SM LHC processes in SANC at NLO level

D. Bardin on behalf of SANC

SM and BSM physics at the LHC

August 3, 2009

SM processes at LHC and perturbation order

- tree level: general purpose tools (PYTHIA or HERWIG, LO+PS), not enough
- NLO(QCD): single or pair (γ, W, Z, t, H) production (MC@NLO, NLO+PS from HERWIG)
- NLO(EW): main topic of this presentation
- higher orders: mFSR (PHOTOS), EW Sudakov logs, NNLO(QCD), N(α)N(α_s)LO

  Dream of MC@NNLO including all above contributions
- and many other items beyond the scope of SANC

Theory is ahead of MC generators

1. NNLO DY

a) K. Melnikov and F. Petriello, PRD 74 (2006) 114017

MC code: FEWZ – Fully Exclusive W, Z Production through NNLO

b) S. Catani *et al.*, arXiv:0903.2120 [hep-ph]

No MC yet, as far as we know.

c) A. Kotikov, J.H. Kuhn and O. Veretin, NPB 788 (2008) 47.
O. Veretin "Drell-Yan Process at NNLO", talk at Calc2009, Dubna, 10-20 July 2009.

2. EW NLO DY

a) W/ZGRAD2

U. Baur, S. Keller and D. Wackeroth, PRD 59 (1999) 013002;
U. Baur, O. Brein, W. Hollik, C. Schappacher and D. Wackeroth, PRD 65 (2002) 033007.

b) DK: S. Dittmaier and M. Kramer, PRD 65 (2002) 073007.

c) HORACE: C.M. Carloni Calame, G.Montagna, O. Nicrosini, and M. Treccani, PRD 69 (2004) 037301.

3. EW NLO for a variety of processes

a) GRACE-loop: G. Belanger *et al.*, Phys. Rept. 430 (2006) 117.

b) SANC.

General Information on SANC

SANC [sancý] (Support of Analytic and Numeric Calculations for experiments at Colliders)

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* Staying at CERN part of this WS

Second phase (2006–2009) — begin to be used for physical applications.
Accessible from servers in Dubna *http://sanc.jinr.ru/* and CERN *http://pcphsanc.cern.ch/*.
Described in:
[1] A. Andonov, et al., Comput. Phys. Comm. 174 (2006) 481–517.
[2] D. Bardin, et al., Comput. Phys. Comm. 177 (2007) 738–756.
[3] A. Andonov, et al., arXiv:0812.4207 [physics. comp-ph].

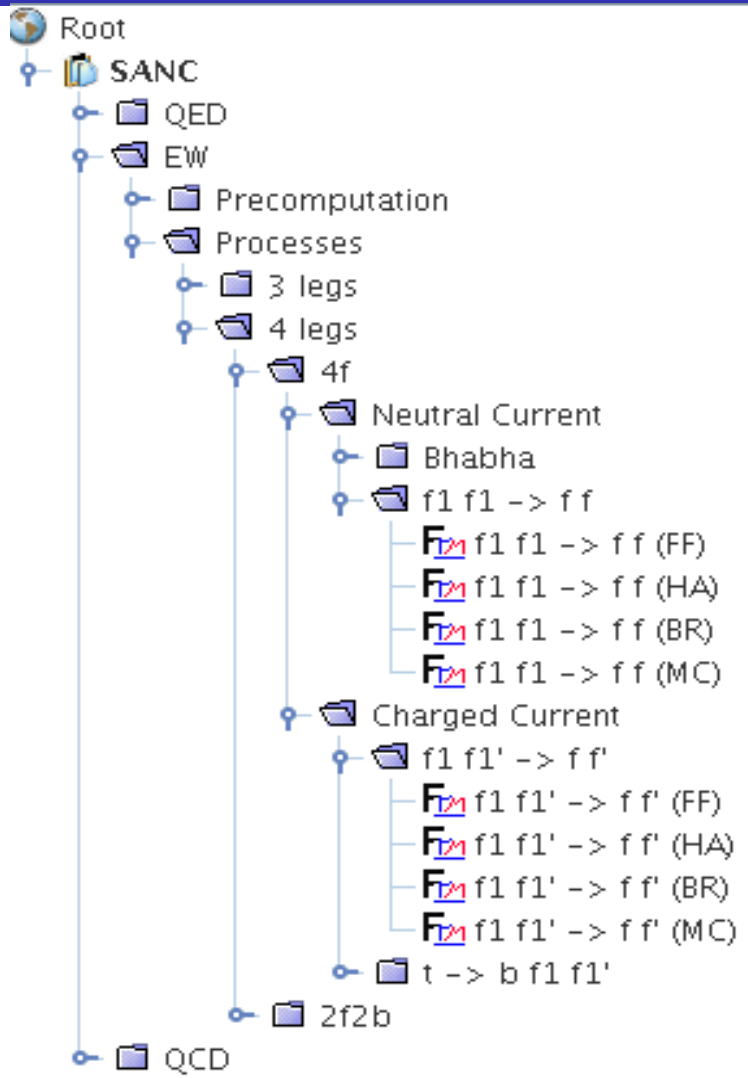
Towards MC@NNLO

Tuned comparison of DY processes within workshops:
0) W mass workshop
http://wwwteor.mi.infn.it/∼vicini/wmass.html
1) Standard Model Handles and Candles Working Group: Tools and Jets Summary Report.
C. Buttar et al. Mar 2008. 94pp. Published in *Les Houches 2007, Physics at TeV colliders* 121-214. arXiv:0803.0678 [hep-ph]
2) Tevatron-for-LHC Report: Top and Electroweak Physics.
By TeV4LHC-Top and Electroweak Working Group (C.E. Gerber et al.). FERMILAB-CONF-07-052-E-T, May 2007. arXiv:0705.3251 [hep-ph]
3) Les houches physics at TeV colliders 2005, standard model and Higgs working group: Summary report.
C. Buttar et al. Apr 2006. 234pp. Contributed to Les Houches Workshop on Physics at TeV Colliders, Les Houches, France, 2-20 May 2005. hep-ph/0604120

SANC participates(ed) in all these WSs.

NB: Important recent paper G. Balossini *at al.* arXiv:0907.0276 [hep-ph]

SANC: Concept of modules (EW+QCD)



SANC chain:

FORM modules →
FORTRAN modules [semi-automatic]

→ sanc_packages_NC/CC
(VEGAS, parton level)
[based on modules, standardized]

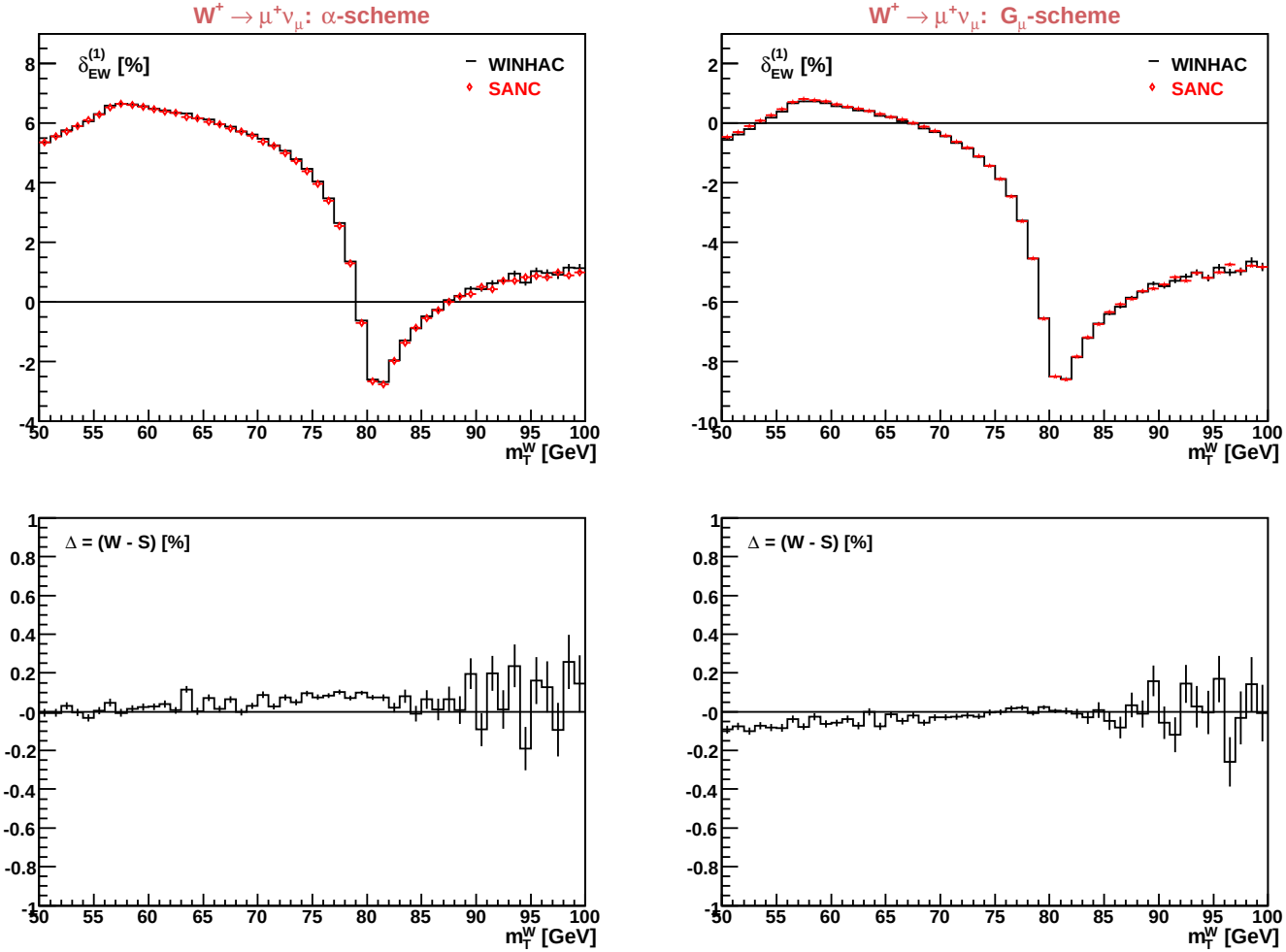
→ sanc_integrators
(VEGAS, hadron level)
[based on modules, hand-made]

→ sanc_generators
(FOAM, hadron level)
[based on modules, hand-made].

Both EW and QCD NLO calculations were advanced up to creation of modules for Drell–Yan like CC and NC processes and some others, e.g. single top production and $q\bar{q} \to H(Z \to)\mu^+\mu^-$.

WINHAC & SANC modules

The distributions of EW NLO corrections in variable $M_{\mathrm{T}}^{\mathrm{W}}$ from SANC and WINHAC for the process $pp \to \mu^+\nu_\mu X$ and the difference $\Delta = W - S, \%$.

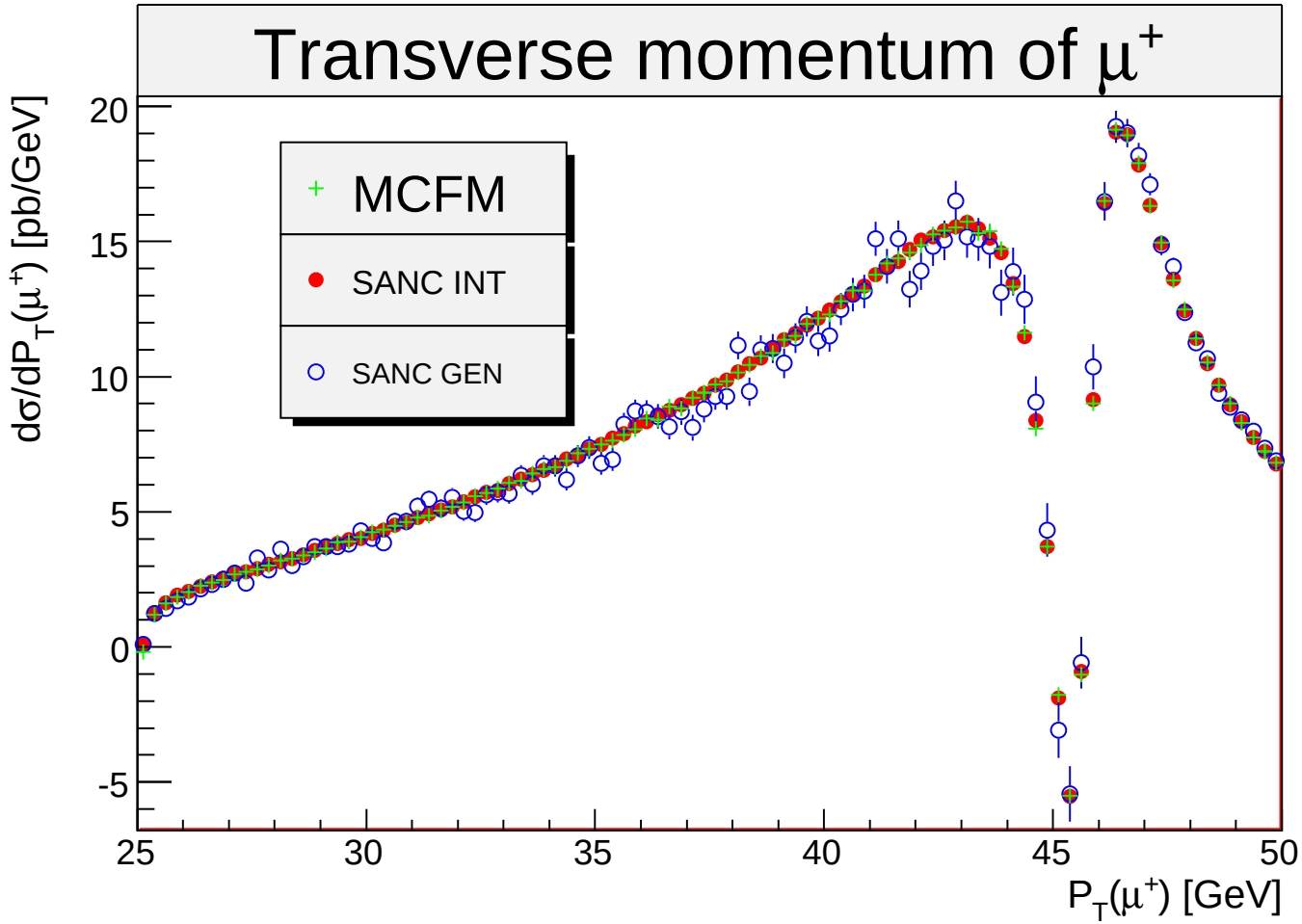


This means the correctness of implementation of EW NLO SANC modules into WINHAC framework.

D. Bardin, S. Bondarenko, S.Jadach, L. Kalinovskaya, W. Placzek, Acta Phys. Polonica, 40 (2009) 75–92.

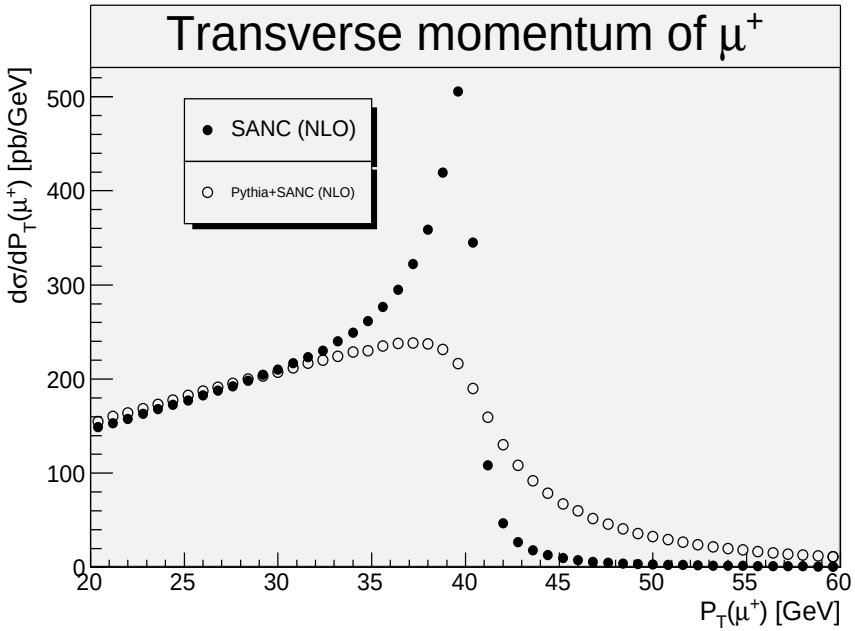
QCD NLO modules, DY NC

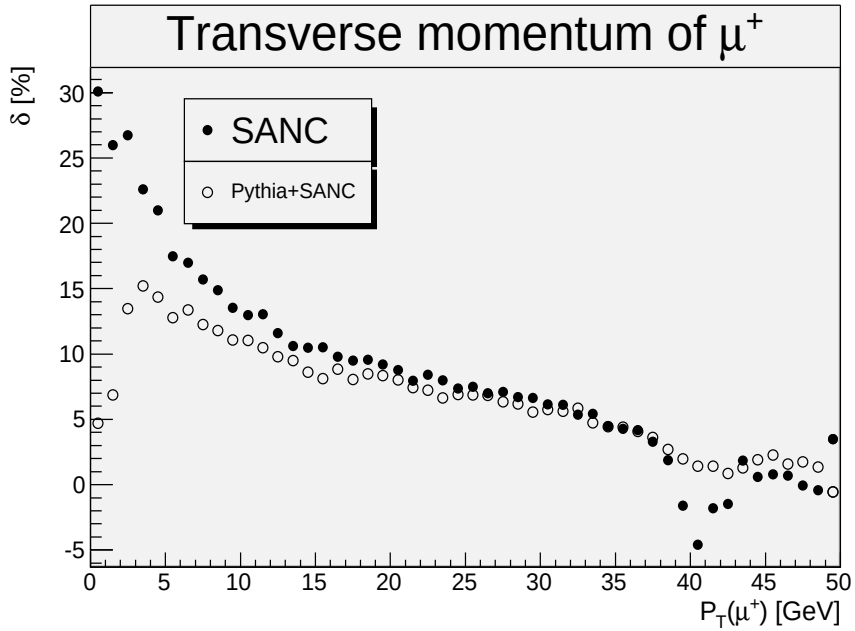
An example of the application of QCD modules appears a comparison of the results of SANC and MCFM for NC DY, realized mainly as one of cross-checks of QCD NLO calculations in SANC.



SANC & PYTHIA: DY CC, muon channel, $\alpha(0)$

EW NLO SANC without PS vs SANC with PS from PYTHIA, $\sigma(pb)$ and $\delta = \sigma^{NLO}/\sigma^{LO} - 1$ (%)

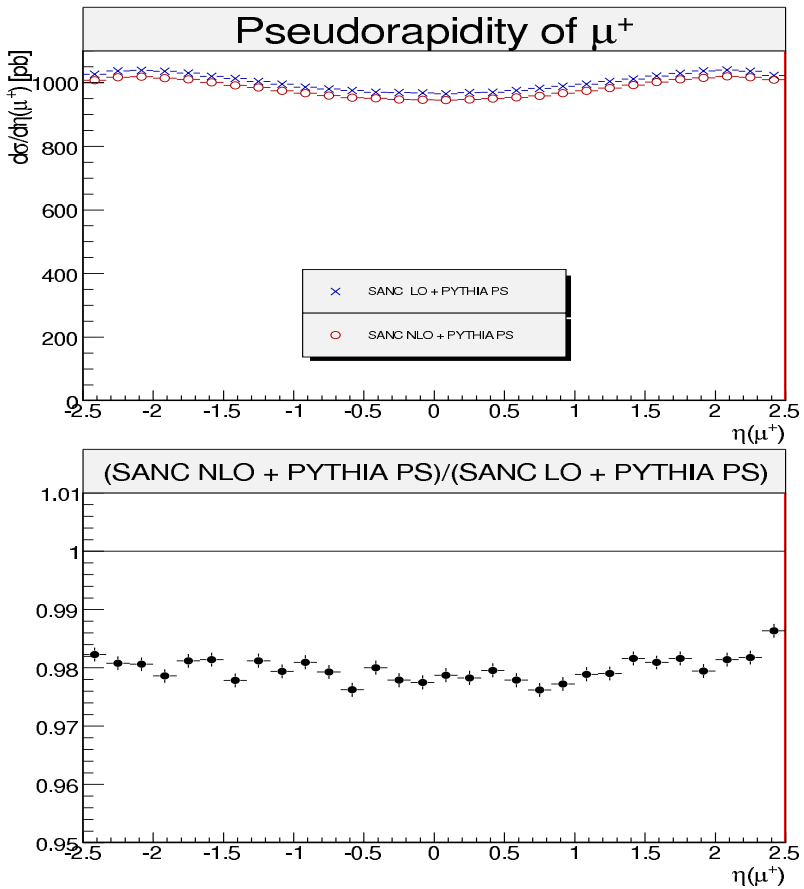


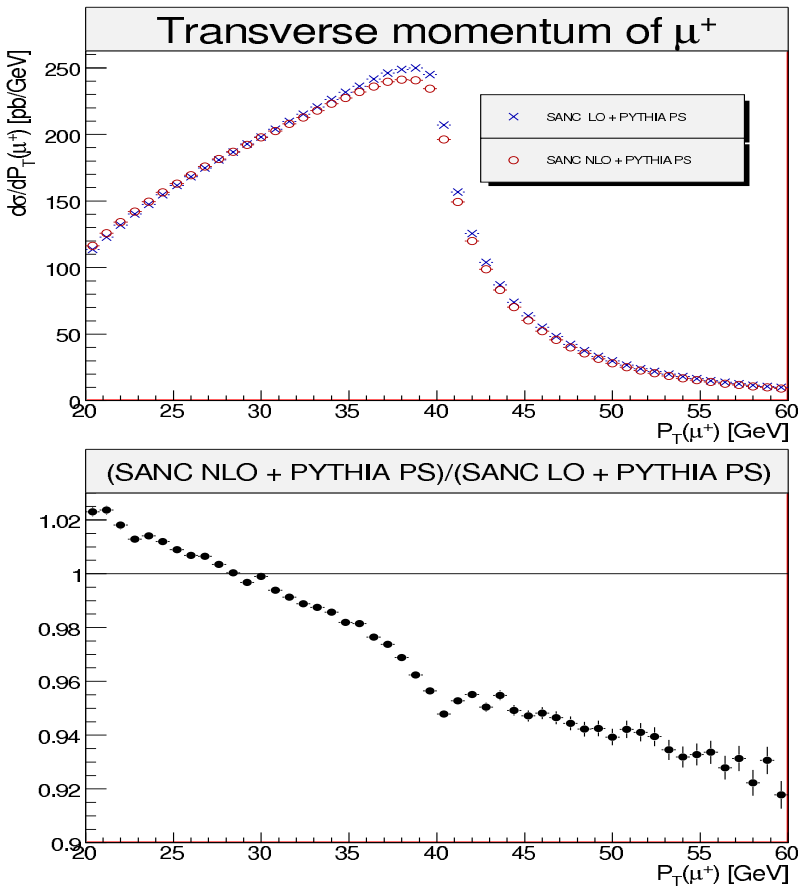


- **Parton showers (PS) drastically change the shape of distributions.**
- **Realistic effects must be computed with PS on.**

SANCvsPYTHIA: DY CC, muon channel, G_F

SANC (EW NLO/LO) vs SANC (EW NLO/ LO) + PS from PYTHIA (we also use HERWIG)





An example of EW weight: $W_{\mathrm{EW}} = \sigma^{NLO}/\sigma^{LO}$.

This Workshop

What SANC has?

- EW NLO modules (including γ-induced processes, MRST2004QED)
- QCD NLO modules
- integrators and generators at hadron level

What is planned to do within this WS?

- implementation of SANC modules to ZINHAC framework, by DB, LK, SB and AA together with Krakow group
- completion of EW NLO + PS from HERWIG, by RS

What can be done soon?

- combined treatment (EW + QCD) @ NLO $\otimes$ PS, AA and RS
- completion of EW+QCD NLO calculations for single top production, DB, LK and SB

What are our near plans?

- common work with O. Veretin *et al.* on inclusion of NNLO in DY MC
- work on MCSANC generator (production and decay), A. Sapronov *et al.*