

# Radiative Corrections to Drell-Yan like processes in SANC

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- Motivation
- Electroweak Radiative Corrections to Drell-Yan in SANC
- QCD effects
- Resulting theoretical precision
- Conclusions

# Motivation (I)

- LHC is not only a *discovery* machine
- SM single  $W$  and  $Z$  production at LHC have large cross sections and clear signatures
- The experimental precision tag is 1%
- CC and NC Drell-Yan processes will be used for
  - luminosity monitoring;
  - $W$  mass and width measurement;
  - extraction of parton density functions;
  - detector calibration;
  - background to many other processes;
  - new physics searches
- Are we ready to provide an adequately accurate theoretical description of Drell-Yan?

# Motivation (II)

We need:

- QCD in NLO and NNLO
- Parton shower effects
- EW radiative corrections in at least one-loop
- Most important higher order effects (re-summed where possible)
- Interplay of QCD and EW effects
- Input: coupling constants, hadronic vacuum polarization, and **parton density functions** for the appropriate energy scale and  $x$ -values
- All relevant effects to be implemented in a **Monte Carlo** event generator

**SANC** is a project for **S**upport of **A**nalytic and **N**umeric calculations for experiments at **C**olliders

<http://sanc.jinr.ru>, <http://pcphsanc.cern.ch>

It is suited for calculations of one-loop QED, EW, and QCD radiative corrections (RC) to various SM processes

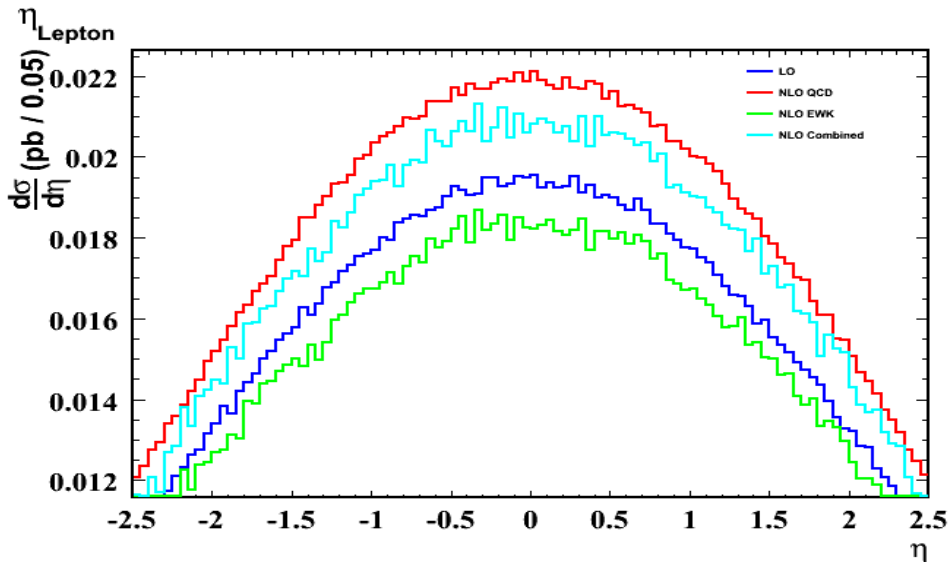
Automatized analytic calculations in SANC provide FORM and FORTRAN modules (see V. Kolesnikov's talk)

For Drell-Yan we have

- Complete one-loop EW RC in CC and NC cases
- Higher order photonic FSR in LLA
- One-loop (NLO) QCD

# QCD & EW corrections interplay

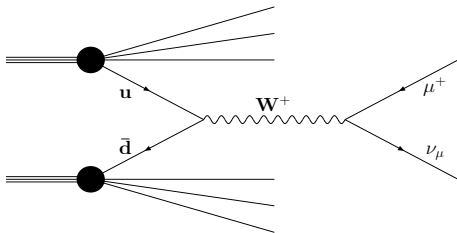
arXiv:0803.0678



# EW RC to Drell-Yan (I)

## Single $W$ and $Z$ production at LHC:

- $p + p \rightarrow W^\pm \rightarrow \ell^\pm + \nu_\ell (+\gamma) + X$
  - $p + p \rightarrow Z/\gamma \rightarrow \ell^+ + \ell^- (+\gamma) + X$
- $\ell = e, \mu$



Complete one-loop EW to DY CC: Europ. Phys. J. C. 2006

Complete one-loop EW to DY NC: Europ. Phys. J. C. 2008

Photon induced processes: ZhETF (JETP) 2008

# EW RC to Drell-Yan (II)

There are two types of partonic subprocesses:

- quark-quark interaction (qq):

$$p[q] + p[\bar{q}] \rightarrow X + \{\gamma, \mathbf{Z}\} \rightarrow X + l^+ + l^- (+\gamma)$$

$$p[q] + p[\bar{q}'] \rightarrow X + \{\mathbf{W}^\pm\} \rightarrow X + l^\pm + \nu_l (+\gamma)$$

- photon-quark interaction ( $\gamma q$ ):

$$p[\gamma] + p[q] \rightarrow X' + q + \{\gamma, \mathbf{Z}\} \rightarrow X + l^+ + l^-$$

$$p[\gamma] + p[q] \rightarrow X' + q' + \{\mathbf{W}^\pm\} \rightarrow X + l^\pm + \nu_l$$

$$l = e, \mu;$$

$$q = u, d, c, s, b$$



# EW RC to Drell-Yan (III)

**Tuned comparison** with results of HORACE and Z(W)GRADE for EW RC to CC and NC DY were performed within *Les Houches '05, '07* and *TEV4LHC* workshops

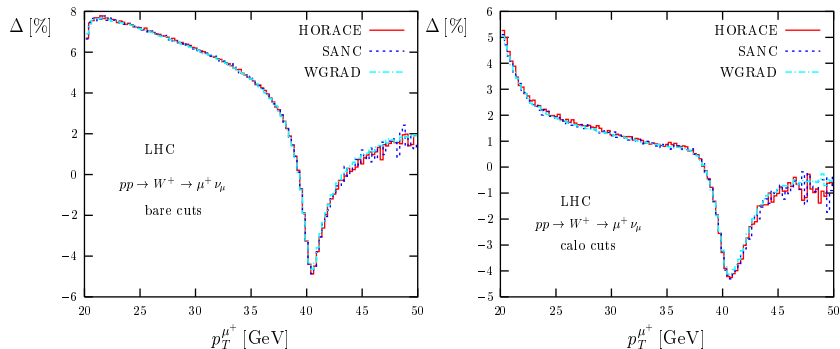
SANC group will contribute to the forthcoming workshop on *W-mass measurement*

C. Buttar *et al.* “*Les Houches Physics at TeV Colliders 2005, Standard Model and Higgs working group: Summary report*”, hep-ph/0604120.

C.E. Gerber *et al.* “*Tevatron-for-LHC Report: Top and Electroweak Physics*,” arXiv:0705.3251 [hep-ph].

C. Buttar *et al.* “*Standard Model Handles and Candles Working Group: Tools and Jets Summary Report*,” arXiv:0803.0678 [hep-ph].

# Tuned comparison of EW RC (I)

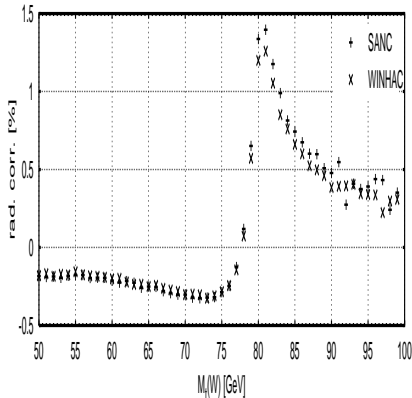
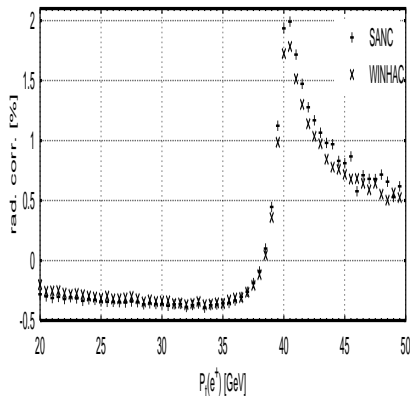


- Set-up:  $P_T(l, \nu) > 20$  GeV,  $|\eta(l)| < 2.5$ ;  $\alpha(0)$  EW scheme; MRST2004QED; NLO QED DIS subtraction scheme

# Higher order photonic FSR

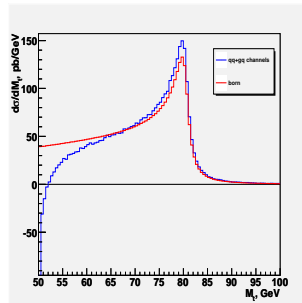
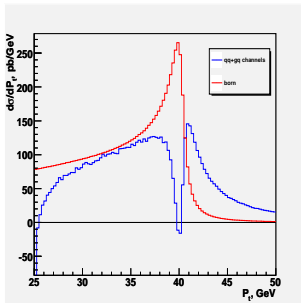
Multiple FSR photon radiation in LLA  
Comparison with WINHAC

**PRELIMINARY**



# QCD in NLO

- One-loop QCD corrections to Drell-Yan are computed in SANC for CC and NC case, including gluon induced sub-processes
- Tuned comparison with MCFM and MC@NLO is in progress
- QCD RC to be soon included into SANC Monte Carlo Drell-Yan event generators

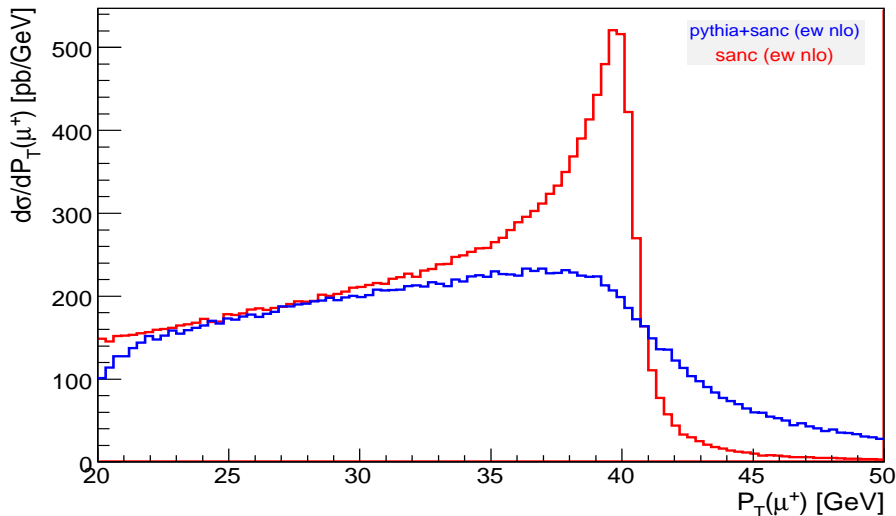


# Interfacing SANC with PYTHIA and HERWIG

- SANC Monte-Carlo generators for neutral and charged current Drell-Yan processes produce unweighted events with help of FOAM algorithm
- The transfer of information between SANC Monte Carlo generator and the general purpose event generators PYTHIA and HERWIG is organized via data files containing the event information in the standard Les Houches Accord format

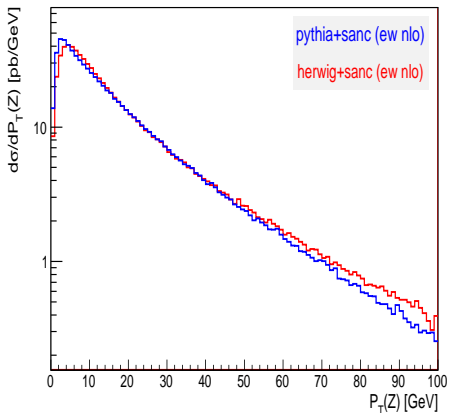
# The effect of parton showers on single-W production

Distribution of transverse momentum of  $\mu^+$

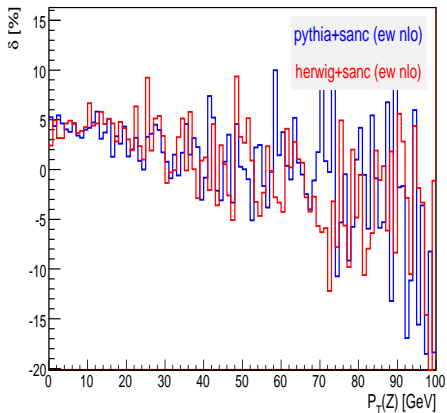


# Distribution of $Z$ transverse momentum

Distribution of transverse momentum of  $Z$



Distribution of transverse momentum of  $Z$



# Theoretical uncertainty

- Uncertainties in PDF, but after a new fit from LHC data ...
- QCD (and QED) factorization scheme and scale dependence
- pure QCD higher order terms  $\Leftarrow$  recent NNLO results by Anastasiou, Melnikov, Petriello *et al.*
- pure EW higher order terms:
  - EW scheme dependence:  $\alpha(0)$  vs.  $G_{\text{Fermi}}$  vs.  $\alpha(M_Z)$
  - resummation of higher order EW Sudakov logs
  - other unknown EW higher order terms (should be small?)
  - hadronic vacuum polarization
  - top and Higgs mass dependence
- Interplay of EW and QCD effects: multiplicative vs. additive treatment
- All this to be quantified within working groups ...



- SANC provides an advanced description of CC and NC Drell-Yan processes
- Monte Carlo event generators are created, their development is continued
- Packages with MC and partonic level modules are available for download (*see report by V. Kolesnikov*)
- SANC modules with EW RC to CC Drell-Yan were implemented in WINHAC event generator
- Tuned comparisons with other groups were performed, some more are planned
- But further theoretical studies are still required for better understanding of DY at LHC