Radiation predictions at the SLHC and irradiation facilities

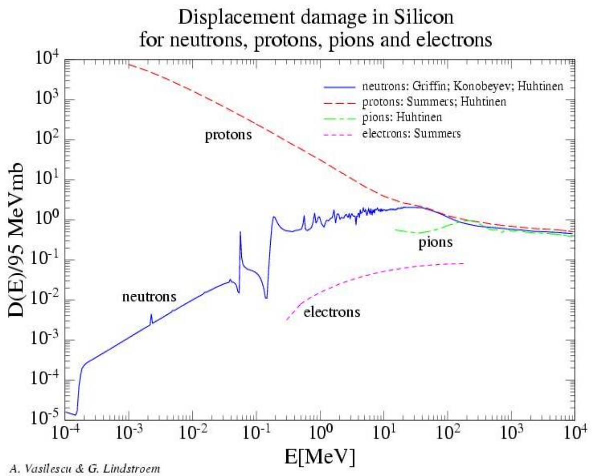
1) Radiation predictions
   - Simulations for the inner tracker
   - Parameterisation of 1MeV-neq fluences
   - Uncertainties/safety-factors
2) Irradiation facilities
   - Proton, pion and neutron facilities, status and plans

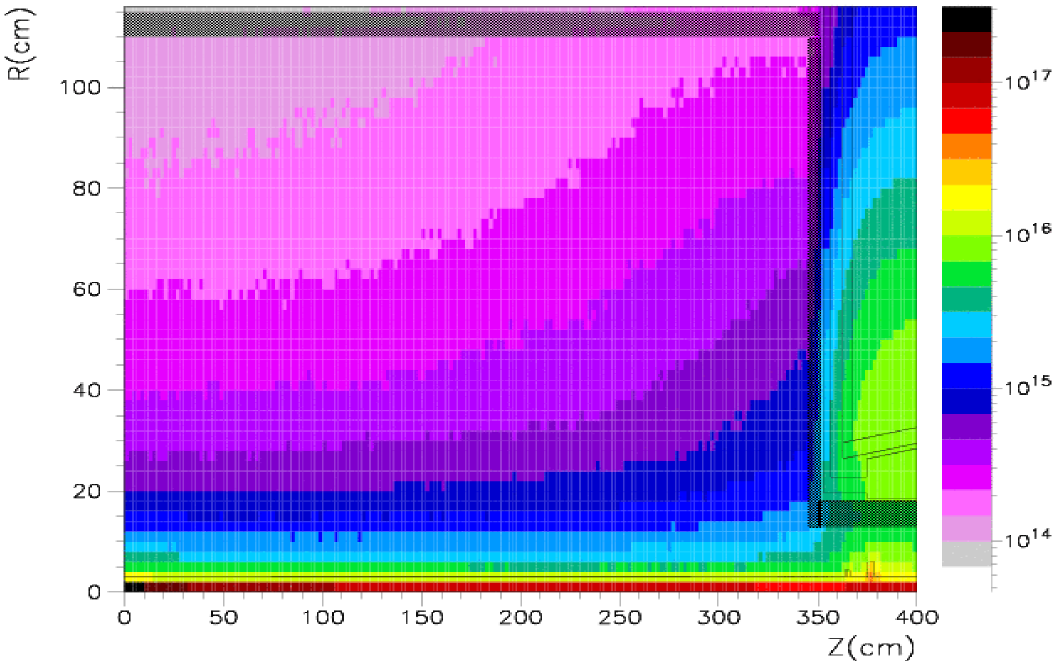
Ian Dawson,
University of Sheffield

ATLAS upgrade workshop,
Liverpool, December 2006

Simulations for the inner tracker

- 1 MeV fluences obtained by convolving particle spectra predicted by FLUKA2006 with "displacement-damage" curves (RD48).



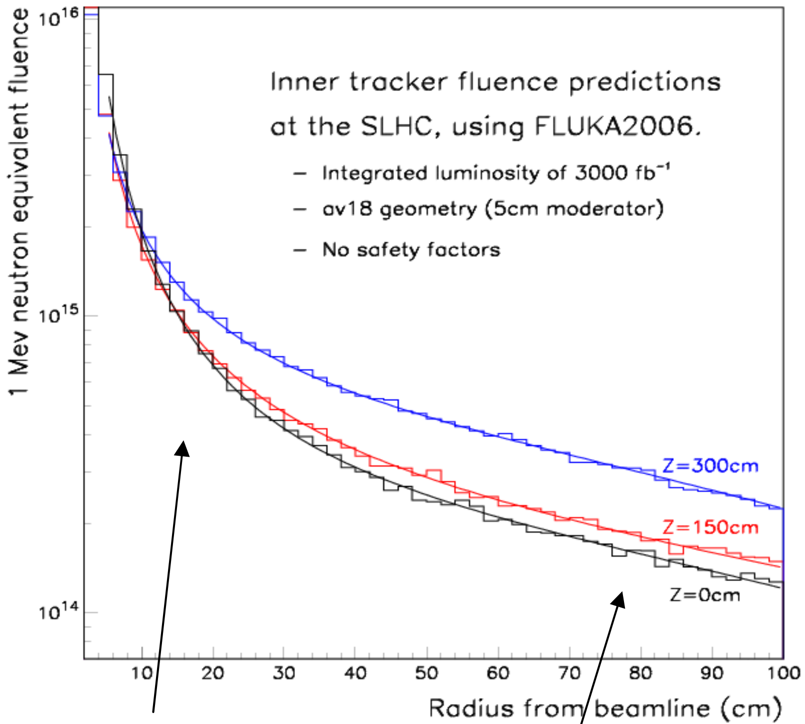


1 MeV equivalent neutron fluences assuming an integrated luminosity of $3000 fb^{-1}$ and 5cm of moderator lining the calorimeters.

- **av18** is current baseline geometry for upgrade studies
  - 5cm neutron moderator lining all the calorimeters
  - no tracker material

→ The beneficial moderating effect of the TRT is lost in an all silicon system. Can be recovered with 5cm of moderator lining barrel (as shown in Genova).

Parameterisation of 1MeV-neq fluences



Fluences at small radii dominated by particles from interaction point.

Fluences at larger radii dominated by neutron-albedo, greatest near endcaps.

- Several requests to **parameterise** inner tracker backgrounds.

$$\Phi(r) = \frac{a_1}{r^2} + \frac{a_2}{r} + a_3 + a_4 \cdot r$$

Z(cm)	a_1	a_2	a_3	a_4
0	1.4×10^{17}	3.7×10^{15}	1.7×10^{14}	-1.0×10^{12}
150	7.0×10^{16}	9.5×10^{15}	9.7×10^{13}	-5.7×10^{11}
300	4.9×10^{16}	1.2×10^{16}	3.0×10^{14}	-2.0×10^{12}

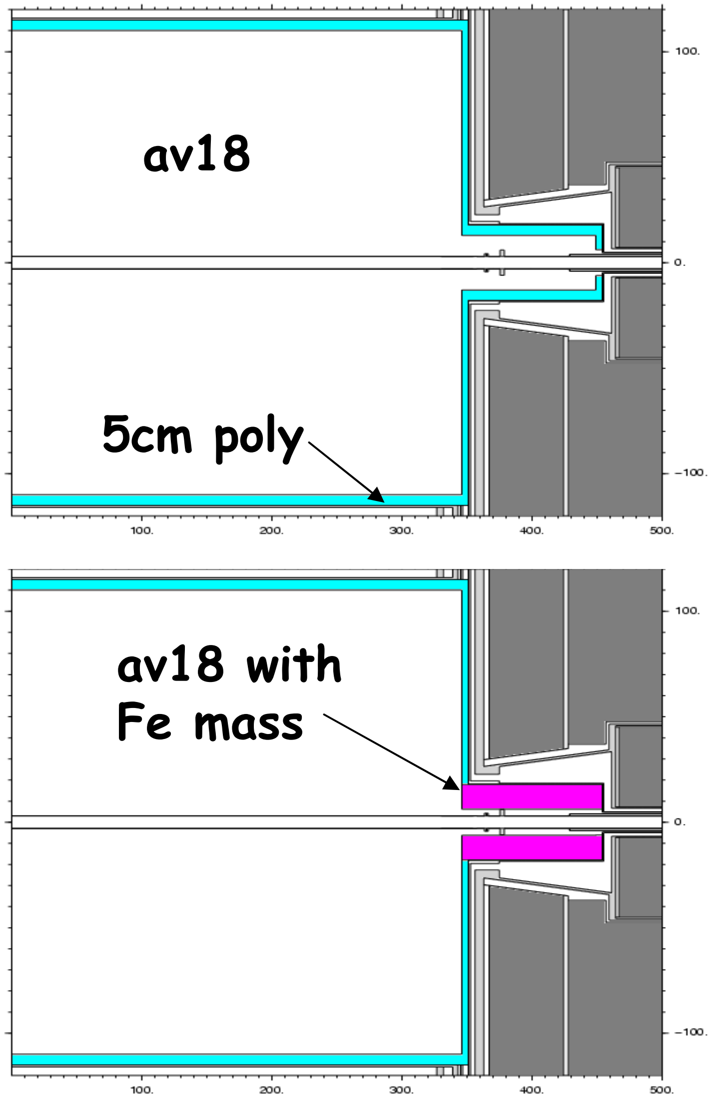
- Parameterise also pion and neutron contributions separately.

- Use these types of plots for future investigations (Eg moderator design, impact of extra material etc.)

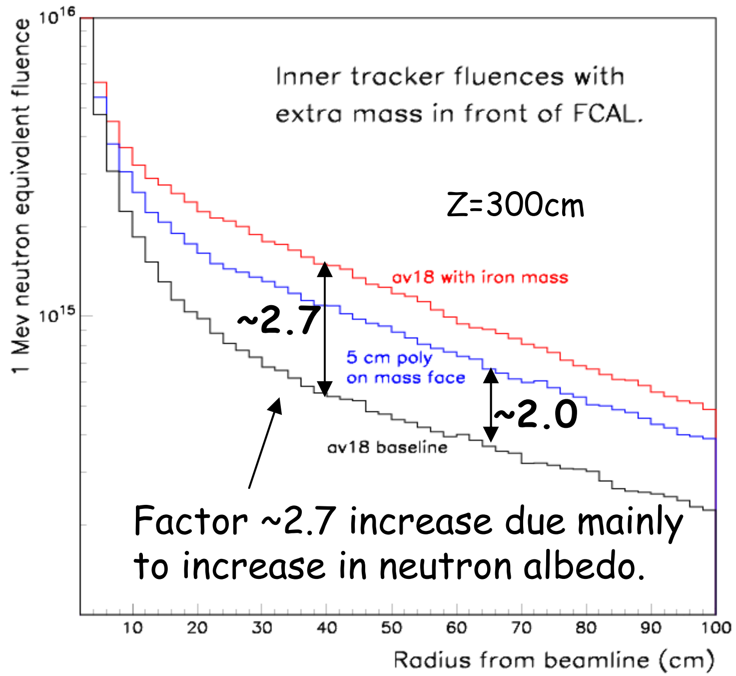
Uncertainties/Safety-factors?

- Until we have better benchmarking data, the uncertainties assumed at the LHC still apply.
  - Event generators ~20%
  - Transport codes ~20%
  - Displacement damage cross sections ~50%
- At the SLHC, the goal seems to be 3000fb^{-1} for the integrated physics luminosity. What safety factors do we assume?
  - At present, 2 × 3000fb^{-1} being used
- Also, until we know what an upgraded detector and machine look like, there may be additional contributions to inner tracker fluences …

Impact of additional mass in front of FCAL on Inner Tracker fluences



- Can 'alcove' region in front of FCAL be used for machine magnets?
  - → Look at 1MeV-neq fluences in tracker volume. (Saying nothing about FCAL).
- Fill 'alcove' with iron. Should be pessimistic? If so, results below give worse case?



Irradiation facilities

- In some cases, irradiations best done through RD50 framework, particularly for sensor R&D.
  - Strong links with many irradiation facilities
  - Lots of experience, expertise and support
- But in many cases, ATLAS groups will want to pursue their own irradiation programmes.
  - Limited beam times available for irradiations so strong coordination with CMS and RD50 etc. will still be necessary.
  - Beam time requests usually have to be planned well in advance.

Irradiation Facilities

The following list contains irradiation facilities made available to members of the RD50 collaboration:

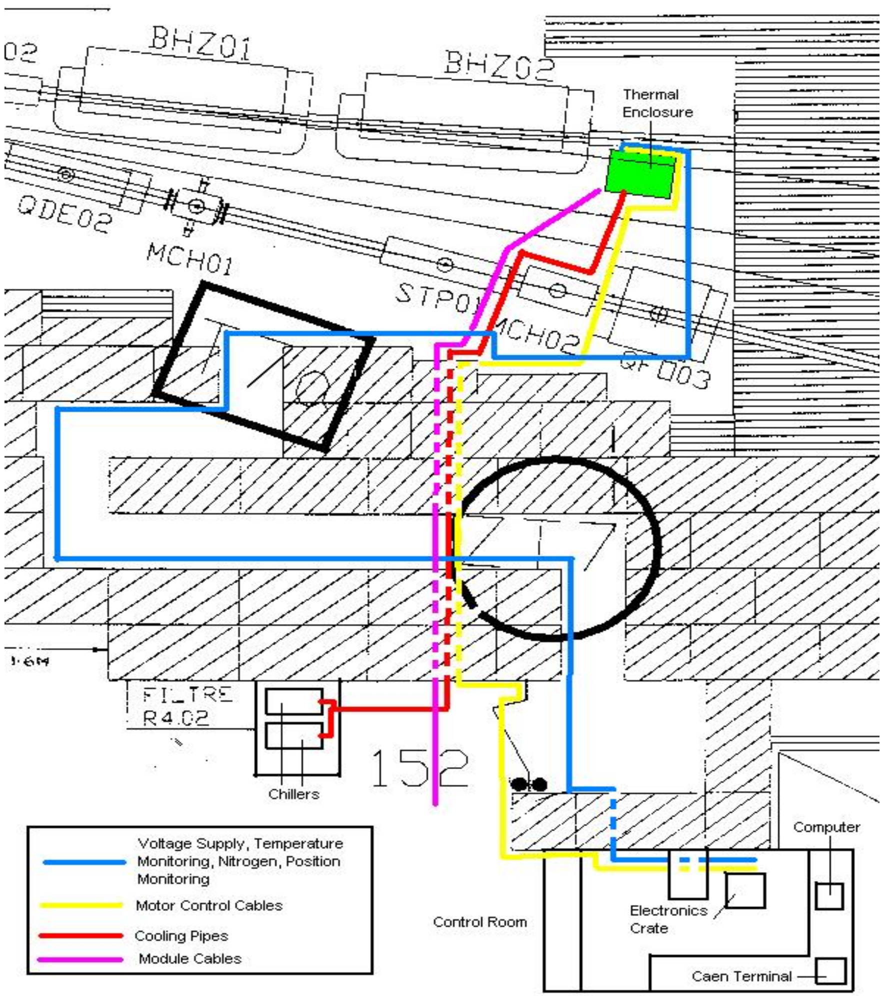
- BNL (Gamma 1.17 and 1.33 MeV)
- CERN (24 GeV/c protons, 1 MeV neutrons) ←- - - - - - - - - - -
- NCSR "Demokritos" (Gamma, protons, neutrons)
- Paul Scherrer Institut (300 MeV/c pions) ←- - - - - - - - - - -
- Université catholique de Louvain (Neutrons 1 to 70 MeV, Protons 10 to 75 MeV, Heavy Ions)
- University of Karlsruhe (26 MeV protons)
- University of Ljubljana (Neutrons) ←- - - - - - - - - - -
- Université de Montréal (Protons up to 11 MeV, ions up to 5.5 MeV/charge)
- University of New Mexico (Gamma, Neutrons)
- University of Padua (27 MeV Protons, 58 MeV Lithium ions, 102 MeV Carbon ions, heavier ions)
- Uniwersytet Warszawski (Heavy ions from 22 to 190 MeV)
- Uppsala universitet (Protons 500 keV to 10 MeV, ions 1 to 50 MeV)

Tohoku University (70MeV protons) ←- - - - - - - - - - -

Link: ATLAS-Radhard

This list is presently maintained by Michael Moll.

Proton Irradiations at CERN



PS Proton Beam

- Beam energy : 24 GeV
- Beam spot : 2×2 cm^2

Standard Flux

- $1\text{-}3 \times 10^{13}$ p cm^{-2} h^{-1}
- 4 days to reach 10^{15} p cm^{-2}

High Flux

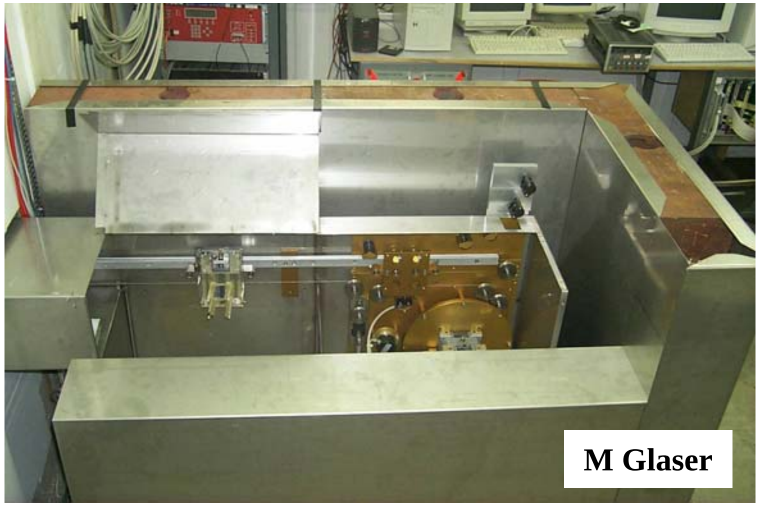
- $6\text{-}8 \times 10^{13}$ p cm^{-2}h^{-1}
- 1 week to reach 10^{16} p cm^{-2}
- Max sample size 1×1 cm^2

T7 facility is run by Maurice Glaser (CERN/PH/DT2/SD)

Proton Irradiations at CERN

IRRAD1

- No restriction on access as it's a shuttle system
- Good for small area high flux irradiations
- But no cooling or bias.



IRRAD5

- Restricted access.
- Designed to power and cool (down to -7°C) ATLAS SCT sensors and modules.
- Box scanned through beam (scanning area = 7 x 7 cm^2)

Proton Irradiations at CERN

- Four irradiation periods requested in 2007 by the PH/DT2/SD group at CERN.
  - P1 : 4 weeks in May with high flux for SLHC tests
  - P2 : 3 weeks in July, standard flux
  - P3 : 3 weeks in August, standard flux
  - P4 : 4 weeks in October with high flux for SLHC tests
- If you want to irradiate in 2007 using CERN's facilities, contact: Maurice.Glaser@cern.ch
- The CERN proton facilities should be available for 2008 and beyond. Deadline for requests for the following year usually in October.

Proton Irradiations at Tohoku University, Japan

AVF Proton Cyclotron

- Beam Energy : 70 MeV
- Target area: 1 × 1cm

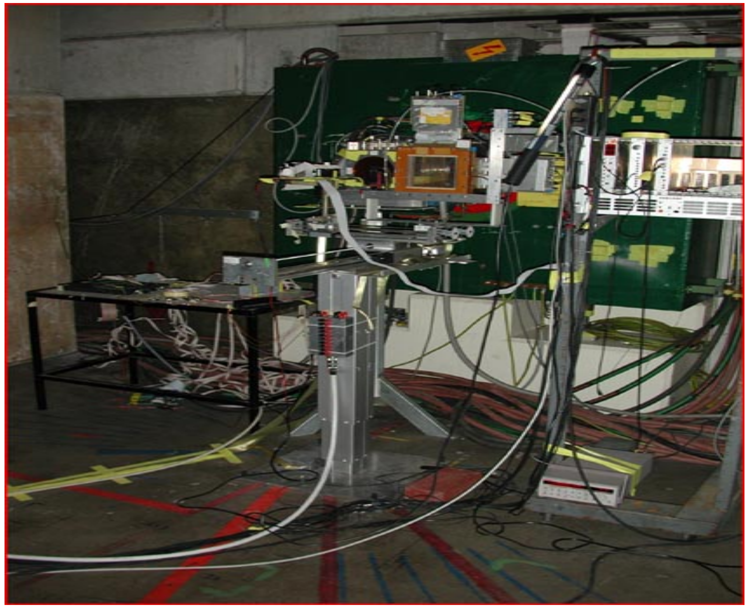
Flux

- 1.0×10^{16} neq cm^{-2} in 5 hours

- Biasing and cooling of detectors possible.
- Restrictions on amount of material to be irradiated.
- Use of facility based on submitted proposals
  - 4 days allocated to KEK-ATLAS group for period April 06 -> March 07

PSI Pion Irradiations

- Radiation backgrounds at LHC/SLHC dominated by charged pions close to interaction point.



PSI Pion Beam

- 5cm along beam line
- Beam Energy : 191 MeV
- Beam Spot: 16mm × 13mm

Flux

- 1.5×10^{14} pions cm^{-2} day^{-1}
- 7 days to reach 10^{15} pions cm^{-2}

- RD50 applied for beam time in 2007. Aiming for fluence of 2×10^{15} pions cm^{-2} .
- Any requests for 2008 should be coordinated with RD50, CMS etc.

Neutron Irradiations at Ljubljana

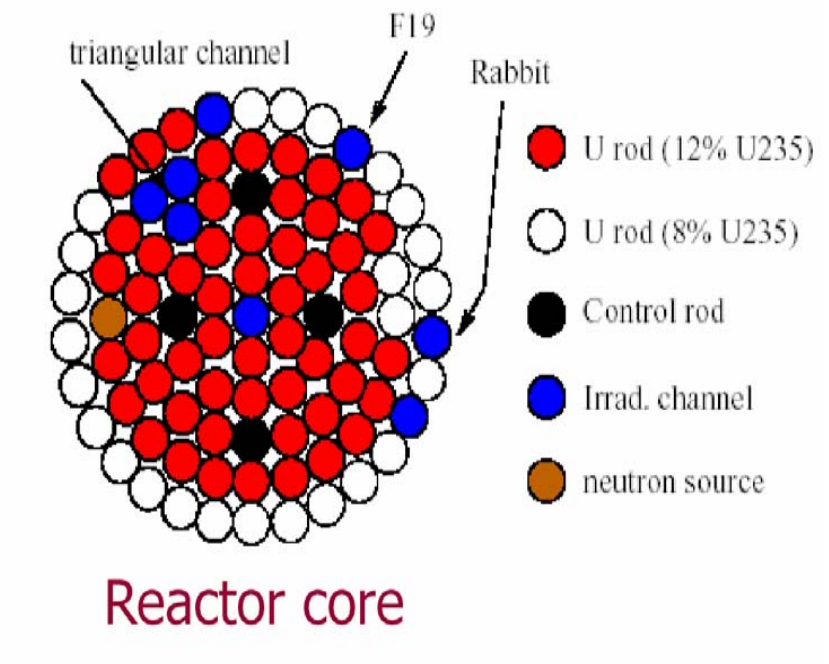
- Samples are irradiated by placing them in the core of a nuclear reactor

Pros

- Very high 1MeV-neq fluences can be obtained.
  - E.g. ATLAS SCT electronics irradiated at reactor power of 25kW, resulting in fluence of 1×10^{13} n/cm^2 in 22 seconds.
- Facility run by colleagues on ATLAS. For information, contact Vladimir.Cindro@ijs.si

Cons

- Sample lengths limited to 15cm.
- Readout and cooling difficult.
- High activation of samples .



Two irradiation sample tubes

- Circular - 2.2cm diameter
- Elliptical - 7×5cm axis lengths

To summarise (1)

Simulations

- Simulation framework set-up to allow SLHC radiation background studies using FLUKA2006, focusing on inner tracker.
  - In near future would like to start looking at moderator design and optimisation.
- Looked at impact of adding material in front of FCAL, investigated impact on inner tracker fluences.
  - 1Mev-neq fluences increase by factors ~2.7 and ~3.2 for iron and copper masses respectively.

To summarise (2)

Irradiation facilities

- Most facilities capable of reaching 1MeV-neq fluences of ~ 10^{15} on reasonable timescales. Reaching 10^{16} more problematic:
  - Possible at CERN/PS 24 GeV proton facility
  - Easy at Tohoku (70MeV) and Karlsruhe (40MeV) proton cyclotrons
  - Easy in Ljubljana nuclear reactor neutron facility
- Irradiating over larger areas will be difficult.
- Cooling and biasing of detectors often available, in particular for proton irradiations. Requirements should be discussed with facility managers.
- Activation of irradiated SLHC components will get worse!