TECHNISCHE UNIVERSITÄT DRESDEN

INSTITUTE OF NUCLEAR AND PARTICLE PHYSICS

FSP ATLAS

ATLAS EXPERIMENT

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Background uncertainty estimation
in the search for a light CP-odd Higgs boson with ATLAS

Session T 82: Higgs, Di-Higgs II
DPG Spring Meeting Dresden, 22nd of March, 2023

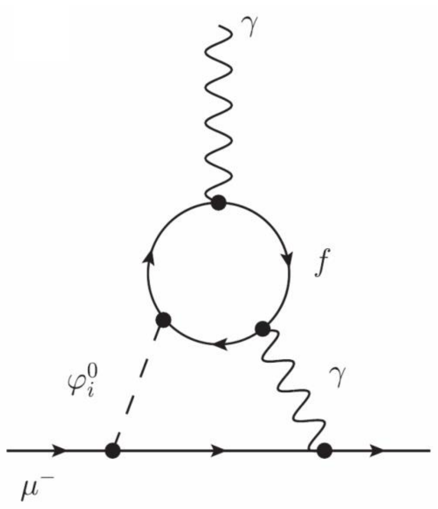
Analysis background

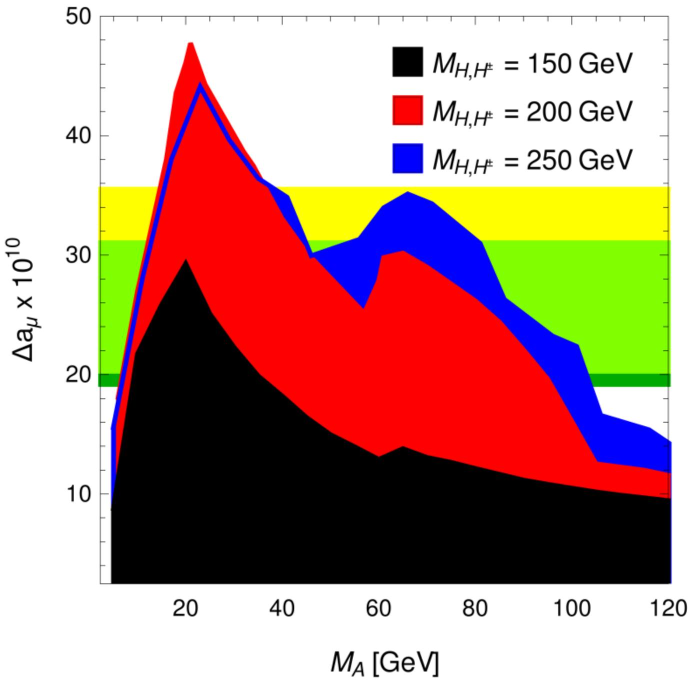
Motivation

Anomalous magnetic moment of the muon a_μ:
Deviation between experiment and SM

Flavour-aligned 2HDM

4 additional Higgs-like particles h, H^+, H^-, A
can explain a_μ deviation if CP-odd A is light





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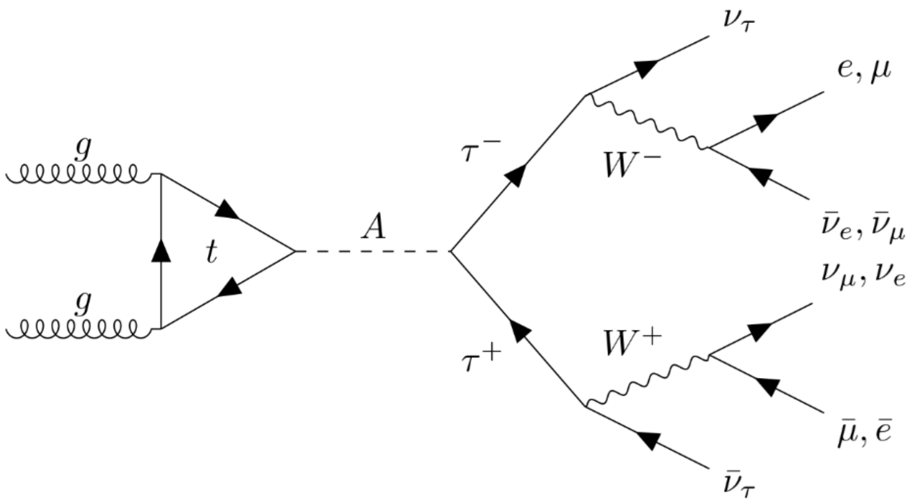
Analysis overview

Search for A boson

Production of A via ggF and top quark loop (without b association)

Decay 100 % to tau pairs

Search in channel $A \rightarrow \tau\,\tau \rightarrow e\,\mu\;(+\nu_e\nu_\mu\nu_\tau\nu_\tau)$



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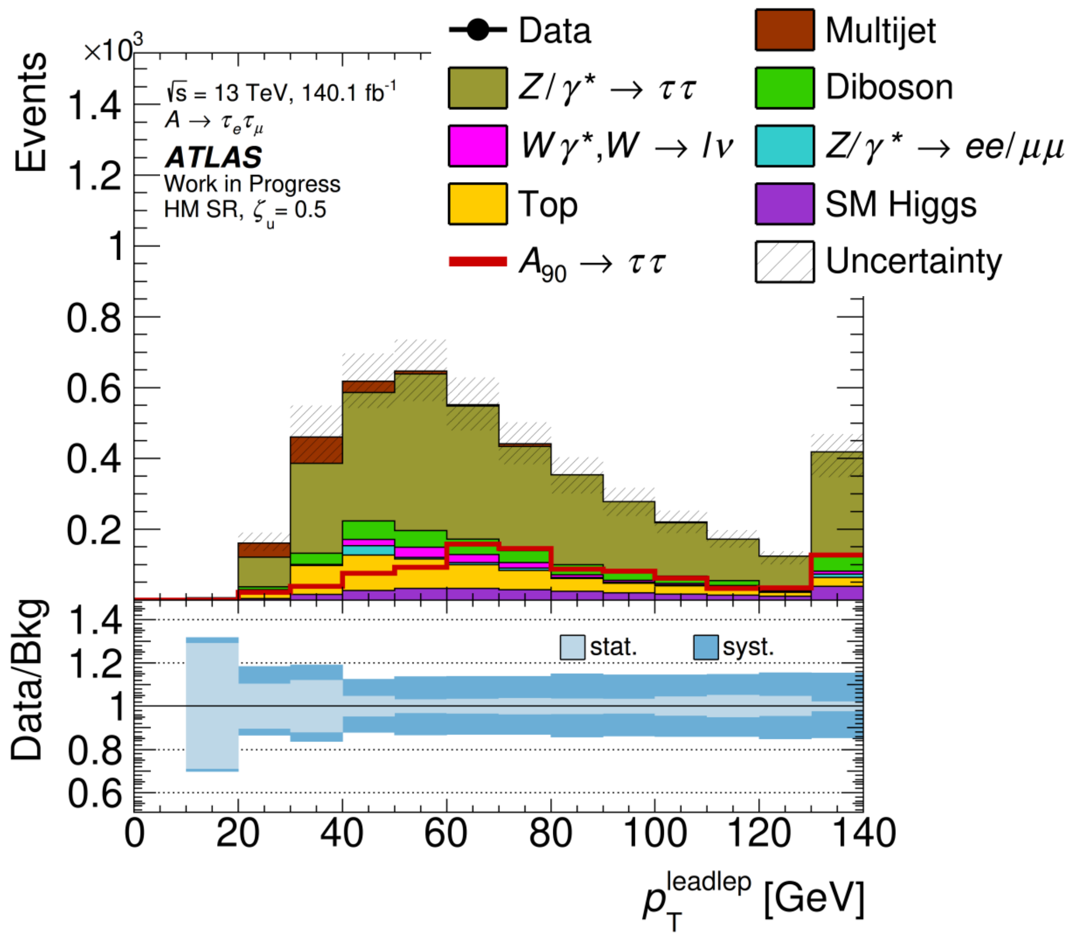
Background processes

- $Z/\gamma^* \to \tau\,\tau$
- Top (mainly $t\bar{t}$)
- Diboson (WW, ZZ, WZ)
- Multijet (misidentified QCD jets)

Non-QCD backgrounds from Monte Carlo simulations



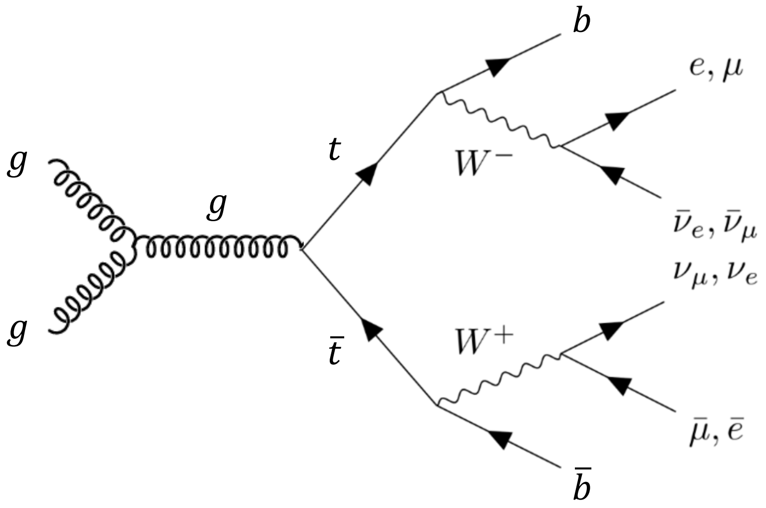
Top background

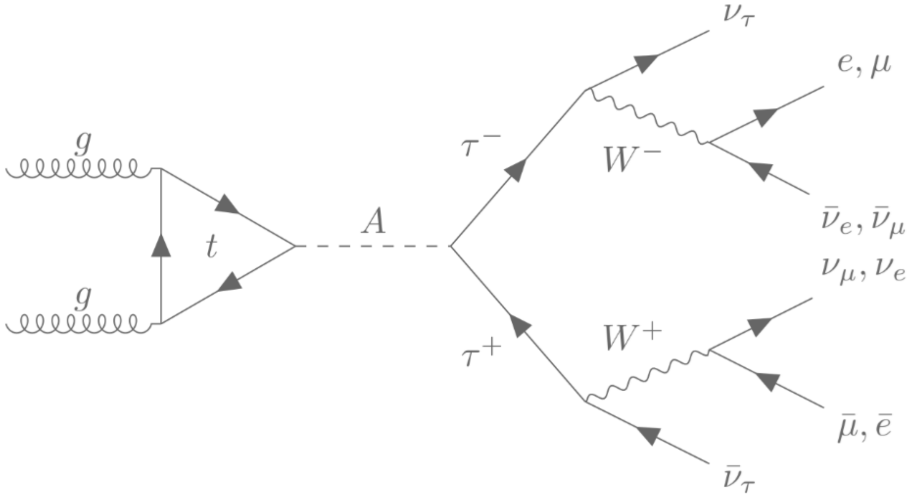
Top quark decay

Conversion via weak force into b, producing $e/\mu + \nu$

Cut to reduce background

B-veto: Reject all events with b-quark jets





Top background

Top quark decay

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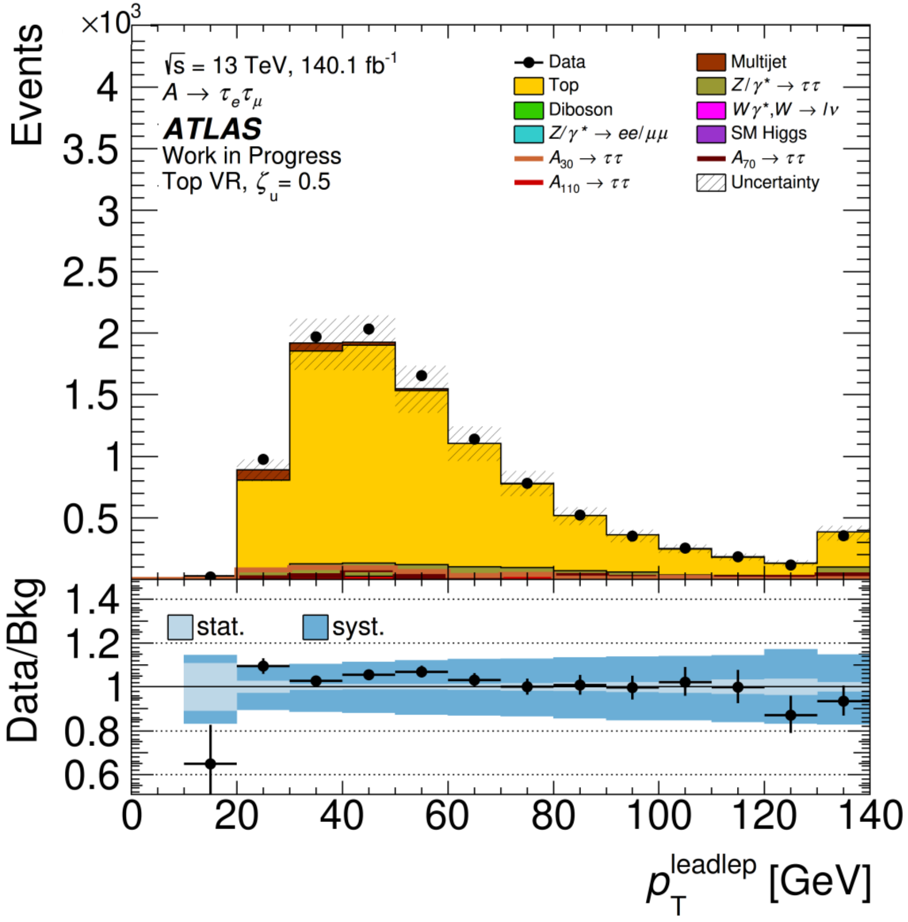
B-veto: Reject all events with b-quark jets

Validation region

Invert b-veto to b-tag

Higher number of top events
→ better for calculating relative uncertainties



Monte Carlo generators

Leading order (LO)

Minimal number of vertices, neglecting higher orders

Next-to leading order (NLO)

Allow for one extra loop or radiated particle

Parton shower (PS)

Repeated radiation and pair production

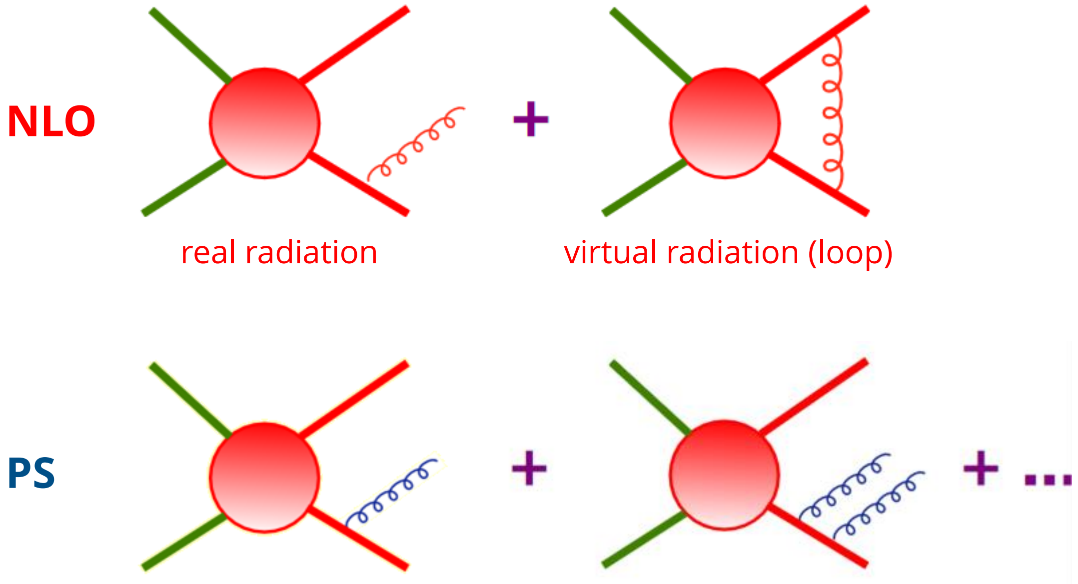
Falling energy scale

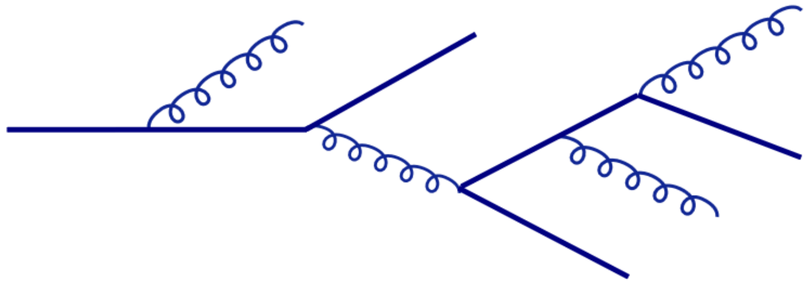
Factorization into a series of independent interactions

Matching

Prevent double-counting of NLO/PS overlap

Methods implemented in POWHEG / MC@NLO





Calculating uncertainties

Comparison with other samples

Swap out components of the generator setup

Herwig 7 instead of Pythia 8 for parton shower

MadGraph5_aMC@NLO instead of POWHEG-BOX for matrix element

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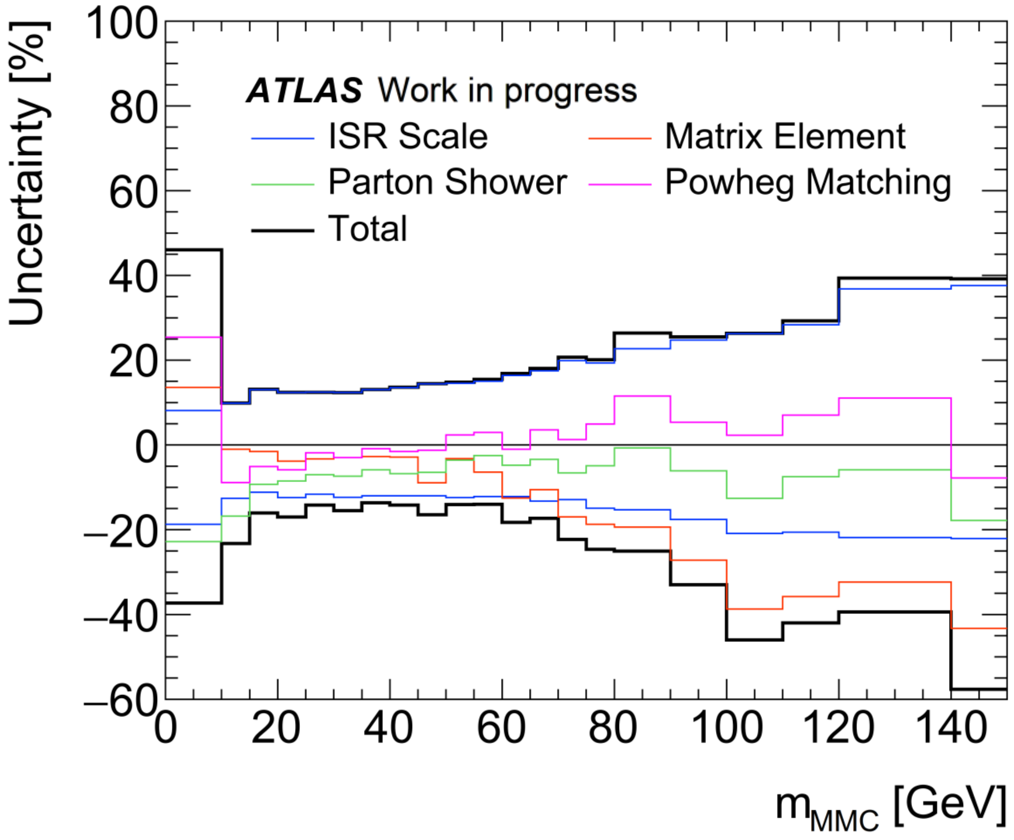
$t\bar{t}$ generator uncertainties



Calculating uncertainties

Comparison with other samples

Swap out components of the generator setup

Herwig 7 instead of Pythia 8 for parton shower

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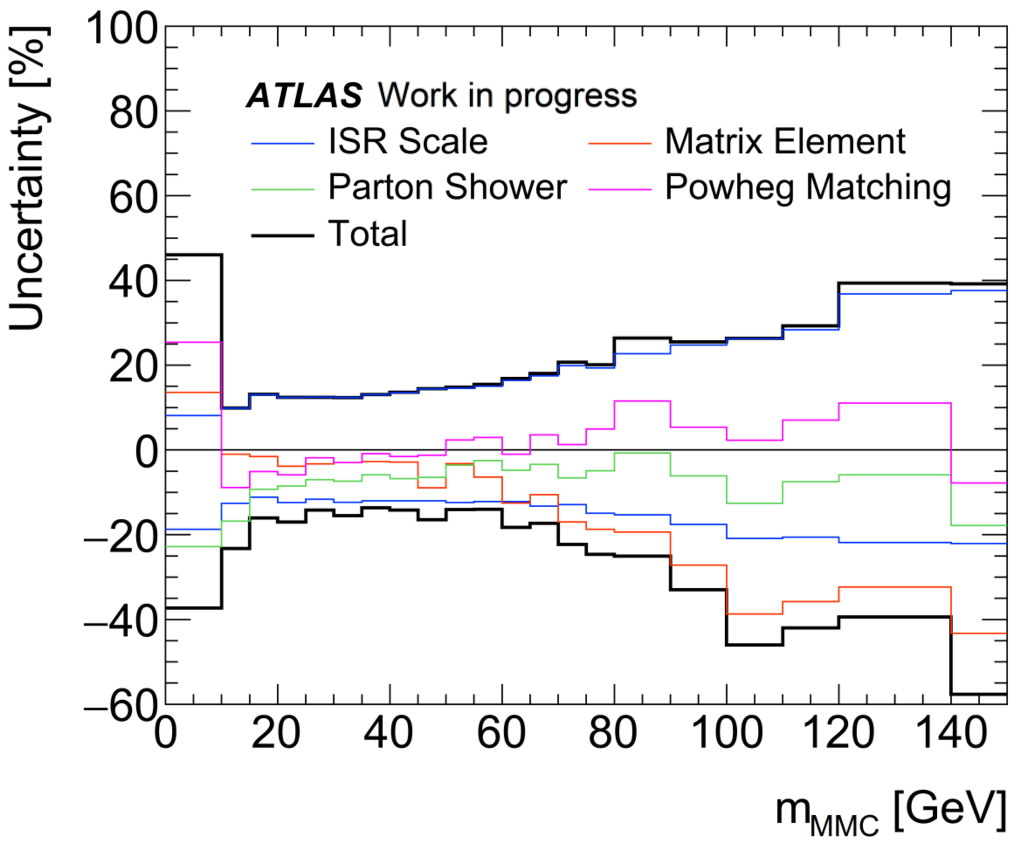
Comparison with different parameter values

Renormalization and factorization scales for initial state radiation (ISR) / final state radiation (FSR)
$(\mu_R, \mu_F) = (1, 1) \rightarrow (0.5, 0.5) \;/\; (2, 2)$

Damping parameter for Powheg matching
$h_{damp} = 1.5\, s_{top} \rightarrow 3.0\, s_{top}$

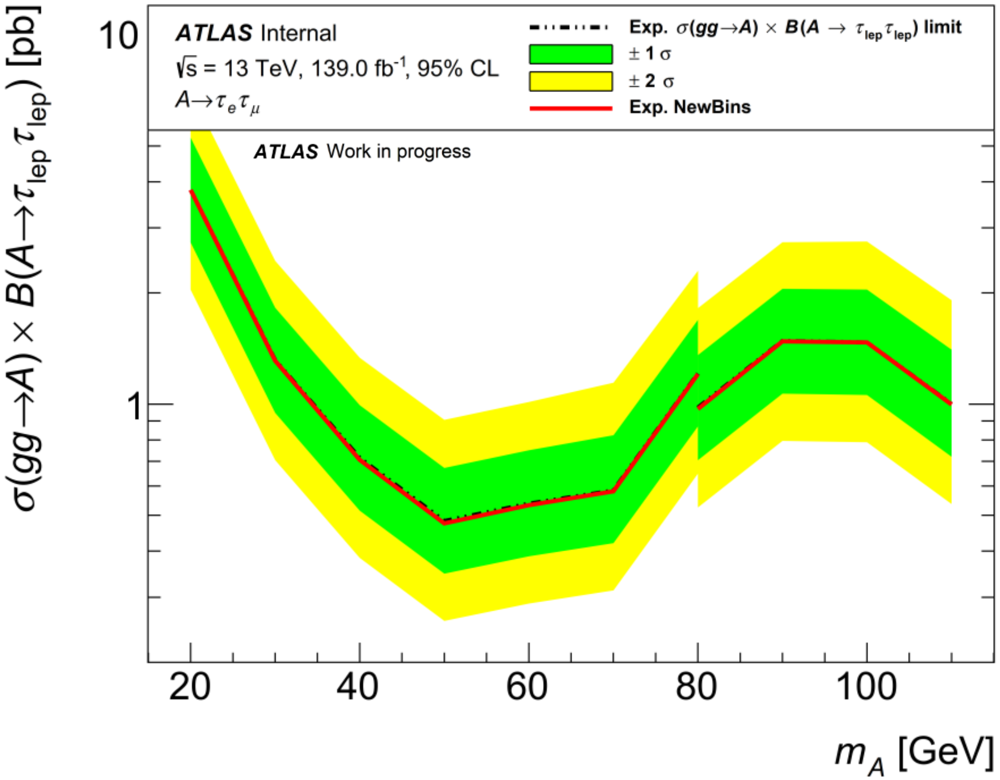
Implemented with alternative event weights

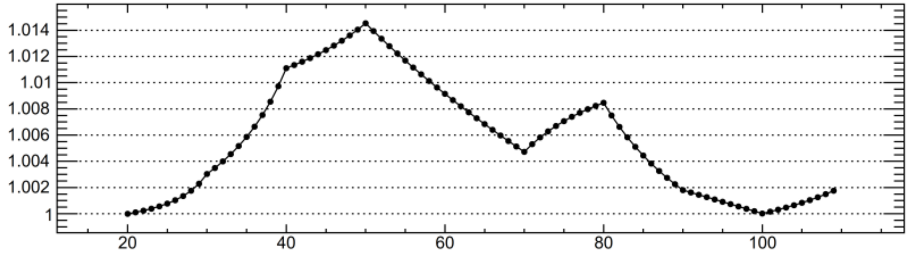
$t\bar{t}$ generator uncertainties



Effect on expected limits

$t\bar{t}$ generator uncertainties





Total theoretical $t\bar{t}$ uncertainty ~20-40%

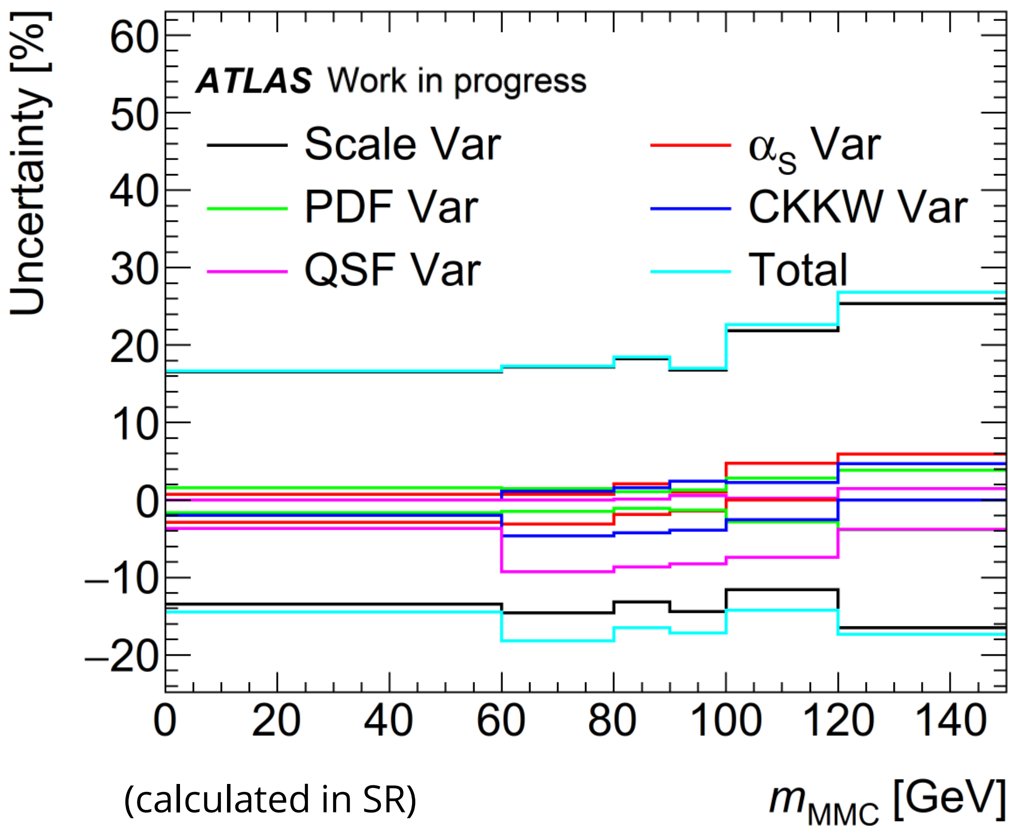
Larger than experimental systematics (~10%)

→ Okay, because background is small enough

Only weakening limits by max. 1.4%

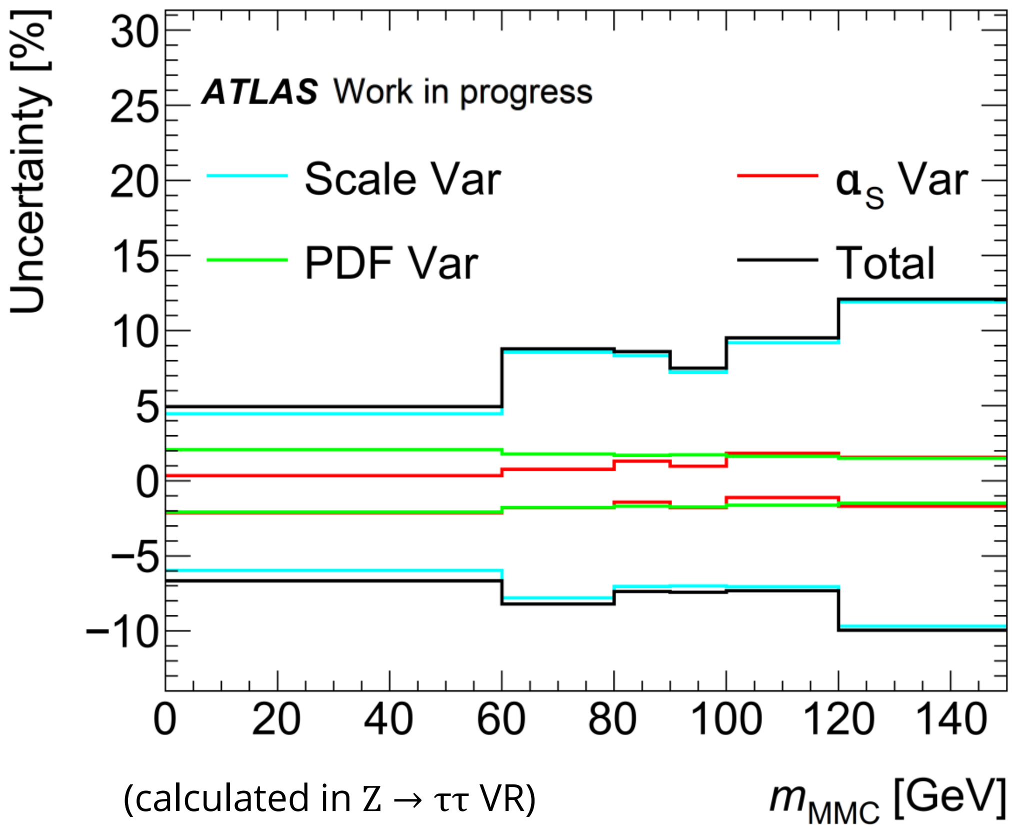
Uncertainties for Z→ττ and Diboson backgrounds

$Z \rightarrow \tau\tau$ generator uncertainties



(calculated in SR)

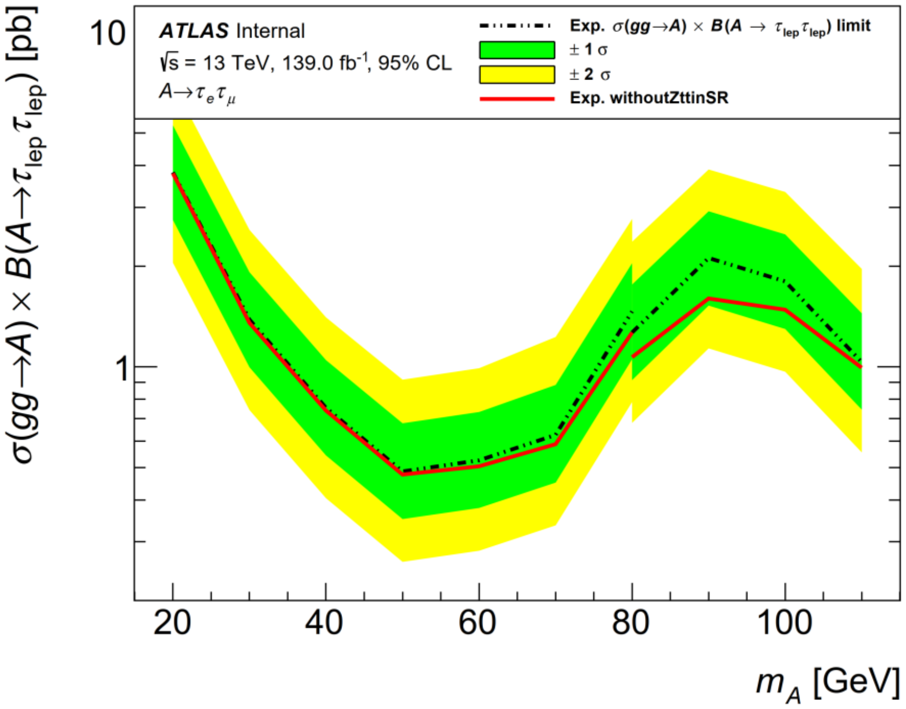
Diboson generator uncertainties

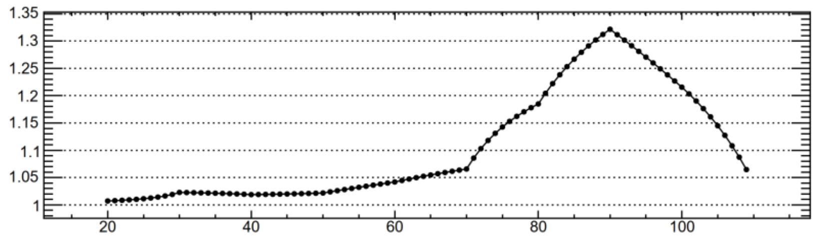


(calculated in $Z \rightarrow \tau\tau$ VR)

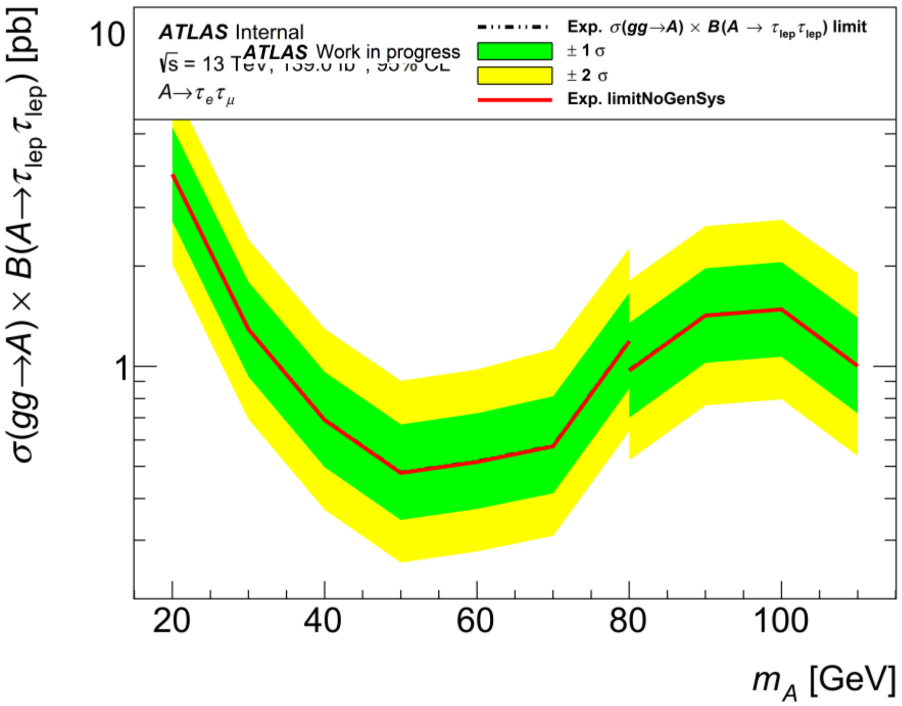
Uncertainties for Z→ττ and Diboson backgrounds

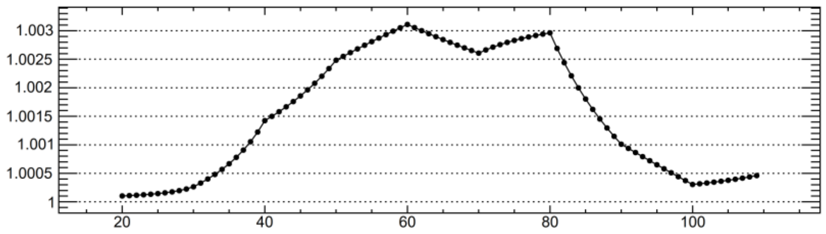
Z → ττ generator uncertainties





Diboson generator uncertainties





Summary

- **Analysis searching for A-boson in final state $e + \mu$**

- **Backgrounds include top decay, Z→ττ, weak bosons**

- **Estimate systematic uncertainties of Monte Carlo generators by comparing with variations**

- **Effect on expected limits varies with background size:**

  Top: max. 1.4%

  Diboson: max. 0.3%

  Z→ττ: max. 35%

Backup

Signal and background expectations in signal region