Fiducial volumes and model dependence
$H \rightarrow \gamma\gamma$ and $H \rightarrow ZZ^* \rightarrow 4l$

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HXSWG Fiducial Task Force
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Introduction

Particle level definitions define what is being unfolded to

$$c_i = \left| \frac{N_i^{det}}{N_i^{ptcl}} \right| \qquad \sigma_i = \frac{N_i}{c_i \times \int L\, dt}$$

See Bijan's talk for the actual unfolding and evaluation of the systematics

Model dependence introduced by this factor when the detector and particle level definitions are different

Particle level definitions are similar to detector level to minimise this – although some deviations may be tolerated in order to make the fiducial volume easier to interpret

ATLAS NOTE

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Proposal for particle-level object and observable definitions for use in physics measurements at the LHC

The ATLAS Collaboration

$H \rightarrow ZZ^* \rightarrow 4l$ fiducial volume

Fiducial volume

- Born level leptons
  - μ $p_T > 6$ GeV , $|\eta| < 2.70$, no iso requirement
  - e $p_T > 7$ GeV , $|\eta| < 2.47$, no iso requirement
- Require two same-flavour-opposite-sign (SFOS) lepton pairs
  - Leading pair: mass m_{12} closest to m_Z
  - Subleading pair: mass m_{34} next closest to m_Z
- Lepton p_T
  - $p_T > 20, 15, 10$ GeV for leading, subleading, subsubleading
- Z mass constraints
  - $50 < m_{12} < 106$ GeV
  - $12 < m_{34} < 115$ GeV
- Lepton separation
  - $\Delta R(l_i,l_j) > 0.1$ (0.2) for same (different) flavour leptons
- J/ψ veto
  - $m(l_i,l_j) > 5$ GeV for all SFOS pairs
- Higgs mass window
  - $118 < m_{4l} < 129$ GeV

Born level = take the truth lepton before it radiates any photons. Alternative is lepton dressing. Studies found that the difference in fiducial acceptance < 0.5 %.

Selections in orange are different at detector and particle level

Selections in blue are identical at detector and particle level

ATLAS recommendation stated in earlier note is to not apply particle level isolation to leptons as detector level iso cuts have a high efficiency

Comments on $H \rightarrow ZZ^* \rightarrow 4l$ fiducial volume

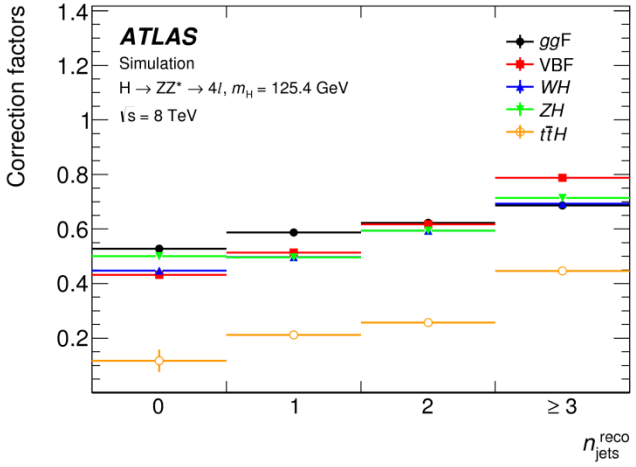
- Jets
  - Clustered from all stable final state particles (except μ,ν)
  - Anti-kt4, $p_T > 30$ GeV, $|y| < 4.4$
  - ΔR to electrons > 0.2
- Events are vetoed if they contain a $Z \rightarrow \tau\tau$
  - For comparison to theory calculations which only consider $Z \rightarrow ee$, $\mu\,\mu$
  - Events with $Z \rightarrow \tau\tau$ would have made 0.5 % contribution to fiducial acceptance
- Lepton track and calorimeter isolations were applied at reco level but not at particle level (for simplicity of fiducial volume)
  - This has a significant impact on model dependence which will be propagated through to the systematic uncertainty
  - **Run-1 statistically limited – even with this effect the systematics are not important, so simplicity of fiducial volume motivates choice not to use particle level isolation**

ggF	VBF	WH	ZH	ttH
0.553	0.572	0.535	0.551	0.417

Correction factors in total fiducial volume

Comments on H → ZZ* → 4l fiducial volume

Case when the difference in correction factors is important



ttH correction factors very different in all nJet bins

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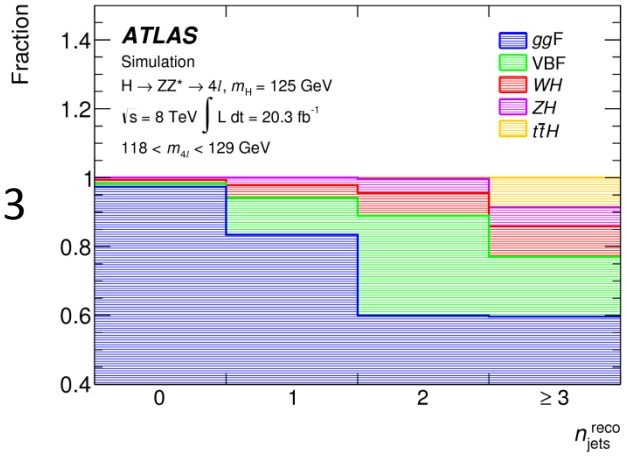

ttH has a signficant contribution to the bin nJet ≥ 3

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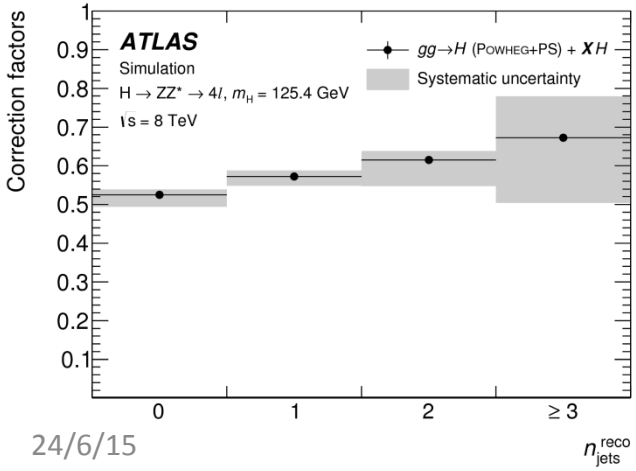


Systematic significant in nJet ≥ 3 bin

Thanks to Sarah for these plots!

$H \rightarrow \gamma\gamma$ fiducial volume

Fiducial volume

- Photons
  - $p_T > 25$ GeV , $|\eta| < 2.37$
  - Isolated (see next slide)
- Dressed leptons
  - μ $p_T > 15$ GeV , $|\eta| < 2.47$, $\Delta R(\gamma) > 0.4$, no isolation applied
  - e $p_T > 15$ GeV , $|\eta| < 2.47$, $\Delta R(\gamma) > 0.4$, no isolation applied
- Diphoton system
  - Two highest p_T photons
- Mass constraints
  - $m_{\gamma\gamma} \in [105,160]$ GeV
  - $p_T / m_{\gamma\gamma} > 0.35$ (0.25) for leading (subleading) photon

Consider stable final state particles which did not originate from hadron → particle or from hadron → τ → particle

Dressed = recombine lepton with all photons in a cone of $\Delta R < 0.1$. Alternative is Born leptons.

Crack region $1.37 < |\eta| < 1.56$ is excluded at reco level only – treated as a detector inefficiency

Additional objects

- Jets
  - $p_T > 30$ GeV , $|y| < 4.4$
  - Anti-kt4 jets from all particles except μ,ν
  - $\Delta R(e) > 0.2$ and $\Delta R(\gamma) > 0.4$
- Missing E_T
  - $\Sigma \underline{p_T}(\nu)$

Comments on H → γγ fiducial volume

➢ Truth isolation

- Photons are required to be isolated at reco level
- It was found that applying a corresponding particle level isolation significantly reduced dependence on physics model
  - ➢ Fiducial region correction factor up to 40 % higher in ttH with no truth iso
  - ➢ Spread of all production mechanisms around < 6 % with truth iso

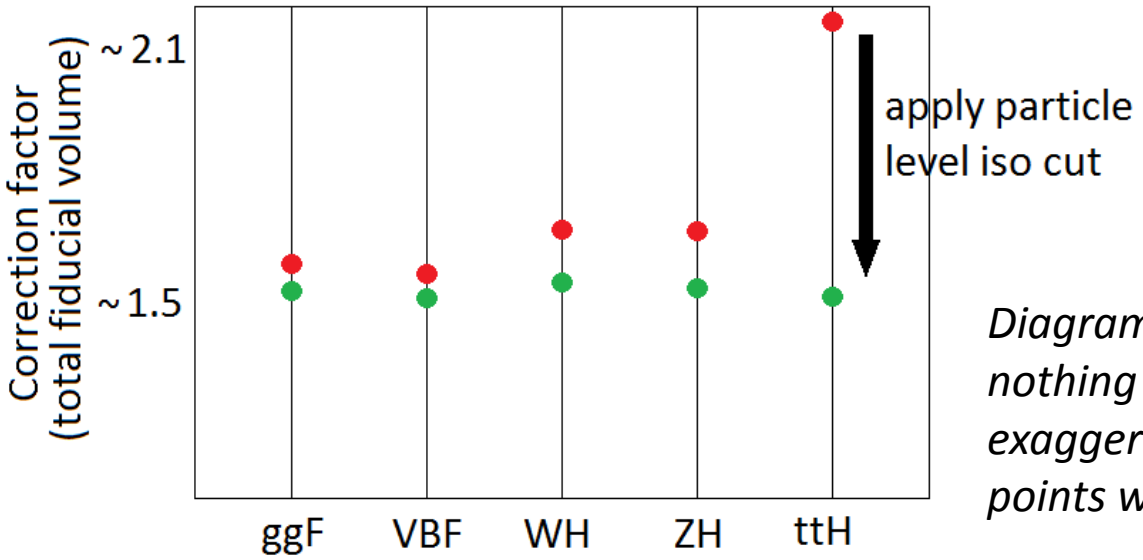
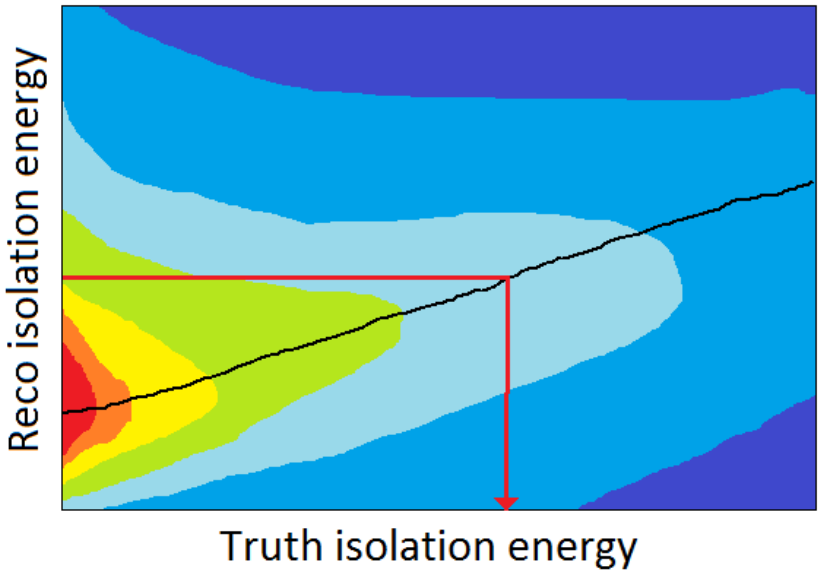


Diagram of real plot – nothing has been exaggerated but take exact points with pinch of salt

Comments on H → γγ fiducial volume

- Truth iso = the 4-vector sum of particles within a cone of R < 0.4, excluding μ,ν, then taking the E_T
- Cut value was determined by pairing truth and reco photons, plotting their isolation energies, and profiling slices of this 2D distribution to map 6 GeV reco onto 14 GeV truth (*right*)



- Truth isolation
  - Reco 6 GeV calorimeter iso cut mapped to 14 GeV truth iso cut
  - A track iso cut also applied at reco, no corresponding truth cut
- Extra fiducial volumes included which apply additional criteria in order to enhance certain physics
  - Jetty events $N_{jets} \geq 1,2$
  - VBF loose at least two jets with $m_{jj} > 400$ GeV and $|\Delta y(jj)| > 2.8$
  - VBF tight VBF loose + $|\Delta\phi(\gamma\gamma,jj)| > 2.6$
  - Leptony events $N_e + N_\mu \geq 1$
  - DM enhanced $E_T^{miss} > 80$ GeV limits set

Summary and outlook

- Particle level definitions defined to be close to detector level
  - Avoid phase space extrapolations during unfolding which introduce model dependence by assuming shapes of distributions
- Other important considerations are
  - Independence wrt physics model (case for photon iso)
  - Simplicity of fiducial volume and ability to compare to theory (case for lepton iso)
- Things which can be looked at
  - Different photon isolation definitions, e.g. Jet veto
  - Run-1 combination allowed μ,ν into jet finding