Model 10 system from Blue Physics consists of several parts: a plastic scintillation detector (PSD), transport optical fibers, a removable cartridge, an acquisition unit box, and a single board computer with the Blue Physics software to visualize and analyze the data in real time.

The PSD has a cylindrical shape of 1 mm diameter and 1mm length, so it has a sensitivity volume of 0.785 mm³. The scintillator has a core material of Polystyrene and a cladding material of acrylic. The scintillating core contains a combination of fluorescent dopants selected to produce the desired scintillation effect. When a pulse of radiation passes through the scintillator it produces a visible light. The intensity of light generated by the PSD (equivalent to the number of photons produced) is proportional to the amount of dose deposited in the sensor by that pulse [1].

The PSD is coupled to one of the transport plastic optical fibers. This plastic optical fiber has a core of Polymethyl-Methacrylate and a cladding of Fluorinated Polymer. It has a diameter of 0.25 mm and it is 20 m long. This fiber and all the other transport optical fiber are covered with a jacket and a plastic flexible tube to protect them from any accidental damage. This fiber will transport the light generated by the PSD to the removable cartridge which will be located outside the radiation room (a.k.a. bunker).

The removable cartridge has all the optical coupling of the transport optical fiber with the transducer that will convert the light signal from the PSD into an electric current. It also has an electric connector that can easily be connected and disconnected to the acquisition unit. Because all the optical connections are inside the cartridge in a fixed position, the end users can easily connect and disconnect the cartridge from the acquisition unit without compromising the delicate optical couplings.

The acquisition unit will accumulate and integrate the electric current sent from the cartridge in a capacitor during a period of time called “integration time”. At the end of the integration time the acquisition unit will read the charge accumulated in the capacitor, transform that analog signal in a digital signal using an Analog to Digital Converter (ADC) and send the digital reading of the charge accumulated in the capacitor to the software.

The Blue Physics software will plot the readings in real time as well as provide the sum of all the charge accumulated during the treatment. It also has several tools to analyze the signals measured and to provide a final calculation of the relative dose and absolute dose measured by the PSD.

Let’s call the set composed by the PSD, transport optical fiber, transducer, capacitor and ADC the Sensor Channel. Also, let’s call the final digital reading from the sensor channel Rs. The reading Rs is a direct reading of the charge accumulated in the capacitor during the integration time, so the units of Rs are Coulombs. Normally expressed in nC.

At the end of the integration time the capacitor will be reset for the next reading. The charge accumulated in the capacitor during the integration time is proportional to the intensity of light received from the Sensor Channel during that time. The integration time can be adjusted by the end user via the Blue Physics software. The integration time can vary from 300 μs up to 300 ms. We recommend to use an integration time of 700 μs for the standard measurements in a LINAC.
Cerenkov effect and how we subtract it

When the high intensity radiation from the LINAC passes through the transport optical fibers it produces Cerenkov Radiation. Cerenkov Radiation is a very well-known effect. It consists of a blue visible light produced in the medium of the optical fiber when the radiation from the LINAC generates electrons that travel through the medium faster than the speed of light in that medium. Cerenkov Radiation light will be added to the light generated by the PSD. The intensity of Cerenkov light will be proportional to the length of transport fiber irradiated and the intensity of the radiation. In order to measure only the light from the sensor ($L_{ss}$) we need to measure and subtract the light produced by Cerenkov effect in the Sensor Channel ($L_{cs}$).

To subtract the Cerenkov effect Model 10 has a second channel called Cerenkov Channel which is identical to the sensor channel with an identical transport fiber, identical transducer, capacitor and ADC but this channel is not connected to the PSD. The transport optical fiber of the Cerenkov channel is set adjacent to the transport fiber of the sensor channel all along its length. The Cerenkov channel is also integrated in the removable cartridge but with its own transducer. This way the light produced by the Cerenkov effect in this Cerenkov channel ($L_{cc}$) will be identical than the light produced by the Cerenkov effect in the sensor channel ($L_{cs}$), because they are both the same fibers, they are adjacent all the way, the same lengths of fiber will be exposed to the same radiation so we can say:

$$L_{cc} = L_{cs}$$  \hspace{1cm} Eq. 1

The final digital reading in nC of the signal from the Cerenkov channel is called $R_c$. This reading will be proportional to the intensity of light in the Cerenkov channel and it will allow us to subtract the Cerenkov effect from the sensor channel and measure only the light from the PSD ($L_{ss}$). This technique was previously described by Beddar et al \textsuperscript{1}. 

![Diagram showing the acquisition unit (AU) and radiation field (BEV) with Cerenkov channel and sensor channel connections.](image-url)
The reading from the Sensor Channel $Rs$ will be proportional to the sum of the intensity of light from the sensor in the Sensor Channel $L_{ss}$ and the intensity of the light produced by the Cerenkov effect in the Sensor Channel $L_{cs}$

$$Rs = K_s \cdot (L_{ss} + L_{cs}) \quad \text{Eq. 2}$$

Where $K_s$ is an unknown constant of proportionality. The units of $K_s$ are nC per photon. It means the charge accumulated in the capacitor per number of photons produced by the scintillating effect and by the Cerenkov effect in the Sensor Channel. $K_s$ depends only on the electronic components in the cartridge and acquisition unit, the optical couplings.

On the other hand, the reading from the Cerenkov Channel will be proportional to the intensity of the light produced only by the Cerenkov effect in that channel

$$Rc = K_c \cdot L_{cc} \quad \text{Eq. 3}$$

Where $K_c$ is also an unknown constant of proportionality for the Cerenkov channel with the same units as $K_s$. Similar than $K_s$, $K_c$ depends only on the electronic components in the cartridge and acquisition unit, the optical couplings.

We are only interested in measuring the light from the sensor using only the readings at the software. Using Eq. 2 and Eq. 3 we can say:

$$L_{ss} = \frac{1}{K_s} \cdot Rs - L_{cs} \quad \text{Eq. 4}$$

We could deduct the light from the sensor $L_{ss}$ using only the readings from Sensor Channel $Rs$ and Cerenkov Channel $Rc$ combining equations Eq. 4, Eq. 1 and Eq. 3:

$$L_{ss} = \frac{1}{K_s} \cdot Rs - \frac{1}{K_c} \cdot Rc \quad \text{Eq. 5}$$

As we mentioned before, the light produced by the scintillator is proportional to the dose deposited at the sensor. Therefore we can add this statement in equation Eq. 5 saying:

$$\text{dose} = kp \cdot \left( \frac{1}{K_s} \cdot Rs - \frac{1}{K_c} \cdot Rc \right) \quad \text{Eq. 6}$$

Where $K_p$ is an unknown constant of proportionality. At this point we are only interested in finding a value from the measurements that will be proportional to the dose. Later we will find a calibration factor $CalF$ which will give me the value of the absolute dose. Because we are now only interested in any experimental value that will be proportional to dose we can chose any constant $K_p$ and we could
say that the right side of equation Eq. 6 is proportional to the dose. We chose $K_p$ to be equal than $K_s$ and we can still use equation Eq. 6 to say:

$$\text{Charge Proportional to Dose} = R_s - K_s/K_c \cdot R_c$$  \hspace{1cm} \text{Eq. 7}$$

Let’s rename the constant $K_s/K_c$:

$$\frac{K_s}{K_c} = ACR$$  \hspace{1cm} \text{Eq. 8}$$

$ACR$ stands for Adjacent Channel Ratio. $ACR$ doesn’t have units and it only indicates a ratio between the two adjacent channels.

So we finally can say that:

$$L_{ss} \propto R_s - ACR \cdot R_c$$  \hspace{1cm} \text{Eq. 9}$$

Which will be equivalent to say

$$\text{Charge Proportional to Dsoe} = R_s - ACR \cdot R_c$$  \hspace{1cm} \text{Eq. 10}$$

Remember that the readings $R_s$ and $R_c$ are electric charges from the capacitors and are measured in nC. Therefore the units of both sides of equation Eq. 10 will be electric charge in nC. Equation Eq. 10 means that we can obtain the charge proportional to the dose deposited in the PSD at any given moment just using the reading from the Sensor Channel and the reading from the Cerenkov Channel. This charge is equivalent to the charge that standard ion chambers and diodes provide when used together with standard electrometers.

We need to know the value of $ACR$. Finding the correct value of $ACR$ is fundamental for the right subtraction of the Cerenkov effect and for a correct dosimetry using Blue Physics system.

As done with traditional ion chambers and diodes the absolute dose can be calculated using cross calibration techniques with a well calibrated ion chamber that the clinic must have using the formula:

$$\text{Absolute Dose} = CalF \cdot (R_s - ACR \cdot R_c)$$  \hspace{1cm} \text{Eq. 11}$$

Where $CalF$ is a calibration Factor that will convert the charge proportional to dose measured in nC to absolute dose measured in cGy. Later in this document we will describe how to calculate $CalF$.

Some considerations to remember about $ACR$:

- $ACR$ is a constant without units.
• ACR doesn’t depend on the length of fiber irradiated at any given moment. The ratio between adjacent channels should always be the same regardless of the lengths of fibers irradiated and the amount of Cerenkov effect produced at any given moment.
• The method of the two adjacent fibers and knowing ACR between them will allow us to subtract Cerenkov effect at any moment and under any circumstances.
• ACR only depends on the small differences between the electronic components in the cartridge and in the AU and the differences in the optical coupling between the transport fibers and the transducers in both channels.
• It is expected to have different ACR’s for different systems. Different models and or different cartridges.
• It is expected to find small differences in ACR between different energies of radiation.
• ACR should be constant over time. However, we recommend to measure ACR frequently (once a day or once a week) until fully confirmation that the ACR value reminds constant over time.
• ACR should always be approximately the same (within a 7% of uncertainty) regardless the method to be used to find the ACR value.

In the following section we will explain several alternative ways to measure the ACR value of the system we are going to utilize for dosimetry.

Method 1. Finding ACR at the factory laboratory before the sensor is placed.

Although this method will never be used by the end user it could be very useful to understand the concept of ACR.

Imaging we want to measure ACR at the factory before we place the sensor at the Sensor Channel. We could put our system in a laboratory set up following this diagram:

![Diagram of laboratory setup to find ACR](image)
In this laboratory set up we don’t have the PSD in the Sensor Channel and we don’t irradiate the fibers with any radiation. We simply expose both transport fibers to the same light source in a way that the intensity of light that passes through the Sensor Channel ($L_{bs}$) will be exactly the same than the intensity of light passing through the Cerenkov Channel ($L_{bc}$).

$$L_{bs} = L_{bc} \quad \text{Eq. 12}$$

In this case the reading at the Sensor Channel $R_s$ will be proportional to the intensity of light $L_{bs}$ and the reading at the Cerenkov Channel $R_c$ will be proportional to the intensity of light $L_{bc}$

$$R_s = K_s \cdot L_{bs} \quad \text{Eq. 13}$$
$$R_c = K_c \cdot L_{bc} \quad \text{Eq. 14}$$

Dividing Eq. 13 and Eq. 14 and using Eq. 8 we obtain:

$$\frac{R_s}{R_c} = \frac{K_s}{K_c} = ACR \quad \text{Eq. 15}$$

It means that under these laboratory conditions we could find $ACR$ in a straightforward way just simply dividing the readings from both channels.

This method is good to understand the concept of the $ACR$ but in reality it is very difficult to perform even at the factory laboratory. It requires a very controlled source of light and its positioning that assures the exact same intensity lights are going through both channels. This is not an easy task, even in a very controlled environment. Right now Blue Physics is not offering this service to find $ACR$ at our facility.

For this reason, we must provide alternative methods where end users can find $ACR$ by themselves taking into account that the Sensor Channel has the PSD installed and using their own radiation delivery equipment.

**Method 2. Changing the length of fiber irradiated while maintaining the dose at the sensor.**

$ACR$ can be found by the end users using their own Linear Accelerator (LINAC). This can be done by creating two different set ups or scenarios, where the length of fiber irradiated changes but the radiation at the sensor doesn’t change.

Let’s suppose we create a set up or scenario (Scenario A) following this diagram:
In this scenario A we are using an asymmetric radiation field where very short length of the transport fibers are irradiated, so very little Cerenkov light will be produced in both channels.

Applying Eq. 9 to this scenario we obtain:

$$L_{sa} \propto R_{sa} - ACR \cdot R_{ca} \quad \text{Eq. 16}$$

We take note of the readings $R_{sa}$ and $R_{ca}$ from both channels. $R_{ca}$ is expected to be very small compared with $R_{sa}$ ($R_{ca}$ should be 10% or less of the reading $R_{sa}$). This is because the Cerenkov effect is going to be very small due to a very short length of the fibers is being irradiated.

Now let's create this second scenario B:
The most important thing to notice about this scenario B is that the length of fibers irradiated have increased with respect scenario A but the dose at the sensor must be exactly the same as in scenario A.

Applying Eq. 9 for scenario B we obtain:

\[ L_{ssb} \propto R_{sb} - ACR \cdot R_{cb} \]  

Eq. 17

In this scenario B we expect \( R_{cb} \) to be much larger than \( R_{ca} \) because a longer length of fiber is under the radiation field and therefore the Cerenkov light will be much higher than in scenario A. That being said, we don’t recommend that in scenario B \( R_{cb} \) to be higher than 40\% of \( R_{sb} \).

Because the dose at the sensor in this scenario is the same as in scenario A, we can say that the intensity of the light produced by the PSD in scenario A \( L_{ssa} \) is identical than the intensity of the light produced by the PSD in scenario B \( L_{ssb} \):

\[ L_{ssa} = L_{ssb} \]  

Eq. 18

Using Eq. 18 and dividing Eq. 16 and Eq. 17 we obtain:

\[ 1 = \frac{R_{sa} - ACR \cdot R_{ca}}{R_{sb} - ACR \cdot R_{cb}} \]  

Eq. 19

And now solving for \( ACR \)

\[ ACR = \frac{R_{sb} - R_{sa}}{R_{cb} - R_{ca}} \]  

Eq. 20

Eq. 20 means that we can find \( ACR \) as a function only of the readings from the Sensor Channel and the Cerenkov Channel in both scenarios.

We must remember that the most important condition we must met to be able to use Eq. 20 and this method is to be sure the dose at the sensor in scenario A is exactly the same as the dose at the sensor in scenario B and the only thing it changes between both scenarios is the length of transport fibers under the radiation field.

We can create these two scenarios in many different ways:

- Using an asymmetric field and rotating the collimator
- Using an asymmetric field and rotating the couch
- Using an asymmetric field and rotating the whole set (for instance using the Sun Nuclear water tank)
- Adding manually an extra length of fiber inside the beam (being sure all the other requirements are met)
One more important thing to remember when using this method is that the reading at the Cerenkov Channel in the scenario B $R_{cb}$ should never be higher than 40% of the signal in the Sensor Channel $R_{sb}$ in that same scenario B. The reason for this limitation is that there is a point when the intensity of the Cerenkov light $L_{cb}$ in the Sensor Channel is too high, it will “eclipse” the light coming from the PSD $L_{sb}$ and the transducer will be dazzled by the light from Cerenkov $L_{cb}$ and won’t be able to capture all the intensity from the PSD light $L_{sb}$. In other words, after we pass the mark of $R_{cb} > 40\%$ of $R_{sb}$ we will be entering in a non-linear phase where Eq. 17 and Eq. 20 won’t be valid anymore. With the current configuration of Blue Physics Model 10 this limit normally occurs if more than 6 cm of the fibers are under the radiation field. It means that Model 10 is not designed to measure accurately fields larger than 12 cm x 12 cm. On the other hand, this method will work very well for all the fields smaller than 12 cm x 12 cm. If you are interested in measuring accurately fields larger than 12 cm x 12 cm we recommend you to acquire another system with larger PSD that will assure we will reach the non-linear phase at a much larger field size.

Another important aspect to take into account when using this method is that in both scenarios the transport fibers must be under electronic equilibrium conditions. In other words, the transport fibers must be at least at 5 cm depth in the water tank or solid water. Using this method when the length of the transport fibers under the radiation field are also in the air may lead to wrong results. Always keep in mind that with this system the transport fibers are like part of the sensor too and you have to be always sure that part of the sensor is always under electronic equilibrium for accurate measurements.

Remember that in this method we don’t need to know the exact length of fiber under the radiation filed in each scenario. This method will work as long as the length of fiber inside the radiation field is substantially different between the scenarios regardless of the length of fiber irradiated at each scenario.

This method has the following advantages:

- It can be done by the end user using their own LINAC without the support from the factory.
- This method is not using any cross calibration. It means we don’t need to use measurements done with other sensors.
- For standard LINACs it can be done relatively quickly just rotating the collimator or the couch using an asymmetric field.
- No special phantoms are required. It can be done in any water tank or solid water phantom or solid water slabs.

This method has the following limitations:

- You need a treatment machine that can deliver asymmetric fields and can rotate the collimator or couch. Not all the treatment machines have this capability (MR-LINAC’s, Zap, Cyber-Knife, Tomo Therapy, Gamma Knife, etc.). For this type of machines we recommend to use one of the other methods to find ACR.
- Users must be 100% sure that the dose delivered to the PSD in scenario A is exactly the same as in scenario B. This is not always obvious. We strongly recommend to re-confirm that the dose at the sensor position in both scenarios is the same using a well know sensor like an ion chamber.
- Users must be extra careful that no more than 6 cm of fiber is under the radiation field or the signal at Cerenkov Channel is no larger than 40% of the signal from the Sensor Channel.
When finding \( ACR \) using this method, we recommend not to use only 2 scenarios. We recommend to repeat the process at several scenarios keeping always the same dose at the PSD in all of them while varying the length of fiber irradiated. For instance, rotating the collimator or the couch at different angles using always the same asymmetric filed. Take note of all the \( R_s \) and \( R_c \) readings and represent them in a plot where the x axis holds the \( R_c \) readings and the y axis holds the values of the \( R_s \) readings like in the following figure:

![Figure 3 How to find ACR using several points of Method 2](image)

All the dots in the picture should be lined up around a regression line. The slope of the regression line will be the value of \( ACR \).

By the way, the independent term of the regression line will be the charge proportional dose that has been delivered in all the scenarios to the PSD.

**Method 3. Cross Calibration**

This method assumes that the user knows with very high certainty the ratio between the dose measurements between two fields of different sizes. For example, the user knows very well the Output Factor value between a reference field of size 10 cm x 10 cm and a filed of 4 cm x 4cm. Let’s call this OF value \( OF4 \).

Then we measure with the Model 10 the \( R_s \) values and \( R_c \) values of those two fields. Let’s call those values \( R_s10, R_c10, R_s4 \) and \( R_c4 \).

Using Eq. 10:

\[
OF4 = \frac{dose(4x4)}{dose(10x10)} = \frac{R_s4 - ACR \cdot R_{cu}}{R_s10 - ACR \cdot R_{c10}}
\]

**Eq. 21**

In Eq. 21 we know \( OF4, R_s4, R_c4, R_s10 \) and \( R_c10 \) but we don’t know \( ACR \). Solving for \( ACR \)
\[
\begin{align*}
    OF4(Rs10 - ACR \cdot Rc10) &= Rs4 - ACR \cdot Rc4 & \text{Eq. 22} \\
    OF4 \cdot Rs10 - OF4 \cdot ACR \cdot Rc10 &= Rs4 - ACR \cdot Rc4 & \text{Eq. 23} \\
    OF4 \cdot Rs10 - Rs4 &= ACR \cdot (OF4 \cdot Rc10 - Rc4) & \text{Eq. 24} \\
    ACR &= \frac{OF4 \cdot Rs10 - Rs4}{OF4 \cdot Rc10 - Rc4} & \text{Eq. 25}
\end{align*}
\]

This is a good way to find \( ACR \) when knowing with high certainty one of the Output Factors (OF) of the user’s machine which has been measured previously with a very trustful sensor like an ionization chamber.

This method to calculate \( ACR \) has been described previously by Underwood et al[2].

In Eq. 25 we are using the example of the OF for the 4x4 field with a reference field of 10x10 but it can be used with any other pair of fields as long as we know very well the OF between those two fields.

This is probably the simplest method to find the correct \( ACR \) with minimum uncertainty. However, it requires measurements with other sensor with a very high certainty of those measurements which is not always possible or those measurements are not available.

Avoid to use the OF of a very small field where measurements with any conventional sensor will have a high uncertainty due to the difficulties to measure small fields in general as described by the IAEA AAPM TRS-483 code. We recommend to use OF of a minimum 4cm x 4cm using a reference of a 10cm x 10cm field, where we know the measurements with conventional ion chambers are very reliable.

This method is ideal for delivery machines that don’t have a collimator to rotate or the couch doesn’t rotate. For instance MR-Linac’s.

When possible, confirm the value of the known OF with a trustful sensor at the moment of following this method. Many times old measurements are not repeatable at the current time.

If you have trustful Monte Carlo calculations and your Monte Carlo model gives you reliable OF’s you can use those values to calculate \( ACR \) following this method.

Method 4. Changing the MU’s of different field sizes to deliver the same dose at the sensor

This method is a combination of method 2 and method 3. It consists on radiating the sensor with different field sizes, positioning the sensor at the center of the field and irradiating each field with a number of MU’s that we know will deliver the same amount of dose to the sensor for each field size. This way we will meet the conditions stated in method 2 where we will have several scenarios where the amount of fiber irradiated changes while the dose at the sensor is maintained. This method is also equivalent to method 3 because in order to deliver the correct amount of MU’s we need previous trustful measurements from other sensors.
After taking several measurements of several field sizes with the right amount of MU’s each we will be able to draw a similar plot than figure 3 and find the regression line which slope will be the value of the AC \( R \) we are looking for.

If you think about the fundamentals of this method you will realized it is totally equivalent to method 3.

We don’t recommend to use very small fields in this method where the calculation of MU’s with conventional sensors will have a high uncertainty.

We also don’t recommend to use very large fields where more than 6 cm of the transport fibers are under the radiation field. Or when the signal from the Cerenkov Channel is larger than 40% of the signal from the Sensor Channel.

Similar to method 3 the downside of this method is that you need to know with high certainty the MU’s required for each field size to deliver always the same amount of dose at the PSD. This is not always possible or the data is not always available. We strongly recommend to measure with a standard ion chamber all the fields to be use with the MU’s calculated and confirm that the dose at the sensor will always be the same for all the fields.

This method is ideal for delivery machines that don’t have a collimator to rotate or the couch doesn’t rotate. For instance MR-Linac’s.

Method 5. Radiating only the fiber

This method consists in finding AC \( R \) following a similar method than in method 1 by irradiating the transport fibers only removing the sensor away from the radiation area. See this illustration of the set up

With this set up the light going through the Sensor Channel and Cerenkov Channel will come only from the Cerenkov effect and not from the PSD.

In this case the calculation of AC \( R \) can be done in a straightforward way using Eq. 15
In order for this method to work, you have to place the PSD in an area where you are totally certain it is going to emit zero light due to the scintillator effect. This can be tested before to assure no signal is received from the sensor.

The PSD needs to be far away from the field to assure that none of the Cerenkov light emitted will be reflected at the sensor.

We recommend to use a very small field to assure no radiation will reach the PSD. Our recommendation is to us a 2.5cm x 2.5cm field approximately and to move the PSD 15 cm away from the edge of that field.

Be sure the two fibers are very well positioned at the center of the field. It can be easily done when using a water tank. Thanks to the fact that Blue Physics system provides the readings in real time. You can move the fibers using the water tank motors while measuring in real time until you obtain a maximum signal in both channels. This will mean you positioned the fibers at the center of that small field.

Also, be sure the fibers are at least at 5 cm depth in the water or solid water to assure good electronic equilibrium at the fibers to produce a good Cerenkov effect in both fibers.

This method is ideal for Radiosurgery delivery machines like Zap, Cyber Knife of Gamma Knife, although it can also be used in MR-LINAC’s or conventional Linac’s too.

Considerations about all the Methods to find $ACR$

As you can see there are several Methods to find $ACR$. Each method has its advantages and disadvantages. In some occasions you will be able to use several of those methods but in other circumstances you won’t be able to use some of the methods described.

When possible, try to use several methods. The expectation is that you should be finding a very similar $ACR$ using any of the methods above. We consider similar $ACR$ when you see differences lower than 7%. Remember that an uncertainty of 7% in $ACR$ measurements doesn’t mean a 7% uncertainty in the final dose calculations. For small fields a 7% uncertainty in the $ACR$ normally is translated to a less than 1% uncertainty during the dose measurements.

If you find differences higher than 7% in $ACR$ when using several methods, it is most probably due to some of the conditions required for the methods are not totally met. Please pay attention to ALL the necessary requirements to apply any of the methods described above.

Always contact Blue Physics Support department if you find high differences when calculating $ACR$ using different methods and when strictly following all the requirements. It is possible that a defective sensor can cause differences in $ACR$ calculations.
The advantage of applying several methods is that they can re-confirm the accuracy of the ACR measured with any of the methods.

When in doubt, we recommend to use the ACR calculated with the Method 3 of Cross Calibration. But be sure you have trustful measurements from a reliable ion chamber.

After finding ACR we recommend to do a final confirmation that the ACR measured is going to produce accurate relative dosimetry readings. This proof can easily be achieved just measuring with Mode 10 two or three OF’s of intermediate fields (let’s say 10 x 10, 5 x 5 and 4 x 4). Then check that the OF’s measured with Blue Physics and using Eq. 10 fit the OF’s of those fields measured with all your other sensors available. If you find a good agreement between all the measurements of those OF ot the intermediat fields you will be sure that you have found the correct ACR that will give you accurate relative dose measurements. We recommend to run this proof only with relative large fields. Don’t use very small fields where the uncertainty of the measurements is very high with any kind of sensor.

Once ACR is found and confirmed, you can introduce the value in the Blue Physics software under the “Settings” module:

![Sensors Information Table](image)

Once the ACR value is introduced in the Blue Physics software. The software will be able to provide the charge proportional to dose of each measurement following Eq. 10 without the need for the end user to do all the math.

**Calibration for absolute dosimetry**

To calculate the amount of absolute dose measured by the sensor we need to find the calibration factor to convert charge measured in nC to cGy (CalF). To do that we first irradiate the sensor under standard calibration conditions (field 10x10cm at 100 cm SSD at 10 cm depth) and we irradiate 100MU that we know delivers 100cGy to the center of the beam, and we take note of the charge proportional to dose measured by the system using Eq. 10 and Eq. 11

\[
CalF = \frac{100}{\text{charge proportional to dose at reference conditions}} \quad \text{Eq. 27}
\]

**CalF** units are cGy/nC

Knowing ACR and the CalF we can calculate the absolute dose based in the readings from both channels using Eq. 11

\[
\text{Absolute Dose} = CalF \cdot (R_s - ACR \cdot R_c) \quad \text{Eq. 28}
\]
The result of this calculation will be the dose measured in cGy.

Once we know $CalF$ we can introduce its value in the Blue Physics software in the “settings” section. This value introduced together with the previous value introduced of ACR will allow the Blue Physics software to provide directly absolute dose readings for any measurement without the need of the end user to do all the math in the previous equation.

![Sensors Information Table]

**REFERENCES:**
