Comparisons of MC codes for W production and decay: framework and first results

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Outline:

- Introduction.
- Parton-level observables, parameters, acceptances, etc.
- Parton-level results.
- Comments on parton-level comparisons.
- Hadron-level observables, parameters, acceptances, etc.
- Conclusions and outlook.

Aims:

- To perform comparisons of various Monte Carlo event generators for single-W production:
  - ▷ at the parton level,
  - ▷ at the hadron level – as close to the real experimental set-up as possible.
- To assess the influence of electroweak (including QED) corrections on main LHC single-W observables:
  - ▷ measurements of M_W and Γ_W,
  - ▷ PDF and parton luminosities measurements, etc.

Participants (agreed so-far):

- **HORACE:** C.M. Carloni Calame, G. Montagna, O. Nicrosini and M. Treccani
  - ▷ **hep-ph/0303102**
- **WGRAD:** U. Baur, S. Keller and D. Wackeroth ▷ hep-ph/9807417
- **WINHAC:** S. Jadach and W. Placzek ▷ hep-ph/0302065

Parton-level observables, parameters, acceptances, etc.

1. **Process:**

$$d\bar{u} \longrightarrow W^- \longrightarrow l^- \bar{\nu}_l, \qquad l = e, \mu,$$

$+z$ axis pointing in d-quark direction.

2. **Input parameters (G_μ scheme and fixed-width scheme):**

$E_{\rm CM} = M_W,$

$m_\nu = 0, \quad m_e = 0.511 \times 10^{-3}\,\text{GeV}, \quad m_\mu = 0.10565836\,\text{GeV},$

$\alpha^{-1} = 137.03599976, \quad G_\mu = 1.16639 \times 10^{-5}\,\text{GeV}^{-2}, \quad \alpha_s = 0.1185,$

$M_W = 80.423\,\text{GeV}, \quad M_Z = 91.1882\,\text{GeV}, \quad \sin^2\theta_W = 1 - \frac{M_W^2}{M_Z^2},$

$\Gamma_W = \frac{3 G_\mu M_W^3}{2\sqrt{2}\pi}\left(1 + \frac{2\alpha_s}{3\pi}\right).$

3. **Radiative corrections:**

▷ Only QED corrections in W decay (no ISR, no interference, no weak corr.):

(a) Born

(b) $\mathcal{O}(\alpha)$

(c) Best $\longrightarrow$ with higher orders (exponentiation, LLs, etc.)

4. **Observables:**

   (1) Charged lepton energy E_l,

   (2) Charged lepton $\cos\theta_l$, where θ_l – lepton polar angle,

   (3) Hardest photon energy E_γ,

   (4) Hardest photon $\cos\theta_\gamma$ for $E_\gamma > 1\,\mathrm{GeV}$, where θ_γ – photon polar angle,

   (5) Total photon energy $\sum_\gamma E_\gamma$.

5. **Acceptances:**

   ▷ BARE – 'bare' lepton 4-momenta, no cuts;

   ▷ CALO – photons recombined with charged lepton if $\angle(l,\gamma) \leq 5^\circ$, no other cuts.

Results (so far):

- **HORACE:** QED parton shower, i.e. LL-type corrections:

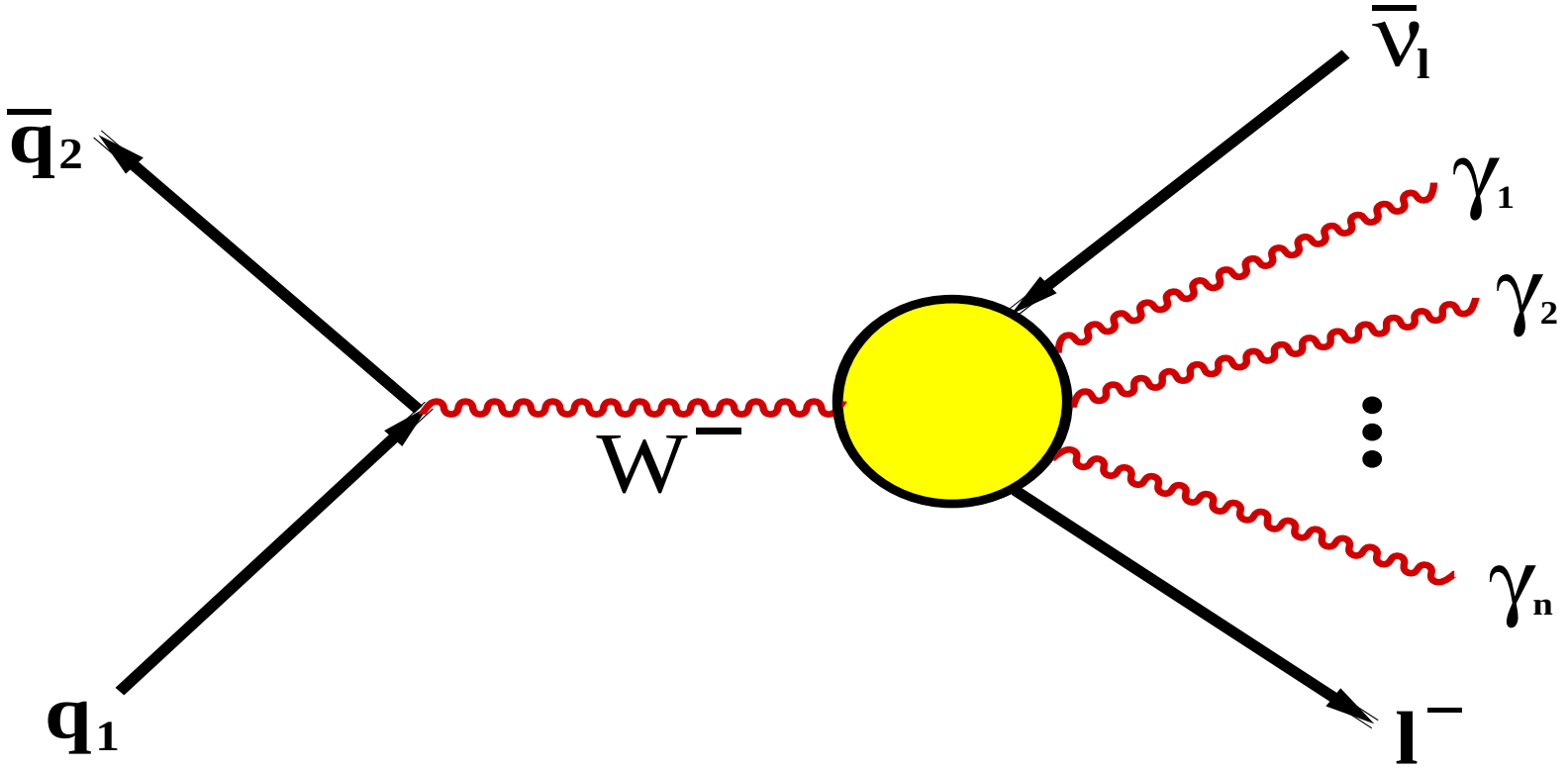
  ▷ PPS – Pure Parton Shower (published version),

  ▷ IPS – Improved Parton Shower: included some non-LL terms (new version).

- **WINHAC:** QED $\mathcal{O}(\alpha)$ YFS exclusive exponentiation, i.e. exact $\mathcal{O}(\alpha)$,
  exact infrared limit, some parts of higher-order non-IR corrections included.

▶ **"Best" predictions: multiphoton radiation in leptonic W decays**

$$d(p_d) + \bar{u}(p_u) \longrightarrow W^-(Q) \longrightarrow l^-(q_l) + \bar{\nu}(q_\nu) + \gamma(k_1) + \ldots + \gamma(k_n), \quad (n = 0, 1, \ldots)$$

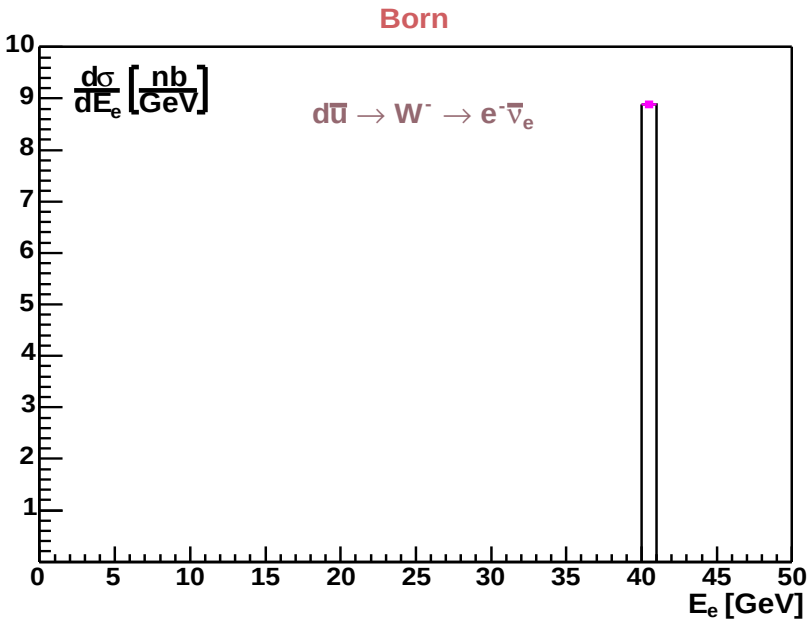


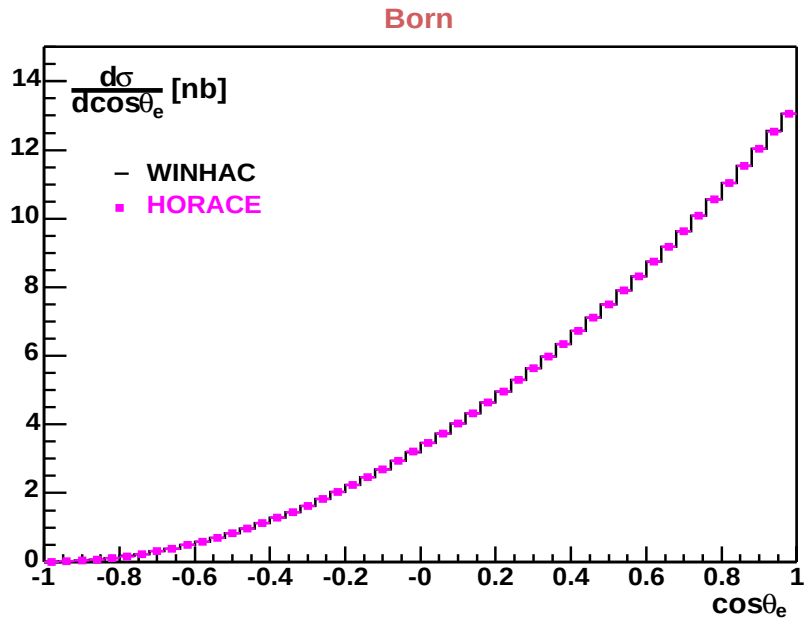
▷ Implemented through different approaches:

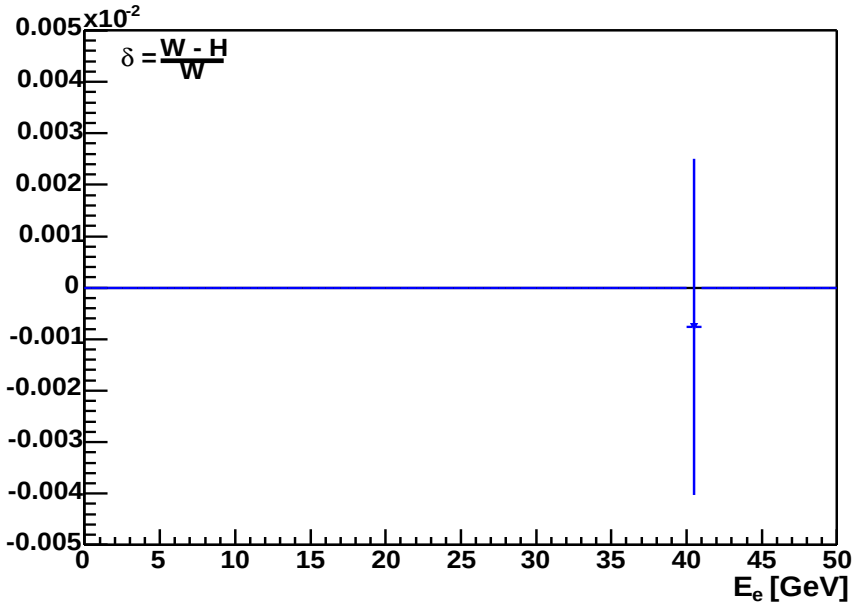
HORACE: QED Parton Shower

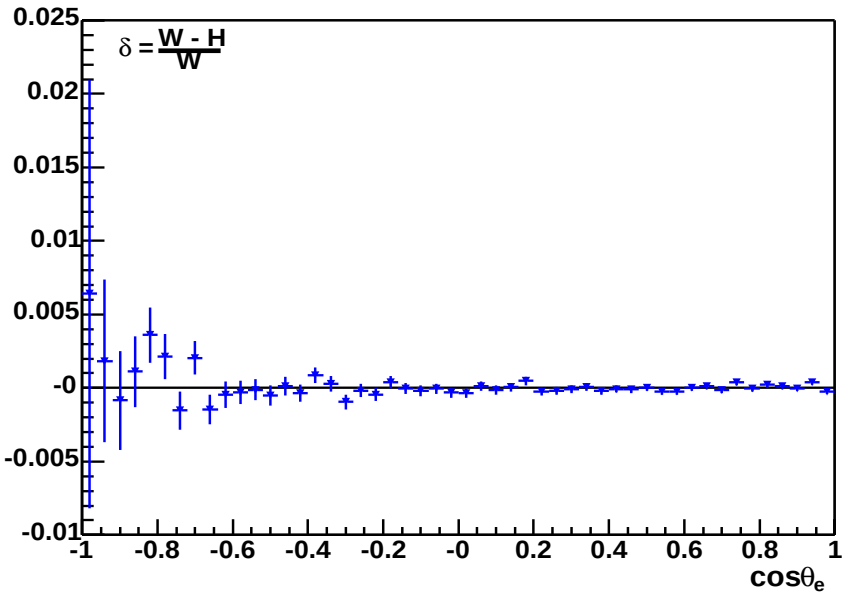
WINHAC: QED YFS Exclusive Exponentiation

HORACE vs. WINHAC: Born level

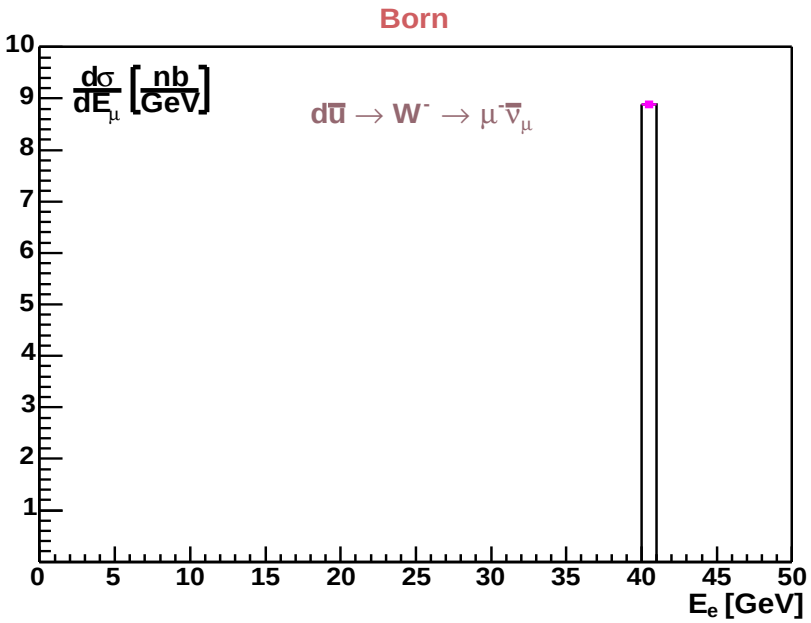


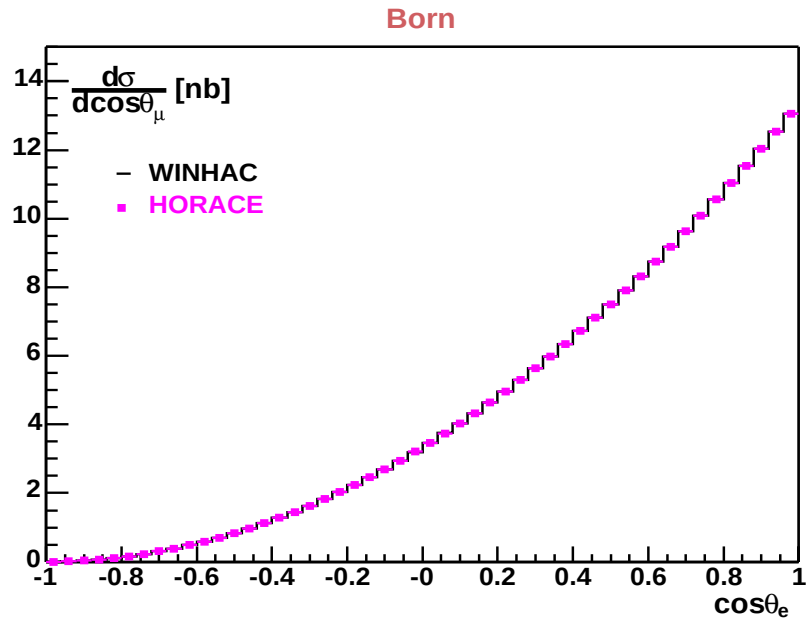


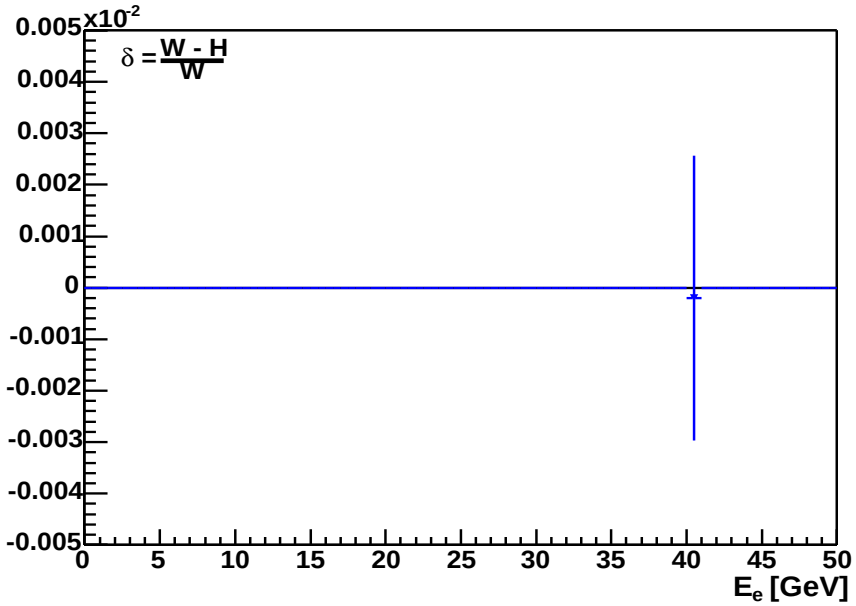


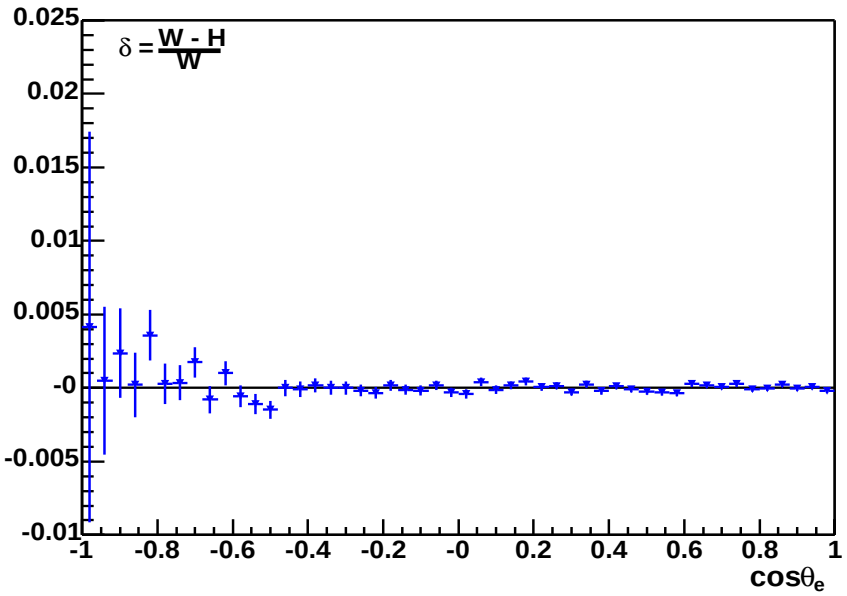


HORACE vs. WINHAC: Born level



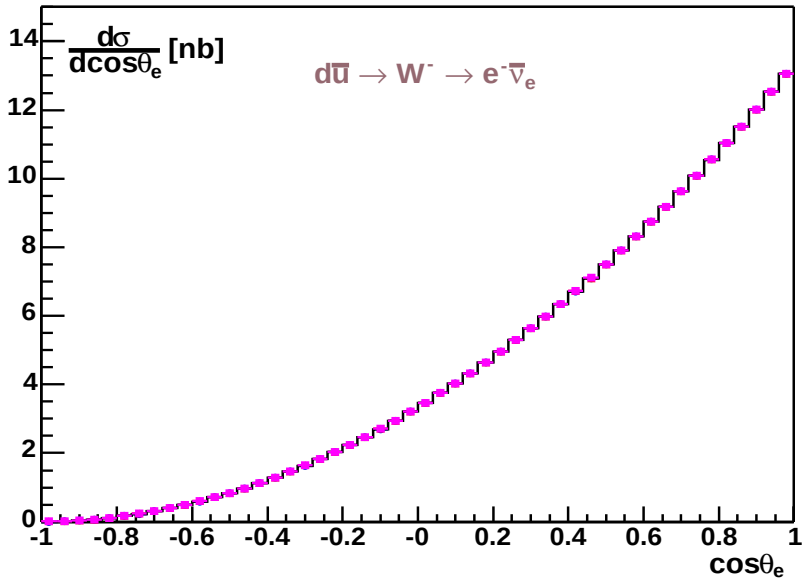




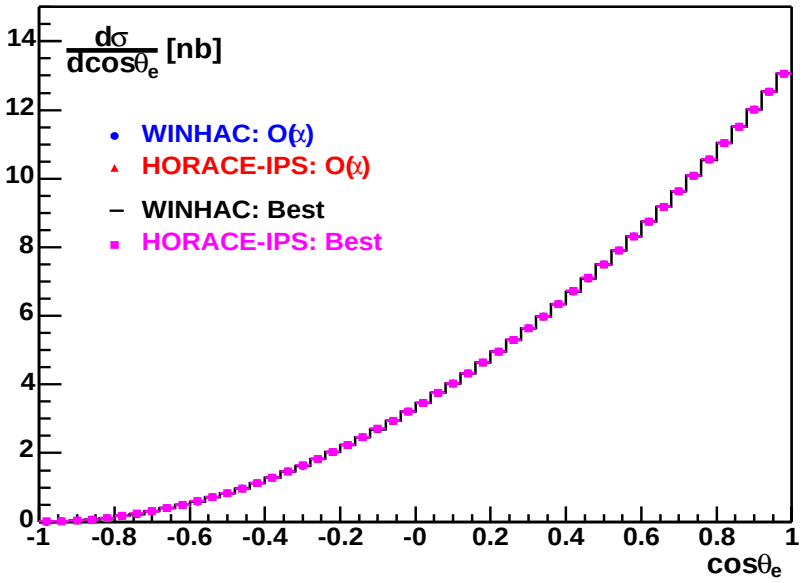


HORACE-IPS vs. WINHAC: $\mathcal{O}(\alpha)$ and Best

BARE



CALO



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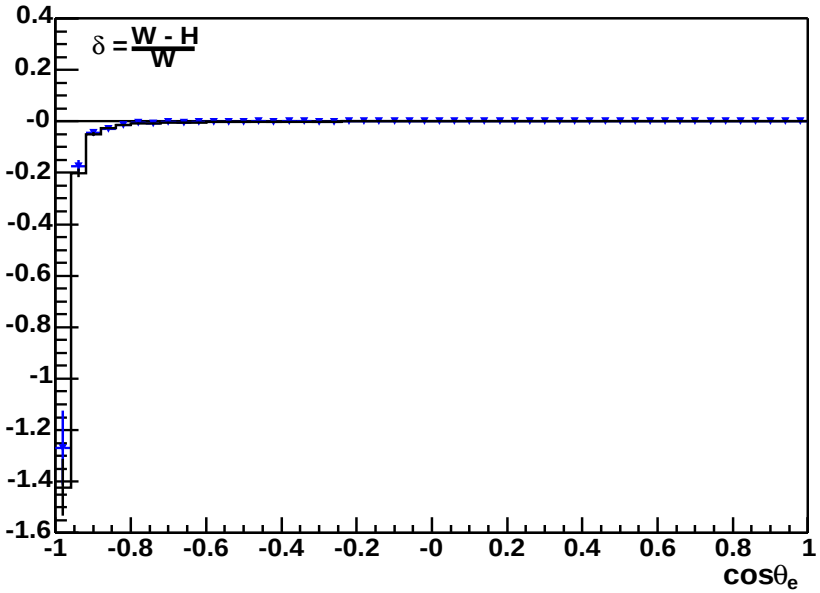

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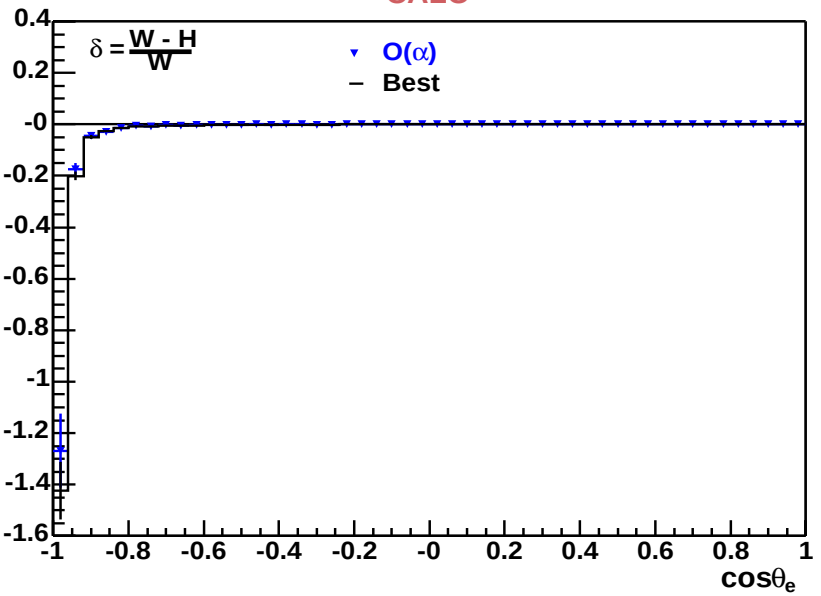

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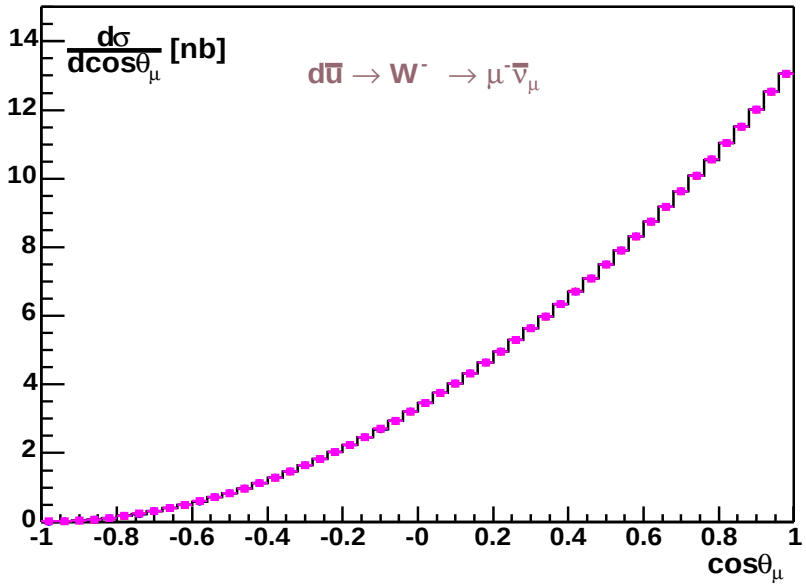

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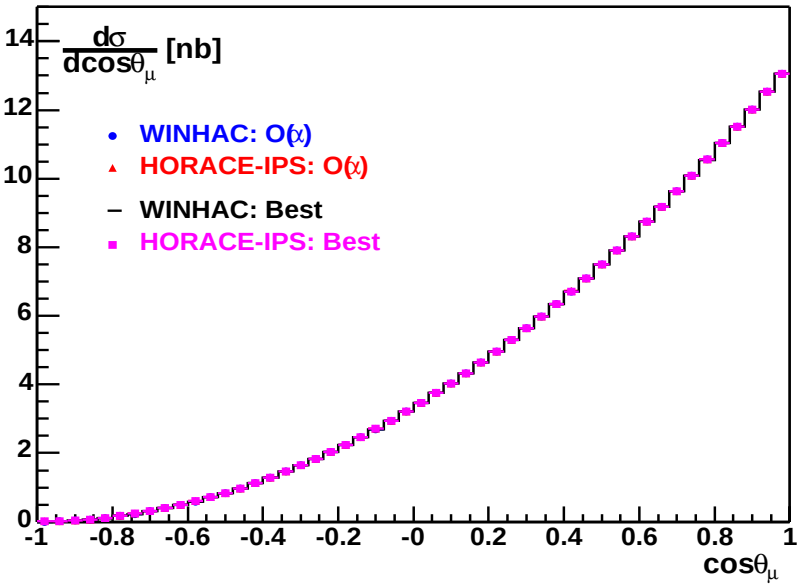

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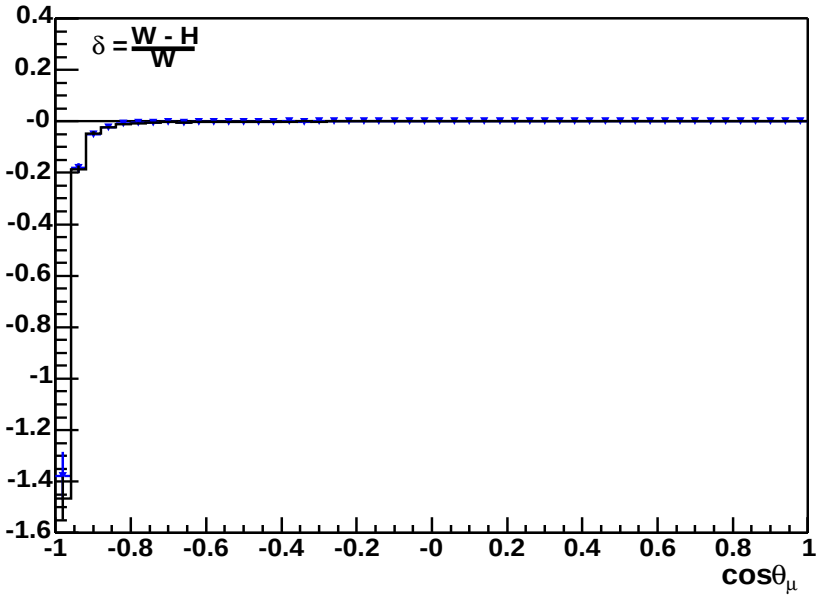

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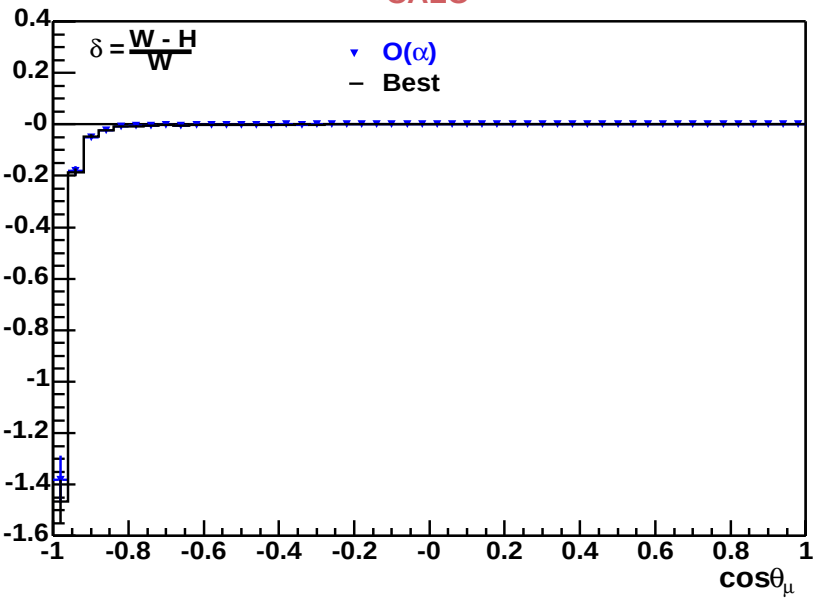

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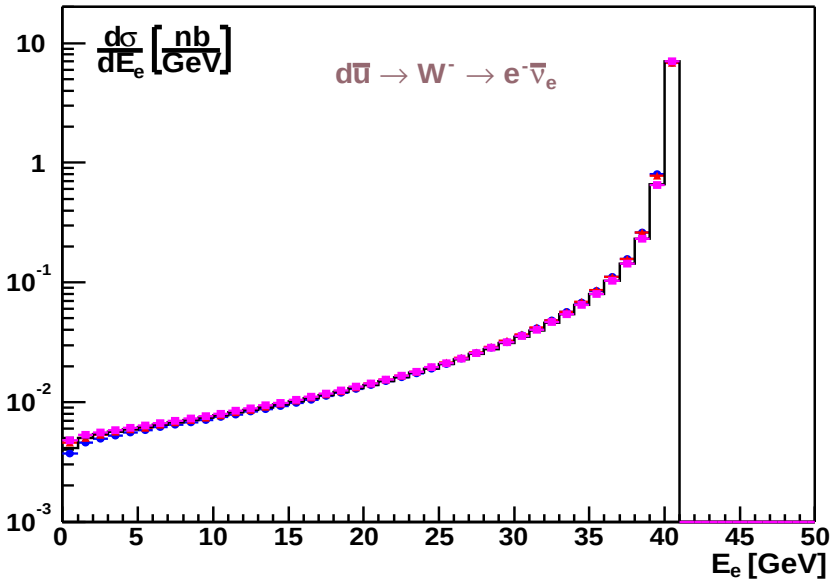

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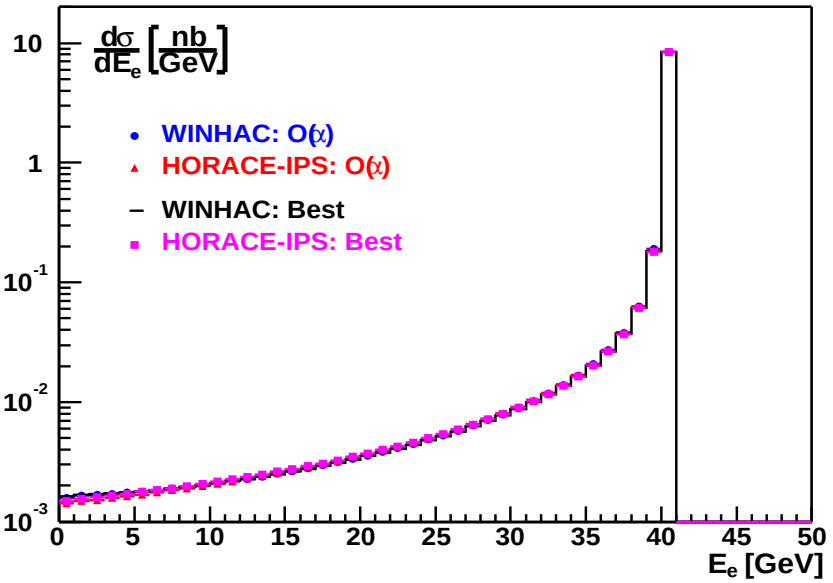

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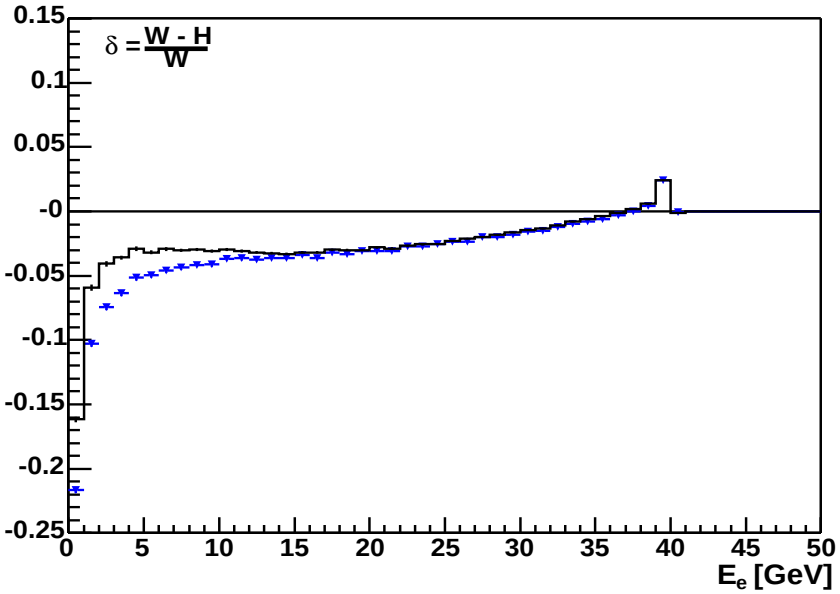

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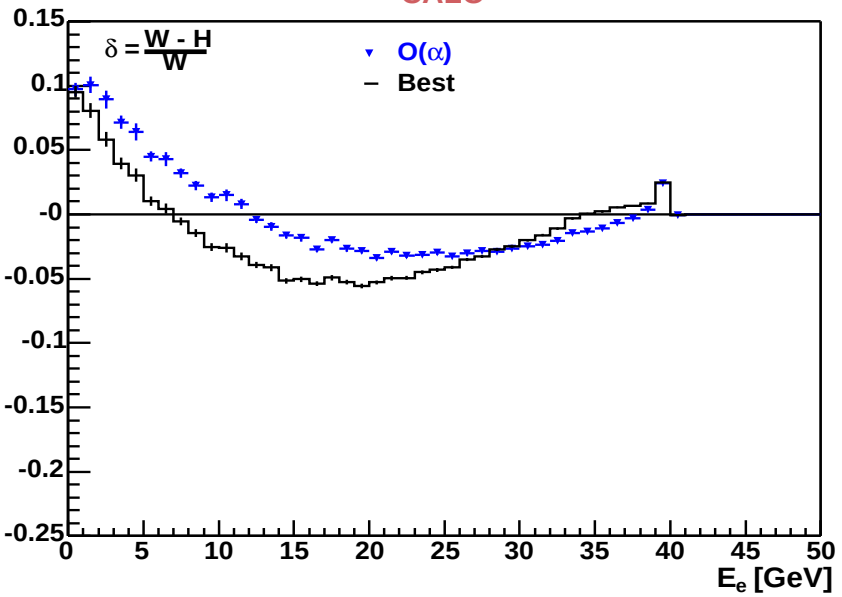

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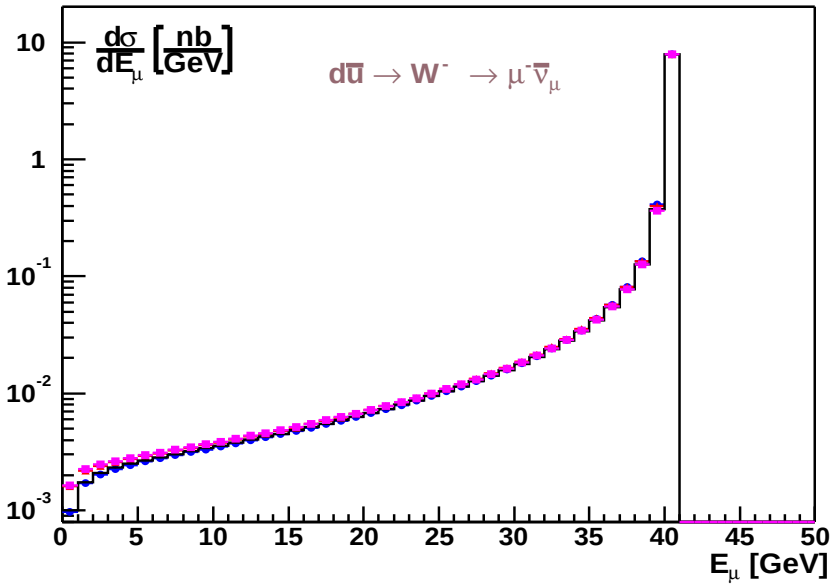

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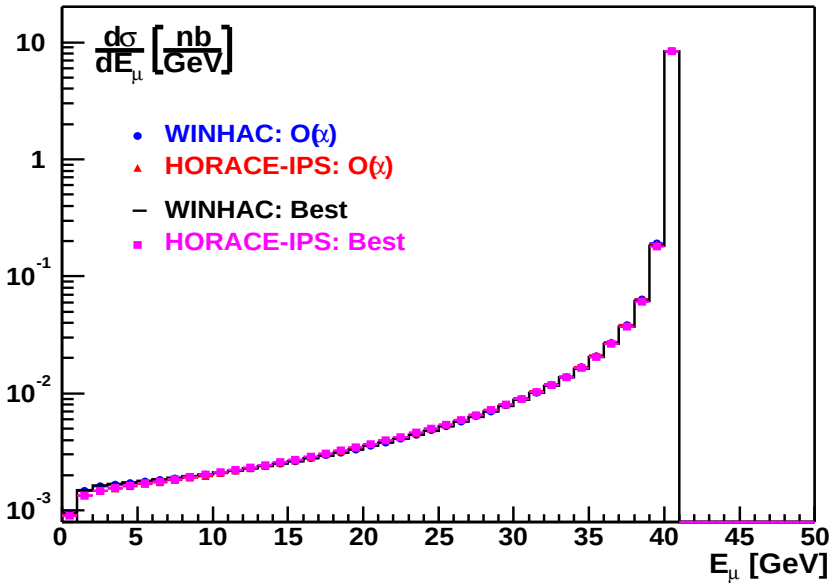

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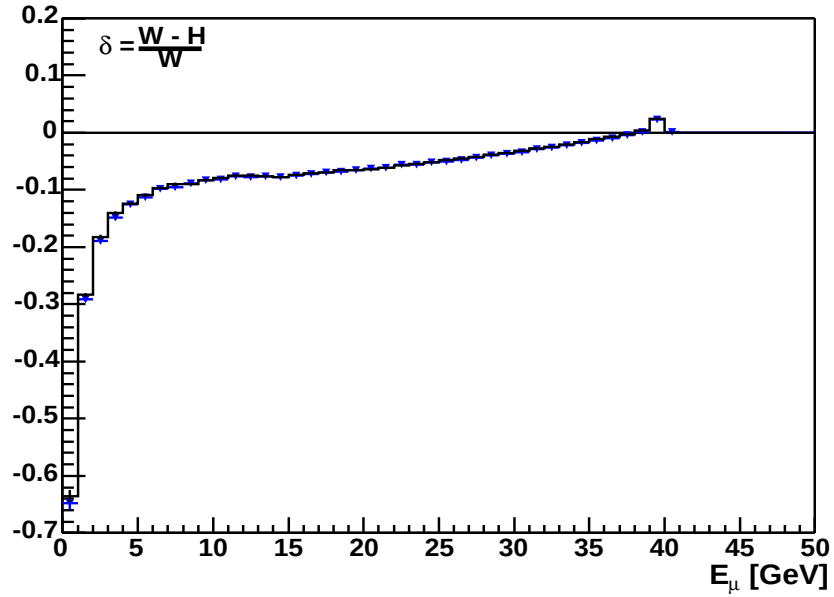

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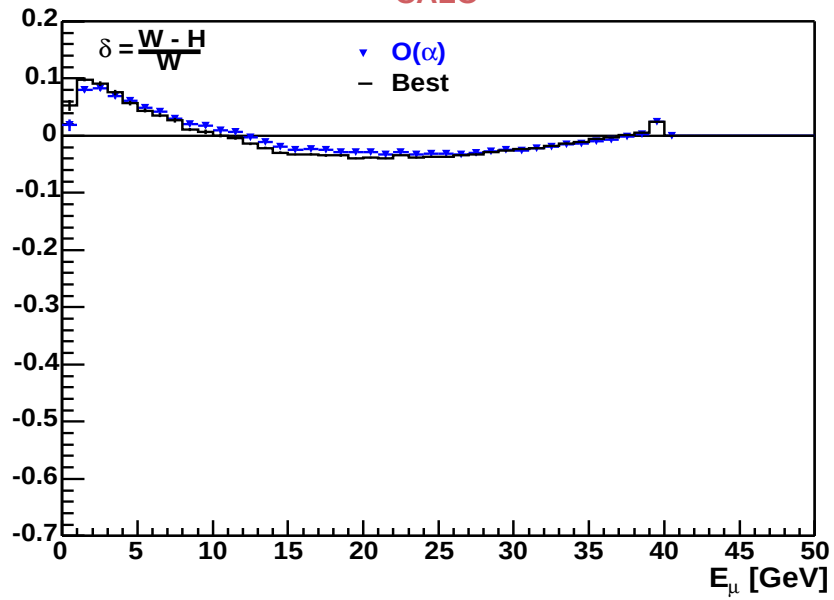

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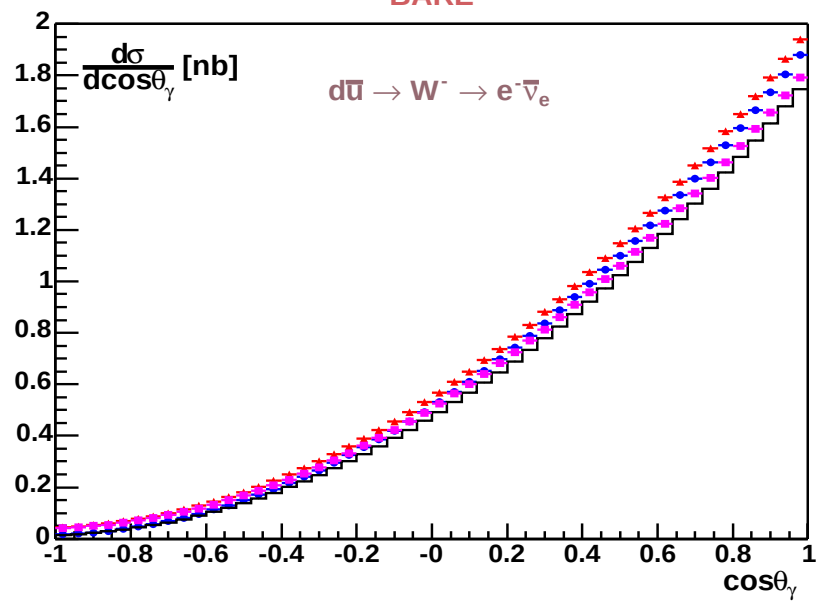

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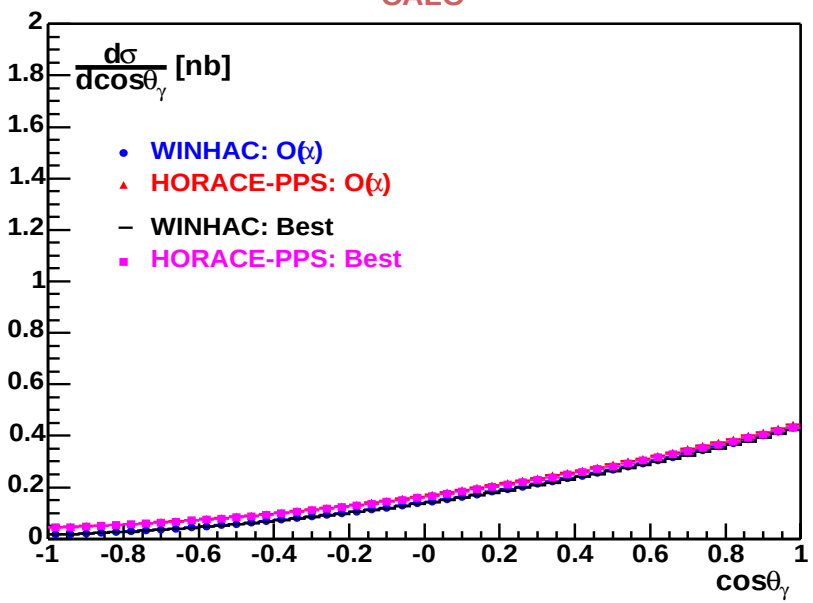

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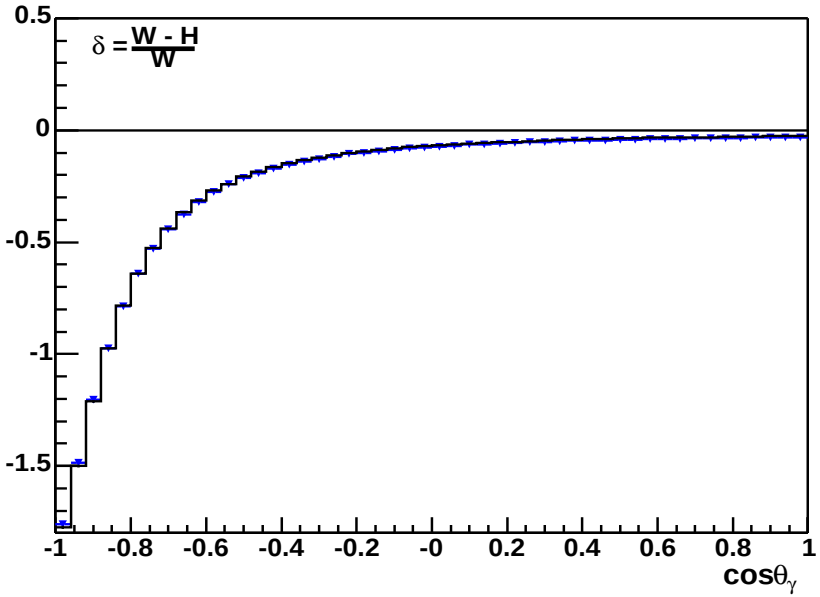

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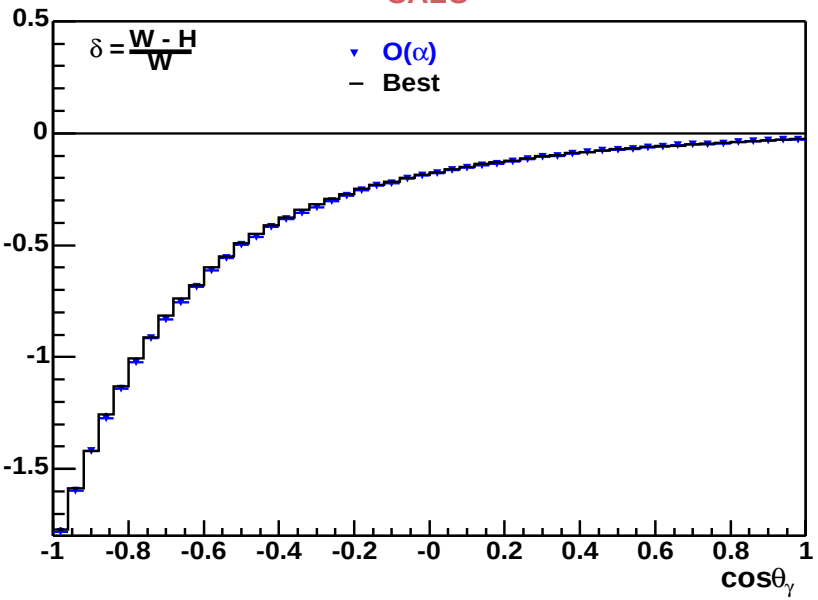

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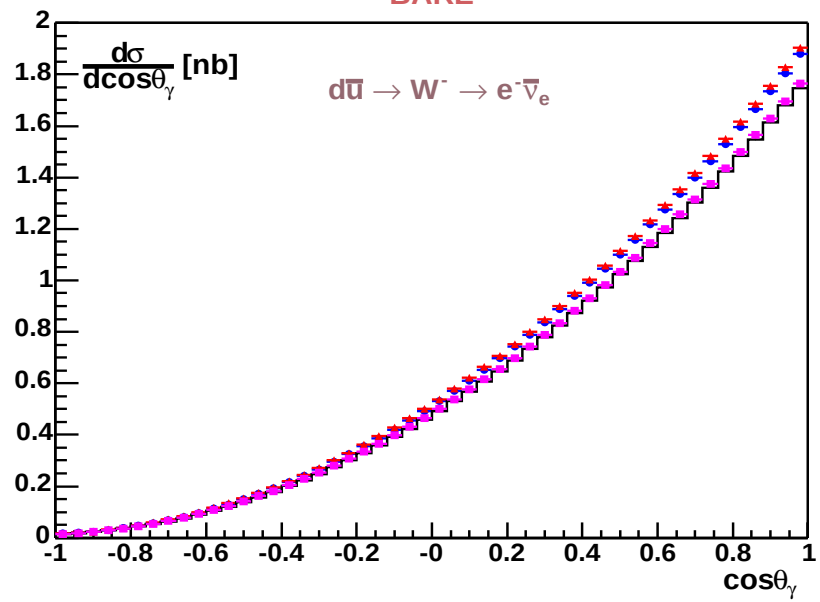

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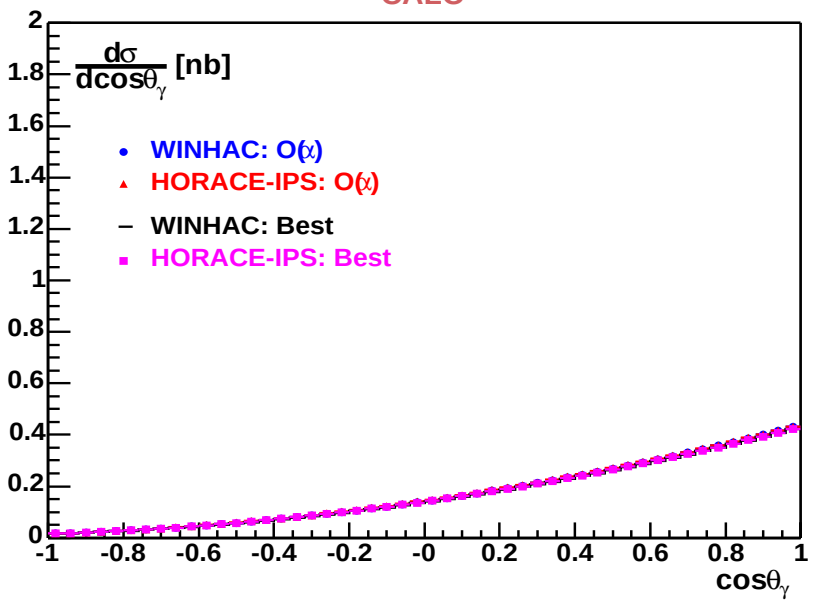

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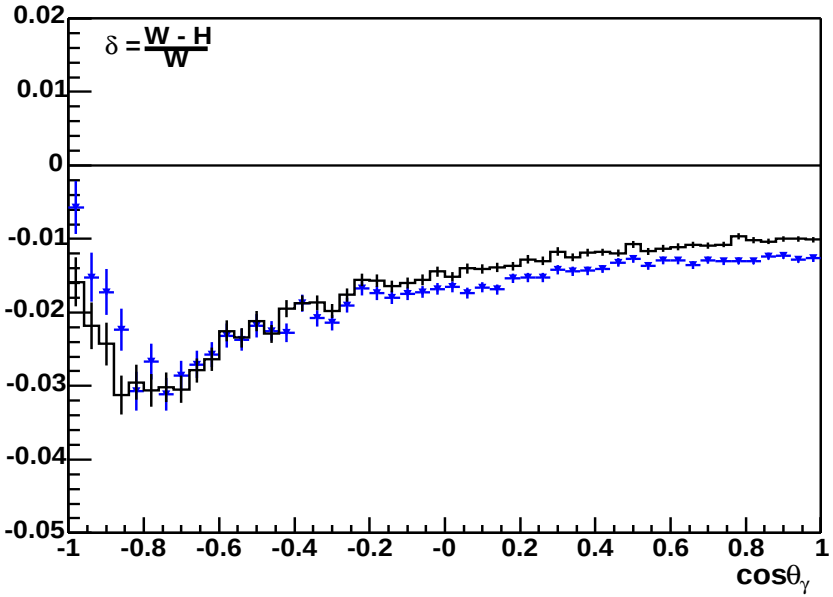

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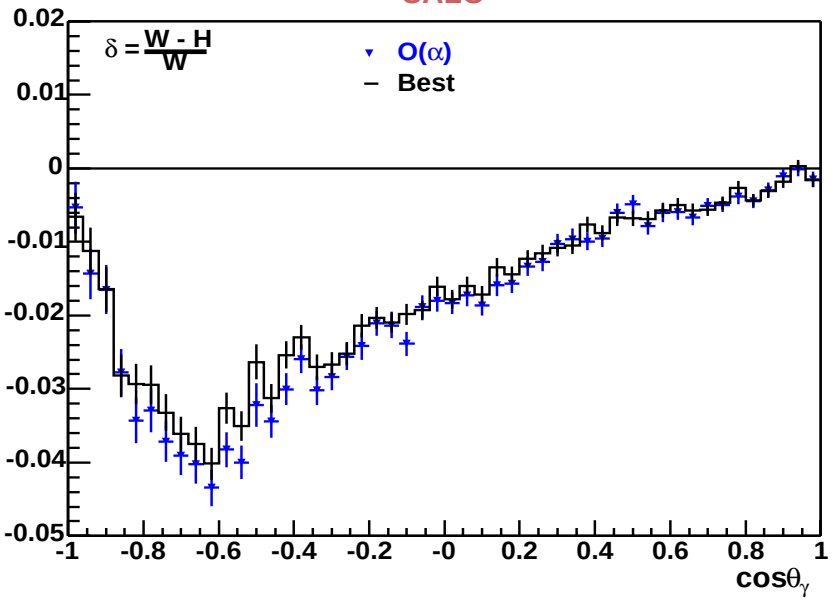

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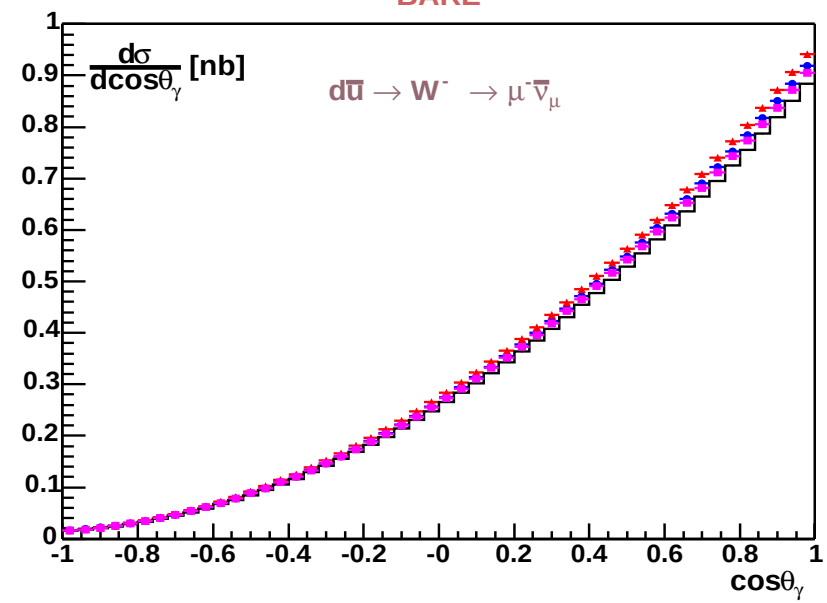

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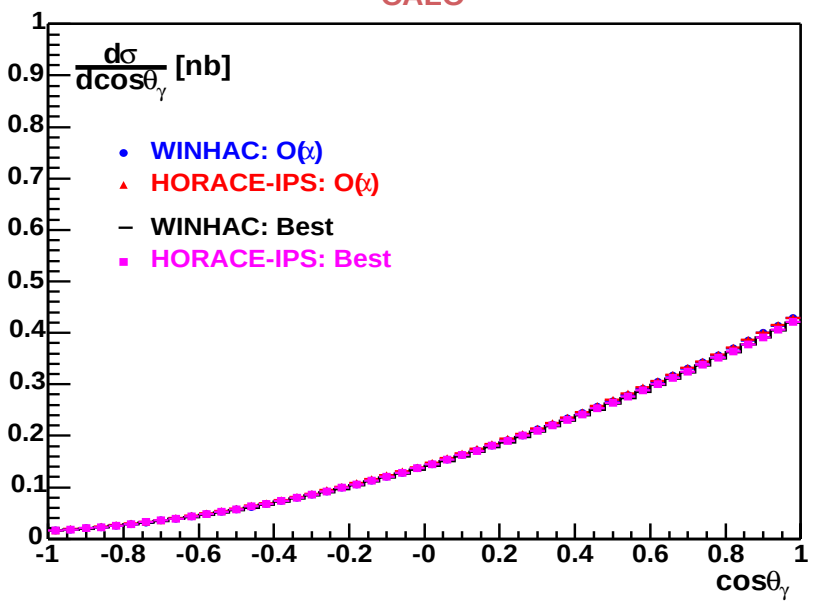

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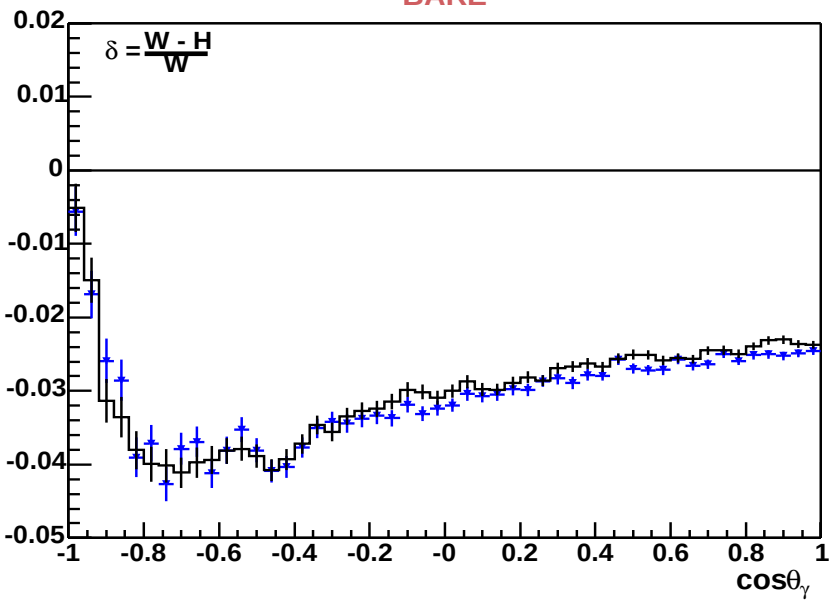

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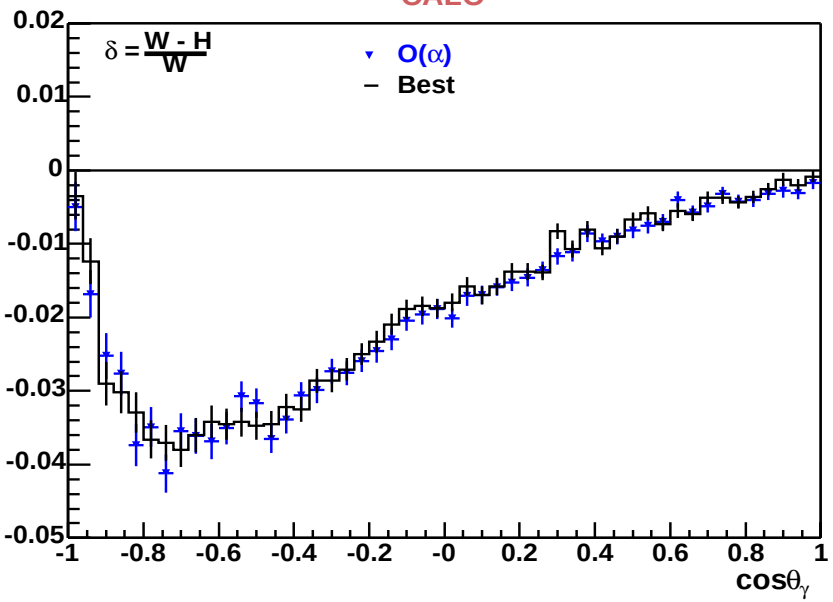

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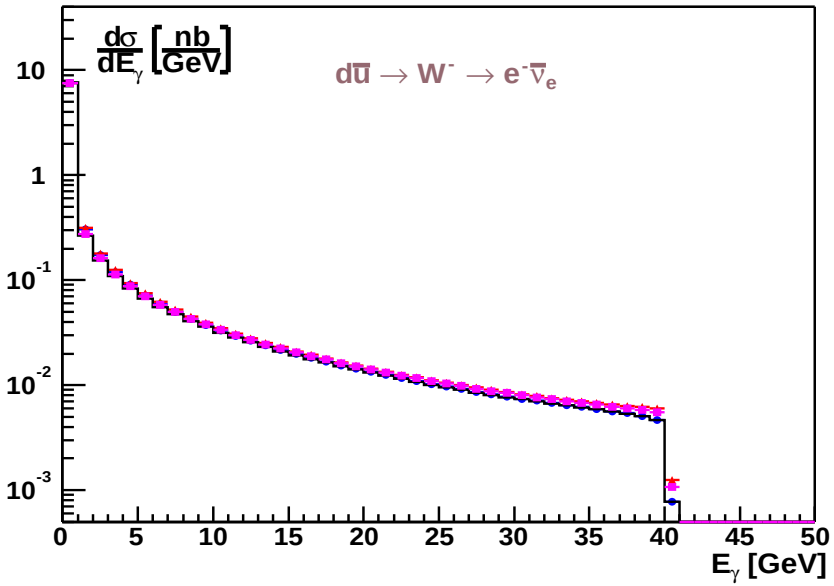

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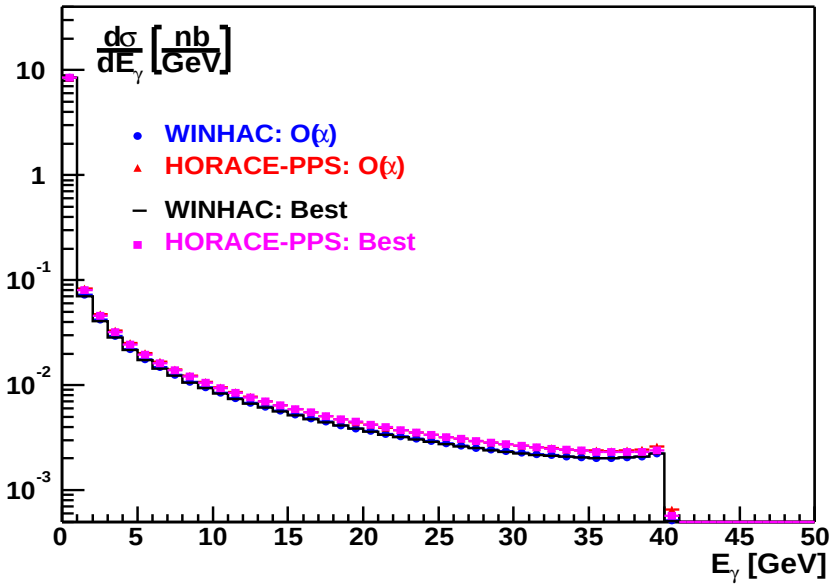

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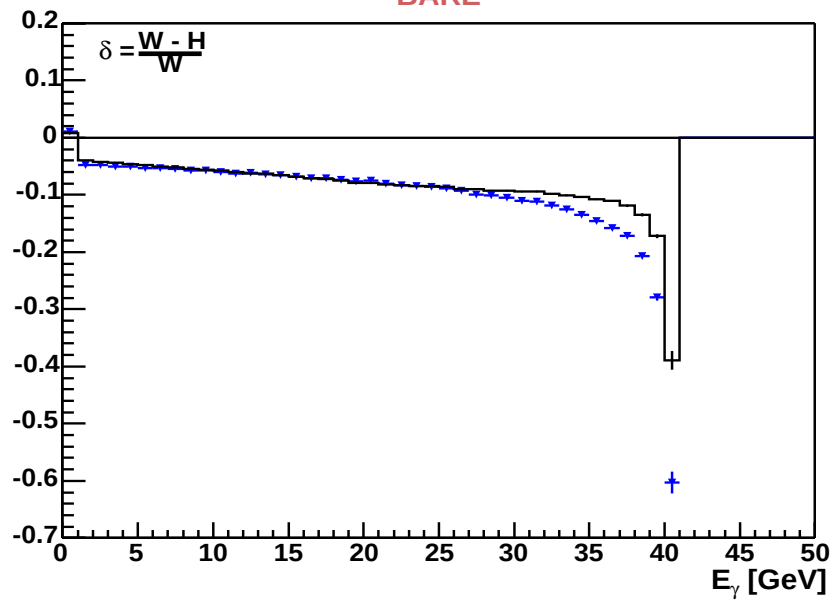

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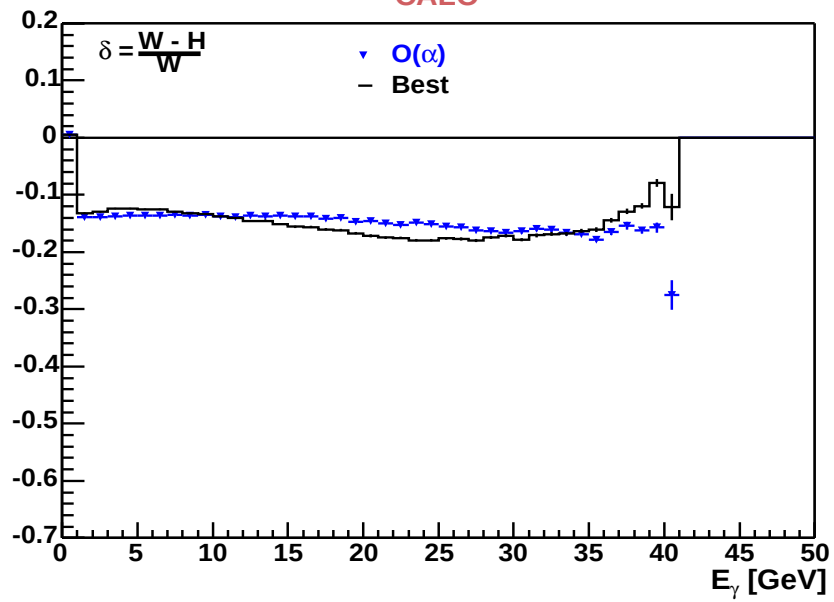

HORACE-IPS vs. WINHAC: $\mathcal{O}(\alpha)$ and Best

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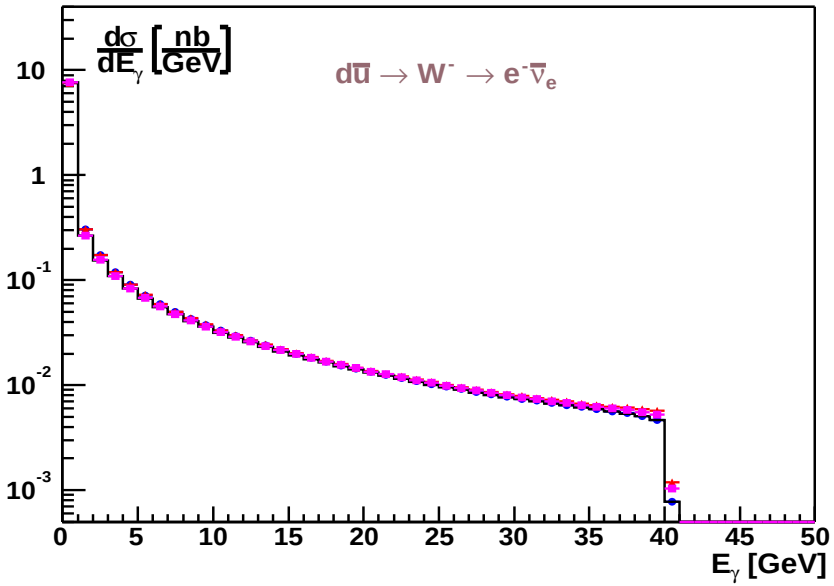

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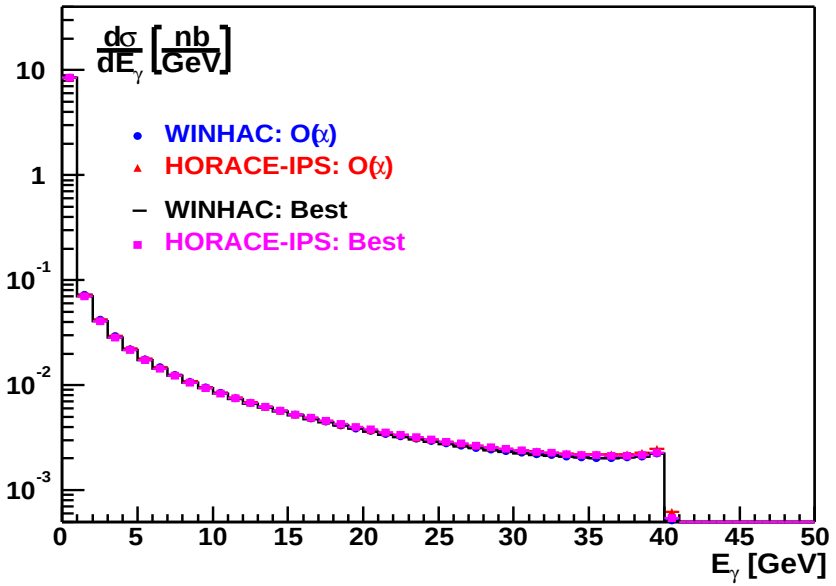

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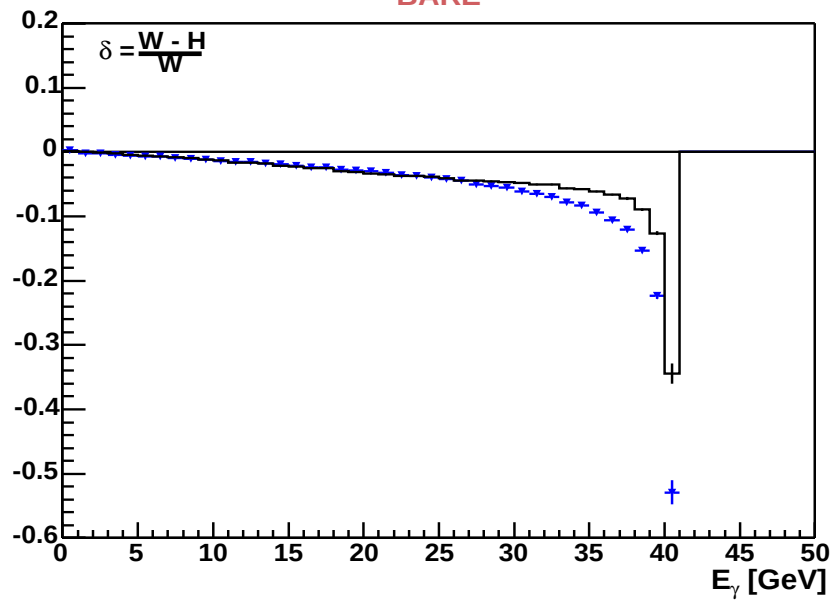

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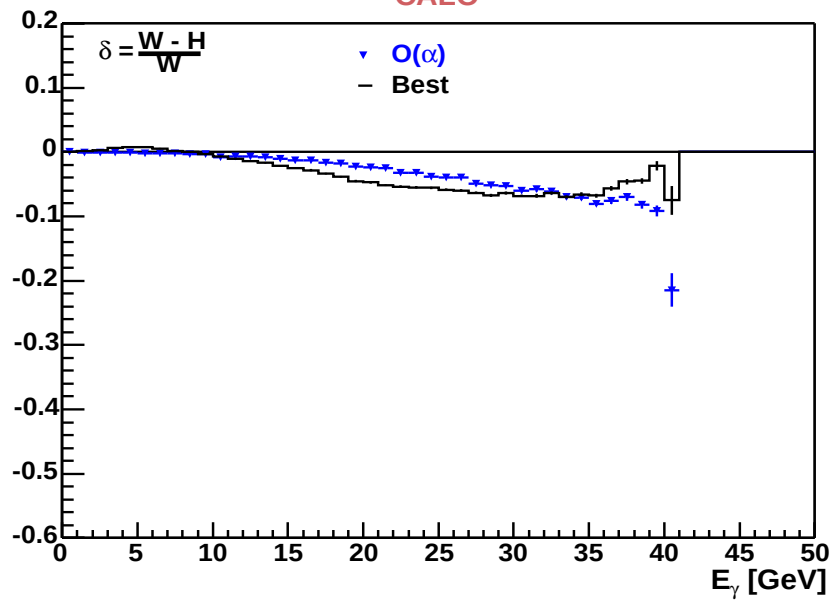

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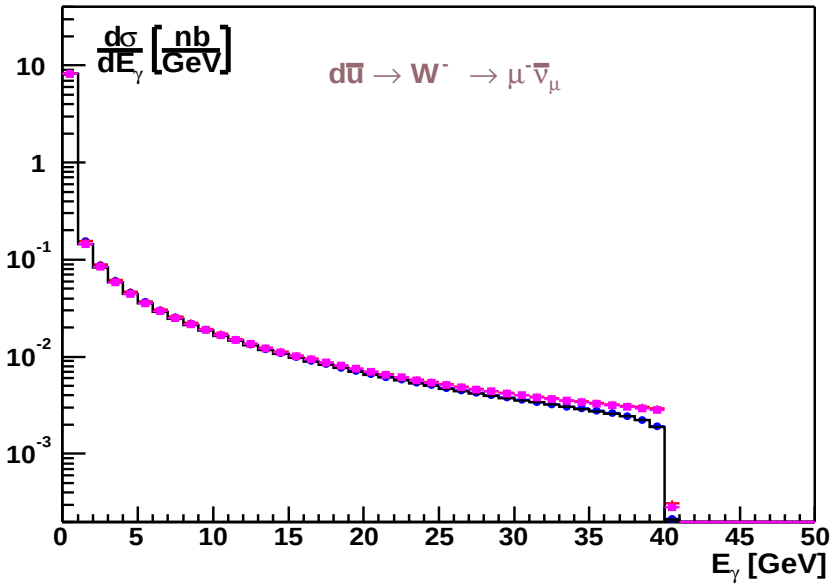

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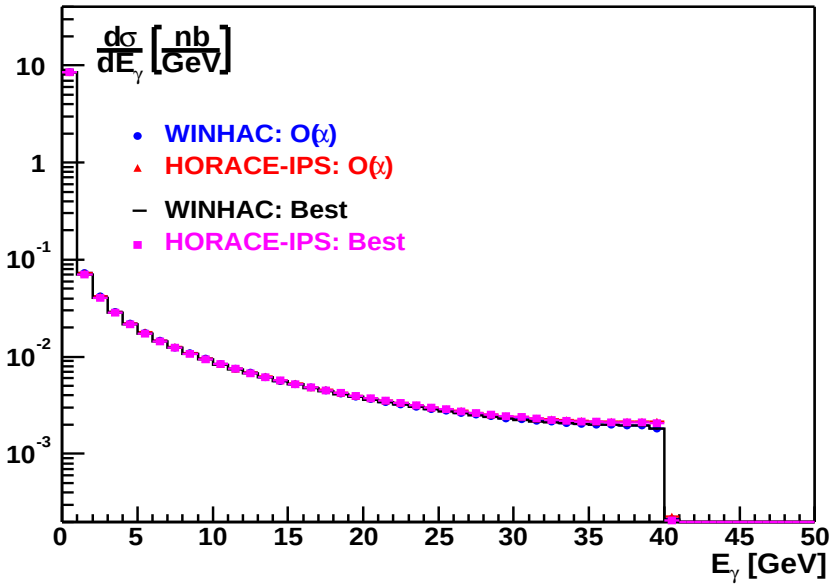

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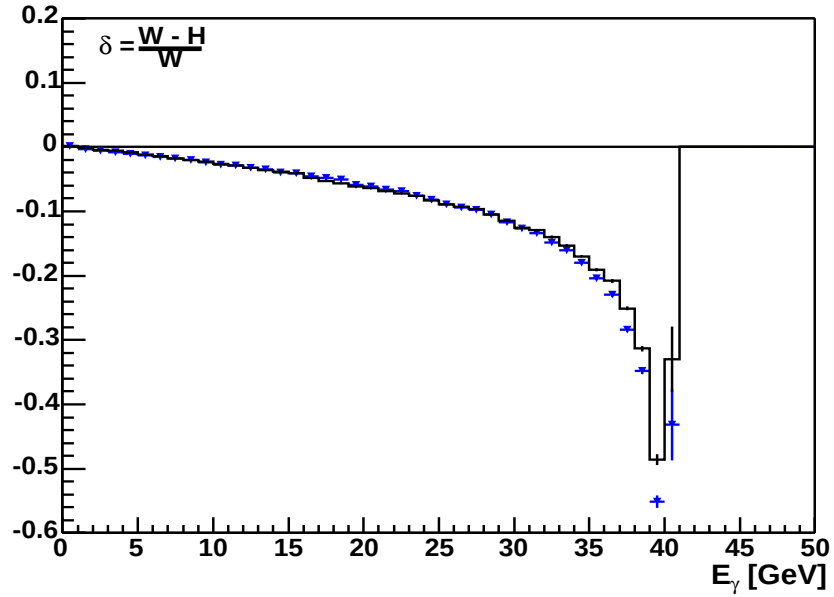

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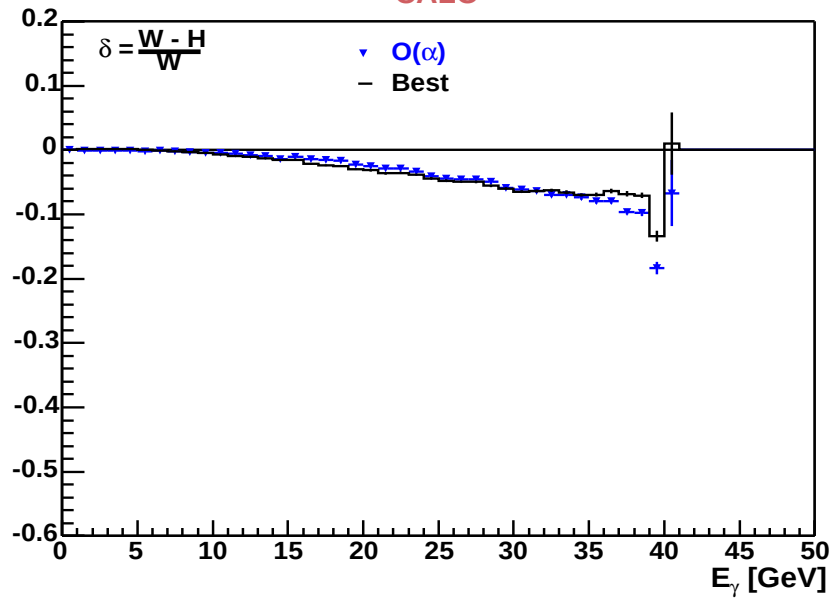

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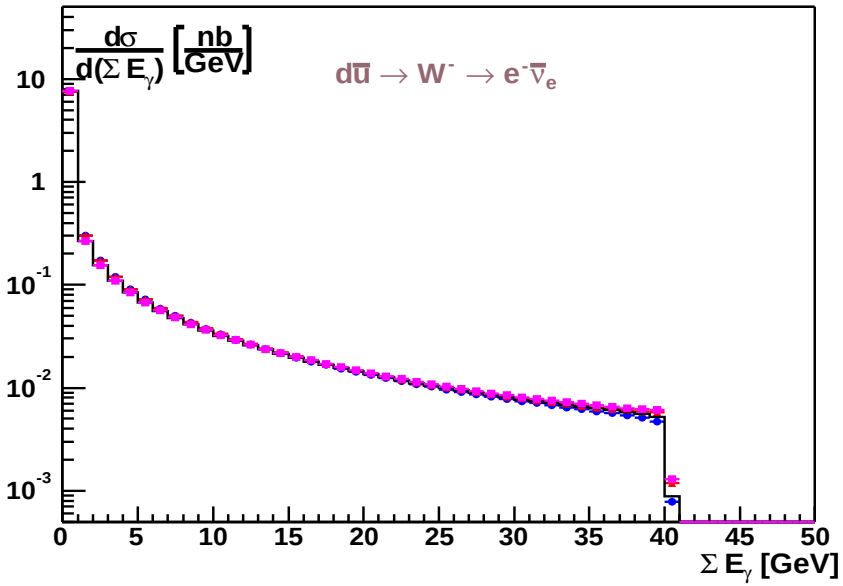

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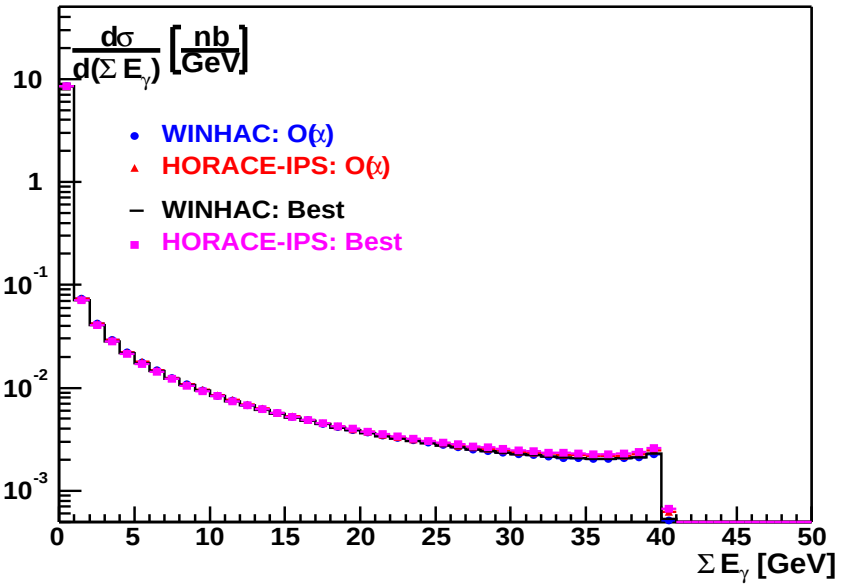

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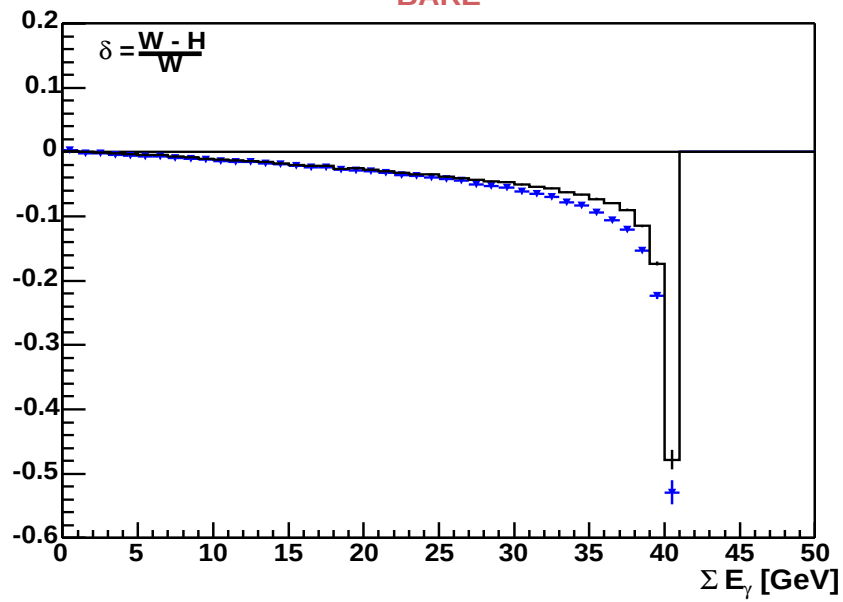

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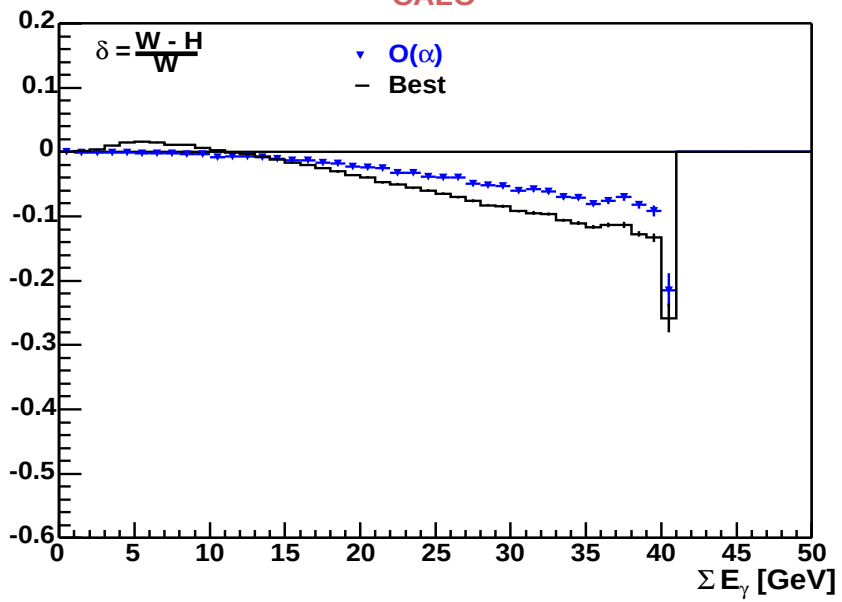

HORACE-IPS vs. WINHAC: $\mathcal{O}(\alpha)$ and Best

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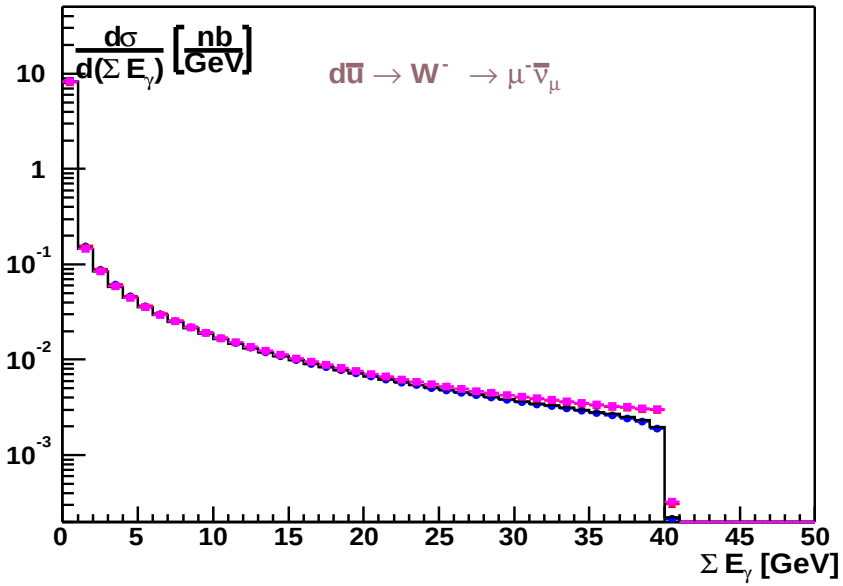

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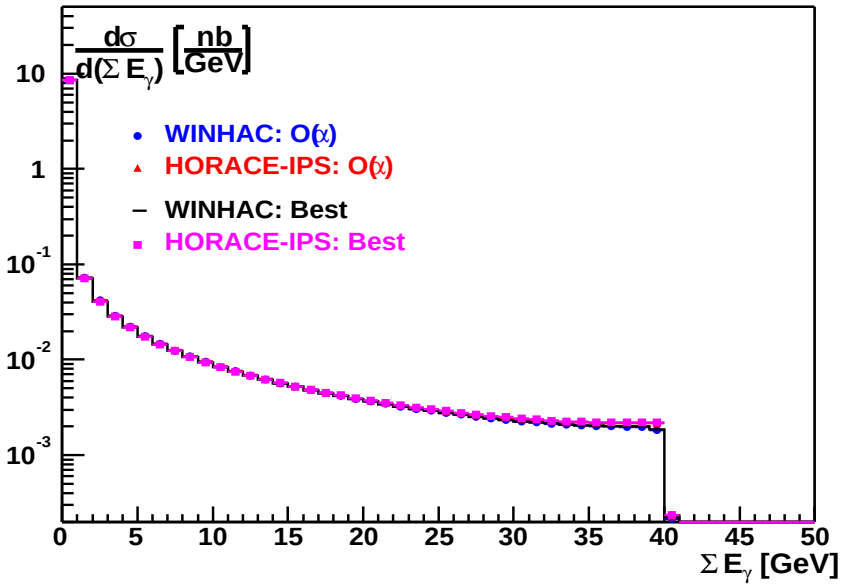

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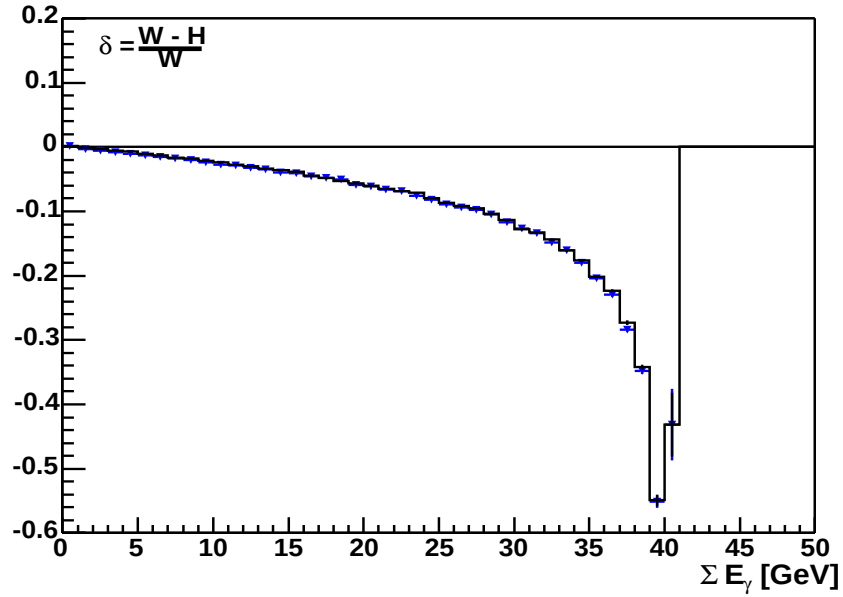

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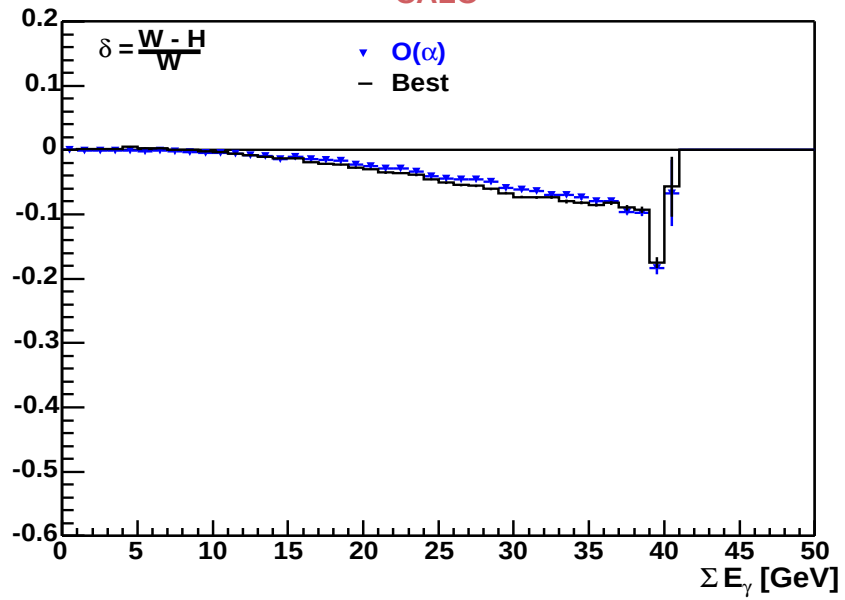
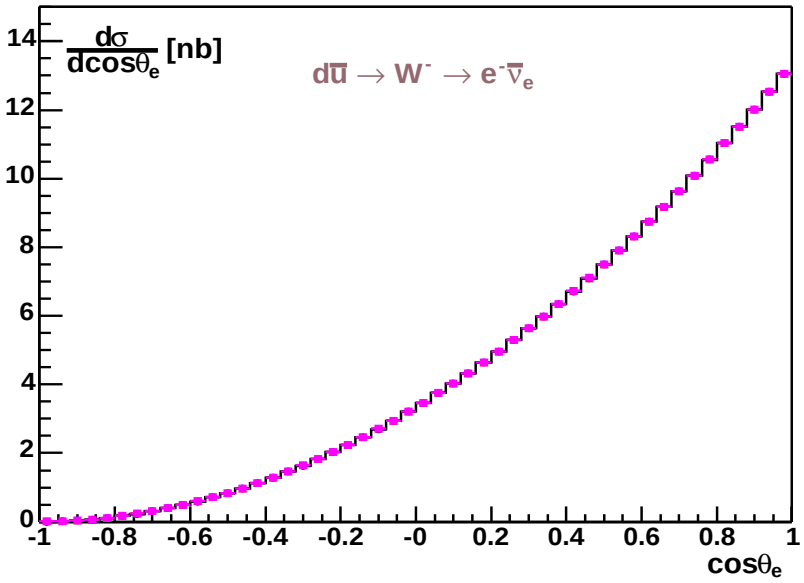


Comments on parton-level comparisons.

- **Differences between HORACE-IPS and WINHAC:**
  - ▷ Up to **a few %** in regions of the large cross section,
  - ▷ Up to **a few tens of %** in regions of the small cross section (particularly where hard non-collinear photons are important).
- **Can we explain these differences?**
  - ▷ Most of the differences seems to come from incomplete $\mathcal{O}(\alpha)$ correction in **HORACE**
    - $\longrightarrow$ Tests of LL-type **PHOTOS** show similar effects (cf. G. Nanava, Z. Was, hep-ph/0303260)
- **How about the higher-order corrections, i.e. beyond $\mathcal{O}(\alpha)$, from the two MC programs?**
  - ▷ They are close to each other $\longrightarrow$ see next slides ...
    - $\Rightarrow$ This support the above statement!

Higher-order corrections: HORACE vs. WINHAC

BARE



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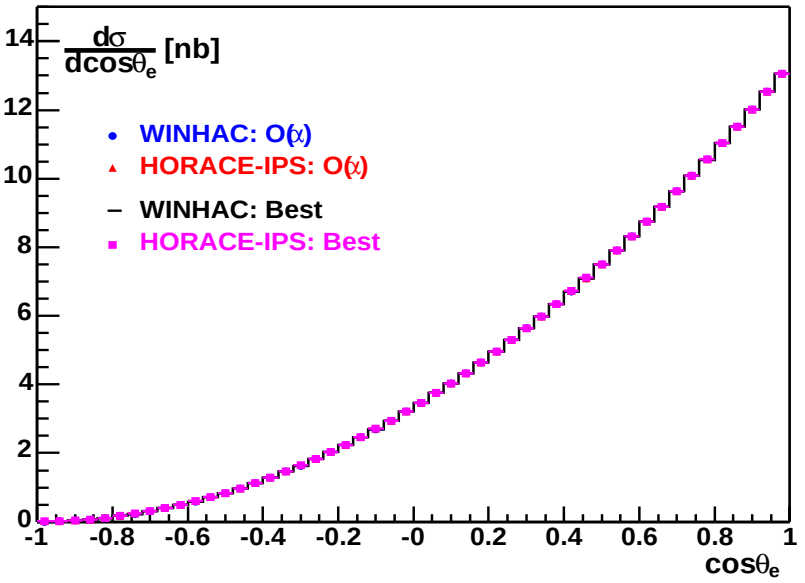

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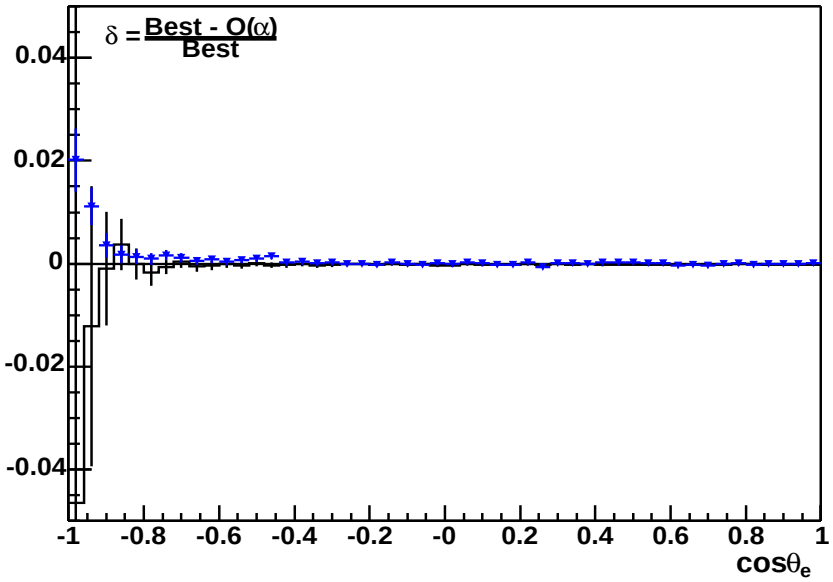

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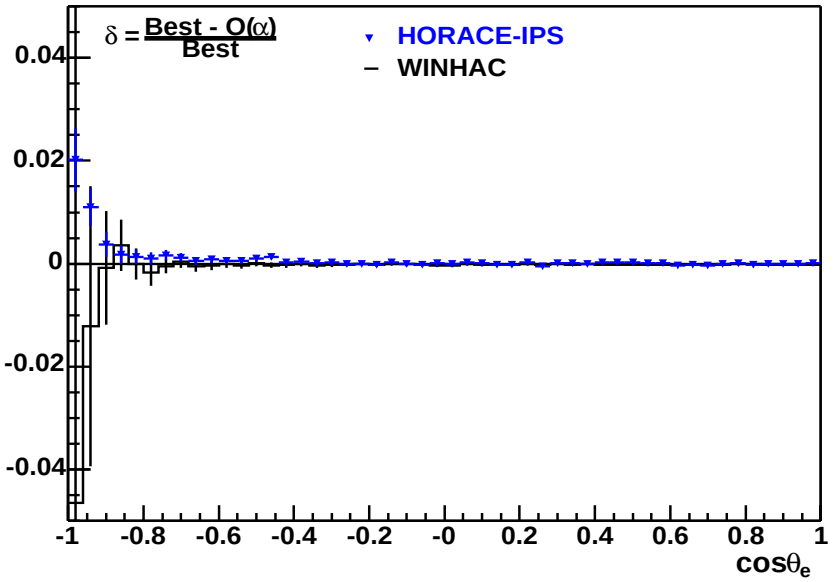

Higher-order corrections: HORACE vs. WINHAC

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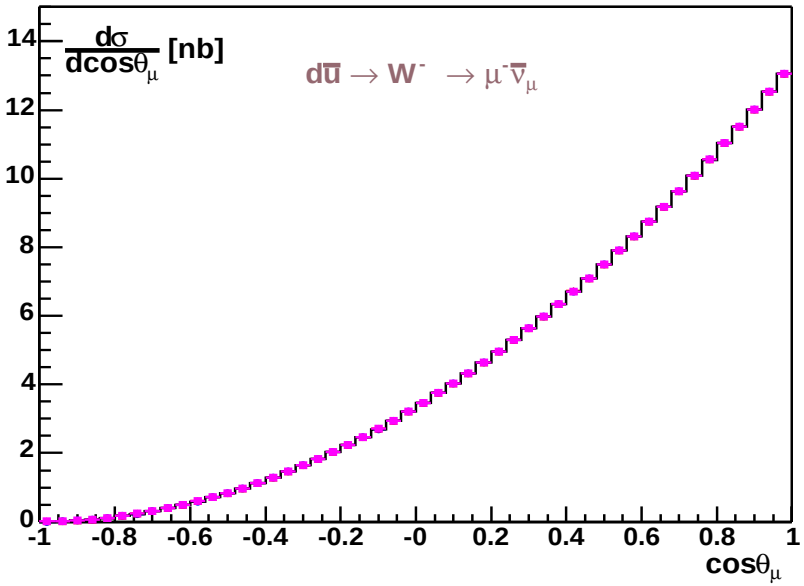

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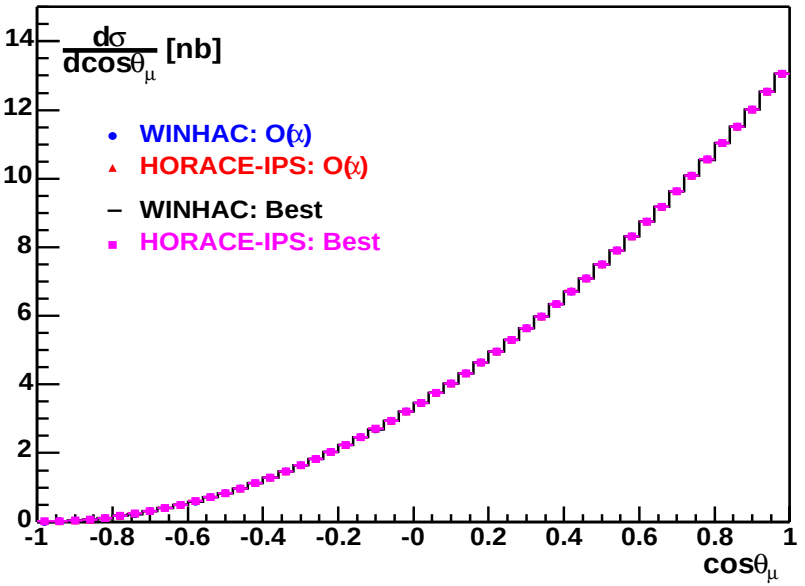

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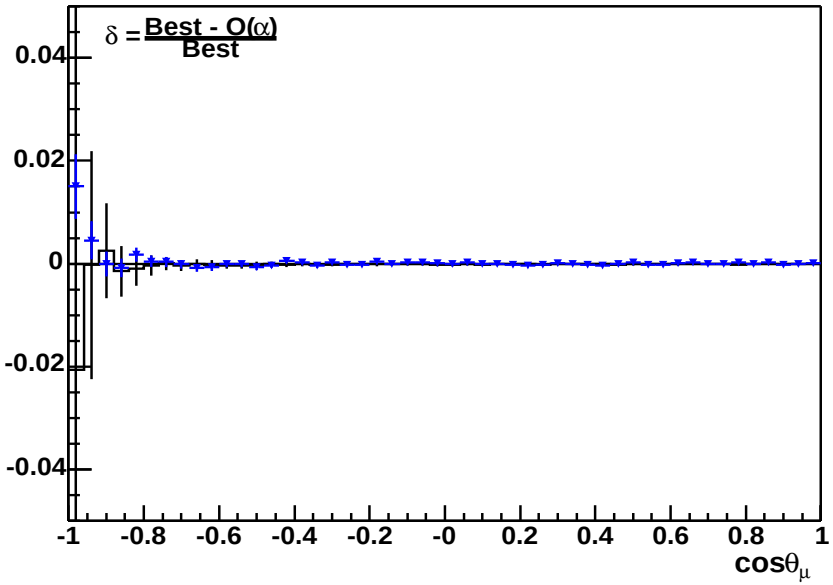

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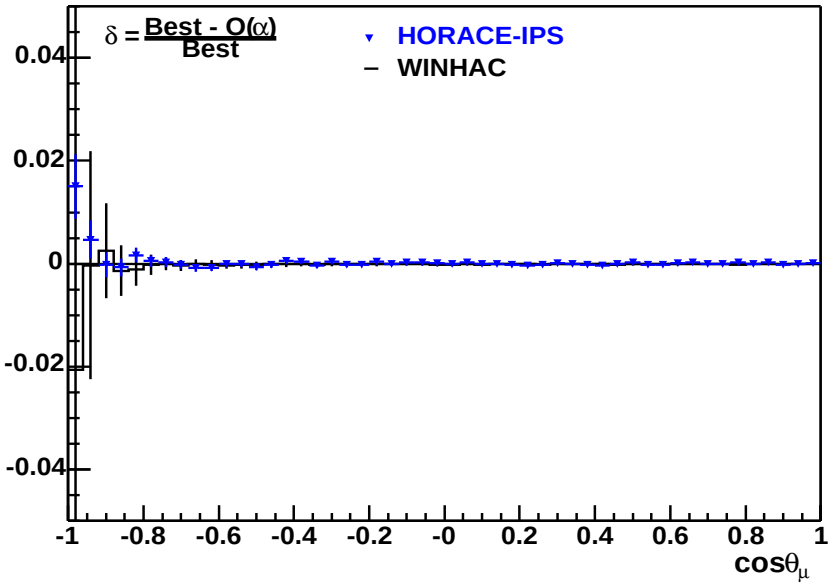

Higher-order corrections: HORACE vs. WINHAC

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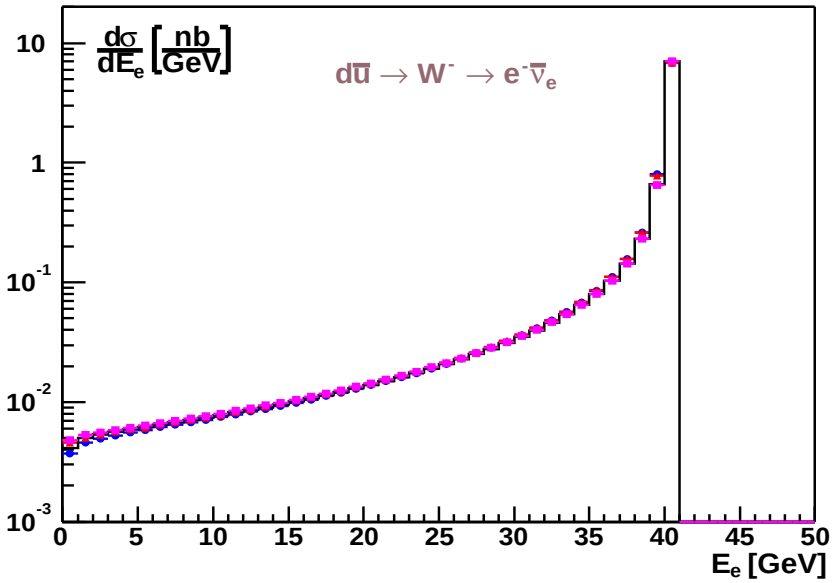

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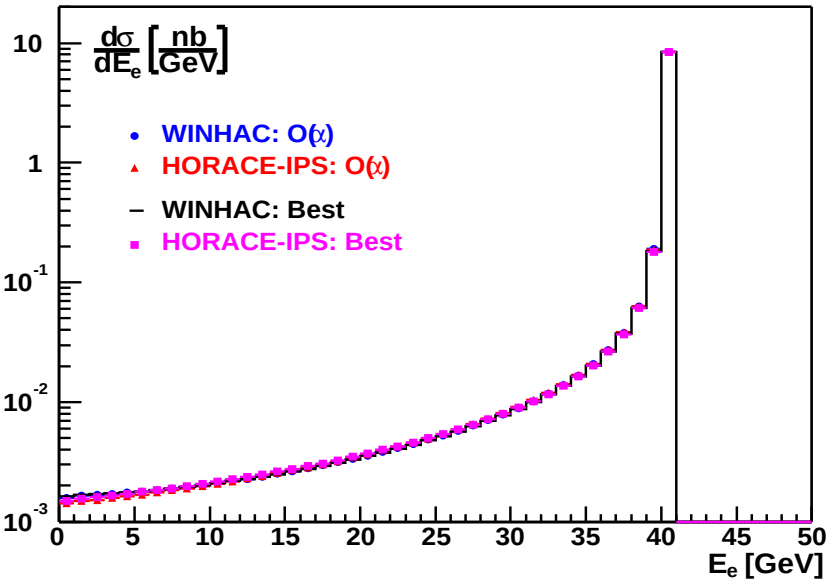

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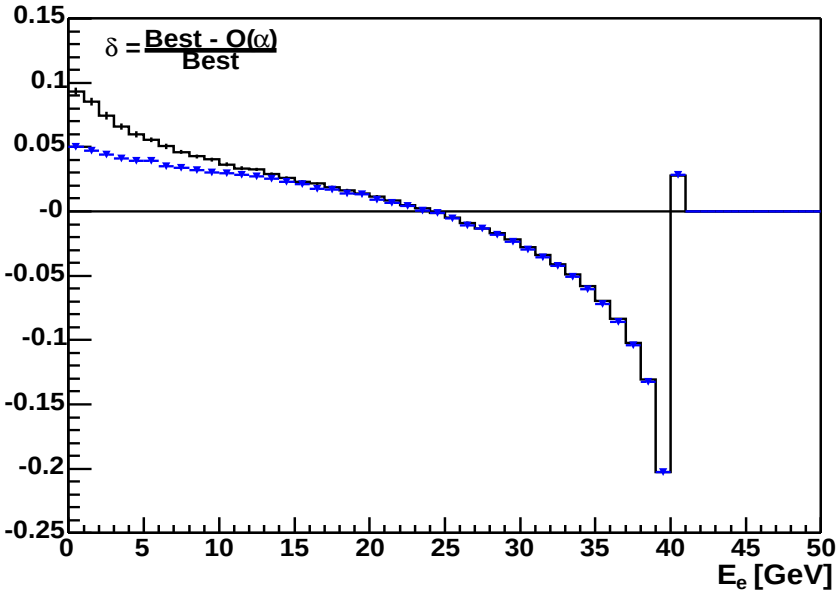

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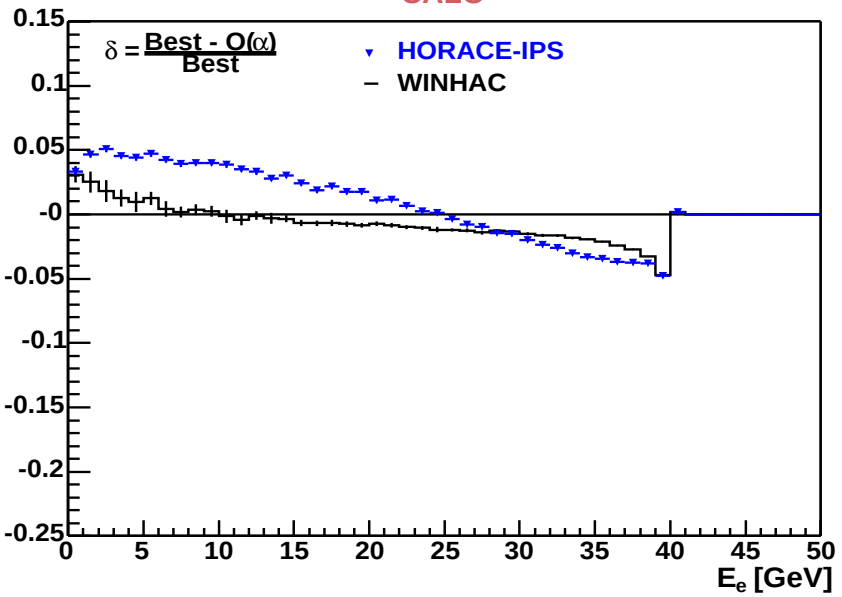

Higher-order corrections: HORACE vs. WINHAC

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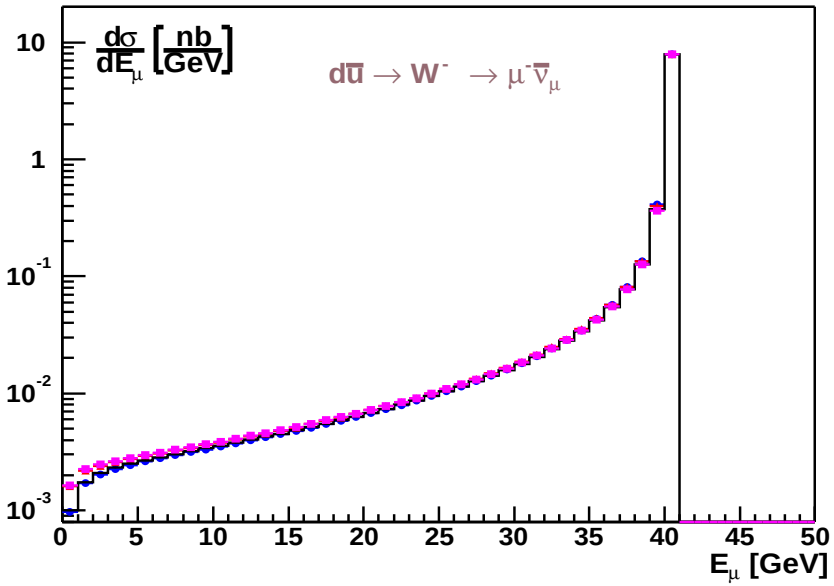

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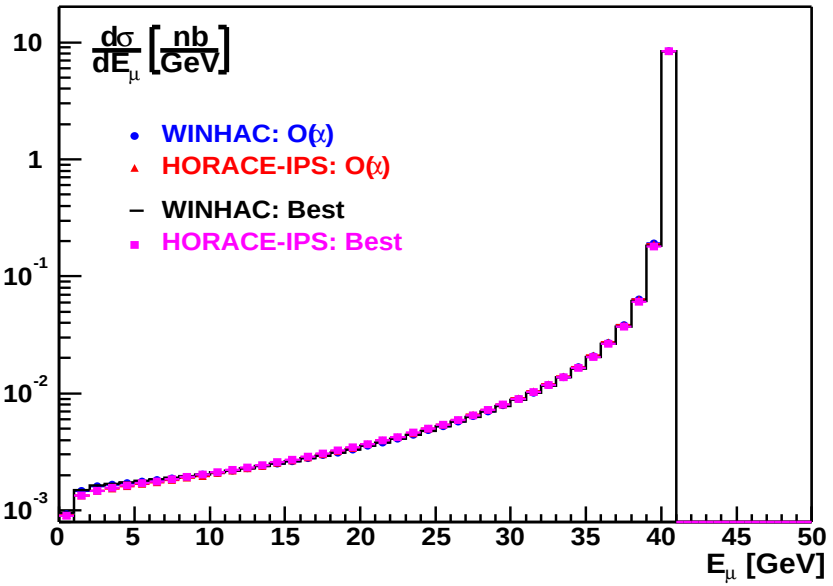

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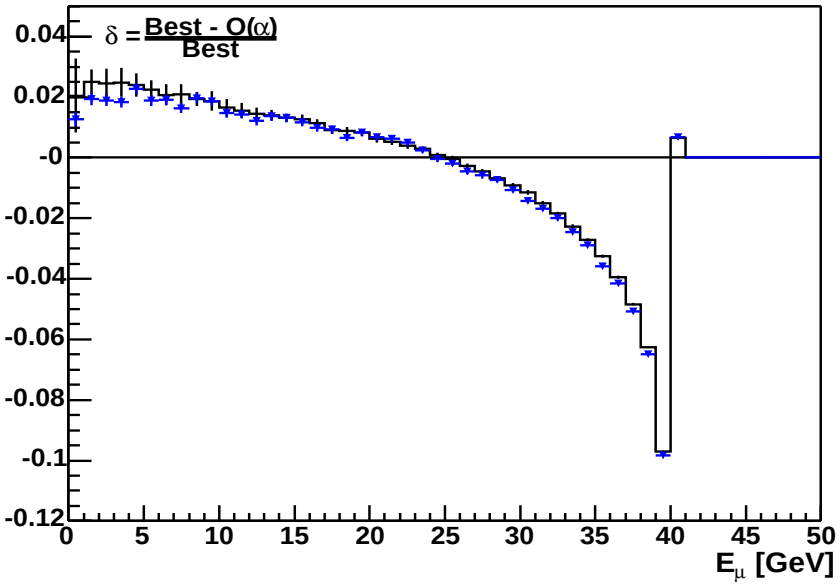

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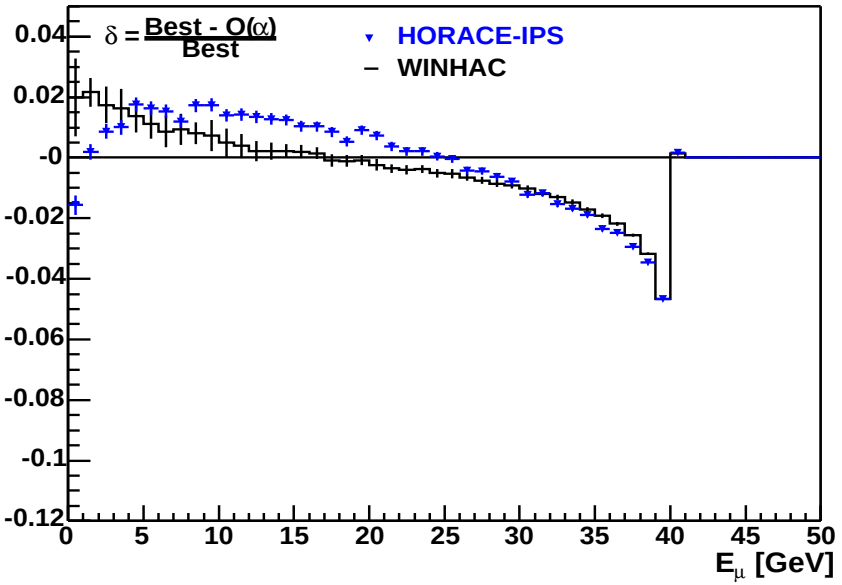
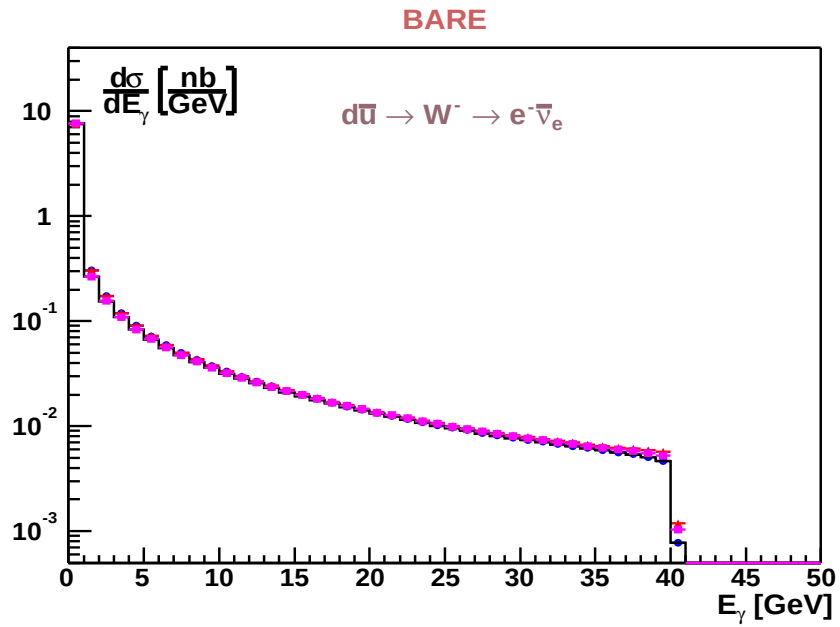
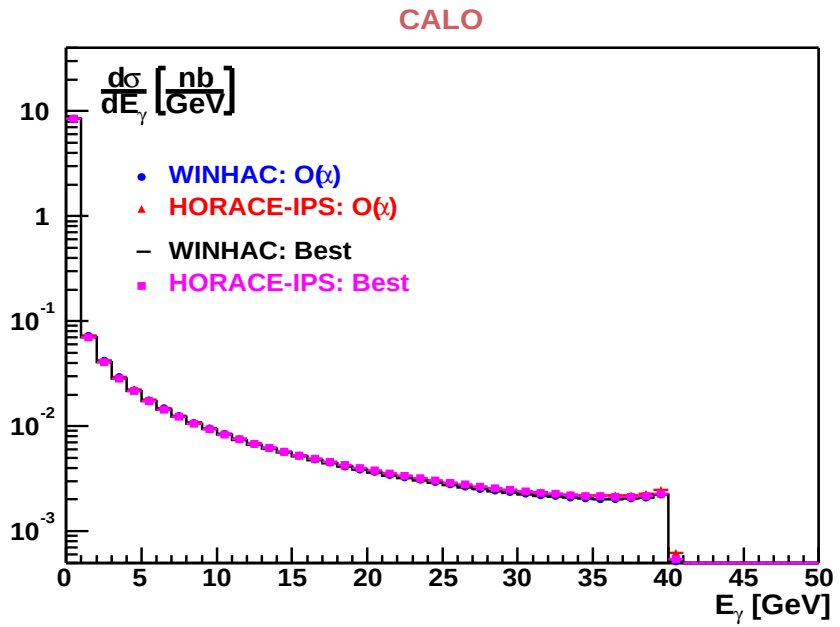
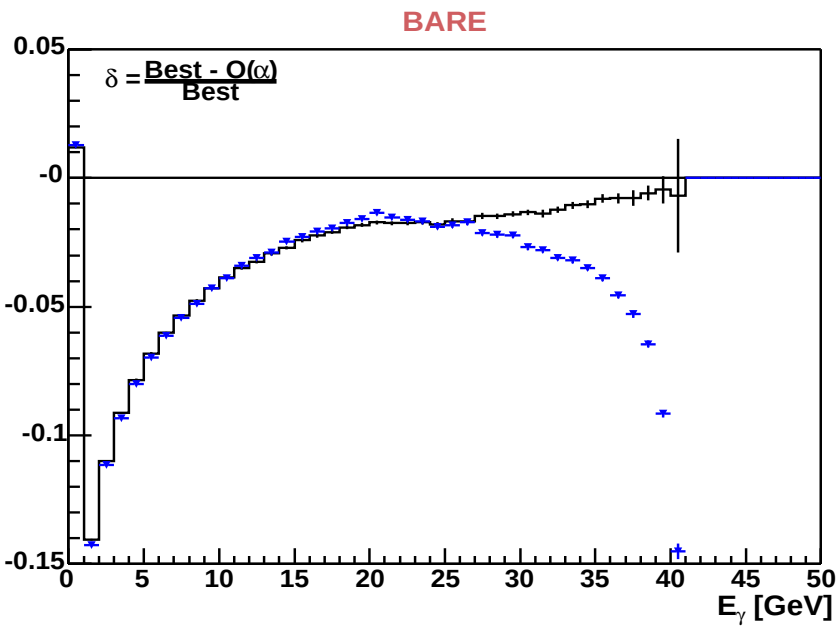
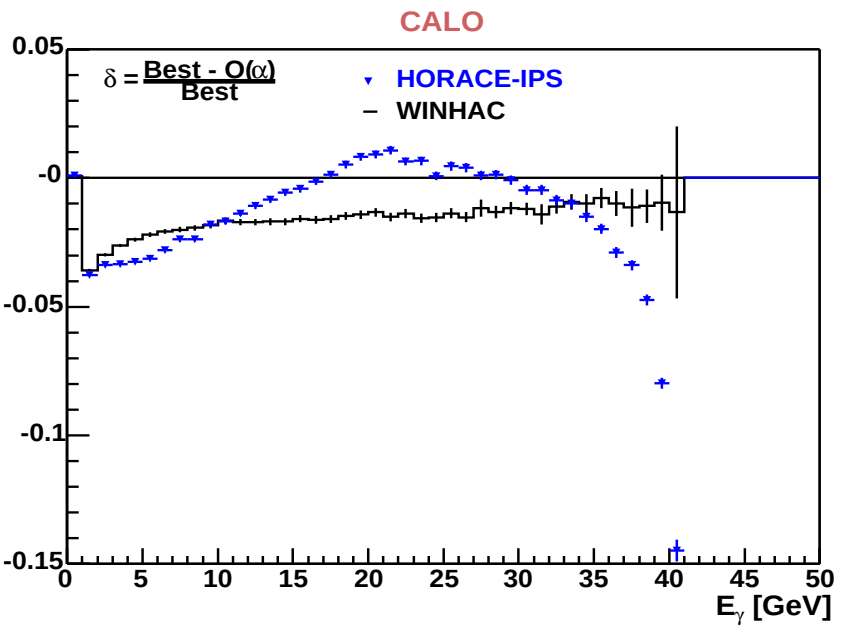


Higher-order corrections: HORACE vs. WINHAC









Higher-order corrections: HORACE vs. WINHAC

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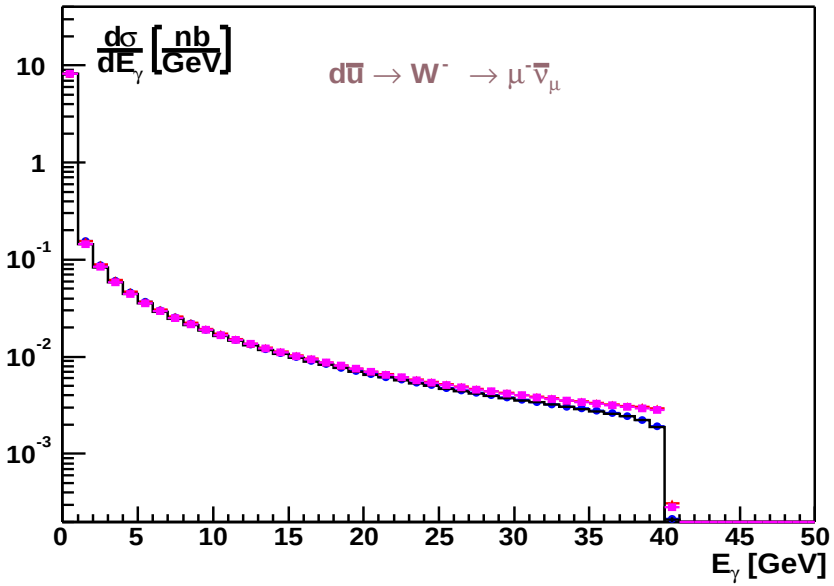

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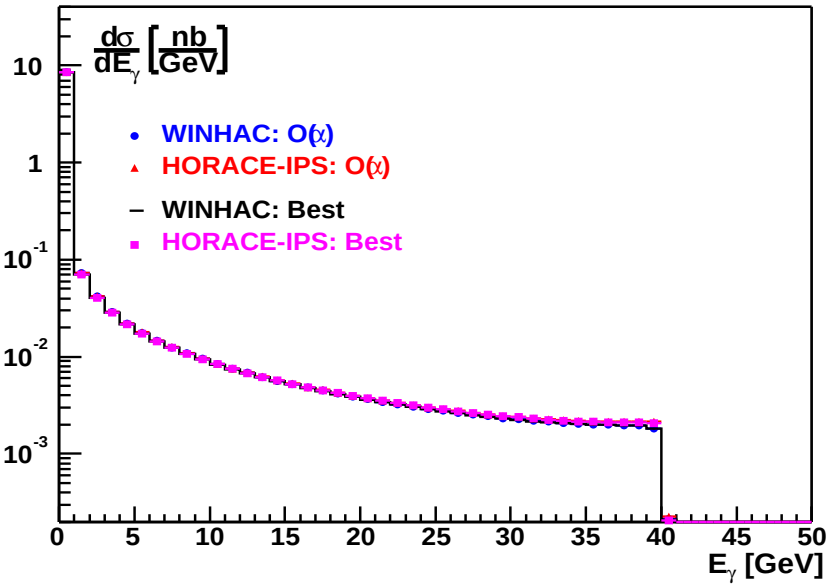

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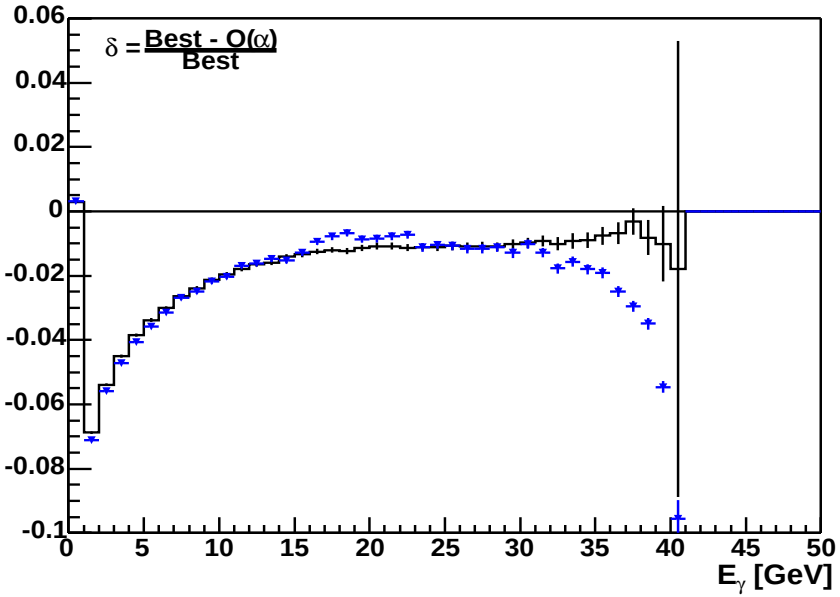

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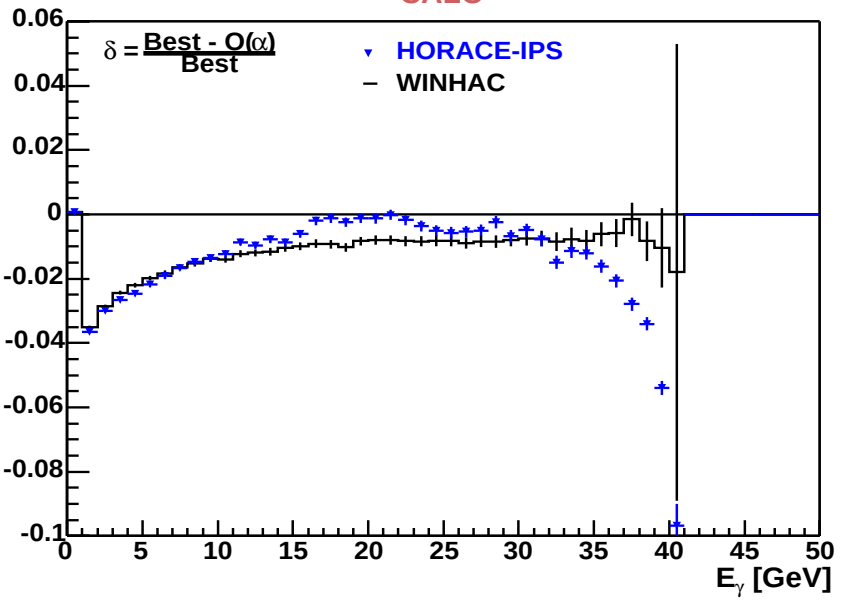

Higher-order corrections: HORACE vs. WINHAC

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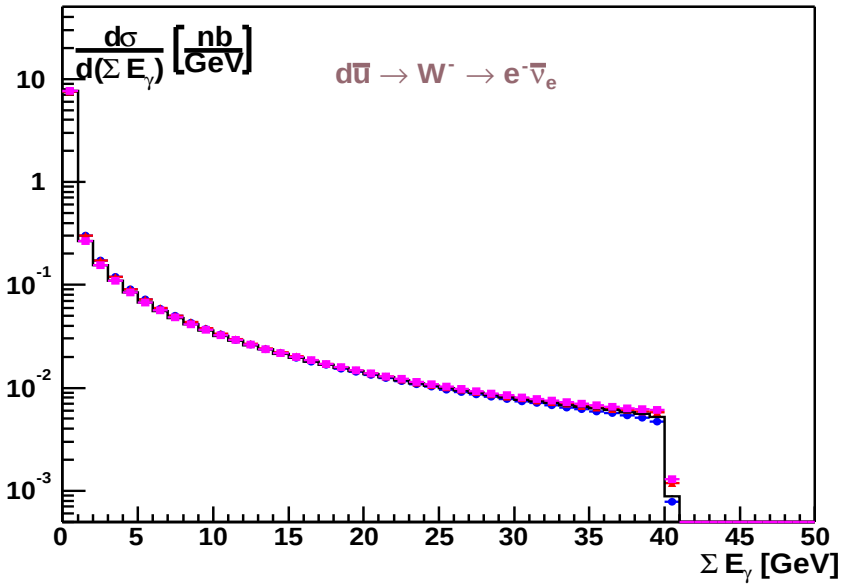

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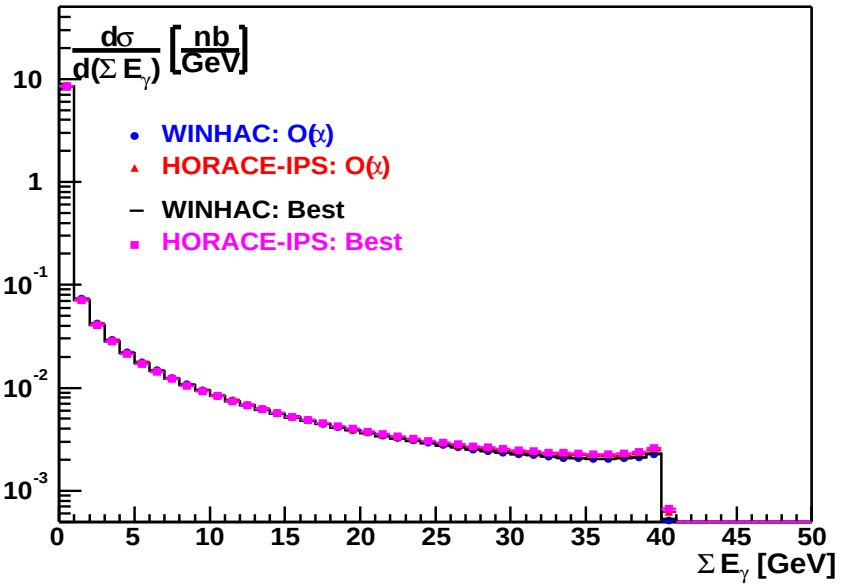

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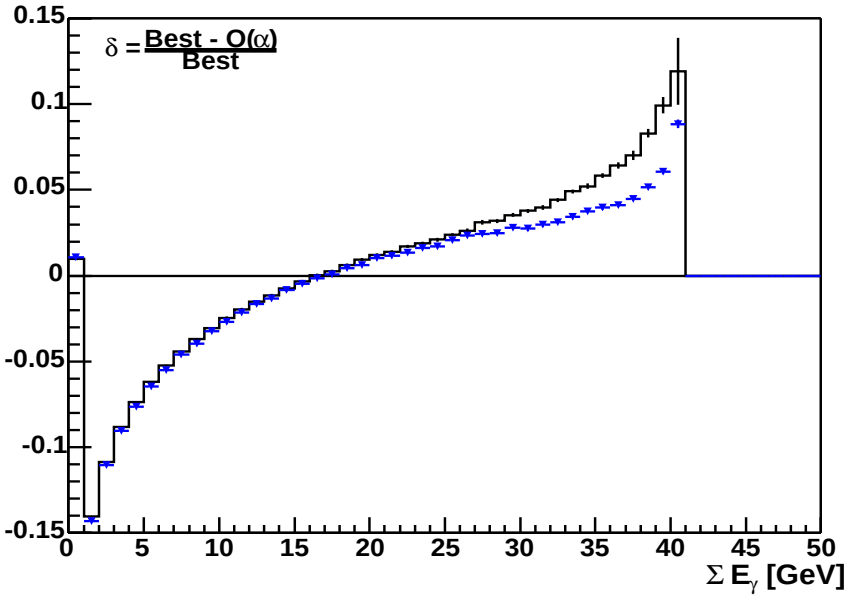

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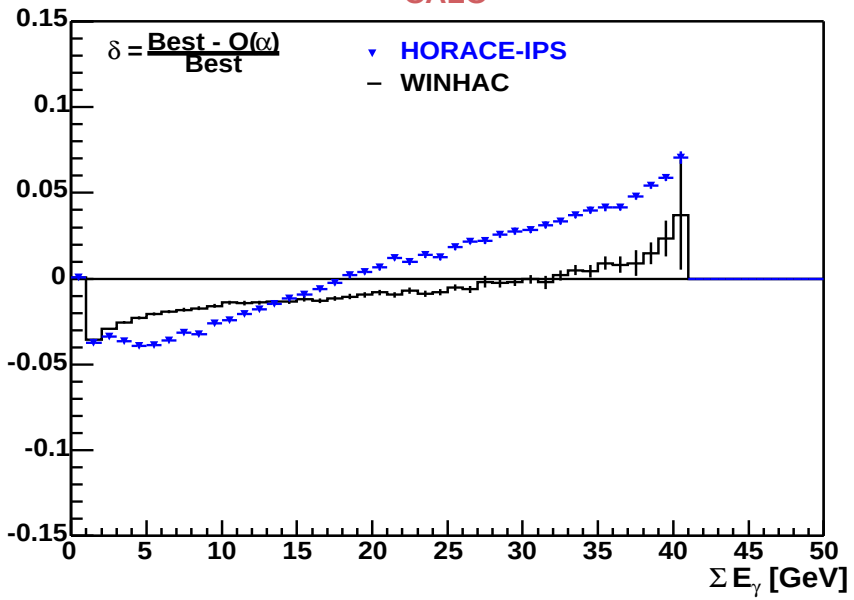

Higher-order corrections: HORACE vs. WINHAC

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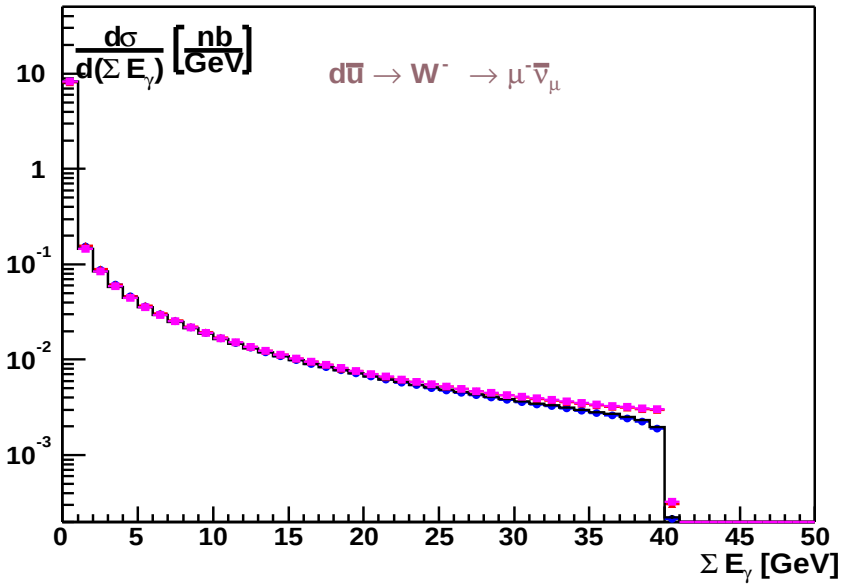

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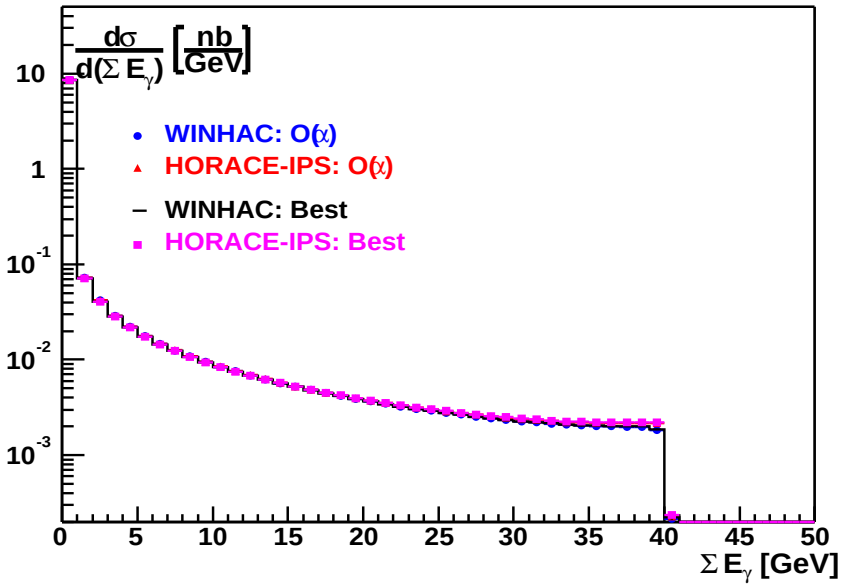

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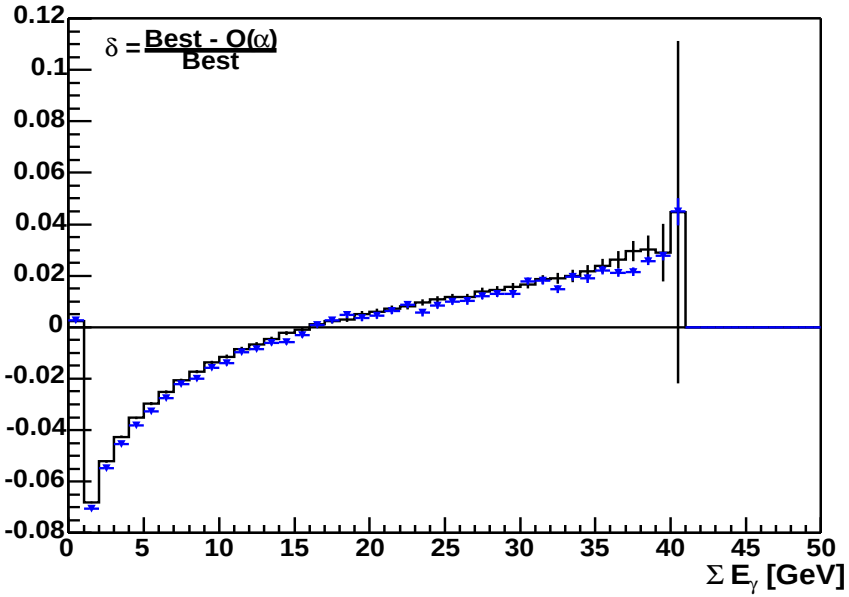

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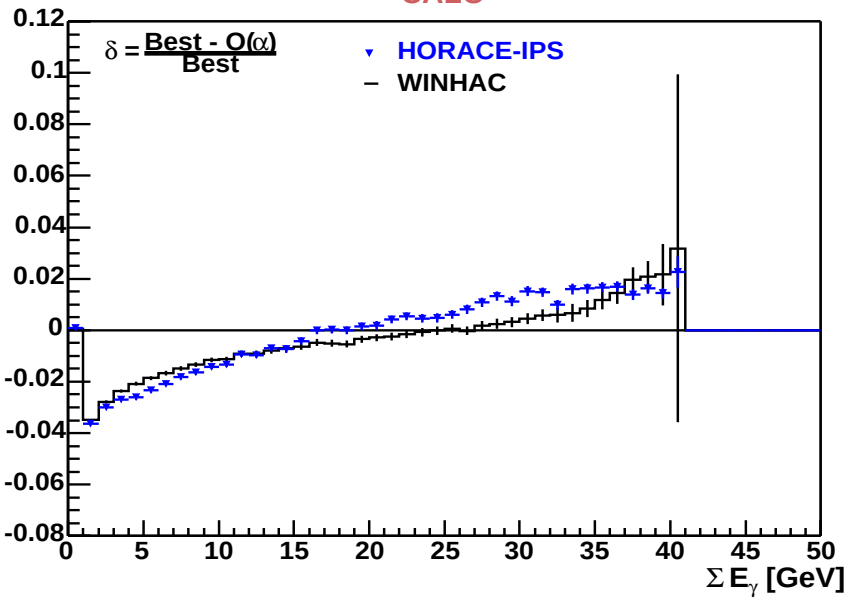

At the hardron level we would like to make comparisons with cuts, selections, etc. which are close to the real experimental set-up!

Selection criteria from ATLAS: (CMS ???)

- charged lepton transverse momentum: $p_T^l > 25\,\mathrm{GeV}$,
- charged lepton pseudorapidity: $|\eta_l| < 2.4$,
- missing transverse energy: $E_T^{\mathrm{miss}} > 25\,\mathrm{GeV}$,
- no jest in the event with: $p_T^j > 30\,\mathrm{GeV}$,
- the recoil system (against the W) transverse momentum: $p_T^{\mathrm{recoil}} < 20\,\mathrm{GeV}$,
- the size of an electron cluster (criteria for recombination of photons with electrons): $d\eta_e \times d\phi_e = 0.075 \times 0.175$
- no photon recombination with muons (?)

Observables:

1. W-boson transverse mass: m_T^W,
2. W-boson rapidity: y_W,
3. charged lepton transverse momentum p_T^l,
4. charged lepton pseudorapidity η_l,
5. photon energy and polar angle (?).

Comparisons:

$\longrightarrow$ **to be done!**

Conclusions and outlook

- **The comparisons at the parton level between two MC codes for single-W production and decay: HORACE (Pavia) and WINHAC (Cracow) have been performed during this workshop.**
- **The differences between the predictions of the two programs seem to be understood**

  $\longrightarrow$ mainly due to incomplete $\mathcal{O}(\alpha)$ correction in **HORACE**.
- **The predictions of the higher-order QED effects from the two programs are similar.**
- **The comparisons at the hadron level will start soon** (this week?)

Announcement:

WINHAC version 1.12 – released on 19 July 2003

$\longrightarrow$ Includes $\mathcal{O}(\alpha)$ EW corrections to W-boson decay – from SANC (D. Bardin et al.)

$\triangleright$ Available at: http://cern.ch/placzek