Fiducial definitions
for multibosons

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Project on common fiducial definitions

- Provide a recommendation for common fiducial phase space selections at generator level for multiboson analyses.
  - Common definitions of charged leptons, missing transverse momentum, jets and other useful quantities.
  - Common selection requirements specific to each channel/final state.
  - Discussed also at LH2023 [arXiv:2406.00708]

- This could be extended adding recommendations for an STXS-like approach.
  - Aim to move from an inclusive to a differential fiducial phase space.
  - Requires relevant differential observables and the bin edges.

- Milestones:
  - A draft of proposal/recommendation to be discussed in the LHC EW general meeting.
  - SciPost publication at the end of 2024.
  - Implement a Rivet plugin with all the recommendations.

Guiding principles

- Unified object definitions across all signatures:
  - Leptons (dressing, pT, eta)
  - Photons (isolation, pT, eta)
  - Jets (definition, pT, eta), jet vetoes
  - MET (definition, pT)
  - Bosons: Z-mass window, transverse mass for W processes

- Unified leptonic cuts across jet bins
  - VV -> VV+jet -> VV+2jets / VBS

- Unified jet requirements cuts across VBF and VBS

Diboson fiducial definitions

Diboson Production: leptonic channels			
Final state	Process	Object	Selection requirements
$\ell^+\ell'^-$+MET	W^+W^-	leptons	$p_{\mathrm{T},\ell^\pm}$ >25 GeV, $|\eta_{\ell^\pm}|$ < 2.5
		MET	MET > 30 GeV
		jets	no b-jets with p_T >30 GeV and within $|\eta|$ < 5.0
		BSM region	$m_{\ell\ell}$: 400-600 GeV, >600 GeV
$\ell^+\ell^-\ell'^\pm$ + MET	$W^\pm Z$	leptons	p_{T,ℓ_1} >25 GeV, $p_{\mathrm{T},\ell_{2/3}}$ >15 GeV, $|\eta_\ell|$ < 2.5
		MET	MET > 30 GeV
		jets	no b-jets with p_T >30 GeV and within $|\eta|$ < 5.0
		bosons	$m_{\mathrm{T},W}$ >30 GeV,
			60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		BSM region	$m_{\mathrm{T},WZ}$: 400-600 GeV, >600 GeV
$\ell^+\ell^-\ell'^+\ell'^-$	ZZ	leptons	2×OSSF-$\ell\ell$, $p_{\mathrm{T},\ell_{1/2/3/4}}$ > 25 / 15 / 10 / 10 GeV,
			$|\eta_\ell|$ < 2.5
		bosons	60 GeV < $m_{\ell^{(\prime)+}\ell^{(\prime)-}}$ < 120 GeV
		BSM region	m_{ZZ}: 0.8-1.0 TeV, >1.0 TeV
$\ell^\pm\gamma$ + MET	$W^\pm\gamma$	leptons	$p_{\mathrm{T},\ell^\pm}$ >35, $|\eta_\ell|$ < 2.5
		photons	$E_{\mathrm{T},\gamma}$ >25, $|\eta_\gamma|$ < 2.5, ΔR(ℓ,γ) > 0.4
		MET	MET > 30 GeV
		bosons	$m_{\mathrm{T},W}$ >50 GeV
		BSM region	$p_{\mathrm{T},\gamma}$: 100-250 GeV, >250 GeV
$\ell^+\ell^-\gamma$	$Z\gamma$	leptons	OSSF-$\ell\ell$, $p_{\mathrm{T}_{\ell_{1/2}}}$ > 35 GeV, $|\eta_\ell|$ < 2.5
		photons	$E_{\mathrm{T},\gamma}$ >25, $|\eta_\gamma|$ < 2.5, ΔR(ℓ,γ) > 0.4
		bosons	60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		BSM region	$p_{\mathrm{T},\gamma}$: 100-250 GeV, >250 GeV
γ+MET	$Z\gamma$	photons	$E_{\mathrm{T},\gamma}$ >25, $|\eta_\gamma|$ < 2.5
		MET	MET > 30 GeV
		BSM region	$p_{\mathrm{T},\gamma}$: 100-250 GeV, >250 GeV

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Triboson fiducial definitions

Triboson Production: leptonic channels			
Final state	Process	Object	Selection requirements
$0\ell\gamma\gamma$: MET + 2 γ	$Z\gamma\gamma$	**MET**	MET > 100 GeV
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5, photon-photon isolation
		BSM region	TBD
$1\ell\gamma\gamma$: $\ell^\pm$ +MET + 2 γ	$W^\pm\gamma\gamma$	**leptons**	p_T >25 GeV, $\|\eta\|$ < 2.5
		MET	MET > 30 GeV
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5,
			$\Delta R(\gamma,\gamma) > 0.4, \Delta R(\ell,\gamma) > 0.4$
		BSM region	TBD
$2\ell\gamma\gamma$: $\ell^+\ell^-$ + 2 γ	$Z\gamma\gamma$	**leptons**	1×OSSF-$\ell\ell$, $p_{T,\ell_{1/2}}$ >25 / 15 GeV, $\|\eta_\ell\|$ < 2.5
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5,
			$\Delta R(\gamma,\gamma) > 0.4, \Delta R(\ell,\gamma) > 0.4$
		bosons	60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		BSM region	TBD
$2\ell\gamma$: $\ell^+\ell'^-$ + MET + γ	$W^+W^-\gamma$	**leptons**	p_T >25, 20 GeV, $\|\eta\|$ < 2.5
		MET	MET > 30 GeV
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5, $\Delta R(\ell,\gamma) > 0.4$
		BSM region	TBD
$3\ell\gamma$: $\ell^+\ell^-\ell'^\pm$ + MET + γ	$W^\pm Z\gamma$	**leptons**	1×OSSF-$\ell\ell$, $p_{T,\ell_{1/2/3}}$ >25,15,10 GeV, $\|\eta_\ell\|$ < 2.5
		bosons	60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5, $\Delta R(\ell,\gamma) > 0.4$
		BSM region	TBD
$4\ell\gamma$: $\ell^+\ell^-\ell'^+\ell'^-$ + γ	$ZZ\gamma$	**leptons**	2×OSSF-$\ell\ell$, $p_{T,\ell_{1/2/3-4}}$ >25,15,10 GeV, $\|\eta_\ell\|$ < 2.5
		bosons	60 GeV < $m_{\ell^{(')+}\ell^{(')-}}$ < 120 GeV
		photons	$E_{T,\gamma}$ >25, $\|\eta_\gamma\|$ < 2.5, $\Delta R(\ell,\gamma) > 0.4$
		BSM region	TBD
4ℓ: $\ell^+\ell^-\ell'^+\ell''^-$ + MET	W^+W^-Z	**leptons**	1×OSSF-$\ell\ell$, $p_{T,\ell}$ >25/15/10/10 GeV, $\|\eta_\ell\|$ < 2.5
		MET	MET > 30 GeV
		bosons	60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		BSM region	TBD
5ℓ: $\ell^+\ell^-\ell'^+\ell'^-\ell^\pm$ +MET	$W^\pm ZZ$	**leptons**	2×OSSF-$\ell\ell$, $p_{T,\ell_{1/2/3-5}}$ > 25/15/10 GeV, $\|\eta_\ell\|$ < 2.5
		MET	MET > 30 GeV
		bosons	60 GeV < $m_{\ell^{(')+}\ell^{(')-}}$ < 120 GeV
		BSM region	TBD

- Leptonic cuts identical between VV and VV+V

VBS Fiducial definitions

Vectorboson Fusion			
Final state	Process	Object	Selection requirements
$\ell^+\ell^- + 2j$	VBF-Z / Zjj	leptons	$p_{\mathrm{T},\ell} > 25$ GeV, $|\eta_\ell| < 2.5$
		jets	$p_{\mathrm{T},j_1} > 50$ GeV, $p_{\mathrm{T},j_2} > 40$ GeV, $|\eta_j| < 4.5$, $m_{jj} > 250$ GeV, $\Delta\eta_{jj} > 2.5$
		bosons	60 GeV $< m_{\ell^+\ell^-} < 120$ GeV
		further jets	jet-veto TBD
		event	$p_{\mathrm{T}}^{\mathrm{balance}} < 0.15$ TBD
		QCD region	$120 < m_{jj} < 250$ GeV
		BSM regions	$m_{jj} > 0.5 - 1, > 1, > 3$ TeV
$\ell^\pm + \mathrm{MET} + 2j$	VBF-$W^\pm$/ $W^\pm jj$	leptons	$p_{\mathrm{T},\ell} > 25$ GeV, $|\eta_\ell| < 2.5$
		jets	$p_{\mathrm{T},j_1} > 50$ GeV, $p_{\mathrm{T},j_2} > 40$ GeV, $|\eta_j| < 4.5$, $m_{jj} > 250$ GeV, $\Delta\eta_{jj} > 2.5$
		further jets	jet-veto TBD
		event	$p_{\mathrm{T}}^{\mathrm{balance}} < 0.15$ TBD
		QCD region	$120 < m_{jj} < 250$ GeV
		BSM regions	$m_{jj} > 0.5 - 1, > 1, > 3$ TeV

VBS Fiducial definitions

Vectorboson Scattering			
Final state	Process	Object	Selection requirements
$\ell^\pm\ell'^\pm$+MET+2j	$W^\pm W^\pm$-VBS / $WWjj$	leptons	$p_{T,\ell_{1,2}}$ >20 GeV, $|\eta_\ell|$ < 2.5
		jets	$p_{T,j_{1,2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV
$\ell^+\ell'^-$+MET+2j	W^+W^--VBS / W^+W^-jj	leptons	$p_{T,\ell_{1,2}}$ >20 GeV, $|\eta_\ell|$ < 2.5
		jets	$p_{T,j_{1/2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV
$\ell^+\ell^-\ell'^\pm$+MET+2j	$W^\pm Z$-VBS / $W^\pm Zjj$	leptons	$p_{T,\ell_{1/2/3}}$ >25/15/10 GeV, $|\eta_\ell|$ < 2.5
		MET	MET > 30 GeV
		bosons	$m_{T,W}$ >30 GeV, 60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		jets	$p_{T,j_{1/2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		further jets	p_T >25 GeV, none in interval between leptons TBD
		event	$p_T^{balance}$ <0.15 TBD
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV
$\ell^+\ell^-\ell'^+\ell'^-$ + 2j	ZZ-VBS / $ZZjj$	leptons	2×OSSF-$\ell\ell$, $p_{T,\ell_{1/2/3-4}}$ > 25/15/10 GeV, $|\eta_\ell|$ < 2.5
		bosons	60 GeV < $m_{\ell^{(\prime)+}\ell^{(\prime)-}}$ < 120 GeV
		jets	$p_{T,j_{1/2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		further jets	p_T >25 GeV, none in interval between leptons
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV
$\ell^\pm\gamma$ + MET + 2j	$W^\pm\gamma$-VBS / $W^\pm\gamma jj$	leptons	$p_{T,\ell^\pm}$ >35, $|\eta_\ell|$ < 2.5
		photons	$E_{T,\gamma}$ >75, $|\eta_\gamma|$ < 2.5, $\Delta R(\ell/j,\gamma)$ > 0.4
		MET	MET > 30 GeV
		bosons	$m_{T,W}$ >50 GeV
		jets	$p_{T,j_{1/2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV
$\ell^+\ell^-\gamma$ + 2j	$Z\gamma$-VBS / $Z\gamma jj$	leptons	$p_{T,\ell_{1,2}}$ >35, $|\eta_\ell|$ < 2.5
		photons	$E_{T,\gamma}$ >75, $|\eta_\gamma|$ < 2.5, $\Delta R(\ell/j,\gamma)$ > 0.4
		bosons	60 GeV < $m_{\ell^+\ell^-}$ < 120 GeV
		jets	$p_{T,j_{1/2}}$ >50/40 GeV, $|\eta_j|$ < 4.5, $\Delta\eta_{jj}$ >2.5, m_{jj} > 250 GeV, $\Delta\eta_{jj}$ >2.5
		QCD region	120 < m_{jj} < 250 GeV
		BSM regions	m_{jj} > 0.5 − 1, > 1, > 2 TeV

- Leptonic cuts identical between VV and VV+2 jets
- 2-jet requirements identical between VBF and VBS

Proposal for STXS-like fiducial selections
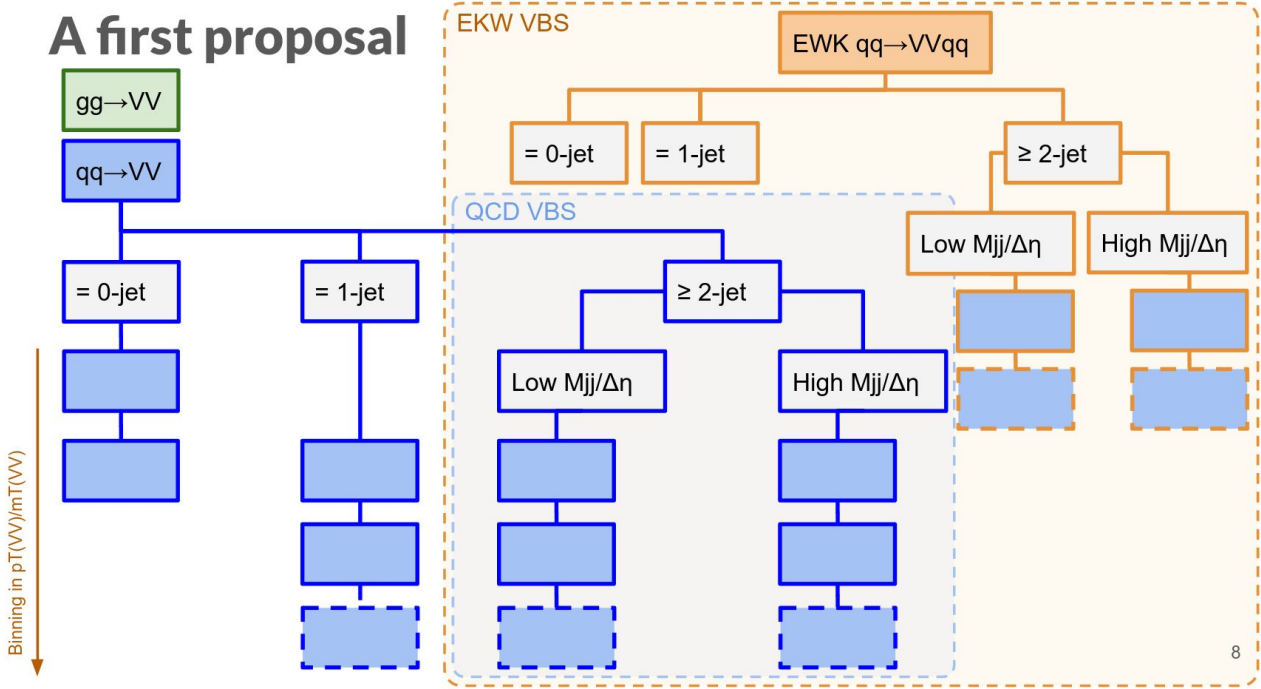
More details here

Some additional thoughts

- **Common definitions for inclusive fiducial regions**
  - Important to facilitate comparisons across experimental results and theory predictions.
  - Allows potential combinations between ATLAS and CMS measurements.

- **STXS-like approach**
  - Particularly interesting for low-statistics measurements that could benefit from combinations of different channels/experiments (e.g. VBS).
  - But also important to define common observables and binning sensitive to EFT effects: such as the tails of m_{VV} distributions.

- **Roadmap**
  - Distribute first "complete" draft until end of July amongst contributors
  - Discussion amongst analysis groups over the summer (coordinated by WG convenors)
  - Dedicated meeting in September (date TBD)
  - Distribute draft agreed within subgroup with community in October
  - Publication in SciPost until end of 2024