

Status of Linac Lattice Study

Overview / Motivation / On-line application / Measurement

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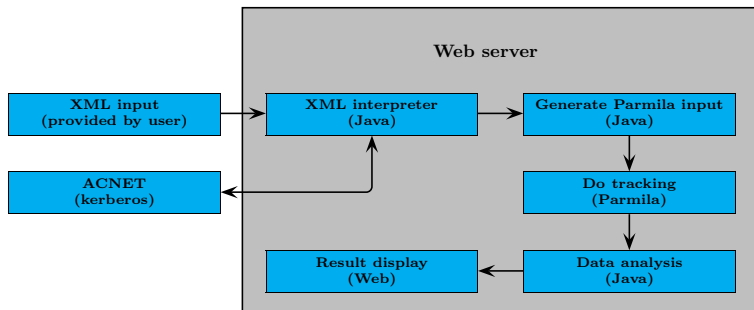
January 11, 2012

Chronological overview

- Until June 2011: David McGinnis manages linac lattice study.
- Oct. 1, 2011: Kim takes over Dave's job. He reviews Dave's work.
- Oct. 10, 2011: Compile a Linac instrumentation list, Linac drift tubes and side couple specifications.
- Oct. 25, 2011: Dave visits Fermilab.
- 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.
- Dec. 1, 2011: Build high energy linac lattice.
- Present: Upgrade Dave's Java code and Web applications. Do beam measurements and compare them with simulation.

- 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 input example

```
<?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"
  bpmym="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)

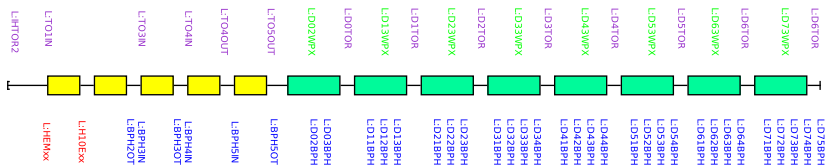
- Build CCL(Coupled Cavity Linac), CCL Table, ExtQuad, QuadLoc, Steering magnet, and Initial distribution.
- Add BPM and Toroid for beam instrument.
- Add ASCII output of simulation result.
- Add comparison of simulation and measurement for beam current and beam position.
- Remodel Web pages for Linac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

Linac lattice

	Energy [MeV]	Quad	Gap/Cavity	Steer
750 keV line	0.75	7	1	1
Tank 1	10.4	56	55	-
Tank 2	37.5	60	59	1
Tank 3	66.2	35	34	1
Tank 4	92.6	29	28	1
Tank 5	116.5	24	23	1
Module 0	116.5	4	20	3
Module 1	142.8	4	64	1
Module 2	180.2	4	64	2
Module 3	229.8	4	64	2
Module 4	271.1	4	64	2
Module 5	313.6	4	64	2
Module 6	357.1	4	64	2
Module 7	401.5	4	64	2

- 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".

Instruments in Fermilab linac



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

- 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)



ACNET Linac/Preacc L11

- 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.

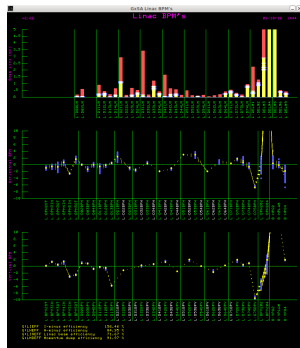
```
PA L11 PLOTS: BPM BLM TOR<NoSets>
L11 PLOT LAUNCHER                               ◆PgM_Tools◆
◆Launch Linac Toroid/BLM Plot◆
◆Launch Linac Tuning Plot◆

Linac Toroid/BLM Plot Full Scale
TOROID < 80>nA
LOSSES < 5>nV

Linac BPM Plot Full Scale
HOR BPM< 10>nA
VER BPM< 10>nA
◆Save Plot◆ ◆Compare Plot◆ ◆Normal Plot◆ ◆Diff Plot◆
◆Save Delta◆ ◆Use Delta◆ ◆Take Delta Profile◆

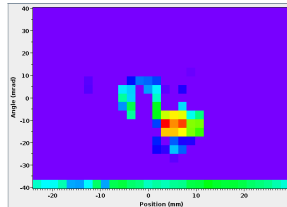
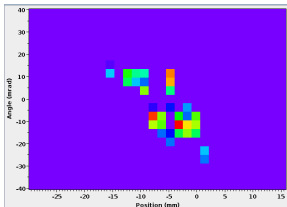
◆Export Plot Data◆

Messages
Linac Tuning Plot Launched
```

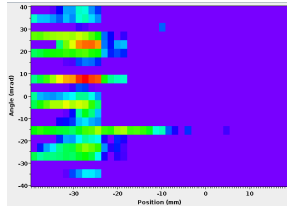
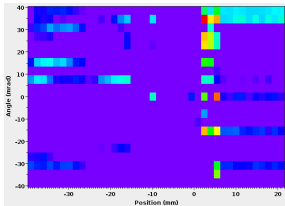


Emittance measurement

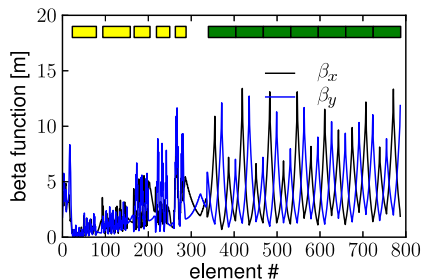
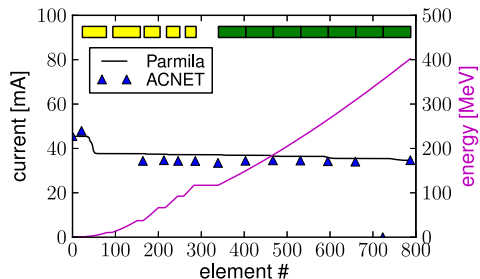
- Measured the emittance for H- at both entrance and exit of Tank1. 10MeV emittance gives strange data (need to be fixed?).
- Emittance at the entrance of Tank1



- Emittance at the exit of Tank1

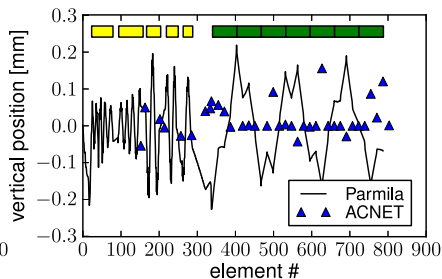
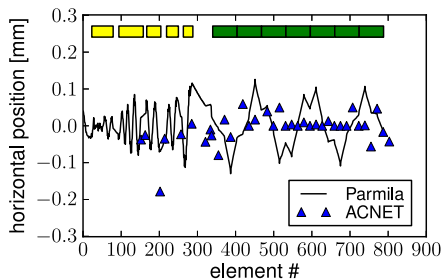


Linac beam current / beta function



- 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 μ A.
- 2D space-charge model induces beam loss 25%. 24% for 3D model.

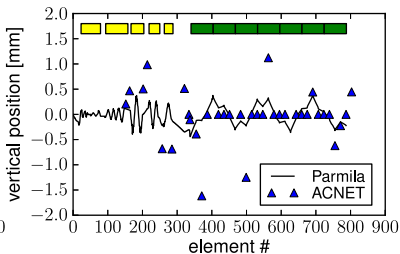
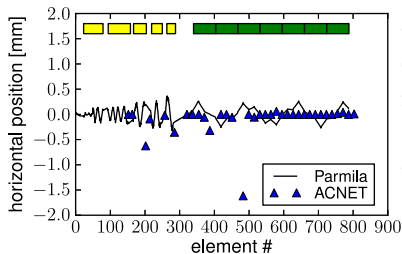
Linac beam position measurement



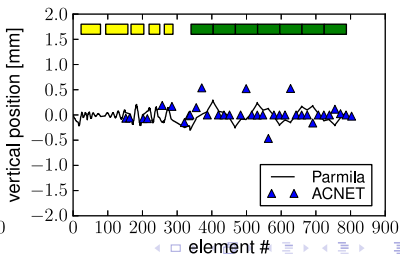
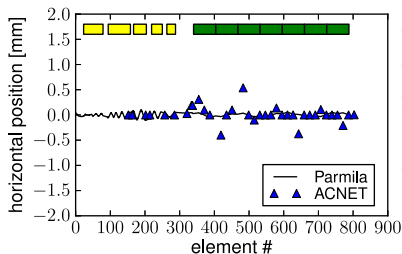
- Baseline measurement with current Linac settings. Beam position is averaged over 24 Linac cycle.
- Initial phase space (β , α , Δx , $\Delta x'$) is not well optimized yet. Initial beam condition strongly affects beam position and beam loss as well.
- Trim magnets are not included in the model. Trim magnet current is set to be a few Amperes in the machine.

Linac beam position measurement

- 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