Timing System at KEK 8-GeV Linac

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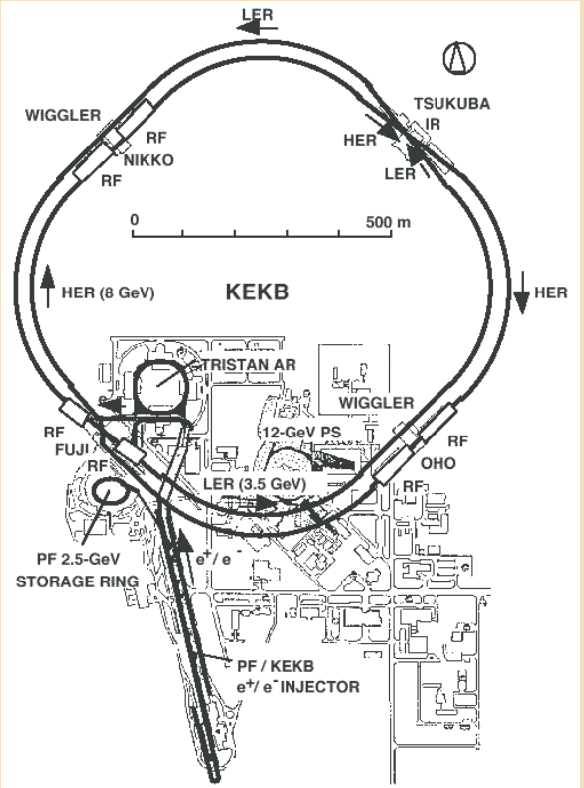
Electron/Positron Linac at KEK

<URL:http://www-linac.kek.jp/>

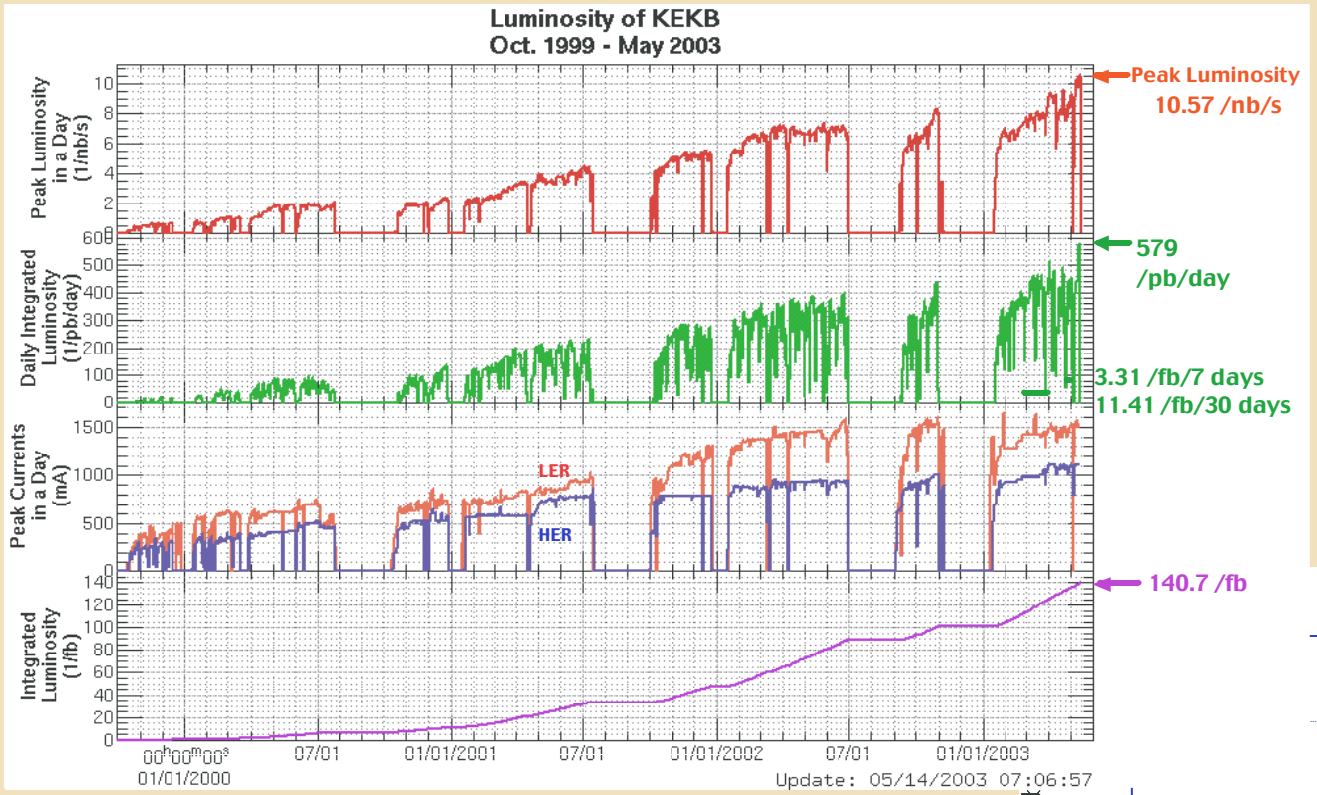
The timing system of the KEK electron linac has been restructured for the KEKB project since a higher precision was required compared with the previous project. It provides precise timing signals for accelerator equipement such as guns, rf sources, beam instrumentation, etc. along the 600-m linac. The signals can be synchronized to one of three rings, KEKB, PF and PF-AR. The clock system consists of five synchronized frequencies to drive different rf systems. The main clock of the timing system is 571.2MHz, which is distributed through a coaxial cable overwrapped with timing pulses. The delayed signals for over 100 devices are generated at 15 timing stations along the linac. Gate pulses are also distributed to enable intermittent measurement, etc. Timing signals are controlled through VME and CAMAC with the linac standard control architecture. The delay step of the timing signals is 1.75 ns and the precision is better than 5 ps depending on the location. It enabled stable long-term operation of the linac and also the recent "two bunch in a pulse" operation with its precise controls.

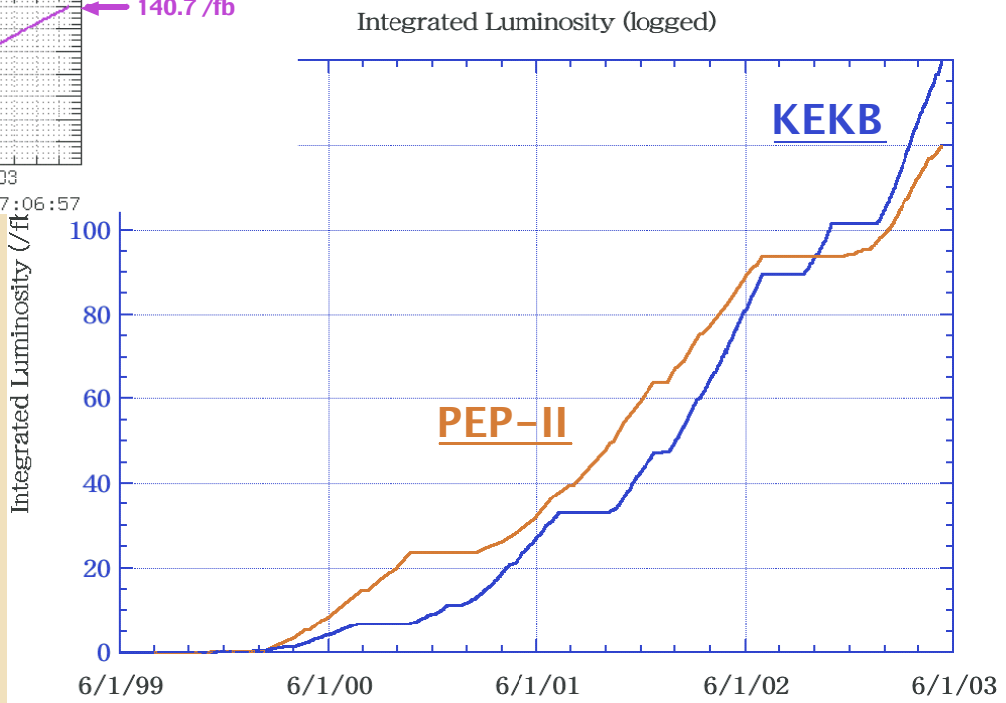
Introduction



- **Experiment Efficiency for B-Factory**
  - KEKB Electron Positron Asymmetric Collider
  - ==⇒ Stable Operation of Linac
    - Further Improvement
    - with 2-bunch and Continuous Injection
- **Timing System**
  - High Precision Injection Timing (<30ps,SingleBunch)
  - Timing Controls for SLED and 2-bunch Inj.
  - More than 100 Timing Devices along 600m
- **Frequent Beam Mode Switch (~50 Times a Day)**

KEKB e–	8 GeV 1.2nC Single Bunch	
KEKB e+,	3.5 GeV 0.64nC Single Bunch	with/without 2 Bunch Injection
	(Primary e– 10nC)	
PF e–	2.5 GeV 0.3nC Multibunch	
PF-AR e–	2.5/3.0 GeV 0.3nC Multibunch	





- KEKB Performance

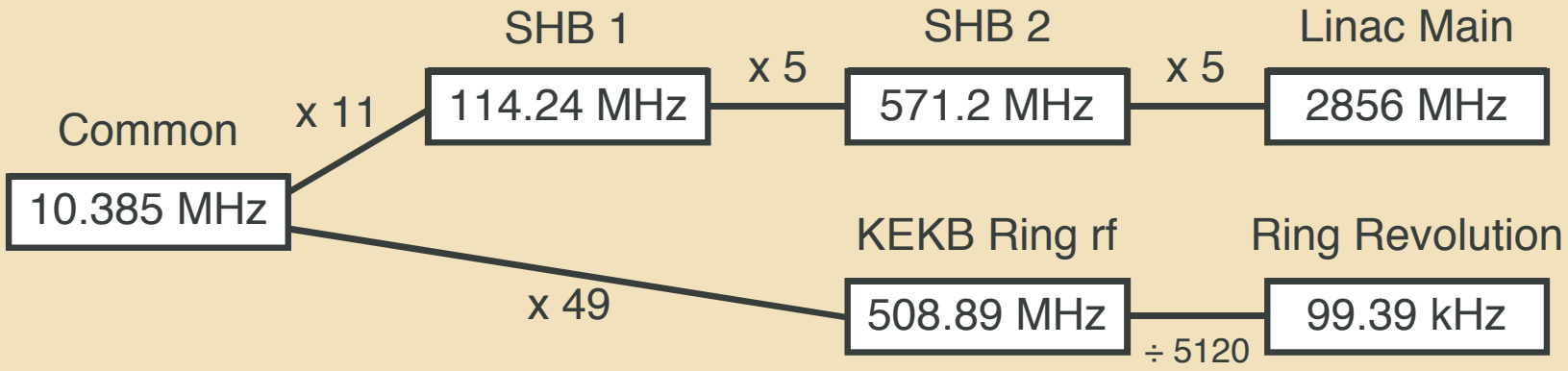
Good Competition with PEP-II

Timing System of Injector Linac

- Timing Delivery for
  - Beam from Electron Gun
  - Pulsed Microwave Generation, Envelope, SLED Energy Doubler
  - Timing for Beam Instrumentation
  - Injection Timing, Kicker/Septum Trigger
- Components Provide
  - Generation of Base Clocks
  - Distribution of Timing Signal
  - Generation of Hundreds of Delayed Signals
    at 15 Timing Stations
  - with Good Collaboration between Several Equipment Groups

Generation of Base Clocks

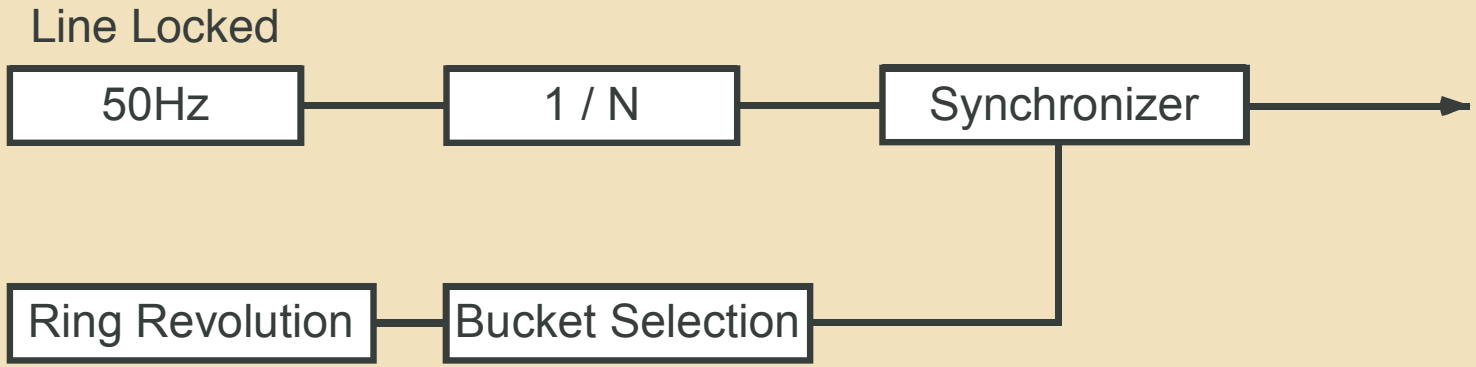
- (300ps Jitter was Allowed in Previous Project TRISTAN
  Asynchronous rf between Linac and Ring)
- In KEKB, Single Bunch Beam with Jitter <30ps Required
  ⇒ Need Integer Relation between rf Frequencies



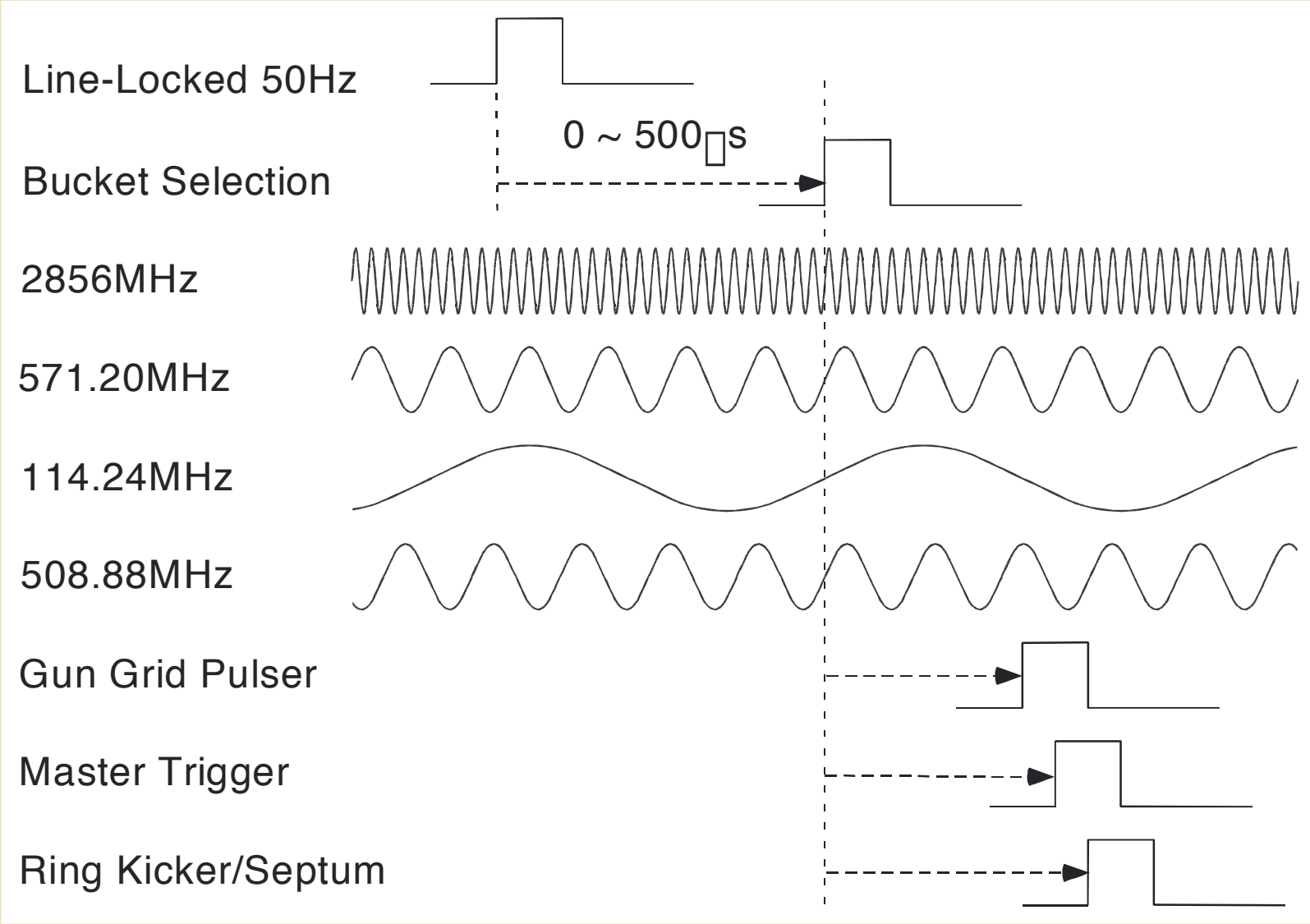
- All rf and Timings should be Based on
  Common Fundamental Frequency 10.385 MHz
- Freq. Multiplier/Divider was Developed for these rfs

Beam Timing

- Beam Timing is Synchronized to Both
  - Power Line Frequency (50Hz) (for Noise Elimination)
  - Revolution Frequency of Each Ring (with Bucket Selection)
- For Bucket Selection in KEKB Injection
  - Synchronizing Also to Common Freq. (10.39MHz)
  - (With Maximum Delay of 0.5ms for 5120 Buckets)
- Can Reduce to 1/N Rate



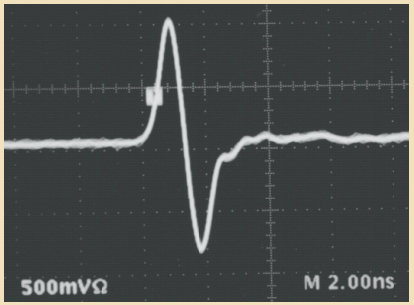
Simplified Timing Chart



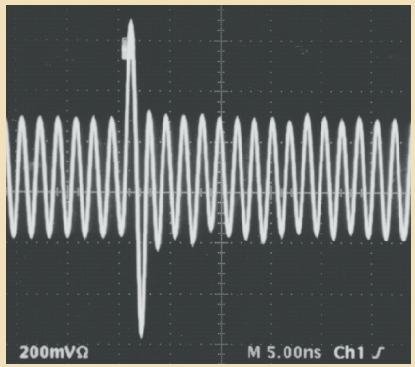
Distribution of Timing and Clock

- Required High-precision Timing at each Equipment
  Different Requirement depending on Equipment
  Precision <10ps, 1ns, 10ns; Step ～1ns
- Distribute Clock (571.2MHz) for Delay Counters
- Over the Same Cable with High Band-width
- 15 Timing Stations

Mono-Pulse Beam Timing

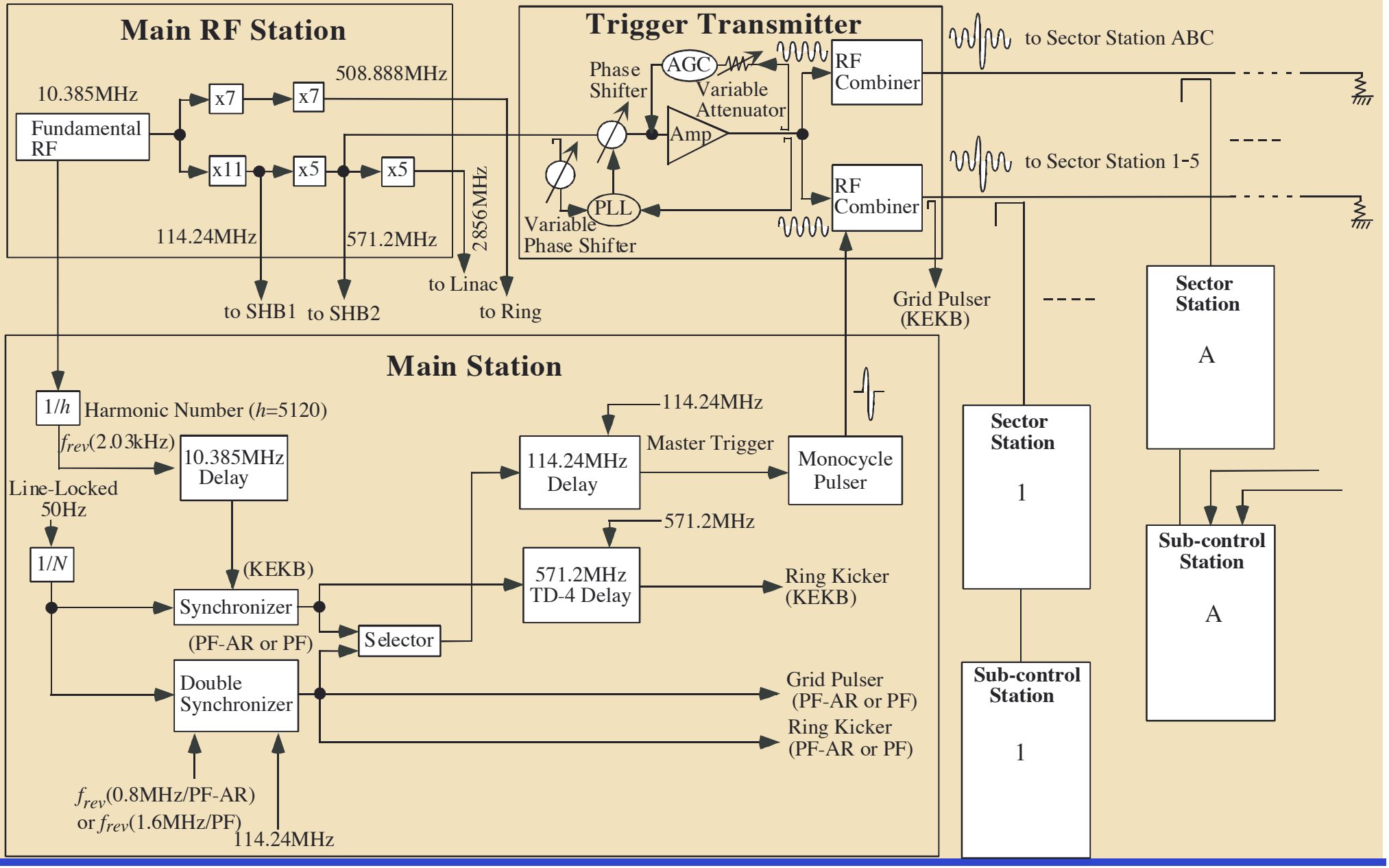


Overwrap with Clock (571.2MHz)



- Re-Generate Timing and Clock at each Station

Simplified Block Diagram

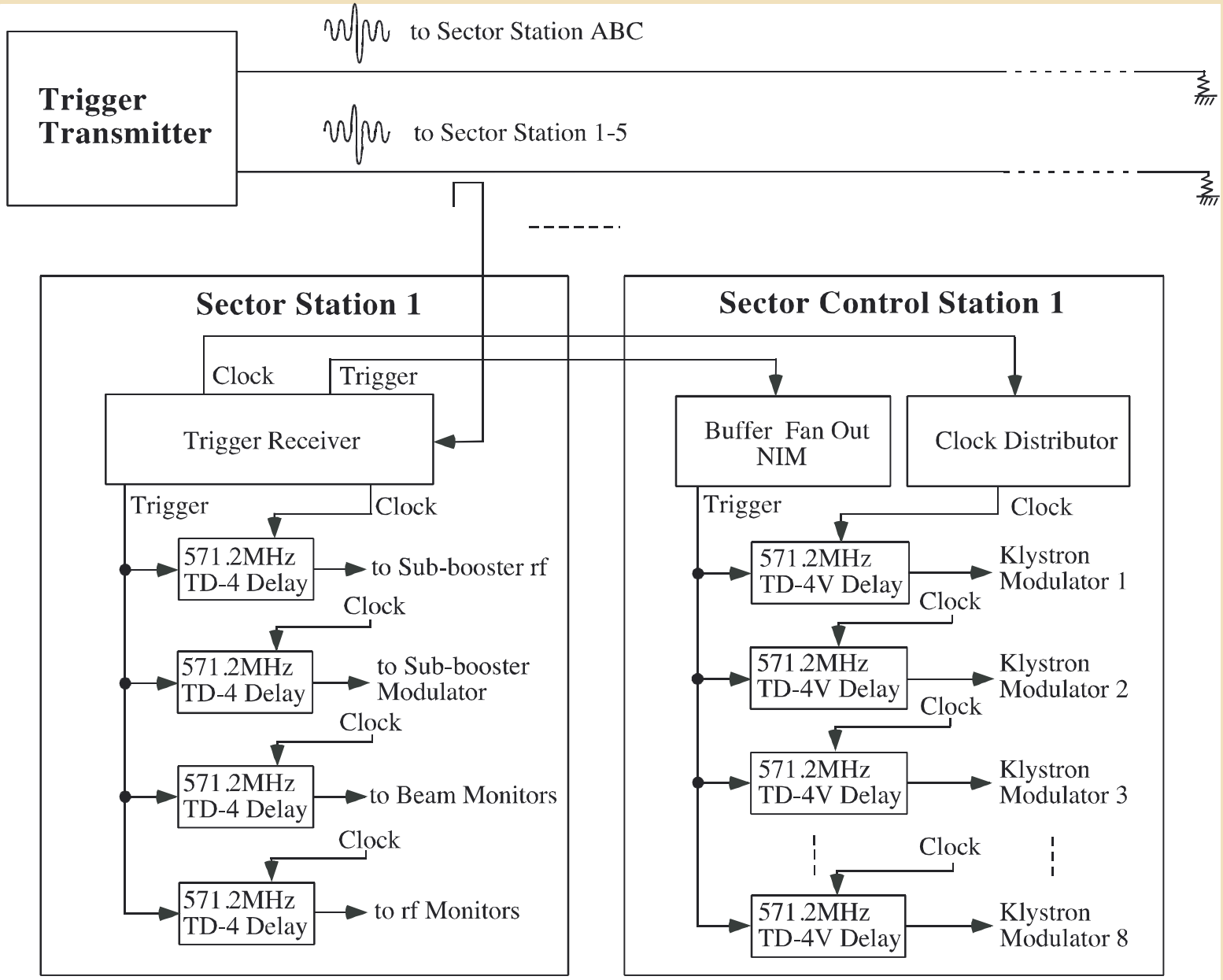


Timing Station

- Main Station and 15 Sub-Stations
- Main Station Generates Base Signals and Distributes them
- Sub-Stations Generate Delayed Timings
- TimingDelay4 (TD4) ECL 16bit Counter Delay (Max 114□s)
- Sub-Stations

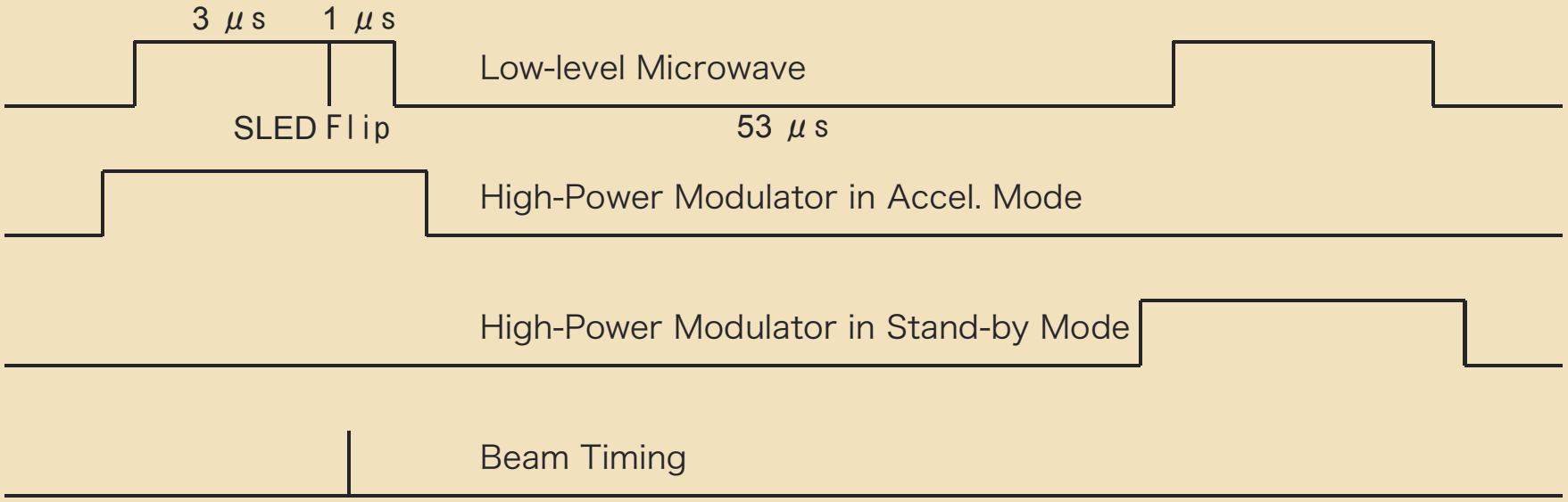
Station	Beam Station	Primary Sub-Station	Secondary Sub-Station
Number	1	9	5
Receiver	TD4R	Trigger Receiver	-
Delay	TD4R	TD4	TD4V
Field Bus	RS232C	CAMAC	VME
Equipment	Beam Gun	Low-level rf Beam Monitor	Modulator

Timing Transmission and Re-generation



Pulsed Microwave Timing

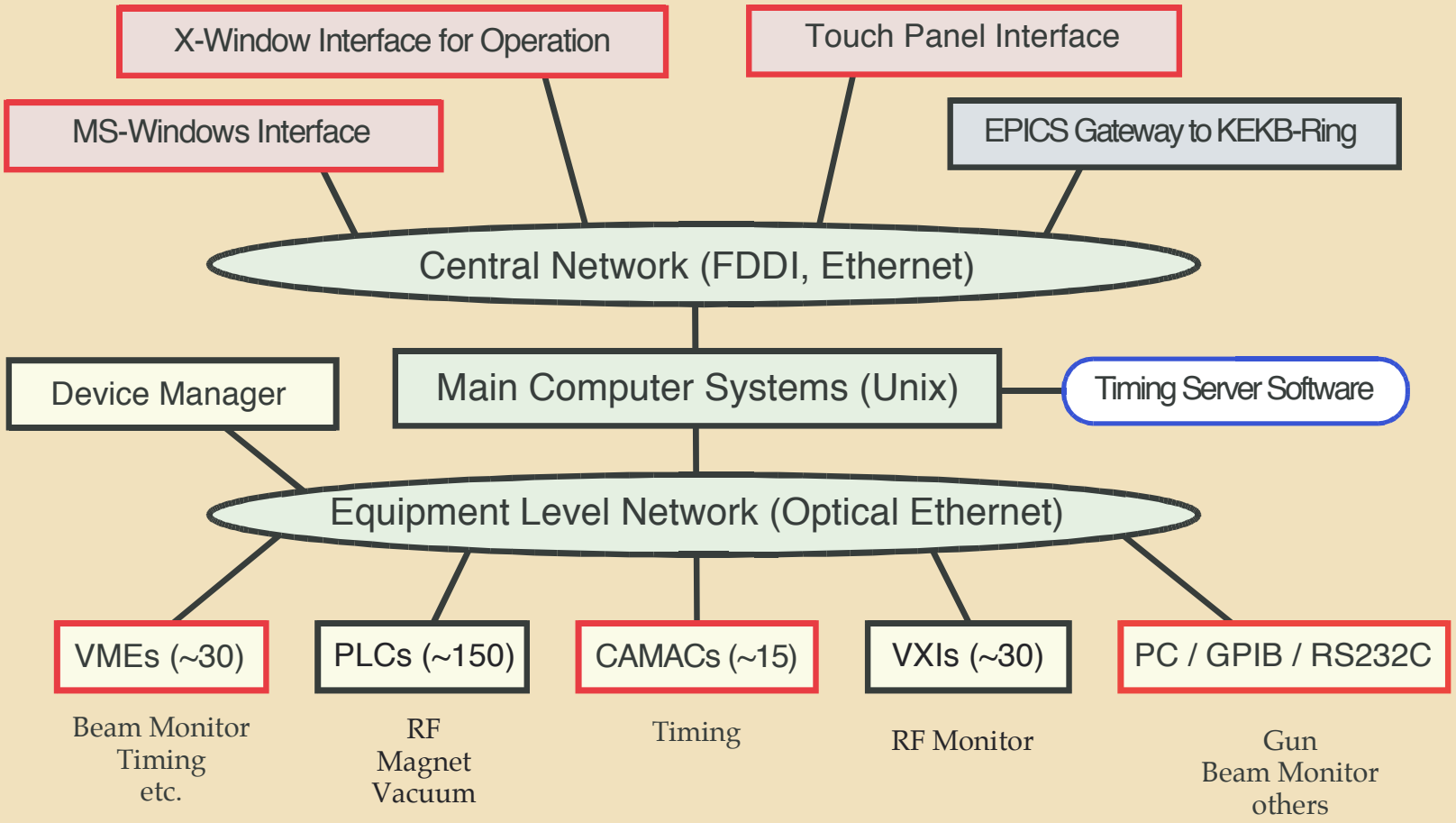
- **Low-level Microwave Timing**
  - Pulse Envelope, SLED (rf Compressor) Phase Flip
  - 57 □s Delayed Pulse for Stand-by rf Units
    - 8 Sub-stations, 32 Timing Signals (~1ns stability)
- **High-power Klystron Modulator Timing**
  - High-voltage Pulse Timing
    - 6 Sub-stations, 59 Timing Signals



Timing for Beam Instrumentations

- **Streak Camera**
  - Precision Much Better than 10ps
  - 4 Locations
- **Beam Position Monitors**
  - Precision Better than 1ns (Software Finds Real Peak Locations)
  - 19 Locations, 90 BPM's
- **Beam Wire Scanners**
  - Precision Better than 1ns
  - 2 Locations, 14 Scanners
- **Source and Beam-Induced Microwave Monitors**
  - Precision Better than 1ns
  - 8 Locations, 30 Monitor Stations

Control System

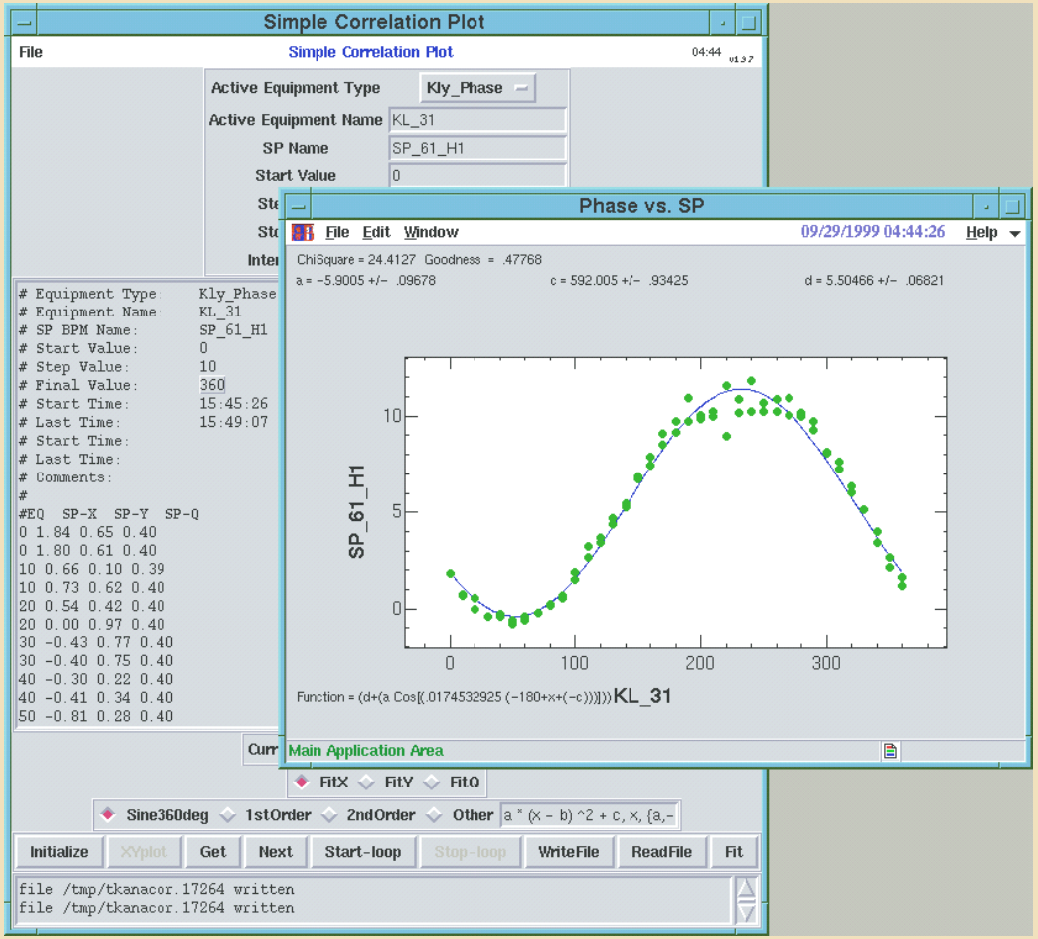


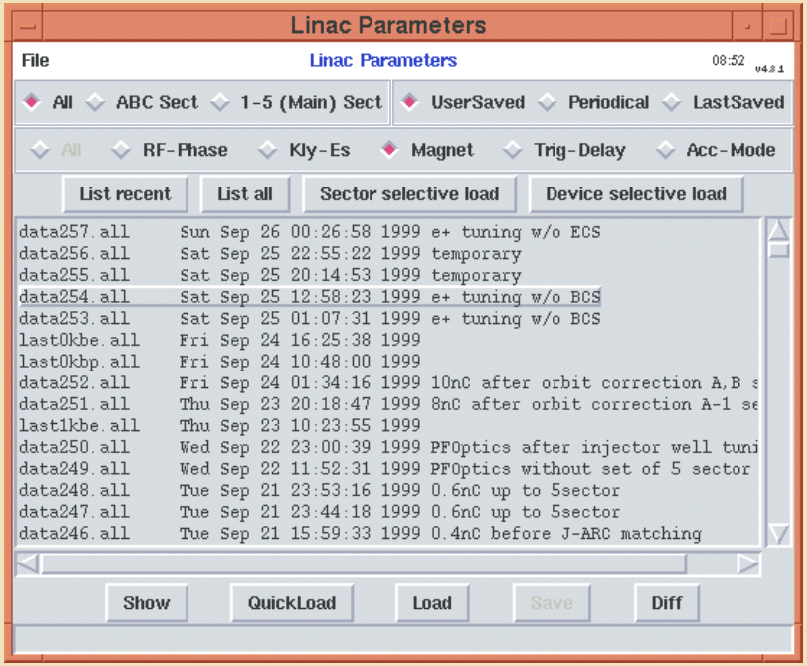
- Red and Blue Boxes are Timing System Related
  Multi-layer Software Hides Hardware Differences

General Operation Tools can be Used with Timings

- Active Correlation Plot enables Automated Parameter Optimization

  Passive Correlation Plots are also Used to Find Multi-Parameter Correlations





- Equipment Parameter Save-Load Panel Has Many Optional Features

Past Troubles

- **Ethernet-CAMAC Driver Software (Hytec ECC)**
  - Did not work well under Multi-server Multi-client Env.
    - Much Work-around Software was Written
- **Very Low-rate Output Failure with TD4/TD4V**
  - Comparator Chips for Input Discrim. and Output Width
    - Stop Output Signals for just 200ms
    - Rate was less than Once in 2 weeks
    - All Comparators were Replaced

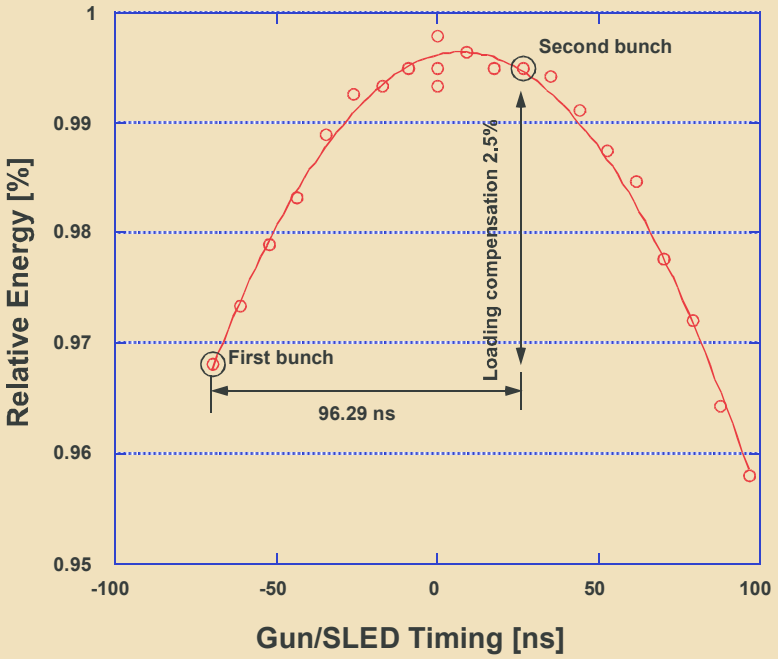
Bunch Energy Difference in 2-bunch Mode

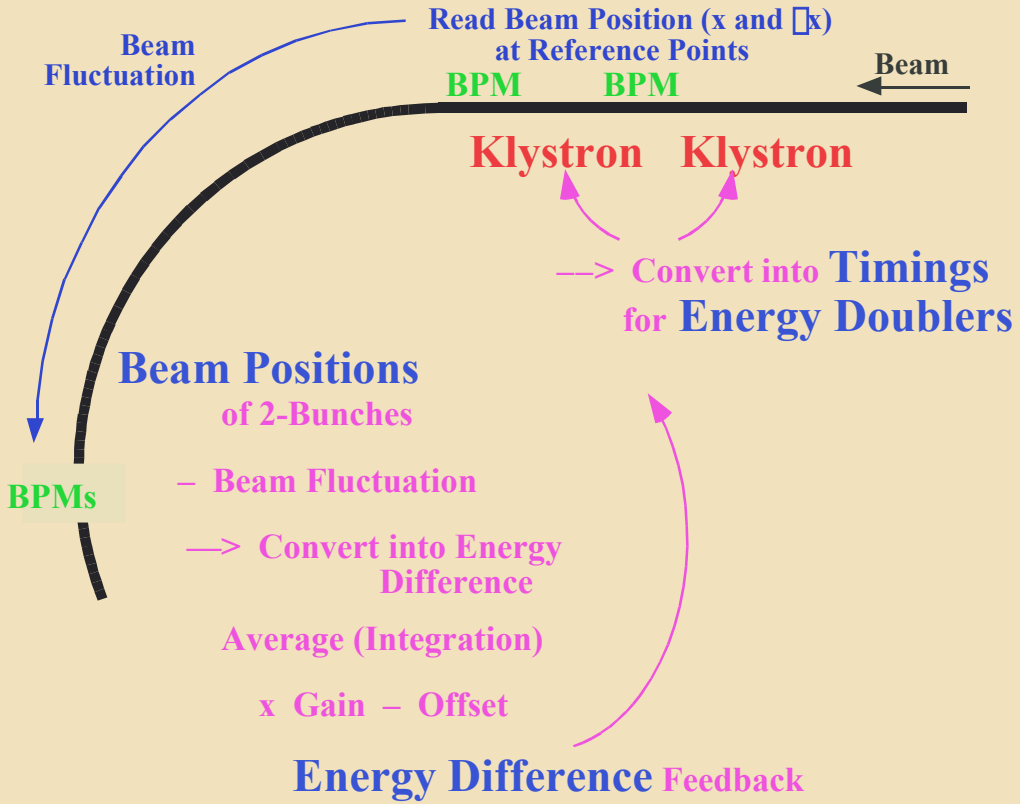
◆ Controls of Energy Difference with rf/SLED Timings

Energy Difference is Dependent on Bunch Current

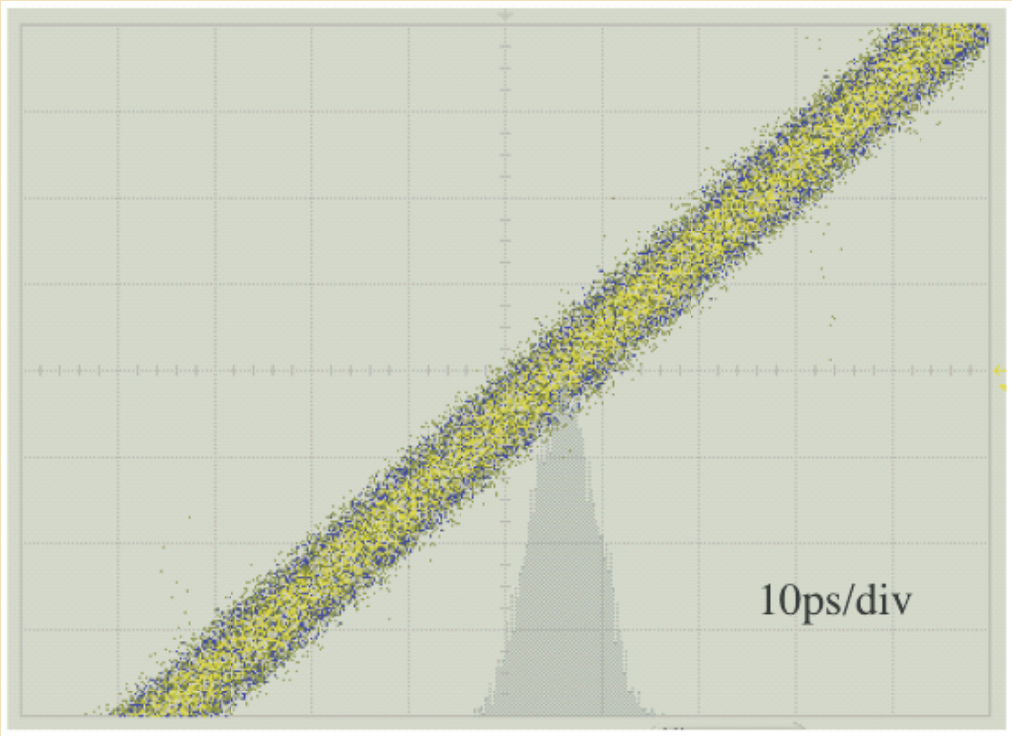
(Primary e- 10nC、Secondary e+ 1nC)

◆ Simple Stabilization Loop



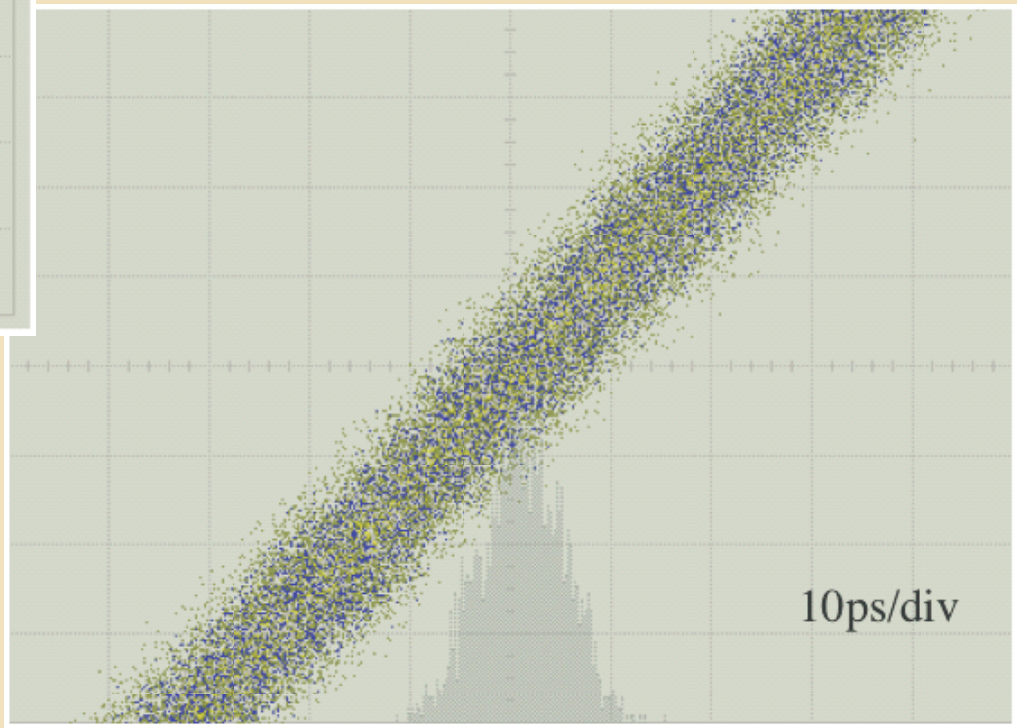


Jitter Evaluation



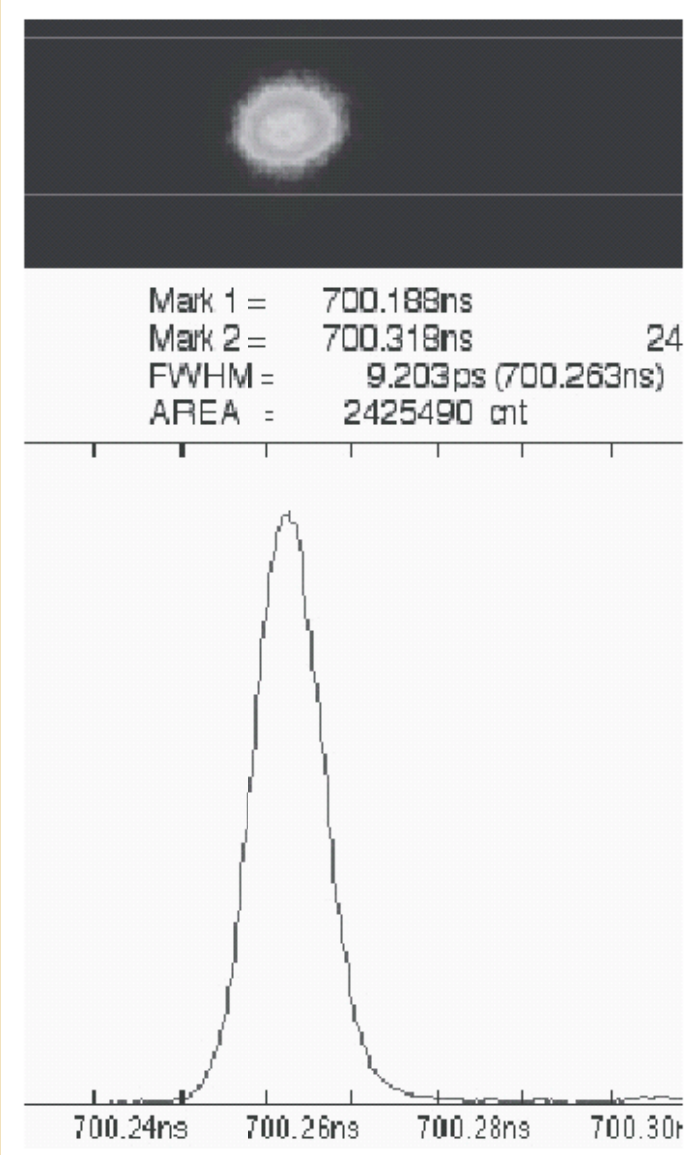
Single TD4
<3ps rms

Turn Around Through
Sector-5 ~400m x 2
<4ps rms



Conclusion and Future

- **Timing System Works as Expected**
  - Achieved Satisfactory Precision
  - Flexible Controls of >100 Delays
- **Performance of Timing System**
  - Based on Beam Width Meas.
    - Far Better than 10ps (~3ps)
- **Surveillance System**
  - Clock Phase Monitor Oscilloscope
  - TD4 Monitor with TDC
- **Improvement of Beam Operation**
  - 50Hz Instrumentations
    - for Fast Beam Feedback etc.
  - Intermittent Beam Monitoring
    - Even During Continuous Injection



Thank you ...