CMS – Compact Muon Solenoid @ NCBJ in 2019

The importance of the hight pT muons treatment for BSM searches at the CMS

Piotr Zalewski

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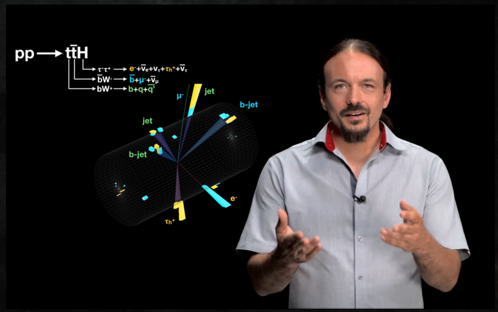
MUO-17-001
High pT muon paper
pre-approval



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10.04.2019

Performance of the reconstruction and identification of high-momentum muons in proton-proton collisions at $\sqrt{s} = 13$ TeV

The CMS Collaboration

Abstract

The CMS detector at the LHC has recorded events from proton-proton collisions, with muon momenta reaching up to 1.8 TeV in the collected dimuon samples. These high-momentum muons allow direct access to new regimes in physics beyond the standard model. Because the physics and reconstruction of these muons are different from those of their lower-momentum counterparts, this paper presents for the first time dedicated studies of efficiencies, momentum assignment, resolution, scale, and showering of very high momentum muons produced at the LHC. These studies are performed using the 2016 and 2017 data sets of proton-proton collisions at $\sqrt{s} = 13$ TeV with integrated luminosities of 36.3 and 42.1 fb^{-1}, respectively.

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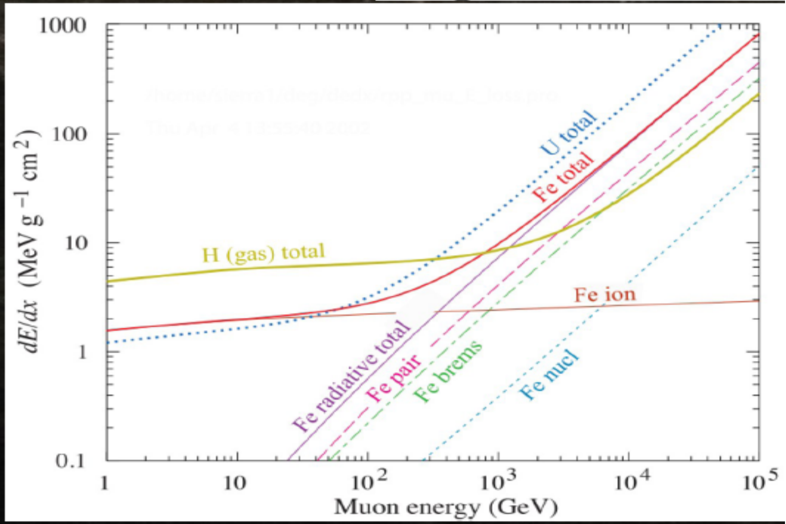
PDFAuthor:	Alberto Escalante, Alice Florent, Piotr Traczyk
PDFTitle:	Performance of the reconstruction and identification of high-momentum muons in proton-proton collisions at sqrt"(s")=13 TeV
PDFSubject:	CMS
PDFKeywords:	CMS, physics, software, computing

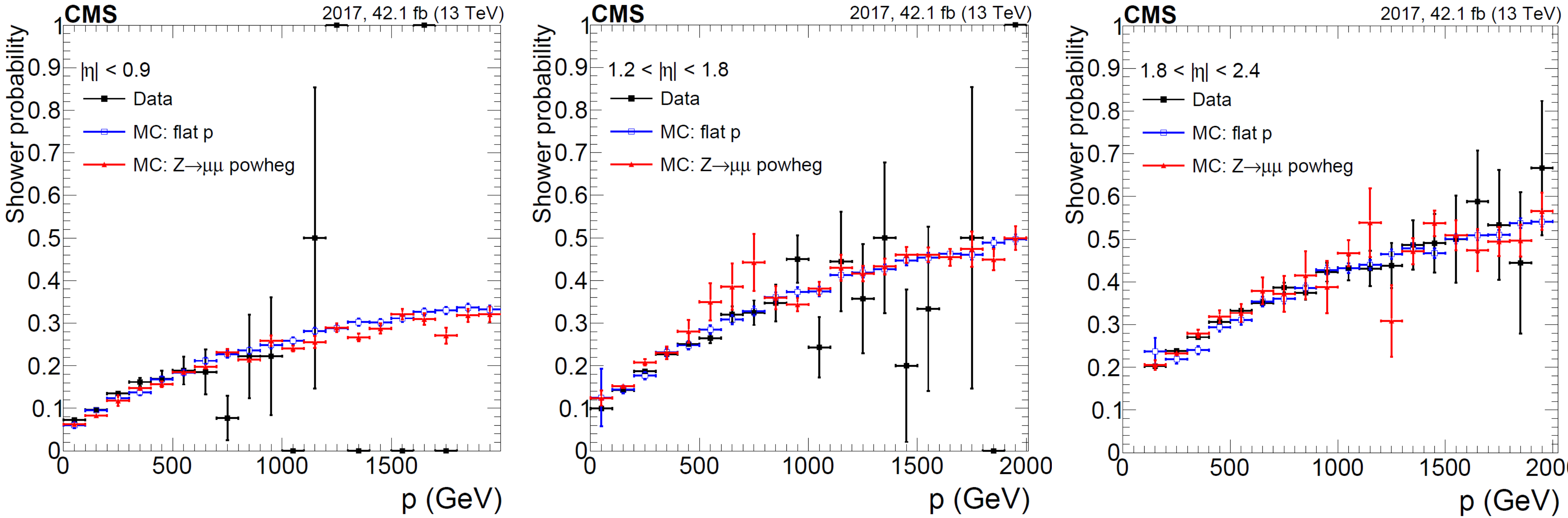
High pT muons: overview

- Two (and a half) main effects contribute to the particularity of the high pT muon case
  - By “high pT” we mean above 200-300 GeV up to over 1 TeV in pT
- Curvature: the precision of momentum determination in a spectrometer gets worse as momentum gets bigger, alignment is becoming more and more important
- Showers: radiative energy losses contaminate the muon chambers and in extreme cases can cause “kinks” in the muon trajectory, making momentum determination tricky
- Statistics: muons in this momentum range are not very abundant, in fact our methods of dealing with them were mostly developed and tuned purely using MC

Showers



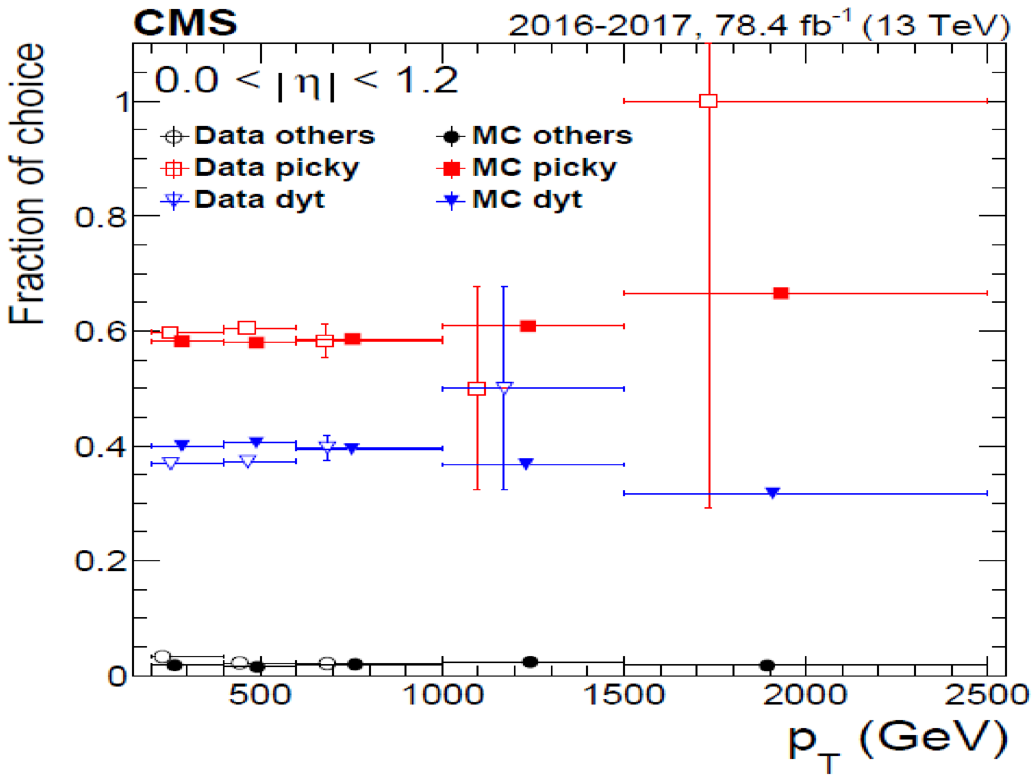
- Above 200-300 GeV muons passing through the iron of the magnet return yoke begin to loose energy primarily via radiative processes
- Muon detectors get contaminated by the resulting E-M cascades
- This is one of the main problems that high pT muon reconstruction has to deal with (together with the challenges of measuring the momentum corresponding to a near-straight track)
- To study showering and it's impact on reconstruction, we developed a set of "shower-tagging" approaches

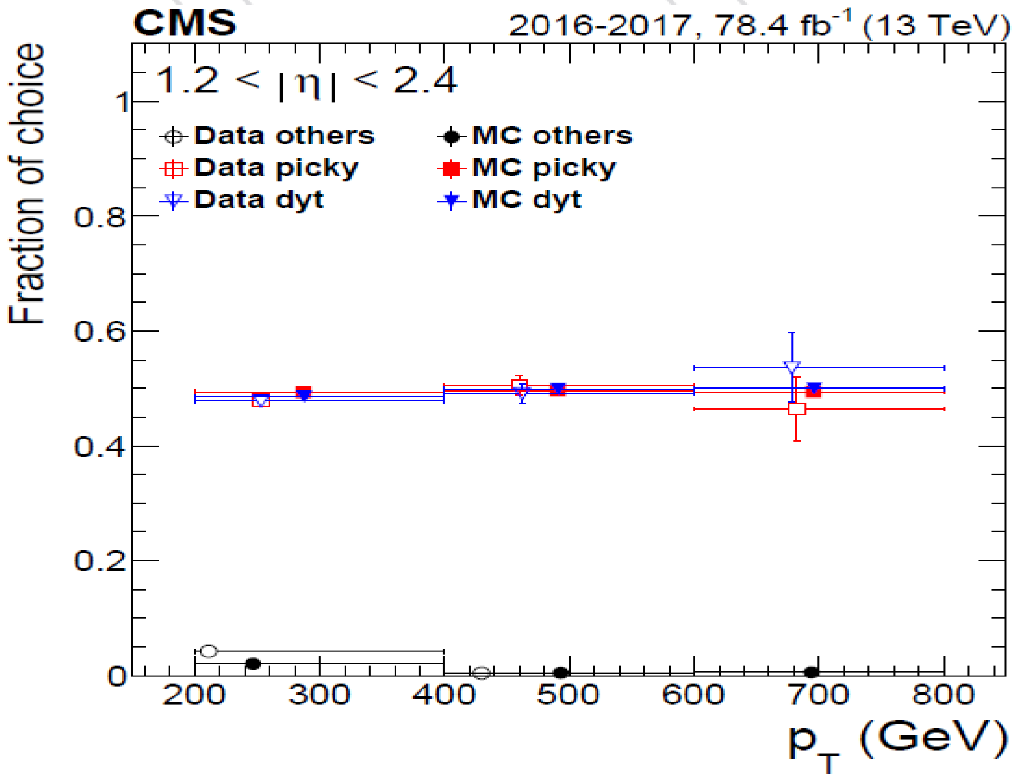


- Comparison of the probability to tag a shower in any station, as a function of the muon p, between gun sample, Drell-Yan simulation and dimuon events (high pT ID, tight isolation, dimuon selection)
- Very good agreement between all the samples:
  - the shower tagging is robust and contamination from spurious hits is under control
  - The simulation models well the data shower probability as a function of p (up to 1-2 TeV)

The Tune P algorithm

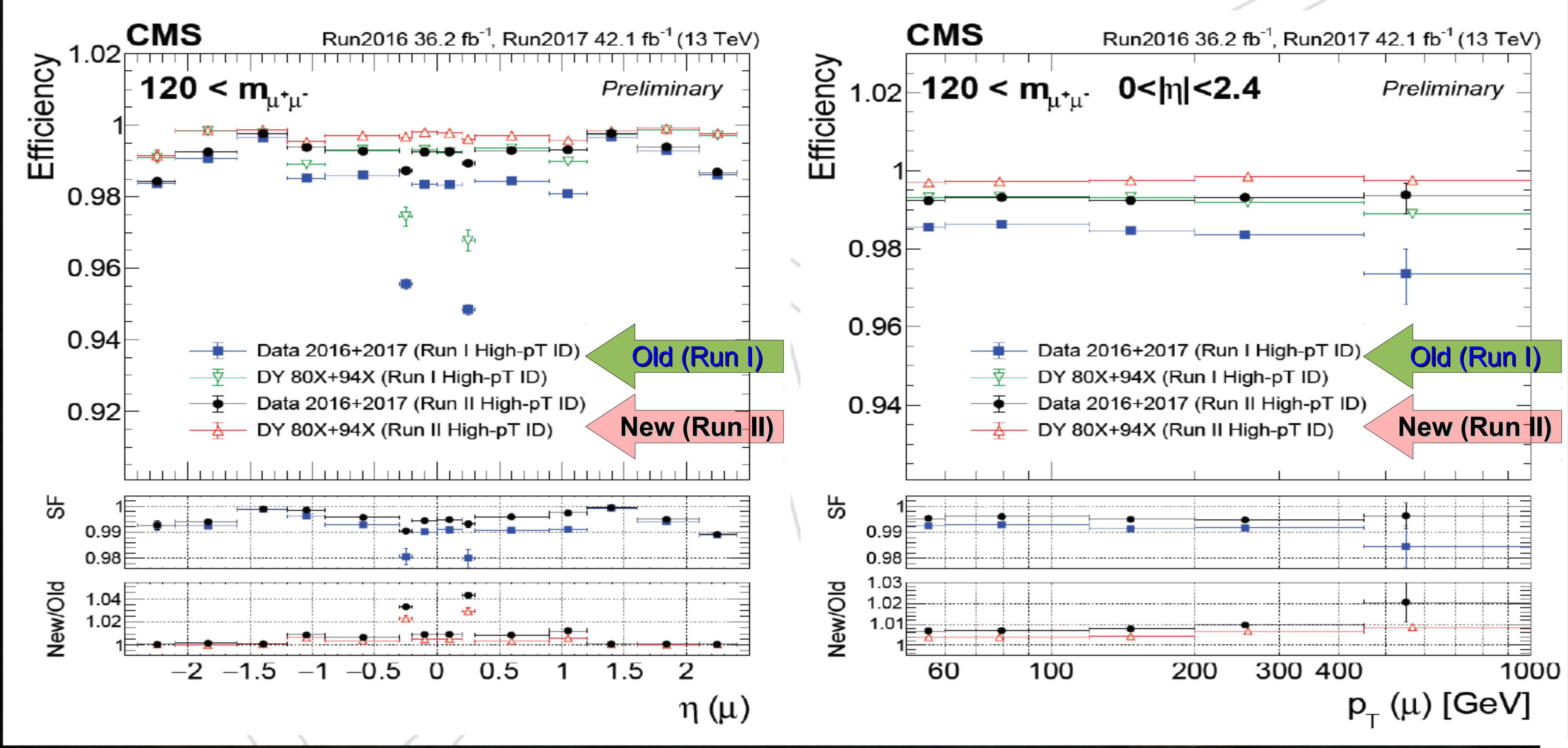
- The TuneP algorithm picks the trajectory to be used for momentum determination from a set of dedicated refits
- The approach aims to mitigate the effect of showers by using a subset of muon stations for the track fit
- The choice that TuneP is making was studied in data and MC, finding a good agreement

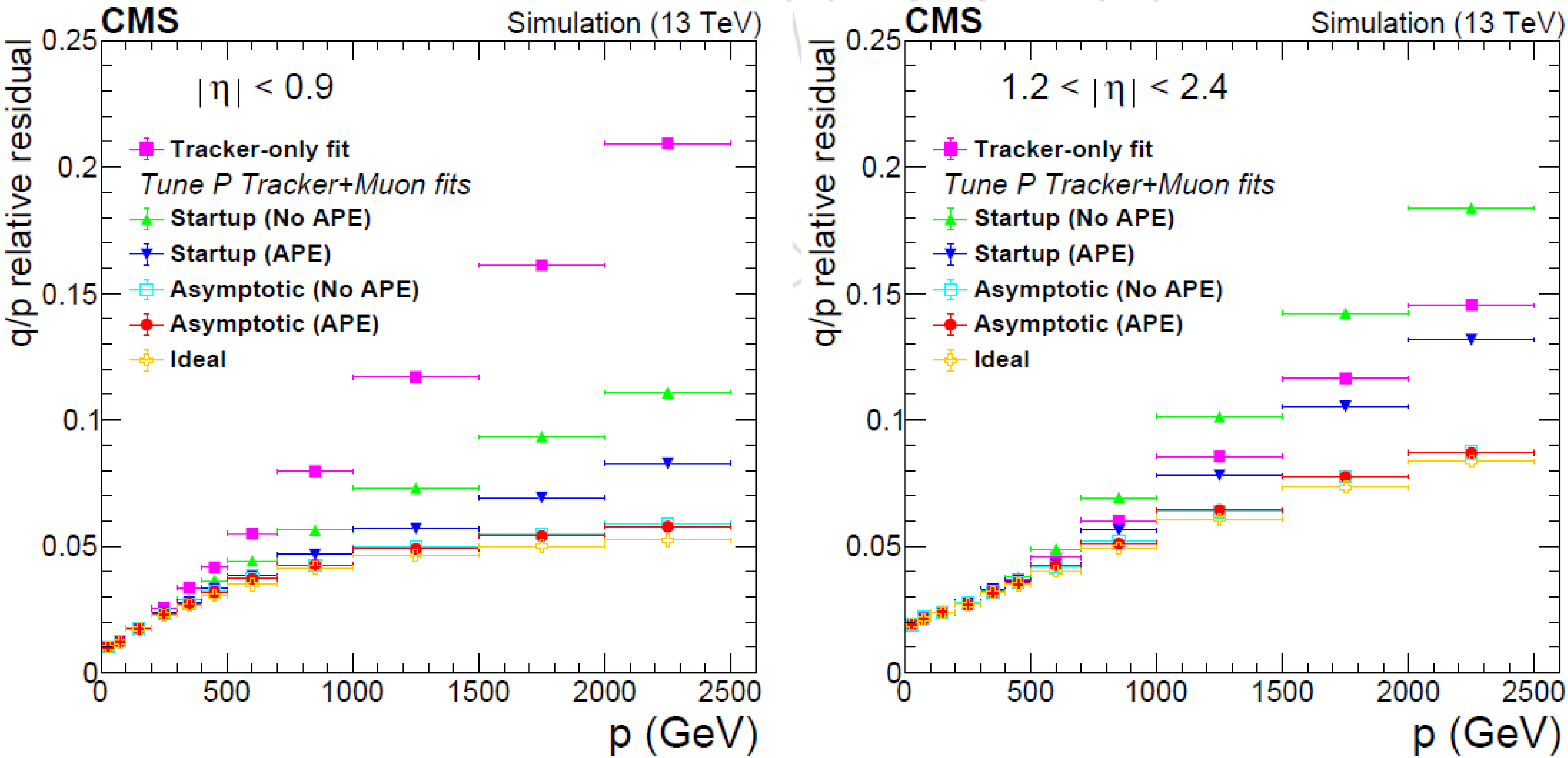




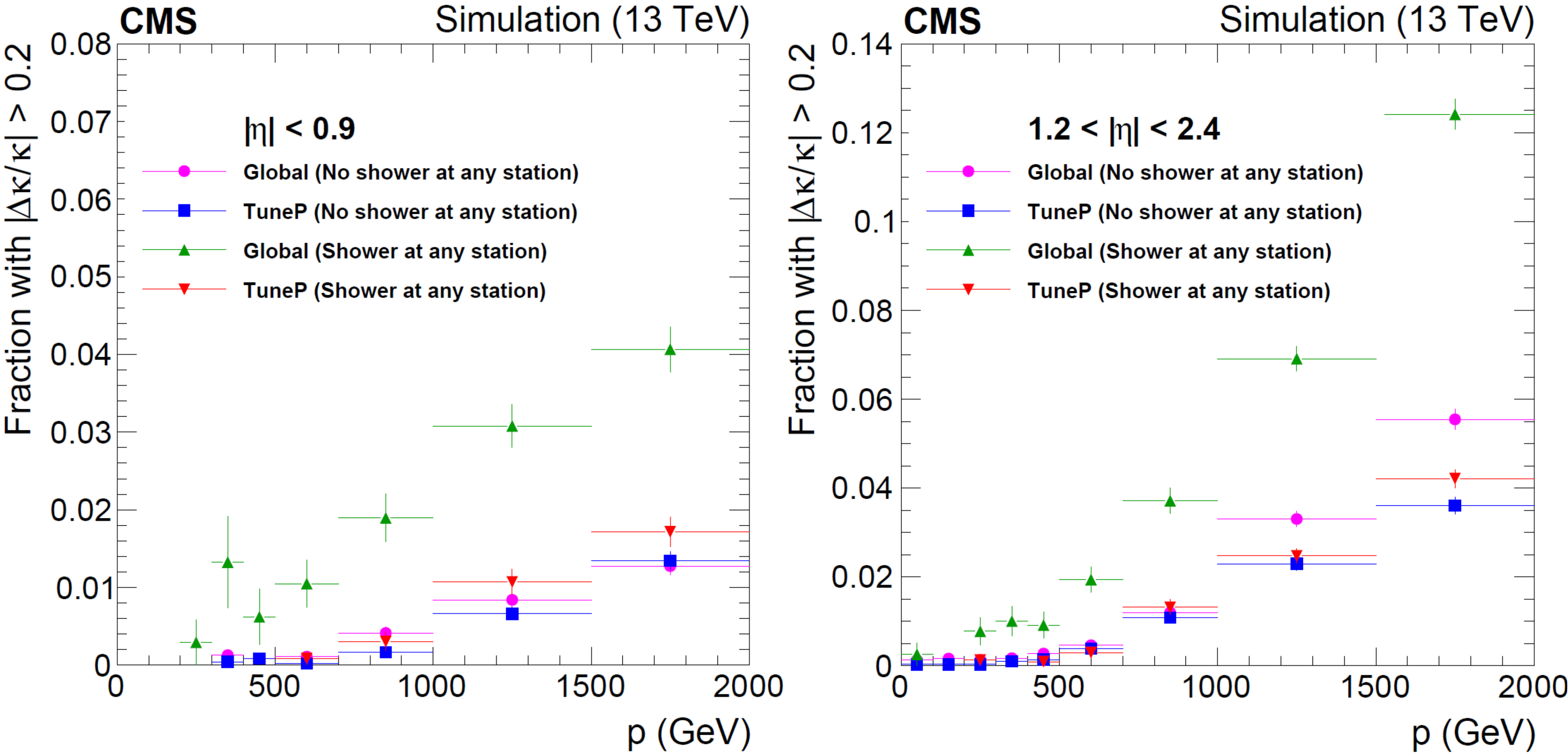
Old/New High-pT ID comparison

- Better efficiency AND better data/MC agreement with new ID





The precision od the "curvature" (q/p) mesurement without the muon system (magenta) compared to the optimal treatment of high pT muons in the muon system (red: Tune P) after final aligment and using "Aligment Positions Errors" (APE).

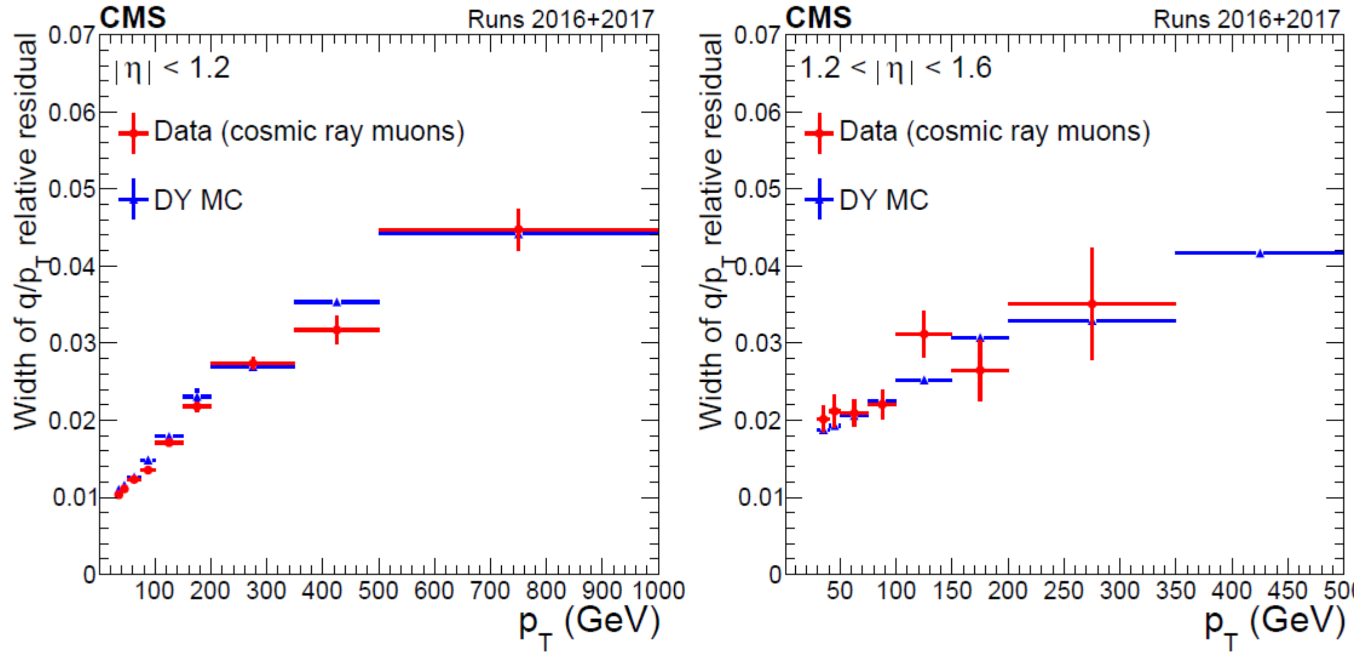


Almost no difference if mouns does not shower (magenta vs blue).

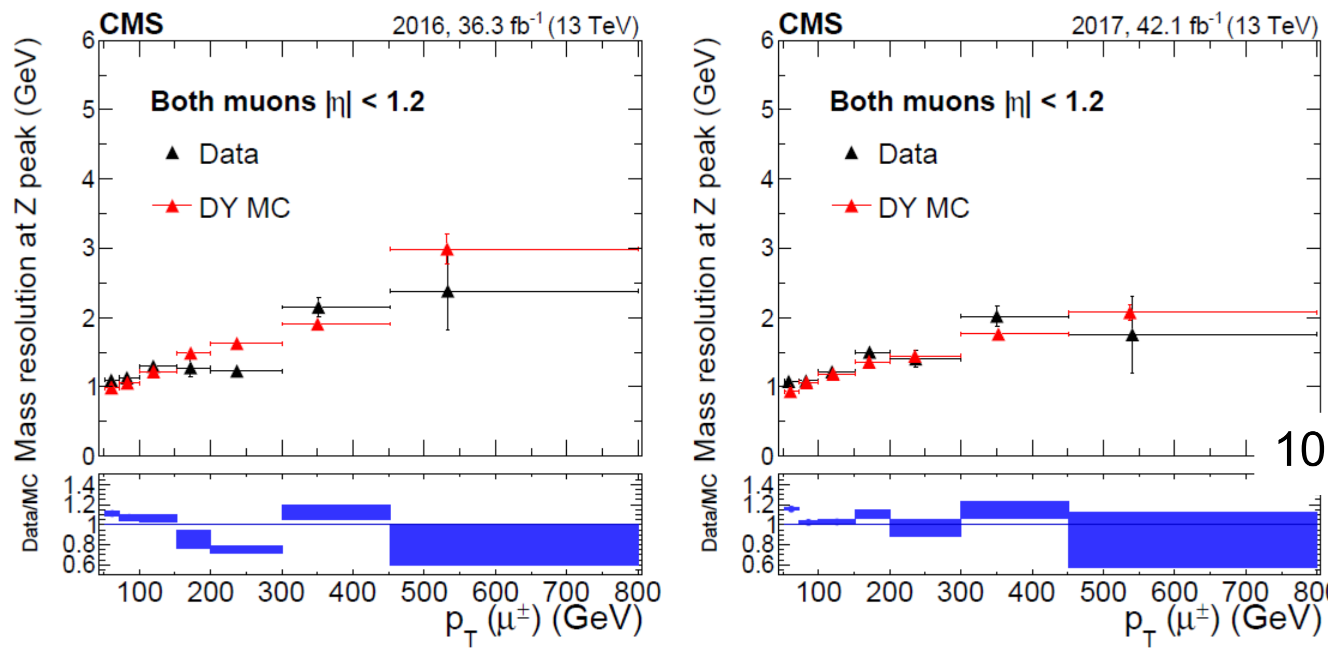
Evident improvement for showering muons (green vs red).

$$R_{\text{cosmic}}(q/p_{\mathrm{T}}) = \frac{(q/p_{\mathrm{T}})^{\text{Upper}} - (q/p_{\mathrm{T}})^{\text{Lower}}}{\sqrt{2}(q/p_{\mathrm{T}})^{\text{Lower}}}$$

The resolution determined using cosmic muons passing close to the interaction point.



Mass resolution for Z to muon pair decays.



High pT muons paper summary

- We studied the performance of high pT muon reconstruction in CMS, using 2016 and 2017 data and MC
- Established connection between data and MC, with good agreement in most cases
- The main features of high pT muons – alignment and showering – are understood and validated
- Very good efficiency of the reconstruction chain, small pT-dependent loss at L1 due to showering
- Momentum determination robust against showers

CMS Physics Analysis Summary

Search for a narrow resonance in high-mass dilepton final states in proton-proton collisions using 140 fb^{-1} of data at $\sqrt{s} = 13$ TeV

A search for physics beyond the standard model is presented using electron or muon pairs with high invariant mass. A data set of proton-proton collisions collected by the CMS experiment at the LHC at $\sqrt{s} = 13$ TeV recorded in years 2016 to 2018 and corresponding to a total integrated luminosity of up to 140 fb^{-1} is analyzed. No significant deviation is observed with respect to the expectation from the standard model backgrounds. Upper limits are set on the ratio of the production cross section times branching ratio of a new narrow dilepton resonance to that of the Z boson and converted into lower limits on the masses of various hypothetical particles. A Z'_{SSM} (Z'_{ψ}) particle, arising in the sequential standard model (superstring-inspired model) is excluded below a mass of 5.15 (4.56) TeV at 95% confidence level.

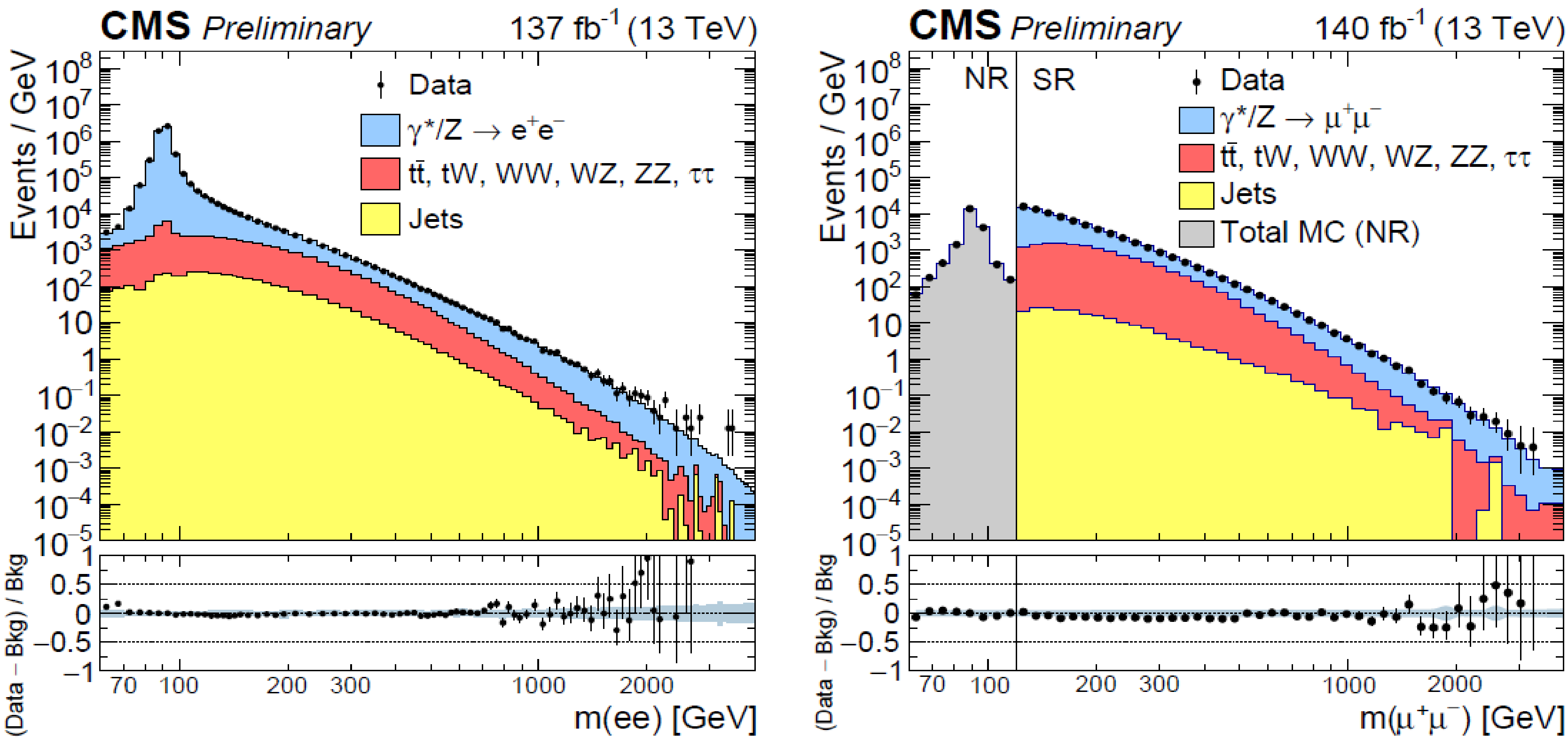


Figure 1: The invariant mass distribution of pairs of (left) electrons and (right) muons observed in data (black dots with statistical error bars) and expected from the SM processes (stacked histograms). For the dimuon channel, a prescaled trigger with a p_T threshold of 27 GeV was used to collect events in the normalization region (NR) with $m_{\mu\mu} < 120$ GeV. The corresponding offline threshold is 30 GeV. Events in the signal region (SR) corresponding to masses above 120 GeV are collected using an unprescaled single muon trigger. The bin width gradually increases with mass. The ratio of the data yields after background subtraction to the background yields is shown on the bottom plots. The blue band represents the various statistical and systematic uncertainties on the background.

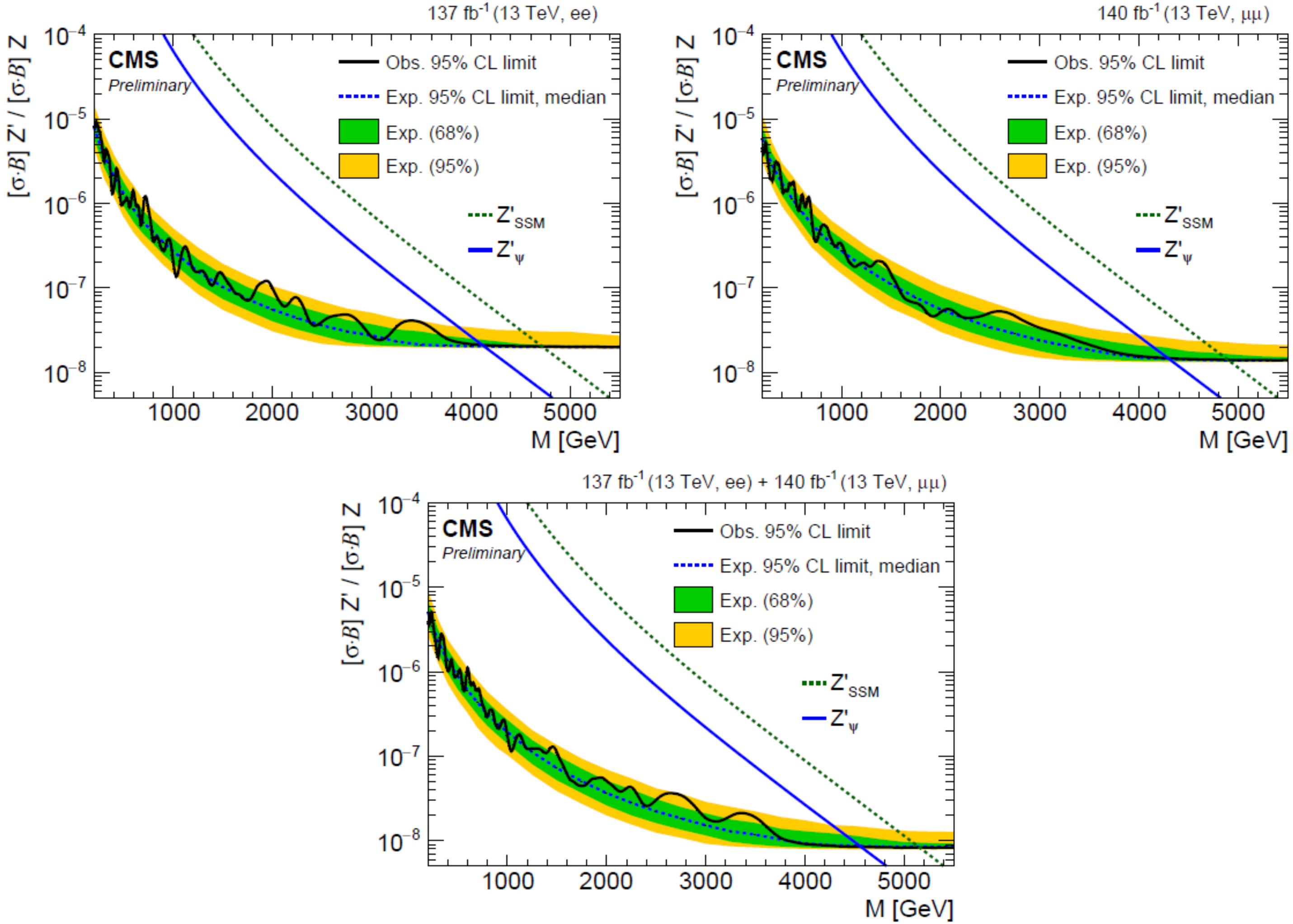


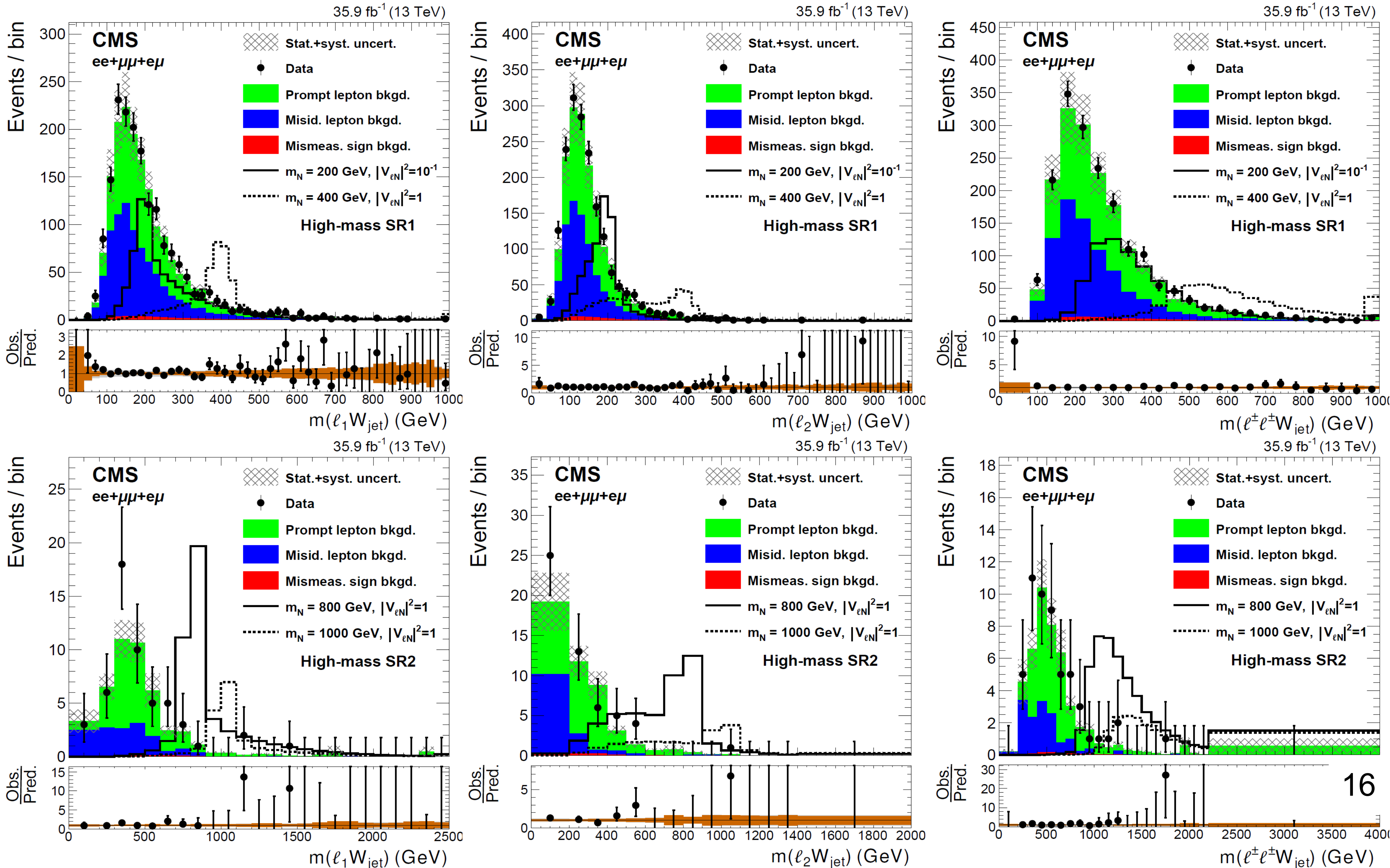
Figure 2: The upper limits at 95% CL on the product of production cross section and branching fraction for a spin-1 resonance with a width equal to 0.6% of the resonance mass, relative to the product of production cross section and branching fraction of a Z boson, for the (top left) dielectron channel, (top right) dimuon channel, and (bottom) their combination. The shaded bands correspond to the 68 and 95% quantiles for the expected limits. Theoretical predictions for the spin-1 Z'_{SSM} and Z'_{ψ} resonances are shown for comparison.

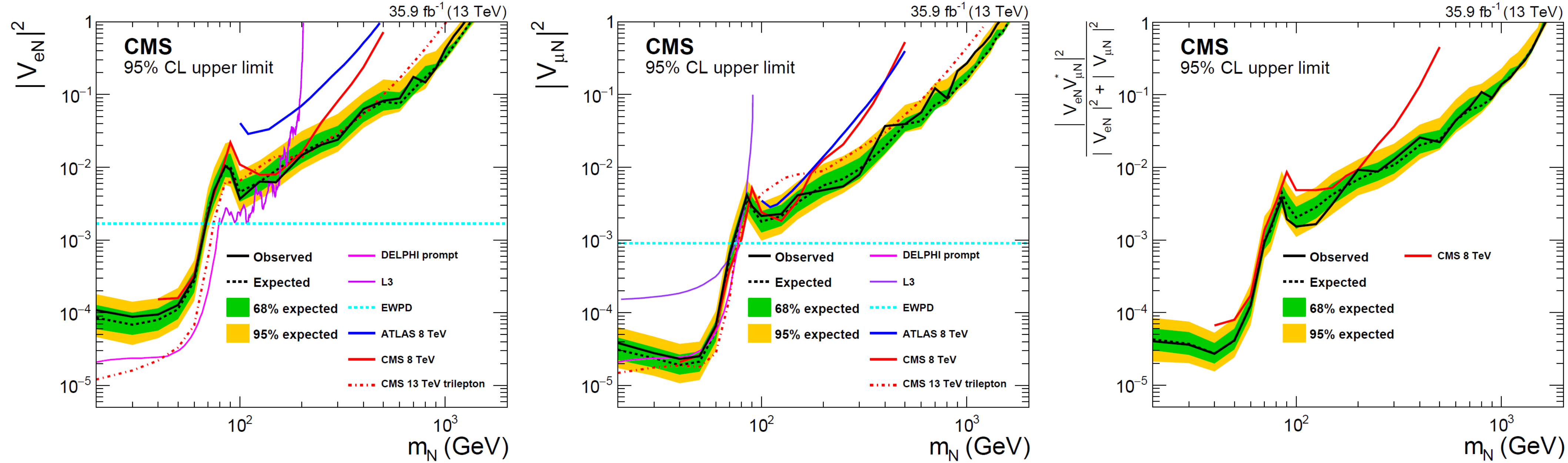
Search for heavy Majorana neutrinos in same-sign dilepton channels in proton-proton collisions at $\sqrt{s} = 13$ TeV

The CMS collaboration

ABSTRACT: A search is performed for a heavy Majorana neutrino (N), produced in leptonic decay of a W boson propagator and decaying into a W boson and a lepton, with the CMS detector at the LHC. The signature used in this search consists of two same-sign leptons, in any flavor combination of electrons and muons, and at least one jet. The data were collected during 2016 in proton-proton collisions at a center-of-mass energy of 13 TeV, corresponding to an integrated luminosity of 35.9 fb^{-1}. The results are found to be consistent with the expected standard model background. Upper limits are set in the mass range between 20 and 1600 GeV in the context of a Type-I seesaw mechanism, on $|V_{\mathrm{eN}}|^2$, $|V_{\mu\mathrm{N}}|^2$, and $|V_{\mathrm{eN}}V^*_{\mu N}|^2/(|V_{\mathrm{eN}}|^2 + |V_{\mu\mathrm{N}}|^2)$, where $V_{\ell\mathrm{N}}$ is the matrix element describing the mixing of N with the standard model neutrino of flavor $\ell = \mathrm{e}, \mu$. For N masses between 20 and 1600 GeV, the upper limits on $|V_{\ell\mathrm{N}}|^2$ range between 2.3×10^{-5} and unity. These are the most restrictive direct limits for heavy Majorana neutrino masses above 430 GeV.

JHEP01(2019)122


35.9 fb^{-1} (13 TeV)
CMS
ee+μμ+eμ
Stat.+syst. uncert.
Data
Prompt lepton bkgd.
Misid. lepton bkgd.
Mismeas. sign bkgd.
m_N = 200 GeV, $|V_{\ell N}|^2=10^{-1}$
m_N = 400 GeV, $|V_{\ell N}|^2=1$
High-mass SR1
m_N = 800 GeV, $|V_{\ell N}|^2=1$
m_N = 1000 GeV, $|V_{\ell N}|^2=1$
High-mass SR2
Events / bin
Obs. / Pred.
$m(\ell_1 W_{jet})$ (GeV)
$m(\ell_2 W_{jet})$ (GeV)
$m(\ell^\pm \ell^\pm W_{jet})$ (GeV)



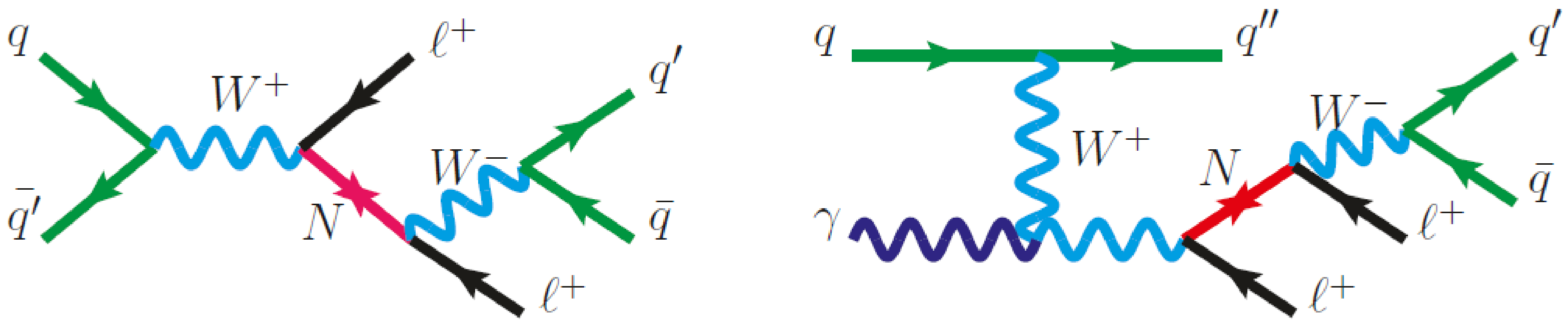


Figure 1. Feynman diagram representing a resonant production of a Majorana neutrino (N), via the s-channel Drell-Yan process (left) and its decay into a lepton and two quarks, resulting in a final state with two same-sign leptons and two quarks from a W boson decay. Feynman diagram for the photon-initiated process (right).

We propose the contribution of Piotr Traczyk
to the following collection of publications by the CMS
to be considered the NCBJ achievement of 2019.

→ **Performance of the reconstruction and identification of high-momentum muons in proton-proton colisions at sqrt(s)=13TeV, CMS Paper MUO-17-001, (7/12/2019, submitted to JINST);**
→ Search for narrow resonance in high-mass dilepton final state in propton-proton collisions using 140/fb of data at sqrt(s)=13TeV, CMS PAS EXO-19-019;
→ Search for heavy Majorana neutrinos in same-sign dilepton channels in proton-proton collisions at sqrt(s)=13TeV, JHEP01(2019)122, https://doi.org/10.1007/JHEP01(2019)122;
→ Search for excited leptons decaying via contact interaction to two leptons and two jets, CMS PAS EXO-18-013;
→ Search for long lived particles that stop in the CMS detector and decay to muons at sqrt(s)=13TeV, CMS PAS EXO-17-004;
→ Search for excited leptons in lepton lepton gamma final states in proton-proton collison at sqrt(s)=13TeV, JHEP04(2019)015, https://doi.org/10.1007/JHEP04(2019)015;
→ Search for contact interactions and large extra dimensions in the dilepton mass spectra from proton-proton collisions at sqrt(s)=13TeV, JHEP04(2019)144, https://doi.org/10.1007/JHEP04(2019)114;
→ Search for heavy right-handed W boson and a heavy neutrino in events with two same flavor leptons and two jets at sqrt(s)=13TeV, JHEP05(2018)148, https://doi.org/10.1007/JHEP05(2018)148;
→ Search for high-mass resonances in final states with a lepton and missing transverse momentum at sqrt(s)=13TeV, JHEP06(2018)128, https://doi.org/10.1007/JHEP06(2018)128.

ttH explained in 5 minutes by Piotr Traczyk → https://www.youtube.com/watch?v=uTvmYmKZ2aY