BPM/LLRF Collaboration on MicroTCA.4

A. Young for BPM team

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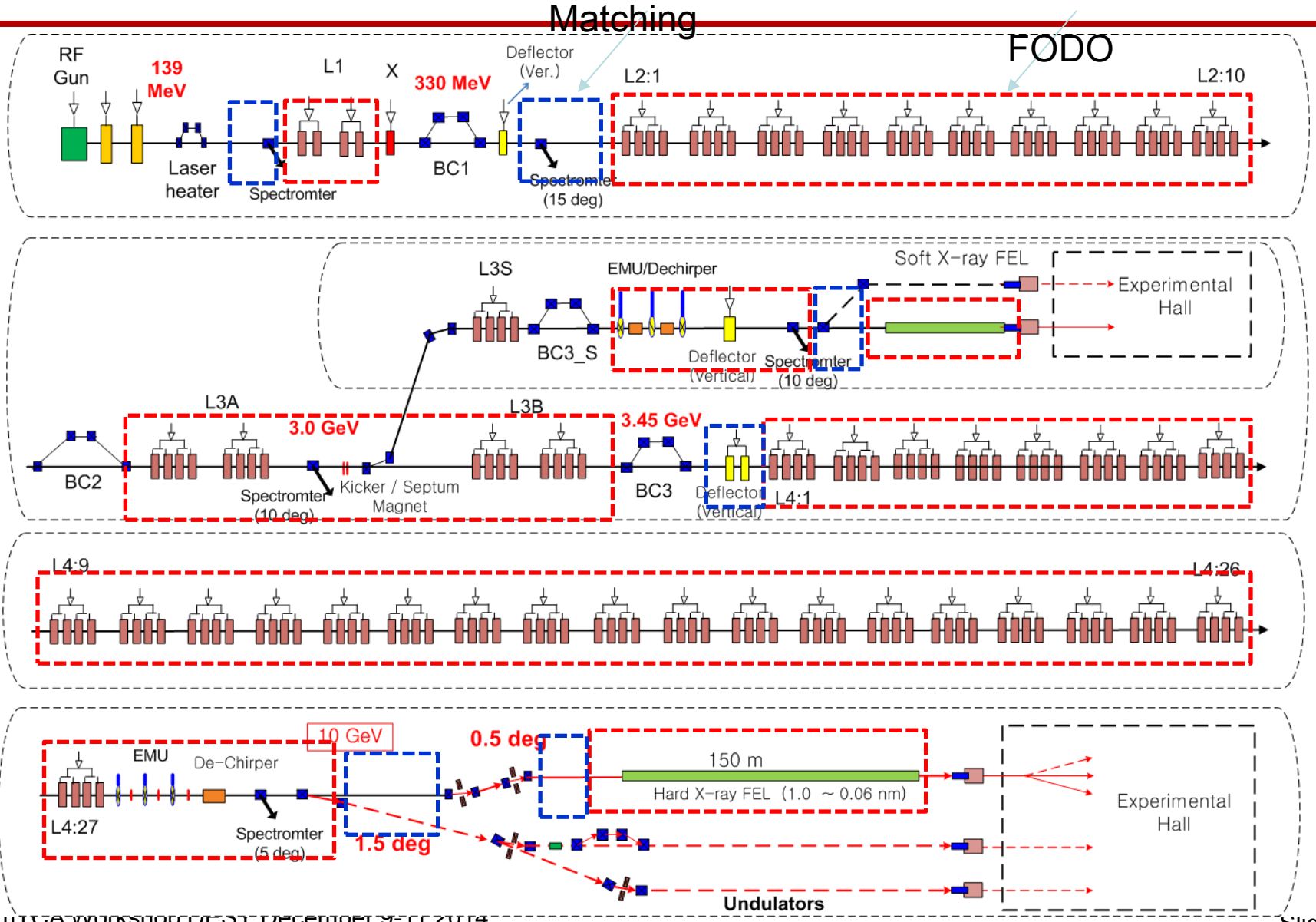
H.S. Kang, C. Kim, G. Mun - PAL

mTCA Workshop DESY December 9-11 2014

Collaboration-Pohang Accelerator Laboratory

The PAL-XFEL is a 0.1-nm hard X-ray FEL project starting from 2011, which aims at providing photon flux higher than 1 x 10^{12} photons/pulse at 0.1 nm using a 0.2 nC / 10 GeV electron linac. The photon flux of 1 x 10^{12} at 0.1 nm corresponds to the FEL power of 30 GW with the pulse length of 60 fs in FWHM. Beam trajectory must be maintained within 5 μm at 250pC in the linear accelerator to obtain this resolution PAL XFEL would like to use the LCLS-II mTCA stripline BPM system

FODO Lattice For Phase-II

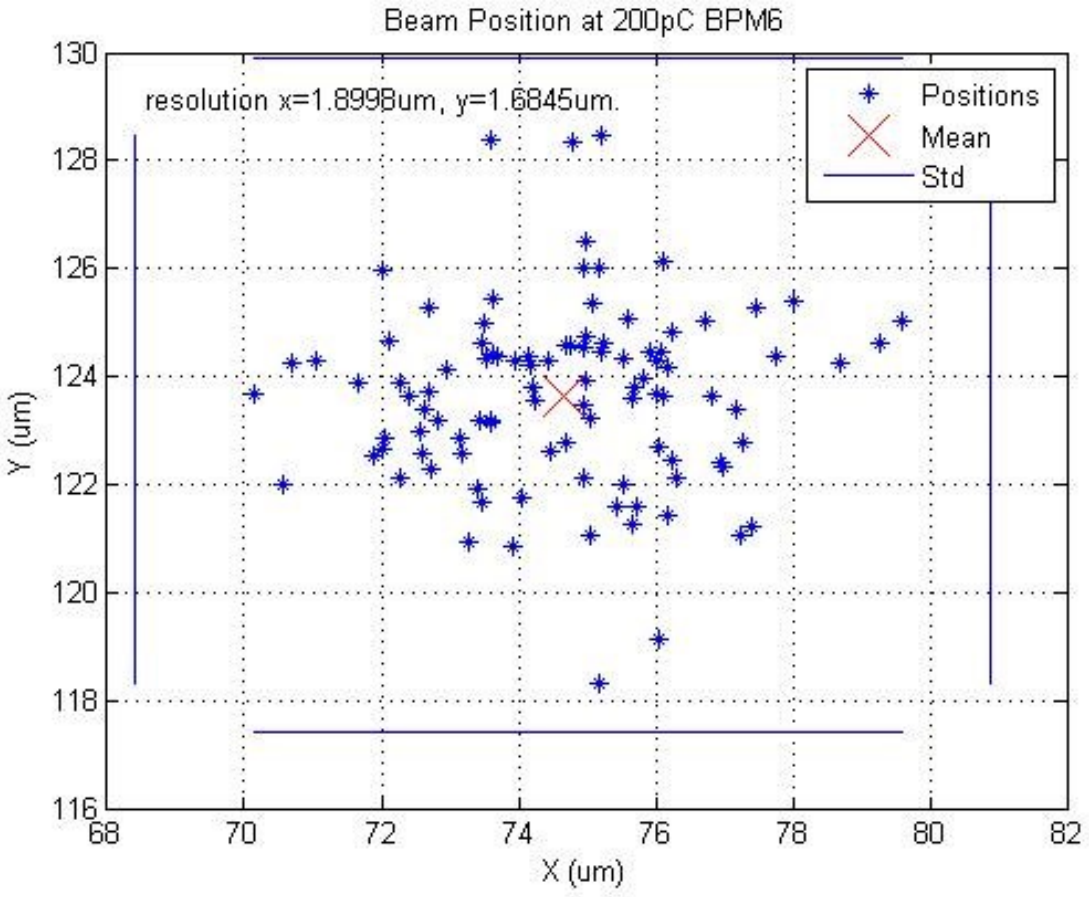


Scope and Goals of the WFO for PAL

The WFO agreement was a collaboration between the Pohang Accelerator Laboratory and SLAC National Laboratory to develop microTCA systems for BPMs.

- The Phase I system consist of 9 AMC modules, 9 RTMs, a power supply, MicroTCA Carrier hub (MCH), CPU, EVR with distribution chassis and a microTCA chassis.
  - Goals of our trip was to commission the microTCA electronics, characterize the 3 BPMs at the ITF, run side by side measurement of the Libera system was successfully complete in June 2014.
- Phase II system consists of designing 144 Stripline BPM RTMs while Pohang Purchases ALL of the infrastructure components such as; a power supply, MicroTCA Carrier hub (MCH), CPU, EVR with distribution chassis and a microTCA chassis.

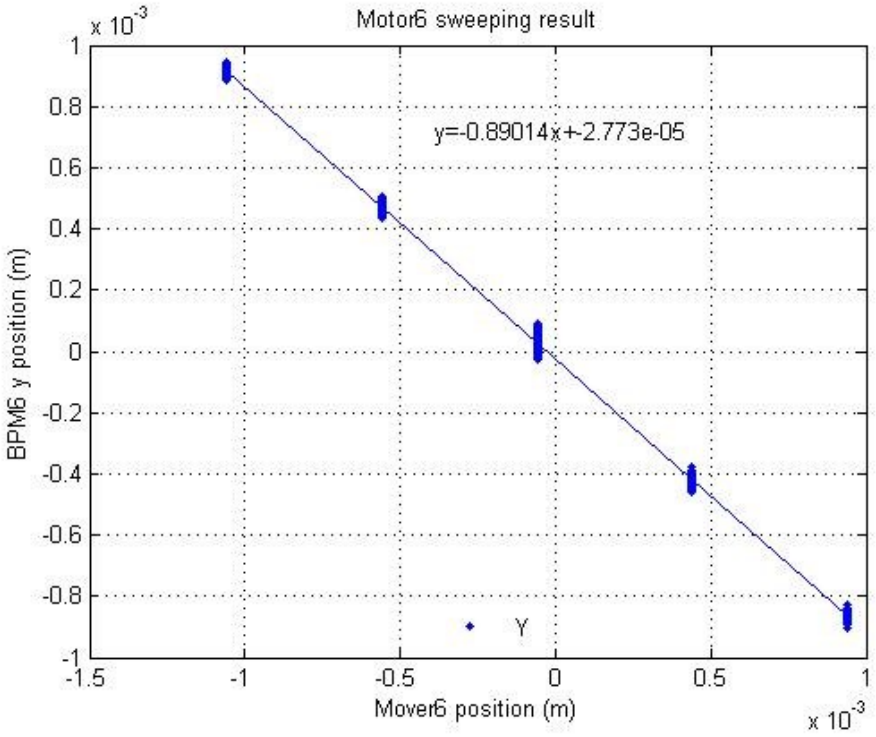
Beam resolution using one BPM

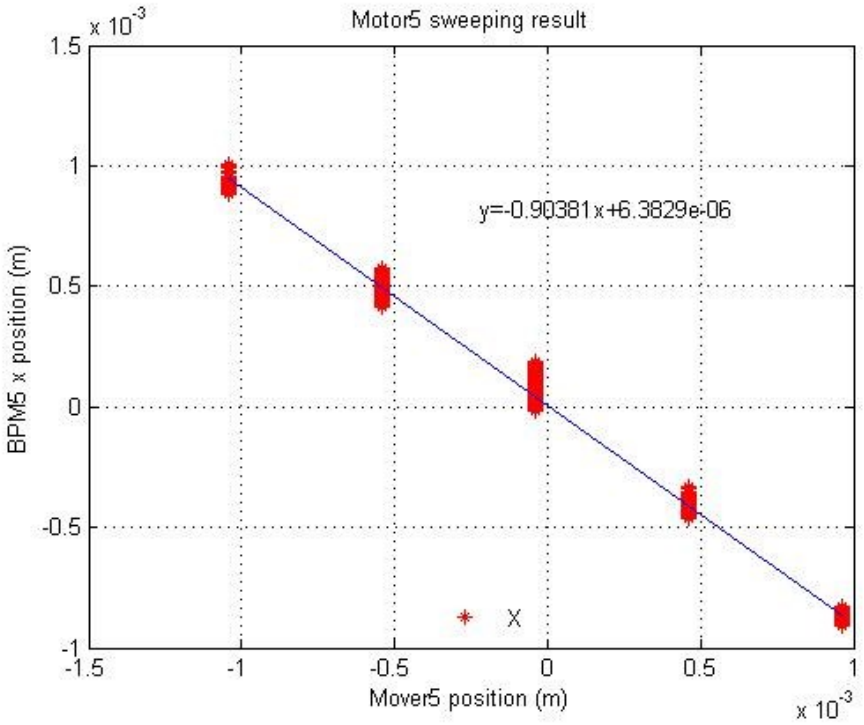


BPM_Resolution_RTM__TEST_20140623T135031

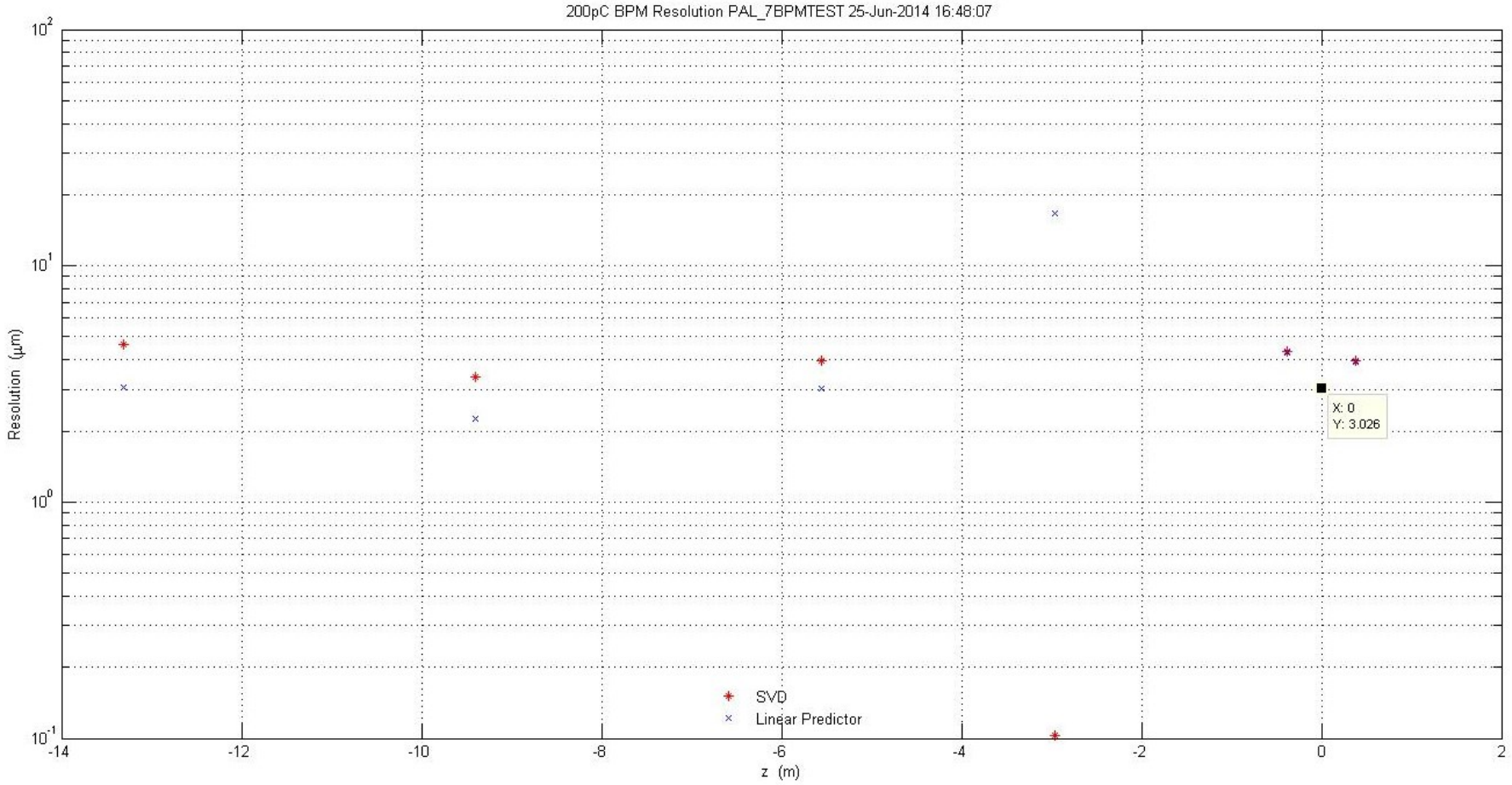
Using a single BPM we can measure the resolution over 100 shots. This is similar to how we measure in our lab. There is a trick to this measurement in that the beam must be centered.

BPM linearity over +1/-1mm

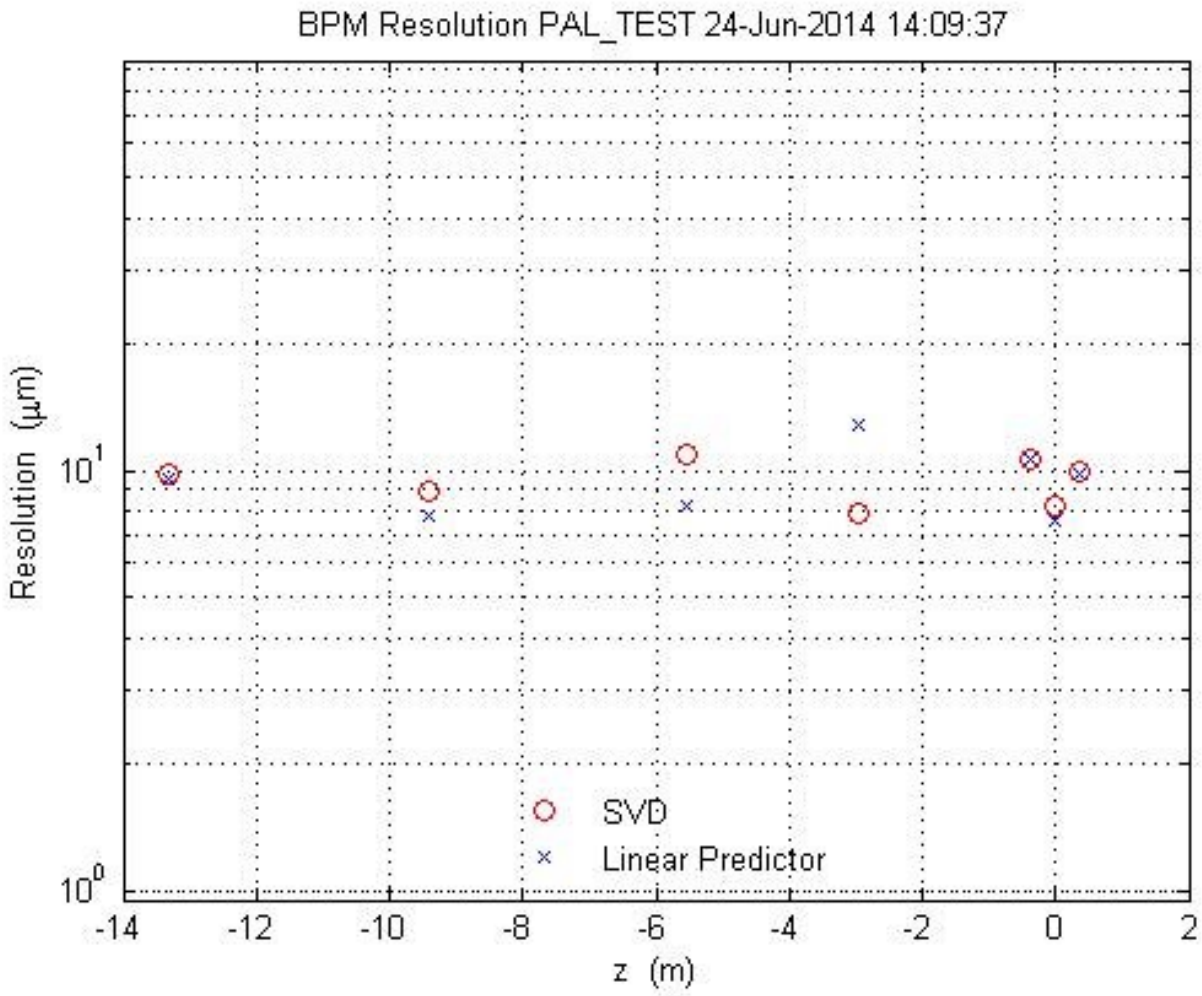




Resolution


200pC BPM Resolution PAL_7BPMTEST 25-Jun-2014 16:48:07
Resolution (µm)
z (m)
SVD
Linear Predictor
X: 0
Y: 3.026

Resoution at 10pC



Phase II Status

- We have ordered front panels, PCB boards, and other long lead items.
- SLAC is developing a new PMC EVR that is compatible with mTCA.4 Zone 3 D1.0 standard. We are collaborating with industry to design the AMC PMC carrier and SLAC is designing the new RTM that will fan-out 10 triggers to an RTM. This will be available early 2015.
- Pohang has ordered most infrastructure components; power supplies, CPU, MCH, EVR with distribution chassis and a microTCA chassis.

ESS Design Philosophy

- **The ESS design:**
  - A highly collaborative project
  - A baseline design based on the most suitable and best technology of today
  - Collaboration partners taking on challenging design issues gave time for ESS to recruit skilled staff for coordination and integration
- **Collaborations enabled the design update process to complete in time for the construction phase**
  - Partners from Pre-Construction have expressed there intention to continue through Construction. Contracts under signature.
  - Contracting under way with additional partners for the construction stage, many new opportunities identified!
  - Crucial to keep the schedule, tunnel is being built…

Collaboration-ESS Laboratory

The European Spallation Source (ESS) aims to be the brightest source of neutrons in the world for scientific research. By the end of this decade (operational ~2019) it will be generating long pulses of neutrons. These will be used in parallel experiments that will foster major advances from aging and health, materials technology for sustainable and renewable energy, to experiments in quantum physics, biomaterials and nano-science. This is equivalent to the SNS in America. ESS plans to design beam Position Monitors (BPMs) and Low-Level RF (LLRF) systems using microTCA platform.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IDEON
Innovation
Environment
Incubators
Venture Capital
Marketing Advice
SCIENCE
VILLAGE
SCANDINAVIA
Neutron
Source
ess
EUROPEAN
SPALLATION
SOURCE

ESS Design

Design Drivers:

High Average Beam Power

5 MW

High Peak Beam Power

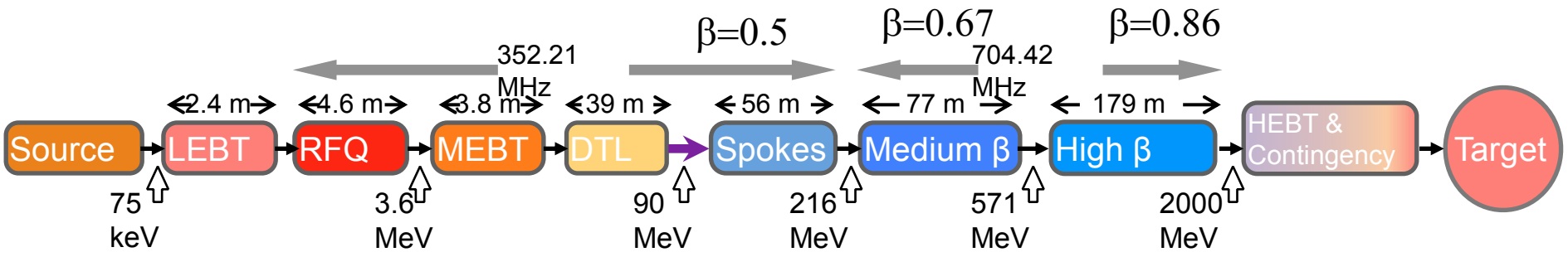
125 MW

High Availability

> 95%

Key parameters:

-2.86 ms pulses
-2 GeV
-62.5 mA peak
-14 Hz
-Protons (H+)
-Low losses
-Minimize energy use
-Flexible design for future upgrades



Why does β matter

$$V_b = \frac{\pi a^2 Z}{2\pi b \beta c} \cdot \frac{dI}{dt} = \frac{\pi a^2 Z}{b \beta c} 2 A_m f_0 I_{avg} .$$

$$P_s = \frac{1}{2} \frac{V_b^{\,2}}{Z} = \frac{2\pi^2 a^4}{b^2 \beta^2 c^2} Z A_m^{\,2} f_0^{\,2} I_{avg}^{\,2}$$

Field lines as a function of β

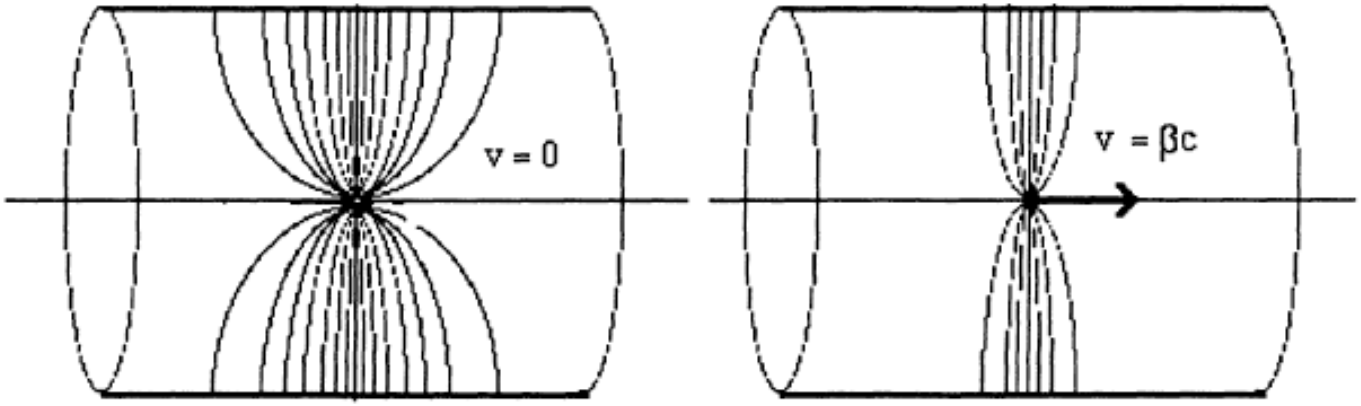


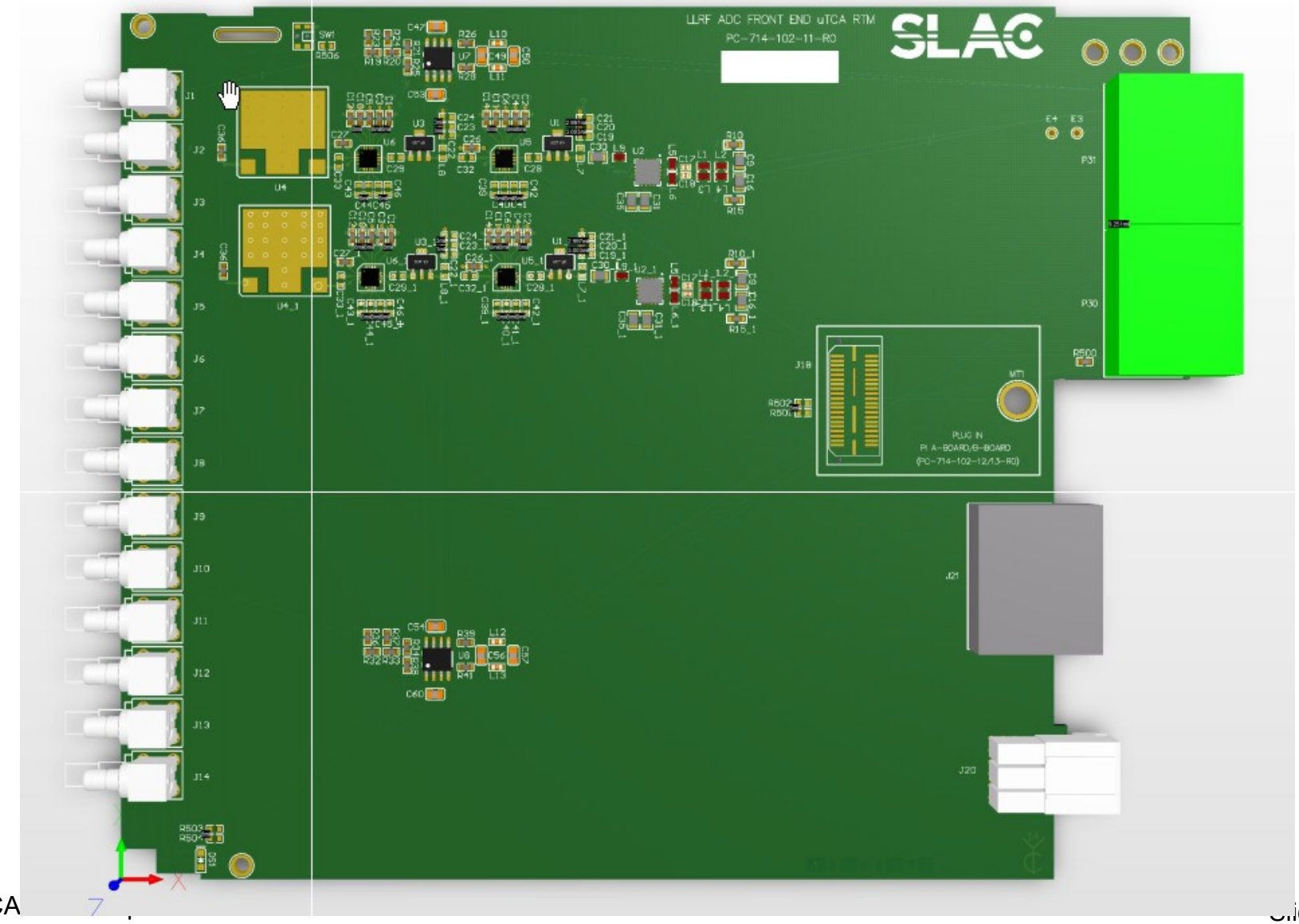
Fig. 12.1. The longitudinal field distribution of a static and moving charge ($\beta = 0.9$) in a grounded conducting cylinder. The longitudinal distribution contracts to a flat disk for highly relativistic particles. For slow particles, the field lines extend about $\pm b/\sqrt{2}$ longitudinally both in front of and behind the particle.

Scope and Goals of the CRADA Agreement with ESS

The CRADA agreement was a collaboration between the ESS Accelerator Laboratory and SLAC National Laboratory to develop microTCA systems for BPMs and LLRF.

- The Phase I system consist of designing a RF Downmixer Rear-Transition-Model (RTM)
- The Phase II system consist of designing a General Purpose FPGA AMC module that could be used as an Event Timing Module, LO generation Module, and BPM calibration Module.
- The Phase III system consist of designing an Event Timing Module RTM.
- Phase IV consist of designing a LO generation and distribution RTM
- Phase V consist of designing a BPM calibrator RTM will switch in a cal tone at a TBD frequency upon receiving a trigger. This cal-tone will be distributed to X- and Y- buttons

Phase I RTM PCB board



Status

- We are designing the down-mixer RTM now.
- We are collaborating with Matthias Hoffman, Krzysztof Czuba, Holger Schlarb, Kay Rehlich for RF backplane and down-mixer RTM design issues.
- SLAC and ESS is collaborating with Matthias Werner and Dirk Lipka for the BPM algorithm.


SLAC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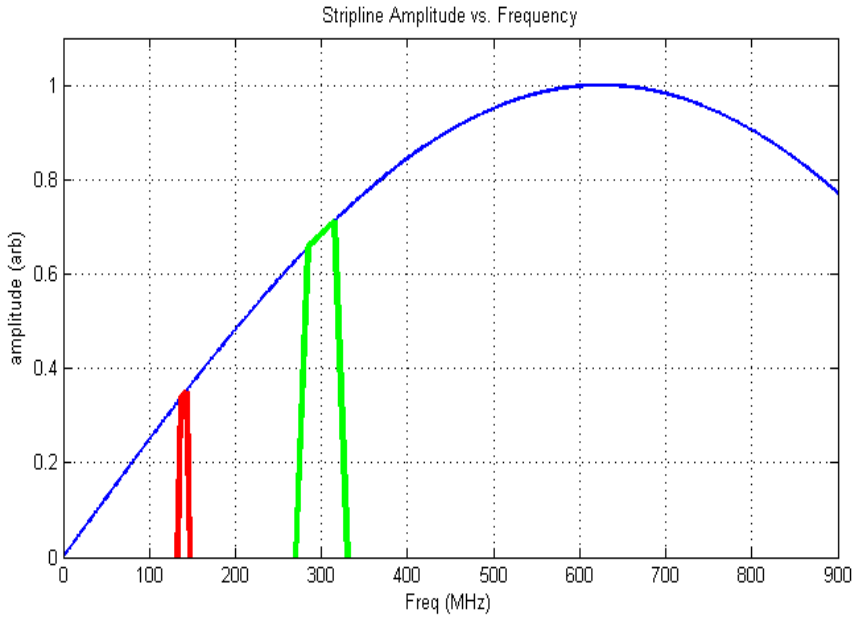
1891

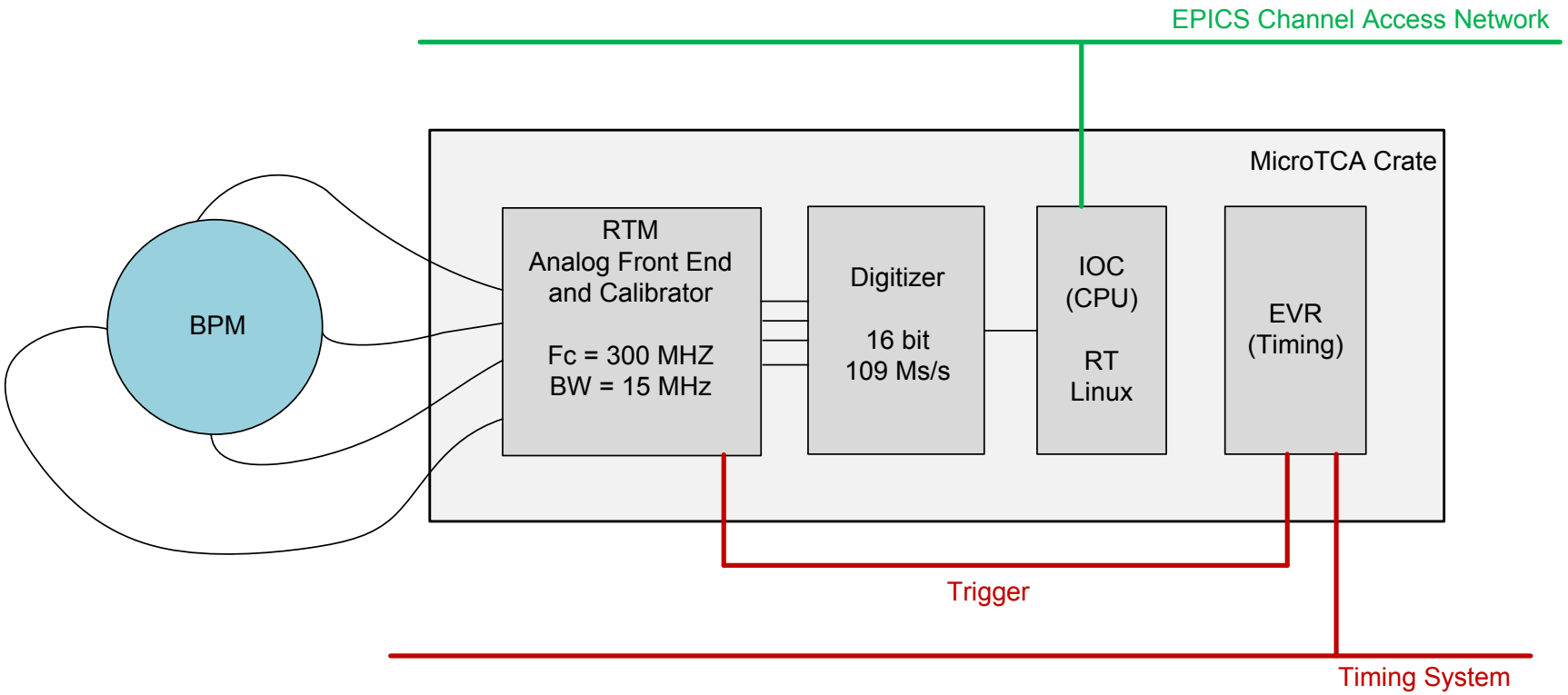
Backup Slides

Scope of Project

- Build BPM control system for new LCLS-II Injector
  - 15 stripline BPMs
    - Standard Linac pickups, 1” diameter, 4.75” length
  - Integration into EPICS control system

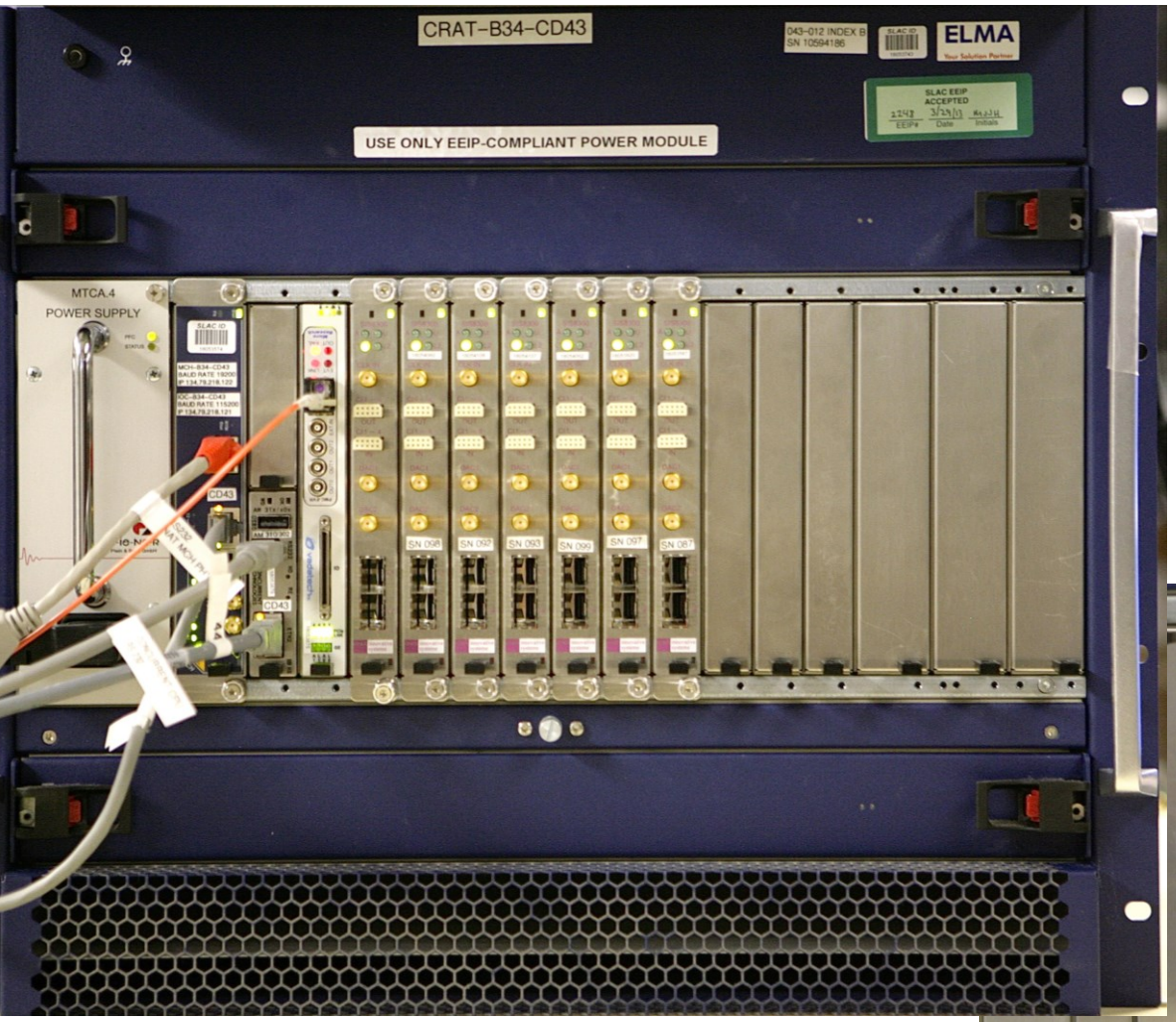


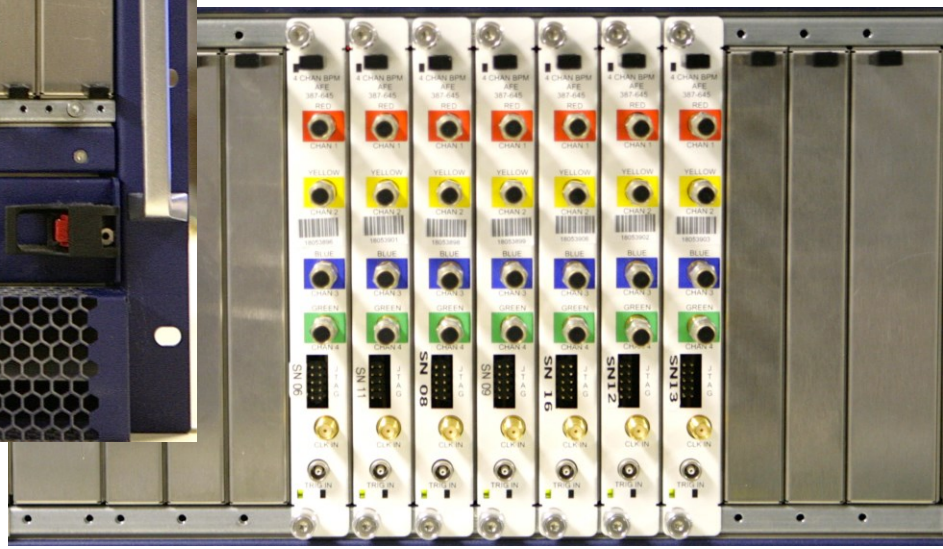
Single BPM System Block Diagram



Old Style Stripline BPM

mTCA Version

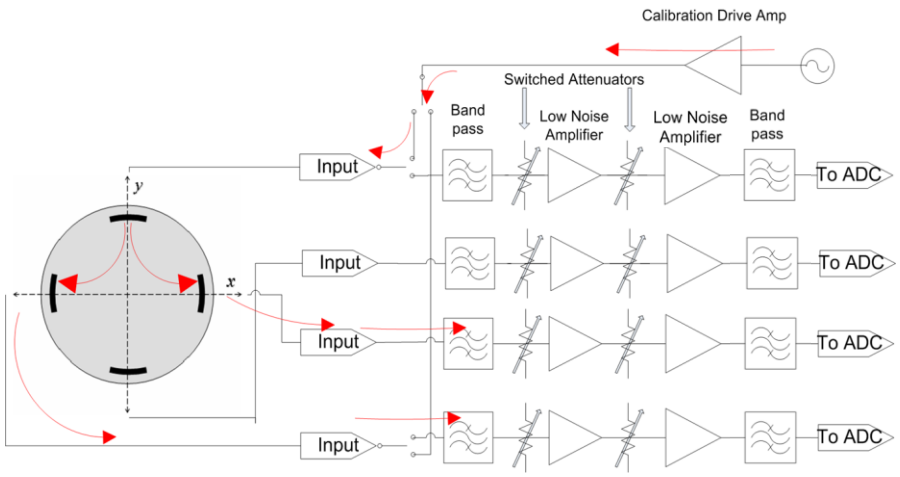


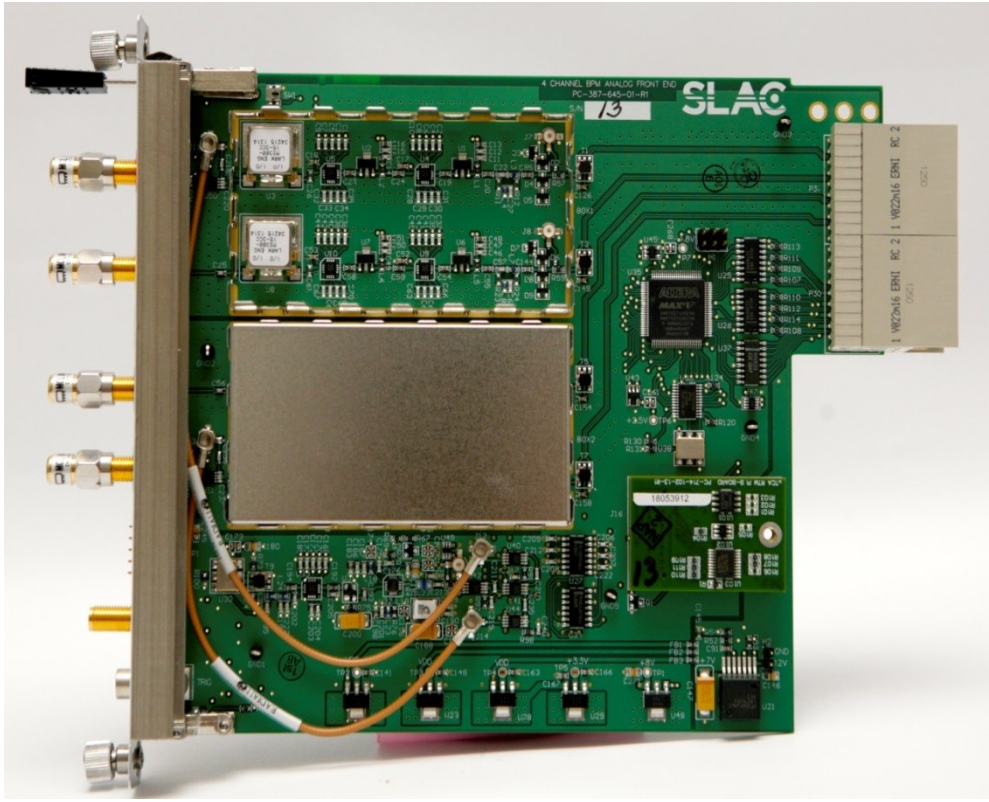


This System is 9U high while the old system was 16U high. There are more diagnostics on the microTCA system.

SLAC BPM AFE Rear-Transition Module

- Analog Front End and Calibrator
  - Designed at SLAC

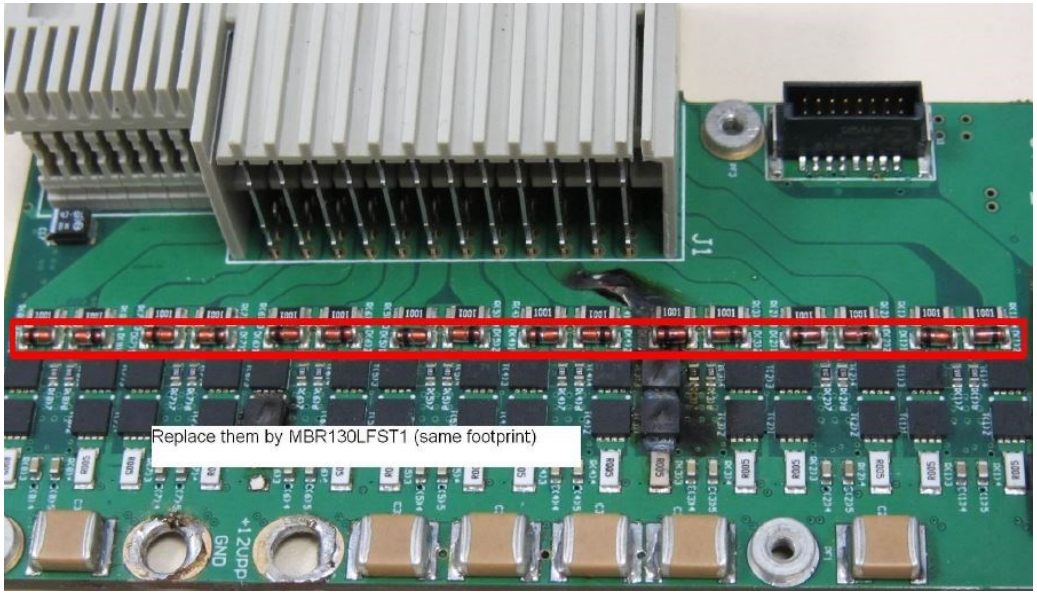




Digitizer

- Struck Digitizer (SIS8300)
- With SLAC modifications
  - For 300 MHz Fc
  - Install user firmware
  - Generate109 MSa/sec sampling clock

Power Supply

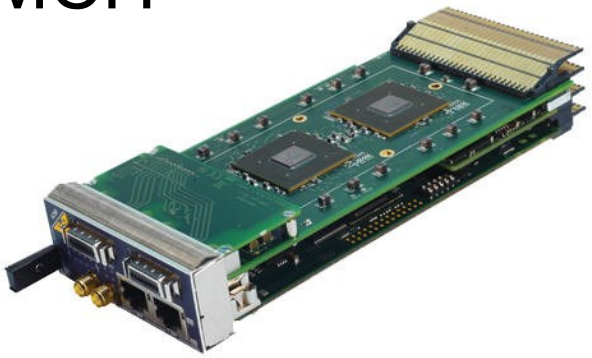


Modified Wiener Power supply to solve in-rush current problem. Wiener has reved the power supply and has been able to increase the power to 1KW. (Thomas Berner Talk Wed at 12:40pm)

MicroTCA Components

- CPU: Concurrent Technologies AM 310/302-52
  - 2-core Core i7 processor
  - 2 GB RAM
  - Ethernet interface
  - Serial port for IOC console

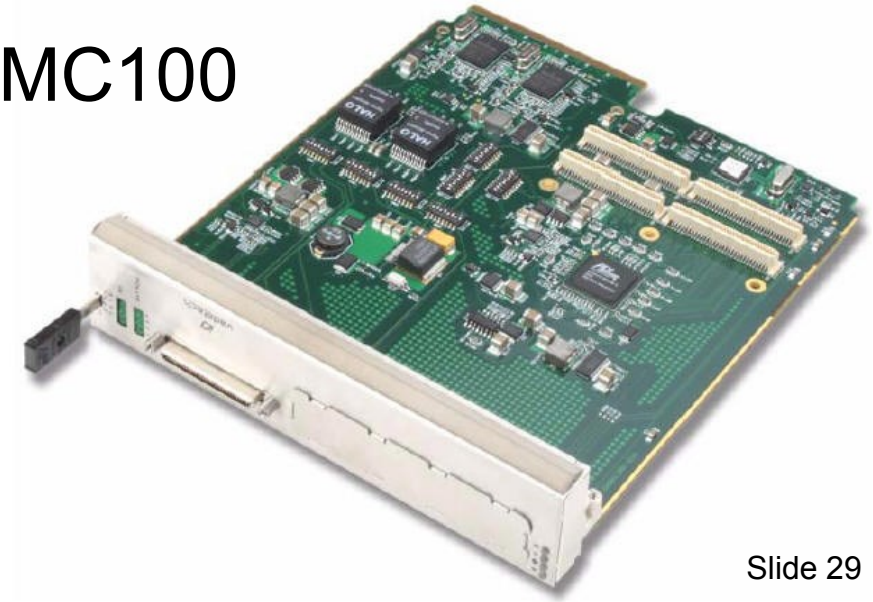
- MicroTCA Carrier Hub: NAT MCH
  - Linux embedded OS
  - 2 Gigabit Ethernet interfaces
  - Serial port for MCH console



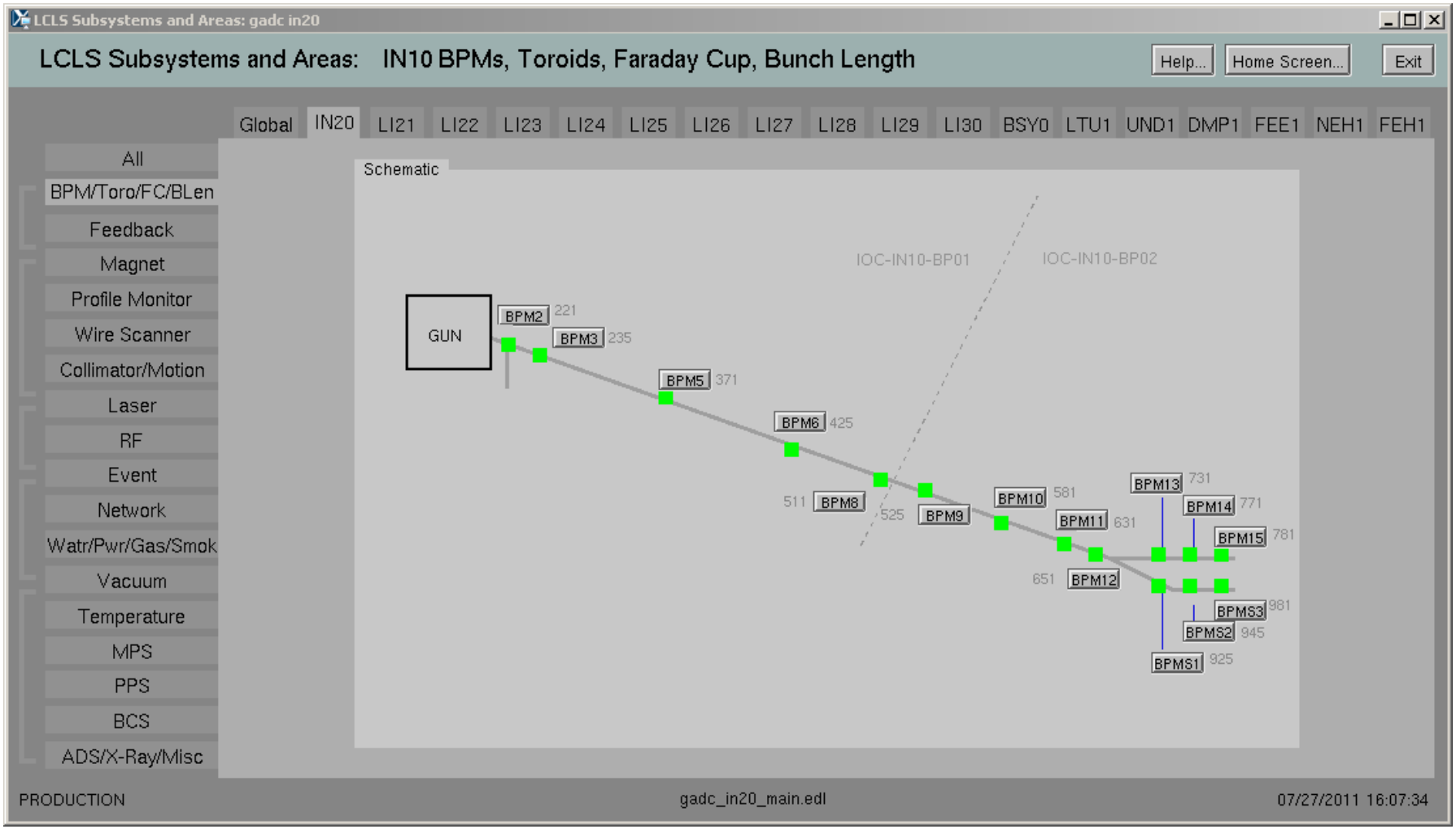
MicroTCA Components

- EVR: Micro-Research Finland PMC-EVR-230
  - Used heavily in LCLS-I
  - 3 front-panel triggers

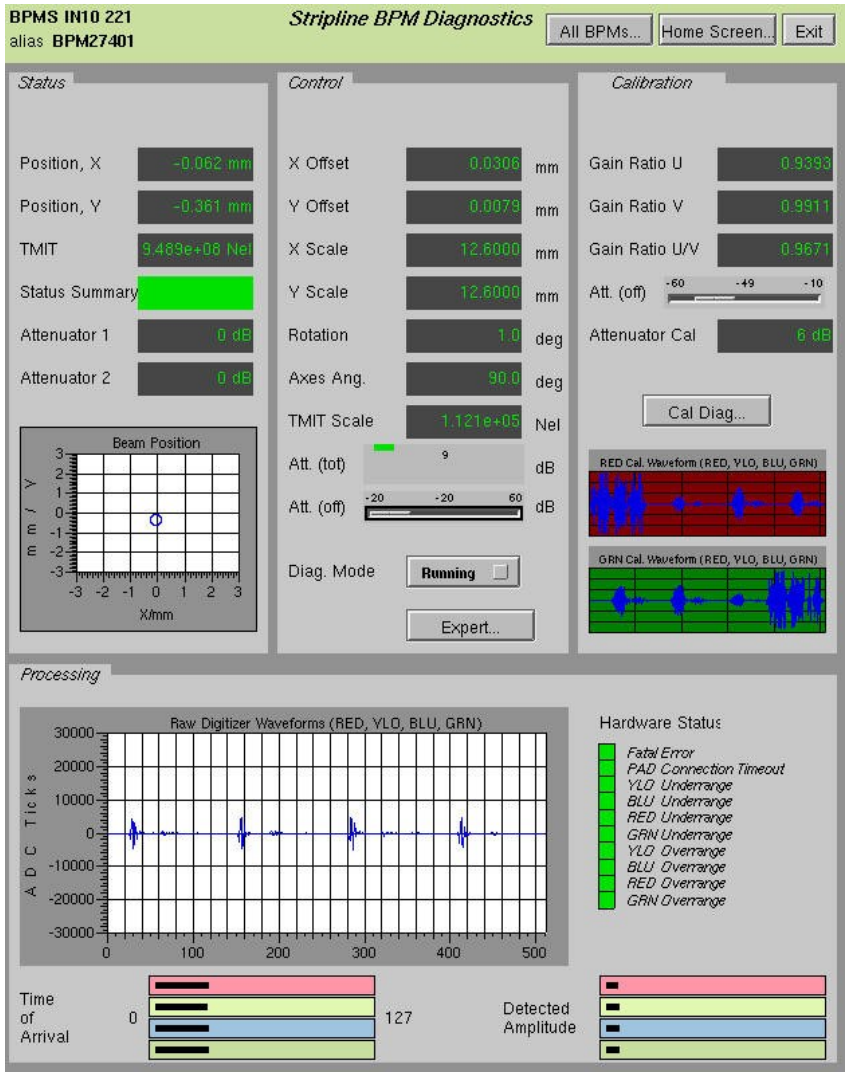
- EVR carrier: Vadatech AMC100



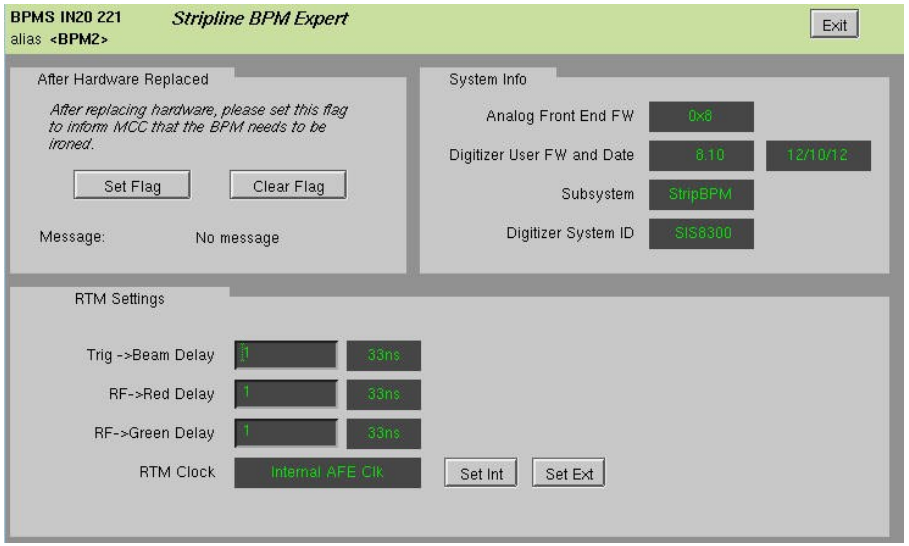
User Interface – Injector BPMs



User Interface – BPM Diagnostics



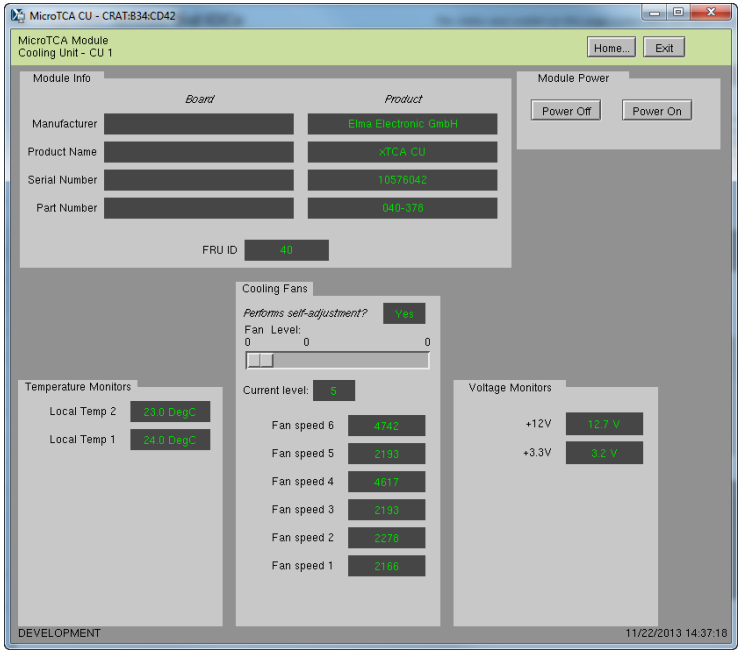
EPICS EDM screens for the Stripline BPMs. This picture shows the real beam and the calibration tone signals after the beam interleaved.

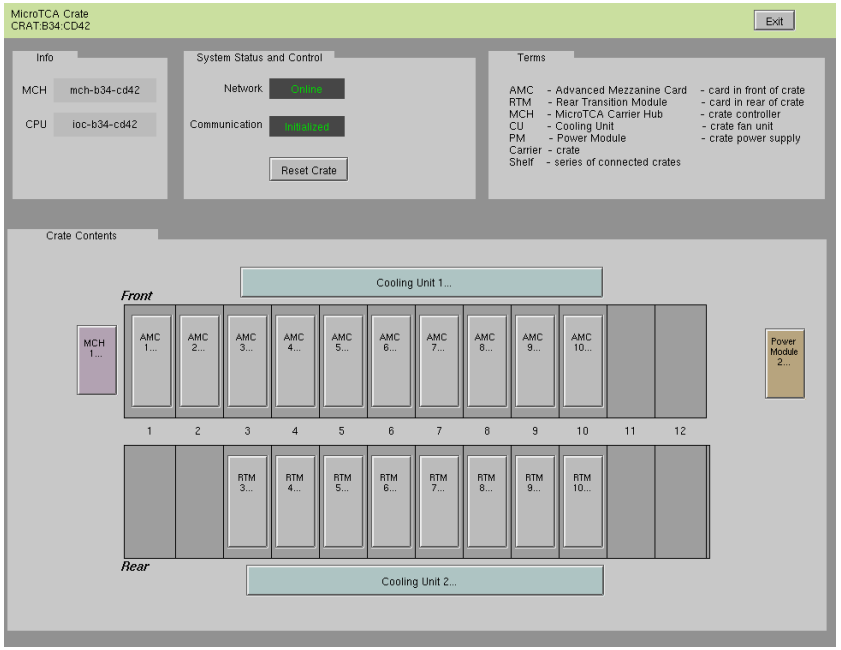


Further information about real-time Linux with microTCA are discussed in Kukhee Kim's talk at 5:15pm today

IPMI Monitoring using EPICS

The SLAC EPICS IPMI software provides remote monitoring and control of MicroTCA systems via their MCHs. EPICS monitors temperature, voltage, current, and fan speed sensors and system reset. These readbacks and control signals are available to users via EPICS PVs. The software runs in an EPICS IOC process and is configured with a list of MicroTCA systems to monitor. For each remote system, it discovers the MCH vendor and uses the appropriate message protocol

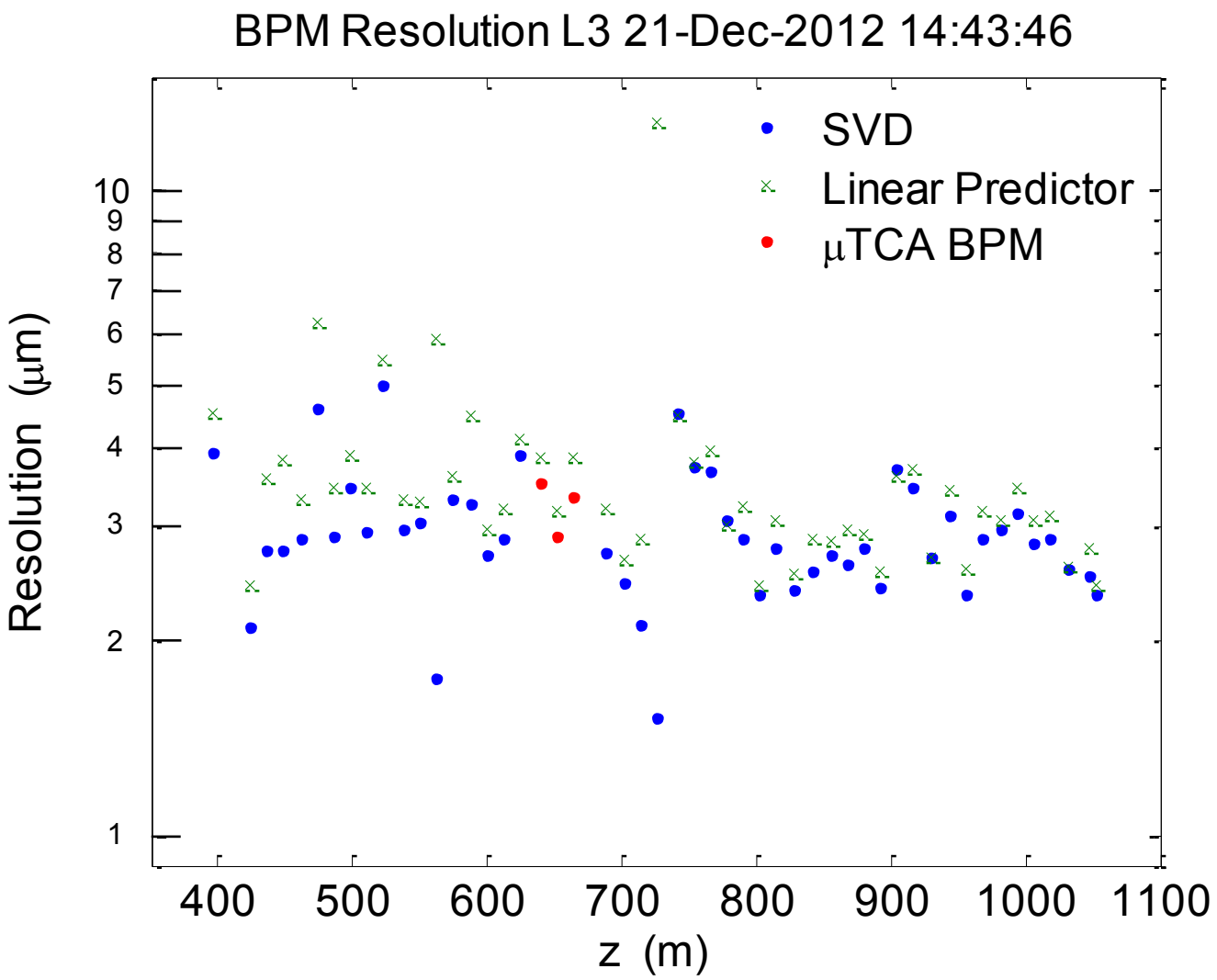




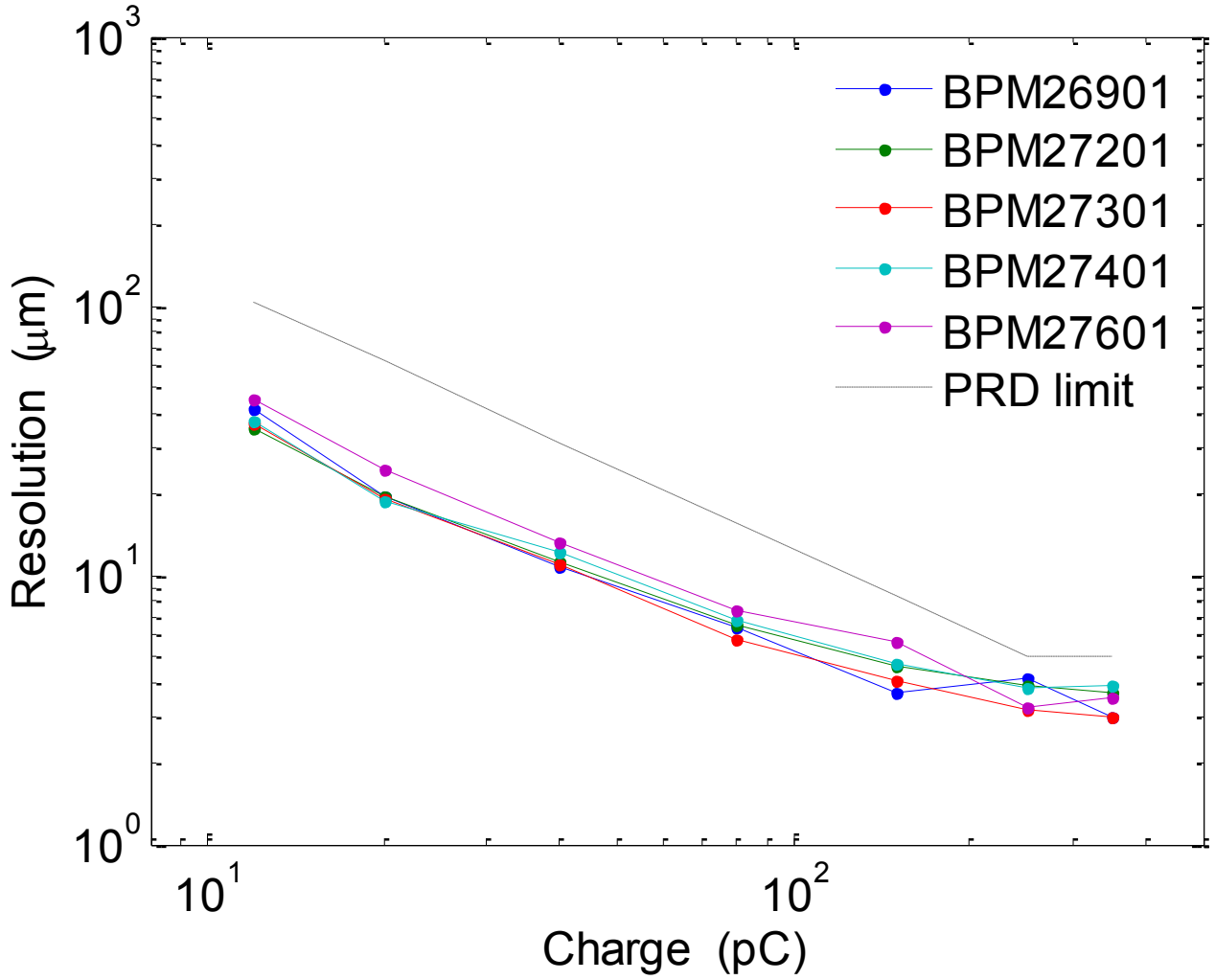
BPM AIP LI27 Demonstration

- Last December, connected 3 LCLS Linac stripline BPMs to new MicroTCA system
- Performance similar to nearby LCLS BPMs
  - Resolution <= 4um at 250 pC
  - Measurements between 10 pC and 350 pC
- Some remaining issues
  - EVR software bug
  - Must be resolved in time for injector commissioning

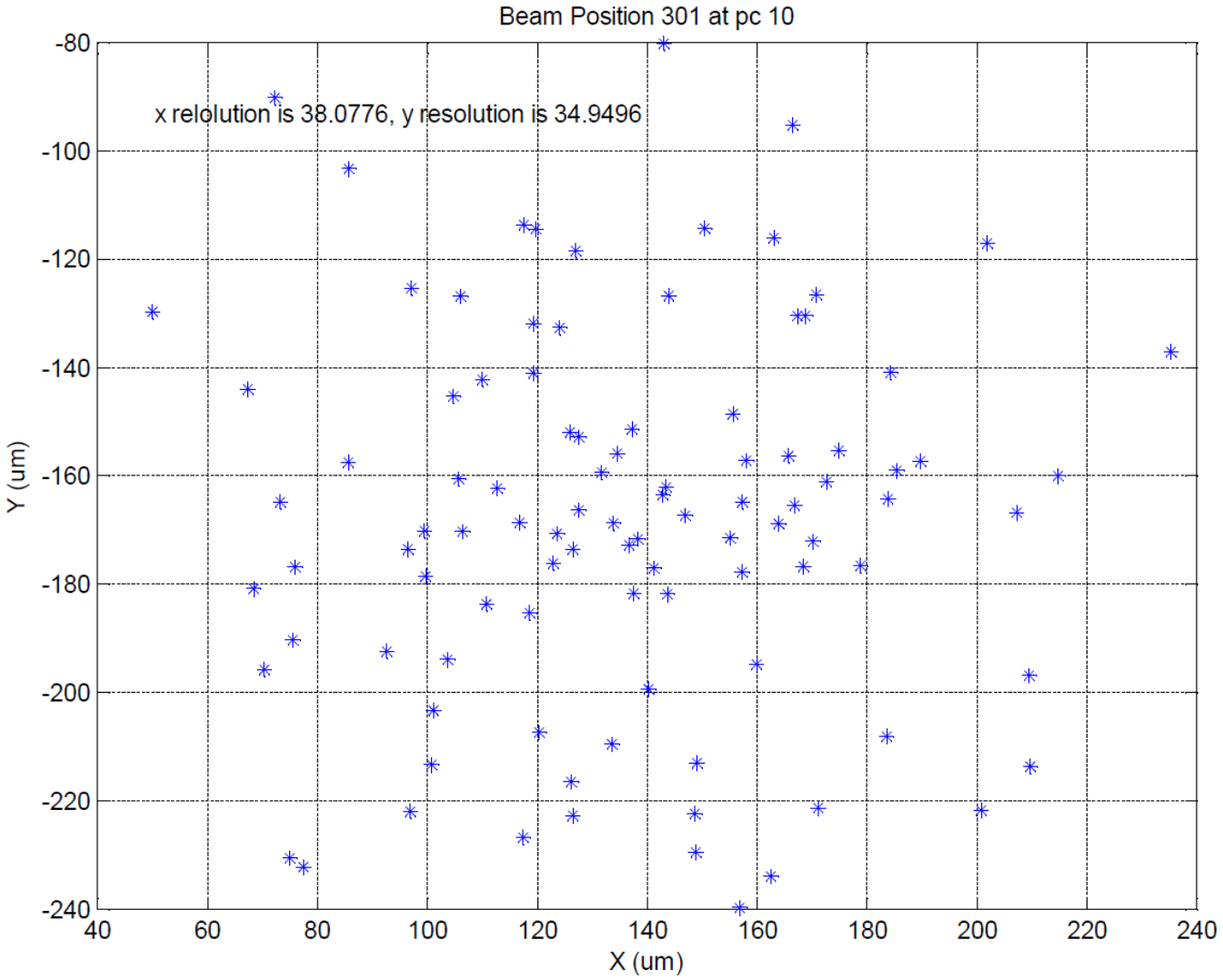
BPM Resolution in L3 at 250 pC (H. Loos)



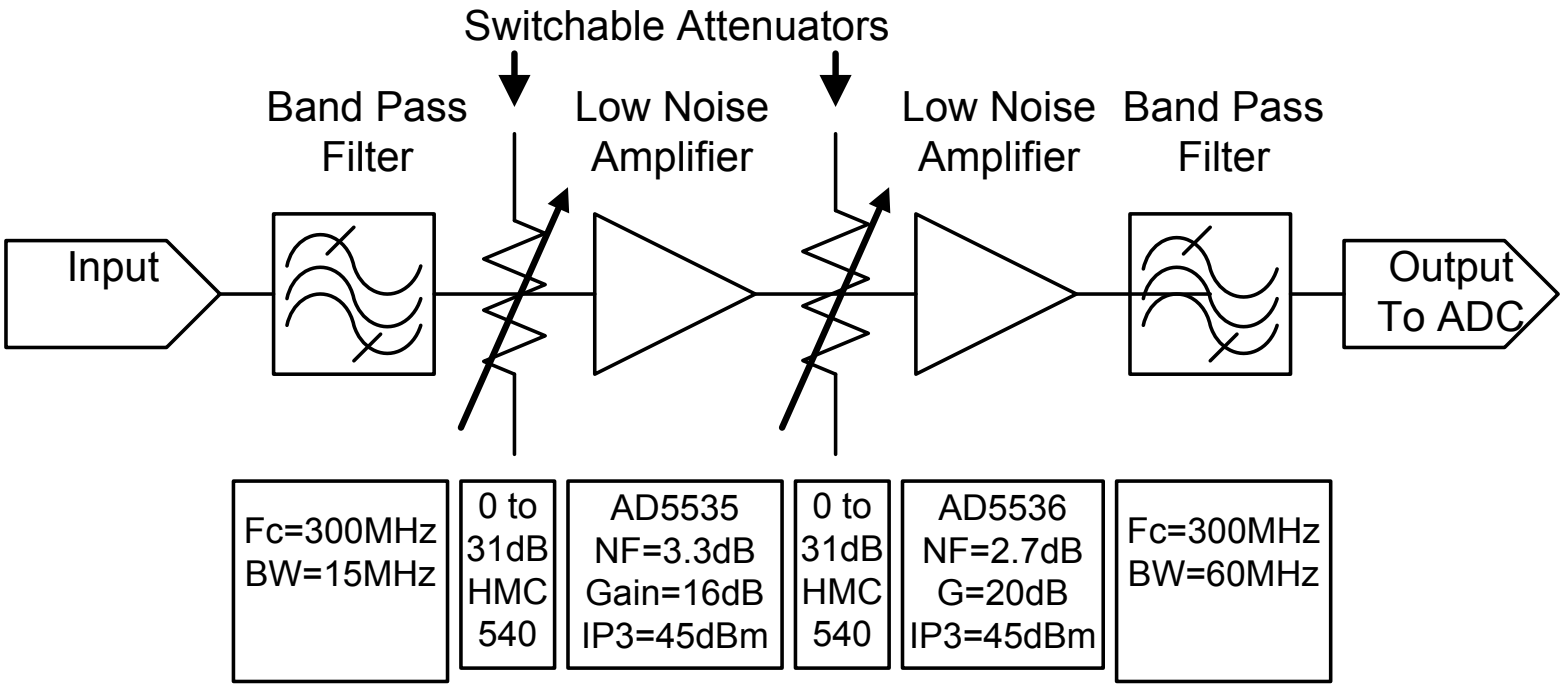
BPM Resolution (H. Loos)



Resolution at 10pC

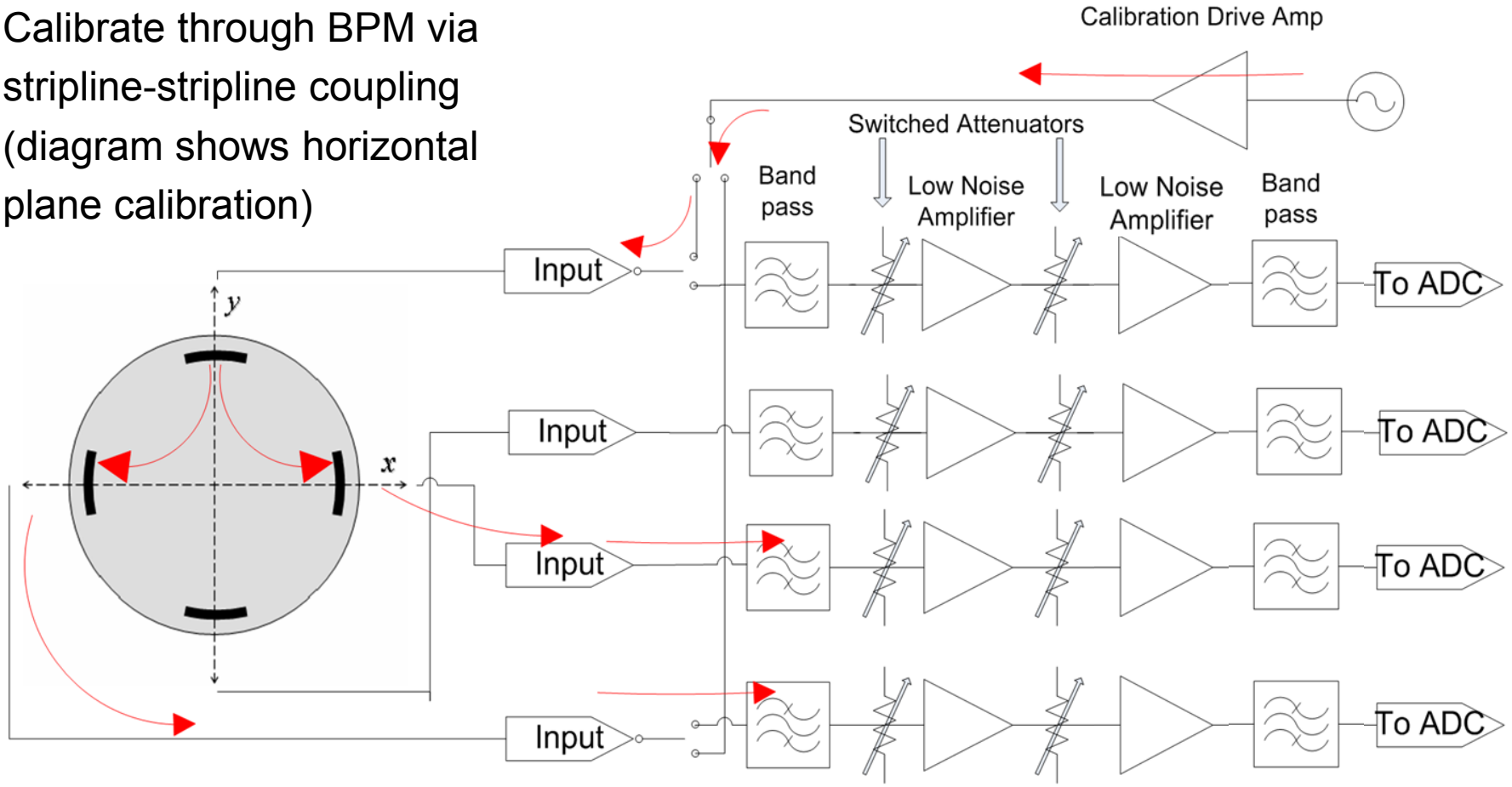


AFE Block Diagram

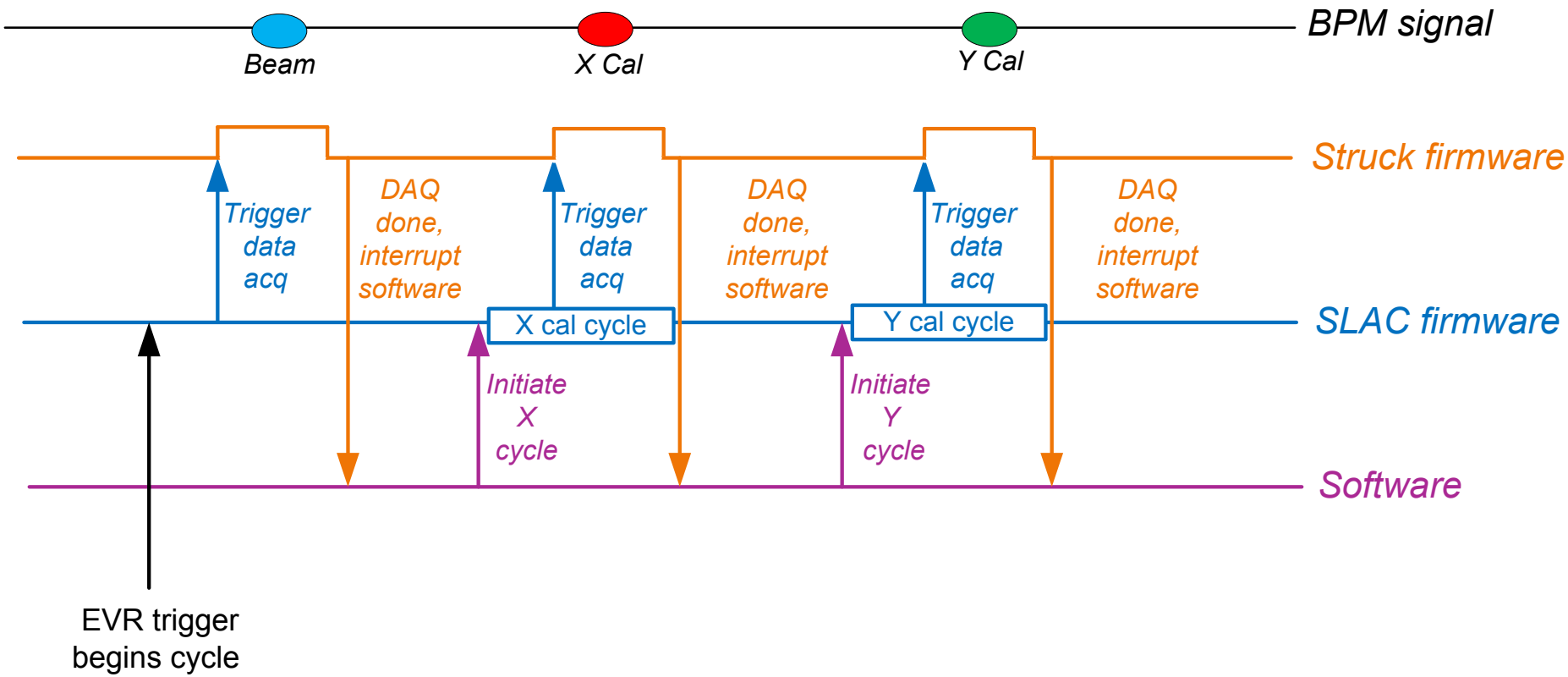


120 Hz Self-Calibration

Calibrate through BPM via stripline-stripline coupling (diagram shows horizontal plane calibration)

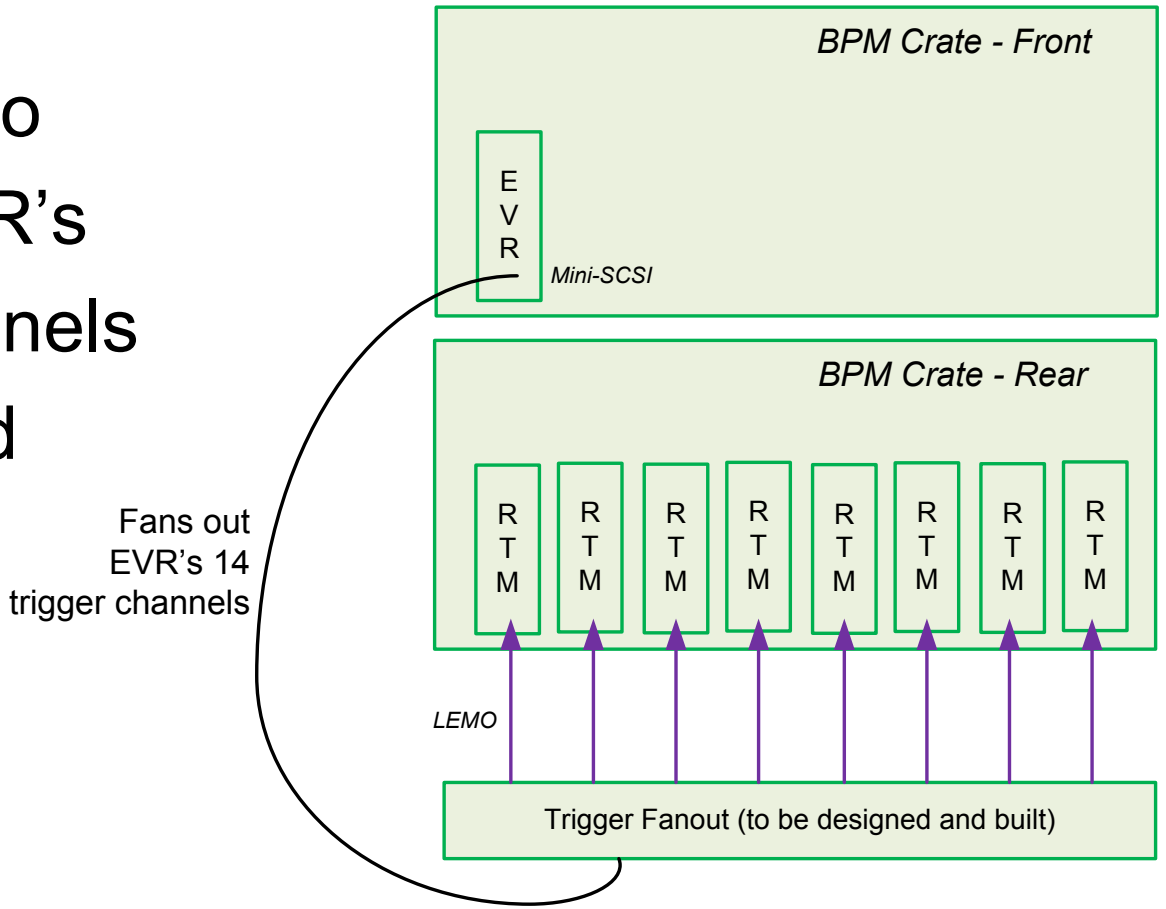


120 Hz Beam-Calibration Cycle

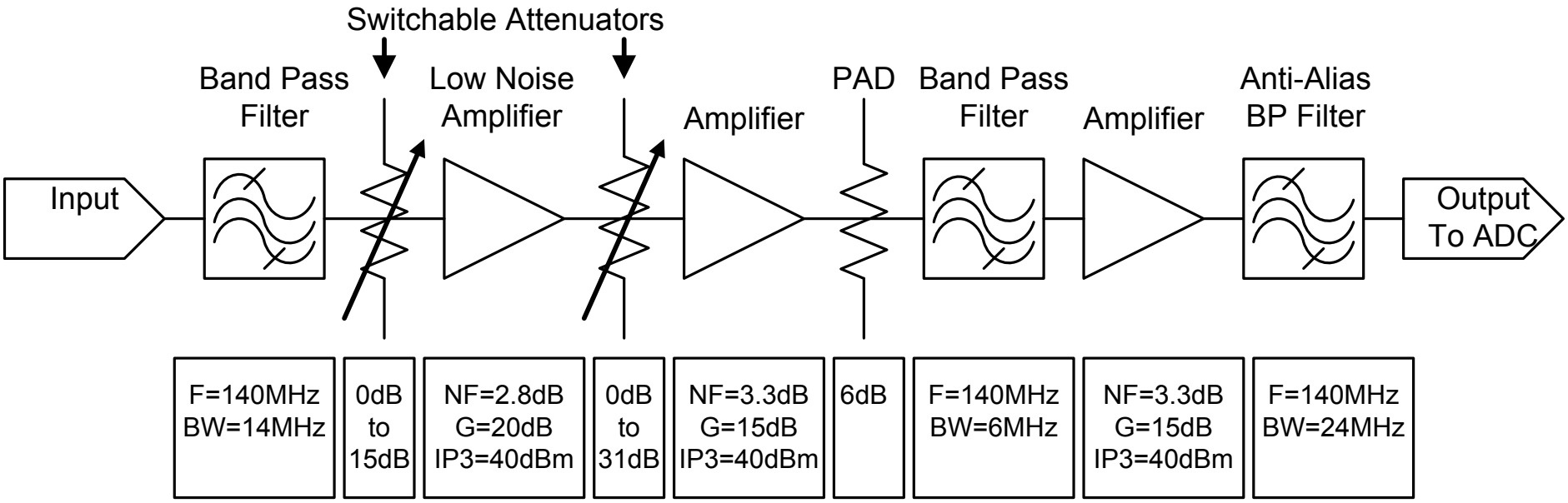


BPM Triggers

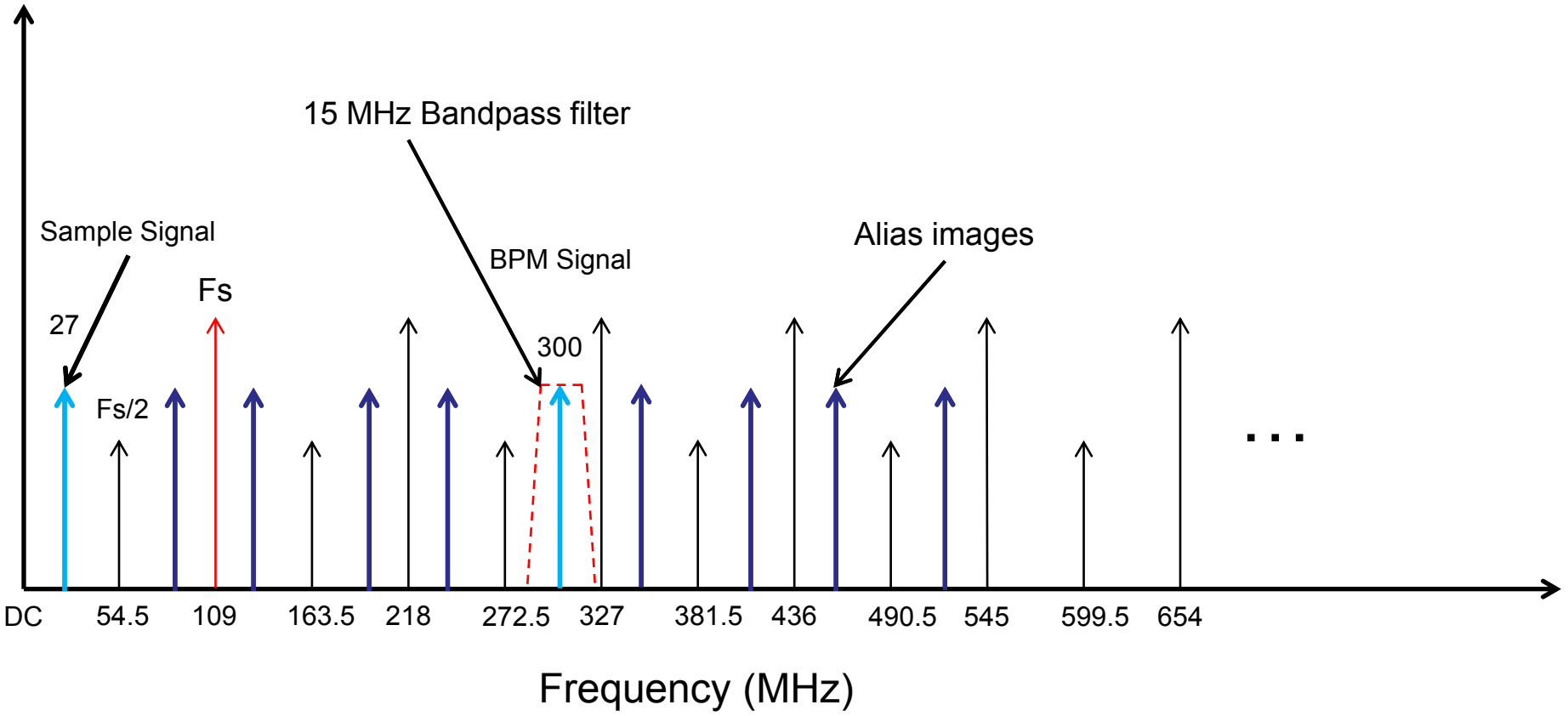
- 1 trigger per BPM (external input to RTM)
- PMC EVR
- Trigger fanout to access the EVR's 14 trigger channels (to be designed and built)



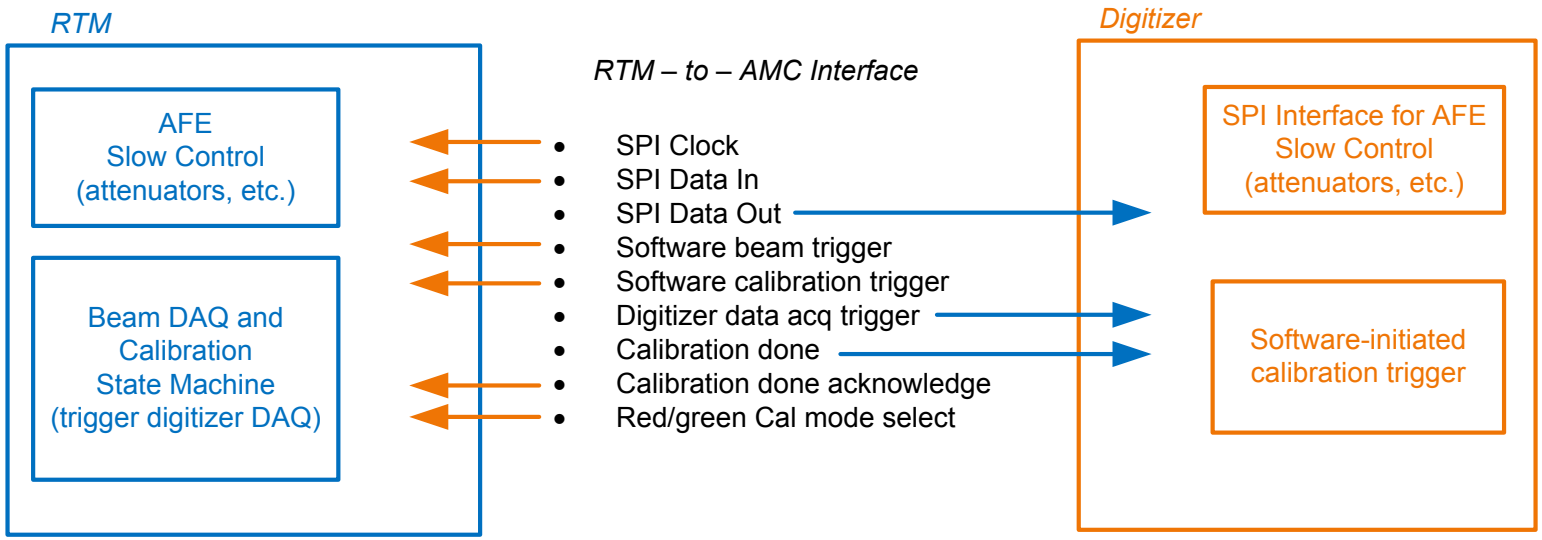
LCLS-I AFE Block Diagram



Review on sampling theory



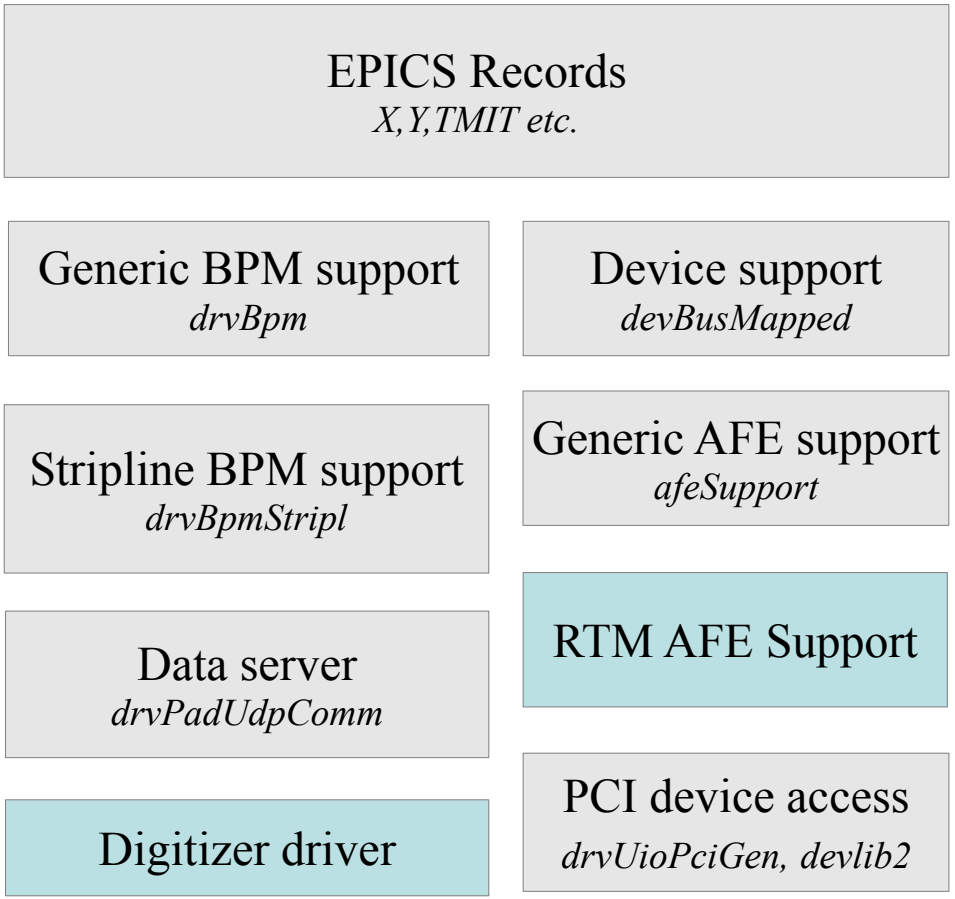
Stripline BPM Firmware



- New internal delays
  - Support future single trigger for all BPMs in crate
- Move real-time support to dedicated hardware lines
  - Real-time software no longer needs to use slow serial interface
- Digitizer
  - New software calibration trigger

Software

- Real-time Linux OS
- Interface to clients (PVs, displays) remains the same
- Use existing BPM application and EPICS support
  - New Struck digitizer driver
  - New AFE driver



Software

- Maintain standard LCLS EPICS implementation
  - EDM displays (operator interface)
  - SCORE (configuration save/compare/restore)
  - Archiving (history plots)
  - Alarms (inform operators of problems)
  - Beam-Synchronous BPM Data Acquisition