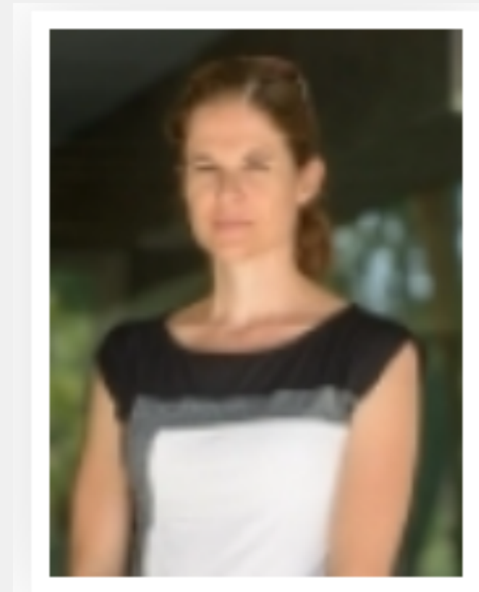
Search for Physics Beyond the Standard Model using the eμ-Symmetry Method

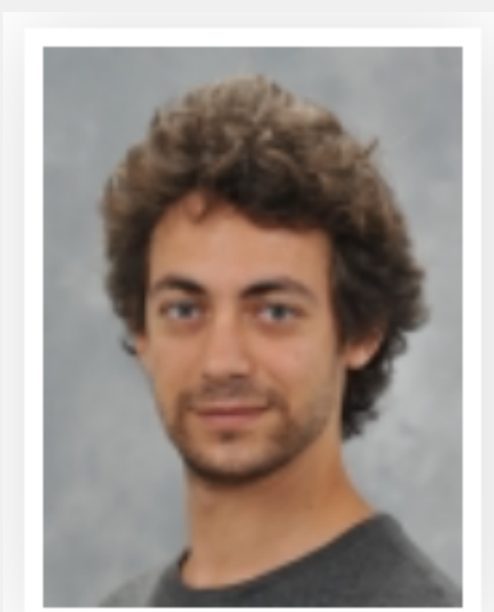
NYUAD and WIS Collaboration - 22/12/2020

Mattias Birman for Shikma Bressler's analysis team

Analysis Team



Shikma Bressler



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Introduction

- The **eμ-symmetry method** is a novel analysis method which is **data-driven**
- Developed to search for new physics in data from High Energy collision experiments
  - ➡ First introduced by us in 2014 [1]
  - ➡ Applied in the search for Higgs Lepton Flavor Violating (LFV) decays using 20 fb^{-1} of data from proton-proton collisions at *c.o.m.* 8 TeV provided by the LHC and collected by the ATLAS detector [2]
  - ➡ Currently being applied in the same search with 139 fb^{-1} of data at *c.o.m.* 13 TeV

[1] https://journals.aps.org/prd/abstract/10.1103/PhysRevD.90.015025
[2] https://link.springer.com/article/10.1140/epjc/s10052-017-4624-0

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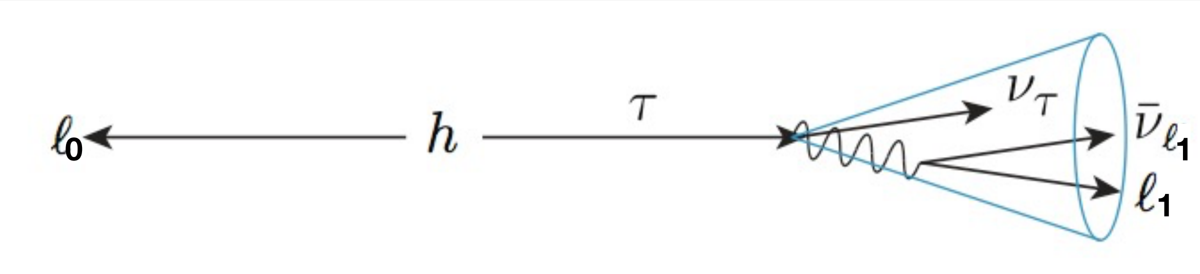
Introduction

- It takes advantage of the approximate **symmetry between electrons and muons expected from SM processes**
  - ➡ Lepton Flavor Universality
  - ➡ Rates will only differ due to phase space effects and Yukawa interactions
    - Expected to be negligible at the energy scales of the LHC

- Enables to **search for new physics by comparing different data samples**
  - ➡ Evades the use of MC simulated data for background estimate, which has large uncertainties
  - ➡ Can be used in a **data-oriented model-independent search** with various datasets containing events with leptonic final-states

Lepton Flavor Violation

- Search for the **Higgs LFV decays**
  - $H \rightarrow \mu\tau \rightarrow \mu e 2\nu$
  - $H \rightarrow e\tau \rightarrow e\mu 2\nu$
- Final state: **1 electron, 1 muon and MET**



eμ/μe-symmetry assumption:

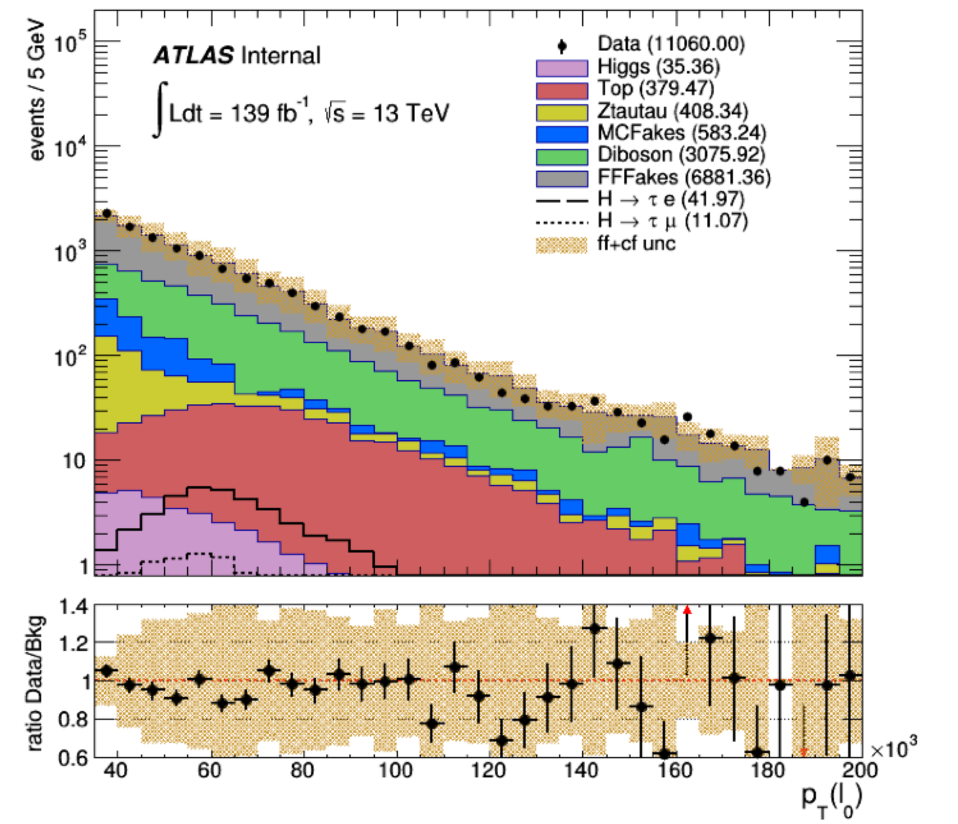
- SM processes **symmetric to switching between electron and muons**
- In signal events, the lepton from the τ decay (ℓ_1) **is softer** than the lepton from the Higgs (ℓ_0) → asymmetry in pT

eμ-symmetry method:

- Split data in 2 based on pT-ordering of the leptons: **eμ-sample** and **μe-sample**
- Compare them and search for a **deviation from the expected eμ/μe-symmetry**
- An asymmetry in the Higgs mass range is interpreted as signal

- The eμ-symmetry is invalidated **after detection**
- Electrons and muons are different objects, measured by different detector systems
  - ➡ Different detection efficiencies
  - ➡ Different fake rates
- Large efforts to estimate and correct for these effects

Fake Background Estimate



MC vs data agreement in the same-sign selection

Efficiency Correction

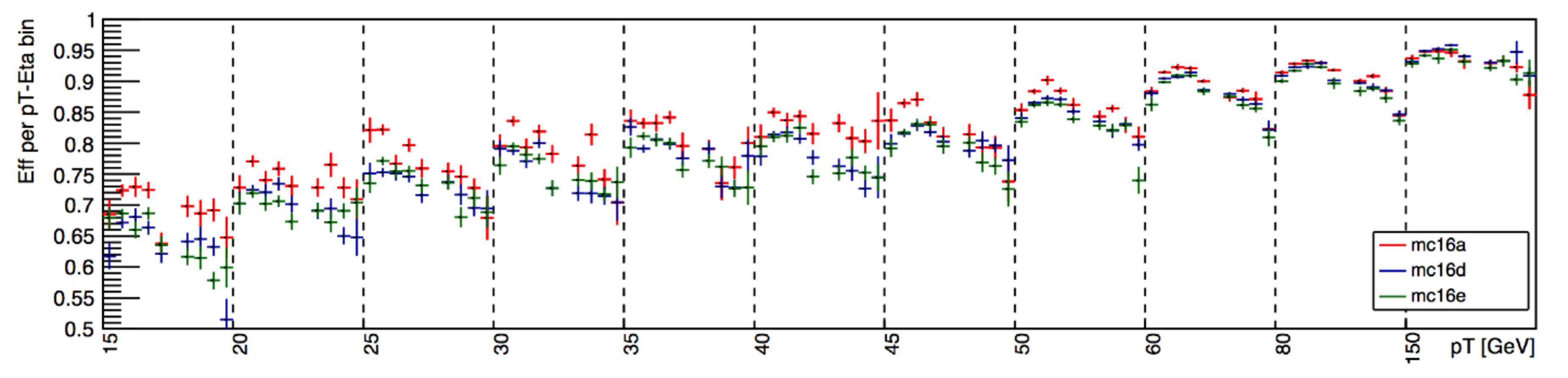
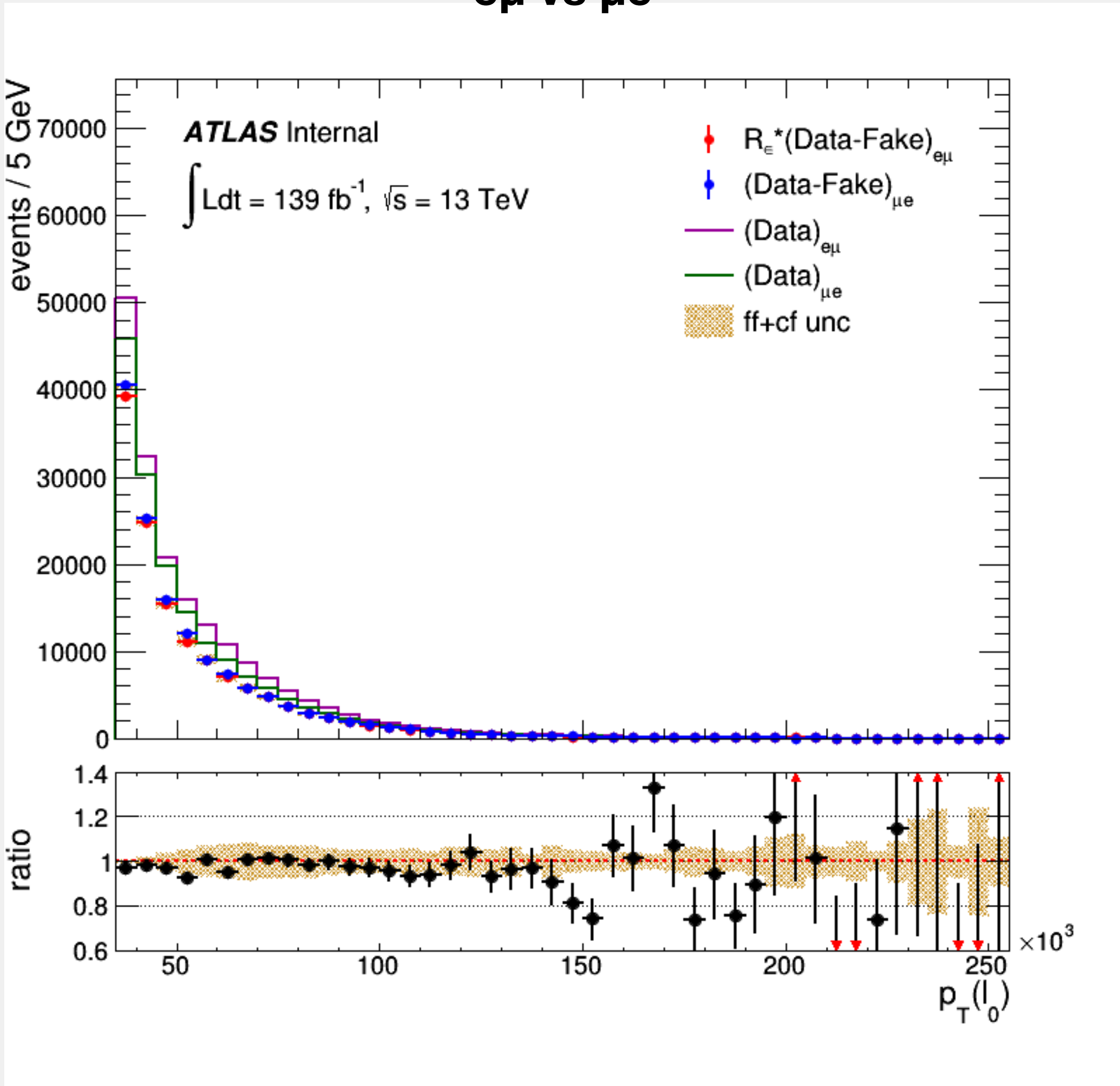


Figure 2: Measured electron MC efficiencies per data-taking year, and per p_T and η bin. mc16a, mc16d and mc16e are the MC campaigns corresponding to data-taking years 2015+16, 2017 and 2018 respectively. Using combined

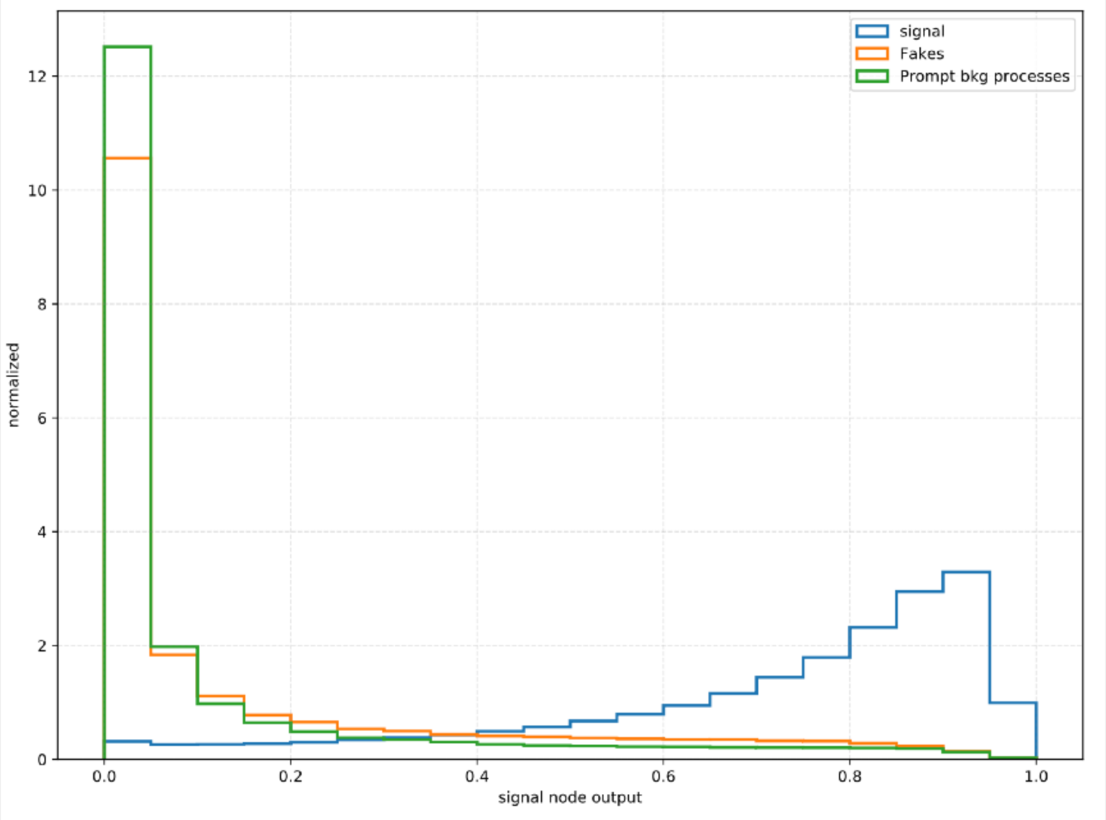
ATLAS Run2 Higgs LFV Search

- Analysis still ongoing but in its final stage
- Preliminary results hint that current bounds could be improved (0.28% for $H \to \mu\tau$ and 0.25% for $H \to e\tau$)

eμ vs μe



Neural Net for enhancing separation of signal and background



In collaboration with ATLAS analysis team, mainly from Freiburg University : Kathrin Becker, Valerie Lang, Tomas Jakoubek, Katharina Schleicher, Markus Schumacher (PI)

Outlook - General Search

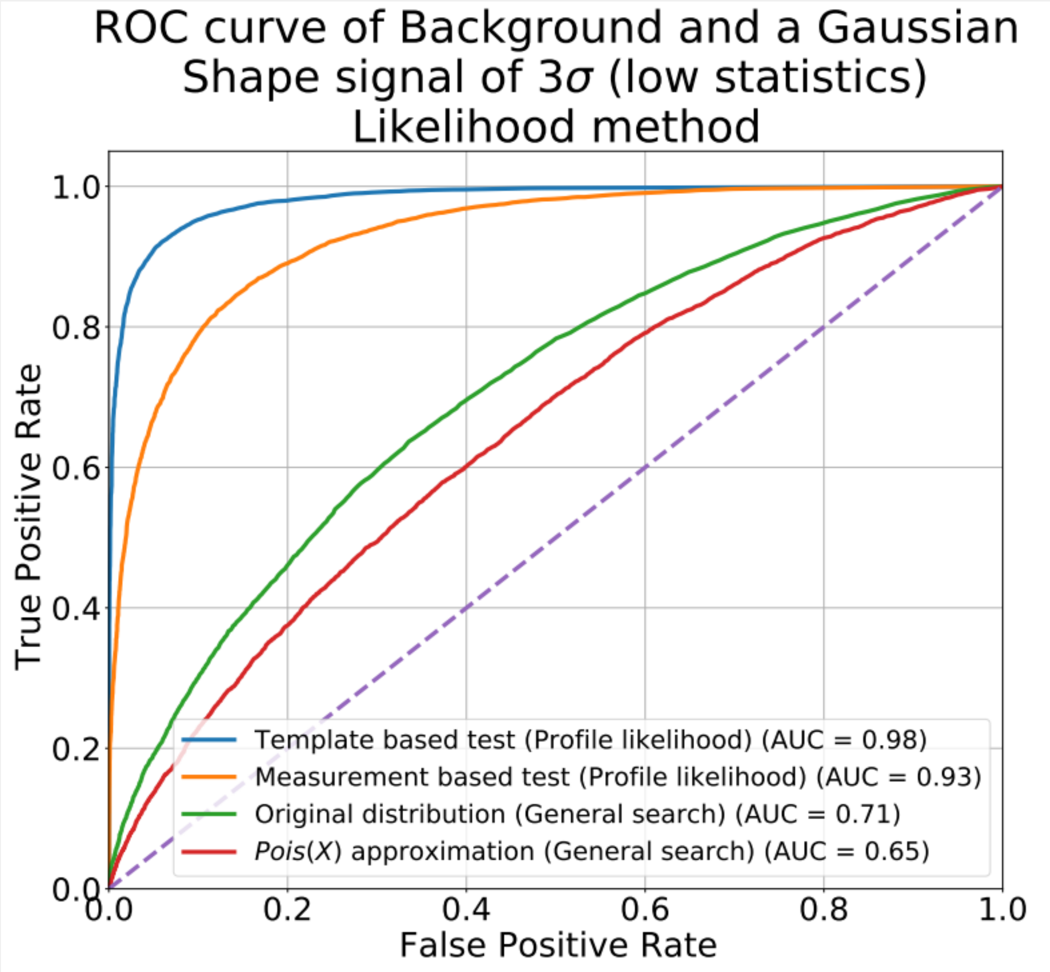
- H LFV search is theoretically well motivated
  - ➡ Showcase power of analysis method
- But any deviation from the expected eμ/μe symmetry is potentially new physics
  - ➡ Why restrict ourselves to the **tiny phase space region** where this specific signal contributes?

- Data-oriented search based on the eμ-symmetry method
  - ➡ Scan full phase-space for deviations from expected symmetry
  - ➡ Model independent
  - ➡ Not restricted to eμ vs μe, can be used for events with various leptonic final states e.g. ee vs μμ

Outlook - General Search

- Development of algorithm for general search is ongoing
  - ➡ How to quantify discrepancy between two **measured** samples in a model-independent way?

- In many scenarios this effort can be mapped into a search for discrepancies between two matrices
  - ➡ Preliminary results comparing sensitivity of simple model-independent Diff test to Profile Likelihood test with known signal
  - ➡ Implementation to simulated data for proof of concept in progress
  - ➡ Lots of room for improvement



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Thanks for Listening!