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)

Dave McGinnis, “LinacLattice Studies”, 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 code
- Parmila - simulation “engine”
- Advantages
  - –Mature program
  - –Used to design Fermilab Linac => it can handle FNAL Linac
- Disadvantages
- –Old program
- –Horrible user interface

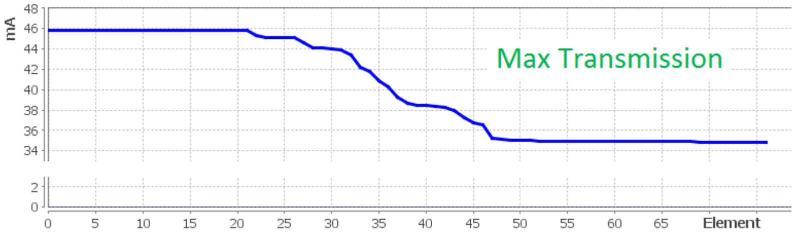
My (VK) comments:
agree ; doubtful

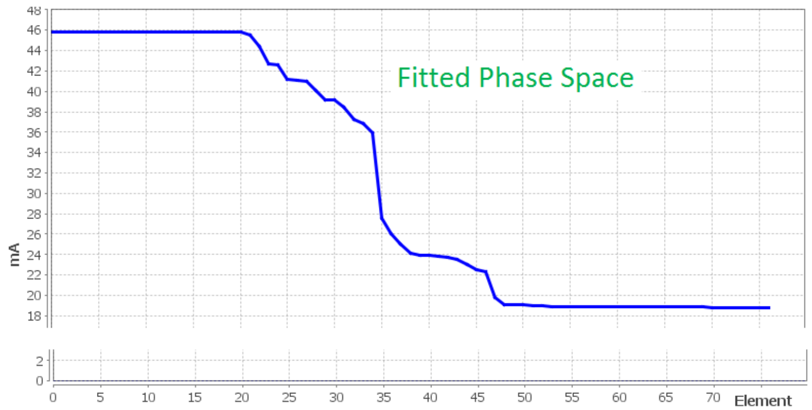
McGinnis, “LinacLattice Studies”, 2011 (cont-ed)

“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

Tank 1 Sumulation Results





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

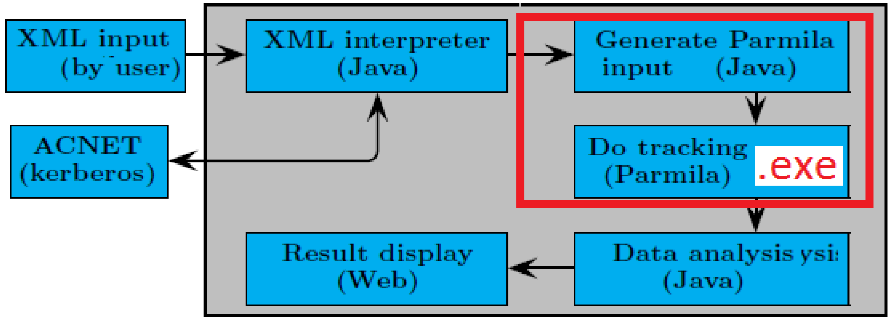
  - Upgrade Dave's Java code

  - beam measurements & compare them with simulation

Parmila input of Tank 1-5 is based on Milorad's work [Fermilab-TM-2245].

Parmila is tracking tool:

- Parmila is a mature program and used to design Fermilab linac.



VK: Used Parmila-code (~200x) is distributed as EXE-file by LANL

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

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

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

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 is a part of the XAL application programming framework developed at SNS	both envelope & single part. tracking. **Algorithms - borrowed from TRACE 3-D (sp.-ch) &PARMILA (RF gaps).**
TRACE 3-D tracks the envelopes	Linear sp-ch; used at early stages of SNS-project
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.

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 !**

Particulary, 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.

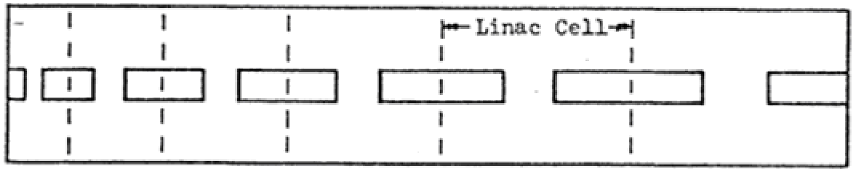
VERSIONS PARMILA has been distributed worldwide over the course of time, and it is likely that the code has experienced many modifications producing many versions. This paper describes the Los Alamos Group AT-6 version. The closest other version, Los Alamos Group AT-1, was the source of the AT-6 version 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.

Modern (~1996) “PARMILA ver. 2” Los Alamos Accelerator Code Group (LAACG):
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



Alvarez linac (DTL) is series of linac cells; **MESSYMESH** "MM" (later **SUPERFISH**) calculates e/m parameters of the linac cell, output RF-field **TTF**s: T, T', S, S', e.g.

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

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

PARMILA works in **two steps**:

1. DT **cell-by-cell generation** vis interation procedures:
   a) GENLIN with the **COFT**-input: TTFs as a quartic polynomials in β_g (only in old versions);
   b) GENLIN2 with **SFDATA**-input: TTF values for a given β_g interpolated for current β-value
2. **Particle tracking** in generated structure: particle coordinates transformed throughout the cells using the interpolated input **TTF**s.

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

Why So Archaic ?

"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

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

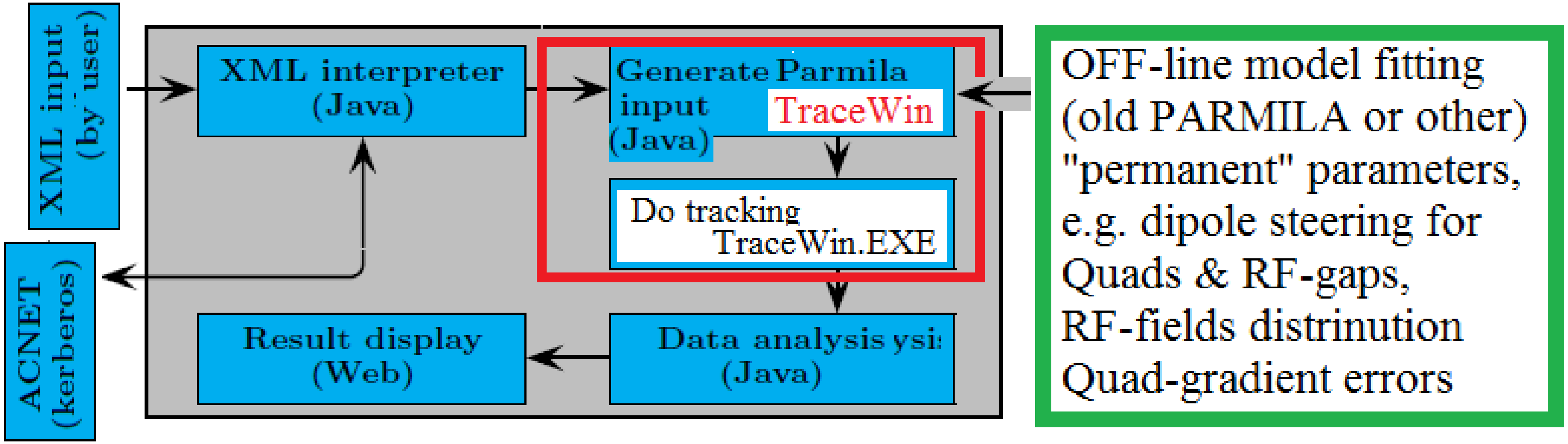
Old PARMILA-1 versions:
some **useful features of original PARMILA** had been removed in 1980-x, e.g.,
steering magnets in drift-tube quadrupoles & quadrupole misalignments

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 ?)

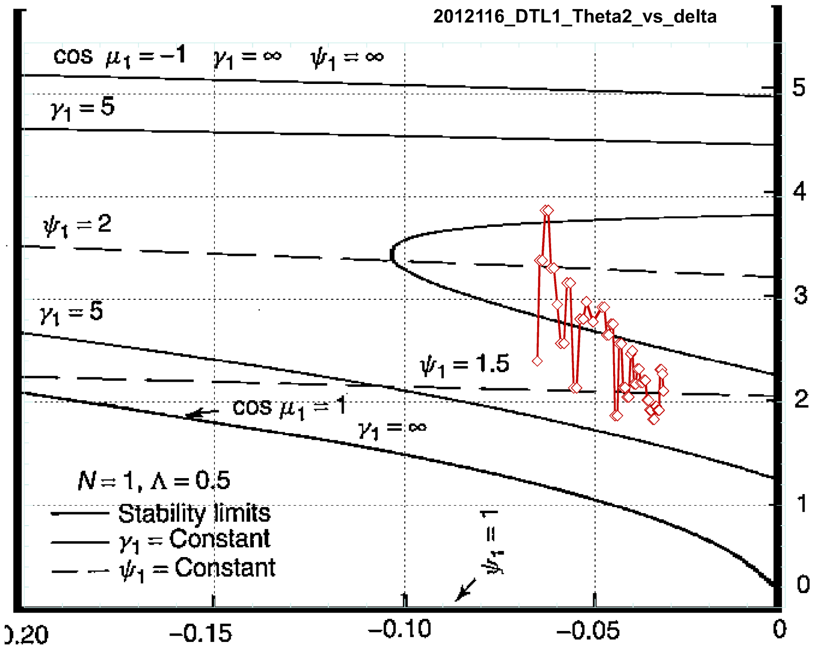
Available linac lattices for FNAL DTL by 2013

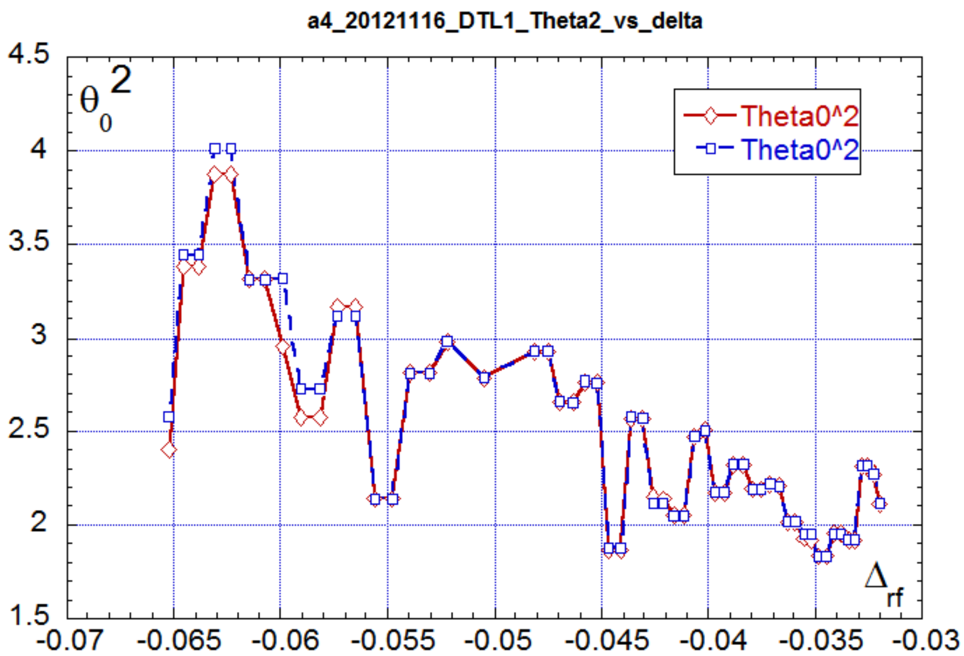
name	File - name	Origin	Parm ver.	TTFs	Comments
FG01	parmilaWhole Linac.lin	J.Stovall (LANL) -> MP(2004) -> D.MG->Kim -> FG	2.35, 2005	SFDATA mixture MM, and non-MM, MPxls (dtl5); Bugs!: TP=S(dtl2); TP<->(dtl5)	DTL1_Tr82%
FG01a	parmila.lin				DTL1_Tr40% Diff. Q-grads
MP01	Whole Linac.txt	from MP comp. MP -> VK	New Parmila on PC ~2004	SFDATA Mixture MM, MPxls	Constructed by M. Popovic, 8-Nov-03 (Bug TP beta=0.1465)
MP01a	Tank1 Linac.txt				
MP02	Hi-dtl.txt		2.33, 2004		
MPrep	Fermilab-TM-2245	Published copy		COFT=>SFDATA	Bug!: the same COFT tables Tank1-a, Tank2-5
MPxls	sfdatat1.xls	from MP comp. MP -> VK		COFT=>SFDATA	Converting coft=>sfdata for “MPrep"
MP03	Lin5in.dat	from MP comp. MP -> VK	“vax-version”	COFT differ from MPrep	Actually UNIX-version

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.recomended 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

C. D. CURTIS, R. W. GOODWIN, E. R. GRAY, P. V. LIVDAHL,
C. W. OWEN, M. F. SHEA AND D. E. YOUNG
National Accelerator Laboratory,† Batavia, Illinois, USA

Received 2 February 1970
Particle Accelerators,
1970, Vol. 1, pp. 93–109

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[9] and are dimensionally identical to the BNL drift tubes.

Proc.1970Proton Lin. Acc.Conf., NAL, Batavia, IL Sep28-Oct2, 1970

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

Donald E. 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, 1969. 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 [1966]) have been used in the design of linacs: 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

CARNE, A. and P. M. LAPOSTOLLE, 1966, Design equations in an Alvarez-type proton linear accelerator, Linear Accelerator Conference 1966, LA Rept. 3609, p. 201.

SWENSON, D. A., 1967, Generation of geometrical dimensions for drift tube linacs, private communication, LA Rept. MP-3/DAS-1.

D. A. Swenson MP-3/DAS-1 June 29, 1967 it is PARMILA!

The design equations derived in this report are essentally identical to those proposed by Carne and Lapostolle.[5] 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. The BNL version has 286 drift tubes, a final energy of 200.305 MeV and a total tank length of 138.242 meters. The LASL version has 286 drift tubes, a final energy of 200.137 MeV and a total tank length of 138.255 meters.

5. A. Carne and P. M. Lapostolle, "Design Equations in an Alvarez-type Proton Linear Accelerator," Proc. of the 1966 Linac Conf., Los Alamos Report LA-3609, 201 (1966).

9-DTL 200-MeV 138m Linac: δL =1.3cm (~0.01%); ΔW = 170keV (~0.1%)

Revision of FNAL DTL linac lattices

name	File - name	Origin	Parm ver.	TTFs	Comments
MM68	Messymesh	Hard copies MP->VK			BNL Final design
AK90	1990 BNL tech. note	1990 A.Knopou	Parmila- of 199x	SFDATA (from COFT in 1970 Benton's BNL-note)	! Printouts for PARMILA input & design
VK01	-	Original by VK	~197x	SFDATA	Only MM68 data

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^+

4. A. Benton, BNL AGSCD Tech. Note No. 119, 1970.
5. G.W. Wheeler, K. Batchelor et al., Particle Accelerators, Vol. 9 (1979) pp. 1-156.
6. Reference 5, p. 30. Table II.2.g.1.

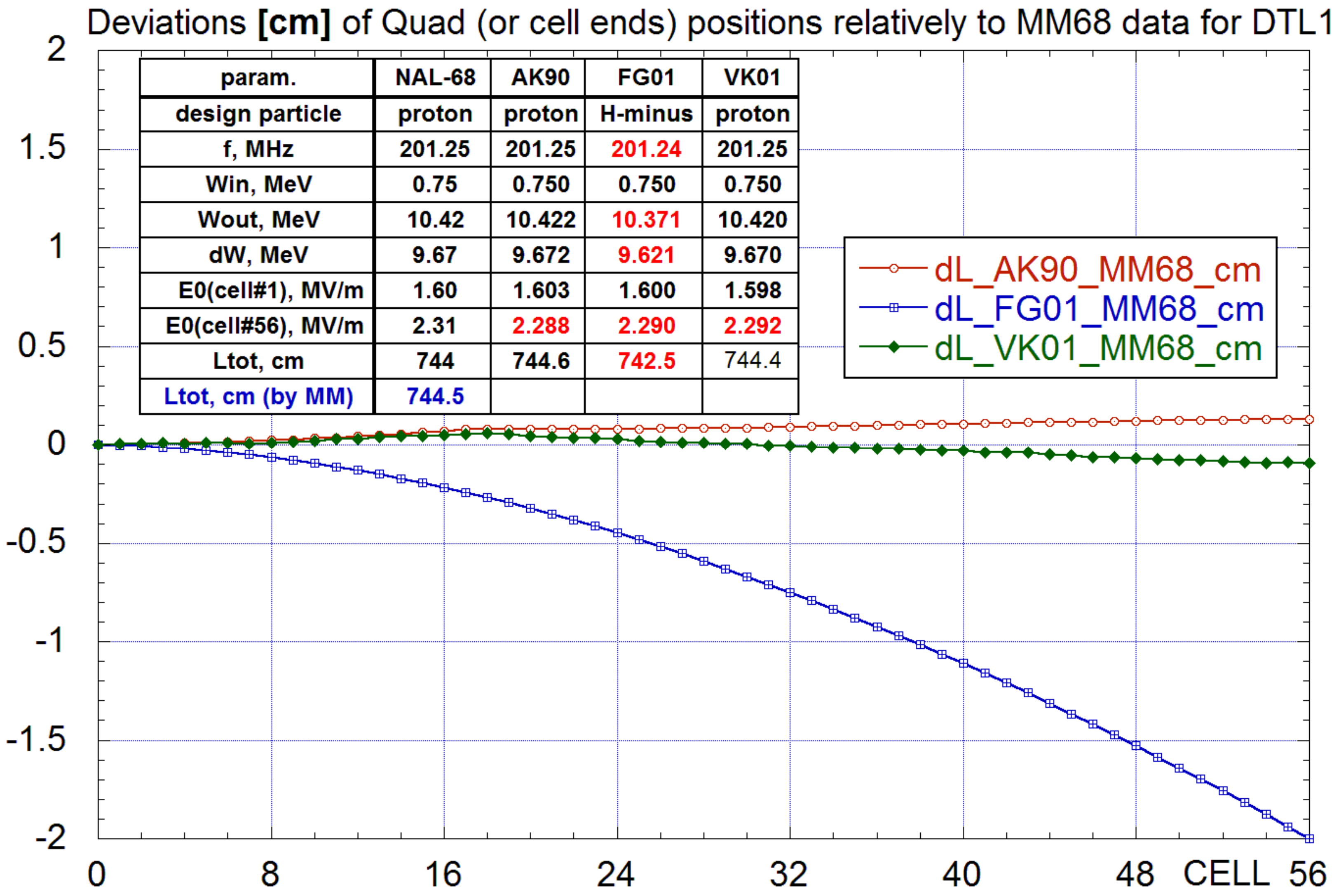
Agreement of basic design parameter with AK90(BNL) lattice

1990 A. Kponou

COMPARISON OF THE ORIGINAL LINAC DESIGN
(G.W. Wheeler, et al., Part: Acc , 1979)
AND THE PARMILA

	CAVITY NUMBERS									
	1 IN	1 OUT	2 IN	2 OUT	3 IN	3 OUT	4 IN	4 OUT	5 IN	5 OUT
BEAM ENERGY (MeV)	.75 .750	10.42 10.422		37.54 37.536		66.18 66.180		92.55 92.555		116.54 116.545
BEAM VELOCITY, β	.04 .040	.148 .1478		.275 .2747		.357 .3570		.414 .4141		.457 .4569
ENERGY GAIN (MeV)	9.67 9.672		27.12 27.114		28.64 28.644		26.37 26.375		23.99 23.990	
CAVITY LENGTH (m)	7.44 7.446		19.02 19.018		16.53 16.527		16.68 16.684		15.58 15.586	
AVERAGE AXIAL FIELD (MV/m)	1.60 1.603	2.31 2.288	2.0 2.001		2.60 2.603		2.60 2.603		2.56 2.562	
ACCUMULATED LENGTH (m)	7.66 7.667		27.28 27.285		44.56 44.562		62.24 62.246		78.82 78.832	
AXIAL TRANSIT TIME FACTOR	.64 .643	.81 .806	.86 .860	.81 .808	.82 .824	.75 .750	.75 .748	.69 .687	.73 .733	.69 .686

Comparison AK90, FG01 and VK01 DTL1 lattices

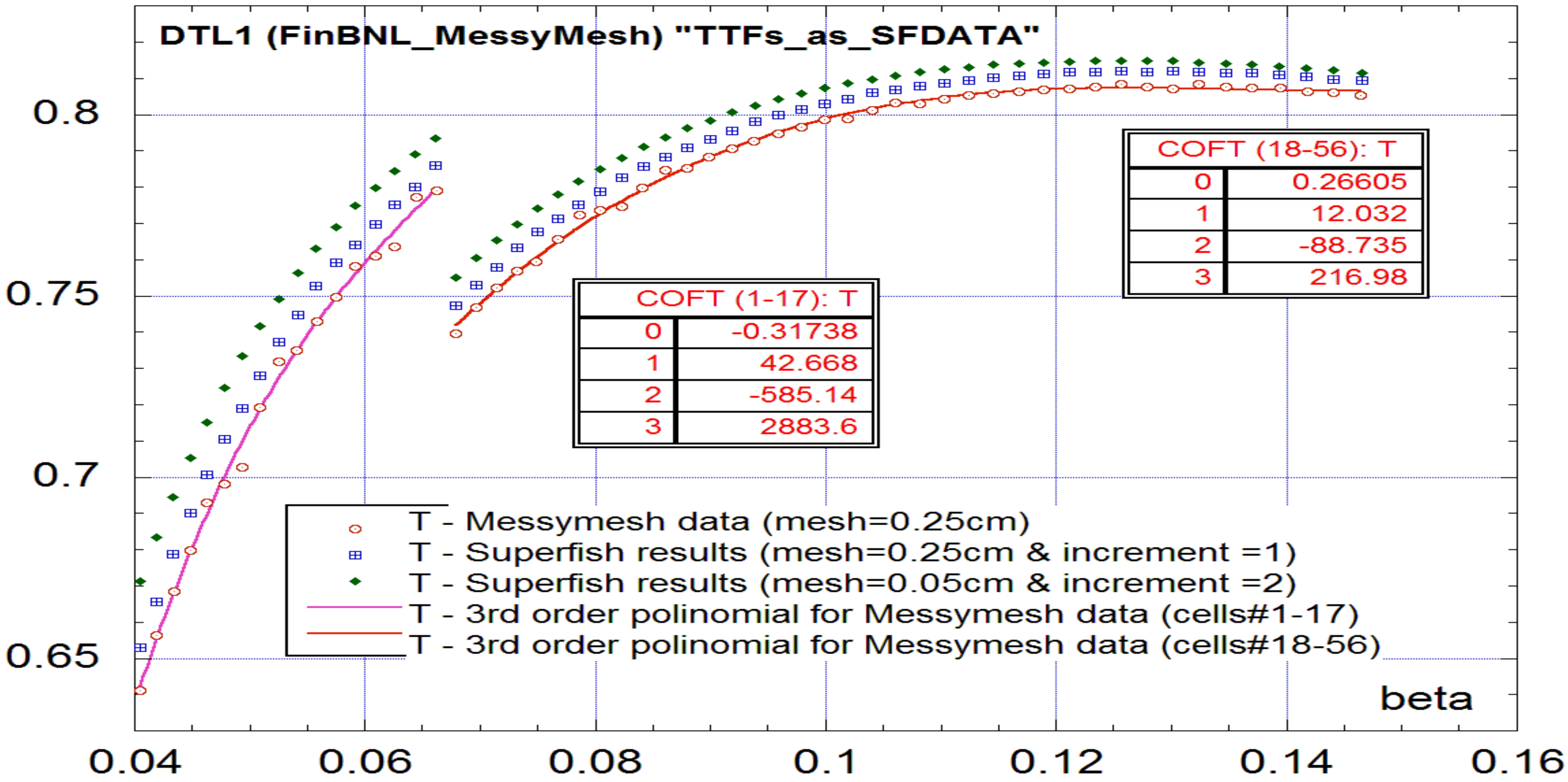


param.	NAL-68	AK90	FG01	VK01
design particle	proton	proton	H-minus	proton
f, MHz	201.25	201.25	201.24	201.25
Win, MeV	0.75	0.750	0.750	0.750
Wout, MeV	10.42	10.422	10.371	10.420
dW, MeV	9.67	9.672	9.621	9.670
E0(cell#1), MV/m	1.60	1.603	1.600	1.598
E0(cell#56), MV/m	2.31	2.288	2.290	2.292
Ltot, cm	744	744.6	742.5	744.4
Ltot, cm (by MM)	744.5			

For other DTLs -> Appendix

TTFs usage with PARMILA

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

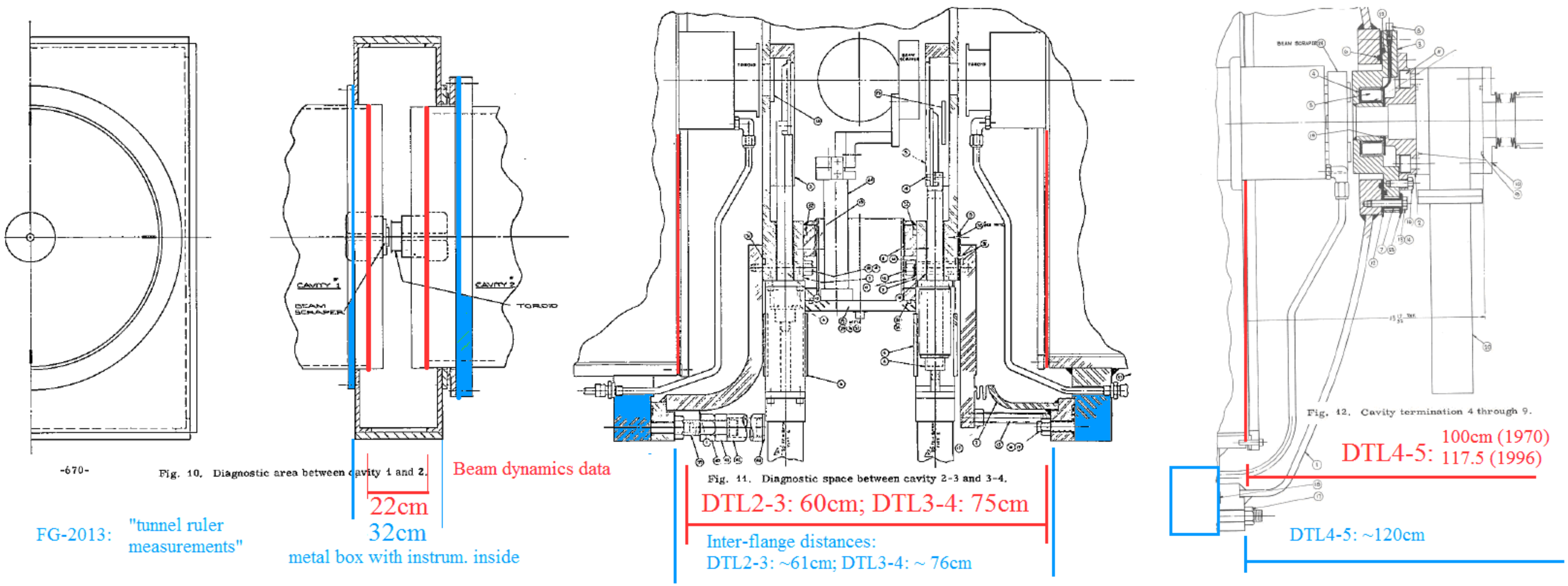


PARMILA should use original for design (step1), and refined for tracking (step2)

Lengths of 116-MEV 5-Tank FNAL DTL

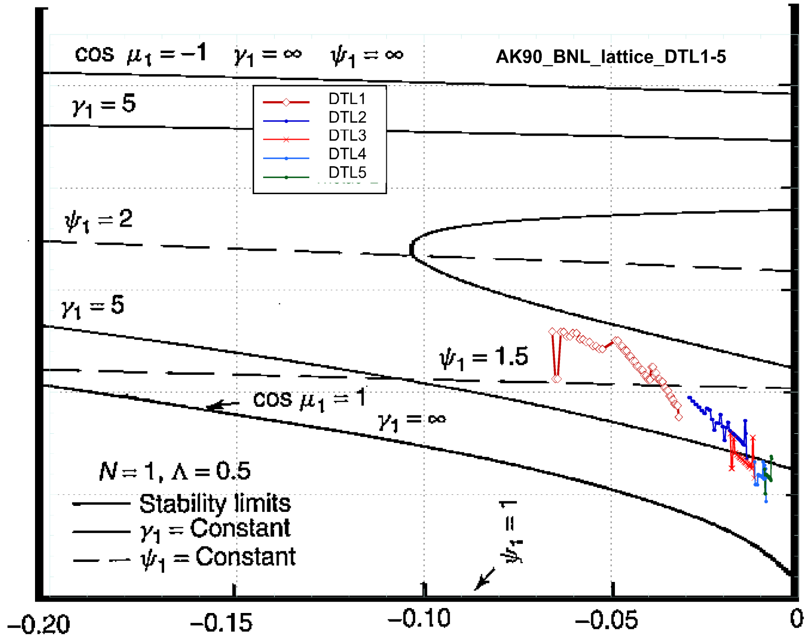
Length parameter, [m]	NAL-1968	AK90	FG01	MP01 MP02	MP03 MP04(~1996)	VK01
DTL1	7.44	7.446	7.425	7.427	7.459	7.444
drift DTL1-DTL2	0.22	0.22	0.218	0.218	0.22	**0.22**
Accumulated length	7.66	7.667(6[14])	7.643	7.645	7.679	7.664
DTL2	19.02	19.018	18.969	18.970	19.05	19.018
drift DTL2-DTL3	0.6_	0.60	0.596	0.596	0.60	~**0.60**
Accumulated length	27.28	27.285(4)	27.208	27.211	27.332	27.282
DTL3	16.53	16.527	16.528	16.528	16.543	16.527
drift DTL3-DTL4	0.75	0.75	0.666	0.666	0.75	**~0.75**
Accumulated length	44.56	44.562(0)	44.401	44.405	44.625	44.559
DTL4	16.68	16.684	16.687	16.694	16.694	16.684
drift DTL4-DTL5	1.0_	1.00	1.041	1.041	1.175	**~1.175**
Accumulated length	62.24	62.246(5)	62.130	62.141	62.494	62.418
DTL5	15.58	15.586	15.554	15.560	15.589	15.583
Accumulated length	77.82[15]	77.832(0)	77.684	77.700	78.084	78.01

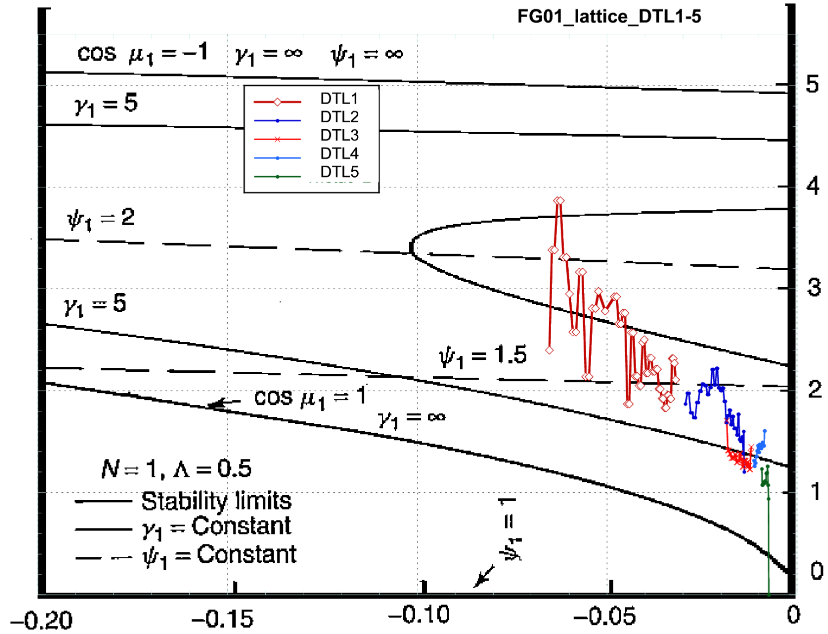
Inter-tank drifts for FNAL DTLs

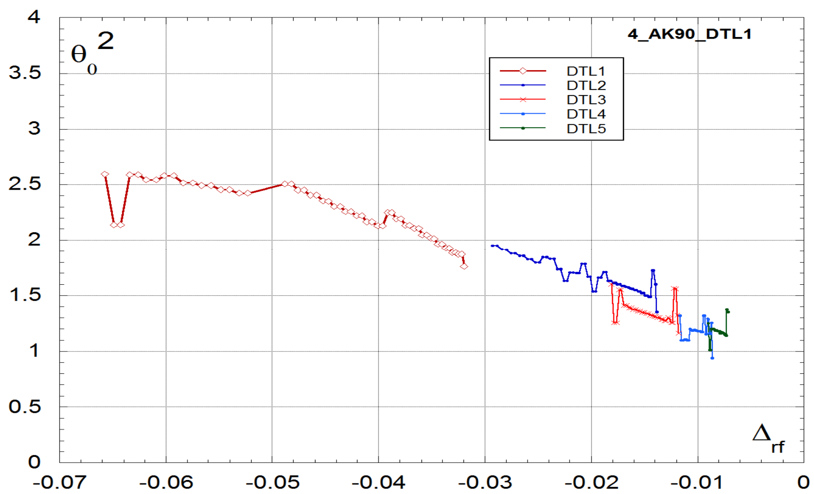


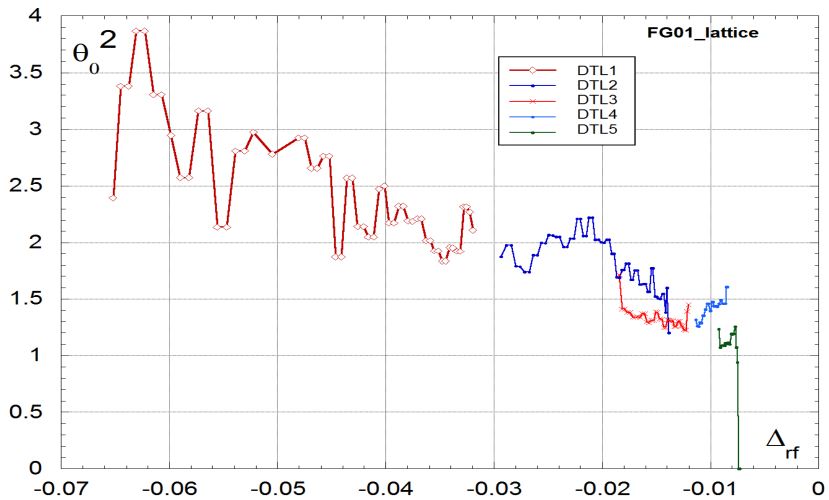
Intertank drifts are important for simulations;
They may be different from original design;
Digitized old drawings from 1970-Linac Conf and ruler measurements allow approximate evaluations;
Detailed drawings with 1993 survey in Appendix

Quad strengths - stability diagrams – BNL vs FNAL

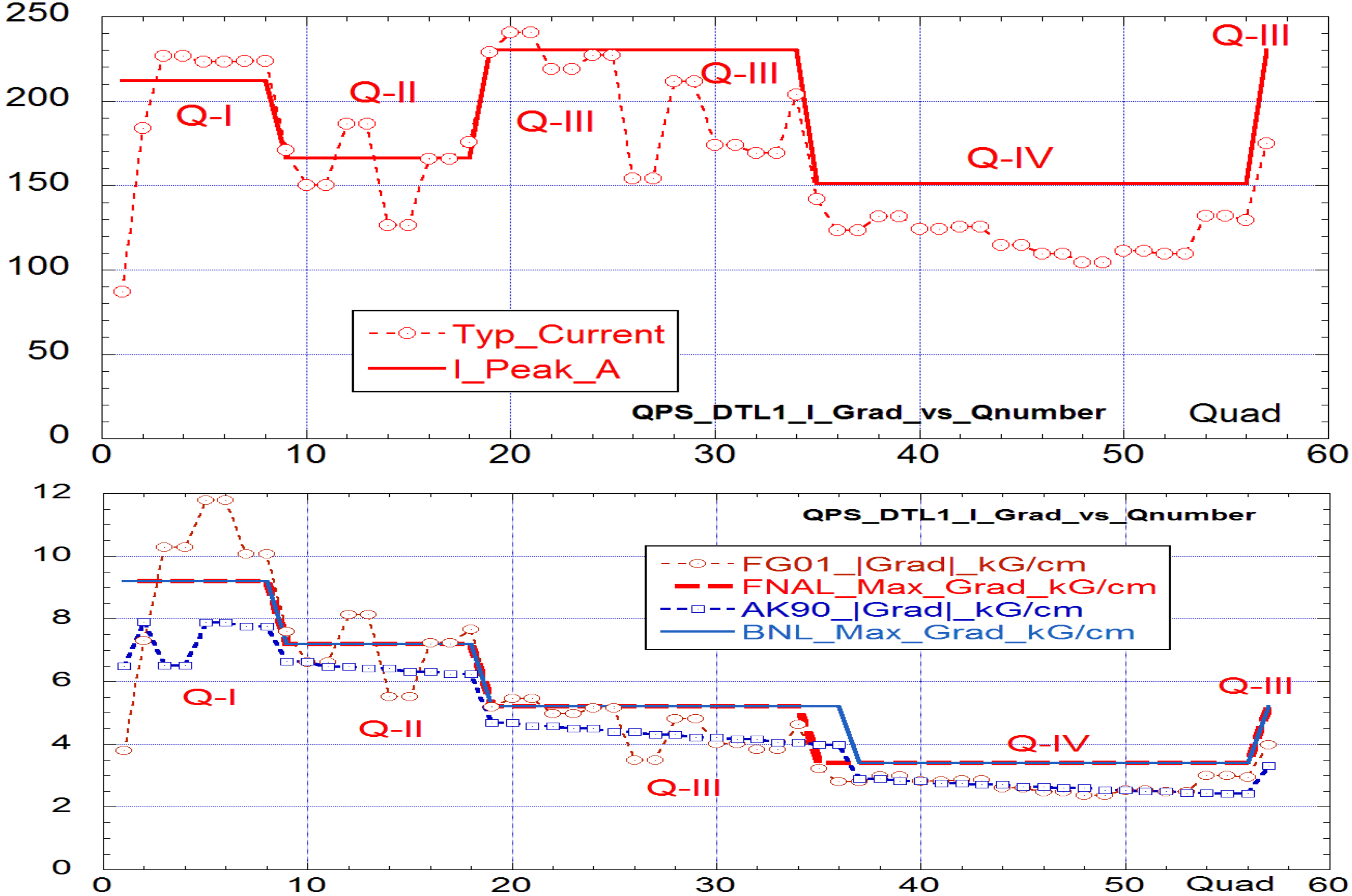








Limits for quad excitation currents and gradients in DTL1 – BNL vs FNAL (DTL1)



Quad specifications (Damm, LinacConf,1970)

QUADRUPOLE FOCUSING SYSTEM FOR THE 200 MEV LINAC* 1970 Linac Conf., p.561

R. Damm, A. Otis and V. LoGrasso Brookhaven National Laboratory

TABLE I 200 MeV Linac Quadrupole Magnet Parameters

agnet	Aperature (cm.)	Length (in.)	Turns/Pole	Equiv. Length (in.)	Max. Grad. (Kg/cm)	I Peak (a.)	Inductance (μ Hy)	Resistance (ohms)	Power Dissipation (watts)
I	2.2	1	21	1.36	9.2	212	440	0.07	55
II	2.2	1-1/4	21	1.61	7.2	166	520	0.09	44
III	2.9	1-3/4	19	2.22	5.2	230	475	0.1	100
IV	2.9	2-3/4	19	3.23	3.4	151	690	0.09	52
V	3.4	4	12	4.48	2.0	192	310	0.08	50
VI	4.4	6	11	6.48	1.0	175	340	0.1	53

M.Popovic, Fermilab-TM-2245 (2004)

summary is from a memo written by Cy Curtis to S. Ohnuma. (VK: not available?)

The excitation is defined as

$$\boxed{B' = 8\pi \cdot 10^{-4} N \frac{I}{r^2} = kI},$$

where B' is in kG/cm, N in turns/pole, I in Amps and r in cm.

The gradients of quads are calculated using current readbacks by ACNET.

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.

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APPENDIX C: ENGINEERING CALCULATIONS

Calculation of Ampere-Turns Required for Quadrupole Coil

The design equation for a quadrupole coil is $NI = \frac{0.398\ G\ b^2}{n}$ (C.1)

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 agee 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 ?)

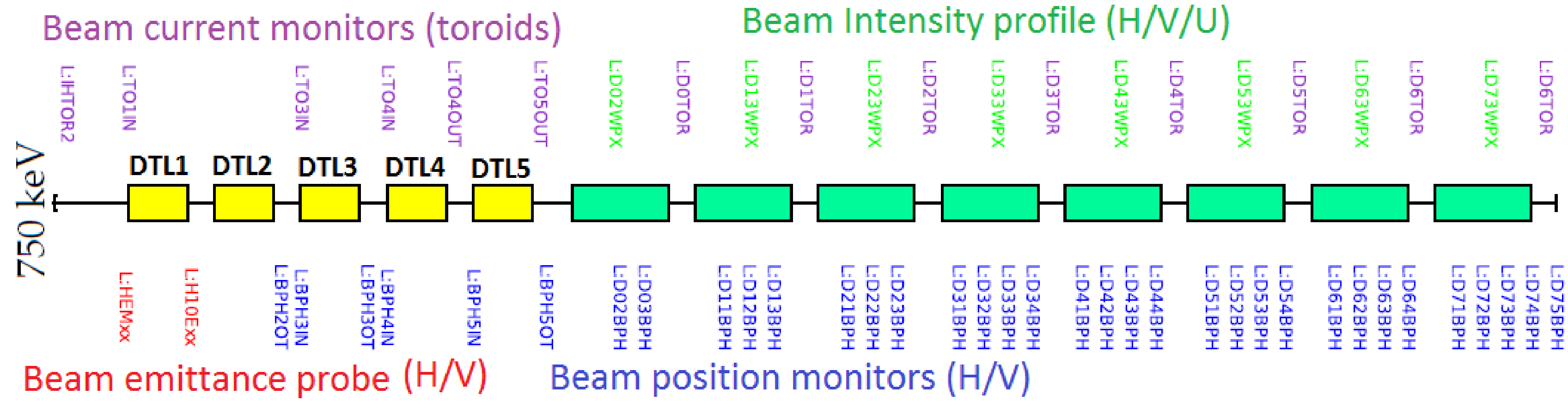
Plans

- 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 misalighnments)
  - 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

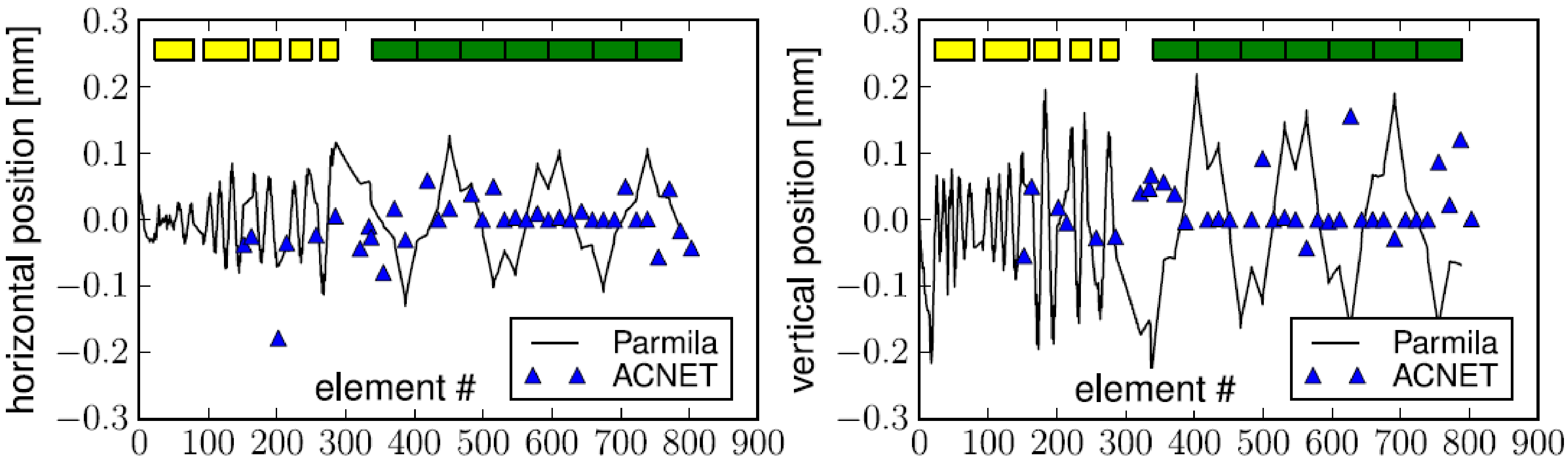
Appendix.
Supporting slides

H.J.Kim, 11-Jan-2012 (continued 1)

Instruments in Fermilab linac



Linac beam position measurement



H.J.Kim, 11-Jan-2012 (continued 2)

Future work

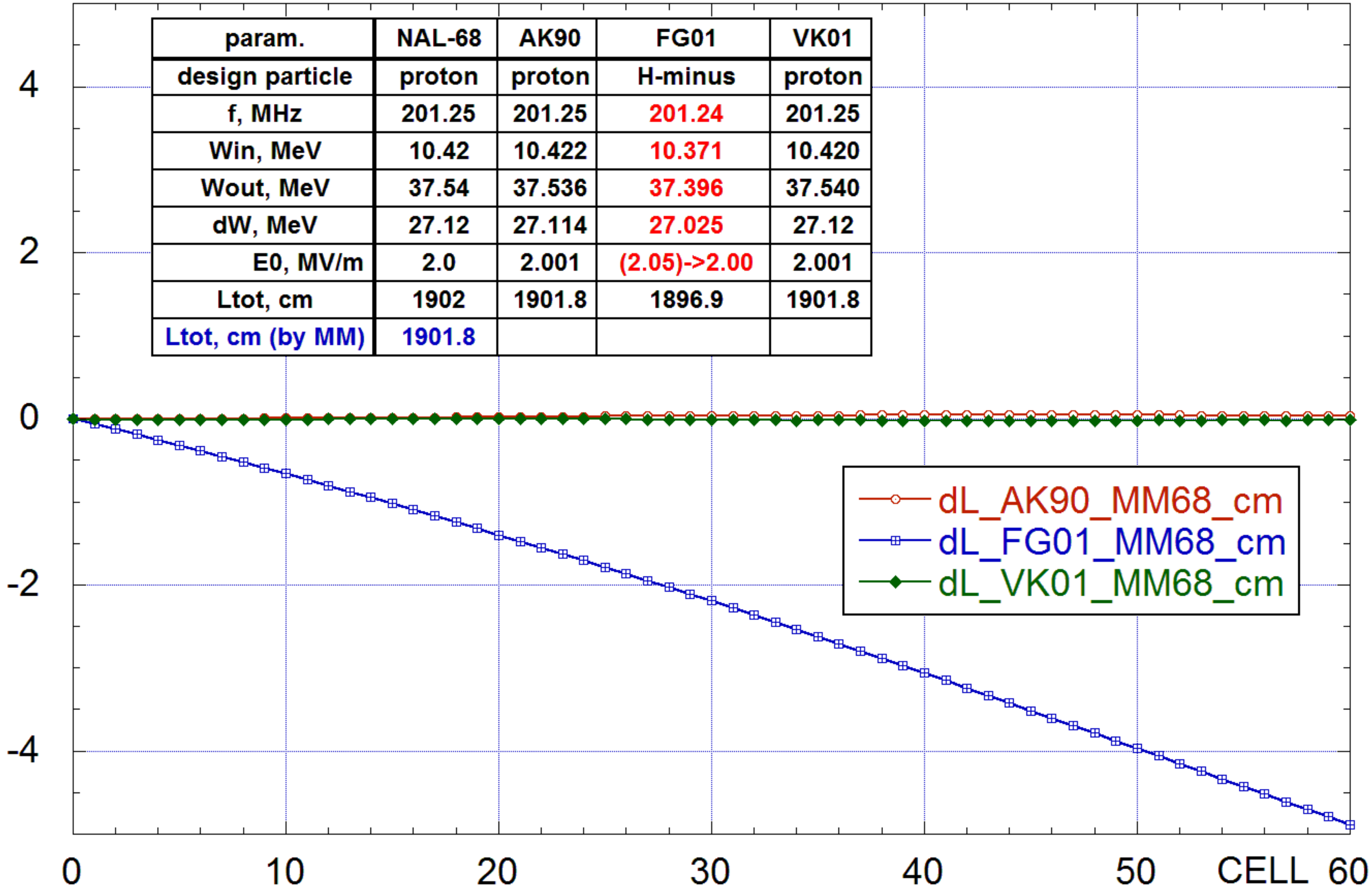
- Optimize initial phase space.
- Get working model of Tank 1
  - Reference emittance meas. at both entrance & exit of Tank 1.
  - Adjust quad current & take emittance measurements.
  - Compare to model.
- Get working model of Tank 1-5 and Module 0-7
  - Take reference position measurements (BPM).
  - 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

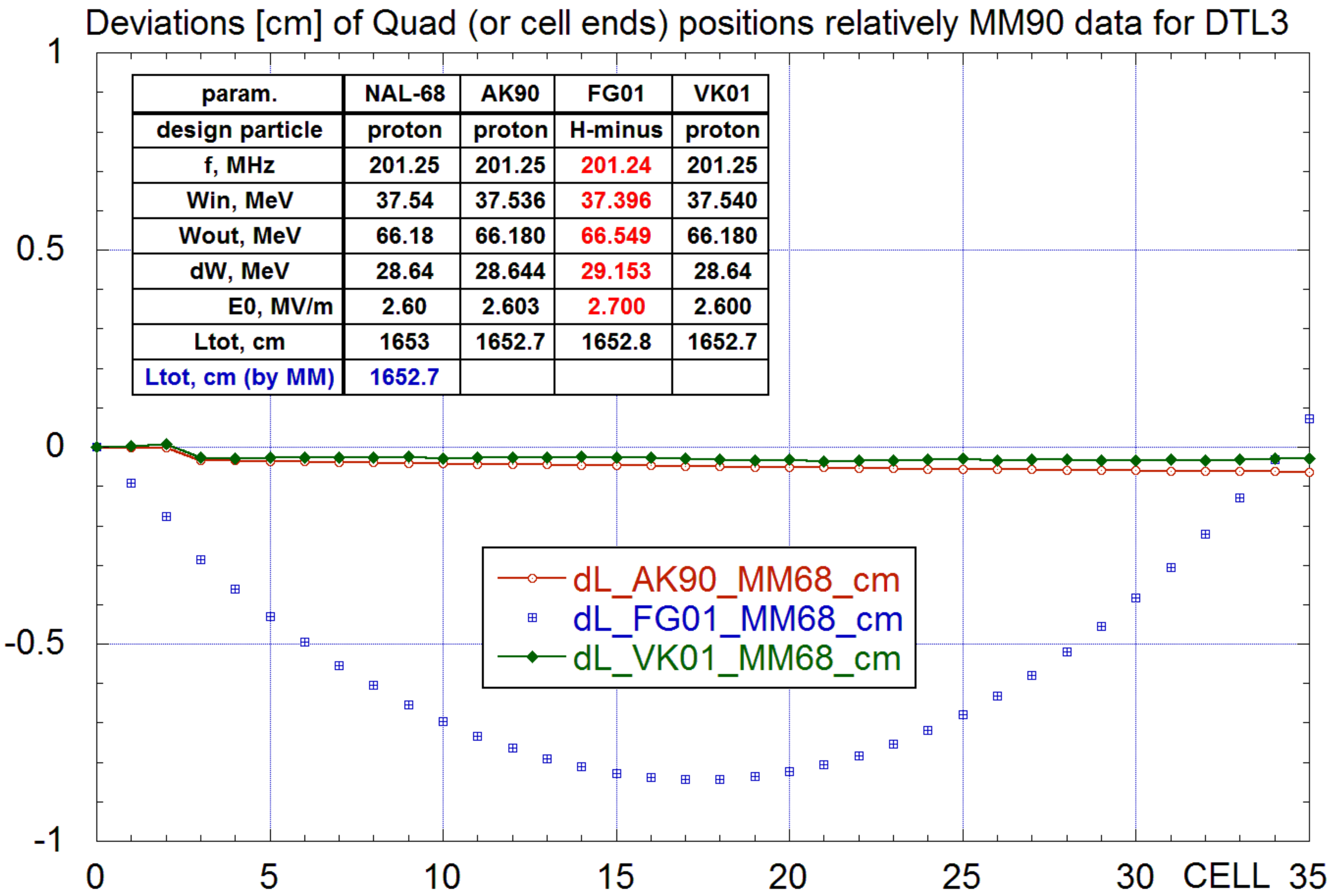
Deviations **[cm]** of Quad (or cell ends) positions relatively to MM68 data for DTL2

param.	NAL-68	AK90	FG01	VK01
design particle	proton	proton	H-minus	proton
f, MHz	201.25	201.25	201.24	201.25
Win, MeV	10.42	10.422	10.371	10.420
Wout, MeV	37.54	37.536	37.396	37.540
dW, MeV	27.12	27.114	27.025	27.12
E0, MV/m	2.0	2.001	(2.05)->2.00	2.001
Ltot, cm	1902	1901.8	1896.9	1901.8
Ltot, cm (by MM)	1901.8			



For other DTLs -> Appendix

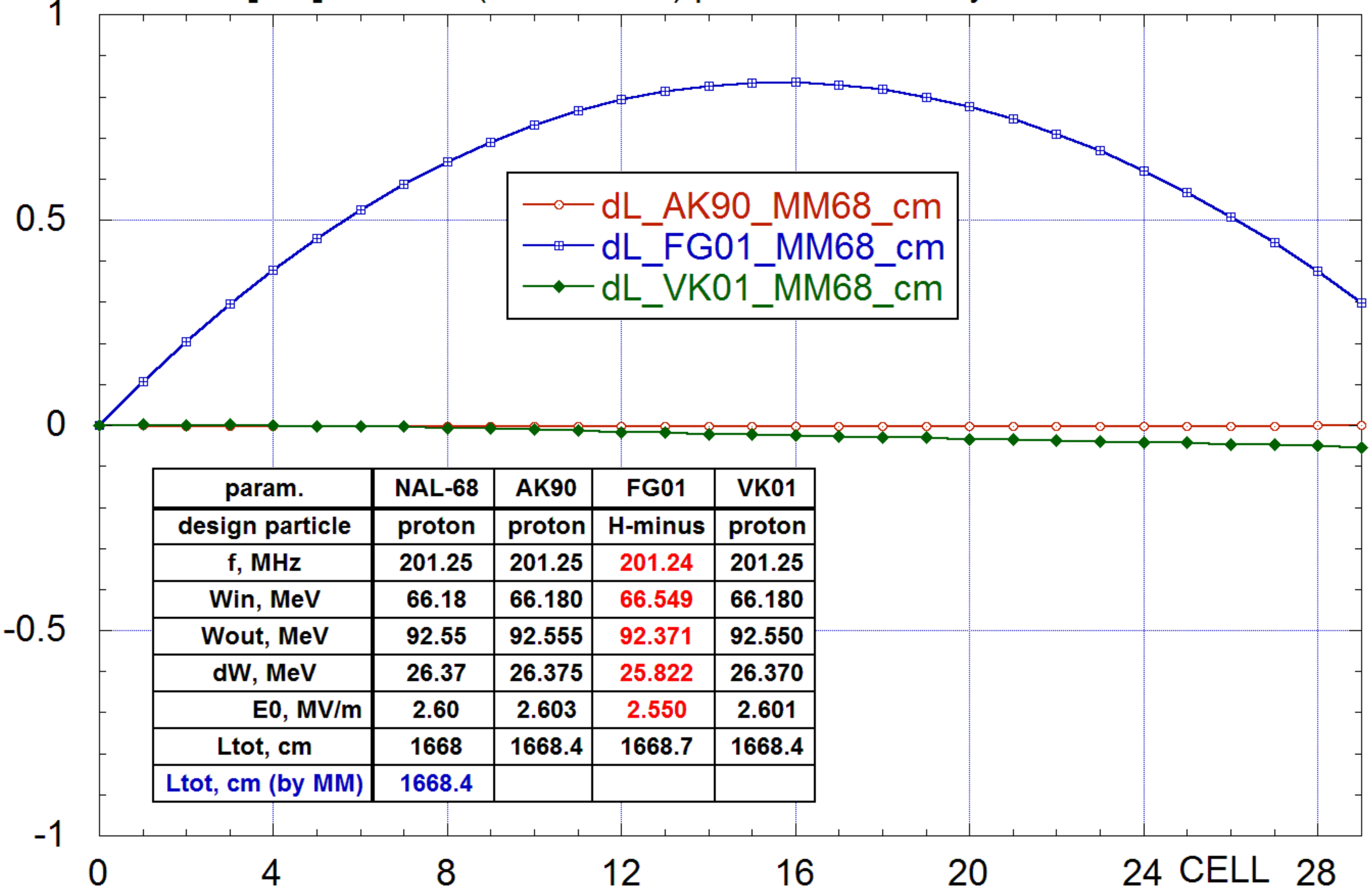
Comparison AK90, FG01 and VK01 DTL3 lattices



param.	NAL-68	AK90	FG01	VK01
design particle	proton	proton	H-minus	proton
f, MHz	201.25	201.25	201.24	201.25
Win, MeV	37.54	37.536	37.396	37.540
Wout, MeV	66.18	66.180	66.549	66.180
dW, MeV	28.64	28.644	29.153	28.64
E0, MV/m	2.60	2.603	2.700	2.600
Ltot, cm	1653	1652.7	1652.8	1652.7
Ltot, cm (by MM)	1652.7			

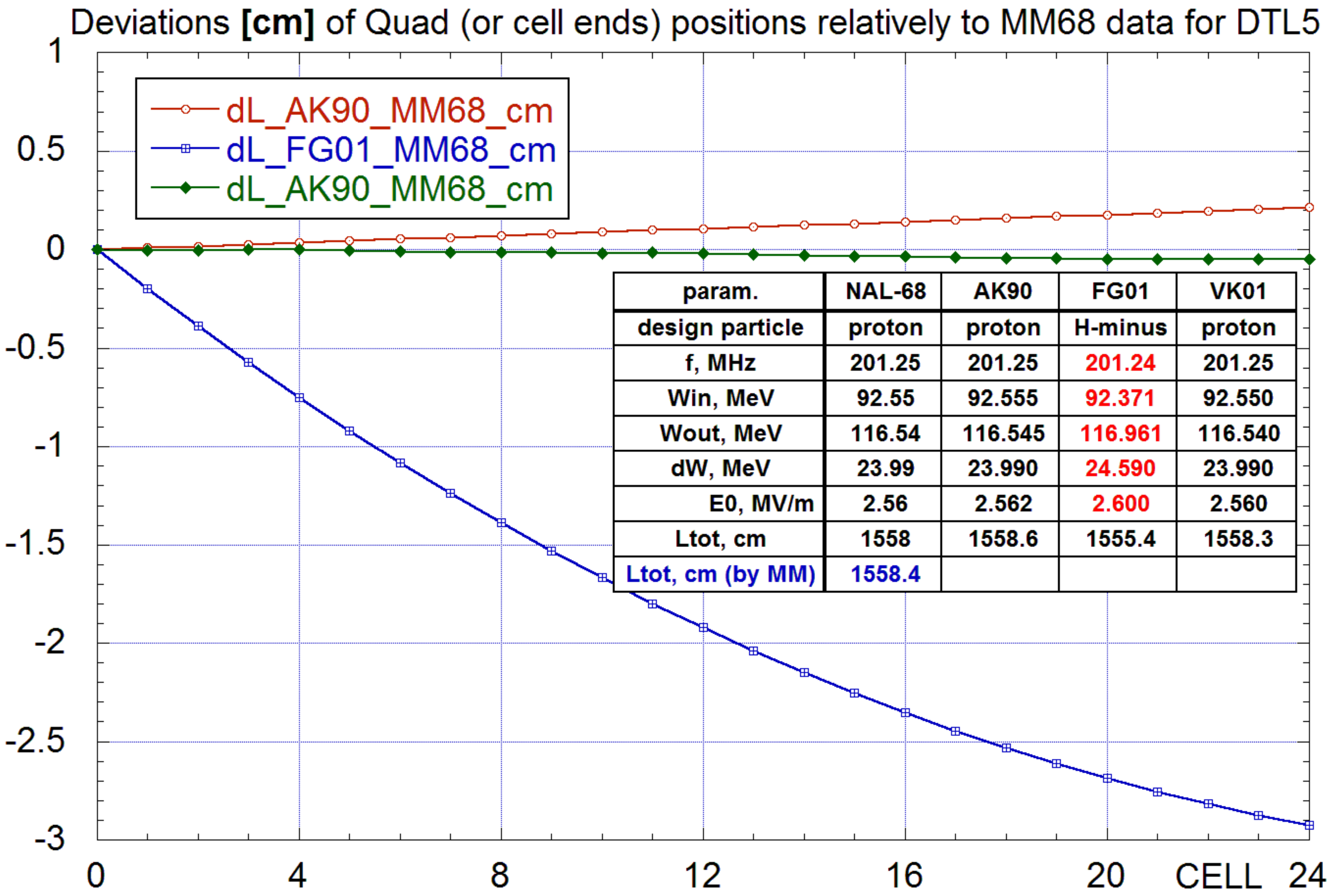
Comparison AK90, FG01 and VK01 DTL4 lattices

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



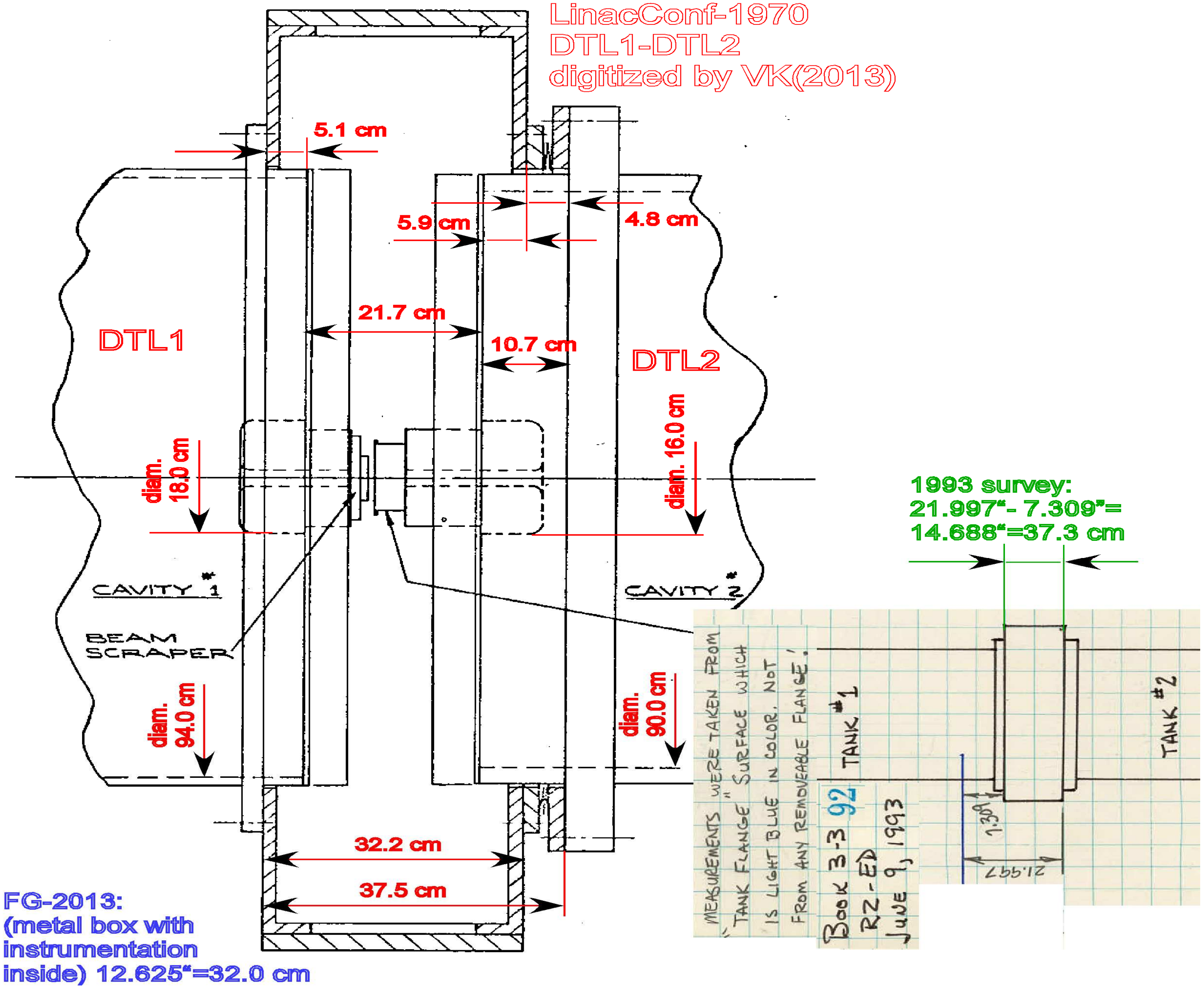
param.	NAL-68	AK90	FG01	VK01
design particle	proton	proton	H-minus	proton
f, MHz	201.25	201.25	201.24	201.25
Win, MeV	66.18	66.180	66.549	66.180
Wout, MeV	92.55	92.555	92.371	92.550
dW, MeV	26.37	26.375	25.822	26.370
E0, MV/m	2.60	2.603	2.550	2.601
Ltot, cm	1668	1668.4	1668.7	1668.4
Ltot, cm (by MM)	1668.4			

Comparison AK90, FG01 and VK01 DTL5 lattices

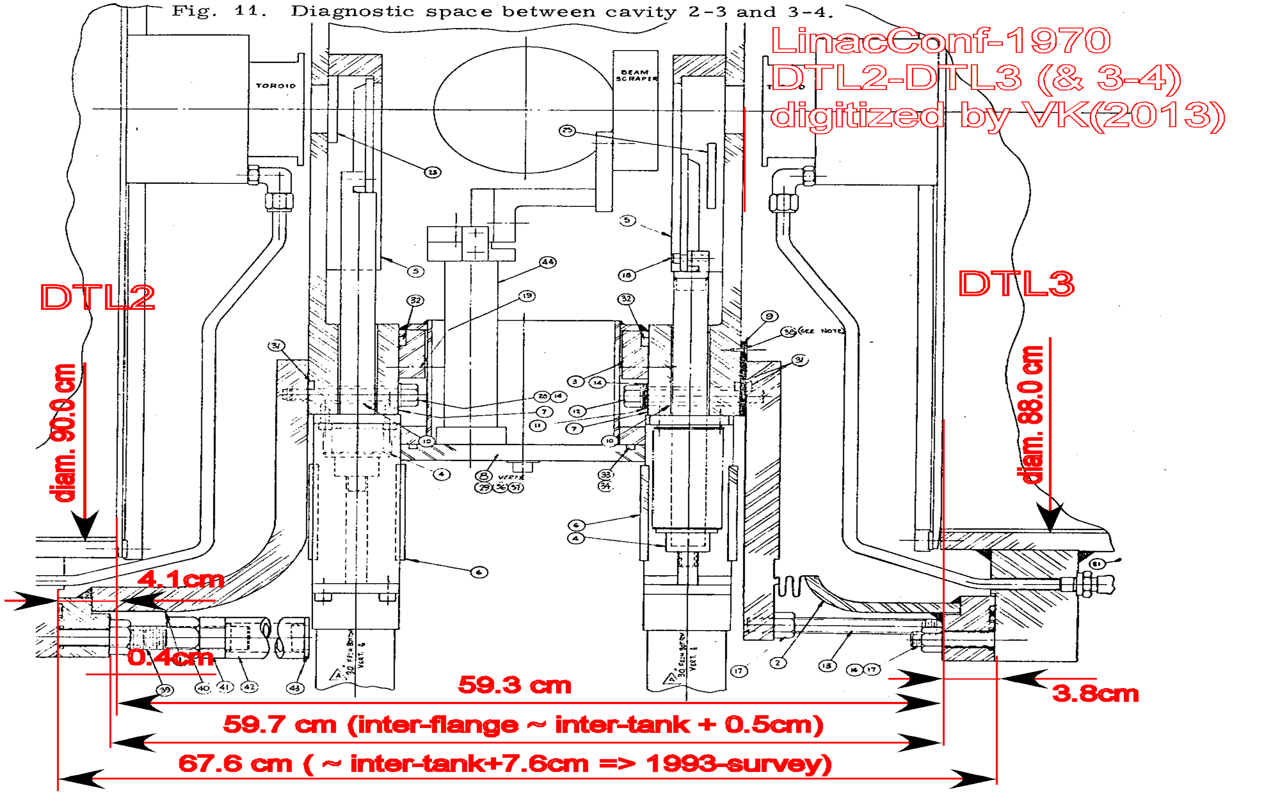


param.	NAL-68	AK90	FG01	VK01
design particle	proton	proton	H-minus	proton
f, MHz	201.25	201.25	201.24	201.25
Win, MeV	92.55	92.555	92.371	92.550
Wout, MeV	116.54	116.545	116.961	116.540
dW, MeV	23.99	23.990	24.590	23.990
E0, MV/m	2.56	2.562	2.600	2.560
Ltot, cm	1558	1558.6	1555.4	1558.3
Ltot, cm (by MM)	1558.4			

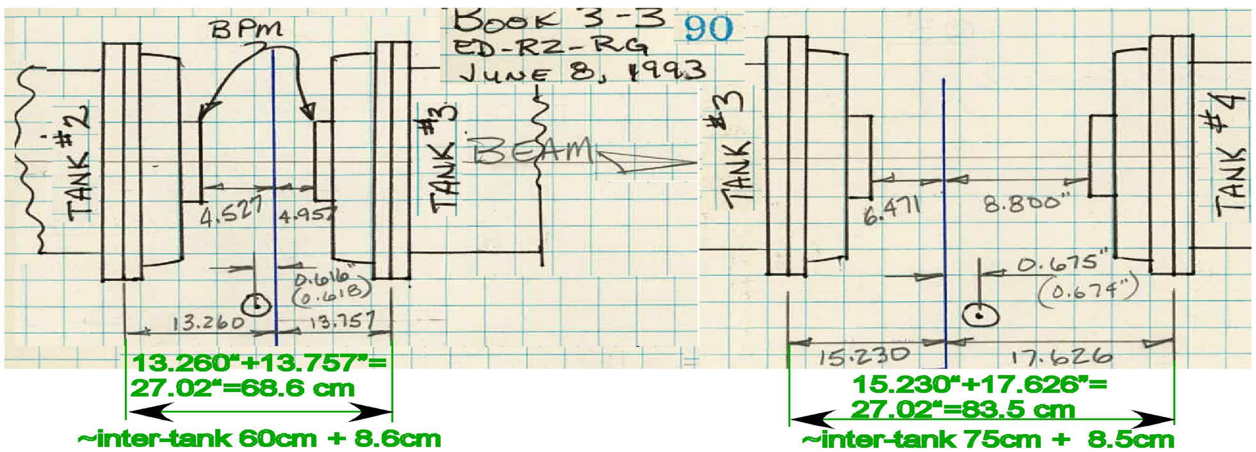
Inter-tank space between DTLs 1 and DTL2



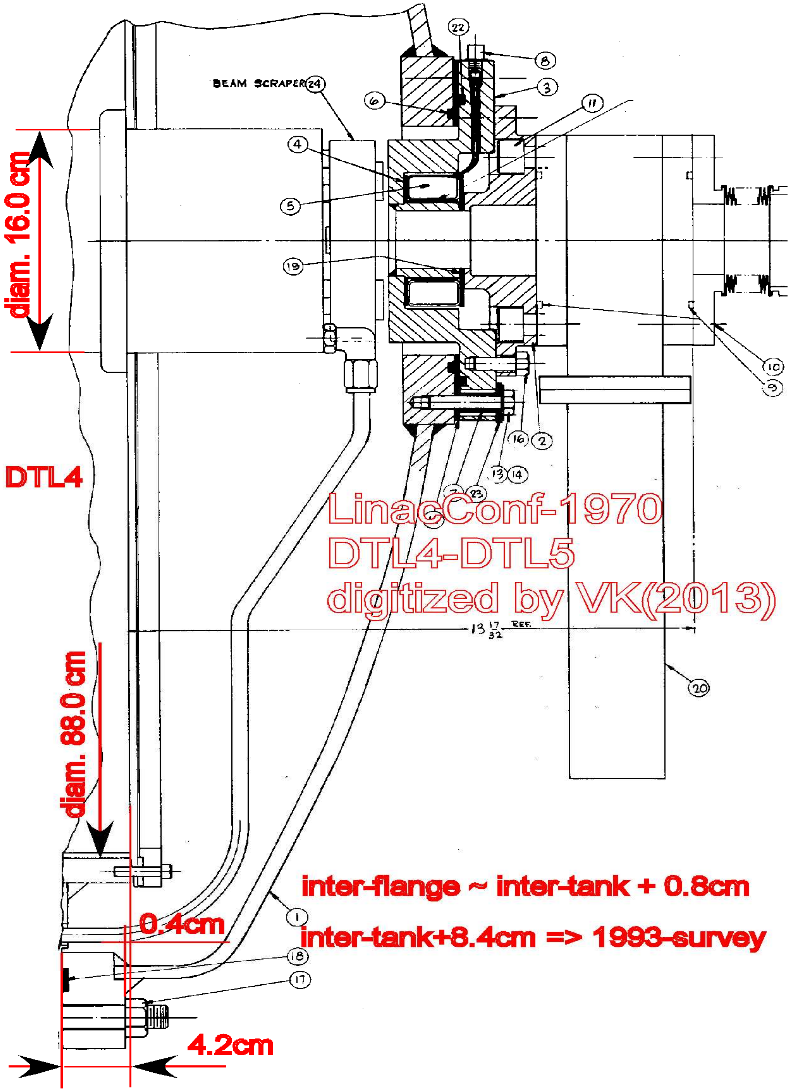
Inter-tank space between DTLs 2&3 and DTLs 3&4

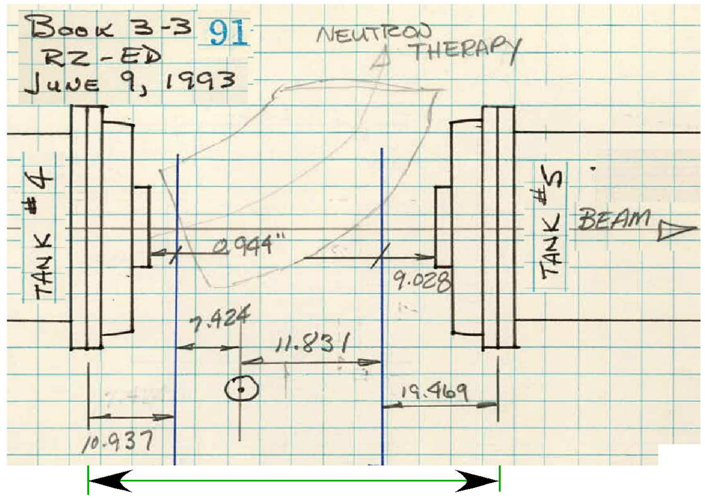


FG-2013 (interflange): DTL2-3: 23.94"=60.8 cm; DTL3-4: 29.75"=75.57cm



Inter-tank space between DTL4 and DTL5





10.937"+7.424"+11.831"+19.469
= 49.661"=126.1 cm
=> inter-tank~117.7(126.1-8.4)

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

Quadrupole locations and their power supplies in FNAL DTL1