

## Standard SANC Modules

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### Abstract

In this note we summarize the status of the standard SANC modules (in the EW and QCD sectors of the Neutral Current branch — version 1.20 and the Charged Current branch — version 1.20). All versions of the codes are accessible from the SANC project servers at Dubna <http://sanc.jinr.ru> and CERN <http://pcphsanc.cern.ch>.

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# 1 Introduction

The status of the theoretical description of the Drell–Yan–like processes [1] was widely overviewed in the recent papers [2, 3] where the necessity of further in-depth study of them both from experimental and theoretical sides was emphasized.

Single W and Z boson production in Drell–Yan-like (DY) processes have clean signature and large cross sections. Their precision studies will be used for determination of the parton density functions, luminosity,  $M_W$ ,  $\sin^2 \theta^{eff}$ ,  $\Gamma_{W,Z}$ . Required precision tag is below 1%, see e.g. [4, 5].

Theoretical calculations of the DY processes for high energy hadronic colliders were performed at the level of one-loop QED and electroweak (EW) radiative corrections (RC) by several groups, see papers [6, 7, 8, 9, 10, 11] and references therein. QCD corrections are known up to the next-to-next-to-leading order [12].

The first attempt to combine EW and QCD corrections was done within the working group “The neutral current Drell–Yan process in the high invariant mass region” of the the 2007 Les Houches Workshop [13]. Existing codes have to meet the requested experimental precision. QED, Weak and QCD one-loop level corrections should be calculated taking into account by oneself, their interplay and all necessary higher order effects.

For users attention we offer two types of SANC outputs <sup>1</sup>:

- stand-alone packages for calculation of the EW and QCD NLO RC at the parton level together with the environment in which it is run, i.e. the Standard SANC FORM (and/or FORTRAN) Modules (SSFM) (see section 2.2);
- MC event generators, for production of event distributions at the hadronic level, based on the FOAM algorithm [16].

In this note we present the first positive experience of the using SSFM’s for DY-like processes for neutral current (NC),

$$q\bar{q} \rightarrow \ell^+\ell^- \tag{1}$$

with  $\ell = \mu, e$ , (the NC DY generator was presented first in talk [17]) and charged current (CC) processes (in — [18])

$$q\bar{q}' \rightarrow \ell\nu_\ell, \tag{2}$$

as stand-alone codes, see also [19] and [20].

The packages for calculations at the partonic level as well as the FOAM-based generators are accessible from SANC project homepages [21].

Moreover, we create tools for checking the implementation of these modules — the integrators of the processes, based on the Vegas algorithm [22]–[23], but presently only for an internal use. We used these integrators in the business of the tuned comparison within the several international workshops for NC and CC DY processes, see Les Houches Workshop Proceedings [24], [13] and Tevatron for LHC Report [25].

In this note we demonstrate the first example of applying EW SSFM into MC generator WINHAC [26]. We checked the work of these modules by means of comparison of the results obtained by SANC integrator DY\_CC\_VEGAS with those produced by the development version WINHAC v1.30 (see Section 3).

The SANC project was presented at several ATLAS MC and SM working group meetings, e.g. [27, 28, 29, 30, 31]. From the project page one can download SANC client software, that allow users to interactively test the workability of the all offered processes, i.e. user may create SSFM’s by oneself (the documentation for SANC client also can be found at the project webpage). However, user may download SSFM from the SANC homepages directly.

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<sup>1</sup>We do not describe SANC system in this note, referring the reader to published papers [14], [15].

## 2 Basics of working with SANC

### 2.1 Working with SANC client

To work with SANC, one must install the SANC client. The SANC client can be downloaded from the SANC project homepage [21]. On the homepage select **Download**, see Fig.1, then download the client, unzip it and follow the instructions in the README file.<sup>2</sup>

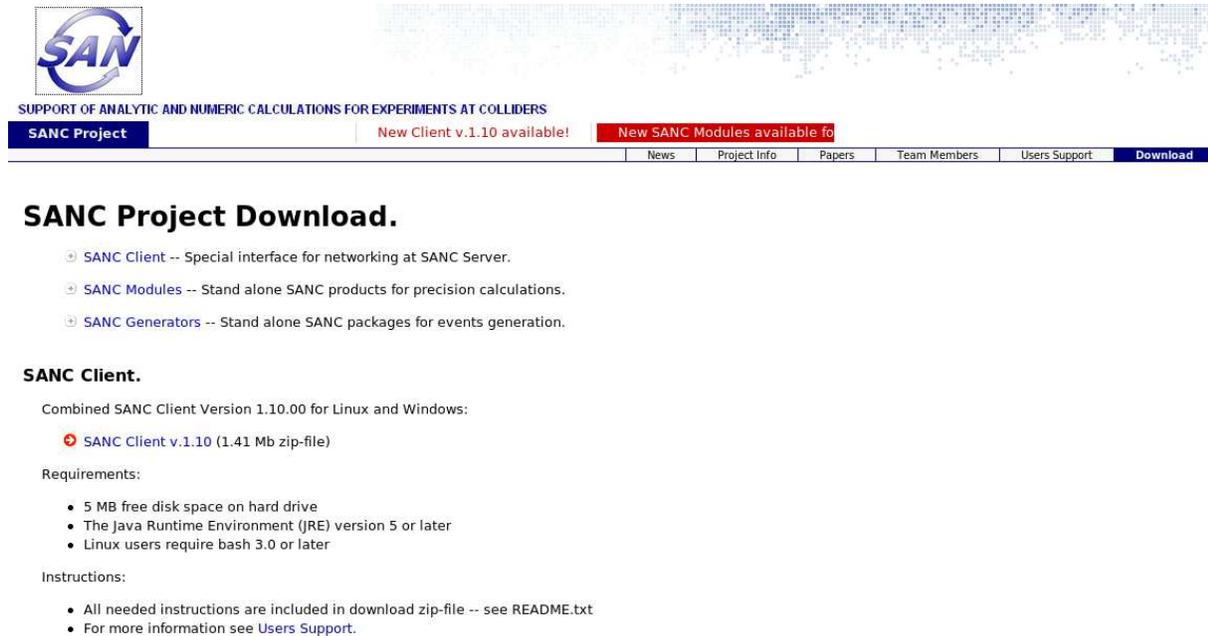


Figure 1: SANC Project Download

### 2.2 SANC tree for Drell–Yan processes

The desired stage of development of the SANC tree for any process is the tree with four FORM modules at the tip of the processes branches. In Fig. 2 we show the location of the  $2f \rightarrow 2f$  CC and NC sub-processes at the SANC tree.

Moving along the menu sequence **SANC**  $\rightarrow$  **EW**  $\rightarrow$  **Processes**  $\rightarrow$  **4 legs**  $\rightarrow$  **4f**  $\rightarrow$  **Neutral Current**  $\rightarrow$  **f1 f1**  $\rightarrow$  **f f (FF,HA,BR,MC)** the user can see a list of the Standard SANC FORM Modules, the scalar Form Factors (**FF**); then at the second module, Helicity Amplitudes (**HA**); then at the third module, the integrated bremsstrahlung (**BR**); and finally at the fourth module, the fully differential bremsstrahlung (**MC**).

The same way exists for the branch of **Charged Current**  $\rightarrow$  **f1 f1'**  $\rightarrow$  **f f'** (**FF,HA,BR,MC**) standard SANC modules, see Fig. 2.

The FORM modules compute online the FF, HA, BR and MC contributions of the corresponding partonic sub-processes.

Each of these modules in turn can be opened, compiled and run as explained in the UserGuide\_v1.10 (see project homepage).

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<sup>2</sup> To install and run SANC client one should have the Java Runtime Environment (JRE) at least version 5.0 Update 5 installed, see section **Minimum System Requirements** of the **Download** page at the SANC project homepage.

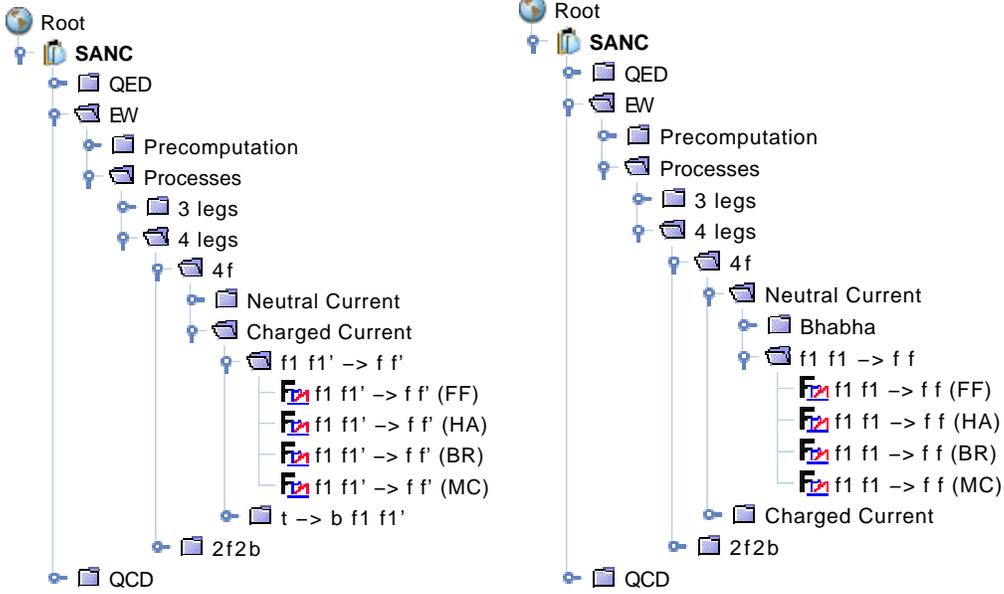


Figure 2: SANC tree for the Drell–Yan processes: Charged and Neutral Current case

For more details of running the existing accessible menu, one can refer to the description of the SANC system in Ref. [14].

Let us consider the types of modules. Each FORM module produces an output, which is in turn an input for creation of the corresponding FORTRAN code by the software s2n.

- **FF** and **HA**

In Ref. [14] we presented the Covariant (CA) and Helicity Amplitudes (HA) for  $f_1 \bar{f}_1 f \bar{f} \rightarrow 0$  NC and CC processes, with all 4-momenta being incoming for any of its cross channels  $s$ ,  $t$  or  $u$ . The expressions for the CA and HA (see Eq.(30) and (33) of the last reference) of these processes are written in terms of scalar FF's.

- **BR** and **MC**

The **BR** module computes the soft and inclusive hard real photon emission:

$$\bar{q} + q \rightarrow \ell + \bar{\ell} + \gamma. \quad (3)$$

We do not discuss the soft photon contribution here, referring the reader to the system itself. As far as hard photons are concerned, we realized two possibilities of the integration over their phase space: the semi-analytical one (module **BR**) and the one by means of a Monte Carlo integrator or generator (module **MC**).

The **MC** module provides fully differential hard bremsstrahlung contribution to the partonic cross section. The contribution is given in a form suitable for further numerical integration or simulation of events in a Monte Carlo generator.

## 2.3 Types of SANC Outputs

As we mentioned in section 1, SANC produces two types of outputs: SSFM and MC generators at the one-loop level.

- Standard SANC FORTRAN Modules, i.e. the list of packages at the parton level for download is, (see Fig.3)

- SANC NC v1.20: SSFMs for the DY NC processes:  $(uu, dd) \rightarrow (\mu\mu, ee)$  [32], SSFMs for the processes:  $ee(uu, dd) \rightarrow HZ$  [15] and NC gluon-induced processes [33];
- SANC CC v1.20: SSFM for the DY CC processes:  $(uu, dd) \rightarrow (\mu\nu_\mu, e\nu_e)$  [34] and CC gluon-induced processes [33].

One has to emphasize that the CC v1.10 contains first SANC modules for the calculation of NLO QCD corrections [35]. Some results about interplay of QCD/EW correction were reported in talks to ATLAS MC group [18],[28],[29].

### SANC Modules.

#### SANC NC package (Neutral Current processes modules).

The previous versions of SANC NC package you can find in SANC Archives.

➔ 15/12/2008 SANC NC v1.20 package (354 Kb tgz-file) [last stable version]

In v1.20 package the modules for new processes are added. Details are in the file CHANGES.

➔ 13/02/2008 SANC NC v1.10 package (300 Kb tgz-file) [stable version]

In v1.10 package the f1f1HZ processes are added. For description of the f1f1HZ processes please refer to the paper D. Bardin et al., Comput. Phys. Comm. 177 (2007) 738-756. Details are in the file CHANGES.

This package is intended for calculation of the 1-loop radiative correction to Drell-Yan Neutral Current processes at partonic level. For a Technical Description of this module please refer to the paper Eur. Phys. J. C54 (2008) 451.

#### SANC CC package (Charged Current processes modules).

The previous versions of SANC CC package you can find in SANC Archives.

➔ 05/12/2008 SANC CC v1.20 package (160 Kb tgz-file) [last stable version]

In v1.20 package the modules for new processes are added. Details are in the file CHANGES.

➔ 28/10/2008 SANC CC v1.11 package (131 Kb tgz-file) [stable version]

In v1.11 package some bugs in the QCD soft-virtual part are fixed. Details are in the file CHANGES.

This package is intended for calculation of the 1-loop radiative correction to Drell-Yan Charged Current processes at partonic level, see A. Arbuzov et al., Eur. Phys. J. C46 (2006) 407.

Figure 3: Available versions of the SSFM

- Standalone MC generators:

The `sanc_**_foam_v1.**` packages are intended for generation of unweighted events of the DY processes in NC and CC sector at the hadronic level taking into account the one-loop EW radiative correction based on FOAM algorithm [16], (see Fig. 6). These generators use the standard SANC Fortran modules for calculation of NLO EW corrections as well as `LoopTools-2.1` [36] and `SancLib-v1-00` libraries for evaluation of scalar and tensor one-loop integrals. Also you need ROOT package to be installed at your computer to use these generators.

In the present version of packages we include the possibility to write the output in data files containing the event information in the standard Les Houches Accord format [37] in order to organize the transfer of information between SANC generators and general purpose programs such as PYTHIA [38] and HERWIG [39].

We advice to read INSTALL for installation instructions, UserGuide.txt for a Technical Description and readme\_foam for FOAM using.

Some results obtained with these generators were presented in two talks to ATLAS MC group [17], [18]. Examples of distributions produced with help of MC generator for single-W production are shown in Fig. 4 and Fig. 5.

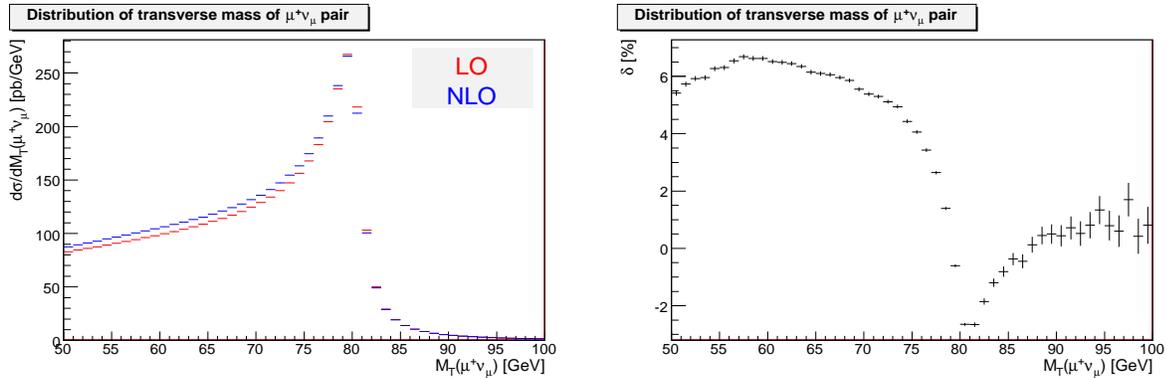


Figure 4: The EW NLO distributions of  $M_T^W$  and the relative corrections

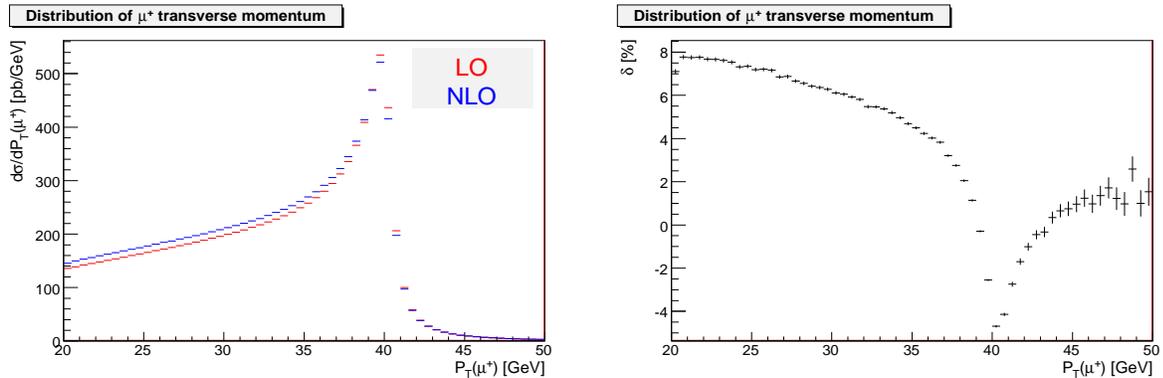


Figure 5: The EW NLO distributions of  $p_T^\mu$  and the relative corrections

## SANC Generators.

### Drell-Yan Neutral Current processes generator.

🔗 [23/05/2008 SANC NC DY FOAM v1.10 package](#) (345 Kb tgz-file) [\[last stable version\]](#)

In v1.10 package the Les Houches format event files is introduced. Details are in the file CHANGES.

🔗 [22/02/2008 SANC NC DY FOAM v1.01 package](#) (584 Kb tgz-file) [\[stable version\]](#)

In v1.01 package the modules are taken from the sanc\_nc\_v1.01 package. Details are in the file CHANGES.

🔗 [25/12/2007 SANC NC DY FOAM v1.00 package](#) (583 Kb tgz-file)

This SANC generator is intended for generation of unweighted events of the Drell-Yan Neutral Current processes at hadronic level taking into account the 1-loop EW radiative correction using the FOAM algorithm. Please read the instructions (in tgz file) for using this package.

### Drell-Yan Charge Current processes generator.

🔗 [15/04/2008 SANC CC DY FOAM v1.00 package](#) (235 Kb tgz-file) [\[last stable version\]](#)

This SANC generator is intended for generation of unweighted events of the Drell-Yan Charge Current processes at hadronic level taking into account the 1-loop EW radiative correction using the FOAM algorithm. Please read the instructions (in tgz file) for using this package. In v1.00 package the modules are taken from the sanc\_cc\_v1.02 package.

Figure 6: SANC MC Generators

## 3 Example of the implementation of the SSFM from SANC to WINHAC.

The result of the implementation of SSFM for EW RC at one-loop level is presented in [26].

For the description of WINHAC and SANC we refer the reader to the literature: for WINHAC to [40], [41] and for SANC to [14]. The goals of the work [26] were:

- to check the implementation of SSFM EW NLO modules into the framework of WINHAC Monte Carlo event generator;
- to perform a tuned comparison of two codes:
  1. the standard SANC integrator DY\_CC\_VEGAS with a modified treatment of ISR QED corrections;
  2. the modified WINHAC, upgraded with the SANC electroweak modules and downgraded to the  $\mathcal{O}(\alpha)$  QED corrections.

We reached the agreement between the WINHAC MC event generator and the SANC MC integrator for the  $\mathcal{O}(\alpha)$  EW corrections to the CC Drell–Yan process at the level of  $\sim 0.025\%$ .

As an example we demonstrate the comparison of the transverse mass  $m_T^W$  distributions for the muon channel in two popular EW parametrization schemes ( $\alpha$  and  $G_\mu$ , see e.g. Ref. [6]) with “simplified bare” cuts, see Fig. 7. The two upper figures show the RC quantity  $\delta_{EW}$  in %, while the two lower figures show absolute deviations  $W-S$  between the two calculations, for details see Ref. [26].

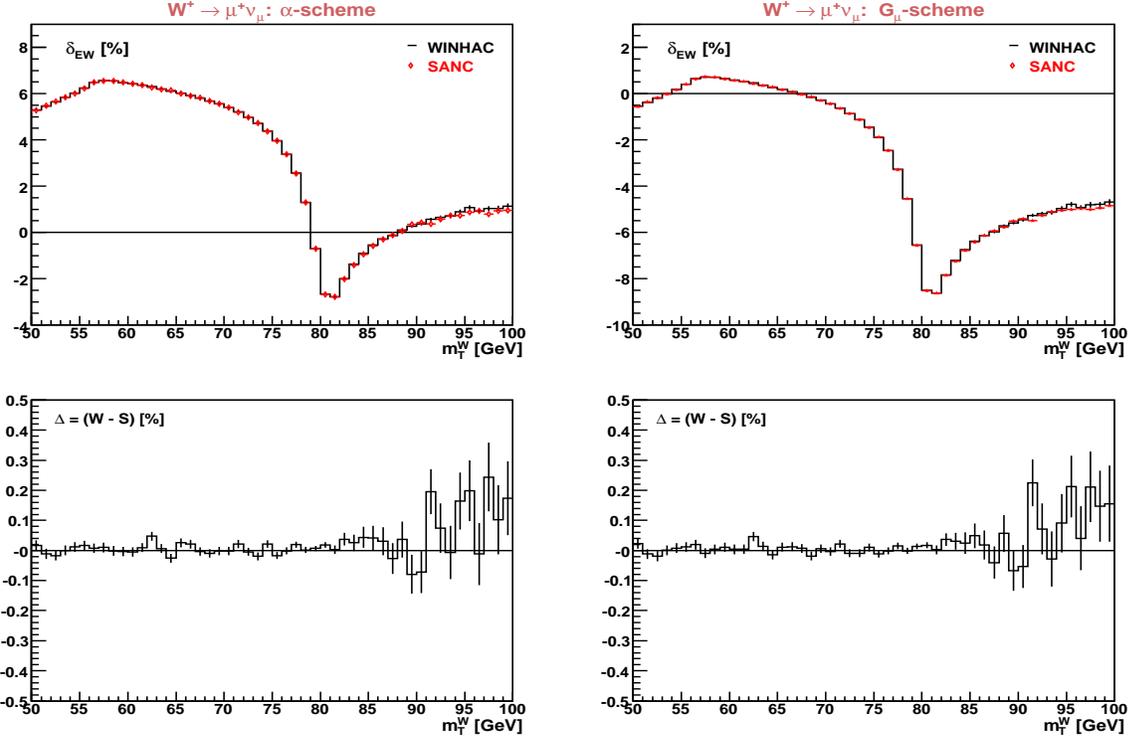


Figure 7: The EW NLO distributions of  $m_T^W$  for the muon channel in two schemes and the absolute deviations between WINHAC and SANC,  $\Delta = W - S$ , both quantities in [%].

## 4 User guide

Here we present the technical description of the SANC NC and SANC CC packages — v.1.20, intended for calculation of the total and differential  $d\sigma/d\cos\vartheta$  cross sections at the partonic level. Conventions, enumerations and descriptions of the options of the main flags are also given.

The packages can be accessed from project homepages [21].

### 4.1 Naming conventions

In SANC we use naming conventions for fields (or particles) shown in Table 1 where N is the field index (here we present only physical particles, omitting ghost fields) and in the columns headed “name” we show the names used internally in SANC. All associated parameter symbols are derived from these names. Thus the mass, charge and weak isospin of the electron are denoted `me1`, `qe1` and `i3e1`, respectively, also the vector and axial vector coupling constants (`ve1`, `ae1`).

### 4.2 Overview of the packages

As an example, we present an overview of the most recent package `sanc_cc.v1.20`<sup>3</sup>. It contains SSFM of two types: the modules `cc_*_xy_zv.f(F)` for 1-loop level EW sub-processes, which are produced by the `s2n` package of SANC project and are governed by main file `main_cc_1loop_vegas.F` written “by hand”; the modules `cc-`

<sup>3</sup>The structure of the package `sanc_nc.v1.20` is similar.

Table 1: List of fields.

bosons			fermions									QCD		
			1st generation			2nd generation			3rd generation					
$N$	field	name	$N$	field	name	$N$	field	name	$N$	field	name	$N$	field	name
1	$A$	gm	11	$\nu_e$	en	15	$\nu_\mu$	mn	19	$\nu_\tau$	tn	23	g	gn
2	$Z$	z	12	$e$	el	16	$\mu$	mo	20	$\tau$	ta			
$\pm 3$	$W^\pm$	w	13	$u$	up	17	$c$	ch	21	$t$	tp			
4	$H$	h	14	$d$	dn	18	$s$	st	22	$b$	bt			

qcd\*\_xy\_zv.f for 1-loop level QCD sub-processes and cc\*\_23\_x\_y\_z.v.f(F) ( cc\*\_23\_x\_y\_z.v.f(F)) for gluon-induced tree level partonic sub-processes together with corresponding main file main\_cc\_trees\_vegas.F. The status of QCD SSF(ORM)M is somewhat different from EW ones; the exist, however, at present time are not yet put into the system. Nevertheless, SSF(ORTRAN)M were produced from FORM log-files by mean of the standard SANC s2n software. Next, the package contains declaration files — \*.h and libraries — \*.a. The folder SanLib\_v1\_02 contains the source files comprising the library for various functions, including Vegas integration and the library itself libSanLib\_v1\_02.a. Here and below “x,y,z” and “v” stand for the standard SANC field indices, i.e. 12 – e, 13 – u, 14 – d, 16 –  $\mu$ , 23 – g, etc. In Table 2 we summarize available in sanc\_cc\_v1.20 1-loop level and in Table 3 all gluon-induced tree level partonic sub-processes, renumbered by the Process IDentifier (PID):

Table 2: Process IDentifier (PID) and available at 1-loop level CC DY sub-processes.

PID	xy_zv	Sub-process
1	1314_1112	$\bar{u} + d \rightarrow \bar{\nu}_e + e^-$
2	1413_1211	$\bar{d} + u \rightarrow e^+ + \nu_e$
3	1314_1516	$\bar{u} + d \rightarrow \bar{\nu}_\mu + \mu^-$
4	1413_1615	$\bar{d} + u \rightarrow \mu^+ + \nu_\mu$
5	1314_1920	$\bar{u} + d \rightarrow \bar{\nu}_\tau + \tau^-$
6	1413_2019	$\bar{d} + u \rightarrow \tau^+ + \nu_\tau$

The total set of files inside the package is:

Instruction files:

README  
RELEASE-NOTES  
CHANGES  
LICENSE.TXT  
INSTALL  
FILES

Declaration files:

s2n\_declare.h

Table 3: Process Identifier (PID) and available at tree level gluon-induced sub-processes.

PID	23_x_y_z_v	Sub-process
PID	(x_23_y_z_v)	Sub-process
7	23_13_14_11_12	$g + u \rightarrow d + \nu_e + e^+$
8	14_23_13_12_11	$g + \bar{d} \rightarrow \bar{u} + \nu_e + e^+$
9	23_14_13_12_11	$g + d \rightarrow u + e^- + \bar{\nu}_e$
10	13_23_14_11_12	$g + \bar{u} \rightarrow \bar{d} + e^- + \bar{\nu}_e$
11	23_13_14_15_16	$g + u \rightarrow d + \nu_\mu + \mu^+$
12	14_23_13_16_15	$g + \bar{d} \rightarrow \bar{u} + \nu_\mu + \mu^+$
13	23_14_13_16_15	$g + d \rightarrow u + \mu^- + \bar{\nu}_\mu$
14	13_23_14_15_16	$g + \bar{u} \rightarrow \bar{d} + \mu^- + \bar{\nu}_\mu$
15	23_13_14_15_16	$g + u \rightarrow d + \nu_\tau + \tau^+$
16	14_23_13_16_15	$g + \bar{d} \rightarrow \bar{u} + \nu_\tau + \tau^+$
17	23_14_13_16_15	$g + d \rightarrow u + \tau^- + \bar{\nu}_\tau$
18	13_23_14_15_16	$g + \bar{u} \rightarrow \bar{d} + \tau^- + \bar{\nu}_\tau$

Initialization and various input files:

```
s2n_init.f
sanc_input.h
leshw_input.h
tev4lhwc_input.h
leshw2007_input.h
```

SSFM originated from

```
cc_ff_xy_zv.F      (FF)
cc_si_xy_zv.f      (HA)
cc_[qcd_]br_xy_zv.f (BR)
```

[this file contains three SSF

```
cc_bo_xy_zv(...), cc_br_xy_zv(...), cc_ha_xy_zv_1spr(...)
cc_qcd_br_xy_zv(...), cc_qcd_ha_xy_zv_1spr(...)]
cc_[qcd_]ha_xy_zv.f (MC)
```

Main file: main\_cc\_1loop\_vegas.F

As a rule of the SANC approach, we subdivide the EW RC into the virtual (loop) ones, the ones due to soft photon emission, and the ones due to hard photon emission with the aid of the soft-hard separator  $\bar{\omega}$ . For all SANC processes we demonstrate the numerical independence off this auxiliary parameter. The adopted form of presentation of the differential cross section at the one-loop level in obvious notation is:

$$d\hat{\sigma}^{1\text{-loop}} = d\hat{\sigma}^{\text{Born}} + d\hat{\sigma}^{\text{Subt}} + d\hat{\sigma}^{\text{Virt+Soft}}(\bar{\omega}) + d\hat{\sigma}^{\text{Hard}}(\bar{\omega}). \quad (4)$$

The second term stands for subtraction of collinear quark mass singularities. It may be  $d\hat{\sigma}^{\text{YFS}}$  or  $d\hat{\sigma}^{\overline{\text{MS}}(\text{DIS})}$ , correspondingly (see [26] and [34]). At the partonic level only  $\overline{\text{MS}}$  option is realized:

$$d\hat{\sigma}^{\overline{\text{MS}}} = d\hat{\sigma} - \Delta\hat{\sigma}^{\overline{\text{MS}}}, \quad (5)$$

where

$$\Delta\hat{\sigma}^{\overline{\text{MS}}} = \lim_{\bar{\omega} \rightarrow 0} [\Delta\hat{\sigma}^{\text{Virt+Soft}}(\bar{\omega}) + \Delta\hat{\sigma}^{\text{Hard}}(\bar{\omega})]^{\overline{\text{MS}}}. \quad (6)$$

It is described in detail in Refs. [34], [32]. At the hadronic level, where Eq. (4) is convoluted with PDF's in the usual way, the other two “subtraction” options (YFS or DIS) were used. The terms, made up of the virtual (loop) ones —  $d\sigma^{\text{Virt}}$ , the ones due to soft photon emission  $d\sigma^{\text{Soft}}$ , and the ones due to hard photon emission  $d\sigma^{\text{Hard}}$  are subdivided into ISR, IFI and FSR in accordance with  $W$ -splitting techniques [6]. An auxiliary parameter  $\bar{\omega}$  separates the soft and hard photonic contributions.

The steps of calculation in the `main_cc_1loop_vegas.F` file are in accordance with Eqs. (4):

- step of declaration and initialization, followed by a call `ProcessInit (pid)`, see Section 4.3 for description of various options of flags;
- step born is realized by flag `iborn=1`,  
 $\underline{d\hat{\sigma}^{\text{Born}}}$  is computed by integration over  $\hat{c}$ , see Ref. [32], of the function\_ew\_1c,  
via call `ProcessBorn (... ,born,...)`
  - and SSFM call `cc_br_xy_zv(... ,born,...)`
- step virt+soft and all subsequent ones are realized by flag `iborn=0`,  
 $\underline{d\hat{\sigma}^{\text{Virt+Soft}}}$  is computed by integration over  $\hat{c}$  of the function\_(ew,qcd)\_1c,  
via call `ProcessVirt_(EW,QCD) (... ,virt,...)`
  - and `Virt(Weak)` by SSFM call `cc_si_xy_zv(... ,sigma)` ,  
(inside this module there exists a call to SSFM `cc_ff_xy_zv(-s,-t,-u)`)
  - and `Virt+Soft(QED,QCD)`
    - \* for QED processes by SSFM call `cc_br_xy_zv(... ,soft,...)`
    - \* for QCD processes by SSFM call `cc_qcd_br_xy_zv(... ,soft,...)`
- step brdq, i.e.  $(\Delta\hat{\sigma})^{\overline{\text{MS}}}$ ,  
via call `ProcessBrdq_(EW,QCD) (... ,brdq,...)`
  - a) first part, i.e.  $(\Delta\hat{\sigma}^{\text{Virt+Soft}})^{\overline{\text{MS}}}$ ,
    - is computed by SSFM call `cc_bo_xy_zv(... ,born)`, multiplied by  $(\delta^{\text{SV}})^{\overline{\text{MS}}}$  — a CC analog of Eq.(19) of [32]
  - b) second part, i.e.  $(d\hat{\sigma}^{\text{Hard}})^{\overline{\text{MS}}}$  is computed by integration over  $\xi$  of the function\_(ew,qcd)\_1s
    - and by SSFM call `cc_bo_xy_zv(... ,bornk)`, using Eq.(12) of [34]
- step hard, i.e.  $d\hat{\sigma}^{\text{Hard}}/d\hat{s}'$  is computed by integration over  $\hat{s}'$  of the function\_(ew,qcd)\_1spr  
via call `ProcessHard_(EW,QCD)_1spr (... ,hard,...)`
  - and SSFM call `cc_[qcd_]ha_xy_zv_1spr (... ,hard)`
or alternatively
  - step hard, i.e.  $d\hat{\sigma}^{\text{Hard}}/d\Phi^{(3)}$  is computed by integration over 4d-phase space of Eq. (6)–(7) of [32]  
of the function\_(ew,qcd)\_4d  
via call `ProcessHard_(EW,QCD) (... ,hard,...)`
    - and SSFM call `cc_[qcd_]ha_xy_zv(... ,hard)`

Main file: main\_cc\_trees\_vegas.F

The presentation of the differential cross section for this case is trivial:

$$d\hat{\sigma}^{\text{trees}} = d\hat{\sigma}^{\text{Born}}. \quad (7)$$

Here the Born-term describes the tree level cross section of one of processes of Table 3. The subtraction of collinear final quark mass singularities for the time being is applied in integrators and generators and is not implemented at the parton level.

### 4.3 Flag options

pid(I) — choice of the 1-loop level sub-process, see Table 2:

**I=1,...,6**

or of the tree level ones of Table 3:

pid(I) **I=7,...18**

iqed(I) — choice of calculations for QED correction:

**I=0** without QED correction

**I=1** with all QED correction

**I=2** with ISR QED correction

**I=3** with IFI QED correction

**I=4** with FSR QED correction

**I=5** with IFI and FSR QED correction

iew(I) — choice of calculations for EW correction:

**I=0** without EW correction

**I=1** with EW correction

iqcd(I) — choice of calculations for EW correction:

**I=0** without QCD correction

**I=1** with QCD correction

iborn(I) — choice of scheme of calculations of the partonic cross section:

**I=1** only Born level

**I=0** Born + 1-loop virtual corrections

gfscheme(I) — choice of the EW scheme:

**I=0**  $\alpha(0)$  scheme

**I=1**  $G_F$  scheme

**I=2**  $G'_F$  scheme

**ilin(I)** — choice of the linearization at the calculation of the partonic cross section:

**I=0** without linearization

**I=1** with linearization, *i.e.* neglecting spurious terms  $\mathcal{O}(\alpha^2)$

**ifgg(I)** — choice of calculations of photonic vacuum polarization  $\mathcal{F}_{gg}$ :

**I=-1** — 0

**I= 0** — 1

**I= 1** —  $1 + k\mathcal{F}_{gg}$

**I= 2** —  $1/(1 - k\mathcal{F}_{gg})$

with  $k = \frac{g^2}{16\pi^2}$ .

**ihard(I)** — types of the hard bremsstrahlung phase-space integrations:

**I=1** integration over  $\hat{s}'$

**I=4** 4d integration

**isetup(I)** — choice of the setup:

**I=0** Standard SANC

**I=1** Les Houches Workshop, 2005

**I=2** TeV4LHC Workshop, 2006

**I=3** Les Houches Workshop, 2007

## 5 Conclusions

In this paper we have described the Standard SANC FORTRAN Modules and presented examples of their application: 1) they were used in the packages at the parton level for quick studies of different features of the given sub-processes: estimates of effects due to variations of input parameters, electroweak schemes, interplay of different RC contributions (EW-QCD, initial and final state radiation) *etc.*; 2) they were implemented in the MC generator WINHAC, increasing thereby its potential possibilities; 3) finally, they were used in the SANC Monte Carlo integrators and event generators that provide distributions of the final state particles with full kinematics, which was interfaced with parton showering codes (PYTHIA and HERWIG) and the events can be further processed through the whole experiment simulation environment.

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