Radiation Abort Policy

My completely unbiased summary
Fair and Balanced (TM)

Talks from
Maarten, Brian, Gabrielle, Michael, Toru, Witold, Tanja,
John and plenty of discussion during and after the talks

• Only covering SVT aborts and EMC inhibits

• All other sub-detectors are quietly accepting whatever the machine delivers
SVT Needs Protection

- Need to last until 2010
- Repairs are possible but take order of $\frac{1}{2}$ year  
  (only one foreseen, scheduled for 2005)
- Spares are limited

- SVT has protected itself in the past $\Rightarrow$ 15,000 beam aborts

- Now we are reviewing how to reduce the number of aborts from 3 on average today to less than 1
- In addition SVT can inhibit injection for short times
EMC Needs Protection

• Light yield is going down and we are not totally sure how “blind” we want to make it (is 30% light loss ok or 60%?)
• EMC can not be repaired at all, so better look out, better do cry…

• EMC is not aborting but inhibiting injection
  – Presently we don’t know how often
  – We have to revisit the method of EMC protection
BaBar and PEP II Need Lumi

- A lot of it!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
- The path to more lumi is typically painful
- **Stable** running slightly below the peak yields typically highest integrated lumi with very decent backgrounds
- Backgrounds have to be small enough to ensure good data quality

➡ Bring data quality and detector protection in sync
SVT Occupancy Studies

$D^*$ Dependence on Occupancy

Divide sample in two according to occupancy:

- 3.5% = low
- 5.5% = higher

8/fb from 2003
Layer 1 occupancy
- 3.5% = low
- 5.5% = higher

10% efficiency reduction

Low occup.: 8.4 $D^*/pb^{-1}$
High occup.: 7.5 $D^*/pb^{-1}$
SVT Occupancy Studies II

Hit Residual Resolution

Resolution increases by 6 μm/10%!
Increases 2x at 20% occupancy

Efficiency falls off very fast above 20% occupancy

20% occupancy might be plenty
SVT Radiation Damage

A) Radiation damage to the SVT wavers:

**Instantaneous**
- Creation of p-stop shorts => inefficiency

**From integrated radiation (bulk damage)**
- Increase in leakage current => shot noise
- Damages to the crystalline structure
  => decrease in charge collection efficiency

B) Radiation damage to the electronics:
- Increase in noise => decrease S/N
- Decrease in gain => decrease S/N
- Digital failures => inefficiency
The effect has been observed in the real system:
65 pin-holes / 20k channels in L1,2

No damage in layer 1 since 2 ½ years!
Most Recent damage in Layer 3 was after a shutdown and might not be beam related
Does SVT still need an Instantaneous Radiation Protection?
SVT Bulk Damage

Several test beams have been organized at SLAC and at Elettra (Trieste) to study bulk damage to the SVT from electrons in the GeV range (0.9 to 3 GeV)

2000: Wafer irradiations to doses up to 5 Mrads using both a direct electron beam and an electron beam scattered by a copper target.
2001: Also tests with non-uniform irradiation to simulate the conditions of middle plane modules
2003: Tests with non-uniform irradiation to study the change in depletion voltage and charge collection efficiency

In spite of type inversion bulk seems to be ok for up to 10 Mrad
Radiation tests performed on Atom chips in 2001 using Co\textsuperscript{60} sources at SLAC and LBL.

Chips powered and running during irradiation (xx\% higher damage if off)

Foreseen decrease of signal/noise down to a factor 2 (mid plane). This determines an upper limit on the ATOM chips lifetime (5Mrads).

No digital failure observed up to 5 MRads (only 7 chips tested)
Radiation Damage Pronounced in Horizontal Plane

Pedestal increase on channels on a few SVT chips
- not fully understood effect, not seen with Co$^{60}$ test
- observed on chips more exposed to radiation (west side only)

Damage to
5 chips in layer 1
5 chips in layer 2

$\Rightarrow \frac{10}{364} = 3\%$

Impact on physics has to be studies, but I would guess it will be not too severe

Acceptable radiation level for these chips might be as low as 3Mrad

SCARY
Radiation Monitoring in EMC

- Array of 115 RadFETs
- Maximum dose seen 1150 Rad
- Dose has a rate of 4-12 Rad/fb⁻¹
- Dose budget is 10 kRad over BaBar life
- Dose map reminds beam backgrounds

Plots by I. Stelzer

09/24/2003 Carsten Hast -- BaBar and PEP II Background Workshop
Dose accumulated by EMC

- Differ by scaling factor, shape similar
- EC sees ~30% more dose then measured by RadFETs
Dose calculated using LC shows:

~45% of EMC dose is accumulated during injection.

How is trickle charge doing?
EMC Radiation During Injection

- EMC can see unique backgrounds, so it needs its own protection
- There was a discussion about the way EMC holds injection when it gets too bad
- Turns out that this is based on a system which was put in place 5 years ago and missed a few update cycles…
- EMC and PEP will be looking in how to signal the PEP operators the injection quality and ensure the wellbeing of the EMC
SVT 2003 Doses in Numbers

Radiation doses from January to June 2003:

<table>
<thead>
<tr>
<th></th>
<th>FW</th>
<th>FE</th>
<th>BW</th>
<th>BE</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOP</td>
<td>81 (14%)</td>
<td>52 (41%)</td>
<td>100 (9%)</td>
<td>25 (55%)</td>
</tr>
<tr>
<td>MID</td>
<td>374 (63%)</td>
<td>333 (67%)</td>
<td>488 (66%)</td>
<td>215 (65%)</td>
</tr>
<tr>
<td>BTM</td>
<td>90 (30%)</td>
<td>59 (38%)</td>
<td>82 (20%)</td>
<td>58 (45%)</td>
</tr>
</tbody>
</table>

Numbers are in krad, (%) is of dose in stable beams

- Dose during stable beam is almost completely in MID plane
- Radiation comes from lost particles
- Injections tend to have more uniform radiation pattern
- Mainly coming from HER injection and into west diodes

09/24/2003 Carsten Hast -- BaBar and PEP II Background Workshop
SVT 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:

Forgiveness (~2 rad)
Threshold (~1 rad/s) (higher in injection)

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

All but 2 look real
(of the 2003 aborts)
SVT Aborts During Injection

Thresholds are higher during injection: What is going on?

Short answer:

We don’t know!
(We is PEP and BaBar)

But clearly it is not too good, dumping beams at the end of the injection cycle…

Homework:
Correlation of SVT aborts with Machine actions (RF, Feedback Trips, etc.)
**Belle Diagnostics of Beam Loss**

- The beam current, beam phase, vertical and horizontal orbits of beam are recorded with oscilloscopes and fast data loggers at every beam abort. The KEKB operators diagnose the reason of the beam loss.

  Yellow — beam phase  
  Cyan — RF power  
  Green — beam current  
  Magenta — abort request

The beam loss starts before the beam phase shifted.
Belle Abort Summary

• After the installation of “beam-phase abort (BPA)”, the rate of accidents to movable mask and Belle due to lost beam reduced significantly. The rate of BPA is 0.5 to 1 times per day.

• Abort due to beam-loss monitors in the tunnel, close to the movable masks and close to Belle/SVD helps to abort the beam before whole beam is lost in the ring and Belle.

• The RF monitor data, beam monitor data and loss monitors are recorded by fast data loggers and oscilloscopes at each beam abort. Analysis of the logged data is indispensable for understanding the reason of beam instability and for determining how to reduce damages to the KEKB and Belle.
BaBar Status

• My understanding is that all sub detectors will be capable to handle the PEP current and lumi projections concerning the radiation damages, though the margins are small

• Occupancies might be quite high and we need to see what physics implications this has and how we want to handle that

  BaBar has to considerably increase its effort to understand implication of high occupancies

(signal MonteCarlo is not necessarily produced with the “right” beam backgrounds if you don’t take care to do it with all machine conditions)
EMC Hardware Injection Inhibit

- EMC inhibits injection with a hardware based system when it gets too bad (not clearly defined)

→ Will consider to introduce a software based system with newly defined limits and procedures

Injection contributes 50% to the radiation damage and EMC would greatly benefit from a reduction of that component
SVT Hardware Injection Inhibit

- Injections produce short (~1-2ms) radiation 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

Protection against very bad injection shots
Operators are forced to reset the system (I think…)

It should be beneficial if EMC and SVT could combine these systems to one (or two) EPICS buttons to ease the operators the diagnostic of their injection difficulties

SVT Software Injection Inhibit
was already shown together with the EMC Injection Inhibit
SVT Software Abort System

The main enforcer of the SVT radiation budget

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

Very successful and helpful for dealing with trapped events
Is getting an “extension button” for special cases
Feedback to the Operators

• Better feedback on injection quality instead of injection inhibit? Eg. “Dose per stored mA”

• Faster signals for tuning (SVTRAD 1.5)
• Diamond signals are now available on oscilloscope (ch 25)

• Pre-abort warning signal before beam aborts
  – Idea would be to automatically try to undo tuning which caused radiation to jump up
• Better analysis of aborts – try to get more detailed classification
• Fast history are now directly available to operators
SVT Radiation Protection is Pretty Close to the Occupancy Limits Demanded by BaBar’s Present Physics Needs

- Soft Abort timer starts at 70 mrad/s
- 70 mrad/s corresponds to 15% average occupancy in horizontal layer 1
- 2 horizontal plane chips are roughly at 30%
What Can We Do to Reduce the Number of SVT Aborts?

- We have to understand them!
- Stan Ecklund has a transient recorder, which looks at currents, BPM, beam loss monitors, etc.
- PEP abort system latches only the first abort signal, not all of them
- RF abort logfiles exist
- SVT has fast history buffer

We have to combine all these and more
What Can We Do to Reduce the Number of SVT Aborts? (II)

1) Changes to abort policy and limits
2) Improvements in feedback to the operators

Quote: Any changes to the abort policy will have to be approved by the SVT management!

In 2002 thresholds were raised considerably
The 5 minute timer was extended to 10 and now even more

Despite the above order, SVT commissioners were always very accommodating in crisis like scrubbing and “just hard times”
What Can We Do to Reduce the Number of SVT Aborts? (III)

Injection aborts

We need to correlate machine happenings with the SVT abort decision: Brian(?) will look into that
After that we could think about playing with
• Abort Thresholds
• Forgiveness

Project for the next few weeks
What Can We Do to Reduce the Number of SVT Aborts? (IV)

- Dump only one beam
- A smarter hardware abort algorithm now?
  - increasing threshold and forgiveness
    (unlikely, since SVT fears discharges)
- Electronics upgrade (Jan 2004): system will be more flexible
  (smarter abort algorithm become possible and definitively are desirable)
- Adding diamonds to soft abort system (more reliable dose measurement) within the next weeks

Not Much!

Except understanding what is going on in the machine and cure it