COMPTON SCATTERING AS ANTIPROTON BEAM DIAGNOSTICS TOOL

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AEGIS

Goals: Measure gravitational acceleration felt by antihydrogen .

1. Exciting positronium into excited Rydberg states for charge exchange with cooled antiprotons.

- Progress has been made in last 4-5 weeks, can now confirm excited Ps

2. Sympathetically cooling antiprotons using C2 anions.

- This needs a lot of work, still haven't confirmed production of C2 anions.
- Still need to construct laser test bed for the experiment focused on laser cooling C2 anions

COMPTON SCATTERING AS ANTIPROTON BEAM DIAGNOSTICS TOOL

Idea: Use high energy pulsed laser aimed at beam of antiprotons to obtain 3D map of beam profile and energy spectrum using Compton scattering.

1. Derive Compton Scattering formula for this scenario.

2. Derive Cross-Section this reaction.

3. If the probability is good come up with design for this.

COMPTON SCATTERING ENERGY SHIFT

- Energy and Momentum Conservation

$$E + w = E' + w' \quad \& \quad \vec{p} + \vec{k} = \overrightarrow{p'} + \overrightarrow{k'}$$

- Assume that antiprotons are initially at rest and have non-relativistic momentum making non-rel. approximation for antiproton energy:

$$w = \frac{1}{2m} * \left(\overrightarrow{p'} \cdot \overrightarrow{p'}\right) + w' \quad \text{where} \quad \overrightarrow{p'} = \vec{k} - \overrightarrow{k'}$$

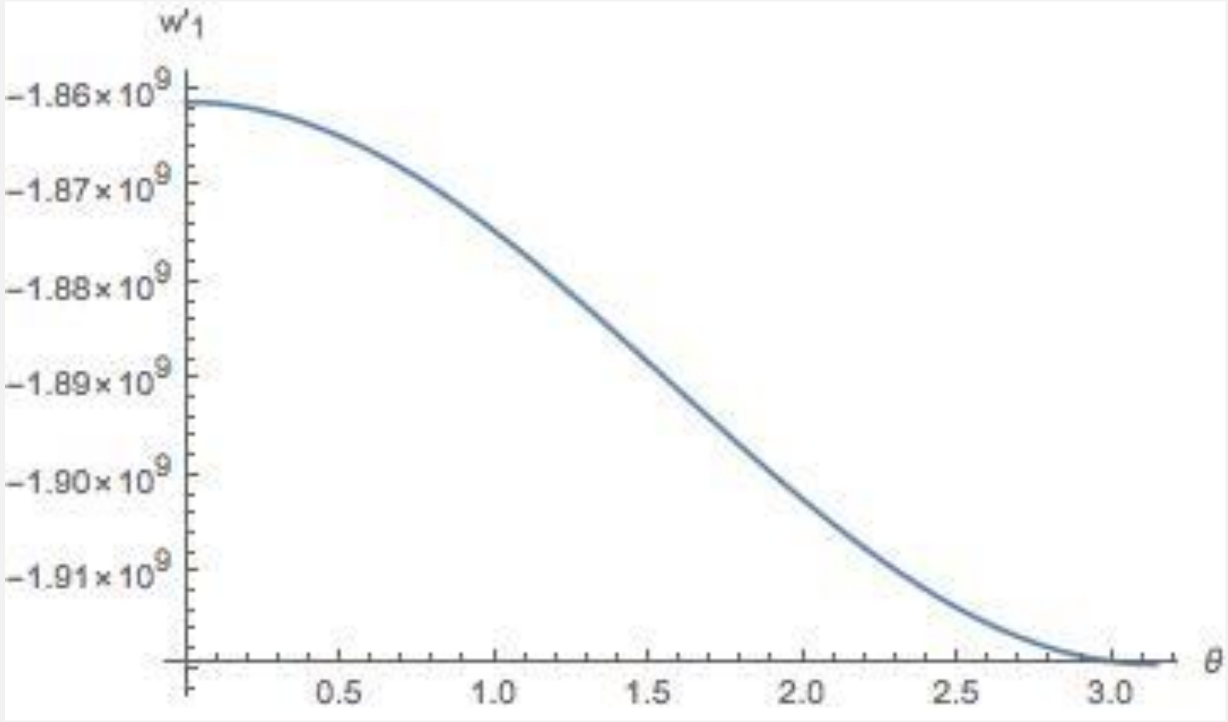
- This gives the quadratic equation:

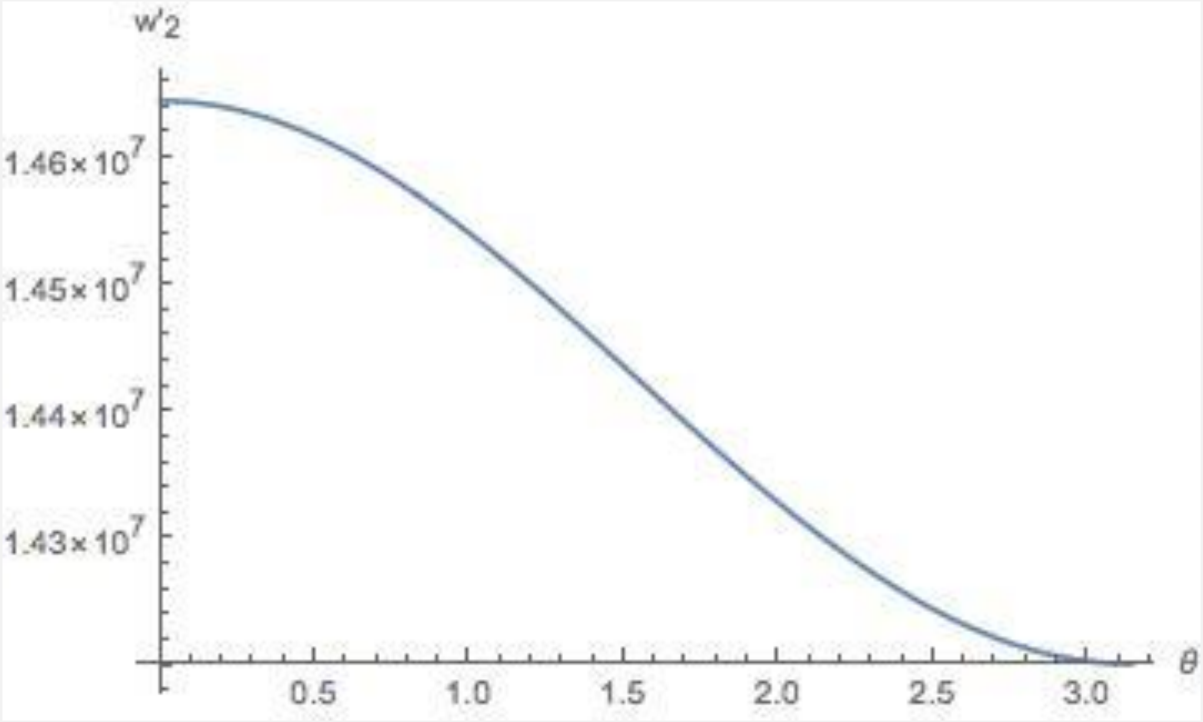
$$w' + \frac{1}{2m}\left[w'^2 + w^2 - 2w'w * \cos(\theta)\right] - w = 0$$

- There are two roots to this equation, one gives negative final frequencies so we will ignore it. The other is:

$$w' = -m + wcos(\theta) + \left(\frac{2m^2 + 4mw - w^2 - 4mwcos(\theta) + w^2\cos(2\theta)}{2}\right)^{1/2}$$

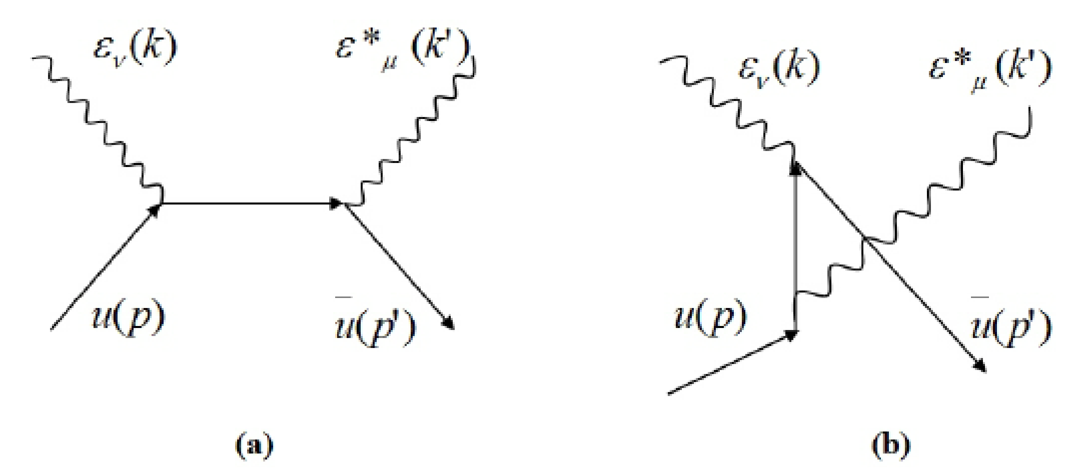
COMPTON SCATTERING ENERGY SHIFT





CROSS SECTION:

- Feynman Diagrams:



- Using the Feynman Rules, these produce two amplitudes:

$$M1 = \ e^2\epsilon(k')^*_v v(p')\gamma^v \frac{\left(p^\mu\gamma_\mu + k^\mu\gamma_\mu + m\right)}{\left((p+k)^2 - m^2\right)}\gamma^\mu\bar{v}(p)\epsilon_\mu\ (k)$$

$$M2 = \ e^2\epsilon_\mu\ (k)v(p')\gamma^v \frac{\left(p^\mu\gamma_\mu - k'^\mu\gamma_\mu + m\right)}{\left((p-k')^2 - m^2\right)}\gamma^\mu\bar{v}(p)\ \epsilon(k')^*_v$$

- The averaged amplitude is:

$$< \overline{M1 + M2}^2 > = < \bar{M}^2 >$$

CROSS SECTION:

- Using the following identities:

$\sum_{s=1,2} v(k)\bar{v}(k) = \; k^{\mu}\gamma_{\mu} - m$ (+ for regualr matter, - for antimatter)

$$\epsilon_{\mu}^{\lambda} \cdot \epsilon_{v}^{\lambda'} = \eta^{\lambda\lambda'}\eta_{\mu v}$$

$$s = (k+p)^2 = m^2 + 2k \cdot p \;\&\; t = (k'-p)^2 = -2k \cdot k'$$

- The averaged amplitude becomes:

$$< \bar{M}^2 > = se^4[\frac{(s-m^2)t^3+(3s^2-2m^2s+3m^4)t^2+4s(s-m^2)^2t+2(s-m^2)^4}{(s-m^2)^2(t+s-m^2)^2}]$$

CROSS SECTION:

- The differential cross section is then defined as:

$$d\sigma = \frac{< \bar{M}^2 >}{4wm} d\Pi_n$$

- Where $d\Pi_n$ is defined as:

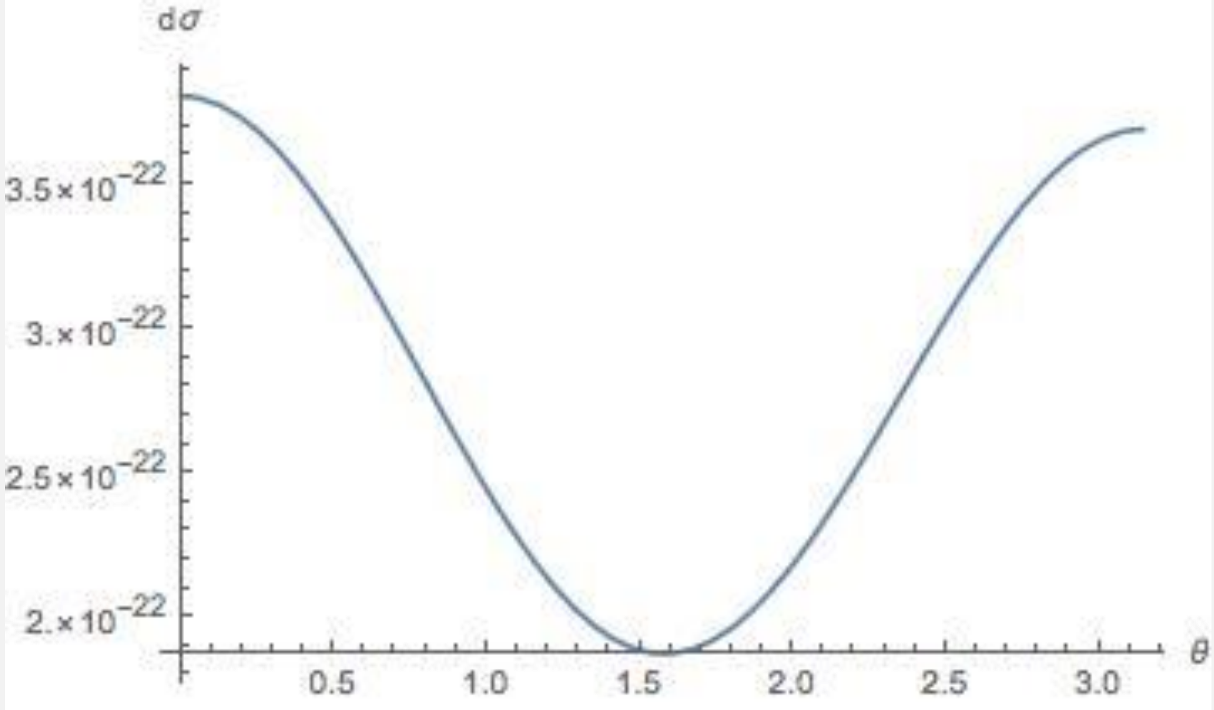
$$d\Pi_n = (2\pi)^4 \delta^{(4)}\left(\sum p_f \; - p - k\right) \prod_{f=1}^{n} \frac{d^3 p_f}{(2\pi)^3} \frac{1}{2E_f}$$

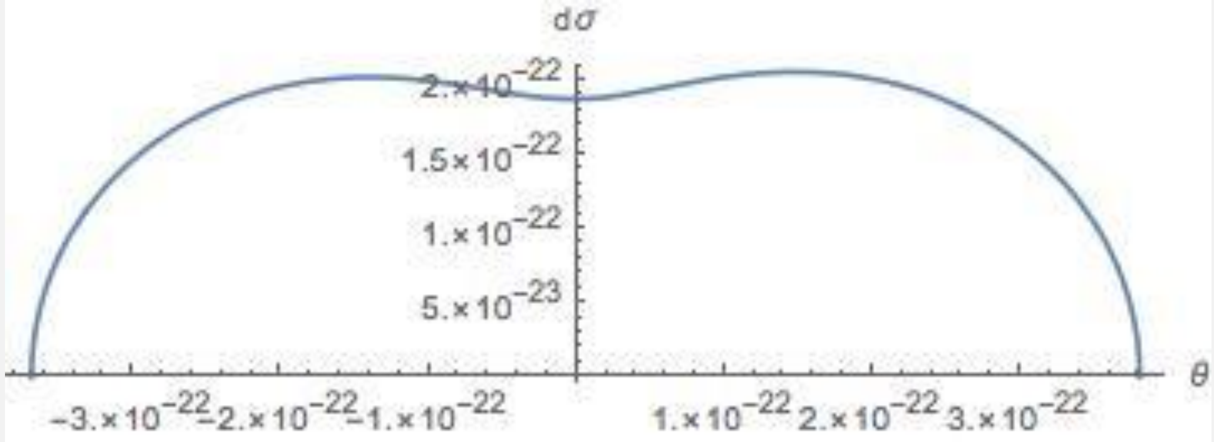
- Setting n=2 and extinguishing the integral over $d^3 p'$ by 3 momentum conservation, you arrive at the following result:

$$\frac{d\sigma}{dcos(\theta)} = \frac{< \bar{M}^2 >}{4wm} \frac{1}{8\pi} \frac{w_0'}{m + \frac{1}{2m}(w_0'^2 + w^2 - 2w_0' w cos(\theta)) \left| 1 + \frac{w_0' - wcos(\theta)}{m} \right|}$$

- Where w_0' is the Compton shifted photon energy.

CROSS SECTION:





CROSS SECTION