1 What HERA benchmarking can tell us

1.1 Simulation ingredients

There are 3 basic parts to the simulation:

1. component list with MTBFs (+MTTRs, etc.),
2. calculation of failure times from MTBFs,
3. failure management: repair planning and recovery.

The calculation of failure times from MTBFs is correct (see document "Failure Probabilities"). This check is purely technical (and mathematical) and does not require the comparison with an existing machine. So as long as the input MTBFs are correct, the program will generate the right number of failures. HERA benchmarking can help us with the MTBFs and with the failure management.

1.2 HERA logbook information

The HERA logbook gives the following information:

- integrated luminosity
- failures of HERA components
- time spent doing repairs
- time and frequency of luminosity running
- time and frequency of filling positrons and protons
- time spent doing luminosity tuning
- downtime caused by pre-accelerators
- downtime caused by experiments
- total downtime

1.3 What can be compared with simulation

1.3.1 Integrated luminosity

Although it is the ultimate goal to get this number right, we will have break down the comparison into smaller parts to identify those pieces of the simulation which are not perfect.

1.3.2 MTBFs of HERA components

From the logbook failure entries, one can derive MTBFs for the different components. This work was done by Michiko Minty. We can compare the HERA MTBFs with the MTBFs used in the ILC simulations.

It is clear that if we use the logbook MTBFs in the simulation, we will get back the real number of failures (output reflects input) because the program correctly generates failures from MTBFs.

1.3.3 Time spent doing repairs

The total time spent doing repairs is influenced by the MTBFs, the MTTRs and the repair planning. Since we put the real MTBFs and MTTRs into the simulation, this number is a check of the repair planning model.

1.3.4 Operation modes

In a storage ring, regular refilling of beams is needed. This has to be taken into account in the simulation and is discussed further in 2. We can compare the time and frequency of the refilling and of the actual luminosity running.

1.3.5 Downtime caused by pre-accelerators

The HERA logbook contains only those pre-accelerator failures that caused HERA downtime. If a pre-accelerator could be repaired without interrupting HERA operation, then this failure does not show up in the logbook. This means that the pre-accelerator MTBFs we extract from the HERA logbook reflect a convolution of the real failure rate and the relevance of the failure for HERA. It is still possible to use these numbers, though. One can put together a component list for the pre-accelerators, with MTBFs for every single component, and then determine the failure frequency of the pre-accelerators. If the simulation correctly models the interplay between pre-accelerators and HERA then we should get the right number of HERA relevant pre-accelerator failures.

2 Storage ring operation

To draw conclusions on the predictive power for ILC operation from a comparison with HERA the program should ideally be the same for both types of colliders. However, a fundamental operational difference is that the beams in a storage ring have to be dumped and refilled after some time. The program will have to be changed to take this into account. In the limit of zero filling time, the linear collider mode of the program would be recovered.

We define “filling” to denote the procedure needed to prepare the beams in HERA with the final beam energies. Filling therefore includes the full pre-accelerator chain plus beam optimisation and acceleration in HERA. It does not include the process of steering the beams to collisions. This is referred to as “luminosity tuning.”

The HERA beams have to be refilled because a large fraction of the positrons is “burnt” in the collisions and the proton beam quality deteriorates. During this filling time, no luminosity can be integrated. For simplicity we assume that the time needed to refill HERA is a constant (working hypothesis: T_F=3h). Similarly we assume the time until refilling is needed to be T_L=10h. The routine refilling then reduces the time during which luminosity can be recorded by a factor $f_L = \frac{T_L}{T_L + T_F} \approx 0.8$.

3 Implementation in program

Here we investigate how the routine refilling procedure could be implemented in the existing program.

3.1 Basic storage ring simulation

A storage ring has 2 operation modes: luminosity operation and filling. The time sequence is shown in Figure 1.

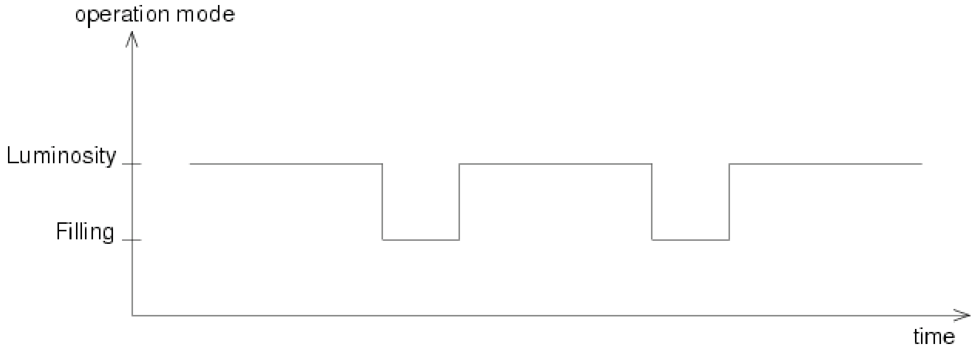

Figure 1: Operation modes of a storage ring.

The map of the simulation steps related to the 2 operation modes is shown in Figure 2. The main loop works as follows:

1. "Events" occur which can be the end of luminosity operation or the end of the filling procedure. These events change the state of the machine and set the next event time.
2. Luminosity is integrated if the machine was in luminosity operation since the last event.
3. The current state of the machine is saved.

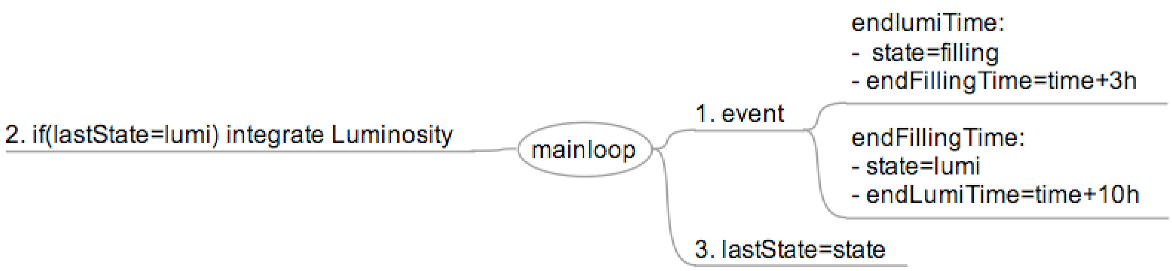

Figure 2: Simple map of storage ring simulation.

For a linear collider, the filling time is negligible. By using a zero filling time, the storage ring simulation can be used to model a linear collider.

3.2 Storage ring simulation with repairs

All failures in a storage ring facility can be divided into 4 different categories (Table 1). (For the following discussion we define a "severe failure" as a failure which brings that part of the machine down.)

- A severe failure in the main ring interrupts luminosity operation. After the component has been repaired, the machine has to be filled before going to luminosity operation again.
- If a pre-accelerator breaks while collisions are produced in the main ring, there is the possibility to repair the pre-accelerator in time before the next filling ("hot repair"). If the repair is not finished, the filling will be delayed.
- If the storage ring or the pre-accelerator breaks during filling, the filling procedure has to be restarted after the repair. (Filling involves parts of HERA and we therefore assume that hot repairs cannot be done in HERA during filling.)

Operation mode	*Failure*	*Consequence of severe failure*
luminosity	storage ring	filling
luminosity	pre-accelerators	hot repair or delayed filling
filling	storage ring	filling
filling	pre-accelerators	filling

Table 1: Effect of failures on operation modes of a storage ring collider.

The map of the simulation of these failures is shown in Figure 3.

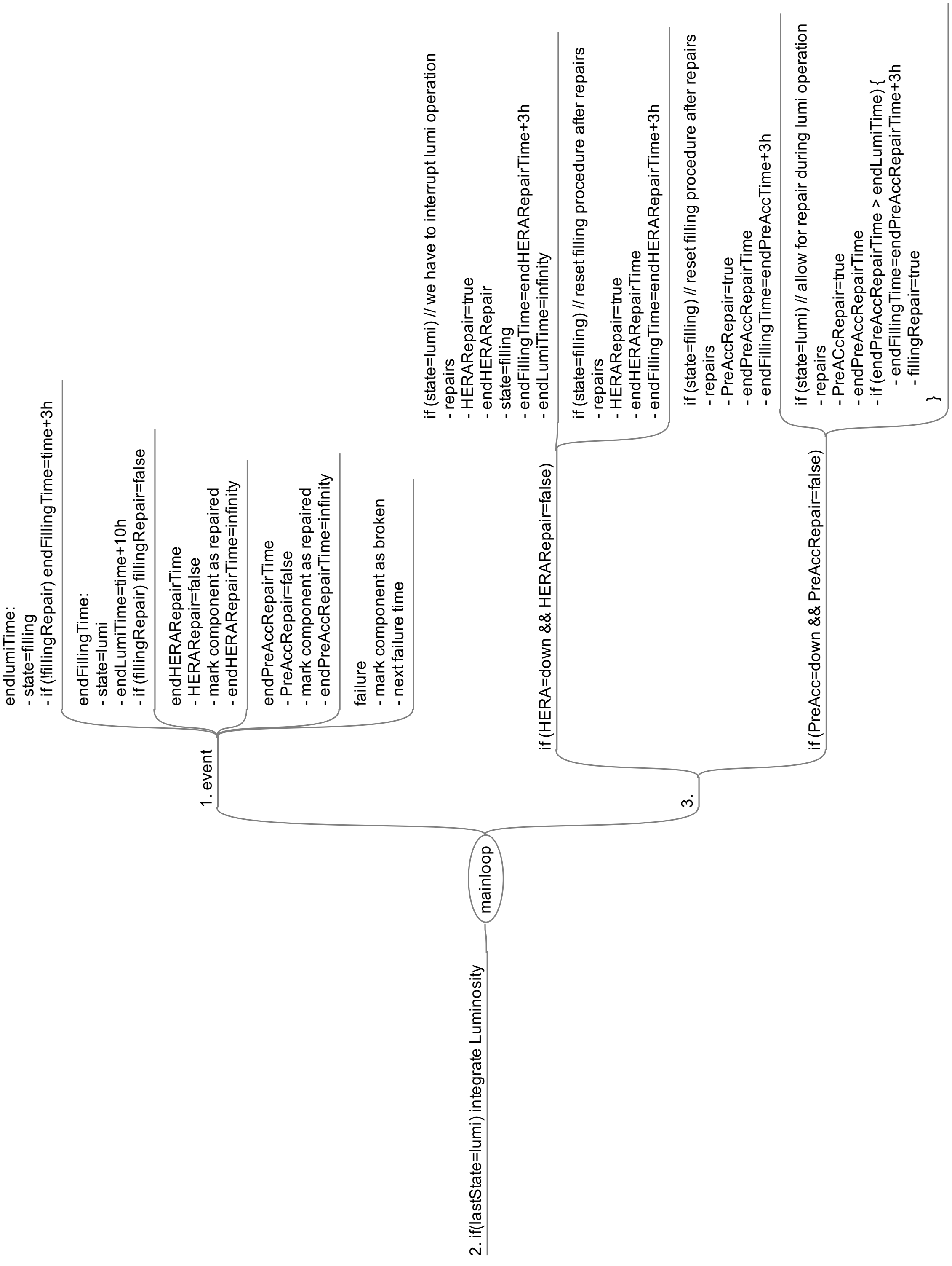

Figure 3: Map of storage ring simulation with failures.