An study of relativistic energy, momentum, and particle colllisions

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Kernel Review

PHYS 305: Computational Physics

Overview

- Background
- Objective
- Project Approach
- Results (thus far)
- Discussion
- Further work

Background

- 1905 (“*Annus Mirabilis”,*

  the Miracle Year!)

- Albert Einstein—from patent office clerk to science rockstar!

Special Relativity

- Postulate 1
  - The laws of physics remain the same in all inertial frames
- Postulate 2
  - The speed of light is invariant in all inertial frames
- What does this mean???

Time Dilation and Length Contraction

- For a fixed frame S and a moving frame S' with velocity v:

$$T = \frac{T_0}{\sqrt{1 - \frac{v^2}{c^2}}} = T_0\gamma$$

$$L = L_0\sqrt{1 - \frac{v^2}{c^2}} = \frac{L_0}{\gamma}$$

- Counterintuitive ideas

Objective

- Show the relationship between relativistic momentum and energy
  - Lab frame vs CM frame
  - Magnitude and scale comparison using different masses (protons, electrons, etc)

$$p_a' = \frac{p_a - \frac{v_{cm}}{c^2} E_a}{\sqrt{1 - \frac{v_{cm}^2}{c^2}}}; \qquad p_b' = \frac{p_b - \frac{v_{cm}}{c^2} E_b}{\sqrt{1 - \frac{v_{cm}^2}{c^2}}};$$

$$E_a' = \frac{E_a - p_a v_{cm}}{\sqrt{1 - \frac{v_{cm}^2}{c^2}}}; \qquad E_b' = \frac{E_b - p_b v_{cm}}{\sqrt{1 - \frac{v_{cm}^2}{c^2}}};$$

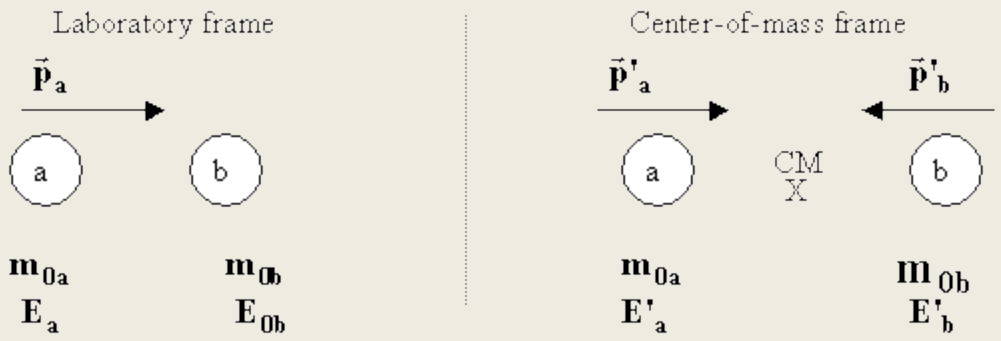


Fig. 1 Two-particle collision observed in lab and CM frames

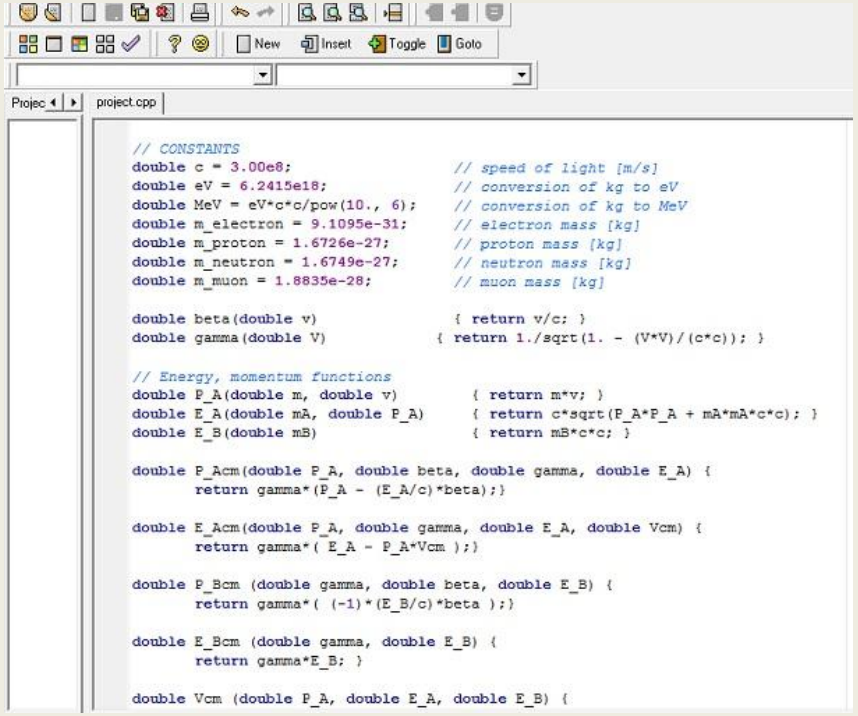
http://teachers.web.cern.ch/teachers/archiv/hst2002/bubblech/mbitu/applications_of_special_relativi.htm

Objective

- Graphically calculate and display the minimum threshold energies in some particle collisions
  - Necessary for the creation of certain particles

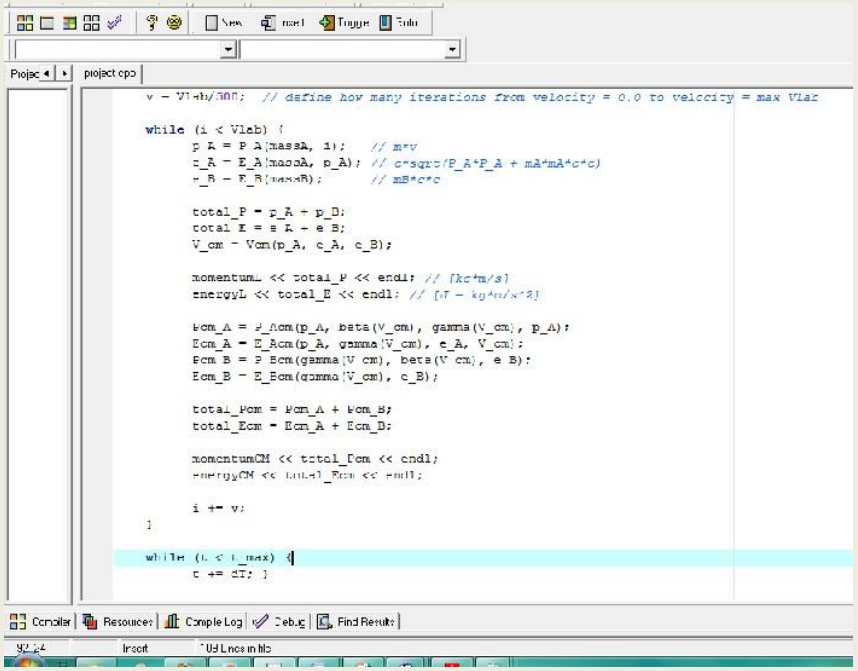
Project Approach

- Defining constants
- Defining functions for momentum and energy
  - Functions passing functions as parameters (BE CAREFUL!)



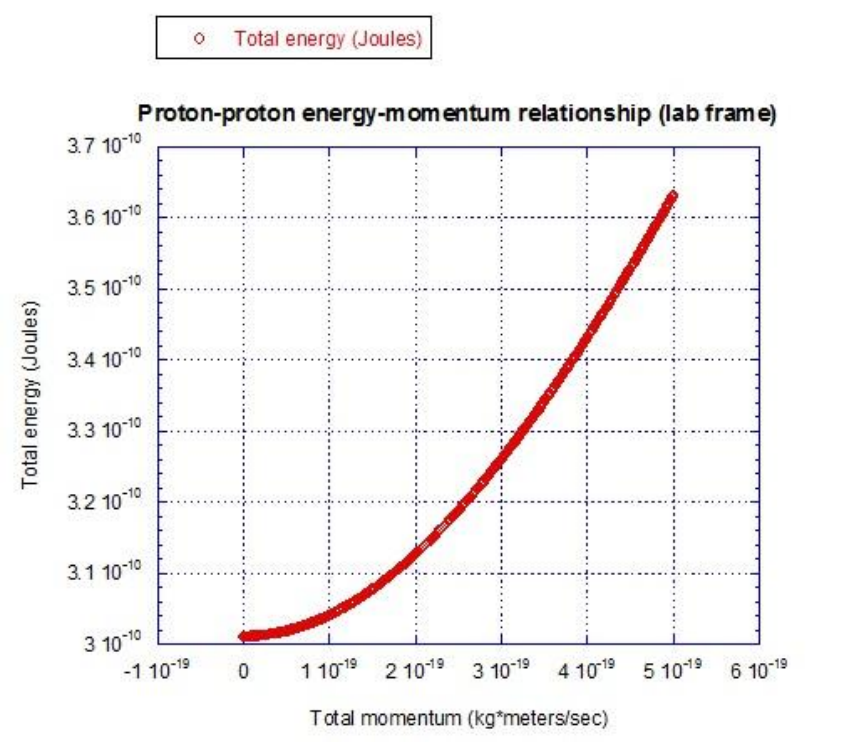
Project Approach

- While-loop
  - Calls and defines energy and momentum functions
  - Calculates total momentum and energy over a varying velocity from 0 to nearly the speed of light

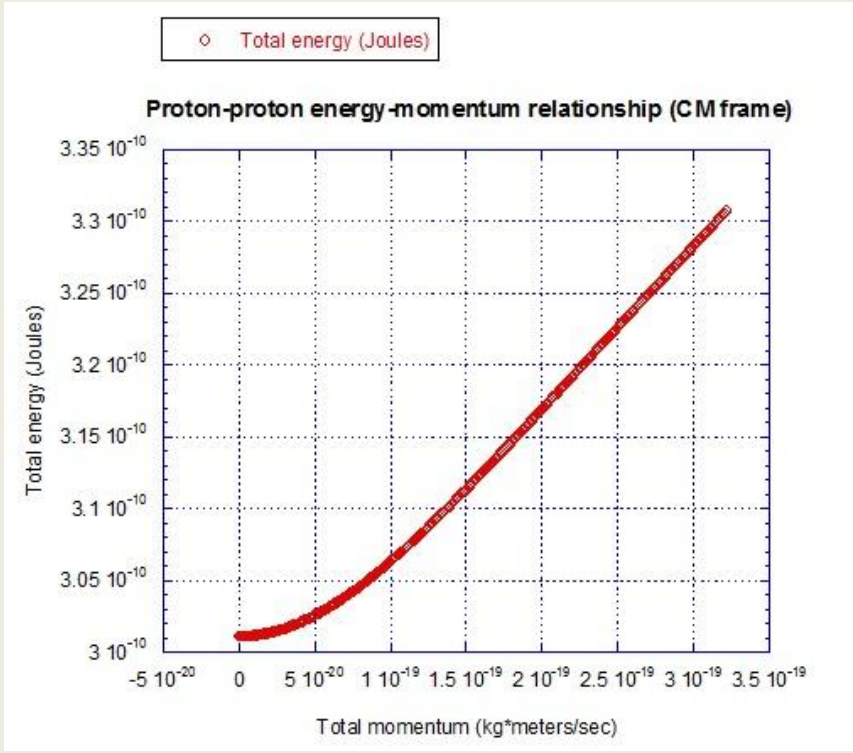


Results (thus far)

Lab frame (0<v<2.99e8)



CM frame (0<v<2.99e8)



Discussion

- Noticeable variation
  - $E_{lab} / E_{CM} \approx 1.098$
  - E_{lab} roughly 0.911 times greater than E_{CM}

- Demonstrates importance of particle colliders using colliding beams (CM frame) instead of colliding with a stationary particle (lab frame)

Discussion

- Some significant things to keep in mind:
  - Many constants—don't lost track!
  - *Many* functions!
    - Need better organization for clarity
    - Solution: stuctures? Arrays?
  - Don't forget—units, units, units!

Project Outlook

- Add asymptotic values of threshold energies needed to create new particles
- Continue with other scenarios of particle collsion
- Experiment with adding new time and position functions

References

- Bitu, R. "Applications of Special Relativity on Particle Physics." http://teachers.web.cern.ch/teachers/archiv/hst2002/bubblech/mbitu/applications_of_special_relativi.htm

- Taylor, John R. "Classical Mechanics". University Science Books. 2005