Electroweak Radiative Corrections to Neutrino DIS

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SANC project

Support of Analytic and Numeric calculations for experiments at Colliders

- Automatized four level computer system for calculation of pseudo– and realistic observables for HEP experiments
- one–loop level, R_ξ gauge, helicity amplitudes
- current version contains basic $3 \to 0$ and $4 \to 0$ SM processes
- accessible via Applet window or SANC–Client; used technologies: JAVA, XML, SOAP
- available at the site [http://www.brg.jinr.ru]
- was already used for physical applications: Acta Phys. Polon. B 34 (2003) 4561; B 34 (2003) 2665
- Here is one more application of the SANC system to ν–DIS @ NOMAD

Neutrino DIS

$$\nu_\mu \quad + \quad N \quad \longrightarrow \nu_\mu(\mu) \quad + \quad X$$

$$R^\nu = \frac{\sigma^\nu_{NC}(\nu_\mu N \to \nu_\mu X)}{\sigma^\nu_{CC}(\nu_\mu N \to \mu^- X)}$$

At the tree-level $\quad R^\nu \sim \frac{1}{2} - \sin^2\theta_W + \frac{20}{27}\sin^4\theta_W$

$$R^- = \frac{\sigma^\nu_{NC}(\nu_\mu N \to \nu_\mu X) - \sigma^{\bar\nu}_{NC}(\bar\nu_\mu N \to \bar\nu_\mu X)}{\sigma^\nu_{CC}(\nu_\mu N \to \mu^- X) - \sigma^{\bar\nu}_{CC}(\bar\nu_\mu N \to \mu^+ X)}$$

NuTeV: $\sin^2\theta_W = 0.2277 \pm 0.0013(\text{stat.}) \pm 0.0009$ **(syst.)**

LEPEWWG: $\sin^2\theta_W = 0.2227 \pm 0.00037$

NOMAD: $\sin^2\theta_W = \; ?$

QED & Weak RC to ν-quark scattering

$$\nu_\mu(k_1) \quad + \quad q_1(p_1) \quad \longrightarrow \nu_\mu(\mu)(k_2) \quad + \quad q_2(p_2) \quad + \quad (\gamma(k))$$

$$\textbf{Virtual} \; + \; \underbrace{\textbf{Soft} \; + \; \textbf{Hard}^\dagger}_{\sim \ \textbf{Pure QED}}$$

† **Experimental conditions:** $\tilde{X} = X + \gamma$

Large logs: $\ln\frac{Q^2}{m_1^2}, \qquad \ln\frac{Q^2}{m_2^2}, \qquad \ln\frac{Q^2}{m_\mu^2}$

$L_i \sim 10$ **for typical** Q^2 **values,** $\qquad \left(\frac{\alpha}{\pi}\right)^2 L_\mu^2 \sim 5\cdot 10^{-4}$

KLN theorem conditions ...

ISR LARGE LOGS

Subtraction scheme should be the same as in PDF:

(discussed earlier in K. Diener, S. Dittmaier, and W. Hollik, PRD69, 2004)

$$\overline{\mathrm{MS}}: \qquad \int_0^1 \mathrm{d}x\, x \frac{\alpha}{2\pi} \left[\frac{1+x^2}{1-x} \left(\ln \frac{\mathbf{M^2}}{m_1^2} - 1 - 2\ln(1-x) \right) \right]_+$$

M **is the** *factorization scale***:**

$$M^2 = Q^2 = \tilde{Q}^2_{\mathrm{hadr}} = 2p_1^0(p_2^0 + k^0)$$

(Re-)Move from QED RC into PDF

$$\frac{\alpha}{2\pi} Q_1^2 \left(-\frac{4}{3} \ln \frac{Q^2}{m_1^2} - \frac{17}{9} \right), \qquad \alpha_{\mathbf{s}}^{\mathrm{eff}} = \alpha_{\mathbf{s}} + \frac{\mathbf{Q_1^2}}{\mathbf{C_F}} \alpha$$

D. Bardin, V. Dokuchaeva (JINR preprint E2-86-260):

$$\delta_{\nu NC} = \frac{\alpha}{2\pi}\, Q_1^2\, \frac{g_L^2 h_L^{(1)} + g_R^2 h_R^{(1)}}{g_L^2 + g_R^2(1-y)^2}\,,$$

$$h_L^{(1)} = -\frac{1}{9} + \frac{2}{3}(1-y) + \frac{1}{12}(1-y)^2 - \frac{4}{3}\ln\frac{Q^2}{m_1^2} - \frac{\pi^2}{3}\,,$$

$$h_R^{(1)} = -\frac{1}{9}(1-y)^2 + \frac{2}{3}(1-y) + \frac{1}{12} - \frac{4}{3}\ln\frac{Q^2}{m_1^2} - \frac{\pi^2}{3}(1-y)^2,$$

$$y = \frac{Q^2}{\hat{s}}\,, \qquad Q^2 = Q_l^2 = 2k_1k_2, \qquad \hat{s} = 2k_1p_1$$

$$\sigma_i = \sigma_i^{\mathrm{Born}}(1+\delta_i^{\mathrm{RC}}), \qquad \sigma_i = \sigma_{NC}^{\nu u},\ \sigma_{CC}^{\nu d},\ etc.$$

=> **Structure functions:** $F_2 \to F_2(1+\delta_2^{\mathrm{RC}})$ **and so on**

Large Logs in CC

$$\delta^{(1)LL}_{\nu CC} = \frac{\alpha}{2\pi} L_\mu \left(2\ln y - \ln(1-y) + \frac{3}{2} - y \right)$$

$$\delta^{(1)LL}_{\bar{\nu} CC} = \frac{\alpha}{2\pi} L_\mu \left(2(1-y)^2 \ln\frac{y}{1-y} + \frac{3}{2} - y \right)$$

$$\delta^{(2)LL}_{\nu CC} = \frac{1}{2}\left(\frac{\alpha}{2\pi}L_\mu\right)^2 \Big[4\ln^2 y - 4\ln y \ln(1-y) + \frac{1}{2}\ln^2(1-y) - 4\zeta_2$$
$$+(6-4y)\ln y + (3y-4)\ln(1-y) + \frac{9}{4}\Big] + \frac{1}{3}\frac{\alpha}{2\pi}L_\mu \delta^{(1)LL}_{\nu CC}$$

$$\delta^{(2)LL}_{\bar{\nu} CC} = \frac{1}{(1-y)^2}\frac{1}{2}\left(\frac{\alpha}{2\pi}L_\mu\right)^2 \Big[4(1-y)^2\Big(\mathrm{Li}_2(1-y) + \ln^2 y + \frac{1}{2}\ln^2(1-y)$$
$$-2\zeta_2\Big) + (6-4y)\ln y + \Big(y - \frac{3}{2}\Big)\ln(1-y) + \frac{9}{4} - 2y\Big] + \frac{1}{3}\frac{\alpha}{2\pi}L_\mu \delta^{(1)LL}_{\bar{\nu} CC}$$

$$L_\mu = \ln\frac{\hat{s}}{m_\mu^2} = \ln\frac{xS}{m_\mu^2}$$

Scheme dependence in weak RC

K.-P. O. Diener, S. Dittmaier, and W. Hollik (Phys. Rev. D69, 2004):

Schemes: $\alpha(0)$, G_{Fermi}, $\alpha(M_Z)$ $\longrightarrow$

$$\boxed{\pm 4 \cdot 10^{-4} \quad \textbf{in} \quad \sin^2\theta_W}$$

$$\delta^{\mathrm{th}}_{\mathrm{EW}} = 4 \cdot 10^{-4}$$

$$\delta^{\mathrm{th}}_{\mathrm{QED}} \lesssim 1 \cdot 10^{-4}$$

$$\boxed{\delta^{\mathrm{th}}(\mathrm{NuTeV}) = 1.1 \cdot 10^{-4} \quad \longrightarrow \delta^{\mathrm{th}} = 3 \cdot 10^{-4}}$$

Numerical results

(ISCH,ILLA),EW Scheme	R^{ν}_{Corr}	ΔR^{ν}	$\Delta \sin^2\theta_W$	R^{-}_{Corr}	ΔR^{-}
(0,1), G_F	0.3046	-0.0127	-0.0189	0.2714	-0.0081
(1,1), G_F	0.3050	-0.0123	-0.0182	0.2724	-0.0071
(1,2), G_F	0.3050	-0.0122	-0.0182	0.2724	-0.0071
(1,2), $\alpha(0)$	0.3049	-0.0124	-0.0184	0.26505	-0.0067

ISCM=0/1: $\overline{\mathrm{MS}}$ subtraction OFF/ON, **ILLA=1/2: $O(\alpha^2 L_\mu^2)$ OFF/ON**

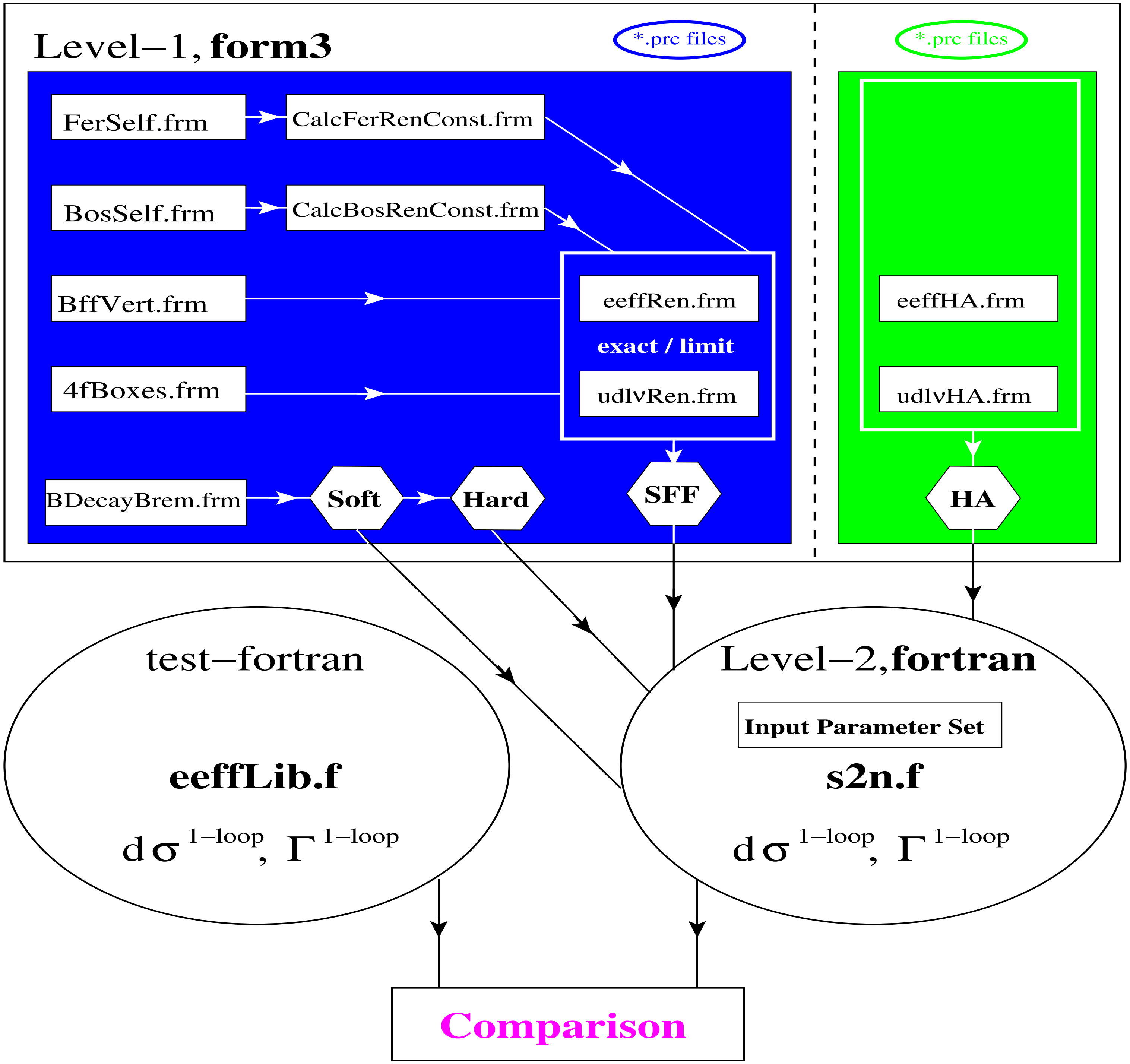
$$\Delta R^{\nu} \approx \left(-1 + \frac{40}{27}\sin^2\theta_W\right)\Delta\sin^2\theta_W$$

$$M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right) = \frac{\pi\alpha}{2G_F}\,\frac{1}{1-\Delta r(\alpha, M_W, M_Z, M_H, m_f)}$$

Comparisons ...

Summary

- QED & EW RC to ν-DIS are updated, quark an lepton mass singularities are treated
- Comparisons between independent calculations are in progress
- Theoretical uncertainty is re-estimated
- Results are implemented into the NOMAD data analysis
- One more application of the SANC system v.0.30 [http://brg.jinr.ru]



Level–1, form3
*.prc files
*.prc files
FerSelf.frm
CalcFerRenConst.frm
BosSelf.frm
CalcBosRenConst.frm
BffVert.frm
eeffRen.frm
exact / limit
4fBoxes.frm
udlvRen.frm
eeffHA.frm
udlvHA.frm
BDecayBrem.frm
Soft
Hard
SFF
HA
test–fortran
eeffLib.f
dσ 1–loop, Γ 1–loop
Level–2,fortran
Input Parameter Set
s2n.f
dσ 1–loop, Γ 1–loop
Comparison