# Project X and a Muon Facility at Fermilab

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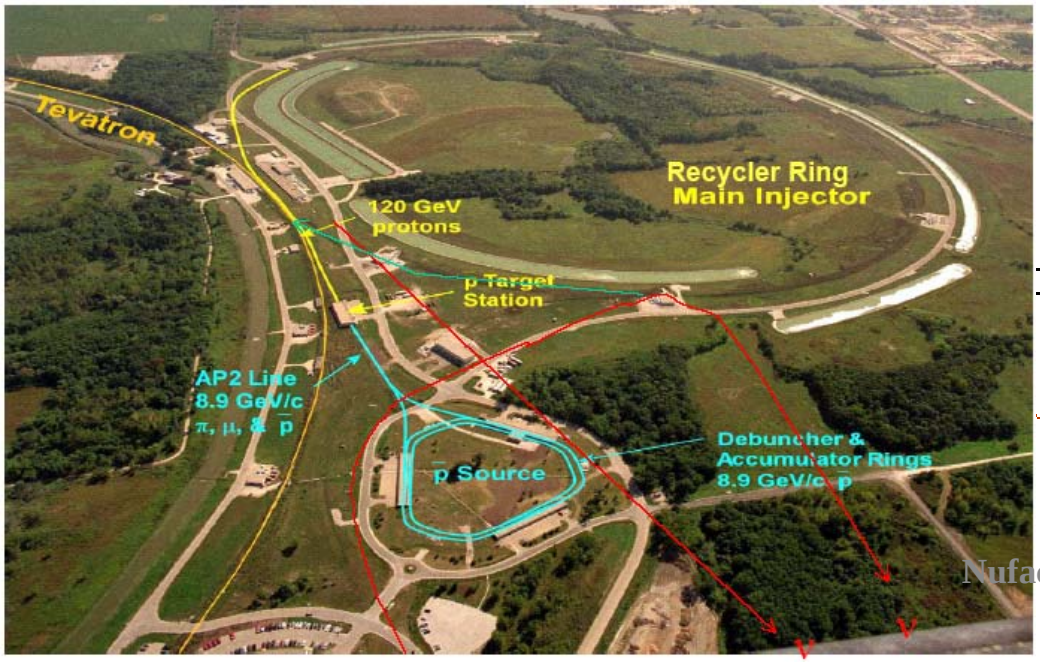
**FNAL**

# FermilabTevatron Accelerator With Main Injector



# Proposed 8-GeV Implementation Plan

- Introduction
- Layouts and Beam Transfer Schemes
  - Booster Era
  - Project X Era (Beam Power = 200 kW @ 8 GeV)
  - Upgraded (4MW) Project X
- Experiments
  - Configurations
  - Proposed Locations
  - Beam Requirements
  - Providing the required proton time distributions

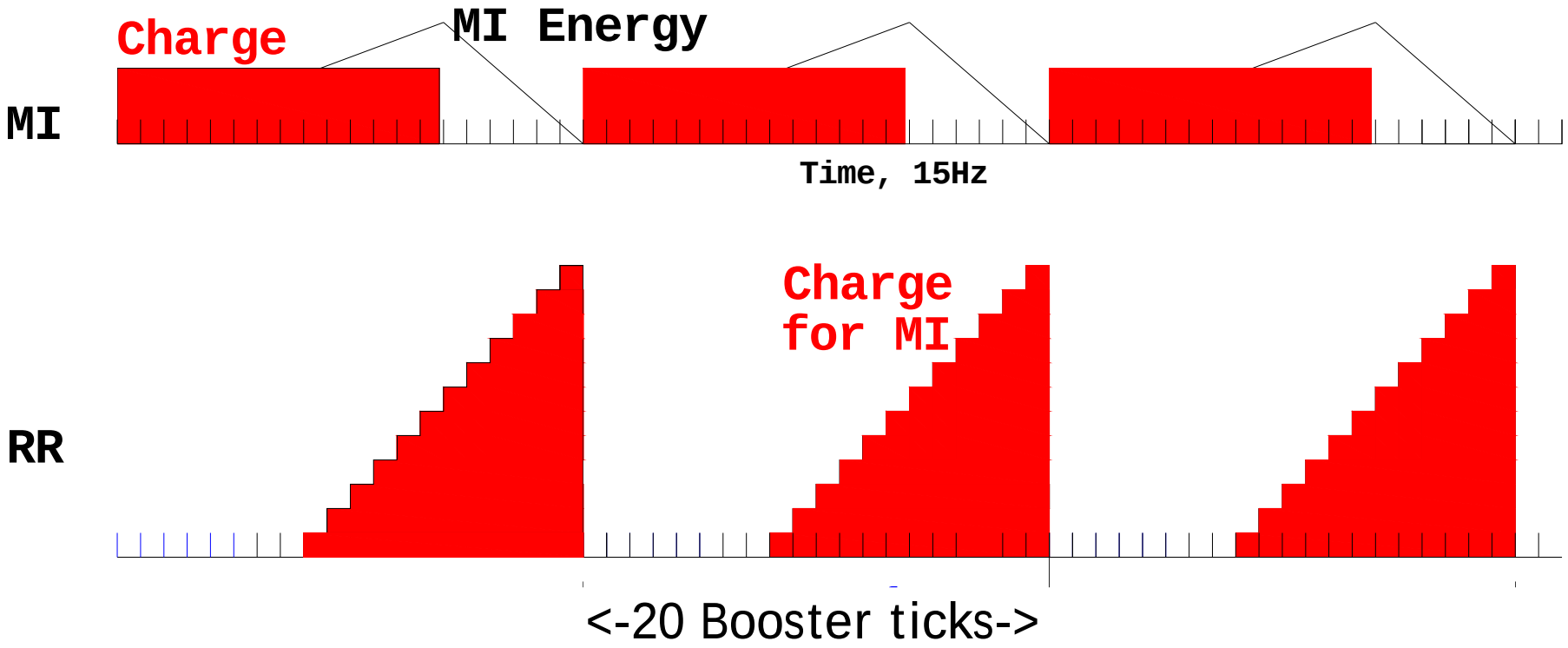
# Experiments and Their Requirements

- Various groups would like to do experiments made possible by intense 8-GeV proton beams:
  - Muon-to-electron conversion
  - Muon g-2
  - K-> $\pi$ $\nu$ $\underline{\nu}$ (with neutral and charged kaons)
  - Muon test beams
  - Neutrino factories based on muon storage rings
  - Muon colliders
  - Accelerator physics research and development
- We've been communicating with them to understand their needs.
  - Most want to start ASAP.
  - Many want a phased approach to high beam power.
  - Various time distributions are desired for proton beam.

# Advantages of the Proposed Plan

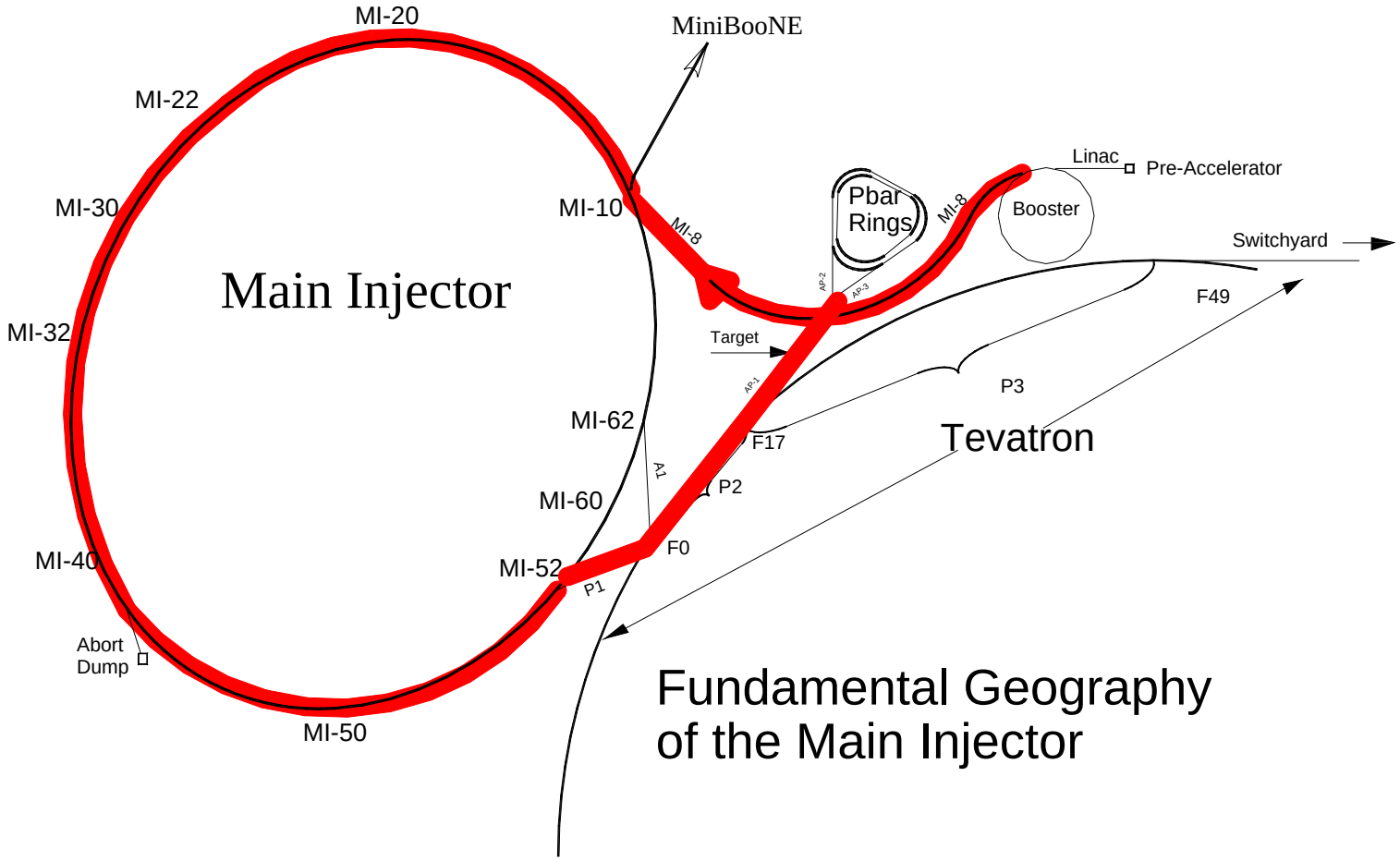
- It's flexible.
  - Experiments can start with Booster beam, then transition to beam from Project X without relocating.
  - Beam time can be shared flexibly.
- It's economical.
  - Existing infrastructure is intensely used.
  - Only one new tunnel for starters, a short one at that
  - Only one new high-power target station/exp't hall
  - All (or most?) 1st-round experiments located in one area
- It can be implemented rapidly.
  - The new tunnel could be built soon as an AIP project.
- It provides a path back to the energy frontier.
  - Target station is located in line with a long-term plan

# MI and RR time lines for NOνA




The Recycler is empty for as many as 8 Booster ticks.

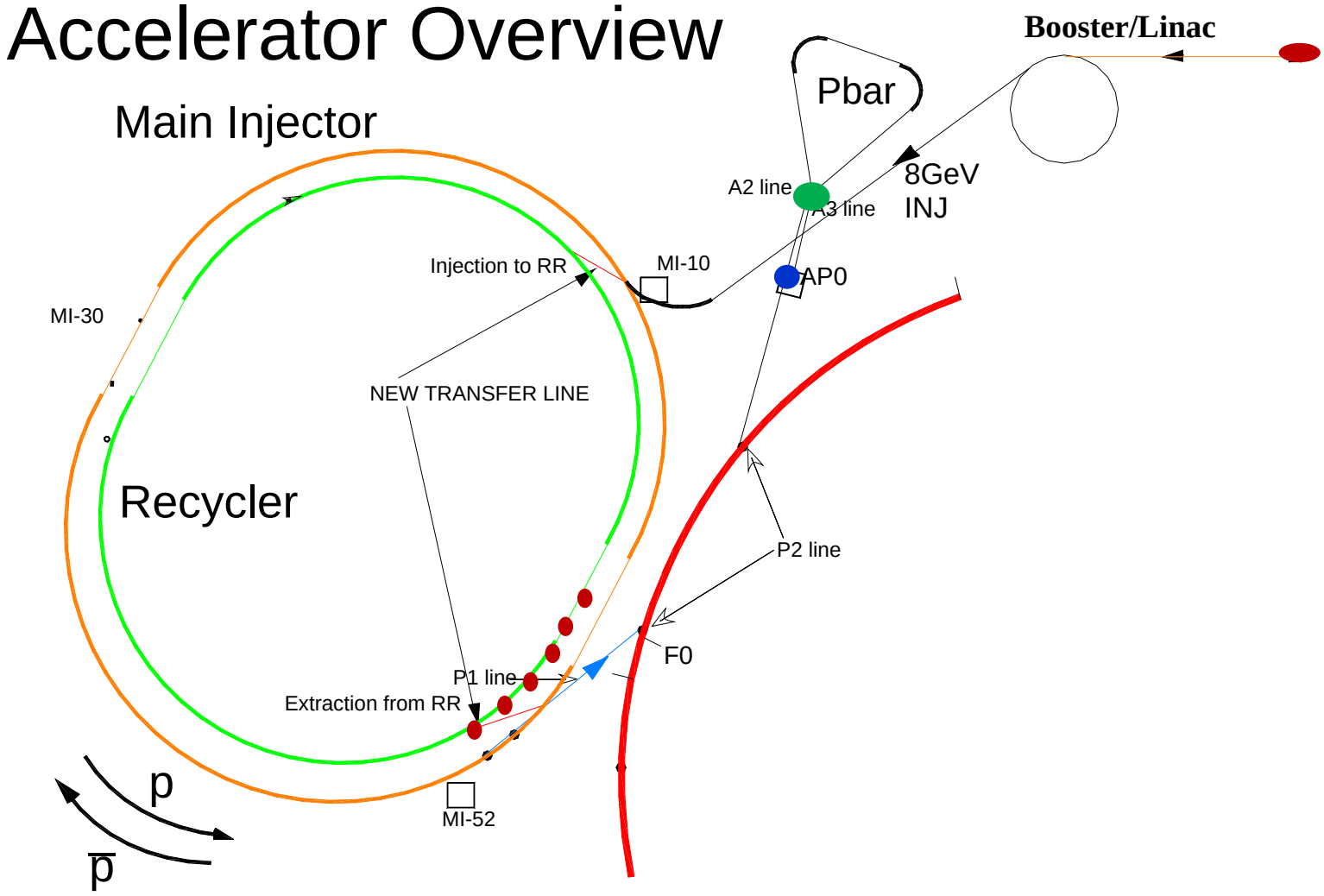
# The proposed beam path, 8GeV Protons




The cheapest route between two rings is via existing beam lines.

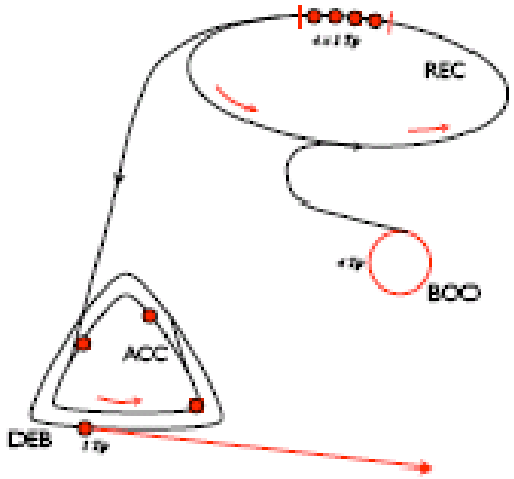
# g-2 Beam Delivery Concept

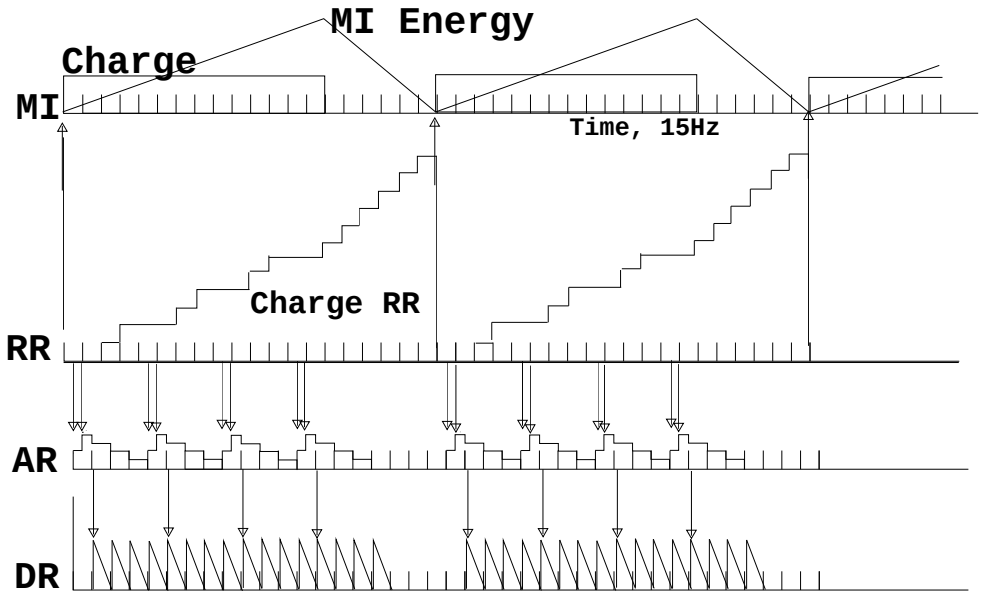
## Accelerator Overview



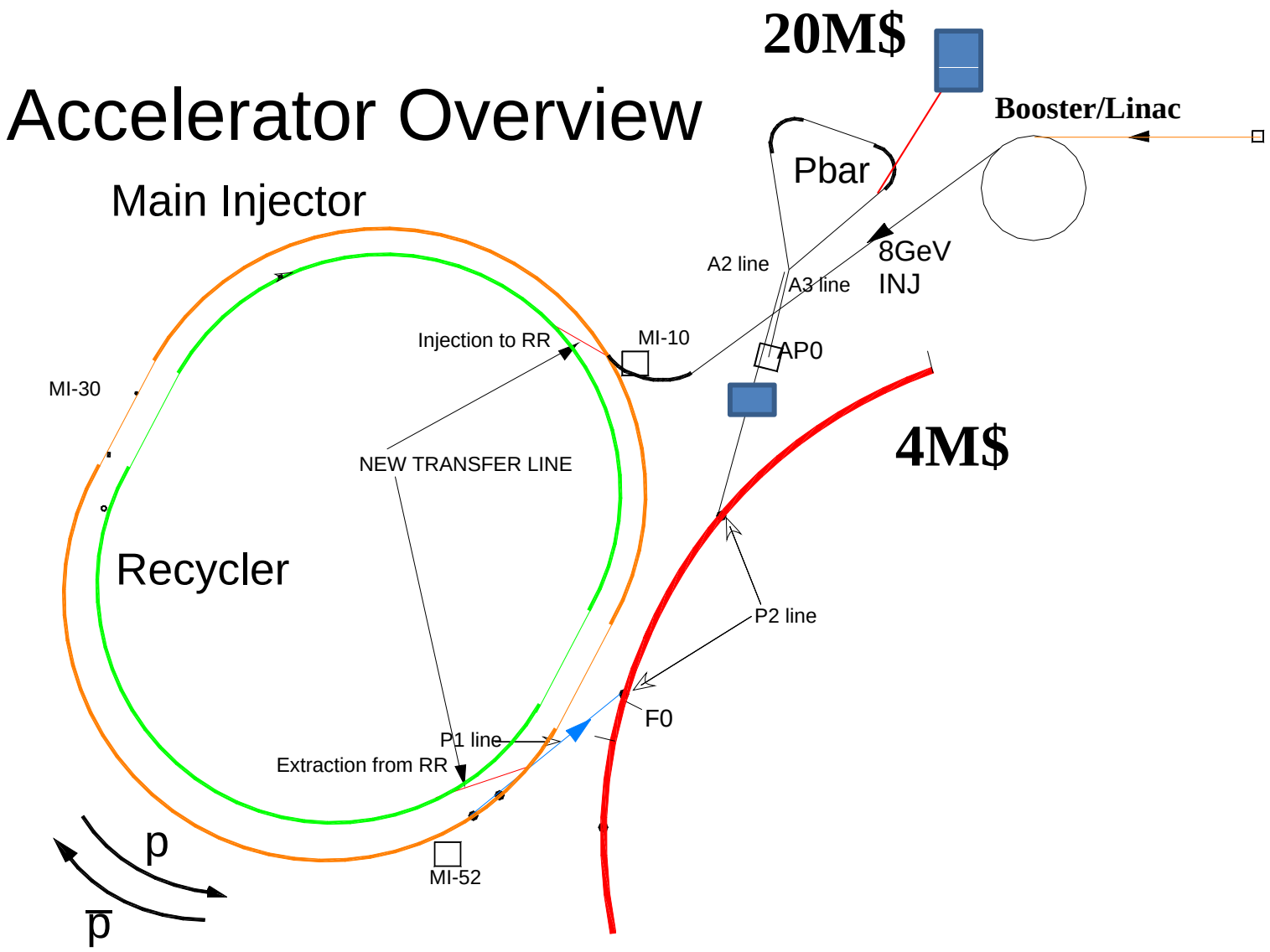
# Timing Diagram/Beam Delivery to mu2e

- Take 2 cycles at time from Booster (thru Recycler)
  - stack in Accumulator
  - (~33ms)
- Form into 4 bunches
  - ~33ms
  - 1 bunch at time transfers to Debuncher
- Stretch Debuncher to slow extraction over 66ms
  - $2.4\times10^{12}$ / bunch
    - ($\delta v < 0.02$)
- Use Recycler to accumulate Booster cycles
  - 12/20 to NuMI (1.33s)
  - 8/20 to mu2e
    - (16/20)duty cycle



# $\mu$2e Beam Delivery Concept



# Recent documentation (note contributors)

**Delivering Protons to the Antiproton Source after the Tevatron Collider Era**

Charles Ankenbrandt, David Harding, David Johnson, David McGinnis, and Milorad Popovic
Fermilab

March 6, 2007

. . .

Communications with Dixon Bogert, Bruce Brown, Steve Geer, Nancy Grossman, Dave Neuffer, and Eric Prebys contributed to the development of the ideas presented here.

# Second Project X Physics Workshop

## Proposed Implementation Plan

## for Physics with Intense 8 GeV Proton Beams

### after the Tevatron Collider Era

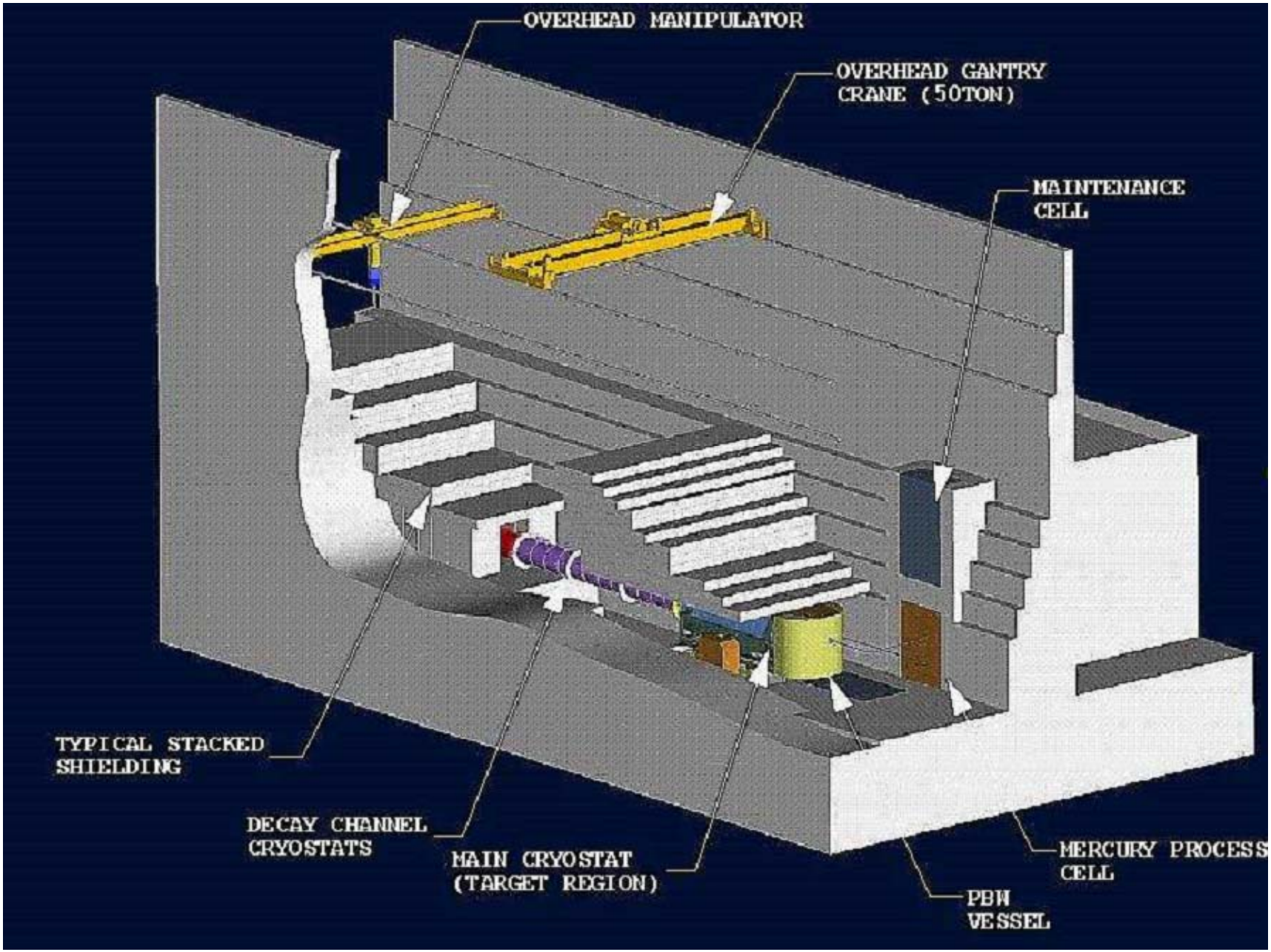
### (A Tunnel Vision)

Chuck Ankenbrandt and Milorad Popovic
Fermilab
January, 2008

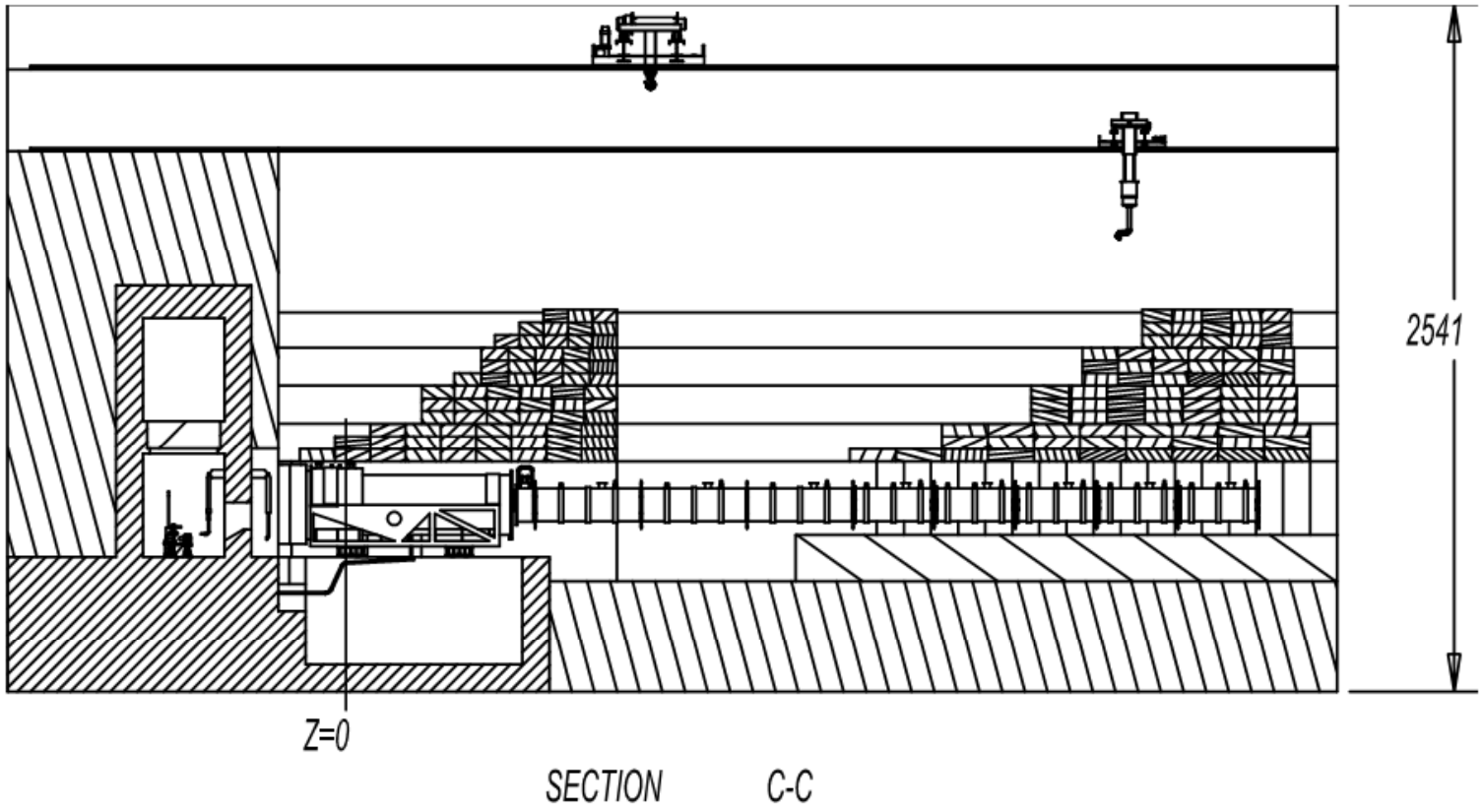
# Booster-era Beam Transfer Scheme

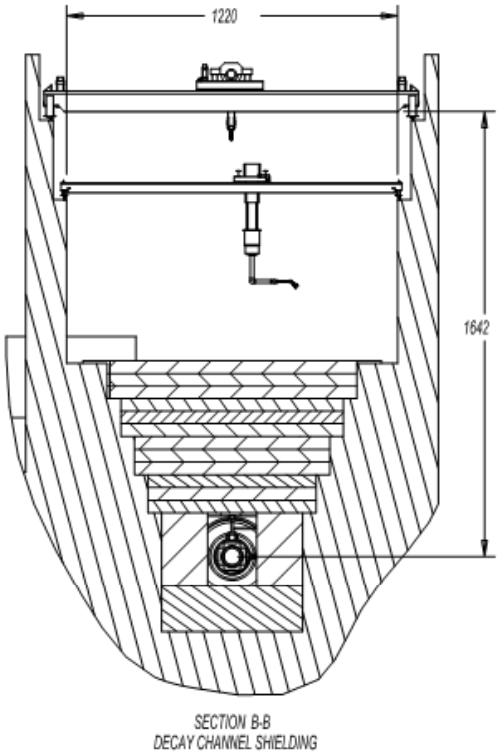

New 200-kW target station that can be upgraded to >2 MW

# 2 MW Target Station for ν Factory or Muon Collider

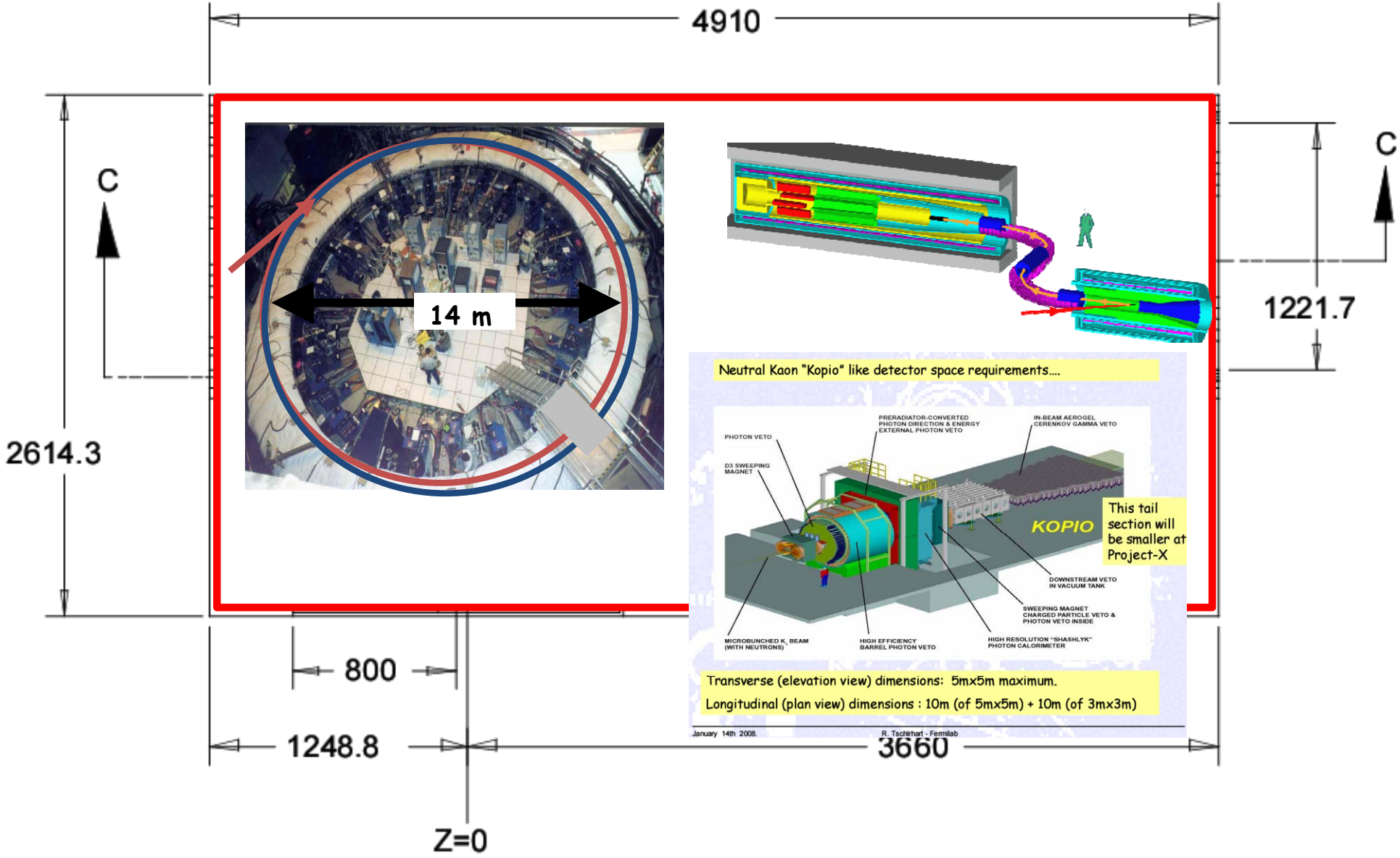


# 2 MW Target Station for ν Factory or Muon Collider

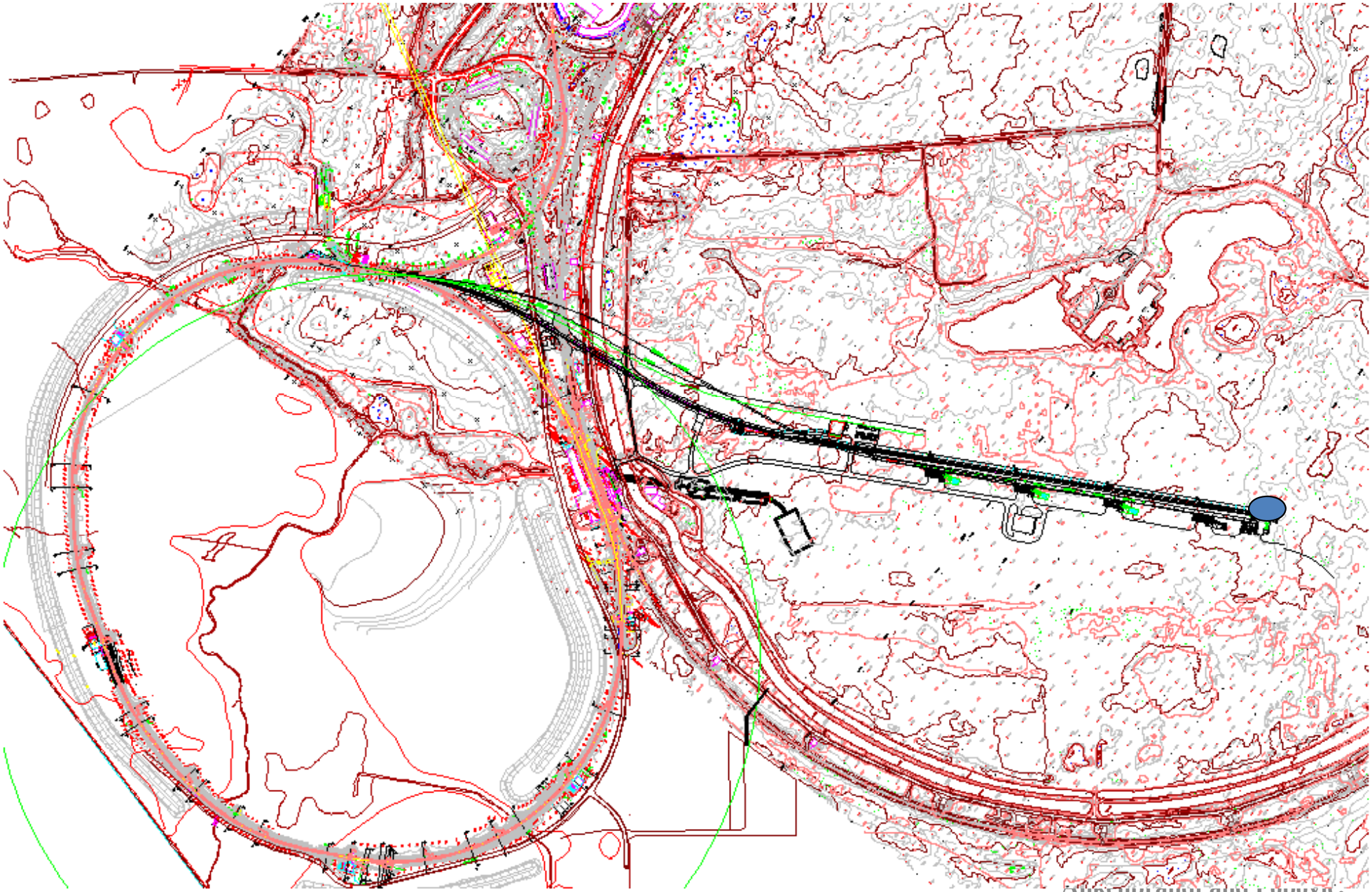


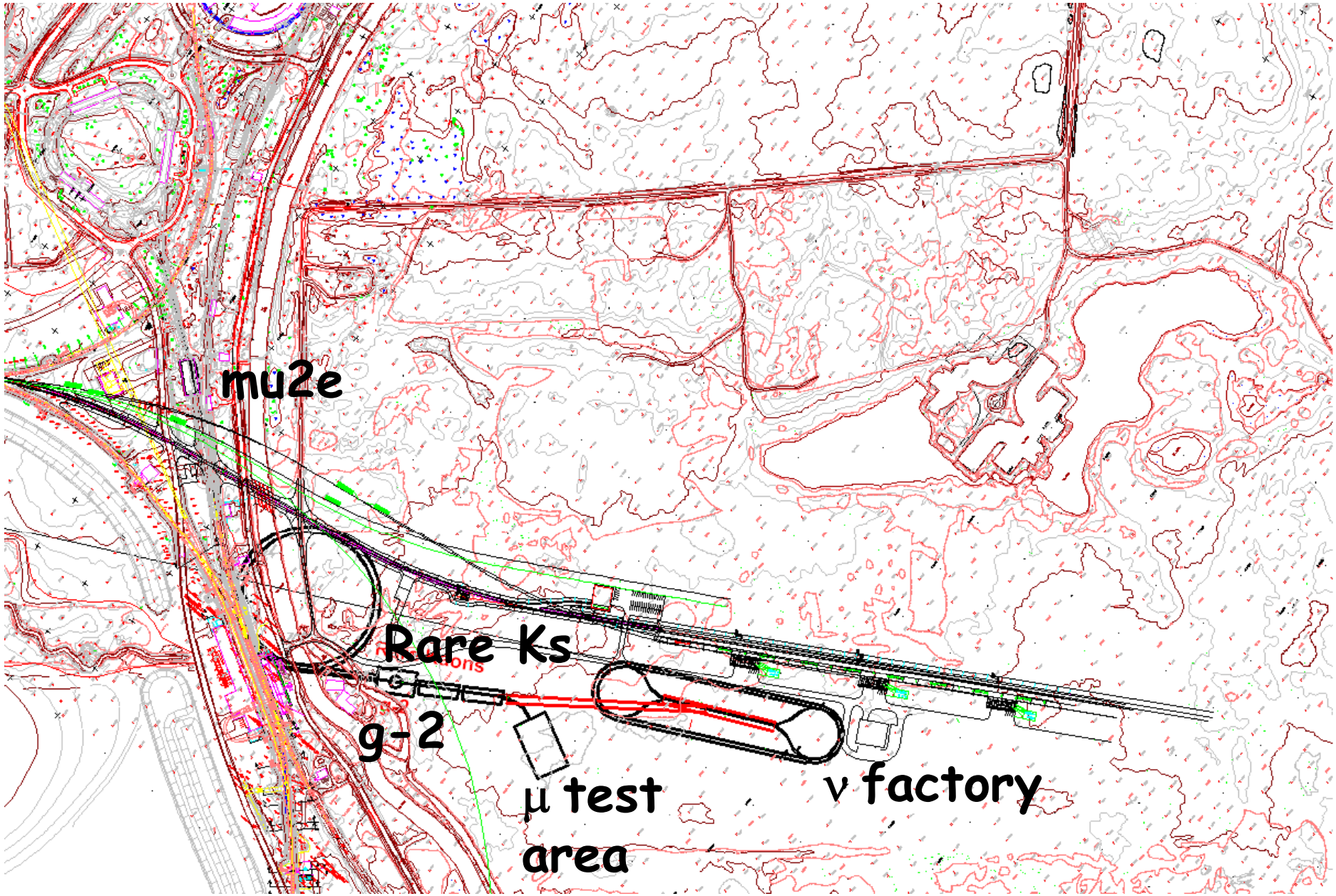
# 4 MW Target Station for ν Factory or Muon Collider



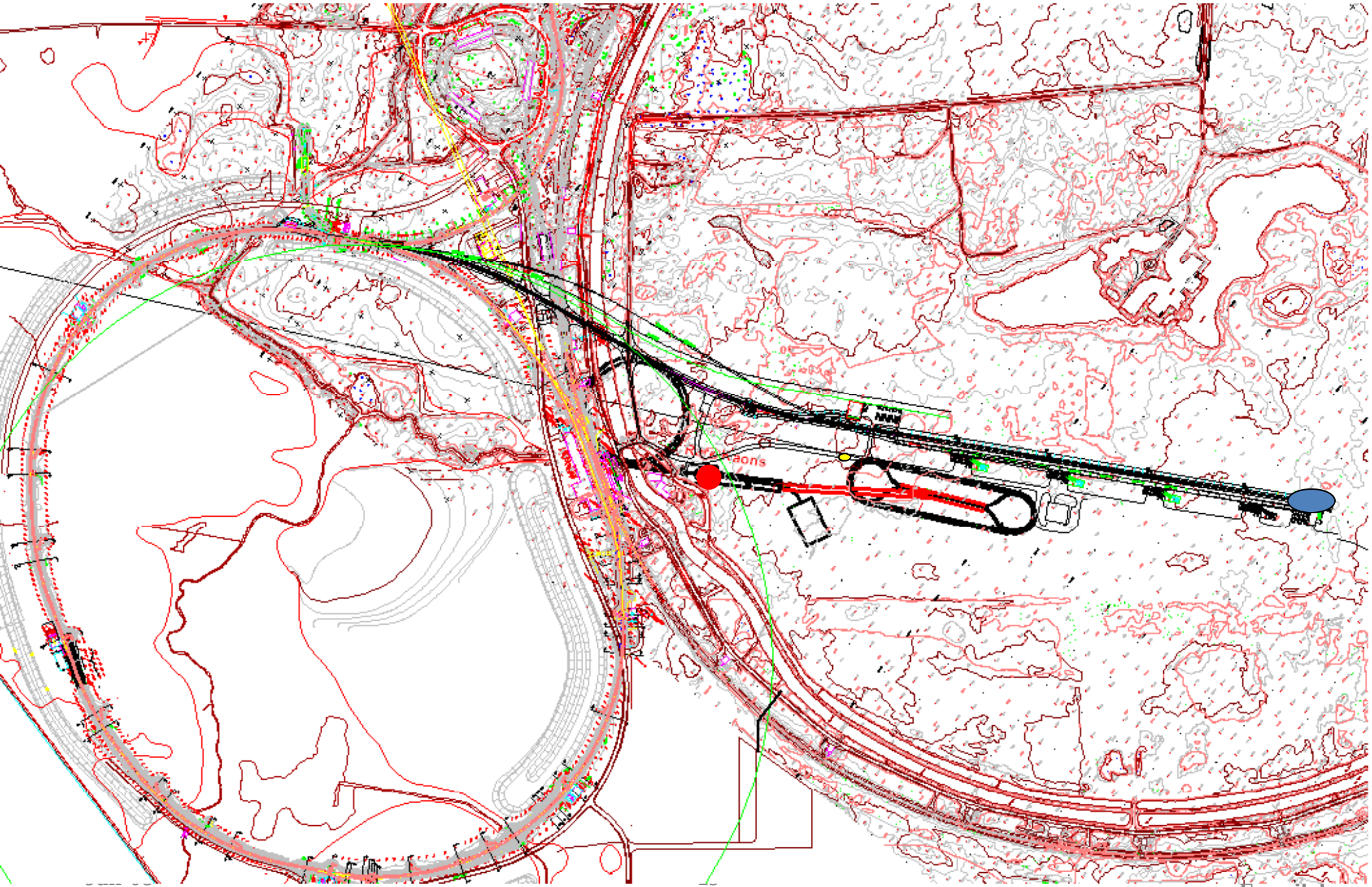
# Beam Path to 200kW target station in Project X Era



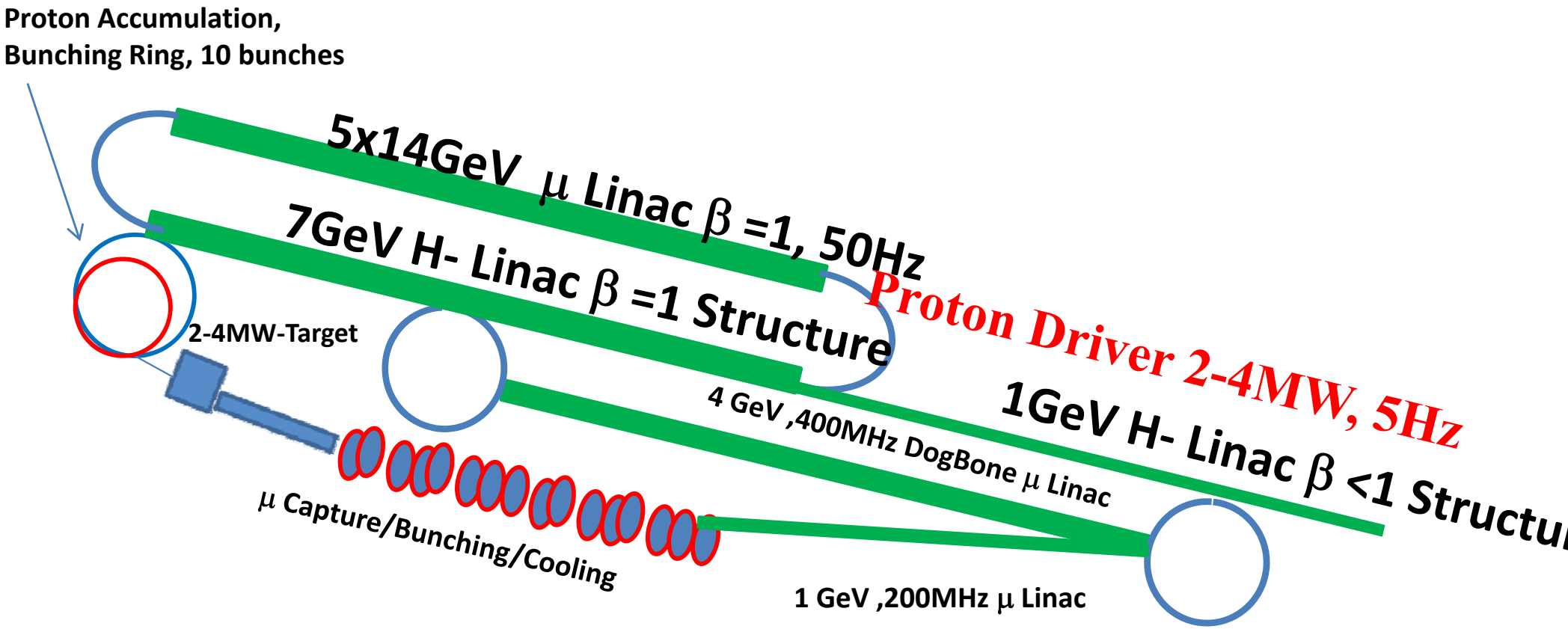
# Sitting of mu2e, g-2, Kaons, μ test area, 4GeV ν Factory

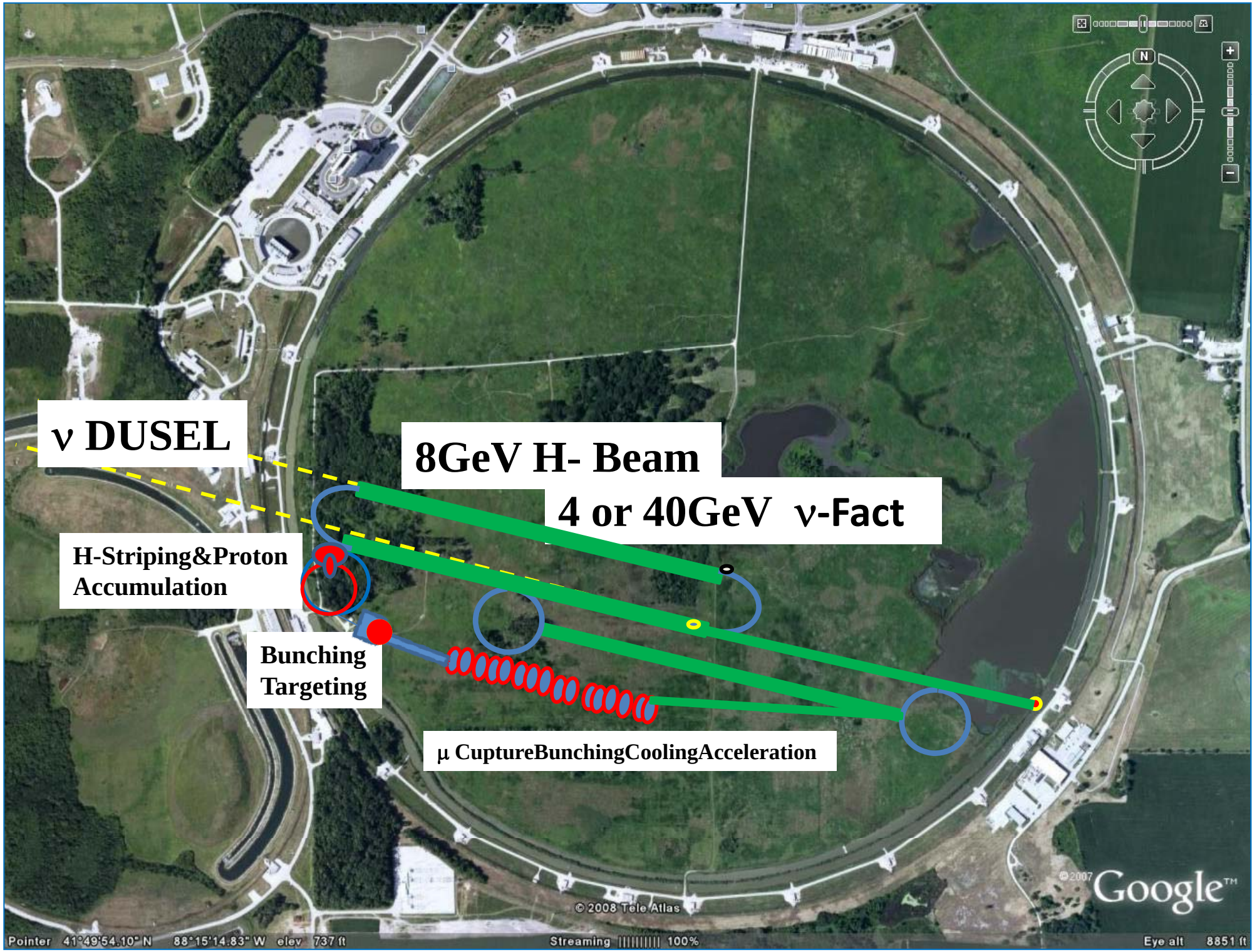


# Path of Beams to 4 GeV ν Factory in Project XLR8 Era

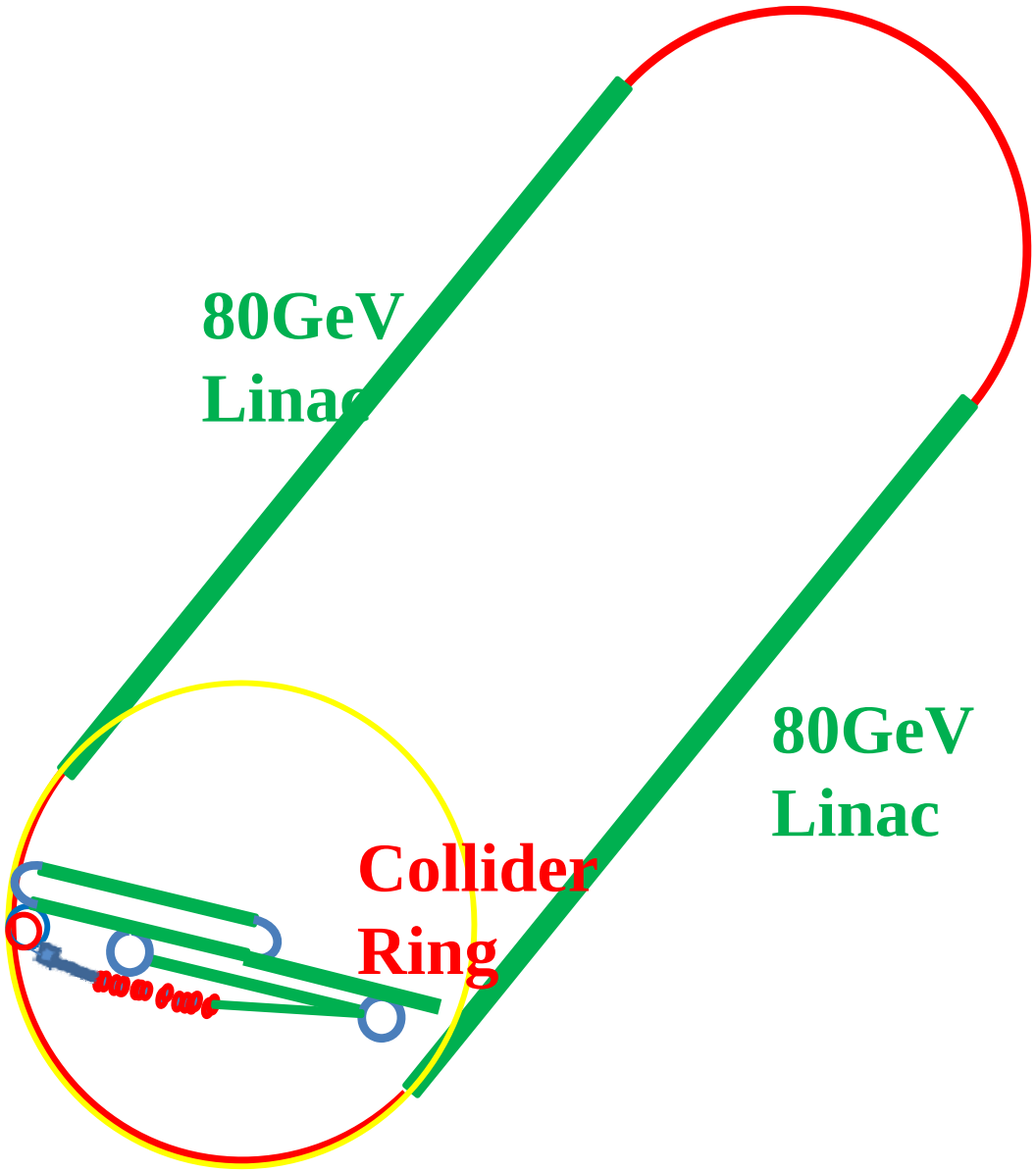


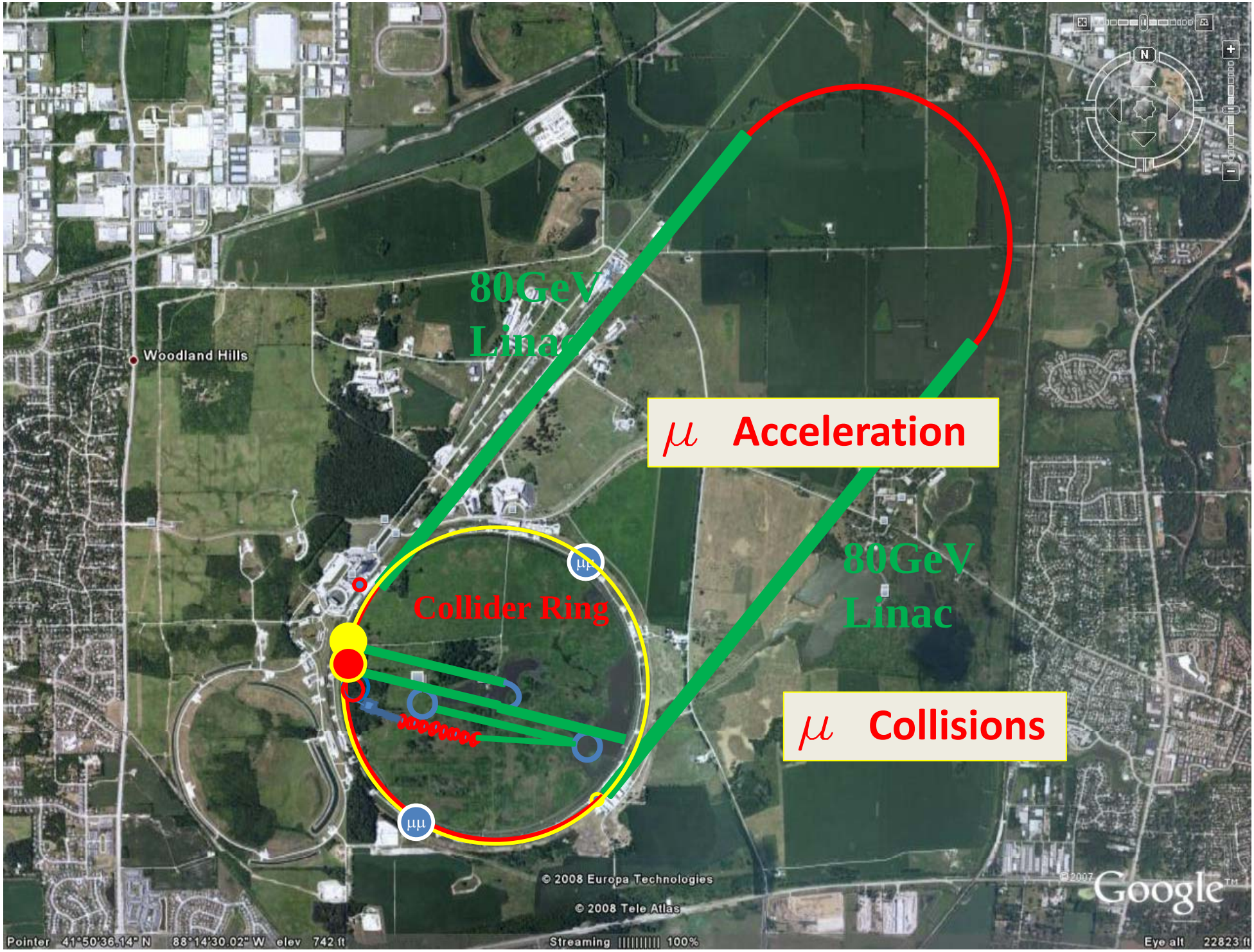
# Neutrino Factory as 1st Step Toward Muon Collider




ν DUSEL
8GeV H- Beam
4 or 40GeV ν-Fact
H-Striping&Proton Accumulation
Bunching Targeting
μ CuptureBunchingCoolingAcceleration
© 2008 Tele Atlas
©2007 Google™
Pointer 41°49'54.10" N 88°15'14.83" W elev 737 ft
Streaming 100%
Eye alt 8851 ft

# Muon Collider Stage

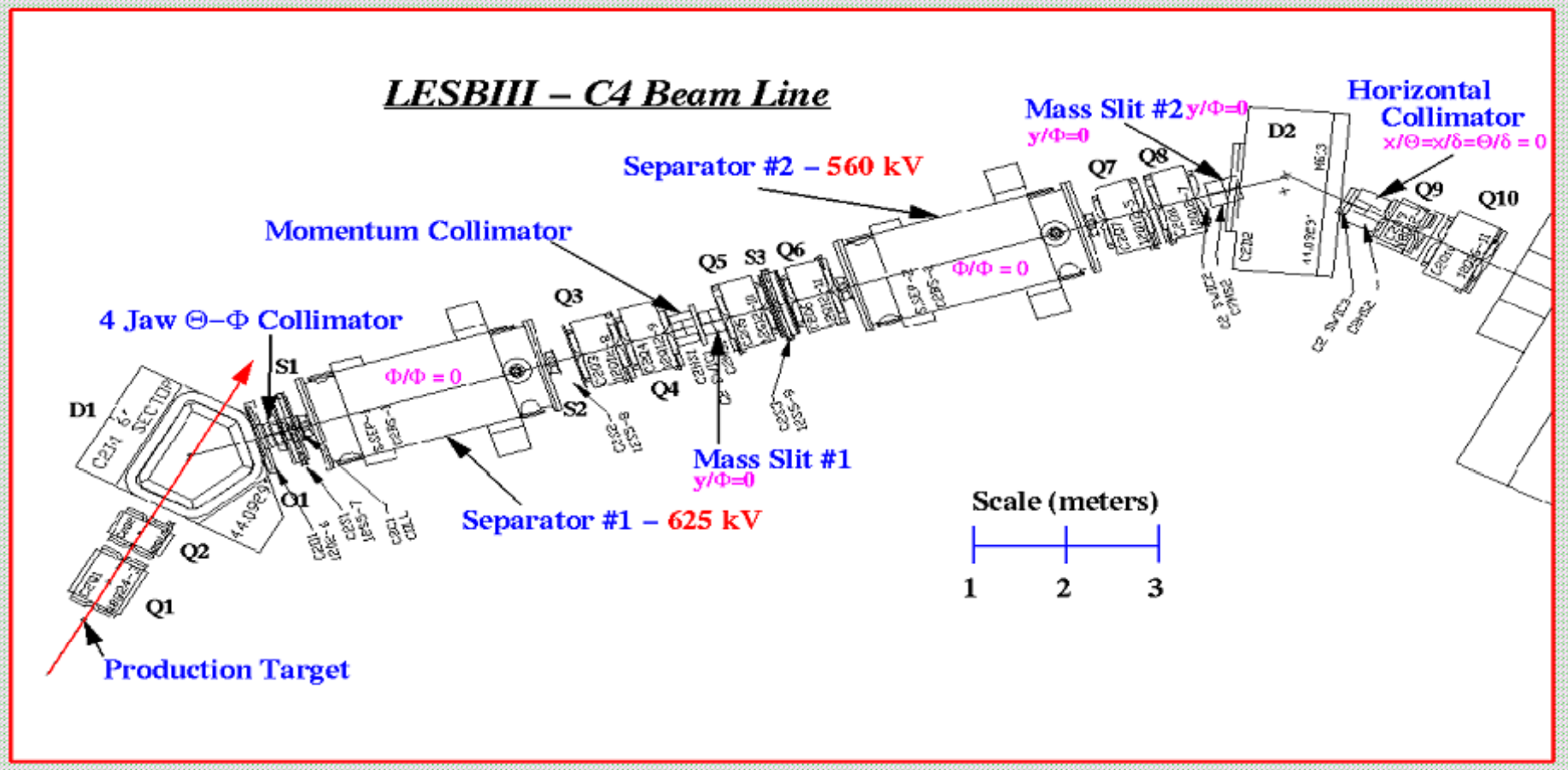



80GeV
Linac
Woodland Hills
μ Acceleration
Collider Ring
80GeV
Linac
μ Collisions
© 2008 Europa Technologies
© 2008 Tele Atlas
Google
Pointer 41°50'36.14" N 88°14'30.02" W elev 742 ft
Streaming 100%
Eye alt 22823 ft


# Stop here

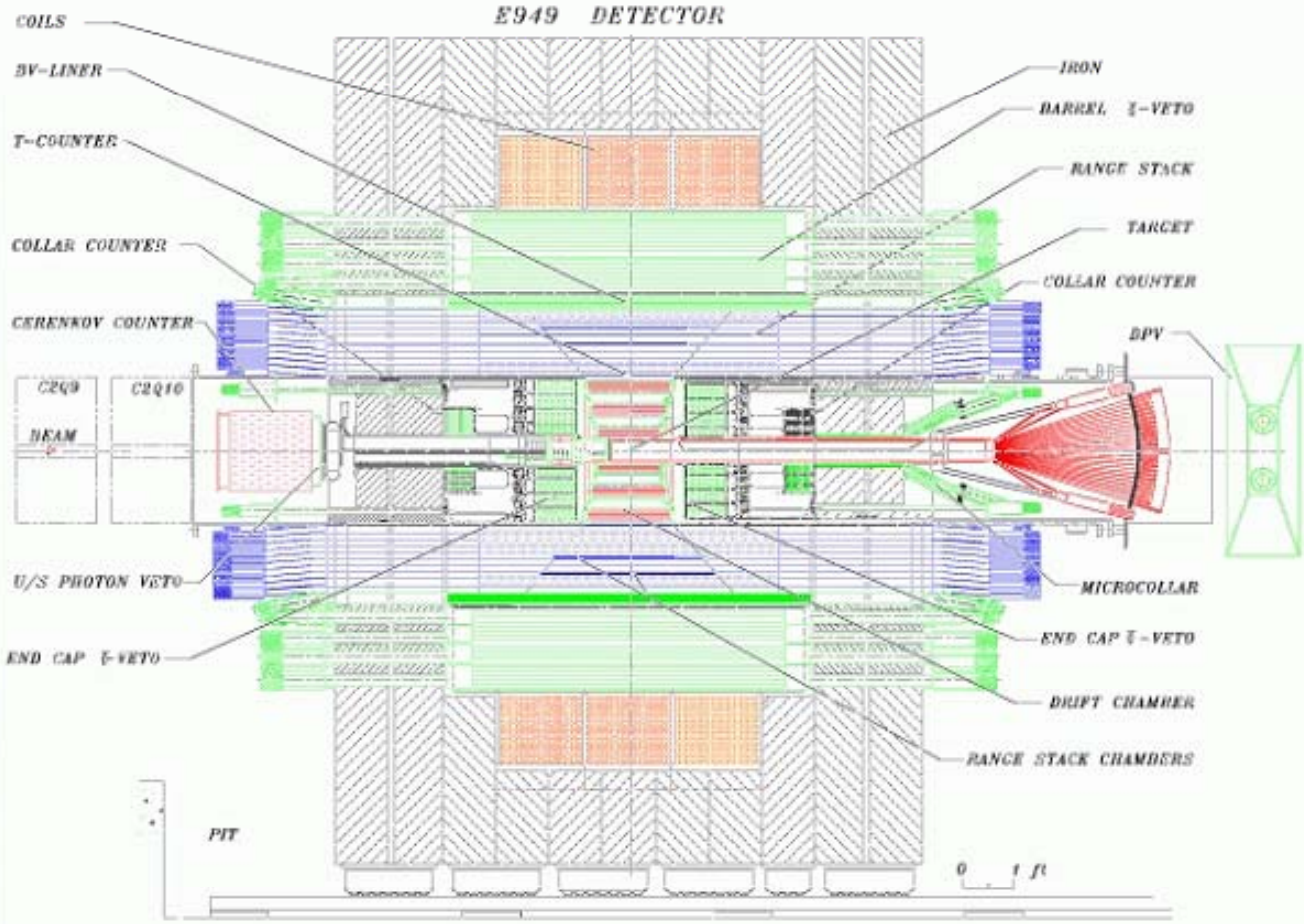
# Rare Kaon Decay Experiments

BNL Charged K+ Beamline shown below, New design for JPARC is 11m in length.




Target station will be 3mx3mx3m followed by a beam line for the Fermilab experiment of (3mx3m transverse) x 11m longitudinal.

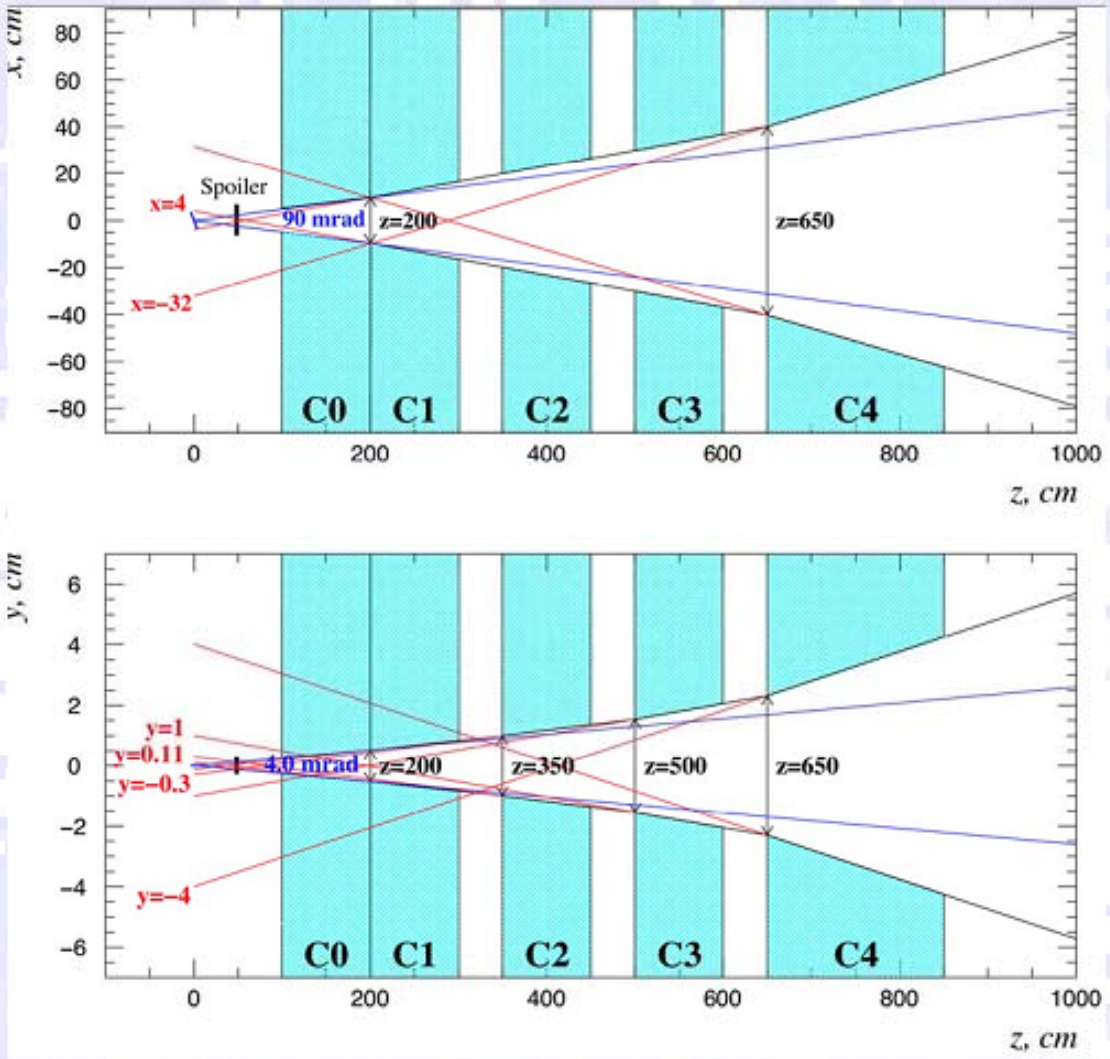
# BNL E787/E949: Stopping K+ Experiment. Next generation experiment at Fermilab would be about half of the radius.




Elevation view of the E949 detector.

Detector at Fermilab will be (2mx2mx2m) which can fit into a 3mx3m transverse hall.

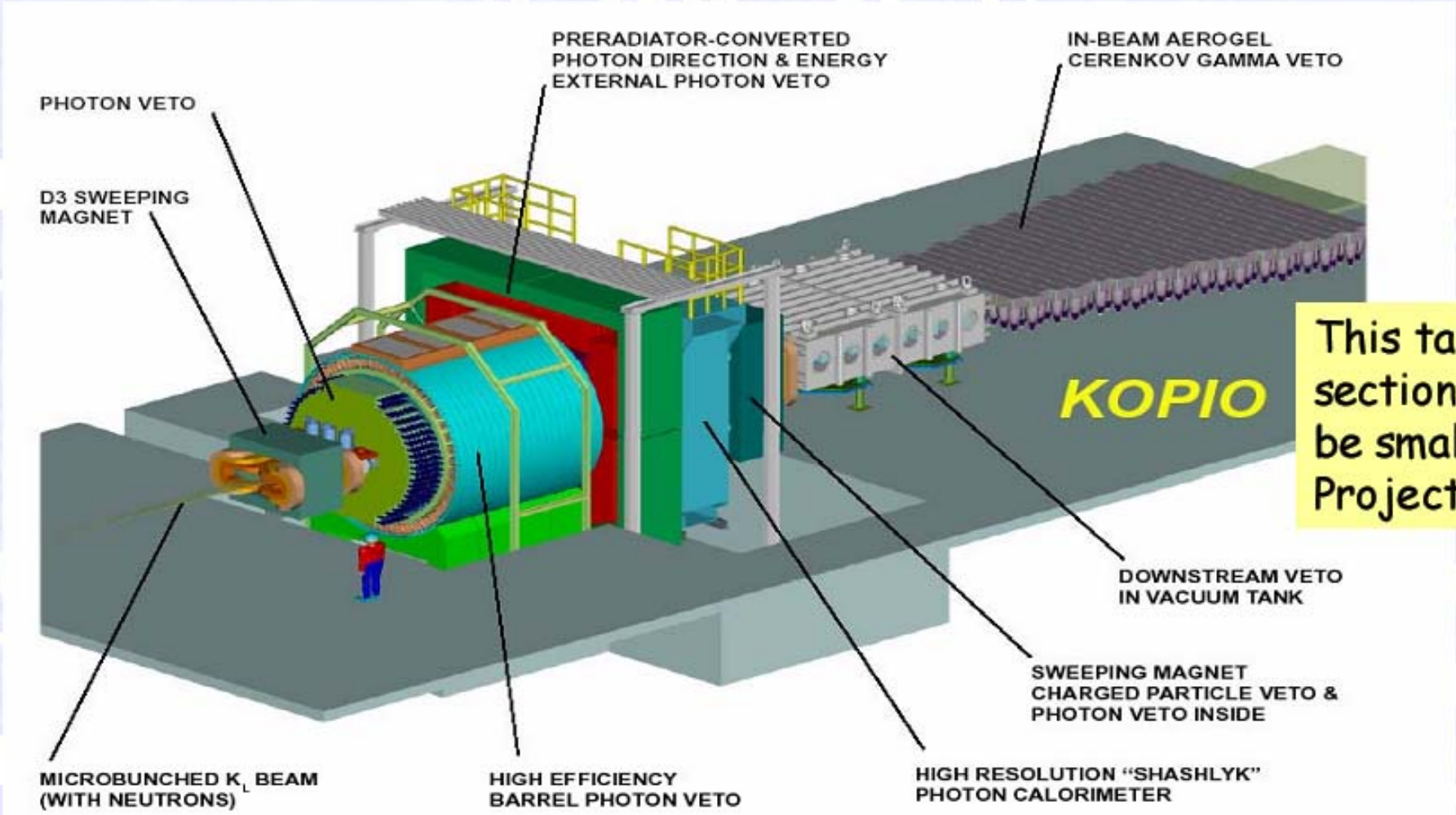
# Neutral Kaon "KOPIO" like beam line space requirements….




X angular space for Fermilab experiment will be closer to the the Y angular space.

Target station will be 3mx3mx3m followed by a beamline that is (2mx2m transverse) x 10m longitudinal length.

# Neutral Kaon "Kopio" like detector space requirements….



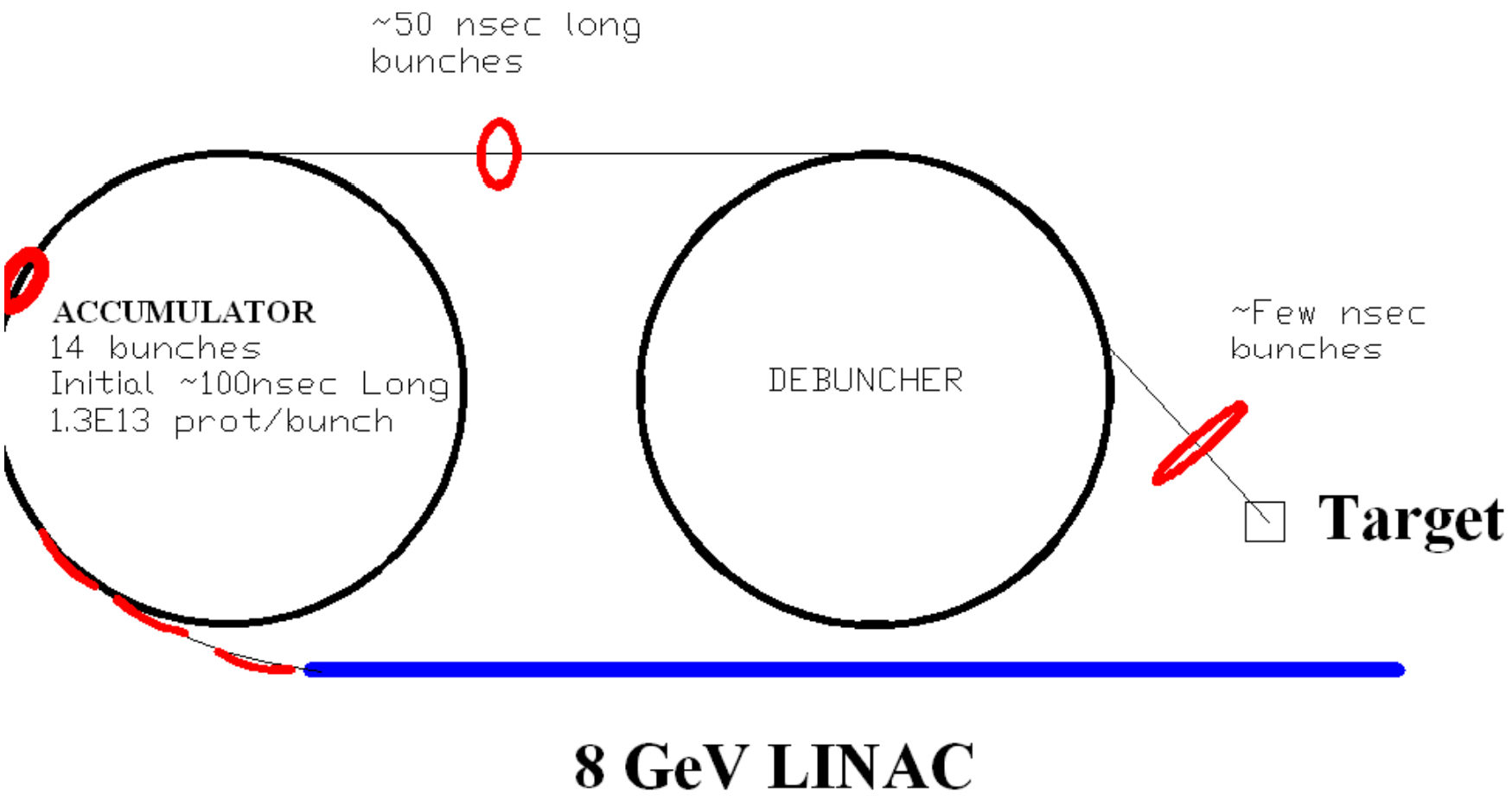

Transverse (elevation view) dimensions: 5mx5m maximum.

Longitudinal (plan view) dimensions : 10m (of 5mx5m) + 10m (of 3mx3m)

# Rare K Decay Experiment Requirements

- Beam Power
  - Booster era: ~ 25 kW
  - Project X era: 200 kW or even more
- Proton time distribution for KOPIO-like experiment
  - Slow spill with high duty cycle
  - Bunch length <~ 300 psec (the shorter the better)
  - Bunch separation ~ 40 nsec
- (Charged K exp't can use KOPIO beam time structure)
- Creating the proton distribution in the Booster era
  - Momentum-stack three Booster batches in the Accumulator
  - Rebunch at ~26.4 MHz
  - Single-turn transfer all 42 bunches to the Debuncher
  - Add high-frequency rf harmonics of 26.4 MHz to ring voltage
  - Resonantly extract from the Debuncher
  - Repeat the above sequence twice per MI cycle

# Providing Proton Bunches for a Neutrino Factory or a Muon Collider



# Booster-Era Beam Timelines for mu2e Experiment