

Top Quarks, Higgs- Yukawa Couplings and Heavy Flavour ID

Markus Cristinziani, Elisabeth Schopf

CmF RA3 Kick-off Meeting, Bonn

7. Oktober 2025



Who are we

→ ATLAS Experiment Group with expertise in top & Higgs with a strong involvement in flavour tagging



Markus (group lead): top, ttH, top BSM, flavour ID



Elisabeth (Junior Faculty/AR): Higgs, quark-Yukawa, flavour ID



Diptaparna Biswas (Postdoc): ML, flavour ID, top



Vadim Kostyukhin (Postdoc): tracking & vertexing, Higgs, top



Gabriel Gomes (PhD student)



Katharina Voß (PhD student)



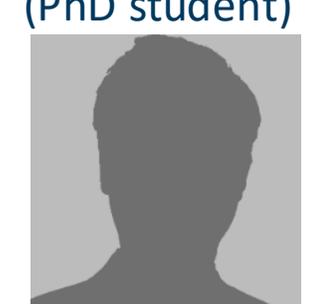
Adam Warnerbring (PhD student)



Nils Kregel (PhD student)



Inês Pinto (PhD student)



Austin Olson (PhD student)

+ other group members with focus on: B-physics, ATLAS Tracker Upgrade, Auger experiment, SHiP experiment

Throughout the presentation:



→ potentially interesting, generalisable topics for work within CmF RA3

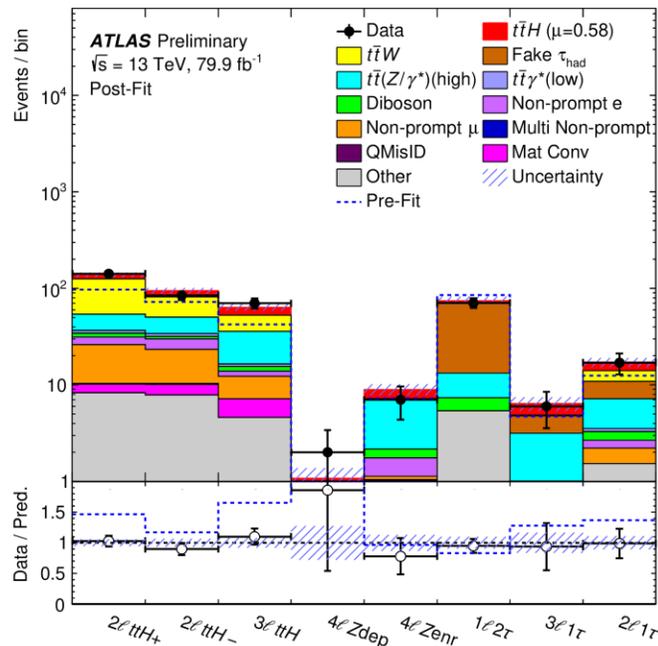


→ topics we are very interested in pursuing further within CmF RA3

Top Physics: “Legacy Expertise”

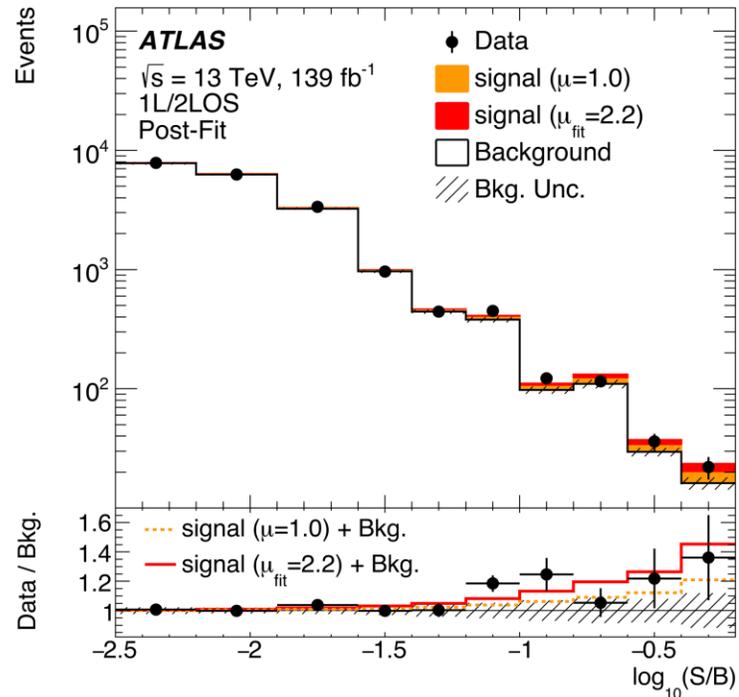
ttH multilepton

ATLAS-CONF-2019-045



Markus, Vadim + former PhD Students

4 tops JHEP 11 (2021) 118



Markus + former PhD Students

PhD theses of N. Bruscano, A. Sciandra, O. Öncel

- Covering full three and four lepton-analyses,
- e.g. fake lepton estimation in multi-lepton channels
 - e.g. BDT training for signal-vs-background

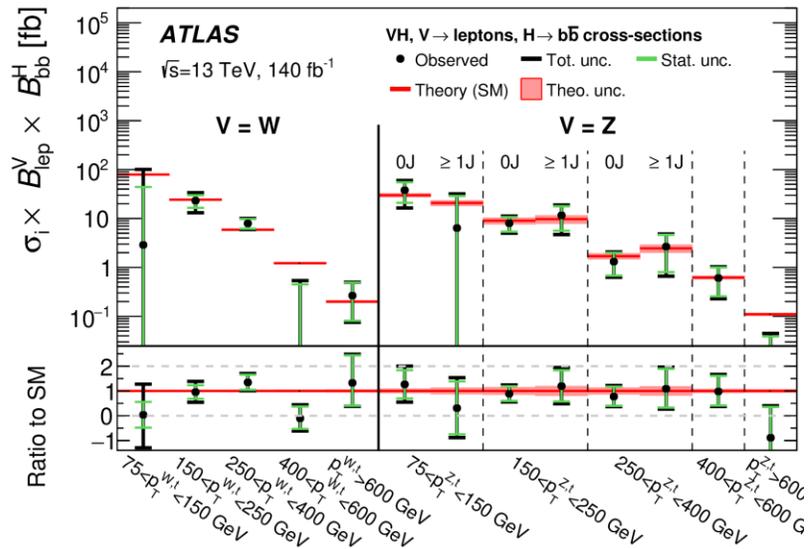
Major challenge in ttH multilepton: modelling of ttW background



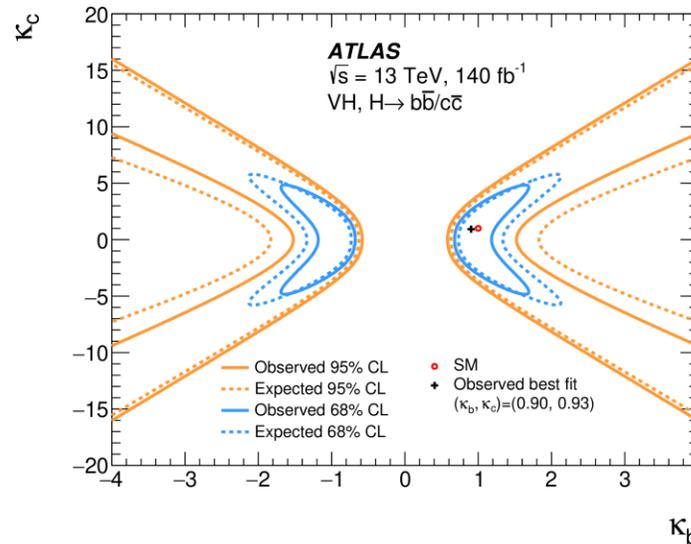
Higgs Physics: “Legacy Expertise”

VH,H→bb x-section

JHEP 04 (2025) 075



VH,H→bb/cc



Elisabeth + former PhD Students

Challenges:

- High-efficiency, high-accuracy simultaneous b+c-jet ID
- Modelling of ttbar and V+jets
- Signal uncertainties, esp. scale uncertainties in gg→ZH

Techniques:

- Standard ML for signal vs background
- Large amount of control regions to measure backgrounds
- Mitigation techniques for limited MC statistics (using ML)
 - Parametrisation of b-tagging and c-tagging efficiency (don't cut but reweight instead)
 - Parametrisation of 2-point uncertainties, e.g. Pythia vs Herwig (don't use alt. MC but reweight)



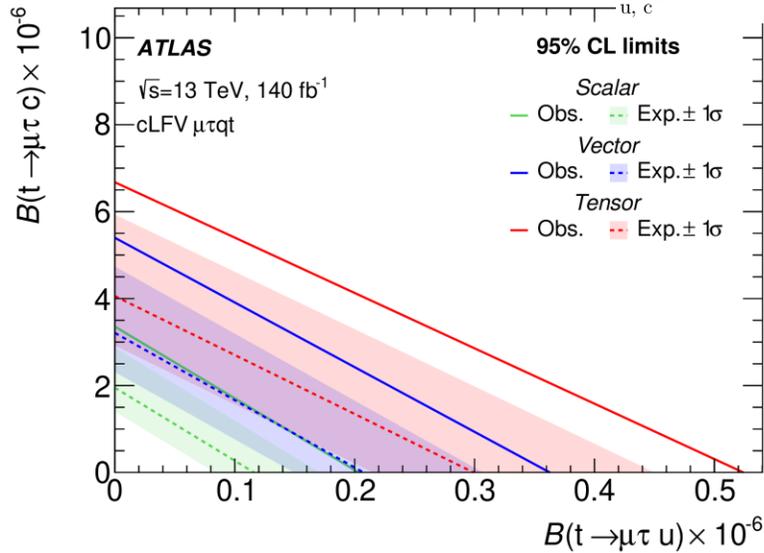
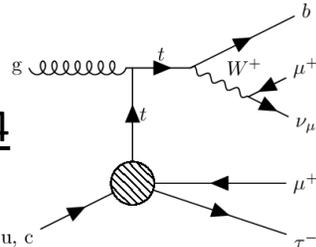
Top Physics: Search for New Physics

New BSM searches with top quarks in ATLAS



Charged lepton-flavour violation in top quark decays

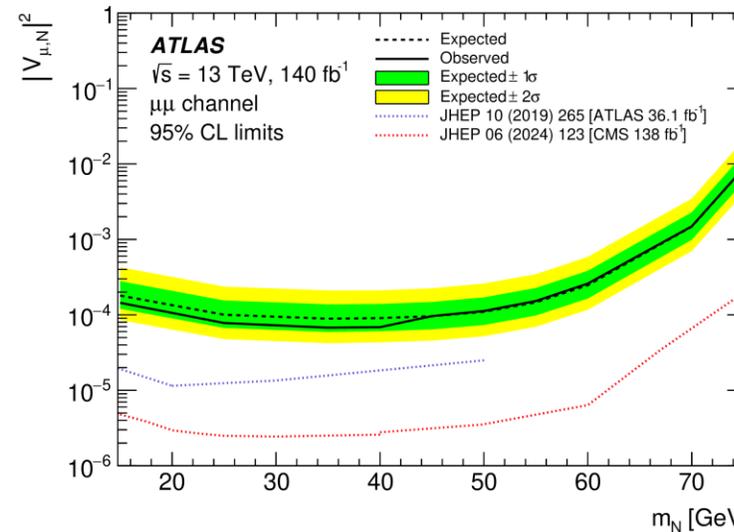
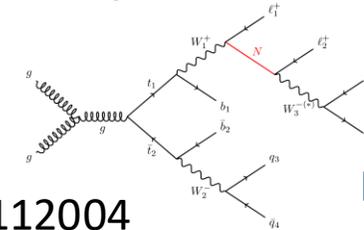
Phys. Rev. D 110 (2024) 012014



Markus, Gabriel + former PhD students

Search for Heavy Neutral Leptons in top quark decays

Phys. Rev. D 110 (2024) 112004



Markus, Diptaparna + former PhD students

First **cLFV** search in ATLAS (PhD thesis: C. Gottardo)

→ Now including cLFV in production: emu+1btag

→ Challenge: large ttbar background → new technique employed: multi-class BDT

First search for **HNL** in top-quark decays (full analysis was PhD thesis of T. Zhao)

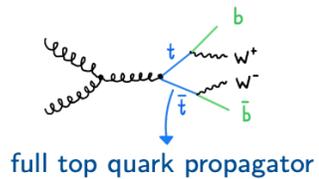
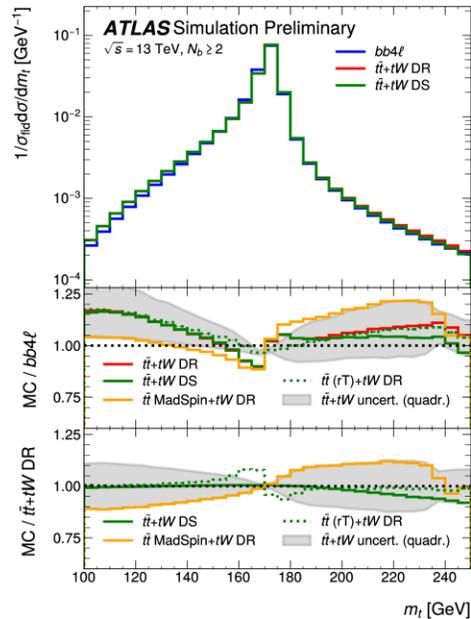


Top Physics: SM Measurements & Modelling

ongoing

Top mass & width measurement, incl. development of bb4l MC samples

→ Many modelling improvements from bb4l sample, e.g.



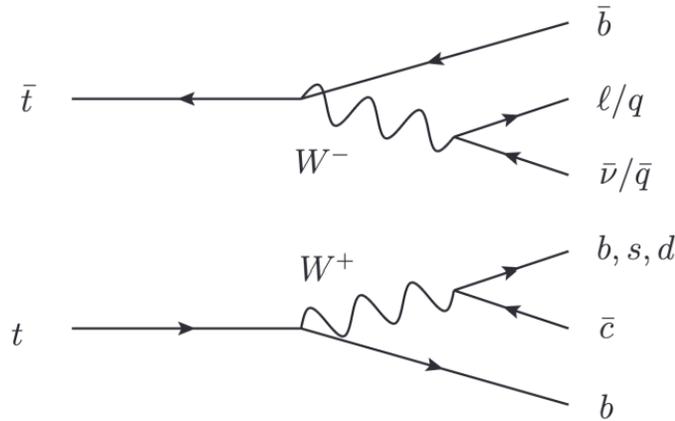
ATL-PHYS-PUB-2025-036

Markus, Katharina in collaboration with Andrea Knue (TUD)

Measurement of V_{cb} in W-boson decays from top quarks

- Extract $|V_{cb}|^2$ from branching-fraction ratio:

$$|V_{cb}|^2 = \frac{\text{BF}(W \rightarrow \bar{c}b)}{\text{BF}(W \rightarrow \bar{c}q)} = \frac{\text{BF}(t\bar{t} \rightarrow b\bar{c}b, \bar{b}l\bar{\nu})}{\text{BF}(t\bar{t} \rightarrow b\bar{c}q, \bar{b}l\bar{\nu})}$$
- Reduced model dependence vs. B-decay measurements



Markus, Elisabeth, Adam

First proof-of-principle analysis ongoing (exp. 25-30% precision)

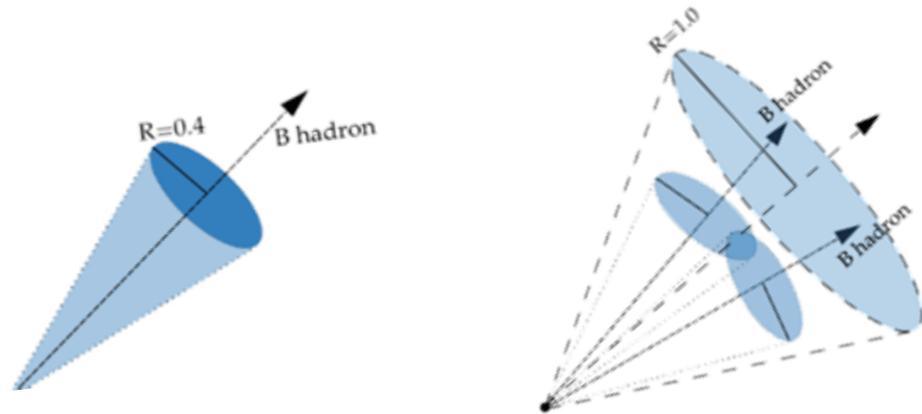
- Revisit with improved analysis techniques and incl. Run-3 data
- Main challenges: $tt+b/c$ background and can't rely on standard c-jet calibration techniques which use single-lepton $ttbar$

Upcoming [Mini-Workshop in Siegen](#) (Oct. 28/29)

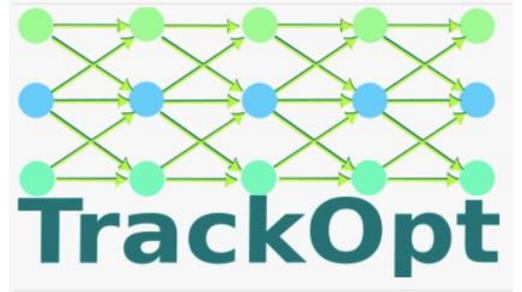


Tracking, Vertexing & Flavour Tagging

ongoing

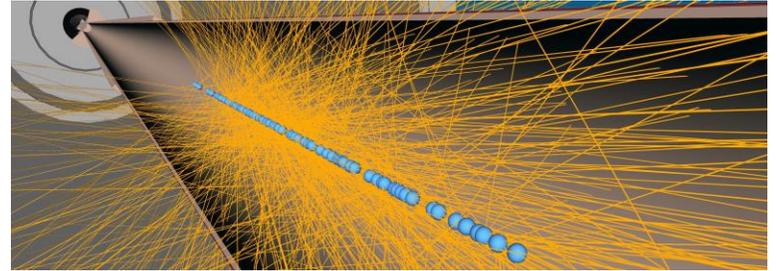


Also ongoing multi-disciplinary effort on track and vertex reconstruction with ML



Small-R and large-R jet tagging:

- Small-R: b or c or other (traditional)
 - New: b or c or tau or s or gluon or other
- ! → How far can performance be pushed? Theoretical foundations on labelling, jet composition, etc.?
- Large-R: $H \rightarrow bb$ or $H \rightarrow cc$ or top or QCD (traditional)
 - New: $H \rightarrow bb$ or $H \rightarrow cc$ or $H \rightarrow \tau\tau$ or top or W or QCD
- ! → Generalisable beyond large-R jet as an object? What other decay topologies would be interesting for (BSM) physics searches?

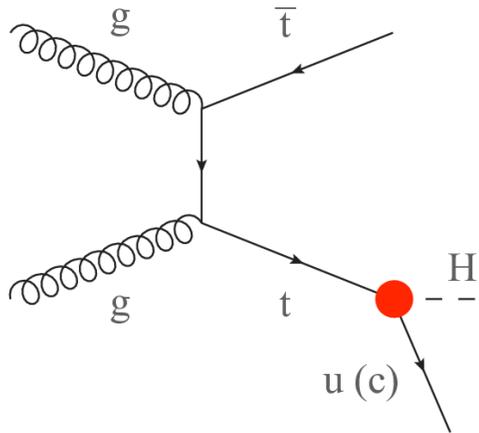


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Top & Higgs Physics – Future Directions

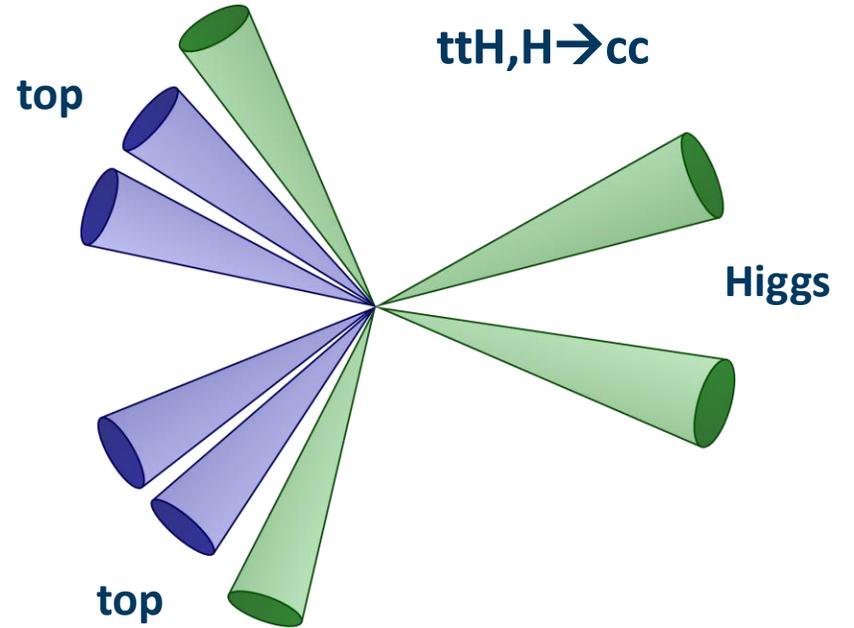
Ramping up

FCNC $t \rightarrow H(bb)c, H(bb)u$



- With new powerful flavour ID can push limit further ($<10^{-4}$)
- **Most promising ways to access $t \rightarrow H u$ channel experimentally?**
- **Interesting BSM models to probe? EFT interpretation?**

Markus, Elisabeth, Ines



- Competitive sensitivity to $VH, H \rightarrow cc$ reachable
- **Main challenge: modelling of $tt+X$ (mostly $tt+qq$) background** 
- **Lots of ttH expertise in our group \rightarrow future opportunities for CP measurements in Higgs; expansion to bbH ?** 

Markus, Elisabeth, Nils, Austin

Outlook

- Lots of expertise in top and Higgs measurements with a focus on lepton+jets final states, esp. lepton+multi-b and lepton+b+c
- ...paired with:
 - Strong involvement in development of flavour identification algorithms
 - Detailed Studies of $t\bar{t}$ modelling, incl. MC model developments and $t\bar{t}+X$ processes
- **Physics directions we are interested to explore in the context of CmF RA3:**
 - FCNC decays
 - CP-violation in $t\bar{t}H$ (potentially $b\bar{b}H$?)
- **Also other opportunities to work together on**
 - Flavour tagging, incl. theoretical foundations
 - Advanced machine learning methods, e.g. in the context of modelling or low level object reconstructions/regression
 - Improvement of (top) MC simulations