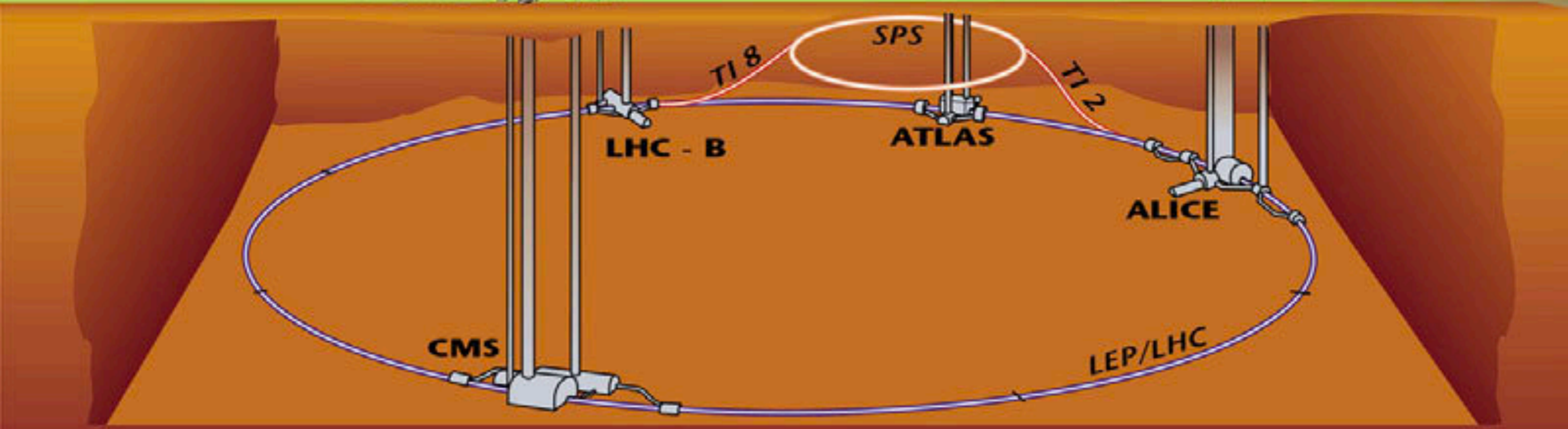
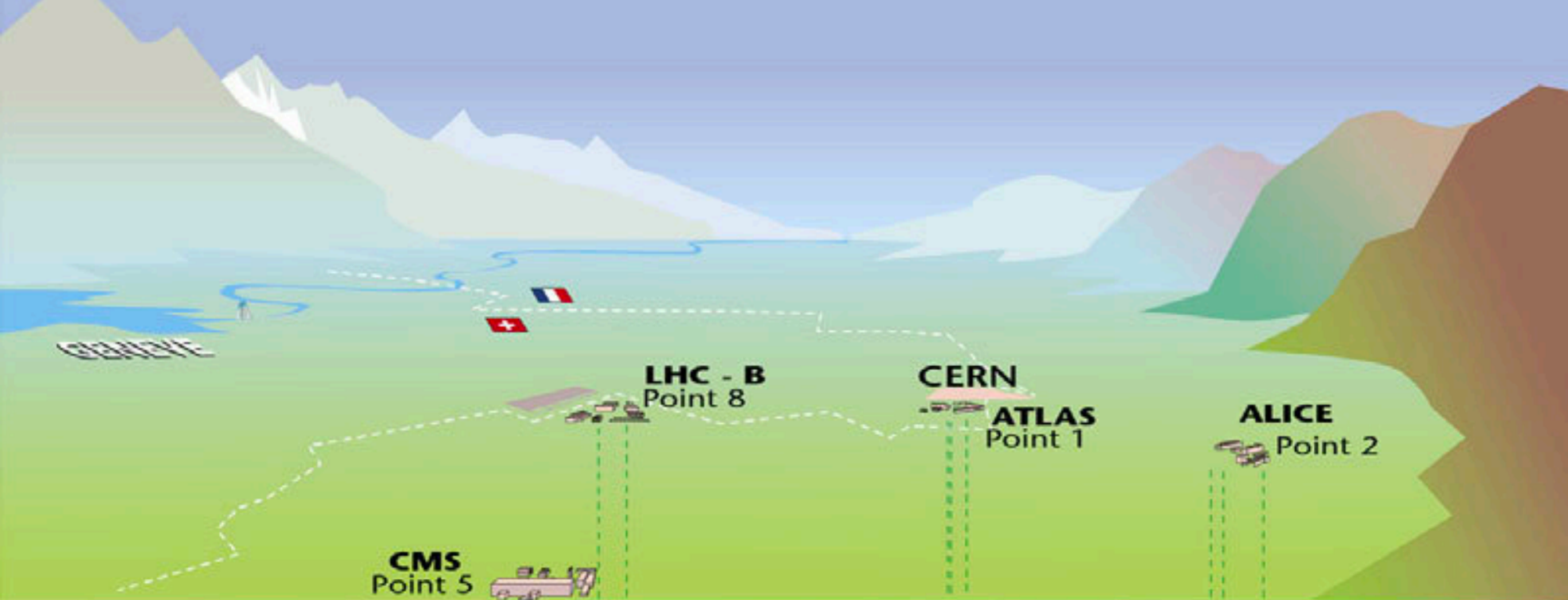


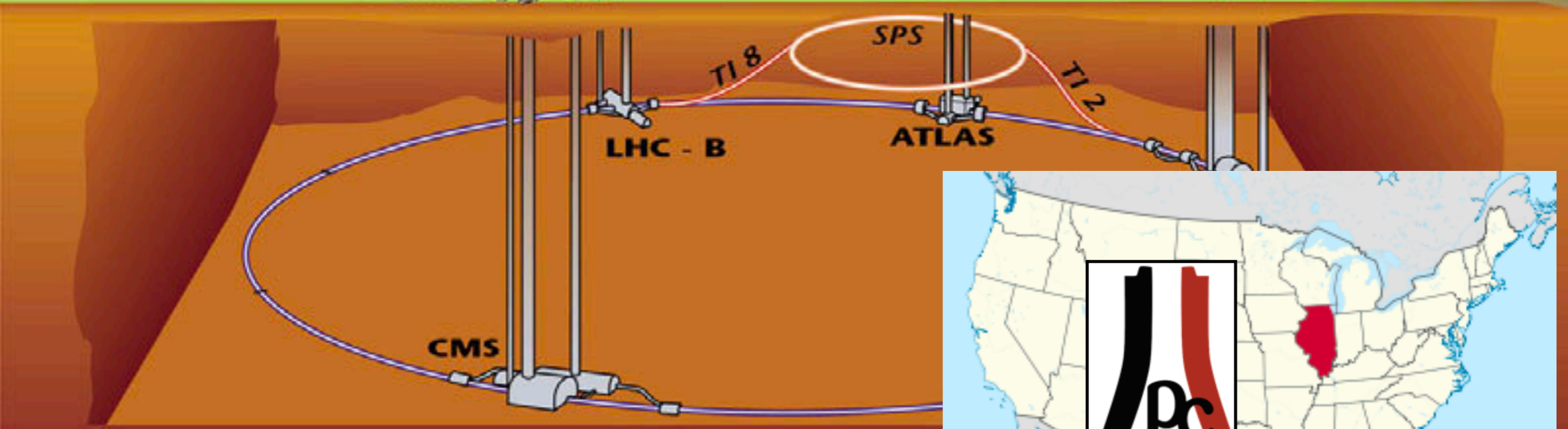
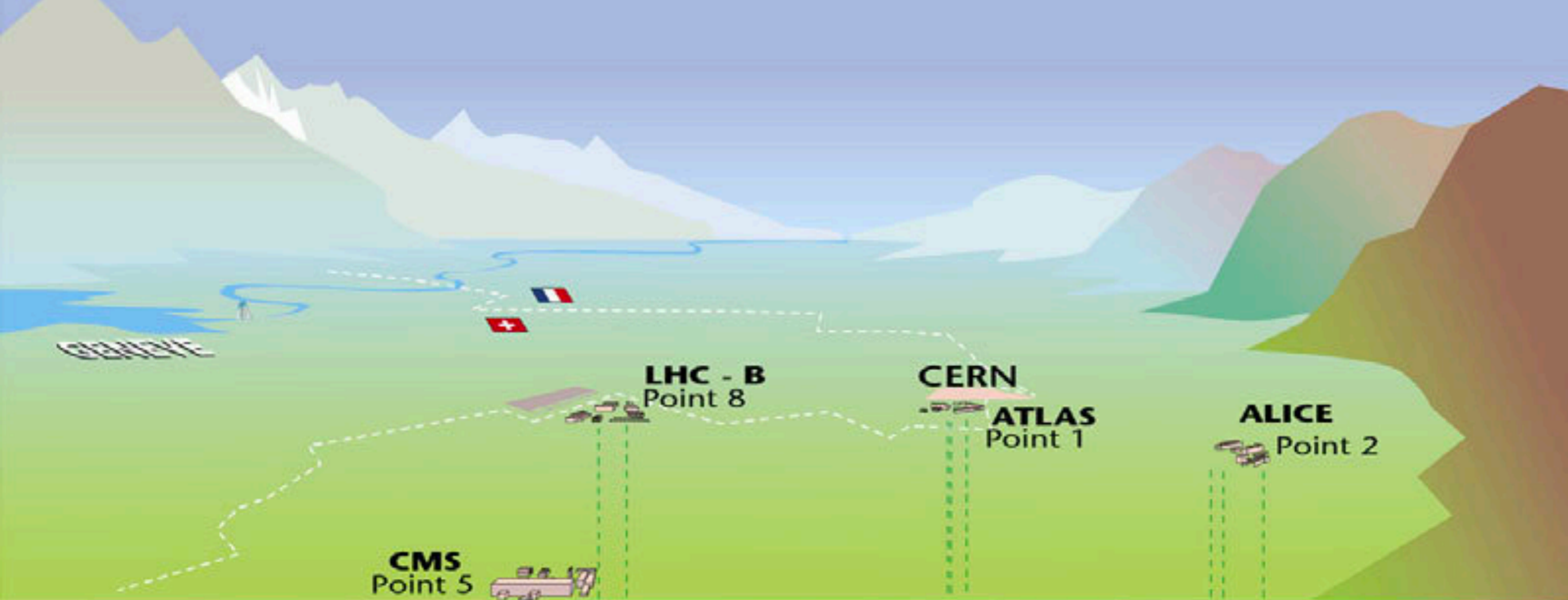
FNAL Users Meeting



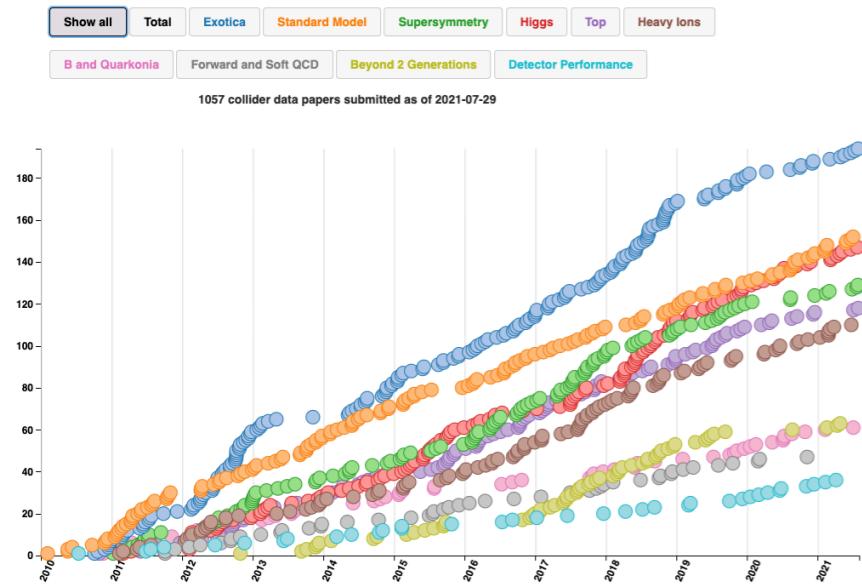
**RECENT RESULTS FROM
THE CMS COLLABORATION**

ISOBEL OJALVO PRINCETON UNIVERSITY AUG 3 2021



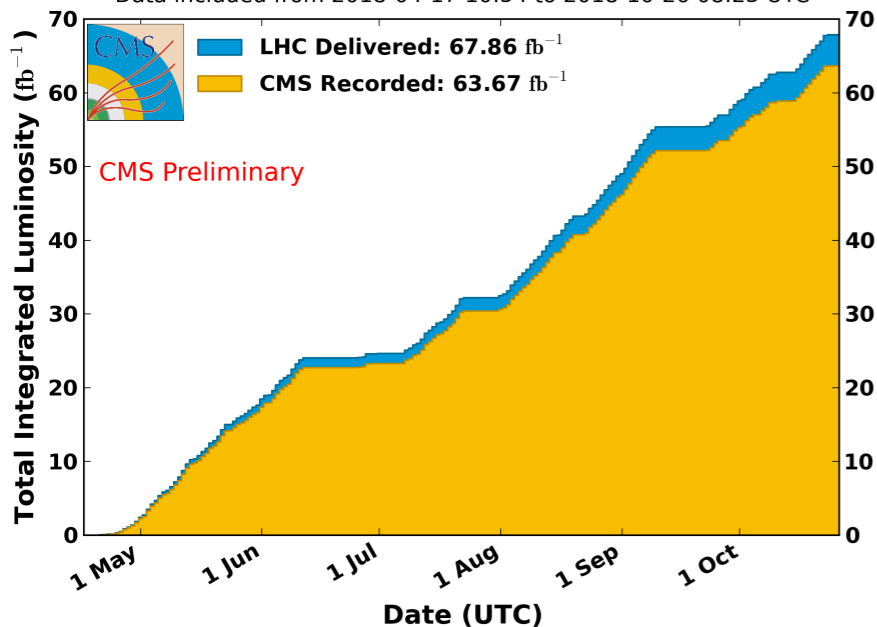


Overview



CMS Integrated Luminosity, pp, 2018, $\sqrt{s} = 13$ TeV

Data included from 2018-04-17 10:54 to 2018-10-26 08:23 UTC



- $\sim 160 \text{ fb}^{-1}$ 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!

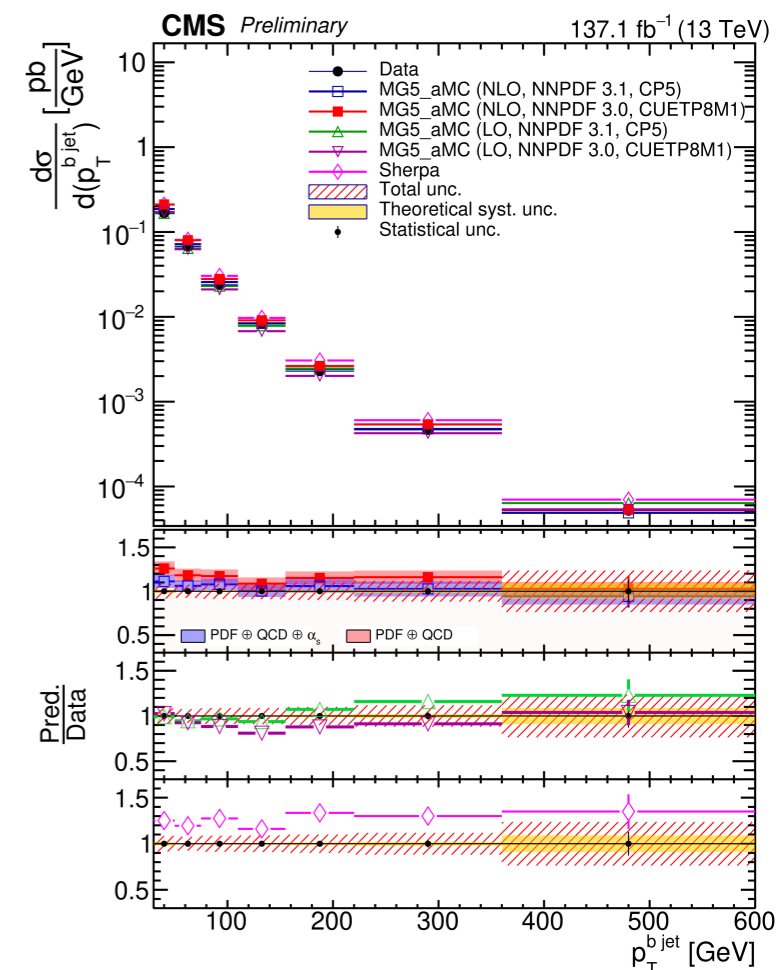
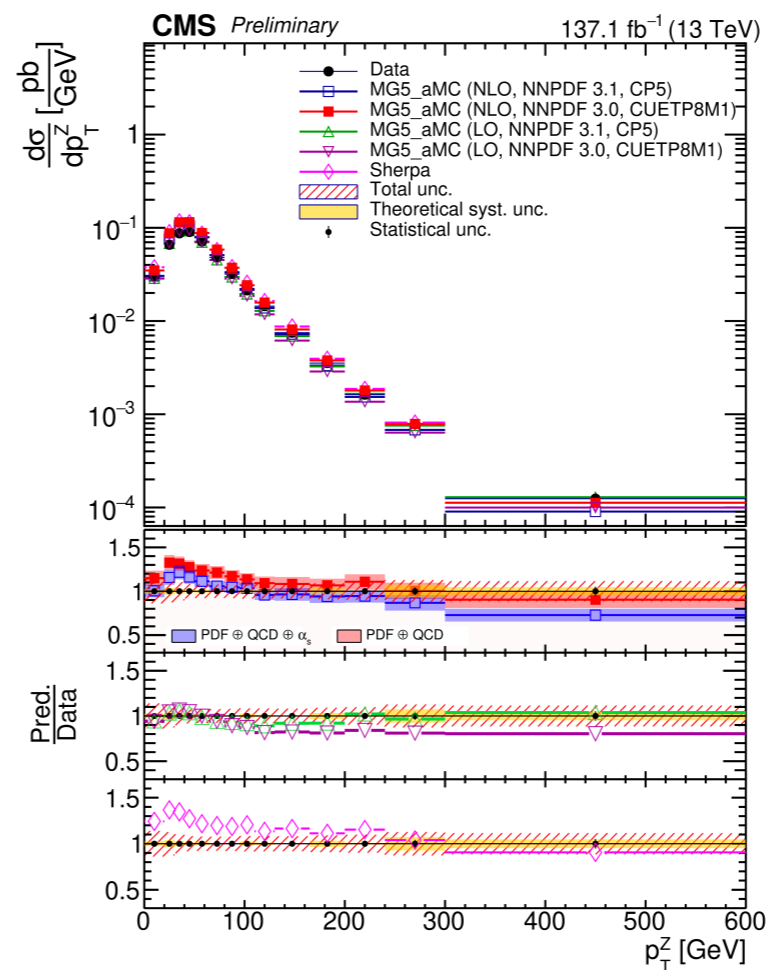
<https://cms-results-search.web.cern.ch/>

TOP-21-001	Probing effective field theory operators in the associated production of top quarks with a Z boson in multilepton final states at 13 TeV	Submitted to J. High Energy Phys.	29 Jul 2021
EXO-20-004	Search for new particles in events with energetic jets and large missing transverse momentum in proton-proton collisions at 13 TeV	Submitted to J. High Energy Phys.	27 Jul 2021
SUS-20-003	Search for chargino-neutralino production in events with Higgs and W bosons using 137 fb ⁻¹	Submitted to J. High Energy Phys.	26 Jul 2021
HIG-20-015	Measurement of the inclusive and differential Higgs boson production cross sections in the decay mode to a pair of τ leptons	Submitted to Phys. Rev. Lett.	23 Jul 2021
SUS-20-002	Combined searches for the production of supersymmetric top quark partners in proton-proton collisions at 13 TeV	Submitted to Eur. Phys. J. C	22 Jul 2021
EXO-20-015	Search for long-lived particles decaying in the CMS endcap muon detectors in proton-proton collisions at 13 TeV	Submitted to Phys. Rev. Lett.	10 Jul 2021
BPH-18-003	Measurement of prompt open-charm production cross sections in proton-proton collisions at 13 TeV	Submitted to J. High Energy Phys.	03 Jul 2021
TOP-18-010	Measurement of the inclusive and differential $t\bar{t}\gamma$ cross sections in the single-lepton channel and EFT interpretation at 13 TeV	Submitted to J. High Energy Phys.	03 Jul 2021
SMP-20-012	Measurements of the electroweak diboson production cross sections in proton-proton collisions at 5.02 TeV using leptonic decays	Submitted to Phys. Rev. Lett.	02 Jul 2021
SMP-21-003	Azimuthal correlations in Z+jets events at 13 TeV	CMS-PAS-SMP-21-003	01 Jul 2021
SMP-21-006	Cross section measurements of jet multiplicity and jet transverse momenta in multijet events at 13 TeV	CMS-PAS-SMP-21-006	01 Jul 2021
SMP-20-011	Measurement and QCD analysis of double-differential inclusive jet cross sections in pp collisions at 13 TeV	CMS-PAS-SMP-20-011	01 Jul 2021
SMP-21-009	Measurement of the double-differential inclusive jet cross section in proton-proton collisions at 5.02 TeV	CMS-PAS-SMP-21-009	01 Jul 2021
SMP-20-015	Measurement of Z+b jets cross section in proton-proton collisions at 13 TeV	CMS-PAS-SMP-20-015	01 Jul 2021
BPH-18-004	Observation of $B_0 \rightarrow \psi(2S)K_0S\pi^+\pi^-$, $B_0 \rightarrow \psi(2S)KS_0\pi^+\pi^-$ and $B_0s \rightarrow \psi(2S)K_0SB_0 \rightarrow \psi(2S)KS_0$ decays	CMS-PAS-BPH-18-004	01 Jul 2021
BPH-21-004	Observation of triple J_ψ meson production in proton-proton collisions at 13 TeV	CMS-PAS-BPH-21-004	01 Jul 2021
SMP-18-014	Precision measurement of the Z invisible width with the CMS experiment in pp collisions at 13 TeV	CMS-PAS-SMP-18-014	01 Jul 2021
FTR-21-001	Prospects for the measurement of vector boson scattering production in leptonic $W_\pm W_\pm$ and WZ diboson events at the High-	CMS-PAS-FTR-21-001	01 Jul 2021
EXO-20-002	Search for a right-handed W boson and heavy neutrino in proton-proton collisions at 13 TeV	CMS-PAS-EXO-20-002	01 Jul 2021
TOP-20-005	Search for CP violation in top quark pair events in the lepton+jets channel at 13 TeV	CMS-PAS-TOP-20-005	01 Jul 2021
EXO-20-013	Search for dark matter particles produced in association with a dark Higgs boson decaying into $W+W^-$ at 13 TeV with the CMS	CMS-PAS-EXO-20-013	01 Jul 2021
SUS-21-001	Search for direct pair production of supersymmetric partners to the τ lepton in the all-hadronic final state at 13 TeV	CMS-PAS-SUS-21-001	01 Jul 2021
HIG-21-003	Search for exotic decay of the Higgs boson into two light pseudoscalars with four photons in the final state at 13 TeV	CMS-PAS-HIG-21-003	01 Jul 2021
TOP-19-002	Search for flavor-changing neutral current interactions of the top quark and the Higgs boson decaying to a bottom quark-antiquark	CMS-PAS-TOP-19-002	01 Jul 2021
B2G-20-013	Search for heavy resonances and nonresonant axion-like particles in semileptonic ZZ, ZW, or ZH final states at 13 TeV	CMS-PAS-B2G-20-013	01 Jul 2021
B2G-20-007	Search for heavy resonances decaying to a pair of boosted Higgs bosons in final states with leptons and a bottom quark-antiquark	CMS-PAS-B2G-20-007	01 Jul 2021
EXO-20-008	Search for heavy resonances decaying to b quarks in proton-proton collisions at 13 TeV	CMS-PAS-EXO-20-008	01 Jul 2021
B2G-21-001	Search for Higgs boson pair production via vector boson fusion with highly Lorentz-boosted Higgs bosons in the four b quark final	CMS-PAS-B2G-21-001	01 Jul 2021
SUS-20-004	Search for higgsinos in channels with two Higgs bosons and missing transverse momentum in proton-proton collisions at 13 TeV	CMS-PAS-SUS-20-004	01 Jul 2021
EXO-20-009	Search for long-lived heavy neutral leptons with displaced vertices in pp collisions at 13 TeV with the CMS detector	CMS-PAS-EXO-20-009	01 Jul 2021
EXO-18-003	Search for long-lived particles decaying to displaced leptons in proton-proton collisions at 13 TeV	CMS-PAS-EXO-18-003	01 Jul 2021
B2G-20-003	Search for new particles in an extended Higgs sector in the four b quark final state at 13 TeV	CMS-PAS-B2G-20-003	01 Jul 2021
B2G-21-002	Search for resonances decaying to three W bosons in the hadronic final state at 13 TeV	CMS-PAS-B2G-21-002	01 Jul 2021
B2G-20-004	Search for resonant Higgs boson pair production in four b quark final state using large-area jets in proton-proton collisions at 13 TeV	CMS-PAS-B2G-20-004	01 Jul 2021
SMP-20-013	Search for vector boson scattering at the LHC Run 2 with CMS data in the semi-leptonic $\ell\nu q\bar{q}$ final state	CMS-PAS-SMP-20-013	01 Jul 2021

Measurement of Z+b jets cross section

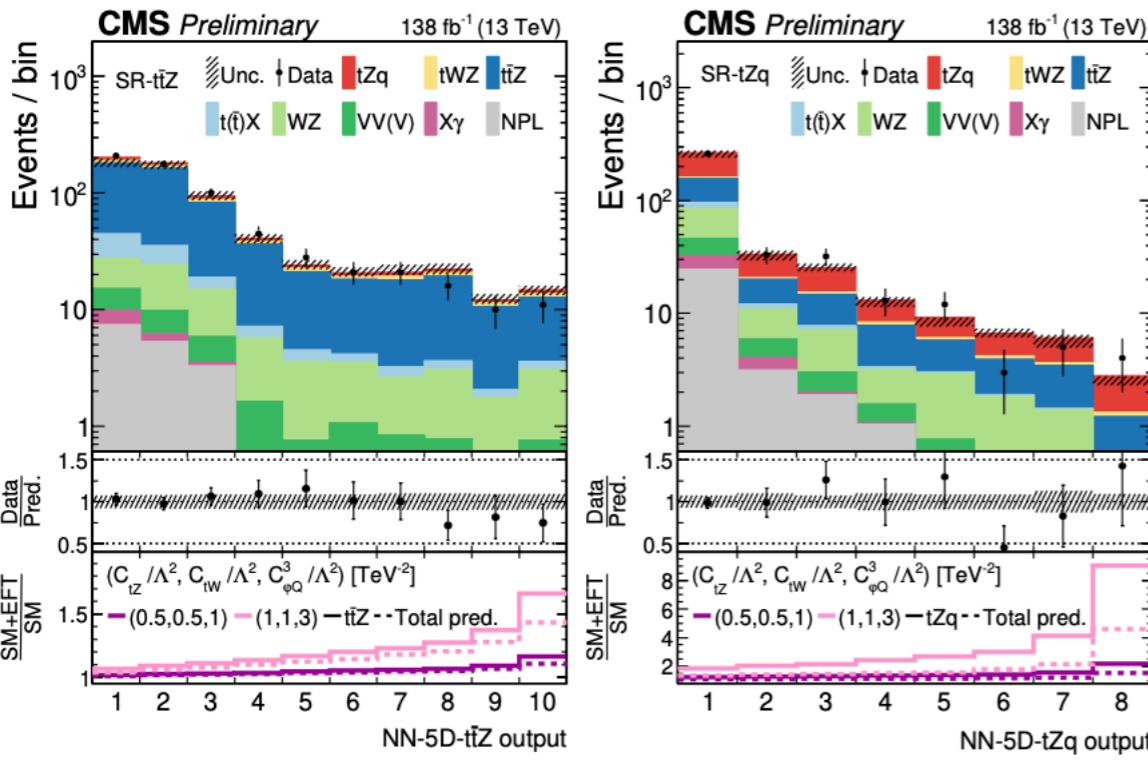
(SMP-20-015)

- 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

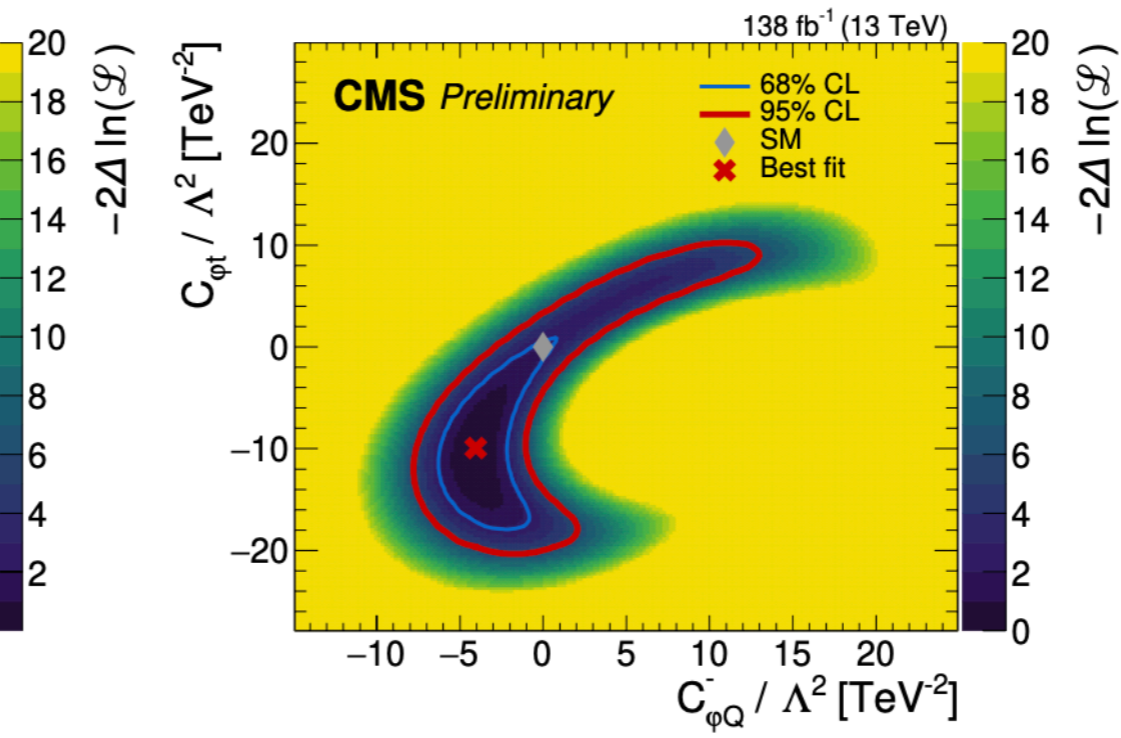
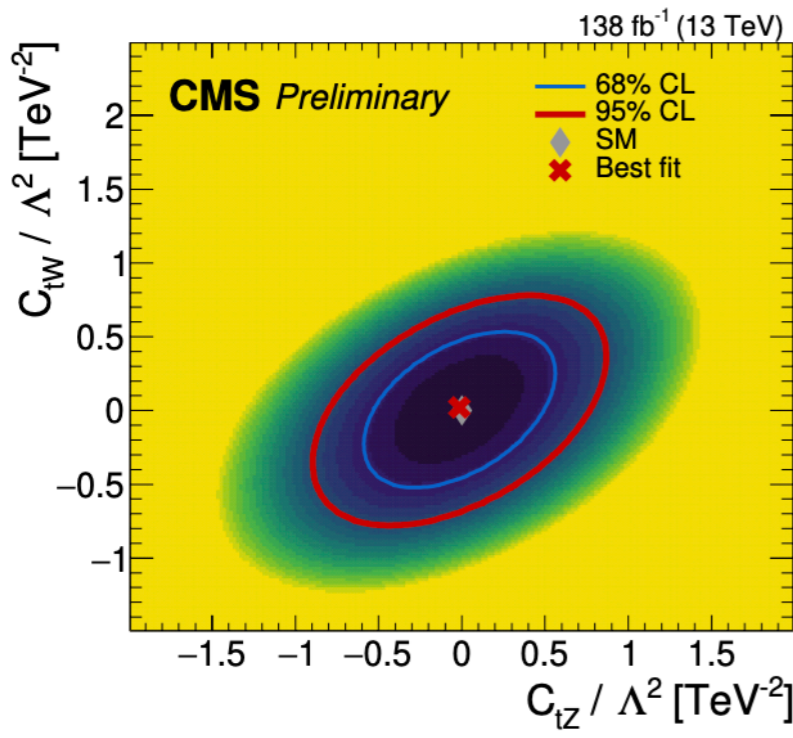


Probing effective field theory (EFT) with $t(t)Z$

(TOP-21-001)



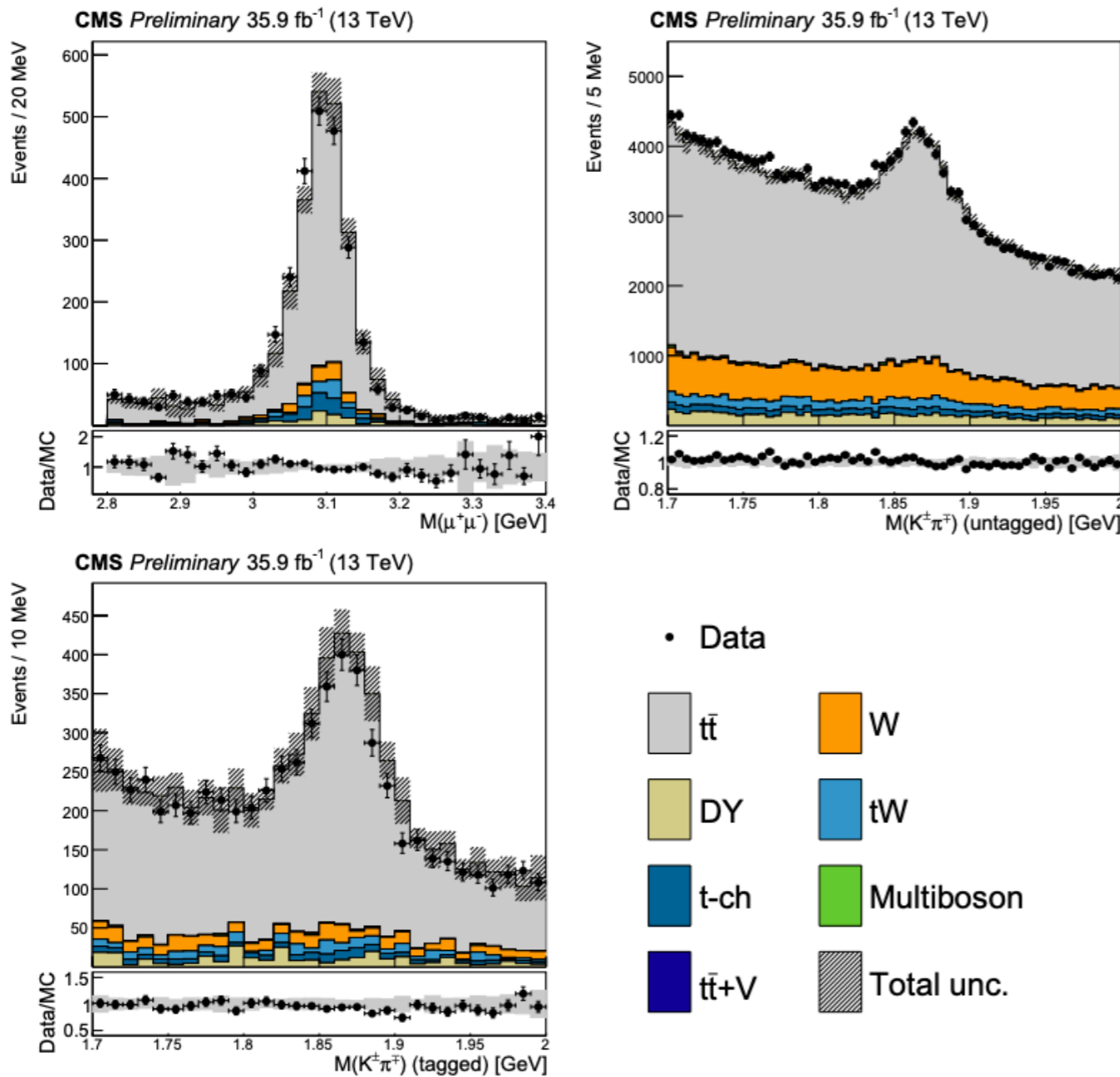
- Considering events with 3/4 light leptons, divided into signal and control (WZ/ZZ) regions
- Machine learning used to optimize sensitivity to each EFT parameter
- Probing 5 dimension-six EFT operators involving top quark(s) and a Z boson
 - All fit simultaneously to data



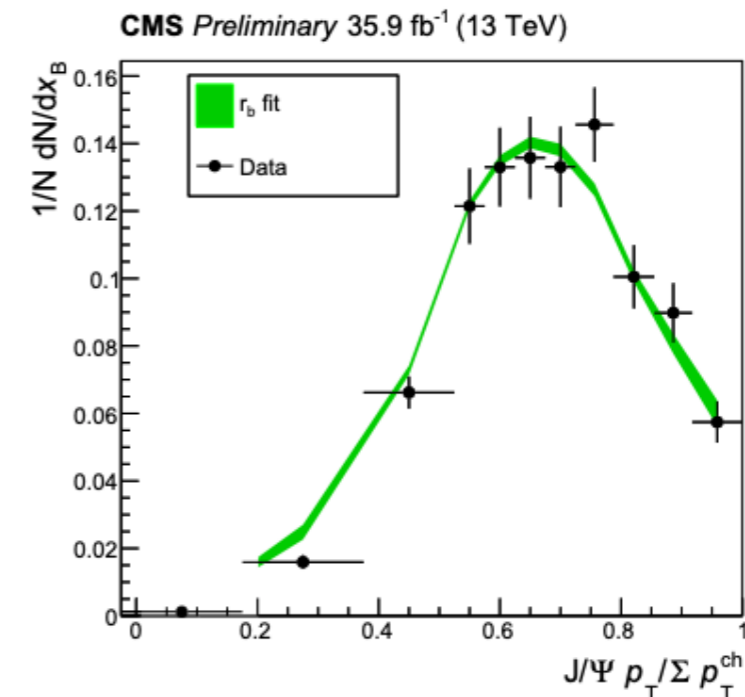
not to be confused with ZZTop

Measurement of the shape of the b quark fragmentation function using charmed mesons

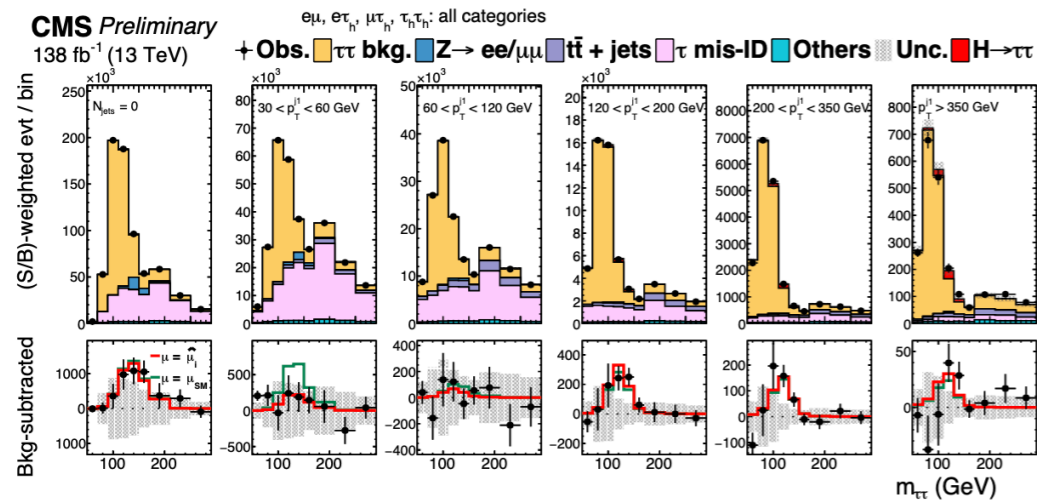
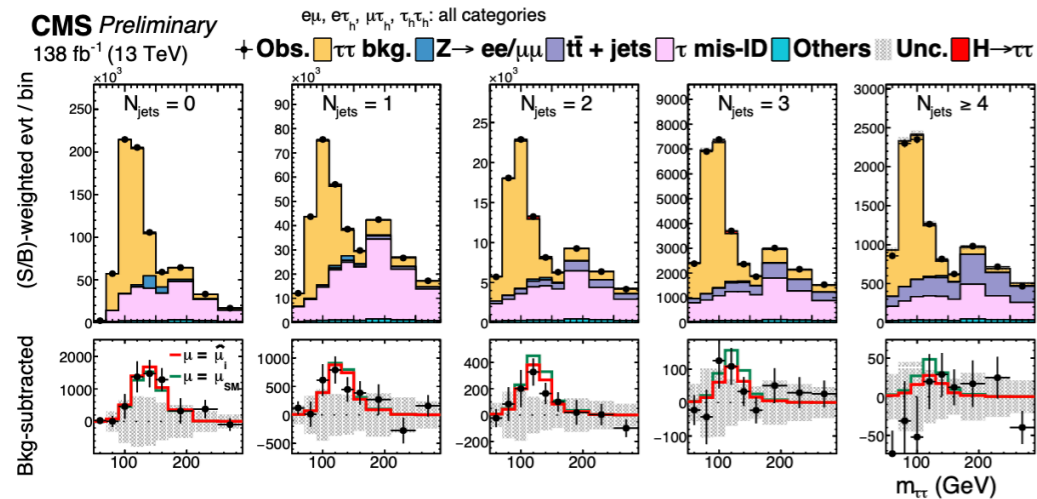
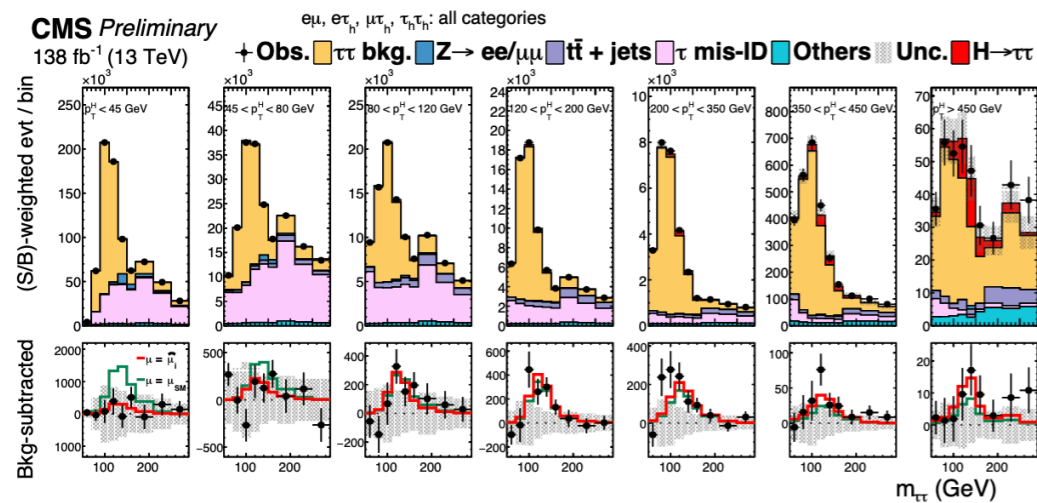
(TOP-18-012)



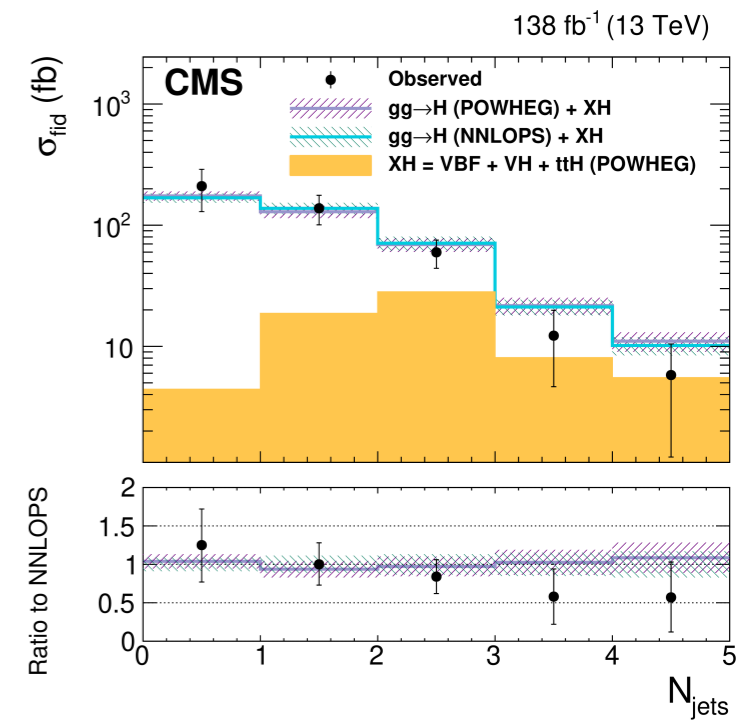
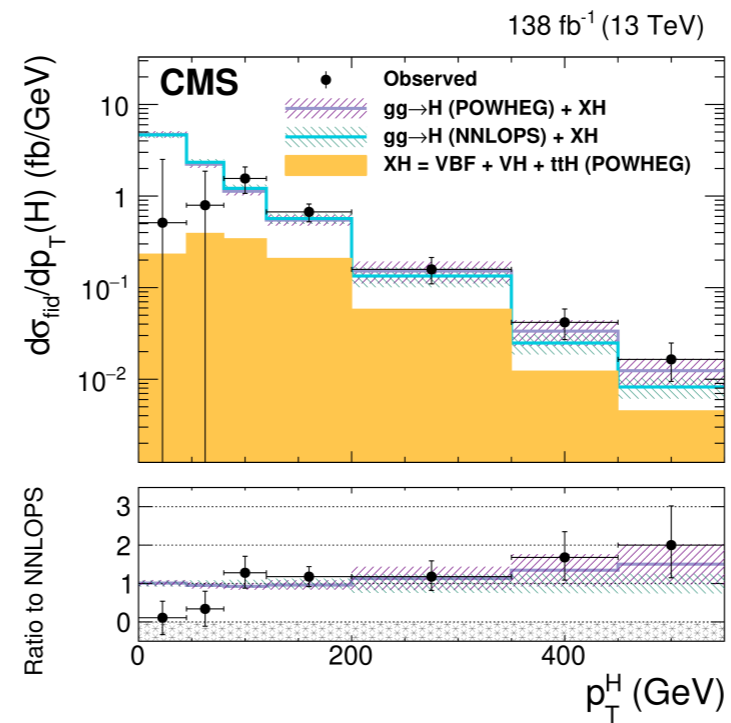
- Charm mesons produced inside b jets from tt pairs are used to determine the shape parameter of the Lund-Bowler fragmentation function
- First measurement of the b quark fragmentation function in tt events at the LHC
- Significantly improves the experimental constraints on the shape of the function



Differential $H \rightarrow \tau\tau$ production cross sections (HIG-20-015)

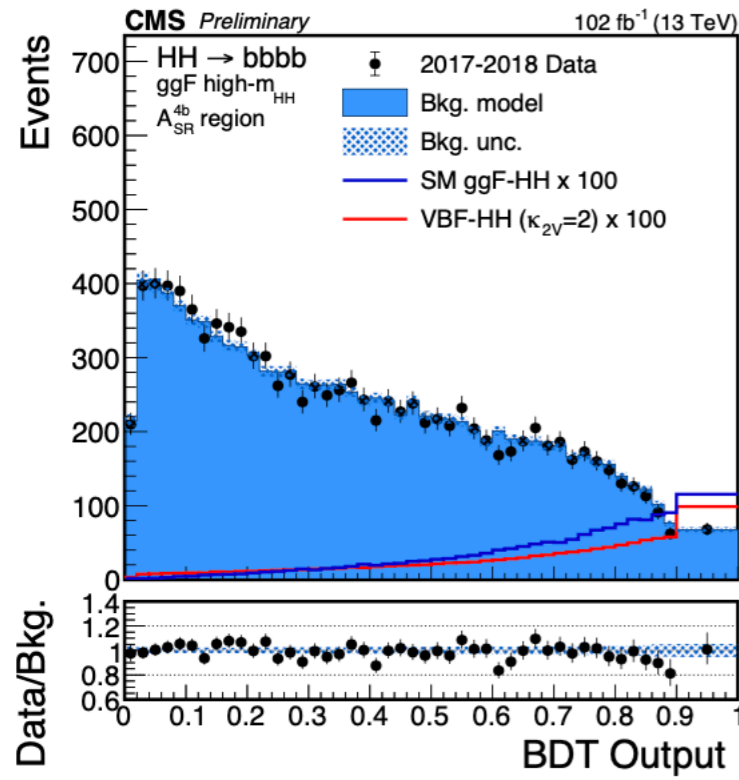


- Using full Run 2 dataset to measure inclusive and differential fiducial cross section
- Particularly sensitive channel in high $p_T(H)$, #Jets, $p_T(\text{leading jet})$
- First differential measurements in this channel

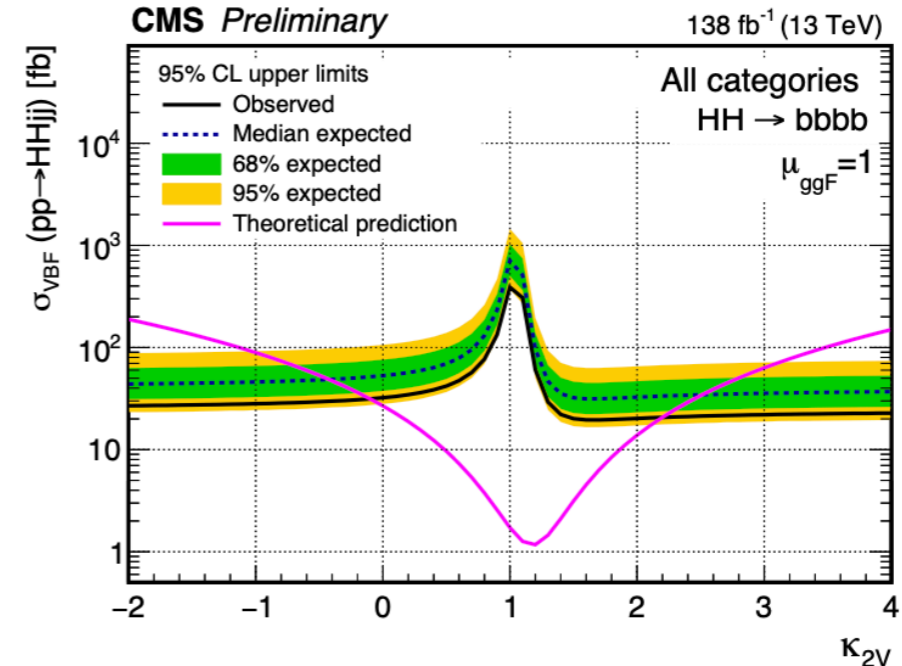
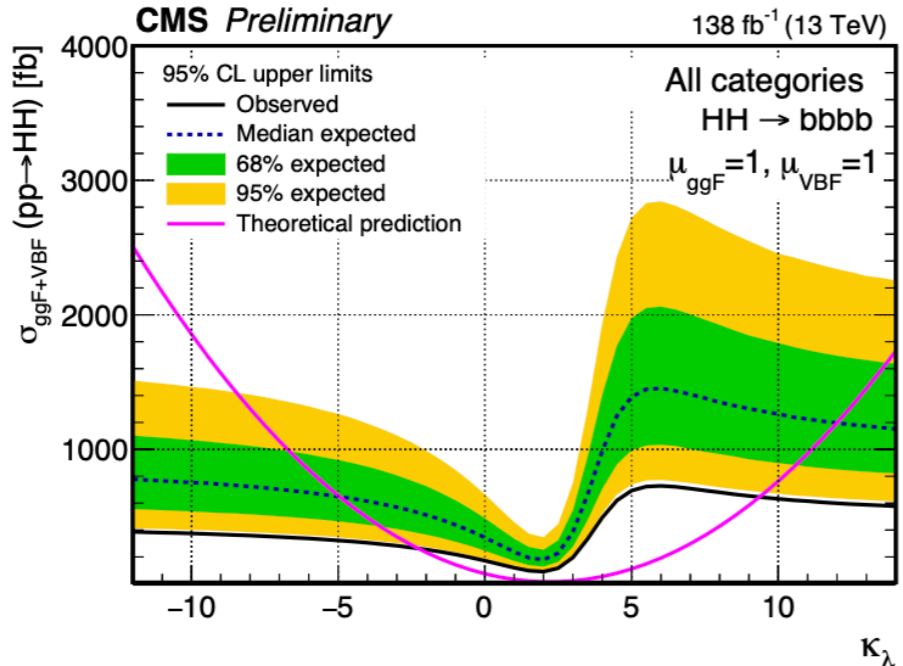


Search for non resonant H(bb)H(bb)

(HIG-20-005)



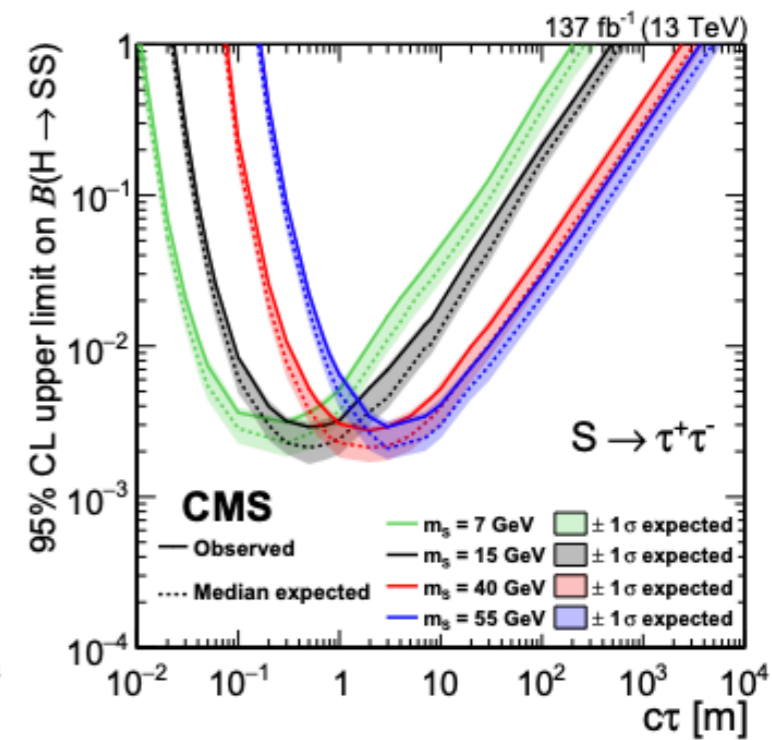
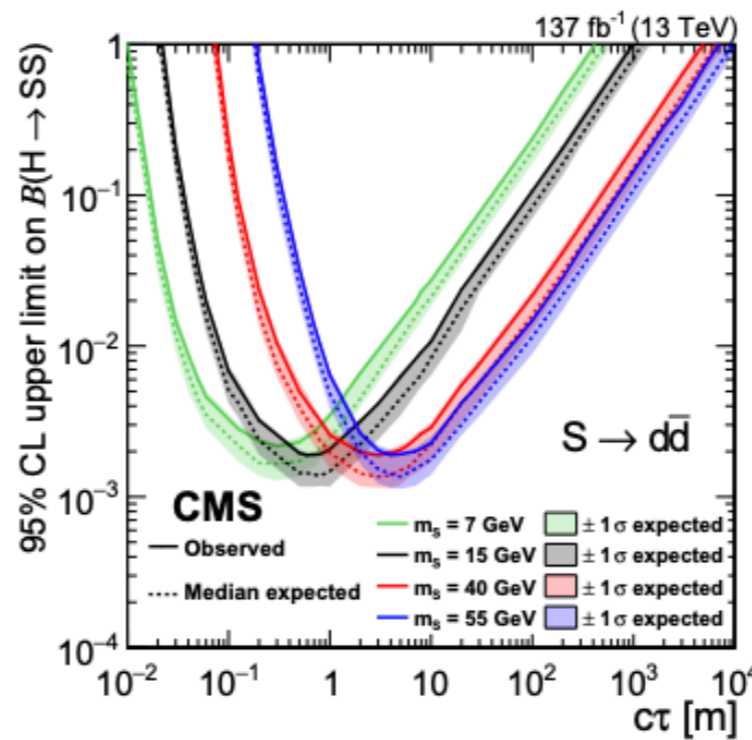
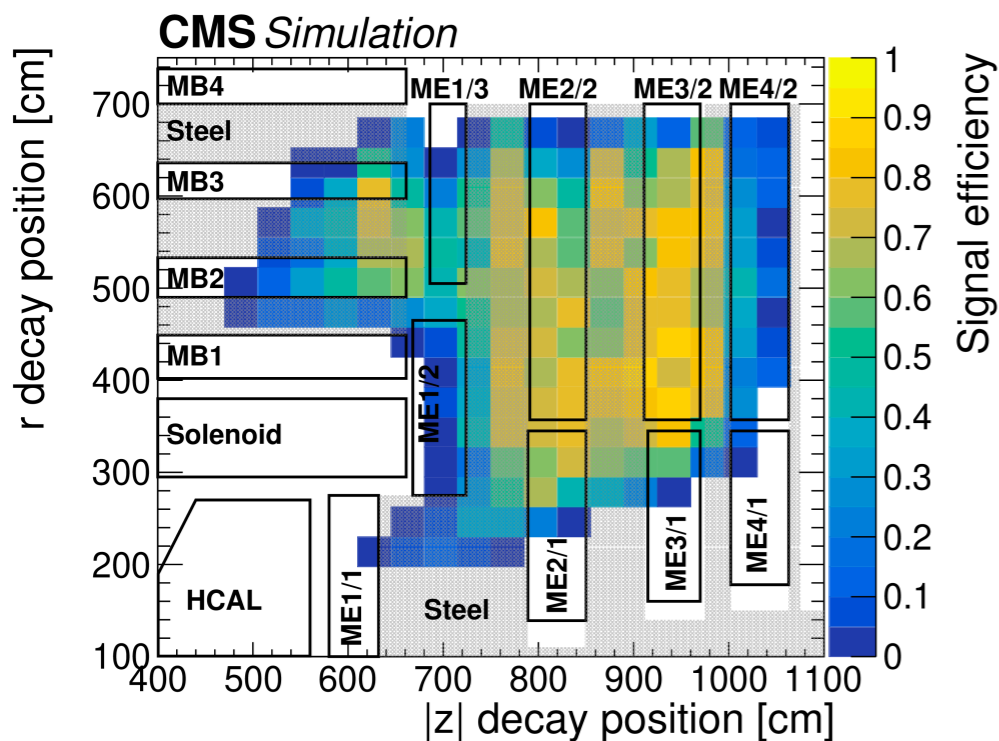
- Di-Higgs production to explore several couplings: HHH, HVV, HHVV
Dedicated triggers with 3 b-jet at HLT
- Targets both gg and VBF production
- New multivariate analysis strategy
New background estimation from multiple control regions
- Benefits from better b-tagging thanks to 2017/2018 upgraded pixel detector, and switch to latest tagger from BTV (DeepFlavour)



Search for long-lived particles decaying in the CMS EC muon detectors

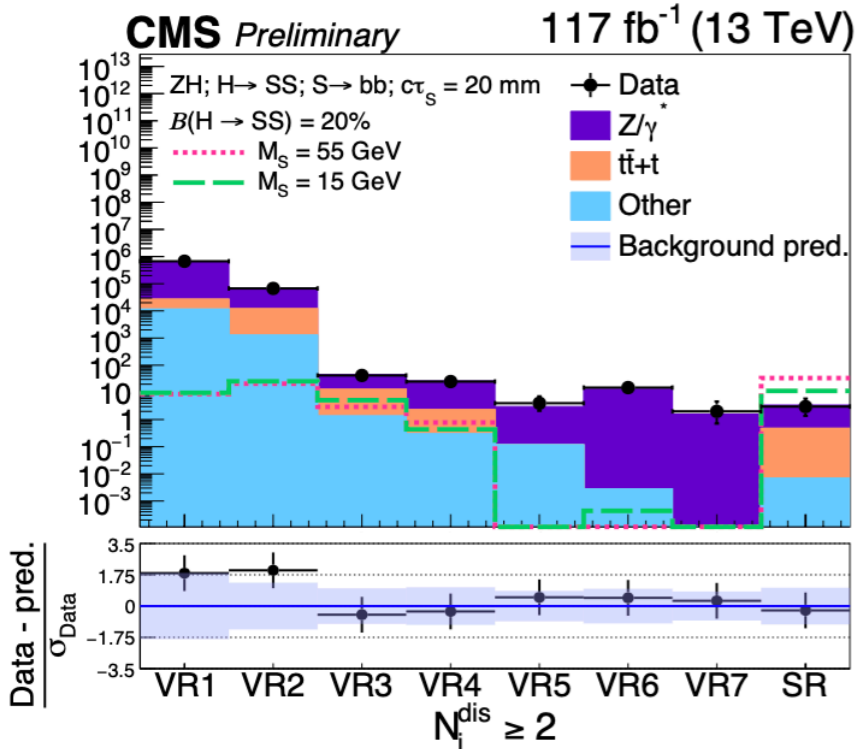
(EXO-20-015)

- Search for a Higgs decaying to two neutral long lived scalars, each decaying to a pair of b-quarks, d-quarks or tau leptons $H \rightarrow SS \rightarrow bb/dd/\tau\tau$
- 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

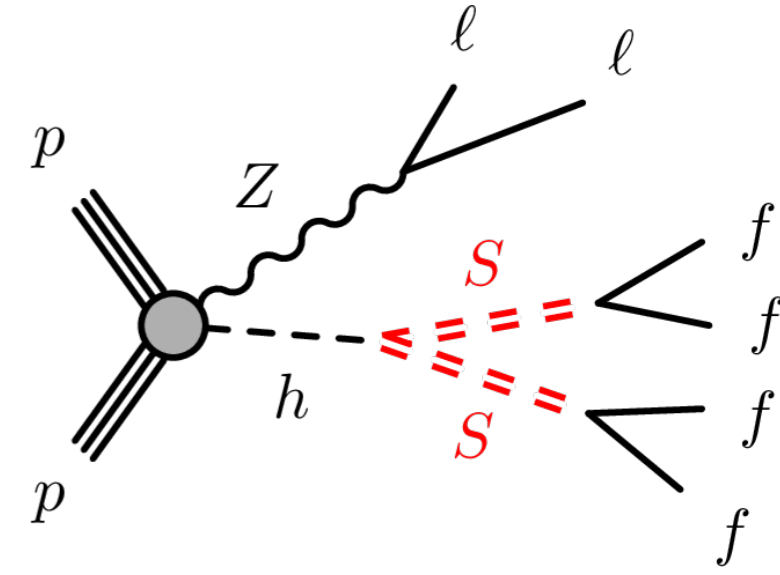
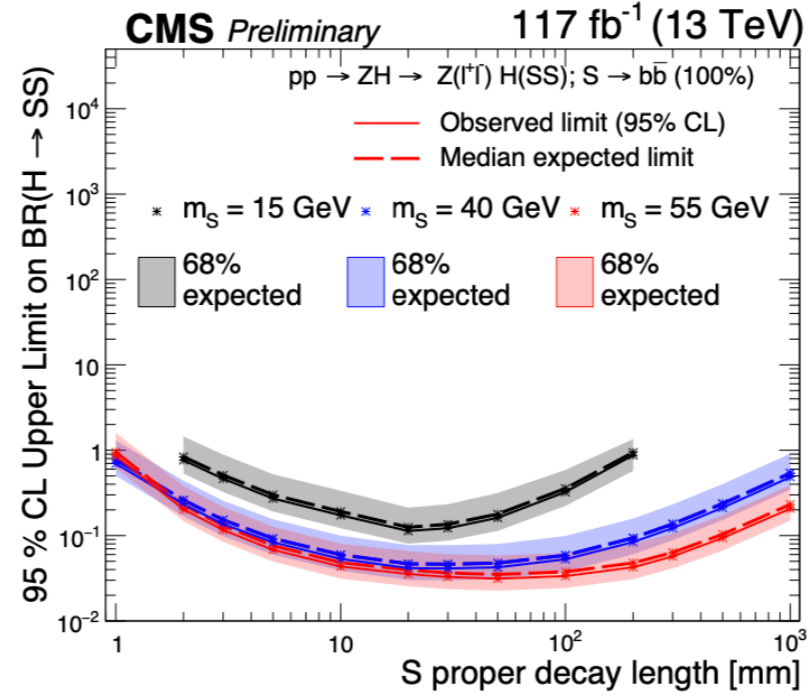
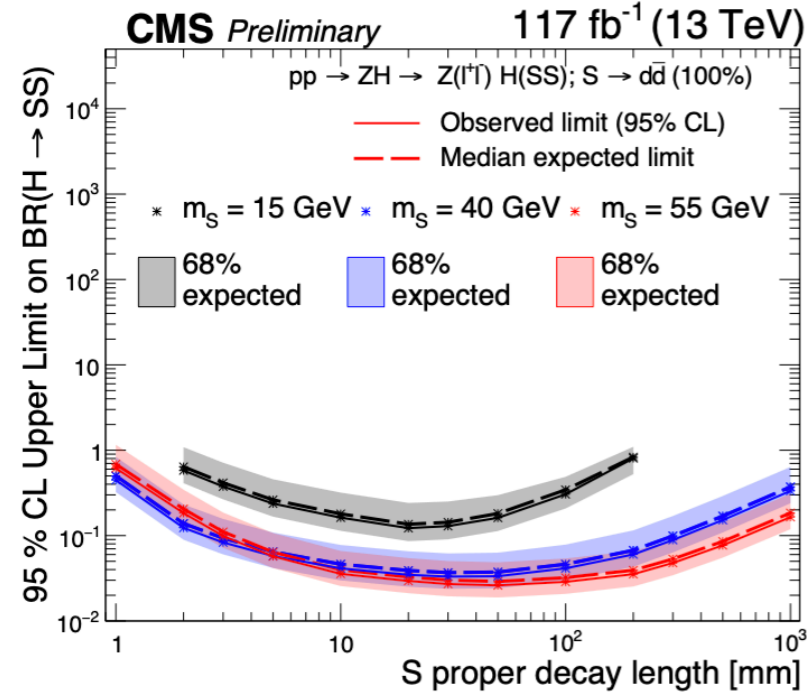


Search for $H \rightarrow$ long-lived particles in associated Z boson production

(EXO-20-003)



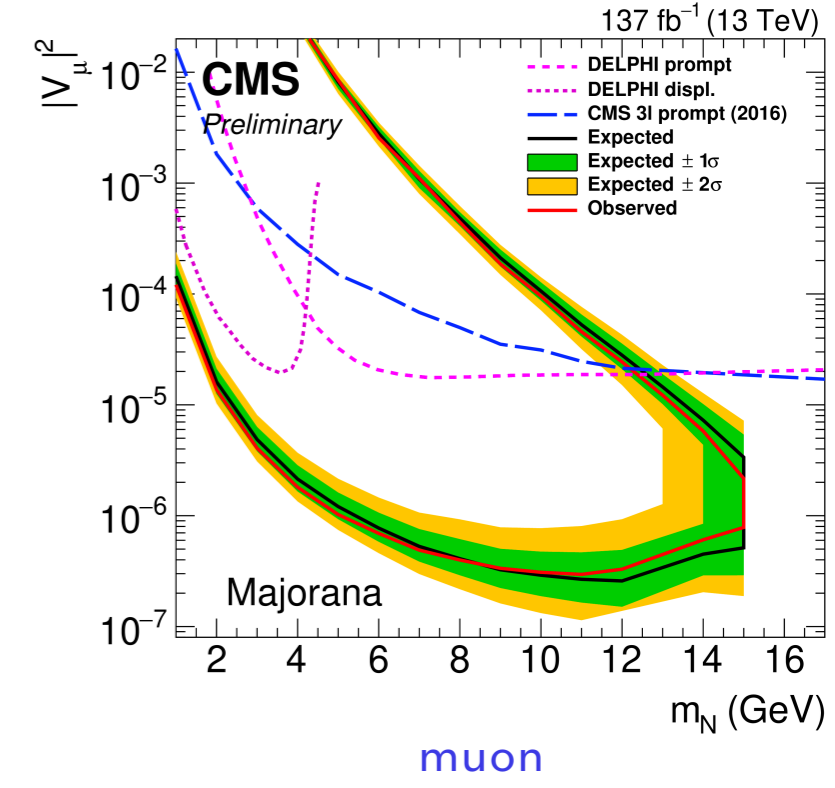
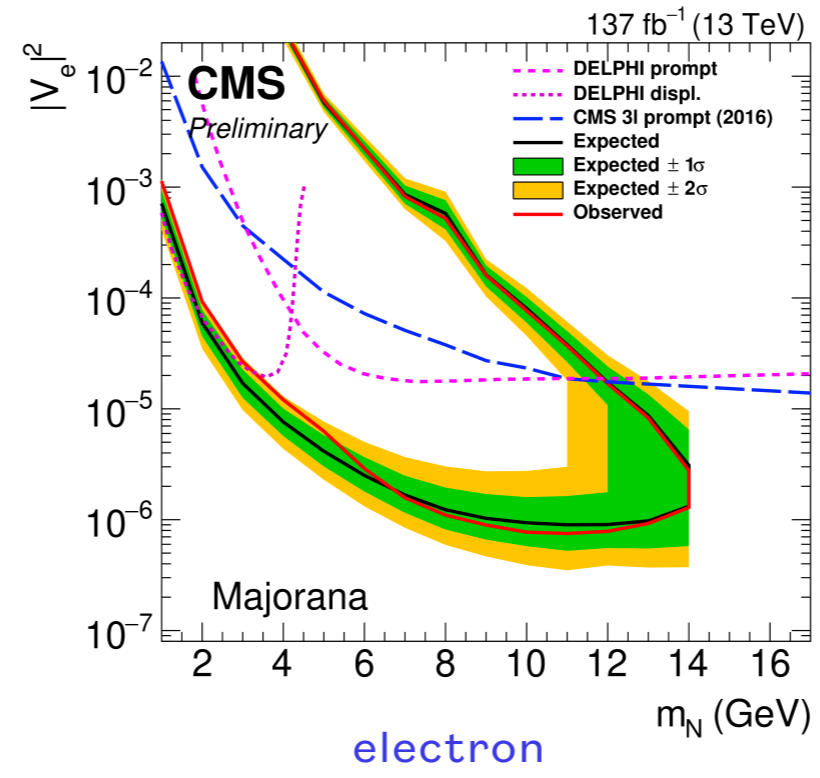
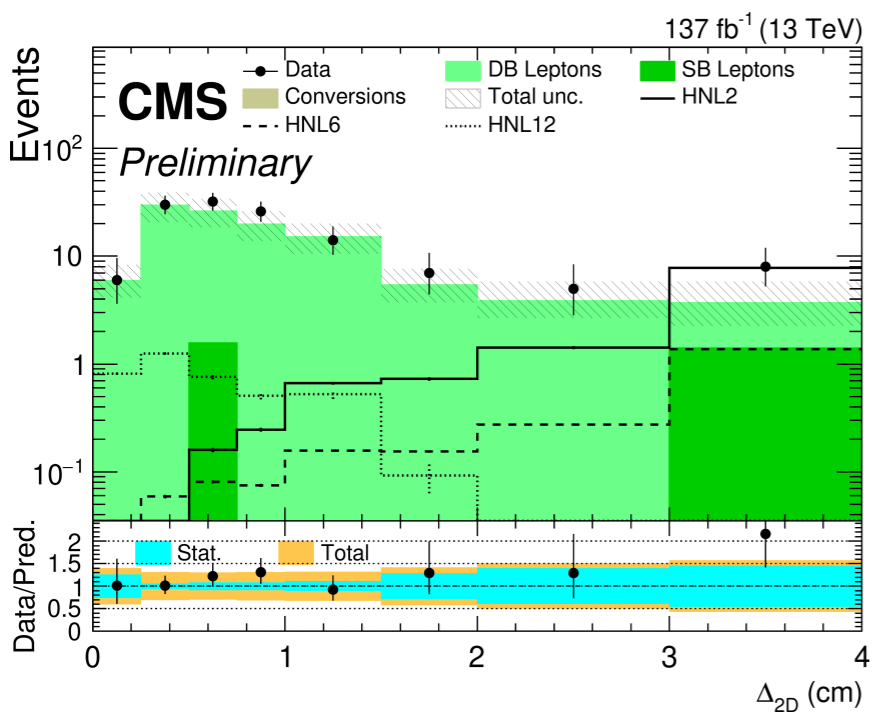
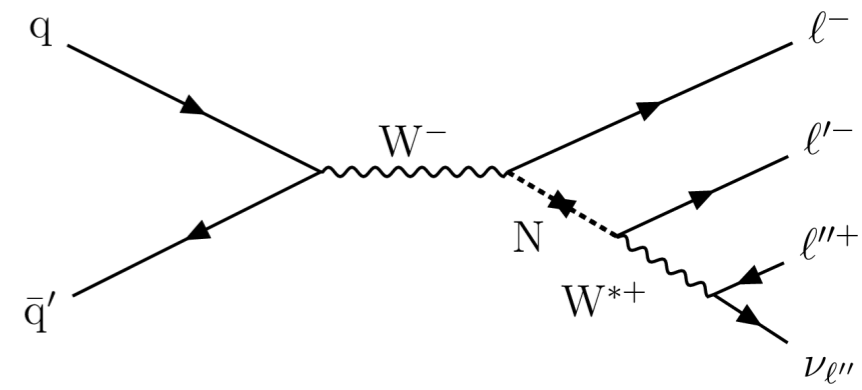
- Looking for pairs of long-lived particles (LLP) further decaying into jets, with associated Z production
- Signal region: at least two displaced jets (3 tracking-based displacement variables)
- Both light (d) and heavy (b) jets are considered. Benchmark model: Higgs decay to a pair of scalar LLP. Probing decay lengths from 1 mm to 1 m



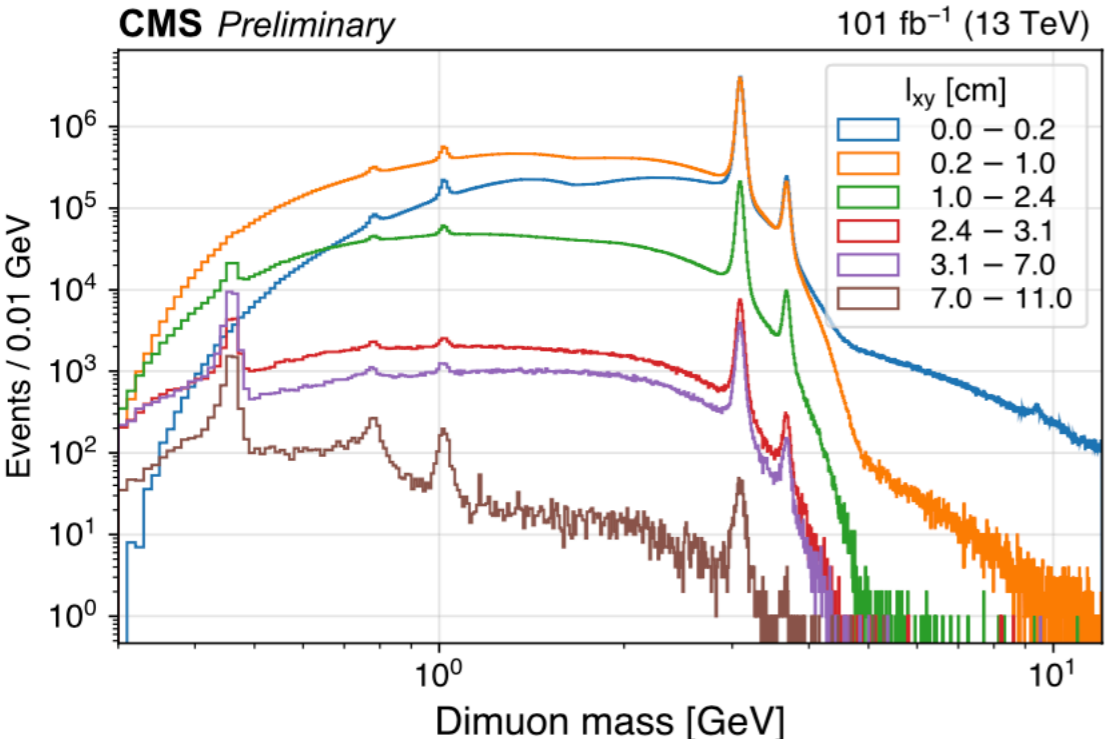
Search for long-lived heavy neutral leptons with displaced vertices

(EXO-20-009)

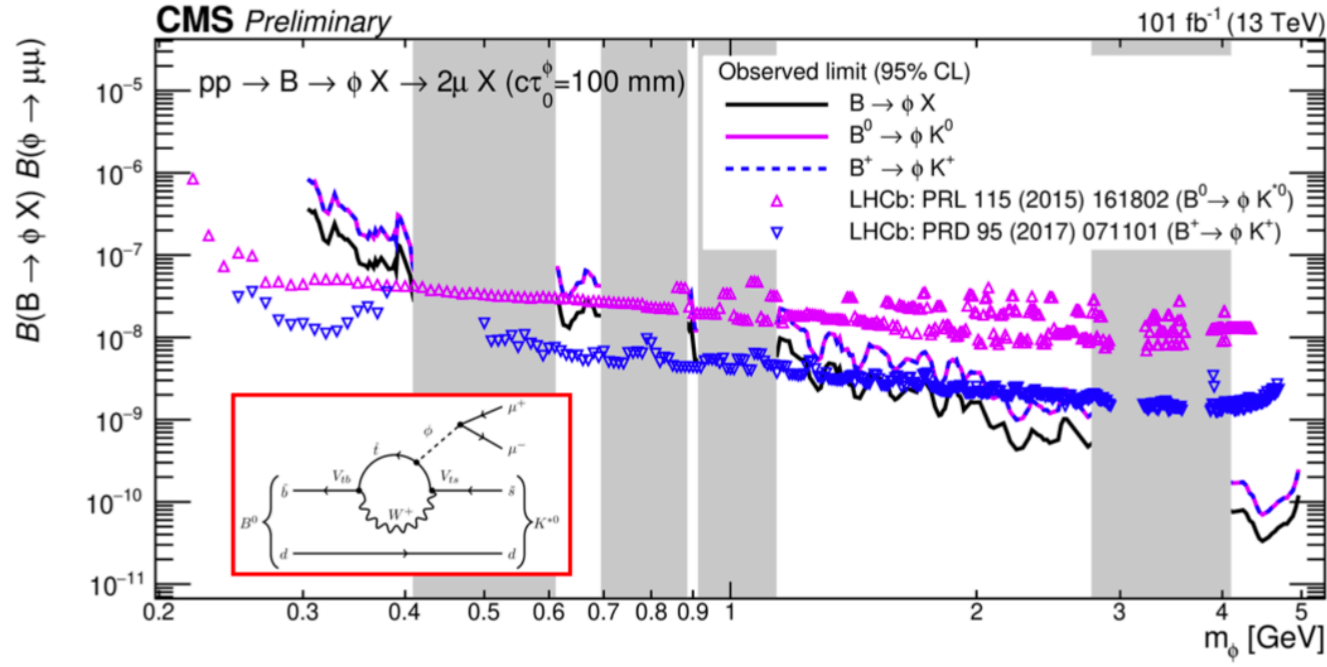
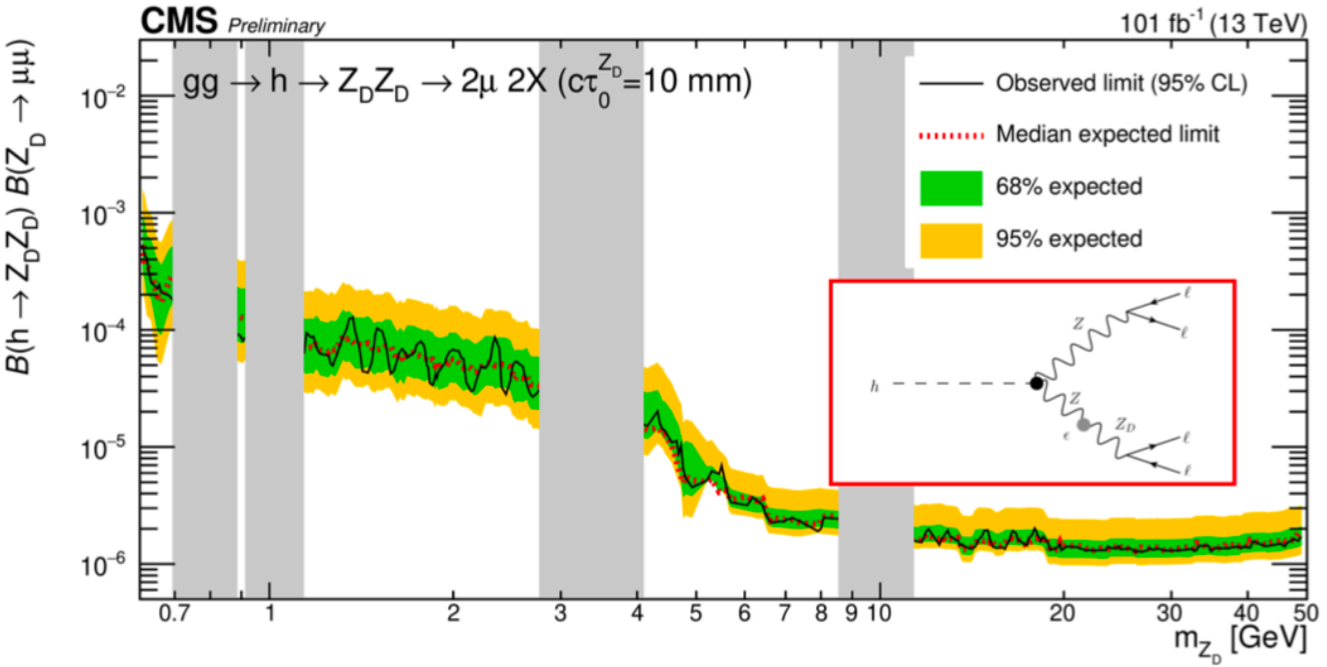
- Search for heavy neutral leptons (right-handed Dirac or Majorana neutrinos)
- For small HNL mass (< 20 GeV) Decay length of these particles can be large enough to produce a resolved secondary vertex in the CMS silicon tracker
Signal: W mediator and two leptons that form a displaced vertex
- No significant deviations from the SM expectations



Search for displaced $\mu\mu$ resonances with scouting data (EXO-20-014)



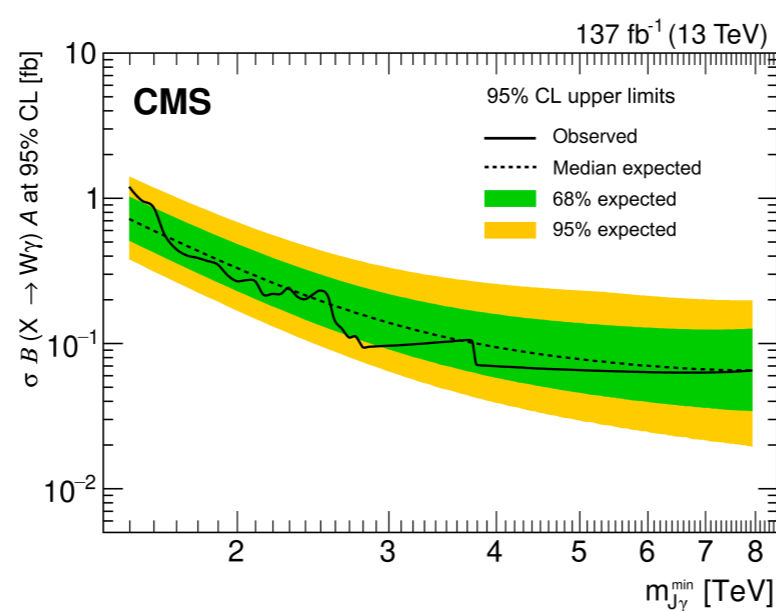
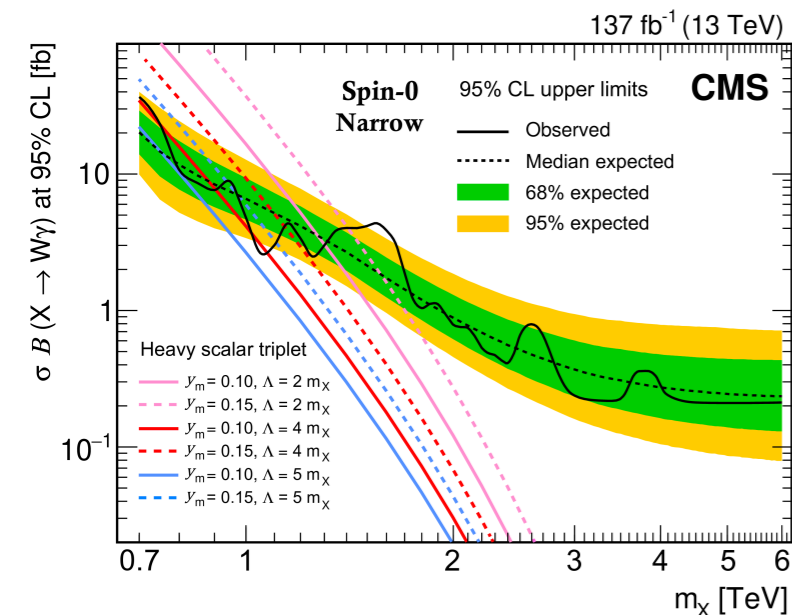
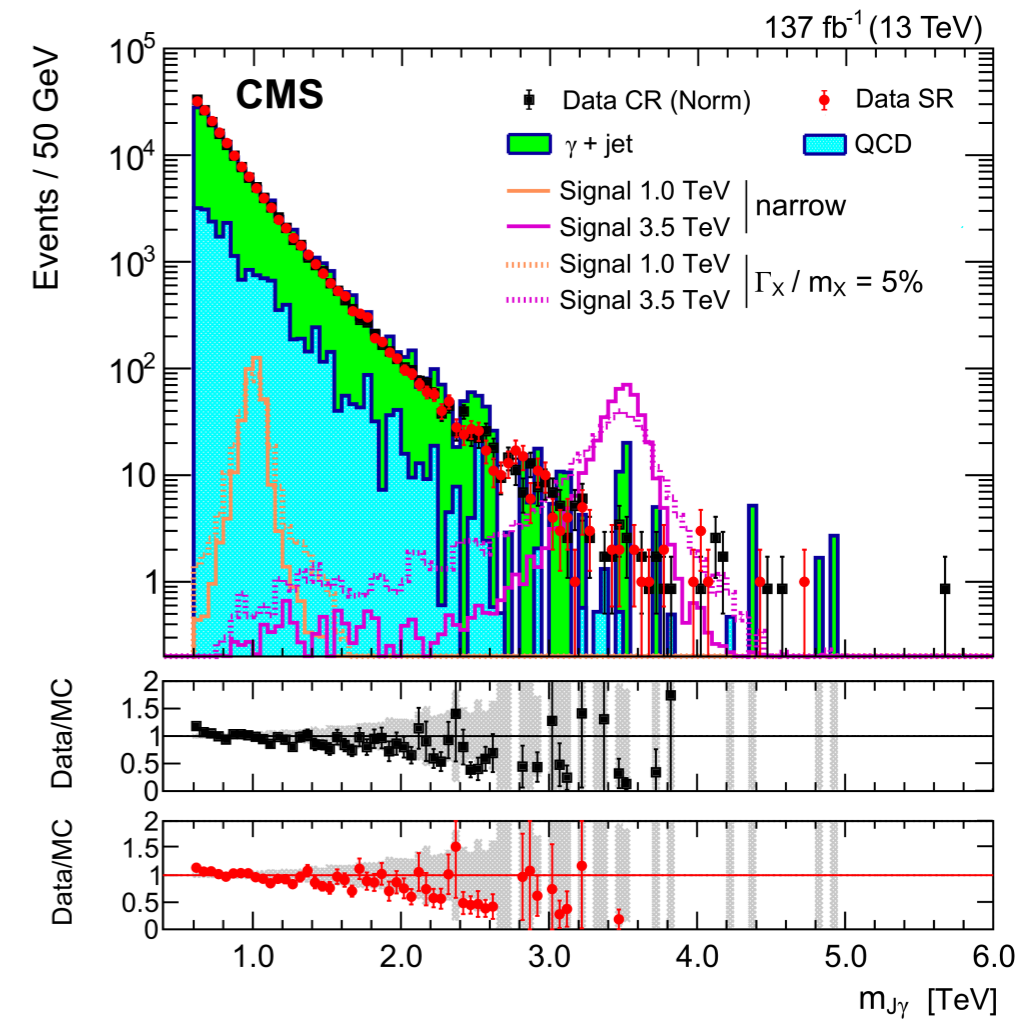
- Using events recorded with low threshold dimuon triggers and reconstructed at HLT only (“scouting”)
- Inspect dimuon invariant mass for various transverse displacement (l_{xy}) of the dimuon pair
- Most stringent limits on a wide mass range for generic resonance
- Competitive with LHCb for $B \rightarrow K + \text{displ. } \varphi(\mu\mu)$ for “high” mass and decay lengths



Search for $W\gamma$ resonances using hadronic decays of Lorentz-boosted W bosons

(EXO-20-001)

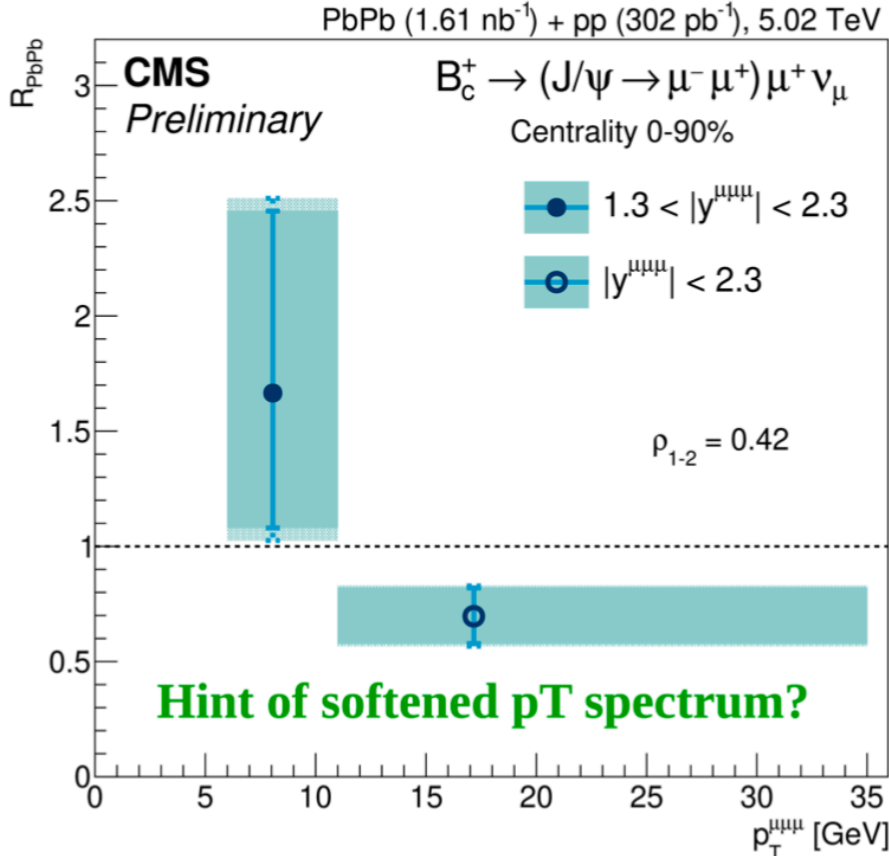
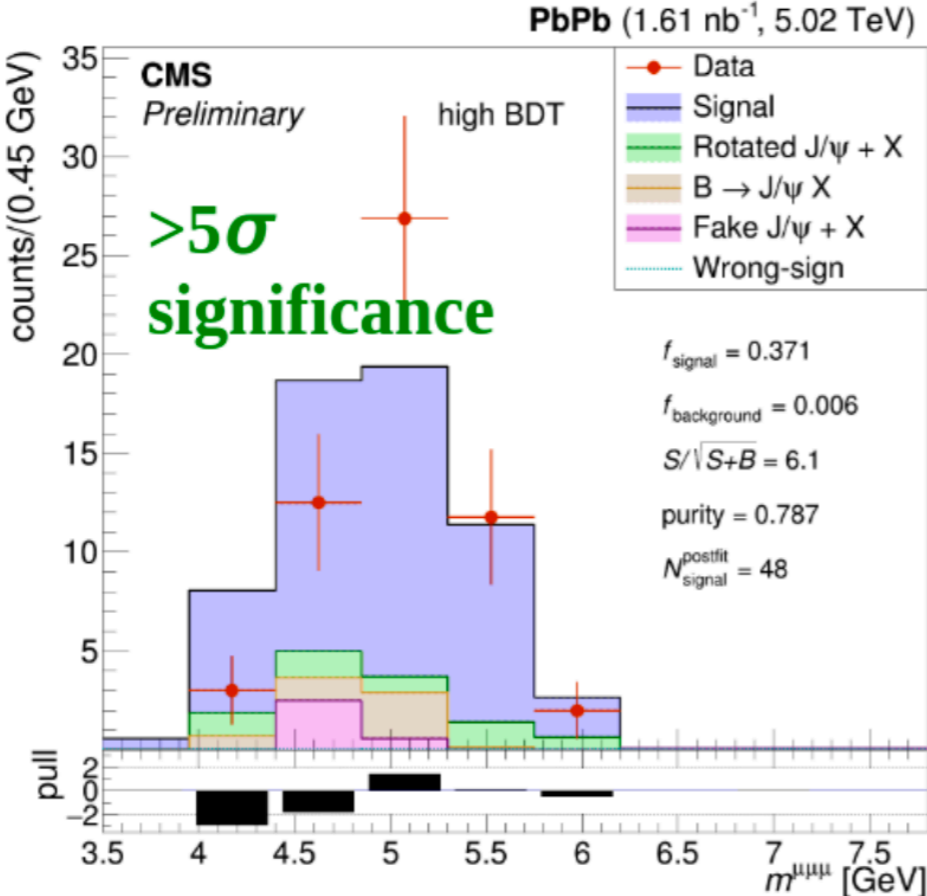
- $W\gamma$ is a signature of multiple BSM theories
 - VV/VH already studied in multiple modes
- W boson is reconstructed via its hadronic decays, with the final-state products forming a single large-radius jet, owing to a high Lorentz boost of the W boson
- $W\gamma$ mass spectrum is parameterized with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



First observation of the Bc+ 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



Looking Forward

