

Experience with SNS Injection and Extraction Kicker Control Systems Using EPICS

EPICS Collaboration Meeting

June 12 -16, 2006

Advanced Photon Source

Argonne National Laboratory

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OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

Little History on How I end up with doing this ...

At noon of last June, shortly I came back from APS on porting RS485 multi-drop support in Asyn with Marty, Dave Gurd came to my office along with Sheng and he said to me, “Johnny, we need you help on Magnet Power Supply Control, starting with Ring Power Supply commissioning support and Sheng is leaving this afternoon.”

Outlines

- **Two Perspectives of Kicker Control Requirements**
 - In ideal world, How it should work (from Accelerator Physicists point of view)
 - In real world, Limitation of Hardware (from PS Engineers point of view)
- **Integration work of Kicker Power Supply Control with SNS timing system**
- **EPICS Contribution for the Kicker Control Systems**
- **Commissioning Experience**
- **Software Maintenance Plan**
- **Summary**

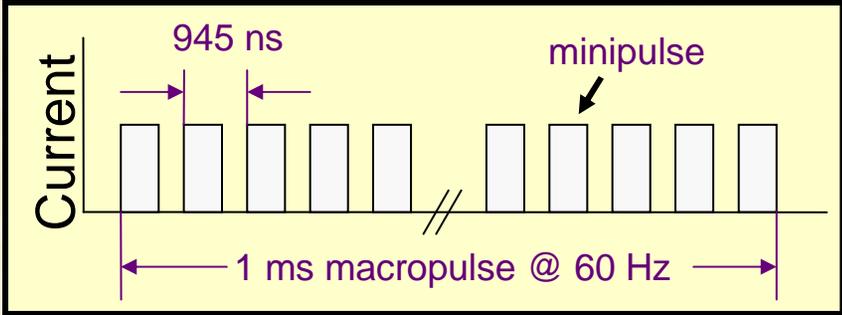
How it should work

Front-End Systems, 7m long
 Generate 2.5 MeV H- Beam of Minipulses, 68% beam, 32% gap, made by chopper, every 945ns for 1 ms long, 60 times per second

Injection Kickers

Extraction Kickers

| Beam Travel Length | |
|--------------------|----|
| FE | 7m |
| LINAC | |
| HEBT | |
| Ring | |



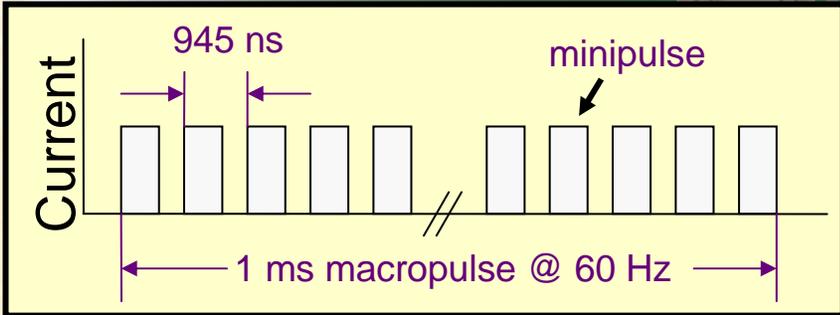
How it Should Work

LINAC Systems, 300m long
Accelerate the H- beam pulse to 1 GeV

Injection Kickers

Extraction Kickers

| Beam Travel Length | |
|--------------------|------|
| FE | 7m |
| LINAC | 300m |
| HEBT | |
| Ring | |



How it Should Work

HEBT Systems, 170m long

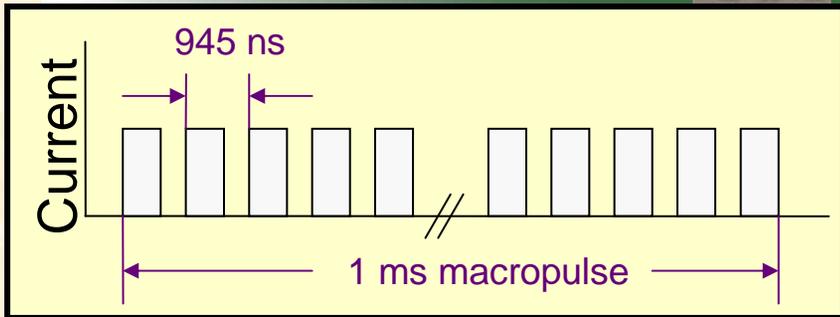
Transport the 1 GeV H- Beam of Minipulese to the strip foil at the Ring Injection;
H- stripped to protons

Injection Kickers

Extraction Kickers

Beam Travel Length

| | |
|-------|------|
| FE | 7m |
| LINAC | 300m |
| HEBT | 170m |
| Ring | |



How it Should Work

Accumulator Ring Systems, 248m circumference

Compress 1 ms long beam pulse to 650 ns; Preprogrammed Inj. Kickers move each mini-pulse transversely to meet beam specs. (*Inj. Painting Process*)

Injection Kickers

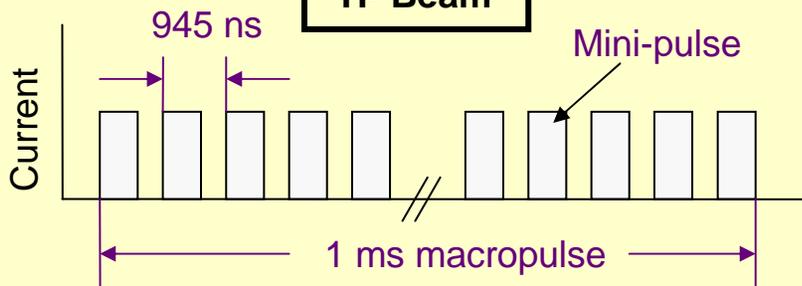
Mini-pulse

Beam Travel Length

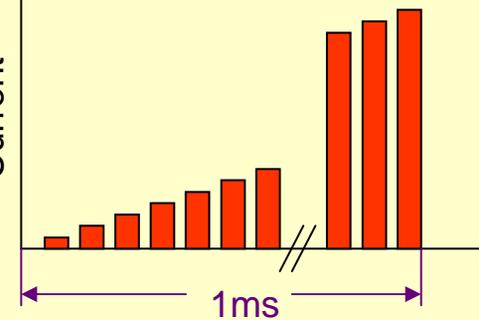
| | |
|-------|------|
| FE | 7m |
| LINAC | 300m |
| HEBT | 170m |
| Ring | 248m |

Proton Beam in the ring

H- Beam

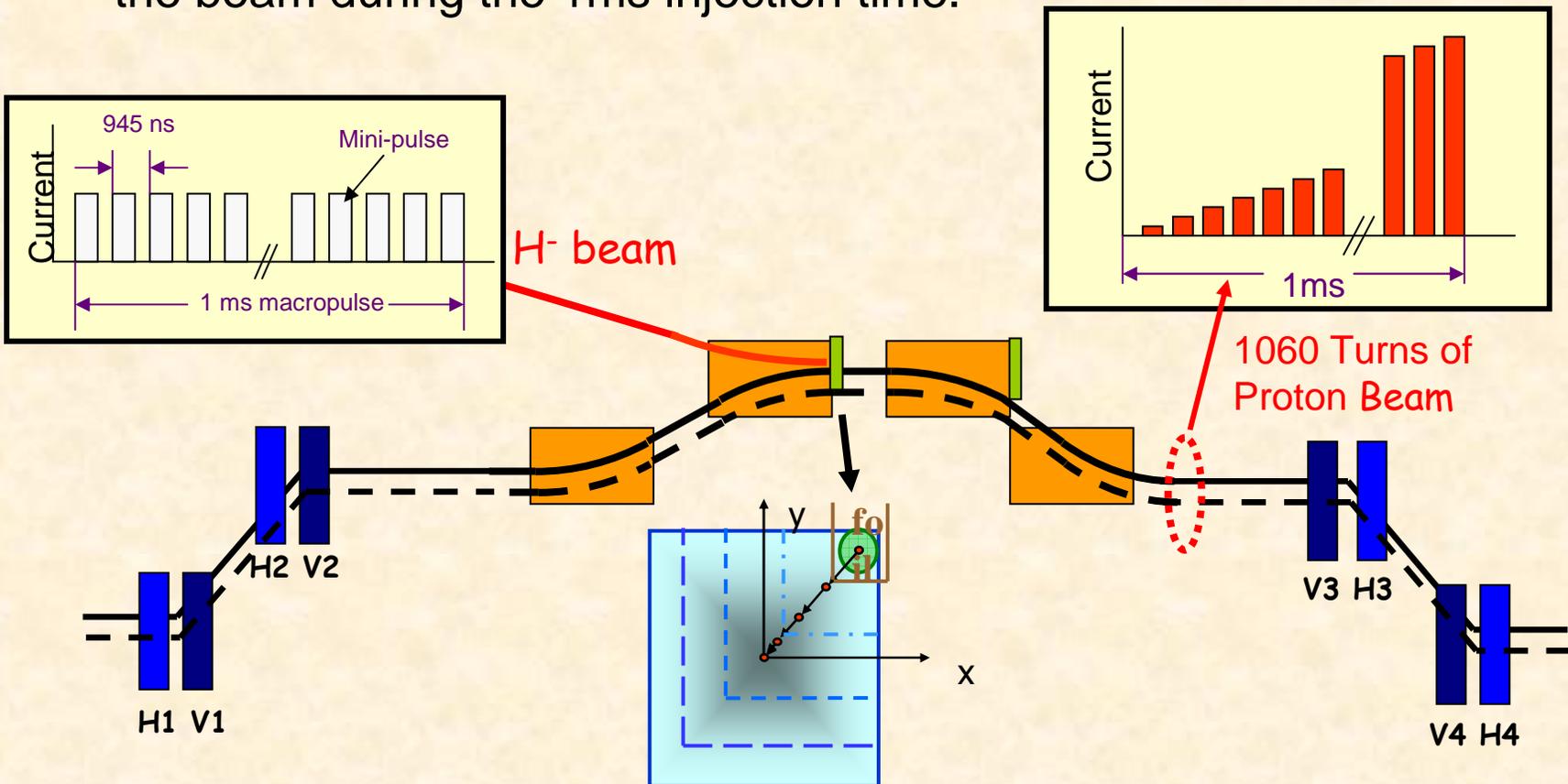


Current

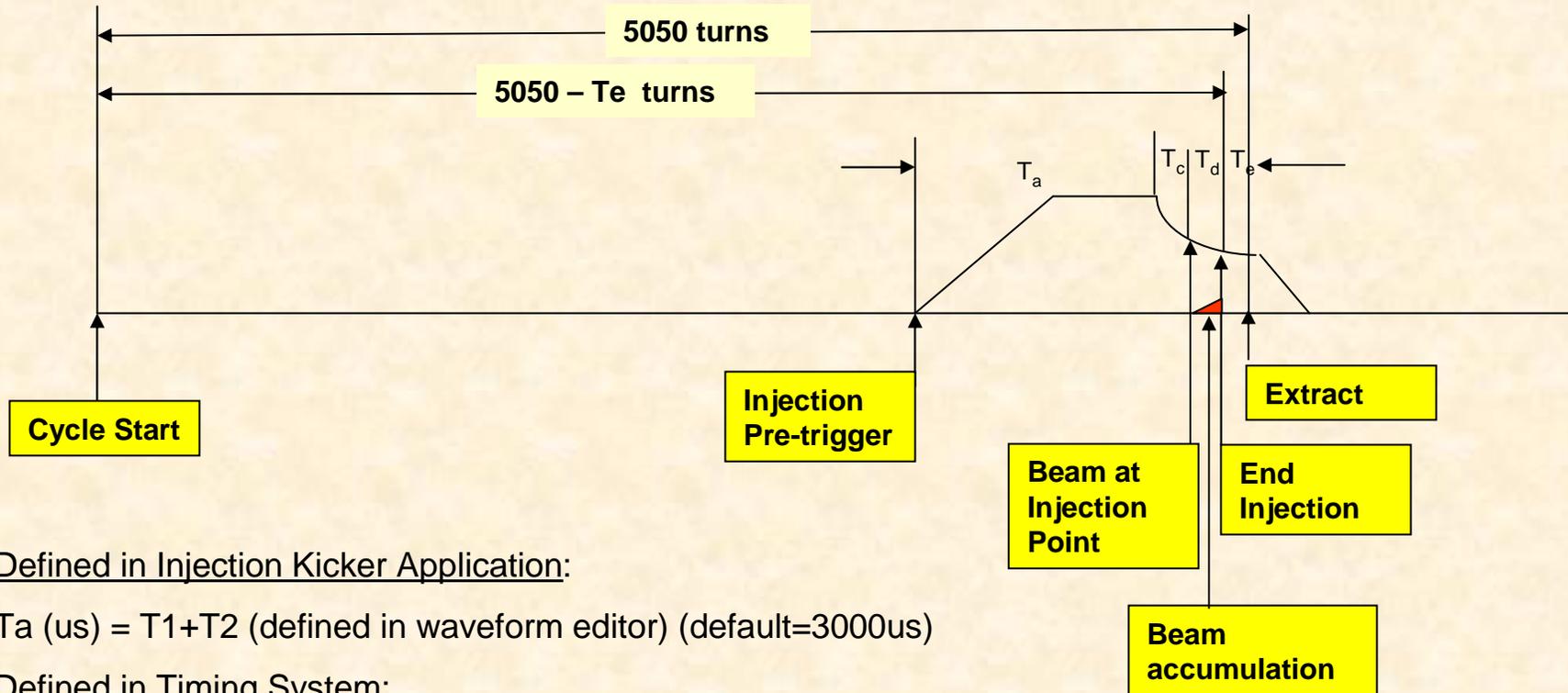


How it works - SNS Inj. Painting Process

SNS Ring Injection Painting Process is performed by 4 horizontal and 4 vertical kickers which produce a controlled dynamic deflection of the beam during the 1ms injection time.



SNS Injection Kicker Timing Requirement



Defined in Injection Kicker Application:

$$T_a \text{ (us)} = T_1 + T_2 \text{ (defined in waveform editor) (default=3000us)}$$

Defined in Timing System:

T_c (turn) = Injection Delay Time

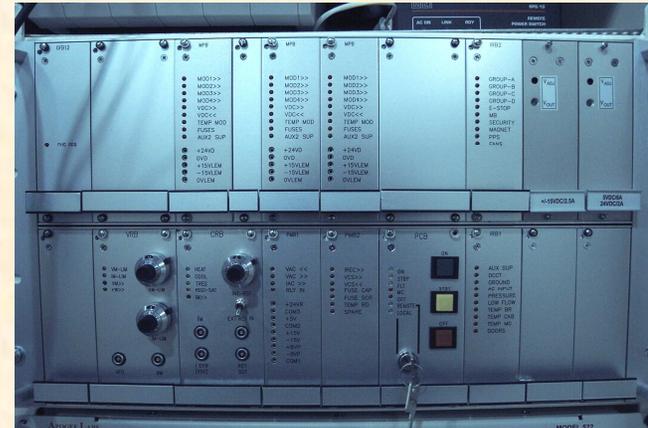
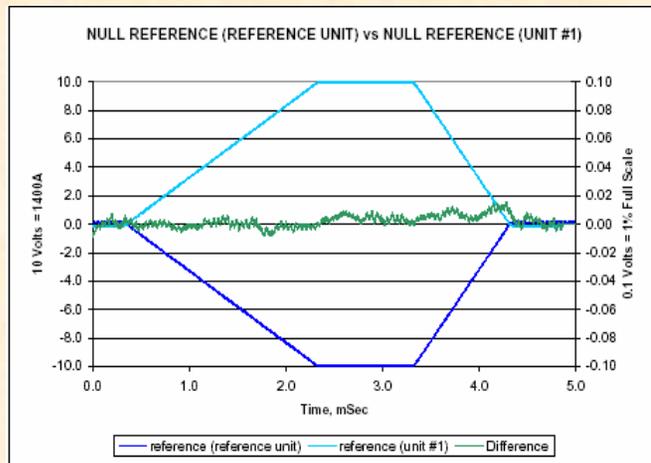
T_d (turn) = Beam Accumulation Time

T_e (turn) = Beam Storage Time

Support single or multi-pulse Injection with delay and storage time variation

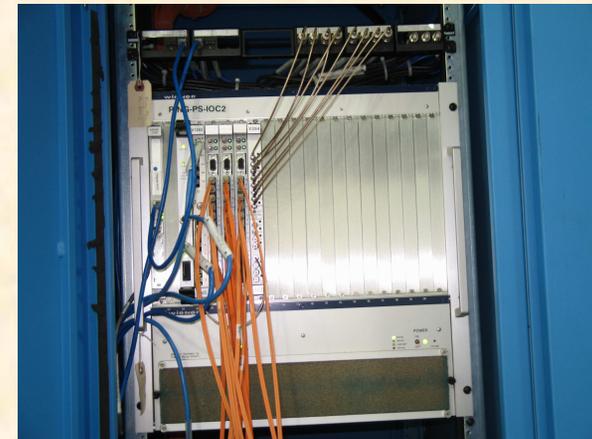
SNS Injection Kicker PS Hardware Limits

- Maximum rep-rate = 60 Hz
- Maximum peak current = 1400 amps
- Voltage = +/- 800 volts
- Ramp rate = 2 ms to 1400 amps
- Maximum hold time = 1 ms
- Fall time = 1 ms
- Maximum duty cycle = 15%
- Maximum dc current = 400 amps

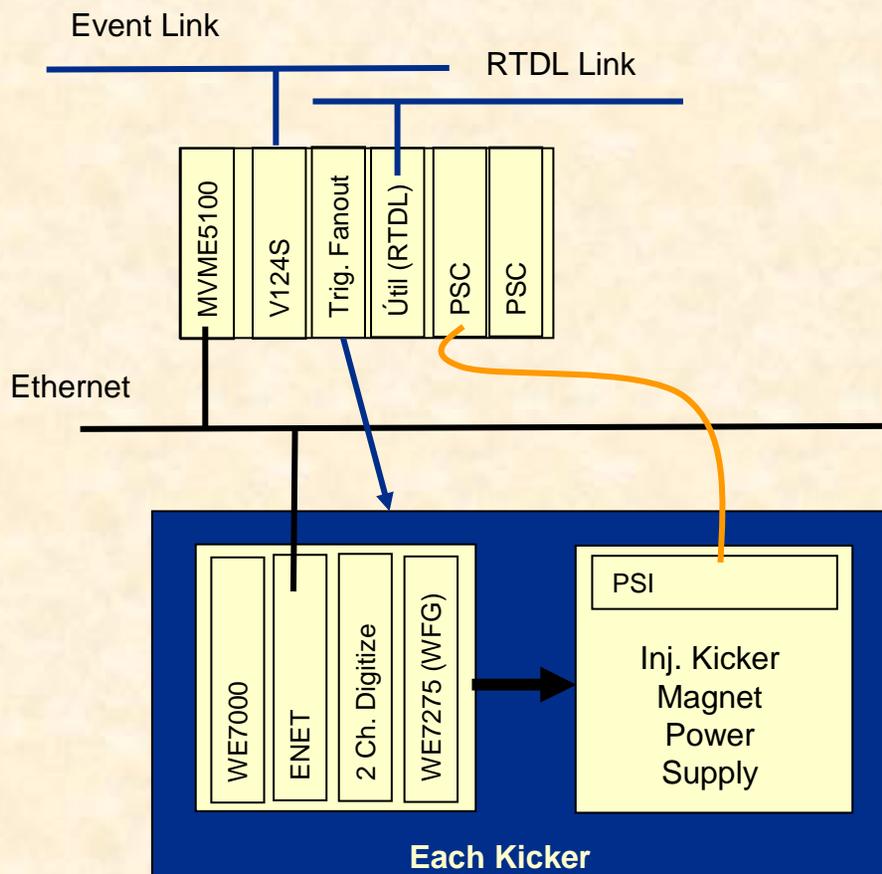


SNS Injection Kicker Control Hardware

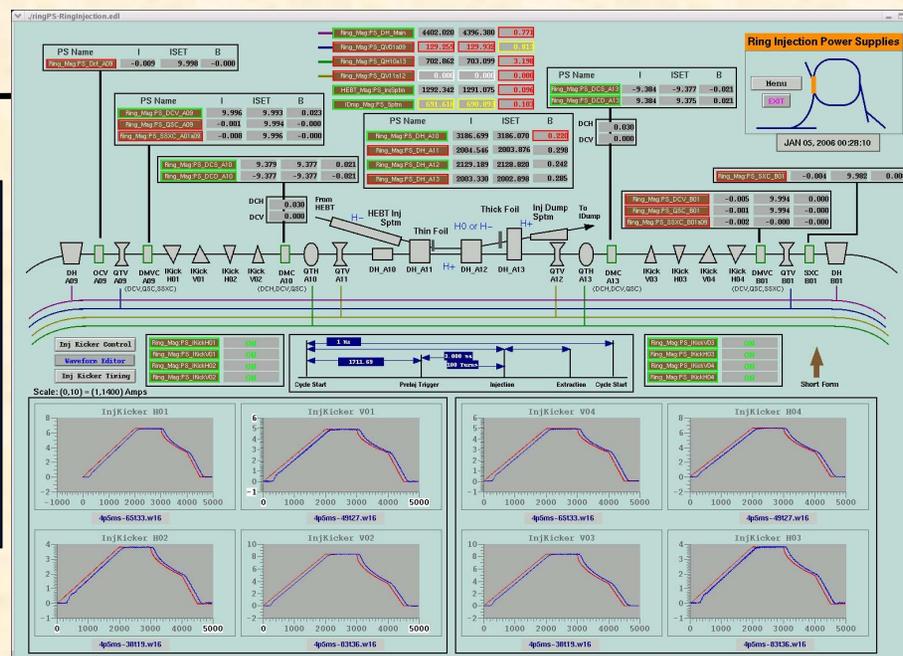
- Each of the kicker power supply equipped with a YOKOGAWA WE7000 system which includes a 10 MHz waveform function generator (WFG) module and a 2-ch, 1MS/s digitizer module and a PSI module.
- A pre-defined painting waveform is downloaded onto the YOKOGAWA WE7000 station and the WFG sends the waveform to the kicker power supply at the timing trigger rate.
- One IOC with MVME5100 Processor with several PSC and Timing Modules



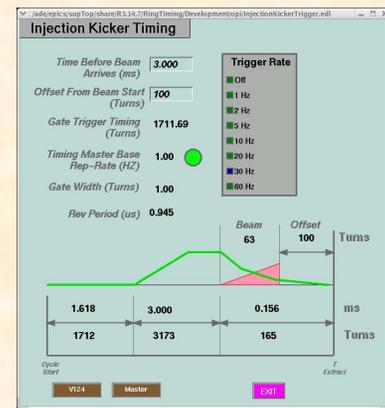
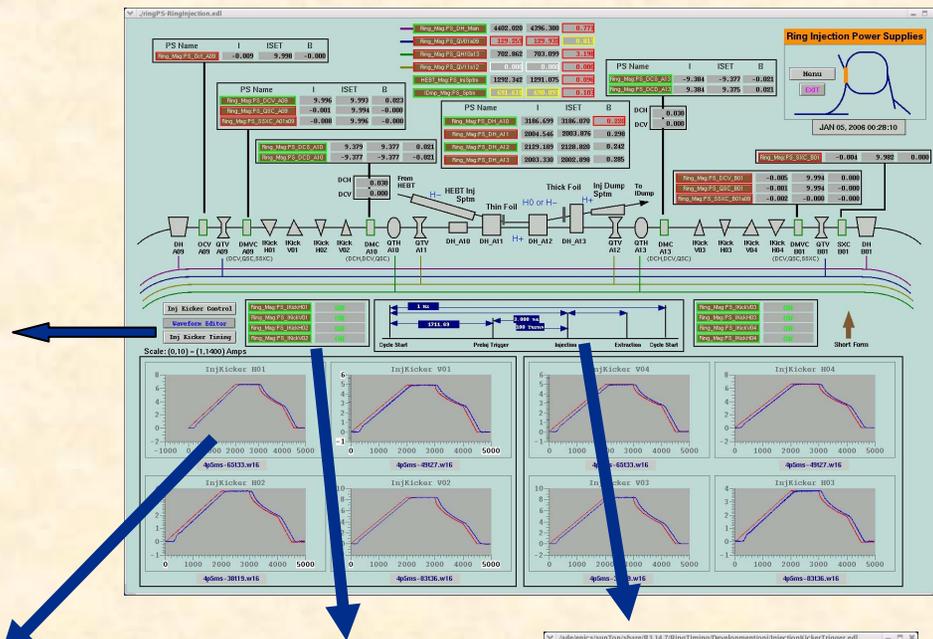
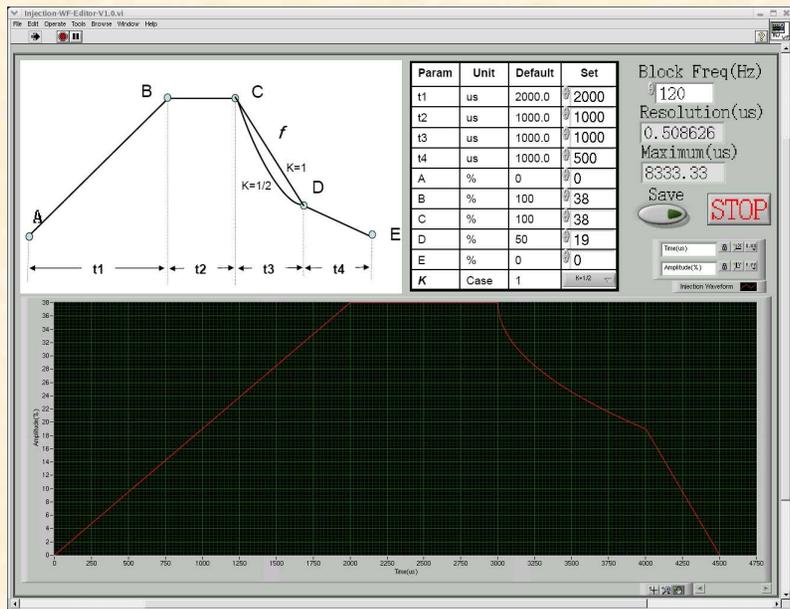
SNS Injection Kicker Control Software



- PSC Device Driver Support
- WE7000 Device Driver Support
- Waveform Editor
- Timing Software Support



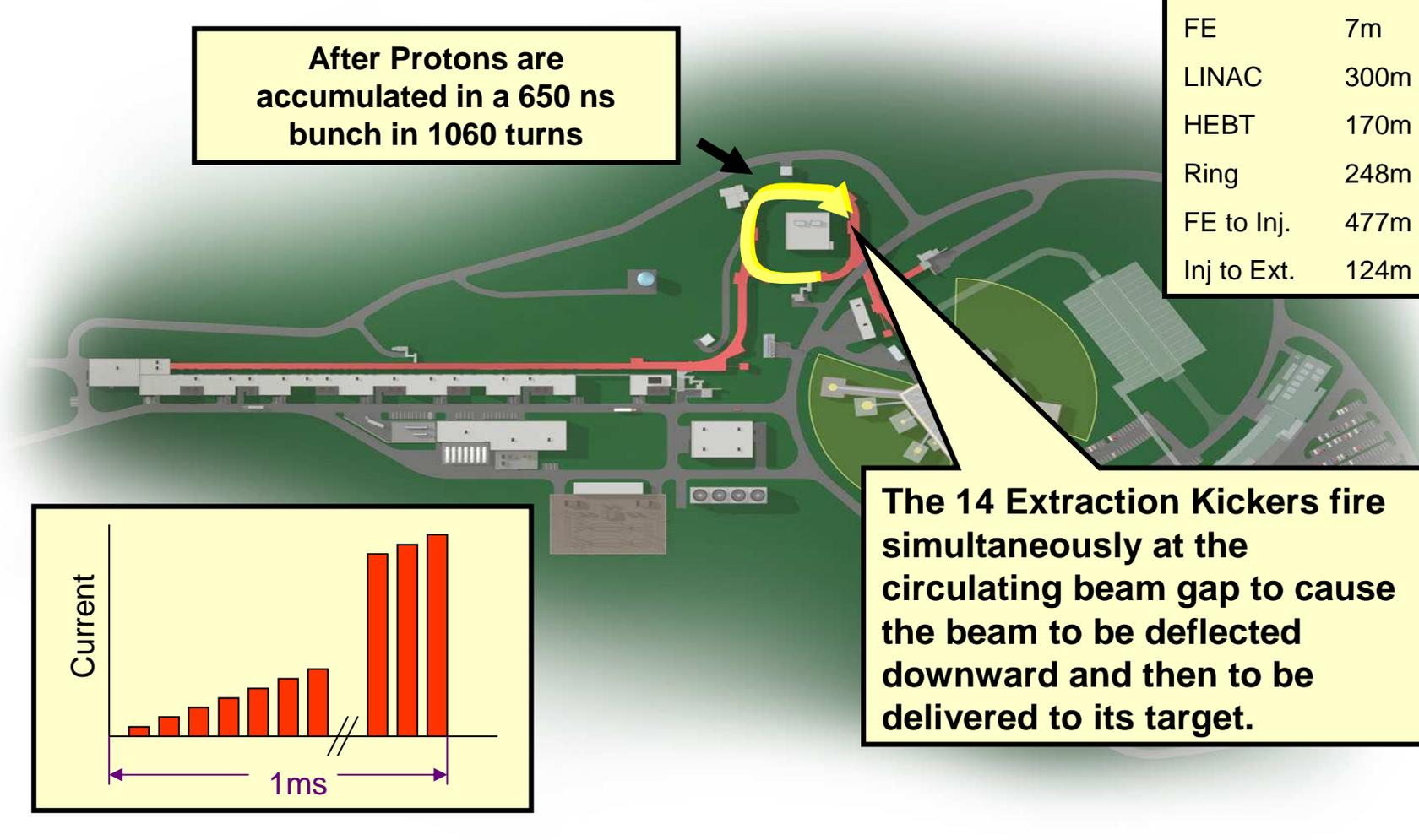
SNS Injection Kicker Control Software



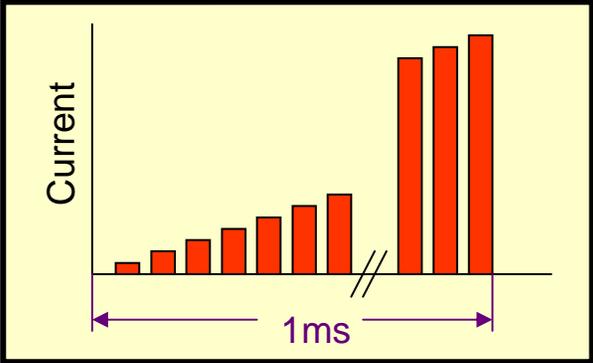
SNS Extraction Kickers

After Protons are accumulated in a 650 ns bunch in 1060 turns

| Beam Travel Length | |
|--------------------|------|
| FE | 7m |
| LINAC | 300m |
| HEBT | 170m |
| Ring | 248m |
| FE to Inj. | 477m |
| Inj to Ext. | 124m |



The 14 Extraction Kickers fire simultaneously at the circulating beam gap to cause the beam to be deflected downward and then to be delivered to its target.



SNS Extr. Kicker Control Hardware

PFN Control Racks

- Circuit breakers
- PSI
- PLC, monitors interlocks
- Auxiliary power supplies
- Voltage and Pulse monitors
- Thyatron Cathode and reservoir heater supplies
- ALE HVPS



SNS Extr. Kicker Control Hardware

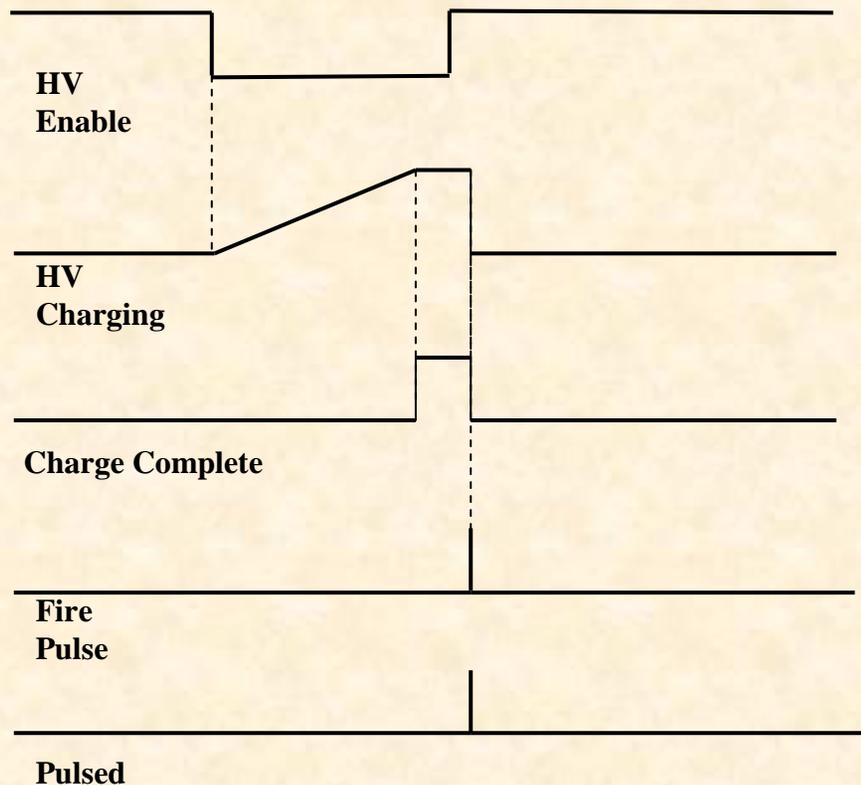
Kicker System Racks

- Timing and Pulse Monitoring
- Top scopes monitors charging voltage
- Bottom scopes monitors current from CT at the magnet
- DG535 delay generators



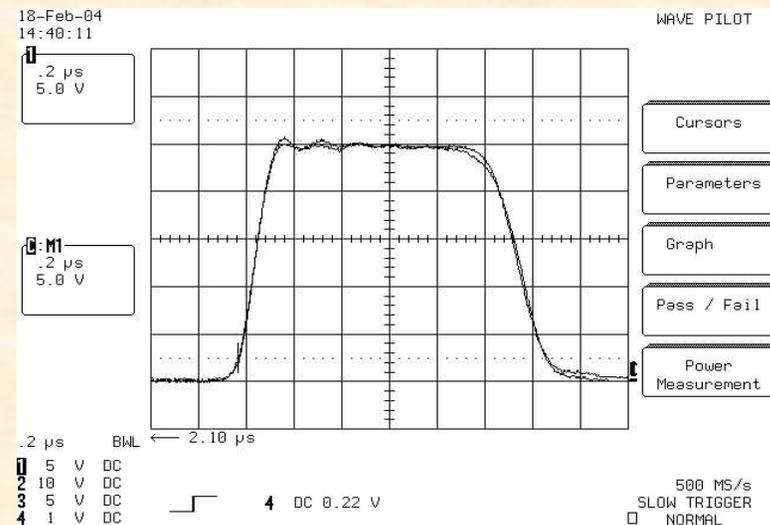
SNS Extr. Kicker Timing Requirements

Extraction Pulse Timing



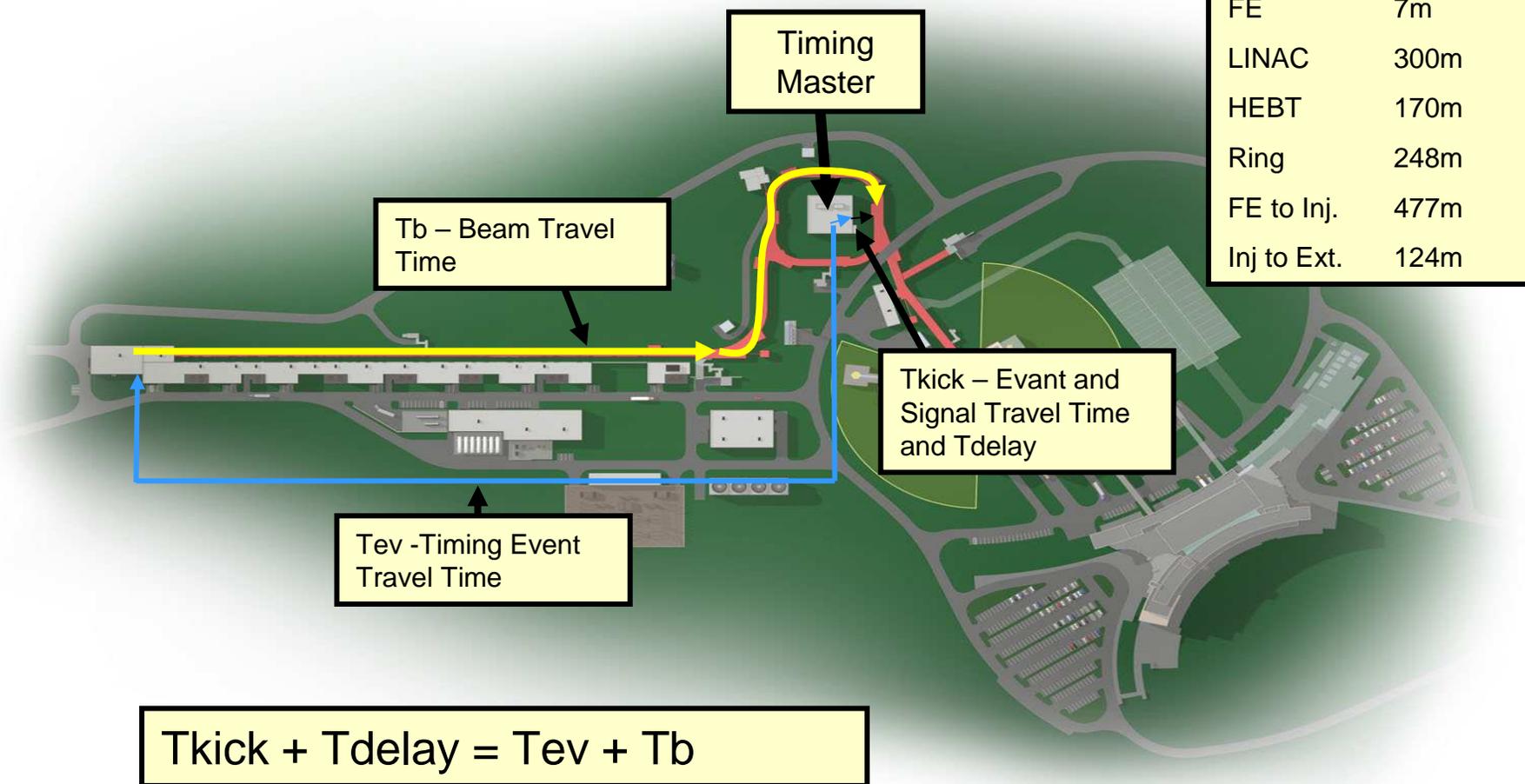
Extraction Current Pulse

- Rise Time = <math><200\text{ ns}</math>, gap time
- Flat Top = 2500 amps for 750 ns, with max of 5% ripple
- System can provide enough kick with 13 out of 14 operational
- CT at the magnet to show current profile
- PFN Charge Time ~13.5 ms

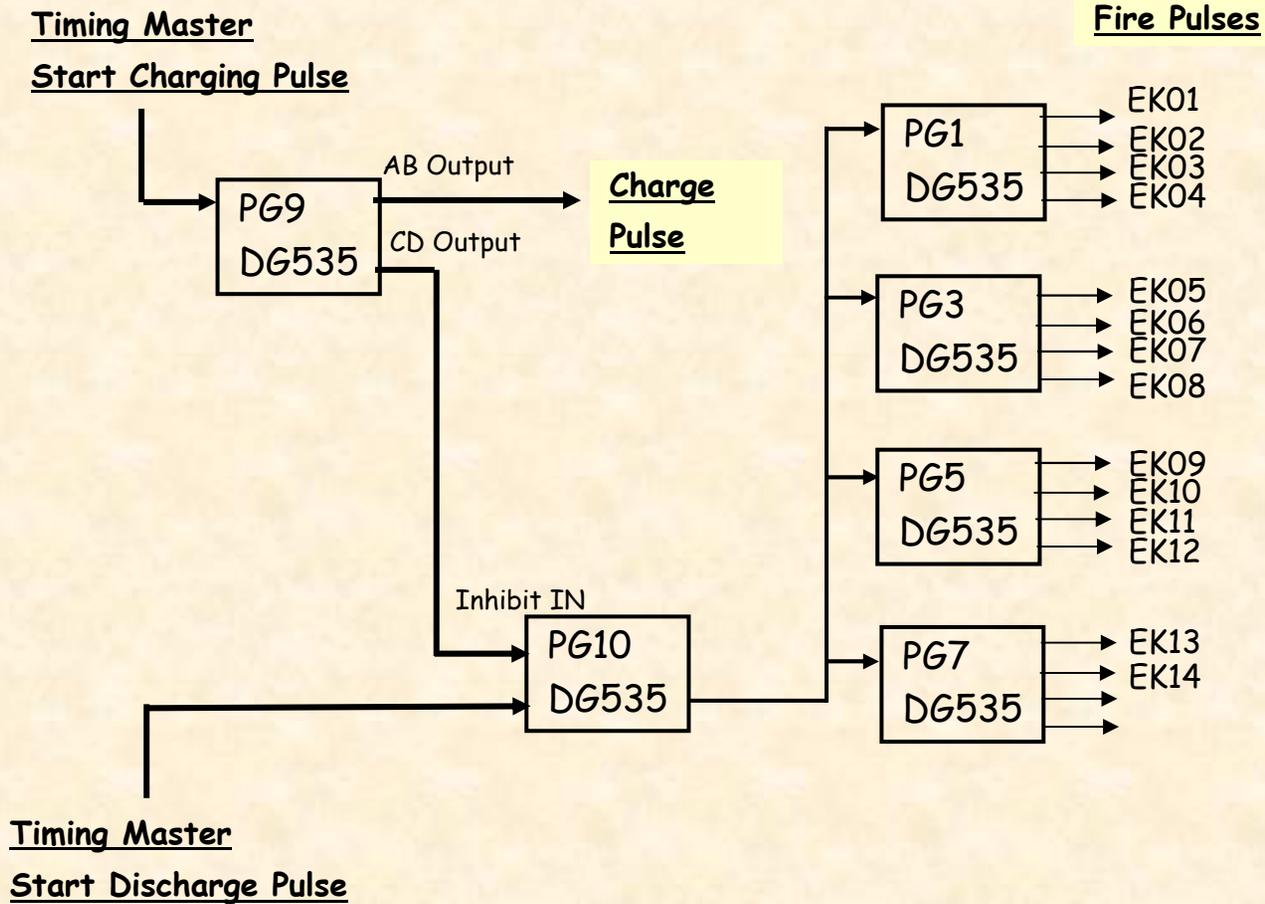


SNS Extr. Kickers – Timing Delay Control Requirement

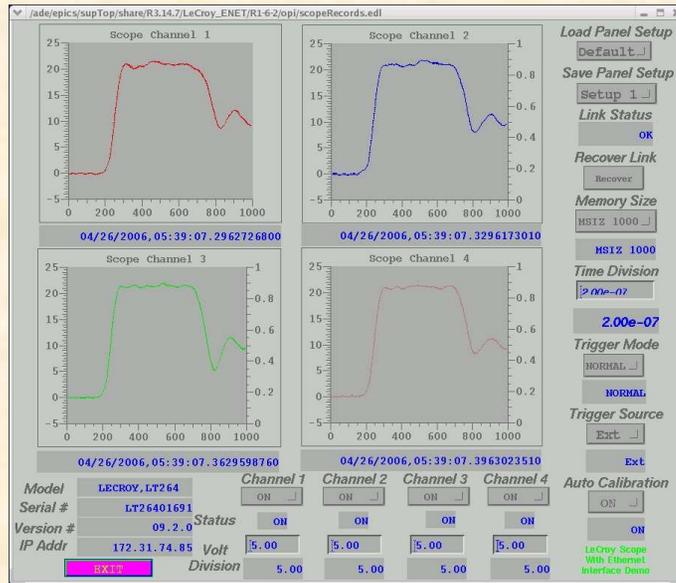
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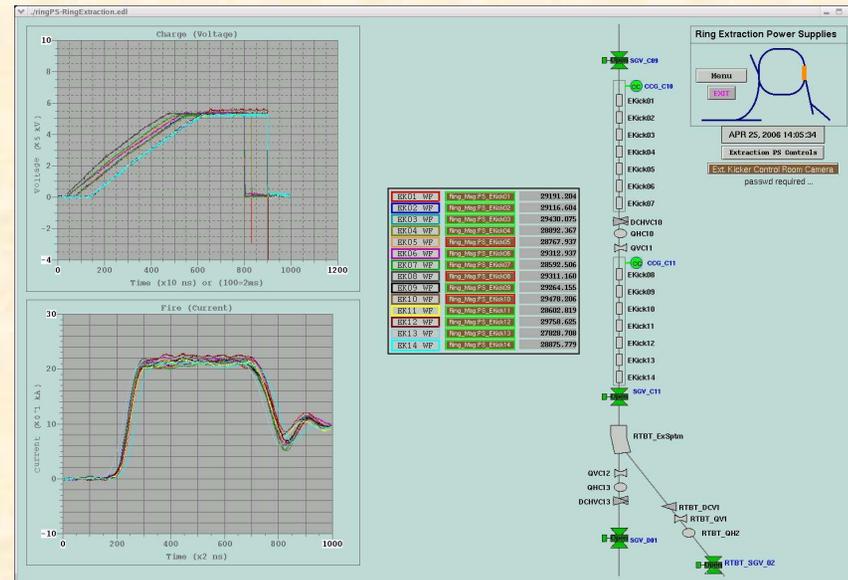
SNS Extr. Kicker Timing Delay Control



SNS Ext. Kicker Control Software



- PSC Device Driver Support
- LeCroy Scope Device Driver Support
- DG535 Device Driver Support
- Timing Software Support



Issues Learned and to-do

- LeCroy Device Driver Support – Move IOC Core onto the Scope (talk with LeCroy on the Library Routines)
- Rewrite Injection Waveform editor in EPICS (by end of July) and support current unit conversion for p-p amplitude knob
- Investigate and resolve DG535 “unreliable” write issue and bring read-only on-line first for the extraction kicker time delay control application
- Test ENET/IP for SCL500 for Ext. Kicker PLCs to minimize “hidden” control parameters
- Waveform array “Bug” in WE7000 devSup ?

Some of Our Lessons Learned

- Closely work with both Ideal and Realistic Experts to understand what they need
- Avoid discussion on control requirements in Ideal World or you will hear “EPICS can’t do this ???” to get depressed
- Control requirements from ideal world is ultimate fixed target; while aiming at this target, we should use phase approach to design and delivery our control system functions based on the limitation of the hardware in timely fashion

Summary

- Injection and Extraction Control Systems were good enough to support SNS CD4 (Good News 😊)
- Through our commissioning experience, we generated a list of improvement items for the kicker control systems (We have job – also good news 😊)
- I am currently writing EPICS Software Documentation that are used for SNS Kicker Control Systems
- Soon We will release Software along with the improvements on the web for EPICS community to share (Link from APS site)

Acknowledgement

Thanks for

- EPICS Collaboration
- BNL SNS Team
- Mike Plum (SNS Physics and Ring Commissioning Manager)
- Ken Rust (SNS Power Supply)
- Dave Thompson (SNS timing support)
- Sheng Peng (SLAC – work inherited from)

The End



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