Status of Linac Lattice Study
Overview / Motivation / On-line application / Measurement

H. J. Kim
Fermi National Accelerator Laboratory

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Until June 2011: David McGinnis manages linac lattice study.

Oct. 1, 2011: Kim takes over Dave’s job. He reviews Dave’s work.


Nov. 21, 2011: Build low energy linac lattice. (Dave built only 750keV and Tank 1 lattice.)

Nov. 23, 2011: Dave sends all his java codes for the linac study.


Present: Upgrade Dave’s Java code and Web applications. Do beam measurements and compare them with simulation.
Goal / Motivation

- Make an on-line lattice model of the Linac.
  - Make a user-friendly GUI interface using Java and Web applications.
  - Develop a lattice for LE and HE linacs.
- Requirements: handle space-charge, scraping, DTL, SCL, and connect ACNET.
- Parmila is chosen as particle tracking tool.
  - Parmila is a mature program and used to design Fermilab linac.
  - Interface is not user-friendly.
- Java is used for ACNET database interface and post-processing the tracking data.
What is an on-line application

- EXtensible Markup Language (XML) is a simple, very flexible text format.
XML interface

- XML is a markup language much like HTML.
- XML is designed to carry data, not to display data.
- XML allows the author to define his own tags and his own document structure.
- XML is both human readable and machine readable.

Parmila format

ccl 402.5 -32.0 7.8 16 1.5 2200.0 8.53 0101 1 0 1 0 1

XML format

```
<Element type="sideCouple" Wfinal="402.5" phiD="-32.0" E0="7.8" Ncav="16" NBlam="1.5" Bgrad="2200.0" Lquad="8.53" Qseq="0101" Qloc="1" Qent="0" Ltype="1" Dds="0" Polarity="1" numCells="500" outputFlag="true" name="Module" ntank="1" />
```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<Parmila title="Fermilab Linac as Build" >
   <Header>
      <Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="L:IHTOR2" logger="Linac" logInt="4" restEnergy="939.294012" charge="-1" />
      <PhaseSpace type="waterbag" npart="10000" alphaX="-2.2" betaX="3.8" emitX="1.2" deltaX="0.0" deltaXp="0.0" alphaY="-4.5" betaY="1.8" emitY="1.0" deltaY="0.0" deltaYp="0.0" phiSpread="180" energySpread="0.001" phiOffset="0" energyOffset="0" seed="0.5" />
   </Header>
   <Structure title="Transport from center of 90 bend to entrance to DTL1" type="transport" id="1" nlast="0" harmonic="1" deltaPhi="0" boreRadius="41" prevDesignPhi="0.0" >
      <Element type="drift" length="1.0" radialAperture="41" nSpaceChargePulses="1" outputFlag="true" name="Drift 1" />
      <Element type="quad" length="120.0" radialAperture="38.1" gradient1="-0.0281" current="L:QTM2E" outputFlag="false" logger="Linac" logInt="4" name="Q2 Up" />
   </Structure>
   <Structure title="FNALasBuild DTL#1 57mA" type="driftTube" id="2" nlast="56" harmonic="1" deltaPhi="-32.0" boreRadius="41" >
   ...
   </Structure>
</Parmila>
ACNET database interface

- The database interface uses D44 application package (gov.fnal.controls.applications.osda.D44Variable).
- An example to the XML input
  - D44 data logger Java interface can be used
    
    `<Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="L:IHTOR2" logger="Linac" logInt="1" restEnergy="939.294012" charge="-1" />`
  
  - D44 interface cannot be used
    
    `<Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="50.0" restEnergy="939.294012" charge="-1" />`

- An example to the beam instrument readout
  
  `<Element type="bpm" index="152" zloc="0" bpmx="L:BPH2OT" bmy="L:BPV2OT" logger="Lina2" logInt="1" name="L:BP[H/V]2OT" />`
  
  `<Element type="toroid" index="0" zloc="0" bcurrent="L:IHTOR2" logger="Linac" logInt="1" name="L:IHTOR2" />`
# Status of Linac application

**Until June 2011 (McGinnis)**

- Build Phase Space, Drift, Quad, Cavity, DriftTube, DTL Quad, and DTL Table in the Java application.

**During Nov. and Dec. 2011 (Kim)**

- Build CCL(Coupled Cavity Linac), CCL Table, ExtQuad, QuadLoc, Steering magnet, and Initial distribution.
- Add BPM and Toroid for beam instrument.
- Add ASCII output of simulation result.
- Add comparison of simulation and measurement for beam current and beam position.
- Remodel Web pages for Linac application
### Linac lattice

<table>
<thead>
<tr>
<th></th>
<th>Energy [MeV]</th>
<th>Quad</th>
<th>Gap/Cavity</th>
<th>Steer</th>
</tr>
</thead>
<tbody>
<tr>
<td>750 keV line</td>
<td>0.75</td>
<td>7</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Tank 1</td>
<td>10.4</td>
<td>56</td>
<td>55</td>
<td>-</td>
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<tr>
<td>Tank 2</td>
<td>37.5</td>
<td>60</td>
<td>59</td>
<td>1</td>
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<tr>
<td>Tank 3</td>
<td>66.2</td>
<td>35</td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td>Tank 4</td>
<td>92.6</td>
<td>29</td>
<td>28</td>
<td>1</td>
</tr>
<tr>
<td>Tank 5</td>
<td>116.5</td>
<td>24</td>
<td>23</td>
<td>1</td>
</tr>
<tr>
<td>Module 0</td>
<td>116.5</td>
<td>4</td>
<td>20</td>
<td>3</td>
</tr>
<tr>
<td>Module 1</td>
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<td>64</td>
<td>1</td>
</tr>
<tr>
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<td>180.2</td>
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<td>64</td>
<td>2</td>
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<td>2</td>
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<tr>
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<td>Module 7</td>
<td>401.5</td>
<td>4</td>
<td>64</td>
<td>2</td>
</tr>
</tbody>
</table>

- Parmila input of Tank 1-5 is based on Milorad’s work [Fermilab-TM-2245].
- Lattice of high energy linac is not available. It is built from “Fermilab Linac Upgrade Conceptual Design Rev. 4A”.

H. J. Kim (Fermilab)

Linac Lattice Study

Jan. 11, 2012
Instruments in Fermilab linac

<table>
<thead>
<tr>
<th>Instrument</th>
<th>750 keV</th>
<th>Tank 1-5</th>
<th>Module 0</th>
<th>Module 1-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam position monitor (H/V)</td>
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<td>3</td>
<td>27</td>
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<tr>
<td>Beam current monitor</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>7</td>
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<tr>
<td>Beam loss monitor</td>
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<td>8</td>
<td>2</td>
<td>30</td>
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<tr>
<td>Beam emittance probe (H/V)</td>
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<td>2</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beam intensity profile (H/V/U)</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Beam velocity</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Beam bunch length</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

- All instruments are added in the lattice as a marker.
- Developed Java code for reading BPM and BCM data from ACNET database.
On-line linac application

- Developed web pages for JavaServer pages.
  - Interpret the XML input.
  - Generate Parmila input.
  - Execute Parmila code.
  - Analyze simulation output.
  - Display result.
- Requirements: Web server + Apache tomcat (v7.0)
- Can use in local computer or in the web.
  - Local usage: http://localhost:8080/LinacApp
  - Web usage: http://<hostname>:8080/LinacApp (not set it up yet)
Fernanda and Junye update the ACNET Linac/Preacc L11 to save the BPM and beam current data. The output is written as an Excel format.
Emittance measurement

- Measured the emittance for H- at both entrance and exit of Tank1. 10MeV emittance gives strange data (need to be fixed?).
- Emittance at the entrance of Tank1

![Image of emittance at entrance of Tank1]

- Emittance at the exit of Tank1

![Image of emittance at exit of Tank1]
Considerable beam loss is observed at Tank 1 during bunching process, especially between 1st and 30th accelerating gaps.

Space-charge contributes to the beam loss. For example, 24% loss with initial beam current 45 mA, but 6% loss with 45 μA.

2D space-charge model induces beam loss 25%. 24% for 3D model.
Baseline measurement with current Linac settings. Beam position is averaged over 24 Linac cycle.

Initial phase space ($\beta, \alpha, \Delta x, \Delta x'$) is not well optimized yet. Initial beam condition strongly affects beam position and beam loss as well.

Trim magnets are not included in the model. Trim magnet current is set to be a few Amperes in the machine.
10% increase of quad current of QTM3C (Q3 center)

10% increase of quad current of QTM3E (Q3 end)
Future work

- Optimize initial phase space.
- Get working model of Tank 1
  - Take reference emittance measurements (emittance probes at both entrance and exit of Tank 1).
  - Adjust quad current and 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.
  - (Compare beam current/loss/profile to model as well.)
- Improve Java web application.
  - Plot simulation results versus longitudinal position instead of element #.
  - Add more analysis result such as beam profile.
- Schedule
  - Updating linac lattice will be done until Mar. 2012.
Acknowledgment

- Beam measurement: Fernanda Garcia
- L11 program: Fernanda Garcia and Junye Wang
- Java application for BPM: Bob Florian
- 10 MeV probe: Fernanda Garcia, Dan Bollinger, AD/Controls personnel and Alex Waller
- Advice: Fernanda Garcia and Valeri Lebedev
- Low energy linac lattice: Milorad Popovic
- Linac Java code: David McGinnis