Top-up At DLS

The first year of top-up operation – preparation and practical experience

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Top-up at DLS

- DLS began delivering 250 mA top-up beam to users in October 2008
- Modelling, trials and peer review prior to top-up operation
- Will discuss preparation for top-up and changes made to ensure continued radiation safety

UK Legislation

- Ionising Radiations Regulations 1999 (IRR99)
- No requirement under IRR99 to submit safety case to HSE (UK regulatory body for safety) before starting top-up operation
- BUT all doses must be kept ALARP and within the 1 mSv y^{-1} limit set by DLS for all staff, users and visitors (→ 0.5 μSv h^{-1} over a 2000 h working year)

Top-up shielding challenges

- DLS design spec did not consider top-up operation
- Will existing beamline shielding cope with possible electron losses from top-up ?
- Effect of abnormal injection losses ?
- Test by calculation and measurements on beamlines

New Radiation Hazards

1. Electrons being lost within storage ring (on ID).
2. Electrons lost in Front End.
3. Electrons transmitted to Beam line.

…all with beamline shutters open !

The Calculations

- Modelled each of the three hazards with simplified beamline / ratchet wall section using FLUKA

- Calculated gamma and neutron dose rates outside optics hutch for electron losses suggested by Accelerator Physics Group.

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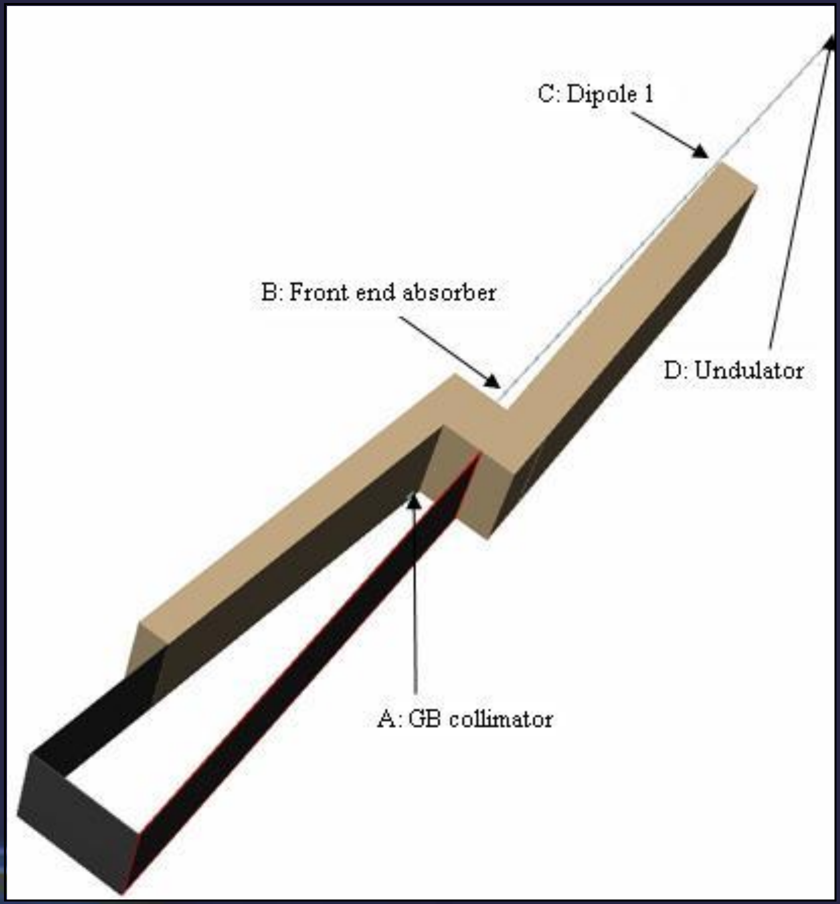
Calculation geometry



A simple model

- Beamline based on MX beamlines (undulator)
- Optics hutch lateral wall: 30 mm Pb
- Ratchet wall aperture: circular, 30 mm OD

- Look at beam scraping vacuum vessel at locations of ID (~20 m upstream of ratchet end wall) and Dipole (~8 m upstream) – hazards 1 and 2.

- Grazing angles 0.1º and 1º on 1.6 mm steel pipe wall

- Look at loss of single injected pulse (hazard 3)

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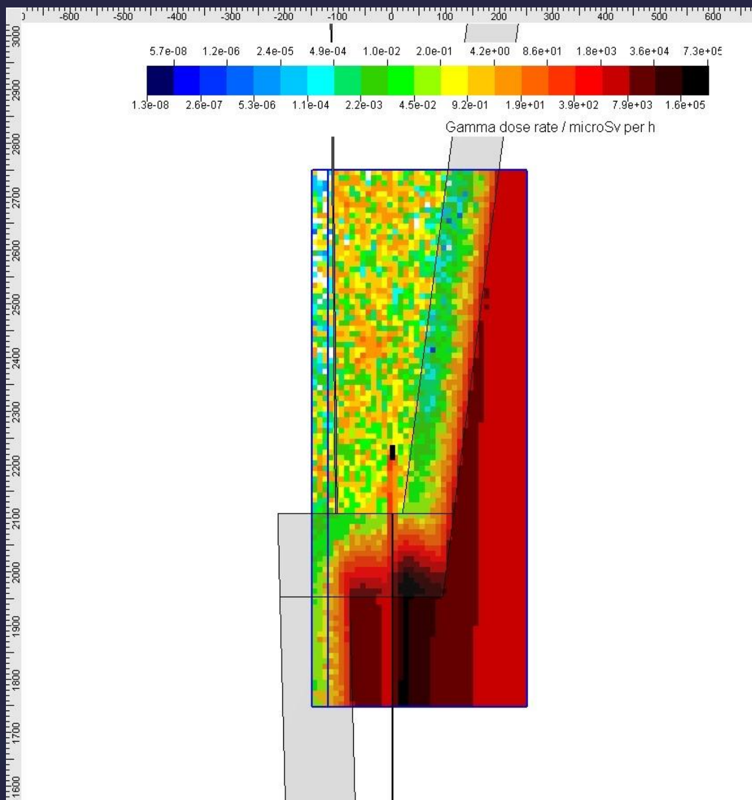
1 & 2, Continuous losses

- Nothing in theory to prevent a continuous loss from poorly injected beam scraping on vacuum vessel or ID – infinite choice of scenarios

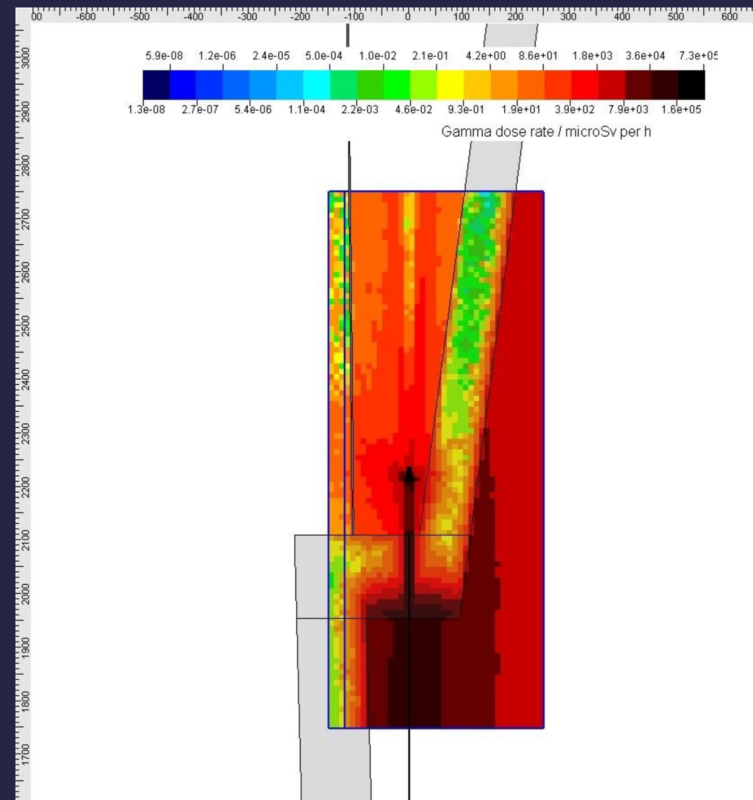
- Pick an angle…< 1^{o}
- Pick a loss rate…5 mA min^{-1}

- Tried to choose numbers consistent with measurement conditions and electron tracking study results

5 mA min^{-1} - gamma

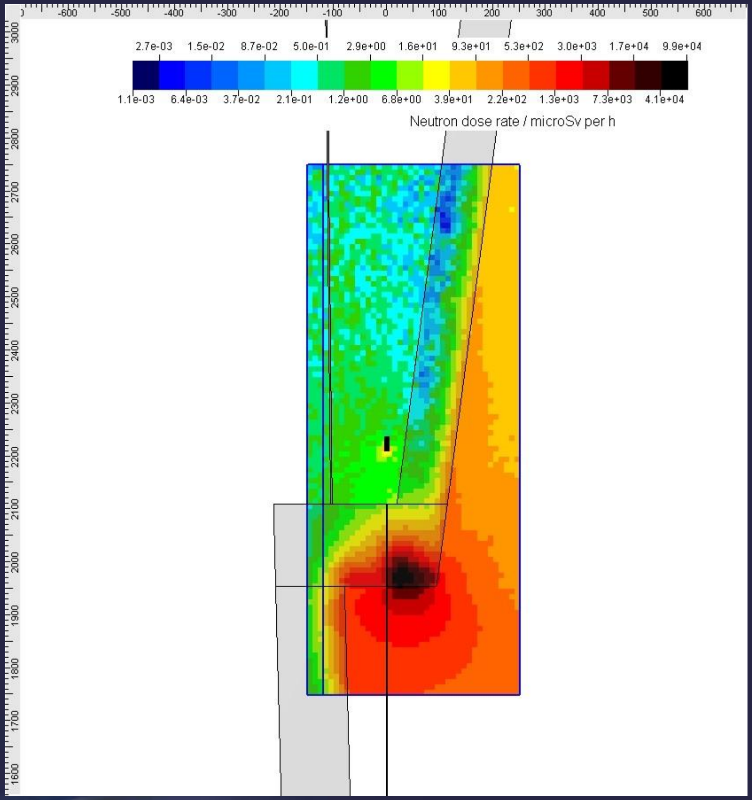


Dipole at 1°

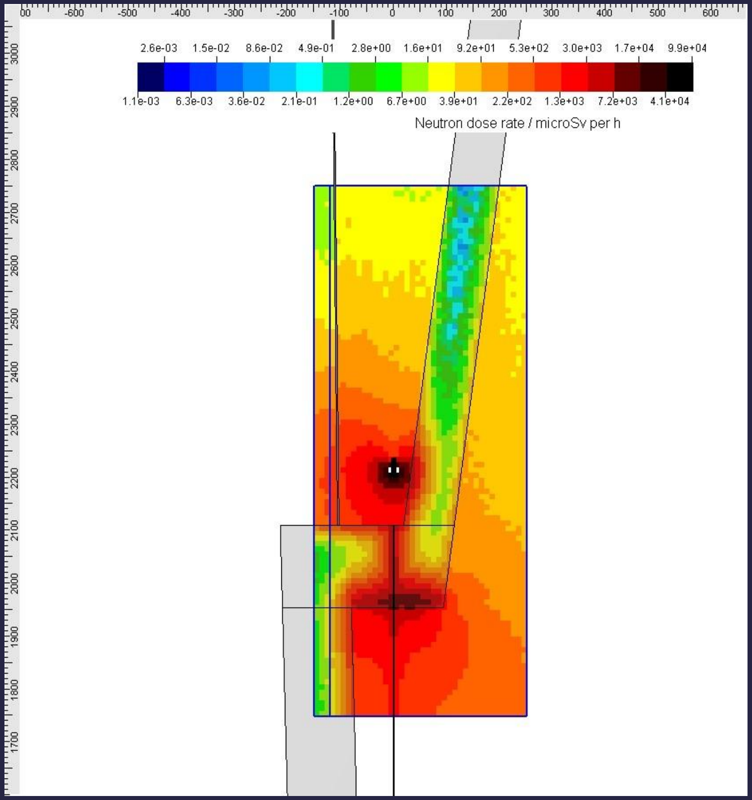


Dipole at 0.1°

5 mA min^{-1} - neutron



Dipole at 1º



Dipole at 0.1º

5 mA min^{-1} loss results

LOCATION / ANGLE	GAMMA	NEUTRON
ID 0.1°	61 μSv h^{-1} 39%	278 μSv h^{-1} 4.4%
ID 1°	32 μSv h^{-1} 50%	3.4 μSv h^{-1} 43%
Dipole 0.1°	105 μSv h^{-1} 21%	737 μSv h^{-1} 3.5%
Dipole 1°	16 μSv h^{-1} ??%	3.8 μSv h^{-1} 27%

Simple model conclusions

- Big difference between 1º and 0.1º angle results – can see why from plots
- For given angle, doesn't matter much whether loss is at ID or Dipole (results are same order of magnitude in both cases)
- At 0.1º angle, dose rate is mostly due to neutrons

Hazards 1 and 2 - summary

- Dose rates less than 1 mSv h^{-1}
- Can add control measures to avoid continuous loss scenario
- Back stop would be that radiation monitors would close shutters in a very few seconds – dose delivered would be less than 1 μSv.

3. Electrons into beamline

- Electron beam injected straight into a beamline hutch if shutter open and major magnet failure occurs – very low probability event
- Accelerator Physics calculations show this cannot happen for >1 pulse
- BUT…Single pulse may be able to escape the BTS and down the beamline before MPS can act to stop it

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Single pulse loss

- Electrons enter optics hutch, strike tungsten Gas Bremsstrahlung Collimator (GBC)
- Hutch shielding not designed to cope with losses of this sort
- Electrons on tungsten will produce neutrons – hutches have no neutron shielding

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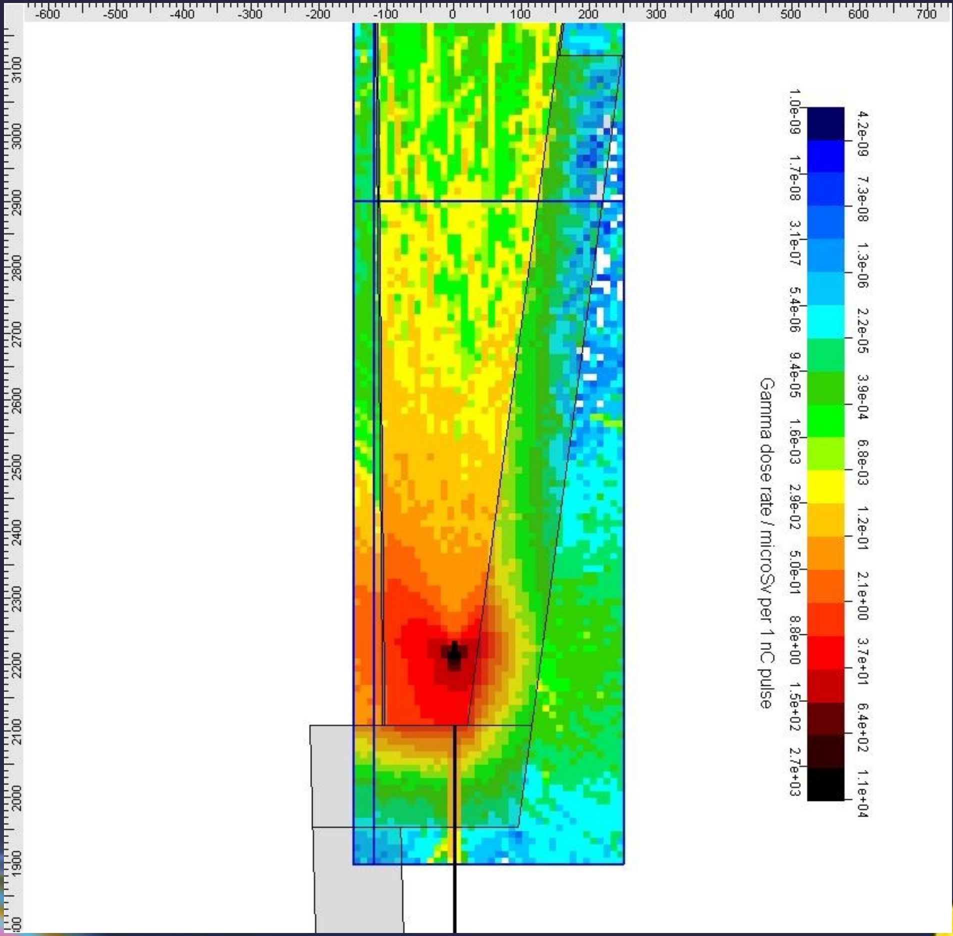
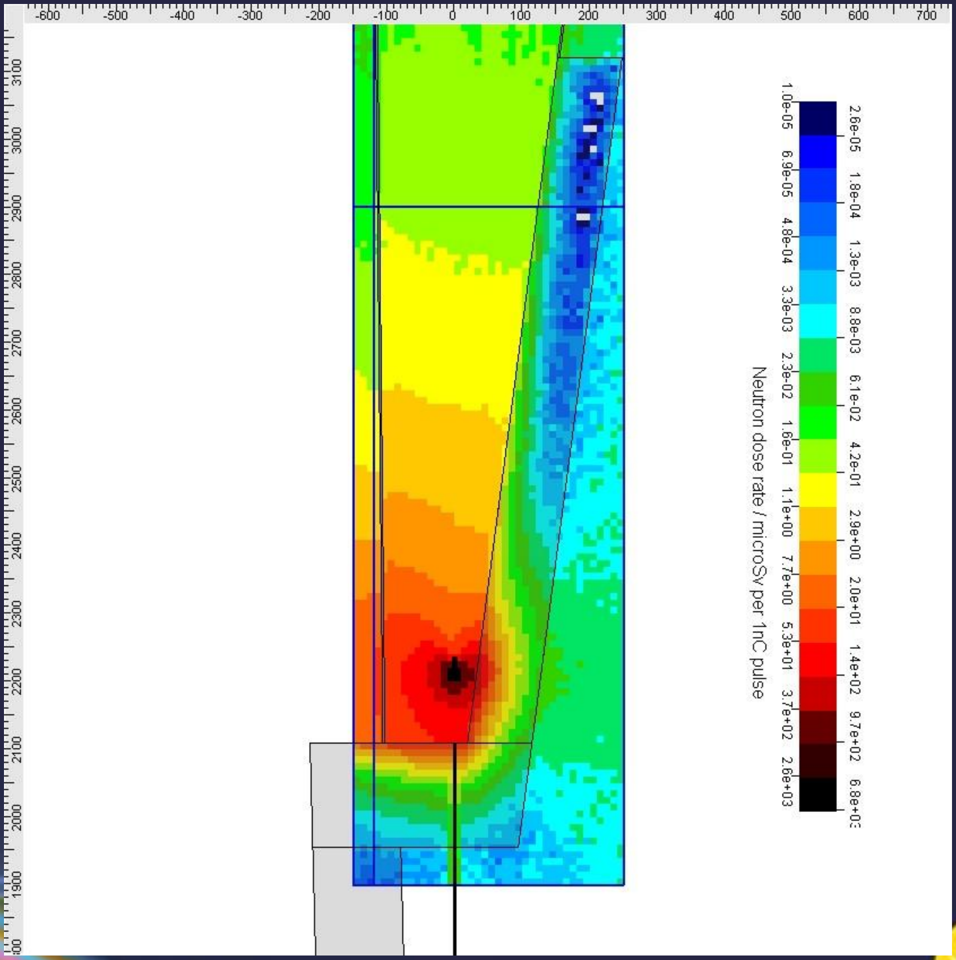
Single pulse - gamma



Single pulse - neutron



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Single pulse results

- Gamma: Max 1.4 μSv nC^{-1} 8 %
- Neutron: Max 24 μSv nC^{-1} 0.6 %

- Typical charge per pulse = 0.1 nC
- Unlikely to trip on instantaneous dose rate – monitors have spike rejection
- Would contribute to integrated dose so doesn't escape detection altogether !

Hazard 3 - summary

- Dose from single 0.1 nC pulse of electrons is not cause for concern

- PSS interlocks on stored beam and injected beam implemented to ensure that this loss mode cannot happen.

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The Measurements…

- Deliberately engineered continuous ‘top-up’ losses (hazard 1 / 2) using beam bumps.

- Scrape beam somewhere upstream of front end – aim for 10 to 20 mA min^{-1} injection rate, may lose ~5 mA min^{-1} at cell of interest

- Measure gamma and neutron dose rates outside optics hutches

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Where ?


Beamline ion chamber – opposite first optical element of beamline
Location of GB collimator
1 0 2
Exit

Which beamlines ?

- Measurements on all operational beamlines, IDs out and in

- I02 just downstream of injection region, can arrange poor injection on top of stored beam

- Other beamlines – have to inject with no stored beam and lose charge locally

Monitors used

Measurement Results

- Didn't see much !
- Difference in results between different beamlines and for IDs in/out not significant
- Typically <1 μSv h^{-1} gamma
- Typically <10 μSv h^{-1} neutron

Measurement Results

- ‘Hot spot’ on hutch side wall tends to be opposite GBC. Caused by off-axis solid target bremsstrahlung striking GBC.

- Gas bremsstrahlung will pass through GBC and scatter off 1st optical element. Later tests without beam bumps confirmed this

- Also see some radiation through ratchet side wall opposite ID

Problems

- Didn’t see much !
- Beam loss location and angle not precisely known – makes detailed comparison with calculations harder (meaningless ?)
- Couldn’t engineer a loss in the right place on dipole beamline B16

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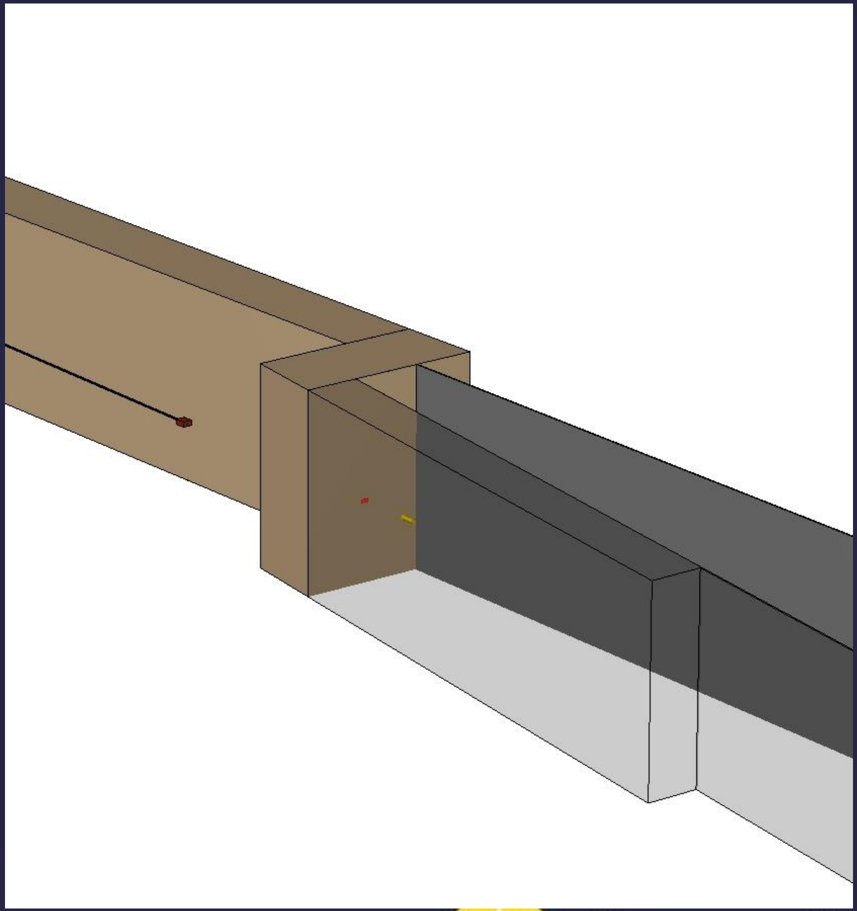
Measurements and model

- Seems that model predicts dose rates at least 10x higher than we actually measure
- Maybe our local electron losses for the measurements weren’t as high as we thought...?
- Maybe the model isn’t good enough…?

Real front end vs model…



Measurements and Modelling - Conclusions

- Calculation results likely to represent ‘worst case’
- Measurements and model agree that neutron monitoring more important than gamma on beamlines for top-up.
- Measurements and model agree that current location of beamline installed monitors may not be optimal.
- Make some changes to safety regime before allowing top-up

Hardware PSS Interlocks

- Top-up requires special key in control panel
- Stored beam > 50 mA
- SR dipole current within 1 % of nominal
- BTS dipole 2 and 3 current within 1 % of nominal (sets limits on injected beam energy - ensures injected electrons cannot be transmitted into any optics hutch)

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Software limits

- Inhibits injection if conditions non-optimal for top-up:
  - No stored beam
  - BTS or SR dipole currents out of range
  - Stored beam lifetime too low
  - SR injection efficiency too low

- Machine operators warned when radiation monitors are approaching integrated dose threshold – can then take preventative measures

Radiation monitoring - 1

- Changed IG1 gamma chambers for IG5 neutron chambers on all beamlines

- IG5 tested in linac vault to confirm response in pulsed field

- More moderated TLDs around optics hutches – opposite GBC and first optics element (monochromator)

Radiation monitoring - 2

- Changed from dose rate control to integrated dose on installed monitors
- Integrate dose over 4-hour periods starting at 9 am: limit 2 μSv h^{-1} per 4-hour period
- Existing alarms on dose rate are still implemented at 4 μSv h^{-1} instantaneous.

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Practical experience to date

- Have only come close to tripping monitors on 4-hour integrated dose during machine development shifts. No problem during user beam
- Relocation of monitors and swap of IG1 to IG5 revealed higher dose rates (up to 15 µSv h^{-1}) outside shielding of injection straight, during injection only.
- Higher integrated doses from more frequent injection raises issues of radiation damage to IDs…topic for a future Radsynch presentation ?

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General Status

- Now 15 operational beam lines (from 7 in 2007).
- Running 250mA top-up mode (from 125mA in decay mode in 2007).

The Future

- TLD experiments looking at doses to components (Insertion Devices) in storage ring.
- More beam lines
- RF cavity test facility opening later 2009.
- Higher beam current?
- Radioactive samples on beam lines (actinides….)

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