TDR lattice of Main Linac: 9+4Q4+9 configuration

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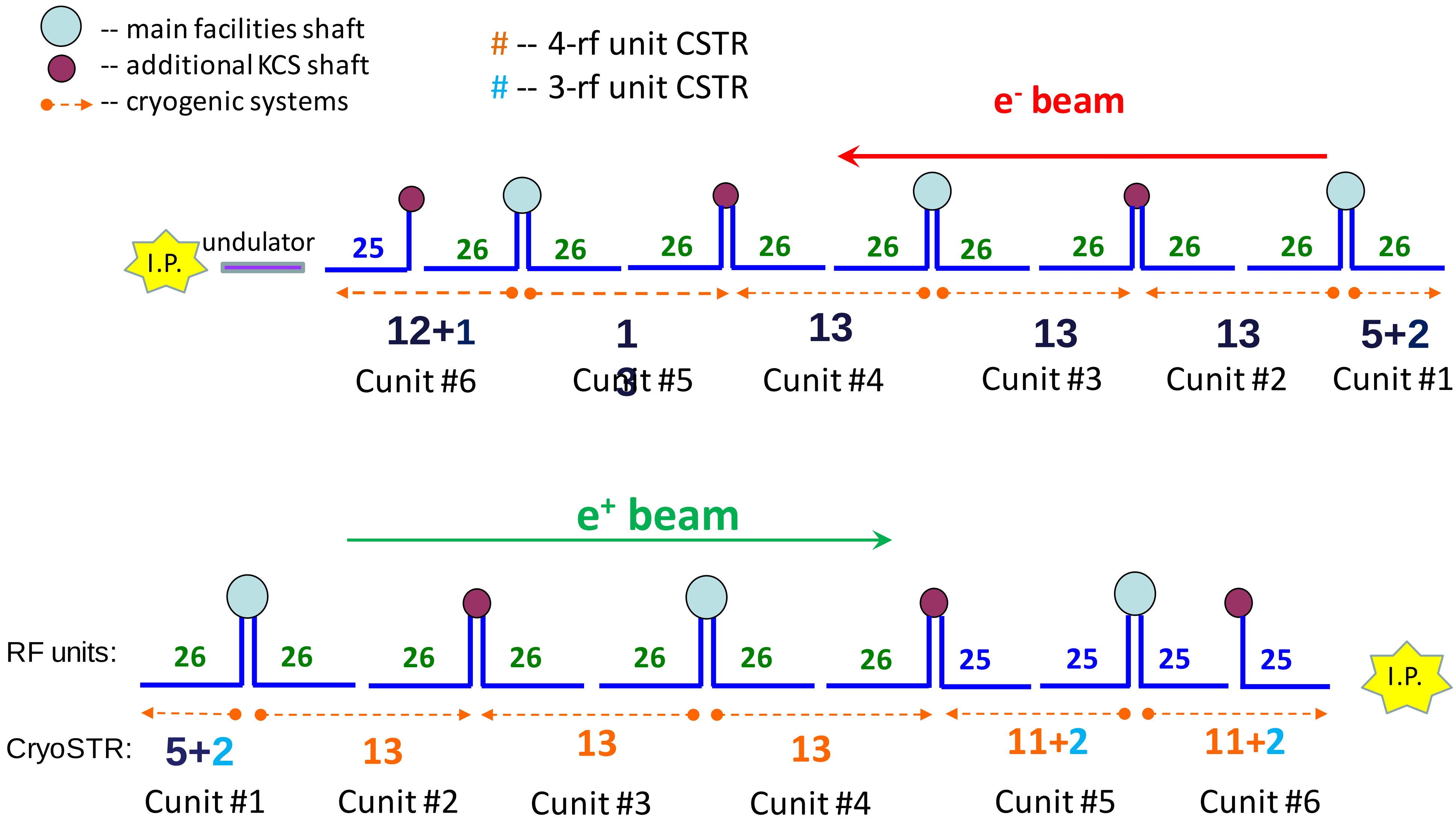
Outline

- Few layouts were considered; a “compromised” layout suggested by Chris Nantista (March-2012) was accepted
- Treaty points:
  “T(P/E)RTML2ML & TPML2BDS/TEML2PS
- ML lattice re-designed with MAD8 (a special version 51.15.s by M.Woodley) following to the approach [*].
- Details of modified matching procedures including optical functions, dispersion minimization and the linac reference orbit following the Earth’s curvature.
- Summary & the present lattice status

* A.Valishev, N.Solyak, M.Woodley, “Status of the ILC Main Linac Lattice Design”, PAC’07, pp.2966-2968, **2007**.

ML "Compromise" version (C.Nantista)

It allows to use most of existing RDR solutions and requires small number of re-matchings



Basic lattice segmentations

Length (m)

Name in Lattice	modules								Length (m)
			without quad	with quad	without quad			warm section (m)	7.652
RFU#	RF unit (lengths in meters)		12.652	12.652	12.652				
			3 modules						37.956

		RF unit	RF unit	RF unit	RF unit	end-box	Length (m)
CSTR#	"4" Long Cryo-String 4-rf unit CSTR	37.956	37.956	37.956	37.956	2.50	
		12 CM's plus string end box					154.324

		RF unit	RF unit	RF unit	end-box	Length (m)
CSTR#	3-rf unit CSTR "3" Short Cryo-String	37.956	37.956	37.956	2.50	
		9 CM's plus string end box				116.368

		Service end-box							
CUNIT #	Cryo-Unit	2.500	CSTR	CSTR	CSTR	CSTR	- - - -	CSTR	CSTR

Layout of Cryo-Units

Positron Main Linac: (72 CSTR = 282 RFunits = 846 CM's)

CUNIT1	7.65	CUNIT2	7.65	CUNIT3	7.65	CUNIT4	7.65	CUNIT5	7.65	CUNIT6

	CSTR "4"		CSTR "3"		RF unit	Length(m)
CUNIT1 =	5		2		26	1006.856
CUNIT2 =	13				52	2008.712
CUNIT3 =	13				52	2008.712
CUNIT4 =	13				52	2008.712
CUNIT5 =	11		2		50	1932.8
CUNIT6 =	11		2		50	1932.8
Total:	**66**		**6**		**282**	**10936.852**

Sbox	01	02	03	04	05	06	07						
Sbox	08	09	10	11	12	13	14	15	16	17	18	19	20
Sbox	21	22	23	24	25	26	27	28	29	30	31	32	33
Sbox	34	35	36	37	38	39	40	41	42	43	44	45	46
Sbox	47	48	49	50	51	52	53	54	55	56	57	58	59
Sbox	60	61	62	63	64	65	66	67	68	69	70	71	72

Legend: 7.65 Warm section 7.652m; Sbox Service box; ## Long (4-RFU) CSTR; ## Short (3-RFU) CSTR

Electron Main Linac: (72 CSTR = 285 RFunits = 855 CM's)

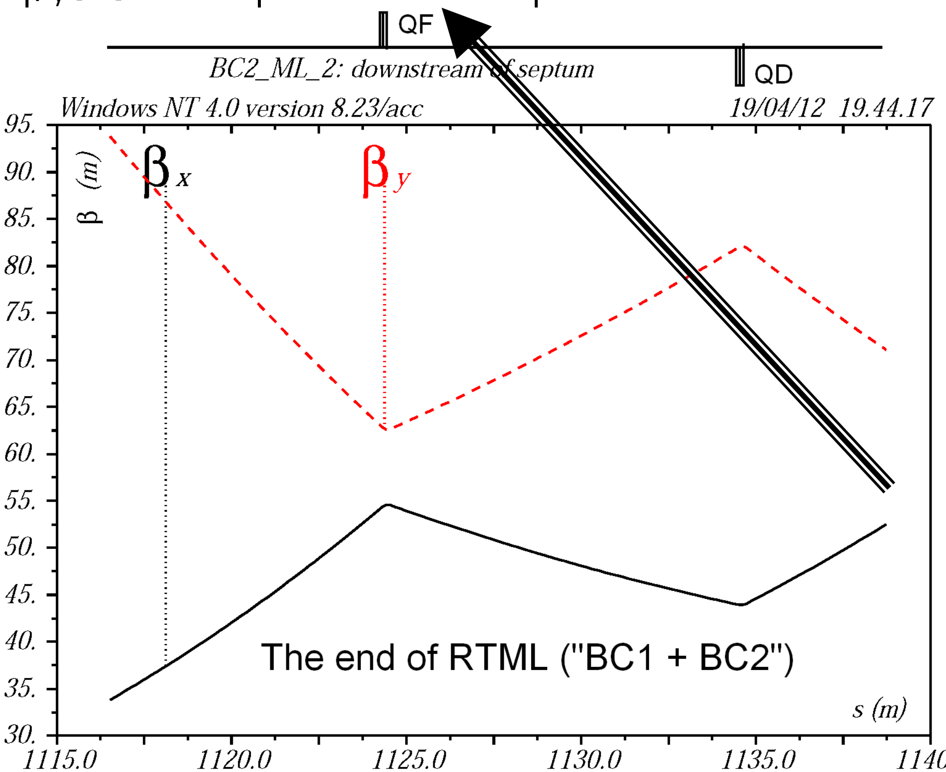
CUNIT1	7.65	CUNIT2	7.65	CUNIT3	7.65	CUNIT4	7.65	CUNIT5	7.65	CUNIT6

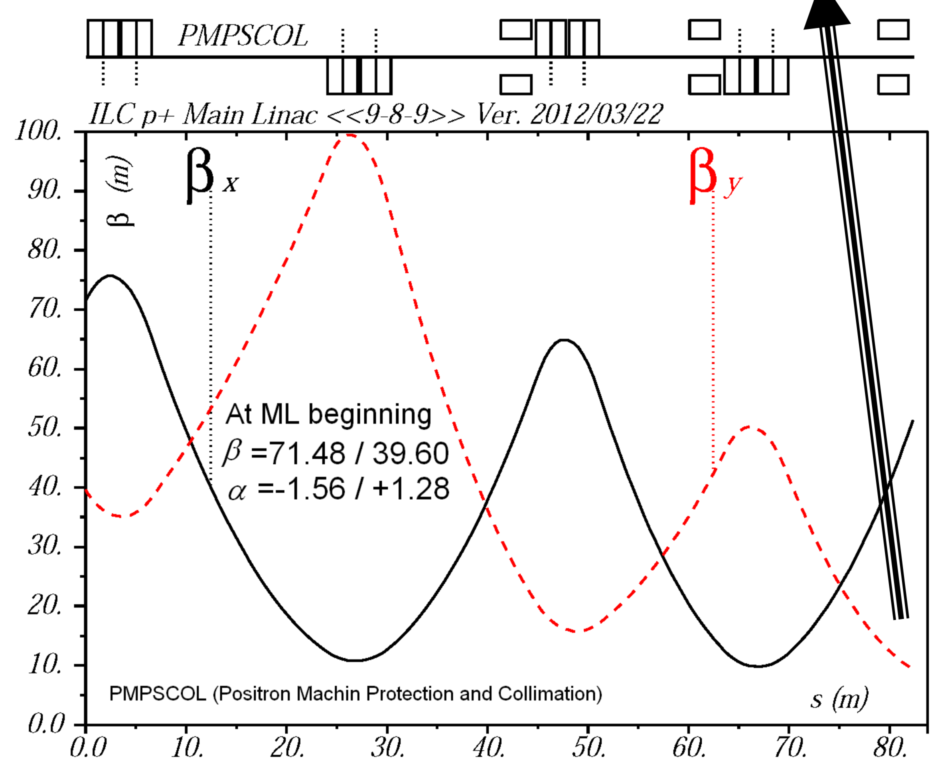
	CSTR "4"		CSTR "3"		RF units	Length (m)
CUNIT1 =	5		2		26	1006.856
CUNIT2 =	13				52	2008.712
CUNIT3 =	13				52	2008.712
CUNIT4 =	13				52	2008.712
CUNIT5 =	13				52	2008.712
CUNIT6 =	12		1		51	1970.756
Total:	**69**		**3**		**285**	**11050.72**

Sbox	01	02	03	04	05	06	07						
Sbox	08	09	10	11	12	13	14	15	16	17	18	19	20
Sbox	21	22	23	24	25	26	27	28	29	30	31	32	33
Sbox	34	35	36	37	38	39	40	41	42	43	44	45	46
Sbox	47	48	49	50	51	52	53	54	55	56	57	58	59
Sbox	60	61	62	63	64	65	66	67	68	69	70	71	72

Optical Functions at ML boundaries

Treaty Point	TERTML2ML	TEML2PS	TPS2EBDS	TPRTML2ML	TPML2BDS
	Electron RTML to Main Linac	Electron Main Linac to Positron Source (Undulator Section)	Positron Source (Undulator Section) to Electron BDS	Positron RTML to Main Linac	Positron Main Linac to BDS
Optics Functions					
α_x	-1.142	-2.402	-2.402	-1.142	-2.402
β_x [m]	52.67	51.33	51.33	52.67	51.33
α_y	1.279	0.4888	0.4888	1.279	0.4888
β_y [m]	70.74	9.395	9.395	70.74	9.395





Actually ML ends at the entry of PMSCOL (p+ machine protection & collimation)

Quadrupoles in ML cells

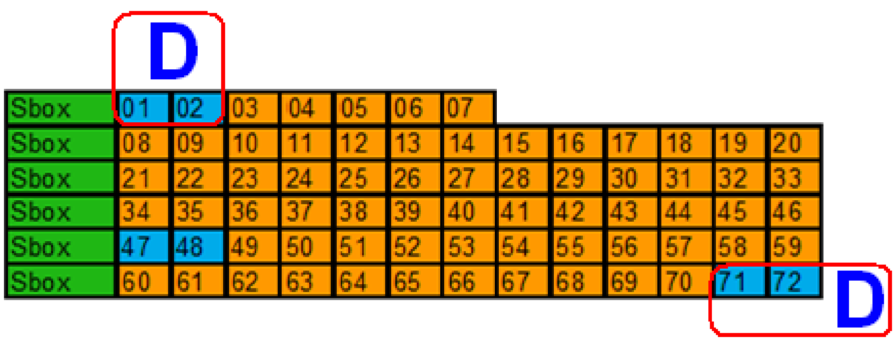
Basic configurations of focusing structure

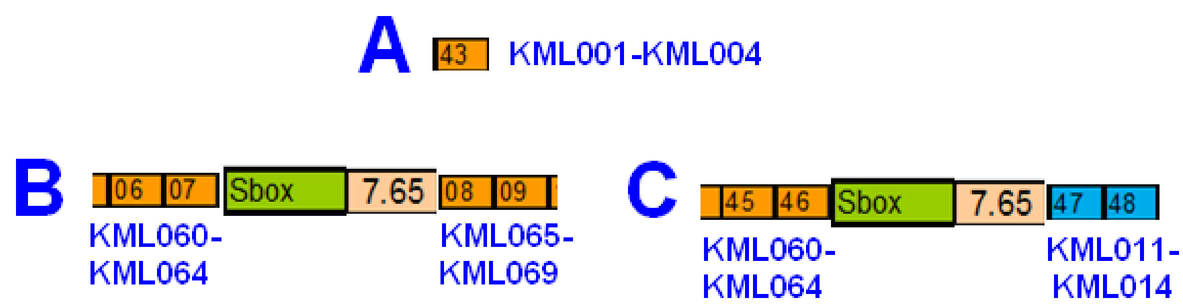
A. Quasi-periodical “long” 4-RFU CSTR inside of regular part of CUNITs :
2 FODO quasi-periodical cells (phase advances ~75/60 degrees) =>
4 quads with K1 denoted as K1=KML001, KML002, KML003, KML004

B. Long 4-RFU CSTR between CUNIT ends separated by warm sections:
“5+5” quad configuration around warm sections with K1 denoted as
KML060-KML064 and KML065-KML069

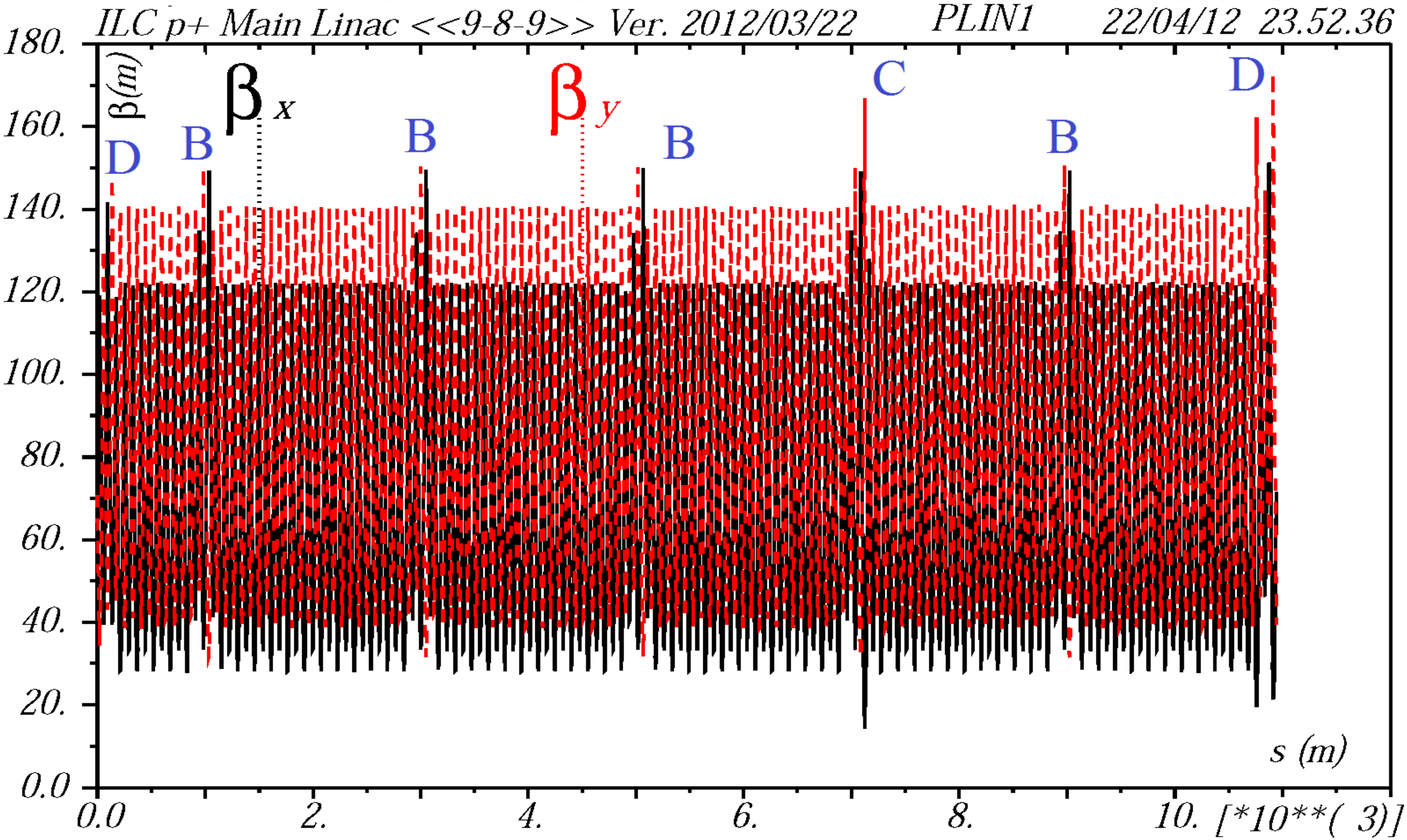
C. Two short 3-RFU CSTR at the beginning of the 5th CUNIT of PLIN:
4 first quads with K1 denoted as K1=KML011, KML012, KML013, KML014

D. 6 quads at the ML beginning and 6 quads at the ML end are used for
matching to the Twiss parameters β and α at ML boundaries.

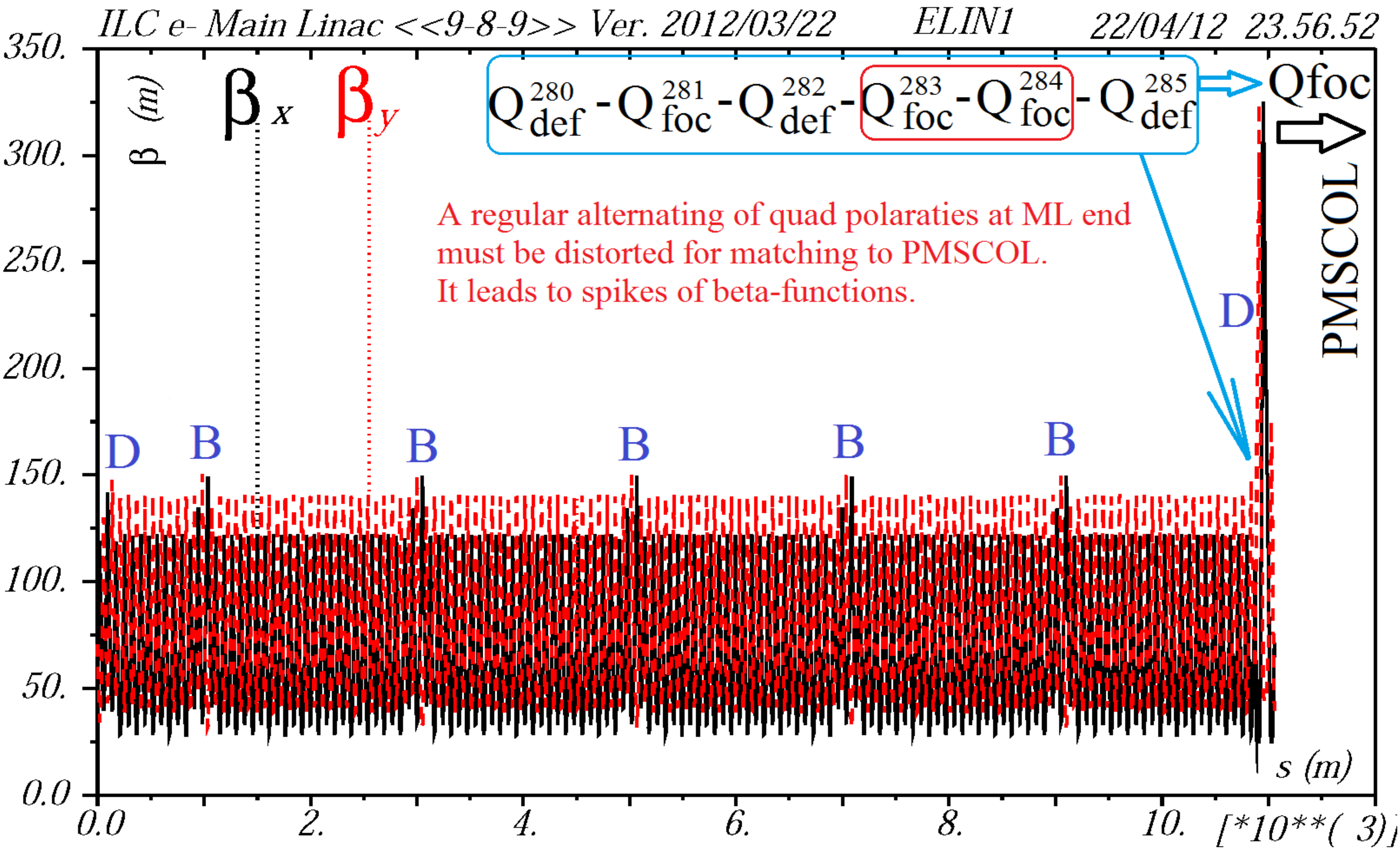




Matched β-functions in PLIN



Matched β – functions in ELIN

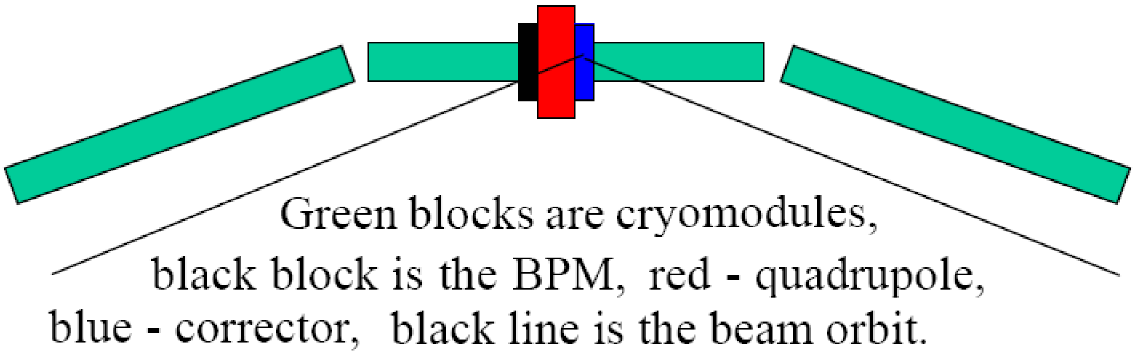


Curvature implementation

- ML follows curvature of the Earth ‘s surface
- Each CM is aligned along the Earth horizon and the beam-line is kinked at the ends of CMs
- Beam-line kinks (MAD8) are implemented as a thin KML-lines consisting of a dipole (MULT, K0L=p) & a vert. corrector (VKICK): The former changes both ref. frame and beam trajectory, the latter cancel the trajectory change
- In MAD8 KMLs are switched on by “SET, CURVE, 1”
- KML-lines are set at both ends of every CM. Several types:
  - **KML1 – between CMs inside of RFUs**
  - **KMLQ – at the ends of CM with quads**
  - **KML2 – between CMs at CSTRs ends**
  - **KML4 – between CMs at CUNITs ends**
  - **KML5 – at the end of the last CM (at ML exit)**
  - **KML8 – at the beginning of the first CM (ML entrance)**

Steering to the Earth's curvature

- The beam trajectory is steered through the centers of quads, i.e. only at every third CM.
- Switch on by "SET, STEER,1"



Match corrector strengths AML# along ML

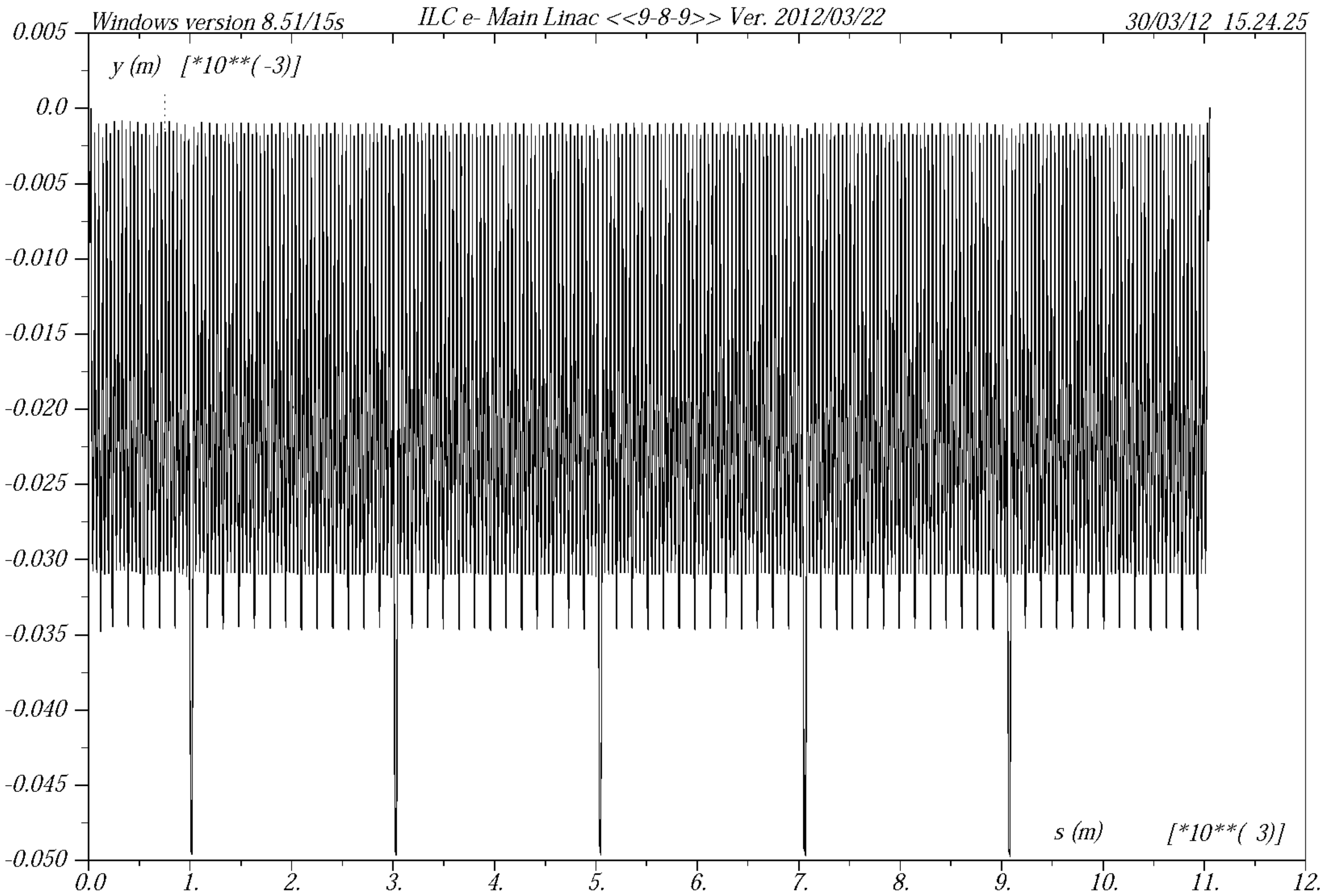
```
MATCH, BETA0=TWSS0
  VARY, AMLY10 (11,13,15,22,23,25)
  ..............................
  CONSTR, PATTERN="YML...", Y=0
   LMDIF, TOL=1.E-20,…
   MIGRAD, TOL=1.E-20, …
ENDMATCH
```

Notice. Another possible constraint with Y>0 (instead of Y=0) minimizing wake-field effects (Kubo's proposal) is not realized yet in the present ML lattice.

Match AML26, AML27 at exit:

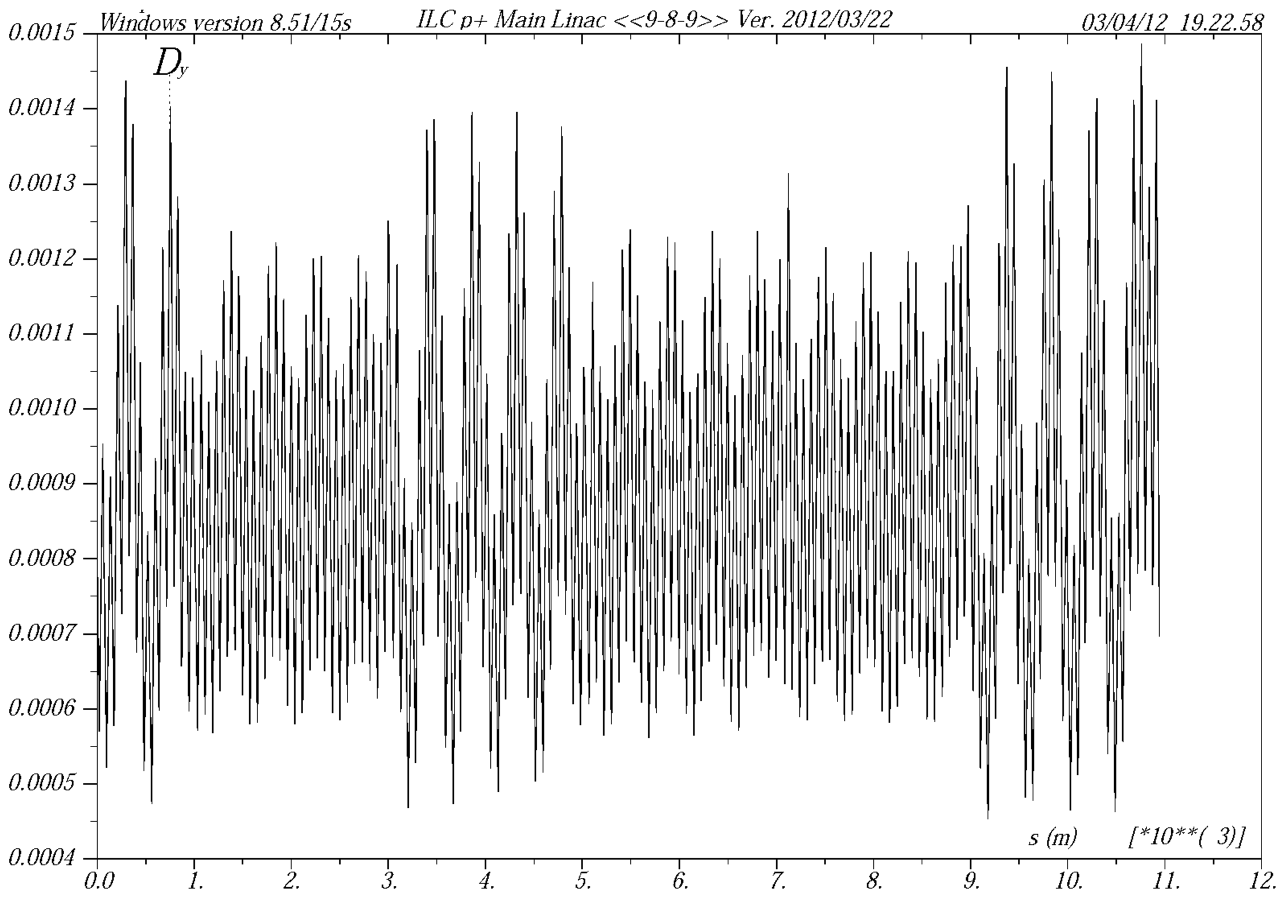
```
MATCH, BETA0=TWSS0
     VARY, AMLY26, STEP=1.E-9
     VARY, AMLY27, STEP=1.E-9
     CONSTR, #E, Y=0, PY=0
     LMDIF, TOL=1.E-20, CALLS=5000
     MIGRAD, TOL=1.E-20, CALLS=5000
   ENDMATCH
```

Beam orbit after steering



Dispersion minimization

- The beam injected into ML must be macthed to the periodic dispersion in curved lattice
- The optimal dispersion at injection (TDY & TDPY) is found by minimizing DY at every defocusing quads

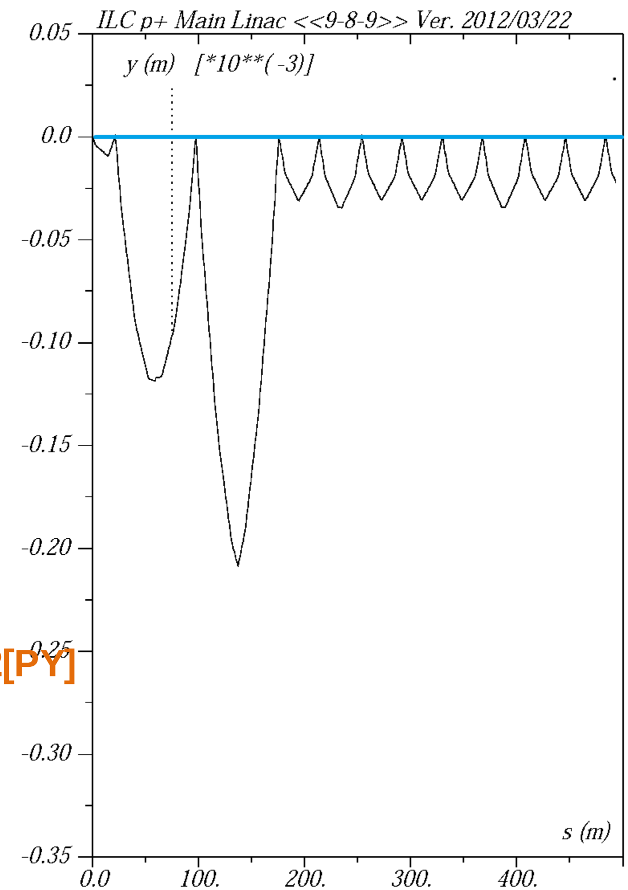


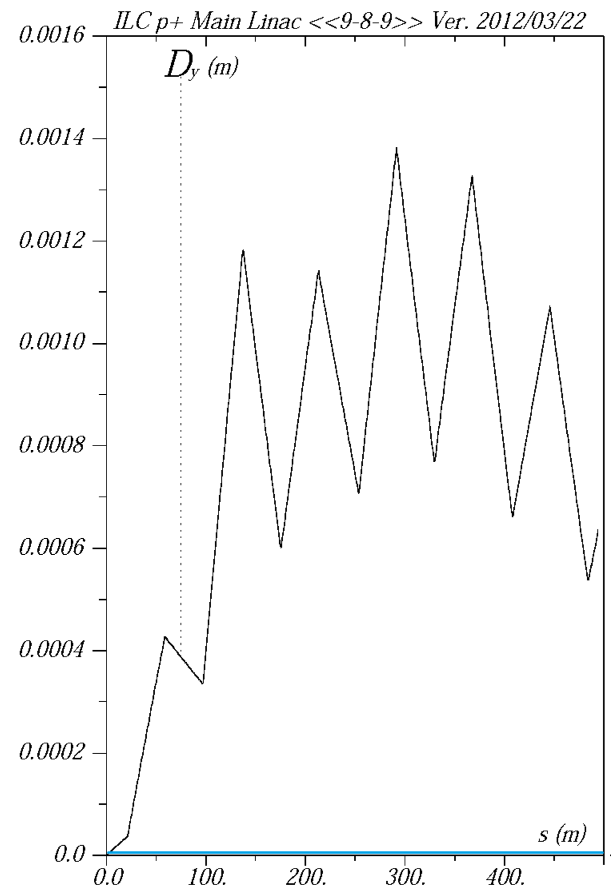

```
! Find TDY & TPDY
SET, CURVE, 1; SET, STEER, 1;
SET, BUMPS, 0; USE, PLIN1

MATCH, BETA0=TWSS0
    VARY, TDY; VARY, TDPY
    WEIGHT, WX=1.E-9
    CONSTR, PATTERN="MQD.*", DY=0
    LMDIF, TOL=1.E-20;
ENDMATCH

! Save solution at the 6th RFU
SET, MDY, TWSS_QML006[DY]
SET, MDPY, TWSS_QML006[DPY]
```

Matching DY & ref. orbit at ML entrance

- RTML end with DY=0 & w/o curvature is matched into ML beginning with DY ≠0 & CURVE=>1;
- 5 additional vertical kicks (AMLYi+AMLDY##**i**) for 5 first correctors at ML beginning are switched on by “SET, BUMPS,1”

```
SET, CURVE, 1;   SET, STEER, 1
SET, BUMPS, 1;   USE, PLIN1
SAVEBETA, TWSS1, YML003
SAVEBETA, TWSS2, YML005
TWISS, BETA0=TWSS0

MATCH, BETA0=TWSS0
VARY, AMLDY11i (12i, 13i, 14i, 15i);
CONSTR, YML003, Y=TWSS1[Y]
CONSTR, YML005, Y=TWSS2[Y], PY=TWSS2[PY]
CONSTR, QML006[1], DY=MDY, DPY=MDPY
LMDIF (MIGRAD), TOL=1.E-20;
ENDMATCH
```





Matching DY & ref. orbit at the ML end

- ML end with DY ≠0 & CURVE=>1; is matched PMSCOL end with DY=0 & w/o curvature
- 5 additional vertical kicks (AMLYi+ AMLDY##o) for the last correctors at ML end are switched on by “SET, BUMPS,1”

!PLIN example:

SET, CURVE, 1; SET, STEER, 1

SET, BUMPS, 1; USE, PLIN1

SAVEBETA, **TWSS1_YML281, YML281 !next-to-last**

TWISS, BETA0=TWSS0

MATCH, BETA0=TWSS0

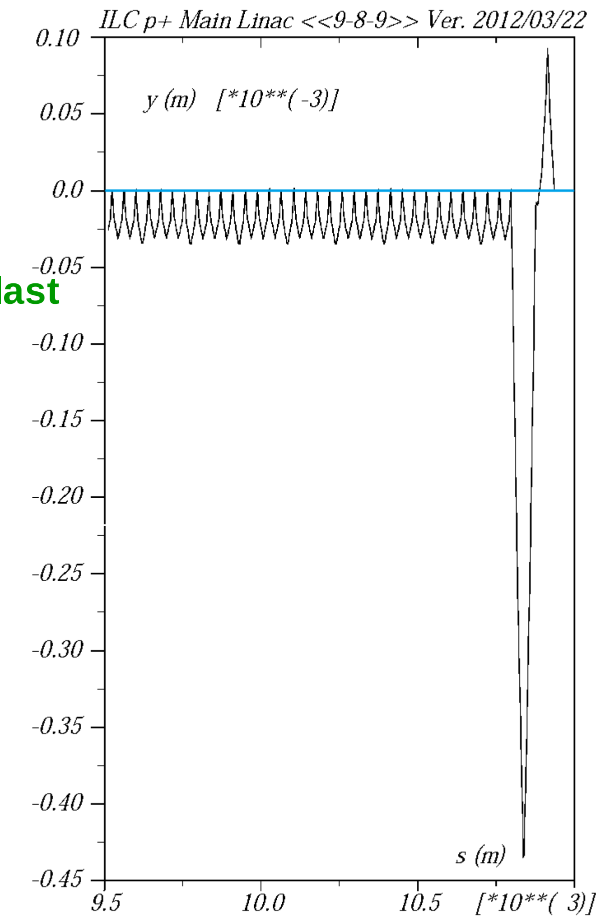
VARY, AMLDY21o (22o, 23o, 24o, 25o);

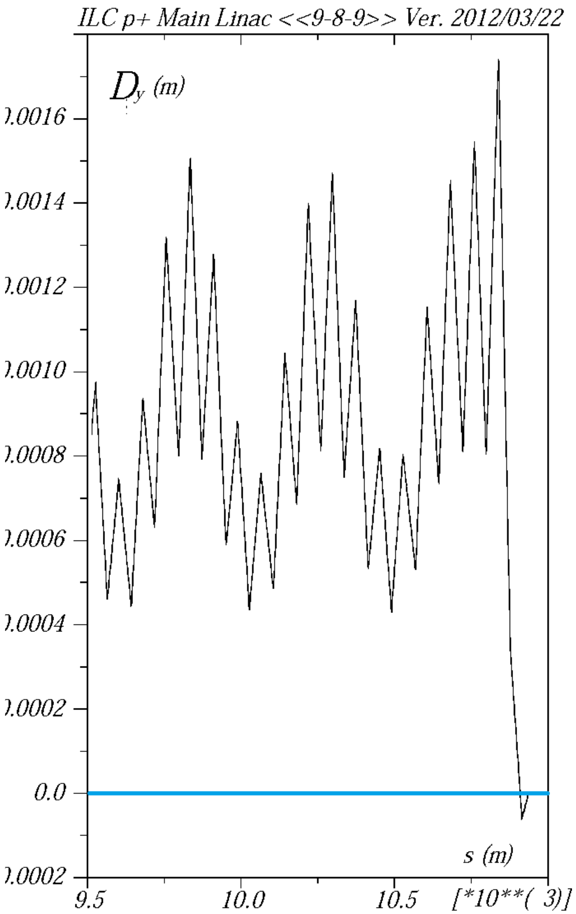
CONSTR, YML281, Y=TWSS1_YML281[Y]

CONSTR, YPLIN2o, Y=0, PY=0, DY=0, DPY=0

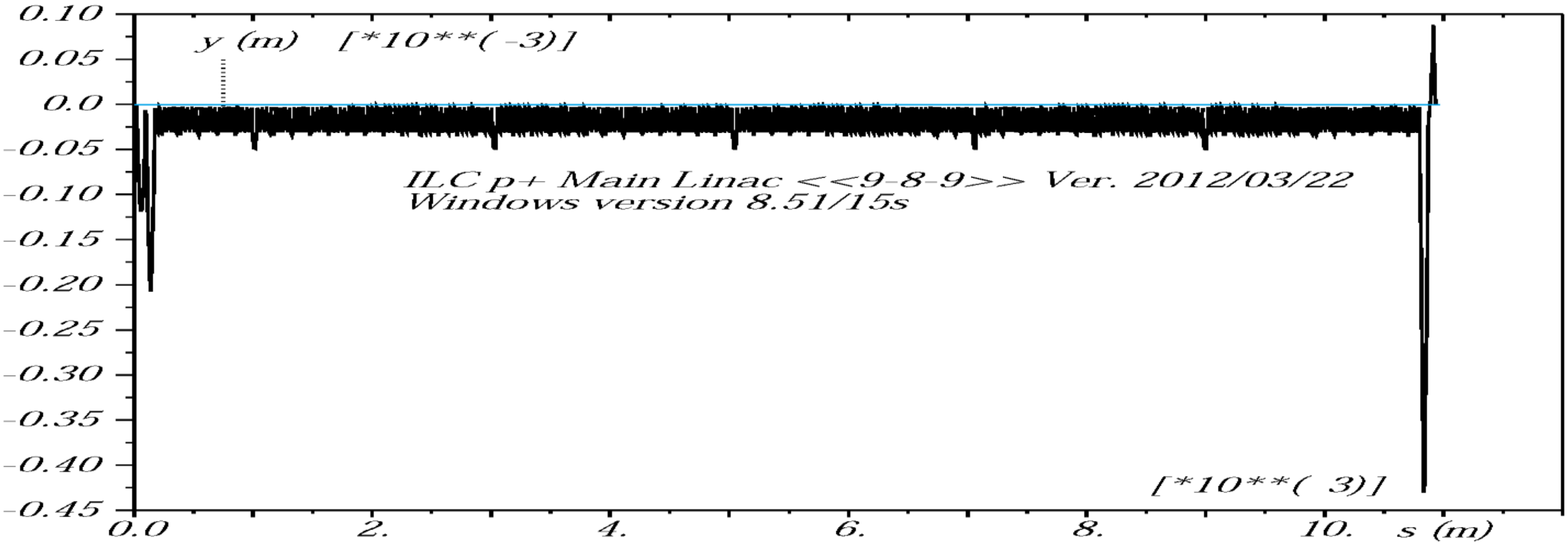
LMDIF (MIGRAD), TOL=1.E-20;

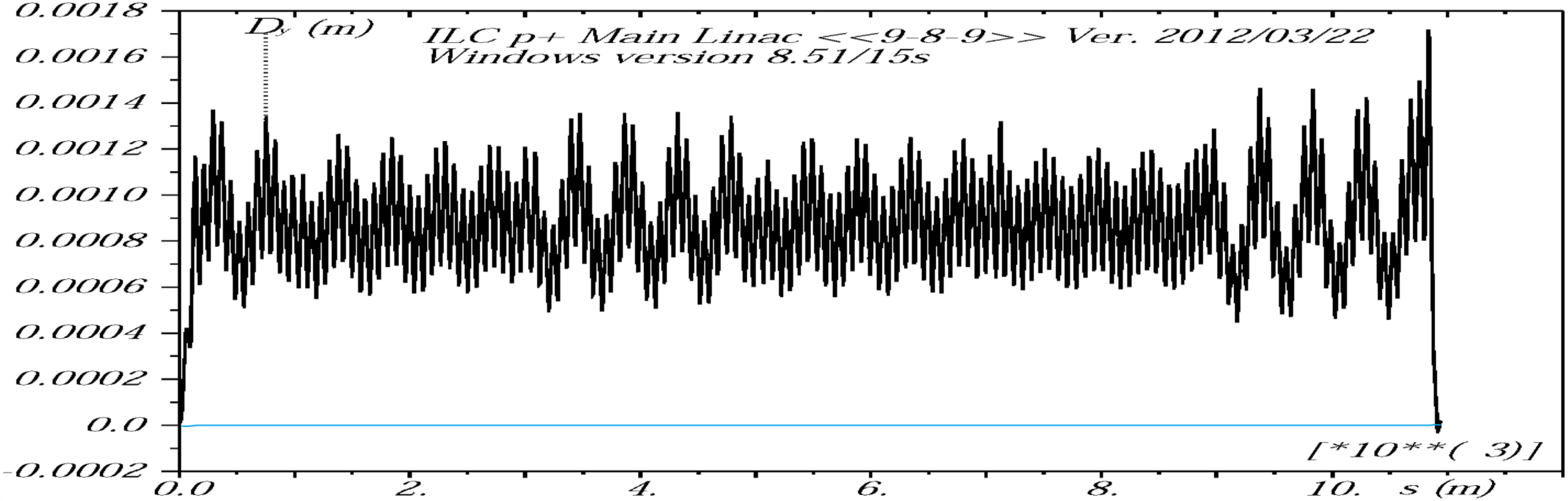
ENDMATCH





Matched DY & Y throughout PLIN





Summary & the present lattice status

- Main Linac lattices (9+4Q4+9 configuration) for TDR version have been re-designed, tuned and matched
- Tuning and matching subroutines previously created for RDR in 2007 are checked and adaptively modified for TDR-2012 version
- Presented outlook of lattice tuning is a helpful reference in a future, since the CM length can be slightly changed in the final designs
- ML lattices are ready for a further non-optical “text-information” polishing (like MAD8 “TYPE” statements)
- ML lattices are documented and will be posted at ILC EDMS.