Mu2e-II: Sensitivity Estimate

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**Working Group Report for
Mu2e-II Workshop
9th December 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.
- Today we will document progress made since the previous Workshop.

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), Leo Borrel (Caltech)

- 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

Analysis/Simulation Meeting - tasks still available...

Task	Contact to discuss	Overview of necessary work	Sign up
conv.		yuri, lisa or sophie	
DIO	conv.	Implement DIO Analysis, produce histograms and yield estimates for final sensitivity calculation	Manolis +
RPC	conv.	Implement RPC Analysis, produce histograms and yield estimates for final sensitivity calculation	Sophie +
ST	conv./Sophie	Analyze Al ST design options, look at alternative materials, read theory papers, GEANT4 sims etc.	Sophie, Leo, David Hitlin +
PT	conv.	Input PT design, analyze [done]	Michael M.
RMC	conv.	Implement RMC Analysis, produce histograms and yield estimates for final sensitivity calculation	Michael M. +
Mu2eX	conv/theory	look at Mu2eX signals, establish sensitivity	Sophie +
Calo	conv/calo	upgrade calorimeter	Leo, Bertrand
Tracker	conv/Dave Brown	upgrade tracker	Dave Brown, Manolis
Cosmics	conv/Yuri	Implement Cosmic Analysis, produce histograms and yield estimates for final sensitivity calculation	
mu->e+	conv/Michael M	Implement mu->e+ study in collaboration with convenors	Michael M. +
Decay in Flight	conv.	Implement DIF Analysis, produce histograms and yield estimates for final sensitivity calculation	Michael H. +
Stats/Analysis	conv.	Help prepare analysis and derive SES/BFUL, understand combining systematics etc.	Sophie, Cole +
CRV	Yuri	Do any necessary work on the CRV - should discuss with CRV group	(possibly done)
Simulation Prep.	conv.	preparing simulations, submitting early stage jobs, validation, general tasks	Convenors+
Infrastructure	conv.	helping write analyzers, preparing workflow etc.	

Progress with Stage 1 Simulation

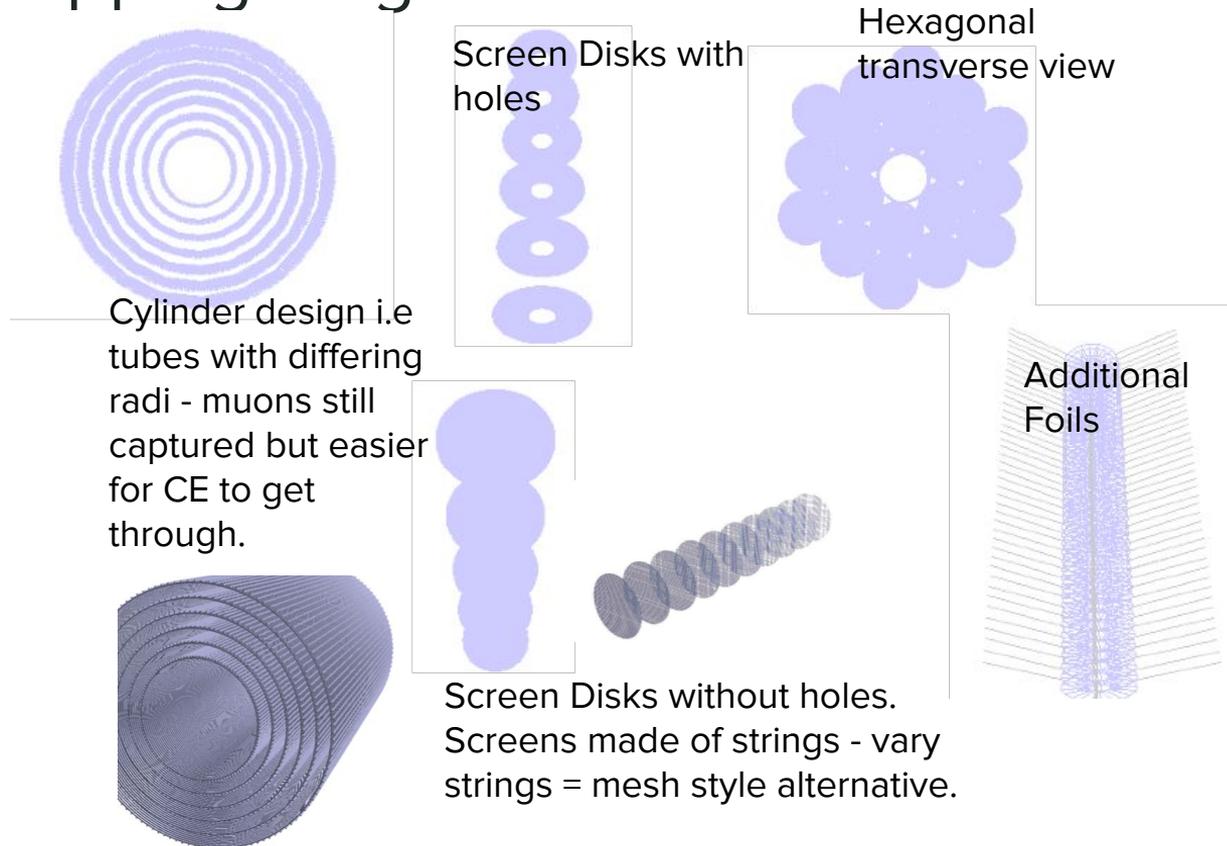- Stage 1 simulation beginning followed by Stage 2.

Progress with Detector Simulations

- **CRV:** Yuri added concrete to geometry model (PR in progress)
- **Calorimeter:** Leo Borrel changing CsI ➜ BaF crystals to stay the same dimensions.
- **Tracker:** David Brown and Manolis Kargiantoulakis will begin with changing wall thickness of straws and removing Gold.

Progress on AI Stopping Target Studies

Previous I eliminated all but the screen and foils:

- This was based on SES and BFUL (90%) optimizations.
- A tool (StatsTool2021) was written to loop over momentum windows and find minimum BFUL.
- RPC and DIO backgrounds where taken into account and Feldman-Coussins used to make limits

Cylinder design i.e tubes with differing radi - muons still captured but easier for CE to get through.

Screen Disks with holes

Hexagonal transverse view

Additional Foils

Screen Disks without holes. Screens made of strings - vary strings = mesh style alternative.

Progress on AI Stopping Target Studies

Momentum window optimized for BFUL.

Targets ranked according to final column i.e. improvement on current Mu2e target

Name	Mom L	Mom H	CE Eff	DIO Eff	SES	BFUL
Screen Hole Mesh	104.325	109.975	0.125 +/- 0.000293	0.307 +/- 0.007	3.053e-18 +/- 7.160e-21	9.000e-18 +/- 4.876e-20
Screen Mesh	104.27	109.975	0.135 +/- 0.000308	0.3262 +/- 0.0078	2.7617e-18 +/- 6.315e-21	9.145e-18 +/- 5.5421e-20
Screen Hole	104.325	109.9	0.131 +/- 0.000287	0.328 +/- 0.00759	2.902e-18 +/- 6.340e-21	8.664e-18 +/- 5.685e-20
Screen Default	104.3	109.95	0.137 +/- 0.000313	0.327 +/- 0.0074	2.732e-18 +/- 6.276e-21	8.602e-18 +/- 4.96e-20
37 Foil (mu2e)	104.275	109.925	0.133 +/- 0.000299	0.319 +/- 0.00758	2.710e-18 +/- 6.097	8.993e-18 +/- 5.413e-20

Decided to stay with the Mu2e style foil target.

Progress on Alternative Targets

	Z	A (amu)	Density g/cm^3	Atoms/cm^3	Atoms/g	Atoms/162g	g Al equiv	Capture rate (10^6/s)	Capture lifetime (ms)
Lithium	3	6.941	0.534	4.63E+22	8.68E+22	1.41E+25	41.67	0.0018	555.556
Aluminum	13	26.982	2.702	6.03E+22	2.23E+22	3.62E+24	162.00	0.7054	1.418
Sulphur	16	32.066	2.0686	3.88E+22	1.88E+22	3.04E+24	192.53	1.352	0.740
Titanium	22	47.867	4.5189	5.68E+22	1.26E+22	2.04E+24	287.59	2.59	0.386
Vanadium	23	50.942	5.96	7.05E+22	1.18E+22	1.92E+24	305.86	3.069	0.326
Gold	79	196.967	19.3	5.90E+22	3.06E+21	4.96E+23	1181.94	13.07	0.077
Lead	82	207.200	11.34	3.30E+22	2.91E+21	4.71E+23	1243.55	13.45	0.074

Please get in touch to join in the studies!

gAl Equ. column tells us what mass we need to have same number of nuclei as our 162 g Al target.

Alternative Stopping Targets

Titanium

- Ran several foil style targets of masses 200-300 g.
- Optimal masses found to be 225-250 g providing SES O(1e-18).
- Resolution in titanium measured to be worse than Al but still < ~ 200 keV/c.

Vanadium

- Added Vanadium to Mu2e-II Offline instances.
- Ran a CE test with 300g target.
- Awaiting DIO radiative corrections parameterization to continue.
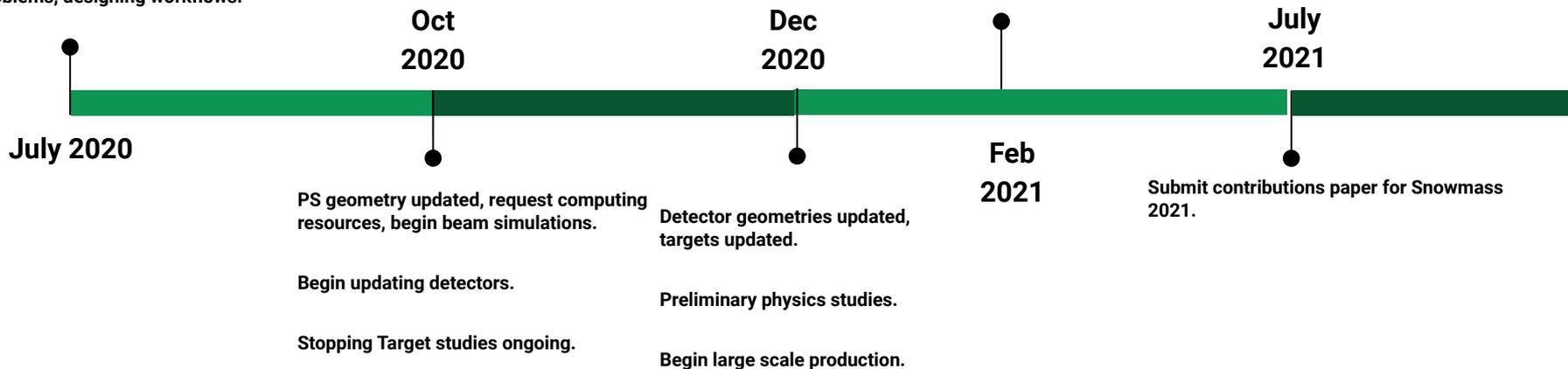- Resolution worse than Al and Ti. Further optimization would follow.

Estimated Timeline

Reiterating the estimated schedule from last meeting:

We are here.

Begin contacting experts and assembling team. Begin assigning tasks, understanding problems, designing workflows.

Preliminary studies finished. Begin final analysis process.

Oct 2020

Dec 2020

July 2021

July 2020

Feb 2021

PS geometry updated, request computing resources, begin beam simulations.

Detector geometries updated, targets updated.

Submit contributions paper for Snowmass 2021.

Begin updating detectors.

Preliminary physics studies.

Stopping Target studies ongoing.

Begin large scale production.

Mu2e-II: Sensitivity Estimate - Introductory Discussion, Snowmass Workshop July 2020

Next Steps

- Next steps:
  - Detector upgrades
  - Physics studies
  - Alternative target studies continue
  - Production simulation campaign
- We will host the second analysis meeting in the coming weeks.

Summary

- Since the last Workshop we have made significant progress.
- We now have the Production Target in our Mu2e-II Offline code.
- Computing resources have been requested.
- Al Stopping Target optimization studies are complete. Alternative target studies are well underway with both theory and simulation studies ongoing.
- Will shortly begin the first Stage 1 simulation.