Stacking & Cooling

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Fermilab AAC Meeting

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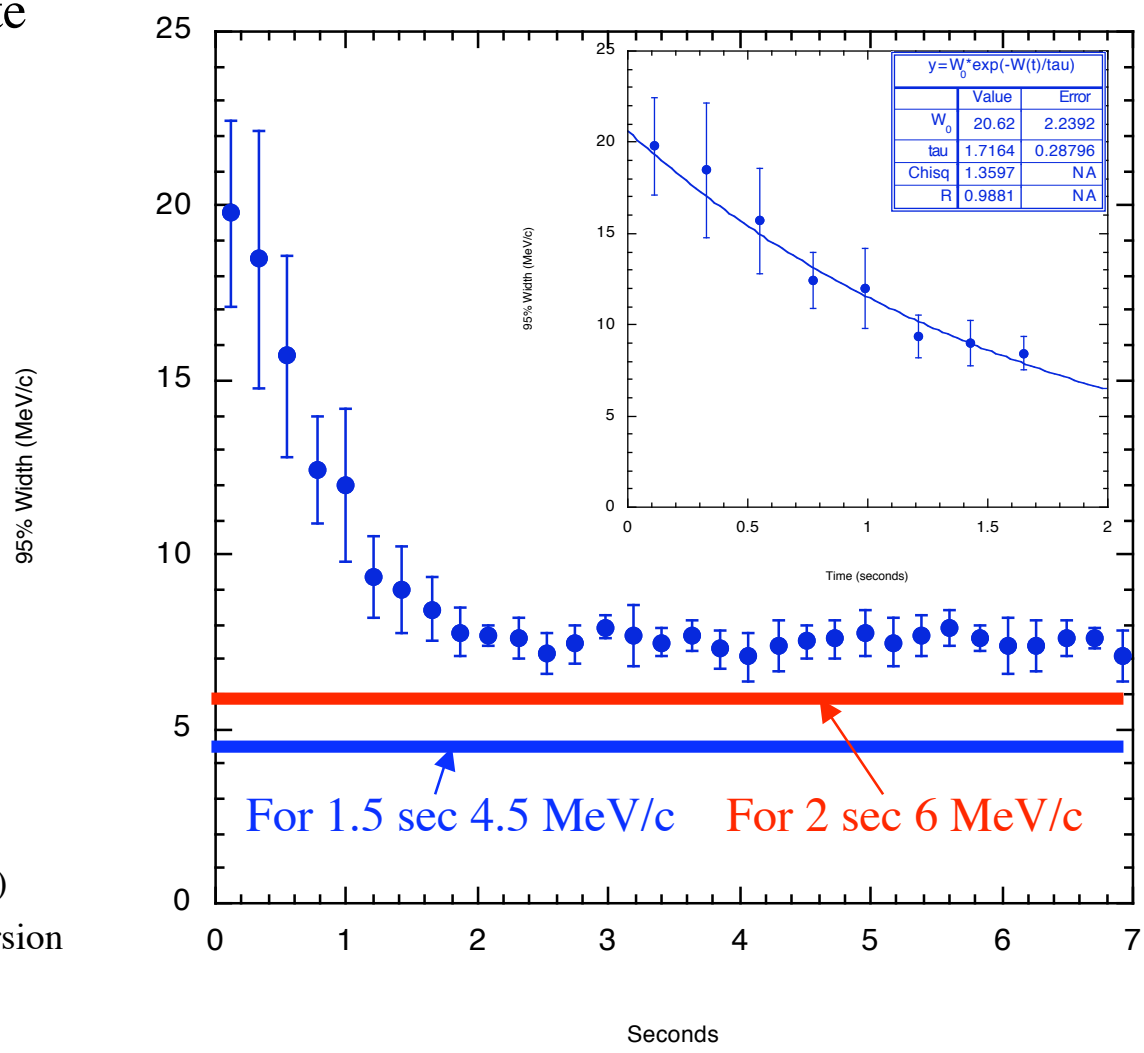
Paul Derwent

Handling >40 mA/hour

- Debuncher
  - 2 second cycles
  - Transfer to Accumulator
    - 6 MeV/c 95% width
    - 50 π
- Accumulator
  - 2 second cycles
  - 30 minutes stacking
    - 20-30e10 maximum density
  - Transfer to Recycler
    - 10 eV-sec
    - 15 π
- Rapid transfers
  - Accumulator to Recycler transfers
  - Every 30 minutes
  - ≤ 5 minutes setup + transfer
- Recycler
  - Electron & Stochastic cooling
  - Stash of 5-10 e12

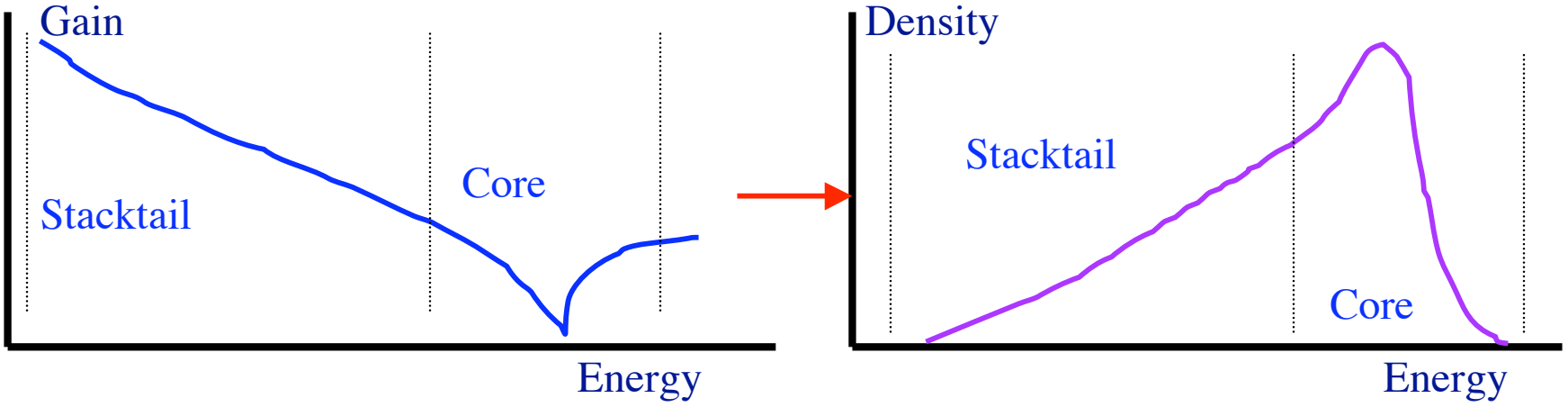
Debuncher Cooling

- Cooling rate and asymptote limited by notch filter dispersion
- Cooling Time
  - Prediction: 0.2 sec
  - 3 measurements:
    - (1.7 ± 0.3,1.4 ± 0.2,1.6 ± 0.2)
    - Average: 1.54 ± 0.13 sec
- Asymptotic value:
  - 7.7 MeV/c 95% width
- ~5000 Notches in system
  - Aligned to same frequency?
  - RMS width 3 Hz
  - Better delay control (<1ps level)
  - New equalizers for phase dispersion



Stochastic Stacking

- van Der Meer solution:
  - Constant Flux: $\frac{\partial \square}{\partial t} = \text{constant}$
  - Solution: $\frac{\partial \square}{\partial E} = \frac{\square}{E_d}$, where E_d characteristic of design $\square = \square_0 \exp\left[\frac{(E - E_i)}{E_d}\right]$
  - Exponential Density Distribution generated by Exponential Gain Distribution
  - Max Flux = $(W^2 |\square| E_d)/(f_0 p \ln(2))$



Using log scales on vertical axis

Stacktail Design Scenario

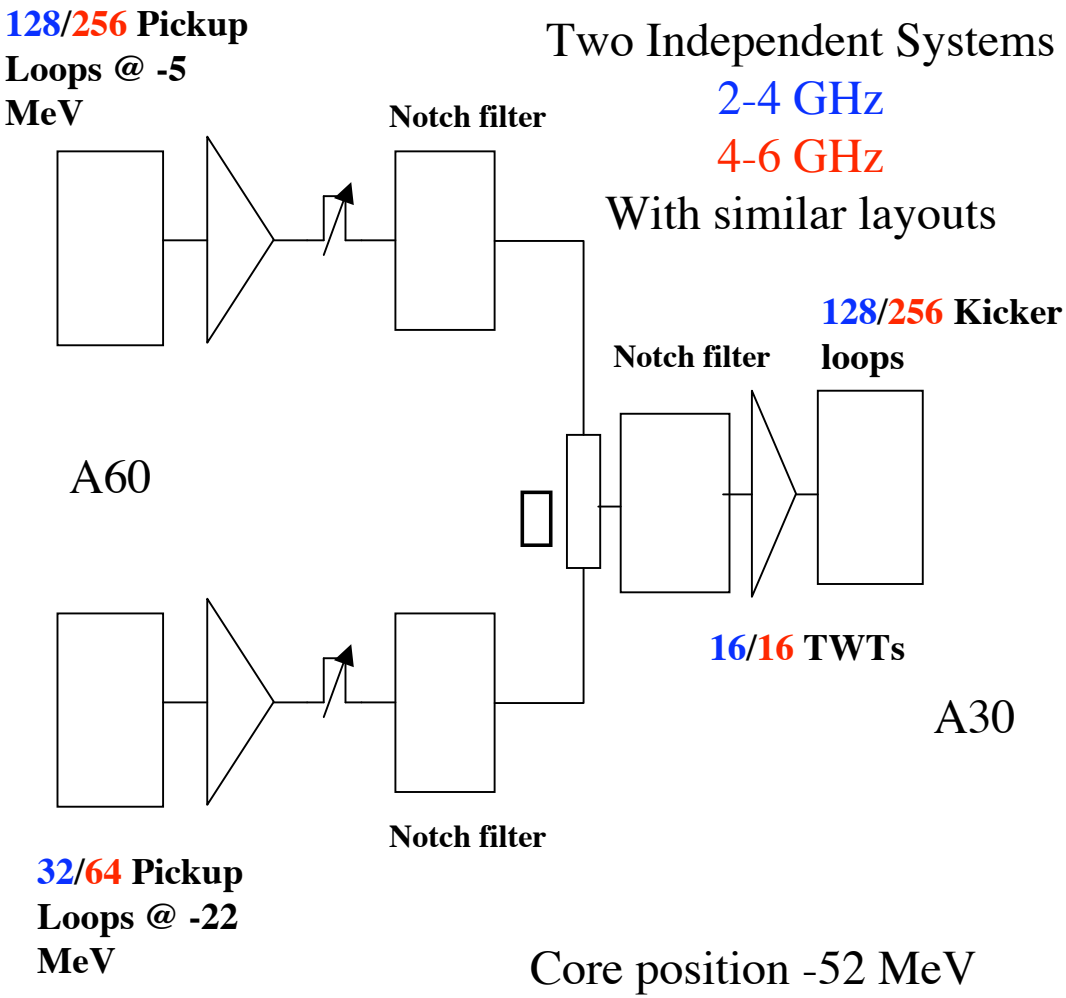
- Goal: 90 mA/hour peak stacking rate in Accumulator
  - x2 design margin above 45 mA/hour
- Accumulate for 30 minutes, transfer to Recycler
  - Optimize for maximum flux, not momentum density
- Change Bandwidth & E_d
  - 2-6 GHz
  - 9 MeV gain slope
  - Maximum flux ~ 102 mA/hour

Specifications

- Input:
  - 50 π transverse emittance
  - 6 MeV/c 95% momentum width
  - 2 second cycle time
- Output:
  - 30 minutes accumulation time
  - 5 minutes extraction
    - ~4.5 minutes setup
    - ~0.5 minute extraction
  - 77 mA/hour average
  - Extract
    - 10 eV-sec
    - Transverse ~12 π

Design Decision

- 2-6 GHz total bandwidth in parallel systems
  - 2-4 GHz band
    - » Equivalent to current stacktail
    - » Utilize existing hardware
    - » Replace $^1/_2$ system
  - 4-6 GHz band
    - » New hardware
      - Pickup & Kicker loops
        - – New design?
      - Electronics
  - Layout similar for both systems

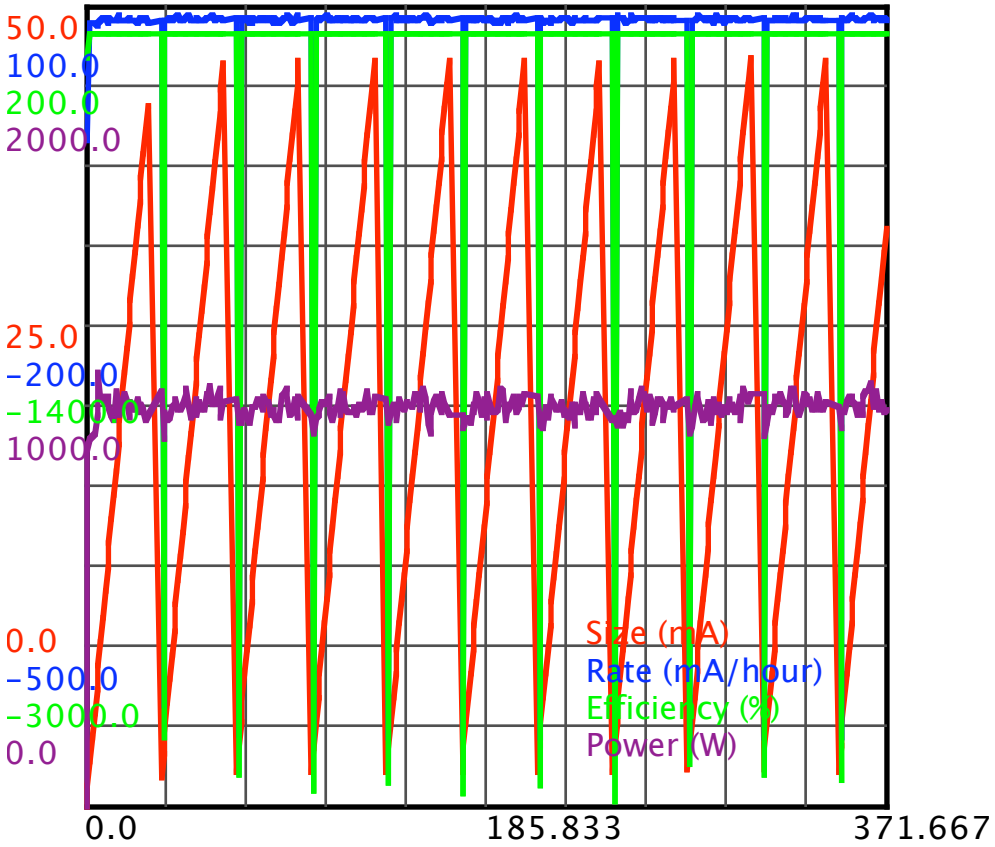


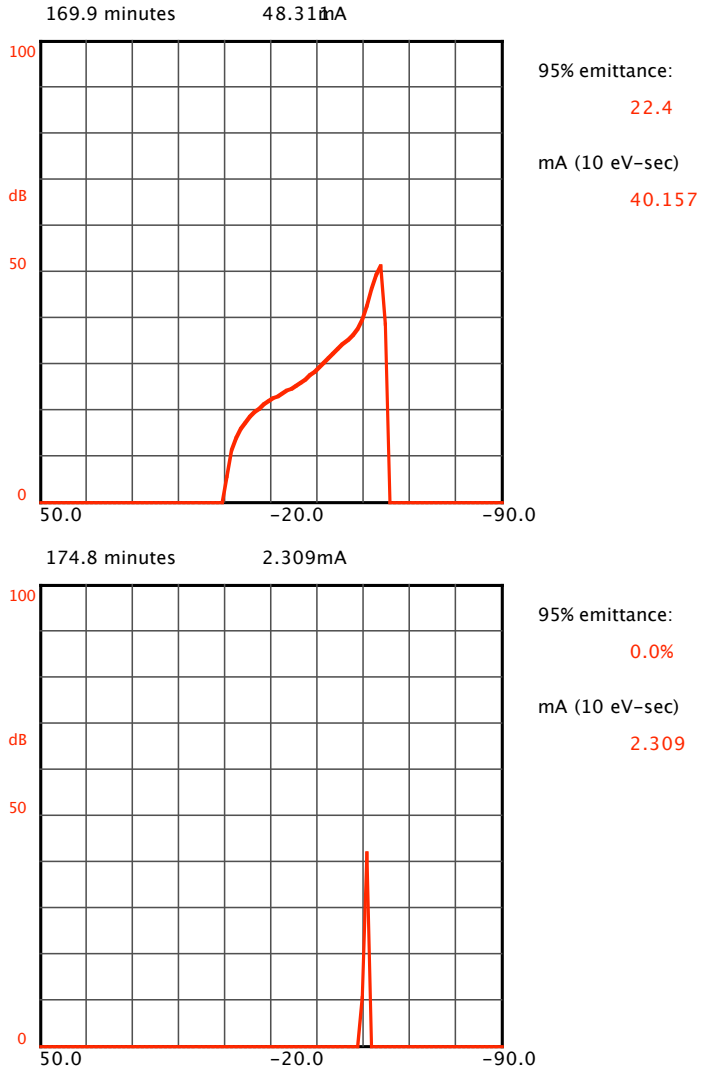
System Parameters

	2-4 GHz System (1/2 current system)	4-6 GHz System To be built
Pickup loops	160	320
Kicker Loops	128	256
Loop Impedance	20 Ω	5 Ω (current) 10 Ω (desired)
Front End Noise Temperature	125 K	125 K
Cryo Amps	8	8
1 Watt Amps	8	8
BAW Notch Filters	3	3
TWTs	20	20
TWT Power Supplies	20	20
Total Power	~500 W	~500 W

Simulation Results

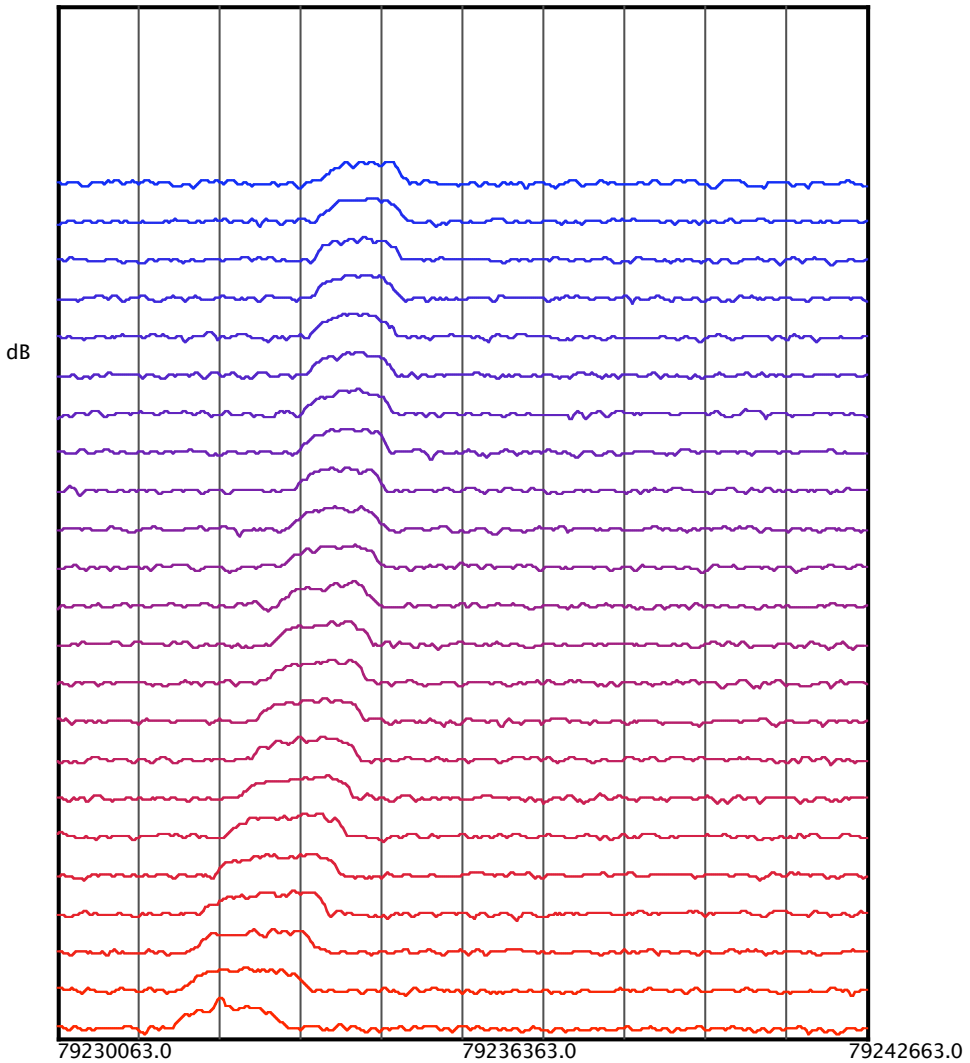
- Stack Rate = 91.9 mA/hour
  - 78.8 mA/hour including extraction time
- ~1 kW total power



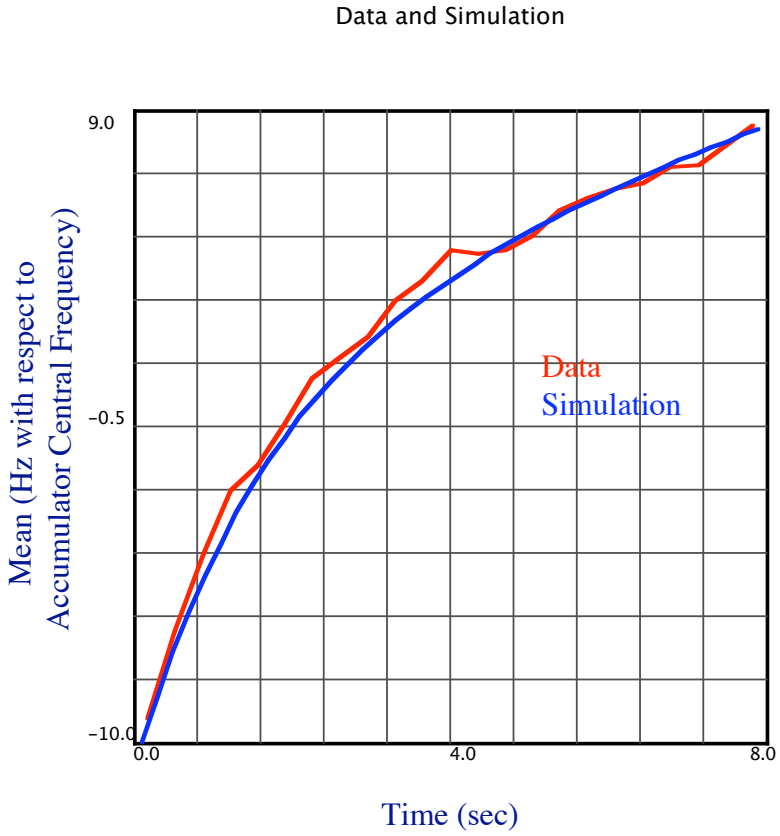


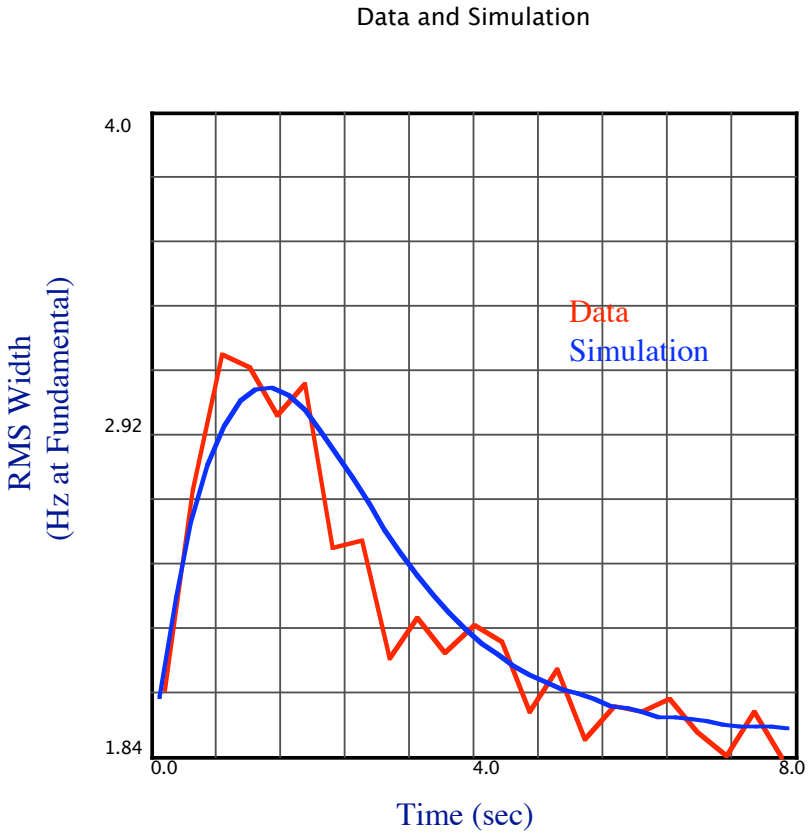
Simulation Tests

- Single Pulse Evolution
  - Single pulse into Accumulator
  - Using 79 MHz longitudinal Schottky, track evolution of the pulse
    - » Motion of the mean
    - » Change in the width
  - Direct Comparison of simulation and current stacktail



Pulse Evolution





Study Plan

- Proton Stacking:
  - Test current systems to their limits
    - » Input Flux and System Power
  - Proton flux ~6x pbar flux
    - » 1996 test: Tev I design
      - 12.2 mA/hour with 5 second cycle
      - Simulation predicted max of ~14 mA/hour
        - – Under different input conditions
  - Debuncher cooling rates: longitudinal and transverse
  - Accumulator Stacktail
    - » Test simulation matching
      - Pulse evolution
      - Stacking rate
- 1 Week dedicated time

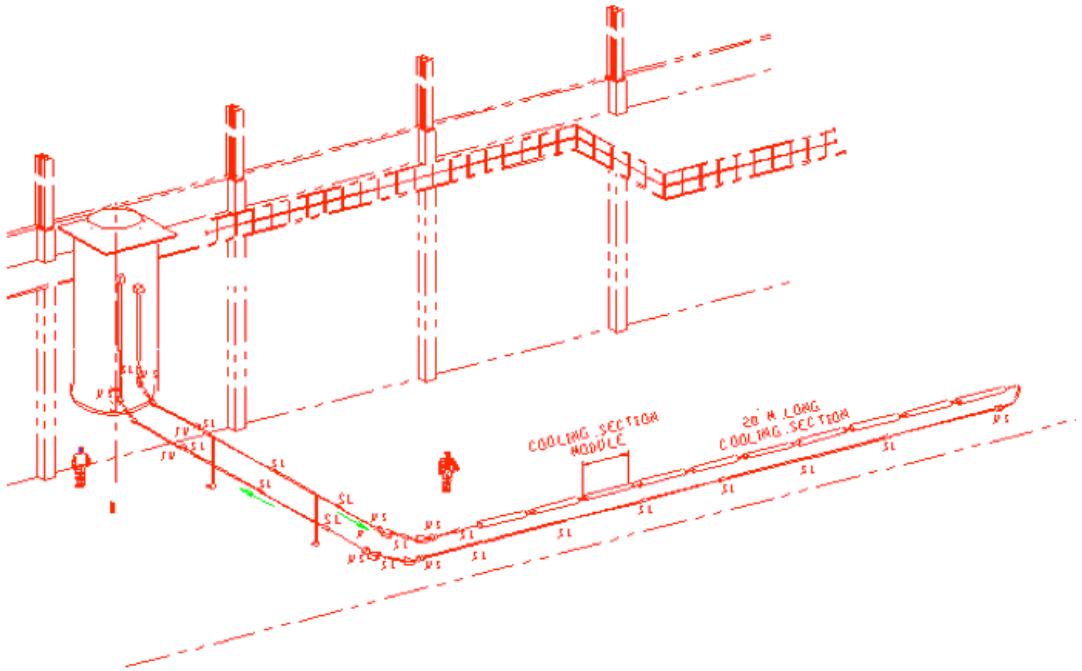
Rapid transfers

- Dec 02: ~1 transfer to Recycler per day
  - To understand mechanics of transfer
  - 60 minutes from stacking to stacking
    - » 30 minutes setup with focus on emittance preservation:
      - Positions in MI & Accumulator
      - Do not do beam line tuneup
    - » 30 minutes for multiple transfer
  - ~80% efficiency
- Plan: Continue with daily transfers
  - Short term: 30 minutes stacking to stacking
  - Beam quality (longitudinal & transverse)
  - 200e10 stash in Recycler
  - Integration into Collider operation

Electron Cooling Test Facility at WideBand Building

Paul Derwent

- 5 MV Van de Graaff accelerator (Pelletron)
  - Will be installed in MI-31
- Prototype Electron beamline
  - Closely resembles final beamline
  - Most will be used in MI tunnel installation



Recycler Electron cooling Project Goals

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	Goal	Achieved?
Recirculated electron beam current	0.5 A	YES
Electron beam kinetic energy	4.3 MeV	YES
Beam angular spread (cooling section)	80 μrad	Not yet
Magnetic field at cathode	600 G	YES
Beam diameter at cathode	5 mm	YES
Energy spread	500 eV	Yes
Pressure (cooling section)	1×10^{-10} Torr	Not yet
Recirculation stability (average)	1 hour	NO 20 min @ 3.5 MeV <4 min @ 4.3 MeV
Beam recovery time	5 min	YES (20 sec)
Typical time between tank openings	1 month (initial) 6 months (final)	YES

Recycler Electron Cooling Schedule

- Completed tests with short U-bend beam line
- Installation of full scale beam line, switchover in late Mar, 2003
- Signed off on construction of building to begin Mar 3, 2003.
  - 11 months construction
  - 6 weeks shutdown to tie in to MI tunnel (late summer, 2003)
  - Installation at MI-31 (Feb-May, 2004)
  - Additional down time for beamline installation and commissioning (possibly summer 2004)
- Testing will continue at WideBand in interim

Handling >40 mA/hour
Where things stand

Paul Derwent

- Debuncher
  - 8 MeV/c asymptotic width
  - 1.5 second cooling time
  - Improve longitudinal cooling rate to achieve desired 6 MeV/c 95% width
  - High flux study with proton stacking in spring
- Rapid transfers
  - Accumulator to Recycler transfers
  - 60 minutes now
    - 80% transfer efficiency
  - 30 minutes short term goal
  - <5 minutes necessary
- Accumulator
  - Design to handle 90 mA/hour peak, 80 mA/hour average
  - Testing simulation with measurements that can be done in current setup
  - High flux study with proton stacking in spring
- Recycler Electron Cooling
  - Steady progress
  - MI 31 construction Mar 2003
  - 11 - 12 month schedule
  - 2 months shutdown for tie-in and commissioning