Future HERA High Luminosity Performance

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6336 m long
920 GeV protons
27.5 GeV electrons/positrons
HERA: Improvements 1999/2000

Beam currents: $e^+$ and $p$

Start luminosity

Efficiency

Average over month
Development of the Luminosity

Linear increase of the integrated Luminosity

The time for a luminosity upgrade of HERA has come

HERA Luminosity 1993-2000

Integrated Luminosity (1/pb)

Days after start of run
The Detector Region
Superconducting Magnet GO
Potential Problems

Focusing:
- Dynamic Aperture OK?
- Polarization OK?, Luminosity OK?
- Can HERA be handled well?

$f_{RF}$ increase:
- Polarization OK?, Luminosity OK?
- Too strong beam-beam force on p?
- Too strong beam-beam force on e?
Emittance and Lumi for 72° Optic

- The Luminosity was initially too small:

\[ L_s (60°) \]

\[ L_s (60°) \]

\[ L_s (72°) \]

\[ L_s (72°) \]

Bunch has no product distribution: \( \rho(x)\rho(y) \Rightarrow \text{coupling} \)

- Luminosity with 72° is large as expected
The kick where half the current is lost leads to a satisfactory dynamic aperture.
Polarization was in the spin matched 72° optic quickly brought to 63% (one day).

- Harmonic bumps were immediately effective
- Decoupling bumps worked well
6 more measurements indicate $f_{\text{Zentrum}} \approx 175Hz$

For the center frequency $f_{\text{Zentrum}} \approx 175Hz$, the luminosity is increased as expected.
Too Strong Beam-Beam Force on p?

$L_s$ is independent of e-current

$T_p$ depends on e-current

Tails depend on e-current
Too Strong Beam-Beam Force on e?

So far no reduction of $L_s$ by the bunch current.

No reduction of $L_s$ by the second experiment.

No reduction of $L_s$ by a larger b-funktionen.
Where are the Beam-Beam Limits?

Upgrade and Ip=140mA: emittance starts to grow
Lumi Reduction by Hourglass Effect

Length 19cm: \( \frac{L(\beta_{py} = 12.5\, cm)}{L_0} = 1.75 \)

12cm: \( \frac{L(\beta_{py} = 12.5\, cm)}{L_0} = 1.9 \)

Luminosity \( (10^{32}) \)

bunch length:
- 6cm
- 20cm
- 30cm

\( \beta_{py} \) (cm)
How will the tune shift parameters change and have these been analyzed by accelerator experiments?

<table>
<thead>
<tr>
<th></th>
<th>$\Delta \nu_{x0}$</th>
<th>$\Delta \nu_x(5)$</th>
<th>$\Delta \nu_{y0}$</th>
<th>$\Delta \nu_y(5)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial p</td>
<td>0.0016</td>
<td>0.00081</td>
<td>0.00044</td>
<td>0.00011</td>
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<tr>
<td>ultimate p</td>
<td>0.0022</td>
<td>0.00060</td>
<td>0.00059</td>
<td>0.00147</td>
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<td>studies p</td>
<td>0.0022</td>
<td>0.0017</td>
<td>0.00061</td>
<td>0.00080</td>
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<tr>
<td>initial e</td>
<td>0.024</td>
<td>0.024</td>
<td>0.045</td>
<td>0.044</td>
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<tr>
<td>ultimate e</td>
<td>0.034</td>
<td>0.036</td>
<td>0.069</td>
<td>0.070</td>
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<tr>
<td>studies e</td>
<td>0.041</td>
<td>0.041</td>
<td>0.085</td>
<td>0.083</td>
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</tbody>
</table>
Resonances with Bunch Length Effect

How will the resonance strength change and have these been analyzed by accelerator experiments?

All large resonance strength are due to the proton bunch length.
The performance goal of HERA is not unrealistic and should not be too hard to achieve.

A shortfall of beam intensity in the short term can be compensated.

<table>
<thead>
<tr>
<th>Energy–p/e</th>
<th>p</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emit. hor/vert</td>
<td>920 GeV</td>
<td>27.5 GeV</td>
</tr>
<tr>
<td>5/5π mm mrad</td>
<td>20/3.4 nm</td>
<td></td>
</tr>
<tr>
<td>β* at IP hor/vert</td>
<td>2.45/0.18 m</td>
<td>0.63/0.26 m</td>
</tr>
<tr>
<td>12/12 σ</td>
<td>20/20 σ</td>
<td></td>
</tr>
<tr>
<td>Aperture hor/vert</td>
<td>103·10^{11}</td>
<td>58 mA</td>
</tr>
<tr>
<td>p per bunch and e-cur.</td>
<td>0.0016/0.0004</td>
<td>0.034/0.051</td>
</tr>
<tr>
<td>Tune shift hor/vert</td>
<td>0.0017/0.0005</td>
<td>0.047/0.069</td>
</tr>
<tr>
<td>Bunch Length</td>
<td>191 mm</td>
<td>0.047/0.069</td>
</tr>
</tbody>
</table>

| Luminosity | 0.74 · 10^{32} cm^{-2}s^{-1} |

<table>
<thead>
<tr>
<th>p</th>
<th>e</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5/3.5π mm mrad</td>
<td>20/2.7 nm</td>
</tr>
<tr>
<td>1.7/0.125 m</td>
<td>0.42/0.17 m</td>
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<tr>
<td>10/10 σ</td>
<td>12/12 σ</td>
</tr>
<tr>
<td>0.0017/0.0005</td>
<td>0.047/0.069</td>
</tr>
</tbody>
</table>

| 1.3 · 10^{32} cm^{-2}s^{-1} |