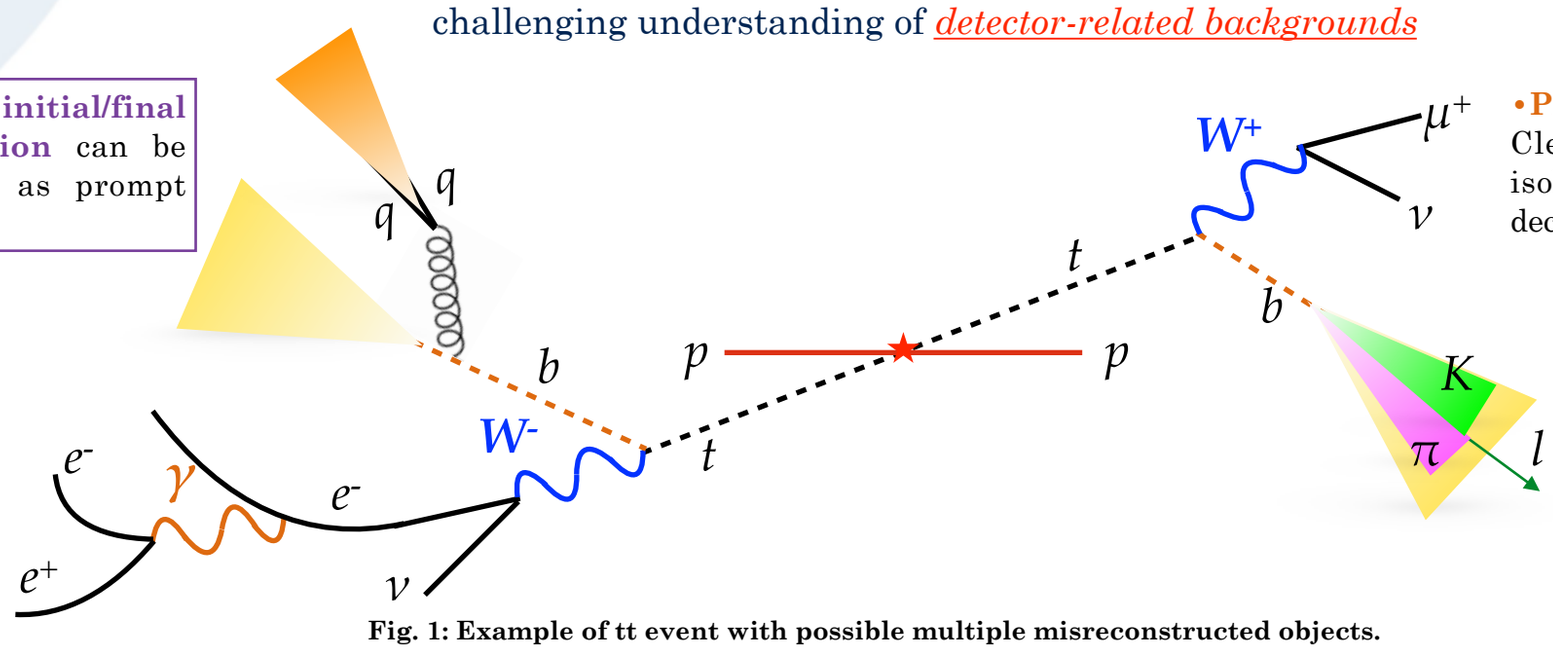
Data-driven methods for misreconstructed objects estimation in lepton final states with ATLAS at √s = 13 TeV

Searches for *new physics* in lepton final states provide powerful signature towards discoveries: challenging understanding of *detector-related backgrounds*

• **Jets from initial/final state radiation** can be misidentified as prompt leptons.

• **Trident event:** $e^- \to e^-\gamma \to e^-e^+e^-$
Electromagnetic cluster can be matched to wrong electron track in ID.



• **Prompt** muon from W^+ decay. Clean signature, high-p_T and isolated. Leptons from Z,W,H decays estimated with simulation.

• **Non-prompt** lepton from a B-hadron secondary decay, which are associated with hadron activities such as K and π. Less isolated object and larger impact parameter.

Fig. 1: Example of tt event with possible multiple misreconstructed objects.

1) Charge misidentification probability

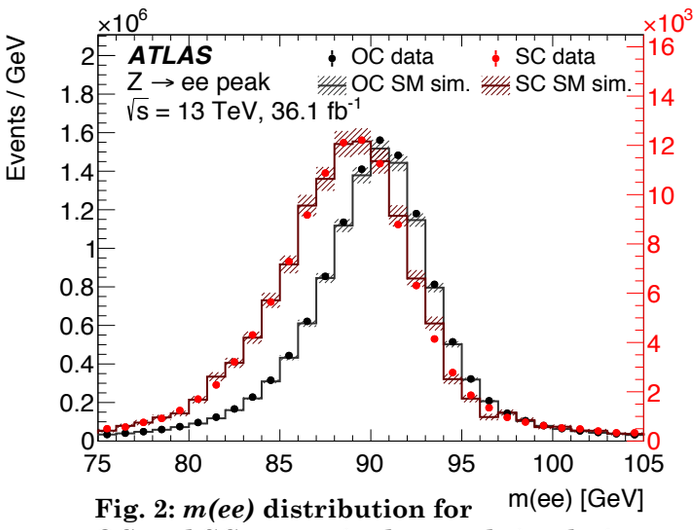


Fig. 2: *m(ee)* distribution for OC and SC events in data and simulation

• ***Z→ee*** sample divided into opposite-charge (OC) or same-charge (SC) events, as in Fig.2.
• Poisson probability to observe N_{SC}:

$$f(N_{SC}^{ij};\lambda) = \frac{\lambda^{N_{SC}^{ij}} e^{-\lambda}}{N_{SC}^{ij}!}$$

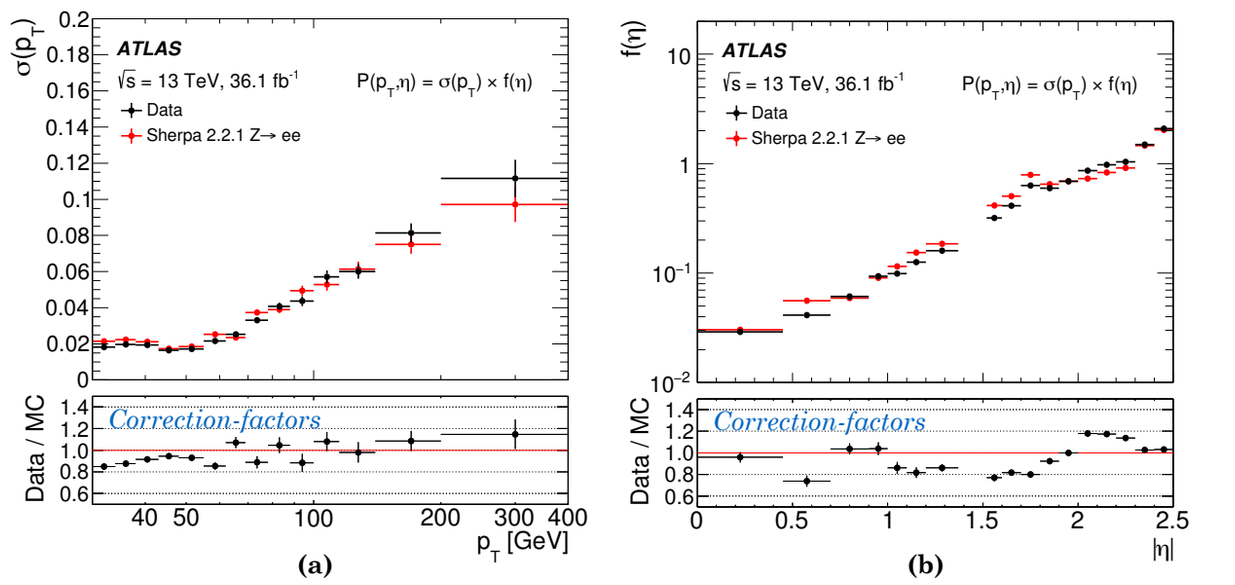
given λ:

$$\lambda = N^{ij}(P_i(1-P_j) + P_j(1-P_i))$$

where $N^{ij} = N^{ij}_{SC} + N^{ij}_{OC}$

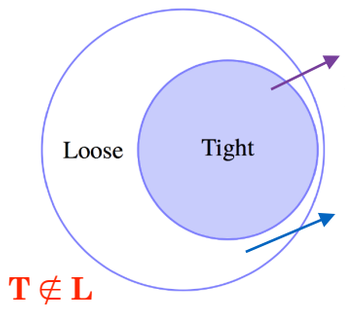
$$-\log L(\boldsymbol{P}|\boldsymbol{N}_{SC},\boldsymbol{N}) = \sum_{i,j} \log(N^{ij}(P_i(1-P_j)+P_j(1-P_i)))N_{SC}^{ij} - N^{ij}(P_i(1-P_j)+P_j(1-P_i))$$

Fig. 3: CF probability $P(p_T,\eta) = \sigma(p_T) \times f(\eta)$: (a) p_T and (b) $|\eta|$ dependences.



• ***Charge Flip (CF)*** probability $P(p_T,\eta)=\sigma(p_T)\times f(\eta)$ applied as a 1D×1D parametrization of electron p_T and $|\eta|$ (Fig.3). *Correction-factors* derived as the ratio between data/MC and applied to simulated CF electrons.

2) Fake lepton background



• **Tight:** pass more stringent identification and isolation criteria. Used to define analysis regions.

• **Loose:** pass required to fail tight isolation requirement. Fake leptons usually less isolated.

Fake-factor:

$$F = \frac{N_{pass}}{N_{fail}}$$

in bins of p_T and $|\eta|$.

Selection for fake-enriched regions	
Muon channel	Electron channel
Single-muon trigger	Single-electron trigger
b-jet veto	*b*-jet veto
One muon and one jet	One electron
p_T(jet) > 35 GeV	Number of tight electrons < 2
$\Delta\phi(\mu, \text{jet}) > 2.7$	$m(ee) \notin [71.2, 111.2]$ GeV
E_T^{miss} < 40 GeV	E_T^{miss} < 25 GeV

Tab.1 : "fake-enriched" control regions used for the measurement of F.

$$N^{fake} = [F(N_{TL}+N_{LT}) - F^2 N_{LL}]_{data} - [F(N_{TL}+N_{LT}) - F^2 N_{LL}]^{prompt}_{MC}$$

Final estimate in all analysis regions.

"Side-bands": events containing at least one loose lepton (N_{TL},N_{LT} and N_{LL}).

Special treatment fow low statistics:

$P(0|\lambda) = 32\%$ → λ=1.14 at 68% CL → $N_{TL} = N_{LT} = N_{LL} = 0.38$

$N_e^{fakeup} = 2\times0.38\times0.5 - 0.38\times0.5^2 \to N_e^{fake} = 0^{+0.285}_{-0.0}$

$N_\mu^{fakeup} = 2\times0.38\times0.9 - 0.38\times0.9^2 \to N_\mu^{fake} = 0^{+0.376}_{-0.0}$

Prevents from 0±0 fake estimate (Fig. 6(b)).

3) Systematic uncertainties

• **Charge-flip:** vary the choice of *Z* peak range; negligible compared to statistical uncertainty in data and simulated events
→ 10%-20% on CF probabilities

• **Fake factor:**
→ alter missing E_T requirement to vary *W+jets* composition
→ change recoiling jet requirements to study fake composition
→ $d_0/|\sigma_{d0}|$ varied up/down by 1 unit
→ normalization of simulated samples varied up/down by 10%
→10% to 20% across p_T and $|\eta|$ bins

4) Methods used in new physics searches

Doubly-charged boson Higgs production: 2,3,4 leptons final states, $N_{jets}\geq0$
Search for *heavy leptons in type III See-Saw* models (see Tadej Novak's poster for more details): 2 leptons, 2 jets and missing E_T.

Fig. 5: (a) m(ee) distribution in a two same-sign leptons region. (b): scalar sum of objects p_T (H_T) plus missing E_T in type III See-Saw search. Used to validate CF with different jet multiplicities.

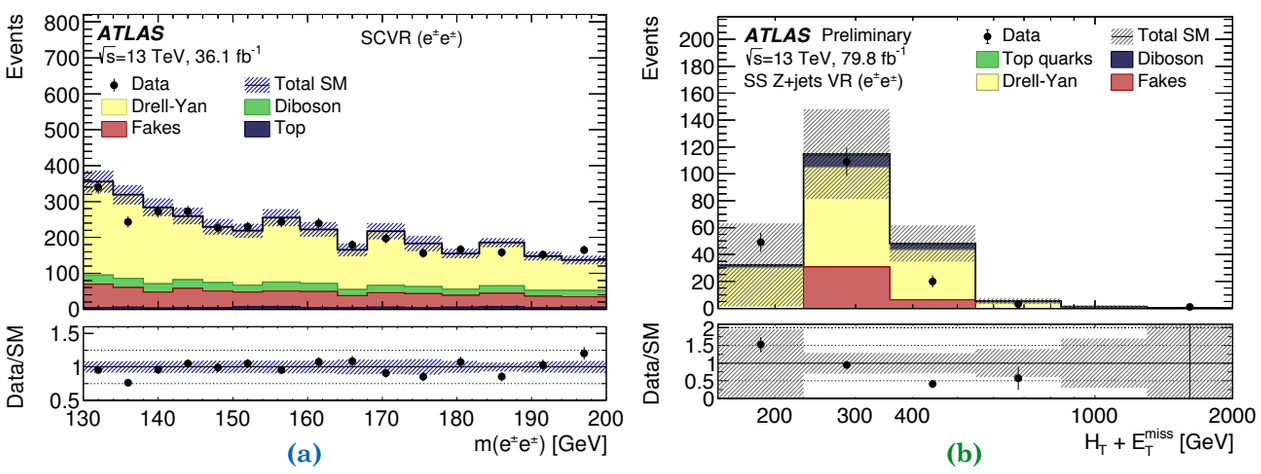
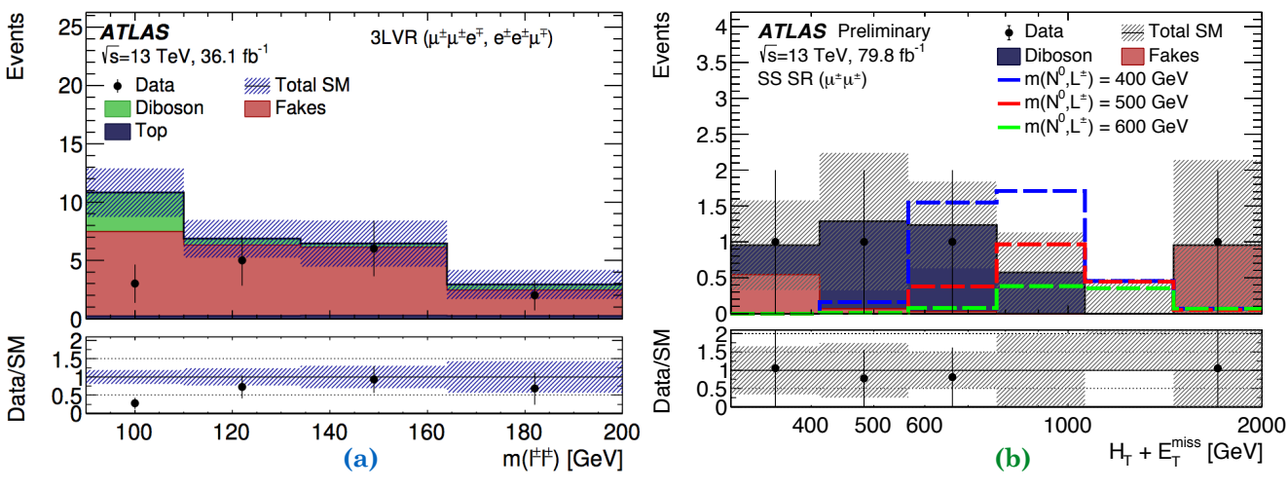


Fig. 6: (a) same-sign invariant mass distribution in a three leptons region, validate fakes in three lepton final states.(b): H_T + missing E_T in muon signal region, shows the Poissonian limit for low statistics side-bands.



Methods validated across different kinematic regimes and event topologies efficiently applied to more than one new physics search.

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