MRPC update

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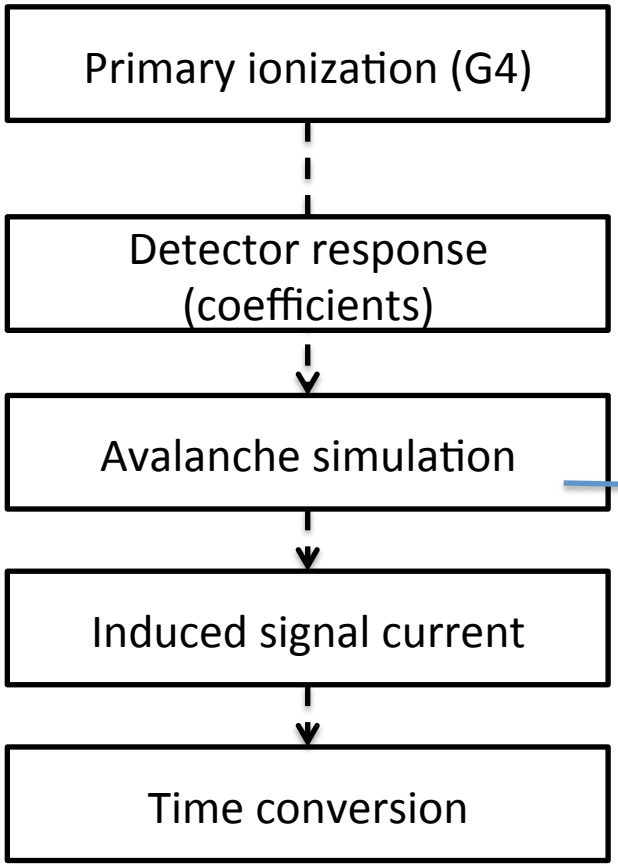
MRPC digitization

- Fast digitization software for MRPC
- Closely followed procedure of the BESIII MRPC simulation
- Specifications from the pCDR design (10 gas gaps with each 0.25mm width, gas mixture: $C_2F_4H_2$ (90%) : SF_6 (5%) : iso-C_4H_{10} (5%)

- More information:
  - MRPC wiki (Fenfen An's presentation, relevant papers, more to be updated)

Basic scheme

- Benchmarking the BESIII MRPC simulation



Ionization and attachment, drift velocity, ...
(currently using the parameters provided by Fenfen An using MAGBOLTZ)

Ramo's theorem

$$i(t) = E_w \cdot v \cdot e_0 \cdot N(t)$$

Avalanche simulation

- Starting with 1-D model (Nucl. Instrum. Meth. A 500 (1-3) (2003) 144)
- Avalanche development can be characterized by two coefficient: Townsend coefficient (α) and attachment coefficient (η)
- P(n,x): probability for an avalanche started with a single electron to contain n electrons after distance x
- General solution is given as:

$$P(n,x)=\begin{cases} k\dfrac{\bar{n}(x)-1}{\bar{n}(x)-k}, & (n=0) \\ \bar{n}(x)\left(\dfrac{1-k}{\bar{n}(x)-k}\right)^{2}\left(\dfrac{\bar{n}(x)-1}{\bar{n}(x)-k}\right)^{n-1}, & (n>0) \end{cases}$$

$$\bar{n}(x)=e^{(\alpha-\eta)x}$$

(average number of electrons)

$$k=\frac{\eta}{\alpha}$$

Avalanche simulation

- Single gap avalanche simulation

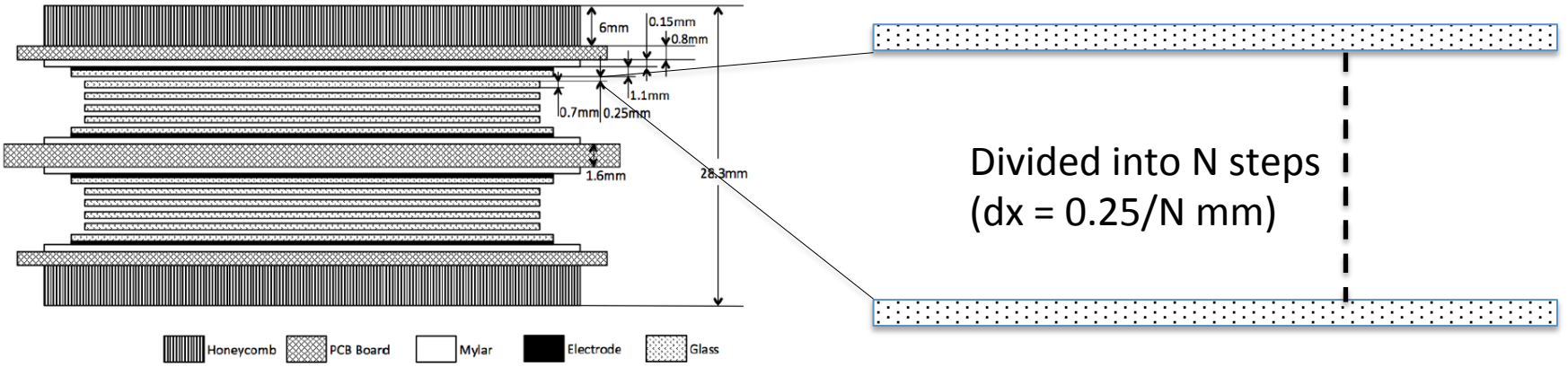
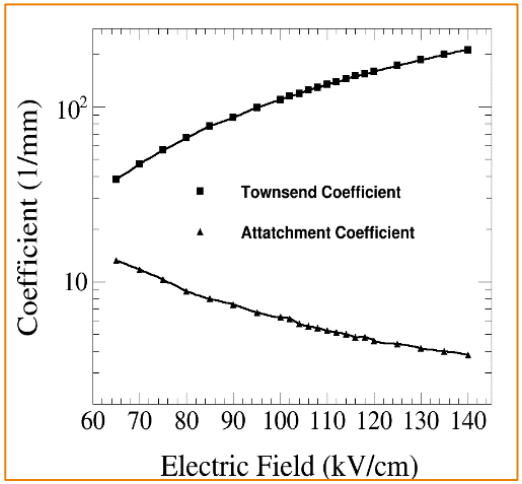


Figure 108: The structure of the MRPC prototype

By Fenfen An (using MAGBOLTZ)



- The positions of primary electrons are given by GEANT4
- For each step, calculate the number of electrons with a probability for ionization/ attachment
- Loop over all electrons until they reach to the end of the gap
  - Very time consuming

Avalanche simulation

>> Loop over all electrons until they reach to the end of the gap

- Very time consuming

- Solutions:
  1. Make use of the central limit theorem

     # of electrons at x+dx can be obtained by drawing a random number from a Gaussian with mean and sigma of $\mu = n_{at\ x}\bar{n}(dx), \quad \sigma_\mu = \sqrt{n_{at\ x}}\sigma(dx)$
  2. Set a limit (simplified space charge effect)

     Exponential avalanche growth stopped by space charge effects

- To simulate space charge effect, 2D model is being considered:
  - Considering both radial and longitudinal
  - At each step, gas parameters need to be calculated dynamically

Avalanche simulation test

- Avalanche by a single electron in a single gap

From the NIM paper
(α = 13/mm, η = 3.5/mm)

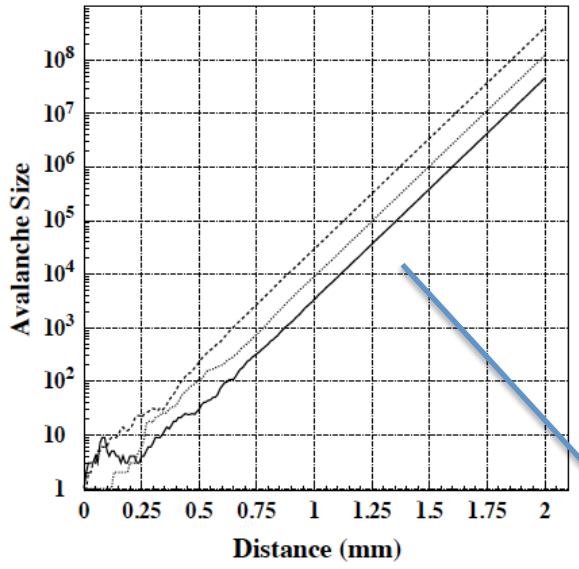
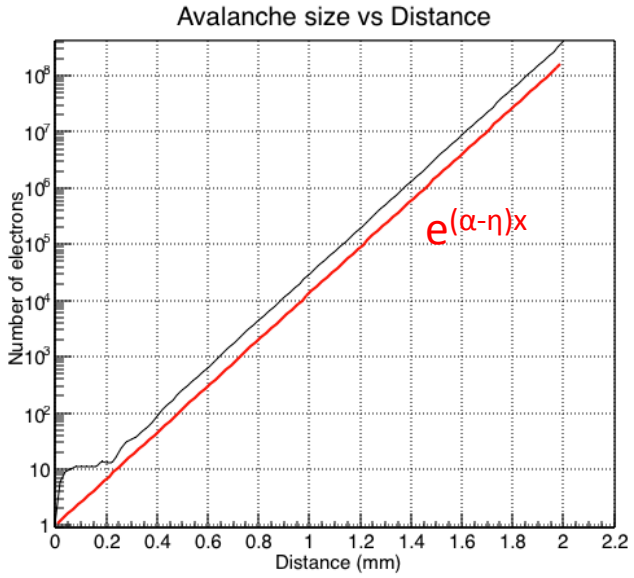


Fig. 6. Avalanches started by a single electron at $x = 0$ for $\alpha = 13/\text{mm}$, $\eta = 3.5/\text{mm}$. We see that the very beginning of the avalanche decides on the final avalanche size. Once the number of electrons is sufficiently large the avalanche grows like $e^{(\alpha-\eta)x}$.

Using our simulation module



Different step size, and therefore difference in the early avalanche → decides final avalanche size

To-do

- Getting the induced signal distribution
- 2D avalanche model for Space charge effect
- Comparing with the test beam result

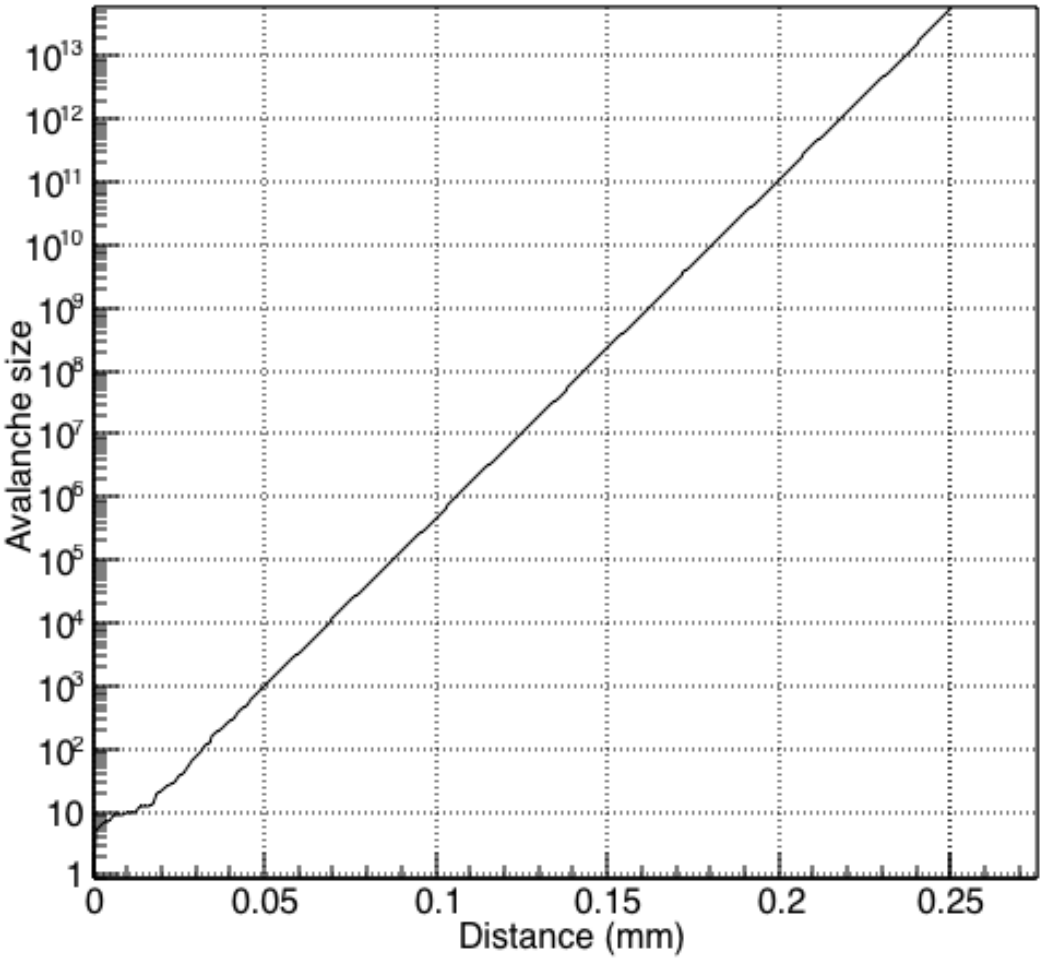
- SBU has a GARFIELD +GEANT4 module that was used to simulate TPC response. For a longer term, we can also implement this.

Backup

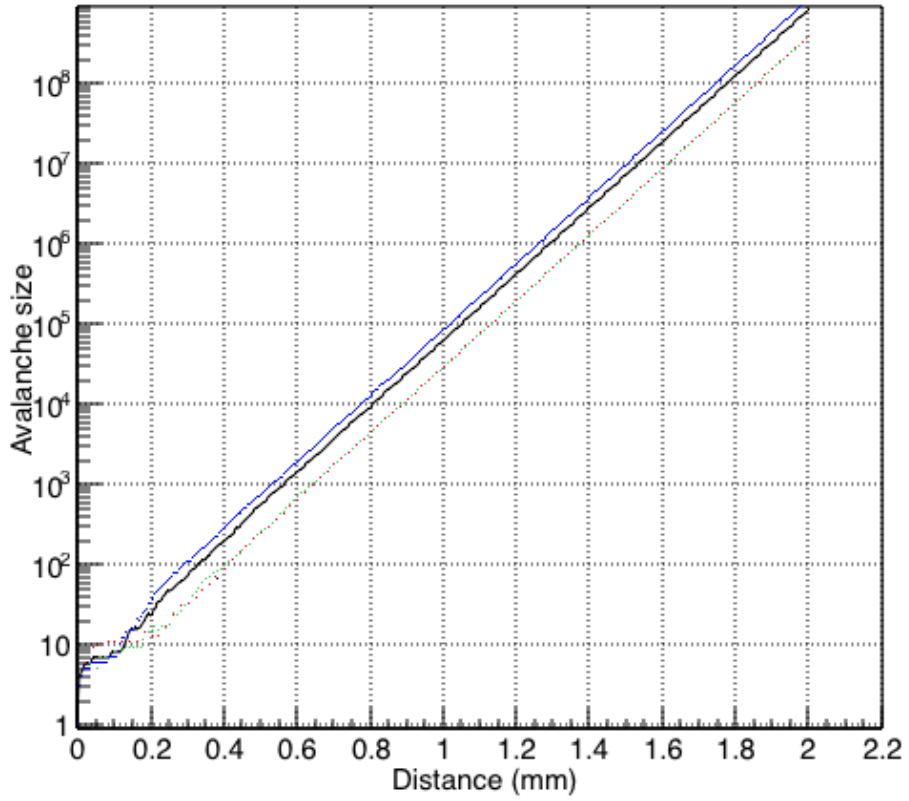
GEANT4 input

- Primary ionization: Select electrons that are
  - not a beam particle (but mother pid == beam)
  - not from photon
  - with primary vertex within a gas gap
- For more detailed simulation, the effect of secondary particles will be also studied.

SoLID MRPC, HV = 108kV/cm



Avalanche size for various step size N



N = 100 (dx = 0.02 mm)
N = 200 (dx = 0.01 mm)
N = 300 (dx = 0.07 mm)
N = 400 (dx = 0.05 mm)

- Standalone simulation
  - e (momentum 0.2 GeV - 1.3 GeV)

Particle		e+, e-,π+,π-,p
momentum	e	200MeV/c~1.3GeV/c
	π	400MeV/c~900MeV/c
	p	500MeV/c~1GeV/c
rate		10~20Hz