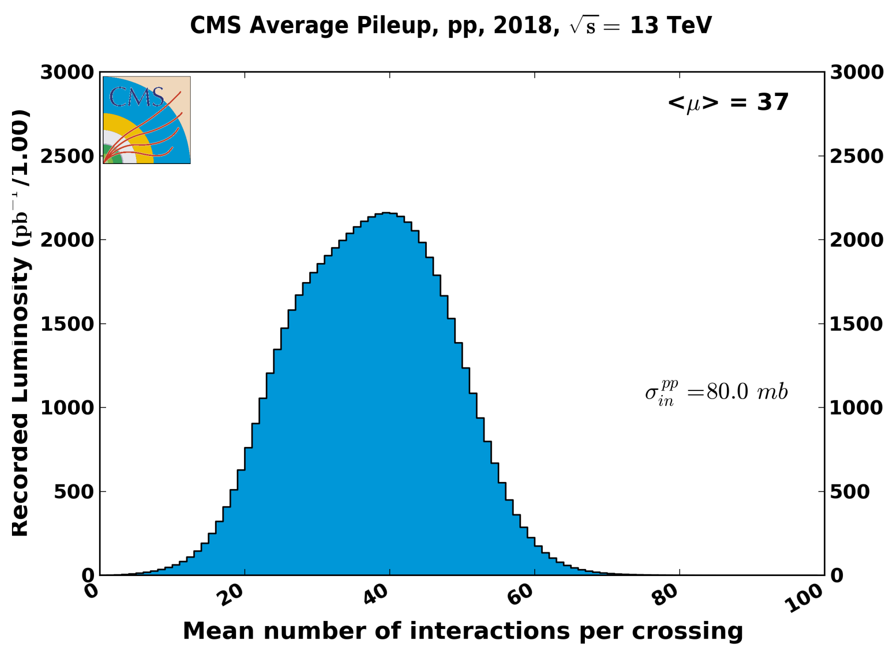
Run 4-5
$<\mu>$~140-200
L up to 7.5E34

2018 pp run

- ~ 94% recording efficiency
  - recorded/delivered
  - peak luminosity grazing 2x10[34] Hz/cm[2]
- ~ 95% validation efficiency
  - validated/delivered

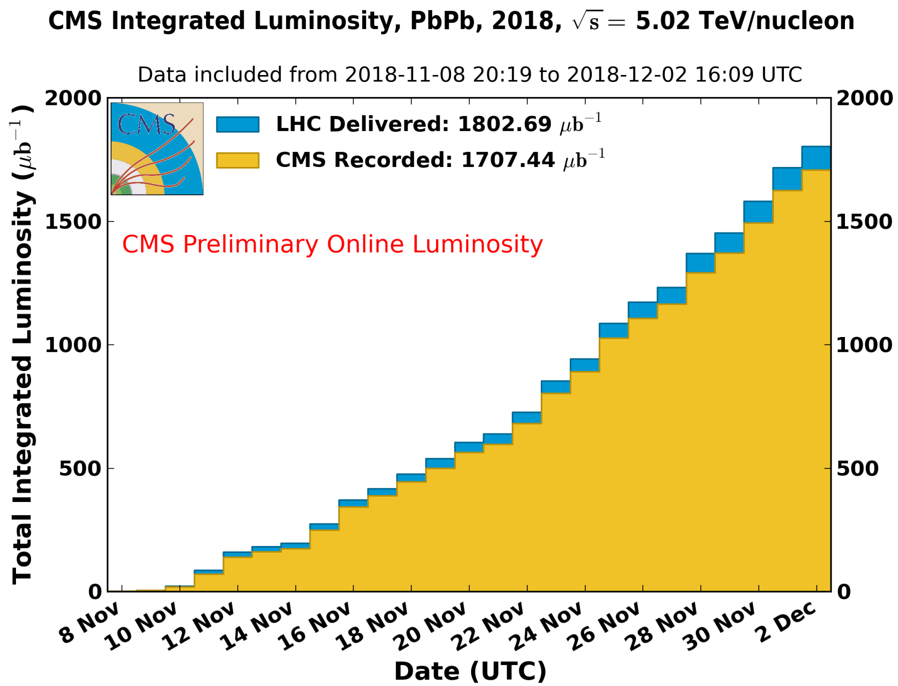




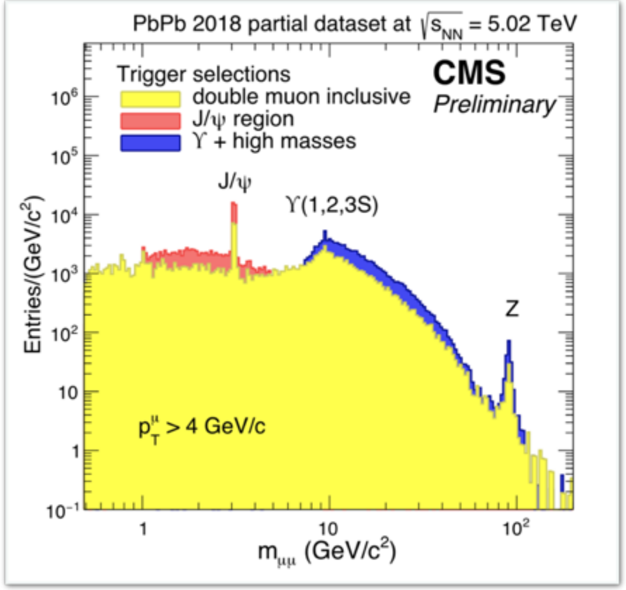


2018 PbPb run

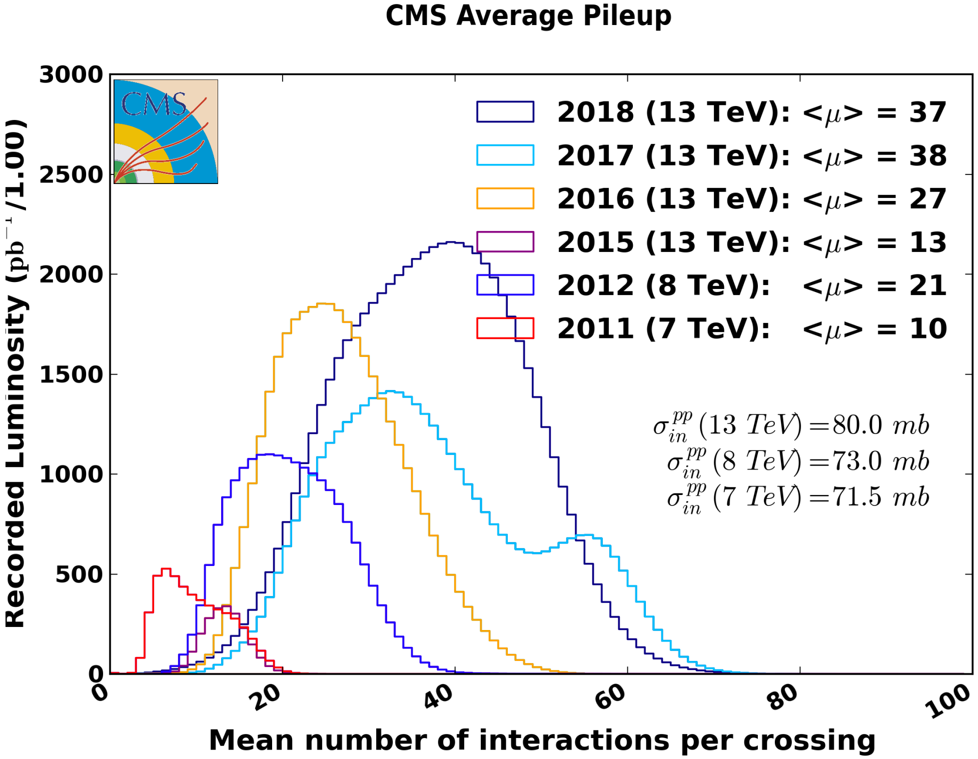
- Collected luminosity ~ 1.80 nb^{-1}
  - about 4.5 billions minimum bias triggers
  - Data quality good: 95% data taking efficiency
- Plan started early in 2018, with all the CMS areas involved
  - Pushing CMS data acquisition up to the maximum: 7.4 GB/s
  - Stable running up to 7 GB/s to offline

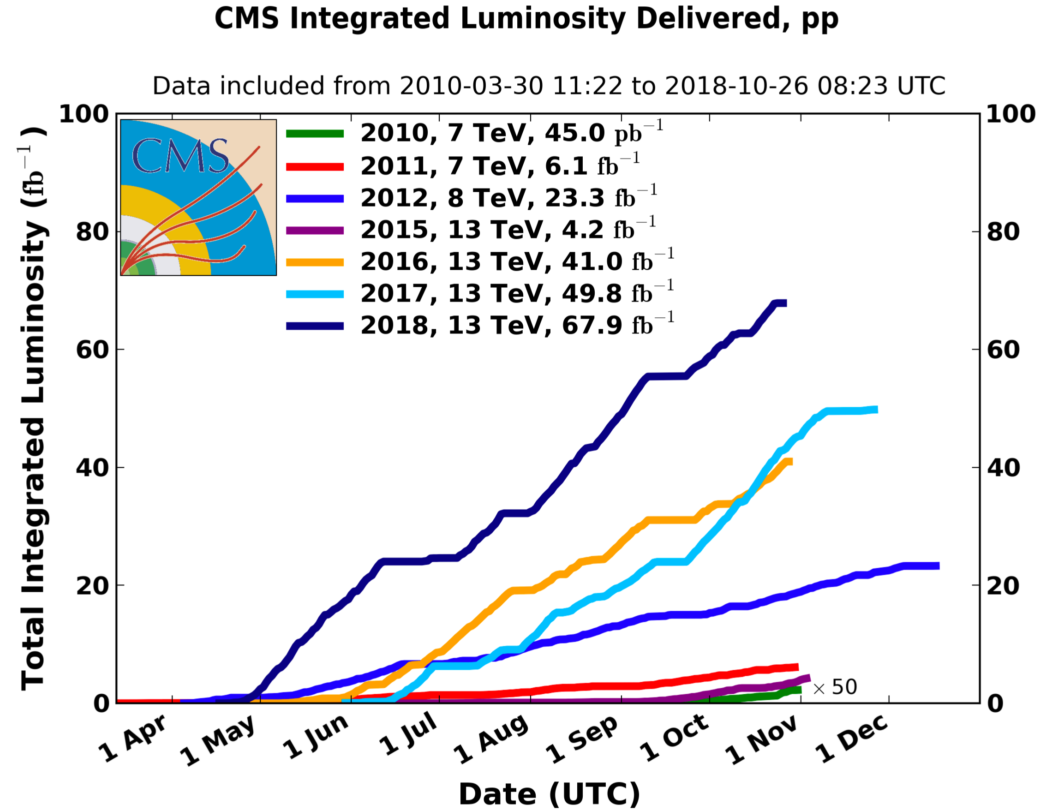


For lack of time I will not show
any results on the HI program but
a fresh new result will be shown in the HI
plenaries concerning the Λ_c production in pp and
PbPb collisions (PAS_HIN-18-009)



Run 1-2 summary





	Int. lumi	<μ>
7 TeV	6.1 fb^{-1}	10
8 TeV	23.3 fb^{-1}	21
13 Tev	162.9 fb^{-1}	37

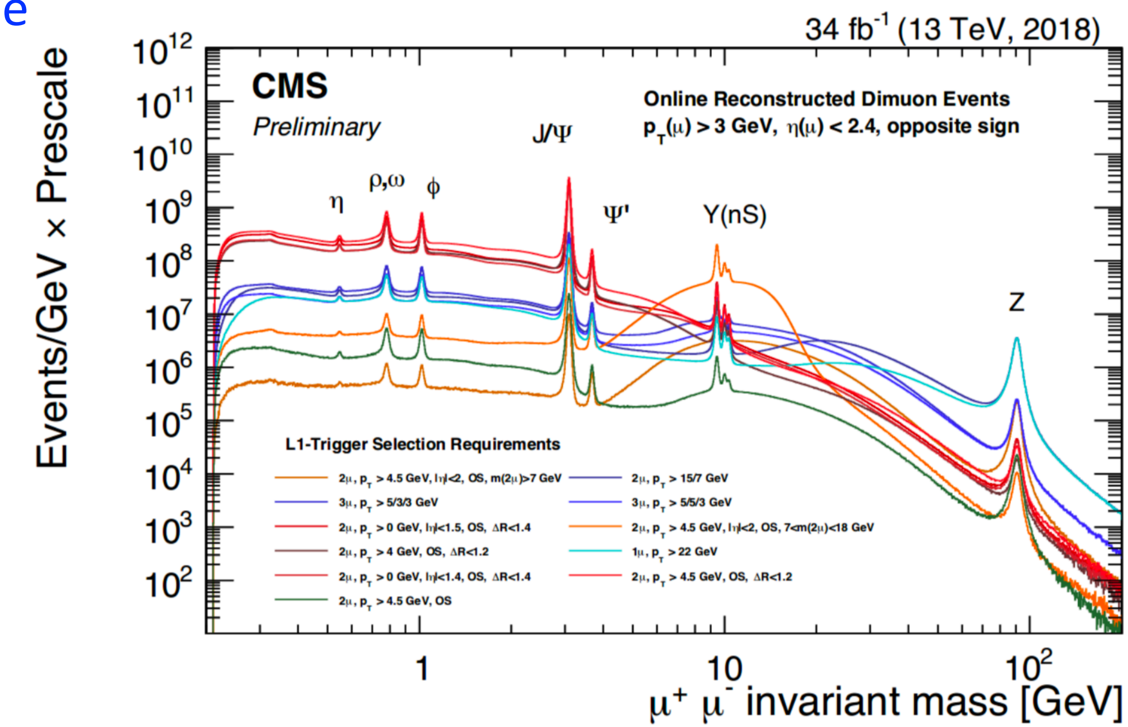
A big thank to the LHC crew for these wonderful achievements!

Run 2 non-orthodox data taking

For more details see HOW2019

Data scouting

- Traditional trigger algorithms usually require high pt particles to reduce the event rate, and then readout the full event information
- Need to reduce the event size to collect events at a higher rate
  - Physics objects produced by the High Level Trigger as the final objects
    - CaloScouting (vertices, muons, calo based jets and MET) → limited by L1 rate
  - ParticleFlow Scouting (vertices, PF muons, PF jets and MET, PF cands.)→ limited by HLT CPU time

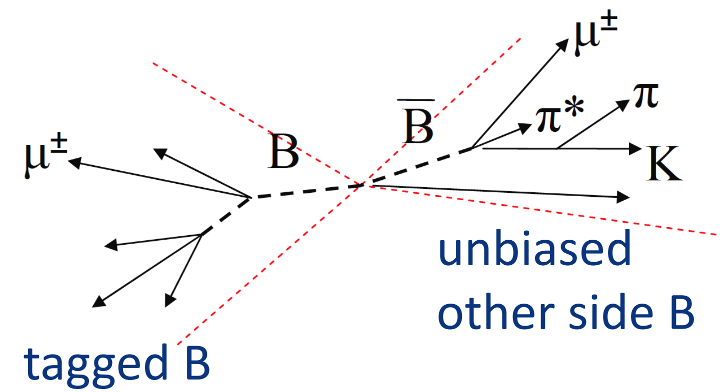


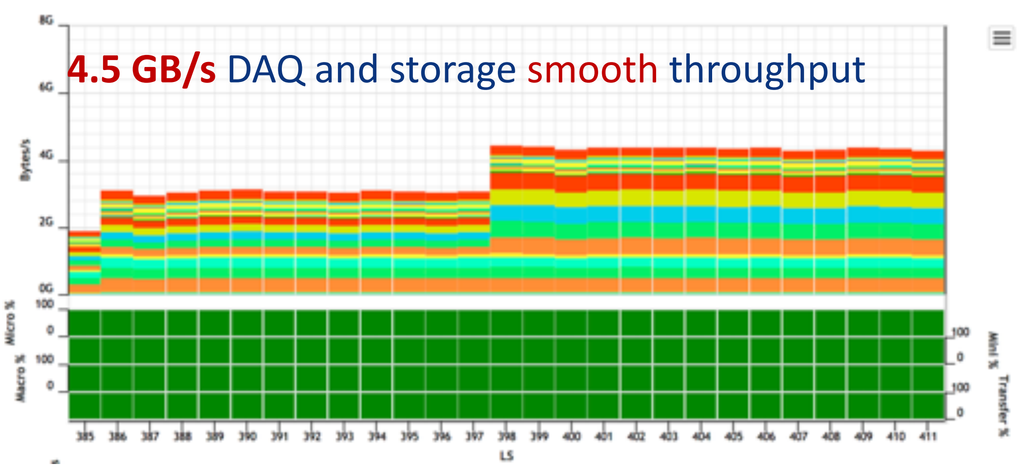
For more details see 4th LLP LHC workshop

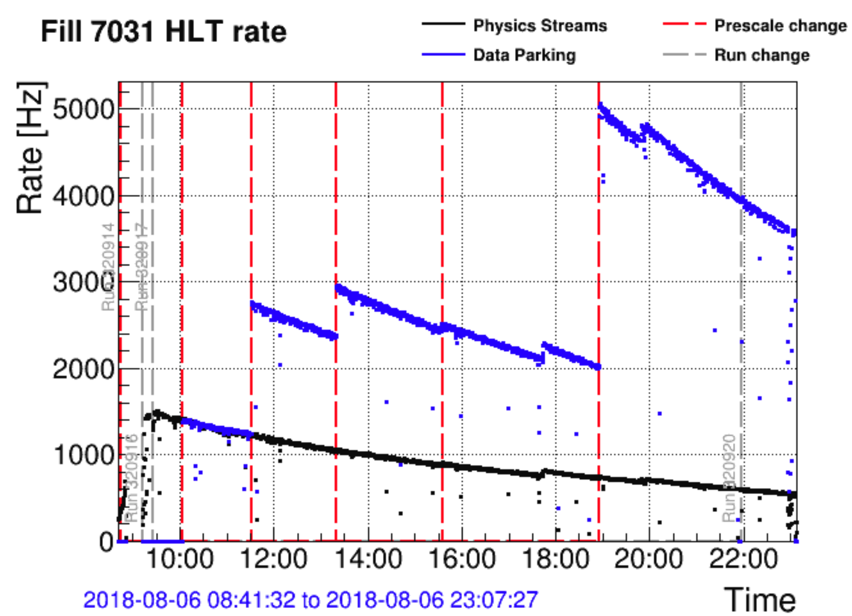
B-parking - a swiss knife for B studies

Plan: store a large unbiased B hadron sample by tagging on the «opposite side» B

- CMS parked (→ no prompt reconstruction) 12 billions of B triggers, a sample 20x larger than Babar’s
- Fit within available computing resources
  - Up to 6 kHz additional rate to tape

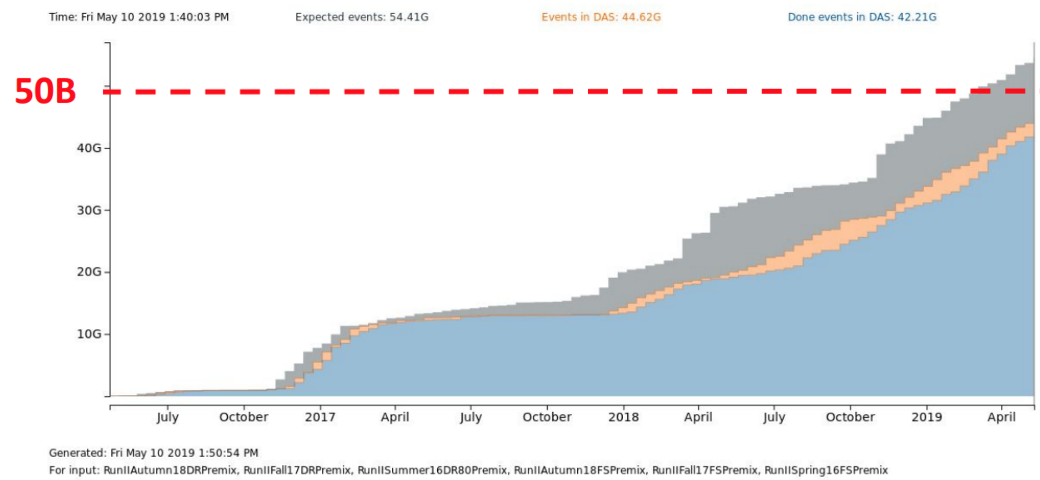




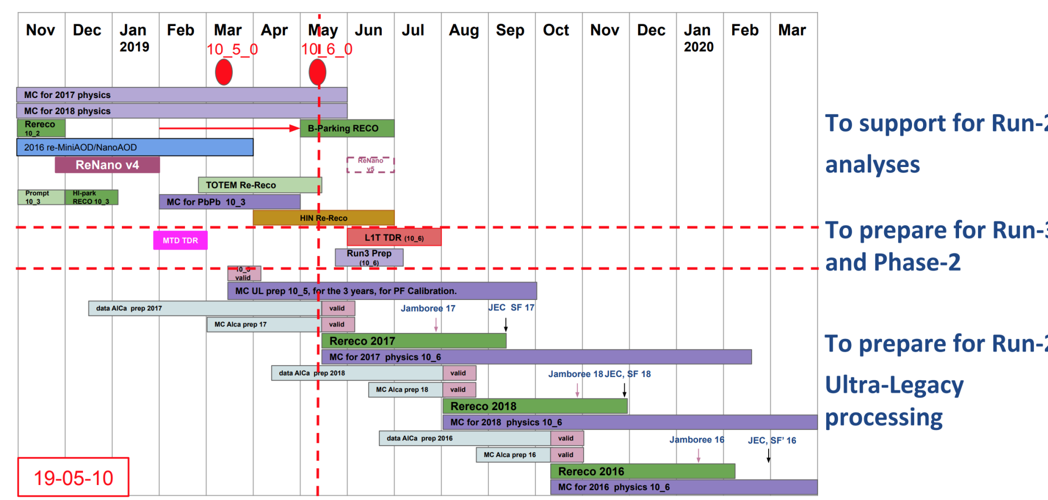


Offline and Computing Performance

- O+C systems were able to cope for simultaneous
  - data taking with larger-than-expected parking and Heavy Ions data taking
  - support for analyses, with 50kCores at any moment (out of 250kCores total)
  - preparation of samples for Phase-II TDRs
  - evolution of our software and services
  - preparation of 50B ('17-'18) MC events



- Long shutdown periods are the most busy for computing:
  - full reprocessing of Run 2: 60 B events expected
  - deploy new services for Run-III: new data management, new geometry and web services infrastructures
  - Get prepared for Phase-II:
    - Adapt to GPUs, FPGAs, via a heterogeneous framework
    - Prepare 2026 operations and resources



Recent Physics Highlights

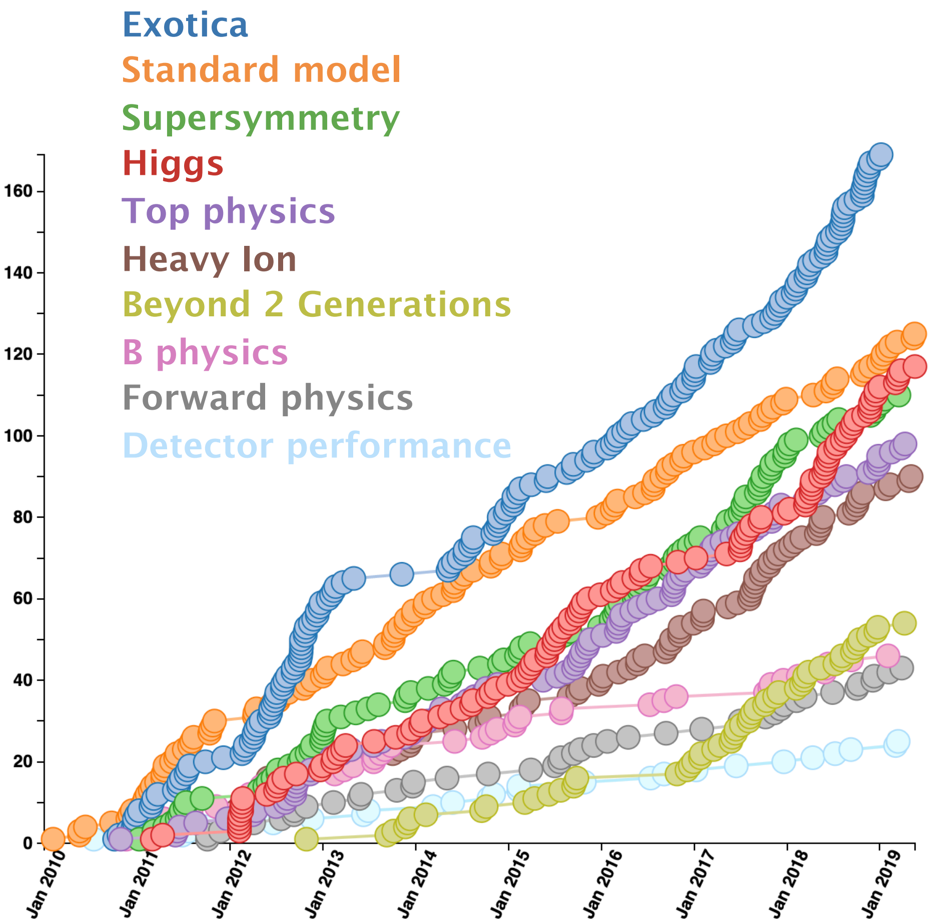
(just as teasers and spoilers:
all details given during the conference
by the real experts)

2019 paper crop so far

876 papers on collider's data out of 901 published

We just celebrated the 900th submitted papers last Friday (and we are now at 901)!

- 141 papers submitted in 2018 (new record!)
- first LHC full run2 statistics paper submitted on on Feb. 1, 2019 (Phys. Rev. Lett. 122 (2019) 132001
- 9 results with full Run 2 data
- ~50 new results since the beginning of 2019
- in the following only few selected results shown



- Summary at:

  http://cms-results.web.cern.ch/cms-results/public-results/publications/

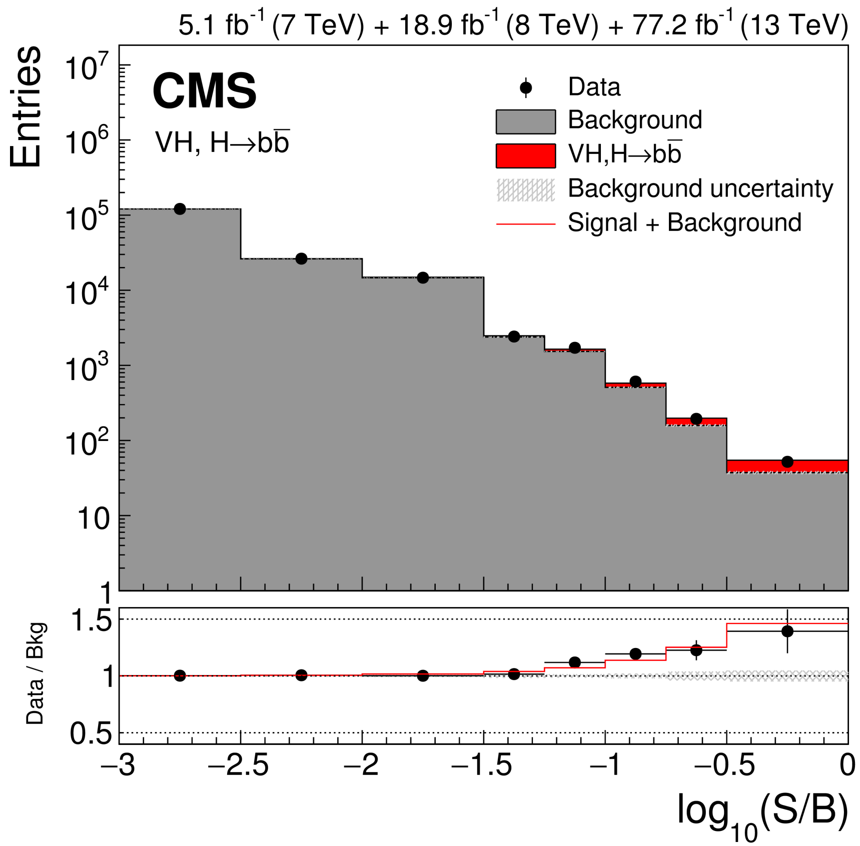
2018 Physics highlights:
Higgs top and bottom Yukawa couplings!

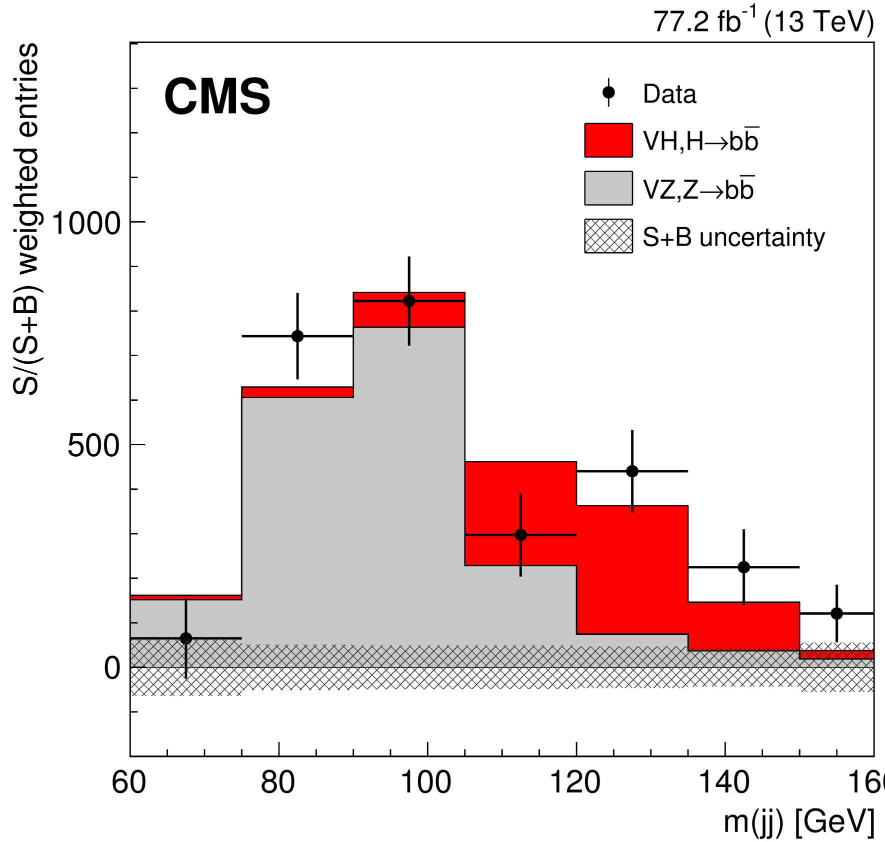
Channel	Date
H→ττ	May 2017
pp→ttH	Apr 2018
H→bb, pp→VH	**Aug 2018**

→ New since LHCP2018

H→bb observation

PRL 121 (2018) 121801





- Both ATLAS and CMS have observed it (>5σ)
- Very complex analyses (multivariate techniques used in every step)

Notes:

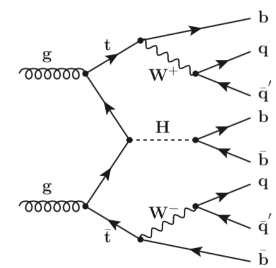
- in CMS the first DNN based analysis
- in CMS first analysis based on 1kB/ event data format (0.1% of the raw format!)

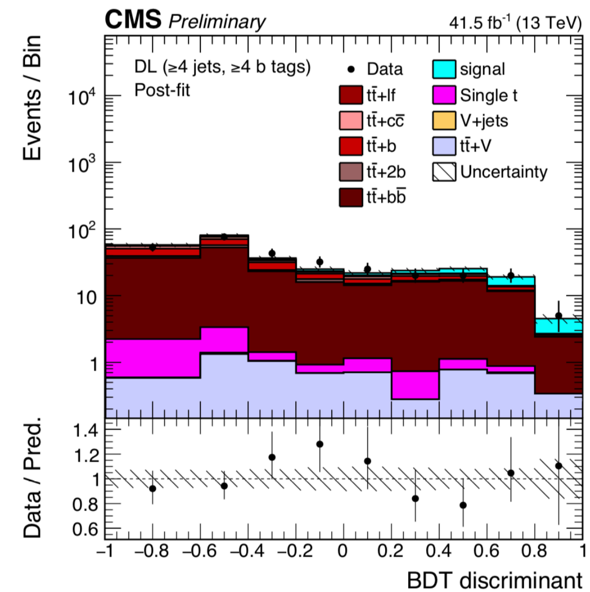
Updated results on ttH(bb)

New

PAS-HIG-18-030, PAS-TOP-18-011

- Inclusion of 2017 data
- Fully consistent with previous analysis:
  - improved treatment of ISR/FSR systematics
  - improved b-tag using deep NN technique
- Three major categories:
  - fully hadronic
    - QCD rejection using shape variable Δη
  - semi-leptonic
    - simplified NN classifier
  - di-leptonic
    - matrix element used as BDT input
- Dominant syst: tt+hf modeling, QCD bkg, b-tag SF
- Synergetic with new ttbb cross section measurement (TOP-18-011)!

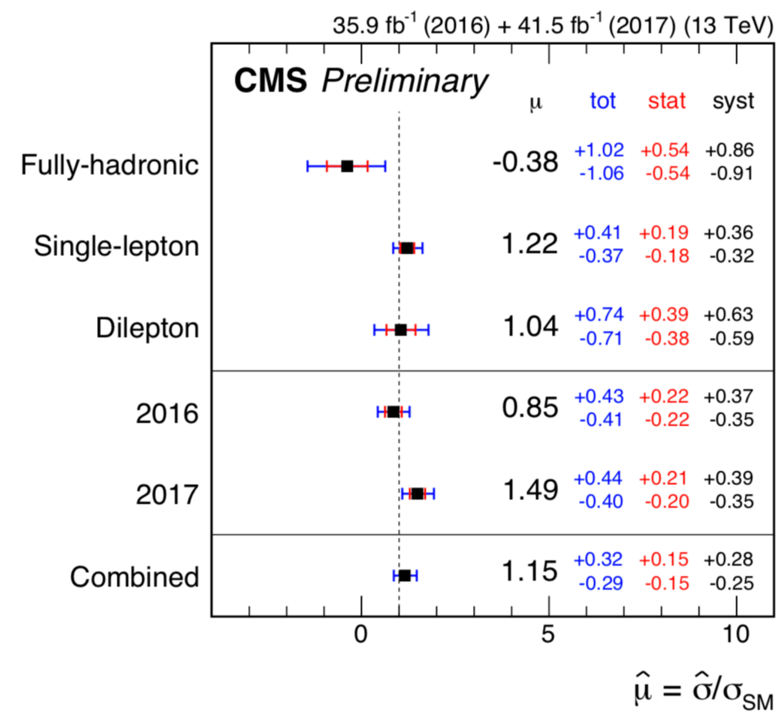




Combining 2016 (35.9 fb^{-1}) and 2017 (41.5 fb^{-1})

$$\mu_{\mathrm{fit}} = 1.15^{+0.32}_{-0.29}\left(^{+0.15}_{-0.15}\ ^{+0.25}_{-0.28}\right)$$

Obs. sign.: 3.9σ (exp. 3.5σ)
in this channel alone!



Z production cross section @13 TeV

New

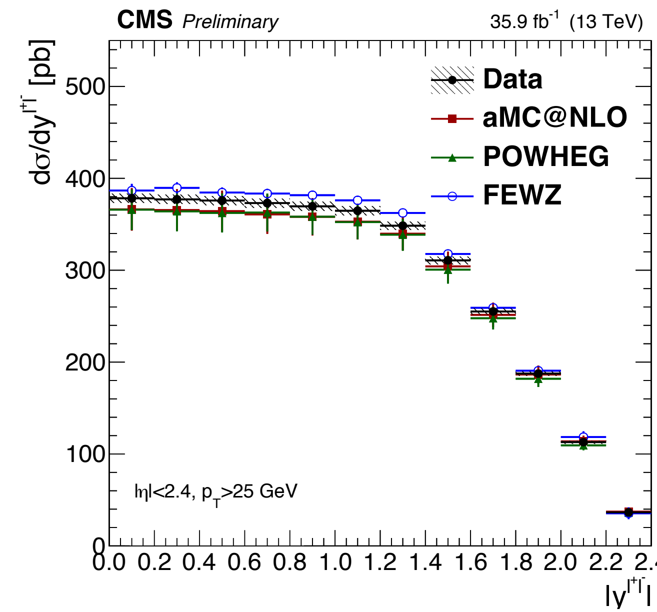
PAS-SMP-17-010

- Testing high order EW and QCD corrections
- Input to M_W and PDF
- Providing:
  - inclusive fiducial cross sections
  - differential in pT, |η| and φ^*
  - double differential in pT, |η|

$$\phi^*_\eta = \tan\left(\frac{\pi - \Delta\phi}{2}\right) \cdot \sin(\theta^*_\eta)$$

$$\cos(\theta^*_\eta) = \tanh\left(\frac{\eta^- - \eta^+}{2}\right)$$

- Compared to state of the art (N)NLO predictions
- Lepton-ID needs to be controlled at the highest possible precision

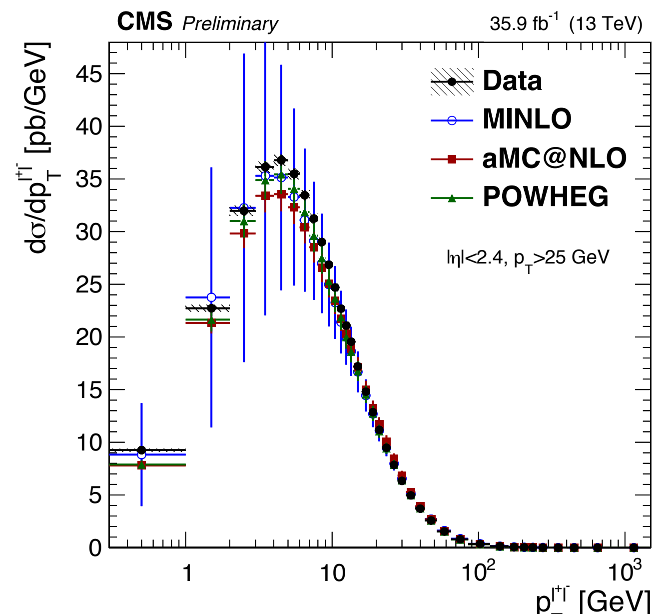


Cross section	$\sigma\,\mathcal{B}$ [pb]
$\sigma_{Z\to\mu\mu}$	$694 \pm 6\,(\mathrm{syst}) \pm 17\,(\mathrm{lumi})$
$\sigma_{Z\to ee}$	$712 \pm 10\,(\mathrm{syst}) \pm 18\,(\mathrm{lumi})$
$\sigma_{Z\to\ell\ell}$	$699 \pm 5\,(\mathrm{syst}) \pm 17\,(\mathrm{lumi})$

Theoretical cross sections:

$\sigma_{Z\to\ell\ell}$ = 682 ± 55 pb (aMC@NLO)

$\sigma_{Z\to\ell\ell}$ = 719 ± 8 pb (FEWZ)

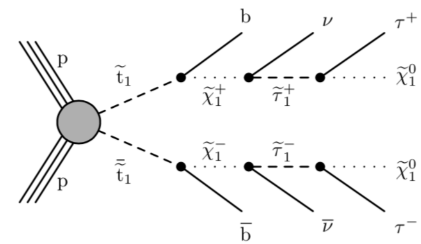


Innovative paths:
unconventional signatures
unconventional triggers
unconventional processing

Search for stop in di-tau final states

PAS-SUS-19-003

- Justified by higgsino-like or high tan β scenarios
- In this scenarios SuSy cascades ends with many taus (and missing momentum)
- Different kinematic regions depending on mass splittings (“*x*” parameter)
- Major bakground (tt) modeled through full data driven technique
- No excess found: top squark mass of up to ~1 TeV excluded for nearly massless neutralinos.

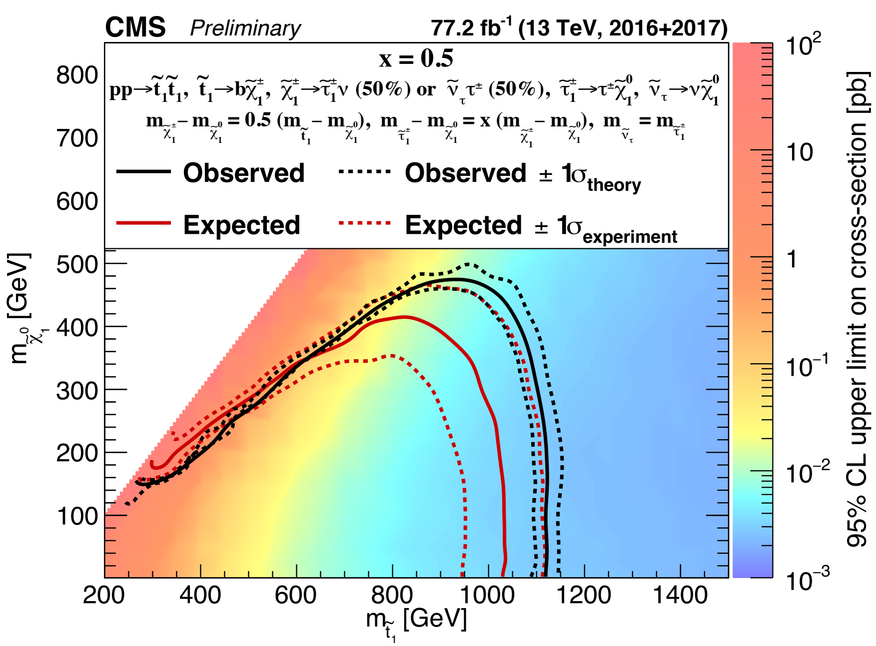


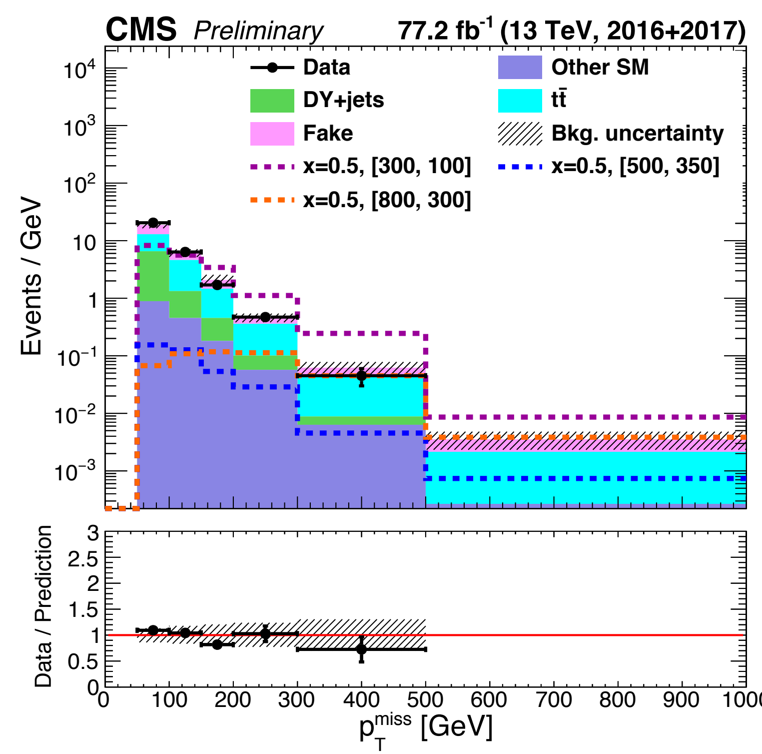
$$m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0} = 0.5\ (m_{\tilde{t}_1} - m_{\tilde{\chi}_1^0})$$

$$m_{\tilde{\tau}_1} - m_{\tilde{\chi}_1^0} = x\ (m_{\tilde{\chi}_1^\pm} - m_{\tilde{\chi}_1^0})$$

$$\text{Assuming } m_{\tilde{\nu}_\tau} = m_{\tilde{\tau}_1}$$

$$x = [0.25,\ 0.5,\ 0.75]$$

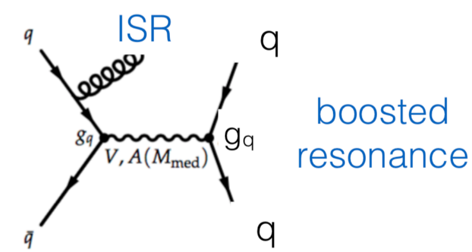




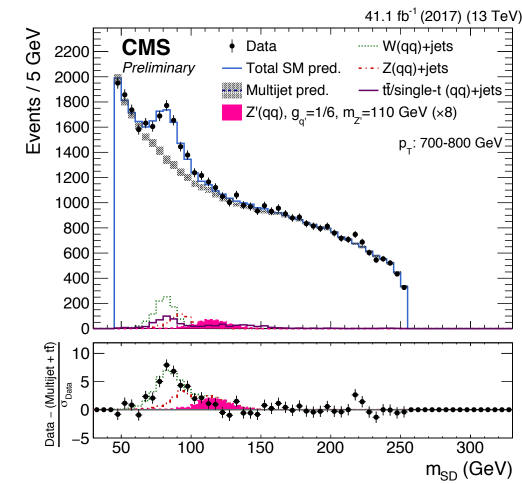
Search for low mass resonances

PAS-EXO-18-012

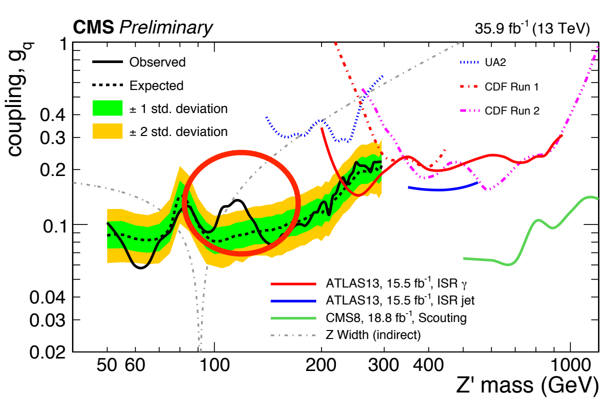
- Search for generic vector resonance coupling to quarks
- Use ISR tag in trigger to explore low mass region
- Use boosted techniques to reconstruct the Z' (AK8 and CA15 jets)
- Slight excess of global significance ~2.2σ around 100 GeV observed using 2016 data (PAS-EXO-17-001)
- New analysis combining with 2017 shows it was likely a statistical fluctuation



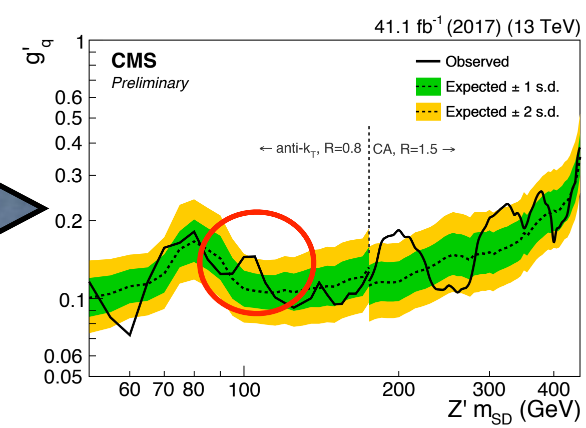
New



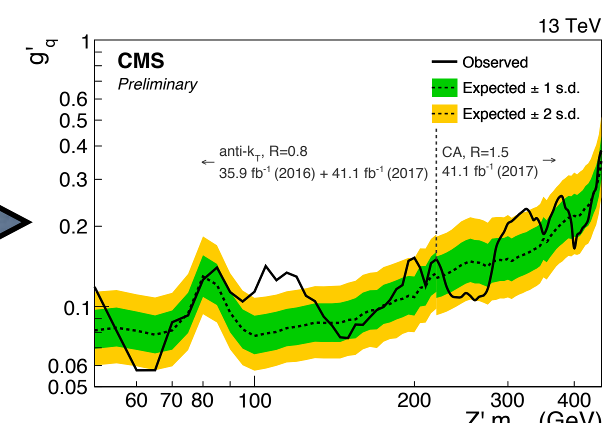
2016 data



2017 data



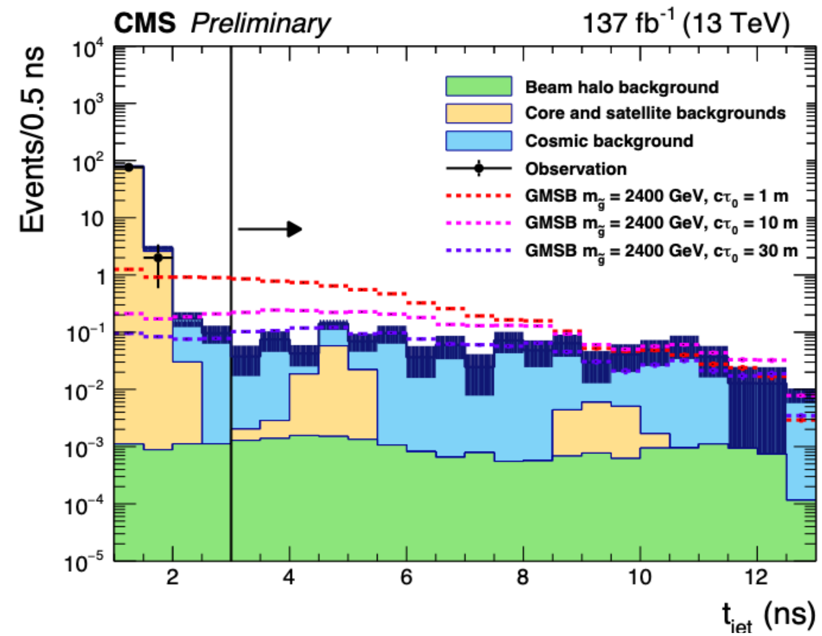
Combined



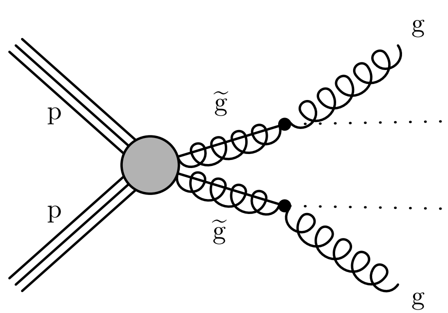
Search for delayed jets

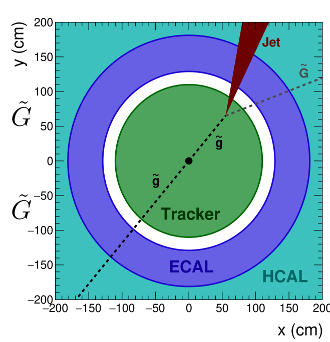
PAS-EXO-19-001

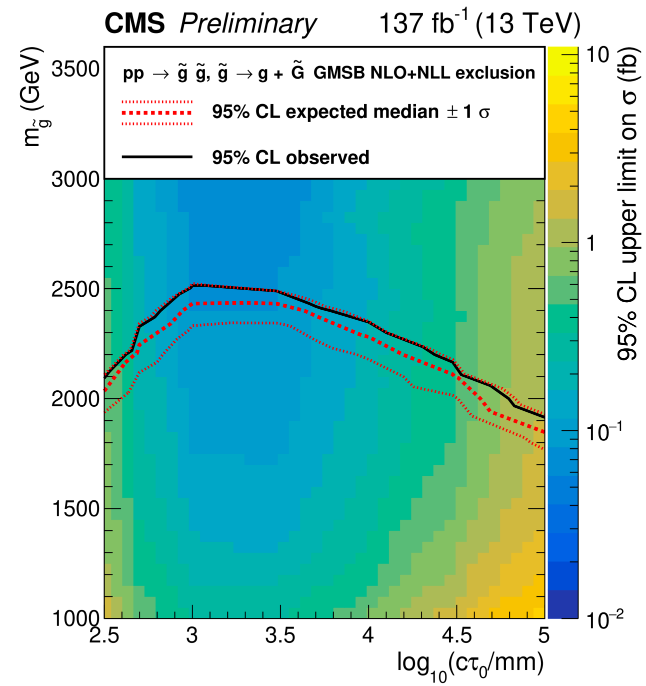
- Many models (SuSy, hidden valley, …) with long-lived particles could give jets in the final state originating far from the interaction
- First search for jets using precise ECAL timing information
  - Specific reconstruction algorithm to extract jet timing from associated ECAL cells
  - Extracts contributions from “unusual” backgrounds like cosmics, beam halo, and pp collisions in “satellite” bunches from data
- Also see long lived chargino search in backup (PAS-SUS-19-008)



Interpreted in a model of gauge mediated SUSY breaking (long-lived gluinos)





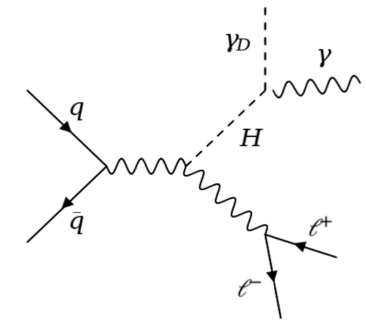


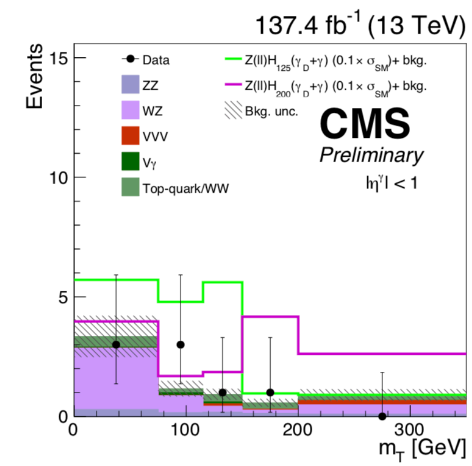
Search for dark photons with full run2 stat

PAS-EXO-19-007

- Look for massless dark photons coupling to Higgs through charged dark sector particles (loop)
- Simple signature:
  - a Z (into leptons)+ a photon
  - little hadronic activity
  - Z+γ recoiling against missing momentum
- Main background from diboson and top production
- Search in several signal regions (mT vs η vs final state configuration)
- no excess seen: set limit on “H” mass vs visible cross section or equivalently on Br(H→inv.+ γ) at fixed mass

New

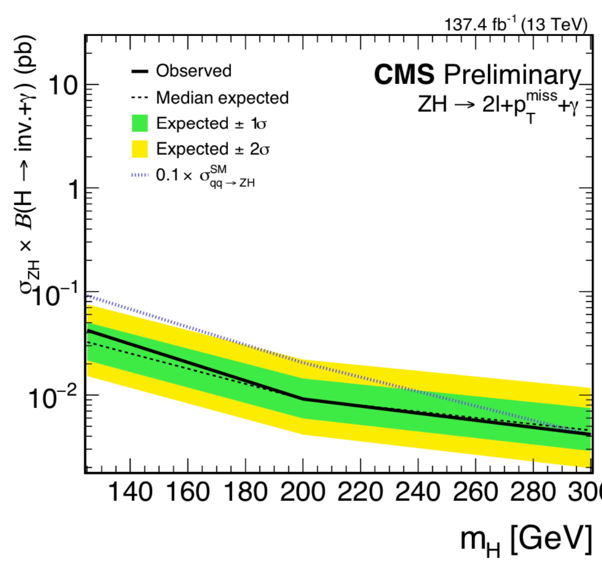


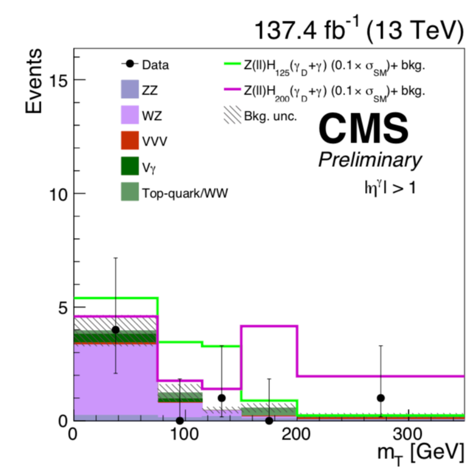


Br(H→inv.+ γ) < 4.6 %

@95% C.L. for m_H=125 GeV

exp.: $(3.6^{+2.0}_{-1.2})$%





Activities during Long Shutdown

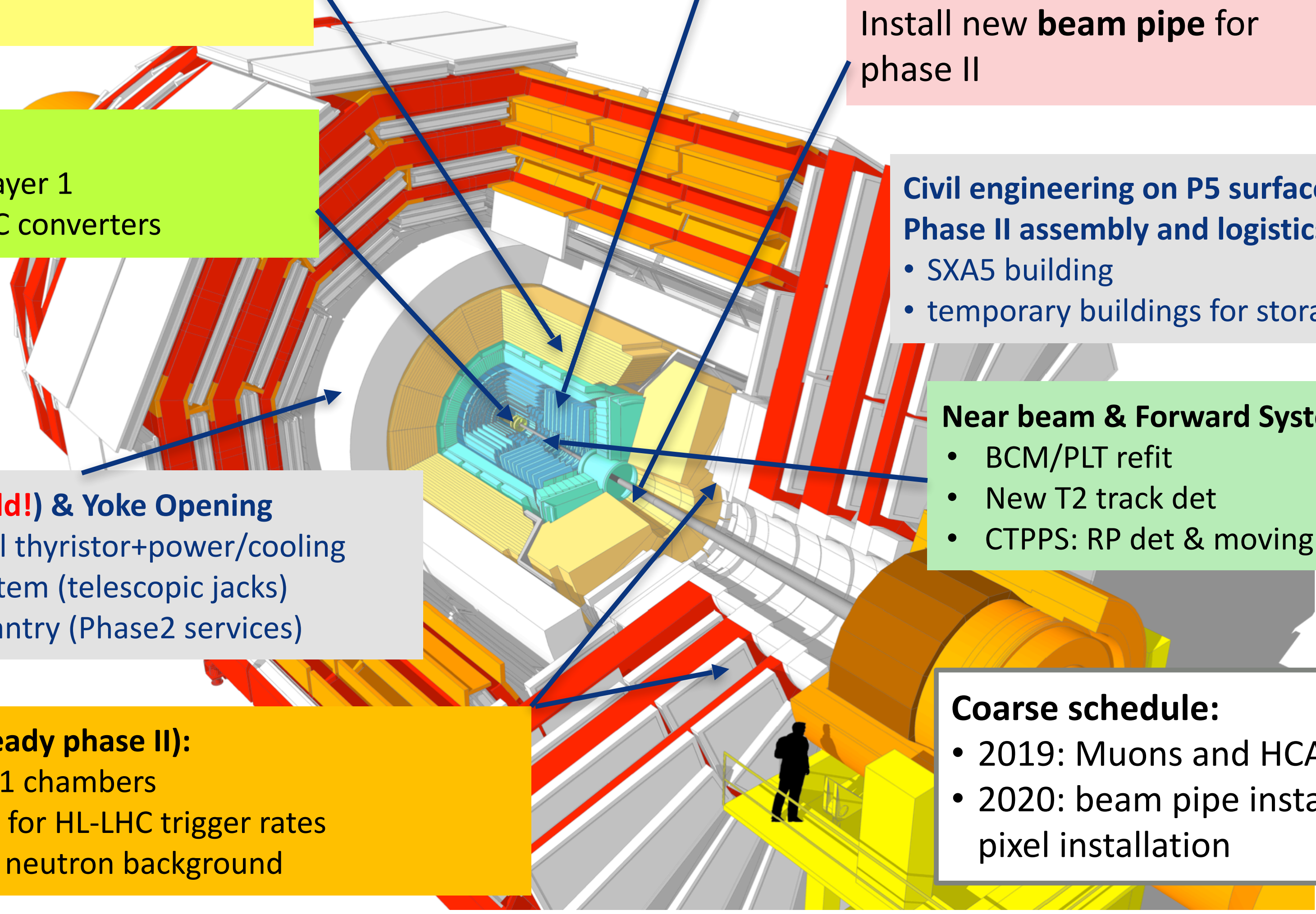
Keep **strip tracker** cold to avoid reverse annealing

HCAL barrel (last phase I): install SiPM+QIE11-based 5Gbps readout

Install new **beam pipe** for phase II

Pixel detector:
- replace barrel layer 1
- replace all DCDC converters

Civil engineering on P5 surface to prepare for Phase II assembly and logistics
- SXA5 building
- temporary buildings for storage/utility



Near beam & Forward Systems
- BCM/PLT refit
- New T2 track det
- CTPPS: RP det & moving sys upgrade

MAGNET (stays cold!) & Yoke Opening
- Cooled freewheel thyristor+power/cooling
- New opening system (telescopic jacks)
- New YE1 cable gantry (Phase2 services)

Muon system (already phase II):
- install GEM GE1/1 chambers
- Upgrade CSC FEE for HL-LHC trigger rates
- Shielding against neutron background

Coarse schedule:
- 2019: Muons and HCAL interleaved
- 2020: beam pipe installation, then pixel installation

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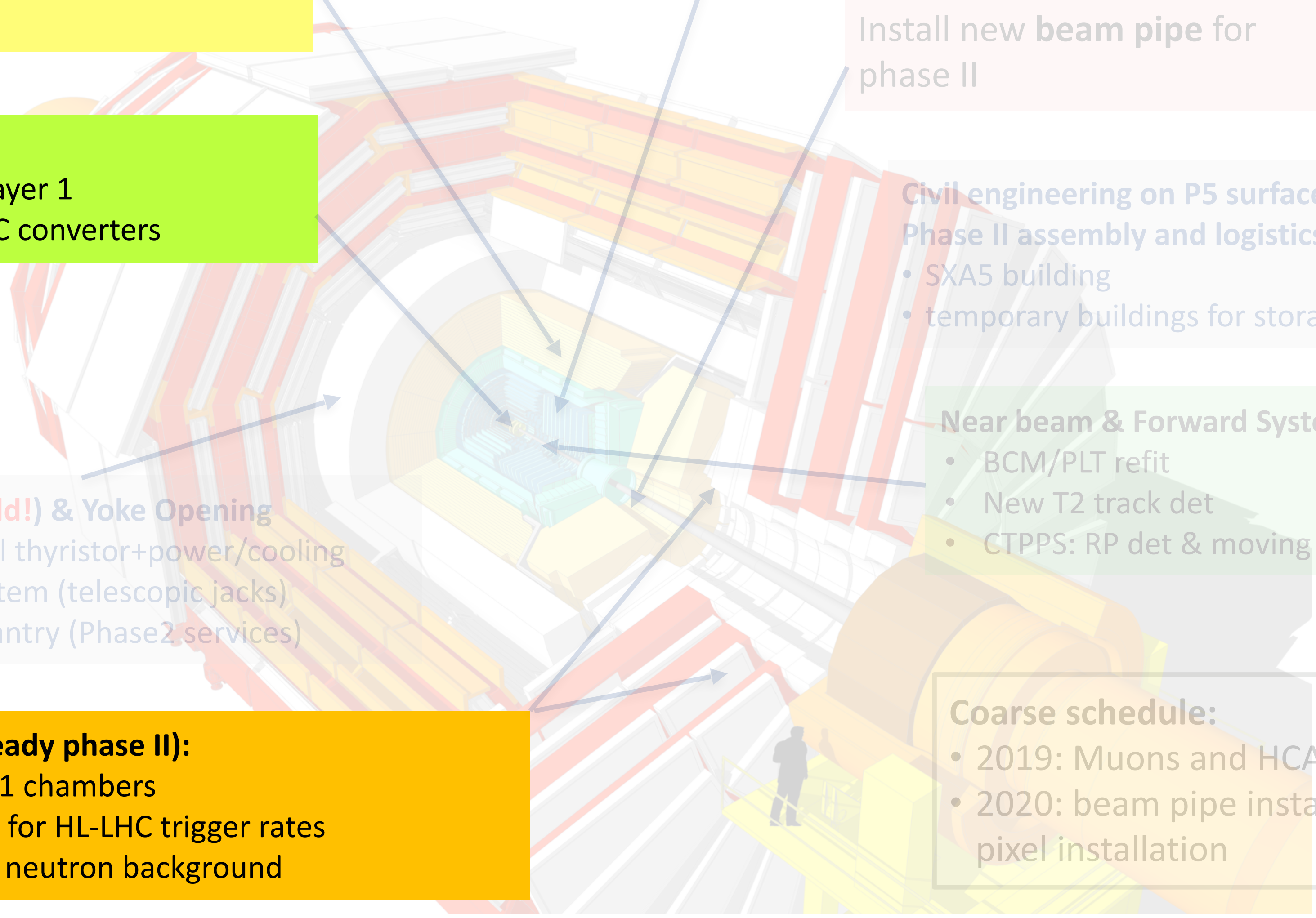

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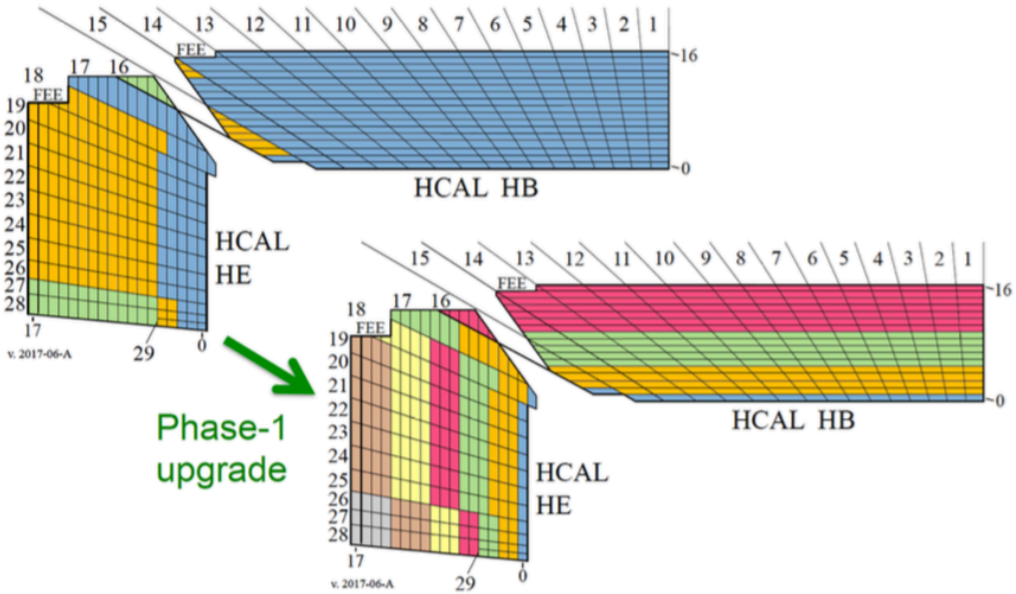
Phase-1 CMS upgrade is almost done, and in line with the planned schedule providing substantial benefits already during Run 2

Hadronic calorimeter

- last phase 1 upgrade!
- replacement of HPDs with SiPM
  - better noise levels, light yield and radiation tolerance
  - provides longitudinal segmentation
- Endcap refurbishment done during Run2
- Barrel refurbishment being completed now



LS2: Phase-1 and Phase-2 upgrades

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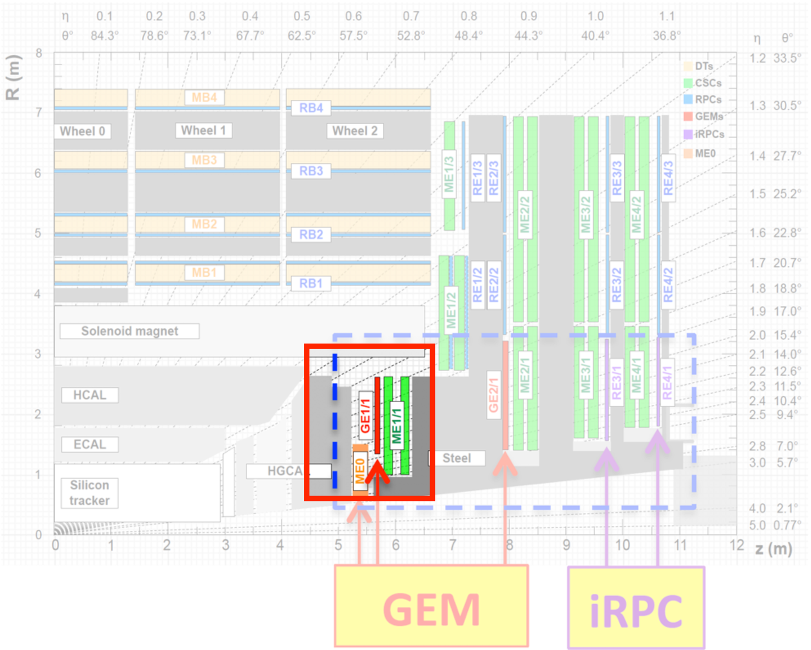
Pixel detector

- The detector was extracted in January.
- Present DCDC converters are at risk of breaking if disabled once total irradiation reaches ~1Mrad (~30 fb^{-1})
  - Will be fully replaced with a corrected version
- Ensure detector longevity for Run 3 despite radiation effects
  - Replace full BPIX Layer 1 after two years of operations as originally planned
    - Layer 1 readout and chip (PROC600) and control chips (TBM) will be replaced with an improved version
  - Ensure the detector can be operated with a larger HV bias 600-800V

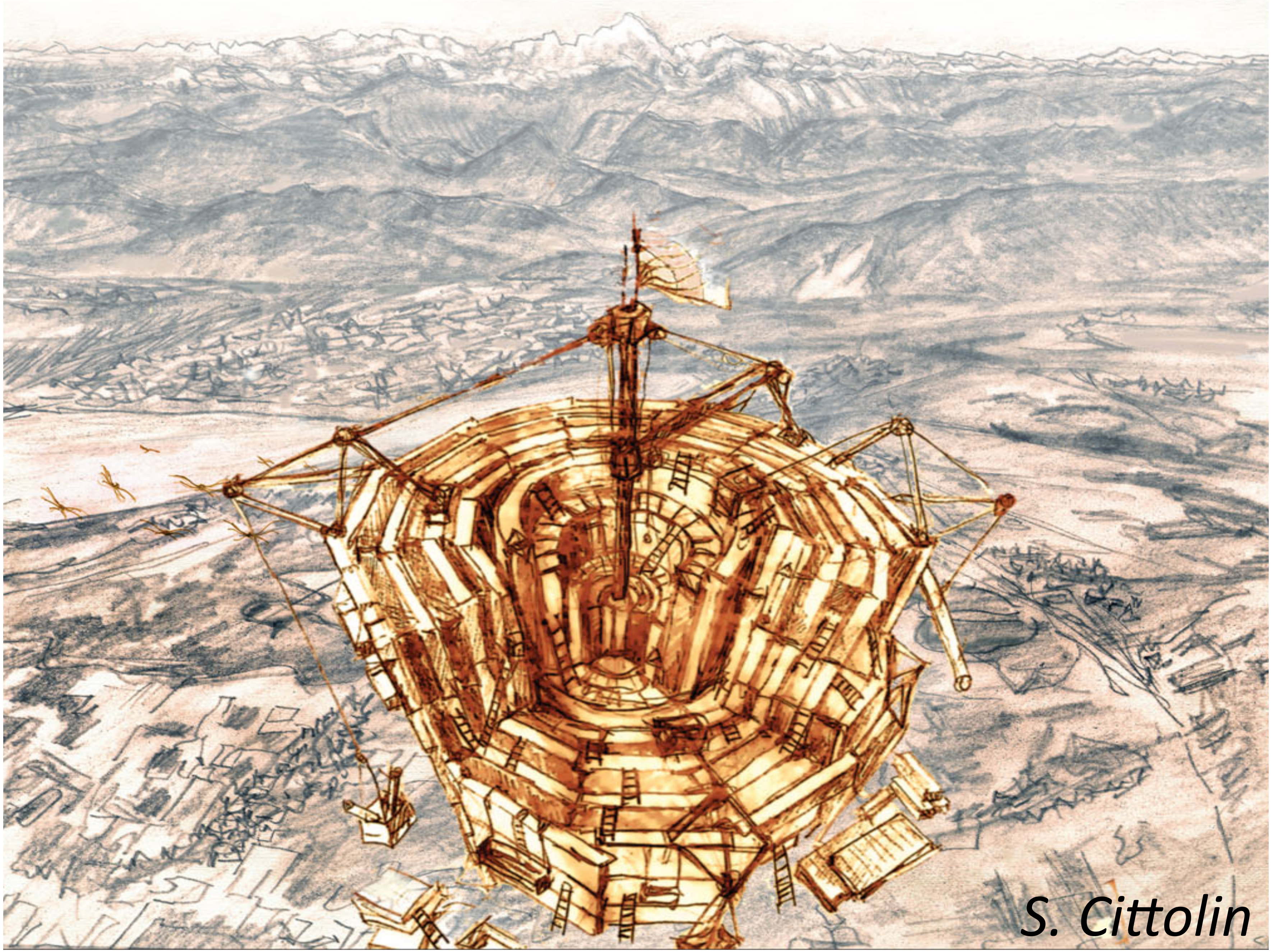
Phase-1 CMS upgrade is almost done, and in line with the planned schedule providing substantial benefits already during Run 2

GEM detector

- first installation of a phase-2 detector (GEM GE1/1)
    - improve muon capabilities in region around 1.5<|η|<2.0
    - redundancy needed for HL-LHC operations
    - high rate capabilities
    - radiation tolerance
- All 144 needed detectors are ready to be installed



Long term future - CMS upgrades



CMS HL-LHC Upgrade

Technical proposal CERN-LHCC-2015-010 https://cds.cern.ch/record/2020886
Scope Document CERN-LHCC-2015-019 https://cds.cern.ch/record/2055167/files/LHCC-G-165.pdf

L1-Trigger/HLT/DAQ

https://cds.cern.ch/record/2283192
https://cds.cern.ch/record/2283193

- Tracks in L1-Trigger at 40 MHz
- PFlow-like selection 750 kHz output
- HLT output 7.5 kHz

Barrel Calorimeters

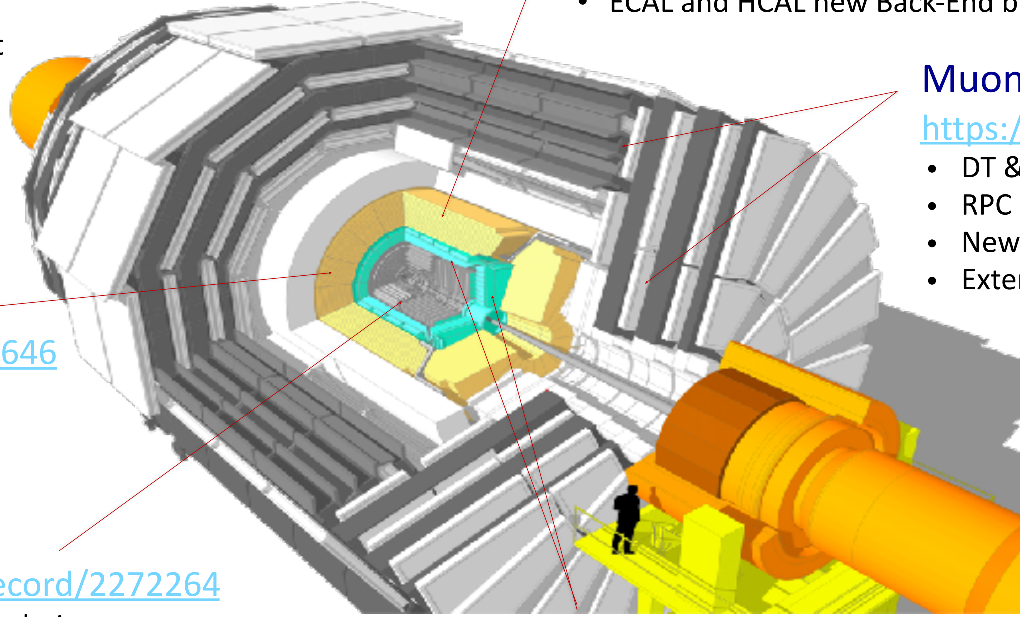
https://cds.cern.ch/record/2283187

- ECAL crystal granularity readout at 40 MHz with precise timing for e/γ at 30 GeV
- ECAL and HCAL new Back-End boards

Muon systems

https://cds.cern.ch/record/2283189

- DT & CSC new FE/BE readout
- RPC link -board
- New GEM/RPC $1.6 < \eta < 2.4$
- Extended coverage to $\eta \simeq 3$



Calorimeter Endcap

https://cds.cern.ch/record/2293646

- 3D showers and precise timing
- Si, Scint+SiPM in Pb/W-SS

Beam Radiation Instr. and Luminosity, and Common Systems and Infrastructure

https://cds.cern.ch/record/2020886

Tracker https://cds.cern.ch/record/2272264

- Si-Strip and Pixels increased granularity
- Design for tracking in L1-Trigger
- Extended coverage to $\eta \simeq 3.8$

MIP Timing Detector

https://cds.cern.ch/record/2296612

Precision timing with:

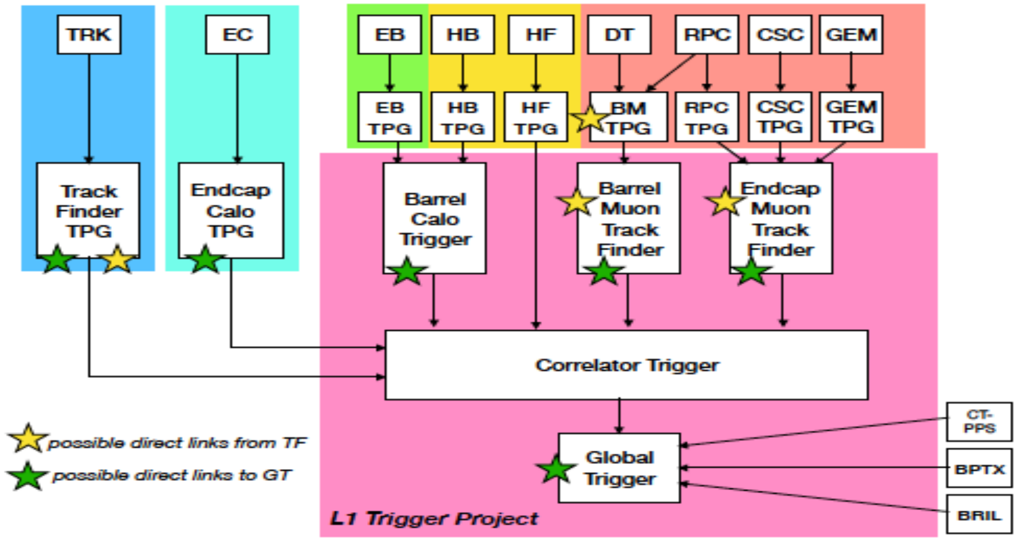
- Barrel layer: Crystals + SiPMs
- Endcap layer: Low Gain Avalanche Diodes

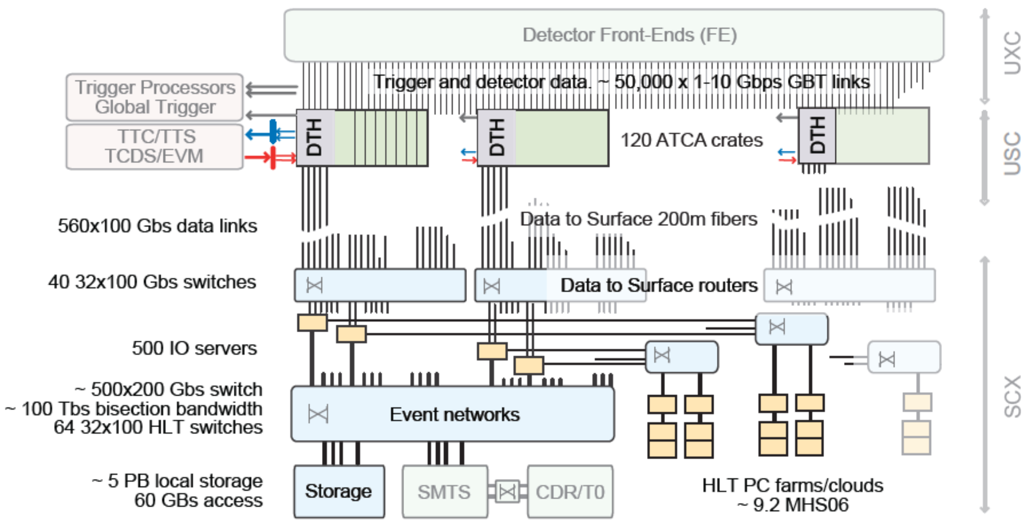
Innovative and extremely challenging new capabilities:

- **Highly granular endcap calorimeter**
- **Level 1 track trigger**
- **Timing detector**

Trigger/DAQ for HL-LHC

- The detector will be read out at a rate of up to 50 Tb/s and an event rate of up to 750 kHz with a 12.5 μs latency
- Selected events will be stored permanently at a rate of 7.5 kHz for offline processing and analysis.
- Increased information available at L1:
  - Increased granularity in the calorimeters
  - Tracking information at L1
- Increased processing ability implies more complex objects and algorithms:
  - Particle Flow at L1!
- Conceptual design; R&D underway
- TDRs will be completed in 2020/2021





CMS Tracker upgrade

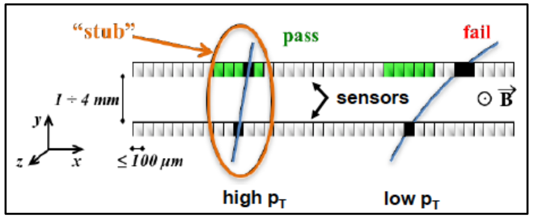
Mechanics and electronics:
- low material budget
- operations at -40 C (CO_2 cooling)
- Readout at 750kHz

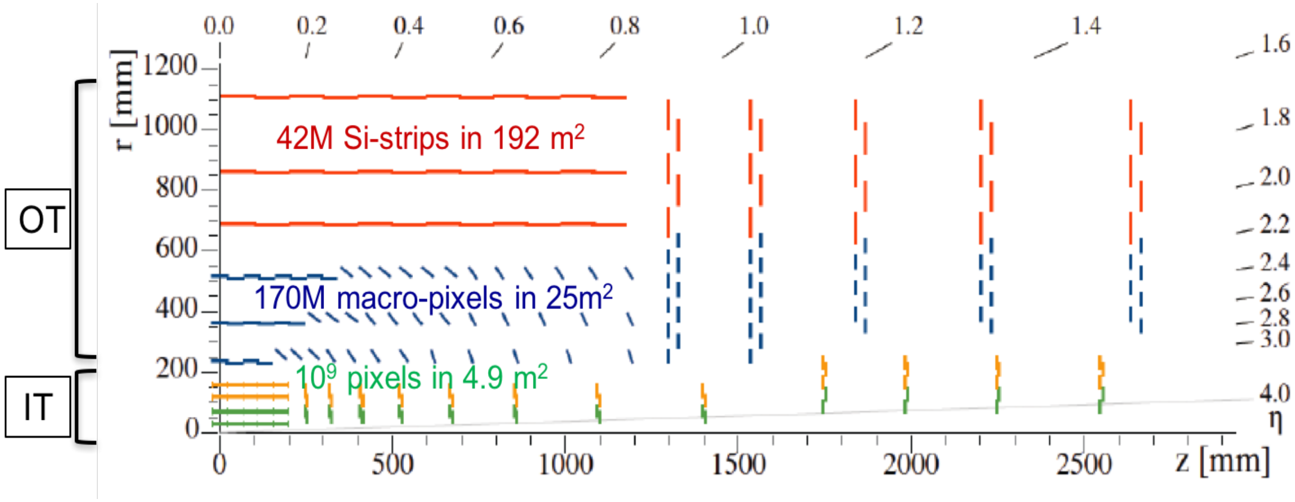
Pixel Tracker:
- 12 forward disk up to η=4
- inner layer at ~3cm from beam
  - 3 GHz/ cm² @ PU200

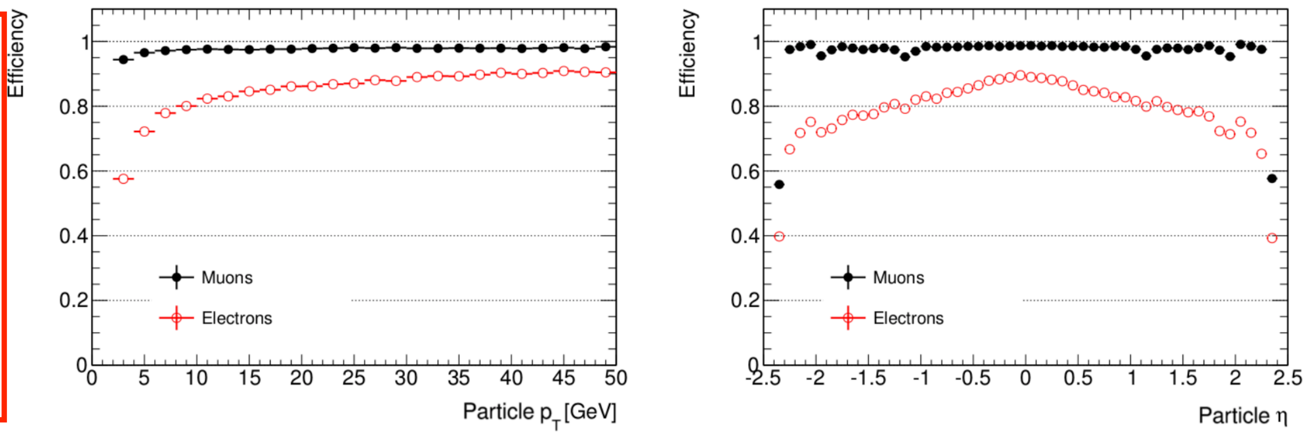
Outer tracker:
- Double-layer modules for trigger purpose

A fundamental asset in HL-LHC:
- allows to keep low thresholds in single objects
- enables PF-like PU mitigation and PF-like algorithms at L1
- paves the way to enhanced scouting at trigger level

2-sensor modules concept for track-trigger



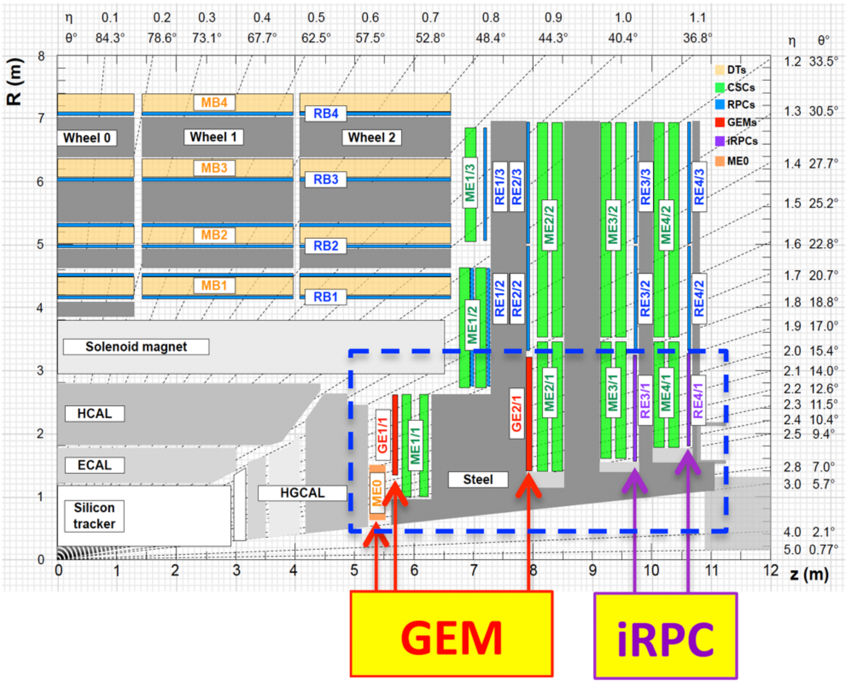


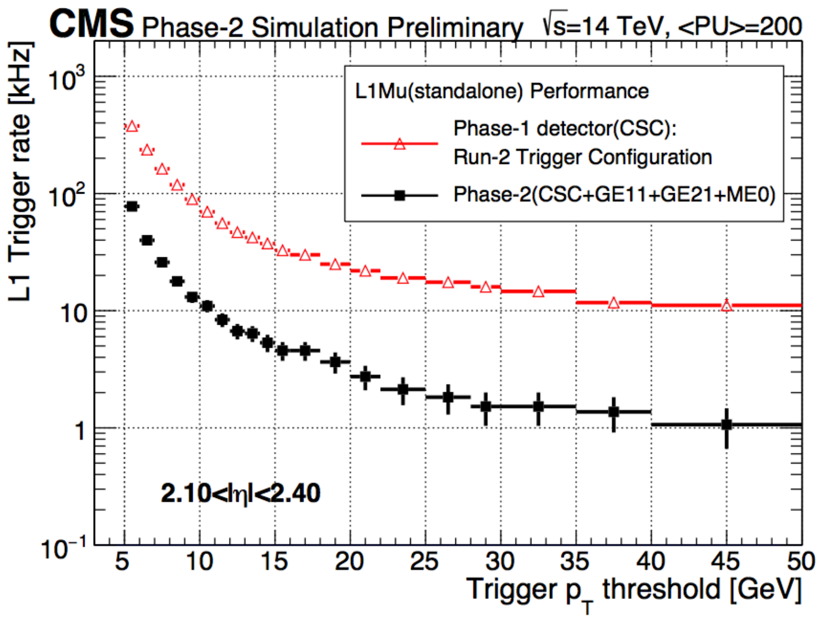


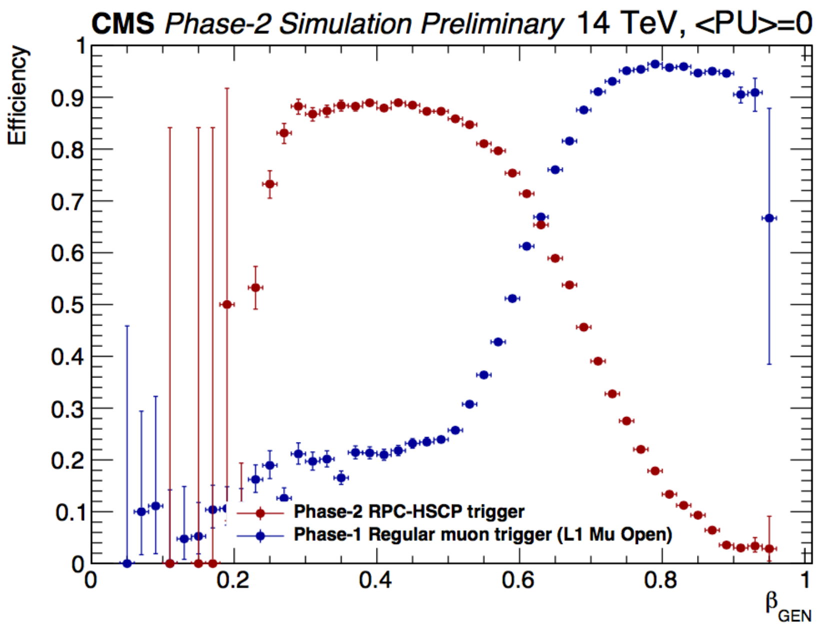
CMS Muon upgrades

Extensions in $1.6 < |\eta| < 2.8$:

- DT, CSC, RPC: front- and backend electronics replacement
- GEM chambers in front of existing forward muon (CSC) system.
- RPC's to improve trigger. Timing capabilities enable long lived/displaced muons triggering at an acceptable rate.
- ME0: New GEM chambers covering up to $|\eta|=2.8$







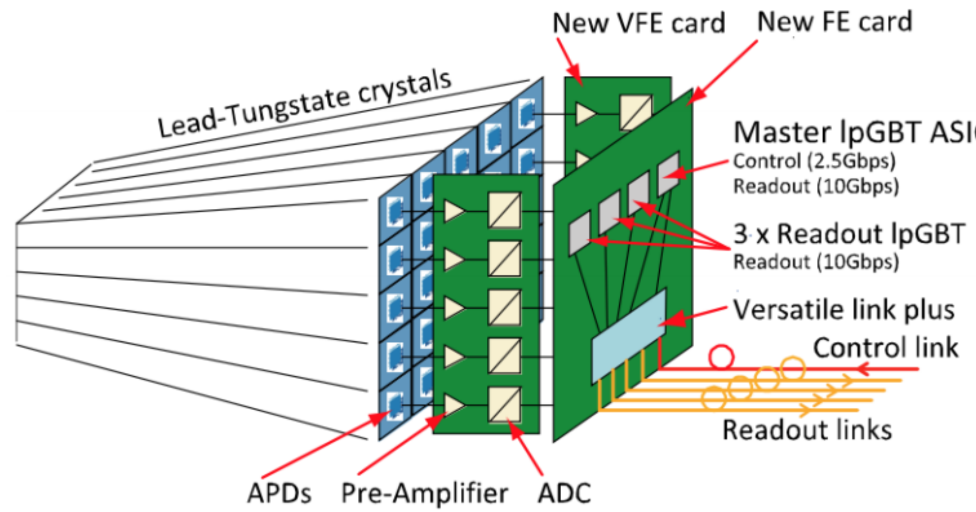
CMS Barrel calorimeter upgrades

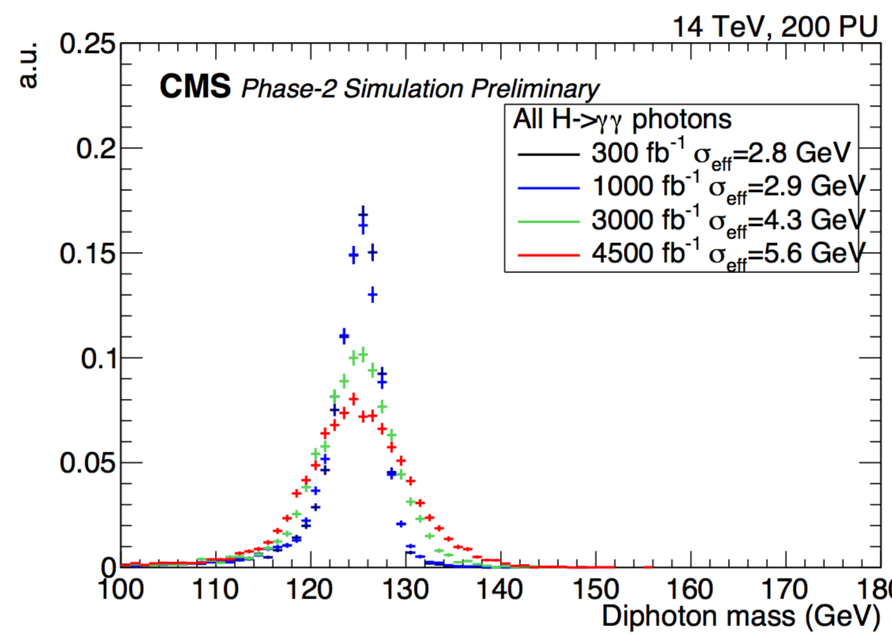
Electromagnetic calorimeter:

- Full detector granularity to hardware trigger (currently xtal towers)
- Upgrade electronics to accommodate trigger rate and latency requirements
- Significantly reduced shaping time and increase of sampling rate to 160 MHz for precision timing (30ps target), improved suppression of anomalous signals and out-of-time pileup

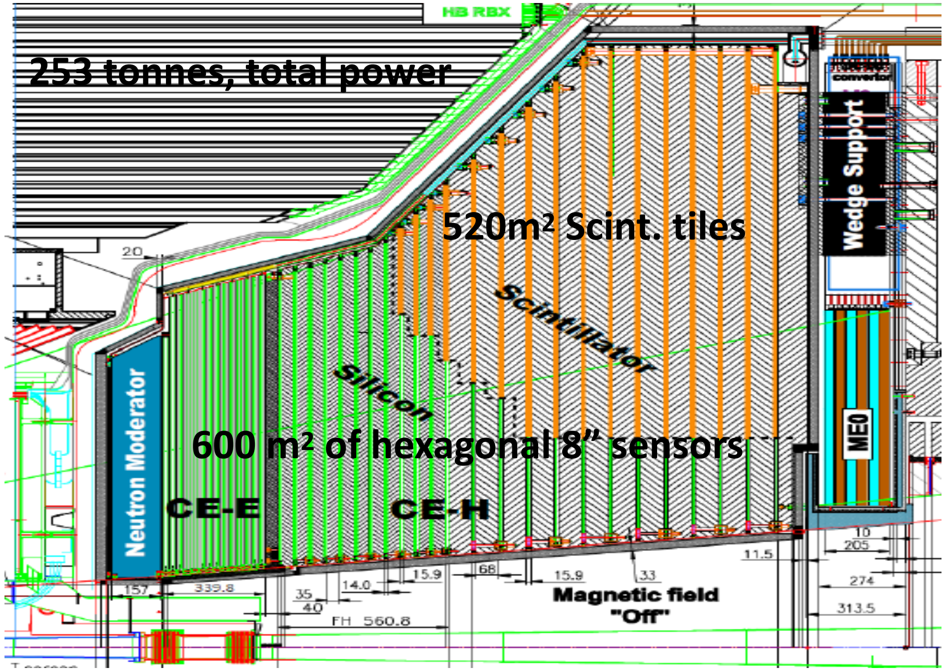
Hadronic barrel calorimeter

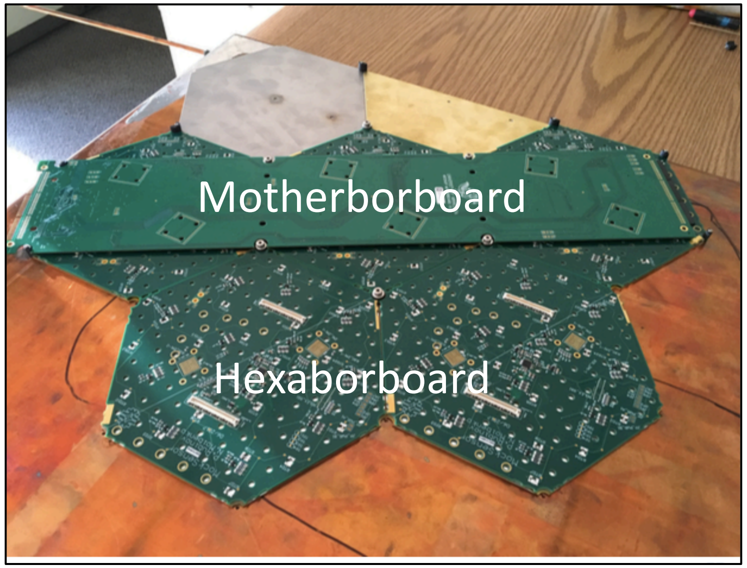
- New back-end electronics
- Usage of longitudinal granularity





CMS End-Cap calorimeter upgrades





Challenging conditions push toward new paradigm:

- High-granularity silicon-based readout (mixed silicon/scintillator in back hadronic)
- Electromagnetic: Si and W/Pb 25 X_0,1.7λ
- Hadronic: Si-only and mixed Si/ Scint, 9.0λ
- ~6 Million channels
- 30 ps time resolution

CMS End-Cap calorimeter upgrades

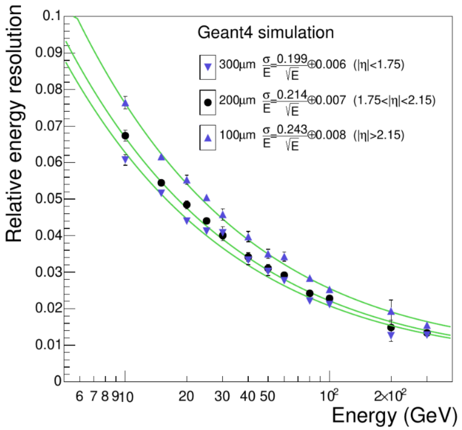
- The high granularity, both in transverse and longitudinal directions, gives powerful handles for pileup mitigation and detailed shower reconstructions.

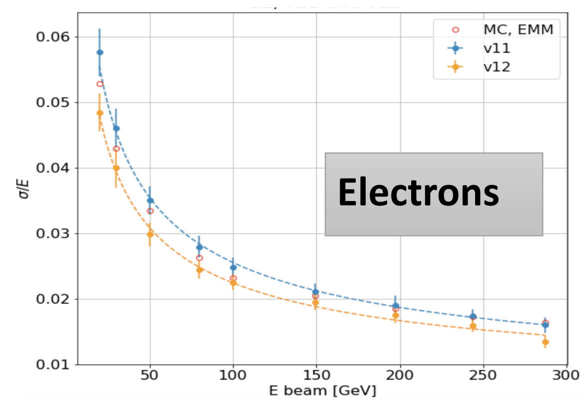
- A full reconstruction is still in the making: natural Particle Flow, standard algorithms do not work in 200 PU.

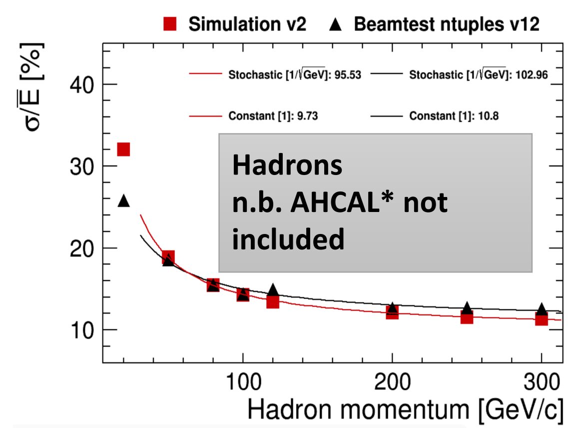
- The low readout thresholds (below MIP threshold) enables in-situ calibration/monitoring as well as stand-alone muon-ID capabilities.

- Electronics will ensure a 30ps timing capabilities for electromagnetic and hadronic showers of sufficiently high energy.

- Analysis of full HGCAL calorimeter “slice” in CERN beam test 08.2019.

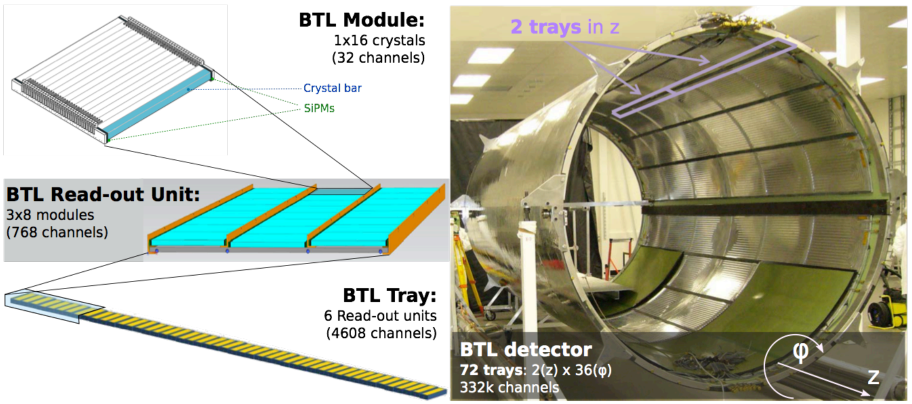


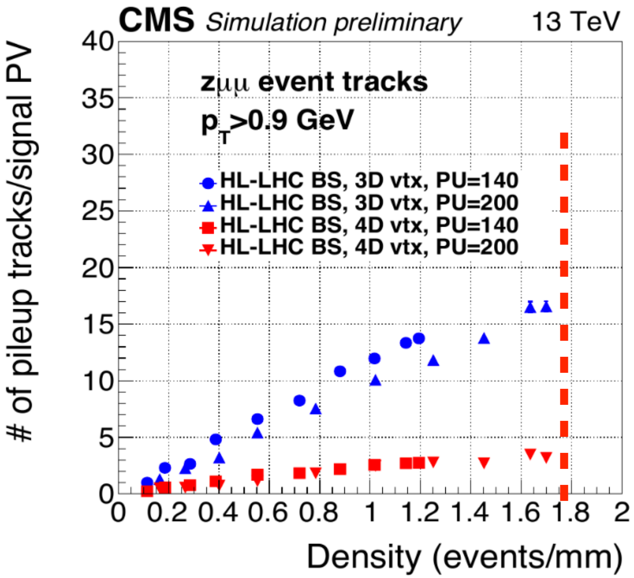




CMS MIP timing detector

Barrel:

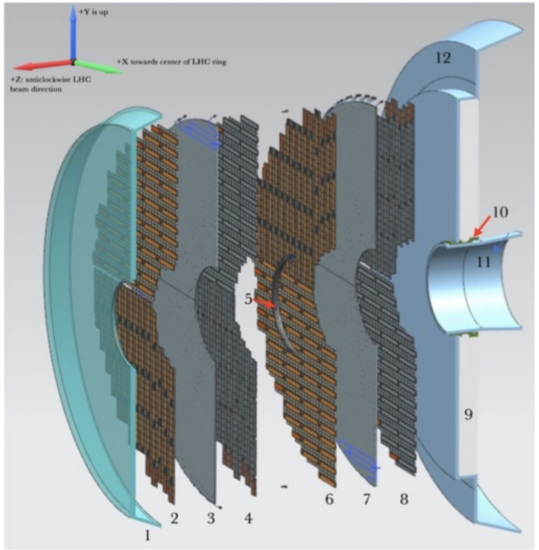




Time resolution: 30 ps (to 50ps)

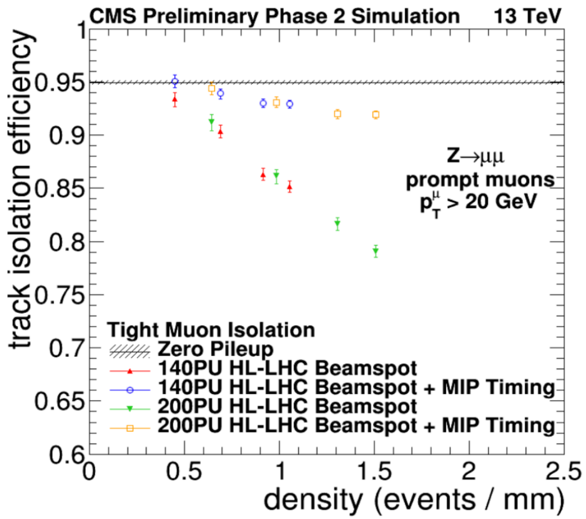
Lyso Crystals 11x11mm^2+ SiPM 4x4mm^2, ~250k channels, 40m^2

Endcap:



Time resolution: 30 ps

Silicon LGAD 1x3mm^2 pads, ~250k ch, 12 m^2

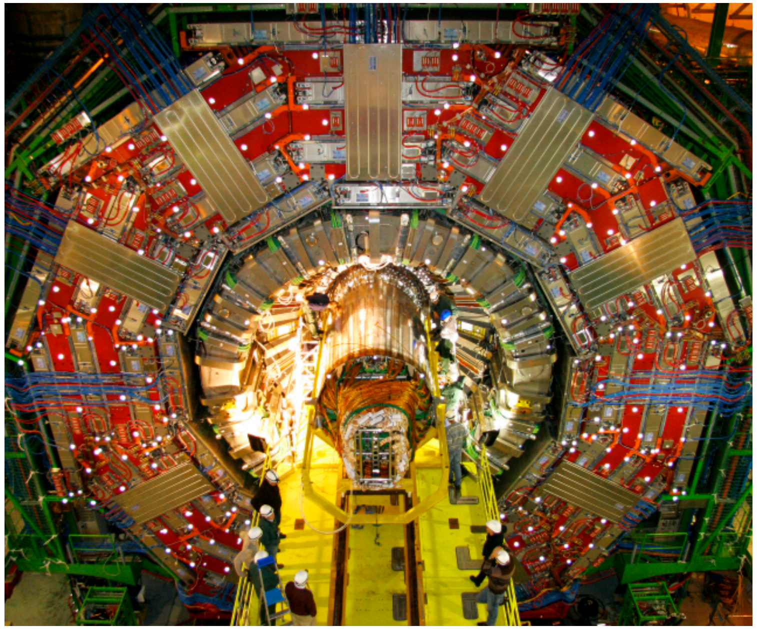


- A reduction of 2-4 times effective pile-up
- a significant improvement in lepton isolation and missing ET is expected

Conclusions

- CMS has collected almost 200 fb^{-1} of extremely good data so far
- The Higgs discovery was just the tip of the iceberg of an enormous physics program (searches, precision measurements, etc.)
- Despite the just started Long Shutdown, we are fully busy on three fronts:
  - completing analyses with full run2 datasets
  - prepare the detector, the data taking and the analysis for Run3
  - getting prepared for the big jump (x10, a.k.a. HL-LHC)
- We already ate the low hanging fruits, the key for the years to come will be flexibility, new ideas, innovative data taking/triggers.

CMS is engaged in all of them

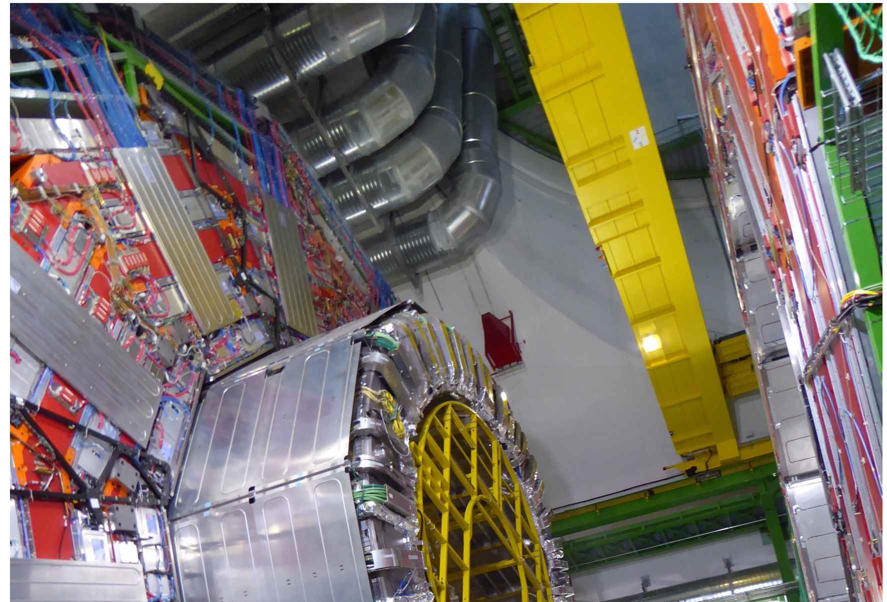


Backup

Current status of CMS detector

CMS.CERN

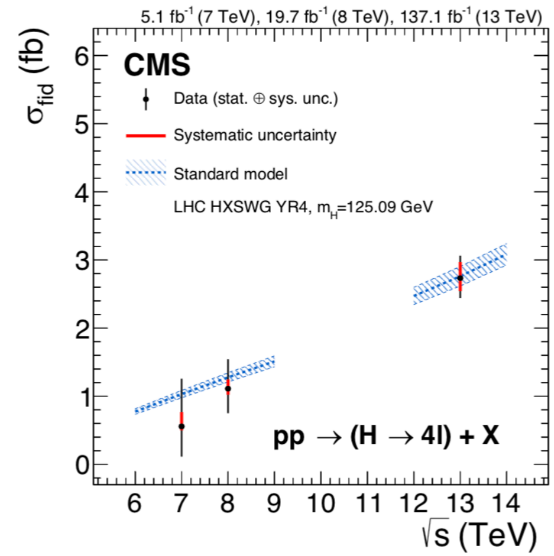
Long shutdown 2 at CMS in full swing: Pixel detector extraction | CMS Experiment

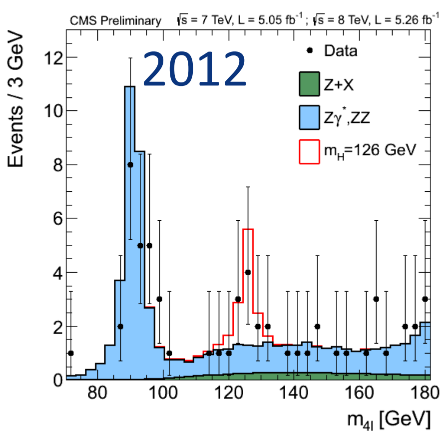


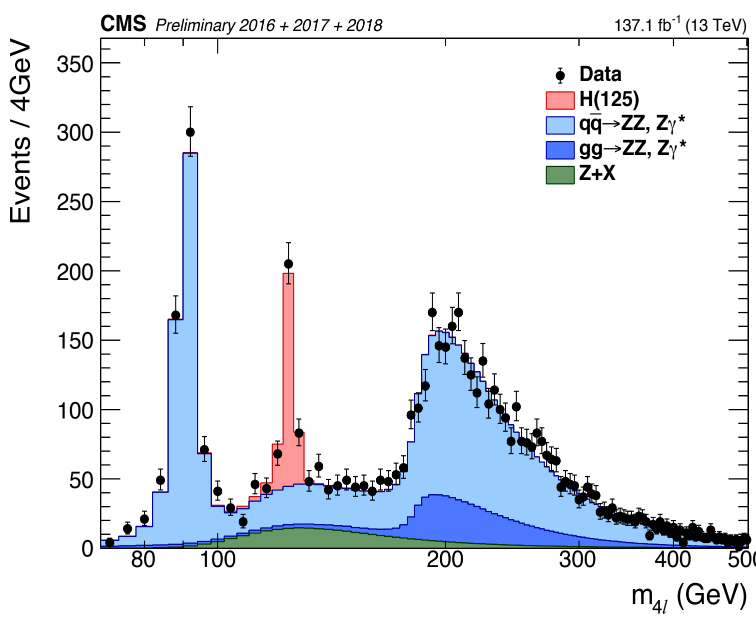
ZZ production in Run 2

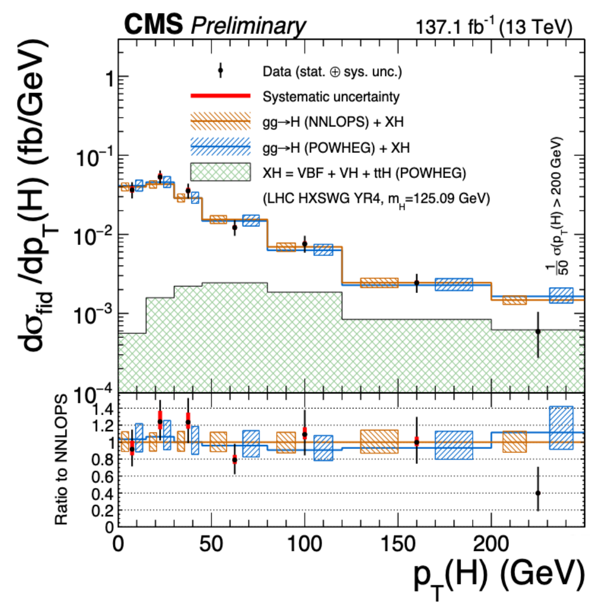
PAS-SMP-19-001,PAS-HIG-19-001

- Investigation of standard model ZZ production, and Higgs decays to ZZ
  - Using data from 2016-2018, ~ 98% of LHC Run 2
- SM cross section now measured with ~ 3% exp. precision:
  - σ_{ZZ} = 17.1 ± 0.3(stat) ± 0.4(syst) ± 0.4(theo) ± 0.3(lumi) pb
  - STXS and fiducial cross sections provided
- Higgs production & decay to ZZ
  - Large dataset allows now for studies of differential distributions





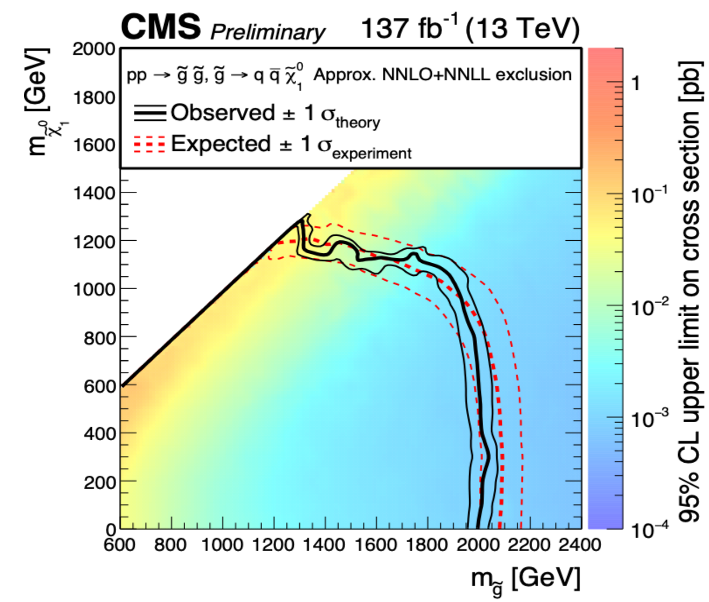


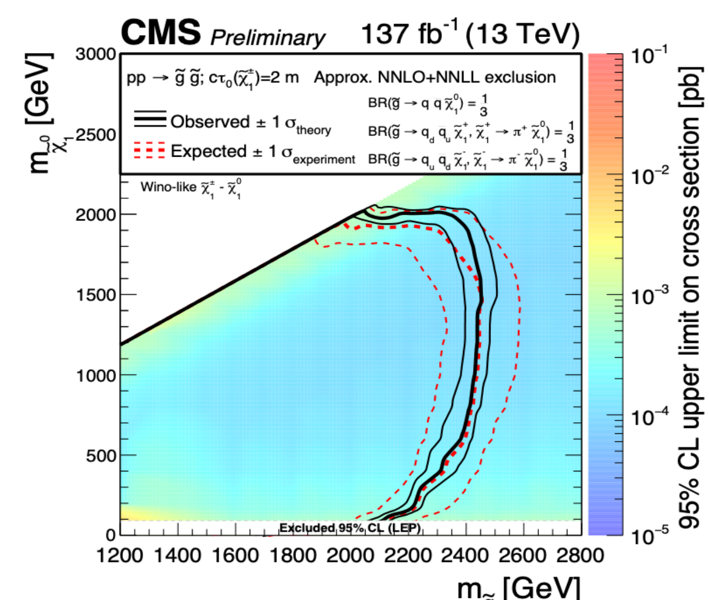


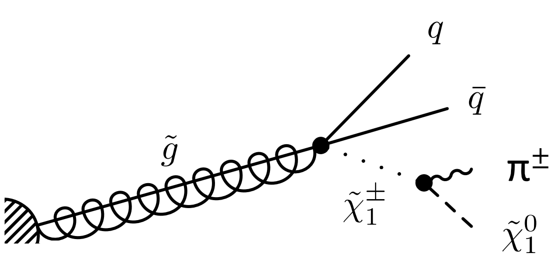
Search for prompt and long-lived SUSY particles

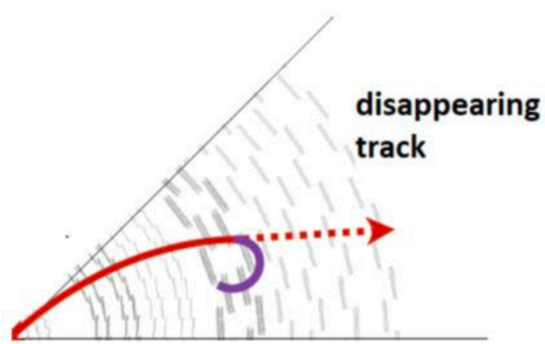
PAS-SUS-19-008

- Search for gluinos and squarks
  - Events with high jet activity and missing p_T
  - MT2 as discriminating variable
- The analysis covers cases of long-lived charged sparticles
  (a frequent signature in typical pMSSM scans)
  - Experimental signature: a short, "disappearing" track
  - Benchmark scenario: almost degenerate lightest charginos and neutralinos



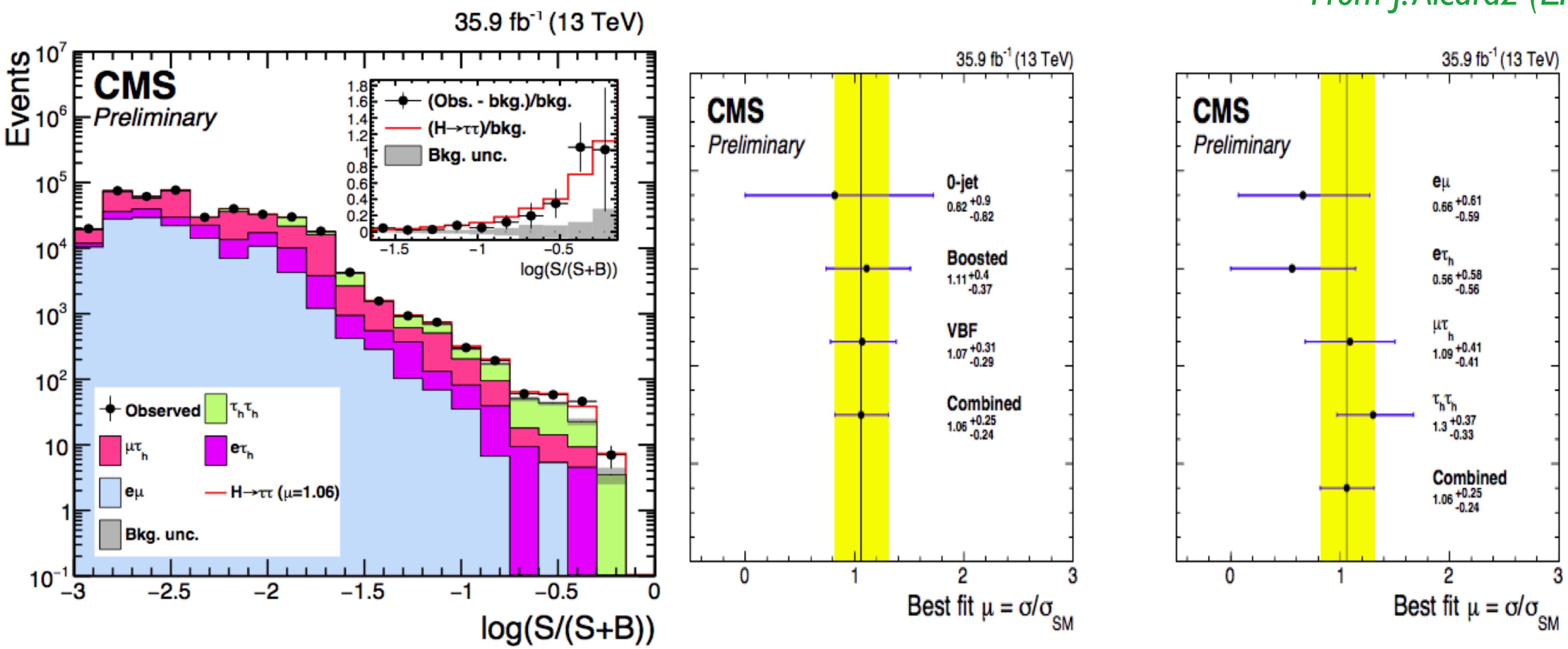






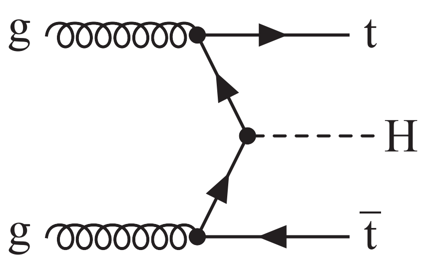
H→ττ observation

From J. Alcaraz (EPS2017)

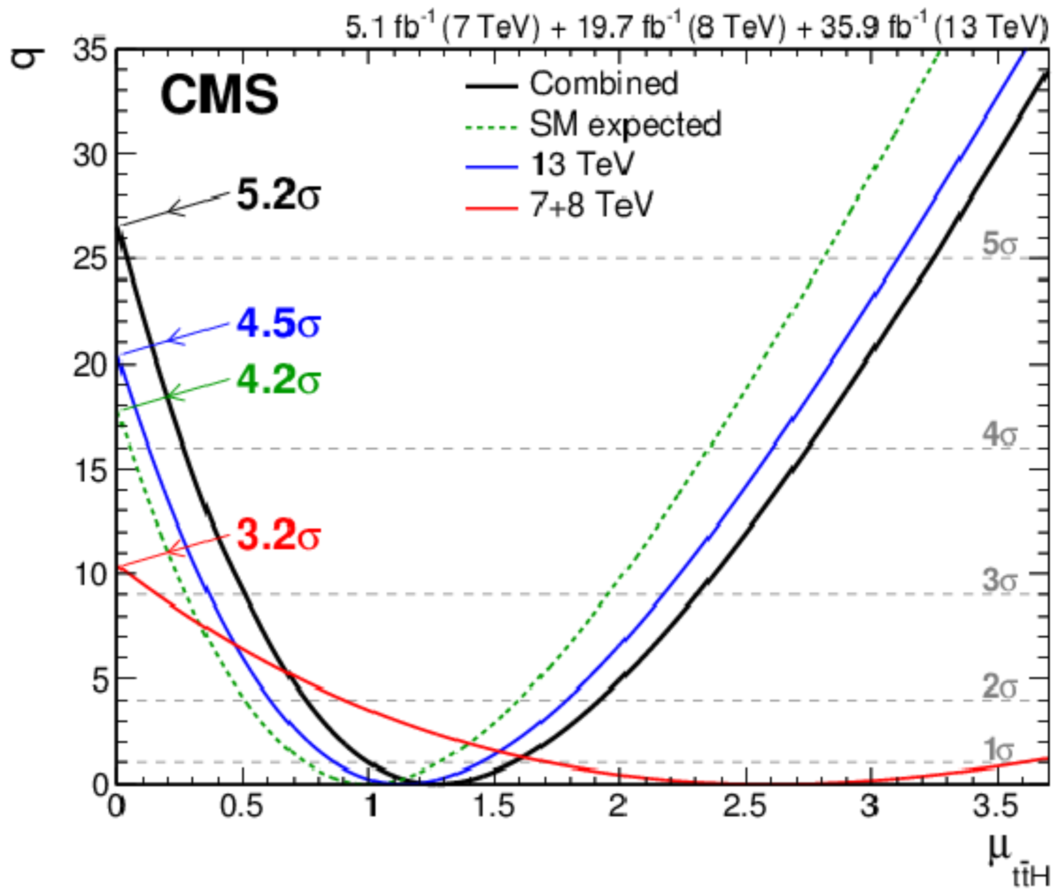


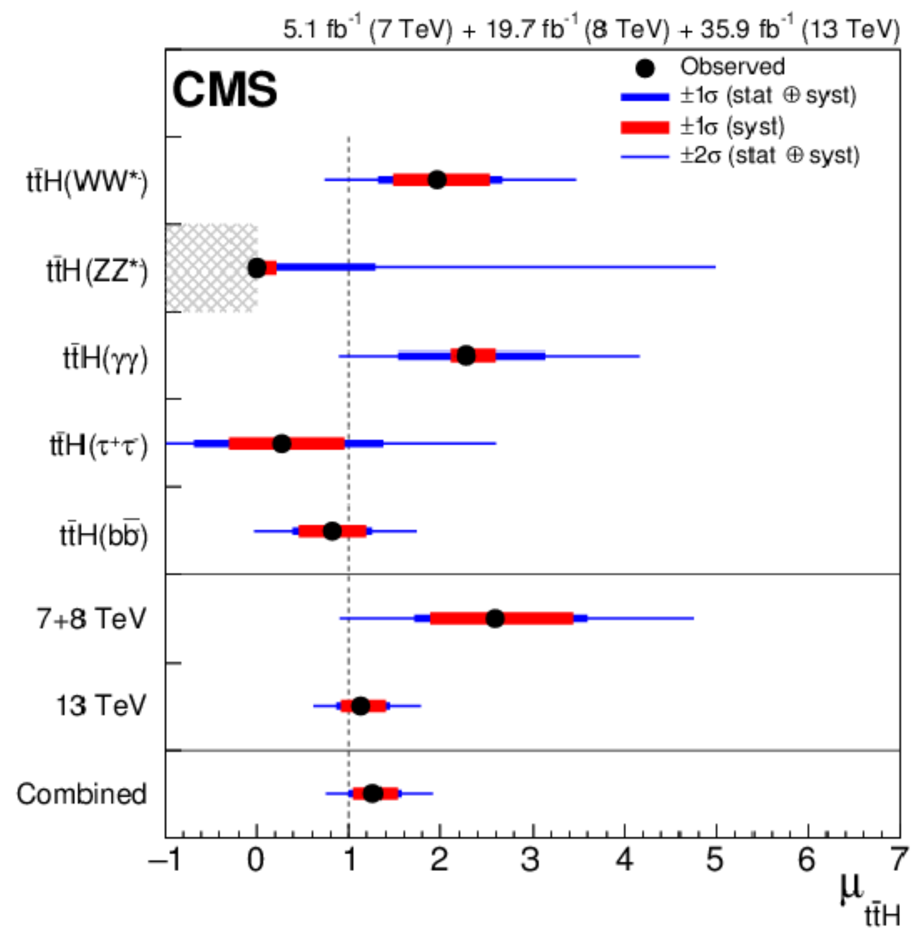
- Dedicated search at 13 TeV using unique CMS tau-tagging capabilities and different enriched categories (gluon-fusion, vector-boson fusion, boosted di-taus):
  - Run2: 4.9σ (4.7σ expected)
  - Combination with previous CMS data: ***5.9σ SIGNIFICANCE (exp.=obs.)***
- First observation of this channel by a single experiment at the LHC
  - Important milestone: direct observation of Higgs coupling to leptons and to fermions of the third generation

ttH observation



- Combination of 7 TeV (5 fb^{-1}), 8 TeV(20fb^{-1}) and 13 TeV (36 fb^{-1}) data
- 5.2 σ reached
- combined announcement with ATLAS





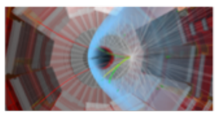
First full Run 2 paper submitted Feb 1st

PHYSICAL REVIEW LETTERS
moving physics forward

APS physics

Dear Sir or Madam,

We are pleased to inform you that the Letter



Observation of two excited B_c^+ states and measurement of the B_c^+ (2S) mass in *pp* collisions at $\sqrt{s}$ = 13 TeV

A.M. Sirunyan *et al.* (CMS Collaboration)
Phys. Rev. Lett. **122**, 132001 (2019)

Published 2 April 2019

has been highlighted by the editors as an Editors' Suggestion. Publication of a Letter is already a considerable achievement, as *Physical Review Letters* accepts fewer than 1/4 of submissions, and is ranked first among physics and mathematics journals by the Google Scholar five-year h-index. A highlighted Letter has additional significance, because only about one Letter in six is highlighted as a Suggestion due to its particular importance, innovation, and broad appeal. Suggestions are downloaded twice as often as the average Letter, and are covered in the press substantially more often. If Suggestions were a separate publication, they would have an Impact Factor of 17. More information about our journal and its history can be found on our webpage prl.aps.org.

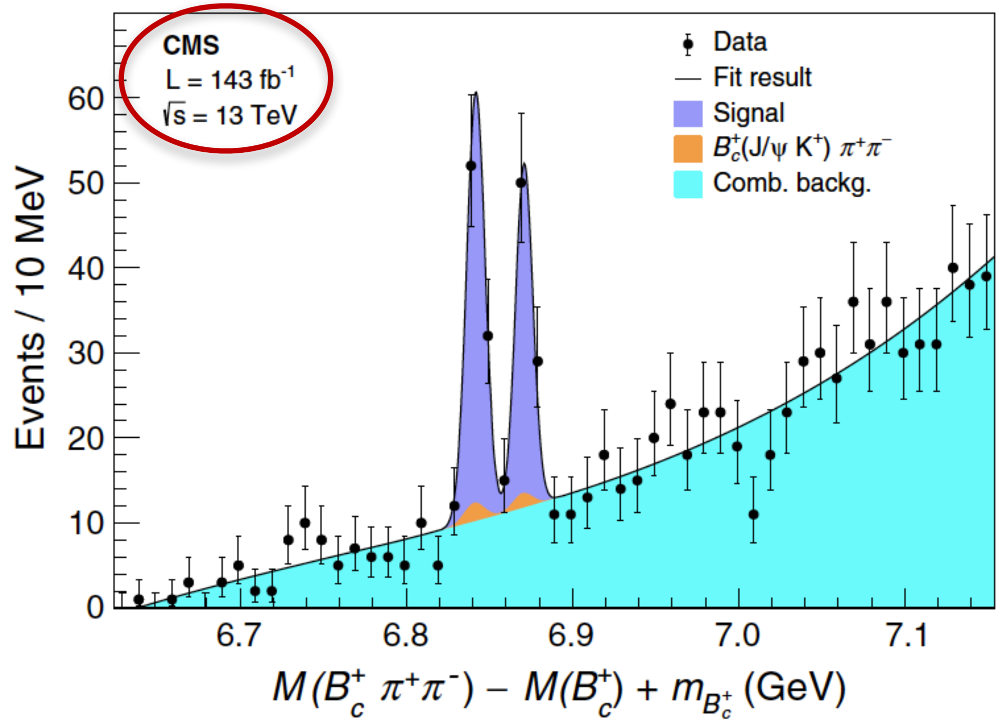
Yours sincerely,

Hugues Chaté
Editor
Physical Review Letters

Michael Thoennessen
Editor in Chief
Physical Review

Physical Review Letters, 1 Research Road, Ridge, NY 11961-2701

Observation of two excited B_c^+ states and measurement of the $B_c^+(2S)$ mass in pp collisions at $\sqrt{s} = 13$ TeV



Highlighted as an Editors' Suggestion
(as it happened last year for:
observations of Hbb, ttH and tops in pPb)

Run 2 non-orthodox data taking

From D. Sperka - HOW2019 conf

Data scouting

- Traditional trigger algorithms usually require high pt particles to reduce the event rate, and then readout the full event information
- Need to reduce the event size to collect events at a higher rate
  - Physics objects produced by the High Level Trigger as the final objects
    - CaloScouting (vertices, muons, calo based jets and MET) → limited by L1 rate
  - ParticleFlow Scouting (vertices, PF muons, PF jets and MET, PF cands.)→ limited by HLT CPU time

Stream	Rate (Hz)	Event Size	Bandwidth (MB/s)
PhysicsMuons	420	0.86 MB	360
PhysicsHadronsTaus	345	0.87 MB	300
ScoutingCaloMuon	4580	8.9 KB	40
ScoutingPF	1380	14.8 KB	20

Selected CMS stream rate, event size, and bandwidth at the beginning of LHC Fill 7334 (23 Oct. 2018, $L \approx 1.5 \times 10^{34} cm^{-2} s^{-1}$)

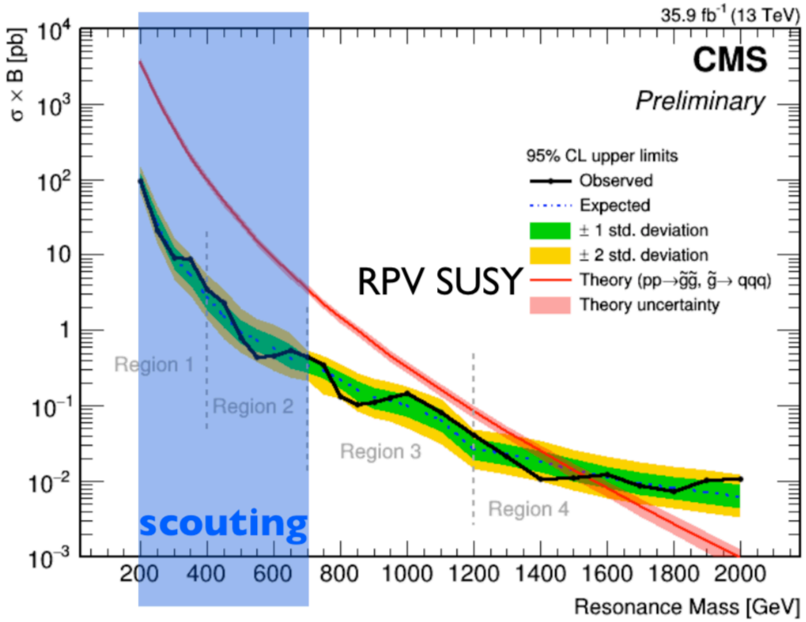
Run 2 non-orthodox data taking

from S. Mukherjee, LLP Amsterdam

Data scouting: recent physics results

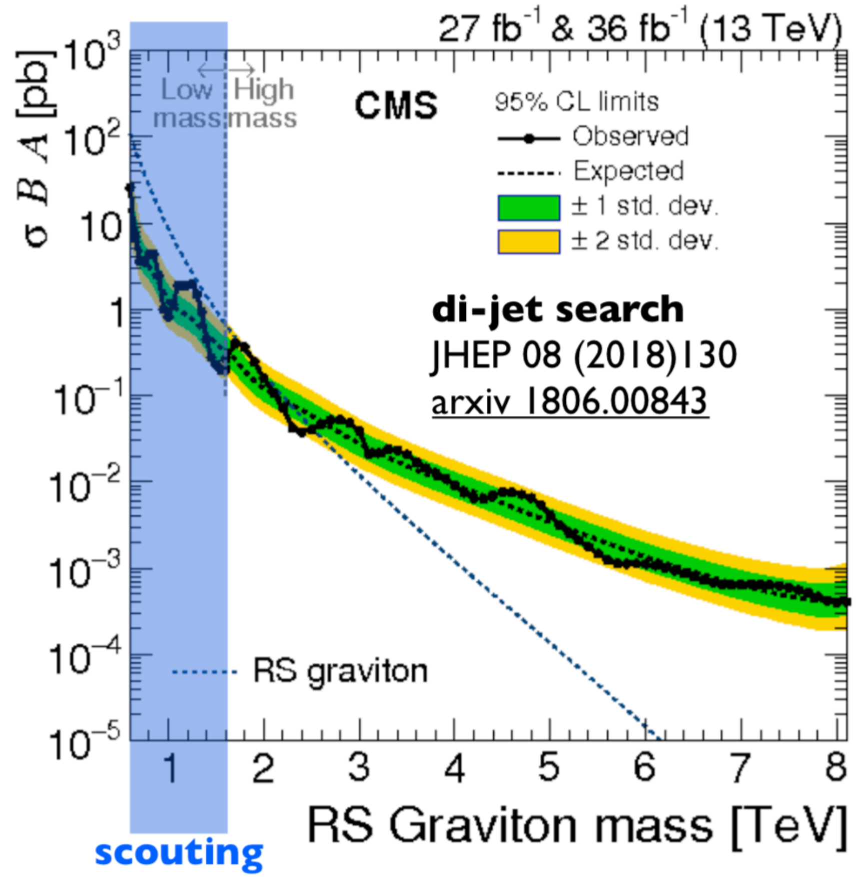
200<Mjjj<700 GeV accessible by H_T PF scouting

tri-jet search
CMS-PAS-EXO-17-030



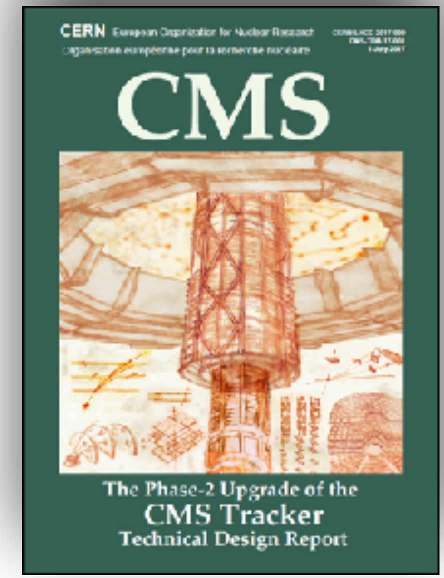
Jet substructure with PF scouting ?
If yes, more searches will be possible.

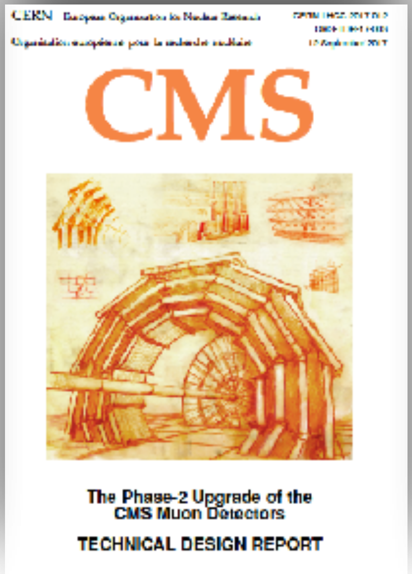
600<Mjj<1600 GeV accessible by H_T calo scouting

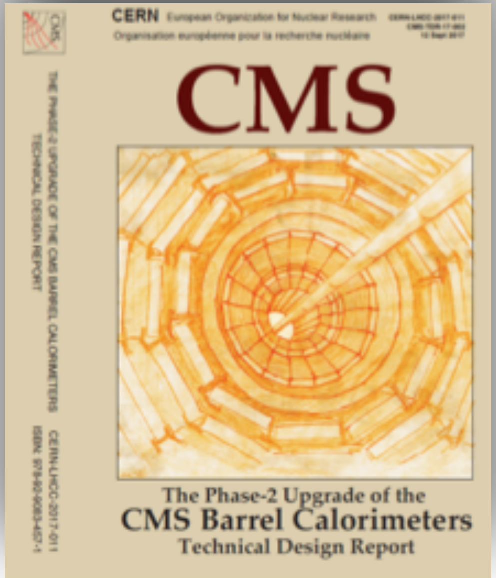


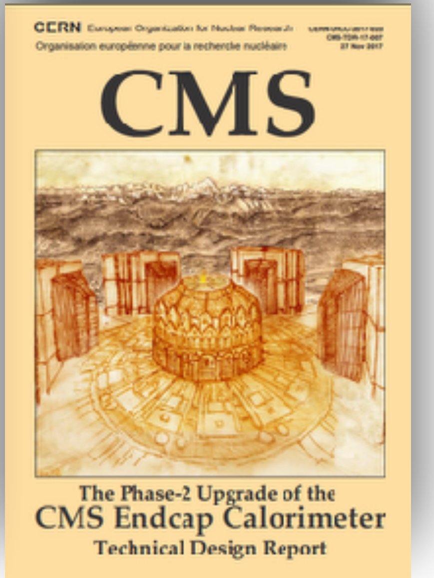
CMS HL-LHC TDRs

Completed



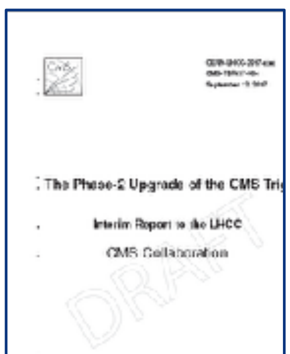






Planned

L1 Trigger

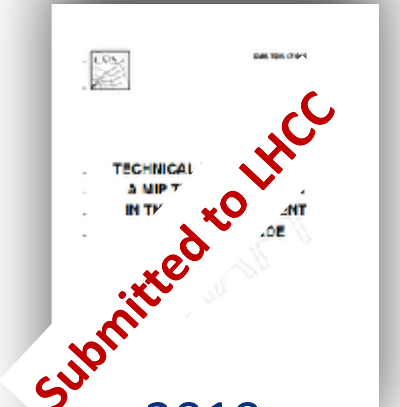


2020

DAQ/HLT

2021

MTD



2019

BRIL

2020/2021

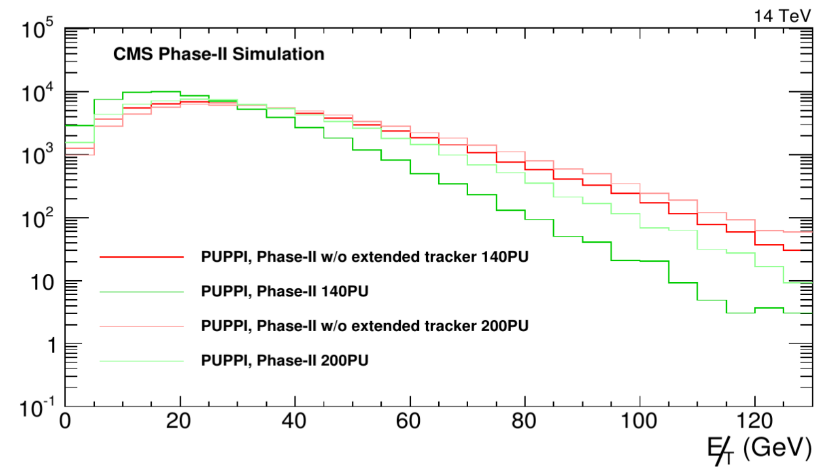
Plus

- PPS (LOI)
- Computing (2022)

CMS MIP timing detector

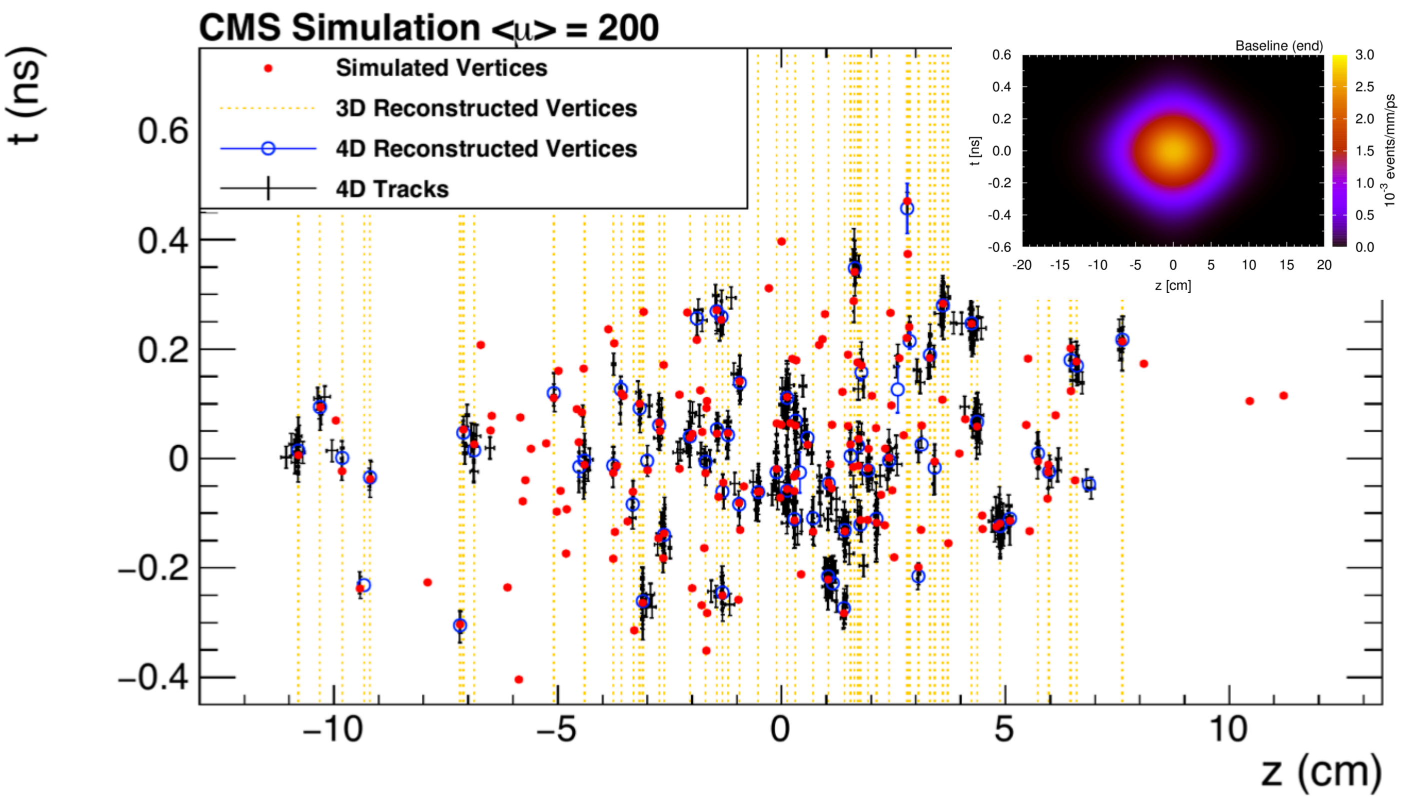
Why do we need timing capability?

- the number of PU events at HL-LHC will not allow to discriminate efficiently between hard scattering and PU vertices causing ambiguities and large tails.



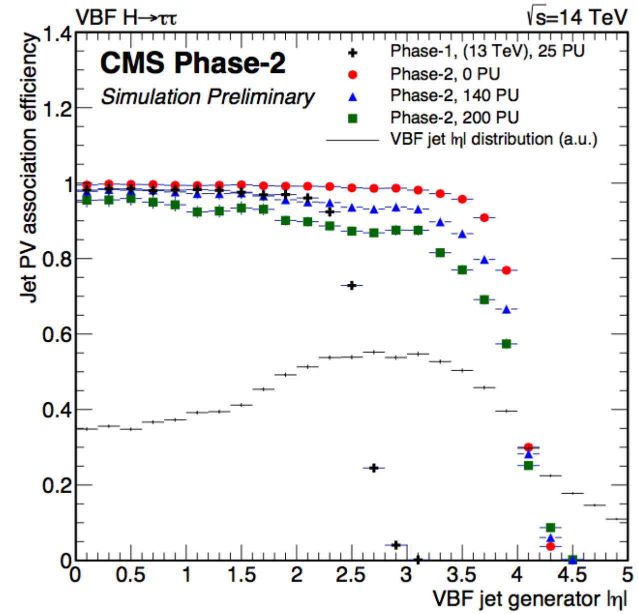
- Vertices will be distributed in space but also in TIME.

- Timing associated to tracks (MIP) will be complementary to timing associated to calorimeter cluster and enable 4D vertexing, de facto reducing the effective PU.



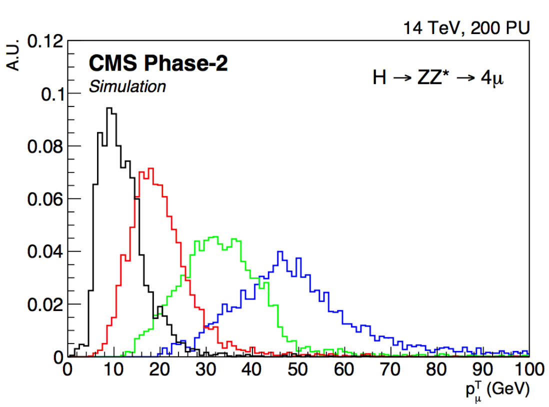
Physics potential enabled by upgraded detectors

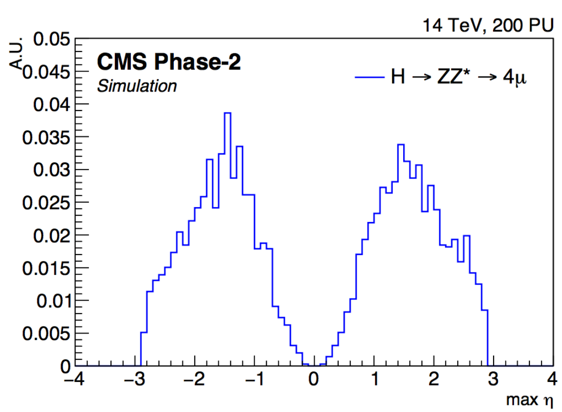
VBF topologies (H→ττ in the specific) gain in acceptance

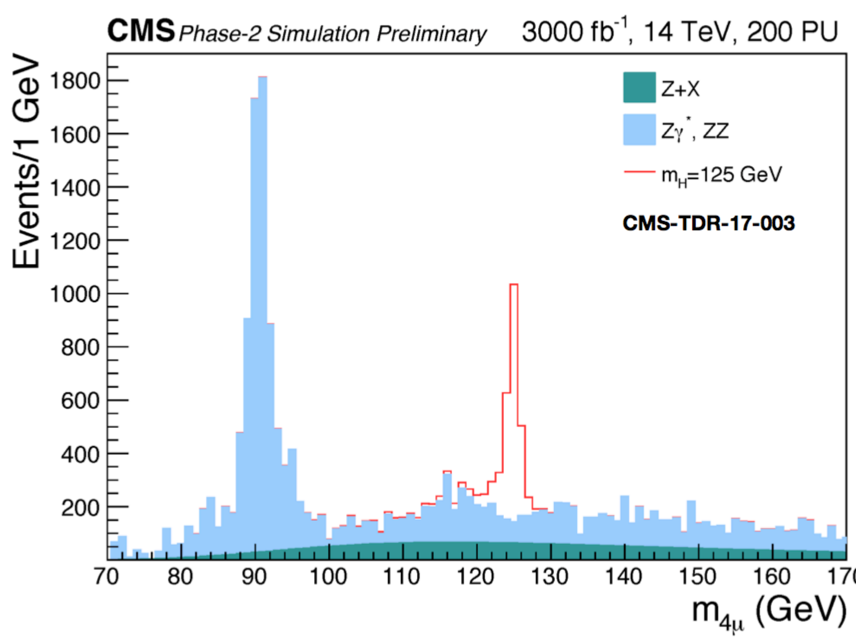


Scenario	ϵ (inclusive)	ϵ ($\|\eta\| > 2.0$)	ϵ ($\|\eta\| > 2.4$)
Phase-1	57%	27%	11%
Phase-2 (200 PU)	84%	79%	76%
Phase-2 (140 PU)	88%	83%	80%
Phase-2 (0 PU)	89%	84%	81%

Higgs into 4 leptons: acceptance increase ~17%



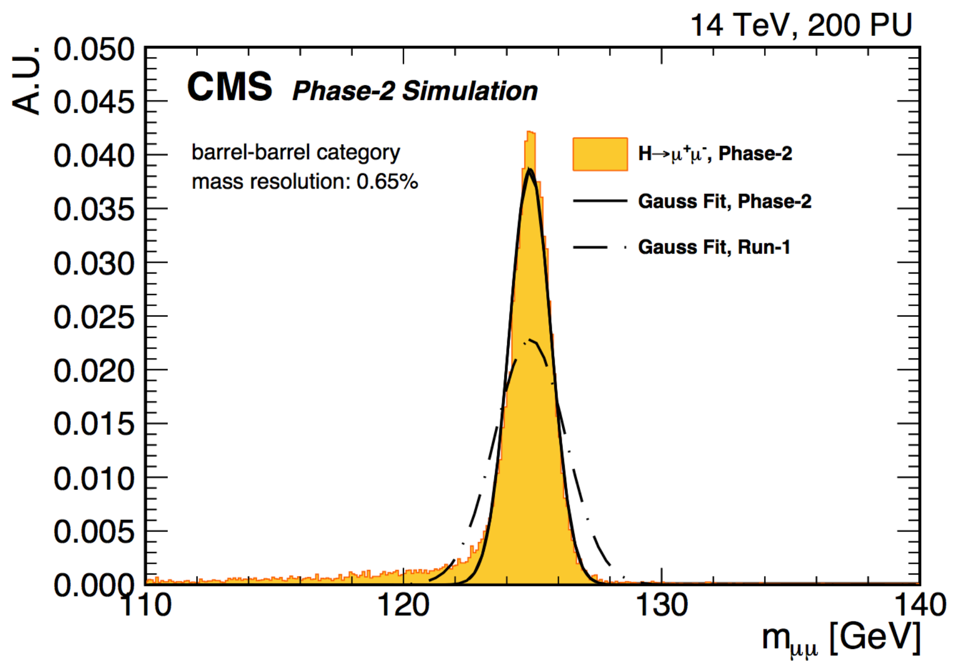




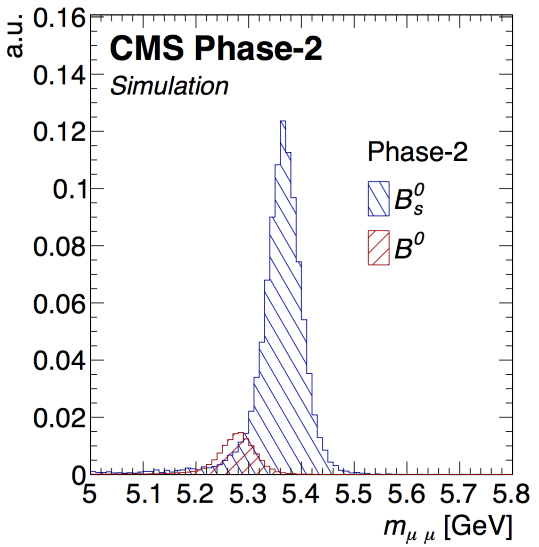
Physics potential enabled by upgraded detectors

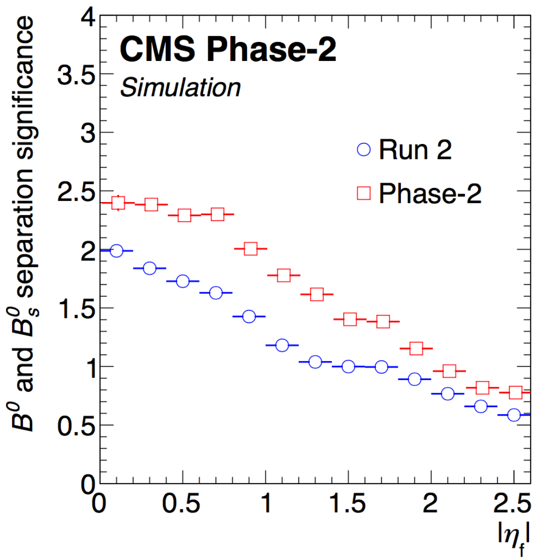
Rare decays capabilities

- $H \rightarrow \mu\mu$ analysis depends critically on di-muon mass resolution.
- New tracker achieves a much better mass resolution (low material budget, better measurement).
- Prospects for 3 ab^{-1} ~ 5% uncertainty



- $B \rightarrow \mu\mu$ separation also depends in di-muon mass resolution.
- 25% significance gain in separation Bd/Bs
- Coverage increase does not help here.





Expected Higgs status ~3000 fb^{-1}

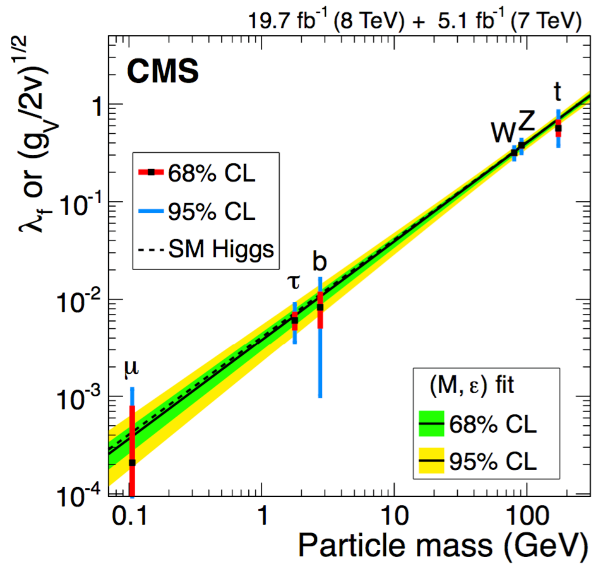
Higgs Physics expectations

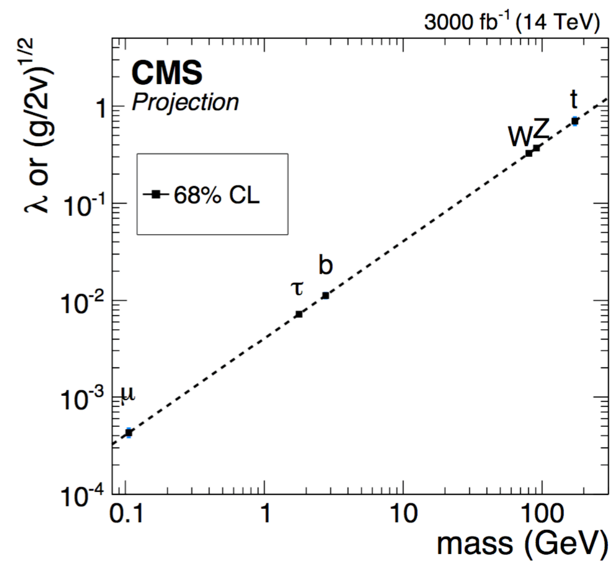
- 150 M Higgs events produced
- 500 K events useful for precision measurements (x 400 w.r.t. now)

Physics subjects

- Higgs precision measurement
  - Mass (100 MeV syst. limited?)
  - Cross-sections
  - Couplings

    ➡ $H \rightarrow \mu\mu$ might be measured at 5-10% level ?
- Possible (but very difficult) $W_L W_L$ scattering ?



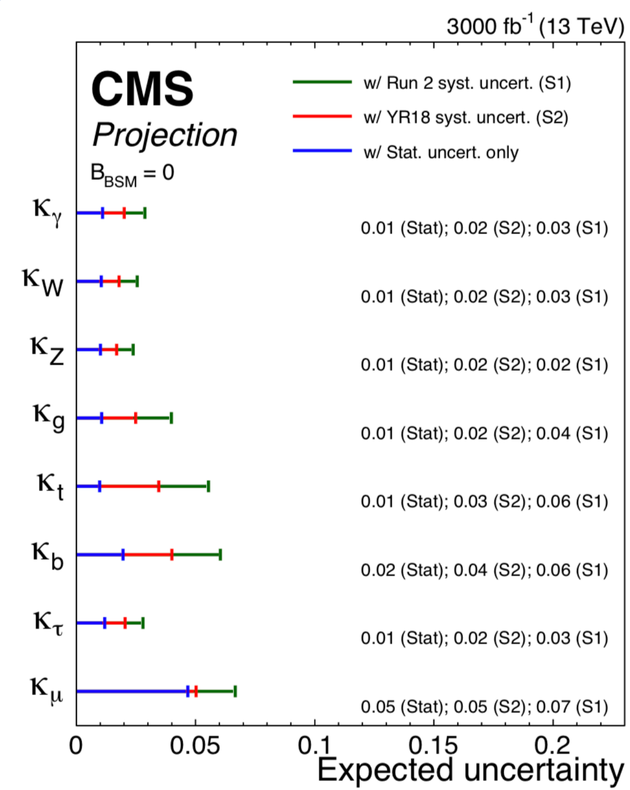


Assumptions on systematic uncertainties:

S1: no change

S2: theory unc. / 2

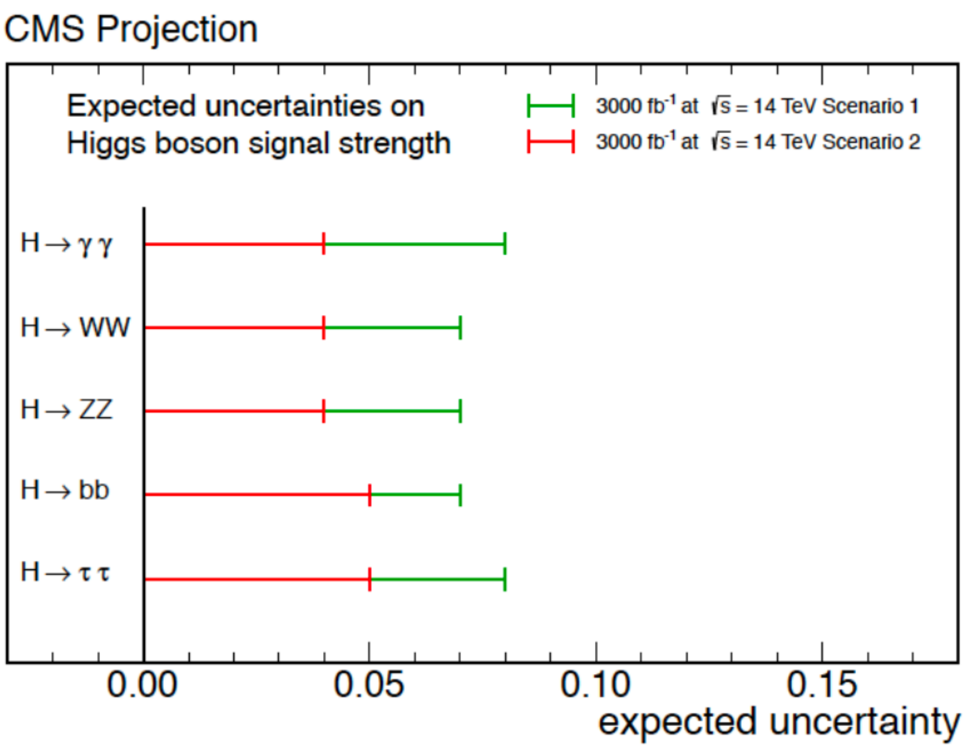
rest goes like $1/\sqrt{L}$

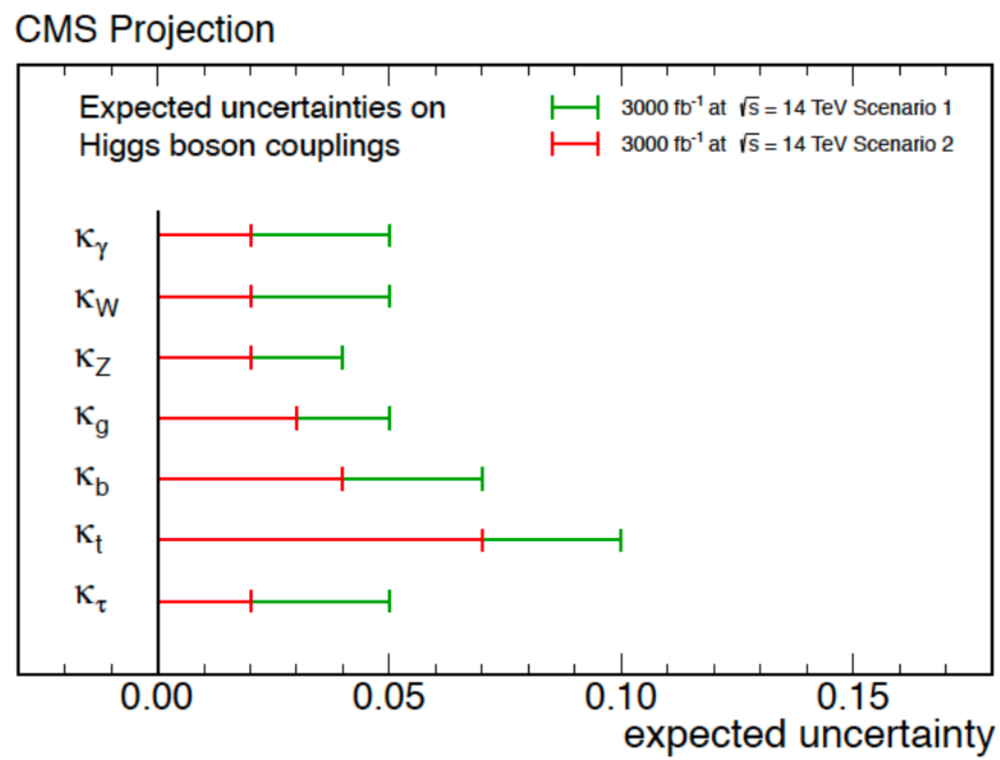


Expected Higgs status end of Run2 ~3000 fb^{-1}

CMS and ATLAS white papers: arXiv:1307.7135 and 1307.7292

Old projections still valids:





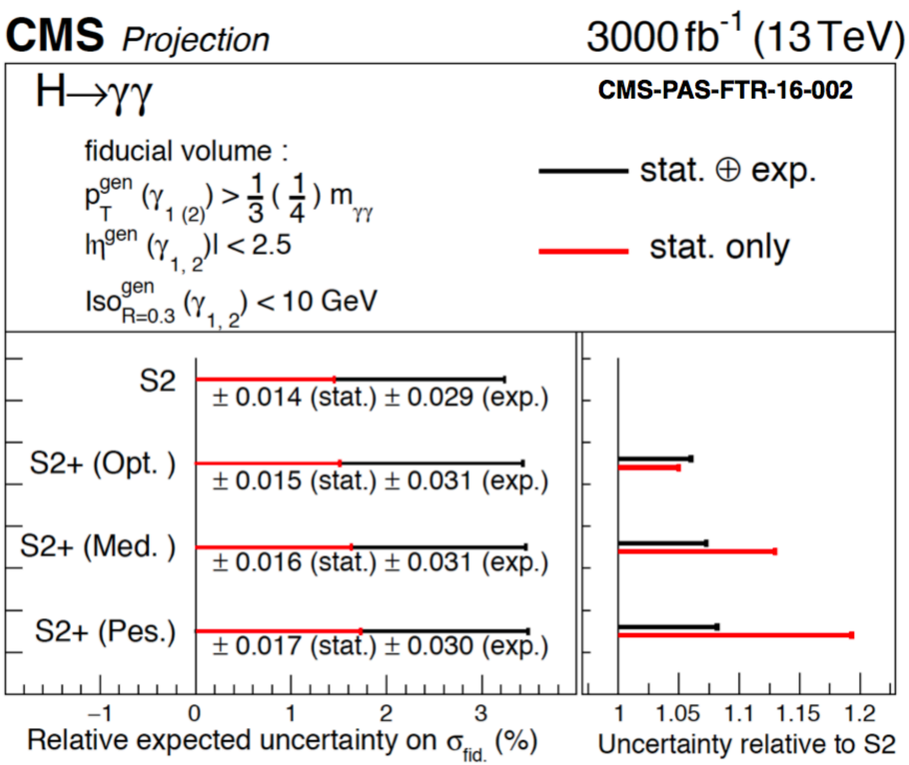
L (fb^{-1})	$\gamma\gamma$	WW	ZZ	bb	$\tau\tau$	$Z\gamma$	$\mu\mu$	inv.
300	[6, 12]	[6, 11]	[7, 11]	[11, 14]	[8, 14]	[62, 62]	[40,42]	[17, 28]
3000	[4, 8]	[4, 7]	[4, 7]	[5, 7]	[5, 8]	[20, 24]	[16,16]	[6, 17]

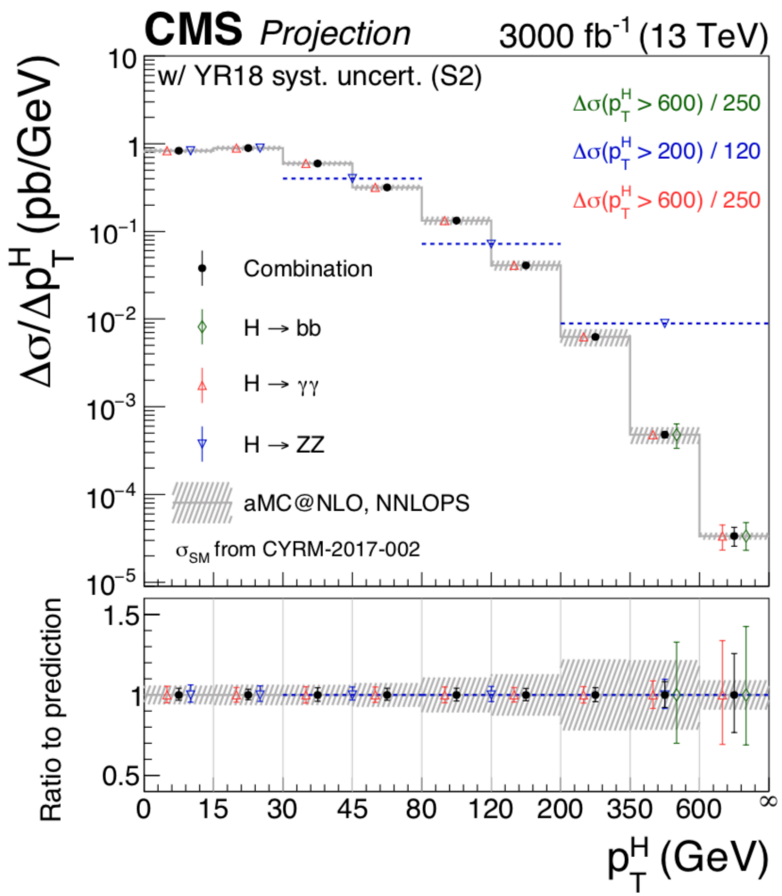
(%)

L (fb^{-1})	κ_γ	κ_W	κ_Z	κ_g	κ_b	κ_t	κ_τ	$\kappa_{Z\gamma}$	$\kappa_{\mu\mu}$	BR_{SM}
300	[5, 7]	[4, 6]	[4, 6]	[6, 8]	[10, 13]	[14, 15]	[6, 8]	[41, 41]	[23, 23]	[14, 18]
3000	[2, 5]	[2, 5]	[2, 4]	[3, 5]	[4, 7]	[7, 10]	[2, 5]	[10, 12]	[8, 8]	[7, 11]

Refined Higgs results projections

- Refined projections based on Run 2 analyses (in a conservative way).
- The “5%” level is reachable!





- Independent of theoretical uncertainty
- Improvement in mass resolution and uncertainty thanks to timing O(30 ps)
- Uncertainties at the level of 5-10 % for the interesting region above 350 GeV

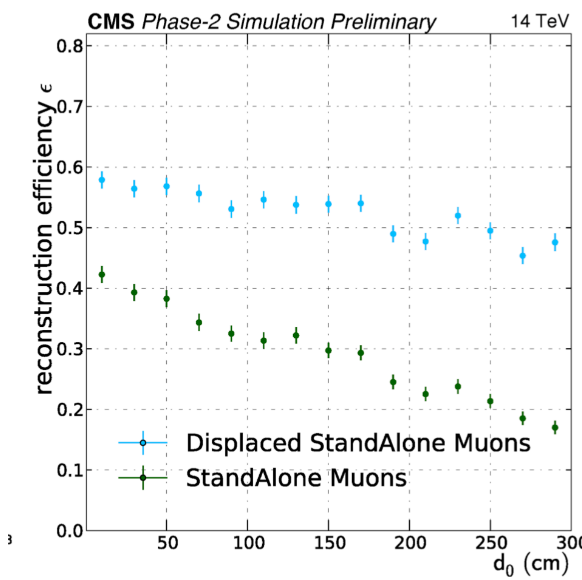
Searches with HL-LHC: long lived

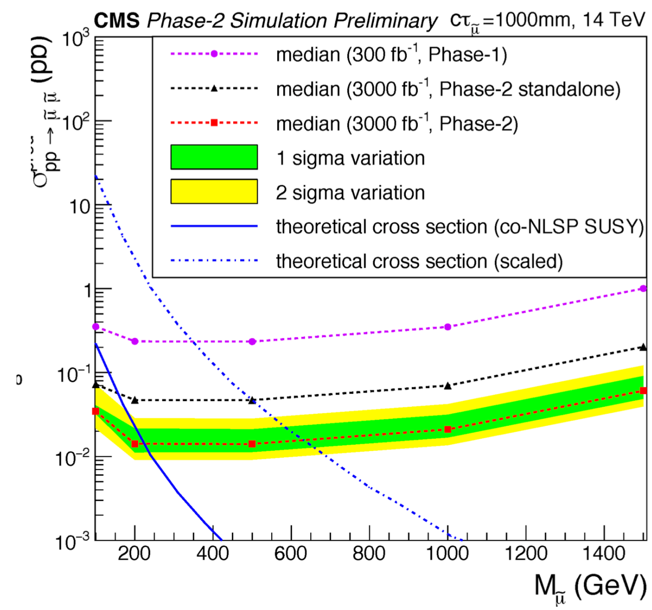
Few examples:

$$\tilde{\mu} \rightarrow \mu + X$$

Smuons:

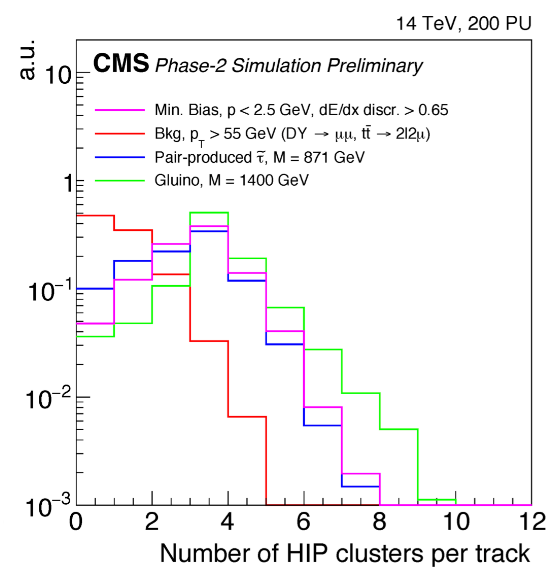
- need to keep/exploit trigger capabilities on displaced muons
- dedicated reconstruction able to cope with unconstrained vertex position

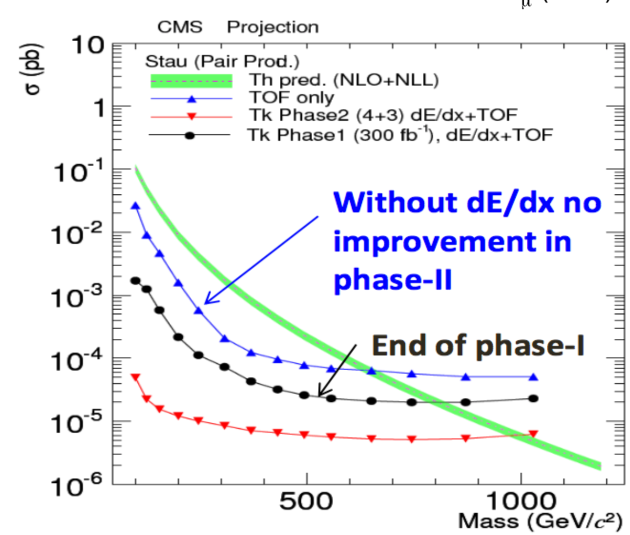




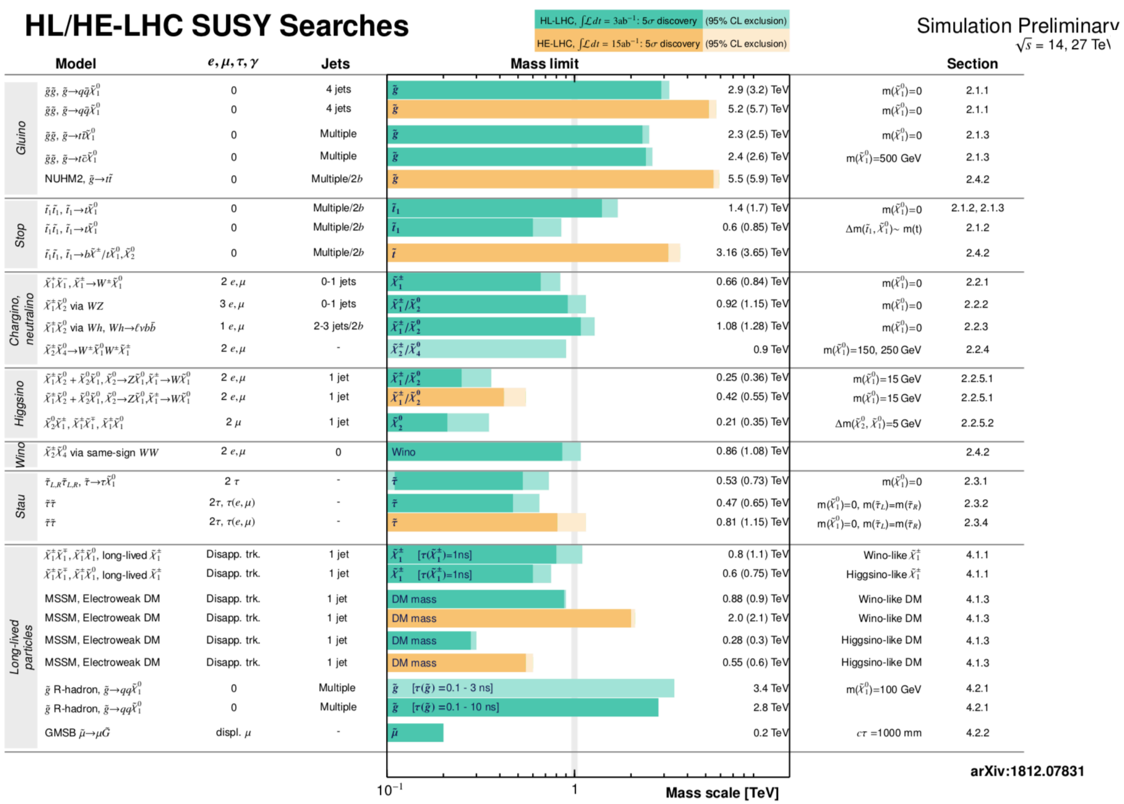
Heavy Stable Charged Particle:

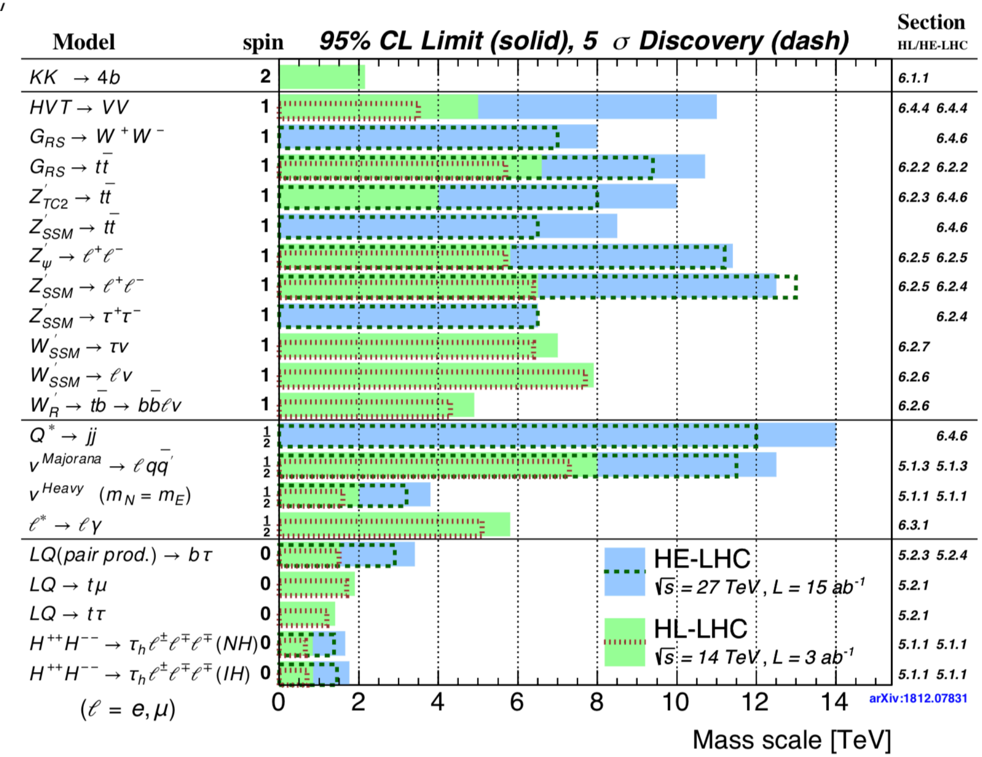
- need to keep dE/dX measurement capabilities (HIP bit in CMS tracker)
- dedicated reconstruction able to cope with unconstrained vertex position





Grand summary of NP reach - projections





No striking news there: depending on channel/systematics we increase our discovery potential by 20% — 100%