Data-driven methods for misreconstructed objects estimation in lepton final states with ATLAS at $\sqrt{s}$ = 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.

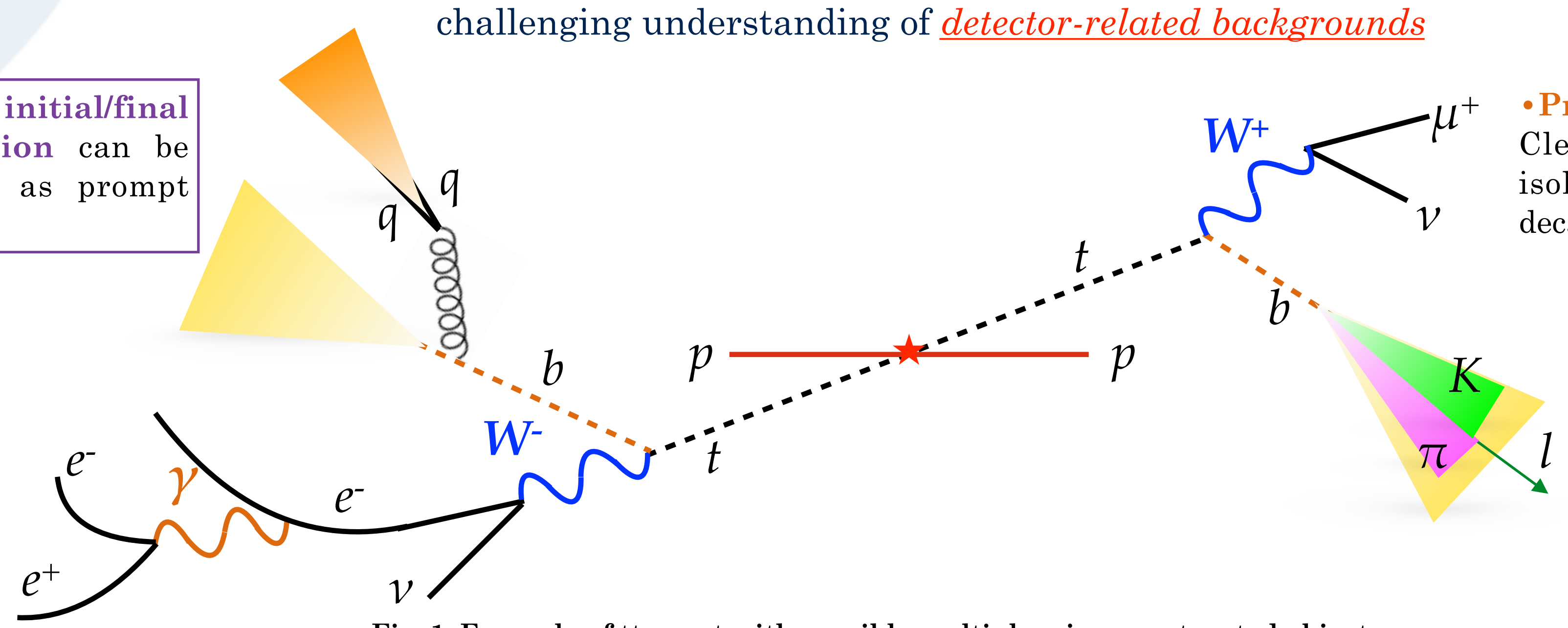


Fig. 1: Example of tt event with possible multiple misreconstructed objects.

•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.

1) Charge misidentification probability

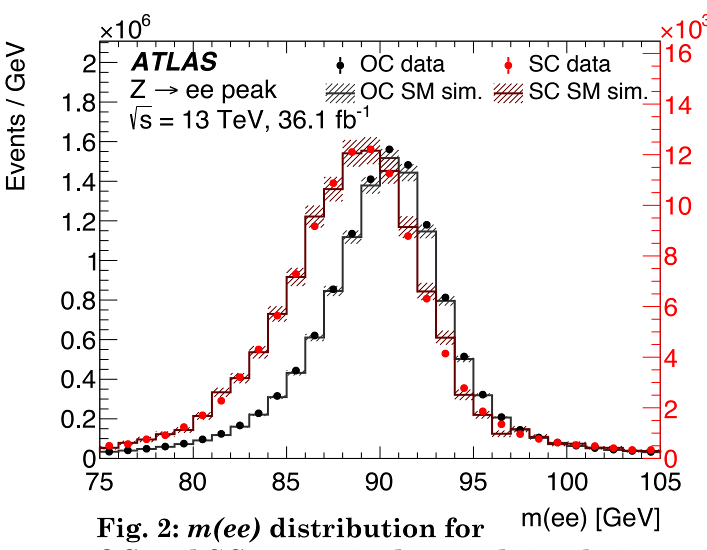


Fig. 2: *m(ee)* distribution for OC and SC events in data and simulation

• ***Z→ee*** sample divided into opposite-charge (OC) or same-charge (SC) events, as in Fig.2.

• Poisson probability to observe N_{SC}:

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

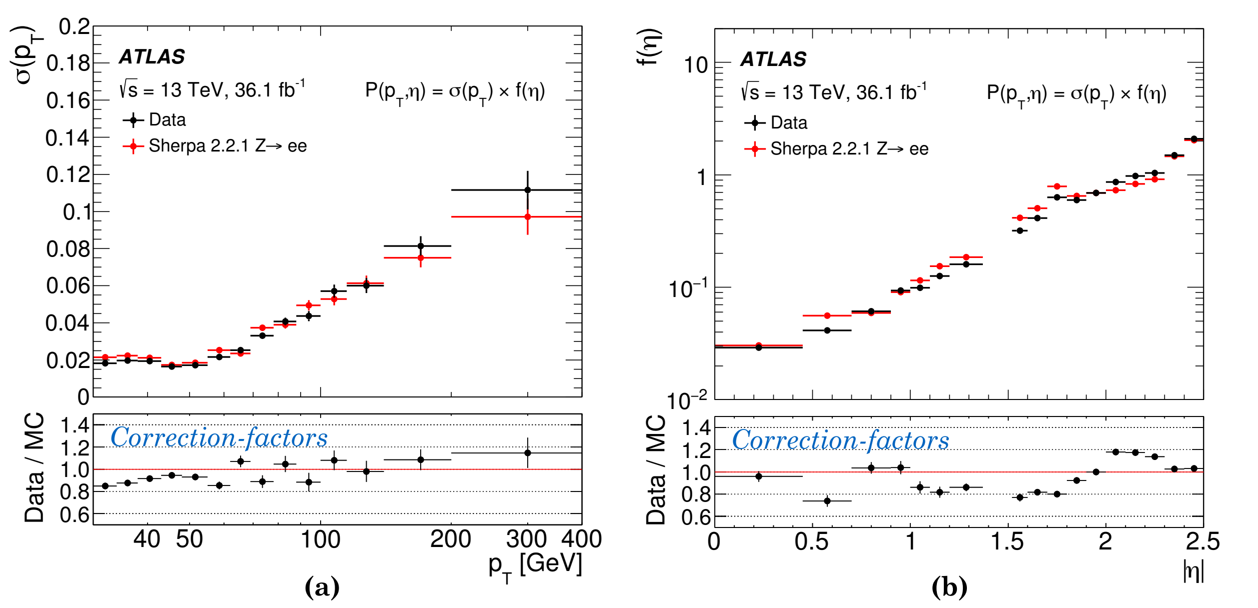
given λ:

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

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

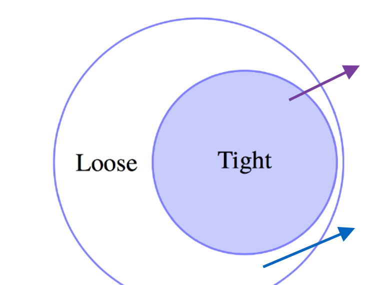
$$-\log L(\mathbf{P}|N_{\rm SC},N) = \sum_{i,j} \log(N^{ij}(P_i(1-P_j)+P_j(1-P_i)))N^{ij}_{\rm SC} - N^{ij}(P_i(1-P_j)+P_j(1-P_i))$$

Fig. 3: CF probability $P(p_T,\eta) = \sigma(p_T) \times f(\eta)$: (a) p_T and (b) |η| 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 |η| (Fig.3). *Correction-factors* derived as the ratio between data/MC and applied to simulated CF electrons.

2) Fake lepton background



T ∉ L

•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:

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

in bins of p_T and |η|.

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
$\Delta\phi(\mu,\rm jet)$ > 2.7	$m(ee) \notin$ [71.2, 111.2] GeV
$E_T^{\rm miss}$ < 40 GeV	$E_T^{\rm miss}$ < 25 GeV

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

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

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 → $N_{TL} = N_{LT} = N_{LL} = 0.38$

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

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

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
→ $d_0/|\sigma_{d_0}|$ varied up/down by 1 unit
→ normalization of simulated samples varied up/down by 10%

→10% to 20% across p_T and |η| bins, from 1% to 20% on total background

4) Methods used in new physics searches

Doubly-charged boson Higgs production: 2,3,4 leptons final states, $N_{\rm jets}\geq0$

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.

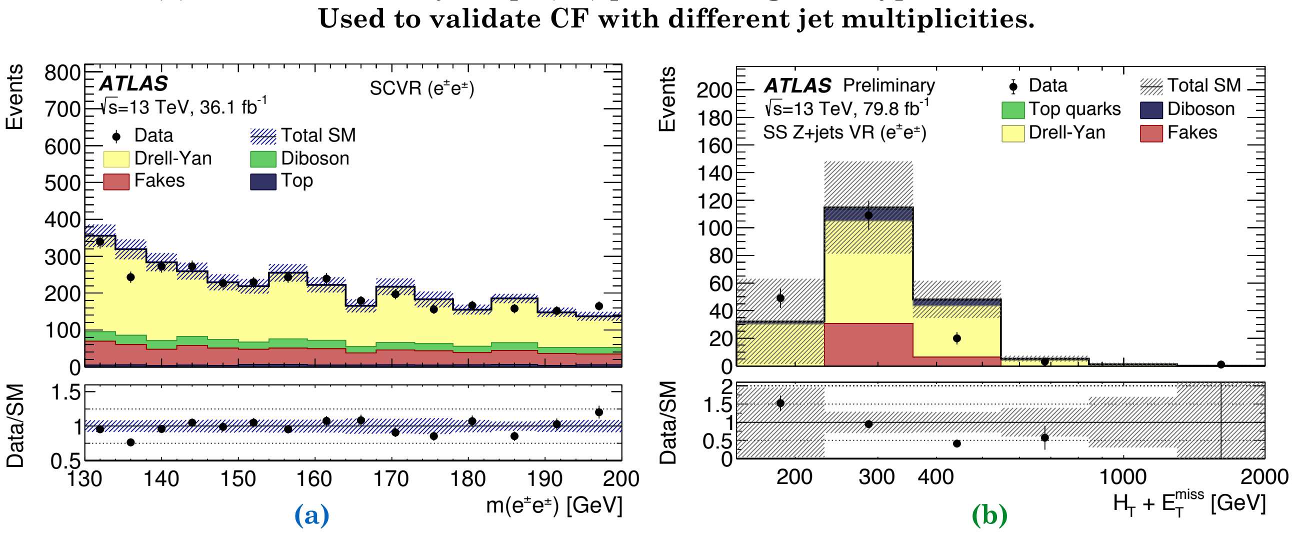
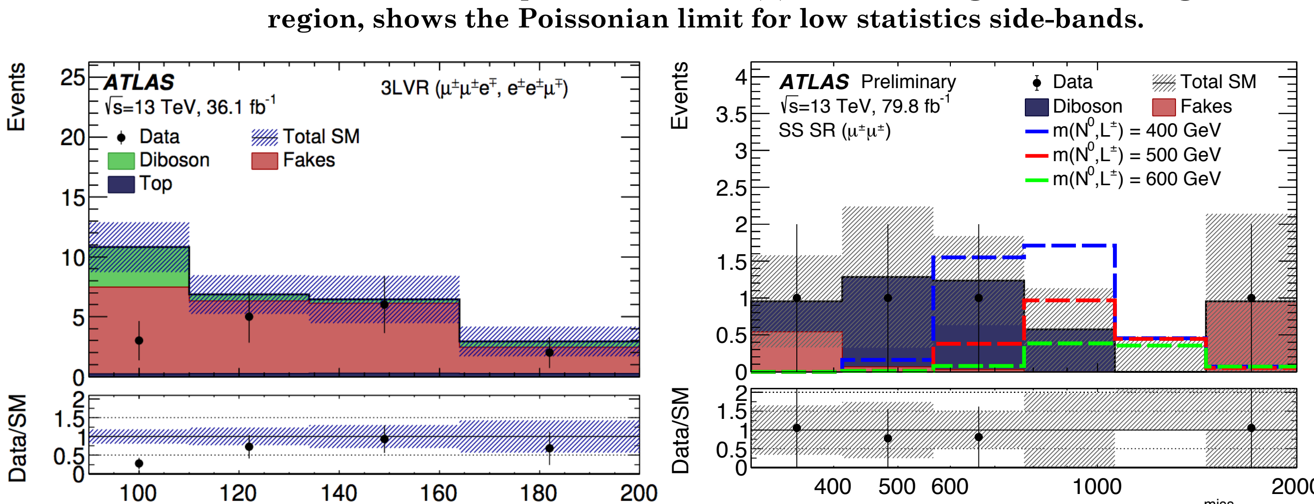


Fig. 6: (a) same-sign invariant mass distribution in a three leptons region, validate fakes in three lepton final states.(b): H_T + missing E_T in muon signal region, shows the Poissonian limit for low statistics side-bands.



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

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