Status on SDT simulation

Ryuta

07/07/2020

Update

- Have investigated the topic around the estimation of dE/dx and its resolution

Energy loss (-dE/dx)

http://pdg.lbl.gov/2020/reviews/rpp2020-rev-passage-particles-matter.pdf

$$\left\langle -\frac{dE}{dx}\right\rangle = Kz^2\frac{Z}{A}\frac{1}{\beta^2}\left[\frac{1}{2}\ln\frac{2m_ec^2\beta^2\gamma^2W_{\max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}\right].$$

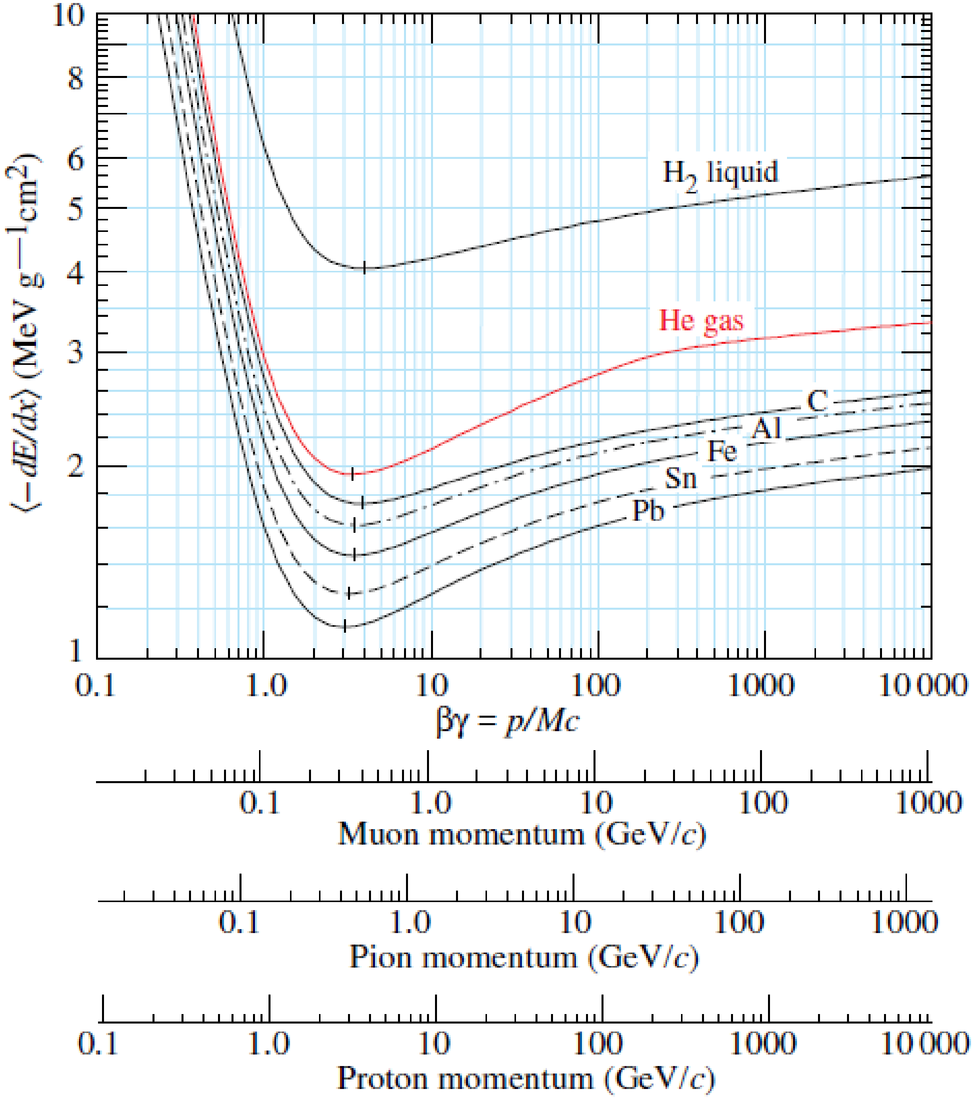
For, $_{18}$Ar (gas), one of typical gas in chamber,
ρ(density) = 1.662e-3 g/cm^3

-dE/dx ~2 MeV・cm^2/g
➔ loss per unit length 1.3 KeV/cm

$$W_{\max} = \frac{2m_ec^2\,\beta^2\gamma^2}{1+2\gamma m_e/M + (m_e/M)^2} \quad \sim \quad 2m_ec^2\,\beta^2\gamma^2$$

(M: incident particle mass)

$K \quad 4\pi N_A r_e^2 m_e c^2 \quad 0.307\,075$ MeV mol^{-1} cm^2



Ref: variable table

Table 34.1: Summary of variables used in this section. The kinematic variables β and γ have their usual relativistic meanings.

Symb.	Definition	Value or (usual) units
m_ec^2	electron mass $\times c^2$	$0.510\,998\,9461(31)$ MeV
r_e	classical electron radius $e^2/4\pi\epsilon_0 m_ec^2$	$2.817\,940\,3227(19)$ fm
α	fine structure constant $e^2/4\pi\epsilon_0\hbar c$	$1/137.035\,999\,139(31)$
N_A	Avogadro's number	$6.022\,140\,857(74)$ $\times 10^{23}$ mol^{-1}
ρ	density	g cm^{-3}
x	mass per unit area	g cm^{-2}
M	incident particle mass	MeV/c^2
E	incident part. energy γMc^2	MeV
T	kinetic energy, $(\gamma-1)Mc^2$	MeV
W	energy transfer to an electron in a single collision	MeV
$W_{\rm max}$	Maximum possible energy transfer to an electron in a single collision	MeV
k	bremsstrahlung photon energy	MeV
z	charge number of incident particle	
Z	atomic number of absorber	
A	atomic mass of absorber	g mol^{-1}
K	$4\pi N_A r_e^2 m_ec^2$ (Coefficient for dE/dx)	$0.307\,075$ MeV mol^{-1} cm^2
I	mean excitation energy	eV (*Nota bene!*)
$\delta(\beta\gamma)$	density effect correction to ionization energy loss	
$\hbar\omega_p$	plasma energy $\sqrt{4\pi N_e r_e^3}\; m_ec^2/\alpha$	$\sqrt{\rho\,\langle Z/A\rangle} \times 28.816$ eV ↳ ρ in g cm^{-3}
N_e	electron density	(units of r_e)$^{-3}$
w_j	weight fraction of the jth element in a compound or mixt.	
n_j	$\propto$ number of jth kind of atoms in a compound or mixture	
X_0	radiation length	g cm^{-2}
E_c	critical energy for electrons	MeV
$E_{\mu c}$	critical energy for muons	GeV
E_s	scale energy $\sqrt{4\pi/\alpha}\; m_ec^2$	21.2052 MeV
R_M	Molière radius	g cm^{-2}

Resolution of dE/dx

http://pdg.lbl.gov/2020/reviews/rpp2020-rev-particle-detectors-accel.pdf

- Straight forward way would be . . .

  -- dE/dx (per unit cell) is proportional to the number of electron/hole pairs typical number is ~ 100 (per cm)

  -- signal multiplication (= gain) factor, $10^4 \sim 10^5$, the total number of carriers, within the drift time is obtained.

  -- need to consider the electronics response: the filter (RC filter), amplifier, and electronics noise (important)

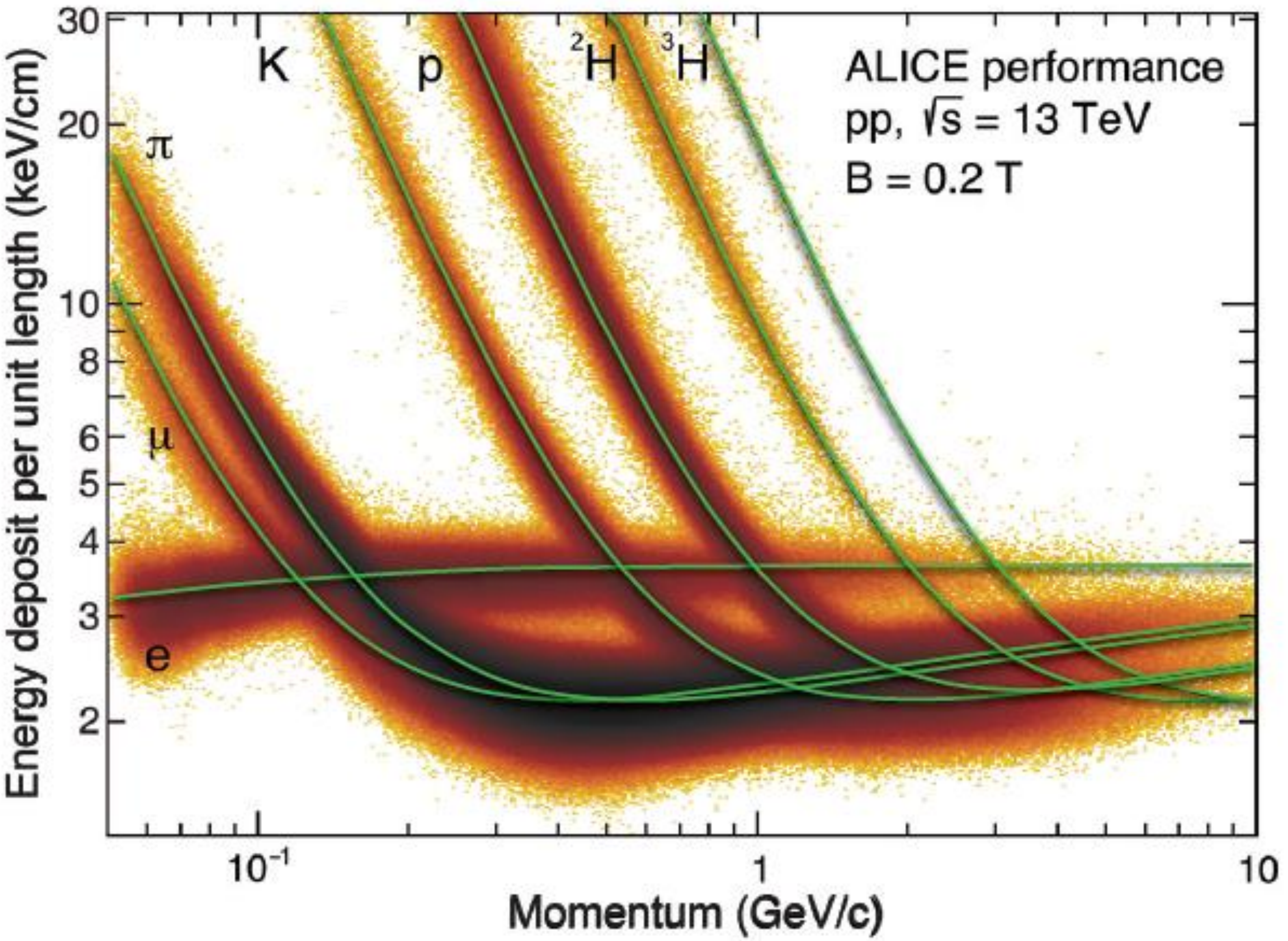


Figure 35.15: Energy deposit versus momentum measured in the ALICE TPC.

➡ Combining those steps, we can estimate the resolution

Resolution of dE/dx

The dependence of the achievable energy resolution on the number of measurements N, on the thickness of the sampling layers t, and on the gas pressure P can be estimated using an empirical formula [135]:

$$\sigma_{dE/dx} = 0.41\, N^{-0.43} (t\, P)^{-0.32}. \tag{35.17}$$

Typical values at nominal pressure are $\sigma_{dE/dx} = 4.5$ to 7.5%, with $t = 0.4$ to 1.5 cm and $N = 40$ up to more than 300. Due to the high gas pressure of 8.5 bar, the resolution achieved with the PEP-4/9 TPC was an unprecedented 3% [136].

[136] H. Aihara *et al.*, IEEE Trans. **NS30**, 63 (1983).

-- It is an old reference of the resolution for a TPC

-- Not sure(confirmed) yet, what condition should be met to apply this formula

For instance, s ~ 0.41 * 222(layers)$^{-0.5}$ * (1cm*1atm)$^{-0.32}$ = 2.8% ↔ 5~7 ? % is somehow we can see in the references