Detecting (Anti-)Deuterons from the LHCb Experiment

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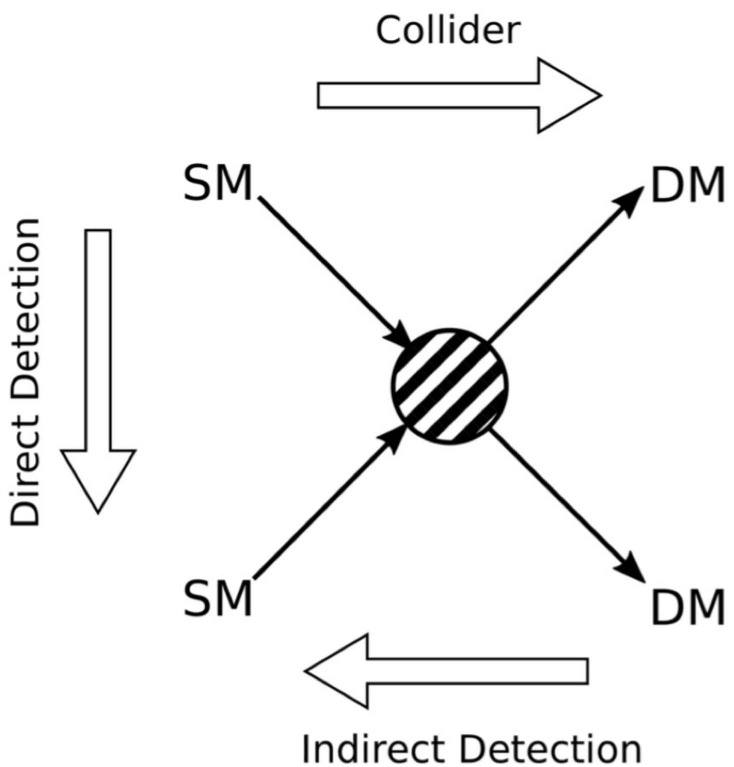
Project Aim and Motivation

- To devise a method to detect (anti-)deuterons from proton-proton collisions in the Large Hadron Collider b (LHCb) experiment
- Deuteron is a proton and neutron (nucleus of deuterium)
- This may help us to better understand properties of dark matter

- Annihilation of standard model particles may produce dark matter
- Annihilation of dark matter may produce detectable standard model particles such as anti-deuterons



Dark matter production schematic. Taken from[3].

Detecting (Anti-)deuterons

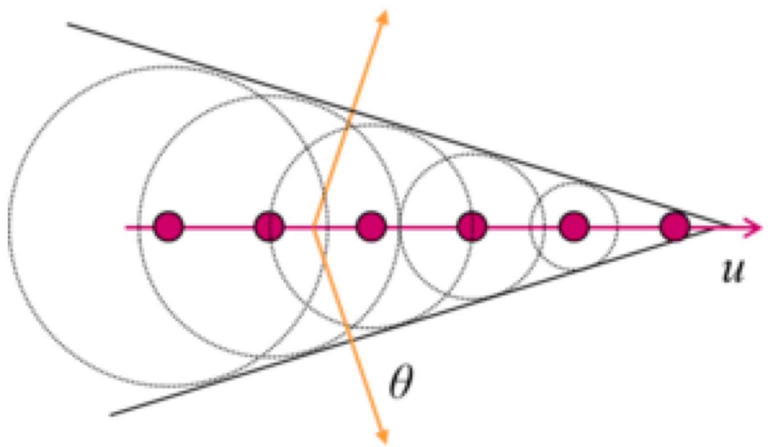
- Anti-deuterons, and thus also deuterons, can be produced in proton-proton (p-p) collisions such as in the LHCb experiment
- LHCb specialises in the differences between matter and antimatter
- To be able to identify particles being detected in the LHCb detector we need both the momentum and velocity of the particle
- The momentum is obtained by the sending particle through a magnetic field.

Cherenkov Radiation

- We can get the velocity of particle from the Cherenkov radiation angle.

- Produced when speed of particle in medium exceeds speed of light in medium, without exceeding speed of light in vacuum.

$$\cos(\theta_{ch})=\frac{1}{n\,\beta}, \quad \beta=\frac{v}{c}$$



Schematic of Cherenkov radiation produced in cone-like shape from a particle. Taken from [4].

Momentum Region

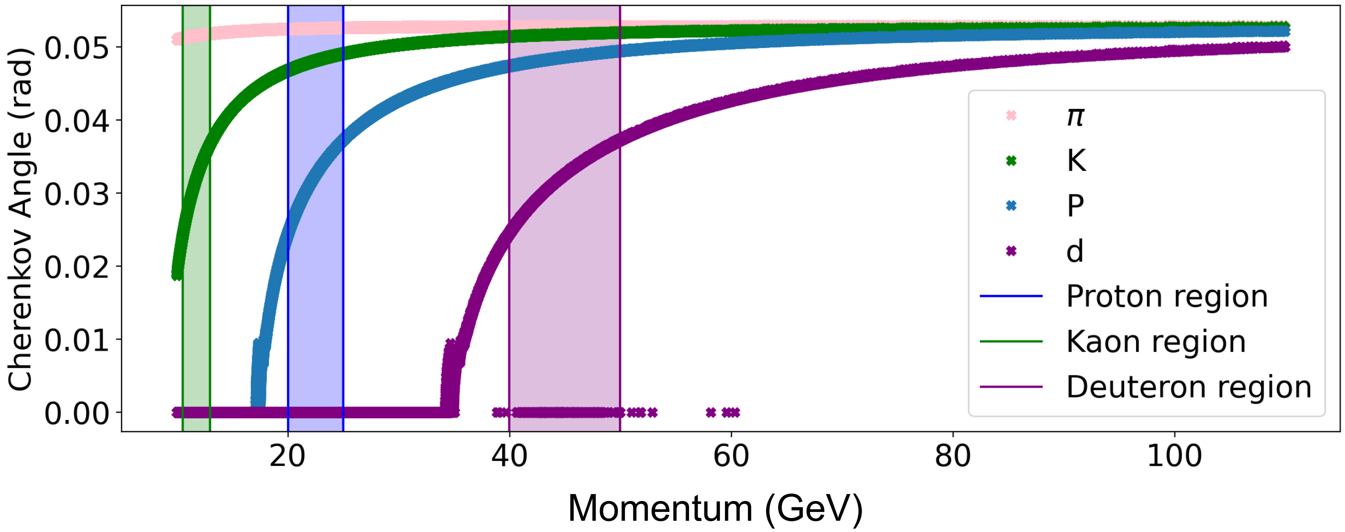
- With momentum and velocity we get the mass of the particle.
- Particles only radiate Cherenkov radiation in a specific momentum region.

Above Threshold

$$\beta = \frac{1}{n}$$

Below Saturation

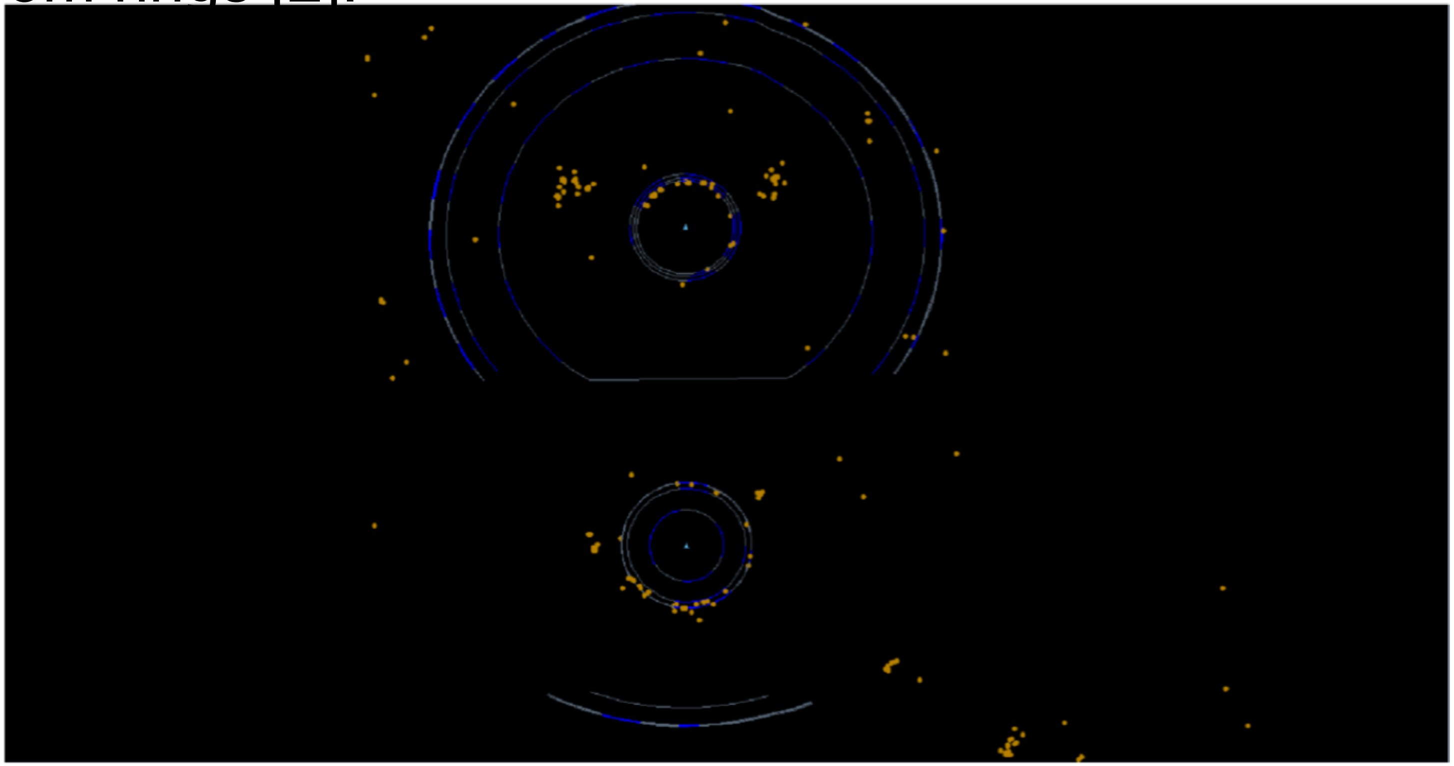
$$\beta \sim 1$$



Cherenkov angle over Momentum. Taken from [1].

RICH Detectors

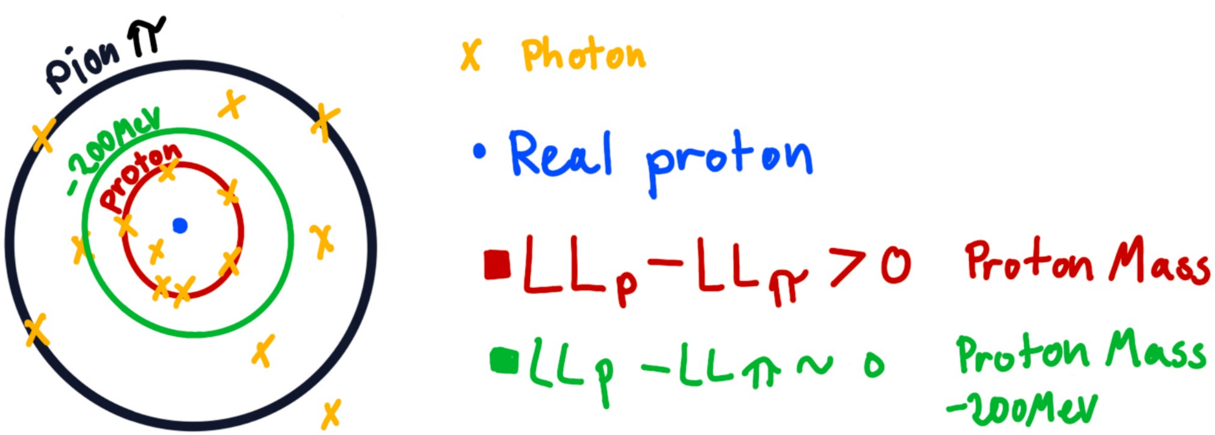
- Ring Imaging Cherenkov (RICH) detectors
- Photons at ring radii gives us mass of particle
- Was found that (anti-)deuterons cannot be detected directly from rings [2].



Expected Cherenkov rings in blue with photons depicted in orange, particle is shown in centre. Taken from (Sepp 2014)[5].

Our Method

- We are looking at ring radii above and below proton mass radius to estimate the background
- The mass of a proton is ~940MeV, we looked at the masses +/- 200MeV from the proton mass and 400MeV above the proton mass
- The data used consists of all the charged particles detected in the LHCb detector from a few seconds of p-p collisions in 2018.



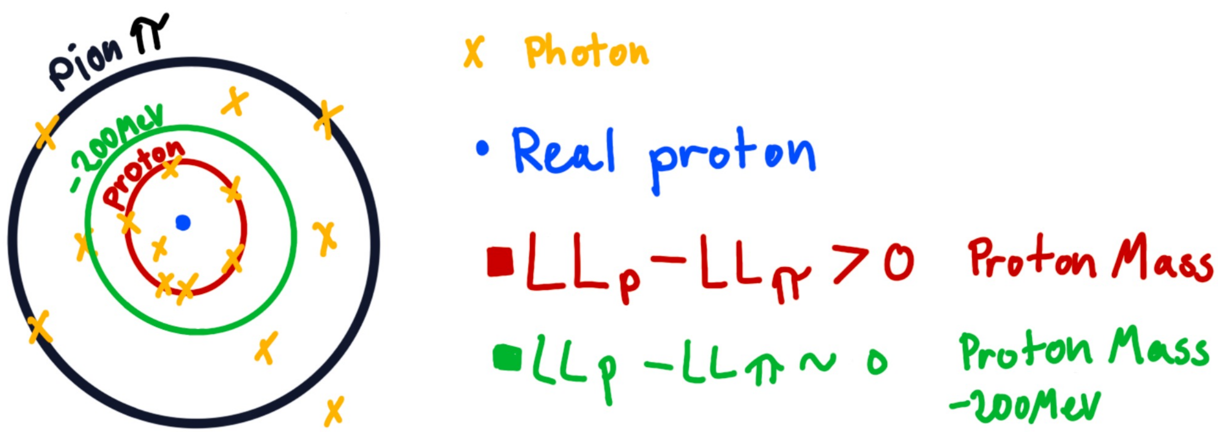
Delta Log Likelihood

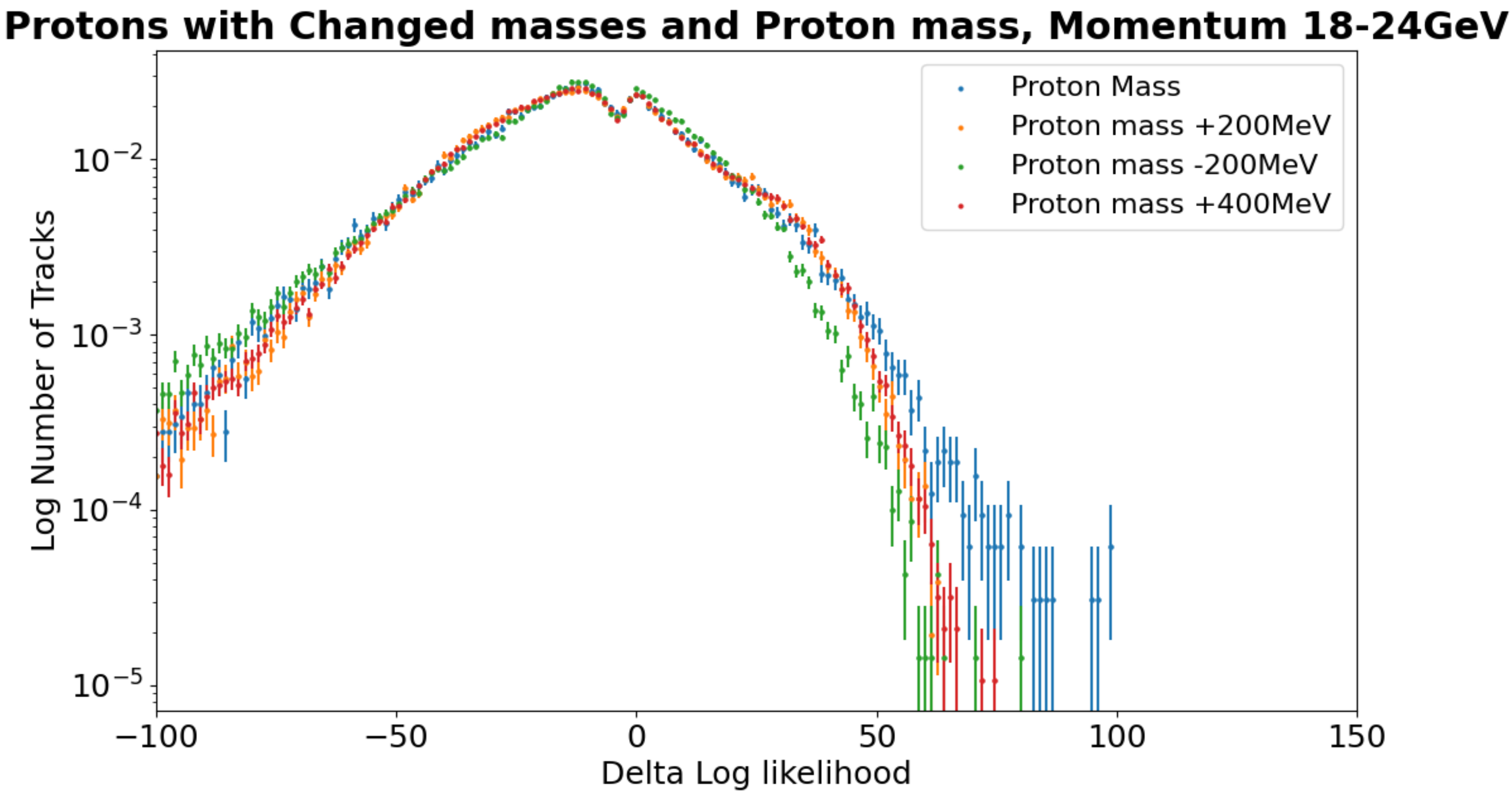
- The delta log likelihood is the log of the ratio of the likelihood that a track corresponds to a proton compared to a pion

$$\Delta LL = LL_{Proton} - LL_{Pion}$$

- If a given detection is a proton, we get a higher positive ΔLL

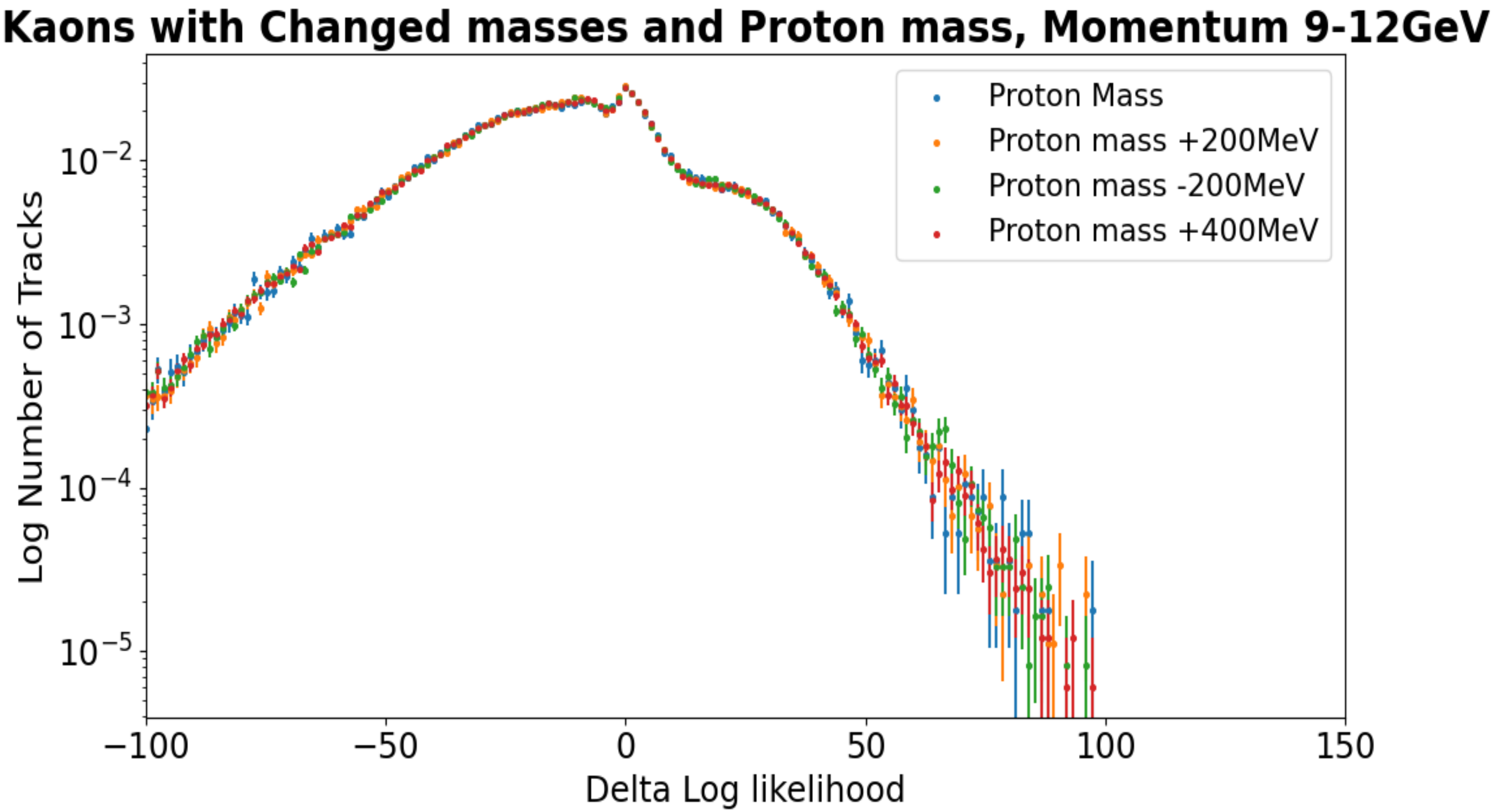
- If a detection is a pion or any other particle we expect $\Delta LL \leq 0$





Log of the Number of Tracks over the ΔLL in the momentum region 18-24GeV. Errors bars depict uncertainty taken to be square root of number of entries.

Results for Kaons



Log of the Number of Tracks over the ΔLL in the momentum region 9-12GeV. Errors bars depict uncertainty taken to be square root of number of entries.

Conclusions & Future Plans

- Method appears to be valid as shown with protons, we can see an obvious difference with proton mass to the changed masses
- Kaons appear unchanged
- More data needs to be analysed
- Apply method to deuterons
- Eventually calculate the number of protons (and deuterons) being detected

References

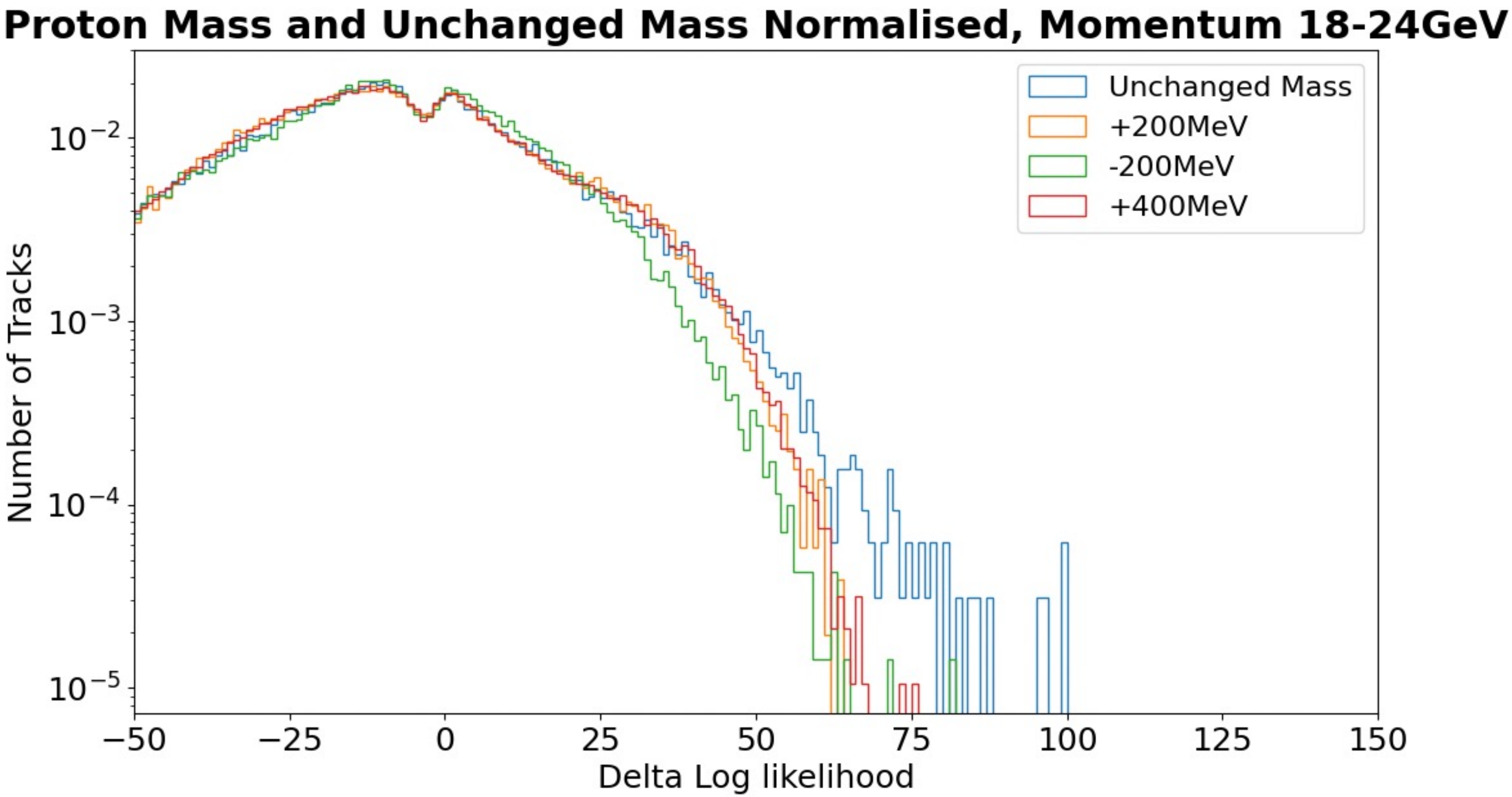
[1] E. Walton, *Searching for (Anti-)Deuterons using the LHCb Detector*, Honours thesis, Department of Physics, Monash University, 2021.

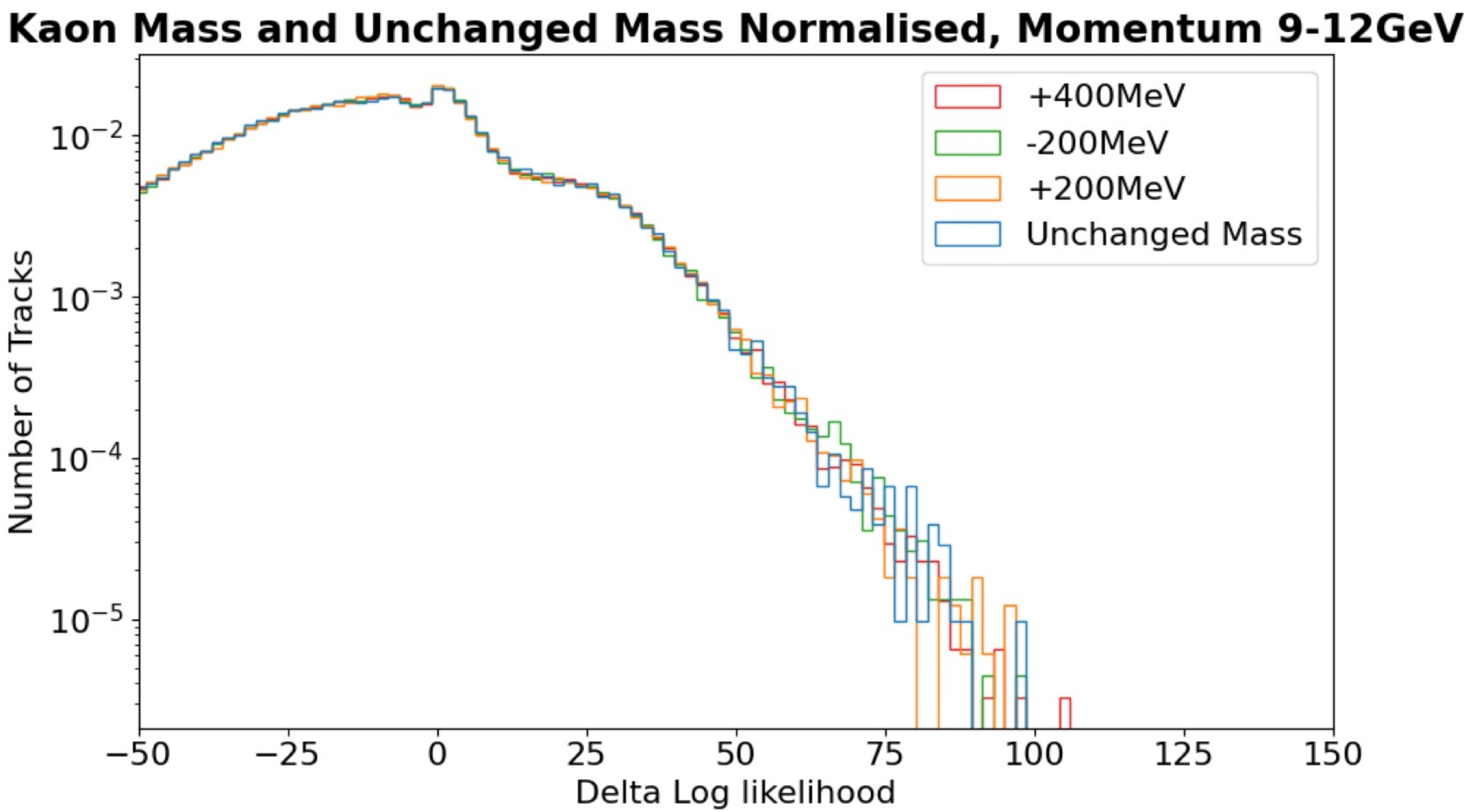
[2] S. K. Baker, *Measurement of Deuterons at LHCb*, PhD thesis, Department of Physics, Imperial College London, 2019.

[3] S. Giagu, *WIMP dark matter searches with the ATLAS detector at the LHC*, Frontiers in Physics 7 (2019) 75.

[4] H. Alaeian, *An Introduction to Cherenkov Radiation*, http://large.stanford.edu/courses/2014/ph241/alaeian2/. Accessed: 2/10/2022.

[5] I. Sepp, *Using Rare Decays to Probe the Standard Model at LHCb*, PhD thesis, Blackett Laboratory, Imperial College London, 2014.


Proton Mass and Unchanged Mass Normalised, Momentum 18-24GeV
Unchanged Mass
+200MeV
-200MeV
+400MeV
Number of Tracks
10^{-2}
10^{-3}
10^{-4}
10^{-5}
−50
−25
0
25
50
75
100
125
150
Delta Log likelihood



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