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RE-ACCELERATION OF ULTRA COLD MUON IN J-PARC MLF*

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Abstract

The ultra cold muon beam by two-photon laser resonant ionization of muonium atoms is unique way to obtain very low emittance muon beam. Its muon source is a surface muon from the muon target in MLF where one percent proton beam from J-PARC RCS is reacted. In close collaboration with the Muon Science Establishment (MUSE) at Material and Life science experimental Facility (MLF) of the Japan Proton Accelerator Research Complex (J-PARC), we are developing the reacceleration system of the ultra cold muon beam. Its optimum accelerating structure is similar to a proton accelerator in low beta part and an electron accelerator in high beta part.

Further the muon bunch is only two bunch corresponding to the bunch structure of the J-PARC RCS. Thus we are testing the dielectric transmission line accelerator based on the photoconductive switch as the alternative acceleration method..

ULTRA COLD MUON IN J-PARC MLF

The surface muon of 4 MeV from proton target is once stopped at the muon target. The muonium is thermally emitted from the target and excited by the VUV laser. The ultra cold muon generated by this method has very low emittance and become the unique probe to the material science and the elementary particle physics.

Figure 1 shows the layout of the MUSE at MLF of J-PARC. The re-acceleration of the ultra cold muon is planned to install for two lines called as U-line and H-line of total four extraction lines.

The H-line will be used for some elementary particle physics experiments including the g-2 experiment which requires 200 MeV muon beam. The U-line is used for the material science. The muon microscopy with the muon re-acceleration is planned to install at U1B area.

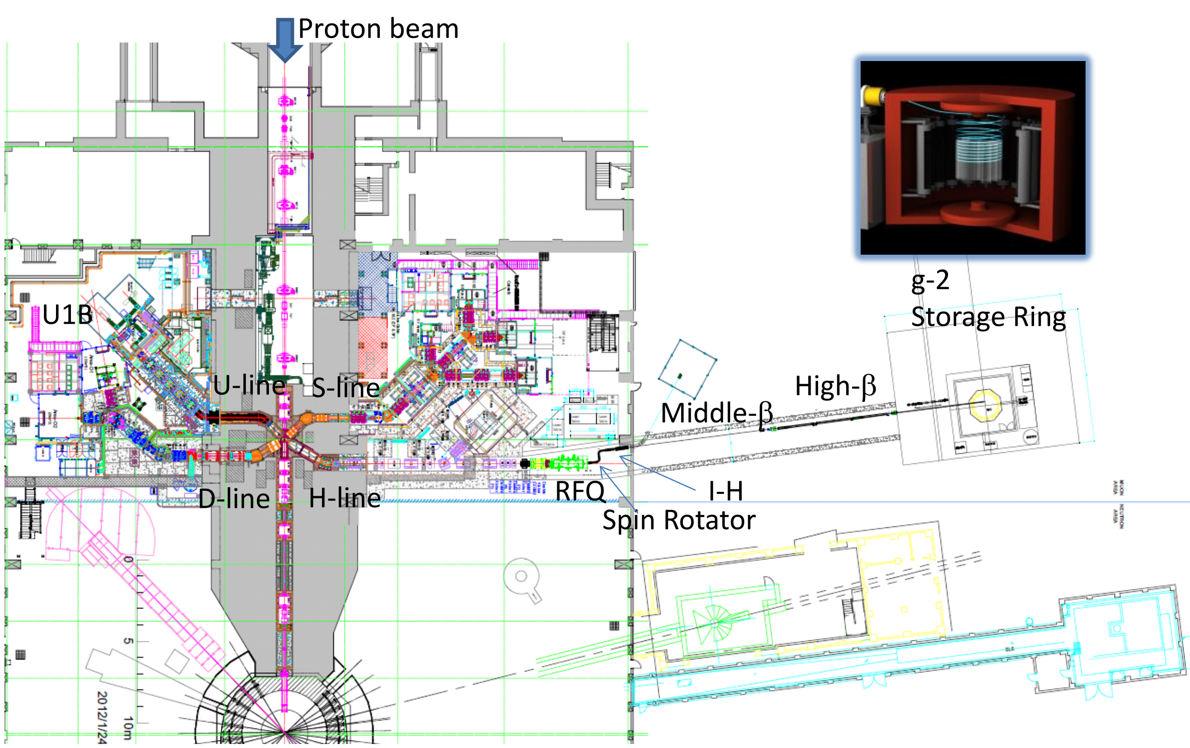

Figure 1: Layout of MUSE at MLF of J-PARC.

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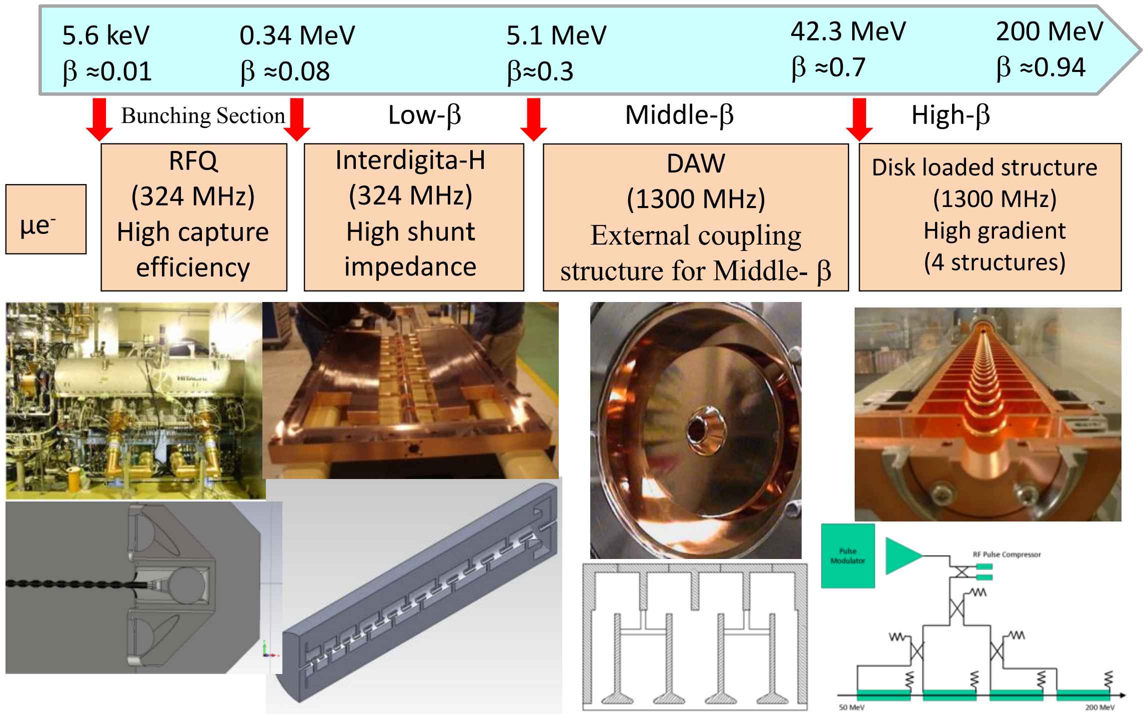

Figure 2: Accelerating system for re-acceleration at H-line for the g-2 experiment.

MUON RE-ACCELERATION AT H-LINE

The muon re-acceleration up to 200 MeV is required for the g-2 experiment at H-line. The LINAC is only way to shorten the total acceleration time within the muon lifetime. Figure 2 shows the plan for the muon re-acceleration LINAC. Those sections corresponding to the particle velocity are required to optimize each accelerating structure. The major constraints come from the existing RFQ and the available velocity region of the disk loaded structure for the high-β region. For the remaining sections, the accelerating structures for the proton accelerator like the J-PARC LINAC can apply. However the bunch duration of the muon beam is much shorter than the proton accelerator. Thus we adopt the accelerating structure which have higher shunt impedance like the I-H for the low-β and the DAW for the middle-β.

Initial Acceleration

The initial DC acceleration voltage of 5.68 keV is determined to fit the input energy of the existing RFQ. The initial bunch length is determined by the muonium excitation laser and the initial pulsed DC acceleration.

RFQ

The RFQ has the good transmission efficiency for the long bunch length of the muon beam caused by the initial acceleration. An existing J-PARC RFQ (RFQ II [1]), which is originally designed for H^- beam, is planned to use since it has the good transmission efficiency of 90 % [2] with 324 MHz bunching. The required power for the muon acceleration scaled from H^- beam is only 4.5 kW.

Low-β

Muon beam, which is pre-accelerated up to 300 keV with a RFQ linac, is boosted up to 3MeV with an Interdigital-Hdrift tube linac (I-H). The adoption of the IH realizes saving of the installation space of an accelerator and manufacturing cost since IH accelerator has higher shunt impedance rather than an Alvarez drift tube linac. We already designed and fabricated the test model of the muon IH accelerating structure [3].

Middle-β

The disk and washer (DAW) is one of the side-coupled linac. It has features in high stability, good vacuum properties and large coupling between cells. It also has high shunt impedance especially in middle-β section.

We adopt the the bi-periodic L-support DAW. The shape of the L-support can minimize the effect on the electric field of acceleration mode. The operation frequency is 1300 MHz since the power source is same as the high-β accelerating structure.

High-β

The disk-loaded traveling wave accelerating structure, which is similar to an electron LINAC, was selected for the high-β section to re-accelerate from 50 MeV to 200 MeV. The advantage is its high electric field of around 15 MV/m to shorten the accelerator length. The RF frequency of 1300 MHz is adequate for the wider phase space, where the klystron [4] and other waveguide components for this frequency band were already developed by the KEKB LINAC group.

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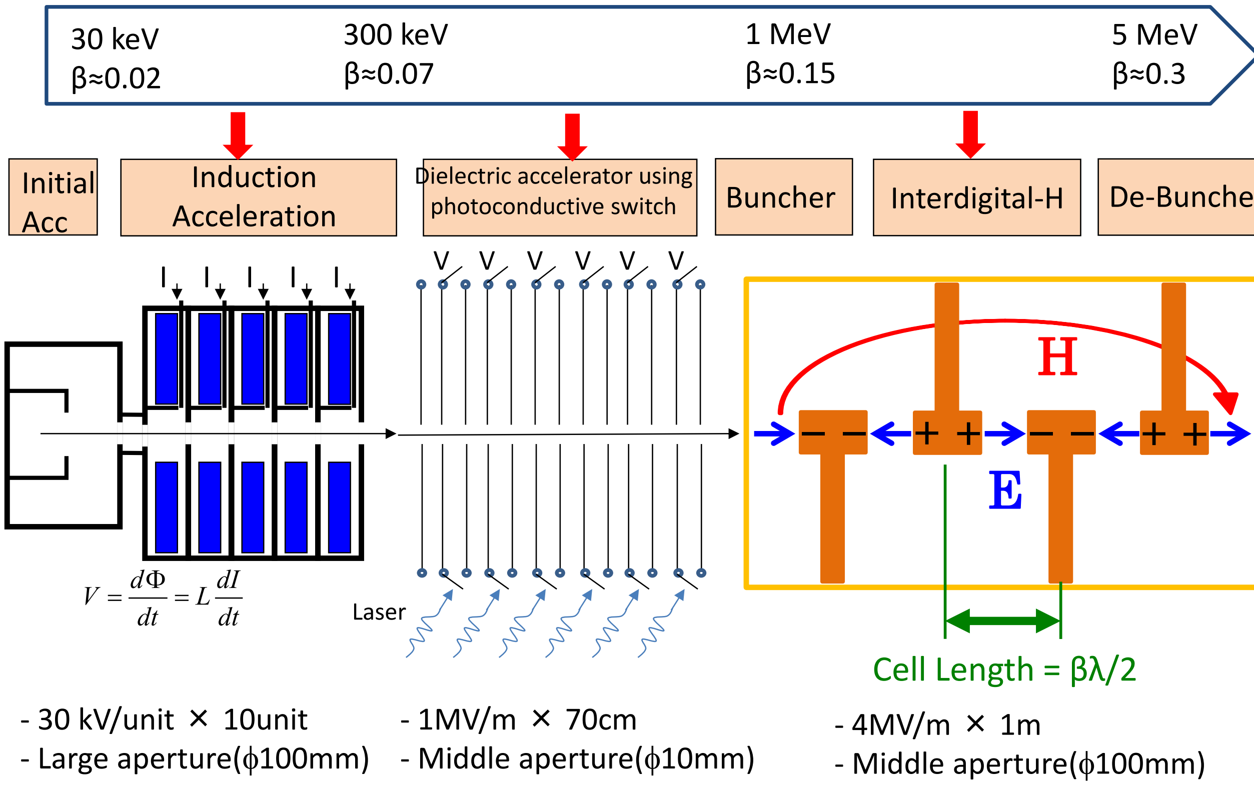

Figure 3: Accelerating system for the re-acceleration at U-line for the muon microscopy.

MUON RE-ACCELERATION AT U-LINE

The target of the re-acceleration at U-line is the muon microscopy. Figure 3 shows the accelerating system at U-line. The variation of the accelerating voltage is required under 1 MeV to probe the different material depth. Further the precise muon acceleration voltage of 5 MeV is required for the transmission microscopy.

Induction Acceleration

The initial DC acceleration voltage of 30 keV is maximum voltage at MUSE configuration. The induction acceleration using the FINEMET magnetic core, which has highest permeability at high frequency, is adopted to accelerate up to 300 keV since the variable voltage and the large aperture are required.

Photoconductive Switch Dielectric Accelerator

After the acceleration up to 300 keV, the beam size becomes smaller and the dielectric accelerator using photoconductive switch can be adopted. This accelerating method is newly developed and uses the Blumlein transmission line with the fast switch using the photoconductive switch irradiated by picosecond laser.

RF Acceleration

A buncher is required before the RF acceleration and another de-buncher is used to flatten the final energy. The same I-H acceleration structure as H-line is adopted.

CONCLUSION

The muon re-acceleration at H-line and U-line is ongoing for the g-2 experiment and the muon microscopy respectively. The accelerator design was almost completed and some important section was already fabricated and under experiment.

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