PEP Run 5 Overview

U. Wienands
PEP-II Run Coordinator
Deputy AD Head for PEP Beams

In preparing this talk I have used slides and material from:
Outline

- Status at end of Run 4/beginning of Run 5
- Run 5a Performance
- Fall 2005 Improvements
- Run 5b performance
- Conclusion
At end of Run 4

- $L_{\text{peak}} = 9.21 \times 10^{33} / \text{cm}^2 / \text{s}$
- Delivered total 256/fb to BaBar
- $I_{\text{LER}} \leq 2600$ mA
- $I_{\text{HER}} \leq 1600$ mA
- Main limitation from the NEG outgassing in IR 2
- Beam currents also close to rf limit
Fall 2004 Downtime Improvements

- LER IR 2 NEG & collimator removal
- LER Rf 4-2
- HER Rf 12-1 split in two
  - 12-1 and 12-2, 2 cav’s ea.
- LER LFB kickers
- LER TFB kicker electrodes & data acquisition
- New LGD Woofers, both rings
- HER bellows fans deployed
- 2 Injection pulsers/ring
- LER X-ray monitor
- LER BBA system
- BIC IOC
  - address stalls & crashes

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18-Jan-06
Run 5a

- Run 5a began on April 16, 2005
  - Completion of PEP Restart Validation Review
  - Delay in LER startup due to leak in e\textsuperscript{+} source
    - Used extra HER time for scrubbing & tuning of rf, feedbacks & vac. fixes
- Site-wide Power Outage in May (2 days)
- Heating of and damage to Beam Position Monitor electrodes (catastrophic vacuum leak) (Mid June)
- 2 Klystron failures (4-3 coll. damage, 12-6 vacuum)
- Numerous rf HVPS issues esp. with EUPEC SCRs
- HER Background due to NEG outgassing
  - QF5L chamber NEG is the culprit
- LER Y Transverse f/b Feedthrough Heating, instability
- Partial Short on an LER Magnet
- Transient Decay of Luminosity
- Cooling of rf-cavity spools
Severed Power Line

Power line loose cables

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On June 18, 2005 we incurred a catastrophic leak in the LER at BPM PR02 1162.

This happened a week after we raised the LER rf voltage to 5.4 MV.
Fallen Button (PR02-1152)

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BPM Feedthrough (Destroyed)

- Altogether 4 buttons fell off
  - 3 in or near IR 2, one in Arc 11
BPM Heating Estimate

- Curves based on present knowledge & measurements
- Operationally, we lowered the LER Rf voltage
  - reduce heating for same beam current

Relative Power vs. bunch current for 1740 bunches
This transient went away within a few weeks after the partially shorted quad got fixed.
QFW1 short

- During the shutdown, QFW1 developed a partial short
- The closeness to the wiggler, the shorting during a downtime and the subtle optical effect made detection difficult, even though we suspected a problem in this area.
- It revealed itself when the short became intermittent leading to orbit changes on Aug. 6.
Signature of QFW1 Short

Phasediff 05-04

after quad fix
# Run 5a MD

## PEP Run 5a MD & parasitic expt. List

<table>
<thead>
<tr>
<th>Date</th>
<th>MD</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>7-Apr-05</td>
<td>HER ORM, &quot;Design config&quot;</td>
<td>data taken 2x, design config. did not work results largely as expected, already some indication of Xing angle</td>
</tr>
<tr>
<td>11-May-05</td>
<td>Charact., tunes, obstruct. scan, long-range rf phase</td>
<td>some gain in spec. Lumi (5%?).</td>
</tr>
<tr>
<td>9-Jun-05</td>
<td>LER 4-rf running at 5.3 MV, bunch length</td>
<td>BPM buttons fell off, getting too hot.</td>
</tr>
<tr>
<td>15-Jun-05</td>
<td>Characterization, MIA, LER ORM</td>
<td>Abort gap shortened to 0.9 % strong droop in lumi</td>
</tr>
<tr>
<td>19-Jun-05</td>
<td>LER back to 3-rf at 4.05 MV, bunch length</td>
<td>LER X seems to be growing</td>
</tr>
<tr>
<td>1-Jul-05</td>
<td>Steer LER flat Arcs 7, 9, 11</td>
<td>trains of 30 better</td>
</tr>
<tr>
<td>6-Jul-05</td>
<td>BPM heating, Abort gap, rf 4-1</td>
<td>LER X seems to grow</td>
</tr>
<tr>
<td>8-Jul-05</td>
<td>Trains of 120</td>
<td>Done, all on now</td>
</tr>
<tr>
<td>9-Jul-05</td>
<td>Transient variation with HER, LER beam current</td>
<td>Used QFCX1 tweaks, not MIA, to fix $\beta$, left in Lsp. about 3 at high I</td>
</tr>
<tr>
<td>10-Jul-05</td>
<td>trains of 30, tune along train, vary 1 ring current</td>
<td>Growth not prop. to I</td>
</tr>
<tr>
<td>12-Jul-05</td>
<td>Characterization, LER IR orbit tests (MIA)</td>
<td>good model!</td>
</tr>
<tr>
<td>22-Jul-05</td>
<td>LER tune vs current</td>
<td>baseline for Klys linearizer test</td>
</tr>
<tr>
<td>31-Jul-05</td>
<td>L2 solenoids on</td>
<td>test uncovered some issues</td>
</tr>
<tr>
<td>2-Aug-05</td>
<td>Steer LER IR flat, use MIA to correct $\beta$</td>
<td>high bunch current, medium total; all LER BBA shunts done</td>
</tr>
<tr>
<td>8-Aug-05</td>
<td>HER Q5 NEG test, Characterization</td>
<td>3 A in the LER!!</td>
</tr>
</tbody>
</table>
Other Machine Tuning

- LER IR orbit excursions reduced by several mm (JLT)
  - reduce max. BPM button temperature
  - LER $\beta_x$ beat caused by IR steering successfully fixed using sextupole bumps (GY et al., $\Rightarrow$ Optics talk)

- LER dispersion tuning critical ingredient to reaching $10^{34}$/cm$^2$/s luminosity
  - model calculations (YC) and implementation of selected combinations (FJD)

- Highest luminosity reached with 1722 bunches and record beam currents
Run 5a Luminosity
• Run 5a also saw $10^{34}$/cm$^2$/s luminosity in PEP!!

PEP-II Luminosity and Currents

10/10/2005 00:01:04 The Quest for $1.0e34$/cm$^2$s
### Peak Luminosity

\[ 10.025 \times 10^{33} \text{ cm}^{-2}\text{sec}^{-1} \]

Oct 9, 2005

1732 bunches  2940 mA LER  1740 mA HER

#### Integration records of delivered luminosity

<table>
<thead>
<tr>
<th>Category</th>
<th>Value</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Best shift (8 hrs, 0:00, 08:00, 16:00)</td>
<td>247.2 pb(^{-1})</td>
<td>Oct 7, 2005</td>
</tr>
<tr>
<td>Best 3 shifts in a row</td>
<td>727.8 pb(^{-1})</td>
<td>Oct 7, 2005</td>
</tr>
<tr>
<td>Best day</td>
<td>710.5 pb(^{-1})</td>
<td>May 24, 2004</td>
</tr>
<tr>
<td>Best 7 days (0:00 to 0:00)</td>
<td>4.464 fb(^{-1})</td>
<td>Jul 25-Jul 31, 2004</td>
</tr>
<tr>
<td>Best week (Sun 0:00 to Sat 24:00)</td>
<td>4.464 fb(^{-1})</td>
<td>Jul 25-Jul 31, 2004</td>
</tr>
<tr>
<td>Peak HER current</td>
<td>1745 mA</td>
<td>Oct 10, 2005</td>
</tr>
<tr>
<td>Peak LER current</td>
<td>2995 mA</td>
<td>Oct 10, 2005</td>
</tr>
<tr>
<td>Best 30 days</td>
<td>16.720 fb(^{-1})</td>
<td>Jul 2 – Jul 31, 2004</td>
</tr>
<tr>
<td>Best month</td>
<td>17.036 fb(^{-1})</td>
<td>July 2004</td>
</tr>
</tbody>
</table>

**Total delivered**: 315 fb\(^{-1}\)
PEP-II Daily Average/Month

PEP-II Daily Average for each Month

Last Updated:
1/13/2006 10:31

M. Sullivan
PEP-II Run 5  Delivered Luminosity in 2005-2006

Last updated:
1/15/2006 12:36

fb^-1

Jan-05  Feb-05  Mar-05  Apr-05  May-05  Jun-05  Jul-05  Aug-05  Sep-05  Oct-05  Nov-05  Dec-05  Jan-06  Feb-06  Mar-06  Apr-06  May-06  Jun-06  Jul-06

72.66
Run 5a average Length of Fill

Average Length of Fill, Run 5a

T_fill (h)

Time since 15-Apr-05, 00:00 (days)

30-fill moving average

Time since 1-Sep-04, 00:00 (days)
2005 Downtime Improvements

• 5 weeks beginning Oct. 10.
  – downtime driven by LCLS & PPS jobs.

• Replaced HER QF5L Vacuum Chamber
  – “Test BPMs” w/o buttons.

• Installed new Collimator in LER at ≈+25 m

• Replaced HER “DS7” Vacuum Transition Chamber

• Removed several LER downstream NEGs
  – Temperatures reach 1000°F

• Replaced 1 NEG in HER Lumi chamber w/ HOM absorb.

• X-Y BPM electronics upgrade, PR08
Downtime Improvements (cont’d)

- New LER Kicker HOM Feedthroughs
- Inspected all LER magnets for shorts or “almost-shorts”
- Installed new SLAC BFK klystron in the HER Rf 12-6
  - present tube has deformed collector & will become spare until determination whether to fix.
- Installed new Comb filters (low-level Rf)
- Install LER “abort spoiler”
  - exit window for LER at risk at much higher current
- Install test BPMs to try solutions for the BPM-heating issue
  - no button, small button, small button w/ guard ring, shorted button
  - => S.Ecklund talk
IR 2 Vacuum Improvements 2005

Q2 SEPTUM
LER Q4
LER Q5
SUPPORT TUBE BELLOWS
IP
X+
Z+
FRANGIBLE LINK
BPM
LER NEG
QF5L chamber
Collimator
Lum. chamber
STRUCTURE ON IR RADIUS
FORWARD (HEB DIRECT.) ↔ BACKWARD (LEB DIRECT.)
QF5L Chamber Installation
Abort Spoiler IR 8

U. Wienands, SLAC-PEP-II PEP MAC Review 18-Jan-06
Run 5b

- PEP beams resumed on Nov. 15.
- Initial vacuum scrubbing proceeded normally
- But the “Fast LER transverse instability” quickly became a major issue
  - already seen in Run 5a, but much lower threshold now
- Instability & aborts from vacuum spikes in IR-2 “backward side” were seen
- HER $\beta_x$ beat is much larger than in Run 5a
  - and $\beta_x^*$ is much smaller as a consequence.
Fast LER Instability

- A fast (>10/ms), vertical instability with limited amplitude of coherent signal
  - Growth rate beyond capability of TFB
  - Already seen in Run 5a

- Onset of beam loss while coherent signal is damping

- Low lying modes (<20) and all bunches participating

- Observation of $2\nu_s$ line in spectrum

- Details in separate talks
Fast LER Instability (cont’d)

- The origin was located by Sasha to be near Rf 4-2
  - Vacuum activity concurrent with this type of abort
  - Confirmed by signal in the wideband diode monitors of the rf system (D. Teytelman)
- The threshold depends on total beam current
  - Varies between 1400 and 2600 mA.
- Observed in collision and single ring
- First observance during Run 5a
  - Some believe already seen in Run 4 but not confirmed
- Now believed to be activity in vacuum system between cavities 4-2A and 4-2B
IR-2 instability

- Transverse instability of both beams accompanied by vacuum activity in IR 2 near the BaBar forward side
  - VGCC 3027, VP3027, VGCC 2187
- Beam tripped by radiation in BaBar
  - LER-sensitive monitor only
- Threshold sensitive to bunch current
- Either beam can trigger it, although the details vary
- First observed around Nov. 9
**Spectrogram LER x**

X-plane, Spectrogram 1:1 4764 turns, 23:1:23 bunches [256 n FFT, 250 overlap]
How to Proceed

• Our investigations have exhausted options without access
  – => going in on Tuesday (yesterday)
  – Boroscope IR 2 forward side
  – Boroscope IR 4
  – If nothing found in IR 2 forward, boroscope IR 2 backward side

• Prime suspects are the Q1/Q2 bellows in IR 2, the bellows between the two 4-2 cavities.
Instability Update

- A possible cause has been identified in IR 4 & is being addressed
- We are still investigating the IR 2 vacuum system
- Details in other talks…
The HER in Run 5b shows a large $\beta$ beat in $x$.

MIA & other methods don’t identify one specific source.

MIA knob being built

Not addressed yet because of the instabilities.
BaBar Beam Sizes

- BaBar is producing a wealth of other info
  - => separate talks
The instabilities have limited luminosity
Run 5b has delivered \( \approx 17.5/fb \) to BaBar
Run 5 total delivery \( \approx 73/fb \)
# Run 5b MD Items

## PEP Run 5b MD & parasitic expt. List

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<thead>
<tr>
<th>Date</th>
<th>MD</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>23-Nov-05</td>
<td>Characterization, BaBar background</td>
<td>HER βx beat large wants to be ≈ -1mr (HER) comp. to Run 5a no effect on instability</td>
</tr>
<tr>
<td>30-Nov-05</td>
<td>Vertical IP angle scan</td>
<td>no effect on fast LER instability</td>
</tr>
<tr>
<td>7-Dec-05</td>
<td>Change LER y tune, y chromaticity</td>
<td>chroma may have slight effect, else no change in instability</td>
</tr>
<tr>
<td></td>
<td>Turn off one ea. LER rf station in turn</td>
<td></td>
</tr>
<tr>
<td>8-Dec-05</td>
<td>Changed LER X chroma, tunes, Lowered LCW temp.</td>
<td></td>
</tr>
<tr>
<td>9-Dec-05</td>
<td>Study fast LER instab. at high I</td>
<td><strong>Maybe less aborts?</strong> less aborts?</td>
</tr>
<tr>
<td></td>
<td>Lowered Vrf to 4.05 MV, installed GProto</td>
<td>no effect on fast LER instability, backed out after 4hrs</td>
</tr>
<tr>
<td>15-Dec-05</td>
<td>Lowered LER IP X angle by -400 μr</td>
<td></td>
</tr>
<tr>
<td>16-Dec-05</td>
<td>Lowered LER rf LCW 95-&gt;90 °F</td>
<td></td>
</tr>
<tr>
<td>17-Dec-05</td>
<td>Switched BPM for Gproto, parked 4-5</td>
<td></td>
</tr>
<tr>
<td>18-Dec-05</td>
<td>Single-Ring LER test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single Ring HER test</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HER Y tune low test</td>
<td></td>
</tr>
<tr>
<td>20-Dec-05</td>
<td>HER LBNL Delay line install</td>
<td></td>
</tr>
<tr>
<td>4-Jan-06</td>
<td>IP Y angle changes, turn off some ion pumps</td>
<td></td>
</tr>
<tr>
<td>5-Jan-06</td>
<td>Brief single ring studies</td>
<td></td>
</tr>
<tr>
<td>6-Jan-06</td>
<td>Revert TFb delay lines to 9-Oct. system</td>
<td></td>
</tr>
<tr>
<td>7-Jan-06</td>
<td>Single LER &amp; collision @ raised SVTRAD threshold</td>
<td></td>
</tr>
<tr>
<td>8-Jan-06</td>
<td>Single HER MD</td>
<td></td>
</tr>
<tr>
<td>11-Jan-06</td>
<td>Collimators out, longer ion gap</td>
<td></td>
</tr>
<tr>
<td>12-Jan-06</td>
<td>Try to cause vacuum bursts with unstable beams</td>
<td></td>
</tr>
<tr>
<td>13-Jan-06</td>
<td>Heating NEG in QF2R, QF5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rf 4-2 abort-optical test</td>
<td></td>
</tr>
<tr>
<td>16-Jan-06</td>
<td>Characterization</td>
<td></td>
</tr>
</tbody>
</table>
PEP-II Run 5 Time Accounting

M. Stanek

Run 5a
18-Apr-2005 through 10-Oct-2005

Run 5b
21-Nov-2005 through 11-Jan-2005

Legend:
- BaBar
- PEP Mach. Dev.
- Tuning
- Unsched. Down
- Sched. Off

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18-Jan-06
Run 5 Time Accounting by Week

Color coding same as in pie charts

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PEP MAC Review
18-Jan-06
Looking Forward: Summer 2006

- More IR-2 chamber improvements
  - QF2R; LER QD4R,L & QF5R,L; HER QD4R,L & QF5R
- Upgrade LER Arc BPM buttons
- Install additional klystron in HER
  - (∼200 mA more beam current)
- Remaining X-Y BPM upgrades
- Klystron Linearizers
- Low-alpha HER lattice upgrade.
- Fast Dither (100 Hz) luminosity feedback upgrade
  - magnets installed, early 2006 commissioning
Conclusion

• Run 5 has been a challenge
  – Initially a slow start but eventually reached $10^{34}$ and broke most Run 4 performance records in Run 5a.
  – Run 5b just as challenging

• The BPM issue has been a serious speed bump in our road towards 2E34
  – We believe we have a plan for success.

• We are making progress on the instability issues…

• We remain optimistic that we can reach our performance goals.
PEP-II Integrated Luminosity

∫\text{Ldt}