Physics Impact of Elevated DS Vacuum Pressure

Andy Edmonds

Future Fermilab Muon Program Workshop, Caltech, March 27th 2023

Introduction

Nominal operating vacuum level for the Mu2e tracker is 10^{-4} Torr of Ar:CO_2

I've recently performed simulations to understand the physics impact of elevated pressures on

- track resolution; and
- hit rates

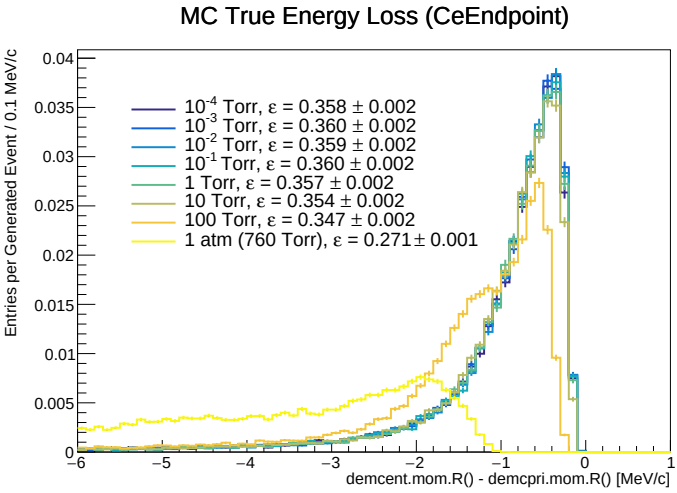
Note: these are not the only considerations, there is also e.g. the Paschen limit, differential pressure across antiproton window, production target lifetime etc.

Effect on High-Energy Electrons

Simulated 100k 105 MeV/c electrons from stopping target with different gas pressures

Shown right: MC true energy loss for different pressures

- efficiencies are $N_{\text{entries}}/N_{\text{gen}}$



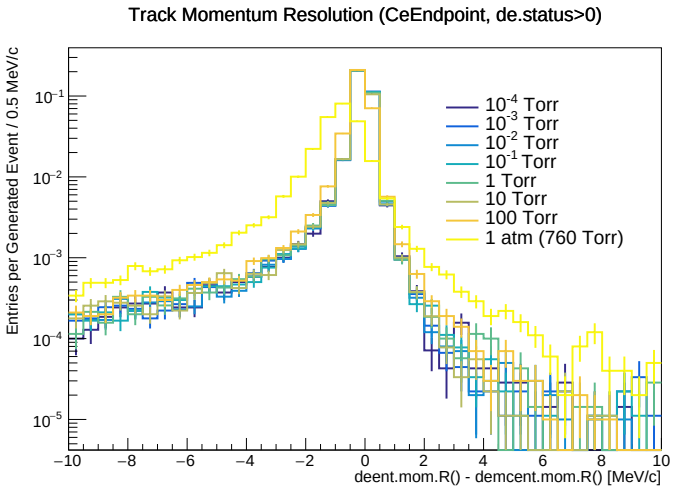
"demcent" = mc momentum of particle at tracker entrance
"demcpri" = mc momentum of particle when created

Effect on High-Energy Electrons

Simulated 100k 105 MeV/c electrons from stopping target with different gas pressures

Shown right: track momentum resolution of successful fits

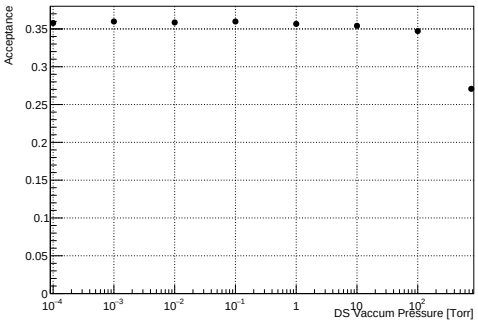
- no other cuts



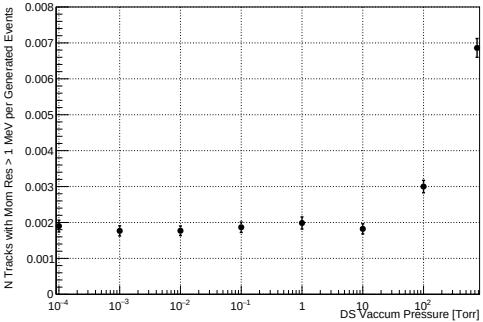
"deent" = reco momentum of particle at tracker entrance
"demcent" = mc momentum of particle at tracker entrance

CeEndpoint Summary

Acceptance vs Pressure



Tracks with mom. res. $>$ 1 MeV/c (no cuts)



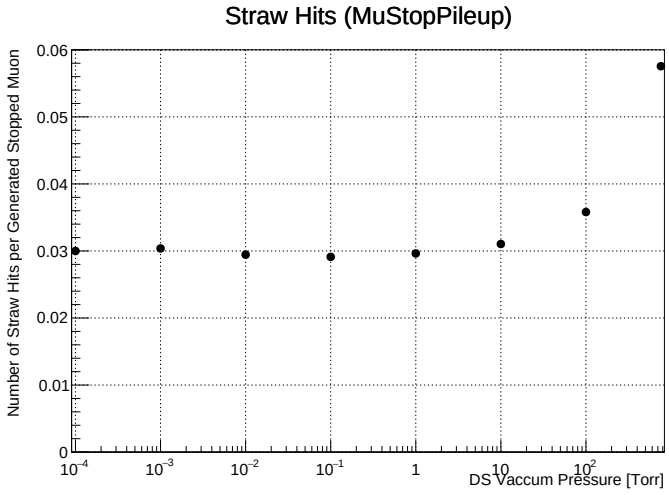
No effect on Ces up to 10 Torr

Straw Hit Rates (from muon stop products)

Simulated 4M muon stops

Shown right: straw hit rate vs. pressure

- includes hits from muon stops in stopping target

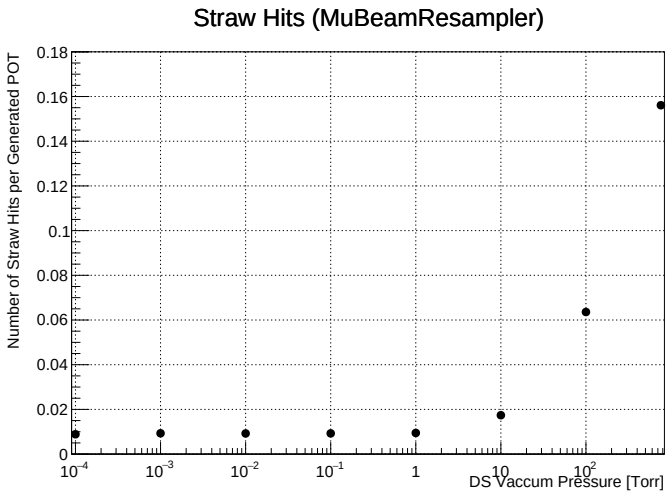


Straw Hit Rates (from muon beam)

Simulated 2M POT, resampled muon part of beam at end of TS by factor of 2 (4M POT equiv.)

Shown right: straw hit rate vs. pressure

- includes hits from muon stops in gas and any hits at early times

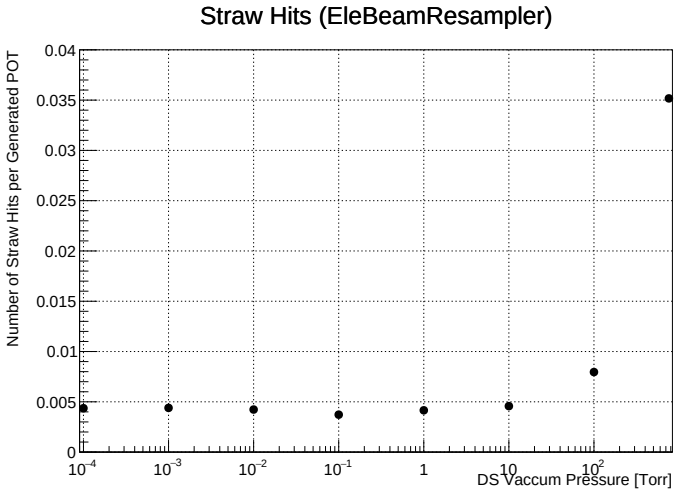


Straw Hit Rates (from muon beam)

Simulated 2M POT, resampled electron part of beam at end of TS by factor of 2 (4M POT equiv.)

Shown right: straw hit rate vs. pressure

- includes hits at early times



Mu2e → Mu2e-II

Mu2e Hit Rates (assuming 0.0015 stopped muons / POT, 39 M POT per pulse):

- from muon stops: 0.03 hits / stopped muon → 4.5 $\times 10^{-5}$ hits / POT → 1.8k hits / pulse
- from beam (all times): 0.015 hits / POT → 585k hits / pulse

Mu2e-II Hit Rates (assuming 9.1×10^{-5} stopped muons / POT, 1.4 B POT per pulse):

- from muon stops: 0.03 hits / stopped muon → 3.8k hits / pulse
- from beam (all times): 0.015 hits / POT → 21 M hits / pulse

Conclusion

Negligible physics impact of pressures up to 1 Torr

- but many other factors to consider

Mu2e $\rightarrow$ Mu2e-II

- hits from muon stops in target increase by a factor of $\sim$2
- hits from beam flash increase by a factor of $\sim$35

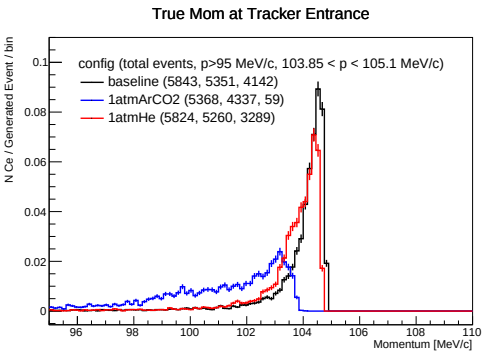
Back Up

Helium instead of Ar:CO_2

A while ago, I took a quick look at 1 atm of He instead of Ar:CO_2

- potential scenario: production target gets too hot, helium could help with cooling

Much less energy loss than 1 atm of Ar:CO_2 but not as good as 10^{-4} Torr of Ar:CO_2



10k CeEndpoints