

Weekly progress

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Contents

1	Term 1	1
1.1	Summer reading	1
1.2	Week 1	1
1.3	Week 2	3
1.4	Week 3	5
1.5	Week 4	5
1.6	Week 5	5
1.7	Week 6	5
1.8	Week 7	5
1.9	Week 8	5
1.10	Week 9	6
1.11	Week 10	6

1 Term 1

1.1 Summer reading

1.2 Week 1

- set up SCRTP account and Github repositories for project
- Risk assessment

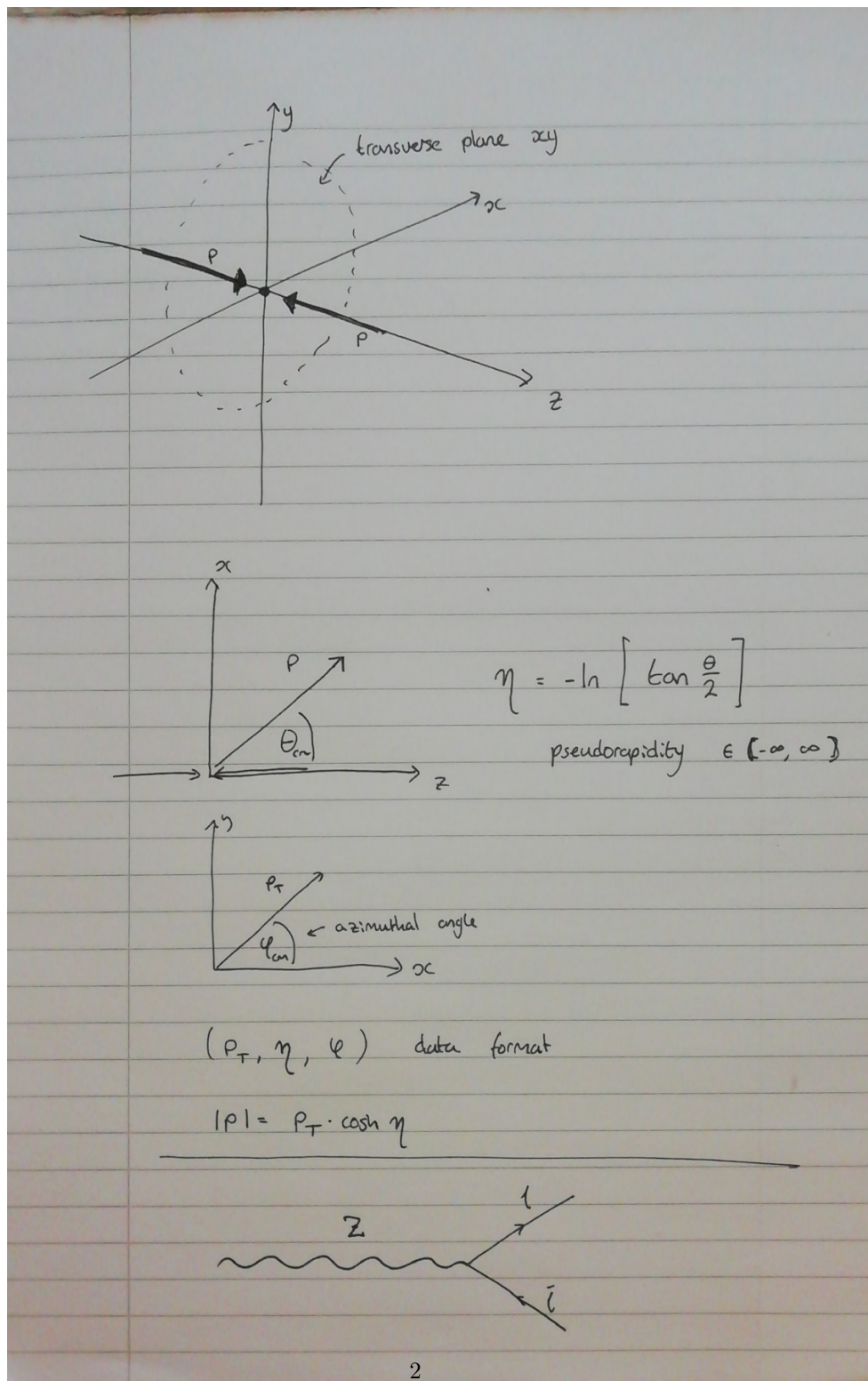


Figure 1: Understanding form of the LHCb momenta data

1.3 Week 2

- Becoming familiar with ROOT[1] and the LHCb dataset
- Worked on using ROOT to find Z boson mass peak as practice for W boson (C++) (Figures 2 & 3)

The whiteboard is divided into two sections: LAB FRAME and Z FRAME.

LAB FRAME

A diagram shows a Z boson (wavy line) decaying into two muons (solid lines). The muon momenta are labeled \vec{p}_1^μ, m_μ and \vec{p}_2^μ, m_μ . The Z boson momentum is labeled \vec{p}_Z^μ, m_Z .

$$W^2 = (\vec{p}_1^\mu + \vec{p}_2^\mu)^2 = (E_1 + E_2)^2 - |\vec{p}_1 + \vec{p}_2|^2$$

$$= E_1^2 + E_2^2 + 2E_1E_2 - |\vec{p}_1|^2 - |\vec{p}_2|^2 - 2\vec{p}_1 \cdot \vec{p}_2$$

$$= m_\mu^2 + m_\mu^2 + |\vec{p}_1|^2 + |\vec{p}_2|^2 + 2E_1E_2 - 2\vec{p}_1 \cdot \vec{p}_2 - |\vec{p}_1|^2 - |\vec{p}_2|^2$$

$$= 2[m_\mu^2 + E_1E_2 - \vec{p}_1 \cdot \vec{p}_2]$$

$$= 2 \left[m_\mu^2 + \sqrt{m_\mu^2 + |\vec{p}_1|^2} \sqrt{m_\mu^2 + |\vec{p}_2|^2} - \vec{p}_1 \cdot \vec{p}_2 \right]$$

assume $m_\mu \approx 0$

$$\Rightarrow W^2 = 2 \left[|\vec{p}_1| |\vec{p}_2| (1 - \cos(\theta_1 + \theta_2)) \right]$$

W^2 frame invariant, so $M_Z \approx \sqrt{2 [p_1 p_2 (1 - \cos(\theta_1 + \theta_2))]}$

Z FRAME

A diagram shows the Z boson at rest. The muon momenta are labeled \vec{p}_1^μ and $\vec{p}_2^\mu = (m_Z, 0, 0, 0)$. The Z boson mass is labeled M_Z .

$$W^2 = M_Z^2$$

Figure 2: Workings for Z boson mass formula

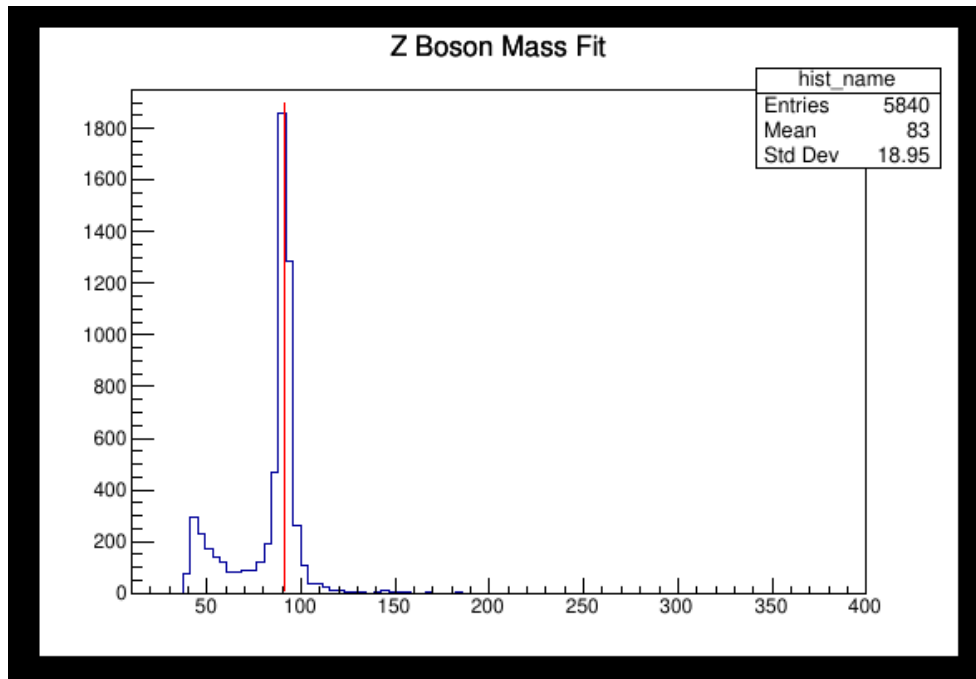


Figure 3: Results using derived Z mass formula with LHCb data

- Found Z mass peak again using Python and TTree/TChain instead (Figure 4)

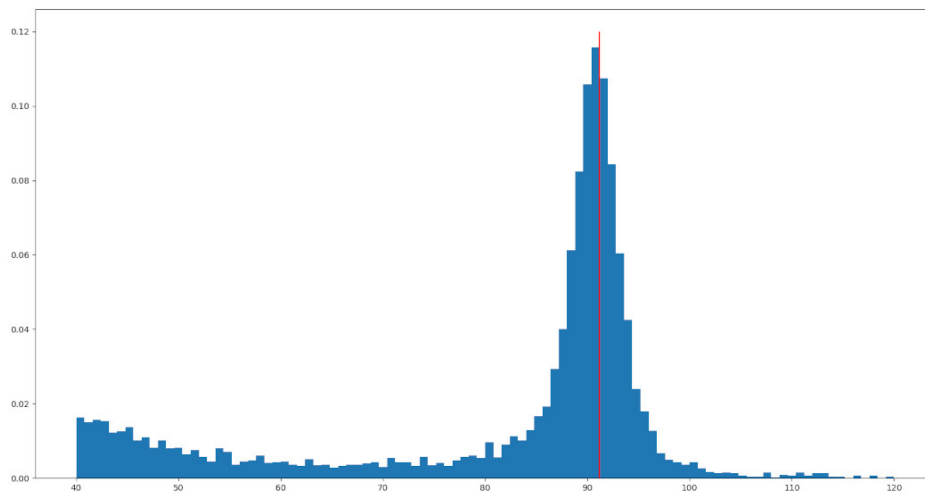


Figure 4: Z mass distribution using LHCb TTree dataset and Python

1.4 Week 3

- Installed Pythia
- Reading through Pythia and ROOT documentation[2]

1.5 Week 4

- Created histograms from LHCb 5TeV dataset
- Consider the highest energy pair of muons from each event

1.6 Week 5

- Refined Pythia code for generating and recording muon events

1.7 Week 6

- Generating theoretical cross sections to compare to 5TeV LHCb data
- Used built-in Pythia functions to obtain a total cross section, which I then used to calculate a weighting for each event recorded

1.8 Week 7

- Hiatus due to severe fatigue episode

1.9 Week 8

- Fixed cross section generating code so recorded muons have the correct weighting [3]
- Restructured code into one C++ file (`generate_z_events.cpp`) to generate muon events and `crosssections.py` to analyse them.

```
Muon pair weighting: 0.03pb
Events generated: 2000.0
Total cross section: (67.96 ± 0.96)pb

Cross section for 60GeV < M < 120GeV
(0.00 ± 0.00)pb

Cross section for pT > 20GeV
(0.00 ± 0.00)pb

Cross section for 2 < pseudorapidity < 4.5
(0.03 ± 0.00)pb
```

Figure 5: Output of `crosssections.py`: cross section for Z production for various cuts, based off the pair of highest energy muons per event generated.

1.10 Week 9

- Attempting to bugfix cross sections - weighting is correct but total cross section is higher than expected and higher than LHCb data analysis gives

1.11 Week 10

- Some attempted bugfixing of cross section generation code
- Mainly busy with other deadlines

References

- [1] ROOT Reference Guide. <https://root.cern/doc/v610/>. Accessed: 2020-10-15.
- [2] Introduction to Pythia 8. <https://arxiv.org/pdf/0710.3820.pdf>. Accessed: 2020-10-15.
- [3] TASI Lectures on Collider Physics. <https://arxiv.org/pdf/1709.04533.pdf>. Accessed: 2020-11-15.