PAUL SCHERRER INSTITUT

PSI

Cigdem Ozkan Loch:: Electron Beam Instrumentation:: Paul Scherrer Institute

Beam Loss Monitoring at SwissFEL

Accelerator Seminar

19 February 2018

SwissFEL Machine Protection System

Purpose of the machine protection system (MPS):

- Protection of the machine (Undulators, electronics, etc)
- Facilitates operation of the machine

Alarm Levels

Level 0 alarm (screen insertion):

- Repetition rate limited to 10Hz

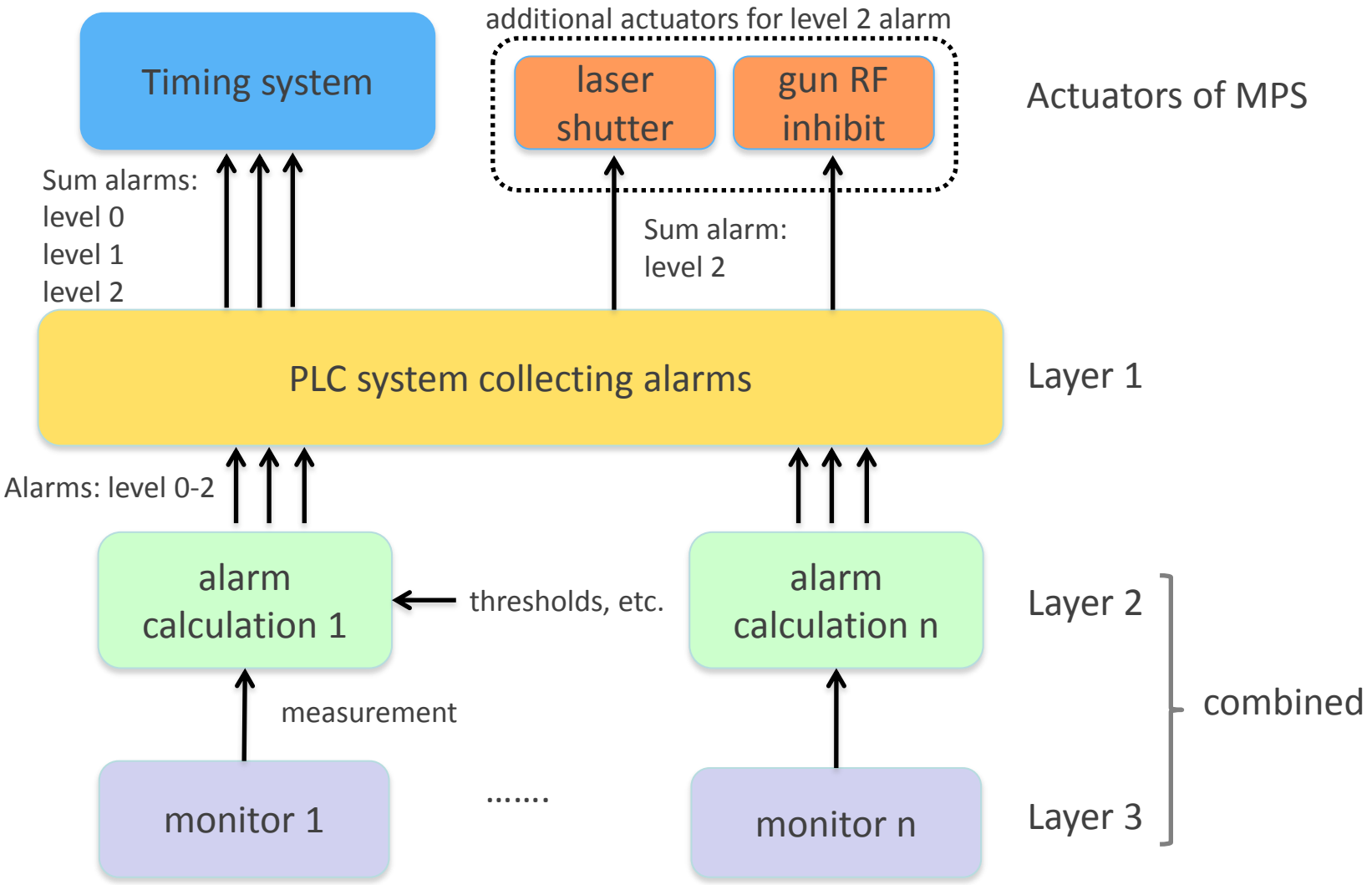
Level 1 alarm (minor):

- Gun RF timing shifted by 10µs
  - No beam generated
  - Gun dark current not accelerated

Level 2 alarm (major):

- Machine will be stopped
  - Laser shutter closed
  - Gun RF turned off

Principle of the MPS

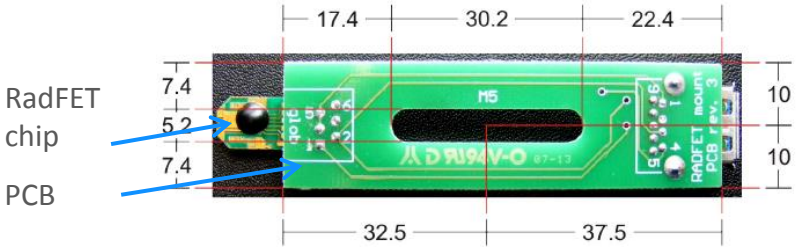


Courtesy of Dr. F. Loehl (PSI)

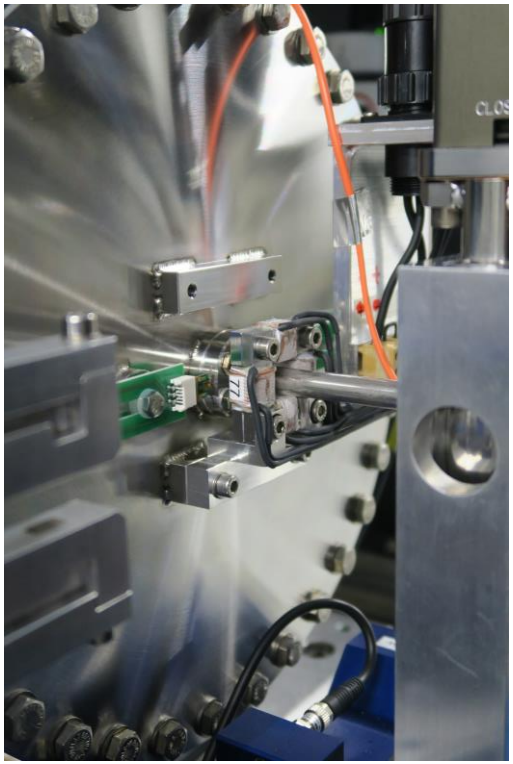
Monitors used in the MPS

	Device	Alarms on
Hardware protection	Beam loss monitors	Beam loss exceeding set alarm threshold
	Beam position monitors	x, y, Q
	Charge monitors (ICT)	Q
	Screen monitors	Inserted/undefined state
	RF stations	Interlock
	Magnet power supply controllers	Magnet error
	Vacuum system	Vacuum error
	Machine mode monitor	Undefined machine mode
Software protection	Dose monitors	Exceeded dose per hour/day
	Differential charge monitoring	
	Charge monitors	Total Q in 1 hour

Dose monitoring



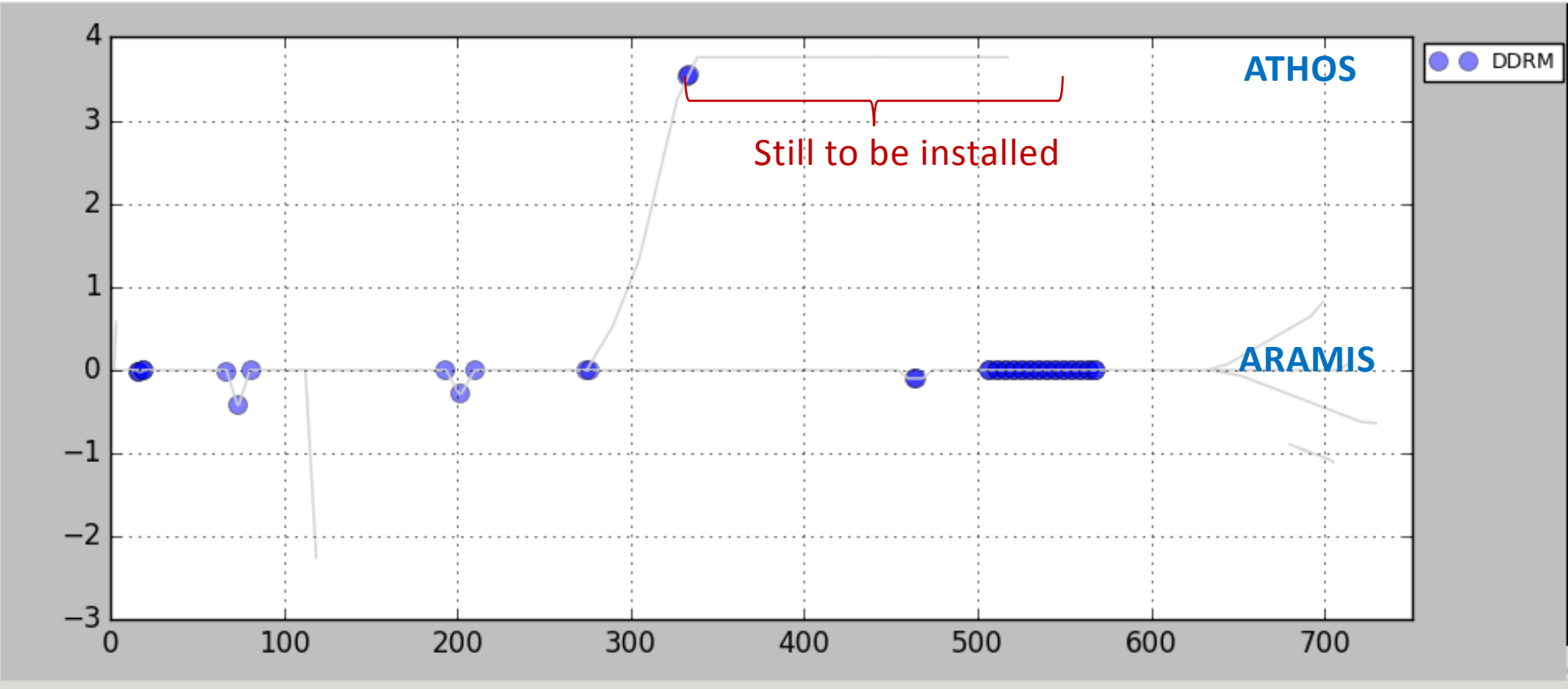
- To track accumulated dose
- Tested at the SITF around Undulator
- Distance of RadFET to the beam pipe flange is ~1mm
- Operated in 25V bias mode * for Undulators
- Minimum integration time 20 seconds
- Undulator protection:
  Closes MPS shutter if permitted dose rate (eg, 0.05Gy/20s) or daily dose limit is exceeded



** L. Froehlich, S. Grulja, F. Loehl, "DOSFET-L02: An advanced online dosimetry system for RadFET sensors", Proceedings of IBIC2013, TUPC45, 2013*

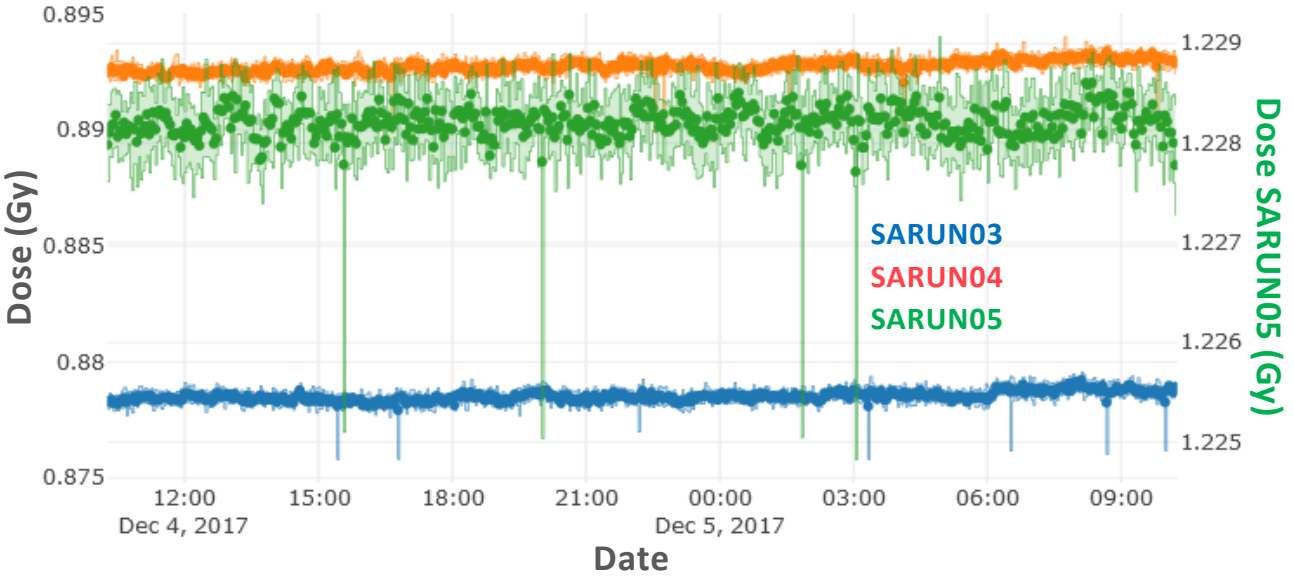
Location

- ARAMIS: 42x RadFETs → 13 DOSFET controllers
- ATHOS: 18x RadFETs → 4 DOSFET controllers

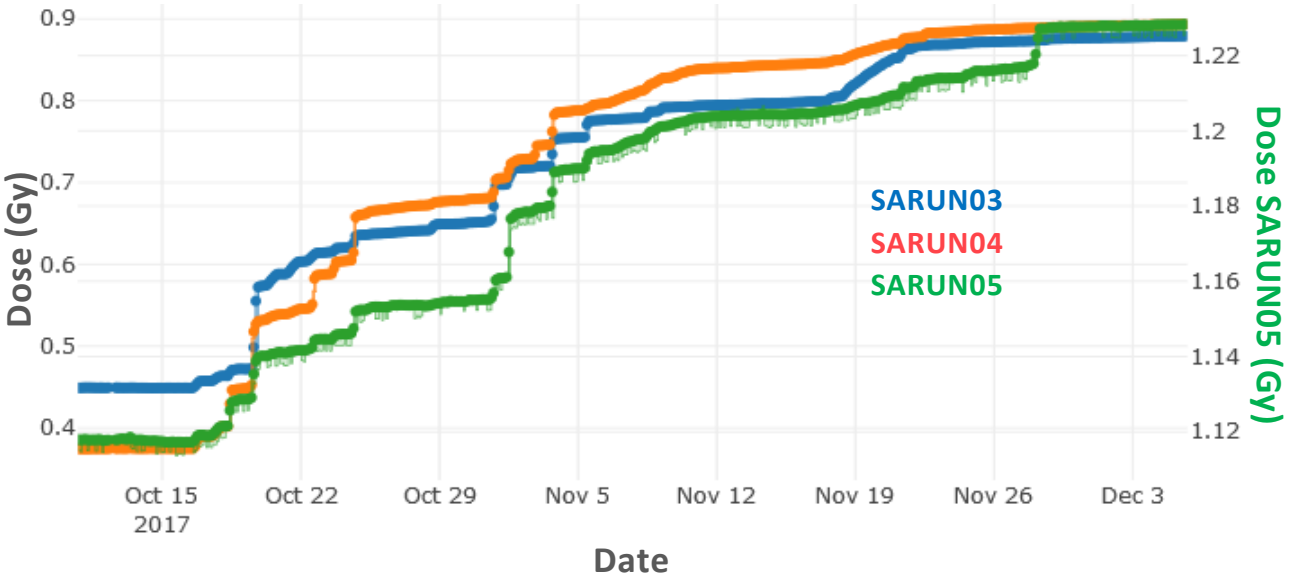


Dose History

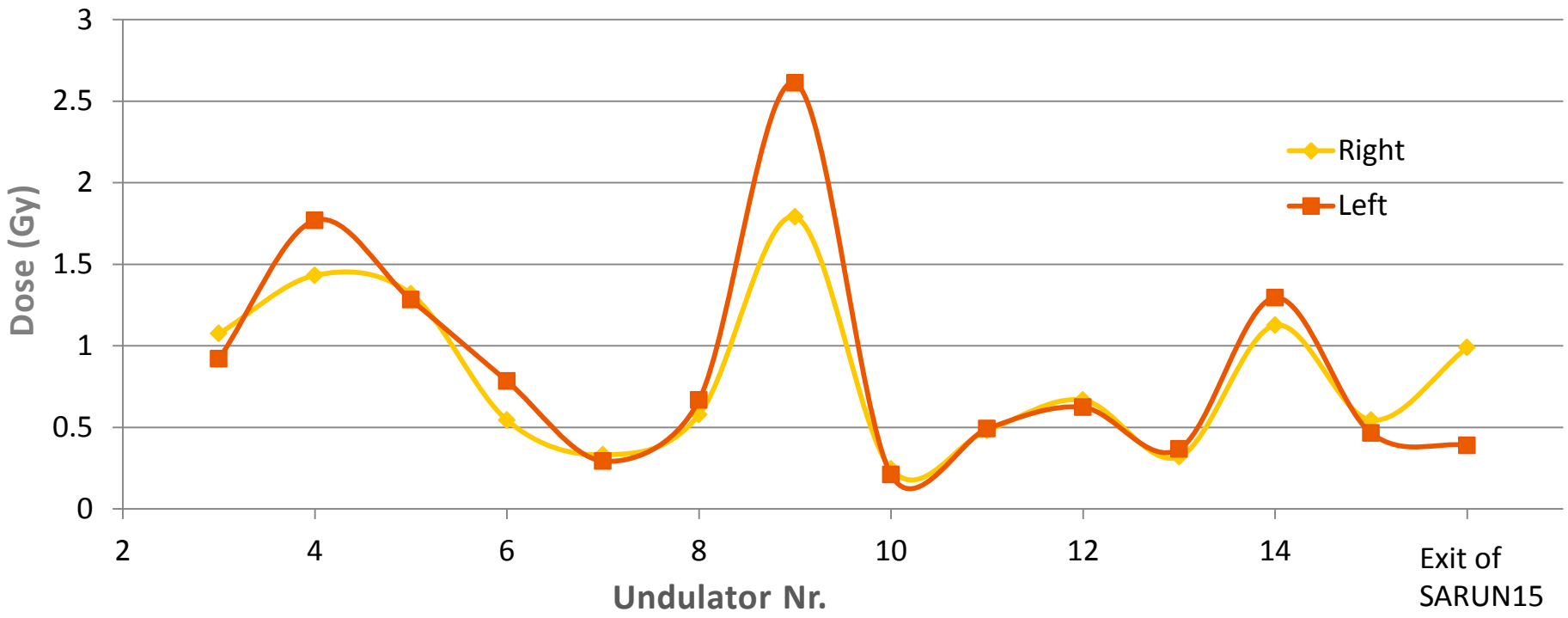
Stable FEL operation 24h



Long term accumulation



Dose rate distribution

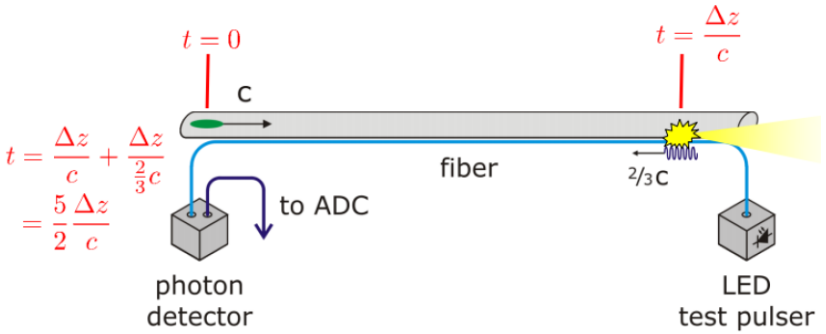


ATHOS Installation

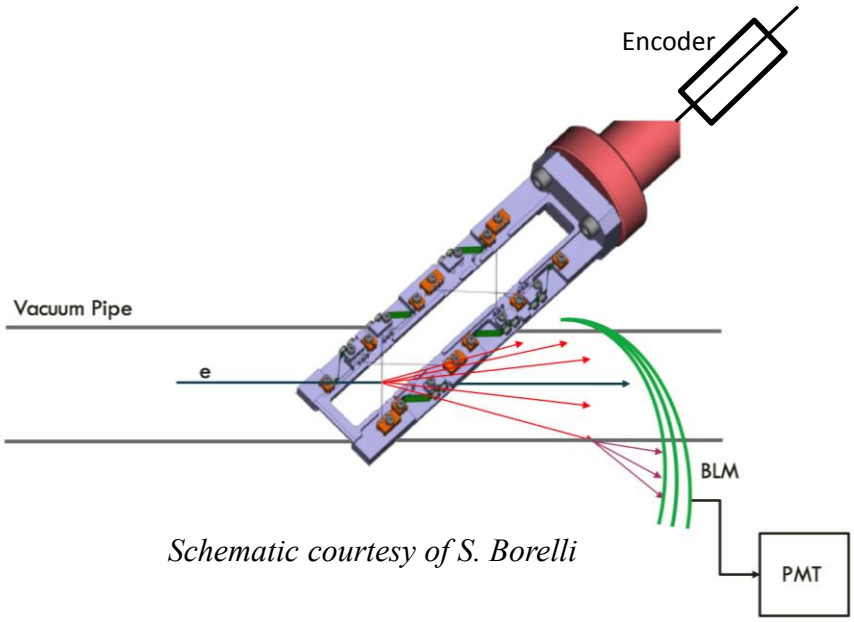
- Ordered:
  - custom USB3.0 cables (50m)
  - DOSFET controllers
- Installation:
  - Cabling from rack to tunnel
  - DOSFET controllers in racks
  - RadFETs on their PCB holders (in-house)
- Configuration & checks

Loss monitors at SwissFEL

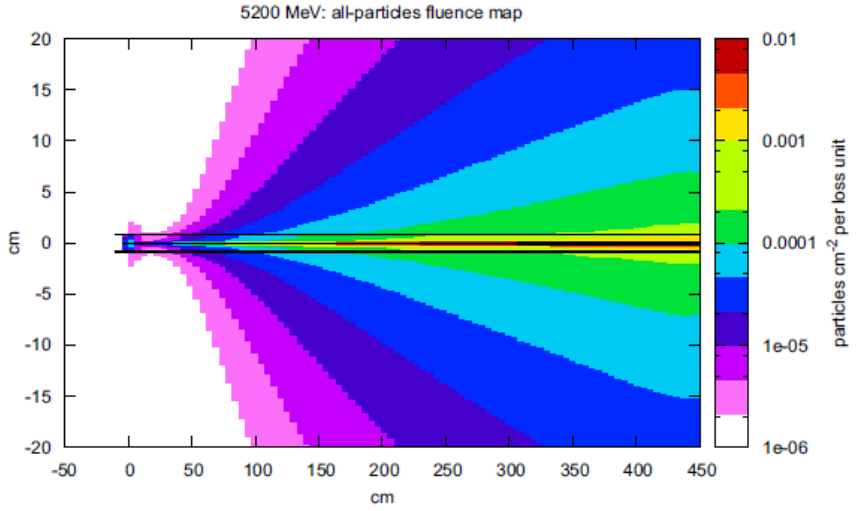
- Loss tracking due to:
  - Insertion of screens, collimators, slits
  - Beam alignment
  - Wire insertions
- Two types of loss monitors:
  - Scintillator based, for localized losses (BLM)
  - Optical fiber for tracking loss positions along the machine (LLM)



Schematic courtesy of L. Froehlich

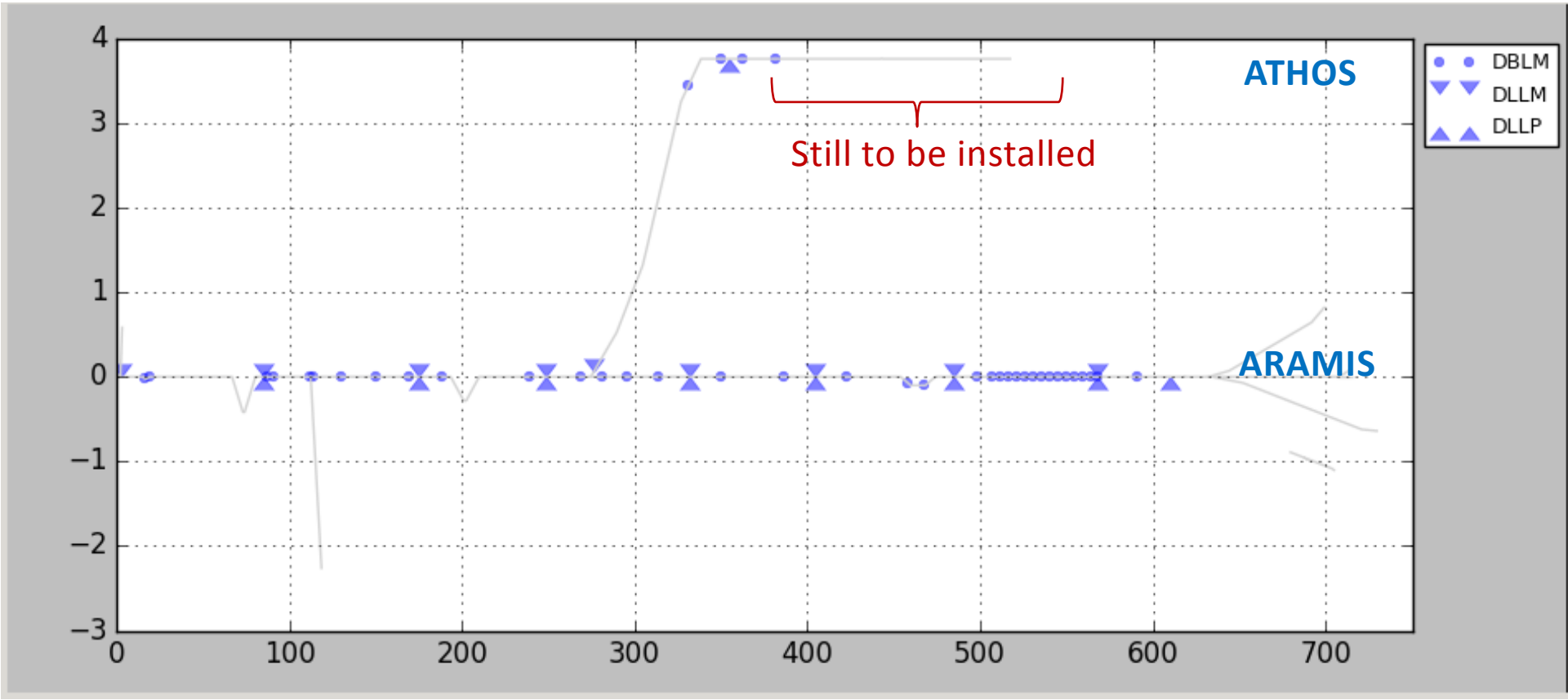


Schematic courtesy of S. Borelli

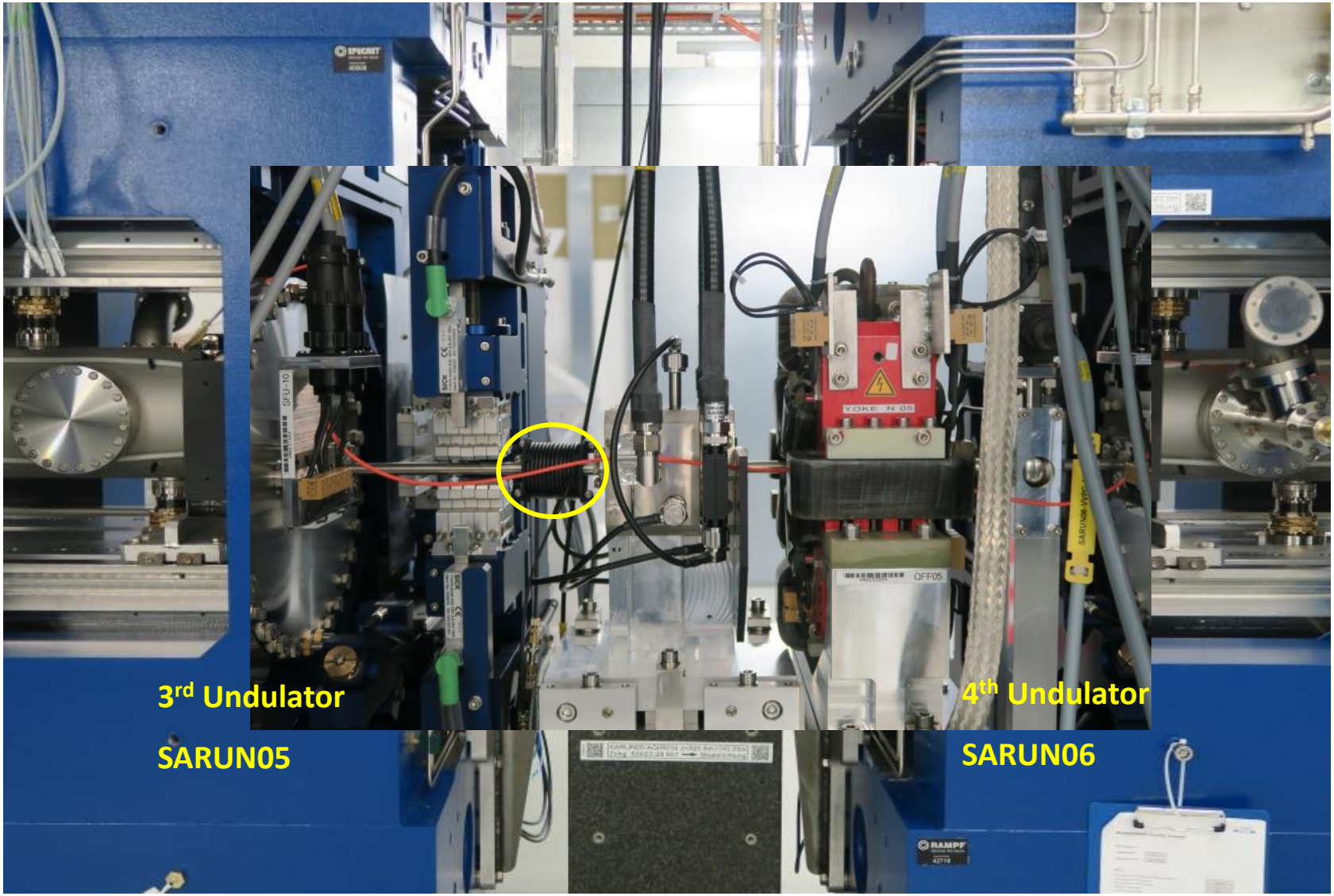


Location

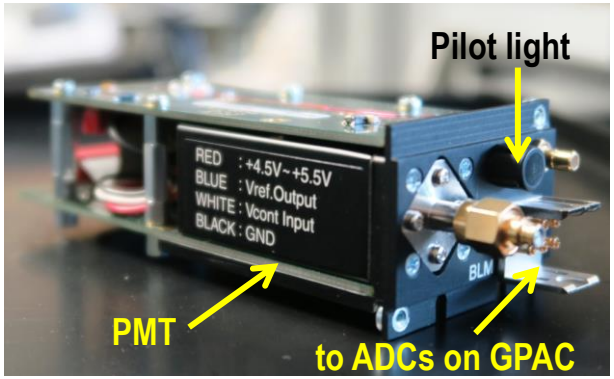
- ARAMIS: 38x BLM + 8x LLM
- ATHOS: 17x BLM + 4x LLM



Location

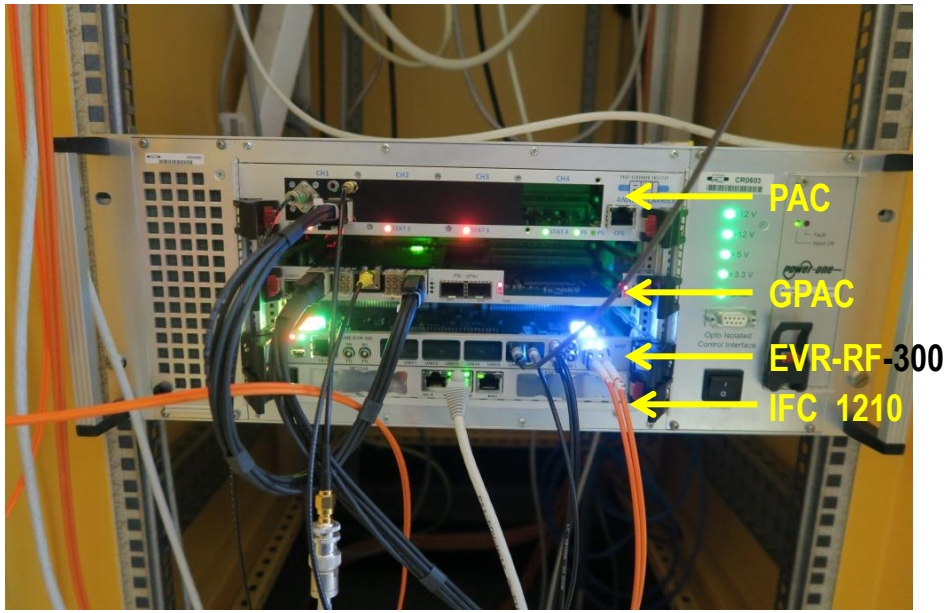


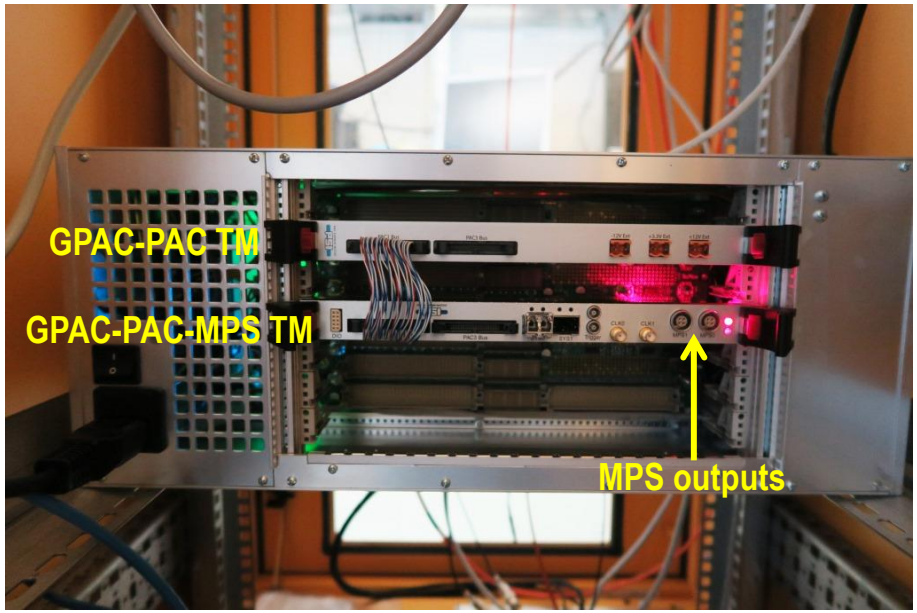
DAQ System Overview



- Analog front-end & digital backend developed at PSI
- Cost reduction: using same readout chain for all
- Common firmware and software solutions

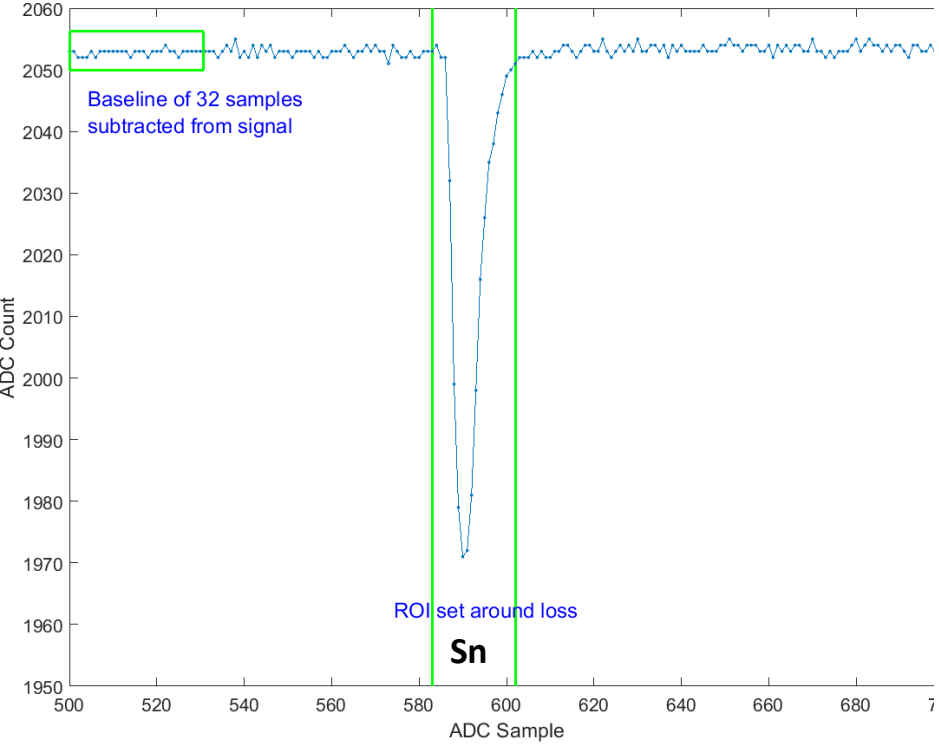
ARAMIS + ATHOS = 28 Systems



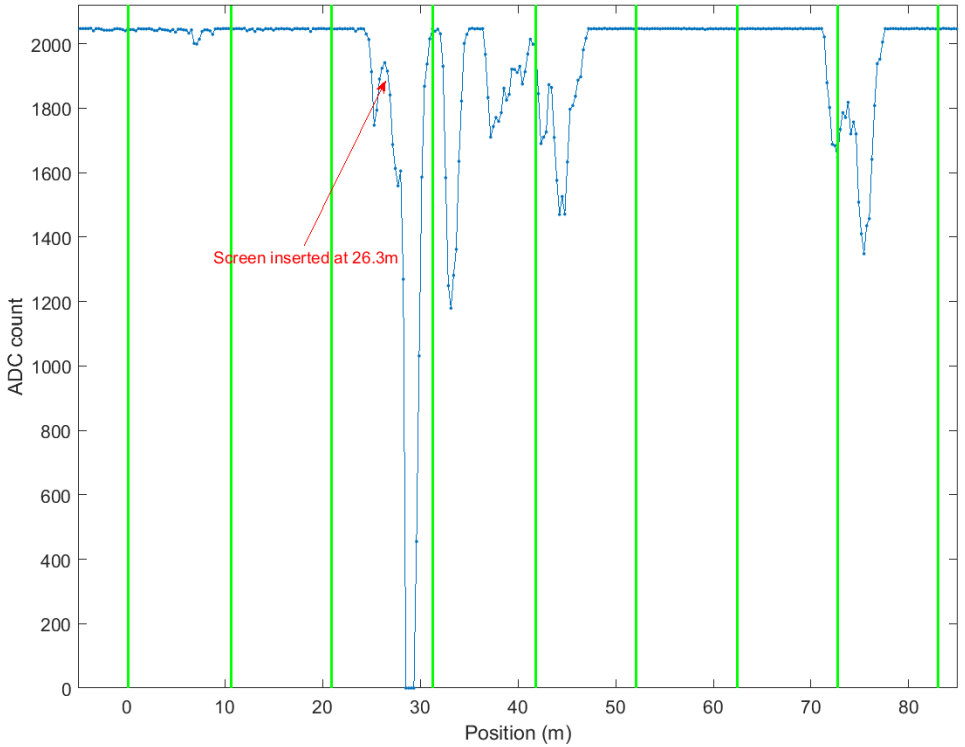


Signal processing

Beam loss monitor



Longitudinal loss monitor

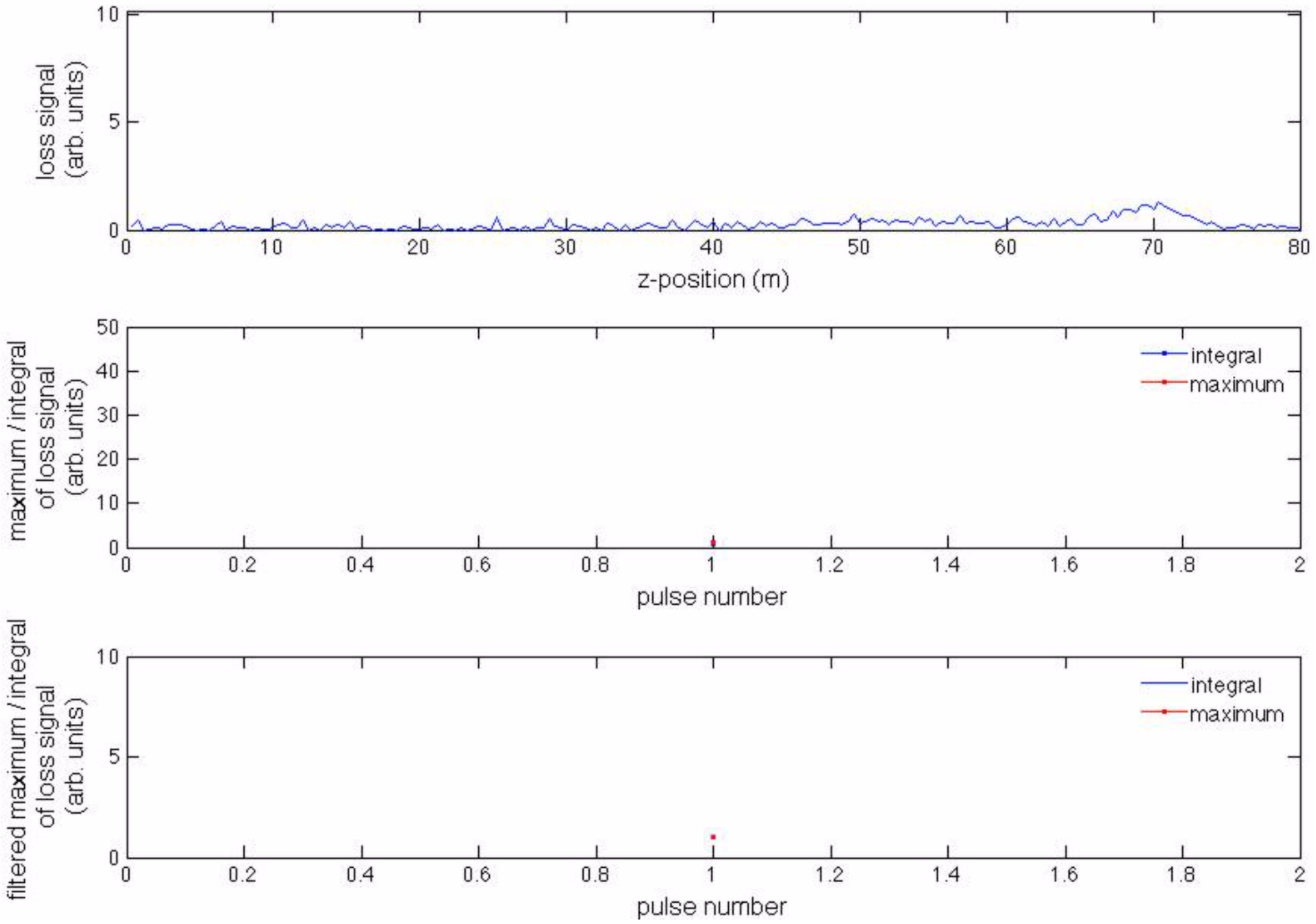


MPS Algorithm: $\frac{1}{2K}\left(avg_n \cdot (K-1) + S_n\right)$

S_n: sum of PMT pulse from single bunch loss
avg_n: previously calculated sum
K: factor for weighted average (filter length)

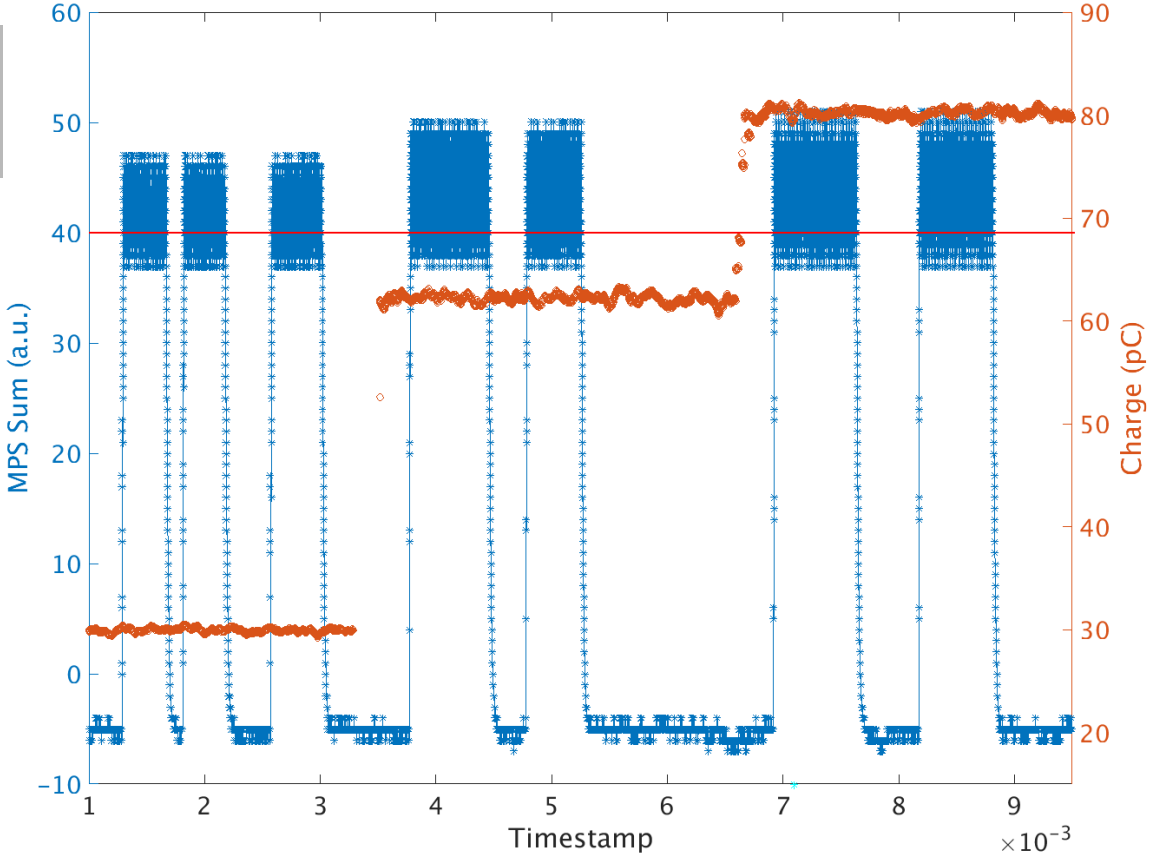
- Once generated Alarm remains active until condition is no longer fulfilled
- Calculations performed at 100Hz, independent of beam repetition rate

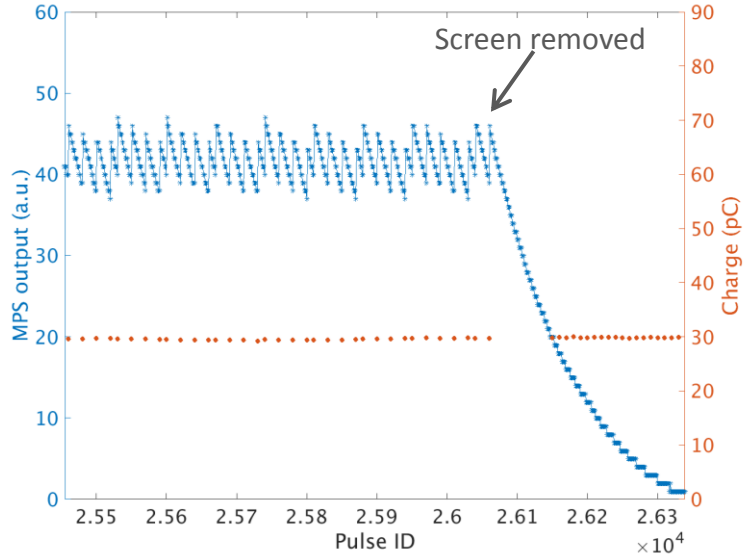
Rate reduction concept

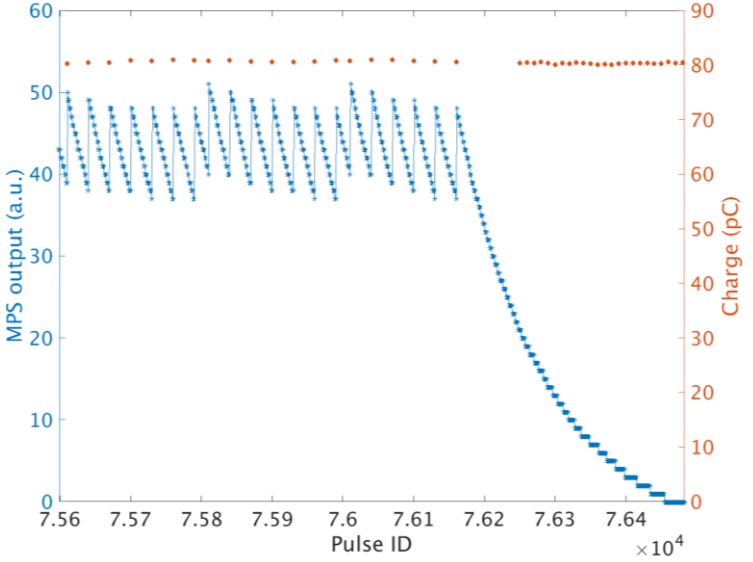


Courtesy of Dr. F. Loehl

Rate reduction in practice



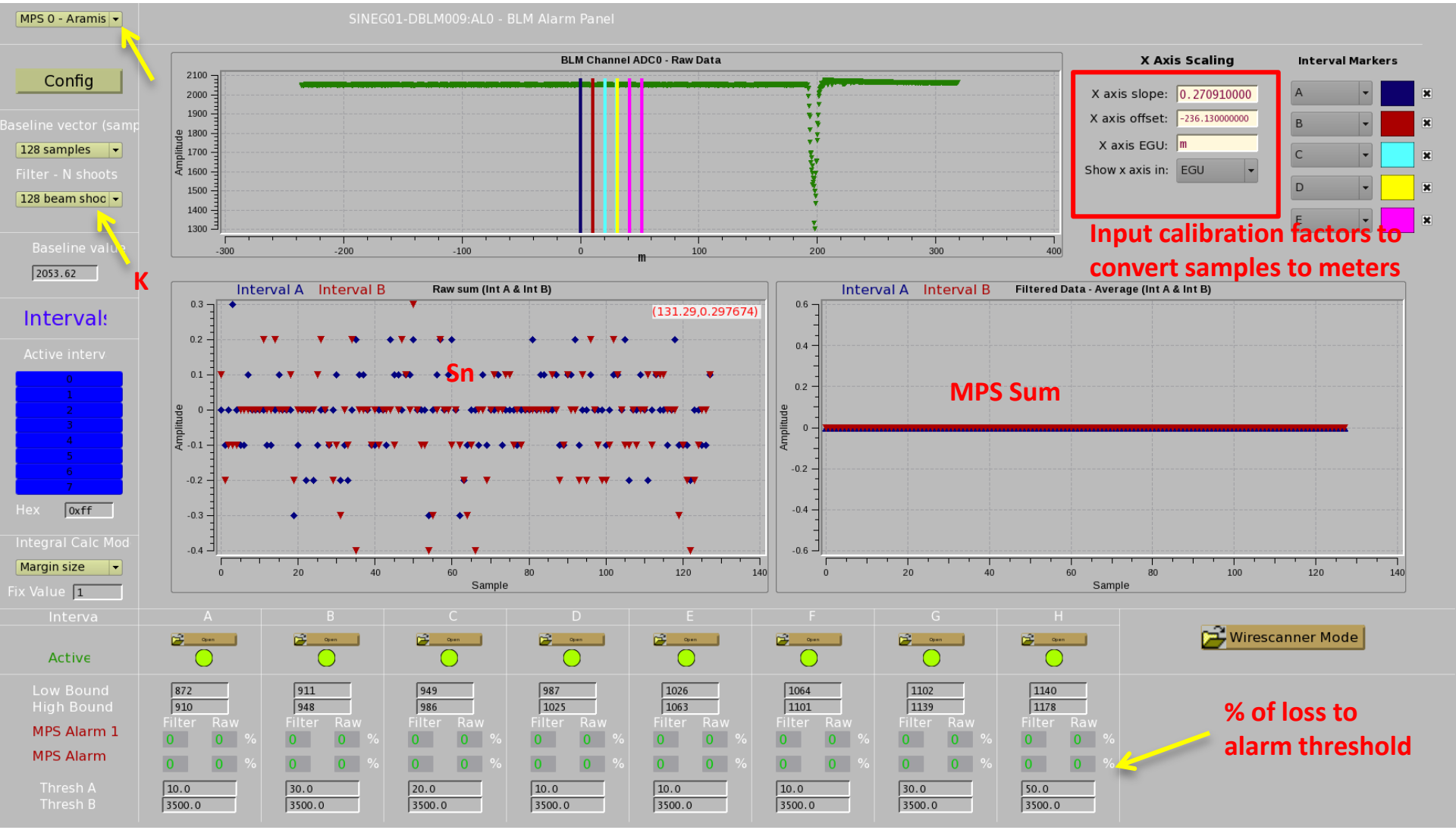




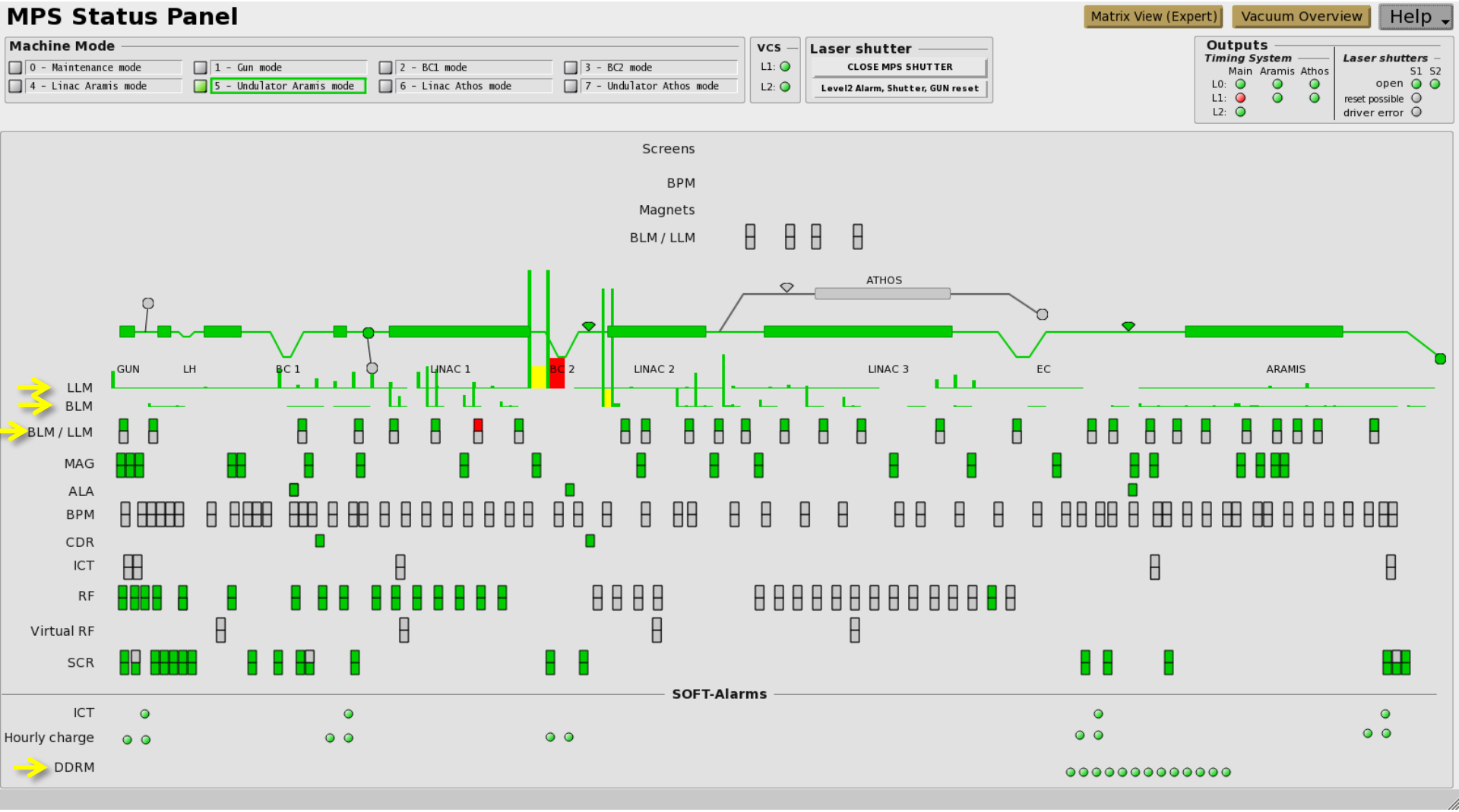
- Dynamically change beam repetition rate
- Around Undulators alarm thresholds are set by looking at the dose rate measured by RadFETs

Loss Monitor Panel

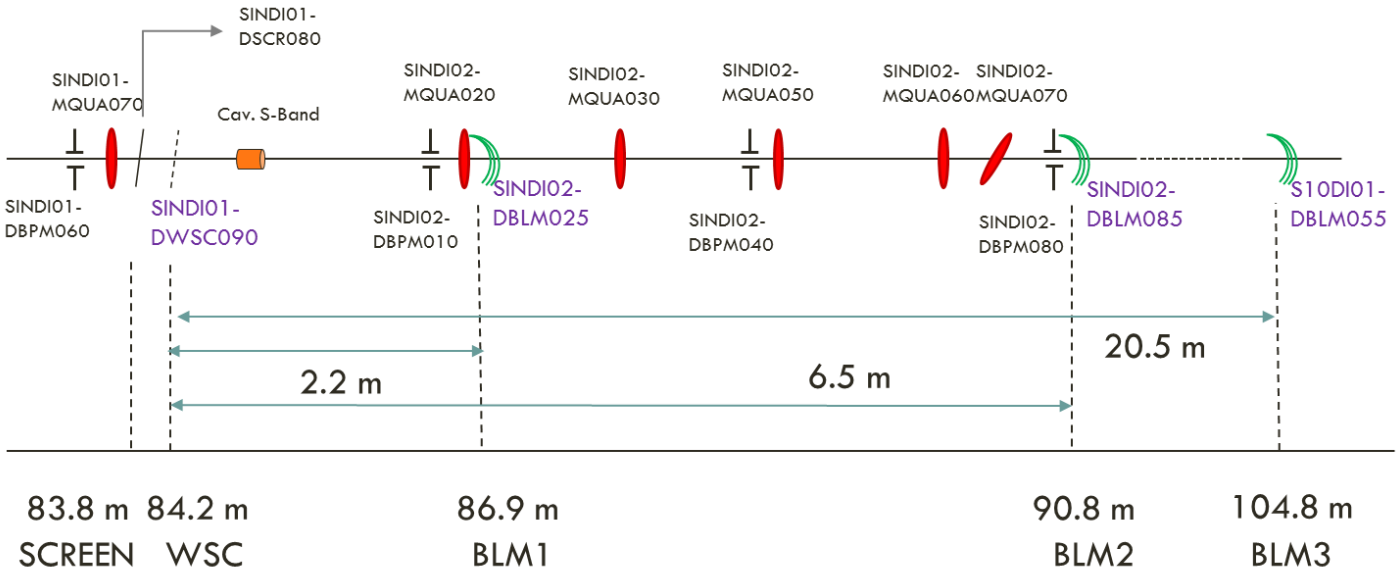
$$\frac{1}{2K}\left(avg_n \cdot (K-1) + S_n\right)$$

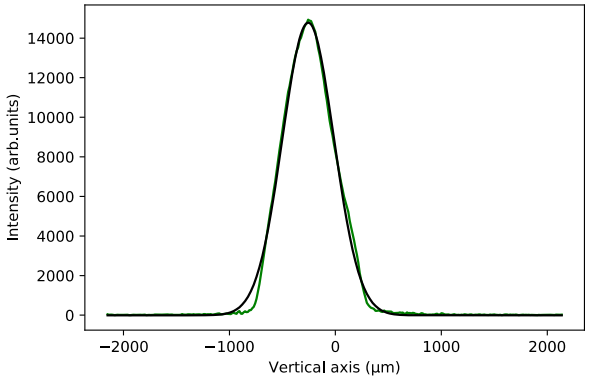


MPS Status Panel



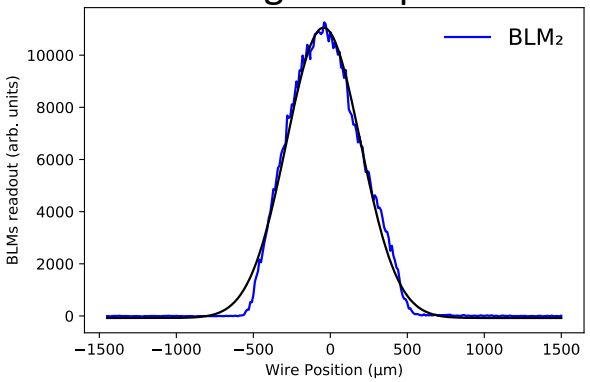
Beam profile measurements wire scanner standard





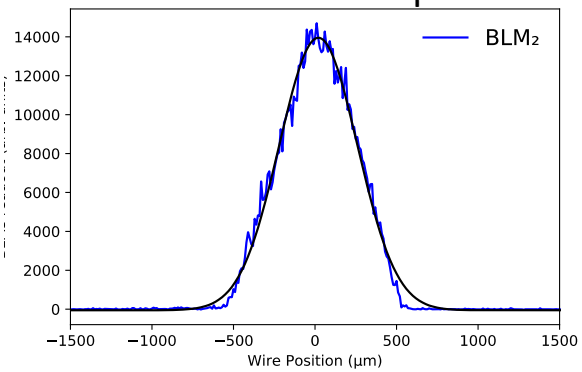
$\bar{\sigma}_y = 240 \pm 2$ (μm)

Tungsten 5 μm



$\bar{\sigma}_y = 238 \pm 2$ (μm)

Aluminum 12.5 μm



$\bar{\sigma}_y = 241 \pm 3$ (μm)

Courtesy of S. Borelli

Loss monitor functionality : Mode Switching

WS Start
WS Stop

SINEG01-DBLM009:AL0 - BLM Wirescanner Panel

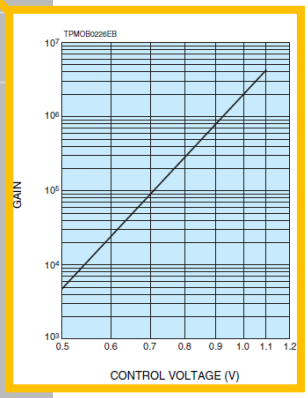
a 11.520
b 12.065
PMT Gain = a exp(b·V)

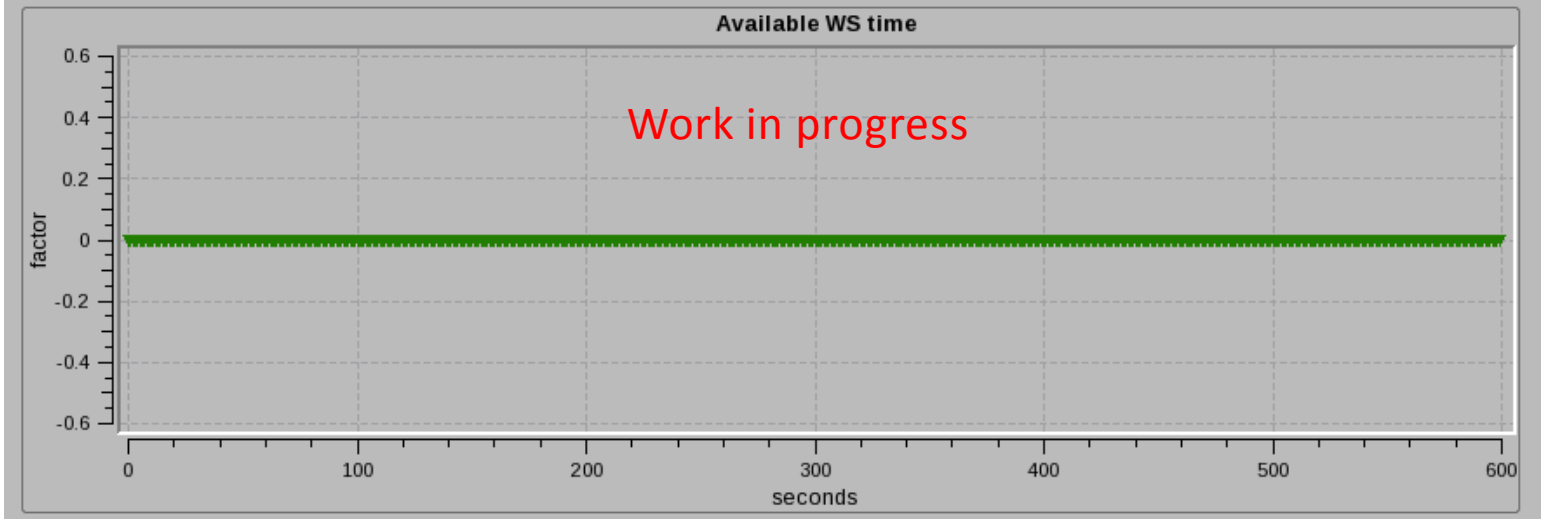
Scan Duration
3 s

Duty Factor
10 %
Time budged available for WS

PAC Source
PIGGY 0

MPS Values			WS Values		
MPS PMT Gain	+0.50	V	WS PMT Gain	+0.60	V
MPS Attenuation	Reference		WS Attenuation	Reference	
MPS Gain PMT	4800.065		WS Gain PMT	16040.061	
MPS Gain Attenuation	1.000		WS Gain Attenuation	1.000	
MPS Gain resize fact	1.000		WS Gain resize facto	1.000	
MPS Gain Total	4800.065		WS Gain Total	16040.061	





ATHOS Installation

- Installation of remaining:
  - Scintillator fibers and POF (rack to tunnel) for 17x BLMs (3x dogleg installed)
  - OF for 4x LLM (rack to tunnel and along beam pipe)
- Will use existing crates in technical gallery
- To be ordered: PAC piggy boards
- In-house: PMT detectors
- Configuration & checks

Operational Aspects

- Loss monitoring systems actively protecting ARAMIS from Day 1
  → Systems handed over to Operations

Important to remember:

- Certain channels are write protected → List of cleared personnel
- Work on timing system or restarting crates can mean changes are not configured on the firmware level → Requires intervention by cleared personnel
- After every system restart, have to make sure MPS settings are loaded correctly & systems initialized → Only cleared personnel!
- Setting gains for the first time requires careful observation of losses (invasive)
- Setting alarm thresholds is not straightforward and only refined through experience → ATHOS will require observation till beam reaches dump (2019)
- Sad demise of two PMTs →maintenance during shutdown helps recognizing issues that otherwise cannot be determined from control room

We are not done yet …

Other than installation along ATHOS …

- Firmware Upgrade:
  - Normalization by PMT gain factor (ready April 2018)
  - Mode switching (ready April 2018)
- 2-bunch commissioning at ARAMIS
- 100 Hz commissioning at ARAMIS: Minor adjustments to alarm thresholds

- Commissioning of ATHOS loss monitors:
  setting gains, setting ROIs (incl. 2-bunch), alarm thresholds
- Commissioning of ATHOS dose rate monitors:
  Check if all monitors are accumulating when losses are generated

Depends on how far the beam is transmitted and if Undulators are ready for use

We create knowledge - today for tomorrow

This work has been possible thanks to the *entire* SwissFEL collaboration, especially:

Daniel Llorente
Patrick Pollet
Enrico Ebner
Florian Loehl
EBI group
Edwin Divall

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Thank you for your attention