DESIGN OF THE 20MEV USER FACILITIES OF PROTON ENGINEERING FRONTIER PROJECT

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Abstract

The user facilities of PEFP (Proton Engineering Frontier Project) were designed. It is composed of two beam lines at the first stage and has possibility of expansion to five beam lines. One is low flux beam line for the technology developments in the fields of biological and space sciences and the other is high flux beam line for the utilization in the fields of nano and material sciences. The flux density is 1×10^{8}~1×10^{10} protons/cm^2-sec and 1×10^{10}~1×10^{13} protons/cm^2-sec each. The available energy range is 5~20MeV and the irradiation area is larger than 10cm in diameter with uniformity more than 90% for both. The specifications of these beam lines mentioned above were decided on the basis of result of user demand survey and operation experience of 45MeV proton beam test beam line installed at the MC-50 cyclotron of KIRAMS (Korea Institute of Radiological and Medical Science)[1]. The key components of these beam lines are bending magnets, magnetic quadrupole doublet or triplet, collimators, scanning magnets, target stage with water cooling system, degrader for energy control, scattering foils for flux control, etc. The beam optics was calculated using TRANSPORT, TRACE 3D and TURTLE simulation code.

RESULTS OF DEMAND SURVEY

The demand survey was performed during last 3 years to decide the specifications of the user facilities for the utilization of 20MeV proton beam [2]. Main application fields of 20MeV proton beam of PEFP are space technology, biological technology, medical science, semiconductor technology and nano technology, etc. The results are summarised as follows;

- Space technology
  - Flux density : 1×10^{8}~1×10^{10} protons/cm^2-sec
  - Maximum irradiation area : > 7cm in diameter
  - Irradiation uniformity : > 90%
- Biological and medical technology
  - Flux density : 1×10^{9}~1×10^{11} protons/cm^2-sec
  - Maximum irradiation area : > 30cm in diameter
  - Irradiation uniformity : > 80%
- Semiconductor technology and material Science
  - Flux density : 1×10^{11}~1×10^{13} protons/cm^2-sec
  - Maximum irradiation area : > 10cm in diameter
  - Irradiation uniformity : > 95%

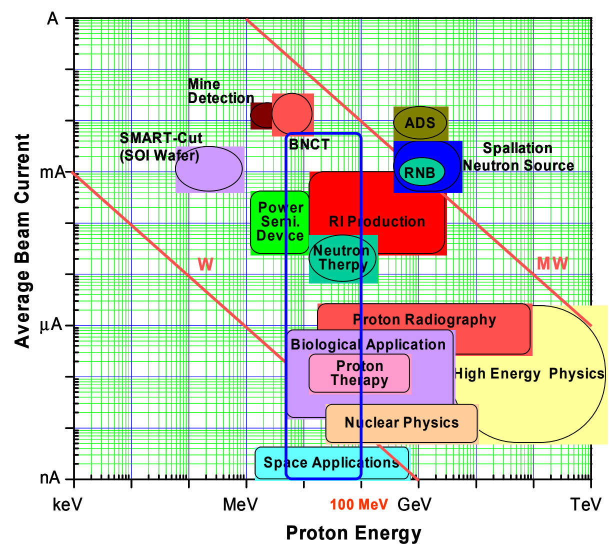


Figure 1: Proton beam application fields.

BEAM LINE COMPONENTS

TRANSPORT, TRACE 3D, and TURTLE code was used for the calculation of the beam optics to design the 20MeV beam lines. At the first time, 20MeV user facilities was composed of 2 beam lines, low flux one for the space and biological technologies and high flux one for the semiconductor technology and nuclear physics.

- Low flux beam line
  - Flux density : 1×10^{8}~1×10^{11} protons/cm^2-sec
  - Maximum irradiation area : > 40cm in diameter
- High flux beam line
  - Flux density : 1×10^{10}~1×10^{13} protons/cm^2-sec
  - Maximum irradiation area : > 10cm in diameter

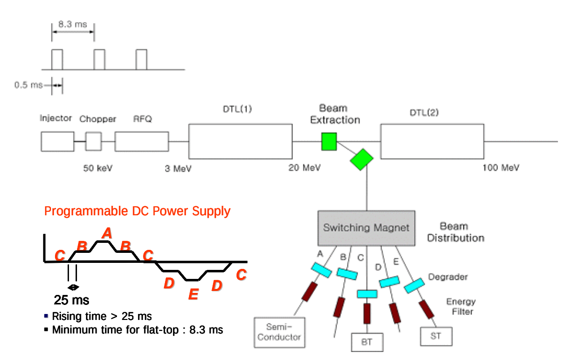


Figure 2: Beam distribution concept.

20MeV proton beam extracted from the accelerator is delivered to 5 beam lines using distribution magnet as shown in Figure 2.

Table 1: Specifications of beam distribution magnet

Bending angle	0^o, $\pm10^o$ & $\pm20^o$
Field integral	0.510 Tm
Magnetic field (10/20)	0/±0.23/±0.45 T
Effective Length	500 mm
Pole gap	50 mm
Switching frequency	2.5 Hz
Rise time	25 ms
Flattop time	> 8.3 ms

The layout of 20MeV proton beam user facilities and beam optics of low flux beam line is described in Figure 3 and Figure 4. In the case of the low flux beam line, the flux density has to be reduced to 1×10^8 ~ 1×10^{10} protons/cm^2-sec to satisfy users' demands. The set of magnetic quadrupole doublet and collimator will be used repeatedly. The maximum heat load at the surface of collimator is not exceeded 0.5kW/cm^2 and the specification of magnetic quadrupole designed by PAL(Pohang Light Source) is shown in Figure 5.

Beam Current	200 µA – 20 mA
Beam Energy	20 MeV & 100 MeV
Pulse Length	100 µs – 1.33 ms
Repetition Rate	1, 5, 15, 30, 60 Hz
# of Beamlines	Max. 5

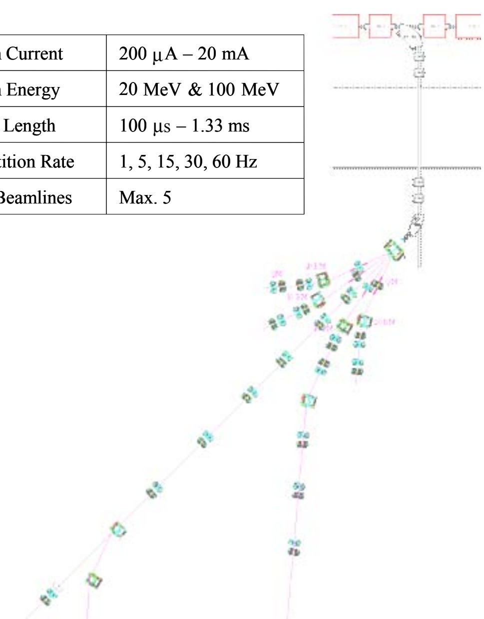


Figure 3: Layout of 20MeV proton beam user facilities.

The deliverable energy range was calculated using SRIM code for the case of using Al degraders to design 20MeV beam line, and the results are shown in Fig. 6. The energy spread is in the range of 15~28% for the 20MeV and 15~35% for the 100MeV. So if some users want to use monochromatic proton beam, the flux density is decreased less than 10%. The range of Al thickness is 0.05~2mm and 0.05~24mm for 20MeV and 100MeV proton beam.

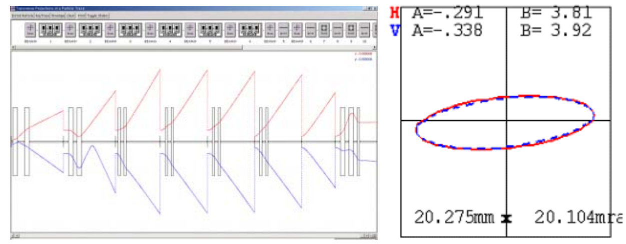
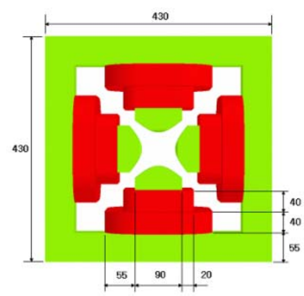


Figure 4: Beam optics of 20MeV low flux beam line.



Field gradient	10 T/m
Effective length	200 mm
Aperture diameter	65 mm
Multipole components	< 1e-3

Figure 5: Specifications of magnetic quadrupole.

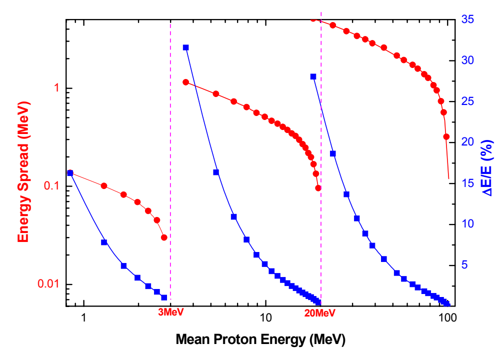


Figure 6: Deliverable proton beam energy range and the energy spread by Al energy degraders.

CONCLUSION

The conceptual design of the 20MeV proton beam user facilities of PEFP was carried out to satisfy the users' demands. The designed 20MeV low flux and high flux beam lines will be installed at the first time. And these beam lines will be very useful for the R&D of proton beam utilization technology in the fields of space and biological technology.

ACKNOWLEDGEMENT

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FUTURE PLAN

We will finish the detail design of the 2 kinds of 20MeV proton beam lines and develop some main components such as magnetic quadrupole, bending magnets, collimator, and scanning system. The prototype of these components will be manufactured and characterized by next year.

REFERENCES

[1] K. R. Kim, B. S. Park, H. R. Lee, K. S. Kang, S. W. Kang, and B. H. Choi, "50MeV Proton Beam Test Facility for Low Flux Beam Utilization Studies of PEFP", APAC 2004, GyeongJu, Korea, March 2004.

[2] K. R. Kim, H. R. Lee, B. S. Park, K. Y. Nam, and B. H. Choi, "Construction of User Facilities for the Proton Beam Utilization of PEFP", PAC 2003, Portland, USA, May 2003.