BPM/LLRF Collaboration on MicroTCA.4

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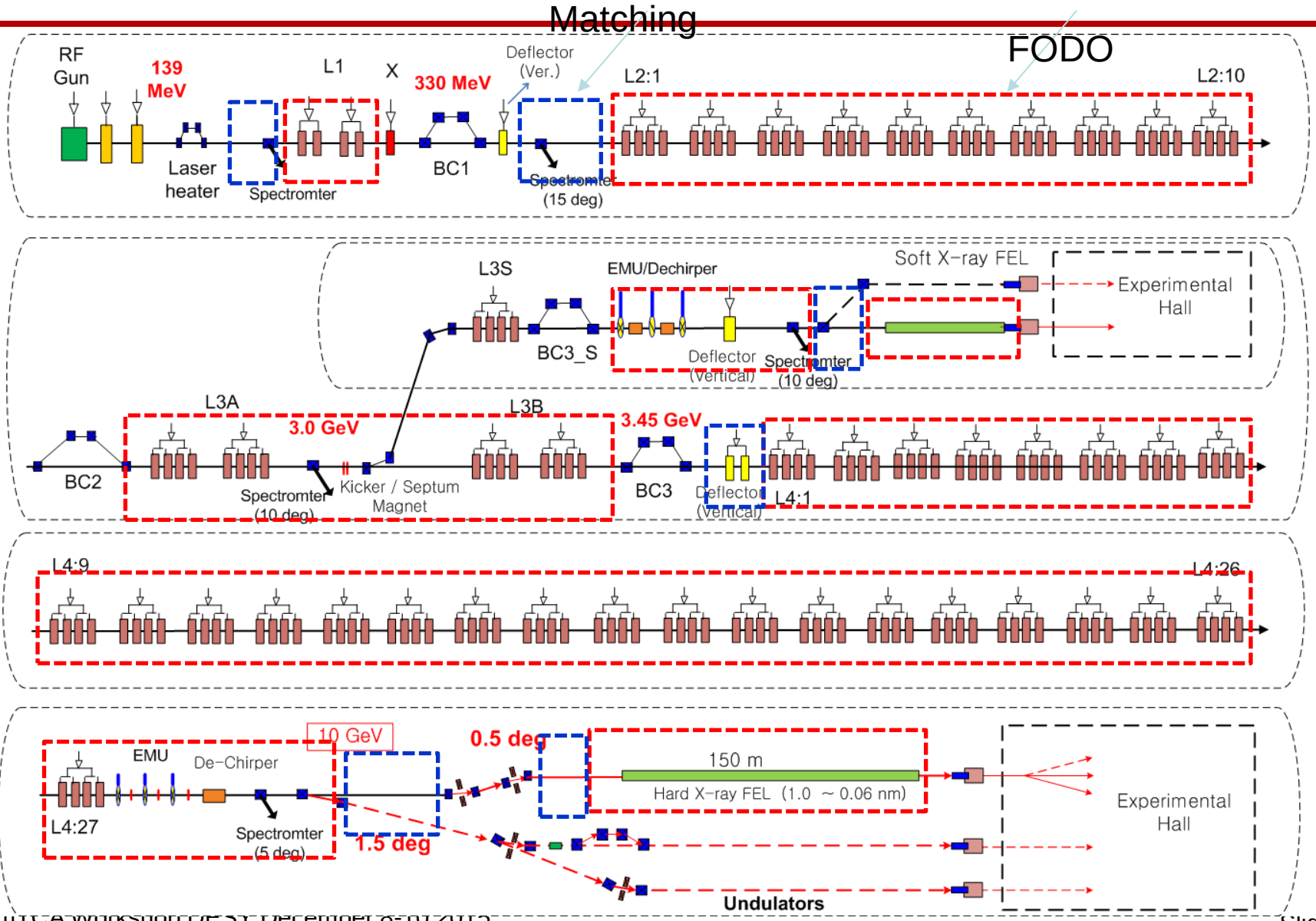
mTCA Workshop DESY December 8-10 2015

Collaboration-Pohang Accelerator Laboratory

October 2015

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

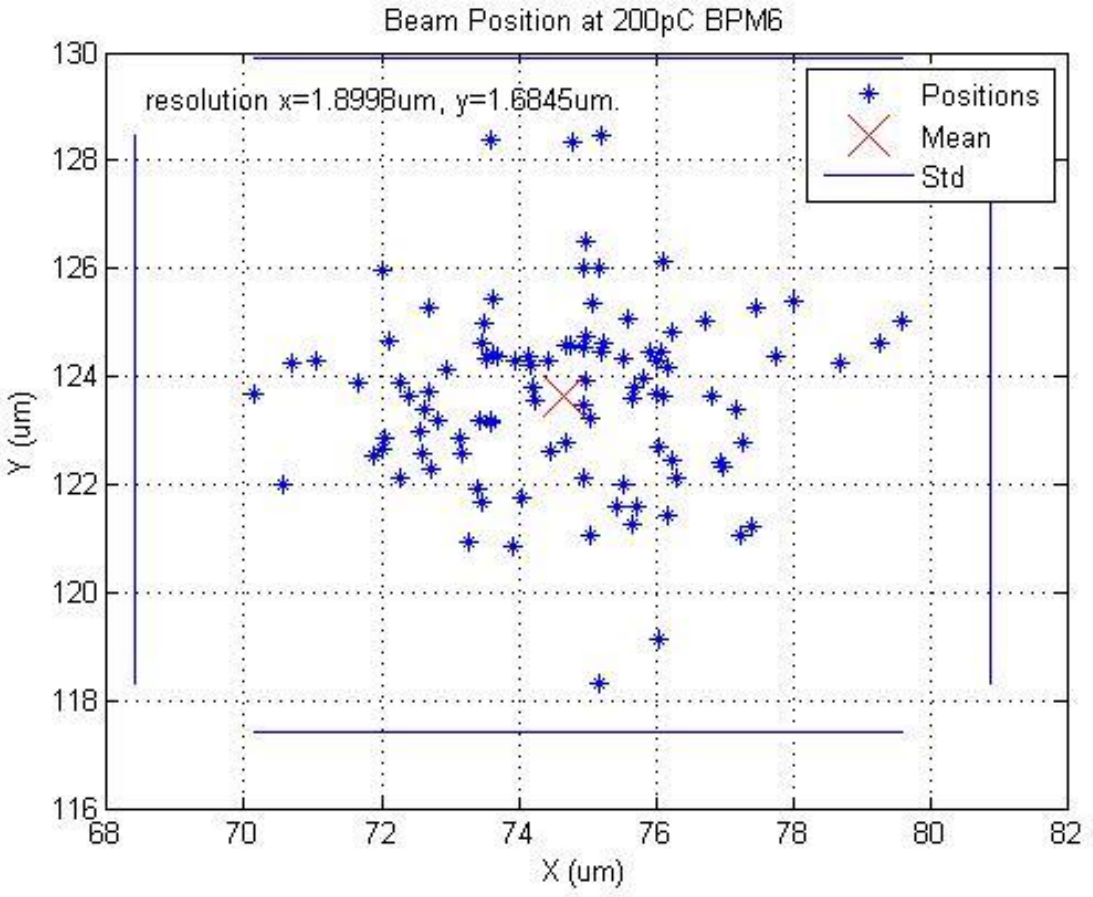


Scope and Goals of the WFO for PAL

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, 19 MicroTCA Carrier hub (MCH), 19 CPU, 19 EVR with distribution chassis and a 19 microTCA chassis.

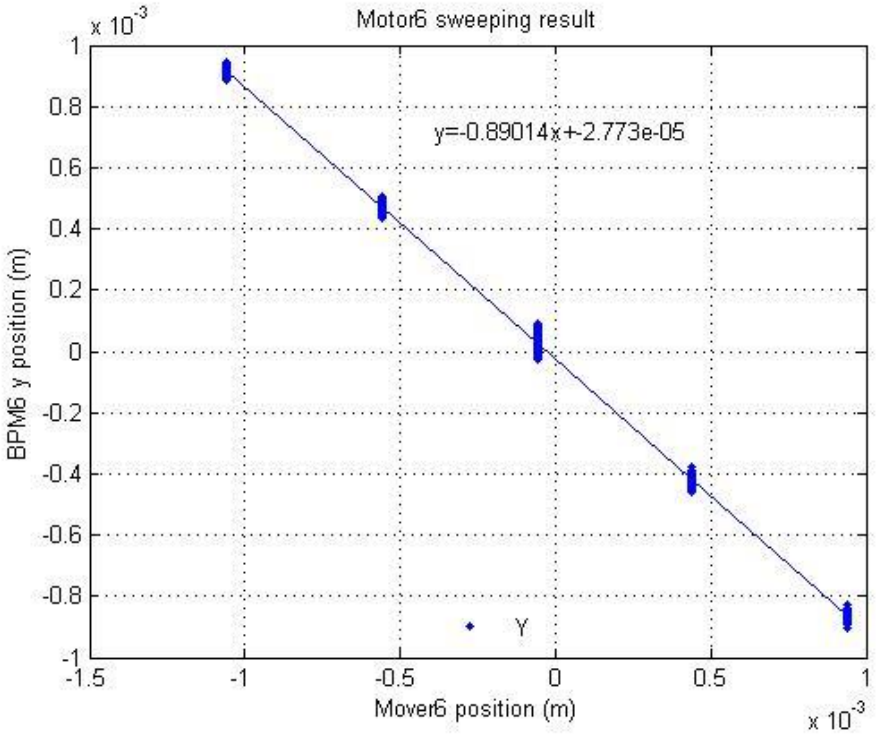
Beam resolution using one BPM

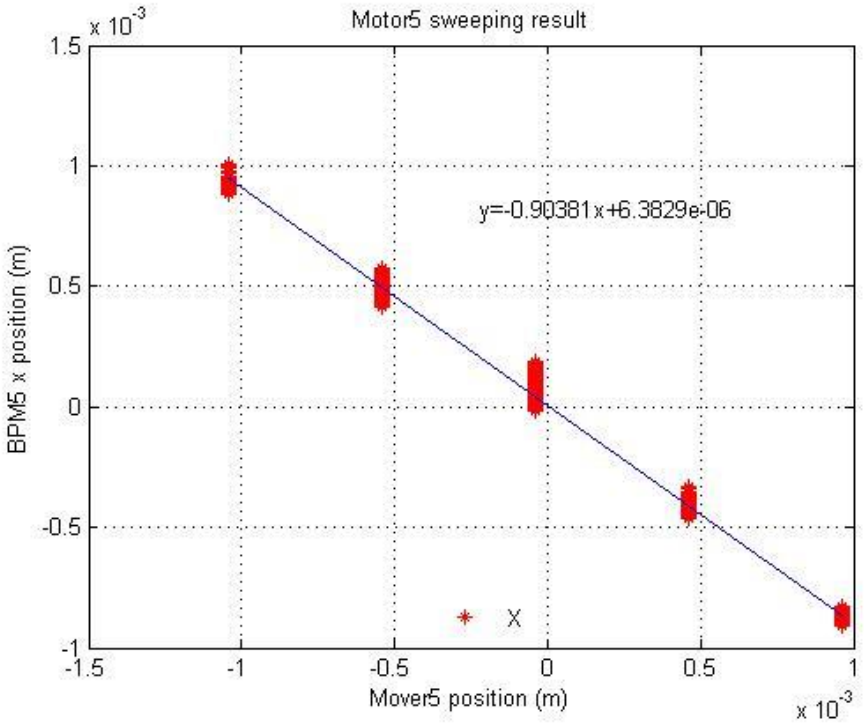


BPM_Resolution_RTM__TEST_20140623T135031

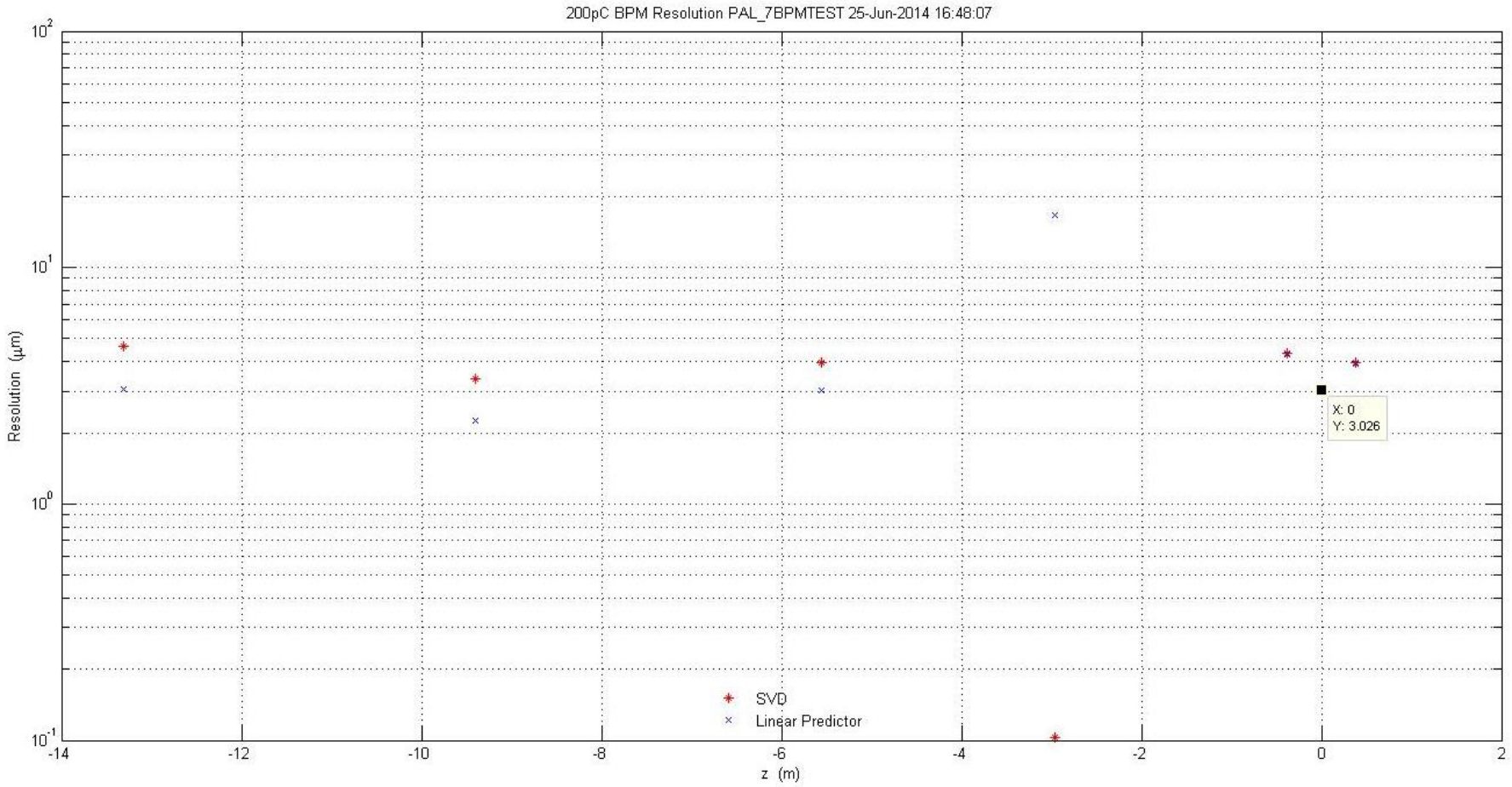
Using a single BPM we can measure the resolution over 100 shots. This is similar to how we measure in our lab. There is a trick to this measurement in that the beam must be centered.

BPM linearity over +1/-1mm

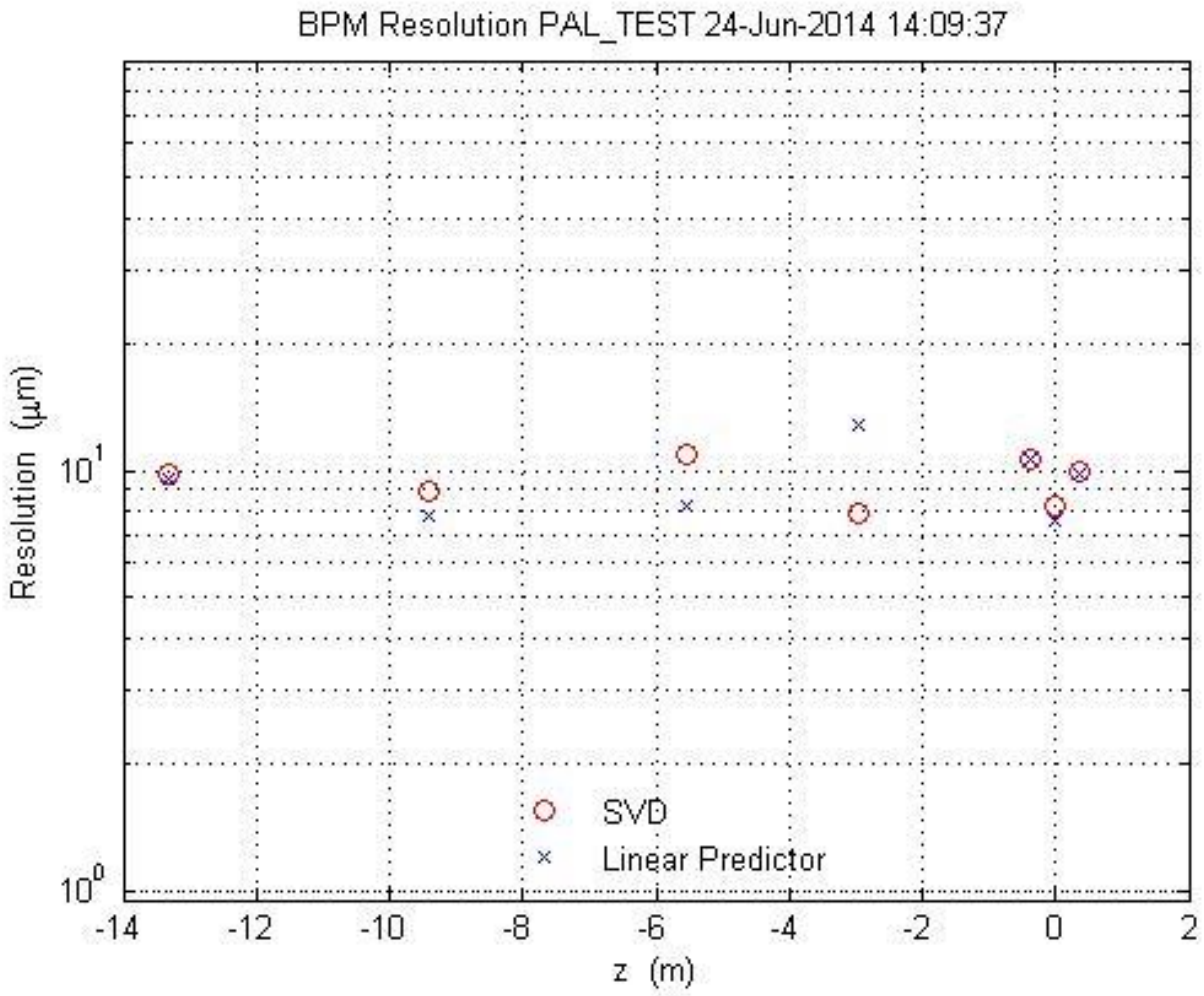




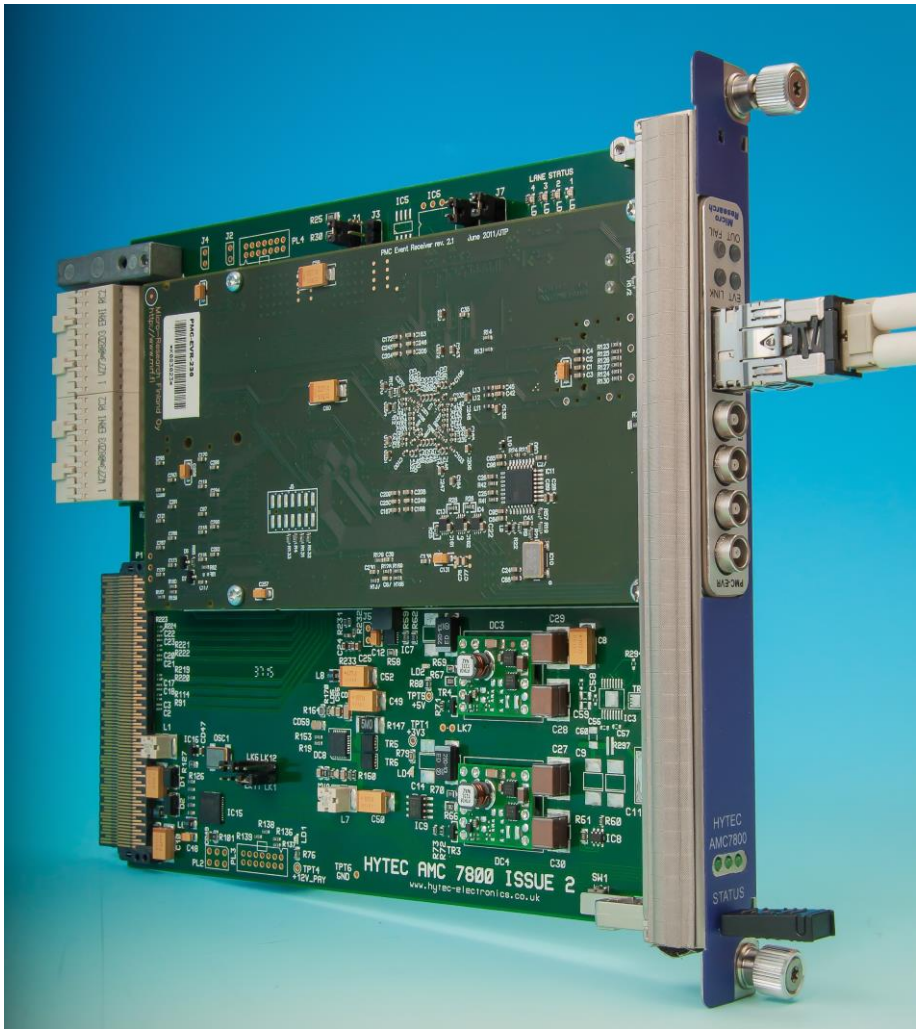
Resolution


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

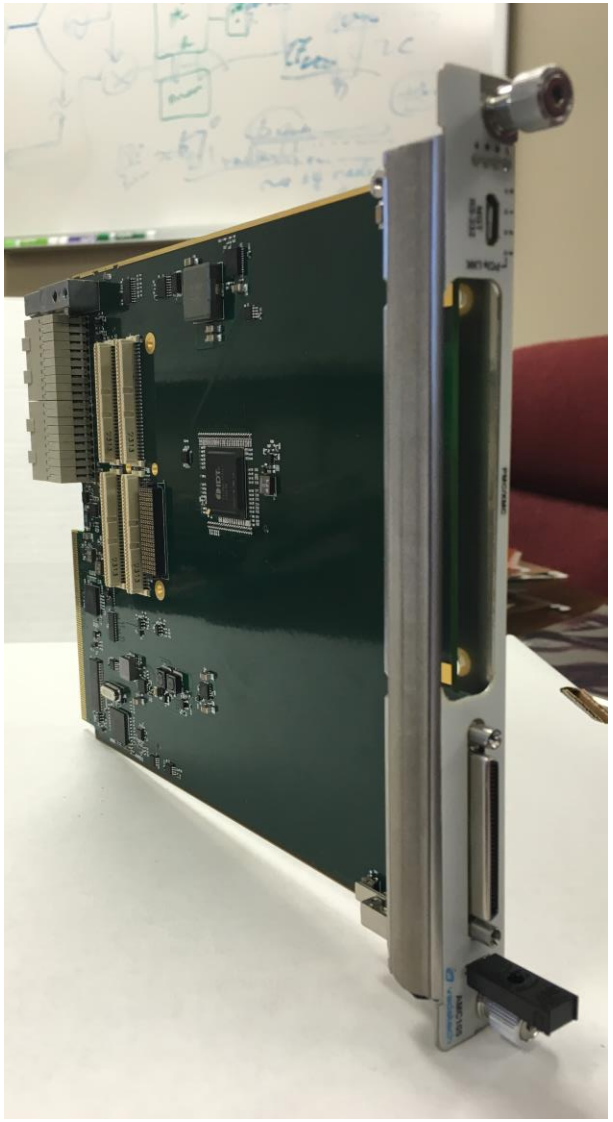
Resoution at 10pC



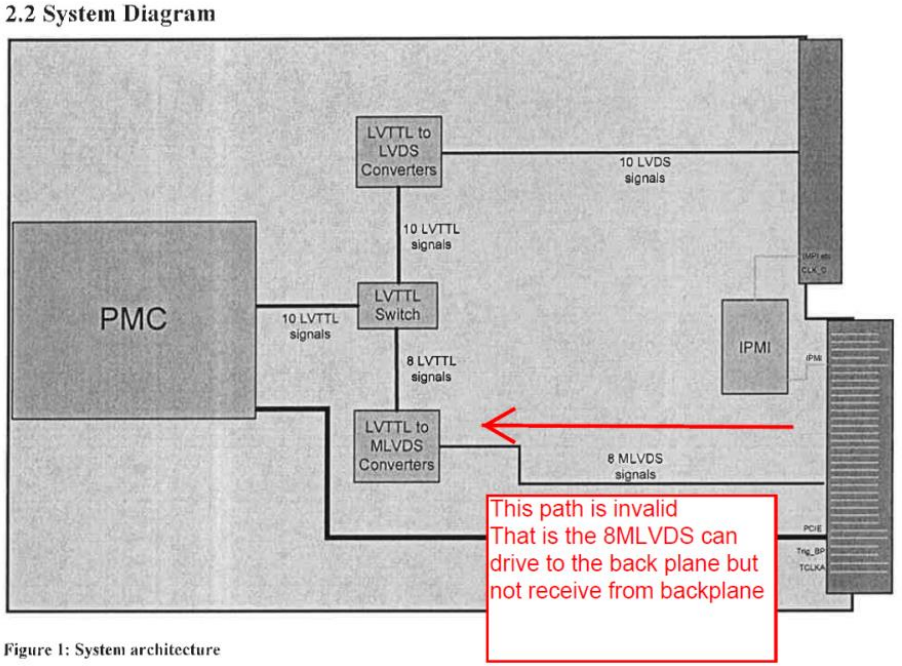
New PMC EVR from Hytec with SLAC RTM



New PMC EVR from Vadatech AMC105



Currently under test, Result in Jan 2016



Lessons Learned in production build

- Automate testing wherever possible. We could test a board in 30min. This still meant you are spending **2 weeks** on testing good boards.
- Just because you built a system with 10 boards with 100% yield does not mean you will have the same yield at 144 boards.
  - The board Assembly house decided to change the process of stuffing the boards instead of a no-wash the washed and then baked the boards which caused the an inductor inside the filter to short a winding or two.
  - We also saw that the output of our first switcher to have a blown output FET.
  - We had sever issues with thermal pads not being soldered.
- Overall yield 85% which means we spent an extra 30 days trouble shooting boards. We only had one board where we had to replace all the components in a BPM channel because there was too many things wrong. BE PREPARED!!

Phase II Status

- We have delivered 144 BPMs to Pohang, tested and commissioned the BPM system for the xFEL.
- SLAC developed a new PMC EVR that is compatible with mTCA.4 Zone 3 D1.0 standard. We collaborated with industry to design the AMC PMC carrier and SLAC is designing the new RTM that will fan-out 10 triggers to an RTM.
- Pohang will have beam in Feb. 2016

ESS CRADA

Pohang Phase III – Cavity BPMs

- Coming in Feb 2016 SLAC will deliver 56 Cavity BPMs systems to Pohang.
  - 5-6 mTCA crates with EVR, RTM fanout, power supplies, MCH
  - New generic mTCA RTM that will mate to SIS8300-L2
  - X-band Super-Heterodyne front-end that will mate to the RTM.

ESS Design Philosophy

- **The ESS design update:**
  - 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.

Copenhagen
Copenhagen-University
CPH Airport

Bridge
SE-DK

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

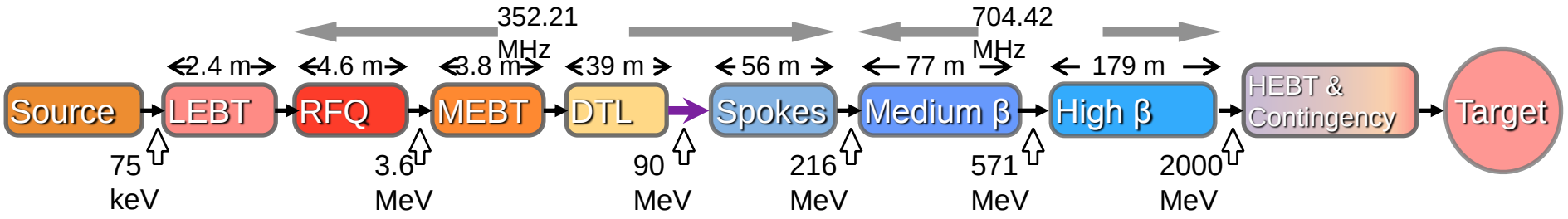
125 MW

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

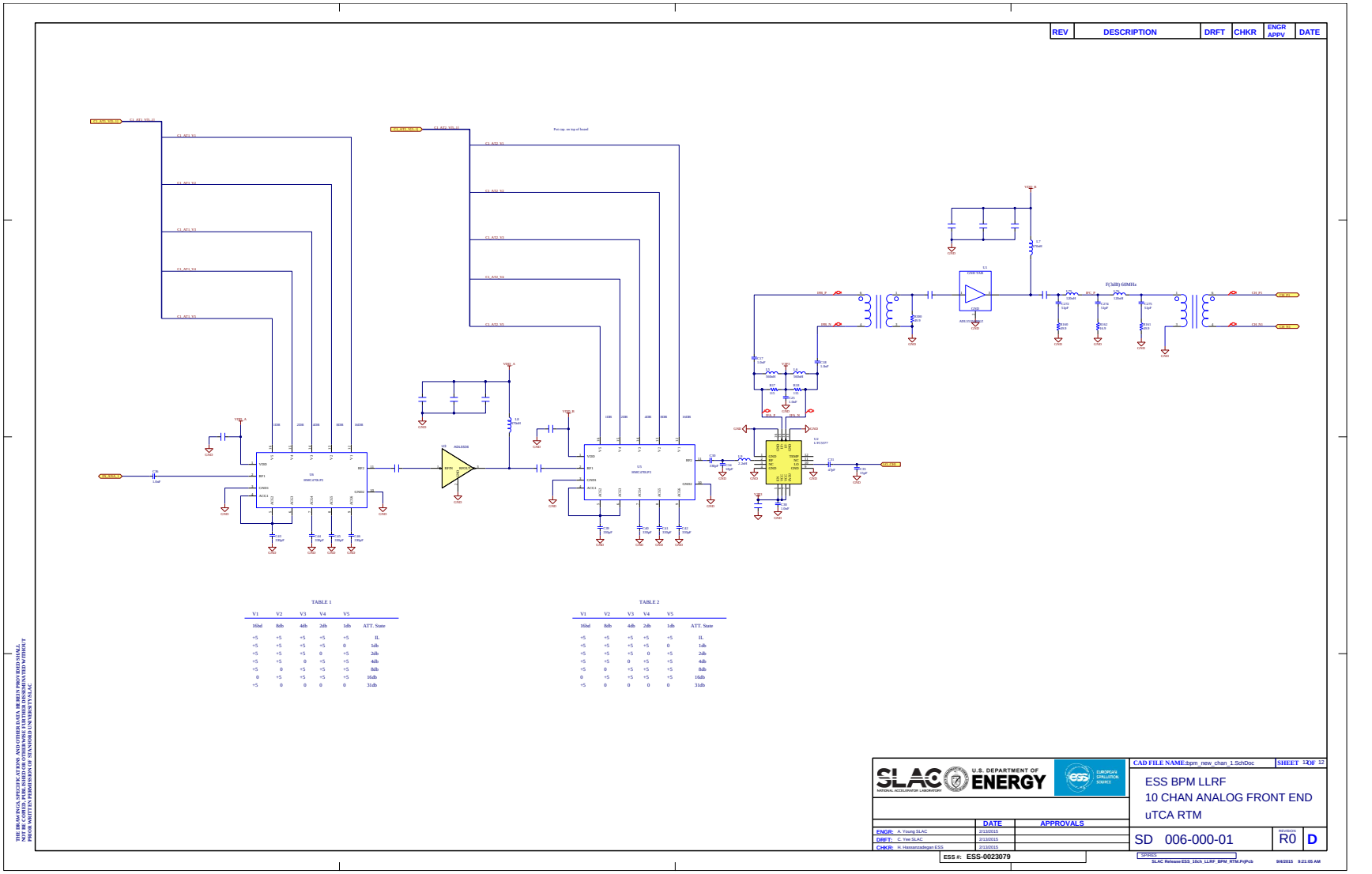


Scope and Goals of the CRADA Agreement with ESS

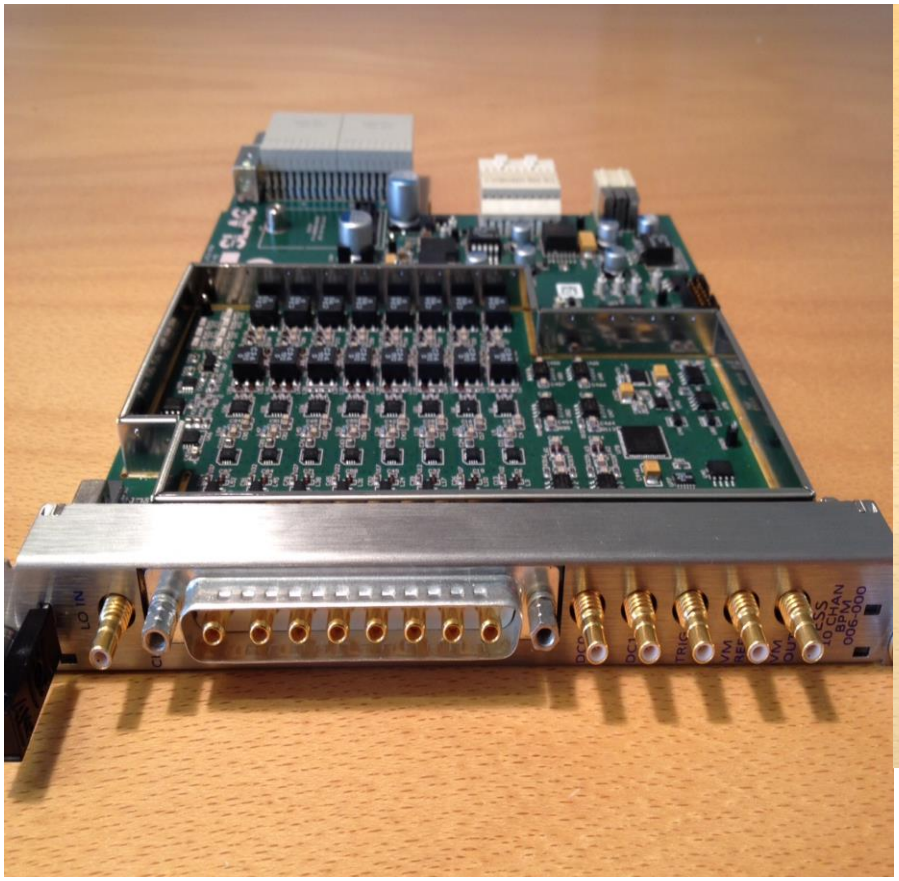
The CRADA agreement was a collaboration between the ESS Accelerator Laboratory and SLAC National Laboratory to develop microTCA systems for BPMs and LLRF.

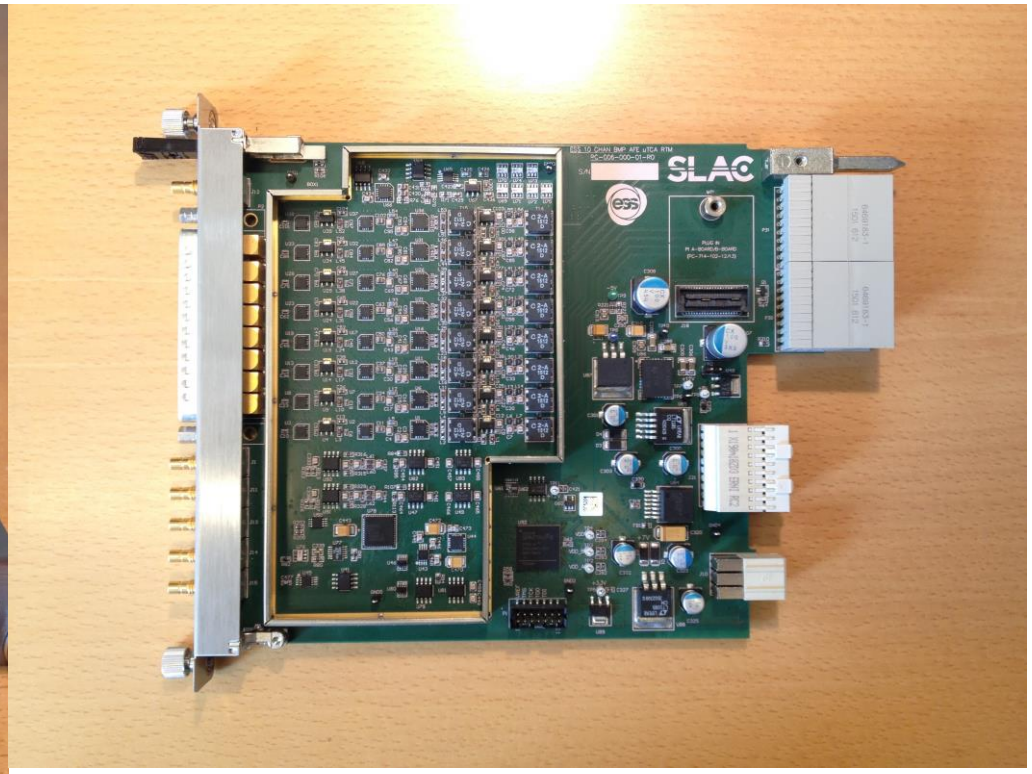
- The Phase I system consist of designing a RF Downmixer Rear-Transition-Model (RTM)
- The Phase II system consist of designing a General Purpose FPGA AMC module that could be used as an Event Timing Module, LO generation Module, and BPM calibration Module.
- The Phase III system consist of designing 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

Super-heterodyne RTM design



Phase I RTM PCB board





Lessons Learned in production build

- SLAC designed the board and then sent it off to Europe for Fabrication. Europe does things differently than the US:
  - The board fabrication changed the layer stack-up which caused the board to be very thick. We had to mill one side to get the proper thickness.
  - RF capacitors that are easy to get in the US take 3 months to get in Europe
  - Longer board fabrication times
  - Longer Assembly times
  - Easier to get Schroff parts, Erni, anything from Europe

Test plan

- The parameters that are of significant importance for both BPM and LLRF include those that have a large influence on resolution and accuracy.
  - S/N ratio,
  - channel-to-channel cross-talk
  - third-order intercept using two-tone measurement technique.
- These measurements check dynamic range, noise from adjacent channels, linearity.
- it is important to make sure that the RTM can be successfully operated within its attenuation range, and the LO, clock and trigger sources configured as desired.
  - To verify an FPGA code and a software driver will be needed. These are basically to control the two on-board attenuators as well the RF switches.
- Similar tests will be done in parallel by the LLRF group using a LLRF prototype connected to a mock-up pillbox cavity.

Status

Over the past two years, SLAC and ESS Beam Instrumentation group have made a successful collaboration to design a new super-heterodyne front-end RTM for the ESS BPM and LLRF systems. The design has been done by SLAC based on the ESS requirements.

- A prototype RTM is being tested at ESS and SLAC
- The current RTM is in principle an ideal choice for the LLRF systems of the low-energy linac in terms of frequency and the number of the AC- and DC-coupled input and vector modulator output ports.

After the RTM performance has been successfully verified in practice, a decision may be taken to go ahead with other RTM variants, thus fulfilling both the BPM and LLRF requirements in the low-energy as well as the high-energy linac.

SLAC NATIONAL ACCELERATOR LABORATORY

ESS EUROPEAN SPALLATION SOURCE

PAL

End

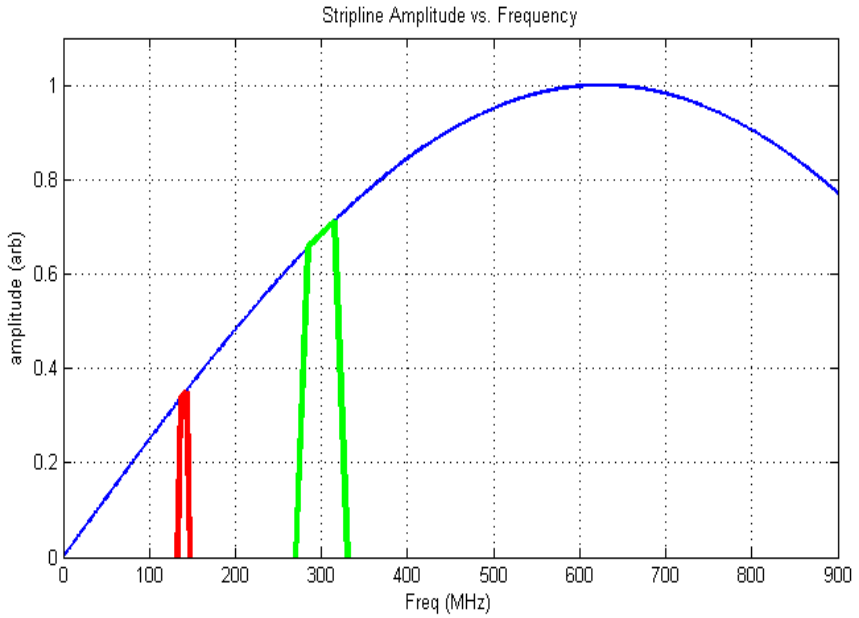
U.S. DEPARTMENT OF ENERGY | Office of Science

LELAND STANFORD JUNIOR UNIVERSITY DIE LUFT DER FREIHEIT WEHT 1891

Backup Slides

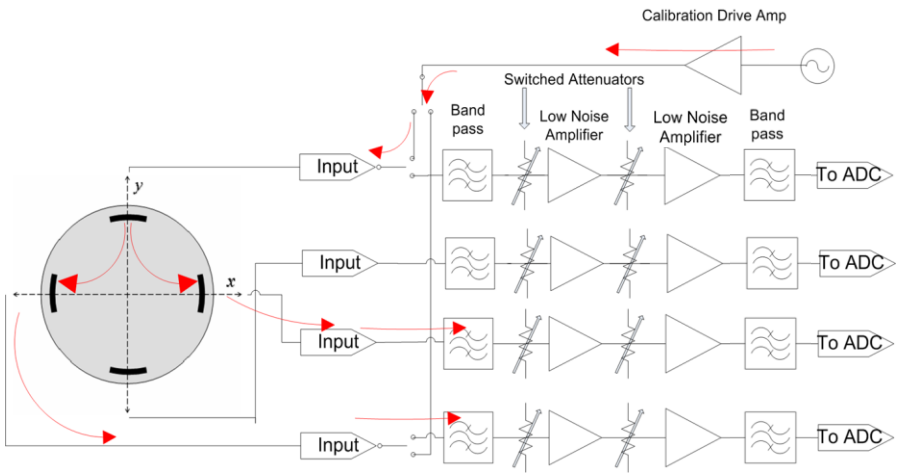
Scope of Project

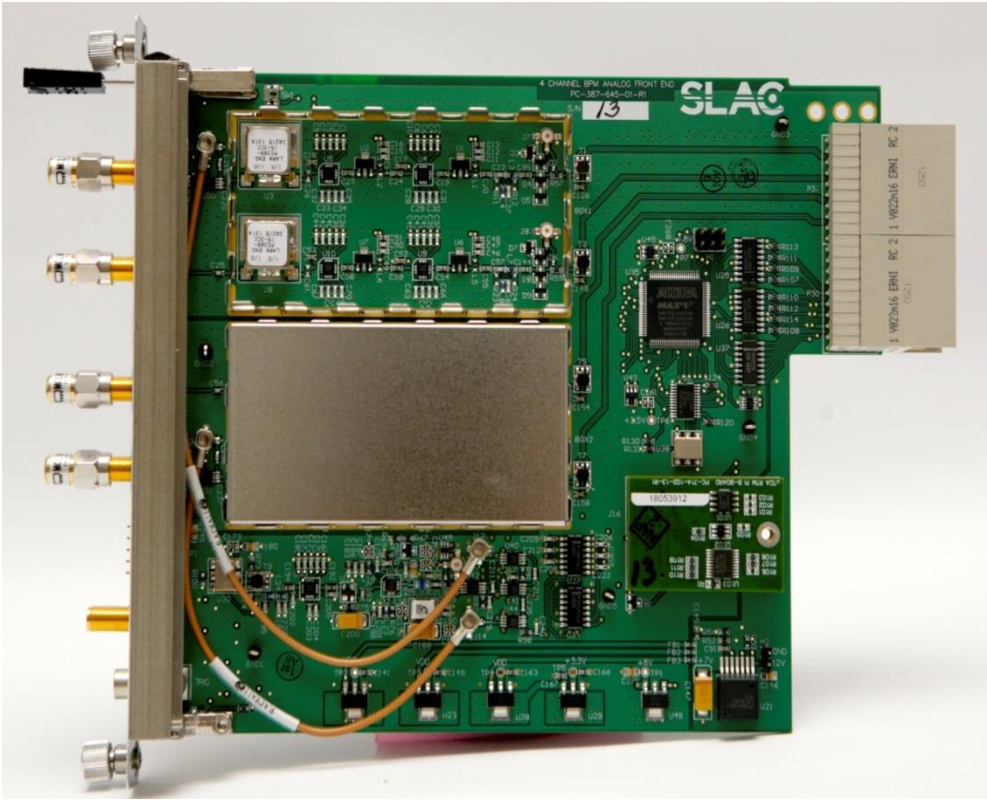
- Build BPM control system for new LCLS-II Injector
  - 15 stripline BPMs
    - Standard Linac pickups, 1” diameter, 4.75” length
  - Integration into EPICS control system



SLAC BPM AFE Rear-Transition Module

- Analog Front End and Calibrator
  - Designed at SLAC

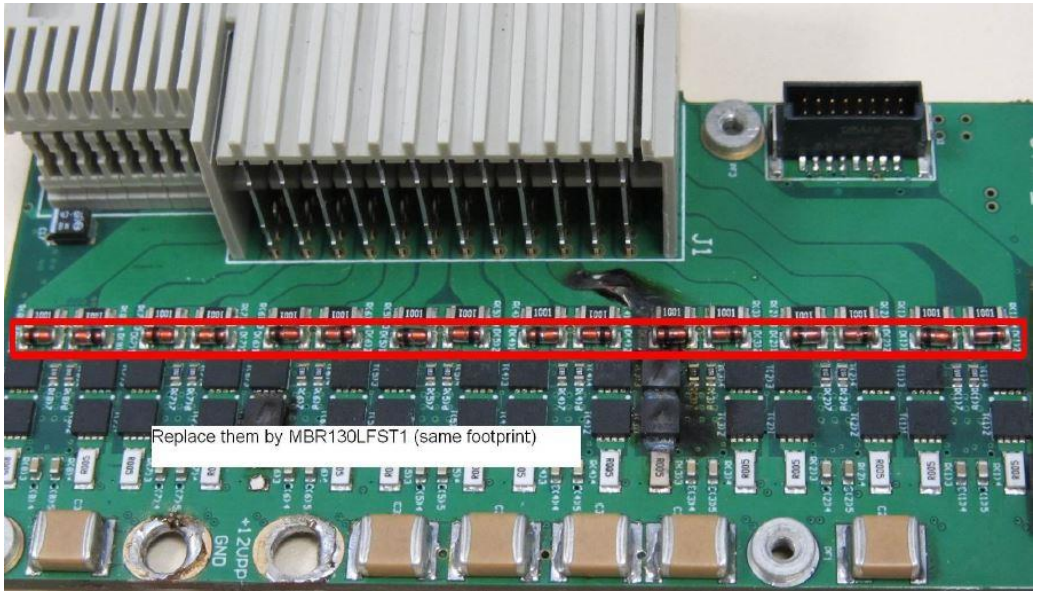




Digitizer

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

Power Supply

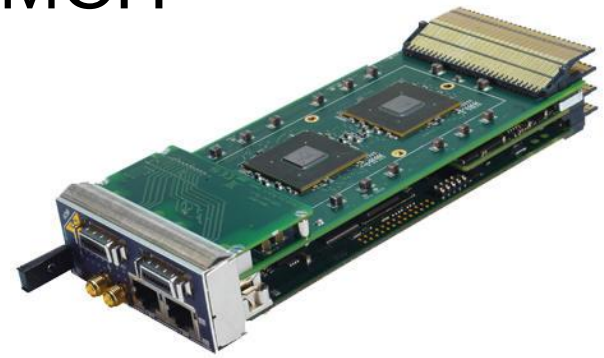


Modified Wiener Power supply to solve in-rush current problem. Wiener has reved the power supply and has been able to increase the power to 1KW. (Thomas Berner Talk Wed at 12:40pm)

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

Review on sampling theory