Summary of the 2009 CNGS TSG4 irradiation tests and perspectives for future tests and facilities

D.Kramer on behalf of the RADWG

Thanks to the users, CNGS experiment, J.Lendaro, D.McFarlane, M.Brugger, K.Roeed, EN/MEF, DG/SCR, Fluka team and the RadMon team (T.Wijnands, A.Nyul, C.Pignard)
27 Jan 2010 RADWG for Chamonix

Outline

- CNGS test facility overview
- Calibration of test positions
- Results reported by users (tunnel / alcoves)
  - CRYO
  - BIC/PIC
  - BLM
  - BPM
  - QPS
  - CL heaters
  - WorldFip
  - Power Converters
  - SURVEY

- Foreseen test activities in 2010
- Conclusions

Fluka simulations for nominal beam assume:
- $100 fb^{-1}$

ARC Fluka simulations use:
- $10^7 s \times 3.64 \times 10^{18} p/s \times 10^{15} \text{mol/m}^3$

2010 luminosity assumed as:
- $0.5 fb^{-1}$

2010 ARC losses assumed as:
- $1/40$ of nominal

Nominal year assumed as 200 days
Temporary procedure for handling irradiated electronics was put in place for CNGS. Valid until 30/11/09 and extended from 19 Jan 2010. RADIOACTIVE electronics WORKSHOP has to be used afterwards.

Measured quantities:
- Dose (SiO$_2$)
- Hadron>20MeV fluence
- 1MeV n$^0$ eq. fluence

Mixed radiation fields similar to the ones expected in LHC.
Temporary procedure for handling irradiated electronics was put in place for CNGS. Valid until 30/11/09 and extended from 19 Jan 2010. RADIOACTIVE electronics WORKSHOP has to be used afterwards.

Mixed radiation fields similar to the ones expected in LHC

> 20 MeV Hadron fluence per primary at station level ( -150 cm < y < -90 cm )
2 Test areas – High & Low flux with multiple calibrated locations

Hottest test area in TSG46:
~ 3.3 Gy(SiO$_2$)/week
~ 1.8 $10^{10} (>20$MeV)$cm^{-2}$/week

1 Week ~ 1e18pot

Hottest test area in TSG45:
~ 28 Gy(SiO$_2$)/week
~ 1.9 $10^{11} (>20$MeV)$cm^{-2}$/week

This is expected in the LHC arcs* in 3 nominal years (10Gy/y)

*Alongside a dipole
Calibrated radiation field data for all test locations accessible via dedicated Java GUI

Like it is the case for FLUKA, Safety Factor of 2 has to be used for all the CNGS measurements (high gradients, small detector size) for CUMULATIVE effects.

By assuming all the devices to be installed in the worst locations, the estimations are more conservative than 2 times! (for SEE related failures)

All the user requests could be fulfilled in 2009 in CNGS at the expense of very crowded periods in the High Dose area (tunnel equip.)
Calibrated radiation field data for all test locations accessible via dedicated Java GUI

Like it is the case for FLUKA, Safety Factor of 2 has to be used for all the CNGS measurements (high gradients, small detector size) for CUMULATIVE effects.

By assuming all the devices to be installed in the worst locations, the estimations are more conservative than 2 times! (for SEE related failures)

All the user requests could be fulfilled in 2009 in CNGS at the expense of very crowded periods in the High Dose area (tunnel equip.).
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by E. Gousiou
CRYO Tunnel Electronics
9500** channels in LHC

Eqiup. tested in CNGS:
- Various inputs (58 channels)
- FIP communication (8 agents)
- Power supply (2 cards)

Observed Errors in CNGS
None**, accuracy within specs

<table>
<thead>
<tr>
<th>Safety factor 2x to be applied for all cumulative effects in this talk</th>
<th>Lifetime in LHC years / MTBF (channel)</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID &gt;500 Gy</td>
<td>500 (12 in DS*)</td>
<td>Not needed. Upper limit on channel failure rate Largely overestimated</td>
</tr>
<tr>
<td>Channel failure cross section upper limit 5e-15cm²</td>
<td>&gt;5.2y**</td>
<td></td>
</tr>
<tr>
<td>MTBF in 2010 lower limit</td>
<td>&gt;200y**</td>
<td></td>
</tr>
</tbody>
</table>

ARC annual levels below MBB
- 4e9cm⁻² E>20MeV
- 1Gy

2009/10
- 1e8cm⁻² E>20MeV
- 25mGy

*Some cards up to MBB8 – monitoring required
CRYO - Protected Areas
Cumulative effects

 Equip. tested in CNGS:
A. 6 QRL electrical heater AC supplies (45 in LHC)
B. 12 Insulated temperature conditioners (2400 in LHC)

Observed Errors in CNGS
A. Solid State Relay damaged
B. DC-DC converter fails

<table>
<thead>
<tr>
<th>A – QRL heater</th>
<th>OK if</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>10Gy</td>
<td>Will be cured by shielding (&amp; relocation in case of UJ56 to bottom floor)</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>2y</td>
<td></td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>400y</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B – Insul. temp.</th>
<th>OK</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>140Gy</td>
<td>Not needed</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>28y</td>
<td></td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>OK</td>
<td></td>
</tr>
</tbody>
</table>

Only used during machine cool down – with no beam
CRYO - Protected Areas
Single Event Errors

Equip. tested in CNGS:
Insulated Temperature Conditioners
Number in alcoves: 2400 channels

Observed Errors in CNGS
SEU on digital isolator

Annual fields in worst location UJ56,14,16
- $5 \times 10^9 \text{cm}^{-2} E > 20\text{MeV}$
- 5Gy
- 2.5$ \times 10^7 \text{cm}^{-2} E > 20\text{MeV}$
- 25mGy

<table>
<thead>
<tr>
<th></th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure cross section (per channel)</td>
<td>2e-9cm$^2$</td>
</tr>
<tr>
<td>MTBF if all in UJ56 for nominal beam</td>
<td>0.2h</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>1.7 days</td>
</tr>
</tbody>
</table>

OK if

27 Jan 2010
RADWG for Chamonix
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by M. Zerlauth & B. Todd

XC95144 x 32
XC95288XL x 32
BIC - Protected Areas
SEEs of CPLD 3.3V [ component test ]

Equip. tested in CNGS:
XILINX CPLD XC9500XL 3.3V
part of BIS signal path (critical)

Number in alcoves: 36

Observed Errors in CNGS
A. 20% of SEUs cause loss of redundancy
B. 80% of SEUs cause false dump

### Annual fields in worst location UA87,23
- 5e7cm⁻² E>20MeV
- 0.05Gy

2010
- 1e7cm⁻² E>20MeV
- 10mGy

### 27 Jan 2010 RADWG for Chamonix 13

<table>
<thead>
<tr>
<th>A / B</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEU cross section (per device)</td>
<td>2.8e-10cm²</td>
</tr>
<tr>
<td>MTBF* loss of redundancy / false dump</td>
<td>10y / 2.5y</td>
</tr>
<tr>
<td>Fault probability in 2010</td>
<td>2e-2 / 8e-2</td>
</tr>
</tbody>
</table>

*if all in UA87 for nominal beam no shielding

Thermal neutron sensitivity could be an issue with 3.3V
BIS/PIC - Protected Areas
SEEs of CPLD 5V [ component test ]

Equip. tested in CNGS:
XILINX CPLD XC9500 5V part of BIS/PIC monitoring paths

Number in alcoves:
336 (CIBUs – 300, PIC - 36)

Observed Errors in CNGS
A. 90% of SEUs cause monitoring problem
B. 10% of SEUs cause false dump

<table>
<thead>
<tr>
<th>A / B</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEU cross section (per device)</td>
<td>3.8e-13cm²</td>
</tr>
<tr>
<td>MTBF* monitoring problem / false dump</td>
<td>8y / 72y</td>
</tr>
<tr>
<td>Fault probability in 2010</td>
<td>6e-4 / 7e-5</td>
</tr>
</tbody>
</table>

*if all in RR13 for nominal beam

Annual fields in worst location RRs:
- 1e9cm⁻² E>20MeV
- 1Gy

2010
- 5e6cm⁻² E>20MeV
- 5mGy

OK

Destructive Latchups of CPLDs should have very low probability in shielded areas due to lower peak energy
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by E.Effinger
BLM - Protected Areas and ARCs
Cumulative and SEE effects

Equip. tested in CNGS:
A. Power Supply Haltec 2.5V (37x)
B. Power Supply Haltec 5V (74x)
C. BLECF tunnel card, PS (600x)

Observed Errors in CNGS
A. Total dose effects, voltage drop
B. Total dose effects, voltage drop
C. 1 SEE leading to false dump

Annual fields in worst location RR13 / ARC (MQ)
- 1e9 / 4e10 cm⁻² E>20MeV
- 1 / 10 Gy

2010
- 5e6 / 1e9 cm⁻² E>20MeV
- 5 / 250 mGy

A,B Power Supplies | Mitigation
---|---
TID | 85/33Gy | Not needed
Nominal lifetime | 85/33y
Lifetime in 2010 | OK

B – BLECF

<table>
<thead>
<tr>
<th></th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>750Gy</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>75y</td>
</tr>
<tr>
<td>SEE cross section</td>
<td>1.9e-13cm²</td>
</tr>
<tr>
<td>MTBF</td>
<td>44days</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>8.8y</td>
</tr>
</tbody>
</table>

27 Jan 2010
RADWG for Chamonix
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by E. Calvo
BPM – tunnel electronics

Equip. tested in CNGS:
A. Intensity card (330x)  Not OK but
B. Power Supply (330x)  OK
C. WorldFIP card (330x)
D. 2 WBTN cards (2160x)  OK

Annual fields in worst location - ARC (MQ)
- 4e10 cm⁻² E>20MeV
- 10 Gy

2010
- 1e9 cm⁻² E>20MeV
- 0.25 Gy

Observed Errors in CNGS
A. After SEE out of range readings
C. After SEE, WBTN calibration off and High sens. mode, max 250um offset for 1min

<table>
<thead>
<tr>
<th>A Int. card / B,C,D WBTN</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>4/&gt;230Gy</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>0.4y/&gt;23y</td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>16y/920y</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>C – WorldFIP card</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE cross section</td>
<td>4e-12cm²</td>
</tr>
<tr>
<td>MTBF</td>
<td>3.8days</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>152days</td>
</tr>
</tbody>
</table>

Channel can be masked by the orbit feedback system
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by R. Denz
nQPS – LHC ARCs [new QPS layer]

Equip. tested in CNGS:
Field-bus coupler type DQAMGS
Number in tunnel: 450

Observed Errors in CNGS
SEE in uFip or FieldDrive freezes the supervision path – access needed prior to next fill to restart the card. Observed analog drifts do not pose problems

<table>
<thead>
<tr>
<th></th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEU cross section</td>
<td>2.8e-10cm² Automatic reset of the WorldFIP. Solution tested successfully in CNGS. To be implemented when the errors start to appear.</td>
</tr>
<tr>
<td>MTBF nominal beam</td>
<td>10h</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>16d</td>
</tr>
</tbody>
</table>

Annual fields in ARCs under dipoles
- 4e9cm⁻² E>20MeV
- 1Gy
- 1e8cm⁻² E>20MeV
- 25mGy

2010

“2009 tests in CNGS confirmed the radiation tolerance of the detection systems of the new QPS layer including the power supplies. Detailed evaluation still to be done”

27 Jan 2010 RADWG for Chamonix
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by S. Le Naour
Current Lead heaters – protected areas

Equip. tested in CNGS:
7 Regulators and Solid State Relays
(UJ&RRs 408x, others not counted: 904x)

Observed Errors in CNGS
Destructive SEE in the regulator – ice formation on DFB after dump => Cryo Start removed

Annual fields in the worst location i.e. UJ56
- 5e9 cm\(^{-2}\) E>20MeV
- 5 Gy

Temperature regulator
<table>
<thead>
<tr>
<th>SEE cross section</th>
<th>2e-11 cm(^2)</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTBF</td>
<td>5days</td>
<td>Not critical for the operation. Only 84 devices in UJs.</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>5y</td>
<td>Shielding will help</td>
</tr>
</tbody>
</table>

Not OK but
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Planned development of the new nanoFIP is covered in the talk of J.Serrano

Data provided by J.Palluel
**WorldFIP – signal repeaters in the tunnel**

**Equip. tested in CNGS:**
2 Repeaters Cu-Cu (320x in ARC)

**Observed Errors in CNGS**
Total dose effect – replacement required before beam on

**Annual fields in worst location - ARC along MB**
- 4e10 cm⁻² E>20MeV
- 10 Gy
- 1e9 cm⁻² E>20MeV
- 0.25 Gy

**Repeater** | **Mitigation**
--- | ---
TID | 165/>250Gy
Fluence h>20MeV | 1.1e12cm⁻²
ARC lifetime | 16y

Device inspected yesterday – drift in an auxiliary part. Annual dose overestimated (cable tray).
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

For detailed results please look in the talk of Y.Thurel

Data provided by Y.Thurel, S.Dubettier
**Power Converters – tunnel and part of alcoves electronics**

 Equip. tested in CNGS:
A. FGC COD (752xARCs)
B. FGC Generic (189+256xUJs,RRs)
C. High precision part SD360 (as B.)
D. Component tests

**Observed Errors in CNGS**
A. B. Crashes of FGC requiring power cycle and therefore dump (so far unexplained - half SEL of CPLD?)
C. Very frequent corruptions only in 350**, 360 OK (more tests needed)

<table>
<thead>
<tr>
<th>A (ARC) / B (UJs) FGCs</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td><strong>OK</strong></td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>100Gy</td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>OK</td>
</tr>
</tbody>
</table>

**Annual fields in worst location – UJ56 / ARC**
- 5e9 / 4e9 cm⁻² E>20MeV
- 5 / 1 Gy

**2010**
- 2.5e7 / 1e8 cm⁻² E>20MeV
- 25 / 25 mGy

**Corruptions of SD350 (Generic FGC) are rather critical due to large cross section**

**Mitigation**

<table>
<thead>
<tr>
<th>A+B – FGC</th>
<th>Not OK?</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE cross section</td>
<td>2.3e⁻¹¹cm²</td>
<td>Shielding will help in UJs,RRs not in ARCs. REDUNDANT!</td>
</tr>
<tr>
<td>MTBF *</td>
<td>1.8days</td>
<td></td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>72days</td>
<td></td>
</tr>
</tbody>
</table>

All crashes occurred only at low fluence -> uncertainty in cross section.
If total fluence considered, MTBF = 7days
User test results

- CRYO
- BIC/PIC
- BLM
- BPM
- QPS
- CL heaters
- WorldFip
- Power Converters
- SURVEY

Data provided by A. Marin
SURVEY—controller electronics from protected areas

Equip. tested in CNGS:
1 Controller crate (6x,UJ56)

Annual fields in worst location – UJ56
- $5 \times 10^9 \, \text{cm}^{-2} \, E > 20 \, \text{MeV}$
- $5 \, \text{Gy}$
- $2.5 \times 10^7 \, \text{cm}^{-2} \, E > 20 \, \text{MeV}$
- $25 \, \text{mGy}$

Observed Errors in CNGS
a) Cumulative effect failure, drifts very small
b) System crashes (likely SEE in the uFip) requiring remote reset via WorldFip, no beam dump

Tripod motor drivers should remain OFF during beam operation (in the same rack)

<table>
<thead>
<tr>
<th>a)</th>
<th>OK</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>100Gy</td>
<td>No problems expected from cumulative effects</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>20y</td>
<td></td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>OK</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b)</th>
<th>OK</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE cross section</td>
<td>$8 \times 10^{-12} \text{cm}^2$</td>
<td>System can remain in 1st floor of UJ56 w/o shielding</td>
</tr>
<tr>
<td>MTBF</td>
<td>4y</td>
<td></td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>800y</td>
<td></td>
</tr>
</tbody>
</table>
List of tests for LHC electronics in external facilities in 2009

- PSI proton beams 60/250MeV used by
  - QPS for component tests
  - WIC for Siemens remote I/Os
  - RadMon for calibrations

- CEA Valduc 1MeV n, 14/5MeV n
  - BLM, CRYO for NIEL
  - RadMon calibrations

- UCL Louvain la Neuve Heavy ions
  - CPLD tests

- NRI Prague (epi)thermal n
  - RadMon calibration
  - Repeater test

- IRA Lausanne Co60
  - RadMon calibrations
Conclusions – no bad surprises

- **Very large effort** has been dedicated by the **equipment groups** to the radiation tolerance **tests** in CNGS!

- **Most** of the electronics systems form the LHC **tunnel** were **tested** in CNGS TSG4 in similar spectra as expected in the LHC

- **Small part** of the systems from the **alcoves** (RRs, UJs, ..) **tested** as well

- Resulting lifetimes from cumulative effects and failure rates from single events were estimated for nominal beam conditions and for 2010 (0.5fb⁻¹) – see the **following Summary Table**

- Many systems suffer from errors in the WorldFip modules (BPM, nQPS, CRYO, SURVEY) - the **nanoFIP** is expected to **help** in some cases

- **Most issues solved by** **HW/FW modifications**

- Several systems rely on the **shielding** improvements

- The BPM intensity card fails at low dose but is required just for commissioning

- The very complex issue of power converters is better covered in the separate talk of Yves
Outlook

- Several users want to do more tests in 2010 at CNGS
  - CRYO, QPS, TE/EPC
- n_TOF could be eventually used as similar facility (2 options) if too many requests for CNGS (unlikely in 2010/11)
  - Modifications would have to be started very soon
  - Mixed field close to target
  - Broad $n^0$ spectrum with rather low flux
- HiRadMat can also be accommodated to host the mixed field electronics tests
  - Requests from users would be required to support the decision
- Sharing of test experiences, beam times (=expenses) and results through RADWG can be very helpful
## Failure rate and lifetime estimations for 2010 and nominal LHC

<table>
<thead>
<tr>
<th>SYSTEM</th>
<th>subsystem</th>
<th>MTBF</th>
<th>Lifetime with nominal beam</th>
<th>MTBF 2010</th>
<th>Lifetime 2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>CRYO</td>
<td>Tunnel channels</td>
<td>&gt;5.2y</td>
<td>500 (12y DS)</td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td></td>
<td>Ins. Temp reading</td>
<td>0.2h</td>
<td>28y</td>
<td>12d</td>
<td>∞</td>
</tr>
<tr>
<td></td>
<td>QRL heater PS</td>
<td>2y</td>
<td></td>
<td></td>
<td>∞</td>
</tr>
<tr>
<td>BIC/PIC</td>
<td>BIS l.o.r./dump</td>
<td>10/2.5y</td>
<td>50/12.5y</td>
<td>∞</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Monitoring/dump</td>
<td>8/72y</td>
<td></td>
<td>∞</td>
<td>∞</td>
</tr>
<tr>
<td>BLM</td>
<td>PS 2.5/5V</td>
<td></td>
<td>33/85y</td>
<td></td>
<td>∞</td>
</tr>
<tr>
<td></td>
<td>BLECF</td>
<td>44d</td>
<td>75y</td>
<td>8.8y</td>
<td>∞</td>
</tr>
<tr>
<td>BPM</td>
<td>WBTN</td>
<td>3.8d</td>
<td>23y</td>
<td>0.75y</td>
<td>∞</td>
</tr>
<tr>
<td></td>
<td>Intensity card</td>
<td></td>
<td>0.4y</td>
<td></td>
<td>16y</td>
</tr>
<tr>
<td>QPS</td>
<td>nQPS</td>
<td>10h</td>
<td></td>
<td>16d</td>
<td></td>
</tr>
<tr>
<td>CL heaters</td>
<td>Temp. controller</td>
<td>5d</td>
<td></td>
<td>5y</td>
<td></td>
</tr>
<tr>
<td>WFip rep.</td>
<td>ARC</td>
<td></td>
<td></td>
<td>16y</td>
<td></td>
</tr>
<tr>
<td>Power Co.</td>
<td>FGC ARC/UJs</td>
<td>1.8d</td>
<td>100/20y</td>
<td>72d</td>
<td>∞</td>
</tr>
<tr>
<td>Survey</td>
<td>Control crate</td>
<td>4y</td>
<td>20y</td>
<td>∞</td>
<td>∞</td>
</tr>
</tbody>
</table>

Lifetime estimations should be divided by safety factor 2
The Hadron>20MeV sensitivity is quite well understood in forward shower regions – very good match with Fluka

- Excellent result behind the TED
- Most of the CNGS positions (match in line of sight to target chamber)
- CERF calibration campaign explored combinations of various settings and fields

Several measurements done in different neutron fields to determine the sensitivity below 20MeV

- Analysis to be finalized
- Measurements at PTB mono-energetic neutron beams are scheduled for 2010

Dose sensitivity calibration measurements yet to be extended to higher doses

- Calibration in Co60 gamma field

1MeV n equivalent fluence calibration to be reviewed for higher fluences

- Calibration in neutron field of air cooled U235 reactor – data available