Monte-Carlo integrator mcsanc-v1.0

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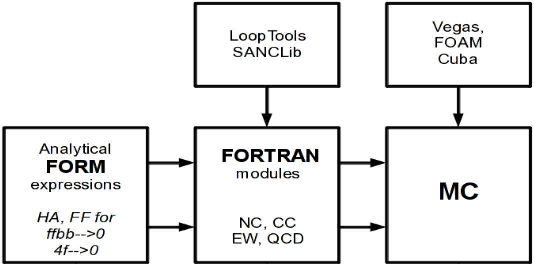
SANC approach and features



- Calculation are performed with the on-mass-shell renormalization scheme in R_ξ gauge
- The total EW NLO cross section is divided into five terms

$$\sigma^{\rm NLOEW} = \sigma^{\rm Born} + \sigma^{\rm virt}(\lambda) + \sigma^{\rm soft}(\lambda, \bar{\omega}) + \sigma^{\rm hard}(\bar{\omega}) + \sigma^{\rm subt}$$

- $\overline{\rm MS}$ or DIS subtraction schemes

mcsanc features

- A Monte-Carlo integrator (weighted events) based on SANC modules
- Calculates fully differential cross section for DY and inclusive cross section for higgs-strahlung and single-top production processes in *pp* collisions for LHC physics
- Provides both NLO EW and QCD corrections
- Supports different EW-schemes: $\alpha(0), \alpha(M_Z), G_\mu$
- Fixed and running factorization and renormalization scale options
- Kinematic cuts, recombination
- Parallel calculation on multicore machines thanks to Cuba library (http://www.feynarts.de/cuba/)
- Easy installation and configuration (GNU autotools, LHAPDF, input configs for physics par-s, cuts, histogramming)

Supported processes

The process id notation is the following: first digit is a sign of EW-current, and the last two digits specify the final particle choice.

$0xx$ - neutral current, $xx = 01(e), 02(\mu), 03(\tau), 04(HZ)$

$\pm 1xx$ - charged current, $xx = 01(e), 02(\mu), 03(\tau), 04(HW)$, $05, 06(t-\mathrm{production}, s-\mathrm{and} \quad t-\mathrm{channels})$

pid	$ff \to$	SANC ref.
001:003	$l^+l^-(l = e, \mu, \tau)$	arXiv:0711.0625,0901.2785
004	$Z^0 + H$	arXiv:hep-ph/0506120,0812.4207
$\pm$ 101:103	$l^\pm + \nu_l$	arXiv:hep-ph/0506110,
$\pm$ 104	$W^\pm + H$	-
105	$t + \bar{b}$ (s-channel)	arXiv:1110.3622,1207.4400
106	$t + q$ (t-channel)	-//-
-105	$\bar{t} + b$ (s-channel)	-//-
-106	$\bar{t} + q$ (t-channel)	-//-

Numerical cross checks with MCFMv6.2: DY and $pp \to VH$ total cross section

The cross checks were performed in the following conditions:

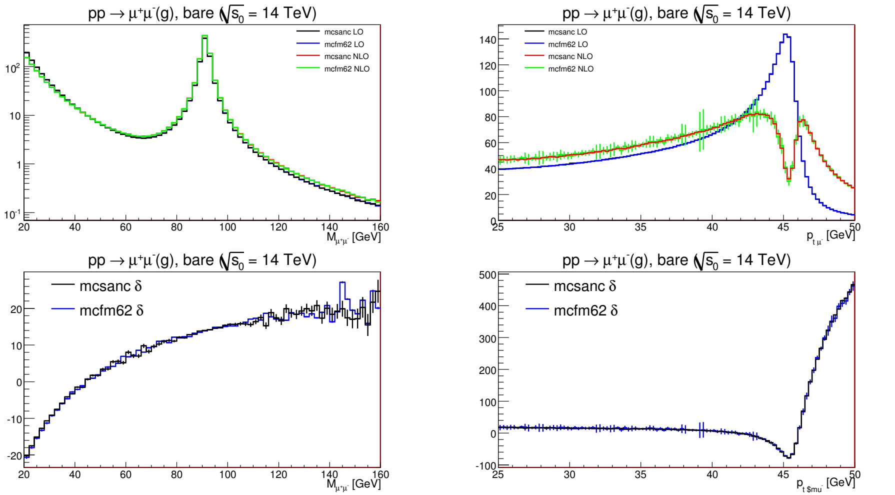
- $\sqrt{s_0} = 14$TeV
- Loose kinematic cuts : $p_T > 0.1 GeV$ ($M_{ll} > 20$GeV for DY)
- CT10 PDF set via LHAPDF
- Physics parameters from PDG-2011 (on 16/05/2012)

pid	002	102	-102	004	104	-104
LO	3338(1)	10696(1)	7981(1)	0.8291(1)	0.9277(1)	0.5883(1)
LO MCFM	3338(1)	10696(1)	7981(1)	0.8292(1)	0.9280(2)	0.5885(1)
NLO QCD	3388(2)	12263(4)	9045(4)	0.9685(3)	1.0897(3)	0.6866(3)
NLO MCFM	3382(1)	12260(1)	9041(5)	0.9686(1)	1.0901(2)	0.6870(1)
δ_{QCD}	1.49(3)	14.66(1)	13.35(3)	16.81(3)	17.47(3)	16.72(5)
NLO EW	3345(1)	10564(1)	7861(1)	0.7877(1)	0.8672(2)	0.5508(1)
δ_{EW}	0.22(1)	-1.23(1)	-1.49(1)	-5.00(2)	-6.52(2)	-6.38(3)

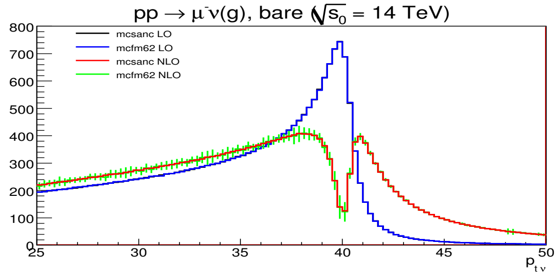
Numerical cross checks: single-t cross section

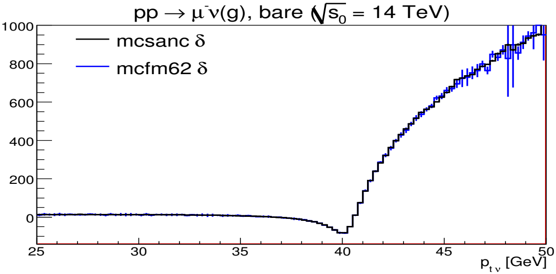
pid	105	-105	106	-106
LO	5.134(1)	3.205(1)	158.73(2)	95.18(2)
LO MCFM	5.133(1)	3.203(1)	158.69(7)	95.27(4)
NLO QCD	6.921(2)	4.313(2)	152.13(9)	90.44(7)
NLO MCFM	6.923(2)	4.309(1)	152.07(14)	90.50(8)
δ_{QCD}	34.79(5)	34.56(8)	-4.17(6)	-4.08(8)
NLO EW	5.022(1)	3.140(1)	164.44(5)	98.65(4)
δ_{EW}	-2.18(1)	-2.02(2)	3.59(3)	3.66(5)

Differential DY cross sections: MCFM comparison

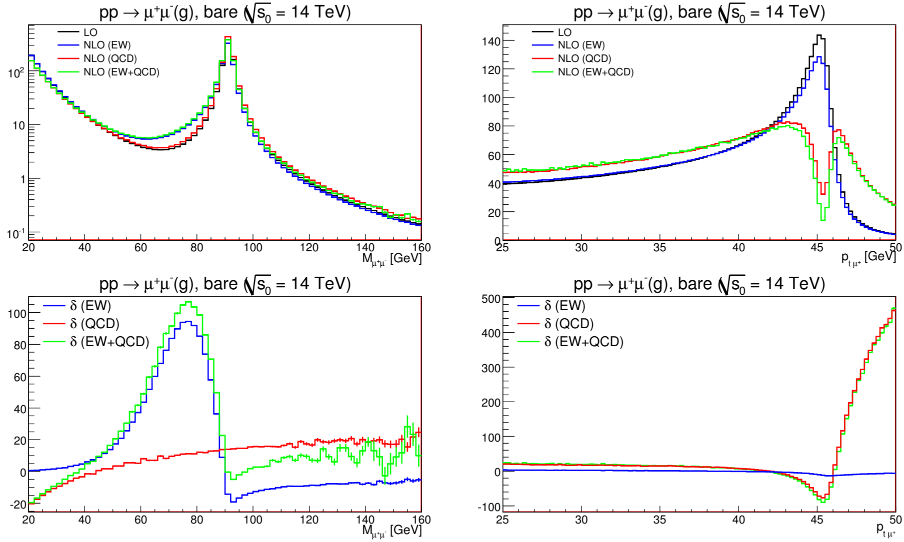


Differential DY cross sections: MCFM comparison



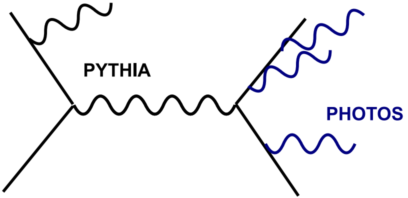


QCD and EW NLO corrections



Estimating missing corrections

For example, standard ATLAS MC generation chain uses PYTHIA and PHOTOS for LO, initial and final state radiation (ISR, FSR), and partonic showers:



In addition SANC implements the following NLO EW corrections, which can be included separately by changing `iqed` flag:

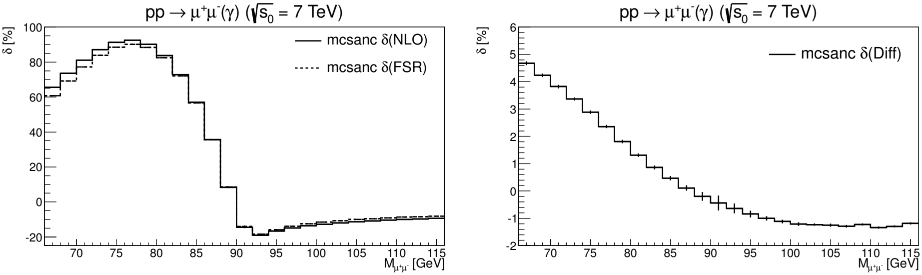
- pure weak (PW)
- initial–final QED interference (IFI)
- what remains of ISR after collinear divergences subtraction

These missed corrections can be evaluated as a difference between the complete NLO EW corrections and the QED FSR ones.

Missed corrections.

The missed corrections are cut-dependent for $M_{\mu^+\mu^-}$ distribution in the $pp \to Z \to \mu^+\mu^-$ process. Around Z-resonance they vary from -1% to 5%.

$$\delta_{M_{ll}}(\mathrm{MISS}) = \delta_{M_{ll}}(\mathrm{NLO} - \mathrm{FSR})$$



Therefore inclusion of these corrections in the analysis is mandatory.

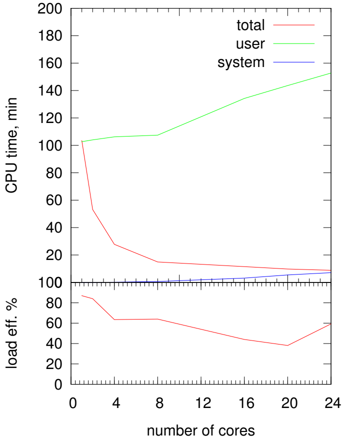
Configuration

```
&Process
  processId       = 102
  run_tag         = 'hist-test'
  sqs0            = 7000d0
  beams           = 1,1
+-- 13 lines: PDFSet = 'CT10.LHgrid'----------
/

&VegasPar
  relAcc          = 1d-3
  absAcc          = 3d0
  nStart          = 1000000
+--  5 lines: nIncrease = 1000000-------------
/

&KinCuts
  cutName         = 'm34', 'mtr',  'pt3',   'pt4',
  cutFlag         = 1       0       1        1
  cutLow          = 20d0,  0d0,    1d-1,    1d-1,
  cutUp           = 7d3, 7d3,      7d3,     7d3,
/

! particle numbering 1+2 -> 3+4+5+... ( FIXME
&FixedBinHist
  fbh_name        = 'm34','mtr',   'pt34',  'pt3',
  fbh_flag        = 3,     0,      3,       0,
  fbh_low         = 66d0, 20d0,    0d0,     0d0,
  fbh_up          = 116d0,70d0,    70d0,    100d0,
  fbh_step        = 2d0,   10d0,   10d0,    1d0,
/

&VarBinHist
  nvbh            = 7,

  vbh_name(1)     = 'm34',
  vbh_flag(1)     = 3,
```

```
&EWPars
  ! Choice of EW scheme: 0 - alpha, 1 - G_mu
  gfscheme                 = 2

  ! scales. -1d0 sets to invariant mass of produ
  fscale                   = -2d0
  rscale                   = -2d0
  ome                      = 1d-5

  ! 1/137.035999679d0 = 7.29735253759924464E-003
  alpha                    = 7.29735253759924464d-3
  gf                       = 1.16637d-5
  alphas                   = 0.1176d0
  !sin2thw                 = 0.2315d0
  conhc                    = 0.389379323d9

  ! boson masses
  mw                       = 80.399d0
  mz                       = 91.1876d0
  mh                       = 120d0
  ma                       = 0d0
  mv                       = 91.1876d0

  ! widths
  wz                       = 2.4952d0
  ww                       = 2.085d0
  wh                       = 1d-3
  wtp                      = 2d0

  ! CKM
  Vud                      = 0.9738d0
  Vus                      = 0.2272d0
```

Persistency and parallelization

- Vegas integration statefile in Cuba and histograms are saved after every iteration and upon run completion. The files can be used to increase statistics or restore from interrupted run (e.g. batch time quota exceeded)
- When run on a multicore systems, the calculation is automatically split by the number of cores or by $CUBACORES environment variable.
- The parallelization efficiency is limited due to inter-process communications: the optimal number of cores is 8, after which the run time doesn't reduce and efficiency (CPU load) is below 50%



Summary

- We present a new Monte-Carlo integrator mcsanc-v1.0
- Based on SANC modules and uses LoopTools and Cuba libraries
- The tool is aimed for calculation of NLO EW and QCD corrections to the DY(fully differential), higgs-strahlung and single-t production (so far inclusive) processes in in pp collisions
- Easily configurable and allows fine tuning with different EW schemes
- The major validations and cross checks have been completed
- Will appear soon on http://sanc.jinr.ru
- The nearest plans are to implement process $pp \to HZ(ll)$ in the narrow-width cascade approach