ATLAS search for an invisibly decaying Higgs boson produced via vector-boson fusion

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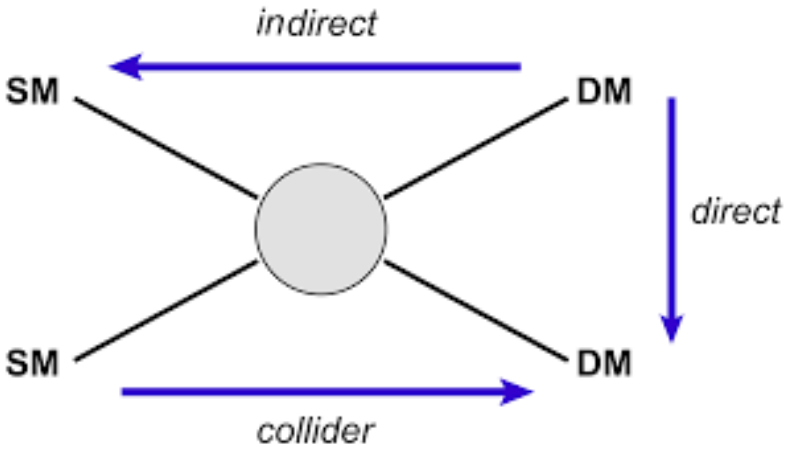
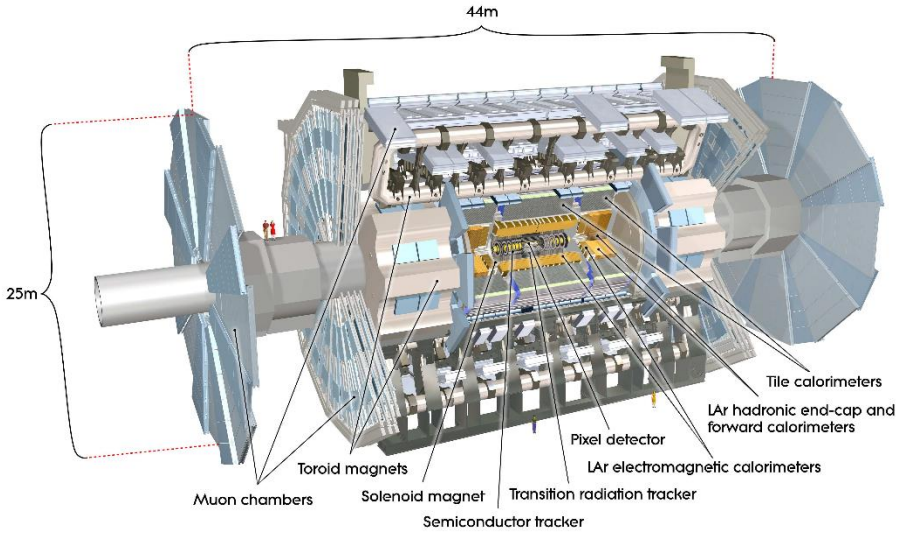
LHC and ATLAS

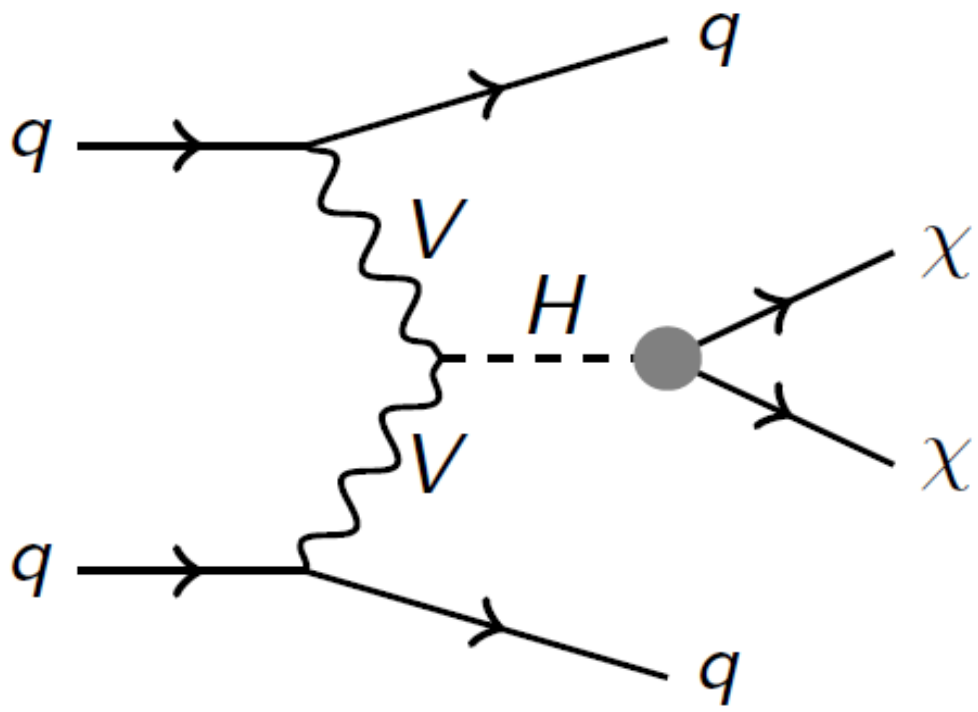


- Looking for possible couplings between SM and DM particles
- DM candidates might exist at the TeV scale
- DM invisible to the detector

- LHC provides proton beams with up 13 TeV centre of mass energy
- Only showing 8 TeV data today, since the most current results are not out yet



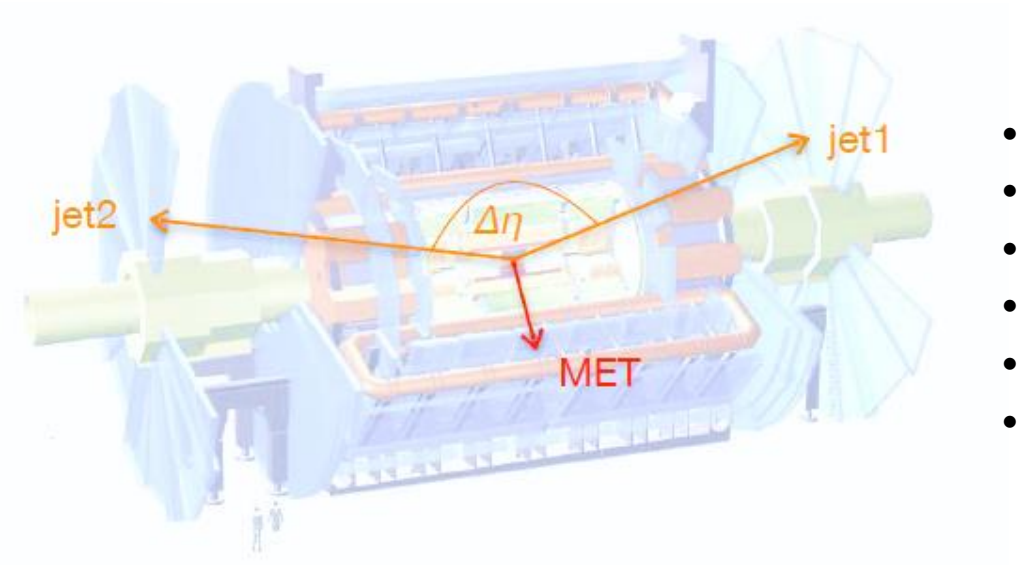
Signal



- Invisible decay of a Higgs produced in Vector Boson Fusion: Two forward jets and missing transverse energy in the final state.
- χ might be a WIMP and dark matter candidate
- Possible evidence for a Higgs portal model

Signal Selection

Requirement	SR1	SR2a	SR2b
Leading Jet p_T	>75 GeV	>120 GeV	>120 GeV
Leading Jet Charge Fraction	N/A	>10%	>10%
Second Jet p_T	>50 GeV	>35 GeV	>35 GeV
m_{jj}	>1 TeV	$0.5 < m_{jj} < 1$ TeV	> 1 TeV
$\eta_{j1} \times \eta_{j2}$		<0	
$\lvert\Delta\eta_{jj}\rvert$	>4.8	>3	$3 < \lvert\Delta\eta_{jj}\rvert < 4.8$
$\lvert\Delta\phi_{jj}\rvert$	<2.5	N/A	
Third Jet Veto p_T Threshold	30 GeV		
$\lvert\Delta\phi_{j,E_T^{miss}}\rvert$	>1.6 for j_1, >1 otherwise	>0.5	
E_T^{miss}	>150 GeV	>200 GeV	

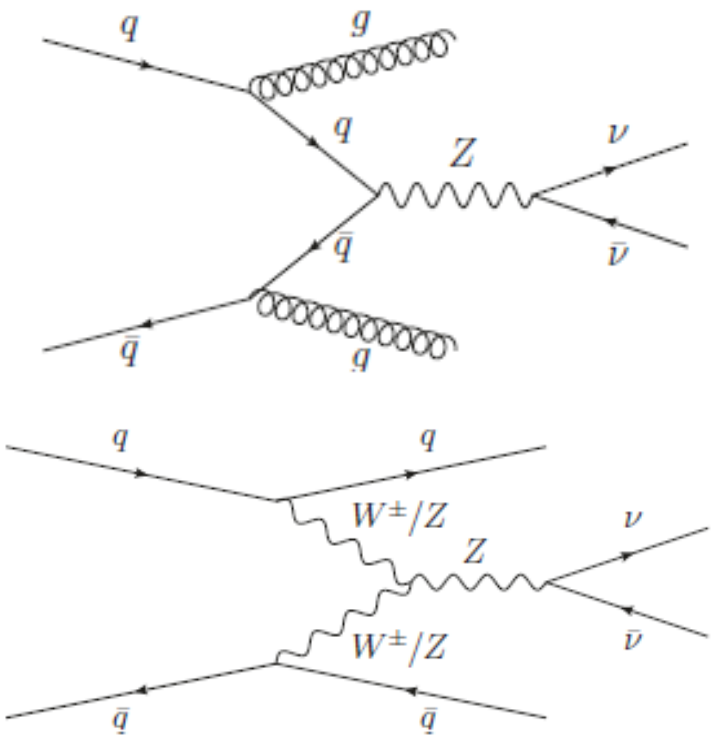


- 3 orthogonal signal regions
- SR2a sensitive to gluon-gluon fusion
- Large dijet mass
- Large seperation in pseudorapidity η
- Large missing transverse energy
- Third jet veto

Main backgrounds

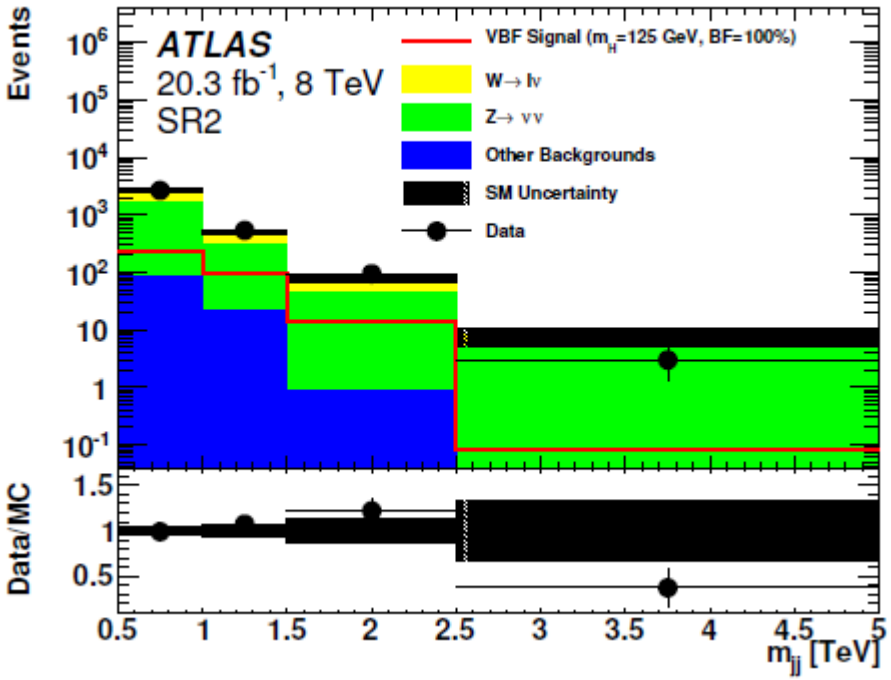
- Background dominated by Z/W->leptons + jets
- Multijet background is small but with large uncertainties
- Signal yields assume a 100% branching fraction to invisible particles

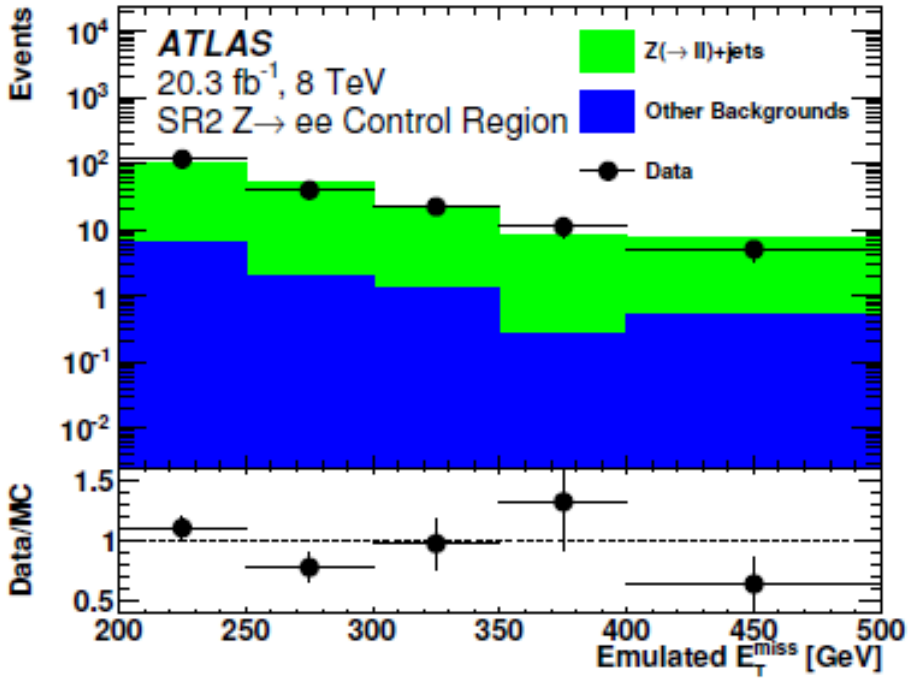
Signal region Process	SR1	SR2a	SR2b
ggF signal	20± 15	58± 22	19± 8
VBF signal	286± 57	182± 19	105±15
$Z(\to \nu\nu)$+jets	339± 37	1580± 90	335±23
$W(\to \ell\nu)$+jets	235± 42	1010± 50	225±16
Multijet	2± 2	20± 20	4± 4
Other backgrounds	1±0.4	64± 9	19± 6
Total background	577± 62	2680±130	583±34
Data	539	2654	636



Control and validation regions

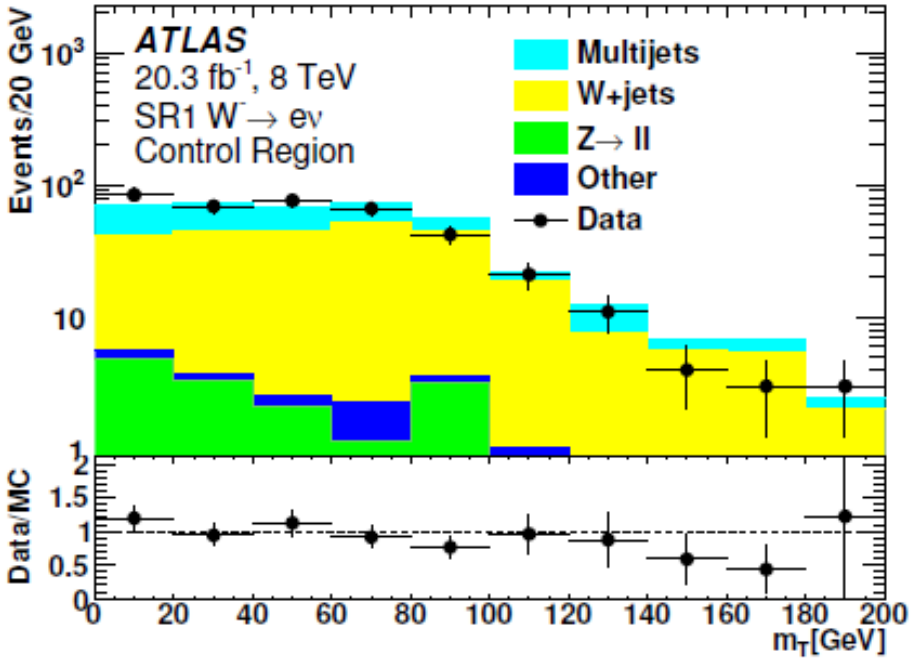
- $Z \rightarrow \nu\nu$+jet estimated using $Z \rightarrow ee/\mu\mu$ and $W \rightarrow e\nu/\mu\nu$ control regions
- $Z_{SR} \sim (Z_{SR}/Z_{CR})^{MC} \times Z_{CR}$
- $Z_{SR} \sim (Z_{SR}/W_{CR})^{MC} \times W_{CR}$

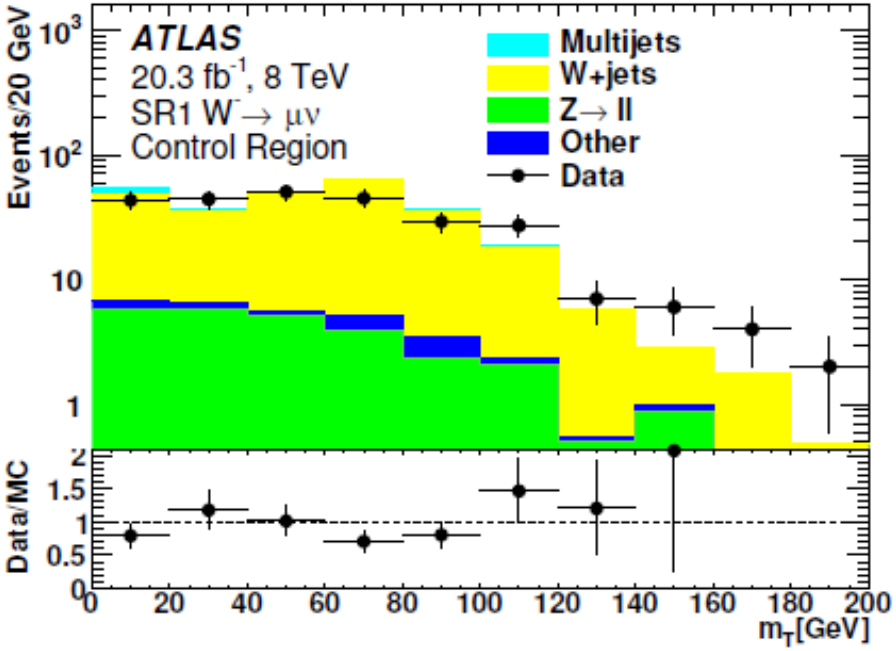




Control and validation regions

- W+jets estimated using $W \rightarrow e\nu/\mu\nu$ control regions
- $W_{SR} \sim (W_{SR}/W_{CR})^{MC} \times W_{CR}$
- Fits to E_T^{miss} and transverse mass: $m_T = \sqrt{2p_T^l E_T^{miss}[1 - \cos(\Delta\phi_{l,E_T^{miss}})]}$





Estimation of the multijet background

- Data-driven estimation
- No invisible particles from the primary process → QCD background from mismeasured or „lost“ jets

Signal region Process	SR1	SR2a	SR2b
ggF signal	20± 15	58± 22	19± 8
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$Z(\rightarrow \nu\nu)$+jets	339± 37	1580± 90	335±23
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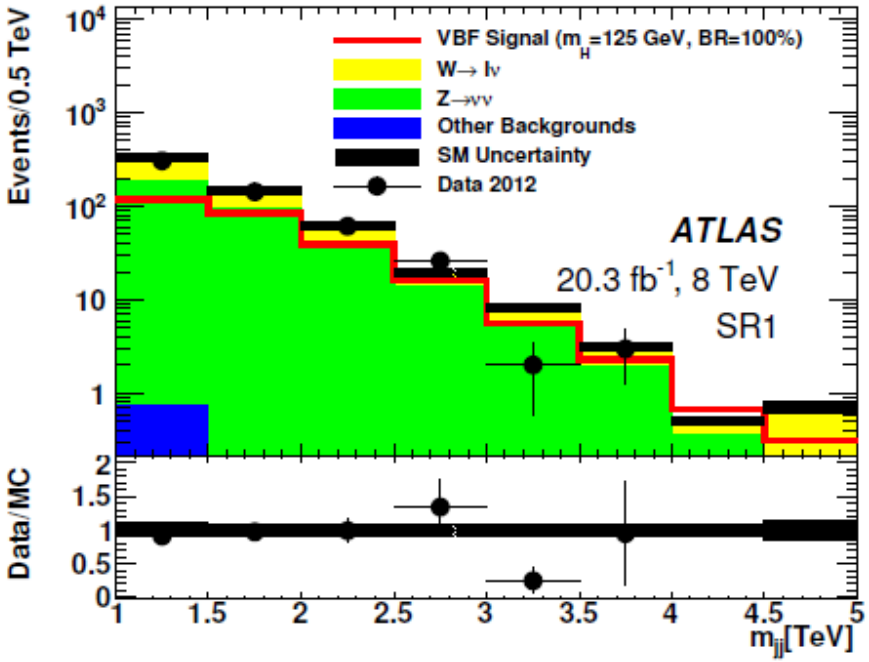
Multijet	2± 2	20± 20	4± 4

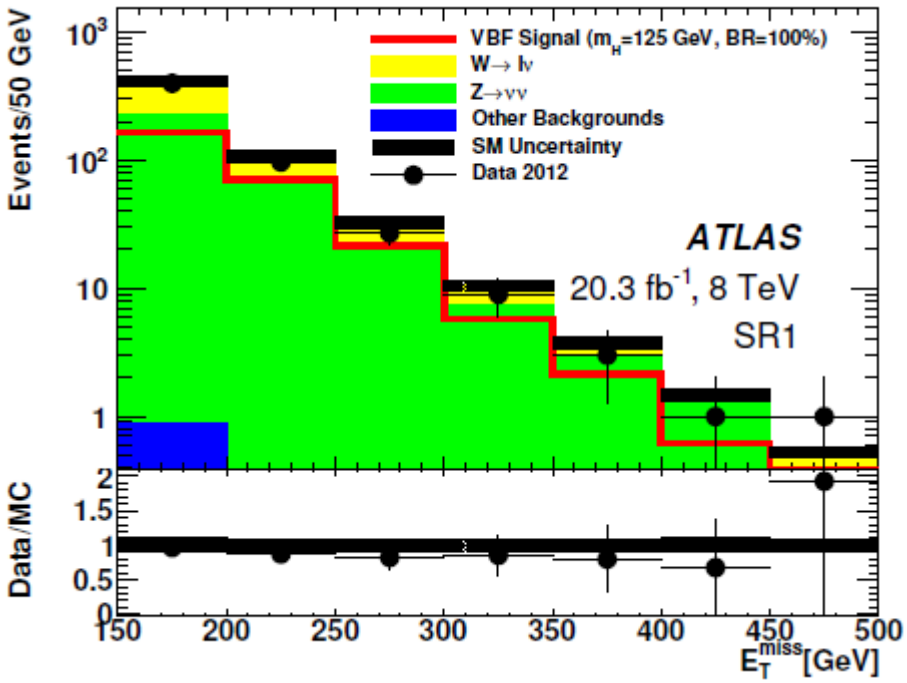
- Assuming 100% uncertainty on the background

- In SR1: control region with inverted $\Delta\phi_{j,E_T^{miss}}$
- Efficiency of each other requirement is determined using the control region
- In SR2: Smearing method assuming fluctuation dominated E_T^{miss}

Signal region fit

- Good MC data agreement
- Global likelihood fit in all signal and control regions
- Correlations between the regions are taken into account





Uncertainties

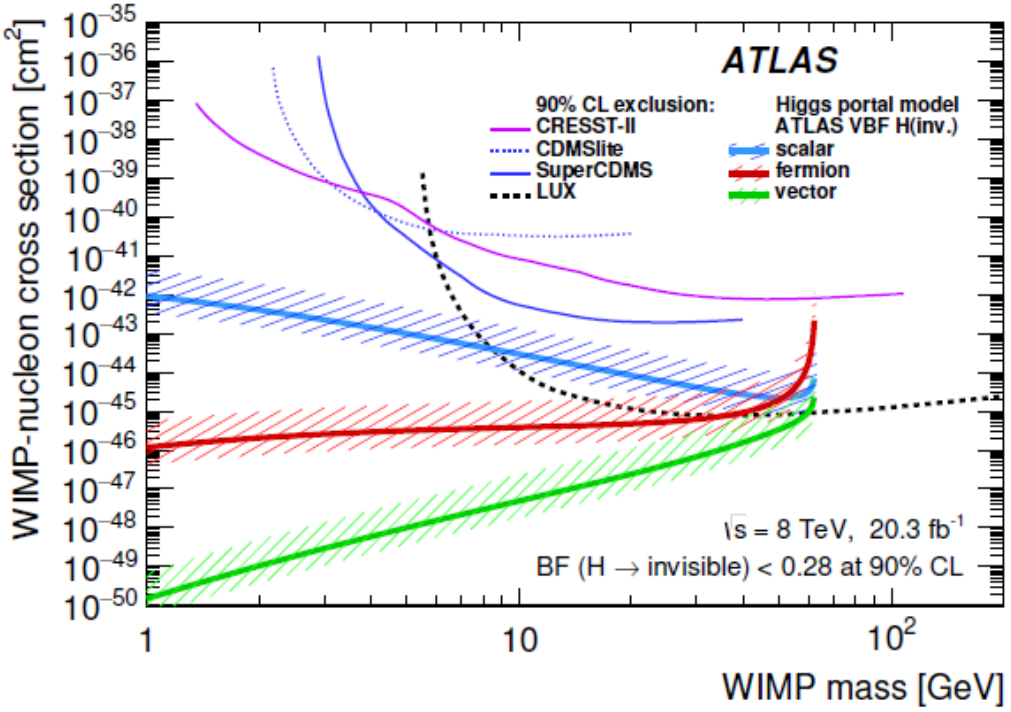
Uncertainty	VBF	ggF	Z or W	Z_{SR}/W_{CR} or W_{SR}/W_{CR}
Jet energy scale	16 9	43 12	17–33 0–11	3–5 1–4
Jet energy resolution	Negligible 3.1	Negligible 3.2	Negligible 0.2–7.6	Negligible 0.5–5.8
Luminosity	2.8	2.8	2.8	Irrelevant
QCD scale	0.2	7.8	5–36 7.5–21	7.8–12 1–2
PDF	2.3 2.8	7.5	3–5 0.1–2.6	1–2
Parton shower	4.4	41 29	9–10	5
Veto on third jet			Negligible	Negligible
Higgs boson p_T	Negligible	9.7	Irrelevant	Irrelevant
MC statistics	2 0.6	46 13	2.3–6.4 0.8–4.5	3.3–6.6

- The ranges correspond to yields in SRs and CRs
- Uncertainties in Luminosity, PDF, Parton shower modelling and factorization are treated as correlated between regions
- Theoretical uncertainties are assumed to be uncorrelated
- The search uses the last column as the uncertainty

Uncertainties on the yields in %. 1st and 2nd rows correspond to SR1 and SR2.

Interpretation and Conclusion

- Limits from Higgs portal model (arXiv:1112.3299)
- Dark sector coupled to the SM via the Higgs boson only
- Considering 3 DM scenarios: Scalar-, Vector- or Majorana-Fermion
- Translated into a Higgs to invisible branching fraction < 0.28 at 90%CL

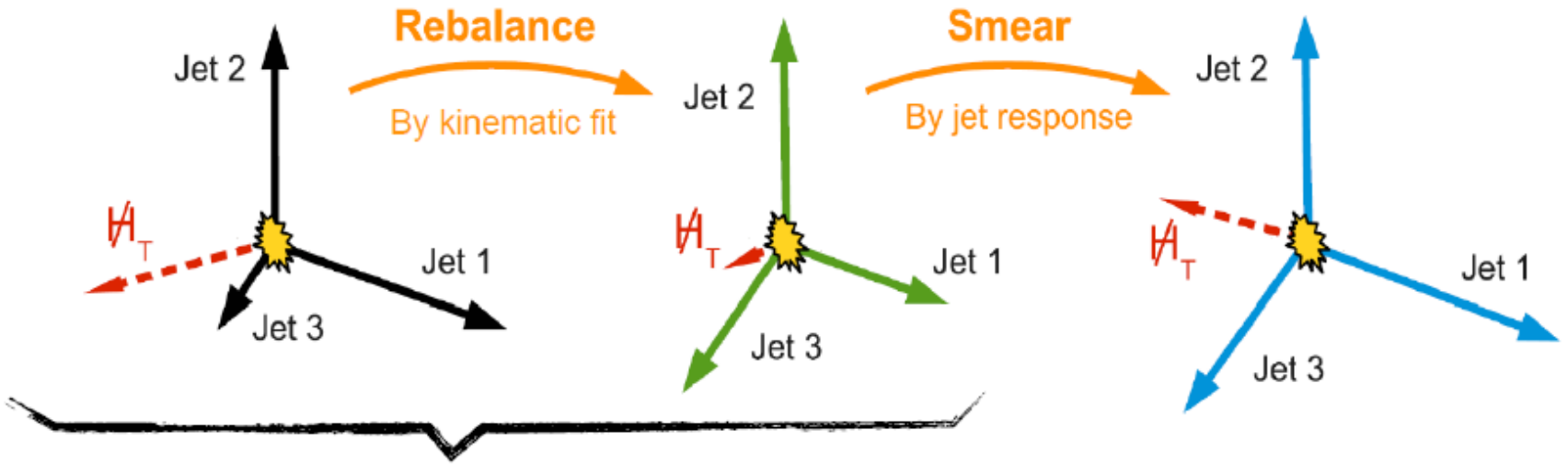


Stay tuned for
Run 2 results…

Backup

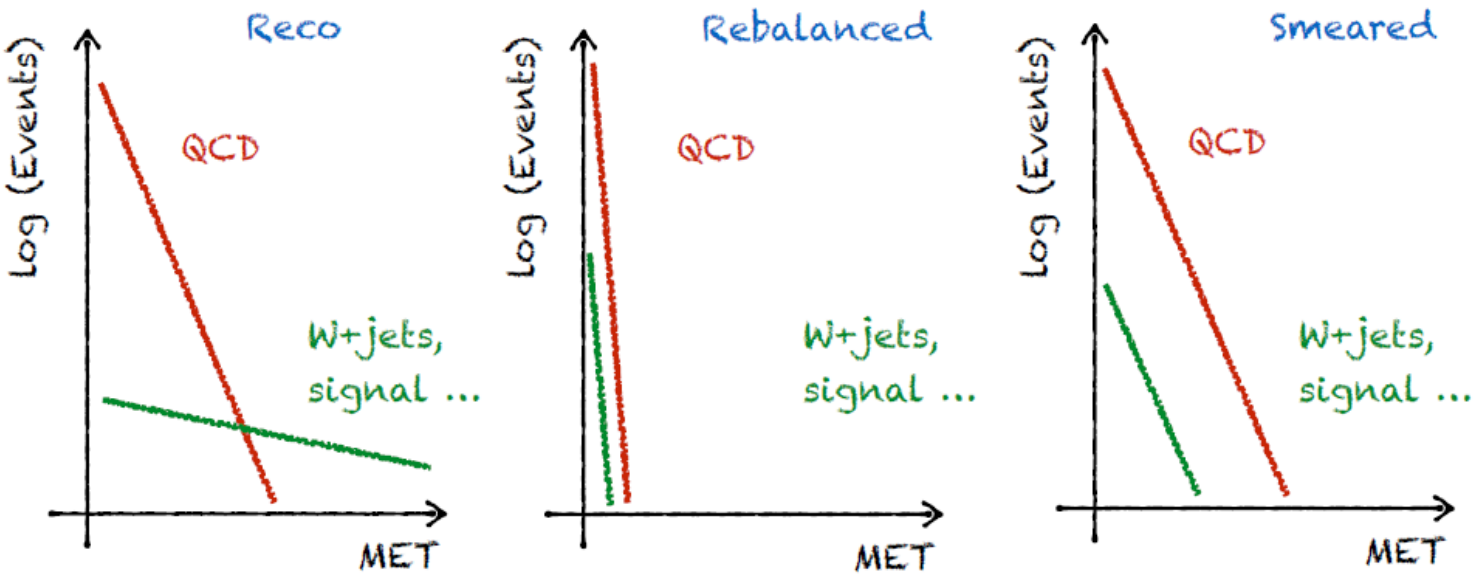
Rebalance and Smear method

- QCD background from mismeasured or „lost“ jets
- → amounts to about 1% of the background, but uncertainties are large
- Rebalance all jets with $p_T > 20$ GeV by kinematic fit
- Smear by jet response template obtained from simulation



Main difference to jet smearing:
Seed events from inclusive jet sample

Rebalance and Smear method



- Non-QCD events made "QCD-like" by rebalancing
- After smearing: non-QCD contribution is negligible

Bibliography

- [1] A. Djouadi, O. Lebedev, Y. Mambrini and J. Quevillon, Implications of LHC searches for Higgs-portal dark matter, Phys. Lett. B 709 (2012) 65 [arXiv:1112.3299] [INSPIRE].