Weekly Progress

---★---★---

1 WEEK 1: 09/08/2021 – 15/08/2021

1.1 TASKS

1. To read: How MC generators work, specifically Pythia8?[1]
2. To read: What is CheckMATE[2]?
3. To read: What are symmetries, especially in quantum mechanics?[3]

1.2 LEARNING OUTCOMES

1.2.1 Noether's Theorem and Continuous Symmetries

Existence of a conserved quantity for every continuous symmetry of a physical system.
$\therefore$ Every symmetry of nature yields a conservation law. Conversely every conservation law reveals an underlying symmetry.
Classical Symmetries[4] $\rightarrow$ Conserved Charges $\rightarrow$ Noether Charges

- For a continuous transformation $q_i \rightarrow \tilde{q}_i = q_i + \delta q_i$ where $q_i = \epsilon q_i$:
  $Q \equiv$ Noether's Charge $= \sum_{i=1}^{N} \delta q_i \frac{\partial L}{\partial q_i} - \lambda(q_i, \dot{q}_i, t)$ remains constant in time t.
- 1. Translation is Space $\rightarrow$ Noether Charge = Momentum
  2. Translation in Time $\rightarrow$ Noether Charge = Hamiltonian (time dependent)
  3. Rotation in Space $\rightarrow$ Noether Charge = Angular Momentum
- Note: If an infinitesimal transformation is a symmetry, we may apply arbitrarily many infinitesimal transformations to recover the invariance of S under finite transformations

[1]Pythia8: https://pythia.org/
Introductory Lecture on Monte Carlo methods for Particle Physics: https://www.youtube.com/watch?v=7B7xc0kjz94&ab_channel=NishitaDesai
[2]CheckMATE: https://checkmate.hepforge.org/
[3]Introduction to Elementary Particles by D. J. Griffiths
[4]Get back to this for field symmetries and quantum symmetries later

1.2.2 What are Monte Carlo Generators?

1.3 WHAT I KNOW

1.4 WHAT I DON'T KNOW

1.4.1 Scattering Theory in Quantum Mechanics:

I would try to complete it by the next week or so. I have a basic idea of what it is. But I don't know about explicit mathematical calculations used to calculate scattering cross-sections.

1.4.2 The Following Equation and 2→2 Hard Collision

I

$$\sum_{a,b} \frac{1}{N_{initial}} \sum_{initial} \sum_{final} \int dx_a \int dx_b \int d(LIPS) f_a(x_a) f_b(x_b) |M|^2 \delta(x_a x_b S - \hat{S})$$

where

$$\begin{aligned} LIPS &\equiv \texttt{Lorentz Invariant Phase Space} \\ f_i(x_i) &\equiv \texttt{the ith Parton Distribution Function} \\ x_i &\equiv \texttt{the momentum fraction } \epsilon\,[0,1] \end{aligned}$$

1.4.3 Partons and Parton Distribution Functions

All I know is that they are the constituent particles of hadrons. For the present case, the hadron under consideration is the proton (Hard Collision at LHC). A follow-up Google search shows that quarks and gluons are commonly referred to as partons. Now it seems that it was pretty lame to ask such a question since p = uud, where u and d represent the up and down quarks (partons) respectively.

The mathematics of the Parton Distribution Function[5] didn't make any sense to me right now. I'm not mathematically equipped to understand it. But, qualitatively, such distributions are used to calculate the probabilities to find partons in a hadron as a function of the fraction of the hadron's (proton's) momentum carried by the parton.

A question to myself: Are PDFs of quarks and gluons different because they have different masses/energies?

1.4.4 Lie Algebra

It is a part of my current semester. Hopefully, I'd get a reasonable understanding of this subject in the next 3-4 months.

[5] An introductory paper on PDFs: https://arxiv.org/pdf/hep-lat/9609018.pdf