On The Geometry of the HEC Readout Channels

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- Local HEC coordinate system
- Readout families
- Readout channels
- Volume and geometrical center
- Neighbors

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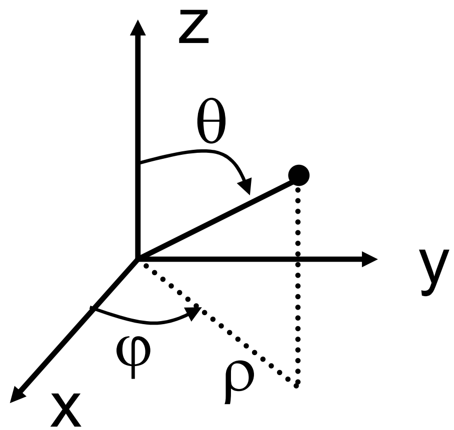
The ideal (pointing) ATLAS coordinate system

- The ρ, θ, φ and η quantities for a point in the ideal (pointing) ATLAS coordinate system are defined in the usual way.
  - Using a cylindrical coordinate system, we obtain the following relations:



$$x = \rho \cos\varphi$$
$$y = \rho \sin\varphi$$
$$z = \rho \cot\theta$$

$$\rho^2 = x^2 + y^2$$

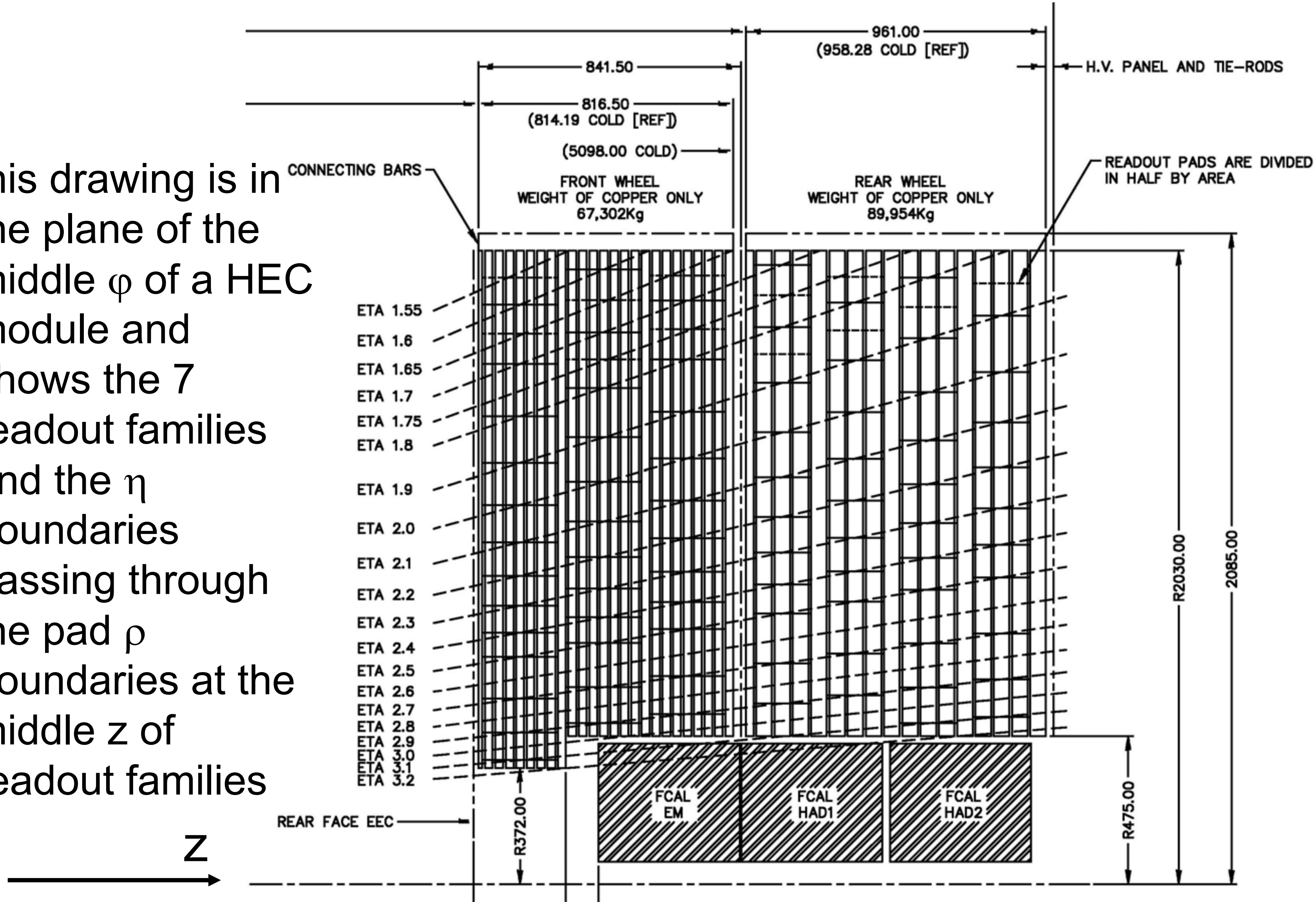
$$\cos\theta = \frac{z}{\sqrt{x^2 + y^2 + z^2}}$$

$$\tan\varphi = \frac{y}{x}$$

$$\eta \equiv -\ln \tan \tfrac{1}{2}\theta$$
$$\theta = 2 \arctan e^{-\eta}$$
$$\sinh\eta = \cot\theta$$
$$\cosh\eta = \operatorname{cosec}\theta$$
$$\tanh\eta = \cos\theta$$

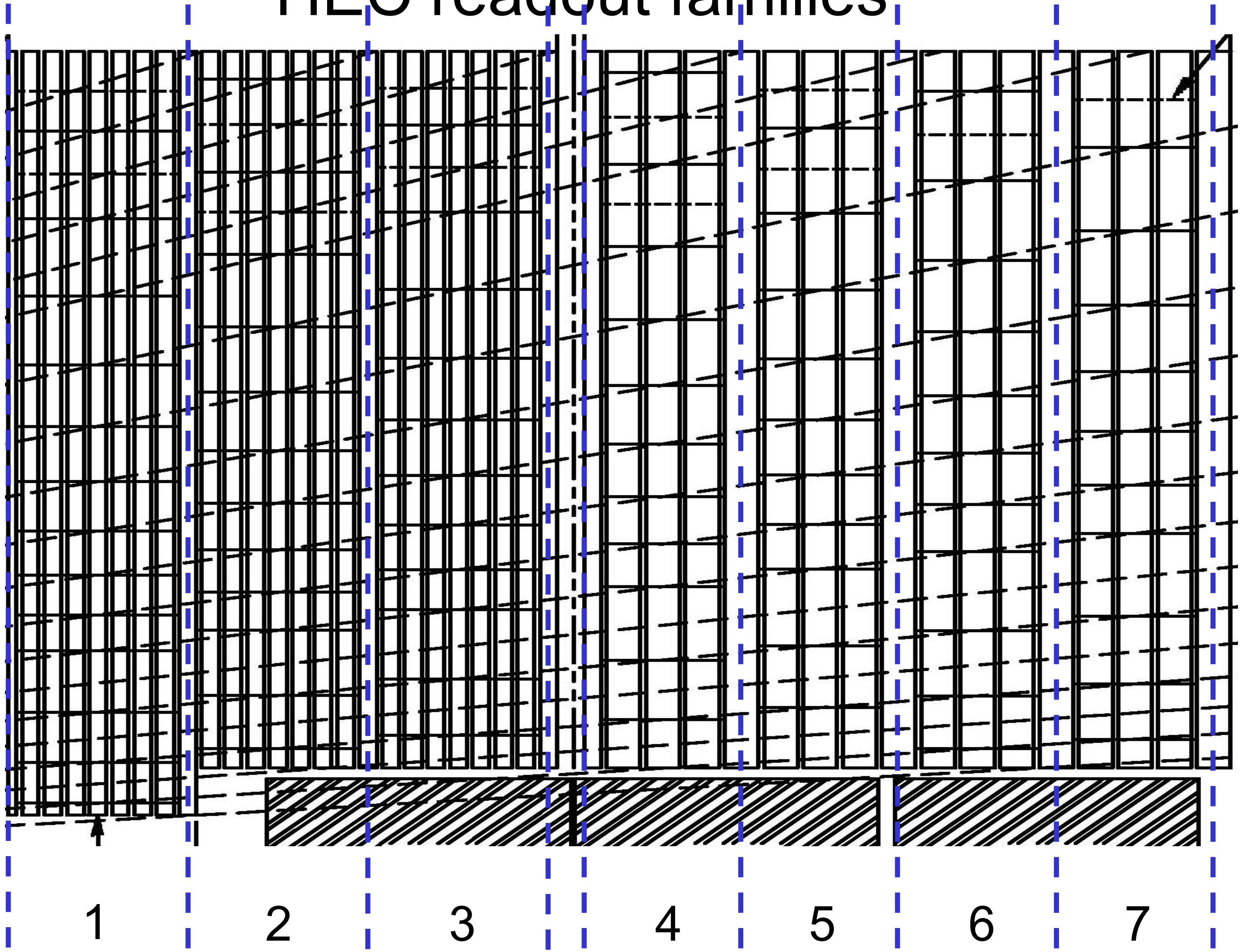
HEC module geometry in ρ-z plane at middle φ

this drawing is in the plane of the middle φ of a HEC module and shows the 7 readout families and the η boundaries passing through the pad ρ boundaries at the middle z of readout families



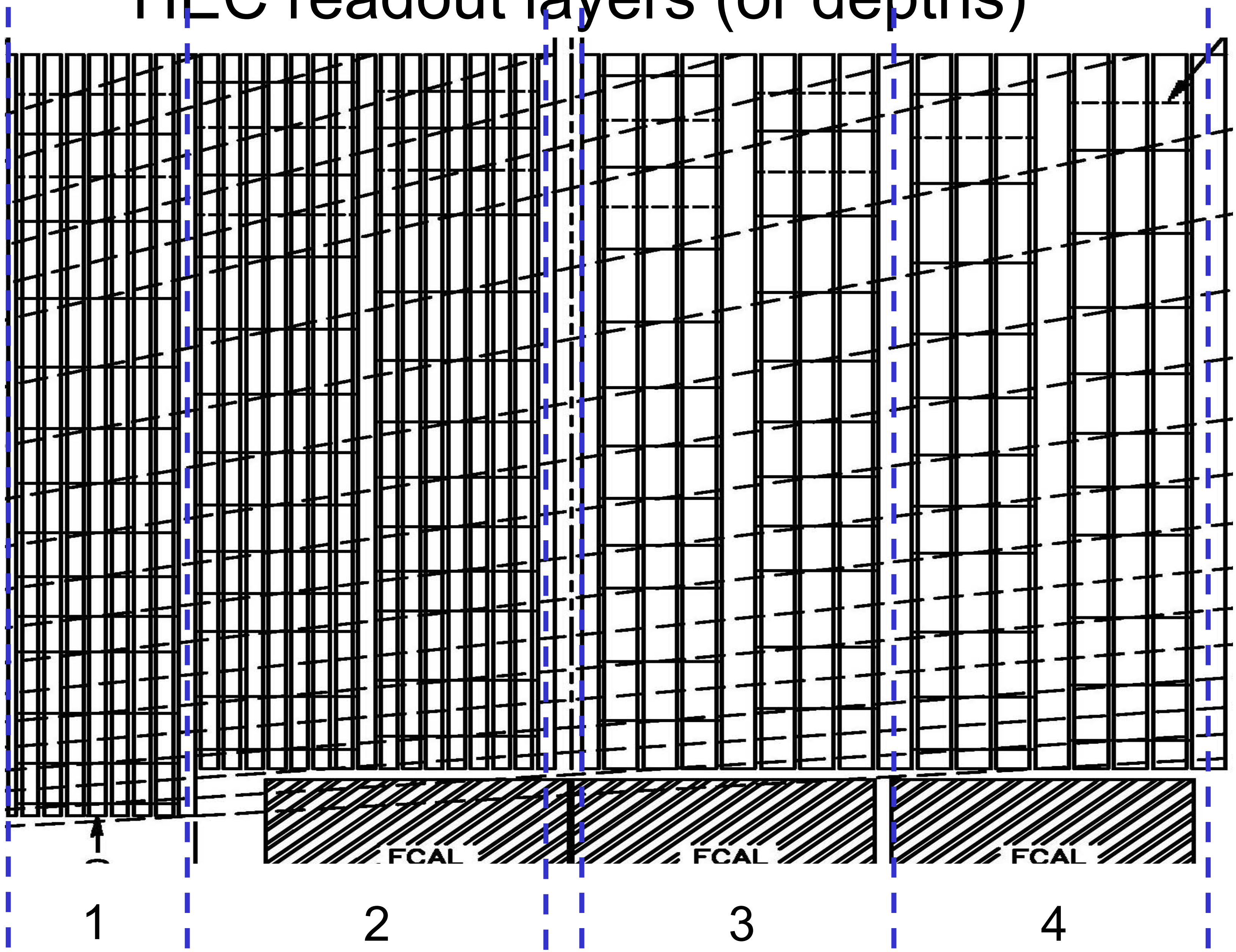
HEC readout families

not to scale!



HEC readout layers (or depths)

not to scale!



HEC module geometry parameters

- For the beam test analysis, the HEC module geometry parameters are kept in a file, available from
  http://particle.phys.uvic.ca/~web-atlas/atlas/hec-emec/geometry/
- It contains HEC readout channel "median" coordinates in the ideal (pointing) ATLAS coordinate system:

  $\bar{\eta}, \Delta\eta$ $\bar{\varphi}, \Delta\varphi$ (in radians) $\bar{z}, \Delta z$ (in cm)
- These quantities do not in general denote the geometrical center of a channel. Rather, we have

$$\eta \in \left[\bar{\eta} - \tfrac{1}{2}\Delta\eta,\ \bar{\eta} + \tfrac{1}{2}\Delta\eta\right]$$
$$\varphi \in \left[\bar{\varphi} - \tfrac{1}{2}\Delta\varphi,\ \bar{\varphi} + \tfrac{1}{2}\Delta\varphi\right]$$
$$z \in \left[\bar{z} - \tfrac{1}{2}\Delta z,\ \bar{z} + \tfrac{1}{2}\Delta z\right]$$

Readout families and readout channels

- A readout channel is composed of either one or two readout families (denoted a and b in order of increasing z)
- The z position of the middle of a family (z_F) and the z width of a family (Δz_F) are related to the readout channel parameters:

$$z_{\mathrm{F}} = \begin{cases} \overline{z} & \text{for channels with one family} \\ \overline{z} - \frac{1}{4}\Delta z & \text{family a} \\ \overline{z} + \frac{1}{4}\Delta z & \text{family b} \end{cases} \quad \text{(family a, b: for channels with two families)}$$

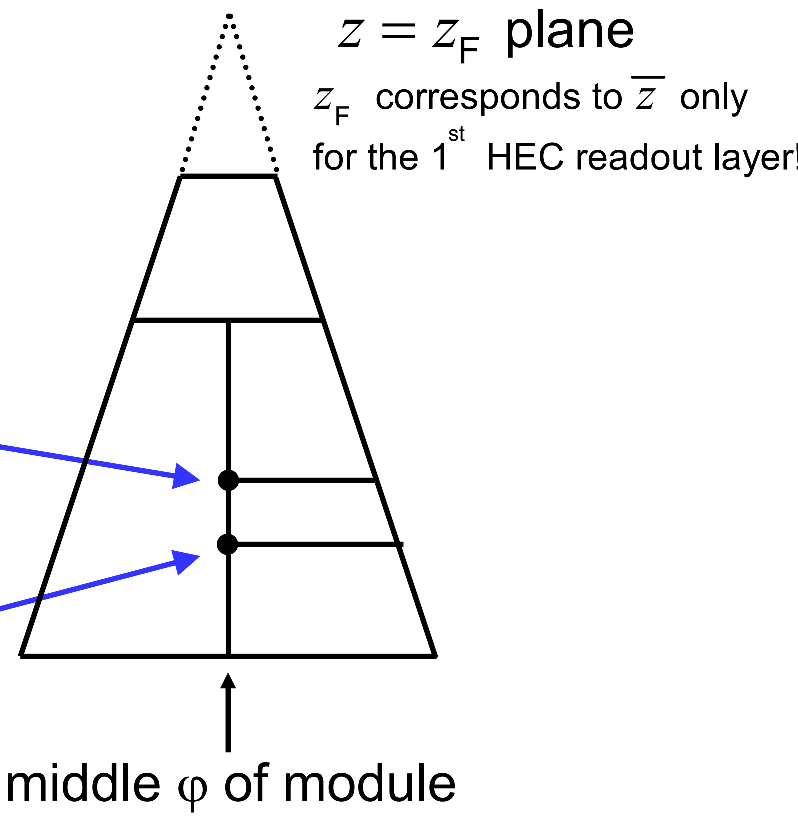
$$\Delta z_{\mathrm{F}} = \begin{cases} \Delta z & \text{for channels with one family} \\ \frac{1}{2}\Delta z & \text{for channels with two families} \end{cases}$$

Pseudorapidity limits

- In the HEC, the pseudorapidity limits of a readout family refer to the middle φ of a module and to the middle z (z_F) of a family
  - there are seven HEC readout families in ATLAS, 5 only in the 2002 combined beam test.
  - Consider the following schematic (not to scale!) of a HEC family in the ρ-φ plane;

$$\rho_1 = \frac{z_F}{\sinh\left(\bar{\eta} + \frac{1}{2}\Delta\eta\right)}$$

$$\rho_2 = \frac{z_F}{\sinh\left(\bar{\eta} - \frac{1}{2}\Delta\eta\right)}$$

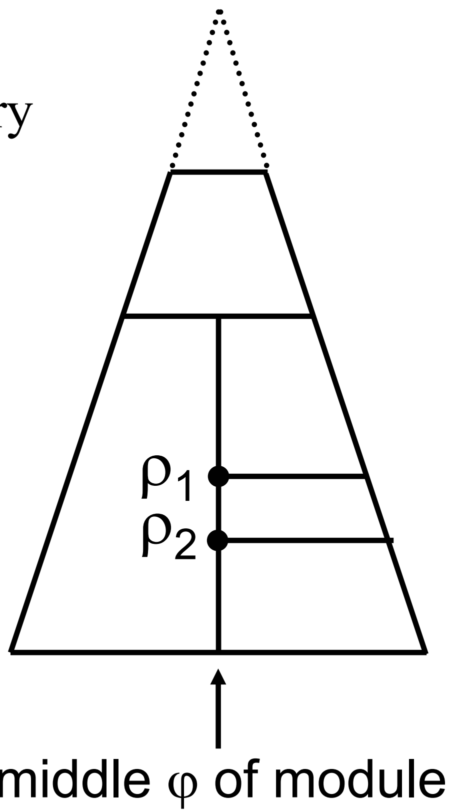


Readout family ρ limits

- The ρ limits of a readout family refer to the middle φ of a module

$$\rho_1 = \begin{cases} 37.20 \text{ cm} & \text{family 1 at high } \eta \text{ boundary} \\ 47.50 \text{ cm} & \text{families} > 1 \text{ at high } \eta \text{ boundary} \\ \dfrac{z_F}{\sinh\left(\bar{\eta} + \frac{1}{2}\Delta\eta\right)} & \text{other families} \end{cases}$$

$$\rho_2 = \begin{cases} 203.00 \text{ cm} & \text{families at low } \eta \text{ boundary} \\ \dfrac{z_F}{\sinh\left(\bar{\eta} - \frac{1}{2}\Delta\eta\right)} & \text{other families} \end{cases}$$



Readout family volume and geometrical center

- First consider the $\Delta\varphi = 2\pi/64$ channels ($\eta \le 2.5$)
  - From elementary geometry we obtain

$$V = \tfrac{1}{2}\Delta z_{\mathrm{F}}\left(\rho_2^2 - \rho_1^2\right)\tan\Delta\varphi$$

$$x_{\mathrm{c}} = \rho_{\mathrm{c}}\cos\varphi_{\mathrm{c}}$$

$$y_{\mathrm{c}} = \rho_{\mathrm{c}}\sin\varphi_{\mathrm{c}}$$

$$z_{\mathrm{c}} = z_{\mathrm{F}}$$

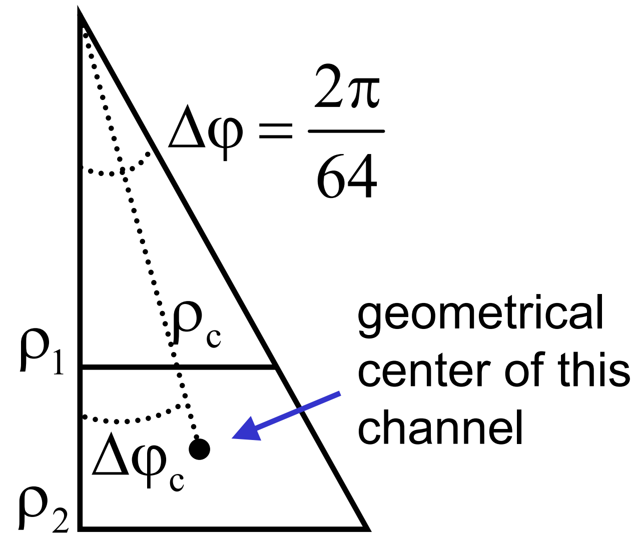
where

$$\rho_{\mathrm{c}} = \frac{2}{3}\left(\frac{\rho_1^2 + \rho_1\rho_2 + \rho_2^2}{\rho_1 + \rho_2}\right)\sec\Delta\varphi_{\mathrm{c}}$$

$$\varphi_{\mathrm{c}} = \overline{\varphi} \pm \left(\Delta\varphi_{\mathrm{c}} - \tfrac{1}{2}\Delta\varphi\right)$$

$$\tan\Delta\varphi_{\mathrm{c}} = \tfrac{1}{2}\tan\Delta\varphi$$

$$\sec\Delta\varphi_{\mathrm{c}} = \sqrt{1 + \tfrac{1}{4}\tan^2\Delta\varphi}$$



The ± depends on which side of the module middle φ plane the channel is

Readout family volume and geometrical center

- Second consider the $\Delta\varphi = 2\pi/32$ channels ($\eta \geq 2.5$)
  - From the previous results we obtain

$$V = \Delta z_{\mathrm{F}}\left(\rho_2^2 - \rho_1^2\right)\tan\left(\tfrac{1}{2}\Delta\varphi\right)$$

$$x_{\mathrm{c}} = \rho_{\mathrm{c}}\cos\varphi_{\mathrm{c}}$$
$$y_{\mathrm{c}} = \rho_{\mathrm{c}}\sin\varphi_{\mathrm{c}}$$
$$z_{\mathrm{c}} = z_{\mathrm{F}}$$

where

$$\rho_{\mathrm{c}} = \frac{2}{3}\left(\frac{\rho_1^2 + \rho_1\rho_2 + \rho_2^2}{\rho_1 + \rho_2}\right)$$
$$\varphi_{\mathrm{c}} = \overline{\varphi}$$

Readout channel volume and geometrical center

- In the case of readout channels with one family, we use the results obtained for that family
- In the case of readout channels with two families, we weigh each family by their volume
  - From the previous results we obtain

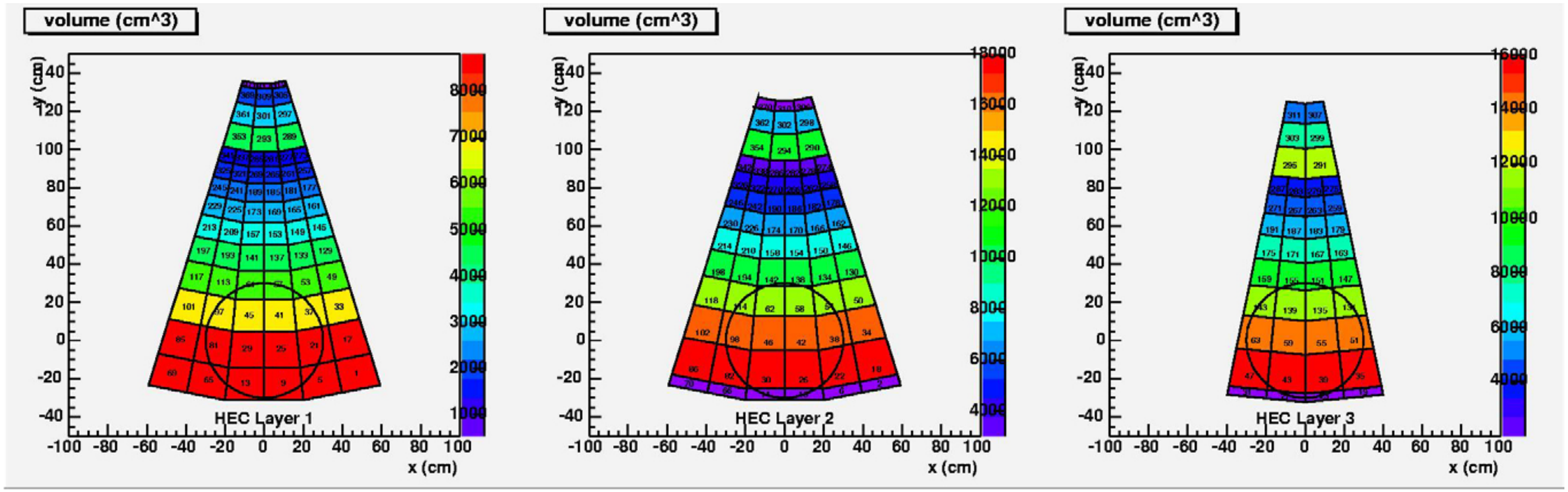
$$V = V_{\mathrm{a}} + V_{\mathrm{b}}$$
$$\vec{r}_{\mathrm{c}} = \omega_{\mathrm{a}} \vec{r}_{\mathrm{a}} + \omega_{\mathrm{b}} \vec{r}_{\mathrm{b}}$$

where

$$\omega_{\mathrm{a}} = \frac{V_{\mathrm{a}}}{V} \qquad \omega_{\mathrm{b}} = \frac{V_{\mathrm{b}}}{V} = 1 - \omega_{\mathrm{a}}$$

Readout channel volume

- The following readout channel volumes are obtained



2002 HEC-EMEC beam test configuration. The numbers refer to the channel numbers for this beam test

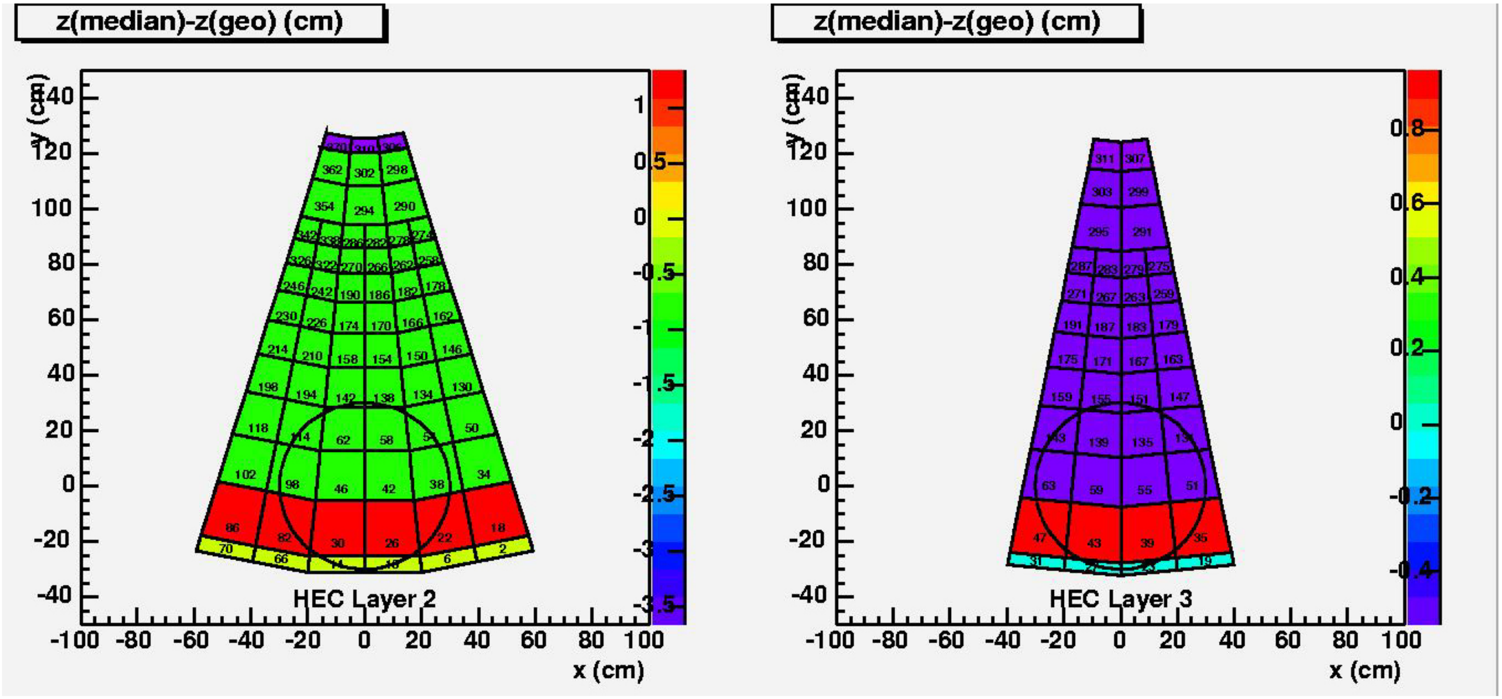
Readout channel geometrical center

- The median center can be a few cm away from the geometrical center, the difference is (almost completely) in z

$$\left|\bar{\eta}-\eta_c\right|<0.009 \qquad \left|\bar{\varphi}-\varphi_c\right|<0.0015 \qquad \left|\bar{z}-z_c\right|<3.7 \text{ cm}$$

No difference in z for layer 1 since all the channels are composed of only one family.

This is also the case for the lowest eta channels in layer 3

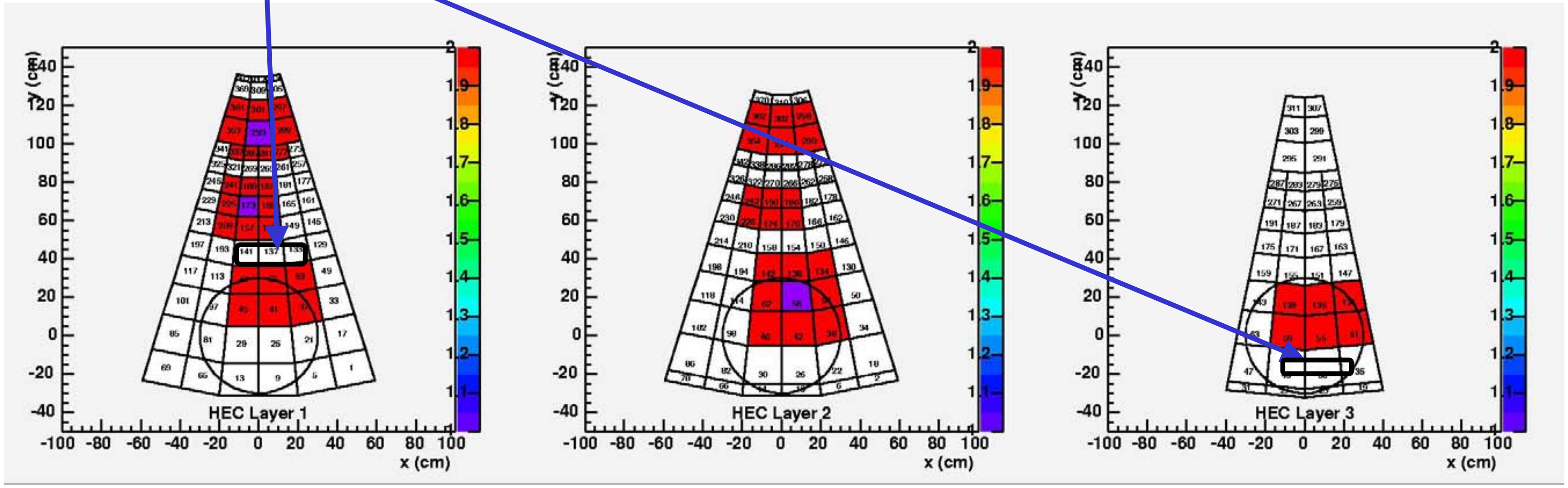


2002 HEC-EMEC beam test configuration. The numbers refer to the channel numbers for this beam test

Readout channel neighbors

- The pseudo-pointing nature of the HEC channels lead to peculiarities in the list of neighbors for a channel
  - Consider three target channels (blue) and their touching neighbors (red)

Notice these are not touching neighbors, as would be obtained if only eta indices were considered



2002 HEC-EMEC beam test configuration. The numbers refer to the channel numbers for this beam test