$t\bar{t}$ generation at FCCee

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Introduction

- News on generation of $t\bar{t}$ events for FCCee.

- In this presentation :

  - Focus on whizard :
    - NLO generation and event weights,
    - Generation at threshold scan,
    - Modelling of ISR and BES.

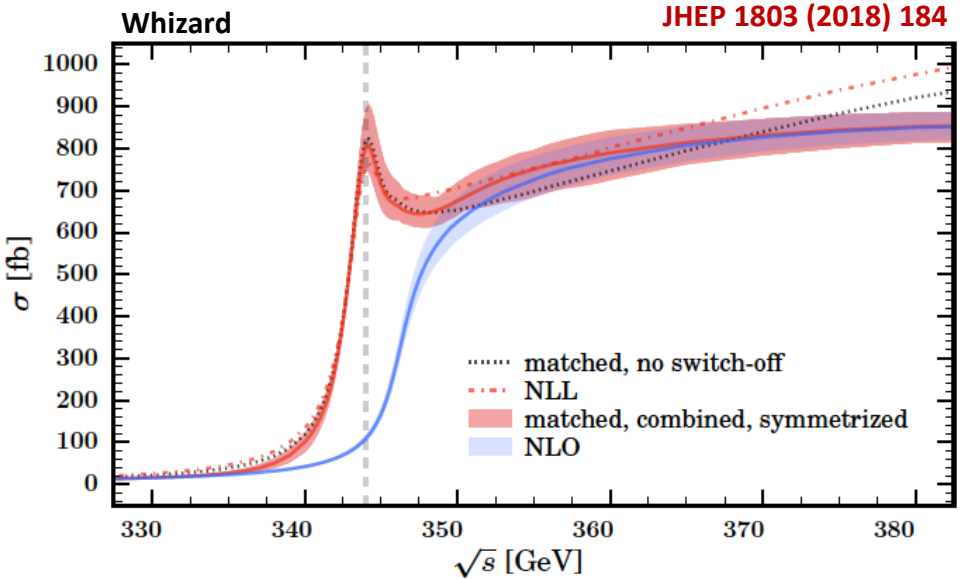
  - Status of the analysis framework (migration to FCCAnalyses).

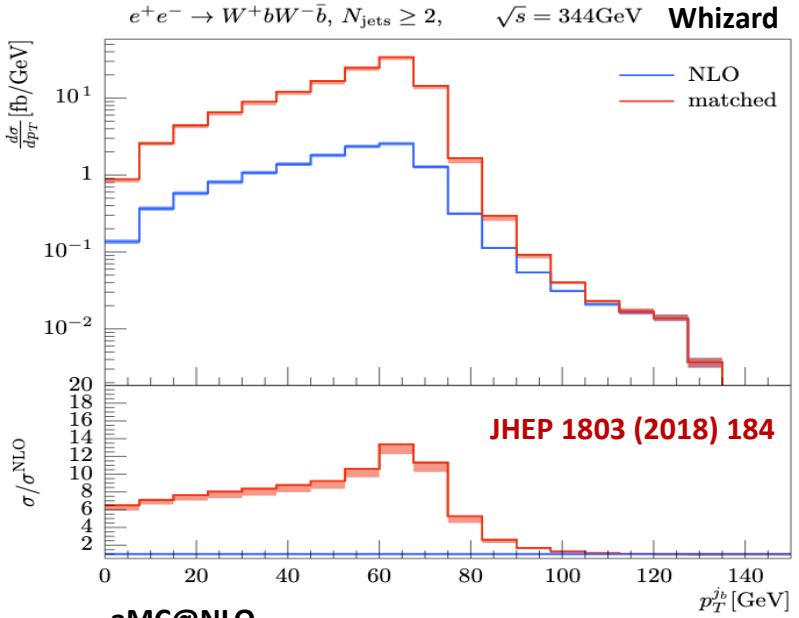
  - Next steps.

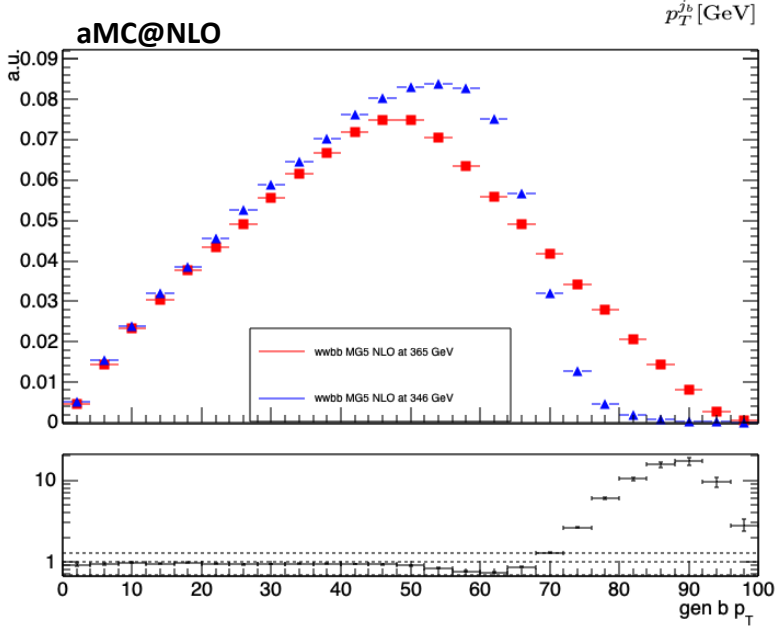
Generators : aMC@NLO and Whizard

- Having “state-of-the-art” generators is a key element for precisions
  - Maximum possible accuracy : NLO QCD+QED,
  - NLL+NLO matching : differential cross sections at threshold, effects of $\sqrt{s}$ on kinematics,
  - Account for the beam effects discussed above,
  - We need at least 2 generators to perform comparisons,
  - **Two generators under investigations** : Whizard and aMC@NLO.

- Both generators cover most of the required features (in a not-yet public release for aMC@NLO link) :
  - NLO accuracy, **Whizard** : QCD , **MadGraph** :QCD (QED under developments for both generators),
  - Initial State (QED) Radiation, **both,**
  - Beamstrahlung : **Whizard** : interface with GuineaPig/CIRCE. **MadGraph** : parametrization fitted to GuineaPig++.
  - Beam Energy Spread : **Whizard** : Gaussian smearing in case of FCCee, **Madgraph** : not available yet.







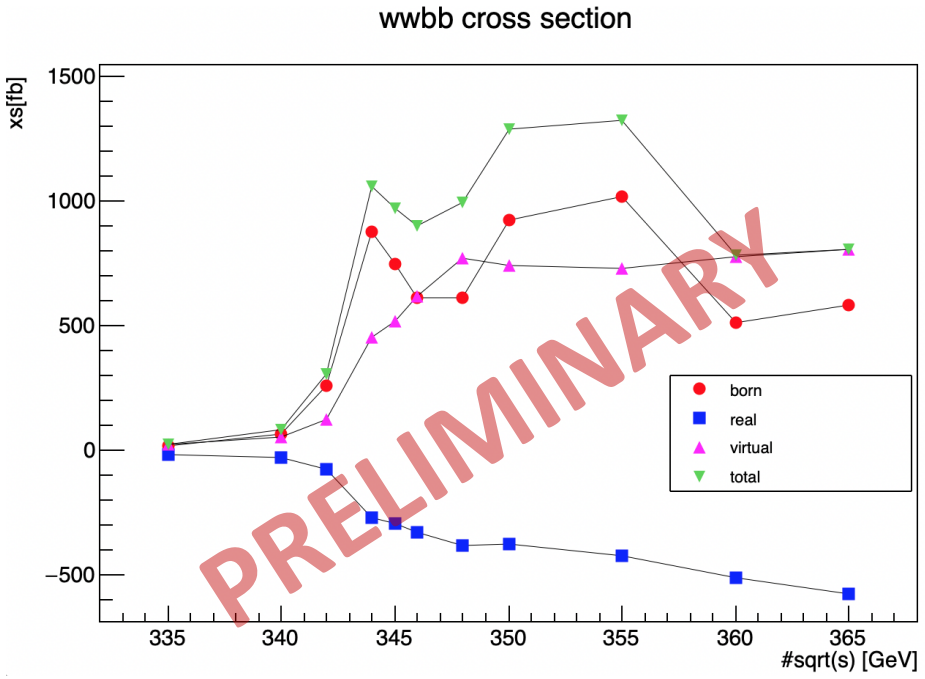
Whizard cross sections at threshold

Whizard installation and running at $t\bar{t}$ threshold

- Calculation of $t\bar{t}$ ($WWb\bar{b}$) (differential) cross sections at threshold.
  - NLO calculation performed with the SM model,
  - To be combined with a dedicated model to reproduce the threshold,
  - Fixed order calculation : can not be used “as is” for event based analyses.

- **Close collaboration with Whizard Authors**
  - **many thanks to them**.

- Installation and running :
  - Complete recipe provided privately by Authors link,
  - Requires the installation of OpenLoop, HepMC, Ocaml,
  - Examples of whizard config files provided in the package (NLO_NLL_matched.sin).



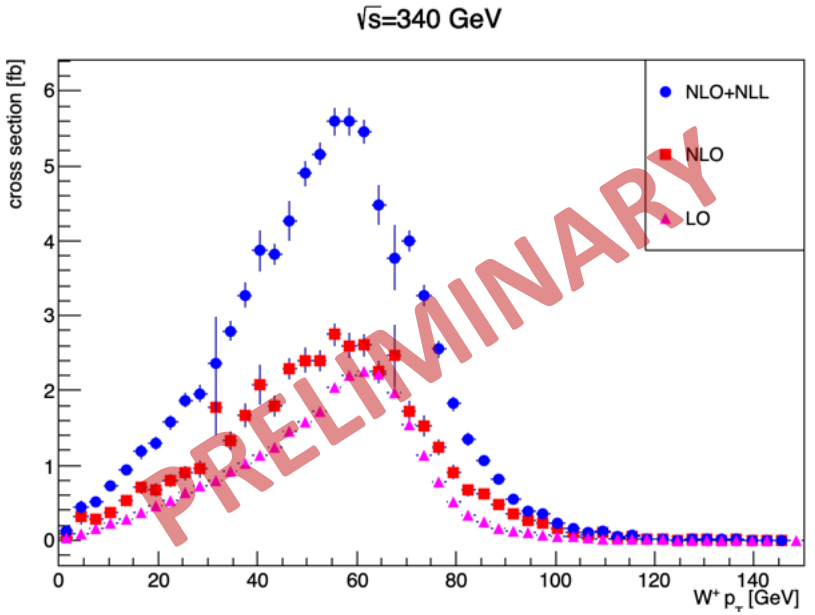
- About the calculations :
  - NLO and ”NLL-matched” calculations required, to be summed,
  - 3 components for each : “Born”, “Real” and “Virtual”, to be summed as well.

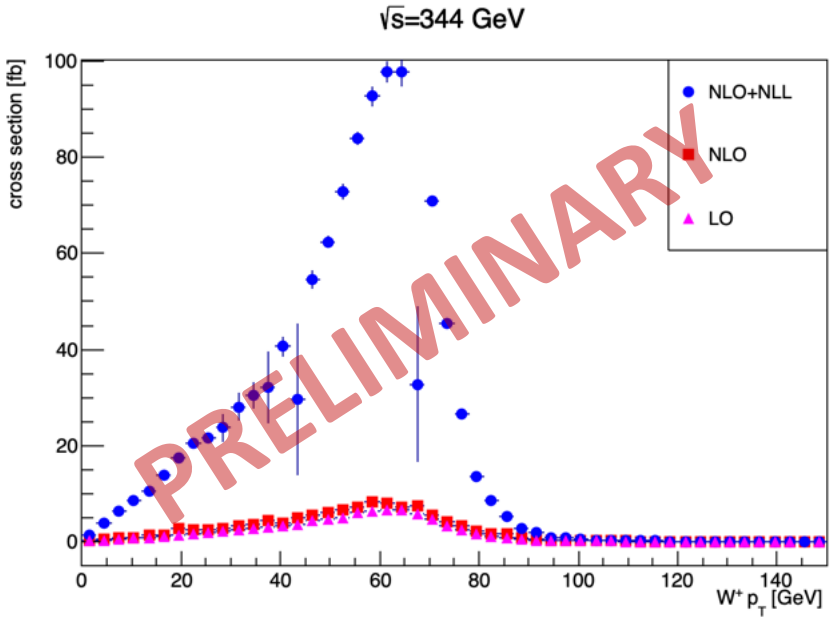
- Observation : “correct” cross section behaviour can be observed up to ~347 GeV. Beyond, the cross sections seems decreases too quickly.

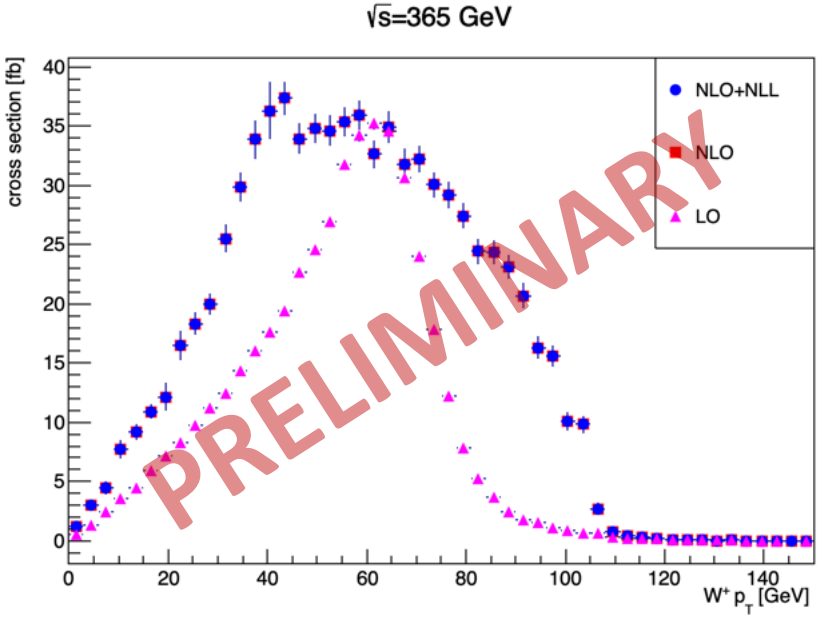
- Whizard Authors are aware and investigating. Could just be a miss-usage issue.

Differential cross section => distributions

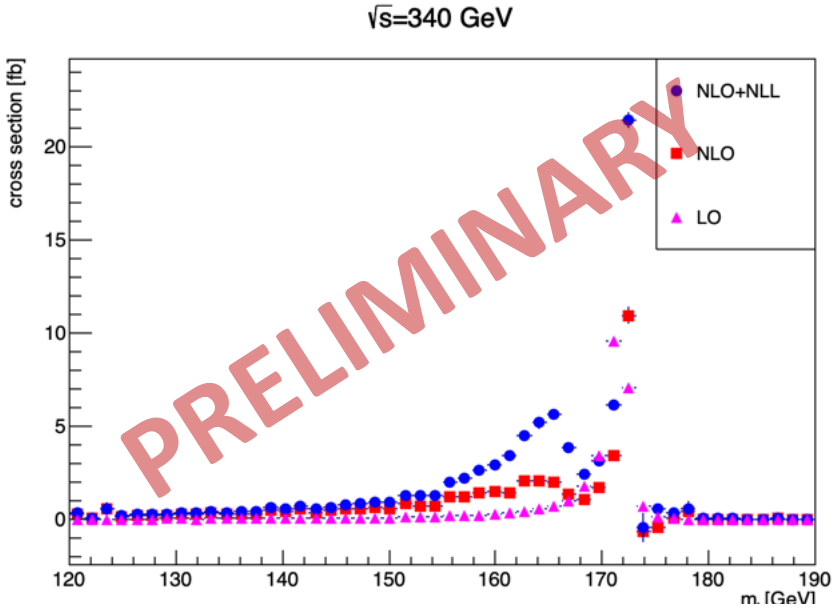
- Combination of events (NLO or Matched) :
  - Generate separately “Born”, “Real” and “Virtual”,
  - Normalised each sample to its sum of MC weights,
  - Particularity of the “Real” sample, it is based on “sub-events” => each event is decomposed in 3 different sub-events, which need to be recombined to get a correct statistical error.
  - The usage of NLO whizard events required a proper accounting of sub-events => implement in FCCSWAnalyses ?

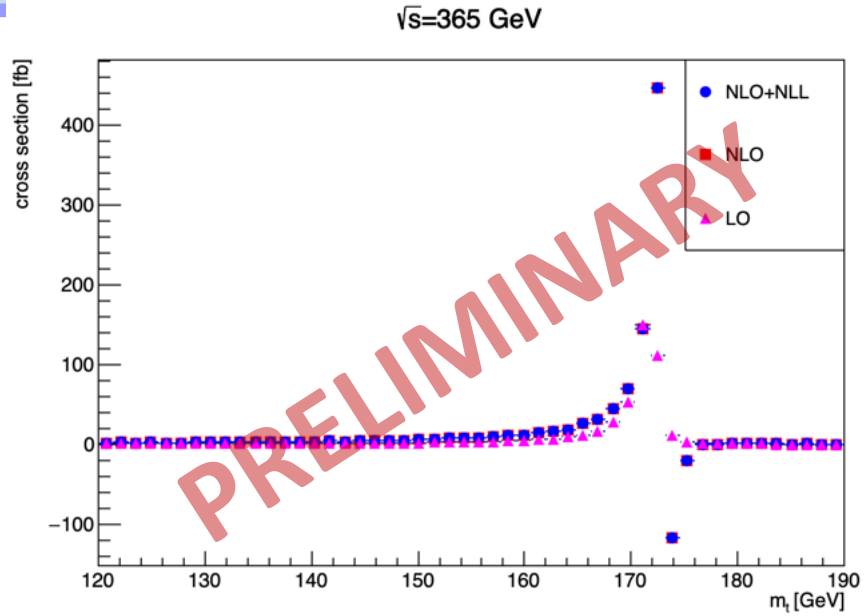


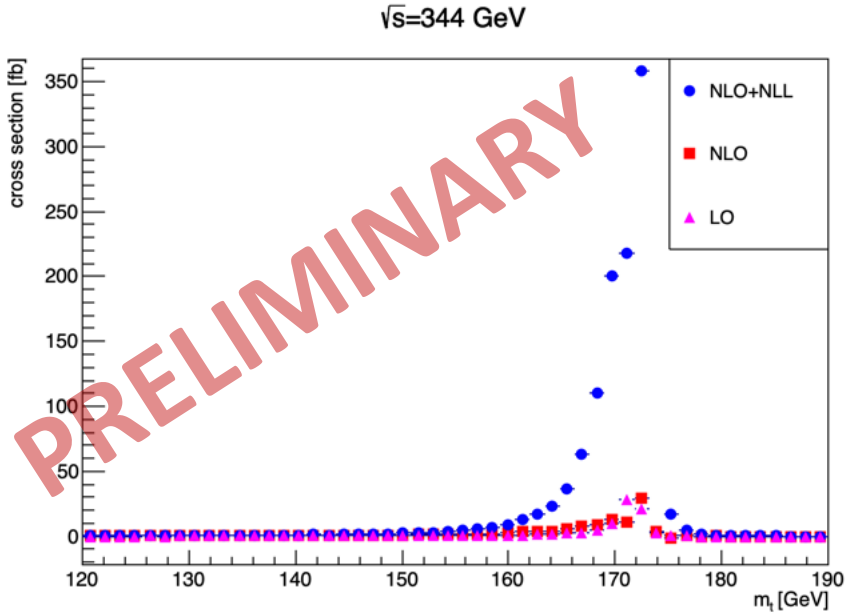




Top mass







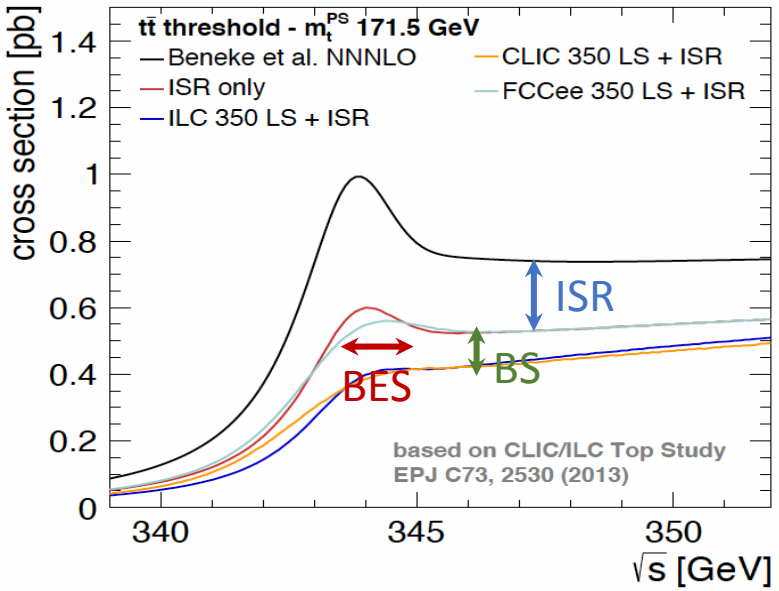
- Wb invariant mass
  - Off-shell tops visible at 340 GeV,
  - Increase of on-shell tops at 344 GeV, already visible from NLO+NLL,
  - shows incorrect shape at 365 GeV, with some negative total cross sections. Integration problems to be investigated.

- **Results to be taken with grains of salt**, (my) proper usage of whizard being reviews by authors.

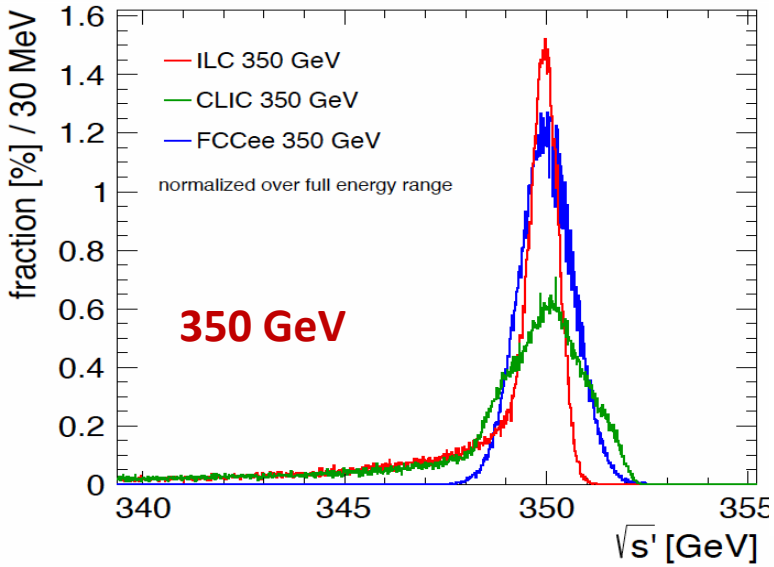
Whizard ISR and BES (LO generation)

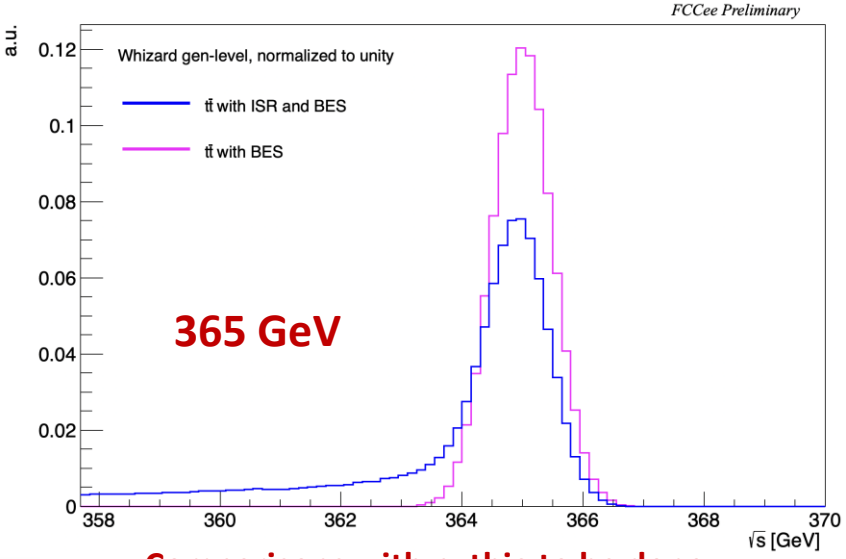
Beam effects/ISR

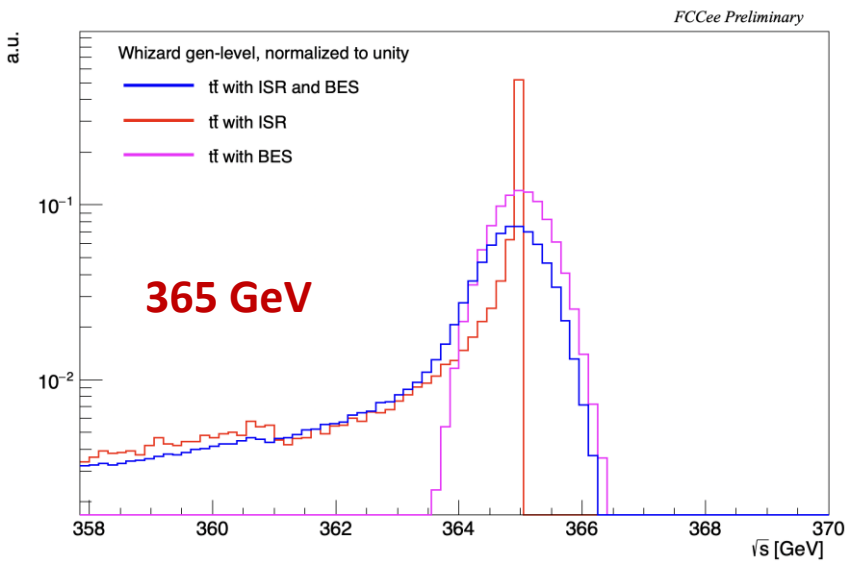
F.Simon, PoS (ICHEP 2016) 872



- ISR and beam effects on the threshold measurement :
  - ISR and Beam Backgrounds : reduces the energy in the e^+e^- centre of mass => tails toward lower energies.
  - Beam Energy Spread (BES) : enlarge the $\sqrt{s}$ distribution. BES ~0.19% per beam.
- At FCCee BES : $\sqrt{s}$ distribution symmetric and gaussian with very good approximation. BS neglected in the following.
- Whizard :
  - ISR implemented. Possible overlap with PS (pythia) to be understood.
  - BES : modelled by a gaussian.







Comparisons with pythia to be done

Toward centralized event generation

- Centralized event generation required for Snowmass analyses (and beyond).
- Whizard generator seems the natural choice, even if comparisons with other generators is important (pyhtia, MG_aMC@NLO).

- Several approaches possible : LO, NLO,
  - $2 \to 2$ $(e^+e^- \to t\bar{t})$, only above threshold, Pythia for decays,
  - $2 \to 4$ $(e^+e^- \to W^+W^-b\bar{b})$, Pythia for decays,
  - $2 \to 6$ $\left(e^+e^- \to f\bar{f}'f\bar{f}'b\bar{b}\right)$, most complete, several process files (one per final states).

- Pythia used for PS and hadronization :
  - Pythia6 is still the default in whizard, interface to Pythia8 is implemented but not recommended,
  - Overlap between Pythia ISR and Whizard ISR ?

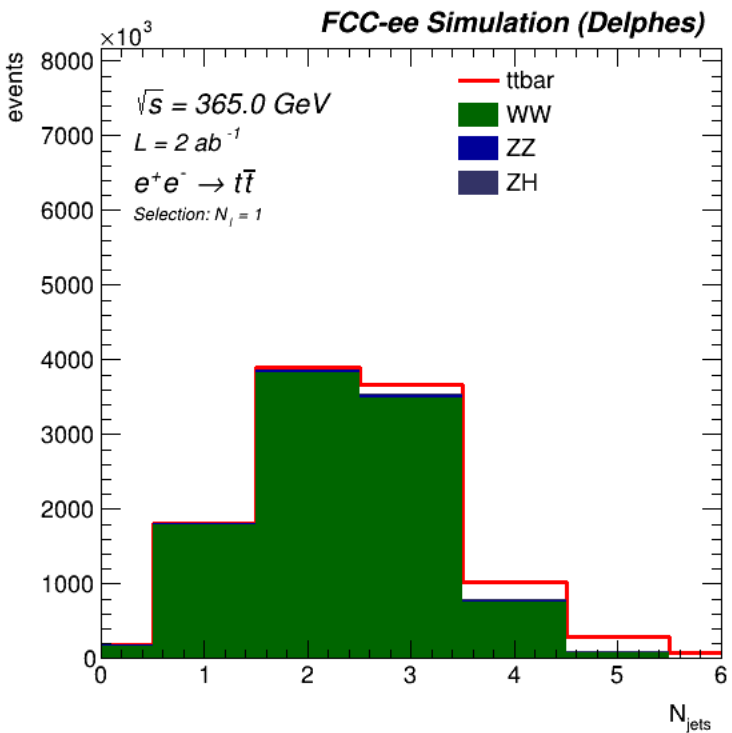
- Parameters to define :
  - Model parameters (masses, couplings, scales),
  - Pythia parameters,
  - Beam parameters and beam backgrounds (BS negligible at first ?)
  - Systematics …

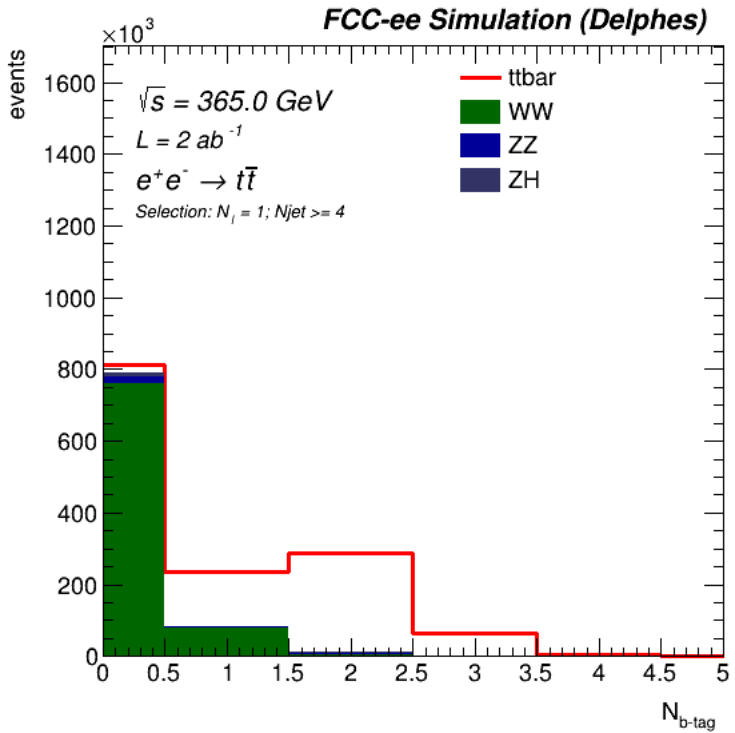
- Get in touch with ILC/CLIC community to reproduce similar samples ?
  - Some details available at https://ilcsoft.desy.de/dbd/generated/other.html
  - Share HepMC samples even ?
  - For production within FCCSW, some work required for automatization ?

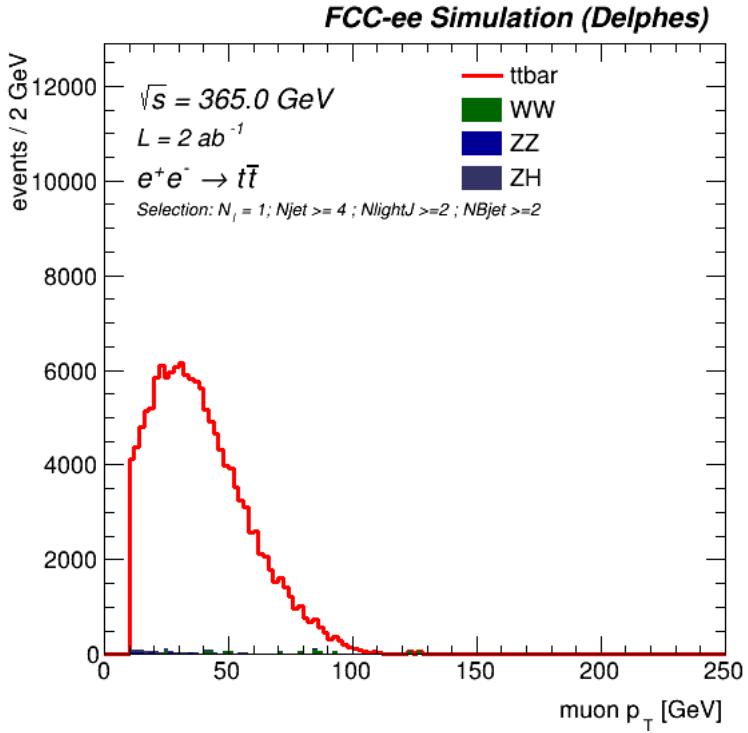
Analysis within FCCSW

- Migration of simple events selection to FCCSWAnalyses (thanks to Clement for the help).

- Baseline for future $t\bar{t}$ specific tools :
  - Baseline event selections, for each channel : **Required to preform MC validation,** various reconstruction algorithms to be tested, optimisation etc…
  - Event reconstruction : Solve events reconstructions using the beam energy information, Deal with combinatorics, Kin-fit to improve the resolution.







Next steps

- Preparation of the production :
  - whizard configurations for signal (and backgrounds),
  - exhaustive list of samples to generate (energy scan and above threshold),
  - Tools for MC validation (plots).

- How to perform the MC production ?
  - Automatization tools for production on CERN cluster ?
  - Separately for LHE (parton level), HepMC (+hadronization/PS/decay) and Delphes ?
  - Storage ? Access to files from outside CERN ?
  - Help from experts to answer these questions ☺.

- In parallel :
  - Investigate the production of systematic samples (scale, α_S, hadronization ? Others ?),
  - Test MG5_aMC@NLO generations with “beam effects”,
  - Start the analyses …