Dectris Module Geometry

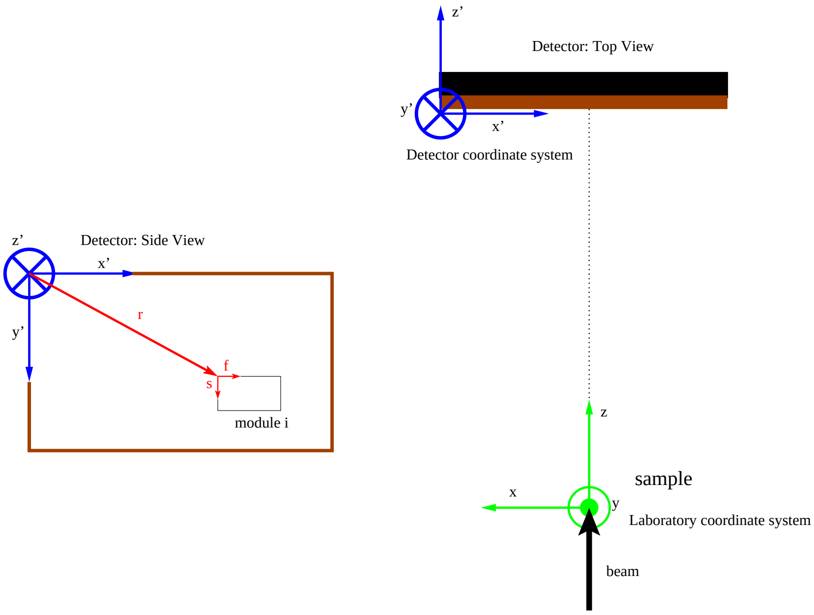

Figure 1: The basic geometry to describe a pixel in a module in a Dectris detector.

A module in the image is described by 1) the pixel address in the upper left corner of the module and 2) by the size of the module measured in number of pixels. Module i has thus the address $\mathbf{M}^i = (m_x^i, m_y^i)$ (the address of the pixel in the upper left corner of module i), and the module size is $\mathbf{H}^i = (h_x^i, h_y^i)$. E.g. for an EIGER 1M detector with two modules, module_000 has the address $\mathbf{M}^0 = (0, 0)$ and the size $\mathbf{H}^0 = (1024, 512)$, and module_001 has the address $\mathbf{M}^1 = (1041, 0)$, assuming a inter-module gap of 17 pixels.
We set the origin of the detector coordinate system to the upper left corner of the detector, in the upper left corner of pixel with address $\mathbf{M}^0 = (0, 0)$. The x'-axis is horizontal along the first module, the y'-axis vertical, and the z'-axis perpendicular to the module: $\mathbf{e}_z = \mathbf{e}_x \times \mathbf{e}_y$. The unit vectors in each direction are called $\mathbf{e}'_x$, $\mathbf{e}'_y$ and $\mathbf{e}'_z$.
In this coordinate system, the vector $\mathbf{r'}_i$ is the position of the *upper left corner* of the pixel with address (m_x^i, m_y^i) in module i. The vector $\mathbf{f'}_i$ (fast coordinate) is the (3D) vector between pixel with the address (m_x^i, m_y^i) and$(m_x^i + 1, m_y^i)$. The vector $\mathbf{s'}_i$ (slow coordinate) is the vector between (m_x^i, m_y^i) and $(m_x^i, m_y^i + 1)$. The vectors $\mathbf{r'}_i$, $\mathbf{f'}_i$ and $\mathbf{s'}_i$ are measured in units of m.
The coordinate $\mathbf{P'}$ of the pixel (p_x, p_y) in module number i is then in the detector coordinate system:

$$\mathbf{P'} = \mathbf{r'}_i + (p_x - m_x^i) \cdot \mathbf{f'}_i + (p_y - m_y^i) \cdot \mathbf{s}'_i \tag{1}$$

where i is the index of the module that contains the pixel.
In order to find the coordinate $\mathbf{P}$ of a pixel with detector coordinates $\mathbf{P'}$ inside

the lab coordinate system, the transformation between lab and detector coordinate system must be given. The transformation consists of a translation and a rotation, defined by the translational parameters $\mathbf{t} = (t_x, t_y, t_z)$ and the rotation matrix $\mathbf{R}$ given as the multiplication of the 3 matrices achieved by rotating the lab coordinate system around the x, the y and the z axis:

$$\mathbf{R} = \begin{pmatrix} R_{00} & R_{01} & R_{02} \\ R_{10} & R_{11} & R_{12} \\ R_{20} & R_{21} & R_{22} \end{pmatrix} \tag{2}$$

$$\mathbf{t} = \begin{pmatrix} t_x \\ t_y \\ t_z \end{pmatrix} \tag{3}$$

where $\mathbf{t}$ is given in lab coordinates.
The lab coordinate system with origin in the sample is given by the 3 unit vectors $\mathbf{e}_x, \mathbf{e}_y, \mathbf{e}_z$.. The components of the point $\mathbf{P} = (P_x, P_y, P_z)$ with detector coordinates $\mathbf{P'} = \left(P'_x, P'_y, P'_z\right)$ are in the lab coordinate system:

$$P_i = \sum_{j \in \{x,y,z\}} R_{ij} P'_j + t_i \quad \texttt{with } i \in \{x, y, z\} \tag{4}$$

Thus, to compute the position of pixel (p_x, p_y) in lab coordinates, one uses equation 1 to compute its position in detector coordinates and equation 4 to transform it to lab coordinates.

Example

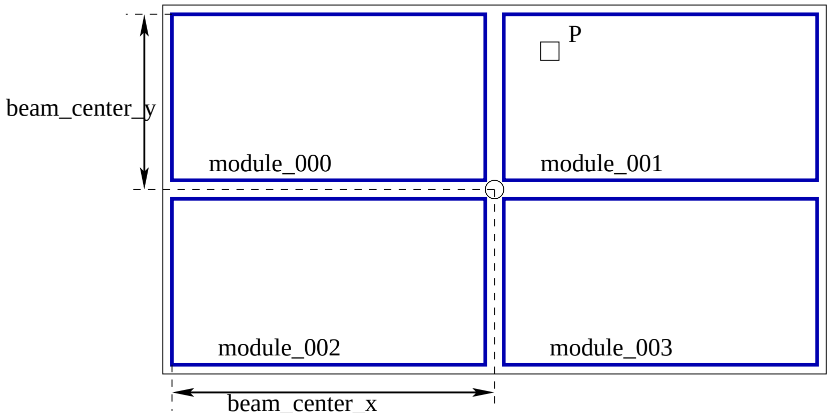

Figure 2: The location of the modules in a (potential) EIGER 2M detector.

Let us assume a planar EIGER 2M detector with 4 modules. It is mounted perpendicular to the beam at a distance of 150 mm from the sample. The beam hits the detector exactly in the center at the pixel coordinates `beam_center_x` and `beam_center_y`. The modules are numbered as in figure 2. Assuming a gap of 17 pixels between modules, the pixel coordinates and sizes of the four modules are:

$$
\begin{array}{lcl}
\mathbf{M}^0 & = & (\quad 0, \quad 0), \quad \mathbf{H}^0 = (1024, 512) \\
\mathbf{M}^1 & = & (\ 1041, \quad 0), \quad \mathbf{H}^1 = (1024, 512) \\
\mathbf{M}^2 & = & (\quad 0, \ 529), \quad \mathbf{H}^2 = (1024, 512) \\
\mathbf{M}^3 & = & (\ 1041, \ 529), \quad \mathbf{H}^3 = (1024, 512)
\end{array}
$$

The vectors $\mathbf{r}'_i$ pointing from the detector origin to each module are then:

$$
\begin{array}{lcl}
\mathbf{r}'_0 & = & (\quad 0, \quad 0, \quad 0)\,\mathtt{m} \\
\mathbf{r}'_1 & = & (\ 0.078075, \quad 0, \quad 0)\,\mathtt{m} \\
\mathbf{r}'_2 & = & (\quad 0, \ 0.039675, \quad 0)\,\mathtt{m} \\
\mathbf{r}'_3 & = & (\ 0.078075, \ 0.039675, \quad 0)\,\mathtt{m}
\end{array}
$$

The vectors $\mathbf{f}'_i$ and $\mathbf{s}'_i$ in the fast and slow pixel directions have for each module the same direction and length:

$$
\begin{array}{lcl}
\mathbf{f}'_0 = \mathbf{f}'_1 = \mathbf{f}'_2 = \mathbf{f}'_3 & = & (75 \cdot 10^{-6}, 0, 0)\,\mathtt{m} \\
\mathbf{s}'_0 = \mathbf{s}'_1 = \mathbf{s}'_2 = \mathbf{s}'_3 & = & (0, 75 \cdot 10^{-6}, 0)\,\mathtt{m}
\end{array}
$$

The pixel with the address $(1150, 42)$ is in module $i = 1$ and has the coordinate in the detector coordinate system:

$$
\begin{array}{lcccccccc}
\mathbf{P}' & = & \mathbf{r}'_2 & + & (p_x - m^1_x) & \cdot & \mathbf{f}'_2 & + & (p_y - m^1_y) \cdot \mathbf{s}'_2 \\
 & = & \begin{pmatrix} 0.078075 \\ 0 \\ 0 \end{pmatrix} & + & (1150 - 1041) & \cdot & \begin{pmatrix} 75 \cdot 10^{-6} \\ 0 \\ 0 \end{pmatrix} & + & (41 - 0) \cdot \begin{pmatrix} 0 \\ 75 \cdot 10^{-6} \\ 0 \end{pmatrix} \\
 & = & \begin{pmatrix} 0.08625 \\ 0.00315 \\ 0 \end{pmatrix} \mathtt{m}
\end{array}
$$

The transformation from the lab system to the detector system is given by a rotation around the $\mathbf{e}_z$ axis of π:

$$
\mathbf{R} = \mathbf{R}_z \cdot \mathbf{R}_y \cdot \mathbf{R}_z = \begin{pmatrix} \cos\pi & -\sin\pi & 0 \\ \sin\pi & \cos\pi & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix}
$$

The translation vector is then in the lab coordinate system:

$$
\mathbf{t} = \begin{pmatrix} t_x \\ t_y \\ t_z \end{pmatrix} = \begin{pmatrix} \mathtt{beam\_center\_x} \cdot 75\,\mu\mathrm{m} \\ \mathtt{beam\_center\_y} \cdot 75\,\mu\mathrm{m} \\ \mathtt{detector\_distance} \end{pmatrix} = \begin{pmatrix} 0.0774375 \\ 0.0390375 \\ 0.15 \end{pmatrix} \mathtt{m} \qquad (5)
$$

The coordinates of the pixel P $\mathbf{P}$ in the coordinates of the lab system is thus:

$$
\mathbf{P} = \mathbf{R} \cdot \mathbf{P}' + \mathbf{t} = \begin{pmatrix} -1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} 0.08625 \\ 0.00315 \\ 0 \end{pmatrix} \mathtt{m} + \begin{pmatrix} 0.0774375 \\ 0.0390375 \\ 0.15 \end{pmatrix} \mathtt{m} = \begin{pmatrix} -0.0088125 \\ 0.0358875 \\ 0.15 \end{pmatrix} \mathtt{m}
$$

Notation in the NeXus Header

In the NeXus header, we describe above vectors with the following notation (based on proposal by T. Richter / H. Bernstein / M. Koennecke / NIAC) in the group `DetectorSpecific`:

```
detectorSpecific:DetectorSpecific
```

```
   detectorOrigin[1] = [1]
         @transformation=translation
         @vector={0, 0, 0}
         @units=m
         @depends_on=""

     detectorModule_001:DetectorModule
         data_origin[2] = [l,m]
         data_size[2] = [n,o]
         module_offset[1] = [0.025]
             @transformation=translation
             @vector={0,0.707, 0.707}
             @units=m
             @depends_on="../detectorOrigin"
         fast_pixel_direction[1] = [0.000172]
             @transformation=translation
             @vector={1,0,0}
             @units=m
             @depends_on="module_offset"
         slow_pixel_direction[1] = [0.000172]
             @transformation=translation
             @vector={0,1,0}
             @units=m
             @depends_on="module_offset"

     detectorModule_002:DetectorModule
          etc. etc.
```

`data_origin` corresponds then to the module address $\mathbf{M}^i = (m^i_x, m^i_y)$, `data_size` to $\mathbf{H}^i = (h^i_x, h^i_y)$, `module_offset` to the vector $\mathbf{r}'_i$, `fast_pixel_direction` to $\mathbf{f}'_i$ and `slow_pixel_direction` to $\mathbf{s}'_i$.
The rotation and translation from the labor system to the detector system is defined in the structure `transformLabToDetector`:

```
detectorSpecific:DetectorSpecific
   transformLabToDetector[1] = [1]
         @rotation={r00, r01, r02\\
                    r10, r11, r12\\
                    r20, r21, r22}
         @translation={tx, ty, tz}
         @units=m
```

Deviation from the Perfect Detector

The above parametrisation is computed from the technical drawings. In case that the effective pixel positions deviate from the ideal ones, the above header items can be complemented:

```
detectorSpecific:DetectorSpecific
     detectorOrigin[1] = [1]
```

```
        @transformation=translation
        @vector={0, 0, 0}
        @transformation=rotation
        @units=m
        @depends_on=""
    detectorModule_001:DetectorModule
        data_origin[2] = [l,m]
        data_size[2] = [n,o]
        module_offset[1] = [0.025]
            @transformation=translation
            @vector={0,0.707,0.707}
            @units=m
            @depends_on="../detectorOrigin"

        delta_module_offset[1] = [0.001]
            @transformation=translation
            @vector={-0.707, 0.0, 0.707}
            @units=m
            @depends_on="../detectorOrigin"

        fast_pixel_direction[1] = [0.000172]
            @transformation=translation
            @vector={1,0,0}
            @units=m
            @depends_on="module_offset"
        delta_fast_pixel_direction[1] = [0.000011]
            @transformation=translation
            @vector={0.707,0.707,0}
            @units=m
            @depends_on="module_offset"


        slow_pixel_direction[1] = [0.000172]
            @transformation=translation
            @vector={0,1,0}
            @units=m
            @depends_on="module_offset"
        delta_slow_pixel_direction[1] = [0.000006]
            @transformation=translation
            @vector={0.707, 0.707, 0}
            @units=m
            @depends_on="module_offset"

    detectorModule_002:DetectorModule
        etc. etc.
```

The 3D position of pixel (p_x, p_y) in the detector coordinate system is then:

$$\mathbf{P} = \mathbf{r}'_i + \mathbf{\Delta r}'_i + (p_x - m^i_x) \cdot \left(\mathbf{f}'_i + \mathbf{\Delta f}'_i\right) + (p_y - m^i_y) \cdot \left(\mathbf{s}'_i + \mathbf{\Delta s}'_i\right) \qquad (6)$$