

Multi-task Convolution Neural Networks for the CHIPS Experiment

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Abstract

LHCb is a -physics detector experiment which will take data at the 14 TeV LHC accelerator at CERN from 2007 onward...

Declaration

This dissertation is the result of my own work, except where explicit reference is made to the work of others, and has not been submitted for another qualification to this or any other university. This dissertation does not exceed the word limit for the respective Degree Committee.

Andy Buckley

Acknowledgements

Of the many people who deserve thanks, some are particularly prominent, such as my supervisor...

Preface

This thesis describes my research on various aspects of the LHCb particle physics program, centred around the LHCb detector and LHC accelerator at CERN in Geneva.

For this example, I'll just mention Chapter 3 and Chapter 2.

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*“Writing in English is the most ingenious torture
ever devised for sins committed in previous lives.”*

— James Joyce

Chapter 1.

Introduction

blah blah blah

Chapter 2.

Neutrino oscillations: theoretical background and current status

“Dear Radioactive Ladies and Gentlemen.”

— Wolfgang Pauli, 1930

TO MAKE - cross-section protection from new line - all ν and $\bar{\nu}$ combos -
proton, neutron, electron, muon, tau etc -

Consider a simple two body decay

Neutrino physics covers the widest possible range of

Proposal of a mysterious undetector particle to explain beta decays in the 1930s through to the resolutions of a 30-year problem with the confirmation of oscillations in the early 2000s and onto the precision era.

Neutrino oscillations first discovered in 1957 when Bruno Pontecorvo proposed a model in which neutrinos oscillate to antineutrinos and back, similar to the kaon. It was actually shown that neutrinos oscillate from one flavour to another.

The field of neutrino physics is ever expanding with a new generation of experiments planned for the coming years.

This chapter aims to provide an introduction to neutrino

blah blah blah

2.1. A history of neutrino oscillations

In the early 20th century, beta decays were assumed to follow the simple two-body process, $A \rightarrow B + e$, where a nuclei spontaneously emits an electron. To conserve both energy and angular momentum the ejected electron should have a discrete kinetic energy related to the difference in mass between the initial and resultant nuclei. However, in 1914, J. Chadwick instead measured a continuous energy spectrum for the electron [1], placing this theory in doubt.

W. Pauli finally proposed a 'desperate solution' in 1930 [2]. If a light, neutrally charged, spin 1/2 particle was also produced in the decay, the continuous energy spectrum could be explained. Initially this mysterious new particle was named the 'neutron'. But, to avoid confusion with the heavy baryon of the same name discovered in 1932, E. Fermi renamed it the 'neutrino' when he formalised beta decay in 1934 [3].

Using Fermi's work H. Bethe and R. Peierls estimated the cross-section of the inverse beta decay process $\nu + p^+ \rightarrow n + e^+$ [4]. They calculated a value of less than the very small 10^{-44}cm^2 and declared 'there is no practically possible way of observing the neutrino.' Although extensive neutrino detection has proved possible it hinted at the huge difficulties experimentalists would face hunting down the neutrino and measuring its properties in the years to come.

The first detection of the neutrino came in 1956 by F. Reines and C. Cowan [5]. A sandwich of

The antineutrino was discovered by Reines and Cowan in 1956, using inverse beta decay in a 200l tank of water, detecting neutrinos from the Los Alamos nuclear reactor.

Muon neutrino discovered by the 'long track' from the decays of pions from a reactor in 1988, got a nobel prize.

DONUT finally found the tau neutrino in 2000 using 800GeV protons from the Tevatron.

This indicates the number of active neutrino states can only be 1.984 ± 0.008 . Therefore, any as yet undiscovered neutrinos must be sterile, in that they do not couple to the weak interaction.

Cosmology can also constrain the number of active neutrino with a value about 3.3 ± 0.27 , the planck satellite did this.

As the standard model of particle physics was developed, neutrinos were presumed to be massless and occur only in the three flavour eigenstates.

Various hints that this was not the case kept appearing, leading to neutrino oscillations, by which one neutrino can oscillate to another flavour and the non-zero masses that follow as a direct consequence from this.

Cowan and Reines 20 years later found the electron antineutrino, produced in the core of a nuclear reactor and Savannah river experiment. 200 litres of cadmium doped water as the target and 1400 litres of liquid scintillator with 100 PMTs, showed the neutrinos detector from inverse beta decay.

In 1962 at the alternating gradient synchrotron at Brookhaven, neutrinos created from pion decays together with muons were observed to produce only muons not electrons, this then confirmed the existence of the muon neutrino.

In 1973, the Gargamelle experiment at CERN using an accelerator produced neutrino beam and a big bubble chamber discovered the existence of weak neutral current interactions. Proving the existence of the neutral Z-boson and confirming the Glashow-Salam-Weinberg theory of electroweak interactions.

Experiments at the LEP e^+e^- collider in the 1990s made precision measurements of the Z decay width, from a fit to the data it showed there are exactly three active generations of neutrinos.

In 2000 the DONUT experiment at the Tevatron collider in Fermilab performed a direct detection of the tau neutrino completing the three flavour picture.

In the solar neutrino sector there is the "solar anomaly" noting a deficit of electron neutrino compared to predictions made by the standard solar model (SSM)

First observed at the Homestack experiment, neutrinos interacted with the chlorine creating radioactive argon atoms, because it is a noble gas it does not bind to the perchloroethylene and it can be extracted by purging the liquid with gaseous helium and then extracted from the helium with a cooled carbon trap.

Gallium was also used by other experiments and Kamiokande also observed the deficit.

Also the fluxes measured were not consistent, depending on the energy range probed. Hinting at oscillations dependent on energy,

SNO finally answered the question when it was able to measure three channels with different relation between the flux of electron neutrinos and the other neutrinos. SNO could prove that the electron neutrinos are changing flavour. While the total flux of all neutrinos remains constant and in agreement with the SSM.

Brookhaven two kinds of neutrinos in Ref. [6]

Gargamelle neutral-currents in Ref. [7]

Observation of the Tau neutrino in Ref. [8]

Precise measurement of z -resonance for three neutrino in Ref. [9]

Homestake deficit observation in Ref. [10]

first SSM predictions used to compare against homestake in Ref. [11]

Kamiokande II deficit in Ref. [12]

SAGE experiment deficit in Ref. [13]

GALLEX experiment deficit in Ref. [14]

SSM Prediction for Ga in Ref. [15]

SNO oscillation measurement in Ref. [16]

Atmospheric kamiokande deficit in Ref. [17]

IMD detector atmospheric deficit in Ref. [18]

Superkamiokande direction atmospheric neutrinos in Ref. [18]

2.2. Neutrino oscillation theory

blah blah blah

2.3. Current status and the future

blah blah blah

Chapter 3.

The CHIPS R&D Project

blah blah blah

Chapter 4.

Data acquisition for CHIPS

blah blah blah

Chapter 5.

A convolutional neural network for CHIPS

blah blah blah

Chapter 6.

Detector optimisation for CHIPS

blah blah blah

Chapter 7.

Conclusion

blah blah blah

Appendix A.

Pointless extras

*“Le savant n’étudie pas la nature parce que cela est utile;
il l’étudie parce qu’il y prend plaisir,
et il y prend plaisir parce qu’elle est belle.”*
— Henri Poincaré, 1854–1912

Appendixes (or should that be “appendices”?) make you look really clever, ’cos it’s like you had more clever stuff to say than could be fitted into the main bit of your thesis. Yeah. So everyone should have at least three of them. . .

A.1. Like, duh

Padding? What do you mean?

A.2. $y = \alpha x^2$

See, maths in titles automatically goes bold where it should (and check the table of contents: it *isn’t* bold there!) Check the source: nothing needs to be specified to make this work. Thanks to Donald Arsenau for the teeny hack that makes this work.

Colophon

This thesis was made in $\text{\LaTeX}2_\epsilon$ using the “hepthesis” class [\[19\]](#).

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