

WG1 Summary

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WG1 overview

- **WG1 focuses on SM Higgs cross-sections and branching ratios**
 - Modelling of main backgrounds for SM cross-section measurements (one subgroup per main production mode)
 - Also includes subgroup dedicated to off-shell cross-section and interference with continuum background
 - Additional subgroup to update Higgs branching ratios (generally less active due to sufficiently-high precision)
- Increasing cross-talk with other WGs: **STXS**, (SM)EFT, BSM Higgs, ...

Since 2019 ...

- One of the directions for the last year was to understand the impact of **parton shower uncertainties and related issues** on Higgs analyses.

- Activities kicked-off in second half of 2019:

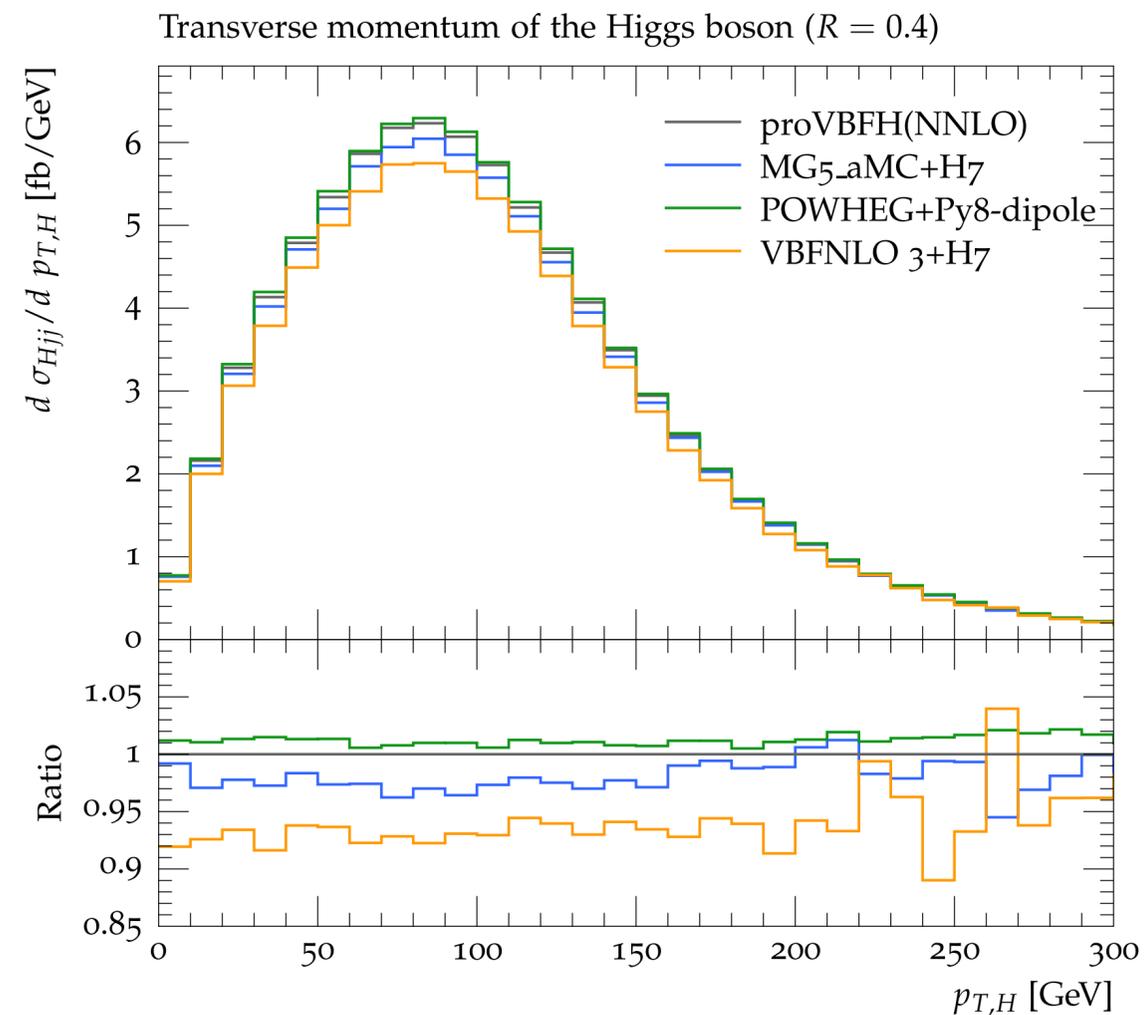
<https://twiki.cern.ch/twiki/bin/view/LHCPhysics/PartonShowerUncertaintiesXSWG1>

- Meeting in April 2020 and ongoing synergy with Les Houches studies.
 - some slow-down due to COVID situation
 - still, important progress made in individual subgroups

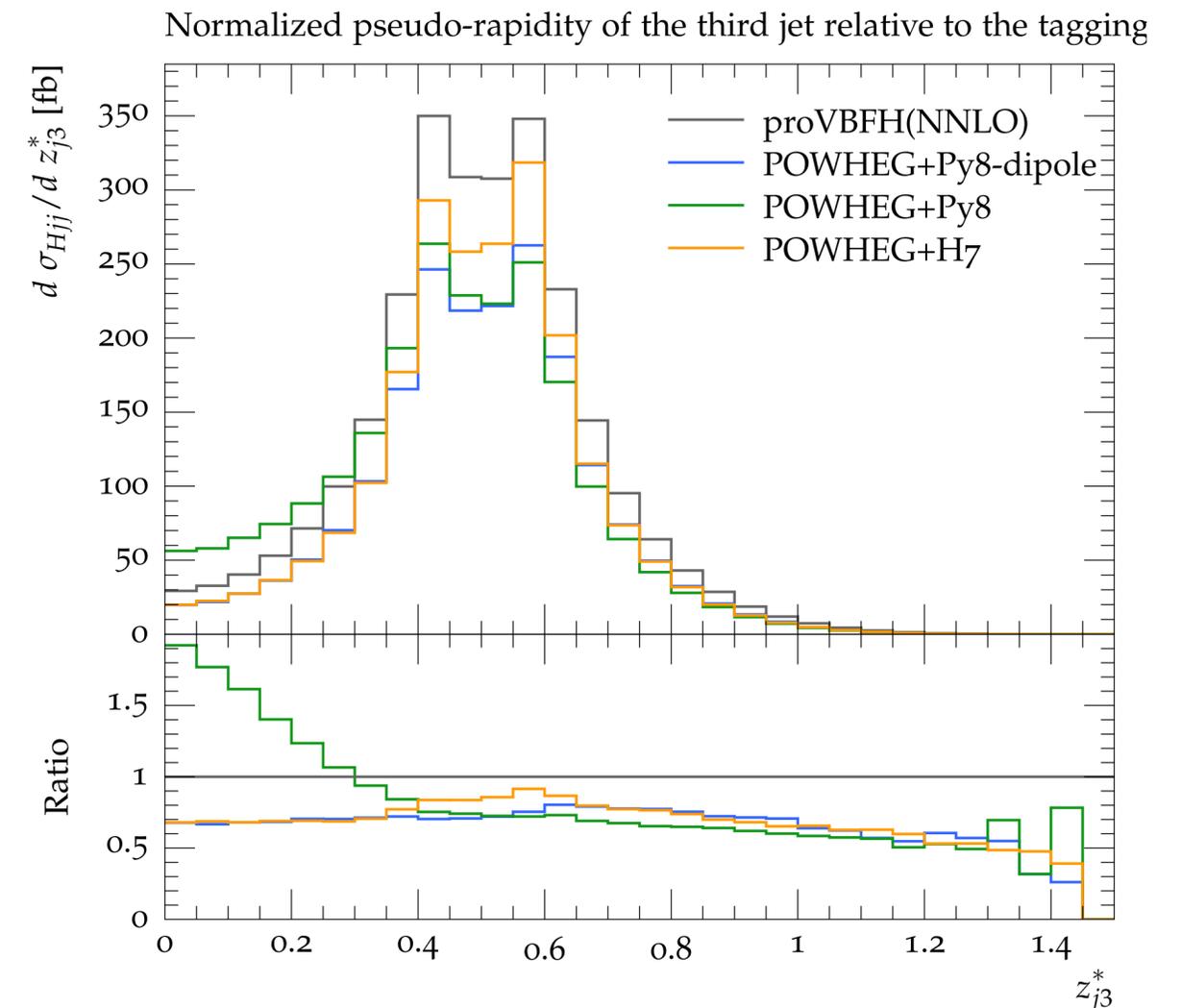
PS uncertainties in VBF

[S. Plaetzer]

- Detailed benchmark study: <https://arxiv.org/abs/2003.12435>
→ color and recoil important for accuracy of shower beyond LO region



NLO-accurate observables: typical differences around 10% (mostly normalization)

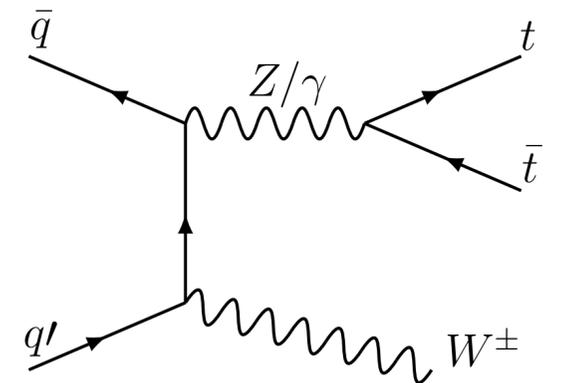


LO-accurate: differences around 20% (after rejecting unphysical schemes)

PS uncertainties for ttH

[L. Reina]

- **H→bb**: exhaustive comparison of MC generators for tt+b jets background
 - important insight from NLO calculation of ttbb+jet [[Buccioni et al.](#)]; generators can now be tuned to reproduce features of extra radiation
 - WG note and publication with final recommendation soon
 - ttbb cross-section → (1.5 x YR4) and reduced MC differences.
- **H→WW/ZZ/tau**: ongoing work to provide complementary NLO+PS prediction (POWHEG-based) for ttW background
 - sizable effects from higher-order QCD and EW diagrams



ttH: full Run 2 results

[M. Moreno Llacer]

ttH			
$H \rightarrow \gamma\gamma$ ✓ narrow Higgs peak ✗ small branching ratio	PRL 125 (2020) 061802 ATLAS-CONF-2020-026	XS, CP STXS PRL 125 (2020) 061801 CMS-PAS-HIG-19-015 XS, CP STXS	stat. dominated. syst. unc.: exp. (γ) > theory
$H \rightarrow WW^*, \tau\tau, ZZ^*$ (multi-lepton) ✓ reasonable rate, moderate bkg ✗ difficult Higgs reconstruction	<i>No new results</i>	CMS-PAS-HIG-19-008 XS	stat. unc. ~ syst. unc. syst. unc.: exp.(non-prompt, taus) ~ theory
$H \rightarrow bb$ ✓ wide Higgs peak, high rate ✗ bad combinatorics, hard bkg	ATLAS-CONF-2020-058 STXS	<i>No new results</i>	stat. unc. < syst. unc. syst. unc: exp. (b-tag) < theory

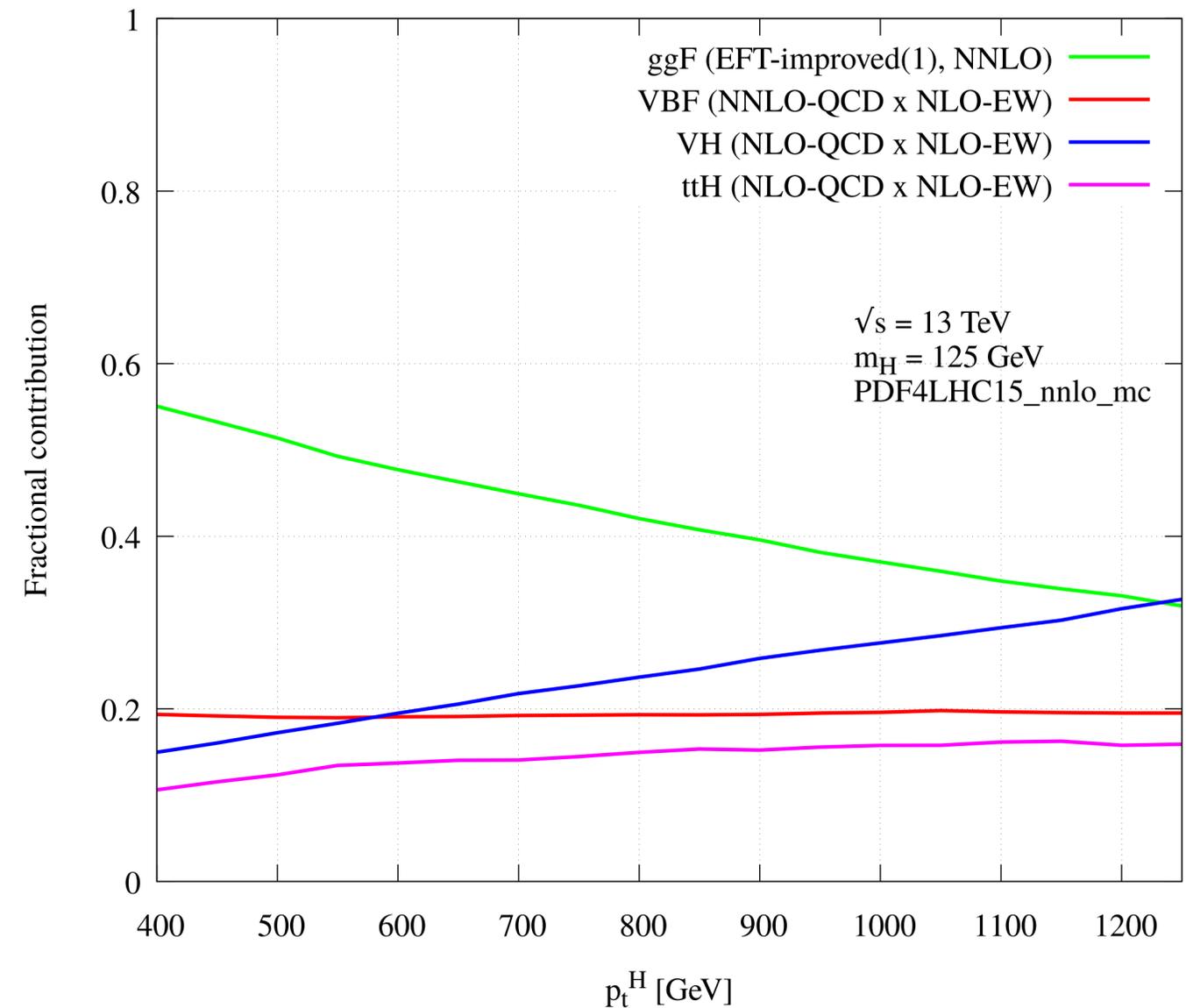
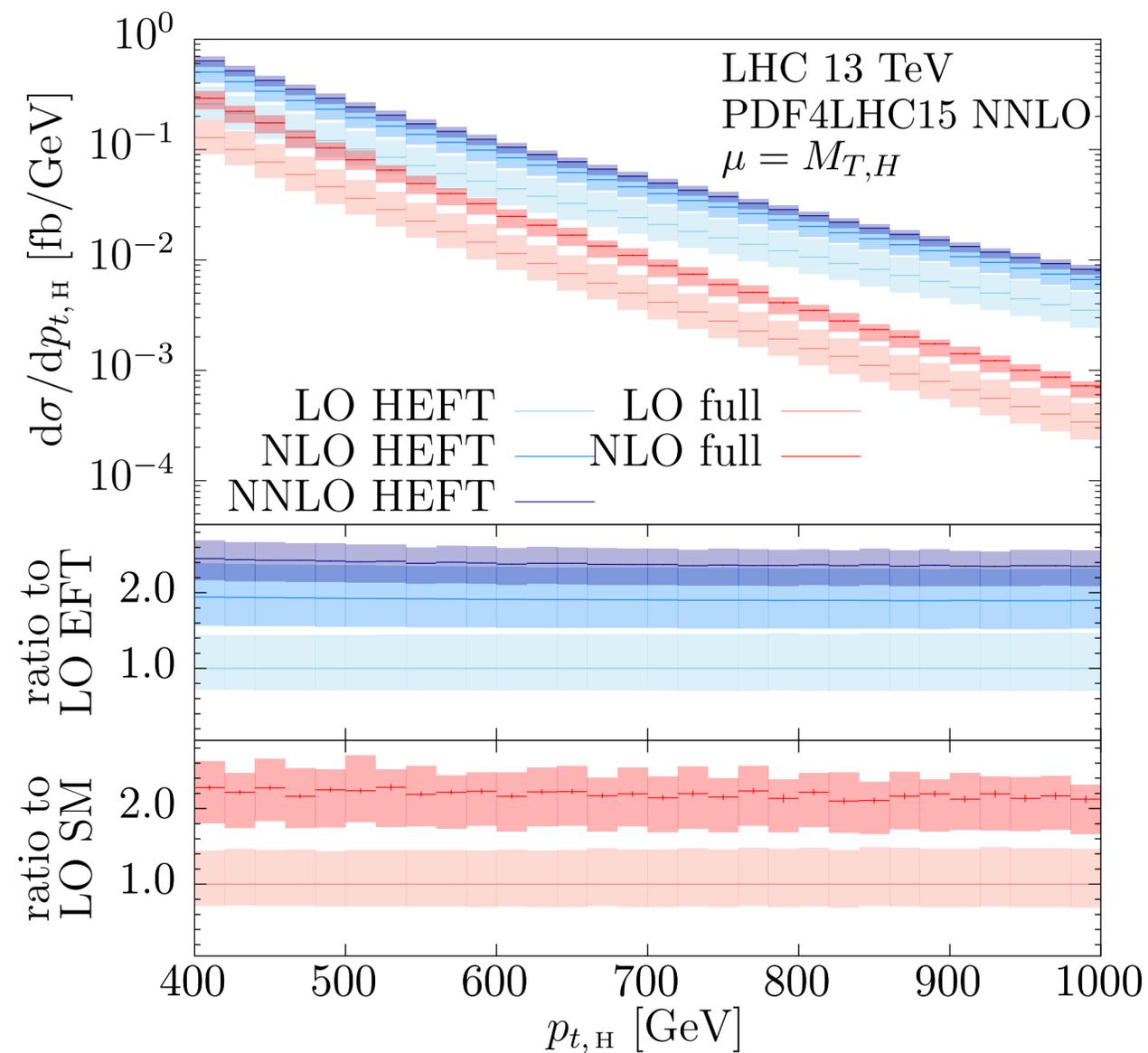
Theoretical un
 Ongoing effort
 better bkg. (t

- ttW: ongoing effort comparing background modelling and estimation of theoretical uncertainties, essential for future CMS+ATLAS combination.
- comparison of MC generator distributions at particle level
- detailed documentation of settings and systematic variations

Gluon fusion

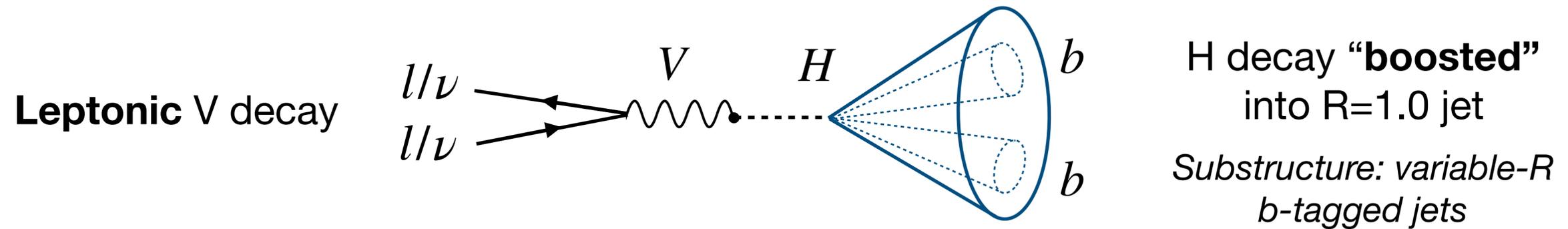
- “Precise predictions for boosted Higgs production”:
LHCHSWG-2019-002 and <https://arxiv.org/pdf/2005.07762.pdf>

[B. Mistlberger]

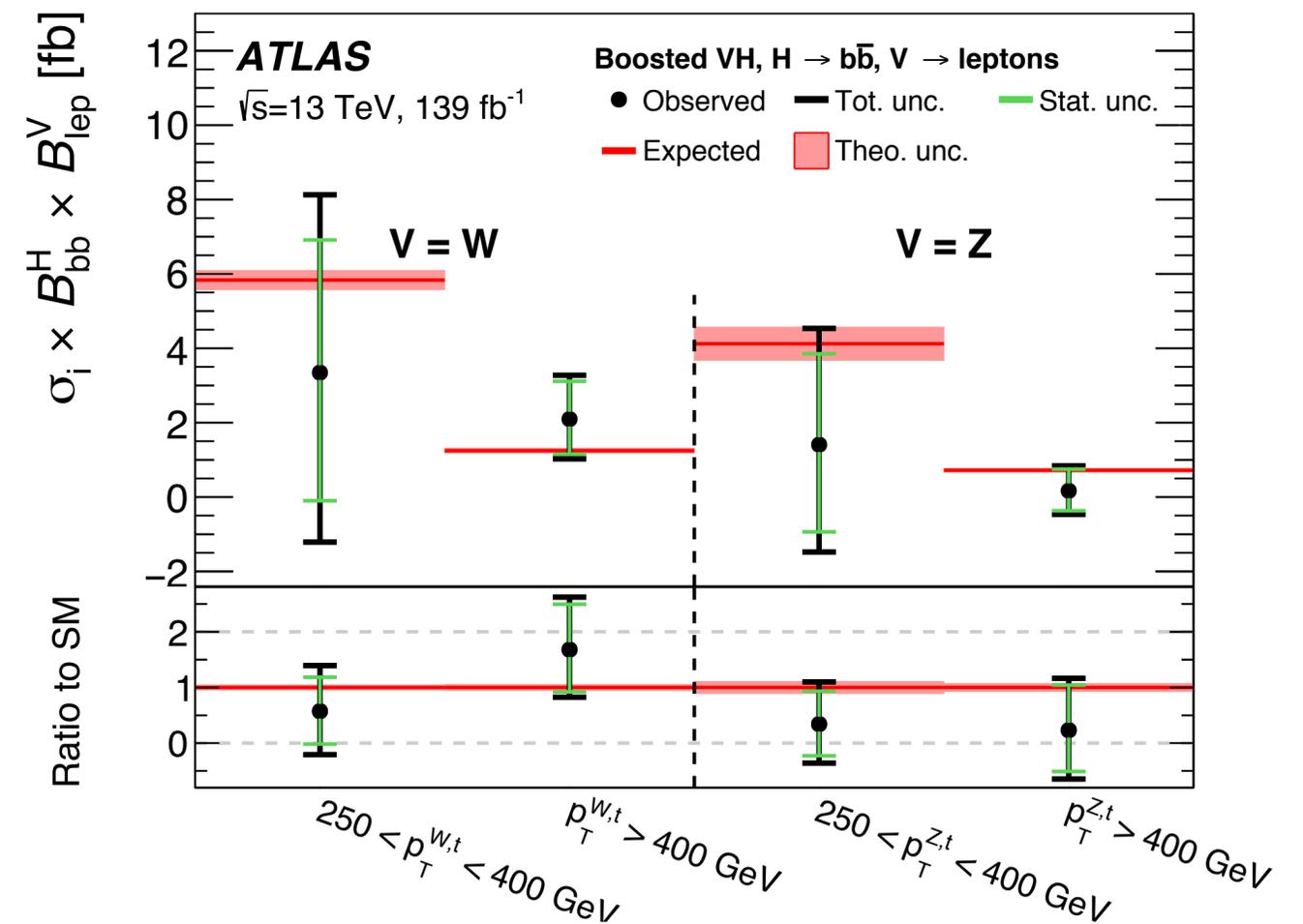


VH: new frontiers

[P. Windischhofer]



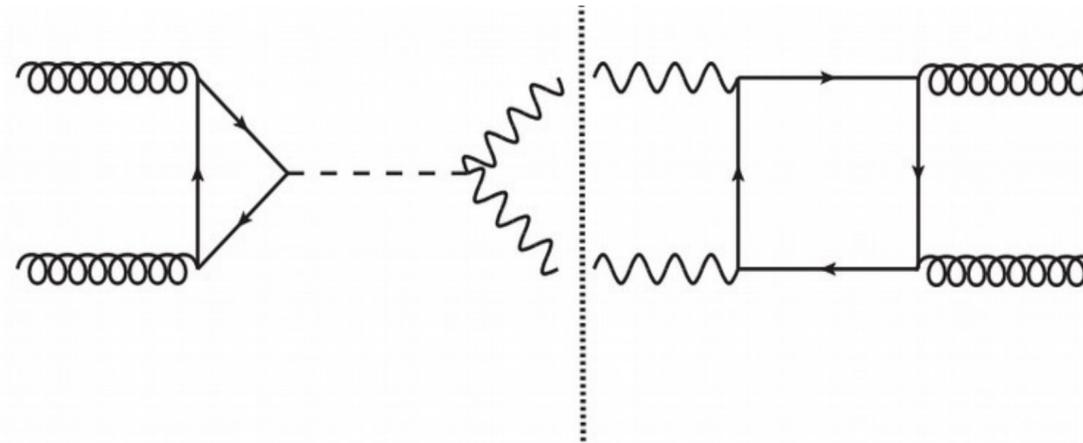
- Combined VH signal strength measured to $\sim 20\%$, agrees with SM.
- Now **sensitivity for differential measurements and boosted regime.**
- $gg \rightarrow ZH$ more important, exploring NLO+PS multi jet merging in place of (out-of-reach) HO corrections



Offshell: new directions

[R. Roentsch]

- **Better tools** for understanding off-shell processes:



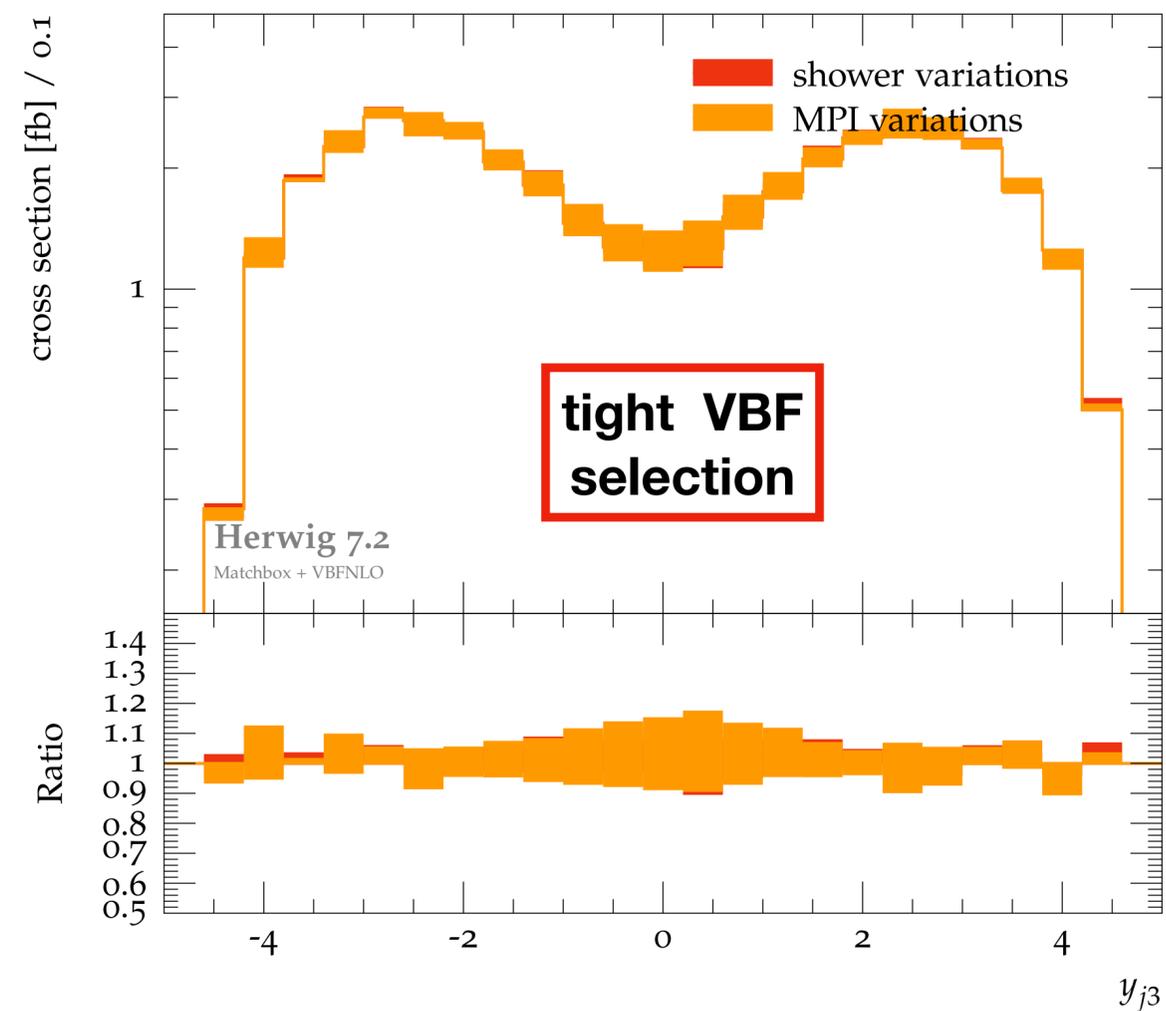
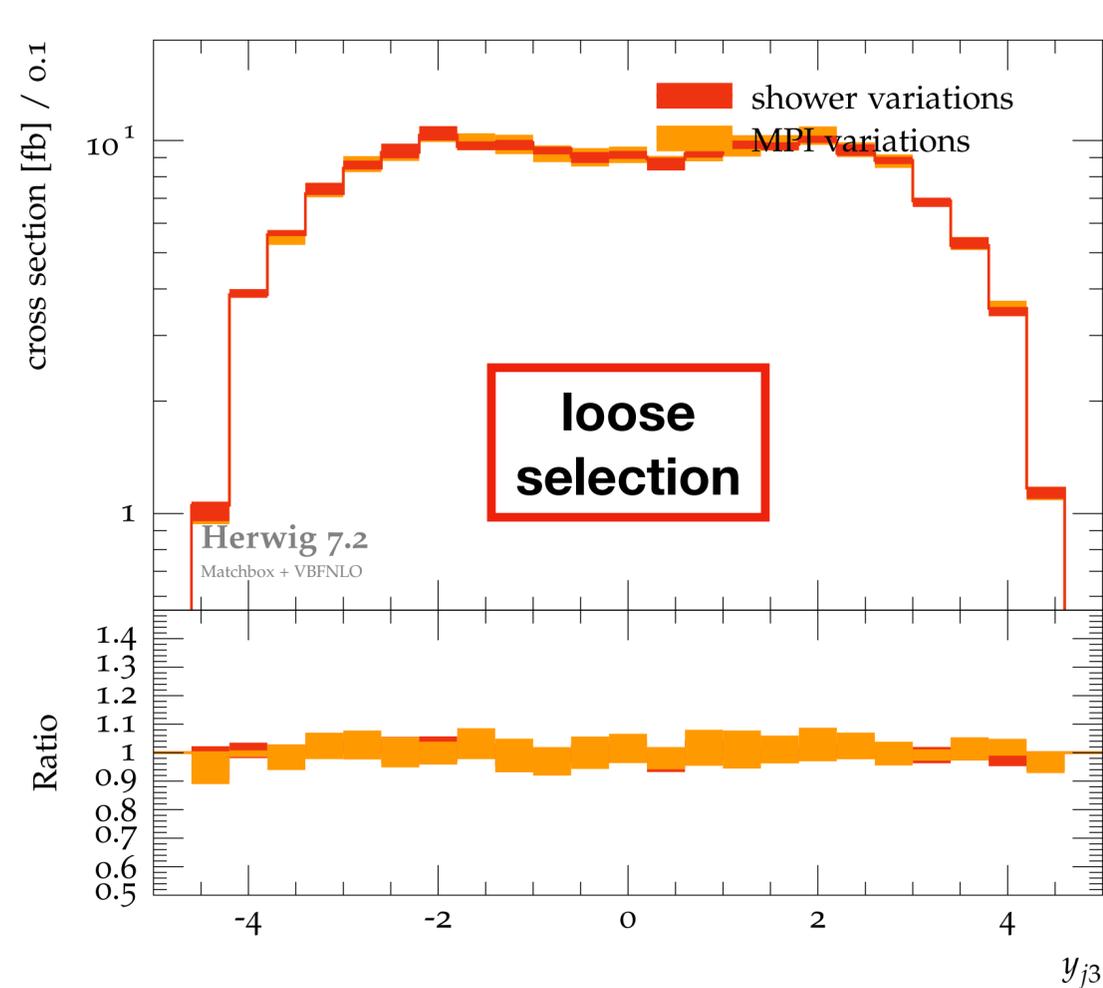
- e.g. $gg \rightarrow ZZ$ just like ZH , loop-induced process so exploring multi-jet merging; also including EW effects, typically large in relevant PS region
- **Interpretation of off-shell measurements** (overlap with WG2):
 - which models/EFTs are most important to study; can off-shell resolve on-shell degeneracies? Hope to harmonize ATLAS and CMS studies
 - project and documentation ongoing (see TWiki for updates)

Future directions

Soft effects in VBF

[S. Plaetzer]

- Preliminary studies (in progress): variation of parameters controlling soft QCD (color reconnection and MPI) as important as pQCD uncertainties.



- What about other processes?

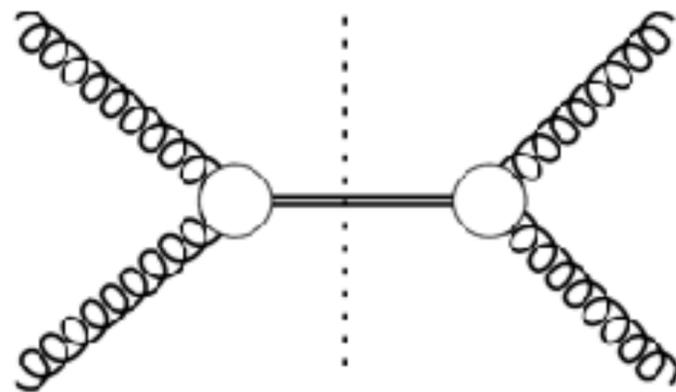
[Buckley, Chen, Ferrario Ravasio, Hoeche, Huston, Plätzer... — in progress]

Parton shower studies

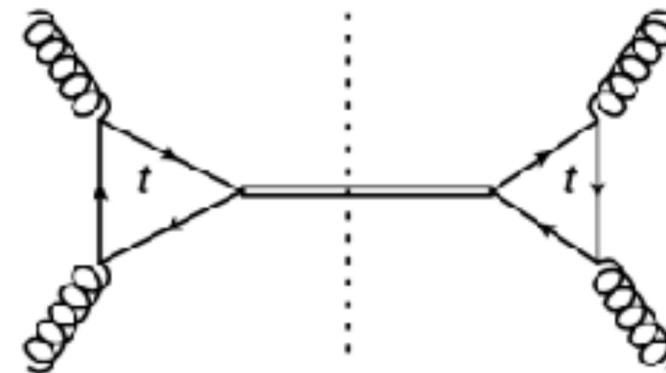
- Plenty of relevant studies complete or very close:
 - soft effects in VBF
 - ttbb, heavy-flavor in gluon fusion, benchmarks for VBF
 - multijet merging for VH and off-shell studies
- Almost time to complete the circle and discuss lessons learned, decide where more work would be useful.
 - a meeting in the first quarter of 2021 would be ideal.

High-mass scalars in gluon fusion

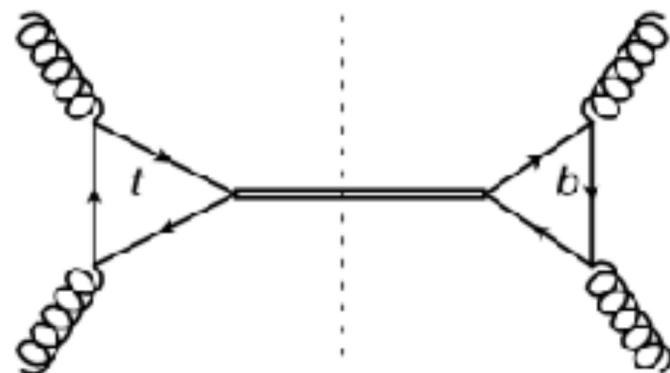
[B. Mistlberger]



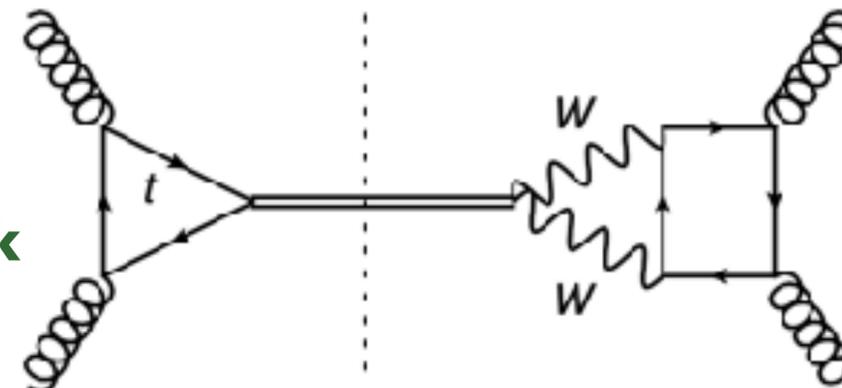
Dim-5 EFT to gluons



Yukawa
to top quark



Yukawa
to top/bottom quark



Yukawa to
top + EWK boson

- Separate couplings, effect of masses and interference terms to allow reinterpretation in as wide a range of BSM scenarios as possible.
- Cross-group (WG1+2+3) effort, aim to **improve clarity** in YR3/4 TWiki.

High-mass scalars in general

[F. Caola, P. Slavich, cross-group session]

- Calculations from YR3/4 available for all production modes, up to ~ 2 TeV.
- Extend exercise in same vein as for ggF, or for higher masses?
 - mostly trivial, within limitations of calculations
- Examples of issues to be aware of:
 - large width violating NWA
 - breaking of DIS-like factorization in VBF calculation
 - Yukawa modifications leading to additional $\log(m_b/m_H)$ enhancement
- Anticipate more cross-group work to **identify use cases, unify presentation, clarify caveats** and **ensure all theory ingredients used correctly and optimally**.

Documentation

- Already a number of new notes in the works for 2021.
 - including YR4-style updates for some topics, e.g. high-mass resonances and ttH backgrounds
- Is it also **time to update cross-section results more generally?**
 - too long (or too soon) since YR4?
 - enough new theoretical input (new calculations, PDF4LHC update)?
 - now exploring new experimental regimes or unforeseen scenarios that mandate an update?
 - uniformity and simplicity (vs. results in YR3, YR4, post-YR4 updates ...)

Changing of the guard

- A number of subgroup convenors have already stepped down or will be rotating out of their roles shortly.
- Terms of WG1 convenors also expiring in the near future

CMS: Alicia Calderon-Tazon → Julie Malcles

Thank-you to all for your work over the last few years!