

Necessity of Beamline Diagnostics Pre-Check



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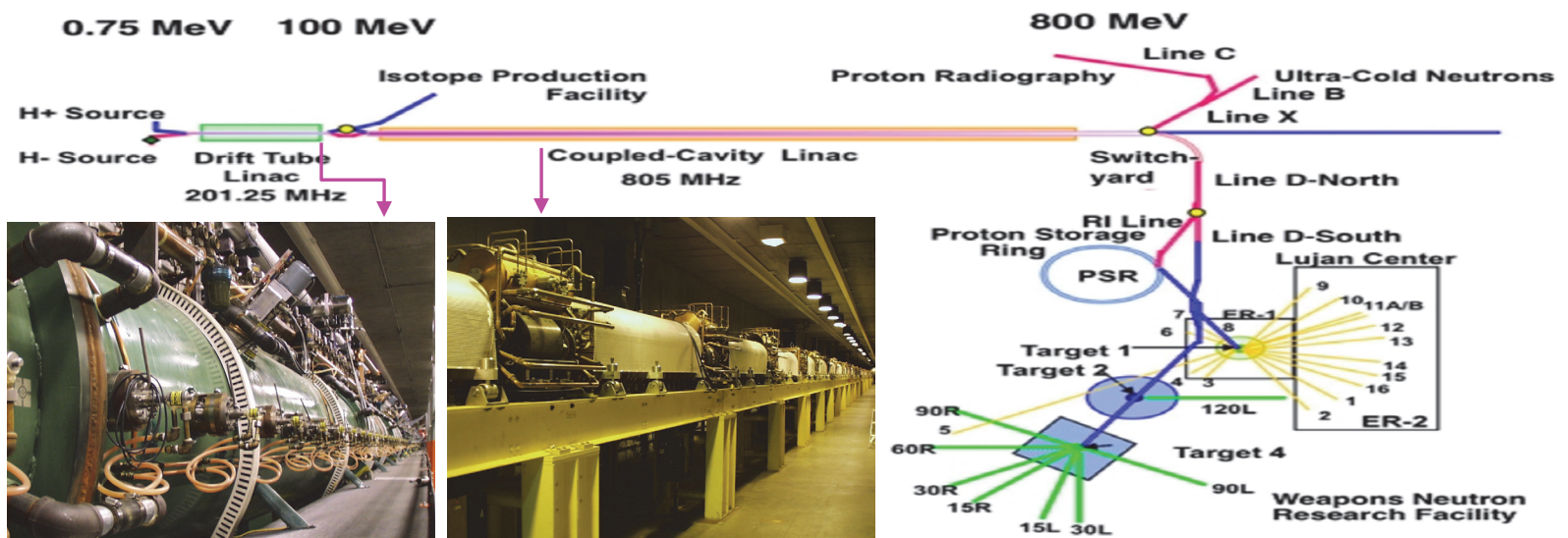
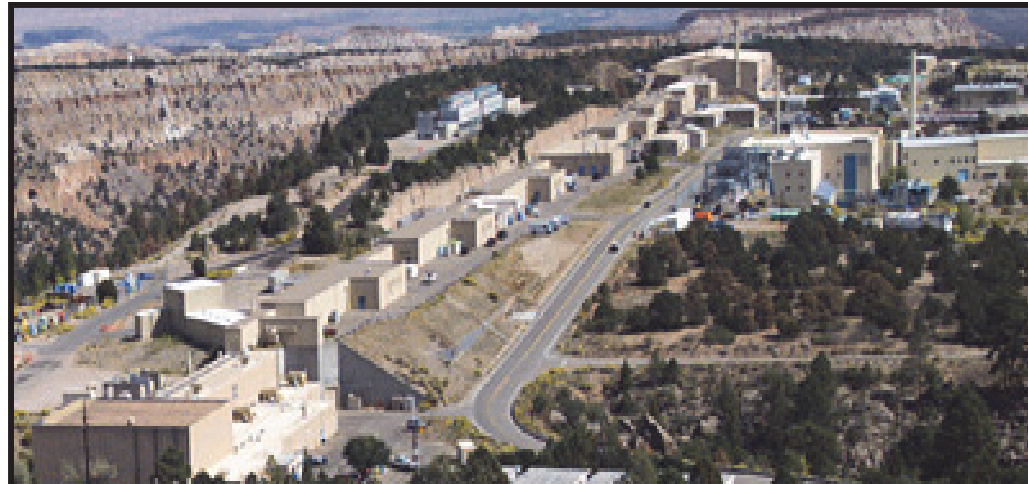
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Outline

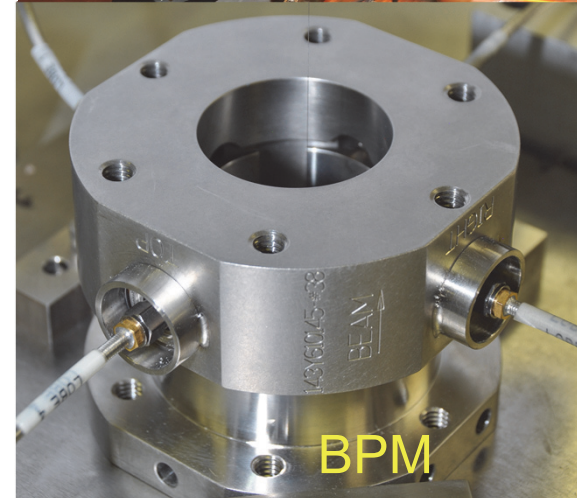
- **Our Beamlines**
- **Beamlines diagnostics**
- **How diagnostics impact our activities**
- **Problems we generally observe during a diagnostic operation**
- **Procedure to mitigate some problems**

Los Alamos Neutron Science Center (LANSCE)



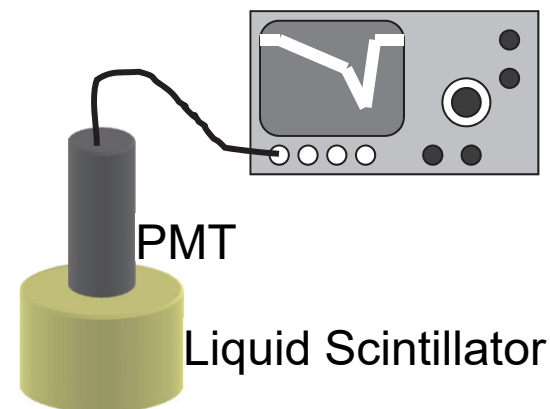
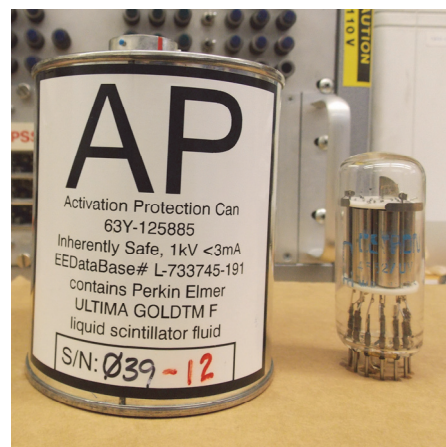
Beam diagnostic measurements

- Transverse profile (Wirescanner
Time gated camera
Harp)
- Centroid (BPM)
- Emittance
- Spill (APs, Machine protection system)
- Beam energy (Delta-t)

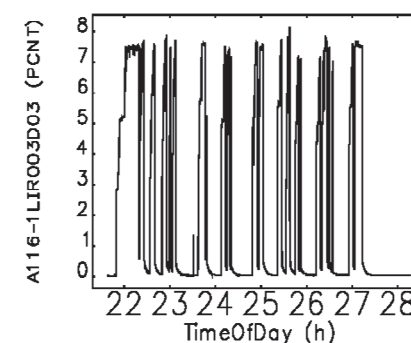
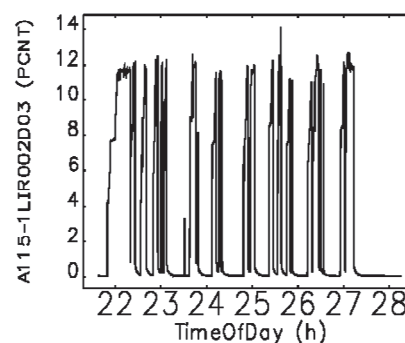
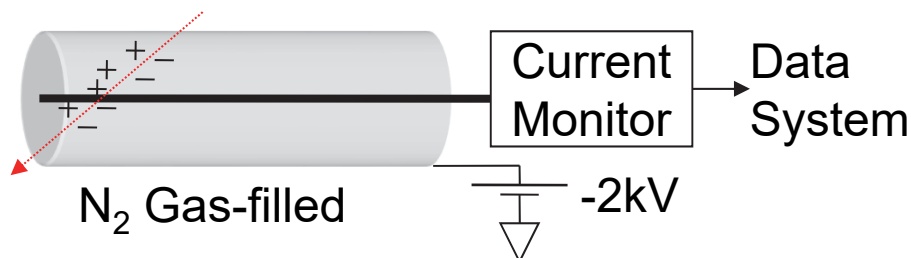


Beam loss monitor system

Activation Protection (AP) device is a scintillation detector. The signal is available both as a waveform (real-time of beam loss across the beam pulse) and integrated to monitor average beam loss.

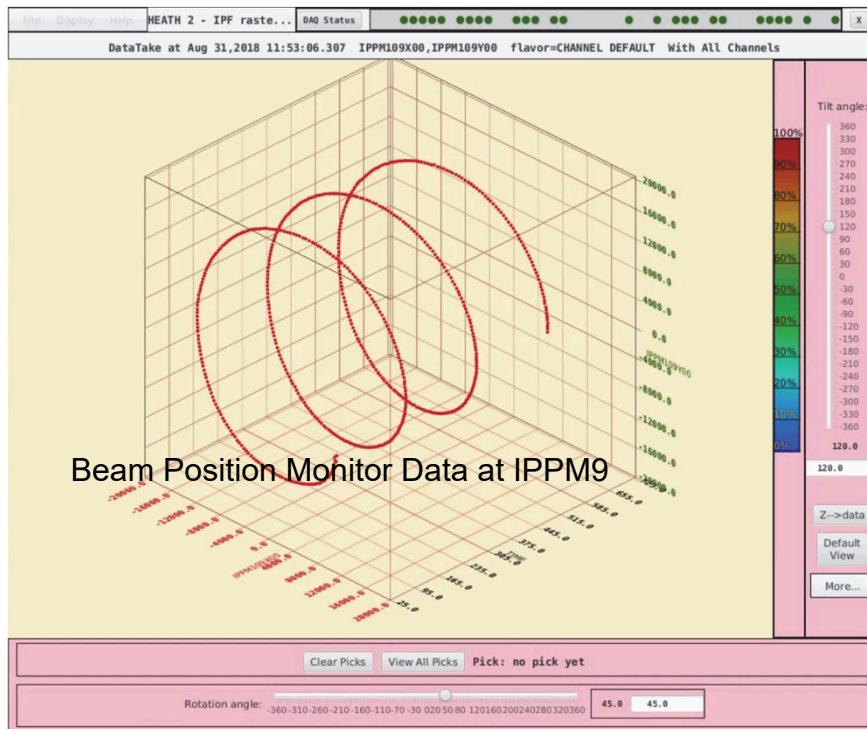


Ion Chamber (IR) detectors are used in the high energy (Line D, PSR, 1L, WNR) transport lines. Ion chamber will not saturate at low duty factors like AP cans do.

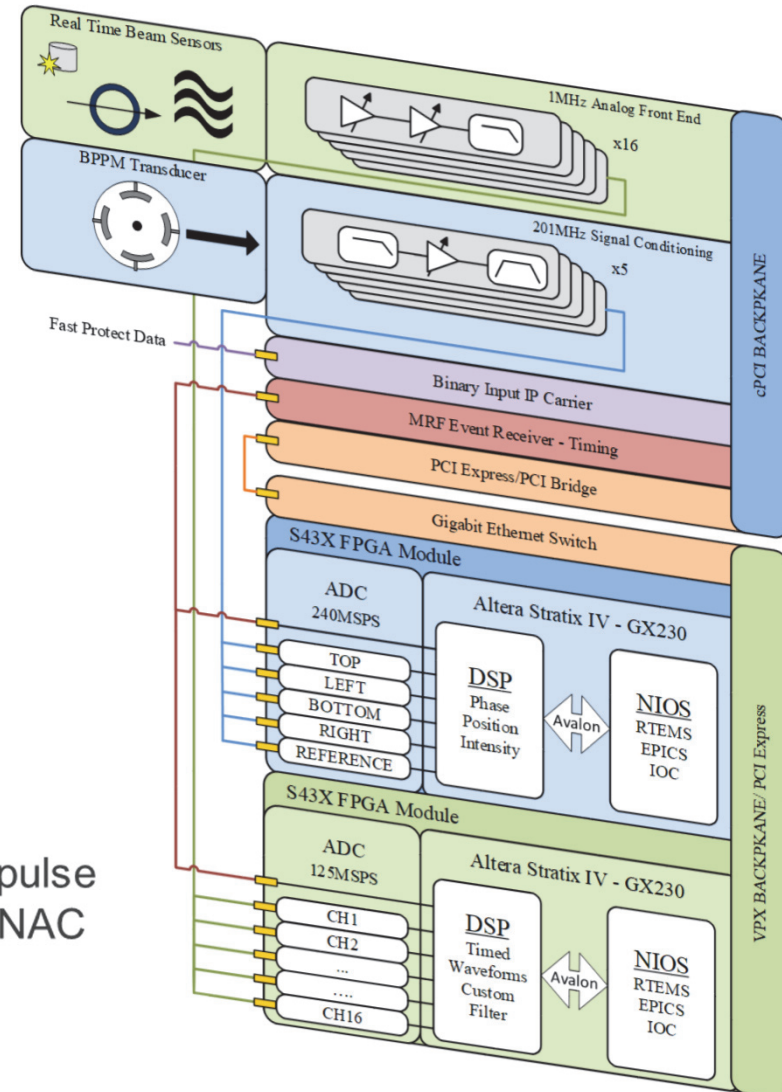


Example of spill data monitor using SDDS

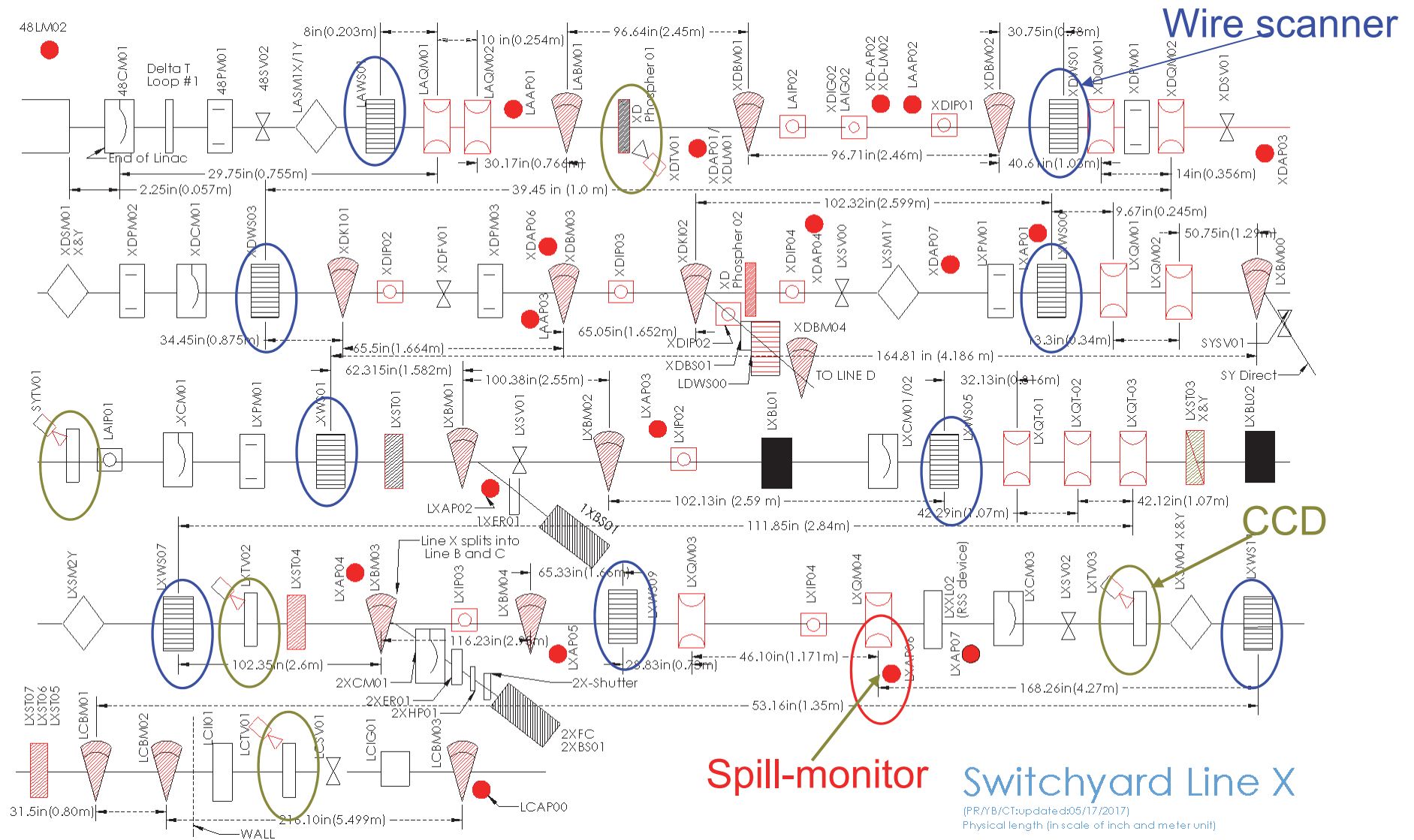
Real time beam position & phase monitoring using BPM



- Enables transverse position across a macro-pulse
- Enables beam energy for IPF and the 805 LINAC

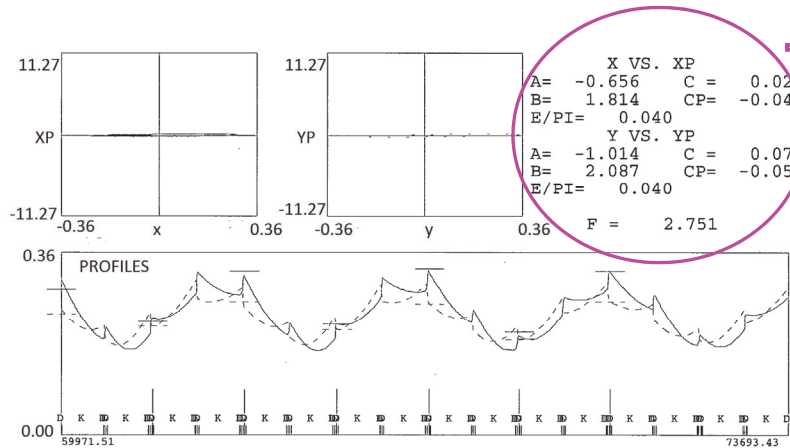


A schematic of diagnostics placement in one of our beamlines



Beam diagnostics are used for various purposes

An example: Beam emittance measurement at the end of 805MHz LINAC to prepare input beam parameters for a beamline study



This is an emittance reconstruction based upon a beam envelope model fit to multiple beam profile measurements.

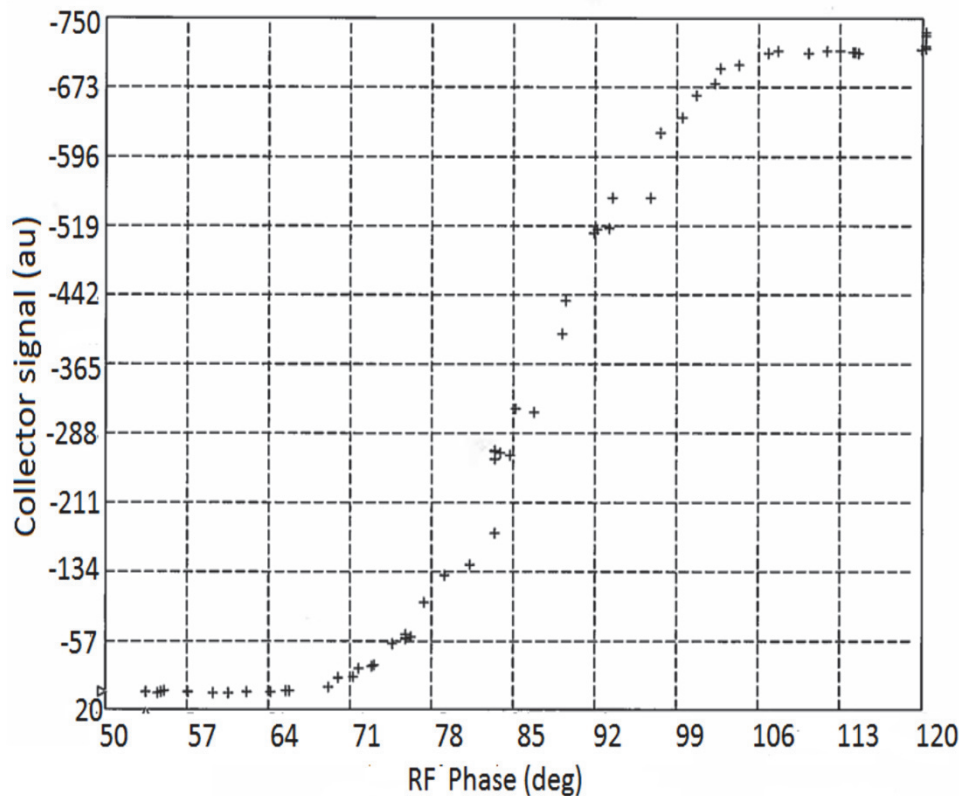
Table 1. TRANSPORT input parameters at 800 MeV.

Parameter	X vs xp	Y vs yp
α	-0.656	-1.014
β	$1.814 \frac{cm}{mrad}$	$2.087 \frac{cm}{mrad}$
ϵ	$0.040 \frac{cm(mrad)}{cm}$	$0.04 \frac{cm(mrad)}{cm}$
$4 \times \epsilon$	$0.16 \frac{cm(mrad)}{cm}$	$0.16 \frac{cm(mrad)}{cm}$
$\gamma = \frac{1+\alpha^2}{\beta}$	$0.788 \frac{mrad}{cm}$	$0.972 \frac{mrad}{cm}$
$x_{max} = \sqrt{\sigma_{11}} = \sqrt{\beta \epsilon}$	0.538 cm	
y_{max}		0.577 cm
$x'_{max} = \sqrt{\sigma_{22}} = \sqrt{\gamma \epsilon}$	0.355 mrad	
y'_{max}		0.394 mrad

TRANSPORT card

1 "BEAM" 0.538 0.355 0.577 0.394 0.52 0.08 1.45913;

Another example of use of diagnostics to measure RF phase to calculate longitudinal beam extent



The absorber/collector located after the 2nd module of the CCL allows us to estimate the longitudinal phase profile of the 100-MeV beam at the entrance to the CCL. 121 MeV refers to the energy thickness of the absorber used in the device.

Estimated Longitudinal beam extent (L)

$$L = \beta(E)\lambda \frac{\Delta\varphi}{360^\circ} XF \approx 0.52 \text{ cm}$$

Where, velocity factor

$$\beta_E = \frac{\sqrt{(\gamma_E)^2 - 1}}{\gamma_E}$$

$$\gamma_E = 1 + \frac{T(=800 \text{ MeV})}{E_0(=938.3 \text{ MeV})}$$

Wavelength of the cavity

$$\lambda = c/f = 37.267 \text{ cm}$$

• Beam phase width, $\Delta\varphi = 25^\circ$

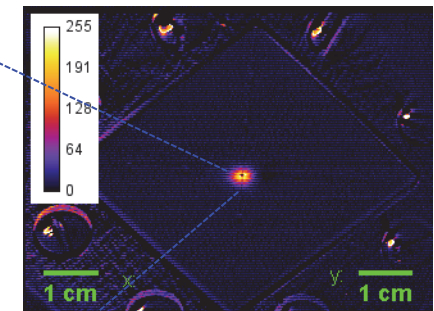
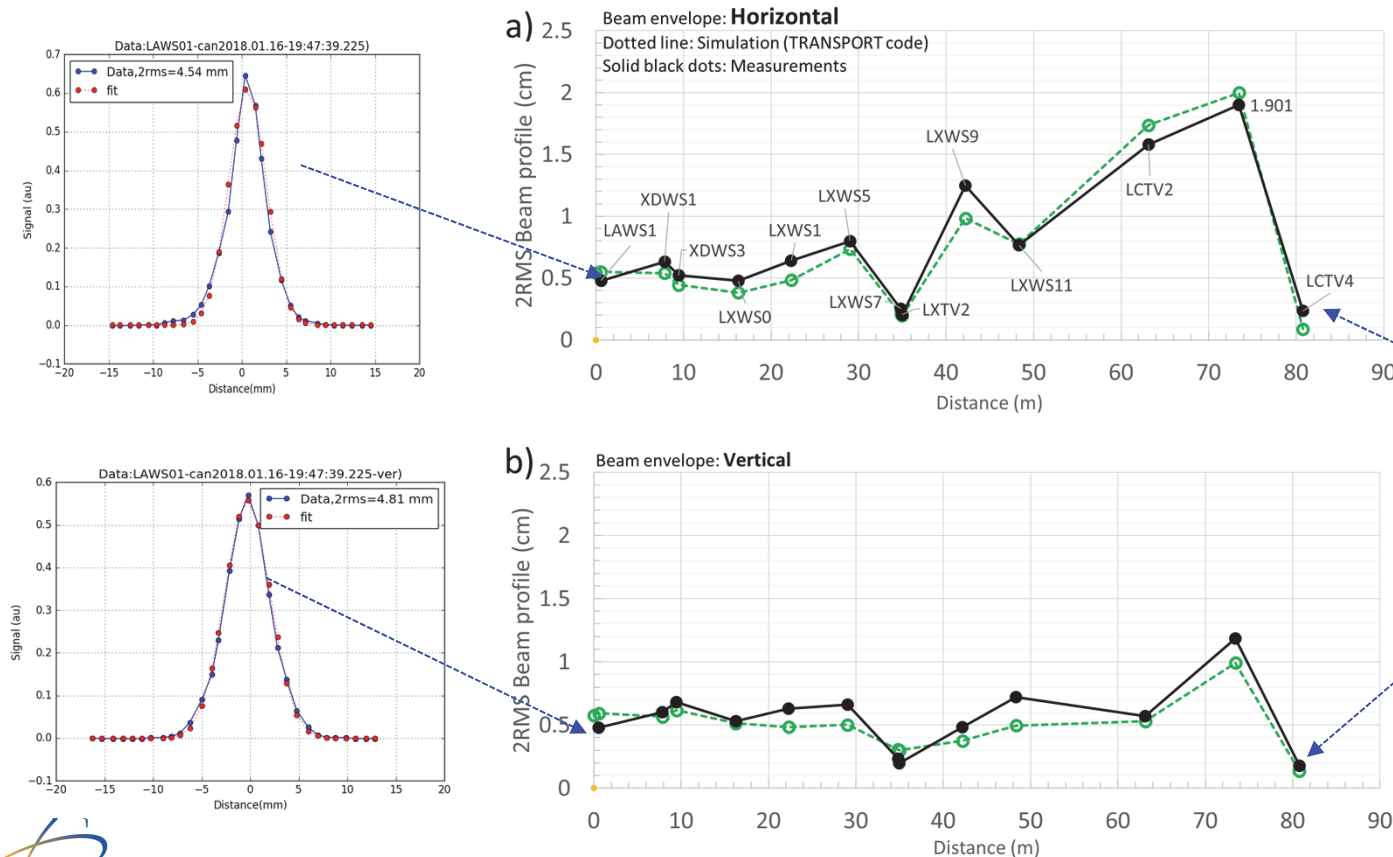
Phase damping factor (F)

$$F = \frac{\Delta\phi_2}{\Delta\phi_1} = \left(\frac{\beta_{121}\gamma_{121}}{\beta_{800}\gamma_{800}} \right)^{3/4} = 0.441$$

Diagnostics data are used to verify simulation

- The beam line contains many bending and focusing elements before it reaches the pRad beam optics system where the beam spot size requirement is nominally 2 mm (RMS).
- TRANSPORT code was utilized, and the beam profile was measured along the beamline using wire scanners (WS) and gated cameras (TV).

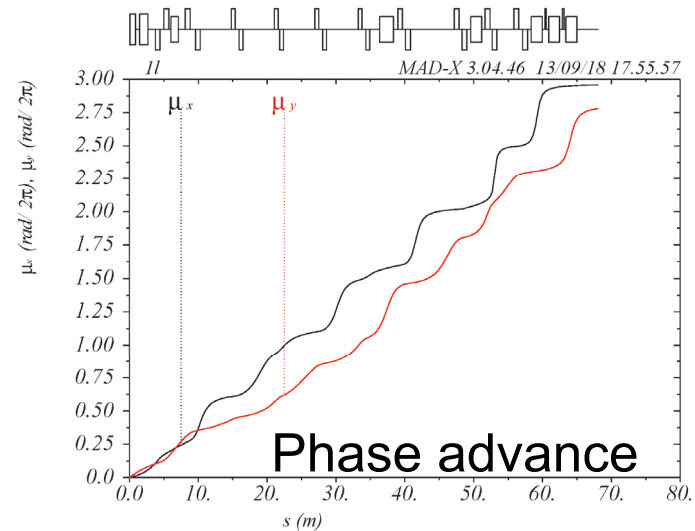
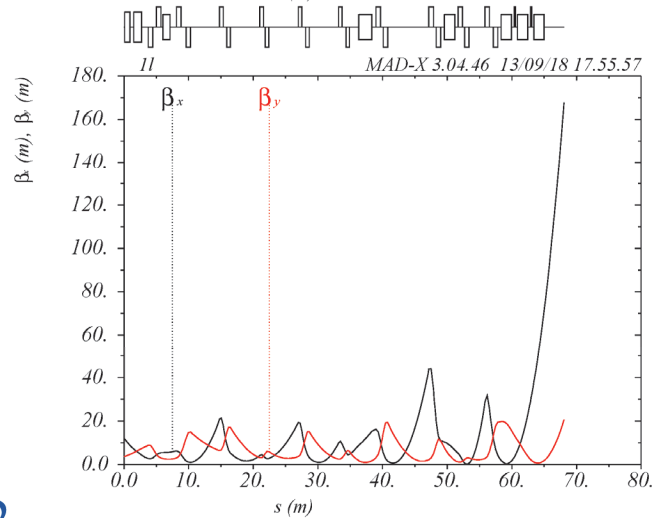
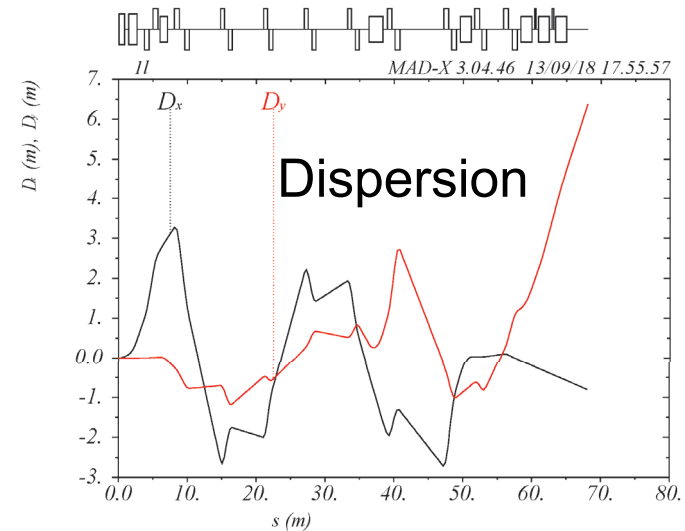
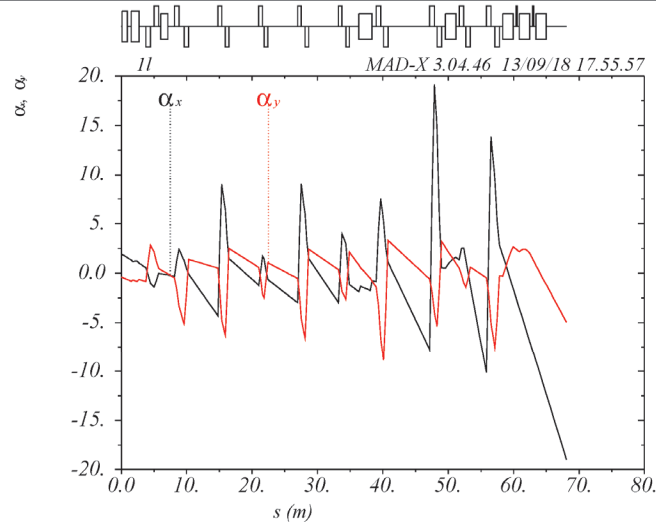
- Measured data and code output data were placed side by side and results show a reasonable agreement.



The study helps to understand the beam profile for any small changes of fields of magnets.

Diagnostics data provide beam information

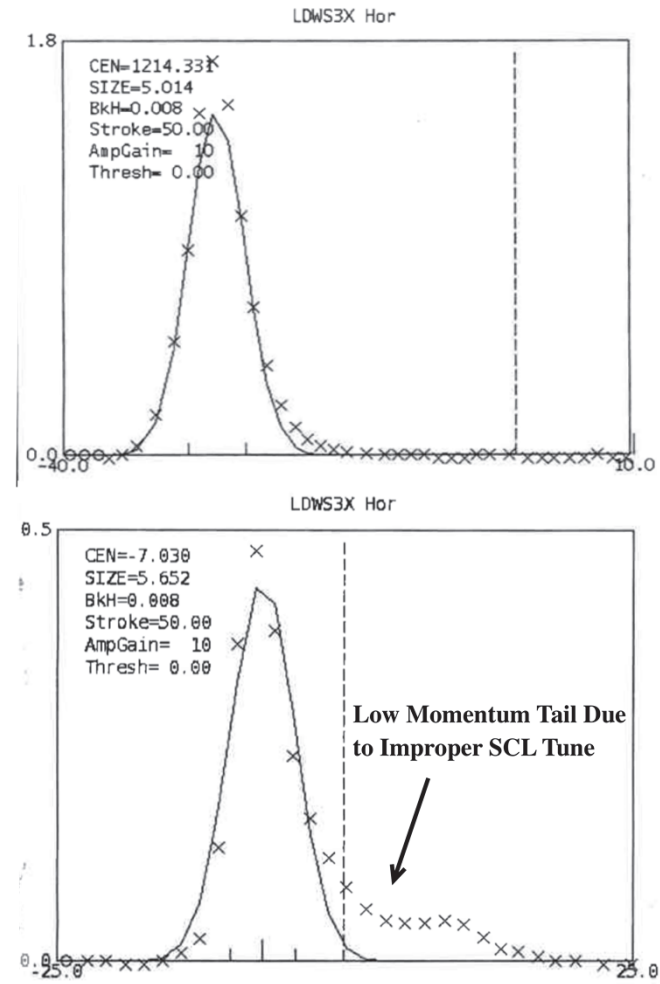
Below are some examples



Wirescan diagnostics are used to examine quality of accelerator tuning

- The 805-MHz side couple cavity linear accelerator phase and amplitude set-points are established by the Δt turn-on procedure.
- The name is derived from the relative time-of-flight measurements that are required.
- Improper phase and amplitude set-points of the RF modules contributes to beam tail formation and high beam losses.

(Note: Measurement being made at high-dispersion point in beam line)



Difficulties we faced in general: View screen camera issues as for an example

- **Camera no longer aligned**

- Spatial alignment (bumped)
- Aperture not set properly



- **Can't see screen**

- Bulbs burn out more frequently because LEDs can't be used in radiation environment
- Lamp misaligned (bumped) or disconnected for other purposes
- Actuator doesn't insert viewing screen due to air issue

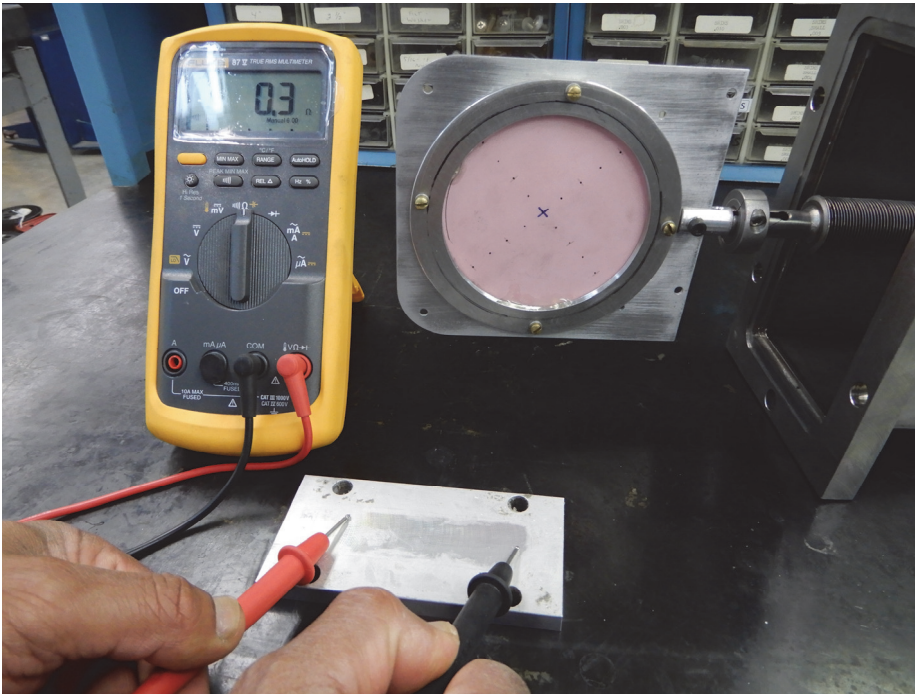
- **Capture data not saved**

- IOC could not reach the fileserver to save the data
- Added a task that attempts to remount the file system (like we already had for the other file system).

- **Video signal quality problems**

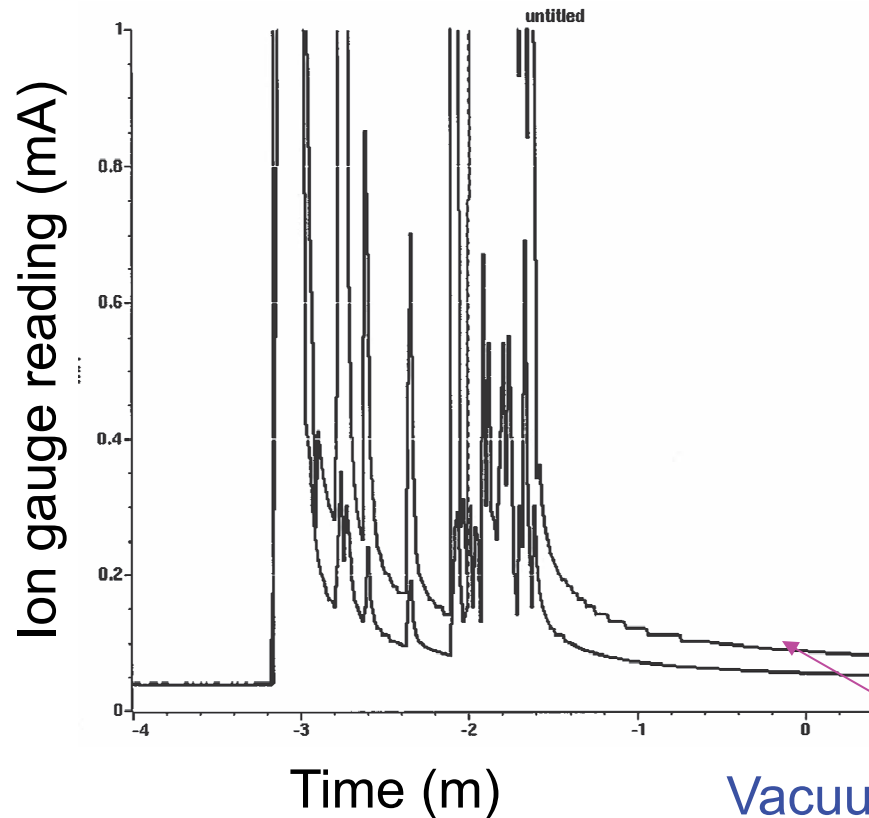
- Camera readout electronics (partial) failure

Al coating / mesh was missing prior to installation



The scintillator surface (right) is non conductor. The electrical charges will not be draining to ground quickly when the beam is impacted on the scintillator. The beam profile measurement may vary for successive shots. Materials damage is reasonable, and thus it can be fragile during insertion impulse (force).

Vacuum excursion occurred during a wire scanner operation



We could avoid terminating an experiment on a schedule day by prior **“proper”** check during a maintenance day.

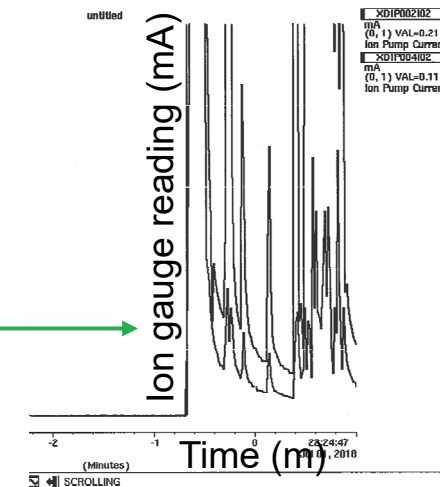
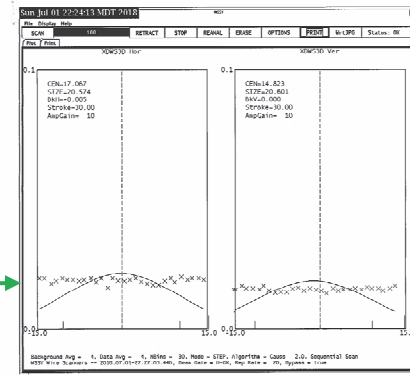
A scenario of a wire scanner pre-check during a maintenance day that helped to run a successful experiment in a next schedule day

Observed parameters:

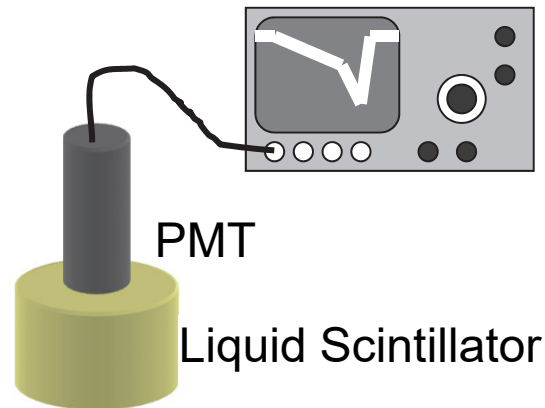
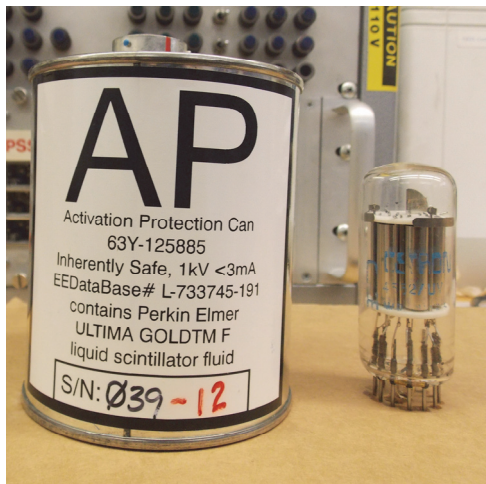
- (i) **Device movement,**
- (ii) **Data collection using software, and**
- (iii) **Vacuum monitor -upstream and downstream of a diagnostic.**

Results:

- 1) 1LWS03-> Normal
- 2) 1LWS02 -> Drive unit (in and out power supply module) had problem and replaced
- 3) ROWS01-> software shows wire scanner is on out-limit but it was reading 6.4 Volts on the drive module (in limit). Unable to confirm device is out from the beamline, tested hardware.
- 4) LXWS05-> Software was not showing data, contacted IC.
- 5) XDWS03-> Vacuum excursion. A high priority work request was placed.

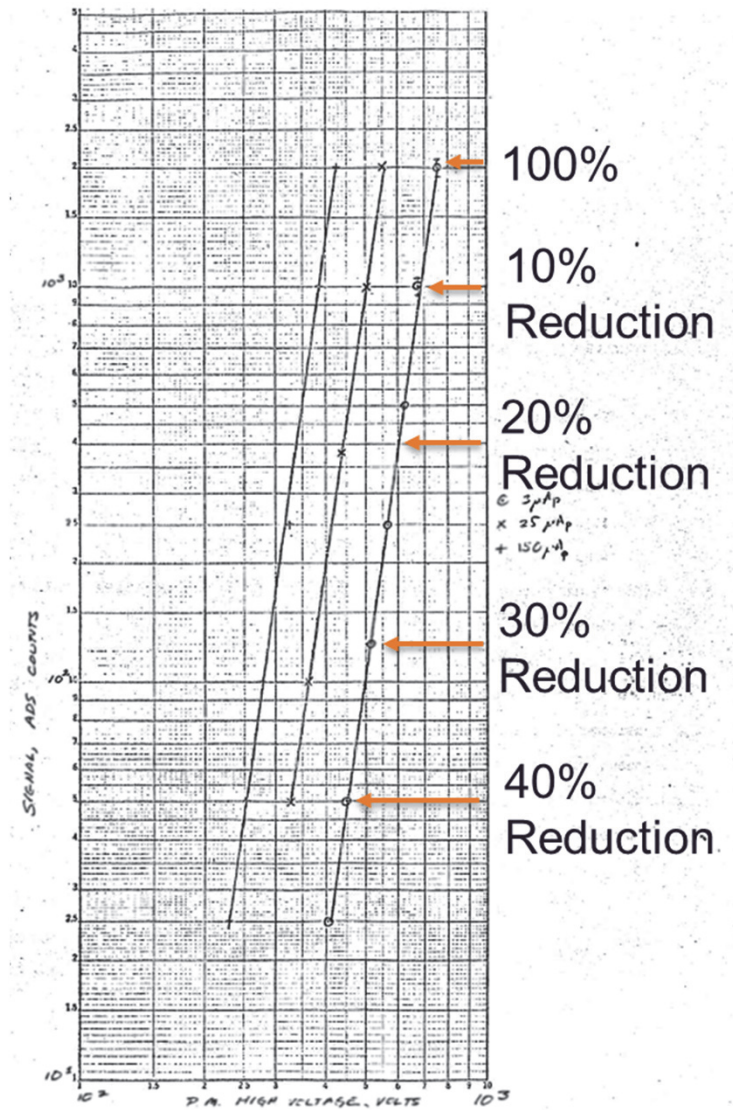


A Pre-check of operational voltage of an APs can avoid compromise of spill monitor and safety



APs sensitivity can be reduced by reducing the HV applied to the can

- A 10% reduction in AP high voltage is equivalent to lowering the sensitivity by 50%

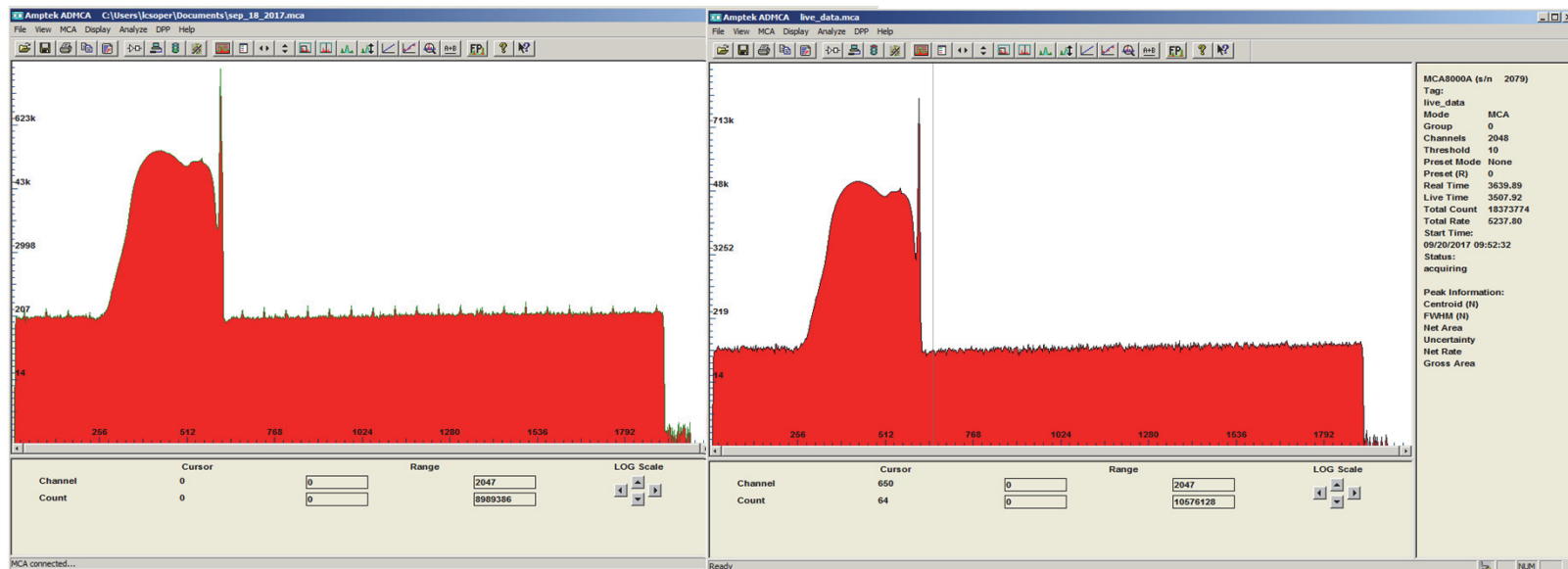


Clean up of unwanted beam not in the main peak to provides right current to a target



Detector consists of a scintillator with photomultiplier tube (PMT)

- Dark current was improved with chopper and buncher corrections.



Summary

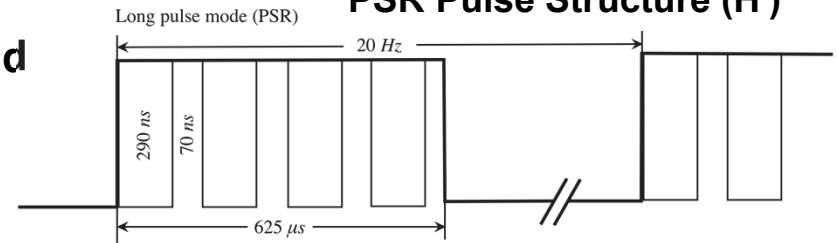
- Accelerators and beam transport systems typically contain numerous beamline diagnostics to measure beam particles distributions, beam emittance, beam energy, to monitor beamline vacuum and beam loss etc.
- As with any aging beamline system, there are legacy diagnostics that are still effective, but replacements are not essential until inevitable.
- It was observed that diagnostics, including legacy and other diagnostics can effects the beam production time if not thoroughly evaluated prior to use.
- To mitigate beam down time, it becomes necessary to pre-check the devices (insertion movement, data collection, beamline vacuum etc.) during any maintenance period.

Backup: Beam time structures at LANSCE

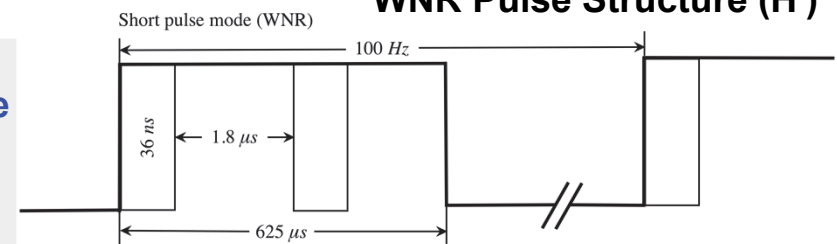
- LANSCE has 5 unique beam structures (4 H⁻ and 1 H⁺)
- Beam structures are produced through a combination of a slow-wave chopper and RF bunching systems in the LEBT

Experimental Area	Repetition Rate(Hz)	Pulse Length (μs)	Current per Bunch (mA)	Average Current (μA)	Average Power (kW)
Lujan Center	20	625	10	100	80
IPF	100	625	4	230	23
WNR	100	625	25	4.0-5.0	3.2-4.0
UCN	20	625	10	10	8
pRAD	1	625	10	<1	<1

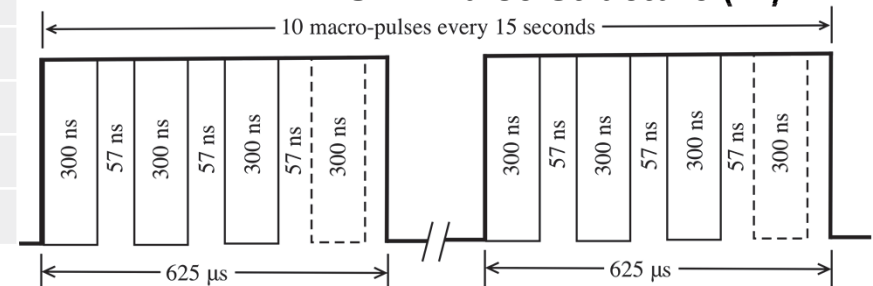
PSR Pulse Structure (H⁻)



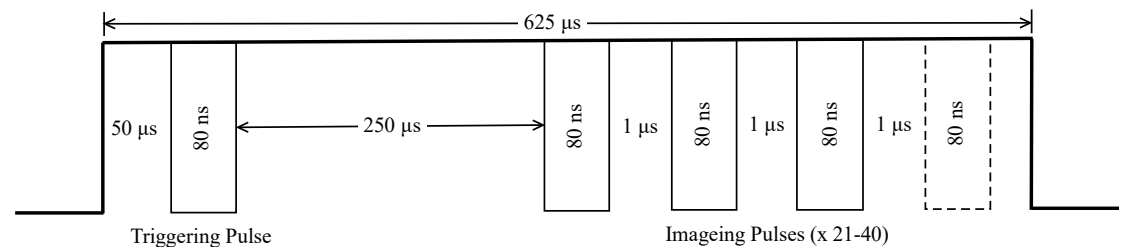
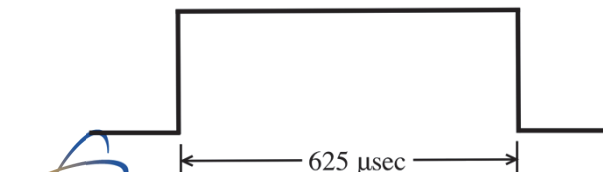
WNR Pulse Structure (H⁻)



UCN Pulse Structure (H⁻)



IPF (H⁺)



pRAD Pulse Structure (H⁻)