Muons from the Fermilab Proton Source

Steve Geer

Some considerations …

TOPICS

1. Muons in the Accumulator: brief comment

2. Muon production using 8 GeV protons – deluxe case

3. Muon production using 8 GeV protons – scaled down case (with an unhidden agenda)

   a) Target & collection
   b) Proton Beam

Muons in the Debuncher

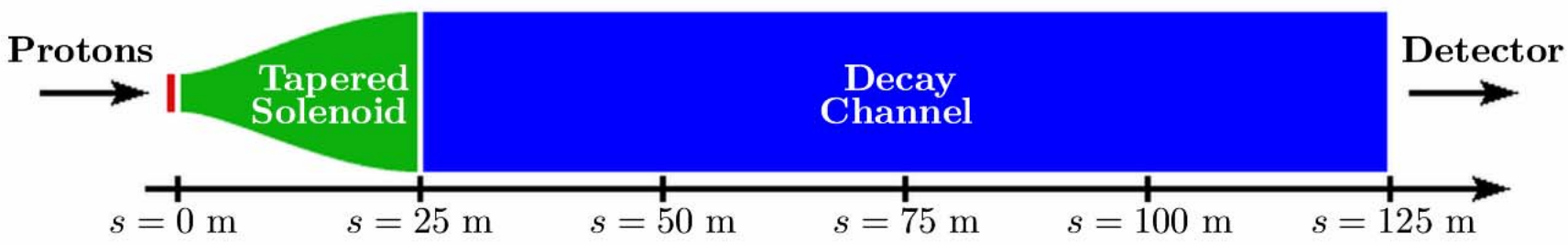
The ratio of muons/antiprotons in the Debuncher has been measured to be 1.0 +- 0.2 (A. Bross et al., NIM A332 (1993) 27.

Note: The pions are gone after 1 turn.

Muon Production & Collection with 8 GeV Protons

S. Brice, S. Geer, K. Paul, R. Tayloe; hep-ex/0408135

Deluxe Design based on Neutrino Factory Studies:



Captures particles with $p_T < eB_0 R_0 / 2$

For 8 GeV primary protons, pion p_T peaks at 150 MeV/c.
Choose B_0 = 20T – 1.25T, R_0 = 7.5cm – 30cm, with $B_0 R_0^2$ constant

MARS simulations yield 0.2 muons/p …momenta O(100 MeV/c), occupying large transverse phase space

Muon Production Rates

S. Brice, S. Geer, K. Paul, R. Tayloe; hep-ex/0408135

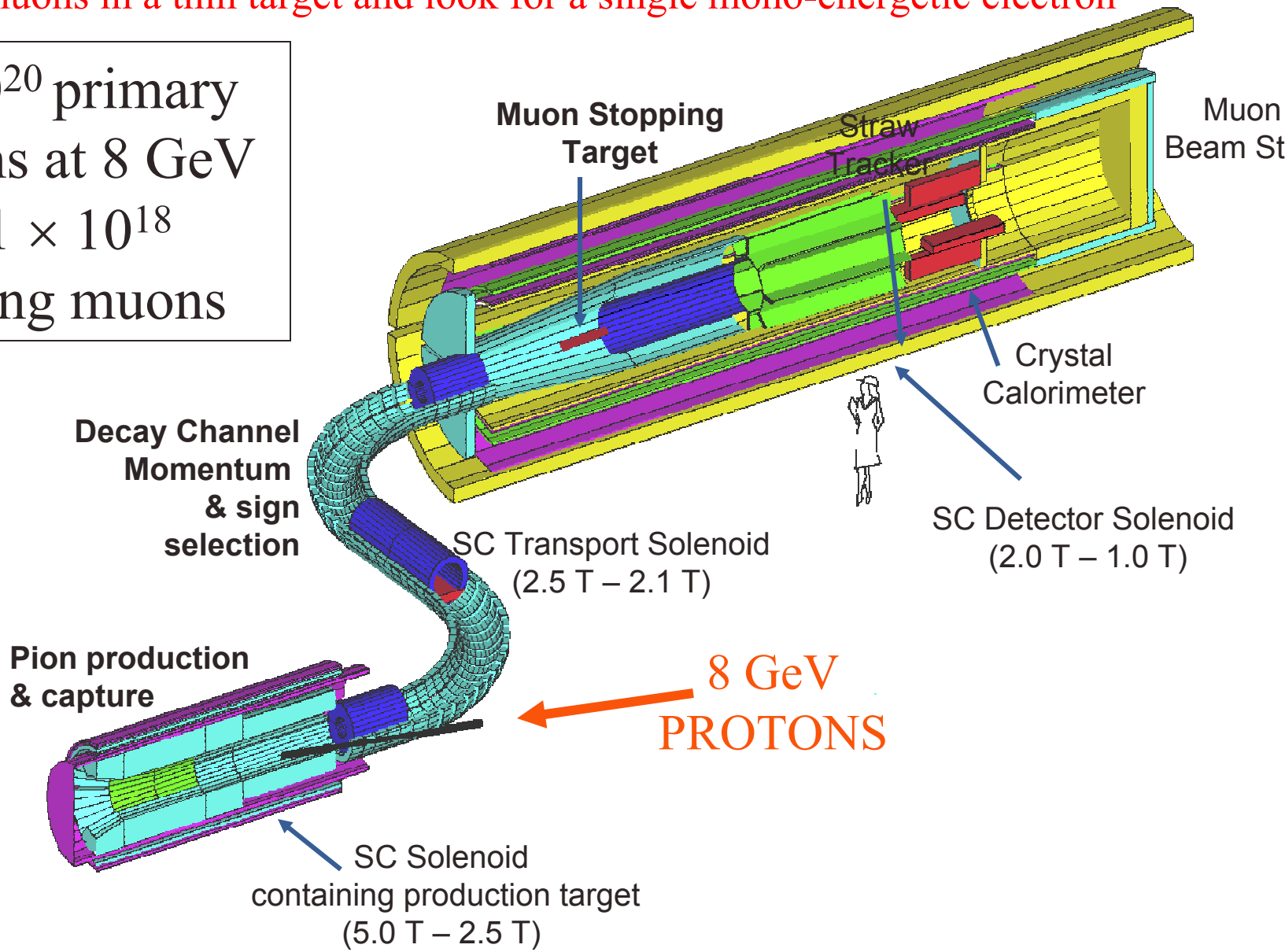
Distance from Target

	S=25m	*50m*	*75m*	*100m*	*125m*
μ^+/p	*0.16*	*0.20*	*0.21*	*0.21*	*0.22*
μ^-/p	*0.16*	*0.20*	*0.21*	*0.21*	*0.21*
π^+/p	*0.095*	*0.051*	*0.030*	*0.020*	*0.014*
π^-/p	*0.087*	*0.044*	*0.025*	*0.016*	*0.011*

Lower Field Solution: MECO PROPOSAL

Stop muons in a thin target and look for a single mono-energetic electron

4×10^{20} primary protons at 8 GeV yield 1×10^{18} stopping muons



Killing 2 Birds with 1 Stone ?

Could the beam needed for a MECO-like experiment at Fermilab also be constructed & used for a Muon Collider R&D program ?

Present thoughts are use the 2010 shutdown to implement the changes needed for the future NuMI program (McGinnis scheme) … and at the same time make the changes needed for the required muon source.

Muon scheme uses 8 GeV prootons from the Booster, momentum stacked in the Accumulator, Rebunched and slow extracted from the Debuncher.

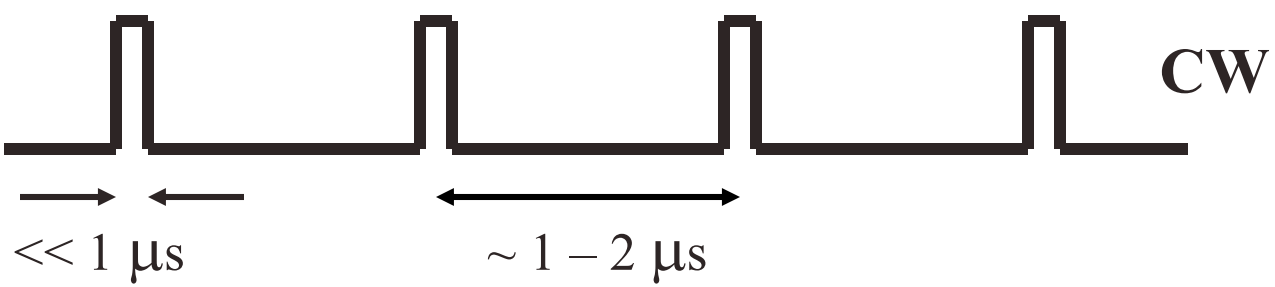
BEAM REQUIREMENTS

To reach MECO goal: Low energy bunched muon beam providing ~10^{18} muons per yr. This requires ~10^{20} primary 8 GeV protons per yr.

Bunch lengths short compared to the lifetime of muons orbiting a nucleus (1.1 μs for Al), with a bunch spacing longer than this time.

Experimental signature: mono-energetic electron & nothing else. To minimize backgrounds, when there is no incoming primary beam there must be no beam at the level of 1 part in 10^9.

Ideal Bunch Structure for a MECO-like Experiment:



FERMILAB PROTON SOURCE

The FNAL Linac accelerates H^- to 400 MeV

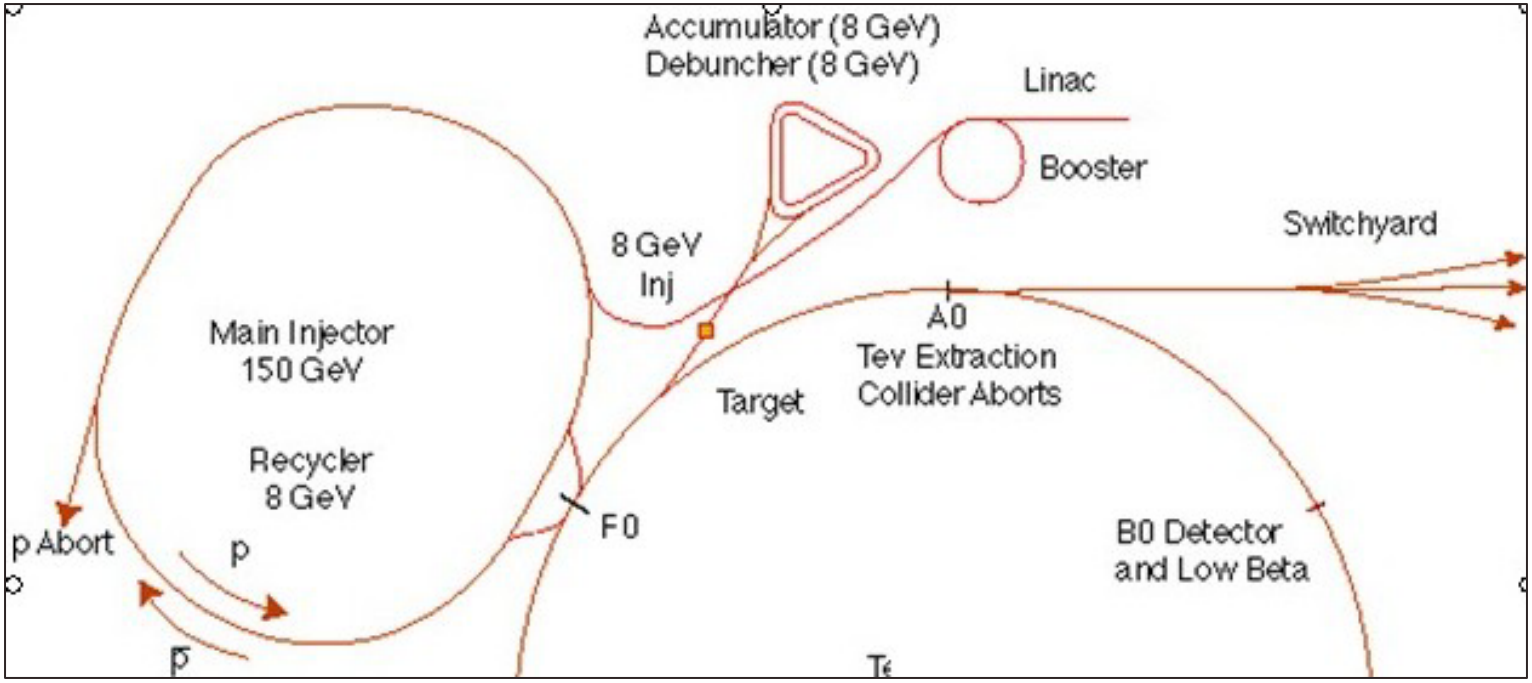
The FNAL Booster accelerates protons to 8 GeV.

The 8 GeV protons are used for MiniBooNE and to feed the Main Injector.

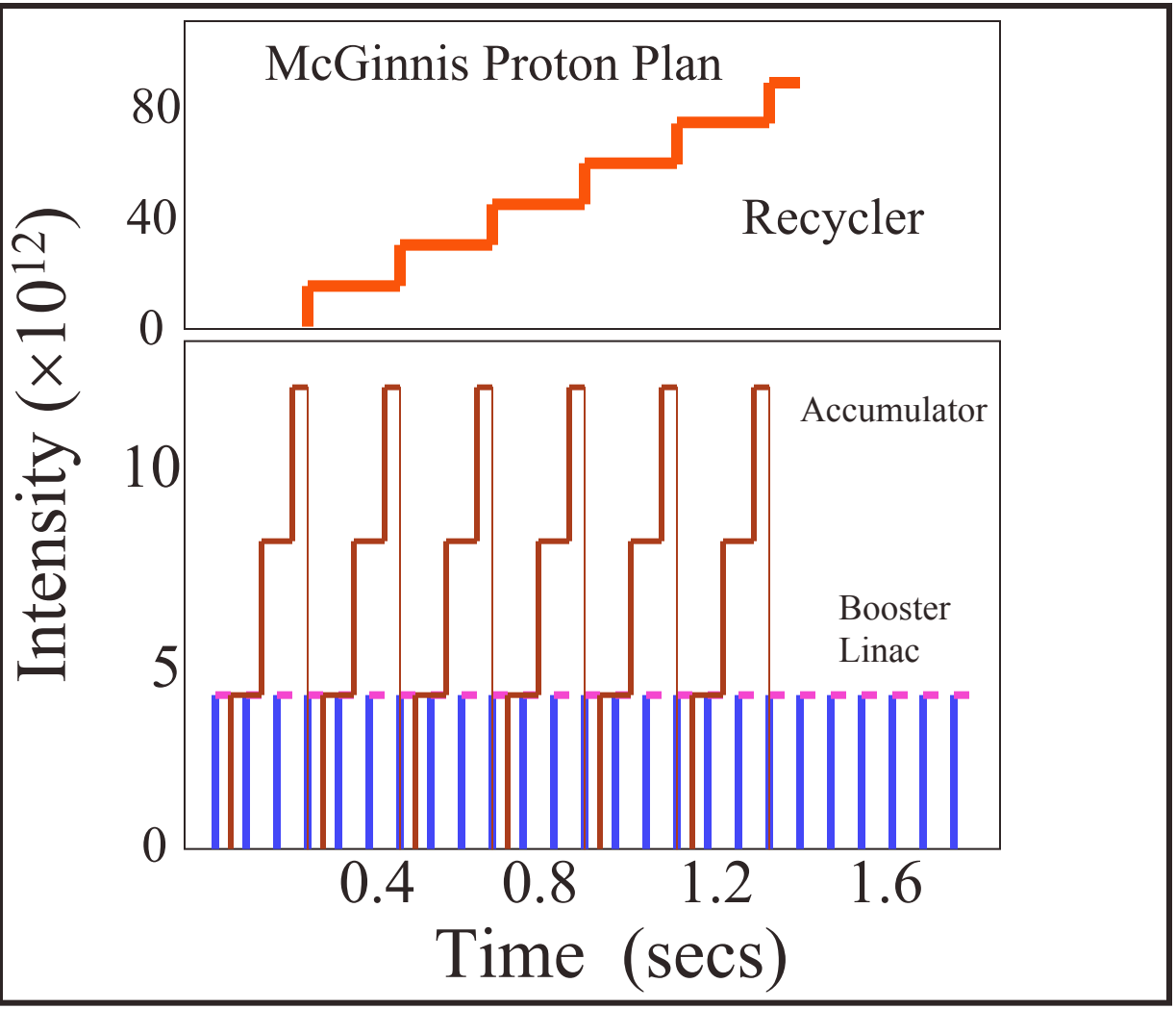
The Main Injector accelerates protons to 120 GeV.

The MI protons are used to make antiprotons (Collider) and neutinos (MINOS).

The Tevatron Collider uses three additional proton source rings (Debuncher, Accumulator, and Recycler).



FERMILAB PROTON SOURCE: NEAR FUTURE



400 MeV Linac cycles at 15 Hz,

8 GeV Booster cycles at 15 Hz.
→ batch / cycle,
4.6×10^{12} p / batch

8 GeV Accumulator Combines 3 Booster batches (momentum stacking) → Recycler

Recycler combines 6 Accumulator stacks (box car stacking)

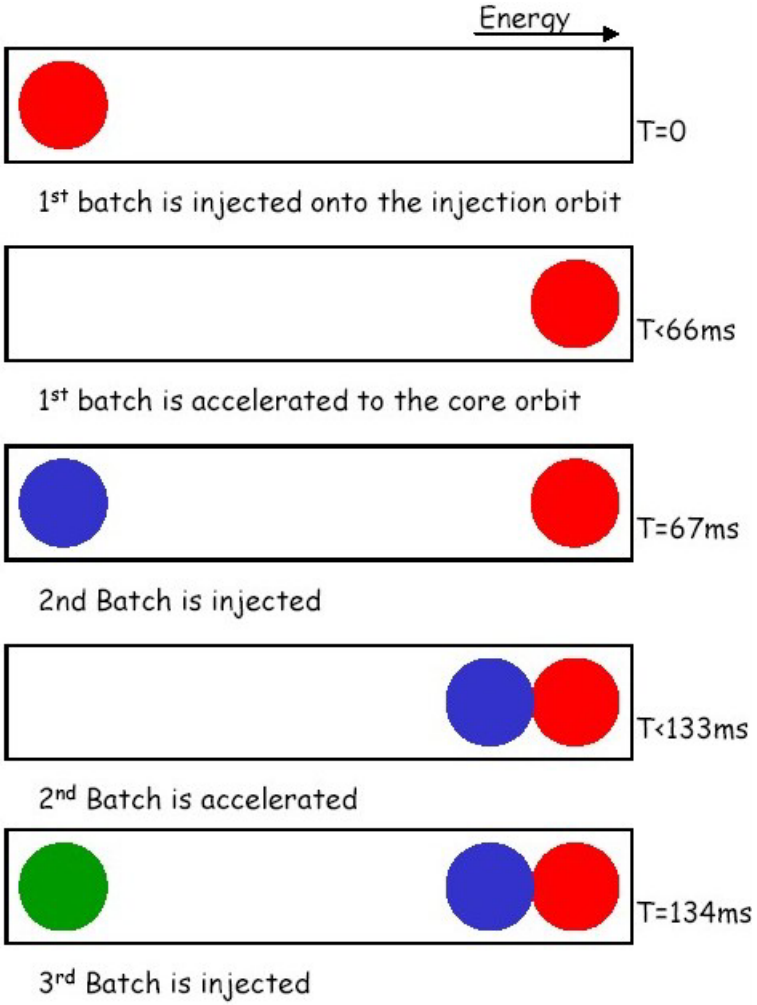
→ MI → 120 GeV
(62×10^{12} p/sec
= 1.2MW)

All this because MI ramp time >> injection time
→ combine 18 Booster Batches / 1.33 sec MI cycle.

MOMENTUM STACKING

(Dave McGinnis)

- Inject in a newly accelerated Booster batch every 67 mS onto the low momentum orbit of the Accumulator
- The freshly injected batch is accelerated towards the core orbit where it is merged and debunched into the core orbit
- Momentum stack 3-4 Booster batches



PRODUCING THE IDEAL BEAM FOR $\mu^- \rightarrow e^-$

The Debuncher is a superb large aperture 8 GeV ring with good field quality, & will be available … so lets use it !

PROPOSED SCHEME

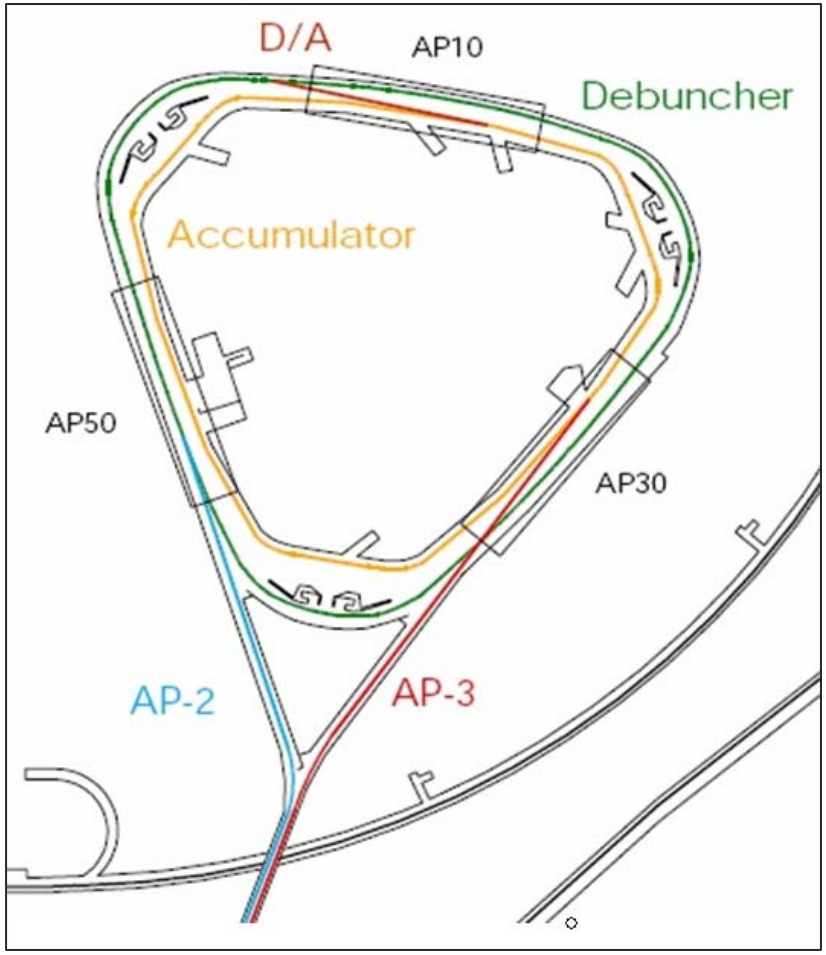
Take 3-4 Booster Batches per MI cycle

Momentum stack them in the Accumulator

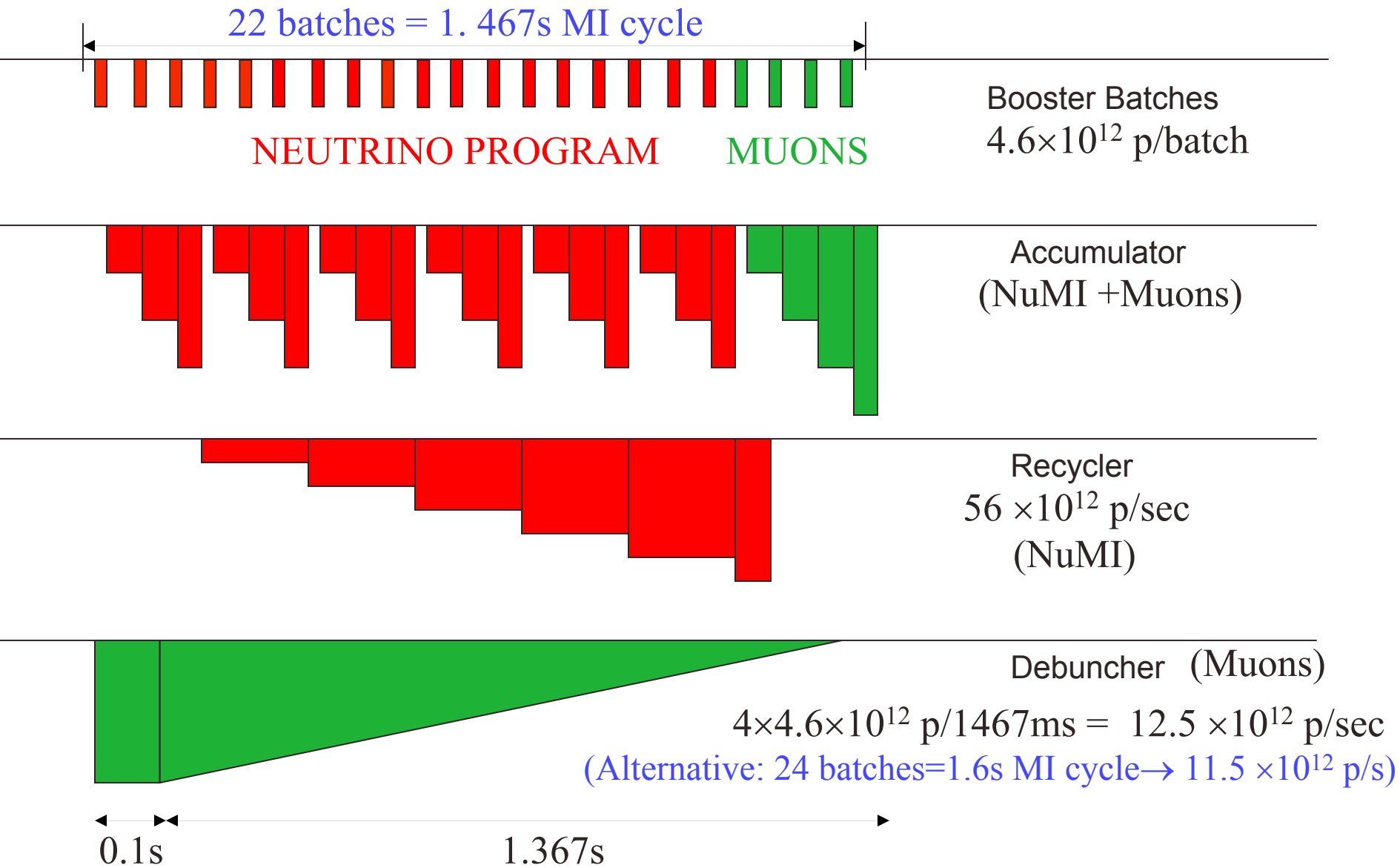
Transfer Accumulator stack to Debuncher

Rebunch (takes ~ 0.1 secs) & slow extract (for ~1.3 sec)

This creates an ~CW beam with the ideal bunch structure, delivers $>10^{20}$ p/yr, & reduces the protons available for the neutrino program by only ~10%.



COEXISTING WITH THE NEUTRINO PROGRAM



PROTON BEAM SPECS

Example: 4.6×10^{12} protons per Booster Batch & a 1.467s MI cycle

Beam Energy	8 GeV
Bunch Trains / sec: f_{TRAIN}	0.682
Bunch Spacing: ΔT_B	1.6 μs
No. of bunches/train: N_B	85×10^4
No. protons/bunch: n_P	2.16×10^7
Bunch Length (2.5σ) : t_B	150 ns (σ=60ns)
Protons/train (4 batches)	1.84×10^{13}
Protons/year (10^7 secs)	1.25×10^{20}

Four years running → 5×10^{20} protons → 1.3×10^{18} stopped muons

MODIFICATIONS: Booster → Accumulator

The Booster is connected to the Accumulator via a re-built AP4 Line

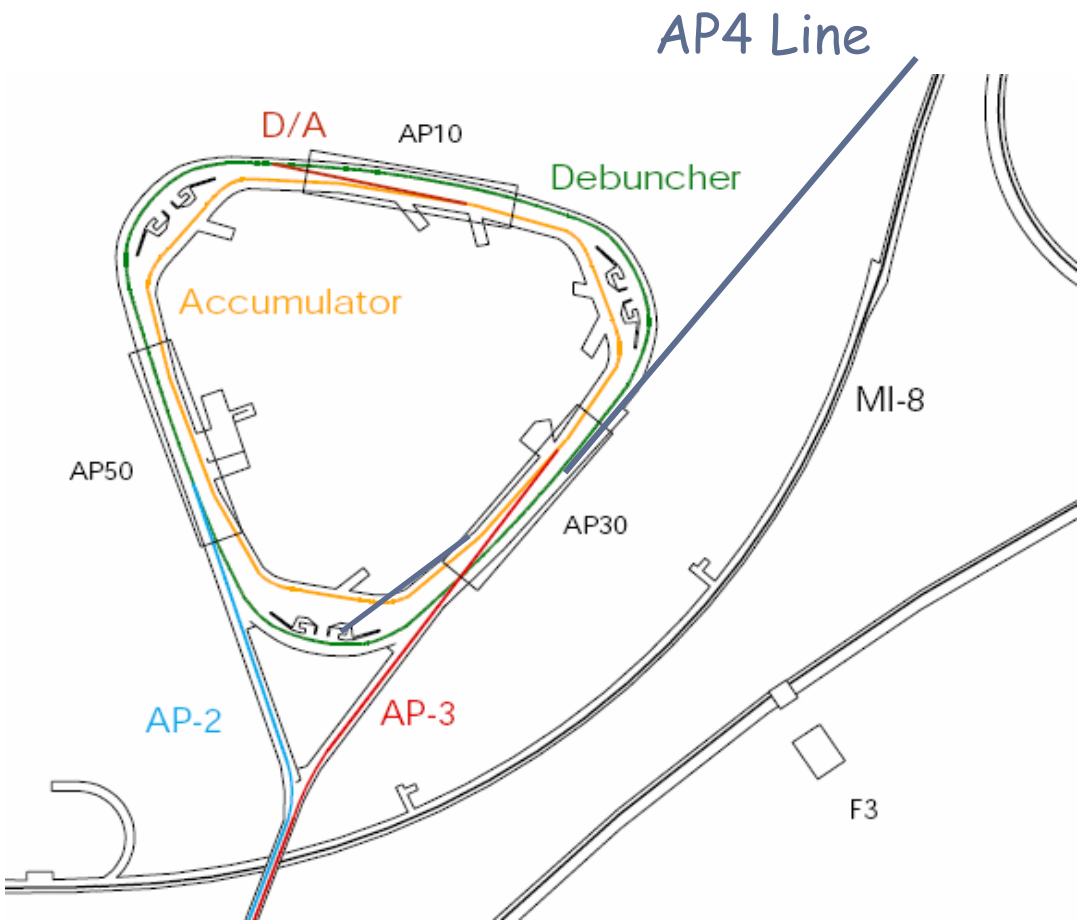
The line comes in A30 underneath the Debuncher

It must cross underneath the Debuncher and rise to the same elevation as the accumulator

The Accumulator injection septum is moved from downstream A10 to the downstream A30

The Accumulator Injection kicker is moved from upstream A20 to upstream A40

NEEDED FOR FUTURE NuMI PROGRAM



MODIFICATIONS: Accumulator → Debuncher

The Accumulator is connected to the Debuncher for μ-to-e injection via the reversed D-A line (A-D line)

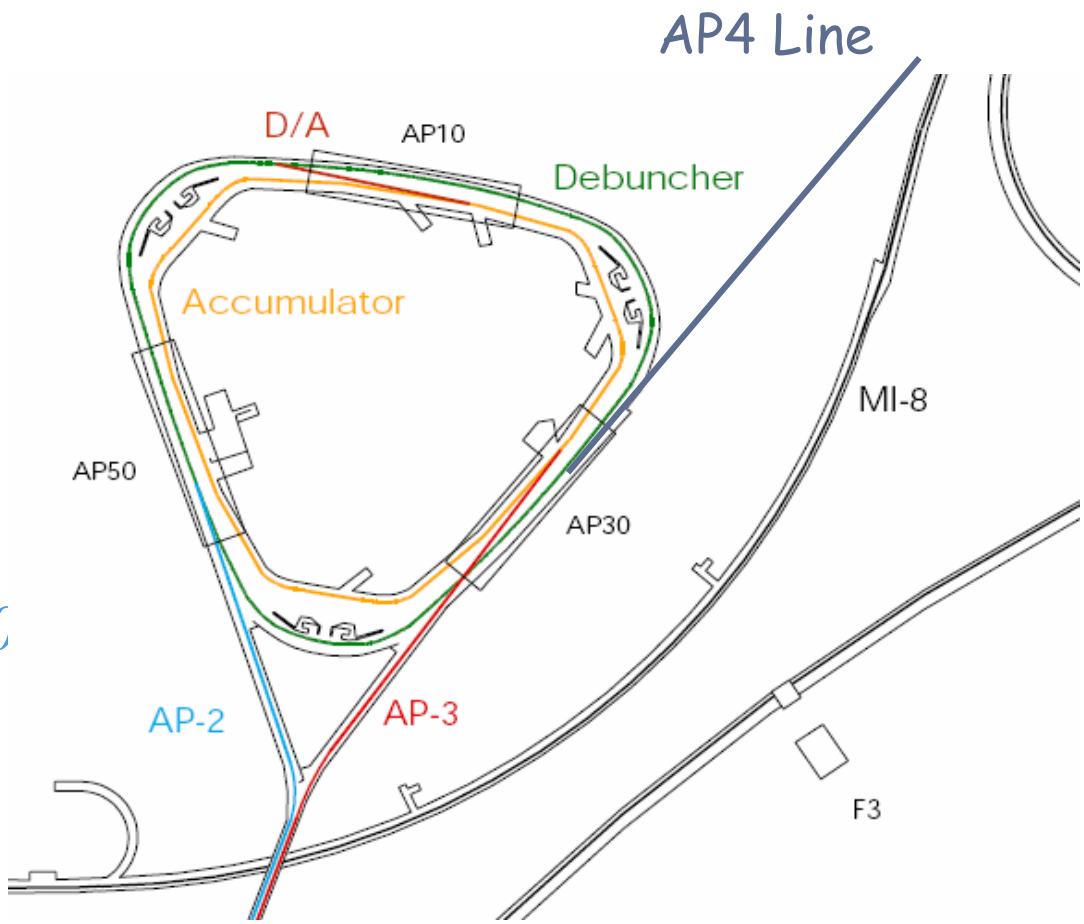
The Accumulator injection kicker is moved from upstream A20 to downstream A40

A new Accumulator septum is placed at upstream A50

The A-D line connects to the Debuncher at downstream D50

The debuncher extraction septum at upstream D10 is moved to be an injection septum at downstream D50

NEEDED FOR MUON PROGRAM



MODIFICATIONS: Debuncher → Experiment

The beam is slow spilled extracted from the Debuncher at either D30 or D50

At D30, the extracted beam goes towards AP3

At D350, the extracted beam heads west

NEEDED FOR MUON EXPERIMENT