Task Force on Project X for Muon Collider

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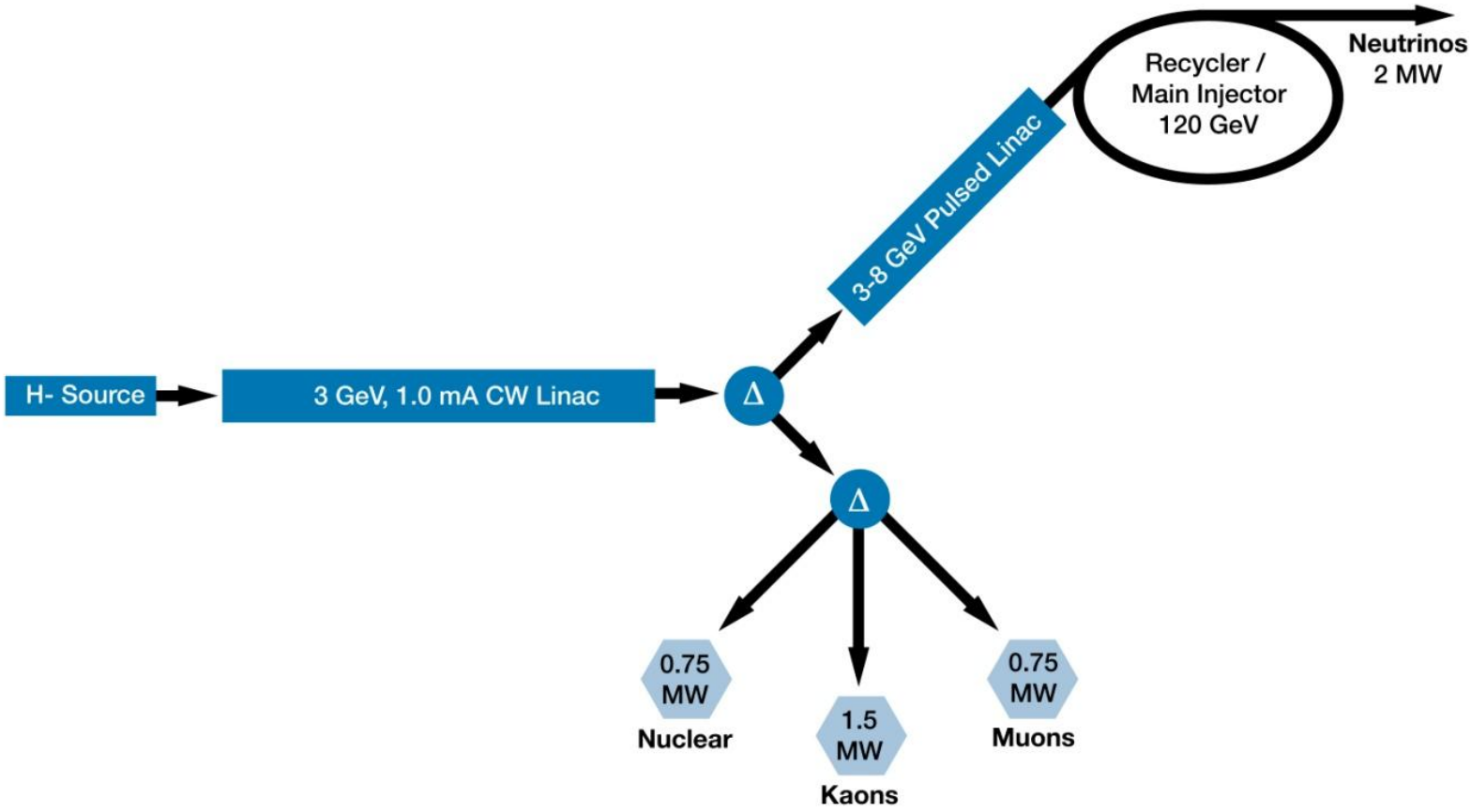
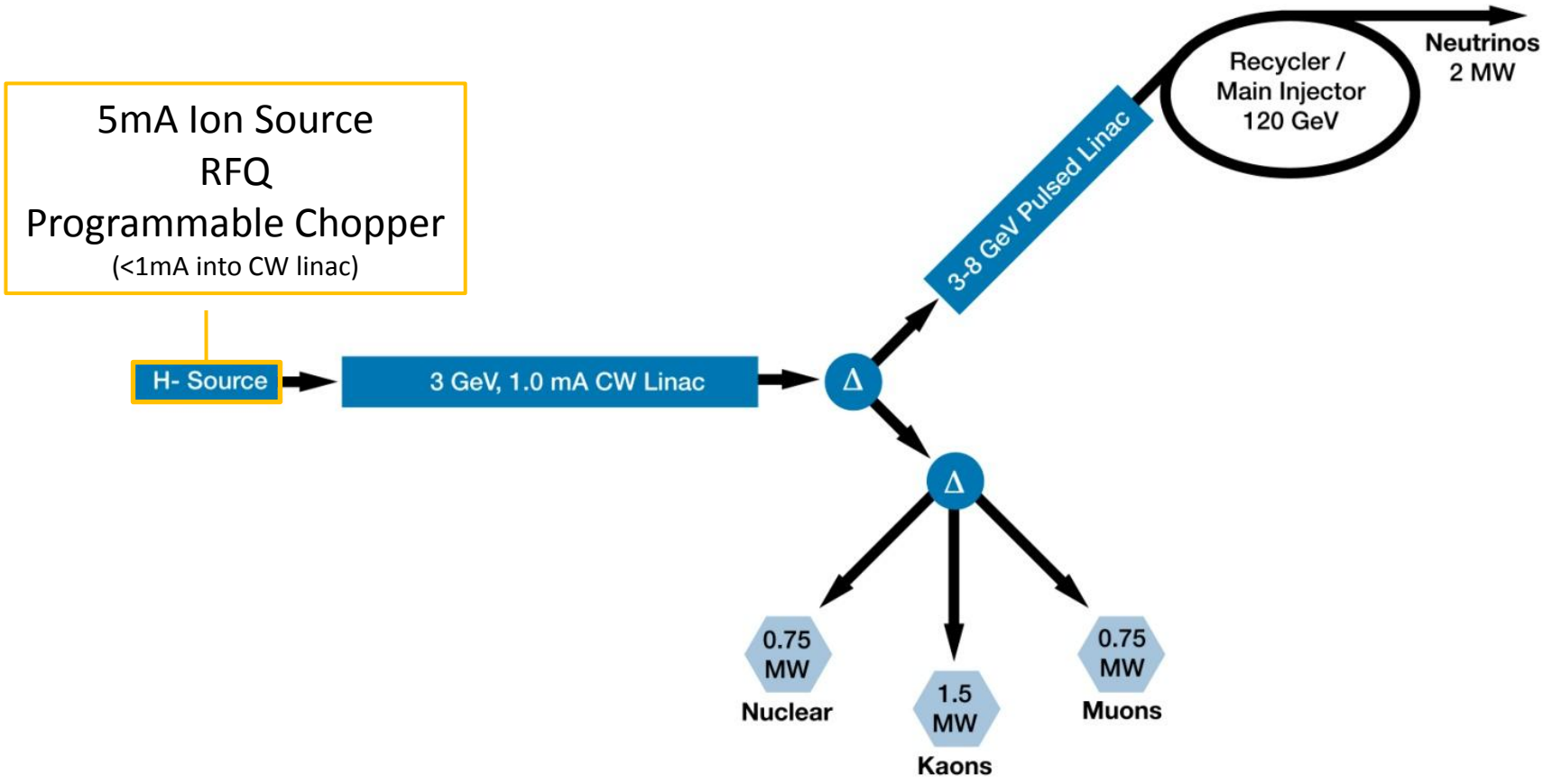
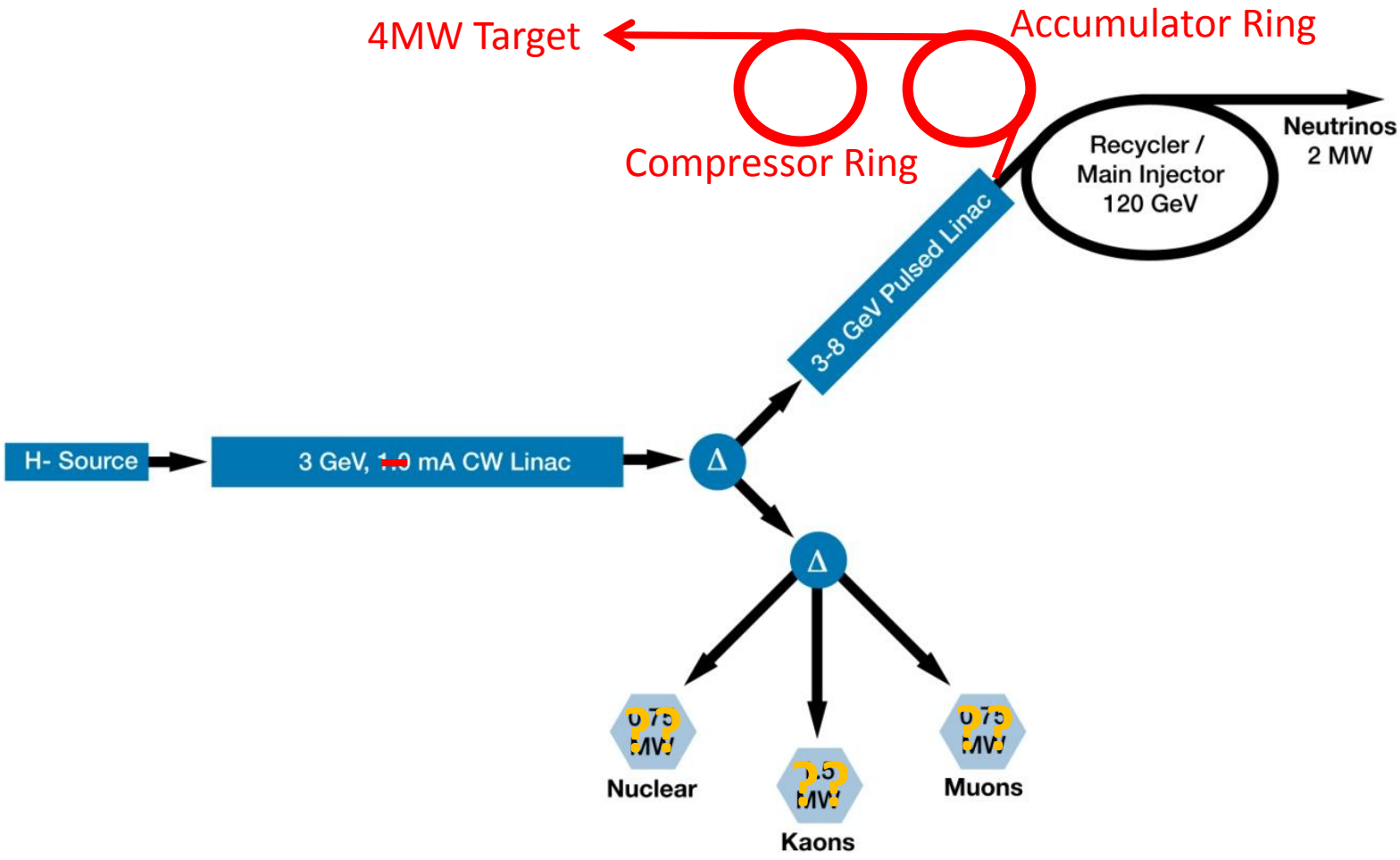
Project X Layout



Project X Layout



Muon Collider Layout



Task Force

- Membership (see extra slide) comes from Project X and Muon Accelerator Program
- Charge (see extra slide) is to outline a plausible solution to achieve the last diagram
  - Upgrade of Project X
    - How affect RDR?
  - Muon Collider beam reformatting
    - Can it be done?

Project X

- CW Linac will support average beam current of 1 mA to 3 GeV
- Pulsed Linac (3-8 GeV) will have a ~5% duty factor
- Possible 8 GeV beam power of 320 kW

- Programmable Chopper System (part of H- source) will provide appropriate bunch structure for the linac experiments as well as fill the appropriate part of the RF buckets in the accumulating Recycler Ring

Muon Collider

- Upgrade Project X
  - 4 MW at 8 GeV
    - Increase particles per linac bunch
    - Increase pulse linac duty factor
- Repackage linac beam for 12-15 Hz delivery
  - Accumulator Ring
    - Collect linac beam into bunches
  - Compressor Ring
    - Narrow bunches to <= 3 ns
  - Delivery as a single bunch (trombone system)
    - Multiple bunches arrive at target at same time

Approach to Date

- Agreed on Project X upgrade numbers
  - Increase to 5 mA average current
  - Increase pulse linac duty factor to 10%

(see next talk by Sergei Nagaitsev)

- Discussed instability limitation for rings
  - Reviewed Valeri Lebedev's presentation at WAHIPA (Oct 2009) of longitudinal instability
    - Defines the maximum power per bunch

(next slide)

- Outlined options/limitations
  - Striping
  - Compressor Ring
  - Delivery Trombone System

Longitudinal Instability

- Lebedev has looked at stability criterion and rearranged terms to determine the maximum beam power per bunch

$$P_{\max} \approx 0.72\,\mathrm{MW}\left(\frac{E}{8\,\mathrm{GeV}}\right)^4\left(\frac{f_{rep}}{15\,\mathrm{Hz}}\right)\left(\frac{L_b\sigma_p}{60\,\mathrm{cm}\times 1\%}\right)^2\left(\frac{10\,\mathrm{m}}{L_{init}}\right)$$

Final Bunch Parameters (Compressor Ring)

Initial Ring Bunch Parameters (Accumulator Ring)

Starting Point for Rings

- Simple numbers to start
  - T_{rev} ~ 800 ns
  - f_{rf} ~ 10 MHz
  - h = 8
  - Injection scheme
    - ~50 ns beam ON followed by ~50 ns NO beam
      - This requires doubling the number of particles per linac bunch with respect to Project X

Next

- Design Work/Concerns
  - Accumulator Ring
    - Striping
    - Instabilities
  - Compressor Ring
    - Bunch Rotation
    - Dipole aperture and large momentum spread
  - Delivery
    - Trombone
    - Beam sizes and angles at target

Extras

Task Force Membership

Alexahin, Yuri
Ankenbrandt, Chuck
Chase, Brian
Gollwitzer, Keith
Jenner, Leo
Kourbanis, Ioanis
Lebedev, Valeri
Nagaitsev, Sergei
Neuffer, Dave
Palmer, Bob
Popovic, Milorad
Yakovlev, Slava
Zisman, Mike

Charge

Neutrino Factories and Muon Colliders require high power (~4MW) proton beams with an energy in the range 5-15 GeV, packaged into short bunches (<3ns), incident upon a liquid Hg jet target. The required repetition rate differs between Neutrino Factories and Muon Colliders, the most demanding (lowest rate) being for a Muon Collider which typically requires a repetition rate of 12 Hz. It is desired that a viable scheme be identified that would enable Project X to be upgraded to meet these requirements.

The Project X – Muon Accelerator Program Joint Task Force should:

1. Identify the challenges.
2. Outline possible solutions, including basic calculations required to establish plausibility.
3. Identify the main technical challenges that must be met to implement the possible solutions.
4. Identify any changes to the existing Project X baseline design that are needed to make the possible solutions achievable.

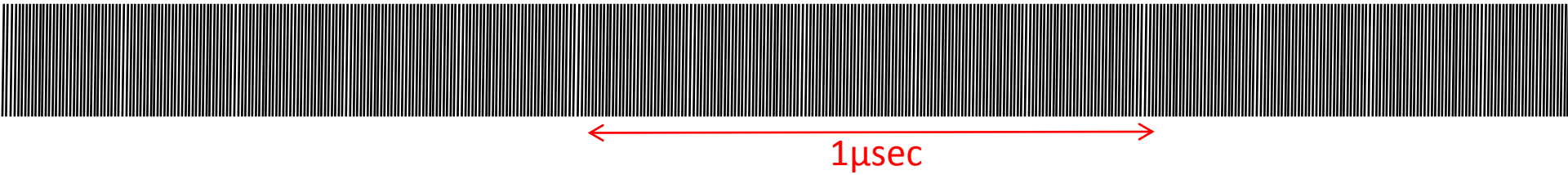
An initial status report should be ready for presentation at the time of the Muon Collider meeting in Telluride (27 June – 1 July 2011). A final report should be completed by January 1, 2012.

Project X H- Source

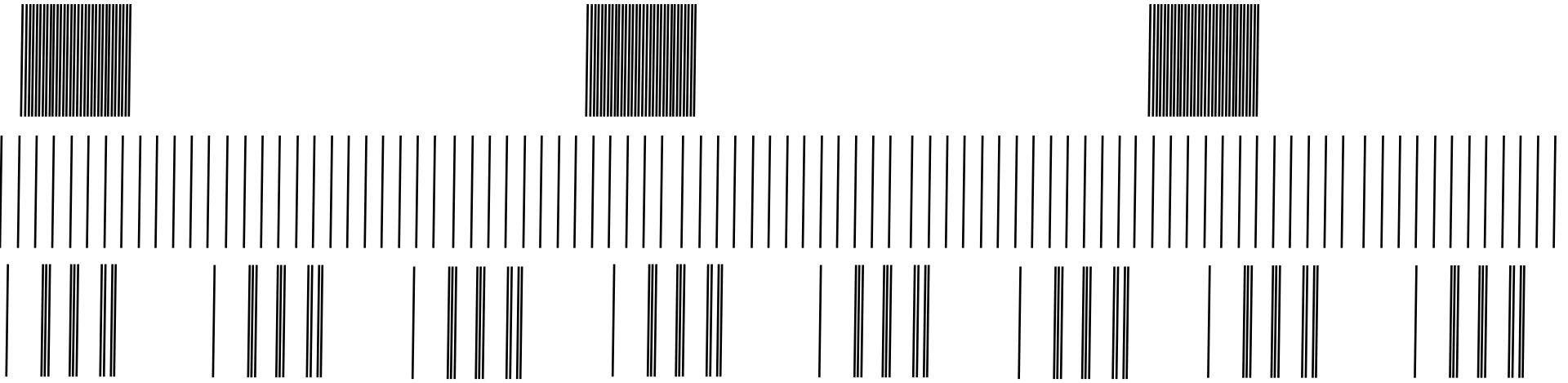
- Composed of several pieces
  - Ion Source
  - RFQ
  - Programmable chopper system
- Parameters
  - 1.9×10^8 particles/bunch
  - 162.5 MHz bunches out of RFQ
  - Chopper system will limit beam to 1 mA average beam power over 1 μsec

Project X Programmable Chopper

RFQ output will be 1.9×10^8 particles per bunch at 162.5MHz



Programmable Chopper can do any arbitrary pattern as long as the average cw linac current is <=1mA for 1µsec

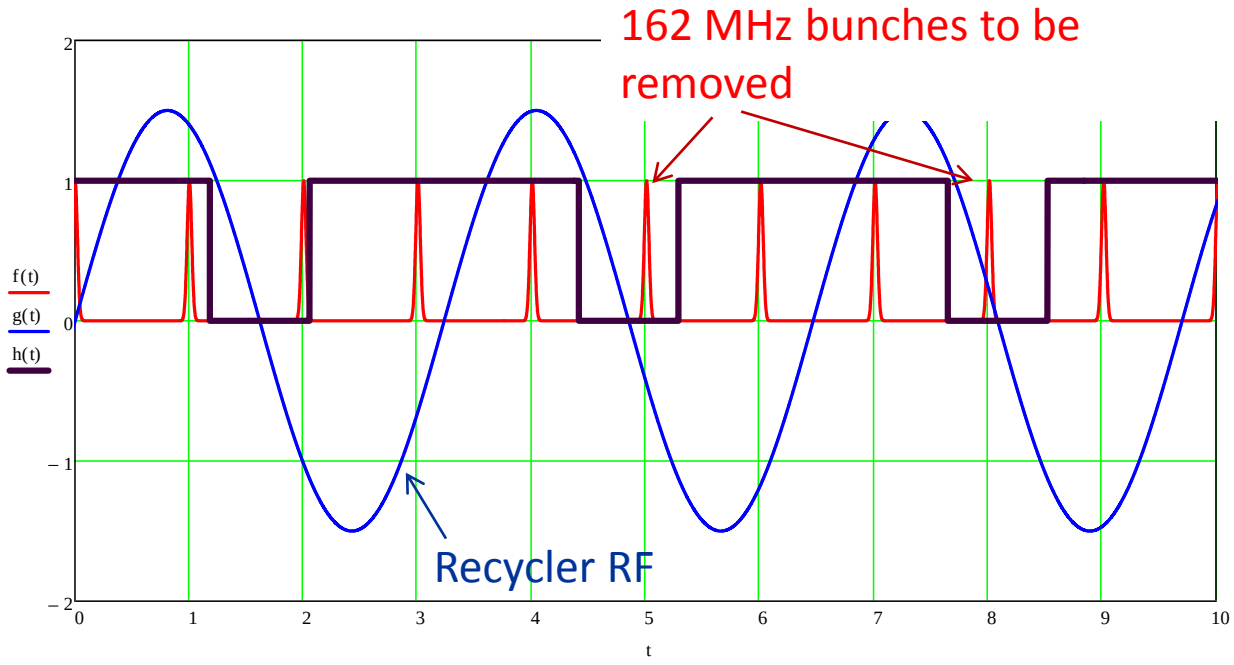


Accumulation in RF buckets

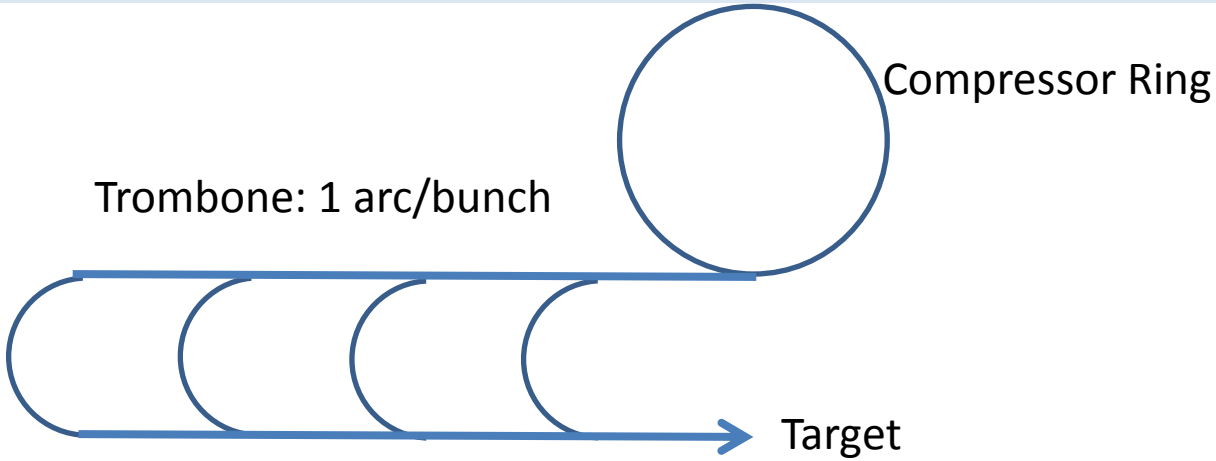
- Desire to have linac beam populate correct phase region of RF, programmable chopper will need to remove beam destined for wrong phase
- Project X will populate +- 120 degrees

Chopping for injection (from Nagaitsev)

- RF frequency at injection into the Recycler : ~53 MHz
- Chopper needs to provide a kicker gap (~200 ns per 11 μs) and needs to remove bunches that fall into "wrong" phase of ring rf voltage.



Trombone Delivery

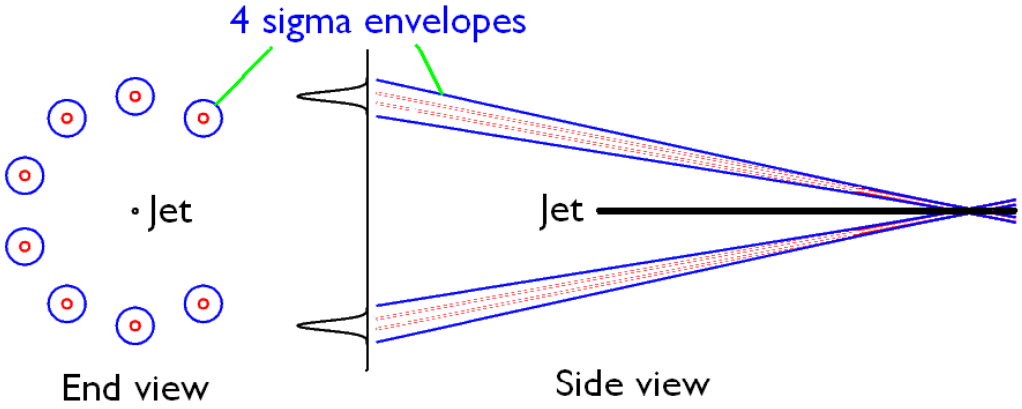


4 bunch example

Muon Collider Proton Driver Trombone Schematic

(not to scale; bunches arrive simultaneously on target)

8 bunch example



Each beam line provides different trajectory to target