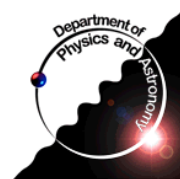


On The Geometry of the HEC Readout Channels

15 August 2003

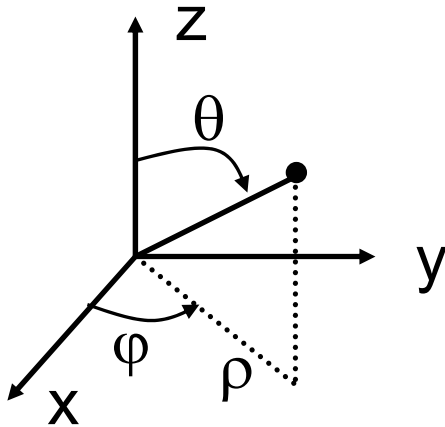
- Local HEC coordinate system
- Readout families
- Readout channels
- Volumes and geometrical centers
- Neighbors



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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:



$$x = \rho \cos \varphi$$

$$y = \rho \sin \varphi$$

$$z = \rho \cot \theta$$

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

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

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

$$\eta \equiv -\ln \tan \frac{1}{2} \theta$$

$$\theta = 2 \arctan e^{-\eta}$$

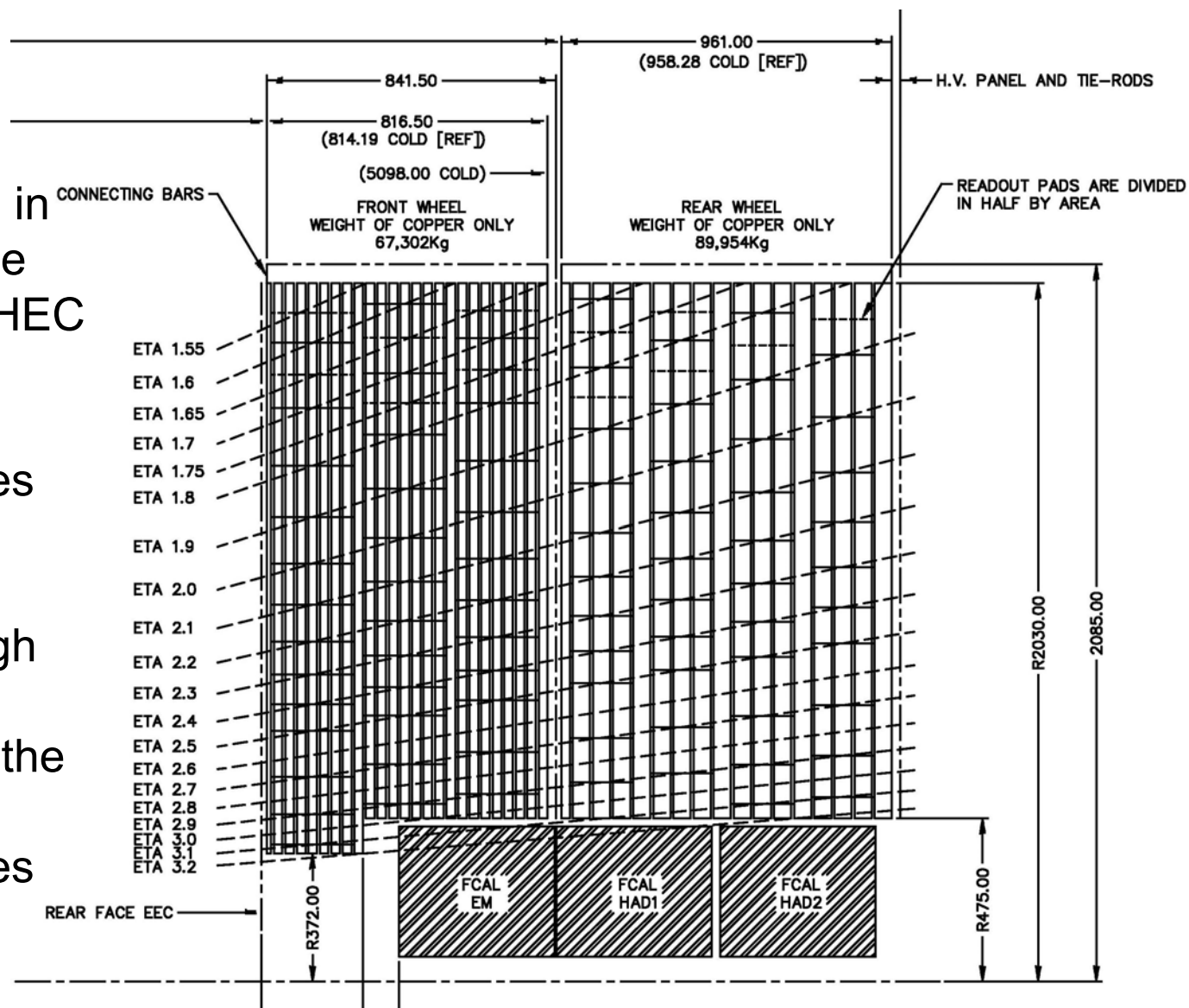
$$\sinh \eta = \cot \theta$$

$$\cosh \eta = \operatorname{cosec} \theta$$

$$\tanh \eta = \cos \theta$$

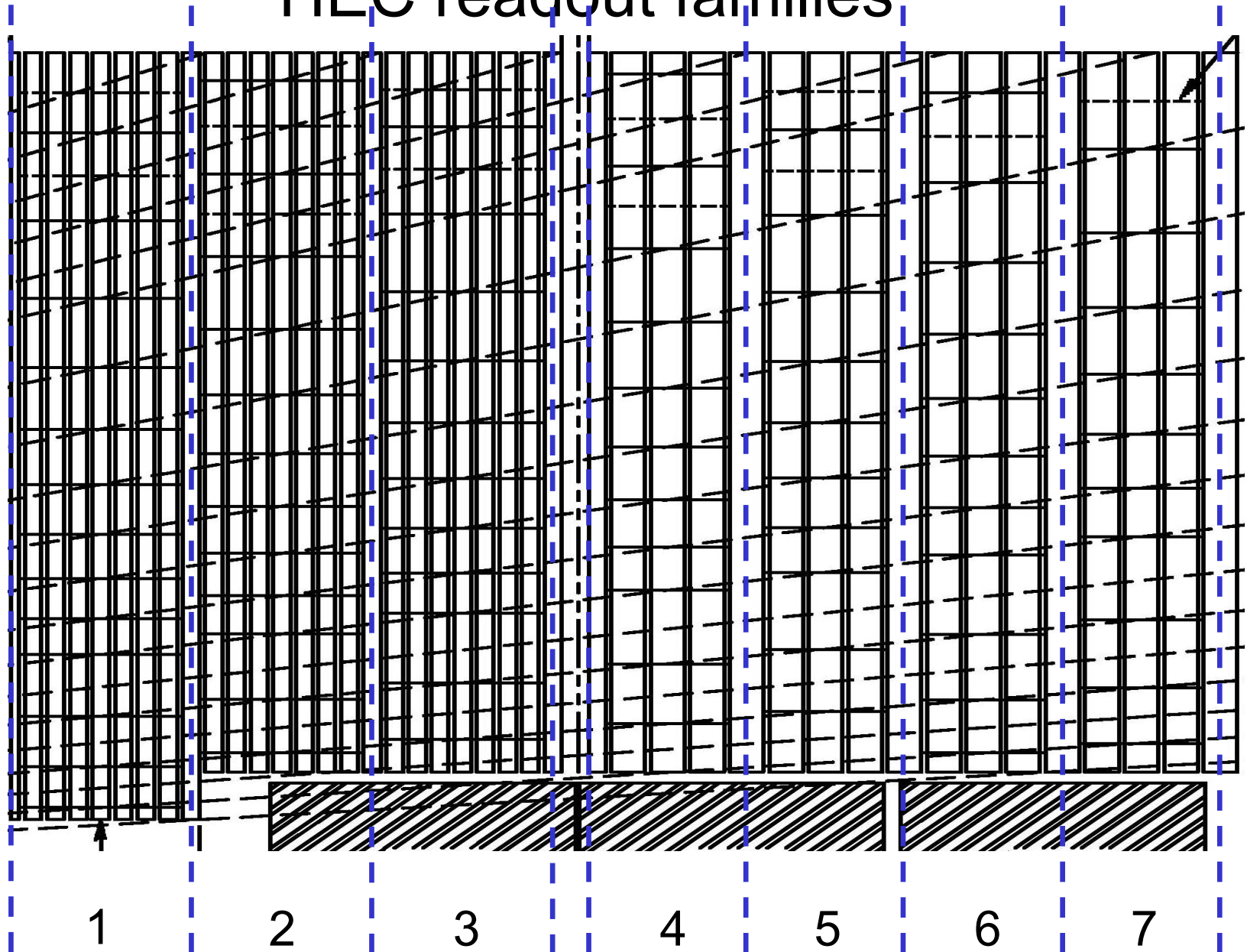
HEC module geometry in ρ -z plane at middle ϕ

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



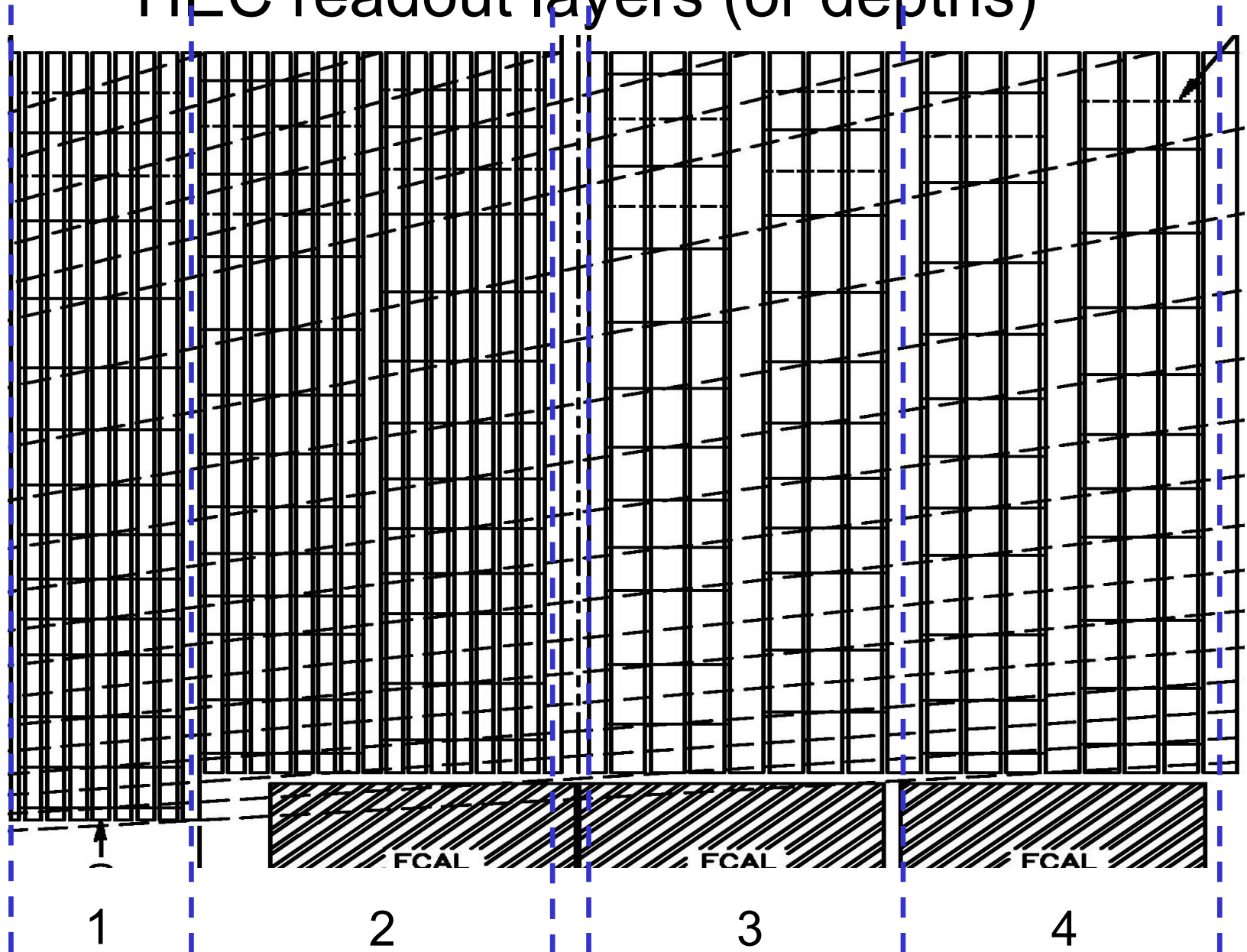
HEC readout families

not to scale!



HEC readout layers (or depths)

not to scale!



HEC readout channel geometry parameters

- For the beam test analysis, the HEC readout channel 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:

$$\bar{\eta}, \Delta\eta \quad \bar{\varphi}, \Delta\varphi \text{ (in radians)} \quad \bar{z}, \Delta z \text{ (in cm)}$$

- These quantities do not in general denote the geometrical center of a readout channel. Rather, we have

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

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

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

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:

$$z_F = \begin{cases} \bar{z} & \text{for channels with one family} \\ \bar{z} - \frac{1}{4} \Delta z & \text{family a} \\ \bar{z} + \frac{1}{4} \Delta z & \text{family b} \end{cases} \quad \text{for channels with two families}$$

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

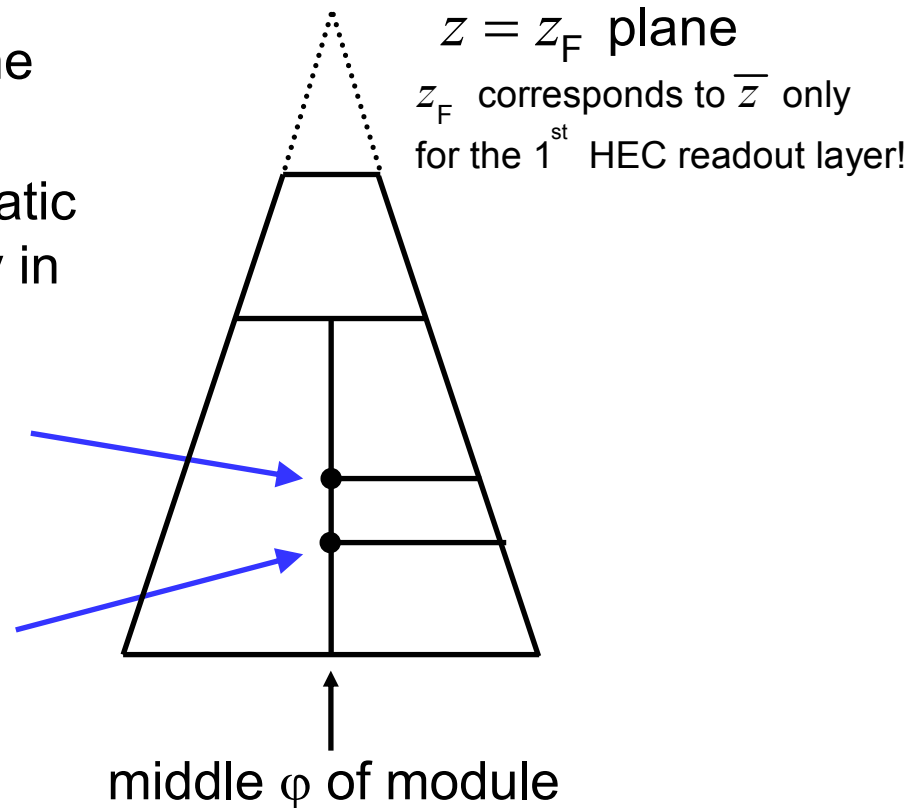
Pseudorapidity limits

- 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;

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

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

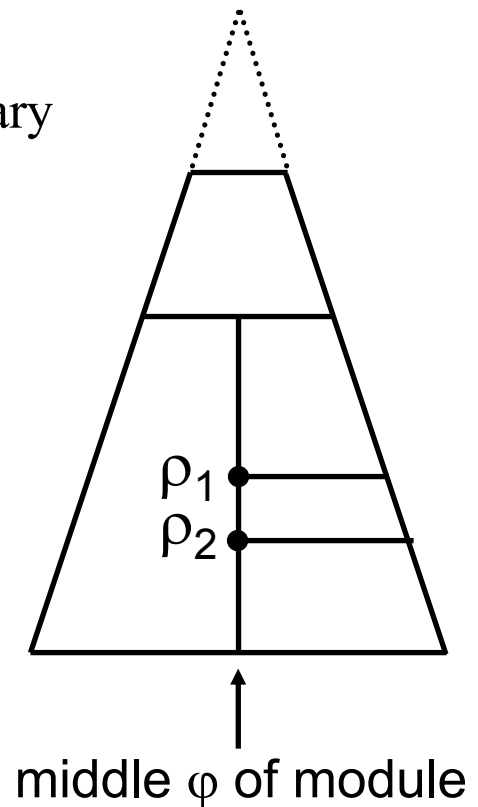


Readout family ρ limits

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

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

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



Readout family volume and geometrical center

■ First consider the $\Delta\varphi = 2\pi/64$ readout channels ($\eta \leq 2.5$)

- From elementary geometry we obtain

$$V = \frac{1}{2} \Delta z_F (\rho_2^2 - \rho_1^2) \tan \Delta\varphi$$

$$x_c = \rho_c \cos \varphi_c$$

$$y_c = \rho_c \sin \varphi_c$$

$$z_c = z_F$$

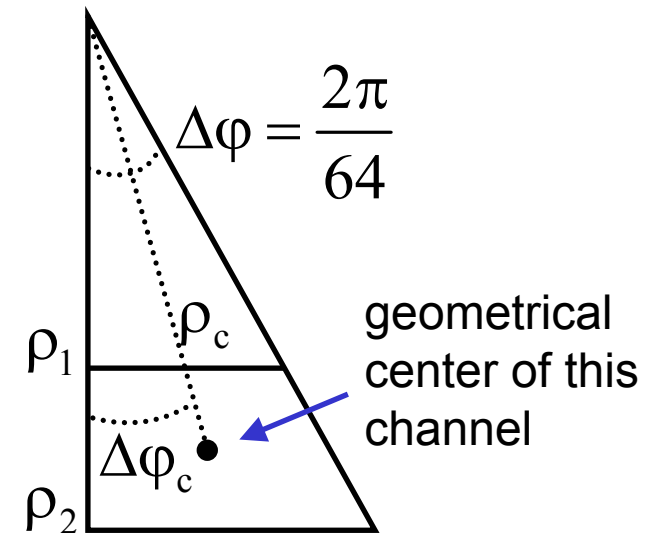
where

$$\rho_c = \frac{2}{3} \left(\frac{\rho_1^2 + \rho_1 \rho_2 + \rho_2^2}{\rho_1 + \rho_2} \right) \sec \Delta\varphi_c$$

$$\varphi_c = \bar{\varphi} \pm \left(\Delta\varphi_c - \frac{1}{2} \Delta\varphi \right)$$

$$\tan \Delta\varphi_c = \frac{1}{2} \tan \Delta\varphi$$

$$\sec \Delta\varphi_c = \sqrt{1 + \frac{1}{4} \tan^2 \Delta\varphi}$$



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

Readout family volume and geometrical center

■ Second consider the $\Delta\varphi = 2\pi/32$ readout channels ($\eta \geq 2.5$)

- From the previous results we obtain

$$V = \Delta z_F (\rho_2^2 - \rho_1^2) \tan\left(\frac{1}{2} \Delta\varphi\right)$$

$$x_c = \rho_c \cos \varphi_c$$

$$y_c = \rho_c \sin \varphi_c$$

$$z_c = z_F$$

where

$$\rho_c = \frac{2}{3} \left(\frac{\rho_1^2 + \rho_1 \rho_2 + \rho_2^2}{\rho_1 + \rho_2} \right)$$

$$\varphi_c = \bar{\varphi}$$

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

$$V = V_a + V_b$$

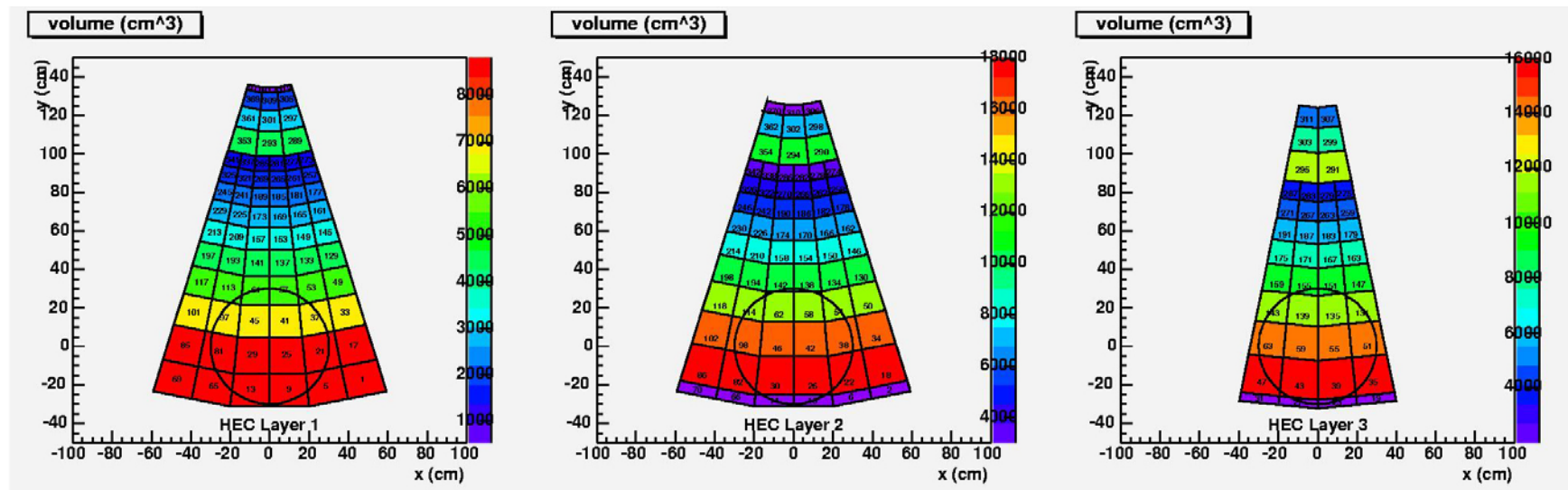
$$\vec{r}_c = \omega_a \vec{r}_a + \omega_b \vec{r}_b$$

where

$$\omega_a = \frac{V_a}{V} \quad \omega_b = \frac{V_b}{V} = 1 - \omega_a$$

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

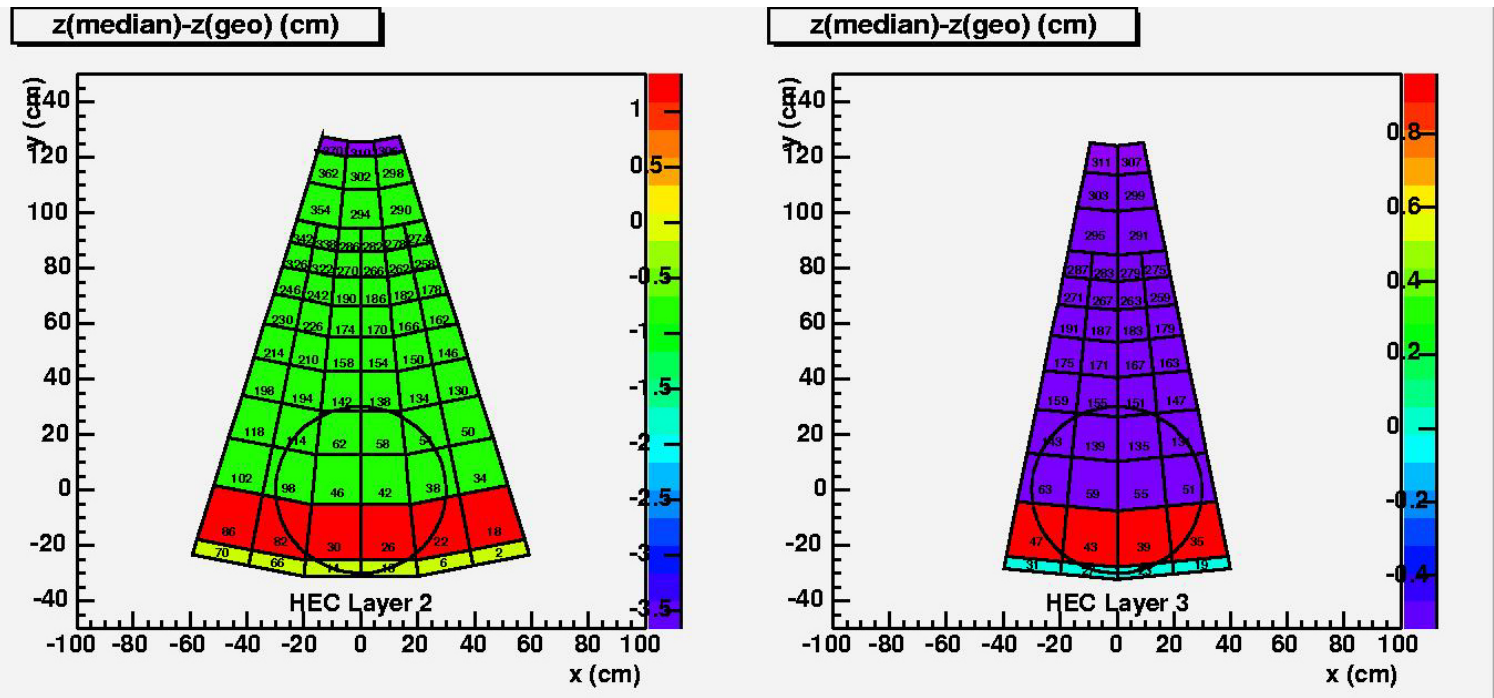
Readout channel geometrical center

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

$$|\bar{\eta} - \eta_c| < 0.009 \quad |\bar{\phi} - \phi_c| < 0.0015 \quad |\bar{z} - z_c| < 3.7 \text{ cm}$$

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

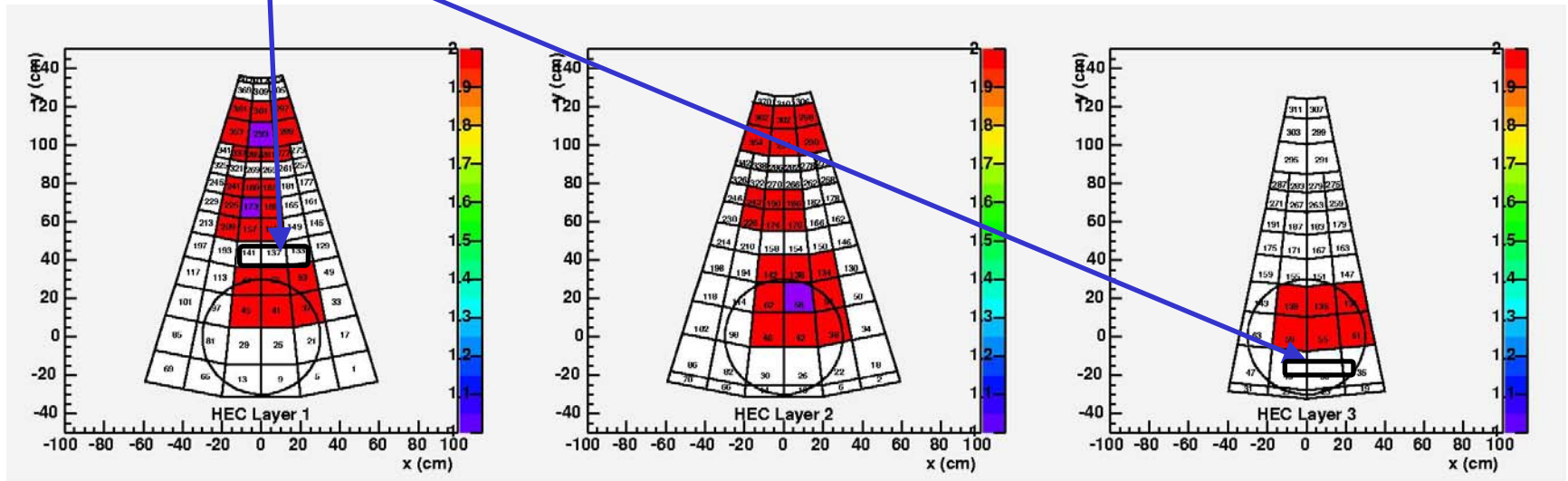


2002 HEC-EMEC beam test configuration. The numbers refer to the channel numbers for this beam test

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