Status of NLO top threshold studies

K.Nowak, **A.F.Żarnecki**
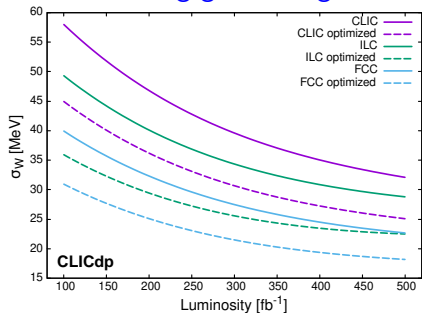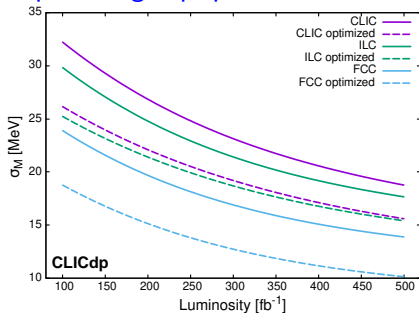
ILD Top/HF group meeting

Outline

1. Motivation

2. Whizard simulation

3. Cross section results

4. Kinematic distributions

5. Conclusions

Recent study: K.Nowak, A.F.Żarnecki

"Optimising top-quark threshold scan at CLIC using genetic algorithm"

Published in: JHEP 07 (2021) 070, arXiv:2103.00522

Top quark mass fit based on cross section measurements only,
beam polarisation not included...
This is clearly not the optimal approach...

Top forward-backward asymmetry and top-quark momentum distribution are also sensitive to the top quark mass and could be included in the fit:
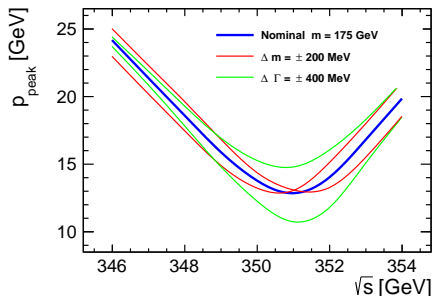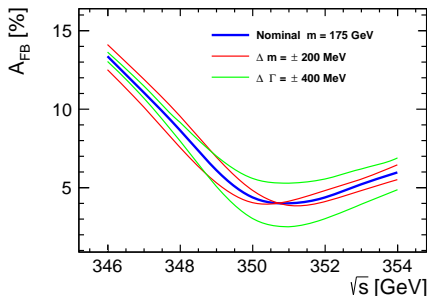
Adapted from: M. Martinez, R. Miquel, "Multiparameter fits to the t anti-t threshold observables at a future $e^+ e^-$ linear collider", Eur. Phys. J. C 27, 49–55 (2003).

Impact of beam polarisation is also crucial!

NLO QCD

NLO QCD corrections calculated in Whizard for arbitrary process
also for top pair production in the continuum...

However, top threshold simulation is a special case:

- resummed threshold effects implemented as effective vertex
  (based on TOPPIK)
- dedicated matching from threshold NLL to continuum NLO

Six terms in the cross section calculation at the threshold:

- 3 NLO terms (born, real and virtual)
- 3 terms from "matched" NLL contribution (born, real and virtual)

NLO QCD

Fixed-order NLO events can also be produced in three different modes:

- Separate weighted
  each of the six components integrated and generated separately

- Combined weighted
  two contributions calculated: full (born+real+virtual) matched NLL
  and full (born+real+virtual) NLO

- Combined unweighted
  as above, but only possible when both contributions positive,
  POWHEG matching (NLO – PS) need to be used
  clearly preferred for event simulation and analysis
  not possible with ISR (matching component negative) ???

Results presented in the following based on Whizard 3.0.1

Cross section for:
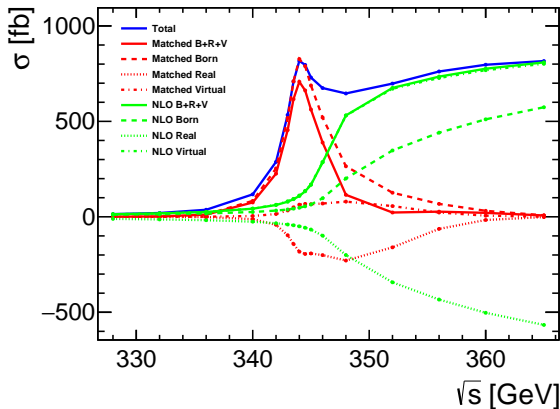
$$e^+ e^- \rightarrow W^+ b \; W^- \bar{b}$$
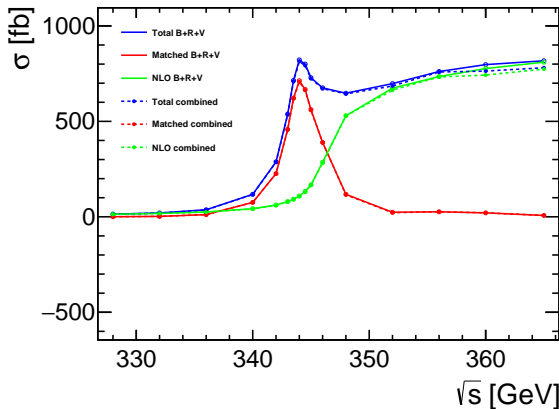
no ISR, no beam spectra, no polarisation

Consistent results for separate and combined calculations of contributions

Cross section for:

$$e^+e^- \rightarrow W^+b \ W^-\bar{b}$$
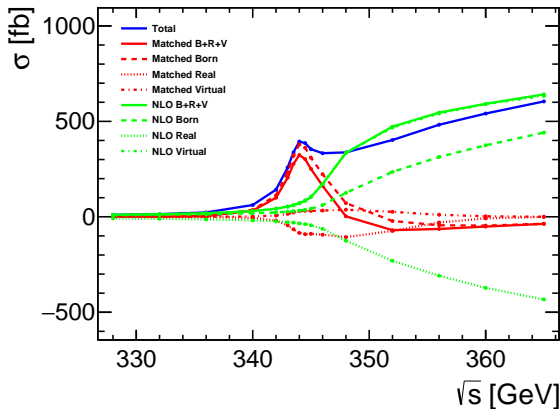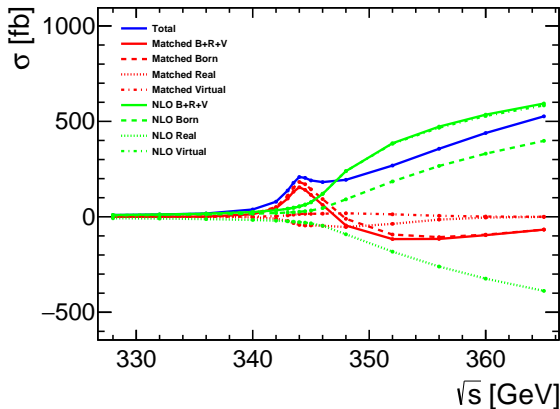
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Consistent results for separate and combined calculations of contributions

Cross section for:

$$e^+e^- \rightarrow W^+b \; W^-\bar{b}$$

with ISR, no beam spectra, no polarisation
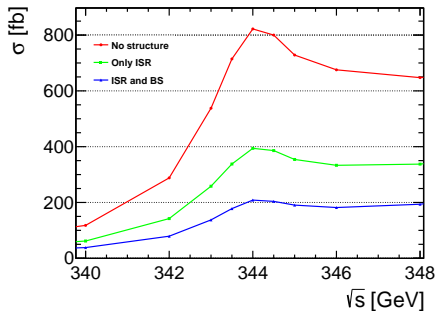
Cross section for:

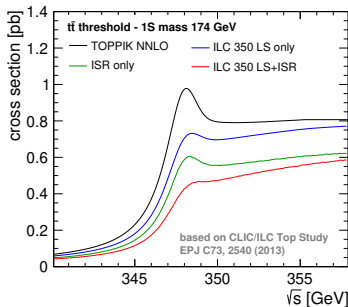$$e^+ e^- \rightarrow W^+ b \, W^- \bar{b}$$

with ISR and beam spectra, no polarisation

Cross section for:

$$e^+ e^- \rightarrow W^+ b\ W^- \bar{b}$$

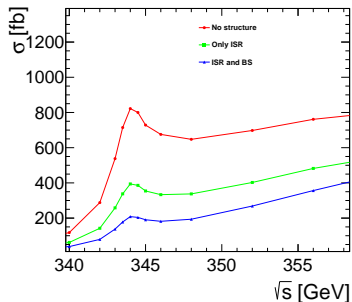Seem OK, but impact of ISR and beam spectra larger than expected

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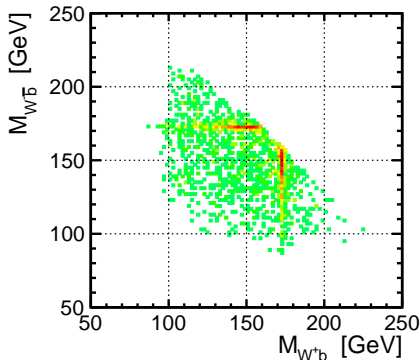Seem OK, but impact of ISR and beam spectra larger than expected
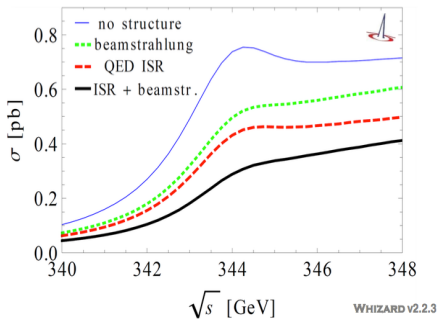
J. Reuter @ Corfu'2017

Cross section for:

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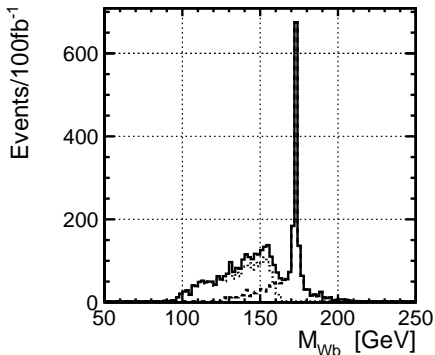Seem OK, but impact of ISR and beam spectra larger than expected
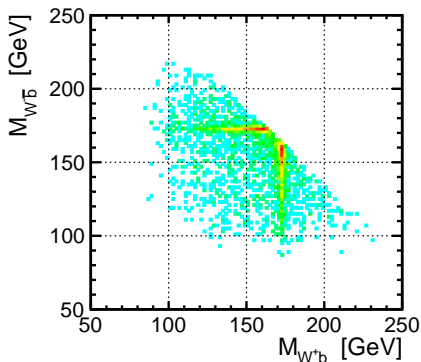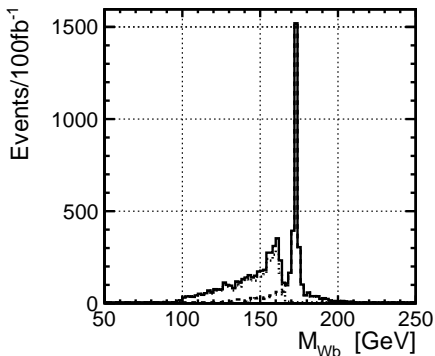

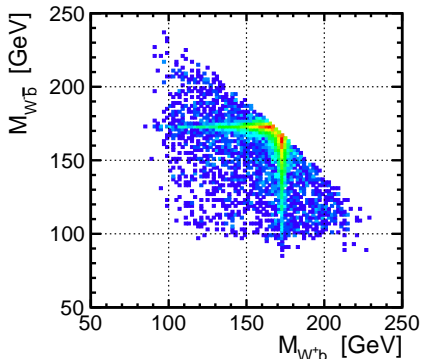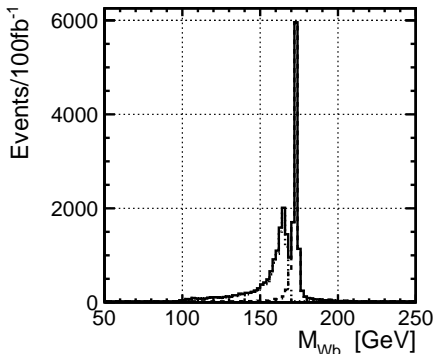
F.Simon, based on arXiv:1303.3758

Combined unweighted simulation (in two parts: matched + nlofull)

$$e^+e^- \rightarrow W^+b \ W^-\bar{b}$$

no ISR, no beam spectra, no polarisation

Invariant mass distributions for $\sqrt{s}$=332 GeV
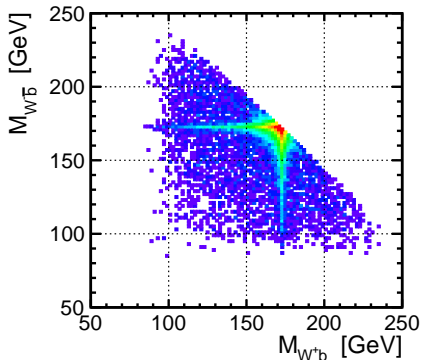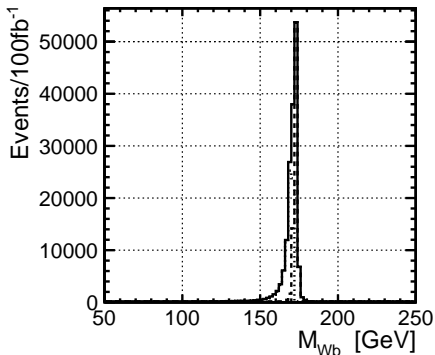
Kinematic distributions

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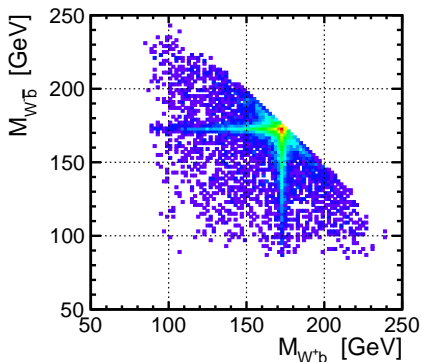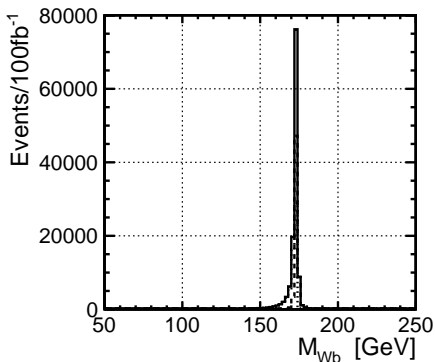
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Invariant mass distributions for $\sqrt{s}$=340 GeV
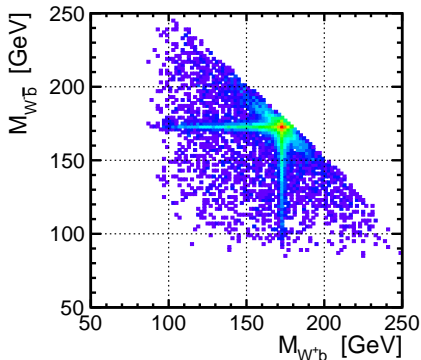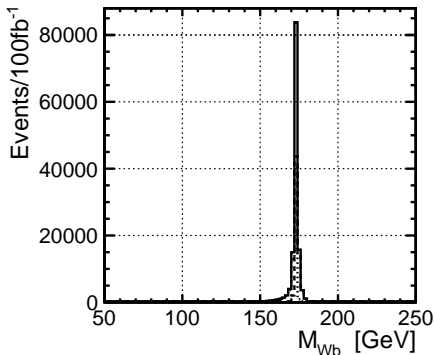
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Invariant mass distributions for $\sqrt{s}$=344 GeV

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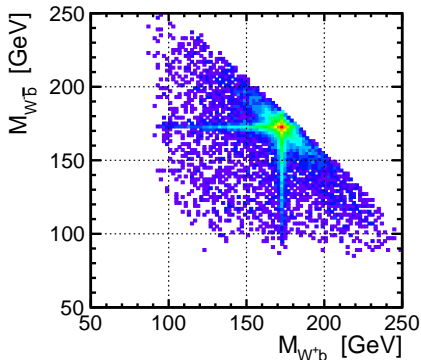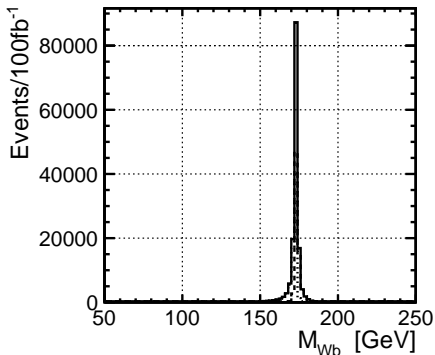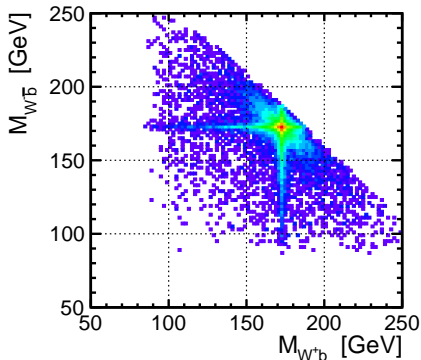
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Invariant mass distributions for $\sqrt{s}=352\,\text{GeV}$
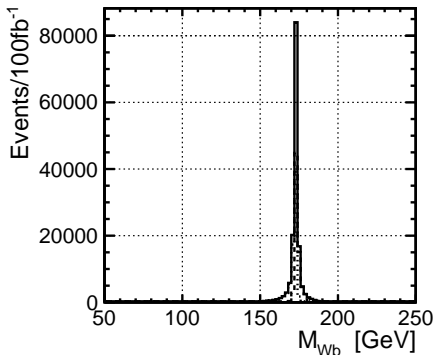
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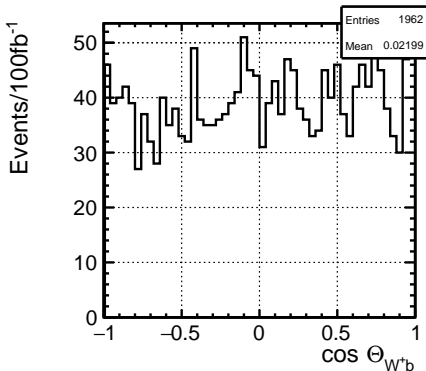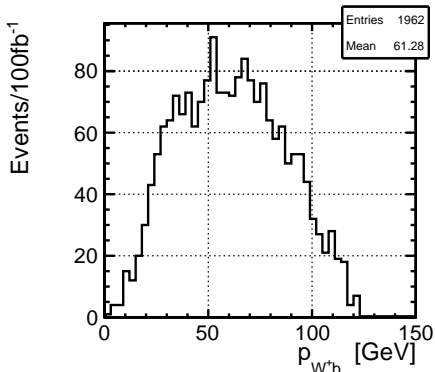
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Invariant mass distributions for $\sqrt{s}$=360 GeV

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Momentum and angular distributions for $\sqrt{s}=332\,\text{GeV}$
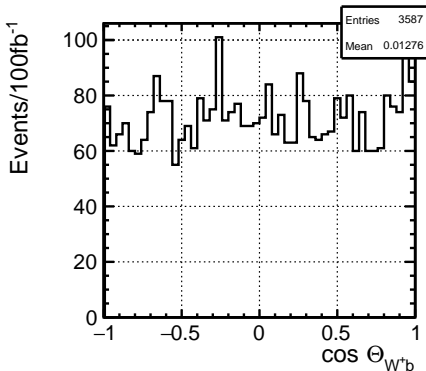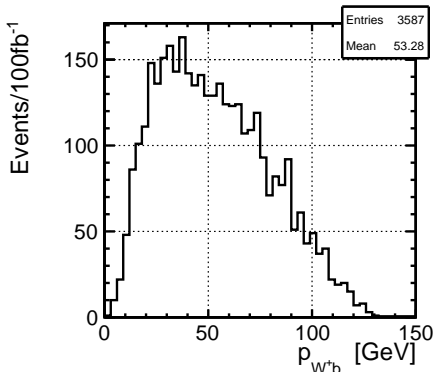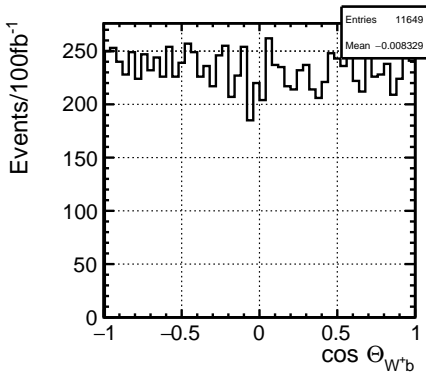
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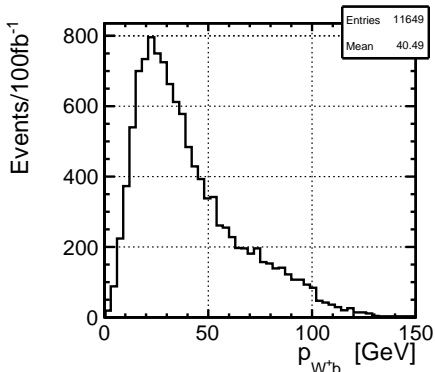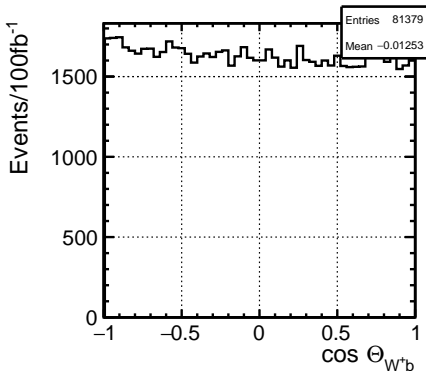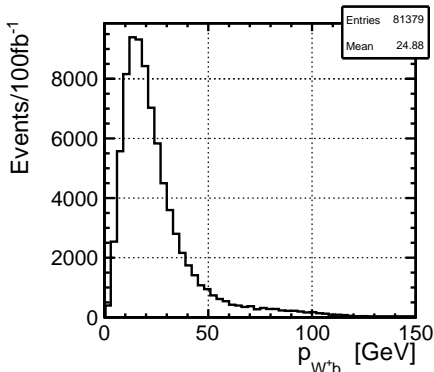
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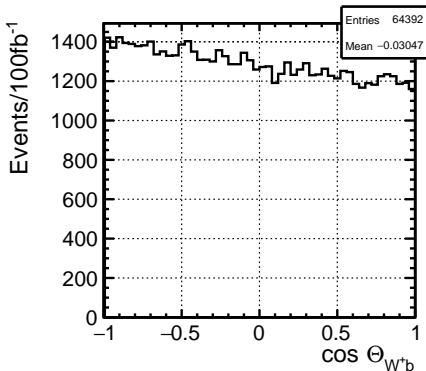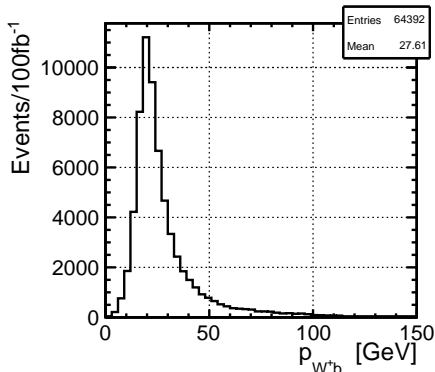
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Momentum and angular distributions for $\sqrt{s}=344\,\text{GeV}$
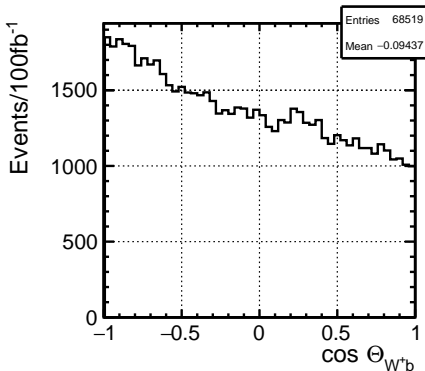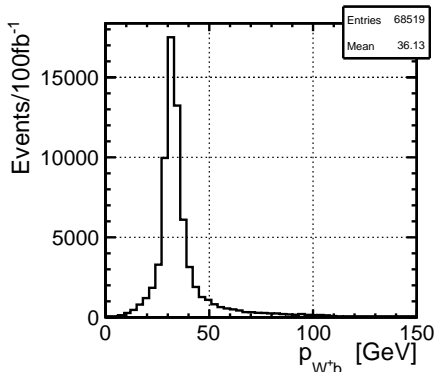
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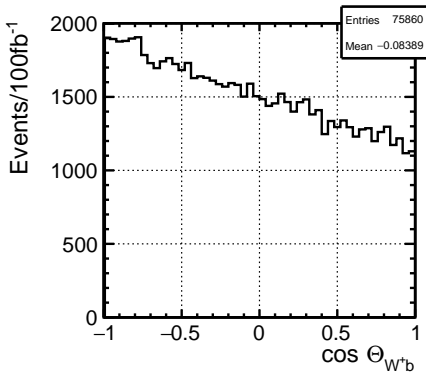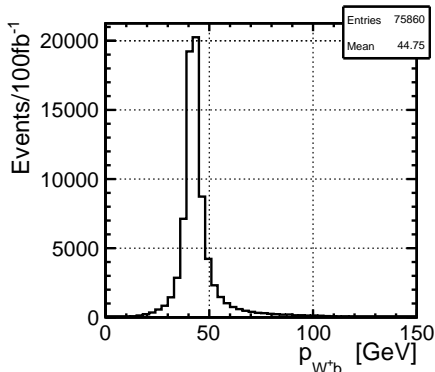
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Momentum and angular distributions for $\sqrt{s}=352\,\text{GeV}$

Kinematic distributions

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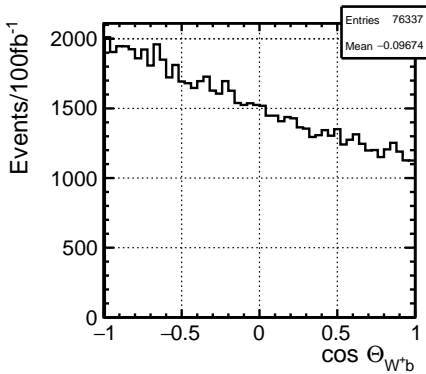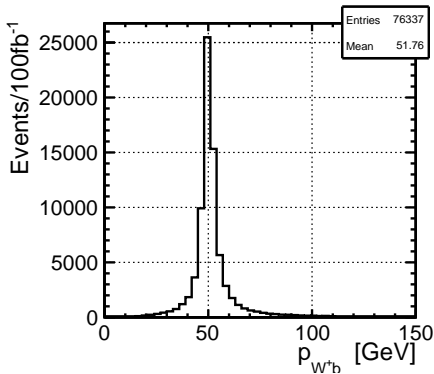Momentum and angular distributions for $\sqrt{s}=356\,\text{GeV}$

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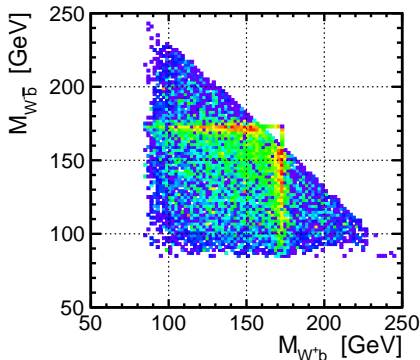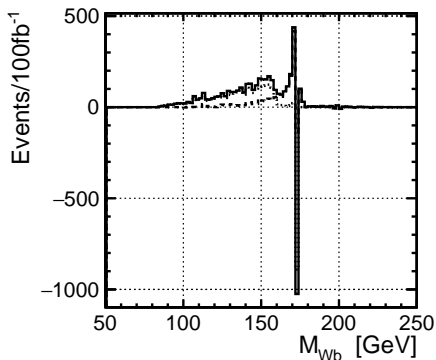
Separate weighted simulation (in six parts)

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Invariant mass distributions for $\sqrt{s}=332\,\text{GeV}$

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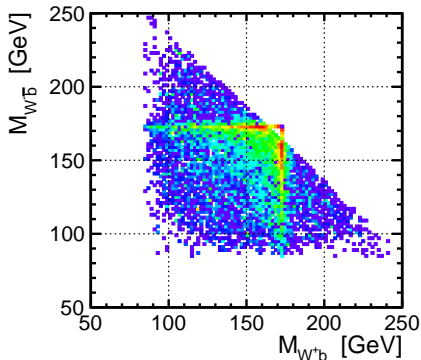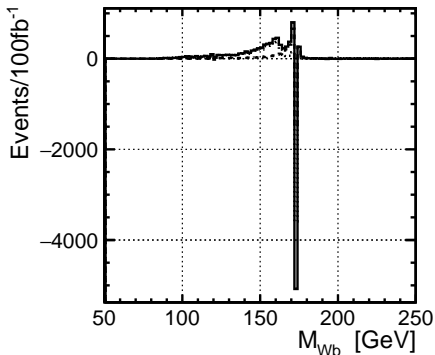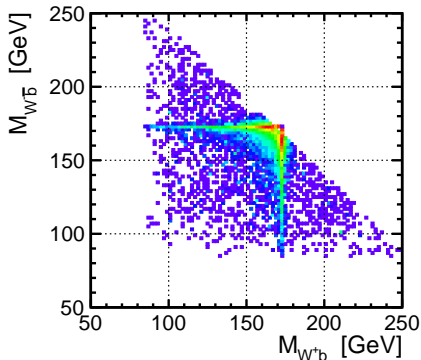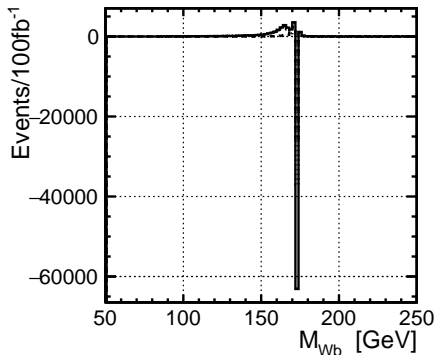Invariant mass distributions for $\sqrt{s}$=336 GeV

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Invariant mass distributions for $\sqrt{s}=340\,\text{GeV}$
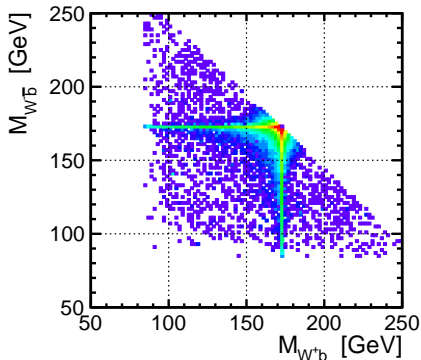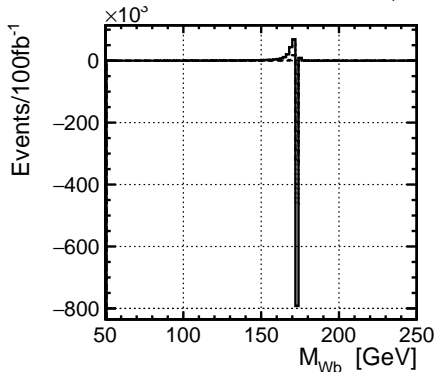
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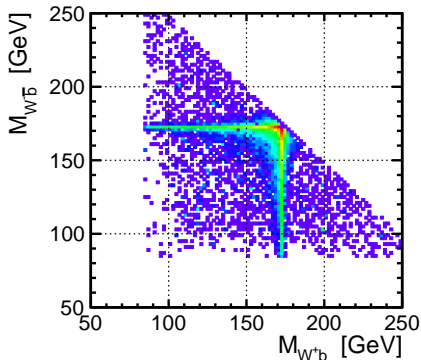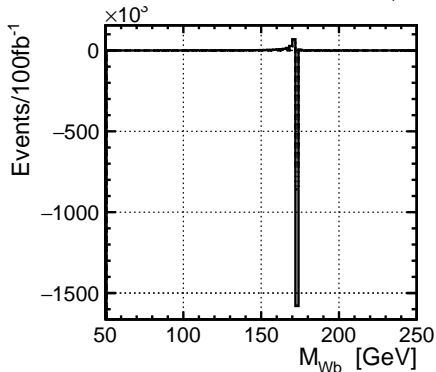
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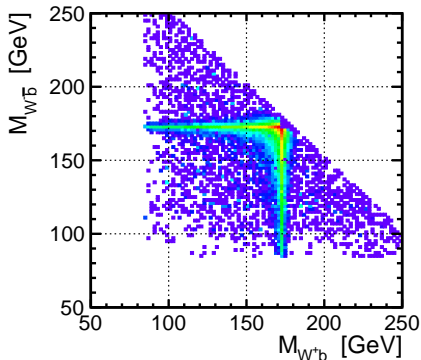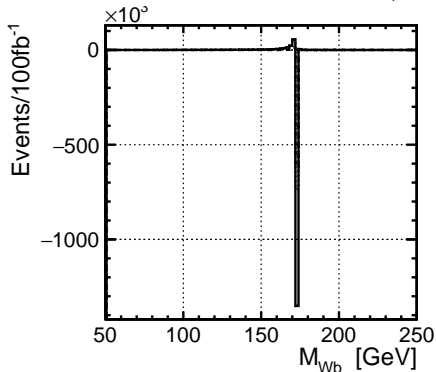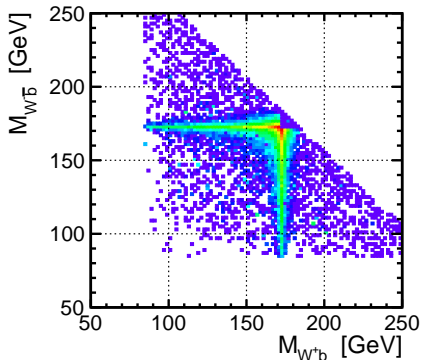Invariant mass distributions for $\sqrt{s}=352\,\text{GeV}$

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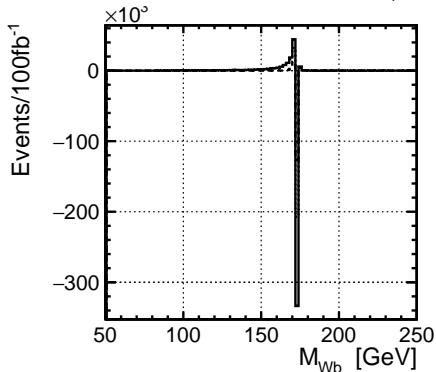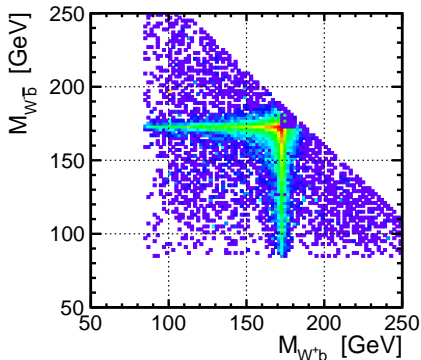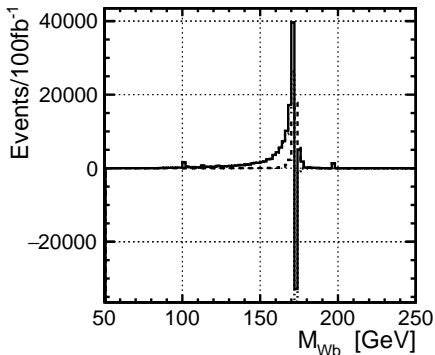
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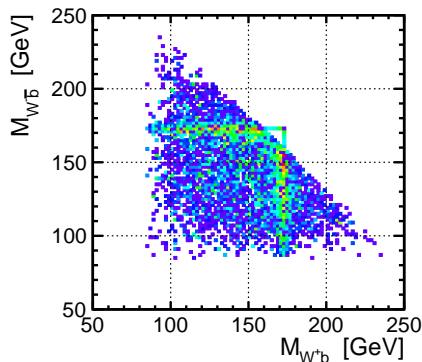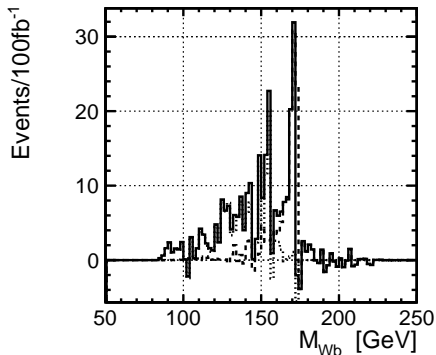
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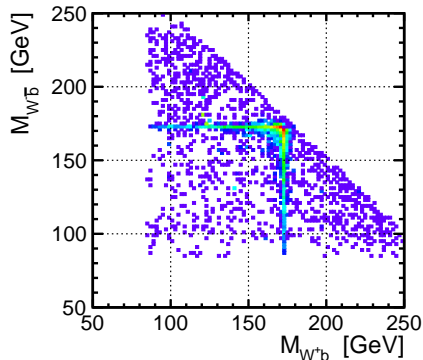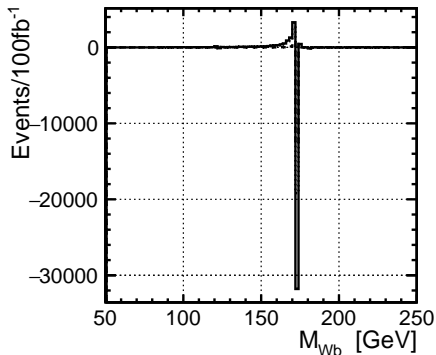
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with ISR and beam spectra, no polarisation

Invariant mass distributions for $\sqrt{s}=332\,\text{GeV}$
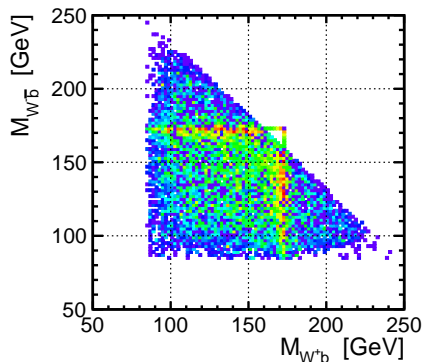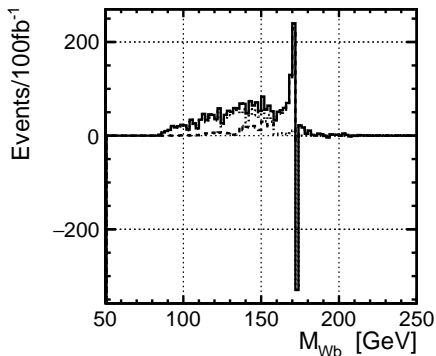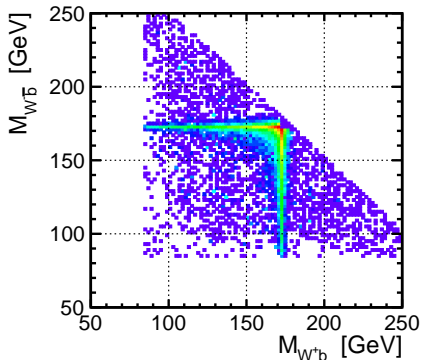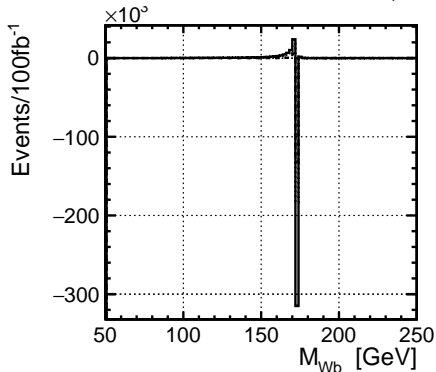
Kinematic distributions

Separate weighted simulation (in six parts)

$$e^+ e^- \rightarrow W^+ b \; W^- \bar{b}$$

with ISR and beam spectra, no polarisation

Invariant mass distributions for $\sqrt{s} = 352\,\text{GeV}$

Working on event generation for top threshold scan with NLO Whizard

"Plain" Whizard seems to run OK,
kinematic distribution also consistent with expectations...

Impact of beam spectra on the cross section seems to be too large.

There is clearly a problem in weighted event simulation: seems like virtual top quarks are forced on-shell, violating energy conservation...

Whizard fails completly, when trying to define beam polarisation...

Experts contacted...