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)
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
- $100\text{fb}^{-1}$

ARC Fluka simulations use
- $10^{-7}s \ 3.64\times10^{18}\text{p/s} \ 10^{15}\text{mol/m}^3$

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

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

Nominal year assumed as 200 days
Testing area in the TSG4 side gallery of CNGS

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

Measured quantities:
- Dose (SiO₂)
- Hadron>20MeV fluence
- 1MeV n⁰ eq. fluence
Testing area in the TSG4 side gallery of CNGS

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 )

Courtesy of K.Roeed

27 Jan 2010

RADWG for Chamonix
2 Test areas – High & Low flux with multiple calibrated locations

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

1 Week ~ \(1e18\text{pot}\)

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

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

27 Jan 2010 *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.)
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

Equip. tested in CNGS:
- Temperature reading (18 Channels)
- Helium level reading (12 Channels)
- Digital inputs (24 Channels)
- Cold mass electrical heater DC supply (4 Channels)
- FIP communication (8 agents)
- Power supply (2 cards)

Observed Errors in CNGS
None**, accuracy within specs

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

2009/10
- 1e8cm^-2 E>20MeV
- 25mGy

<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</td>
<td>&gt;500 Gy</td>
<td>500 (12 in DS*)</td>
</tr>
<tr>
<td>Channel failure cross section upper limit</td>
<td>3e-13cm^2</td>
<td>&gt;18 days**</td>
</tr>
<tr>
<td>MTBF in 2010 lower limit</td>
<td></td>
<td>&gt;3.6y**</td>
</tr>
</tbody>
</table>

*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

---

### Annual fields in worst location UJ56,14,16

- **5e9cm⁻² E>20MeV**
- **5Gy**

**2010**

- **2.5e7cm⁻² E>20MeV**
- **25mGy**

---

### Performance Summary:

<table>
<thead>
<tr>
<th>A – QRL heater</th>
<th><strong>OK if</strong></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><strong>OK</strong></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
- 5e9cm² E>20MeV
- 5Gy

2010
- 2.5e7cm² E>20MeV
- 25mGy

<table>
<thead>
<tr>
<th></th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure cross section (per channel)</td>
<td>2e-9cm²</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>1.7days</td>
</tr>
</tbody>
</table>
User test results

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

Data provided by M. Zerlauth & B. Todd
**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

<table>
<thead>
<tr>
<th>A / B</th>
<th>Mitigation</th>
</tr>
</thead>
</table>
| SEU cross section (per device) | 2.8e-10cm²  
New quick shielding effective by factor ~10 for TED, maze near TCDI,TDI to be reinforced. Simulations to be performed. |
| MTBF* loss of redundancy / false dump | 10y / 2.5y  
Fault probability in 2010 | 2e-2 / 8e-2 |

*if all in UA87 for nominal beam no shielding  

Thermal neutron sensitivity could be an issue with 3.3V

**Annual fields in worst location UA87,23**  
- 5e7cm⁻² E>20MeV  
- 0.05Gy  
- 1e7cm⁻² E>20MeV  
- 10mGy  

2010
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  

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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

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

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

<table>
<thead>
<tr>
<th>A,B Power Supplies</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>85/33Gy</td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td>85/33y</td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>OK</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B – BLECF</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-13cm(^2)</td>
</tr>
<tr>
<td>MTBF</td>
<td>44days</td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>8.8y</td>
</tr>
</tbody>
</table>

Not needed, handled by remote reset via HV
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

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>

MTBF in 2010 152days

Channel can be masked by the orbit feedback system

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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 (per device)</td>
<td>2.8e-10cm²</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

Annual fields in ARCs under dipoles

- 4e9cm⁻² E>20MeV
- 1Gy
- 1e8cm⁻² E>20MeV
- 25mGy

“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”

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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

2010
- 2.5e7 cm⁻² E>20MeV
- 25 mGy

<table>
<thead>
<tr>
<th>Temperature regulator</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE cross section</td>
<td>Not critical for the operation. Only 84 devices in UJs.</td>
</tr>
<tr>
<td>2e-11 cm²</td>
<td>Shielding will help</td>
</tr>
<tr>
<td>MTBF</td>
<td></td>
</tr>
<tr>
<td>5days</td>
<td></td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td></td>
</tr>
<tr>
<td>5y</td>
<td></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

2010
- 1e9 cm⁻² E>20MeV
- 0.25 Gy

<table>
<thead>
<tr>
<th>Repeater</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>165/&gt;250Gy</td>
</tr>
<tr>
<td>Fluence h&gt;20MeV</td>
<td>1.1e12 cm⁻²</td>
</tr>
<tr>
<td>ARC lifetime</td>
<td>16y</td>
</tr>
</tbody>
</table>

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)

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

<table>
<thead>
<tr>
<th>A (ARC) / B (UJs) FGCs</th>
<th>Mitigation</th>
<th>A+B – FGC</th>
<th>Not OK?</th>
<th>Mitigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TID</td>
<td>OK</td>
<td>100Gy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nominal lifetime</td>
<td></td>
<td>100y/20y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifetime in 2010</td>
<td>OK</td>
<td></td>
<td></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)

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

Annual fields in worst location – UJ56
- 5e9 cm⁻² E>20MeV
- 5 Gy

2010
- 2.5e7 cm⁻² E>20MeV
- 25 mGy

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

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

<table>
<thead>
<tr>
<th>b)</th>
<th>OK</th>
<th>Mitigation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SEE cross section</td>
<td>8e-12cm²</td>
<td>System can remain in 1st floor of UJ56 w/o shielding</td>
<td></td>
</tr>
<tr>
<td>MTBF</td>
<td>4y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MTBF in 2010</td>
<td>800y</td>
<td></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;18d</td>
<td>500 (12y DS)</td>
<td>&gt;3.6y</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>16d</td>
<td></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>WFit rep.</td>
<td>ARC</td>
<td></td>
<td>16y</td>
<td></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