Mu2e-II: Sensitivity Estimate

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Working Group Report for
Mu2e-II Workshop
26th August 2020

Introduction

- The Sensitivity & Simulation group brings together everyone's efforts and aims to make the final calculation of the SES for the Mu2e-II design for Snowmass 2021.
- It is vital that we engage with all the other sub-groups and experts to ensure we have the most up-to-date information in the Mu2e-II Offline Software.
- Once we have updated geometries we can begin the large scale simulation campaign which is necessary for the physics analysis.
- Today we will document progress made since the previous Workshop in July 2020.

Sensitivity Estimates Group Details

- Co-conveners are **Lisa Goodenough (FNAL), Sophie Middleton (CalTech), and Yuri Oksuzian (ANL)**
- Current group members: Rebecca Chislett (UCL), Michael Hedges (Purdue), Cole Kampa (Northwestern), Manolis Kargiantoulakis (FNAL), Michael Mackenzie (Northwestern)

- Mailing list: mu2e-ii-sensitivity@listserv.fnal.gov
- Slack channel: #mu2e-ii_sensitivity_and_simulations (in Mu2e domain)

Please contact us if you are interested in joining

Summary of Meeting with PS/PT Team

Very productive discussion with the PS, PT, and Accelerator teams. Main take-aways are:

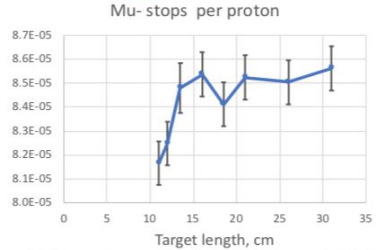
- M. Mackenzie will implement a preliminary design into Mu2e-II Offline: he is modifying the geometry config file to

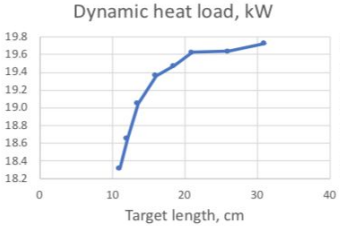
  (1) remove the pbar absorbers

  (2) adding several configurable production target options

- Designs will be based on work done by Vitaly et al. as part of LDRD work
- This is crucial first step in Mu2e-II Simulation Campaign

W target for 100-kW 800-MeV proton beam





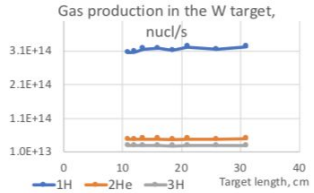
Peak Edep density
For the W target
(first upstream cm) :
8450 W/cm^3
(1.08E-11 J/cm^3/p)

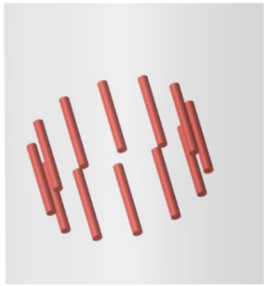
For a 16-cm-long straight W target (R=0.3 cm):

6.67E18 mu- stops/5yr (8.54(9)E-5 stops/p)

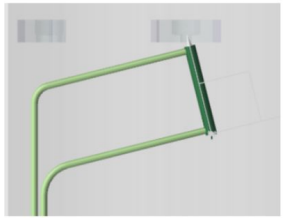
339 DPA/yr (Nordlund model); for comparison:

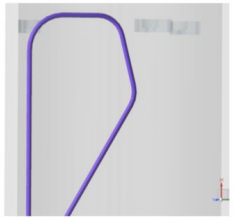
8.0E17 mu- stops/5yr (0.00134 stops/p) for the baseline Mu2e (Hayman), dynamic heat load in the baseline is ~739 W, see doc-db 24265-v2 (K.Lynch)





Rotating Elements

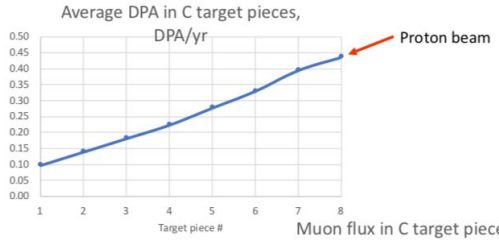


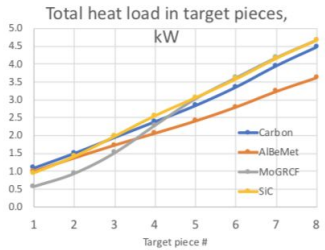


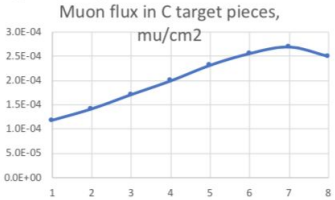
Fixed Granular with Gas Cooling

Conveyor

Low-density material targets







Peak Edep density (piece #8)
For the C target:
228 W/cm^3 (2.92E-13 J/cm^3/p)

For more details:
Mu2e doc-db 33926

Summary of Meeting with Theory Convenors

Understanding Sensitivity to $\mu \rightarrow e+X$:

- This decay is possible in many theories of BSM physics that include light scalars (such as majorons and axion-like particles) or extra-light gauge bosons
- Mu2e-II may be able to improve on current bounds for BR $\mu \rightarrow e+X$
- See e.g. arXiv:1110.2874v2 [hep-ph], arXiv:2005.07894[hep-ph]
- Sophie has begun implementing spectrum for $\mu \rightarrow e+J$ where J is a majoron:

$$\left.\frac{1}{\Gamma_0}\frac{d\Gamma}{dE_e}\right|_{\mathrm{Al},\, E_e > 100\ \mathrm{MeV}}$$

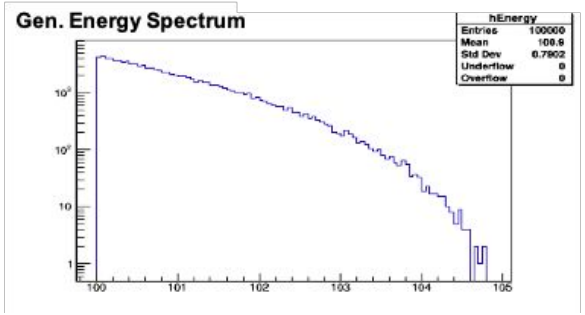
$$= \frac{1}{m_\mu}\left(3.289\times10^{-10}\delta + 3.137\times10^{-7}\delta^2 + 1.027\times10^{-4}\delta^3 + 1.438\times10^{-3}\delta^4 + 2.419\times10^{-3}\delta^5 + 1.215\times10^{-1}\delta^6\right).$$

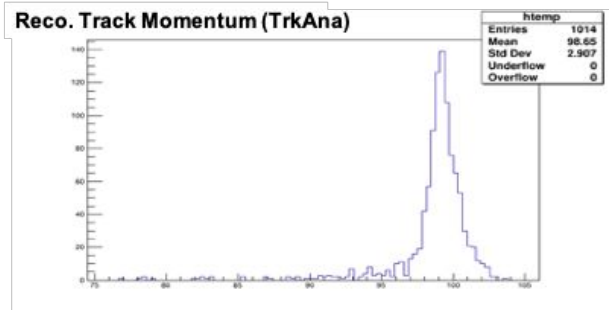
$$\delta := \frac{E_\mu - E_e - \frac{E_e^2}{2m_N}}{m_\mu}.$$

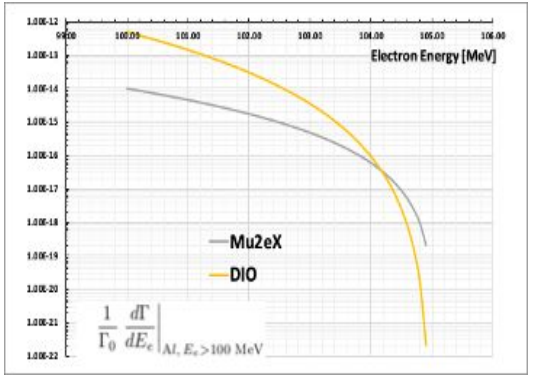
Summary of Meeting with Theory Convenors

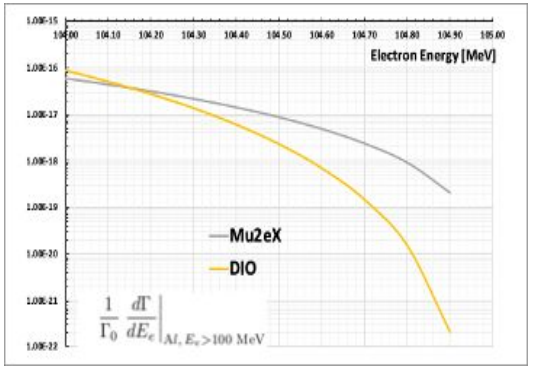
Understanding Sensitivity to $\mu \rightarrow e+X$:

- Need to understand sensitivity in context of DIO in Mu2e-II environment
- Generate spectrum → Reconstruction code → What do we see?





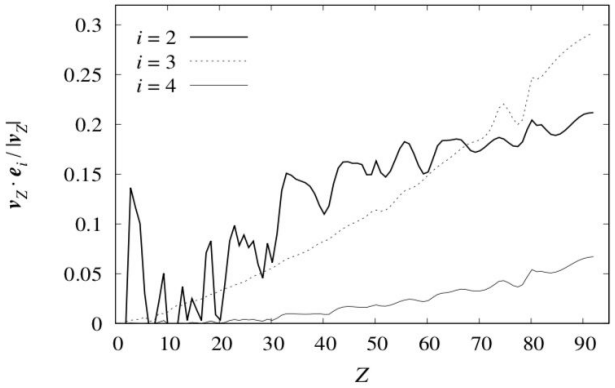




Summary of Meeting with Theory Convenors

Lithium as a Stopping Target:

- Literature reviewed: arXiv:1810.018842
- Comparing heavy to light targets can distinguish scalar vs vector coefficients
- Lithium also has a long lifetime, making it appropriate for a Mu2e style experiment
- As part of the Mu2e-II process a small team has began undergoing a Stopping Target literature review
- Lithium has not yet been discussed
- We know Lithium target would be difficult practically, but not impossible -further research is required here



Outcome of discussion on Mu2e-II Offline Code Location/Practices

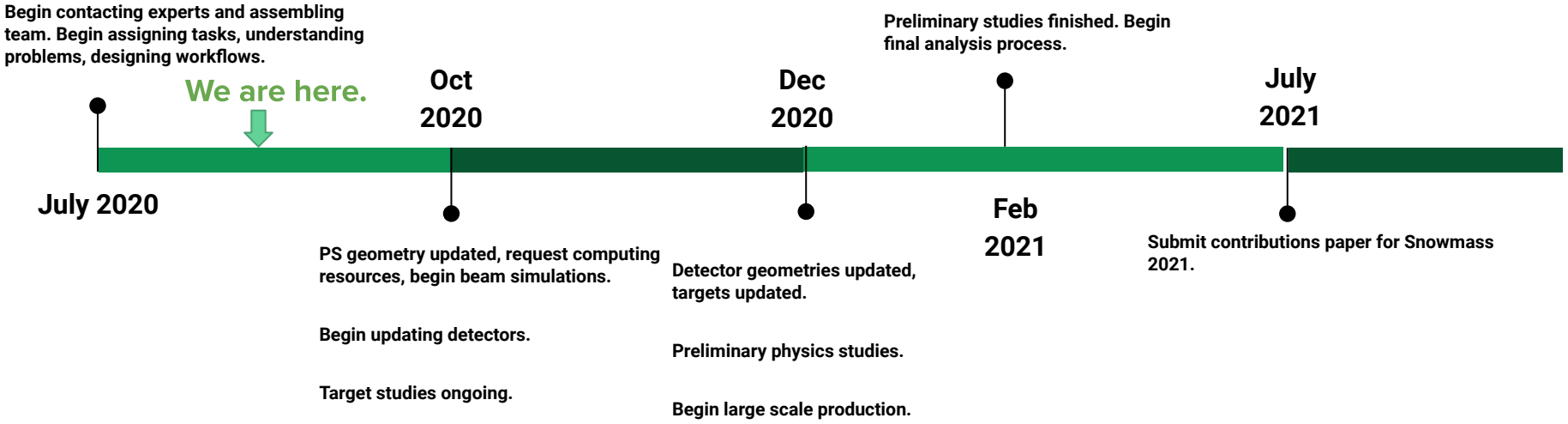
- Following a detailed conversation with the Mu2e Computing Group we have decided that the Mu2e-II code will be a branch of the Mu2e/Offline code:

https://github.com/Mu2e/Offline/tree/Mu2eII_SM21

- There are some rules for putting in PRs on this branch - these are detailed in the README of this branch

Estimated Timeline

Reiterating the estimated schedule from last meeting:



Next: Requesting Computing Resources

- We will apply for 6M (1.5M/quarter) CPU hours on the HPC system at ANL
- These resources can be used for Mu2e and Mu2e-II simulations efforts

Summary & Next Steps

- Since the last Workshop we have made significant progress, and have communicated with several other groups
- We are beginning to implement the updated PS geometry. Once this is complete we can begin simulations
- Over the next month we aim to continue to communicate with geometry experts and request resources necessary for the simulation campaign