On the possibility to reconstruct the event vertex

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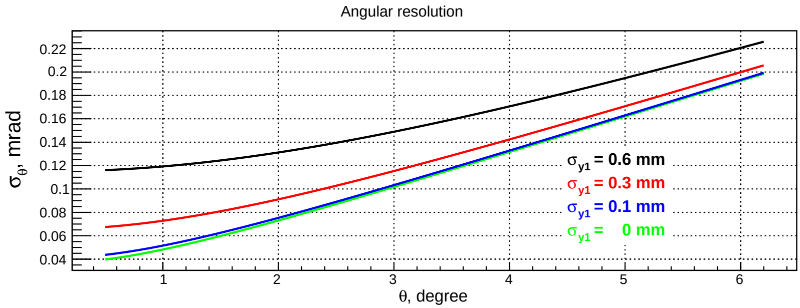
Scheme 1: a single tracking layer + the beam position

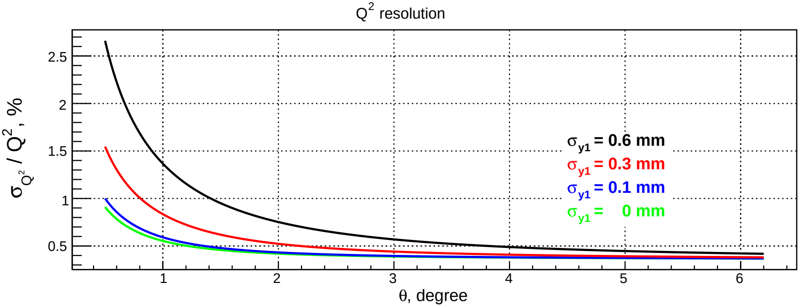
Variable	Value	Comment
σ_{y_0}	0.2 mm	Due to the known beam position
σ_{z_0}	10 mm	Due to the target length (40 mm $= \pm 2\sigma$)
z_1	550 cm	It corresponds to $\theta_{max} \approx 6.2^\circ$
σ_E/E	10^{-4}	The beam energy uncertainty

$$\theta = \arctan\frac{y_1}{z_1}, \quad \sigma_\theta = \frac{1}{y_1^2+z_1^2}\sqrt{y_1^2\sigma_{z_0}^2 + z_1^2(\sigma_{y_0}^2+\sigma_{y_1}^2)}$$

$$Q^2 = \frac{2ME^2(1-\cos\theta)}{M+E(1-\cos\theta)}, \quad \frac{\sigma_{Q^2}}{Q^2} \approx \sqrt{\left(\frac{2\sigma_E}{E}\right)^2 + \left(\frac{\sigma_\theta \sin\theta}{1-\cos\theta}\right)^2}$$

Angular and Q^2 resolutions for the scheme 1





Taking account of the multiple Coulomb scattering

$$\sigma_\theta^{\text{m.sc.}} = \frac{13.6\ \text{MeV}}{\beta c p} z \sqrt{\frac{x}{X_0}} \left(1 + 0.038 \ln \frac{x}{X_0}\right)$$

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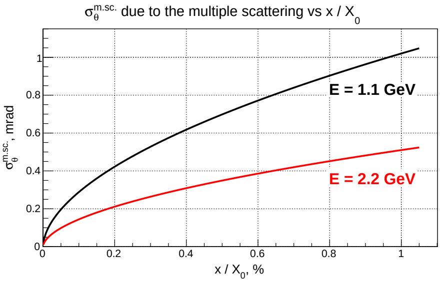
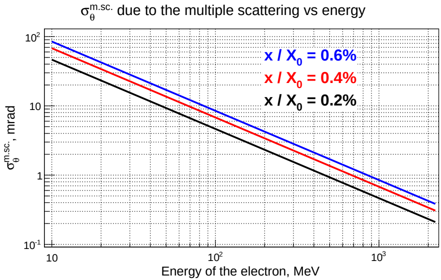
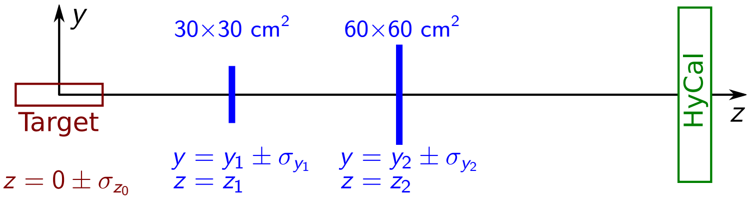
Material	Rad. length X_0, g/cm^2	Density ρ, g/cm^3
Cu	12.86	8.96
Al	24.01	2.70
Kapton	40.58	1.42





Scheme 2: two GEM layers + the beam position



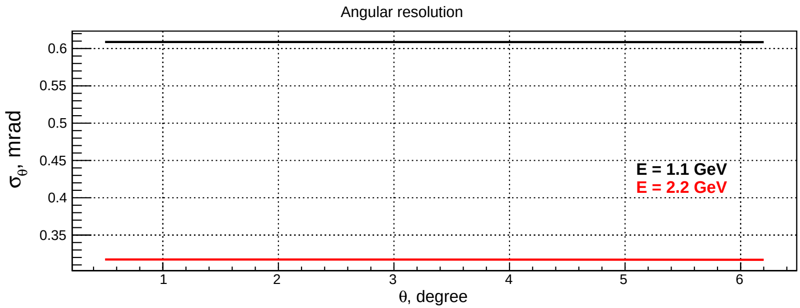
Variable	Value	Comment
σ_{z_0}	10 mm	Due to the target length (40 mm $= \pm 2\sigma$)
z_1	138 cm	Size of 30×30 cm^2
z_2	275 cm	Size of 60×60 cm^2
σ_{y_1}, σ_{y_2}	0.1 mm	Typical for GEM
$\sigma_\theta^{\text{m.sc.}}$	0.6 mrad	For $E = 1.1$ GeV and $x/X_0 \approx 0.4\%$
	0.3 mrad	For $E = 2.2$ GeV and $x/X_0 \approx 0.4\%$

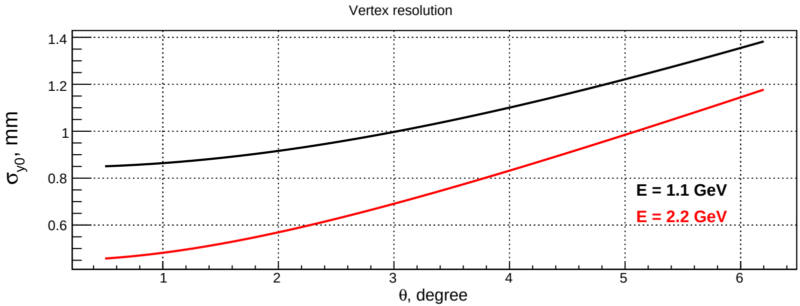
Step 1: determine y-coordinate of the vertex (using two GEMs)

$$\theta = \arctan \frac{y_2 - y_1}{z_2 - z_1}, \quad \sigma_\theta^2 = (\sigma_\theta^{\text{m.sc.}})^2 + \frac{(z_2 - z_1)^2 \left(\sigma_{y_1}^2 + \sigma_{y_2}^2\right)}{\left[(y_2 - y_1)^2 + (z_2 - z_1)^2\right]^2}$$

$$y_0 = y_1 - z_1 \tan\theta, \quad \sigma_{y_0} = \sqrt{\sigma_{y_1}^2 + \sigma_{z_0}^2 \tan^2\theta + \frac{z_1^2}{\cos^4\theta}\,\sigma_\theta^2}$$

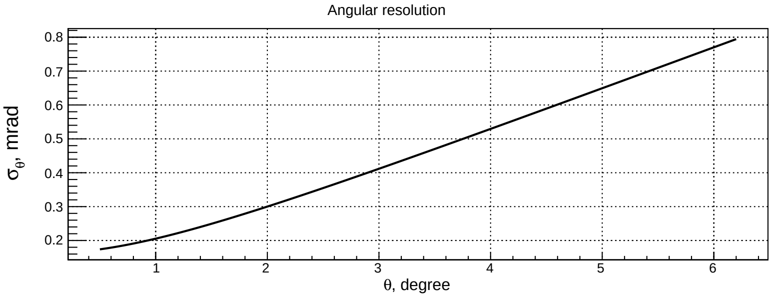
Scheme 2: two GEM layers + the beam position

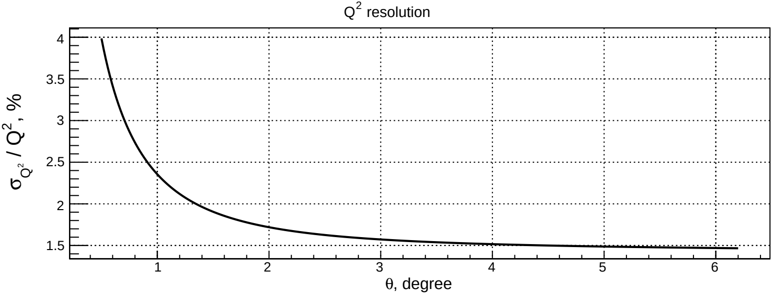




Scheme 2: two GEM layers + the beam position

Step 2: determine θ and Q^2 (using the first GEM and the beam position)





Conclusions

- There is the possibility do determine the y-coordinate of the vertex with an accuracy of $0.5-1.4$ mm. In principle, it is enough to reject the events due to the beam halo interaction with the target walls.
- It requires two GEM layers of a reasonable size, but the radiation length of the first GEM is critically important (not more than $0.4\% X_0$ including an additional protection to operate in vacuum).
- Unfortunately, the multiple scattering is worse for soft electrons, i.e. for the Møller process.
- Probably, the discussed geometry is better compatible with a helium box (from the second GEM to HyCal).
- The angular and Q^2 resolutions will be worse due to the multiple scattering but, probably, still satisfactory.
- The algorithm of determining θ and Q^2 can be a little improved (by taking into account the second GEM).
- Probably, the geometry can be further optimized.