Life After the Energy Frontier: The Future of Fermilab

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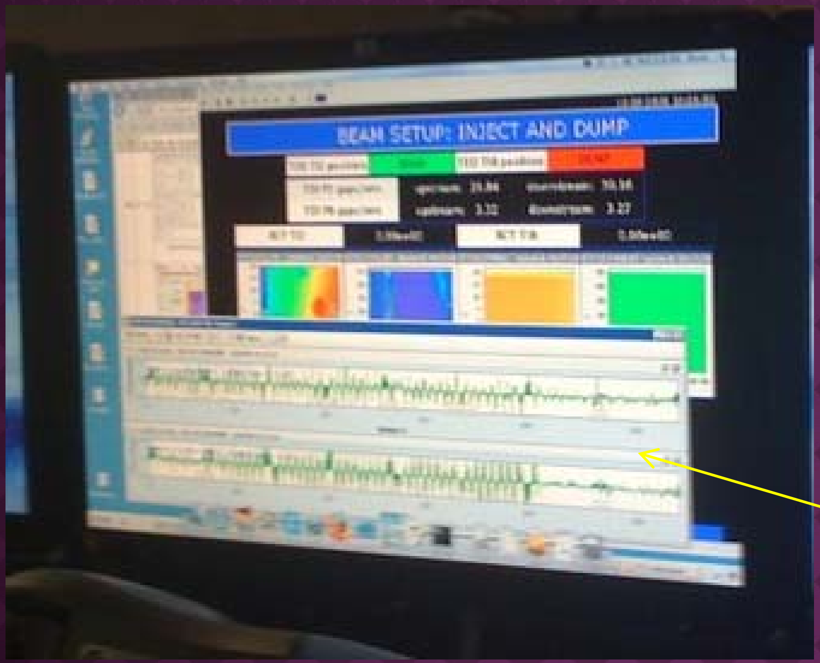
Fermilab



First circulating beam in LHC

Background

- For over 20 years, the Fermilab Tevatron has been the highest energy collider in the world, and it has been the centerpiece of the lab's physics program.
- This will change *very* soon, when the LHC begins to accelerate and collide beams.
- The current Tevatron experimental program is expected to run through roughly mid 2010, after which it will be superceded by the LHC physics program.
- If Fermilab intends to keep an accelerator based program, it must identify exciting physics that can be done at energies well below the energy frontier.

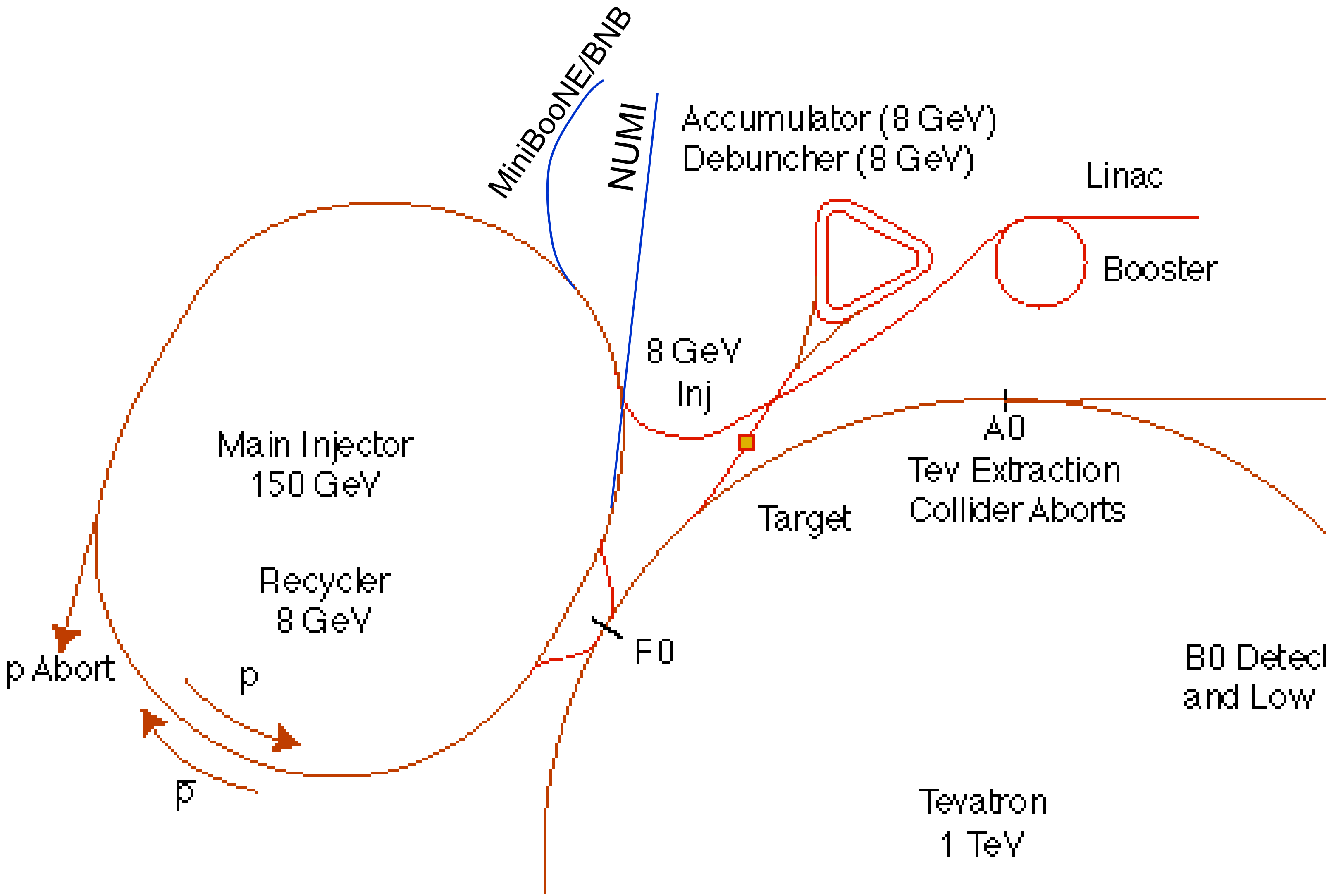
Outline

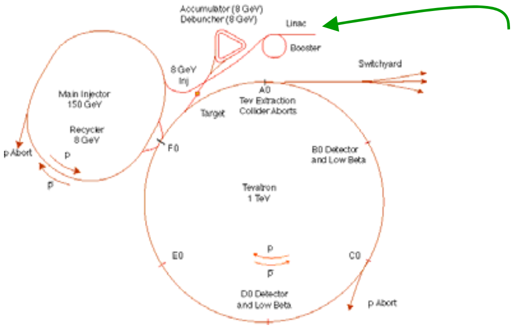
- Brief history of Fermilab and the Tevatron
- Current physics program
  - Tevatron
  - Neutrino physics
- Recent events
  - EPP2010 report
  - What the hell?
  - P5 report
- Physics of the “intensity frontier”
  - Neutrinos
  - Precision physics
  - Neutino factories/muon colliders
- Long term plans
  - Project X
- Intermediate program
  - Teaching an old dog new tricks
- Where we’re at

History

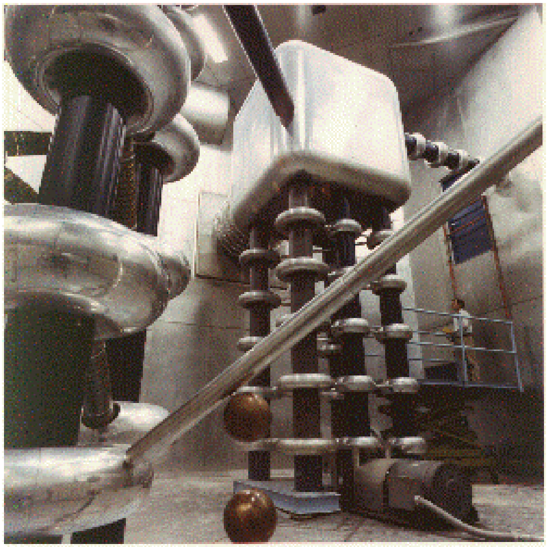
- 1968 – Construction begins.
- 1972 – First 200 GeV beam in the Main Ring.
- 1983 – First (512 GeV) beam in the Tevatron ("Energy Doubler"). Old Main Ring serves as "injector".
- 1985 – First proton-antiproton collisions observed at CDF (1.6 TeV CoM).
- 1995 – Top quark discovery. End of Run I.
- 1999 – Main Injector complete.
- 2001 – Run II begins.
- 2005 – MINOS begins

The Fermilab Accelerator Complex

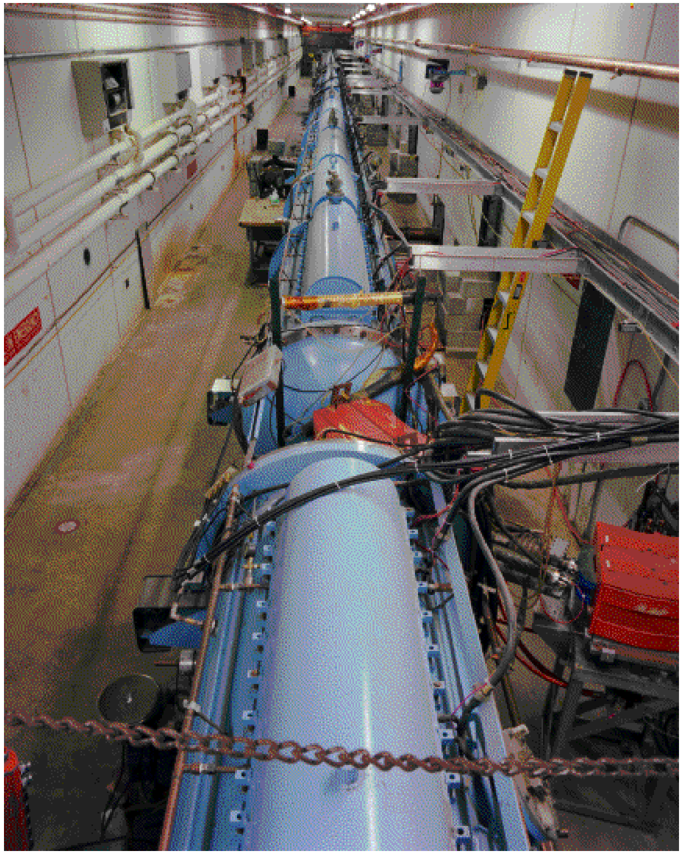




Preac(cellerator) and Linac

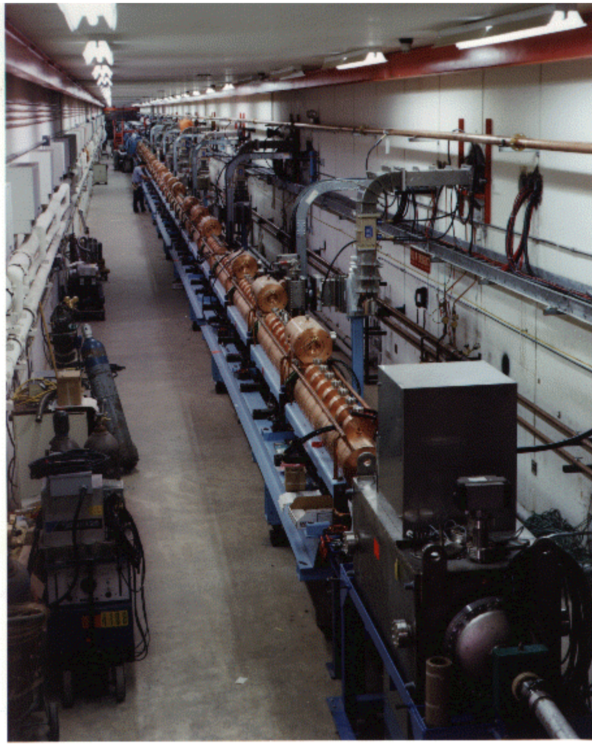


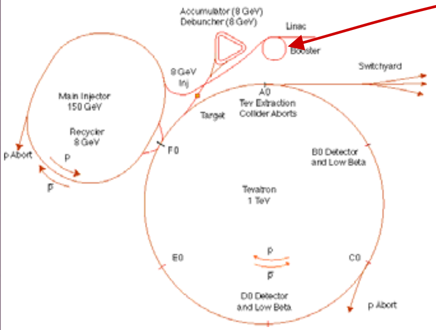
"Preac" - Static Cockroft-Walton generator accelerates H- ions from 0 to 750 KeV.



"Old linac"(LEL)- accelerate H- ions from 750 keV to 116 MeV

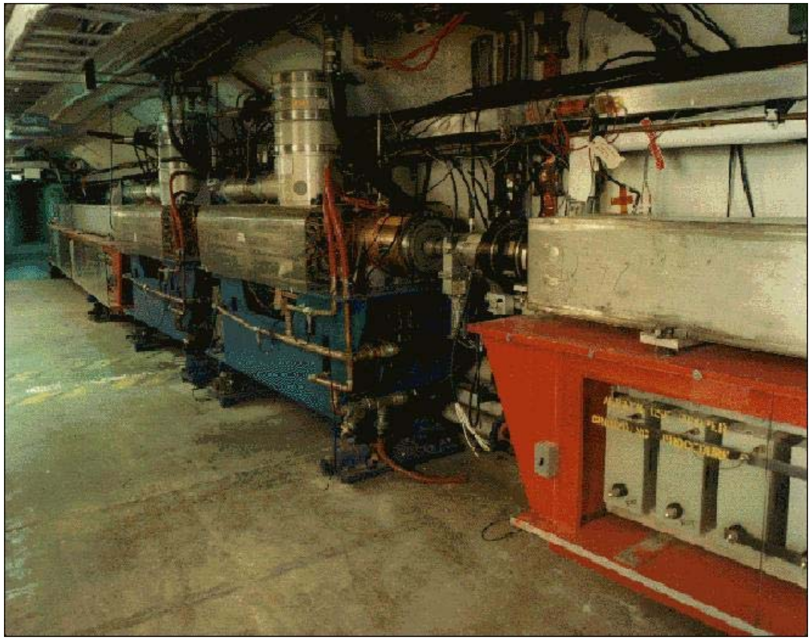
"New linac" (HEL)- Accelerate H- ions from 116 MeV to 400 MeV

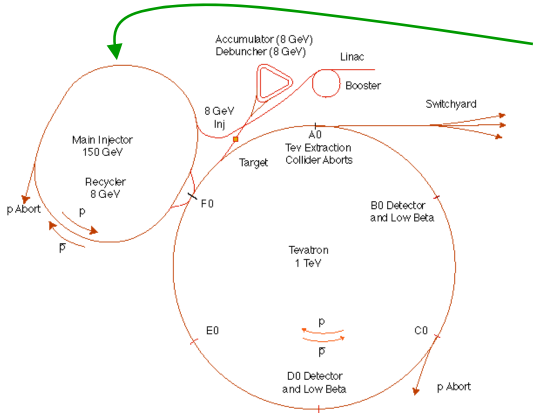




Booster

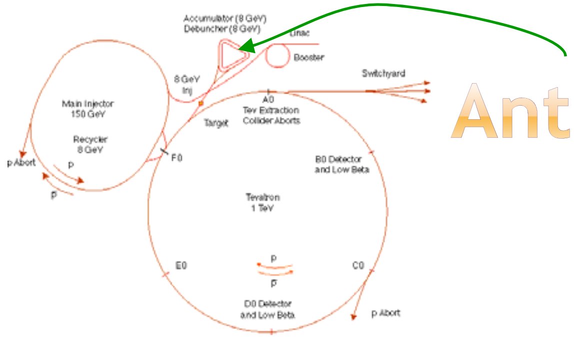
- Accelerates the 400 MeV beam from the Linac to 8 GeV
  - Operates in a 15 Hz offset resonant circuit
  - Sets fundamental clock of accelerator complex
- From the Booster, 8 GeV beam can be directed to
  - The Main Injector
  - The Booster Neutrino Beam (MiniBooNE)
  - A dump.
- More or less original equipment





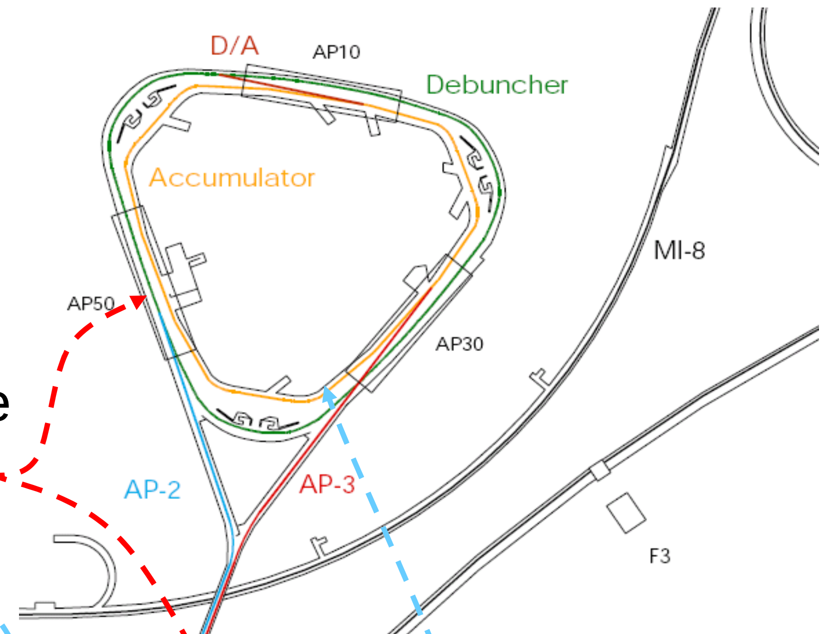
Main Injector/Recycler

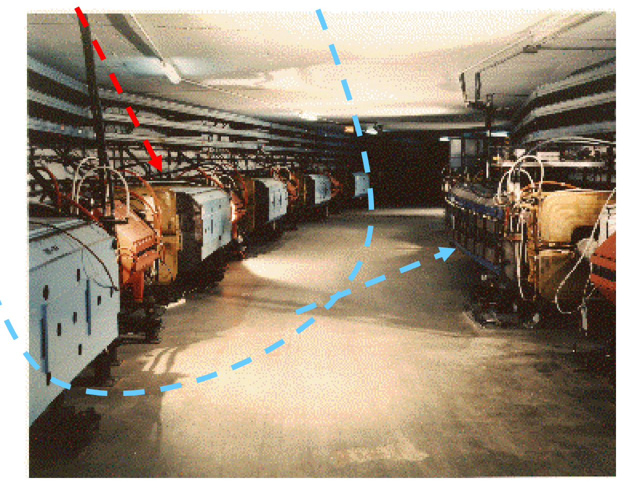
- The Main Injector can accept 8 GeV protons OR antiprotons from
  - Booster
  - The anti-proton accumulator
  - The Recycler (which shares the same tunnel and stores antiprotons)
- It can accelerate protons to 120 GeV (in a minimum of 1.4 s) and deliver them to
  - The antiproton production target.
  - The fixed target area.
  - The NUMI beamline.
- It can accelerate protons OR antiprotons to 150 GeV and inject them into the Tevatron.



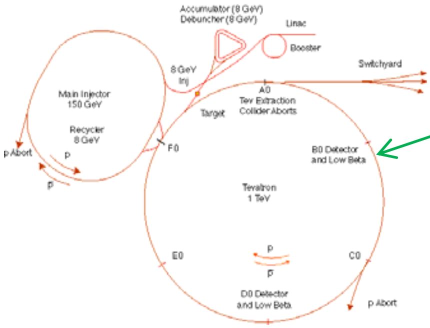
Antiproton Debuncher/Accumulator

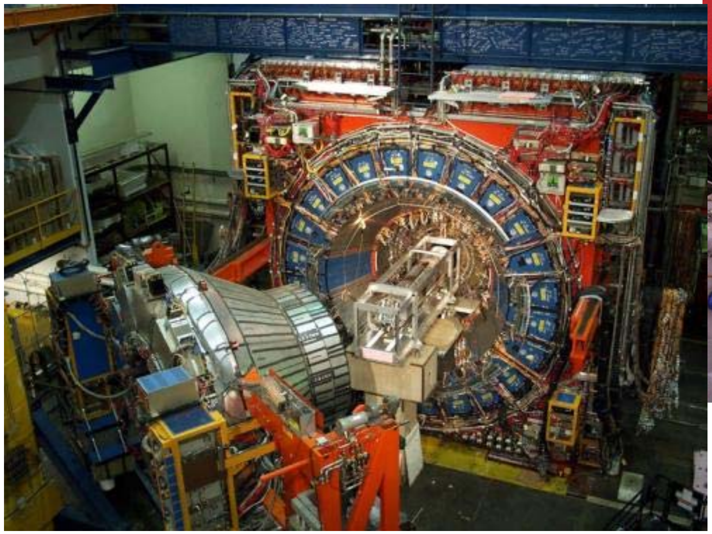
- Protons are accelerated to 120 GeV in Main Injector and extracted to pBar target
- pBars are collected and phase rotated in the "Debuncher"
- Transferred to the "Accumulator", where they are cooled and stacked





Tevatron





- Takes 150 GeV protons (clockwise) and antiproton (counterclockwise)
- Accelerates them 980 GeV
- Collides them at two detectors (CDF and D0)
- Formerly supported a high energy fixed target program.

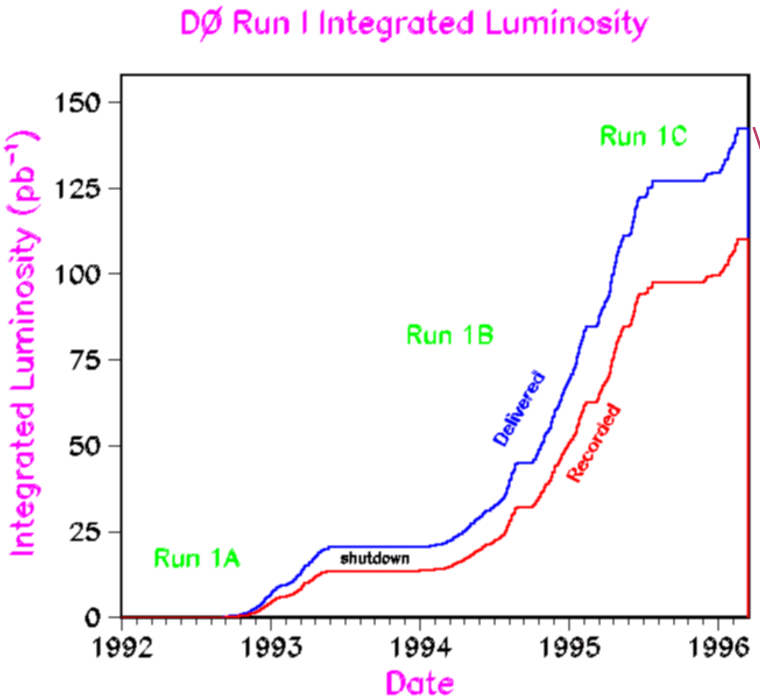
Present Operation

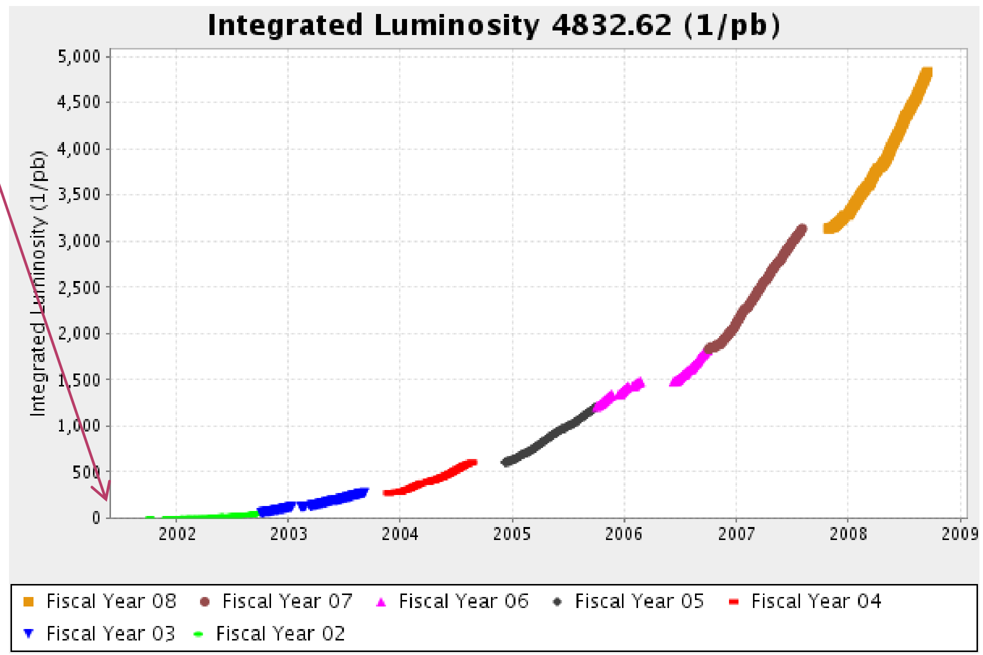
- 11 Proton batches (~4.5e13) are loaded into the Main Injector and accelerated to 120 GeV every 2.2 seconds:
  - 2 of these are extracted for antiproton production
  - 9 are extracted for neutrino production in the NuMI line.
- Antiprotons are phase rotated and cooled in the Debuncher, tranferred to the Accumulator, where they are further cooled and stacked.
- When a few ~10^{11} are accumulated, they are transferred to the Recycler, where they are "stashed".
- After about a day (~3×10^{12} antiprotons), these are accelerated to 150 GeV and injected into the Tevatron along with protons, where they collide while the production process repeats.
- While the Main Injector is ramping, 8 GeV protons are sent to the MiniBooNE/SciBooNE neutrino experiment.

Tevatron Performance

Main Injector Operation

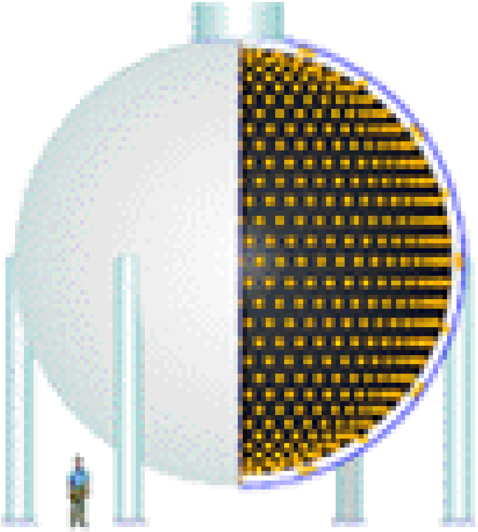
Recycler Operation





Fermilab Neutrino Program

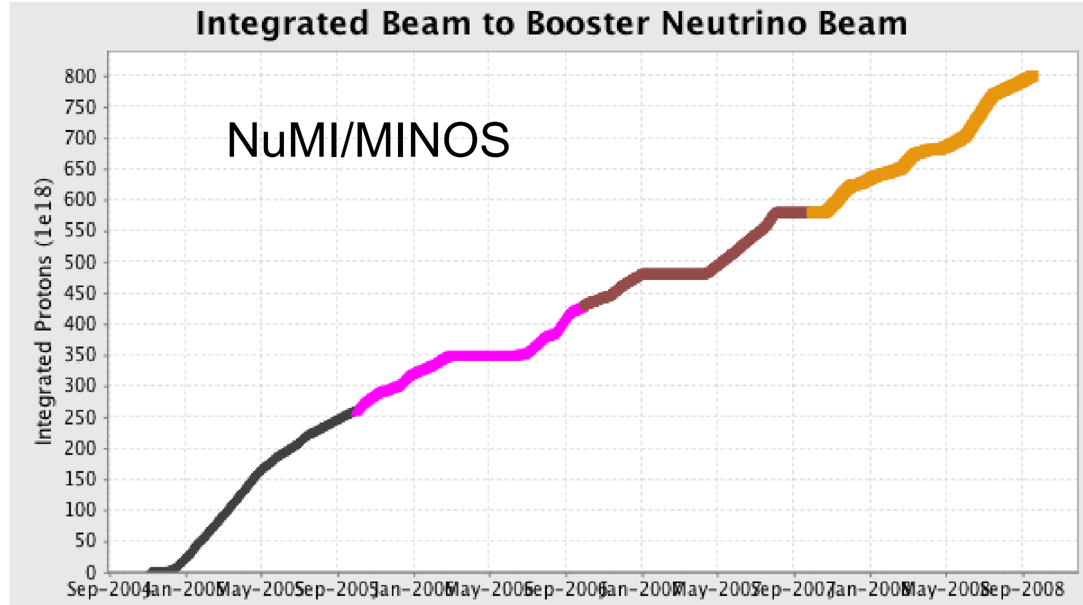
- MiniBooNE
  - Use 8 GeV proton beam (L/E ~1)
  - Confirm or refute LSND anomalous result
  - Published null result in 2007

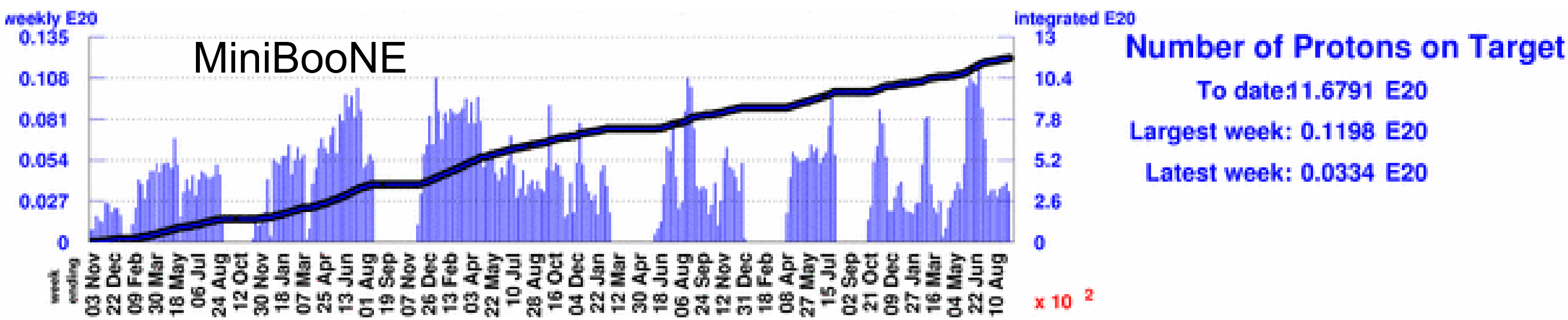


- NuMI/Minos
  - Neutrinos from 120 GeV Main Injector beam
  - Detector 750 km away (L/E ~100)
  - Measure $\nu_\mu \leftrightarrow \nu_\tau$ (atmospheric "neutrino problem")

Neutrino beam lines

- NuMI / MINOS
  - ~8×10^{20} protons
- MiniBooNE
  - 11.7×10^{20} protons





Planning for the future: EPP2010

- It's been realized for some time that it makes no sense to keep running the Tevatron once the LHC begins producing physics (~2010)
- In 2004, the Elementary Particle Physics (EPP) 2010 panel was formed to plan for the future of US high energy physics in an LHC dominated world.
  - "Interesting" make up
    - ~half non-physicists
    - Chaired by and economist!
    - NO representation by Fermilab, the country's only remaining HEP lab and the lab most affected by the report.
  - Assumed fairly generous funding based on Presidential budget request, "Gathering Storm Report", ACA, etc
- Gave highest priority to ILC
  - Fermilab planned to make ILC primary focus of activity following the termination of the collider program.

What happened?

- In spite of the positive sign from the President and both houses, the budget that finally emerged from the omnibus committee in December 2007 *slashed* the HEP budget
  - Fermilab got about a $50M cut
  - Specific charge to halt work on ILC and NOvA
  - Plans to lay off ~10% of staff
- Over the next few months
  - Involuntary reductions eliminated through a combination of voluntary separation incentives and emergency funding.
  - Realization sets in that we cannot hang out hopes on the ILC.

Plan for the future (second try): P5 report

- In January 2008, the Particle Physics Project Priotization Panel (P5)
  - ALL physicists, Fermilab well represented

  was given the following (partial) charge:

> A U.S. strategic plan to implement the highest priority science in the context of available funding and world-wide capabilities and collaborations must be developed. Your report should provide recommendations on the priorities for an optimized high energy physics program over the next ten years (FY 2009-2018), under the following four funding profile scenarios:
>
> - Constant effort at the FY 2008 funding level (i.e.; funding in FY 2009 at the level provided by the FY 2008 Omnibus Bill inflated by 3.5% and thereafter inflated by 3.5% per year in the out-years)
> - Constant effort at the FY 2007 funding level (i.e.; funding in FY 2009 at the level provided in FY 2007 inflated 3.5% per year over two years and thereafter inflated by a 3.5% in the out-years).
> - Doubling of funding over a ten year period starting in FY 2007 (i.e.; funding in FY 2009 at the level provided in FY 2007 inflated 6.5.% per year over two years and thereafter inflated by 6.5% per year in the out-years)
> - Additional funding above the previous level, in priority order, associated with specific activities needed to mount a leadership program that addresses the scientific opportunities identified in the EPP2010 report.

P5 major findings*

- **Progress in achieving the goals of particle physics requires advancements at the:**
  - **Energy Frontier**
  - **Intensity (or precision) Frontier**
  - **Cosmic (or particle astrophysics) Frontier**

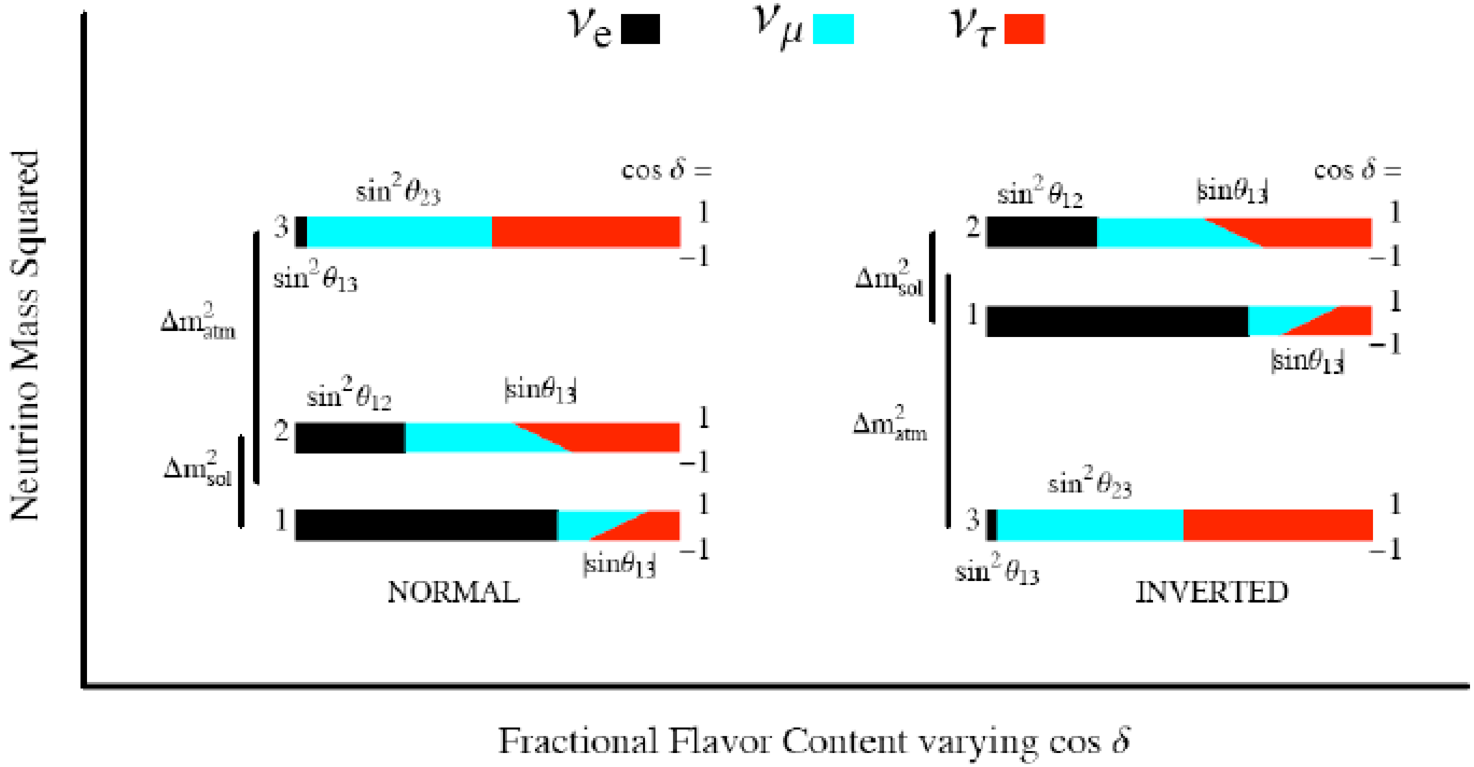
  (each provides a unique window for insight about the fundamental forces/particles of nature)
- **LHC offers an outstanding opportunity for discoveries at the Energy Frontier**
  - Resources will be needed to support the extraction of the science by U.S. scientists
  - Resources will be needed for planned accelerator and detector upgrades
- **An opportunity exists for the U.S. to become a world leader at the Intensity Frontier**
  - Central is an intense neutrino beam and large underground long-based line detector
  - Building on infrastructure at Fermilab and partnering with NSF
  - Develops infrastructure that positions the U.S. to regain Energy Frontier (Muon Collider)
- **Promising opportunities for advancing particle physics identified at Cosmic Frontier**
  - Requires partnering with NASA, NSF, etc.
- **HEP at its core is an accelerator based experimental science**
  - Accelerator R&D develops technologies needed by the field and that benefit the nation

*as reported by Dennis Kovar at the Fermilab Users' Meeting, June 2008

What is "The Intensity Frontier"?

- Neutrino Physics
  - NOvA – intense NuMI beam to an off-axis detector near the Canadian border
  - DUSEL – an even more intense beam pointed at the Deep Underground Science and Engineering Laboratory, to be built at the Homestake Mine, SD
- Precision measurements
  - Muon to electron
  - Anomalous muon magnetic moment (g-2).
  - Precision kaon physics
- Advanced R&D
  - Muon based neutrino factory
  - Muon collider

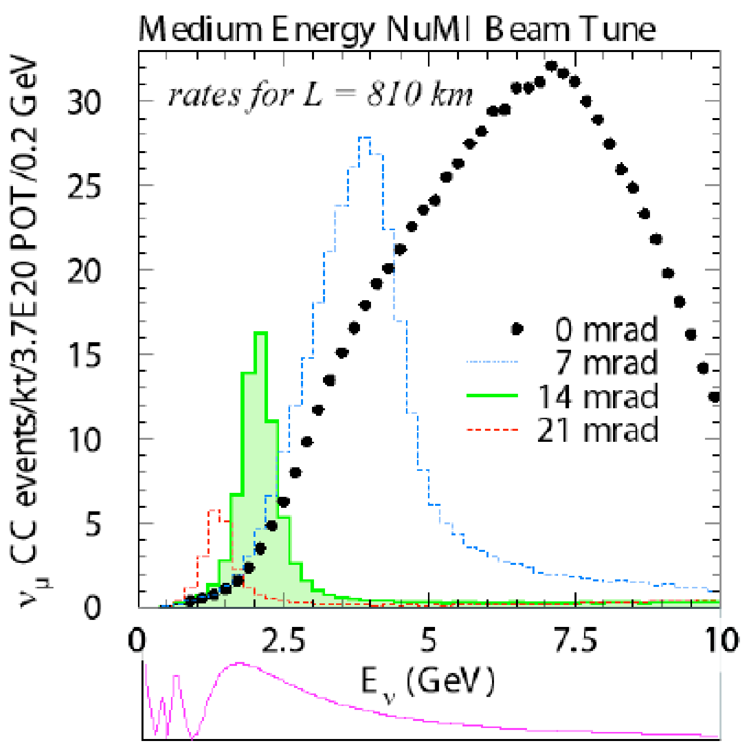
Long baseline neutrino program



- What is the size of θ_{13}?
- Is the hierarch normal or inverted?
- What is the value of δ_{CP}?

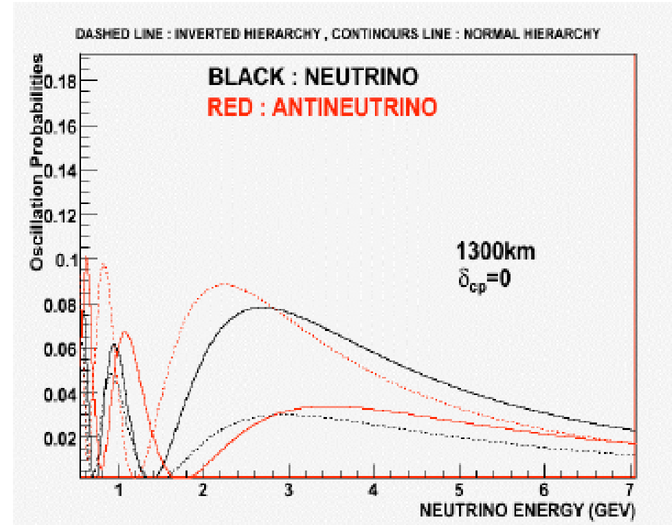
Experimental techniques

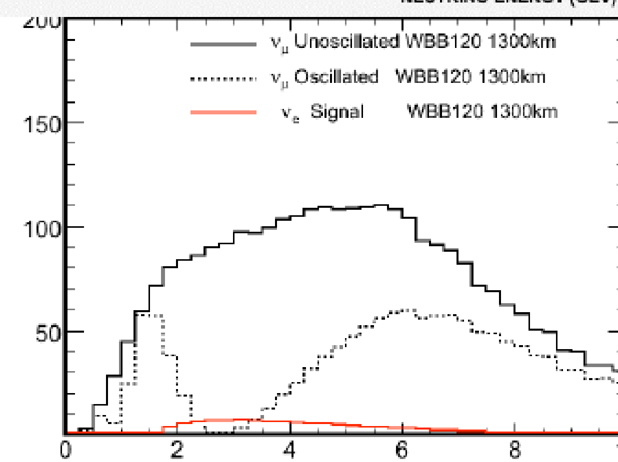
Off-axis/narrow band beam



NOvA approach

On-axis/wide band beam

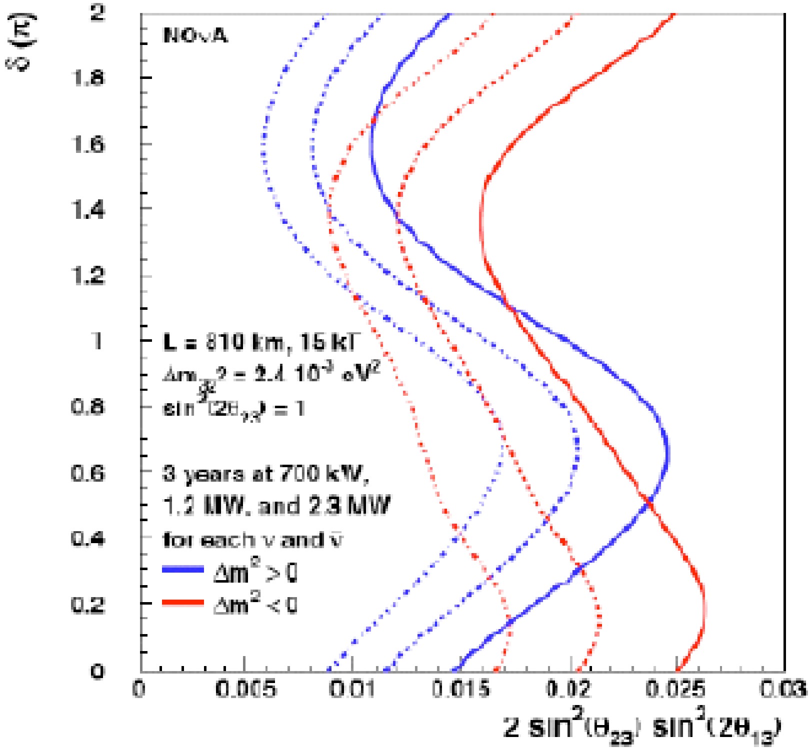




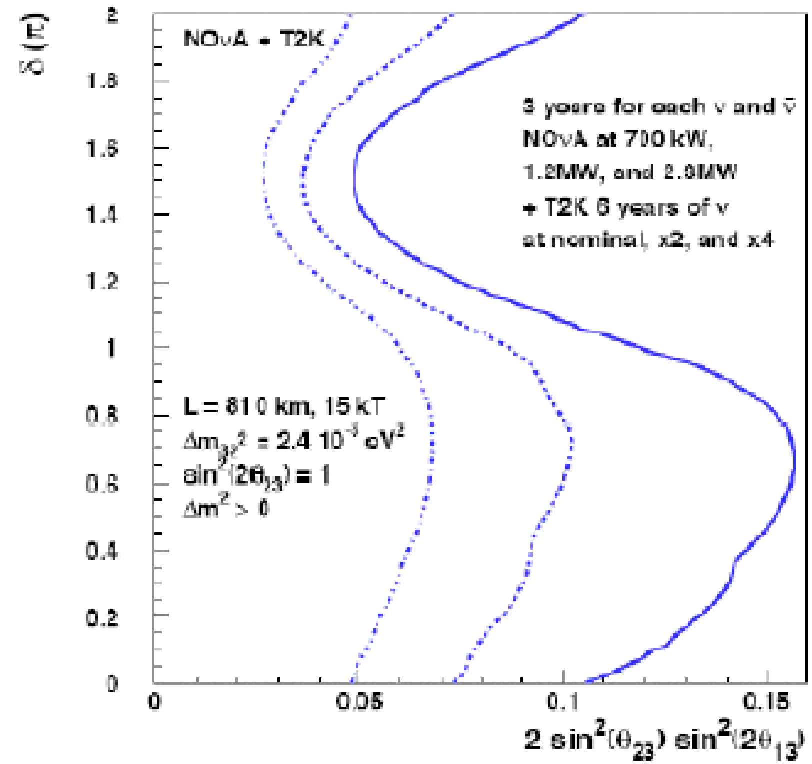
Potential long baseline (DUSEL) experiment

NOvA Experiment Sensitivities (shown by G.Feldman at P5 2008 SLAC meeting)

3 σ Sensitivity to $\sin^2(2\theta_{13}) \neq 0$



95% C.L. resolution of the mass hierarchy

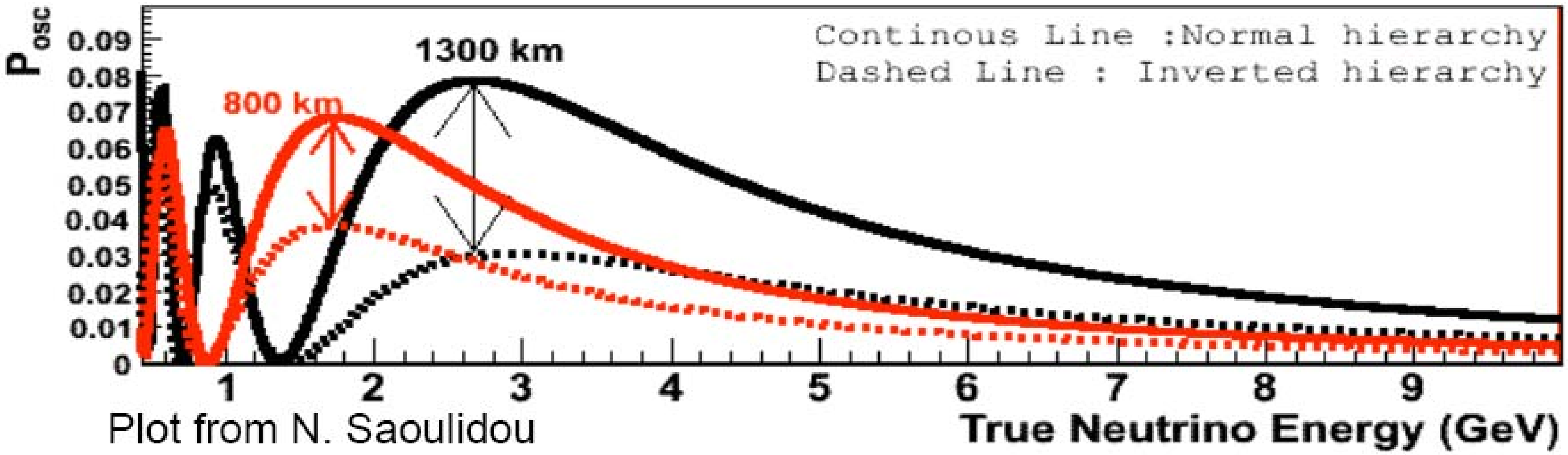


Normal Ordering

Lines ~represent equal numbers

Of signal events for a given set of $\sin^2 2\theta_{13}, \delta_{CP}$

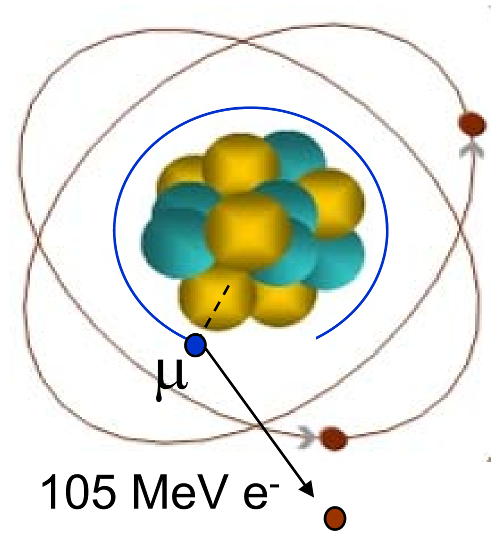
Advantages of a longer baseline



Plot from N. Saoulidou

- Oscillation maxima are moved to higher energy
- Matter effects are significantly larger

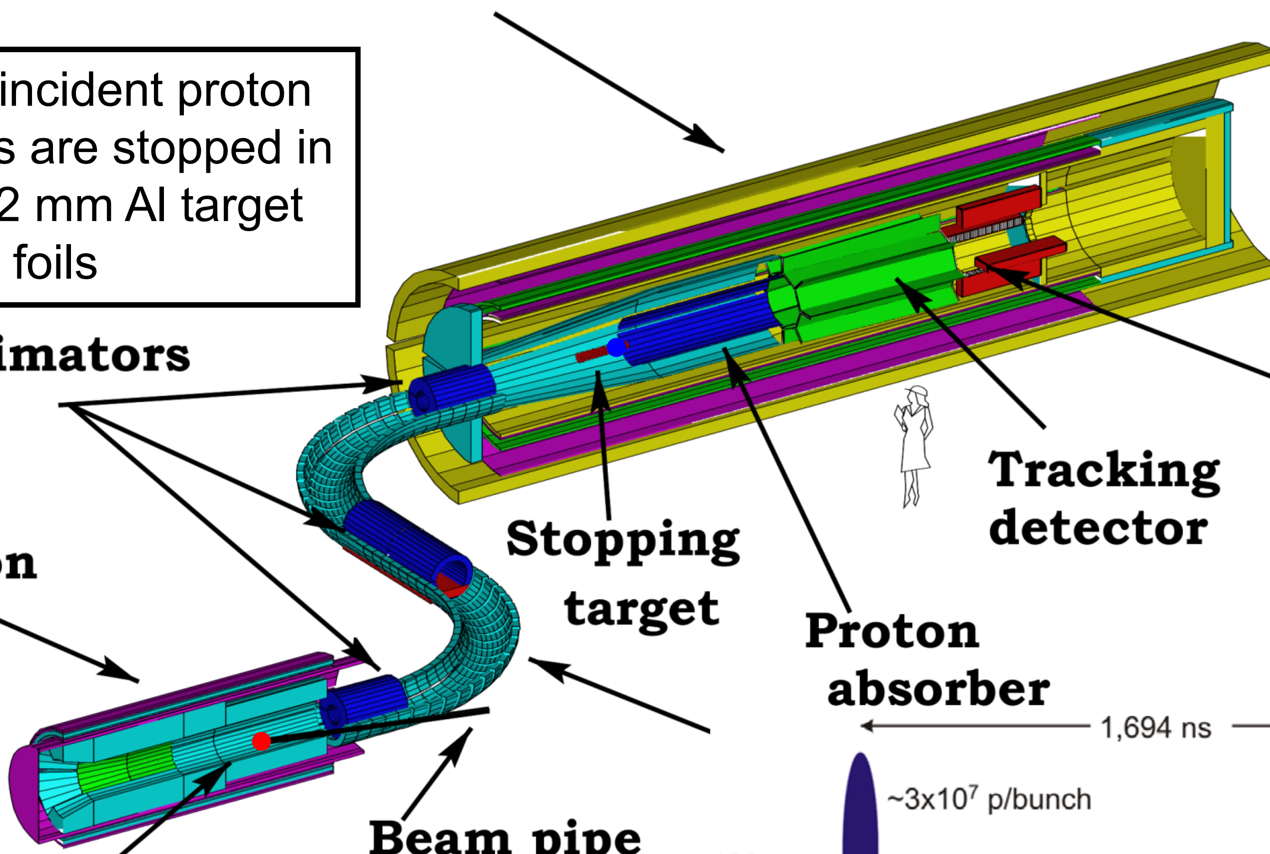
Muon-to-Electron Conversion: $\mu+N \rightarrow e+N$

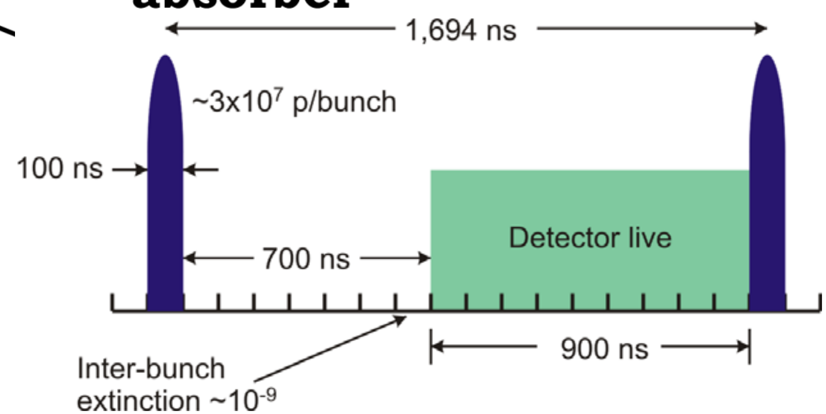


- When captured by a nucleus, a muon will have an enhanced probability of exchanging a virtual particle with the nucleus.
- This reaction recoils against the entire nucleus, producing the striking signature of a *mono-energetic electron* carrying most of the muon rest energy
- Similar to $\mu \rightarrow e\gamma$, with important advantages:
  - No combinatorial background
  - Because the virtual particle can be a photon *or* heavy neutral boson, this reaction is sensitive to a broader range of BSM physics
- Relative rate of $\mu \rightarrow e\gamma$ and $\mu N \rightarrow eN$ is the most important clue regarding the details of the physics
- We are planning a new experiment at Fermilab (Mu2e), based on the MECO experiment which was proposed at Brookhaven, which can improve the existing limit by more than four orders of magnitude.

mu2e Muon Beam and Detector

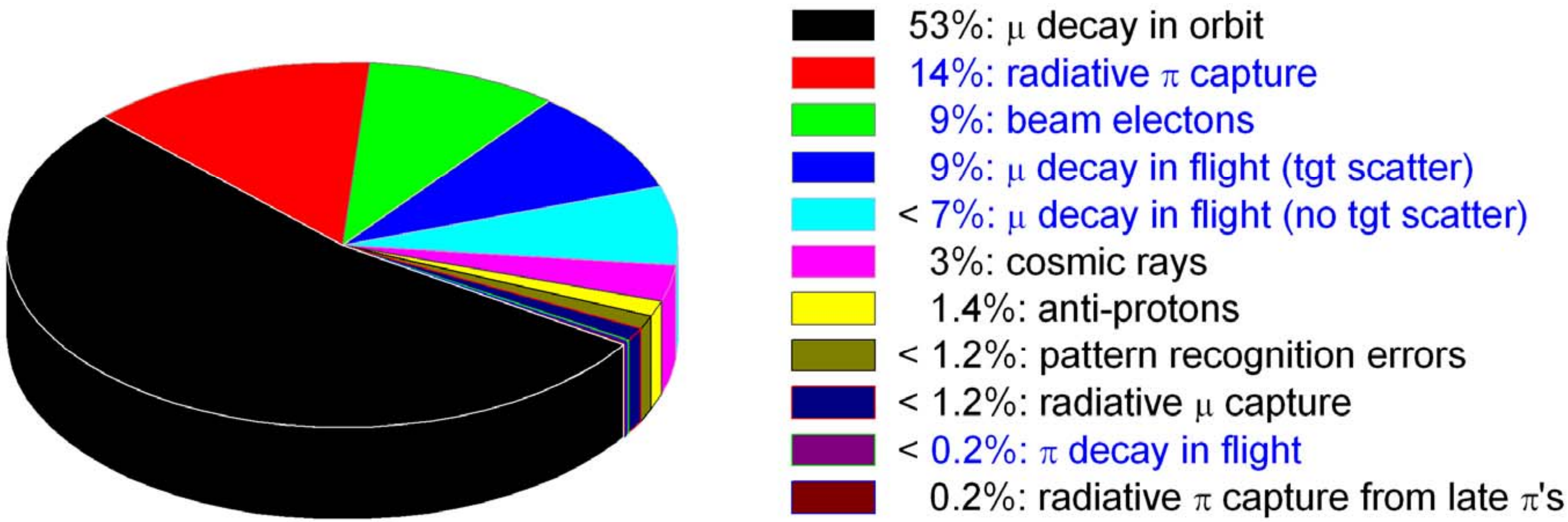
for every incident proton 0.0025 μ^{-}'s are stopped in the 17 0.2 mm Al target foils





MECO spectrometer design

μ to e sensitivity



Blue text: beam related.

Roughly half of background is beam related, and half interbunch contamination related

Total background per 4×10^{20} protons, 2×10^{7} s: 0.43 events

Signal for $R_{\mu e} = 10^{-16}$:	5 events
Single even sensitivity:	2×10^{-17}
90% C.L. upper limit if no signal:	6×10^{-17}

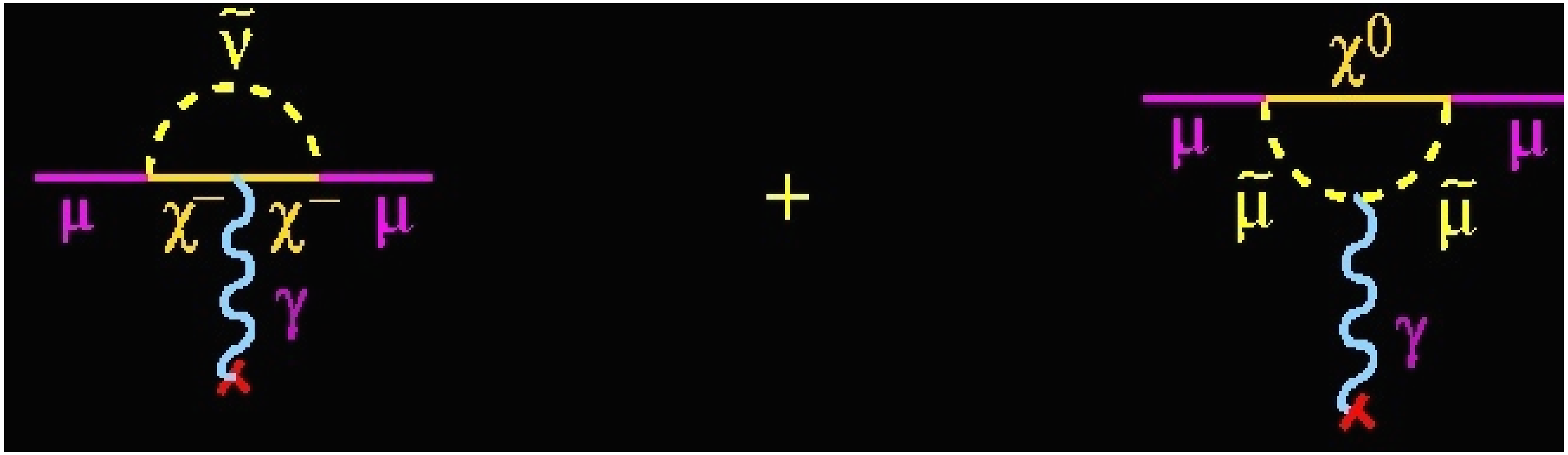
Muon Anomalous Magnetic Moment (g-2)

- To lowest order, the muon magnetic moment (*g*) is 2
- *g* is perturbed by contributions from virtual loops, from both the Standard Model and (possibly) beyond.
- The calculation and measurement of the "anomalous magnetic moment

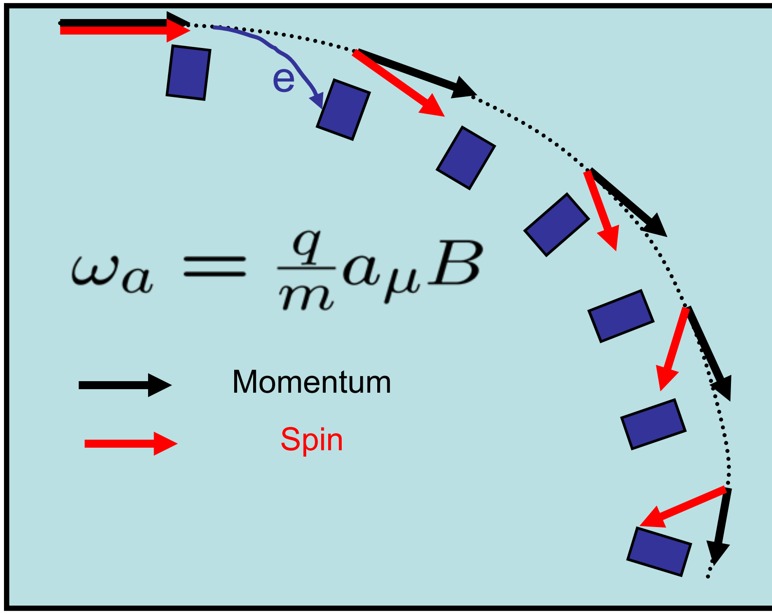
$$\alpha_\mu \equiv \frac{(g-2)}{2}$$

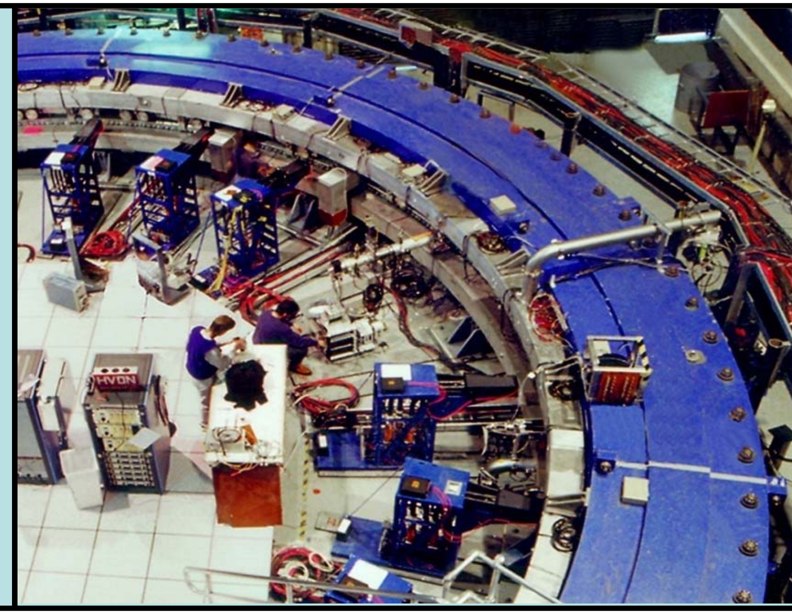
stands as one of the most precise tests of the Standard Mode

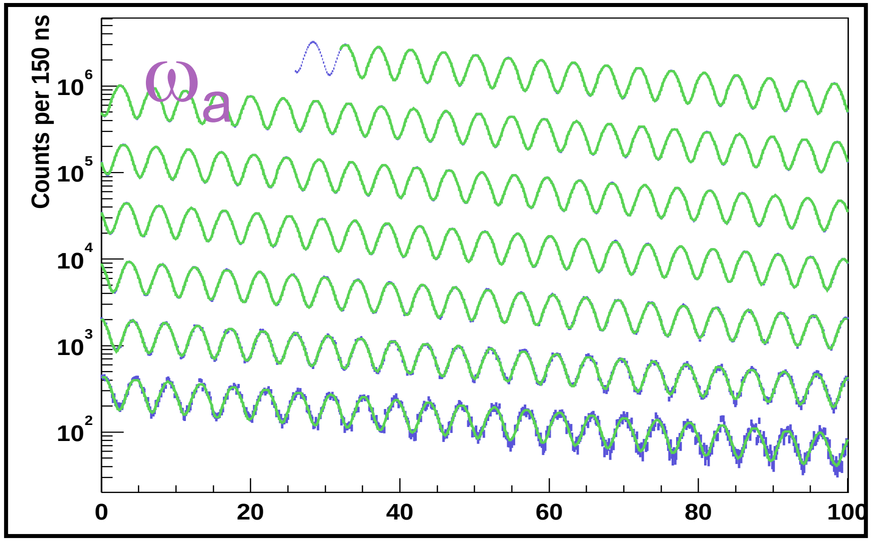
- New physics enters through loops, eg SUSY



Measurement of g-2 (at BNL)







- α_μ is determined from the ratio of the muon precession frequency (ω_a) and the magnetic field (*B*).

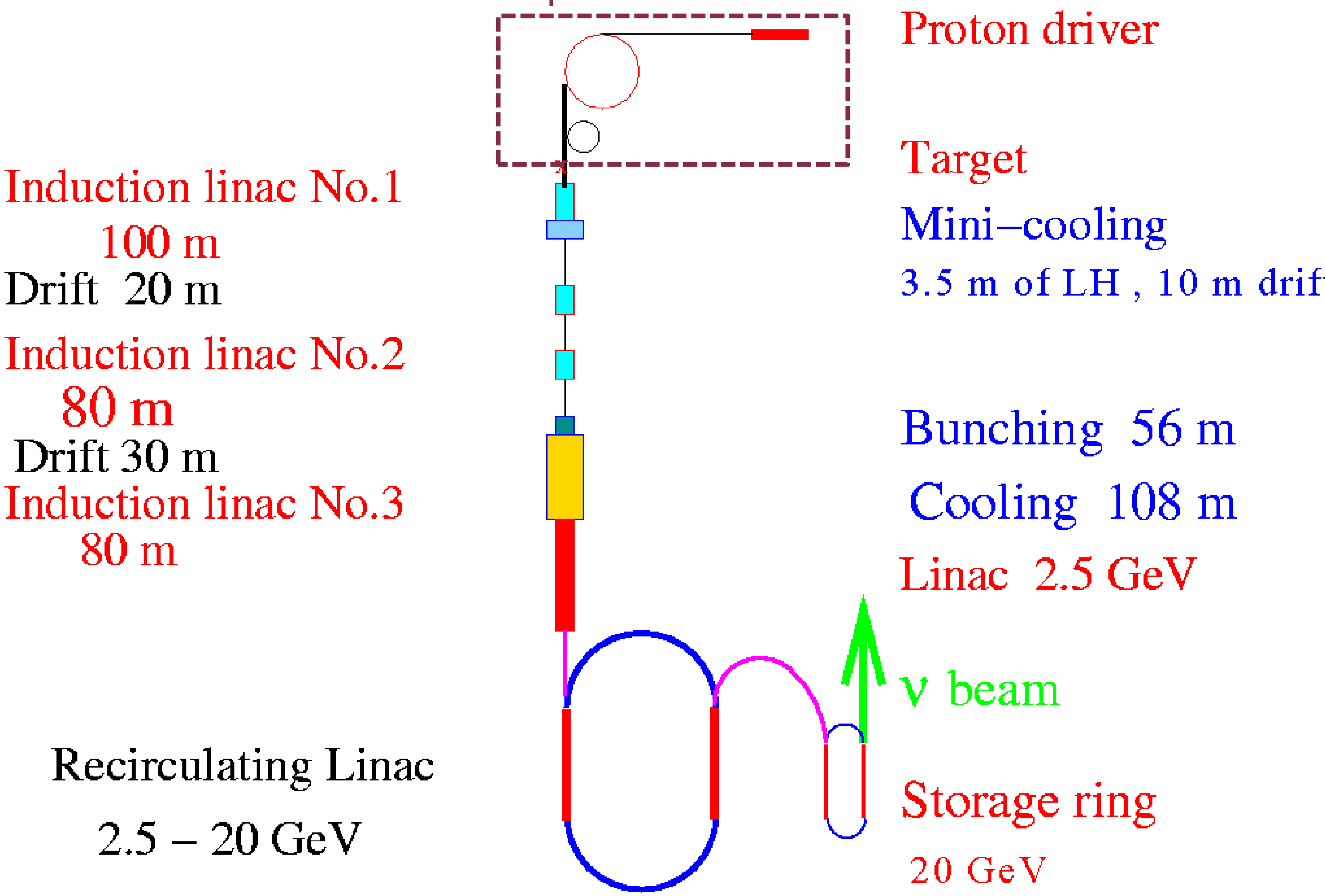
Systematic errors on ω_a (ppm)

Potentially improved experiment at FNAL

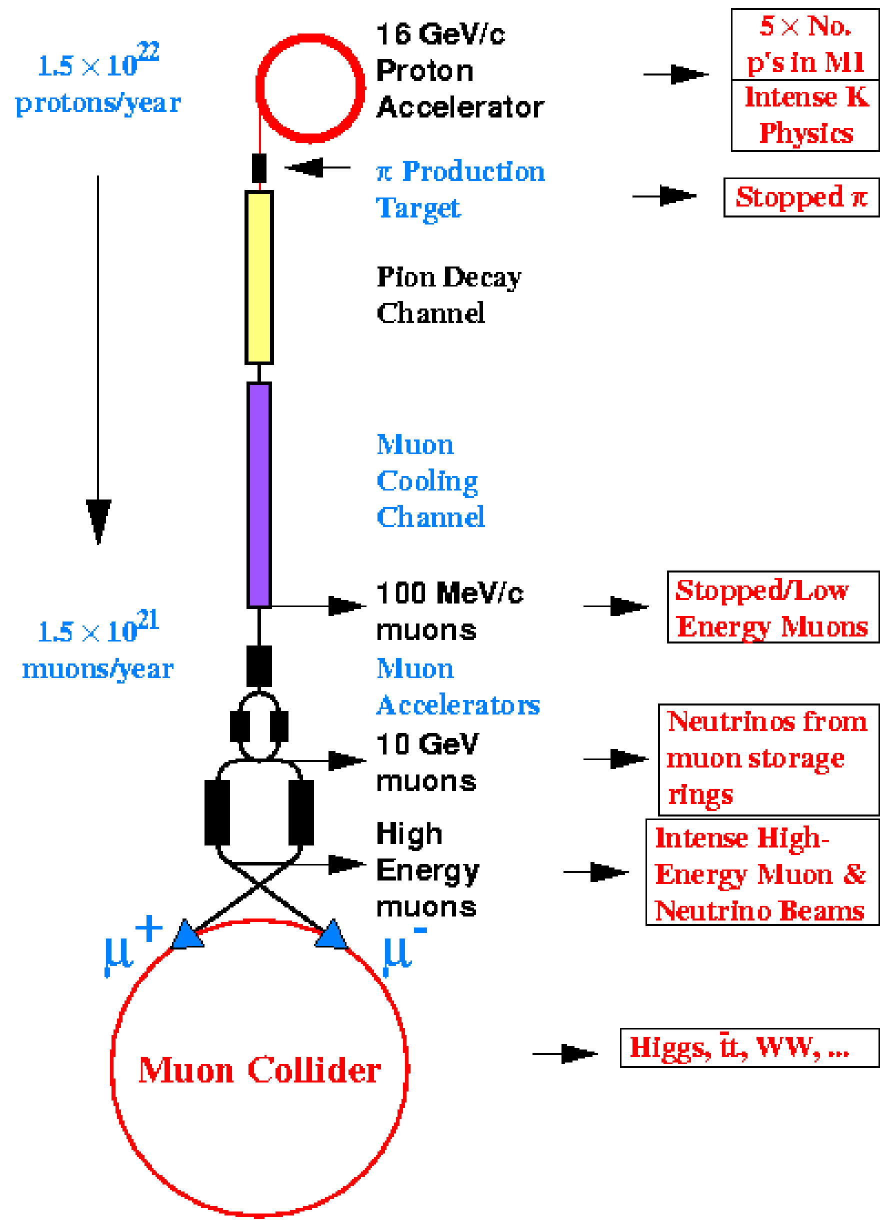
$\sigma_{systematic}$	1999	2000	2001	Future
Pile-up	0.13	0.13	0.08	0.04
AGS Background	0.10	0.10	0.015*	
Lost Muons	0.10	0.10	0.09	0.04
Timing Shifts	0.10	0.02	0.02	
E-Field, Pitch	0.08	0.03	0.06*	0.05
Fitting/Binning	0.07	0.06	0.06*	
CBO	0.05	0.21	0.07	0.04
Beam Debunching	0.04	0.04	0.04*	
Gain Change	0.02	0.13	0.13	0.03
total	0.3	0.31	0.21	~0.09

Longer term: neutrino factory

Requires and intense proton source!!



Even longer term: muon collider



Getting to the frontier: limits to proton intensity

- Total proton rate from Proton Source (Linac+Booster):
  - Booster batch size
    - ~4-5E12 protons/batch, depending on beam quality required.
  - Booster repetition rate
    - 15 Hz instantaneous
    - Currently ~9Hz, limited by RF system.
  - Beam loss
    - Damage and/or activation of Booster components
    - Above ground radiation
- Total protons accelerated in Main Injector:
  - Maximum main injector load
    - Six "slots" for booster batches (3E13)
    - Up to ~11 with slip stacking (4.5-5.5E13)
    - Beam stability (RF issues)
    - Beam loss concerns
  - Cycle time:
    - 1.4s + loading time (1/15s per booster batch)

~original hardware

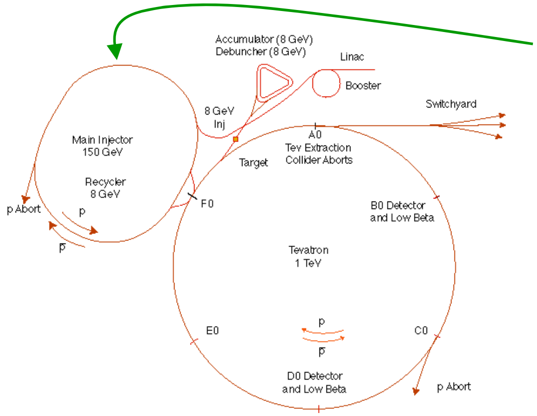
Getting to high intensity: Project X

- Maximizing the intensity of the Main Injector will require replacing Fermilab's aging proton source.
- "Proton Drivers" based on both linacs and synchrotrons have been considered:
  - Synchrotron probably cheaper
  - Linac has more performance headroom and more capacity at 8 GeV.
- In 2007 the Long Range Steering committee endorsed a design based on a linac incorporating ILC RF technology
  - *Temporarily* named "Project X"

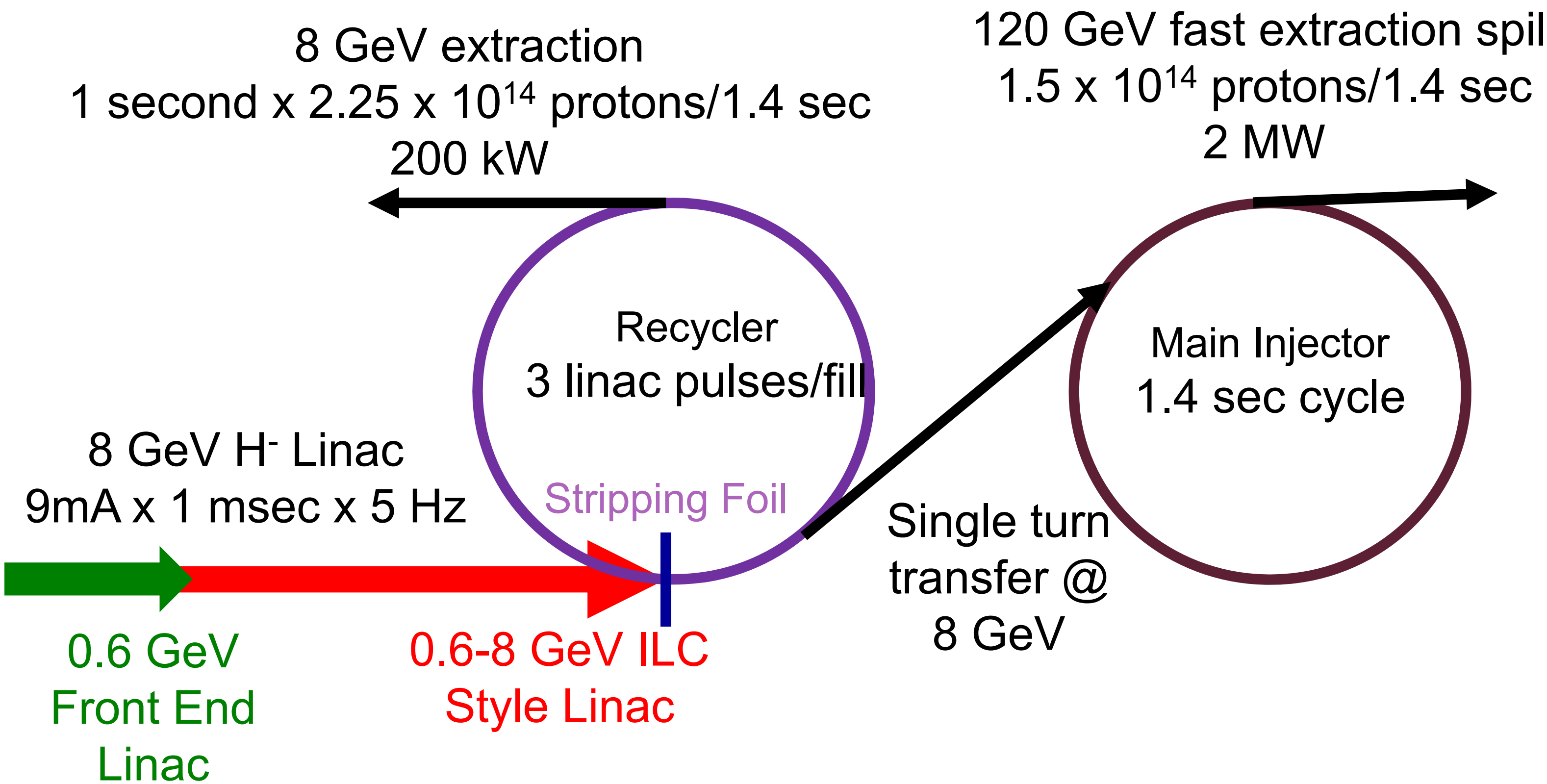
Some issues with ILC technology

- With a new RF system, the Main Injector should be able to accelerate up to ~1.6×10^{14} protons every 1.33 seconds.
  - ~2.3 MW at 120 GeV
- The baseline ILC specification is
  - 9 mA for 1 ms at 5 Hz
- At that rate, it would take three pulses to "fill" the Main Injector
- Proposal: strip and pre-stack pulses in the Recycler, prior to transferring them to the Main Injector
  - Has added advantages that extra pulses would also be stripped, and potentially RF manipulated for other users.

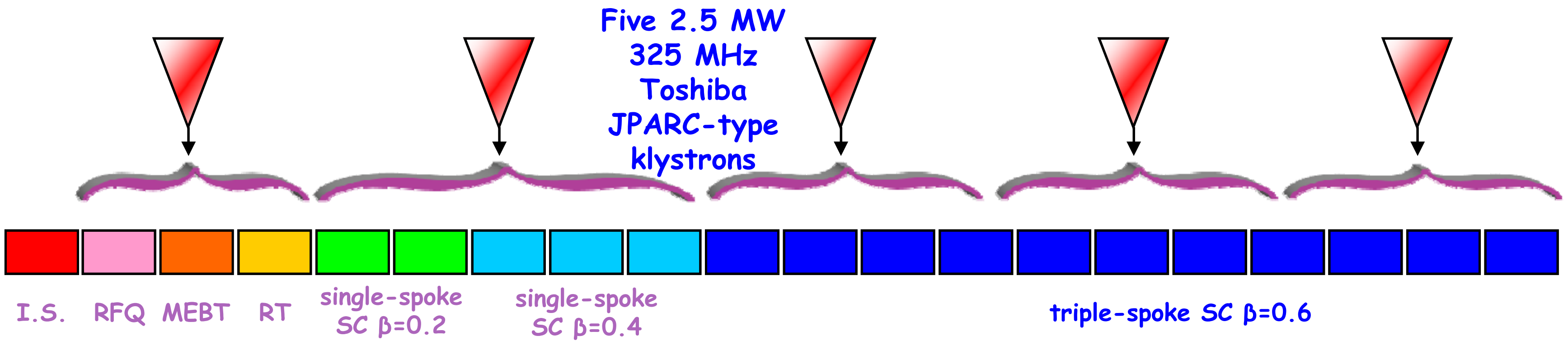
Review: Main Injector/Recycler



Strawman Project X concept*



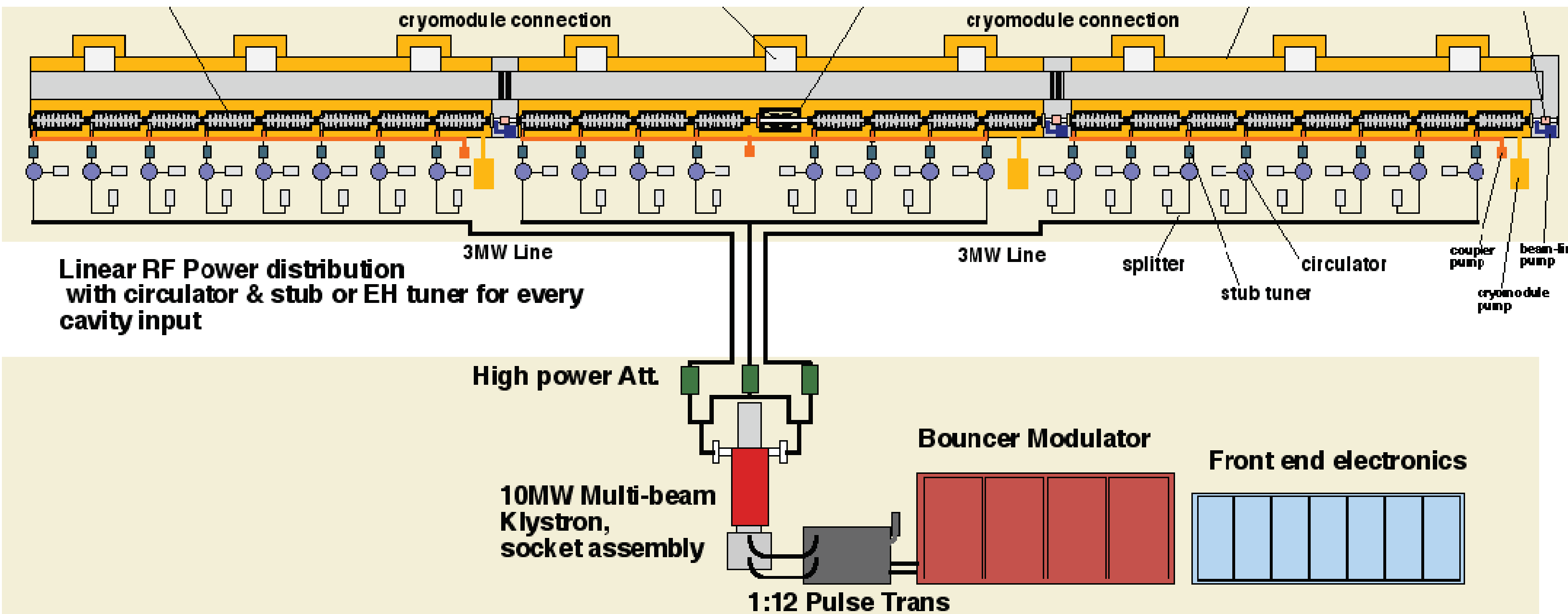
Low-energy linac (HINS) layout



	Ion Source	RFQ	MEBT	Room Temp	SSR1	SSR2	TSR
Eout	50 keV	2.5 MeV	2.5 MeV	10 MeV	30 MeV	120 MeV	~600 MeV
Zout	0.7 m	3.7 m	5.7 m	15.8 m	31 m	61 m	188m
Cavities			2 buncher cavities and fast beam chopper	16 copper CH-spoke cavities	18 single-spoke SC $\beta=0.2$ cavities	33 single-spoke SC $\beta=0.4$ cavities	66 triple-spoke SC $\beta=0.6$ cavities
Gradient					10 MV/m	10 MV/m	10 MV/m
Focusing			3 SC solenoids	16 SC solenoids	18 SC solenoids	18 SC solenoids	66 SC quads
Cryomodules					2	3	11

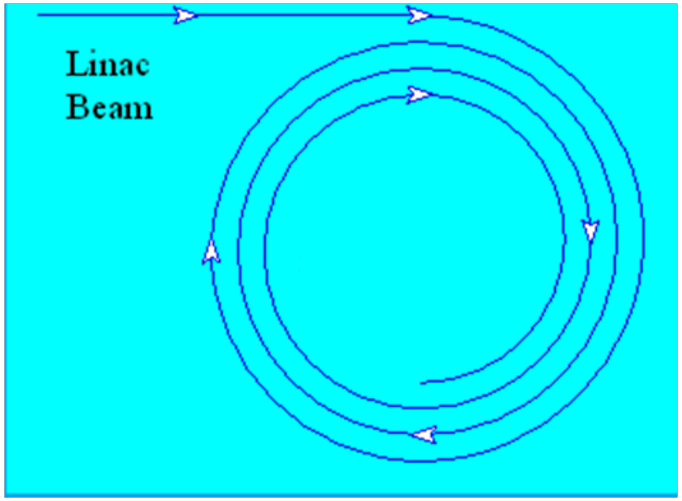
ILC Cryo Unit: basic building block of HEL

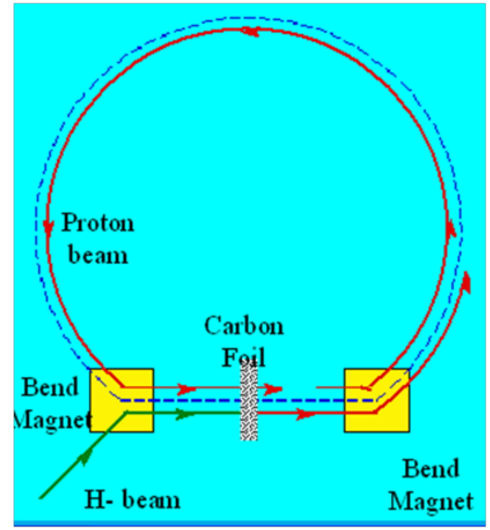
- Some 650 units of this type will be required for the ILC and about 15 for Project -X

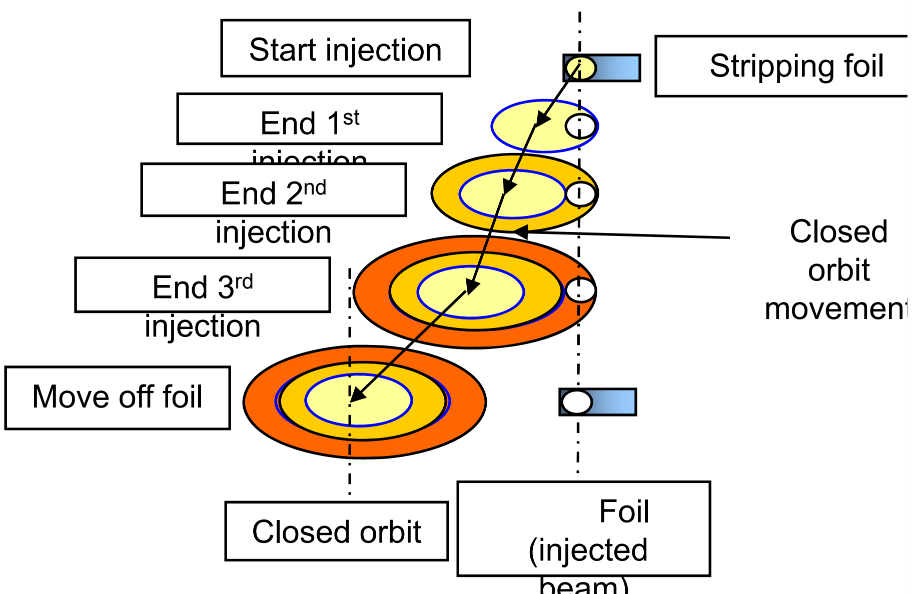


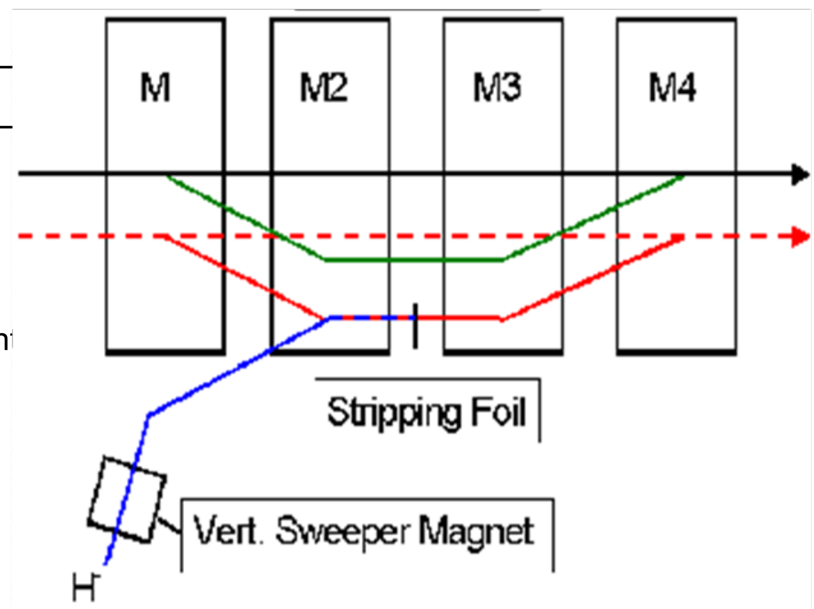
ILC RF Unit: 24-26 Cavities, 3 CM, klystron, Modulator, LLRF

H- Injection


Linac
Beam


Proton
beam
Carbon
Foil
Bend
Magnet
H- beam
Bend
Magnet


Start injection
Stripping foil
End 1st injection
End 2nd injection
End 3rd injection
Closed
orbit
movement
Move off foil
Closed orbit
Foil
(injected
beam)


M
M2
M3
M4
Stripping Foil
Vert. Sweeper Magnet
H

Low energy vs. high energy with Project X

- In the baseline scenario, the 5 Hz Project X linac sets a fundamental clock for the complex.
- It produces one 9mA*1ms = 5.3×10^{13} protons/linac "blast" each of these "ticks"
  - 50 kW @ 8 GeV
  - 750 kW @ 120 GeV
- It takes 3 of these to "fill" the Main Injector
- It takes 1.4 seconds, or 7 ticks to ramp the Main Injector to 120 GeV, extract, and ramp back down.
- This potentially leaves 4 blasts, or 200 kW, available for 8 GeV programs.
  - If we are injecting into the Recycler, the beam is already stripped and can be RF manipulated, although this has duty factor issues.
  - Might be better to have a dedicated "stretcher" ring.
- There are trade offs if we change the energy of the high energy beam.

Background: Proton Economics in Project X Era*

- Assume
  - 9mA*1ms = 5.3×10^{13} protons/linac "blast"
  - Main Injector ramp time⁺ = $T = .44\ \mathrm{s} + (.89\ \mathrm{s}) \times \frac{K}{120\ \mathrm{GeV}}$

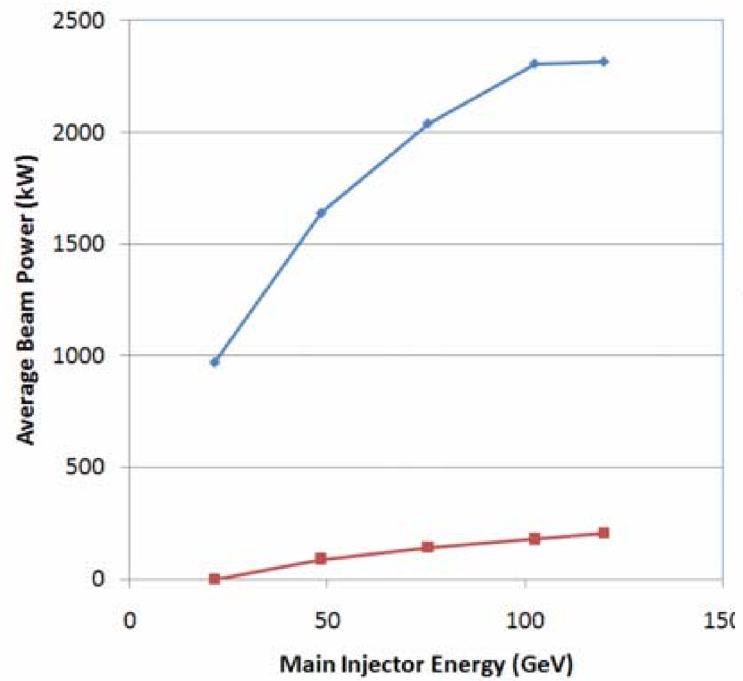
NOT simply linear!

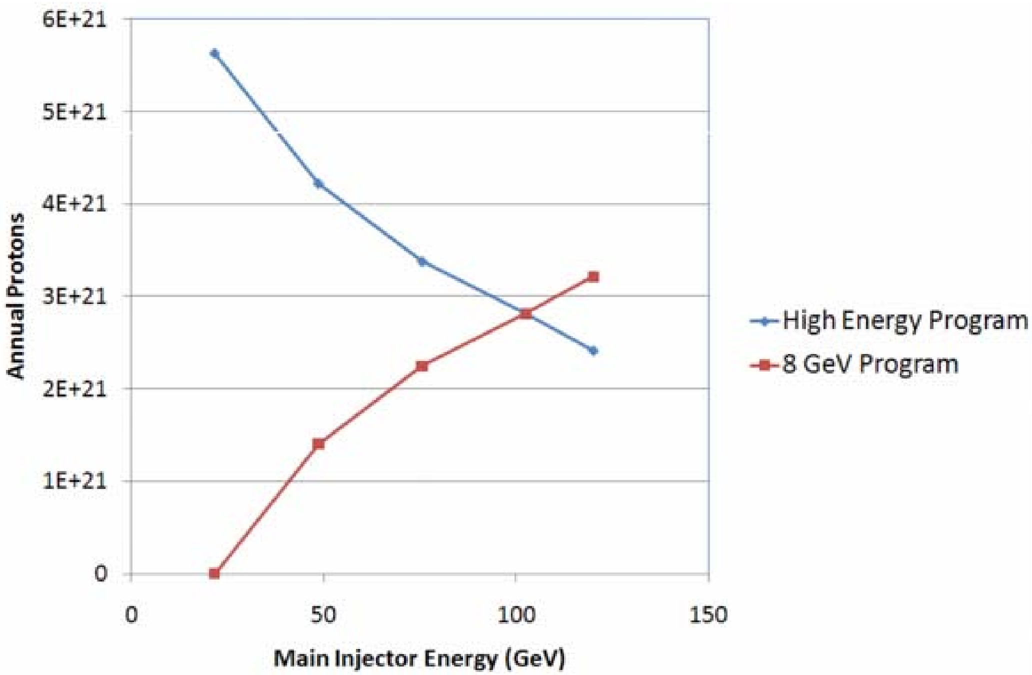
Cycle Time		High Energy Program				8 GeV Program			
Ticks	Sec.	Energy (GeV)	Pulses	Power (MW)	Annual Prot. ($\times 10^{20}$)	Pulses	Avg. Power (kW)	Duty Factor	Annual Prot. ($\times 10^{20}$)
3	0.6	22	3	1.0	56	0	0	0	0
4	0.8	49	3	1.6	42	1	90	25%	14
5	1.0	76	3	2.0	34	2	144	40%	23
6	1.2	102	3	2.3	28	3	180	50%	28
7	1.4	120	3	2.3	24	4	206	57%	32

Assuming no stretcher ring

*Prebys and Ankenbrandt, ProdDev-DOC-334
⁺R. Zwaska, FNAL-BEAMDOC-2393

Power and Protons





Changes since initial Project X report

- With the priority of the ILC reduced, there is less emphasis on exact compatibility in the high energy Linac
- Propose: going from ILC spec of 1 klystron/3 cromodules to 1 klystron/2:
  - Reduce fill time: 1ms flat top -> 1.25 ms
  - Increase total power from 285kW (ILC spec) to 500 kW (1/2 klystron)
  - Allow the Main Injector to be filled with a single pulse!
- This would eliminate the need to inject into the Recycler.
- We would now have ~1MW of 8 GeV protons available
  - However, we lose the important advantage of automatically stripping them in the Recycler (might choose to strip there anyway).

8 GeV linac parameters

Proposed new parameters

	Proton Driver Phase 1 Design	Proton Driver Phase 2 Design	HINS capability	Project X Base Design (Nov-07)	Project X ICD (Aug-08)	
Particle	H-	H-	H+ then H-	H-	H-	
Nominal Bunch Frequency/Spacing	325 3.1	325 3.1	325 3.1	325 3.1	325 3.1	MHz nsec
Particles per Pulse	15.6	15.6	37.5 *	5.6	15.6	E13
Pulse Length (beam)	3	1	3/1	1	1.25	msec
Average Pulse Current	8.3	25	~20	9	20	mA
Pulse Rep. Rate	2.5	10	2.5/10	5	5	Hz
Chopping -6% @ 89KHz and 33% @ 53MHz	37.5%	37.5%	0 - 37.5%	37.5%	37.5%	
Bunch Current	13.3	39.8	32	14.3	32	mA
Bunch Intensity	2.5 41	7.6 122	6.1 98	2.7 ** 44	6.1 98	E8 pCoul

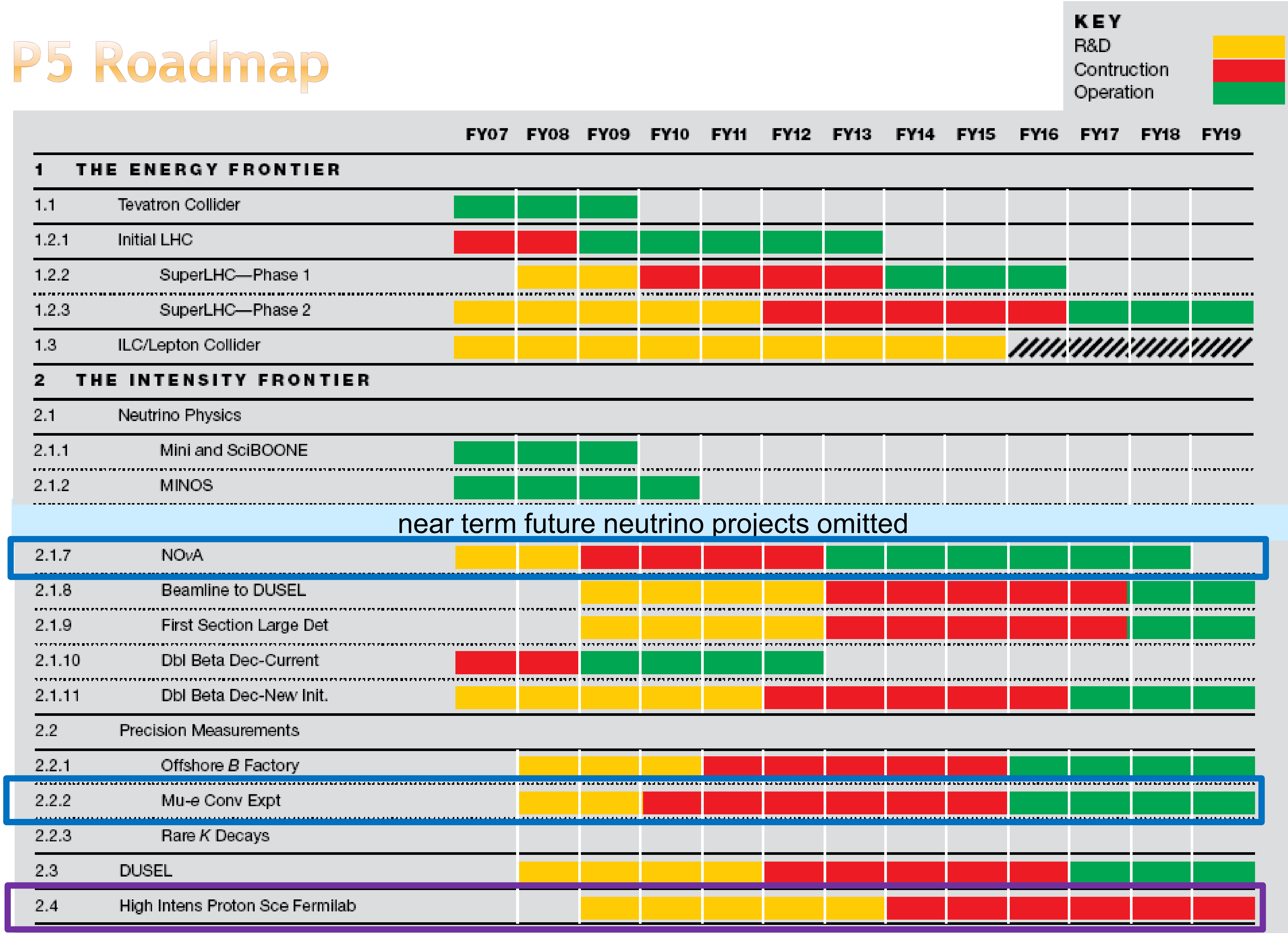
* full un-chopped 3 msec pulse at klystron-limited 20 mA

** ILC bunch intensity is 2E10 (electrons)

Scale of Project X

- The total cost of Project X will be on the order of $750M
- Even with a fairly optimistic funding profile, it will not be operational before the end of the next decade.
- In the mean time, some of the most exciting physics can be pursued with much more modest modifications to the existing complex. In particular,
  - NOvA off axist neutrino experiment
  - Mu2e
  - g-2?
- NOvA (and perhaps initial DUSEL) will be supported with modest modifications to the existing complex.
- Other 8 GeV physics can be supported by re-tasking the antiproton Accumulator and Debuncher as a versatile a *proton* storage facility.

P5 Roadmap



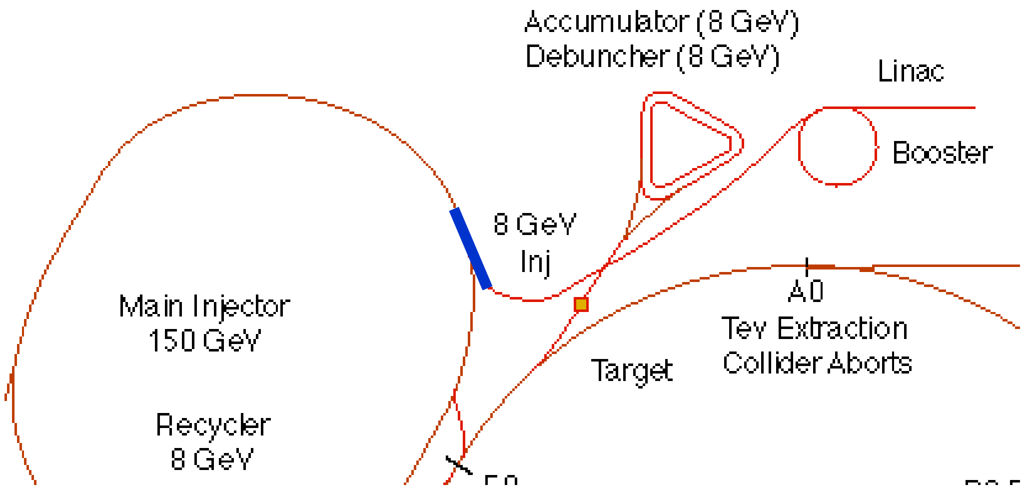
Note: high intensity program starts *before* Project X!

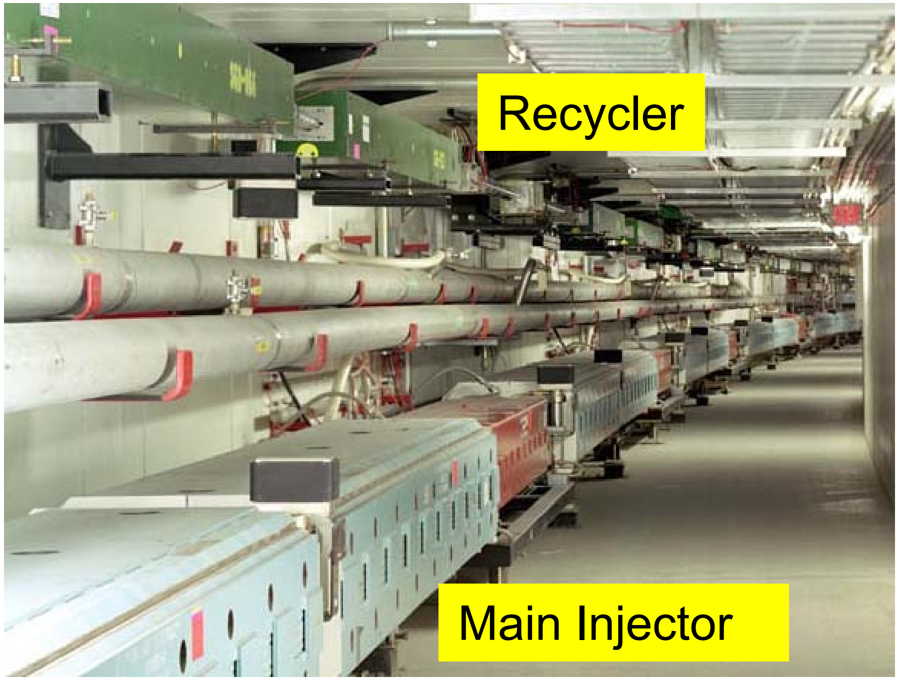
Proton economics (existing proton source)

- Booster 15 Hz "batch" rate establishes a fundamental clock and unit of protons (4-5e12)
- Currently load 11 batches in Main Injector
  - Period = (11(load) + 22(ramp))/15 = 2.2 s
    - 2 for pBar, 9 for NuMI
  - Of the remaining 22/2.2 batches, send "as many as we can" to 8 GeV (see next slide)
- NoVA era
  - Preload 12 proton batches in Recycler to eliminate load time
  - Shorten MI cycle to 20 tickes = 1.33 seconds
  - *Potentially* 8 booster batches/1.33 seconds available
    - = 6 Hz
    - = 2.4e13 p/sec (assuming 4E12 batches)
    - = 4.8e20 p/yr

NOvA modifications

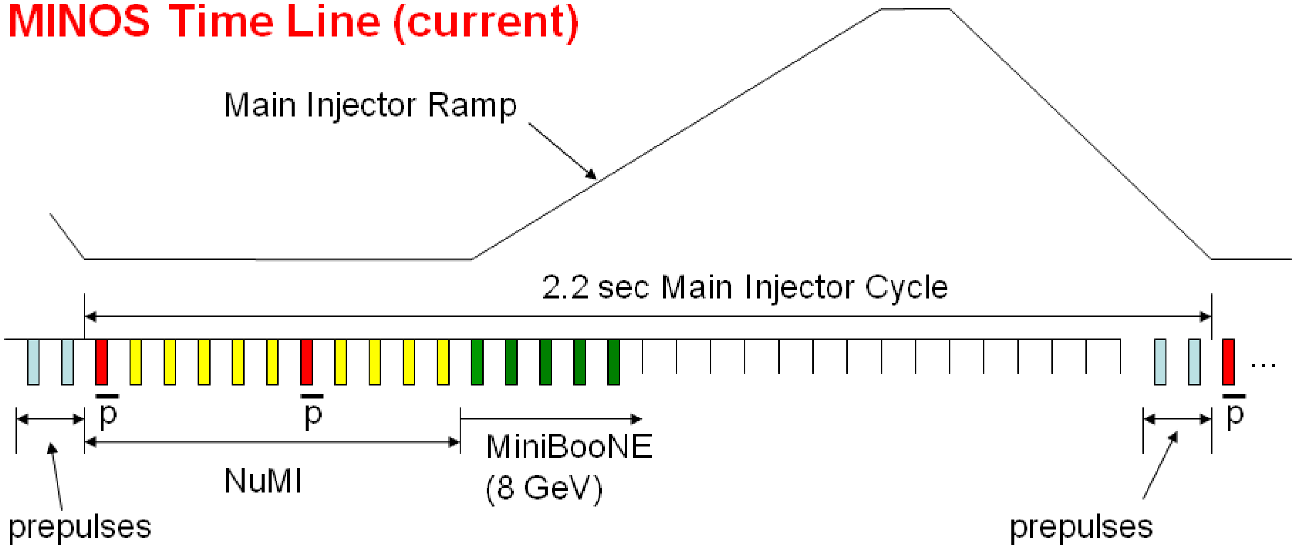
- Currently, all transfer lines in and out of the 8 GeV Recycler go through the Main Injector.
- In the NOvA era, a dedicated line will be added, allowing protons to be injected directly into the Recycler and "preloaded" while the Main Injector is ramping.





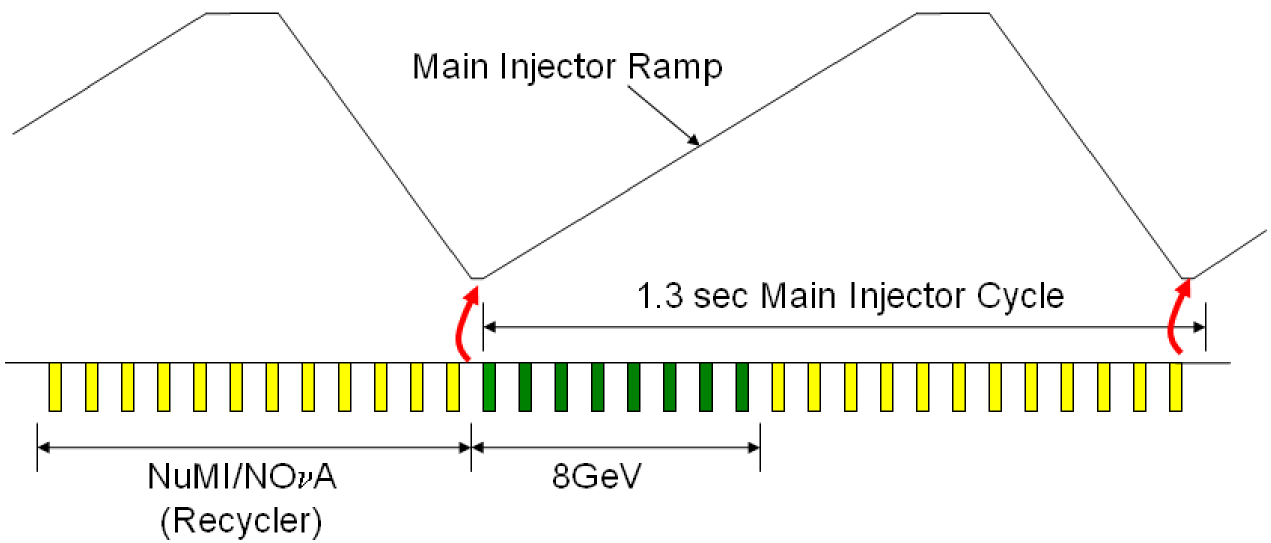
NOνA time line improvements

MINOS Time Line (current)



300 kW

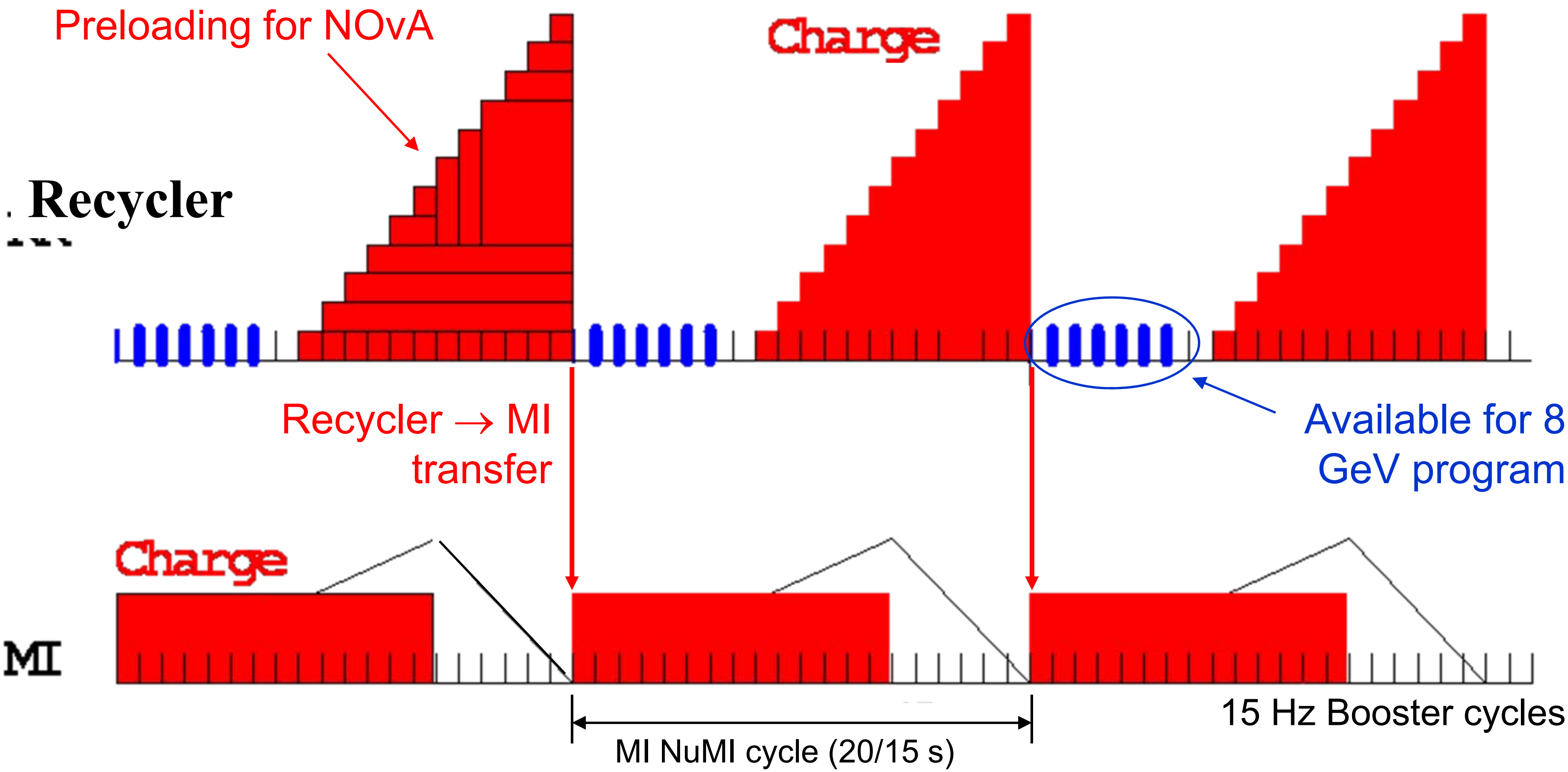
NOνA Time Line



700 kW

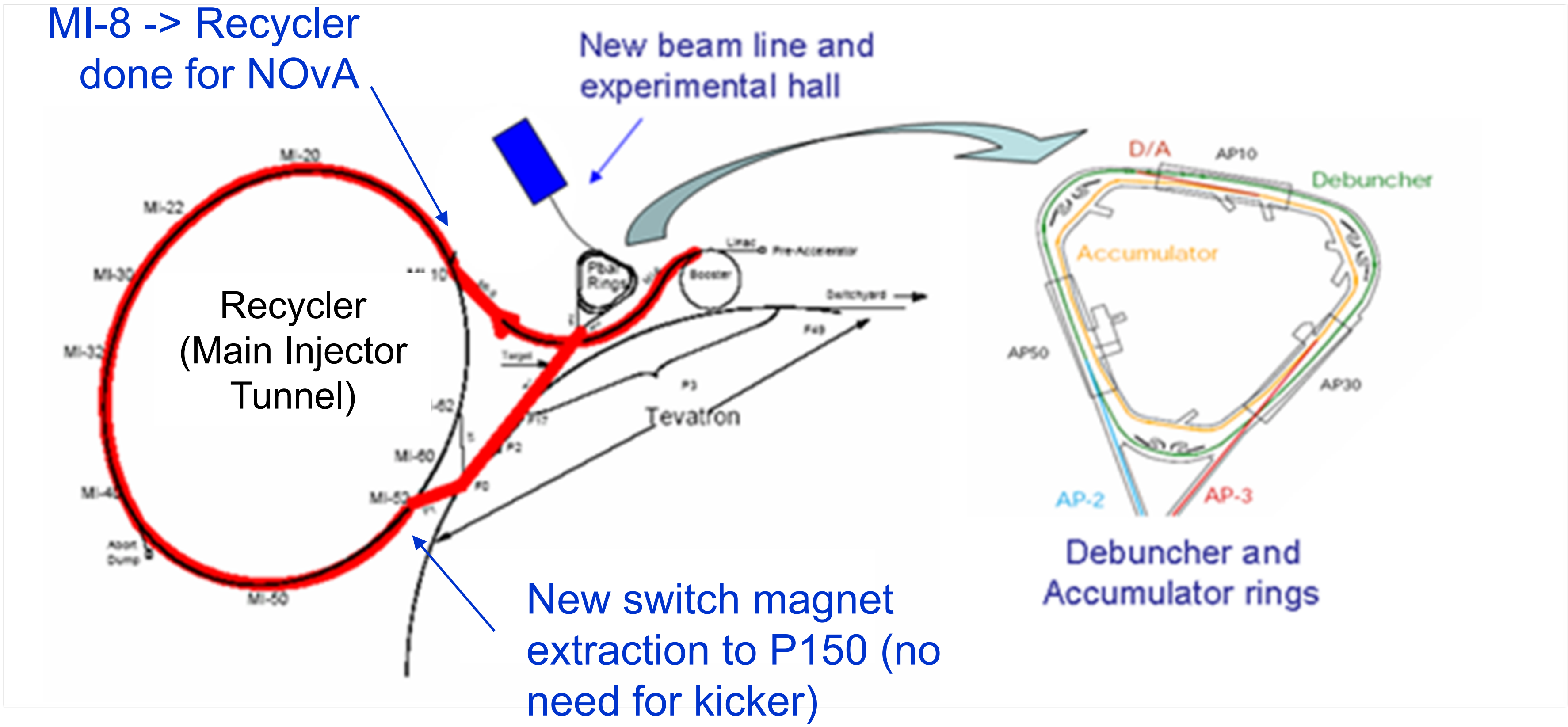
Extra protons: NOvA era

MI uses 12 of 20 available Booster Batches per 1.33 second cycle



Roughly 8*(4x10^{12} batch)/(1.33 s)*(2x10^{7} s/year)=4.8x10^{20} protons/year available

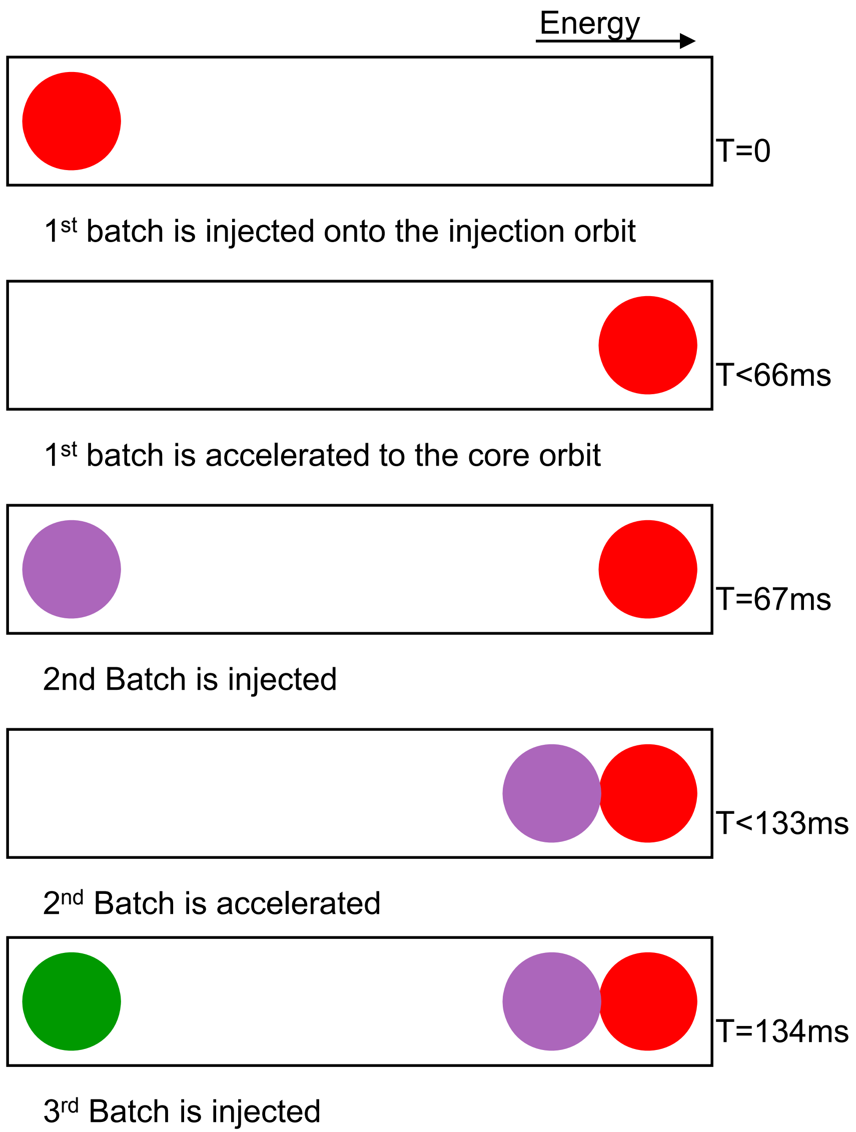
8 GeV protons: "Boomerang" Scheme



- Deliver beam to Accumulator/Debuncher enclosure with minimal beam line modifications and *no civil construction*.

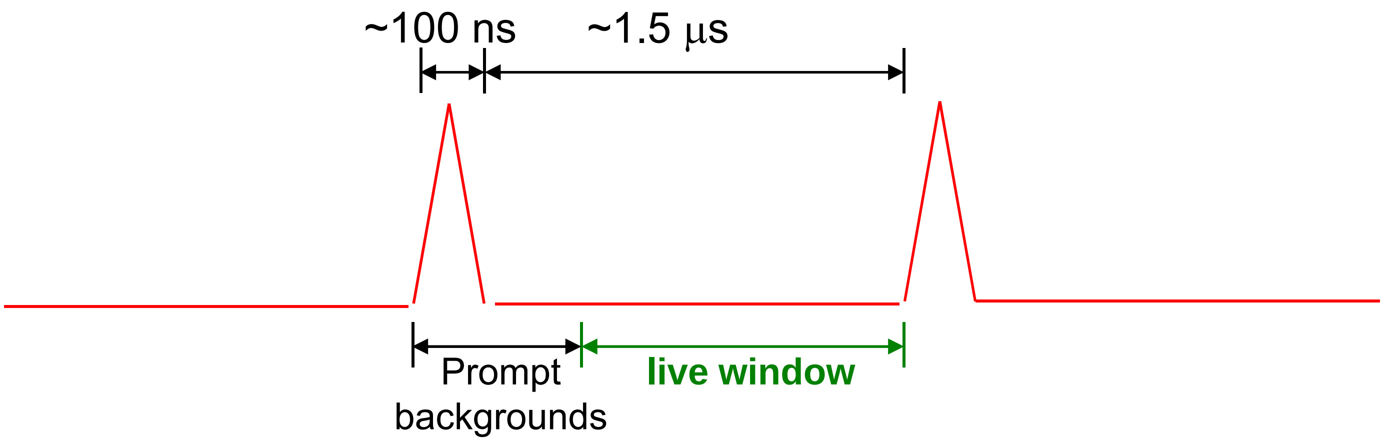
Momentum stacking in accumulator

- Inject 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
- They are then transferred to the Debuncher, where they can be rebunched, slow extracted according to experimental needs.



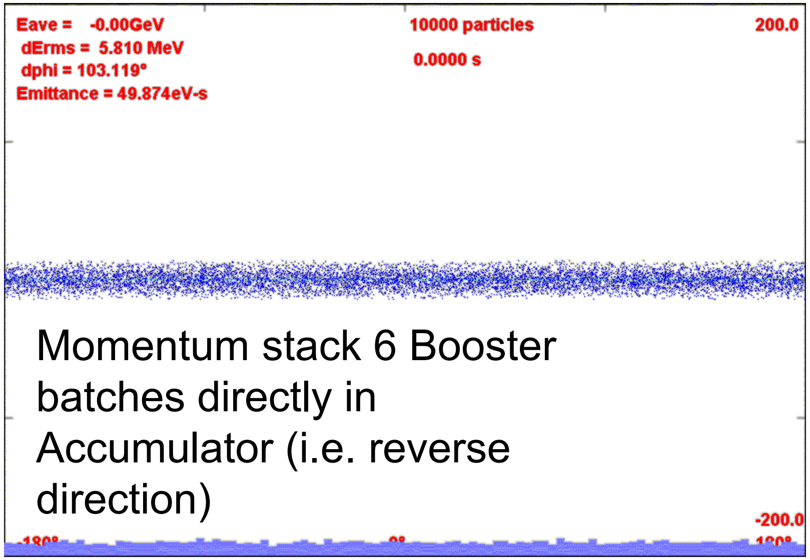
Example: beam structure for Mu2e

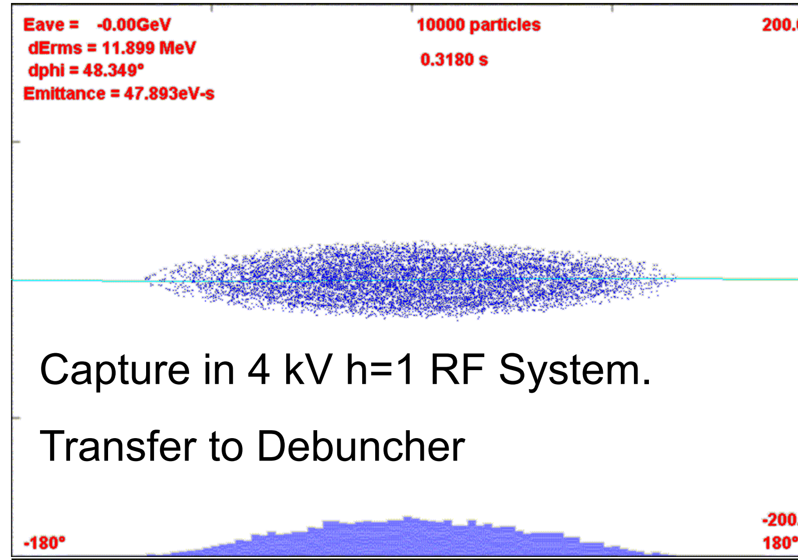
- Eliminate prompt beam backgrounds by using a primary beam with short proton pulses with separation on the order of a muon life time

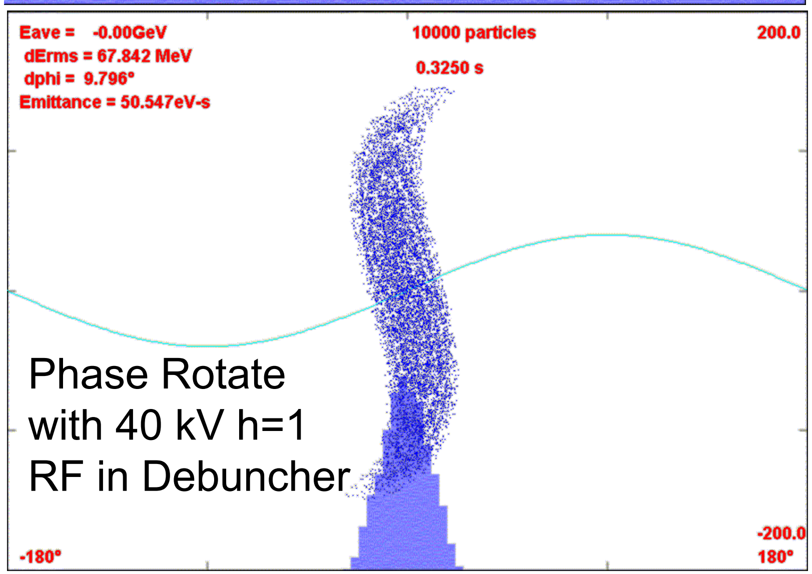


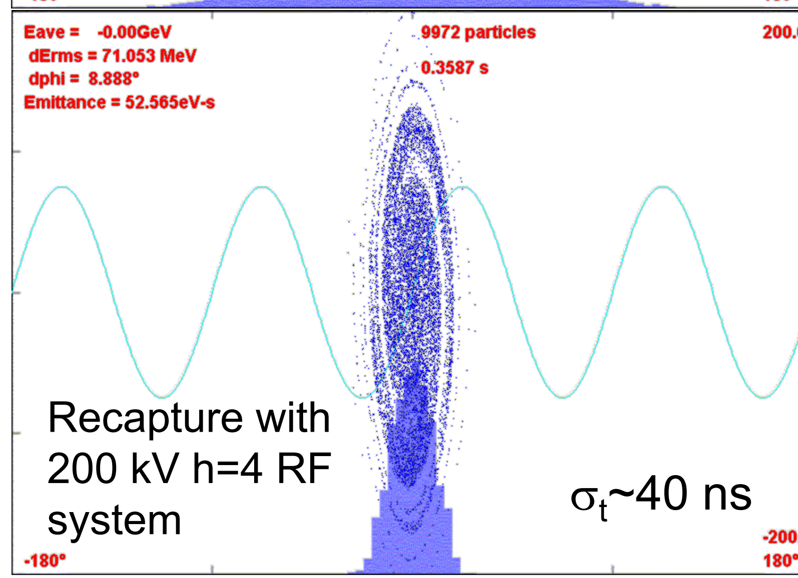
- Optimum period just happens to be exactly the period of the Debuncher.
- Plan: rebunch into into a single bunch and slow extract to experiment.

Rebunching in Accumulator/Debuncher

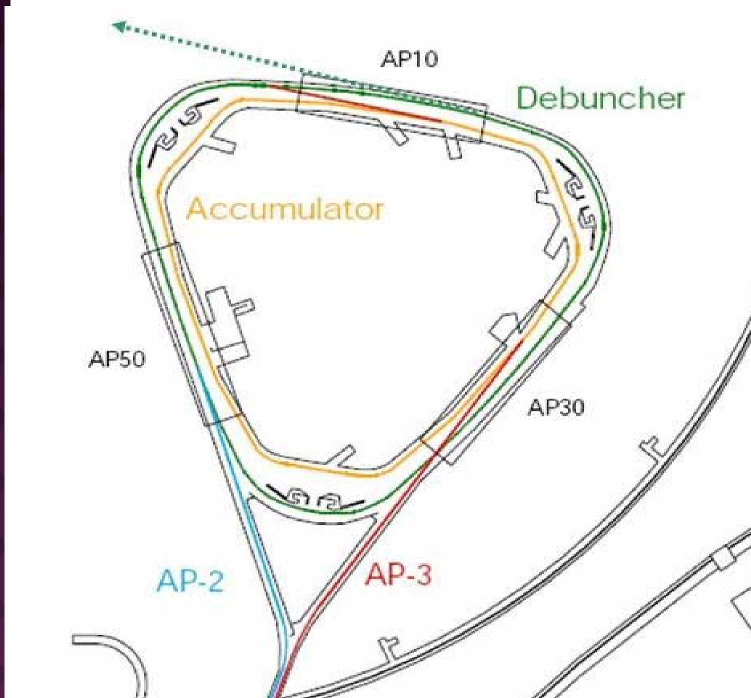




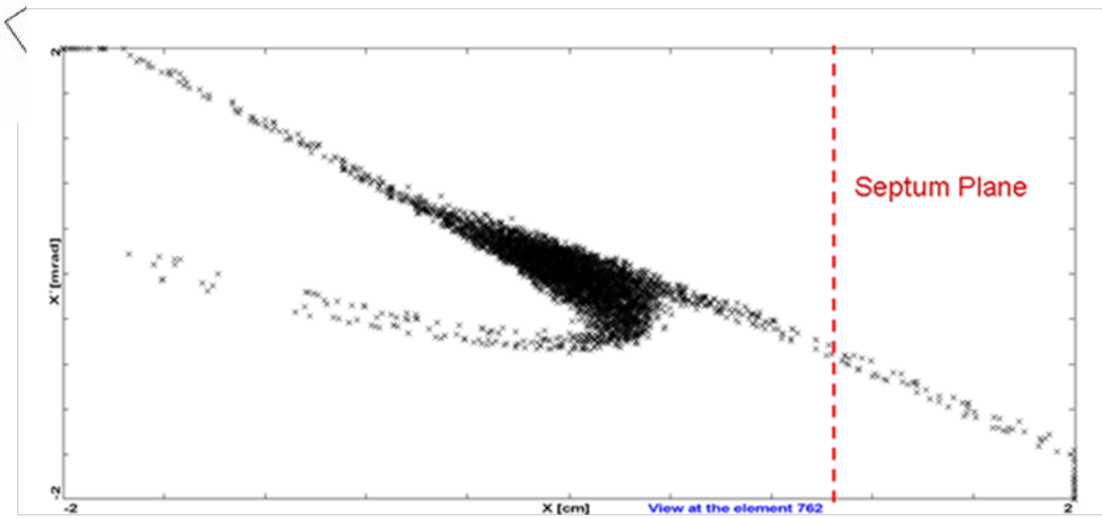




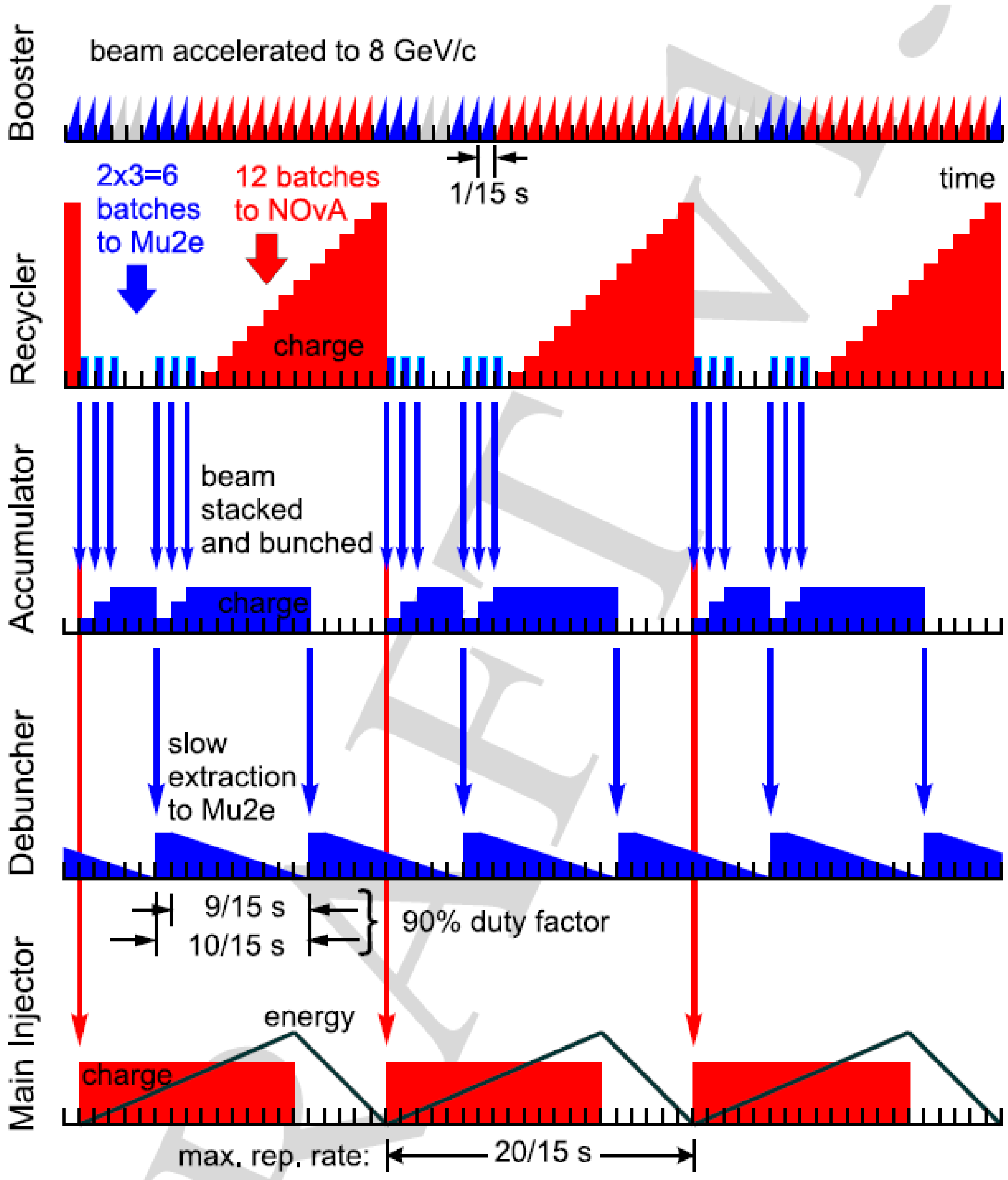
Resonant Extraction



- Exploit 29/3 resonance
- Extraction hardware similar to Main Injector
  - Septum: 80 kV/1cm x 3m
  - Lambertson+C magnet ~.8T x 3m



Timeline in NOvA/Mu2e era



Status of all this stuff

- Tevatron
  - Approved to run through FY09
  - Will *probably* run through FY10
- ILC
  - Budget severely cut
  - Reduced to R&D, primarily in superconducting RF
- Project X
  - Preconceptual design document
  - Two physics workshops and one accelerator workshop
  - Working on "Initial Configuration Document" (ICD) in hopes of getting CD-0 in the fall
  - Workshop in the fall

Status (cont'd)

- NOvA
  - CD-2 signed by Orbach. CD-3a on Ocober 24th
- DUSEL
  - High marks by P5. Proceeding with conceptual design
- Mu2e
  - Very high marks by P5 (pursue under all funding scenarios)
  - Writing proposal for Oct. 1 (Fall PAC), CD-0 shortly after
- g-2
  - Collaboration forming.
  - Trying to get the cost down
- Muon collider/Neutrino factory
  - Lots of excitement and good research
  - Trying to get better organized.

Things I didn't talk about

- LHC involvement
  - Fermilab has played a significant role in the CMS experiment and the LHC itself.
  - Plans increased involvement in these, as well as ATLAS, after the Tevatron
  - US LHC Accelerator Research Program (LARP)
    - What I really spend most of my time on!!
- Other proposed physics
  - Rare kaon decay physics (K->pnn, charged and neutral)
  - High energy neutrino program (NuSonG)
  - These were given a low priority by P5, but continue to be actively investigated.
- ILC!
  - Still lots of people working on ILC stuff (mostly under the aegis of "SRF R&D")
  - Might return at some point
- Non-accelerator physics
  - Pierre Auger
  - CDMS
  - Sloan Digital Sky Survey

Summary

- Life will change for Fermilab when the LHC starts to take real data.
- Nevertheless, we plan to continue to support an cutting edge *accelerator-based* physics program.
- We have developed both an intermediate and a long range program, which can accommodate a range of funding scenarios.