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Radiative Corrections to Drell-Yan-like Processes in SANC

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A high precision description of Drell-Yan-like processes (single Z and W boson production) at LHC is constructed with help of the semi-automatic SANC system. One-loop electroweak and QCD corrections to neutral and charged current channels are presented. Comparisons with calculations of other groups were performed. The resulting theoretical uncertainty is discussed.

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1. Motivation

Charged and neutral current Drell–Yan (DY) processes are very important for precision tests of the Standard Model (SM) at hadron colliders. They have large cross sections, clear signatures in detectors and a rather accurate theoretical description. So these processes will provide standard candles for detector calibration during the first stage of LHC running. Single Z and W boson production will be also used for extraction of partonic density functions (PDF) in the kinematical region which has not been accessed by earlier experiments. It is planned to get the most precise experimental values for the mass and width of W boson using the future high statistics data on the CC DY process. DY processes will also provide background to many other reactions being of interest at LHC. Moreover, even some new physics searches like the ones for contact four-fermion interactions will be performed in these channels. Therefore it is crucial to control the theoretical predictions for production cross sections and kinematic distributions of both the NC and CC DY processes. In this context the sub-title of the ACAT-2008 workshop can read as: "Are we ready to provide an adequately accurate theoretical description of Drell-Yan processes at LHC?"

The experimental precision tag for Drell-Yan processes is about 1%. That means we need to provide the accuracy of theoretical predictions of about 0.3% in order not to spoil the results of the forthcoming data analysis. This is a challenge for the theory. We need to control several different effects and their interplay: 1) high precision parton density functions (PDF); 2) perturbative QCD at NLO and NNLO; 3) parton shower effects; 4) complete one-loop electroweak (EW) radiative corrections (RC); 5) relevant higher order EW and QED effects (re-summed where possible). All the relevant effects should be taken into a Monte Carlo (MC) event generator, or in a self-consistent system of several MC generators responsible for particular effects.

SANC is a project for Support of Analytic and Numeric calculations for experiments at Colliders [1, 2]. It is accessible at `http://sanc.jinr.ru/` and `http://pcphsanc.cern.ch/`. The SANC system is suited for calculations of one-loop QED, EW, and QCD RC to various SM processes. Automatized analytic calculations in SANC provide `FORM` and `FORTRAN` modules [3] (see also V. Kolesnikov's contribution to these Proceedings).

For Drell-Yan-like processes within the SANC project we calculated:

— complete one-loop EW RC in CC and NC cases,

— higher order photonic FSR in the leading logarithm approximation,

— NLO QCD corrections.

2. QCD corrections

QCD radiative corrections to DY have been extensively studied in the literature [4, 5, 6]. Recently the corresponding NNLO corrections for differential distributions have been derived [7]. There are several MC generators taking into account QCD NLO corrections and some higher order effects *e.g.* MC@NLO [8], POWHEG [9], MCFM [10], and ResBos [11]. With help of SANC we also evaluated the NLO QCD corrections [12] using the factorization scheme with massive quarks. Our results are in a good agreement with the ones of MCFM for both CC and NC channels, Fig. 1.

For a realistic application, one has to take into account also QCD parton showers, see e.g. Fig. 2 where their effect is shown for the μ^+ transverse distribution. It can be done with help of the

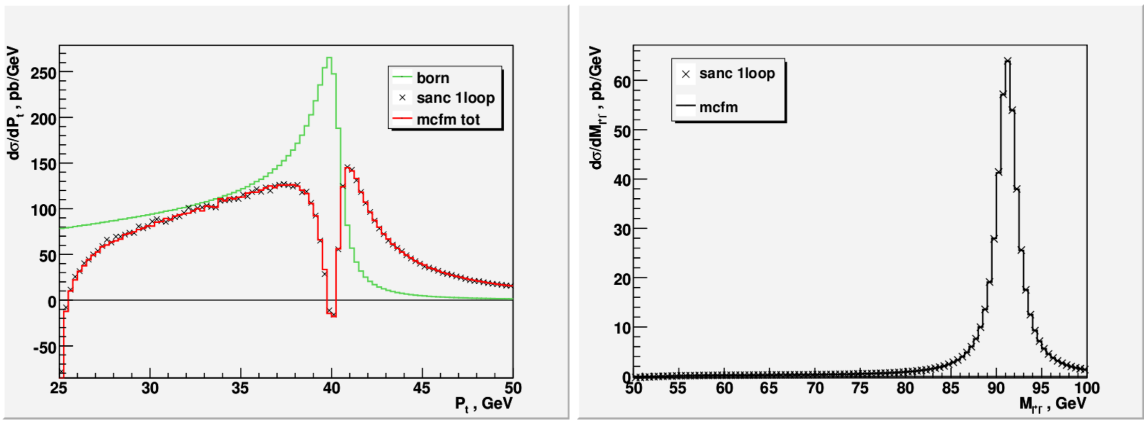

Figure 1: Lepton transverse momentum in CC DY with and w/o parton shower effects(left) and Z-boson transverse momentum distribution in NC DY.

standard packages like PYTHIA [13] and HERWIG [14]. Note that the showers will wash out the negatively weighted events, which can be seen in the resonance region in Fig. 1.

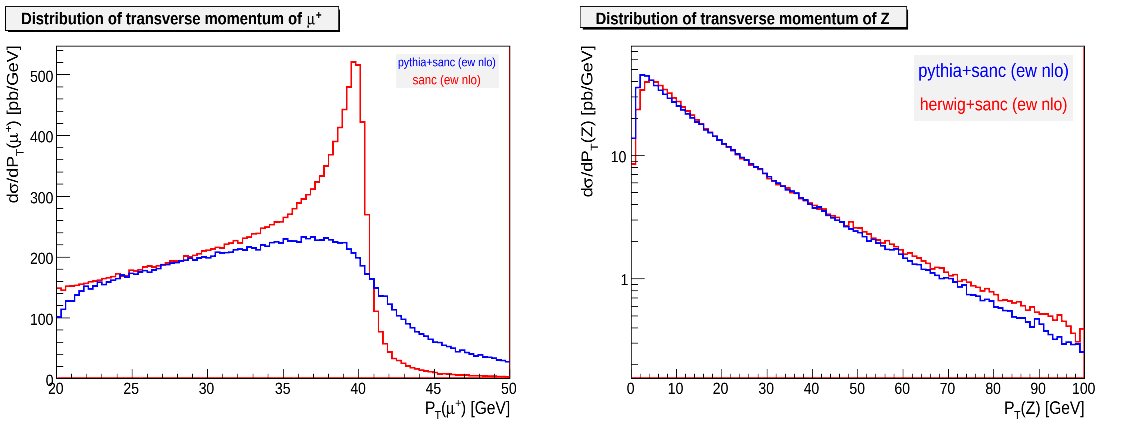

Figure 2: Lepton transverse momentum in CC DY with and w/o parton shower effects(left) and Z-boson transverse momentum distribution in NC DY with different parton shower models.

3. EW corrections

It has been shown in Sect. 3 [U. Baur *et al.*] of Ref. [15] that EW corrections to inclusive DY cross sections and to their differential distributions in the $Z(W)$-resonance region are comparable in size with the QCD ones. Roughly, the EW RC are only about two times less than the QCD ones. Naively one would expect the relation to be of the order of $\alpha_{QED}(M_Z)/\alpha_{QCD}(MZ) \sim 0.1$. EW corrections have an enhancement due to the EW Sudakov logarithms and the final state radiation off charged leptons.

The one-loop EW RC were computed for the DY processes by SANC in Refs. [16, 17, 18] and extensively compared with results of other groups, see *e.g.* Refs. [15, 19, 20]. An excellent agreement was established for tuned comparisons both in CC and NC currents, see *e.g.* Fig. 3 taken from Ref. [19].

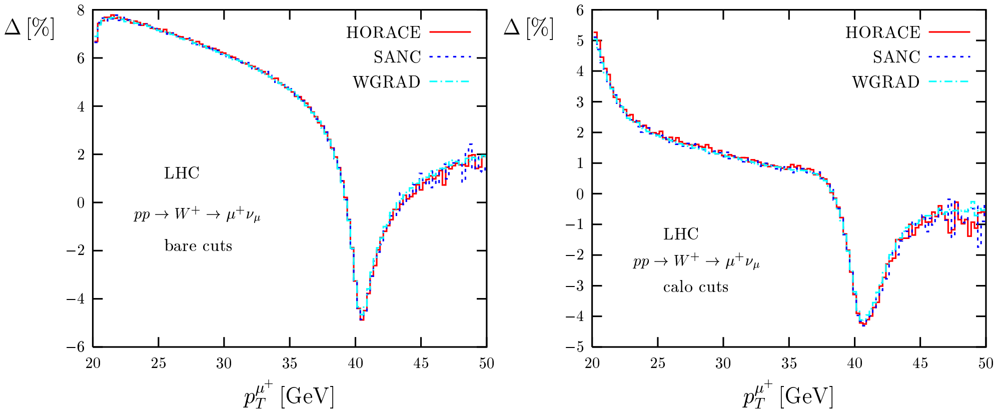

Figure 3: RC to μ^+ transverse momentum in CC DY for BARE (left) and CALO (right) set-ups.

Recently, the standard SANC modules for parton-level DY cross sections with one-loop EW RC have been implemented into the MC event generator WINHAC [20, 21]. Preliminary results of comparisons performed between SANC and WINHAC for higher order contributions due to multiple final state radiation in CC DY show a good agreement, in spite of different methods used for description of the effect, see Fig. 4.

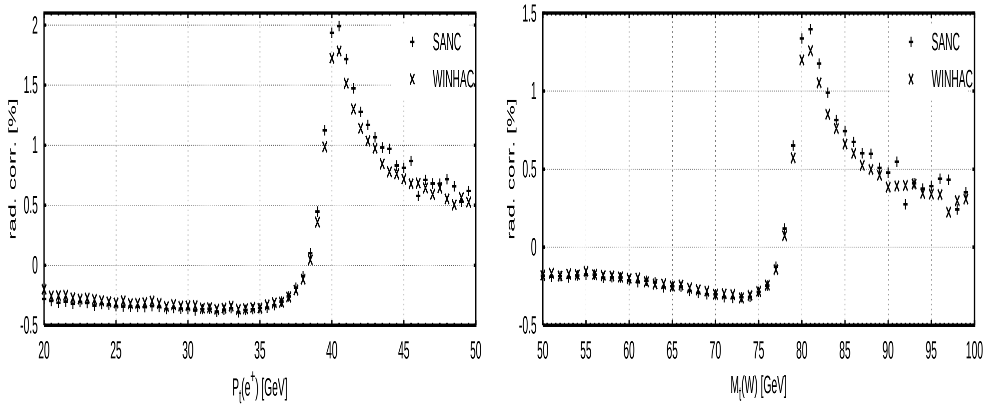

Figure 4: Higher order FSR corrections in percent for BARE positron transverse momentum (left) and W transverse mass (right) distributions in CC DY.

4. Outlook

The resulting theoretical uncertainty in description of DY processes at LHC should combine errors coming from several sources: 1) PDF parameterization; 2) QCD (and QED) factorization scheme and scale dependence; 3) pure QCD higher order terms; 4) pure EW higher order terms; 5) interplay between EW and QCD effects. The present accuracy of PDF in the kinematical region relevant for LHC lead to a huge uncertainty in DY cross section of the order of 5% or even more. The situation will be improved only after new fits of PDF based on the LHC data (on DY!). QCD and QED evolution in PDF should be taken into account simultaneously. Factorization scheme and scale dependence in the present calculation and computer codes are considerable. They should be reduced by adjustment of the scheme and scale choices and by including relevant higher order effects. To get the requested precision we need an advanced implementation in Monte Carlo codes of NNLO QCD corrections and soft gluon re-summation. Complete two-loop EW corrections to Drell-Yan hardly can be calculated in the nearest future, but some numerically important contributions like the EW Sudakov logs or two-loop vacuum polarization and multiple final state radiation, are to be taken into account. In the ideal case all the relevant effects should be combined in a single Monte Carlo event generator or at least in a system (or chain) of generators, which can add up different effects. Interplay of these effects like additive or multiplicative treatment of EW and QCD corrections has to be studied. A lot of work in this direction has been already done. Several groups are participating in workshops and tuned comparison programs. The SANC group continues development of its own codes for DY description as well as participation in knowledge exchange with other groups.

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