Matrix element calculations versus approximate ones.

Case of SANC and PHOTOS.

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Main Topics:

- **Introduction**
- **Presentation of PHOTOS and SANC.**
- **Comparisons.**
- **Example of use at LHC ($2 \to 8(+)$-body process) and at LC ($2 \to 6(+)$-body process)**
- **Summary and outlook.**

Examples from papers (incomplete list) by: A. Andonov, E. Barberio, D. Bardin, B. van Eijk, P. Golonka, S. Jadach, G. Nanava, T. Pierzchala, E. Richter-Was, Z. W., M. Worek. **Slides on http://home.cern.ch/wasm**

Main references:

1. A. Andonov, S. Jadach, G. Nanava, Z. Wąs, “Comparison of SANC with KORALZ and PHOTOS” CERN-TH/2002-315
2. D. Bardin et al., hep-ph/0209297, hep-ph/0202004
3. E. Barberio, B. van Eijk, Z. Wąs, *Comput. Phys. Commun.* **66** (1991) 115-128, ibid. **79** (1994) 291-308
4. P. Golonka, T. Pierzchala, E. Richter-Was, Z. Wąs, M. Worek at work (upgraded TPJU 10/2000, hep-ph/0009302), technical stuff.
5. E. Richter-Wąs, “Hard bremsstrahlung photons in the $t\bar{t}$ production and decay: a background for the intermediate Higgs search”, ATLAS internal notes: PHYS-NO 027 (1993) and PHYS-NO 032 (1993) (addendum), Z. Phys C **61** (1994) 323.

Main ideas:

1. In the phenomenology of High Energy Physics on has to provide calculations for Standard Model and New Physics processes.
2. Question of precision is always an issue, but not always the same level is needed.
3. Question of comfort in use is often equally important.
4. Class of solution: 4-particle, 6-particle, ... generators combined with ISR generators (for QED or QCD).
5. Another class, use of density matrices to separate large multiplicity processes into smaller sub-processes. Needed specially in case of τ-lepton, see e.g. M. Worek talk*.
6. For tool useful in tests of multifermion generators see P. Golonka talk+.
7. In every case it is convenient to have a tool for simulation of radiative corrections (FSR) in decay of 'any' particle or resonance.

* Slides on http://hpjmiady.ifj.edu.pl/˜worek/

\+ Slides on http://piters.home.cern.ch/piters/

Mother-daughter

Generally all evens comong out of Monte Carlo generators are written into event records, where:

- every particles has attributed properties,
- origins and eventually descendants,
- sometimes decay vertices have attributed properties as well.

F77 HEPEVT common block

Is one of the example of such a data structure.

PHOTOS

an algorithm for radiative (bremsstrahlung) corrections in decay of resonances and/or particles is using this data structure.

Warning: Note that it is possible only because PHOTOS algorithm relies on approximations which are in conflicts of general properties of QM

PHOTOS bases on mother-daughter tree

E. Barberio, B. van Eijk, Z. Was, Comput. Phys. Commun. (1991) .

It was developped starting from the careful downgrading from the full treatment of M.E. in MUSTRAAL (F. Berends, R. Kleiss, S. Jadach, Comput. Phys. Commun. (1982)) For the decay of Z to obtain 'factorizable' form.

Extended to work for the decay of 'any' particle or resonance.

It heavily uses mother-daughter relations in `HEPEVT` and ocasionally replaces sub-branch of individual decay with the one including bremsstrahlung photon.

- Thus it is bound to be not better than LL (may be NLL)
- Safety backup: Comparisons with M.E. Monte Carlos whenever available.
- E.g. $\tau \to e\nu\bar{\nu}\gamma$, $\tau \to \pi\nu\gamma$, $Z \to \mu^+\mu^-\gamma(\gamma)$, $gg \to t\bar{t}\gamma\gamma$.

In many cases tests are not available ... but there is progress,

SANC system

At present for one-loop Electroweak Standard model prediction, including virtual and real photon emissions, for the decays of on-shell vector and scalar bosons $B \to f\bar{f}(\gamma)$, where B is a vector boson Z or W or a Standard Model (SM) Higgs.

It is expected to collect 30 years of D. Bardin experience of loops for LEP into environment for teaching and start for future works.

First applications:

- complete $\mathcal{O}(\alpha)$ calculation (and MC) for $Z \to l\bar{l}\gamma$.
- complete $\mathcal{O}(\alpha)$ calculation (and MC) for $H \to l\bar{l}\gamma$.
- complete $\mathcal{O}(\alpha)$ calculation (and MC) for $W^- \to l\bar{\nu}\gamma$.

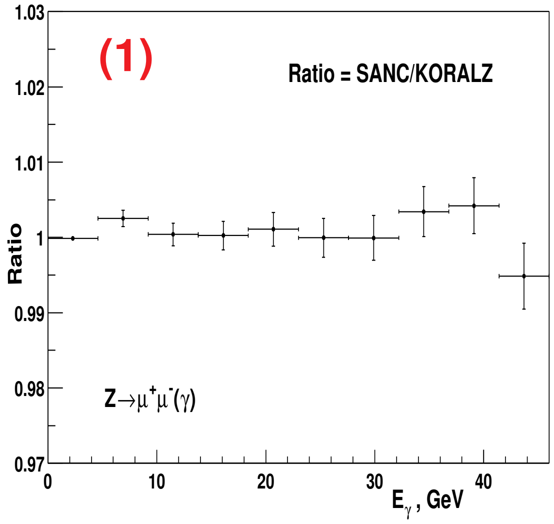
KORALZ as test for SANC;

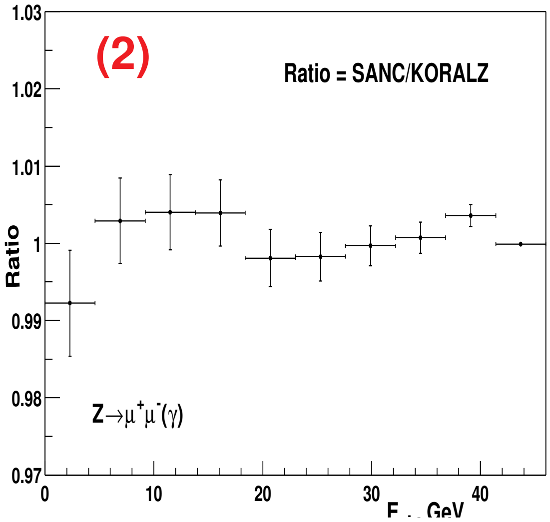
$Z \rightarrow \mu^+\mu^-$ and four tests:

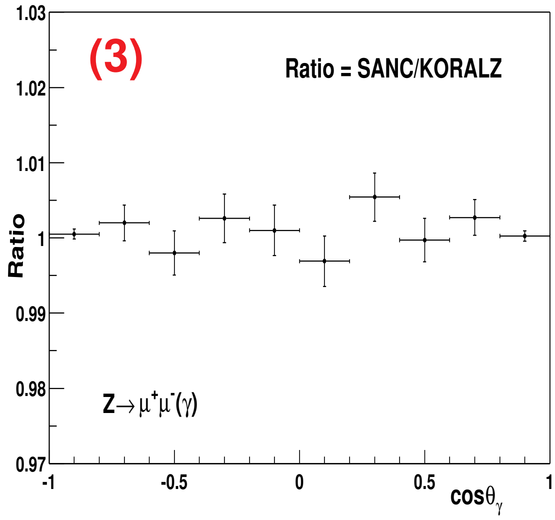
(1) Photon energy (ll) **(2)** Charged lepton energy (ll)

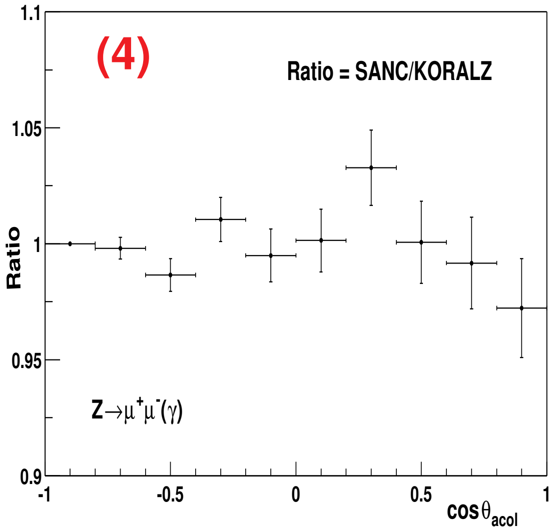
(3) Photon angular distribution (soft)

(4) leptons acollinearity (nl)







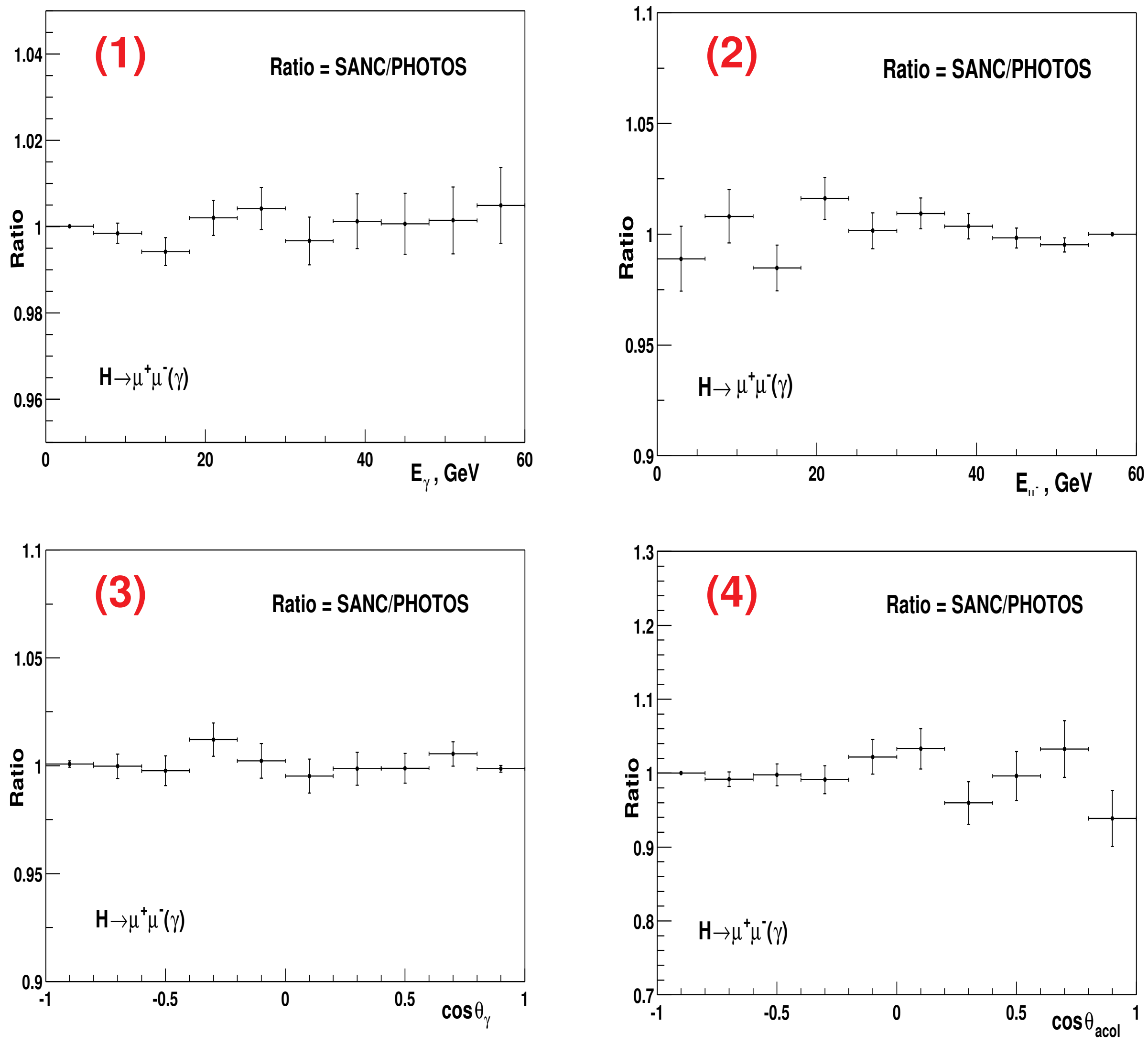


$h \to \mu^+\mu^-$ and tests:

(1) Photon energy (ll) **(2)** Charged lepton energy (ll)

(3) Photon angular distribution (soft)

(4) leptons acollinearity (nl)



Tests 1 2 check SANC, 1 2 3 4 check PHOTOS.

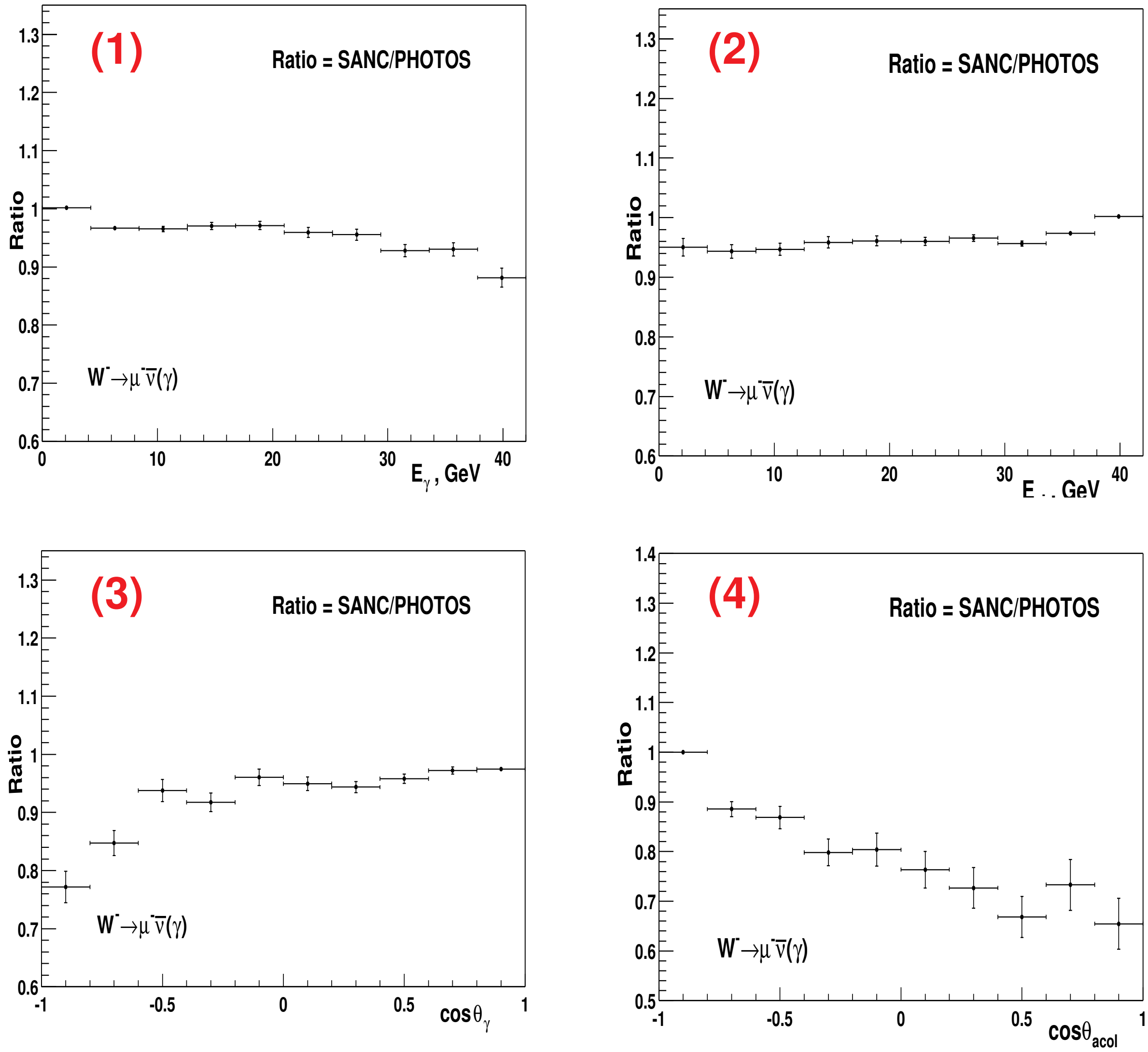
PHOTOS and SANC check each o.

$W \to \mu^- \bar{\nu}$ and four tests:

(1) Photon energy (ll) **(2)** Charged lepton energy (ll)

(3) Photon angular distribution (soft)

(4) leptons acollinearity (nl)

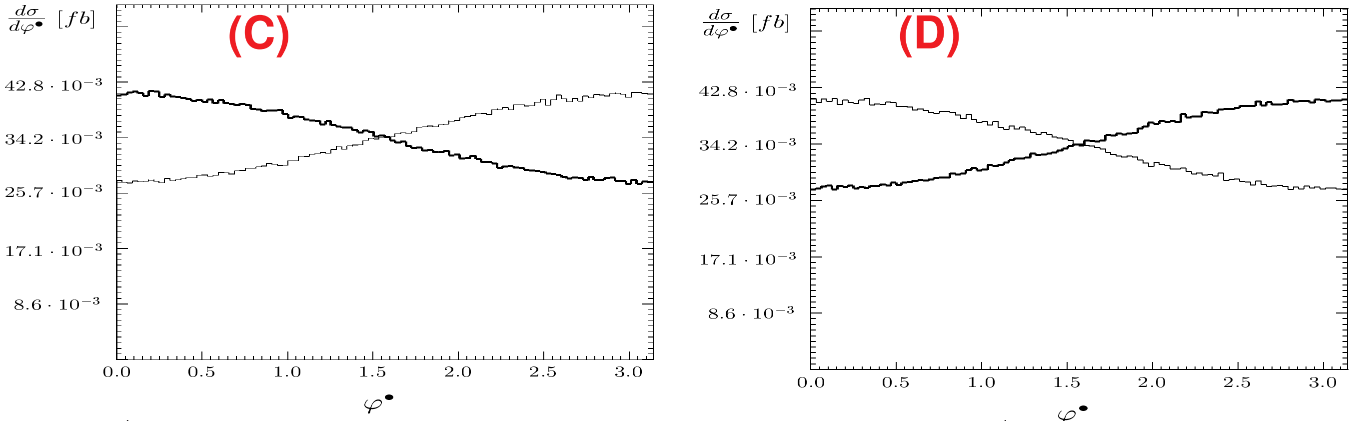


Tests 1 2 check SANC, 1 2 3 4 check PHOTOS.

Case of $h \to \tau^+\tau^- \to \nu\pi^-\pi^0\bar{\nu}\pi^+\pi^0$

Thanks to excellent agreement of PHOTOS with SANC, we can conclude that in the case of observables for Higgs boson parity measurement at LC, bremsstrahlung can be safelly included in the simmulation.

Let me recall one plot from talk by M. Worek:



The $\rho^+\rho^-$ decay products' acoplanarity distribution angle, $\varphi^\bullet$, in the rest frame of the $\rho^+\rho^-$ pair. A cut on the differences of the $\pi^\pm\pi^0$ energies defined in their respective replacement $\tau^\pm$ rest frames to be of the same sign, selection $\mathcal{C}_{reco}$, is used in the left plot and the opposite sign, selection $\mathcal{D}_{reco}$, is used for the right plot. All smearing is included. Thick lines denote the case of the scalar Higgs boson and thin lines the pseudoscalar one. Units valid for the 500 GeV e^+e^- CMS (scalar 120 GeV mass) Higgsstrahlung production only. Otherwise arbitrary units.

Effects of radiative corrections and detector smearing can be studied together. We can check now how effects of false reconstruction of π^0's due to bremsstrahlung affect those pictures.

Case of $pp \to t\bar{t}\gamma\gamma$

In searches of Higgs boson at LHC, $h \to \gamma\gamma$ channel is expected to provide important signature. Background control is essential.

One of possible sources consist of $pp \to t\bar{t}; t \to bW; W \to l\nu$ plus up to double bremsstrahlung at every step of the cascade.

$2 \to 8$ process !!!

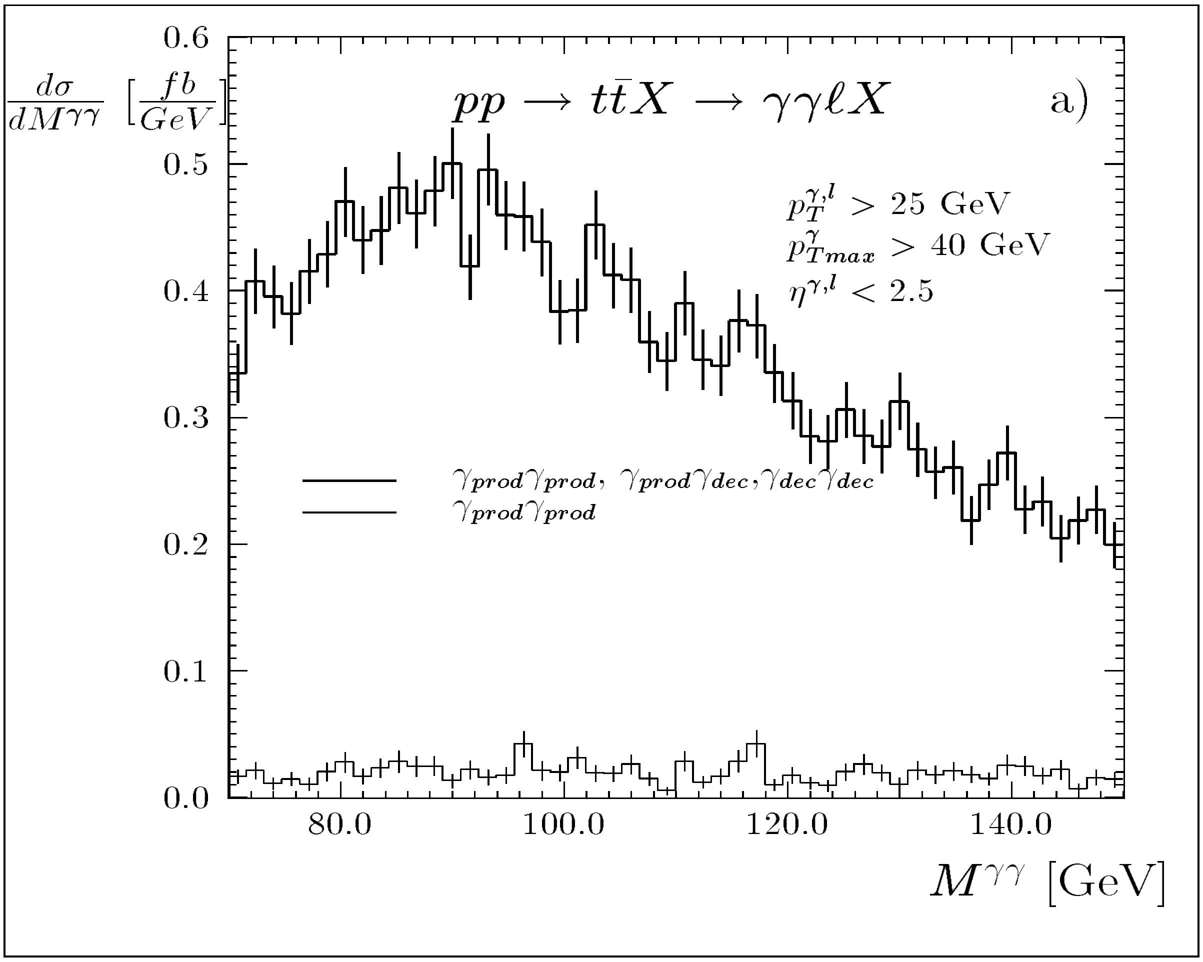
Precision required is not extremelly high at present (but will need to improve).

1. Hard process can be separated into 'steps'.
2. PHOTOS can be used to generate double bremsstrahlung at every step.
3. In particlular $W \to l\nu$

Thanks to reported study control of the theoretical uncertainty for the plots like below can be improved. Luckily PHOTOS over-shoots high p_t bremsstrahlung. Room for improvement.

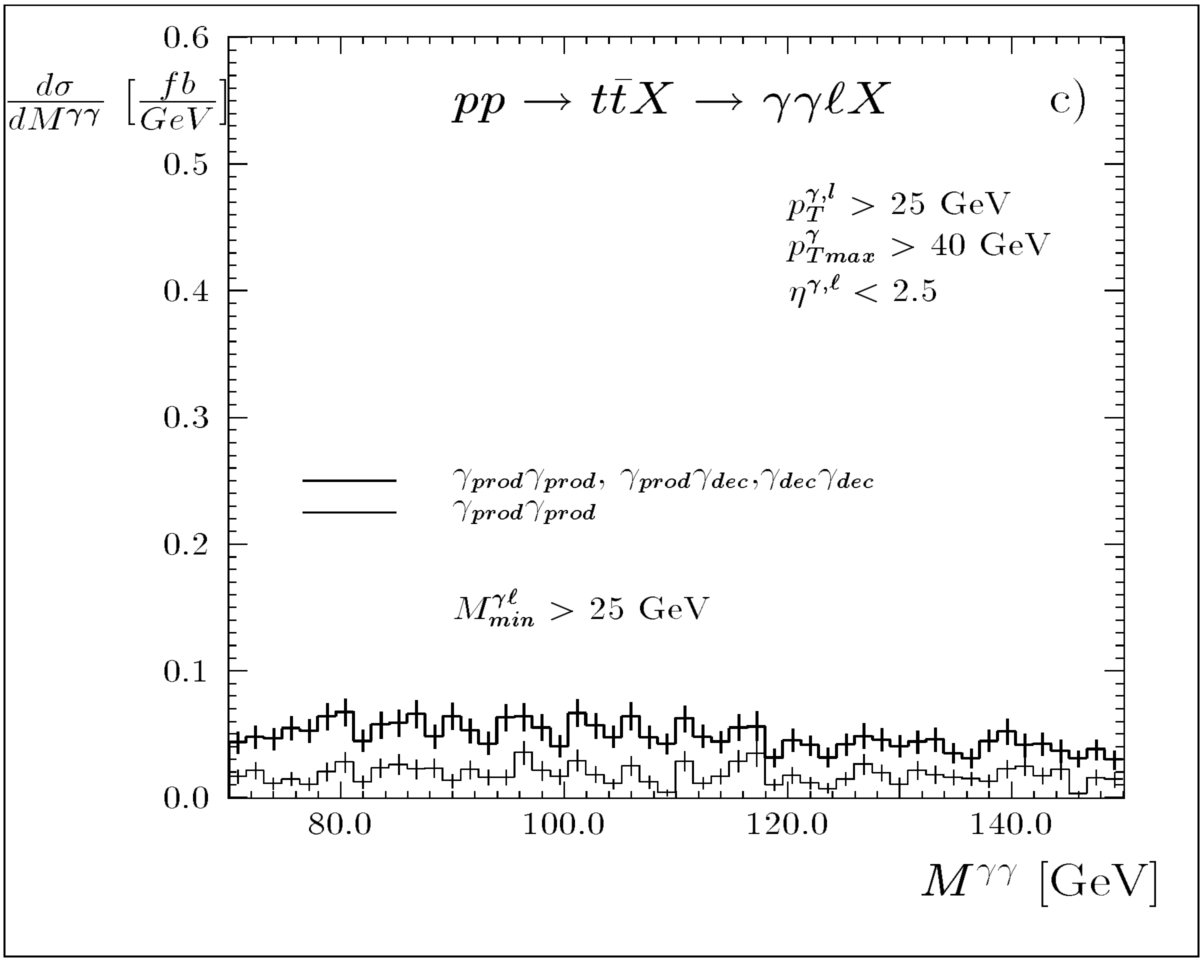
From ATLAS note phys-93-027

Fig. 5



From ATLAS note phys-93-027

Fig. 5



Conclusions

Main points

- Status of PHOTOS and SANC projects was reviewed.
- First practical applications for SANC were defined. It turned out to be helpful in checking uncertainties of PHOTOS predictions for bremsstrahlung in W and h boson decays .
- It is of some phenomenological value for LC and LHC projects. of the programs!