

Beam Phase Measurement System in CSNS Linac

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Abstract

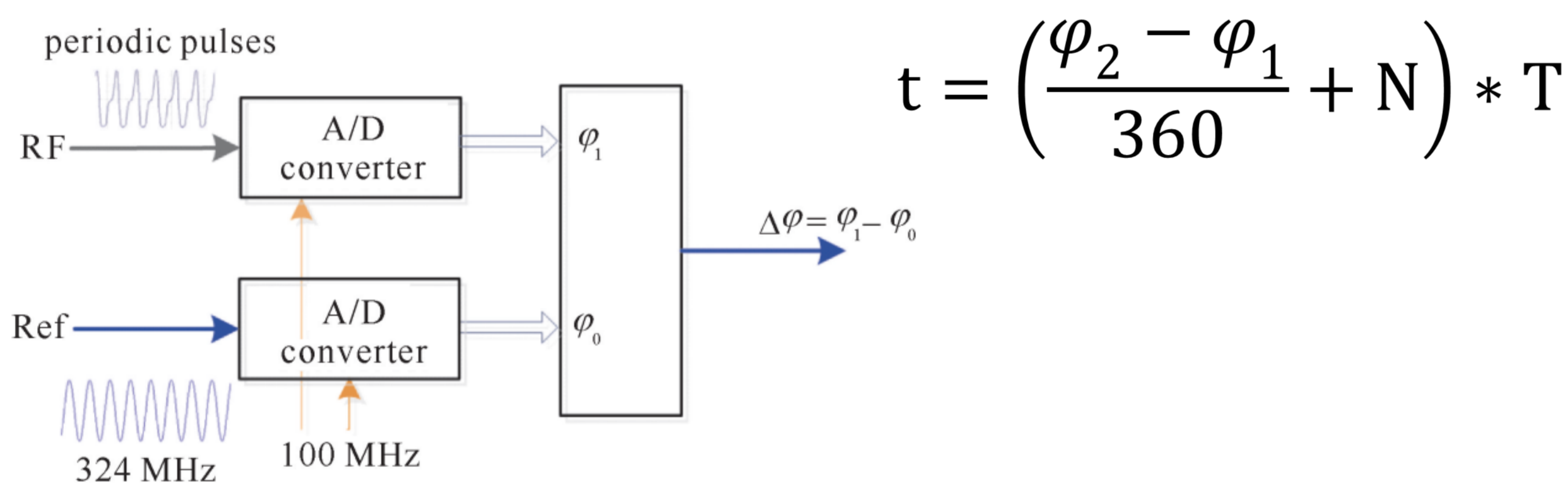
We developed beam phase measurement system ourselves in CSNS (China Spallation Neutron Source). The resolution of the system is less than 0.1° and the accuracy is better than 1° . It played a key role in CSNS Linac commissioning especially in RFQ and DTL commissioning. Further we measured the beam energy by TOF (Time of Flight) method base on this system. The energy accuracy is less than 0.1 MeV.

Introduction

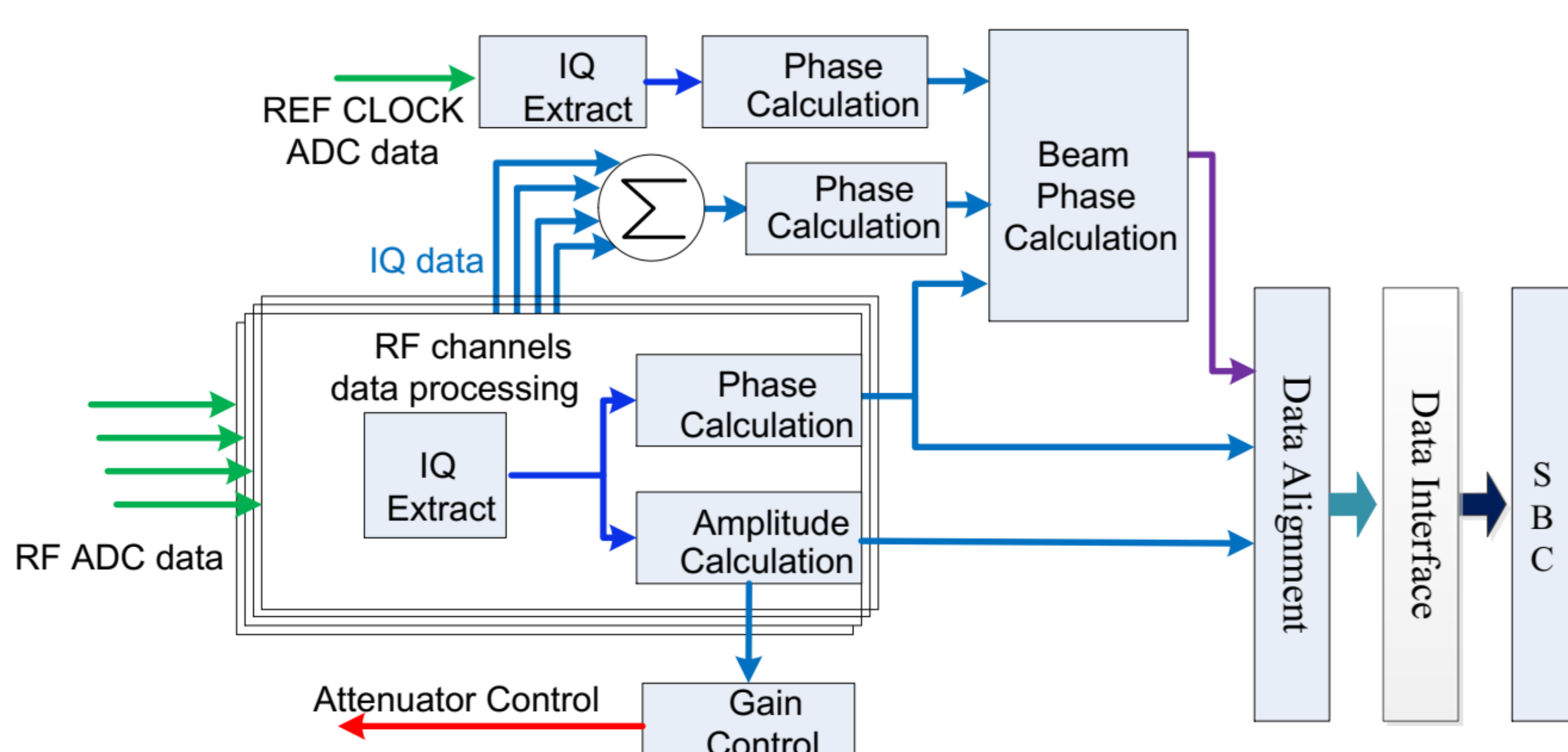
The repeat period of H- beam macro-pulse is 40ms and pulse width is about $500\mu s$. The radio frequency of beam is 324 MHz and the beam micro-pulse duty ratio is about 30%.

Beam Phase Measurement System

FCT sensors are used as beam phase detectors. The electronics are researched and developed by IHEP and CETC-38 together in China.

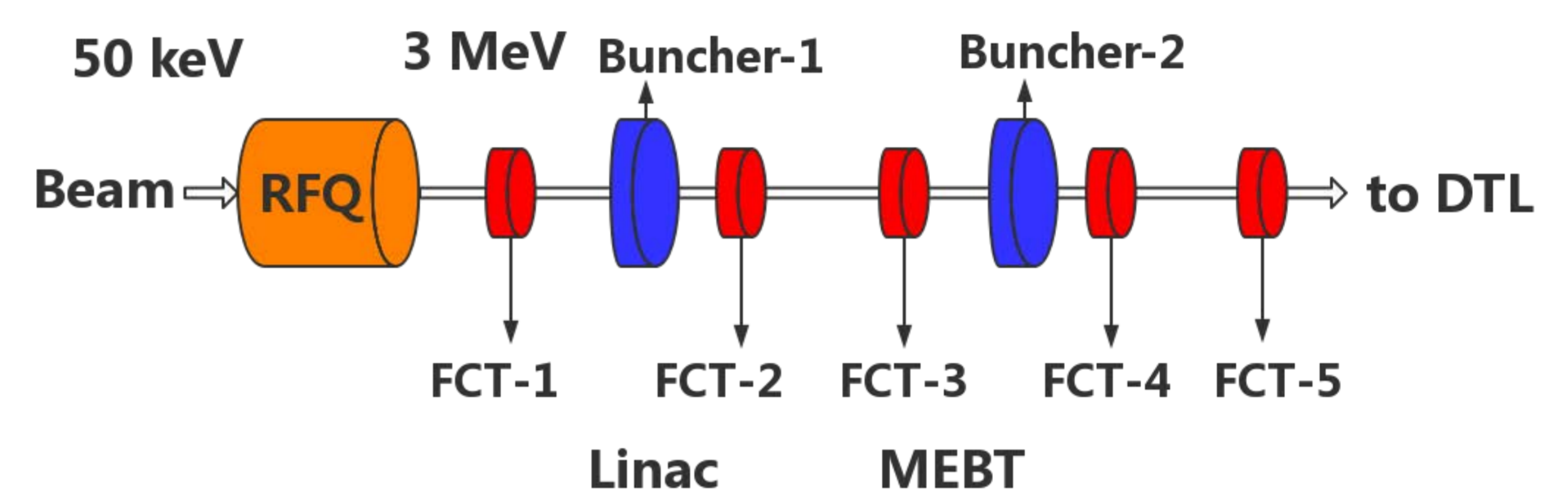


Sub-sampling technology has been adopted to realize the electronics. The ADC sample clock is just 100 MHz. Each channel's phase output is the difference between FCT output signal phase and a reference signal phase. The reference signal is a 324 MHz sine wave signal which from the same RF frequency source with beam. Non-coherent digital IQ demodulation technology and CORDIC algorithm are used for phase calculation in FPGA.

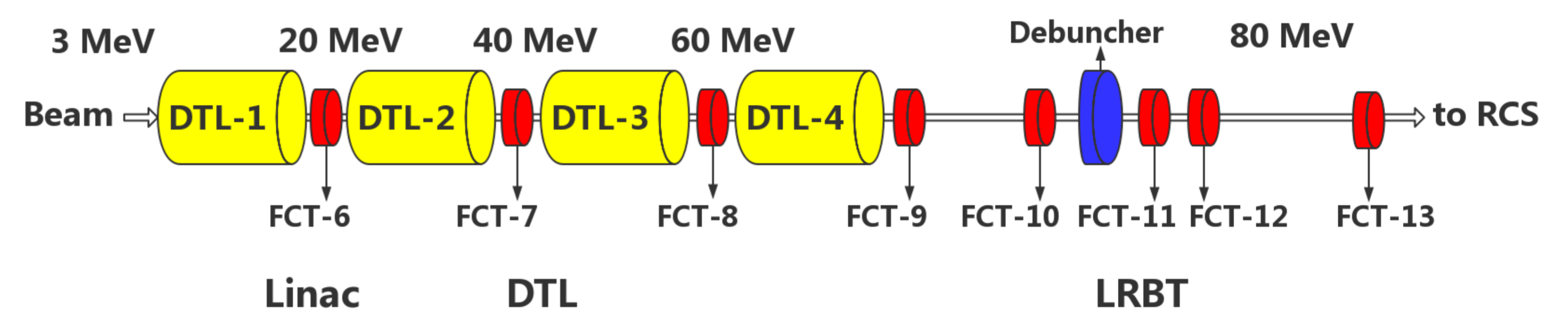


Beam Energy Measurement

There are 5 FCT sensors and 1 set electronics could be used to compute beam energy after beam pass through RFQ, Buncher-1, Buncher-2 in CSNS Linac MEBT.



And there are 8 FCT sensors and 1 set electronics be used to compute beam energy after beam pass through 4 DTL cavities and Debuncher.



T is the RF frequency of beam, here $T=1/324$ MHz, and the N is the period number estimated by the theory energy. We could adjust it manually in practice. So it is an indirect method to measure beam energy.

Any two FCT sensors could be calculated a energy number using formula left. We followed two principles:

- 1, each combination should be consistent with others. For example, N is 25 when you choose FCT-1 and FCT-2, N is 20 when you choose FCT-2 and FCT-3, therefore N only could be 45 when you choose FCT-1 and FCT-3.
- 2, The farther of distance between FCTs, the more accurate result you got. The result of FCT-1 and FCT-3 is more accurate than the result of FCT-1 and FCT-2.

Energy[MeV]	Theory	Measured	Deviation
RFQ	3.0258	3.0284	+0.08%
DTL-1	21.67	21.73	+0.28%
DTL-2	41.42	41.54	+0.29%
DTL-3	61.07	61.36	+0.47%
DTL-4	80.09	80.34	+0.31%

The energy measurement precision of the indirect method in TOF depends on the period number N. The resolution using our beam phase measurement is less than 0.01 MeV, the accuracy is about 0.02 MeV in any fixed combination, and the accuracy is 0.1 MeV after take all combinations into account.