Status of Low-Energy Linac Lattice Update

Valery Kapin

13-Feb-2013

PIP General Meeting
Contents

• Review previous talks:
  - D.McGinnis(2011); - H.J.Kim(Jan-2012)
• New restart in Oct-2012 by VK
• Optics reconstruction for accelerator model
• SNS: XAL(Java) online models
• PARMILA new vs old versions
• A new configuration for on/off-line modeling
• Overview FNAL DTL lattices
• FNAL & BNL designs – history
• New lattice based on MM68 data is well agree with BNL 1990 lattice and all published design specifications
• Questions on intertank distances and quad strength
• About on-line modeling DTL’s pre-injector (4-rod RFQ)
Goal

• Make an on-line lattice model of the Linac

Requirements

➢ Handle space charge
➢ Handle scraping
➢ Handle drift tubes and side coupled cavity structures
➢ Connect to ACNET
➢ Reasonable simulation time
➢ Straightforward interface

Decision

• Use a tracking program instead of an envelope code

• Parmila - simulation “engine”

• Advantages
  ➢ Mature program
  ➢ Used to design Fermilab Linac => it can handle FNAL Linac

• Disadvantages
  ➢ Old program
  ➢ Horrible user interface

My (VK) comments:
agree ; doubtful

“Model is useless unless it can be verified with real data”

Parmila input files are hard to work with
=> XML Interface:
  o Easy to understand
  o connection to online database

Future Work:
  ◆ Get working model of Tank 1
  Something wrong with the lattice?
  Emittance probe ? Tank 1?

Future-Future Work (Tank1):
  ◆ optimum position & angle into & out
  ◆ optimum phase-space
  ◆ develop “lattice based” operations
    (set positions & quads)
  ◆ Understand Tank 1 Phase Scan

Future-Future-Future Work:
  ◆ Get & verify on-line model of Linac
  ◆ “Lattice based” operations for entire linac
  ◆ Revisit phase-scans for gradient settings
H.J.Kim, Status of Linac Lattice Study, 11-Jan-2012, Beams-doc-4042-v3

Chronological overview
• Until June 2011: D.McGinnis manages linac lattice study.
• Oct. 1, 2011: Kim takes over Dave’s job:
  - a Linac instrumentation list
  - Linac DTL & SC specifications.
  - Build LE energy linac lattice (750keV & Tank1 by Dave).
  - Build HE linac lattice
  - Upgrade Dave’s Java code
  - beam measurements & compare them with simulation

Parmila is tracking tool:
• Parmila is a mature program and used to design Fermilab linac.

Parmila input of Tank 1-5 is based on Milorad’s work [Fermilab-TM-2245].
New restart in Oct-2012 for “Update Linac code in Parmila & Trace Win to match actual measurements” by V.Kapin

V.Kapin got a duty for the above subject:
6 months term with duty 0.25-FTLs
(officially 1st Oct 2012 - 31st March 2013)

Preliminary task formulations:
• Make off-line simulations for FNAL linac with predictions verified with real beam data
• understand why PARMILA does not reproduce experiments, e.g., transmission drop in DTL1 at specific lattice parameters.
• Prepare fitting procedures based on measurements of difference orbits (linear optics reconstruction)

Accompanying difficulties:
• I never met either McGinnis or Kim => the only info are their talk slides
• The single source of info – Fernanda, who is not involved in all details
• Although I am familiar with LE ion linac design, I never did a fitting for a working linac (only some coding for “optic-reconstruction” in Tevatron with Y.Alexahin)
Review of available information

Main subjects:

- general review of optics reconstruction for transport lines and linacs
- how optics reconstruction done in other existing linacs (e.g. high intensity SNS linac, Oak-Ridge):
  - tracking codes used
  - fitting procedures details and results
- review of PARMILA code history and versions
- revision of existing DTL linac lattice:
  - reviews of old publications at the time of (F)NAL-Linac creation
  - lattice history (Kim->McGinnis->Milorad->…)
**Optics reconstruction for accelerator model**

Optics reconstruction (or accelerator model calibration) via Response Matrix Method (also Kim’s note on diff. orbits):

- Systematic method to calibrate accelerator model
- The basic idea to minimize the difference between measured and calculated (from model).
- BPM responses to changes in steering magnet strengths by adjusting various model parameters (as strengths of dipole correctors and quadrupoles), and BPM gains.
- It has been used for transport lines and electron linacs

\[
\chi^2 = \sum_{i,j} \left[ R_{i,j}^{\text{meas}} - R_{i,j}^{\text{model}}(\xi_1, \xi_2, \ldots) \right]^2 / \sigma_{i,\text{BPM}}^2
\]

Where \(i\) for BPMs and \(j\) for steering magnets (~quad misalignments), \(\xi\) are model parameters to be adjusted for the minimization.

V.Kapin, PIP meeting, Feb-2013
Optics reconstruction (continued)

DTL is the chain of Quads (57&61 in DTL1&2) & RF gaps (56&60) featured by energy variations and high space charge forces; It can not be simulated by matrices (as in Kim’s note on diff. orbits); Some linac code with space-charge should be used (Parmila?)

We do not know exact design specifications for FNAL linac; => Tolerances for all elements and their strength are potentially unknown model parameters (~hundreds); =>Total number of model parameters is huge, and only 1 BPM exist at the exit of DTL1+DTL2 chain.

To my knowledge this kind of method had never been used for DTL’s to calibrate DT (Quad) positions and Quad and RF gap strengths, which are well known as design parameters with small tolerances (~50mkm).

Specific situation of old FNAL linac – possible degradation of DT(Quad) alignments, tank field distributions and quads parameters.

It is important to restore an original design parameters of DTL lattice. It will drastically reduce number of unknown model parameters.
on-line model in other linac labs (e.g. SNS linac )

Review of papers (e.g. Shishlo, HB2010) about on-line modeling of SNS (ORNL) high intensity linac:  
PARMILA (modern version >1998) is not used for on-line models!

| XAL (~2002) online model | both envelope & single part. tracking.  
Algorithms - borrowed from TRACE 3-D (sp.-ch) & PARMILA (RF gaps). |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TRACE 3-D tracks the envelopes</td>
<td>Linear sp-ch; used at early stages of SNS-project</td>
</tr>
</tbody>
</table>
| PARMILA (ver.2 LANL ~200x) | Used at design stage of SNS linac  
Now used occasionally: online beam matching & offline analysis |
| TRACK – full 3D field maps | for benchmarking with other codes |

A simulation of **the center of the bunch**: **All of the codes** mentioned above can do this **except PARMILA which do not have dipole corrector elements**, and therefore cannot be used for orbit analysis and corrections.

V.Kapin, PIP meeting, Feb-2013
XAL (~2002) online model at SNS linac

• SNS-people use a specially written in 2001-2002 tracking code called as "on-line model XAL" which is based on algorithms taken from PARMILA & TRACE-3D and implemented as Java code.
• They also created special modeling libraries during several years for every particular on-line modeling task.
• Some tasks has no a good “model & measurements” agreements
• Whole (end-to-end) linac modeling is not realistic task! Only by parts!
• There is a Web-page where they announce a devoted workshops for usage of their libraries. => it simply means that usage and adaptations of their libraries require a considerable efforts!

Particularly, SNS-people uses a tracking program with available source code (Java). It simplifes the linac modeling and optimization fittings. Might be an old PARMILA version with source code is a solution?
PARMILA versions

G.P. Boicourt: PARMILA overview, 1988 Workshop at San Diego:

PARMILA, in its original form, was written by Don Swenson at MURA about 1963. It was brought to Los Alamos by him about 1964.

**VERSIONS** PARMILA has been distributed worldwide over the course of time, and it is likely that the code has experienced many modifications producing many versions. This paper describes the Los Alamos Group AT-6 version. The closest other version, Los Alamos Group AT-1, was the source of the AT-6 version in 1979. While developing the AT-6 version, there was a strong attempt to preserve the modeling of the AT-1 version, but not the coding.

Distributed as PARMILA.exe: “http://laacg1.lanl.gov/laacg/services/services.phtml”
(c) Copyright, 1984-2005 by the Regents of the University of California.

So, any old PARMILA originated from < 1983 are out of the copyright!

It should be realized that the LAACG PARMILA-2 written in FORTRAN-90 is actually a new different code based on the original code PARMILA (FORTRAN-IV). XAL(Java) based on Parmila’s algorithms has a similar relation to old PARMILA!
Relevant details of PARMILA structure

PARMILA works in two steps:
1. DT cell-by-cell generation via iteration procedures:
   a) GENLIN with the COFT-input: TTFs as a quartic polynomials in $\beta_g$ (only in old versions);
   b) GENLIN2 with SFDATA-input: TTF values for a given $\beta_g$ interpolated for current $\beta$-value
2. Particle tracking in generated structure:
   particle coordinates transformed throughout the cells using the interpolated input TTFs.

Alvarez linac (DTL) is a series of linac cells; MESSYMESH “MM” (later SUPERFISH) calculates e/m parameters of the linac cell, output RF-field TTFs: $T$, $T'$, $S$, $S'$, e.g.

$$T = \frac{1}{E_0 L} \int_{-L/2}^{L/2} E(z) \cos \frac{2\pi z}{L} dz,$$

where $E_0 = \frac{1}{L} \int_{-L/2}^{L/2} E(z) dz$

BTW, if wrong TTFs: OK - for 1, bad - for 2

"Linear Accelerators" ed by P.M. Lapostolle & A.L. Septier, 1970 ("Red linacs bible")

C.I.2b A.CARNE ET AL. NUMERICAL METHODS. ACCELERATION BY A GAP 771 single-step transformation with TTFs ("1") vs. multi-step Runge-Kutta integrator it is worthwhile to compare the single integration per gap description suggested in this chapter with the alternative method of multiple step integration of the basic equations of particle motion. The disadvantages of this second method are two-fold: firstly, it is necessary to store large quantities of field coefficients, secondly it is time consuming because of large numbers of integration steps per cell.
Old PARMILA vs PARMILA-2

Modern PARMILA-2 code:
• is basically design code for a NEW linac, allowing its theoretical analysis with random (not regular!) Q-errors and misalignments
• there is no options to use steering magnets (or Q-misalignments) in long DTLs.
• it outputs parameters of total beam for a fixed set of plots
• even a simple table with particle tracks is not available.
• it is *.exe-file and can not be modified at all.

My conclusion (agreed with SNS strategy):
PARMILA-2 can not be effectively used for fitting of the DTL linac model

Old PARMILA-1 versions:
some useful features of original PARMILA had been removed in 1980-x, e.g., steering magnets in drift-tube quadrupoles & quadrupole misalignments

I am considering an alternative possibility to use an old version of PARMILA, which still has both steering dipole magnets in drift-tubes and Q-misalignments.
A new configuration for on/off-line modeling

TraceWin as possible alternative:
- A wide range elements,
- static and dynamic error simulations for all elements,
- 1D, 2D, 3D static and dynamic fields map (with superposition capability),
- envelope and macro-particle tracking simulations,
- automatic transverse and longitudinal beam tuning,
- simple correction procedure based on diagnostics

Other approach: TracWin.exe driven by external fitting code (CPU-time - huge ?)
Available linac lattices for FNAL DTL by 2013

<table>
<thead>
<tr>
<th>Name</th>
<th>File - name</th>
<th>Origin</th>
<th>Parm ver.</th>
<th>TTFs</th>
<th>Comments</th>
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<td>FG01</td>
<td>parmilaWholeLinac.lin</td>
<td>J.Stovall (LANL) -&gt; MP(2004) -&gt; D.MG-&gt;Kim -&gt; FG</td>
<td>2.35, 2005</td>
<td>SFDATA mixture MM, and non-MM, MPxls (dtl5); Bugs!: TP=S(dtl2); TP&lt;-&gt;(dtl5)</td>
<td>DTL1_Tr82%</td>
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<td>DTL1_Tr40% Diff. Q-grads</td>
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<td>MP01</td>
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<td>from MP comp. MP -&gt; VK</td>
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<td>Constructed by M. Popovic, 8-Nov-03</td>
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<td></td>
<td></td>
<td></td>
<td>SFDATA Mixture MM, MPxls</td>
<td>(Bug TP beta=0.1465)</td>
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<td>MP01a</td>
<td>Tank1 Linac.txt</td>
<td>New Parmila on PC ~2004</td>
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<td>MP02</td>
<td>Hi-dtl.txt</td>
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<td>2.33, 2004</td>
<td></td>
<td></td>
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<td>MPrep</td>
<td>Fermilab-TM-2245</td>
<td>Published copy</td>
<td></td>
<td>COFT=&gt;SFDATA</td>
<td>Bug!: the same COFT tables Tank1-a, Tank2-5</td>
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<td>MPxls</td>
<td>sfdatat1.xls</td>
<td>from MP comp. MP -&gt; VK</td>
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<td>COFT=&gt;SFDATA</td>
<td>Converting coft=&gt;sfdata for “MPrep”</td>
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<td>from MP comp. MP -&gt; VK</td>
<td>“vax-version”</td>
<td>COFT differ from MPrep</td>
<td>Actually UNIX-version</td>
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</tbody>
</table>

V.Kapin, PIP meeting, Feb-2013
Compare FG01 (Tr 82% in DTL1) & FG01a (Tr 40%) lattices

Two lattices differ only by Q-strengths (experimental, slides McGinnis talk?).

Jumps within stable area instead of theor. recommended a smooth curve. May be Quads work also as steering dipoles?!

The points for Smith-Gluckstern stability diagrams are very close. Details of lost particles trajectories are needed. Is it possible in PARMILA-2?
(F)NAL & BNL DTL tank geometries are the same


National Accelerator Laboratory,† Batavia, Illinois, USA

Received 2 February 1970

Particle Accelerators,


THE OPERATION OF THE FIRST SECTION OF THE NAL LINEAR ACCELERATOR

This linac is part of a collaborative effort with Brookhaven National Laboratory (BNL) and Los Alamos Scientific Laboratory (LASL). The NAL linac design is similar to that of the new 200-MeV injector for the alternating gradient synchrotron at BNL.

The BNL drift tube and cavity specifications were adopted to save design effort and to allow early construction. The drift tubes are fabricated according to dimensions calculated by the MESSYMESH program and are dimensionally identical to the BNL drift tubes.


CONSTRUCTION PROGRESS AND INITIAL PERFORMANCE OF THE NAL 200-MeV LINEAR ACCELERATOR

Donald F. Young National Accelerator Laboratory* Batavia, Illinois 60510

Construction of the first section of the NAL 200-MeV linac was started in May 1968 as a prototype to test the design and to allow the development of subsystems required in the final linac. Protons were first accelerated in this section in June 1969. Construction of the final linac systems began in July 1970. Many of the prototype units were moved to the permanent linac building in January 1970. The first section (10 MeV) of the final linac operated in April 1970, the first three sections (66 MeV) in August, 1970, and the first six sections (139 MeV) in September 1970. Initial performance data of these operating sections, problems experienced and design performance for the completed linac are presented.

Basically, the NAL linac is patterned after the BNL linac which is the result of a collaborative effort in this country starting in 1964.
BNL DTL tank had NOT been designed by PARMILA

"Linear Accelerators" ed by P.M.Lapostolle & A.L.Septier, 1970 ("Red linacs bible")

C.1.2b A.CARNE ET AL. NUMERICAL METHODS. ACCELERATION BY A GAP 771

The above methods (Carne and Lapostolle [1968]) have been used in the design of linear accelerators: for example, the 20 MeV injector for Saturne (Promé [1966]) and the BNL 200 MeV injector for the AGS. A closely similar method has also been given by Swenson [1967], who found very close agreement in a comparative design of the BNL linac.

References


The design equations derived in this report are essentially identical to those proposed by Carne and Lapostolle. The design of the 200 MeV BNL injector linac is based on the Carne-Lapostolle design equations. The BNL linac was recently generated using the routines described in this report, and the agreement with the final BNL geometry as generated at BNL is excellent.

9-DTL 200-MeV 138m Linac: \( \delta L = 1.3 \text{cm} \sim 0.01\%\); \( \Delta W = 170 \text{keV} \sim 0.1\% \)

V.Kapin, PIP meeting, Feb-2013
Revision of FNAL DTL linac lattices

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<td>MM68</td>
<td>Messymesh</td>
<td>Hard copies MP-&gt;VK</td>
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<td>BNL Final design</td>
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<td>AK90</td>
<td>1990 BNL tech. note</td>
<td>1990 A.Knopou</td>
<td>Parmila-of 199x</td>
<td>SFDATA (from COFT in 1970 Benton's BNL-note)</td>
<td>! Printouts for PARMILA input &amp; design</td>
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<td>VK01</td>
<td>-</td>
<td>Original by VK</td>
<td>~197x</td>
<td>SFDATA</td>
<td>Only MM68 data</td>
</tr>
</tbody>
</table>

1990 A. Kponou  SIMULATING THE 200 MeV LINAC USING PARMILA

In the intervening years since the Linac was designed and built, personnel involved in the original work have dispersed, the evolution of computers has rendered obsolete the codes that were used in the design, and sophisticated ones have been developed. The SFDATA tables of coefficients used to calculate transit time factors and other parameters, were prepared from the COFT tables in Benton’s report on the original design calculations.4 Other information was obtained from the "Blue Book", the definitive Linac report,5 and from Linac operations personnel. The CHANGE cards are used to replace the quadrupole lengths and gradients produced by the linac generating subroutine, GENLIN2, with working values. The sequence of alternating quadrupole polarities was determined from information in the Blue Book.6 for H⁺

6. Reference 5, p. 30. Table II.2.g.1.
Agreement of basic design parameter with AK90(BNL) lattice

1990 A. Kponoou

COMPARISON OF THE ORIGINAL LINAC DESIGN

AND THE PARMILA

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<th>1 OUT</th>
<th>2 IN</th>
<th>2 OUT</th>
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<th>3 OUT</th>
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<td>92.55</td>
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<td>.750</td>
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<td>V.Kapin, PIP meeting, Feb-2013</td>
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</table>
Comparison AK90, FG01 and VK01 DTL1 lattices

Deviations [cm] of Quad (or cell ends) positions relatively to MM68 data for DTL1

<table>
<thead>
<tr>
<th>param.</th>
<th>NAL-68</th>
<th>AK90</th>
<th>FG01</th>
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<td>proton</td>
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<td>201.25</td>
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<td>744.6</td>
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<td>Ltot, cm (by MM)</td>
<td>744.5</td>
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</table>

For other DTLs -> Appendix
TTFs usage with PARMILA

Fig.: Original Messymesh TTFs used for design; TTFs recalculated with SUPERFISH (with coarse and refined mesh)

DTL1 (FinBNL_MessyMesh) "TTFs_as_SFDATA"

<table>
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<tr>
<th>COFT (1-17): T</th>
<th></th>
<th>COFT (18-56): T</th>
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<td>3</td>
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PARMILA should use original for design (step1), and refined for tracking (step2)
# Lengths of 116-MEV 5-Tank FNAL DTL

<table>
<thead>
<tr>
<th>Length parameter, [m]</th>
<th>NAL-1968</th>
<th>AK90</th>
<th>FG01</th>
<th>MP01</th>
<th>MP02</th>
<th>MP03</th>
<th>MP04(~1996)</th>
<th>VK01</th>
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<tr>
<td>DTL1</td>
<td>7.44</td>
<td>7.446</td>
<td>7.425</td>
<td>7.427</td>
<td>7.459</td>
<td>7.444</td>
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<tr>
<td>drift DTL1-DTL2</td>
<td>0.22</td>
<td>0.22</td>
<td>0.218</td>
<td>0.218</td>
<td>0.22</td>
<td>0.22</td>
<td></td>
<td>0.22</td>
</tr>
<tr>
<td>Accumulated length</td>
<td>7.66</td>
<td>7.667(6\textsuperscript{14})</td>
<td>7.643</td>
<td>7.645</td>
<td>7.679</td>
<td>7.664</td>
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<td>DTL2</td>
<td>19.02</td>
<td>19.018</td>
<td>18.969</td>
<td>18.970</td>
<td>19.05</td>
<td>19.018</td>
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<tr>
<td>drift DTL2-DTL3</td>
<td>0.6</td>
<td>0.60</td>
<td>0.596</td>
<td>0.596</td>
<td>0.60</td>
<td>~0.60</td>
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<td></td>
</tr>
<tr>
<td>Accumulated length</td>
<td>27.28</td>
<td>27.285(4)</td>
<td>27.208</td>
<td>27.211</td>
<td>27.332</td>
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<td>drift DTL3-DTL4</td>
<td>0.75</td>
<td>0.75</td>
<td>0.666</td>
<td>0.666</td>
<td>0.75</td>
<td>~0.75</td>
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<tr>
<td>Accumulated length</td>
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<td>44.562(0)</td>
<td>44.401</td>
<td>44.405</td>
<td>44.625</td>
<td>44.559</td>
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<td></td>
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<tr>
<td>drift DTL4-DTL5</td>
<td>1.0</td>
<td>1.00</td>
<td>1.041</td>
<td>1.041</td>
<td>1.175</td>
<td>~1.175</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DTL5</td>
<td>15.58</td>
<td>15.586</td>
<td>15.554</td>
<td>15.560</td>
<td>15.589</td>
<td>15.583</td>
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<td></td>
</tr>
<tr>
<td>Accumulated length</td>
<td>77.82\textsuperscript{15}</td>
<td>77.832(0)</td>
<td>77.684</td>
<td>77.700</td>
<td>78.084</td>
<td>78.01</td>
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</tbody>
</table>

V.Kapin, PIP meeting, Feb-2013
Inter-tank drifts are important for simulations; They may be different from original design; Digitized old drawings from 1970-Linac Conf and ruler measurements allow approximate evaluations; Detailed drawings with 1993 survey in Appendix

V. Kapin, PIP meeting, Feb-2013
Quad strengths - stability diagrams – BNL vs FNAL
Limits for quad excitation currents and gradients in DTL1 – BNL vs FNAL (DTL1)

V. Kapin, PIP meeting, Feb-2013
The design of proton linear accelerators for energies up to 200 MeV / Austin, B ; Edwards, T W ; O'Meara, J E ; Palmer, M L ; Swenson, D A ; Young, D E MURA-713. - 1965. - 159 p.

APPENDIX C: ENGINEERING CALCULATIONS

Calculation of Ampere-Turns Required for Quadrupole Coil

The design equation for a quadrupole coil is

\[ NI = \frac{0.388 \cdot G \cdot b^2}{n} \quad \text{(C. 1)} \]

where

- \( N \) = number of turns per pole
- \( I \) = current in turns, amperes
- \( G \) = flux gradient, gauss/cm
- \( b \) = half circle aperture, cm

\( n \) = an efficiency term which will usually be about 90% for pole tip fluxes of less than 12.5 kG.
About on-line modeling for 4-rod RFQ

- I had worked on 4-rod RFQ in 198x-199x (EPAC-94, Linac-94) both RF electrodynamics and beam dynamics.
- At that time, it was clear that there are additional non-quadrupole fields in 4-rod RFQ (Kolomiets-Yaramishev at GSI and Kapin in Kyoto Univ.).
- Schempp was informed about it, but actually ignored.
- Problems are in matching section and regular RFQ channel (beam centroid has curved trajectory), where additional components generated.
- Experimentally 4-rod RFQ never had a transmission as PARMTEQ predicted (for the same emittance).
- 95% transmission in RAL 4-rod RFQ is a trick, 30% of beam is lost before in LEBT (where beam emittance is actually reduced).
- It is known that for very small emittance the transmission can be 100% even without any matcher and small curved trajectory in regular channel.
- Recently, I revealed that PARMTEQ-M used for 4-rod RFQ simulations has no necessary field components! It is appropriate only for symmetric RFQ structures like 4-vane RFQ.
- Thus, simulations of 4-RFQ with PARMTEQ-M will not agree with experiments.
Summary

- Modern PARMILA is not appropriate for off-line modeling
- SNS XAL or old PARMILA are possible candidates
- Optics reconstruction demands to restore original design
- PARMILA versions are overviewed
- New configuration: “old PARMILA + TraceWin” is suggested
- Available FNAL DTL lattices have unclear origins and small bugs
- BNL & F(NAL) DTL are twins
- PARMILA was not used for BNL (FNAL) linac design
- Restored BNL PARMILA lattice (AK90) is agree with MM68
- New FNAL lattice based on MM8 is agree with BNL-AK90
- Inter-tank drifts are known only approximately
- Stability diagram shows strange jumps for operating points
- Excitation currents and gradients are near limits (to be re-set ?)
Plans

- Write all collected information in report
- Release an official lattice specification based on Messymesh tables
- If approved, modify old PARMILA:
  - Prepare for using within external optimization subroutines
  - Necessary knobs for optimization algorithm
  - Add new elements (e.g. RF dipoles simulating for RF-gap misalignments)
  - Use separate TTFs for design (MM68) and tracking (SUPERFISH)
- Beam dynamics simulation of existing measurements data
- Formulate and prepare possible fitting algorithms
- Supply TraceWin lattice with fitting results
- Help with off/on-line simulation of 4-rod RFQs:
  - Modify old PARMTEQ to include specific 4-rod RFQ fields in radial matching section and regular RFQ channel Ss
  - MWS simulation of 4-rod RFQ, define specific 4-rod field components
  - Provide realistic 4-rod RFQ lattice for usage in on-line model
Appendix.
Supporting slides
Instruments in Fermilab linac

Beam current monitors (toroids) 

Beam Intensity profile (H/V/U)

Beam emittance probe (H/V) 

Beam position monitors (H/V)

Linac beam position measurement

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Future work

• Optimize initial phase space.

• Get working model of Tank 1
  – Reference emittance meas. at both entrance & exit of Tank 1.
  – Adjust quad current & take emittance measurements.
  – Compare to model.

• Get working model of Tank 1-5 and Module 0-7
  – Take reference position measurements (BPM).
  – Adjust trim and take position measurements.
  – Repeat above two steps with different quad settings.
  – Compare to model.

Schedule: Updating linac lattice will be done until Mar. 2012.
Comparison AK90, FG01 and VK01 DTL2 lattices

Deviations [cm] of Quad (or cell ends) positions relatively to MM68 data for DTL2

<table>
<thead>
<tr>
<th>param.</th>
<th>NAL-68</th>
<th>AK90</th>
<th>FG01</th>
<th>VK01</th>
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<td>design particle</td>
<td>proton</td>
<td>proton</td>
<td>H-minus</td>
<td>proton</td>
</tr>
<tr>
<td>f, MHz</td>
<td>201.25</td>
<td>201.25</td>
<td>201.24</td>
<td>201.25</td>
</tr>
<tr>
<td>Win, MeV</td>
<td>10.42</td>
<td>10.422</td>
<td>10.371</td>
<td>10.420</td>
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<tr>
<td>Wout, MeV</td>
<td>37.54</td>
<td>37.536</td>
<td>37.396</td>
<td>37.540</td>
</tr>
<tr>
<td>dW, MeV</td>
<td>27.12</td>
<td>27.114</td>
<td>27.025</td>
<td>27.12</td>
</tr>
<tr>
<td>E0, MV/m</td>
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<td>2.001</td>
<td>(2.05)-&gt;2.00</td>
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<tr>
<td>Ltot, cm</td>
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For other DTLs -> Appendix  
V. Kapin, PIP meeting, Feb-2013
Comparison AK90, FG01 and VK01 DTL3 lattices

Deviations [cm] of Quad (or cell ends) positions relatively MM90 data for DTL3

<table>
<thead>
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<td>proton</td>
<td>proton</td>
<td>H-minus</td>
<td>proton</td>
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<tr>
<td>f, MHz</td>
<td>201.25</td>
<td>201.25</td>
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<td>201.25</td>
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<tr>
<td>Win, MeV</td>
<td>37.54</td>
<td>37.536</td>
<td>37.396</td>
<td>37.540</td>
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<tr>
<td>Wout, MeV</td>
<td>66.18</td>
<td>66.180</td>
<td>66.549</td>
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<tr>
<td>dW, MeV</td>
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Comparison AK90, FG01 and VK01 DTL4 lattices

Deviations [cm] of Quad (or cell ends) positions relatively to MM68 data for DTL4

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<td>proton</td>
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<td>f, MHz</td>
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<td>201.25</td>
<td>201.24</td>
<td>201.25</td>
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<tr>
<td>Win, MeV</td>
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<td>66.180</td>
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<tr>
<td>Wout, MeV</td>
<td>92.55</td>
<td>92.555</td>
<td>92.371</td>
<td>92.550</td>
</tr>
<tr>
<td>E0, MV/m</td>
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<td>Ltot, cm (by MM)</td>
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Comparison AK90, FG01 and VK01 DTL5 lattices

Deviations [cm] of Quad (or cell ends) positions relatively to MM68 data for DTL5

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<tr>
<td>f, MHz</td>
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<td>Win, MeV</td>
<td>92.55</td>
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<td>E0, MV/m</td>
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<td>Ltot, cm (by MM)</td>
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Inter-tank space between DTLs 1 and DTL2

DG-2013: (metal box with instrumentation inside) 12.625" = 32.0 cm


21.7 cm 10.7 cm

5.1 cm 5.0 cm 4.8 cm

D TL1

CA VITY 1

BEAM SCRAPE R

diam. 94.0 cm
diam. 62.0 cm

D TL2

CA VITY 2

LinacConf-1970
DTL1-DTL2
digitized by VK(2013)

V.Kapin, PIP meeting, Feb-2013
Inter-tank space between DTLs 2&3 and DTLs 3&4

Fig. 11. Diagnostic space between cavity 2-3 and 3-4.

LinacConf-1970
DTL2-DTL3 (3-4) (digitized by VK(2013))

FG-2013 (Interflange): DTL2-3: 23.94"=60.8 cm; DTL3-4: 29.75"=75.57 cm
Inter-tank space between DTL4 and DTL5

FG-2013 (Interflange): DTL4-5: 47.5"=120.7cm => inter-tank~119.9cm (120.7-0.8)

10.837"+7.424"+11.831"+19.469"
= 49.661"=126.1 cm
=> inter-tank~117.7(126.1-8.4)
Quadrupole locations and their power supplies in FNAL DTL1

<table>
<thead>
<tr>
<th>Q#</th>
<th>Type 1 (L=2.54cm; R&lt;sub&gt;aper&lt;/sub&gt;=1.1cm; 21 turns/pole)</th>
<th>Type 2 (L=3.175cm; R&lt;sub&gt;aper&lt;/sub&gt;=1.1cm; 21 turns/pole)</th>
<th>Type 3 (L=4.445cm; R&lt;sub&gt;aper&lt;/sub&gt;=1.45cm; 19 turns/pole)</th>
<th>Type 4 (L=5.985cm; R&lt;sub&gt;aper&lt;/sub&gt;=1.45cm; 19 turns/pole)</th>
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</thead>
<tbody>
<tr>
<td>Q1</td>
<td>Q2</td>
<td>Q3</td>
<td>Q4</td>
<td>Q5</td>
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<td>Cell #</td>
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<td>5.80</td>
<td>5.92</td>
<td>7.04</td>
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MP-2004: Q# | QPS # | PARMILA: Quad # | Cell # |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Q# | -Foc | -Defoc |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

BNL-AK1990:

<table>
<thead>
<tr>
<th>Q#</th>
<th>Type 3</th>
<th>Type 4 (L=6.985cm; R&lt;sub&gt;aper&lt;/sub&gt;=1.45cm; 19 turns/pole)</th>
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</thead>
<tbody>
<tr>
<td>Q16</td>
<td>Q17</td>
<td>Q18</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PARMILA: Quad #</td>
<td>Cell #</td>
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<tr>
<td>some DT length:</td>
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<td>10.79</td>
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MP-2004: Q# | QPS # | PARMILA: Quad # | Cell # |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Q# | -Foc | -Defoc |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

V.Kapin, PIP meeting, Feb-2013