JENNIFER2 Summer School 2021: A Brief Report

December 14, 2021

Overview and the related bifurcation of the Report

The report consists of five parts/sections (broadly). Each of the parts/sections corresponds to a single field discussed at the JENNIFER2 [1] Summer School. The respective parts/sections are named accordingly.
These parts/sections have several other listed items. For convenience, footnotes point to the web address of the lecture slides.
Also, I've added my comments on what I know/don't know and what I find exciting.
NOTE: I have skipped Heavy Quark[2,3] and Tau Lepton Physics[4] because I didn't attend those lectures.

1 Flavour Physics

My Comments:

- What I know:
  - Some Relativistic Quantum Mechanics. Currently reading about scattering theory and Partial Wave Analysis to fill up the remaining loopholes
  - Nature of Lagrangian densities in QCD and QED
  - Basic Group Theory and Lie Algebra (barely scratched the surface of Lie ALgebra)
  - Physical ideology behind the Higgs Field and the corresponding mechanism

*Retained this part since the Document looks good and formatted
[1] JENNIFER2 School's main webpage: https://indico.belle2.org/event/4071/overview
[2] https://indico.belle2.org/event/4071/contributions/22446/attachments/12251/18730/DTonelli-Flavor-Jennifer2021-part1.pdf
[3] https://indico.belle2.org/event/4071/contributions/22460/attachments/12265/18749/DTonelli-FlavorJennifer2021-part2.pdf
[4] https://indico.belle2.org/event/4071/contributions/22469/attachments/12298/18781/Jeniffer_SummerSchool.pdf

- What I don't know:
  - Explicit Mathematical Details behind tensor products of Orthogonal(Unitary) Groups
  - A lot of QCD and QED (barely scratched the surface)
  - Derived properties of Charged and Neutral Current Reactions
  - The real mathematical framework on which CKM matrix is based on.
  - The nitty gritty details and mathematical pecularities of flavour mixing and corresponding anamoly.
  - Explicit nature of CP violations in B-mesons and Kaons
- Observations:
  - The diagonalisation of mass matrices in the Fermion Generations reminds me of small oscillation problems in Classical Mechanics
  - CKM matrix is a complicated form to represent three coupled pendulums
  - GIM mechanism looks interesting but is inherently linked to the CKM matrix.

Lectures:

- Lecture 1[5]
  - Overview of Fundamental Interactions
  - Relativistic Quantum Mechanics
  - Revving up Relativistic Quantum Mechanics to full-fledged Quantum Field Theories.
  - Discussion on QCD and QED Lagrangian densities and the corresponding derived quantities
  - Comments on Tensor Products of Unitary and Special Unitary Groups... hence, the Electroweak Gauge Theory
  - Symmetries and their breaking: The Mass problem when the gauge symmetry breaks
  - Some comments on Higgs Mechanism
- Lecture 2[6]
  - Family structure of the Standard Model
  - Mass matrices

[5] https://indico.belle2.org/event/4071/contributions/22436/attachments/12202/18637/JENNIFER_2021-Flavour-1.pdf

[6] https://indico.belle2.org/event/4071/contributions/22441/attachments/12217/18656/JENNIFER_2021-Flavour-2.pdf

  - Flavour mixing
  - CP violation
  - CPT violation to the rescue

- Lecture 3[7]

  - Continuation of Lecture 2 with more practical examples of CP violation
  - Discussion on Kaons and B-mesons

2 Accelerator and Detector Physics

My comments:

- What I Know:

  - Tensorial Special Relativity

- What I don't know:

  - Betatron
  - Phase Stability in accelerating particles
  - How Quadrupole Magnets work
  - Odd-pole magnets are difficult(impossible) to make because magnetic monopoles don't exist? But there are odd order terms in magnetic potential expansion?
  - Mathematics of Synchotron radiation (haven't read about retarded potential, hence this is expected)
  - Nitty gritties of J/ψ
  - Drift chambers, Scintillators and much of the engineering aspect of different detection mechanism

- Observations

  - Focussing principle and mechanism is identical across every field (accelerators or spectroscopy)
  - Mesmerized by the sheer size of accelerators
  - Dark Matter measurements are fixed target scattering expts.
  - IceCube and Baikal GVD use cherenkov detection

[7] https://indico.belle2.org/event/4071/contributions/22444/attachments/12244/18700/JENNIFER_2021-Flavour-3.pdf

Lectures:

- Lecture 1[8]
  - Lorentz Force and its applications
  - Types of accelerators viz. DC, RF, Drift Tubes, Synchotron, Cyclotrons, Betatron
  - Historical review of particle production
  - Engineering aspects of accelerators.
  - J-PARC and S-KEKB
- Lecture 2[9]
  - Fixed target expts.
  - Analysing collisions, e.g. J/ψ
  - Cherenkov radiation
  - Drift Chambers
  - Scintillators
- Lecture 3[10]
  - Effects of mass of particles on their detection capabilites, typical example: Super-Kamiokande
  - Using calorimetry to segregate particles
  - Some more stuff which I didn't understand

3 Statistics

My comments:

- What I know
  - Probability Theory and Distribution Functions
  - Working level knowledge of Supervised learning
  - Kind of sufficient knowlege about Frequeny and Bayesian Statistics
- What I don't know

[8] https://indico.belle2.org/event/4071/contributions/22439/attachments/12197/18632/Masuzawa.pdf

[9] https://indico.belle2.org/event/4071/contributions/22440/attachments/12209/18645/jennifer2021-krizan-part1.pdf

[10] https://indico.belle2.org/event/4071/contributions/22442/attachments/12222/18671/jennifer2021-krizan-part2.pdf

  - Loopholes in MC Data
  - Not content with my understanding of ML and DL
  - Scope for improvement in Statistics
  - Big Data
  - Graph Theory

- Observations
  - The presence of a signal in every observed data kind of bothers me a bit. I'm acquainted with the 5σ rule, but it stills sounds a bit weird.

Lectures:

- Lecture 1[11]
  - Histograms
  - Distributions
  - Efficiency and Purity of Selection
  - Somehow finding a signal in abstract data
  - Good old Gaussian and corresponding convolutions
- Lecture 2[12]
  - Fitting, Under-Fitting and Over-Fitting
  - Toys
  - Specific examples
- Lecture 3[13]
  - Everything about ML and DL: Supervised/Unsupervised Learning, Random Forresting, Neural Networks
  - Higgs Experimental Breakthrough using ML and DL
- Lecture 4[14]

[11] https://indico.belle2.org/event/4071/contributions/22443/attachments/12226/18705/bolognesi_statistics_1.pdf
[12] https://indico.belle2.org/event/4071/contributions/22445/attachments/12248/18704/bolognesi_statistics_2.pdf
[13] https://indico.belle2.org/event/4071/contributions/22465/attachments/12288/18762/NNlecture_2021_SofiaVallecorsa.pdf
[14] https://indico.belle2.org/event/4071/contributions/22468/attachments/12300/18784/DL_JenniferLecture_SofiaVallecorsa_2021.pdf

  - Hypothesis Testing
  - Data Mining
  - (Don't know what the following stuff means)
  - Deep Neural Networks
  - Convolutional Neural Networks
  - Recurring Neural Networks

4 Neutrino Physics

My comments: Pointed out in Section 1
Aspirations: The field that I want to work in (maybe?)

- Lecture 1[15]
- Lecture 2[16]

Everything about neutrinos that has been discovered was discussed in these 2 lectures.

5 Dark Matter and New Physics Searches

- What I don't know
  - Everything about this subject
- Observations
  - I liked the description of analogous Standard Model for Dark Matter particles, i.e. a Dark Standard Model!

Lectures:

- Lecture 1[17]
  - Finding the new Lagrangian Densities
  - Muon g-2 Experiment
  - Dark Matter Candidates (Supersymmetry and its breaking?)
  - Comments on Dark Sector

[15] https://indico.belle2.org/event/4071/contributions/22461/attachments/12273/18740/JENNIFER-blondel-2021-neutrinos-part-1.pdf
[16] https://indico.belle2.org/event/4071/contributions/22462/attachments/12282/18753/JENNIFER-blondel-2019-neutrinos-part-2.pdf
[17] https://indico.belle2.org/event/4071/contributions/22470/attachments/12301/18785/2021_07_26_JENNIFER_ferber_v2.pdf