Measurement of Longitudinal Bunch Profile and Twiss Parameters in SNS LINAC

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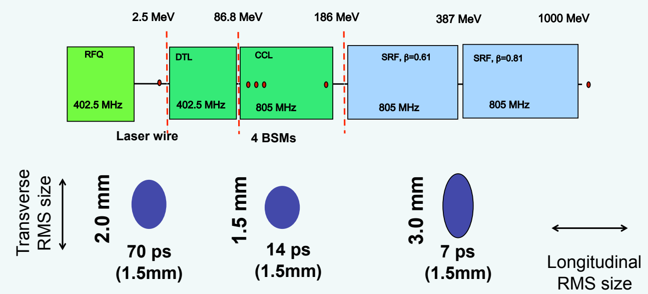
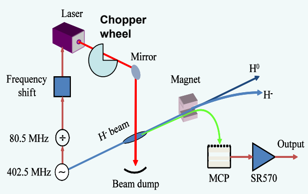
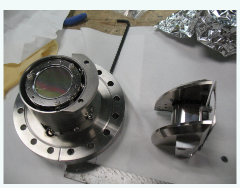
Abstract

We are reporting on the latest progress in the longitudinal beam profile and emittance diagnostics development at SNS. In order to characterize the longitudinal phase space of the beam in the SNS 1GeV proton linac the bunch profiles need to be measured with a few picoseconds accuracy. The original SNS set of diagnostics included only four interceptive Feschenko-style longitudinal profile monitors in the normal conducting part of the linac at 100MeV. Two recently added systems are: a non-interceptive laser scanner in the injector at 2.5MeV and a novel non-interceptive method for longitudinal Twiss parameters measurement using the beam position monitors in the Super Conducting Linac (SCL) at 300MeV. This paper presents details of these two diagnostics; discuss their performance, resolution limitations and future development plans.

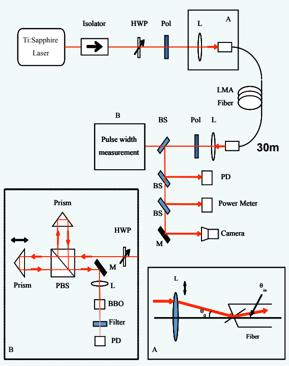




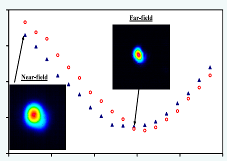
Longitudinal profile measurement layout



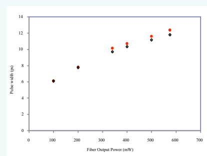
Electron detector: MCP and magnet



Laser system layout

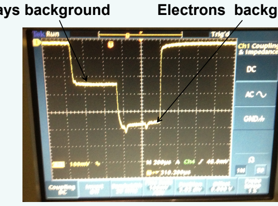


Laser spot size after fiber

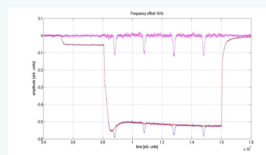


Laser pulse length after fiber

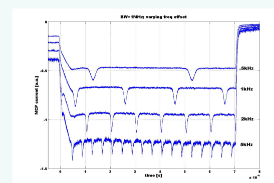
X-rays background   Electrons background



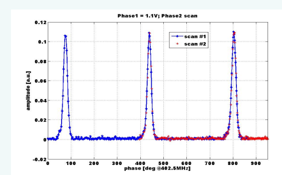
Raw signal from electron detector



Automated background subtraction



Measurement in 'frequency offset' mode



Measurement in 'phase scan' mode

1. Bunch length can be derived from BPM sum signal amplitude
   - SNS BPM is a strip-line pick-up with narrow band receiver

$$u_\omega = \frac{JA_g}{I_0\left(\frac{\omega\cdot R}{\beta\gamma c}\right)}\cdot e^{-\frac{(\omega\sigma)^2}{2}} \longrightarrow \sigma = \frac{180^0}{\pi}\cdot\sqrt{-2\ln\left(\frac{u_\omega}{A}\right)}$$

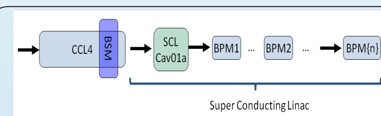
2. Calibration constant can be measured for each BPM using short bunch

$$\sigma\omega \ll 1 \qquad e^{-\frac{\omega^2\sigma^2}{2}}\approx 1 \qquad A\approx u_\omega$$

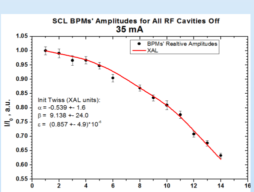
3. Bunch length increases and can be measured if RF is off in linac cavities

$$\sigma\omega\approx 1 \qquad \frac{\delta\sigma}{\sigma}=\frac{1}{(\omega\sigma)^2}\frac{\delta u_\omega}{u_\omega}$$

4. Initial Twiss parameters can be derived from bunch length vs. distance curve
   - Error is high if bunch expansion is dominated by space charge force
5. Add one cavity with variable parameter (phase) to increase effect of Twiss parameters
6. Input Twiss parameters can be found by fitting model (1 cavity + drift) to phase scan data
   - This is similar to Twiss parameters measurement with "quad scan" technique

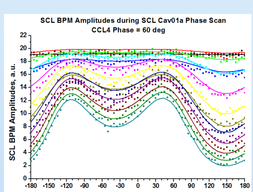


Free expansion



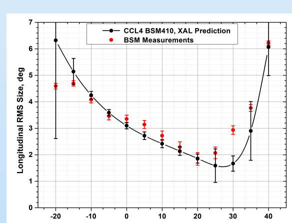
α	β [deg/MeV]	ε [MeV deg]
-0.5 ± 1.6	33 ± 86	0.7 ± 4.2

Phase scan

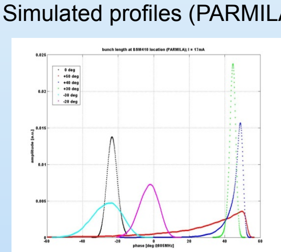


α	β [deg/MeV]	ε [MeV deg]
-0.56 ± 0.02	19.1 ± .5	0.8 ± 0.01

Comparison with BSM



Simulated profiles (PARMILA)



Measured profiles (BSM)