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Design and Development of Permanent Magnet Quadrupoles for Low Energy High Intensity Proton Accelerator

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Abstract : Bhabha Atomic Research Centre, Trombay is developing low energy high intensity Proton Accelerator (LEHIPA) as pre-injector for 1 GeV proton accelerator for accelerator driven sub-critical reactor system (ADSS). LEHIPA consists of RFQ (Radio Frequency Quadrupole) and DTL (Drift Tube Linac) as major accelerating structures. DTL is RF resonator operating in TM010 mode and provides longitudinal E-field for acceleration of charged particles. The RF design of drift tubes of DTL was carried out to maximize the shunt impedance; this demands the diameter of drift tubes (DTs) to be as low as possible. The width of the DT is however determined by the particle β and trade-off between a transit time factor and effective accelerating voltage in the DT gap. The array of Drift Tubes inside DTL shields the accelerating particle from decelerating RF phase and provides transverse focusing to the charged particles which otherwise tends to diverge due to Columbic repulsions and due to transverse e-field at entry of DTs. The magnetic lenses housed inside DTS controls the transverse emittance of the beam. Quadrupole magnets are preferred over solenoid magnets due to relative high focusing strength of former over later. The availability of small volume inside DTs for housing magnetic quadrupoles has motivated the usage of permanent magnet quadrupoles rather than Electromagnetic Quadrupoles (EMQ). This provides another advantage as joule heating is avoided which would have added thermal loaded in the continuous cycle accelerator. The beam dynamics requires uniformity of integral magnetic gradient to be better than ±0.5% with the nominal value of 2.05 tesla. The paper describes the magnetic design of the PMQ using Sm2Co17 rare earth permanent magnets. The paper discusses the results of five pre-series prototype fabrications and qualification of their prototype permanent magnet quadrupoles and a full scale DT developed with embedded PMQs. The paper discusses the magnetic pole design for optimizing integral Gdl uniformity and the value of higher order multipoles. A novel but simple method of tuning the integral Gdl is discussed.

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