Plans for $t\bar{t}$ studies

for coming analyses

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Introduction

- The top-quark program at FCCee is vast :
  - $t\bar{t}$ threshold (mass, width, yukawa, α_s) and anomalous couplings, (single-) top quark FCNC etc…

- Letter of Interests for Snowmass submitted, related opportunities :
  - Restart activities, but also improve analysis techniques, expand the list of possible measurements, innovate,
  - Particular effort on the impact of beam related effects and detector optimisation,
  - Room for collaborations !

- In this talk ($t\bar{t}$ threshold oriented) :
  - Quick reminder of physics opportunities,
  - Short discussions of the plan.
  - Status of investigations on MC generations, reproducing the peak-shape of the cross section and plans for ISR/beam effects.

Snowmass LoI

Snowmass2021 - Letter of Interest

Top quark physics at FCC-ee

Thematic Areas:

- (EF03) EW Physics: Heavy flavor and top quark physics
- (EF04) EW Physics: EW Precision Physics and constraining new physics

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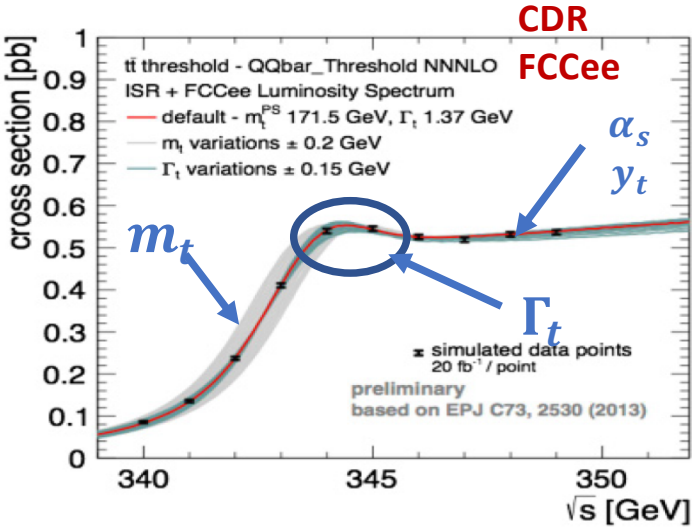
Link to the LoI

First step : $t\bar{t}$ threshold scan

- Cross section measurements while scanning $\sqrt{s}$,
  - Top-quark mass => high precision, resolving top mass "ambiguities" (MC mass vs mass in various renorm. scheme).
  - Can also be used to measure top quark width, yukawa and α_s.



- Cross section measurement precision : 1-2% to reach <200 MeV.

- Expected mass precisions (CLIC analysis revisited for FCCee):
  - Stat uncertainty at ~15 MeV,
  - Beam energy, reconstruction efficiency and background contamination ~50 MeV ,
  - And luminosity ... ~10 MeV,
  - **Total uncertainty below 100 MeV**, previous measurements of α_s => **reduction to < 50 MeV could be achievable**.

- Experimental uncertainties (close to be) dominated by statistics is reachable at the FCCee.
- Still significant impact of theory uncertainties : requires a significant effort from theory community.

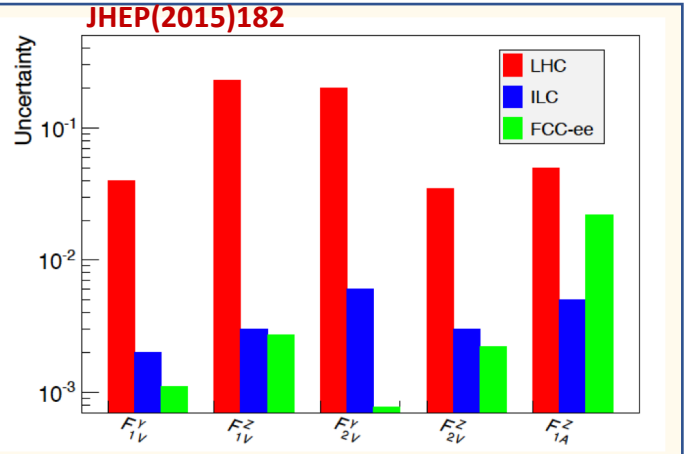
- Analyses techniques develop for the $t\bar{t}$ threshold scan can(should) be used for "beyond" threshold analyses.

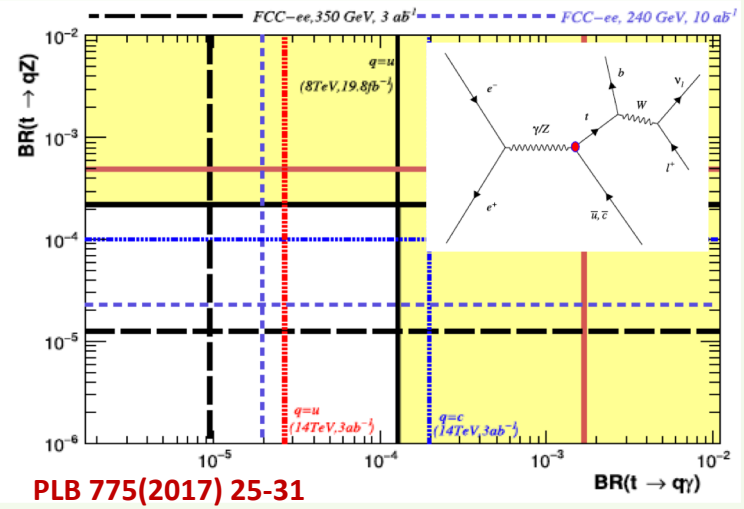
Top quark couplings to bosons

- Sensitivity on (anomalous) $t\bar{t}$ EWK couplings.
- Based on lepton energy and polar angle :
  - very low expected experimental uncertainties,
  - dominated by stat. uncertainties (and theory).
- Lower integrated lumi and larger boost at higher energies => better precision at 365 GeV than higher energies.

Help needed

JHEP(2015)182





PLB 775(2017) 25-31

Uncovered

- Top-quark FCNC couplings to γ, Z, H usually probed in top quarks decays in $t\bar{t}$ (probably to be updated).
- Interesting channels at lepton colliders : single top production possible for $t\gamma$ and tZ-FCNC.
- Very promising channels : higher cross section, limited by statistics and background contamination (Wjj), $t\bar{t}$ channels still useful to disentangle $t\gamma$ from tZ.
- Large impact of b and c-tagging.

Plan for coming studies for $t\bar{t}$ threshold

1. Study/compare MC generators, also for ISR and beam effects.
   - Ultimately, use Whizard with proper description of the $t\bar{t}$ threshold,
   - In the mean time, generate events with Whizard or Madgraph LO/NLO, to start implementing the analyses.

2. MC generation and validation
   - Signal and dominant backgrounds (common generator cards ?),
   - Generate at 365 GeV and perform validations, then generate for the different $\sqrt{s}$ points.

3. Fast simulation with Delphes within FCCSW, validation and understanding of parameters.

4. Implementation of a baseline events selection.

5. Setup counting experiment, and implement stat and systematics uncertainties.

6. Optimisation to minimise the overall uncertainty
   - event selections or/and detector performances (modifying Delphes card, regenerate, determine the impact). Automatization is a key point here.

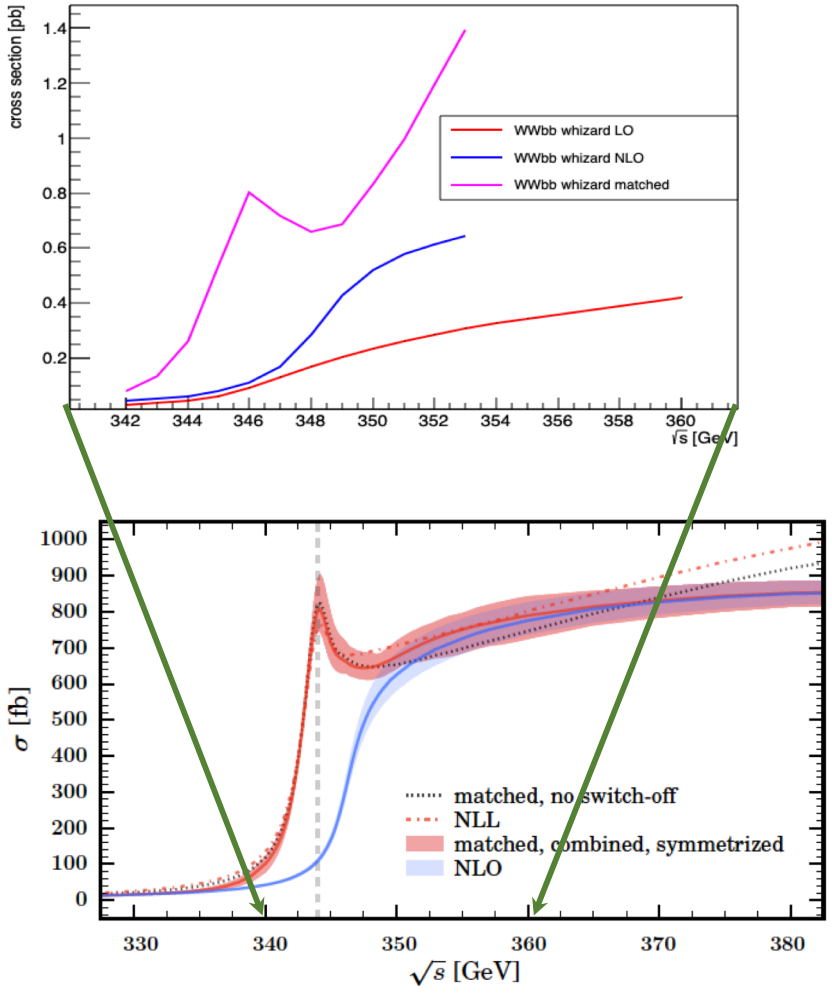
7. Implement and tests of a shape-based analysis.

8. Use experience to perform other properties measurements and searches (EFT).

Room for collaborations!

Reproducing $t\bar{t}$ threshold with Whizard

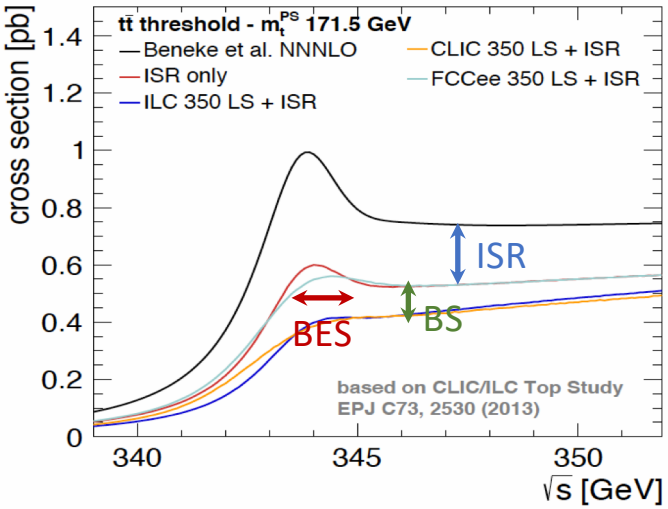
Many thanks to Juergen and Whizard authors

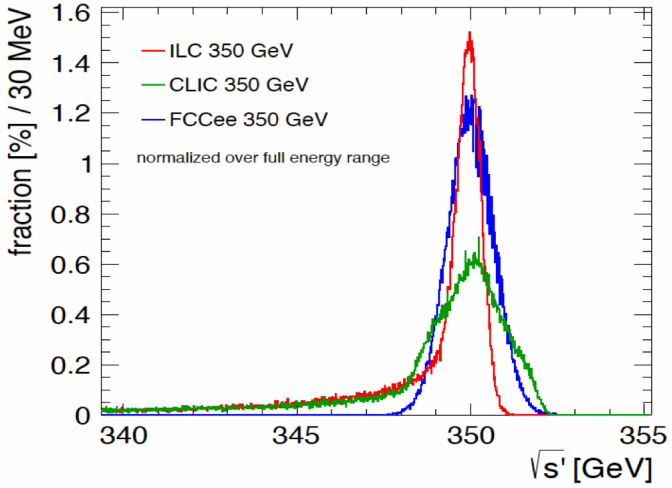


- Attempt to reproduce the results presented in the Whizard paper (JHEP 1803 (2018) 184).
- The peak is visible and the NLO calculation seems ok.
- But for higher $\sqrt{s}$ the calculated cross section increases too fast => under investigation.
- Event generation "complicated". Whizard Authors kindly agreed provide, in the coming days, a recipe for events generation for physics studies.
- Generation with Madgraph at NLO QCD available soon (not clear if it can reproduce the threshold peak).

Beam effects/ISR

F.Simon, PoS (ICHEP 2016) 872





- ISR and beam effects for different events generator : Whizard and Madgraph (no public release for MG yet link)
  - Initial State (QED) Radiation, intrinsic implementation for both generators.
- Beamstrahlung :
  - **Whizard** : interface with GuineaPig++ for Whizard1, but CIRCE for Whizard2.
  - **MadGraph** : parametrization fitted to GuineaPig++.
- Beam Energy Spread :
  - **Whizard** : CIRCE or possibly Gaussian smearing,
  - **Madgraph** : not available yet.
- Whizard seems a good starting point for studies (most complete description of beam effects).
- Magraph is definitely worth testing (also for comparisons) but public release needed.

Outlook and timescales

- Starting to prepare $t\bar{t}$ threshold scan analysis, first efforts spent on MC generators.

- Out of the box usage of LO/NLO generations and FastSim should allows to (relatively) quickly start implementing analyses into FCCSW.

- "Short" term goals :
  - Reproduce the mass, width, yukawa and α_s measurements from the $t\bar{t}$ threshold scan,
  - Study the optimisation of detector performances, based on fastsim studies.

- Baseline analysis for a much larger physics program !

- A lot to do, there is room for nice collaborations !