SVTRAD Tasks

Tasks for the SVTRAD system:

- Protect the SVT against radiation bursts
- Measure instantaneous and integrated radiation doses
- Enforce long term SVT radiation budget
- Provide feedback for PEP-II operators on radiation levels

Requirements:

- Be able to abort beam in <1 ms
- Measure dose rates from 1 mrad/s to 1 krad/s
- Report dose rates at ~1 Hz
- Measure integrated radiation dose with 10% precision
SVTRAD Overview

- Silicon PIN-diode
- SVTRAD board
- PEP-II beam abort system
- Radiation signals
- Beam dump signals
- BaBar Detector Control system
- Shift crew and log files
- Control and monitoring
SVTRAD PIN-diodes

Radiation Sensors:
- Reverse biased (50 V) Si PIN-diodes
- Twelve 1cm x 1cm x 300µm diodes
- Ionizing rad. produces e-h pairs
- Charge proportional to dose
  - $1\ \text{nC} = 5.2\ \text{mrad}$

Leakage Currents:
- Diodes have large leakage currents
  - Signal currents: 1-10 nA
  - Leakage currents: 0.3-3 µA
  - Increases with dose (2nA per krad)
  - Temp. dependent (10% per °C)
  - Needs to be carefully tracked
Diamond Sensors

- Diodes will be replaced in 2005
- Plan to replace with diamonds
  - Signals similar to PIN-diodes
  - Do not have leakage current
- Two diamonds installed in 2002
  - Wanted to gain experience

- Diamond signals are available
- Signals have very low noise
- Will be included in abort system some time in run 4
SVTRAD Electronics

- Have four 6U VME boards which handles three diodes each
- Responsible for issuing fast beam dumps (1ms-1s timescale)
- Makes precision measurements of current through diodes

Only MID diodes used to evaluate abort decisions
Path through abort circuit degrades signal by factor ~100

Electronics to be upgraded end of 2003 - see Maartens talk
SVTRAD Software

- SVTRAD boards are controlled via EPICS system
- Sets thresholds and calibrates the SVTRAD boards
- Reports when a fast abort has occurred
- Reads out and displays dose rates
- Archives dose rates and integrated doses

Operator Display:

<table>
<thead>
<tr>
<th></th>
<th>Rate (mR/s)</th>
<th>Alm</th>
<th>Trp</th>
</tr>
</thead>
<tbody>
<tr>
<td>FW - Top</td>
<td>0.45</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FW - Mid</td>
<td>6.27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FW - Btm</td>
<td>3.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE - Top</td>
<td>3.57</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE - Mid</td>
<td>27.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FE - Btm</td>
<td>3.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW - Top</td>
<td>3.96</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW - Mid</td>
<td>10.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW - Btm</td>
<td>1.64</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE - Top</td>
<td>0.48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE - Mid</td>
<td>-6.04</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE - Btm</td>
<td>0.84</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BW - Diam</td>
<td>1.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BE - Diam</td>
<td>-4.39</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Stripcharts of dose rate history:
Calibrations

- Need to know diode leakage current to estimate radiation signal
- Measured during periods with no beam (e.g. no radiation)
- Changes with temperature and integrated radiation dose
  - Extrapolate leakage current from temperature and dose meas.
- Calibrations must be done frequently to avoid fake aborts
- Monitoring and abort circuits need separate calibrations

**Monitoring Calibration:**
- Automatic at every beam loss
- Takes 30 seconds and continues until injection starts
- Can get confused if there is radiation from injection, but no beam is being stored

**Abort Circuit Calibration:**
- Initiated by shift crew
- Currently done every 24-48 hours
- Takes ~5 minutes
- “No beam” condition is enforced in hardware during calibration
Hardware Aborts

- Protects SVT from immediate damage (~1 Rad in 1 ms)
- Reduces radiation damage by quickly aborting beams in situations of very high radiation rates
- On a “trip” both beams are dumped within 100 µs

Principle of fast abort decision:

Small dose rate excursions above threshold does not abort the beams - the higher the rate the shorter the time span we allow it to occur!
2003 Thresholds

- Thresholds have increased several times since 1999
- Current thresholds are adjusted to abort beams roughly simultaneously on forward and backward diodes and high enough to avoid fake aborts
- During injections SVT is not biased and therefore not vulnerable to damage from discharge - therefore the thresholds are higher!

<table>
<thead>
<tr>
<th>Thresholds:</th>
<th>Injection</th>
<th>Stored</th>
<th>Forgiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>FW:MID</td>
<td>3000 mrad/s</td>
<td>600 mrad/s</td>
<td>2.5 rad</td>
</tr>
<tr>
<td>FE:MID</td>
<td>5000 mrad/s</td>
<td>1000 mrad/s</td>
<td>2.0 rad</td>
</tr>
<tr>
<td>BW:MID</td>
<td>6250 mrad/s</td>
<td>1250 mrad/s</td>
<td>2.5 rad</td>
</tr>
<tr>
<td>BE:MID</td>
<td>3500 mrad/s</td>
<td>700 mrad/s</td>
<td>2.0 rad</td>
</tr>
</tbody>
</table>

One possible policy-change is to change the ratio between threshold and forgiveness during injection.
Injection Inhibits

- Injections produce short (~1-2ms) radiation burst
- No need to abort beams because of a trip on an injection burst
- If abort signal is sent within 1 ms of an injection, beams are not dumped, but injection is halted
- Less than 10% of SVTRAD trips are injection inhibits

Example (10 Hz HER injection):
Fast History Buffer

- Fine-grained history of radiation is saved on every SVTRAD abort
- Stores 3-5 seconds of data with resolution of 1 ms (50 ms for MID)
- History available on the web and from radiation displays
- Data confirms that aborts are due to real radiation
- Radiation level in very fast aborts (1-10 ms) cannot be seen due to saturation of monitoring circuit
The main enforcement of the SVT radiation budget is done by the so-called “Soft Abort System”

**Soft abort system:**
- Counts how many minutes a MID diode is above a threshold
- Beams are aborted if above threshold for ten consecutive minutes
- Counter is reset if average below limit for one minute
- PEP-II usually adjusts or dumps beams before soft abort system does

**Soft Abort limits:**
- FE:MID: 80 mrad/s
- FW:MID: 70 mrad/s
- BE:MID: 50 mrad/s

**Problems:**
- BW:MID is not used in soft abort system as its leakage current is very sensitive to radiation damage
- FW:MID limit is higher than wished for (50 mrad/s) due to unstable leakage current

Foresee to include diamond sensors in soft abort system in Run 4
During injection dose rates can exceed soft abort limits. Not a problem if beam currents are also rising quickly. Therefore a different system ("Soft Injection System") is used.

**Soft Injection System:**
- Compare accumulated dose to beam current in a fill/top-off.
- West diodes compare to HER, East diodes to LER.
- If much worse than average injection is inhibited for 10 seconds - alerts operators.
- Limit is raised after each inhibit - used to abort beams after six inhibits. Not anymore.

If PEP-II is coasting, but not in "stable beams", system goes to soft abort system.

Can we provide better feedback on injection quality?
SVTRAD Performance

The SVTRAD system has prevented serious damage to SVT
- No SVT module has been lost in four years
- Some (<200) p-stop shorts created (mainly up to 2001)

Integrated radiation dose is within 4 Mrad budget
- All modules are below 50% of the projected maximum dose
- Starting to see unexpected radiation effects in a few chips
- Midplane modules will need to be exchanged in 2005

SVTRAD itself:
- No “catastrophic” failures
  - Two boards have been exchanged
  - Several thermistors have become disconnected or shorted
  - One diode (BW:MID) has wildly varying leakage current
- Precision is degrading due to rising leakage currents
- Some fake aborts due to leakage current increases and temperature variations
Trip History

Number of trips significantly decreased with time
Now average about 3 trips per day
Still a significant fraction of PEP-II beam aborts
Detailed 2003 Trip History

**FW: MID**
- Dominates soft aborts

**BW: MID**
- Dominates fast aborts
- All but two looks real!

**FE: MID**
- Most fast aborts are very fast (<10 ms)
- Bad vacuum
- Fast aborts always coincide with FE: MID

**BE: MID**
- Soft aborts underestimated due to operator aborts
Injection Aborts

Many aborts during injection, where thresholds are higher
Any common cause?

Looked at beam currents at injection aborts
Most aborts occur at the top of a fill - presumably during tuning?
Means we get full dose of an injection twice!
Could we benefit from higher limits or better feedback to operators?
Looking fast history plots, radiation goes up in 10 to 500 ms
FW: MID threshold had to be raised to avoid fake aborts
Still, we had some fake aborts in June 2003 - will only get worse
BW diamond also detects trapped events
Propose to add diamonds to soft abort system soon
SVTRAD Problems

- Main issue is the high leakage current in PIN-diode
  - Mainly affect monitoring and soft abort system
  - Leakage current needs to be known with 1 nA precision
  - Requires temperature precision better than 0.005 °C
  - Dose dependence and annealing complicates

Pedestal evolution:

- BW:MID is already almost unusable
- FW:MID and FE:MID will be soon (2004?)

- Have some electronics issues
- Will be addressed with upgrade
What Can We Improve?

- Beam aborts should be reduced to absolute minimum
  - Aborts cause loss of luminosity
  - Frequent aborts tend to make machine more unstable
  - Need to keep the SVT safe from immediate damage
  - Sometimes beam aborts are the only way to get to useful lumi
- At the same time, need to keep integrated dose as low as possible
  - At the moment we are not sure SVT can take 5 Mrad
  - 2008-9 data will be of little use without the inner SVT layers...

- Have divided improvements into two categories:
  - Changes to abort policy and limits
  - Improvements in feedback to the operators

Any changes to the abort policy will have to be approved by the SVT management!
Changes to Abort Policy?

Possible changes:
- Hardware limits during injection
  - Can we remove aborts by allowing spikes for slightly longer?
- Allow operators to extend 10-minute timer by 5 or 10 minutes
  - Idea is mainly to have enough time to try and understand why radiation level is too high
- A smarter hardware abort algorithm?
  - After electronics upgrade (Jan 2004), system will be more flexible
- Adding diamonds to soft abort system

Things less likely to change:
- Hardware abort limits during stable beams
- Soft abort limits
  - It is the main enforcement of SVT budget
  - We now have higher limits during vacuum scrubbing
  - Will need to go up in the future with currents at 2-4 A
## Improving Feedback

<table>
<thead>
<tr>
<th>Some items which has come up in past discussions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Better feedback on injection quality than injection inhibit?</td>
</tr>
<tr>
<td>✭ Both instantaneous measure and for a complete fill/top-off</td>
</tr>
<tr>
<td>✭ Is “dose per stored mA” the right measure?</td>
</tr>
<tr>
<td>Faster signals for tuning</td>
</tr>
<tr>
<td>✭ Diamond signals are now available on oscilloscope (ch 25)</td>
</tr>
<tr>
<td>✭ Diode signals will become available with SVTRAD 1.5</td>
</tr>
<tr>
<td>Pre-abort warning signal before beam aborts</td>
</tr>
<tr>
<td>✭ Suggested to send signal when halfway or so to abort limit</td>
</tr>
<tr>
<td>✭ Idea would be to automatically try to undo tuning which caused radiation to jump up</td>
</tr>
<tr>
<td>✭ Would come 0.5-100 ms before actual abort - can control system react on that time scale?</td>
</tr>
<tr>
<td>Better analysis of aborts - try to get more detailed classification</td>
</tr>
<tr>
<td>✭ Fast history are now directly available to operators</td>
</tr>
</tbody>
</table>
SVTRAD protects SVT against radiation bursts and monitors integrated radiation doses
Have given description of current algorithm
Indicated a few places where system can be tweaked
Major constraint is the budget uncertainty