# Suggestions for the CsI Acquisition, Test and Storage

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This document provides a list of suggestions for the procurement, handling, testing and shipping of CsI crystals for the GLAST calorimeter based on our experience with the prototype calorimeters we built in 1996, 1997 and 1999. This is not meant to be the final specifications document and is mostly meant as a private conveying of our views and experience to our Swedish collaborators.

## Sources

The crystals for the GLAST calorimeter will consist of thallium-doped Cesium-Iodide, or CsI(Tl), or CsI, for short. This material is available from a number of suppliers around the world. Based on the experience of large particle physics calorimeters constructed from the same material, there are four or five dominant CsI manufacturers around the world. One in China, one in the United Kingdom, one in Japan, one in France, and one in the Ukraine. The Japanese source was used for the original GLAST prototype but seems to have stopped growing its own material and is therefore no longer a primary source. The source from the UK has had problems supplying us and other groups with material of reliable quality and was excluded on those grounds. Samples of the Chinese material built for the Babar experiment were examined and large mechanical flaws or cracks were very noticeable in the crystals. Given the launch environment for a space mission, this material was also excluded. (The Babar experience with the Chinese provider is that it is the most improved manufacturer. It started out with the least reliable light yield and apparently improved to be the most reproducible. It might therefore be worth revisiting the quality of the Chinese material. )

The remaining suppliers are Crismatec in France, and Amcrys-H of the Ukraine. The GLAST 1999 prototype calorimeter was built with 50% French material and 50% Ukrainian material. The French material was purchased. It is interesting to note that quote submitted by the French vendor was substantially higher than the cost through the Ukrainian vendor. When made aware of the large discrepancy between their price and the competition, a new quote was made with a much more reasonably price per crystal (~$950 per crystal). This lesson is worth remembering, if one is shopping for a good deal. The Ukrainian material was acquired through the STCU (Science and Technology Center Ukraine). STCU is an organization set up by western nations (US, Canada, Japan, EU, Sweden) after the cold war to retrain or keep busy at home former soviet block nuclear scientists. The material was a deliverable on a grant written to the STCU by Amcrys, with our support (I actually wrote a draft they modified and submitted), so it actually was free to us. STCU will most likely not subsidize the whole operation, but could be useful nonetheless. STCU is willing to act as a facilitator on international projects for a small fee (5-8%, I do not remember the exact number). If the Amcrys material is being considered, the use of STCU as a facilitator is highly recommended.

The easiest way I found to deal with Amcrys was through email (amcrys-h@ovs.kharkov.ua). Contacts there are Vadim Lyubinsky (a sales manager type person), or Vladimir Yankelevich (R&D). The points of Contact at Crismatec were Frans Kniest (sales manager) and Dr. Erik Duloisy (R&D). Frans has taken on a new position within the company but should still be a good starting point.

**Specification**

The crystals will have dimensions of 19.6x 27.1x 341.4 mm, for now. These figures can only be finalized when the mechanical design matures. The current values should be good enough to start contract negotiations. The final values will probably not change by more than 1 mm in the short dimensions, and by 2-3 mm in the long dimension. One can expect that there might be a small change in the dimensions after the first full prototype is built. A dimension should probably be agreed upon for the engineering model, with the final dimension to be determined after the engineering model is built.

The material quality is best specified by requiring a certain energy resolution under certain testing conditions. We recommend measurements made with photomultiplier tubes on the two small faces of the crystal and a radioactive source irradiating the crystals from a perpendicular direction.

The energy resolution should be specified to be better than 15% (TBR) Full Width at Half Maximum for the sum of the signals using the 1275 keV line of a collimated Na-22 source. This is valid for 10 (TBR) points uniformly sampling the length of the crystal, i.e. every 3.1 cm (TBR). The crystal is to be surrounded by highly reflective white material along the long sides during the testing. Tetratec should be provided for this test.

Other mechanical specifications are:
-The crystal dimensions have a tolerance of ± 100 micron (TBR) in all three dimensions.
-The crystals should have six faces that flat to ± 100 micron (TBR).
-The crystals should have a fine polish finish.
-The crystals should have no visible scratches, cracks or dents.
-The crystal faces should be parallel to a maximum deviation of ± 100 micron (TBR).
-The crystal faces should be perpendicular enough that the maximal deviation from the planned plane is less that 100 micron (TBR).

Crismatec did not like the ± 100 micron specifications, and asked that they be changed to 200 micron for the crystals delivered for the 1999 prototype. They did meet the modified specifications, to the extent we measured them. Amcrys did not object to the specifications, but their crystals were less flat than Crismatec's, with a number of the crystals not meeting the specification in terms of flatness. They claimed after the fact that they did not have a flatness specification and that they could have met it if they had known. There will be an issue about how far the specifications can be relaxed with the French mechanical design.

The French version of the mechanical design will probably want beveled edges along the four long edges. This bevel needs to be defined before ordering. A 45 degree, 1 mm (TBR) wide bevel might be a good starting point.

**Light Tapering**

The position of a gamma ray interaction along the length of a CsI crystal is determined by the relative light collected at each end of the crystal. The amount of variation in the relative light yield at each end can be tuned by treating the surface of the crystals. For the 1999 prototype, the preferred light tapering was not known when the crystals were specified for Amcrys. The surface treatment was therefore performed at NRL. When the Crismatec crystals were ordered, the desired tapering was already known, and it was specified in the contract. It is recommended that the light tapering be applied on the crystals at the factory. The tapering is achieved by roughening the two narrow long sides of the crystals (the 2 surfaces with dimensions 19.6 x 341.4 mm). The tapering is specified to be monotonic and such that the light collected from the far end of a crystal is 60% ± 10% (TBR) of the light collected at the near end. This is specified to hold for measurements from both ends of the crystal.

The light tapering measurements are done at the same time as the light yield measurements. The tests are to be performed at the factory, and checked after delivery.

**Acquisition**

The acquisition of all the crystals will probably have to happen in two or three steps. The engineering model will need crystals in late 2001. This will require a purchase early in 2001. This might require contract negotiation to start in late 2000. The engineering prototype will need 96 crystals when fully assembled. One should therefore plan to purchase ~ 120 crystals. This allows for some spare crystals, but also some crystals for various other tests that will be needed (mechanical, irradiation, etc).

There currently is a plan for a second engineering model. This would require another ~ 120 crystals. It would be purchased after the first engineering model crystals are delivered. This would involve a late 2001 purchase, for an early 2002 delivery.

The full GLAST array will have 16 flight units + 2 spares, or 18 x 96 crystals, which is 1728 crystals. If one were to specify 10% spares, that would come to ~ 1900 crystals (not counting the engineering models). Both crystal manufacturers can handle these quantities, and both could support delivering them within an 18-month period. They off course prefer long steady contract, whereas the GLAST project timeline is best suited by an instantaneous delivery. One should probably consider a contract for a basic quantity of crystals, with an option to extend the contract for up to a certain number of crystals by a certain date. By the time the last crystals of the base order are manufactured, we should have a pretty good idea how many spares we really need. If two vendors are used, we can use the option to boost shipments from the preferred provider.

## Shipping

The crystals from both vendors were shipped to us in sealed plastic bags surrounded by Styrofoam. Crismatec shipped each crystal in a separate bag, whereas Amcrys vacuum packed a number of crystals in a single vacuum pack. Both approaches seemed to work well. We probably need to check with NASA quality assurance people what additional requirements are needed for flight material, if any. We might consider using a number of hard-shell boxes with foam layers with cutouts to hold the crystals. This is probably worth it in the long term. Some special shipping arrangements might need to be made because shipping companies sometimes flag the "Cs" as a dangerous material. Then of course there are all the issues of customs.

## Wrapping

The crystals from Amcrys were wrapped in 2 layers of Tyvek, and the Tyvek end was held by a strip of scotch tape along the length of a crystal. The tape did leave some residue on the surface of the crystal (bleeding through the Tyvek) and is not a very good idea. (A couple of small pieces of a better tape might solve this problem.) The Tyvek sleeve had the advantage that the crystal could be slipped in and out of its sleeve repeatedly, which is necessary for all the steps to be taken during testing and characterization. The Crismatec material was wrapped in material very similar to our Tetratec, which is a very porous, very white Teflon. The Tetratec wrap has various advantages. It is soft and somewhat protects the crystal. It has the optimal properties for the light yield measurements. It sticks somewhat to the crystal, so the crystal will not slide out of it. The disadvantages are that it is porous, so if someone handles a wrapped crystal with their bare hands, there could be surface damage. It also takes somewhat longer to wrap and unwrap than it takes to slide in and out of a Tyvek sleeve.
We currently see no reason to consider materials other than Tyvek or Tetratec.

Whatever material is chosen, one must ensure that it is used by both suppliers, if 2 suppliers of crystals are used. One should provide it to the supplier, to ensure the right materials are used. If one carefully plans the order of tests and measurements, a crystal would not need to be unwrapped too often (once for the various mechanical characterization steps) and then a Tetratec-type wrap would be desirable. The crystals could travel on to their next destination (France, US) in their original wrapping material.

## Storage

The crystals must be stored in a dry environment since they are mildly hygroscopic. While no problems were encountered at NRL, there are many stories of instances of crystal polish (including GLAST crystals) gone bad because of moisture. The storage area for all crystals should either have a controlled low humidity, or be slowly flushed with a dry gas, presumably dry nitrogen. Depending on the building used, one might have to think about disabling a sprinkler system in the storage area. An accidental (or non accidental) discharge of a sprinkler system could be very damaging to CsI. The crystals should be stored near or at room temperature at a controlled

temperature to avoid condensation and to have a known temperature while doing light yield measurements. (The light yield is temperature dependent).
The crystals should be stored on flat, smooth surfaces to ensure no marks or indentations are made into the crystals (CsI is relatively soft). This is an easy task. We just used plexiglass sheets covered with a soft material.
The shelves, or drawers holding the crystals must be strong! CsI has a density of 4.5, so it easy to store tens of kg in a small space. If drawers are used, one should lay the crystals with their long axis perpendicular to the direction of motion of the drawer. (We had an instance of crystals sliding when a drawer was opened too fast and the crystal long axis was in the direction of motion. )
The crystals are better stored in a dark environment, to avoid activating some phosphorescence in the CsI, although we have never noticed such effects and current-day CsI does not seem to suffer from this much.

## Crystal Origin Documentation

The CsI crystals are machined out of larger crystals called boules. The boules are roughly cylinders. The Amcrys boules can be very large, with diameters up to 50 cm and height of 50 cm. The Crismatec boules have a similar diameter, but are much shorter, with a height of ~ 15 cm. Although we did not require this for the 1999 prototype material, one should require documentation of where in a boule each crystal comes from. This would be relevant if any defective crystals are found. The neighboring crystals presumably should undergo some additional testing. Since boules tend to have a gradient in thallium along the axis of the cylinder, one might want to specify that crystals be cut perpendicular to the axis of symmetry of the boule. If the light yield in a crystal is low, the whole boule would be suspect and all crystals from that boule would need to be identified. The same thing applies if CsI from a specific boule turns out to more susceptible to radiation damage than others (this can happen).

## Boule Samples

As stated above, there might be significant deviations of crystal properties between different boules of CsI. One should therefore require sample material from each boule. This material could be kept as reference material for that boule and could be use for destructive testing (radiation damage studies). Of course, one does not want to use too much material for this. A convenient set of samples would be to require 3 (TBR) samples for each boule. The samples could be polished cylinders (easy to machine and polish) of dimensions 2.5 cm diameter and 2.5 cm tall. These dimensions would make it easy to test the samples with standard photo-multiplier tubes.

## Light Yield and Taper Test

As stated above, the crystal light yield and light taper are measured with photomultiplier tubes on the two small faces of the crystal and a remote-controlled motor-driven radioactive source irradiating the crystals from a perpendicular direction. This set up should be mounted in a light-tight box with easy access to change out crystals and reposition the photomultiplier tubes (with some TBD pressure) against the face of the crystals, without getting irradiated. The optical coupling between the photomultiplier tube and the crystal should be a dry contact. The photomultiplier tubes should be readout by standard laboratory nuclear electronics consisting of shaping amplifiers and ADCs. The setup would presumably be controlled by a PC that would also act a data acquisition system.

The radioactive source strength should be selected to maximize the count rate without getting in trouble because of an excessive count rate, in the crystal or in the electronics. This rate is < 500 Hz (from a 2 ms slow component of the light fall off in CsI), so say 250 Hz. This rate is also convenient for most laboratory electronics systems. The source will need to be a lead pig for radiation protection reasons. The pig should have a hole that acts as the collimator for the source. The size of the hole (and the size of the active part of the radioactive source) should be ~ 5 mm (TBR). The exact shape of the hole still needs to be specified. The desired Na-22 source activity will then be 10s of microCuries, depending on the exact source-crystal separation.

We have a setup at NRL that could serve as a guide for other system. Identical copies of this setup should exist at each manufacturing site, as well as each site handling crystals before they have PIN diodes attached to them.

## Metrology

When crystals are first unwrapped, they should be photographed or scanned to record any blemishes or scratches, etc. This should be done for the two projections showing long sides of the crystals.

The crystal should be measured to check if they meet the mechanical specifications.

The overall dimensions can be measured using an automated measuring station coupled to a PC, or by hand. Given the large number of crystals and multiple points per crystals, an automated station is desirable. The dimensions along the long sides should be measured every 5 (TBD) cm, in both dimensions. The dimension measured across the end small surface needs only be measured at 2(TBD) points.

The flatness, parallelism and perpendicularism need to be measured with different instrumention. The crystals need to be positioned on a table with a probe that samples the position of one small point on the surface of the crystal. The probe can be programmed to measure many points on a surface on a 2-dimensional grid. A surface map can then be constructed. These measurements are time consuming and might not be necessary for each crystal surface. One should probably measure a few crystals from each batch once the required-quality crystals have reproducibly been delivered by the manufacturer. One should check with quality control people if this is acceptable.

A convenient tool might be a set of laboratory reference “U” shaped slots. The slots are built to the maximal allowed size of a crystal in one dimension. If a crystal does not easily fit in the slot, it should be flagged.

## Handling Procedures

Since CsI is hygroscopic, it should always be handled with latex (or similar) gloves. We noticed that one has to be careful about the kind of glove to use. Some gloves are powdered for convenience of the user, but this powder leaves a residue on the crystals. One should therefore use powder-free gloves. A note of caution here is the incredible number of gloves one can through is this process. Gloves should obviously be replaced if one went anywhere near a source of moisture with the glove (cold drinks, sweat, etc.).

All the spaces where crystals will be handled should be clean and dry. Crystals should be kept on flat, smooth surfaces, even when not in long-term storage. It is also best to never leave part of a crystal hanging over the end of a bench or table.

Because of toxicity concerns with Cs or I, it might be worth checking with a local safety administration on regulations regarding the handling and storing of large amounts of CsI.

## Serial Numbers

All crystals are identical (hopefully). The only way to distinguish tem is therefore by their serial number. Manufacturers like their own numbering scheme, and GLAST will like its own numbering scheme. Crystals will therefore have a manufacturer serial number until they are assigned an additional GLAST serial number. The manufacturers typically put the serial number on the outside of the crystal wrapping. This is convenient and can be copied with the GLAST serial number. The problem arises when a crystal is taken out of its wrapper for mechanical or other measurements. The real problems start when more than one crystal is unwrapped at the same time, possibly causing confusion. We originally assumed that each crystal would be marked with a unique mark on the actual crystal to avoid a loss of identity. This should still be considered. For the 1999 prototype, we approached the problem twofold. No two crystals were ever allowed to be unwrapped at the same time. In addition, whenever a crystal was unwrapped, it was labeled with a small adhesive kapton label on which the crystal serial number was written. The label was removed when the crystal was reinserted in its wrapper.

## Documentation

For convenience, a set of different databases for the crystals should be kept. One should track incoming material, i.e. shipments from the crystal manufacturer. The database should track what crystals were shipped on what dates with what shipper in what containers, when they arrived, and who unpacked and logged the material into storage. A similar database is needed for material going out for the next step in the assembly process.

A separate database could track the material associated with each boule. This data base would be the main one to keep track of all the samples.
The main database would be the one that stores the characteristics of each crystal. Each crystal should have its own record in the database. The database should be computerized, so that test data can easily be transferred from testing stations to the database.

The record for each crystal should include:
-manufacturer serial number
-lot number
-local serial number
-information about the boule and location within a boule
-date shipped
-date arrived
-person unpacking and storing
-a copy of all the testing performed by the manufacturer. This should included light yield measurements as well as dimensional measurements. The manufacturer should be provided with database software so that the records can easily be integrated into the main database.
-dimensional measurements, with date and identification of person and test station
-flatness measurements, with date and identification of the person and test station
-digital photographs or optical scans (2 projections) of the bare crystals
-light yield and light tapering measurements with date and identification of the person and test station. Both the raw data (spectra at each point) and the processed data (light yield curves) should be kept in the database.
-a table with the electronic settings and configuration used for the above tests. This should included which radioactive source was used, the data integration times etc.
-a location to enter comments and remarks should accompany each testing or measurement sheet.
-date shipped out and associated persons, crates, shipping company tracking information
-acknowledged receipt by recipient

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