Improvements in performance of the Muon Campus beamline

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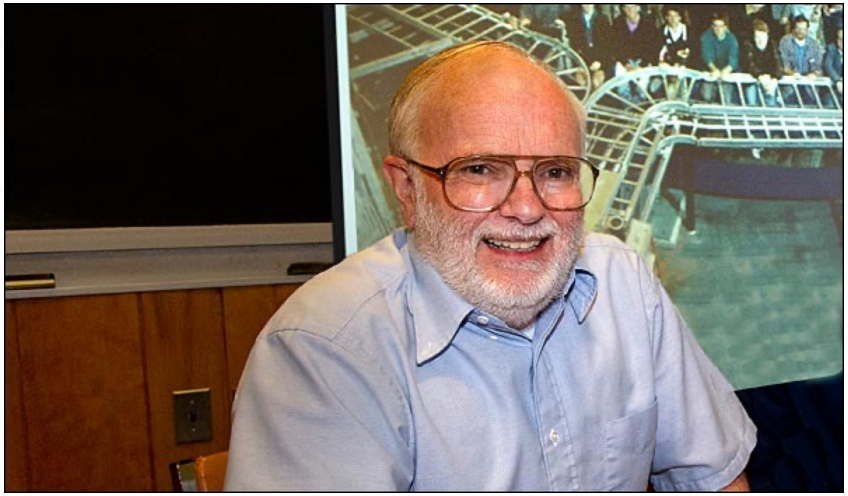
Fermi National Accelerator Laboratory

g-2 collaboration workshop
March 24, 2018

Outline

- Expected performance of the Muon Campus accelerator
  - End-to-end simulation model
  - Muon, pion and proton rates
- Possibilities for improvements
  - Describe a novel idea that could increase the # of stored muons
  - Expected performance
  - Future work
- Summary

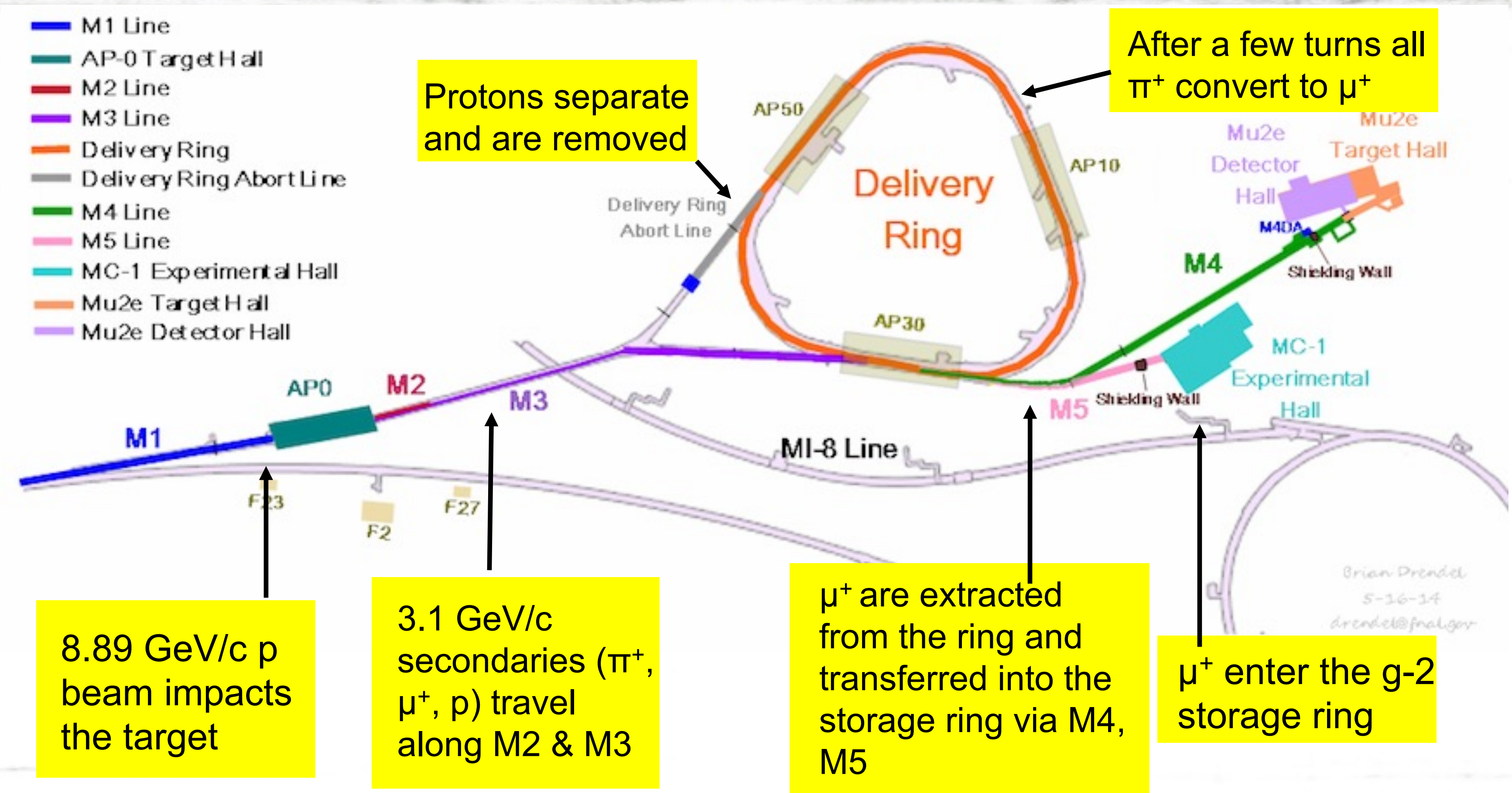
Special thanks



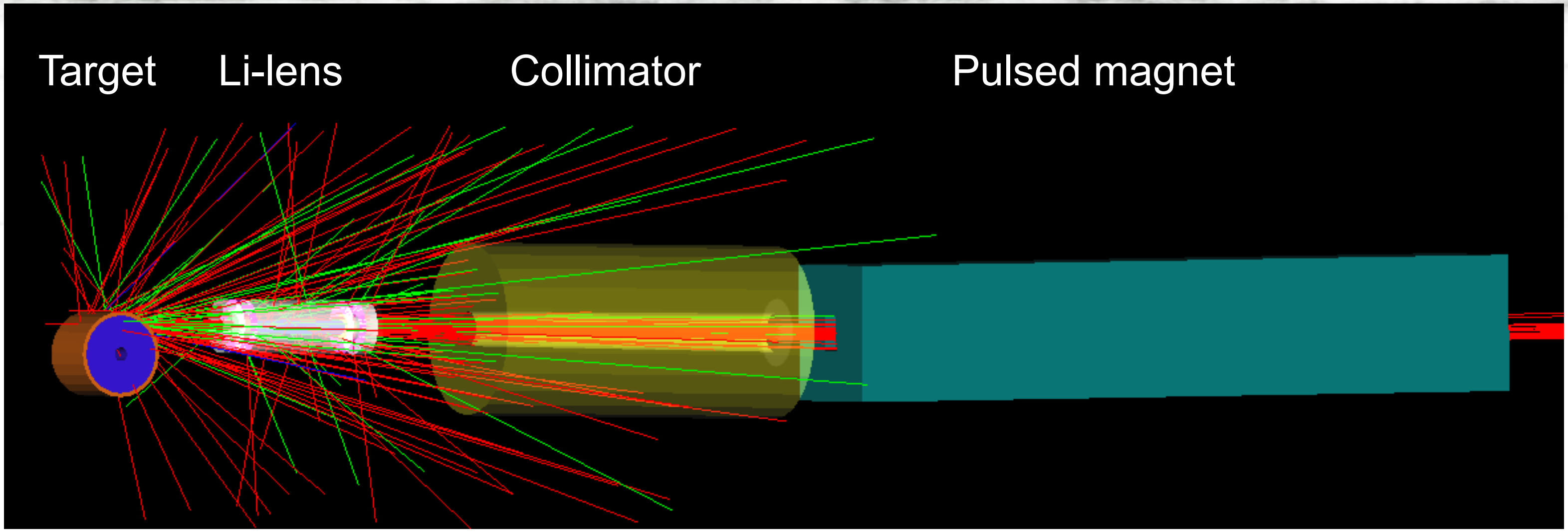
Bill Morse (BNL)

Joe Bradley (Univ. Edinburgh)

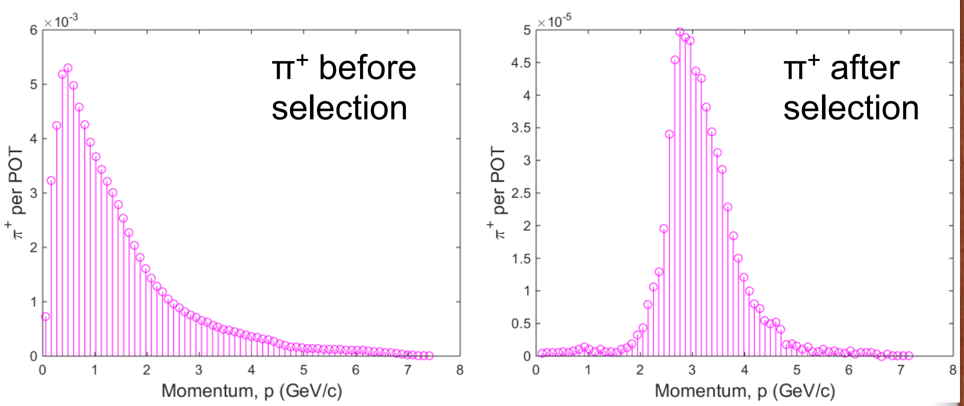
Muon Campus overview



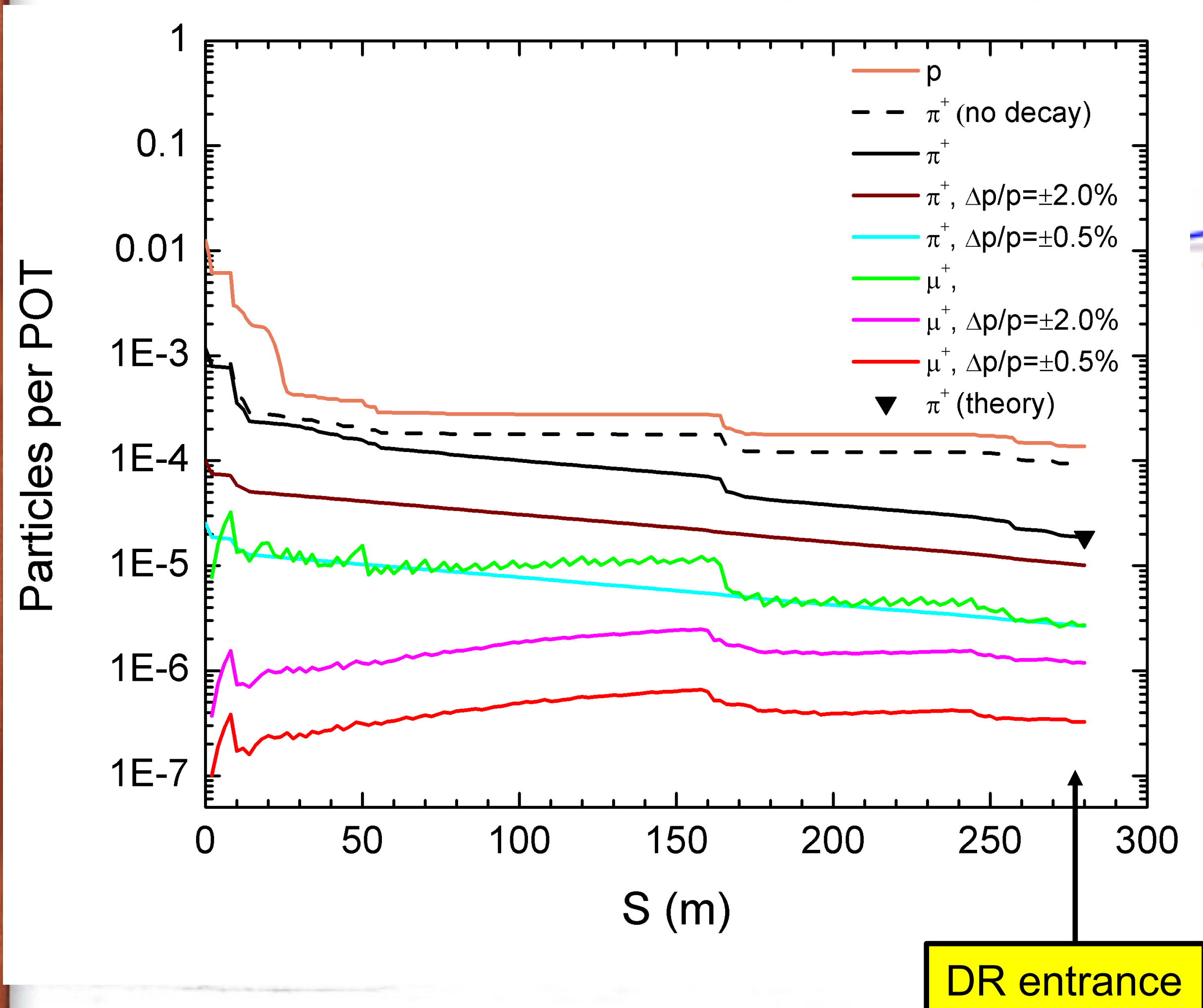
Target station



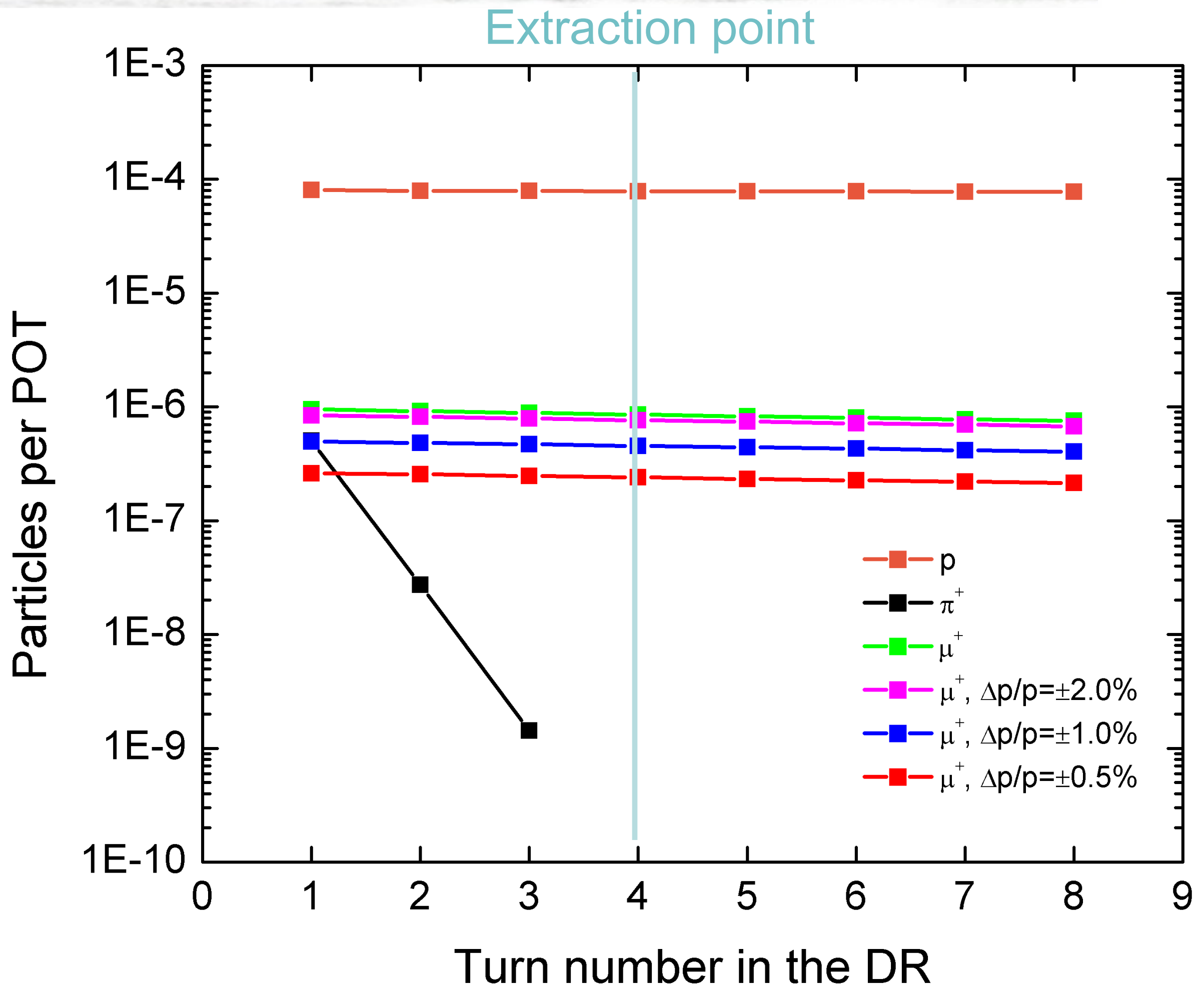
Parameter	Value
Protons on target (POT) per pulse	10^{12}
Pulse width	120 ns
Number of pulses	16
Cycle length	1.4 s
Incoming beam momentum	8.89 GeV/c
Selection momentum	3.1 GeV/c



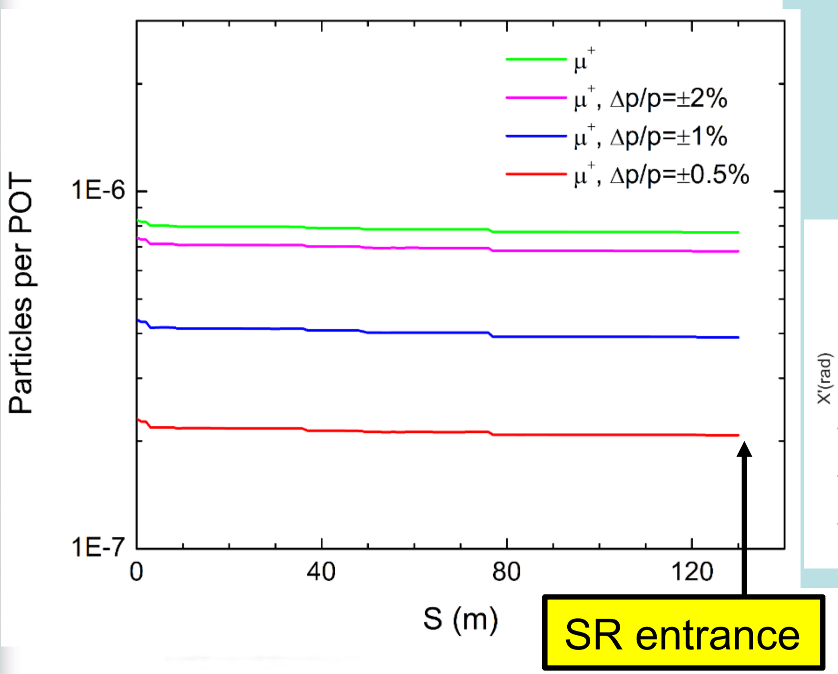
Performance within M2 & M3 lines



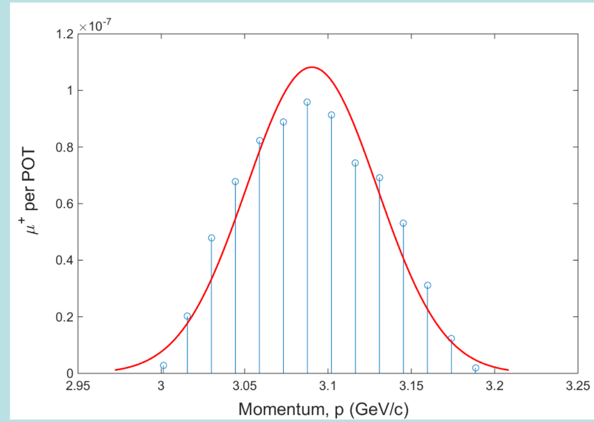
Performance in the Delivery Ring (DR)

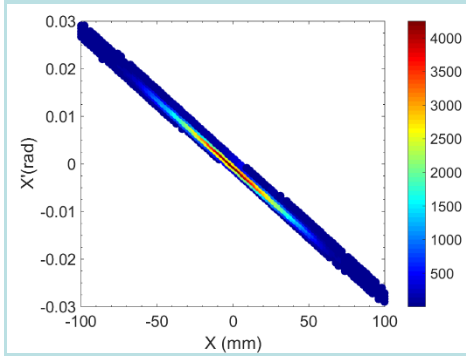


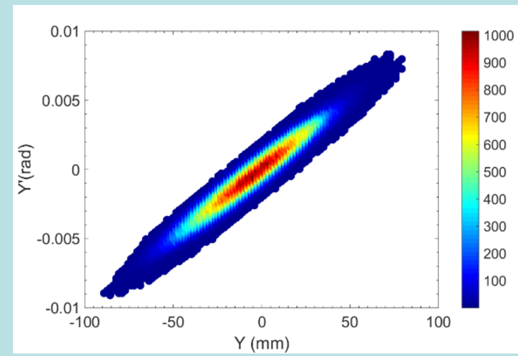
Performance within M4 & M5 lines



Beam at SR Entrance







- Simulation predicts ~7x10^5 muons per fill make it to the SR

New publication

PHYSICAL REVIEW ACCELERATORS AND BEAMS **20,** 111003 (2017)

Accelerator performance analysis of the Fermilab Muon Campus

Diktys Stratakis, Mary E. Convery, Carol Johnstone,
John Johnstone, James P. Morgan, and Dean Still
Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA

Jason D. Crnkovic, Vladimir Tishchenko, and William M. Morse
Brookhaven National Laboratory, Upton, New York 11973, USA

Michael J. Syphers
*Northern Illinois University, DeKalb, Illinois 60115, USA,
and Fermi National Accelerator Laboratory, Batavia, Illinois 60510, USA*
(Received 29 March 2017; published 21 November 2017)

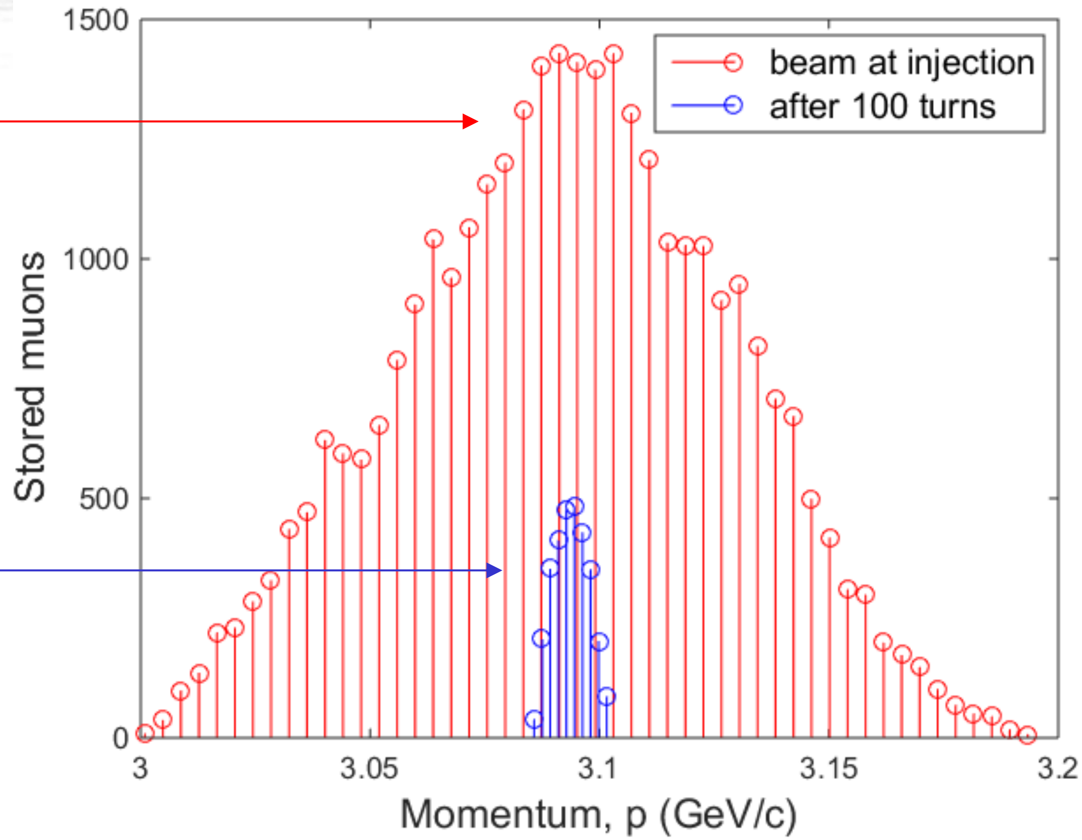
Fermilab is dedicated to hosting world-class experiments in search of new physics that will operate in the coming years. The Muon g-2 Experiment is one such experiment that will determine with unprecedented precision the muon anomalous magnetic moment, which offers an important test of the Standard Model. We describe in this study the accelerator facility that will deliver a muon beam to this experiment. We first present the lattice design that allows for efficient capture, transport, and delivery of polarized muon beams. We then numerically examine its performance by simulating pion production in the target, muon collection by the downstream beam line optics, as well as transport of muon polarization. We finally establish the conditions required for the safe removal of unwanted secondary particles that minimizes contamination of the final beam.

DOI: 10.1103/PhysRevAccelBeams.20.111003

Storage ring momentum acceptance

$\sigma_P/p = \pm 1.1\%$

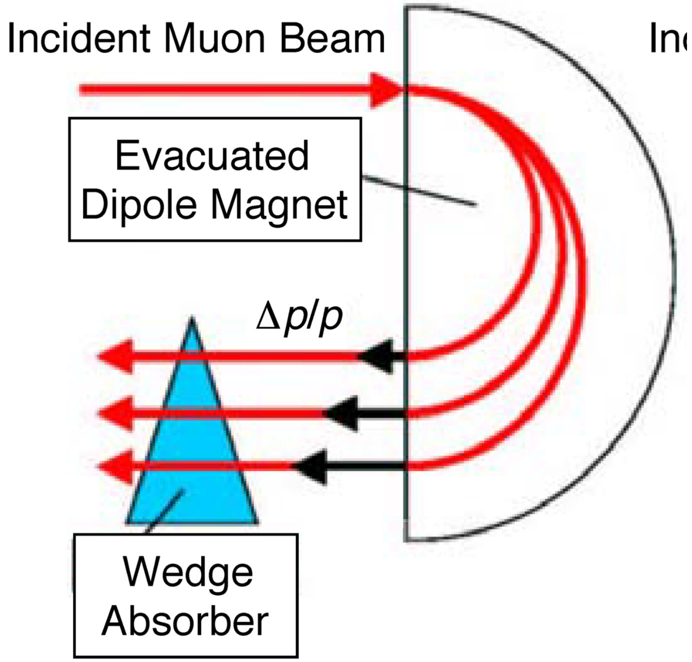
$\sigma_P/p = \pm 0.2\%$



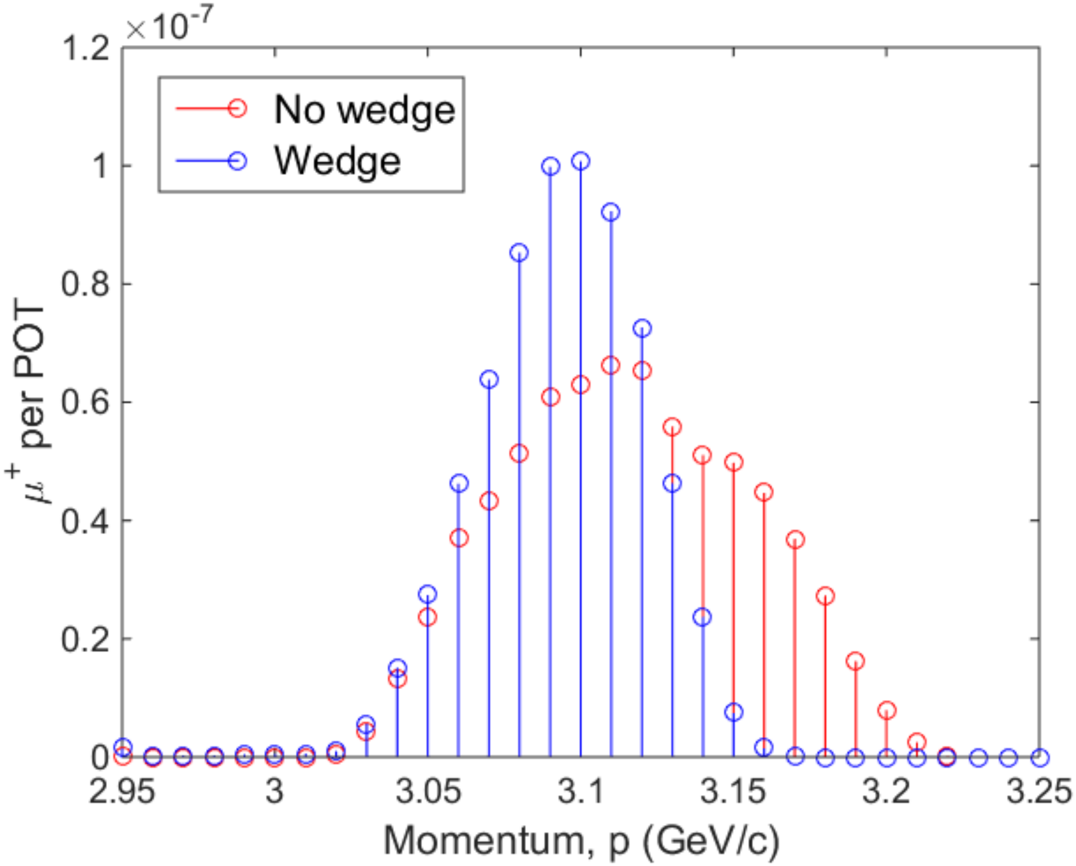
- Storage ring accepts particles only within $\sigma_p/p = 0.2\%$
- That means that more than 80% of the incoming beam is lost

The cooling proposal

- Place a wedge material in a dispersive area in such a way that the high-energy particles traverse more material than the low energy ones.
- This way the net energy spread is reduced



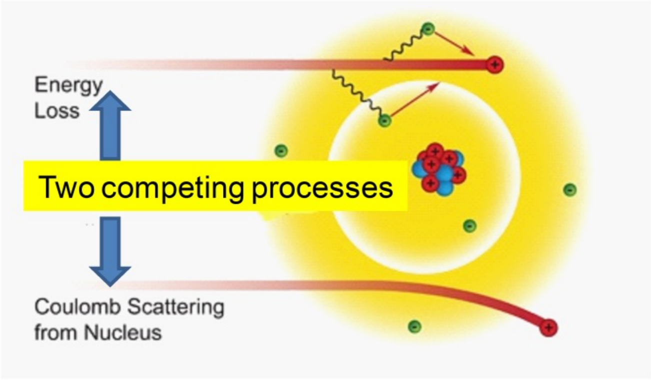
Performance



- The wedge tailors the momentum of an initial 3.115 GeV/c beam so that to maximize magic momentum muons

Cooling requirements

- There are competing processes involved in ionization cooling
  - Cooling from ionization of the material
  - Heating from Coulomb scattering



- We require a material with:
  - Low atomic number Z to reduce scattering
- We require a location with:
  - High dispersion
  - Low beta function...

LDRD funding request

- Sep. 2017: Preproposal submitted at Fermilab
- Oct. 2017: Encouraged for full proposal submission
- Dec. 2017: Full proposal submitted
- Mar. 2018: Proposal accepted
  - Top 3 among 51 proposals

Proposal phases

- Proposal is divided into six phases
- Phase I: Choice of material and location
- Phase II: Modeling
- Phase III: Engineering Design
- Phase IV: Fabrication
- Phase V: Installation
- Phase VI: Testing

Background

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **16**, 091001 (2013)

Tapered channel for six-dimensional muon cooling towards micron-scale emittances

Diktys Stratakis, Richard C. Fernow, J. Scott Berg, and Robert B. Palmer
Brookhaven National Laboratory, Upton, New York 11973, USA
(Received 19 June 2013; published 23 September 2013)

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **17**, 071001 (2014)

Conceptual design and modeling of particle-matter interaction cooling systems for muon based applications

Diktys Stratakis and H. Kamal Sayed
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Chris T. Rogers
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Jaroslaw Pasternak
Imperial College, London, SW7 2BW United Kingdom and STFC Rutherford Appleton Laboratory, Didcot, OX11 0QX, United Kingdom
(Received 13 October 2013; published 14 July 2014)

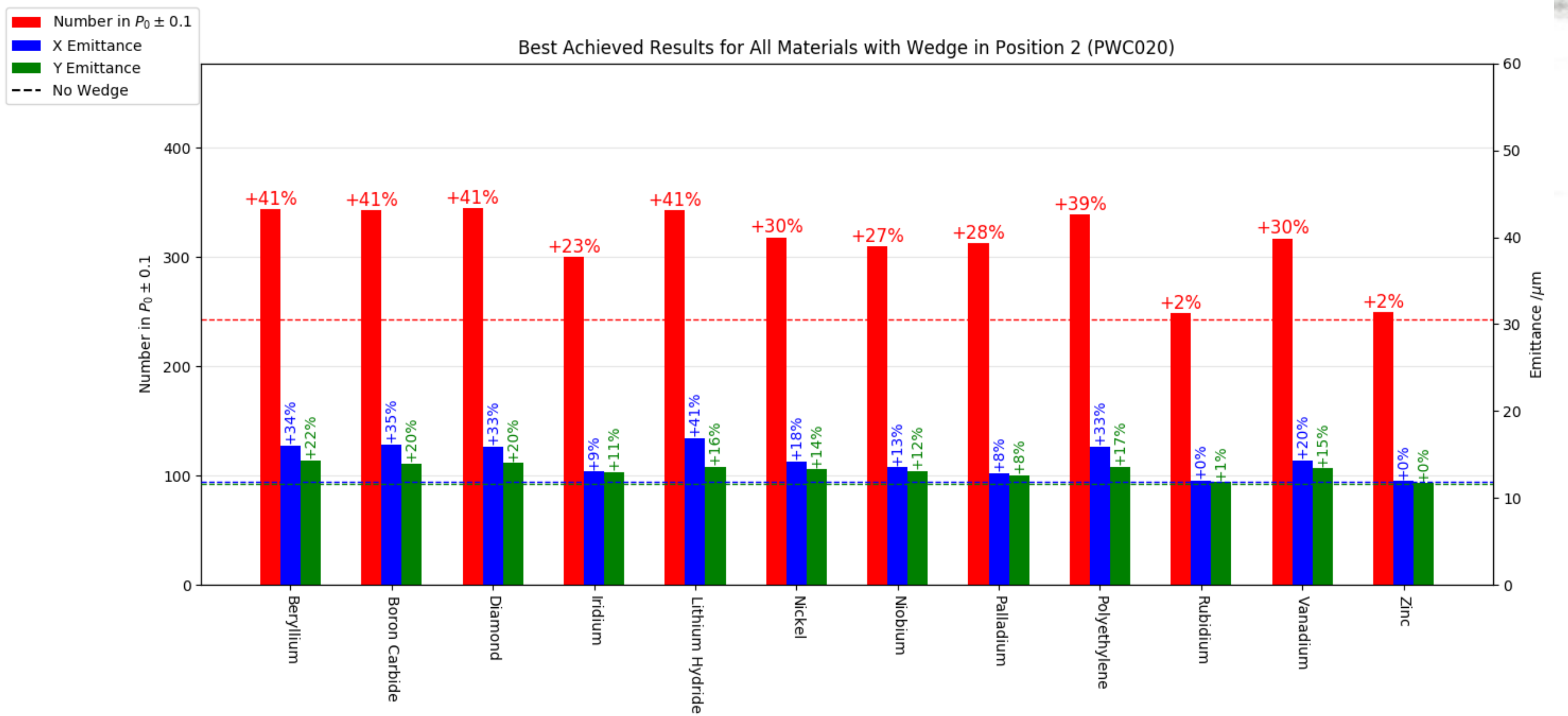
PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **18**, 044201 (2015)

Influence of space-charge fields on the cooling process of muon beams

Diktys Stratakis and Robert B. Palmer
Brookhaven National Laboratory, Upton, New York 11973, USA

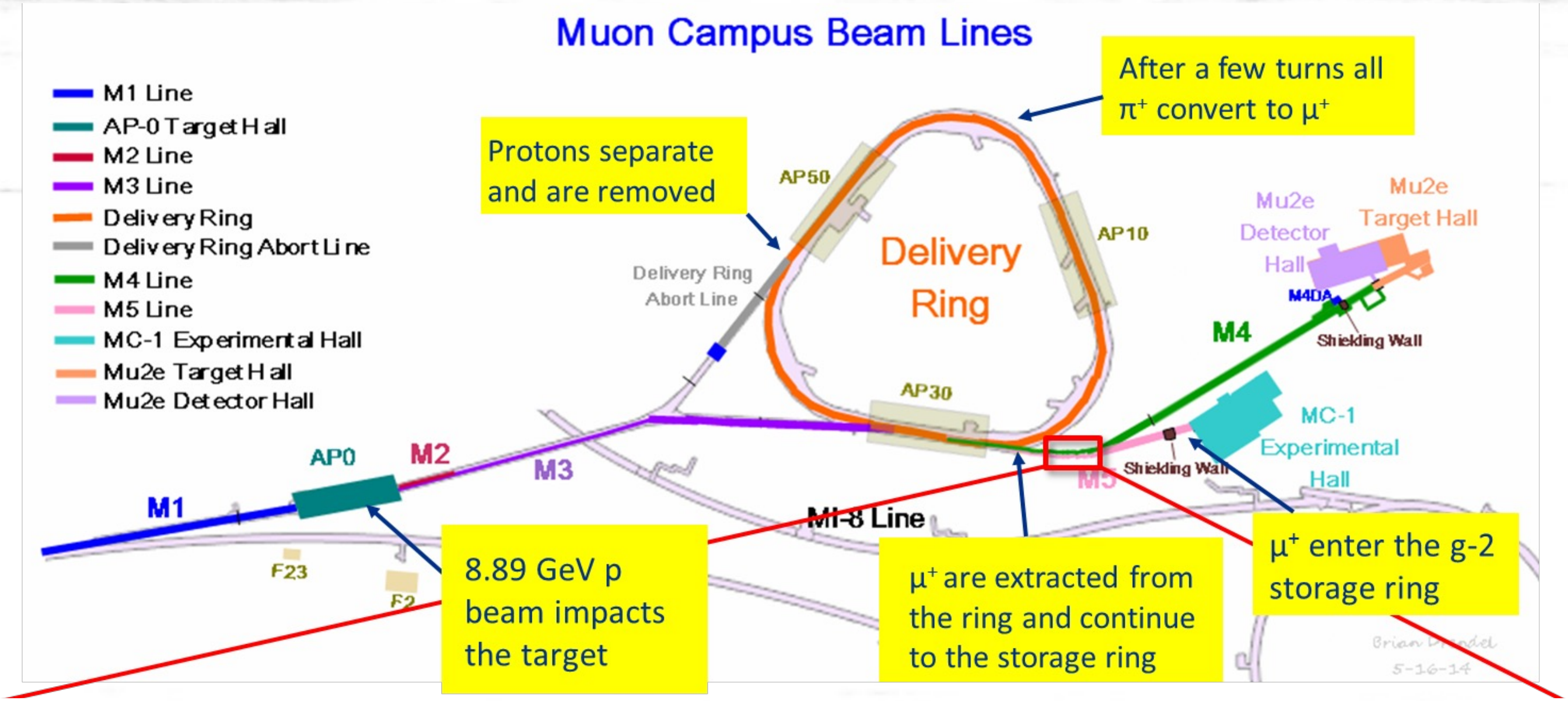
David P. Grote
Lawrence Livermore National Laboratory, Livermore, California 94550, USA
(Received 15 November 2014; published 7 April 2015)

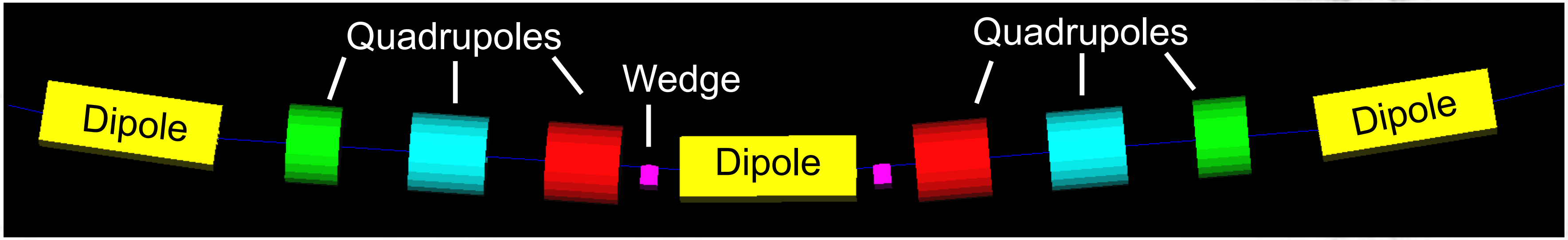
Choice of material



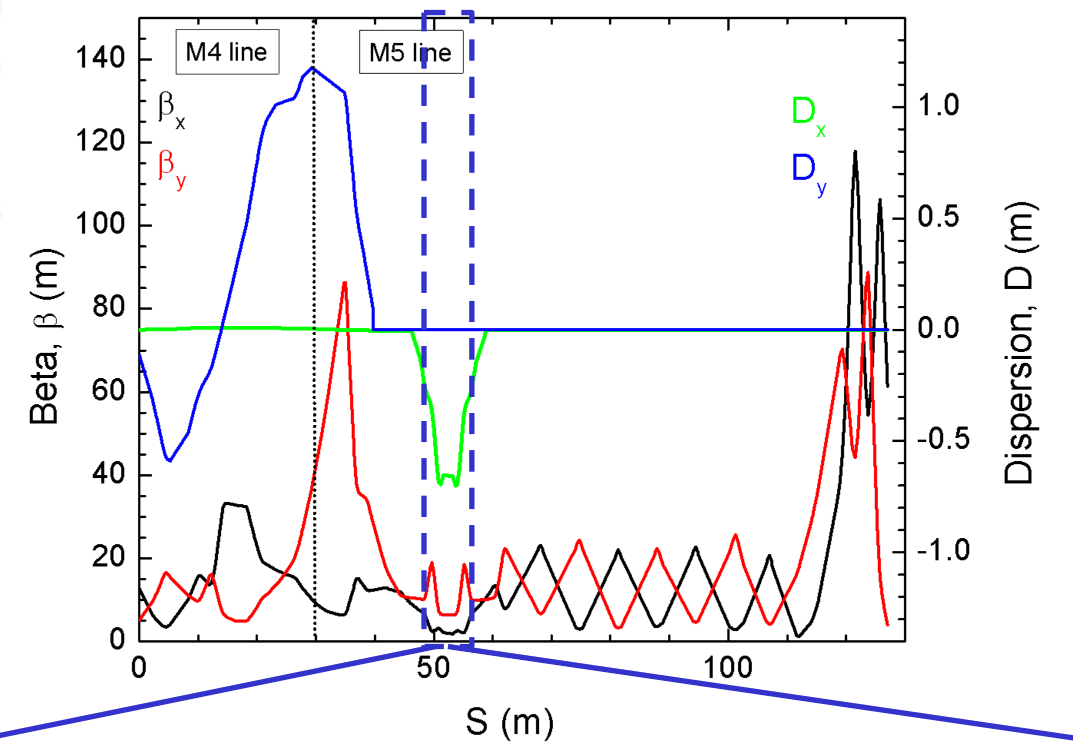
- Detailed study: Bradley et al. gm2-docdb-8081
- Polyethylene is cost effective, readily available and can be machined easily into the desired shapes

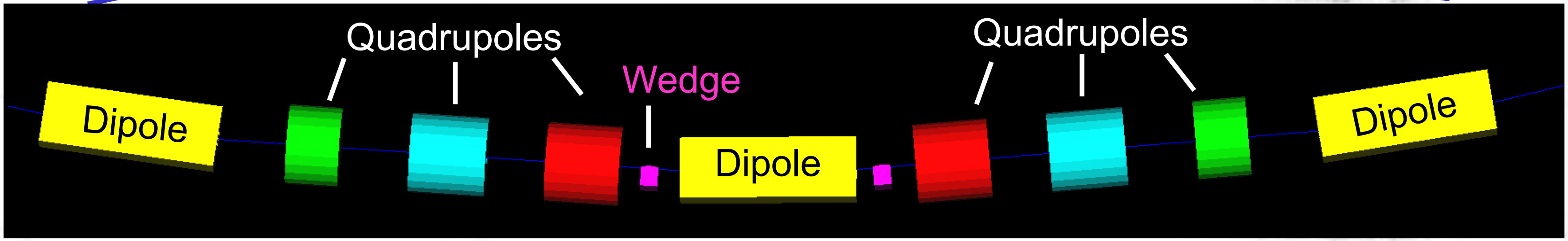
Choice of location (1)



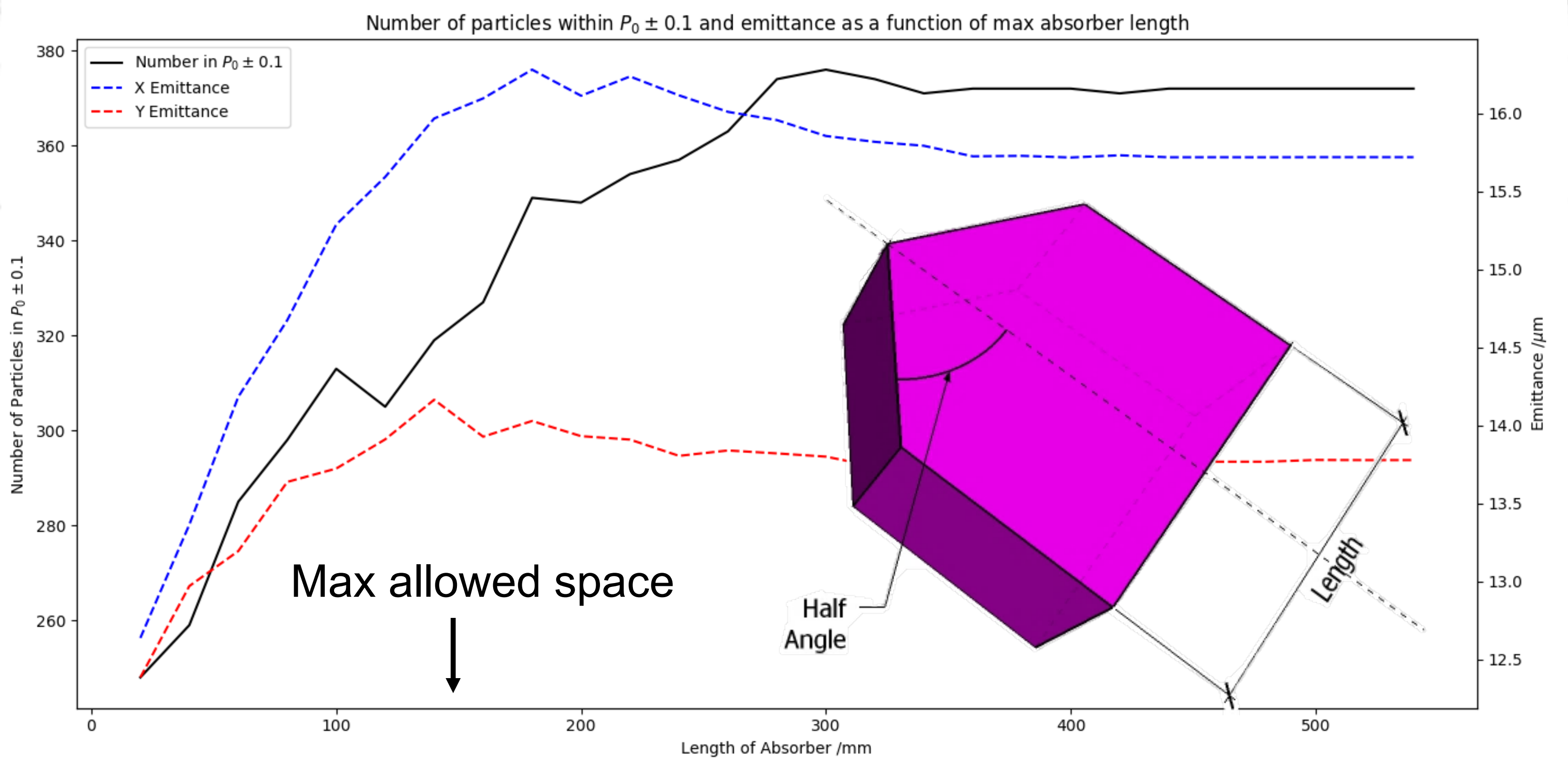


Choice of location (2)



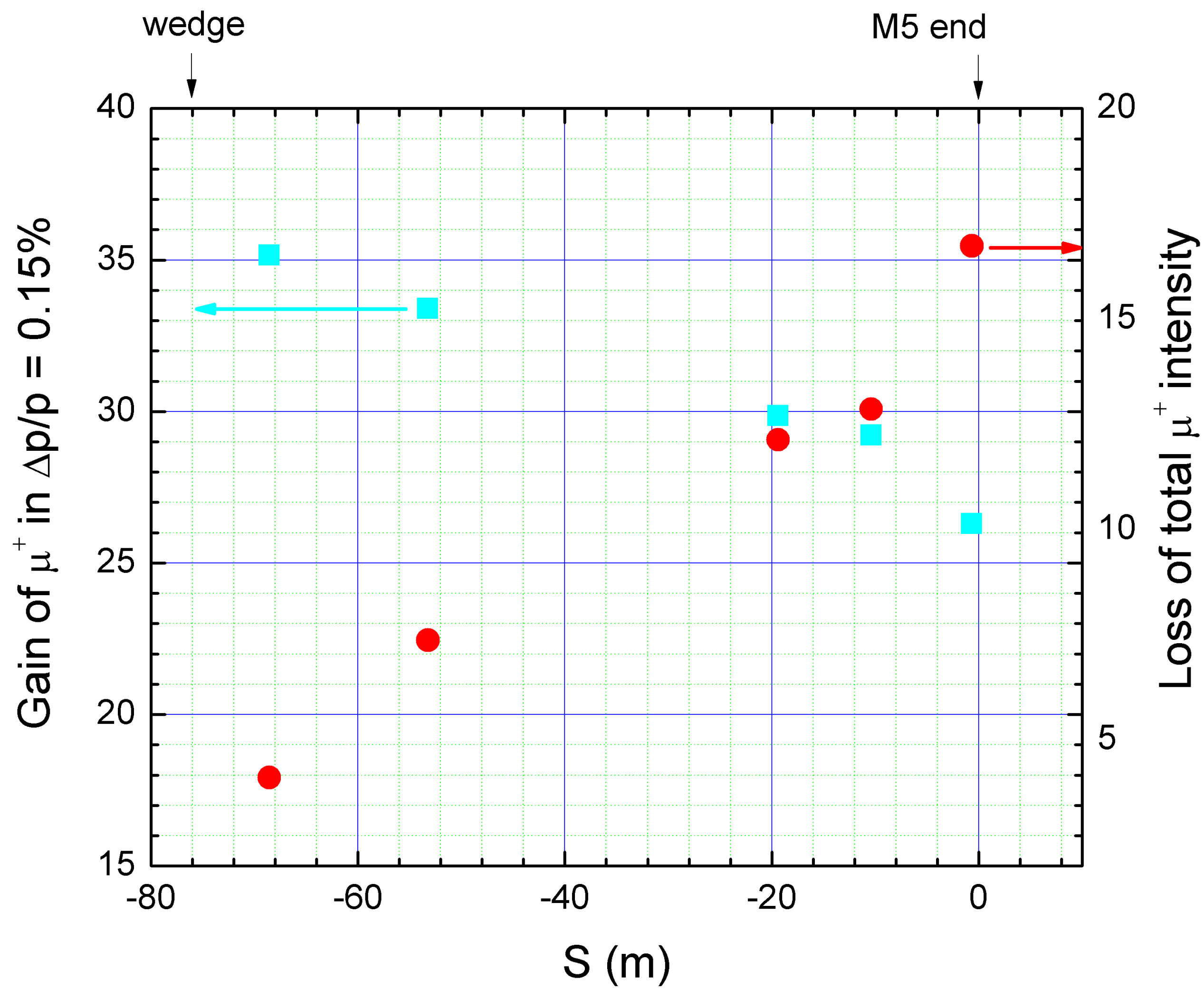


Design constrains



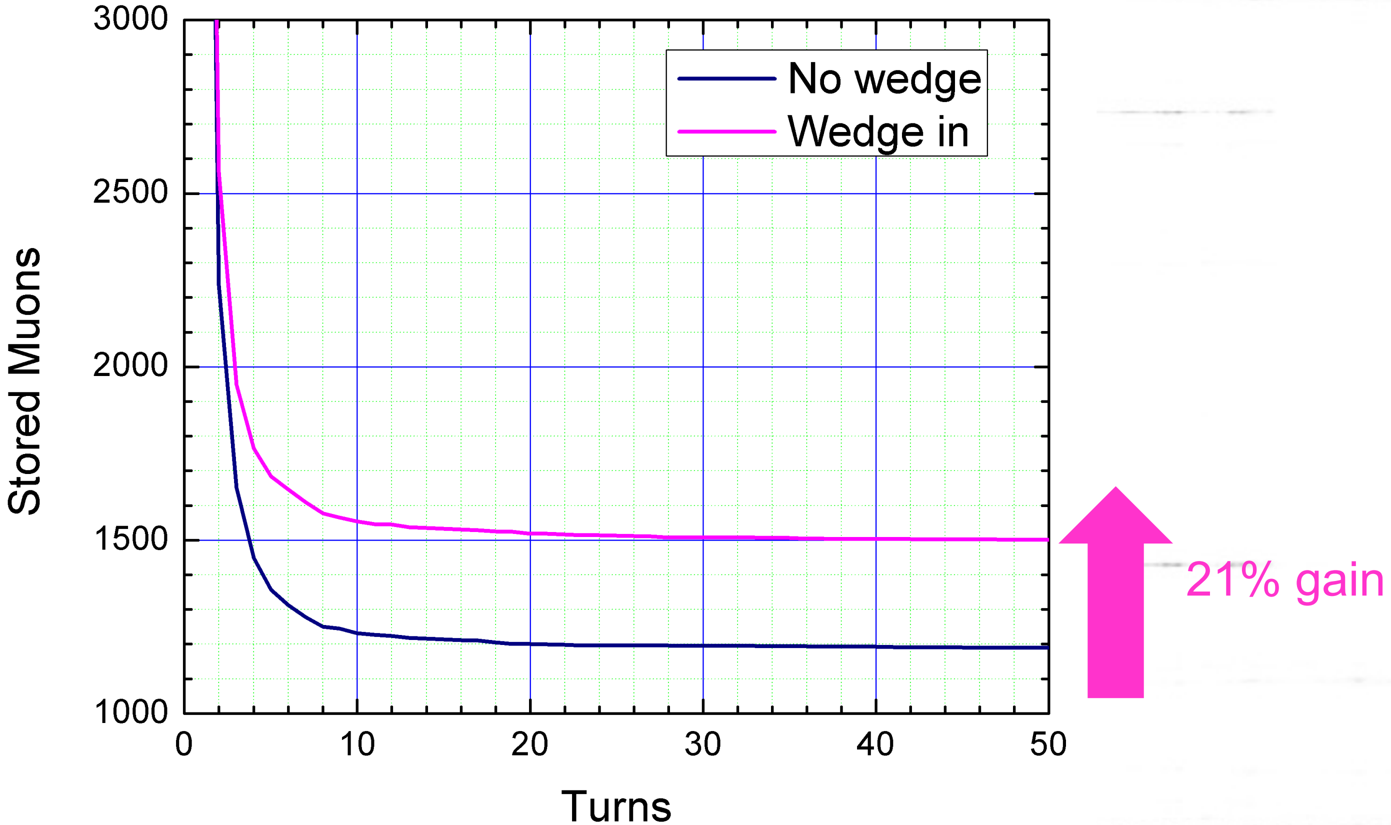
- The maximum allowable space is 150 mm. For this reason two wedges will be installed

Performance along the M4-M5 lines



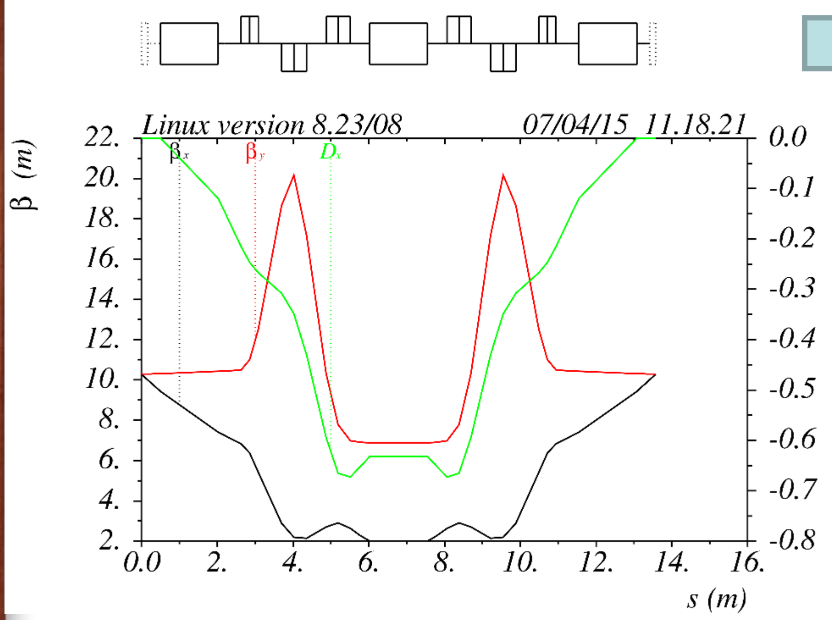
Increasing the stored muons

- Simulations inside the Muon g-2 storage ring have been performed

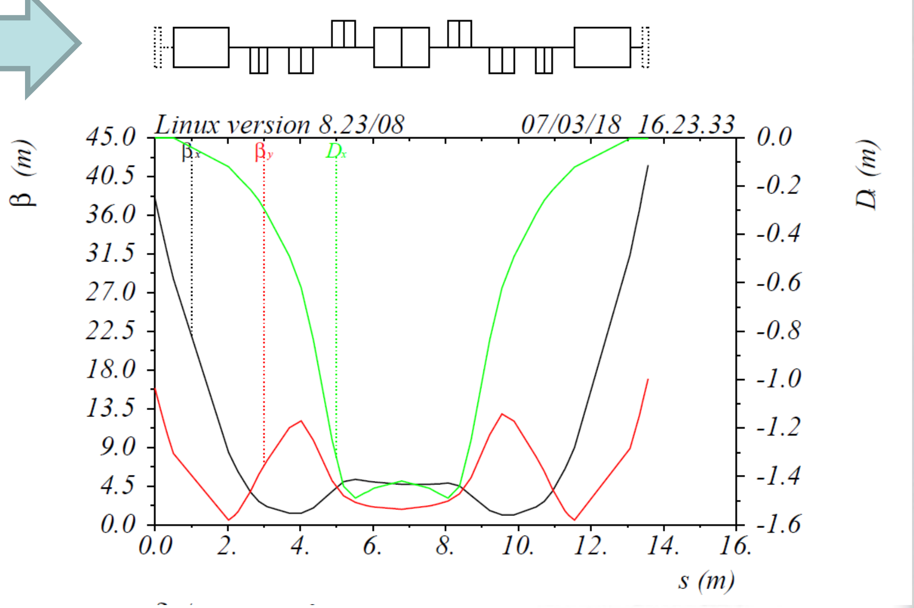


Future optics improvement

Current design of M5 bend

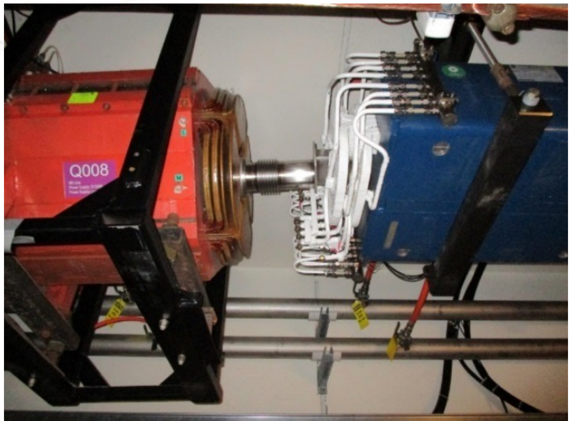


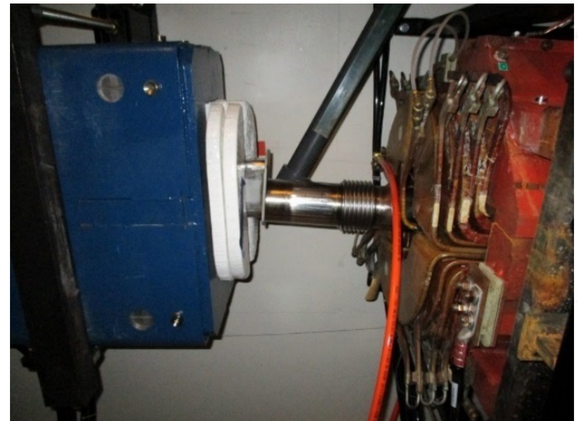
Proposed design of M5 bend

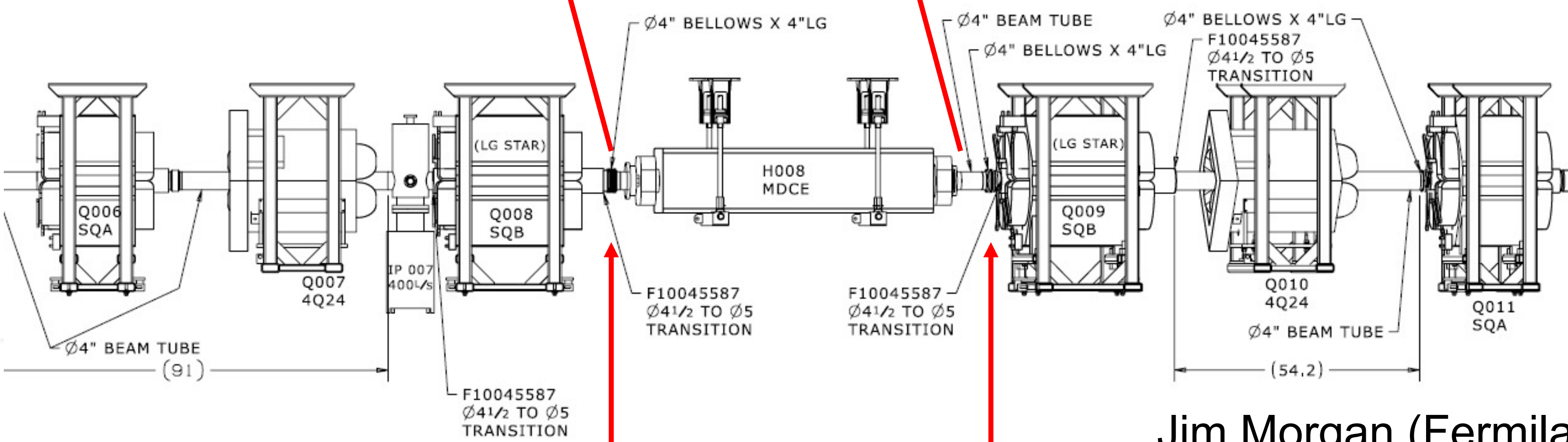


Carol Johnstone (Fermilab)

Engineering design (1)



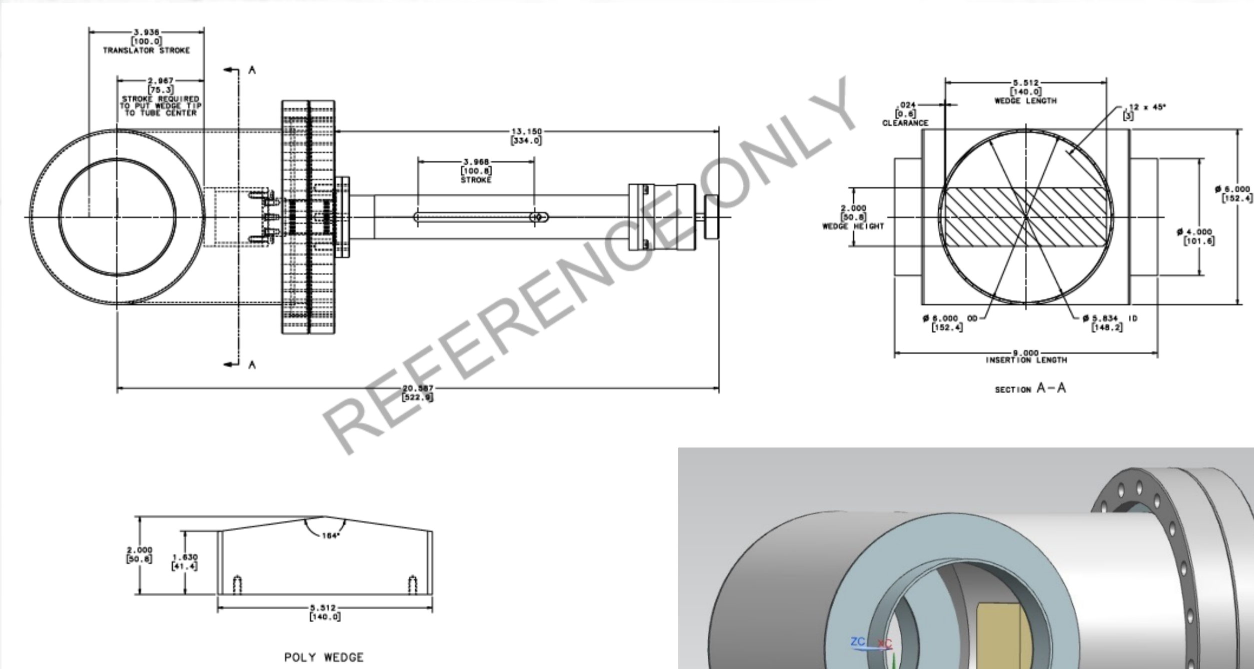


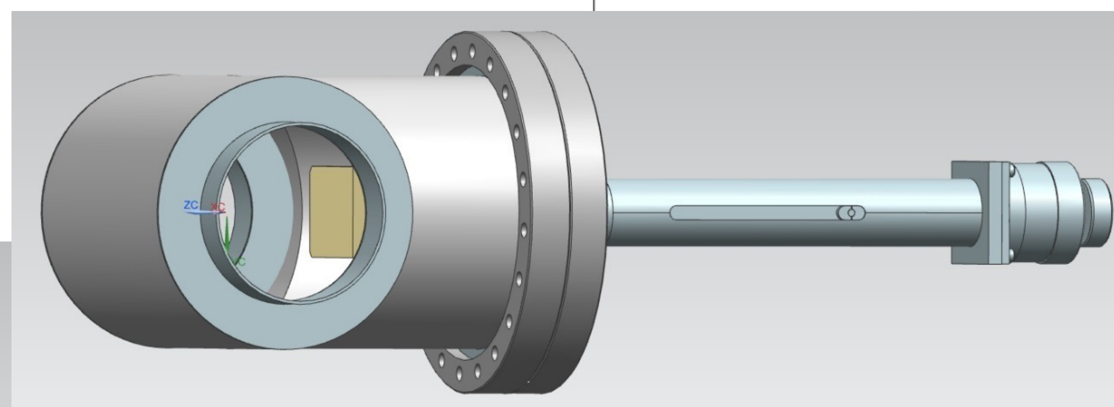


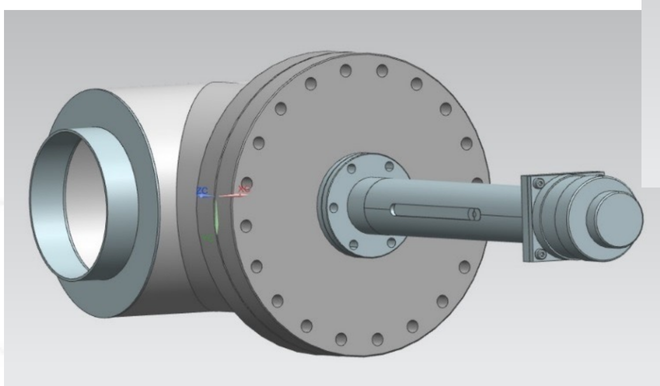
Jim Morgan (Fermilab)

Proposed wedge locations

Engineering design (2)







Dirk Hurd and Jesse Batko (Fermilab)

Timeline

Task	M-18	A-18	M-18	J-18	J-18	A-18	S-18	O-18	N-18
1) Select wedge best parameters	x	x							
2) M4-M5 optics optimization		x	x						
3) Engineering drawings		x	x						
4) Order parts			x	x					
5) Fabrication				x	x				
6) Installing system					x	x	x		
7) Test system							x	x	x

Conclusions

- Developed a end-to-end simulation model for the Muon Campus – first results published in Phys. Rev. AB
- Through Fermilab's Laboratory Directed Research Development (LDRD) program we have been awarded a grant to design, install and test a wedge in the Fermilab Muon Campus
- It will provide improvements in the number of stored muons that are required to minimize the statistical uncertainty in the Muon g-2 measurement.
- Devices are relatively inexpensive and straightforward to implement and thus the benefits to the Experiment potentially can be high for a fairly modest investment.