Presentazione del dott. Andrea Bellora
Dottorato di Ricerca in Fisica - XXXIV Ciclo
Università degli Studi di Torino

Dottorando: Dott. Andrea Bellora
Relatore: Prof.sa Ada Maria Solano
Co-relatore: Prof.sa Maria Margherita Obertino
Titolo della tesi: *Performance of the 3D pixel tracker of the CMS Precision Proton Spectrometer and study of anomalous couplings in exclusive production at the LHC*

Durante il triennio di dottorato il dott. Andrea Bellora ha seguito e sostenuto l'esame relativo ai seguenti corsi della Scuola:

- Experimental Techniques for neutron detection;
- Data Analysis Techniques;
- Advanced Topics in Higgs Physics;
- The Hunt for Physics Beyond the Standard Model;
- Big Data Science and Machine Learning;
- Python in The Lab;
- Introduction to FPGA programming using Xilinx Vivado and VHDL.

L'attività di ricerca del dott. Andrea Bellora si è svolta nell'ambito dell'esperimento CMS del CERN e si è focalizzata sullo studio delle performance del tracciatore del Precision Proton Spectrometer (PPS) nel Run2 del Large Hadron Collider (LHC), sulla preparazione del rivelatore in vista del Run3 e sullo studio della produzione centrale esclusiva coi dati del Run2.

PPS è costituito da rivelatori di tracciamento e di tempo di volo installati a circa 220 m dal punto di interazione di CMS, ai due lati del rivelatore centrale dell'esperimento, lungo le linee di fascio (settori 45 e 56 del LHC). Scopo di PPS è misurare i protoni di alta energia che emergono intatti nelle interazioni pp -> pXp e vengono diffusi a piccolissimo angolo all'interno del tubo a vuoto dell'acceleratore. I rivelatori sono inseriti all'interno di strutture meccaniche mobili dette Roman Pot (RP) così da poterli avvicinare ad una distanza di pochi mm dal fascio. Il tracciatore di PPS é costituito da due

stazioni per settore, entrambe equipaggiate con 6 piani di sensori a pixel al silicio 3D letti dal readout chip (ROC) PSI46dig.

Il dott. Bellora ha dedicato il primo periodo del dottorato allo studio delle performance del tracciatore negli anni 2017 e 2018 del Run2. A causa della prossimità al fascio, il rivelatore opera in una zona ad alto e non uniforme irraggiamento che danneggia il ROC, causando una diminuzione dell'efficienza nel tempo. Tale problema è stato in parte mitigato spostando verticalmente le stazioni a step di 0.5 mm in modo tale da allontanare la zona irraggiata dal fascio e allungare la vita del rivelatore. Il dott. Bellora ha sviluppato in prima persona le metodologie con cui si è valutato l'andamento temporale delle efficienze dei singoli piani e della quattro stazioni di misura, affrontando in modo critico e competente le diverse problematiche insorte durante lo studio. Il suo lavoro è stato presentato a diverse conferenze ed è riportato in una nota pubblica della collaborazione CMS (CMS-DP-2019-036, 2019), di cui è il principale autore.

In parallelo agli studi sul rivelatore, il dott. Bellora ha contribuito agli studi sulla ricostruzione della traccia del protone. I parametri cinematici (momento e angolo di scattering) vengono ricostruiti combinando le informazioni delle due stazioni di misura installate nello setsso settore (ricostruzione MultiRP). Il dott. Bellora ha contribuito a questi studi fornendo i valori di efficienza della ricostruzione MultiRP attualmente usati nelle analisi. Questo lavoro è stato da lui descritto nell'articolo sulla ricostruzione del protone attualmente in fase di revisione interna.

PPS prenderà dati nel prossimo Run3 con nuovi rivelatori, un chip di lettura parzialmente modificato (PROC600) e un sistema di movimentazione dei sensori controllabile da remoto. Tale sistema permetterà di spostare i sensori a passi di 500 μm per un massimo di 6 mm, senza dover effettuare accessi al tunnel di LHC e con frequenza maggiore di quanto sia stato possibile nel Run2. Nell'ultimo anno, il dott. Bellora si è occupato dell'aggiornamento e dei test del software di acquisizione (PixelOnline) del nuovo rivelatore e ha disegnato, dal punto di vista hardware e software, il sistema di controllo del motore con cui verranno spostati i sensori. Per determinare quando effettuare gli spostamenti sarà necessario monitorare costantemente l'efficienza del rivelatore durante la presa dati. Il dott. Bellora ha sviluppato una piattaforma per la misura automatica delle efficienze; tale piattaforma verrà utilizzata anche per la determinazione della risoluzione dei rivelatori di tempo di volo. Nello scorso ottobre, il primo pacchetto con i nuovi rivelatori e il sistema di movimentazione è stato assemblato e testato utilizzando il sistema finale di raffreddamento e di tenuta del vuoto; il dott. Bellora si è occupato in prima persona dei test e della calibrazione dei nuovi sensori effettuata con il software PixelOnline.

Il dott. Bellora ha affiancato alle attività sul rivelatore, fondamentali per l'esperimento, diversi studi di produzione centrale esclusiva nei quali PPS svolge un ruolo chiave. Al termine del primo anno, in collaborazione col gruppo di Genova, ha contribuito ad impostare l'analisi volta a studiare la produzione centrale esclusiva di $t\bar{t}$ sui dati acquisiti nel 2017. In parallelo, in collaborazione con il gruppo dell'Università del Kansas, ha svolto uno studio fenomenologico volto ad implementare nella simulazione Monte Carlo la produzione anomala di $t\bar{t}$ per via di accoppiamenti quartici $\gamma\gamma t\bar{t}$. Il dott. Bellora, in particolare, si è occupato dell'implementazione di questi processi di produzione in simulazioni Monte Carlo basate su Madgraph e FPMC; ha quindi prodotto un campione di eventi e, simulando un rivelatore con le caratteristiche di CMS, ha valutato la sensitività della ricerca di produzione anomala di $t\bar{t}$ con protoni diffusi nello stato finale. Questo studio è stato presentato dal dott. Bellora a una conferenza internazionale e verrà descritto in un articolo attualmente in preparazione.

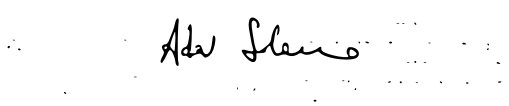
Infine, nell'ultimo anno, il dott. Bellora si è focalizzato sullo studio della produzione esclusiva di coppie di bosoni vettori. Nel processo preso in considerazione, i due protoni incidenti interagiscono radiando ciascuno un fotone quasi reale di alta energia ma rimanendo intatti, e nell'interazione tra i due fotoni viene prodotta una coppia di bosoni WW o ZZ. La misura dei due protoni diffusi in PPS, unita a quella dei due bosoni nel rivelatore centrale di CMS, permette di ridurre in modo significativo gli eventi di fondo. Questi processi rivestono grande interesse in quanto consentono lo studio degli accoppiamenti quartici $\gamma\gamma$WW e $\gamma\gamma$ZZ in eventi particolarmente puliti, dando accesso ad eventuale nuova fisica attraverso l'osservazione di deviazioni rispetto alle predizioni del Modello Standard. Il dott. Bellora si è occupato della definizione della strategia di analisi e della generazione degli eventi Monte Carlo e sta partecipando in modo attivo all'analisi e al suo processo di approvazione. Ha inoltre riportato il suo lavoro nella nota interna di CMS e contribuirà alla scrittura dell'articolo.

Durante la sua attività di ricerca il dott. Andrea Bellora ha mostrato grande indipendenza nel perseguire gli obiettivi della ricerca, affrontando criticamente tutti gli studi che ha compiuto. Con il lavoro presentato in questa tesi ha contribuito in modo originale all'avanzamento delle conoscenze scientifiche nel campo della fisica delle particelle elementari e degli strumenti per la sua indagine. Egli ha raggiunto una vasta ed accurata competenza nel campo dello studio dei rivelatori, sia dal punto di vista hardware sia software. Allo stesso tempo, anche supportato da una solida preparazione accademica, ha affrontato con maturità scientifica lo studio di canali di fisica importanti per il progetto.

Pertanto si esprime grande apprezzamento per l'eccellente lavoro svolto dal dott. Andrea Bellora durante il triennio del Dottorato di Ricerca.

Torino, 26/11/2021

Il relatore
Prof.sa Ada Maria Solano



Partecipazione a scuole e conferenze

- CMS Data Analysis School, Pisa, Italia, 2019;
- INFN School of Statistics, Paestum, Italia, 2019;
- XXVIII giornate di studio sui rivelatori scuola F. Bonaudi, Cogne, Italia, 2019;
- XXXII International Seminar of Nuclear and Subnuclear Physics "Francesco Romano", remote, 2021 (talk);
- Low-x, *The CMS Precision Proton Spectrometer (PPS): results, status and prospects*, **plenary talk**, Nicosia, Cipro, 2019;
- 105° Congresso Nazionale della Società Italiana di Fisica, *Il Precision Proton Spectrometer di CMS e le sue prestazioni durante il Run2*, **parallel talk**, L'Aquila, Italia, 2019;
- "Trento" workshop on advanced silicon radiation detection, *Performance and prospects of the PPS tracking system*, **plenary talk**, Vienna, Austria, 2020;
- Low-x, *Anomalous $\gamma\gamma\bar{t}$ scattering at the LHC*, **plenary talk**, Isola d'Elba, Italia, 2021;
- Workshop annuale dell'esperimento CMS ad LHC, *PPS: preparation for Run 3*, **plenary talk**, Napoli, Italia, 2021;
- TOTEM-PPS Upgrade Workshop, *The RPIX performance in Run2*, **plenary talk**, CERN, Switzerland, 2020;
- 10 talks alle sessioni parallele dedicate "PPS General Meeting" durante le CMS Week;

Visite e stages

- INFN CERN Associate da Settembre 2020 a Settembre 2021;

Elenco delle pubblicazioni con diretto contributo

- CMS Collaboration, *Efficiency of the Pixel sensors used in the Precision Proton Spectrometer: radiation damage*, CMS-DP-2019-036, 2019;

- CMS and TOTEM Collaborations, *Proton reconstruction with the Precision Proton Spectrometer (PPS) in Run2*, CMS-DP-2020-047, 2019;

- CMS and TOTEM Collaborations, *The PPS tracking system: performance in LHC Run2 and prospects for LHC Run3*, Proceedings, 15th Topical Seminar on Innovative Particle and Radiation Detectors (IPhys. Rev. D19), J. Instrum. 15 05, 2020;

- CMS and TOTEM Collaborations, *The CMS Precision Proton Spectrometer timing system: performance in Run2, future upgrades and sensor radiation hardness studies*, Proceedings, 15th Topical Seminar on Innovative Particle and Radiation Detectors (IPhys. Rev. D19), J. Instrum. 15 05, 2020;

- CMS Collaboration, *The CMS Precision Proton Spectrometer at the HL-LHC – Expression of Interest*, CERN-CMS-NOTE-2020-008, arXiv:2103.02752, 2020;

- CMS and TOTEM Collaborations, *Diphoton production in 2016 data with two protons in CT-PPS*, CERN-EP-2021-191, arXiv:2110.05916, 2020 (submitted to Phys. Rev. Lett.);

- CMS and TOTEM Collaborations, *Proton reconstruction with the Precision Proton Spectrometer in Run2*, (CMS internal review ongoing, targeting J. Instrum.);

- CMS and TOTEM Collaborations, *Search for Exclusive Production of top quark pairs at* $\sqrt{s} = 13\ TeV$, (CMS internal review ongoing, targeting J. High Energy Phys.);

- CMS and TOTEM Collaborations, *Probing anomalous quartic gauge couplings in vector boson pair exclusive production at* $\sqrt{s} = 13\ TeV$, (CMS internal review ongoing, targeting J. High Energy Phys.);

- CMS Collaboration,*The Precision Proton Spectrometer 3D pixel tracker performance in Run 2*, (paper in preparation);

- A. Bellora, C. Baldenegro, S. Fichet,G. von Gersdorff, M. Pitt, C. Royon, *Probing anomalous quartic couplings in* $\gamma\gamma \to t\bar{t}$ *exclusive production at the LHC*, (Low-x 2021 conference proceeding and paper in preparation);

Elenco completo delle pubblicazioni

- Tumasyan, A. et al., CMS Collaboration, *Combined searches for the production of supersymmetric top quark partners in proton–proton collisions at* $\sqrt{s}$ *= 13 TeV*, Eur. Phys. J. C 81 970, 2021

- Tumasyan, A. et al., CMS Collaboration, *Study of Z boson plus jets events using variables sensitive to double-parton scattering in pp collisions at 13 TeV*, J. High Energy Phys. 10 176, 2021

- Tumasyan, A. et al., CMS Collaboration, *Measurements of the pp* $\rightarrow$ *W*$\pm\gamma\gamma$ *and pp* $\rightarrow$ *Z*$\gamma\gamma$ *cross sections at* $\sqrt{s}$ *= 13 TeV and limits on anomalous quartic gauge couplings*, J. High Energy Phys. 10 174, 2021

- Tumasyan, A. et al., CMS Collaboration, *Measurement of the electroweak production of Z*γ *and two jets in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV and constraints on anomalous quartic gauge couplings*, Phys. Rev. D 104 072001, 2021

- Tumasyan, A. et al., CMS Collaboration, *Search for chargino-neutralino production in events with Higgs and W bosons using 137 fb*-1 *of proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, J. High Energy Phys. 10 045, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of Forward Neutron Multiplicity Dependence of Dimuon Acoplanarity in Ultraperipheral Pb-Pb Collisions at* $\sqrt{s}$*NN = 5.02 TeV*, Phys. Rev. Lett. 127 122001, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *First measurement of the cross section for top quark pair production with additional charm jets using dileptonic final states in pp collisions at* $\sqrt{s}$ *= 13TeV*, Phys. Lett. B 820 136565, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for W′ bosons decaying to a top and a bottom quark at* $\sqrt{s}$ *= 13TeV in the hadronic final state*, Phys. Lett. B 820 136535, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Constraints on the Initial State of Pb-Pb Collisions via Measurements of Z -Boson Yields and Azimuthal Anisotropy at* $\sqrt{s}$*NN=5.02 TeV*, Phys. Rev. Lett. 127 102002, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Constraints on anomalous Higgs boson couplings to vector bosons and fermions in its production and decay using the four-lepton final state*, Phys. Rev. D 104 052004, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for long-lived particles decaying to jets with displaced vertices in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. D 104 052011, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of angular distance and momentum ratio distributions in three-jet and Z + two-jet final states in pp collisions*, Eur. Phys. J. C 81 852, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Precision luminosity measurement in proton–proton collisions at* $\sqrt{s}$ *= 13TeV in 2015 and 2016 at CMS*, Eur. Phys. J. C 81 800, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for top squark production in fully hadronic final states in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. D 104 052001, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for the rare decay of the W boson into a pion and a photon in proton-proton collisions at* $\sqrt{s}$ *= 13TeV*, Phys. Lett. B 819 136409, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the azimuthal anisotropy of Y(1S) and Y(2S) mesons in PbPb collisions at* $\sqrt{sNN}$*=5.02TeV*, Phys. Lett. B 819 136385, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for lepton-flavor violating decays of the Higgs boson in the* $\mu\tau$ *and* $e\tau$ *final states in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. D 104 032013, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for top squarks in final states with two top quarks and several light-flavor jets in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. D 104 032006, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Hard color-singlet exchange in dijet events in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. D 104 032009, 2021
- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for a heavy vector resonance decaying to a Z boson and a Higgs boson in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, Eur. Phys. J. C 81 688, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for charged Higgs bosons produced in vector boson fusion processes and decaying into vector boson pairs in proton–proton collisions at* $\sqrt{s} = 13TeV$, Eur. Phys. J. C 81 723, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for long-lived particles using displaced jets in proton-proton collisions at* $\sqrt{s} = 13$ TeV, Phys. Rev. D 104 012015, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of Higgs boson production cross sections and couplings in the diphoton decay channel at* $\sqrt{s} = 13$ TeV, J. High Energy Phys. 7 027, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for resonant and nonresonant new phenomena in high-mass dilepton final states at* $\sqrt{s} = 13$ TeV, J. High Energy Phys. 7 208, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Performance of the CMS muon trigger system in proton-proton collisions at* $\sqrt{s} = 13$ TeV, J. Instrum. 16 P07001, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *MUSiC: a model-unspecific search for new physics in proton–proton collisions at* $\sqrt{s} = 13TeV$, Eur. Phys. J. C 81 629, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of a New Excited Beauty Strange Baryon Decaying to* $\Xi_b^- \pi^+ \pi^-$, Phys. Rev. Lett. 126 252003, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the* $W\gamma$ *Production Cross Section in Proton-Proton Collisions at* $\sqrt{s} = 13$ TeV *and Constraints on Effective Field Theory Coefficients*, Phys. Rev. Lett. 126 252002, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of production cross sections of the Higgs boson in the four-lepton final state in proton–proton collisions at* $\sqrt{s} = 13$ TeV, Eur. Phys. J. C 81 488, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of prompt D0 and* $D\bar{0}$ *meson azimuthal anisotropy and search for strong electric fields in PbPb collisions at* $\sqrt{sNN} = 5.02$ TeV, Phys. Lett. B 816 136253, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the CP-violating phase Φ_s in the $B_s^0 \to J/\Psi\Phi(1020) \to \mu^+\mu^- K^+K^-$ channel in proton-proton collisions at $\sqrt{s} = 13TeV$*, Phys. Lett. B 816 136188, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Study of Drell-Yan dimuon production in proton-lead collisions at $\sqrt{sNN} = 8.16$ TeV*, J. High Energy Phys. 5 182, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *First measurement of large area jet transverse momentum spectra in heavy-ion collisions*, J. High Energy Phys. 5 284, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Electron and photon reconstruction and identification with the CMS experiment at the CERN LHC*, J. Instrum. 16 P05014, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of the differential cross sections of the production of Z + jets and γ + jets and of Z boson emission collinear with a jet in pp collisions at $\sqrt{s} = 13$ TeV*, J. High Energy Phys. 5 285, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the Z boson differential production cross section using its invisible decay mode ($Z \to \nu\bar{\nu}$) in proton-proton collisions at $\sqrt{s} = 13$ TeV*, J. High Energy Phys. 5 205, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of b jet shapes in proton-proton collisions at $\sqrt{s} = 5.02$ TeV*, J. High Energy Phys. 5 054, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the Higgs boson production rate in association with top quarks in final states with electrons, muons, and hadronically decaying tau leptons at $\sqrt{s} = 13$ TeV*, Eur. Phys. J. C 81 378, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Angular analysis of the decay B+ $\to$ K*(892)+ μ + μ − in proton-proton collisions at $\sqrt{s} = 8$ TeV*, J. High Energy Phys. 4 124, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of differential cross sections for Z bosons produced in association with charm jets in pp collisions at $\sqrt{s} = 13$ TeV*, J. High Energy Phys. 4 109, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Erratum to: Search for dark matter produced in association with a leptonically decaying Z boson in proton–proton collisions at $\sqrt{s}$ = 13 TeV(The European Physical Journal C, (2021), 81, 1, (13), 10.1140/Eur. Phys. J. C/s10052-020-08739-5)*, Eur. Phys. J. C 81 333, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Development and validation of HERWIG 7 tunes from CMS underlying-event measurements*, Eur. Phys. J. C 81 312, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of differential t t ¯ production cross sections using top quarks at large transverse momenta in pp collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 103 052008, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for nonresonant Higgs boson pair production in final states with two bottom quarks and two photons in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 3 257, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the inclusive and differential Higgs boson production cross sections in the leptonic WW decay mode at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 3 003, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for new physics in top quark production with additional leptons in proton-proton collisions at $\sqrt{s}$ = 13 TeV using effective field theory*, J. High Energy Phys. 3 095, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for dark photons in Higgs boson production via vector boson fusion in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 3 011, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Studies of charm and beauty hadron long-range correlations in pp and pPb collisions at LHC energies*, Phys. Lett. B 813 136036, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Evidence for electroweak production of four charged leptons and two jets in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Phys. Lett. B 812 135992, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of production cross sections of polarized same-sign W boson pairs in association*

with two jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV, Phys. Lett. B 812 136018, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Evidence for Higgs boson decay to a pair of muons*, J. High Energy Phys. 1 148, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for the lepton flavor violating decay $\tau \to 3\mu$ in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 1 163, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for dark matter produced in association with a leptonically decaying Z boson in proton–proton collisions at $\sqrt{s}$ = 13 TeV*, Eur. Phys. J. C 81 013, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for top squark pair production using dilepton final states in pp collision data collected at $\sqrt{s}$ = 13TeV*, Eur. Phys. J. C 81 003, 2021

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of electroweak production of $W\gamma$ with two jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Lett. B 811 135988, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for bottom-type, vectorlike quark pair production in a fully hadronic final state in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 112004, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *A Deep Neural Network for Simultaneous Estimation of b Jet Energy and Resolution*, Comput. softw. big sci., 4 010, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Dependence of inclusive jet production on the anti-kT distance parameter in pp collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 12 082, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Inclusive search for highly boosted Higgs bosons decaying to bottom quark-antiquark pairs in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 12 085, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of the W boson rapidity, helicity, double-differential cross sections, and charge asymmetry in pp collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 092012, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the top quark Yukawa coupling from $t\bar{t}$ kinematic distributions in the dilepton final state in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 092013, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Evidence for Top Quark Production in Nucleus-Nucleus Collisions*, Phys. Rev. Lett. 125 222001, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of Bc (2S)+ and Bc∗ (2S)+ cross section ratios in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 092007, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Investigation into the event-activity dependence of Υ(nS) relative production in proton-proton collisions at $\sqrt{s}$ = 7 TeV*, J. High Energy Phys. 11 001, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for decays of the 125 GeV Higgs boson into a Z boson and a ρ or Φ meson*, J. High Energy Phys. 11 039, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of production cross sections of WZ and same-sign WW boson pairs in association with two jets in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Phys. Lett. B 809 135710, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of the B_s^0 $\rightarrow$X(3872)Φ Decay*, Phys. Rev. Lett. 125 152001, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of the Production of Three Massive Gauge Bosons at $\sqrt{s}$ = 13 TeV*, Phys. Rev. Lett. 125 151802, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Performance of the CMS Level-1 trigger in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. Instrum. 15 P10017, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of CKM matrix elements in single top quark t-channel production in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Lett. B 808 135609, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the Y(1S) pair production cross section and search for resonances decaying to Y(1S)μ+μ− in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Phys. Lett. B 808 135578, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Pileup mitigation at CMS in 13 TeV data*, J. Instrum. 15 P09018, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for supersymmetry in proton-proton collisions at $\sqrt{s}$ = 13 TeV in events with high-momentum Z bosons and missing transverse momentum*, J. High Energy Phys. 9 149, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of t t ¯ H Production and the CP Structure of the Yukawa Interaction between the Higgs Boson and Top Quark in the Diphoton Decay Channel*, Phys. Rev. Lett. 125 061801, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for resonant pair production of Higgs bosons in the bbZZ channel in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 032003, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the associated production of a Z boson with charm or bottom quark jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 032007, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Combination of the W boson polarization measurements in top quark decays using ATLAS and CMS data at $\sqrt{s}$ = 8 TeV*, J. High Energy Phys. 8 051, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for a light pseudoscalar Higgs boson in the boosted $\mu\mu\tau\tau$ final state in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 8 139, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for physics beyond the standard model in events with jets and two same-sign or at least three charged leptons in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Eur. Phys. J. C 80 752, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for disappearing tracks in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Phys. Lett. B 806 135502, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of quark- and gluon-like jet fractions using jet charge in PbPb and pp collisions at 5.02 TeV*, J. High Energy Phys. 7 115, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for charged Higgs bosons decaying into a top and a bottom quark in the all-jet final state of pp collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 7 126, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the cross section for t t ¯ production with additional jets and b jets in pp collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 7 125, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *The production of isolated photons in PbPb and pp collisions at $\sqrt{s}$NN = 5.02 TeV*, J. High Energy Phys. 7 116, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for dijet resonances using events with three jets in proton-proton collisions at $\sqrt{s}$ = 13TeV*, Phys. Lett. B 805 135448, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *A measurement of the Higgs boson mass in the diphoton decay channel*, Phys. Lett. B 805 135425, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements with silicon photomultipliers of dose-rate effects in the radiation damage of plastic scintillator tiles in the CMS hadron endcap calorimeter*, J. Instrum. 15 P06009, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Identification of heavy, energetic, hadronically decaying particles using machine-learning techniques*, J. Instrum. 15 P06005, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the top quark forward-backward production asymmetry and the anomalous chromoelectric and chromomagnetic moments in pp collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 6 146, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the cross section for electroweak production of a Z boson, a photon and two jets in proton-proton collisions at $\sqrt{s}$ = 13 TeV and constraints on anomalous quartic couplings*, J. High Energy Phys. 6 076, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Determination of the strong coupling constant $\alpha_s(m_Z)$ from measurements of inclusive W± and Z boson production cross sections in proton-proton collisions at $\sqrt{s}$ = 7 and 8 TeV*, J. High Energy Phys. 6 018, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the jet mass distribution and top quark mass in hadronic decays of boosted top quarks in pp collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. Lett. 124 202001, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Study of J/*Ψ *meson production inside jets in pp collisions at* $\sqrt{s}$ *= 8 TeV*, Phys. Lett. B 804 135409, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for direct top squark pair production in events with one lepton, jets, and missing transverse momentum at 13 TeV with the CMS experiment*, J. High Energy Phys. 5 032, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for high mass dijet resonances with a new background prediction method in proton-proton collisions at* $\sqrt{s}$ *= 13 TeV*, J. High Energy Phys. 5 033, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Constraints on the* χ_{c1} *versus* χ_{c2} *Polarizations in Proton-Proton Collisions at* $\sqrt{s}$ *= 8 TeV*, Phys. Rev. Lett. 124 162002, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Study of excited* Λ_b^0 *states decaying to* $\Lambda_b^0\pi^+\pi^-$ *in proton-proton collisions at* $\sqrt{s}$ *= 13TeV*, Phys. Lett. B 803 135345, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the* $t\bar{t}b\bar{b}$ *production cross section in the all-jet final state in pp collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Lett. B 803 135285, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Running of the top quark mass from proton-proton collisions at* $\sqrt{s}$ *= 13TeV*, Phys. Lett. B 803 135263, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for a Narrow Resonance Lighter than 200 GeV Decaying to a Pair of Muons in Proton-Proton Collisions at* $\sqrt{s}$ *= 13 TeV*, Phys. Rev. Lett. 124 131802, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of properties of Bs0* $\rightarrow \mu+\mu-$ *decays and search for B0* $\rightarrow \mu+\mu-$ *with the CMS experiment*, J. High Energy Phys. 4 188, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Observation of the* $\lambda_b^0 \to J/\Psi\Lambda\Phi$ *decay in proton-proton collisions at* $\sqrt{s} = 13TeV$, Phys. Lett. B 802 135203, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for supersymmetry in pp collisions at* $\sqrt{s} = 13$ *TeV with 137 fb-1 in final states with a single lepton using the sum of masses of large-radius jets*, Phys. Rev. D 101 052010, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *A search for the standard model Higgs boson decaying to charm quarks*, J. High Energy Phys. 3 131, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for physics beyond the standard model in multilepton final states in proton-proton collisions at* $\sqrt{s} = 13$ *TeV*, J. High Energy Phys. 3 051, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for new neutral Higgs bosons through the* $H \to ZA \to \ell+\ell-b\ b^{-}$ *process in pp collisions at* $\sqrt{s} = 13$ *TeV*, J. High Energy Phys. 3 055, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Performance of the reconstruction and identification of high-momentum muons in proton-proton collisions at* $\sqrt{s} = 13$ *TeV*, J. Instrum. 15 P02027, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurement of the top quark pair production cross section in dilepton final states containing one* τ *lepton in pp collisions at* $\sqrt{s} = 13$ *TeV*, J. High Energy Phys. 2 191, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for top squark pair production in a final state with two tau leptons in proton-proton collisions at* $\sqrt{s} = 13$ *TeV*, J. High Energy Phys. 2 015, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for production of four top quarks in final states with same-sign or multiple leptons in proton–proton collisions at* $\sqrt{s} = 13TeV$, Eur. Phys. J. C 80 075, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for Supersymmetry with a Compressed Mass Spectrum in Events with a Soft* τ *Lepton, a Highly Energetic Jet, and Large Missing Transverse Momentum in Proton-Proton Collisions at* $\sqrt{s} = 13$ *TeV*, Phys. Rev. Lett. 124 041803, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *W+W- boson pair production in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 102 092001, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for electroweak production of a vector-like T quark using fully hadronic final states*, J. High Energy Phys. 1 036, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Searches for physics beyond the standard model with the MT 2 variable in hadronic final states with and without disappearing tracks in proton–proton collisions at $\sqrt{s}$ = 13 TeV*, Eur. Phys. J. C 80 003, 2020

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for low mass vector resonances decaying into quark-antiquark pairs in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 100 112007, 2019

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for long-lived particles using delayed photons in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, Phys. Rev. D 100 112003, 2019

- Sirunyan, A.M., A. et al., CMS Collaboration, *Measurements of differential Z boson production cross sections in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 12 061, 2019

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for supersymmetry using Higgs boson to diphoton decays at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 11 109, 2019

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for supersymmetry in proton-proton collisions at 13 TeV in final states with jets and missing transverse momentum*, J. High Energy Phys. 10 244, 2019

- Sirunyan, A.M., A. et al., CMS Collaboration, *Search for dark photons in decays of Higgs bosons produced in association with Z bosons in proton-proton collisions at $\sqrt{s}$ = 13 TeV*, J. High Energy Phys. 10 139, 2019