Radiative Bhabha scattering

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Reminder: Questions about radiative Bhabha scattering

Launchpad `https://answers.launchpad.net/whizard/+question/685180`

Status Open

Details
- Process to generate: $e^+e^- \to e^+e^-\gamma$ at 3 TeV (background to monophoton if both of the electrons are either very soft or stay in the beam pipe)
- ideally no cuts can be placed on the electrons, only on the photon
- Requirements on the photon do also bias the electron kinematics a bit, but nevertheless we do not get a convergence with Whizard if no electron cuts are applied $\to$ numerical singularity?
- How can we know in a well-defined way what is the part of the cross section we are missing when we apply cuts on the electrons?
- Or can we generate samples without cuts on the electrons by applying the phs_q_scale setting and get a cross section we can trust?

Sindarin An example sindarin can be found here: `https://cernbox.cern.ch/index.php/s/1i3EFSz0BGS6ftS`

More info More info `https://indico.cern.ch/event/842877/contributions/3602728/`

Extended precision

- $e^+e^- \to e^+e^-\gamma$ at 3 TeV
- Using Whizard with extended precision
- For the following settings it is possible to obtain reasonably good convergence

```
phs_q_scale = 1e-4 GeV
beams = e1, E1 => circe2 => isr
isr_mass = me
cuts = let @me_photons = select if Index > 2 [A] in all E > 10 GeV [@me_photons] and all
Theta > 7 degree [@me_photons] and all Theta < 173 degree [@me_photons]
(In the case of no ISR, the index for ME photons starts at zero)
iterations = 10:1000000:"gw", 5:500000:""
```

Cross check with LEP

Monophoton selection

- Jean-Jacques: cross check with LEP data from hep-ex/0402002
  - single photon analysis
  - this corresponds to the case of ISR, but no BS, and no cuts applied to the electrons
  - $\nu\nu\gamma$ can be reproduced
  - $ee\gamma$ is a factor 7 too large in the simulation (applying a Q cut of 1 GeV leads to good agreement though)

Wide-angle inclusive ee selection: CERN-EP-99-181

- Selection requires e+ and e- in the fiducial volume, cut on energy of the electron
- Simulation for process ee $\rightarrow$ ee γ (γ in matrix element)
- Good agreement found
- Good agreement also for ee $\rightarrow \mu\mu\gamma$

Convergence

Sindarin:

```
model = SM_CKM
alphas = 0
phs_q_scale = 1e-4 GeV
process decay_proc = e1, E1 => e1, E1, A
sqrts = 3000 GeV
beams = e1, E1 => circe2 => isr
?keep_beams = true
!isr_order = 3
?isr_handler = true
$isr_handler_mode = "recoil"
isr_alpha = 0.0072993
isr_mass = me
$circe2_file =
"/cvmfs/clicdp.cern.ch/software/WHIZARD/circe_files/CLIC/3TeVeeMapPB0.67E0.0Mi0.15.circe"
$circe2_design = "CLIC"
?circe2_polarized = false
cuts = let @me_photons = select if Index > 2 [A] in all E > 10 GeV
[@me_photons] and all Theta > 7 degree [@me_photons] and all Theta < 173
degree [@me_photons]
integrate (decay_proc) {iterations = 10:1000000:"gw", 5:500000:""}
```

Example run:

```
|=============================================================================|
| It Calls Integral[fb] Error[fb] Err[%] Acc Eff[%] Chi2 N[It] |
|=============================================================================|
 1 999984 4.3705426E+04 5.86E+03 13.40 134.00* 0.01
 2 999970 4.8171110E+04 2.21E+03 4.59 45.92* 0.01
 3 999958 4.8468336E+04 2.25E+03 4.65 46.48 0.01
 4 999946 4.7865732E+04 1.00E+03 2.09 20.89* 0.03
 5 999930 4.8370385E+04 1.06E+03 2.20 22.01 0.02
 6 999916 4.8617372E+04 1.05E+03 2.16 21.56* 0.02
 7 999902 4.8150421E+04 7.86E+02 1.63 16.32* 0.04
 8 999892 5.0041556E+04 9.30E+02 1.86 18.58 0.03
 9 999880 5.1229072E+04 1.70E+03 3.32 33.15 0.02
 10 999874 4.8406760E+04 6.23E+02 1.29 12.86* 0.06
|-------------------------------------|
 10 9999252 4.8619626E+04 3.35E+02 0.69 21.77 0.06 0.73 10
|-------------------------------------|
 11 499988 4.8104579E+04 9.08E+02 1.89 13.35 0.07
 12 499988 4.9474628E+04 1.11E+03 2.24 15.83 0.04
 13 499988 4.6669981E+04 7.80E+02 1.67 11.82* 0.04
 14 499988 4.9638795E+04 1.50E+03 3.02 21.34 0.03
 15 499988 4.8943040E+04 9.35E+02 1.91 13.51* 0.03
|-------------------------------------|
 15 2499940 4.8181403E+04 4.36E+02 0.91 14.31 0.03 1.68 5
|=============================================================================|
```

$\Rightarrow$ good convergence

ISR mass

- The stability of the convergence seems to be dependent on the value of the `isr_mass` parameter
- For the settings from above, but different `isr_mass` settings, the behavior is:

  `isr_mass = 0.000510`: good convergence
  `isr_mass = me`: good convergence
  `isr_mass = 0.000512`: no convergence (cross section jumps by multiple orders of magnitude)
- If the `phs_q_scale` is reset to default, all cases independent of `isr_mass` behave similarly unstable (somewhat converging, but large error)
- We would like to understand the reason for this behavior

Influence of ISR and beamspectrum

Cross sections in fb:

$e^+e^- \to e^+e^-\gamma$

	no BS	with BS
no ISR	1.1E+04	1.2E+06
with ISR	2E+04	5E+04

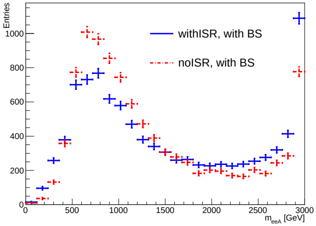
comparison: $e^+e^- \to \mu\mu\gamma$

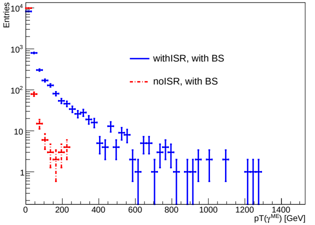
	no BS	with BS
no ISR	1.23e+01	2.79e+01
with ISR	1.91e+01	4.24e+01

- If ISR is applied, the cross section is a factor 2.5 higher with beamspectrum than without beamspectrum. This might be possible physically, considering that the BS enhances the contribution of lower-E regions with higher cross section. However, the cross section grows from 2E+04 at 3 TeV to 3.6E+04 at 1.5 TeV [no ISR, no BS: fixed $\sqrt{s}$], so it is not immediately obvious how to get a factor of 2.5. (This is consistent with Jean-Jacques' test from October.)
- The cross section **without** ISR is a factor of 100 higher with Beamspectrum $\to$ this seems too much of a difference to be physical (compare to argument above: cross section does not grow so much with lower $\sqrt{s}$). How can this be explained?
- One can turn this question around and say that with the beam spectrum included, the cross section decreases by a factor of 25 from the no-ISR value when ISR is applied. Also this seams a too large influence of ISR
- Could it be an effect of problematic areas of phase space in the Beam Spectrum, whose influence is small when ISR is applied? This is suggested by the fact that if a small Q cut is applied in the no ISR, with BS case, the cross section is immediately lowered:
  - cut: `all M < -1 [incoming e1, e1]` and `all M < -1 [incoming E1, E1]` $\Rightarrow$ cross section: 1.9E+04
  - and with even smaller Q cut (M < -0.001): 2.7E+04
- There is no such inconsistency for muons

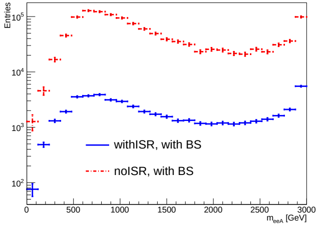
Kinematic comparisons for ee $\rightarrow$ eeA +BS [+ ISR]

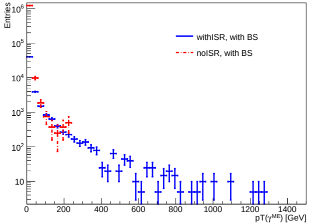
normalised to the same area:





normalized to the cross section:





m_{eeA}: invariant mass of the final state electrons and the matrix-element and ISR photons

$pT(\gamma^{ME})$: pT of the matrix-element photon

Conclusions and questions

What we have learned:

- very useful to ensure better convergence: phs_q_scale = 1e-4 GeV
- isr_mass = me must be set (for larger isr_mass, no convergence) $\rightarrow$ why does this have an influence at all?
- with these settings, it is possible to get cross sections that converge, without applying cuts on the electrons

Questions:

- Why is there a problem when `isr_mass` is not set to `me`?
- Why is there a factor 100 between using BS and not using BS, if no ISR is applied? This seems unphysical to us.
- Given these inconsistencies, we still do not know which number we can trust or which settings to use to get the right cross section.

Discussion with Whizard authors

- The generation with photon in the matrix element plus ISR is not well defined and should not be used, as the ISR calculation assumes no photon from the ME.
- We will follow up regarding the factor 100 between the cases with and without BS when not using ISR: more detailed investigation of cross section dependence on $\sqrt{s}$
- Investigation of the cross check to LEP: no agreement in the monophoton analysis (while all other cross checks give reasonable agreement)
- It makes sense that the issue is not in ee $\to \mu\mu\gamma$ because this only has the t-channel and lacks the Coulomb singularity
- They will follow up the `isr_mass` issue