Fermilab

# Lithium Lens ANSYS Mechanical Simulation for Muon g-2

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## Muon g-2 Overview

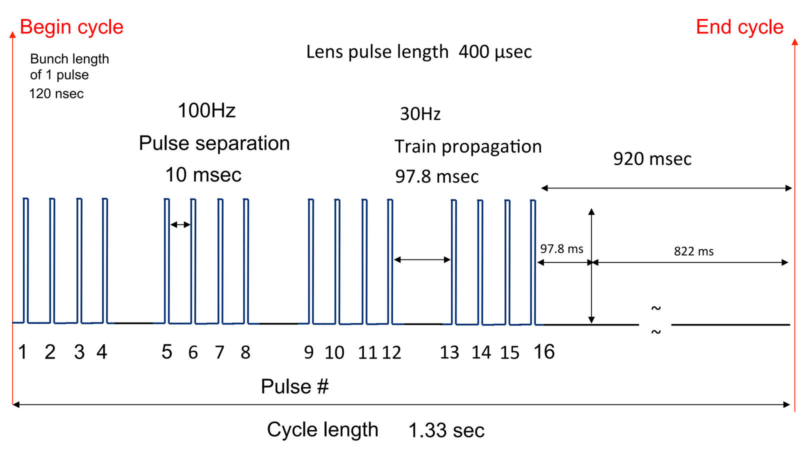
- The Lithium Collection Lens was used in the Fermilab Tevatron collider run for over two decades to focus and ultimately collect anti-protons:
  - 450 kA peak current produces a gradient of 670 T/m; normal operating condition
  - 8e12 protons per pulse on target at 120 GeV
  - Maximum repetition rate of 0.5 Hz, is roughly 1e6 pulses per month
- Muon g-2 intends to use the Lithium Collection Lens to focus pions that decay to muons
  - Peak current of 155 kA produces a gradient of 230 T/m
  - 1e12 protons per pulse on target at 8.9 GeV
  - Average repetition rate of 12 Hz, is 1e6 pulses per day

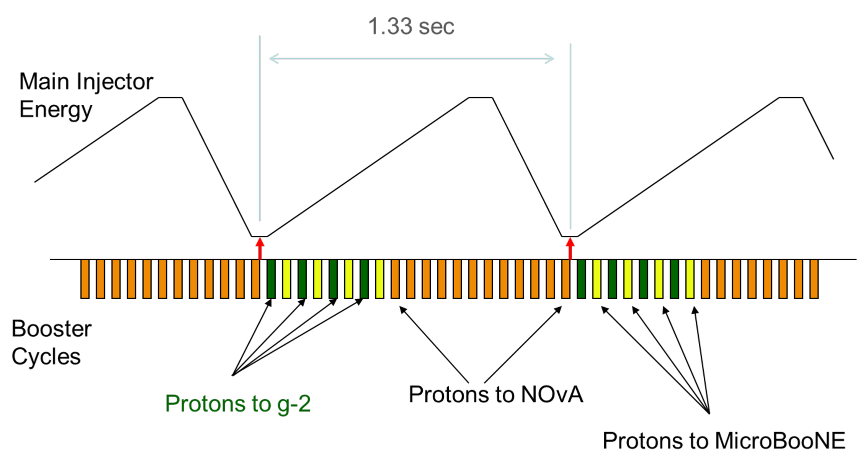
Beam from Booster
1 Batch from Booster Injected into Recycler
Recycler will rebunch the 1 batch into 4 bunches
Bunches will kicked out or recycler to beam line to target
Pions travel & decay -> muons & circulate delivery ring N turns
Muons are kicked out to g-2 beamline and into muon ring

## Analysis uses Scaled Thermal Loading with Muon g-2 Pulse Train

- Original ANSYS analysis was developed in 2004 by P. Hurh and S. Tariq
  - Designed for 670 kA producing 1000 T/m gradient
  - Electromagnetic, Thermal, Structural
  - Non-linear material properties, including lithium creep parameters
- Analysis for Muon g-2 uses scaled thermal inputs:
  - Protons Per Pulse – Reduced to 1/8 of original analysis
  - MARS deposition – Reduced to 20% of original analysis
  - Peak Current – Reduced to 23% of original analysis
- Muon g-2 pulse train input
  - 16 pulses every 1.33 seconds, 12 Hz average pulse rate
  - 4 groups of 4 pulses at 100 Hz

Muon g-2 Pulse Train at the Target (12Hz mode)



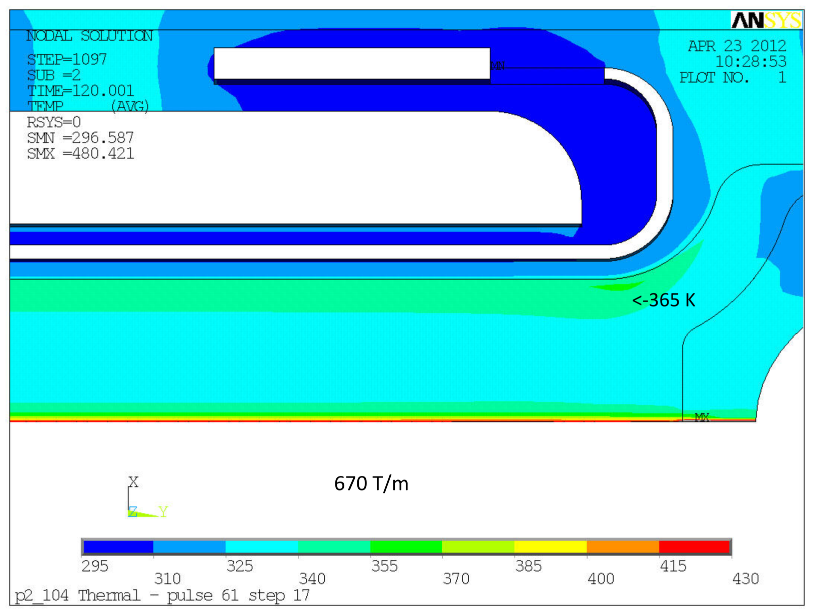



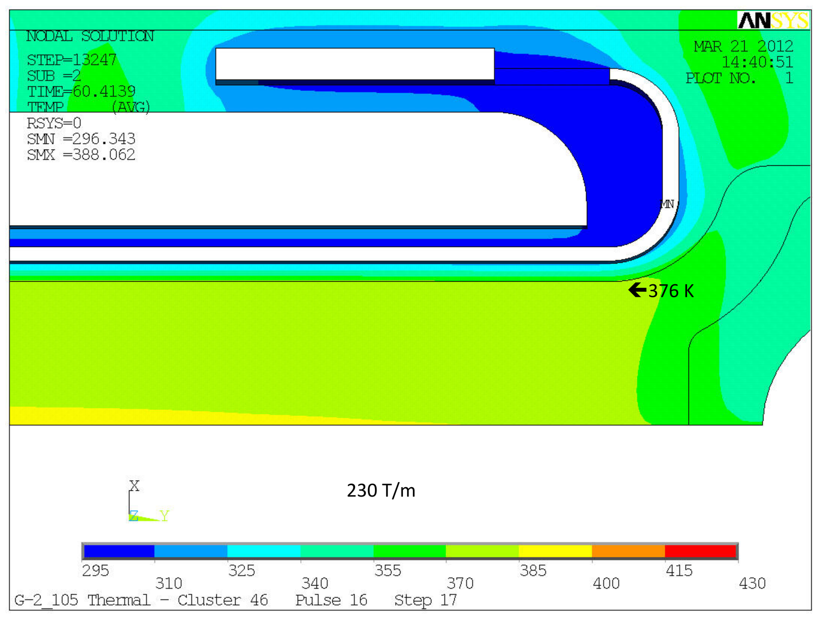

## Conclusions

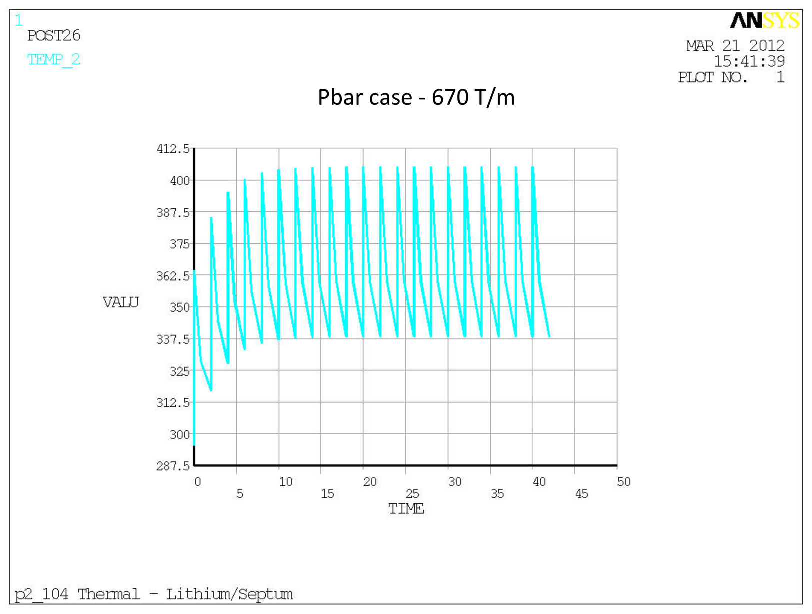
- Fatigue parameters are much better for the Muon g-2 case compared to the Pbar case
- Per pulse thermal load is less for Muon g-2, but higher rep rate causes overall higher heat load
  - Higher average temperature in lithium causes higher static stresses in septum
- Reducing lithium preload from 3800 psi down to 2200 psi could reduce static stresses without adversely impacting fatigue resistance
- "NoVA-Off" analysis looked at running conditions of 20, 24 and 28 pulses/cycle
  - While 20 pulses/cycle is possible, higher heat loading (septum stress) is a concern
  - Lithium melting (at 453.75 K) would be catastrophic

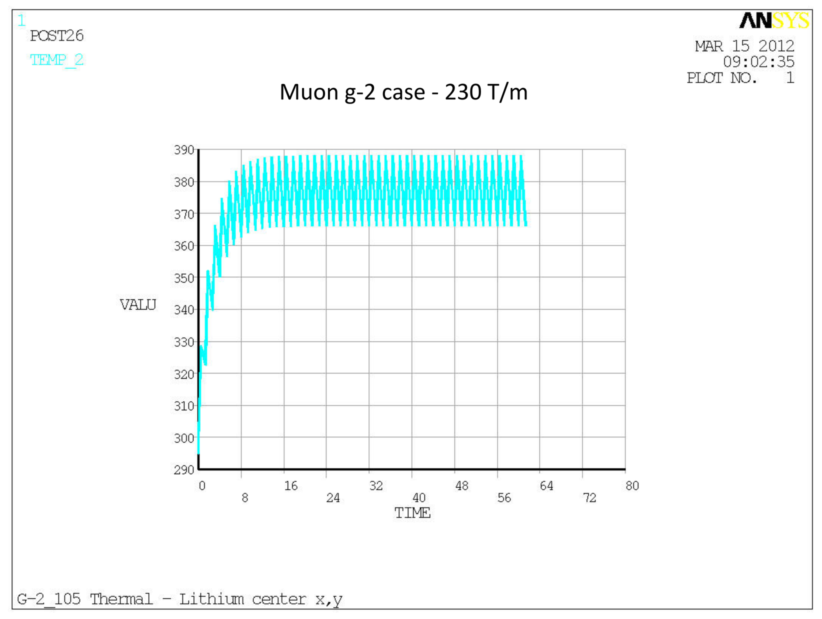
## Thermal Comparison

- Pbar case: has corner hot spot and beam center extreme
- Muon g-2 case: has higher average temperatures in the lithium, which increases static stress
- Muon g-2 case: cyclical temperature oscillations per pulse are drastically reduced



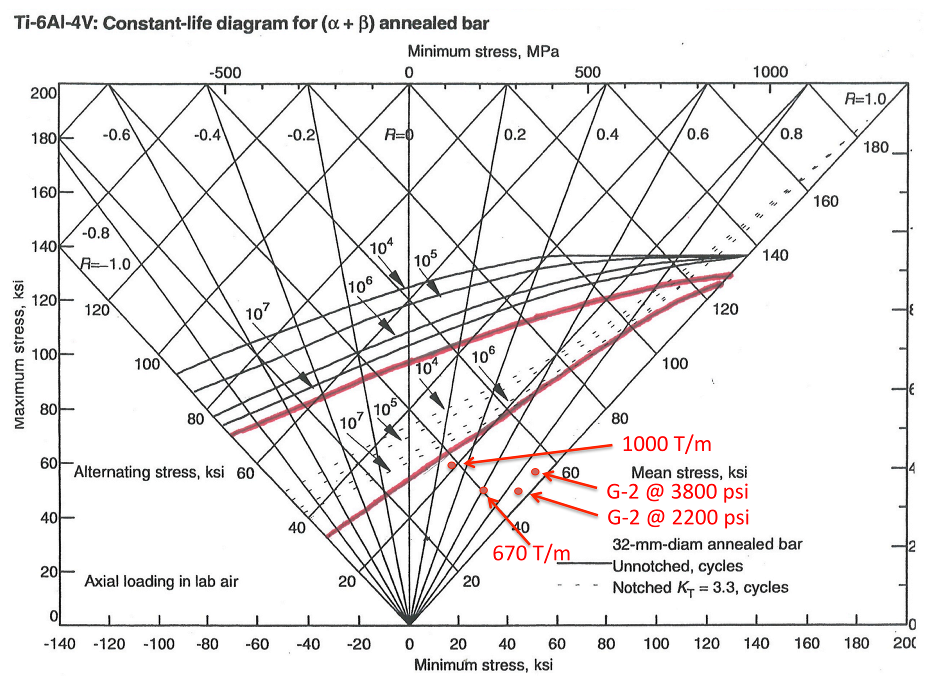




## Stress & Fatigue Comparison, NoVA Off Analysis

- Fatigue "R" value is ratio of min/max cyclical stress
  - Pbar case showed that fatigue was the primary failure concern
  - Muon g-2 case shows that fatigue is probably not a concern

Stress Comparison

| | | | | | |
|---|---|---|---|---|---|
| | Preload | 3800 psi | 3800 psi | 3800 psi | 2200 psi |
| | Grad | 1000 | 670 | 230 | 230 |
| | | ksi | ksi | ksi | ksi |
| SZ | Min | 11.60 | 29.01 | 53.66 | 43.51 |
| | Max | 63.09 | 48.59 | 58.31 | 46.41 |
| | Mean | 37.35 | 38.80 | 55.98 | 44.96 |
| | Alt | 51.49 | 19.58 | 4.64 | 2.90 |
| | R | 0.18 | 0.60 | 0.92 | 0.94 |
| SEQV | Min | 17.40 | 30.75 | 57.73 | 43.51 |
| | Max | 63.09 | 50.76 | 61.06 | 49.02 |
| | Mean | 40.25 | 40.76 | 59.39 | 46.27 |
| | Alt | 45.69 | 20.02 | 3.34 | 5.51 |
| | R | 0.28 | 0.61 | 0.95 | 0.89 |




- Mean stress is higher for Muon g2
  - Due to higher lithium temperature and Pbar lithium fill preload