WHIZARD in past and future mass-productions for the ILC

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Outline

The LOI

The ILC Letters of intent were submitted in February 2010. They contained the proposed detector hardware, and performance studies of benchmarks:

- Defined by the ILC physics panel.
- Chosen to bring forward experimentally difficult cases.
- Generation of samples should be common.
- Reactions:
  - $\mathrm{e^+e^-} \rightarrow ZH$ at 250 GeV. Recoil and reconstructed mass, BR:s.
  - $\mathrm{e^+e^-} \rightarrow \tau^+\tau^-$ at 500 GeV. Asymmetries, polarisation.
  - $\mathrm{e^+e^-} \rightarrow t\bar{t}$ at 500 GeV(fully hadronic). Asymmetries.
  - $\mathrm{e^+e^-} \rightarrow \tilde{\chi}^0_2\tilde{\chi}^0_2$ or $\tilde{\chi}^\pm_1\tilde{\chi}^\pm_1$, with $\tilde{\chi}^0_2$ and $\tilde{\chi}^\pm_1$ degenerate and $\Delta(\tilde{\chi}^0_1, \tilde{\chi}^0_2) > M_Z$
- And the full SM as background, including $\gamma\gamma$, Compton's, bhabha's...

Generators for LOI

How was it done for the LOI ?

- Basically, all done
  - At one place (SLAC)
  - By one person (Tim Barklow)
  - With one generator (Whizard 1.40)
- In addition, some signal samples were done elsewhere by other people and with different Whizard versions
- In ILD, the generated files were ftp:ed from SLAC, stored on the grid, entered into the database, and used as input to Mokka+Marlin.

In ILD: 12.9 Mevents at 500 GeV fully simulated and reconstructed.

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The DBD

As a companion to the ILC TDR, a "Detailed Baseline Detector document" will delivered by the end of 2012.

- Also for the DBD, there are bench-marks:
  - $e^+e^- \to \nu\bar{\nu}h^0$
  - $e^+e^- \to t\bar{t}h^0$
  - $e^+e^- \to W^+W^-$
- All at E_{CMS}=1TeV
- Machine backgrounds and same-bunch crossing $\gamma\gamma$ events should be overlaid (in some way...)
- "Relevant" physics backgrounds should be generated.
  - However, since all 6 and even 8 and 10 fermions are background to the first two, and the third is 80 % of the 4 fermions by itself, one could just as well do the entire SM, only excluding the high cross-section $\gamma\gamma$, Compton's, and back-to-back bhabha's

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The DBD

In addition:

Re-visit the physics case

- LHC input !
- Need not be full simulation (as the bench-marks). Could be:
  - Full simulation.
  - Fast simulation.
  - Simple 4-vector smearing.
  - Pure theory.
- A separate physics volume, edited by M. Peskin.

The road to the DBD benchmarks

Why not do the same as for the LOI?

- Tim Barklow will not do it alone, due to his work-load
- There are a number of short-comings with the version of Whizard used:
  - Diagonal CKM
  - No tau polarisation in decays
  - Hadronisation tune in PYTHIA
  - Colour-flow and helicity information
- Whizard is not ideal for some specific channels which might need other generators:
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  - > 6 fermions
  - bhabha
  - tth, ttz, ttbb
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Common Task Group for Generators

The research director asked that a cross-region and cross-concept working group should be created to look into the generator-issues of the DBD.

Members

- Tim Barklow, SiD/Americas
- Akiya Miyamoto.ILD/Asia
- M.B., ILD/Europe

Since, CLIC has also joined

- Stephane Poss

Issues for the common task group

- Work sharing:
  - Be able to run production-scale Whizard at KEK's local computer, the NAF, or the ILC-VO GRID.
  - Tools for mass production.
  - Manage generated samples: Storing generated files, documentation, knowing they will be used by both SiD and ILD, ie. by different production systems.
- Develop a plan for MC sample generation for DBD and ILC baseline assessment work
- Signal samples: What and How?
- SM background samples: What and How?
- Beam backgrounds: What and How?

Initial working meeting at SLAC (Tim, Akiya, MB) in May last year.

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Generator choice

SM will be done with Whizard

- Whizard version by choice : 1.95. Has
  - CKM correct
  - Colour flow
  - Spin
- Latest version at that time was 2.0.2, but “Note that some of the features of WHIZARD 1 (esp. ILC) have not yet been re-enabled.” (Whizard home-page).
- Fragmentation: Latest PYTHIA6 (6.422). PYTHIA8 is out but “To some extent this switch is nominal, since 8.1 does not yet offer a complete replacement of 6.4, and is not yet tested and tuned enough to be recommended for major production runs.” (PYTHIA home-page).

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Whizard development: Technical

Technical issues needed to be solved to be site-independent:

- Whizard used to need to be compiled with Intel's commercial Fortran compiler ifort, but now Scientific Linux 5 comes with GNU gfortran4.3 as an option, which works. Does not link with code compiled with gcc 4.1 (default in SL5) ⇒ need to recompile other packages as well.
- NB: Even in the next version of Scientific Linux, gcc will be version 4.3: this is what RHEL 6 ships with (presumably the base of SL6). This also goes for other industrial grade distro's like Debian-stable.
- Previously, all was done on 32-bit systems, but as 64-bit ones are getting increasingly wide-spread, it would be preferable that all is checked to run on 64-bit as well ⇒ also CERNLIB needs to be compiled in 64-bit.

Whizard development: Production Tools

- Tim's scripts to run Whizard jobs at the SLAC batch server migrated and adapted to the KEK environment, and to DESY.
- An SVN project holding Whizard source-code, installation scripts and process-description files has been set up at CERN by Stephane.
- As generation production will now be distributed → An information file with file-locations, generator settings, etc. should be updated by each generation job.
  This information could then be entered into each concepts own full-fledged production database. A proposal by is on the table.

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Whizard customisation

Problem with Whizard 1:

- Many channels: For the LOI, SM alone is made of 2348 distinct Whizard channels. With diagonal CKM-matrix !
- This is a problem for the production-team, but even more so for the end-user.
- Possible solution, with in the steering language of Whizard 1 (Westron ? Some might even argue that it is the Dark Language...)
    - Flavour-summed channels. After all, who cares if it is a u,d, or s quark ? Will reduce the 2348+ channels to a few tens. Two options:
        - Sum in phase-space evaluation: Higher gain in simplicity and CPU-time,but less flexible.
        - Channel mixing in generation: Any set of channels can be merged.
    - Both options are pursued, as well as mixes of them

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- PYTHIA 6.422 is used for hadronisation in order to use the LEP latest parameters. Got input from LEP collaborations.
- Tau-polarisation in decay (which PYTHIA knows nothing about): Existing TAUOLA interface standardised, for polarisation-dependent τ-decays. Also for τ's in fragmentation $W \to \tau\nu$. Verified to work correctly - Thanks for advice Gudi!
- Extension of information in the event record:
  - Colour singlet system information and particle spin.
  - Beam-particles before and after beamstruhlung.
  - Process ID in each event record.
- Coding of FSR and other "surprising" records in HEPEVT. Work in progress by B. Vormwald.

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PYTHIA tuning

The problem:

- Neutral hadrons
- LEP I : 1.00 K_S^0 ($\Leftrightarrow K_L^0$) per event, but PYTHIA has 1.12
- Idem for protons ($\Leftrightarrow$ neutrons), 1.22 vs 0.98 .

Ie. for the PFA, the default PYTHIA settings will give worse jet-energy resolution than the LEP data shows !

I've collected information from

- DELPHI - Klaus Hamacher.
- ALEPH - Gerald Rudolph.
- OPAL - David Ward.

The DELPHI tune included changes to the code of PYTHIA, and was not further considered.

PYTHIA tuning: Method

The method

- Generate LEP I data with “our” Whizard 1.95:
  - E_{CMS} = 91.19 GeV
  - Un-polarised beams
  - No beam-strahlung, no incoming energy spread.
  - ISR on.
  - $Z \to q\bar{q}, q = udsc$ or b.
- Set the PYTHIA parameters with the *pythia_parameters* keyword in the *simulation_input* section of whizard.in.
- Find number of generated particles of a large set of types.
- Compare with LEP I data : A. Böhrer, Phys. Rep. **291**,107 (1997), and R. Barete & al., Phys. Rep. **294**,1 (1998).

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PYTHIA tuning: Results

	Standard tune	ALEPH tune	OPAL tune	LEP combined data
nch	20.6246	20.5660	20.5685	20.9400 +- 0.1900
nchlept	0.5075	0.5225	0.5132	- - -
np	1.2190	1.0827	0.9110	0.9750 +- 0.0870
npi	17.1178	17.2965	17.5467	17.0500 +- 0.4300
nK	2.2879	2.1868	2.1108	2.3600 +- 0.1100
nchhyp	0.1731	0.2069	0.1608	- - -
npi0	9.6814	9.8511	9.8866	9.3800 +- 0.4500
neta	1.0170	1.0637	0.8630	0.9530 +- 0.0760
nrho	1.5184	1.3938	1.4292	1.2900 +- 0.1200
nomega	1.3685	1.3148	1.9402	1.1100 +- 0.1000
nK0L	1.1057	1.0575	1.0164	- - -
nK0S	1.1168	1.0608	1.0150	1.0040 +- 0.0150
nlambda	0.3939	0.3874	0.3278	0.3700 +- 0.0100
nn	1.1661	1.0541	0.8664	- - -
ndelta0	0.1932	0.1626	0.0953	- - -
nsigima0	0.0746	0.0890	0.0669	0.0710 +- 0.0130
nsigma+	0.1434	0.1725	0.1340	0.1750 +- 0.0290
nxi*0	0.0053	0.0057	0.0034	0.0056 +- 0.0011
nXi-	0.0289	0.0334	0.0263	0.0264 +- 0.0018
nOmega-	0.0009	0.0011	0.0005	0.0011 +- 0.0003
ndelta++	0.1928	0.1613	0.0985	0.0870 +- 0.0330
nbar	3.9524	3.6166	2.8177	- - -
nhfbar	0.1425	0.0891	0.1169	- - -

PYTHIA tuning: Results

PULLS

	Standard tune	ALEPH tune	OPAL tune
nch	-1.64	-1.95	-1.94
np	2.80	1.24	-0.73
npi	0.16	0.57	1.15
nK	-0.65	-1.57	-2.26
npi0	0.67	1.05	1.12
neta	0.84	1.45	-1.18
nrho	1.90	0.86	1.16
nomega	2.58	2.04	8.28
nK0S	6.97	3.52	0.68
nlambda	2.25	1.64	-4.02
nsigima0	0.27	1.37	-0.32
nsigma+	-1.09	-0.09	-1.41
nxi*0	-0.26	0.05	-1.91
nXi-	1.23	3.34	-0.07
nOmega-	-0.63	0.03	-1.76
ndelta++	3.20	2.25	0.35
Xi2	89.53	49.45	108.79
Xi2 w/o omega	82.88	45.28	40.30

PYTHIA tuning: Results at ILC energies

Values for jet-energy studies: uds pairs, no beam-strahlung, no ISR (ie. Z^* at rest)

	Standard	ALEPH	OPAL
nch	37.4267	36.5445	37.4975
nchlept	0.4756	0.4830	0.4801
np	2.5812	2.2791	1.8439
npi	31.1060	30.9720	32.3830
nK	3.7395	3.2933	3.2706
nchhyp	0.3555	0.4261	0.3190
npi0	17.2502	17.3328	17.7834
neta	1.9174	2.0046	1.6515
nrho	2.9557	2.6488	2.7931
nomega	2.7231	2.6373	4.0894
nK0L	1.8069	1.6254	1.6119
nK0S	1.8006	1.6178	1.6120
nlambda	0.7843	0.7834	0.6261
nn	2.5109	2.2355	1.7778
ndelta0	0.4239	0.3588	0.2091
nsigima0	0.1572	0.1822	0.1320
nsigma+	0.3002	0.3562	0.2647
nxi*0	0.0103	0.0131	0.0067
nXi-	0.0542	0.0677	0.0532
nOmega-	0.0011	0.0022	0.0012
ndelta++	0.4240	0.3521	0.2101
nbar	8.4164	7.6572	5.7244
nhfbar	0.0171	0.0127	0.0150

PYTHIA tuning: conclusion

So: except for the large discrepancy for the ω: (that no tune gets right, anyhow)

- OPAL is slightly closer to the data than ALEPH.
- The ALEPH tune is significantly off for the K^0:s, while the OPAL tune is OK.
- OPAL is also closer for protons.
- For ALL baryons, OPAL is below the data while ALEPH is above the data.

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K^0_S and p ($\Leftrightarrow K^0_L$ and n) $\Rightarrow$

- ALEPH: 9% too many neutral hadrons.
- OPAL: 3% too few neutral hadrons.
- Standard PYTHIA: 18% too many neutral hadrons.

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K_S^0 and p ($\Leftrightarrow K_L^0$ and n) $\Rightarrow$

Use OPAL

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Aliases

Aliases: in the process definition file, eg.:

alias q u:d:s:c:b

Then one can define eg.:

qq e1,E1 q,q omega w:c,c

to get all $e^+e^- \rightarrow q\bar{q}$ processes in one go.
However: all masses must be equal !

What does that do to eg. b-fragmentation ??!

Aliases

Check fragmentation:

- m_b=5.5 GeV
- m_b=0 GeV
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No problem: fragmentation is in PYTHIA, uses it's own (correct) quark-masses.

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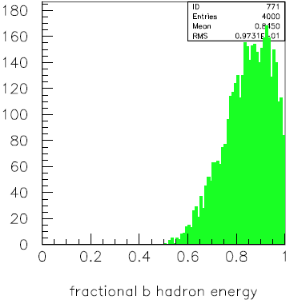

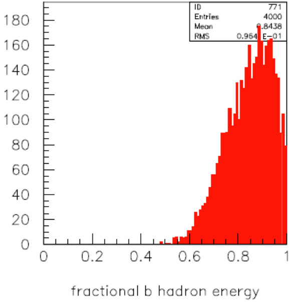

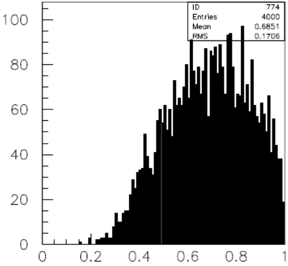

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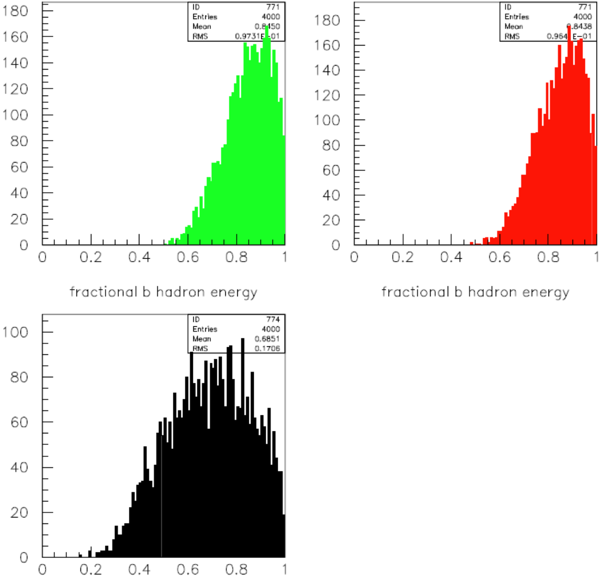

Beam-strahlung

Due to the very strongly focused beams, the fields (both E and B) has a large bending power on the other beam. Consequences:

- Primary beam is focused by the other beam.
- Strong bending $\rightarrow$ much synchrotron radiation. Widens the distribution of the primary $e^{\pm}$ energy.
- Photons
  - ... get Compton-backscattered $\rightarrow$ photon component of beam, long tail to lower energies for the $e^{\pm}$.
  - ... interact with photons (synchrotron ones, or virtual ones) in the other beam $\rightarrow$ $e^{\pm}$-pairs.
- So, there will be a component of $e^{\pm}$ with the *opposite* charge to that of its parent beam.
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Beam-strahlung: Pairs

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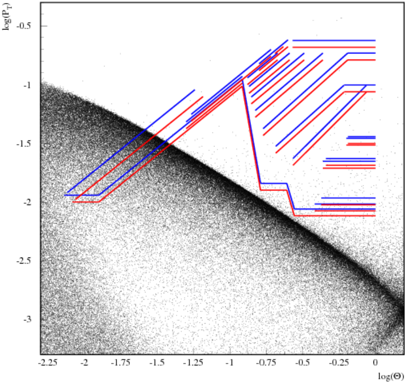
To study the effect, also draw the detector in these coordinates:

Place it at the p_T-θ corresponding to the p_T and θ a particle should have to turn back at the radius and z of the detector.

Beam-strahlung: Pairs

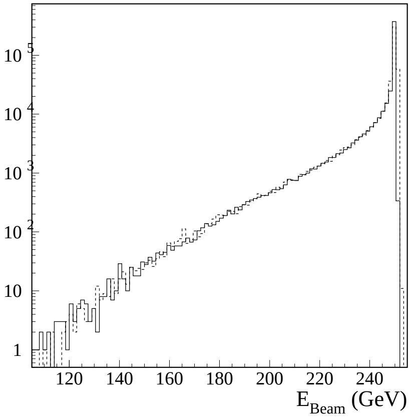
Example:
Pairs in ILD, B1b parameter-set at 1 TeV. Generated with GuineaPig.
429000 particles /BX.



Beam-strahlung: Spectrum

- Full beam-spectra for electrons (dash) and positrons (solid), at 500 GeV, Low-Charge parameter-set.
- ... and the peak.
- These spectra need to be known to Whizard

We need the functionality of Whizard 1's user.f90 !



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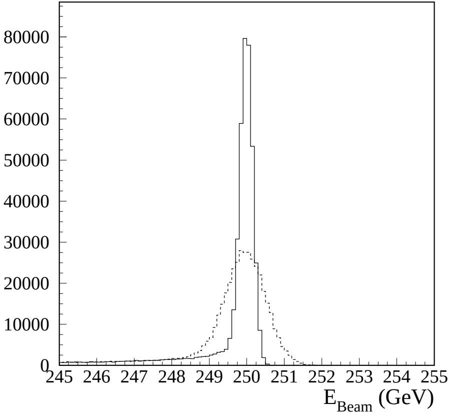

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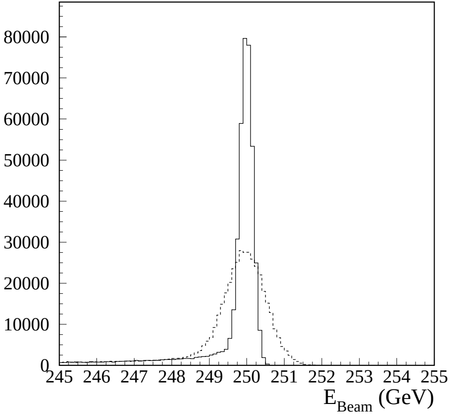

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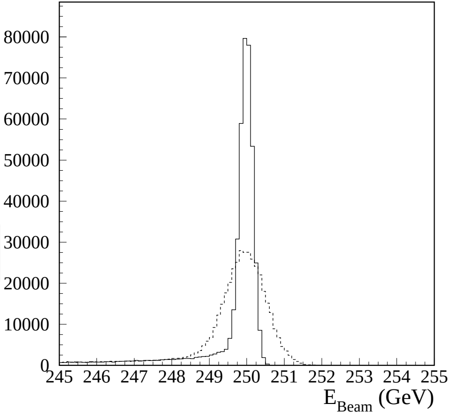

Status of generator samples : $\nu\nu h$

Assigned to Tim B.

- $\nu\nu h$: Includes $h \to gg$ and WW^*, so need 6-fermion background.
  - Potentially large advantage with aliasing, esp. when Cabibbo suppressed decays included.
  - However: Integration gets very time-consuming with aliasing$\to$ go back to to separate final states
  - Advancing well: Full sample ready to be generated. Pilot generation of 100k + additional $h \to \mu\mu$ ongoing.

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Status of generator samples : *WW*

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- *WW*: All setup at DESY.
  - Integration of all 4 fermion final-states: over-night job, with per mil uncertainty on cross-section
  - Generation of 1 ab^{-1} also over-night job for non-electron final states.
  - STDHEP:s on grid, log-files, steerings, diagram-plots, etc. on the web (http://www.desy.de/ berggren/4f_production/)
  - Need some automatic error detection.
- Organisation:
  - Hierarchy: ZZ or WW or ZZWWmix / hadronic or leptonic or semi-leptonic / four beam polarisations
  - Separate single boson ($XXee$,$XX\nu_e\nu_e$ or $XXe\nu_e$) final states (t-channel!) from rest.
  - Total number of cases = 36. Compare: 140 possible 4f final states $\times$ 4 polarisations without aliases+ grouping.
- NB: Cross-sections are in the 10 pb^{-1} range $\rightarrow$ we are asked to fully simulate tens of millions of events !!!

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Assigned to Akiya

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  - H+4-jet+$l\nu$ signal: 2 days CPU for integration to converge with 0.3
  - H+6-jet signal: 700 Whizard channels in one aliased process. 14 days for 4 iterations of integration and 3 % accuracy (typically 10 iterations needed)
  - 6-jet+$l\nu$ background: failed to generate the Fortran code describing the diagrams.
- Alternatives:
  - simplify Whizard
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    - But then $\Gamma_Z = 0$.
  - Physsim
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Plan for beam background samples

- By GuineaPig. T. Hartin is helping us to produce the needed simulation
  - Disrupted beams
  - Beam-strahlung photons
  - Pairs.

  The first two are used as input beam-spectra for Whizard, the third comes for “free”.
- Other backgrounds with BDSIM. Help assured from experts (P.Bambade and T. Murayama), but definite beam design before it is useful to initiate work.
  - Synchrotron radiation.
  - Beam-halo muons.
  - Neutrons.
- Two-photon mini-jets: Dedicated PYTHIA simulation.

Conclusions and outlook

- Whizard, the main work-horse of the LOI SM simulation, has been updated to the most current, ILC-usable version, and is ready to use for the DBD.
- The issues on list of needed amelioration have been solved.
- The way to feed information from generation to the production database should be tested.
- Initial full-scale production of the *WW* sample at 1 TeVhas been done, and is soon coming for $\nu\nu h$.
- For *ttH*, Whizard can't take the load (esp for the 8f background). Physsim will be used for this channel.
- Larger scale test of the physics of new Whizard version and the new tune of fragmentation will be needed
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- Larger scale test of the physics of new Whizard version and the new tune of fragmentation will be needed
- On-going work on background generation and overlay techniques.
- The final OK from our machine-colleagues on the 1 TeV beam-parameters is all that is missing to start the mass-production.

Conclusions and outlook

- Whizard, the main work-horse of the LOI SM simulation, has been updated to the most current, ILC-usable version, and is ready to use for the DBD.
- The issues on list of needed amelioration have been solved.
- The way to feed information from generation to the production database should be tested.
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