Engineering run expected PXL hit density

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units

The hit rate on the PXL detector

$$\frac{dN}{dA} = \frac{dN}{d\eta} \cdot \frac{1}{\sqrt{r^2 + z^2}} \cdot \frac{1}{2 \cdot \pi \cdot r}$$

from Eq.A-3 and Eq. A1-7

hits per area for an event

$\frac{dN}{d\eta}$ n per pseudo rapidity

r detector radius

z interaction source distance along the beam direction

for z = 0

$$\frac{dN}{dA} = \frac{dN}{d\eta} \cdot \frac{1}{2 \cdot \pi \cdot r^2}$$

for z >> r

$$\frac{dN}{dA} = \frac{dN}{d\eta} \cdot \frac{1}{2 \cdot \pi \cdot z \cdot r}$$

$$HR(r,z) = L \cdot \sigma \cdot \frac{dN}{d\eta} \cdot \left(\frac{1}{\sqrt{r^2 + z^2}} \cdot \frac{1}{2 \cdot \pi \cdot r} \right)$$

hit rate per area on the PXL layer

L Luminosity

σ pp cross section

This depends on the interaction diamond

Assume the interaction diamond is Gaussian with $\sigma_d = 30\text{cm}$

Weight the z term accordingly and let $r = 2.5\text{cm}$

$$\int_{-10 \cdot \sigma_d}^{10 \cdot \sigma_d} \frac{1}{\sigma_d \cdot \sqrt{2 \cdot \pi}} \cdot \exp\left(\frac{-z^2}{2 \cdot \sigma_d^2} \right) \cdot \frac{1}{\sqrt{r^2 + z^2}} \, dz = 0.086 \, \frac{1}{\text{cm}}$$

solving numerically

$$HRa = L \cdot \sigma \cdot \frac{dN}{d\eta} \cdot \frac{1}{2 \cdot \pi \cdot r} \cdot \left(0.086 \, \frac{1}{\text{cm}} \right)$$

Hit rate integrated over the diamond source distribution

$L \cdot \sigma = 400\text{kHz}$ to 700kHz for proton run beginning of fill, from Ernst Sichtermann

$$\frac{dN}{d\eta} = 6$$

$$HRa = 400\text{kHz} \cdot 6 \cdot \frac{1}{2 \cdot \pi \cdot r} \cdot \left(0.086 \frac{1}{\text{cm}}\right) = 13.1 \frac{\text{kHz}}{\text{cm}^2}$$

Hit rate averaged over diamond

$\tau_i = 186\mu\text{s}$ PXL integration time

$$HRa \cdot \tau_i = 2.4 \frac{1}{\text{cm}^2}$$

Expected hit density at the center of the PXL inner layer at full pp luminosity with a interaction diamond of sigma = 30 cm

source at z = 0

At the outer layer radius the expected hit density

$r = 8\text{cm}$

$$HRa = 400\text{kHz} \cdot 6 \cdot \frac{1}{2 \cdot \pi \cdot r} \cdot \left(0.056 \frac{1}{\text{cm}}\right) = 2.7 \frac{\text{kHz}}{\text{cm}^2}$$

$$HRa \cdot \tau_i = 0.5 \frac{1}{\text{cm}^2}$$

Expected hit density at the center of the PXL outer layer at full pp luminosity with a interaction diamond of sigma = 30 cm

Scales slower than 1/r^2, but faster than 1/r.

Appendix A1

Lifted from: **TPC Rev 2006 abrv for Ron.xmcd**

Derivation of

$$S(r) = \frac{dq}{dVdt} = L \cdot \sigma \cdot \frac{dN}{d\eta} \cdot \frac{dN_i}{ds} \cdot \frac{q_e}{2 \cdot \pi \cdot r^2}$$

Eq. A1-1 the rate of positive ion generation per volume

using a cylindrical coordinate geometry (Fig. A1-1).

$\frac{dN}{d\eta}$	number of tracks per unit pseudo rapidity, assumed constant
$\frac{dN_i}{ds}$	number of ion-electron pairs created per unit length along the track
L	Luminosity
σ	cross section
q_e	electron charge

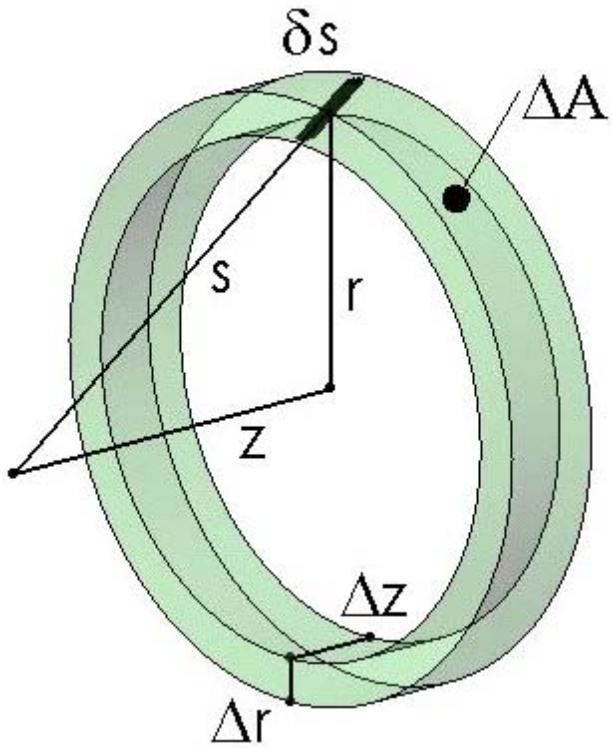

Fig. A1-1 Elemental volume with track along s leaving ionization segment δs

from the geometry illustrated in Fig. A1-1

$$\Delta q = \frac{dN}{dA}\cdot\Delta A\cdot\frac{dN_i}{ds}\cdot\delta s\cdot q_e \qquad \text{Eq. A1-2}$$

where

$$\frac{dN}{dA} = \frac{dN}{dz}\cdot\frac{1}{2\cdot\pi\cdot r} = \frac{dN}{d\eta}\cdot\frac{d\eta}{dz}\cdot\frac{1}{2\cdot\pi\cdot r} \qquad \text{Eq. A1-3}$$

is for a collision, the average number of tracks per area impinging on the inside surface of the elemental volume in Fig. A1-1

and

$$\delta s = \Delta r\cdot\frac{s}{r} = \Delta r\cdot\frac{\sqrt{r^2 + z^2}}{r} \qquad \text{Eq. A1-4}$$

is the length of the track segment passing through the elemental volume

$$\Delta V = \Delta A\cdot\Delta r \qquad \text{Eq. A1-5}$$

is the elemental volume

combining Eq. A1-2 through Eq. A1-5 gives

$$\frac{dq}{dV} = \frac{\Delta q}{\Delta V} = \frac{\frac{dN}{d\eta}\cdot\frac{d\eta}{dz}\cdot\frac{1}{2\cdot\pi\cdot r}\cdot\Delta A\cdot\frac{dN_i}{ds}\cdot\Delta r\cdot\frac{\sqrt{r^2+z^2}}{r}\cdot q_e}{\Delta A\cdot\Delta r} = \frac{dN}{d\eta}\cdot\frac{d\eta}{dz}\cdot\frac{dN_i}{ds}\cdot\frac{\sqrt{r^2+z^2}}{2\cdot\pi\cdot r^2}\cdot q_e \qquad \text{Eq. A1-6}$$

the charge volume density left by a single collision

To find $\frac{d\eta}{dz}$ use the definition of pseudo rapidity

$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right) \qquad \text{and} \qquad \theta = \operatorname{atan}\left(\frac{r}{z}\right)$$

to get

$$\eta(r,z) = \ln\left(\frac{\sqrt{z^2+r^2}+z}{r}\right)$$

and taking the derivative

$$\frac{d\eta}{dz} = \frac{1}{\sqrt{r^2+z^2}} \qquad \text{Eq. A1-7}$$

combine Eq. A1-7 and A1-6 to eliminate $\frac{d\eta}{dz}$

and multiply by the event rate $L\cdot\sigma$

gives the following expression for the generation rate of positive ions per volume

$$\frac{dq}{dVdt} = L\cdot\sigma\cdot\frac{dN}{d\eta}\cdot\frac{dN_i}{ds}\cdot\frac{q_e}{2\cdot\pi\cdot r^2} \qquad \text{Eq. A1-8}$$

which is uniform in z, i.e. it does not matter where in z the collision occurred.

A similar and perhaps more straight forward derivation has been done starting with spherical coordinates which gives the same expression. This will be added later.

References:

1. C:\Documents and Settings\Howard Wieman\My Documents\space charge distortion STAR\ TwoD5.MCD