The new MC-2020 250 GeV data sets - and why you should use them

part 1 - samples, beam parameters & physics

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[1]DESY, Hamburg

ILD general meeting, December 8, 2020

Outline

1. Why: MC requirements for linear colliders
2. How: Generating the full SM
   - Process classification
   - Physics generator
   - Generating beam properties
3. What: ILC 250 GeV Generation production
   - Whizard 1.95 $\rightarrow$ 2.8.5
   - Beams
   - Generation status
4. Conclusions

MC requirements for linear colliders

- Future LCs aim for extremely high precision measurements.
  - $\Rightarrow$ Need excellent detector, well controlled machine conditions
  - But also the best possible estimate of backgrounds.
- So: MC statistics or lacking channels must not be a major source of systematic errors $\Rightarrow$
  - All SM channels yielding at least a few events under the full lifetime of the projects need to be generated, with statistics largely exceeding that of the real data.
  - Also machine conditions need to be accurately taken into account.

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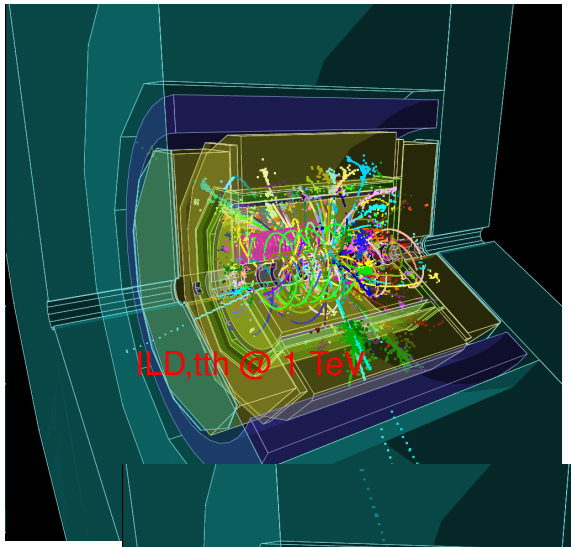
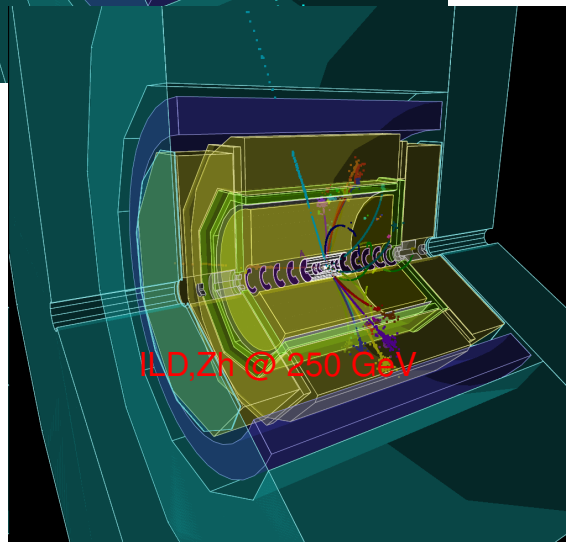
Generating the full SM

- At an LC, ALL events are interesting !
- Huge spread in cross-sections
- But for any given study, it might be a tiny cross-section one that dominates...
- ... or maybe a tiny fraction of a huge cross-section one.
- We want to make nice stacked histos of different backgrounds - different from analysis to analysis.
- $\Rightarrow$ Good idea to separate channels in an intelligent and well documented way





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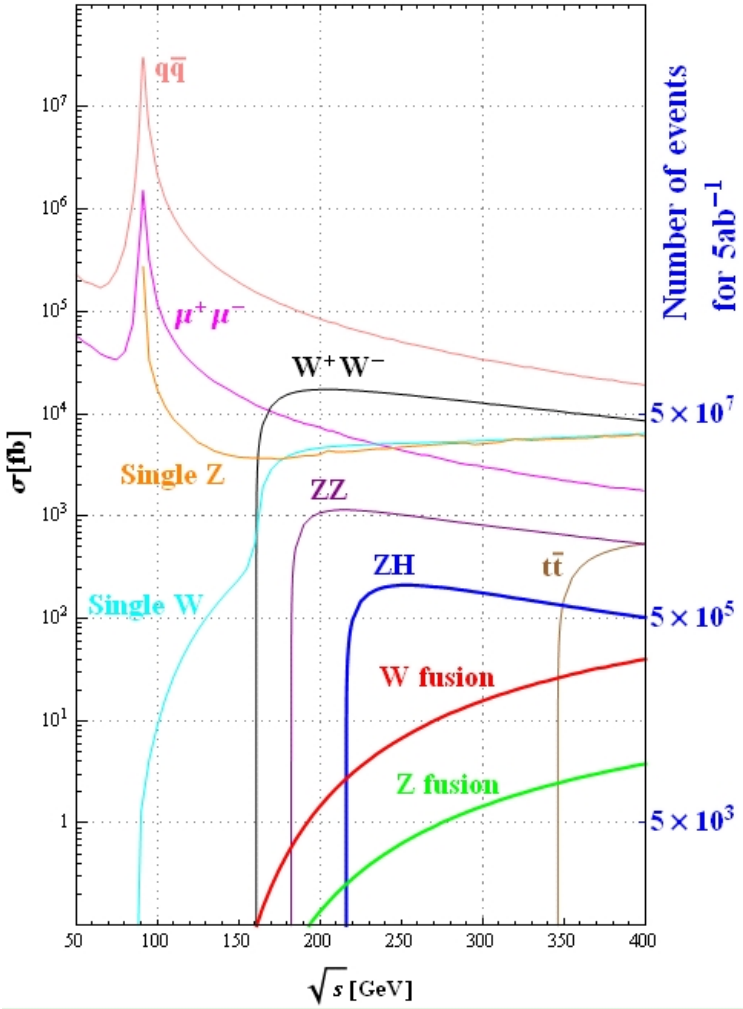

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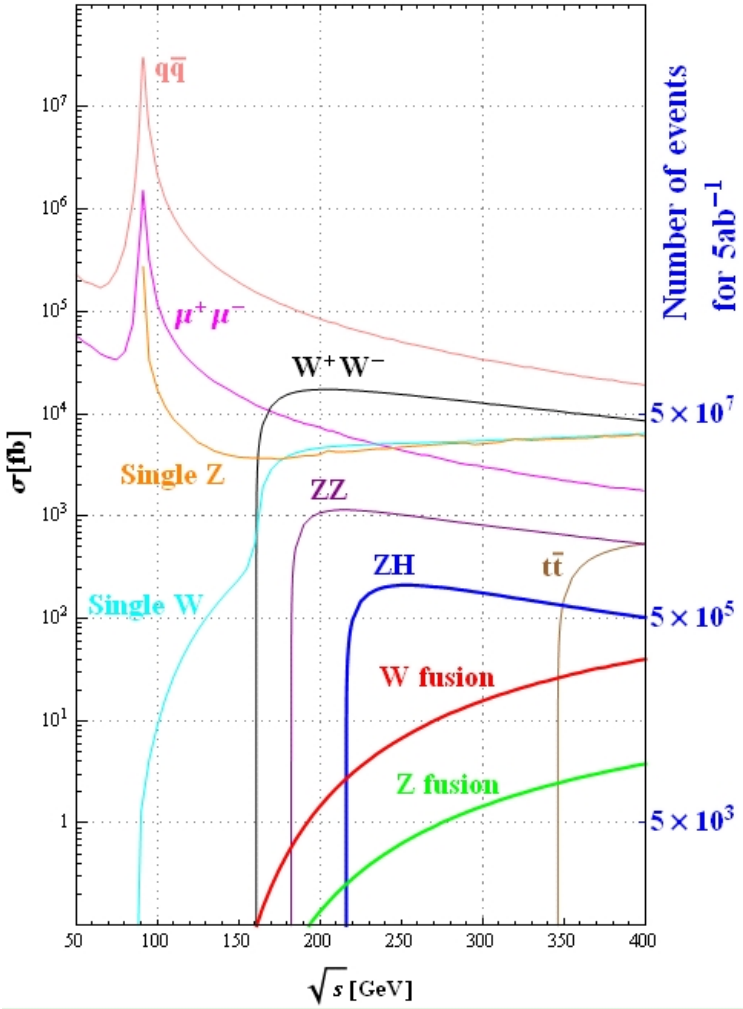

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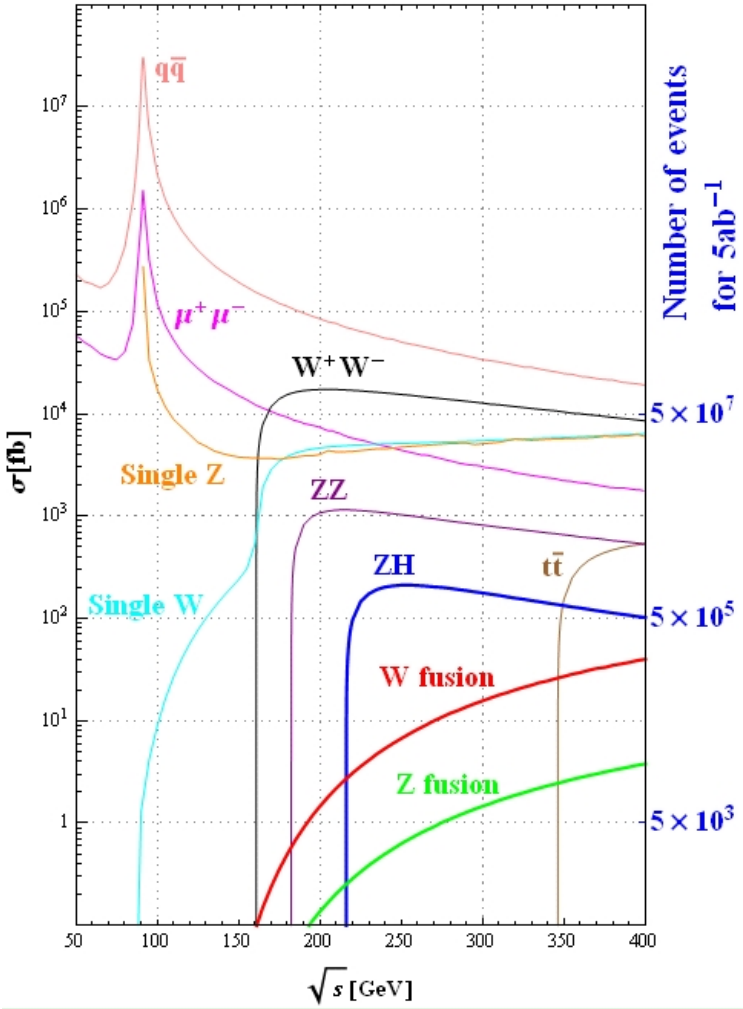

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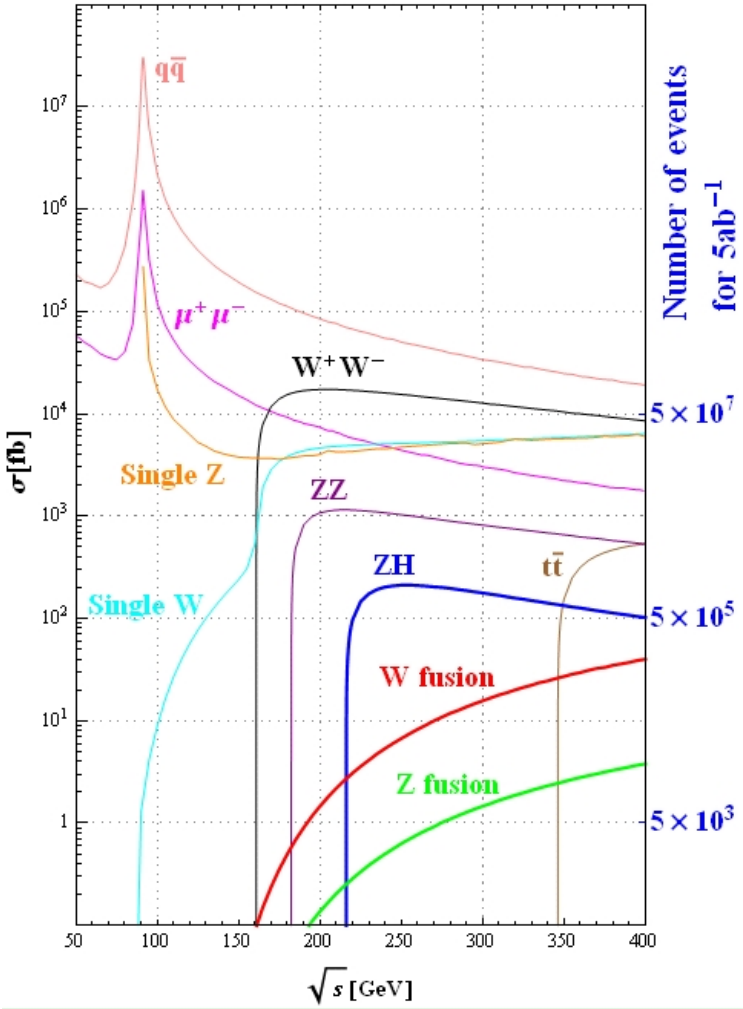

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Process classification

- Initial state
  - ee, eγ or $\gamma\gamma$
  - e - polarisation and γ type (real or virtual)
- Final state
  - Number of fermions (1 to 8)
  - Flavour-grouping: W or Z, or ambiguous
  - leptonic, hadronic, semi-leptoni (+ neutrino only, for Z-leptonic)
- Special considerations
  - Eg. 4f with $|L_e|$=2 $\Rightarrow$ dominated by single W or single Z (t-channel !)
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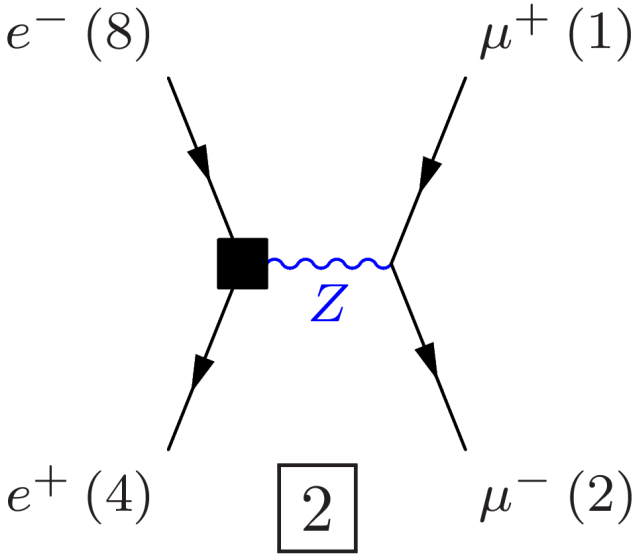

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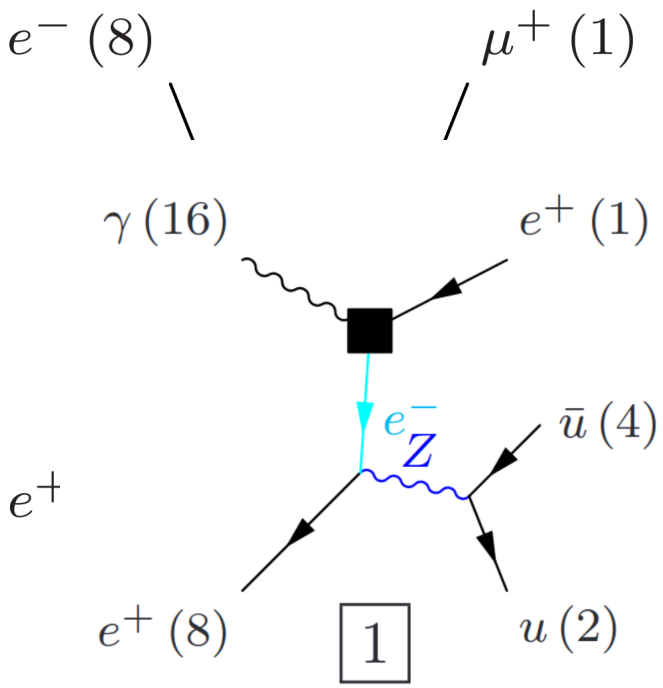

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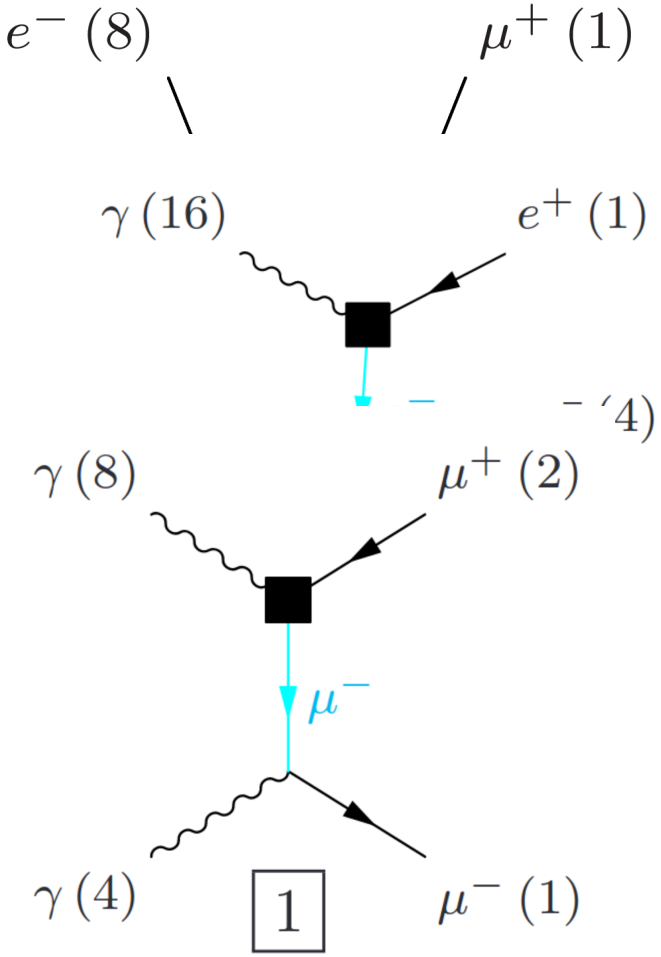

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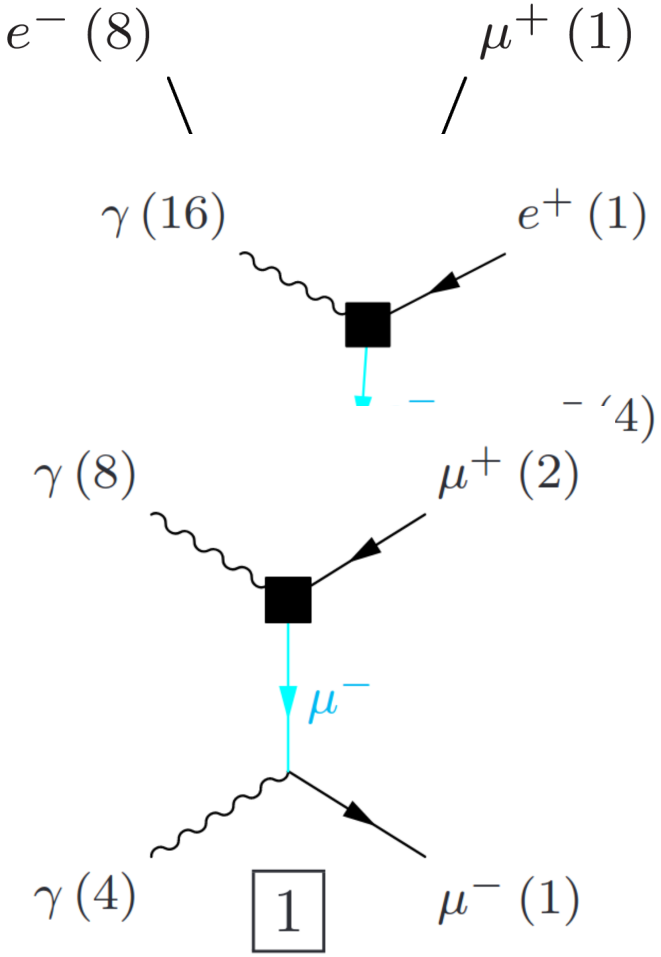

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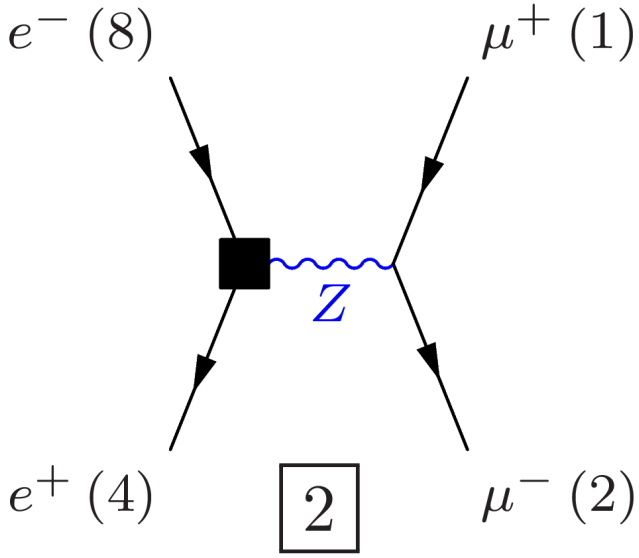

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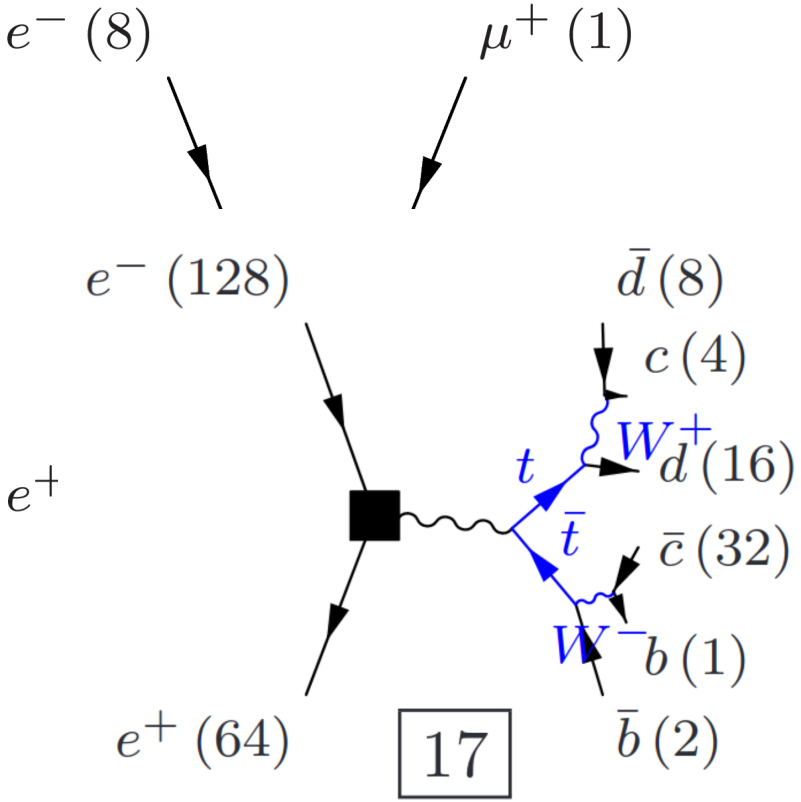

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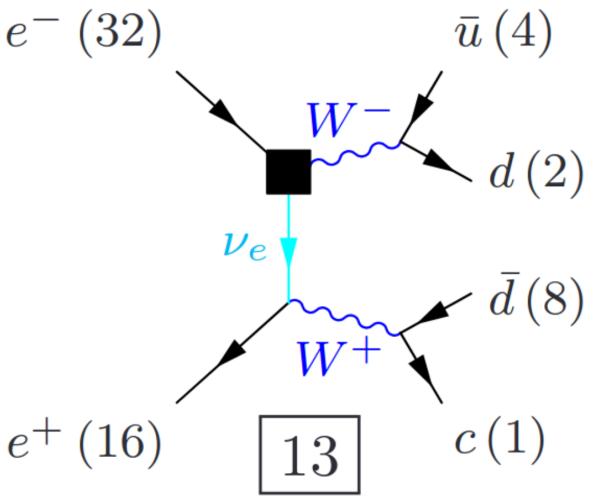

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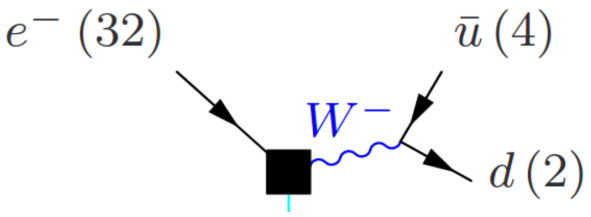

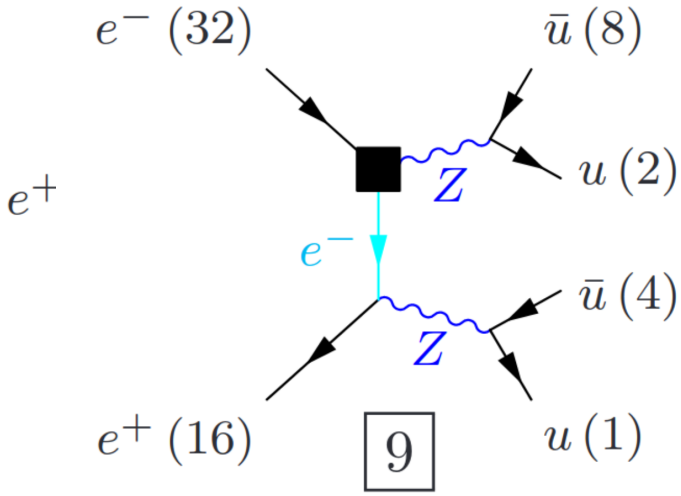

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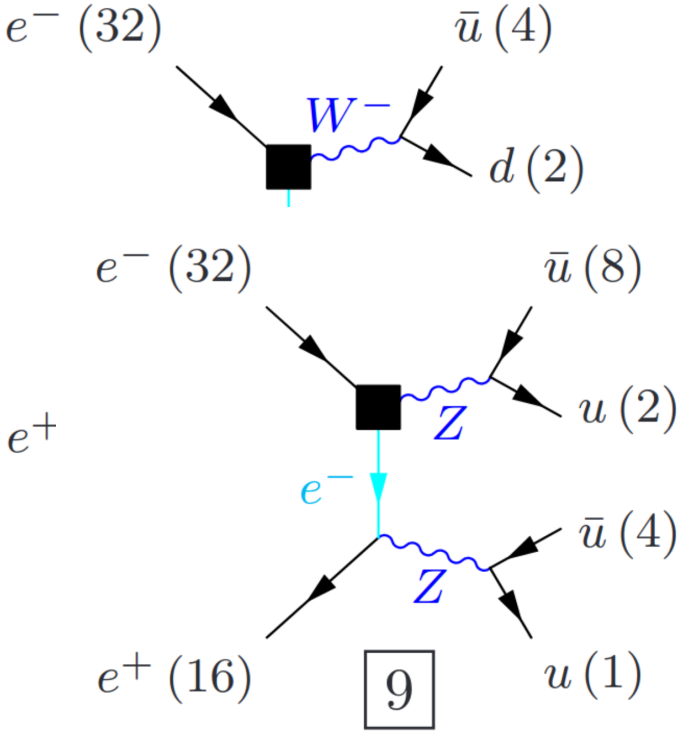

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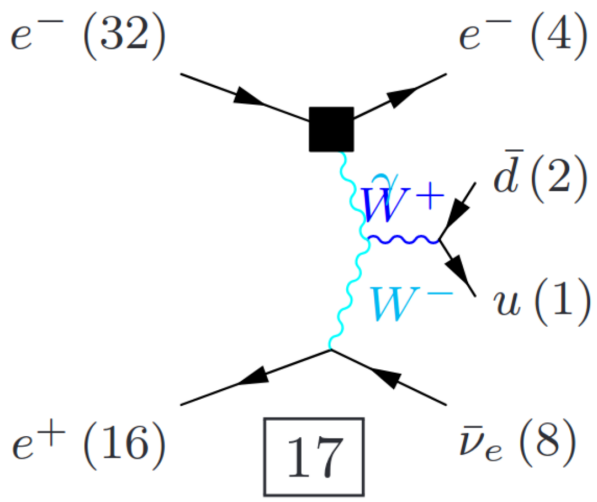

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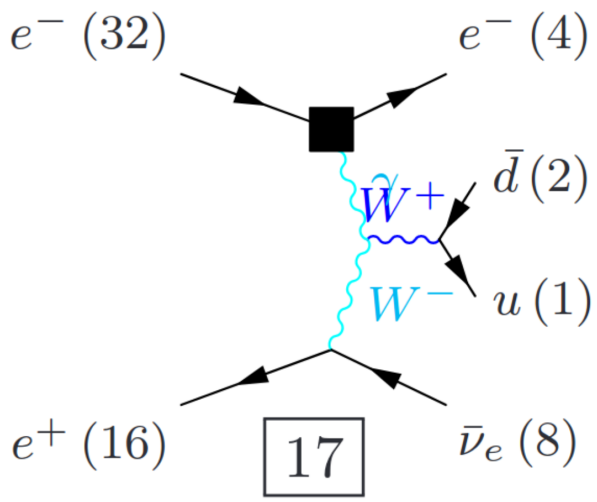
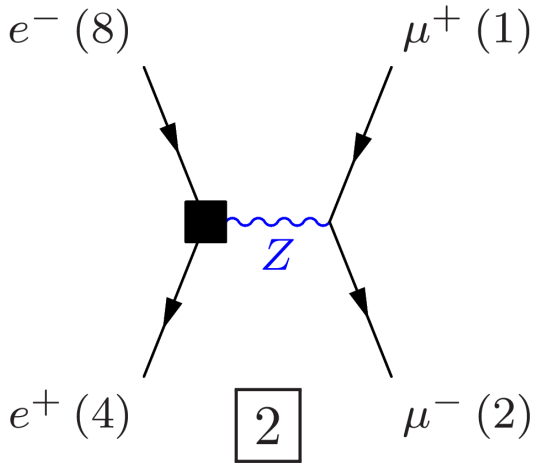


Main generator: Whizard

Whizard is the generator of choice for e^+e^-

- Full matrix-element evaluation.
  Only at tree-level but:
  - Polarised beams.
  - Full helicity treatment.
  - Full colour flow, passed from the hard interaction to the P.S. code.
  - Can handle beam-spectrum, using Circe2.
  - Can handle polarised τ-decays, using TAUOLA [Comp Phys Comm,64,p275].
  - And: Can do $2 \to 8$ processes.
- ... which is more important than NLO for e^+e^- ! That was just one 5f tree-level diagram of ~ 500...



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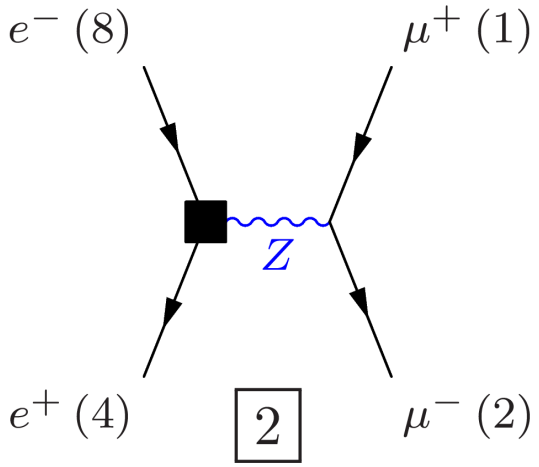

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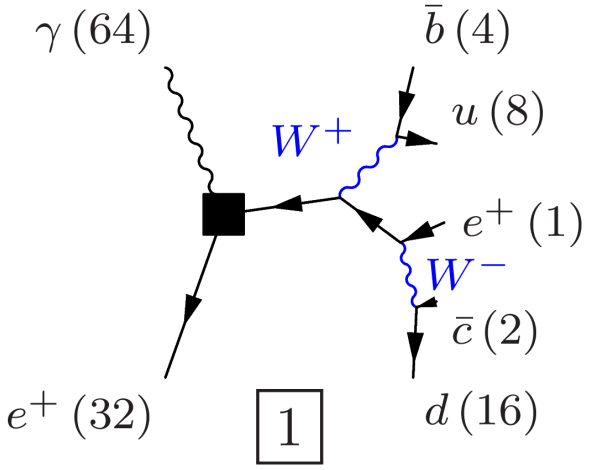

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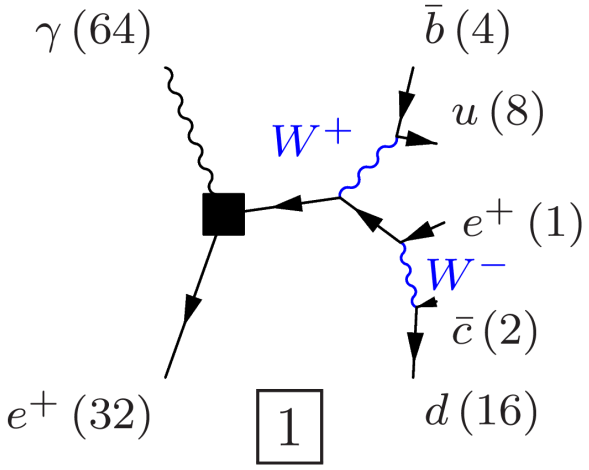

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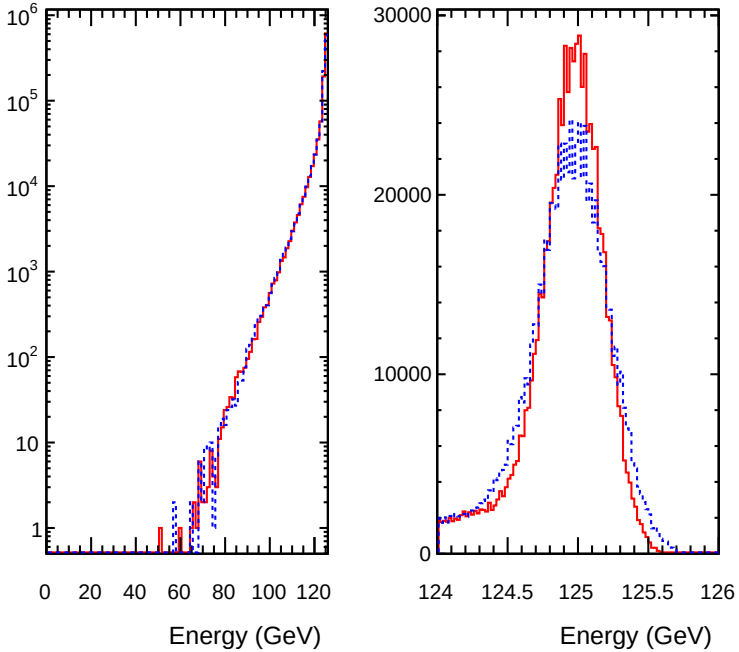
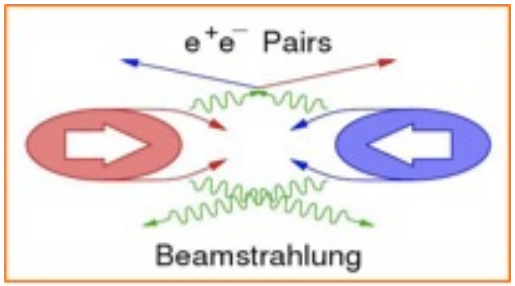
- The subsequent parton-shower and hadronisation is done by PYTHIA6.4.
  - LCGG has tuned hadronisation using input from OPAL at LEPII [Phys.Rept. 291 (1997) 107-217, D. Ward, private communication.].
- The process-definition given in the Whizard steering file (aka the *sindarin*) is also the driver for the scripts that organises the production: One ring to rule them all.
- Use powerful grouping and aliasing capabilities of sindarin to assure that no processes are over-looked.

Beam effects

- Beam-spectrum.
  1. Incoming beam-spread
  2. But also: very strongly focused beams ⇒ Beam-beam interactions
- Photons
  1. How many photons?
  2. Are they virtual or real?
- Need beam-beam interaction simulation input.
- Simulate interaction region: GuineaPig [CERN-PS-99-014-LP]. Gives:
  - Beam-spectrum for electrons and positrons independently
  - Amount and spectrum of real photons
  - Distribution of interaction point





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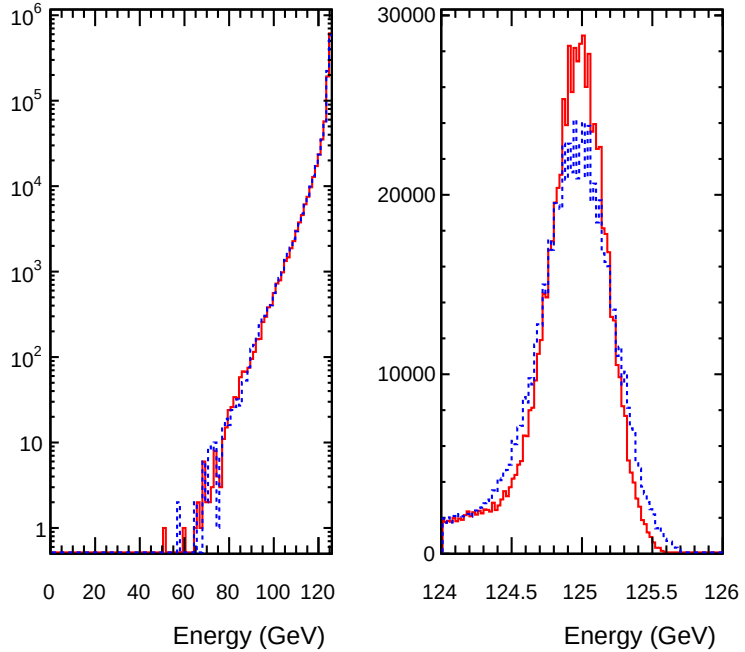

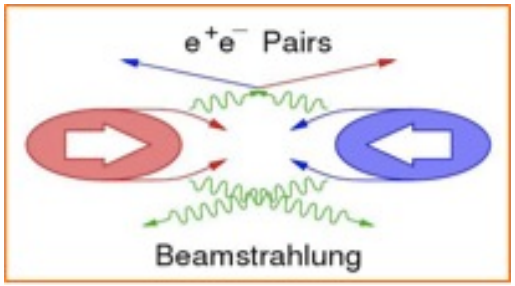

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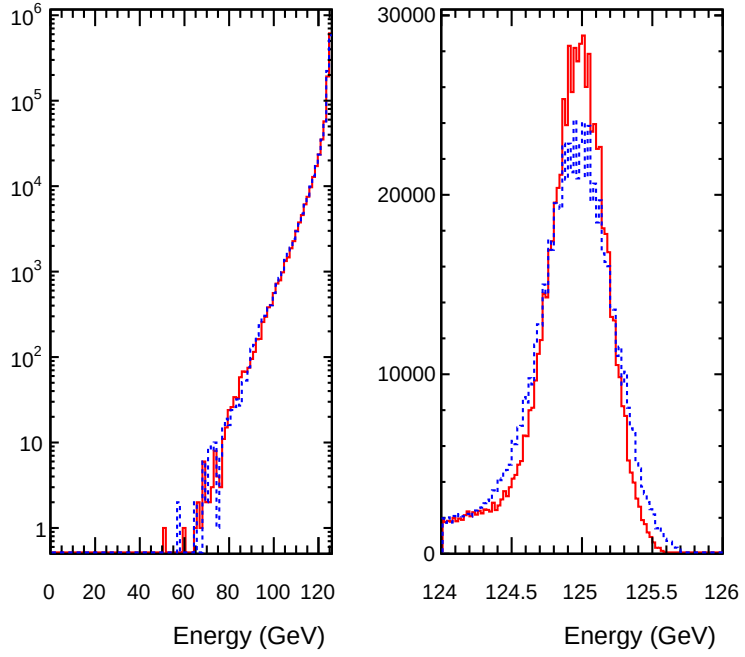

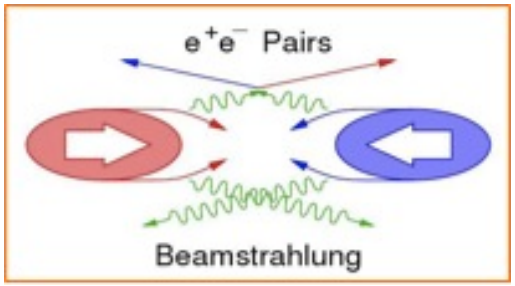

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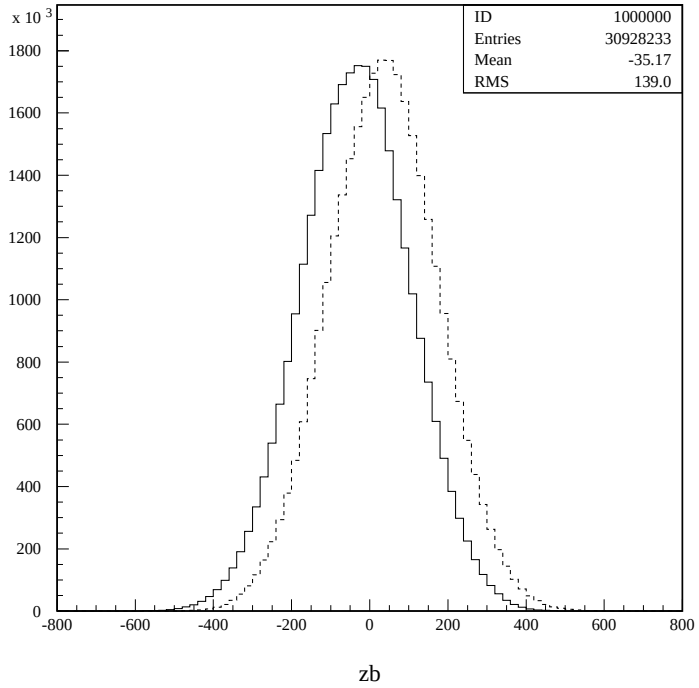

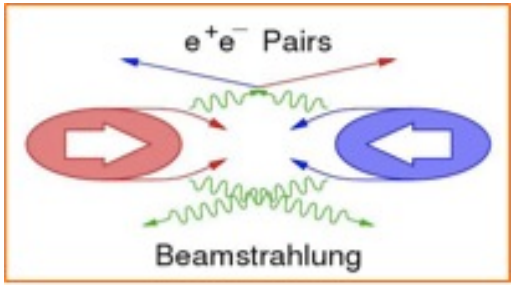

Spurious interactions ("pile-up")

Two types:

- Pair-background: Pair-creation of photons in the beam by the strong fields. GuineaPig can generate the full activity during a beam-crossing (a "BX").
- low-$p_\perp$ hadrons, ie. $\gamma^{(*)}\gamma^{(*)}$ interaction with small $M_{\gamma\gamma}$ and multiplicity. NB: only $\mathcal{O}(1)$/BX !
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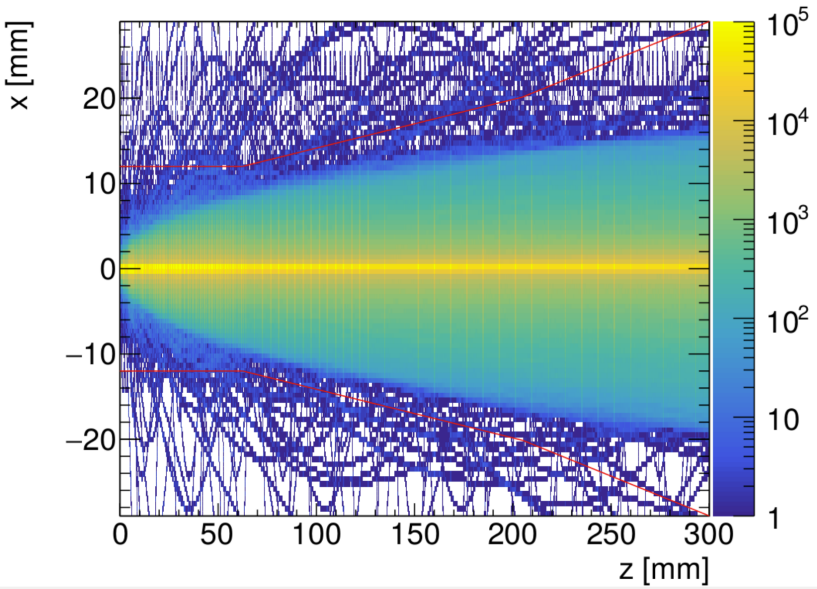

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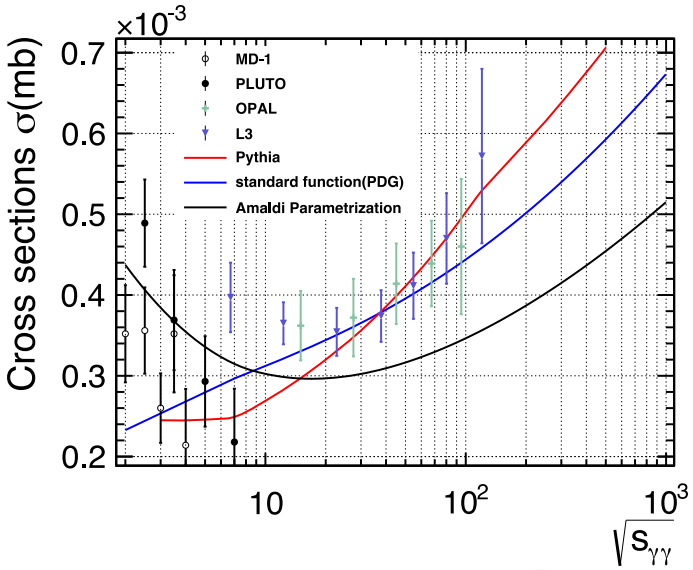

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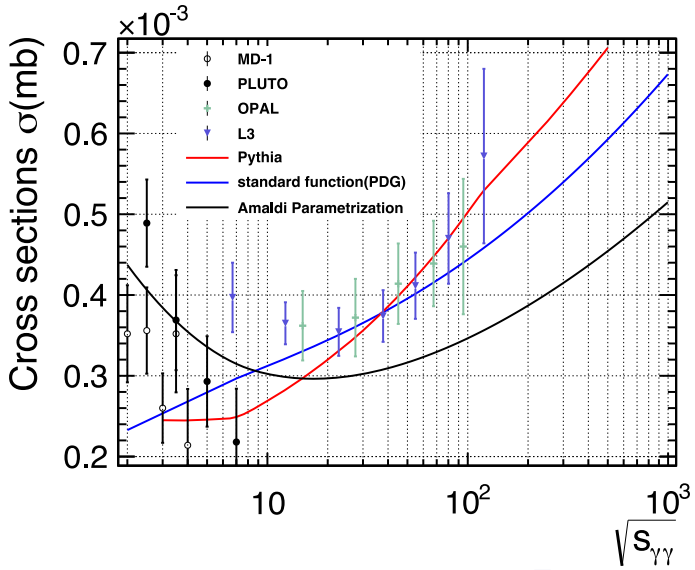

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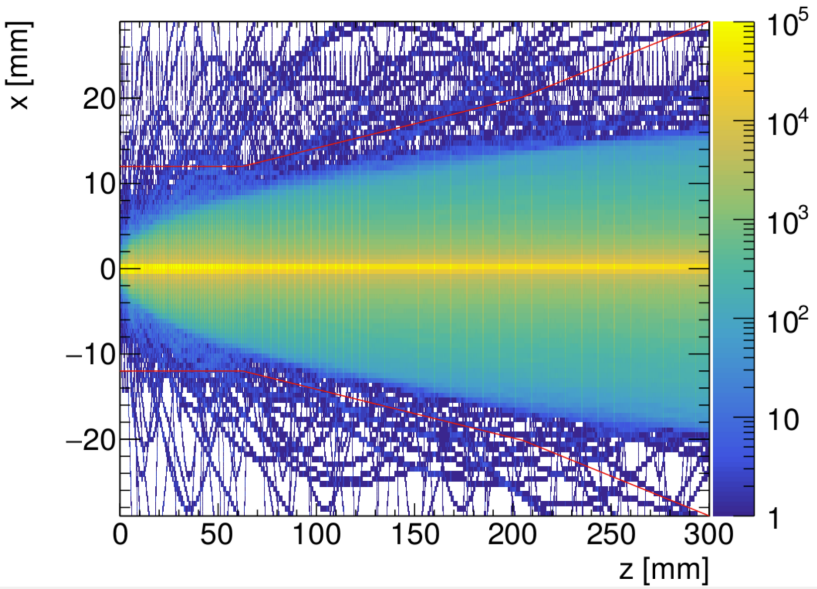

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ILC 250 GeV Generation production

Currently, ILC is doing a new full production at 250 GeV, 10 times larger than the one done for the DBD/IDR, and about twice the expected real data-set. NB: Also includes the Higgs signal.

proposal for statistics of 250 GeV generators

process\pol.	eL.pR	eR.pL	eL.pL	eR.pR
2f_l, 2f_h	5 ab^{-1}	5 ab^{-1}	1 ab^{-1}	1 ab^{-1}
all 4f				
all 6f	10K	10K	10K	10K
2f_bhabhag	1 ab^{-1}	1 ab^{-1}	1 ab^{-1}	1 ab^{-1}
h->inclusive	1 ab^{-1}	1 ab^{-1}	1 ab^{-1}	1 ab^{-1}
h->each mode (5x9 channels)	100K	100K	10K	10K

most of the irreducible background will then have x10 more than expectation at ILC250

aa_2f, aa_4f: 1 ab^{-1} each initial state

ILC 250 GeV production: Whizard 1.x → 2.x

- DBD was done with v. 1.95
- v2.x is a major re-write; we finally use v2.8.5. Many new features.
  - New, better steering
  - Things done by us now part of the main code:
    - Interface to FastJet (kt, Durham, Cambridge, Cone algorithms)
    - Interface with Tauola++ (tau decays)
    - Beam spectrum, ISR, Beam-strahlung, Photon PDF
    - Interface to Pythia6 (parton showering, hadronization)
  - Generated events directly in LCIO format.
  - Samples from new BSM models much easier to create, using tools like UFO.
  - And also:
    - Interface to Pythia8 (parton showering, hadronization)
    - Interface to Madgraph5 (matrix element generation)
    - Interface to Madgraph5aMC@NLO (matrix element generation, NLO)
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Whizard 1.x → 2.x issues.

Polarised τ decays

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Colour-connection

- Whizard colour connects quarks ⇒ transfer to Pythia P.S. code.
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- We worked with the authors to fix this: Mark connection by artificial resonances in the event before handing over to Pythia.
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Virtual incoming γ:s

- $e^+e^- \to e^+e^- f\bar{f}$ is generated in different ways, depending on the Q^2 between in- and out-going $e^{+(-)}$:
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  2. One high, the other low: as M.E. of $e^{+(-)}\gamma^* \to e^{+(-)} f\bar{f}$
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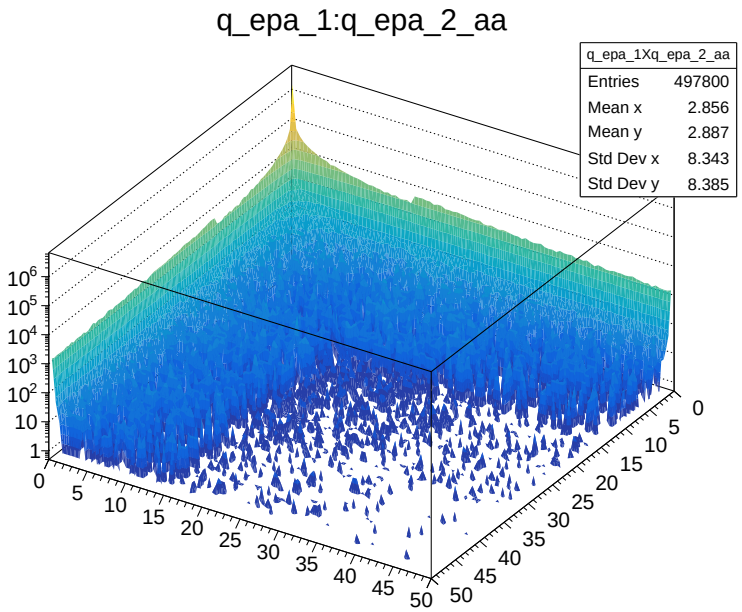
  where the γ^* is generated with the EPA off an incoming $e^{+(-)}$. The scattered $e^{+(-)}$ is present in the final state (the "beam-remnant").



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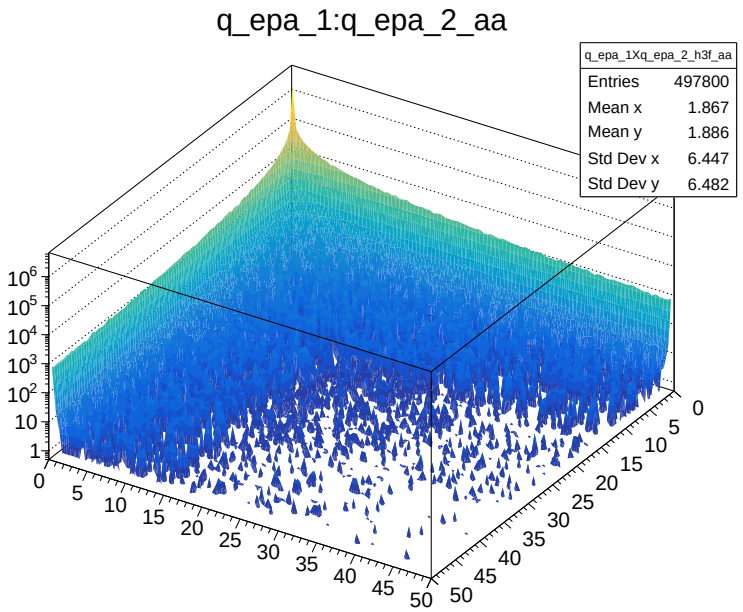

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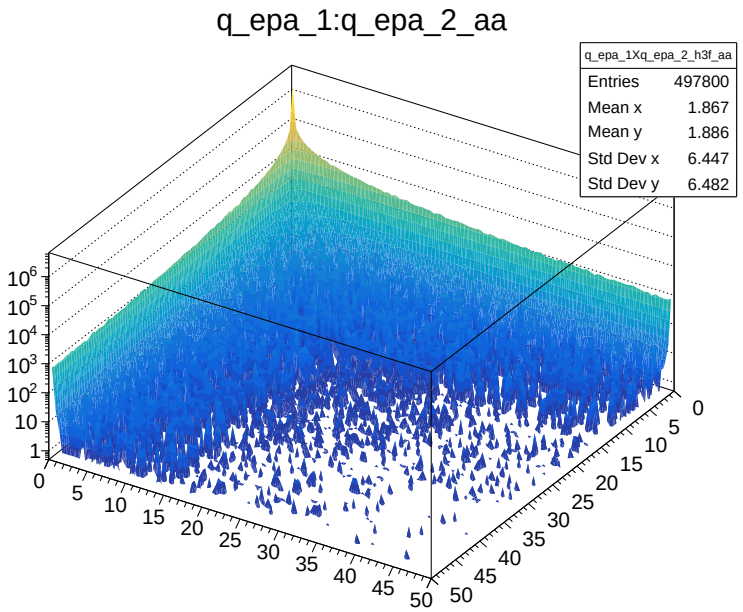

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Beams: TDR ⇒ SetA

Beam parameters

- The beam-parameters of this production are different from the TDR ones !
- At TDR times, the focus was on 500 GeV, and the 250 GeV did not receive much attention.
- Since, the "SetA" beam-settings have been found to be optimal for the Higgs-factory stage.
- It buys more luminosity, but also more disruption ⇒ more background, larger tails.
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- For $\leq$ 5f (w/o virtual γ induced ones): 116 channels.
- As of today, 104 channels are done, producing 2.7 billion events in 15788 LCIO files details, occupying 5.4 TB. This used 7233 CPU hours, obtained in $\sim$ 10 days.
  - The remaining channels are only $\mathcal{O}(10000)$ events.
  - In addition, there are 96 channels with virtual γ:s to come, $\sim$0.5 billion events.
- In most cases: one channel = one generation job, but in some processes alone represent $\sim$ billion events: split in several jobs. In total, 478 jobs have been completed.
- At the end of each job, the events (in LCIO format), metadata, and input+log-file tarballs are uploaded to the grid.
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Conclusions

- The precision-goal of future e^+e^- colliders are such that it is not permissible that MC statistics or coverage could constitute an major systematic uncertainty.
- We showed how the generation of the full SM, with statistics well above the expected H20@250 data set is achieved.
  - It consists of bringing a large number of different codes together:
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The new samples not only represents a huge increase in statistics, and ameliorations in physics description, but are the only ones that correctly represents the current machine conditions @ 250 GeV.

They should replace the 250-TDR samples for any physics analysis ASAP.

BACKUP

BACKUP SLIDES

Documentation

Created by generation job, driven by the contents of the process-definition Sindarin script and common conditions. It goes into:

- The event header:
  - Process-id, beam nature ($e^{+(-)}$ or γ), beam polarisation, beam spectrum, cross-section, run- and event-number of each event.
- The generator meta-data files:
  - Condenses job-specific information from Whizard logs.
  - Contains: process, cross section, polarisation, file-names, total number of events generated, total integrated luminosity, technicalities, ...
  - Browasble on the Web and uploaded to the Grid.
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The files: where and what

- The files can be found on
  - .../ilc/prod/ilc/mc-2020/generated/250-SetA/*
- Anatomy of the file-name:
  - E250-SetA.P4f_ww_h.Gwhizard-2_8_5.eL.pR.I500066.317.slcio
    - E250-SetA: [illegible]
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    - P4f_ww_h =P(rocess)[(aa_[1])number of final state particles] _[NC/CC/mixed flavour combination]_[hadronic/leptonic/semi-leptonicfinal state]
    - Gwhizard-2_8_5 =G(enerator)[name and version of generator] (NB: Unfortunately, this tag is suppressed in the name of the DST files...)
    - eL = e(lectron beam)[polarisation (L/R) or γ type (W/B)]
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[1] added to $\gamma\gamma$ events to separate from e^+e^- events with the same number of fermions

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- The format is LCIO, the contents is one MCParticle collection/event
  - This is not the MCParticle you will see on the DST: Obviously, on the DST, particles created in the detector simulation and from overlay are added. But not only:
    - The crossing-angle boost is added.
    - The production point has been swimmed around.
    - For flying particles, the effect of the detector B-field and energy loss is added, so that the decay properties are modified.
- The event numbers are unique, without gaps.
  - The event header contains run and events number which is now unique, and carried on all the way to the DST.
- The header also contains the cross-section of the process. A GOTCHA: the true cross-section. It does not take into account that the luminosity for e^+e^-, $e^{+(-)}\gamma$ and $\gamma\gamma$ processes are different!
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