Vertex position and luminosity

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1 Time and vertex displacement

Measuring P_A enables us to determine the vertex position. The idea is simply:

$$\delta P_A = \left(\frac{dP_A}{dz}\right)\delta z. \tag{1}$$

The main drawback here is the great difficulty in determining $\frac{dP_A}{dz}$ via simulation, because of great mass distribution sensitivity. But putting that aside, we can estimate the time needed, for significant estimation of vertex displacement. What we want is

$$\delta P_A \geq S\sigma_{P_A}, \tag{2}$$

where S is desired significance. Since $P_A = \frac{N_A}{N_A+N_C}$, where N_i is the number of detected tracks, one can write

$$\sigma_{P_A} = \sqrt{\frac{N_A N_C}{(N_A+N_C)^3}} \sim \sqrt{\frac{1}{8N}}. \tag{3}$$

where we approximated $N = N_A = N_C$ close to $z = 0$. We can also write

$$N = N_{BX} N_{pp}(\mathfrak{L}) r_{TR} P_A, \tag{4}$$

where N_{BX} is the number of bunch crossings in given time interval t. If we assume they appear t_0 apart we can write $N_{BX} = \frac{t}{t_0}$. N_{pp} is number of proton-proton collisions at certain luminosity, so $N_{pp} = \frac{\mathfrak{L}}{\mathfrak{L}_0}$. r_{TR} represents the track rate in one proton-proton collision. Putting all together we have

$$N = \frac{t}{t_0}\frac{\mathfrak{L}}{\mathfrak{L}_0} r_{TR} P_A \tag{5}$$

and the condition (2) is

$$\left(\frac{dP_A}{dz}\right)\delta z \geq S\sqrt{\frac{t_0\mathfrak{L}_0}{8t\mathfrak{L} r_{TR} P_A}}. \tag{6}$$

Form here the time can be expressed:

$$t \geq t_0 \frac{1}{8 r_{TR} P_A \left(\frac{dP_A}{dz}\right)^2} \frac{\mathfrak{L}_0}{\mathfrak{L}} \frac{1}{(\delta z)^2}. \tag{7}$$

From simulation we know: $P_A = \frac{1}{2}$, $r_{TR} = 0.4$, $t_0 = 25\,\mathrm{ns}$ and $\left(\frac{dP_A}{dz}\right) = -0.11/\mathrm{m}$. With this values the figure 1 has been ploted.

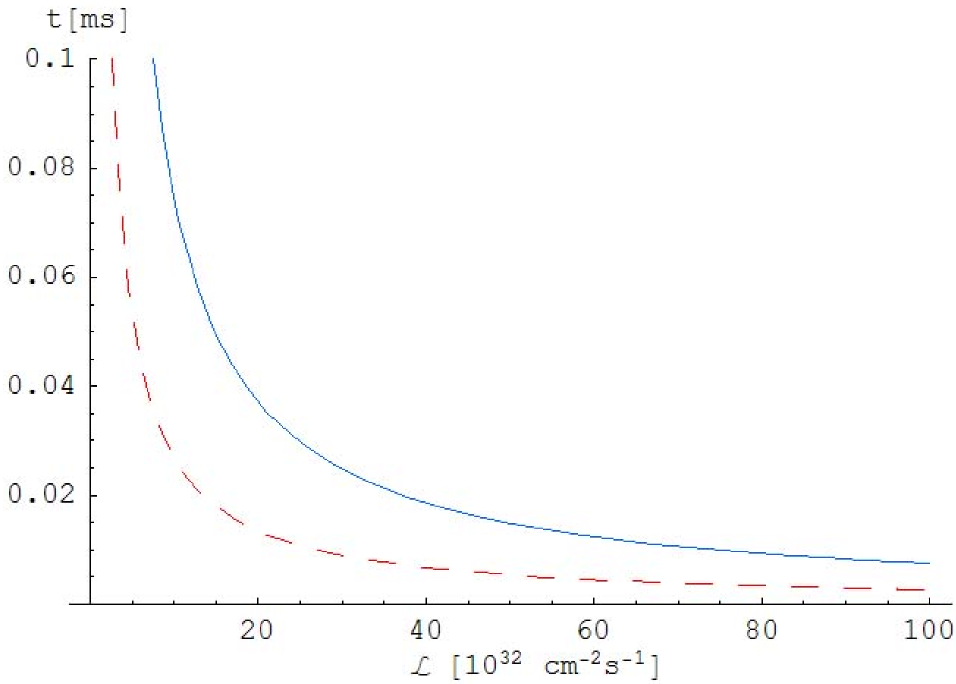

Figure 1: Luminosity dependence, of time needed, for 3 sigma (dashed red line) and for 5 sigma (continuous blue line) significance. The displacement is 10 cm.

2 Luminosity

Since the P_A is luminosity independent, it can not be used for luminosity measurement. Here coincidences are expected to be the best choice. Coincidences versus luminosity are plotted on figre 2.

The problem appears at high luminosities where coincidence rate saturates. Here one must be more selective. Therefore figure 3 has been plotted. It represents coincidence rate versus luminosity for precisely 1, 2, 3 or 4 tracks on each side.

It can be seen that in the case of one track in each side we get the luminosity dependence. But now for each measured rate there are two possible luminosities. To resolve this, the measurements of total coincidence rate and the measurements of selective 1-1 coincidence rate should be combined. But one can do even slightly better. Instead of 1-1 coincidence, we accept any event which has exactly one track on either side (there is no condition for the other side). The rate for these events is plotted in figure 4. The rate is somewhat higher, the luminosity dependence is little stronger at high luminosities and the peak moved. Around this peak luminosity can only be measured via total coincidence rate.

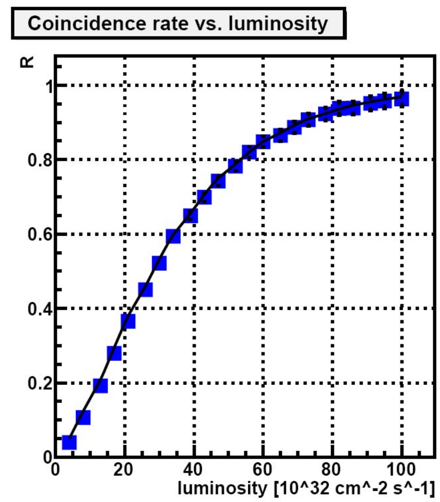

Figure 2: Total coincidence rate (something on each side) versus luminosity. At high luminosities there is small luminosity dependence.

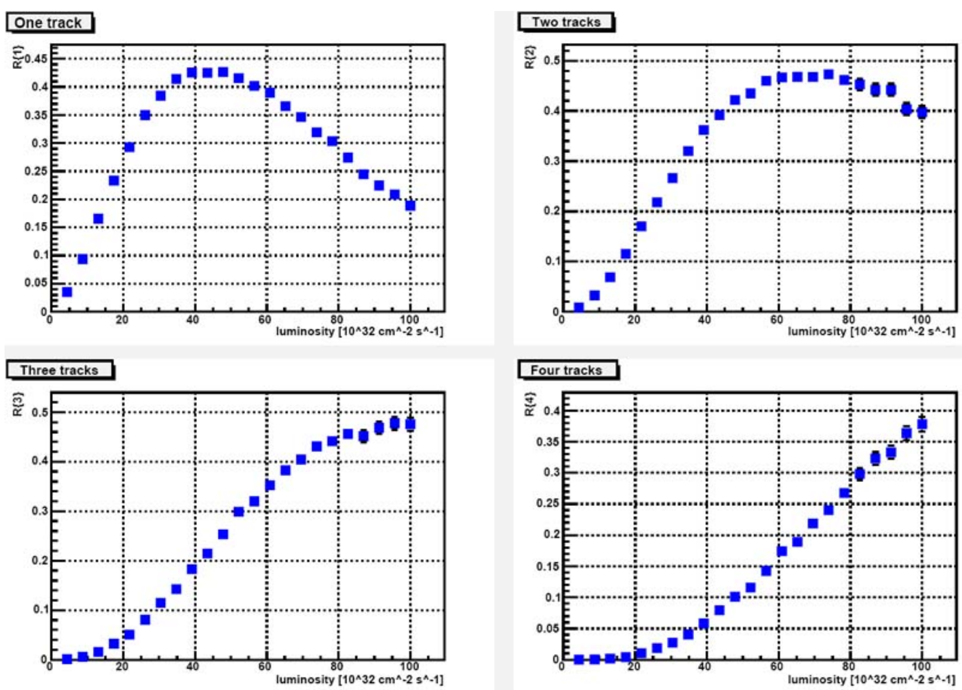

Figure 3: Rate of events with precisely n tracks on each side. Graphs are for n=1,2,3 or 4.

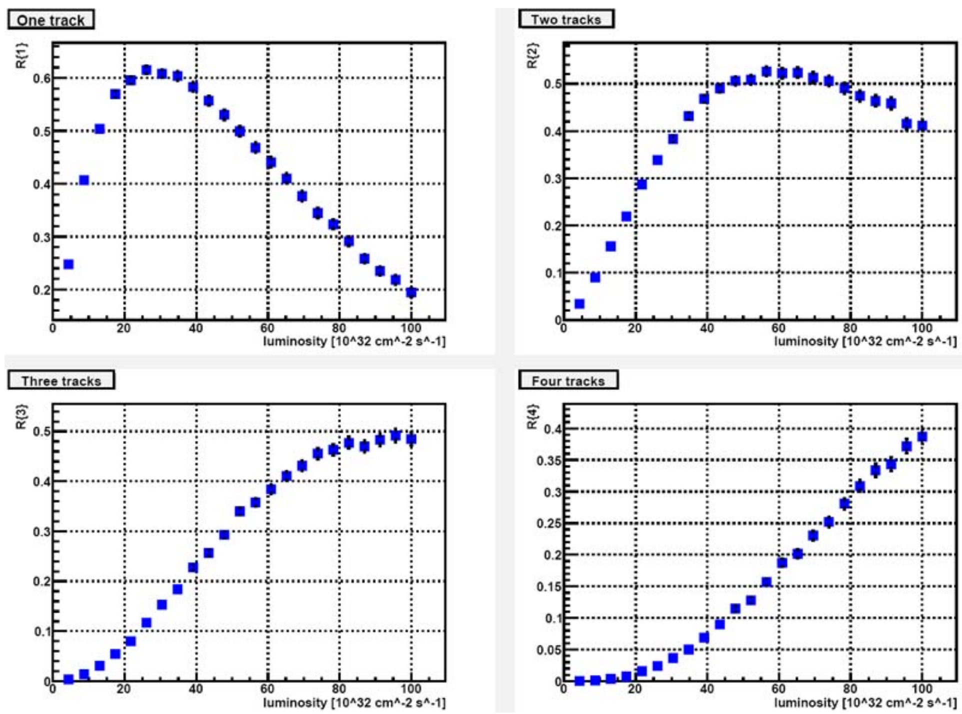

Figure 4: Rate for events where the condition is: exactly n tracks on one side and there is no condition on the other side . Graphs are for n=1,2,3 or 4.