# Accumulator Stacktail Upgrade

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# Upgrade Philosophy

- Support Maximum stacking rate:
  - Slip Stacking success
  - Lens Upgrade success
  - AP2 & Debuncher Acceptance upgrades success
- Design margin:  factor of two
  - 80 mA/hour max

# Maximum Flux Calculation

- van der Meer method
  - Exponential gain slope
  - Exponential density
  - Constant Flux
  - Max Flux = $(W^2|\eta|E_d)/(f_o p \ln(F_{max}/F_{min})$
    - W bandwidth, $F_{max}$ and $F_{min}$ frequency range
    - $f_o$ beam revolution frequency, p beam momentum
    - $|\eta|$ phase slip factor
    - $E_d$ characteristic gain slope

# Stacktail Design Scenario

- Goal: 80 mA/hour stacking rate in Accumulator
  - x2 design margin above 40 mA/hour
- Accumulate for 30 - 60 minutes, transfer to Recycler
  - Optimize maximum flux, not momentum density
  - Maximum stack size 50-60 mA to avoid falloff in rate
- Change Bandwidth or $E_d$?

# Design Constraints

- Recycler sets longitudinal emittance for transfers (10 eV-sec)
- "long" stacking interval to minimize # of transfers
  - Largest core density
    - Large momentum aperture
    - Small $E_d$
- Bandwidth better than $E_d$
  - Larger $E_d$ needs larger momentum aperture for similar core density
  - Momentum aperture defined by frequency range (overlapping Shottky bands) and notch filters

# Design Scenarios

| Stacktail Bandwidth (GHz) | Core Bandwidth (GHz) | $E_d$ Stacktail (MeV) | $E_d$ Core (MeV) | Energy Aperture (MeV) | Core Width (MeV) | Fraction Unstacked (%) |
|---|---|---|---|---|---|---|
| 2-4 | 4-8 | 20 | 5 | 77.4 | 9.6 | 50% |
| 2-6 | 4-8 | 8 | 5 | 48.4 | 9.6 | 66% |
| 2-6 | 2-6 | 8 | 8 | 45.2 | 12.8 | 55% |
| 4-8 | 4-8 | 5 | 5 | 33.9 | 9.6 | 72% |

http://www-bd.fnal.gov/doereview03/Current/02_Pbar_stacking_cooling.pdf

# Increasing Maximum Flux

## Increase Bandwidth

2-6 GHz

9 MeV gain slope

Maximum flux ~102 mA/hour

New pickups and kickers

4-8 GHz core system

## Increase $E_d$

2-4 GHz

18 MeV gain slope

Maximum flux ~80 mA/hour

Move pickup tanks

2-4 or 4-8 GHz core system

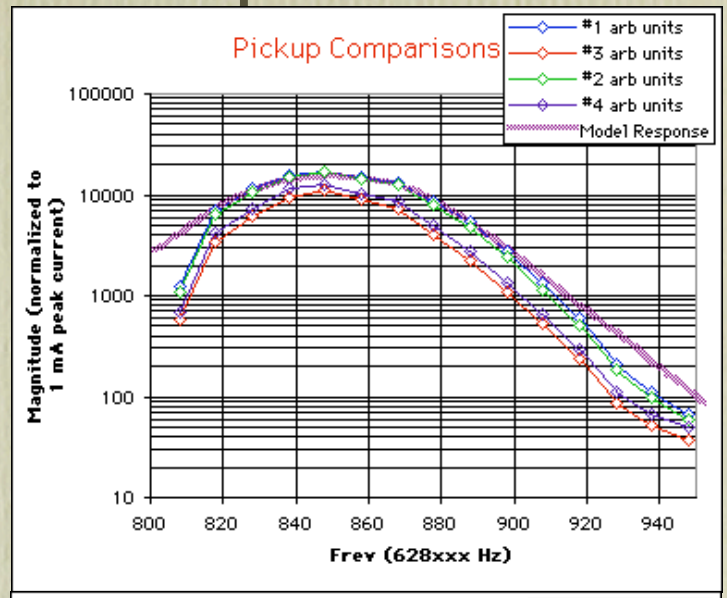
## Simulation Model is a numerical integration of Fokker-Planck equation, including Feedback

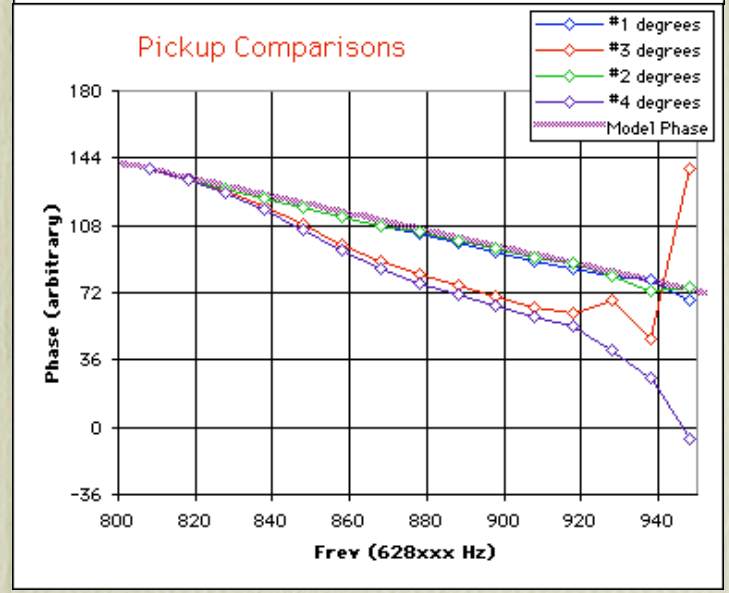
Two scenarios:
Full bandwidth available & Half bandwidth available

Nota Bene: Half bandwidth at same center gives ~ half maximum rate

# Modelling Pickups

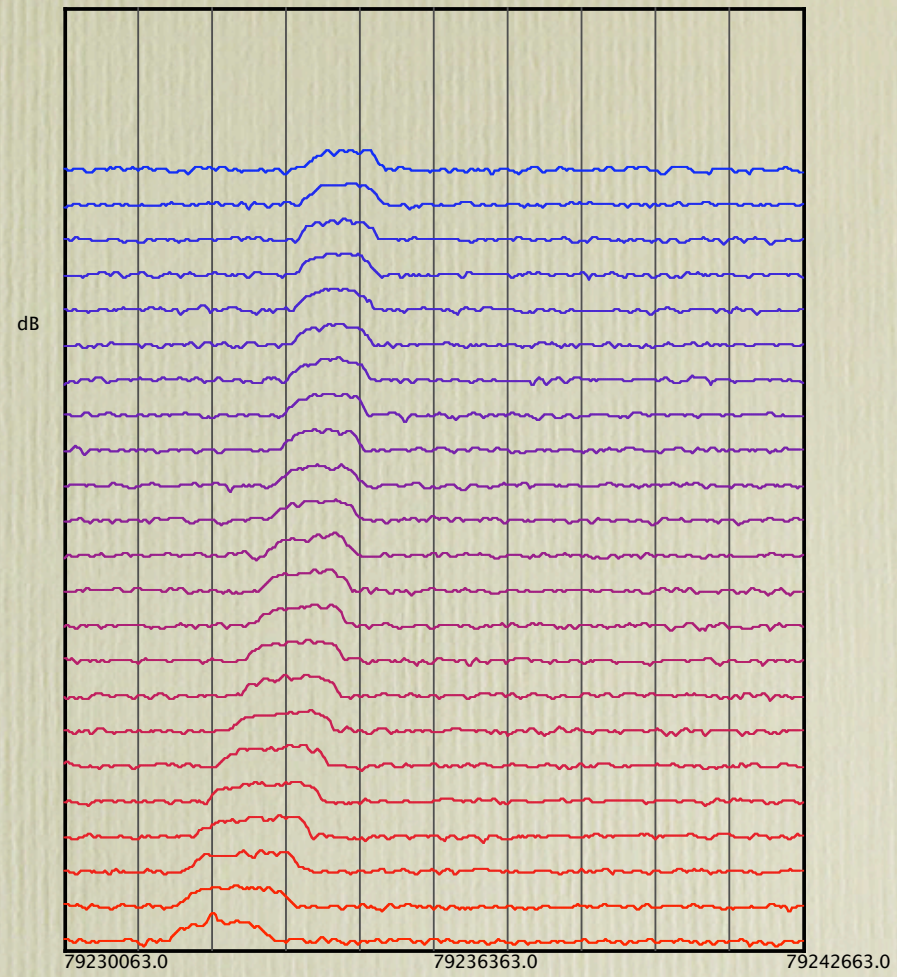
- 1997: Test with 4 pickup designs
  - varying width
  - varying angle
- Compared to model:
  - integrate image charge to calculate response
  - function of aperture, pickup shape
  - Shape and phase well predicted



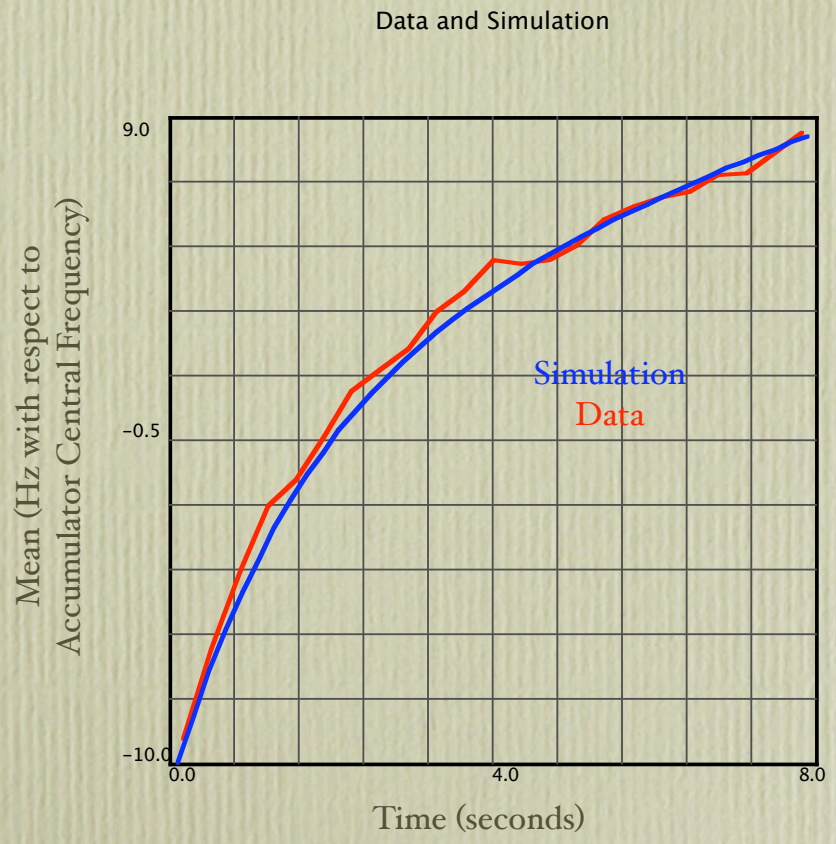



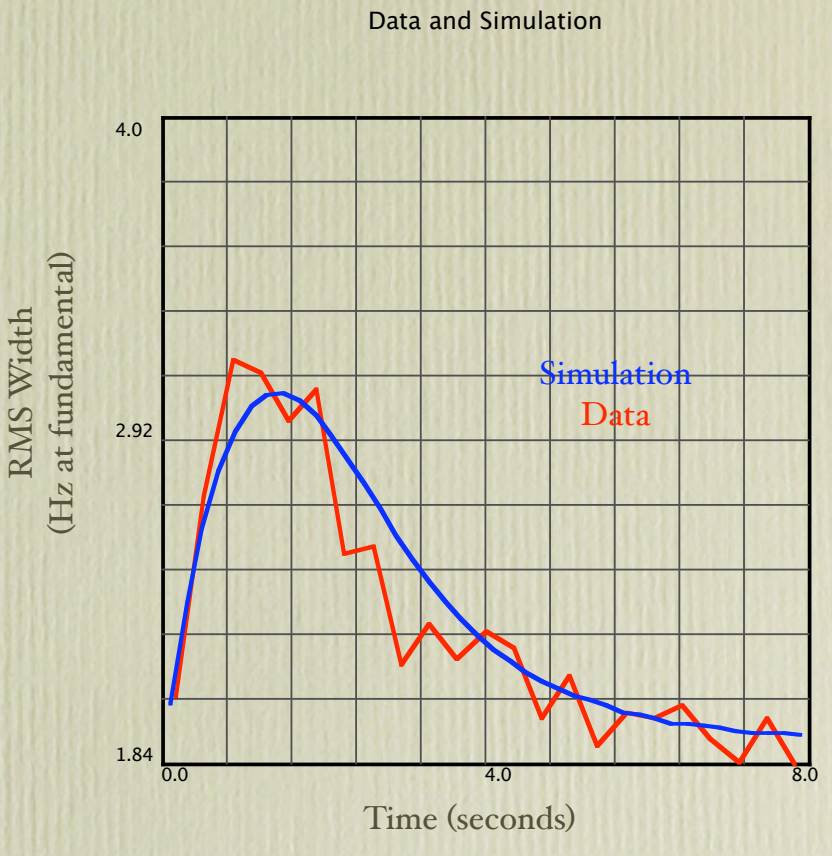
# Simulation Tests

- Single Pulse Evolution
  - Track Evolution of:
    - Pulse mean
    - Pulse RMS
- Direct Comparison of simulation and hardware



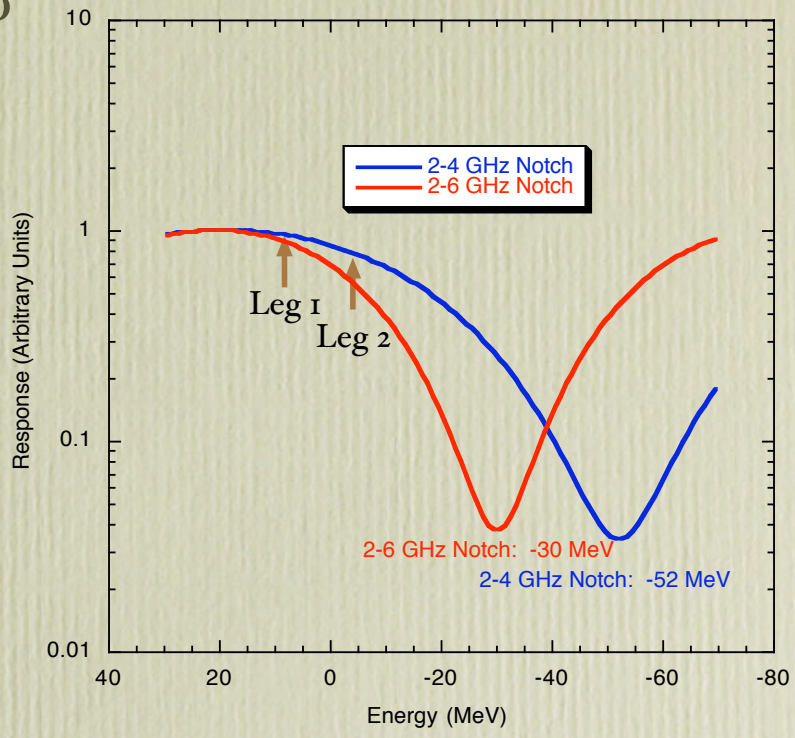
# Pulse Evolution



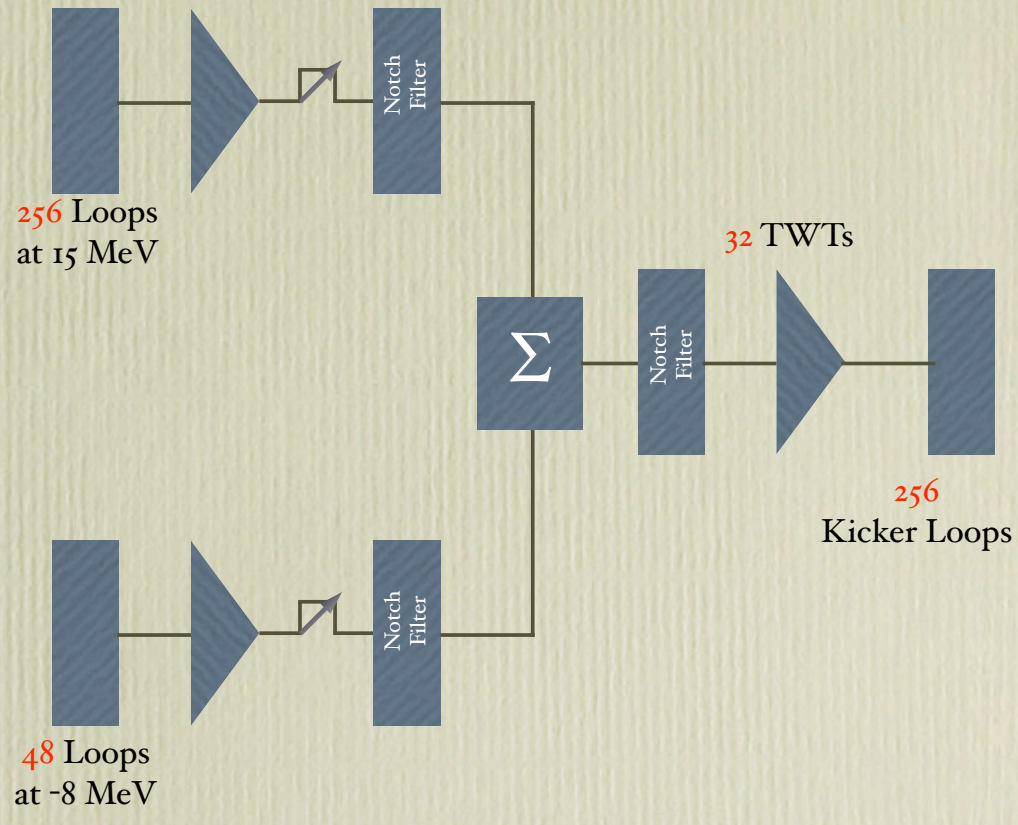
# Notch Filters and Energy Aperture

- van der Meer solution: exponential gain leads to constant flux
- WANT TO STOP AND ACCUMULATE!
- Null out the stacktail pickup signal
  - convolution of pickup and notch response
- Contributes energy aperture for stacking
  - distance between peak and notch
  - depends on frequency band

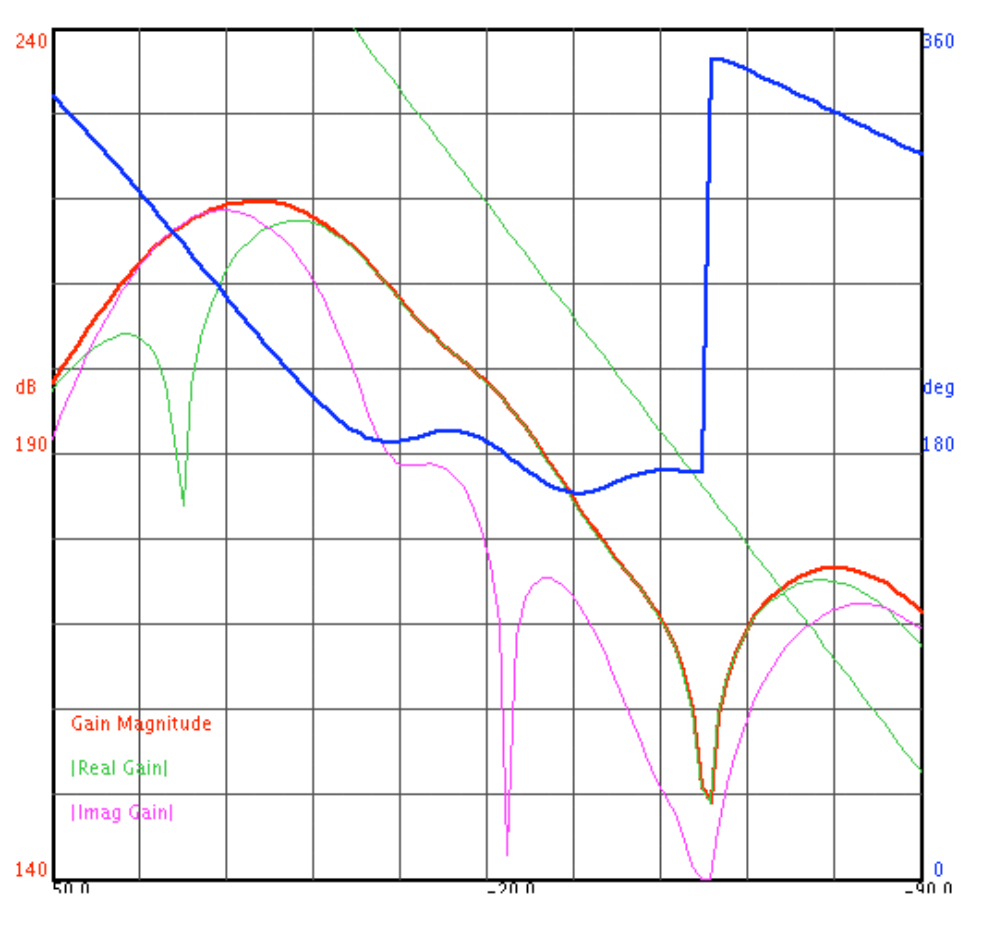


# Increase $E_d$ -- tank move option

- Move positions of pickups and change electronics settings to change $E_d$ while keeping 2-4 GHz
  - 1 mm move on 2 tanks (A60-1 & A60-4)
  - 7 mm move on 1 tank (A60-3)
- Target $E_d$ ~18 MeV
  - simulation achieved ~16 MeV
  - to keep good match into core
- Maximum stacking rate ~70 mA/hour

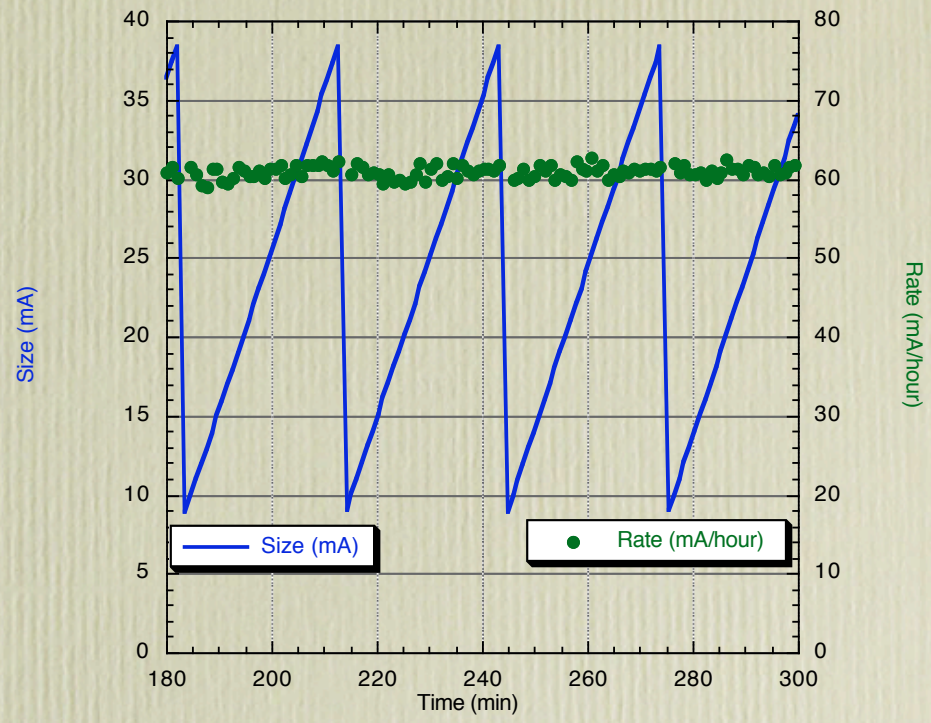


# Gain and Phase:  Tank move option



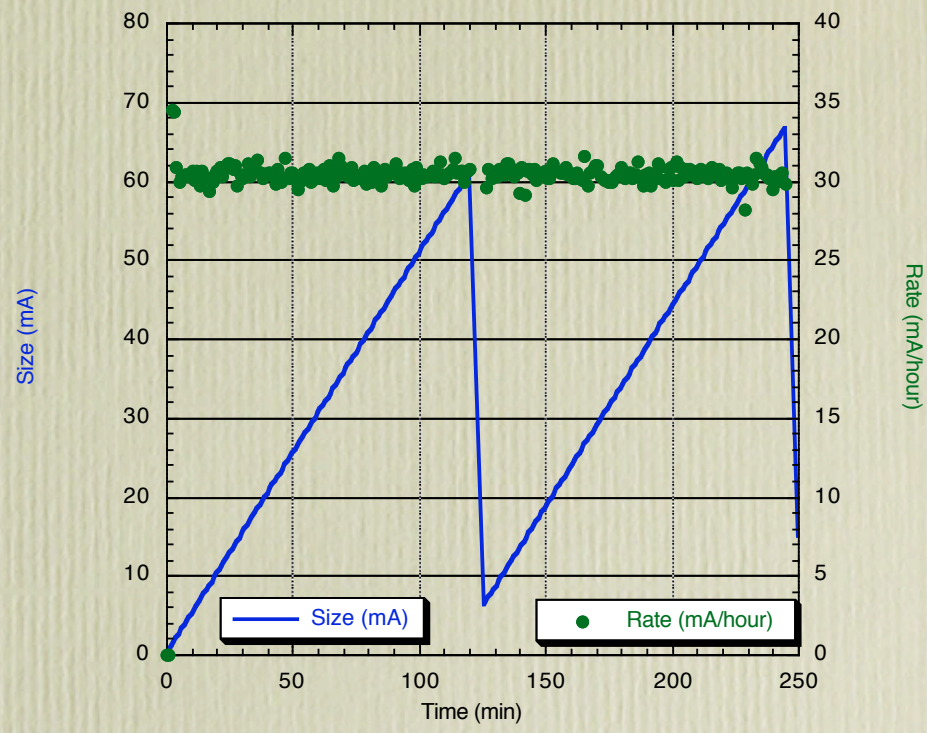
# Tank move simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use full bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 60 mA/hour for 30 minutes



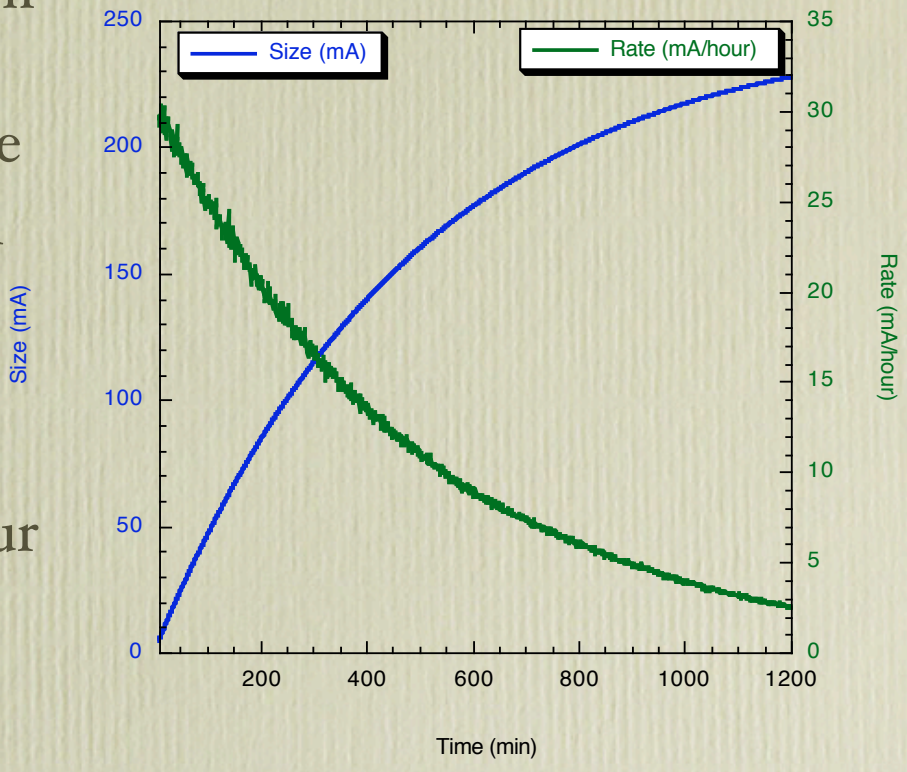
# Tank move simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use half bandwidth
- Transfer every 120 minutes, 5.5 minute/ transfer
- Sustains 30 mA/hour for 120 minutes



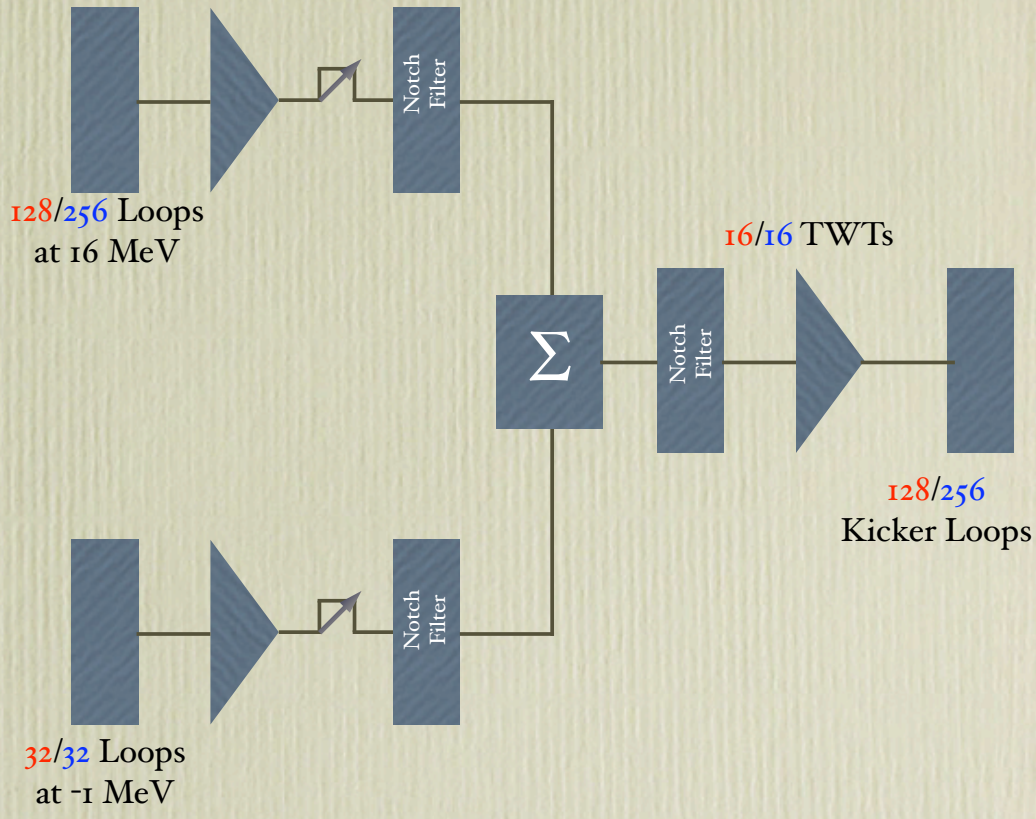
# Tank Move Simulation Results

- For Mixed Mode operation, assume rate falls of with size (based on current performance)
  - NUMI sets 2 sec cycle
  - Sample injected beam by varying RF bucket size
- Use Half bandwidth
  - Initial rate 30 mA/hour
  - Falls off linearly with maximum of 250 mA
  - Struggles above 230 mA



# Increase Bandwidth

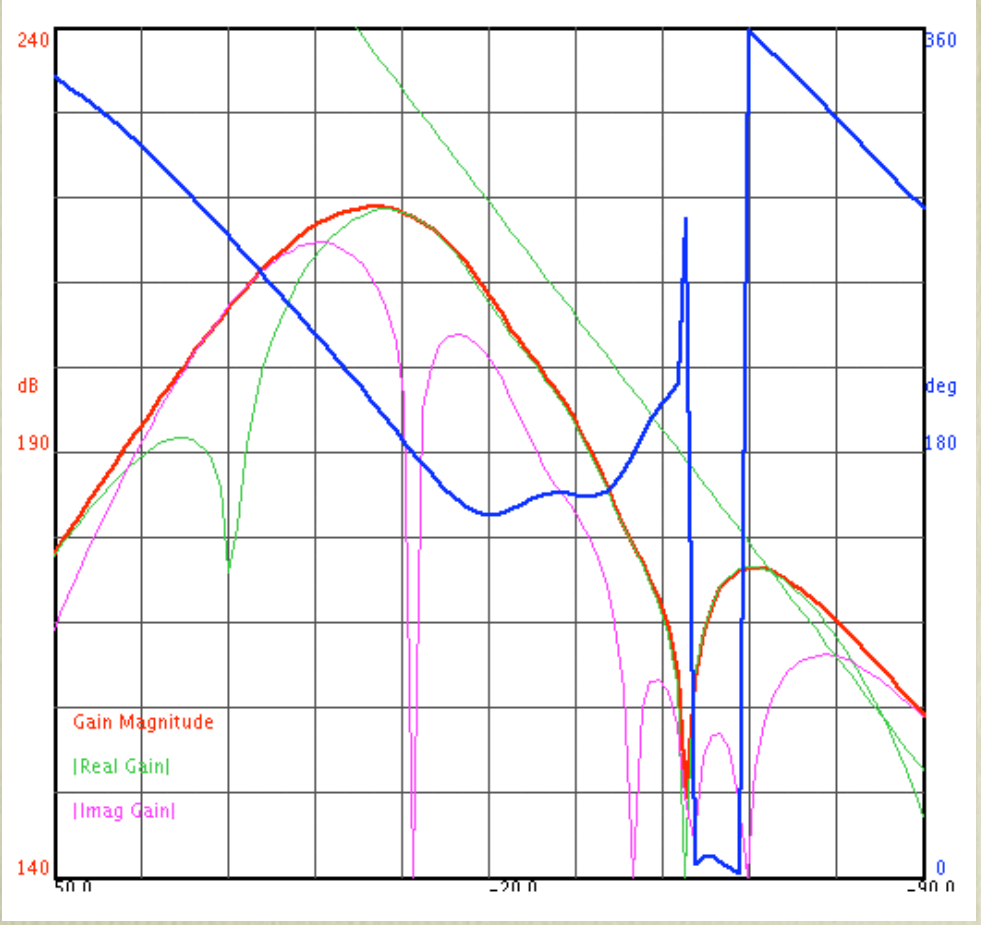
- 2-6 GHz total bandwidth in parallel systems
  - 2-4 GHz band
    - Utilize existing hardware
    - Equivalent to current stacktail
    - Remove $^{1}/_{2}$ system
  - 4-6 GHz band
    - New Hardware
      - Pickup and Kickers
      - Electronics
  - Core pickups centered at -30 MeV



# 2-6 GHz System Parameters

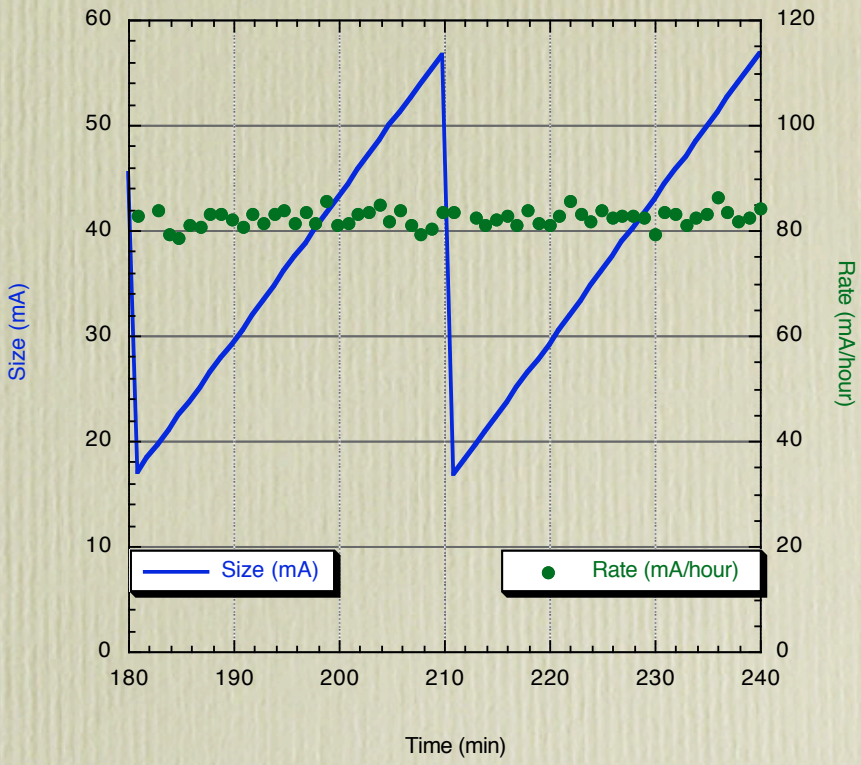
| | 2-4 GHz System | 4-6 GHz System |
|---|---|---|
| Pickup Loops | 160 | 288 |
| Kicker Loops | 128 | 256 |
| Loop Impedance | 20 Ω | 5-10 Ω |
| Front End Noise Temperature | 125 K | 125 K |
| Cryogenic Amps | 8 | 8 |
| 1 Watt Amps | 8 | 8 |
| Notch Filters | 3 | 3 |
| TWTs | 20 | 20 |
| TWT Power Supplies | 20 | 20 |
| Total Power | ~500 W | ~500 W |

# Gain and Phase 2-6 GHz design



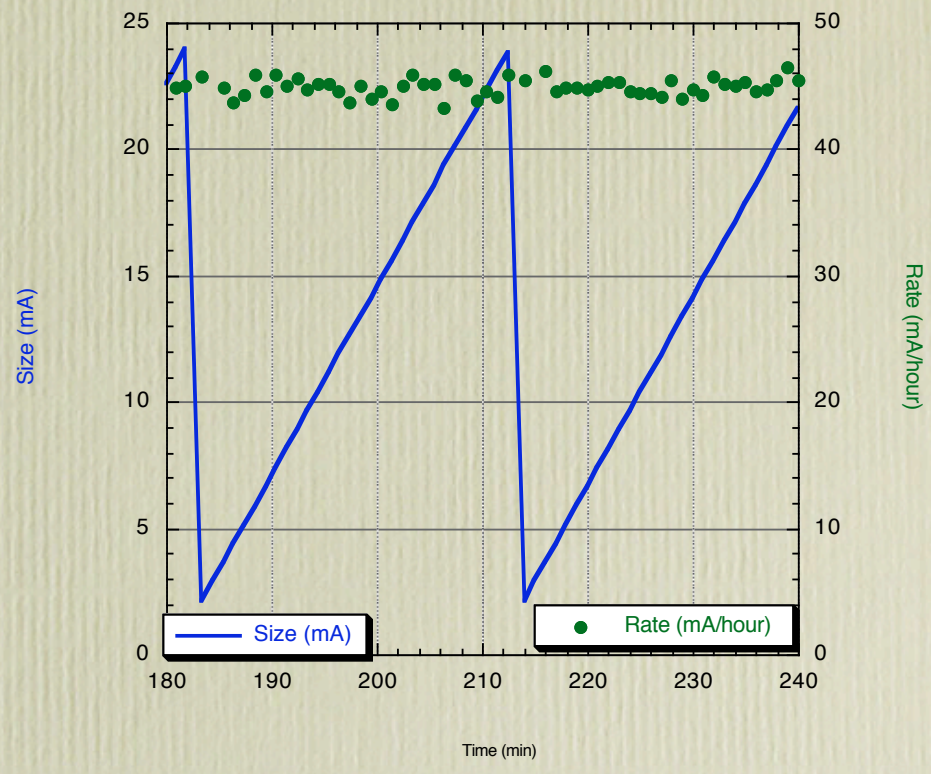
# 2-6 GHz simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use full bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 80 mA/hour for 30 minutes



# 2-6 GHz simulation results

- Time Integration of Fokker-Planck Equation, including feedback effects
- Use half bandwidth
- Transfer every 30 minutes, 1 minute/ transfer
- Sustains 45 mA/hour for 30 minutes



# Summary

- Increase Stacking rate
  - via Bandwidth:  can handle up to 80 mA/hour
    - significant hardware upgrades
    - pickups, kickers, electronics in 4-6 GHz region
      - Ralph & Ding on electronics aspects
      - Joel on mechanical aspects
  - via $E_d$:  can handle up to 60 mA/hour
    - moving pickup positions (through moving tanks) and ajdusting electronics settings
  - dependent upon Recycler being final repository