

MEtop  
top FCNC event generator

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# Outline

Introduction

FCNC Direct Top generation

NLO simulation

EW and 4F operators

The generator

Conclusions

# The physical problem

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- ▶ Flavour Changing Neutral Currents (FCNC)
- ▶  $t \rightarrow b, W^+$  (SM),  $t \rightarrow G, u$  (FCNC)
- ▶ FCNC highly suppressed in the SM

$BR(t \rightarrow FCNC)$ in several modes						
	SM	QS	2HDM	FC 2HDM	MSSM	R SUSY
$t \rightarrow q\gamma$	$\sim 10^{-14}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-6}$
$t \rightarrow qZ$	$\sim 10^{-14}$	$\sim 10^{-4}$	$\sim 10^{-7}$	$\sim 10^{-10}$	$\sim 10^{-6}$	$\sim 10^{-5}$
$t \rightarrow qg$	$\sim 10^{-12}$	$\sim 10^{-7}$	$\sim 10^{-4}$	$\sim 10^{-5}$	$\sim 10^{-5}$	$\sim 10^{-4}$

Acta Phys. Polon. B 35, 2695 (2004) [arXiv:hep-ph/0409342]

# Effective Lagrangian

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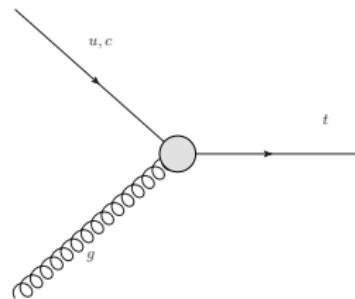
$$\mathcal{L}_{Total} = \mathcal{L}_{SM} + \frac{1}{\Lambda^5} \mathcal{L}^{(5)} + \frac{1}{\Lambda^6} \mathcal{L}^{(6)}$$

- ▶ FCNC can be studied through an effective Lagrangian
- ▶ This extra Lagrangian terms will be composed by effective operators that obey SM symmetries
- ▶ Buchmuller and Wyler calculated all possible operators of dimension 6 that respect the SM symmetries (Nucl. Phys. B 268 (1986) 621.)
- ▶ Now reduced by B. Grzadkowski, M. Iskrzynski, M. Misiak, J. Rosiek (arXiv:1008.4884v2)

$$\frac{ico_1 g_s}{\Lambda} \bar{u} \lambda^a \sigma^{\mu\nu} (f_u + h_u \gamma_5) t G_{\mu\nu}^a + H.C.$$

# LO event generation

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- ▶ Generate phase-space for  $2 \rightarrow 1$  process
- ▶ Weight with  $|M|^2 \times PDF_1 \times PDF_2$
- ▶ Write the events within "Les Houches Accord"
- ▶ Shower and Hadronization (PYTHIA or HERWIG)
- ▶ Simulate the detector (DELPHES)

# Inclusive NLO Direct top cross sections

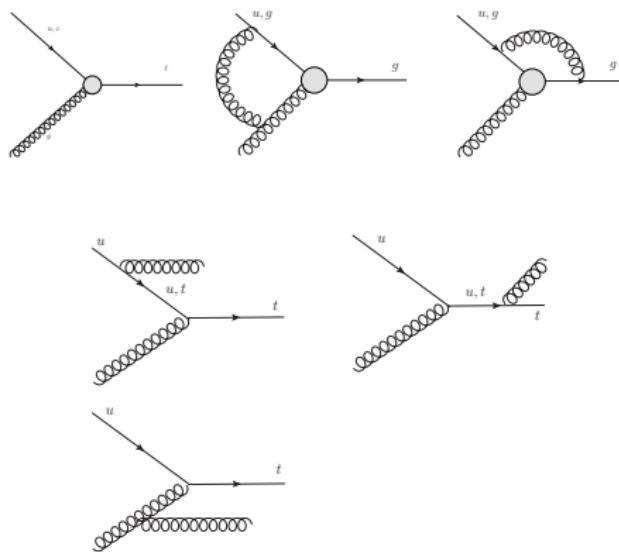
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FCNC Direct top cross sections ( $\frac{k_{tg}^g}{\Lambda} = 0.01 \text{ Tev}^{-1}$ ) (pb) (PRD 72 074018 (2005))				
Subprocess	LHC (LO)	LHC (NLO)	Tevatron Run2 (LO)	Tevatron Run2 (NLO)
$gu \rightarrow t$	11.068	16.818	0.259	0.413
$gc \rightarrow t$	1.817	2.537	0.0176	0.0283

- ▶ The NLO cross section highly enhanced
- ▶ About 60% for Tevatron and 40%-50% for LHC
- ▶ FCNC BR limits improvements of the same order
- ▶ It is desirable to generate NLO Direct top events

# Next to Leading order

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$$\sigma_{NLO} = \int_m d\sigma^{Born} + \int_m d\sigma^{virtual} + \int_{m+1} d\sigma^{Real}$$

## NLO generation

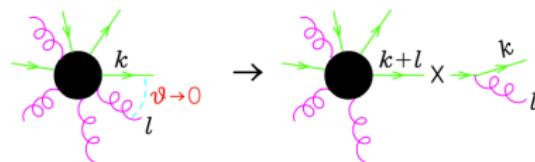
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$$\sigma_{NLO} = \int_m d\sigma^{Born} + \int_m d\sigma^{virtual} + \int_{m+1} d\sigma^{Real}$$

- ▶ The analytical calculation is "easily" done.
- ▶ Full phase-space is totally integrated and infrared infinities are cancelled
- ▶ Problem to generate events because there are two different configurations ( $m$  and  $m+1$ )

## NLO approximation

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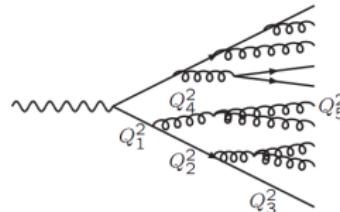


$$|M_{m+1}|^2 d\Phi_{m+1} \rightarrow |M_m|^2 d\Phi_m \frac{\alpha_S}{2\pi} \frac{dt}{t} P_{q,qg}(z)$$

- ▶ For low PT and low energies the NLO corrections can be approximated by a branching mechanism (shower)
- ▶ Approximation highly broken for high PT
- ▶ We can use different approaches for different PT  
(Matching)

# NLO approximation

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Sudakov form factor provides  
“time” ordering of shower:  
lower  $Q^2 \iff$  longer times

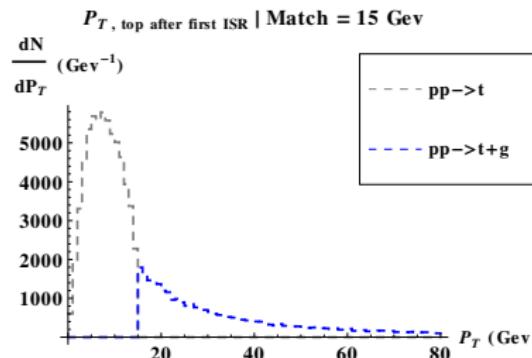
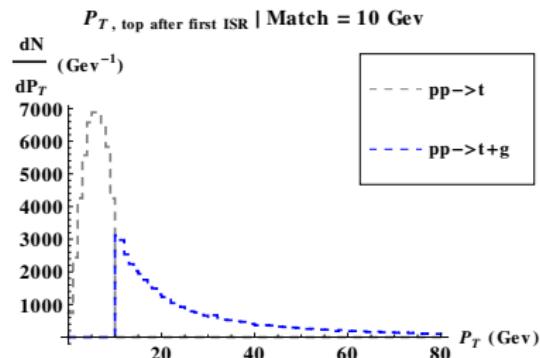
$$\begin{aligned} Q_1^2 &> Q_2^2 > Q_3^2 \\ Q_1^2 &> Q_4^2 > Q_5^2 \\ \text{etc.} \end{aligned}$$

- ▶ generate LO Direct top
- ▶ Veto for  $PT > PT_{match}$  in Showering
- ▶ If Showering made by PT order, we can just set the max  $PT = PT_{match}$
- ▶ generate events LO with real emission with  $PT(g) > PT_{match}$
- ▶ Normalise to the total NLO cross section

$$\sigma^{NLO} = k\sigma_{PT(g) < PT_{match}}^{LO} + \sigma_{PT(g) > PT_{match}}^{Real}$$

# First ISR

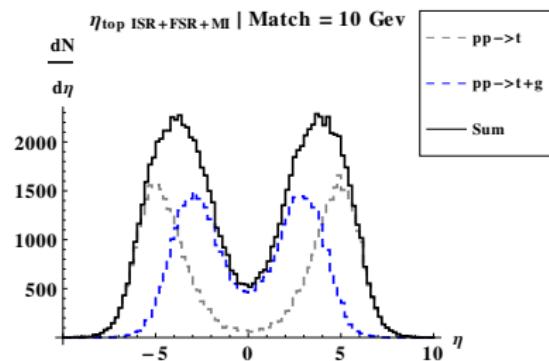
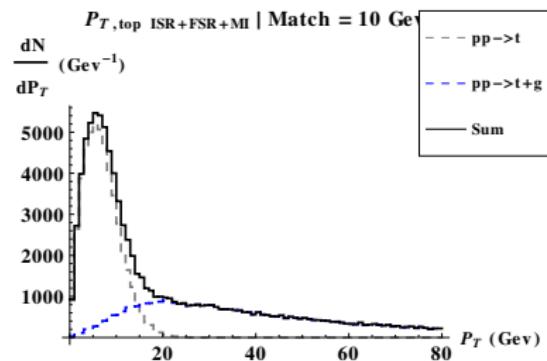
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- ▶ We choose the match according to the smoothness of the distribution
- ▶  $P_{T,\text{match}}$  works as a resolution parameter and can be considered as a systematic error.

# Full Shower

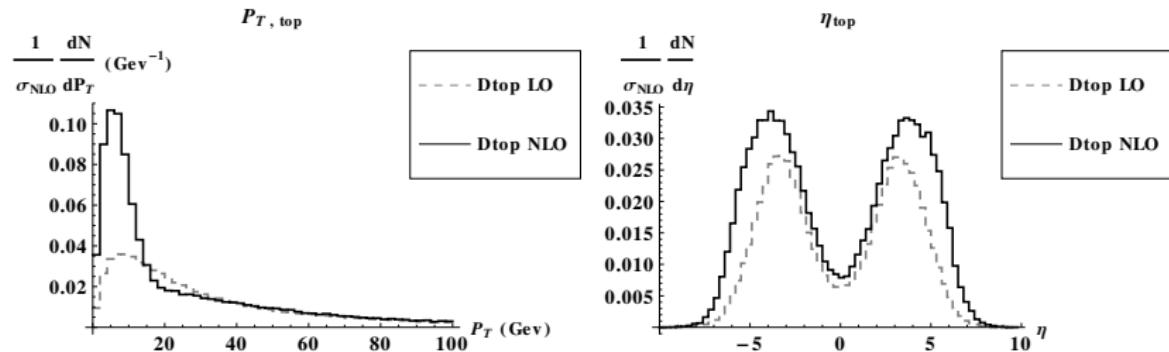
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- Direct top at NLO after ISR+FSR+MI

# NLO vs LO

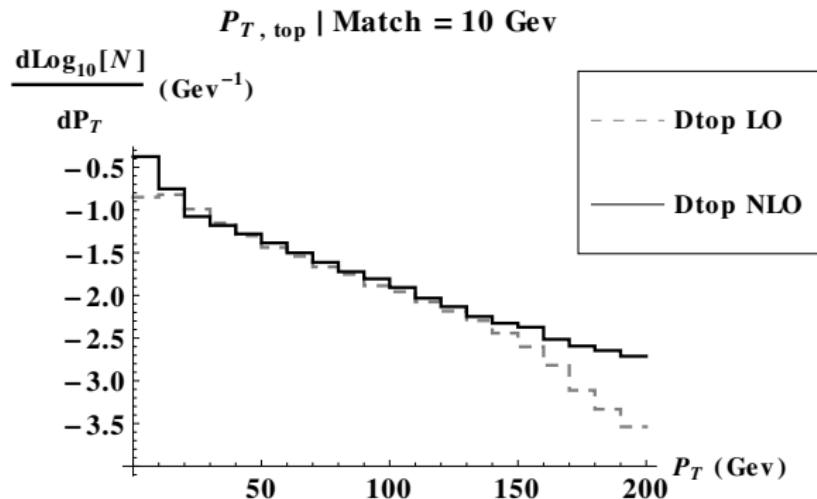
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- ▶ Direct top at NLO vs LO
- ▶ More than just a K-factor
- ▶ Consequences when top reconstructed
- ▶ Asymmetries cuts under study

# NLO vs LO

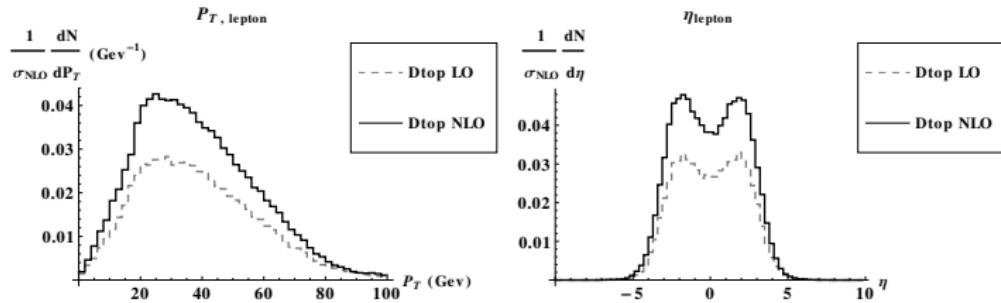
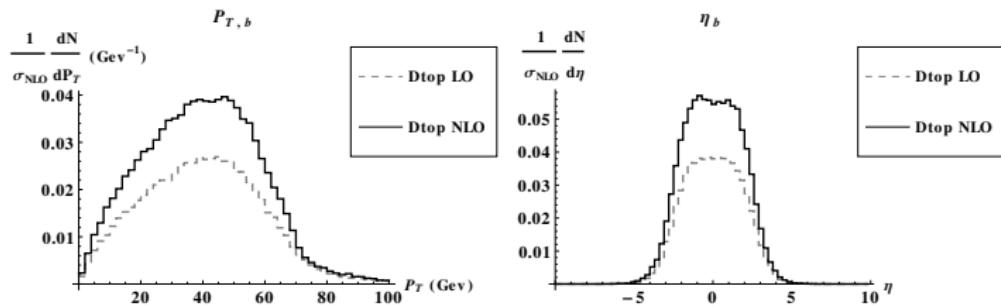
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- ▶ Hard region corrected.

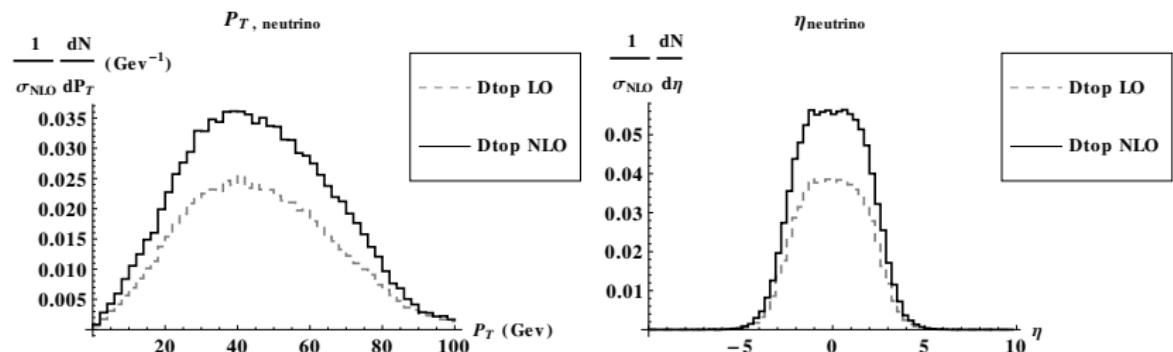
# NLO vs LO

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# NLO vs LO

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- ▶ top products distributions can be reproduced through a K-factor

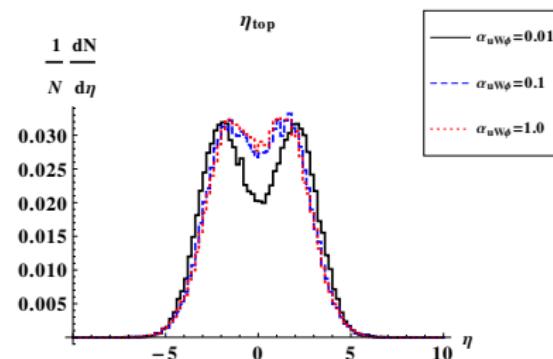
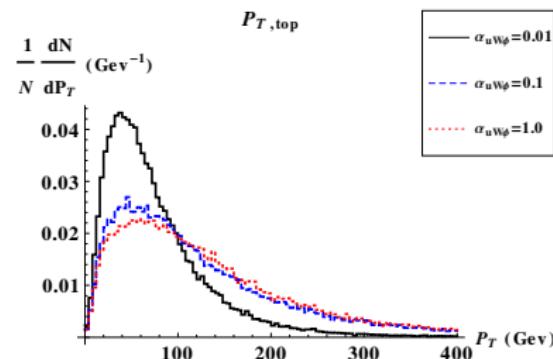
## Single top beyond the strong FCNC operators

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- ▶ Electroweak and 4F operators contribute to FCNC Single top.
- ▶ Different sets of independent EW and 4F operators are included.
- ▶ Possibility to introduce extra operators.

# EW operators

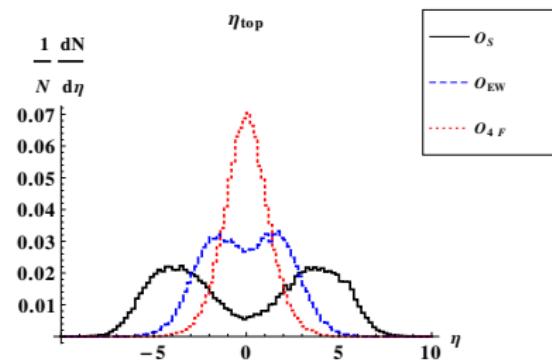
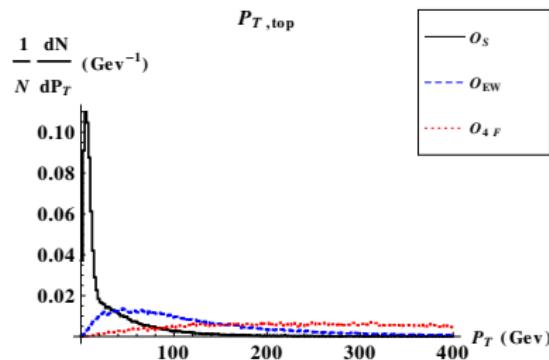
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- ▶ SM Single top competes with Electroweak FCNC interactions

# 4F operators

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- ▶ Different operators result in different distributions

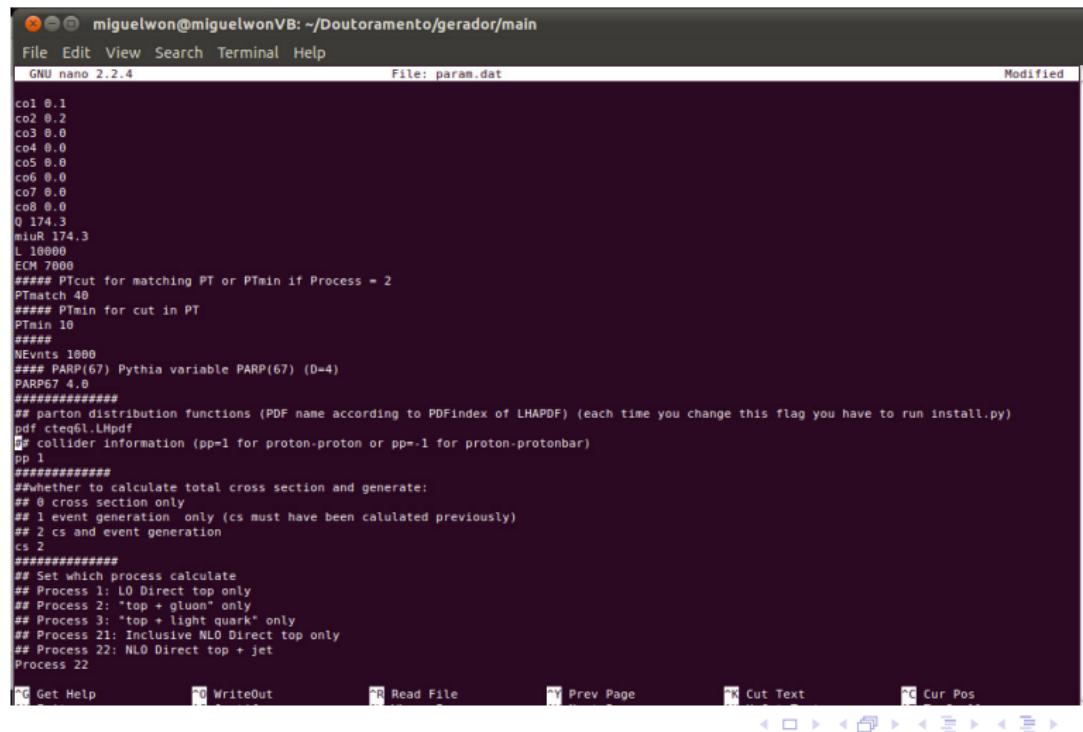
# Code

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- ▶ Written in C and python 2.6
- ▶ Feynman Rules were calculated using LanHep
- ▶ Amplitudes calculated with CalcHep
- ▶ Cuba library for Vegas integration
  
- ▶ Events written in LHE
- ▶ Spin correlations included (switch on and off)
- ▶ New interactions can be included

# User friendly

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miguelwon@miguelwonVB: ~/Doutoramento/gerador/main

```
File Edit View Search Terminal Help
GNU nano 2.2.4 File: param.dat Modified :+.

col 0.1
co2 0.2
co3 0.0
co4 0.0
co5 0.0
co6 0.0
co7 0.0
co8 0.0
Q 174.3
muR 174.3
L 10000
ECH 7000
##### PTcut for matching PT or PTmin if Process = 2
PTmatch 40
##### PTmin for cut in PT
PTmin 10
#####
NEvents 1000
##### PARP(67) Pythia variable PARP(67) (D=4)
PARP67 4.0
#####
## parton distribution functions (PDF name according to PDFindex of LHAPDF) (each time you change this flag you have to run install.py)
pdf cteq6L_LMpdf
## collider information (pp=1 for proton-proton or pp=-1 for proton-protonbar)
pp 1
#####
##Whether to calculate total cross section and generate:
## 0 cross section only
## 1 event generation only (cs must have been calculated previously)
## 2 cs and event generation
cs 2
#####
## Set which process calculate
## Process 1: L0 Direct top only
## Process 2: "top + gluon" only
## Process 3: "top + light quark" only
## Process 21: Inclusive NLO Direct top only
## Process 22: NLO Direct top + jet
Process 22

G Get Help W WriteOut R Read File Y Prev Page C Cut Text C Cur Pos
```

## Info

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```
miguelwon@miguelwonVB: ~/Doutoramento/gerador/main/Events
File Edit View Search Terminal Help
GNU nano 2.2.4                               File: runinfo.txt                         Modified
col = 0.1
c02 = 0.2
c03 = 0.0
c04 = 0.0
c05 = 0.0
c06 = 0.0
c07 = 0.0
c08 = 0.0
Q = 174.3
miuR = 174.3
L = 100000.0
ECM = 7000.0
PMatch = 40.0
PTmin = 10.0
NEvents = 1000
PdfSet = cteq6L.LHpdf

PARP(67) = 4.0

Process information:

Direct top in NLO approximation
Process | CS | NEvents | Kfactor
u, G -> t | 3.165e+00 | 39 | 1.30
U, G -> T | 6.056e-01 | 6 | 1.43
G, u -> t | 3.165e+00 | 36 | 1.30
G, U -> T | 6.057e-01 | 6 | 1.43
c, G -> t | 1.250e+00 | 17 | 1.47
C, G -> T | 1.250e+00 | 16 | 1.47
G, c -> t | 1.250e+00 | 15 | 1.47
G, C -> T | 1.250e+00 | 11 | 1.47
u, G -> G, t | 5.450e-01 | 9 | 1.00
U, G -> G, T | 6.040e-02 | 1 | 1.00
G, u -> G, t | 5.450e-01 | 13 | 1.00
G, U -> G, T | 6.030e-02 | 1 | 1.00
C, G -> G, T | 9.990e-02 | 1 | 1.00
G, c -> G, t | 9.990e-02 | 1 | 1.00
G, C -> G, T | 9.990e-02 | 1 | 1.00
u, u -> u, t | 2.330e-01 | 3 | 1.00

FG Get Help   FO WriteOut   FR Read File   FV Prev Page   FC Cut Text   FC Cur Pos

```

# Conclusions

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- ▶ MEtop is a FCNC Direct top generator at NLO
- ▶ top products distributions can be simulated through a K-factor
- ▶ NLO corrections enhanced by top reconstructed analysis
- ▶ Events can be used in PYTHIA without the need of an interface
- ▶ Set of electroweak and 4F operators are included
- ▶ Possibility to compare different Lorentz structures

# How to get it

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The screenshot shows a web browser window with the address bar containing "coimbra.ipp.pt/~miguelwon/MEtop/". The main content area has a yellow background and displays the following text:

### MEtop- a generator for single top production via FCNC interactions

MEtop is a MC event generator of single top quark production via Flavor Changing Neutral Currents interactions. The MEtop event generator allows Next-to-Leading-Order direct top production  $pp \rightarrow t$  and Leading-Order production of several other single top processes. A few packages with definite sets of dimension six operators are available: Strong, Strong+Electroweak and Strong+4F. The first one is light version of MEtop, where only one effective operator was introduced (responsible for strong FCNC). The second version includes one for strong FCNC and six electroweak FCNC, and finally, the third is equivalent but with a set of strong and nine 4-fermions operators.

[Strong \(light version\)](#)  
[Strong+Electroweak](#)  
[Strong+4F](#)

Contact: miguel.won@coimbra.ipp.pt