RECENT HIGHLIGHTS (PHYSICS AND PERFORMANCE) FROM CMS
OUTLINE OF THE TALK

- Performance and detector status
- Physics highlights (2016 data)
  - QCD multijet production
  - Electroweak production
  - Top physics (not covered in this talk)
  - Higgs Physics
  - Searches for New Physics
**CMS DETECTOR**

**CMS DETECTOR**

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

**STEEL RETURN YOKE**

- 12,500 tonnes

**SILICON TRACKERS**

- Pixel (100x150 μm) ~16m² ~66M channels
- Microstrips (80x180 μm) ~200m² ~9.6M channels

**SUPERCONDUCTING SOLENOID**

- Niobium titanium coil carrying ~18,000 A

**MUON CHAMBERS**

- Barrel: 250 Drift Tube, 880 Resistive Plate Chambers
- Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

**PRESHOWER**

- Silicon strips ~16m² ~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
CMS DETECTOR

- Total weight: 14,000 tonnes
- Overall diameter: 15.0 m
- Overall length: 28.7 m
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GEM GE1/1 slice demonstrator

New pixel

Upgraded HF readout

SUPERCONDUCTING SOLENOID
Niobium titanium coil carrying ~18,000A

MUON CHAMBERS
- Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
- Endcaps: 468 Cathode Strip, 432 Resistive Plate Chambers

PRESHOWER
- Silicon strips ~16m² ~137,000 channels

CRYSTAL ELECTROMAGNETIC CALORIMETER (ECAL)
~76,000 scintillating PbWO₄ crystals

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

- $\eta=0$
- $\eta=0.5$
- $\eta=1.0$
- $\eta=1.5$
- $\eta=2.0$
- $\eta=2.5$

- 50.0 cm

**Legacy**

- $\eta=0$
- $\eta=0.5$
- $\eta=1.0$
- $\eta=1.5$
- $\eta=2.0$
- $\eta=2.5$

- New CMS pixel detector
  - 4 layers / 3 disks
    - Improved readout electronics
    - Innermost barrel layer closer to the interaction point
    - Lower material budget
CMS Integrated Luminosity, pp

Data included from 2010-03-30 11:22 to 2017-09-04 09:08 UTC

- 2010, 7 TeV, 45.0 fb⁻¹
- 2011, 7 TeV, 6.1 fb⁻¹
- 2012, 8 TeV, 23.3 fb⁻¹
- 2015, 13 TeV, 4.2 fb⁻¹
- 2016, 13 TeV, 40.8 fb⁻¹
- 2017, 13 TeV, 20.5 fb⁻¹

CMS Peak Luminosity Per Day, pp

Data included from 2010-03-30 11:22 to 2017-09-04 09:08 UTC

- 2010, 7 TeV, max. 203.8 Hz/µb
- 2011, 7 TeV, max. 4.0 Hz/nb
- 2012, 8 TeV, max. 7.7 Hz/nb
- 2015, 13 TeV, max. 5.1 Hz/nb
- 2016, 13 TeV, max. 15.3 Hz/nb
- 2017, 13 TeV, max. 17.3 Hz/nb

Nominal value

Increased by a factor of 50
- HLT triple matching efficiency for tracks going through four pixel layers
- 97%, in agreement with MonteCarlo
- Pixel layer residuals in agreement with expectations at this stage
Pixel performance is very important for the identification of secondary vertices
  - Extremely important for $b$-tagging

Significance of IP at the level of 2016 or better

Settings for layer 1 of pixels still not completely optimal
  - Improvements foreseen in the near future
Measurement of the stability of the relative energy scale measured in the invariant mass distribution of $\pi^0 \rightarrow \gamma\gamma$ in the ECAL barrel
IMPROVEMENTS OF L1 TRIGGER

- Full upgrade of the L1 trigger system in LS1 to deal with luminosities of up to $2 \cdot 10^{34}$ cm$^2$s$^{-1}$
- Improved L1 electron reconstruction with respect to the 2016 strategy
- Better resolution $\Rightarrow$ sharper turn-on
IMPROVEMENTS IN THE MUON L1 TRIGGER

- L1 muon trigger system improvements implemented before the start of 2017 data taking
- Improved L1 muon track finding
- Improved L1 muon $p_T$ resolution
- L1 muon trigger with 25 GeV threshold expected to stay unprescaled for the whole 2017 data taking
$E_{T}^{\text{MISS}}$ RESOLUTION

- Compare the well measured $Z \rightarrow \ell\ell$ system against the recoiling hadronic system
- Taking into account parallel and transverse components separately
- Comparison between Particle flow and PUPPI method

![Diagram showing vector relationships and particle flow](image)

**CMS Preliminary**

$4.8 \text{ pb}^{-1}$ (13 TeV)

- Type 1 PF $E_{T}^{\text{miss}}$
- Type 1 Puppi $E_{T}^{\text{miss}}$

Response Corrected, $q_{T} > 20$

**Number of vertices**

![Graph showing comparison of $\sigma (u)$ vs number of vertices for Type 1 PF and Type 1 Puppi](image)
OVERALL MUON PERFORMANCE

- Rediscovering low mass dimuon resonances with the detector in its current shape

CMS-DP-2017-029
OUTLINE OF THE TALK

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  - Higgs Physics
  - Searches for New Physics
VECTOR BOSON SCATTERING AND ANOMALOUS QUARTIC COUPLINGS

- $\mu_{ZZjj} = 1.39^{+0.72}_{-0.57}$ (stat.) $^{+0.46}_{-0.31}$ (sys.)
- 2.7 (1.6) standard deviations observed (expected)

$-0.46 < f_{T0}/\Lambda^4 < 0.44$
$-0.61 < f_{T1}/\Lambda^4 < 0.61$
$-1.2 < f_{T2}/\Lambda^4 < 1.2$
$-0.84 < f_{T8}/\Lambda^4 < 0.84$
$-1.8 < f_{T9}/\Lambda^4 < 1.8$
Weak mixing angle measured in forward-backward asymmetry ($A_{FB}$) of DY ($e^+e^-, \mu^+\mu^-$) events in 8 TeV collisions

- $\sin^2 \theta_{eff}$ extracted by performing a fit to the $m_\ell\ell$ and $\eta$ dependence of $A_{FB}$
- Most precise determination of $\sin^2 \theta_{eff}$ at LHC
- pdf uncertainties also get constrained in the fit

CMS-SMP-16-007
OUTLINE OF THE TALK

- Performance and detector status

- Physics highlights (2016 data)
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  - Top physics
  - Higgs Physics
  - Searches for New Physics

- Measurement of the $\alpha_S$ running over 3 orders of magnitude
QCD DIFFERENTIAL JET PRODUCTION

- Dijet topology unfolded as a function of $p_T$ and jet mass
- Jet mass is sensitive to QCD parton showering and used in analyses with boosted objects
- Differential cross-section measured with & without jet grooming to remove low energy portions of the jet arising from soft radiation
- MC predictions for jet mass spectra are found to be improved with jet grooming

CMS-SMP-16-010
OUTLINE OF THE TALK

- Performance and detector status

- Physics highlights (2016 data)
  - Electroweak production
  - QCD multijet production
  - Top physics
  - Higgs Physics
  - Searches for New Physics

![Graph showing particle mass vs. normalized cross section](image)
Resolved $H \rightarrow b\bar{b}$ production is covered by overwhelming QCD background

Boosted regime (Higgs recoiling against one or several jets) is an opportunity to overcome this issue

In boosted regime two $b$-jets are merged into a single jet

A double $b$-tagging algorithm is used to identify the merged jet defining a passing and non-passing regions

Signal extracted by performing likelihood fit to $m_{SD}$ and $p_T$ of the jet in signal and control regions

$H \rightarrow b\bar{b}$: 1.5$\sigma$ (0.7$\sigma$ expected)  

$Z \rightarrow b\bar{b}$: 5.1$\sigma$ (5.8$\sigma$ expected)
**Search of VH(→ b¯b)**

- Channels with 0, 1, 2 charged leptons
- 21 control regions and 7 BDT discriminator distributions
- Signal extraction performed by simultaneous likelihood fit of signal and backgrounds for all channels to the BDT distribution
- Method validated measuring the VZ (Z → b¯b) process, observed with 4.96σ
- Combination with CMS Run I (7 & 8 TeV) 3.8σ (3.8 expected)
- Evidence for H → b¯b decay

**CMS-HIG-16-044**
Four-lepton (4µ, 4e, 2µ2e) final states allow full and precise reconstruction of the Higgs kinematics

Categories dedicated to target VBF, VH and ttH production channels

Sensitivity driven by “untagged” region (gluon fusion)

Analysis exploits matrix element techniques for the signal extraction and production channel categorization

\[ m_H = 125.26 \pm 0.21 \text{ GeV} \]

Precision at the level of 8 TeV
Signal is extracted by performing a 2D likelihood fit $L = L(m_{4\ell}) L(D_{bkg}^{\text{kin}} | m_{4\ell})$

- Signal strength: $\mu = 1.05 \pm 0.18$
- Going differential
- Fiducial cross-section

**arXiv:1706.09936**
**Observation of** $H \to \tau\tau$ **Decay**

- Search based on four channels: $\tau_h\tau_h$, $\mu\tau_h$, $e\tau_h$, $e\mu$
- Categories based on the production mode: 0-jet (gluon fusion), VBF, boosted (gluon fusion in association with jets)
- Signal extracted through a likelihood fit to mass distributions and $\tau_h$ decay modes

$\mu = 1.05^{+0.25}_{-0.24}$, $4.9 \sigma$ observed (4.7 expected), $5.9 \sigma$ combined with Run I

- Observation of the $H \to \tau\tau$ decay
**ttH IN MULTILEPTON CHANNEL**

- **Final states with** \( \ell^\pm \ell^\pm \), \( 3 \ell \), \( 4 \ell \)

- **Categorization based on number of leptons, flavour, \( N_b \)-jets, lepton charge**

- **Fit extracted by ML fit of likelihood discriminant against \( tt \) and \( ttV \)**

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**More details in P. Vischia’s talk**
OUTLINE OF THE TALK

- Performance and detector status

- Physics highlights (2016 data)
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  - Searches for New Physics
CMS has a very vast SUSY searches programme  
I will only cover a personal selection of these results
SEARCHES FOR STOPS

- Natural SUSY $\Rightarrow$ small stop mass $\mathcal{O}(1$ TeV)
- CMS is being able to probe stop masses up to 1 TeV

$pp \to \tilde{t}\tilde{t}, \tilde{t} \to t\tilde{\chi}_1^0$

**CMS Preliminary**

35.9 fb$^{-1}$ (13 TeV)

More details in D. Guest’s talk
SEARCHES FOR ELECTROWEAK-INOS

- Combination of several chargino/neutralino production searches in different channels:
  - multi-lepton, low $p_T$ dileptons, OSSF dilepton, WH, razor $H \rightarrow \gamma\gamma$, H+MET
  - Optimized $\geq 3l$ search for compressed region
  - Different neutralino decay modes taken into account

Sensitivity enhanced in the compressed region
SEARCHES FOR EDGES IN $m_{\ell\ell}$ DISTRIBUTION

- Some Supersymmetric models predict edge-like features in $m_{\ell\ell}$ produced in the decay of sleptons
- Searches for edges in 2-lep OS searches drew attention in run I, where an excess was observed
- Search was performed with the full 2016 dataset ⇒ no sign of the excess

[Graph showing edge-like features in $m_{\ell\ell}$ distributions for 8 TeV and 13 TeV datasets]
 Searches for dark matter in complementary channels
Dijet Resonances

- Two-fold approach:
  - Search for peaks in the steeply dijet invariant mass spectrum
  - Search in the angular correlation between the two jets sensitive to larger couplings and widths

![Graph showing dijet mass distribution and comparison between data and fit]

CMS Preliminary Data Fit

- gg (2.0 TeV)
- qg (4.0 TeV)
- qq (6.0 TeV)

χ² / ndf = 38.9 / 39 = 1.0
Wide PF-jets
m_j > 1.25 TeV
|η| < 2.5, |Δη| < 2.5

EXO-16-046

35.9 fb⁻¹ (13 TeV)
Search for lower mass boosted resonances
- Topology is a boosted $Z'$ recoiling against an ISR jet
- Exclusion complementary to other searches

**Dijet Resonances - Low Mass Region**

- **Data**
  - Multijet pred.
  - Total SM pred.
  - $W \rightarrow q\bar{q}$+jets
  - $Z \rightarrow q\bar{q}$+jets
  - $Z'(qq)$, $g = 1/6, m_z = 135$ GeV

- **Number of events/5 GeV**
  - $p_T$: 600-700 GeV

- **Data/Prediction**
  - 0.9
  - 1
  - 1.1

- **Z' mass (GeV)**
  - 50
  - 60
  - 100
  - 200
  - 300

- **Z Width (indirect)**
  - Observed
  - Expected

- **± 1 std. deviation**
  - ± 2 std. deviation

- **CMS Preliminary (13 TeV)**
  - 35.9 fb$^{-1}$
  - ATLAS13, 15.5 fb$^{-1}$, ISR jet
  - CMS8, 18.8 fb$^{-1}$, Scouting

**EXO-17-001**
CONCLUSIONS

- CMS is in good shape
  - Outstanding performance after several detector upgrades and the installation of a new pixel detector
- Results using more than 30 fb$^{-1}$ of 13 TeV are being released
  - Observation of $H \rightarrow b\bar{b}$ and $H \rightarrow \tau\tau$ decay modes
  - Most precise measurement of $\sin^2\theta^{\text{eff}}$ at LHC
  - Improved SUSY searches for electroweakinos
  - Many more...
- More CMS measurements and searches in progress, and more luminosity being collected in 2017-2018
Thanks for your attention! Questions?