ILC Global Operations & Availability

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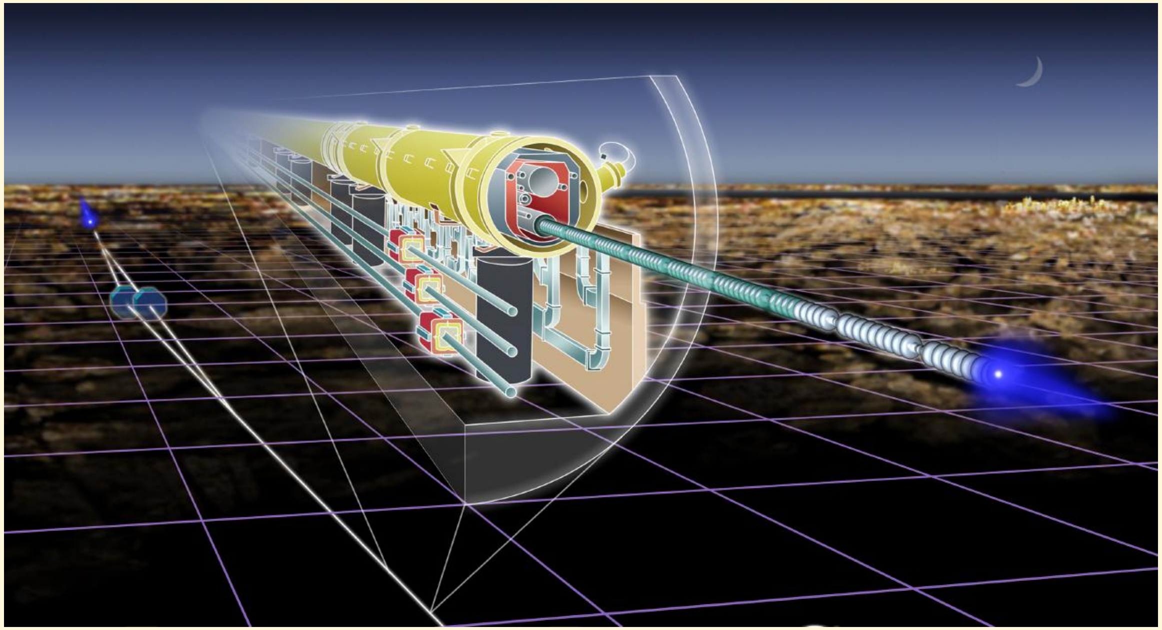
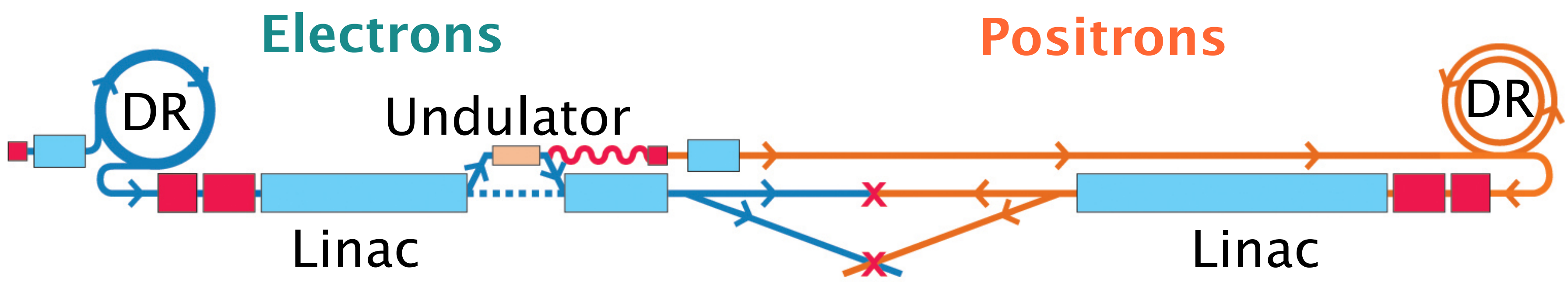
der Deutschen Physikalischen Gesellschaft
Dortmund, 29. März 2006



- Assessment of ILC availability: Monte Carlo simulation
- How the global design is driven by availability considerations
- Benchmarking of the simulation

ILC Baseline Layout

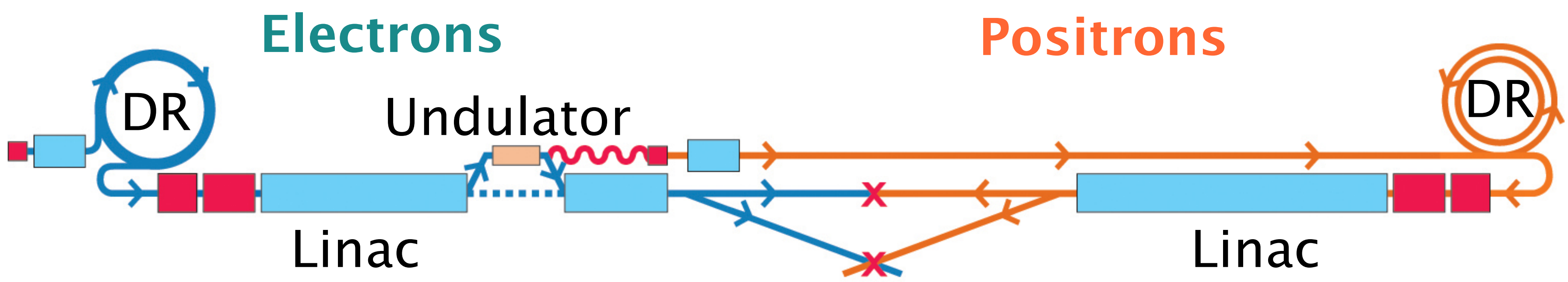


- E_{CMS}=500 GeV
- 2 collision points (2mrad, 20mrad crossing angle)
- 2 linac tunnels (main+service)
- e^+ from conversion of undulator photons, +auxiliary e^+ source
- damping rings: 6.6km, 2 stacked rings for e^+ (electron cloud)

Baseline configuration document (BCD):

http://www.linearcollider.org/wiki/doku.php?id=bcd:bcd_home

ILC Baseline Layout



What is the uptime of this machine?

Monte Carlo Simulation
(Tom Himel, SLAC)

calculates ILC uptime from component failures
http://www-project.slac.stanford.edu/ilc/acceldev/ops/avail/default.htm

Detailed component list:

magnets, power supplies, vacuum pumps, etc.

Stochastic approach: generate component failures

every component has a mean-time-between-failures (MTBF) and mean-time-to-repair

Failures degrade ILC performance:

examples:

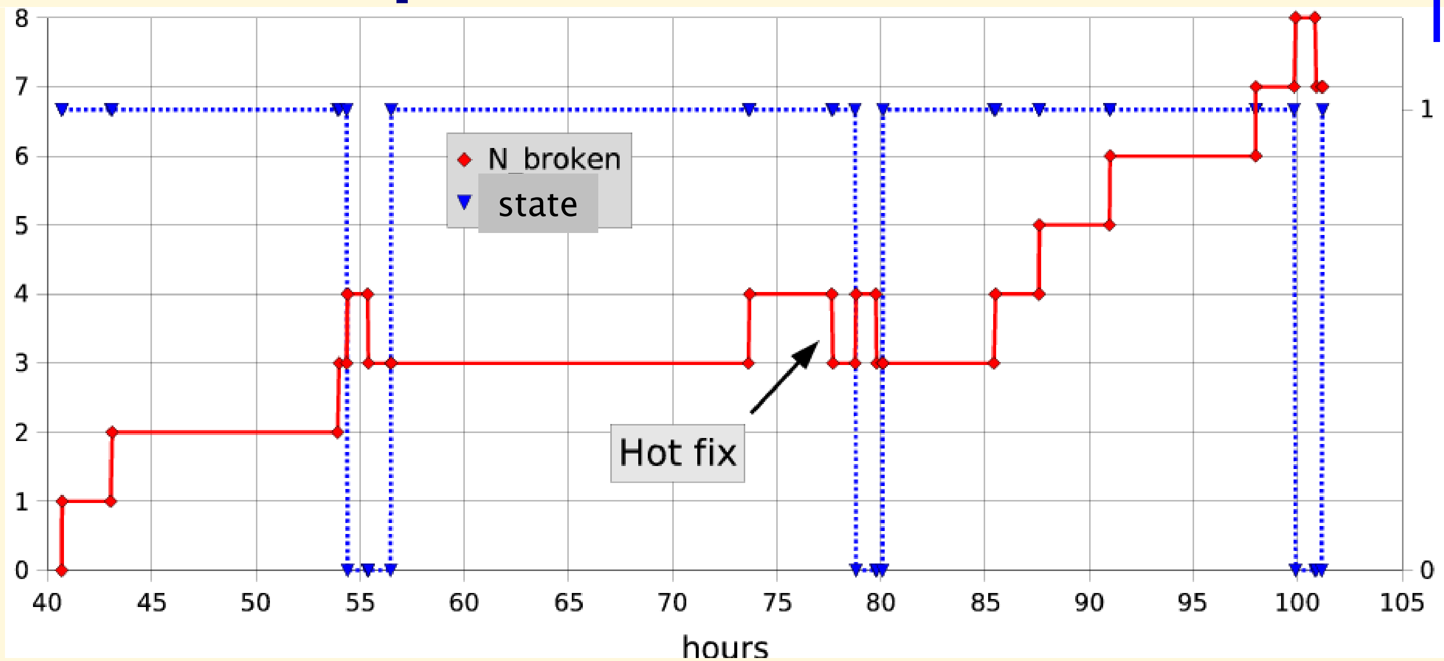
failure	ILC performance
klystron	reduced linac energy
quadrupole magnet in linac	reduced luminosity
quadrupole magnet in DR	broken ILC

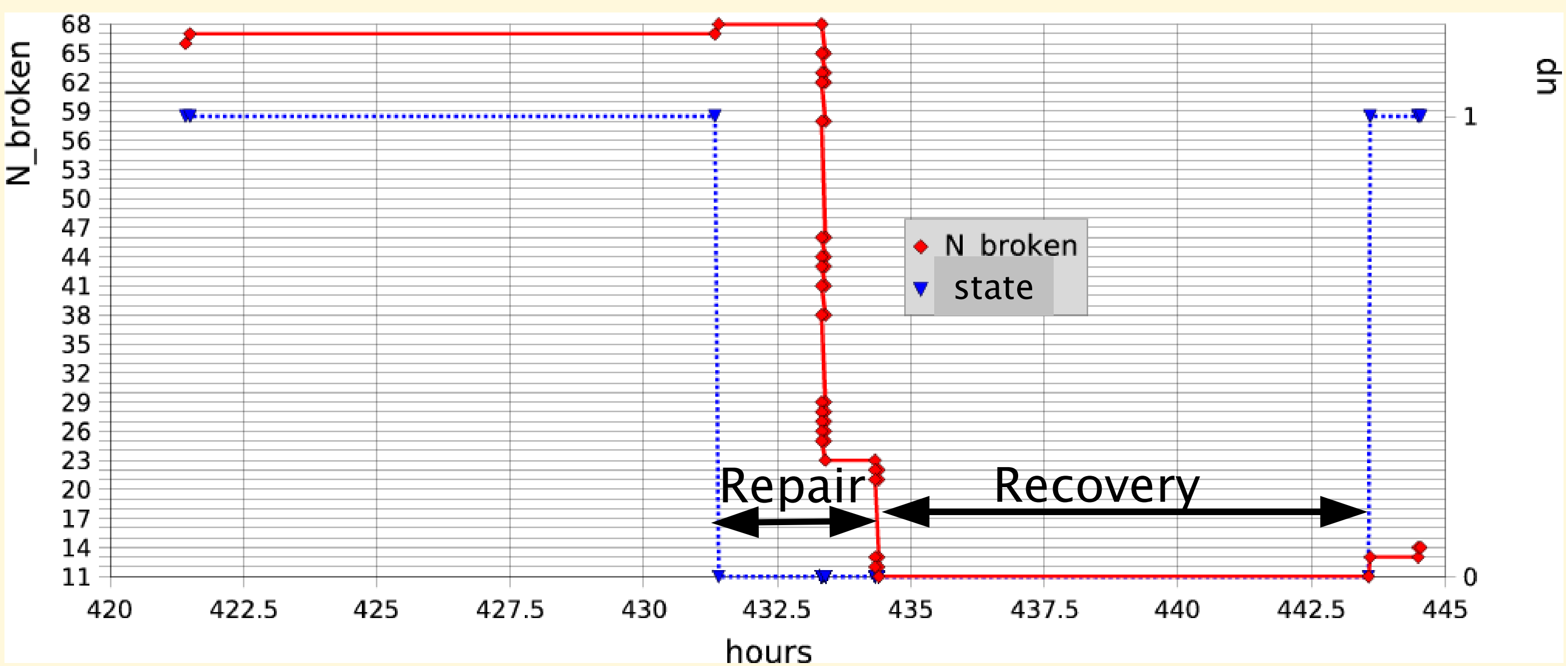
machine "down" if: luminosity $\mathcal{L}<0.5\ \mathcal{L}_{nominal}$ or $E_{CMS}<500$ GeV (or DR HV requirements not met)

Example Simulation

broken components

ILC state
up
down





Repair & Recovery

Different repair scenarios (component dependent):

- "hot repairs" (during ILC running), main linac tunnel access needed, no access needed
- example: a service tunnel reduces accesses

Recovery of beam ("tune time"):

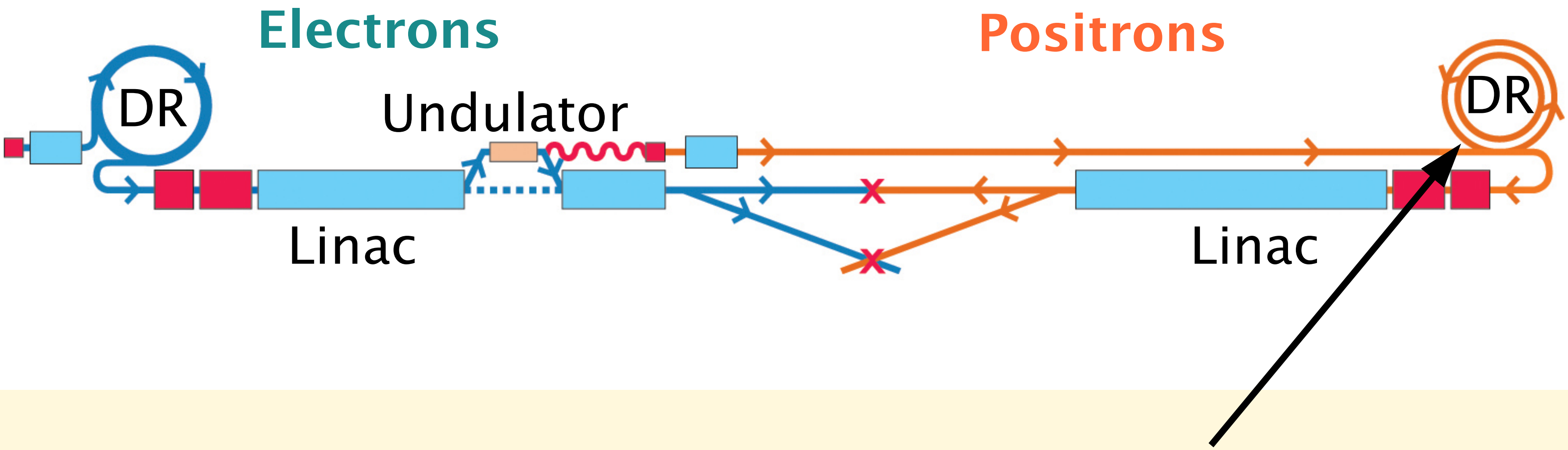
- *time to recover well-tuned beam in a section is proportional to the time this section was **without beam*** (typically 10%)
- example: e^- damping ring failure
  if e^+ created independently of e^- → can keep e^+ beam
  → faster ILC recovery

⟷ global ILC layout

Machine development:

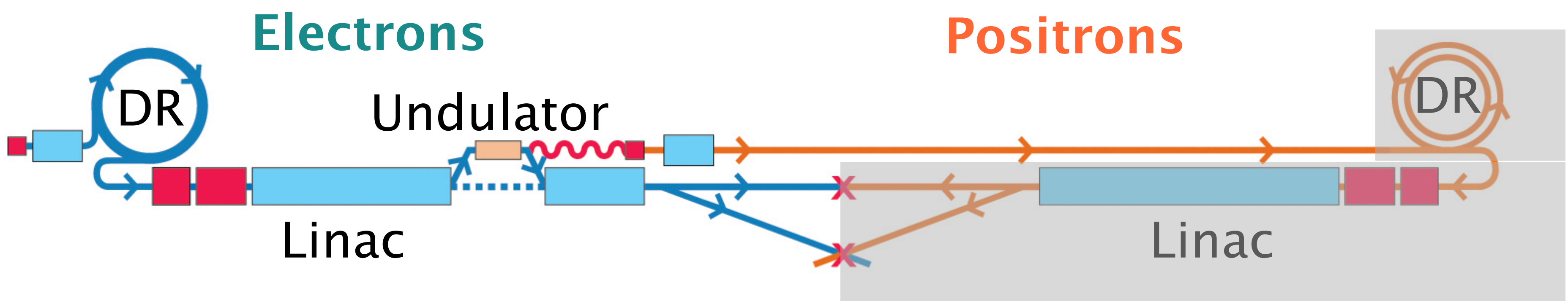
every ILC section needs 1% (damping rings: 2%) of total simulation time for improvement studies

Recovery Example



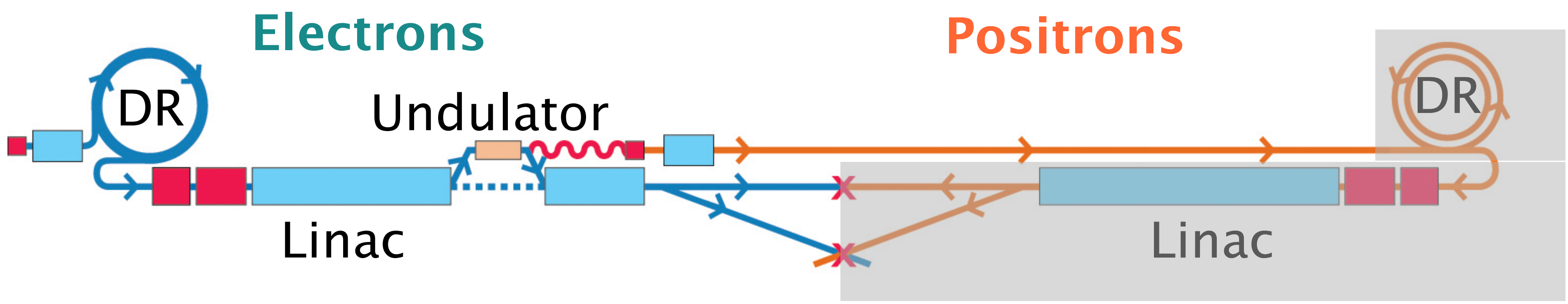
- e^+ damping ring failure

Recovery Example



- e^+ damping ring failure
- e^+ side down

Recovery Example

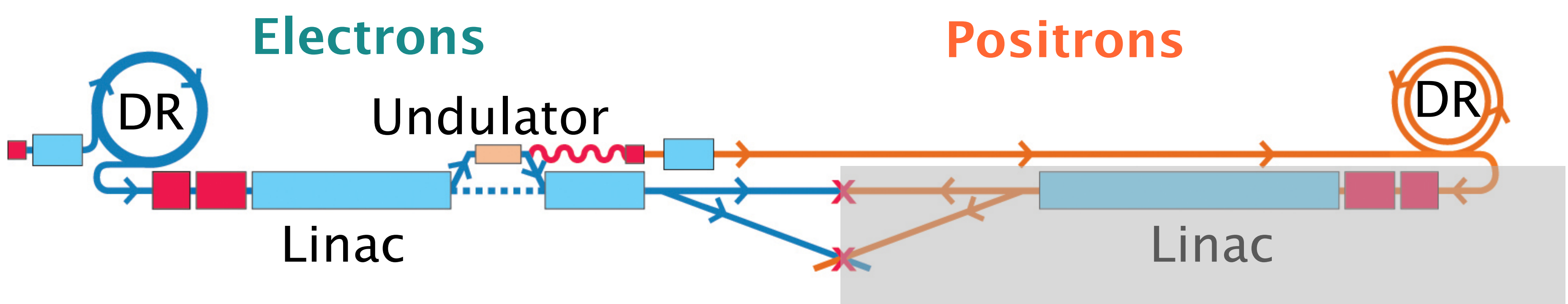


can still run e^- side

- maintain stable running
- machine studies

- e^+ damping ring failure
- e^+ side down

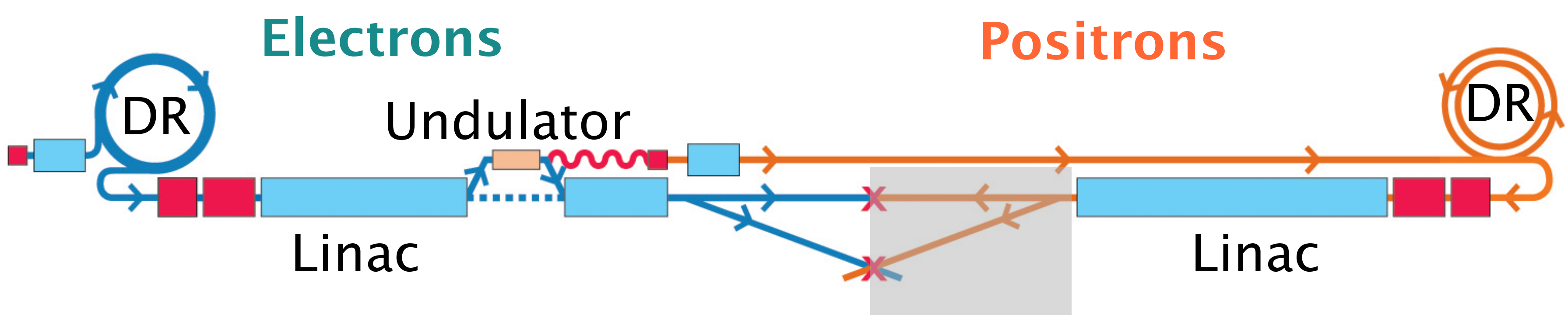
Recovery Example



can still run e⁻ side
- maintain stable running
- machine studies

- e⁺ damping ring repaired and tuned

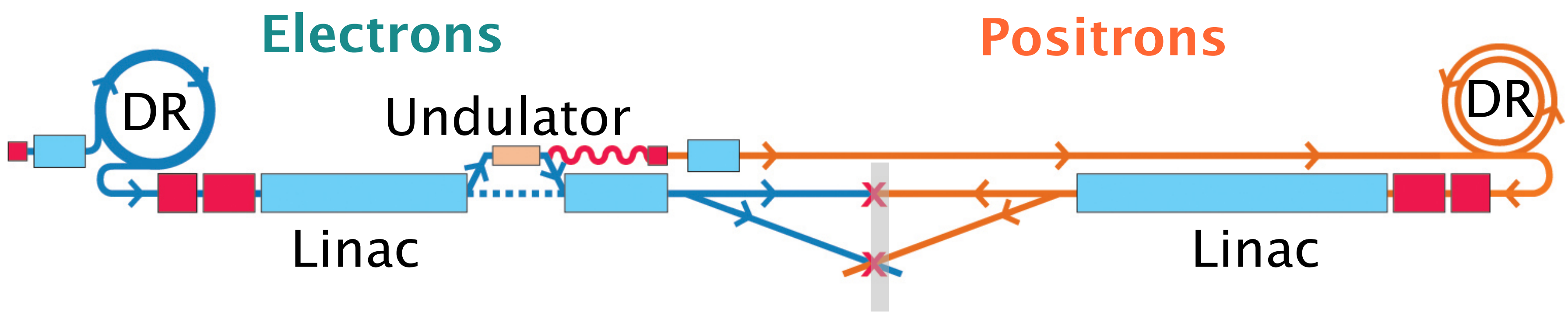
Recovery Example



can still run e⁻ side
- maintain stable running
- machine studies

- e^+ damping ring repaired and tuned
- e^+ main linac tuned

Recovery Example

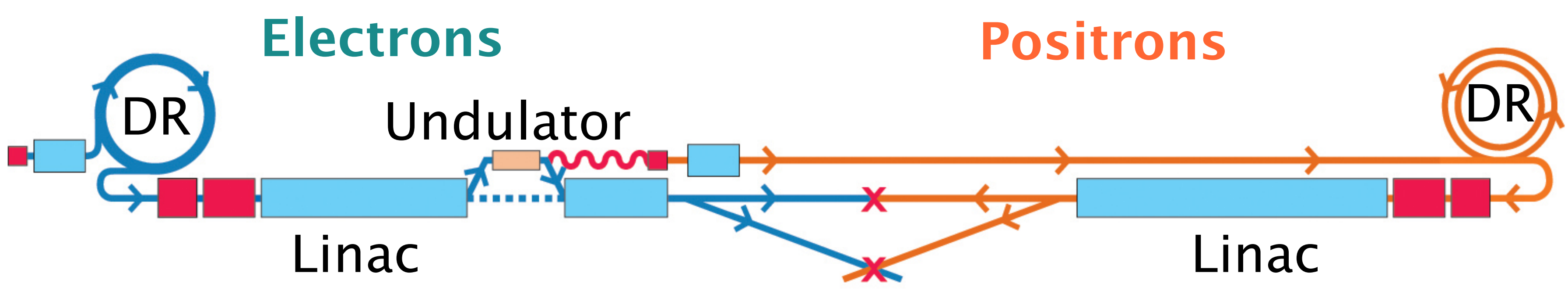


can still run e⁻ side

- maintain stable running
- machine studies

- e⁺ damping ring repaired and tuned
- e⁺ main linac tuned
- e⁺ beam delivery system tuned

Recovery Example



can still run e^- side
- maintain stable running
- machine studies

- e^+ damping ring repaired and tuned
- e^+ main linac tuned
- e^+ beam delivery system tuned
- IP region tuned

→ ILC back up and running

Simulation Output

- total ILC downtime
- downtime per component
- downtime per accelerator section

Optimise:
- make components more reliable
- add spare components (redundancy)
- change global layout

Goal: ILC should deliver luminosity ~85% of the time

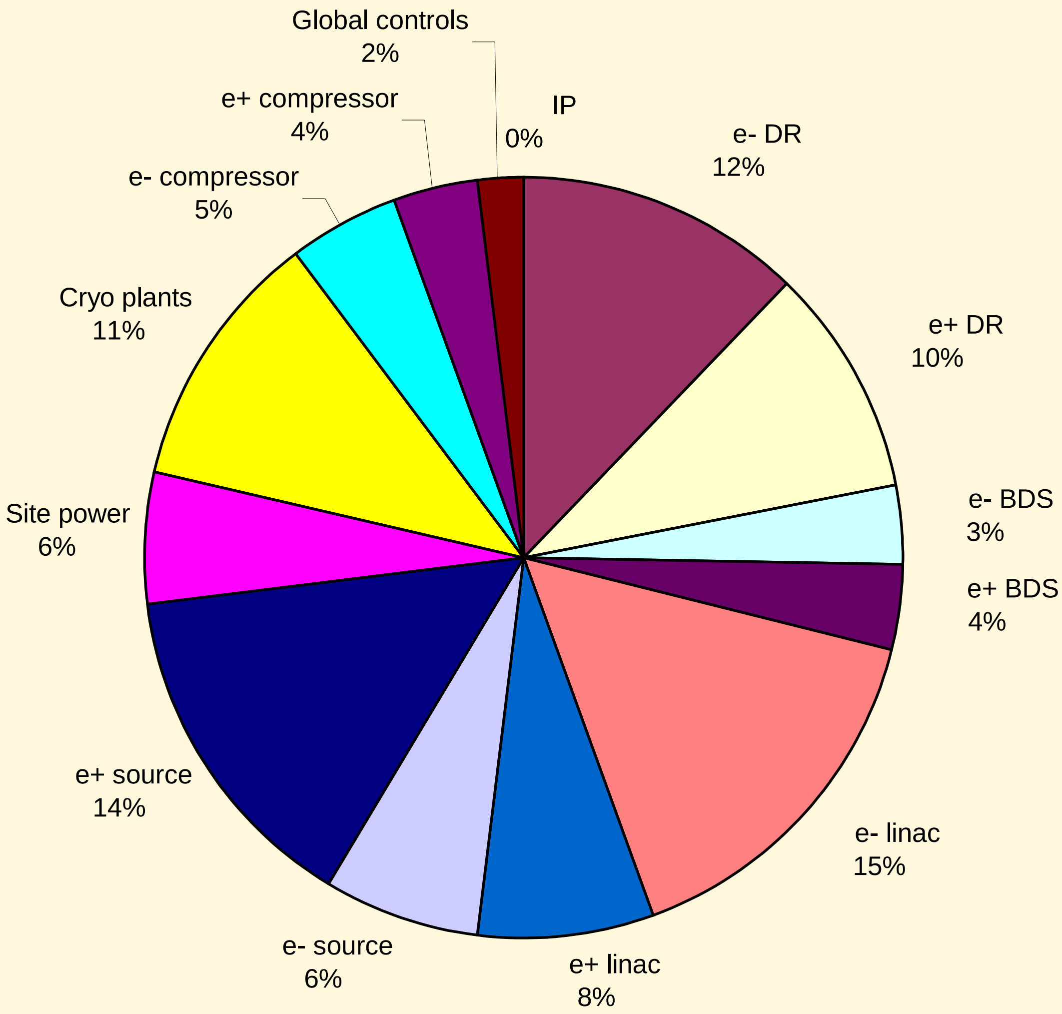
How 85% uptime is achieved

- 3% energy overhead in main linac; low energy linacs: 5% (5 GeV damping ring injector, e^+ accelerator to 250 MeV, ...)
- 1 hot-swappable spare klystron/modulator per low energy linac
- klystrons and electronics in service tunnel can be hot-swapped, (not so in main linac tunnel)
- dumps and shielding in accelerator sections: people can work with beam in upstream section
- many more details (see BCD)

Critical Components

Device	Improvement factor A that gives 17% downtime for 2 tunnel undulator e+ source	Downtime (%) due to these devices for 2 tunnel undulator e+ source with strong keep_alive	Improvement factor B for 1 tunnel undulator e+ source, 6% energy overhead	Improvement factor C for 1 tunnel undulator e+ source, 3% energy overhead	Nominal MTBF (hours)
magnets - water cooled	**20**	0.4	20	20	1,000,000
power supply controllers	**10**	0.6	**50**	50	100,000
flow switches	**10**	0.5	10	10	250,000
water instrumention near pump	**10**	0.2	10	**30**	30,000
power supplies	**5**	0.2	5	5	200,000
kicker pulser	**5**	0.3	5	5	100,000
coupler interlock sensors	**5**	0.2	5	5	1,000,000
collimators and beam stoppers	**5**	0.3	5	5	100,000
all electronics modules	**3**	1.0	**10**	10	100,000
AC breakers < 500 kW		0.8	**10**	10	360,000
vacuum valve controllers		1.1	**5**	5	190,000
regional MPS system		1.1	**5**	5	5,000
power supply - corrector		0.9	**3**	3	400,000
vacuum valves		0.8	**3**	3	1,000,000
water pumps		0.4	**3**	3	120,000
modulator		0.4		**3**	50,000
klystron - linac		0.8		**5**	40,000
coupler interlock electronics		0.4		**5**	1,000,000
vacuum pumps		0.9			10,000,000
controls backbone		0.8			300,000
additional linac energy overhead			**3%**		3%

Downtime per ILC section



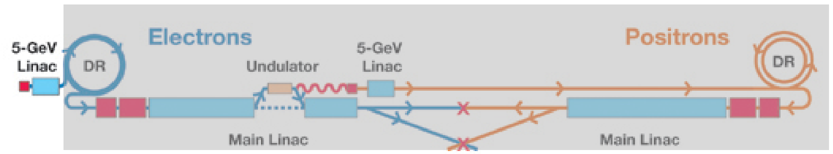
large contributions (>10%) from

- e^+ source (transport line)
- e^- linac (split by undulator)
- damping rings
- cryo plant

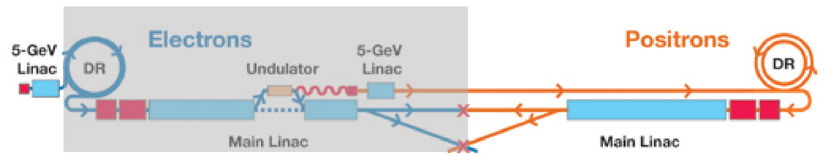
Auxiliary e^+ Source

positron source	ILC uptime
undulator	69%
undulator+auxiliary	78%
conventional	80%

Example:
e^- damping ring failure:
without aux. source:



with aux. source:



undulator w/o aux. source
leads to reduced uptime
because of e^+/e^- arm coupling
(recovery and machine development)

auxiliary positron source:

- stand-by conventional source of low intensity (~10%)
- 2h switch-over time
- required intensity driven by sensitivity of Beam Position Monitors

Service Tunnel

for high availability need access to RF, modulators, power supplies, and electronics while linac is running

Tunnel configuration	**Simulated % time integrating luminosity under normal running conditions**	**Simulated % time integrating luminosity when commissioning***
a single tunnel without robotic repair	64%	25%
a single tunnel with robotic repair	73%	Not simulated
two tunnels where the support tunnel is always accessible	78%	46%
two tunnels where the support tunnel is only accessible when the RF is turned off	72%	Not simulated

*MTBFs halved, required machine development time doubled

Service Tunnel

pros:

- significant increase in uptime, especially for commissioning
- (some) electronics do not have to be radiation-hard
- higher availability → shorter ILC running (save on running cost)

cons:

- **expensive to build:** increases total ILC construction cost by a few % O(€100M)
- improved uptime can be achieved for 1 tunnel by additional redundancy
- service tunnel radiation-safe?
  (radiation leaking in from main tunnel through connecting tunnels?)

Baseline: 2 tunnels (but still a debated subject)

decision might in the end depend on site location:

- local construction cost (tunnel depth)
- local safety regulations

Benchmarking

- simulation has built-in philosophies (e.g., recovery algorithm) based on SLAC experience
- no SLC operation data for comparison available (detailed log book)

Is the simulation close to reality?

→ 2 comparisons: HERA and PEP-II

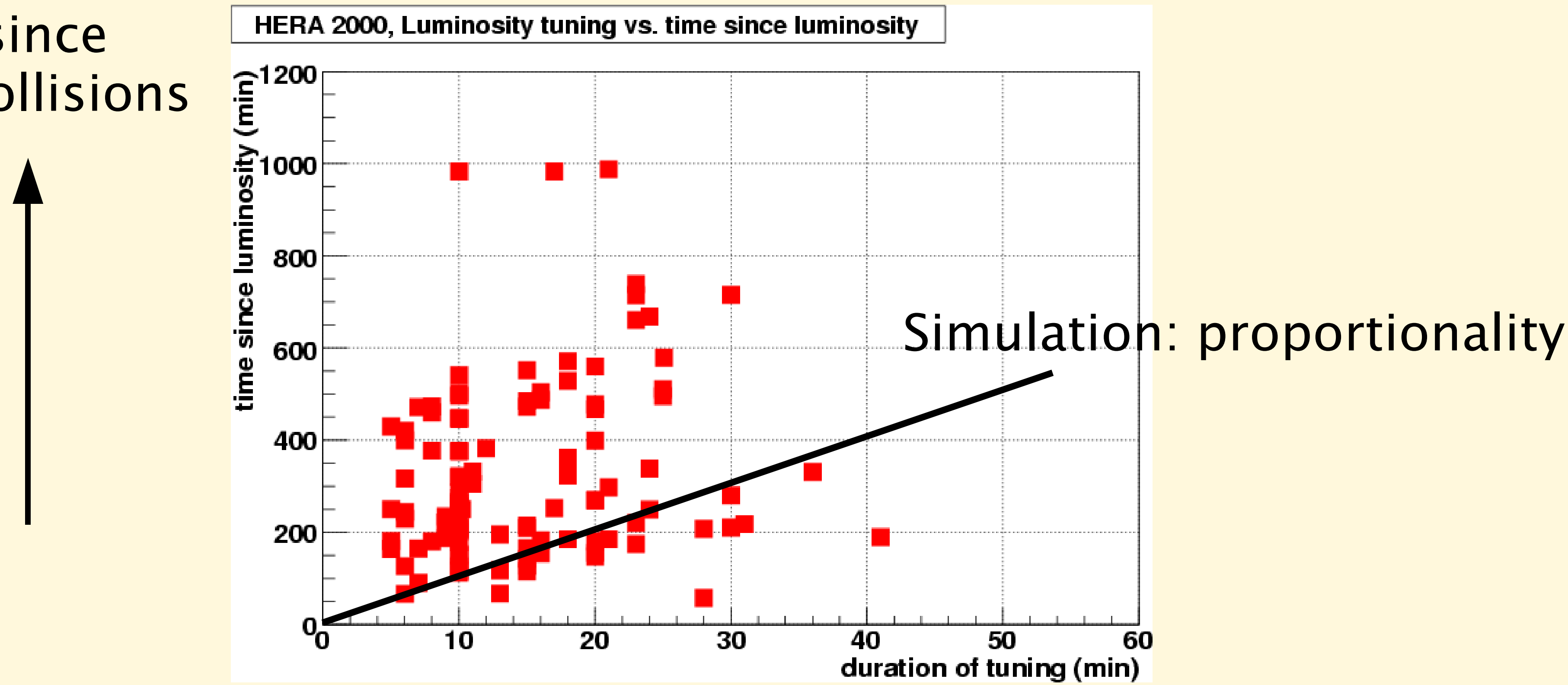
focusing on:
assumption that recovery time proportional to time without beam

The largest contribution is from tuning of the IP region (=luminosity tuning) because both beams are needed.

HERA Comparison

ep storage ring, DESY

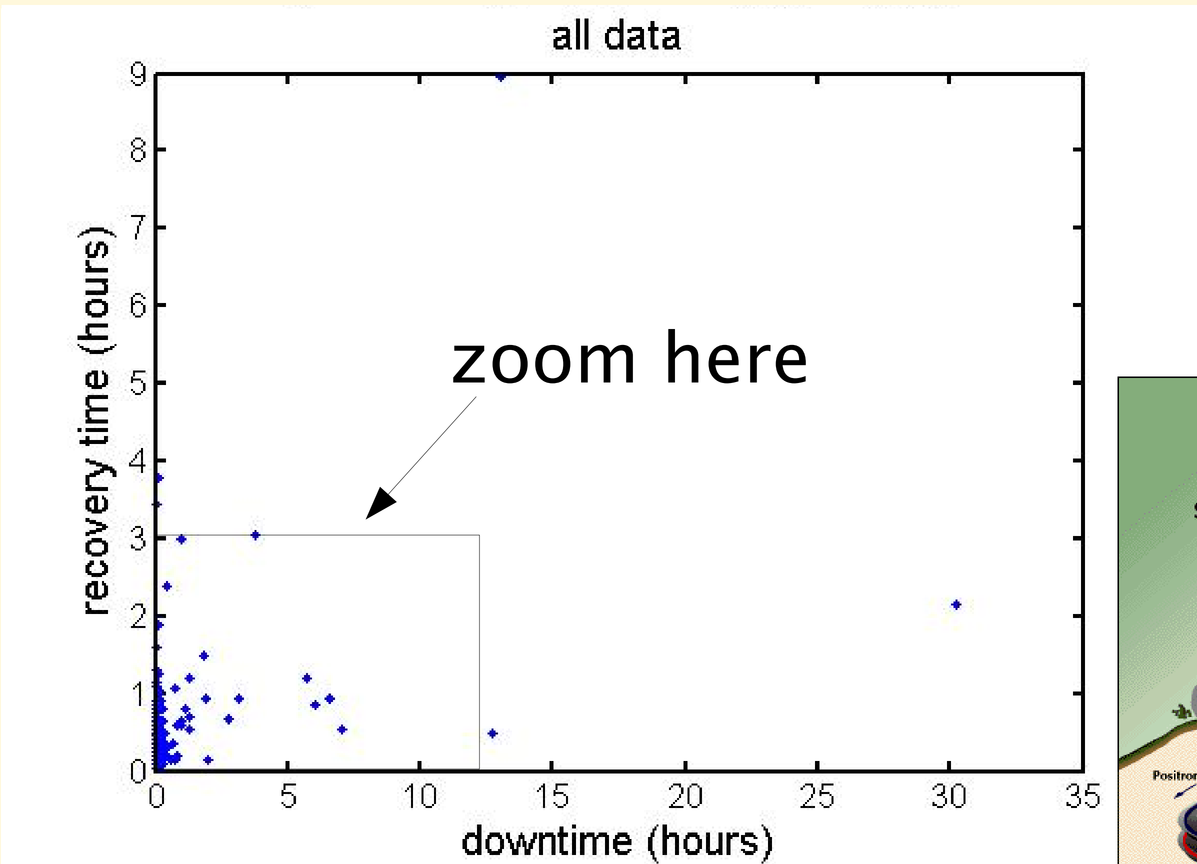
time since last collisions



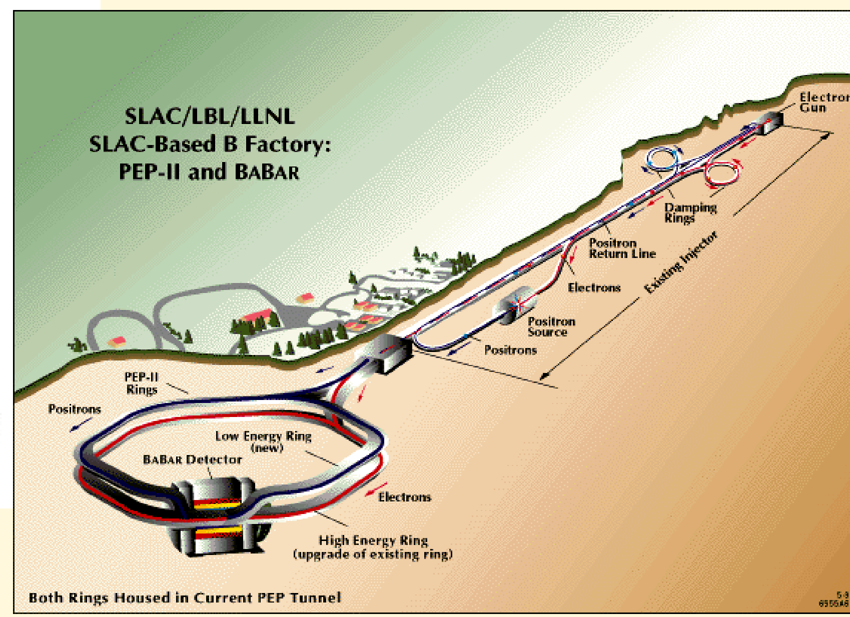
HERA: No correlation

PEP-II Comparison

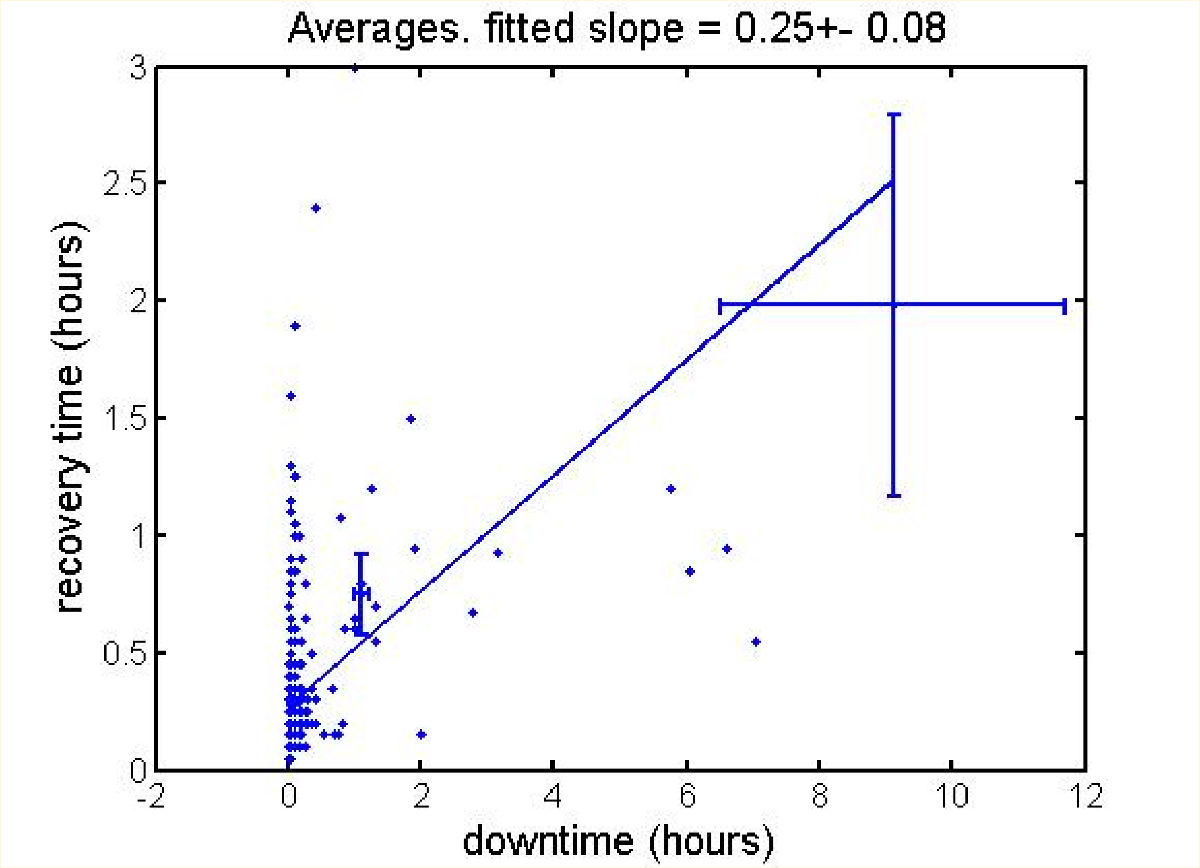
(J Nelson, SLAC)



e+e− storage ring, SLAC



PEP-II Comparison
(J Nelson, SLAC)



no clear trend

Benchmarking Results

- no justification of tune-time proportionality from benchmarking
- simulation with fixed average tune-time is different:
  Example: positron source comparison

	Description	time integrating lum (%)	time scheduled MD (%)
proportional tune-time	conventional	81.8	4.4
	undulator	68.1	12.0
fixed tune-time	conv. fixed tune-time	82.5	5.3
	undulator fixed tune-time	74.1	12.4

remaining difference due to machine development

Summary & Conclusions

- For the first time an accelerator is constructed with quantitative global availability assessment.
- Availability considerations have big (costly) impact on global ILC layout:
  - 2 tunnels favoured.
- Key components have to be made more reliable.
- Simulation must be improved, e.g., benchmarking suggestive of different recovery algorithm.

Downtime per ILC system