Increasing Proton Driver Bunch Train Length

J. Scott Berg Brookhaven National Laboratory Fourth IDS-NF Plenary Meeting 14 October 2009

Neutrino Factory Bunch Structure



 Proton driver energy ramps every 20 ms
 Less frequently, more space charge issues
 More frequently, more average power for muon RF

3 bunches accelerated
 More bunches, less space charge





Neutrino Factory Bunch Structure









Jet Disruption









Neutrino Factory Bunch Structure



- Bunches extracted one at a time
 - \Box At least 17 μ s between bunches
 - Train extracted from FFAG before next injected
 - \Box All bunches arrive within 40 μ s
 - All bunches hit jet target before breakup
 Forces maximum 3 bunches
- Before target, bunch length reduced to 1–3 ns
 Reduce longitudinal emittance of muons





Beam Loading

- Muon bunch train extracts energy from accelerating cavities
- Replace energy before next train
 - Otherwise won't gain same energy
 - Weak/nonexistent synchrotron oscillation
 - Potentially correct with multiple RF frequencies: difficult and inefficient
- Power into input coupler limited: 500–1000 kW
 Takes time to replace energy







Beam Loading: Calculation

- $\circ 2.0 \times 10^{12}$ muons in bunch train (both signs)
- Extract 4.1 J per cavity per pass
- 017 FFAG turns, 500 kW maximum
 - \Box 139 μ s to replenish
 - $\square\,278~\mu s$ for all 3 bunch trains
- More optimistic: 13 turns, 1 MW maximum
 - 106 µs for all 3 trains
 Less efficient FFAG design







MERIT Results

- Look directly at proton production
- First pulse corresponding to 4 MW IDS-NF
- Delay second smaller pulse
- Look at relative production per proton

○ Results

□ Consistent with no loss with 350 μ s delay □ 5% loss with 700 μ s delay







Pion Production Ratio

Ratio Target In-Out/Target Out







Proposal: Revise Time for Multiple Proton Bunches



Most pessimistic number: 278 µs for all 3
 Could discuss being more optimistic
 Challenge of input coupler, or
 Force choice of less efficient FFAG

 Benefit: accelerates all three bunch trains to same energy without costly RF manipulations
 Consistent with MERIT results





Penalty for Longer Bunch Spacing



Increased duty factor in front end RF
 200 µs now, goes up to 478 µs
 Longer time to hold bunches in proton driver





More Bunch Trains Possible

- Timing constraints forced maximum 3 bunches
 Now free of this constraint
- Storage ring
 - Requires RF to keep trains separated, or
 - Longer storage ring
- Easier on proton driver
- Less beam loading droop down bunch train

