STUDIES OF BEAM LOSS MONITOR WITH EPICS MONITORING SYSTEM AT ARRONAX C70 CYCLOTRON

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Abstract

Arronax is a multi-particle high energy and high intensity cyclotron. Operation accelerator developments aims at increasing operation tuning accuracy and stability for both experimental research and development irradiation works and radioisotope production and requires for these beam monitoring systems. The status of the development of beam loss monitor (BLM) and the integration of the data acquisition chain to a new monitoring system based on the Experimental Physics and Industrial Control System (EPICS) are presented. Studies of beam dynamics experiments were performed at high beam proton intensity and BLM characteristics studies at low beam intensity. G4Beamline simulations[2] is also used to study beam and beam line parameters in ideal conditions.

Introduction:

Arronax is a multi-particle (proton, alpha, deuteron) high energy and high intensity cyclotron. Several beamlines are dedicated to high intensity operation and one beamline is devoted to experiments at low intensity. Runs with proton beams up to 70 MeV and 150 uA are performed regularly on targets for radioisotope production. The intensity is foreseen to be increased in the near future[4].

In order to support present operation, transition towards higher intensities and prepare developments of beam lines and experiments, it is essential to study several global beam characteristics. To study those beam characteristics, development of new diagnostics and proper monitoring system is needed to support operators.

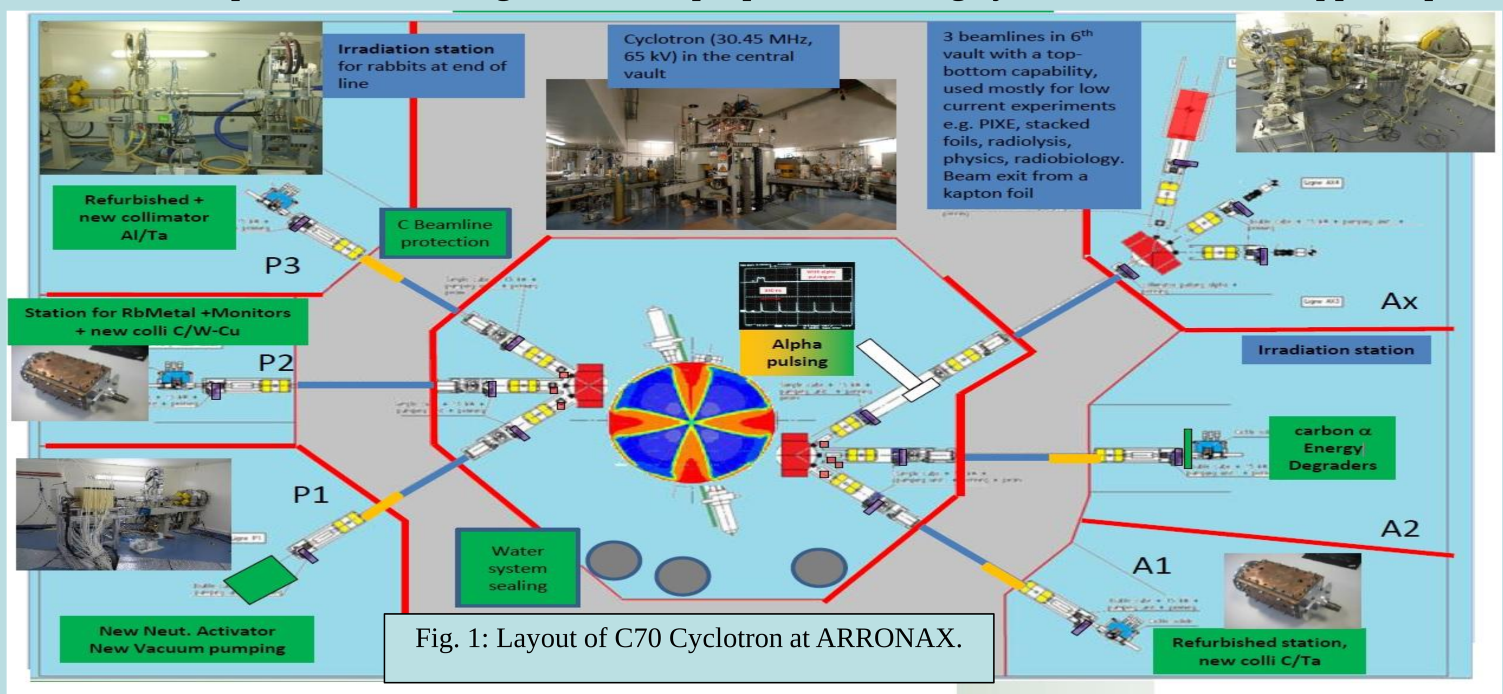

Fig. 1: Layout of C70 Cyclotron at ARRONAX.

Objective:

Aim is to focus on studies of beam dynamics, beam quality, dimension, shape, intensities and particle losses along the beam lines. These studies would lead towards far better beam monitoring strategies which could help operators in beam tuning in accordance to cyclotron uses for experiments (i.e. at high intensities and also at very low intensities, few 100 pA). For this work:

- It is necessary to implement and use specific diagnostics such as Beam Loss Monitor (BLM) is the primary system to be implemented as an effort towards machine protection. These monitors are expected to give indication of the local transverse dimension and position of the beam when losses occur, specifically at potential weak locations [3]. For online monitoring, integration of the data acquisition to the EPICS network has been carried out.
- BLM are tested using the EPICS software [1] with dedicated 8-channel intensity integration electronics based on the beagle-bone computer provided by iThemba Labs, replacing the original labview software. The objective is to integrate all monitors to the EPICS synchronized network.
- Idea is to use several BLM's placed at different location of a single beam line to monitor beam losses and quality through out the beam line. It would also help operators to improve beam quality and safe guard the machine.

Beam loss monitors (BLM): Air ionisation chamber around the beam pipe.

- ✓ Preliminary goal: check mechanical suitability around several beam pipes, electronics, and the chain of data measurements.
- ✓ Final Goal: Check losses

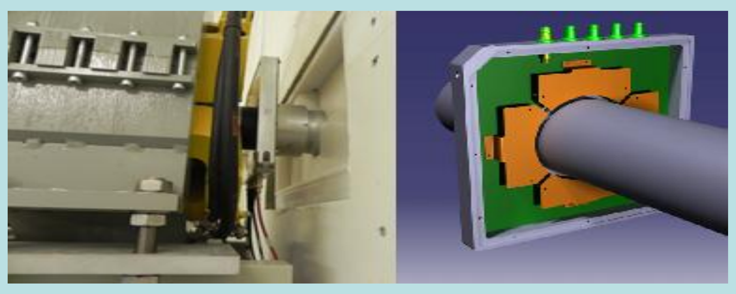

Fig. 2: BLM placement on a beam pipe

Experiments with High intensity (µA) beam

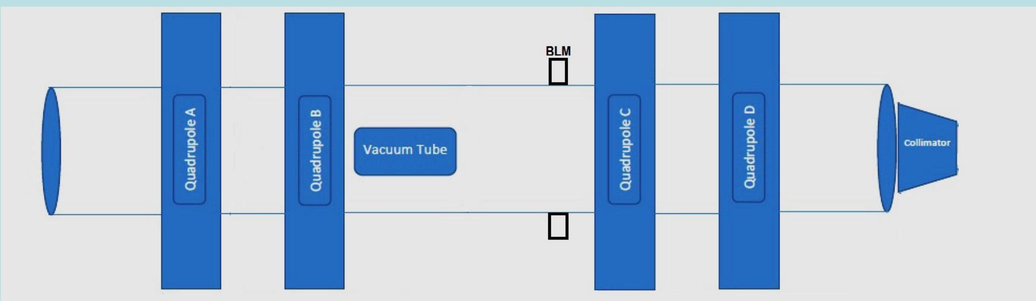

Fig. 3: Layout of A1 Beamline

- Experiments performed on A1 beam line to study beam size and beam losses by quadrupole intensity modification (quadrupole scan).
- 4 Quadrupoles, 1 BLM, collimator installed on this beam line (fig. 3).
- Collimator has 4 fingers which indicates beam geometry and position.
- BLM installed at a location where potentially beam size is large.

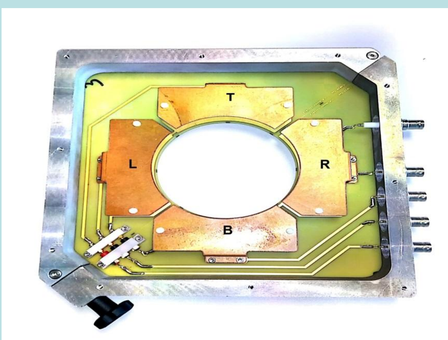

Fig. 4: BLM Data interpretation

- Horizontal beam size (L+R)
- Horizontal beam movement or positioning. (L-R)
- Relative horizontal beam movement with respect to beam size (L-R)/(L+R)

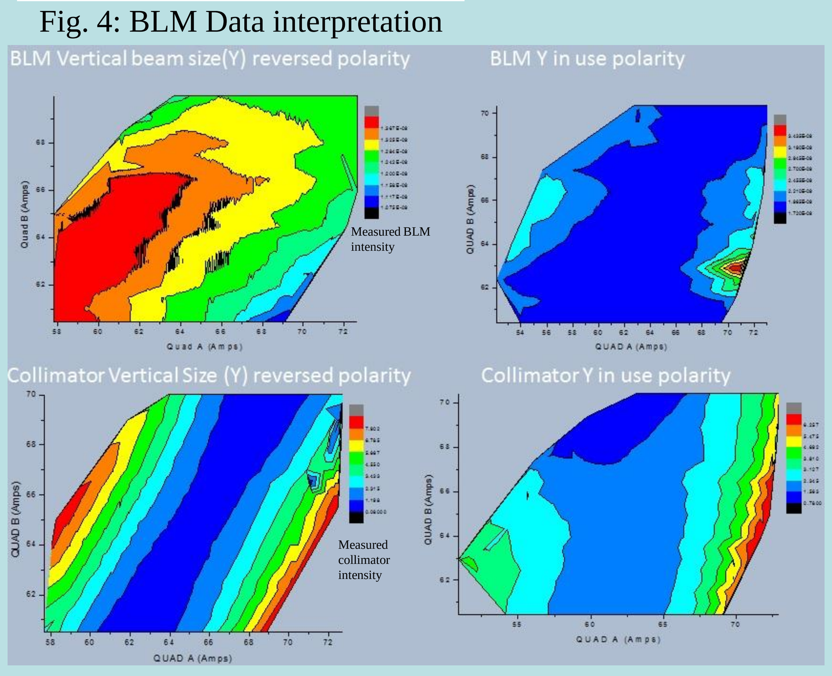

Fig. 5: Complete scan of pair of Quadrupole vs. BLM/Collimator signal

- BLM and collimator signals are plotted here during complete quadrupole scan.
- Plots shows the change in beam envelop size at BLM and collimator with several quadrupole settings.
- Desired quadrupole setting is the one where beam geometry is smaller at BLM location.
- Helpful to reduce beam losses.
- In reverse polarity, losses have reduced which needs to be studied by more experiments (Fig. 5).

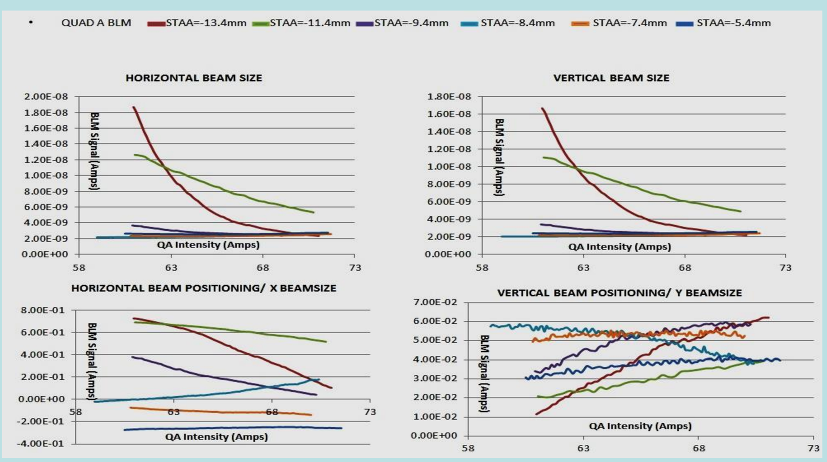

Fig. 6: Partial Quadrupole scans with different stripper foil location

- STAA (fig. 6) is the position of stripper foil and it changed horizontal phase space of the beam entering in a beam line.
- With the change in angle of the beam entering beam line, BLM shows how beam is moving.
- This study tells about the best beam angle for a most stable beam.

G4Beamline[2] Simulations

Simulations of Quad Scan in ideal condition to study beam dynamics

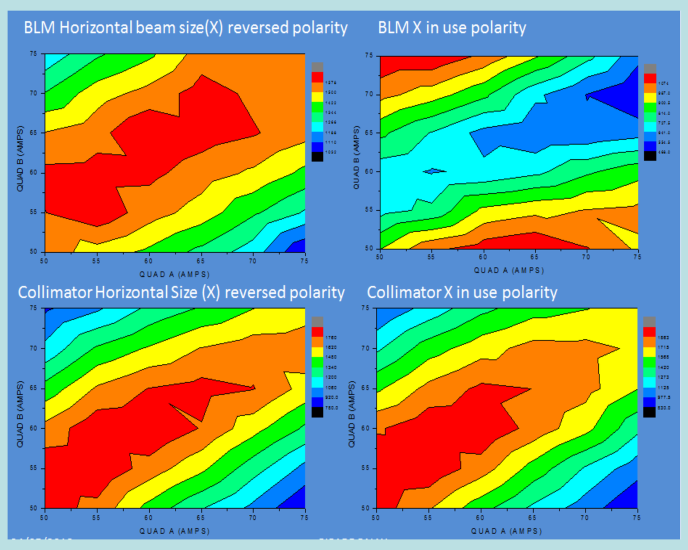

Fig. 6: Complete quadrupole scan to compare the impact of change in quadrupole polarity on beam geometry

- Simulations allow to study similar experiments in ideal condition (Fig. 6).
- Results from simulation may differ but gives a better understanding about beam dynamics and performed experiment.

Change in beam or beam line parameters	Significant change in tendencies			
	Experiments		Simulations	
	BLM	Collimator	BLM	Collimator
Beam Intensity	NO	NO	NO	NO
Beam Centering	-	-	YES	NO
Quadrupole (Pair) Polarity	YES	NO	YES	NO

Fig. 7: Comparison of experimental and simulation results

- Simulations and experimental results (Fig 7.) indicating that BLM can give a lot of information about beam dynamics.
- G4Beamline Simulation has shown potential to study beam dynamics in ideal conditions to support experiments.

Simulations to analyse beam envelop in idea condition

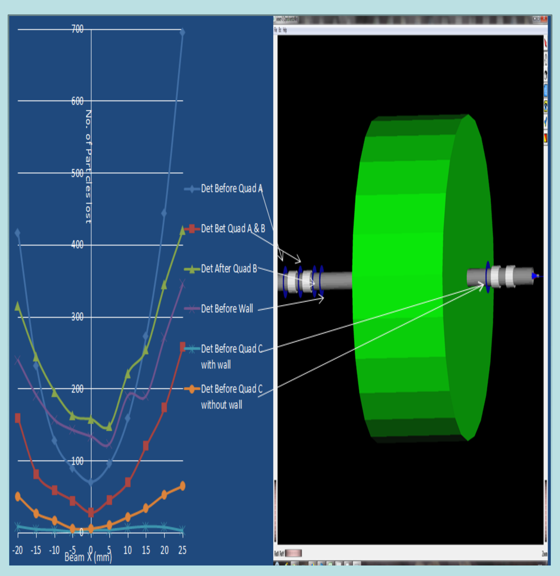

Fig. 8: Beam line losses at different locations with respect to beam centering in horizontal direction

- Simulation to analyse beam losses with fixed beam geometry.
- Also, effect on beam losses with beam centering.
- Effect of wall on beam loss detection.
- Simulations of envelop size (Fig 8.) gives probability of places where BLM should be placed.

Experiments with Low intensity (pA) beam

- Experiments performed on AX beam line to study BLM.
- To compare BLM signals with other BLMs.
- Types of particle detection.
- Response of BLM signals to direct and indirect beam particle interactions with different beam intensity.

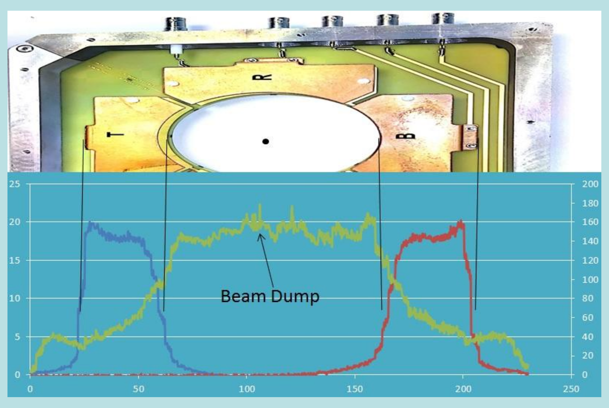

Fig. 9: BLM signals after data analysis which clearly shows the actual geometry of the BLM

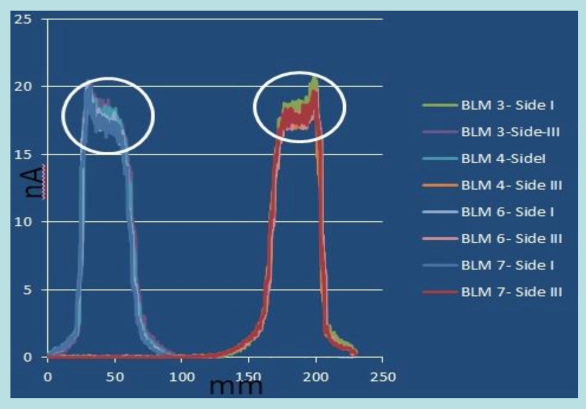

Fig. 10: BLM signals with its sides compared with different BLMs

- 4 different BLM studied (Fig. 10) to find differences between them.
- BLM signals during the experiment from EPICS monitoring system were exactly similar which are coming after data analysis (Fig. 9).

- Fig. 11 is showing results from the experiments.
- Difference between BLMs is in acceptable limits.
- Experiments indicated that several BLM can be used on a single beam line.
- In future, several BLMs at different points will be placed and will be synchronize with EPICS network.
- Operators will be able to monitor the beam through out the beam Line (At BLM locations).

BLM Characterisation	BLM 3	BLM 4	BLM 6	BLM 7
BLM Sides Precision	±10%			
Charged Particle detection senstivity (Low energy and High energy)	High			
Uncharged Particle detection senstivity (X-ray, Gamma, etc)	Very Low			
Calibration uniformity	Yes			
Detector Output Signal	Current Integration			

Fig. 11: BLM Properties from experimental results

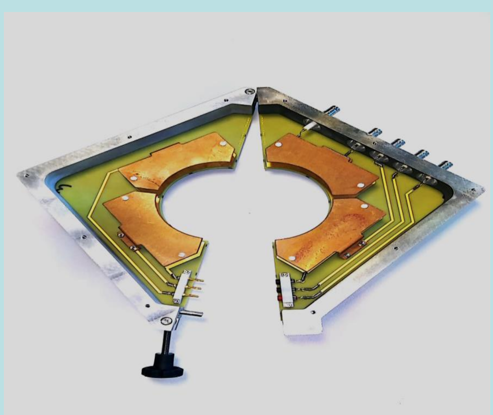

Fig. 12: BLM structure and active plates

What is so special and new about this BLM?

- Electronic circuit of this BLM is very basic and simple (Fig 12).
- Cost effective.
- It is very easy to install on a beam pipe.
- Non destructive monitoring.
- 2D monitoring is possible.
- Potential to Monitor beam dimension and centering.

CONCLUSION

EPICS monitoring and data acquisition system proved to be an effective tool for the purpose of the experimental works presented here. The installed BLM is giving significant and useful information of the beam with the setting modification performed in the beam line. These studies are indicating that the additional BLM and online integration into EPICS can be a very helpful tool for operators to track the beam. In Future experiments and simulations, studies will be done to develop a strategy for operators to do online beam centering, envelop size and emittance measurements.

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