Few-body polarimetry using elastic scattering

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ANALYZING POWER for POLARIZED LIGHT IONS

M and Z: mass and charge of ion with magnetic moment μ

μ: is in units of nuclear magnetons with proton mass m

A_{N}: the analyzing power for an incident polarized ion is

2 Im (non-flip* × spin-flip) / (non-flip^{2} + spin-flip^{2})

amplitudes here may be re-scaled by a complex number

non-flip: $i + \rho - \frac{t_C}{t} e^{i\,\delta_C - (b_h - b_e)\,t}$

$\frac{m}{\sqrt{-t}}$ spin-flip: $i\,I + R - \frac{t_C}{2t} \left(\frac{\mu}{Z} - \frac{m}{M} \right) e^{i\delta_C - (b_h - b_m)t}$

EM and hadronic equal at: $-t_C = \frac{4hc\, Z\,\tilde{Z}}{137\,\sigma_{\mathrm{tot}}} \approx \frac{Z\,\tilde{Z}}{14\,\sigma_{\mathrm{tot}}}\ (\mathrm{GeV}/c)^2$

For $0.001 < -t < 0.01$ Coulomb phase and slope effects: change in ρ

ANALYZING POWER AT LOW MOMENTUM TRANSFER

The analyzing power for an incident polarized hadron is approximately

$$\frac{m}{\sqrt{-t}}\,A_{\rm N} \;=\; \frac{\left(\frac{\mu}{Z}-\frac{m}{M}-2I\right)\frac{t_C}{t}-2R+2\varrho I}{\frac{t_C^2}{t^2}-2(\varrho+\delta_C)\frac{t_C}{t}+1+\rho^2+R^2+I^2}$$

Further terms are discussed in Poblaguev et al., PRL 123 (2019) 16, 162001

The spin $\frac{\mu}{m}$ and charge $\frac{Z}{M}$ terms arise from Gordon decompositiion (1928)

The A_N peak involves the hadronic spin-flip term I which needs to be known

Multiplying by the square of $x=\frac{t}{t_C}$, the analyzing power is approximately

$$\frac{m}{\sqrt{-t_C}}\,\frac{A_{\rm N}}{\sqrt{x}} \;=\; \frac{\left(\frac{\mu}{Z}-\frac{m}{M}-2I\right)x-2R\,x^2}{1-2(\varrho+\delta_C)\,x+x^2}$$

At $0.001<-t<0.01$ squared hadronic spin-flip terms are relatively small

Ignoring R, ϱ, and δ_C enables an immediate profile of the analyzing power

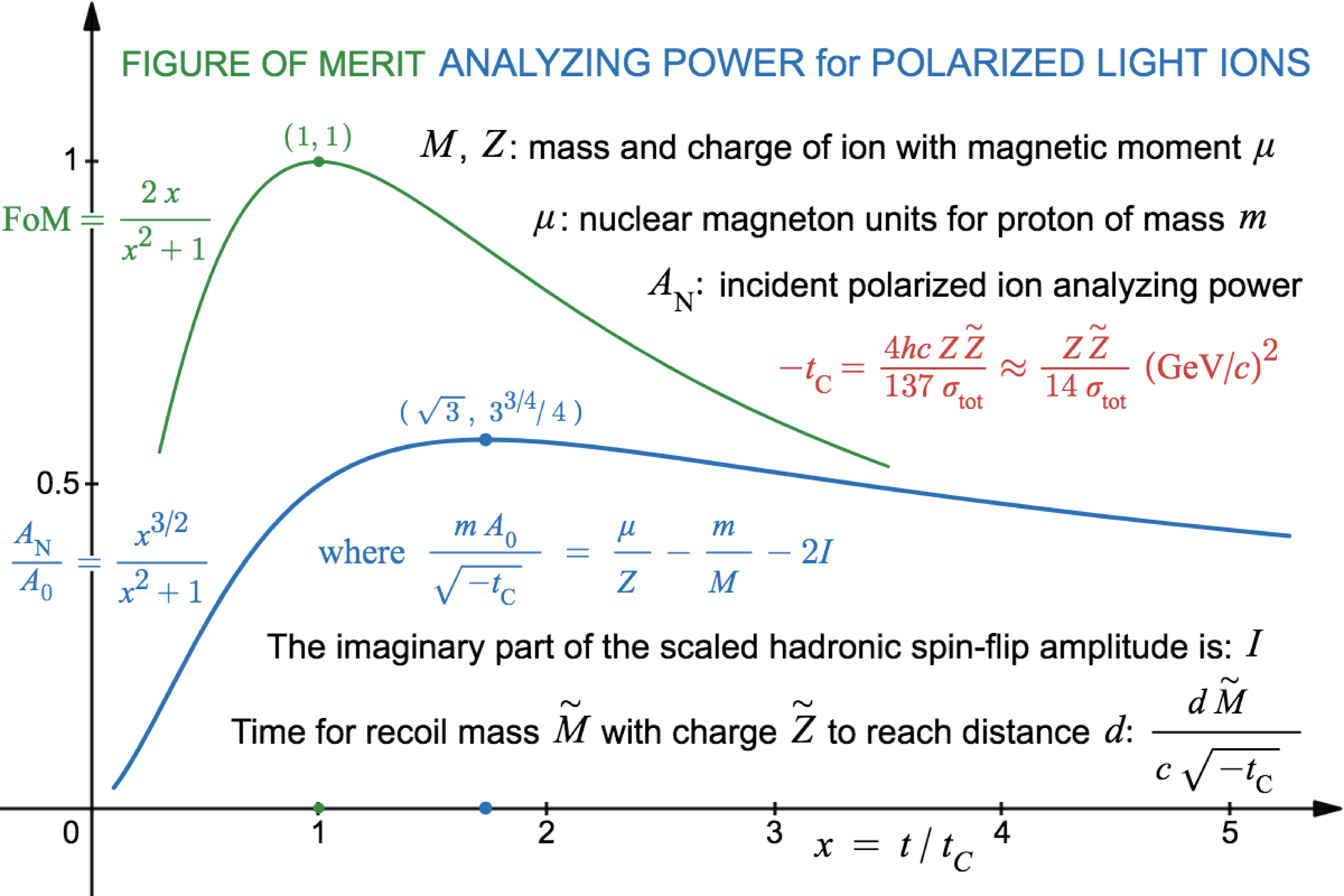
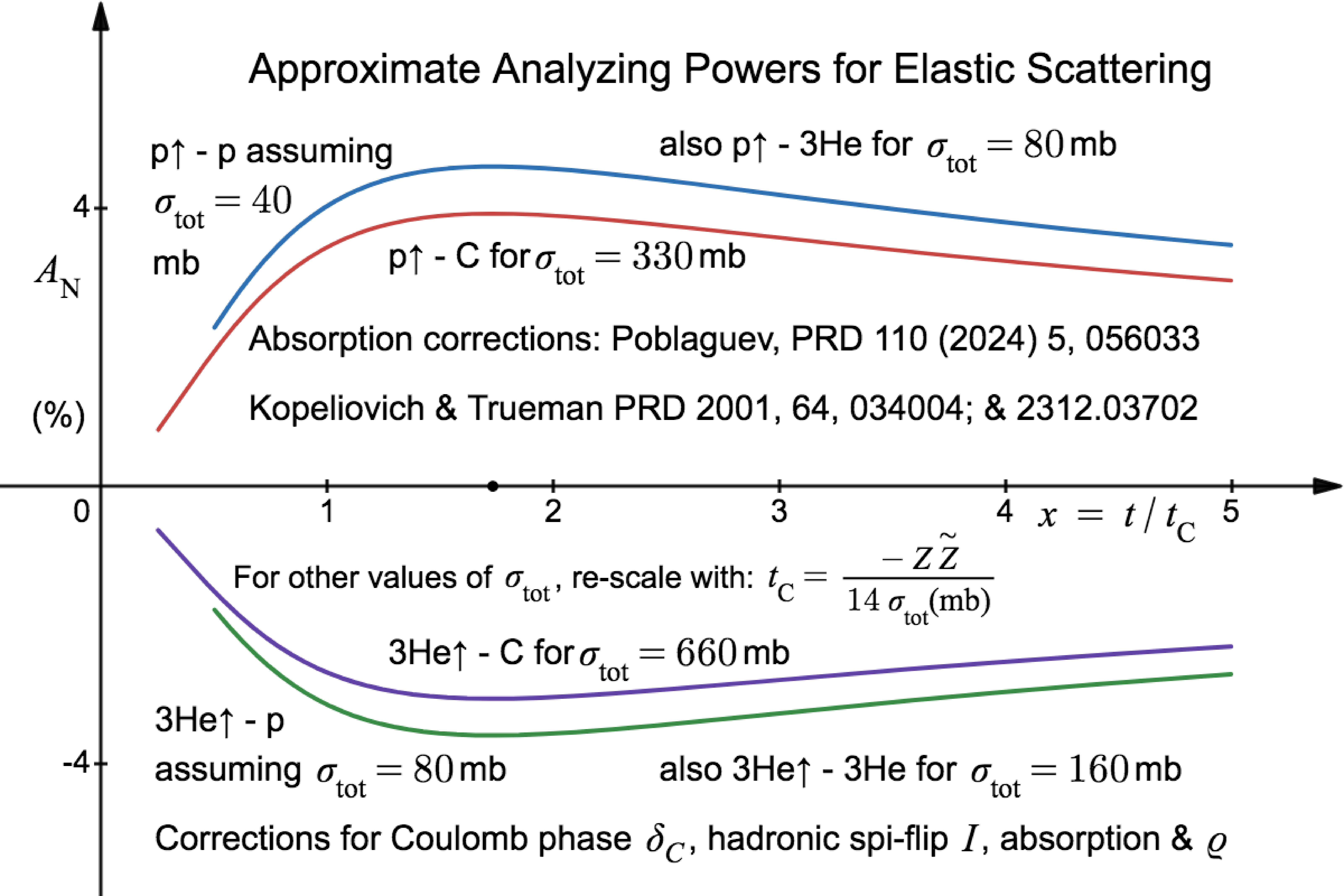


FIGURE OF MERIT ANALYZING POWER for POLARIZED LIGHT IONS
(1, 1)
M, Z: mass and charge of ion with magnetic moment μ
$\mathrm{FoM} = \frac{2x}{x^2+1}$
μ: nuclear magneton units for proton of mass m
A_N: incident polarized ion analyzing power
$-t_C = \frac{4hc\, Z\tilde{Z}}{137\,\sigma_{tot}} \approx \frac{Z\tilde{Z}}{14\,\sigma_{tot}}\ (\mathrm{GeV}/c)^2$
$(\sqrt{3},\ 3^{3/4}/4)$
1
0.5
$\frac{A_N}{A_0} = \frac{x^{3/2}}{x^2+1}$
where $\frac{m\,A_0}{\sqrt{-t_C}} = \frac{\mu}{Z} - \frac{m}{M} - 2I$
The imaginary part of the scaled hadronic spin-flip amplitude is: I
Time for recoil mass $\tilde{M}$ with charge $\tilde{Z}$ to reach distance d: $\frac{d\,\tilde{M}}{c\sqrt{-t_C}}$
0
1
2
3
4
5
$x = t\,/\,t_C$


Approximate Analyzing Powers for Elastic Scattering
p↑ - p assuming $\sigma_{\text{tot}} = 40$ mb
also p↑ - 3He for $\sigma_{\text{tot}} = 80$ mb
p↑ - C for $\sigma_{\text{tot}} = 330$ mb
Absorption corrections: Poblaguev, PRD 110 (2024) 5, 056033
Kopeliovich & Trueman PRD 2001, 64, 034004; & 2312.03702
A_N
(%)
4
-4
0
1
2
3
4
5
$x = t / t_C$
For other values of σ_{tot}, re-scale with: $t_C = \frac{-Z\tilde{Z}}{14\,\sigma_{\text{tot}}(\text{mb})}$
3He↑ - C for $\sigma_{\text{tot}} = 660$ mb
3He↑ - p assuming $\sigma_{\text{tot}} = 80$ mb
also 3He↑ - 3He for $\sigma_{\text{tot}} = 160$ mb
Corrections for Coulomb phase δ_C, hadronic spi-flip I, absorption & ϱ