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Note technique
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Attenuation of Radiation in the Access Labyrinths and Service Ducts between the ATLAS Experimental and Service Caverns

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Abstract

This note presents calculations for the ATLAS experimental area made using the FLUKA96 code to determine the attenuation of radiation passing through the access labyrinths and service ducts connecting the experimental cavern to the service cavern. A detailed geometry description of the ducts has been used in this assessment and requests for modifications made, when necessary, to reduce radiation levels below the design limits in the service cavern. A comparison between these detailed calculations and previous estimates based on the so-called "universal curves" shows good agreement.

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1. Introduction and geometry description

The ATLAS experiment will be located at Point 1 of the LHC collider. The civil engineering design for the underground areas has been completed and detailed calculations of radiation levels and the propagation of radiation through the many cable-ducts and access-ways are necessary to confirm that design levels have been respected.

A general view of the underground area is shown in Figure 1. The existing LEP pits (PM15, PX15) are shown together with all the LHC constructions including the experimental and service caverns and the service ducts and labyrinths (UJ14, UL14, US 15, UL16, UJ16) . The propagation of radiation through the large shafts (PX14 and PX16) and the consequent dose rates in the assembly hall (SX15) at the surface level (80 m above the detector) were calculated in a previous report [1]. The present paper is mainly concerned with the passage-ways connecting the experimental cavern (UX15) and the side service cavern (USA15). These passage-ways will be used for the access of personnel and the installation of cables; they differ in cross-sectional area and length, according to their final use.

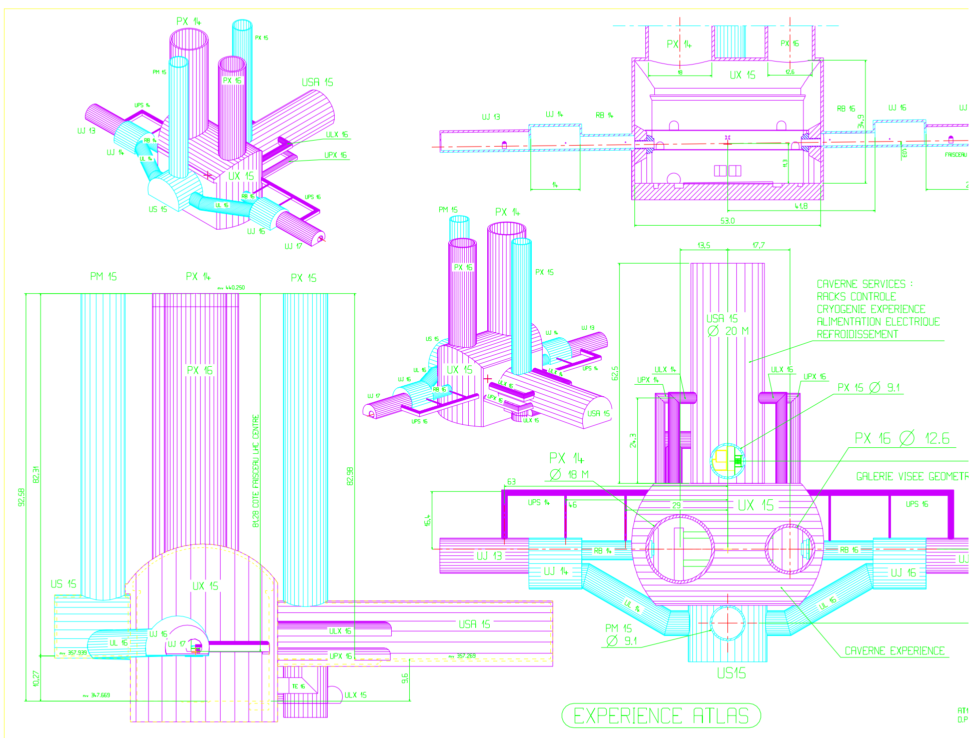

Figure 1: The ATLAS experimental area at LHC Point 1.

Details of these different types of passage-ways are shown in Figure 2. At the floor level of the experimental cavern, it is possible to see (coupe AA) the personnel access-way (ULX15) connecting the cavern to the lift inside the shaft PX15. A gate will be installed between the exit of the lift and the entrance to the tunnel to forbid access to the tunnel and the experimental cavern when the beam is on.

The main cable ducts (TE14 and TE16) are shown in coupe BB of Figure 2. These are two large ducts of rectangular cross-section departing at 30° from the experimental cavern in the horizontal plane and 2 m above the floor of the cavern: they then bend vertically to enter the service cavern

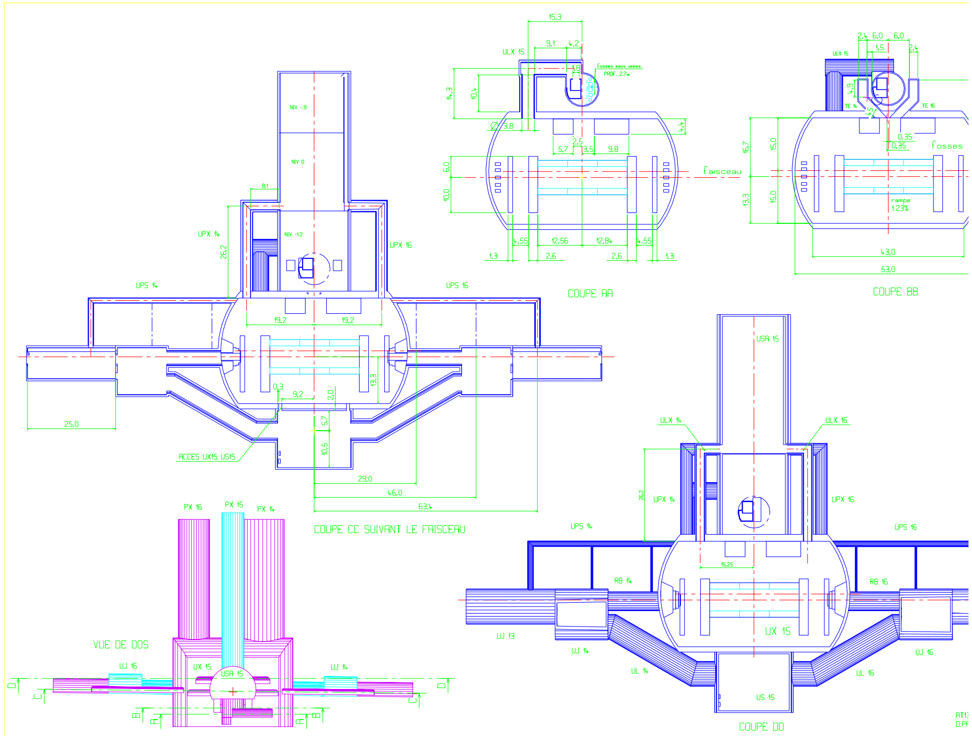

Figure 2: Details of the access-ways to the experimental area at Point 1.

via its floor which is about 8 m higher, as shown in Figure 3.

At the beam level there will be two passage-ways (UPX14 and UPX16). One of them will be used for personnel access and the other for cables and other services. Connecting the higher level of the experimental cavern and the third floor of the service cavern, there will be two further passage-ways (ULX14 and ULX16), with dimensions similar to those below but with a shorter second leg, used entirely for the installation of services. As for ULX15, all these passage-ways will be closed by gates at the service cavern end to prevent access when the LHC beam is operational.

Finally there will be four straight circular ducts, with a diameter of 30 cm, where the trigger cables will be housed. These ducts pass through the main shield walls in a skew fashion at 45°.

2. FLUKA simulations

The calculations were carried out with the 1996 version of the particle interaction and transport code FLUKA (see Fassó *et al.* [2, 3]). The program has been used to simulate the hadronic component of the particle cascade in the underground caverns, the ducts and the main shielding wall. The electromagnetic cascade was omitted in the present studies since the aim was only to provide a measure of the attenuation in the ducts.

The geometry is described in a right-handed orthogonal system with its origin at p-p interaction point; x is the vertical axis and y points towards the centre of the LHC ring. The z axis coincides with the beam.

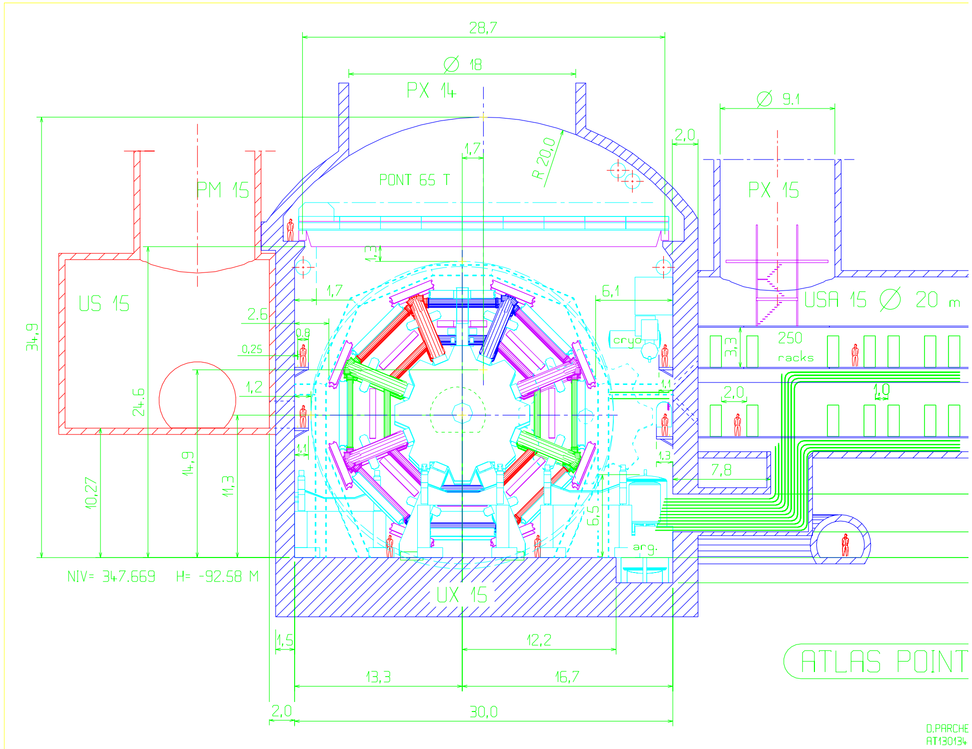

Figure 3: ATLAS vertical cross-section.

Ambient dose equivalent due to neutrons, protons and charged pions has been derived directly from their fluences by multiplying the latter by energy dependent conversion coefficients, as given in the paper by Huhtinen and Stevenson [4].

The lower energy thresholds for particle transport were chosen taking into account the dose equivalent conversion factors. They were set to 1 MeV for all hadrons except neutrons which were followed down to 0.414 eV.

Concrete in the lining of the ducts and the main shielding wall was assumed to have a density of 2.35 g / cm^3 and with the following chemical composition (the values in brackets give the corresponding mass fractions): oxygen (50.0%), silicon (20.0%), calcium (19.5%), aluminium (3.0%), iron (1.4%), hydrogen (0.6%), carbon (3.0%), sodium (1.0%), magnesium (0.5%) and potassium (1.0%). Air in the caverns and ducts was replaced by vacuum to speed up the simulations.

Particle back-scattering from the concrete walls of the tunnels was taken into account by approximating the walls by a layer of concrete with a thickness of 30 cm. The rock behind this layer was treated as ”black hole”, *i.e.* as a region absorbing all particles which enter into it.

To enhance the statistical significance of the results for the radiation environment in the service cavern, the particle transport through the main shielding wall was strongly biased. For this purpose the main wall was subdivided into slices of 20 cm thickness to force an increase of the particle population (together with a decrease of their weight) by increasing the region importances by about a factor of 1.4 behind each slice. This factor compensates for the exponential attenuation in the concrete wall, keeping the history population roughly constant. Region importances in the tunnels were increased by a factor of three at depths determined with the “universal curves” [5]. Importances in the duct walls were reduced by a factor of three with respect to the adjacent tunnel regions.

In order to reduce the simulation time, the real radiation field in the experimental cavern generated by the cascades of secondaries from the p-p collisions was not used. Instead a source file was written of particles leaving a concrete cylindrical shell of 5 m outer radius and 50 cm thickness in which an axial cylindrical iron target of 5 cm radius was struck by 100 GeV protons. As the particles were read from this source file for use in the duct attenuation simulations, the z co-ordinate was chosen from a region of values which covered the appropriate duct entrance, the x and y direction cosines were reflected so that the particles were directed towards the duct entrance and the x and y co-ordinates translated so that the particles came from the nearest quadrant.

3. Attenuation in the ducts.

Since the dose rate in the service cavern is governed by the thickness of the main shield wall which has a thickness of 2 m, the attenuation in the ducts will be judged by comparing the attenuation provided to that of the main shield which reduces the radiation level by more than a factor of 55. In this report, a duct design will be considered as satisfactory if it gives an attenuation factor of 100.

3.1 Attenuation in UPX14/16

UPX14 and UPX16 are the access ways at the ground-floor level of the service cavern. Results of the simulations for the ducts are shown in Figure 4. Each colour change represents an attenuation of one order of magnitude. It will be seen that the attenuation in these shafts easily meets the design goal of two orders of magnitude.

3.2 Attenuation in ULX14/16

ULX14 and ULX16 are the service ducts at the first-floor level of the service cavern. Results of the simulations for the ducts are shown in Figure 5. As before each colour change represents an attenuation of one order of magnitude. The second leg of these ducts is shorter that that of UPX14/16, but the attenuation in these shafts still easily meets the design goal of two orders of magnitude.

3.3 Attenuation in ULX15

The ULX15 labyrinth is the large service access at the ground-floor level of the experimental cavern. Results of the simulations for this duct are shown in Figure 6. There are two colour changes per order of magnitude. The attenuation in this access-way easily meets the design goal of two orders of magnitude.

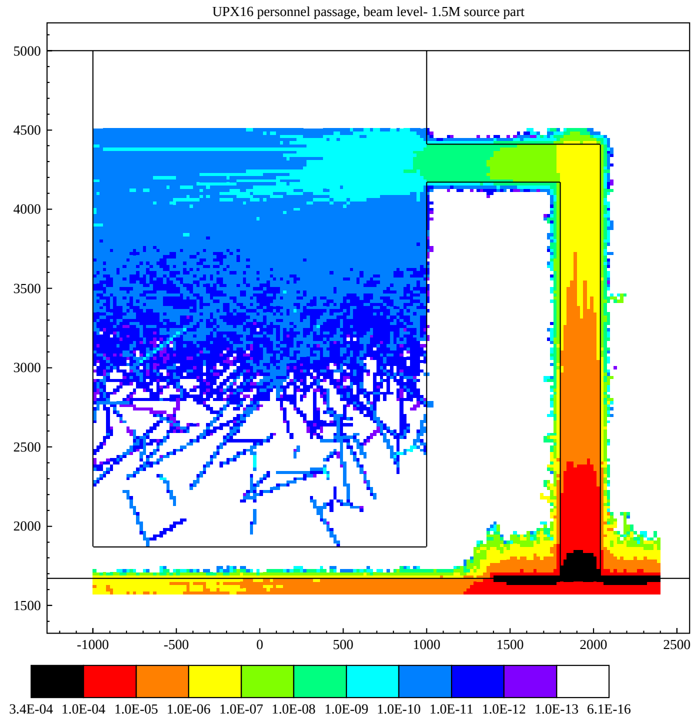

Figure 4: Dose attenuation in UPX16. All dimensions are in cm.

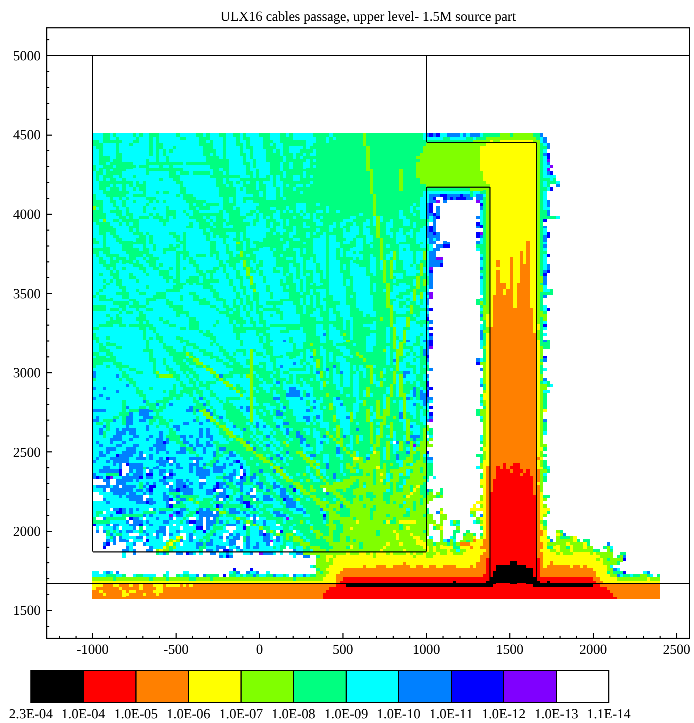

Figure 5: Dose attenuation in ULX16. All dimensions are in cm.

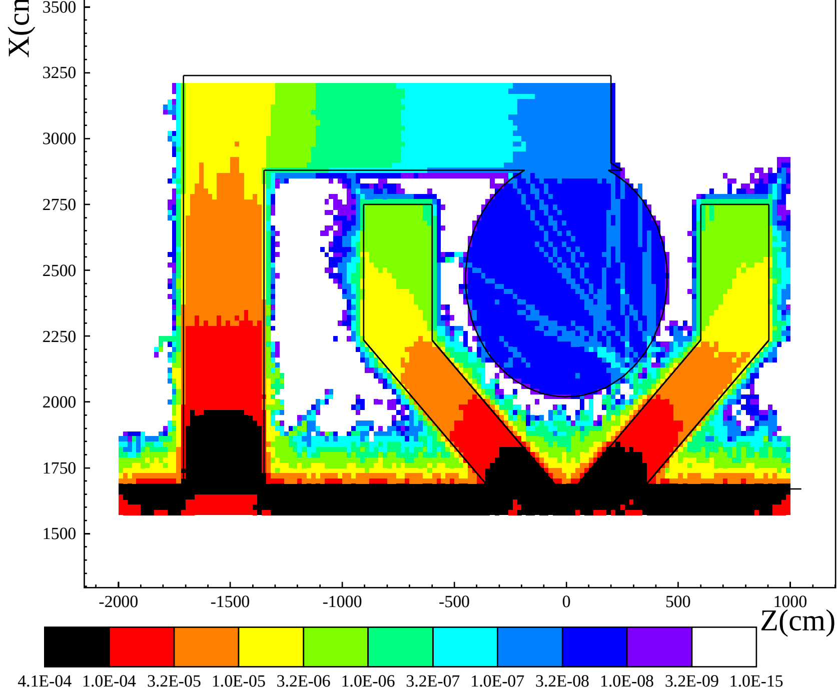

Figure 6: Dose attenuation in ULX15, TE14 and TE16 (horizontal cut).

3.4 Attenuation in TE14/16

TE14 and TE16 are the two large cable ducts above the floor level of the experimental cavern. Results of the simulations for these ducts are shown in Figure 6, with the second leg shown in Figure 7. There are two colour changes per order of magnitude. The attenuation in these ducts just exceeds that required to meet the design goal of two orders of magnitude.

3.5 Attenuation in trigger cable ducts

The attenuation in the trigger cable ducts is shown in Figure 7. The upper figure shows a section through the plane of the ducts. There are two colour changes per an order of magnitude. The attenuation only just meets the design goal of two orders of magnitude. The lower figure shows a contour of the dose in the last slice of the main shield wall on the service cavern side. The effect of the reduction in the efficiency of the main shield by replacing concrete by the unfilled ducts is clearly visible. However, when partially filled with cables, the attenuation will be greater than in the present simulation where the ducts contained only vacuum.

3.6 Summary

The attenuation provided by the different ducts and access-ways is summarized in Table 1 and plotted in Figure 9. All meet the design criteria, and all but the trigger cable-ducts have sufficient safety margins. Estimates obtained using the “Universal” curves [5] are also given. There is very good agreement between these estimates and those obtained by using FLUKA.

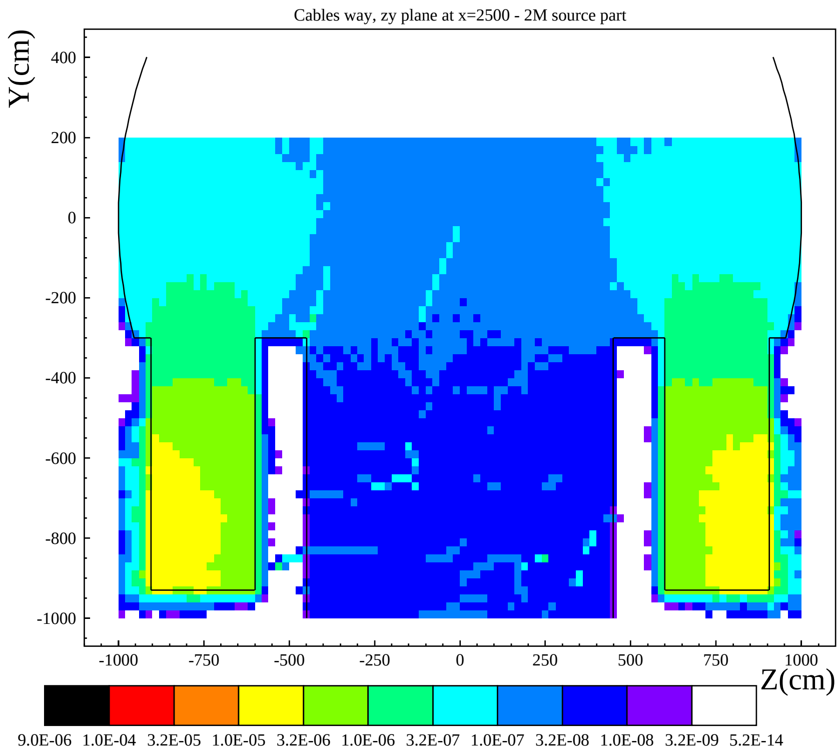

Figure 7: Dose attenuation in TE14 and TE16 (vertical cut).

Table 1: Dose attenuation factors for the different ducts.

Duct	Radius (cm)	Length of first leg d1 (cm)	Length of second leg d2 (cm)	Attenuation "Universal" Curves	Attenuation FLUKA
ULX15	190	1390	1730	$\approx 1.0 \times 10^{-4}$	$1.6 \times 10^{-4} \pm 5\%$
UPX16	120	2620	920	$\approx 1.0 \times 10^{-5}$	$9.0 \times 10^{-6} \pm 8\%$
ULX16	140	2640	520	$\approx 1.0 \times 10^{-4}$	$1.2 \times 10^{-4} \pm 6\%$
TE16*	300×300	800	800	$\approx 1.0 \times 10^{-3}$	$8.1 \times 10^{-4} \pm 3\%$
Trigger	15	280	–	$\approx 3.0 \times 10^{-3}$	4.0×10^{-3}

$*$ Square section

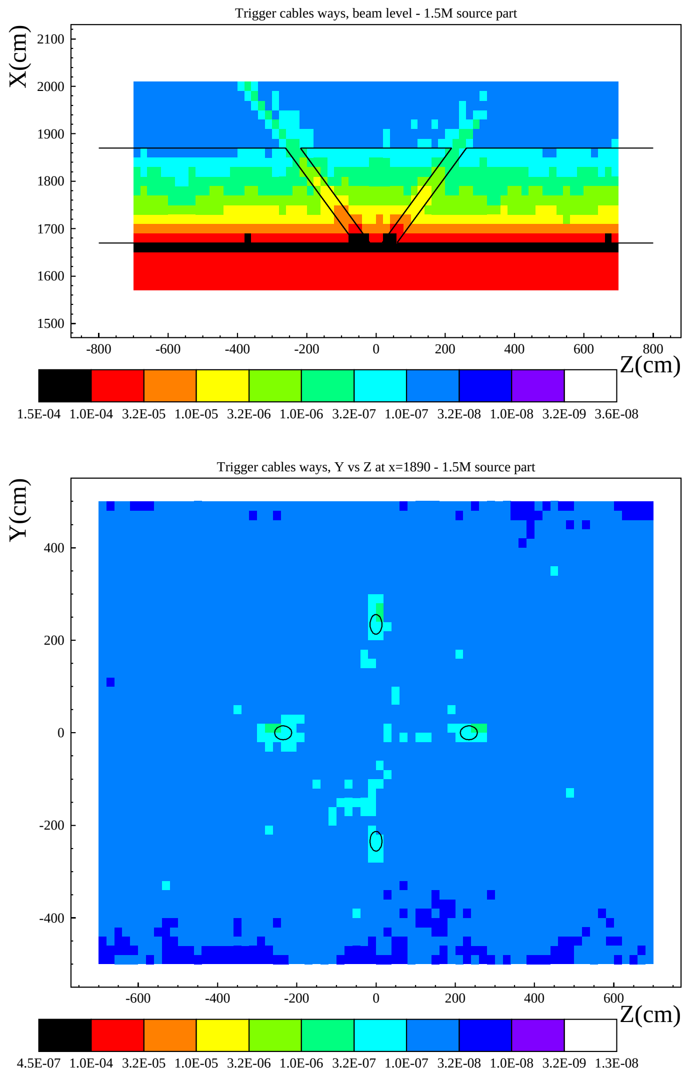

Figure 8: Dose attenuation in the trigger cable ducts.

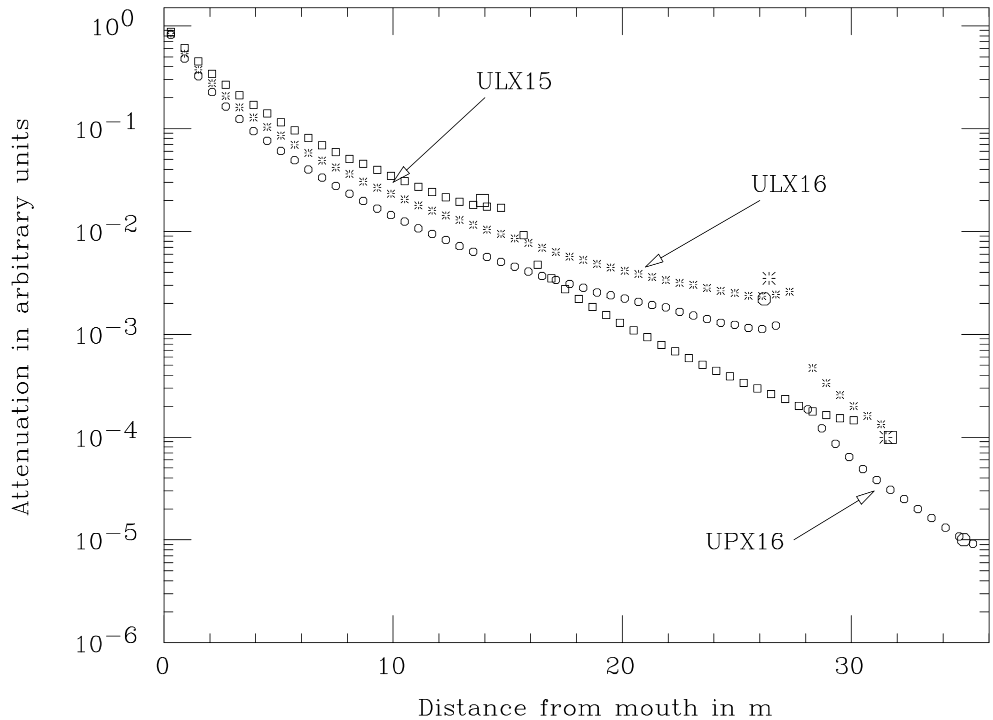

Figure 9: Dose attenuation in the major ATLAS ducts. Open circle – UPX16; open squares – ULX16: stars – ULX15. The larger symbols represent the estimates made using the “Universal” Curves

Acknowledgements

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