PEP-II Vacuum Issues over the last year

Stan Ecklund for PEP-II team
DOE Operations Review
April 26-27, 2006
Overview of Vacuum Events

- IR2 Q1/Q2 Absorber Bellows
  - Cracked SiC-AlN ceramic absorber
  - Faulty RF seal design corrected Mar. 2006

- Gap Ring in IR4, near LER RF Cavities
  - Dec 2005
  - Identified and repaired in a few weeks

- NEG
  - Ongoing since 2003
  - RF screen leakage heats NEG material, releasing H₂
  - Removed NEG material in weak screens, New chambers

- BPM feed-thru
  - June 2005
  - Heating due to 7 GHz button resonance and HOM heating
  - Limit Beam Parameters: $\sigma_z$, position, bunch current
  - Smaller buttons Aug. 2006

- Various leaks
Luminosity April 2005 - 2006

Corrected Luminosity
$10^{30}/cm^2s$ or $/ub/s$

- BPM feed-thru
- IR2 Q1/Q2 Bellows
- IR4 Gap Rings

Interval: 180
Mean: 3258.4
Sigma: 3016.5
Last data point: 18-Apr-2006 08:47:44

April 26-27, 2006
PEP-II DOE Operations Review - Vacuum Issues
LER and HER Current
Q1/Q2 Absorber Bellows

• Started Dec 2005
• Observations
  – Short (few second) spikes of vacuum pressure near IP
  – Background spikes on LER sensitive monitors
  – Dip in Luminosity
  – Sometimes correlated with beam blow-up and motion.
  – BaBar Radiation aborts beam if spike large
  – Threshold on LER current, with some dependence on HER
  – Spatial profile and time points to ~ 3 m from IP, incoming LER
  – RGA indicates M=14,28 spikes
  – Single LER beam can cause events at higher threshold
  – More bunches results in higher threshold (total current)
Interaction Region Layout

- 8020 pump
- 3044 pump
- 4042 gauge
- LER frangible link
- 2187 gauge
- 7039 gauge
- 7043 pump
- Detector
- SIG 10 HER sensitive
- SIG 11 LER sensitive
- Support tube end bellows
- Backward Q2 NEG
- Forward Q2 NEG

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Resources to Diagnose IR2 Vacuum Spikes

- **Help from many groups:**
  - PEP-II, BaBar, Material Science Group, Klystron Dept., High Power RF Group, Vacuum Dept., Pulsed Kicker Group, and LBNL

- Vacuum pump, gauge logging at 1 Hz using EPICs Archiver and Strip charts.
  - Z location from amplitude of spike
- Abort Transient Logger at 1 KHz
  - Time and vacuum model give Z location
- RGA spectra
  - Type of gas released
  - Not an air leak
- He leak check lines
  - Looked for external leaks during spike events
- Controlled Leak valve and NEG heating calibrate gauge response
- Video of synchrotron monitor beam sizes
- Bore Scope of inside chamber,
  - Identifies protruding RF fingers
  - Probed for loose tiles
- Looked for Temperature dependence of bellows, NEG
- Excited beam motion trying to induce vacuum event
- Vacuum model to understand time dependence and predict source
Most Difficult Vacuum Problem

• IR4 problem started at same time as in IR2
• Transient, somewhat random behavior
• Location techniques good to about 1 m
• Both beams present in this area
• HOM from both beams affect larger area
• Required opening detector to access
• This vacuum problem was the most subtle and hard to diagnose problem PEP-II has had.
• We solved it in a timely way over two months with a strong team
More or less typical event

Data from March 6th
Typical event from Feb 5th

Pressure values are in nTorr

LER frangible link

Forward Q2 NEG

Support tube end bellows

Backward Q2 NEG

Detector

0.08

2.25

1364

993

LER frangible link

122

Neg pump

Forward (HEB DIRECT) ← → Backward (LEB DIRECT)
Average of 8 events normalized to 2187 gauge

Diagram showing:
- LER
- HER
- Detector
- Forward Q2 NEG
- Support tube end bellows
- Backward Q2 NEG
- LER frangible link
- NEG pump

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Data from February 4th
LER current when we had a vacuum spike

Average of abort threshold
Heating NEG as a gas source

- Forward Q2 produces profile similar to spike events
Abort Logger – Luminosity Signal
Abort Logger – Vacuum signals

![Vacuum signal graph]

VCC3027
VP8020
VCC2187
VGH7039

Log (Torr)

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SVT Background Signals

LER sensitive monitors (FE,BE) larger than HER sensitive (FW,BW)
RGA Scan Sustained Event (Jan)

Gases of note:
N, N₂, some Ar, possibly CO₂

U. Wienands,
SLAC-PEP-II
Mtg 7-Mar-06
Correlations in Pressure Data

Compare measurements from 50 vacuum aborts to see how consistent the different aborts are:

- **Peak Pressure**
  - Linear correlation indicates a single source location of pressure burst with varying pressure intensity

- **Peak Time**
  - Δt = 644 ms, RMS = 42 ms

Brian Petersen
Summary

Vacuum data has been analyzed in several different ways. Analyses are within 1m of each other:

- Fit Shape, HN: $2.9 \pm 0.6$ m
- Leading Edge, HN, MK: $2.1 \pm 0.8$ m
- Leading Edge, HN, AC: $1.8 \pm 0.7$ m
- Diode Analysis, BP: $2.6 \pm 0.3$ m
- "Average": $2.3$ m

Best guess: source is in Q1/Q2 bellows

Brian Petersen
Bore Scope shows some fingers not fully engaged on the backward side (bent out into the beam aperture)
Q1/Q2R Bellows before installation (SM)
Down Work

- **Jan 17-23**
  - Bore Scope all suspect chambers
  - Removed pump chamber and absorber.
  - Installed controlled leak
  - Installed He leak check lines
- **Feb 22-26**
  - Replaced LER incoming Q4R chamber
  - Moved RGA closer to suspect area
  - Moved controlled leak closer
  - Bore Scope again
- **March 22- April 1**
  - Removed backward Q1/Q2 bellows and installed it in the forward position
  - Removed suspect forward Q1/Q2 bellows
  - Replaced forward Q2R chamber with new unit having improved design
  - Installed previous version(1) of Q1/Q2 bellows into backward position
    - 2 rows of tiles instead of 4
  - Installed new Improved RF seals in the forward and backward position
    - The solution
Removed forward Q1/Q2 bellows section
Close up of damage to the tiles
Another close up
RF seal – note the bolt head

RF finger seen in borescope videos
Cu posts not brazed to the tile
Q1/Q2 Bellows RF Seal

Old

New
New RF seal – Compound J seal
New Q2 Chamber
IR4 Vacuum Gap Ring Problem

Vacuum spike area

RF seal installation procedure problem
NEG Heating

• LER
  – Some (type C) IR2 LER NEG pumps became hot and outgassed H2
  – LER type C NEG’s removed 2004, 2005
  – New Q4 and Q5 chambers with improved screens 2006

• HER
  – Q5L NEG out-gassed H₂ above 1500 ma
    • Chamber replaced 2005
  – Forward Q5R chamber
    • Starting to show out-gassing
    • will be replaced 2006
  – Some similar screens in upstream chambers
    • BLF, B3 ( E type )
    • Not causing a problem yet
Screen Types

• A: Diam 0.125 holes x 0.125 deep on 0.167 centers
• B: Windows in side of chamber with welded in, 0.040" thk screens containing 0.118" square holes
• C: 8 through slots with welded in 0.020" thk screens containing 0.118" wide transverse slots [Q5L ]
• D: 6 full length slots 0.145" wide x 1/4" deep and through holes within slots diam 1/4" x 1/4" deep
• E: 14 through slots with welded in 0.020" thk screens containing 0.118" wide transverse slots [BLF …]
• F: Windows in bottom of chamber with welded in, 0.080 thk screens containing 0.118 square holes [Lumi ]
• W: Wiggler, screen in horiz plane +-x, 0.118 square holes, 0.088 x 0.118 at edge, 0.030 thick Cu
Background (BW) correlates with Pressure (VP7043 Lumi Pump)
Pressure vs. Current
Before and After New Q5L Chamber

Before

\[ A = MB60::DCCT:SUMY 1440 \text{ pts} \]
Linear corr. coeff. \((r) = 0.5995737\)
2-sided Signif. of \(r = 0.000000\)
Time Range: 26-JUL-2005 00:00:00 - 2-AUG-2005 00:00:00.

After

\[ A = MB60::DCCT:SUMY 1441 \text{ pts} \]
Linear corr. coeff. \((r) = 0.8975757\)
2-sided Signif. of \(r = 0.000000\)
Time Range: 14-APR-2006 00:00:00 - 21-APR-2006 00:00:00.

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Q5R NEG Pressure and Backgrounds vs. Current. New chamber ready to install (2006)

HISTORY CORRELATION

$B = A + 2.525 \log [LATA \times P \times 0.26]$

4404 points

$A = MB50:DCCT:SUMY$ 1440 points

Linear corr. coeff. $(r) = 0.5384862$

2-sided signif. of $r = 0.000000$


20-APR-06 17:04:36

HISTORY CORRELATION

$B = A + 2.525 \log [LATA \times P \times 0.26]$

4404 points

$A = MB50:DCCT:SUMY$ 1440 points

Linear corr. coeff. $(r) = 0.5437250$

2-sided signif. of $r = 0.000000$


20-APR-06 17:08:26

April 26-27, 2006

PEP-II DOE Operations Review - Vacuum Issues
LER BPM Vacuum Feed - Thru Issues

- BPM failure under high Power conditions in June 2005
  - Lost 5 buttons in IR2 outgoing LER
    - At 5.4 MV LER RF gap Voltage (6/9 – 6/19) and
    - I=2400 ma and
    - 1445 bunches
    - Large orbit excursions (10 mm)
  - Dirty vacuum vent due to failed feed-thru
    - Slow vacuum recovery over months

- Steps to ameliorate
  - Understand beam dependence including bunch length.
  - Lab. measurements
  - Beam test of new button designs.

- Future running
  - To Aug 2006
    - Reduced gap voltage 4.5 MV
    - Currents up to 3300 ma
    - More bunches 1720
  - After 2006 down, new buttons in LER ARC, pull IR2 buttons.
LER Beam Current and RF Voltage History

LER Current (mA)

LER Total RF Voltage

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LER IR2 chamber Cu (HER) Button Geometry
LER BPM

• Straight BPM has $R = 44.45$ mm vs. 31 for LER ARC and IR2
• Expect Straight BPM to have $\frac{1}{2}$ the power of LER ARC and IR2 BPM’s
June 2005 Event

- Thermocouple T1162QUA indicates R btn falls 14 June
- beam orbit at (5,-2)
- 2022 heats up when 1162 falls due to HOM
- Ran with fallen button till vacuum leak
Vacuum leak at BPM

- PR02 1162
  - LER outgoing
  - In HER arc-type duct
    - Hexagonal Cu

- Burned Cable
  - Lower aisle side
  - Vac leak through center of coax
Understanding BPM absorbed Power – Assumptions

• $dT \sim \text{Power} \sim \sum i_b^2 f(\sigma_z) g(x,y)$
  $= N_b i_b^2 f(\sigma_z) g(x,y)$

• Assume power absorbed at one frequency (7 GHz)
  $f(\sigma_z) = \exp(- (\omega_r \sigma_z/c)^2) / \exp(- (\omega_r \sigma_0/c)^2)$

• Bunch lengthening and scale with $V_{rf}^{-1/2}$
  $\sigma_z = \sqrt{V_0/V_{rf}} (\sigma_0 + \sigma_i i_b)$
  $f(\sigma_z) = \exp(-\omega_r^2 (V_0/V_{rf}) ((\sigma_0 + \sigma_i i_b)/c)^2) / \exp(- (\omega_r \sigma_0/c)^2)$

• Position dependence from calculated signal
  $g(x,y) \sim \text{signal}^2$
LER Bunch Lengthening with current (from Sasha Novokhatski)

\[(\sigma_0 + \sigma_i i_b)\]
\[ f(\sigma_z) \]
\[ N_b i_b^2 f(\sigma_z) \]
Position Dependence
\[ g(x,y) \]
from (Steve Smith)

HER Arc Chamber Power Ratio vs. Position
Normalized to Centered Beam
(for beam within 20 mm of duct center)

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PEP-II DOE Operations Review - Vacuum Issues 51
### Parameters where BPM buttons fell off

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<tr>
<th>Date</th>
<th>Micr</th>
<th>BPM unit</th>
<th>Button</th>
<th>LER I</th>
<th>Nb</th>
<th>ib</th>
<th>Vrf</th>
<th>x</th>
<th>y</th>
<th>g= geom. power factor</th>
<th>T fall</th>
<th>T ok</th>
<th>T amb</th>
<th>dT fall</th>
<th>Sum ib^2</th>
<th>f= relative bunch shape Power</th>
<th>relative P= sum(b^2) *f'g</th>
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LER Test New BPM Buttons

• Installed 3 new (modified) buttons in LER during October 2005 down
  – Short on 15 mm button
  – 7 mm no insert
  – 7 mm with insert
  – Feed-through, no button
  – Compare with normal 15 mm button

• Measured
  – Temperature Rise at collar
  – Power out cable to Filter-Isolator (FIB) Load Resistor
Test Button Results at I = 2.2 A
7 mm button with insert is winner

<table>
<thead>
<tr>
<th>Unit</th>
<th>FIB dT (F)</th>
<th>FIB Power = dT/1.3</th>
<th>Button collar dT (F)</th>
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<td>BPM 1022 15 mm shorted</td>
<td>76</td>
<td>58</td>
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<td>BPM 1032 15 mm Normal</td>
<td>35</td>
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<td>BPM 1052 7 mm without insert</td>
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<td>BPM 1092 7 mm with insert</td>
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<td>13</td>
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<tr>
<td>BPM 2152 feed-thrus only</td>
<td>?</td>
<td>?</td>
<td>2 to 3</td>
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BPM Button Heating - Summary

• No clear threshold for all buttons to fall
• Have a formula, but
  – HOM’s are a complication not included
  – Assumes f=7 GHz absorption in 15 mm button
• Monitoring BPM signals for a fallen button
• Monitoring thermocouples in IR2 incoming LER
• Stay below parameters of June failure till buttons are improved in 2006 down.
• Run 5B
  – Limit Current to 3.3 A
  – Limit LER RF V to 4.5 MV
  – Limit Orbit offset to 3 mm
  – Watch TC and raw signal for change
• Run 6
  – LER ARC – Install new 7 mm buttons
    • Expect smaller 7 mm buttons to receive ¼ Power
    • Button resonance 2 x higher
  – IR2 Straight - bare feed-through
  – LER Straight should be OK with ½ power in larger chamber
Vacuum Summary

• We have encountered some difficult vacuum problems
• Which we diagnosed the effectively
• Involving expert help.
• We built improved components to install in a timely manner
• Have new components coming for Aug. 2006 downtime
• Plan to operate efficiently and safely at increased luminosity and beam currents.
Extra Slides
Pump down after dirty vents

- Slow months time scale for recovery
- Outgoing beam-line more tolerant than ingoing!
Lab Test - BPM Heating Experiment

- Power applied to button with 25 ohm, 25 W resistor as a heater.
- Measured current and voltage.
- Thermocouples (6) measured:
  - Heater resistor
  - Button (2)
  - BPM collar (normal QUA location)
  - BPM cable (new RGBY tc) or center pin of connector
  - Cu Chamber about 1 inch from BPM
Lab Test - Run 3 Data
Lab Test - Run 3 Results

- Button dT / Collar dT = 15 to 18
- Button dT/Power = 9 to 14 deg C / Watt
- T vs. Power not linear
  - Convective cooling
  - Radiative cooling

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<th>T_btn1</th>
<th>T_btn2</th>
<th>T_clr</th>
<th>T_cbl</th>
<th>T_Cu</th>
<th>Power</th>
<th>dT_Cu</th>
<th>clr_Cu</th>
<th>dT_cbl-Cu</th>
<th>dT_btn-Cu</th>
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<th>dT_btn/Power</th>
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