RECENT RESULTS FROM THE CMS COLLABORATION

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Overview

- ~160 fb\(^{-1}\) of proton-proton collisions at 13 TeV delivered during Run 2
- Also collected and analyzed Heavy Ion pPb and PbPb collisions
- 1057 papers submitted as of July 29 2021
- 56 Papers/Physics Analysis Summaries made public since May 1 2021
- FNAL’s LPC serves as a nexus for the CMS community in the US!

https://cms-results-search.web.cern.ch/
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Measurement of Z+b jets cross section

- Measurement of integrated cross sections of the $Z + \geq 1$ b jet and $Z + \geq 2$ b jets

- Measurements can be used in further optimization of various kinematic observables

- Described well by MG5_AMC(LO) but overestimated by MG5_AMC(NLO)

- Attributable to variations in shapes of observables and settings (PDFs, MC tunes, matching schemes) used in those simulations
Probing effective field theory (EFT) with $t(t)Z$

(TOP-21-001)

- Considering events with 3/4 light leptons, divided into signal and control (WZ/ZZ) regions
- Machine learning used to optimize sensitivity to each EFT parameter
- Probing 5 dimension-six EFT operators involving top quark(s) and a Z boson
  - All fit simultaneously to data

Not to be confused with ZZTop
Measurement of the shape of the b quark fragmentation function using charmed mesons

(TOP-18-012)

- Charm mesons produced inside b jets from tt pairs are used to determine the shape parameter of the Lund-Bowler fragmentation function
- First measurement of the b quark fragmentation function in tt events at the LHC
- Significantly improves the experimental constraints on the shape of the function
Differential $H \to \tau\tau$ production cross sections

(HIG-20-015)

- Using full Run 2 dataset to measure inclusive and differential fiducial cross section
- Particularly sensitive channel in high $p_T(H)$, #Jets, $p_T$(leading jet)
- First differential measurements in this channel
Search for non resonant $H(bb)H(bb)$

(HIG-20-005)

• Di-Higgs production to explore several couplings: $HHH$, $HVV$, $HHVV$
  Dedicated triggers with 3 b-jet at HLT

• Targets both gg and VBF production

• New multivariate analysis strategy
  New background estimation from multiple control regions

• Benefits from better b-tagging thanks to 2017/2018 upgraded pixel detector, and switch to latest tagger from BTV (DeepFlavour)
Search for long-lived particles decaying in the CMS EC muon detectors

- **Search for a Higgs decaying to two neutral long lived scalars, each decaying to a pair of b-quarks, d-quarks or tau leptons** \( H \rightarrow SS \rightarrow bb/dd/tautau \)
- Novel reconstruction technique uses the CMS endcap muon detectors as a calorimeter
- Hits in the CSC are clustered using the DBScan algorithm
- Method is validated using Z events where one muon undergoes bremsstrahlung in the Endcap Muon Detector and the photon produces an EM shower

**EXO-20-015**
Search for $H \to$ long-lived particles in associated Z boson production

**CMS Preliminary**

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

- Looking for pairs of long-lived particles (LLP) further decaying into jets, with associated Z production

- Signal region: at least two displaced jets (3 tracking-based displacement variables)

- Both light (d) and heavy (b) jets are considered. Benchmark model: Higgs decay to a pair of scalar LLP. Probing decay lengths from 1 mm to 1 m
Search for long-lived heavy neutral leptons with displaced vertices

(Exo-20-009)

- Search for heavy neutral leptons (right-handed Dirac or Majorana neutrinos)

- For small HNL mass (< 20 GeV) Decay length of these particles can be large enough to produce a resolved secondary vertex in the CMS silicon tracker

**Signal:** W mediator and two leptons that form a displaced vertex

- No significant deviations from the SM expectations
Search for displaced $\mu\mu\mu$ resonances with scouting data

(EXO-20-014)

- Using events recorded with low threshold dimuon triggers and reconstructed at HLT only (“scouting”)
- Inspect dimuon invariant mass for various transverse displacement ($l_{xy}$) of the dimuon pair
- Most stringent limits on a wide mass range for generic resonance
- Competitive with LHCb for $B \to K_\pi$ displ. $\varphi(\mu\mu)$ for “high” mass and decay lengths
Search for $W\gamma$ resonances using hadronic decays of Lorentz-boosted $W$ bosons

- $W\gamma$ is a signature of multiple BSM theories
- $VV/VH$ already studied in multiple modes
- $W$ boson is reconstructed via its hadronic decays, with the final-state products forming a single large-radius jet, owing to a high Lorentz boost of the $W$ boson
- $W\gamma$ mass spectrum is parameterized with a smoothly falling background function and examined for the presence of resonance-like signals
First observation of the $B_{c}^{+}$ meson in Pb Pb collisions

(HIN-20-004)

- Looking for $B_{c}^{+} \rightarrow J/\psi(\mu\mu) + \mu\nu\mu$
- Only (unexcited) meson containing $b$ and $c$ quark
- Theory expectation ranges from $O(1x)$ to $O(1000x)$ enhancement for inclusive cross section
- Signal extracted from $M(\mu\mu\mu)$ and BDT(vertex+kinematics)
- Unique insight into the interplay between suppression and enhancement mechanisms in HI

> $5\sigma$ significance

Hint of softened $p_T$ spectrum?
Looking Forward

LHC / HL-LHC Plan

- Run 1
  - LS1
    - Splice consolidation button collimators R2E project
  - Experiment beam pipes
  - 7 TeV
  - 2011
  - Nominal Lumi
  - 30 fb⁻¹

- Run 2
  - LS2
    - Diodes Consolidation LIU Installation
    - Civil Eng. P1-PS
  - 13 - 14 TeV
  - 2015
  - 160 fb⁻¹

- Run 3
  - LS3
    - ATLAS - CMS upgrade phase 1
    - ALICE - LHCb upgrade
    - 2019
  - 350 fb⁻¹
  - 2020
  - 2021

- HL-LHC
  - ATLAS - CMS HL upgrade
  - 2022
  - 2023
  - 2024
  - Inner triplet radiation limit
  - 2025
  - 2026
  - 2027
  - 2040
  - 5 to 7.5 x nominal Lumi
  - Integrated luminosity
  - 3000 fb⁻¹
  - 4000 fb⁻¹

HL-LHC Technical Equipment:
- Design Study
- Prototypes
- Construction
- Installation & Commissioning
- Physics

HL-LHC Civil Engineering:
- Definition
- Excavation
- Buildings

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RECENT CMS RESULTS

PRINCETON UNIVERSITY