Information-Request/Submittal/Release		Number	S	038-0018
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Project	MACS		Revision ☐	
Originator	T. D. Pike		**If revision, provide the following:**	
Date	May 25, 2004		**Previous Submittal**	
Database Reference	TBD		**ECR/ECN**	

Scope

Specification for the MACS Double Crystal Analyzer (DXA)

Purpose

To provide performance specifications for the MACS Double Crystal Analyzer (DXA) mechanism to allow the corresponding sub-projects to proceed in parallel with the general development of MACS.

Description

Text and images that specify the functional requirements for the Double Crystal Analyzer(DXA), and that define the interface with the rest of MACS. The mechanical interface is defined for both securing the DXA and attachment of the P.G. crystals.

Filing

When filed as a submittal, this form and the information attached to it transforms into a released document when it is signed by all parties named in it. The form with attachments is kept on file in the office of the NIST chief engineer. When attachments are electronic in nature (such as electronic CAD data) that information and its hierarchical position in the project design tree shall be identified in or under this submittal. Information Requests, Submittals and Releases are numbered separately, yet sequentially.

Change Process

Anyone can propose a change to documentation that is released under this form. To such end an Engineering Change Request (ECR) is filed. A priori, the change board is composed of the individuals that signed the submittal against which the ECR is drawn. Approval of the ECR turns it into an Engineering Change Notice (ECN), which gives authority to prepare a new submittal. The new submittal covers at least the fully executed ECN. Approval of the new submittal signifies close-out (full implementation) of the ECN.

Endorsements (list composition is part of release and determines Change Board for ECR/N's)

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S 038-0018

General Specification for Development of the Double Crystal Analyzer System

for the

Multi-Axis Crystal Spectrometer (MACS)

Developed by

Johns Hopkins University
Department of Physics and Astronomy

and

National Institute of Standards and Technology
Center for Neutron Research

Specification NG-0 –5.5 DXA

Revision 4

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1 *Summary*

This document describes the requirements for a system of twenty double crystal PG(002) analyzer assemblies that each cover the range of scattering angles from 40^o to 140^o. Each of the twenty channels shall be mechanically independent with a well-defined mechanical interface for attachment to the MACS detection system. The system of analyzers shall be fully integrated with appropriate control electronics such that the scattering angle for each of the twenty channels can be set via commands to a central DXA processor from the MACS instrument control computer.

From a purely mechanical point of view, the PG crystals may be thought of as mirrors that reflect from the bulk. Mechanism testing shall be performed with light reflected from first surface mirrors with half the thickness of the PG located on the PG mounting stage.

The Double Crystal Analyzer (DXA) System is a sub assembly of the Multi Axis Crystal Spectrometer (MACS) under development at the NIST Center for Neutron Research (NCNR). The Top Level Specification for MACS provides background material for understanding the context of the DXA sub-project within the overall project.

Further, the DXA sub-project shall follow the standards and practices found in the Top Level Specification (available at http://www.pha.jhu.edu/~broholm/MACS/).

Detailed mechanical and electrical specifications follow.

2 *Definitions*

2.1 DXA: The double crystal analyzer mechanism for a single channel of the MACS detector system. Twenty such devices are required for the complete MACS detector. Refer to **figures 1, 6, 7 and 10.**

2.2 C1: The first analyzer crystal assembly that will be in direct view of the sample. C1 rotates about a vertical axis that passes through the center of mass of the reflecting material. C1 shall deflect the neutron beam towards the right as viewed along the direction of travel.

2.3 C2: The second analyzer crystal assembly that will be in direct view of the spectroscopic detector. C2 rotates about a vertical axis that passes through the center of mass of the reflecting material. C2 shall deflect the neutron beam towards the left as viewed along the direction of travel.

2.4 PG: Highly Oriented Pyrolytic Graphite. This material will be supplied to the vendor by the NIST Center for Neutron Research. It will be in the form of nine rectangular plates with dimensions 60.0 mm × 20.0 mm × 2.00 mm for each C1 and nine similar plates for each C2 for a total of 360 plates. The plates will be numbered and must be assembled in a prescribed order to form C1 and C2 for each of the twenty channels that make up the MACS detector.

3 Functional description

3.1 Crystal assemblies

C1 and C2 shall hold part of a cylindrical shell of the NIST provided PG. The cylinder axis shall be horizontal and lie at beam height to within 1 mm. The radius of curvature shall be 500 mm. The projected dimensions of the reflecting surfaces shall be width × height ≈ 60 mm × 180 mm. The axis of rotation for C1 and for C2 shall pass through the center of mass of the corresponding reflecting material to within 1 mm.

3.2 Mirror Attachment

The two mirrors of each DXA are attached to the respective axis by means of the bracket shown in **figures 3 and 4.**

3.3 Overall motion required

The DXA shall enable a coupled translation and rotation of C1 and C2 as shown in Fig. 1. When C1 and C2 lie on the central dashed line, C, the DXA is said to be in the reference position and $x_1=x_2=0$. C1 and C2 translate parallel and in opposite directions such that $x_1=x_2$ at all times. Denote the line that connects the two axes of rotation by L12. $\mathbf{n}_1$ and $\mathbf{n}_2$ shall be anti-parallel and bisect the angles formed by L12 and the corresponding translation direction. Preference is given to a single rotating mechanical input.

3.4 Summary of required motion

The DXA concept shall provide motion for two reflecting surfaces (mirrors) such that 1) the input angle and output angle with respect to the incident and output beams are equal, 2) the input and output beams are parallel, and 3) the centers of the first and second mirrors are equidistant from the center axis, C (central dashed line in Fig. 1). These constraints shall be satisfied throughout the range of motion of the mechanism. Refer to **figures 1 and 2.**

3.5 Quantitative specification of motion

The spacing between the two translation axes shall be d=70.0(1) mm. The relation between translation and rotation shall be $x_1 = x_2 = \frac{1}{2} d \cot 2\theta$. The scattering angle, 2θ, is defined in Fig. 1 and shall span the range from 40° to 140°. Correspondingly, x_1 and x_2 span the range from 41.71 mm to -41.71 mm. As viewed from above, the beam is deflected clockwise at C1 and counter clockwise at C2.

3.6 Extent of travel

The input and output beams are separated by 70mm. The mirrors shall rotate through a minimum of 50 degrees, translating correspondingly. The end of travel shall be 20 degrees or less at one end and 70 degrees of more at the other. This corresponds to the mirrors traveling horizontally approximately 42 mm each way about the center axis C.

3.7 Collimation

Course collimation shall be provided by a series of steel blades between C1 & C2 that shall rotate simultaneously to maintain parallelism with the line L12. (Blades will be

Gadolinium coated at NIST.) The horizontal extent of the blades, L_B, shall be maximized without interfering with C1, C2, or the incident and final neutron beams. The perpendicular blade spacing shall be less than or equal to $L_B / 5$. The blade thickness shall not exceed 0.65 mm. (N.B. Practical center-to center spacing is 16 mm) Refer to **figures 8 and 9.**

3.8 Mechanical Tolerances

3.8.1 Positional Tolerances – Crystals

3.8.1.1 **Rotation:** The tolerance for orientation of the PG platelets that make up C1 and C2 shall be 0.05^o for rotation about a vertical axis and 0.2^o for rotation about any horizontal axis. (n.b. This tolerance applies to the P.G. and P.G. crystal holders, which will be supplied complete for mounting. First surface surrogate mirrors with a thickness of 1.0 mm (half that of the PG), utilizing a common mounting means will be required to perform prototype and production unit acceptance tests.)

3.8.1.2 **Translation:** The Crystals shall be constrained and located to the vertical axis of the mass center of the nine P.G. Crystals. The crystals shall be held firmly in place to within 0.1 mm of the true position location with respect to all axes of translation.

3.8.2 Actuation Tolerances – Mechanical Accuracy & Repeatability

3.8.2.1 **Rotational Accuracy**: The mechanism shall be capable of mechanically resolving distinct equal increments of 2.0 minutes of arc, or less, throughout the entire range of motion.

3.8.2.2 **Rotational Repeatability:** The mechanism shall be capable of repeating a given angular setting to within 1.0 minutes of arc, or less, throughout the entire range of motion.

3.8.2.3 **Translational Accuracy:** A beam projected at the DXA according to the schematic in **figure 2** shall not deviate more than 1.0 mm T.I R. (total indicator reading) in the horizontal direction (sketch plane) or 3.0 mm T.I.R. in the vertical direction throughout the entire range of motion.

3.8.2.4 **Translational Repeatability:** The beam position shall be repeatable within 0.25 mm T.I R. in the horizontal direction (sketch plane) or 0.75 mm T.I.R. in the vertical direction throughout the entire range of motion.

3.8.3 Actuation Tolerances for collimator blades

The collimator blades shall be parallel to L12 in Fig. 1 to within 0.5 degrees throughout the range of travel. The blade orientation shall be repeatable to within 0.1 degrees following repositioning.

3.9 Setting speed

It shall take less than 5 sec to move a given DXA over its full range. It shall take less than 1 sec to change 2θ for a single DXA by 1^o. It shall take less than 3 sec to move all DXAs by 1^o and it shall take less than 8 sec to move all DXAs over their full range.

3.10 Reliability

Normal use of each DXA is estimated at an average of 50 movements per day with a maximum number of movements in a single day of 500. The DXA will be in a low radiation environment. The DXA shall be true to tolerance for at least 2 years of normal use before any realignment is needed. The mean time between failures that require mechanical or electrical access shall exceed 4 years under normal operating conditions.

3.11 Home positions

There shall be a well-defined "home" position for each DXA to which the device can return to within the given tolerance when prompted by a home command. The physical scattering angle corresponding to this home position shall be the same for all channels to within the setting tolerance.

3.12 Hard limits

Hard limits at the extreme ranges of safe travel shall protect the DXAs from damage associated with any attempt to drive beyond range.

4 Mechanical interface

4.1 Living space

The dimensions of the DXA base (Not including the actual crystal assemblies and any connecting drive shafts and motors) shall be minimized subject to the following constraints: width cannot exceed 100 mm and depth cannot exceed 75 mm. The distance from beam height to the top of C1 and C2 shall be less than 95 mm. Consideration should be given to the possibility of remote location of the motion actuator, which can be accommodated within shielding below or behind the DXA (behind downstream from C2). The exact distance from the DXA mounting surface to beam height will be specified to the DXA project when the location of the mounting plate within the MACS detector shielding has been determined. This specification shall not further constrain the aforementioned maximum DXA base depth.

4.2 Mechanical Mounting

A mechanical mounting method shall be provided within the following constraints:

1. The mounting surface shall consist of three equal sized pads each with an area between 3.0 and 6.0 Square Centimeters. (e.g. 14.1 mm sq. or 12.5 mm circular pad.)
2. The triangular area contained between the centers of the mounting pads shall be between 30 and 60 Square Centimeters. (e.g. 135 mm x 60 mm)
3. The mounting surface shall be normal to the axes mirror rotation to within 0.1 mm
4. Two 5.00 mm diameter holes (1 circular, 1 slotted) shall act as alignment points. The centers shall be separated by at least 150 mm.

5. The attachment means will locate the DXA to within Ten arc-seconds (Ten arc-seconds per channel, at 1.000 meter is equivalent to a chord length of 0.0485 mm)
6. Final locations for the above features will be subject to NIST/JHU approval.
7. An example of a design that meets the above conditions is shown in **figure 5**

4.3 Orienting interface

Each DXA shall attach to the rest of the MACS detector system through an orienting mechanical interface. This interface shall be designed by the DXA project so that a DXA can be removed vertically from the shielding well that it occupies without side access. The crystal rotation/translation mechanism shall be in absolute alignment with this orienting mechanism to within the tolerances described in section 3.8.

4.4 Tolerance verification

The DXA sub-project shall devise and carry out optical and/or mechanical measurements, which demonstrate that the reflecting surfaces of the twenty DXAs can be positioned to within the required tolerances with respect to their individual mounting interfaces.

4.5 Magnetic Fields

The DXA system shall be unaffected by static magnetic fields up to 20 Gauss and magnetic field gradient up to 0.6 Gauss/cm. For reference, such field conditions are found approximately half a foot from a common permanent magnet and should not represent a challenge for most mechanical and electrical systems. For testing purposes, a permanent magnet will be provided along with instructions of how far from its center the magnetic field conditions mimic those which can occur at the location of the DXAs in MACS.

5 Electrical Specifications

The twenty DXA units that make up the detector system shall interface with the MACS instrument control computer through a single RS232 communication line. Control electronics that is not in the DXA base will be mounted on the mobile MACS detector system so dimensions of such should be minimized.

5.1 Power

One standard single-phase 110VAC circuit will be available for electrical power.

5.2 Device connections

Unless there is a demonstrable advantage to do otherwise, connections between the control systems and the motors, encoders, and limits are to be achieved using the NCNR motor connection standard. Furthermore, cables running between any external control electronics and DXA assemblies shall be kept as few in number and short in length as is practicable.

5.3 Communications

5.3.1 Physical Medium

Communications to the collection of controllers driving the DXA assemblies will be via a single RS232 line. TCP/IP communications via a single 100-base-T Ethernet cable are also acceptable.

5.3.2 Controller Addressing

Bussed addressing of the 20 motors is required. There is a preference for using VME based indexers.

5.3.3 Controller Syntax

Commands between the instrument control computer and the controllers are preferably in the form of ASCII strings. Controllers are expected to minimally honor the following commands:

a. Move to specified position
b. Load specified destination
c. Go to loaded destination (for simultaneous commanded moves)
d. Return motion status (moving/stopped)
e. Abort motion in progress (immediately)
f. Find home position
g. Report current position
h. Report limit status

5.4 Operator Panel

If it is practicable, an operator panel is to be furnished to manually drive the individual DXA units and display their positions.

5.5 Recovery after loss of power

Unexpected loss of power shall have no effect on the DXA system following restoration of power. In particular, the system shall automatically return to a well-defined state following restoration of power and be ready for a new command from the instrument control computer.

6 Additional Notes

The contractor for the MBT shall develop specifications for the following:

- Paint, plating & finishes
- Inspection & test procedures
- Regular and preventive maintenance schedule

Project level approval is required for the following:

- Motive and power transmission elements
- Switches and electrical connectors
- Power & communications standards

Project Engineering Contacts

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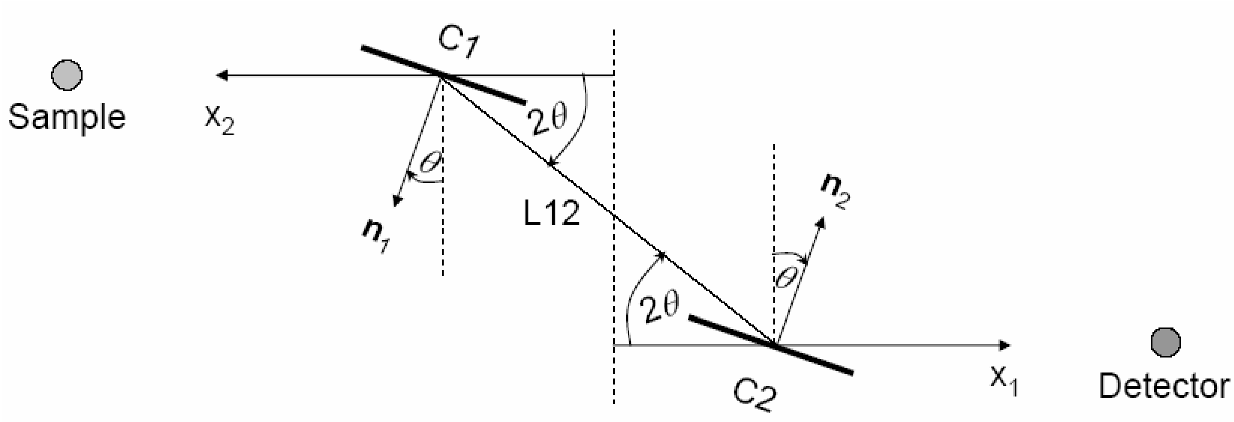

Figure 1 Schematic top view of the DXA showing the required motion.

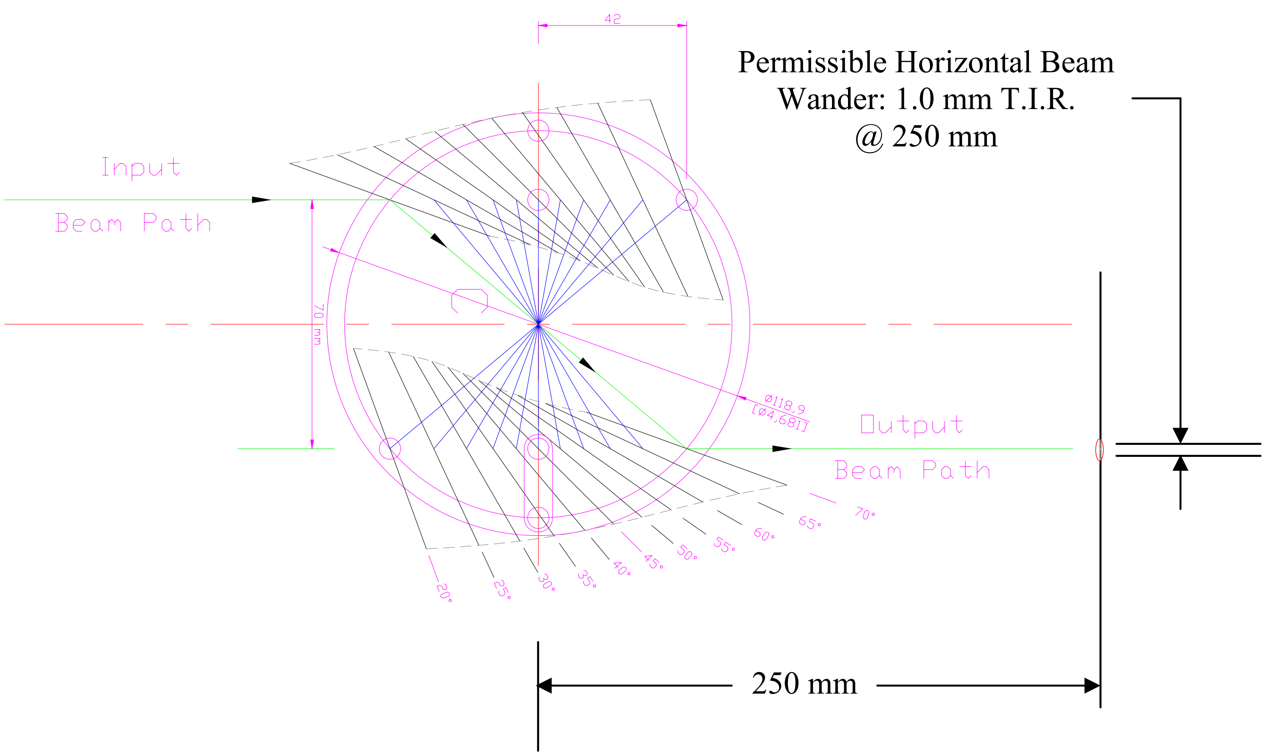

Figure 2 Schematic top view of the DXA showing the range of motion and beam projection tolerance.

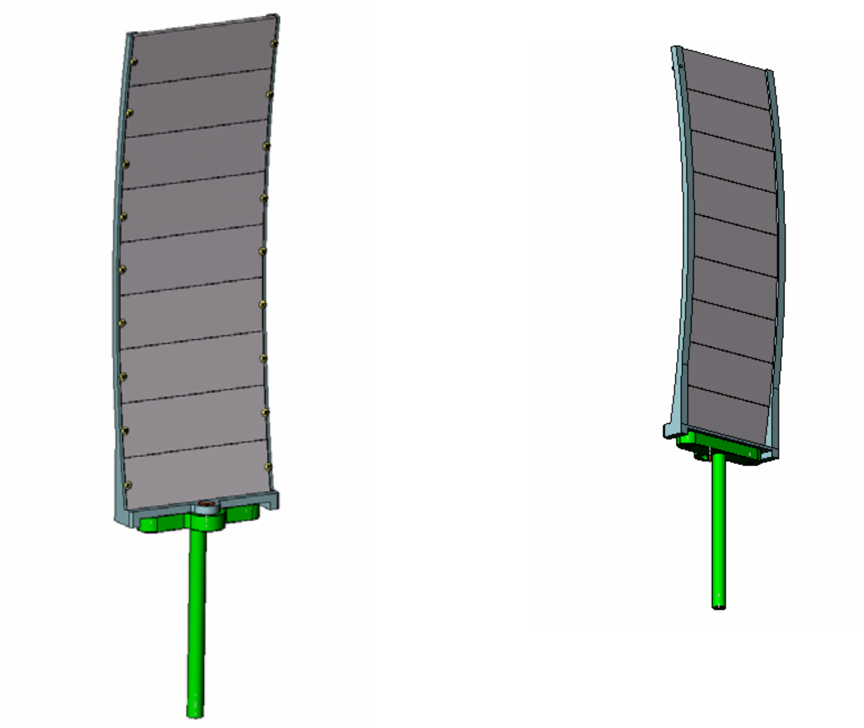

Figure 3 DXA Mirror Post Assembly

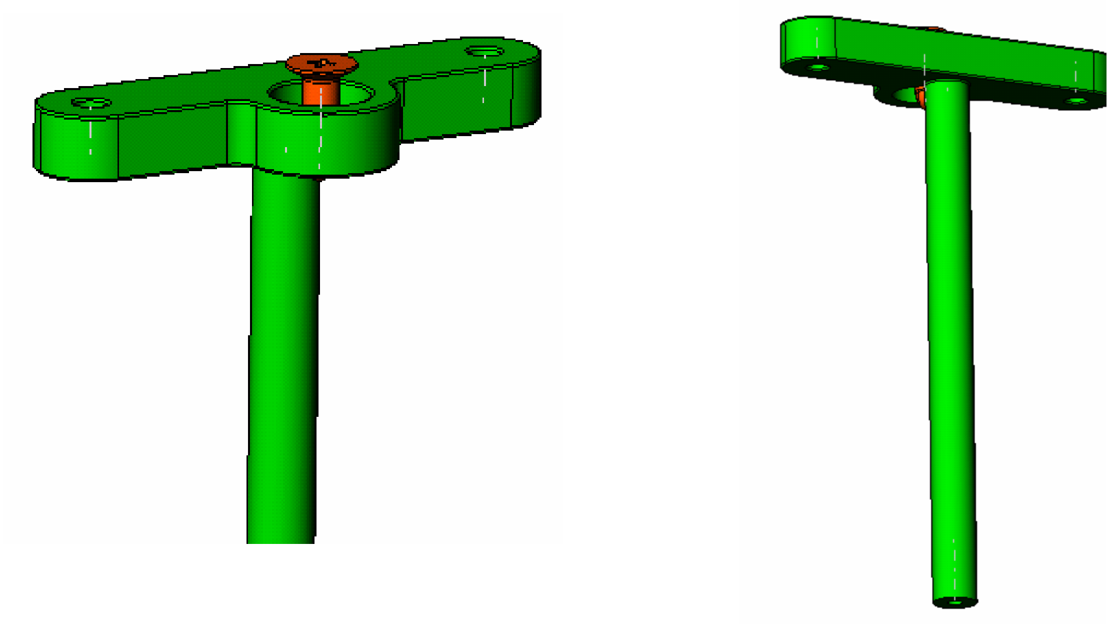

Figure 4 DXA Mirror Post with Quarter –Turn Hardware

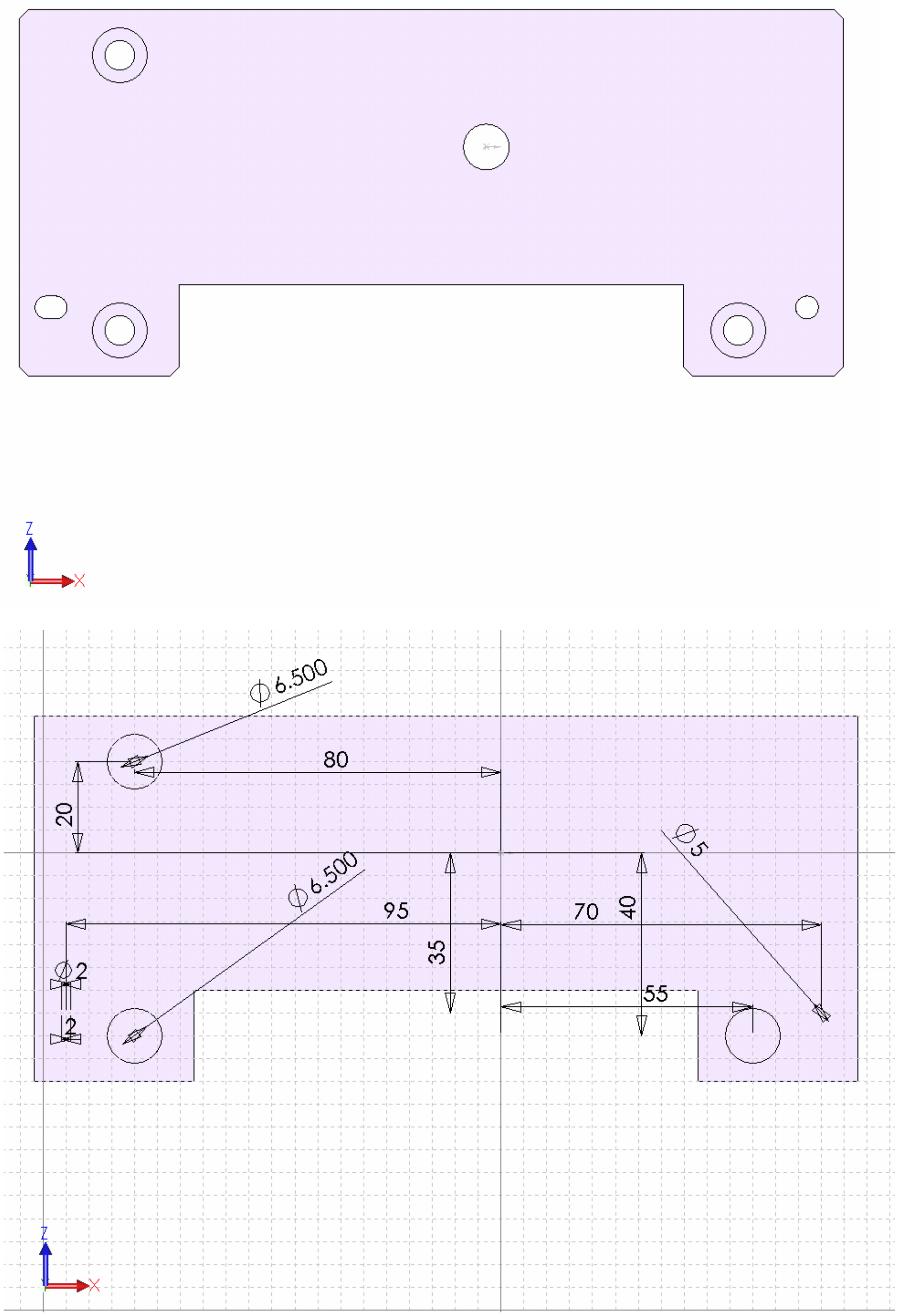

Figure 5 Mounting Detail Example

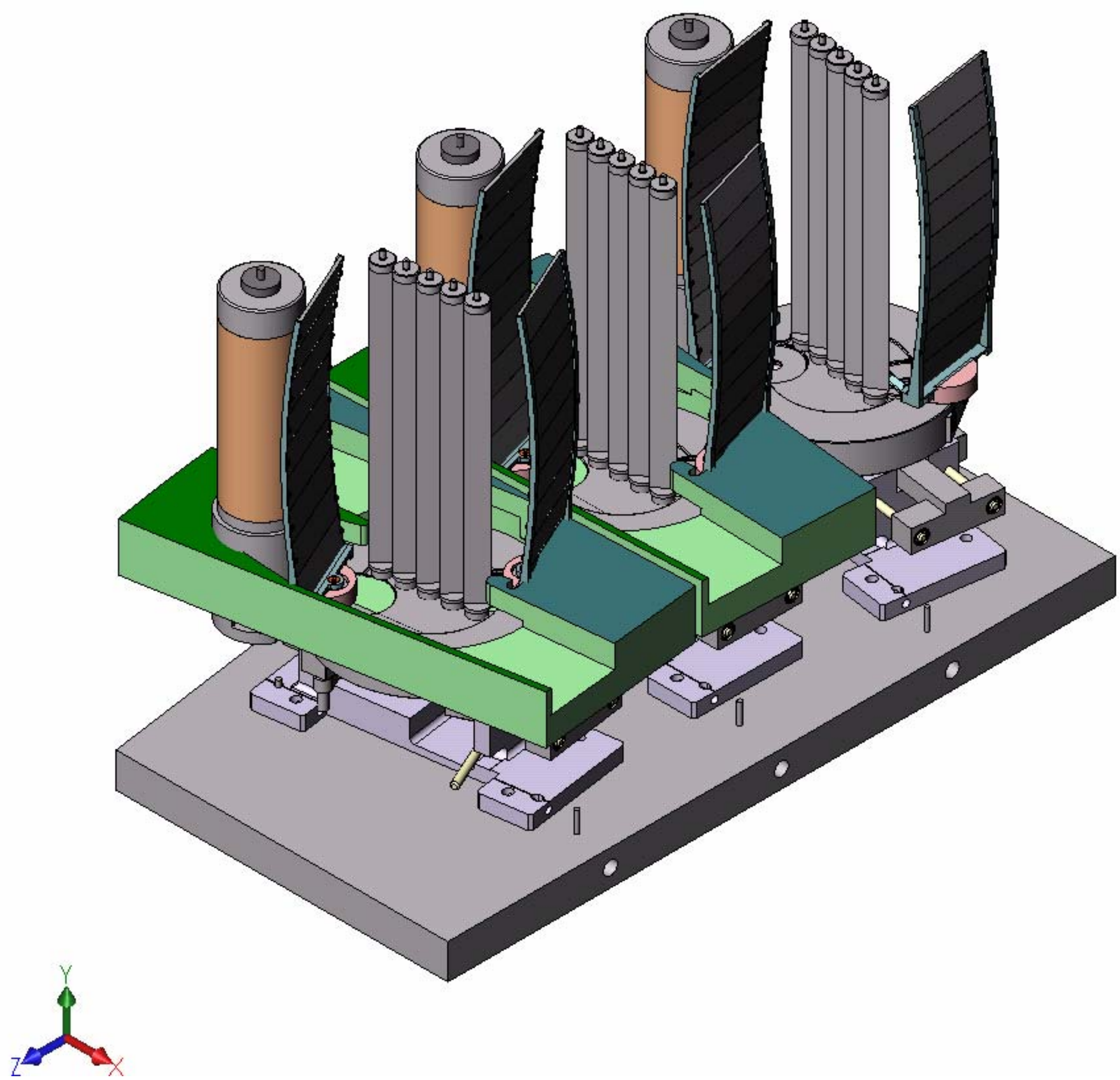

Figure 6 Concept Sketch showing three DXA units with partially removed mounting plate and partially removed shielding.

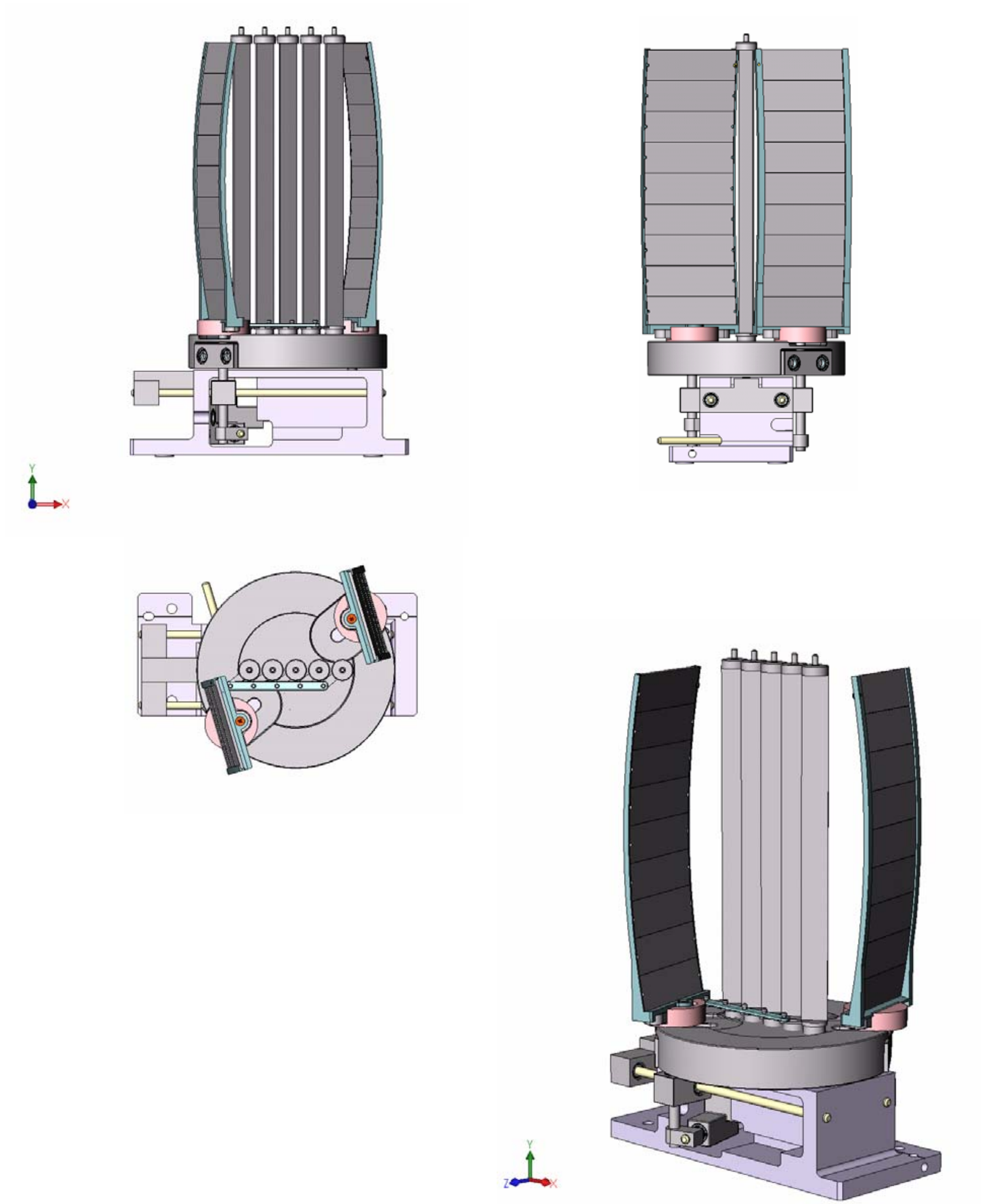

Figure 7 Concept Sketch showing three views and perspective of a DXA unit

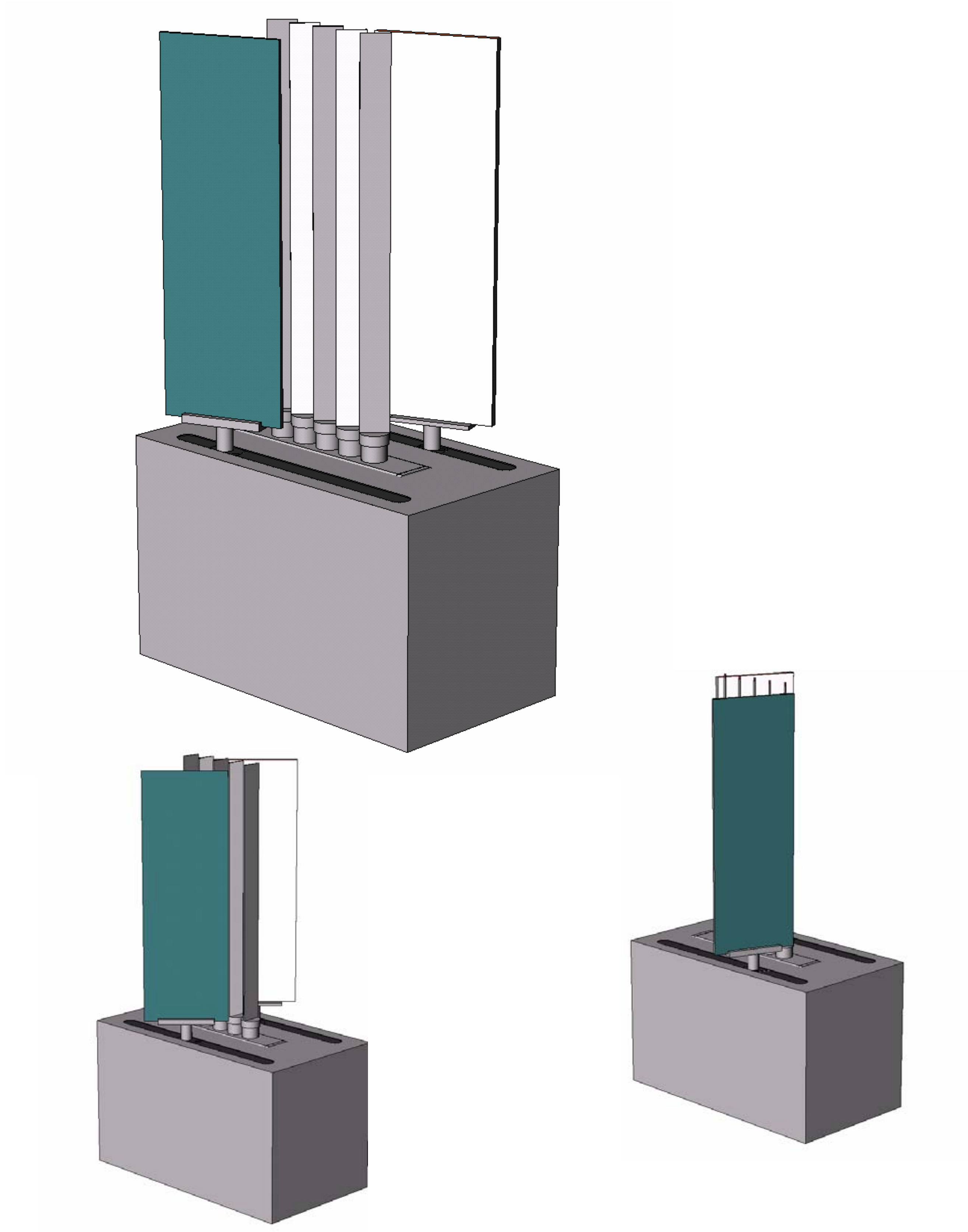

Figure 8 Concept Sketch showing three angular positions (40, 90 & 140 degrees) of DXA unit

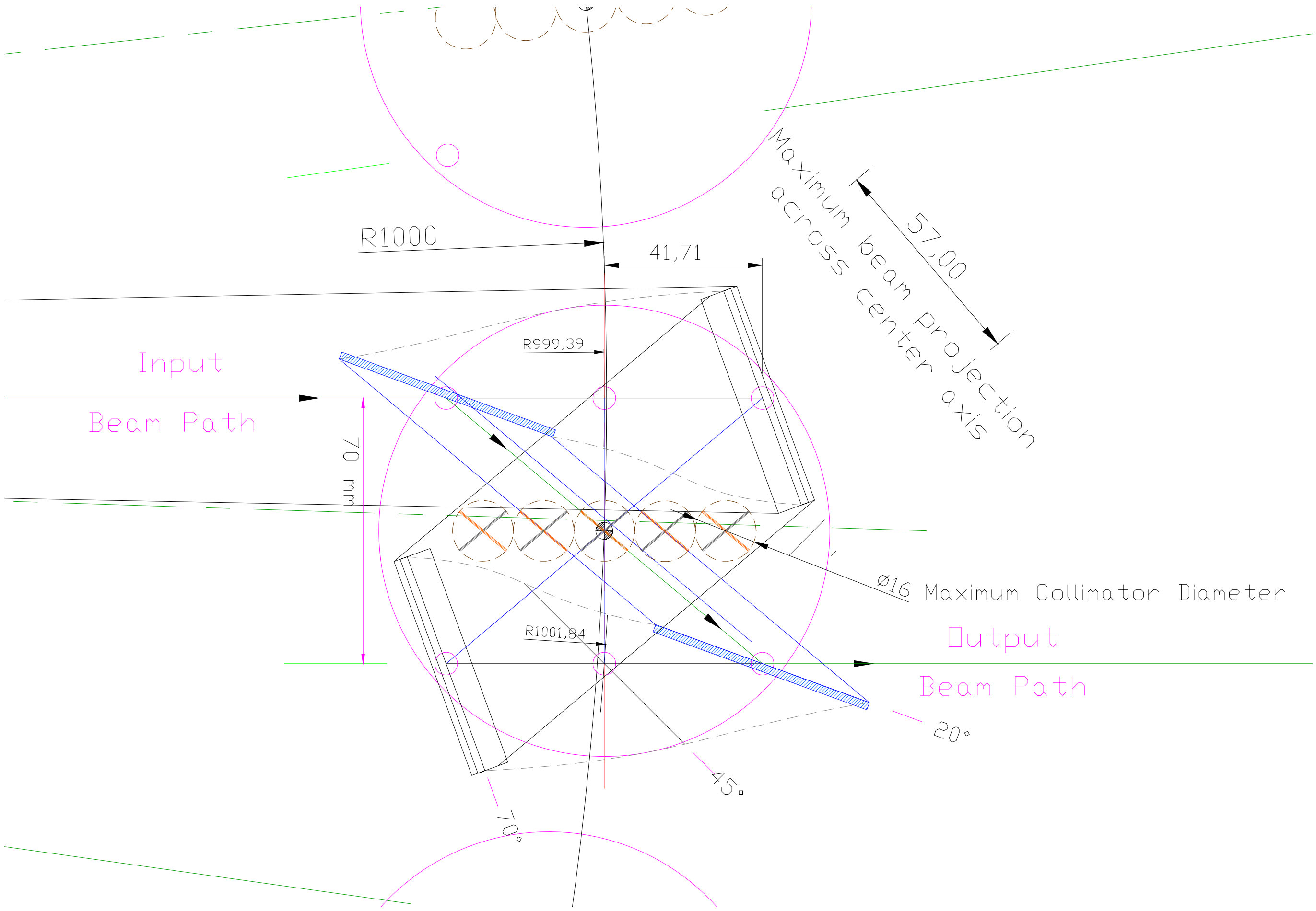

Figure 9 Layout showing Collimator Geometry for the DXA units

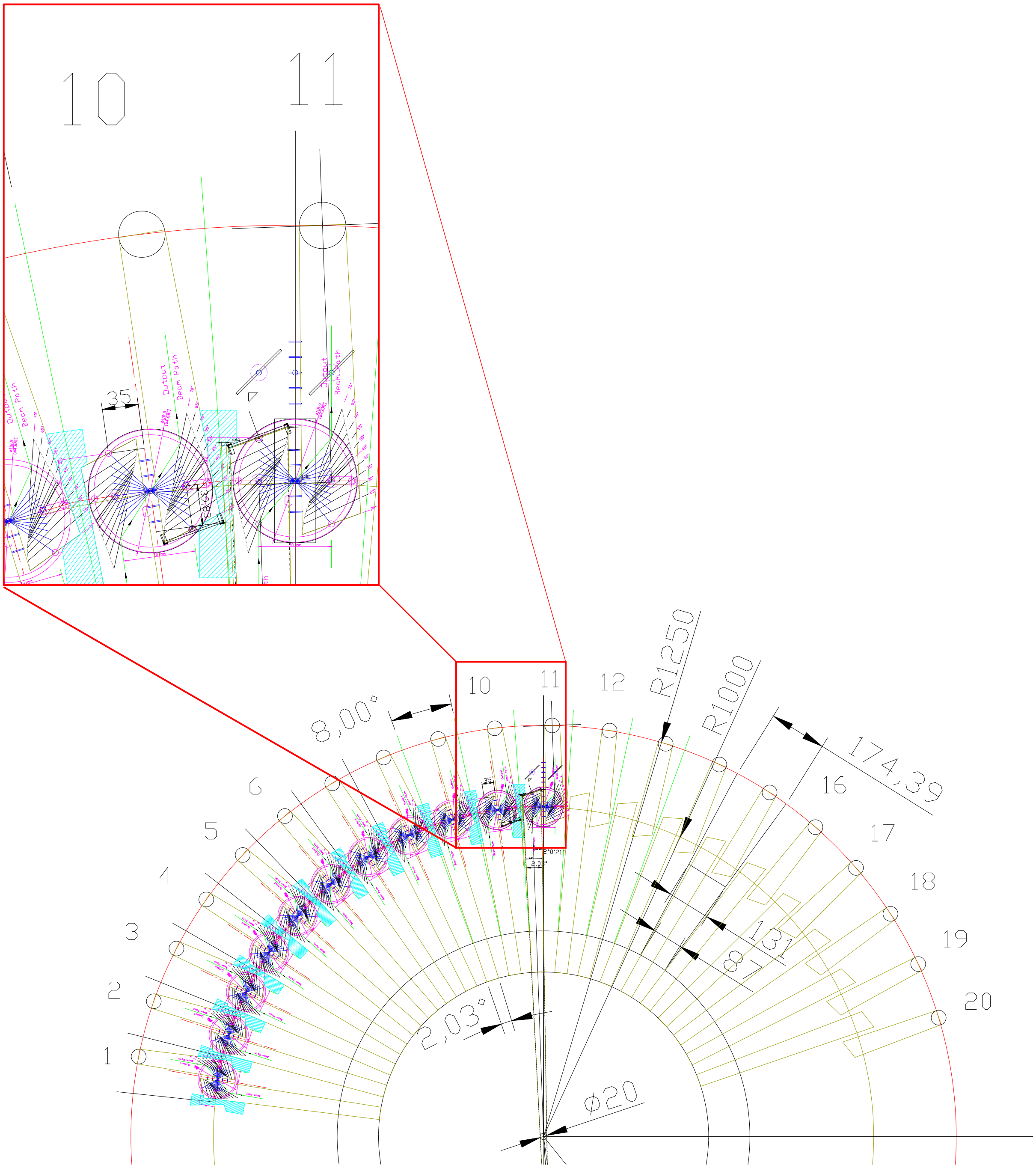

Figure 10 Layout showing relative positions of the twenty DXA units in the Analyzer Assembly