Charged-particle R_{AA} in Pb-Pb collisions at 5.02 TeV from CMS

8.1 Simple parton energy loss model

In the lecture a simplified parton energy loss model was discussed which assumed a constant fractional energy loss $\varepsilon_{\text{loss}} = |\Delta p_T|/p_T = \text{const.}$ In this problem we consider the case of a constant absolute energy loss Δ, i.e., the transverse momentum after the energy loss is given by $p_T' = p_T - \Delta$.

a) Write down the formula for the charged-hadron $R_{AA}(p_T)$ for a transverse momentum spectrum described by

$$\frac{1}{p_T}\frac{dN}{dp_T} \propto \frac{1}{p_T^n} \tag{1}$$

assuming a constant absolute energy loss.

Assuming no energy loss:

$$R_{AA} = \frac{dN/dp_T\,|_{A+A}}{\langle T_{AA}\rangle\; d\sigma_{\text{inv}}/dp_T\,|_{p+p}} = \frac{c\;/\;p_T^{n-1}}{\langle T_{AA}\rangle\; d\sigma_{\text{inv}}/dp_T\,|_{p+p}} = 1 \tag{2}$$

Considering energy loss:

$$\frac{dN}{dp_T'} = \frac{dN}{dp_T}\frac{dp_T}{dp_T'} = c\cdot\frac{1}{(p_T)^{n-1}}\cdot 1 = c\cdot\frac{1}{(p_T'+\Delta)^{n-1}} = \frac{c}{p_T'^{\,n-1}}\left(\frac{p_T'}{p_T'+\Delta}\right)^{n-1} \tag{3}$$

$$R_{AA} = \frac{dN/dp_T'\,|_{A+A}}{\langle T_{AA}\rangle\; d\sigma_{\text{inv}}/dp_T'\,|_{p+p}} = \frac{c\;/\;p_T'^{\,n-1}}{\langle T_{AA}\rangle\; d\sigma_{\text{inv}}/dp_T'\,|_{p+p}}\left(\frac{p_T'}{p_T'+\Delta}\right)^{n-1} = 1\cdot\left(\frac{p_T'}{p_T'+\Delta}\right)^{n-1} \tag{4}$$

$$\implies R_{AA} = \left(\frac{p_T'}{p_T'+\Delta}\right)^{n-1} \tag{5}$$

b) Determine the value Δ which describes the $R_{AA}(p_T)$ measured in central (0-5%) Pb-Pb collisions for p_T > 25 GeV/c best.

In [2]:

```
import numpy as np
import matplotlib.pyplot as plt
from scipy.optimize import curve_fit
```

CMS Raa vs. pT data for 0-5% most central Pb-Pb (arXiv:1611.01664) available on hepdata. Read data as comma separated values:

In [3]:

```
pt, Raa, RaaStatErr = np.loadtxt('HEPData-ins1496050-v1-Table_8.csv', delimiter=',', usec
```

In [30]:

```
#Definition of R_AA
def R_AA(pt,n, Delta):
    return (pt/(pt+Delta))**(n-1)

#Fitting using only p_T < 25 GeV/c
fp = 22
```

```
used_bounds = ([6.29, 0], [6.35, 25])
ini_par = [6.3, 5]

popt, pcov = curve_fit(R_AA, pt[fp:], Raa[fp:], ini_par, sigma = RaaStatErr[fp:], absolute

#Plot measurement
plt.figure(figsize = (10,7))
plt.xlabel('$p_T$ [GeV/c]', fontsize = 18)
plt.ylabel('$R_{AA}(p_T)$', fontsize = 18)
plt.errorbar(pt, Raa, yerr=RaaStatErr, fmt='o', color = "black", label = "CMS 5.02 TeV, 0-
# plt.xscale("log")

#Plot fitted function
plt.plot(pt[fp:], R_AA(pt[fp:],*popt), color = "red", label ="Model")

Delta, Delta_err = round(popt[1],1), round(np.sqrt(pcov[1,1]),1)
plt.text(0.7,0.85, str("$\Delta = ($" + str(Delta) +"$\pm$" + str(Delta_err) + ") GeV/c"),
plt.legend(loc = 2, fontsize = 18)
```

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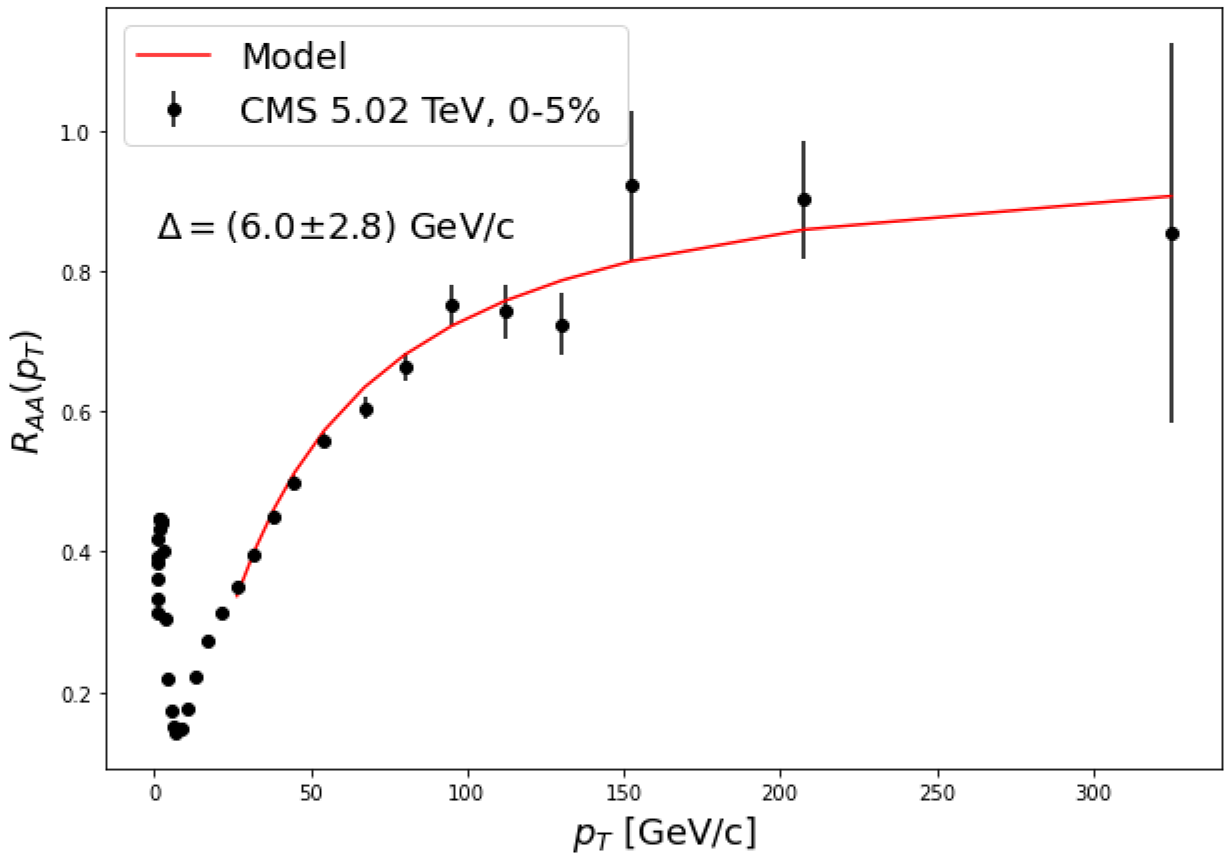
Out[30]: <matplotlib.legend.Legend at 0x256cfc00c40>
```



```
In [ ]:
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