1) Why Beyond Standard Model physics?
- Dark Matter: No potential candidate in SM.
- Neutrino oscillations: Mass of neutrinos and their smallness not explained.
- Baryon asymmetry: CP violation?
- Hierarchy problem: Extra generation of matter particles?

2) BSM physics may give multiple leptons

Vector-Like Lepton (VLL) doublet
- Two non-chiral, mass-degenerate fermions: V & \nu_V
- Arise in models like SUSY & large ED.
- Yukawa coupling to SM leptons, same quantum numbers.
- \nu_V decay through Z/\nu, decay through W.
- Total 8 distinct production and decay modes.

A new light scalar in SM: \phi
- Arise in extended Higgs sectors, SUSY, dark sector.
- Simplified model – CP-even or CP-odd \phi, produced with top quark pairs.
- Production cross section proportional to g_t^2.
- \phi decay controlled by g_{\nu_V}^2.
- Decay controlled by g_{tV}.
- g_{\nu_V} decays to electrons or muons.

Type-III Seesaw Mechanism: fermionic triplet
- Mass-degenerate: Dirac \Sigma, \Sigma and a Majorana \Sigma_0.
- SM neutrinos are Majorana, coupling to \Sigma_0.
- \Sigma, \Sigma_0 production: decay through W/Z/b.
- All mixing angles to different lepton flavors studied.
- Total 27 distinct production and decay modes.

3) Multilepton Analysis Strategy

- Event categories: ≥4L, 3L and 2L + pT ≥10 GeV (L=\eta/\mu)
- Regions divided kinematically, signal populates them differently from SM.
- Counting experiment combining bins of discriminating variables.

VLL doublet signal regions

5) Standard Model Backgrounds

<table>
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<th>Background source</th>
<th>Leading processes</th>
<th>Estimation method</th>
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<td>Irreducible</td>
<td>WZ, ZZ, t\bar{t}, Z\gamma</td>
<td>Simulation</td>
<td>Normalized in 2L/3L CRs</td>
</tr>
</tbody>
</table>
| Misidentified (jets → leptons) | DY, WW, Z\gamma | Data | Developed for
|              |                  | Simulated        | p_{Tmiss} > 50 GeV 2L/3L CRs and MC |
| Photon conversions (asymmetric) | DY, WW, Z\gamma | Simulation        | Normalized in
|              |                  |                   | 2L CRs |
| Rare             | VV, tt, WW, Higgs | Simulation        | No normalisation |

Prompt Background CRs

- Irreducible
- Misidentified
- Conversion

3D matrix method
- Universal prompt and fake rates for leptons.
- Rates measured using low p_{Tmiss} OSSF CR, parameterised by lepton p_{T}, \eta and the multiplicity of tracks in the event.
- Rates corrected using simulation for t\bar{t}jet effects.

Uncertainties
- Largely dominated by the WZ, ZZ, and t\bar{t} normalization factors (-25%) as well as the misidentified lepton contributions (50-40%).
- Contributions from rare (20%), conversion (20%), and those due to scale factors & electron charge misidentification (<<10%) have a negligible impact.

6) Interpreting the results

- A comprehensive and inclusive full Run 2 multilepton result.
- Adding tau-enriched channels: ≥4L, ≥3L + pT ≥10 GeV
- Many probes: Light leptons, taus, b-jets and p_{Tmiss}.
- Additional signal models: X, VLL singlet, Right handed neutrinos.
- Classic cut-and-count as well as machine learning based techniques.
- Model-independent limits in the various multilepton signal regions.

7) Future plans

- In bins of b-jets & p_{Tmiss}.

References -

Angira Rastogi (IISER Pune) - On behalf of the CMS collaboration

The multilepton searchlight at CMS