Sub-group 2 (4f) Status Report *

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Contributions from:

- `CompHEP`
- `GRACE`
- `KORALW + YFSWW3`
- `NEXTCALIBUR`
- `PVALPHA`
- `RACOONWW`
- `WPHACT`

*presented by G. Passarino

Several groups have contributed at various levels, ranging from few numbers to the – almost – complete collection, see

- http://www.to.infn.it/~giampier/lep2.html

From this huge reference collection few relevant samples have been extracted: those where a comparison was possible. Our rule is:

- We do not want to nominate the winner in a MC contest, rather we need to establish a safe estimate of theoretical uncertainty.

$\boxed{\textbf{Single } W}$

- An old comparison has been extended to cover

1. $e^+e^- \to q\overline{q}e\nu(\gamma)$, $|\cos\theta_e| > 0.997$, either $M(q\overline{q}) > 45\,$GeV or $E_{q_1}, E_{q_2} > 15\,$GeV, inclusive cross-section accuracy 2%, photon energy and polar angle ($|\cos\theta_\gamma| < 0.997$ (0.9995)) spectrum
2. $e^+e^- \to e\nu e\nu(\gamma)$, $|\cos\theta_e| > 0.997$, $E_e > 15\,$GeV, $|\cos\theta_e| < 0.7$ (0.95), inclusive cross-section accuracy 5%, photon energy and polar angle ($|\cos\theta_\gamma| < 0.997$ (0.9995)) spectrum.
3. $e^+e^- \to e\nu\mu\nu(\gamma)$ and $e^+e^- \to e\nu\tau\nu(\gamma)$, $|\cos\theta_e| > 0.997$, $E_{\mu/\tau} > 15\,$GeV, $|\cos\theta_{\mu/\tau}| < 0.95$, inclusive cross-section accuracy 5%, photon energy and polar angle ($|\cos\theta_\gamma| < 0.997$ (0.9995)) spectrum.

we want to check:

- $\otimes$ technical precision, BORN (no ISR) is enough,
- $\otimes$ correct inclusion of QED radiation,
- $\otimes$ **QCD** correction, especially in the *low-mass* region.

Answer 1 Technical precision is not a problem anymore, we all agree on *single-W* cross-sections and distributions, even for $\theta_e < 0.1^\circ$ (`even for leptonic final states`).

- On σ_{Born} the technical accuracy is 0.1%, the same for $d\sigma/d\theta_e$ for $\theta_e \to 0$.
  - News are: `NEXTCALIBUR` with masses, uses a massive matrix element program called `HELAC`[1]
  - A completely independent check through `WTO`.
  - `WPHACT` has the implementation of the Imaginary Fermion Loop-scheme, besides the usual fixed-width-scheme)

[1] `HELAC` is a recursive algorithm for electroweak amplitude calculations based on Dyson-Schwinger equations developed by A. Kanaki and C .G. Papadopoulos.

- Not only invariant-mass cuts, but also energy-cuts have been tested:

	$\sqrt{s} = 183\,\mathrm{GeV}$	$\sqrt{s} = 189\,\mathrm{GeV}$	$\sqrt{s} = 200\,\mathrm{GeV}$
`NEXTCALIBUR`	26.483 ± 0.041	29.679 ± 0.047	35.893 ± 0.048
`PVALPHA`	26.47 ± 0.04	29.70 ± 0.04	35.93 ± 0.05

Table 1: Cross-sections [fb] for $e^+e^- \to e^-\overline{\nu}_e\mu^+\overline{\nu}_\mu$.

	$\sqrt{s} = 183\,\mathrm{GeV}$	$\sqrt{s} = 189\,\mathrm{GeV}$	$\sqrt{s} = 200\,\mathrm{GeV}$
`NEXTCALIBUR`	26.422 ± 0.035	29.655 ± 0.046	35.954 ± 0.052
`PVALPHA`	26.3 ± 0.2	29.6 ± 0.2	35.92 ± 0.05

Table 2: Cross-sections [fb] for $e^+e^- \to e^-\overline{\nu}_e\tau^+\overline{\nu}_\tau$.

- There are results also for $e^+e^-\nu_e\overline{\nu}_e$, from `WPHACT` and from `NEXTCALIBUR`.
- There is an, apparently, stronger energy dependence of CompHEP in σ_{Born}. **Overall**-scheme?

Answer 2 QCD and resolved photon are still unanswered.

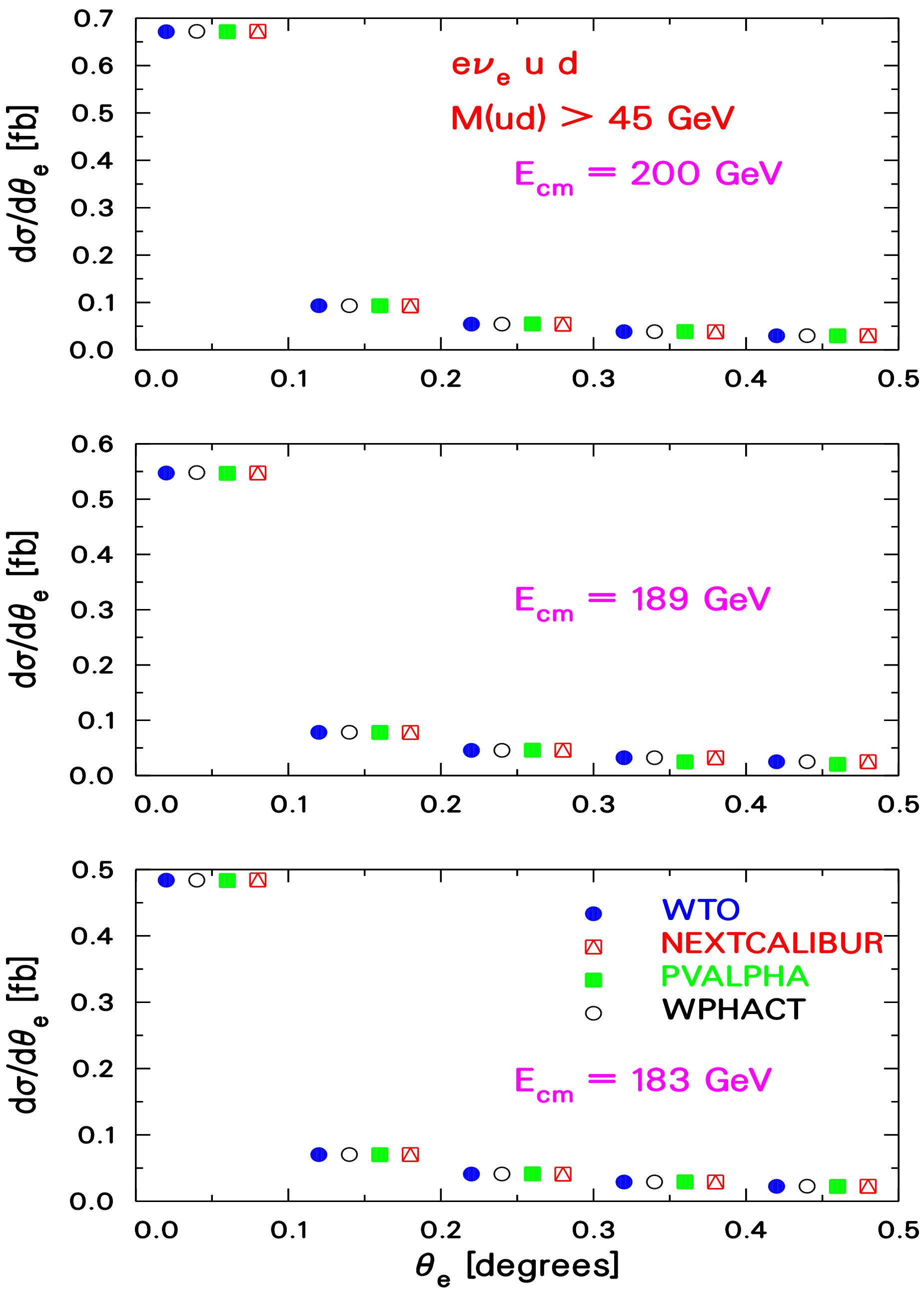


Figure 1: θ_e distributions for $u\overline{d}\mu^-\overline{\nu}_\mu$.

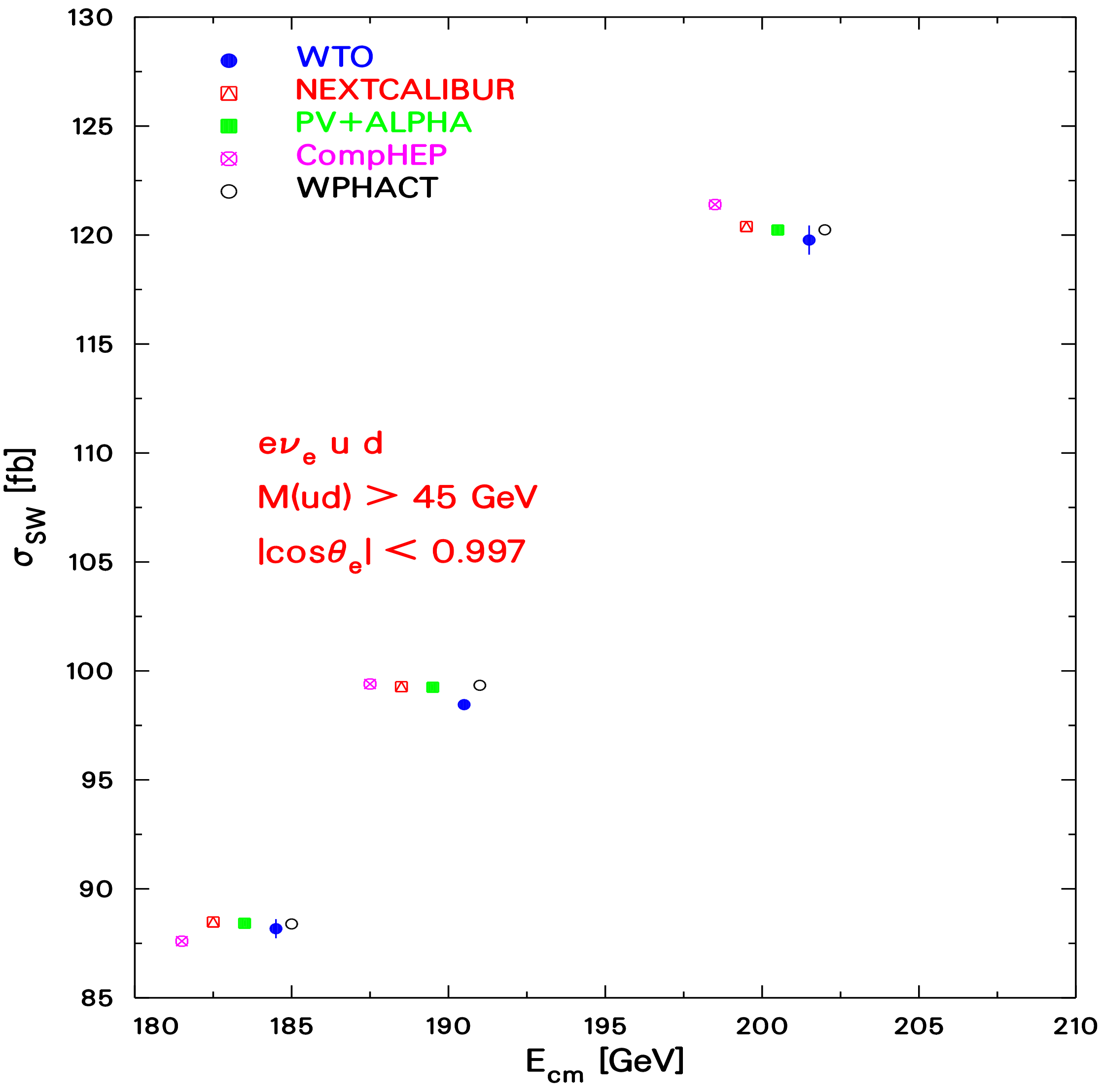


Figure 2: Single-W cross-sections for $u\overline{d}\mu^-\overline{\nu}_\mu$.

$\theta^{\rm min}_{e^-,{\rm beam}}$	0.1°	0.5°	1°	5°	10°
Running width	1.36(1)	0.654(3)	0.6249(4)	0.60167(6)	0.58907(5)
Fixed width	0.641(1)	0.6256(8)	0.6188(5)	0.6020(2)	0.58915(5)
Running width + γWW vertex factor	0.641(1)	0.6245(5)	0.6187(5)	0.60190(2)	0.589242(8)
Full FL scheme	0.642(3)	0.630(1)	0.6247(4)	0.6100(2)	0.59771(7)

Table 3: Total cross-sections in pb at $\sqrt{s} = 175$ GeV with canonical cuts except between the outgoing electron and either beam as predicted by WTO for the CC20 process.

Answer 3 Scale in *single-W*. It is somewhat connected to the gauge-invariant treatment. Everything has been used: *overall*, *fixed-width* and *Imaginary Fermion Loop* (by `WPHACT`).

– However, scale is connected to the real part of the corrections, so we need *Complete FL* for *single-W*, that nobody has (`WTO` will). Scale is important, we use ($M_Z = 91.1867$ GeV, $M_W = 80.350$ GeV)

$$s^2_W = 1 - \frac{M^2_W}{M^2_Z}, \qquad \alpha = 4\sqrt{2}\,\frac{G_F M^2_W s^2_W}{4\,\pi},$$
$$\alpha_{\rm QED} = 1/131.95798$$

when, in the t-channel, the scale is $Q^2 \approx 0$.

– Some old result in Tab.(3):

Answer 4 s-channel SF are not adequate enough to include QED radiation. See talks by `Kurihara` and `Pallavicini` for a status report on improvements/th uncertainty. Further **Questions**:

single - W is $s \oplus t$- channels. For t-channel it looks like

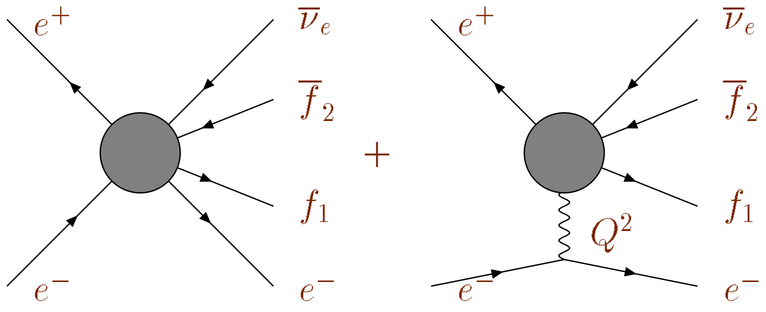
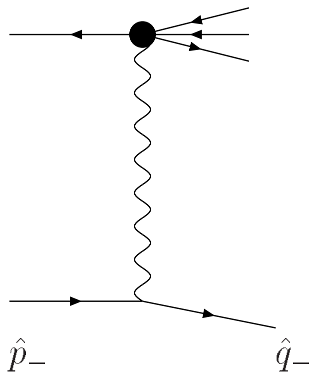


Figure 3: The CC20 family of diagrams with the explicit component containing a t-channel photon.

- The cross-section is proportional to



$$\int d\Phi_3 \qquad \frac{1}{\hat{Q}^4}\,\hat{L}_{\mu\nu}\hat{W}_{\mu\nu}$$

$$\begin{aligned} \hat{Q} &= \hat{p}_- - q_- \\ \hat{L}_{\mu\nu} &= \frac{1}{2}\,\hat{Q}^2\delta_{\mu\nu} + \hat{p}_{\mu}\hat{q}_{\nu} + \hat{q}_{-\mu}\hat{p}_{-\nu} \end{aligned}$$

$$\int d\Phi_3 \hat{W}_{\mu\nu} = \hat{W}_1\,(-\delta_{\mu\nu} + \frac{\hat{Q}_\mu\hat{Q}_\nu}{\hat{Q}^2}) - \frac{\hat{Q}^2}{(\hat{p}_+\cdot\hat{Q})^2}\,\hat{W}_2\,\mathcal{P}_\mu\mathcal{P}_\nu$$

$$\mathcal{P}^\mu = \hat{p}_+^\mu - \frac{\hat{p}_+ \cdot \hat{Q}}{\hat{Q}^2}\,\hat{Q}^\mu$$

- where $\hat{p}$ and $\hat{q}$ denote emission of soft and collinear photons.
- Usually, $p_-^2 = \hat{p}_-^2 = 0$ and $q_-^2 = \hat{q}_-^2 = 0$, and one writes $\hat{p}_- = x_{\rm in}\, p_-$ and $\hat{q}_- = q_-/x_{\rm out}$ with the kernel cross-section to be weighted with SF or whatever. Here, however, masses matter and the electrons are in a virtual state, off their mass-shell.
- A possible choice is

$$(\hat{p}_-)^2 = -m_e^2 + \frac{1}{2}\,(1-\beta)\,(1-x_{\rm in})\,s \sim -x_{\rm in}\,m_e^2$$

The important facts are that $\hat{Q}_\mu \hat{L}_{\mu\nu} = 0$ (gauge invariance)

- Instead we get

$$\hat{Q}_\mu \hat{L}_{\mu\nu} = 4\,(1-x_{\rm in})\,m_e^2\,q_{-\nu} + 4\,(1-\frac{1}{x_{\rm in}})\,m_e^2\,p_{-\nu}.$$

- Even if you insist in putting $\hat{p}_- = x_{\rm in} p_-$ and $p_-^2 = -m_e^2$ gauge invariance is violated by terms of $\mathcal{O}\left(m_e^2/s\right)$.

- The effect of constant terms on the Q^2-integrated photon flux-function can be as much as 6%. Gauge invariance violation affects this term, resulting in some *intrinsic theoretical uncertainty*.

- Additional remarks:
  - Of course, the exact matrix element for *single W* + visible γ preserves gauge invariance. However, it requires masses and, therefore, cannot be evaluated by 4f + γ massless MC.

- **Conclusions** for *single-W*:
  1. Born technical accuracy is satisfactory $\approx 0.1\%$,
  2. but there is a discrepancy for leptonic final states.
  3. ISR technical precision $\oplus$ theoretical accuracy yet to be fixed.

$$\boxed{\textbf{4f} \oplus \textbf{a visible } \gamma.}$$

- In a vast majority of cases our main problem is represented by the inclusion of QED radiation. Could we improve upon our treatment of QED radiation or give some safe estimate of the theoretical uncertainty associated with it?

- The first step is represented by the inclusion of one *visible* γ

- For all processes, we requested radiative corrections and radiative photons, discussing energy and polar-angle spectra. Typical minimal requirements on photons were: energy $E_\gamma > 1$ GeV; polar angle $|\cos\theta_\gamma| <$

$0.985, 0.997, 0.9995$ depending on channel; and minimal angle between photon and any charged final-state fermion $\xi > 5°$.

- A first comparison:

	$\sqrt{s} = 183\,\mathrm{GeV}$	$\sqrt{s} = 189\,\mathrm{GeV}$	$\sqrt{s} = 200\,\mathrm{GeV}$
PVALPHA	78.80 ± 0.26	75.18 ± 0.24	70.19 ± 0.19
CompHEP$^{1)}$			60.7 ± 0.8
CompHEP$^{2)}$			68.9 ± 0.9
GRACE			79.7 ± 0.2
RACOONWW			73.4 ± 0.1

Table 4: Cross-section for $e^+e^- \to \mu^-\overline{\nu}_\mu u\overline{d}\gamma$.

1. Overall
2. Fixed-width

Answer 5 When numbers are available we can compare and:

– **Differences seems to be** $> 15\%$

- More work?

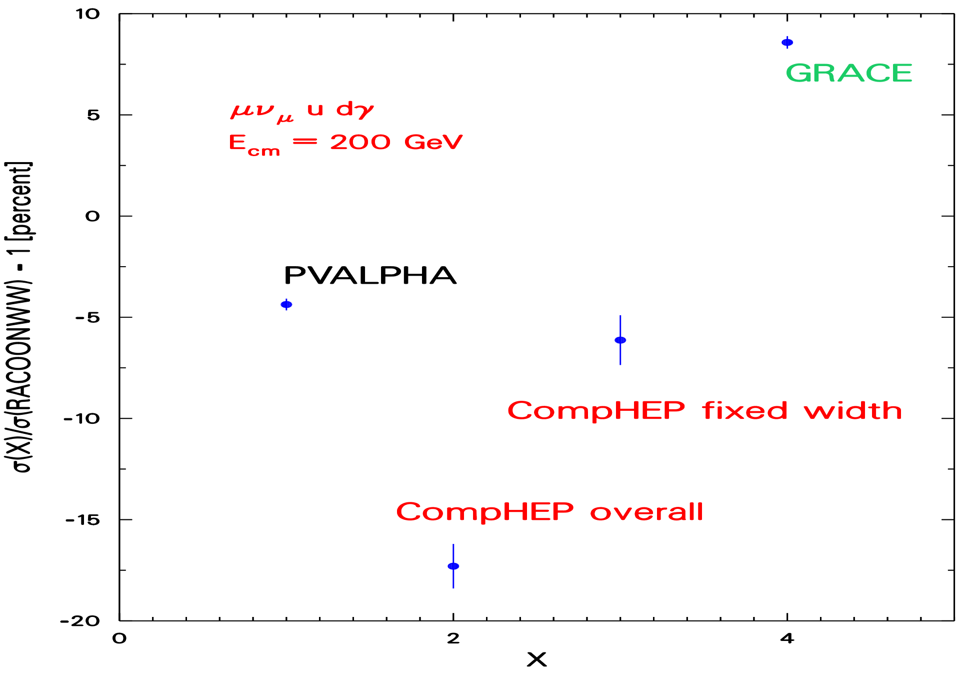


Figure 4: Total cross-sections for $u\overline{d}\mu^-\overline{\nu}_\mu$.

There are several more results where, however, we cannot compare, the intersection being empty.

	4f + γ processes		
	183	189	200
	$e^-\overline{\nu}_e u\overline{d}\gamma$		
PVALPHA	71.09 ± 0.16	75.56 ± 0.22	81.18 ± 0.23
	$\mu^-\overline{\nu}_\mu \tau^+\nu_\tau\gamma$		
PVALPHA	26.62 ± 0.05	28.30 ± 0.06	29.45 ± 0.07
RACOONWW			27.09 ± 0.04
	$e^-\overline{\nu}_e \mu^+\nu_\mu\gamma$		
PVALPHA	27.02 ± 0.06	28.89 ± 0.07	30.32 ± 0.07
	$e^-\overline{\nu}_e u\overline{d}\gamma$		
PVALPHA	71.09 ± 0.16	76.56 ± 0.22	81.18 ± 0.23
	$u\overline{d}c\overline{s}\gamma$		
PVALPHA	181.9 ± 0.3	196.3 ± 0.4	208.0 ± 0.4
	$e^+e^-\nu_e\overline{\nu}_e\gamma$		
RACOONWW			30.63 ± 0.05
	$\mu^-\overline{\nu}_\mu \tau^+\nu_{tau}\gamma$		
RACOONWW			27.09 ± 0.04

Table 5: Miscellanea for 4f + γ.

- Not only total cross-sections have been produced but also distributions.
- Again, they are shown only for the case of *maximal* comparison.

First the CC11 family

Answer 6 `KORALW` has multiple-options in presence of multi-photonic events. It can define distributions for

1. *visible* γ (*radiative*) or
2. *all photons*, i.e. no cuts, in which case one can take only

   a the most energetic photon to determine energy and angles (*hardest), or*

   b *the sum (*sum*).*

- There is a substantial agreement between `PVALPHA` and `RACOONWW` (when available) and with `GRACE` (despite somehow large fluctuations in the `GRACE` histograms). A different convention $e^- \leftrightarrow e^+$ is suspected for `RACOONWW` in the $\cos\theta_\gamma$ distribution, see Fig. ??.

  Also a substantial agreement is registered between `PVALPHA` and `GRACE` for mass distributions.

  CompHEP always shows large fluctuations in the histograms. A Blowup of the $\cos\theta_\gamma$-distributions shows with total cross-sections that are $60.7 \pm 0.8\,$fb for CompHEP and $73.4 \pm 0.1\,$fb for RACOONWW.

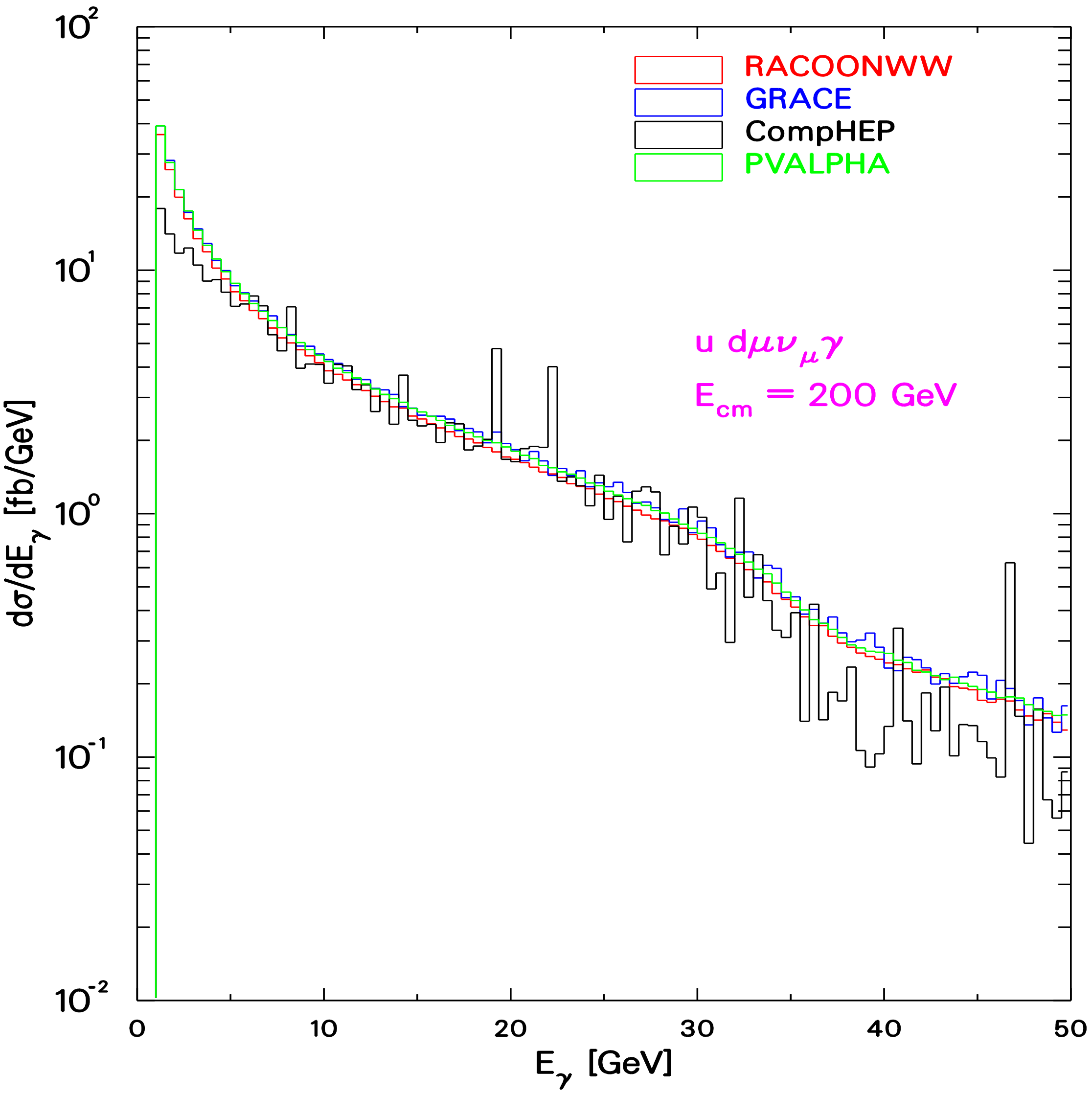


Figure 5: E_γ spectrum for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

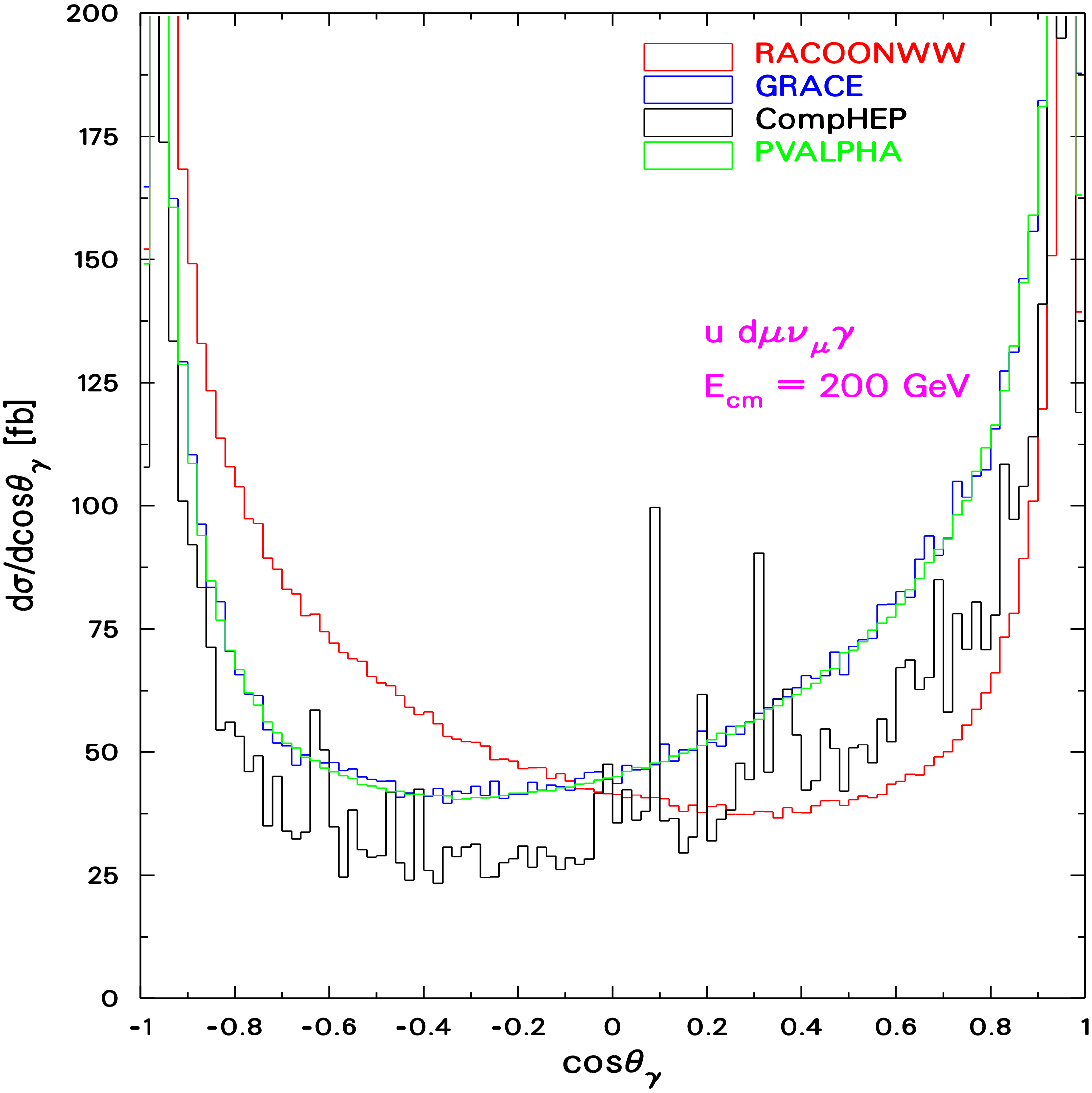


Figure 6: $\cos\theta_\gamma$ spectrum for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

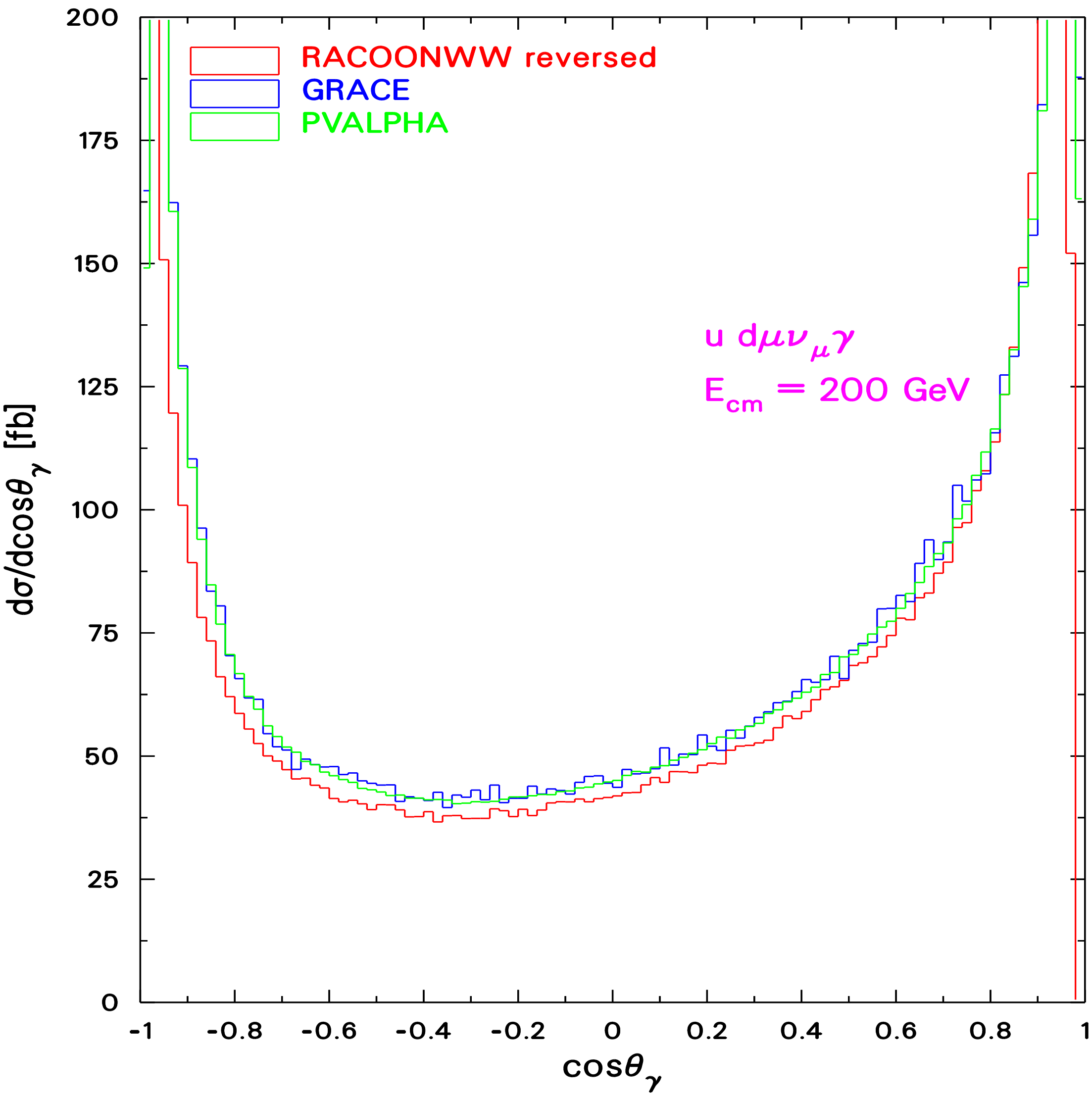


Figure 7: $\cos\theta_\gamma$ spectrum for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$ with RACOONWW reversed.

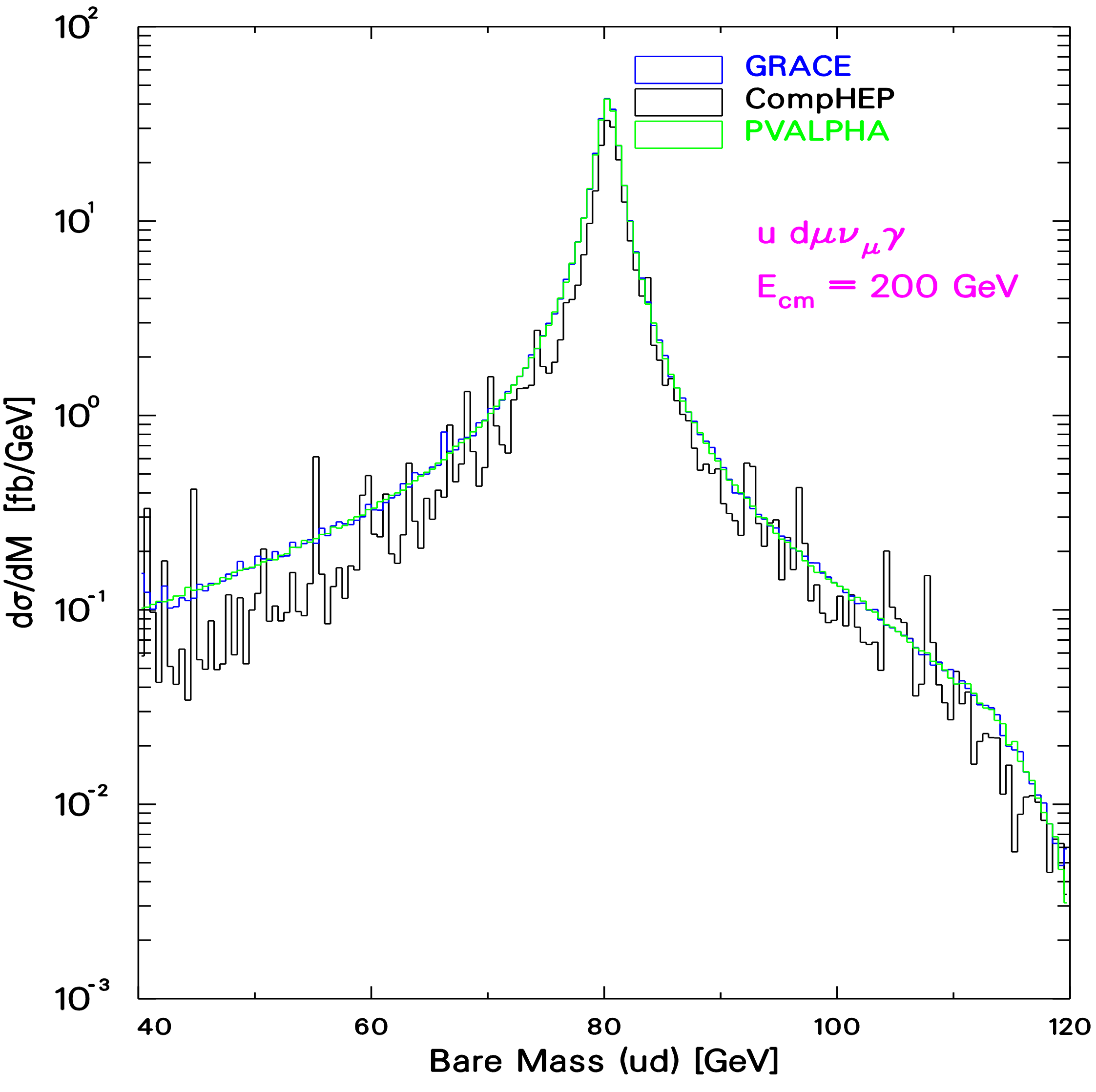


Figure 8: *Bare M* spectrum for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

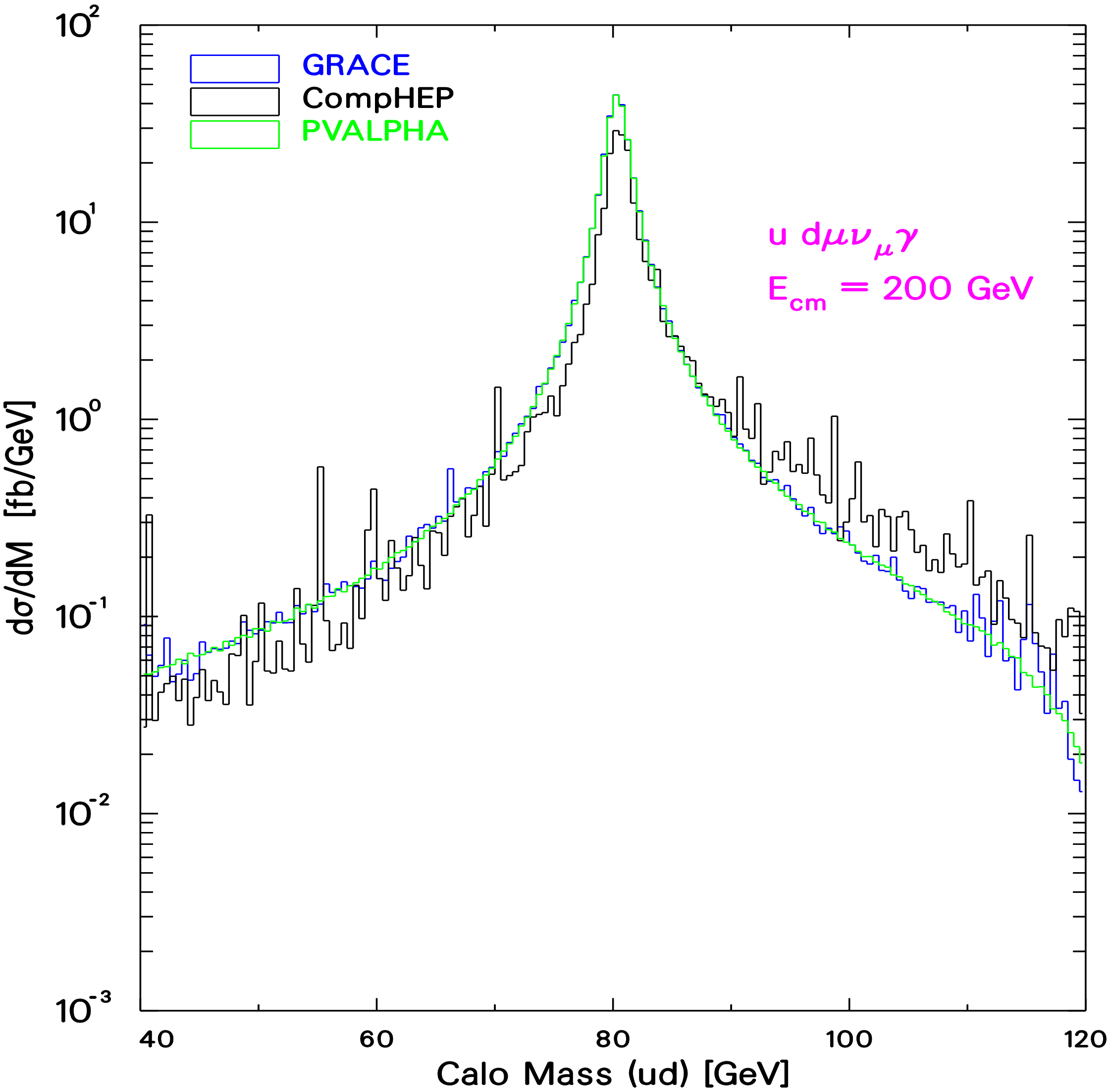


Figure 9: *Calo M* spectrum for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

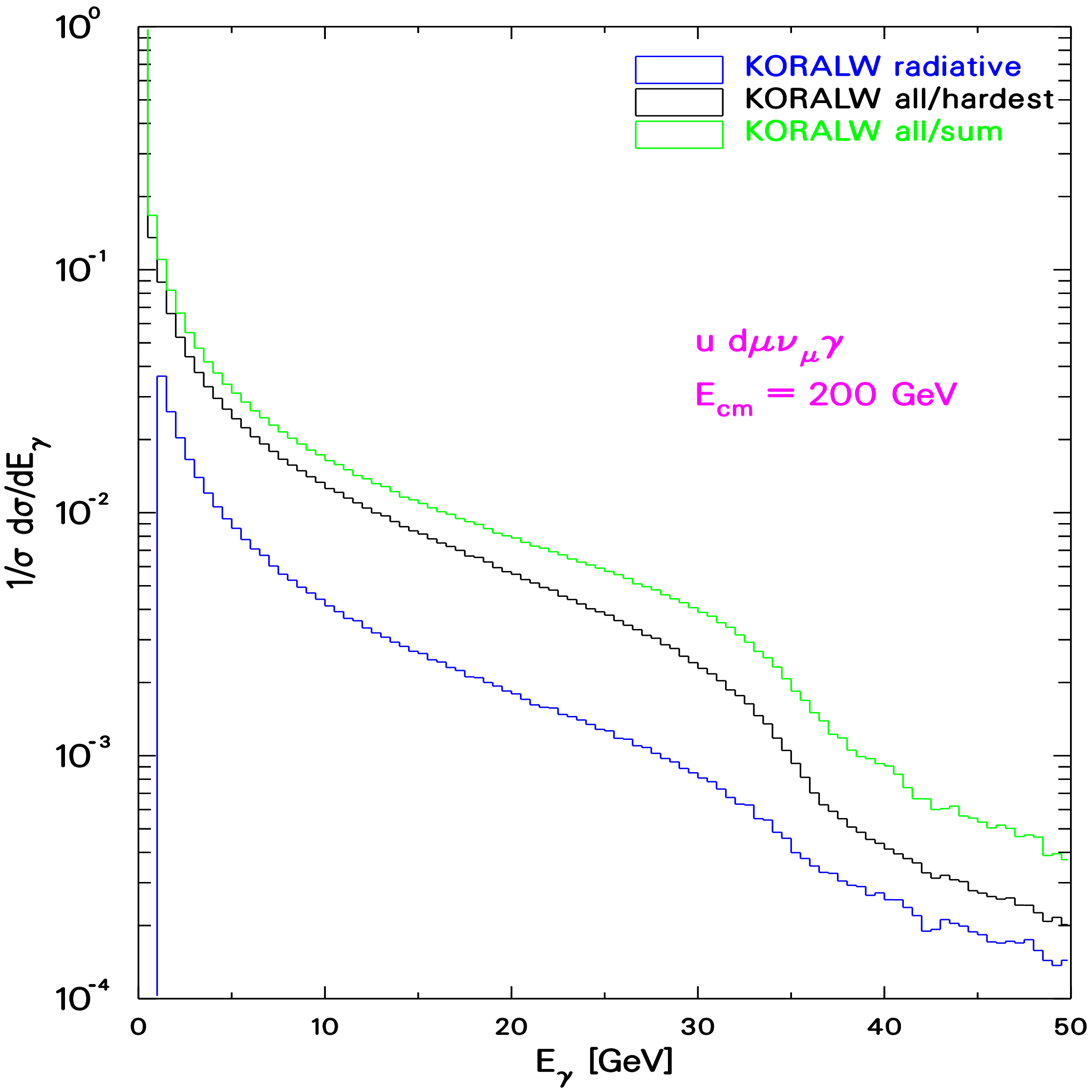


Figure 10: `KORALW` E_γ spectra for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

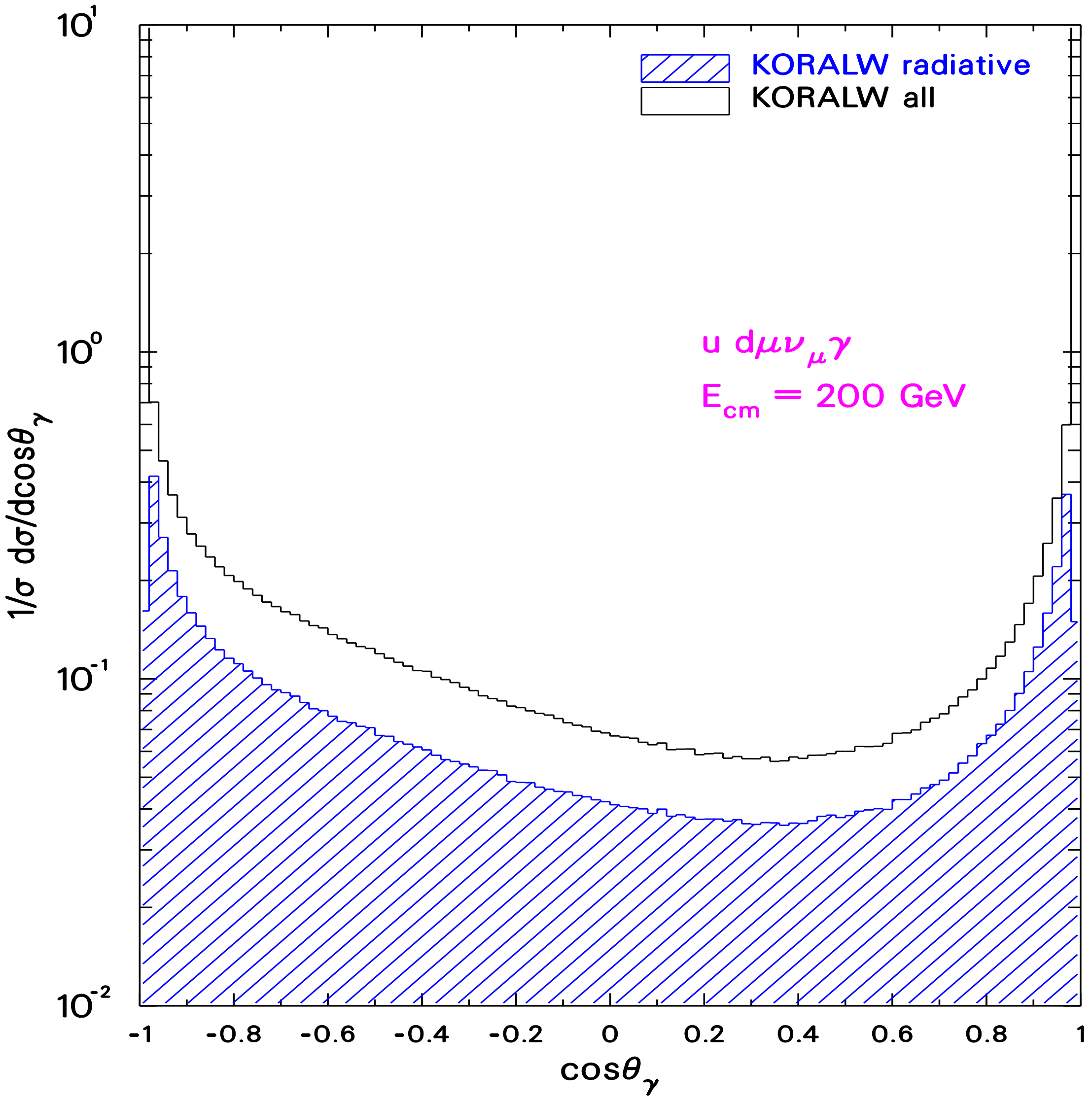


Figure 11: KORALW $\cos\theta_\gamma$ spectra for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

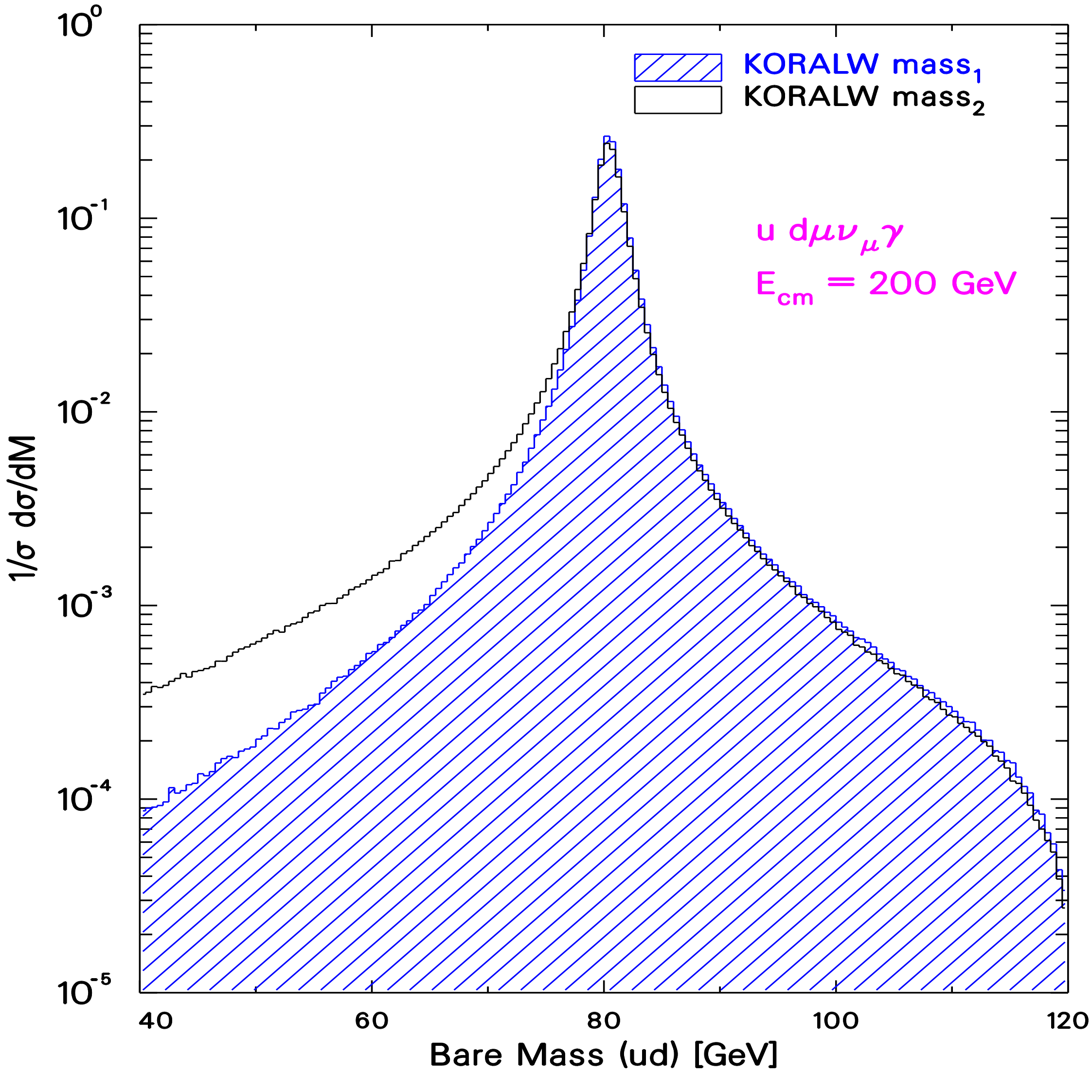


Figure 12: KORALW *Bare M* spectra for $u\bar{d}\mu^-\bar{\nu}_\mu\gamma$.

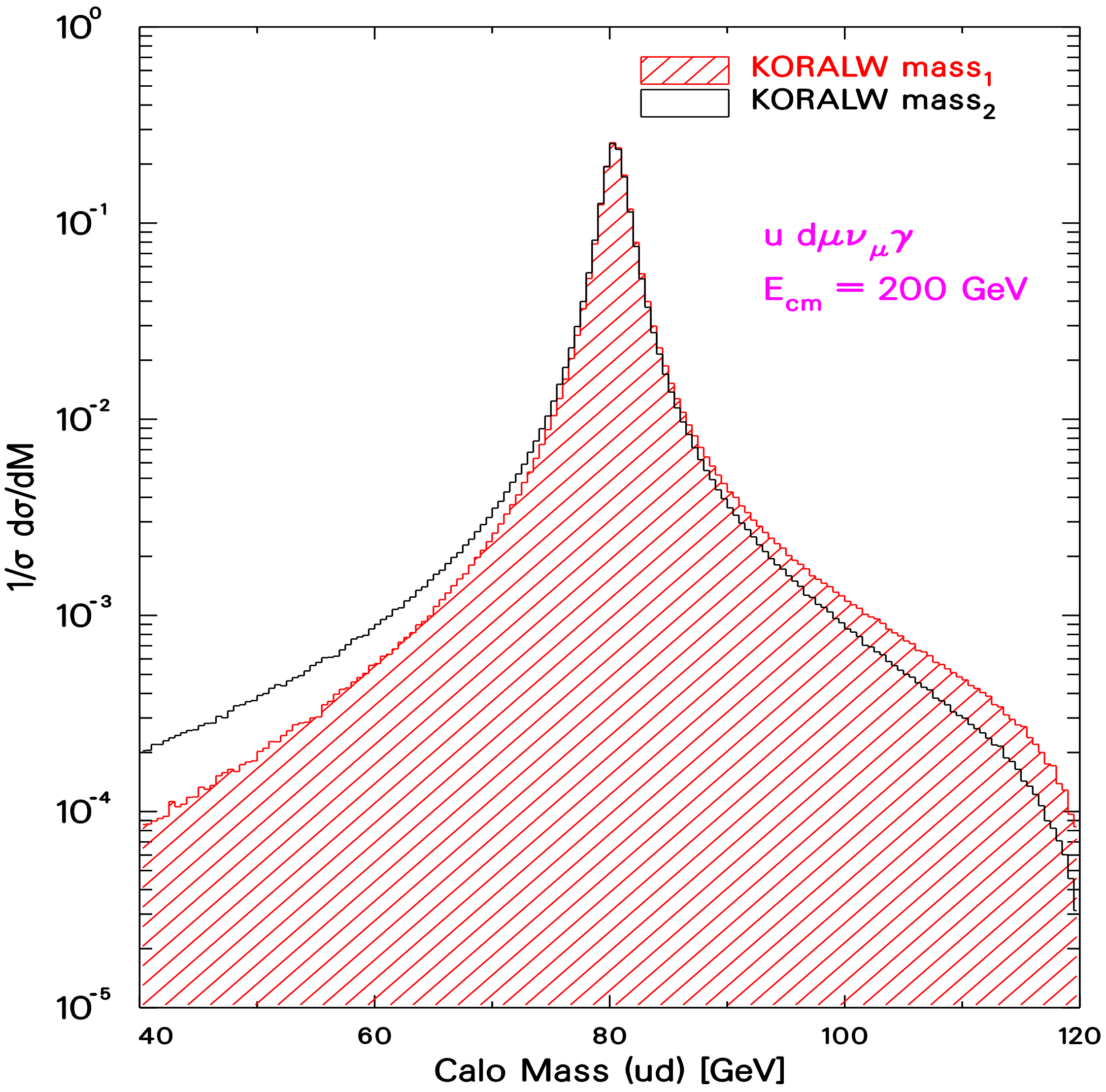


Figure 13: KORALW *Calo M* spectra for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

For KORALW there is a Question. How is performed the calculation for *non-radiative* events?

Next the CC20 family

Answer 7 PVALPHA and GRACE, apparently, have selected different configurations.

PVALPHA $e^+e^- \to \overline{q}qe\nu(\gamma)$ (**CC20**), q-flavour blind, $|\cos\theta_e| < 0.985$, $E_e > 5\,\mathrm{GeV}$, $M(q\overline{q}) > 10\,\mathrm{GeV}$ (full mass region); ($|\cos\theta_\gamma| < 0.985$ (0.997)).

GRACE

- $e^+e^- \to q\overline{q}e\nu(\gamma)$, $|\cos\theta_e| > 0.997$, either $M(q\overline{q}) > 45\,\mathrm{GeV}$ or $E_{q_1}, E_{q_2} > 15\,\mathrm{GeV}$, ($|\cos\theta_\gamma| < 0.997$ (0.9995)).

- i.e., WW signal versus *single*-W signal. Indeed their total cross sections are $81.18 \pm 0.23\,\mathrm{fb}$ (PVALPHA) and $4.62 \pm 0.11\,\mathrm{fb}$ (GRACE).
- Only one distribution has been shown for KORALW.

Question: How many codes can deal with *single*- W signal plus a *visible photon*?

Conclusions for 4f + visible γ. There is some disagreement for σ_{tot} that must be solved before we can talk about theoretical accuracy.

$\mathcal{O}(\alpha)$ CC03, NC02 and DPA

- The present attribution of a theoretical error on **CC03** (WW) and **NC02** (ZZ) cross-section is still based on GENTLE/4FAN inclusion of ISR radiation (QED only) through the so-called *split-technique*.

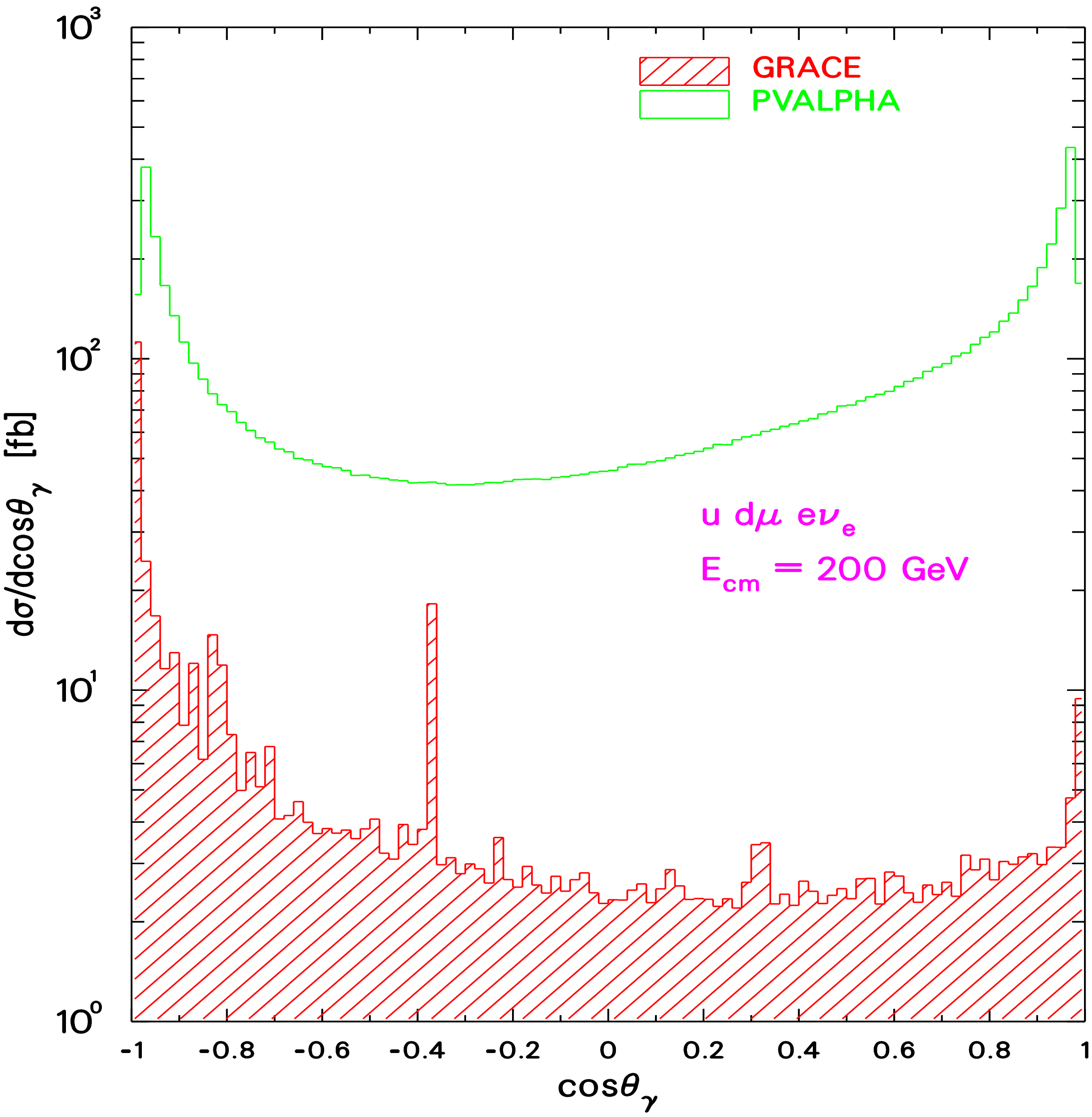


Figure 14: E_γ spectrum for $u\overline{d}e^-\overline{\nu}_e\gamma$.

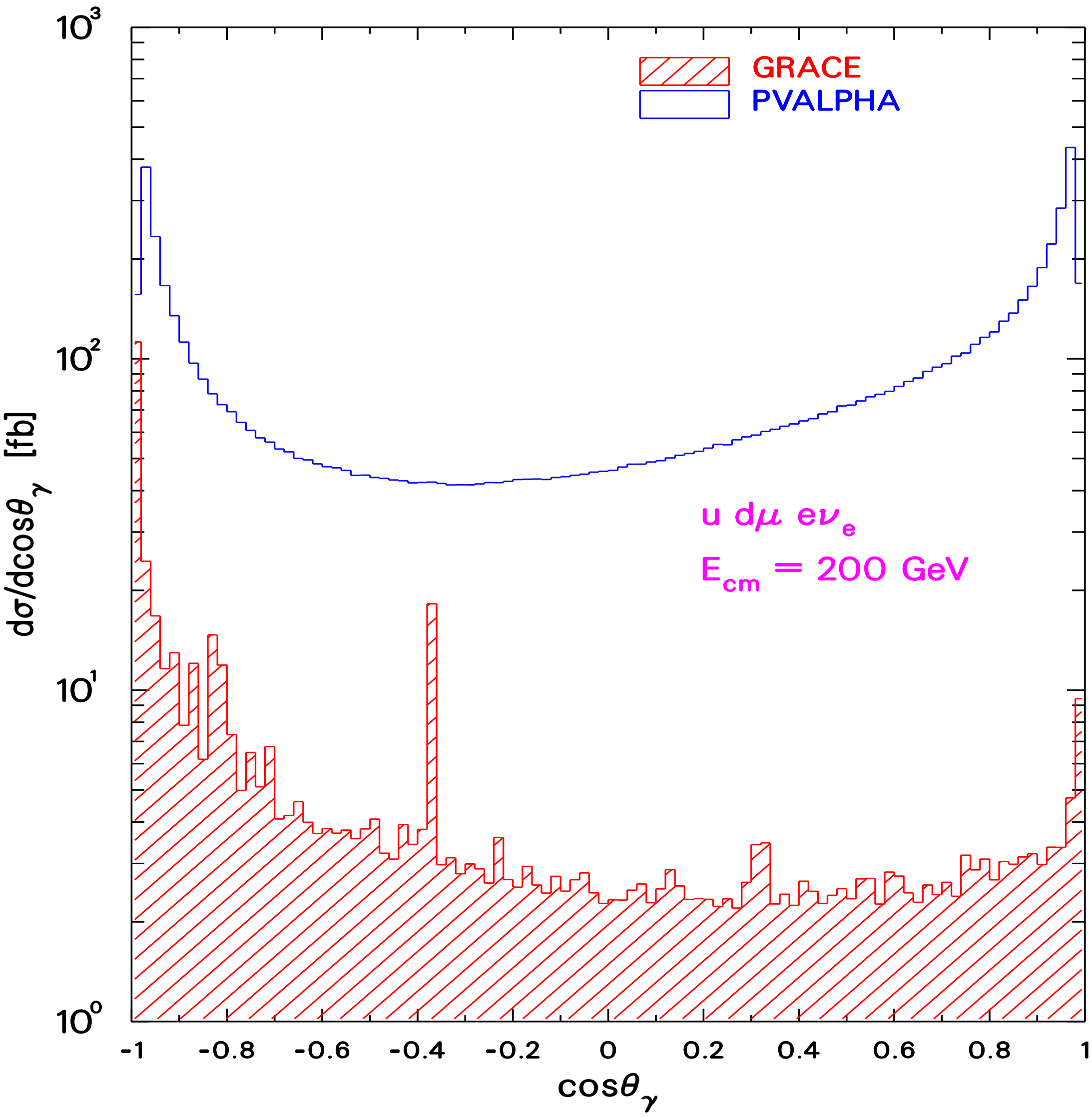


Figure 15: $\cos\theta_\gamma$ spectrum for $u\overline{d}e^-\overline{\nu}_e\gamma$.

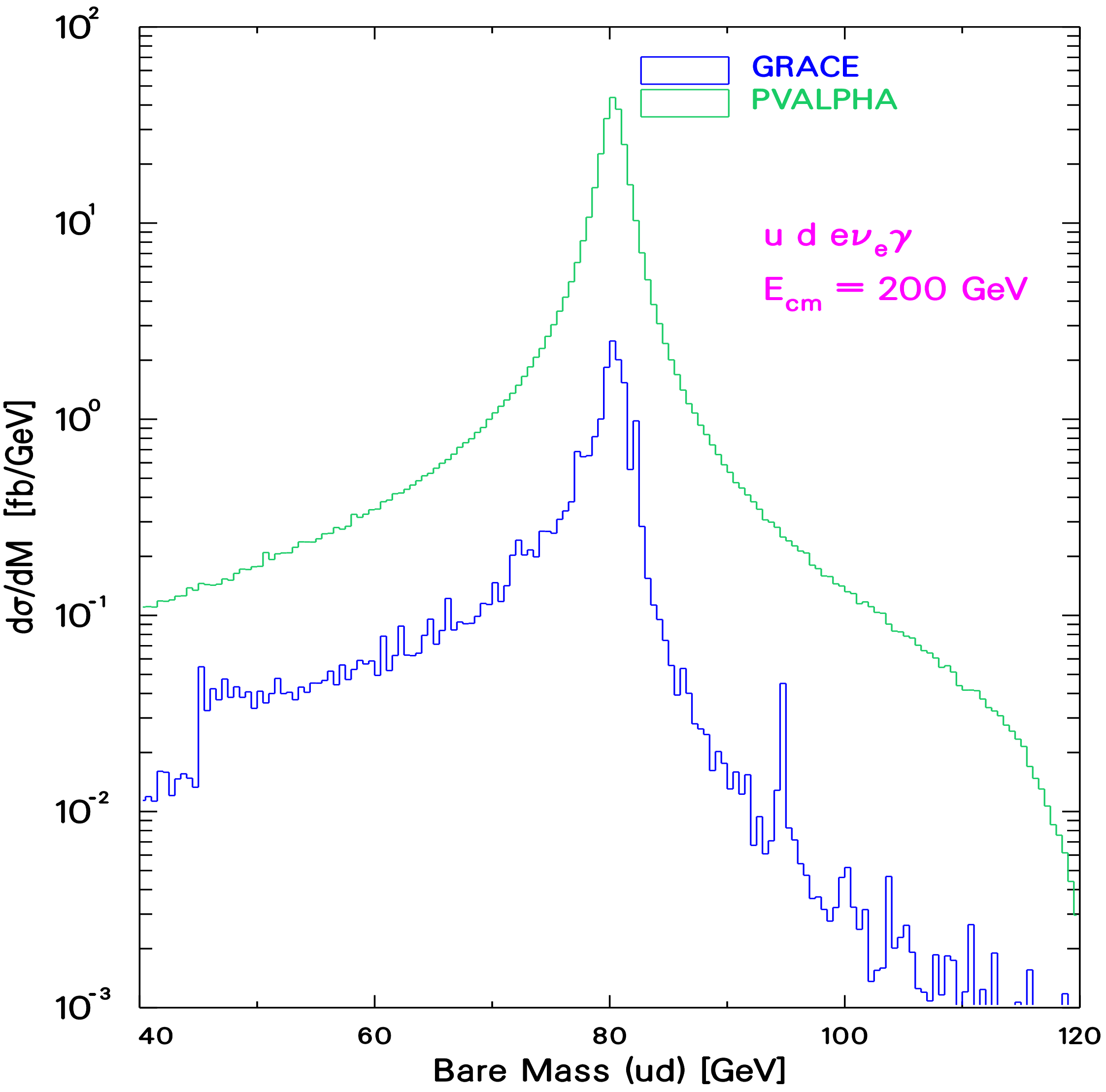


Figure 16: *Bare M* spectrum for $u\overline{d}e^-\overline{\nu}_e\gamma$.

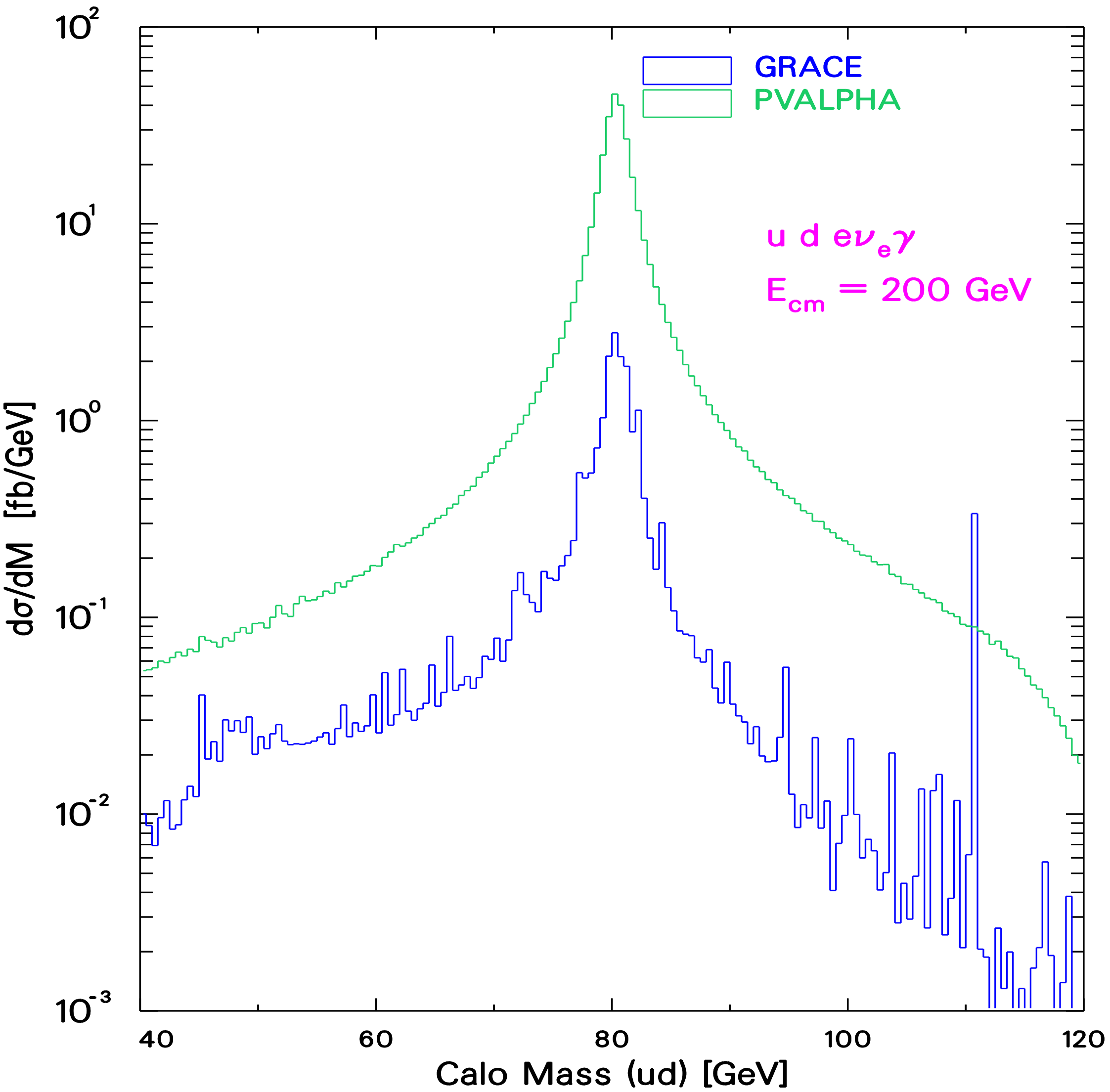


Figure 17: *Calo M* spectrum for $u\overline{d}e^-\overline{\nu}_e\gamma$.

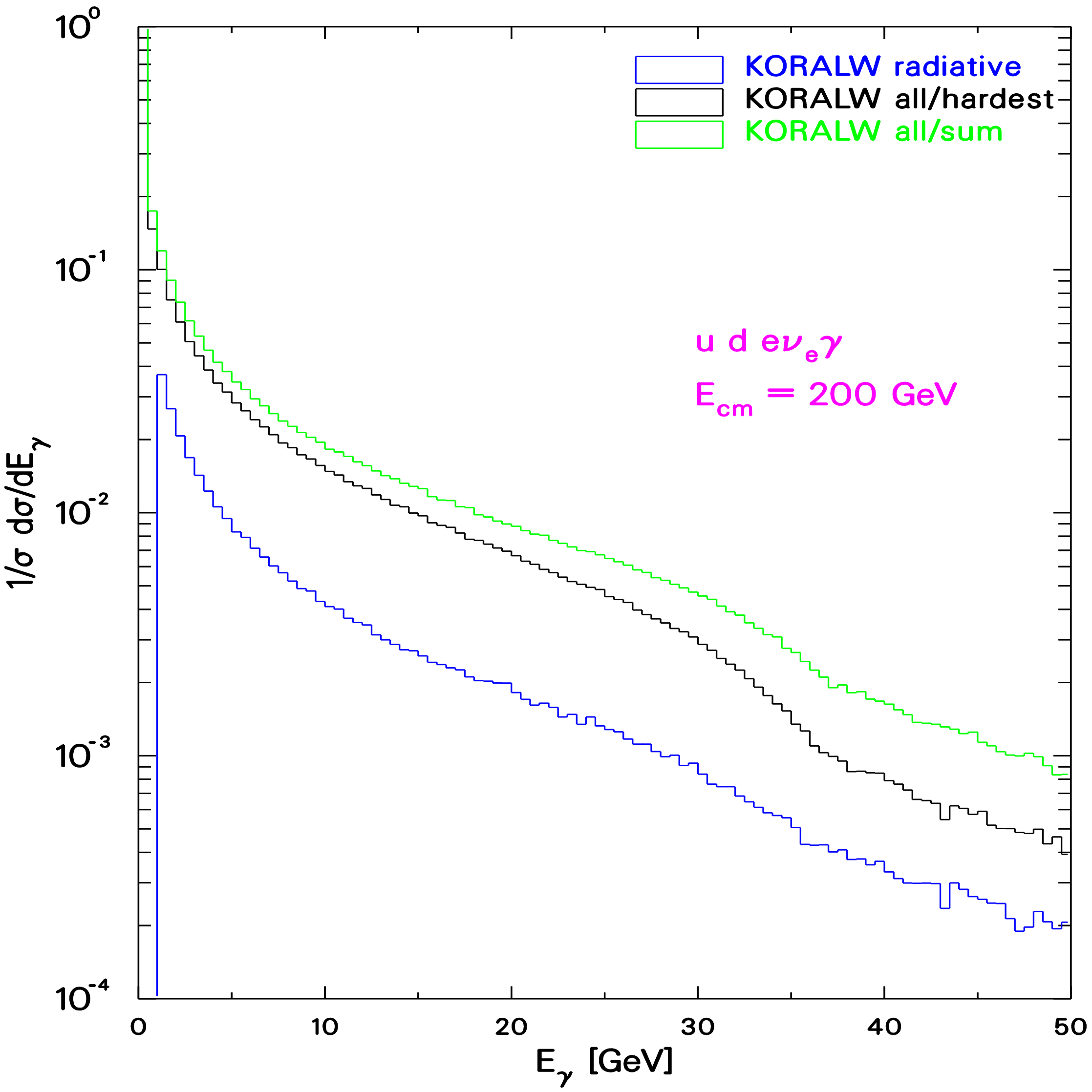


Figure 18: `KORALW` E_γ spectra for $u\overline{d}e^-\overline{\nu}_e\gamma$.

– Inclusion of radiative electroweak correction in DPA-approximation has to replace the old estimate.

What is DPA?

– **DPA** isolates the poles at the complex squared masses, with gauge invariant residues which are then projected onto the respective on-shell gauge invariant counterparts:

NB the projection is from the off-shell phase space to the on-shell phase space.

– for details, see S. Dittmaier and W. Placzek talks.

– They will answer about the theoretical error still associated with **DPA**, but there is another **Question**, having to do with **DPA** definition. It goes back to R. Stuart.

– Let p_+, p_- be the momenta associated with the WW or ZZ pairs. The general matrix element takes the form:

$$\begin{aligned}\mathcal{M}\left(\dots, p_+, p_-, \dots\right) &= \sum_i L_i\left(\dots, p_+, p_-, \dots\right) \\ &\times \mathcal{M}_i\left(p_+^2, p_-^2, \text{invariants}\right).\end{aligned}$$

where L_i stands for the *covariants* with external fermion-wavefunctions attached, that forms a basis for the spinor/Lorentz tensor structure.

– The $\mathcal{M}_i$ are scalar-functions of the independent invariants of the problem.

Question Why should the L_i enter into the DPA definition? Shouldn't we define DPA by taking the leading terms in a Laurant expansion of $\mathcal{M}_i$?

$$\mathcal{M}_{\mathrm{DPA}}\left(\dots,p_+,p_-,\dots\right) = \sum_i L_i\left(\dots,p_+,p_-,\dots\right) \times \mathcal{M}_i^{\mathrm{DPA}}\left(s_p,s_p,\mathrm{invariants}\right).$$

Is it not true that the external fermion wavefunctions should not enter in the expansion process? If so the kinematics of the problem is unchanged.

- A gauge-invariant DPA-definition tells you that **DPA** in two different gauges differ because of single-resonant terms which are zero in the double-resonant approximation.
- Of course, one always compute

$$d\sigma = d\sigma_{\mathrm{DPA}}^{\mathrm{Born}}\left(1+\delta_{\mathrm{DPA}}\right) + \left[d\sigma_{4f}^{\mathrm{Born}} - d\sigma_{\mathrm{DPA}}^{\mathrm{Born}}\right],$$

so that the difference only shows up at $\mathcal{O}\left(\alpha/\pi\right)$, but it could be within our target of 0.5%.

Available DPA results

- `RACOONWW` started by computing the total cross section including Born + $\mathcal{O}\left(\alpha\right)$ corrections, taking into account all diagrams contributing to a specific final state (i.e. WW-mediated + all backround diagrams).
- Additionally, they imposed a cut on $\angle$ (beam, charged fermion) to obtain well-defined invariant mass distributions.

– Their input parameters:

$$\begin{aligned} \alpha(0) &= 1/137.0359895, G_F = 0.1166370E-04, \\ M_W &= 80.350 \ \text{GeV}, M_Z = 91.1867 \ \text{GeV}, M_H = 150 \ \text{GeV}, \\ \Gamma_W &= 2.08699 \ \text{GeV}, \Gamma_Z = 2.49471 \ \text{GeV}, \end{aligned}$$

– RACOONWW computes Γ_W at 1-loop. They work in the G_F-scheme, i.e. replacing $\alpha(0)$ by the usual expression in terms of G_F.

– Besides the recombination of the photon with final state fermions, they also require that the angle between photon and the beam $> 5°$;

otherwise the photon is considered to be not observable (i.e. they set the photon four-momentum to zero). They reject the event when the angle between beam and charged fermion is $< 10°$.

$\cos\theta_\gamma$	CompHEP	RACOONWW
0.90	70.46 ± 3.65	59.81 ± 0.02
0.92	121.61 ± 29.24	75.38 ± 0.02
0.94	97.48 ± 4.83	104.20 ± 0.03
0.96	162.44 ± 8.61	170.42 ± 0.05
0.98	59.46 ± 4.05	69.67 ± 0.02

Table 6: $\cos\theta_\gamma$ [fb] distribution for $e^+e^- \to \mu^-\overline{\nu}_\mu u\overline{d}\gamma$.

	Born	Best
$u\overline{d}s\overline{c}$	2067.08 ± 0.27	1788.64 ± 0.36
$u\overline{d}d\overline{u}$	2251.52 ± 1.79	2003.22 ± 1.29
$u\overline{d}\mu^-\overline{\nu}_\mu$	675.45 ± 0.13	593.45 ± 0.12
$u\overline{d}e^-\overline{\nu}_e$	708.26 ± 0.40	619.97 ± 0.37
$\mu^-\overline{\nu}_\mu\tau^+\nu_\tau$	219.71 ± 0.04	195.62 ± 0.04
$u\overline{u}u\overline{u}$	141.06 ± 0.14	189.10 ± 0.40
$u\overline{u}\mu^-\mu^+$	17.13 ± 0.02	16.76 ± 0.03
$u\overline{u}e^-e^+$	55.16 ± 0.32	-
$u\overline{u}\nu_\mu\overline{\nu}_\mu$	22.50 ± 0.04	20.56 ± 0.04
$\mu^-\mu^+\tau^-\tau^+$	5.93 ± 0.01	5.74 ± 0.01

Table 7: `KORALW` cross-section (fb) at $\sqrt{s} = 200\,\mathrm{GeV}$.

– There are also `RACOONWW` **DPA** distributions. They are on a restricted range since the **DPA** is not valid outside the resonance region, so we don't now how to interpret the results far away from the resonance.

– YFSWW3 gives several results, including a **best** estimate of $17.09 \pm 0.01\,\mathrm{pb}$ for all WW. KORALW also gives several **NC** results in Tab.(7): How are **NC** processes calculated with KORALW? Is this 4f with the GRACE matrix elements built into KORALW?

	Born	Best
$u\overline{d}s\overline{c}$ [fb]	2066.91 ± 0.40	1757.25 ± 0.96
$u\overline{d}d\overline{u}$ [fb]	2067.37 ± 0.41	1760.65 ± 0.82
$u\overline{d}\mu^- \overline{\nu}_\mu$ [fb]	688.99 ± 0.16	594.40 ± 0.26
$u\overline{d}e^- \overline{\nu}_e$ [fb]	689.13 ± 0.13	594.44 ± 0.27
$\mu^- \overline{\nu}_\mu \tau^+ \nu_\tau$ [fb]	229.57 ± 0.05	200.65 ± 0.09
all WW channels [pb]	18.59649 ± 0.00383	17.09010 ± 0.00771

Table 8: `YFSWW3` total cross-sections for the *Born*-level and the *Best*-level calculation (together with statistical errors) with NO CUTS APPLIED at $\sqrt{s} = 200\,\mathrm{GeV}$.

	TH Bare	TH calo
$u\overline{d}\mu^- \overline{\nu}_\mu$ [fb]	568.3 ± 0.3	568.8 ± 0.3
$\tau^+, \nu_\tau \mu^- \overline{\nu}_\mu$ [fb]	191.4 ± 0.1	191.6 ± 0.1
$u\overline{d}s\overline{c}$ [fb]	1687.9 ± 0.9	1689.0 ± 0.9

Table 9: `RACOONWW` total cross-sections for the *Bare*-level and the *Calo*-level calculation (together with statistical errors) at $\sqrt{s} = 200\,\mathrm{GeV}$.

- We encourage GENTLE/4FAN to also produce **CC03** numbers for comparison.

Last answer Clearly these numbers should not be compared. If we, nevertheless, take them for their face value, we find 568.8 fb against 594.4 fb for $u\overline{d}\mu^{-}\overline{\nu}_{\mu}$.

- When we cannot compare two different **DPA**'s, e.g. YFSWW3 with RACOONWW, we are in the twilight zone.

For this reason we have been asking RACOONWW to do more. Now we have their results for the total cross-sections without imposing **any cut**.

They provide two values for the **Born cross-section**, denoted by *full* where they

* take into account all contributing diagrams

and denoted by **CC03** when

* only the WW signal diagrams are considered.

Their corrected cross-section, denoted by **Best**, comprises

* the **full Born** and the **full** $\mathcal{O}(\alpha)$ corrections, i.e. **virtual corrections** in **DPA** + complete real photon contribution.
* You might observe that they wrote two independent MCs, which mainly differ in the method used to cope with the arising **soft** and **collinear** singularites.

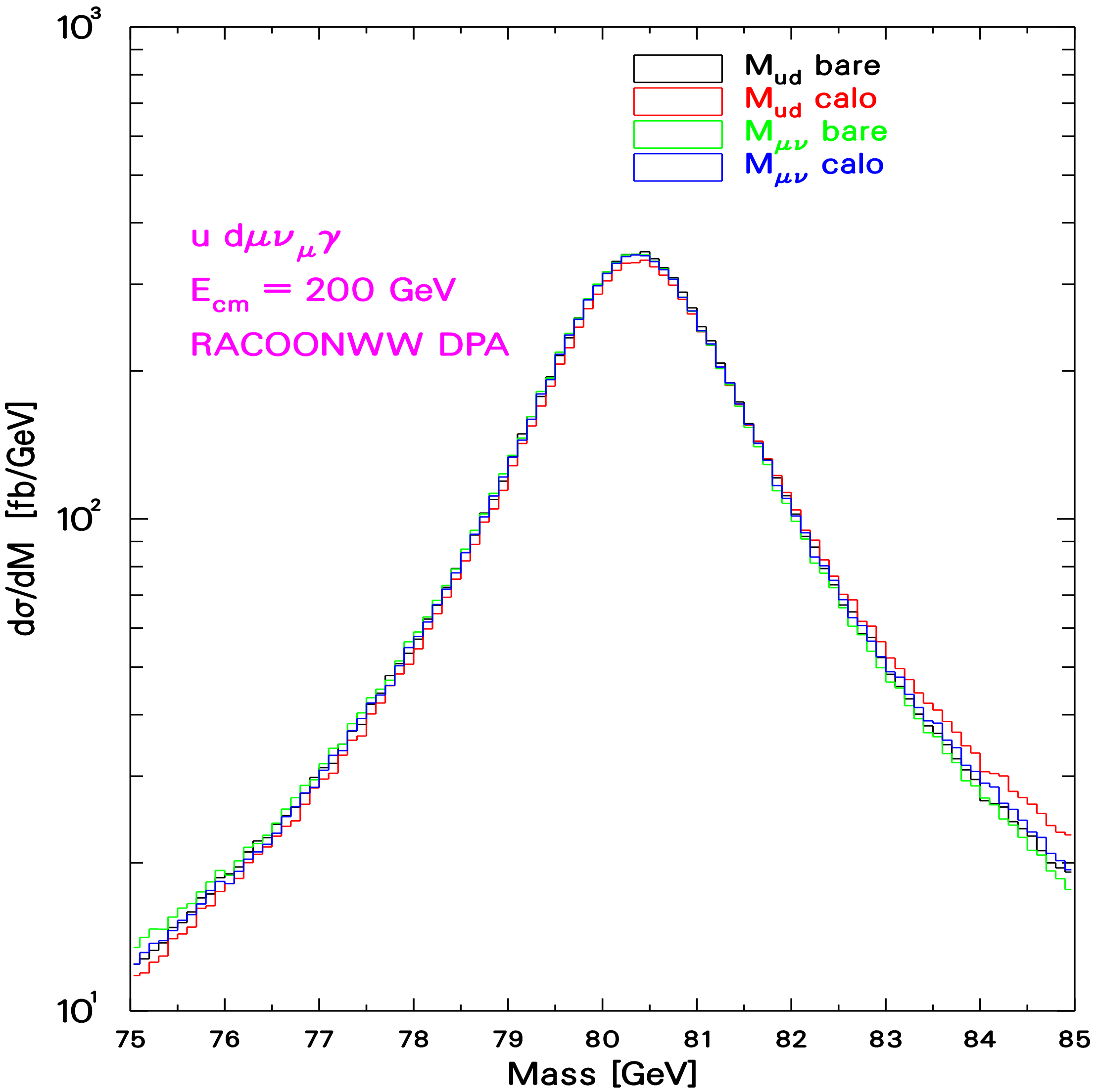


Figure 19: DPA (from RACOONWW) of *Bare* and *Calo* M spectra for $u\overline{d}\mu^-\overline{\nu}_\mu\gamma$.

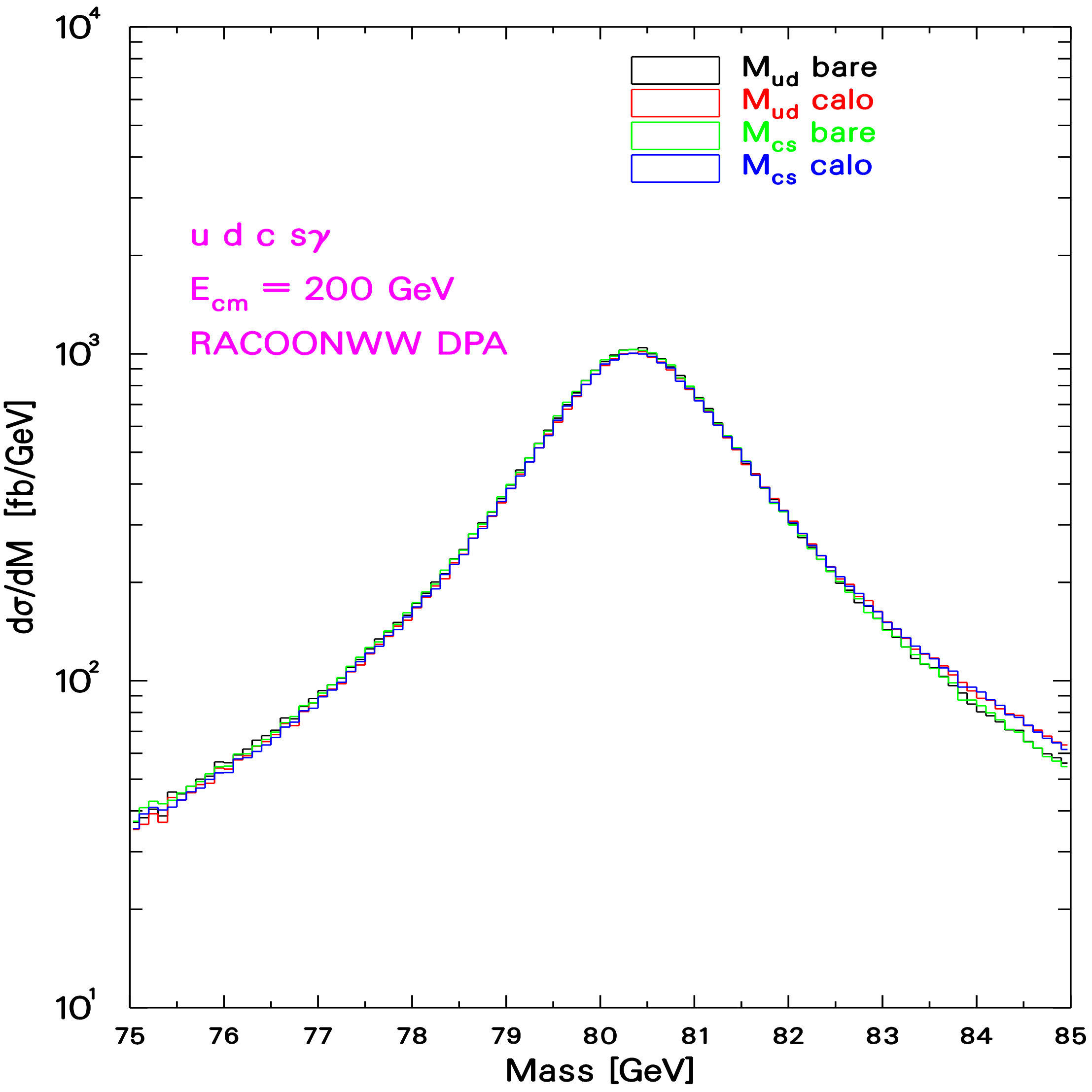


Figure 20: DPA (from RACOONWW) of *Bare* and *Calo* M spectra for $u\overline{d}s\overline{c}\gamma$.

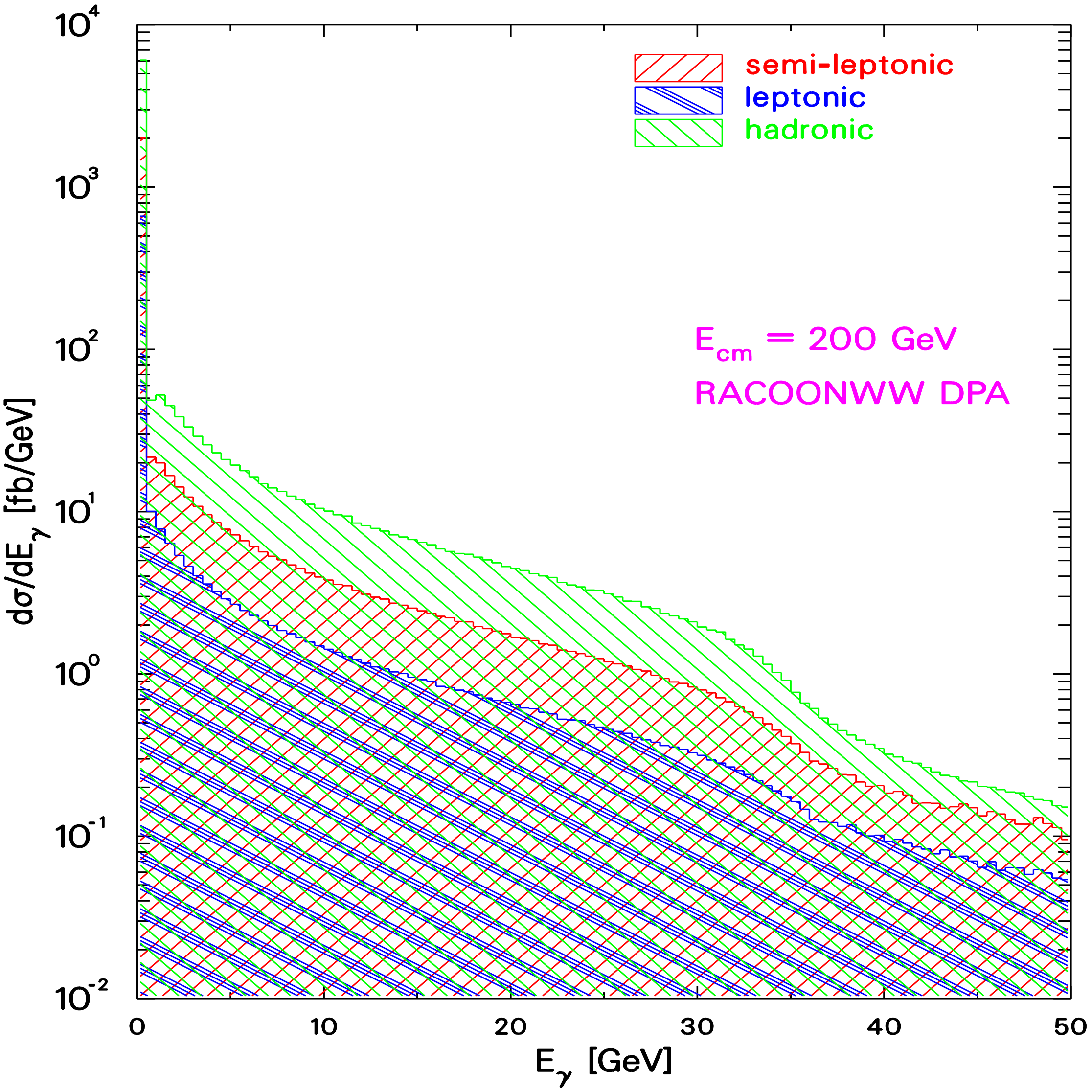


Figure 21: DPA (from `RACOONWW`) spectra for E_γ for semi-leptonic, leptonic and hadronic channels.

The results of the MC which uses the **subtraction method** are denoted by **sub**, and **ps.sl.** denotes the results when using **phase space slicing**.

		Born: $\sigma_{\rm tot}$ [pb]	Best: $\sigma_{\rm tot}$ [pb]	
		CC03	full	full
$u\overline{d}s\overline{c}$	sub ps.sl	1.97733 ± 0.00079 1.97740 ± 0.00080	1.97884 ± 0.00085 1.98030 ± 0.00081	1.78938 ± 0.00085 1.79096 ± 0.00165
$u\overline{d}\mu^-\overline{\nu}_\mu$	sub ps.sl	0.65911 ± 0.00026 0.65913 ± 0.00027	0.65957 ± 0.00028 0.66009 ± 0.00027	0.59700 ± 0.00031 0.59668 ± 0.00057
$\nu_\mu\mu^+\tau^-\overline{\nu}_\tau$	sub ps.sl	0.21970 ± 0.00009 0.21971 ± 0.00009	0.21984 ± 0.00009 0.22001 ± 0.00009	0.19914 ± 0.00010 0.19892 ± 0.00023

Table 10: `RACOONWW` total cross-sections for DPA at $\sqrt{s} = 200\,\text{GeV}$.

– The final two questions are for `YFSWW3` and for the experimenters: `RACOONWW` can take into account all diagrams contributing to a specific final state (i.e. WW-mediated + all backround diagrams). They should be able to avoid cuts. What is the exact situation for `YFSWW3`? Is it the *pure* CCO3 $\mathcal{O}(\alpha)$ fully-extrapolated?

– What the experimenters like? **NO-CUTS**? **ALL-DIAGRAMS**? **3 Diagrams**?

Conclusions

- With respect to the original proposal and given our by now fixed deadline we are in a bad shape:

1. not enough numbers have been produced to obtain a wide spectrum of comparisons,
2. a statement on **theoretyical accuracy** is not (yet) complete.

We wanted to understand:

- the uncertainty for WW and ZZ cross-sections. This implies the famous *de-strategy*: missing canonical cuts among the four experiments one has
  to subtract enough *background* from the data to define the *signal* to be computed by theory.
  Note that the *signal* itself is defined by availability of theoretical predictions.

  a) `YFSWW3` defines a pure CC03 $\mathcal{O}(\alpha)$ signal without cuts. The uncertainty is left to some internal estimate (no global estimate). The remaining error is, totally, assigned to the subtraction procedure.

  b) `RACOONWW` always includes some background, a procedure that we like on the theory side, but which will never receive attention from experimenters. Moreover, the CPU-time barrier is, to all effects, a no-go theorem.

- Thanks to Polish efficiency, German precision and some Italian phantasy we can now compare two different **DPA**'s, e.g. YFSWW3 with RACOONWW, we are a little away from the twilight zone.

We have RACOONWW/YFSWW3 - 1 [percent]

– $u\overline{d}s\overline{c}$, $\quad 1.81 \pm 0.06$

– $u\overline{d}\mu^-\overline{\nu}_\mu$, 0.44 ± 0.07

– $\nu_\mu\mu^+\tau^-\overline{\nu}_\tau$, -0.75 ± 0.07

- Therefore, we are, now, better than before, when electroweak radiative corrections were not available. Now we have **DPAs**. We need to understand their basics elements and their differences.

QED radiation. To test the goodness of parton-shower seems as difficult as winning a twin double.

We are late in our project, exact matrix-elements for one hard-photon have been produced but additional work is needed since the overall agreement is not yet satisfactory. Beyond $\mathcal{O}(\alpha)$ event generation is still a matter of debate.

Nobody has found time to describe shifts in the distributions induced by extra photons and to compare with parton-shower.

Furthermore, we have to register the tendency of accumulating uncorrelated results, favoring the technical performances of single generators, instead of covering physics issues.

Once more, generators have been already selected and by the end of February the game is over, no new generator will be adopted, no matter how good.

There is more glory in solving a specific problem, relevant to the final analysis, than in a clonation of your neighbor's MC.

⊙ We need something more from you. What is the *theoretical accuracy* of (some of) the processes? Can we put a percent accuracy to each or at least some? The final **YR** should contain this, for as many processes of the 4f proposal as possible.

Beware of nemesis