Welcome to DESY

Kay Wittenburg
Group leader MDI
(Machine Diagnostic and Instrumentation)
On behalf of DITANET

7th Ditanet workshop
on beam loss monitoring
(5-7 December 2011, DESY)
Welcome to DESY!
Deutsches Elektronen Synchrotron
National Research Center
Member of Helmholtz-Gemeinschaft
Two locations (Hamburg and Zeuthen)
about 2000 employees in Hamburg and Zeuthen
Tasks and Goals:
• Development and utilization of particle accelerators
• Particle and Astroparticle Physics
• Research with Photons (Synchrotron Radiation)
DESY research
∞ small
Elementary particles
Unification of forces
∞ complex
Nanoscience, Biology, …
Synchrotron radiation
X-ray lasers
∞ large
Cosmology
Astrophysics
∞
universum
∞
nano cosmos
Condensed Matter
Contents:

HERA History
BLMs at HERA-p
BLMs at HERA-e

Kay Wittenburg
7th Ditanet workshop on beam loss monitoring
(5-7 December 2011, DESY)
1968       Woodstock
1977       C.H Llewellyn-Smith and B.H. Wiik publ. physics with e-p collider
1981       Proposal for a e/p Collider Ring at DESY
1984       start of construction
1988       Commissioning of the Electronen Storage Ring
1991       Commissioning of the Protonen Storage Ring
Okt. 1991  first e/p Collisions
1992       Detectoren H1 & ZEUS „on Beam Position“
1995       HERMES Experiment
1996       HERA-B Experiment
1998       Proton energy increased to 920 GeV, NEG pumps against dust problem
1999       Design Luminosity reached
2000       Maximum luminosität: $\Lambda \geq 2 \times 10^{31} \text{ cm}^{-2} \text{ sec}^{-1}$
2001       Luminosity upgrade, Spin Rotators for H1 and ZEUS
2003       Final Lumi upgrade, 1st longitud. polarization in high energy ep collis.
2007       Final shut down after 15 years of data taking

10 years from proposal to success

Slide from Bernhard Holzer
Physics with Large Electron-Proton Colliding Rings

by

C. H. Llewellyn-Smith
University of Oxford

B. H. Wiik
Deutsches Elektronen-Synchrotron DESY, Hamburg

NOTKESSTRASSE 85 - 2 Hamburg 52

The "Red DESY Report," in which Christopher H. Llewellyn-Smith, who later became Director General of CERN, and Bjørn H. Wiik first published their ideas for a large electron-proton accelerator in 1977.
Circumference: 6.3 km
Proton Beam: Injection Energy 40 GeV
Lumi-Energy (820) 920 GeV
Electron Beam: Injection Energy 12 GeV
Lumi Energy 27.5 GeV
Magnetic field p-ring: 5.1 Tesla
at I=5500 A for 920 GeV

HERA at DESY, Hamburg, Germany

422 s.c. dipole magnets
224 s.c. main quads,
400 s.c. correction quads
200 s.c. correction dipoles
> 1000 n.c. electron magnets

Slides from Bernhard Holzer
Basic Layout of the Machine

HERA is a double ring collider:

→ two independent storage rings

→ 4 straight sections for experiments

→ collision of protons & electrons at two interaction regions (North/South)

→ internal gas target at IR East (polarized e-Beam, HERMES)

→ internal wiretarget at IR West (p-beam, HERA B)

Preaccelerators               max. energy       length/circ.
LINAC II:  e-/e+               450 MeV            70 m
LINAC III:  p                   50 MeV             32 m
PIA:  e-/e+ (Accumulator)      450 MeV            29 m
DESY II:  e-/e+                 8 GeV              293 m
DESY III:  p                    7,5 GeV/c          317 m
PETRA II:  e-/e+: 12 GeV       p: 40 GeV/c        2304 m

Slides from Bernhard Holzer
Particle detector ZEUS in HERA hall south
size: 12m * 11m * 20m
weight: 3600 t

HERA Hall South during construction

HERA Tunnel drilling machine HERAKLES
The $\beta$-functions in the interaction region (IR) were reduced and more quadrupoles were installed, some very close to the IR. For the HERA Lumi upgrade the number of power supplies (quadrupoles) in the high $\beta$ region increased from 6 to 14.

The beam has a high sensitivity to field-changes of these low-$\beta$–insertion quadrupoles. It was calculated (later!!!) that a 1% change of the magnet current already leads to dramatic beam losses. Therefore a trip of such a power supply will lead to very fast beam losses ($<<5$ ms) even if the time constant $\tau_M$ of such a coil is in the order of some hundred milliseconds.
and the luminosity ... which is in the end what we are paid for.
Integrated Luminosity

Max Lumi reached, Lumi-Upgrade Problems solved
Synchrotron-Light Fan of the Electron (Positron) Beam

When passing through the Interaction Region the Positrons emit Radiation with a Power of \( P_{\text{ges.}} = 30 \text{ kW} \)

After upgrade the power had increased and the shielding of the experiments was insufficient \( \rightarrow \) high background! Improved in 2003
Synchrotron Radiation

beam energy \( E_0 = 27.5 \text{ GeV} \)

bending radius \( R = 608 \text{ m} \)

wave length: \( \lambda \approx 0.016 \text{ nm} \)

critical energy

\( E_{\text{crit}} \approx 45 \text{ keV} \ldots 88 \text{ keV} \)

→ hard x rays
Requirements to BLMs at HERAp

- Detection of proton losses outside the cryostat of the sc magnets.
- To measure losses in the presence of strong synchrotron radiation from the adjacent electron ring.
- Automatic beam dump at dangerous loss rates before a quench occurs. => fast
- Adequate radiation hardness.
- Cheap because of a large number of monitors (>250 positions).
SR Background

- Effective shielding needs 5 cm lead
- Large size detectors excluded
- Quench-Signal/SR ratio with 5 cm lead shield:
  - Short ion chamber: $7.5 \times 10^2$
  - Szintil. counter: $0.8 \times 10^2$
  - ACEM: $5.0 \times 10^2$
  - Solid state: $4.6 \times 10^2$

Dynamic range is far too small for beam loss induced quench protection!

How these numbers where calculated?
We performed Monte Carlo calculations to simulate the beam loss and the energy deposition in the coils. The critical losses were determined from the critical energy deposition in 1 cm$^3$ coil volume (hot spot).

BLMs cannot protect against instantaneous losses!

At Tevatron (Ref. 6) they observe beam loss induced quenches at a continuous loss rate (/s) 16 times higher than instantaneous losses.

Ref. 6: THE TEVATRON BEAM POSITION AND BEAM LOSS MONITORING SYSTEMS.
Published in Proc. 12th Int. Conf. on High Energy Accelerators, pp. 609-615
Energy deposition in magnets

a) quench level of a cable (820 GeV/c)  

For NbTi cables (HERA):
- \( B = 5 \, \text{T} \) (at coil, 4.7 T in gap), \( T_b = \text{He bath temp} = 4.4 \, \text{K} \)

Critical values:
- \( T_c \) (\( B=0, I=0 \)) = 9.2 K; \( B_c = 14.5 \, \text{T} \)
- \( T_c \) (\( B, I=0 \)) = \( T_c \) (0) \( \cdot \) \((1 - (B/ B_c))^{0.59} \)  
  \[ \text{Ref. 2a} \]

Current sharing temp.:
- \( T_{cs} \) (\( B, I \)) = \( T_b + (T_c(B, I=0) - T_b) \cdot (1 - J_{op}/J_c) \)  
  \[ \text{Ref. 2a} \]

Critical current:
- \( J_c = J_c(B, T) \) see \text{Ref. 2b}  

With
- \( J_{op} = \text{HERA operating current} \approx 0.7 \cdot J_c = 5025 \, \text{A} \)

\[ \Rightarrow T_{cs}(B, J_{op}) = 5.2 \, \text{K} \]

\[ \Rightarrow \Delta T_c = 0.8 \, \text{K} \]

between He-bath-temp. (\( T_b \)) and quench-temp (\( T_{cs} \)).
a) quench level of a cable  cont.

Heat capacity $c_p$ of Copper-NbTi composite cable:

\[
c_p = 10^{-3} \varepsilon \left\{ (6.8/\varepsilon + 43.8) \cdot T^3 + (97.4 + 69.8 \cdot B) \cdot T \right\} \text{[mJ/cm}^3 \cdot \text{K]} \tag{Ref 2a}
\]

$\varepsilon$ is the superconductor fraction of the cable: $\varepsilon = 0.36$ for HERA Type cable

\[
\Rightarrow c_p = 2.63 \text{ mJ/cm}^3 \cdot \text{K}^{-1}
\]

\[
\Rightarrow E_{\text{dep}} = 2.1 \text{ mJ/cm}^3 \text{ is needed for a temperature increase of } \Delta T_c = 0.8 \text{ K}
\]

(at 820 GeV/c)

with minimum propagation zone calculation, still adiabatic: \( \text{Ref. 1} \)

An energy of 1 mJ would be sufficient to heat a 12 mm long section of the HERA cable adiabatically above the critical temperature. If no cooling by surrounding liquid helium was present this energy deposition would then actually trigger a quench. The stability can
**Other Refs:** (at nom. Energy) \((\rho = 7.9 \text{ g/cm}^3, \text{ area} = 0.15 \text{ cm}^2)\)

**Tevatron:** \(\Delta T_c = 1 \text{ K} ; \ E_{\text{dep}} = 1 \text{ mJ/g} = 7.9 \text{ mJ/cm}^3 \)  
Ref. 3

**SSC Magnets:** \(\Delta T_c = 0.6 \text{ K} ; \ E_{\text{dep}} = 0.2 \text{ mJ/g} = 1.6 \text{ mJ/cm}^3 \)  
Ref 4

**Fermilab Energy doubler:** \(\Delta T_c = 1.4 \text{ K} ; \ E_{\text{dep}} = 9.8 \text{ mJ/cm}^3 \)  
Ref 5

**HERA:** \(\Delta T_c = 0.8 \text{ K} ; \ E_{\text{dep}} = 2.1 \text{ mJ/cm}^3 \)  
(6.6 mJ/cm³)

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Ref. 3: VanGinneken, A.; FERMILAB-Pub-87/113 Quenching induced by beam loss at the TEVATRON.
Ref. 4: Quench analysis of the energy deposition in the SSC magnets and radiation shielding of the low Beta IR quadrupoles.
Ref. 5: SENSITIVITY OF AN ENERGY DOUBLER DIPOLE TO BEAM INDUCED QUENCHES. By B. Cox,P.O.Mazur, A. Van Ginneken(Fermilab).
Ref. 5a: Fermilab design report, 1979
and

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**About the same energy is required to quench at 820 (4.4 K) and 920 (4 K):**

![Energy Dependence Graph](chart.png)

- **Tb = 4.0 K**
- **Tb = 4.4 K**

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**Diagram:**
- **x-axis:** beam energy [GeV/c]
- **y-axis:** mJ/cm³

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**Graph Details:**
- The graph shows the energy deposition (in mJ/cm³) as a function of beam energy (in GeV/c).
- The lines represent different temperatures: **Tb = 4.0 K** and **Tb = 4.4 K**.
- About the same energy is required to quench at 820 (4.4 K) and 920 (4 K).
Tolerable loss rates (calculations) cont.

- So far: All calculations valid for dipoles, but losses are expected mainly in quadrupoles
- Quads: Same cable, same temp., same current, smaller B (increase $T_{cs}$)
- Measurements of quench currents at 4.75 K:
  Mean ($\pm \sigma$): Dipoles 6458 A ($\pm$ 114 A); Quads: 7383 A ($\pm$ 148 A)
  Weakest: Dipole: 6154 A, Quad: 6518 A
  Calculated with previous formulas: $J_c = 6340$ A
- Go on with BLM system conception with previous numbers and use differences as safety margins.
Response, energy deposition, calibration and locations of BLMs were calculated by Monte Carlo Simulations.

Use of “Gheisha8” (1986 – 89), precursor of “Geant”

H. Fesefeld, The Simulation of Hadronic Shower – Physics and Application; Aachen, PITHA 85/02
Positions of BLMs

- Collimators
- max. beta function (Quadrupoles near Experiments, normal conducting
- Each superconducting Quadrupole (Quench)
SR Background

- Effective shielding needs 5 cm lead
- Large size detectors excluded

Quench-Signal/SR ratio with 5 cm lead shield:
- Short ion chamber: $7.5 \cdot 10^2$
- Szintil. counter: $0.8 \cdot 10^2$
- ACEM: $5.0 \cdot 10^2$
- Solid state: $4.6 \cdot 10^2$

Dynamic range is far too small for reliable beam loss induced quench protection!
PIN Photodiodes to satisfy the special conditions in HERA

- Two PIN-PDs in coincidence to count charged particles

- Signal (in Si):
  - \( \text{dE/dx} = 3.7 \text{ MeV/cm} \)
  - 3.7 eV/e-hole pair
  - \( \Rightarrow 10^{-15} \text{ C/MIP} \)
  - \( \Rightarrow 10\,000 \text{ e}^-/\text{MIP} \)

- Small dimensions:
  - Area: \( 2.75 \times 2.75 \text{ mm}^2 \) (7.56 mm²)
  - or \( 20 \times 7.5 \text{ mm}^2 \) (150 mm²)

- Costs:
  - 1 $ for small PD
  - 100 $ for big PD

BPW34
Old drawing from about 1989
Spectrum of the deposit energy in the PIN Diode

by MIPs (Source: $^{108}$Ru; max. 2 MeV $\beta$)

The typical Landau distribution of energy loss in the 100 micron depletion layer of the PIN Diode
The BLM

- High efficiency to charged particles:
  - 70% for single diode, 30% in coincidence

- TTL output for counting, $t < 96$ ns (bunch distance)

- Very low noise:
  - Dark count rate $< 0.01$ Hz
  - max. count rate $> 10.4$ MHz

- Very high dynamic range: $> 10^9$

- Insensitive to synchrotron radiation:
  - Efficiency to $\gamma$: $3.5 \cdot 10^{-5}$
  - Coincidence + lead: $< 1$ Hz at 1.5 Gy/h (e- ring at max.)
  - With full SR still $10^7$ dynamic range

Sensitive and fast amplifier with low noise and with a fast coincidence following.
- Integration time: 5.2 ms
- Short mode buffer: $128 \cdot 5.2 \text{ ms} = 666 \text{ ms}$
- Long mode buffer: $128 \cdot \text{mean short} = 85 \text{ s}$
- Stop data taking in case of alarm
- Archiving
- Function check
Beam Loss Monitor System setup

Coin-\textit{zidenz} 

adjust. thresh.

Count

adjustable threshold

Alarm at 64 counts (920 GeV)

Post-mortem-recorder

Max 100 m coax cable + control cable

Integration time constant for all BLMs

Hera-Beamline

5.2ms reset

Alarm-loop
Response, calibration and settings of BLMs at 5 ms integration time

Critical Proton Loss Rates and Alarm Thresholds and Quench Levels vs Momentum

lost protons / 5 ms

expected critical proton losses / 5 ms

allowed proton losses / 5 ms

Safety margin about 10

Momentum [GeV/c]
Response, calibration and settings of BLMs cont.

Response of BLM:
Fit includes:
- Sensitivity of the BLM to radiation created by lost protons
- Amount of radiation at BLM position created by lost protons

Counts/lost proton $[\cdot 10^{-6}]$  protons/count $[\cdot 10^4]$

<table>
<thead>
<tr>
<th>Counts/lost proton $[\cdot 10^{-6}]$</th>
<th>protons/count $[\cdot 10^4]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>1.67</td>
<td>1.67</td>
</tr>
<tr>
<td>2.5</td>
<td>2.5</td>
</tr>
<tr>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>14.2</td>
<td>14.2</td>
</tr>
</tbody>
</table>

simplified fit: $1 \text{ count} = 1.5 \times 10^7 / p$ [lost protons]

BLM calibration at the superconducting quadrupole

Ref 7: S. Schlögl, II Institut für Experimentalphysik der Universität Hamburg
Einsatz von PIN-Photodioden als Protonen-Strahlverlustmonitore bei HERA
Diploma thesis, DESY-HERA-92-03
Ref. 8: F. Ridoutt, II Institut für Experimentalphysik der Universität Hamburg
Das Ansprechvermögen des PIN Dioden Strahlverlustmonitors
Internal Note: PKTR note No. 91 (1993)
Response, calibration and settings of BLMs cont.

![Graph showing the response, calibration, and settings of BLMs with MIPs/proton/cm^2 on the y-axis and beam energy on the x-axis. The graph includes data from 2005 (Geant) and 1989 (Gheisha8).]
Critical rates

Two types of thresholds:

1. 1/10 of critical loss rate produce an alarm (rates varies with energy)

2. More than 4 BLMs above 1. dump the beam (for all energies above injection)
BLM calibration

Calibration quite good, measured lifetime by current decay and losses agree within factor 2
No quench

Dump due to losses

HERA BLM Alarm System
Some Beam Loss Induced Quenches

Failure in Main Alarm loop
HERA ring view

Less than 4 BLM alarms

Quench at OL 198

Short mode (5.2 ms / bin)

Long mode (666 ms / bin)
Other loss types:

Fast losses, but > 5.2 ms

Quench 40 s after losses!
(note: here long mode)

Already an indication, that the threshold is close to the quench level
Quench around HERA

Number of Quenches

- 32 different locations
- 75 quenches (1994-2005)

most at 300 GeV/c in 1996, since 1997 4 BLMs at 198m locations

Location of magnet
Quench experiences (comparison with calculations) cont.

Critical Proton Loss Rates and Alarm Thresholds and Quench Levels vs Momentum

long losses; mean value of 666 ms
Quenches due to very fast losses < 5.2 ms (after upgrade)
Statistics of 5 ms events

5 ms events

Counts/Year

Year


Action: faster Alarms

Rf Interlock active
+920 Gev upgrade
Lumi-upgrade
long shutdown

2 x Kicker (Quench), 1 x ???

fast Alarm
Quenches
5 ms
Adding more and faster alarms to avoid 5 ms events
New Beam-Loss-Alarm-Topology at DESY

- Magnet current-Alarm
- Internal Power-Supply-Alarm
- Galv. Trenn.
- BLMs + BPMs + Alarm-modules
- ACCT-Alarm
- DCCT-Alarm
- DUMP
- Alarm loop-Zentrale
- More Failure inputs: PS, HF, ...
- Faster Active New
- Faster clock rate
Statistic BLM events 1995 - 1997

- **Errors**
- **Quenches**
- **5 ms events**
- **BLM-Alarms**

**Weeks and Events**: The graph shows the distribution of events per week across the years 1995 to 1997. The x-axis represents weeks, and the y-axis represents the number of events per week.

**Beam Current**: The vertical axis on the right side of the graph represents the beam current in mA, ranging from 0 to 100.

**Color Coding**: Different colors represent different types of events or alarms: blue for errors, red for quenches, yellow for 5 ms events, and green for BLM-Alarms.
Since Week 39 (1998)
RF interlock active
Less BLM alarms,
less 5 ms events,
less quenches

2001 start after 5 month shutdown (Lumi upgrade)
Clean Dump due to HF alarm
start after 5 month shutdown (Lumi upgrade)

All by 5 ms PS failure events
Statistic BLMp events 2004 - 2006

Quenches 2004-06:
9 x Injection/Kicker
11 x <4 BLM Alarm (local bumps)

Yellow: new 5 ms protection system, no quench
### Quenches 1994 - 2006

**Slow losses**  
**Very fast losses (< 5ms)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection</td>
<td>26%</td>
</tr>
<tr>
<td>ALZ</td>
<td>11%</td>
</tr>
<tr>
<td>RF</td>
<td>7%</td>
</tr>
<tr>
<td>5 ms events</td>
<td>17%</td>
</tr>
<tr>
<td>Diverse</td>
<td>8%</td>
</tr>
<tr>
<td>Kollimator</td>
<td>3%</td>
</tr>
<tr>
<td>Operating</td>
<td>3%</td>
</tr>
<tr>
<td>BLMs &lt;4</td>
<td>9%</td>
</tr>
<tr>
<td>Magnet PS</td>
<td>11%</td>
</tr>
<tr>
<td>Unknown</td>
<td>5%</td>
</tr>
</tbody>
</table>

**1994-2006**

<table>
<thead>
<tr>
<th>BLM-Alarms</th>
<th>Quenches</th>
</tr>
</thead>
<tbody>
<tr>
<td>1152</td>
<td>228</td>
</tr>
</tbody>
</table>

**False dumps: 29 = 2%**
Mainly due to electron losses

**More about failures:**
K. Wittenburg (DESY): Beam loss & machine protection
33rd ICFA ADVANCED BEAM DYNAMICS WORKSHOP on HIGH INTENSITY & HIGH BRIGHTNESS HADRON BEAMS Bensheim, Germany

**Note:** A quench in HERA is not a disaster! It takes typ. 1-2 h to recover from cryogenic...
Conclusions for HERAp

• Threshold of Quenches is about factor 5 below calculated critical beam loss (count) rate (response of BLM). All safety margins were eaten up.
  – Possible Reasons ???:
    • Simulations (no magnetic field) => not, Geant simul. agree with old simul.
    • Loss position inside Quadrupol
    • Inaccurate parameters in calculation
    • ...

• Quench probability depends on beam losses, not on weak magnets.
• Threshold of 4 BLMs is too weak, sometimes only 1 BML is affected.
• Very fast losses (< 5 ms) can occur.
Story (1):

Statement: In HERA each cold Quad has a BPM.
Instruction: Install a BLM close to each BPM to cover all cold Quads.
DONE

Events: Quenches of one magnet in the middle of the arc during ramp.
Observation: No orbit distortion, no beam losses.

?????

After a few days, some tries, some quenches:
Observation 2: The correction coils in this area showed higher values
Calculations: The correction coils drive a local closed bump.
WHY THE BPM and BLM DIDN’T SHOW ANYTHING????
Observation 3: There is no BPM (because there is a cold-box. No BPM foreseen)
Observation 4: Therefore there is no BLM (see above)
Analysis: The automatic Orbit correction makes the local bump by accident.

Consequence: Now we installed a BLM!

=> flexible system
Story (2):
Due to a **wrong cabling**, the alarms of 20 BLMs were subtracted and not added

Story (3):
Fieldbus-commands for other modules on the bus were interpreted by the Alarm Handler Electronic ALZ (Alarmzentrale)
=> changed threshold of required alarms from 4 to 30!
Alarm Zentrale failure:
Threshold went from 5 to 30
BLMs in HERAe
Already in 1993

Normally determined by scattering processes at the residual gas atoms in the beam pipe (positrons)

Reduced lifetime due to “dust” (electrons)
HERA $\text{e}^-$-Lifetime

- Sudden \textit{lifetime reduction} and lifetime recovery during electron operation
- At the same time \textit{increased beam loss} measured
- Theory: trapping of positive ionized dust particles by the negative charged electron beam
- If the \textit{number of bunches or current} is increased, the probability of dust trapping gets higher
Installation of 220 BLMs at HERAe to measure losses

Fig. 2: The directions of synchrotron radiation and losses

The backscattered SR in pipe is the dominating background source.
Fig. 1 (from Ref. 3): a) The copper inlay and b) the reduction of the background rates (actually it was measured with a lead inlay, but copper has the same effect!)
BLM rates during energy ramp

Fig. 3: Four different BLMs during ramping of HERAe. The upper and lower one are unchanged BLMs while the two in the center are equipped with a copper layer between the diodes as well as an additional lead layer between the BLMs and the beam pipe. The numbers below each picture is the count rate at maximum. The scale is logarithmic.
The Loss Mechanism
Electrons loose energy $\Delta E$ due to inelastic scattering (Bremsstrahlung) mainly on the nuclei of the residual gas molecules. The deviation of the electron orbit from the nominal orbit depends on the dispersion function in the accelerator and on $\Delta E$. The electrons may be lost at one of the next dispersion maxima (Fig. 1). Therefore these maxima are the most sensitive positions for measurements of beam losses (in HERAe: horizontal focusing quadrupoles in the arcs). The lifetime of a stored electron beam is normally limited by the average vacuum pressure in the beam pipe. Under special conditions, micro particles can be trapped by the electron beam, resulting in a decrease of lifetime and an increase of beam losses at these maximum [4].

Trajectory of Electrons after Energy Loss
The Monitor is sensitive for the previous FODO cell only
Path and cross section

The BLM is behind the Quad!
Shower distribution on vacuum chamber

Shower is shorter than the length of the Quadrupole
HERA electron losses in space and time
Figure 4: ZEUS e-gated background detector rates during a typical HERA electron run showing response to the passage of disrupting particles through the beam.

HERA operated with $e^+$ 1994-1997
Sudden breakdown of the beam lifetime due to dust ~1µm size dust particle above ~10mA beam current

Emitted by the integrated ion pumps, confirmed by experiments with BLMs

Replace all integrated ion pumps by NEG pumps in 1997/98
Story 4: Vacuum leakage detected by BLMs

Fixing of vacuum leakages at 16.Sept. 97
... and up she flies luminosity run at HERA

HERA II run ended in June 2007 😞 and the upgrade of the PETRA ring into the 3rd generation Light source PETRA III started immediately 😊
• 24 PIN-BLMs are now installed in PETRAIII near the undulators to protect them from radiation damage.
HERA today:
Open on a public day.

The future of HERA is unknown

Thanks for your interest in history
The End
87.541 mA  T = 211.5 h  Loss [%/h] 0.47
Avoiding Quenches, what to do: cont.

Some more proposals, not (yet) tested at DESY

• More sensitive thresholds on all BLMs
• Less than 4 BLM Alarms required to dump the beam =>
  might be more sensitive to malfunction of BLMs
  o add. dump criteria: Long losses at one location near threshold.
• Increase weight of BLMs at collimators and other aperture limits (e.g. dispersion)
• More reliable Alarm system
• Block injection in a not well prepared machine
• Better educated operation crew => will help in any case
Calibration at the proton collimators (second jaw) with small diode (7.3 mm^2)

Calibration at the proton collimators (first jaw) with small diode (7.3 mm^2)

Note: Gain of sensitivity by 200 when using large diodes (2 x 0.75 cm^2)
Ground motion at HERA

Figure 3. Frequency spectrum of the lost protons

Figure 4. Spectrum of the ground or magnet motion

The electron synchrotron DESY II presents a load to the mains that varies at 12.5 Hz. The mains variations penetrate through power supplies to the magnetic field in some magnets of HERA. The line around 16.5 Hz may have something to do with the frequency used by the German railway. These two lines are absent in the ground/magnet motion spectrum.

(K.H. Mess, EPAC 1994)
Specific Luminosity

- High specific luminosity with electrons for 2004/05 run:
  \[ L_s = 1.8 - 2.2 \times 10^{30} \text{ cm}^{-1} \cdot \text{s}^{-1} \cdot \text{mA}^{-2} \]

- Specific Luminosity is larger than the design value of
  \[ L_s = 1.84 \times 10^{30} \text{ cm}^{-1} \cdot \text{s}^{-1} \cdot \text{mA}^{-2} \]

- One reason for higher specific luminosity compared to last year with positrons (1.2 - 1.6 \times 10^{30}) is the smaller proton emittance and bunch length

- Calculated specific luminosity based on measured beam parameters can describe the measurements of H1 and ZEUS sufficiently good
Fig. 4: BLM count rates versus lifetime of the HERAe beam. The lifetime of the HERAe beam was adjusted by the amplitude of a local bump in the north or south region around the adjacent BLM, respectively.

Internal Note DESY MDI-99-02
Improvements of the HERA Electron Beam Loss Monitor System
by
Kay Wittenburg, DESY, MDI
Many thanks to

idente K. H. Mess (DESY)
idente M. Swars (retired)
idente K. Willmer (->)
idente S. Schlögl (->)
idente F. Ridoutt (DESY)
idente H. Schultz (DESY)
idente P. Duval, H. Wu (DESY)
idente a lot of DESY colleagues
Transient-recorder outputs from two "5 ms Quenches" in 1996:
Analog Output of a PIN Diode on the Main Collimator
Tolerable loss rates

- Match the BLM response to the cryogenic time constant. Tevatron => 16 ms (Ref. 6).

- Decisions: Measure loss rates in ≈ 5 ms intervals = alarm time binning.

- Definition: critical loss rate/5.2 ms = cont. loss rate · 5.2 · 10^{-3}

- Accepted loss rate ≤ 1/10 critical loss rate

- BLMs on superconducting Quads (+ warm Quads)