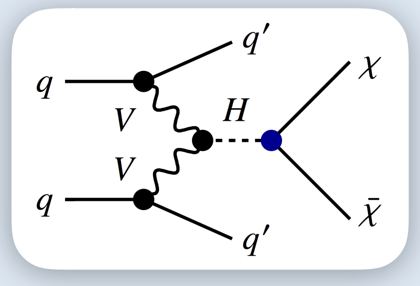
Search for invisibly decaying Higgs bosons produced in vector boson fusion with ATLAS in Run 2

EPS-HEP2021

ATLAS-CONF-2020-008

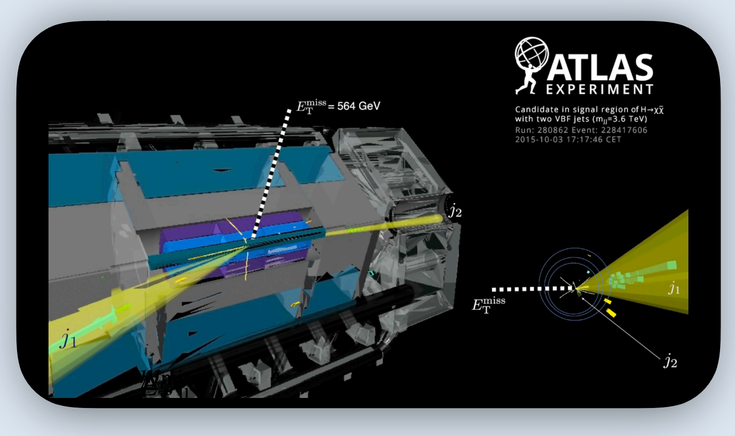
Introduction



- Astrophysical measurements strongly imply existence of dark matter (for example in form of WIMPs χ)
- Higgs boson might act as portal to dark sector
- LHC signature: invisibly decaying Higgs bosons
- Standard Model: $H \to ZZ \to 4\nu$ with BR=0.12 %
- Use full Run 2 data set (139 fb^{-1}) collected with ATLAS detector
- Important improvements w.r.t. to previous iterations: forward pile-up rejection, increased MC statistics, more data, improved signal acceptance and background rejection, improved Rebalance and Smear method for multijet estimate

Signal

- VBF Higgs boson production most sensitive channel: two high-energetic jets with large rapidity gap allows for background rejection
- Signal expected at large $E_{\mathrm{T}}^{\mathrm{miss}}$



- Important signal region selections:

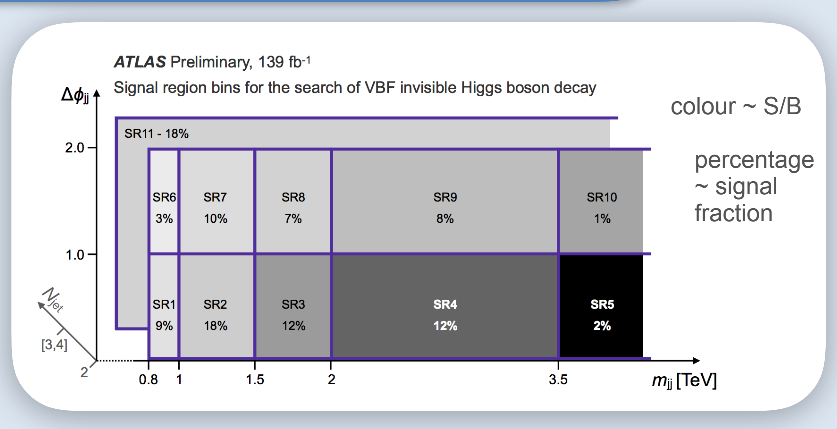
$E_{\mathrm{T}}^{\mathrm{miss}} > 200$ GeV	no leptons	$fJVT_{1,2} < 0.5$	$\eta_0 \cdot \eta_1 < 0$
$H_{\mathrm{T}}^{\mathrm{miss}} > 180$ GeV	no photons	$p_{\mathrm{T},1} > 80$ GeV	$\Delta\phi_{jj} < 2$
$2 \leq n_{\mathrm{jet}} \leq 4$	$m_{jj} > 800$ GeV	$p_{\mathrm{T},2} > 50$ GeV	$\Delta\eta_{jj} > 3.8$

- Allow for initial and final state radiation ($n_{\mathrm{jet}} = 3{,}4$) with centrality C and m_{rel} cut

$$C_{\mathrm{jet}=3,4} = \exp\left(-\frac{4}{(\eta_1-\eta_2)^2}\cdot\left(\eta_j - \frac{\eta_1+\eta_2}{2}\right)^2\right) < 0.6$$

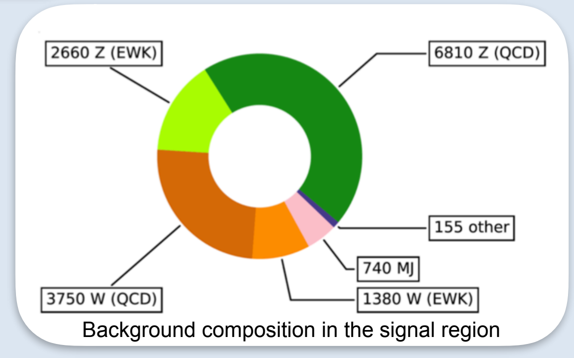
$$m_{i=3,4,\mathrm{rel}} = \min\{m_{1i}, m_{2i}\}/m_{jj} < 0.05$$

- Signal region divided in m_{jj}, n_{jet} and $\Delta\phi_{jj}$ to enhance signal sensitivity
- Most sensitivity at large m_{jj}

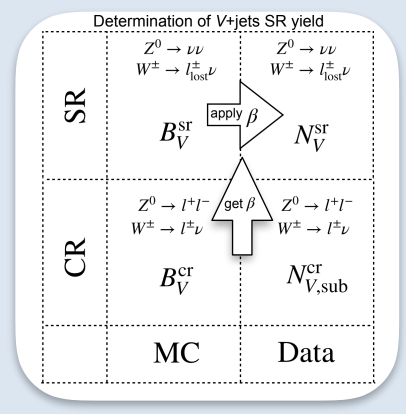


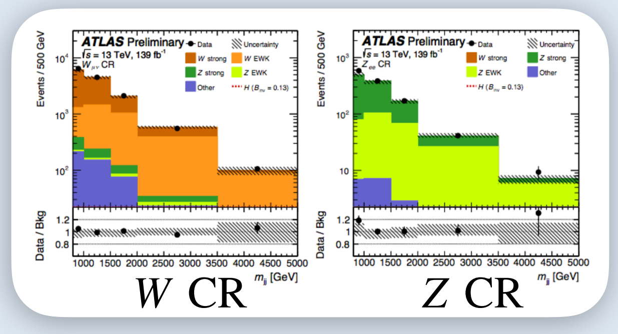
Backgrounds

- Main backgrounds are V+jets processes: $Z \to \nu\nu$ and $W \to l_{\mathrm{lost}}\nu$ both QCD and EWK production
- Reduced Monte Carlo statistical uncertainty by means of importance sampling w.r.t. m_{jj}
- CRs with one and two identified leptons used to constrain V+jets backgrounds
- Extrapolate from CR to SR with independent scale factors β (ratio data/MC) for W and Z

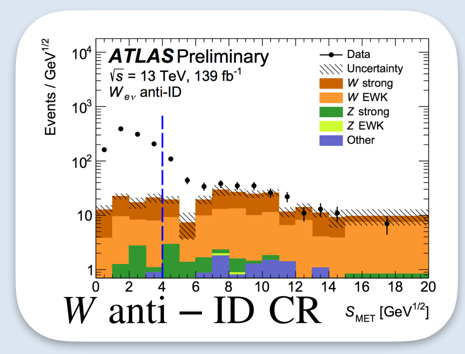


Background composition in the signal region

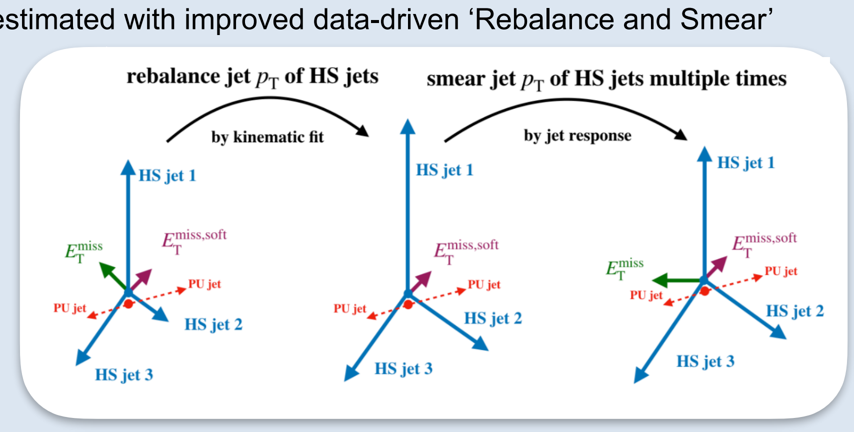




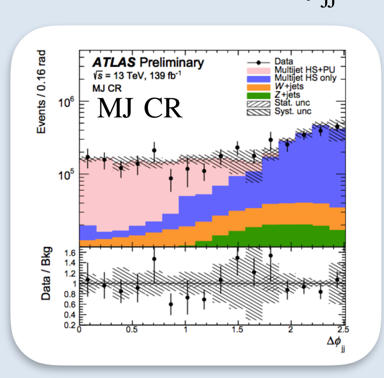
- Electron fakes in W CR via template fit in anti-ID CR:
- Use MET significance $S_{\mathrm{MET}} > 4\sqrt{\mathrm{GeV}}$ as discriminator of fake-e and e
- Measure ratio R of high to low S_{MET} in fake-enriched anti-ID CR
- Scale fake-e in W CR by applying R in low S_{MET} W CR

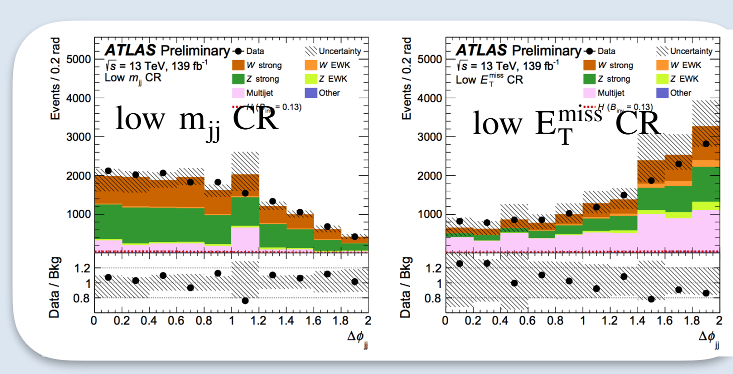


- Multijet (MJ) background expected to be small but important due to large uncertainties
- MJ background estimated with improved data-driven ‘Rebalance and Smear’



- Split MJ background into HS-only and HS+PU topology, normalise fractions in MJ CR in $\Delta\phi_{jj}$
- Final prediction obtained in $E_{\mathrm{T}}^{\mathrm{miss}}$-triggered data in low m_{jj} and low $E_{\mathrm{T}}^{\mathrm{miss}}$ CRs



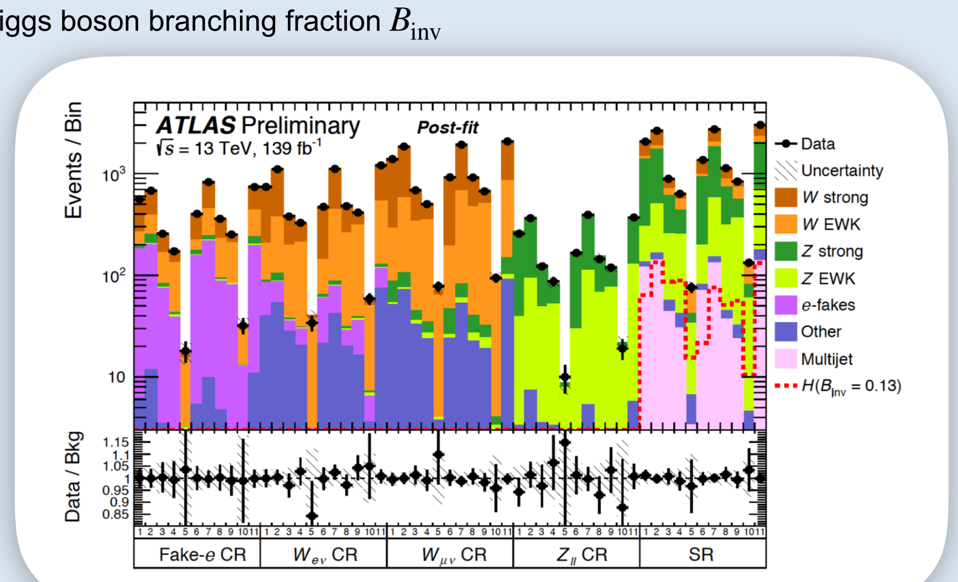


Results

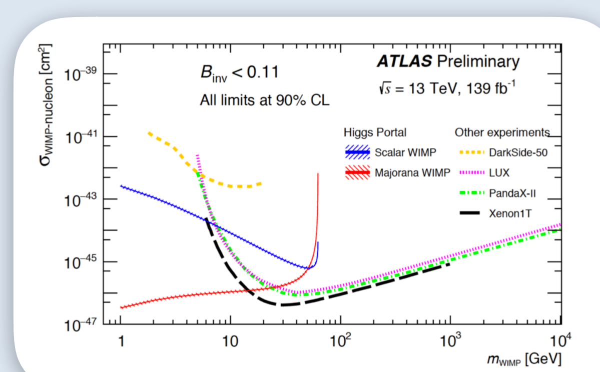
- Profile maximum likelihood fit in SR and CRs
- In absence of signal, set 95% CL upper limit on invisible Standard Model Higgs boson branching fraction B_{inv}
- Observed and expected: **13 %**
- Statistics and multijet modelling dominant uncertainties

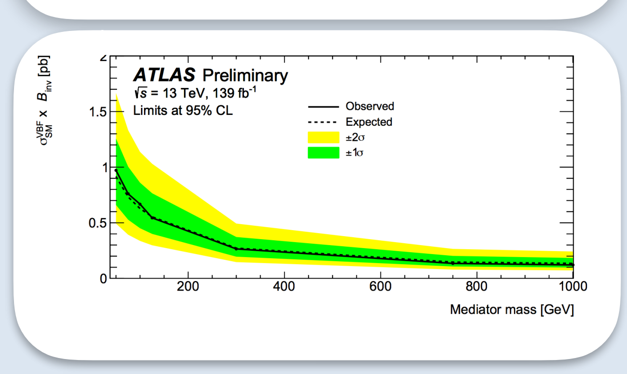
Impact of uncertainties

Source	Δ [%]
Jet energy scale	1.8
Jet energy resolution	5.5
Lepton	4.6
Other	1.9
Multijet	7.0
V+jets theory	1.6
Signal theory	1.0
MC stats.	7.9
Data stats.	17.3



- Comparison to direct dark matter searches by interpretation in terms of WIMP-nucleon cross section
- Complementarity of direct searches and LHC searches for exclusion regions
- Also obtain upper limit on $\sigma \cdot B_{\mathrm{inv}}$ for other scalar mediator particles as a function of its mass: 0.97 at 50 GeV to 0.12 for 1 TeV





Arthur Linß

ErUM-FSP T02 ATLAS
HELMHOLTZ SPITZENFORSCHUNG FÜR GROSSE HERAUSFORDERUNGEN
DESY
ATLAS EXPERIMENT