NOνA Accelerator Upgrades: Status

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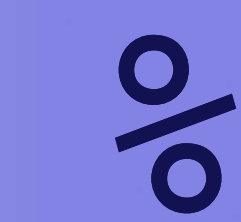
About this talk

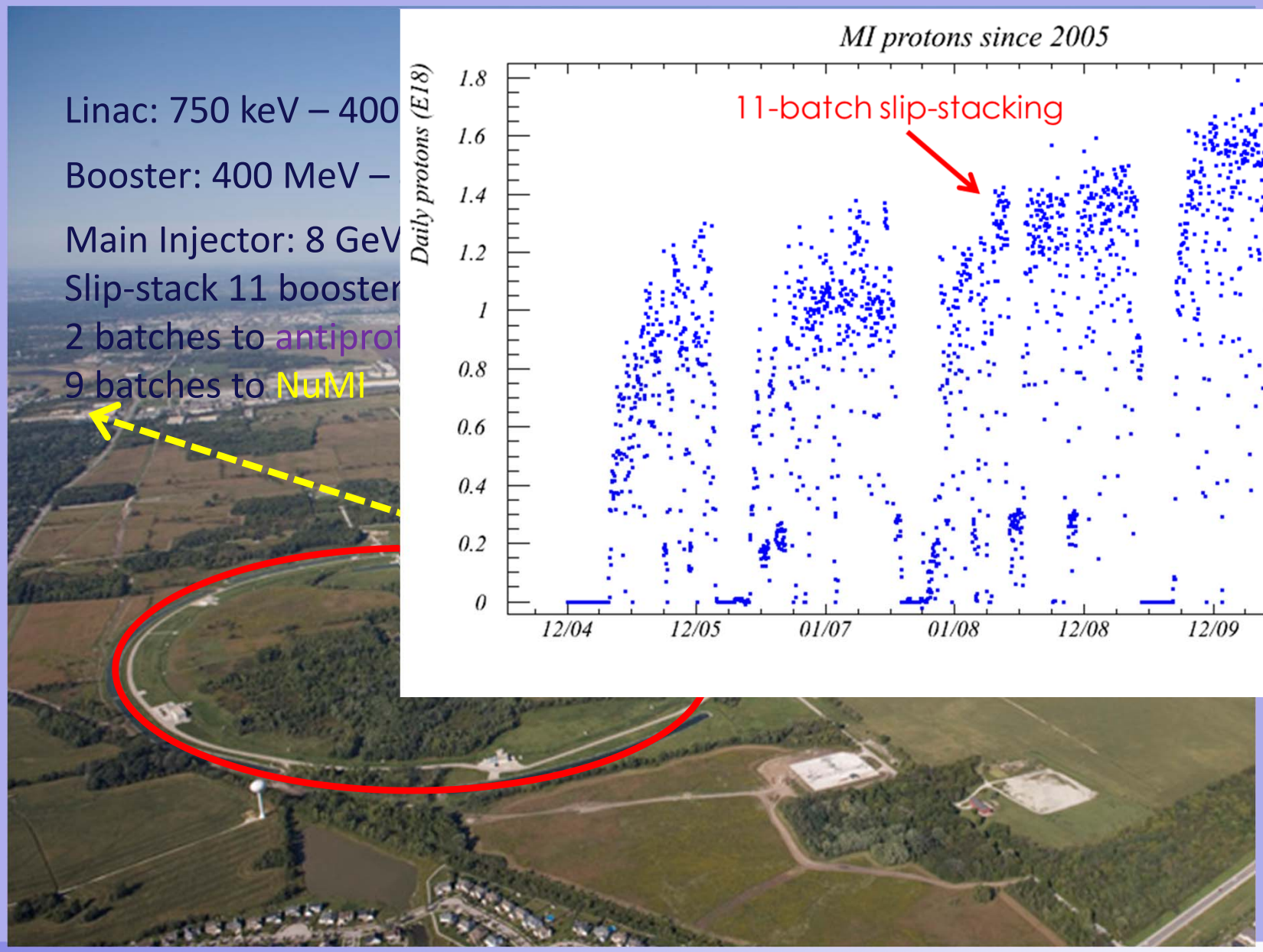


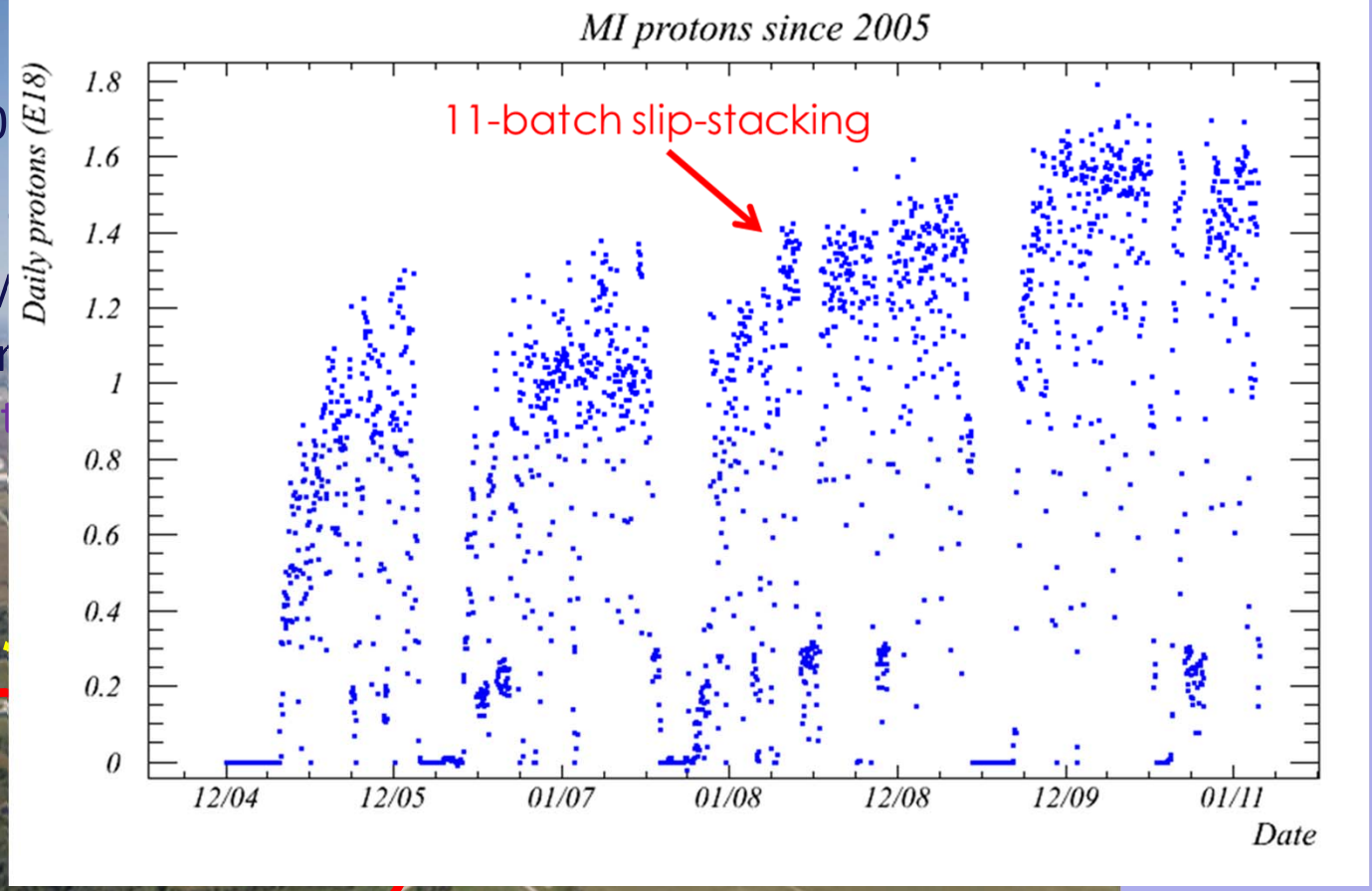
- This talk is not about the wonderful physics programme offered by the NOνA beamline
  - NOνA
  - MINERνA
  - MINOS+
    - See plenary talk by Jeff Hartnell this morning

- Brief overview of current accelerator complex
- Major upgrades required for NOνA
- Status & schedule

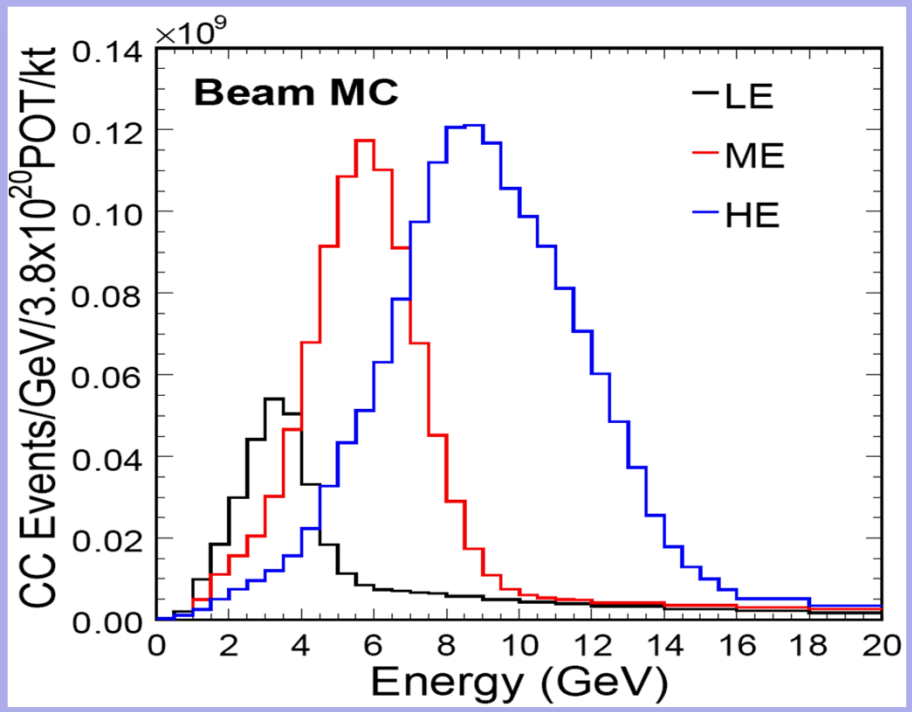
- This talk does not contain every detail of the upgrade project
  - Please feel free to ask about your favourite subject

Current NuMI operation

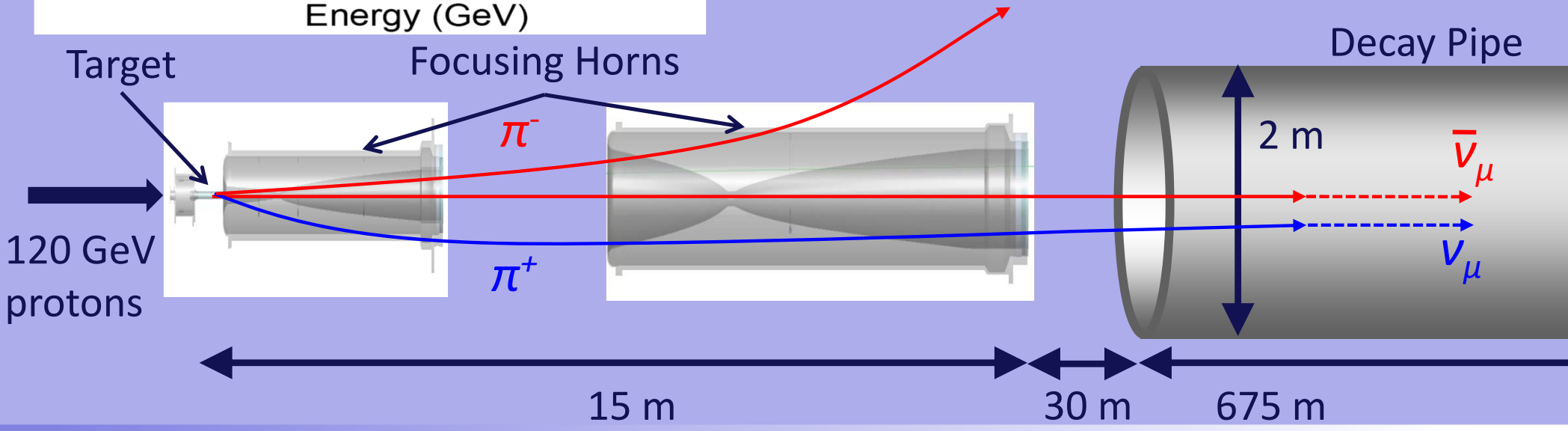




NuMI neutrino beam



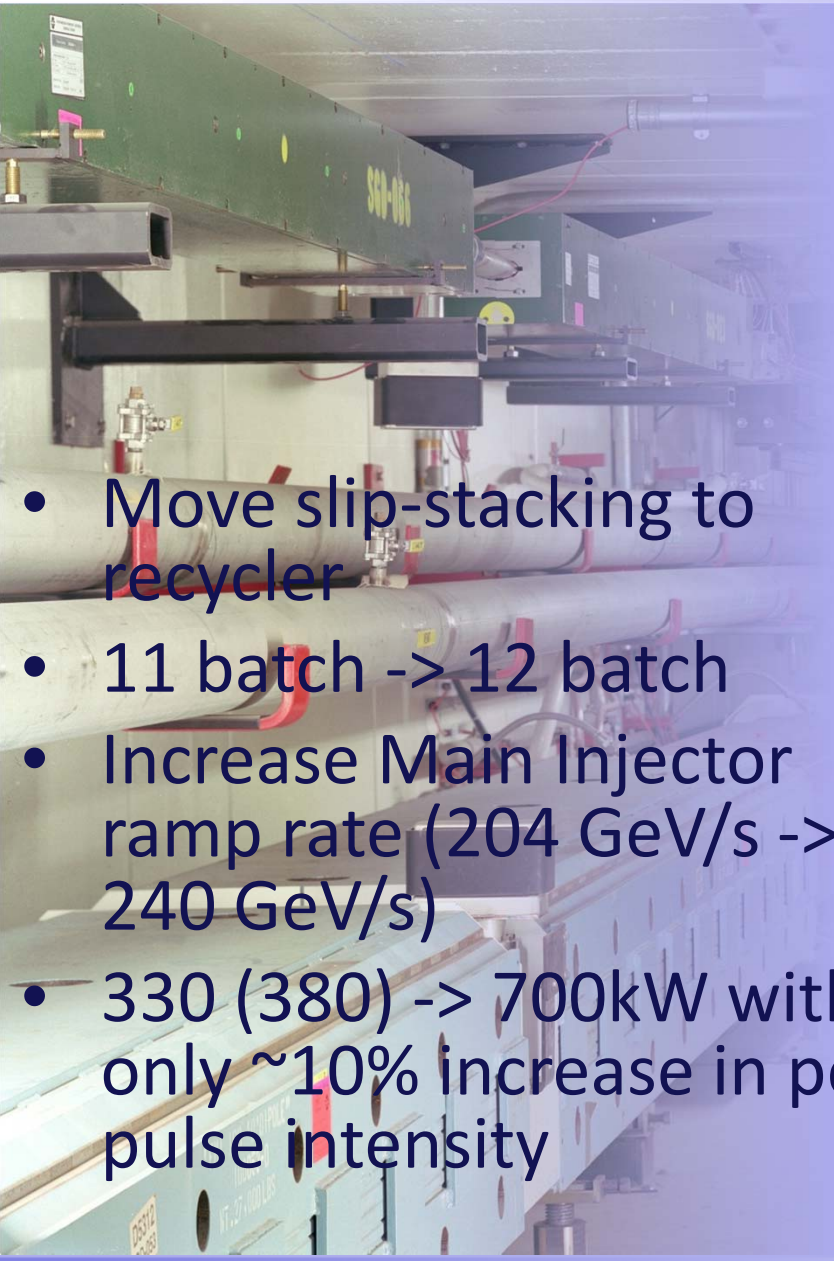
- Neutrino energy tuned by moving target (usually LE)
- Change horn polarity to select $\bar{\nu}_\mu$ or ν_μ



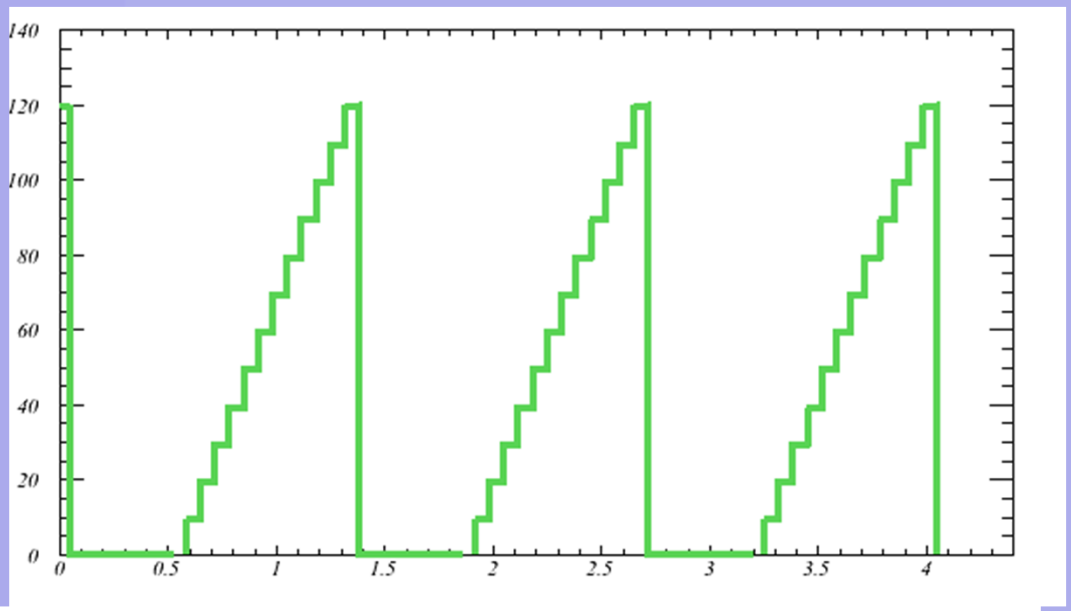
NOνA upgrades

- Increase NuMI primary proton beam power
  - 330 (380) kW -> 700 kW
- Additional focus on loss control
  - Double the beam power
  - Same tunnels
- Change neutrino beam energy (focussing)
  - Optimize flux at off-axis NOνA location

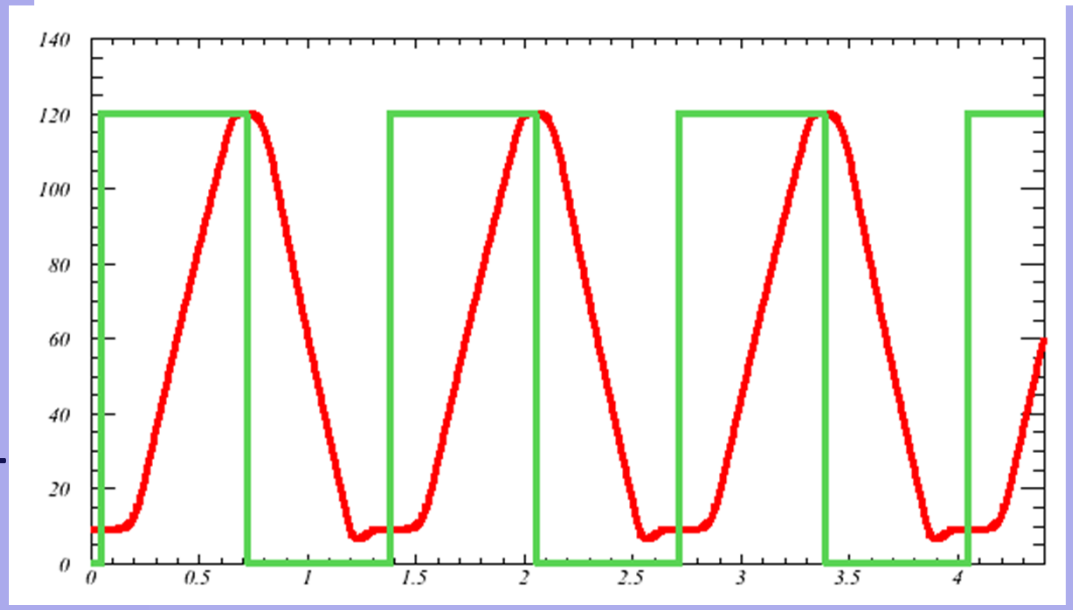
Increasing beam power



- Move slip-stacking to recycler
- 11 batch -> 12 batch
- Increase Main Injector ramp rate (204 GeV/s -> 240 GeV/s)
- 330 (380) -> 700kW with only ~10% increase in per-pulse intensity



Recycler



Main Injector

So need to rebuild recycler

- Remove:
  - Old transfer lines
    - Small aperture (pbar: $6\pi/2\pi$, protons: $15–20\pi$)
  - Stochastic cooling
  - Electron cooling
    - Pelletron
    - Rebuild MI-30 with FODO lattice
  - Various odds and ends that might be aperture restrictions
- Add:
  - New injection line from MI8 to recycler
  - New RR->MI transfer line
  - 53 MHz RF system for slip-stacking
  - Instrumentation
    - BPMs
    - Low-mass Ti multiwires
    - IPMs
  - Must maintain vacuum at 10^{-10} – 10^{-11} torr (TSPs)

New MI-8 line

- Switched dipole at 849
  - ADCW (wide-gap modification of old ADC magnet)
- Strontium Ferrite permanent magnet dipoles like rest of MI-8
- Two Samarium Cobalt dipoles (space constraints)
- Strontium Ferrite recycler quads, powered quad trims for lattice matching

Installation in MI8

- 1-week shutdown in March 2011
  - Electric company replacing switchgear offsite
- Installed first PDD magnet in new MI8

Rebuild 30 straight

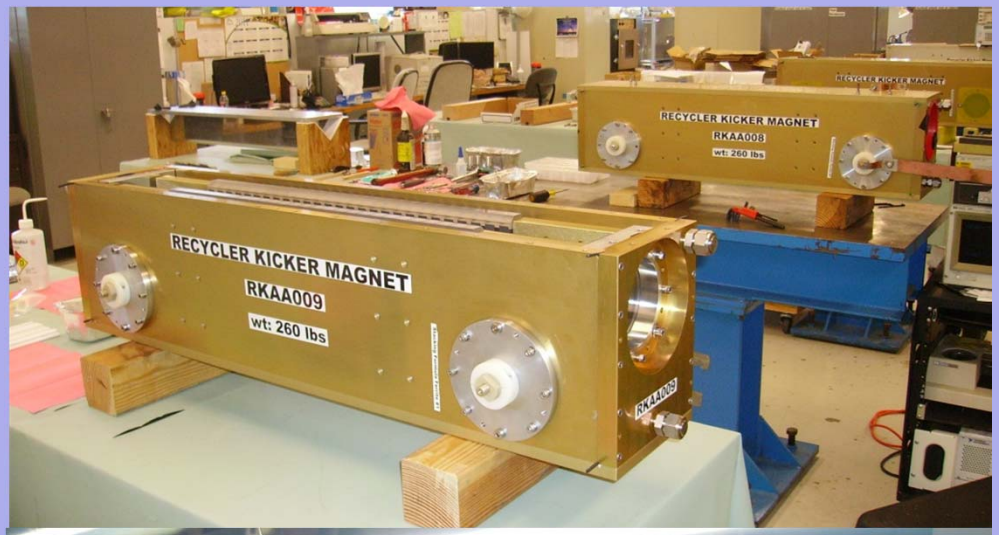
- New permanent quads for 30 straight in recycler
  - Total cost cheaper than re-making existing quads
  - ALARA

53 MHz RF in Recycler

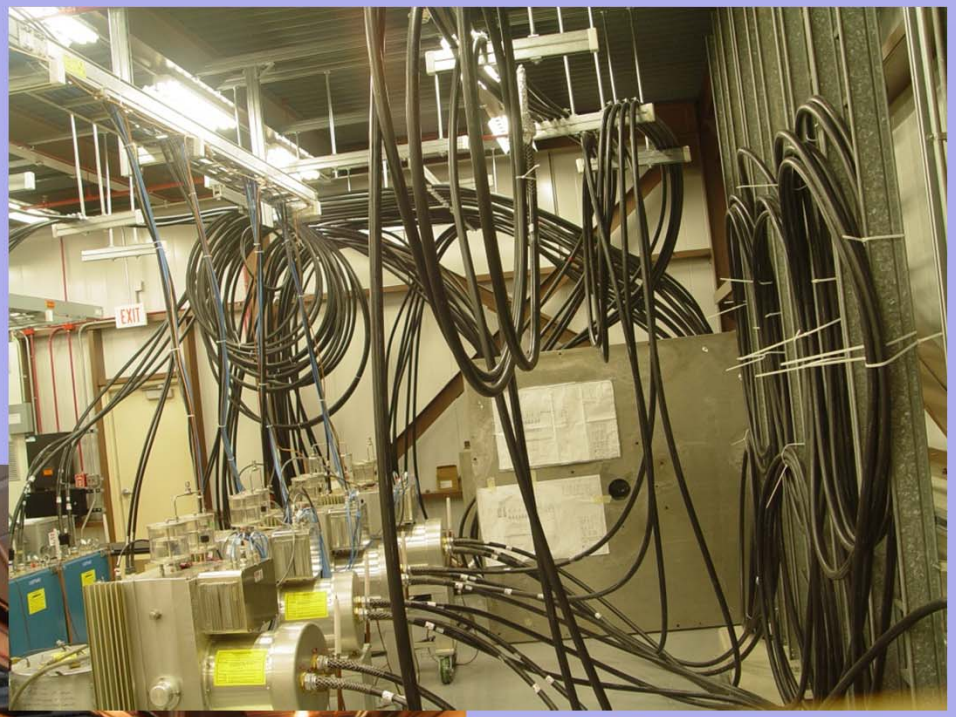
- Build 3 RF cavities
  - A, B and hot spare
  - 150 kV per cavity
  - Operating range: 52.809 MHz ± 1260 Hz
  - 10 KHz fast (~40 µs) phase shifters from Proton Driver
- Recycle PAs and modulators from Tevatron
- LLRF close to a copy of MI system

11 batches -> 12 batches

- Currently place 81 bunches every 86 in MI
- For NOνA, place 81 bunches every 84 in Recycler. (84 = 588/7)
- Faster rising/falling edges -> many short kickers (6)
- Already have 7 RKA magnets in MI: Gap Clearing Kicker system for loss control

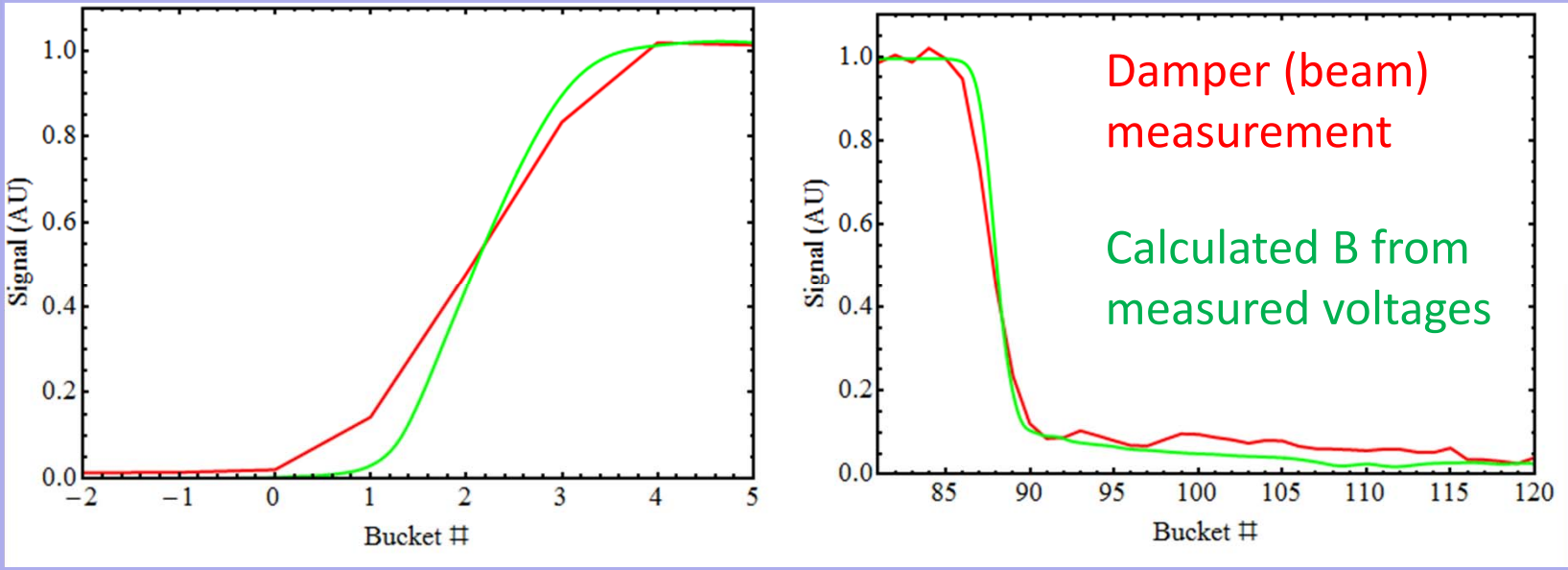


Gap Clearing Kicker System



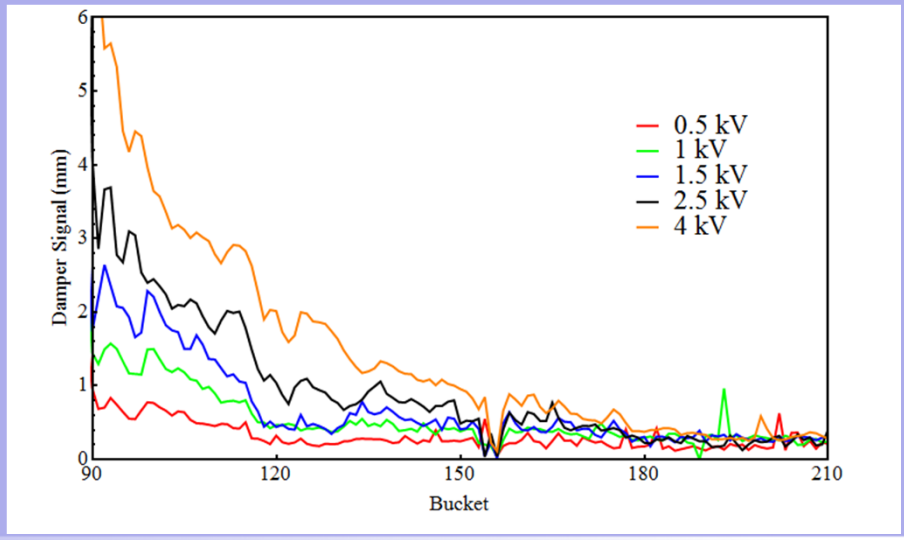
6/7 magnets will move up to recycler for NOvA

GCK measurements

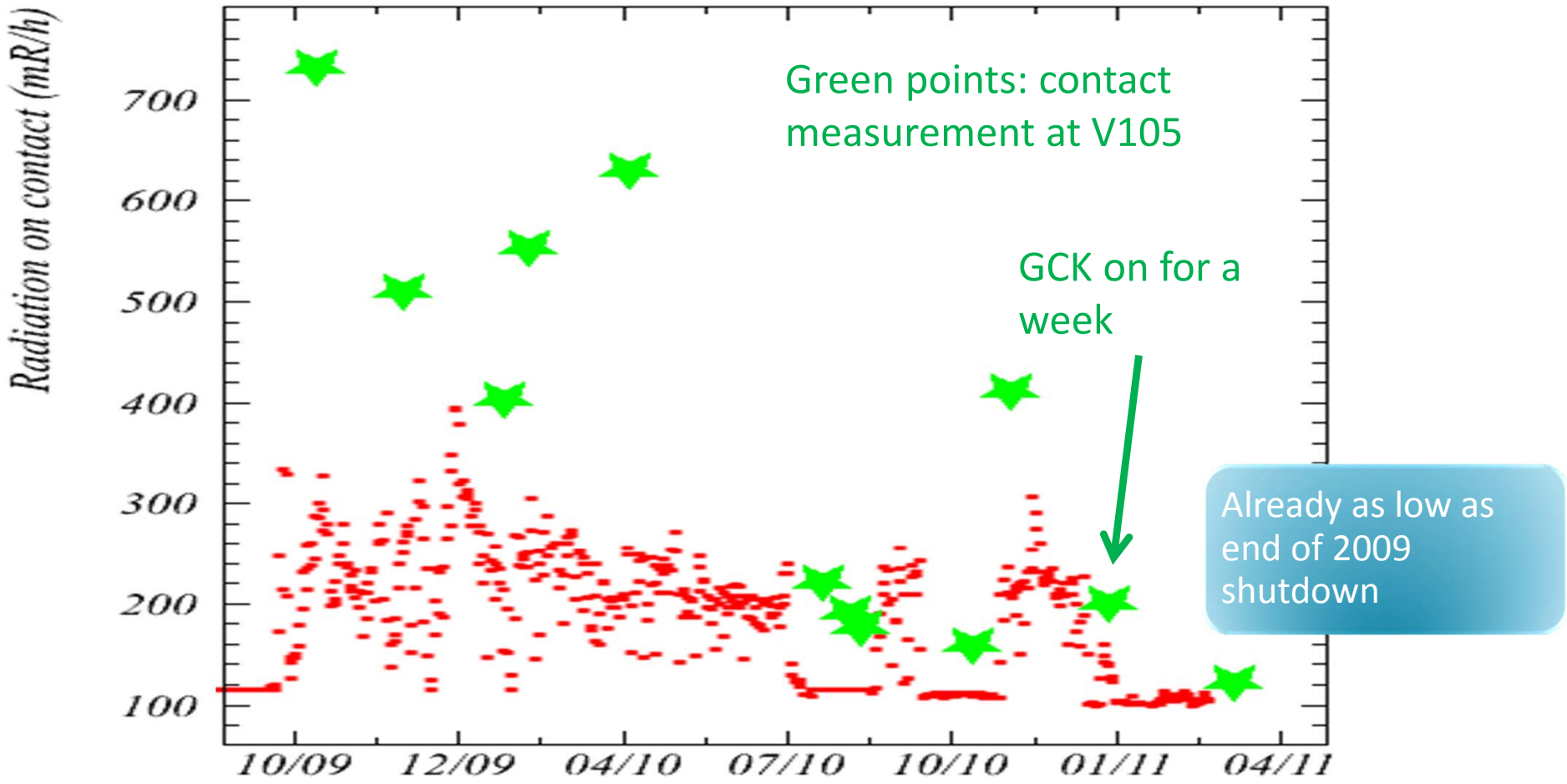


- Edges within specification
- Slower edge in damper measurement might be artifact

- For recycler, building “tail bumper” to cancel tail
- Tail measurement similar to electrical measurements (good)

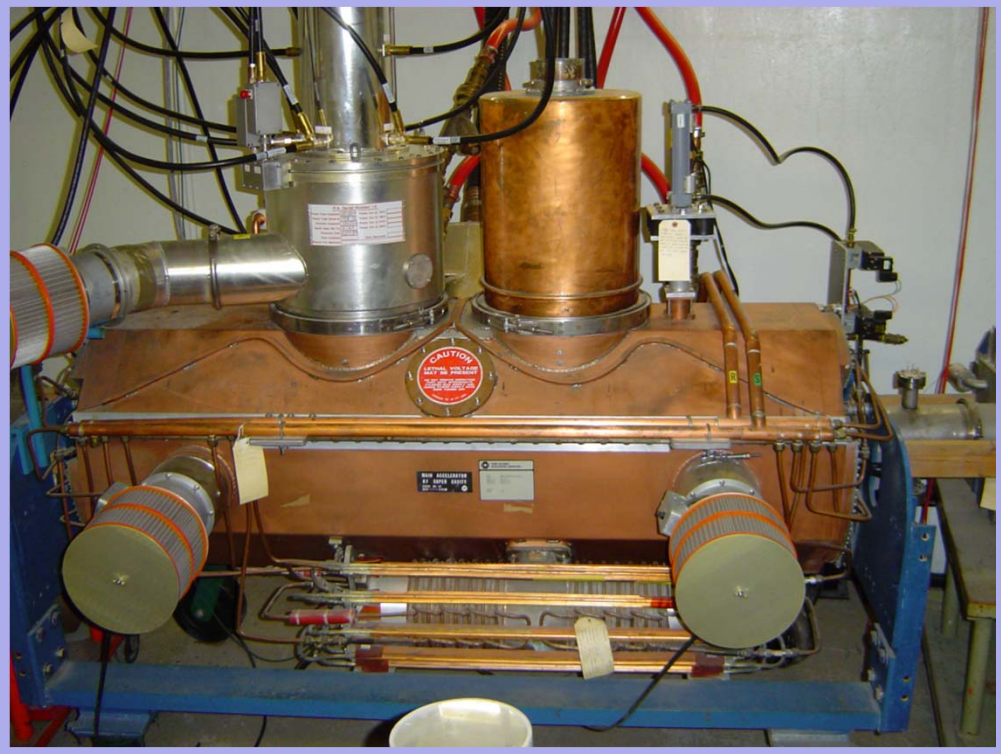


GCK reducing local losses

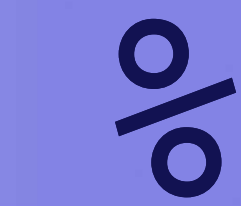


Increase MI ramp rate

- 2 new MI cavities to maintain bucket area
- New transformer for vertical quad bus
- Increased heat load on cooling ponds
  - Will need more cooling for summer – study underway looking at future cooling needs (not just NOνA)
    - More ponds?
    - Run a chiller in summer?
    - Shade ponds?



Beamline upgrades

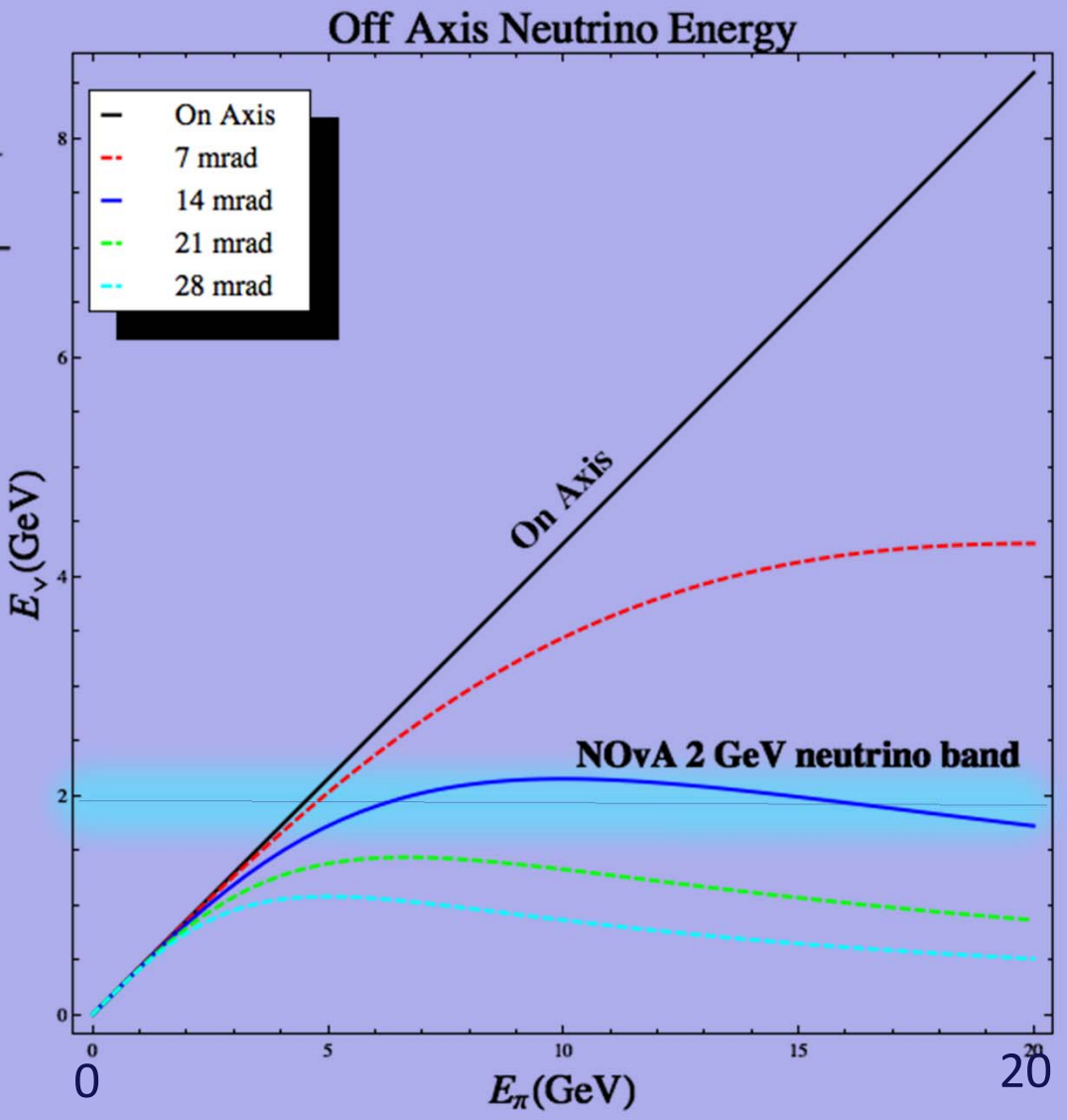


- Increase rep rate
  - 2.2s (2.0s) -> 1.33s
- Replace 5 3Q120 quads with ones from A150 beamline (better cooling)
- Upgrade magnet power supplies
  - Faster ramp
  - BULB
    - Better regulation
    - Current monitor -> beam permit
- New kicker power supply
- Beam intensity doubled, but beam loss in water-bearing rock must not double
  - New 1 mil Ti multiwires - lower mass in beam

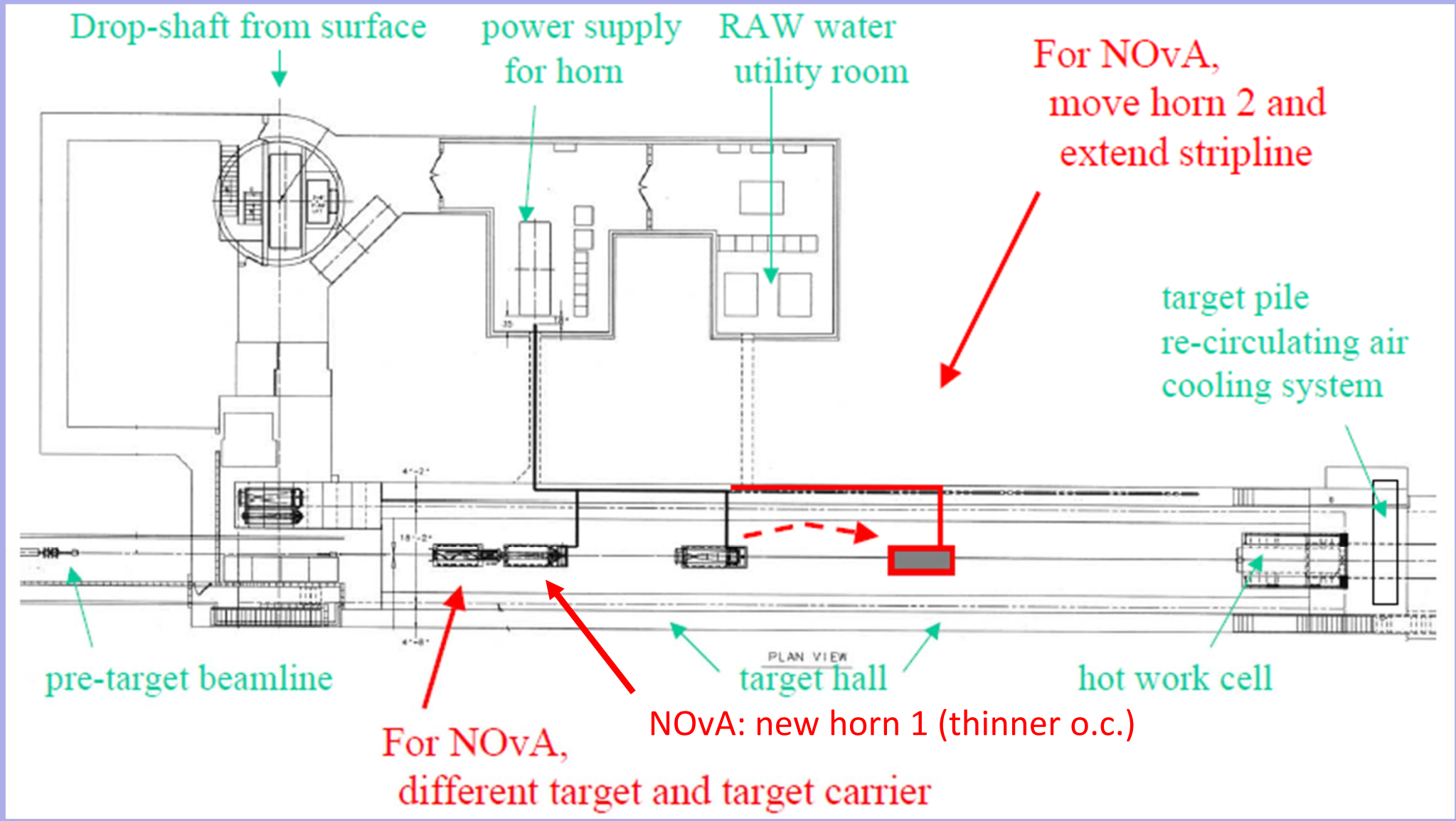
Off-axis neutrino beam

$$E_\nu = \frac{\left(1 - \frac{m_\mu^2}{m_{\pi,K}^2}\right) E_{\pi,K}}{1 + \gamma^2\theta^2}$$

- Off-axis, neutrino energy driven by angle
- Adjust focusing to optimize flux

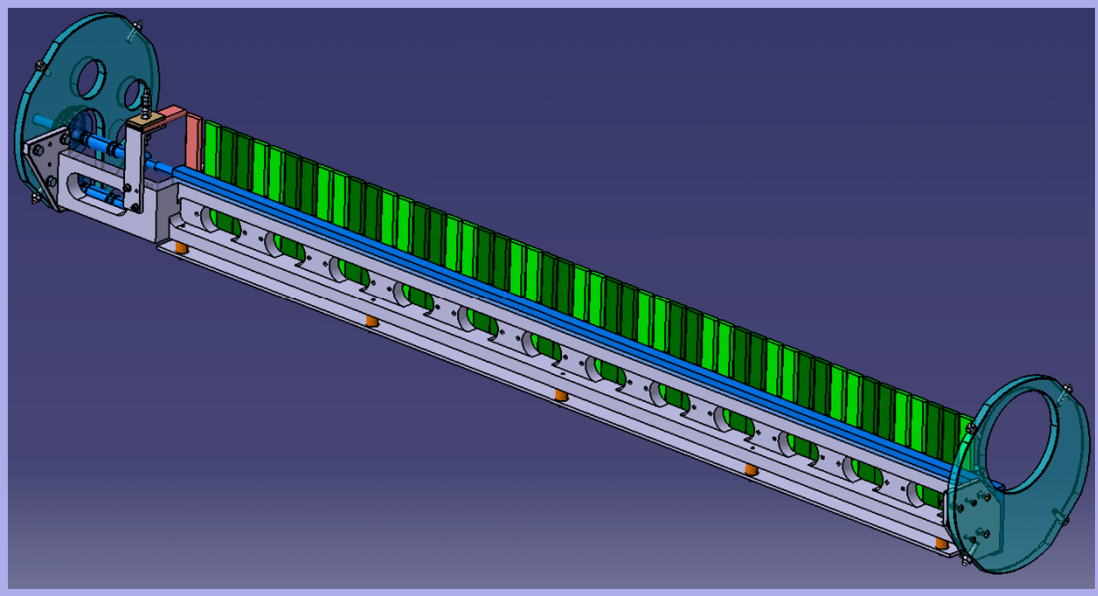


Target Hall Upgrades



NOνA target

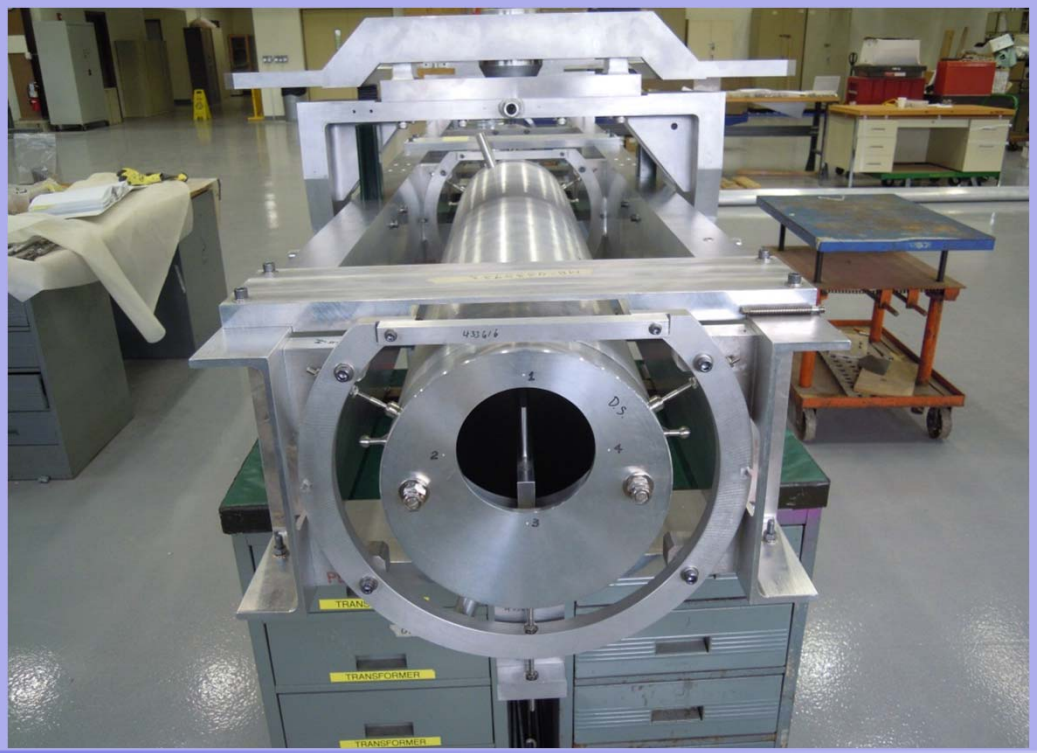
- NuMI target (top) must fit inside horn 1
  - Small, mechanically weak. Recent problems – failure of water cooling lines
- NOνA target (right) upstream of horn 1 (neutrino energy from off-axis angle)
  - Much more robust design. Water cooling 8 times further away from beam than NuMI

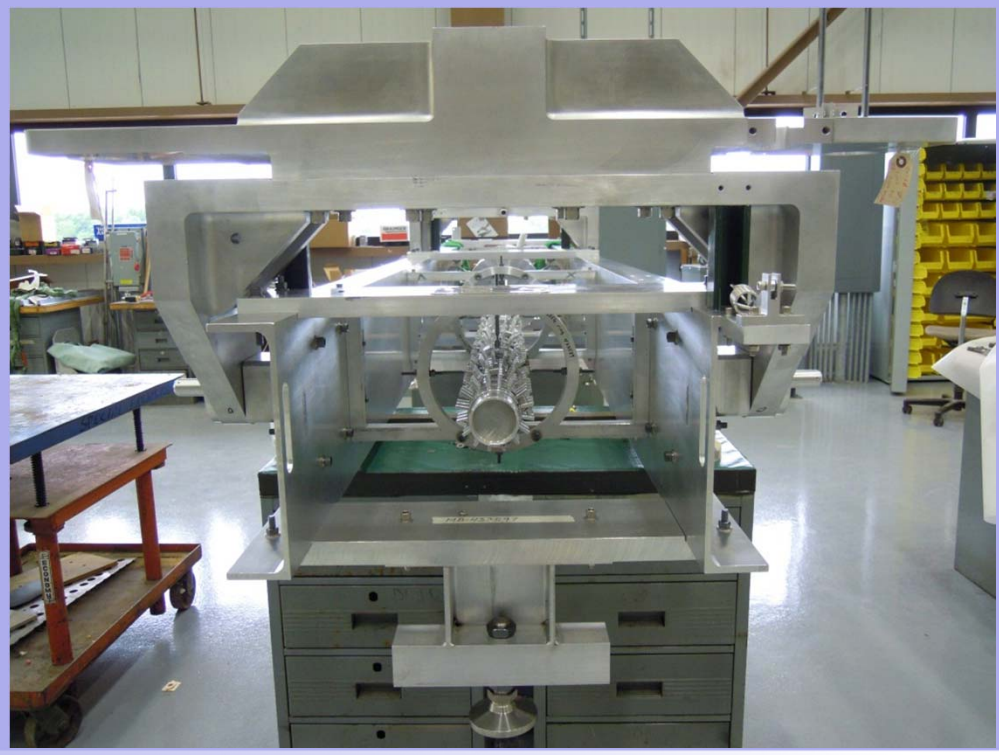


- Target construction in progress – delivery this fall

Target Carrier

- "Prototype" carrier complete
  - Expect to use as first production carrier
  - Shown here with target/baffle mockup





Schedule & Summary

- Tevatron operation completes by October 1
- Begin NOνA shutdown March 5 2012
  - Shutdown scheduled for 11 months
  - Current installation schedule has work completed in 8-9 months
    - Then commission new accelerator complex
    - If accelerator work done before NuMI, can get an early start on commissioning
- NOνA accelerator upgrades proceed on schedule
- I look forward to commissioning the new complex and swift progress towards 700 kW

NOνA Accelerator Upgrades: Status

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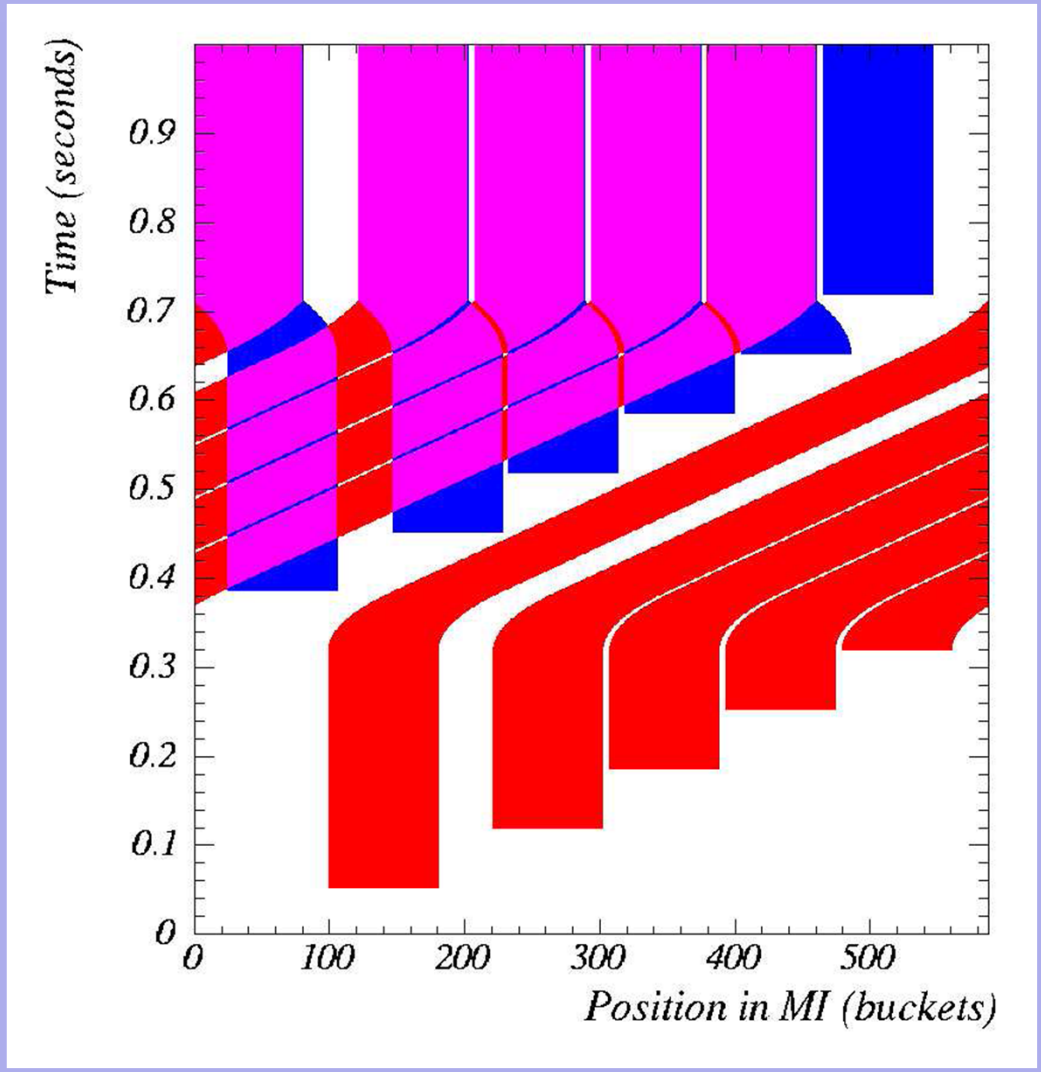
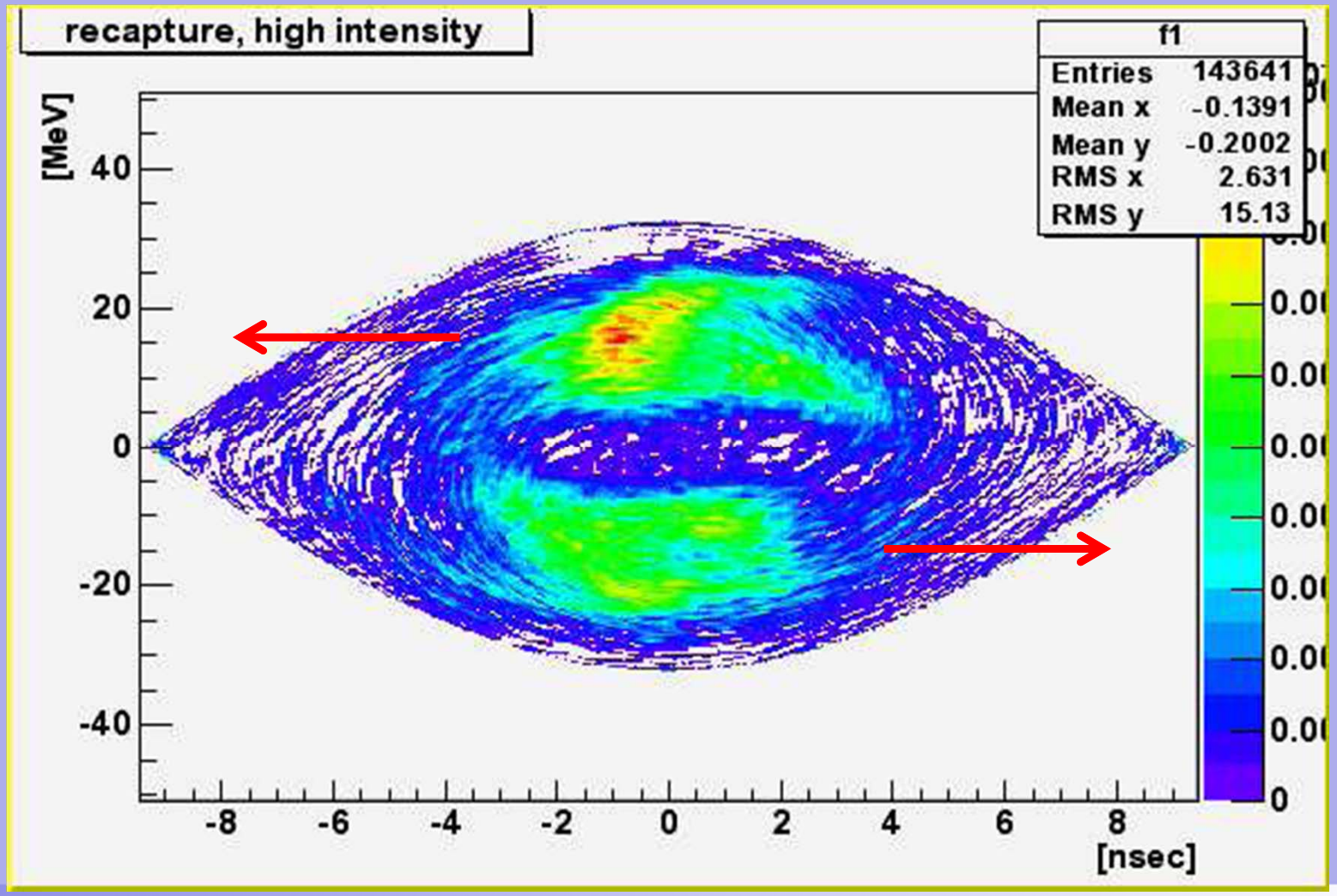
Slip-stacking

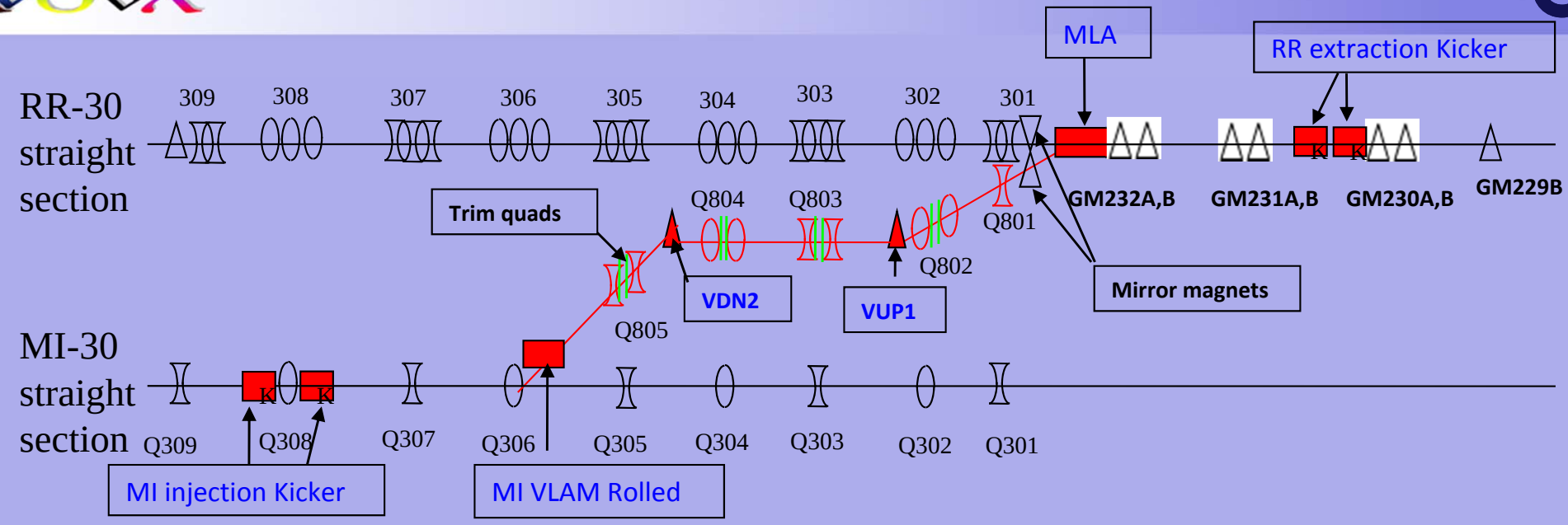
- Neutrino experiments want more beam!
- Inject 11 batches rather than 6
  - But pay for it with increased losses
  - (<95% efficiency)



Slip-stacking recapture (real data)



Transfer and new MI8 lines

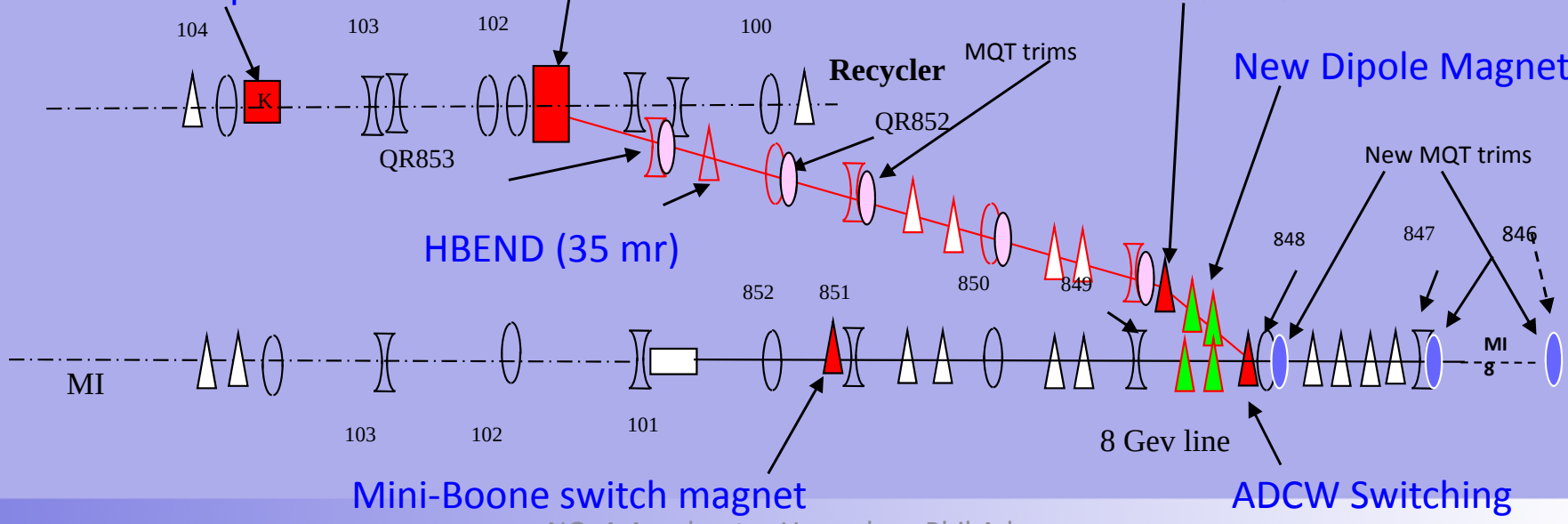


HKICK (1.208 mr)
5 kickers 1 bumpers

VLAM (MLAW) 13.6 mr (DC)

V2 (PDD) 19.2 mr

New Dipole Magnets



HBEND (35 mr)

Mini-Boone switch magnet

ADCW Switching