ILC Availability Simulation

(Status Report)

Eckhard Elsen and Sebastian Schätzel

DESY

ILC Meeting
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History and Outline

US Linear Collider Technology Options Study (4 March '04)

→ Availability computer program (Tom Himel, SLAC)
http://www.slac.stanford.edu/~tmh/availability/

- calculate downtime of LC based on failure probabilities of components
- quantitative comparison of LC designs

Today:

- Basics of failure probabilities
- Tom Himel's program
- Conventional vs. undulator positron source

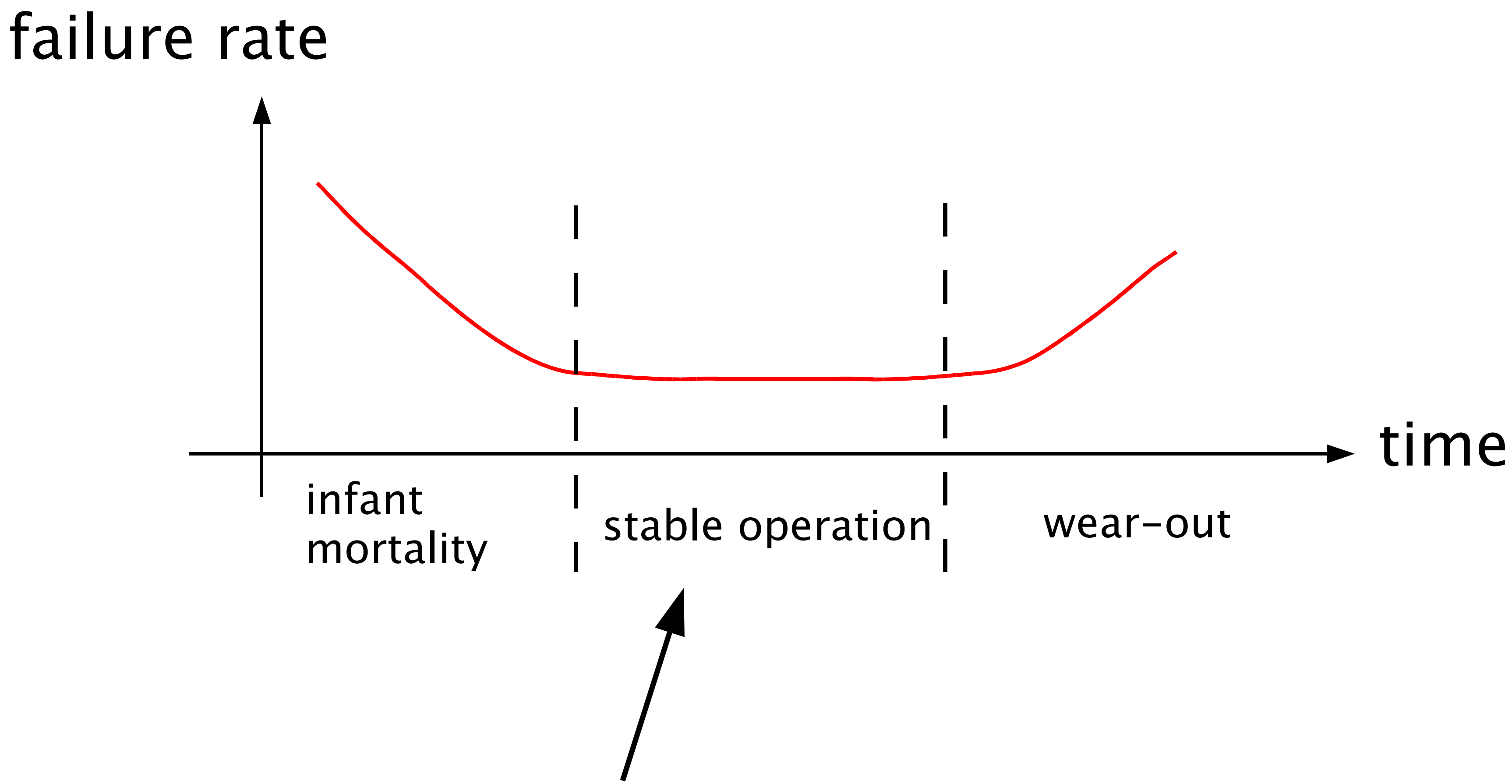
Availability

Here: fraction of time when accelerator provides "useful luminosity"

Availability engineering

- ensure performance of devices
- identify critical parts of a machine
- how to build a complex factory?

Bath–tub curve



simulation assumes stable accelerator operation

Failure Probabilities

N devices, constant failure rate λ

$$\frac{dN}{dt} = -\lambda N \quad \longrightarrow \quad N(t) = N_0 e^{-\lambda t}$$

Probability of failure until t:

$$P_{\mathrm{fail}}(t) \equiv \frac{\#\ \text{broken devices(t)}}{\#\ \text{all devices}} = 1 - e^{-\lambda t}$$

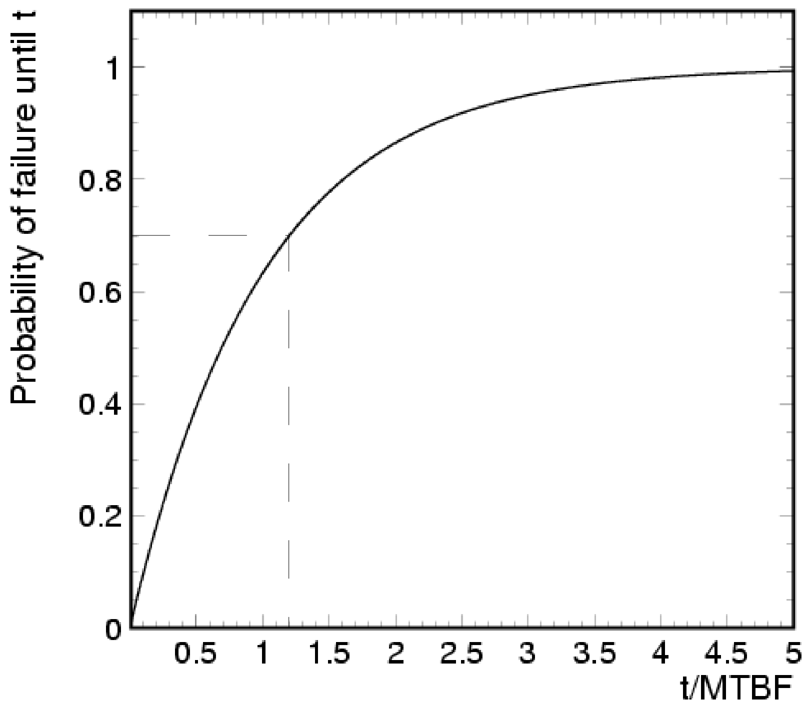
mean time between failures

$$T \equiv \int_0^\infty dt\ t\ \frac{dP_{\mathrm{fail}}}{dt} = \frac{1}{\lambda}$$

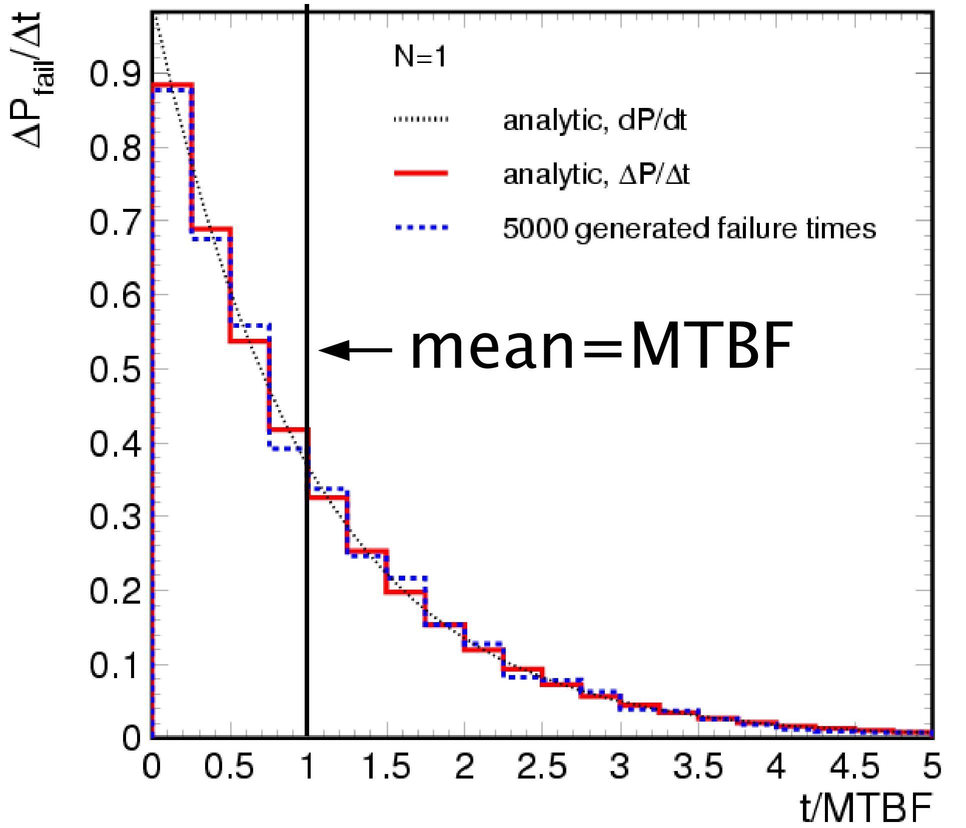
Generation of next failure time

1. random number between 0 and 1
2. convert into next failure time using $P_{fail}(t)$

$$P_{fail}(t) = 1 - e^{-t/T}$$



Generated Failure Times



Program Input and Output

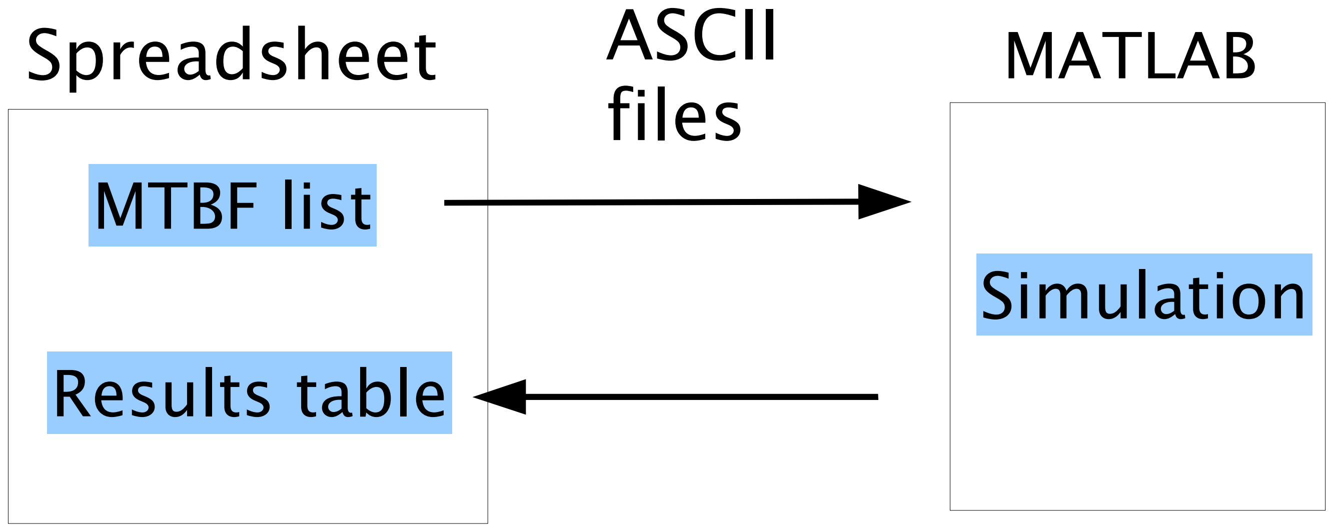
Input MTBF for all components

component name	subsys/segment	region	problem name	quantity	parameter affected	add/ mult	degradation	MTBF	MTTR	access needed	n repair people
cryo plant	beamline	sitewide	broken	1	luminosity	mult	0	1.00E+03	10	0	4
VacP power supply	beamline	e+ DR	broken	2048	luminosity	mult	1.00	1.0E+05	1	1	1
...											

Output downtime table

% time down incl forced MD	15.2
% time fully up integrating lum or sched MI	84.8
% time integrating lum	74
% time scheduled MD	10.8
% time actual opportunistic MD	1.2
% time useless down	14
number of accesses per month	3.93

Program Setup



MATLAB running on Solaris computer (Thanks to MVP!)

MATLAB program structure

read input

determine 1st failure time for every component

time = min(failure times)

time loop {

    case (event) in {

        – failure

            machine down?,
            schedule for repair,
            determine next failure time, ...

        – repair finished

            machine up?, ...

        ...

    }

    time = time of next event

}

write output

Definition of Downtime

time when machine parameters below minimum values

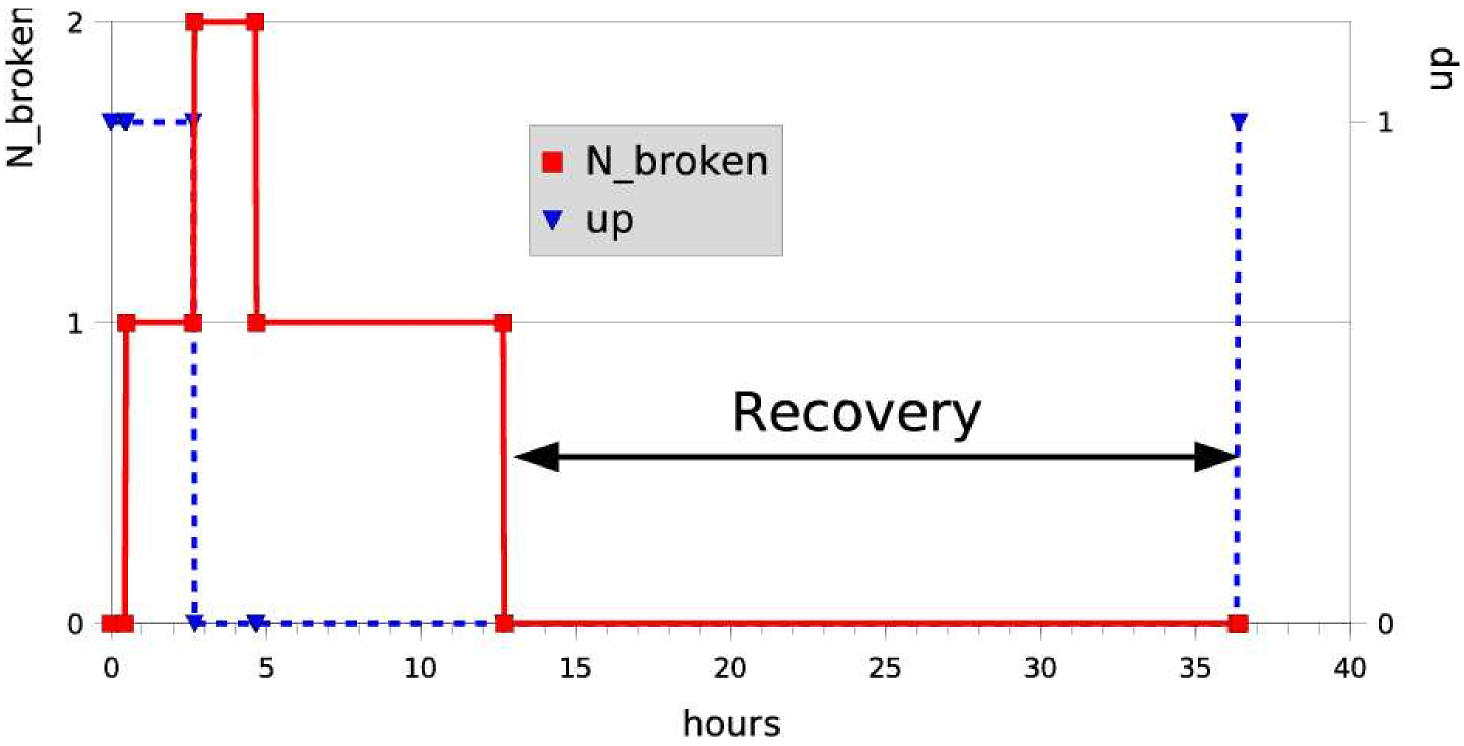
"no useful luminosity"

Parameter	design value	minimum value
luminosity	1.00E+034	5.00E+033
e- energy overhead	20000	0
e+ energy overhead	20000	0
e- DR RF HV	54	49.5
e+ DR RF HV	54	49.5
e- DR inj kick	0.63	0.6
e- DR ext kick	0.63	0.6
e+ DR inj kick	0.63	0.6
e+ DR ext kick	0.63	0.6

component failures decrease parameters

component name	subsys/segment	region	problem name	quantity	parameter affected	add/mult	degradation	MTBF	MTTR	access needed	n repair people
cryo plant	beamline	sitewide	broken	1	luminosity	mult	0	1.00E+03	10	0	4
VacP power supply	beamline	e+ DR	broken	2048	luminosity	mult	1.00	1.0E+05	1	1	1
quad or corr	beamline	e+ DR	retuned	2049	luminosity	mult	0.99	1.0E+50	2		1
Wigglers	beamline	e+ DR	broken	90	luminosity	mult	0.00	1.0E+07	8		1
Kickers - injection	beamline	e+ DR	broken	21	e+ DR inj kick	add	-0.03	1.0E+05	8		1
…											

Example Simulation



- vacuum pump breaks at 0.5 hours, no degradation
- cryo plant breaks at 3h, Lumi=0, machine down
- pump repaired at 5h, plant at 13h
- long recovery (23h)

Recovery procedure

sequential tuning

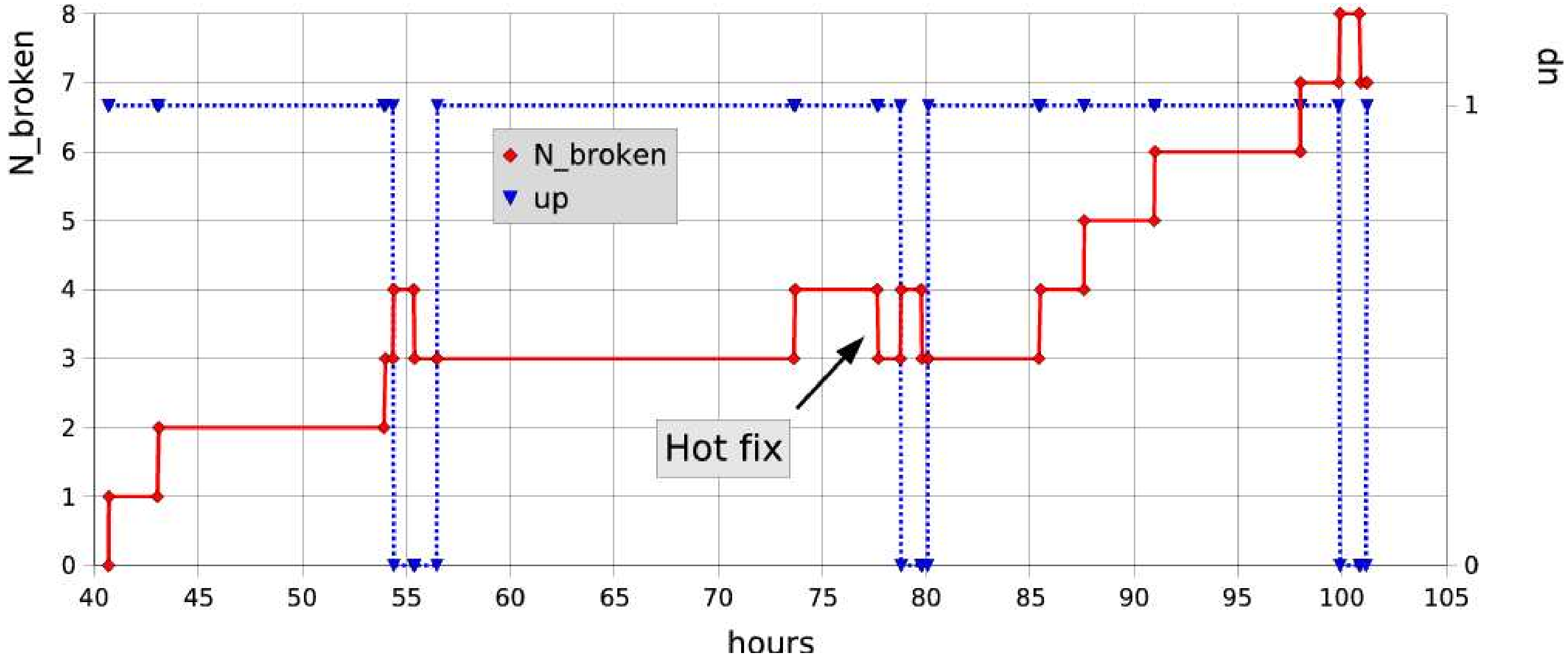
undulator positron source

	name	upstream	access hours	recovery hours	tune-time fraction
	sitewide	none	0	0	0
e^- arm	e- injector	sitewide	1	1	0.1
	e- DR	e- injector	1	1	0.2
	e- compressor	e- DR	1	1	0.1
	e- linac	e- compressor	1	1	0.1
	e- BDS	e- linac	1	1	0.1
e^+ arm	e+ source	e- linac	1	1	0.1
	e+ PDR	e+ PDR	1	1	0.2
	e+ DR	e+ source	1	1	0.2
	e+ compressore+ DR		1	1	0.1
	e+ linac	e+ compressoı	1	1	0.1
	e+ BDS	e+ linac	1	1	0.1
IP region	IP	e+ BDS	1	1	0.2

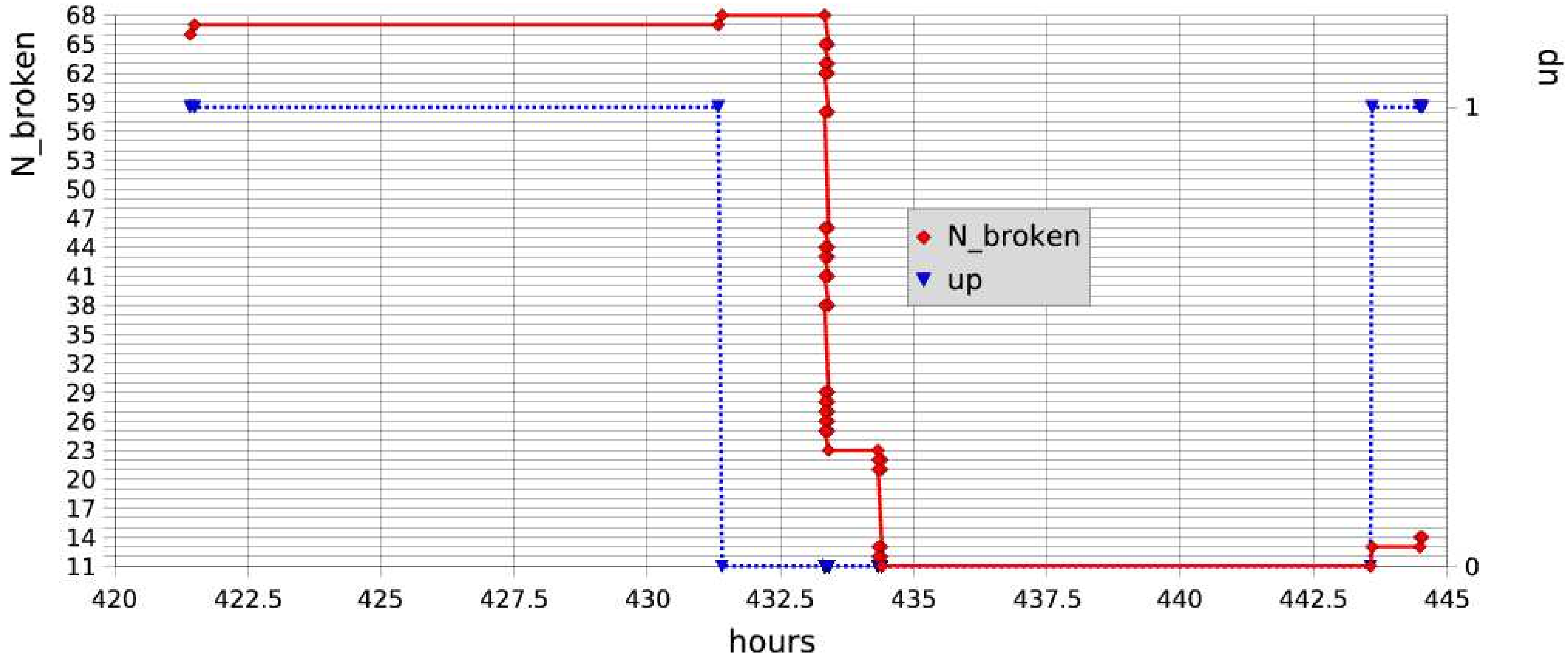
tunetime = tunetime fraction * total downtime (includes tunetime of upstream regions)

More Examples

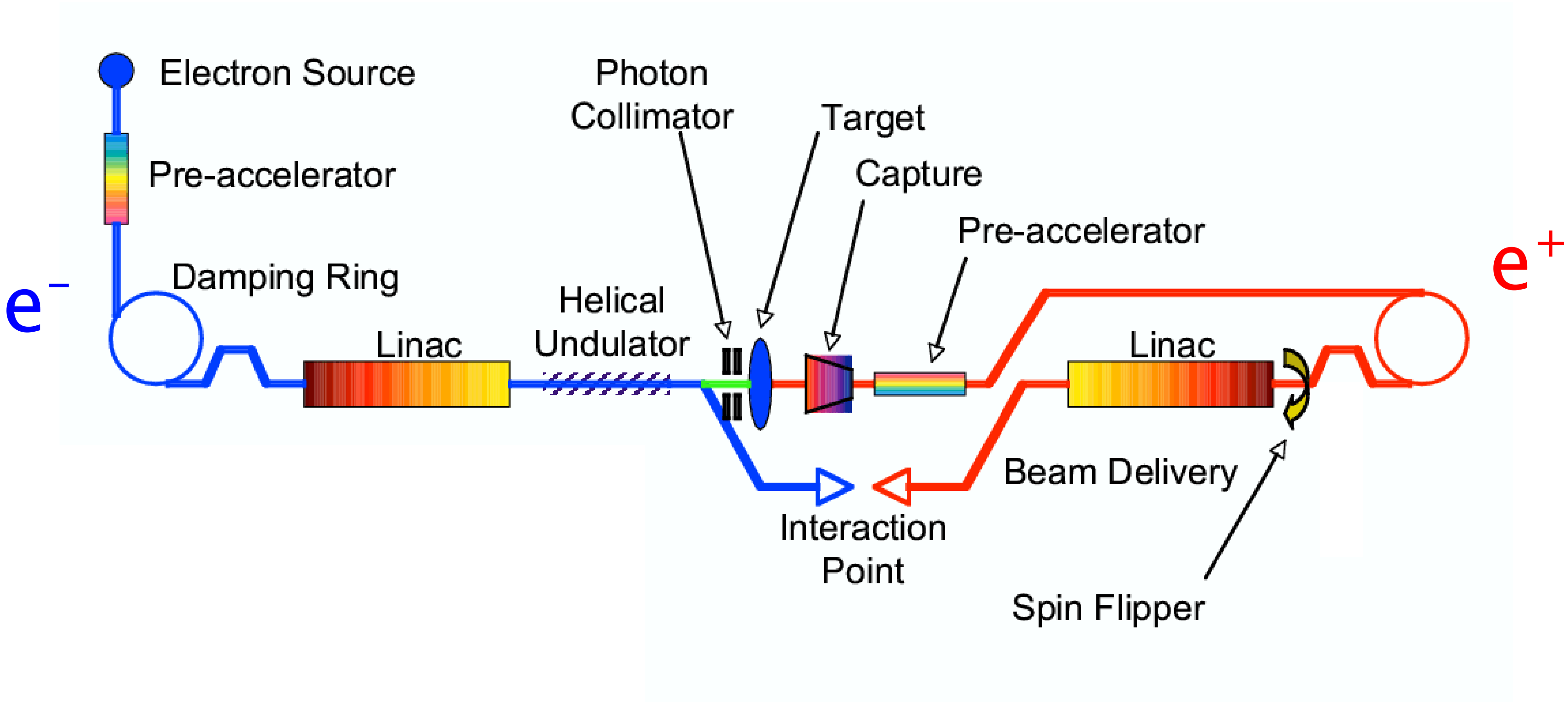
repair during running (hot fix)



many repairs

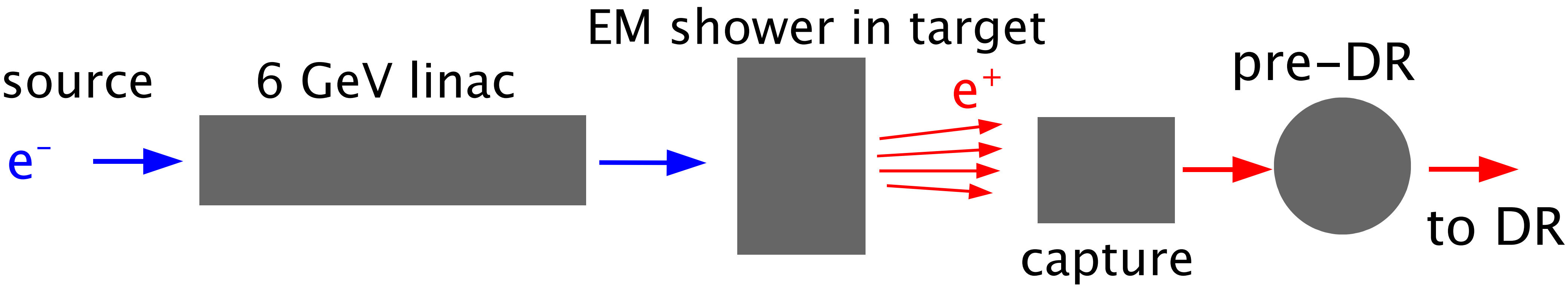


Undulator Positron Source



– need e^- beam to produce e^+ beam
+ low neutron production rate (thin target)
+ no pre-damping ring needed
+ polarised e^+

Conventional Positron Source



+ e^+ beam independent of e^- beam
– target at stress limit
– large neutron rates (thick target), radiation damage
– pre–damping ring needed
– unpolarised e^+

Undulator/conv. e^+ sources in US study

"The fact that an undulator positron source requires well tuned high energy electrons before positrons can be produced significantly reduces the integrated luminosity of a LC."

Downtime	conventional	undulator
US study	11.8%	15.5%

- due to dependence on e^- beam
  - sequential tuning procedure; tunetime proportional to downtime
  - machine development in 2 accelerator regions simultaneously for conv. source

Where US study can be improved

- not implemented:
  - e^- driver linac (conv.)
  - pre-damping ring (conv.)
  - auxiliary source (undulator)

- same MTBF
  should be smaller for conv. (stress limit, radiation damage)

- unrealistic assumption: tuning time $\propto$ time w/o beam
  even if no work in region

All points in favour of conv. source

Extension of conv. source simulation

e^- driver linac (6 GeV)

approximated using
5 GeV e^- injector

pre–Damping ring

as modelled by Tom
for "warm" LC options

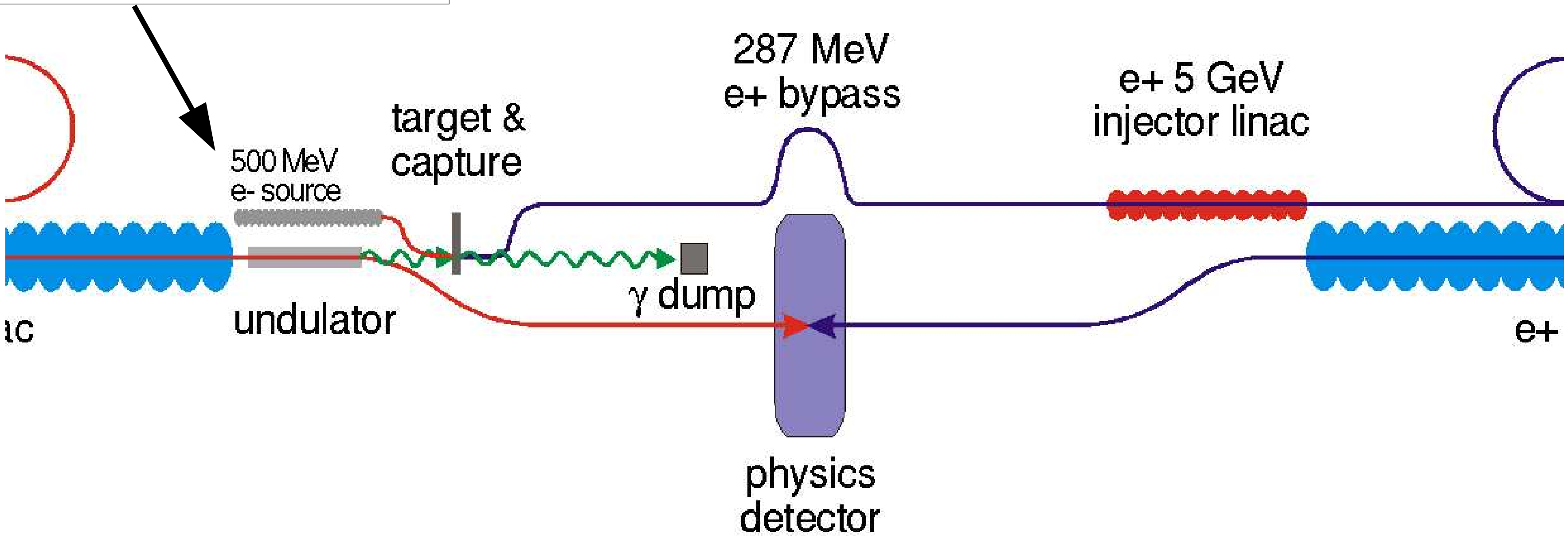
MTBF of conventional source

assume 75% of
undulator MTBF

Downtime	conv.	undulator
US study	11.8%	15.5%
+ driver	13.0%	
+ pre-DR	14.7%	
+ 75% MTBF	15.0%	

Add auxiliary source for undulator option

Aux. source (500 MeV)



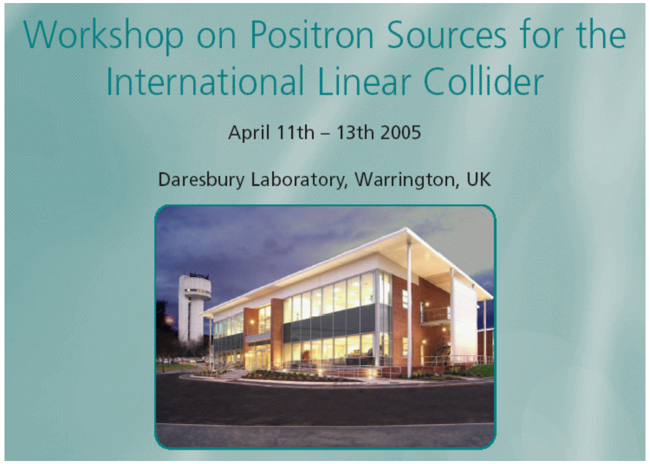
- provides low intensity e^+ beam
- used for tuning of e^+ arm (+machine development)

We assume: tune-time fraction in e^+ arm reduced to 50% (75%)

Results

Downtime	conventional	undulator
US study	11.8%	15.5%
+ driver	13.0%	
+ pre-DR	14.7%	
+ 75% MTBF	15.0%	
+ aux. (75%)		14.1%
+ aux. (50%)		13.0%

← shown at Daresbury

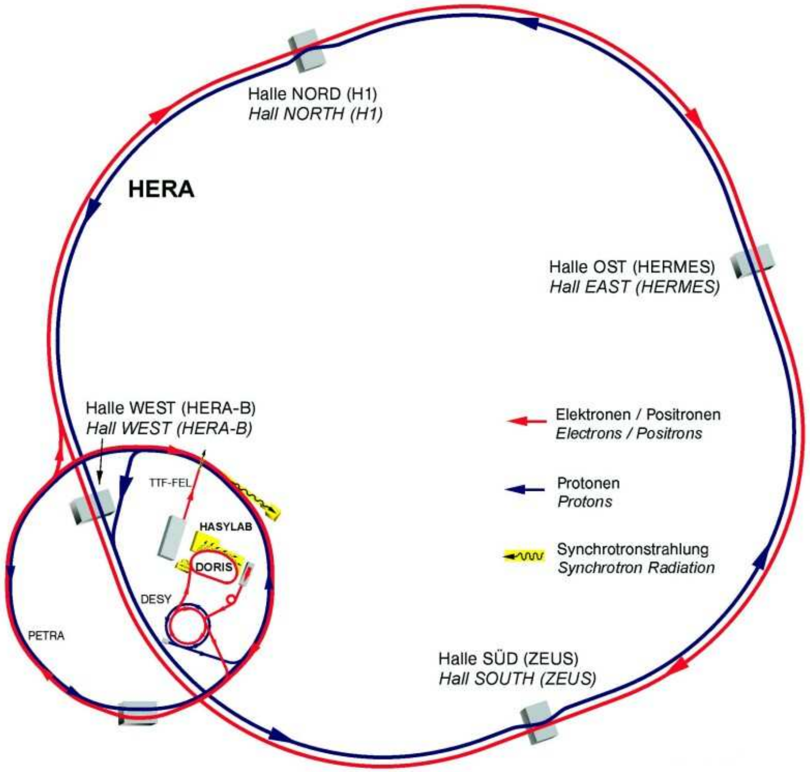


Conclusions:

similar downtimes
aux. source important

Benchmarking: HERA

compare simulation with existing machine



started by Michiko Minty

need list of components and MTBFs

storage ring: adapt code?

Summary

- working setup of Tom's program
- undulator vs. conventional positron source:
  - more realistic simulation of conv. source
  - added auxiliary source for undulator option
  - both options give similar downtimes

Next Steps

- HERA
- commissioning phase
- recovery procedure
- machine development