

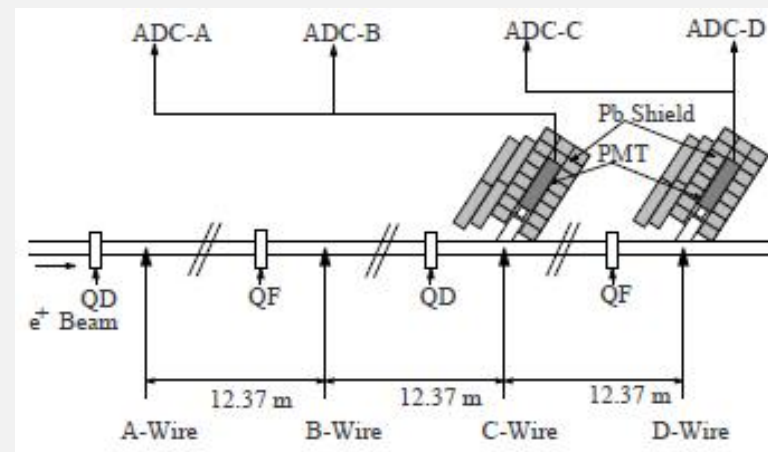
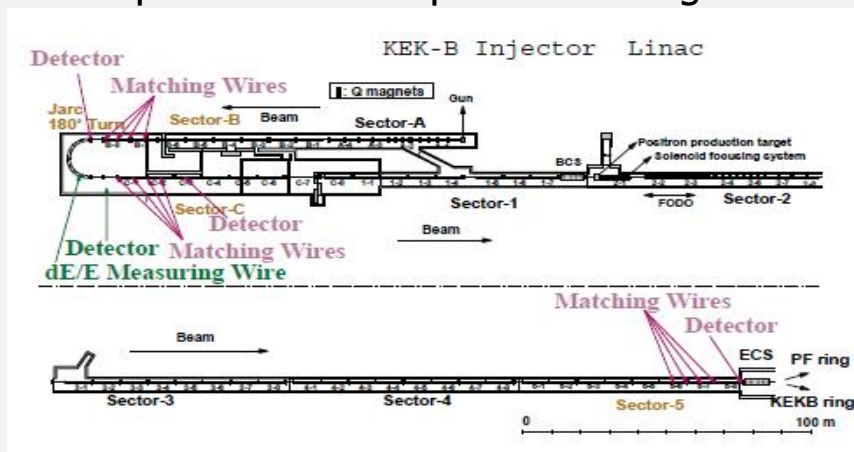
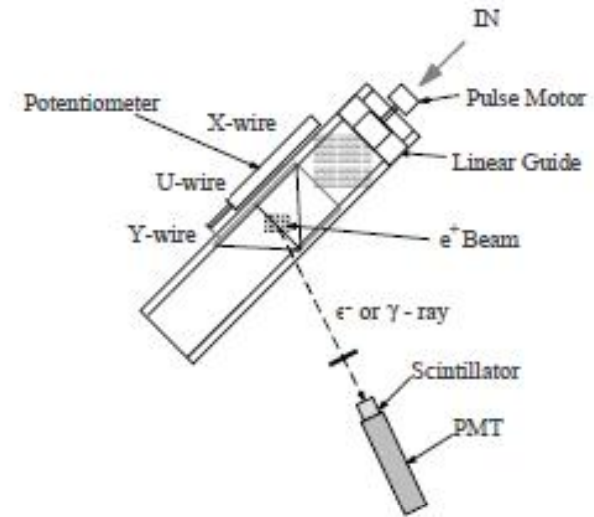
# **Development of fast controls for Beam Wire Scanner at SuperKEKB**

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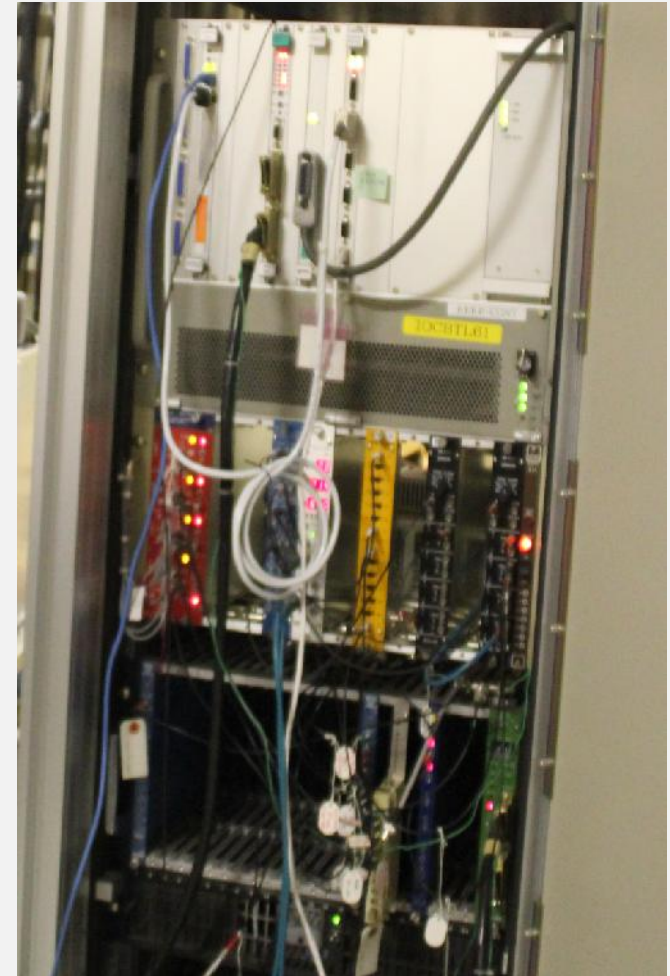
# What is Wire-scanner?

- Used for Non-destructive monitoring of beam profile
- A frame holding 100 $\mu$ m Tungsten wire forming X, Y & U wires perpendicular to beam
- A stepper motor drive to move the frame inside beam line
- A PMT with Plastic Scintillator to detect Bremsstrahlung emitted due to interaction of wire with Beam
- A control & data acquisition system
- A set of three (atleast) wire-scanner for measuring beam emittance & Twiss parameter for optics matching

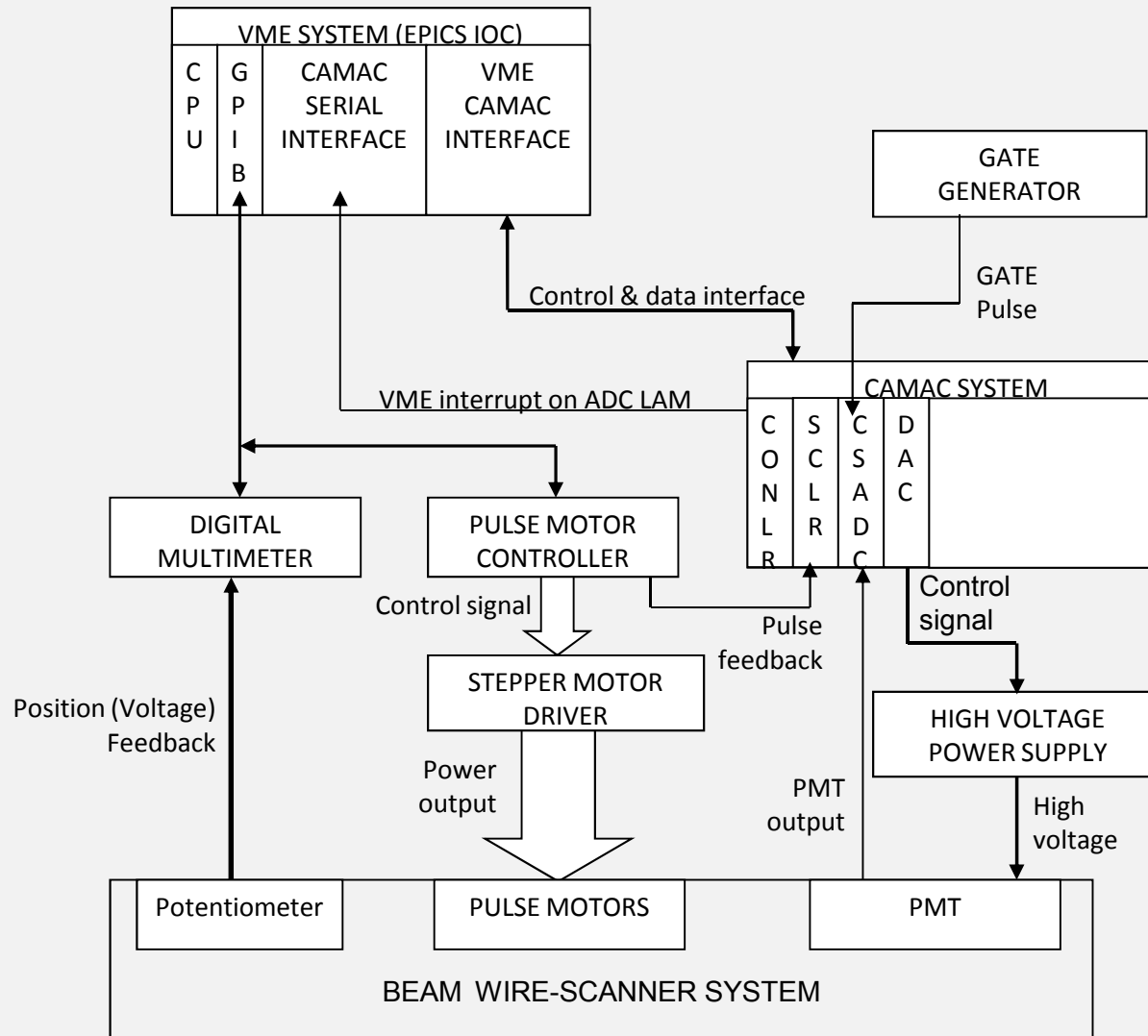


# Existing system

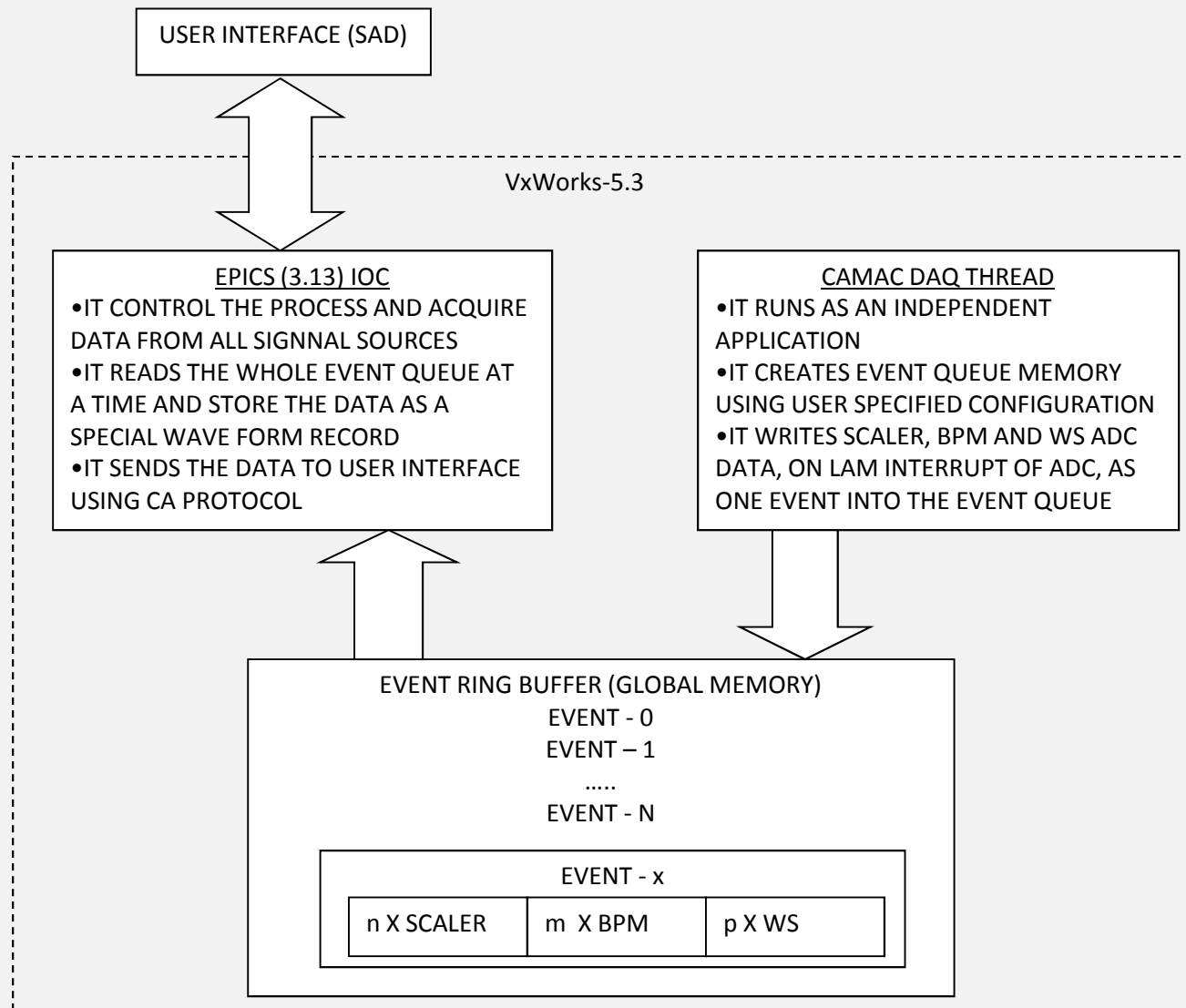
- VME/CAMAC system
- EPICS Base-3.13 and Vx-Works 5.3
- PowerCore 6750 CPU card
- 12 ch Lecroy CAMAC ADC
- VME GPIB controller to communicate with Pulse motor controller & Digital Multimeter
- ADC Gate signal generated from Beam timing signal, no information about beam mode
- Beam mode identification using dedicated ADC channel for each beam mode
- IOC independent process for acquiring Beam data and wire position signal and saving in buffer
- Uniform wire speed while scanning the beam
- Not suitable for acquiring multiple beam mode data



# Existing system (hardware architecture)



# Existing system (software architecture)



# Why is the new controls for Wire-scanner?

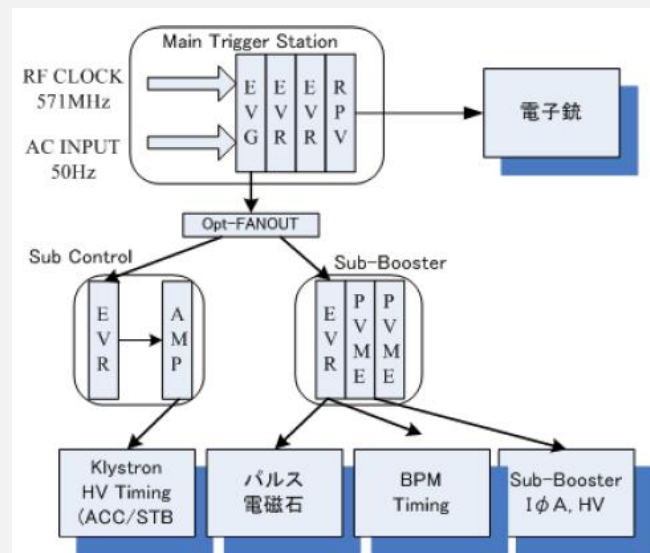
- 8 GeV LINAC, simultaneously, injects  $e^-$  and  $e^+$  beam of different characteristics into
  - KEKB high-energy ring (HER) – 8.0 GeV, 2nC
  - KEKB low-energy ring (LER) – 3.5 GeV, 2nC
  - Photon Factory (PF) – 2.5 GeV, 0.1nC
  - PF/AR – 3.0 GeV, 0.1nC
- The operation of all equipments along BT are synchronized by LINAC Timing system for simultaneous injection
- A wire-scanner data acquisition system, synchronized with Timing system, can measure beam profiles of multiple beam modes simultaneously in a single run
- Identification of beam modes can be done using timing information available from timing system
- Simultaneous measurement reduces measurement time and hence improves the overall efficiency of the transport line
- May help in PF and PF/AR beam studies without degradation of luminosity at KEKB!

# LINAC Timing system

- MRF's series-230 Event Generator/Receiver
- 114.24 MHz event rate
- Multi/Single mode fiber connectivity
- Timing precision < 10ps
- 20msec Beam switching
- Control approx. 1000 devices in LINAC
- Every pulse (20msec) corresponds a beam mode
- 10 different defined beam modes
- One beam pulse contains several event codes
  - ❖ At least one Main event code and a preparation code
  - ❖ 50 defined event codes
- Main event code and preparation event code are in sequence
  - ❖ Main event triggers timing signal
  - ❖ Preparation event trigger software to exchange analog & delay parameters
- Total number of receiver: 17 (+ 1)

## Reference:

"Timing system towards SuperKEKB controls " – Kazuro Furukawa, EPICS Collaboration Meeting, NSRRC, June 2011



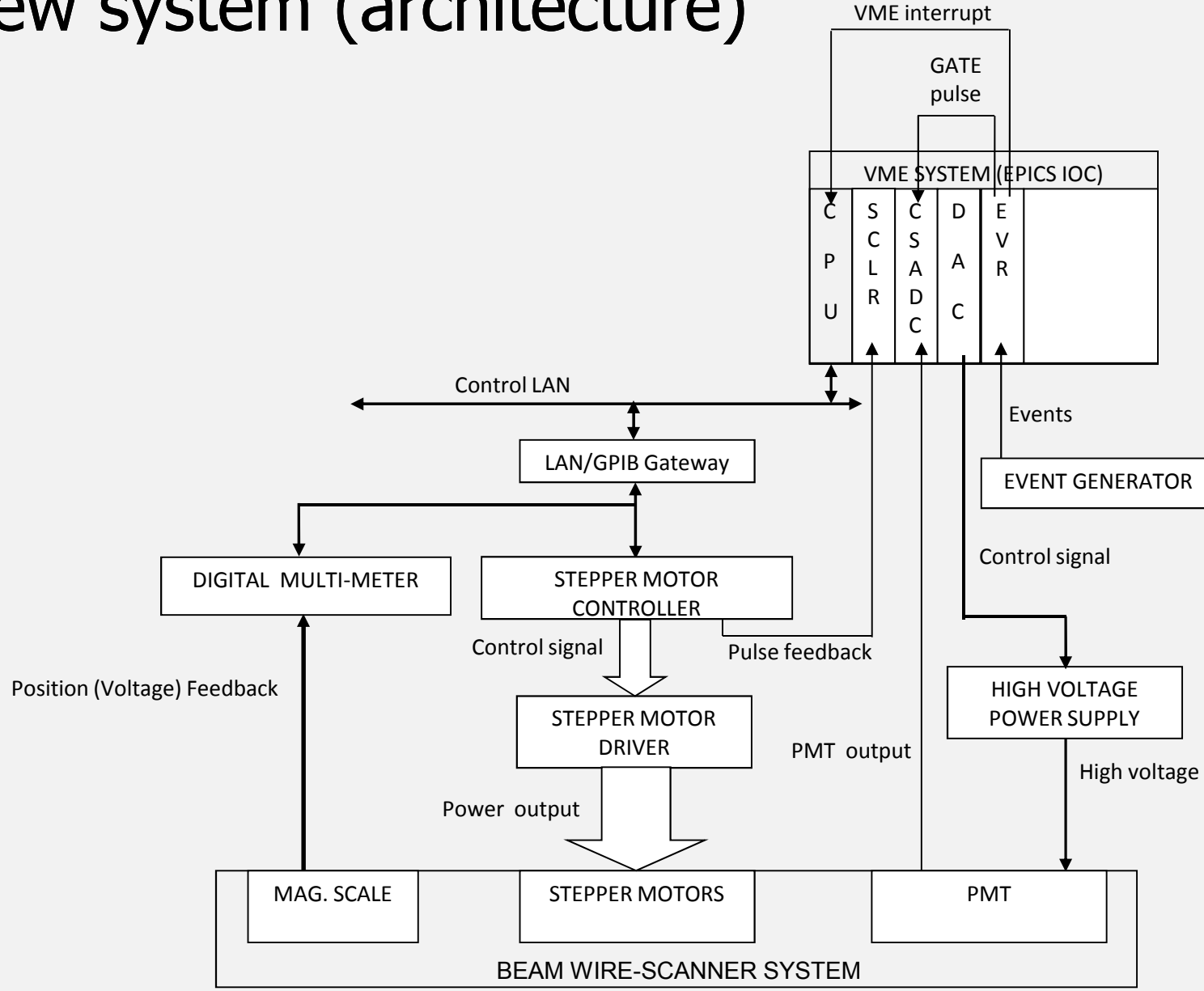
# New system

- Emerson MVME5500 CPU card, EPICS Base-3.14.12.1 and Vx-works 6.8 combination
- VME based ADC (14bit, 15 $\mu$ sec conversion time), Scaler and DAC hardware.
- MRF's event receiver module (VME-EVR-230RF) - synchronizing the data acquisition process with LINAC timing system
- A LAN/GPIB converter to communicate with Pulse motor controller (PMC) and Digital Multimeter (DMM) for control and data acquisition.
- ADC Gate generated by event receiver – less complicated hardware setup
- Multispeed wire movement to minimize time of scan and maximize useful data
- Options to user for selecting beam modes for data acquisition
- Application specific EPICS record to retain data format for SAD user interface
- Installed at Sector 5 of LINAC BT





# New system (architecture)



# Event Receiver

## ➤ Basic feature

- ❖ Manufacturer – Micro Research Finland, Model - VME-EVR-230RF
- ❖ Bit rate 1.0 to 2.5 Gbps, event clock rate 50 MHz to 125 MHz
- ❖ Four programmable front panel TTL outputs
- ❖ Two front panel TTL inputs
- ❖ Three differential CML pattern outputs capable of RF recovery
- ❖ Two universal I/O slots
- ❖ Rear I/O
- ❖ Jitter typically < 15 ps rms for TTL outputs, < 5 ps rms for CML outputs
- ❖ Support VME64x CR/CSR addressing mode

## ➤ EPICS device support

- ✓ Already available at EPICS Hardware support inventory (mrfioc2-2.0.0.tar.gz)  
(<http://sourceforge.net/projects/epics/files/mrfioc2/>)
- ✓ As current EPICS version does not support CR/CSR addressing mode in OS independent manner, hence devLib2 module (devlib2-2.2.tar.gz)  
(<http://sourceforge.net/projects/epics/files/devlib2/>)
- ✓ EPICS MSI tool to build the above modules (msi1-5.tar.gz)  
(<http://www.aps.anl.gov/epics/extensions/msi/index.php>)

# Event Receiver (configuration)

- EPICS device driver configuration (Different experience from usual VME device configuration!)
  - ❖ Setting up module (IOC initialisation)  
mrmEvrSetupVME(NAME, SlotNo, MapAddr, IntrLevel, IntrVectorAddr)  
**NOT Identified by SLOT No, but by NAME - different from usual EPICS VME device support style!**
  - ❖ Each feature (register) is accessed by "Module name:Feature name" (OBJ) and property name (PROP) fields  
e.g. field(OUT , "@OBJ=EVR1:Pul0, PROP=Delay") => writing into register  
field(INP , "@OBJ=EVR1:Pul0, PROP=Delay") => reading from register  
Little difficult to trace NAME of each register, hence better to copy and modify sample records!!
  - ❖ Four record types – ai, ao, longout & longin
  - ❖ Four device types (DTYP)
    - "Obj Prop uint32" – for longin & longout records
    - "Obj Prop double" – for ai & ao records
    - "EVR Pulser Mapping" – for mapping Event codes to pulse generator (longout record)
    - "EVR Event" – for mapping Event codes to EPICS Event (longout record)
- Important properties to configure
  - ❖ Enabling the module - *field(OUT , "@OBJ=EVR1, PROP=Enable")*
  - ❖ Setting up Clock - *field(OUT , "@OBJ=EVR1, PROP=Clock")*
  - ❖ Setting up Time stamp source - *field(OUT , "@OBJ=EVR1, PROP=Timestamp Clock")*
  - ❖ Mapping front panel output to pulse generator - *field( OUT , "@OBJ=EVR1:FrontOut0, PROP=Map")*
  - ❖ Enabling & Configuring pulse generator (i.e. delay, width, polarity) - *field(OUT , "@OBJ=EVR1:Pul0, PROP=Polarity")*
  - ❖ Mapping timing event to pulse generator - *field( OUT , "@OBJ=EVR1:Pul0, Func=\$(F=Trig)")*
  - ❖ Mapping timing event to EPICS Event - *field(OUT , "@OBJ=EVR1,Code=31")*

# Event Receiver (tuning)

- Synchronization of reference clock with incoming events from event generator
- Clock Reference generated internally
  - Micrel SY87739L Protocol Transparent Fractional-N synthesizer, reference clock of 24 MHz
- LINAC event rate is 114.24 MHz
- Relation between event rate & reference clock for Micrel SY87739L is

$$\text{Event rate (MHz)} = [ (M/N) \times \{P - (Q_{(p-1)} / (Q_p + Q_{(p-1)}))\} \times \text{Fref} ] / \text{PostDivSel}$$

where

$$\text{Fref} = 24.0 \text{ MHz}$$

$$\text{PostDivSel} = 6$$

$$M = 14, N = 14, \text{ therefore } M/N = 1$$

$$P = \text{Mod}[(\text{Event rate} \times \text{postDivSel}) / \text{Fref}] = 29$$

$$Q_{(p-1)} = 14$$

$$Q_p = 32 - Q_{(p-1)} = 18, \text{ as } Q_p + Q_{(p-1)} = 32$$

the bit pattern of configuration word

$$\mathbf{0000-Q_p(5)-Q_{(p-1)}(5)-P(4)-000-PostDivSel(5)-N(3)-M(3)}$$

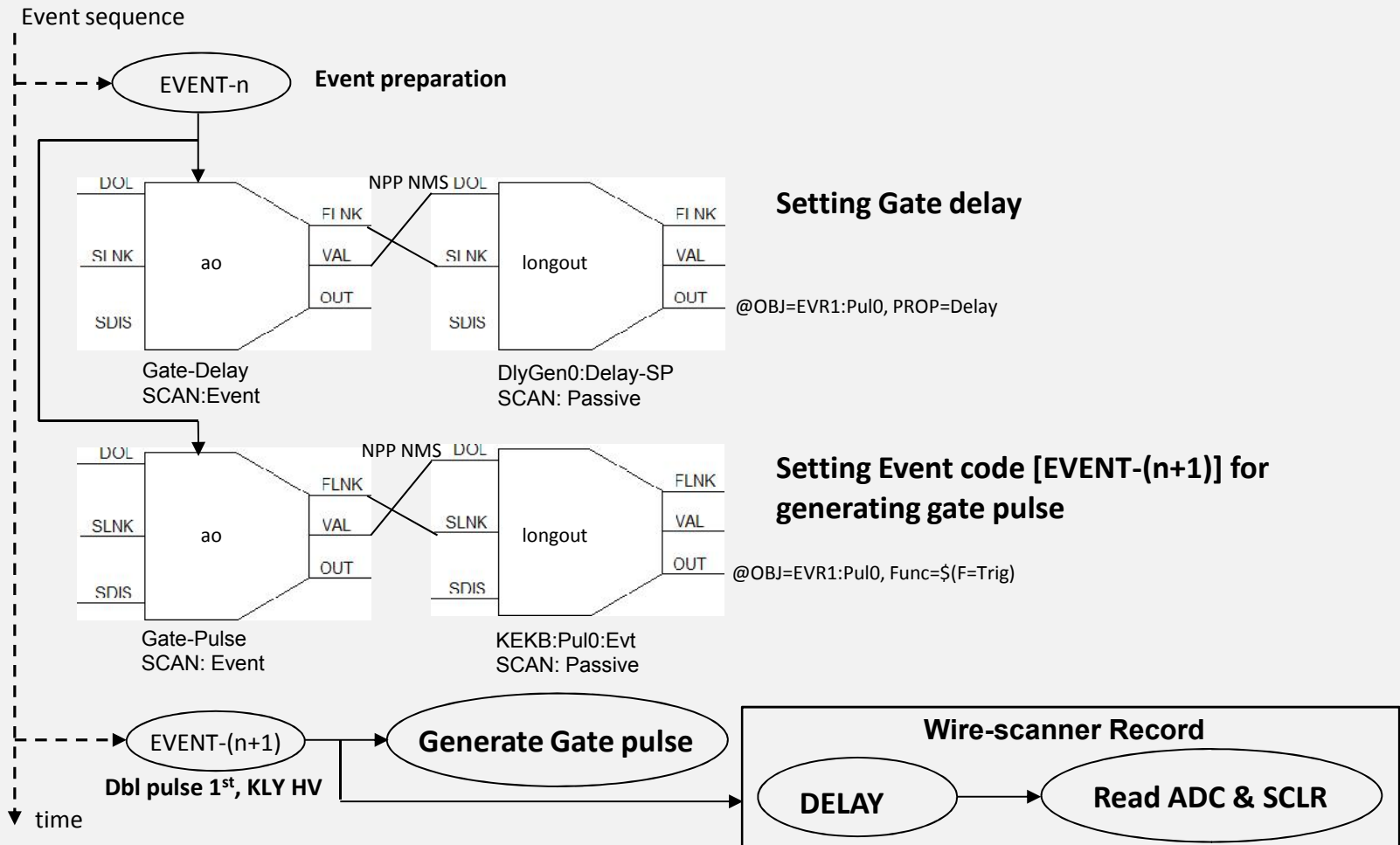
Hence the configuration word for 114.24 MHz is

$$\mathbf{\underline{093B01AD}} \text{ (0000-10010-01110-1100-000-00110-101-101)}$$

- The configuration word to be stored in EVR non-volatile memory 10baseT network interface

# Data acquisition strategy

- **Requirement:** configuration of pulse generator (i.e. delay & timing event) for each beam mode to generate ADC Gate synchronized with beam pulse
- **Solution:** Utilize two consecutive timing events for pulse generator configuration and data acquisition



# Wire-scanner (WS) Record

## ➤ Why a new record?

To keep the interface (software) to Wire-scanner User interface (SAD panel) UNCHANGED,  
To minimize impact on OTHER proven PROCESSES

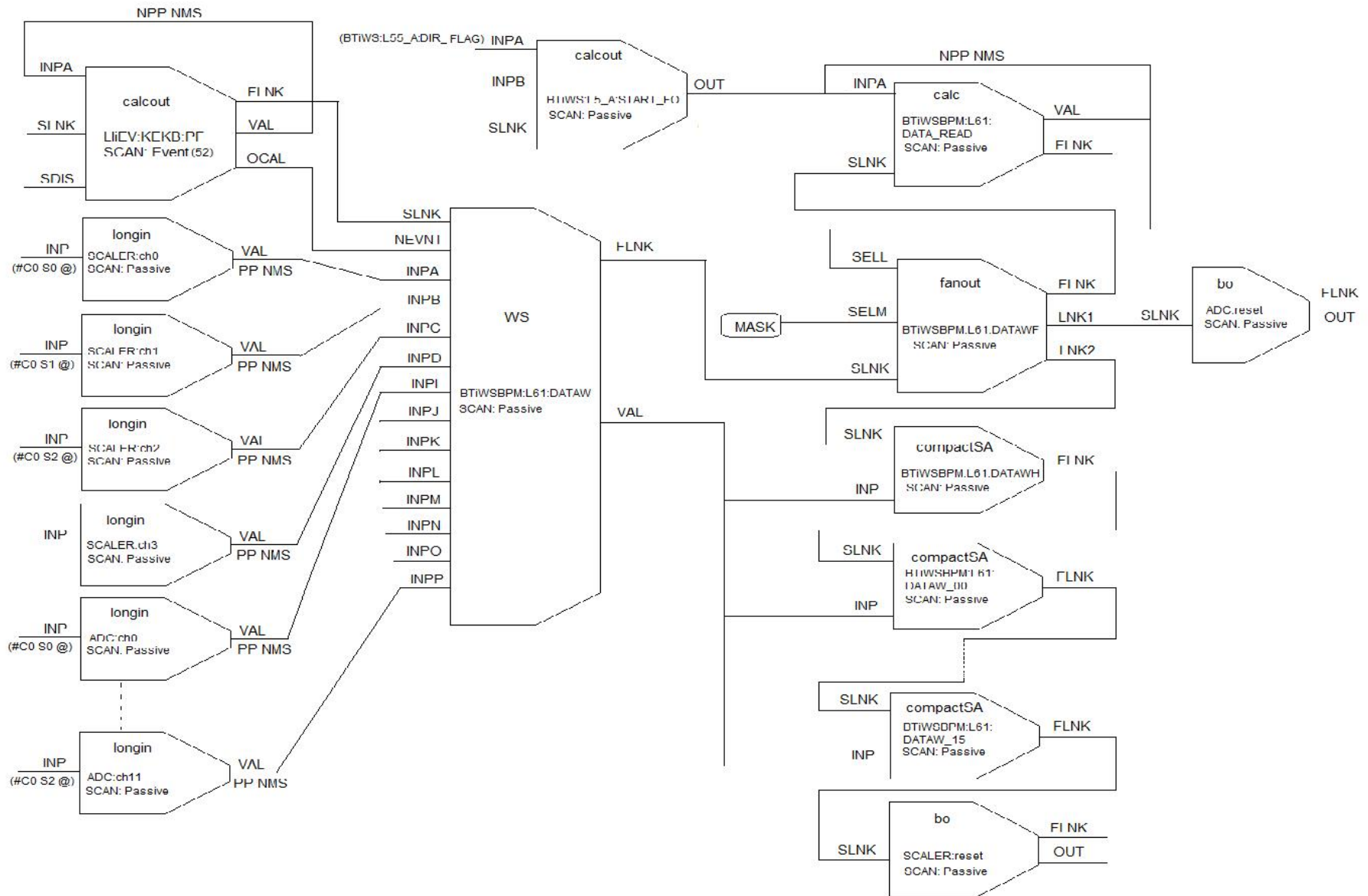
## ➤ Features

- ✓ Application specific – suit the purpose of wire scanner system
- ✓ A waveform record with multiple input links (26, INPA....INPZ) for collecting data
- ✓ A Ring Buffer, appending an array of data (from input links) on every scan
- ✓ Provision for delay the processing – to ensure completion of ADC conversion (if LAM is absent!)
- ✓ Fields for defining number of SCALER, BPM (4 ADC per BPM) and wire-scanner ADC channel
- ✓ Field for appending BEAM mode (event code) to data on every scan for identification
- ✓ Option for resetting the buffer
- ✓ Option for calibrating BPM signal using calibration data (Not yet tested!)
- ✓ Field for defining calibration data file path

## ✓ Constraint

SCALER, BPM and ADC data sources (pv links) should be defined in sequence at the input links (i.e. from INPA.....) according to the respective numbers

# Record link

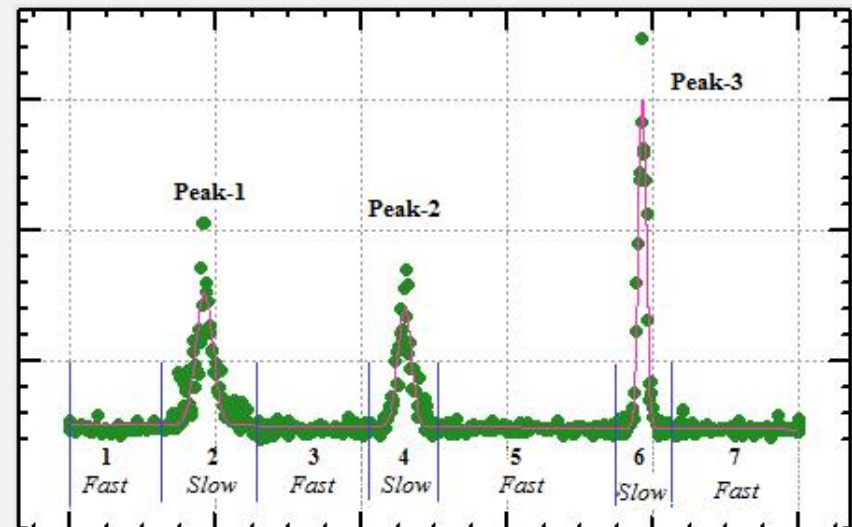


# Wire-scanner movement

- Driven by Pulse motor (4 $\mu$ m/pulse) – maximum distance of 100mm
- Controlled by 4 channel Pulse Motor Controller with GPIB interface and
  - ❖ Provisions for Mechanical and Logical Limit to restrict over drive
  - ❖ Pulse feedback while moving forward direction only
  - ❖ Options for HIGH / MEDIUM / LOW speed movement
  - ❖ Options for Relative / Absolute movement
- **Why Multi-speed scan?**
  - X, Y & U wire interact with beam at three distinct regions of whole span
  - Slow speed scanning at regions of interactions results into better beam profile
  - Higher speed (Fast) at other regions results into optimum scan time

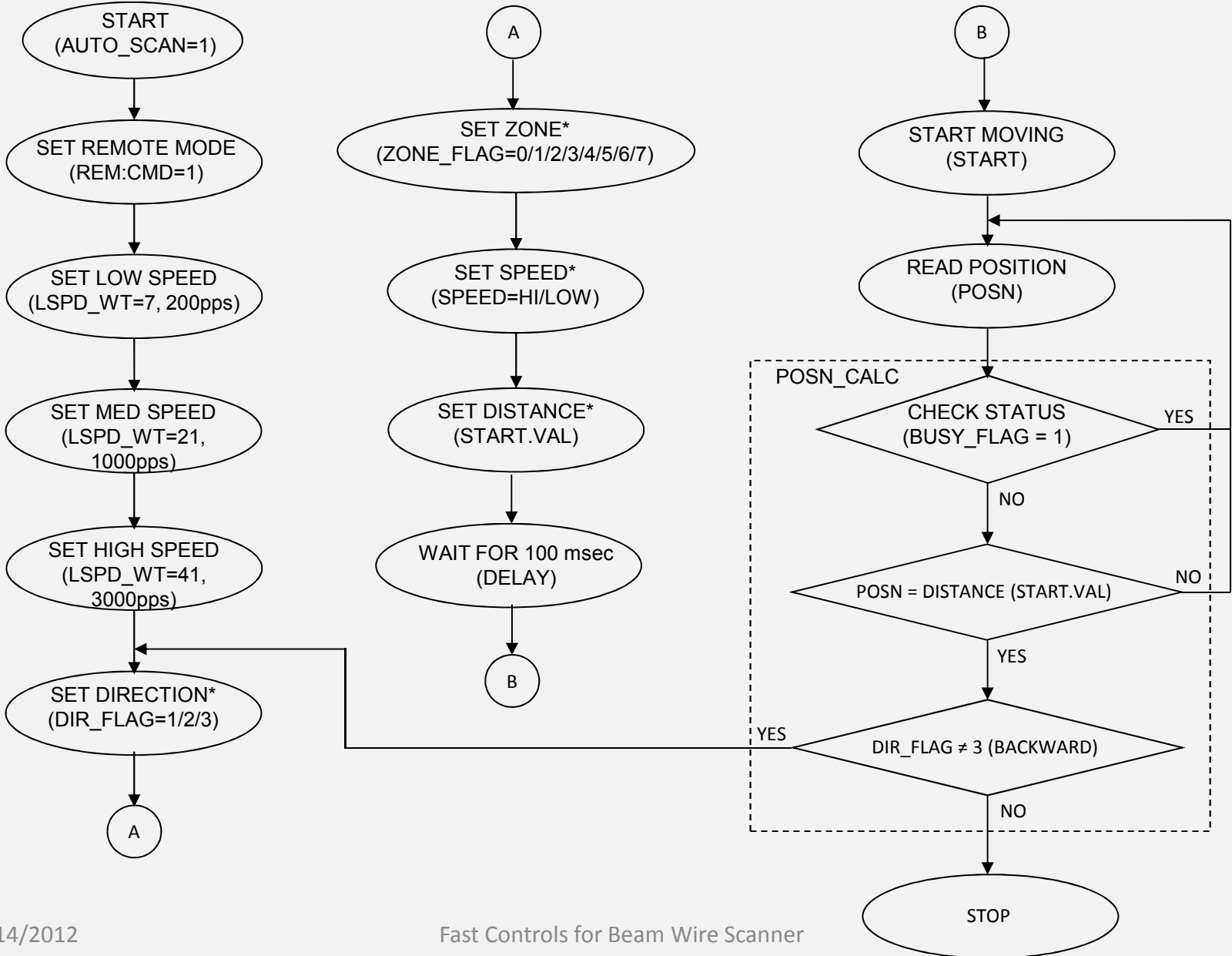
## ➤ Implementation

- Divide span of movement into seven regions (as shown in Fig)
- Slow speed regions are defined by peak position and width around the peak
- Defining HIGH & LOW speed values
- Absolute scan, to restrict over drive



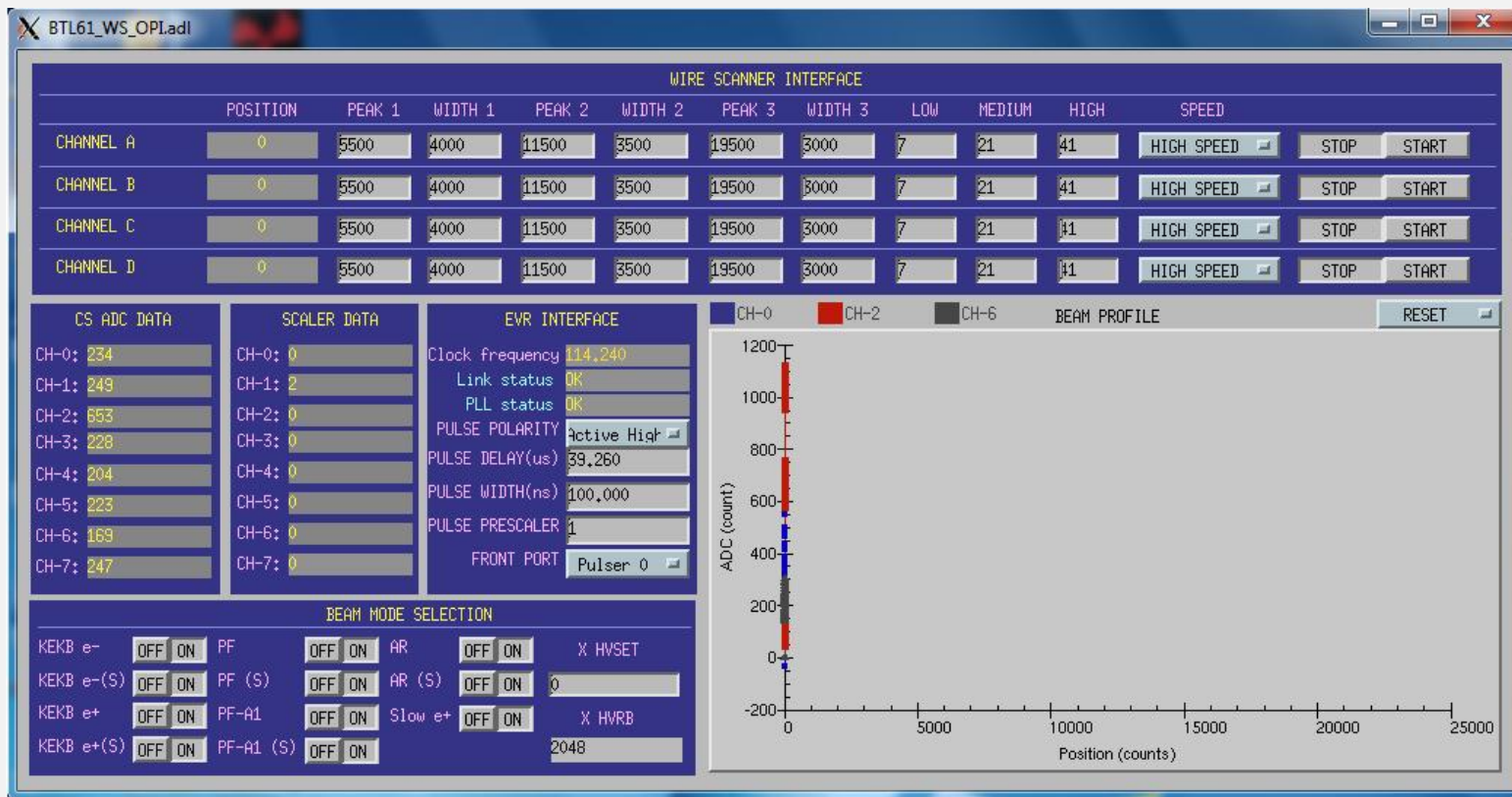


# Wire-scanner movement (Flow-chart)



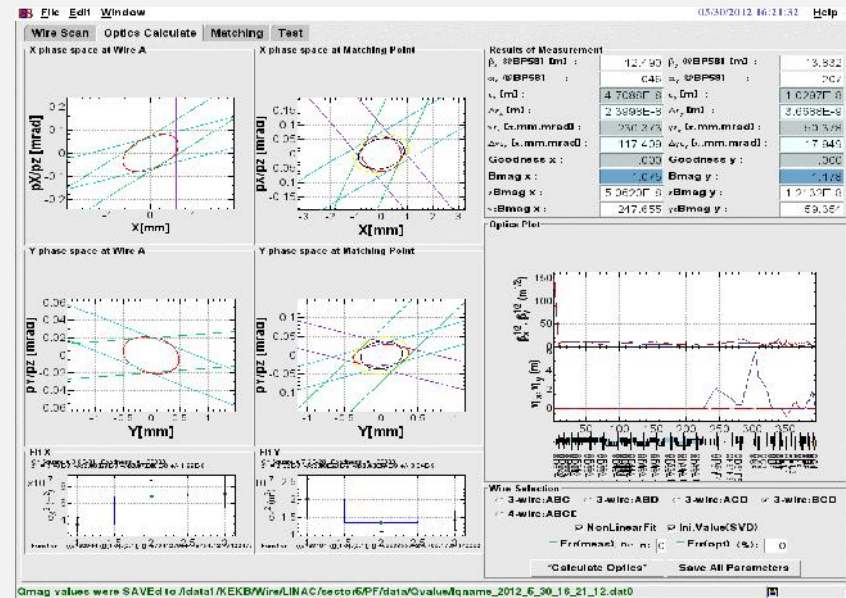
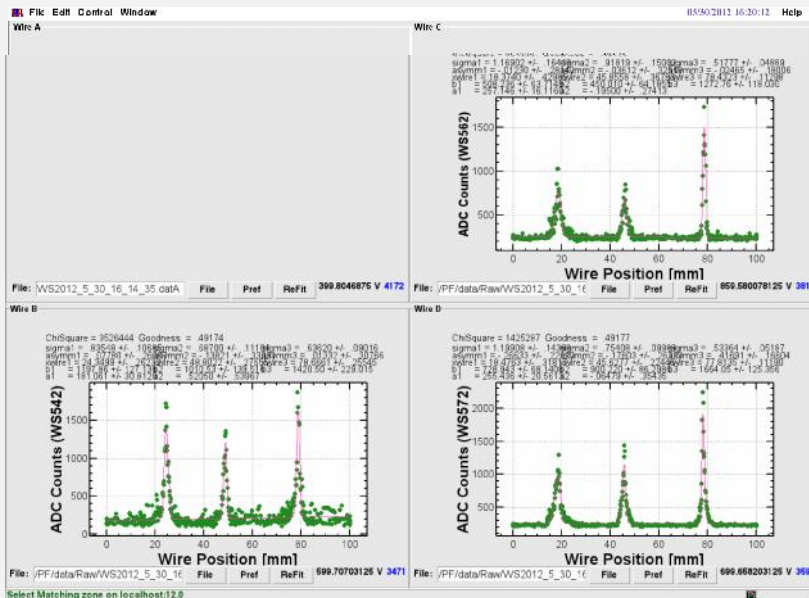
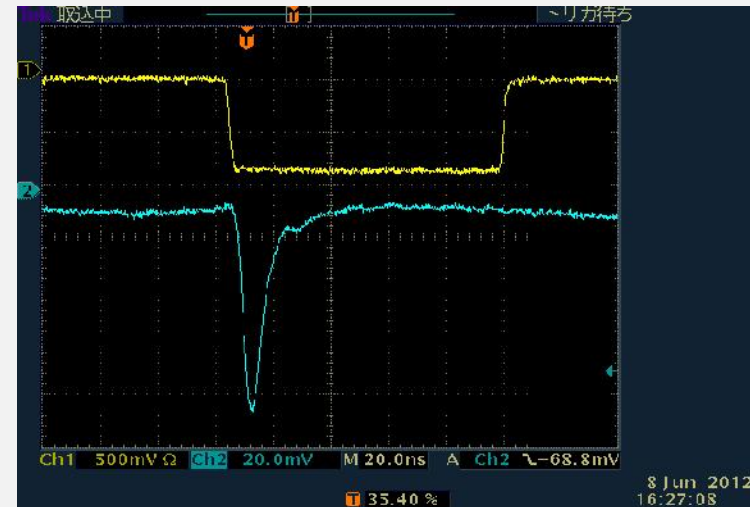
# User interface (MEDM)

- To control and monitor the data acquisition process, built using MEDM
- Provisions provided for
  - ❖ Defining peak positions and corresponding width around them
  - ❖ Specifying HIGH / MEDIUM / LOW speed index
  - ❖ Specifying EVR output, Pulse delay, pulse width, polarity etc. for particular BEAM mode
  - ❖ Selecting BEAM modes



# Test Results

As obtained, seems to be satisfactory!



## **Sincere Regards to:**

Kazuro Furukawa

Tatsuro Nakamura

Naoko Iida

## **Special Thanks to:**

Tomohiro Okazaki

Shiro Kusano

**Thank you!**