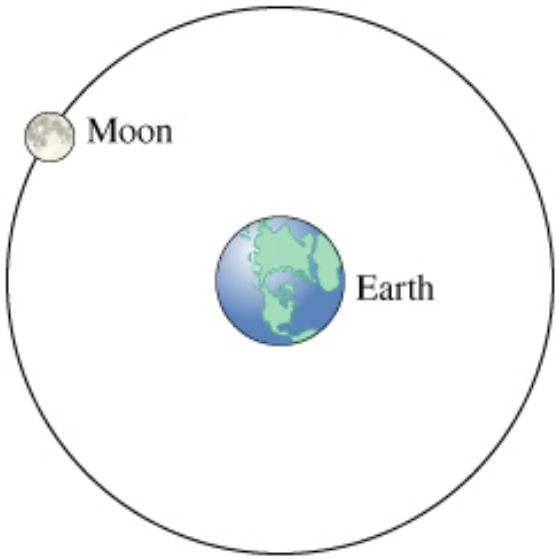
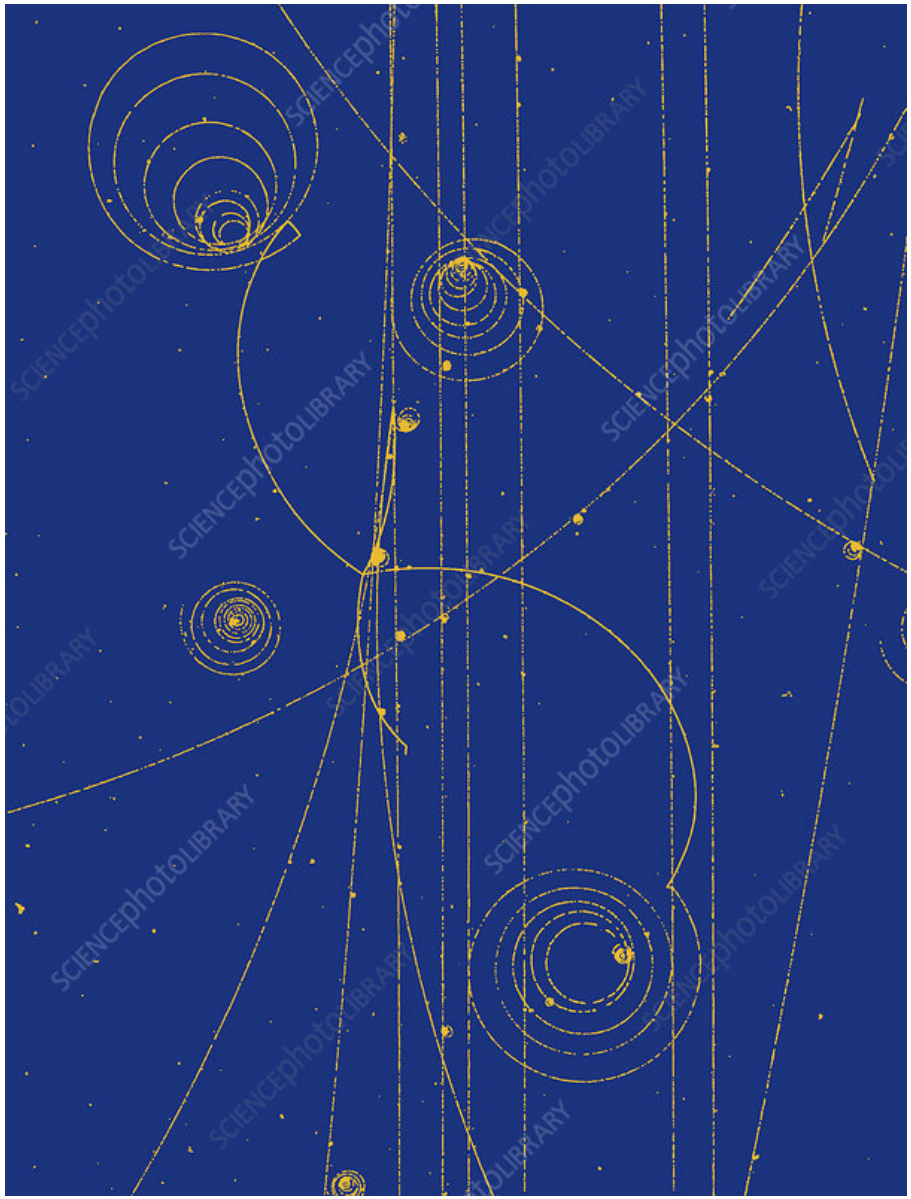
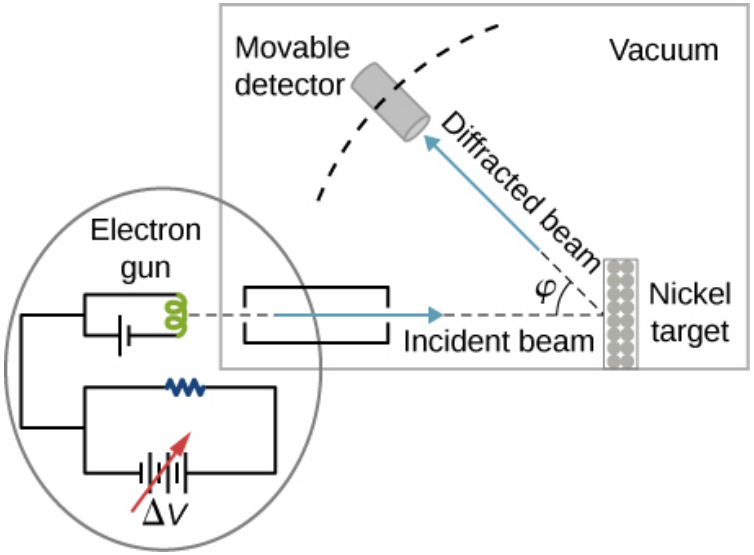
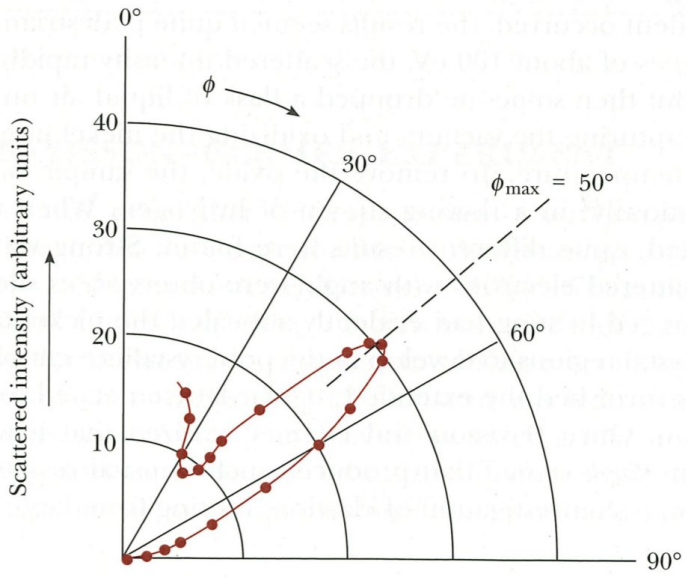
What's a Particle?





Particles transfer energy to other particles by collisions - their trajectories are altered by the forces acting among them. The first figure shows the setup of Davisson and Germer to make an electron beam with $E_{beam} = 54$ eV, collide it elastically with a nickel target, and measure the angular distribution. The result is shown in the second figure. The scattered intensity is proportional to the distance of the point from the origin. What is the intensity pattern for elastically scattered electrons? Use the peak at $\phi = 50^\circ$ to extract information about the beam-target interaction.





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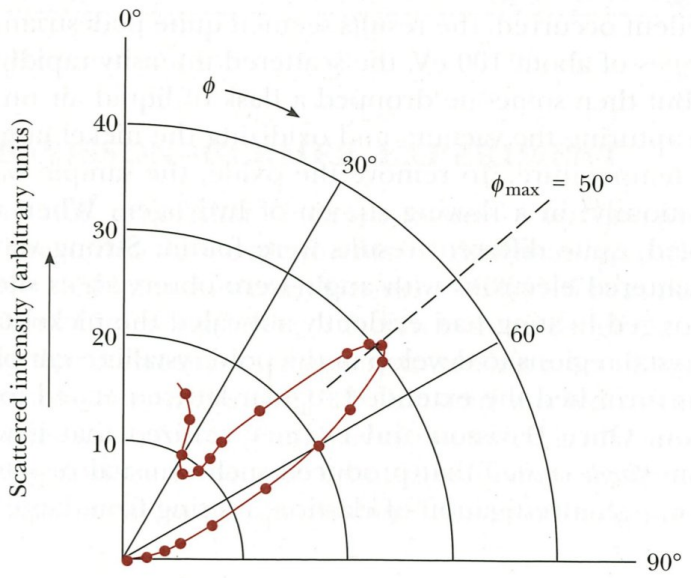
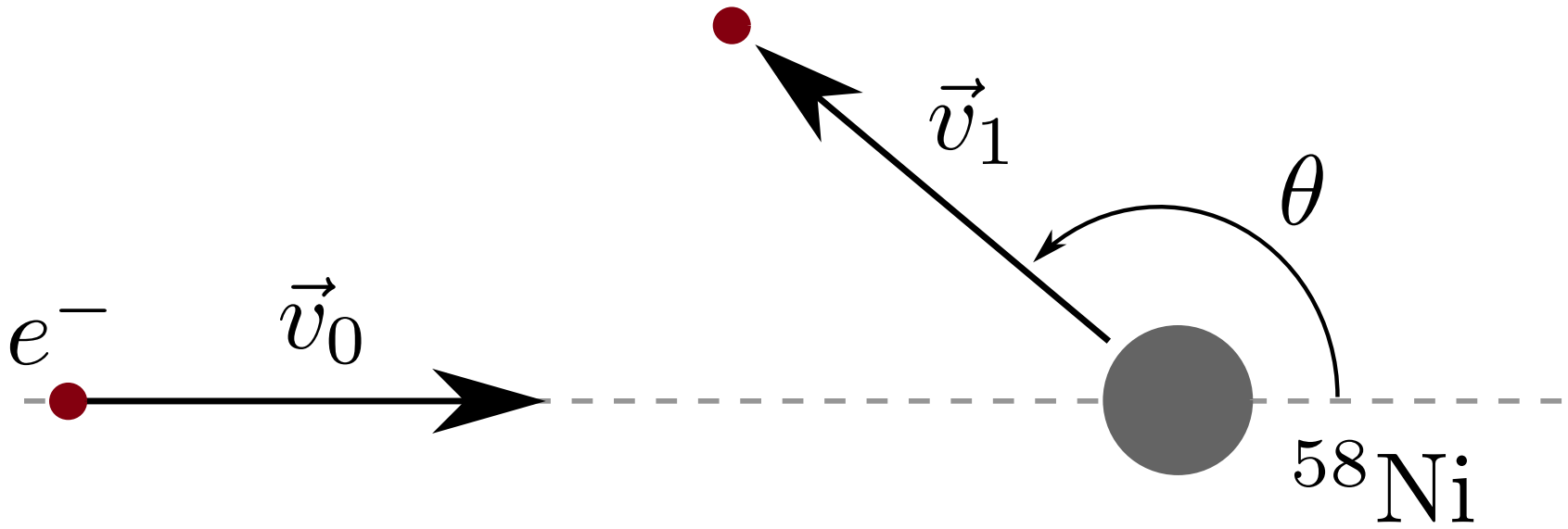
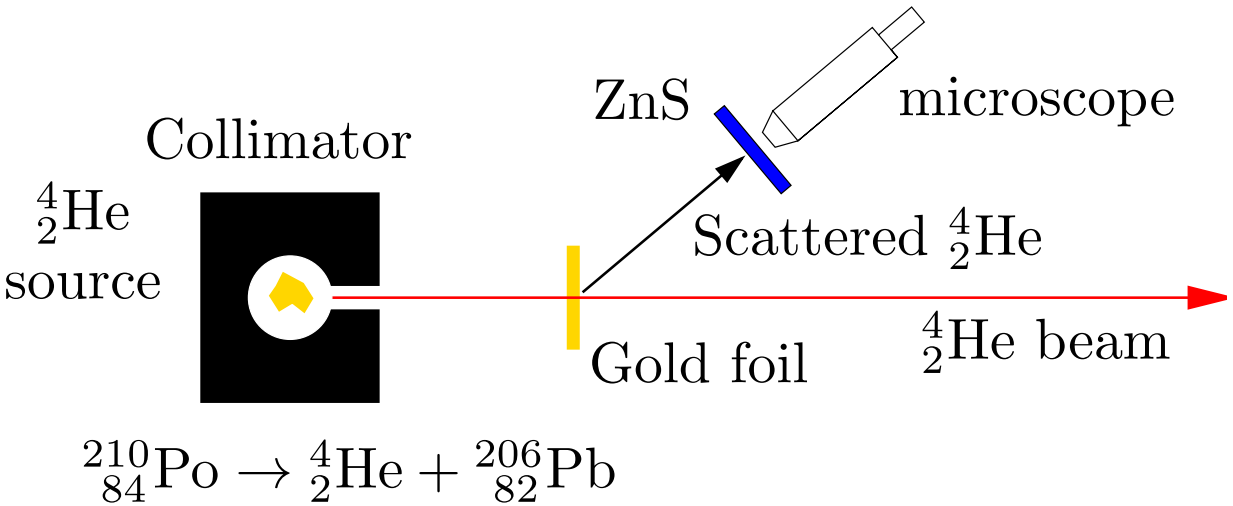


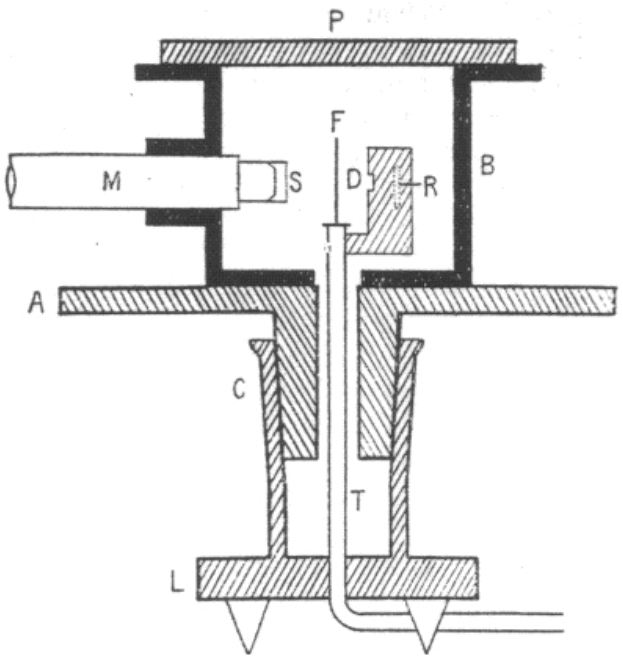
Consider the elastic collision of an electron of energy $E_{beam} = 54\ \mathrm{eV}$ with a $^{58}\mathrm{Ni}$ target. If the scattered electron is detected at an angle $\theta_e = 130°$, what is its energy?



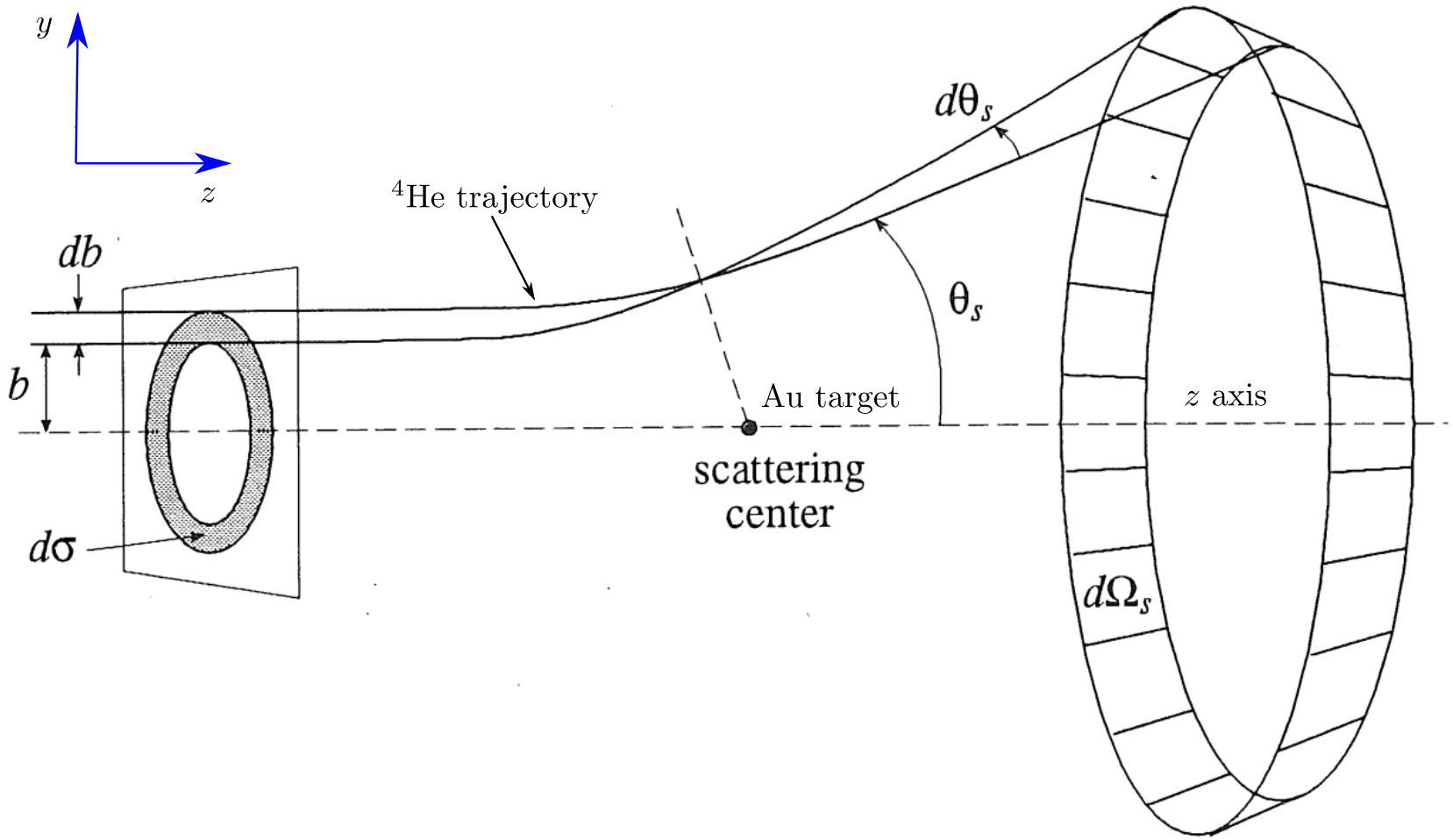
Ernest Rutherford discovered the atomic nucleus in 1913 with the apparatus shown below. What is the distance of closest approach of a $^{4}\mathrm{He}$ nucleus to the $^{197}_{79}\mathrm{Au}$ target nucleus if only the Coulomb force is active? Is the Coulomb force the only one active? The energy of the $^{4}\mathrm{He}$ emitted by the $^{210}_{84}\mathrm{Po}$ to make the beam is $\mathrm{E}(^{4}\mathrm{He}) = 5.407\ \mathrm{MeV}$. How much does the differential cross section change from 90° to 180°?



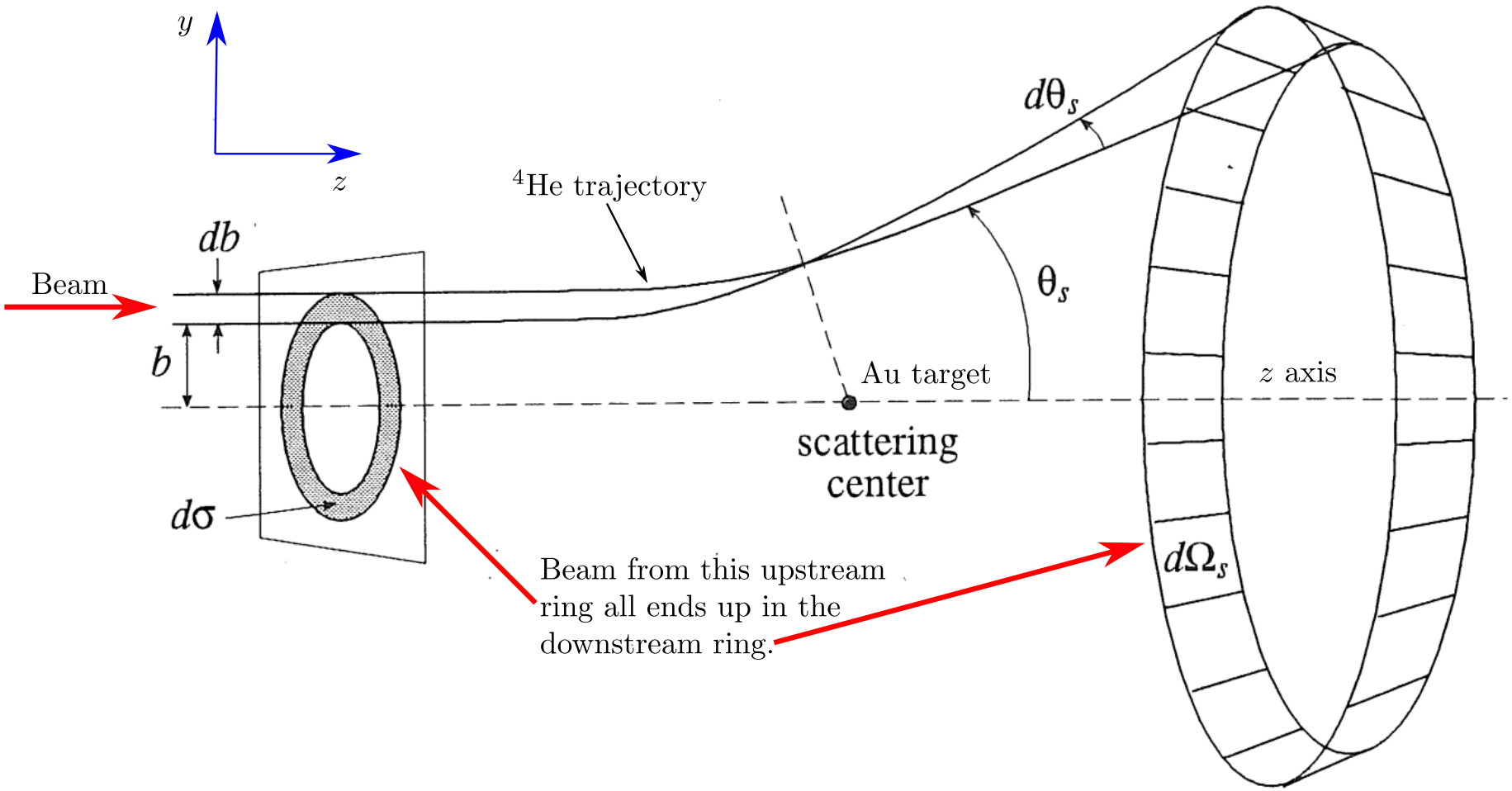
$$^{210}_{84}\mathrm{Po} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{206}_{82}\mathrm{Pb}$$



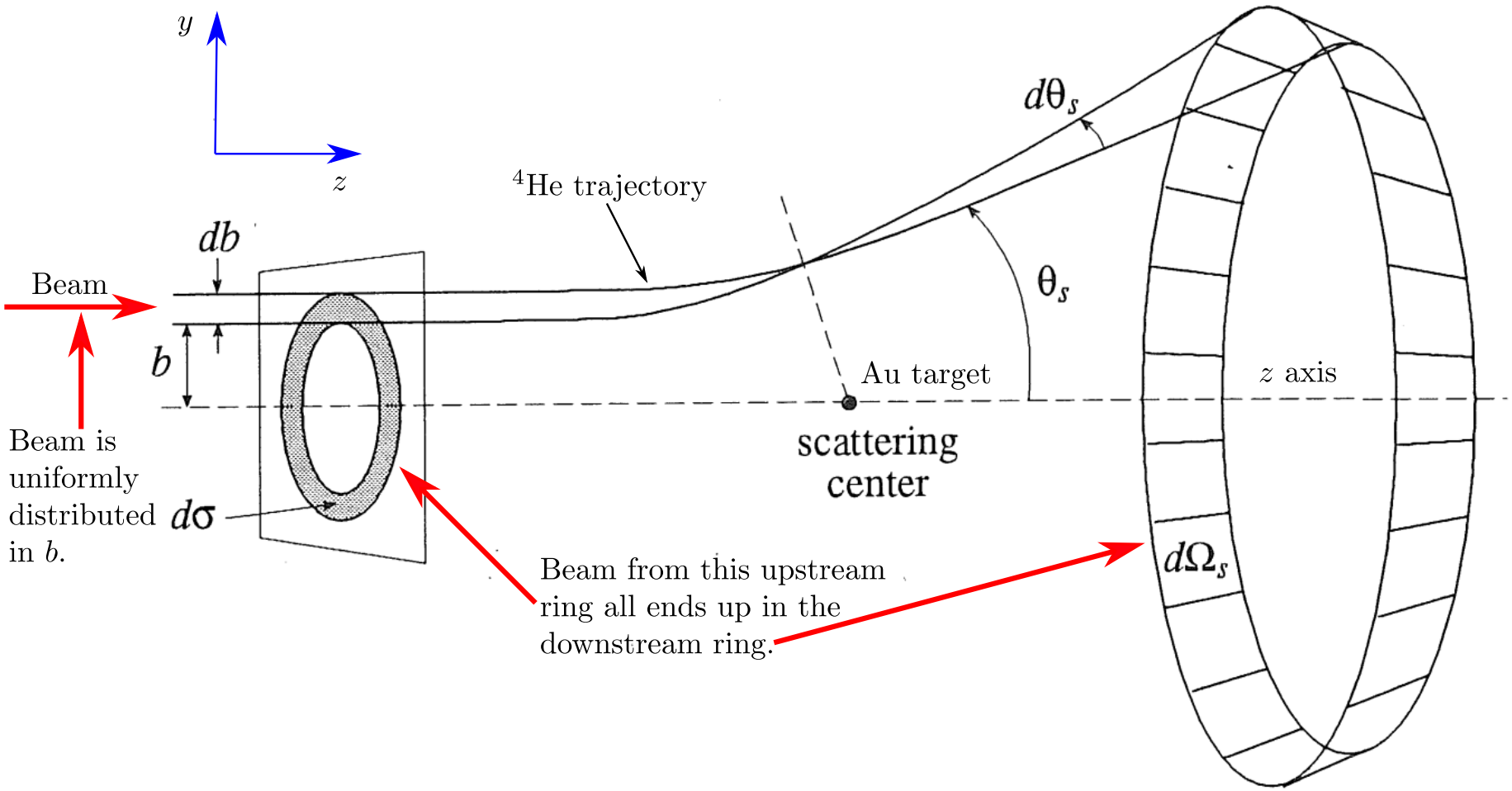
The Differential Cross Section - 2



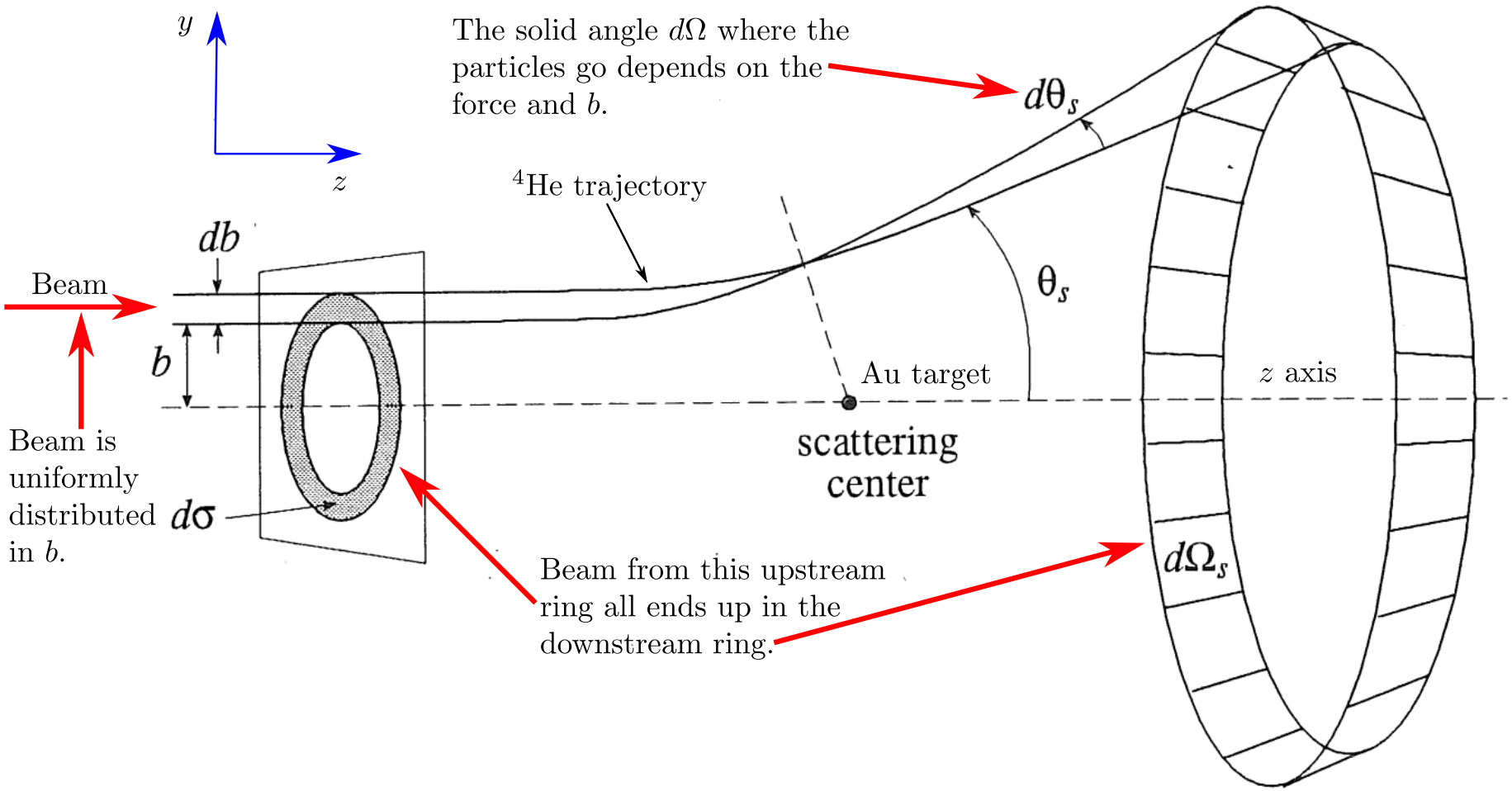
The Differential Cross Section - 3



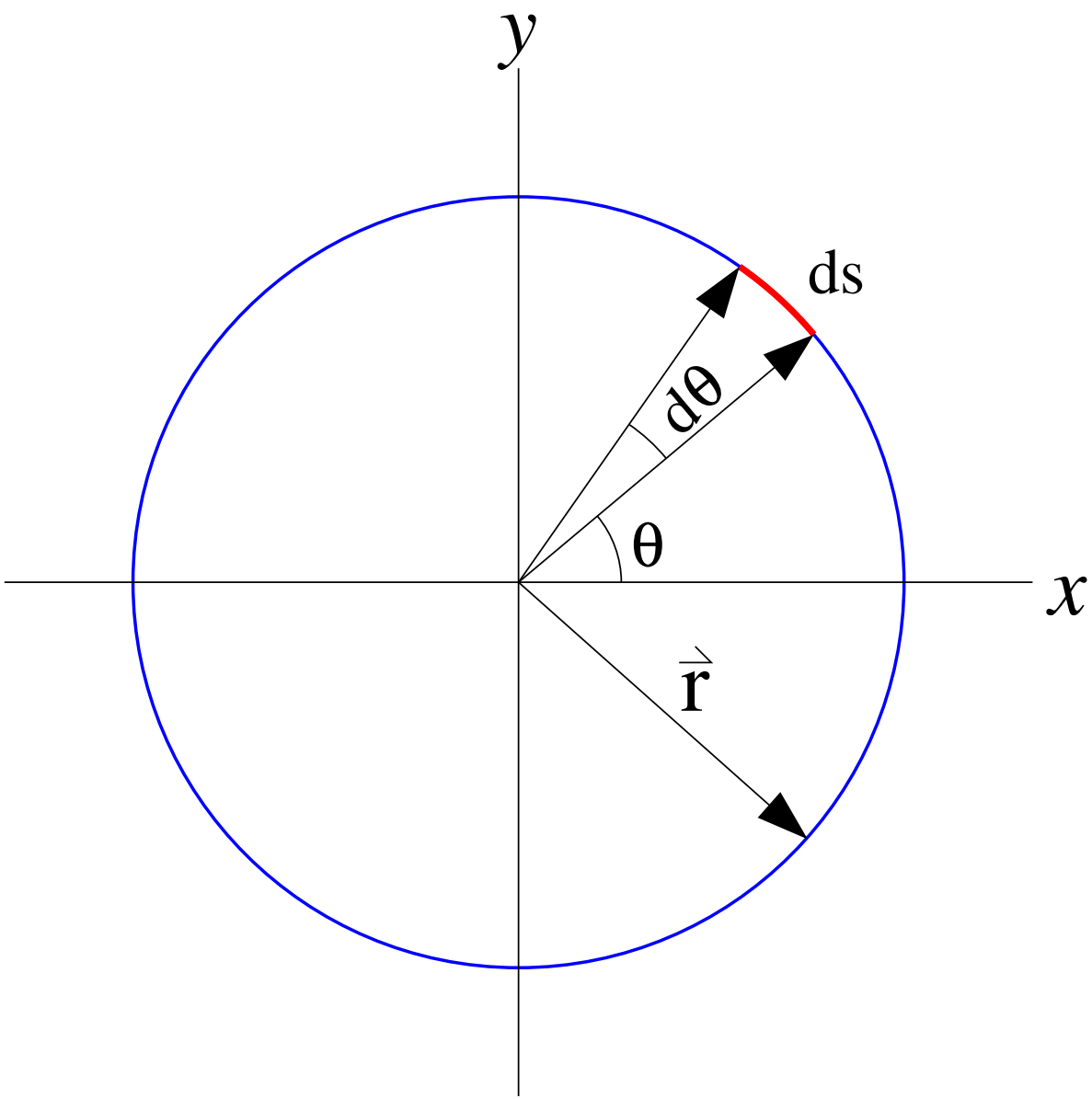
The Differential Cross Section - 4



The Differential Cross Section - 5

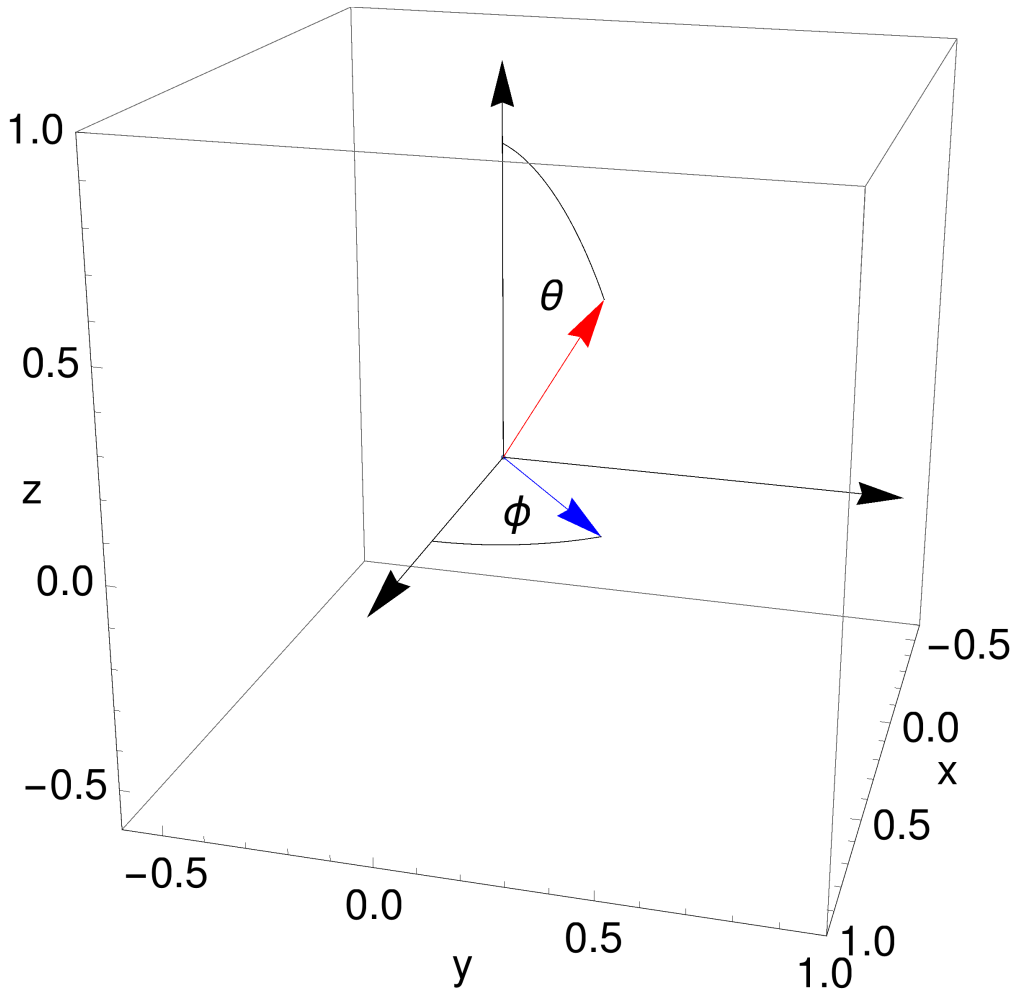


What is an Angle? 10

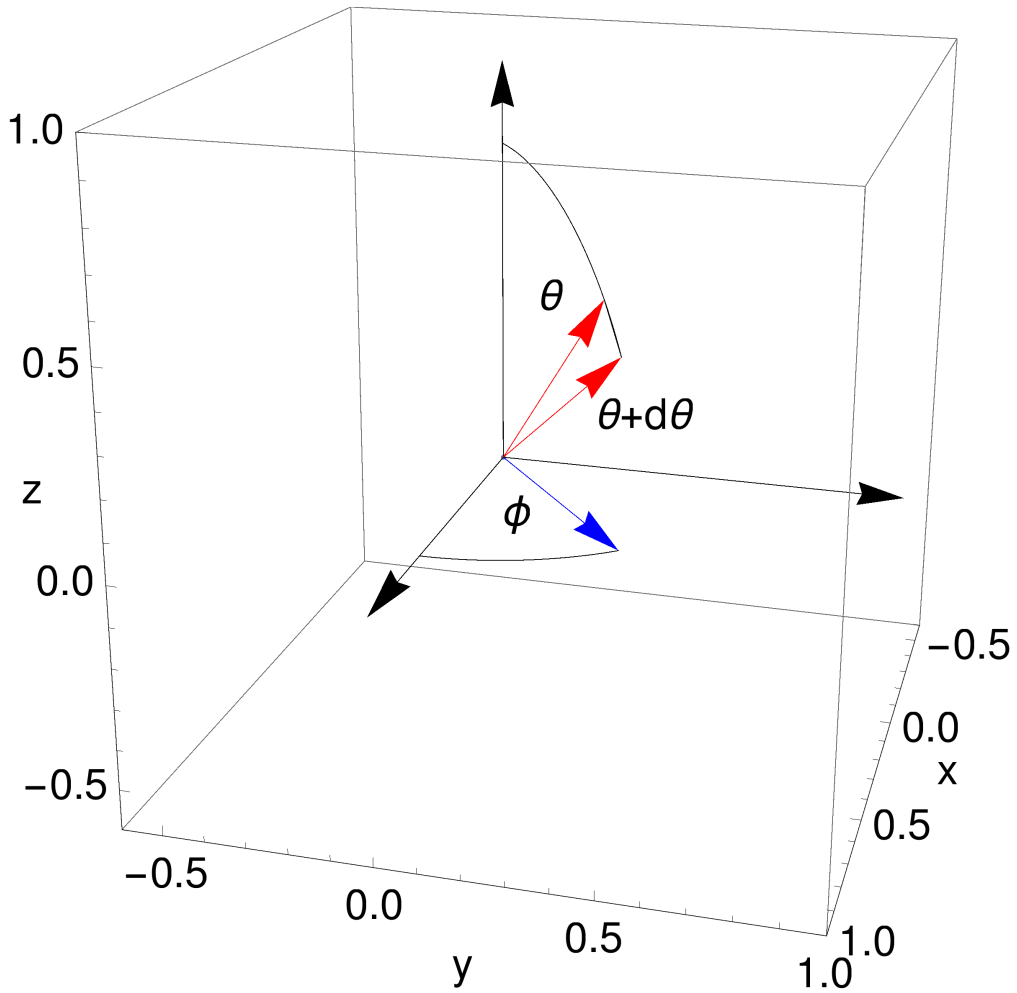


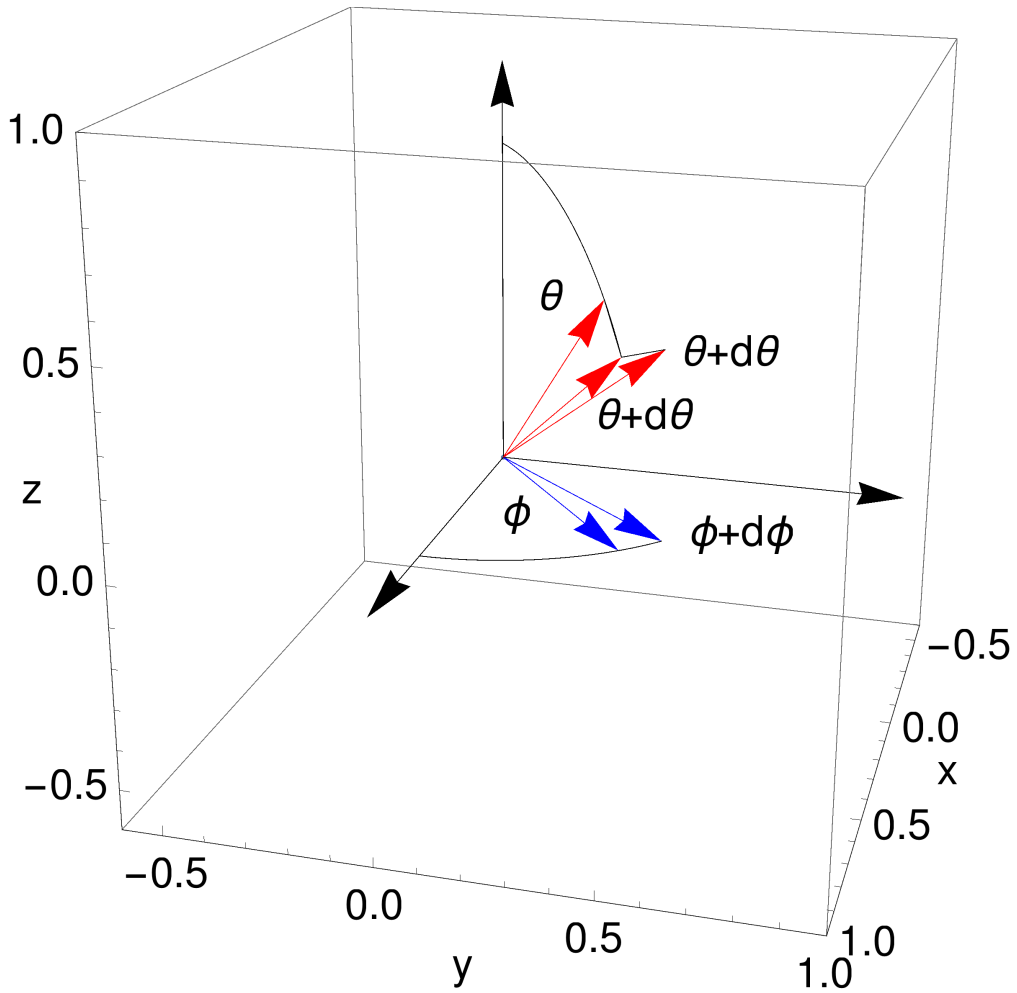
$$d\theta = \frac{ds}{|\vec{r}|}$$

Solid Angle

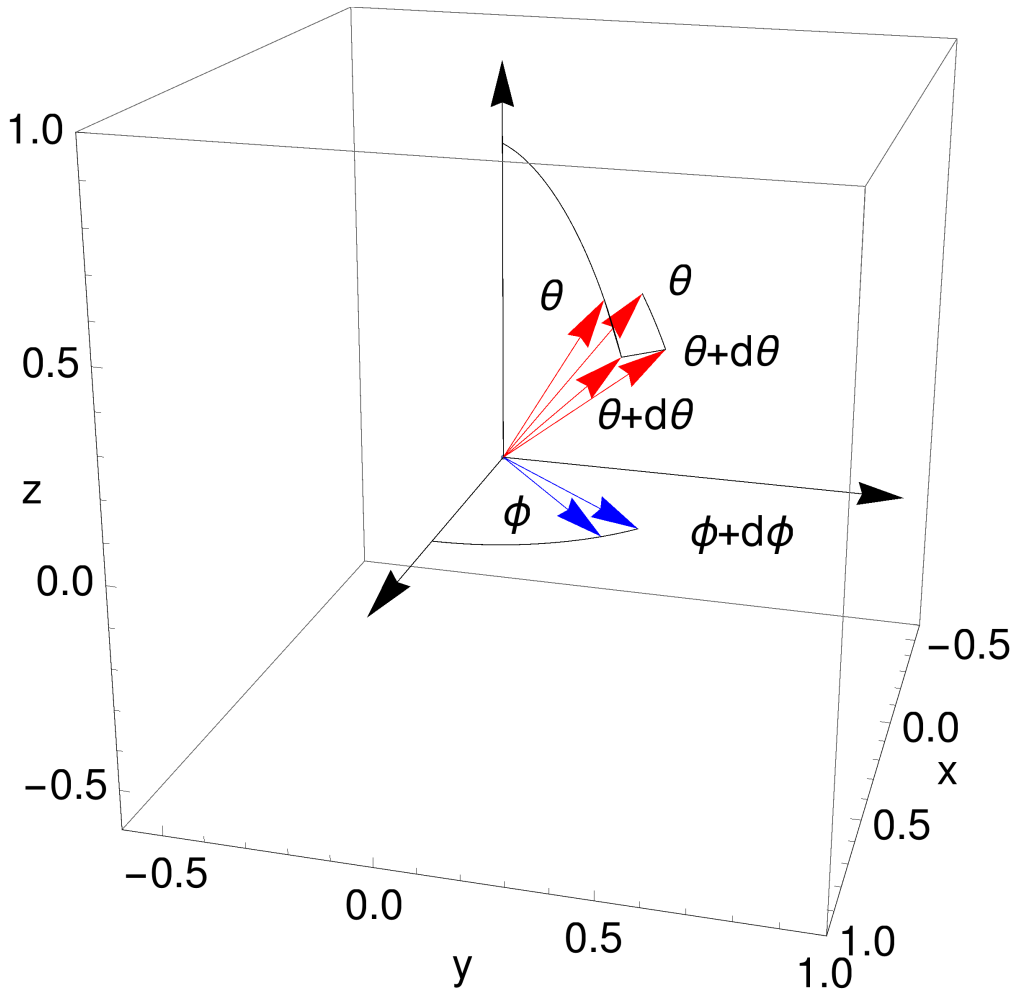


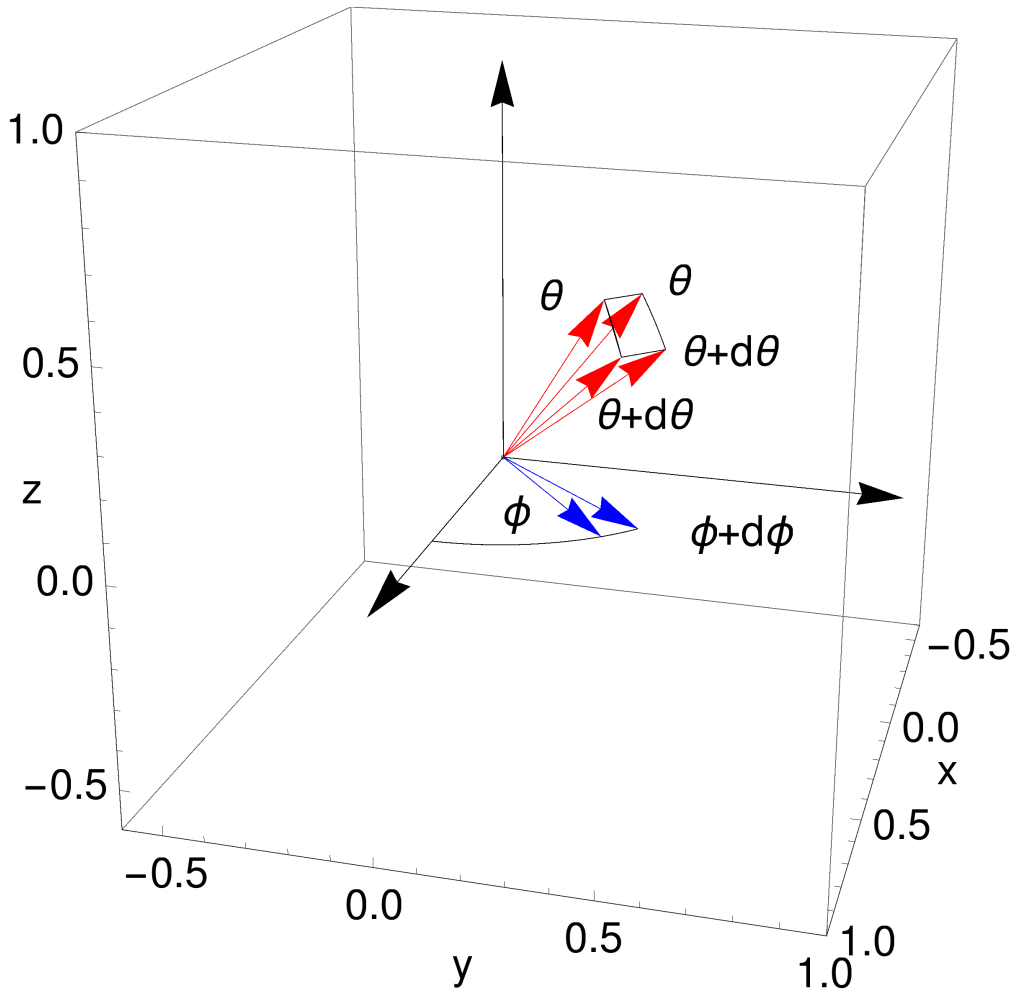
Solid Angle

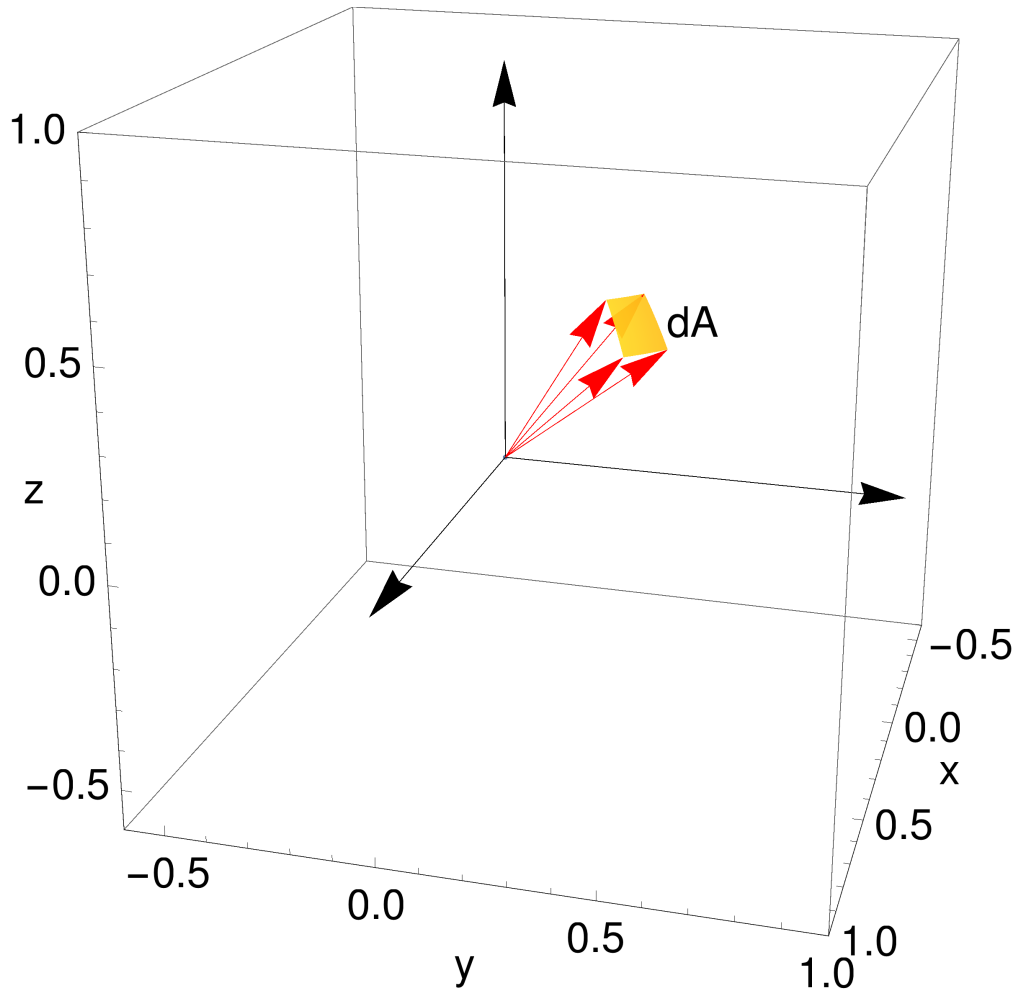


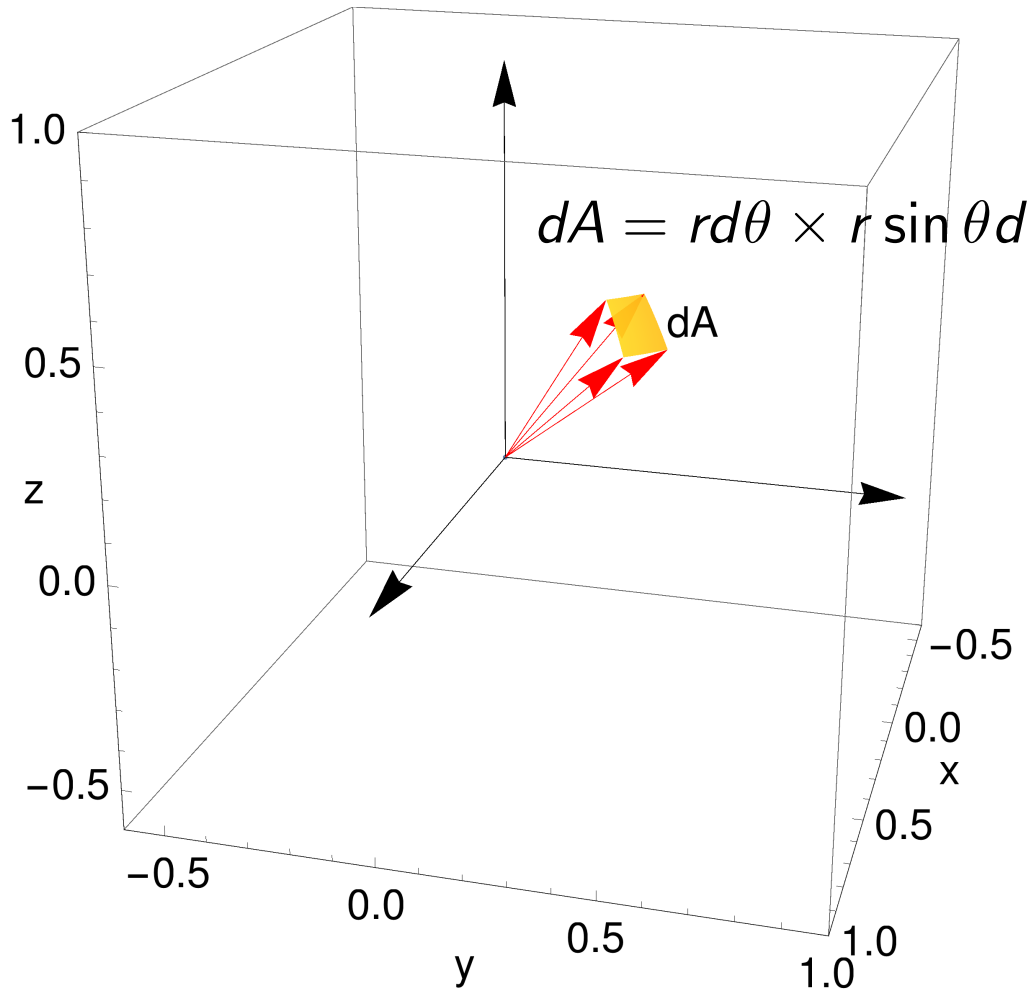

1.0
0.5
z
0.0
−0.5
−0.5
0.0
0.5
1.0
y
−0.5
0.0
0.5
1.0
x
θ
θ+dθ
θ+dθ
ϕ
ϕ+dϕ

Solid Angle

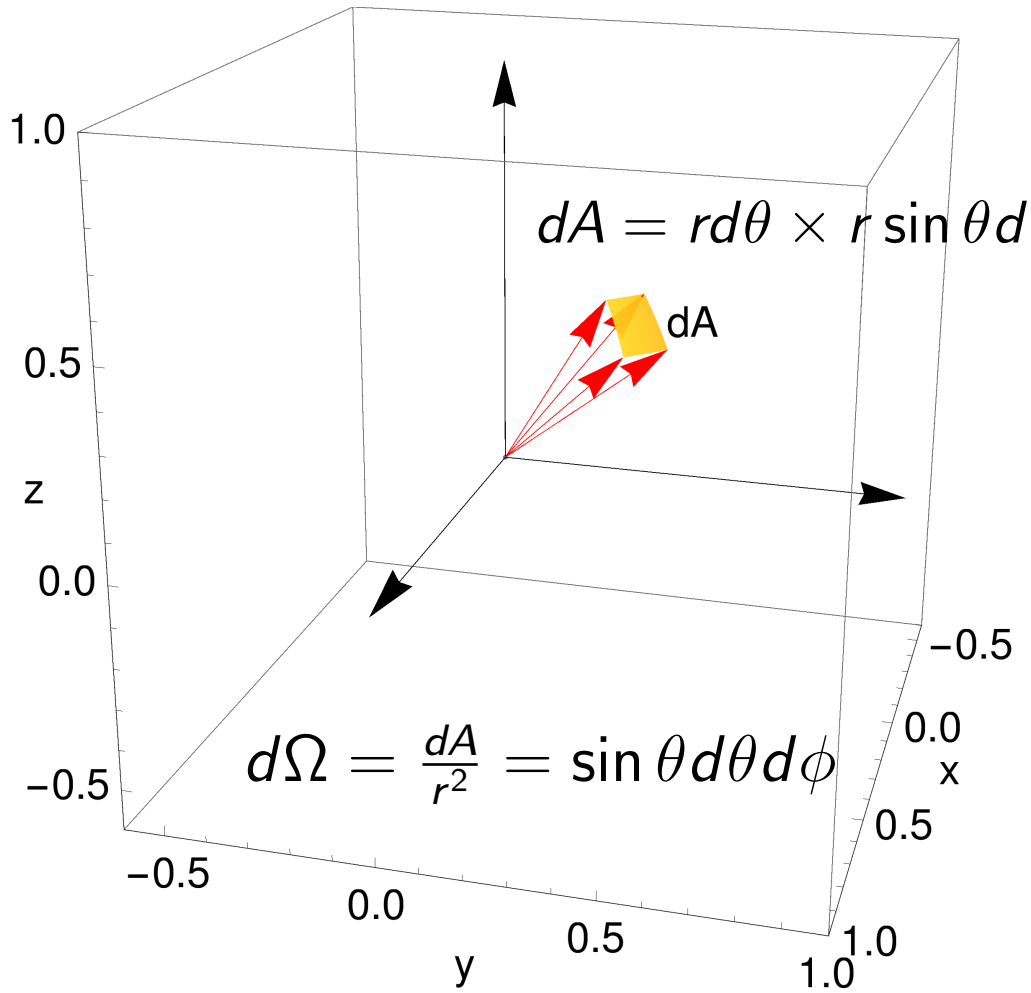



1.0
0.5
z
0.0
−0.5
−0.5
0.0
0.5
1.0
y
−0.5
0.0
0.5
1.0
x
θ
θ
θ+dθ
θ+dθ
ϕ
ϕ+dϕ

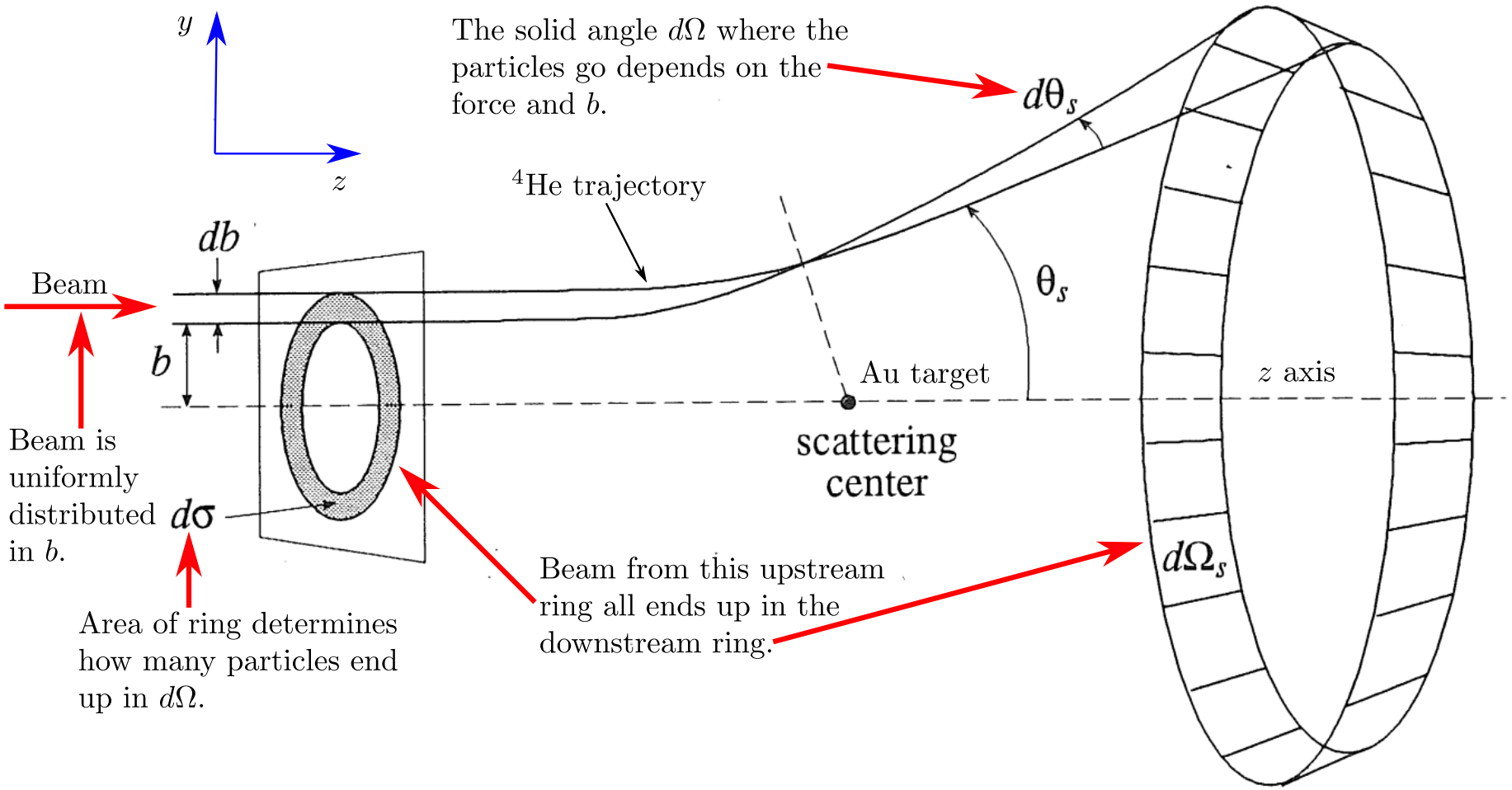

1.0
0.5
z
0.0
−0.5
−0.5
0.0
0.5
1.0
y
−0.5
0.0
0.5
1.0
x
dA



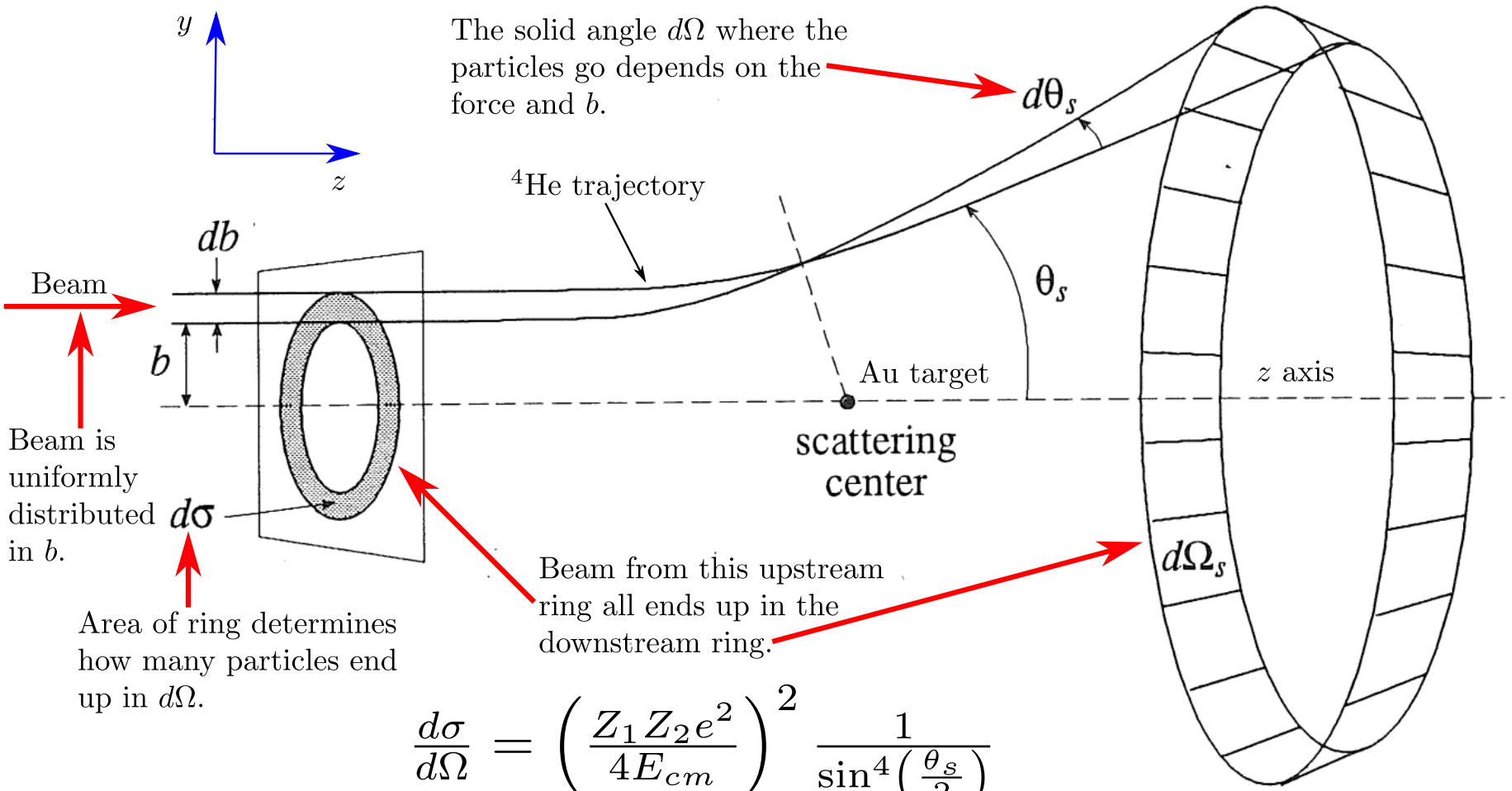
$$dA = rd\theta \times r\sin\theta d\phi = r^2 \sin\theta d\theta d\phi$$


$dA = rd\theta \times r\sin\theta d\phi = r^2 \sin\theta d\theta d\phi$
dA
$d\Omega = \frac{dA}{r^2} = \sin\theta d\theta d\phi$
1.0
0.5
z
0.0
−0.5
−0.5
0.0
0.5
1.0
y
−0.5
0.0
0.5
1.0
x

The Differential Cross Section - 6

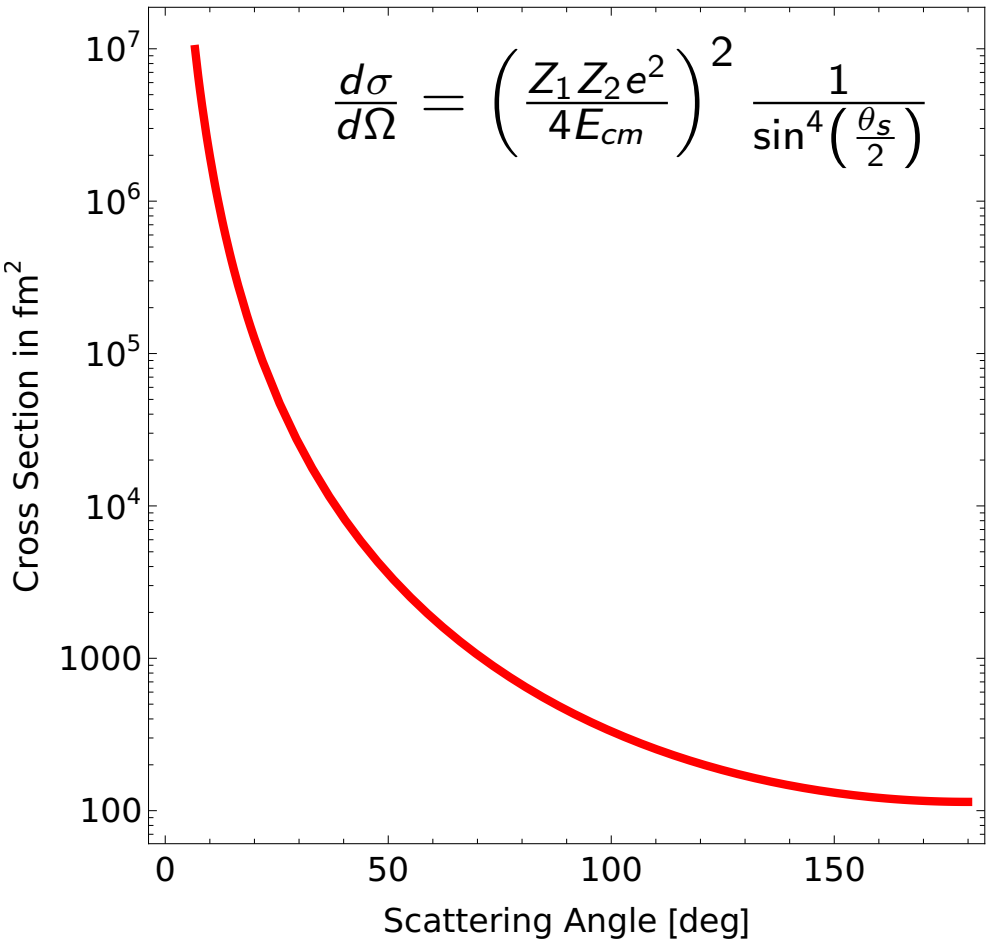


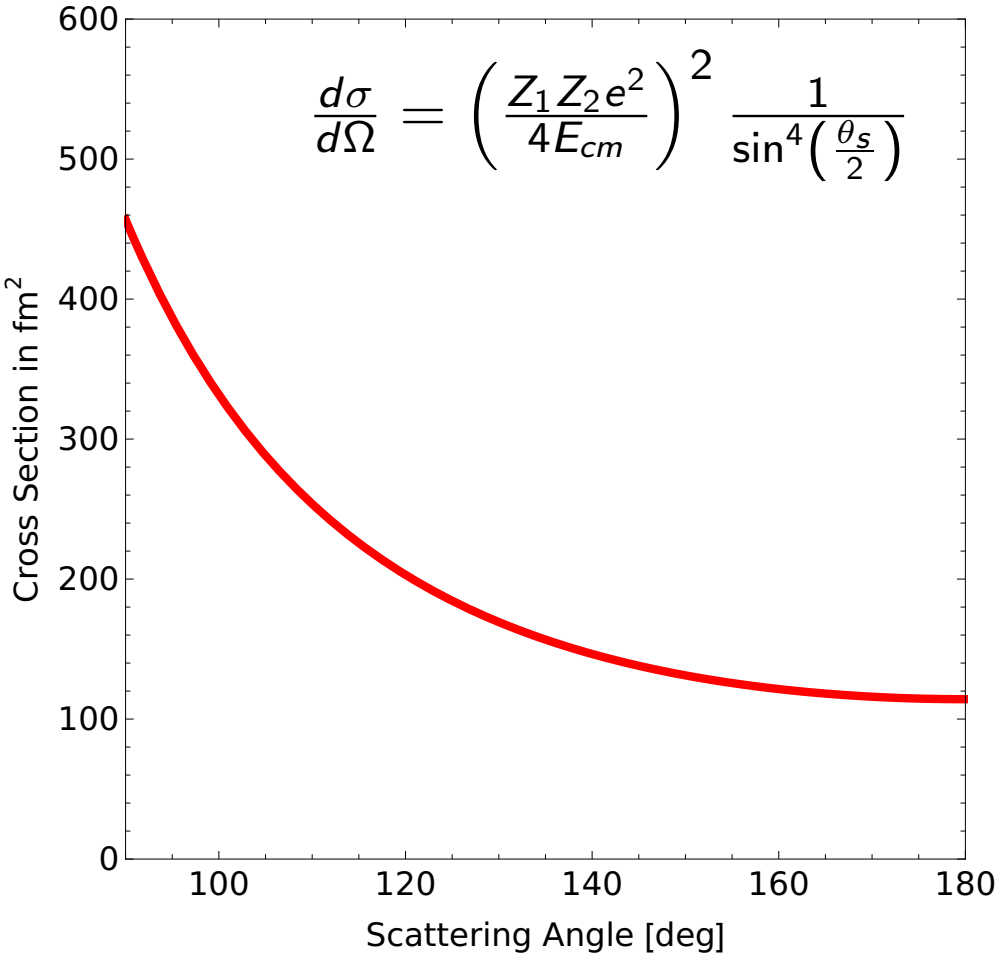
The Differential Cross Section - 7



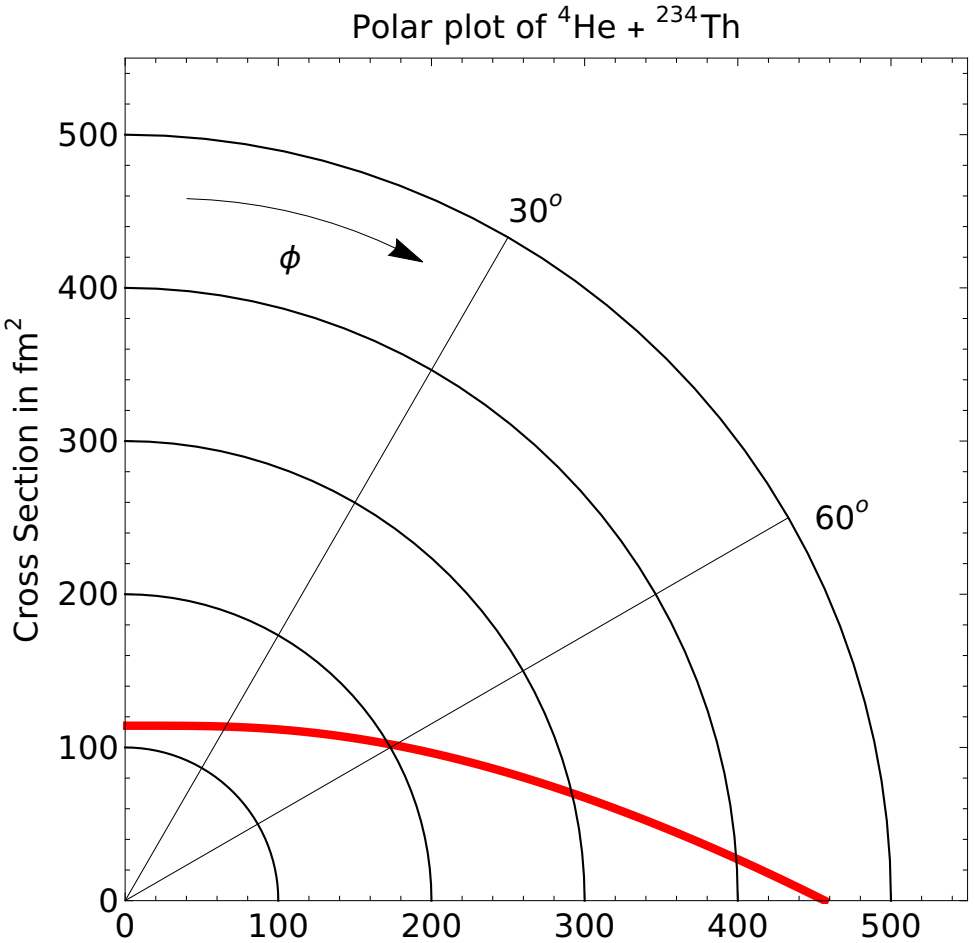
$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E_{cm}}\right)^2 \frac{1}{\sin^4\left(\frac{\theta_s}{2}\right)}$$

The Predicted Differential Cross Section - 1

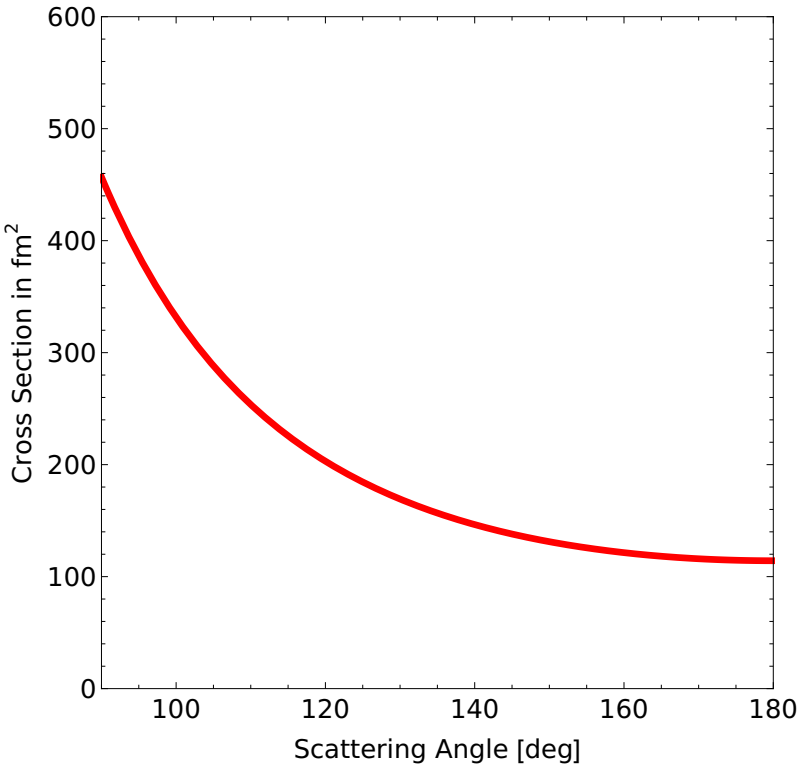


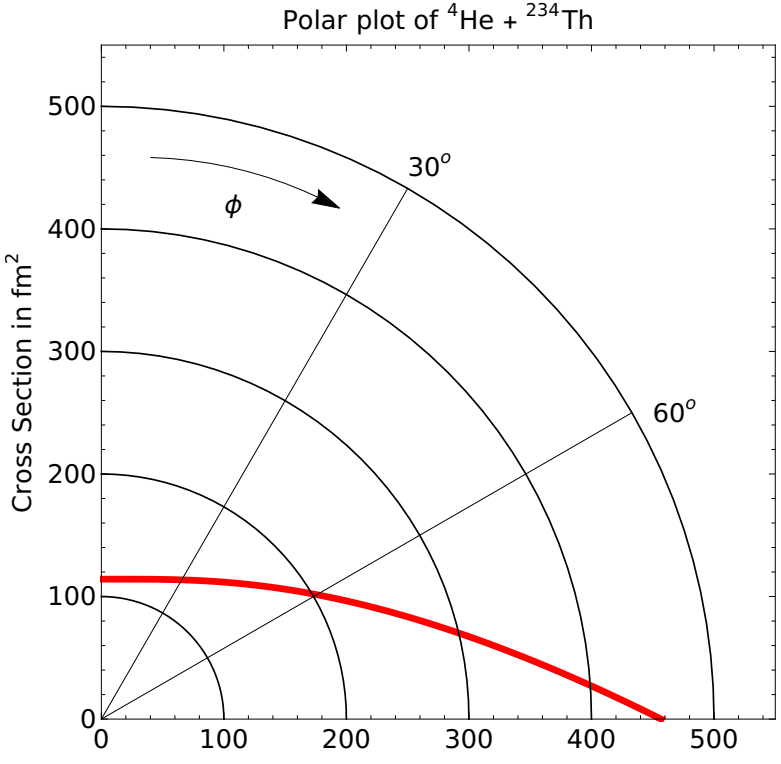

$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E_{cm}}\right)^2 \frac{1}{\sin^4\left(\frac{\theta_s}{2}\right)}$
Cross Section in fm^2
600
500
400
300
200
100
0
100
120
140
160
180
Scattering Angle [deg]

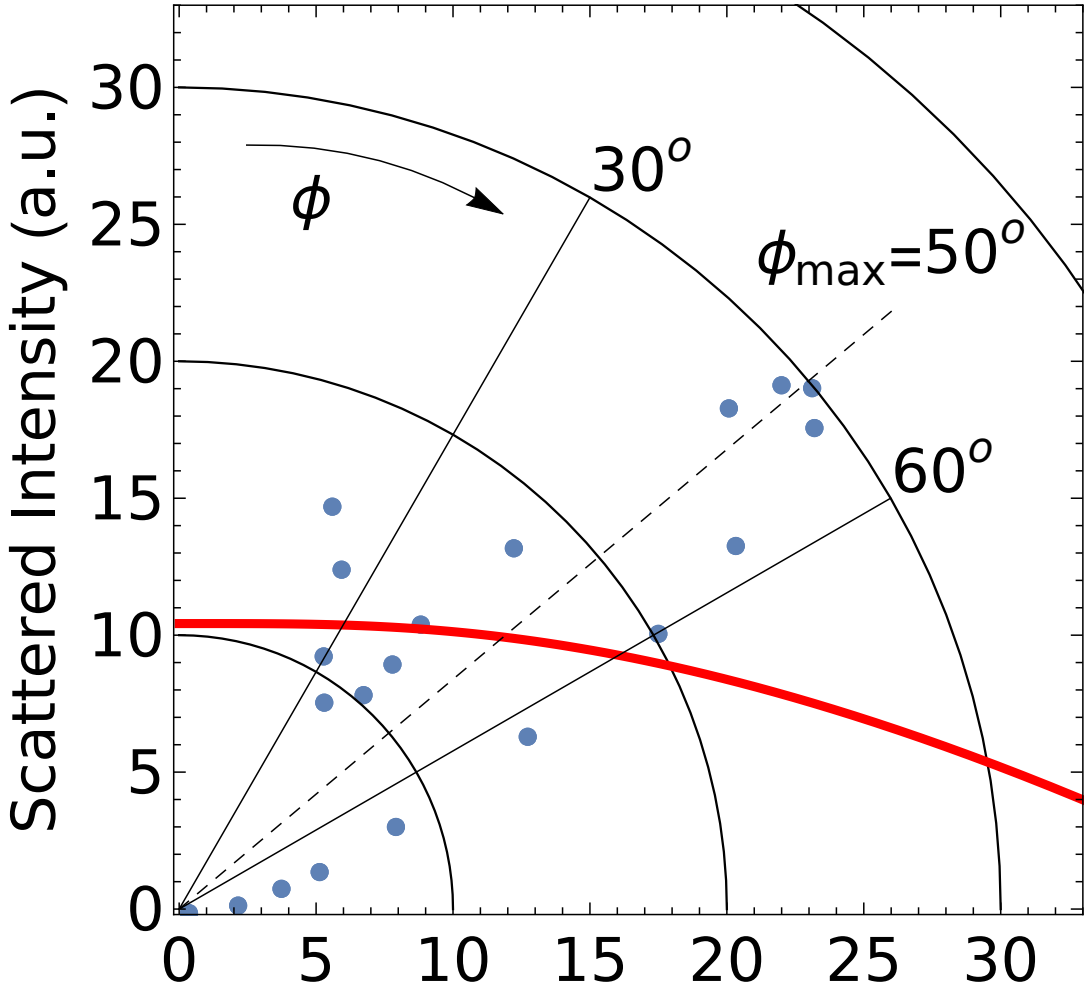
Polar Plot of Predicted Differential Cross Section 24



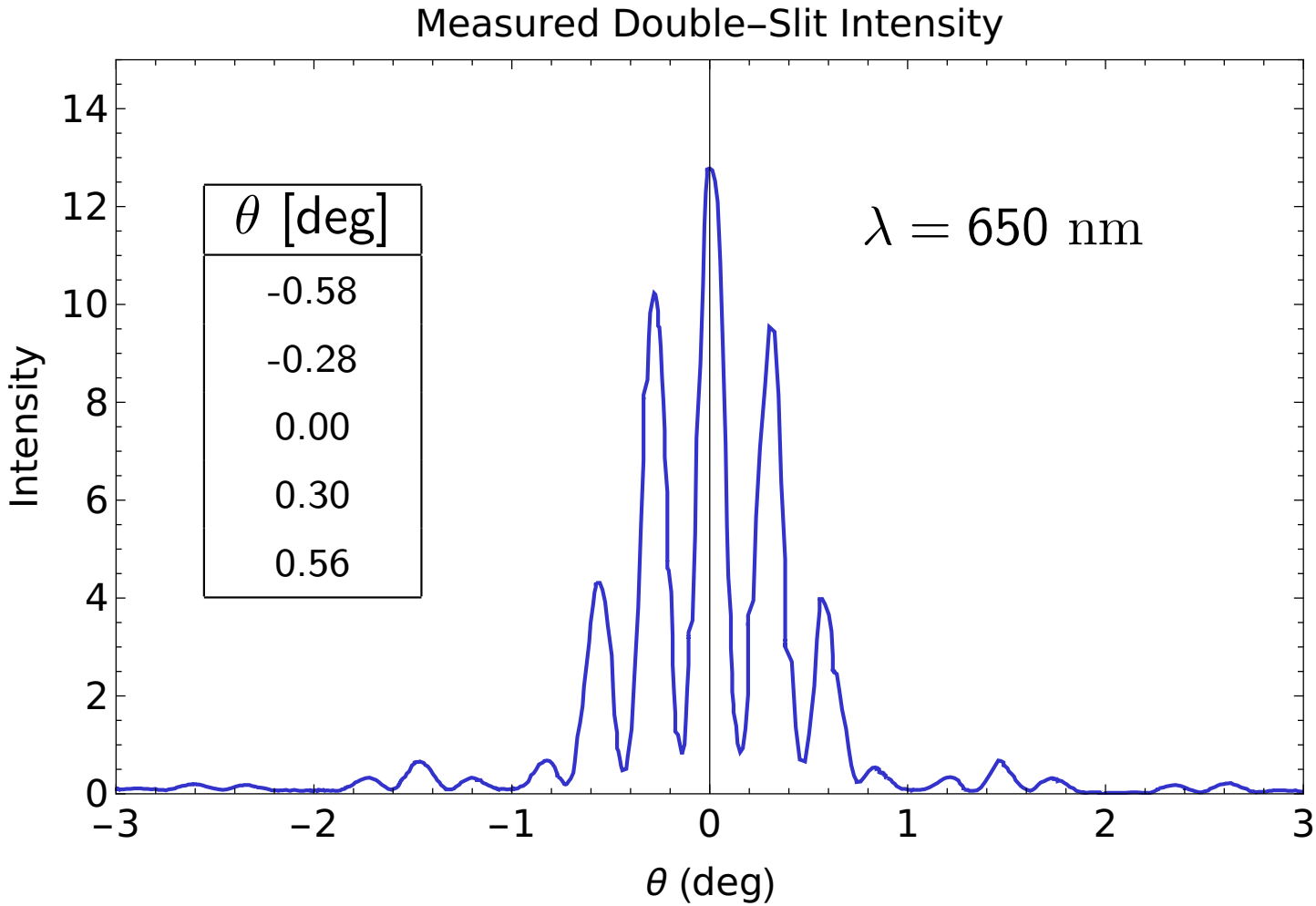
$$\frac{d\sigma}{d\Omega} = \left(\frac{Z_1 Z_2 e^2}{4E_{cm}}\right)^2 \frac{1}{\sin^4\left(\frac{\theta_s}{2}\right)}$$

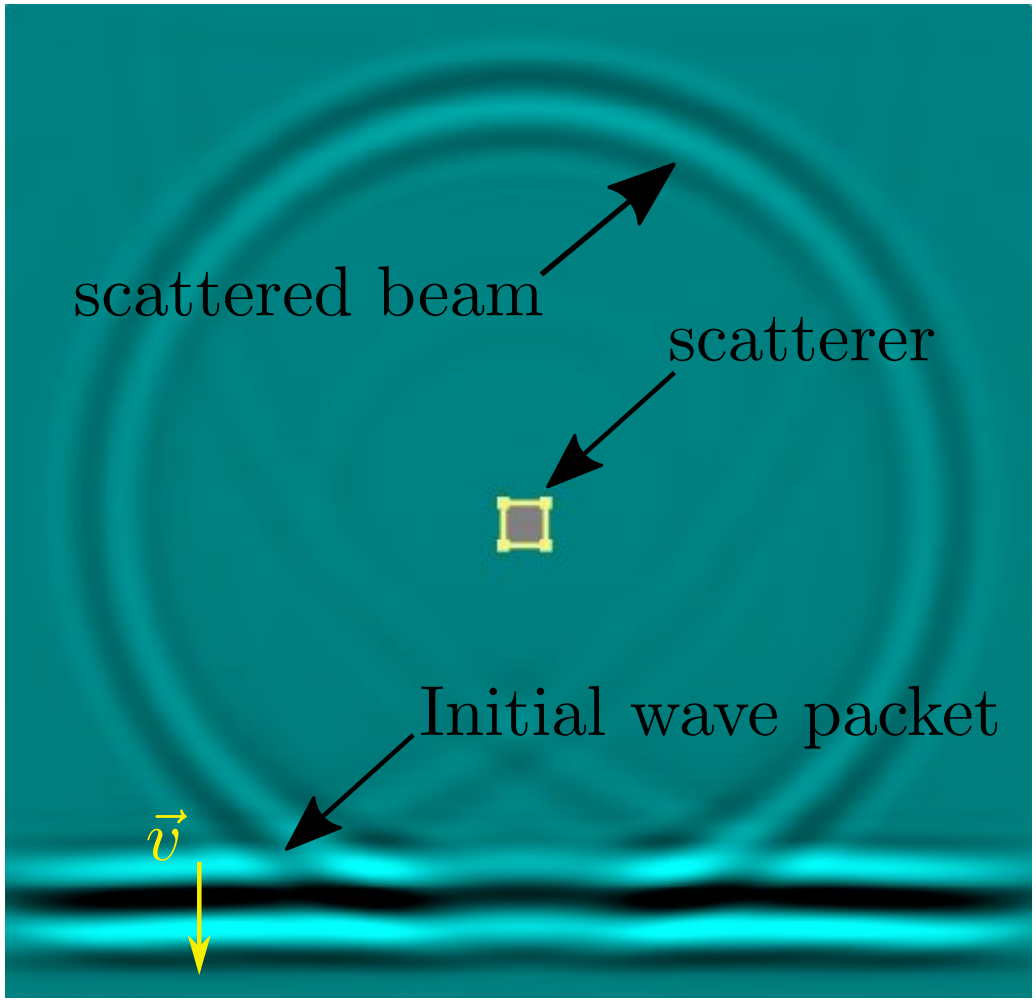





Scattered Intensity (a.u.)
0
5
10
15
20
25
30
ϕ
30^o
$\phi_{max}=50^o$
60^o

A double slit interference pattern from Physics 132 is shown below. The angular distance of the closest bright spots to the central peak is shown in the inset.





The video is here. The simulations are here (use Scattering 1) and here (use Scattering example).

1. Maxwell showed that EM waves transmit energy and momentum.

$$p = \frac{\textit{energy absorbed}}{c} = \frac{E}{c}$$

2. Planck used the quantum hypothesis first to explain blackbody light emission.

$$E = hf$$

3. Louis de Broglie proposed in 1924 that electrons have wave-like properties.

$$p = \frac{E}{c} = \frac{hf}{c} = \frac{h}{\lambda}$$

He was a grad student at the University of Paris at the time.

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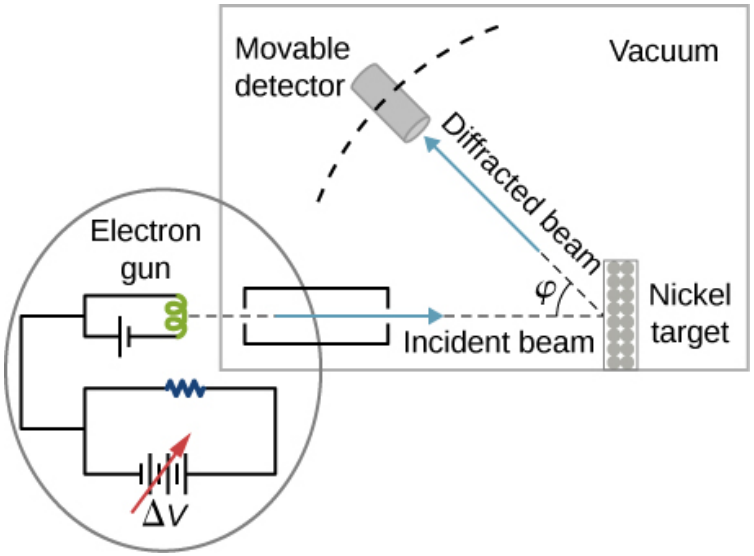
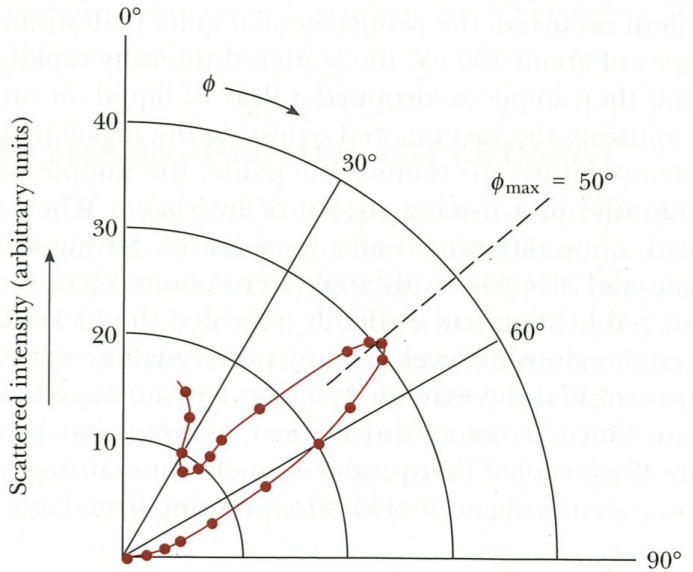
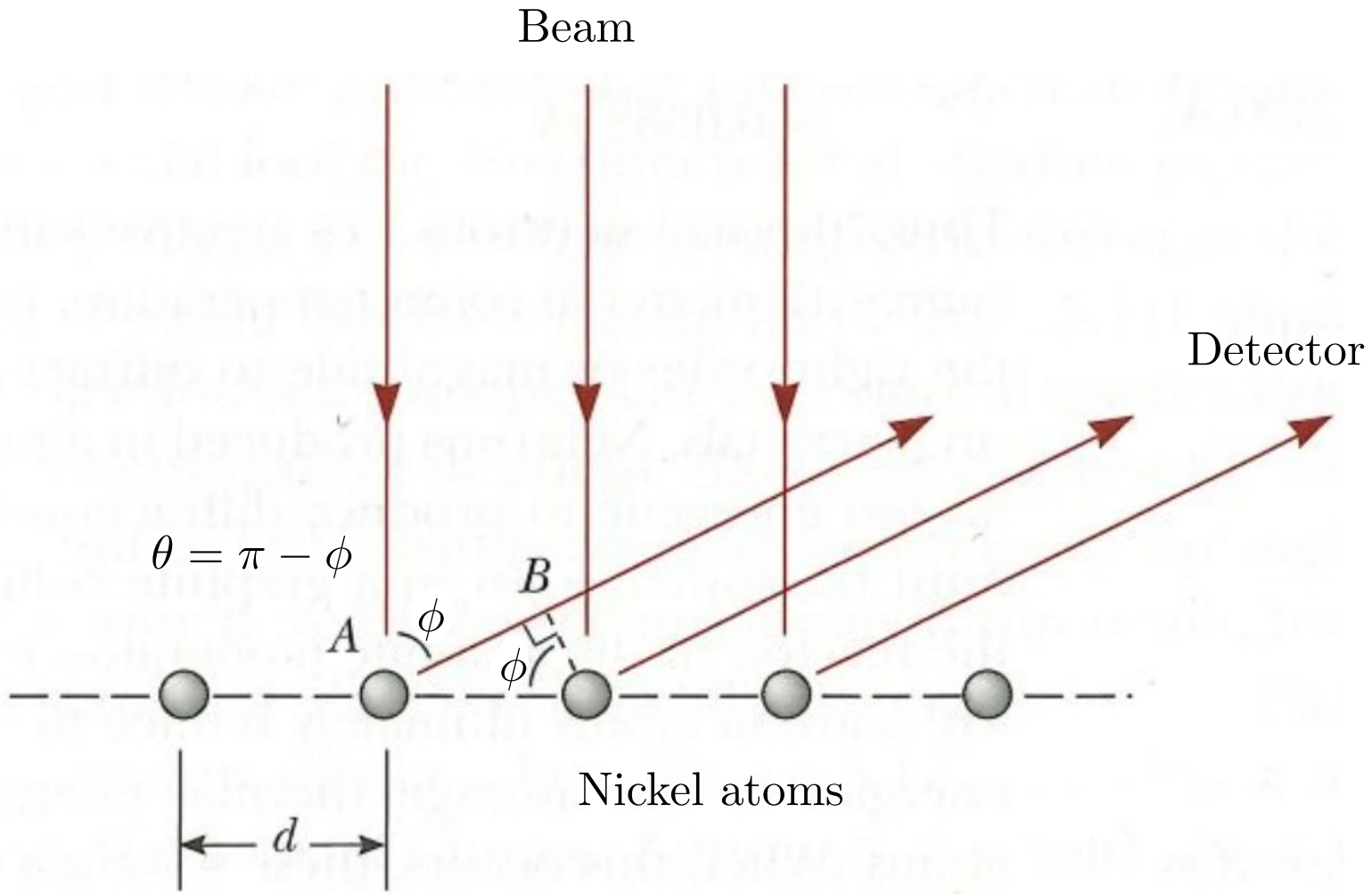




Electron Waves Hitting Nickel



The video is here. The simulations are here (use Scattering 1) and here (use Scattering example) .

Comparing Angular Distributions