Linac Lattice Studies

Dave McGinnis

June 23, 2011

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 program
- Use Parmila as the simulation “engine”
- Advantages
  - Mature program
  - Used to design Fermilab Linac so it can handle Fermilab Linac Structures
- Disadvantages
  - Old program
  - Horrible user interface

XML Interface

- Parmila input files are hard to work with
  - Do not take variables so linking to online data is difficult
  - Extremely long and cryptic commands make data entry error prone
    - Tank 1 DTL command:
    - dtl 1 10.25 -32.0 1.6 0.000592 2.31 0.0 0.0 2.275 0.0 3.454 1 1 11 0.0 1.0 1.25 19 0 0 1 0 0 0 0 0
- Developed an XML interface makes it
  - possible to connect to online database
  - Easy to understand

XML Interface

- XML is human and machine readable
  - DTL commands goes from:

```
dtl 1 10.25 -32.0 1.6 0.000592 2.31 0.0 0.0 2.275 0.0 3.454 1 1 11 0.0 1.0 1.25 19 0 0 1 0 0 0 0 0
```

```
<Element type="driftTube" outputFlag="false"  name="Drift Tube 1"
    ntank="1"   Wfinal="10.25" phiS="-32.0" Eo="1.6"   Ctilt="0.000592" EOMax="2.31" Dz="0.0"    Dphi="0.0" CO="2.275" C1="0.0"
    QL="3.454"  lat="1"        Qstart="1"   QEnd="11"  Dze="0.0"        Rb1="1.0"    Rb2="1.25"  NNBR="19"  Pmax="0"
    NBlam="1"   Rtype="0"      DNphi="0"    Nstart="0" Nend="0"         phiSmax="0"  numCells="56"  >
```

- Developed a Java class structure to build any Parmila element
- So far have built a library of Parmila elements:
  - Phase Space, Drift, Quad, Cavity, DriftTube, DTL Quad, DTL Table

XML Input

Phase Space

Drift

Quad

Cavity

Sim. Setup

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?><!--blah--><!--
--><Parmila title="Fermilab DTL Linac as Build" >
    <Header>
        <Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="L:IHTOR2" logger="Linac" logInt="4"
            restEnergy="938.27201323" charge="-1" />
        <PhaseSpace type="ellipse" npart="10000"
            alphaX="2.7"  betaX="0.7" emitX="1.2" deltaX="0.2" deltaXp="-0.5"
            alphaY="-5" betaY="4.1" emitY="1.0" deltaY="-0.1" deltaYp="-4.3"
            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" >
        <Element type="drift" length="1.0" radialAperture="41" nSpaceChargePulses="1" outputFlag="true"  name="Drift 1" />
        <Element type="drift" length="91.075" radialAperture="41" nSpaceChargePulses="1" outputFlag="false"  name="Drift 2"/>
        <Element type="comment" text="----------TRIPLET 2-------------------" />
        <Element type="quad" length="120.0" radialAperture="38.1" gradient1="-0.0281" current="L:QTM2E" outputFlag="false" logger="
        <Element type="drift" length="19.5" radialAperture="41" nSpaceChargePulses="1" outputFlag="false"  name="Drift Q2 1" />
        <Element type="quad" length="240.0" radialAperture="38.1" gradient1="0.0281" current="L:QTM2C" outputFlag="false" logger="L:
        <Element type="drift" length="19.5" radialAperture="41" nSpaceChargePulses="1" outputFlag="false"  name="Drift Q2 2" />
        <Element type="quad" length="120.0" radialAperture="38.1" gradient1="-0.0281" current="L:QTM2E" outputFlag="false" logger="
        <Element type="comment" text="----------TRIPLET 2 End-----------------" />
        <Element type="drift" length="304.9125" radialAperture="41" nSpaceChargePulses="1" outputFlag="false"  name="Drift to Bunch
        <Element type="comment" text="------------BUNCHER--------------------" />
        <Element type="drift" length="107.95" radialAperture="15" nSpaceChargePulses="1" outputFlag="false"  name="Drift Buncher 1"
        <Element type="cavity" radialAperture="15" deltaEnergyMax="0.033" gradientMultiplier="L:GRBHI" logger="Linac" logInt="4"  h
        <Element type="drift" length="107.95" radialAperture="15" nSpaceChargePulses="1" outputFlag="false" name="Drift Buncher 2" ,
        <Element type="comment" text="------------BUNCHER End--------------------" />
        <Element type="drift" length="25.4" radialAperture="41" nSpaceChargePulses="1" outputFlag="false" name="Drift to Trim" />
        <Element type="drift" length="57.15" radialAperture="41" nSpaceChargePulses="1" outputFlag="false" name="Trim" />
        <Element type="drift" length="84.14" radialAperture="41" nSpaceChargePulses="1" outputFlag="false" name="Drift to Q3" />
        <Element type="comment" text="----------TRIPLET 3-------------------" />
        <Element type="quad" length="80" radialAperture="38.1" gradient1="-3.7e-2" gradient2="+4.2e-5" current="L:QTM3E" logger="Lin
        <Element type="drift" length="19.5" radialAperture="38.1" nSpaceChargePulses="1" outputFlag="false" name="Drift Q3 1" />
        <Element type="comment" text="----------multiplied gradient by 2 for Q3C because of two power supplies--------------------
        <Element type="quad" length="160.0" radialAperture="38.1" gradient1="7.4e-2" gradient2="-9.84e-5" current="L:QTM3C" logger="
        <Element type="drift" length="19.5" radialAperture="38.1" nSpaceChargePulses="1" outputFlag="false" name="Drift Q3 2" />
        <Element type="quad" length="80.0" radialAperture="38.1" gradient1="-3.7e-2" gradient2="+4.2e-5" current="L:QTM3E" logger="
        <Element type="comment" text="---------------------------------------" />
        <Element type="drift" length="80" radialAperture="41" nSpaceChargePulses="1" outputFlag="true" name="Drift to Probe" />
        <Element type="comment" text="------End of Transfer line-------------" />
        <Element type="scheff" deltaR=".2" deltaZ="5.0" nr="20" nz="40" nbunch="1" nbetalambda="0" remesh="3" />
    </Structure>
</Parmila>
```

XML Interface Output: Parmila Run File

```
title
Fermilab DTL Linac as Build
Linac  0.75 201.24 45.03173828125 938.27201323 -1
Input 8 10000 2.7 70 0.003 -5 410 0.0025 180 0.001 0.0 0.02 -0.0005 -0.01 -0.0043 0 0 0.5
Structure 1 0 201.24 201.24 0
title
Transport from center of 90 bend to entrance to DTL1
Transport 0.0
Bore 4.1
Drift 0.1 4.1 1 1                                                    ;Last Cell = 1 Name = Drift 1
Drift 9.108 4.1 0 1                                                  ;Last Cell = 2 Name = Drift 2
; -----------TRIPLET 2-------------------
Quad 12 3.81 0 -313.947 0                                            ;Last Cell = 3 Name = Q2 Up -  Current = 111.725 Amps
Drift 1.95 4.1 0 1                                                   ;Last Cell = 4 Name = Drift Q2 1
Quad 24 3.81 0 298.554 0                                             ;Last Cell = 5 Name = Q2 Center -  Current = 106.247 Amps
Drift 1.95 4.1 0 1                                                   ;Last Cell = 6 Name = Drift Q2 2
Quad 12 3.81 0 -313.947 0                                            ;Last Cell = 7 Name = Q2 Down -  Current = 111.725 Amps
; -----------TRIPLET 2 End--------------------
Drift 30.491 4.1 0 1                                                 ;Last Cell = 8 Name = Drift to Buncher
; ------------BUNCHER---------------------
Drift 10.795 1.5 0 1                                                 ;Last Cell = 9 Name = Drift Buncher 1
cavity 0 1.5 0 0.00523681640625 201.24 -90.0                         ;Last Cell = 10 Name = Buncher
Drift 10.795 1.5 0 1                                                 ;Last Cell = 11 Name = Drift Buncher 2
; ------------BUNCHER End---------------------
Drift 2.54 4.1 0 1                                                   ;Last Cell = 12 Name = Drift to Trim
Drift 5.715 4.1 0 1                                                  ;Last Cell = 13 Name = Trim
Drift 8.414 4.1 0 1                                                  ;Last Cell = 14 Name = Drift to Q3
; -----------TRIPLET 3-------------------
Quad 8 3.81 0 -665.609 0                                             ;Last Cell = 15 Name = Q3 Up -  Current = 251.953 Amps
Drift 1.95 3.81 0 1                                                  ;Last Cell = 16 Name = Drift Q3 1
; -----------multiplied gradient by 2 for Q3C because of two power supplies--------------------
Quad 16 3.81 0 778.278 0                                             ;Last Cell = 17 Name = Q3 Center Up -  Current = 126.427 Amps
Drift 1.95 3.81 0 1                                                  ;Last Cell = 18 Name = Drift Q3 2
Quad 8 3.81 0 -665.609 0                                             ;Last Cell = 19 Name = Q3 Down -  Current = 251.953 Amps
; ---------------------------------------
Drift 8 4.1 1 1                                                      ;Last Cell = 20 Name = Drift to Probe
; ------End of Transfer line-------------
scheff .2 5.0 20 40 1 0 3
DumpDists 1 20
prtbeam
begin
end
```

ACNET Database Interface

- The database interface is generic enough so that it can be extended to any database interface
- A specific example to the D44 logger Java interface was developed

```
<Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="L:IHTOR2" logger="Linac" logInt="4"
    restEnergy="938.27201323" charge="-1" />
```

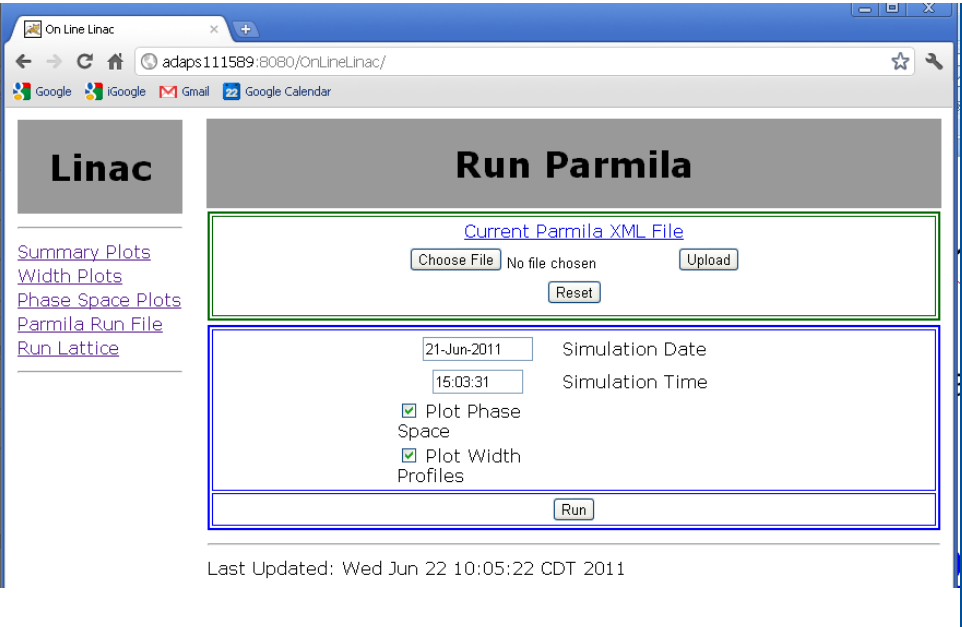
D44 interface

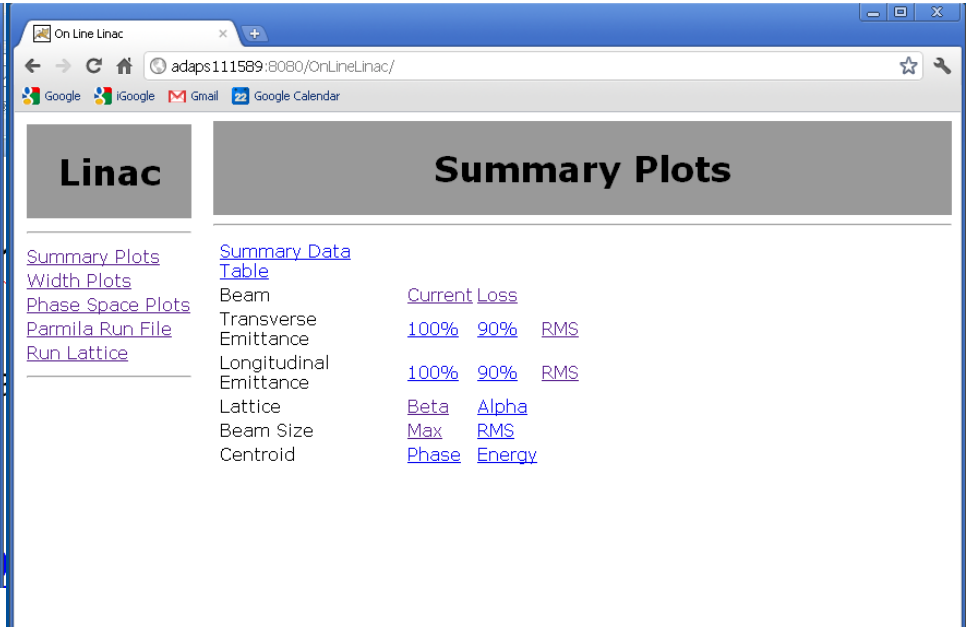
- or no interface can be used

```
<Linac kineticEnergy="0.75" bunchFrequency="201.24" beamCurrent="43.0" restEnergy="938.27201323" charge="-1" />
```

OnLine Linac Web Page

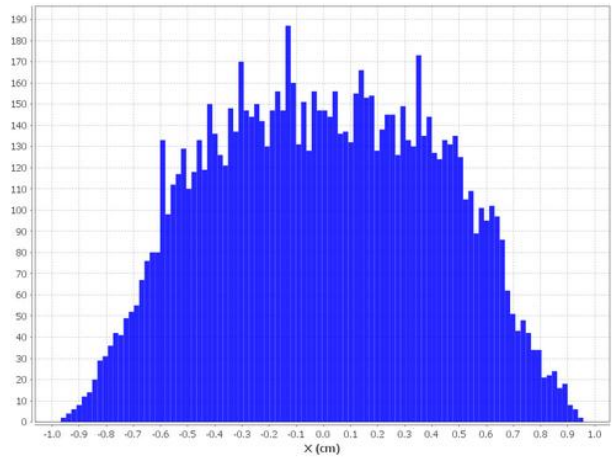
- Developed a set of active web pages - java server pages (*.jsp) to simulate and display the linac lattice
- http://adaps111589:8080/OnLineLinac/

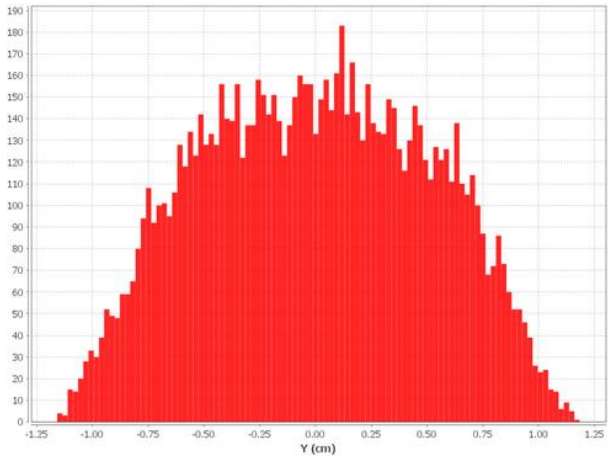


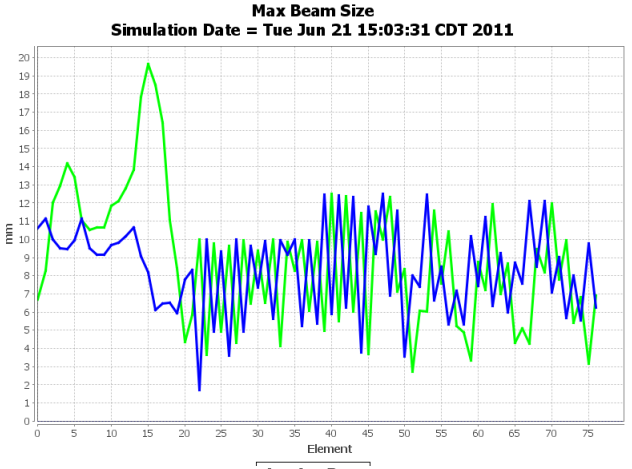


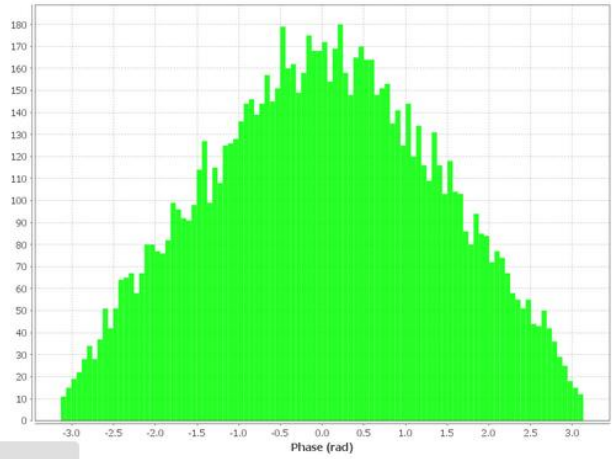
OnLine Linac Web Page Plots

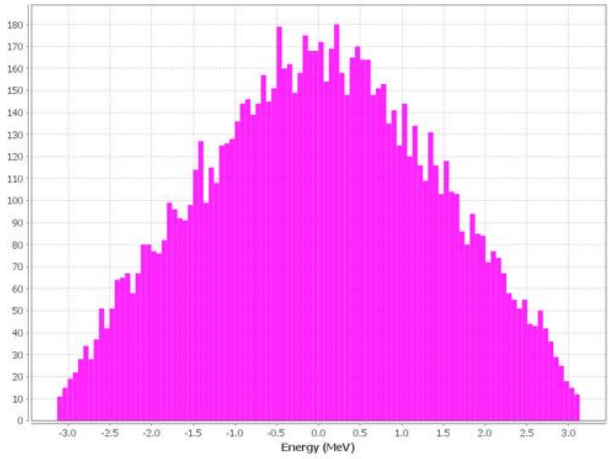
(End of Buncher – 45mA)

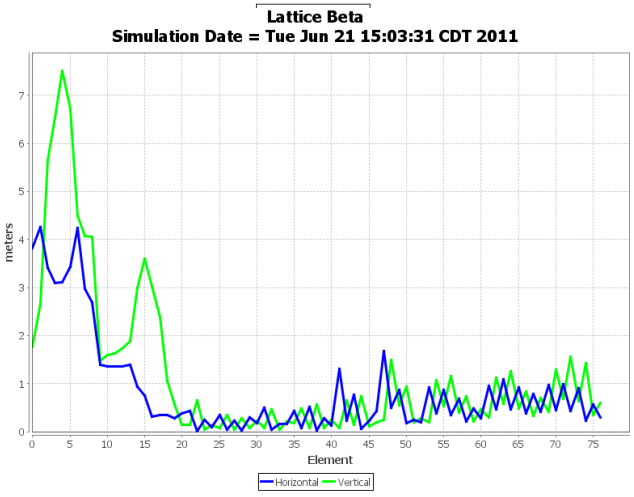






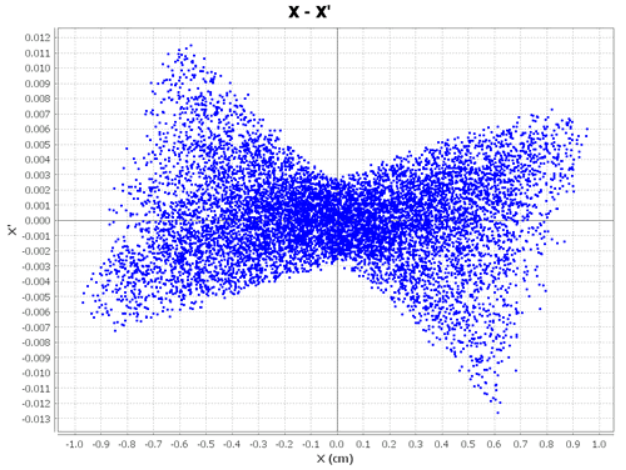


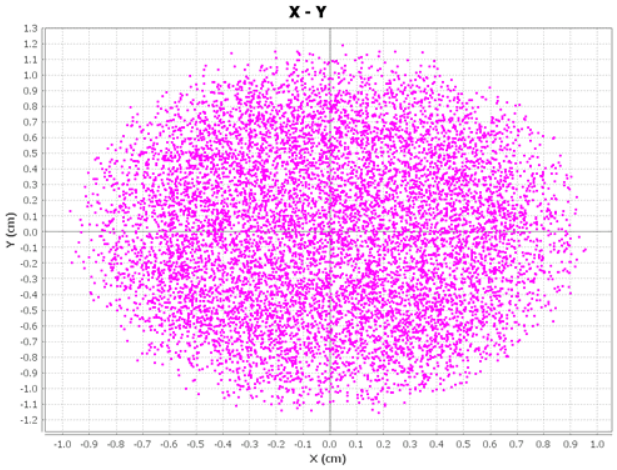


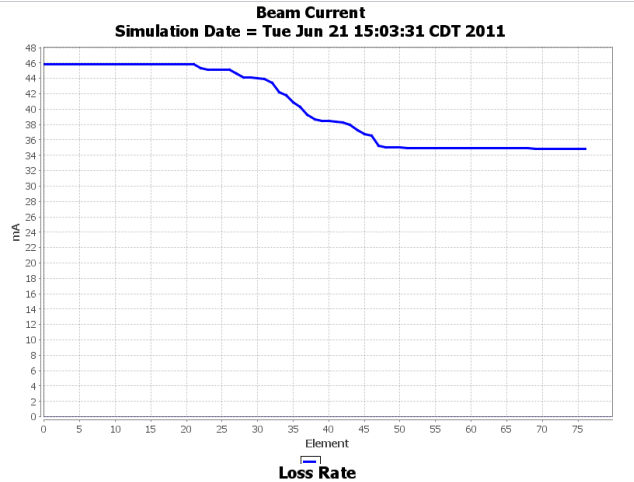


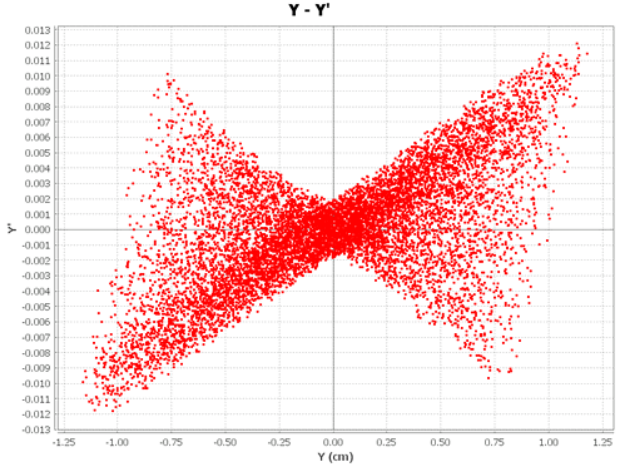
OnLine Linac Web Page Plots

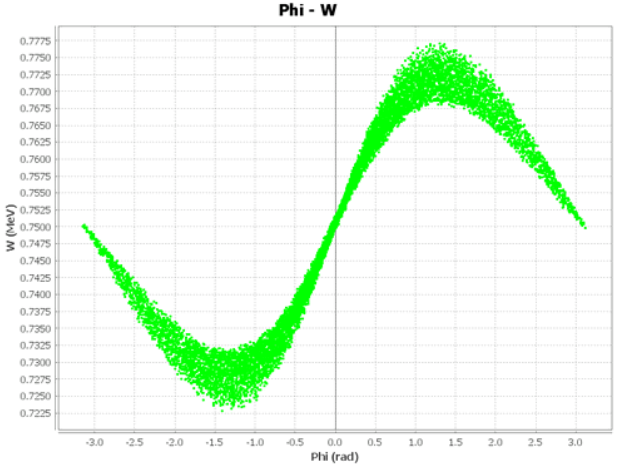
(End of Buncher – 45mA)

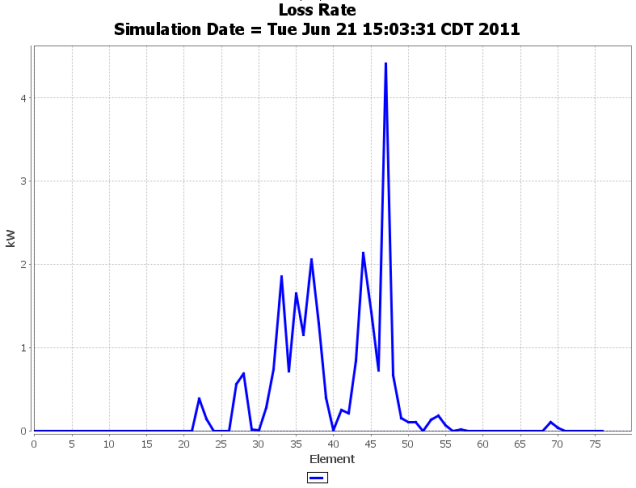






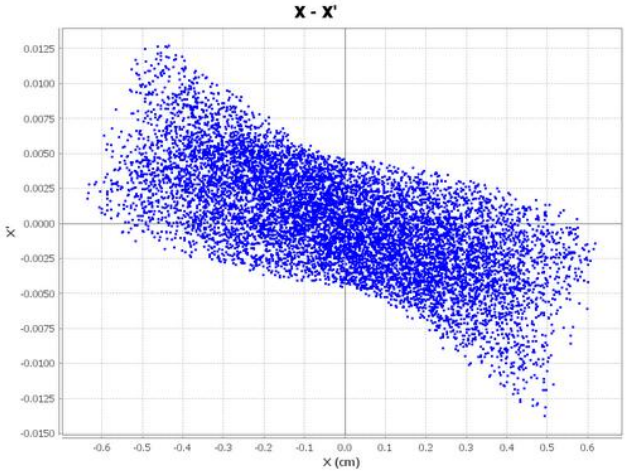


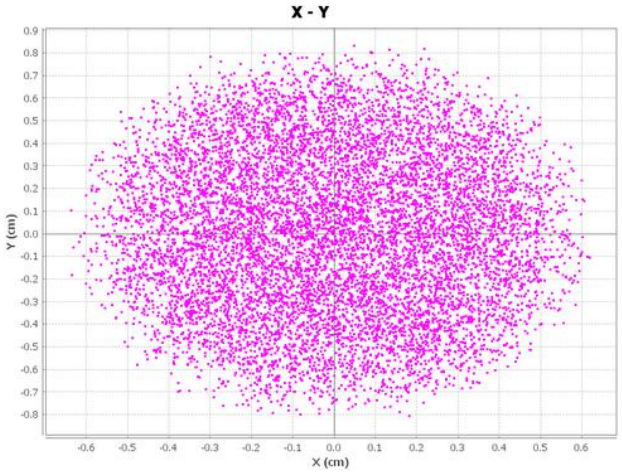


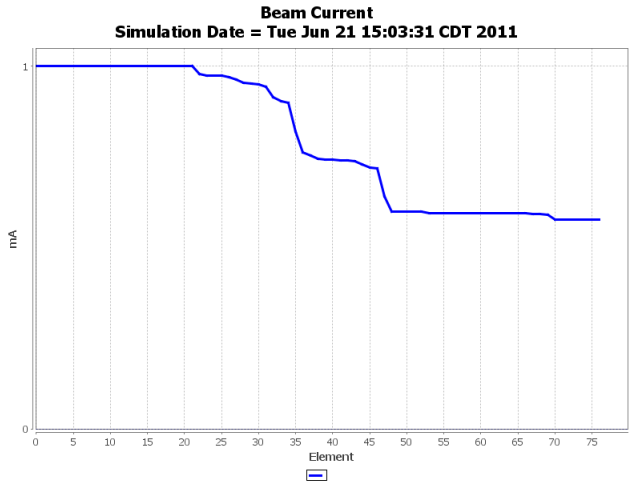


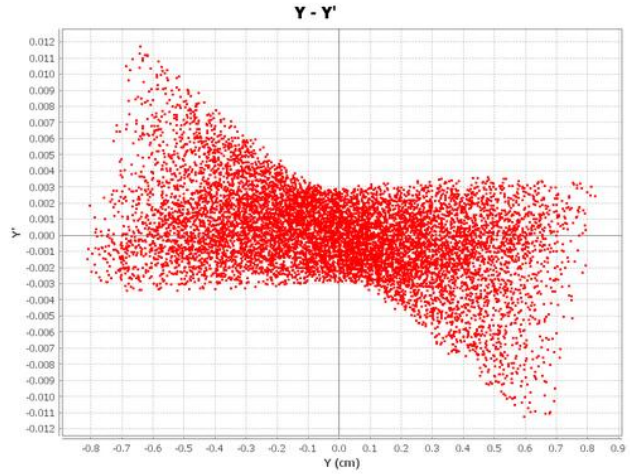
OnLine Linac Web Page Plots

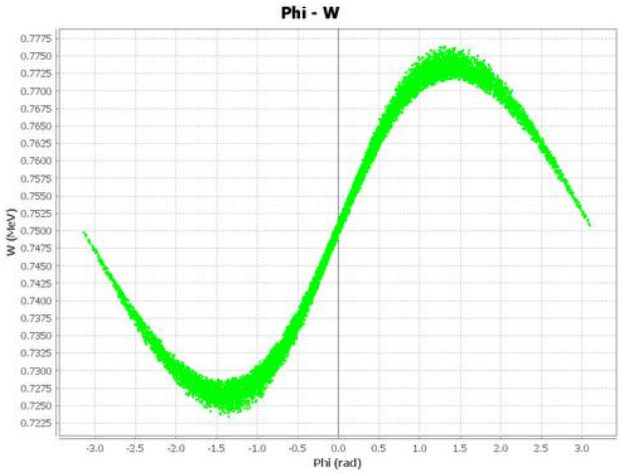
(End of Buncher – 1mA)

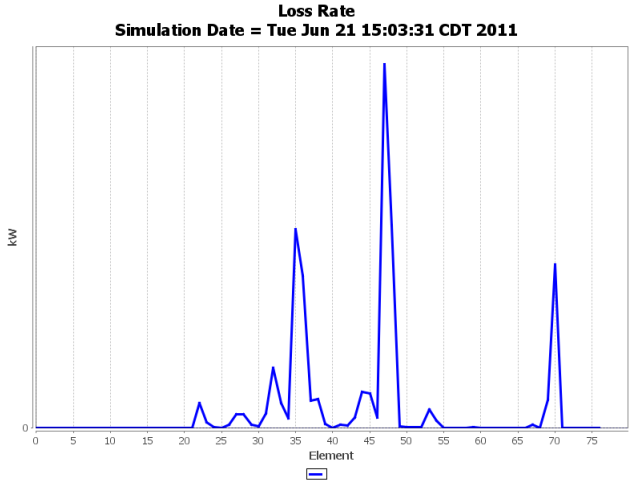




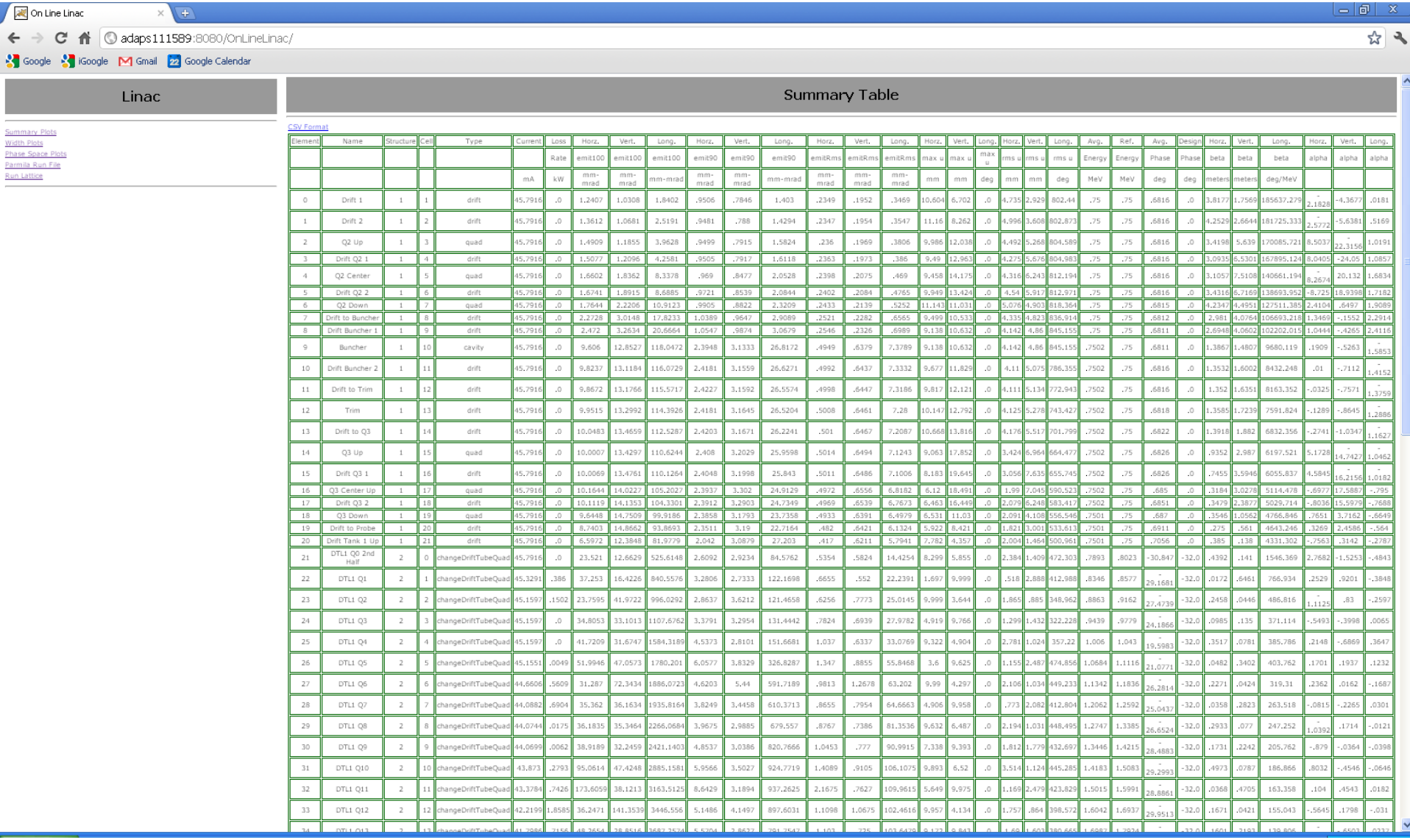








OnLine Linac Summary Table

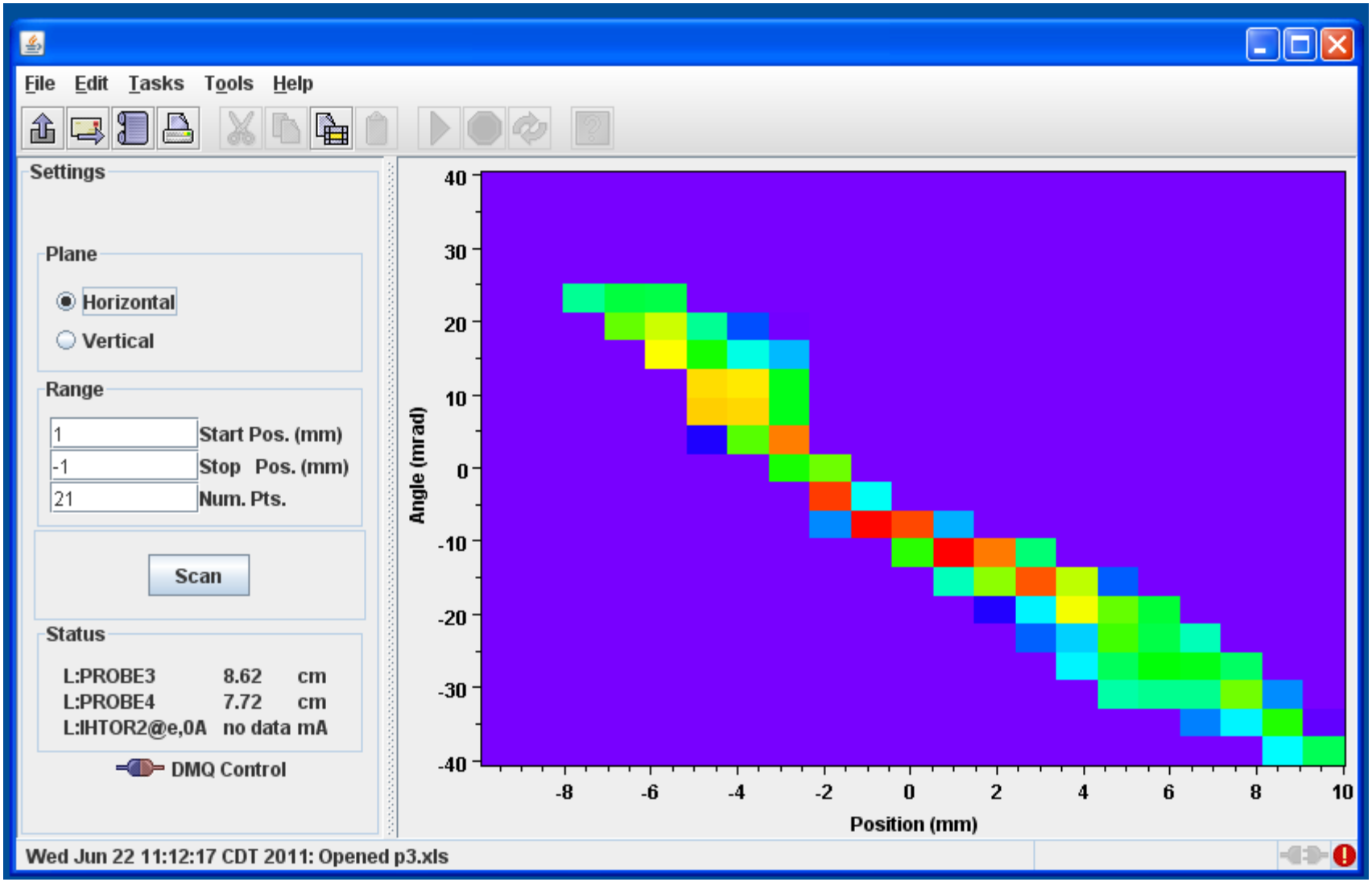


Element	Name	Structure	Cell	Type	Current	Loss	Horz.	Vert.	Long.	Horz.	Vert.	Long.	Horz.	Vert.	Long.	Horz.	Vert.	Long.	Horz.	Vert.	Long.	Avg.	Ref.	Avg.	Design	Horz.	Vert.	Long.	Horz.	Vert.	Long.
						Rate	emit100	emit100	emit100	emit90	emit90	emit90	emitRms	emitRms	emitRms	max u	max u	max u	rms u	rms u	rms u	Energy	Energy	Phase	Phase	beta	beta	beta	alpha	alpha	alpha
					mA	kW	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm-mrad	mm	mm	deg	mm	mm	deg	MeV	MeV	deg	deg	meters	meters	deg/MeV			
0	Drift 1	1	1	drift	45.7916	.0	1.2407	1.0308	1.8402	.9506	.7846	1.403	.2349	.1952	.3469	10.604	6.702	.0	4.735	2.929	802.44	.75	.75	.6816	.0	3.8177	1.7569	185637.279	-2.1828	-4.3677	.0181
1	Drift 2	1	2	drift	45.7916	.0	1.3612	1.0681	2.5191	.9481	.788	1.4294	.2347	.1954	.3547	11.16	8.262	.0	4.996	3.608	802.873	.75	.75	.6816	.0	4.2529	2.6644	181725.333	-2.5772	-5.6381	.5169
2	Q2 Up	1	3	quad	45.7916	.0	1.4909	1.1855	3.9628	.9499	.7915	1.5824	.236	.1969	.3806	9.986	12.038	.0	4.492	5.268	804.589	.75	.75	.6816	.0	3.4198	5.639	170085.721	8.5037	22.3156	1.0191
3	Drift Q2 1	1	4	drift	45.7916	.0	1.5077	1.2096	4.2581	.9505	.7917	1.6118	.2363	.1973	.386	9.49	12.963	.0	4.275	5.676	804.983	.75	.75	.6816	.0	3.0935	6.5301	167895.124	8.0405	-24.05	1.0857
4	Q2 Center	1	5	quad	45.7916	.0	1.6602	1.8362	8.3378	.969	.8477	2.0528	.2398	.2075	.469	9.458	14.175	.0	4.316	6.243	812.194	.75	.75	.6816	.0	3.1057	7.5108	140661.194	-8.2674	20.132	1.6834
5	Drift Q2 2	1	6	drift	45.7916	.0	1.6741	1.8915	8.6885	.9721	.8539	2.0844	.2402	.2084	.4765	9.949	13.424	.0	4.54	5.917	812.971	.75	.75	.6816	.0	3.4316	6.7169	138693.952	-8.725	18.9398	1.7182
6	Q2 Down	1	7	quad	45.7916	.0	1.7644	2.2206	10.9123	.9905	.8822	2.3209	.2433	.2139	.5252	11.143	11.031	.0	5.076	4.903	818.364	.75	.75	.6815	.0	4.2347	4.4951	127511.385	2.4104	.6497	1.9089
7	Drift to Buncher	1	8	drift	45.7916	.0	2.2728	3.0148	17.8233	1.0389	.9647	2.9089	.2521	.2282	.6565	9.499	10.533	.0	4.335	4.823	836.914	.75	.75	.6812	.0	2.981	4.0764	106693.218	1.3469	-.1552	2.2914
8	Drift Buncher 1	1	9	drift	45.7916	.0	2.472	3.2634	20.6664	1.0547	.9874	3.0679	.2546	.2326	.6989	9.138	10.632	.0	4.142	4.86	845.155	.75	.75	.6811	.0	2.6948	4.0602	102202.015	1.0444	-.4265	2.4116
9	Buncher	1	10	cavity	45.7916	.0	9.606	12.8527	118.0472	2.3948	3.1333	26.8172	.4949	.6379	7.3789	9.138	10.632	.0	4.142	4.86	845.155	.7502	.75	.6811	.0	1.3867	1.4807	9680.119	.1909	-.5263	-1.5853
10	Drift Buncher 2	1	11	drift	45.7916	.0	9.8237	13.1184	116.0729	2.4181	3.1559	26.6271	.4992	.6437	7.3332	9.677	11.829	.0	4.11	5.075	786.355	.7502	.75	.6816	.0	1.3532	1.6002	8432.248	.01	-.7112	-1.4152
11	Drift to Trim	1	12	drift	45.7916	.0	9.8672	13.1766	115.5717	2.4227	3.1592	26.5574	.4998	.6447	7.3186	9.817	12.121	.0	4.111	5.134	772.943	.7502	.75	.6816	.0	1.352	1.6351	8163.352	-.0325	-.7571	-1.3759
12	Trim	1	13	drift	45.7916	.0	9.9515	13.2992	114.3926	2.4181	3.1645	26.5204	.5008	.6461	7.28	10.147	12.792	.0	4.125	5.278	743.427	.7502	.75	.6818	.0	1.3585	1.7239	7591.824	-.1289	-.8645	-1.2886
13	Drift to Q3	1	14	drift	45.7916	.0	10.0483	13.4659	112.5287	2.4203	3.1671	26.2241	.501	.6467	7.2087	10.668	13.816	.0	4.176	5.517	701.799	.7502	.75	.6822	.0	1.3918	1.882	6832.356	-.2741	-1.0347	-1.1627
14	Q3 Up	1	15	quad	45.7916	.0	10.0007	13.4297	110.6244	2.408	3.2029	25.9598	.5014	.6494	7.1243	9.063	17.852	.0	3.424	6.964	664.477	.7502	.75	.6826	.0	.9352	2.987	6197.521	5.1728	-14.7427	-1.0462
15	Drift Q3 1	1	16	drift	45.7916	.0	10.0069	13.4761	110.1264	2.4048	3.1998	25.843	.5011	.6486	7.1006	8.183	19.645	.0	3.056	7.635	655.745	.7502	.75	.6826	.0	.7455	3.5946	6055.837	1.5845	-16.2156	-1.0182
16	Q3 Center Up	1	17	quad	45.7916	.0	10.1644	14.0227	105.2027	2.3937	3.302	24.9129	.4972	.6556	6.8182	6.12	18.491	.0	1.99	7.045	590.523	.7502	.75	.685	.0	.3184	3.0278	5114.478	-.6977	17.5887	-.795
17	Drift Q3 2	1	18	drift	45.7916	.0	10.1119	14.1353	104.3301	2.3912	3.2903	24.7349	.4969	.6539	6.7673	6.463	16.449	.0	2.079	6.248	583.417	.7502	.75	.6851	.0	.3479	2.3877	5029.714	-.8036	15.5979	-.7688
18	Q3 Down	1	19	quad	45.7916	.0	9.8448	14.7509	99.9186	2.3858	3.1793	23.7358	.4933	.6391	6.4979	6.531	11.03	.0	2.091	4.108	556.546	.7501	.75	.687	.0	.3546	1.0562	4766.846	.7651	3.7162	-.6649
19	Drift to Probe	1	20	drift	45.7916	.0	8.7403	14.8662	93.8693	2.3511	3.19	22.7164	.482	.6421	6.1324	5.922	8.421	.0	1.821	3.001	533.613	.7501	.75	.6911	.0	.275	.561	4643.246	.3269	2.4586	-.564
20	Drift Tank 1 Up	1	21	drift	45.7916	.0	6.5972	12.3848	81.9779	2.042	3.0879	27.203	.417	.6211	5.7941	7.782	4.357	.0	2.004	1.464	500.961	.7501	.75	.7056	.0	.385	.138	4331.302	-.7563	.3142	-.2787
21	DTL1 Q0 2nd Half	2	0	changeDriftTubeQuad	45.7916	.0	23.521	12.6629	525.6148	2.6092	2.9234	84.5762	.5354	.5824	14.4254	8.299	5.855	.0	2.384	1.409	472.303	.7893	.8023	-30.847	-32.0	.4392	.141	1546.369	2.7682	-1.5253	-.4843
22	DTL1 Q1	2	1	changeDriftTubeQuad	45.3291	.386	37.253	16.4226	840.5576	3.2806	2.7333	122.1698	.6655	.552	22.2391	1.697	9.999	.0	.518	2.888	412.988	.8346	.8577	-29.1681	-32.0	.0172	.6461	766.934	.2529	.9201	-.3848
23	DTL1 Q2	2	2	changeDriftTubeQuad	45.1597	.1502	23.7595	41.9722	996.0292	2.8637	3.6212	121.4658	.6256	.7773	25.0145	9.999	3.644	.0	1.865	.885	348.962	.8863	.9162	-27.4739	-32.0	.2458	.0446	486.816	-1.1125	.83	-.2597
24	DTL1 Q3	2	3	changeDriftTubeQuad	45.1597	.0	34.8053	33.1013	1107.6762	3.3791	3.2954	131.4442	.7824	.6939	27.9782	4.919	9.766	.0	1.299	1.432	322.228	.9439	.9779	-24.1866	-32.0	.0985	.135	371.114	-.5493	-.3998	.0065
25	DTL1 Q4	2	4	changeDriftTubeQuad	45.1597	.0	41.7209	31.6747	1584.3189	4.5373	2.8101	151.6681	1.037	.6337	33.0769	9.322	4.904	.0	2.781	1.024	357.22	1.006	1.043	-19.5983	-32.0	.3517	.0781	385.786	.2148	-.6869	.3647
26	DTL1 Q5	2	5	changeDriftTubeQuad	45.1551	.0049	51.9946	47.0573	1780.201	6.0577	3.8329	326.8287	1.347	.8855	55.8468	3.6	9.625	.0	1.155	2.487	474.856	1.0684	1.1116	-21.0771	-32.0	.0482	.3402	403.762	.1701	.1937	.1232
27	DTL1 Q6	2	6	changeDriftTubeQuad	44.6606	.5609	31.287	72.3434	1886.0723	4.6203	5.44	591.7189	.9813	1.2678	63.202	9.99	4.297	.0	2.106	1.034	449.233	1.1342	1.1836	-26.2814	-32.0	.2271	.0424	319.31	.2362	.0162	-.1687
28	DTL1 Q7	2	7	changeDriftTubeQuad	44.0882	.6904	35.362	36.1634	1935.8164	3.8249	3.4458	610.3713	.8655	.7954	64.6663	4.906	9.958	.0	.773	2.082	412.804	1.2062	1.2592	-25.0437	-32.0	.0358	.2823	263.518	-.0815	-.2265	.0301
29	DTL1 Q8	2	8	changeDriftTubeQuad	44.0744	.0175	36.1835	35.3464	2266.0684	3.9675	2.9885	679.557	.8767	.7386	81.3536	9.632	6.487	.0	2.194	1.031	448.495	1.2747	1.3385	-26.6524	-32.0	.2933	.077	247.252	-1.0392	.1714	-.0121
30	DTL1 Q9	2	9	changeDriftTubeQuad	44.0699	.0062	38.9189	32.2459	2421.1403	4.8537	3.0386	820.7666	1.0453	.777	90.9915	7.338	9.393	.0	1.812	1.779	432.697	1.3446	1.4215	-28.4883	-32.0	.1731	.2242	205.762	-.879	-.0364	-.0398
31	DTL1 Q10	2	10	changeDriftTubeQuad	43.873	.2793	95.0614	47.4248	2885.1581	5.9566	3.5027	924.7719	1.4089	.9105	106.1075	9.893	6.52	.0	3.514	1.124	445.285	1.4183	1.5083	-29.2993	-32.0	.4973	.0787	186.866	.8032	-.4546	-.0646
32	DTL1 Q11	2	11	changeDriftTubeQuad	43.3784	.7426	173.6059	38.1213	3163.5125	8.6429	3.1894	937.2625	2.1675	.7627	109.9615	5.649	9.975	.0	1.169	2.479	423.829	1.5015	1.5991	-28.8861	-32.0	.0368	.4705	163.358	.104	.4543	.0182
33	DTL1 Q12	2	12	changeDriftTubeQuad	42.2199	1.8585	36.2471	141.3539	3446.556	5.1486	4.1497	897.6031	1.1098	1.0675	102.4616	9.957	4.134	.0	1.757	.864	398.572	1.6042	1.6937	-29.9513	-32.0	.1671	.0421	155.043	-.5645	.1798	-.031
34	DTL1 Q13	2	13	changeDriftTubeQuad	41.2986	.7156	48.2654	28.8516	3682.3574	5.5704	2.8627	791.7547	1.403	.775	103.6478	8.172	9.843	.0	1.69	1.603	380.669	1.6983	1.7834	-31.0	-32.0	.1601	.3193	139.806	-.5503	.6503	.0232

750 keV Line Emittance Probe Data Acquisition Application

- Model is useless unless it can be verified with real data
- There are emittance probes for both planes located immediately upstream of Tank 1
  - 20 wires per probe with an angular resolution of 4 mrad
  - Read-out and probe control are connected to ACNET
  - Currently a manual application program exits but requires a fair amount with user intervention and setup
- Developed a Java application program to make rapid automatic scans
  - using the new DMQ interface (A. Petrov)
  - uses the standard Fermilab Controls Dept. Java Swing framework
  - Scans take about 2 minutes per plane
    - Should be able to speed up to 1 min /scan
  - Data saved in tab delimited ASCI format (for Excel users) with time stamps for use in analysis

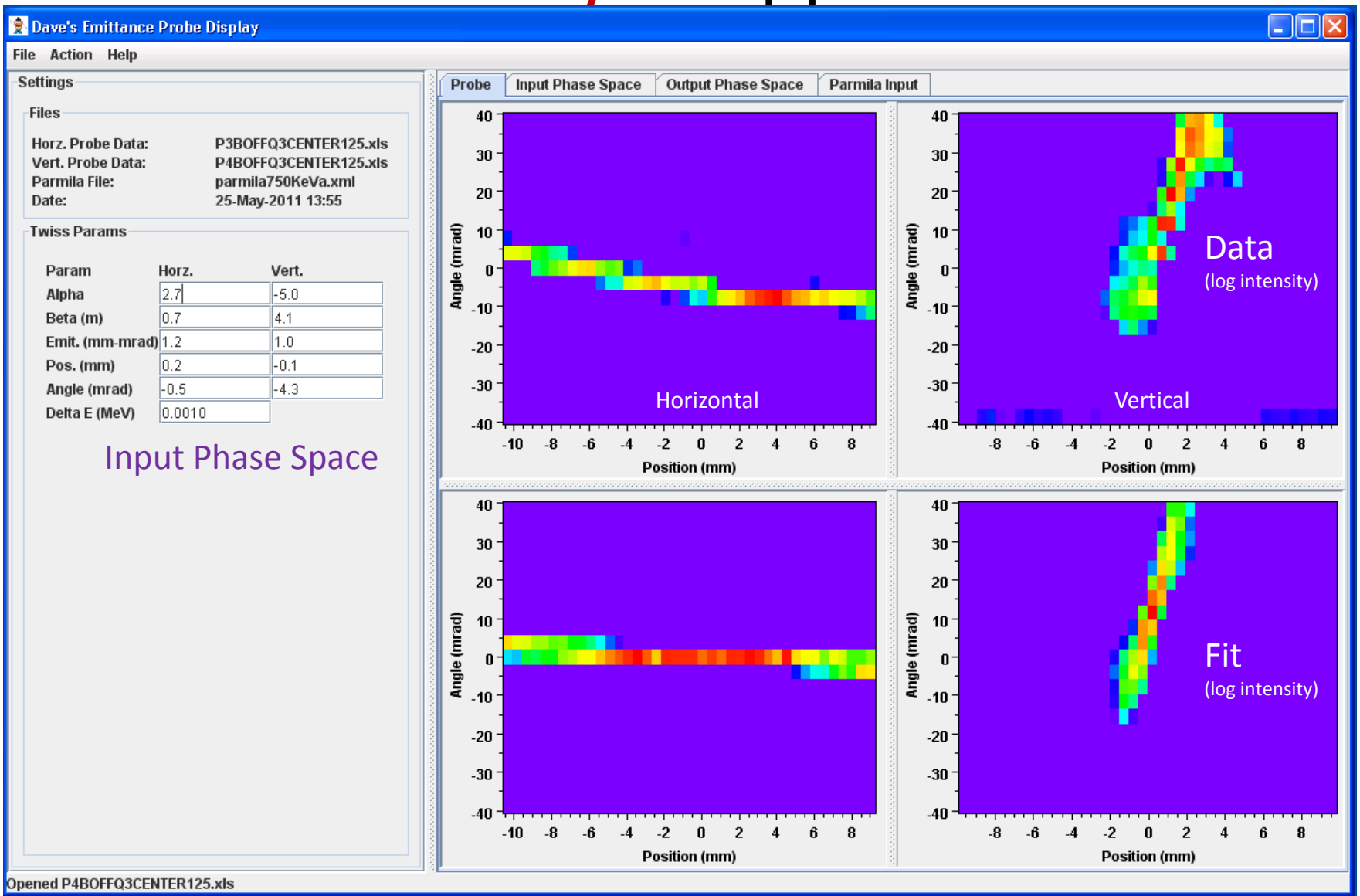
750 keV Line Emittance Probe Data Acquisition Application



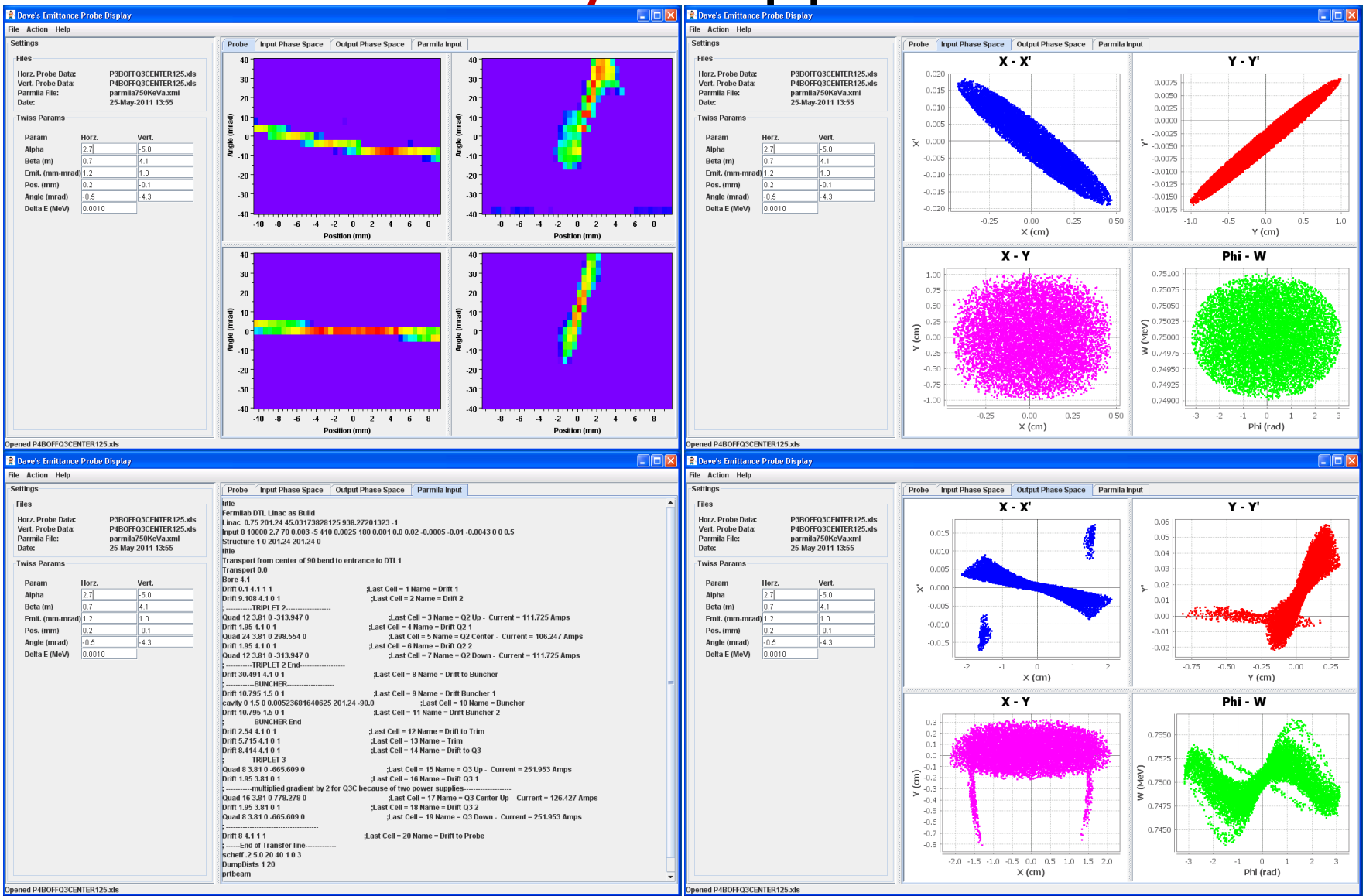
750 keV Line Emittance Probe Data Analysis Application

- The emittance probe data not only depends on the quad currents in the 750 keV line but requires knowledge of the input phase space from the source
- A set of applications were developed to fit the input phase space to the probe data
  - Reads raw emittance probe data from the 750 keV Line Emittance Probe Data Acquisition Application and displays it
  - Reads in XML Parmila Interface file
    - Reads data logged quad currents
    - displays simulation of emittance probe
  - Displays input and output phase space
  - Displays raw Parmila file

750 keV Line Emittance Probe Data Analysis Application



750 keV Line Emittance Probe Data Analysis Application



Emittance Probe Fitter

- Since there are 11 variables that describe the input phase space and one emittance probe,

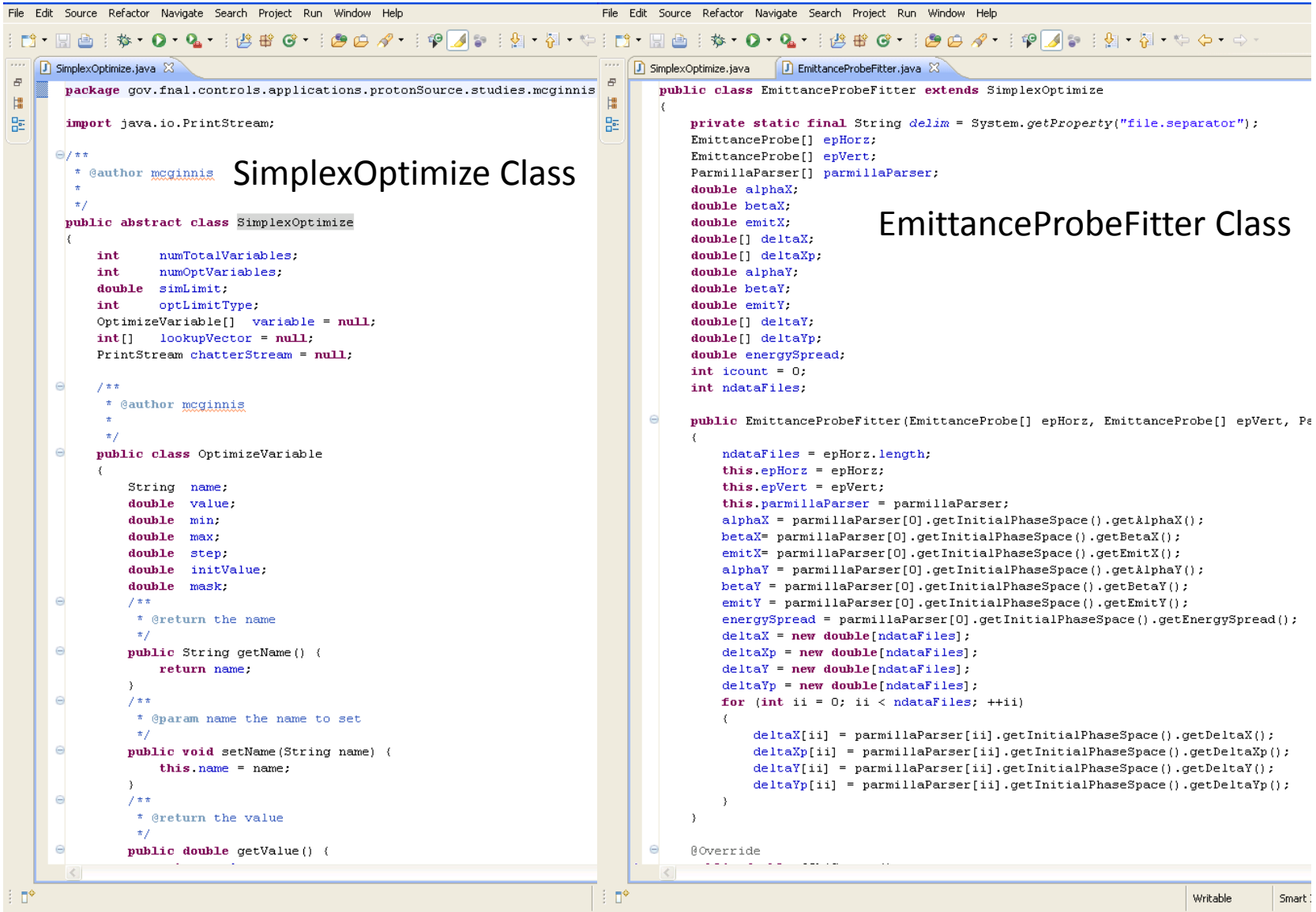
$$\alpha_x, \beta_x, \varepsilon_x, \alpha_y, \beta_y, \varepsilon_y, \delta x, \delta x', \delta y, \delta y', \delta W$$

- One lattice (or set of quad currents) does not provide enough constraints to uniquely fit the input phase space
- Making multiple emittance probe measurements
  - with the same input phase space
  - but different lattices (sets of quad currents)
- Would constrain the determination of the input phase space much better

Emittance Probe Fitter

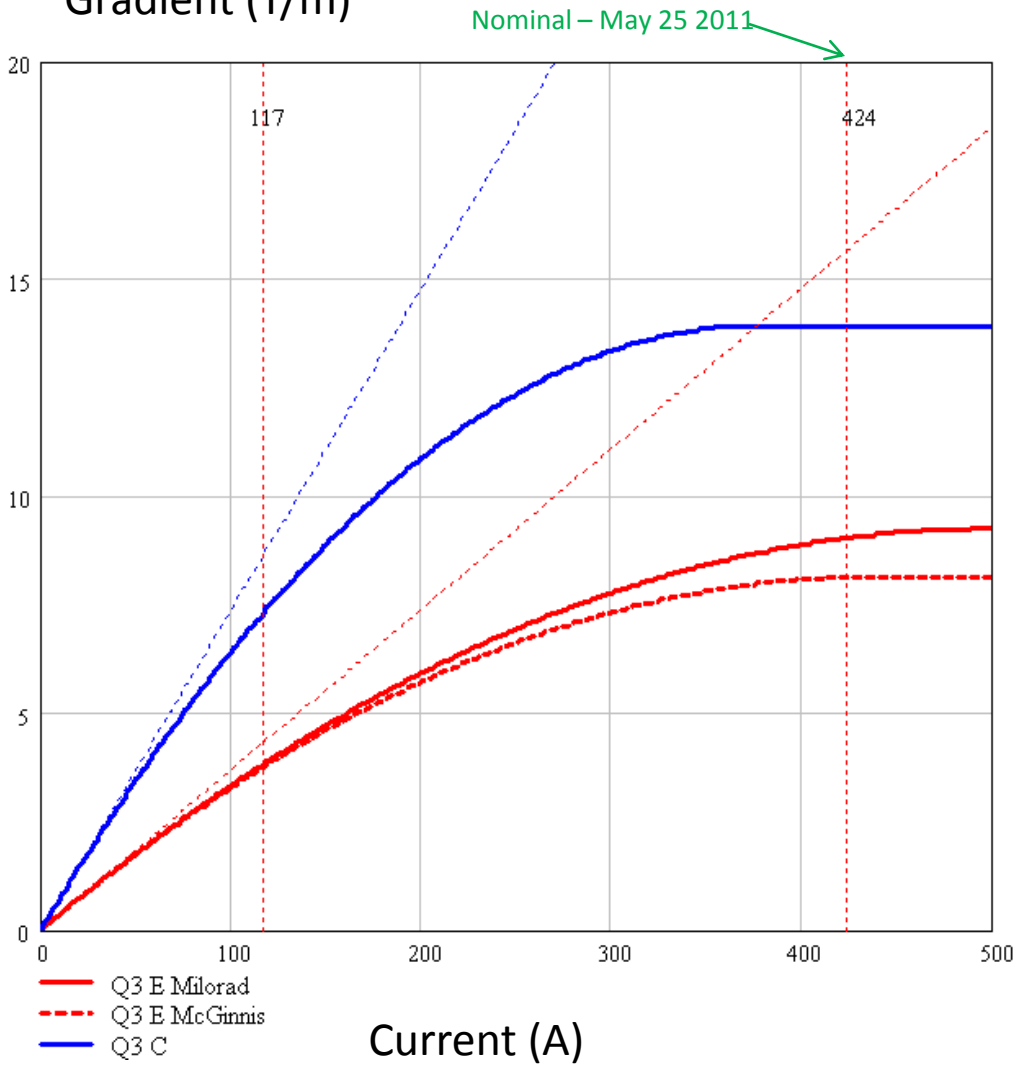
- Fitting by hand would take a long time, if ever, to converge
- An abstract Java class was developed based on the “SIMPLEX” minimization algorithm that can be used for any optimization problem
- The SimplexOptimize Java class is extended to EmittanceProbeFitter class
  - to fit a number emittance probe measurements
  - With different lattices
  - For the same input phase space

SimplexOptimize Abstract Java Class



Q3 Saturation

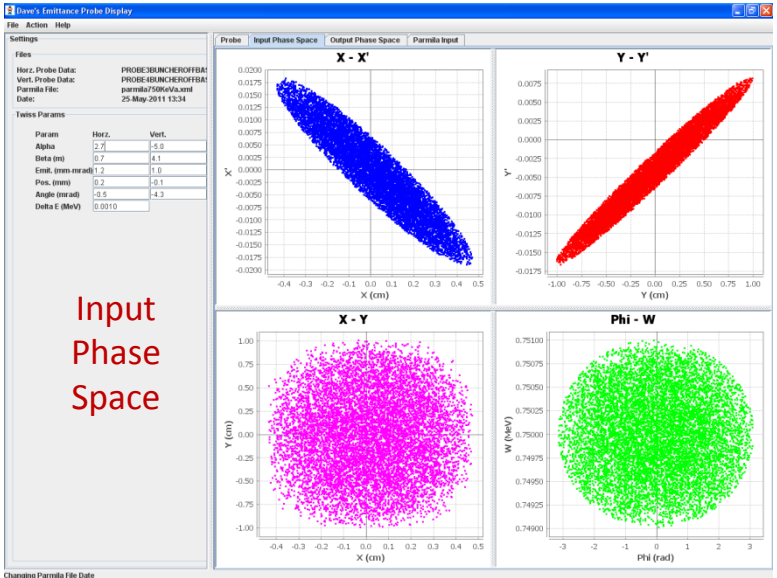
- One issue the analysis has to deal with is that the Q3 triplets are run very hard into saturation
- The XML Parmila interface handles this complication with a user-defined polynomial fits to the excitation curves

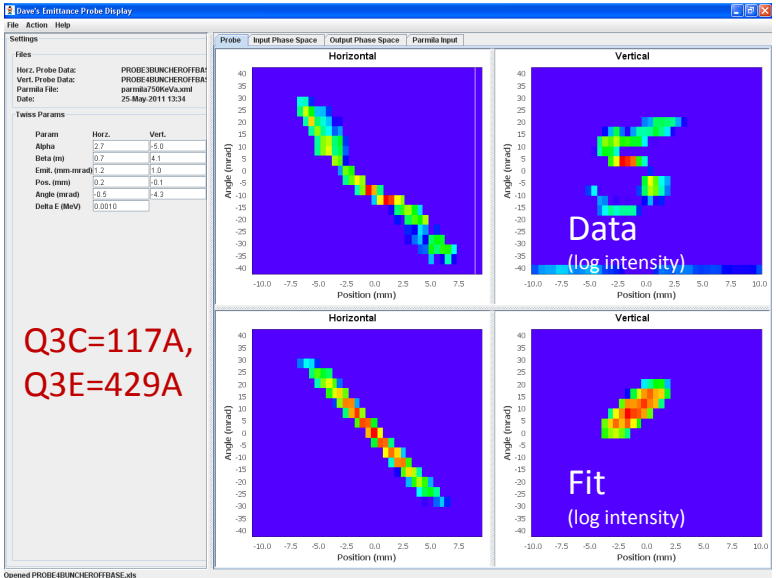


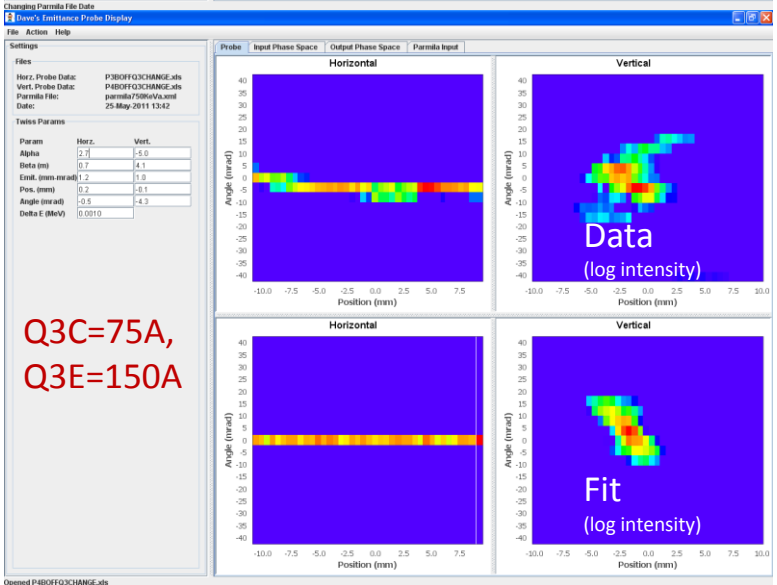
*Data from C. Schmidt

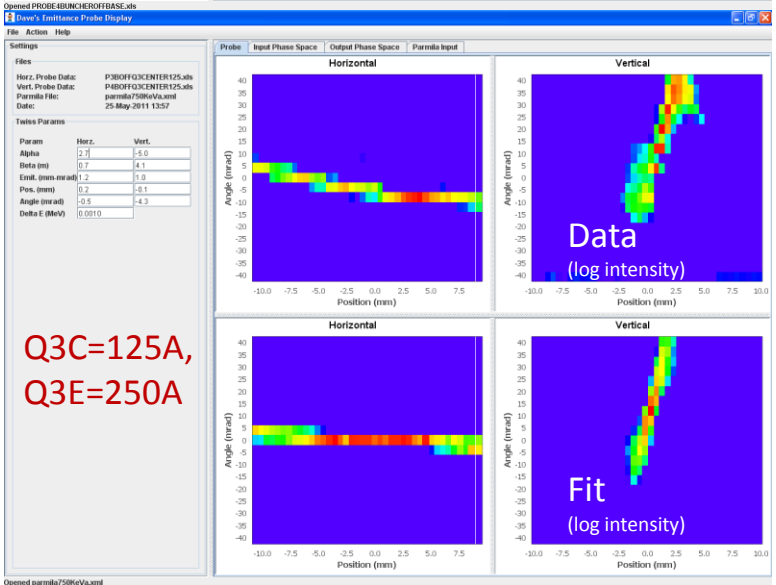
Emittance Fit Optimization Results

(May 25 2011)



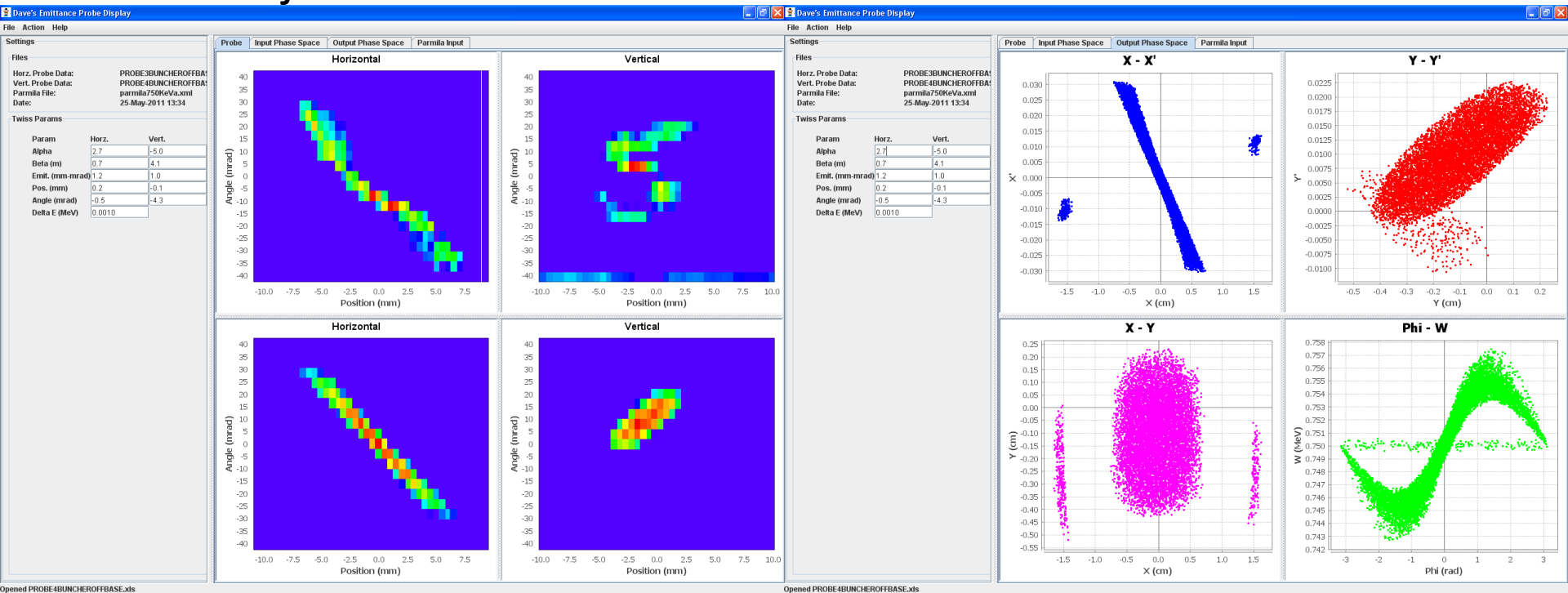






Scraping

- Both Data and Model show evidence of scraping
- To match scraping, need to have more accurate knowledge of:
  - aperture
  - trajectories



Tank 1 Model

parmila.xml | wholeLinac.txt | parmilaTank1Max062111.xml

```
        <Element type="drift" length="19.5" radialAperture="38.1" nSpaceChargePulses="1" outputFlag="false" name="Drift Q3 2" />
        <Element type="quad" length="80.0" radialAperture="38.1" gradient1="-3.7e-2" gradient2="+4.2e-5" current="L:QTM3E" logger="Linac" logInt="4"  outputFlag="true" name="Q3 Down" />
        <Element type="comment" text="-------------------------------------" />
        <Element type="drift" length="80" radialAperture="41" nSpaceChargePulses="1" outputFlag="true" name="Drift to Probe" />
        <Element type="drift" length="167" radialAperture="41" nSpaceChargePulses="1" outputFlag="true" name="Drift Tank 1 Up" />
        <Element type="comment" text="------End of Transfer line-------------" />
        <Element type="scheff" deltaR=".2" deltaZ="5.0" nr="20" nz="40" nbunch="1" nbetalambda="0" remesh="3" />
    </Structure>
    <Structure title="FNALasBuild DTL#1 57mA, by M.Popovic" type="driftTube" id="2" nlast="56" harmonic="1" deltaPhi="-32.0" boreRadius="41" >
        <Element type="driftTube" outputFlag="false"  name="Drift Tube 1"
            ntank="1"   Wfinal="10.25" phiS="-32.0" Eo="1.6"    Ctilt="0.000592" EOMax="2.31" Dz="0.0"    Dphi="0.0" CO="2.275" Cl="0.0"
            QL="3.454"  lat="1"        Qstart="1"   QEnd="11"  Dze="0.0"        Rb1="1.0"    Rb2="1.25"  NNBR="19"  Pmax="0"
            NBlam="1"   Rtype="0"      DNphi="0"    Nstart="0" Nend="0"         phiSmax="0"  numCells="56"  >
            <SFDataLine Beta="0.03996" T="0.63762" TP="0.08721" S="0.55225" SP="0.03649" gbl="0.21346" Z="65.18799" EEO="1" Tave="0.63762" dZctr="0" />
            <SFDataLine Beta="0.04133" T="0.65021" TP="0.08545" S="0.54739" SP="0.03817" gbl="0.21480" Z="65.58824" EEO="1" Tave="0.65021" dZctr="0" />
            <SFDataLine Beta="0.04274" T="0.66236" TP="0.08370" S="0.54256" SP="0.03978" gbl="0.21617" Z="65.98097" EEO="1" Tave="0.66236" dZctr="0" />
            <SFDataLine Beta="0.04418" T="0.67400" TP="0.08197" S="0.53777" SP="0.04130" gbl="0.21758" Z="66.36953" EEO="1" Tave="0.67400" dZctr="0" />
            <SFDataLine Beta="0.04565" T="0.68511" TP="0.08026" S="0.53304" SP="0.04272" gbl="0.21901" Z="66.75761" EEO="1" Tave="0.68511" dZctr="0" />
            <SFDataLine Beta="0.04715" T="0.69567" TP="0.07857" S="0.52838" SP="0.04405" gbl="0.22047" Z="67.14766" EEO="1" Tave="0.69567" dZctr="0" />
            <SFDataLine Beta="0.04868" T="0.70567" TP="0.07691" S="0.52381" SP="0.04528" gbl="0.22196" Z="67.54117" EEO="1" Tave="0.70567" dZctr="0" />
            <SFDataLine Beta="0.05024" T="0.71510" TP="0.07528" S="0.51934" SP="0.04641" gbl="0.22347" Z="67.93866" EEO="1" Tave="0.71510" dZctr="0" />
            <SFDataLine Beta="0.05182" T="0.72395" TP="0.07370" S="0.51497" SP="0.04745" gbl="0.22501" Z="68.33956" EEO="1" Tave="0.72395" dZctr="0" />
            <SFDataLine Beta="0.05343" T="0.73223" TP="0.07215" S="0.51073" SP="0.04840" gbl="0.22658" Z="68.74254" EEO="1" Tave="0.73223" dZctr="0" />
            <SFDataLine Beta="0.05506" T="0.73996" TP="0.07065" S="0.50662" SP="0.04925" gbl="0.22817" Z="69.14523" EEO="1" Tave="0.73996" dZctr="0" />
            <SFDataLine Beta="0.05672" T="0.74713" TP="0.06920" S="0.50266" SP="0.05001" gbl="0.22978" Z="69.54439" EEO="1" Tave="0.74713" dZctr="0" />
            <SFDataLine Beta="0.05840" T="0.75378" TP="0.06780" S="0.49885" SP="0.05069" gbl="0.23142" Z="69.93581" EEO="1" Tave="0.75378" dZctr="0" />
            <SFDataLine Beta="0.05957" T="0.75806" TP="0.06687" S="0.49632" SP="0.05111" gbl="0.23256" Z="70.19853" EEO="1" Tave="0.75806" dZctr="0" />
```

DTL Structure

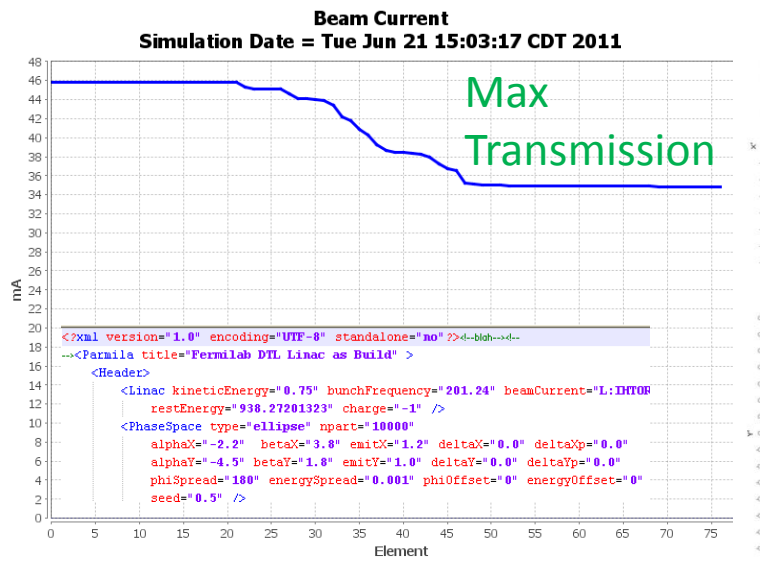
Cell Gap Table

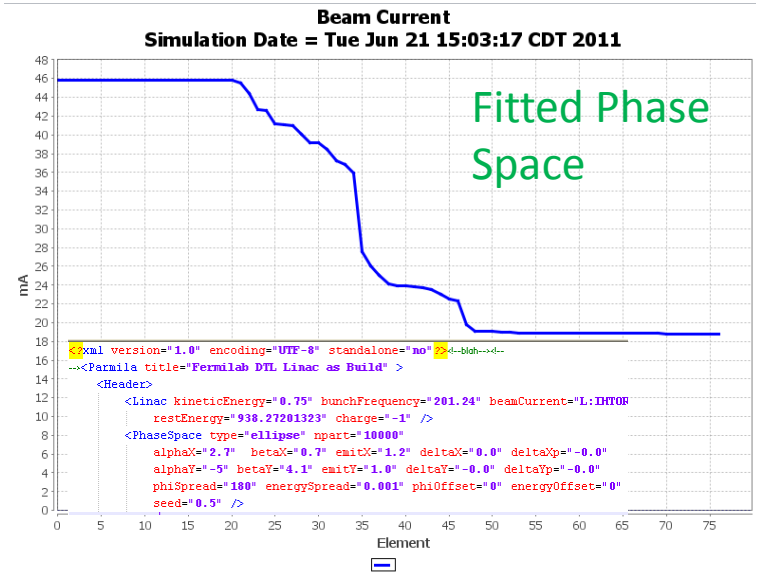
```
            <SFDataLine Beta="0.12909" T="0.80730" TP="0.05608" S="0.47721" SP="0.05766" gbl="0.29359" Z="74.04469" EEO="1" Tave="0.80730" dZctr="0" />
            <SFDataLine Beta="0.13137" T="0.80717" TP="0.05614" S="0.47796" SP="0.05780" gbl="0.29554" Z="74.07244" EEO="1" Tave="0.80717" dZctr="0" />
            <SFDataLine Beta="0.13366" T="0.80700" TP="0.05623" S="0.47878" SP="0.05795" gbl="0.29750" Z="74.08621" EEO="1" Tave="0.80700" dZctr="0" />
            <SFDataLine Beta="0.13598" T="0.80680" TP="0.05635" S="0.47967" SP="0.05811" gbl="0.29948" Z="74.08439" EEO="1" Tave="0.80680" dZctr="0" />
            <SFDataLine Beta="0.13831" T="0.80659" TP="0.05649" S="0.48062" SP="0.05828" gbl="0.30147" Z="74.06527" EEO="1" Tave="0.80659" dZctr="0" />
            <SFDataLine Beta="0.14066" T="0.80639" TP="0.05666" S="0.48162" SP="0.05846" gbl="0.30346" Z="74.02707" EEO="1" Tave="0.80639" dZctr="0" />
            <SFDataLine Beta="0.14303" T="0.80621" TP="0.05685" S="0.48267" SP="0.05866" gbl="0.30547" Z="73.96795" EEO="1" Tave="0.80621" dZctr="0" />
            <SFDataLine Beta="0.14541" T="0.80607" TP="0.05707" S="0.48376" SP="0.05888" gbl="0.30749" Z="73.88602" EEO="1" Tave="0.80607" dZctr="0" />
            <Element type="changeDriftTubeQuad" cell="0" length="17.272" radialAperture="20" gradient="0.436" current="L:QPS101" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q0 2nd Half" />
            <Element type="changeDriftTubeQuad" cell="1" length="34.544" radialAperture="20" gradient="-0.436" current="L:QPS102" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q1" />
            <Element type="changeDriftTubeQuad" cell="2" length="34.544" radialAperture="20" gradient="0.436" current="L:QPS103" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q2" />
            <Element type="changeDriftTubeQuad" cell="3" length="34.544" radialAperture="20" gradient="-0.436" current="L:QPS103" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q3" />
            <Element type="changeDriftTubeQuad" cell="4" length="34.544" radialAperture="20" gradient="0.436" current="L:QPS104" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q4" />
            <Element type="changeDriftTubeQuad" cell="5" length="34.544" radialAperture="20" gradient="-0.436" current="L:QPS104" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q5" />
            <Element type="changeDriftTubeQuad" cell="6" length="34.544" radialAperture="20" gradient="0.436" current="L:QPS105" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q6" />
            <Element type="changeDriftTubeQuad" cell="7" length="34.544" radialAperture="20" gradient="-0.436" current="L:QPS105" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q7" />
            <Element type="changeDriftTubeQuad" cell="8" length="40.9" radialAperture="20" gradient="0.436" current="L:QPS106" logger="Lina2" logInt="4" outputFlag="false" name="DTL1 Q8" />
```

Quad Table

eXtensible Markup Language file | length : 23826 lines : 166 | Ln : 1 Col : 1 Sel : 0 | Dos\Windows | ANSI as UTF-8 | INS

Tank 1 Simulation Results





Future Work

- Get working model of Tank 1
  - Is there something wrong with the lattice descriptions?
  - Is there something wrong with the emittance probe?
  - Is there something wrong with Tank 1?
- Tackle this with one-bump studies
  - 1. Take reference position measurements (probe and/or bpm)
  - 2. Adjust trim and take position measurements
  - 3. Repeat Steps 1-2 with different quad settings
  - 4. Compare to model

Future-Future Work

- Remove (minimize) Quad Steering from 750keV line and Tank 1.
- Determine optimum position and angle into and out of Tank 1
- Determine optimum phase space into Tank 1
- Develop “lattice based” operations
  - Set positions with orbit steering
  - Set quads for input phase space
  - Adjust with small tweeks (and update new optimum conditions)
- Understand Tank 1 Phase Scan

Future, Future, Future Work

- Get and verify complete on-line model of Linac
- Develop “lattice based” operations for entire linac
  - Set positions with orbit steering
  - Set quads for optimum lattice
  - Adjust with small tweeks (and update new optimum conditions)
- Revisit phase-scans verify gradient settings of the Linac

Summary

- Developed framework for an on-line mode of the Fermilab Linac using XML and Parmila
- Developed Linac Model web interface
- Developed 750 keV Line Emittance Probe Data Acquisition Application
- Developed 750 keV Line Emittance Probe Data Analysis Application
- Develop optimization framework for fitting source phase space
- Developed initial on-line lattice models.