The Concept of the ATLAS Liquid Argon Purity Monitoring System


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Abstract

In this note we present the two types of liquid argon purity monitors, the basic monitor using radioactive sources and the laser chamber monitor, which will be implemented in ATLAS. The monitors operate at a purity in the order of 1 ppm oxygen equivalent with a resolution and stability of < 0.1 ppm. The positions of the basic monitors in the ATLAS cryostats and the locations for the laser chamber monitors in contact with the liquid argon of the cryostats are presented. The numbers of cables and feedthrough connections for the 10 basic monitors per end cap cryostat and for the 9 basic monitors in the barrel cryostat are given.

1 Introduction

The signal of drifting electrons in liquid argon detectors is decreased by recombination and by the attachment of electrons to electronegative molecules like O\textsubscript{2}, called "impurities" [1]. While the mean recombination rate is constant for a fixed electric field and geometry the concentration of impurities has to be controlled since a possible change effects the resolution of the calorimeter. For homogeneously distributed impurities the attachment process is determined by a rate constant [1] which can be converted into a finite lifetime \( \tau \) of the electrons. Therefore the time depending amount of drifting charge \( Q_{\text{ideal}}(t) \) in the calorimeter gap is reduced by an exponential factor:

\[
Q_{\text{see}}(t) = Q_{\text{ideal}}(t) e^{-\frac{t}{\lambda}}.
\]

The life time \( \tau \) corresponds to a mean free path length \( \lambda \) for the absorption of conduction electrons by impurities in liquid argon according to

\[
\lambda(|\vec{E}|) = v_D(|\vec{E}|) \tau(|\vec{E}|).
\]
with $v_D(\bar{E})$ being the electron drift velocity in an electric field $\bar{E}$.

Since the calorimeter signal depends on the current $I_{cen}(t) = Q_{cen} v_D / d$ with the gap width $d$ and therefore on the charge collected during a specific shaping time $t_s$, it is necessary to monitor the variations in the electron lifetime $\tau$ to achieve a stable calibration of the calorimeter.

According to ref. [2] an estimation of the O$_2$-equivalent concentration of impurities $p$ is possible using the formula:

$$p = \alpha \frac{E[kV/cm]}{\lambda[cm]} \quad \text{with} \quad \alpha = 0.15.$$  

Since the calorimeter electronics is designed to minimize the effect of impurities, special monitoring devices highly sensitive to the electron lifetime $\tau$ are necessary.

In the past, different purity measuring devices were developed with different interests in mind [5, 6]. All are chambers using the signal of drifting electrons in a homogeneous electric field. One type uses ionizing particles from radioactive sources to produce the electrons [2, 4], the other type creates photoelectrons by UV laser light shining on a metal cathode [3]. Both the prototypes of the so called $\alpha$- or $\beta$-chambers and the so called laser chamber will be described below. The laser chamber has the advantage to measure directly and simultaneously the electron lifetime and the drift velocity as opposed to the $\alpha$- and $\beta$-chambers which only allow a relative determination of the electron lifetime. Therefore the laser chamber provides the calibration for the source based chambers.

The purity monitoring concept for the three liquid argon cryostats of ATLAS foresees the installation of several basic monitors, which are combinations of $\alpha$- and $\beta$-chambers, inside the cryostats close to the calorimeters, and one laser chamber in contact with the liquid argon of each cryostat. This concept includes cold preamplifiers for most of the monitors as described below.

For testing and developing purposes a suitable vacuum and cryogenic system has been set up at the Mainz physics institute. This equipment may also be used to measure poisoning effects due to materials brought into the liquid argon.

Furthermore a moveable purity measuring system using our probes has been designed at Mainz and is being constructed. In the future it may be used to examine samples of liquid argon for impurities.

## 2 Purity Monitoring Devices

### 2.1 The Basic Monitor

#### 2.1.1 Dynamics of the $\alpha$- and $\beta$-chamber

Figure 1 shows a schematic view of both ionization chambers.

![Schematic view of the $\alpha$- and the $\beta$-chamber.](image)

In the $\alpha$-chamber strongly ionizing $\alpha$-particles from an $^{241}$Am source produce electron ion pairs in the liquid argon within approximately 100 $\mu$m in front of the
LARG-Note: Purity Monitoring System

cathode. The quasi pointlike electron charge drifting in the electric field \( \vec{E} \) induces a signal on the anode which is converted into a voltage signal by a charge sensitive preamplifier. The ratio of measured charge to the total charge produced is given by

\[
\frac{Q_{\text{meas}}}{Q_0} = \frac{\lambda}{d} \left( 1 - e^{-d/\lambda} \right) \frac{2f}{\sqrt{\pi}} \int_0^\infty x \frac{\sqrt{x}}{f^2 + 1} \, dx
\]

with the gap width \( d \) and \( f = |\vec{E}|/|\vec{E}_{\text{sat}}| \), the ratio of the applied field to the saturation field \([7, 2]\). The second term accounts for recombination which cannot be neglected for high spatial electron ion pair concentrations.

Since the second term remains constant for a given electric field it is possible to monitor changes in the mean free path length for absorption \( \lambda \) and thus the stability of the liquid argon purity. Using special fast readout electronics it is possible to extract the electron drift velocity and lifetime from the signal shape \([25]\). This possibility will also be looked into.

The \( \beta \)-chamber exploits the fixed energy of the conversion electrons from a \(^{207}\)Bi source mounted on the cathode to produce an approximately 3 mm long track of electron ion pairs. The electrons drift towards the anode passing a Frisch grid which electrically shields the anode from the first gap. Electrons in the second gap induce a signal on the anode which again is converted to a voltage signal by a charge sensitive preamplifier.

Because of the more complex geometry the expression for the charge yield \( Q_{\text{meas}}/Q_0 \) becomes more complicated \([8]\). However, with the electron being a minimum ionizing particle, the recombination term hardly contributes to the \( \vec{E} \)-field dependence.

The \( \beta \)-chamber allows to monitor the stability of the mean free path length \( \lambda \) as well as an estimation of its absolute value using data from a HV-scan \([2]\). In addition, the determination of the effective mean ionisation energy, the \( W \) value, is possible.

2.1.2 Mechanics of the Basic Monitor

The basic monitor consists of one \( \alpha \)- and one \( \beta \)-chamber together with a board for HV blocking resistors and two preamplifiers. Everything is mounted on a solid stainless steel plate. The entire assembly is mechanically shielded by a case of perforated stainless steel sheets. For the complete basic monitor two alternative outer envelopes have been defined:

<table>
<thead>
<tr>
<th>type</th>
<th>name</th>
<th>height x width x length</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>'compact'</td>
<td>90 x 65 x 120 mm$^3$</td>
</tr>
<tr>
<td>B</td>
<td>'flat and long'</td>
<td>40 x 65 x 220 mm$^3$</td>
</tr>
</tbody>
</table>

Figure 2 shows a picture of the current prototype. The chambers are made out of stainless steel and Polyimide \([9]\) as spacer material. The main parameters are summarized in Table 1. To ensure the transparency of the Frisch grid in the \( \beta \)-chamber the field ratio has to be adjusted according to \([10]\).

2.1.3 Cables and Front End Electronics

For the basic monitor the electrical connections as listed in Table 2 are necessary. In the future the signal lines may become differentially driven lines, thus requiring a different type of cable.

In the warm part of the front end electronics the signal of each chamber needs to be shaped and a trigger has to be extracted from the signal itself. The shaped pulses then have to be recorded for subsequent analysis.
Figure 2: Photograph of the basic monitor prototype.

<table>
<thead>
<tr>
<th>chamber type</th>
<th>distance cathode to grid</th>
<th>α</th>
<th>β</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>grid to anode</td>
<td>2 mm, no grid</td>
<td>10 mm</td>
</tr>
<tr>
<td>Frisch grid</td>
<td>pitch</td>
<td>2 mm</td>
<td>1 mm</td>
</tr>
<tr>
<td></td>
<td>bar width</td>
<td>100 μm</td>
<td></td>
</tr>
<tr>
<td>sources</td>
<td>$</td>
<td>E_{c-a}</td>
<td>/</td>
</tr>
<tr>
<td>ion, particle</td>
<td>1:3</td>
<td>1 : 3</td>
<td></td>
</tr>
<tr>
<td>activity</td>
<td>$\alpha \approx 5.5$ MeV</td>
<td>conv. $e^- \approx 1$ MeV</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 kBq</td>
<td>18.5 Bq</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Parameters of the basic monitor prototype.

Figure 3 shows a schematic view of the discrete electronics as used for the basic monitor prototype. The cold preamplifier [11] with a rise time in response to a delta pulse of approximately 80 ns and a time constant of ~1 ms integrates the induced current into an output voltage signal. The transceiver matching the impedances is put into a shielded case on top of the feedthrough. The signal is split into two spectroscopy amplifiers, which act as shapers (shaping time 1 μs) and amplifiers. The first uses its internal delay to allow the trigger to process the gate for the qVt, which finally histograms the height of the shaped pulse using its peak (V-) mode.

<table>
<thead>
<tr>
<th>purpose</th>
<th>type</th>
<th>α-chamber</th>
<th>β-chamber</th>
<th>sum</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV up to 3kV</td>
<td>HV</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Preamp supply (-6V, 0V, +12V)</td>
<td>coax</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>signal</td>
<td>coax</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>calibration pulses</td>
<td>coax</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 2: Number of cables for one basic monitor.
2.1.4 Performance in the HEC Test Beam

The prototype basic monitor was implemented in the HEC test beam cryostat during the September data taking period. The liquid argon purity was measured to approximately 1 ppm O_2 using an oxygen meter.

A spectrum of the α-chamber at |E| = 12.5 kV is shown in Fig. 4. The three smaller peaks on the right hand side are produced by a pulser for calibration purposes. On the left hand side the falling slope of the noise spectrum is visible above our trigger threshold. The low noise (for both chambers) at a level of approximately 1 mV is a precondition to directly trigger on the typical signal output of a few mV in the case of the α-chamber. Data have been regularly taken during normal operation during the test beam period. Part of the data was taken during special runs with varying HV. The evaluation is still in progress.

In the case of the β-chamber the collected charge and thus the signal output was too small to be triggered on. The chamber was designed for the local Mainz purity...
system which requires a much better liquid argon purity than 1 ppm for poisoning studies. Therefore the 1 ppm of the HEC test beam cryostat was already beyond the sensitivity of the chamber. For the next test run the chamber will be replaced by another chamber with the appropriate sensitivity.

2.2 The Laser Chamber

2.2.1 Principle of the Laser Chamber

The left hand side of Fig. 5 shows a schematic view of the laser chamber. Pulses of UV-laser light brought onto the gold coated cathode by a quartz fiber produce photo electrons at the cathode. While the electrons drift through the electric field towards the anode they pass two Frisch grids, the cathode and the anode grid. These grids shield the middle drift space electrostatically from the anode and the cathode, which are connected to the same charge sensitive preamplifier by a decoupling capacitor each. The four electrodes define an increasing electric field since the field ratio at the Frisch grids has to be adjusted to allow for optimal transparency [10].

![Schematic view and picture of the laser chamber prototype.](image)

Figure 5: Schematic view and picture of the laser chamber prototype.

Figure 6 shows the ideal output signal of the laser chamber and its variation for different electron lifetimes. The electron lifetime is extracted from the signal shape by means of a fit [8] as well as the electron drift time through the shielded gap. Since the sensitivity of the laser chamber varies with the applied field, lifetimes from 1 to 100 μs are shown as an example for a fixed field with the parameters of the laser chamber prototype (see below). The corresponding oxygen equivalent concentration of impurities is given for orientation.

2.2.2 Mechanics of the Laser Chamber

The laser chamber monitor consists of the chamber made from stainless steel and Polyimide [9], one board for the HV blocking resistors and the preamplifier board. The components are mounted into a perforated metal box for mechanical protection. The maximum outer envelope has been defined to:

<table>
<thead>
<tr>
<th>envelope of</th>
<th>height x width x length</th>
</tr>
</thead>
<tbody>
<tr>
<td>laser chamber</td>
<td>80 x 100 x 130 mm³</td>
</tr>
</tbody>
</table>

The most important technical parameters of the prototype laser chamber [3], the quartz fiber [12] and the Nd:YAG laser [13] are listed in Table 3.
Figure 6: Laser chamber signal for different electron lifetimes as an example given for the geometry and field as used for poisoning studies. The corresponding concentrations of impurities in oxygen equivalents are given [2].

<table>
<thead>
<tr>
<th>distance</th>
<th>2 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>cathode to cathode grid</td>
<td>10 mm</td>
</tr>
<tr>
<td>cathode grid to anode grid</td>
<td>2 mm</td>
</tr>
<tr>
<td>anode grid to anode</td>
<td>1 mm</td>
</tr>
<tr>
<td>Frisch-grid pitch</td>
<td>100 μm</td>
</tr>
<tr>
<td>width of grid bars</td>
<td>1 : 3</td>
</tr>
<tr>
<td>field ratio across each grid</td>
<td></td>
</tr>
<tr>
<td>quartz fiber: approximate length</td>
<td>4 m</td>
</tr>
<tr>
<td>diameter of core/cladding</td>
<td>1000/1100 μm</td>
</tr>
<tr>
<td>numerical aperture</td>
<td>0.22</td>
</tr>
<tr>
<td>attenuation @ 266 nm</td>
<td>10 % per m</td>
</tr>
<tr>
<td>laser:</td>
<td></td>
</tr>
<tr>
<td>wavelength</td>
<td>266 nm</td>
</tr>
<tr>
<td>repetition rate</td>
<td>2 Hz</td>
</tr>
<tr>
<td>pulse width</td>
<td>8 ns</td>
</tr>
<tr>
<td>average pulse energy</td>
<td>1.5 mJ</td>
</tr>
</tbody>
</table>

Table 3: Parameters of the laser chamber prototype.

2.2.3 Cables and Front End Electronics

The electrical connections for one laser chamber are listed in Table 4 below. In the future the signal lines may become differentially driven lines, thus requiring a different type of cable. In addition a quartz fiber for the UV-light is needed.

The signal of the preamplifier’s output needs to be recorded for each laser trigger individually. A FADC is required to sample the waveform.

For the prototype the same preamplifier[11] as for the basic monitor is used in combination with a digital scope connected to a computer.
<table>
<thead>
<tr>
<th>purpose</th>
<th>type</th>
<th>laser-chamber</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV up to 3kV</td>
<td>HV</td>
<td>3</td>
</tr>
<tr>
<td>Preamp supply</td>
<td>coax</td>
<td>3</td>
</tr>
<tr>
<td>(-6V, 0V, +12V) signal</td>
<td>coax</td>
<td>1</td>
</tr>
<tr>
<td>calibration pulses</td>
<td>coax</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 4: Number of cables for one laser chamber monitor.

2.2.4 Prototype performance

On the right hand side of Fig. 5 a picture of our prototype laser chamber [14] is shown. The amplitude for a typical signal amounts to several hundred mV and the signal lasts a few μs as plotted in Fig. 7. A fit has been developed [3, 8] which describes the waveform rather well. The first rising step which is an artefact probably due to photo electrons produced at the cathode grid by photons reflected by the cathode’s slope. Other cathode designs attacking this problem are currently being studied [15].

Figure 7: Typical pulse of the laser chamber prototype with an overlay of the fitted function $\tau \approx 20\mu s$.

3 The ATLAS Liquid Argon Purity Monitoring System

3.1 Importance of Purity Monitoring for ATLAS calorimeters

The impact of electro-negative impurities on drifting electrons has been discussed above. In the case of a calorimeter cell with an electric field $E$ over a gap of the width $d$, charged particles crossing the cell produce a homogeneous track of electrons (and positive ions) which are subject to trapping during their drift. Therefore
the total integrated charge $Q_{\text{tot}}$, which in the ideal case of infinite electron lifetime
sums up to $\frac{1}{\lambda}$ of the produced free electron charge (after recombination), is decreased
considerably depending on the electron mean free path length for absorption $\lambda$, that
means the electron lifetime. This effect is reduced by only integrating the induced
current up to a certain clipping time $t_c$, at the cost of a smaller total integrated
charge. (This approach is called ‘initial current readout’ [22, 23].) The remaining
effect of impurities parametrized by the mean free path length for absorption
normalized to the gap width $\frac{\lambda}{d}$ is given by the following equation:

$$
\frac{Q_{t_c}}{Q_{\text{ideal}}} \left( \frac{\lambda}{d} \right) = \frac{\Gamma (1 - \frac{T_d}{T_{\text{d}}})}{T_{\text{d}}} + \left( \frac{T_{\text{d}}}{T_{\text{d}}} \frac{\epsilon^{\lambda/d} - 1}{\epsilon^{\lambda/d} - 1} \right) \left( 1 - \frac{T_{\text{d}}}{T_{\text{d}}} \right)
$$

for $t_c \leq T_{\text{d}}$

where $Q_{\text{ideal}}$ denotes the total charge integrated up to $t_c$ in the ideal case of
infinite $\lambda$ and $T_{\text{d}}$ is the maximum electron drift time.

Fig. 8 shows the dependence of $\frac{Q_{t_c}}{Q_{\text{ideal}}}$ on $\lambda$ for three different values of clipping
times $t_c$. The corresponding concentrations of impurities in ppm oxygen equivalents
are denoted using the parameters of the hadronic endcap calorimeter (HEC). The
effect of the clipping time, which will be 20 ns for the HEC [24], is clearly seen.

![Figure 8](image_url)

Figure 8: Charge yield vs. the normalized mean free path length of electrons in a
calorimeter cell for different clipping times $t_c$. The corresponding concentration of
impurities $p$ is given for a gap width $d = 2$ mm and a nominal field $|\vec{E}| = 10$ kV/cm
(HEC) [24, 16].

Since the total integrated charge depends on the impurities it is important to
monitor changes in the concentration of impurities, thus in the electron lifetime, in
order to achieve a stable calibration. As shown in Table 5 for the HEC parameters
and an assumed impurity of 1 ppm the relative change in the charge yield is at the
0.01% level for ±0.1 ppm and a clipping time of 20 ns. Therefore the requirement
$p_{\text{LAr}} < 1$ ppm for the liquid argon purity is sufficient.


<table>
<thead>
<tr>
<th>$t_c$</th>
<th>$Q_{stat}/Q_{ideal}$</th>
<th>$\pm 0.1$ ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq T_d$</td>
<td>95.70%</td>
<td>$\pm 0.42$ %</td>
</tr>
<tr>
<td>$\leq 40$ ns</td>
<td>99.74%</td>
<td>$\pm 0.03$ %</td>
</tr>
<tr>
<td>$\leq 20$ ns</td>
<td>99.87%</td>
<td>$\pm 0.01$ %</td>
</tr>
</tbody>
</table>

Table 5: Charge yield for different clipping times $t_c$.

3.2 Positioning in the Cryostats

3.2.1 General Considerations

The placement of the liquid argon purity monitors in the cryostats is guided by the need to monitor the liquid argon purity close to the different calorimeters, by the wish to cover the entire cryostat and by the amount of available space. Since the basic monitors (with the exception of the basic monitors in the FCAL region) will be equipped with cold preamplifiers they will be placed on the outer radius of the different calorimeter wheels in order to suffer less from radiation.

In addition there will be one laser chamber per cryostat to measure the absolute electron lifetime in the liquid argon. Its precision measurement allows an initial purity measurement and a calibration of the basic monitors. Since the laser chambers require an additional feedthrough for the UV-light fiber, they will be placed further outward in the liquid argon expansion system. Possible noise induced by the laser is no problem since the laser chamber data will only be taken when considered necessary.

The first proposal for the basic monitors’ positions as presented in [18, 19] has been discussed and improved.

3.2.2 General Remarks on the Number of Cables and Feedthrough Pins

The numbers of cables and feedthrough connectors needed for the liquid argon purity system are given separately for the barrel and the end cap cryostats. For the low voltage and signal connectors 64 pins per connector (2 rows of 32) were assumed. (Compare to [17].)

The number of lines per basic monitor were given in Table 2 above.

The numbers of FT-connections needed for the HV and LV correspond to the number of cables. In order to avoid cross-talk the signal pins will be shielded from each other by low voltage pins placed inbetween. For the calibration lines a similar scheme is foreseen. The signal lines may become differentially driven lines and therefore two pins per signal line are reserved.

The feedthrough pins for the signal lines and the calibration lines of different basic monitors in one cryostat should be grouped on one or more connector(s) separated by type.

The operating HV will be 2.5 kV, therefore the HV-feedthroughs should allow for up to 3 kV.

Spare lines should be put into the cryostats to avoid problems due to broken cables during the installation of the monitors. There should be at least one spare line of each type per monitor. Whether there is a need for spare feedthrough pins depends on the installation procedure.

3.2.3 Barrel Cryostat

3.2.3.1 Placement in the Barrel Cryostat  The entire barrel cryostat will be equipped with 9 basic monitors as shown in Fig. 9. They will be located at 3 positions in $z$ (at both ends and in the middle of the cryostat) on the outer
circumference of the barrel electromagnetic calorimeter at 3 different heights. The 3 monitors placed on half height are put on alternate sides in \( z \). Two of the three monitors at \( z \approx 0 \) will be mounted on one half barrel, the remaining on the other.

![Basic Monitors in Barrel Cryostat](image)

**Figure 9:** Locations of the basic monitors inside the barrel cryostat. This longitudinal placement is repeated 3 times at the top, middle height and bottom of the cryostat. In total there are 9 basic monitors.

**3.2.3.2 Number of cables and feedthroughs** The following table summarizes the number of lines for a half barrel barrel. The number of connectors needed is given per half barrel allowing for 5 basic monitors. Per half barrel 1 connector (+1 reserved for the separation of signal and calibrations lines) and 15 HV lines are needed.

<table>
<thead>
<tr>
<th>type</th>
<th>no. of lines per half barrel</th>
<th>no. of pins per half barrel</th>
<th>connectors per half barrel</th>
<th>full barrel</th>
</tr>
</thead>
<tbody>
<tr>
<td>signal</td>
<td>10</td>
<td>10 + 10</td>
<td>1 + 1</td>
<td>2 + 2</td>
</tr>
<tr>
<td>calibration</td>
<td>10</td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>low voltage</td>
<td>30</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HV</td>
<td>15</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**3.2.4 End Cap Cryostats**

**3.2.4.1 Placement in the End Cap Cryostat** Per end cap there will be 10 basic monitors. 8 basic monitors with cold electronics will be distributed on
or close to the outer radius of the electromagnetic (EMEC) and hadronic end cap calorimeters (HEC) in 3 positions in \( z \) and at 3 different heights.

As shown in Figs. 10 and 11 two probes (No. 7 and 8) of the geometric type B will be at the top and bottom on the outer circumference of the EMEC. They are mounted into the outer frame of the EMEC modules thus taking up less of the limited space between the calorimeter and the cryostat wall [26].

Another 3 basic monitors (No. 4, 5 and 6) will be placed on three different heights in between the first and second wheel of the HEC. They are partially embedded into a pocket of 15 mm depth machined into the last copper plate of the first wheel since there is not sufficient space on the outer circumference of the HEC modules. This allows for a maximum height of 40 mm for the monitors [27]. These pockets will be located close to the outer circumference of the HEC modules.

On the back of the calorimeter 3 basic monitors (No. 1, 2 and 3) of type B will be mounted onto the last copper plate of the second HEC wheel close (\( \approx 20 \) cm inwards) to the outer circumference of the absorber plates. They will be again placed at top (No. 1), half height (No. 2) and bottom (No. 3).

Two special monitors with remote electronics are situated in the vicinity of the forward calorimeter (FCAL). One basic monitor of type B (No. 10) is placed into a liquid argon filled pocket cut into the absorber behind the FCAL.

In front of the FCAL a single alpha cell (No. 9) will be put into a pocket of the cryostat wall filled with liquid argon. This pocket will use a cylindrical tube (inner diameter 60 mm, inner depth 40 mm) reaching into the vacuum filled space in front of the FCAL as shown in Fig. 12 [28].
3.2.4.2 Number of cables and feedthroughs The number of connectors needed is summarized per end cap (one side) in the following table. For one end cap 2 connectors (+2 reserved for the separation of the signal and calibration lines) and 30 HV lines are needed.

<table>
<thead>
<tr>
<th>type</th>
<th>total no of lines</th>
<th>total no of pins</th>
<th>connectors for one EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>signal</td>
<td>20</td>
<td>20 + 20</td>
<td>2 + 2</td>
</tr>
<tr>
<td>calibration</td>
<td>20</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>low voltage</td>
<td>60</td>
<td>60</td>
<td></td>
</tr>
<tr>
<td>HV</td>
<td>30</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

3.2.5 Placement of the Laser Chambers

For an absolute measurement of the electron lifetime one laser chamber is foreseen per cryostat (3 in total). Since an UV-laser and a special quartz fiber feedthrough is needed for the operation, the laser chambers are located in the expansion vessels of each cryostat, which allows to use warm feedthroughs on top of the expansion vessels for the quartz fiber as well as for the supply and signal lines (cf. Table 4). The liquid argon level of the expansion vessels is about 2.5 m above the top of the cryostats and there is little liquid argon convection expected due to the lengths of the liquid argon pipes of 20 to 30 m. Nevertheless it is important to install a laser chamber in order to determine the initial purity and to calibrate the basic monitors.

Since measurements with the laser chamber may be done anytime there is no need to run at the same time with data taking. Therefore possible noise from the laser should be of no concern.
4 Summary and Future Activities

Prototypes of the basic monitor and the laser chamber monitor have been built. The basic monitor has been tested in the HEC test beam cryostat and the performance of the laser chamber has been evaluated at Mainz. A concept for the positioning of the purity monitors inside the ATLAS cryostats has been drawn up.

The basic monitors will be further optimized with respect to the range of sensitivity needed in the ATLAS liquid argon environment. The basic monitor will be used in the HEC test beam. For the laser chamber different cathode designs are under study to avoid the problem of reflections [15].

In order to finalize the plan for the implementation of the purity probes detailed information on the available space and the possibilities of mounting the monitors has to be provided by the different subgroups and discussed.

Furthermore the ATLAS group at Mainz is working on a second local cryogenic system [20] to test materials for liquid argon poisoning and a portable stand-alone purity monitoring system [21].

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