b-associated Higgs production in SHERPA

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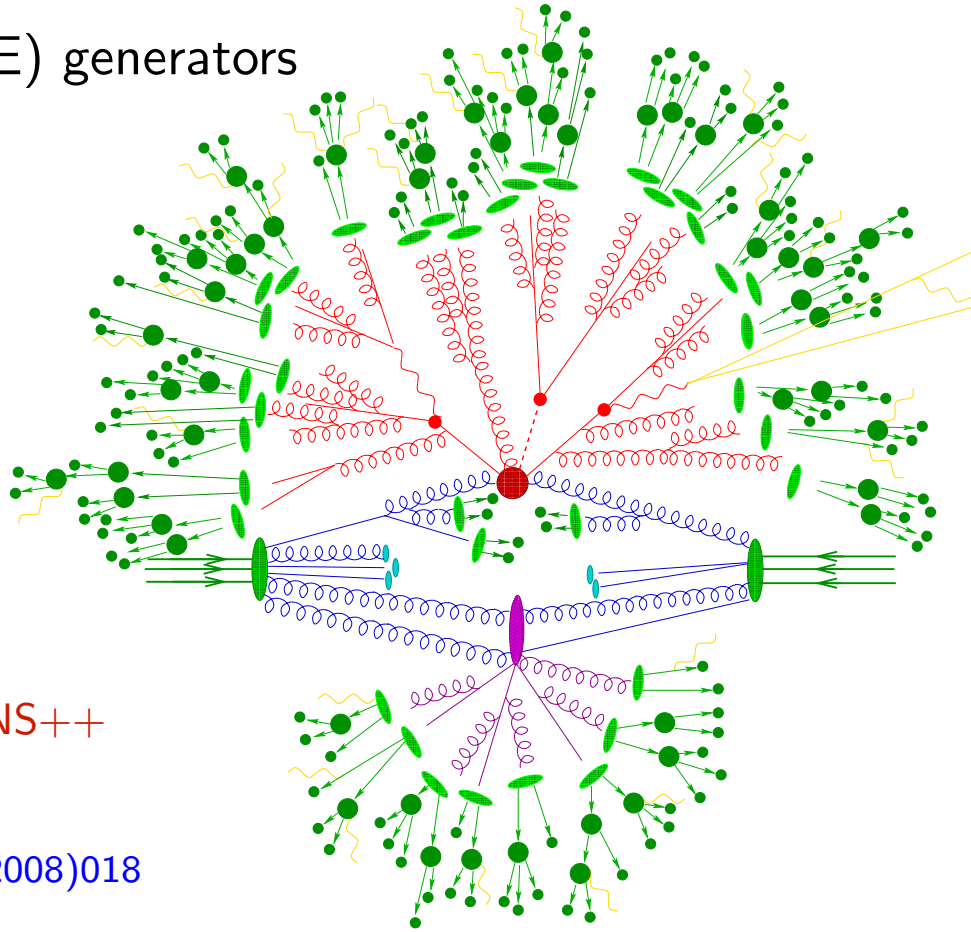
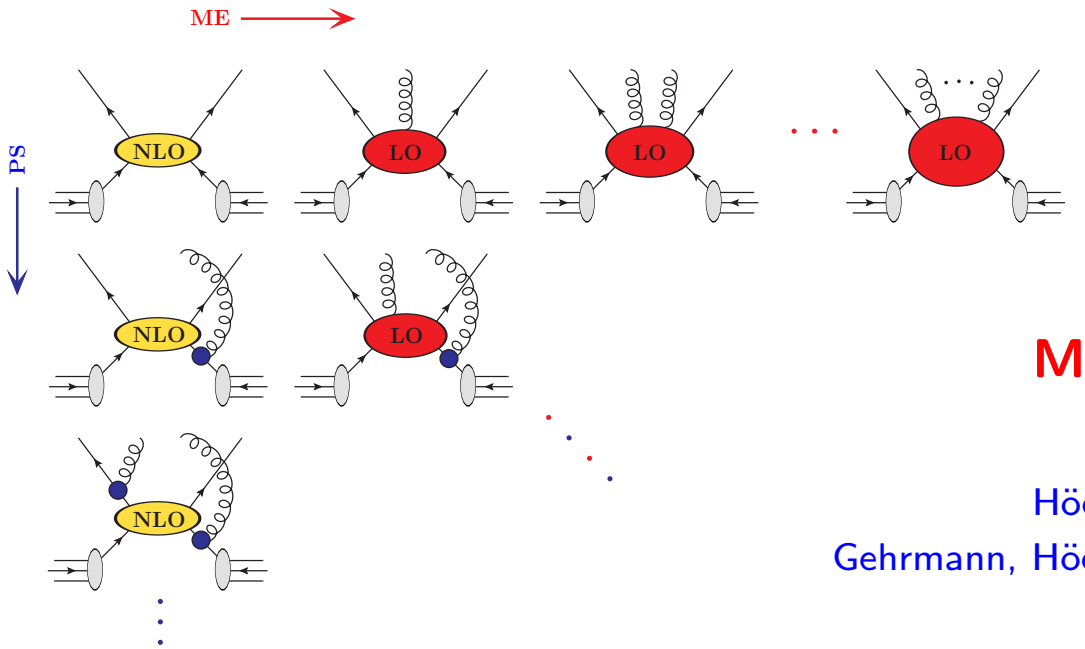
The SHERPA event generator framework

- Two multi-purpose Matrix Element (ME) generators
  AMEGIC++ JHEP02(2002)044, EPJC53(2008)501
  COMIX JHEP12(2008)039, PRL109(2012)042001
- A Parton Shower (PS) generator
  CSSHOWER++ JHEP03(2008)038
- A multiple interaction simulation
  à la Pythia AMISIC++ hep-ph/0601012
- A cluster fragmentation module
  AHADIC++ EPJC36(2004)381
- A hadron and τ decay package HADRONS++
- A higher order QED generator using
  YFS-resummation PHOTONS++ JHEP12(2008)018
- A minimum bias simulation SHRiMPS to appear



Sherpa's traditional strength is the perturbative part of the event
MEPS (CKKW), S-MC@NLO, MENLOPS, MEPS@NLO

MEPS@NLO

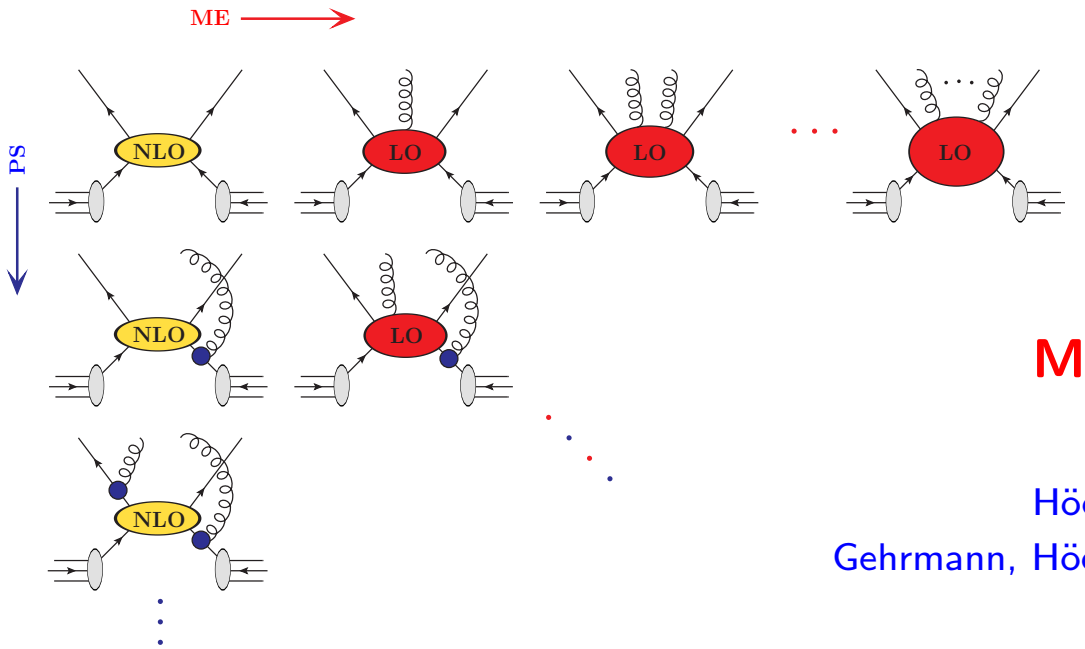


MENLOPS

Hamilton, Nason JHEP06(2010)039
Höche, Krauss, MS, Siegert JHEP08(2011)123
Gehrmann, Höche, Krauss, MS, Siegert JHEP01(2013)144

- matrix elements (ME) and parton showers (PS) are approximations in different regions of phase space
- MENLOPS supplements core NLOPS with higher multiplicities LOPS
- first step towards MEPS@NLO; combines multiple NLOPS
  – keeping either accuracy

MEPS@NLO



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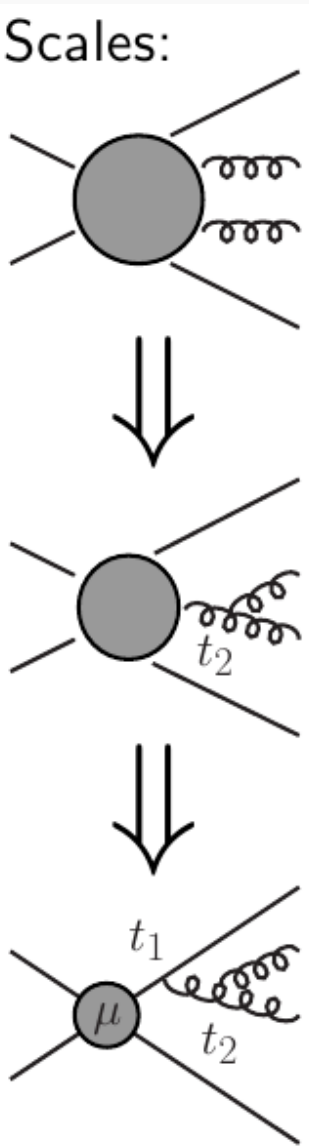


- matrix elements (ME) and parton showers (PS) are approxim different regions of phase space
- MENLOPS supplements core NLOPS with higher multiplicities
- first step towards MEPS@NLO; combines multiple NLOPS – keeping either accuracy

$$\alpha_s^{k+n}(\mu_R) = \alpha_s^k(\mu_{\text{core}})\,\alpha_s(t_1)\cdots\alpha_s(t_n)$$

Recent results

Multijet merging at NLO accuracy (MEPS@NLO)

- $pp \to W +$ jets – SHERPA+BLACKHAT Höche, Krauss, MS, Siegert JHEP04(2013)027
- $e^+e^- \to$ jets – SHERPA+BLACKHAT
  Gehrmann, Höche, Krauss, MS, Siegert JHEP01(2013)144
- $pp \to h +$ jets – SHERPA+GOSAM/MCFM
  Höche, Krauss, MS, Siegert, contribution to YR3 arXiv:1307.1347
  Höche, Krauss, MS Phys.Rev.D90(2014)014012
  MS, Zapp, contribution to LH'13 arXiv:1405.1067
- $p\bar{p} \to t\bar{t} +$ jets – SHERPA+GOSAM/OPENLOOPS
  Höche, Huang, Luisoni, MS, Winter Phys.Rev.D88(2013)014040
  Höche, Krauss, Maierhöfer, Pozzorini, MS, Siegert arXiv:1402.6293
- $pp \to 4\ell +$ jets – SHERPA+OPENLOOPS
  Cascioli, Höche, Krauss, Maierhöfer, Pozzorini, Siegert JHEP01(2014)046
- $pp \to VH +$ jets, $pp \to VV +$ jets, $pp \to VVV +$ jets
  – SHERPA+OPENLOOPS
  Höche, Krauss, Pozzorini, MS, Thompson, Zapp Phys.Rev.D89(2014)093015

$\Rightarrow$ process independent implementation, all public code

$\Rightarrow$ your process is not on the list yet? give it a try

b-associated Higgs production – setup

Recently studied in Wiesemann et.al. arXiv:1409.5301

Here:

4F calculation

- $pp \to hbb$+jets
  0j@NLO; 1,2j@LO
- includes
  $gg \to hbb$, $q\bar{q} \to hbb$,
  $gg \to hbbg$, $gq \to hbbq$,
  $qq \to hbbg$, etc.
- intricate scale choice due to coloured objects in the final state, use CKKW scale choice (see below)

$\Rightarrow$ vary by factor 2

- virtual corrections from OpenLoops

5F calculation

- $pp \to h$+jets
  so far only 0-3j@LO
  (no ggF component)
- includes
  $bb \to h$, $bb \to hg$, $gb \to hb$,
  $bb \to hgg$, $gb \to hgb$,
  $gg \to hbb$, etc.
- scale choices straight forward
  $\Rightarrow$ usual CKKW scales with core scales $\mu_{R/F} = \mu_Q = m_h$

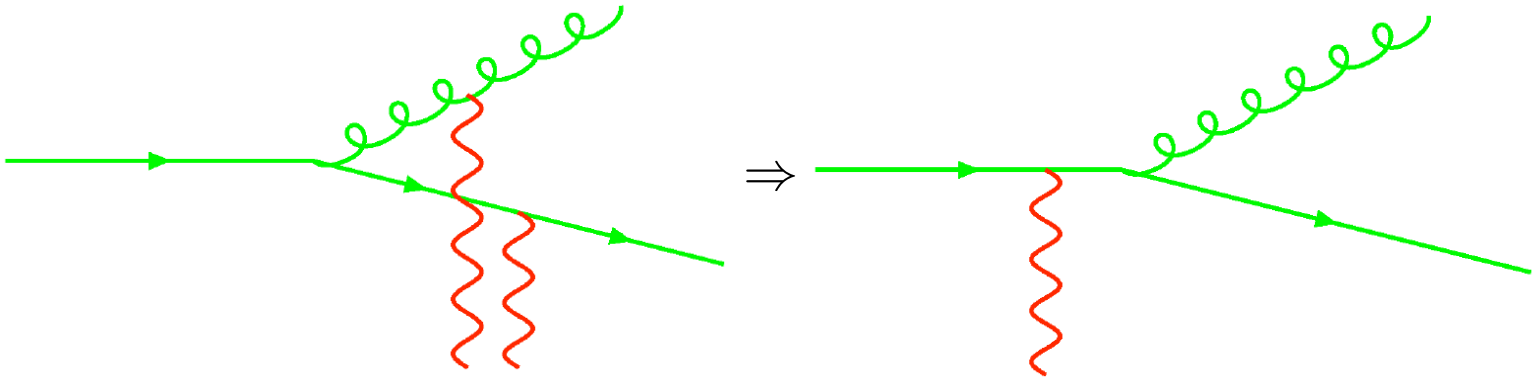
$\Rightarrow$ vary by factor 2

- virtual corrections from OpenLoops

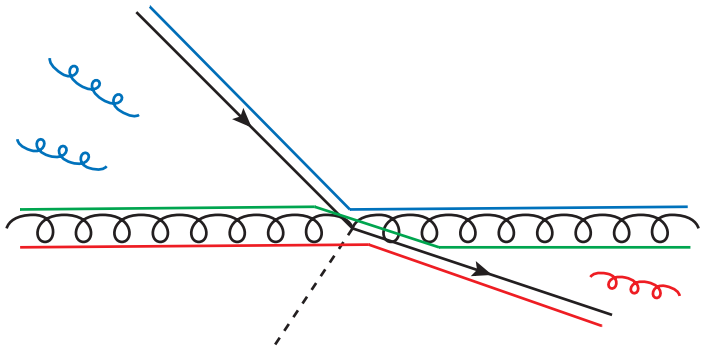
Parton showers in $pp \to X b\bar{b}$

- when matching fixed-order to parton shower care must be taken when there are coloured objects in the final state
- parton showers approximate parton emission in the collinear limit
  $\to$ no knowledge about interferences

$\Rightarrow$ coherence effects not described by splitting functions of external legs

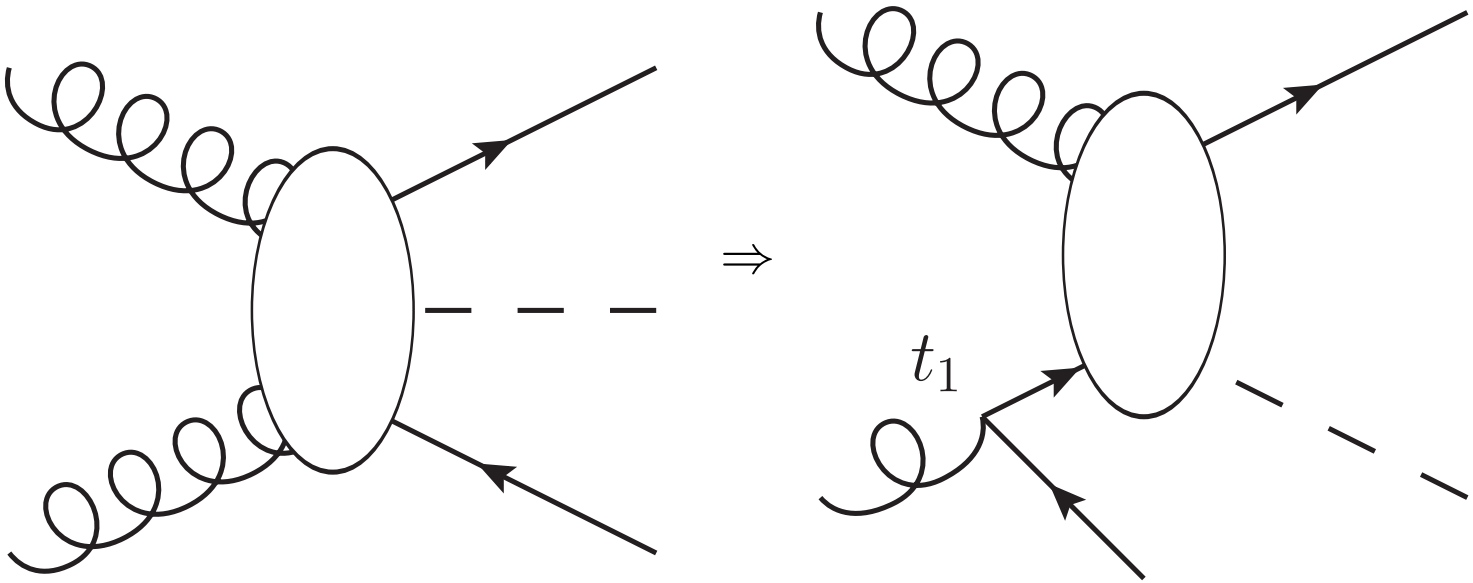


- radiation must be constrained within the opening angle of the colour dipole



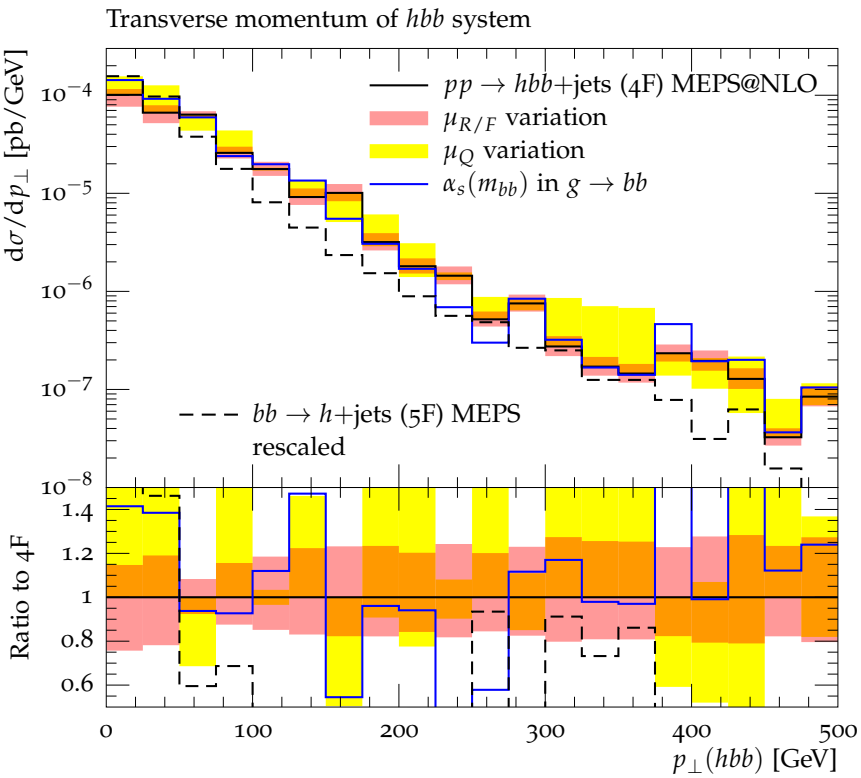
Parton shower starting conditions for $pp \to X b\bar{b}$

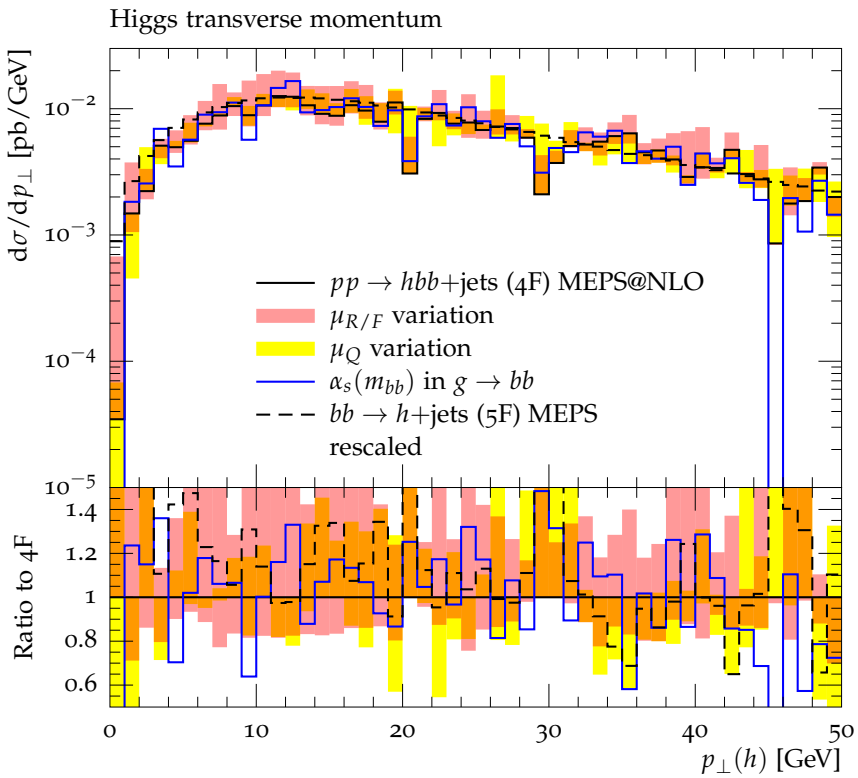
One way of addressing the above issue is through clustering in CKKW approach.
Reduce



$\to$ starting scale needs to be of the order of t
$\to$ set starting scale on $2 \to 2$ to $\mu_Q = m_\perp(h)$
in the following also use for μ_R the solution of $\alpha_s^2(\mu_R) = \alpha_s(m_h)\alpha_s(t)$ and $\mu_F = \mu_Q$

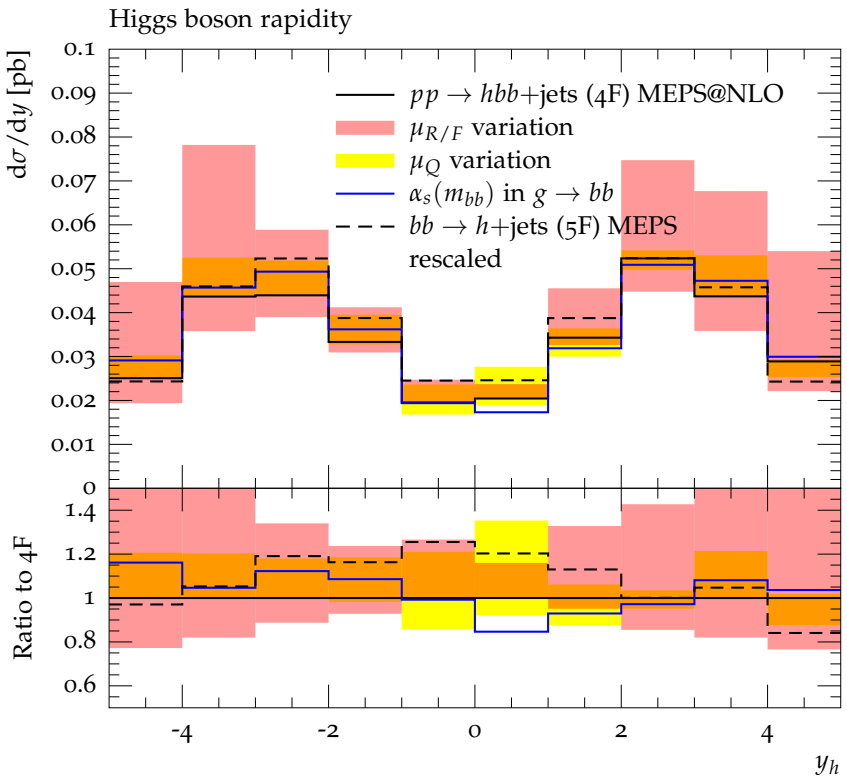
very preliminary results





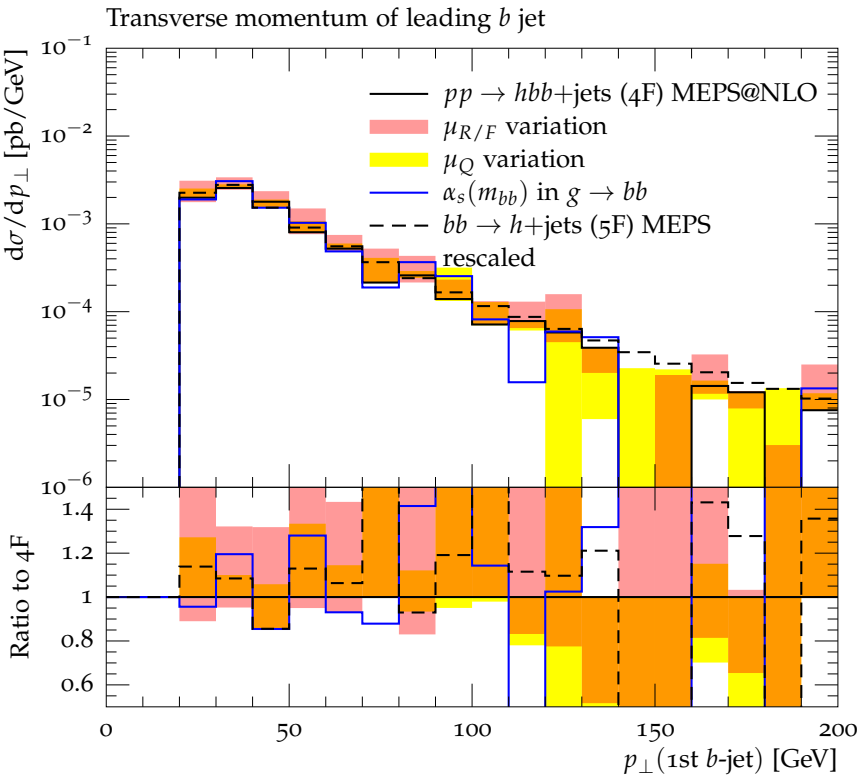
- $p_\perp(hbb)$ is somewhat softer in 5F
- hardly any impact of choice of scale in $g \to bb$ splitting
  $\to$ most likely because leading b-jets couple to Higgs
  $\to$ hardly any contribution from soft $g \to bb$ splittings

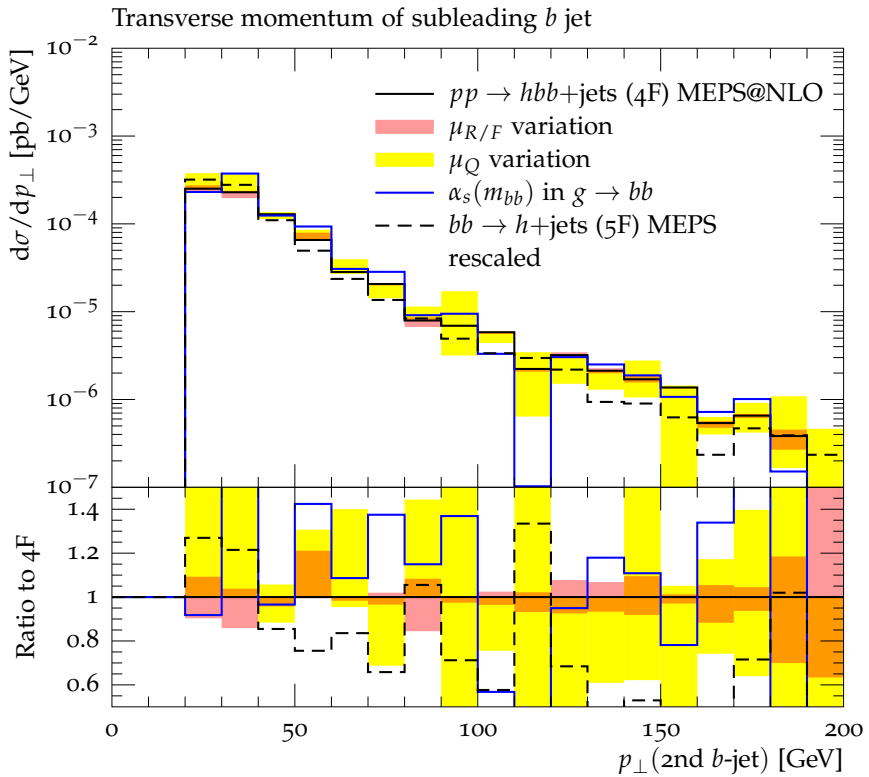
very preliminary results



- 5F slightly more central, but might be changed when going to NLO in 5F
- hardly any impact of choice of scale in $g \to bb$ splitting

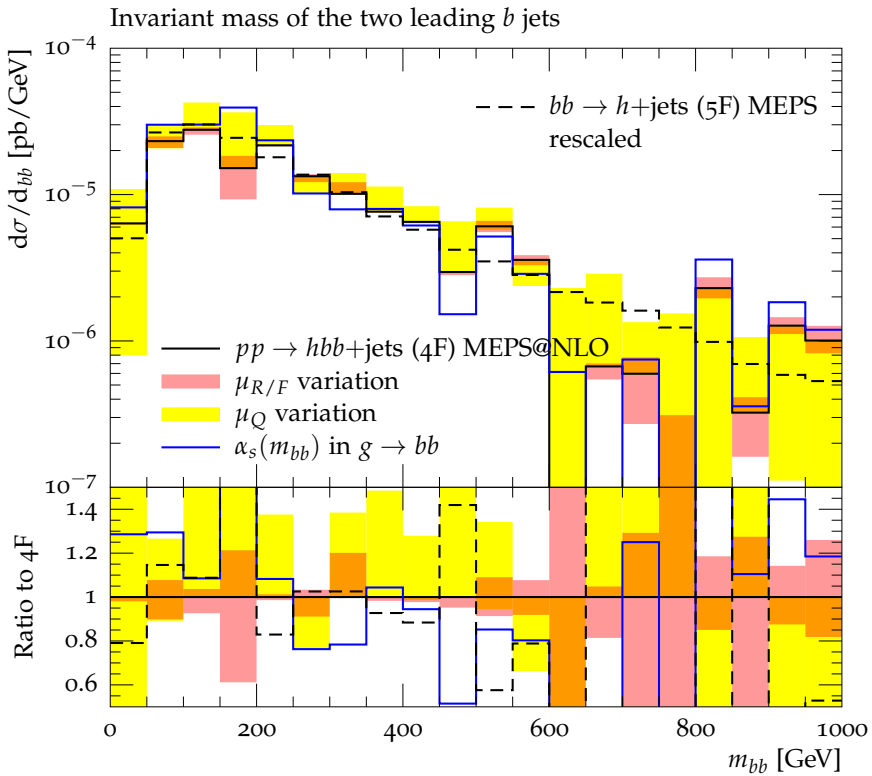
very preliminary results

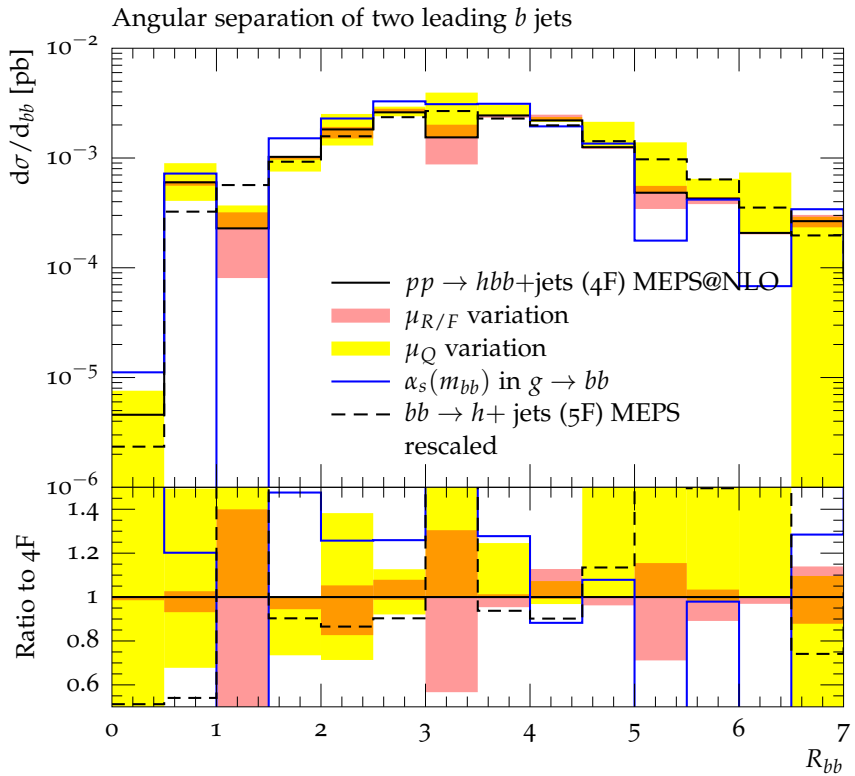




- good agreement for $p_\perp$(1st b-jet)
- $p_\perp$(2nd b-jet) is somewhat softer in 5F
- hardly any impact of choice of scale in $g \to bb$ splitting

very preliminary results





- good agreement between 4F and 5F
- deviations in small R_{bb}, where expected
- impact of choice of scale in $g \to bb$ splitting at small R_{bb}

Conclusions

- many subtleties in b-associated (colour neutral) boson production (4F)
  $\rightarrow$ care must be taken when setting up the parton shower when coloured objects are present in the final state
  $\rightarrow$ need to understand parton shower approximation and angular ordering
- 4F calculation can use consistent setting of y_b and m_b,
  5F calculation needs y_b with $m_b = 0$
- perurbative uncertainties due to $\mu_{R/F}$, μ_Q and Q_{cut} can be assessed in the fixed-order part
- so far: parton level study with limited statistics
  assessed $\mu_{R/F}$ and μ_Q uncertainties so far
- validate choices against somewhat similar processes like $pp \rightarrow Zbb$

current release SHERPA-2.1.1

http://sherpa.hepforge.org

Thank you for your attention!