Alessandro BALLESTRERO
Torino

Single W at zero e^- angle

Results from
COMPHEP, ERATO, EXCALIBUR, GRC4F,
KORALW, WPHACT

- Introduction
- The proposed comparison
- Partecipants
- Results
- Comments and suggestions

Cern
LEP MiniWorkshop
March 1999

Introduction

Relevance of the **events with 1 or 2 electrons in the forward region** as signal and/or background.
Single W, Single Z, $\gamma\gamma$, one isolated lepton, two fermions + missing energy, ...
These processes, divergent in the $m_e \to 0$ limit, have been theoretically analyzed and calculated since a long time both in Weizsacker Williams (equivalent photon) approximation and with full matrix elements.
At high energies (LEP, LC) however, numerical uncertainties remain as a consequence of:

- large *gauge cancellations*

- large *numerical cancellations*

- appearance of *logarithmic contributions* (mass effects) both from electron vertex and multiperipheral contributions

- need for complicated phase space mappings

For this reason **it has been decided to compare results** of different codes and to examine the reliability of the results.

We have started with CC20: $e^+e^- \to e^-\bar{\nu}_e u\bar{d}$

Final proposal for forward electron CC20 comparison

Process CC20: $e^+e^- \to e^-\bar{\nu}_e u\bar{d}$

1. Total cross section with Hadronic Cuts at $\sqrt{s}$= 183 GeV and 190 GeV, with and without ISR.
2. Forward cross section, namely the previous cross section with Hadronic Cuts plus the additional cut

   $0.997 < cos_\theta(e) < 1$

   at $\sqrt{s}$= 183 GeV and 190 GeV, with and without ISR.
3. final electron energy distribution with Hadronic Cuts, 100 bins in the range $0 < E(3) < \sqrt{s}$ at $\sqrt{s}$= 183 GeV and 190 GeV, with and without ISR.
4. final electron angular distribution with Hadronic Cuts, 50 bins in the range $0 < \theta(e) < 10$ degrees at $\sqrt{s}$= 183 GeV and 190 GeV, with and without ISR.

Hadronic Cuts

E(u) > 3 GeV, E(d) > 3 GeV, m(ud)> 5 GeV,

INPUT

Without: QCD naive corrections, gluonic corrections, Coulomb corrections, final state QED radiation, anomalous couplings.
Numerical values of the parameters fixed.

Partecipants

For this meeting the following groups have produced results:

- **Comphep** Fully massive. "Overall prescription" to preserve gauge invariance.
- **Grace** Fully massive. $L_{\mu\nu}$ transform method
- **Koralw** Fully massive. $L_{\mu\nu}$ transform method ? Uses the M.E of Grace.
- **Wphact** Fully massive. Fixed W width in t channel.
- **Excalibur** Massless (Fudge). Fixed W width in t channel.
- **Erato** Massless (Fudge). Fixed W width in t channel.

Passarino has not been able to restore **WTO** (Improved W.W. approximation) in time for this meeting. WTO results are important as the approach is different and complementary to the previous ones

After the results from Grace have appeared, **Comphep** has also modified his "Overall prescription" and applied it only to t-channel contributions. In such a way the results are much more similar to the other Fully massive codes.
So we will have two sets: **Comphep1** and **Comphep2**.

CompHEP calculation of $e^+e^- \to e^-\bar{\nu}_e u\bar{d}$: some technical details of the cross check for LEP2 workshop 1999

E. Boos and M. Dubinin

CompHEP codes and manual can be downloaded from the WWW page:
Moscow, INP MSU `http://theory.npi.msu.su/~comphep`
DESY-Zeuthen mirror `http://www.ifh.de/~pukhov`

- 210 squared diagrams and interference terms of CC20 are calculated symbolically in the 'tHooft-Feynman gauge by means of CompHEP symbolic module, all fermion masses nonzero

- symbolic results are converted to REAL*8 FORTRAN codes for individual squared diagrams and interference terms, compiled and linked to CompHEP kinematics module and VEGAS adaptive MC integrator. Several cross checks of results using REAL*16 codes were done also and in all cases the difference well below 1 standard deviation level (1std) was observed.

- five phase space mappings are introduced: one for t-channel gamma peak (forward electron), two for t-channel u and d quark exchanges in the ladder (CC-DIS) diagram and two for s-channel W resonances

- "overall prescription" for the Breit-Wigner propagator is used, when to preserve gauge invariance squared diagrams are summed and then multiplied by a factor

$$|\frac{q^2 - m_W^2}{q^2 - m_W^2 + i\, m_W \Gamma_W}|^2$$

- equivalent photon approximation is not used, t-channel gamma pole is regulated by the exact kinematical bound (of order $t_{min} = -m_e^2 * (\hat{s}/s)^2$)

- multichannel MC with 10^6 sample points and the generation of $5{\cdot}10^5$ weighted events takes 2.5 hours CPU/1 total cross section point (HP-UX, IRIX64), giving (1std of MC)/σ_{tot} of order 0.3%.

- ISR corretions are calculated in the structure function approach (E.A. Kuraev, V.S. Fadin, Sov.J.Nucl.Phys. 41 (1985) 466, S. Jadach, B.F.L. Ward, Comp.Phys.Commun. 56 (1990) 351)

 GRC4F

GRC4F: A FOUR-FERMION EVENT GENERATOR FOR e^+e^- COLLISIONS

hep-ph/9605312, Comput.Phys.Commun.100:128-156,1997

- Tree level Helicity amplitudes produced by "GRACE": Feynman diagram automatic computation system (http://www-sc.kek.jp/minami/)
  - Fermion masses $\surd$
  - Full spin correlations $\surd$
- Unweighted events: BASES/SPRING for integration and event generation
- All 76 four-fermion final states (all diagrams included)
- Selection of "Generic" process: i.e. $e^+e^- \longrightarrow q\bar{q}q\bar{q}$
- ISR, FSR
  - Structure Functions (ISR)
  - QED Parton shower like (QEDPS) for s-channel diagrams (t-channel, in preparation, see Kurihara's talk)
- Beamstrahlung: "Circe" $\surd$, "Luminous" in progress
- Treatment of the W-width gauge violation: $L\mu\nu$ transform method: hep-ph/9412215, Phys.Lett B349 367-374,1995
- Interface to Pythia for parton shower and hadronisation
- Coulomb correction between intermediate W's $\surd$
- Gluon contribution (hadronic processes) $\surd$
- Anomalous couplings $\surd$

`WPHACT`

E. Accomando and A. Ballestrero

Technical features for single W

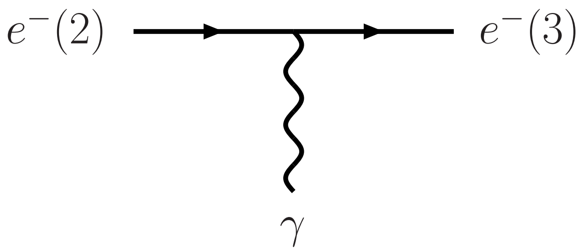
- `WPHACT` computes all 4-f processes (including Higgs, neutral Susy-Higgs, AC, ..)
- In the first version accounted exactly only for b-masses
- Now **full massive** CC M.E. have been **added** (important for forward electrons)

  One can choose among massive, massless or massless with massive b's depending on process, cuts,..
- W.I.P. for new massive NC and MIX M.E. as well
- A **new phase space** suited **for forward electrons** (single W, single Z, gamma gamma) has been introduced.
- Checks with other phase spaces and for M.E. cancellations have been performed
- Actual CPU time *for forward region* is $\approx$ 10 hours for per mille accuracy with all distributions on Digital alpha station.

The (fudge) zero angle treatment in EXCALIBUR

The t channel singularity in

$$e^+(1)\ e^-(2) \to e^-(3)\ \bar{\nu}(4)\ u(5)\ \bar{d}(6) \quad \text{is}$$



Introduce massive ($\tilde{p}_{2,3}$) and massless ($p_{2,3}$) momenta.

Furthermore, $\tilde{t} = (\tilde{p}_3 - \tilde{p}_2)^2$, $\quad t = (p_3 - p_2)^2$,

$$q_i = \sqrt{E_i^2 - m_e^2} \quad \text{and} \quad \mu_i = \frac{m_e}{E_i}.$$

One gets

$$\begin{aligned} \tilde{t} &= 2\,m_e^2 - 2\,\tilde{p}_2 \cdot \tilde{p}_3 = -2\,\{E_2E_3 - q_2q_3\cos\theta - m_e^2\} \\ &\leq -2\,\{E_2E_3 - q_2q_3 - m_e^2\} \equiv \tilde{t}_0\,. \end{aligned}$$

An effective cut on $\cos\theta$ is then introduced, in the massless case, is such a way that $t \leq \tilde{t}_0$:

$$t = -2\,p_2 \cdot p_3 = -2\,E_2E_3\,(1-\cos\theta) \leq -2\,\{E_2E_3 - q_2q_3 - m_e^2\}\,.$$

Therefore the final formula reads

$$(1-\cos\theta) \geq \left\{1 - \mu_2\mu_3 - (1-\mu_2^2)^{\frac{1}{2}}\ (1-\mu_3^2)^{\frac{1}{2}}\right\}\,.$$

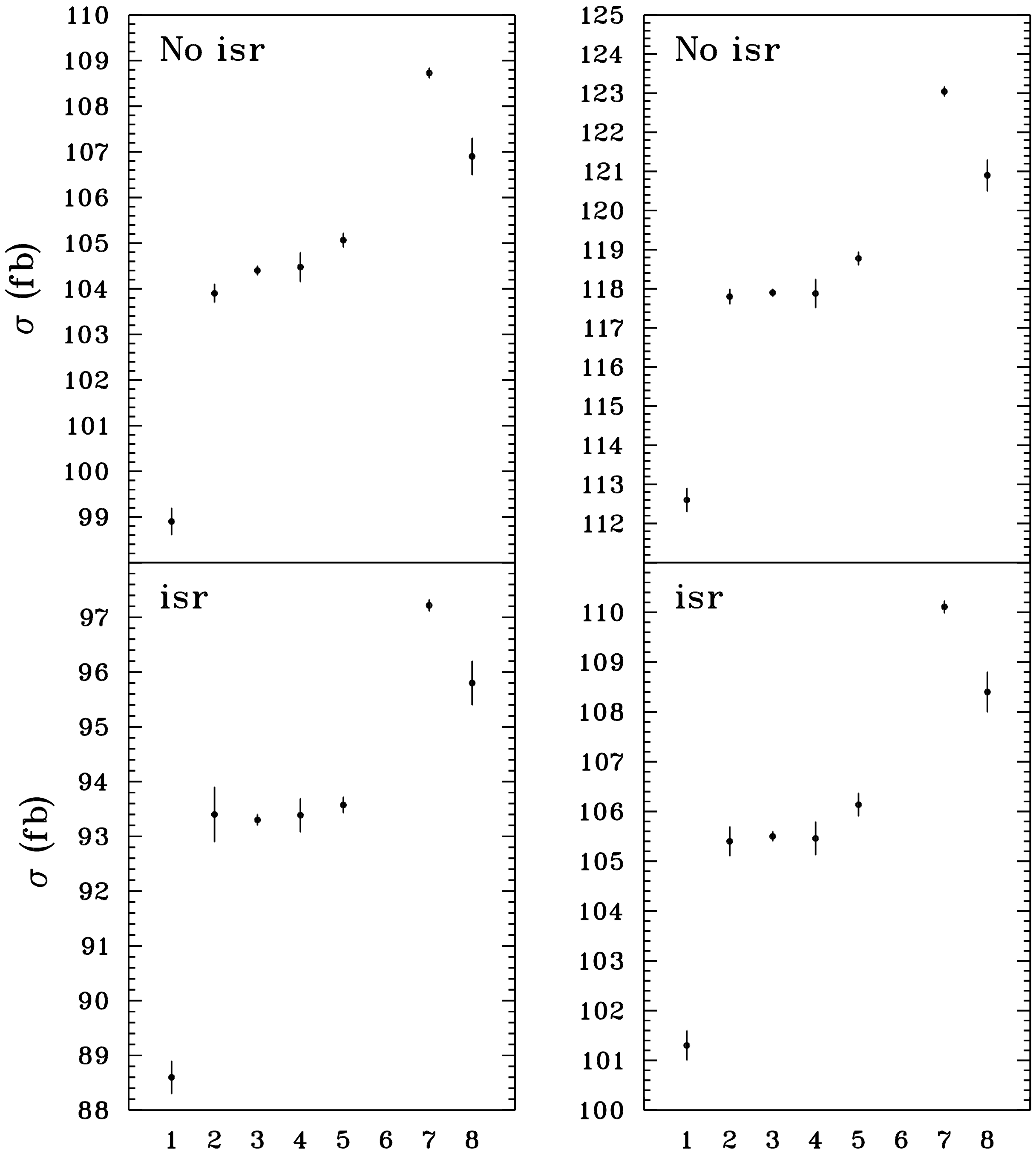
Note that, in order to compute the effective cut, the energy of the outgoing electron $e^-(3)$ must be known.

$e\nu ud$

$\cos\theta(e) > .997$

m(ud) > 5 GeV E(u) > 3 GeV E(d) > 3 GeV

183 GeV 190 GeV

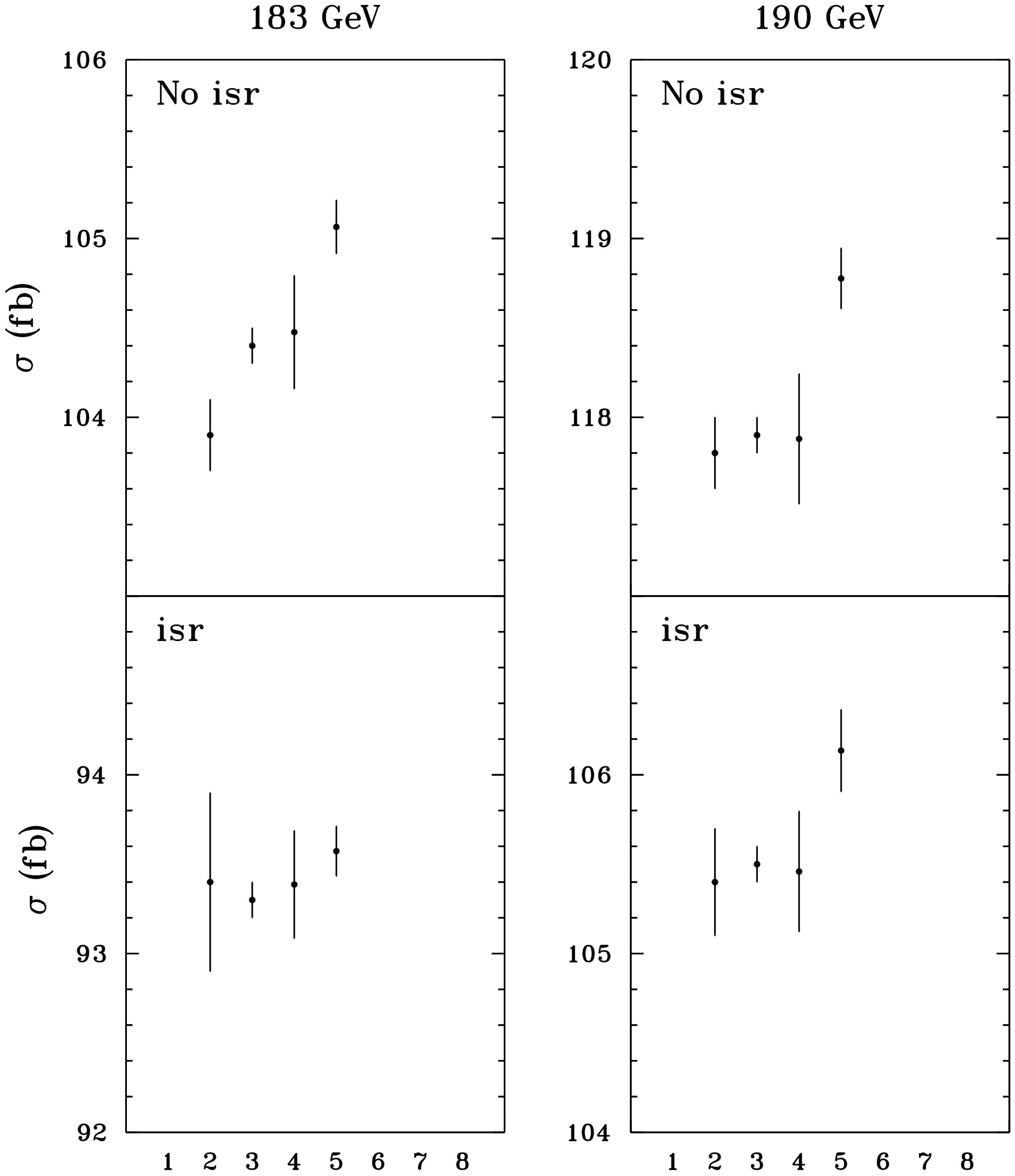


1=comphep1 2=comphep2 3=grc4f 4=koralw
5=wphact 7=excalibur 8=erato

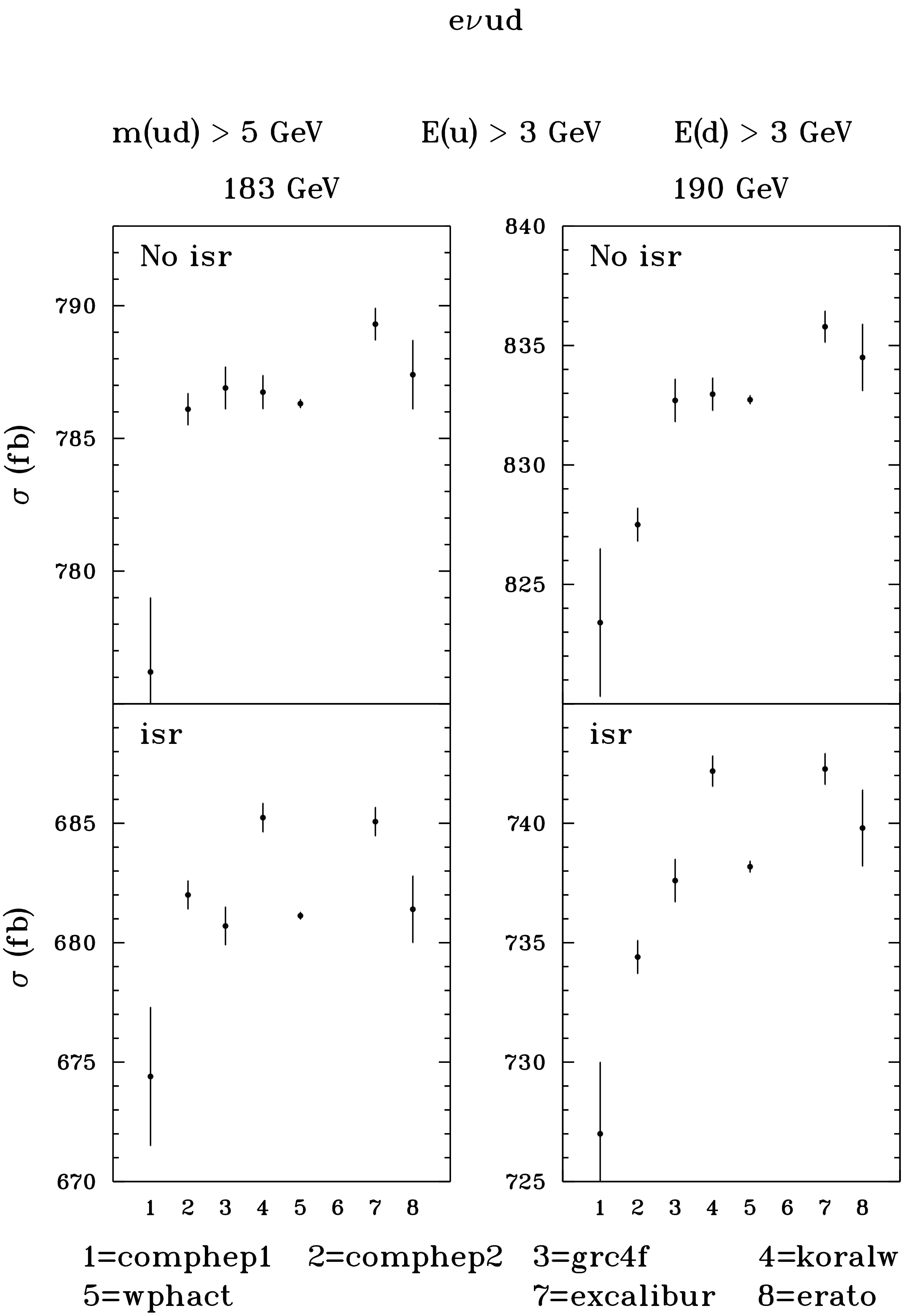
eνud

$\cos\theta(e) > .997$

m(ud) > 5 GeV   E(u) > 3 GeV   E(d) > 3 GeV

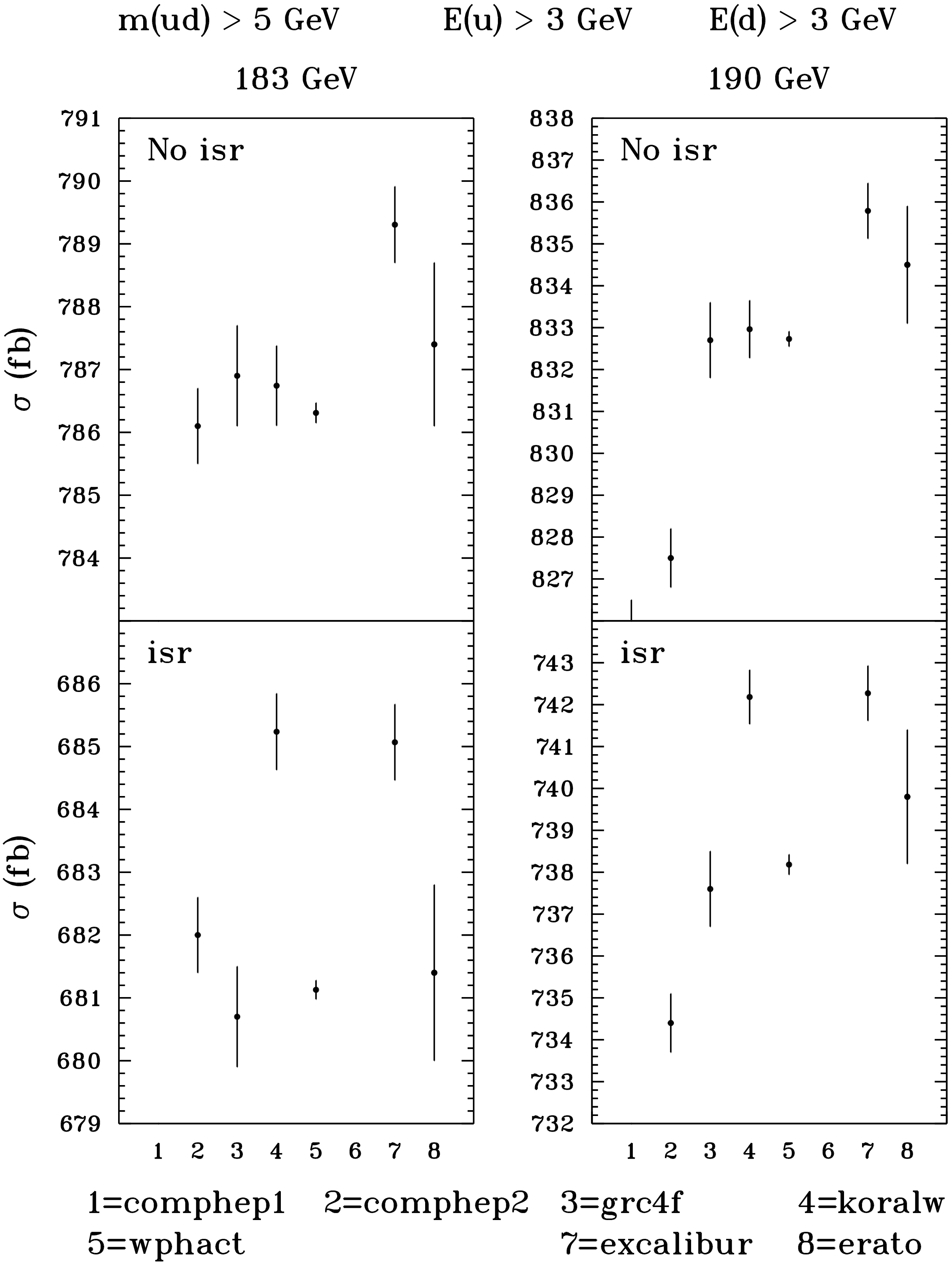


1=comphep1   2=comphep2   3=grc4f   4=koralw
5=wphact   7=excalibur

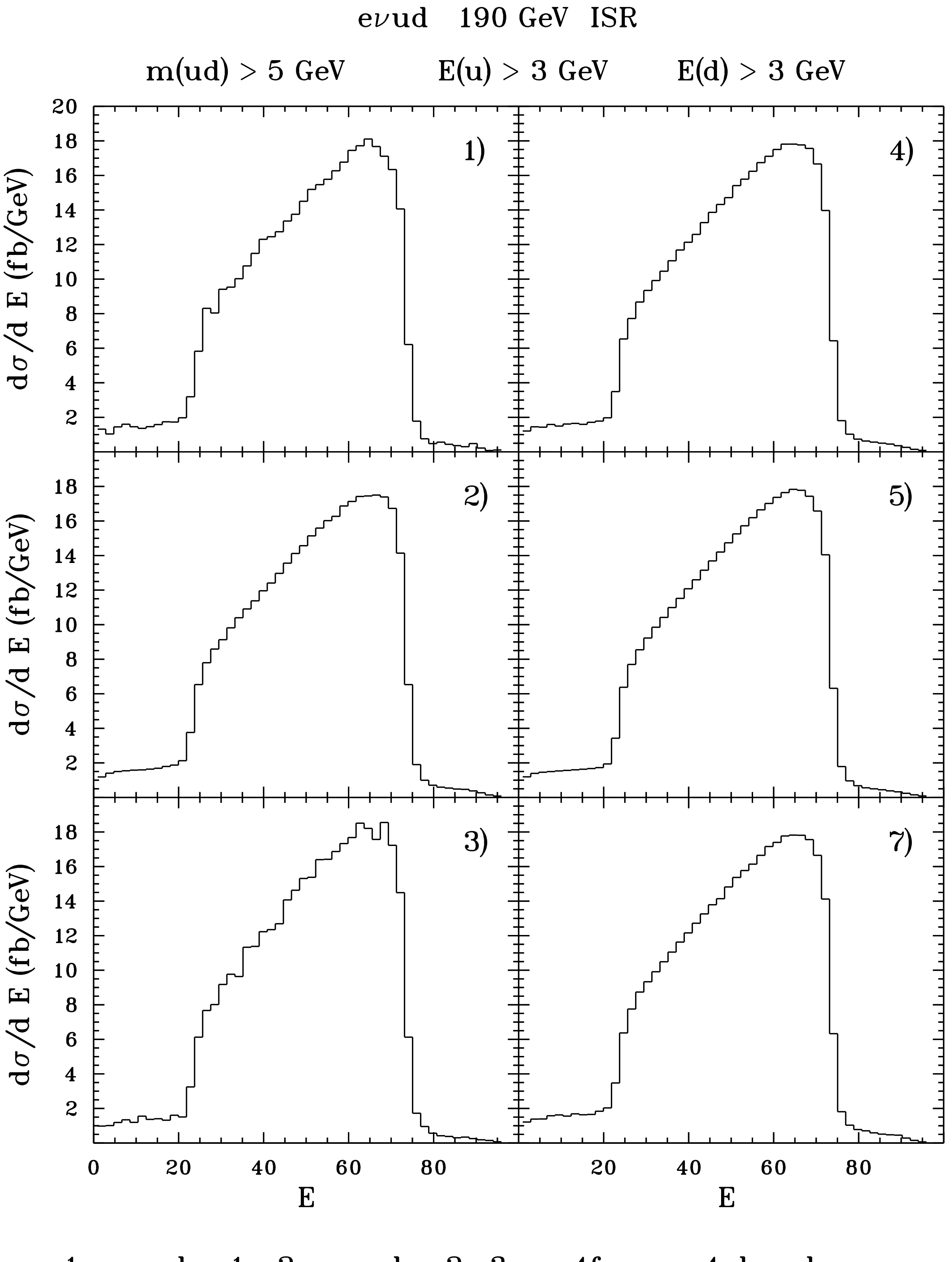


eνud
m(ud) > 5 GeV
E(u) > 3 GeV
E(d) > 3 GeV
183 GeV
190 GeV
No isr
isr
σ (fb)
790
785
780
685
680
675
670
840
835
830
825
740
735
730
725
1 2 3 4 5 6 7 8
1=comphep1
2=comphep2
3=grc4f
4=koralw
5=wphact
7=excalibur
8=erato

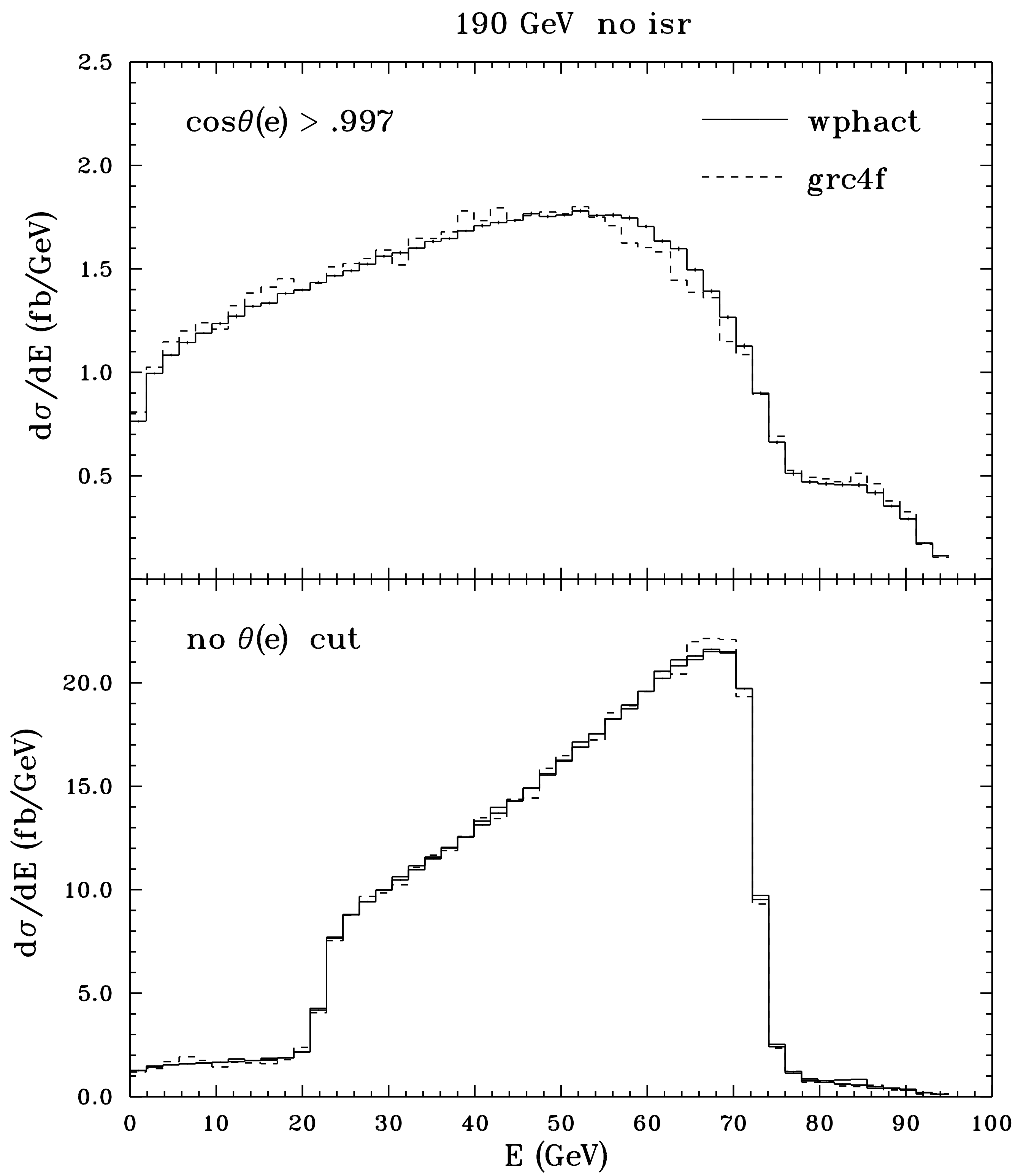
$e\nu ud$



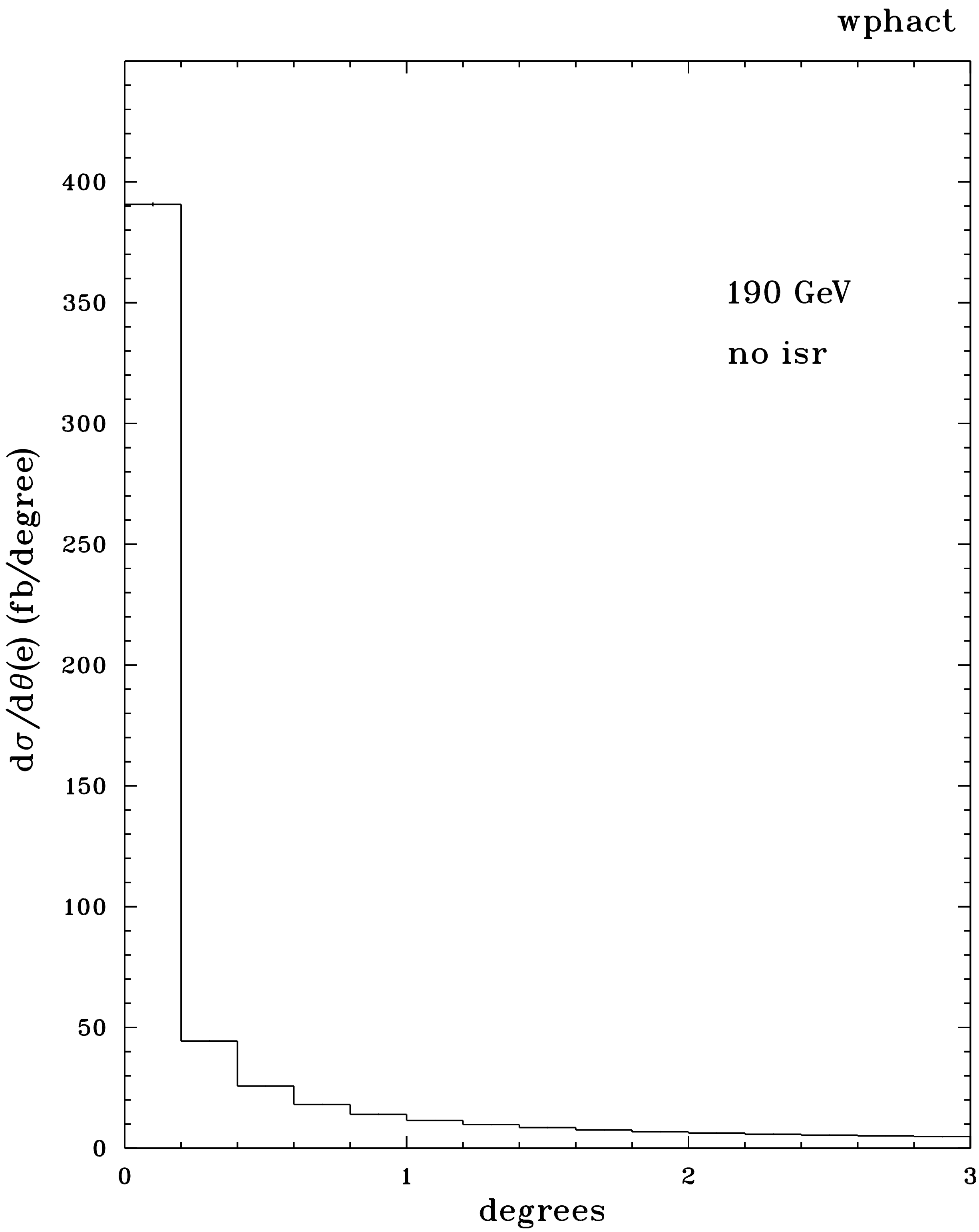
m(ud) > 5 GeV
E(u) > 3 GeV
E(d) > 3 GeV
183 GeV
190 GeV
No isr
No isr
isr
isr
σ (fb)
σ (fb)
1=comphep1
2=comphep2
3=grc4f
4=koralw
5=wphact
7=excalibur
8=erato



eνud 190 GeV ISR
m(ud) > 5 GeV E(u) > 3 GeV E(d) > 3 GeV
dσ/d E (fb/GeV)
1)
2)
3)
4)
5)
7)
E
1=comphep1 2=comphep2 3=grc4f 4=koralw
5=wphact 7=excalibur



190 GeV no isr
cosθ(e) > .997
wphact
grc4f
no θ(e) cut
dσ/dE (fb/GeV)
dσ/dE (fb/GeV)
E (GeV)
2.5
2.0
1.5
1.0
0.5
20.0
15.0
10.0
5.0
0.0
0
10
20
30
40
50
60
70
80
90
100

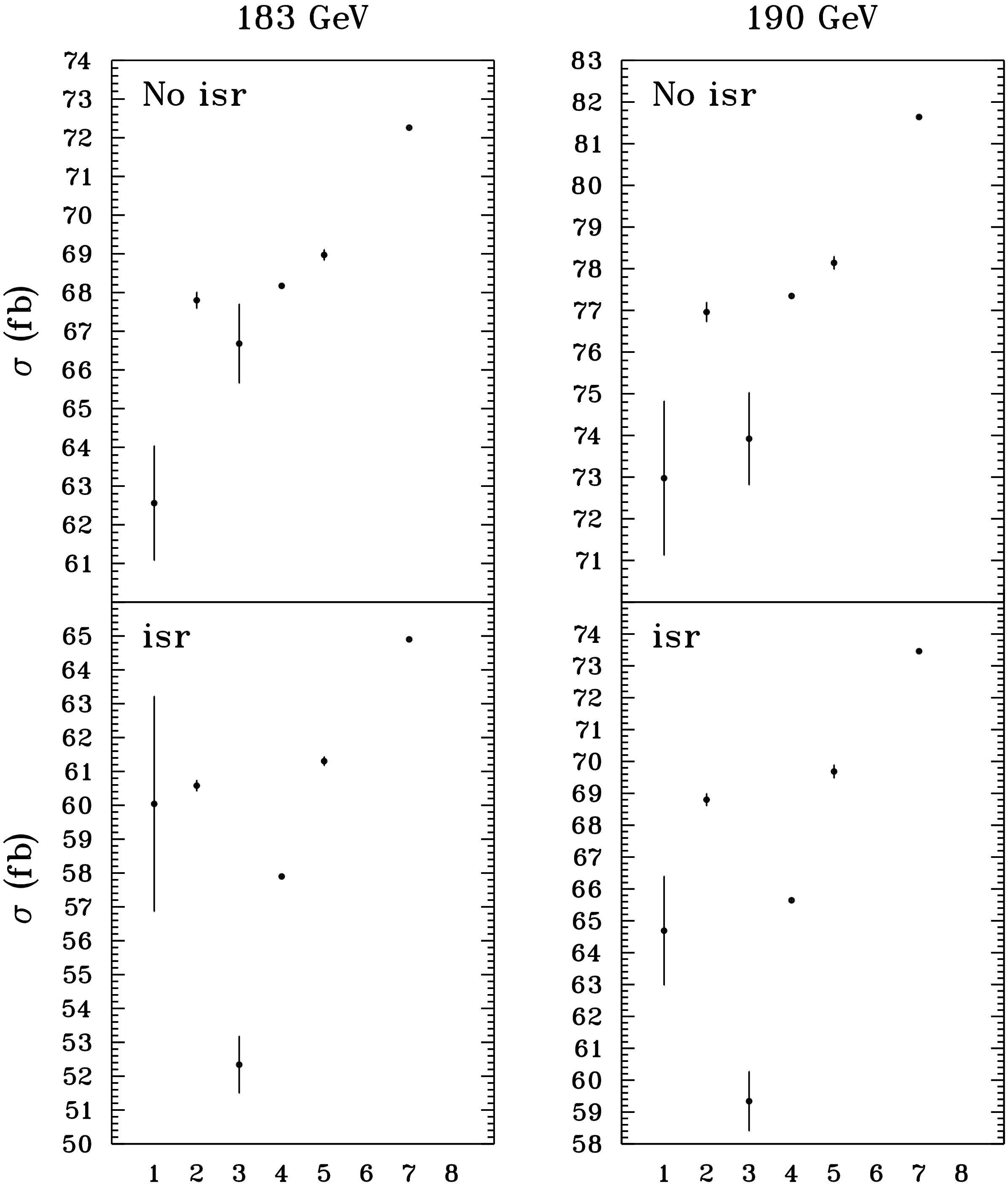


wphact
190 GeV
no isr
dσ/dθ(e) (fb/degree)
degrees
0
50
100
150
200
250
300
350
400
1
2
3

eνud

distribution first bin: $\theta(e) < 0.2$ degrees

m(ud) > 5 GeV   E(u) > 3 GeV   E(d) > 3 GeV



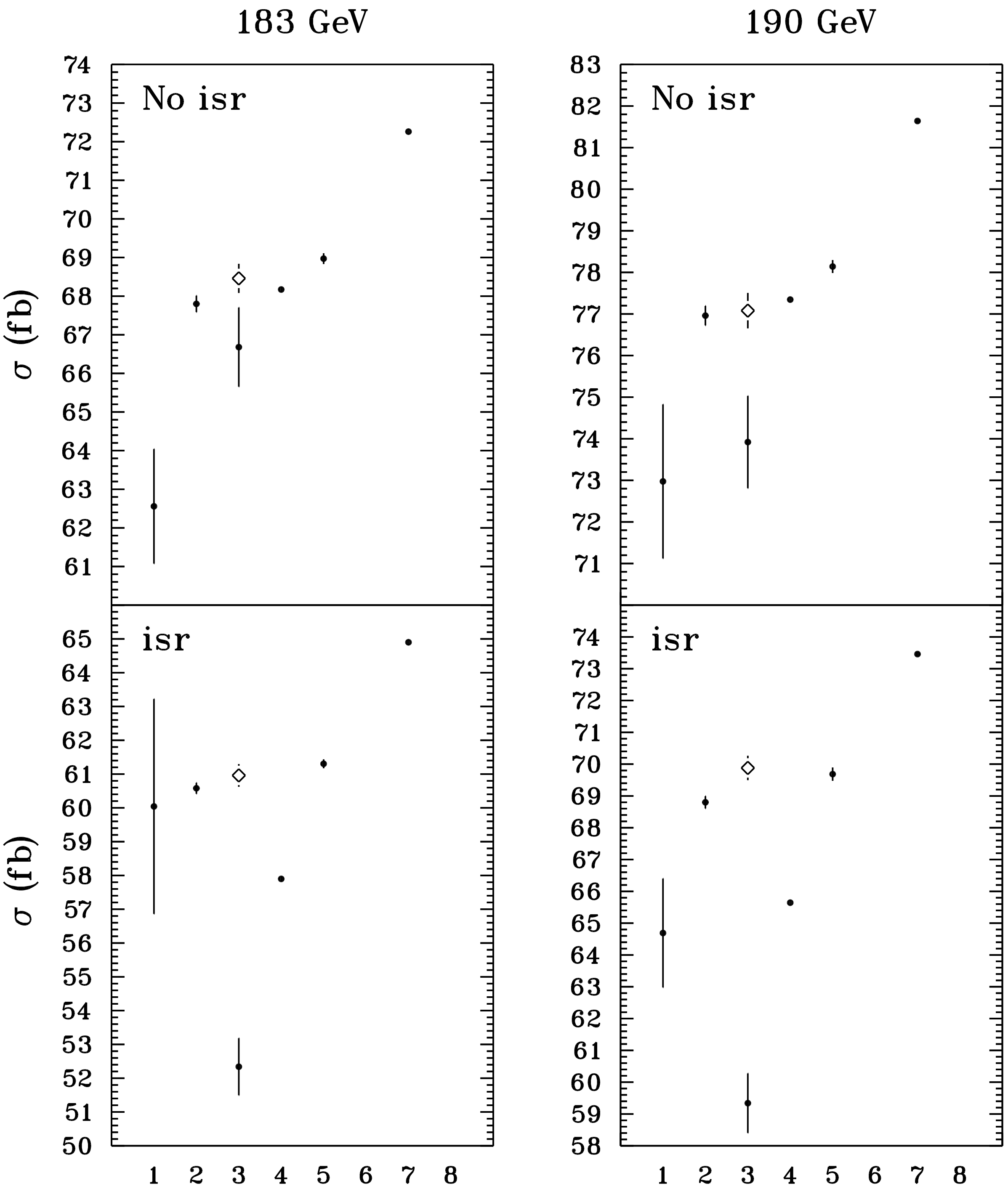
1=comphep1 2=comphep2 3=grc4f 4=koralw
5=wphact 7=excalibur

no errors quoted by 4, 7 (not requested)

eνud

distribution first bin: $\theta(e) < 0.2$ degrees

m(ud) > 5 GeV E(u) > 3 GeV E(d) > 3 GeV



1=comphep1 2=comphep2 3=grc4f 4=koralw
5=wphact 7=excalibur

◇ grc4f with $\cos\theta(e) < .997$ angular cut

Comments and suggestions

Just consider the **forward region**:
in the rest of phase space agreement is good.

- Massless (fudge) results are $\approx 5\%$ higher than the massive ones. Maybe they can improve, but surely massless programs cannot get some terms (for instance constant m_e contributions). Mass of both electrons and quarks are relevant.
- Massive codes agree better that 1%.

  But

  - this is true if we consider only one of the two Comphep results, which use a gauge preserving method which might be questionable
  - there might be some discrepancies in the very forward region ($\theta(e) < .2$)
  - Apart from Comphep only two different M.E. implementations remain.
- It seems that we have reliable phace spaces, but some doubts may remain on M.E. Even if they coincide, they may both miss some important contribution.

  For this reason the comparison also with WW approach (WTO) is important.

- Finally, before going to $\gamma\gamma$, other final states as

$$\mu\nu e\bar{\nu} \text{ and } e^+\nu e^-\bar{\nu}$$

  would test other problematic regions of the phase space.

- Experimental input is needed

  - to understand the relative relevance of new processes to study

  - to define realistc cuts and avoid useless perfomances