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High Energy Beam Transport along the 68-m LANSCE 1L Beamline to Optimize Neutron Production*

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Abstract

An 800 MeV proton beam of up to 150 μA is accumulated in the LANCSE Proton Storage Ring (PSR) for 1800 turns and delivered to the Lujan Center, one of five user facilities at the LANSCE linear accelerator center, to generate an intense beam of pulsed neutrons for studies in academia, national security and industry. The Lujan Center beam transport line, known as 1L beamline, is over 68 meters in length, starting from a wire scanner ROWS01 in the extraction line of PSR. The beamline consists of several bending and focusing elements and ends at the 1L target where the beam spot size is nominally 3cm (2RMS). The next 1L target, Mark IV target, has been designed to optimize the neutron production for the Lujan center to improve high energy flux and resolution. As part of the safety review of this design, it is necessary to know the beam intensity and size on the new target. Alignment data of the beam line was measured with a laser tracking system and was compared with legacy measurements. Using the new measurement of the beamline, calculated beam sizes using the LANL version of the beam envelope code TRANSPORT [1] and CERN code MAD-X [2] are compared. The input beam parameters for the codes were extracted from an ORBIT code [3] analysis of the proton storage ring beam. The beam envelope measurements were made at various locations throughout the beamline using wire scanners. The predicted beam envelopes and measured data agree within expected errors.

1L Beamline

- ❑ The 1L beamline starting at ROWS01, consists of
- 20 quadrupole,
- 8 bending magnets,
- 5 wire scanners for beam profile measurements,
- 11 beam position monitors (BPMs), current monitors, vacuum system, & associate mechanical & electrical systems.
- The effective lengths of each quadrupole vary from 0.56m to 0.7m with half aperture 0.05m to 0.077m. These magnets are powered for 1.7kG to 3.88kG field.
- ❑ Three 30^0 beam bending magnets are located upstream of the target, & used to bend the beam a total of 90^0 to place the beam on target which is surrounded by a safety shielding.

Input Beam Parameters

- Beam size (2rms): x=2.096 cm, y=1.3265 cm
- Beam emittance: $\varepsilon_x=3.60\times10^{-5}$ m-rad, and $\varepsilon_y=3.60\times10^{-5}$ m-rad
- Correlation parameters: $r_{12}=-8.87\times10^{-1}$, and $r_{34}=1$
- Twiss parameters: $\alpha_x=1.927$, and $\alpha_y=-0.4$
  $\beta_x=12.175$m, and $\beta_y=3.72$m
- Pulse patter width: 290ns
- Circumference of the PSR ring: 90.26m
- Time of revolution (TOF): 358.112ns
- Beam bunch length=73.093m

Table 1: Basic relationship of Twiss parameters

Parameters		
Beam	Horizontal (x)	Vertical (y)
Beam size (cm)	$x = \sqrt{\sigma_{11}} = \sqrt{\varepsilon_x \beta_x}$	$y = \sqrt{\sigma_{33}} = \sqrt{\varepsilon_y \beta_y}$
Divergence (mr)	$x' = \sqrt{\sigma_{22}} = \sqrt{\varepsilon_x \gamma_x}$	$y' = \sqrt{\sigma_{44}} = \sqrt{\varepsilon_y \gamma_y}$
x- x' correlation	$\alpha_x = \frac{r_{12}}{\sqrt{1-r_{12}^2}}$	$\alpha_y = \frac{r_{34}}{\sqrt{1-r_{34}^2}}$
Twiss parameter	$\beta_x = \frac{\sqrt{\sigma_{11}}}{\sqrt{\sigma_{22}}}\sqrt{\left(1+\alpha_x^2\right)}$	$\beta_y = \frac{\sqrt{\sigma_{33}}}{\sqrt{\sigma_{44}}}\sqrt{\left(1+\alpha_x^2\right)}$

- Longitudinal beam extension: 28.72m (2rms)
- Momentum of central trajectory: 1.457 GeV/c
- Beam energy : 795.1 MeV, Total energy: 1.733 GeV
- Energy parameters: γ=1.847 , and β=-0.841
- Energy spread: 2.32×10^{-3} GeV
- Relative energy spread: 1.343×10^{-3}
- Longitudinal beam emittance=1.34×10^{-3} m-rad

$$\frac{\Delta p}{p_0}=0.056\%$$

1L Cell, TRANSPORT & MAD-X

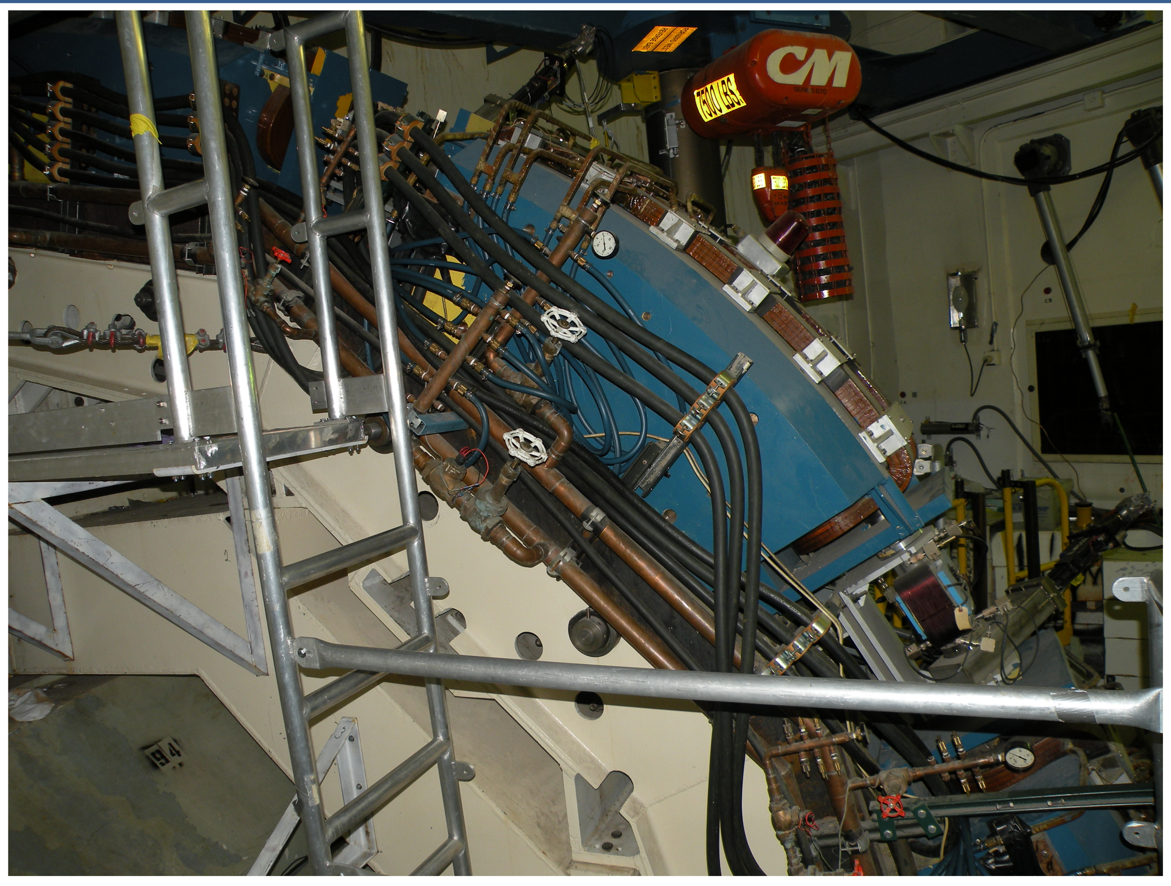

Figure 1: One of three 30^0 beam bending magnets located at upstream of the 1L target.

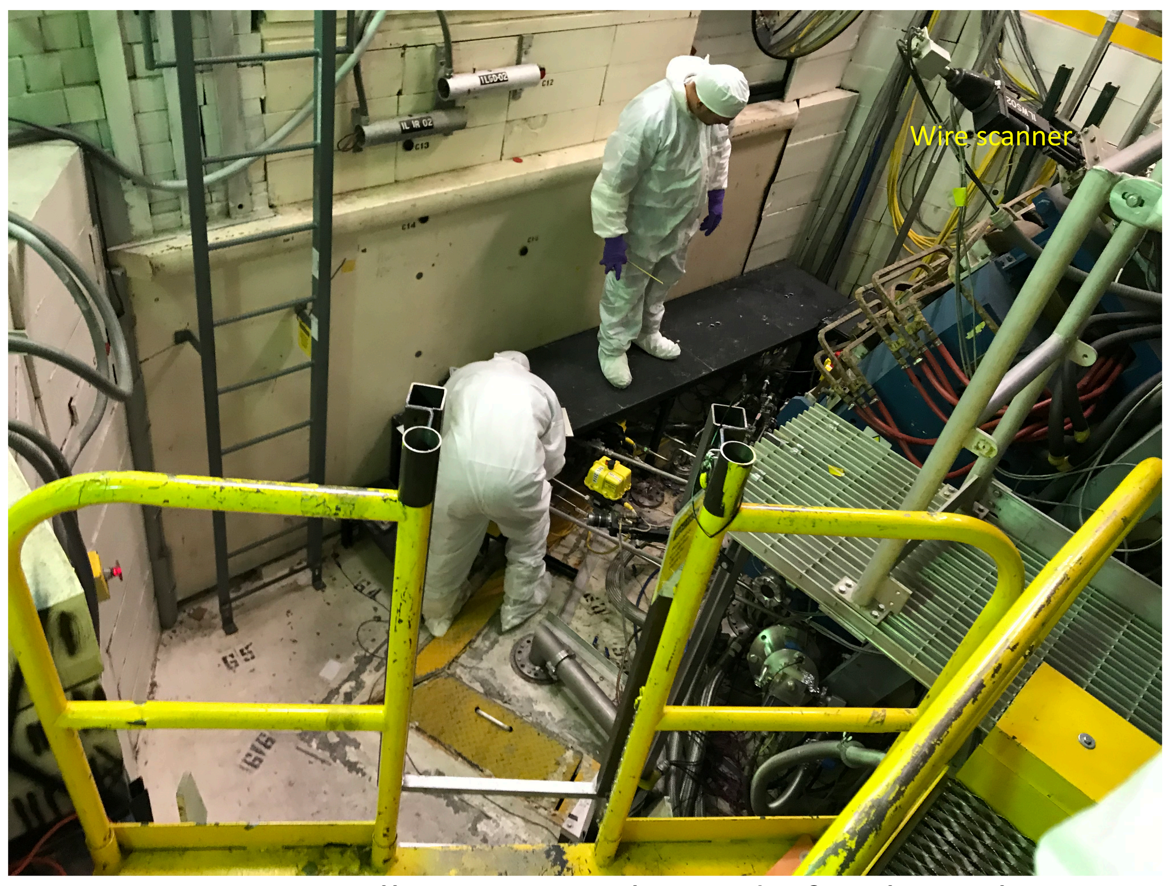

Figure 2: 1L Cell picture at the end of 1L beamline.

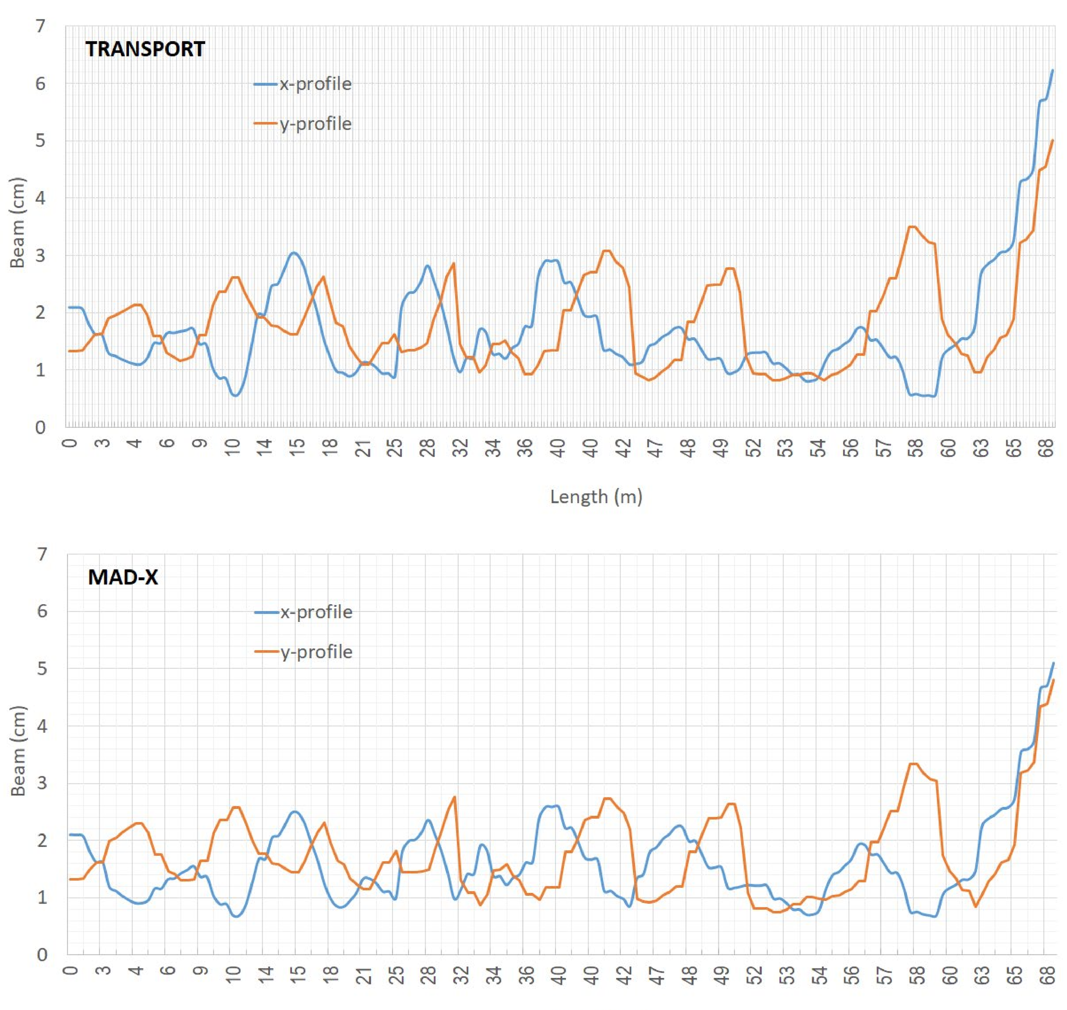

Figure3: Calculated horizontal and vertical beam profiles using TRANSPORT (top) and MAD-X (bottom).

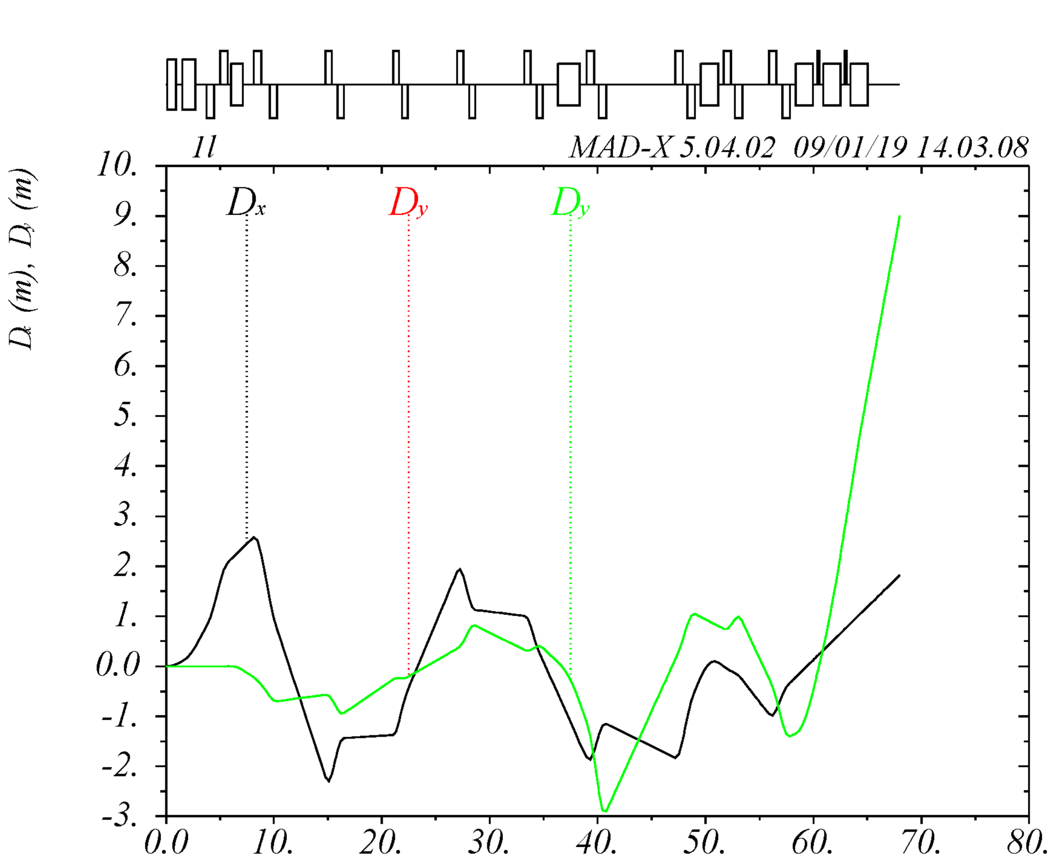

Figure 4: Beam dispersion, using MAD-X.

Simulation & Measurements

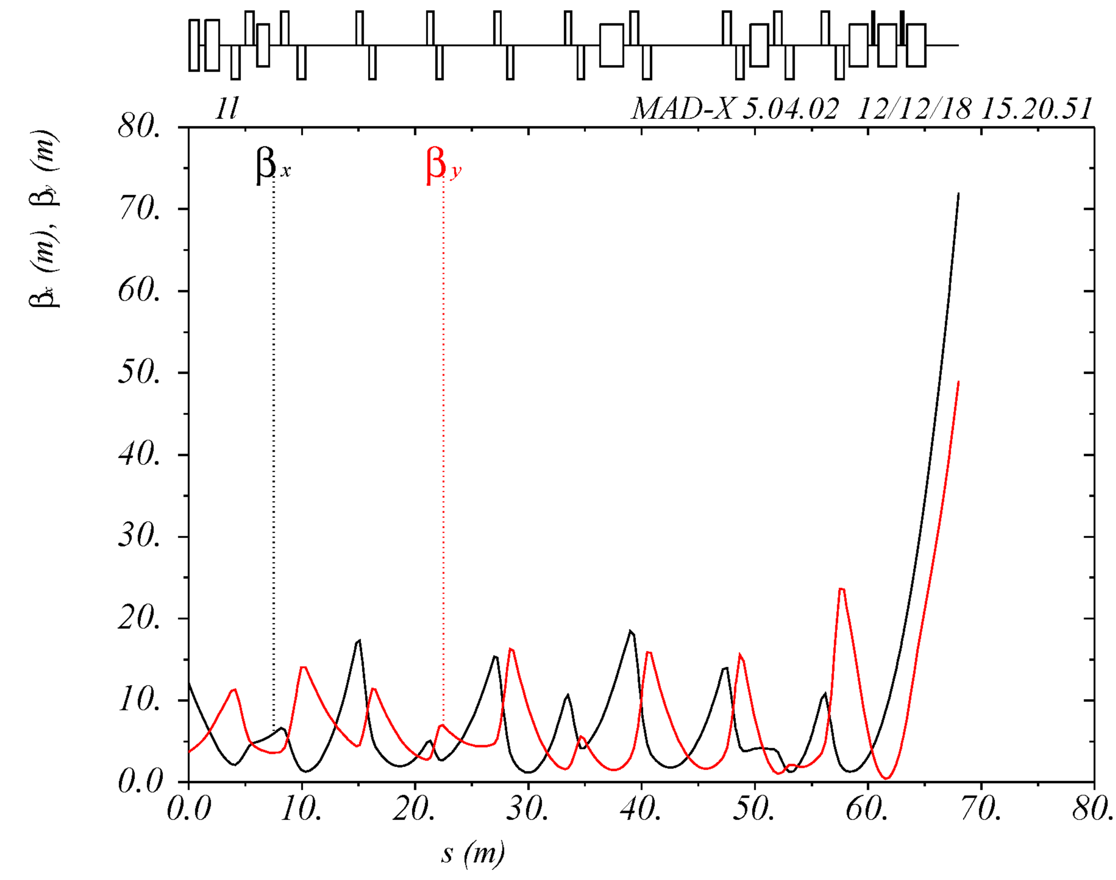

Figure 5: Calculated Twiss parameter β (a ratio of square of the beam size and emittance), using MAD-X.

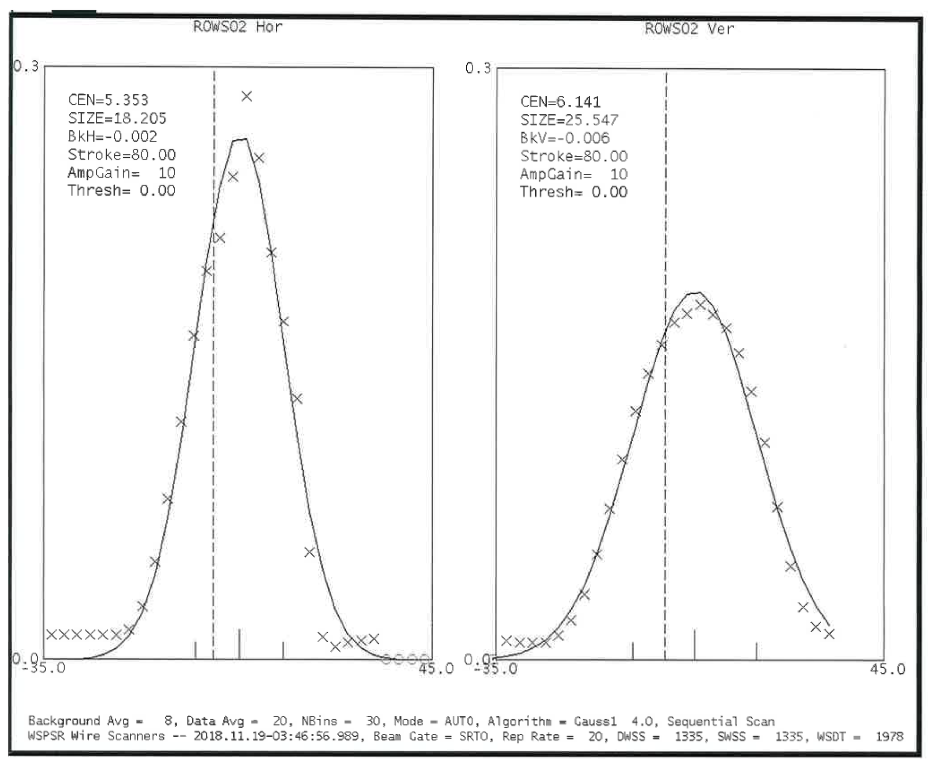

Figure 6: An example of 800 MeV beam profile measurement using wire scanner (20Hz, I=18.8μA, CD=1, PW=200ns.

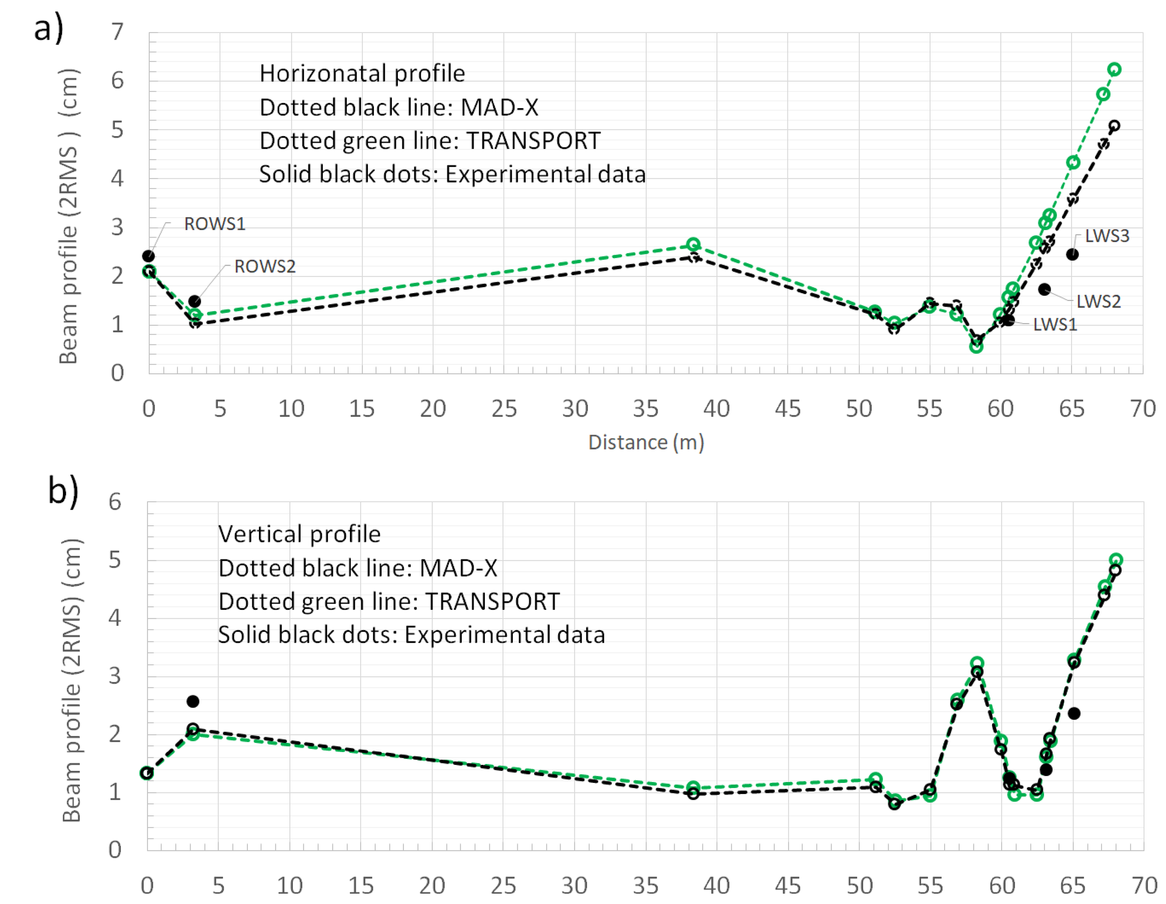

Figure 7: Measured (black dots) and calculated (hollow circles in dotted line) profiles along the beamline.

Summary

The input beam parameters for the codes were extracted from an ORBIT code analysis of the proton storage ring beam. The envelope measurements were made at various locations throughout the beamline using wire scanners. The predicted beam envelopes and measured data agree within expected errors. Although the comparison of measurements and models results were studied to better understand the beamline tuning process, further work is needed to optimize the size at target location and find the causes the differences of the beam size near the target between simulation and measurements.

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References:

[1] K. L. Brown, F. Rothacker, D. C. Carey, Ch. Iselin, "TRANSPORT a computer program for designing charged particle beam transport systems, SLAC-91, Rev.3, Available from the National Technical Info. Service, U.S. Depat. of Commerce, 5285 Port Royal Road, Springfield, VA 22161.
[2] MAD-X--Methodical Accelerator Design, CERN prog. Library entry: T5001, CERN, Geneva 1990.
[3] J. Holmes, `Recent Enhancements to the ORBIT Code', TUPEC080, Proc. of IPAC'10, Kyoto, JPN, 2010, p1901. See also, J. A. Holmes et. al., in the ICFA Beam Dynamics Newsletter, Vol. 30, 2003.

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