What can we learn at ATF2 concerning ILC backgrounds?

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The ATF2 project aims at demonstrating the strong vertical electron beam focusing capability, down to the few tens of nanometers level, of a down scale prototype of the final focus system of the next generation of e+e- machines. ATF2 offers opportunities to check in a real accelerator environment case for the performances of the beam transport and background generation code, used in the simulation of the future e+e- machines, BDSIM [4], and for the performances of its underneath particle-matter simulation code, Geant4.

1 Background sources : From ILC to ATF2

As an electron-positron collider, the ILC may provide a very clean experimental environment compared to hadron colliders, but it is certainly not background-free. The rates for events from high-energy electron-positron interactions are low: at the nominal luminosity of \(2 \times 10^{34} \text{cm}^{-2} \text{s}^{-1}\), there will be less than one hard electroweak interaction per second at 500 GeV, even for processes that are not in the main focus of physical analyses. Consequently, the most important source of unwanted interactions are machine induced backgrounds. This term denotes all particles that are produced due to the operation of the accelerator itself and due to collective effects from the collision of the particle bunches as a whole. Various sources of background can be studied at ATF2, in order to test and improve the simulation codes and methods, which can be useful to understand and evaluate the next Linear Collider sources of backgrounds.

- Machine produced background before IP
- Beam beam background at IP
- Spent beam background

1.1 Machine-related backgrounds

The background level due to the machine needs careful evaluation and development of means to reduce it. It can to a large extend be influenced by the design of the beam delivery system.

1.1.1 Beam tails (Halo) from linac

Particle fluxes generated in the interactions of a beam halo with the collimators in the ILC Beam Delivery System (BDS) can exceed tolerable levels for the collider detectors and create hostile radiation environment in the interaction region (IR hall). At ATF2, the beam tail (halo) generated background is an important source of background for beam diagnostic systems, and one way to reduce it, is to use dedicated collimators. The beam halo has also been measured in order to improve the simulations of the background since the beam profile enters as an input parameter for the simulation.
1.1.2 Synchrotron radiations

This is major background at FFTB experiment, but at ATF2, critical energy at bending magnet (assuming 1 Tesla) is about 1 keV. As a result, synchrotron photons can be easily stopped by beam pipe.

1.1.3 Beam-gas scattering

The four possible mechanisms of beam scattering [1] are: the scattering from blackbody thermal photons, inelastic scattering from residual gas molecules (beam-gas Bremsstrahlung), elastic beam-gas scatterings (relativistic Coulomb scattering) and the scattering off atomic electrons. The background generated by the beam-gas scattering is negligible at ATF2 since the beam line is relatively short (less than 100m), but can contribute to the beam halo due to large angle scattering.

1.2 Beam-Beam background @ IP

A major contribution to machine-induced backgrounds are electron-positron pairs that are created in the scattering of beamstrahlung photons. Since this background needs two beams, it cannot be accessed and studied at ATF2.

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1.3 Neutron background

Neutrons will be produced wherever particles are lost, but predominantly by the high-power beam in the beam dump. The hottest regions of the whole accelerator complex clearly are the beam dumps, which have to absorb a total power of approximately 10 MW each. Note that the 500 GeV machine beam power is 11 MW and the 1 TeV machine beam power is 18 MW [8]. In the case of water dumps, the incident particles will produce neutrons in amounts of the order of $10^{12}$ particles per bunch crossing. Earlier studies [7] showed that a small amount of these neutrons (around $10^7$ particles) can escape from the dump and move back into the beam tunnel, but again only a tiny fraction (around $10^4$ particles) can reach the detector.

The ATF2 1.3 GeV beam ends up in an iron made dump, generating low energetic neutron and electromagnetic background. Measuring this background is a good opportunity to test for the performances of background generation codes used to predict ILC background levels.

2 Background simulation and measurement @ ATF2

ATF2 (Accelerator Test Facility 2) [2] is a final focus test bench for ILC. It has 2 major goals, which are achievement and maintenance of 37 nm beam size by ILC-like beam optics and stabilization of beam position to nanometer level.

At ATF2, multiple source of background enters quasi-simultaneously the beam tunnel making difficult to use the beam diagnostic systems. On the other hand, that multiple background represent a good opportunity to test in accelerator environment simulation tools that are used to simulate the next e+e- background.

2.1 Measurement apparatus

To disentangle the various sources of background, a simple and flexible apparatus system has been designed and built: it is made of a set of readout modules that can either be grouped in a longitudinally segmented mini-calorimeter, with the possibility to insert radiator medium, or used individually for synchronized multi-point measurements. Each module is made of one crystal (plastic scintillator or pure CsI) and a fast photomultiplier tube. Both crystals are sensitive to electromagnetic background and neutron signals as well, with difference concerning the neutron background. Neutrons do not produce ionization directly in scintillation crystals, but can be detected through their interaction with the nuclei of a suitable element. Fast Neutrons can interact with materials that contain a large concentration of hydrogen atoms (protons), for example organic materials, by means of elastic scattering in which case the energy of the neutron is (partially) transfered to the protons which on their turn can produce scintillation light. Using the above principle, fast neutrons can be detected in any organic (plastic) scintillator. From the pulse shapes measured at ATF2, it comes out that plastic scintillators are more sensitive to fast neutrons and CsI crystals can see large neutron energy spectrum and are useful to measure slow (thermal) neutrons.

In order to discriminate neutrons from electromagnetic background, the particles time of flight is used since the neutrons are in general delayed from direct electromagnetic background.

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2.2 Simulation tools

The simulations are done with BDSIM and stand alone GEANT4 codes for specific studies. BDSIM is a code that combines accelerator-style particle tracking with traditional Geant-style tracking based on Runge-Kutta techniques. This approach means that particle beams can be tracked efficiently when inside the beampipe, while also enabling full Geant processes when beam-particles interact with beamline apertures. Tracking of the resulting secondary particles is automatic. A standard simulation efficiency is relatively poor as soon as one need enough statistics on a detector placed off beamline axis. Indeed, the statistic is mainly focused around the beam core inside the beampipe. One way to enhance the counts in a given off axis detector is to generate enough particles by consuming computing time to

Figure 3: Picture of the built modules in a mini-longitudinal calorimeter configuration. Tungsten slabs are used as radiator medium.

Figure 4: First signals at ATf2: pink and yellow signals are coming from the modules containing plastic scintillators and the blue curve corresponds to a module containing pure CsI crystal.

Figure 5: Simulation of the neutron background on the Shintake photon detector. Specific event biasing methods have been used in order to have enough statistics in the detector, and understand the impact of dedicated shielding.

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compensate the low cross sections for any unlikely situations. Geant4 provides event biasing techniques which may be used to save computing time. Such techniques have been used in order to simulate the neutron background in the gamma detector used at ATF2 in the nanometer beam size measurement, the Shintake monitor[6].

3 Summary and outlook

Background measurement program has been started at ATF2 in order to test in real accelerator environment simulation tools that are used to simulate the next ILC background levels. A dedicated apparatus, specific to small ATF2 final focus area, specific to ATF2 multiple background, has been studied and built. First background measurements have been done in 2009 and specific simulation have been done in order to understand the measurements.

Next years will be dedicated to make other dedicated measurements and put constraints on the simulation tools BDSIM and GEANT4.

References

[1] P. Tenenbaum, Beam-Gas and Thermal Photon Scattering in the NLC Main Linac as a Source of Beam Halo, LCC-Note-0051 (2001).
[2] ATF2 Collaboration, ATF2 Proposal, KEK Report 2005-2 (2005)
[3] ROOT User's guide http://root.cern.ch
[4] I. Agapov et al., The BDSIM Toolkit, EUROTeV Report 2006-014 (2006)
[5] Geant4 User's guide, http://wwwasd.web.cern.ch/wwwasd/geant4
[6] T. Shintake, Nucl. Inst. and Meth., A311 455 (1992)
[7] Gregor Wagner. Neutron background studies at the TESLA collider. Technical Report LC-DET-2001-048, LC Note, January (2001)
[8] R. Appleby, (Manchester U.), J.R.J. Bennett, T. Broome, C. Densham, H. Vincke, (CERN) The Charged beam dumps for the international linear collider Conference (EPAC 06), Edinburgh, Scotland, 26-30 Jun (2006)