A MEBT Concept Based on Double Alpha Magnets for Project-X

M. Popovic and J.-F. Ostiguy

Abstract

This note describes a folded MEBT concept for Project-X. The optics is analogous to that of the ion stripping section used in the Fermilab PET Project [1]. The optics is also well-suited for a MEBT.

Introduction

The concept presented in this note is motivated by a desire to reduce costs for the first stage of ProjectX, nominally a 1 GeV H- linac. Assuming a new linac sited as an extension of the existing 400 MeV linac, a 15% reduction in tunnel length could be achieved. Furthermore, it would eliminate the need for expensive buncher cavity(ies) and associated RF hardware.

The proposed "folded" MEBT consists of two 270 deg combined function dipoles and five quadrupoles. It can satisfy the requirements stated in A. Shemyakin's recent presentation [2] on the current baseline linear, magnetically focused MEBT.

MEBT

Figure 1a shows a Trace3D simulation of the folded MEBT. Figure 1b is a corresponding sketch of the entire layout showing the two alpha (combined function) magnets and the 5 quadrupoles.

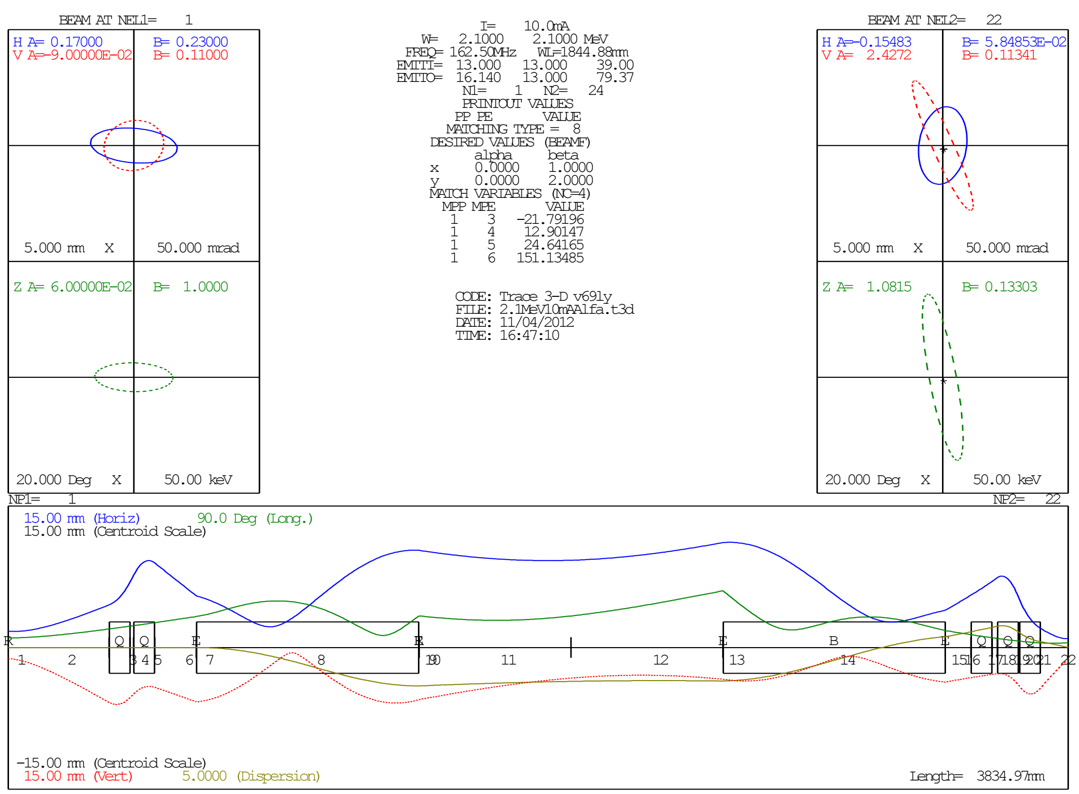


Figure 1a. Trace3D simulation of the folded MEBT.

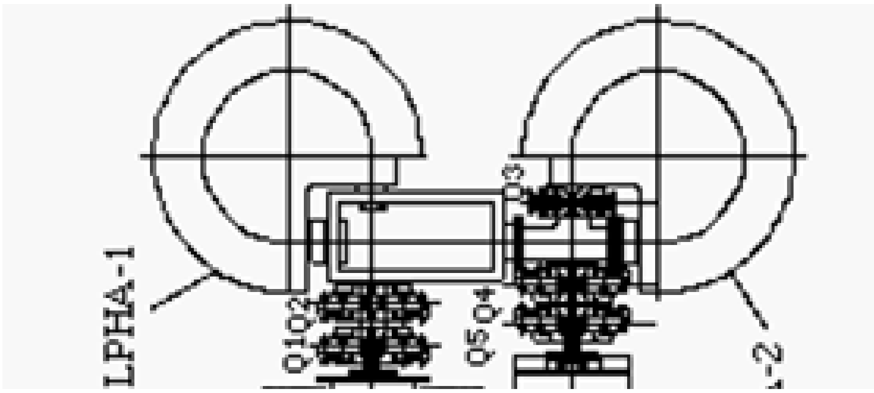


Figure 1b. Mechanical drawing showing real configuration of two Alpha magnets and matching quadrupoles.

The input beam, assumed to be emerging from the 162.5 MHz RFQ, has the parameters presented in Table 1.

Parameter	X	Y	Z(RFdegree-keV)
Emittance Un(95%, mm-mrad)	13	13	39.0 (normalized)
alpha	0.17	-0.09	0.06
Beta(mm/mrad)	0.23	0.11	1.0 (deg/keV)

Table1. Input beam parameters.

Upstream of the first 270 deg bend, drift space available on both sides of the matching quad doublet can accommodate a fast kicker and an absorber. In this region, the vertical beam size (95%) is less than 12 mm comfortably within the kicker aperture (16mm gap).

Downstream of the matching doublet, the beam is transported through two 270 deg combined function dipoles. These dipoles provide focusing in both transverse planes; in addition they provide net longitudinal focusing through dispersion.

The first dipole has its entrance pole face rotated by 25 degrees and a field gradient index of 0.54. The exit angle is -2.7 degrees. The second dipole is a mirror image of the first one, with the position of entrance and exit faces inverted. The dipole field in both magnets is ~ 1.2 T with bend radius of 0.17m.

The drift space (~1.1 meter) between the two dipoles can accommodate a second fast kicker and beam absorber and could be made longer if needed. In this region, the maximum vertical beam size is 12 mm.

Upon exiting the second 270 deg bend, the beam enters a third region containing three quadrupoles and a drift space to allow matching to the downstream accelerating structure. All magnetic elements are warm and normal conducting, running in DC mode.

Kickers and Bunch Selection

As outlined in reference [2], the Project-X MEBT goals are as follows:

- Form the bunch structure required for the linac
- Bunch-by-bunch selection
- Match optical functions between the RFQ and SRF
- Measure the properties of the beam emerging from the RFQ
- Clean the transverse particle halo

Bunch-by bunch selection is the most challenging requirement. Fast kickers coupled with absorbers of sufficient capacity are needed. In this design, two kicker-absorber pairs are employed, as shown in Figure 2.

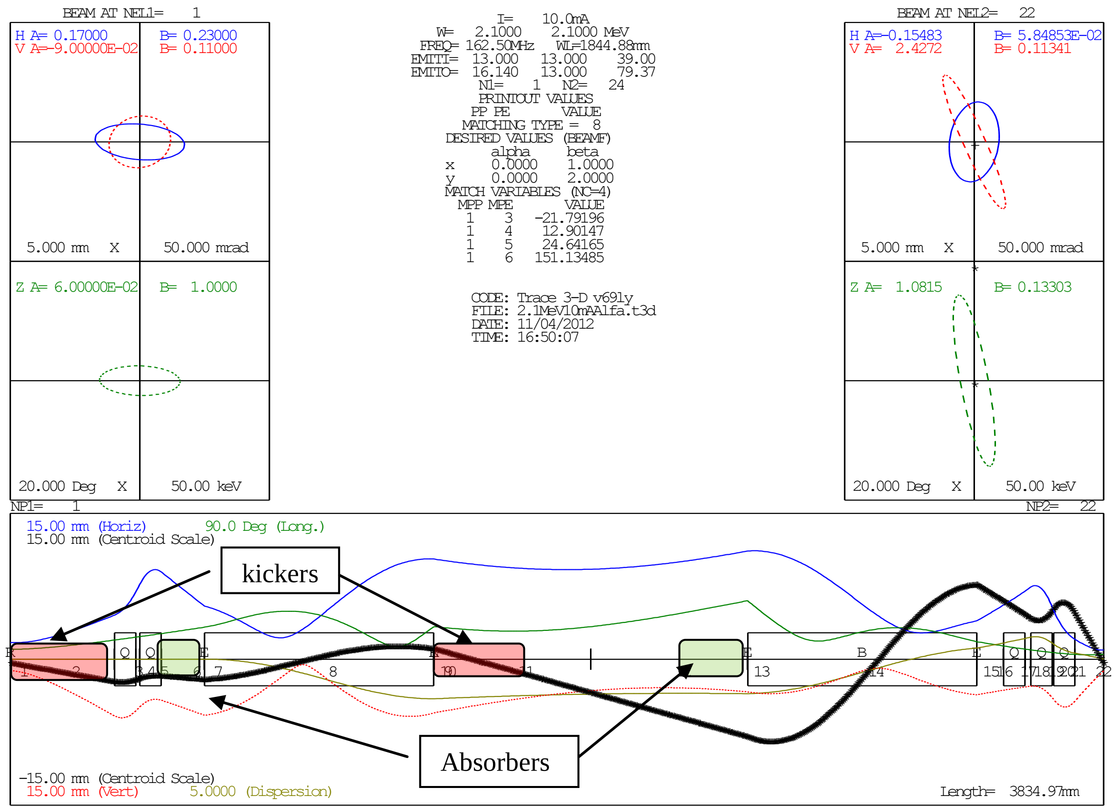


Figure 2. Heavy line is the beam centroid in the vertical plane. The red boxes are kickers; the green ones are absorbers.

We assume that the kickers and absorbers would be as designed for the baseline linear MEBT. Each kicker is ~50 cm long and has a 16 mm gap. We assume that they can operate at +/- 400V per plate, producing a 6 mrad kick. The first kicker deflects approximately 25% of the beam on the first absorber. The rest of the beam is removed using a second kicker absorber pair downstream of the first dipole bend . Given the size and mass of the bending magnets, they should be able to handle a small amount of residual kicked beam not intercepted by the absorbers.

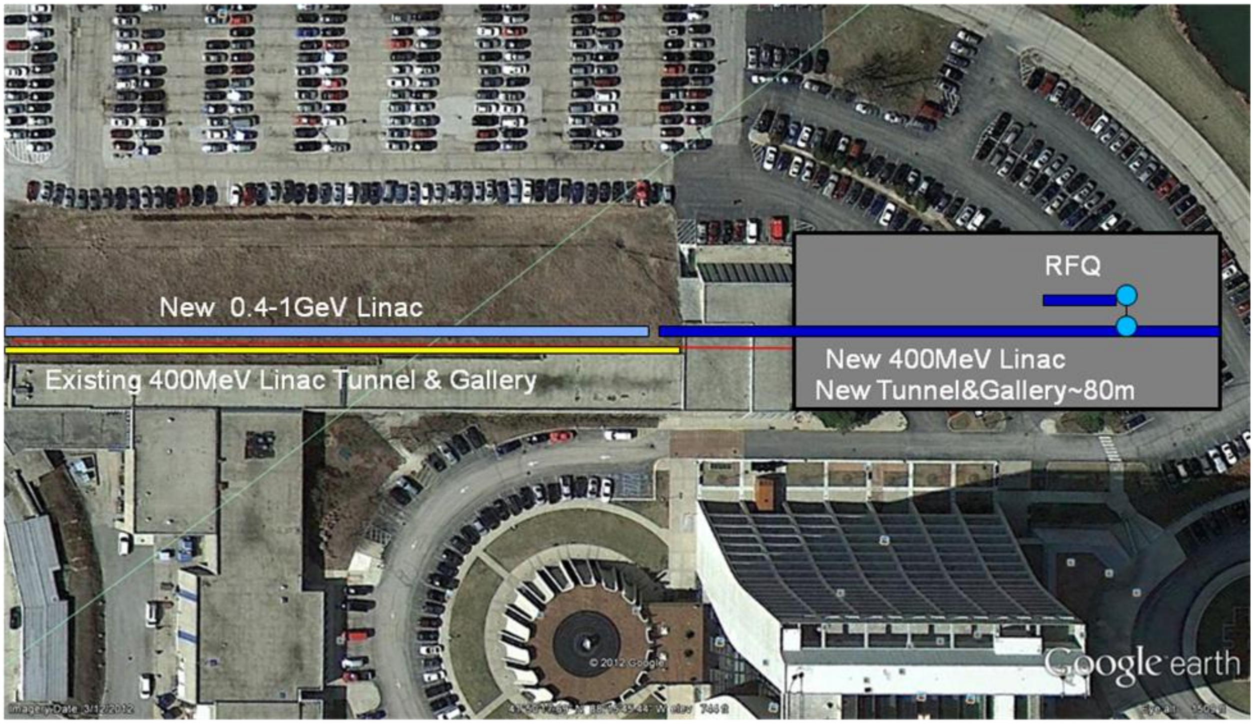
The optics of the folded MEBT is somewhat dependent on bunch charge. While adjusting the strengths of the quadrupoles is a straightforward matter, it may be necessary to adjust the face angles of the 270 deg bends. For this reason, it is envisioned that these magnets should be equipped with removable end-packs.

Conclusions

A folded MEBT concept, based on double alpha magnets has been presented. The optics was successfully used for the PET Project [1] and would satisfy the requirements for ProjectX [2]. In comparison with the current baseline linear MEBT the quadrupole count is reduced from 25 to 5, no expensive CW RF bunchers and rf stations are required, and the tunnel length is reduced by approximately 15 m. All these factors should result in significant front end cost reductions. Figure 3 illustrates how a folded MEBT efficiently uses the available longitudinal space, potentially reducing construction costs by 15%.

It is worth mentioning that the magnet fabrication costs for the PET projects are known. In 1996 dollars, the cost for 2 magnets was 74 K and the power supply cost was 2.5 K. Since then, overall inflation was on the order of 50%. While this may be an underestimation in this specific case, it is unlikely to exceed 200%.

In closing, we note that the MEBT technical challenges are driven by the adopted 162.5 MHz bunch structure. Lowering the bunch frequency to 81 MHz would significantly simplify problems with bunch selection. Using laser neutralization of H-, it might even be possible to eliminate the need for a MEBT. These topics are beyond the scope this note.



M. Popovic

Figure 3. To save on civil construction and avoid any significant down time, new 80 meter tunnel is proposed to be built as extension of the present LINAC tunnel. The new tunnel will house new 400 MeV linac that will be part of new 1 GeV linac.

References

1. PET Project, http://www-linac.fnal.gov/pet/papers/
2. Shemyakin, Presentation at ProjectX collaboration Meeting, April 2012 http://projectx-docdb.fnal.gov/cgi-bin/RetrieveFile?docid=1020;filename=2012_04_10_CollabMeeting_MEBT_2.pdf;version=2

Appendix

For completeness we have included Trace3D input file that was used in this note and the sketch of PET Accelerator.

```
&DATA
 ER=   939.30000  Q= 1.0000  W=     2.10000  XI=     10.000
 EMITI =     13.000000     13.000000     39.000000
 BEAMI =       0.17000       0.23000      -0.09000       0.11000       0.06000       1.00000
 BEAMF =       0.00000       1.00000       0.00000       2.00000       0.00000       2.50000
 BEAMCI=       0.00000       0.00000       0.00000       0.00000       0.00000       0.00000
 FREQ=   162.500  PQEXT=  2.50  ICHROM= 0  IBS= 0  XC=  15.0000
 XM=   5.0000  XPM=  50.0000  YM=  15.00  DPM=  20.00  DWM=    50.00  DPP=  90.00
 DISPR=   5.0000 BETAX=   0.00 BETAY   0.00
 XMI=   5.0000  XPMI=  50.0000  XMF=   5.0000  XPMF=  50.0000
 DPMI=  20.0000  DPMF=  20.0000  DWMI=  50.0000  DWMF=  50.0000
 N1=    1  N2=   24  SMAX=   5.0  PQSMAX=   2.5  NEL1=    1   NEL2=   22   NP1=    1   NP2=   22
```

```
MT=  8  NC= 4  IPLANE= 0 0 0  MP=1,00003 1,00004 1,00005 1,00006 1,00009 1,00010
 MVC=0,00000, 0 0,00000, 0 0,00000, 0 0,00000, 0 0,00000, 0 0,00000, 0
VAL=     0.0000000     0.0000000     0.0000000     0.0000000     0.0000000     0.0000000
CMT(001)='        ' NT(001)=   15  A(1,001)=0.30000000      2.0000000      0.0000000      0.0000000
CMT(002)='        ' NT(002)=    1  A(1,002)= 364.72000
CMT(003)='        ' NT(003)=    3  A(1,003)=-21.791964      76.200000      0.0000000      0.0000000      0.0000000
CMT(004)='        ' NT(004)=    1  A(1,004)= 12.901467
CMT(005)='        ' NT(005)=    3  A(1,005)= 24.641653      76.200000      0.0000000      0.0000000      0.0000000
CMT(006)='        ' NT(006)=    1  A(1,006)= 151.13485
CMT(007)='        ' NT(007)=    9  A(1,007)= 25.000000      170.80000      16.000000      0.0000000      0.0000000
CMT(008)='        ' NT(008)=    8  A(1,008)= 270.00000      170.80000      0.54000000      0.0000000
CMT(009)='        ' NT(009)=    9  A(1,009)=-2.7000000      170.80000      16.000000      0.0000000      0.0000000
CMT(010)='        ' NT(010)=   15  A(1,010)=0.30000000      2.0000000      0.0000000      0.0000000
CMT(011)='        ' NT(011)=    1  A(1,011)= 550.00000
CMT(012)='        ' NT(012)=   16  A(1,012)= 11.000000
CMT(013)='        ' NT(013)=   16  A(1,013)= 9.0000000
CMT(014)='        ' NT(014)=   16  A(1,014)= 8.0000000
CMT(015)='        ' NT(015)=   16  A(1,015)= 7.0000000
CMT(016)='        ' NT(016)=    1  A(1,016)= 92.394960
CMT(017)='        ' NT(017)=    3  A(1,017)=-.68699251      76.200000      0.0000000      0.0000000      0.0000000
CMT(018)='        ' NT(018)=    1  A(1,018)= 20.000000
CMT(019)='        ' NT(019)=    3  A(1,019)= 36.170429      76.200000      0.0000000      0.0000000      0.0000000
CMT(020)='        ' NT(020)=    1  A(1,020)= 3.0630623
CMT(021)='        ' NT(021)=    3  A(1,021)=-43.071448      76.200000      0.0000000      0.0000000      0.0000000
CMT(022)='        ' NT(022)=    1  A(1,022)= 100.00000
WS(1)=   0.00000    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
WS(8)=   0.00000    0.00000    0.00000    0.00000    0.00000    0.00000    0.00000
SIGI(1,1)= 2.990000     -2.210000      0.000000      0.000000      0.000000      0.000000
SIGI(1,2)=-2.210000      58.15522      0.000000      0.000000      0.000000      0.000000
SIGI(1,3)= 0.000000      0.000000      1.430000      1.170000      0.000000      0.000000
SIGI(1,4)= 0.000000      0.000000      1.170000      119.1391      0.000000      0.000000
SIGI(1,5)= 0.000000      0.000000      0.000000      0.000000      4.564411      0.1908145
SIGI(1,6)= 0.000000      0.000000      0.000000      0.000000      0.1908145     2.223801
COMENT='                                        '
&END
```

---------------------------The End --

PET ACCELERATOR