

METop top FCNC event generator

Miguel Won^{1 2} Rita Coimbra^{1 2} Rui Santos^{3 4}
Antonio Onofre^{2 5}

¹University of Coimbra

²LIP

³ISEL

⁴CFTC

⁵University of Minho



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Outline

Introduction

FCNC Direct Top generation

NLO calculation

The generator

Cross-check

Summary



The physical problem

- ▶ 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]

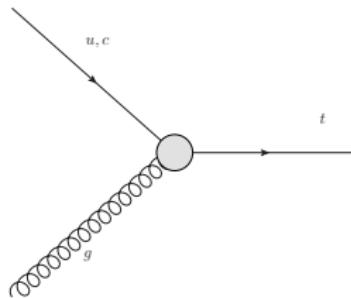
Effective Lagrangian

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

- ▶ 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



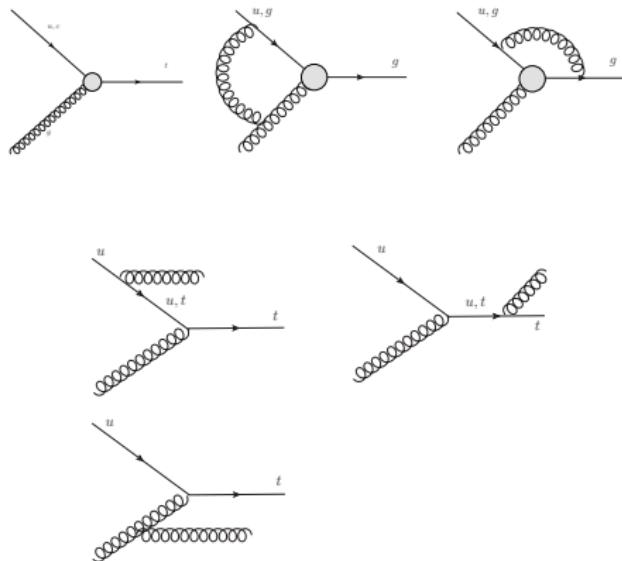
- ▶ Generate phase-space for $2 \rightarrow 1$ process
- ▶ Weight with $|M|^2 \times PDF_1 \times PDF_2$
- ▶ Write the events within "Les Houches Accord"
- ▶ Shower and Hadronization (PYTHIA or HERWIG)
- ▶ Simulate the detector (DELPHES)

Inclusive NLO Direct top cross sections

FCNC Direct top cross sections ($\frac{k_{tq}^g}{\Lambda} = 0.01 \text{ Tev}^{-1}$) (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



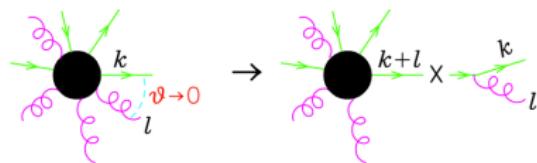
$$\sigma_{NLO} = \int_m d\sigma^{Born} + \int_m d\sigma^{virtual} + \int_{m+1} d\sigma^{Real}$$

NLO generation

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

- ▶ 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 $m+1$)

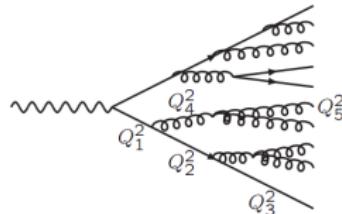
NLO approximation



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

- ▶ 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



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

$$Q_1^2 > Q_2^2 > Q_3^2$$
$$Q_1^2 > Q_4^2 > Q_5^2$$

etc.

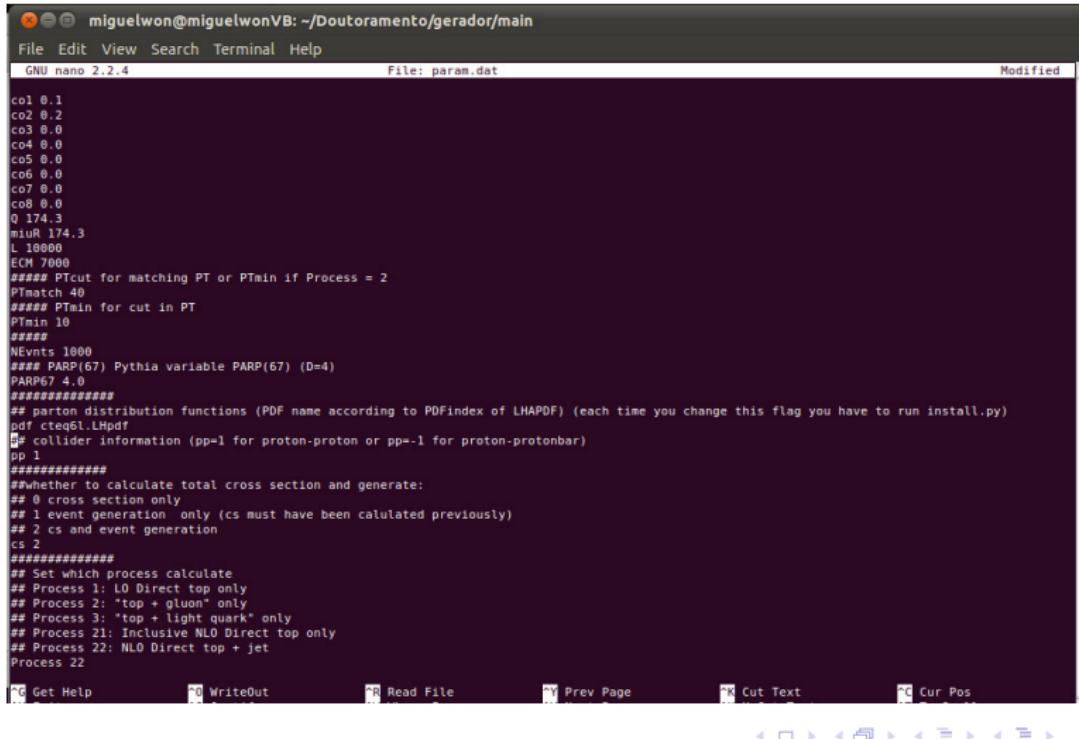
- ▶ generate LO Direct top
- ▶ Veto for $PT > PT_{match}$ in Showering
- ▶ If Showering made by PT order, we can just set the max $PT = PT_{match}$
- ▶ generate events LO with real emission with $PT(g) > PT_{match}$
- ▶ Normalize to the total NLO cross section

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

Code

- ▶ Written in C and python 2.6
- ▶ Feynman Rules were calculated using LanHep
- ▶ Amplitudes calculated with CalcHep
- ▶ Cuba library for Vegas integration

User friendly



miguelwon@miguelwonVB: ~/Doutoramento/gerador/main

File Edit View Search Terminal Help

File: param.dat Modified ↗

```
GNU nano 2.2.4
```

```
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
ECM 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
```

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Navigation icons: back, forward, search, etc.

Some MEtop properties

- ▶ W and top widths taken into account
- ▶ Spin correlations are included (switch on and off)
- ▶ In addition to the Strong FCNC it is included electroweak and 4f FCNC
- ▶ New interactions can be included

The generator

Info

```
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 = 10000.0
ECM = 7000.0
PTmatch = 40.0
PMin = 10.0
NEvents = 1000
PdfSet = ctq6L.LHpdf

PARP(67) = 4.0

Process information:

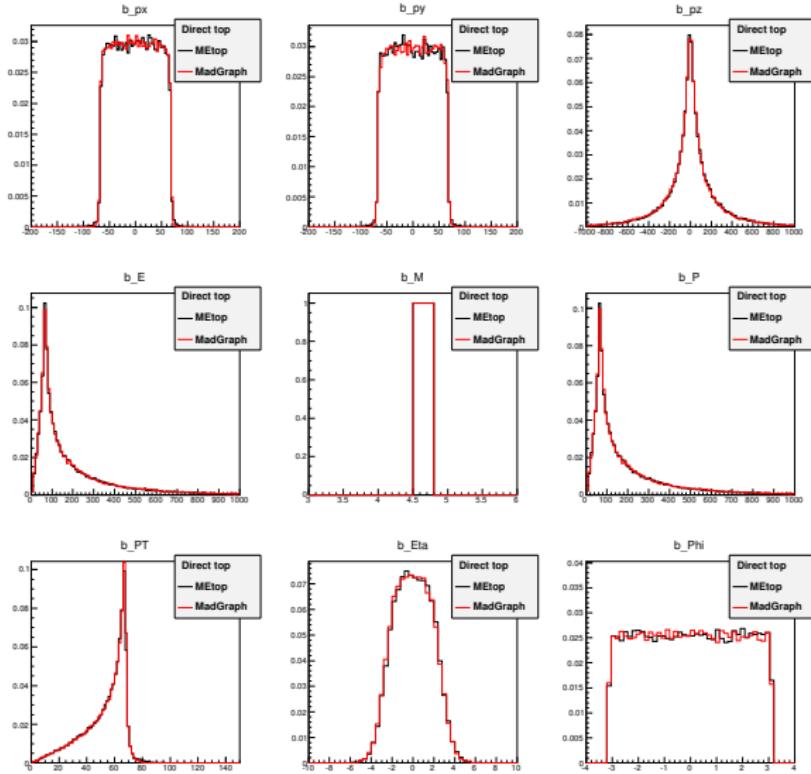
Direct top in NLO approximation
Process | CS | NEvents | Kfactor
u, G -> t | 3.165e+00 | 39 | 1.38
U, G -> T | 6.056e-01 | 6 | 1.43
G, u -> t | 3.165e+00 | 36 | 1.38
G, U -> T | 6.057e-01 | 6 | 1.43
c, G -> t | 1.250e+00 | 17 | 1.47
C, G -> T | 1.250e+00 | 16 | 1.47
G, c -> t | 1.250e+00 | 15 | 1.47
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

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```

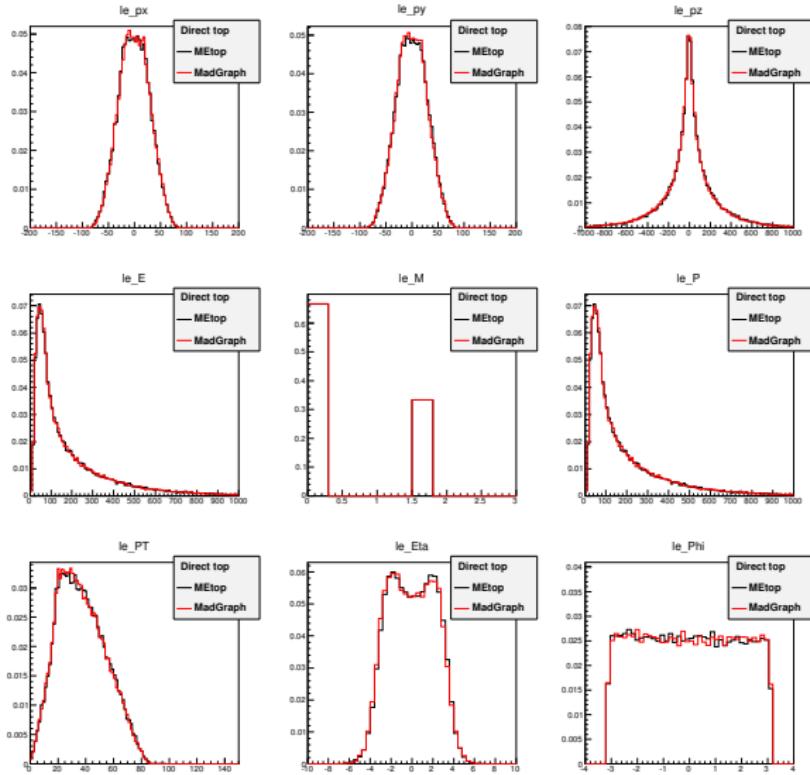
Cross-check with a different MC generator

- ▶ Strong FCNC were introduced in MadGraph 5
- ▶ Generated Direct top and top+gluon events

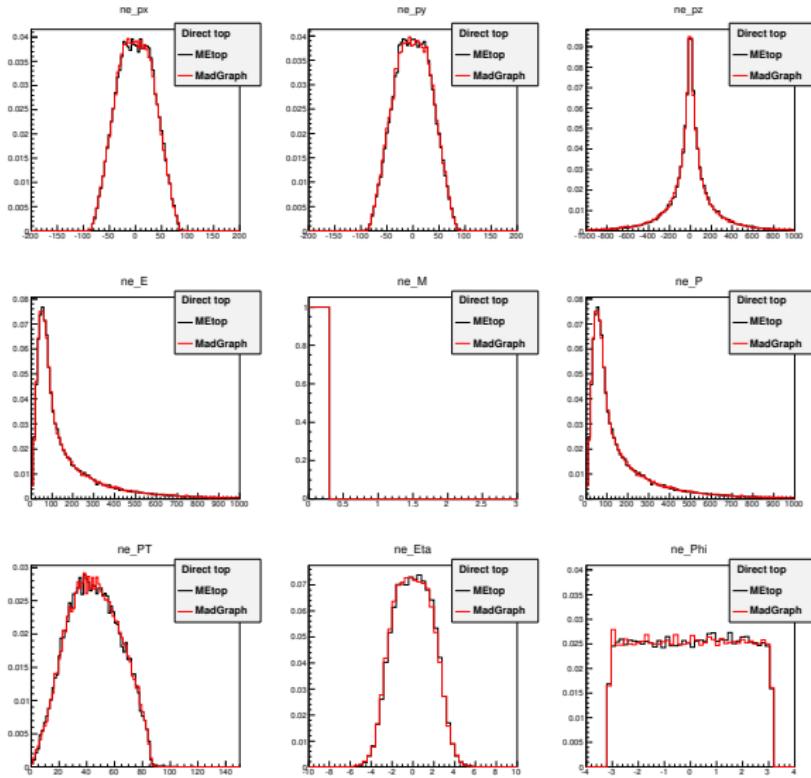
Direct top



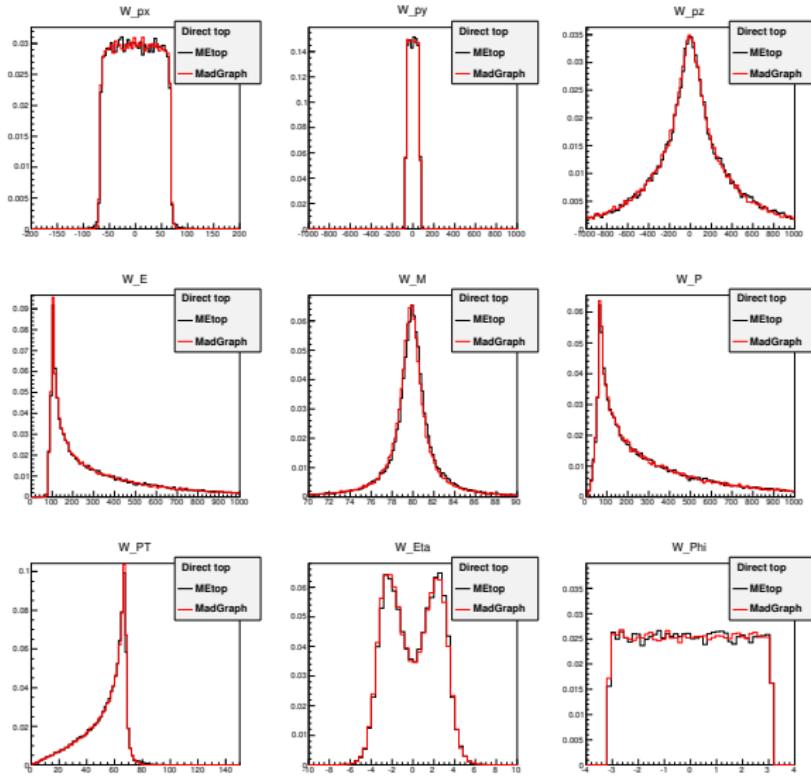
Direct top



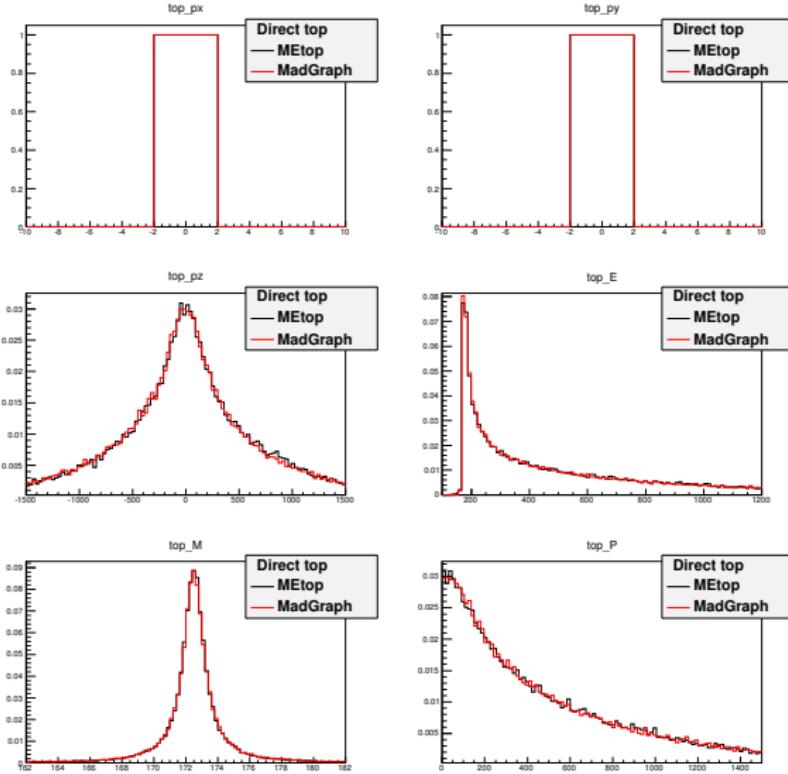
Direct top



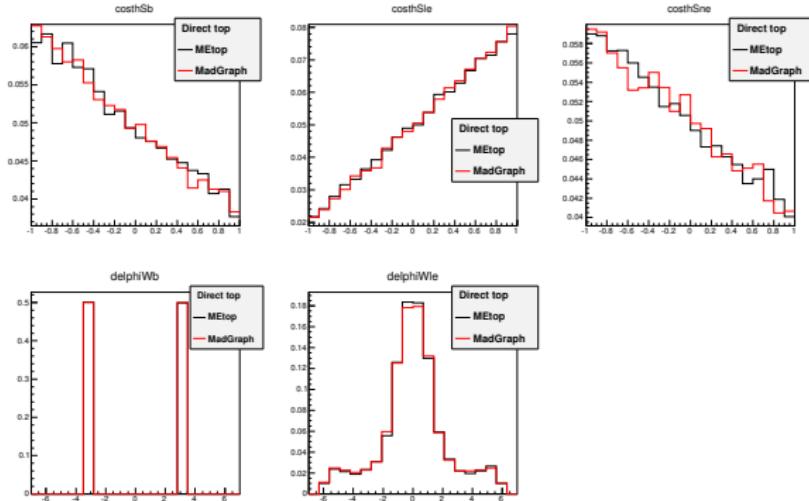
Direct top



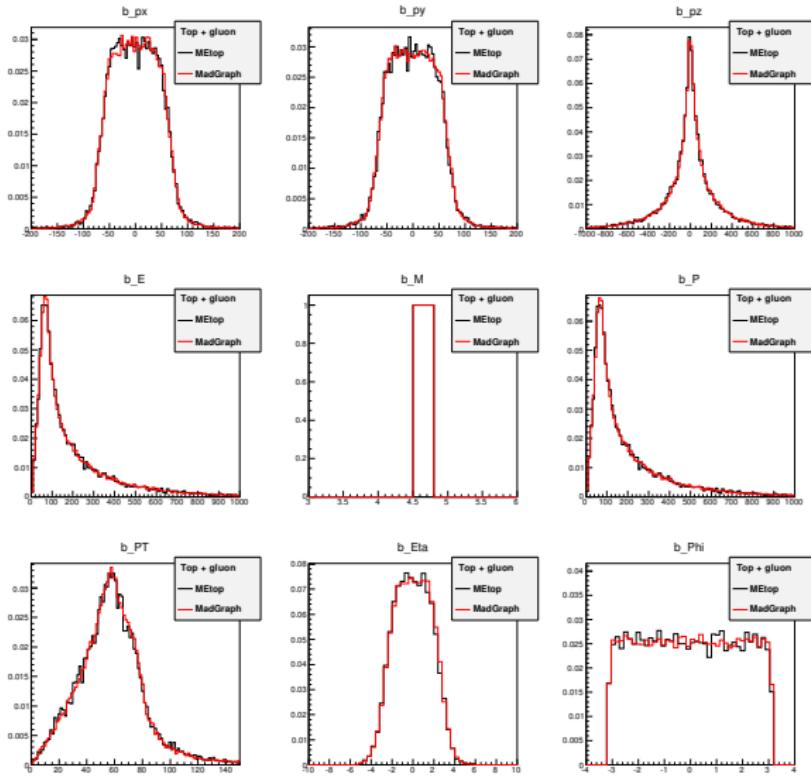
Direct top



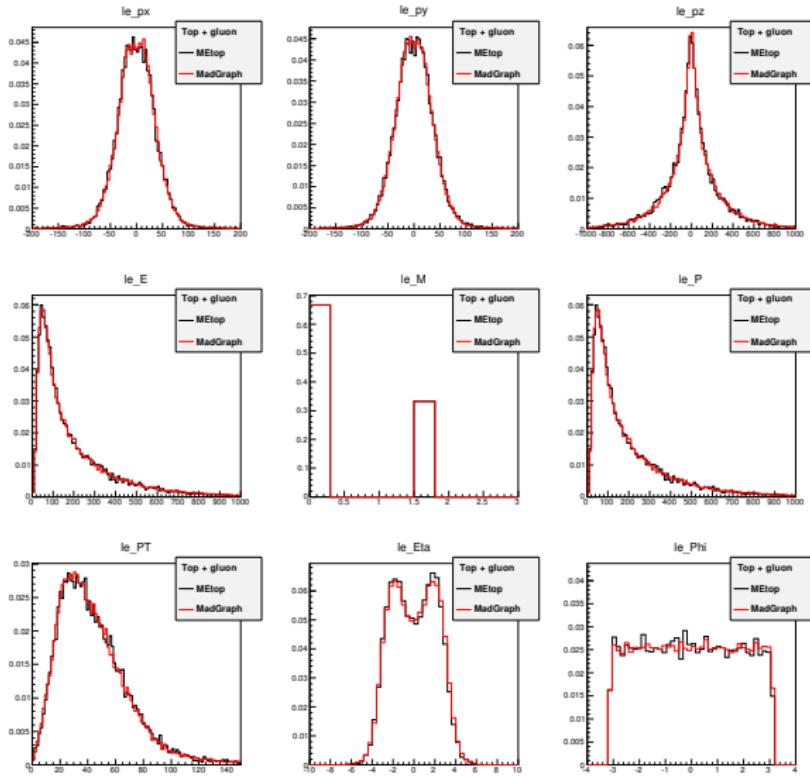
Direct top



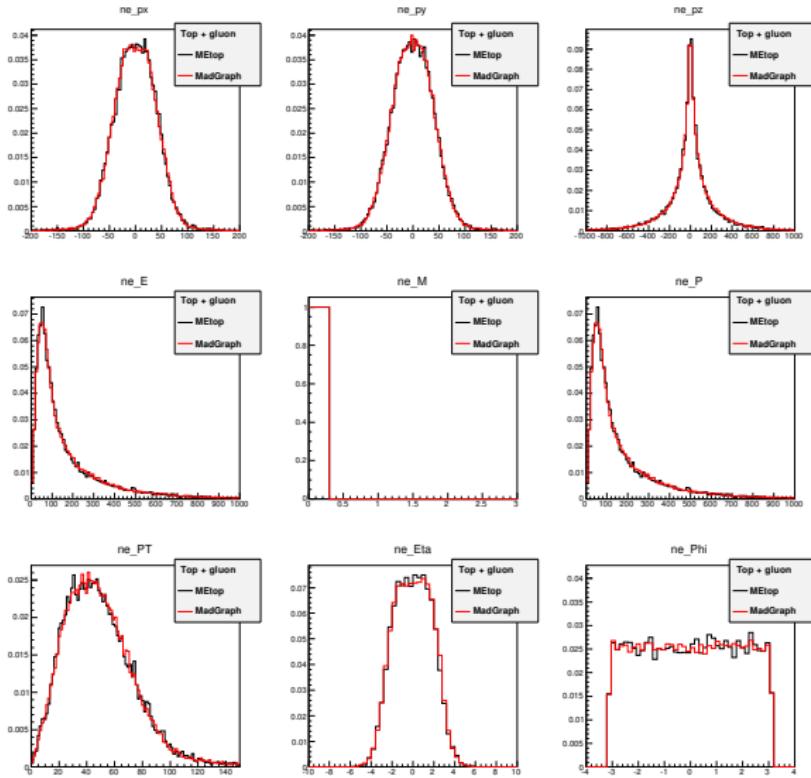
top+gluon



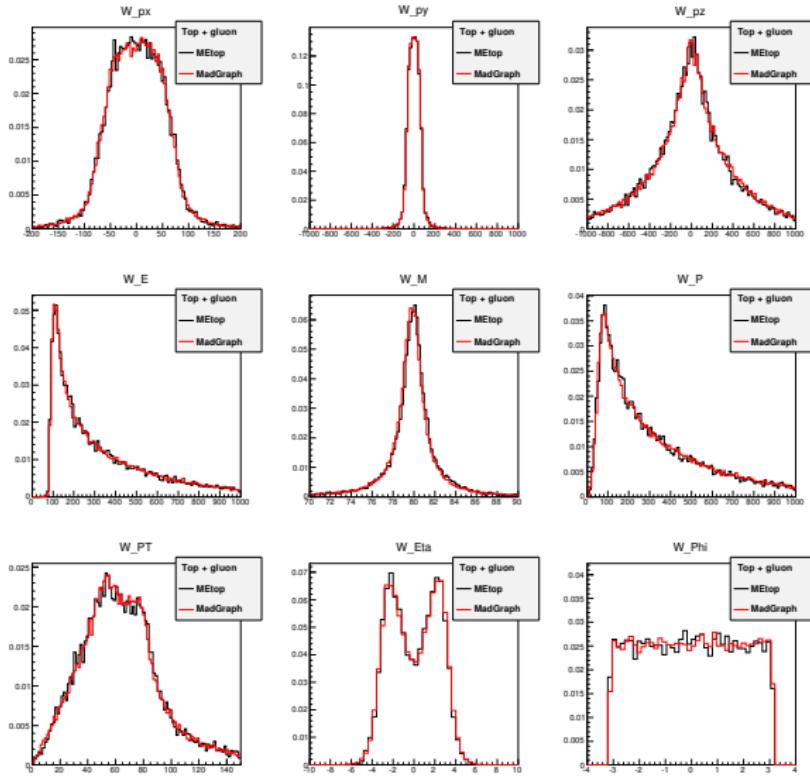
top+gluon



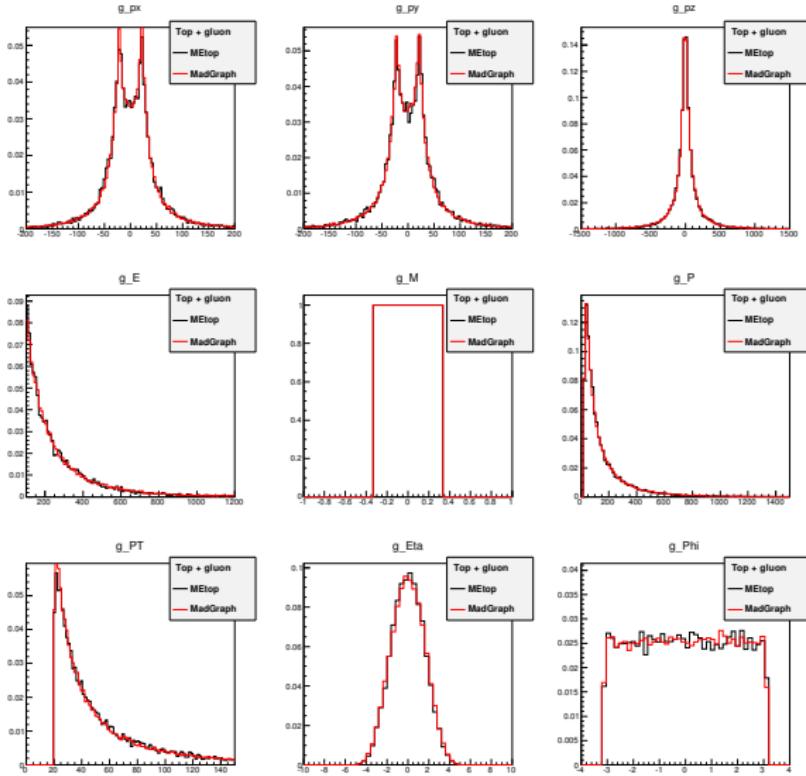
top+gluon



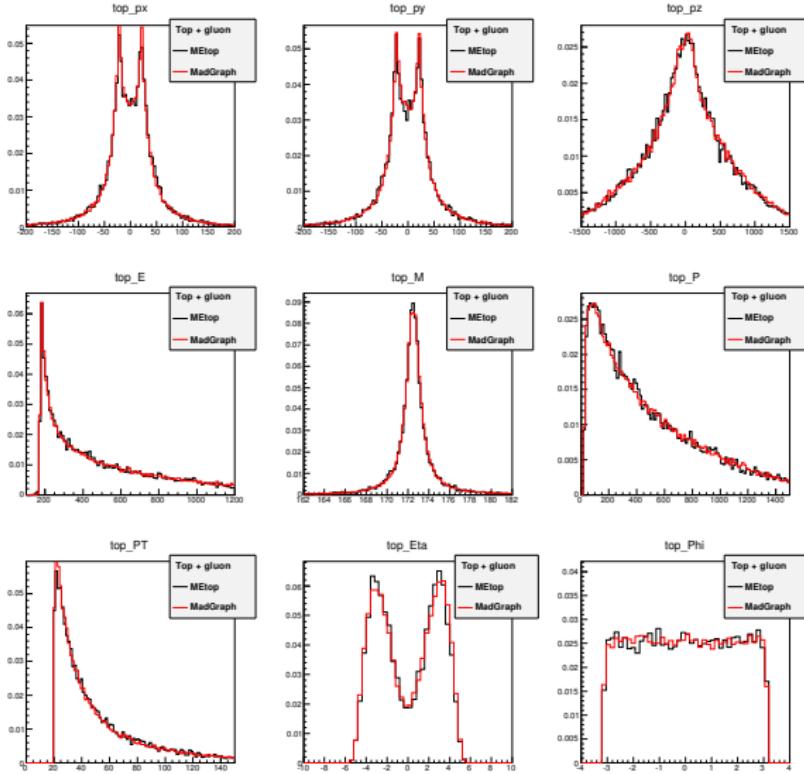
top+gluon



top+gluon

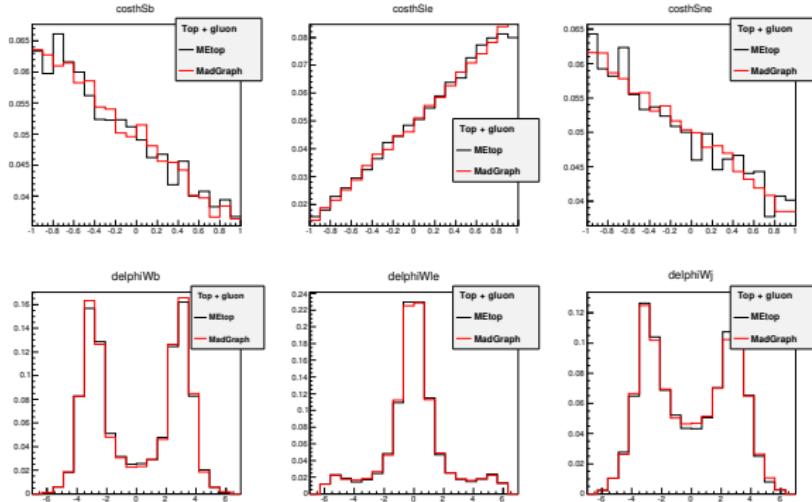


top+gluon

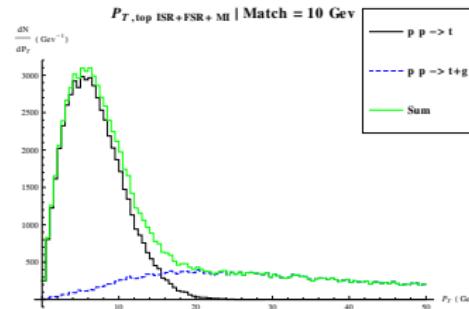
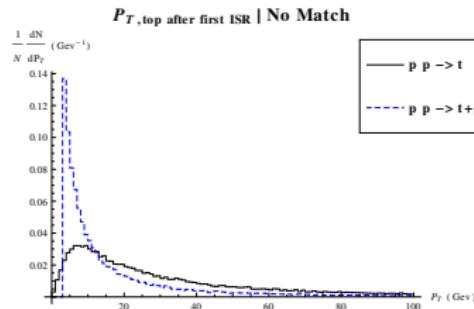


└ Cross-check

top+gluon



Matching



Recap

- ▶ NLO Direct top cross section highly enhanced in NLO approximation
- ▶ NLO events desirable
- ▶ Not possible to generate NLO events using conventional methods
- ▶ Divide the phase-space and use shower for low PT and $|M|^2 d\Phi_{m+1}$ for high PT
- ▶ Normalize
- ▶ Generate events according the cross sections
- ▶ Shower (PT ordered scheme) and hadronize



To be done

- ▶ Cross-check with Protos (Friedrich Conrad: Wuppertal group)
- ▶ Include FCNC $t\bar{t}$
- ▶ Online availability (webpage creation)