



LBNF Horn Requirements for Option Zero

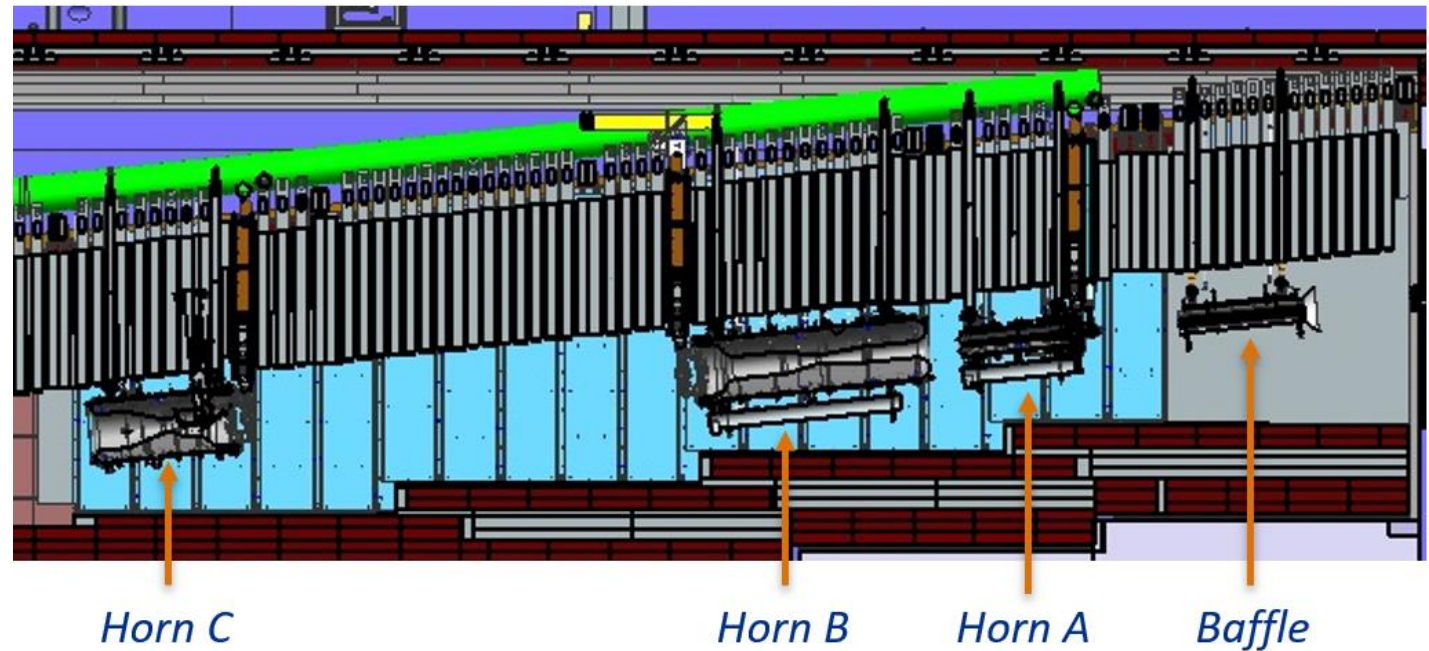
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Accelerators Capabilities Enhancement Workshop

1/31/2023

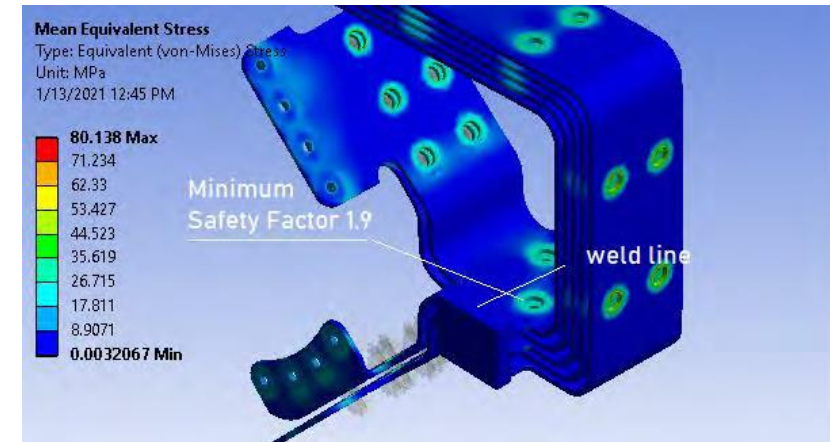
Agenda

- Horn A
 - Challenges at 2.4 MW
 - Capabilities of 1.2 MW Design
 - NuMI Stripline Experience
- Horns B & C
 - Challenges at 2.4 MW
 - Capabilities of 1.2 MW Design
- Option Zero R&D Estimates
- Summary



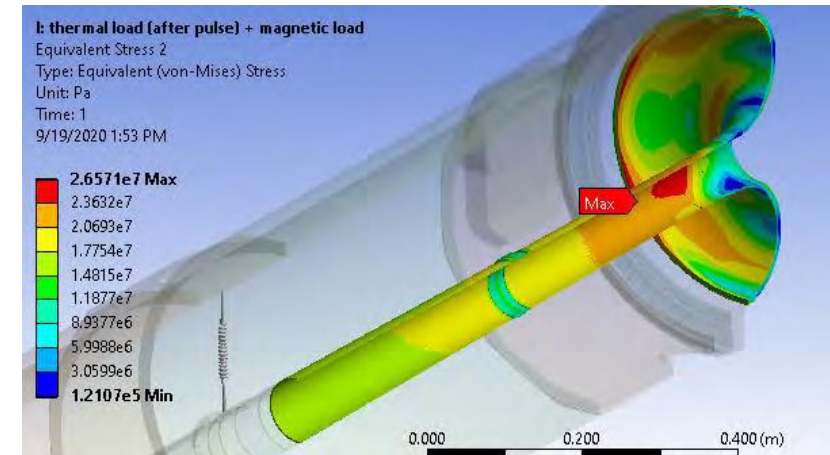
Horn A – 2.4 MW Challenges

- For Option Zero, horns must pulse at 1.8x frequency of current design
- FEA was analyzed at 1.2 MW
 - 120 GeV, 1.2 s rep rate, 7.5×10^{13} protons/cycle
- Weakest areas at 1.2 MW require redesign for 2.4 MW



Location of lowest SF on stripline

Difference at 2.4 MW	Physical Effect	Affected Major Component
Higher thermal load from beam	<ul style="list-style-type: none"> • Higher temperatures • Higher stresses 	Inner conductor
Increased pulse rate	<ul style="list-style-type: none"> • Increased Joule heating • More cycles • Fatigue lifetime reached sooner 	Stripline



Equivalent stress in inner conductor

Horn A – Capabilities of 1.2 MW Design

- Stripline and inner conductor are limiting factors in how far Horn A can be pushed past 1.2 MW
- Rough scaling:
 - **Stripline**
 - Current design cannot exceed 1.2 MW
 - **Inner conductor**
 - Remove 15% EDEP uncertainty, SF=2:
 - **Very roughly:** 1.8 MW

Lowest Fatigue Safety Factors for Horn A

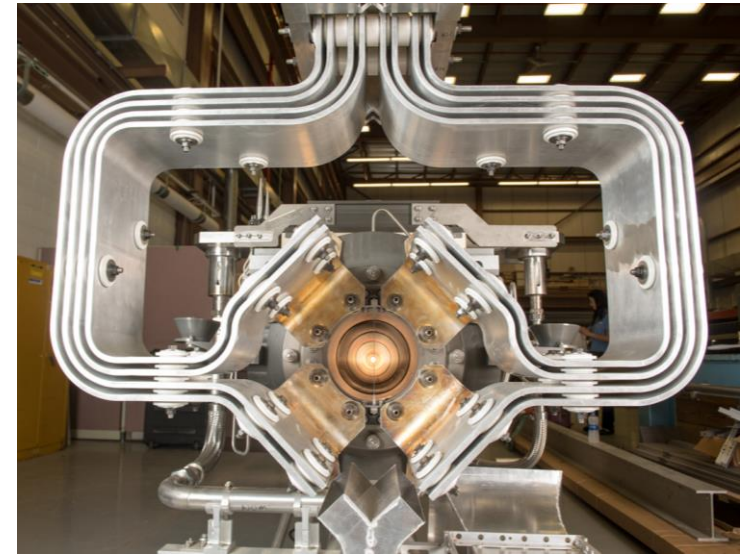
Region	Safety Factor
Inner conductor weld 2a	2.5
Inner conductor DS	4.4
Stripline weld 2a	1.9

NuMI Stripline Experience

- NuMI Horn 1 (1 MW) stripline has low SFs in some regions
 - Has not failed
 - Much higher SFs in other areas than LBNF
- Previous Horn 1 & Horn 2 striplines have failed
 - Stripline failure also influenced by vibration

SF (min)	Stripline (away from bolt hole)	Bolt hole	Connection area with horn
Al 6101-T6	SF>5	SF=1.64 (based on the peak number)	N/A
Al6013-T6	SF>4	SF=2.5 (based on the peak number)	SF=2 (based on the peak number)

1 MW Horn 1 stripline safety factors

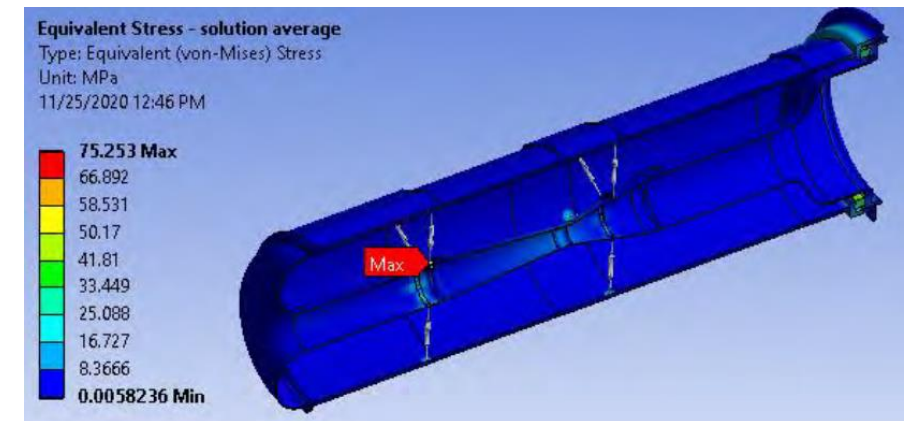


1 MW Horn 1 stripline

Horns B & C – 2.4 MW Challenges

- All FEA analyzed at 1.2 MW
 - 120 GeV, 1.2 s rep rate, 7.5×10^{13} protons/cycle
- Higher safety factors than Horn A at 1.2 MW

Difference at 2.4 MW	Physical Effect	Affected Major Component
Higher thermal load from beam	<ul style="list-style-type: none">• Higher temperatures• Higher stresses	Inner conductor
Increased pulse rate	<ul style="list-style-type: none">• Increased Joule heating• More cycles• Fatigue lifetime reached sooner	Stripline



Equivalent stress in Horn B inner conductor

Horns B & C – Capabilities of 1.2 MW Design

- Rough scaling:
 - **Stripline**
 - Current design cannot exceed 1.2 MW
 - SF of 1.53 < 2
 - **Horn B inner conductor**
 - Remove 15% uncertainty in EDEP data, SF=2:
 - **Very roughly:** 2 MW
 - **Horn C inner conductor**
 - High fatigue safety factor suggests no issues at 2.4 MW

Lowest Fatigue Safety Factors for Horns B & C

Region	Safety Factor
Horn B inner conductor	3.6
Horn B/C stripline	1.53
Horn C inner conductor	8

Option Zero R&D Estimates

- New EDEP needed for Option Zero
 - FEA to be re-run using Option Zero EDEP
- Power supply would require ~\$200k M&S upgrade from current design

Horn	Task	Labor (0.3 FTE)	Duration
A	Option Zero Mars EDEP	1 scientist	2 months
	FEA <ul style="list-style-type: none"> • Conductors • Stripline thermal + structural • Spider supports • Water tank • Hangers 	2 engineers	4-6 months
B	Option Zero Mars EDEP	1 scientist	2 months
	FEA <ul style="list-style-type: none"> • Horn B conductors • Stripline thermal+ structural • Stripline CFD • Water tank • Hangers • Crosshairs 	2 engineers	4-6 months
C	Option Zero Mars EDEP	1 scientist	2 months
	FEA <ul style="list-style-type: none"> • Horn C conductors 	2 engineers	2 months

Summary

- FEA must be re-done using Option Zero EDEP data
- Modifications needed are driven by FEA results
 - Horn A
 - Re-designed inner conductor and stripline
 - Horns B & C
 - Stripline redesign
 - Inner conductors could be pushed further past 1.2 MW than Horn A