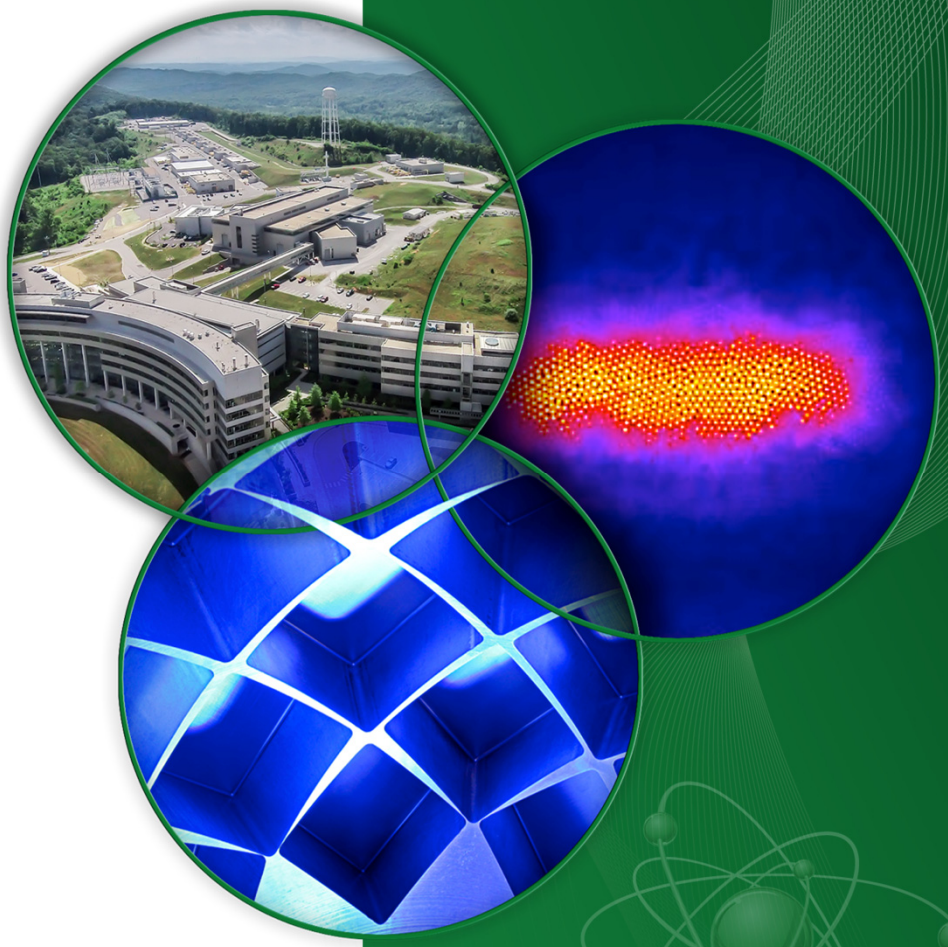
SNS Beam Diagnostics: Ten Years After Commissioning



A. Aleksandrov

Oak Ridge National Laboratory,

USA

ORNL is managed by UT-Battelle
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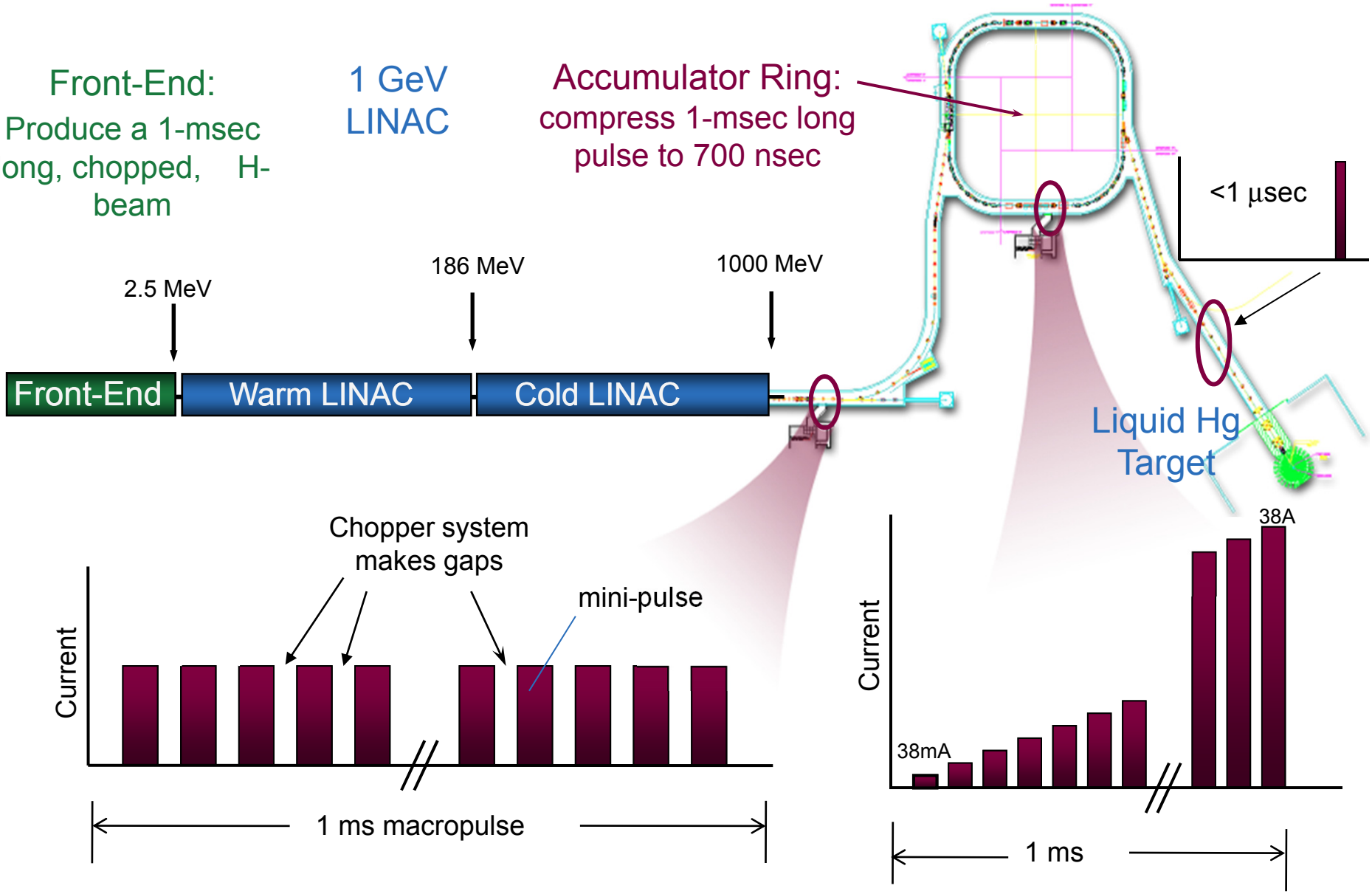
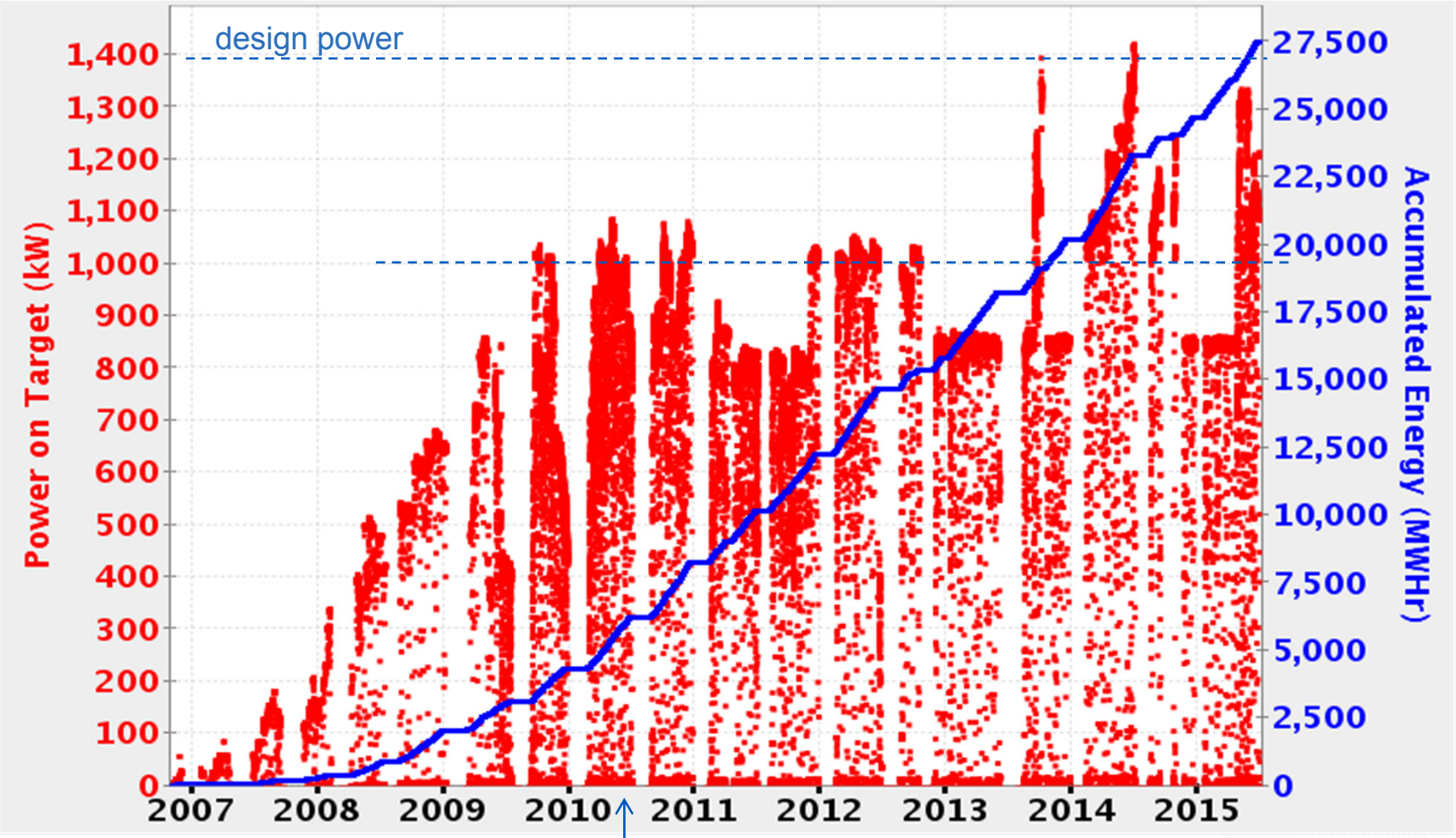
OAK RIDGE National Laboratory | SPALLATION NEUTRON SOURCE

Spallation Neutron Source Accelerator



History plot of SNS beam power



BIW2010, SNS Beam Diagnostics Experience and Lessons Learned

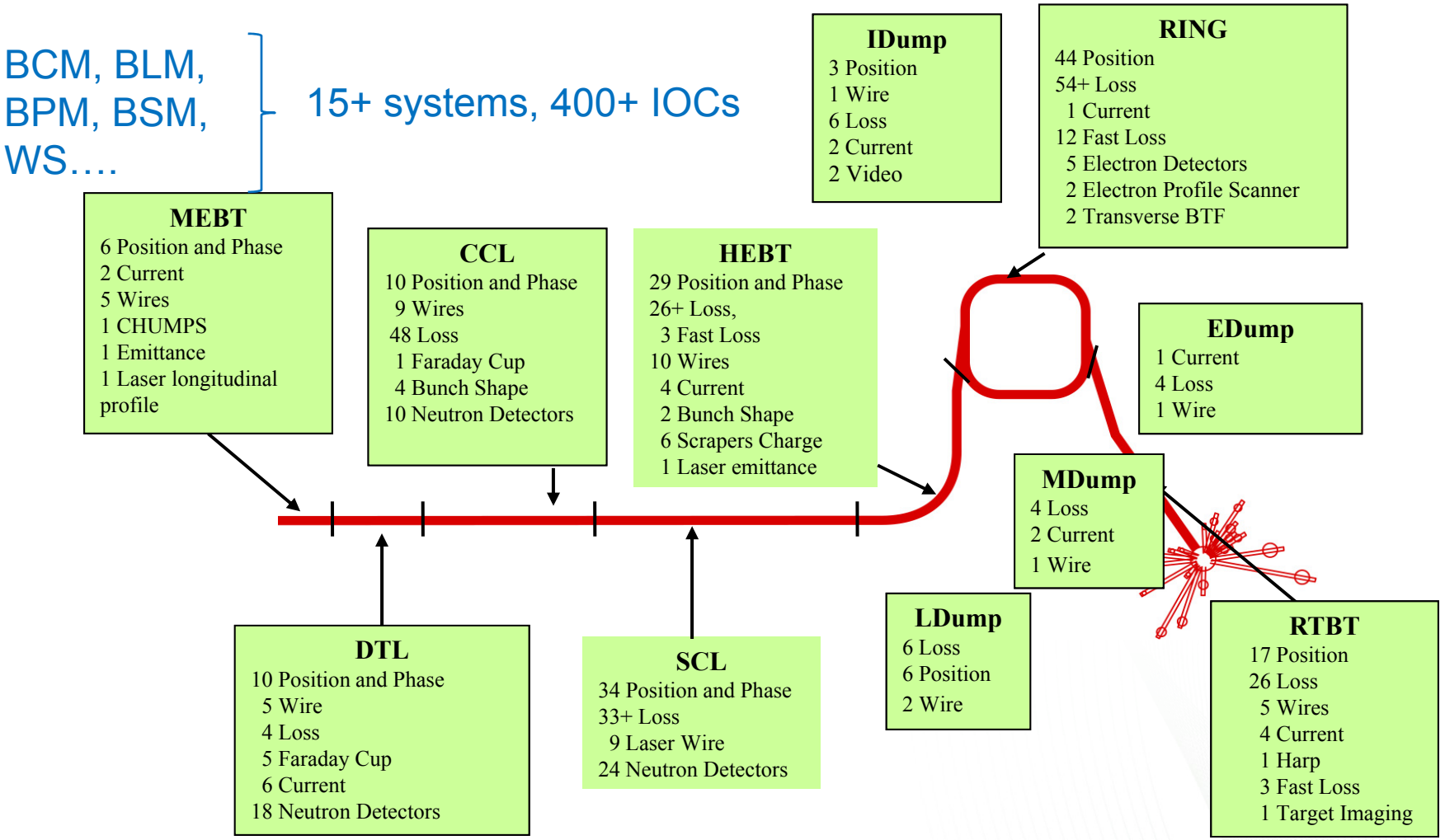
~ 4700 hours/year

Second Target Station Project:

Double beam power to 2.8 MW

- Increase energy from 1GeV to 1.3GeV by adding 36 Super Conducting linac cavities
- Increase beam current by 50%
- Enables second target station in 2020s
- Beam Instrumentation Group Involvement
  - more of the same: BCM, BPM, WS
  - Intra-bunch ring feedback system
  - laser stripping injection

SNS Beam Instrumentation Systems are Numerous, Diverse and Growing in Number



SNS Beam Diagnostics Performance Assessment

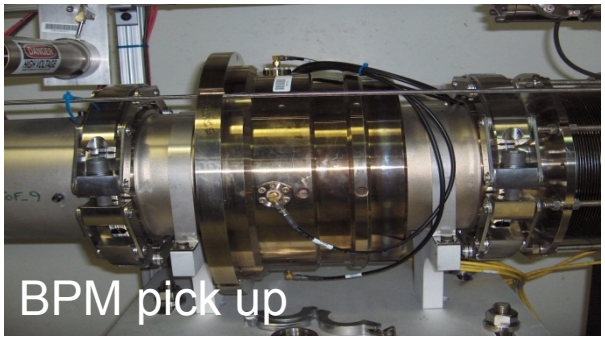
now 1-2 years 3-5 years

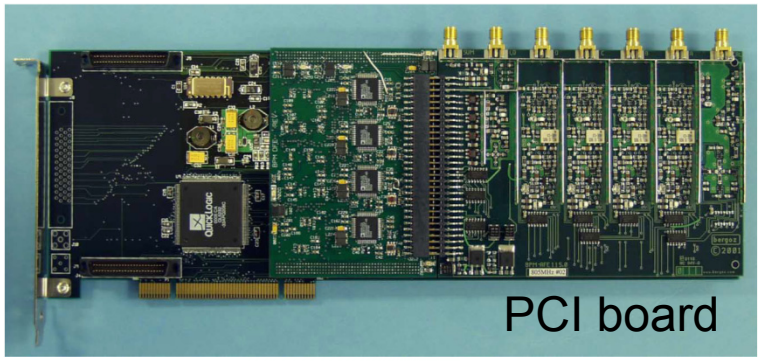
Model based machine tuning

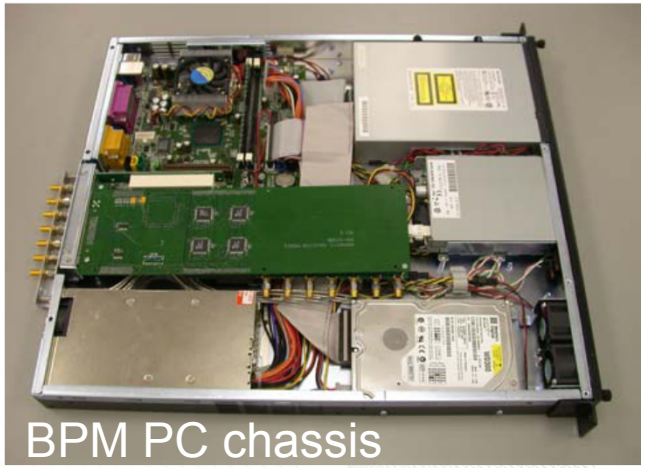
	Function	Neutron Production	Machine Tuning	Single particle model	RMS model	Hi Res model	Obsolescence problem
BCM (18)	current						
BLM (360)	radiation						♪ 0.5M$
BPM (160)	Position x, y, z						♪ 1.5M$
Target Harp (1)	Transverse profile, 1D						
WS (40)	Transverse profile, 1D					♪	
Laser WS (10)	Transverse profile, 1D						
BSM (6)	Longitudinal profile, 1D						
Laser BSM (1)	Longitudinal profile, 1D						
2.5 MeV emm (1)	Transverse emittance, 2D						
1 GeV emm (1)	Transverse emittance, 2D					♪	

Beam Position and Phase Monitors (BPMs)

- Main tool for machine tuning and troubleshooting
  - Phase measurements for linac tune-up
  - Position measurements for trajectory correction, injection set-up and centering beam on dumps and target
- 160 strip-line pick-ups
  - 96 “linac type” operate at 402.5MHz and 805MHz
  - 64 “ring type” operate at low frequency, 5MHz BW
- Custom made PCI analog front-end and digital cards
- LabView software under embedded Windows XP on individual PCs (one per pick-up), 1Hz trigger rate
- Meets all accuracy specs but reliability is not stellar
- **Hardware obsolescence is major problem**
  - **Parts, cards, PC motherboards, OS upgrades**
- **Short term solution: stock up on spares**
- **Long term solution: new system**


BPM pick up

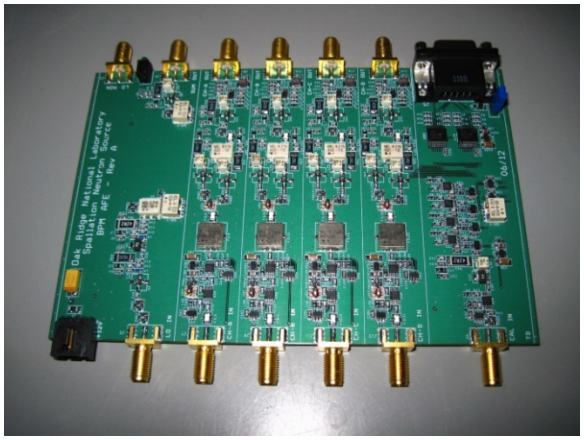

PCI board


BPM PC chassis

Our approach to all new electronics designs is to minimize in-house design efforts

In-house design

Commercial Off-The-Shelf (COTS)



Analog Front-End

Analog-To-Digital Conversion

General Purpose FPGA

Crate and controller

High Level Language Programming

Linac BPM electronics in the field

AFE and digital

Digital

AFE

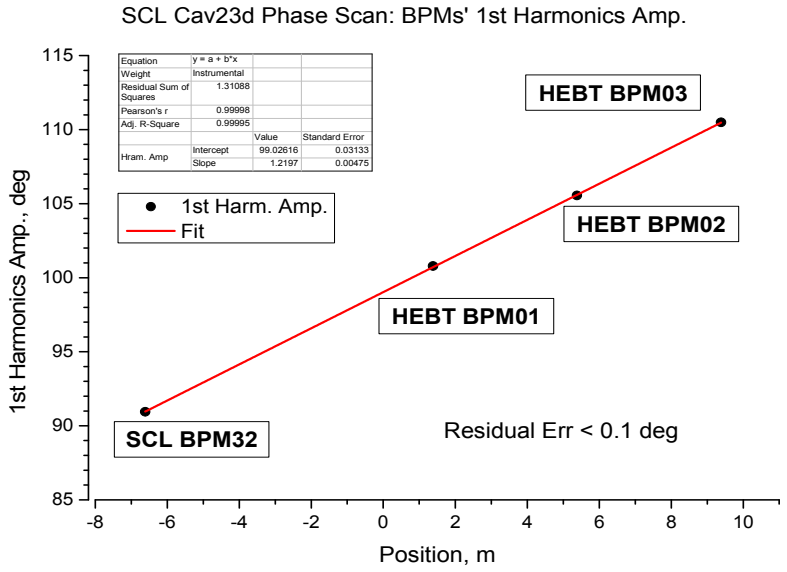
Old BPM electronics

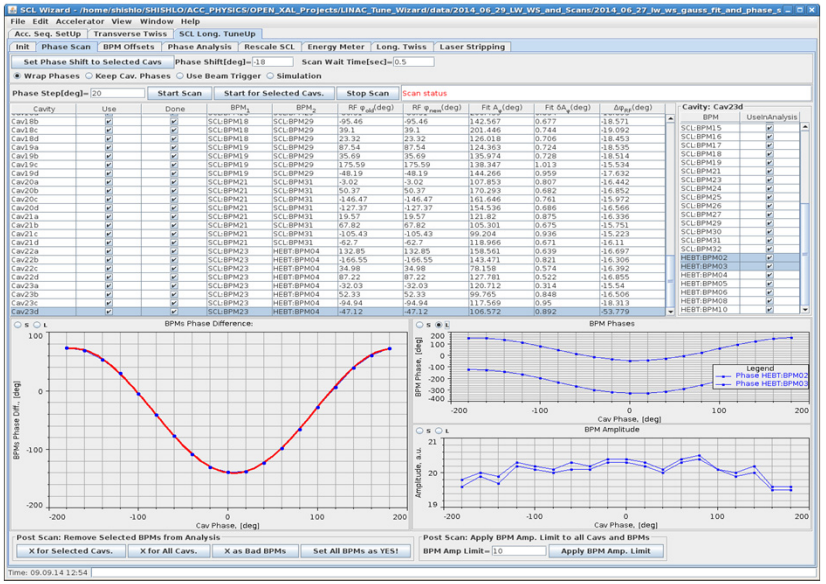
1 BPM per chassis

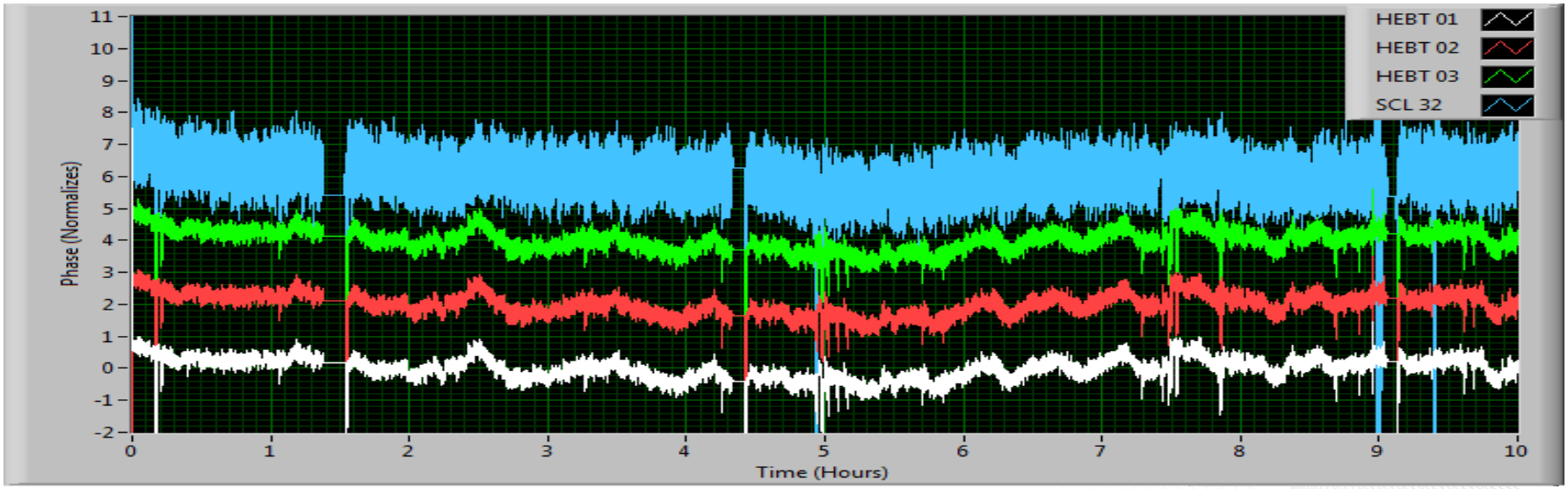
New BPM electronics

6 BPMs per crate

New BPM electronics tested with beam

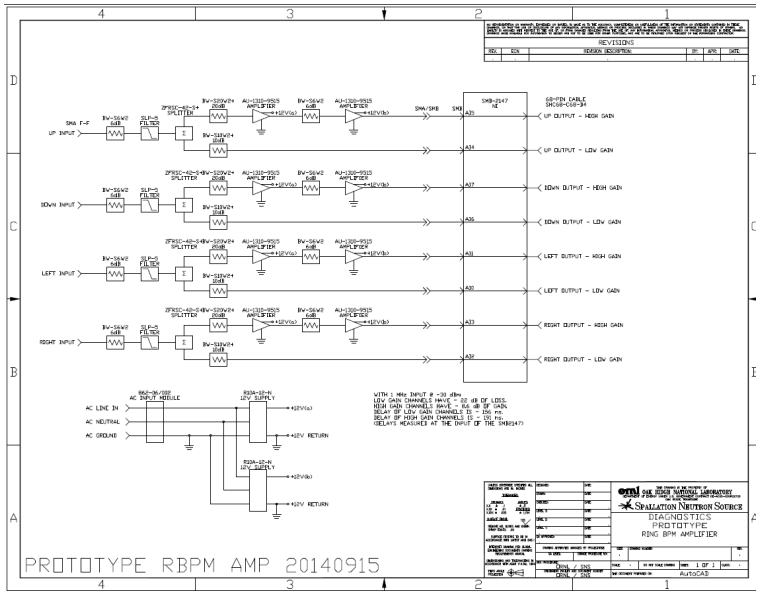


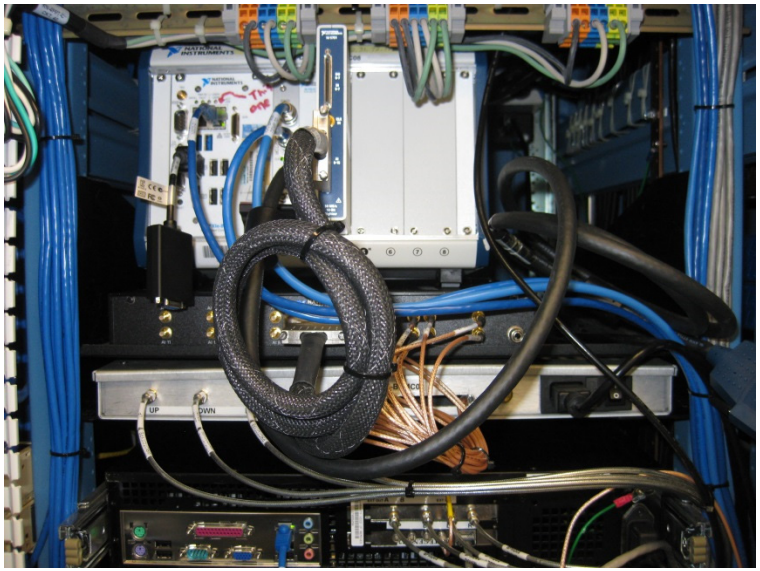




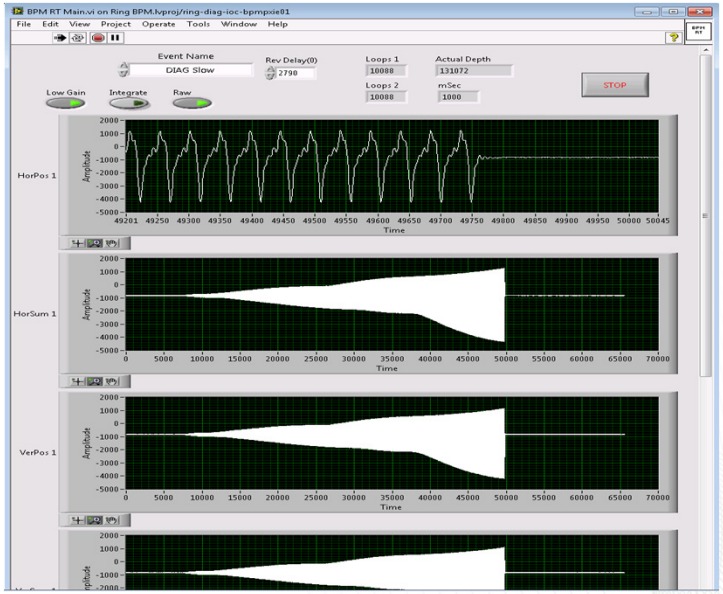
Courtesy of C.Long and A.Shishlo

Ring BPM prototype electronics





- 8 BPMs per crate
- Parallel “high” – “low” gain channels combined in FPGA to cover 60dB dynamic range (instead of fast gain switching in the current design)
- AFE prototype developed
- One BPM set tested with beam
- PCB is being designed



Courtesy of R. Dickson

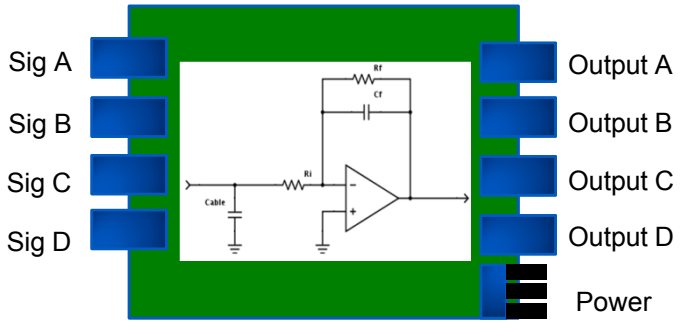
Beam Loss Monitors (BLMs)

- Major tool for machine protection and tuning
- Ionization Chamber Detectors (307)
- Scintillation Detectors (55)
  - Neutron detectors
  - Fast loss detectors
- Multi-channel analog front-end VME cards
- Digital electronics in VME crate
- VxWorks software
- Very reliable

- **Hardware obsolescence is becoming a problem**
- **Short term solution: stock up on spares**
- **Long term solution: new electronics**

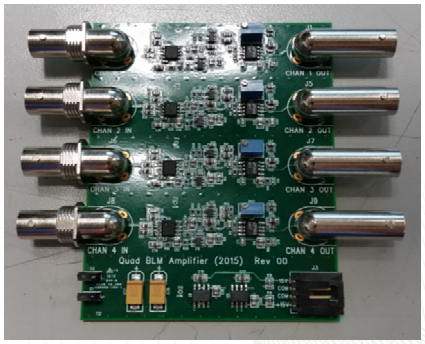
“Next BLM” system concept

- Detectors and cabling shell stay the same
- Analog electronics should be as simple as possible
  - Four different flavors of chassis
  - Two flavors of custom 4-channel front end card
- Unification of the chassis, boards, power supplies



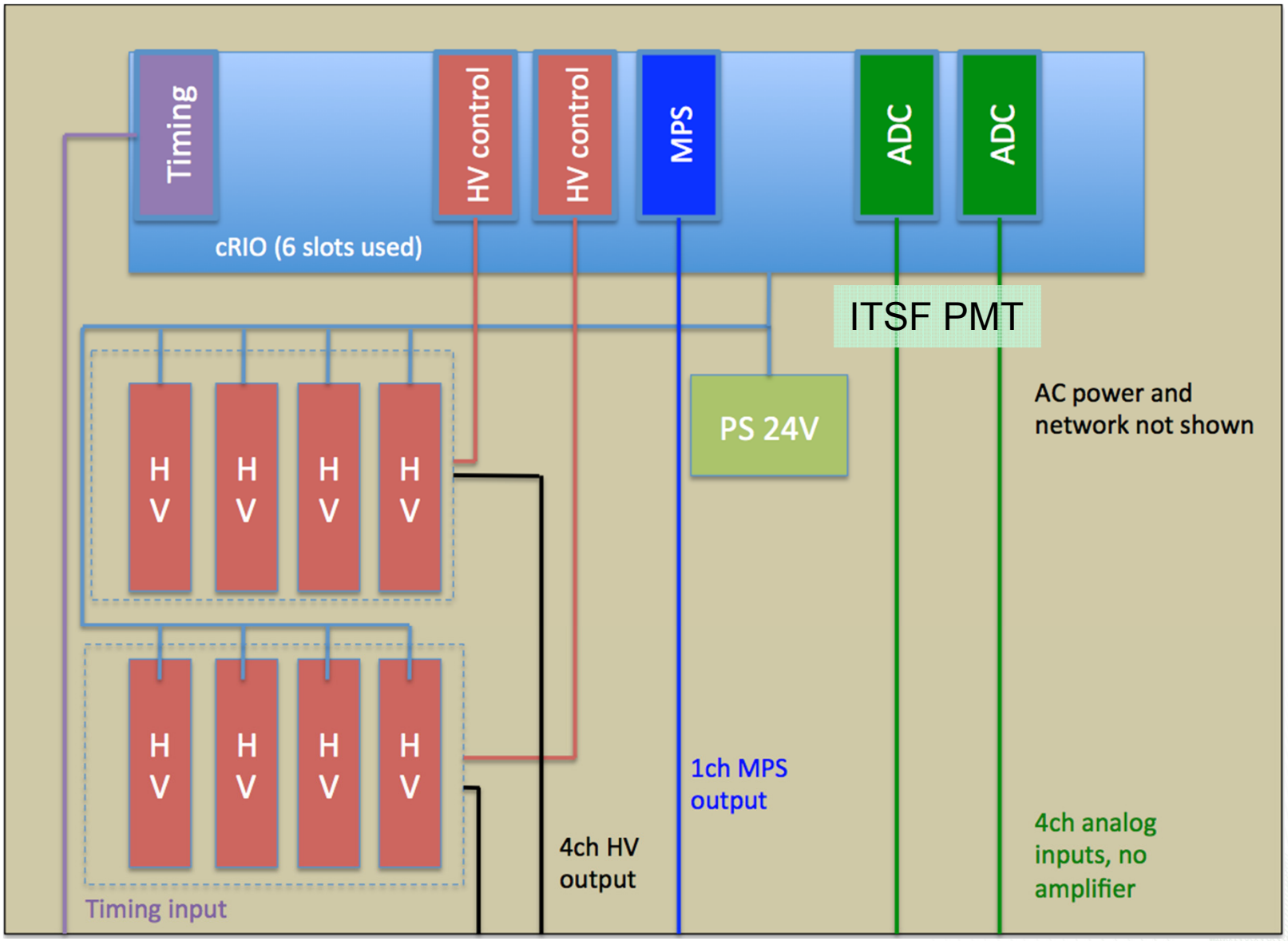
Flavor	Purpose	# Signals	# HV	# MPS	Amplifier	Comment
ITSF	PMTs in ITSF	8	8	1	None	Will have just one MPS channel
Ion Chamber	Regular BLM	16	4	16	IC Amp	Standard IC in accelerator
Target BLM	Target Facility	8	8	0	Target Amp	Sensitive DC amplifier for target people
Neutron Detector	NDs	8	8	8	IC Amp	Standard ND in accelerator

Amplifier	Gain (Ohm)	Min Current (nA)	BW (Hz)	Sampling (kS/s)
IC Amp	600k	2	200k	1000
Target Amp	100M	0.01	1	100



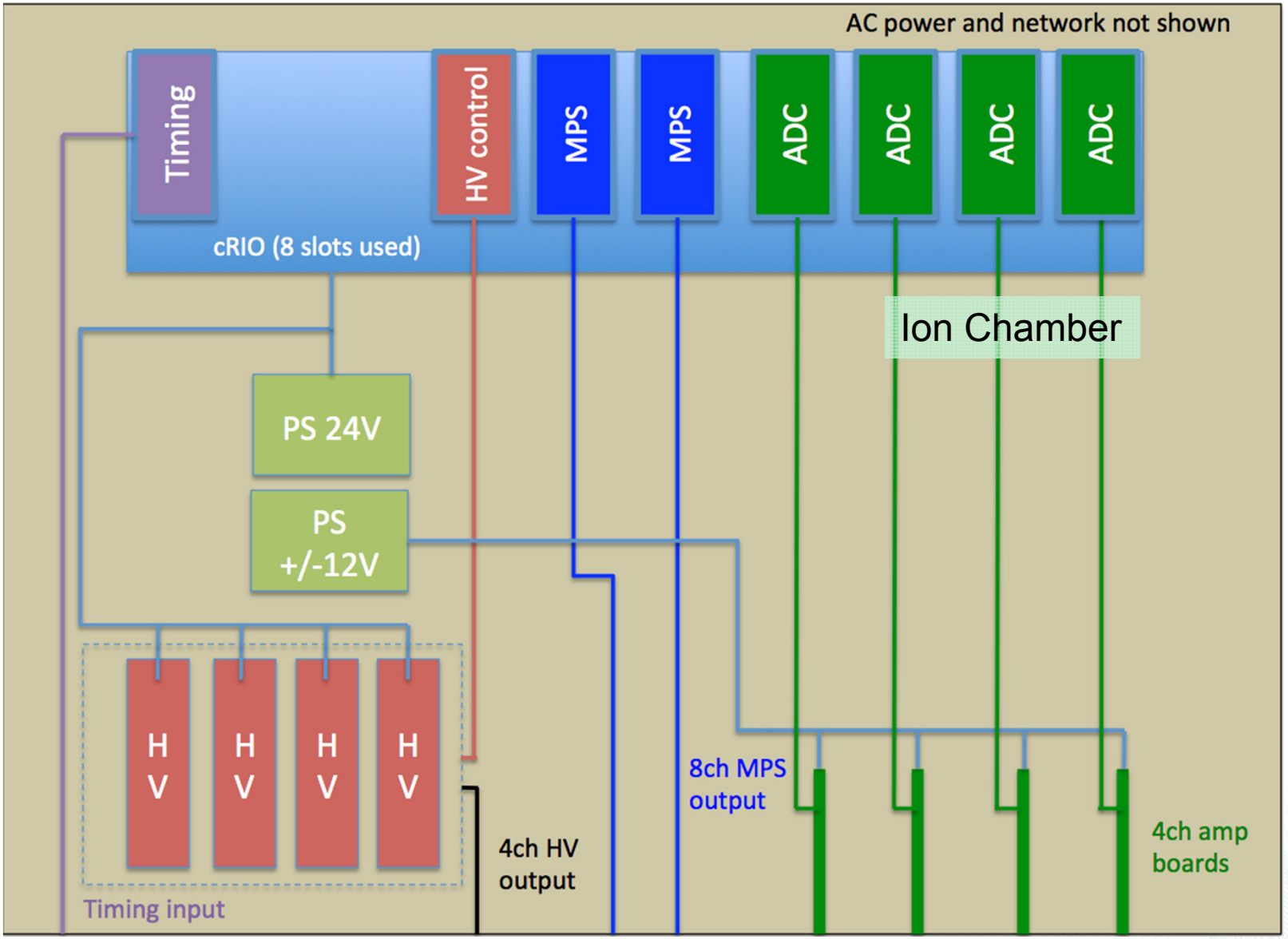
Courtesy of A. Zhukov

4U Chassis layout for ITSF



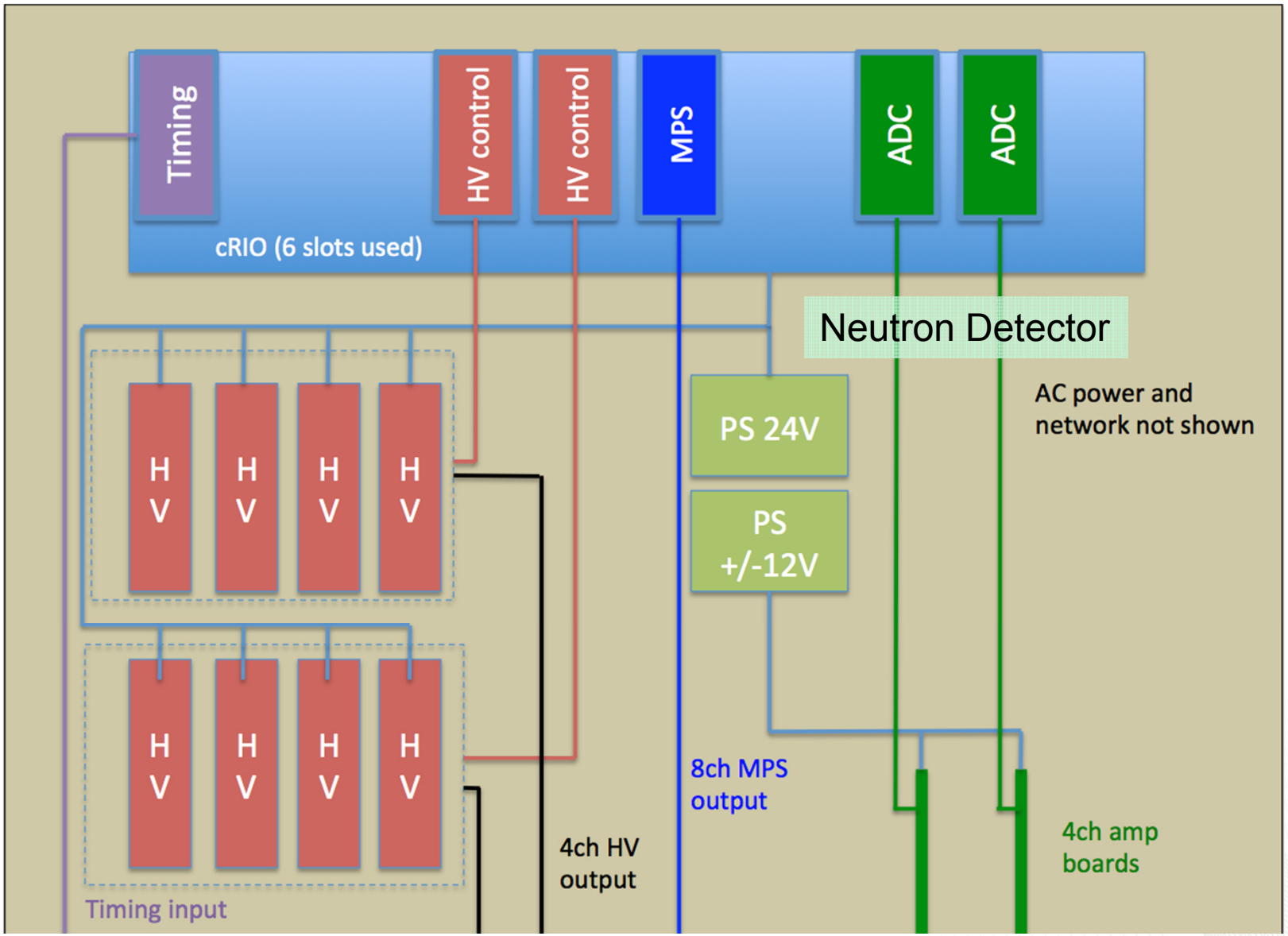
Courtesy of A. Zhukov

4U Chassis layout for ITSF



Courtesy of A. Zhukov

4U Chassis layout for ITSF

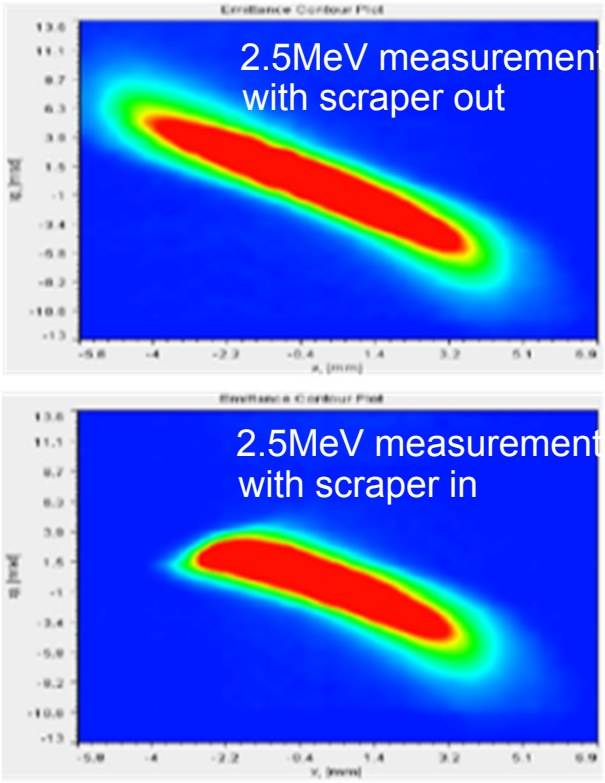


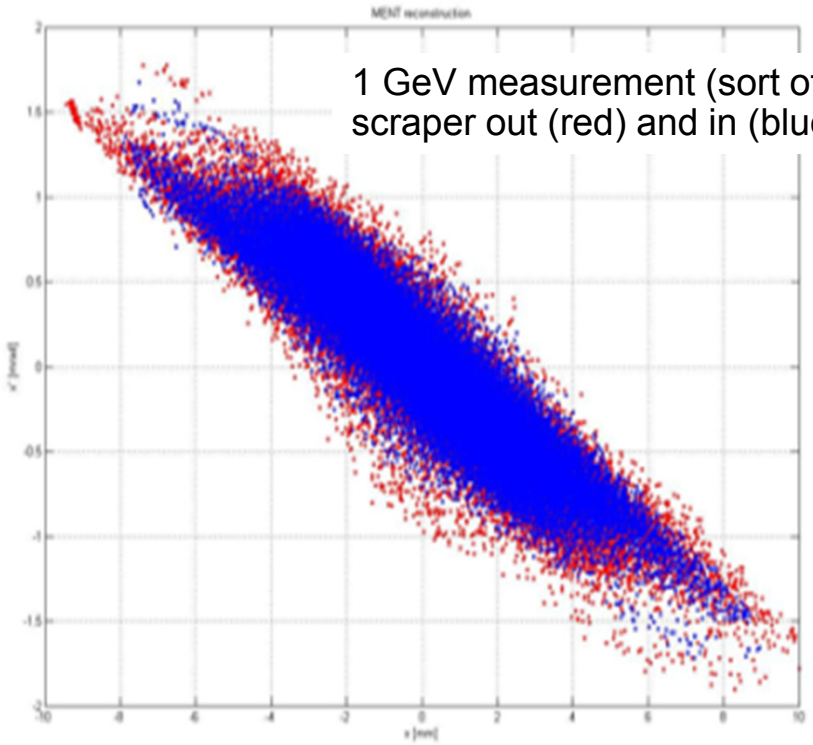
Courtesy of A. Zhukov

8 channels PMT BLM chassis in the field

High resolution PIC model development

- Request for emittance measurements (2-D at least)
  - At as many locations as possible: 2.5MeV, 1GeV, in between
  - High dynamic range: 10^4 - 10^6

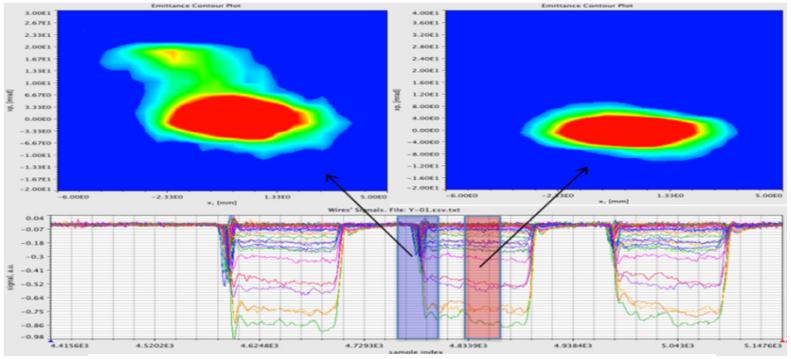




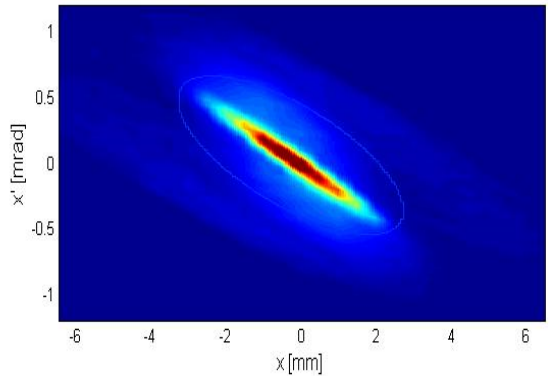
An example of beam transport measurement with ~10^3 dynamic range

Available large dynamic range diagnostics

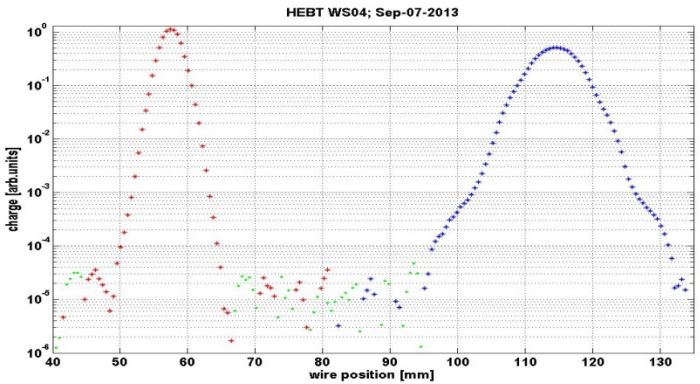
- 2.5 MeV slit-slit emittance scan
  - 10^4-10^5 dynamic range
  - 20ns temporal resolution



- 1 GeV laser emittance scan
  - 10^3 dynamic range
  - 10ns temporal resolution

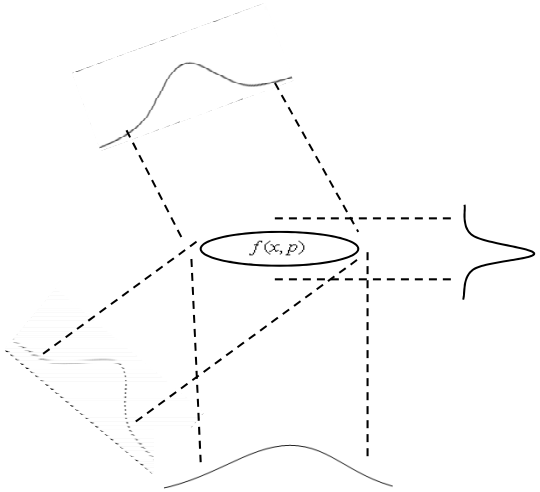


- Wire scanners
  - 10^5 dynamic range
  - 50us time resolution

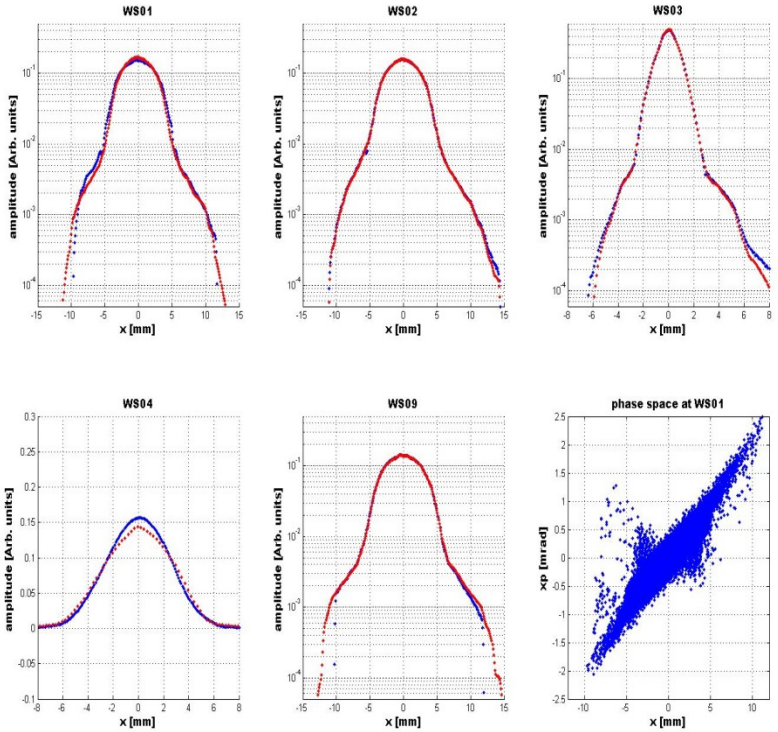


Need to learn using wire scanners for phase space measurements

MENT Tomographic Reconstruction of 2-D Emittance from 1-D Profiles



Comparison of measured and reconstructed profiles



Reconstructed 2-d distribution

- **Reconstruction seems to works very well in HEBT**
  - Need to verify using laser emittance measurements
  - High resolution reconstruction requires iterative procedure. 10^3 dynamic range demonstrated
- **Plan to extend to SCL, Warm Linac, MEBT**
  - Requires good transport model
  - Problem of space charge

Many thanks to SNS Beam Instrumentation Team members who provided material for this talk:

Wim Blokland, Richard Dickson, Cary Long,

Yun Liu, and Sasha Zhukov

and

Thank you for your attention!