Garfield Simulation of Scintillation Ionization Detector (SID)

Outline
• Physics case
• Scintillation Ionization Detector (SID)
• Garfield Simulation
• summary

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Physics case

Super Heavy Elements (SHE):  
- Stable elements (theoretical prediction)  
- Located at the island of stability (Z=114, N=184)  
- Production cross-section at laboratory is very low ( ~ 1 pb)

- Identification of (SHE) by the detection of spontaneous fission fragments.

\[ ^{208}\text{Pb} + ^{44}\text{Ca} \rightarrow ^{252}\text{No} \rightarrow ^{250}\text{No} + 2\text{n} \]
Scintillation Ionization Detector (SID)

MWPC is made of:
• 3 vertical wire planes (x)
• 2 horizontal wire planes (y)
• each wire plane is separated by grounded Mylar stopper

MWPC is made of:
• Scintillation detector
• Segmented Multi-Wire Proportional Chamber (MWPC)
• In the same gas (CF4)

• Pressure of the gas adjusted to stop the SHE inside one of the grounded stopping Mylar foils
• Scintillation part used for fast selection of the incoming heavy nuclei
Scintillation Ionization Detector (SID) (continued ...)

Wire-plane:
- 19 sense wires (Anode)
- 20 field shaping wires (Cathode)
- 0.1 inches distance between A and K
- High positive voltage at Anode
- Cathode at ground potential

- position
- angular distribution of the fission fragments
Garfield Simulation

Garfield:
- computer program for the detailed simulation gaseous detectors
- An interface to the Magboltz program for the computation of electron transport properties in gas

1. Electric field

- Large electric field near Anode wire
- Amplification takes place around Anode wire ~ 5 times radii
2. Electron drift and ion drift

- Number of electrons collected at anode is inversely proportional to the cathode voltage
- Cathode voltage must be less than 60% of Anode for ~100% electron collection at Anode

Only 65 percentage of the total ions are collected at Cathode for a Cathode voltage of 0V
3. Gas gain

\[ G(\Delta x) = \exp \left( \int_{x_0}^{x_1} \alpha(E(x)) \, dx - \int_{x_0}^{x_1} a(E(x)) \, dx \right) \]

- Townsend coefficient \( \alpha \): Mean number of ionization per unit length
- Attachment coefficient \( a \): Mean number of attachment of electron per unit length

Single electron response - Polya distribution

\[ \frac{\partial p_{\text{ioni}}}{\partial x} = \alpha \left( b + \frac{1 - b}{N} \right) \]

\[ P(N_{\text{SER}}, \theta) = C \frac{(\theta + 1)^{\theta + 1}}{\Gamma(\theta + 1)} \left[ \frac{N_{\text{SER}}}{N_{\text{SER}}} \right]^{\theta} \exp \left( - (\theta + 1) \frac{N_{\text{SER}}}{N_{\text{SER}}} \right) \]

\( N_{\text{SER}} \) is the current size of avalanche, \( \theta = b^{-1} \)
4. Resolution

Relative gain variance

\[ f = \frac{1}{1 + \theta} = \left( \frac{\sigma_{SER}}{N_{SER}} \right)^2 \]

Energy resolution is

\[
\left( \frac{\sigma_Q}{Q} \right)^2 = \left( \frac{\sigma_{N_0}}{N_0} \right)^2 + \frac{1}{N_0} \left( \frac{\sigma_{N_{SER}}}{N_{SER}} \right)^2 = \frac{F}{N_0} + \frac{f}{N_0}
\]

F, Fano factor of gas:

- Measure of dispersion of the probability distribution of fano noise ie: Variance / Mean

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<th>Anode Voltage</th>
<th>Gain (deterministic)</th>
<th>Gain (Garfield)</th>
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5. Signal

- Total signal duration \( \sim 4.5 \) mS
- Electron pulse duration < 125 nS
- Rise time \( \sim 35 \) nS
6. Tuning

- Sensitivity of pre-amplifier ~ 0.7 mV/MeV (Si)
- Energy needed to generate one electron pair in silicon detector is \( W \sim 3.6 \text{ eV} \)
- Total number of electron needed to detect 0.7 mV is, \( \frac{1 \text{ MeV}}{3.6 \text{ eV}} = 2.7 \times 10^5 \bar{e} \)

- If one of the spontaneous fission products of \(^{252}\text{Cf}, ^{140}\text{Xe}\) (with an initial energy of 80 MeV) pass through SID, It will generate an output signal of 6.1 mV (with a gain of 1 and gas pressure is at 100 mbar)

- For an alpha particle with an initial energy of 5 MeV, the signal generated is of 0.1 mV (gain of 1 and gas at 100 mbar)
Summary

- In order to detect alpha particle, we must have a gain around 100
- The output voltage for this gain would be too big (0.61 V) for heavy nuclei.
- Energy loss of SHE in Mylar and the thickness of Mylar has to be calculated
Thank you