Multi-task Convolution Neural Networks for the Chips Experiment

Josh Chalcraft Tingey
of University College London

A dissertation submitted to University College London
for the degree of Doctor of Philosophy

Abstract

LHCb is a b-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 **??** and Chapter **??**.

Contents

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

— James Joyce

Chapter 1.

Common blocks

hello ello llo

This .tex file aims to outline how various things should be implemented within the thesis from references to diagrams the symbols etc...

- We use english spelling of everything throughout the thesis

- Write the way that is natural in your head, so you are not contorting your thoughts to fit an unnatural style

- We capitalise just the first word in section, chapter and whole-document titling.

- Don't have unnecessary hyphens for weird phrases, just write it as you would in clear plain english

- Use short sentences most of the time to make work clearer and punchier. More than two lines is probably bad.

- Use the 'english comma' to show how to read the text

- Use non-breaking spaces all over the place

- spell out small numbers

- Prefer the default float-spec, [tbp],

- Also read booktabs' excellent manual on how table formatting should look: in short, never use vertical rules.

- Standard Model is capitalised

- Put all particle in italics (hepnames and hepparticles does this all for you)

- eV
- eV
- Minos

eV

C++

eV

$\int \mathrm{d}x \sin^n x \cos^m x$.

- Chips
- NOvA
- Minos

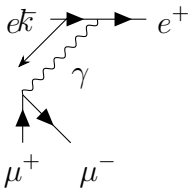
"Laws were made to be broken."
— Christopher North, 1785–1854

Section **??** Table **??** Ref. [**?**]

$\nu + p^+ \to n + e^+$

[1].

Once upon a time there was Chips which was very nice for NOvA which like to use 10 GeV because of Minos which was very naughty



Symmetries, either intact or broken, have proved to be at the heart of how matter interacts. The Standard Model of fundamental interactions (SM) is composed of three independent continuous symmetry groups denoted $\mathrm{SU}(3) \times \mathrm{SU}(2) \times \mathrm{U}(1)$, representing the strong force, weak isospin and hypercharge respectively [**?**, **?**, **?**].

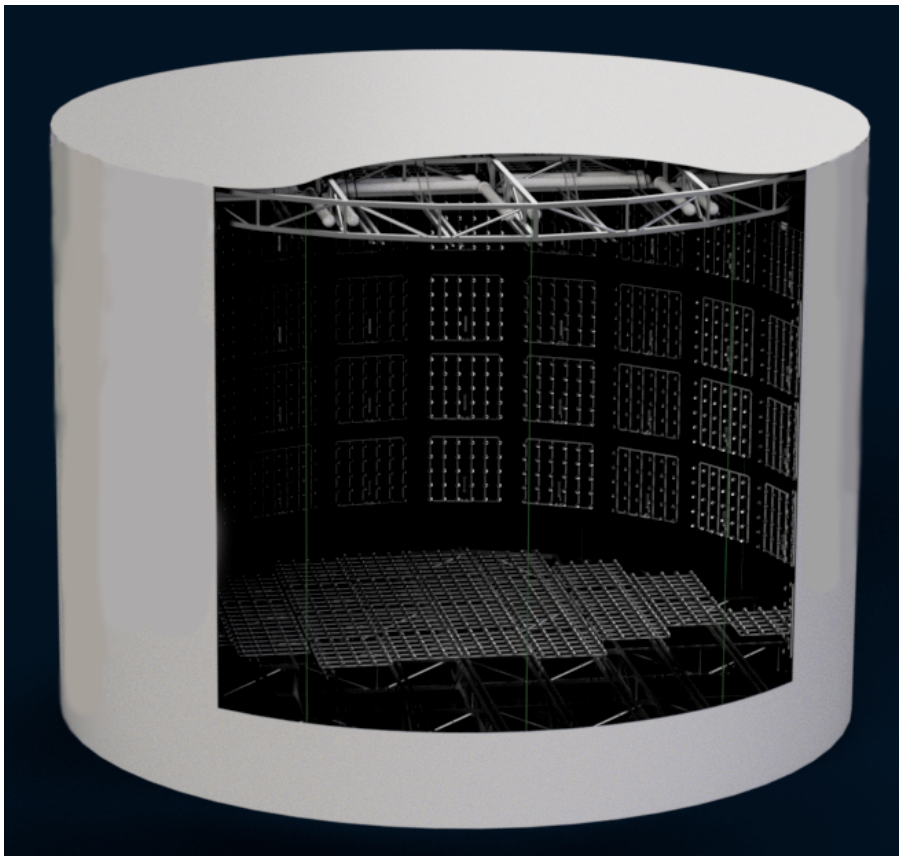


Figure 1.1.: CKM Fitter constraints on α from combined $B \to \pi\pi$, $B \to \rho\pi$ and $B \to \rho\rho$ decay analyses.

1.1. Neutral meson mixing

We can go a long way with an effective Hamiltonian approach in canonical single-particle quantum mechanics. To do this we construct a wavefunction from a combination of a generic neutral meson state $|X^0\rangle$ and its anti-state $|\overline{X}^0\rangle$:

Since both b-hadrons are preferentially produced in the same direction and are forward-boosted along the beam-pipe, the detector is not required to have full 4π solid-angle coverage. LHCb takes advantage of this by using a wedge-shaped single-arm detector with angular acceptance 10-300 mrad in the horizontal (bending) plane [**?**].

⋮

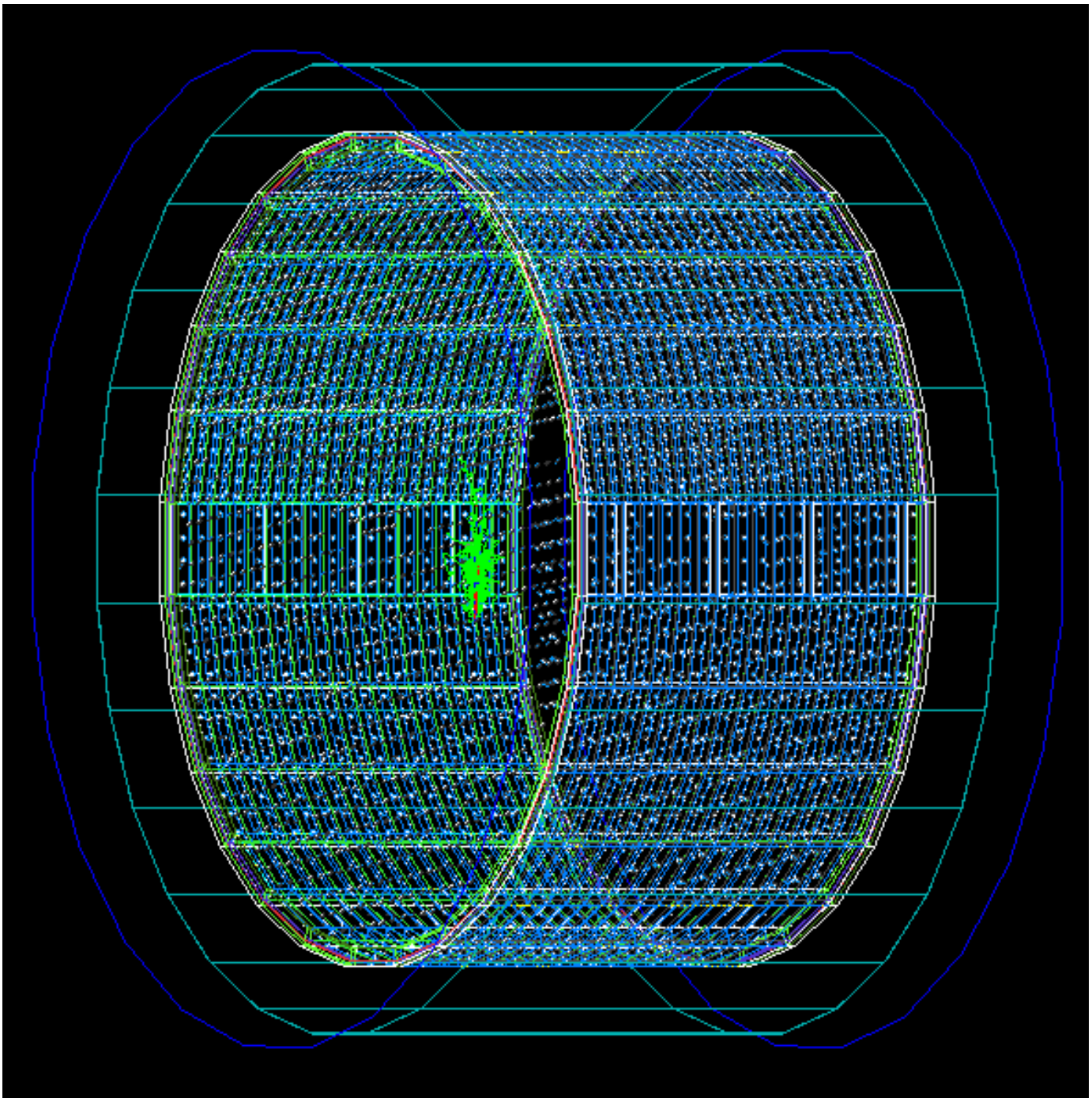


Figure 1.2.: Cross-section view of LHCb, cut in the non-bending y–z plane.

The detector is illustrated in Figure 1.1, showing the overall scale of the experiment.

$$|\psi(t)\rangle = a(t)|X^0\rangle + b(t)|\overline{X}^0\rangle \tag{1.1}$$

which is governed by a time-dependent matrix differential equation,

$$\imath\frac{\partial}{\partial t}\begin{pmatrix} a \\ b \end{pmatrix} = \underbrace{\begin{pmatrix} M_{11} - \frac{\imath}{2}\Gamma_{11} & M_{12} - \frac{\imath}{2}\Gamma_{12} \\ M_{12}^* - \frac{\imath}{2}\Gamma_{12}^* & M_{22} - \frac{\imath}{2}\Gamma_{22} \end{pmatrix}}_{\mathbf{H}} \begin{pmatrix} a \\ b \end{pmatrix}. \tag{1.2}$$

The single-sided detector design was chosen in preference to a two-armed design since the detector dimensions are restricted by the layout of the IP8 (ex-Delphi) cavern in which LHCb is located. Using all the available space for a single-arm spectrometer more than compensates in performance for the ∼50% drop in luminosity.

1.2. The Čerenkov mechanism

A Huygens construction in terms of spherical shells of probability for photon emission as the particle progresses along its track shows an effective "shock-front" of Čerenkov emission. This corresponds to an emission cone of opening angle θ_C around the momentum vector for each point on the track,

$$\cos\,\theta_C = \frac{1}{n\beta} + \frac{\hbar k}{2p}\left(1 - \frac{1}{n^2}\right) \tag{1.3a}$$

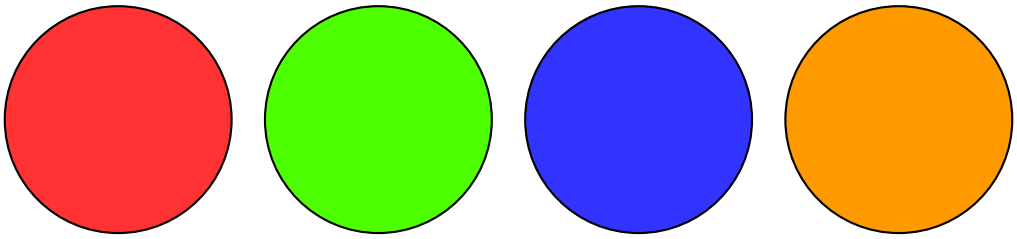
$$\sim \frac{1}{n\beta} \tag{1.3b}$$

where $\beta \equiv v/c$, the relativistic velocity fraction.

1.3. Trigger system

An overview of the LHCb trigger characteristics broken down by level is shown in Table 1.1.

Here are some funky floats using "continued captions", i.e. for a semantically collected group of float contents which are too numerous to fit into a single float, such as the pretty circles in the following figure:



(a) Example 1a **(b)** Example 1b **(c)** Example 1c **(d)** Example 1d

Figure 1.3.: Demonstration of `subfig` continued captions.

This mechanism means that the same float label is used for both pages of floats. Note that we can refer to Figure 1.3 in general, or to Figure 1.3g on page 7 in particular!

Just for the hell of it, let's also refer to Section 1.1.

Here are some funky floats using "continued captions", i.e. for a semantically collected group of float contents which are too numerous to fit into a single float, such as the pretty circles in the following figure

1.4. Convolutional Neural Networks

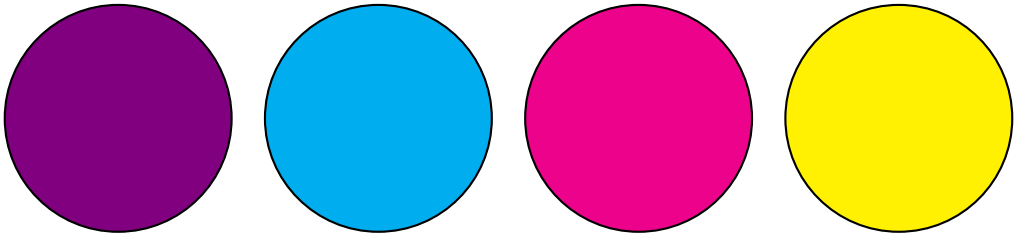
1.5. CHIPS Events

The expected beam flux at the CHIPS detector location is found from reweighting current

We can use current NuMI beam simulations

	L0	L1	HLT
Input rate	40 MHz	1 MHz	40 kHz
Output rate	1 MHz	40 kHz	2 kHz
Location	On detector	Counting room	Counting room

Table 1.1.: Characteristics of the trigger levels and offline analysis.



(e) Example 1e **(f)** Example 1f **(g)** Example 1g **(h)** Example 1h

Figure 1.3.: Demonstration of `subfig` continued captions (continued).

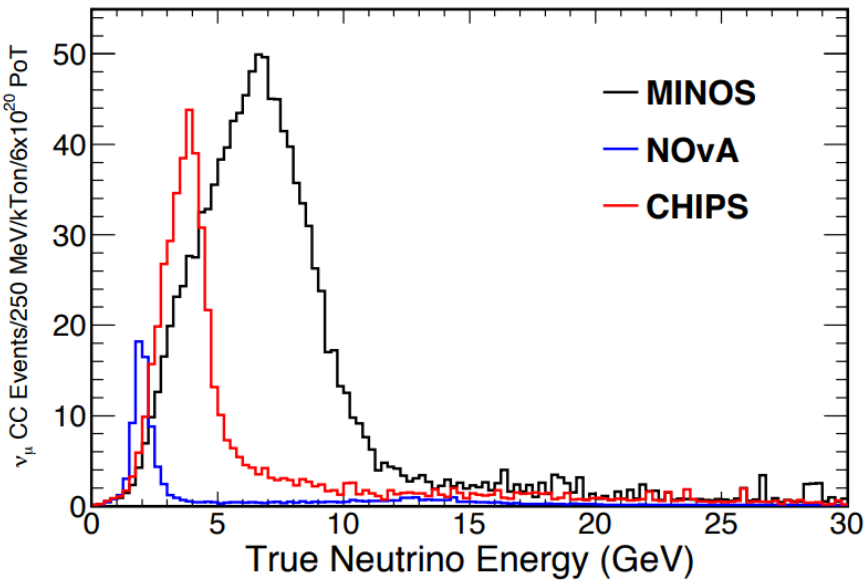


Figure 1.4.: CKM Fitter constraints on α from combined $B \to \pi\pi$, $B \to \rho\pi$ and $B \to \rho\rho$ decay analyses.

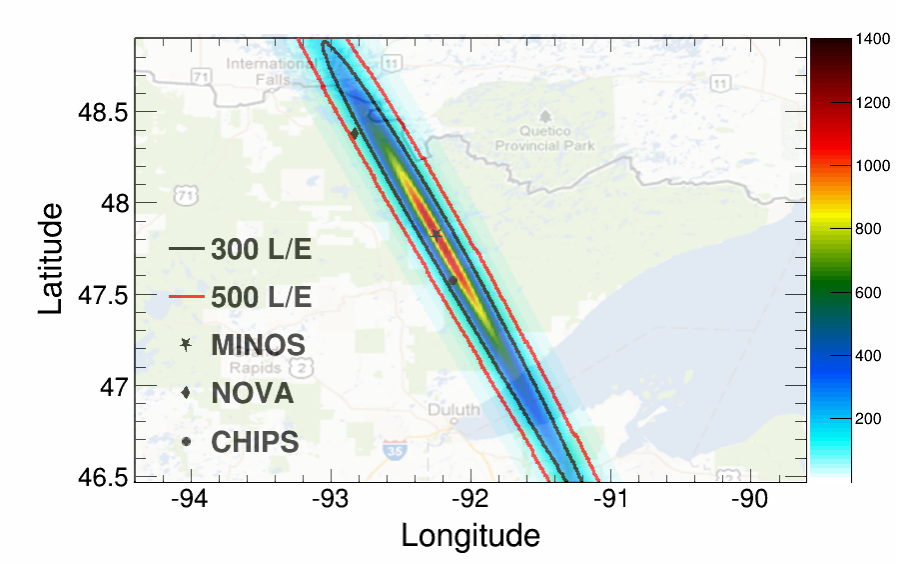


Figure 1.5.: CKM Fitter constraints on α from combined $B \to \pi\pi$, $B \to \rho\pi$ and $B \to \rho\rho$ decay analyses.

Current NuMI beam experiments

Once upon a time there was CHIPS which was very nice for NOvA which like to use 10 GeV

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 LaTeX 2_ε using the "hepthesis" class [2].

Bibliography

[1] J. Chadwick, Verh. Phys. Gesell. **1**6, 383 (1914).

[2] A. Buckley, The hepthesis LaTeX class.

List of figures

List of tables