PROBING TOP QUARK FCNC IN γP COLLISIONS AT EP COLLIDERS WITH DETECTOR SIMULATION

TopFCNC Study Group

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INTRODUCTION

- The top quark FCNC interactions would be a good test of new physics at present and future colliders. These interactions can be described by the effective Lagrangian

Current study is based on interaction terms

$$\mathcal{L}_{FCNC} = \sum_{q=u,c} \frac{g_s}{2m_t}\bar{q}\lambda^a\sigma^{\mu\nu}(\zeta^L_{qt}P^L + \zeta^R_{qt}P^R)tG^a_{\mu\nu} - \frac{1}{\sqrt{2}}\bar{q}(\eta^L_{qt}P^L + \eta^R_{qt}P^R)tH -$$
$$-\frac{g_W}{2c_W}\bar{q}\gamma^\mu(X^L_{qt}P_L + X^R_{qt}P_R)tZ_\mu + \frac{g_W}{4c_W m_Z}\bar{q}\sigma^{\mu\nu}(K^L_{qt}P_L + K^R_{qt}P_R)tZ_{\mu\nu} +$$
$$+\frac{e}{2m_t}\bar{q}\sigma^{\mu\nu}(\lambda^L_{qt}P_L + \lambda^R_{qt}P_R)tA_{\mu\nu} + H.c.$$

scaled to top mass

- *NPB812(2009)181*

Madgraph: topFCNC_UFO from FeynRules

Previous study were based on interaction terms

$$L = -g_e \sum_{q=u,c} Q_q \frac{\kappa_q}{\Lambda}\bar{t}\sigma^{\mu\nu}(f_q + h_q\gamma_5)qA_{\mu\nu} + h.c.$$

scaled to lambda

- ***LHeC CDR 2012***
- *PLB685(2010)170*

CalcHEP: top FCNC author defined

PROCESSES AND DIAGRAMS

Signal diagrams related to the process a p > w^+ j within MG5

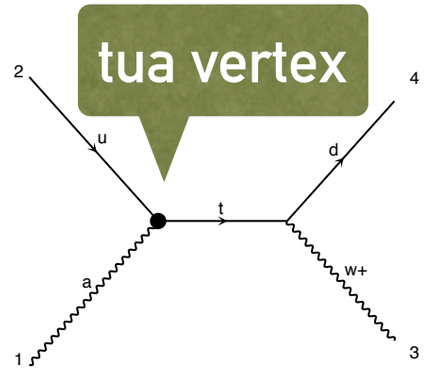
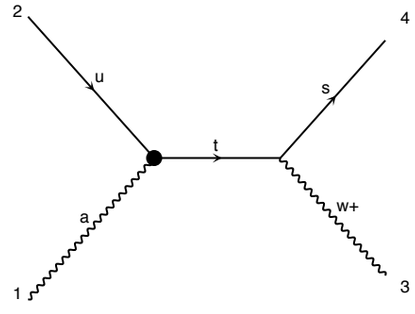


diagram 2 NP=1, QCD=0, QED=2



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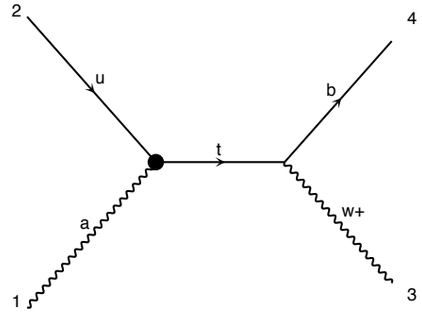

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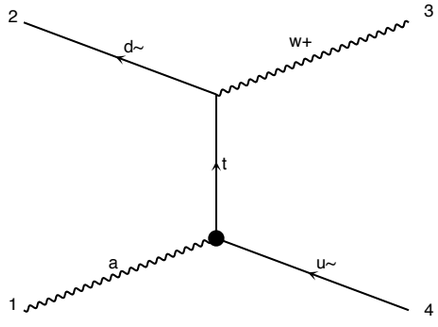
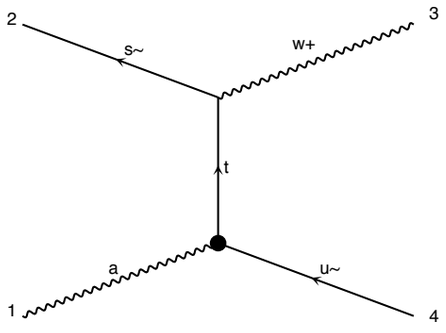


diagram 2 NP=1, QCD=0, QED=2



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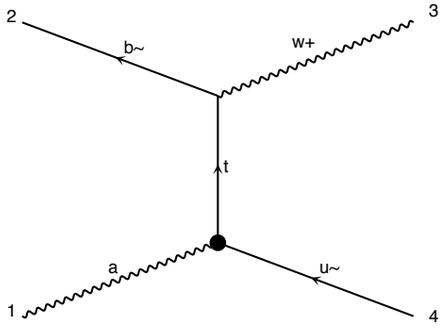

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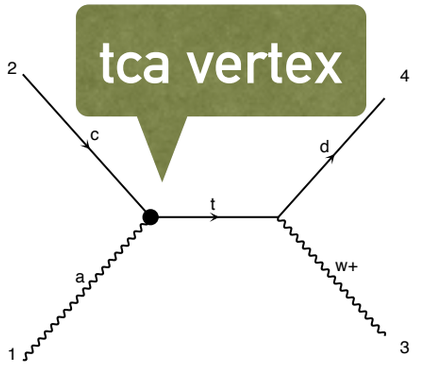

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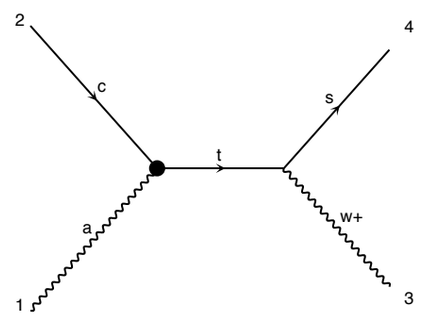

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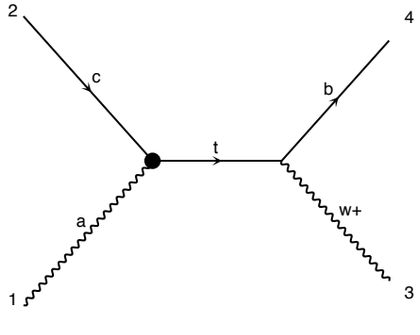

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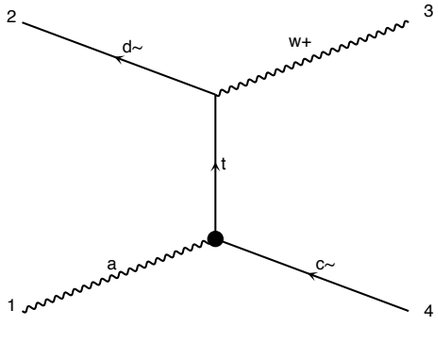

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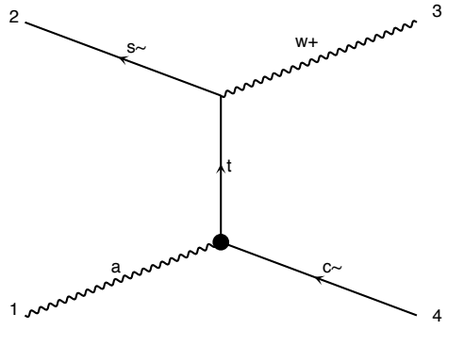

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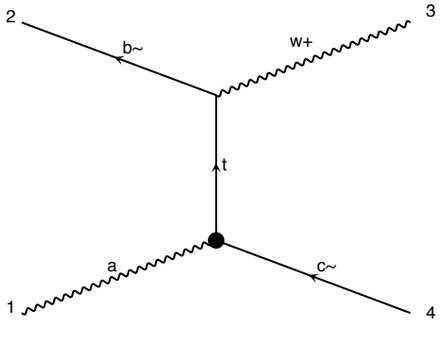


diagram 2 NP=1, QCD=0, QED=2

CROSS SECTIONS

LASER	Cross section (pb) for $\gamma p \to W^+ b$		
Collision	SM	SM+FCNC($\lambda = 0.1$)	SM+FCNC($\lambda = 0.01$)
LHeC$-\gamma p$	1.037×10^{-2}	2.795×10^{1}	2.899×10^{-1}
FCC-ep$-\gamma p$	4.849×10^{-2}	5.600×10^{1}	6.073×10^{-1}

Cross sections for the process γp —>W⁺b in the LHeC and FCC-ep based γp collisions.

LASER	Cross section (pb) for $\gamma p \to W^+ j$		
Collision	SM	SM+FCNC($\lambda = 0.1$)	SM+FCNC($\lambda = 0.01$)
LHeC$-\gamma p$	7.247×10^{1}	9.906×10^{1}	7.279×10^{1}
FCC-ep$-\gamma p$	1.919×10^{2}	2.453×10^{2}	1.924×10^{2}

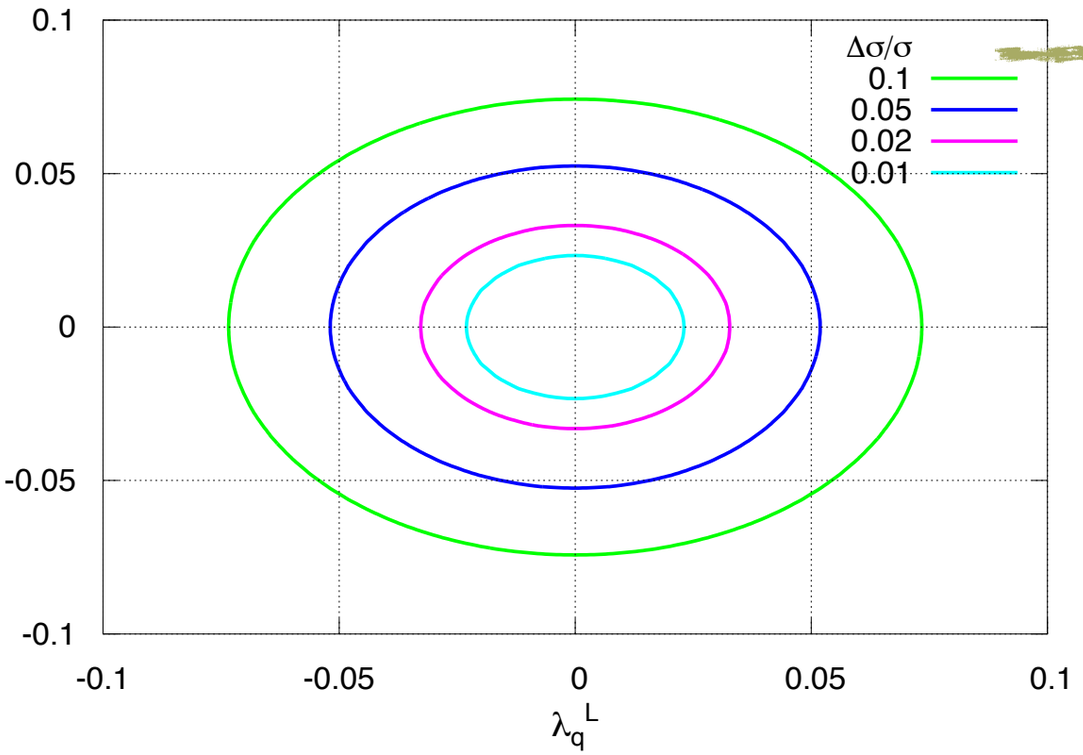
Cross sections for process γp —>W⁺j in the LHeC and FCC-ep based γp collisions.

We find that cross section for laser option is about an order of magnitude larger than epa option.

EPA	Cross section (pb) for process $\gamma p \to W^+ b + X$		
Collision	SM	SM+FCNC($\lambda = 0.1$)	SM+FCNC($\lambda = 0.01$)
LHeC$-\gamma p$	7.512×10^{-4}	3.597×10^{0}	3.677×10^{-2}
FCC-ep$-\gamma p$	4.494×10^{-3}	9.517×10^{0}	9.962×10^{-2}

EPA	Cross section (pb) for $\gamma p \to W^+ j + X$		
Collision	SM	SM+FCNC($\lambda = 0.1$)	SM+FCNC($\lambda = 0.01$)
LHeC$-\gamma p$	6.337×10^{0}	9.982×10^{0}	6.379×10^{0}
FCC-ep$-\gamma p$	1.962×10^{1}	2.797×10^{1}	1.976×10^{1}

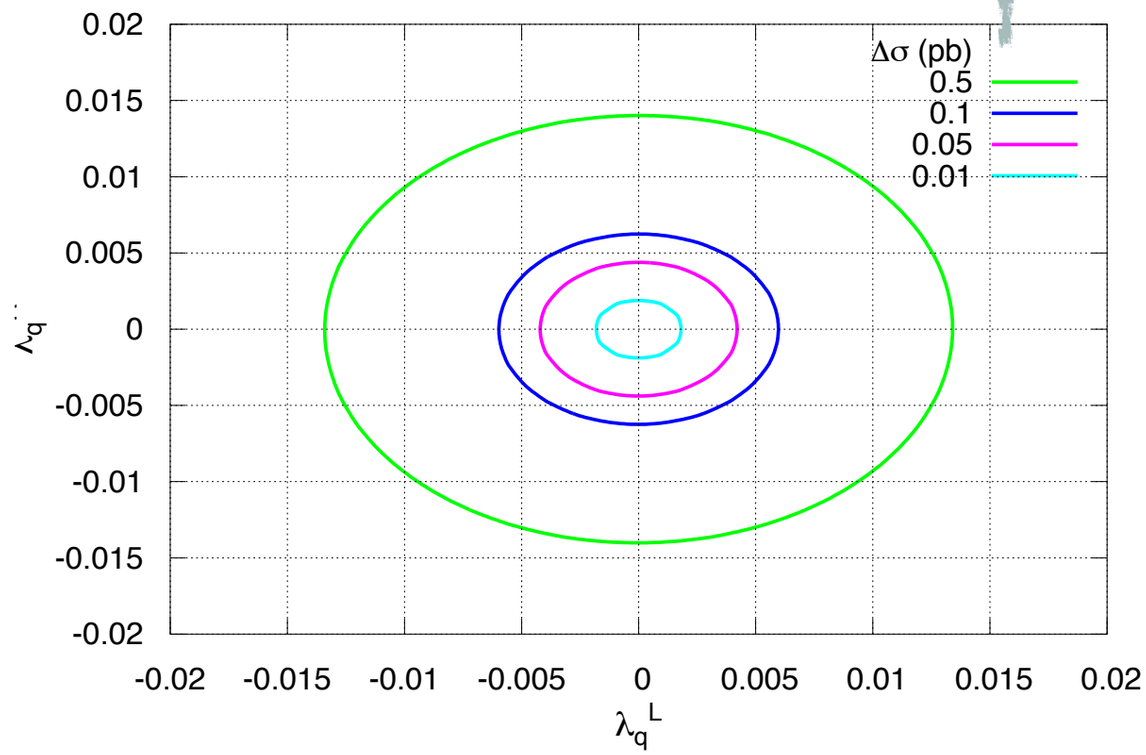
CROSS SECTIONS



LHeC(epa): Ee=60 GeV, Ep=7 TeV

$\Delta\sigma/\sigma = (\sigma_{S+B} - \sigma_B)/\sigma_B$

$\Delta\sigma = \sigma_{S+B} - \sigma_B$



FCC-ep(laser): Ee=60 GeV, Ep=50 TeV

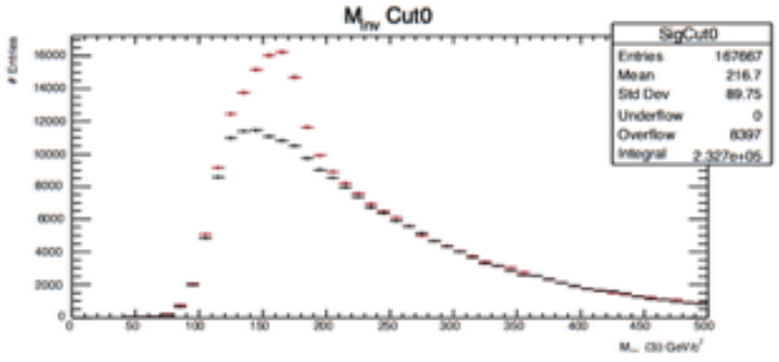
We find that cross section depends on approximately the same strength to the left and right type couplings of tqγ FCNC vertex.

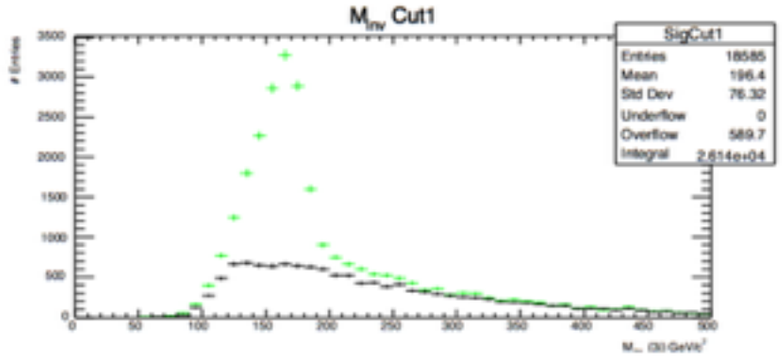
DETECTOR SIMULATION

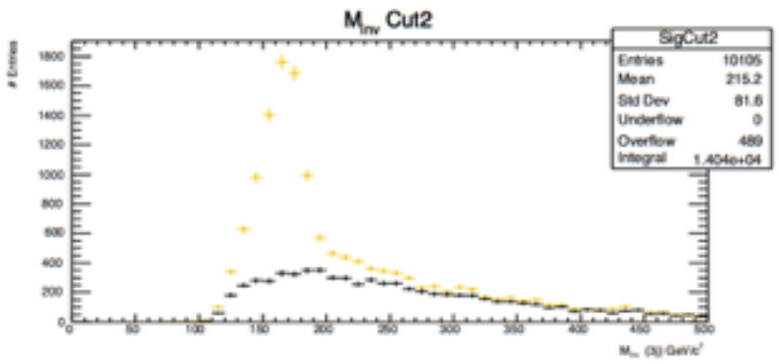
- For cross section calculation of the process $\gamma p \rightarrow W^{+} j$ and event generation we use **Madgraph version 2.4.2**.
- For LHeC based γp collisions (epa/laser) simulation we use **Delphes version 3.3.2** with detector cards
  - delphes_card_ATLAS.dat detector card
  - we tried a LHeC detector card, but with a different efficiency
- For FCC-ep based γp collisions (epa/laser) simulation we use
  - delphes_card_FCC.dat detector card (*with a modification* $p_T min = 20$)
  - may need to be improved for asymmetric ep/γp collisions
- Simulate events with preselection cuts (from both run card and detector card).

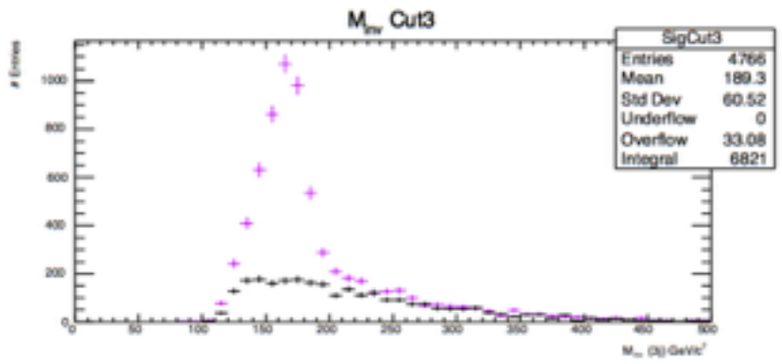
ANALYSIS

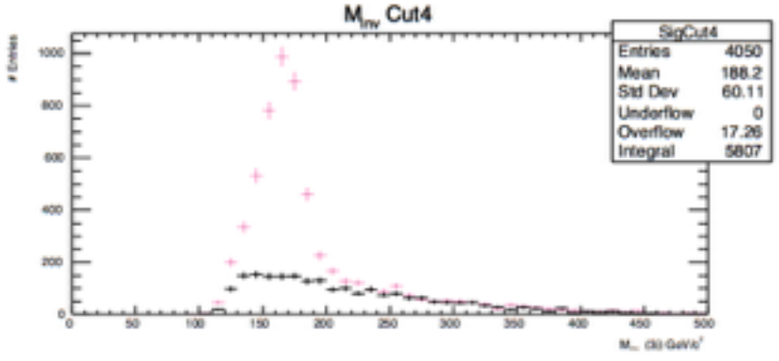
➤ Top quark invariant mass plots after cuts for LHeC(epa)

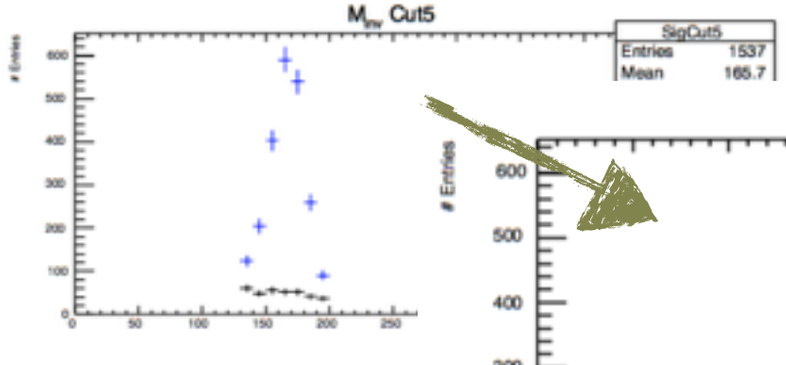




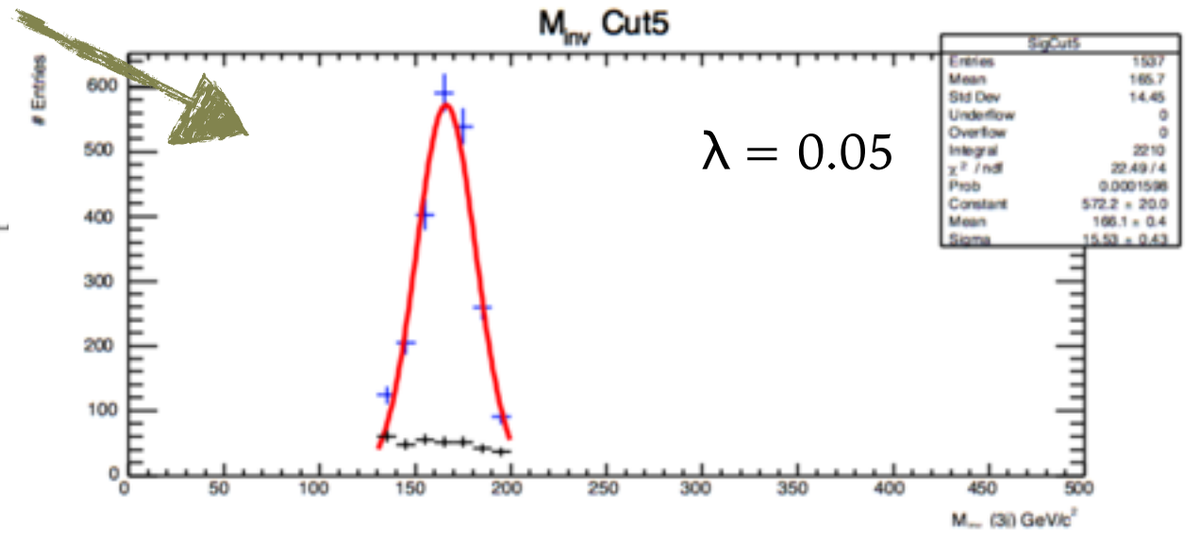






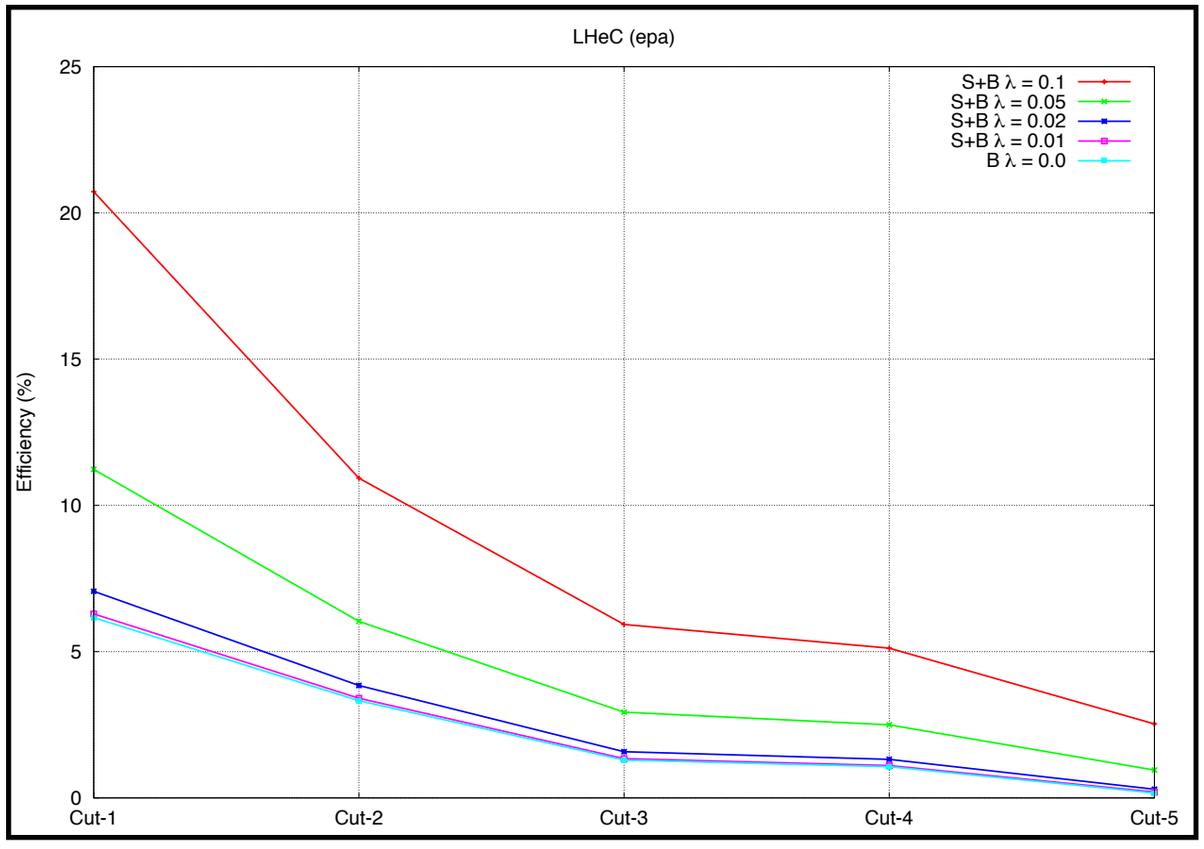


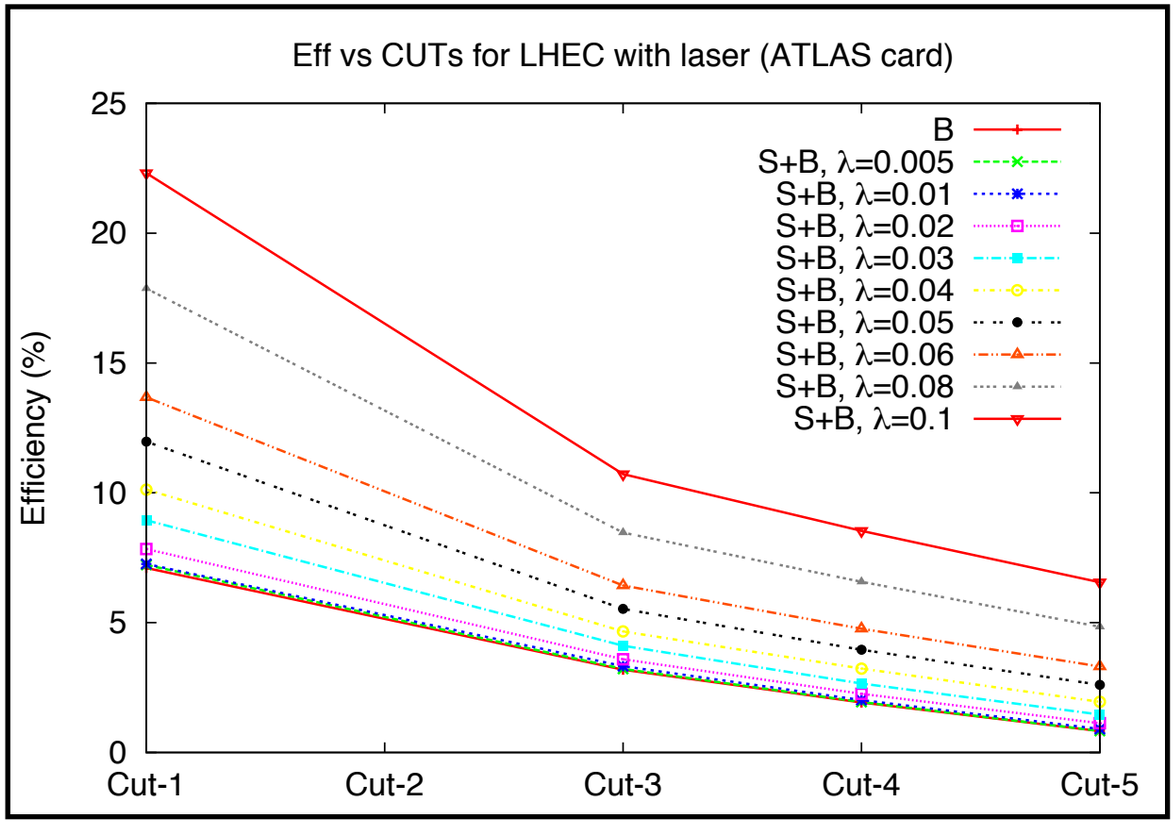
Cuts		
Cut-0	(Preselection cuts)	$Jets \geqslant 3$
Cut-1	$Jets \geqslant 3$	Jet with b-tag
Cut-2	$p_T(j_2, j_3) > 30$	$p_T(j_b) > 40$
Cut-3	$-2.5 < \eta(j_1, j_2, j_3) < 0$	Region
Cut-4	$50 < M_{inv}(j_2, j_3) < 100GeV$	W mass rec.
Cut-5	$130 < M(j_b + j_2 + j_3) < 200GeV$	Top mass rec.



ANALYSIS

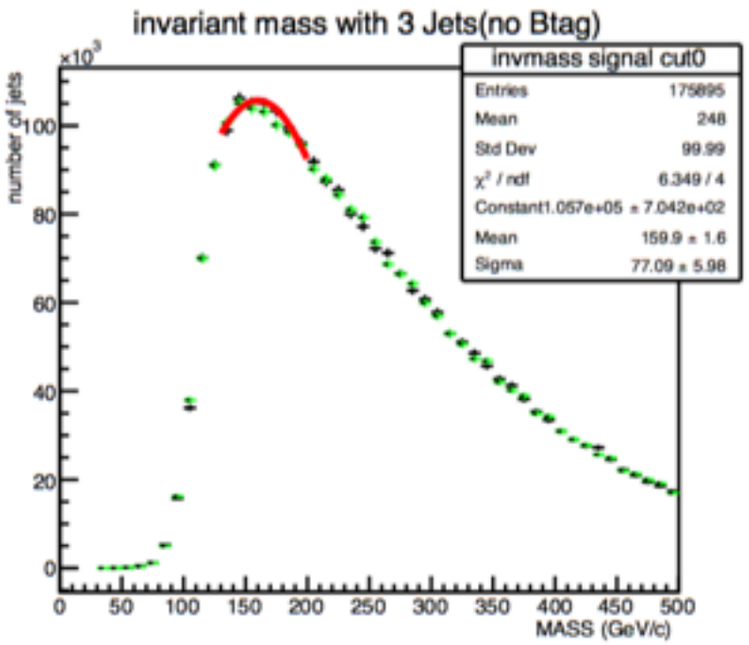
- Signal and background number of events 500k
  - Cut efficiency plots for three jets originating from W+jet in the final state at LHeC with epa/laser options

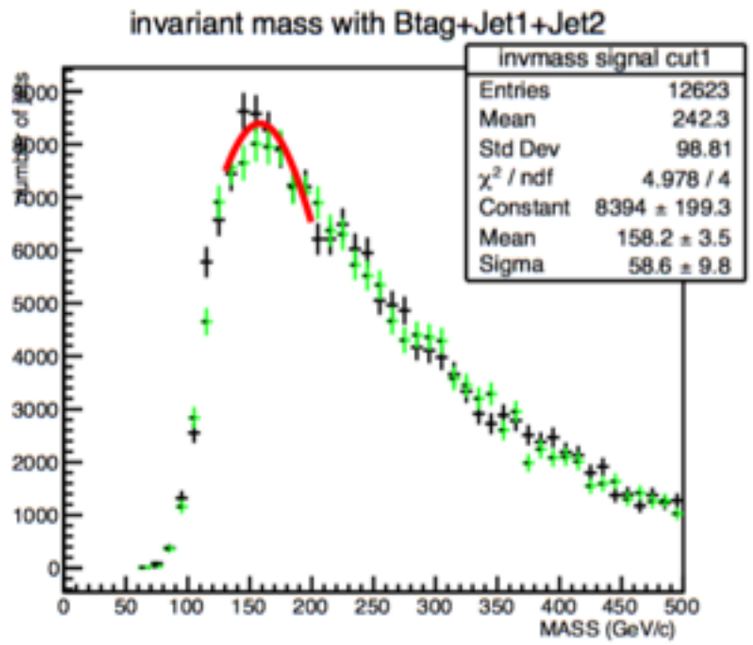


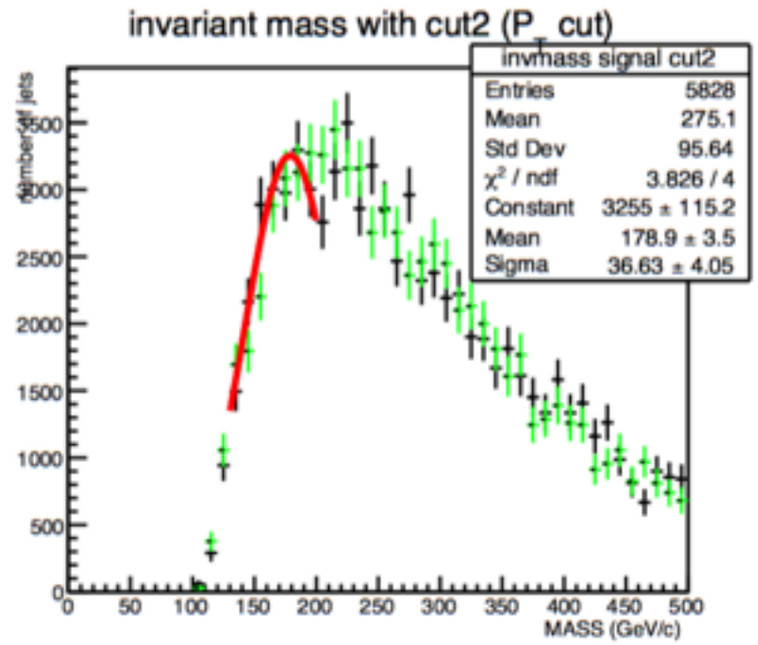


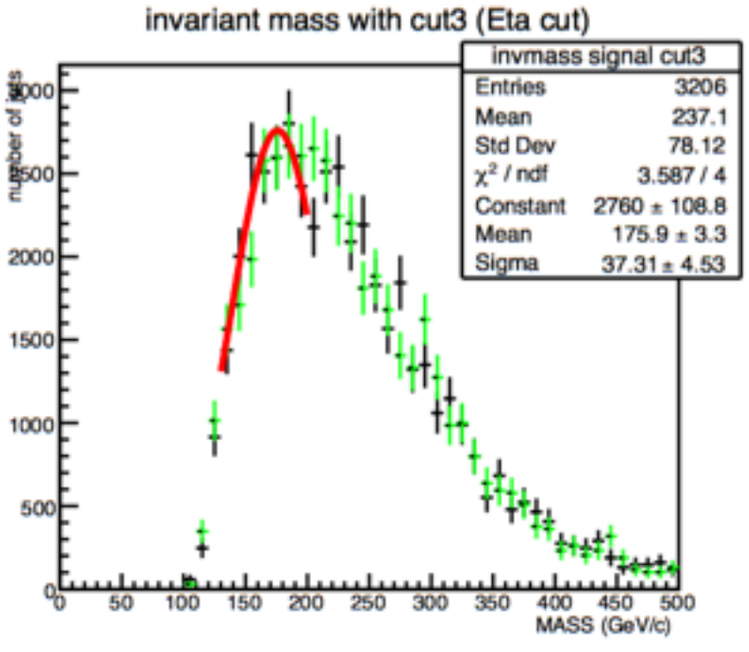
ANALYSIS

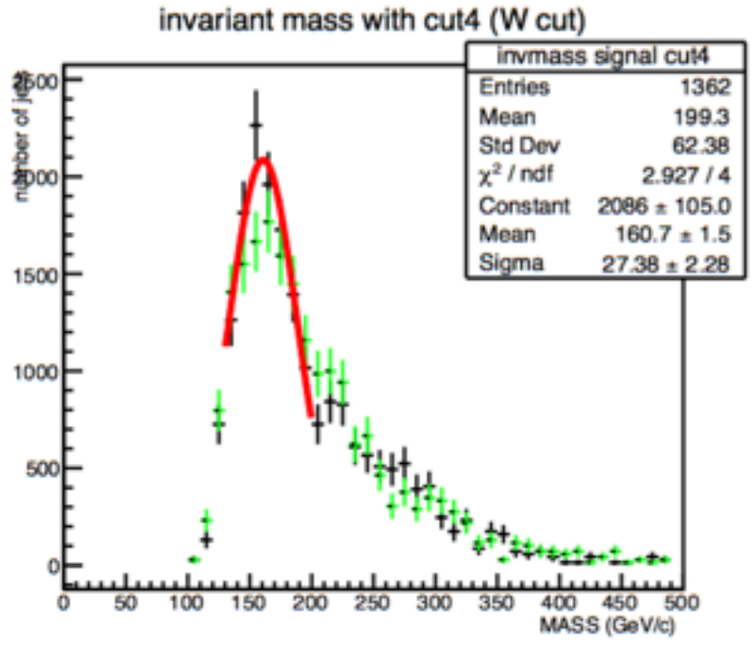
➤ Top quark invariant mass plots after cuts for LHeC(laser)

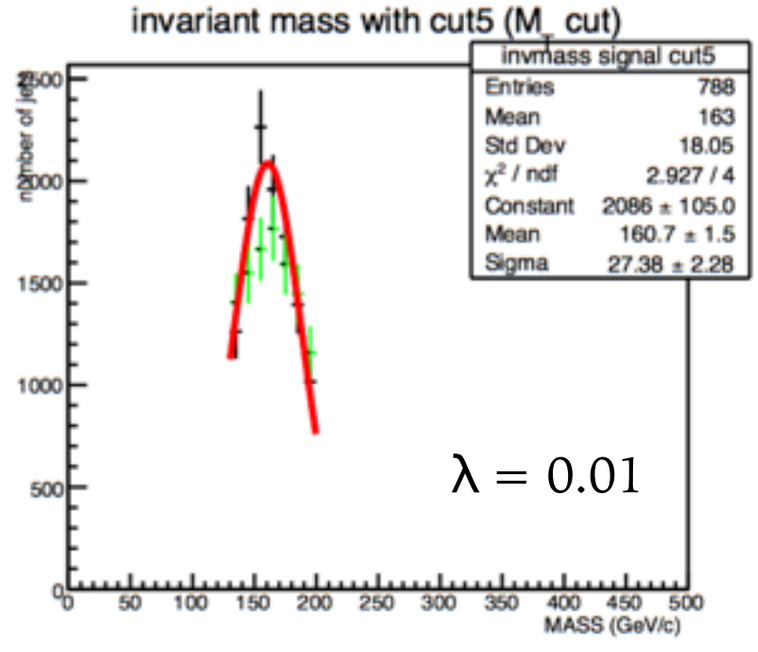






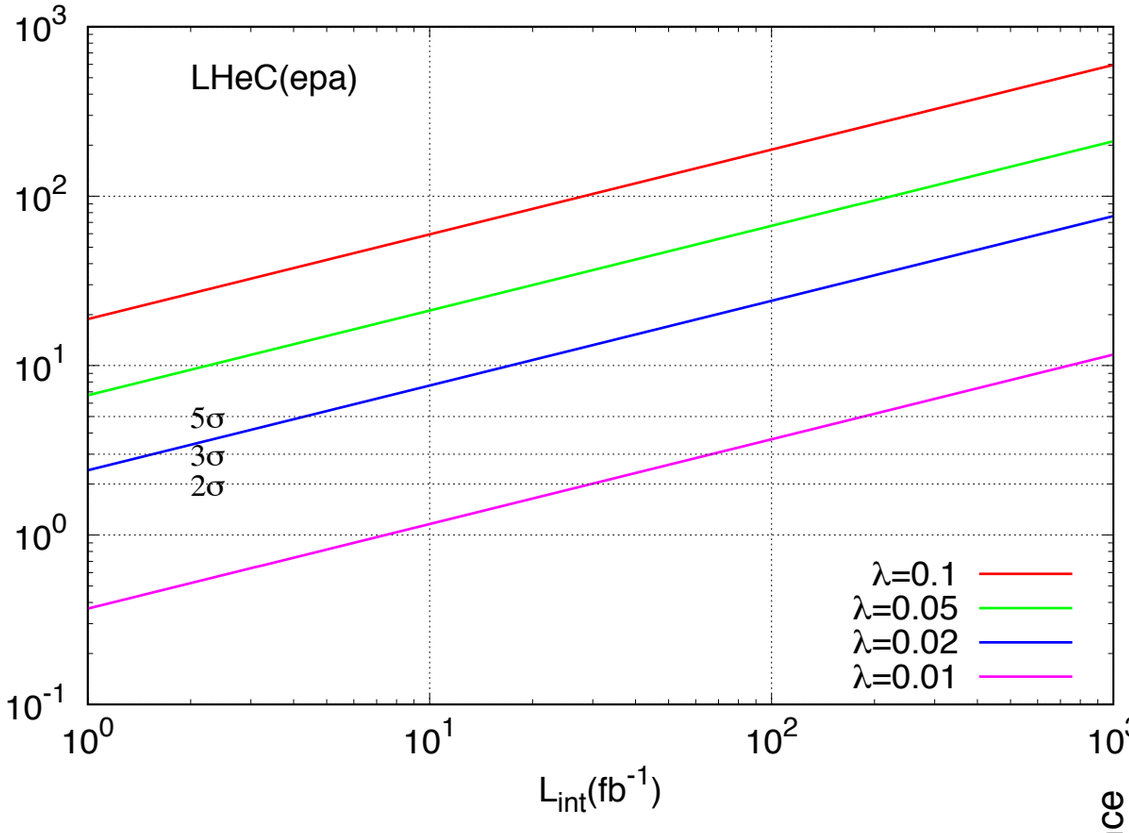






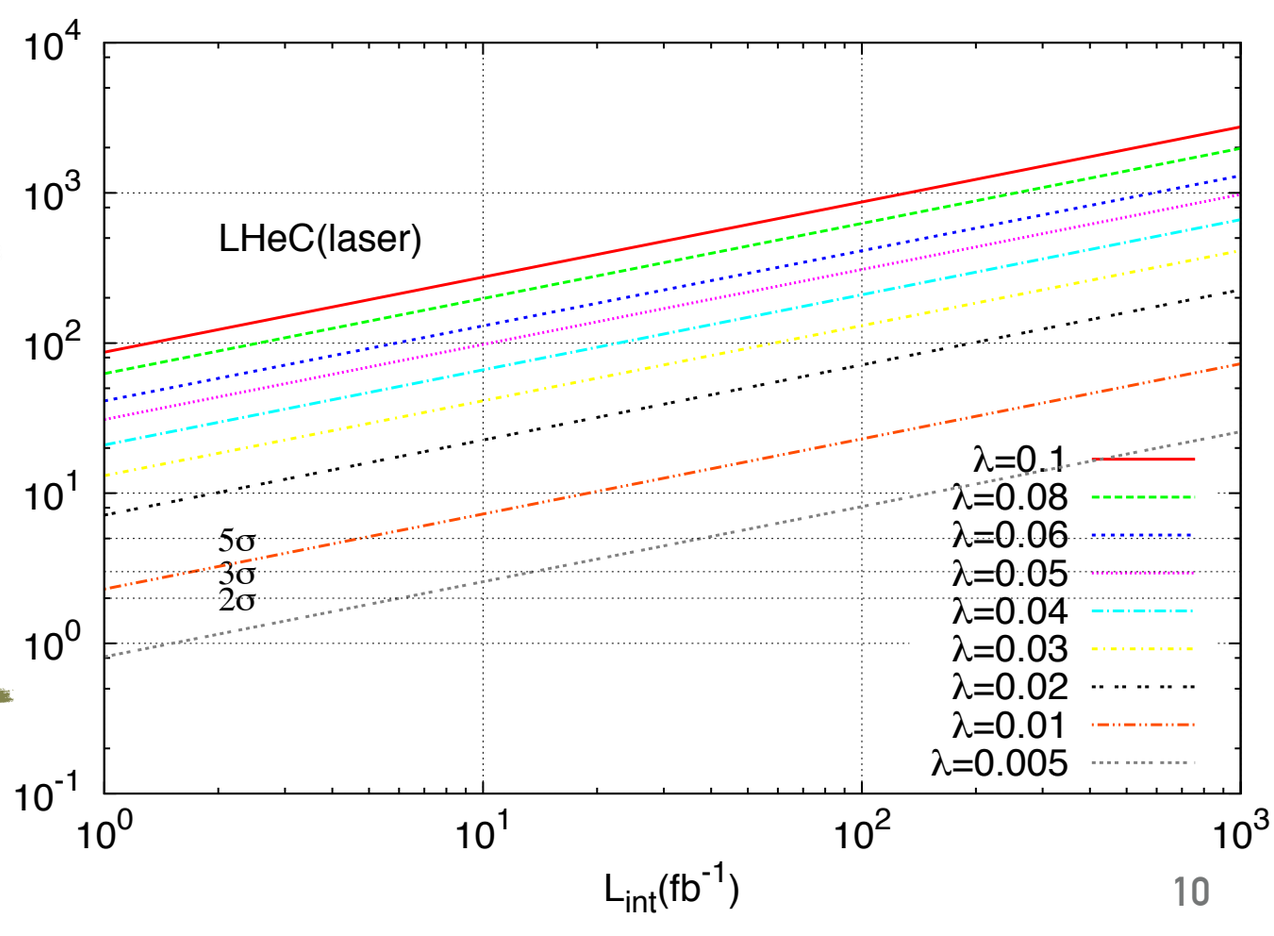
ANALYSIS

- Statistical significance



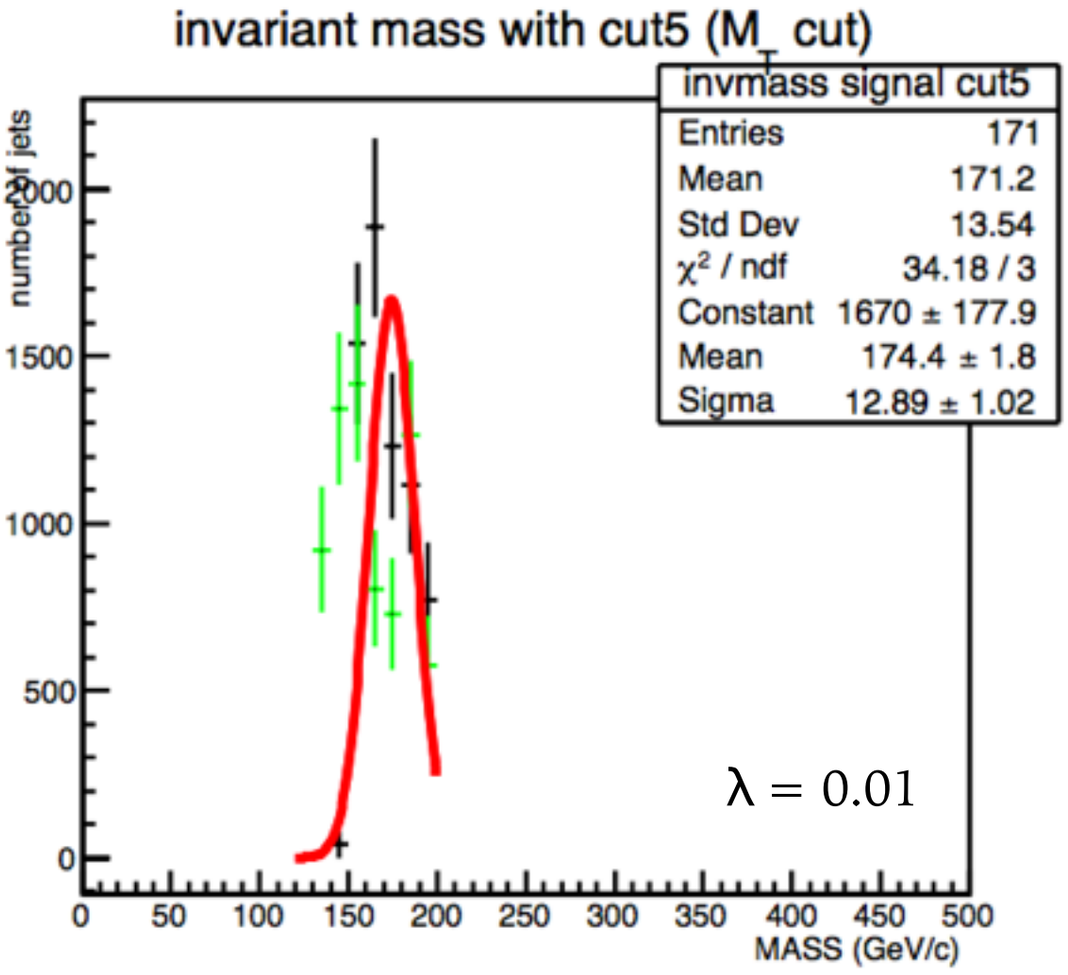
- Significance 3σ for λ=0.01 at LHeC(epa) with L_{int}=70/fb.

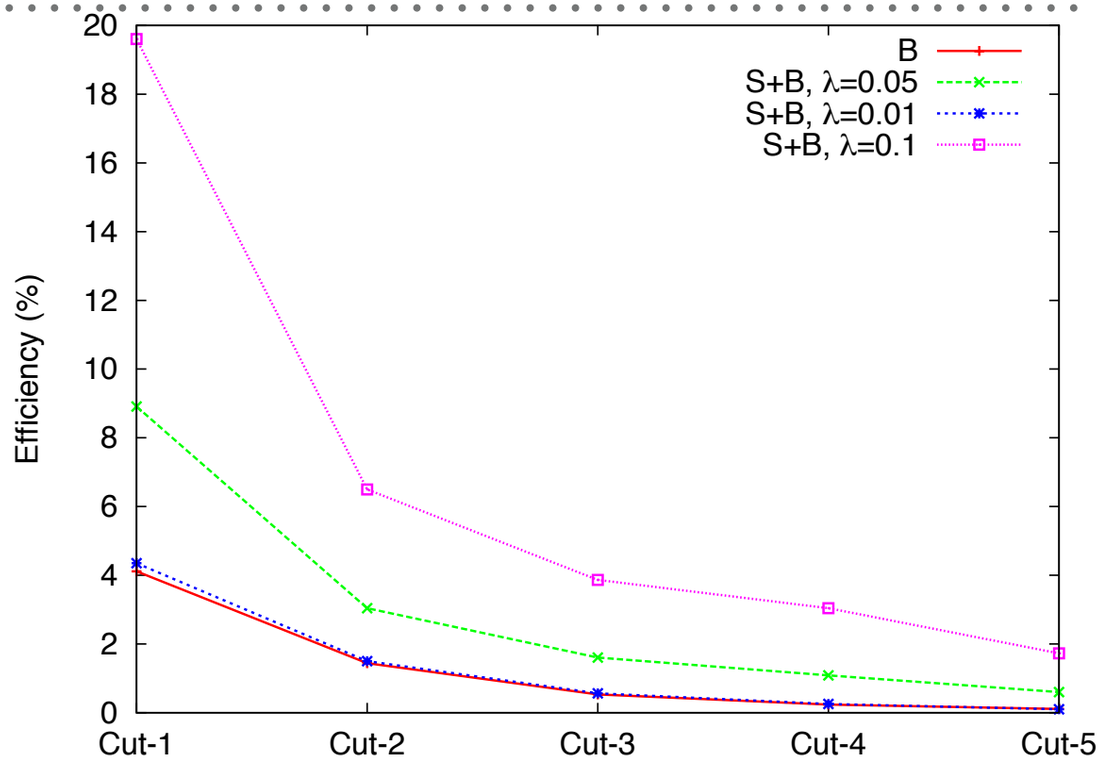
- Significance 3σ for λ=0.005 at LHeC (laser) with L_{int}=15/fb.

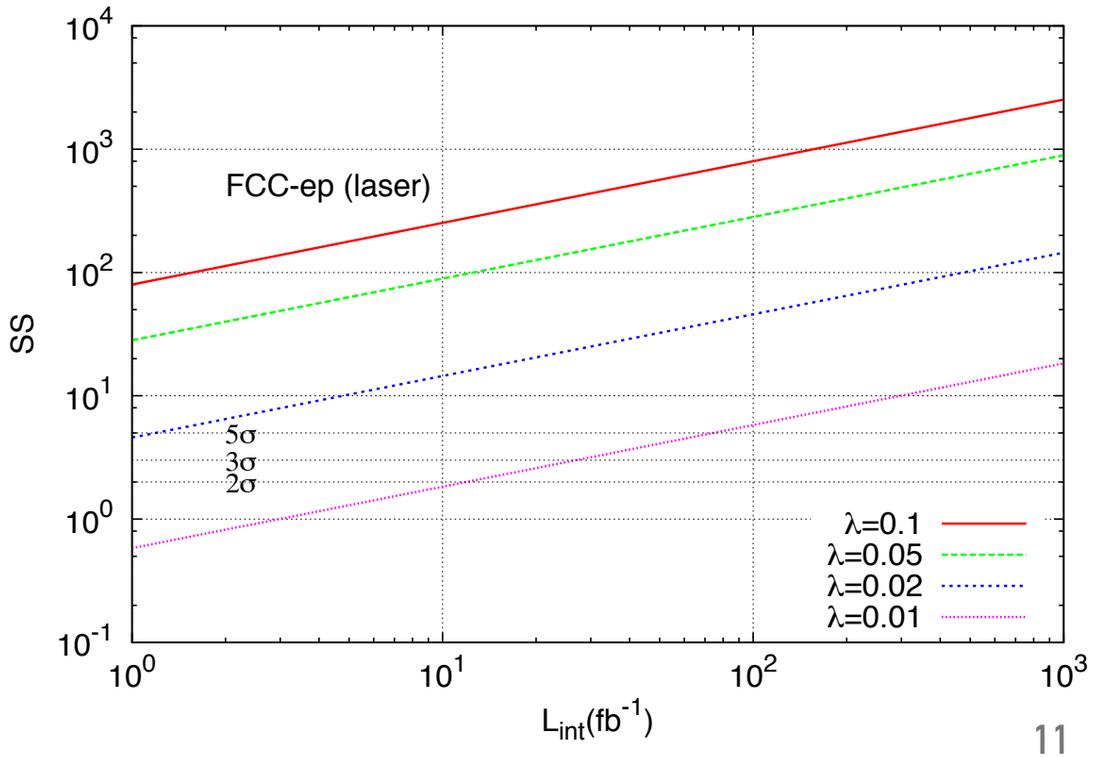


ANALYSIS FOR FCC-EP(LASER)

- Top mass reconstruction, Cut efficiency and Statistical significance, simulation with Delphes FCC detector card.







SUMMARY

In this study, we use topFCNC_UFO model within MG5

- Cross section calculation and event generation
  - scan for $\lambda_{L/R}$ =-0.1 : 0.1
  - signal+background for W+j (where j=u,d,s,c,b)
- for detector simulation we use Delphes detector card
  - ATLAS card for LHeC
  - FCC card for FCC-ep
- invariant mass M(3j) of three-jets
  - one is tagged as b-jet, other two are light jets
  - top mass and W mass reconstruction
  - preselection cuts+cuts-1/2/3/4/5
- cut efficiencies plot, significance plot
- luminosity need for 3 sigma

■ *We find a sensitivity to* λ*=0.005 for* L_{int}*=15/fb in* γp *collisions at LHeC(laser) with Ee=60 GeV, Ep=7 TeV.*

■ *It is obtained a sensitivity to* λ*=0.01 for 25/fb in* γp *collisions at FCC-ep(laser) with Ee=60 GeV, Ep=50 TeV.*

For next meeting

- try to improve reconstruction at low lambda
- comparison the results with previous study
- preparation of a Note

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