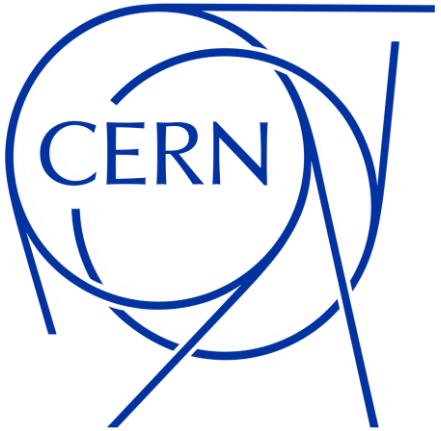

Studies of Short-Lived Kaon Decays at LHCb

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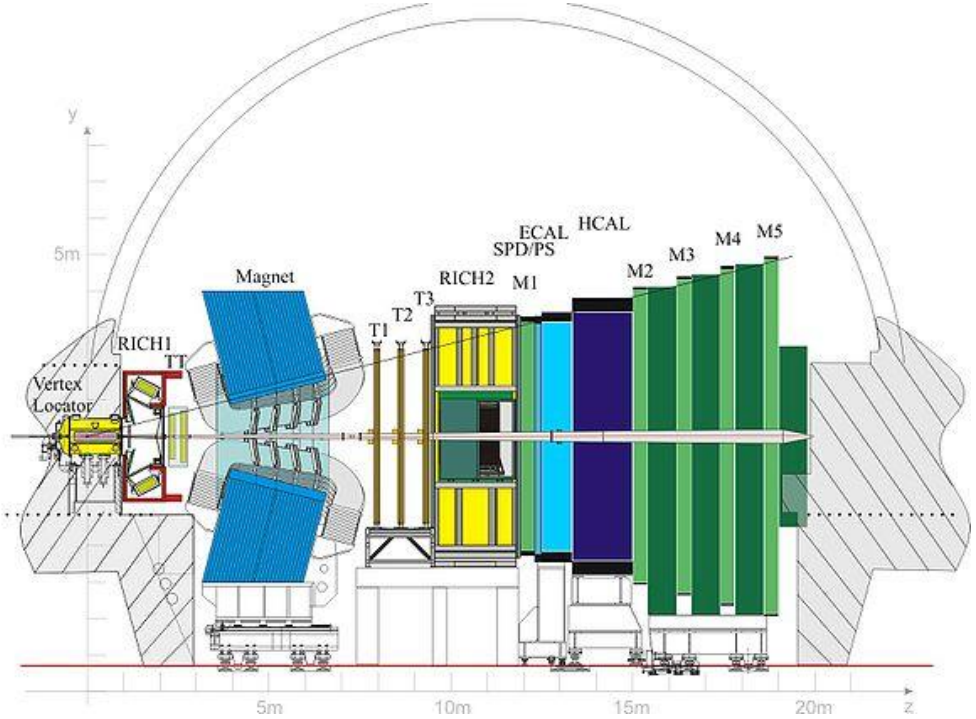
Overview of Experiment

- **Name: The Large Hadron Collider Beauty (LHCb) Experiment.**
- **Main focus: Matter-Antimatter Asymmetry & the beauty quark.**
- **Unique aspect: The LHCb only focuses on forward-moving particles (Unlike, say, ATLAS and CMS)**

What I worked on: Analysing the decays of the short-lived kaons via programs written within Python (Experimental/Analytical Physics)

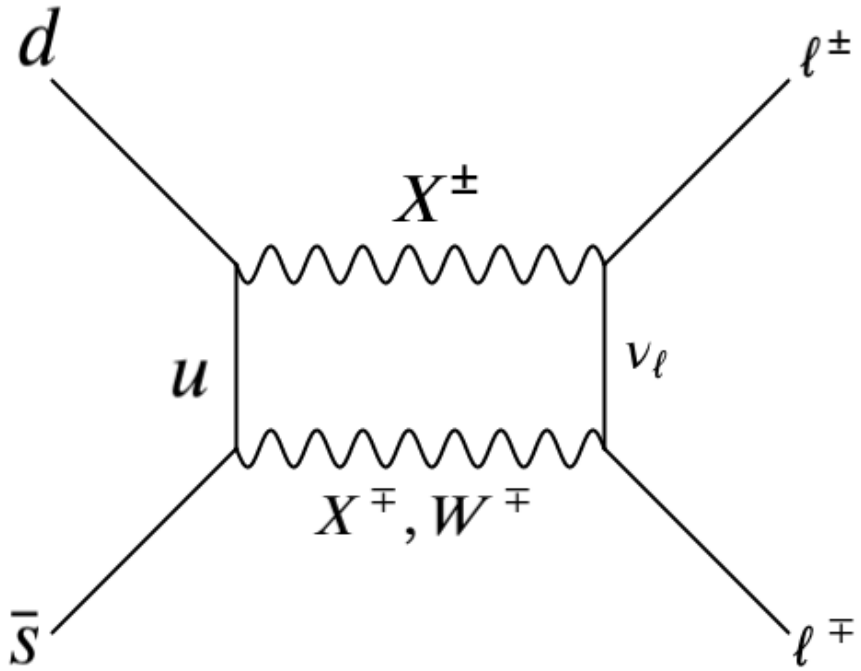


Some Definitions

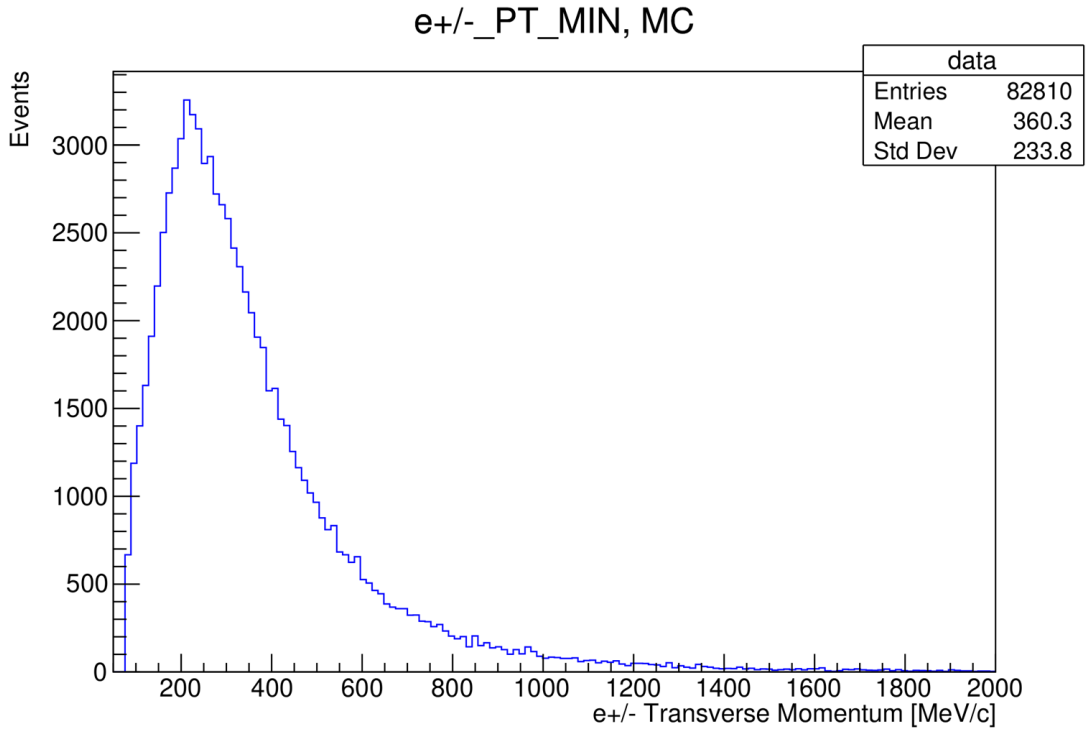
- **High-Level Trigger(HLT): A software application to help decide what events are interesting**
  - HLT1: Conducts partial-reconstruction of events
  - HLT2: Conducts complete reconstruction of events
    - Work was done entirely within HLT2
- **Reconstruction: The process of generating a set of tracks that model the path a particle takes through a detector.**
- **Rate: How many events are created within a given time period (i.e events/second)**
- **Cut: a maximum and/or minimum placed on a certain variable**
  - Completely up to the programmer to decide this value
  - Ex: electron pt > 80 MeV

Motivations

- **Decay of $K_s^0 \rightarrow e^+ + e^-$ can serve as a probe into beyond standard-model Physics.**



- **LHCb has undergone an upgrade, so it is now possible to study processes with low-pt electrons.**



Making Some Histograms - The Basics (1/2)

- Code being shown: The test line that was written for $K_s^0 \rightarrow e^+ + e^-$

- First function defines the cuts that will be applied to the electrons

- Second function defines the cuts that will be applied to the K-short candidates

```
#------------------------------------------------------------------------------------------------------
        #Full disclosure, this is test code written by a moron. As per Murphy's law, what can go wrong will go wrong#

def electrons_for_Ks():
        pvs = make_pvs()
        cut = F.require_all(
                F.P > 3 * GeV,
                F.PT > 0.3 * MeV,
                F.CHI2DOF <  16, #9,
                F.MINIP(pvs) > 0.5 * mm, #1.0 * mm,
                F.MINIPCHI2(pvs) > 25., #36.,
                F.PID_E > -3,
                F.SIZE(pvs) > 0,
        )
        return ParticleFilter(make_long_electrons_with_brem(), F.FILTER(cut))


def K_short_for_e(electrons, pvs): #Changed the name to see what happens
        combination_code = F.require_all(
                in_range(400 * MeV, F.MASS, 600 * MeV),  # mass of the combination
                F.MAXDOCACHI2CUT(25.),
                F.MAXDOCACUT(0.2 * mm),
                F.SIZE(pvs) > 0,
        )
        vertex_code = F.require_all(
                F.BPVLTIME(pvs) > 0.0045 * ns,
                F.BPVVDZ(pvs) > 0. * mm,
                F.MAXDOCACHI2CUT(25.),
                F.MAXDOCACUT(0.2 * mm),
                F.CHI2DOF < 25.,
                F.MINIP(pvs) / F.BPVVDZ(pvs) < 1. / 60,
                F.MINIP(pvs) < 0.4 * mm,
                F.BPVVDRHO(pvs) > 3. * mm,
                F.BPVDIRA(pvs) > 0.999,
                F.SIZE(pvs) > 0,
        )
```

Important note: This code was used for learning purposes

Making Some Histograms - The Basics (2/2)

Feed the simulation files through the written test line, then you've managed to generate some results!

```
Input files
options.input_type = "ROOT"
options.input_files = [
        "root://x509up_u89950@eoslhcb.cern.ch//eos/lhcb/grid/prod/lhcb/MC/Upgrade/XDIGI/00154132/0000/00154132_00000012_1.xdigi",
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```
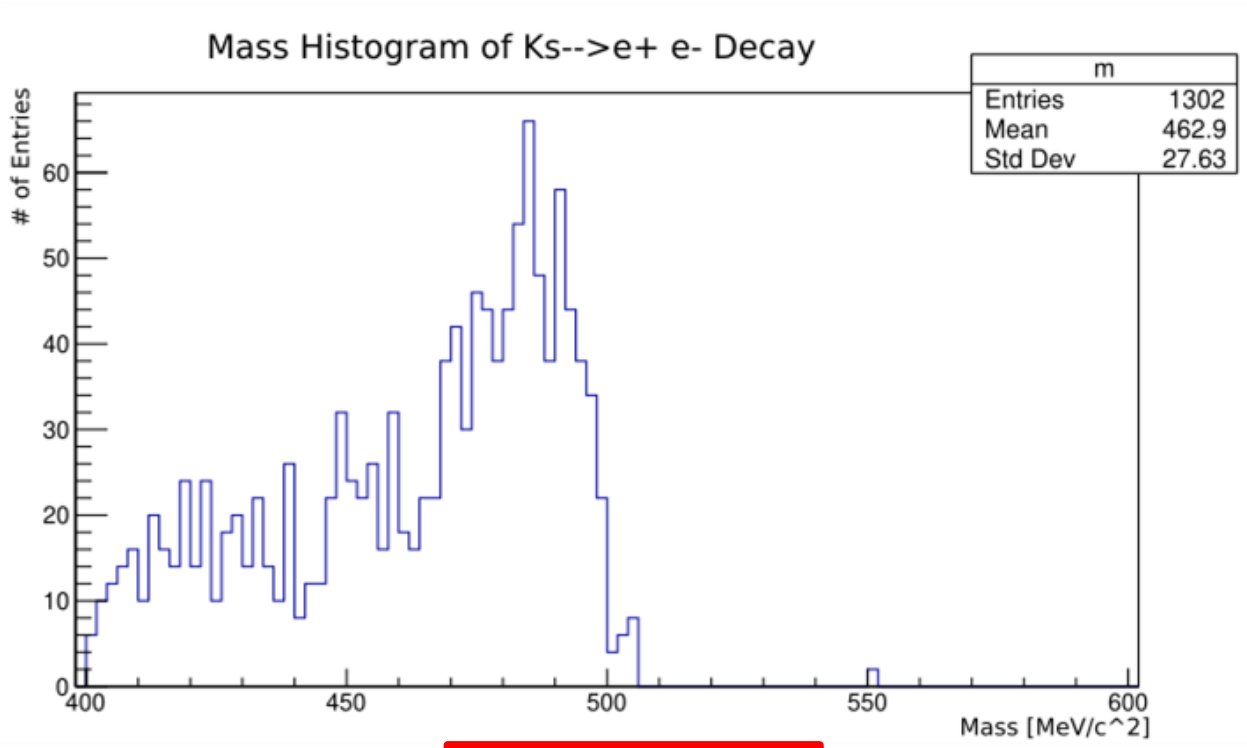
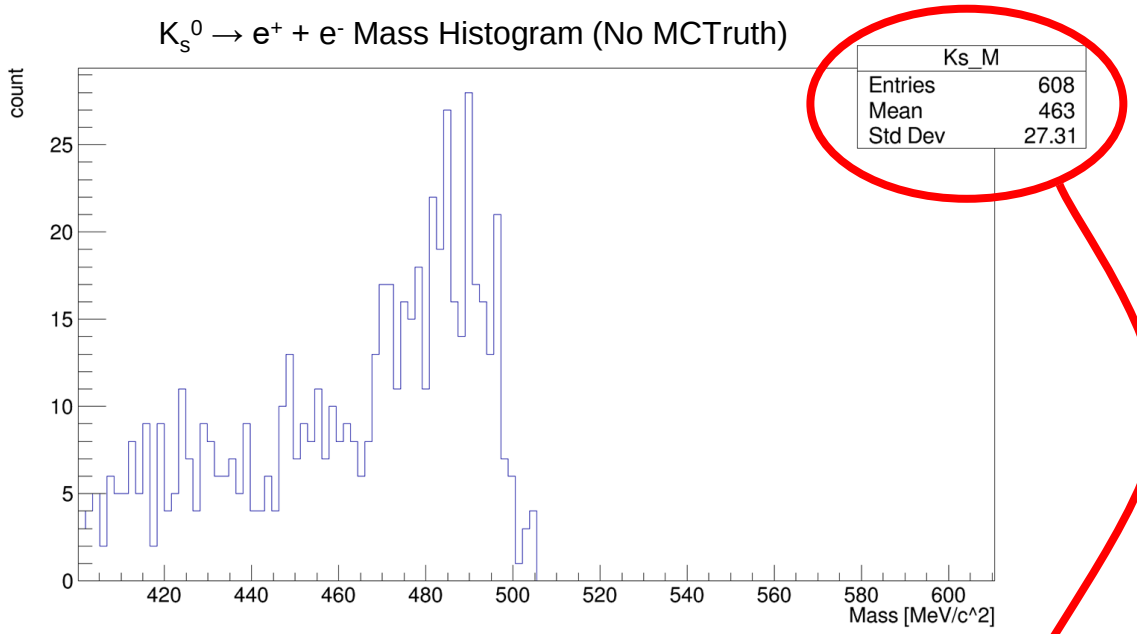



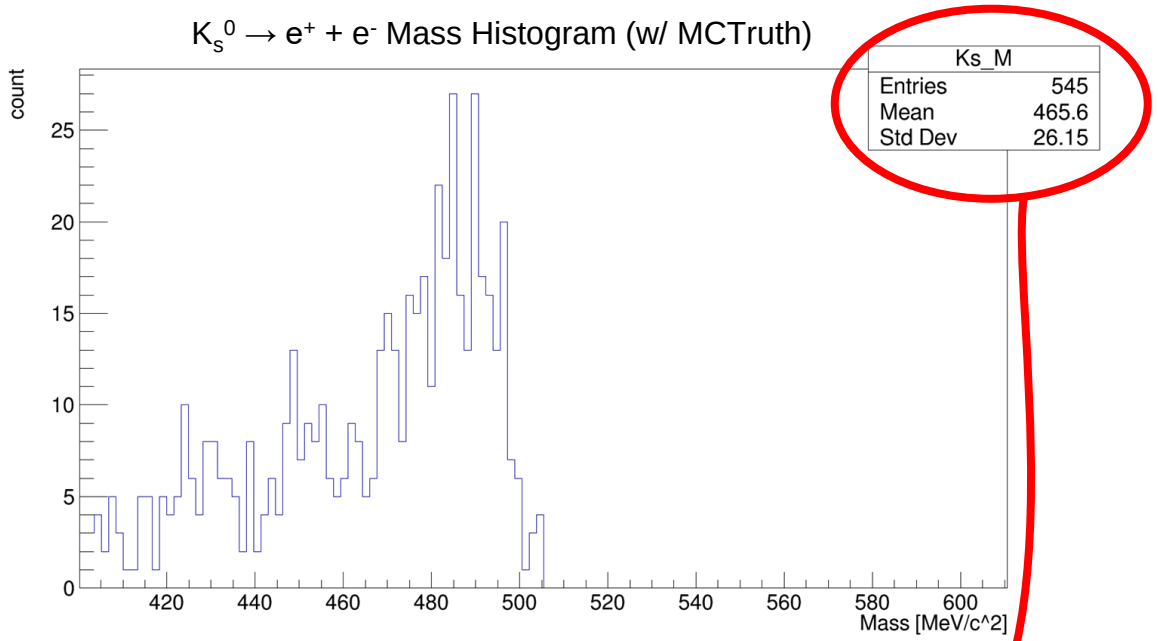
Input files → A Histogram

Making Some Histograms - Verifying the Results

Histogram without MCTruth

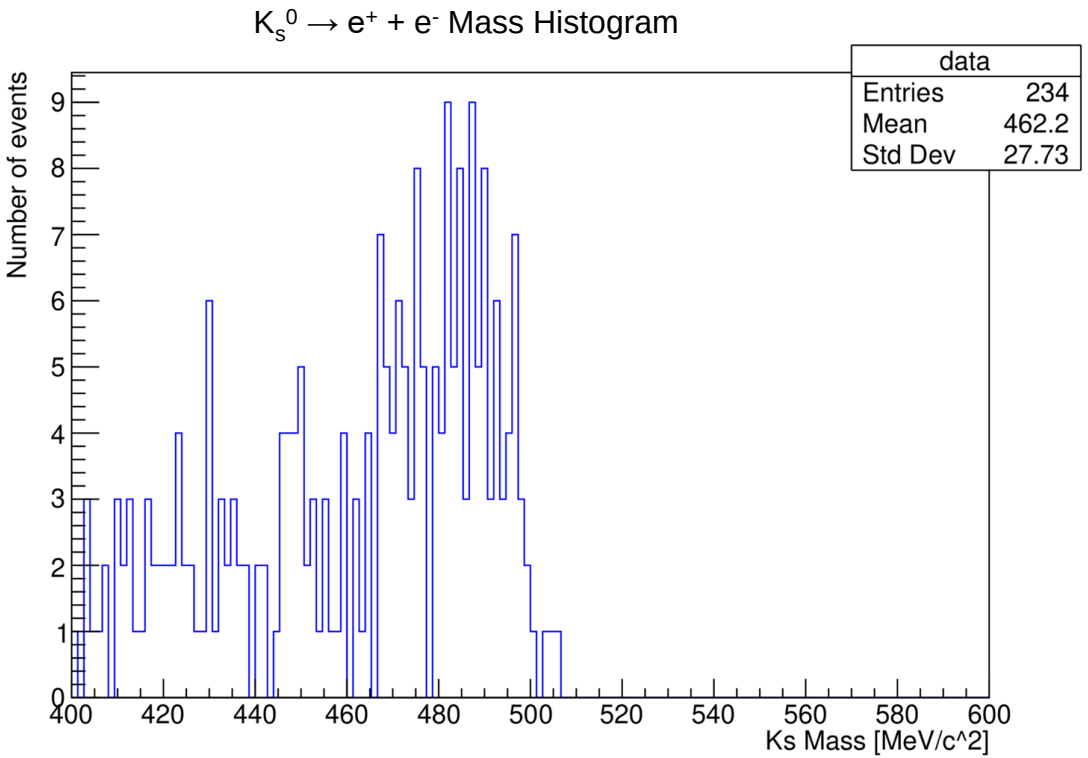


Histogram with MCTruth

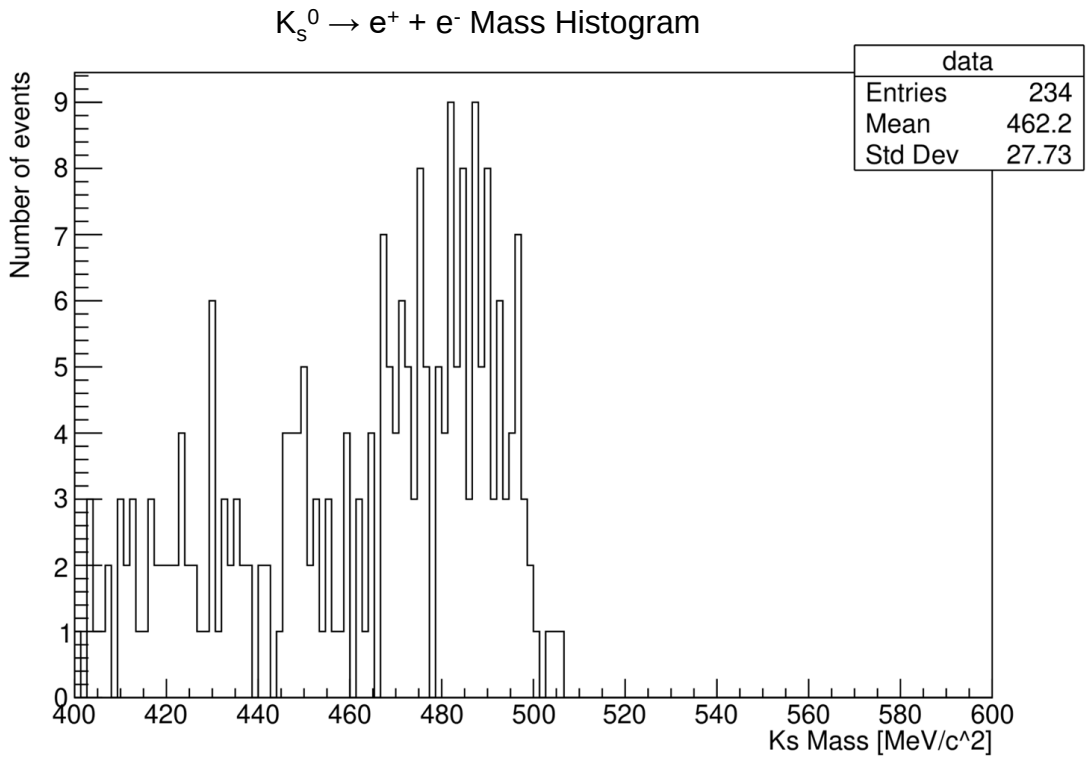


Notice the difference?

Final Results-
Effect of Bremsstrahlung on Ks mass histogram



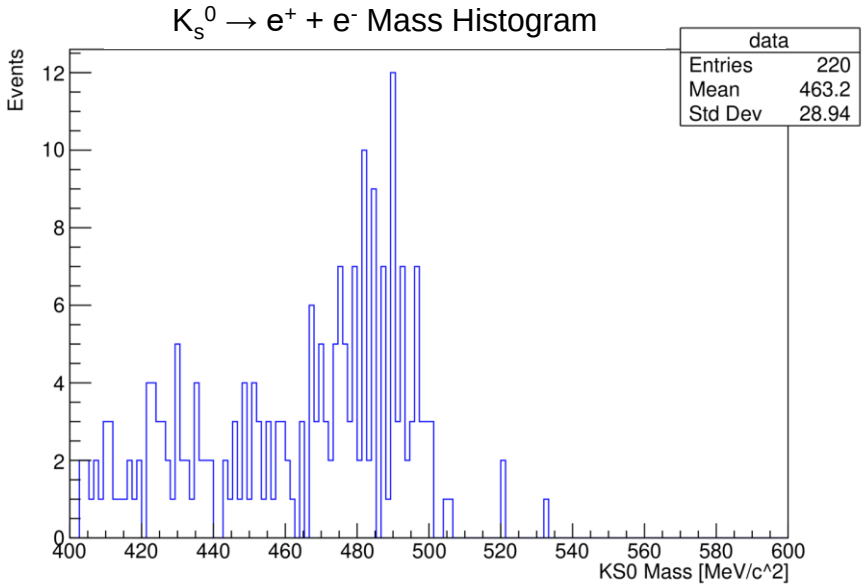
Histogram that has been corrected for the Bremsstrahlung effect



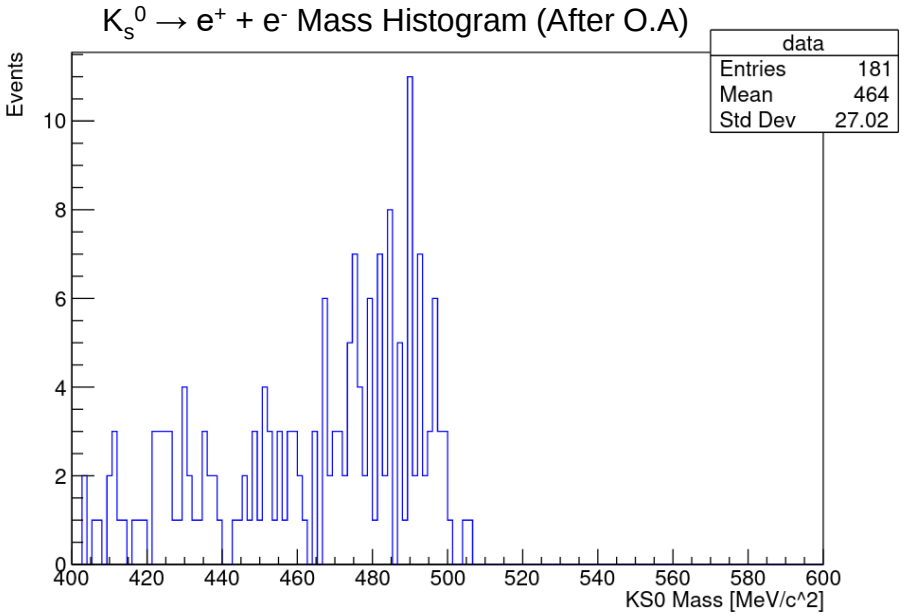
Histogram that has not been corrected for the Bremsstrahlung effect

Final Results - Offline Analysis

- **Main purpose was to optimize cuts used in generation of $K_s^0 \rightarrow e^+ + e^-$ mass histogram.**
  - Maximum rate of a line: **100 Hz**
  - Rate output of $K_s^0 \rightarrow e^+ + e^-$ line: **880 Hz**
- **To minimize the rate, offline analysis is required.**



- reduction in events: **~18%**
- New rate output: **~551 Hz**



What I Have Learned

- **I have learned…**
  - How research within the LHCb collaboration is conducted.
  - How to write an HLT2 line as well as run tests on that line to learn more about the reconstructed events.
  - More about Python and the various ways it can be used for data analysis.
  - How to work in Linux.
  - How to work with ROOT (to a degree).

- **Quick Acknowledgement: I never would have gotten this far without my supervisor, Dr. Sergio Arguedas Cuendis. He helped me at every step along the way, and I cannot thank him enough for being there to answer my questions (even the stupid ones).**

Conclusion

What's been done:

- **A peak has been found in the $K_s^0 \rightarrow e^+ + e^-$ mass histogram**
  - (As far as I know) this measurement has never been made before within the LHCb
- **The results within the mass histogram have been proven to be signal events**
  - Proven via Monte Carlo Truth
- **Bremsstrahlung has been proven to have no effect on the mass histogram**
  - More work is needed

What still needs to be done:

- **Verification is needed for the Bremsstrahlung result.**
- **The rate of $K_s^0 \rightarrow e^+ + e^-$ needs to be lowered even further**
  - Rate has been brought down to 551 Hz. That's progress, but it's still too high.

Thank you for a great summer. It was quite the journey

Any Questions?

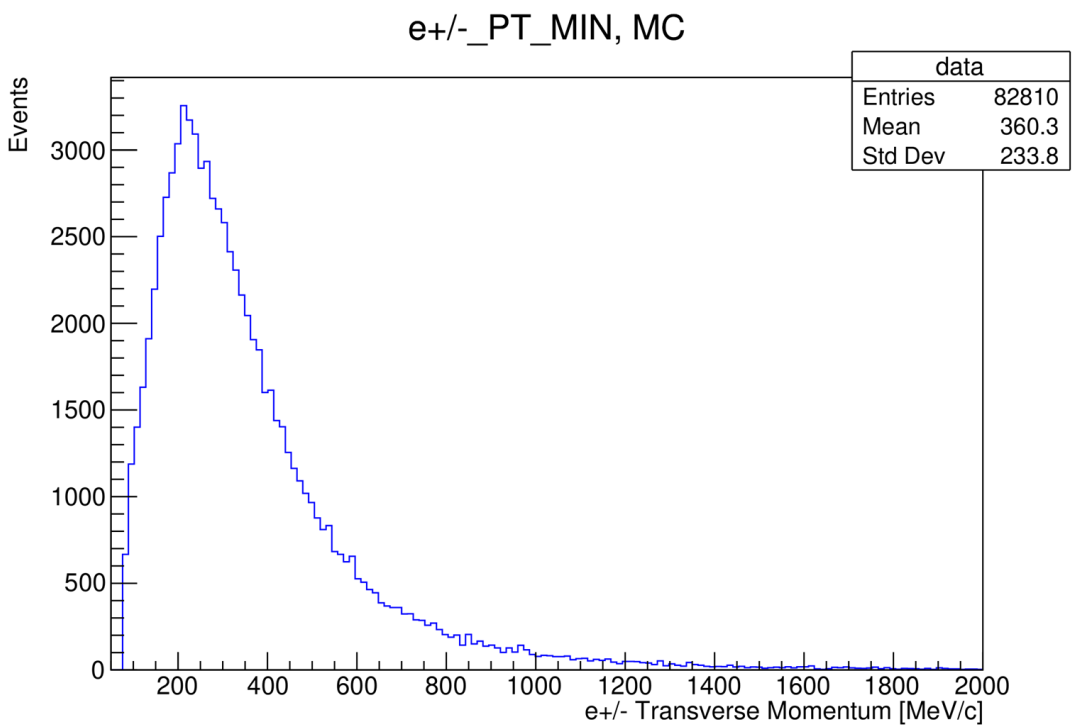
Backup Slides

Table of cuts

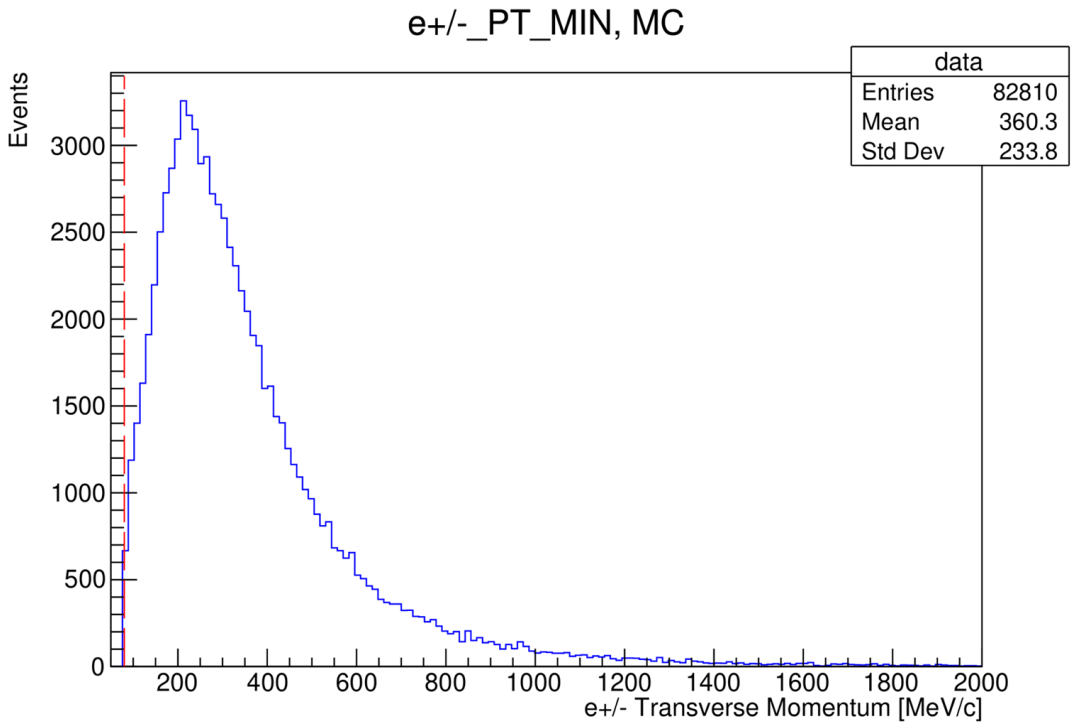
Variables	Default cuts	Tight cuts
e+/-_P_MIN	3.e3 MeV (3 GeV)	3.e3 MeV (3 GeV)
e+/-_PT_MIN	80 Mev	115 MeV
e+/-_PID_E_MIN	-3	-3
e+/-_CHI2DOF_MAX	9	2.5
e+/-_MINIP	1 mm	1 mm
e+/-_MINIPCHI2	36	256.
Ks_BPVVDZ_MIN	0 mm	0 mm
Ks_BPVVDRHO_MIN	3 mm	3.7 mm
Ks_BPVDIRA_MIN	0.999	0.996
Ks_BPVLTIME_MIN	0.0045 ns	0.0045 ns
Ks_MAX_IPBPVVDZ_RATIO	1 / 60	1 / 60
Ks_MAXIP	0.4 mm	0.3 mm
Ks_MAXDOCACUT	0.2 mm	0.2 mm
Ks_MAXDOCACHI2CUT	25.	25.

Histograms of Variables used (1/3)

- **Electron transverse momentum**



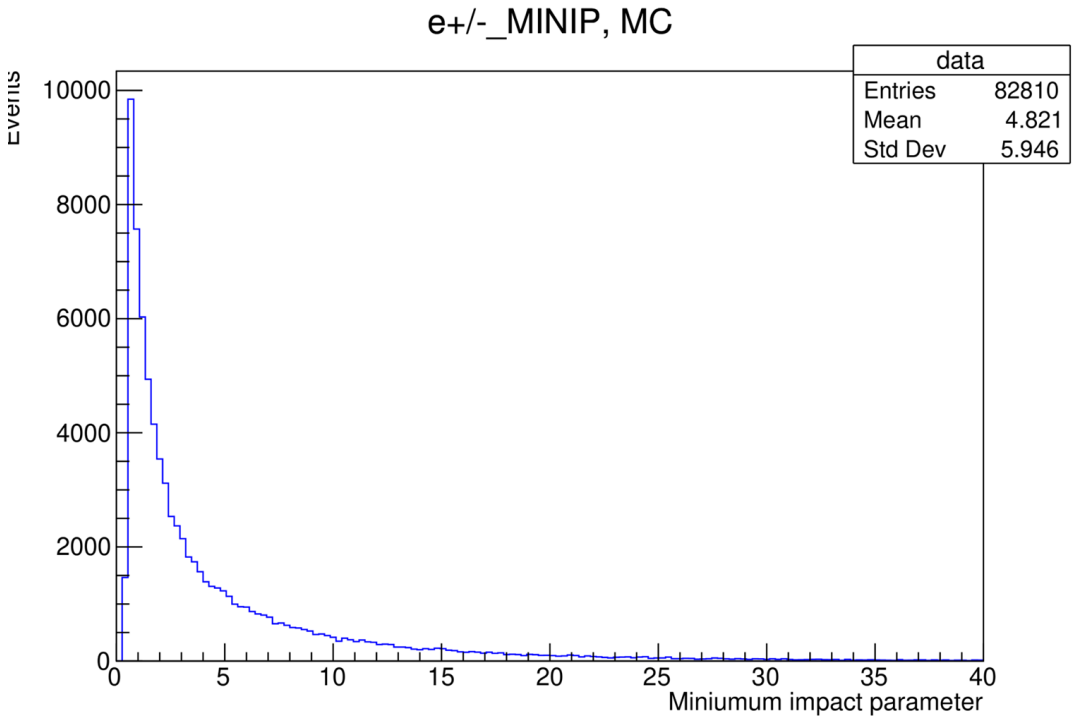
(No cut)



(Default cut)

Histograms of Variables used (2/3)

- **Electron minimum impact parameter**



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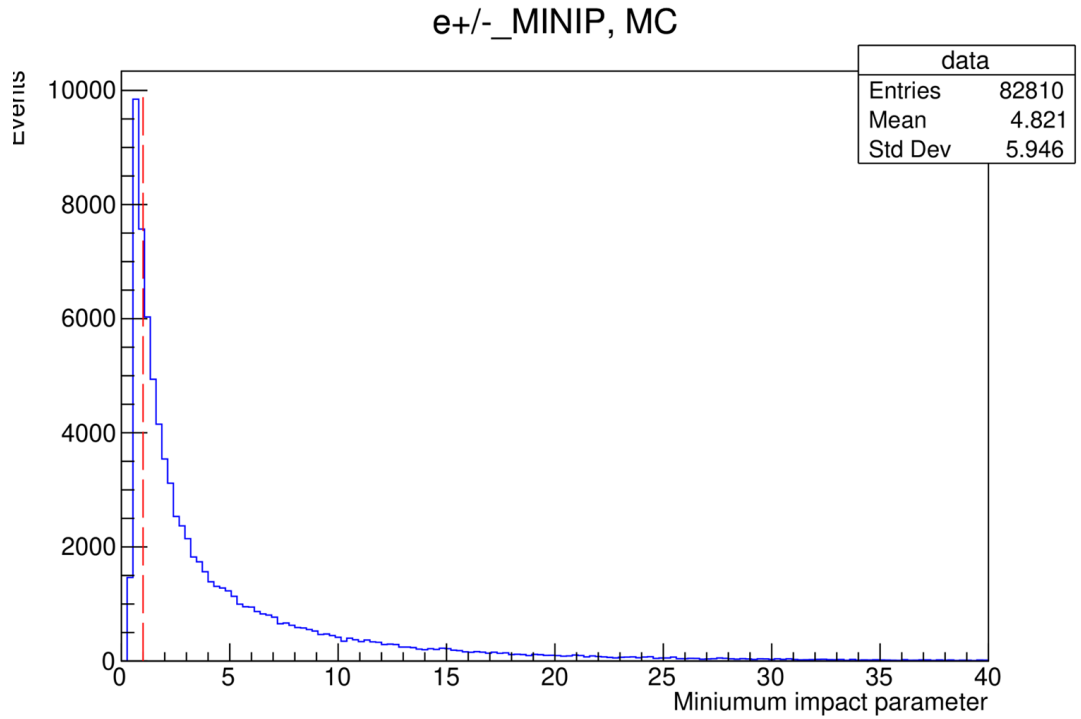
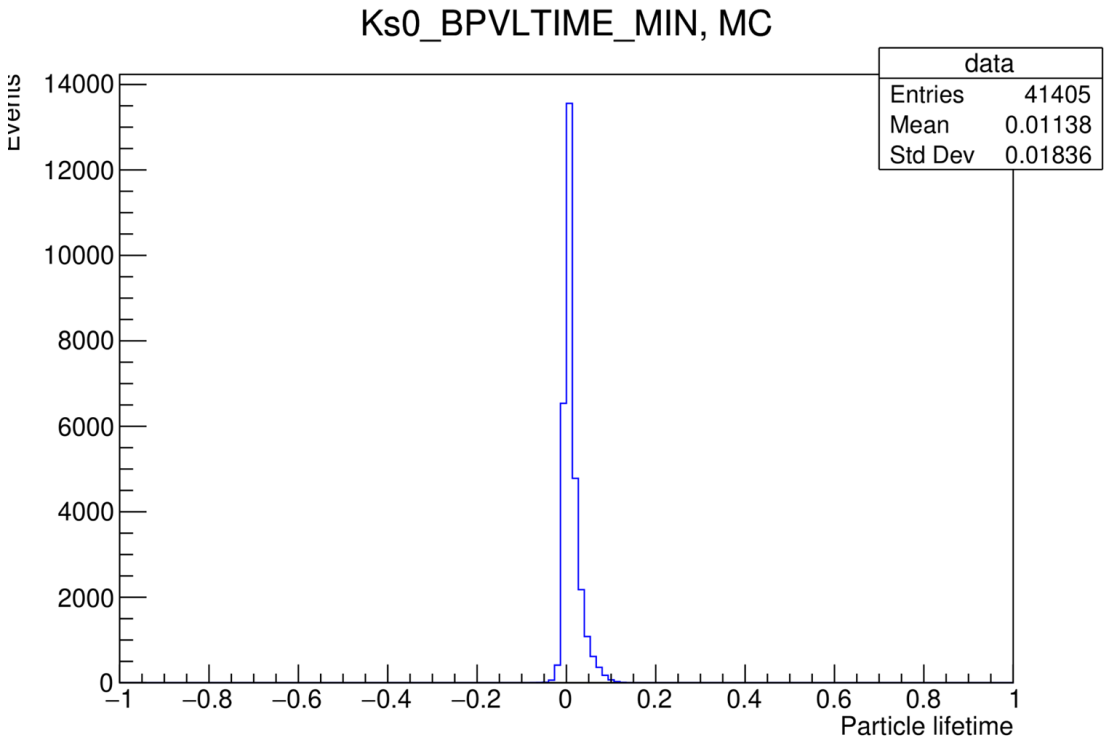


(Default cut)

Histograms of Variables used (3/3)

- **K-short minimum lifetime**



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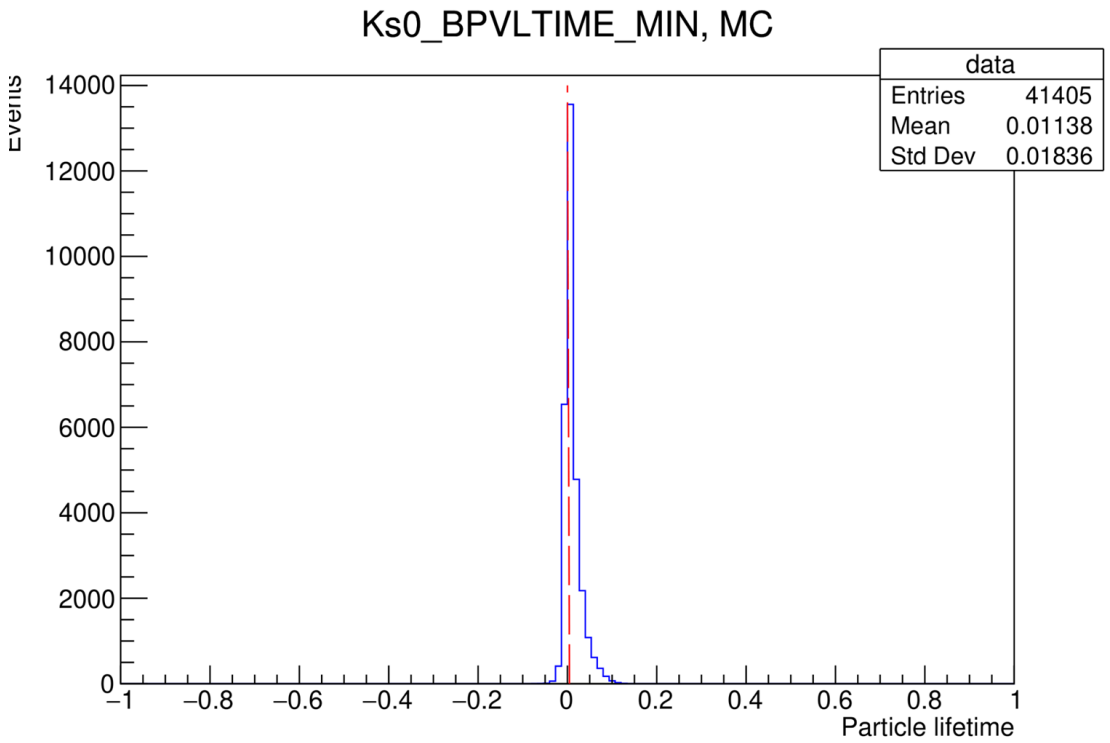

(Default cut)

HLT1 Line for $K_s^0 \rightarrow e^+ + e^-$

- **Merge request for decay line**
- lhcb/Allen!1134

- **Intended for strange decays such as $K_s^0 \rightarrow e^+ + e^-$.**
  - Work is still being done on this line

LHCb dataflow