FCNC top decay **t -> c γ** @ 380 GeV

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CLICdp Collaboration Meeting

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FCNC top decay

- Standard model prediction of top quark decay into up-type quarks only via higher order loops, branching ratio ~ 10^{-14}
- In BSM models the branching ratio is significantly increased by either allowing tree level processes (2HDM, exotic quarks) or enhancing the loop diagrams (MSSM, R violating SUSY, 2HDM)
- Observation of FCNC processes would **indicate new physics**
- Decay channel of interest: t -> c γ
  Has a clear experimental signature
- Investigate the capability of observing/excluding this process with CLIC

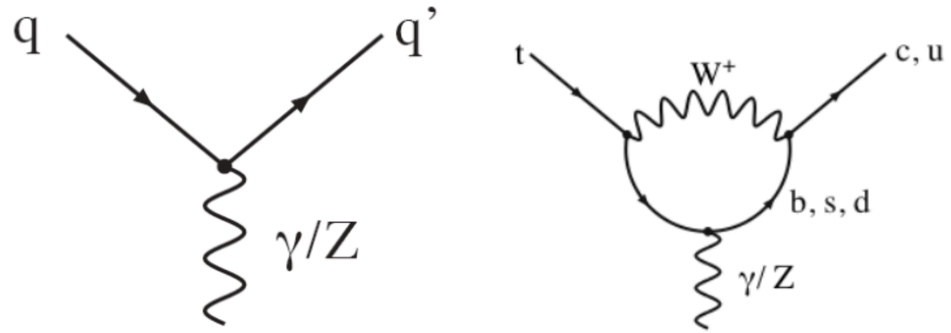


Figure 1.3: Feynman diagrams for the $t \to qZ$ FCNC decay. (a) Shows a tree level (first order) diagram which is absent in the standard model. (b) Shows an example of a higher order loop diagram, a.k.a. penguin diagram, which is allowed.

Mode	SM	MSSM	R SUSY	Exotic quarks	2HDM
t -> c γ	4.6 10^{-14}	2 10^{-6}	1 10^{-6}	7.5 10^{-9}	~10^{-6}

Limits from LHC

- Most recent result from CMS in proton-proton at 8 TeV (single top production in association with a photon)
  - JHEP 04 (2016) 035, arXiv:1511.03951
- Limit on the branching ratio **$B(t\to c\gamma) < 1.7\ 10^{-3}$**, currently most stringent limit
- Expected limits for CMS @ HL-LHC $B(t\to c\gamma) < 3.4\ 10^{-4} \sim 2.0\ 10^{-4}$ for 3 ab^{-1} at 14 TeV
  - CMS-DP-2016-064
- Aim: find the expected limit on $B(t\to c\gamma)$ at lepton colliders

Analysis setup

- Top pair production @ 380 GeV
  Signal generated in Whizard 2.2.8 in 2HDM(III) model, B(t->cγ) = 0.1%
  Reconstruction in CLIC_ILD detector model

- Fully hadronic decay channel: One top decays into **c γ**, the other to **W b** (standard decay)

- Event signature:

  - a high energy photon (50 - 140 GeV)
    a high energy c-jet (50 - 140 GeV)
    a b-jet
    two more light jets from W decay

Analysis setup

- Using ILCSoft v01-17-09
- Event reconstruction in PandoraPFA (LooseSelectedPandoraPFANewPFOs)
- Select high energy photon with E > 50 GeV (reject events without)
- Search for isolated leptons
- Vertexing, jet reconstruction and flavour tagging with LCFI+ using the Valencia jet clustering algorithm
- Kinematic reconstruction of top pairs
- Signal and background X^2
- Multivariate analysis (TMVA) to select signal and background

$$\chi^2_{signal} = \frac{(m_{top1} - 172.5)^2}{(10.0)^2} + \frac{(m_{top2} - 172.5)^2}{(7.0)^2} + \frac{(m_W - 80.4)^2}{(6.0)^2}$$

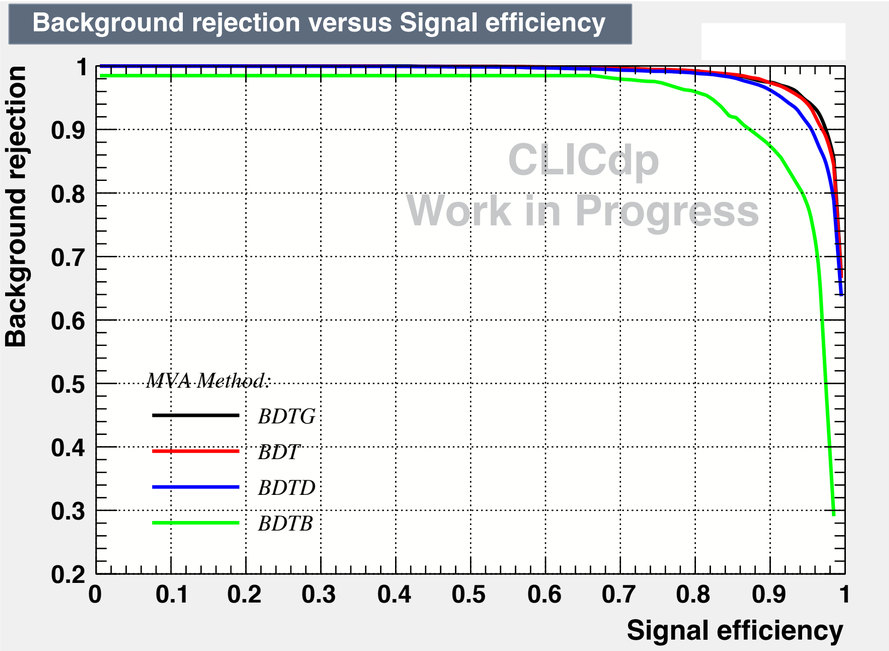
$$\chi^2_{background} = \frac{(m_{top1} - 172.5)^2}{(11.0)^2} + \frac{(m_{top2} - 172.5)^2}{(13.0)^2} + \frac{(m_W - 80.4)^2}{(6.0)^2} + \frac{(m_W - 80.4)^2}{(6.0)^2}$$

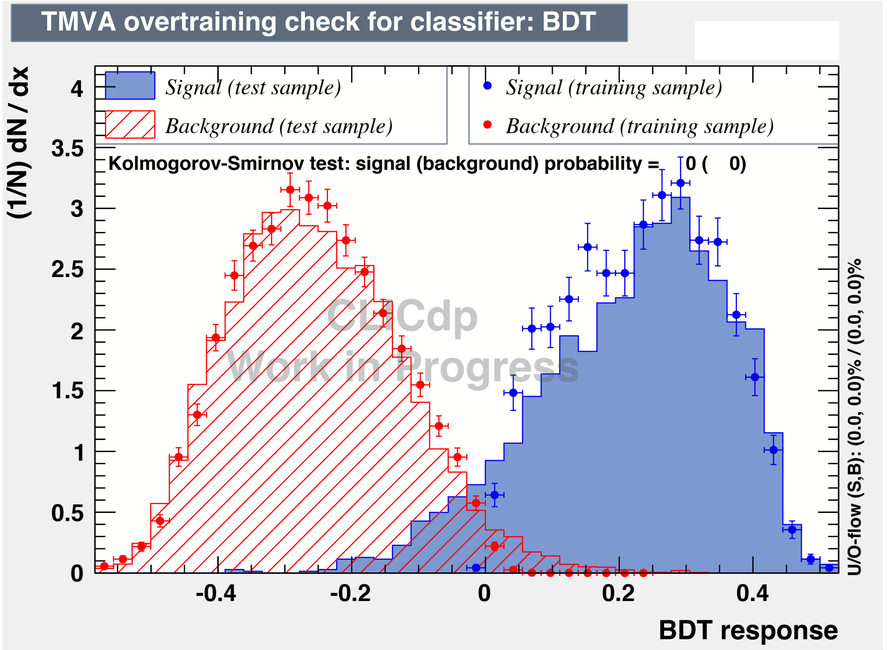
Test samples

- 5489 signal events
- 296500 ttbar background events from standard MC production
  (Signal sample (6-fermion production compatible with ttbar) at 380 GeV assuming unpolarised beams)
- Preselect events with a high energy photon, E > 50 GeV
  - keeps 92% of signal and 5% of background

TMVA

- TMVA to select signal and background: Boosted Decision Tree (BDT)
- Only for events with a photon with E > 50 GeV
  -> low statistics: 2526 signal and 7765 background events
- 42 input variables (photon properties, jet properties, flavour tagging, invariant mass etc.)
  -> overtraining?





Invariant mass

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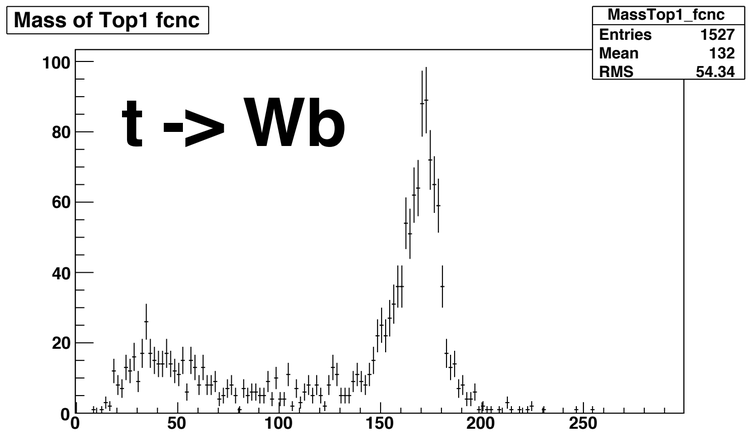
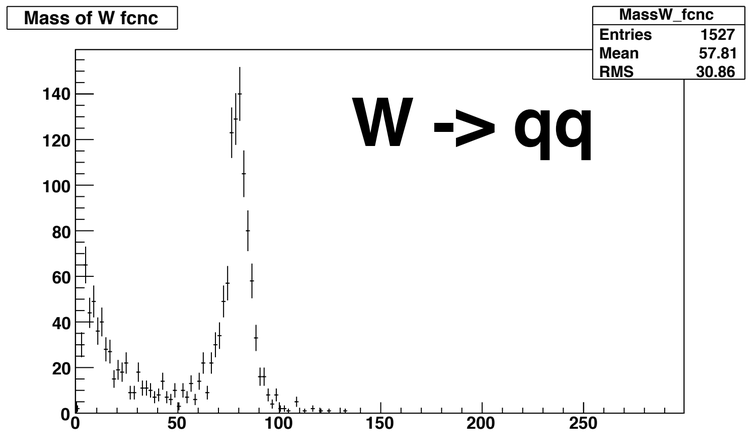
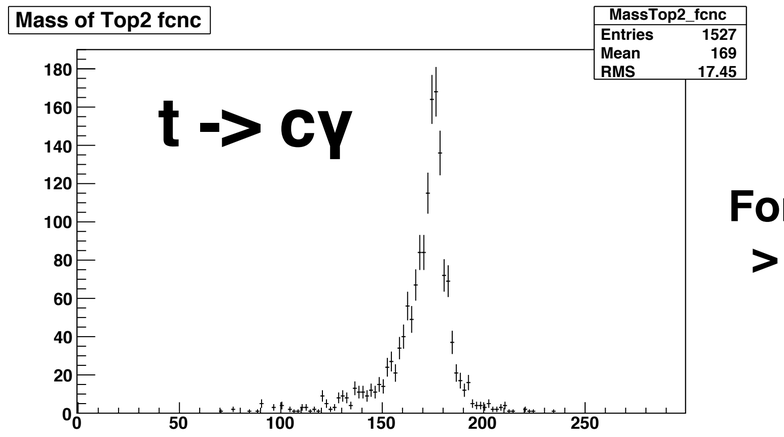
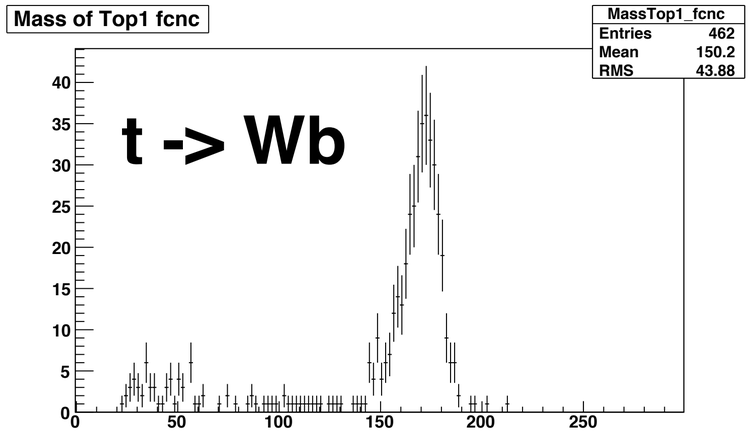
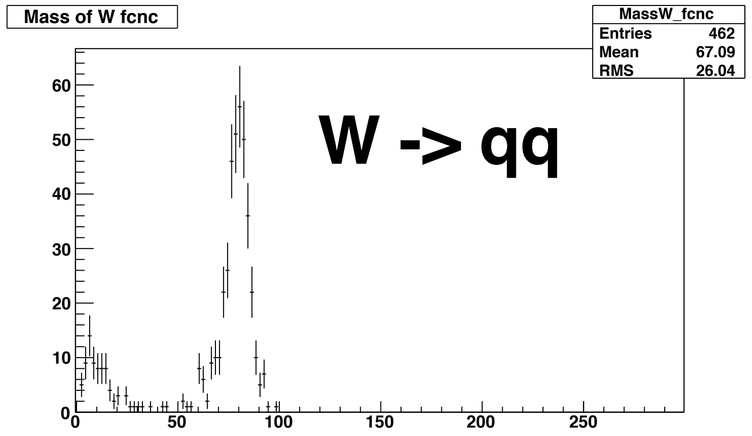


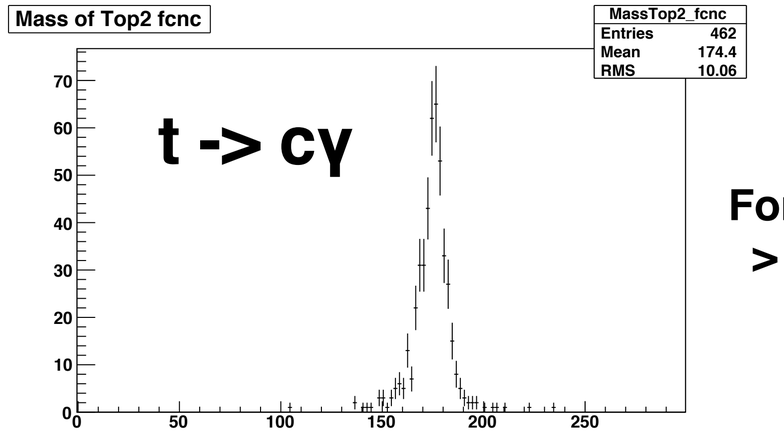




For BDT > 0.20







For BDT > 0.35

Signal and background fractions

- Background at maximally 10^{-3}
- BDT cut needs to be optimised
- Limits: 95% CL on B(t->cγ) @ 500 fb^{-1}
  BDT > 0.2 : 1.9 10^{-4}
  BDT > 0.35 : 4.4 10^{-5}

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	Signal	Background
high energy photon	**0.92**	**0.052**
BDT > 0.0	0.918	0.04495
BDT > 0.05	0.868	0.02241
BDT > 0.1	0.796	0.00966
BDT > 0.15	0.703	0.00489
BDT > 0.2	0.599	0.0018
BDT > 0.25	0.468	0.0009
BDT > 0.3	0.320	0.00026
BDT > 0.35	0.183	0.0
Total	**0.84 - 0.17**	**0.0023 - 0.0**

Next steps

- Current results hint at a good sensitivity to this channel at 380 GeV
- Limits of the order of 10^{-4} are feasible
- To do
  - Include e^+e^- ->qqqq sample at 380 GeV (needs to be generated)
  - Further improve background rejection / signal selection
  - Optimise TMVA approach
  - Apply same analysis to 500 GeV for ILC limits

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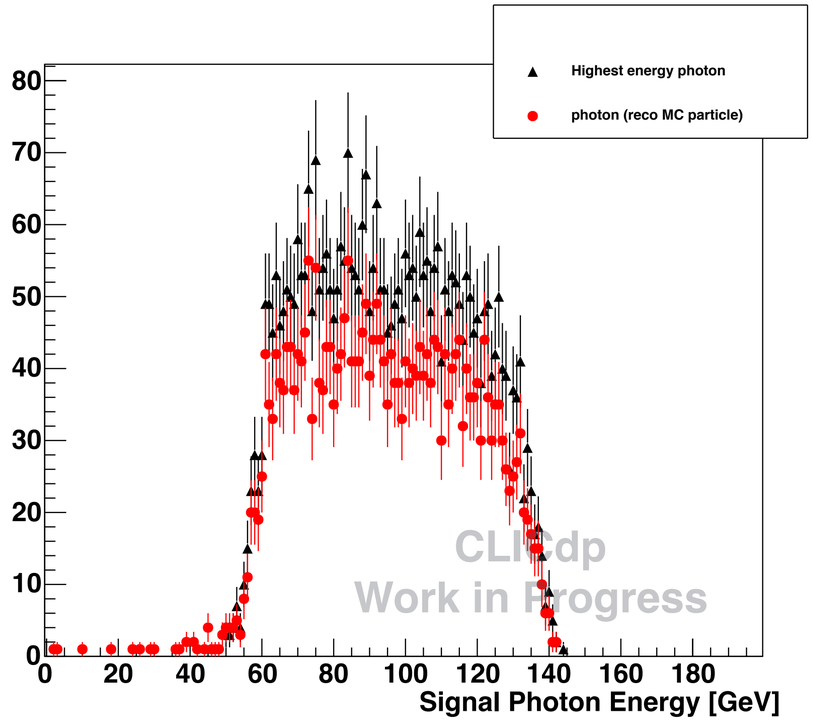
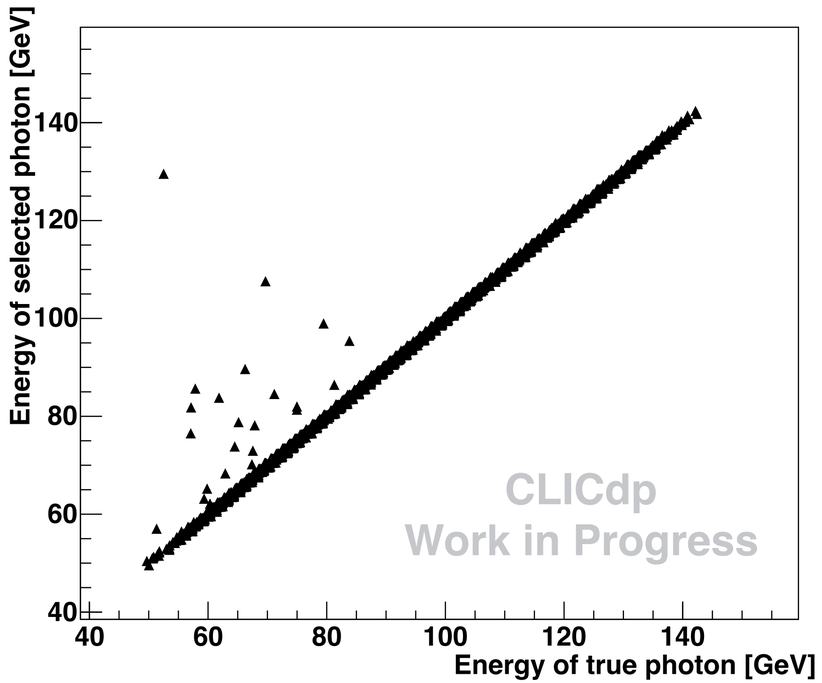
Thank you for your attention

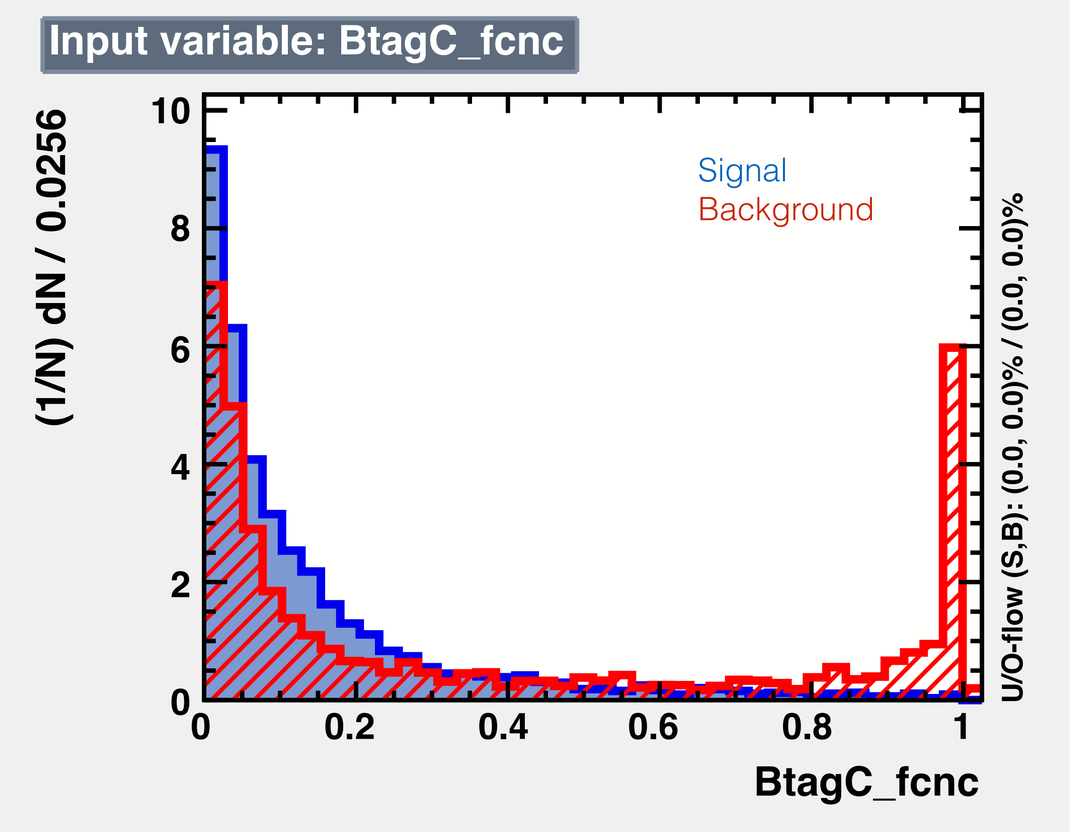
Identifying high energy photon





- The photon from the FCNC decay can be identified with high efficiency

B tag of selected C jet



Cut based signal and background fractions

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Accepted fraction	**0.3050**	**0.0027**	**0.0002**	**0**	**0.0014**
signal	0.2510	0.0004	0.000045	0	0.0003
background	0.0539	0.0023	0.00015	0	0.0011

- Signal efficiency 25%
- Leptonic and semi-leptonic background events ~ 10^{-5}
- Hadronic background events ~ 10^{-4}
- Based on these efficiencies limits on B(t->cγ) of the order of 10^{-4} are feasible