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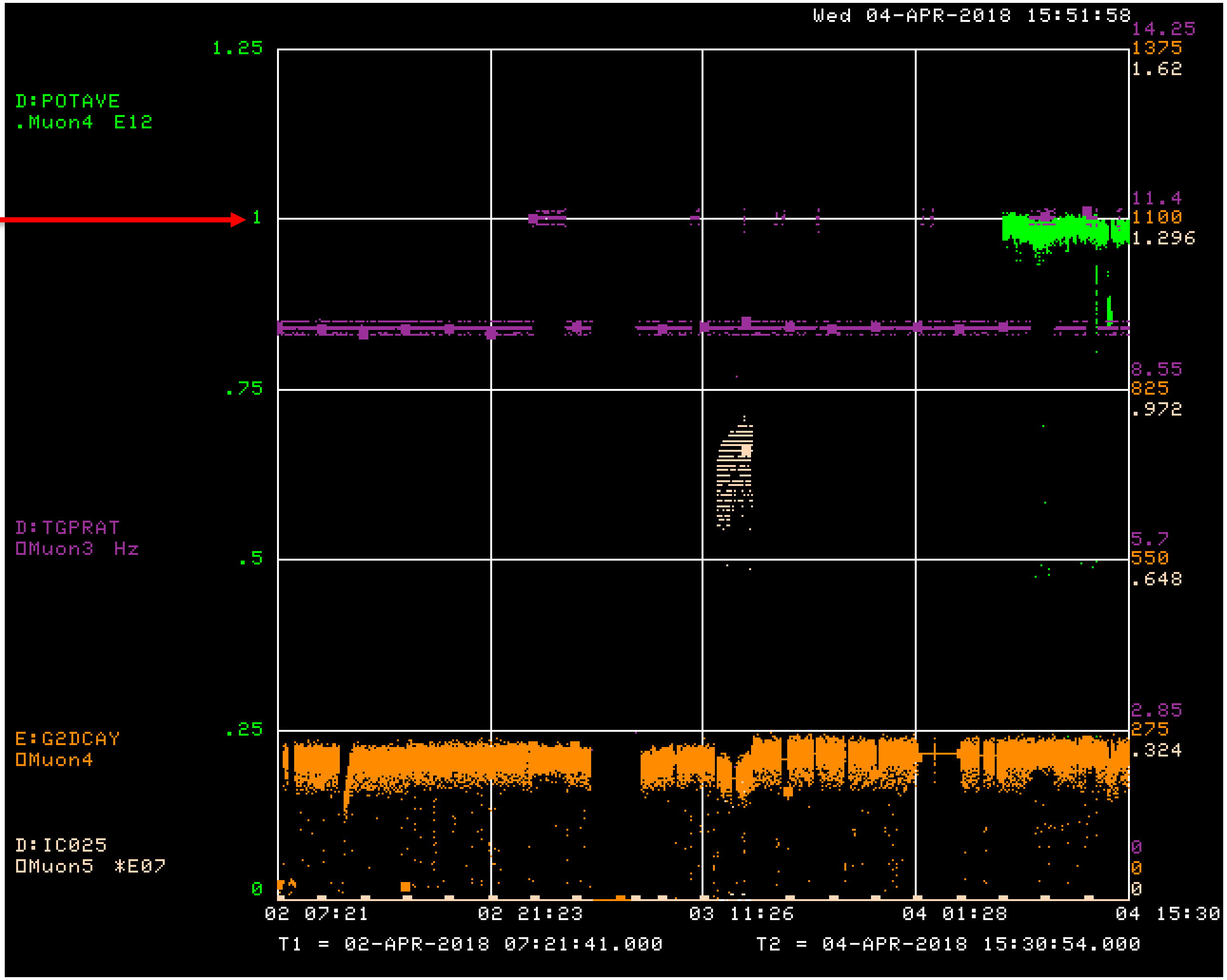
Proton PMG

Jerry Annala

Possible Improvements to Muon Flux to g-2

5 April 2018

Present performance



Simulation prediction

Repetition rate

Particles to end of beam line

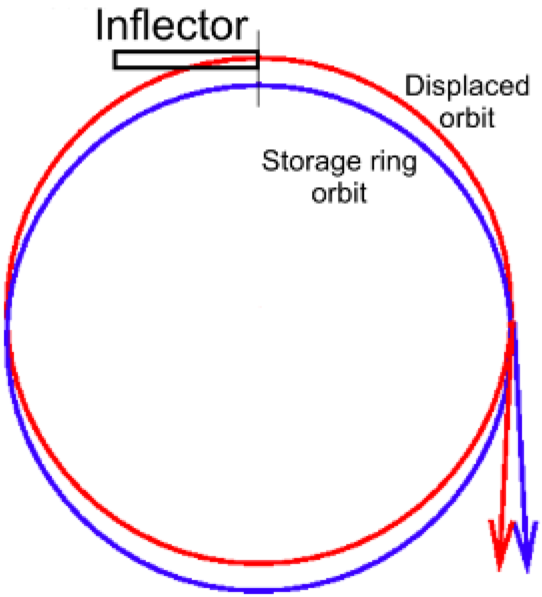
Protons on Target

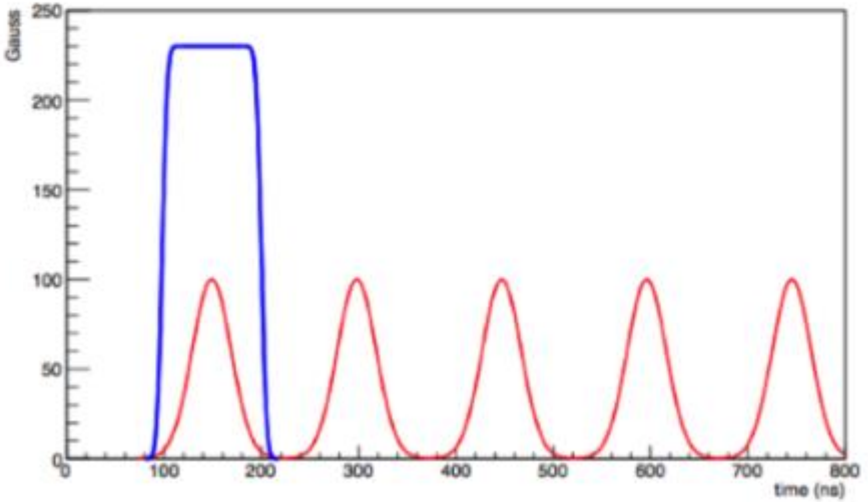
Positrons detected from muon decay

Possible Improvement list

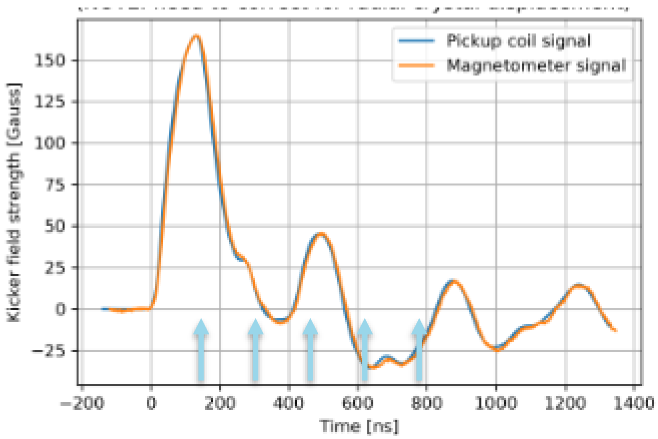
- g-2 storage ring injection kicker improvement
- New Inflector
- PS replacement for 2 circuits in primary beam line
- New target design
- Narrower bunches from Recycler
- More tuning circuits in M2/M3 lines
  - Collimators in M2/M3 lines
  - More profile monitors in M2/M3 lines
- More tuning circuits in primary beam line
- Higher lithium lens gradient
- Muon momentum cooling wedge

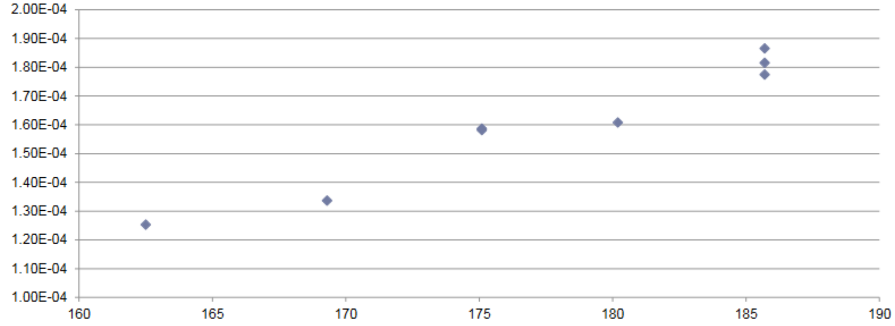
Storage Ring Kicker





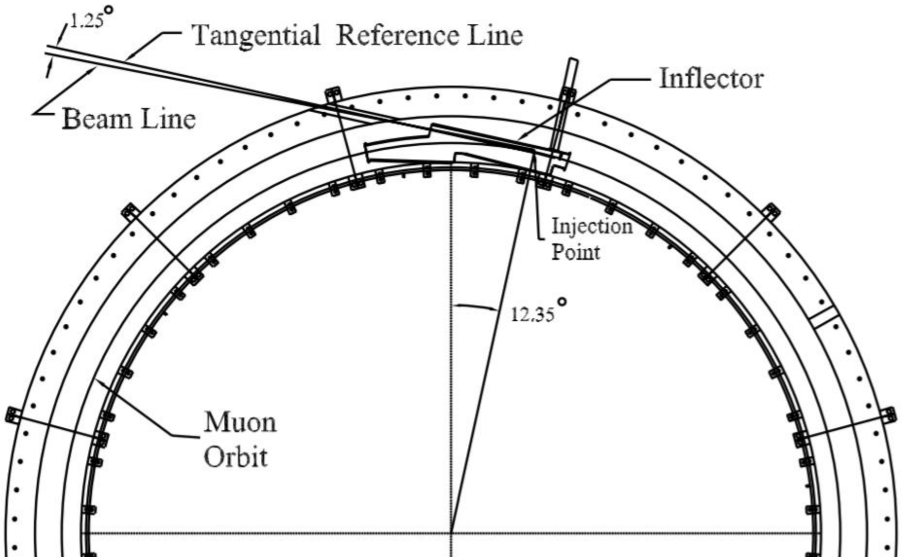
Alex Keshavarzi





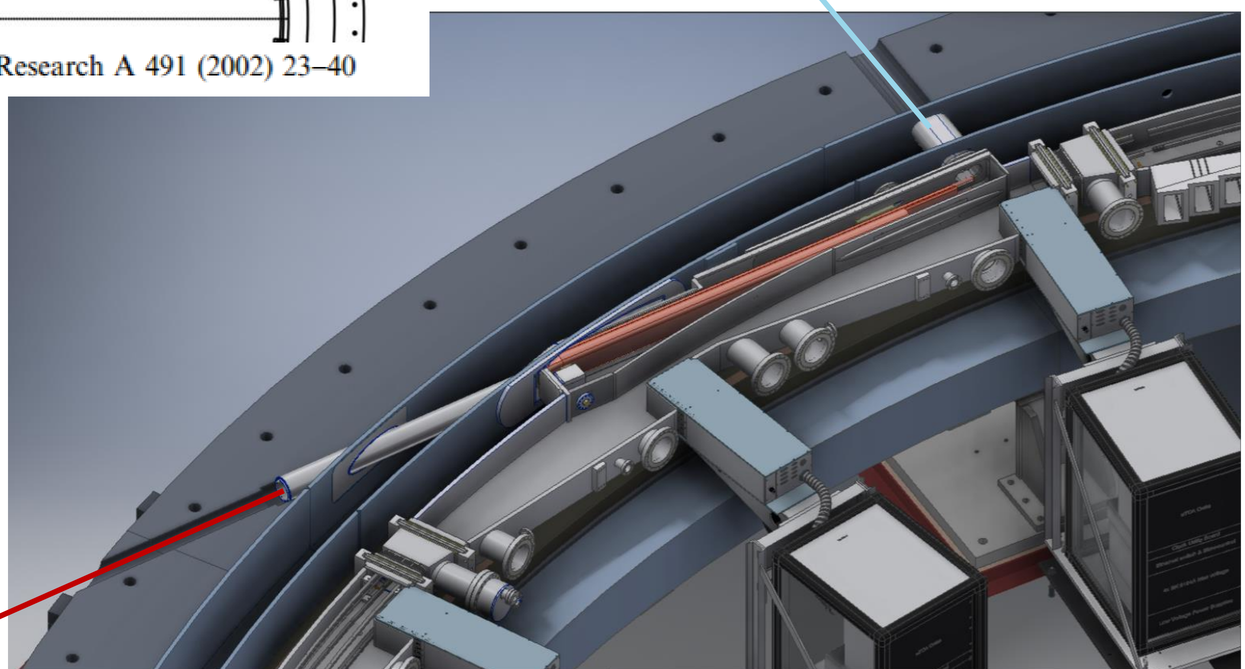
Adam Schreckenberger

K. Badgley



Nuclear Instruments and Methods in Physics Research A 491 (2002) 23–40

Lead and Cryo

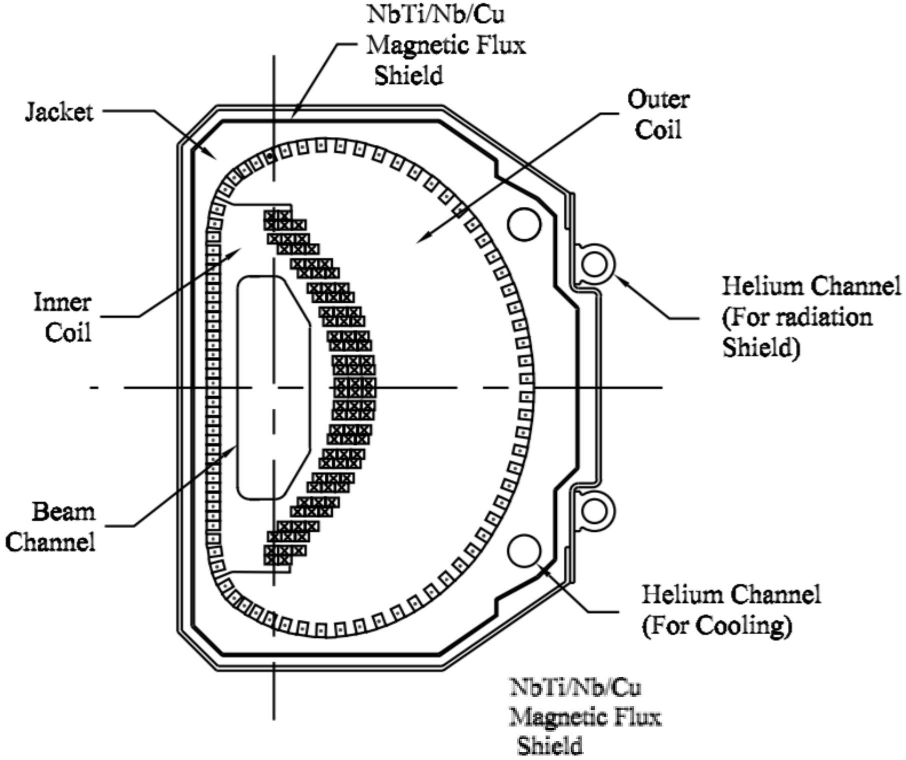


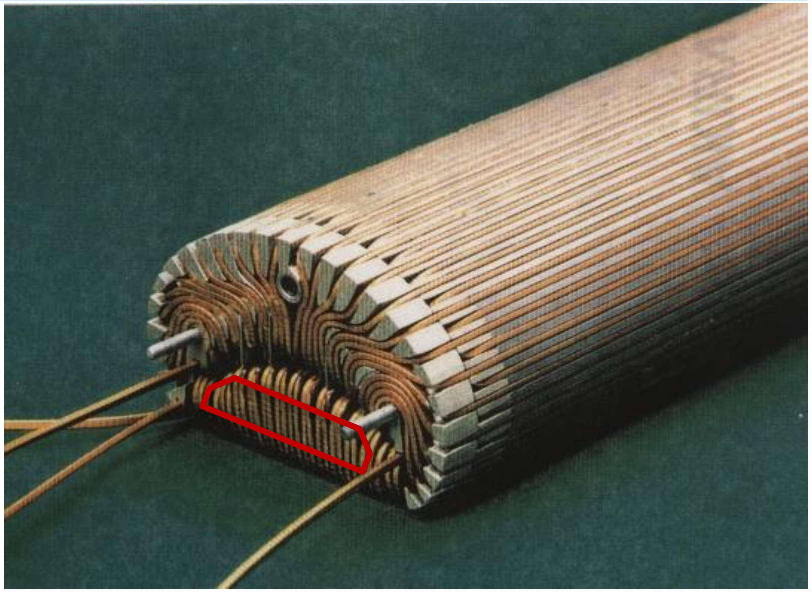
Beam Line

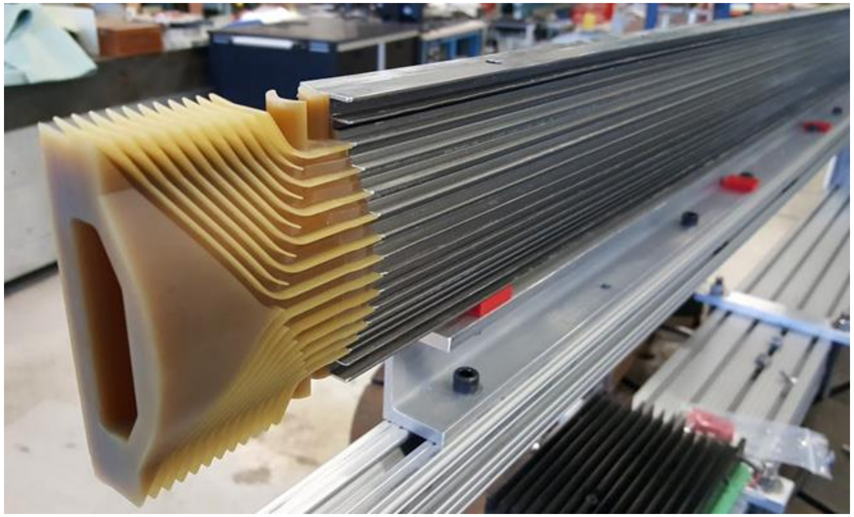
Jarek Kasper

K. Badgley

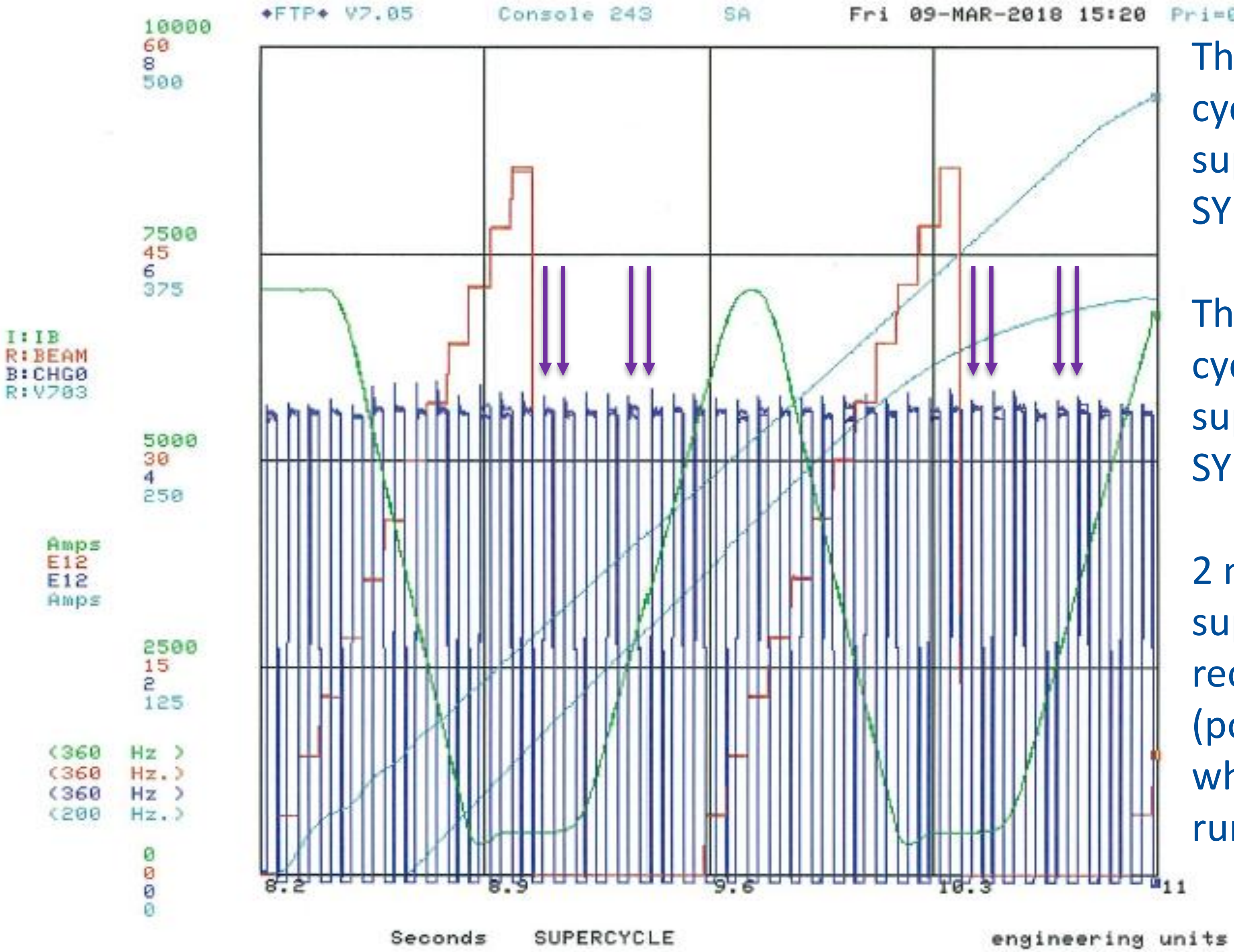
Inflector anatomy







Faster Power Supplies in Beam Line



There are 43 g-2 cycles per supercycle when SY not running

There are 36 g-2 cycles per supercycle when SY is running

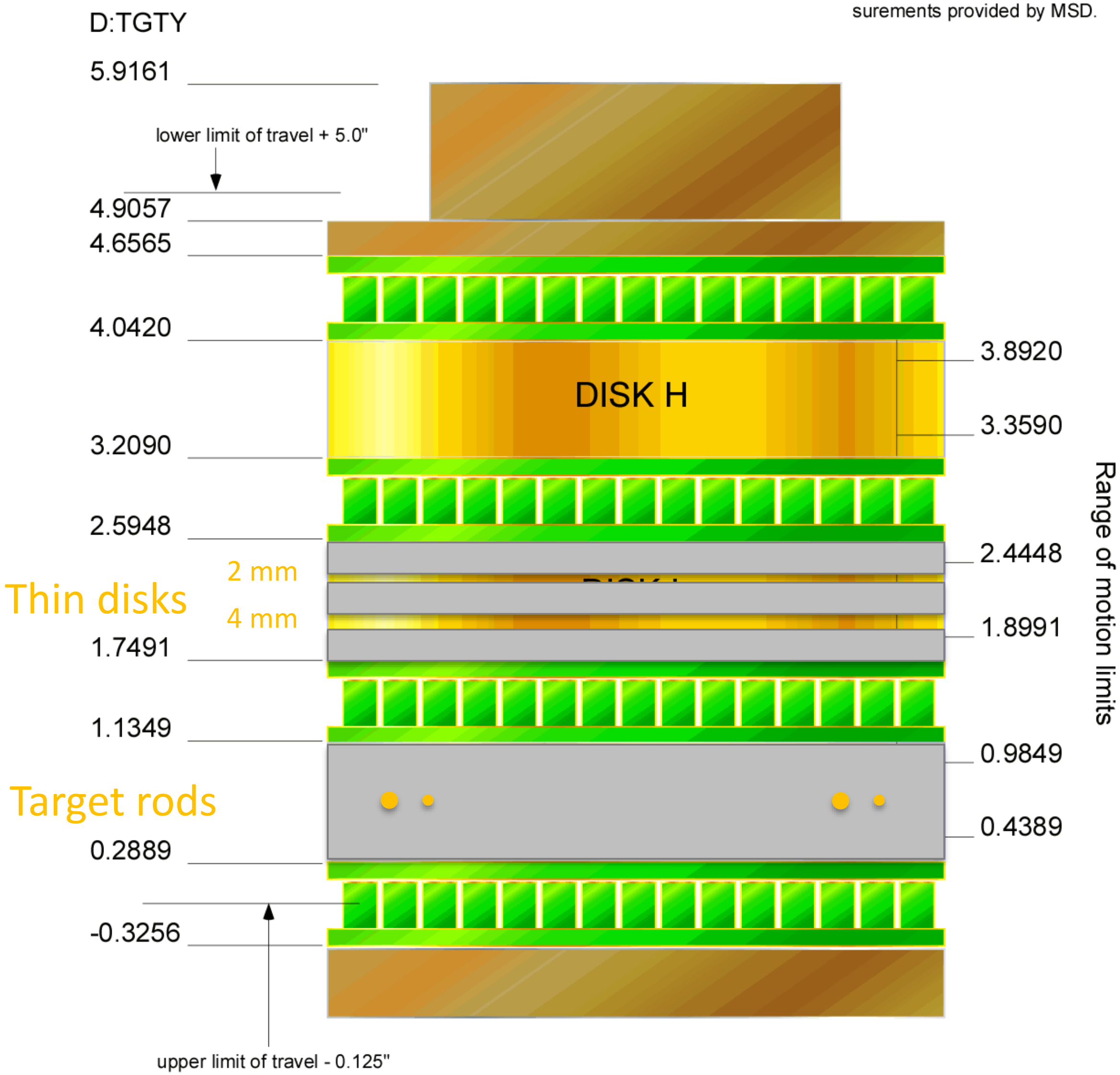
2 new power supplies could recover 3 (possibly 4) cycles when SY is running

New Target Design

- Early simulations predicted that optimizing target shape could yield up to 40% more pions.
- Modified design involves geometries that minimize the internal absorption and scattering of pions once the are created.
- Experience with Pbar production hinted that the gains would be smaller
- Limited funds, resources, and schedule were factors in deciding to use the existing antiproton production target.
- The Target Systems Department has begun the effort to produce a spare target
- It is worth investigating the concepts from the early simulations
- Resources for engineering and fabrication for this purpose are very limited

Proposed Target with new disks

Positions determined 5/10/07 with beam at upper cooling disk lower CU/air junction and 2nd cooling disk upper Cu/air junction. All other positions determined from as-built measurements provided by MSD.



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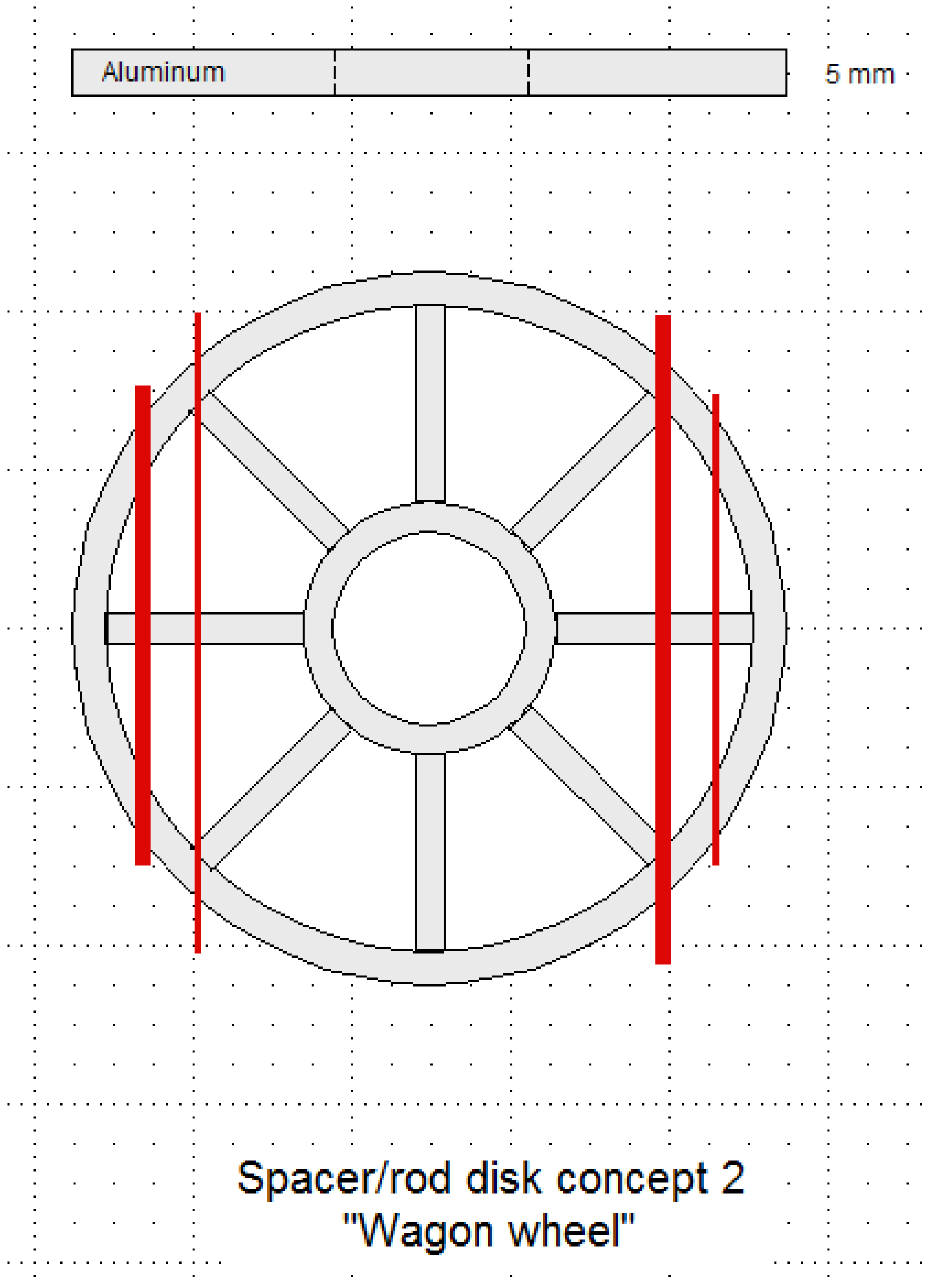
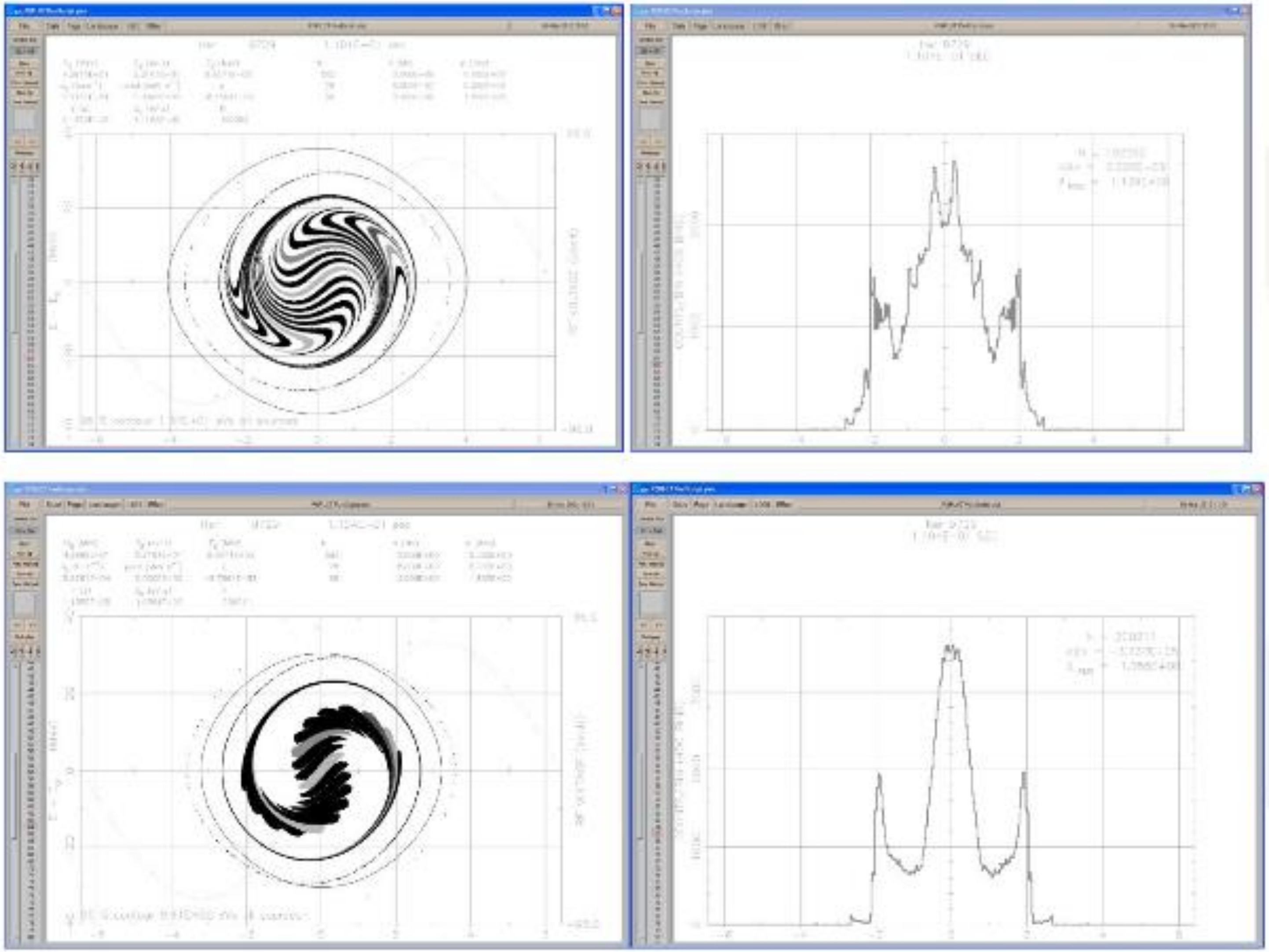


Spacer/rod disk concept 2
"Wagon wheel"

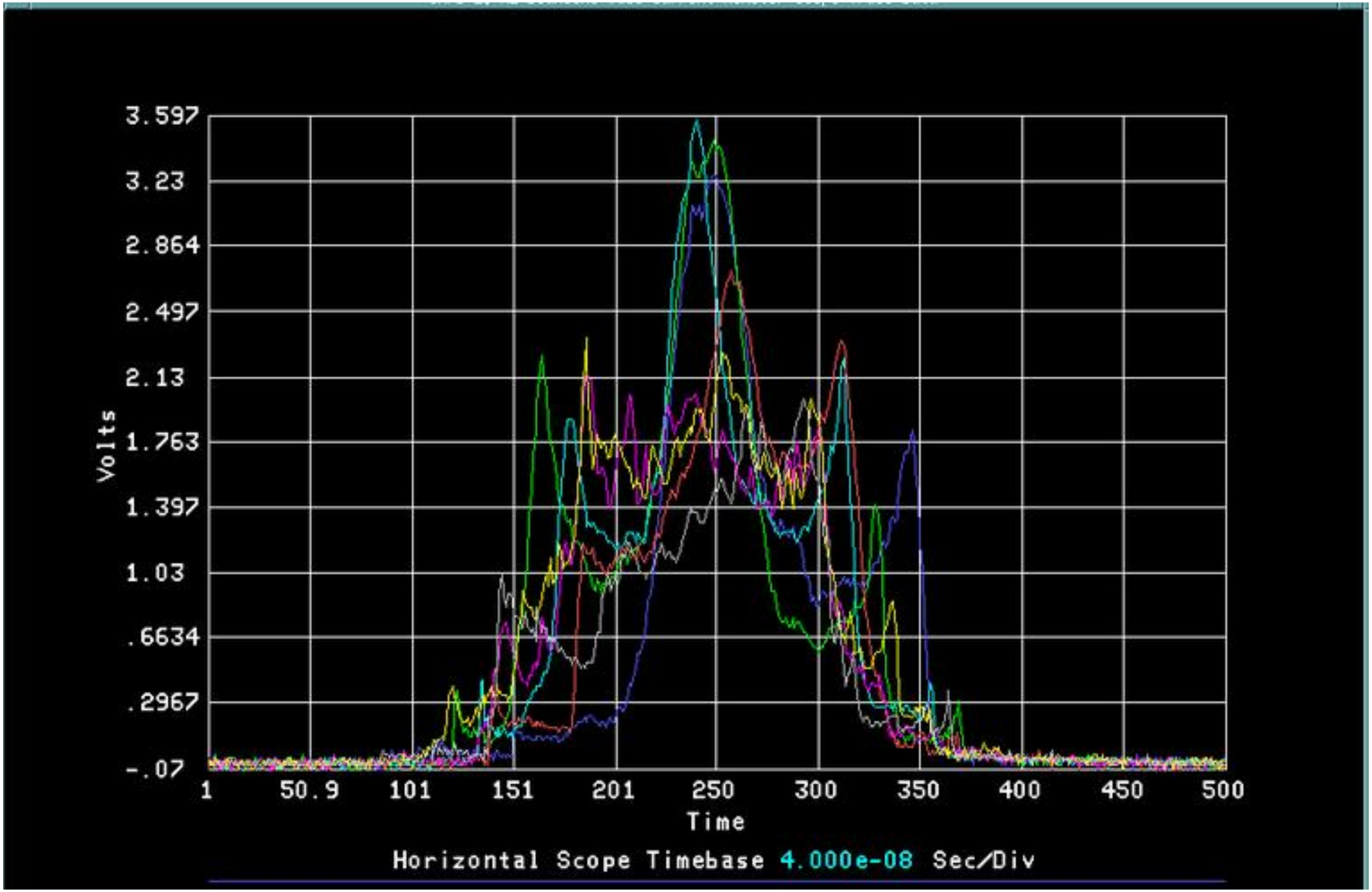
Shorter bunches from RR

- Do bunch formation with 1 Booster batch instead of 2
  - Takes bigger hit out of the rest of the program
  - Or – fewer transfers to g-2
  - Possible gain – All bunches would have structure of first four bunches we see now.
- Install New RF system
  - Lots of $$$
  - 7.5 MHz cavities
    - Lower bunch intensity requiring more transfers
  - More 2.5 MHz cavities
    - Would use spare and DR cavity
    - Eliminates doing Mu2e studies
    - Space and infrastructure constraints in RR
- Form bunches from 17 or 15 booster bunches rather than 21
  - Lower intensity per bunch (possibly able to recoup this loss)
  - Much higher demand on laser notcher in Linac

Simulations of bunch formation in Recycler



M1 line wall current monitor showing all 8 pulses

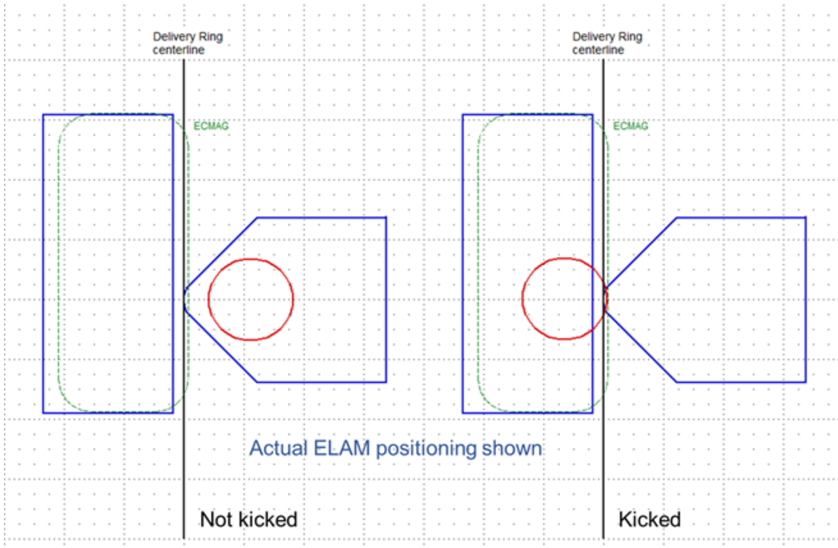


New Tuning Circuits in M2/M3 Lines

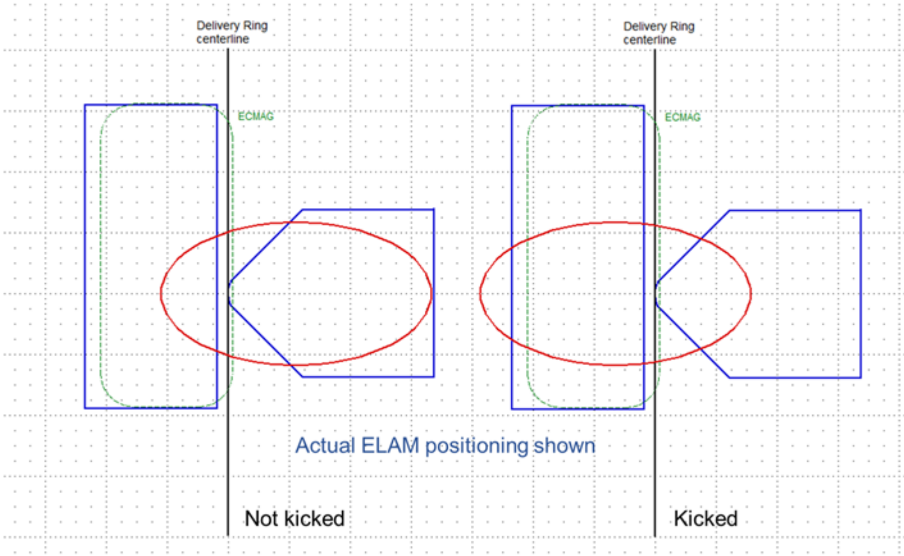
- Issues are coming into focus but not fully understood
- More diagnostics would be useful in understanding problems
- Collimators to control the momentum slice of beam being studied
- More profile monitors to better isolate location of errors
- Solutions might involve alignment and more correctors
- Beam is large but the impact on stored muons is not clear.

Optics correction in M2/M3 line

- Previously shown slide shows effects of optics errors on beam size in small aperture extraction Lambertson.



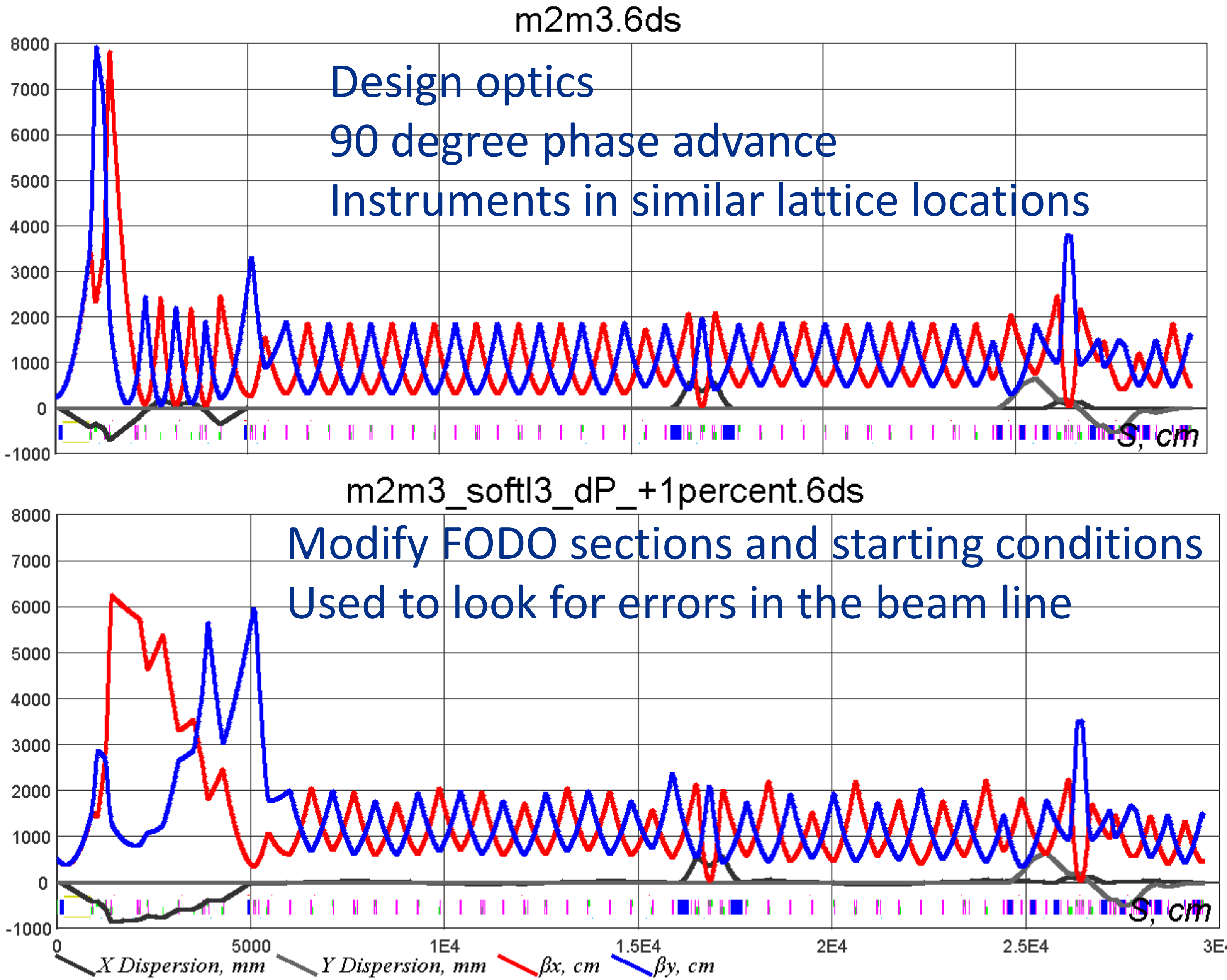
Designed beam size



Issues with larger beam size

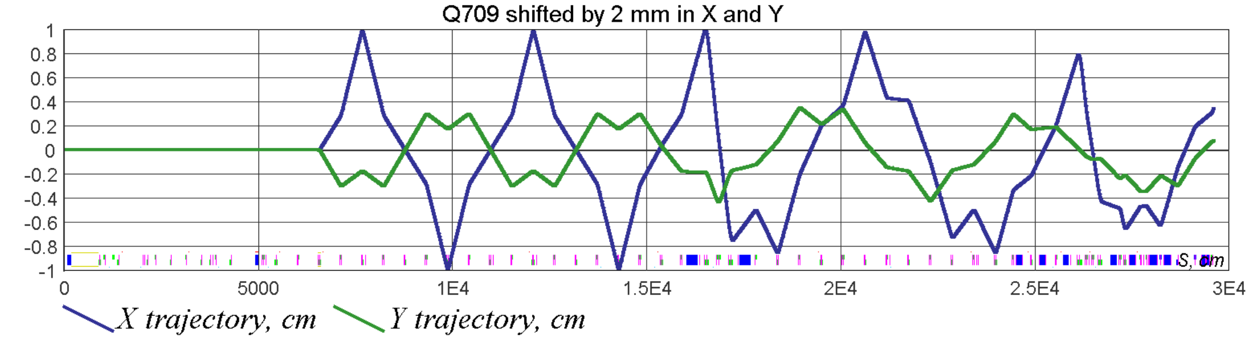
This was presented as largest impact issue to address

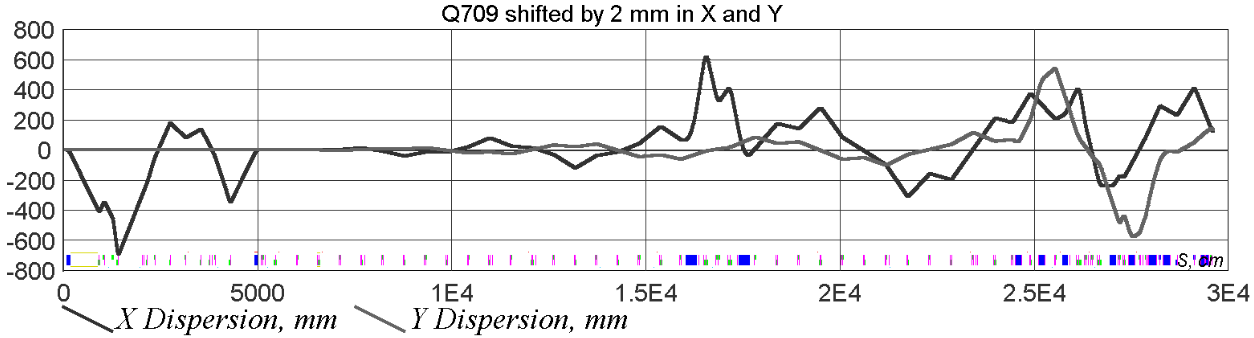
M2/M3 line optics analysis



Second-order linear dispersion

- Trajectory wave goes forever after the excitation by single trim or misaligned focusing element
  - In each consequent focusing element second-order dispersion gets small addition, always in phase, because trajectory oscillates with the same phase advance as dispersion
  - In reality, particle with dp/p may stay bounded because of chromatic effects

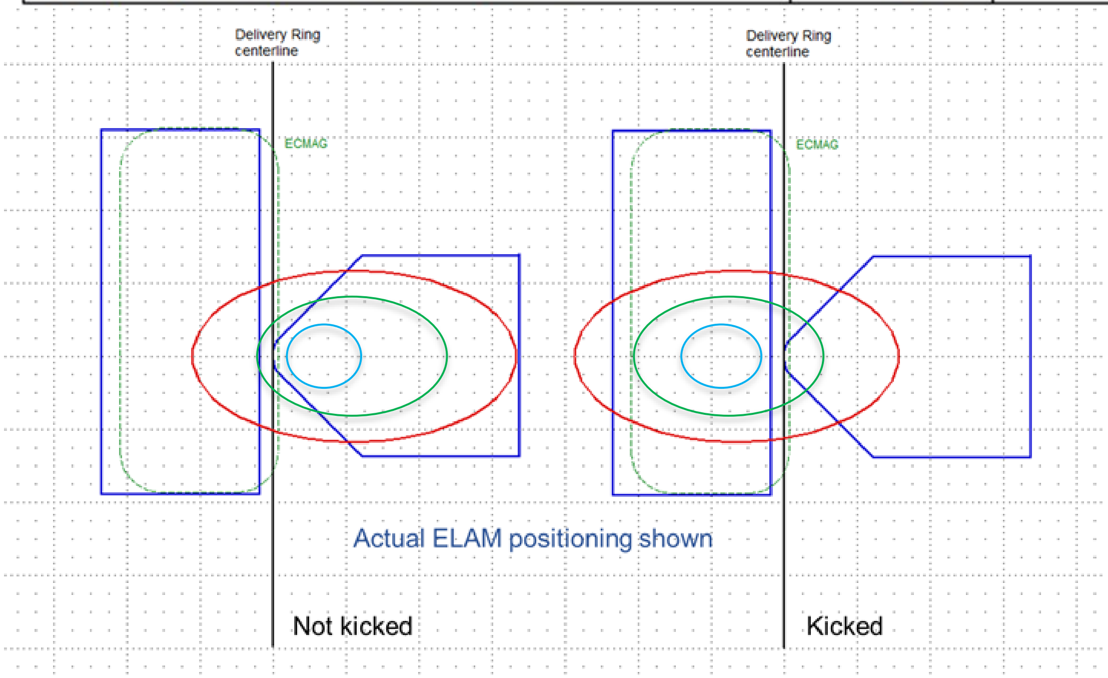




Ultimate Impact of M2/M3 beam size growth is unclear

Table 5.1: Event rate calculation using a bottom-up approach.

Item	Factor	Value per fill
Protons on target		10^{12} p
Positive pions captured in FODO, $\delta p/p = \pm 0.5\%$	1.2×10^{-4}	1.2×10^{8}
Muons captured and transmitted to SR, $\delta p/p = \pm 2\%$	0.67%	8.1×10^{5}
Transmission efficiency after commissioning	90%	7.3×10^{5}
Transmission and capture in SR	$(2.5 \pm 0.5)\%$	1.8×10^{4}
Stored muons after scraping	87%	1.6×10^{4}
Stored muons after 30 μs	63%	1.0×10^{4}
Accepted positrons above E = 1.86 GeV	10.7%	1.1×10^{3}



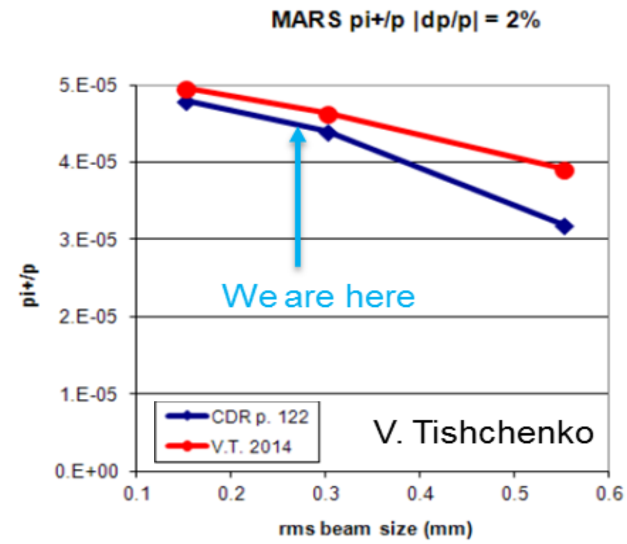
Momentum aperture of M2/M3 line ± 4%

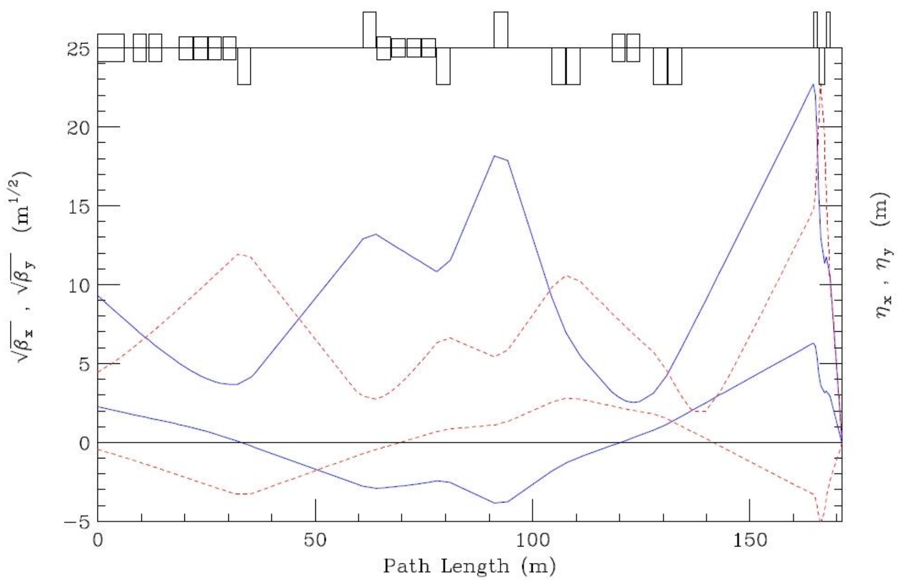
Momentum aperture of Deliver Ring ± 2%

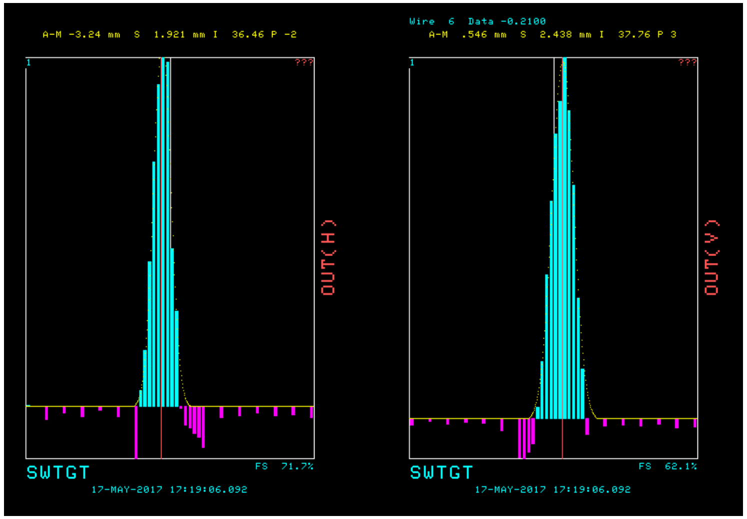
Momentum aperture of g-2 storage ring ± .25%

Primary beam line improvements

- Achieving smaller spot size of $\sigma_x = \sigma_y = 0.15$ mm could improve yield by 5-10%
- Currently $\sigma_x = 0.25$ mm $\sigma_y = 0.30$ mm
- Expect to take a lot of work







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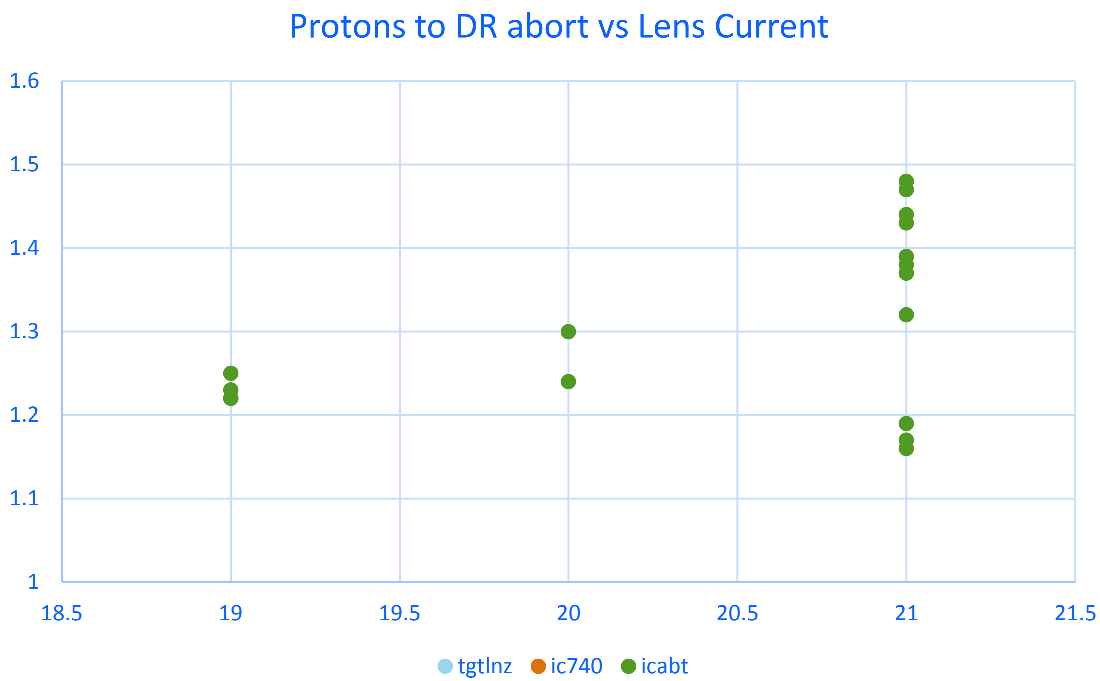
Higher Lens Gradient



- Higher yield is possible at higher gradient
- 18 million pulses was lifetime of best lens in collider operation

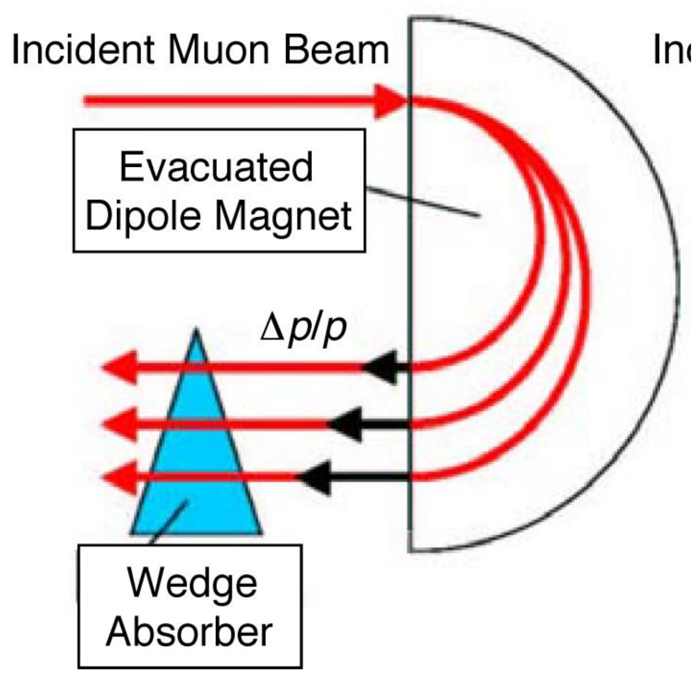
- Target Systems Department is getting started estimating effort to make another spare lens just to support current operation.
- The lens experiences 1 million pulses per day during normal operation

Muon Momentum Cooling Wedge

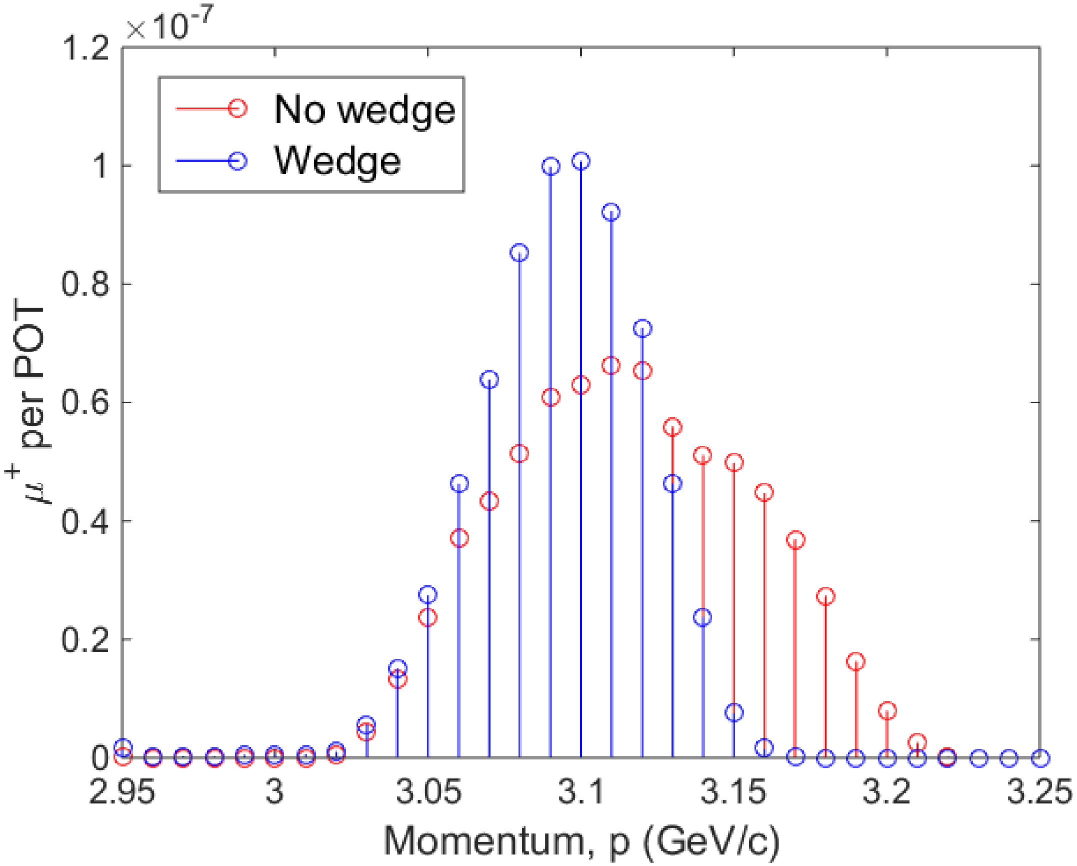
- Increase the number of muons in the momentum acceptance of the g-2 storage ring.
- LDRD proposal by Diktys Stratakis is being implemented
- $340K awarded with a goal of a single installation in the M5 line this summer
- Estimated gain in stored muons is 20%

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

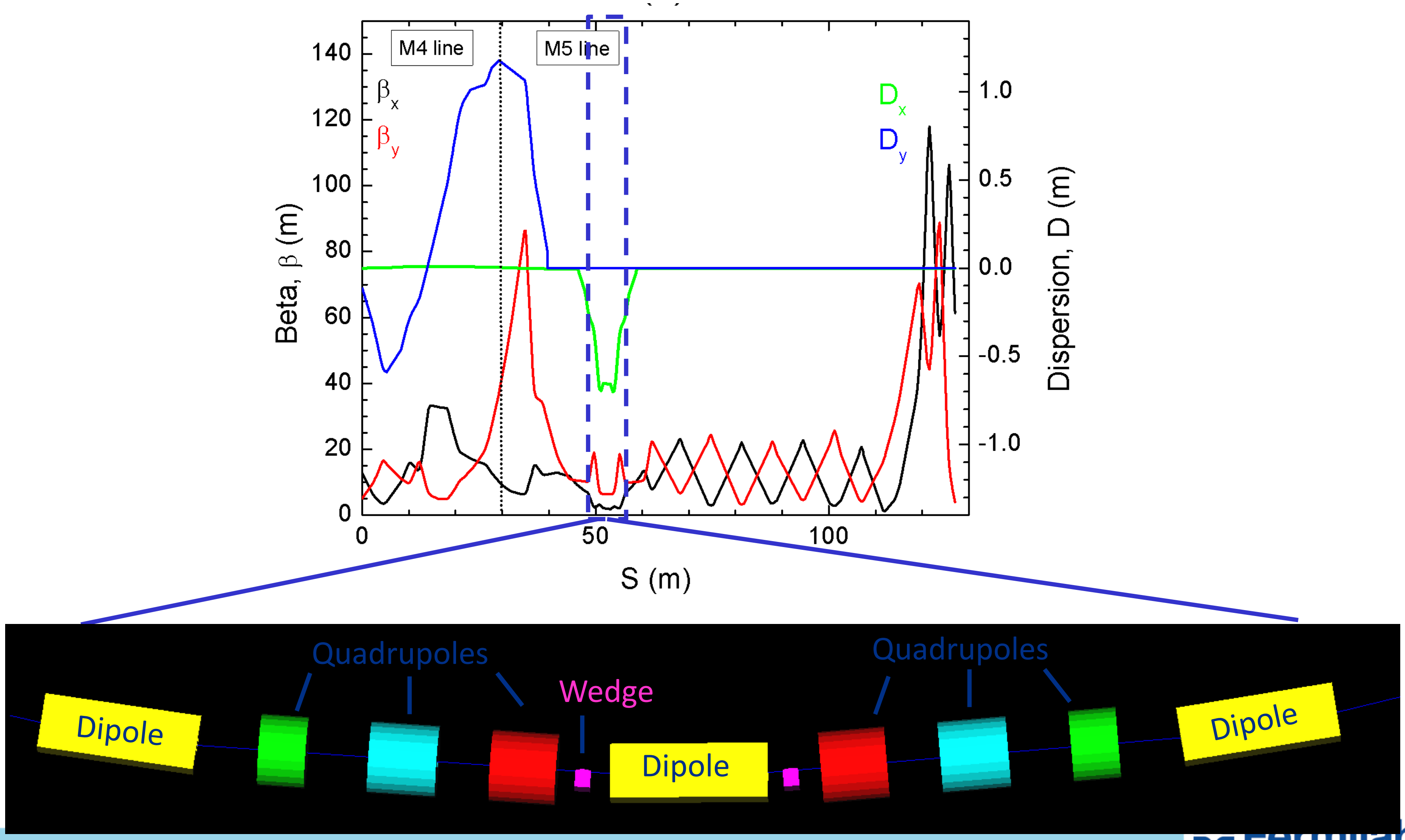


Performance



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

Choice of location (2)



Improvement	cost	Increase in stored muons	Comment
Storage Ring kicker	expensive	30%	This improvement could come from an additional kicker or just improved waveform. This will be expensive and time consuming. The gain factor here comes with high uncertainty and depends o the bunch shape of the injected muons.
New Inflector	Covered by project left over?	40%	Material in the beam seems to have more of an effect than I thought it would, so I believe the op end inflector has a big upside if it works as planned.
PS replacement	$50K ($150K)	8% (%11)	Three cycles after the SY cycles can be gained by installing higher voltage supplies. It is possible (but not a sure thing) that one cycle before the SY cycle could be gained by the additional expens of using 2 quadrant supplies (an extra $80K)
New Targets	10%-40%	$50K	TSD feels that producing a new replacement target is a necessary support activity. Creating them with test sections seems to be a worth while addition at reasonable cost. Simulations suggest tha a yield gain of up to 40% is possible, but practical experience would suggest that 10% is a more likely outcome. Currently trying to identify resources.
New knobs for M2/M3 line			Our studies to determine what is needed have not progress far enough to specify this improvement. More diagnostics would certainly aid in the investigation.
Higher lens gradient	20%	$600K	Higher lens gradient would result in increased pion yield. The needed improvements would be to mediate increased failure rates that would come with the higher gradient. The costs shown here are for one extra spare lens and extra RG-220 cable to be readied for rapid replacement.
Shorter bunches from RR	< 20%		It is unclear if any of these improvements can be realized. Additional RF cavities are expensive ar it is not known if there is enough momentum aperture to take advantage of this. Implementing the laser notcher would require that the bunch intensity could increase to compensate for the missing bunches. Proton source experts think the bunch intensity can be increased, but upgrade to the laser system would be required.
Expansion of wedge LDRD			Evaluating the wedge idea as designed for the LDRD project is probably necessary before plannin any further implementation. The LDRD is funded at $314K for an estimated improvement of 20%

Summary

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