EHF 89/59

XV EHF Workshop, Lecce

THE HIGH-ENERGY PROTON LINAC (DTL & SCL)

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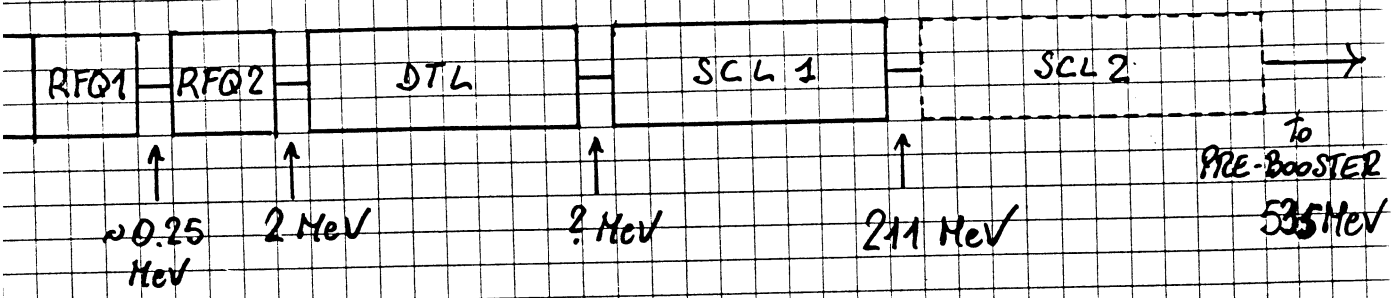
THE NEW INJECTION SCHEME

(Eindhoven Workshop, June 1989)



FEATURES :

- Clean bunch to bucket transfer ⇒ no losses
  proper matching
- "human" size (⇒ "human" cost)
- 1300 MHz "standard" Klystron frequency
- staged approach to the "nominal" EHF
  (⇒ possibility to upgrade both energy & current)

CHALLENGES :

- Huge beam compression ⇒ very high CURRENTS
- Clean bunch To bucket transfer, but
  - bigger longitudinal emittance
  - frequency jump RFQ2/DTL

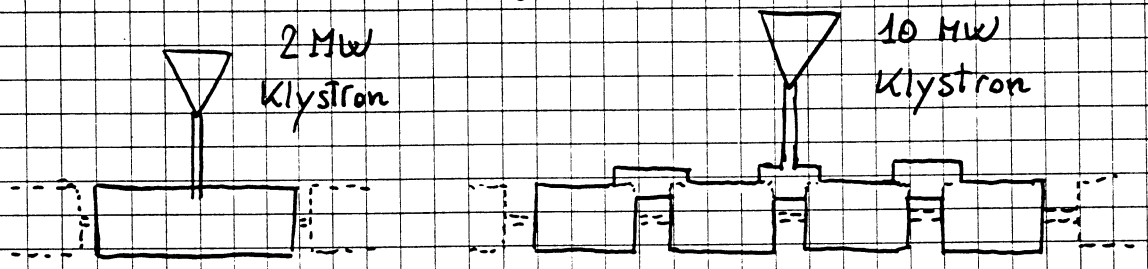
  ⇒ need for careful longitudinal matching

DESIGN CRITERIA FOR DTL - SCL

(1) STRUCTURES OPTIMIZED FOR POWER CONSUMPTION AND LENGTH

practically:

- retain the cells design which has been established for the EHF proposal (only small adjustments for newer frequencies)
- ~~not~~ maintain the same general layout:



DTL 2MW Klystrons each feeding 1 tank

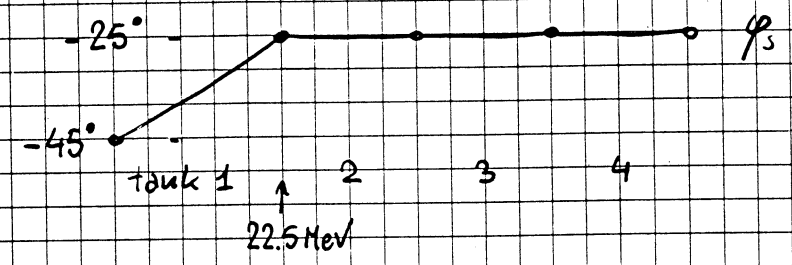
Tank diameter decreasing for high efficiency

SCL 10 MW Klystrons feeding a module of 4 tanks connected by bridge couplers. Number of cells per tank is constant. All the cells in a tank are equal.

(2) SAFE OPERATION ⇐ Peak fields about the Kilpatrick value

(3) LONGITUDINAL MATCHING

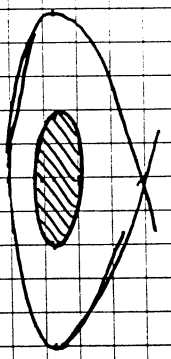
- DTL : The synchronous phase increases in tank #1 from $-45°$ to $-25°$ and then stays at $-25°$



1. $-45°$ at input is optimized to hold the high $\Delta\varphi$ of beam out of the RFQs
2. As $\Delta\varphi$ shrinks with acceleration, φ_s increases shrinking accordingly the bucket and allowing a higher efficiency

INPUT $W = 2$ MeV
$\beta = 0.065$

OUT TANK 1
$W = 22.5$ MeV
$\beta = 0.215$



PHASE $-45°$
⇒ HIGH (PH.) ACCEPTANCE

PHASE $= -25°$
⇒ HIGH EFFICIENCY

E.F constant at transition tank 1 → tank 2

- SCL : $\varphi_s = -28°$ to hold the beam from DTL (need of a rebunching system!)

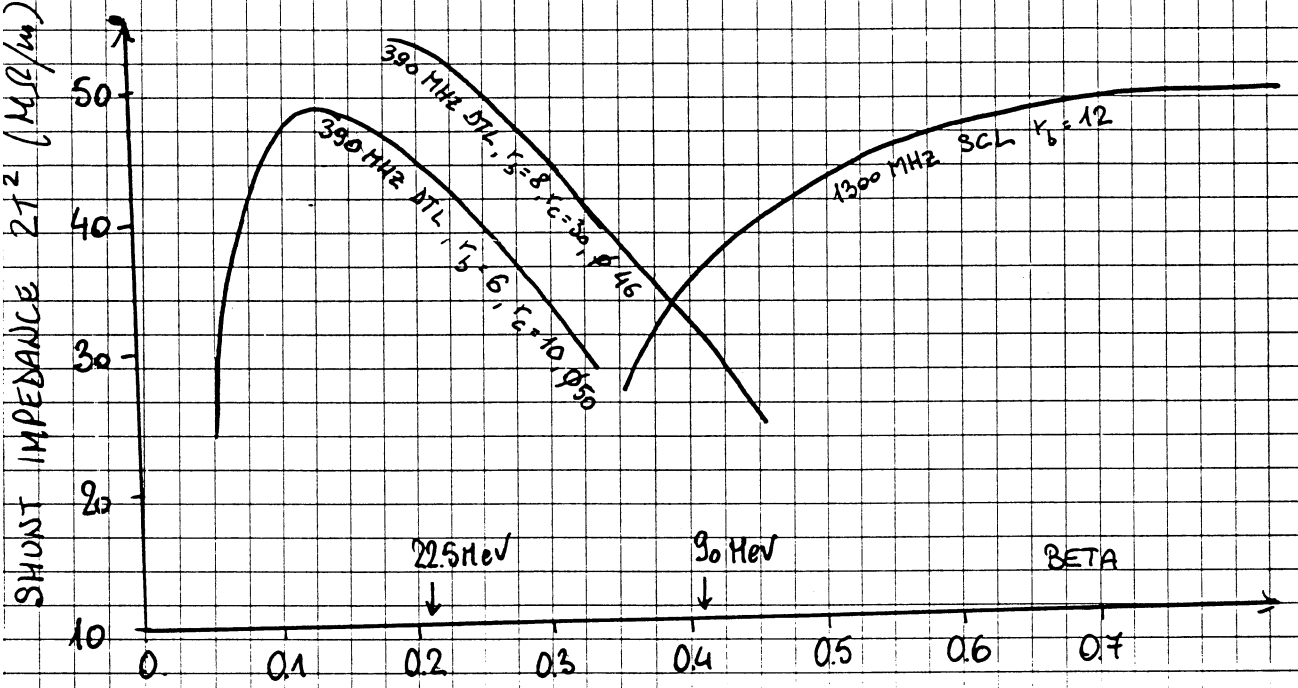
(4) TRANSVERSE MATCHING

Easier. The bore hole increases to account for field errors, aberrations, misalignements :

6 mm DTL tank 1
8 mm DTL tanks 2,3,4
12 mm SCL

(5) CHOICE OF TRANSFER ENERGIES

Criterion 1 : High efficiency (= shunt impedance ZT^2)



Criterion 2 : Number of tanks

Criterion 3 : Acceptance of SCL must be enough to house the DTL bunch

⇒ optimum transfer energy between DTL and SCL has been found 90 MeV

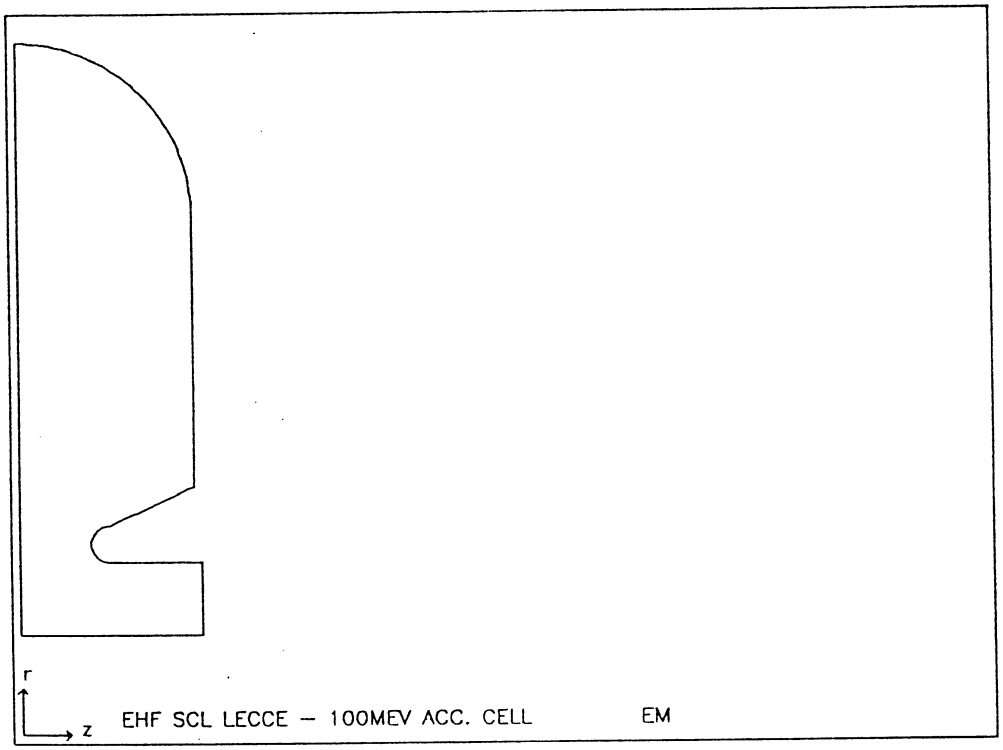
DEFINITION OF DTL AND SCL LAYOUTS

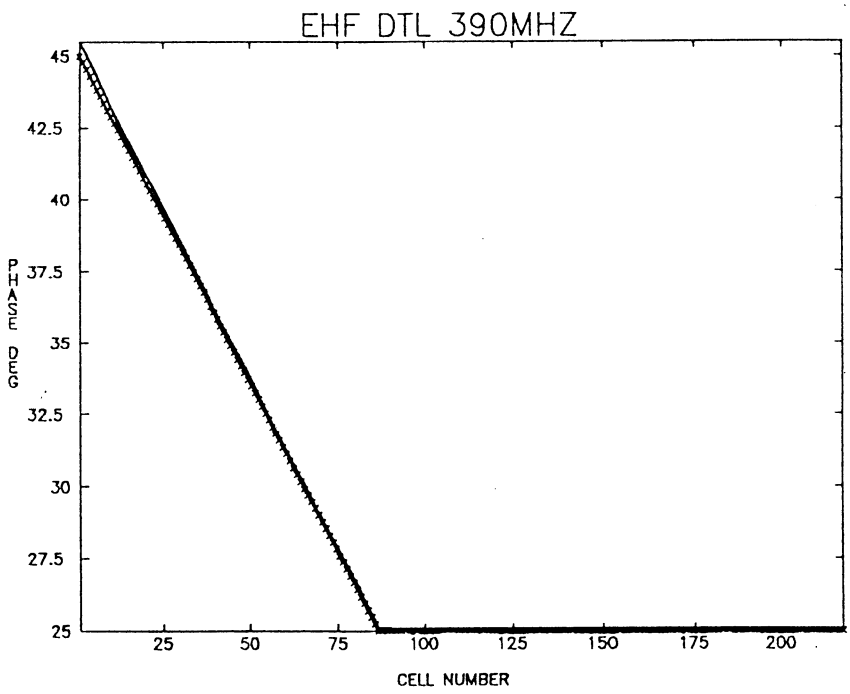
Standard computer codes :

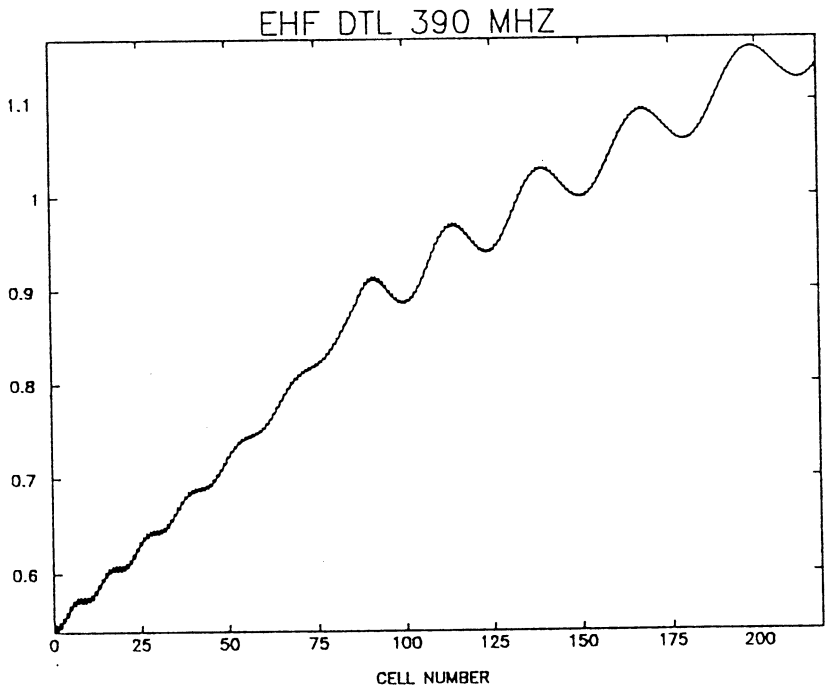
DTL : CLAS → GENLIN → ADAPT → MARRO

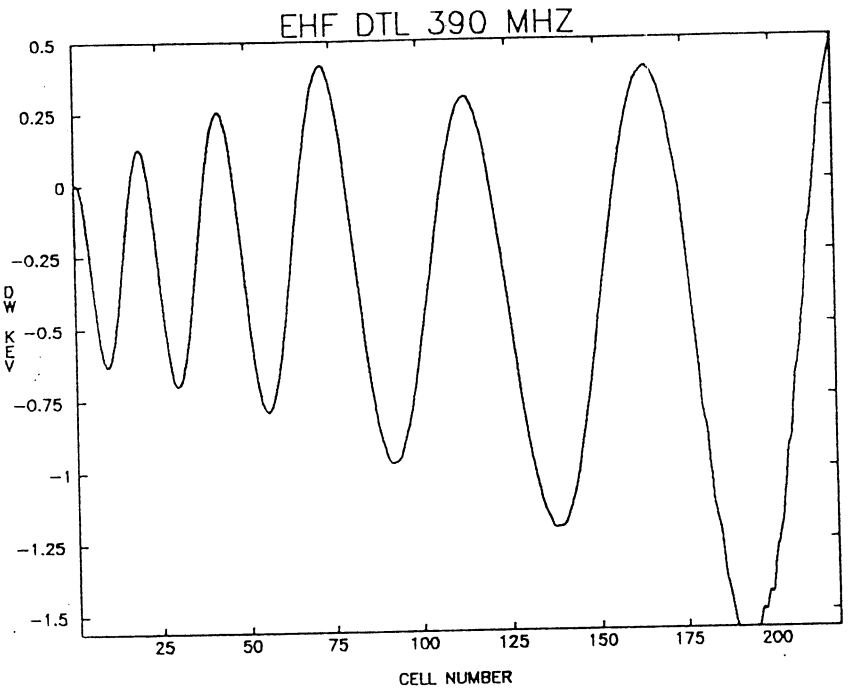
SCL : SUPERFISH → CCLDSN → LINAC

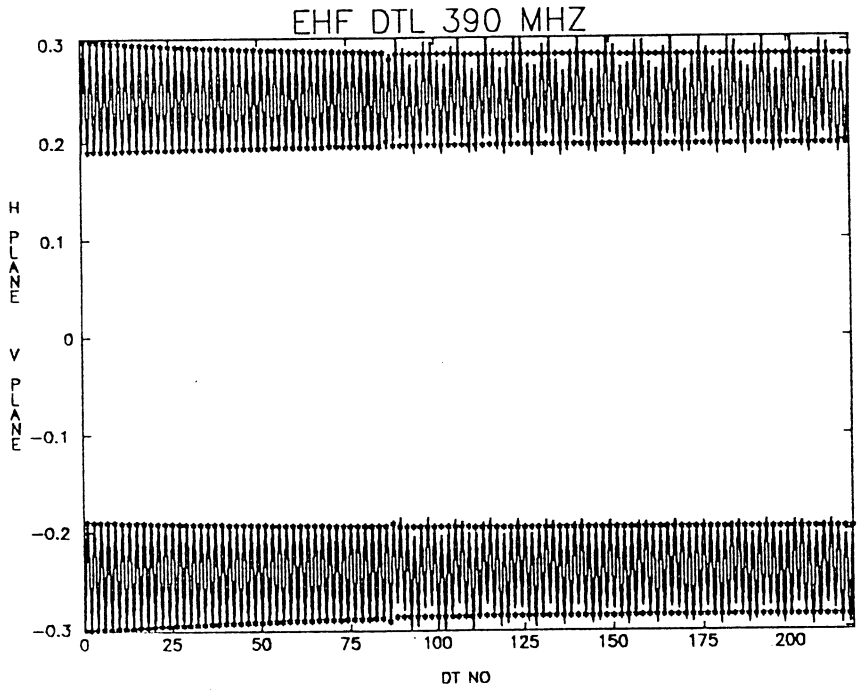
cavity design	definition of linac layout & of focusing system	particles tracking inside the linac


r
z
EHF SCL LECCE – 100MEV ACC. CELL
EM


EHF DTL 390MHZ
45
42.5
40
37.5
35
32.5
30
27.5
25
PHASE DEG
25
50
75
100
125
150
175
200
CELL NUMBER


EHF DTL 390 MHZ
1.1
1
0.9
0.8
0.7
0.6
0
25
50
75
100
125
150
175
200
CELL NUMBER


EHF DTL 390 MHZ
0.5
0.25
0
−0.25
−0.5
−0.75
−1
−1.25
−1.5
DW KEV
25
50
75
100
125
150
175
200
CELL NUMBER


EHF DTL 390 MHZ
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
H PLANE
V PLANE
0
25
50
75
100
125
150
175
200
DT NO

```
 ENTER NSEC,FREQ,WINIT,QF,XMUO,XI,XIMAX,ET,EL
 CCL LINAC DESIGN, FREQ= 1300.0 MHZ, WIN=  90.0 MEV
 QFACTOR=0.80, CURRENT= 0.010 AMPS ET=    0.64000E-03  EL=     0.25000E+02
 ENTER PMAX,WF,PHIS,DR,QL,S,XMUF,NTPK,NC

, CONSTANT PARAMETERS FOR SECTION  1
 POWER= 7.8 MW, PHIS=-28.DEG, DR= 25., QL= 10., S= 20. CM  4TANK PER KLY

  NT  NC  LENGTH  TOTL L  ENERGY   EOT  ZTSQ  PHID    PS    PB    PRF   HP
CURRENT VALUE = 0.200AMPS
 POWER GIVEN BY THE KLYSTRON N =          1       7.78982258
   1  28  134.74   178.9   98.54 7.091  36.5 -42.7 1.855 0.085 1.940 3.313
   2  28  139.97   364.7  107.45 7.128  37.8 -41.8 1.882 0.089 1.971 3.319
   3  28  145.09   557.2  116.73 7.163  39.0 -41.1 1.910 0.093 2.003 3.327
   4  28  150.10   756.4  126.36 7.194  40.1 -40.4 1.938 0.096 2.035 3.337
 POWER GIVEN BY THE KLYSTRON N =          2       7.79893875
   5  28  154.93   961.8  136.12 7.062  41.1 -39.4 1.880 0.098 1.978 3.333
   6  28  159.60  1173.5  146.20 7.085  42.0 -38.8 1.906 0.101 2.007 3.346
   7  28  164.15  1391.1  156.59 7.105  42.9 -38.3 1.932 0.104 2.036 3.361
   8  28  168.58  1614.6  167.29 7.122  43.7 -37.7 1.957 0.107 2.064 3.376
 POWER GIVEN BY THE KLYSTRON N =          3       7.81747437
   9  28  172.82  1843.6  177.90 6.901  44.4 -36.9 1.853 0.106 1.959 3.371
  10  28  176.88  2078.0  188.79 6.912  45.1 -36.5 1.875 0.109 1.984 3.389
  11  28  180.83  2317.5  199.92 6.921  45.7 -36.1 1.897 0.111 2.008 3.408
  12  28  184.66  2562.2  211.31 6.927  46.2 -35.7 1.918 0.114 2.032 3.428
 TOTAL POWER = 24.017 MWTOTAL TANKS LENGTH    1932.345

 DYNAMICAL PARAMETERS
  NT   MUL ALPHAL  BETAL   MUT  ALPHAX   BETAX  ALPHAY   BETAY
     SIGMAOT              =  63.7227478
   1  86.2  0.174 19.373  50.0   0.327   145.4   3.103   414.2
   2  84.0  0.170 17.971  50.0   0.314   152.8   2.910   418.2
   3  81.9  0.167 16.733  50.0   0.302   160.1   2.739   422.4
   4  79.8  0.163 15.633  50.0   0.291   167.2   2.586   426.6
   5  77.1  0.158 14.813  50.0   0.274   174.2   2.424   429.6
   6  75.2  0.154 13.942  50.0   0.264   180.9   2.304   433.8
   7  73.3  0.150 13.156  50.0   0.254   187.4   2.196   438.0
   8  71.5  0.147 12.442  50.0   0.244   193.7   2.097   442.1
   9  68.7  0.142 11.996  50.0   0.228   200.1   1.979   444.5
  10  67.1  0.138 11.413  50.0   0.220   205.9   1.901   448.4
  11  65.5  0.135 10.877  50.0   0.213   211.6   1.829   452.3
  12  63.9  0.132 10.385  50.0   0.205   217.1   1.763   456.1
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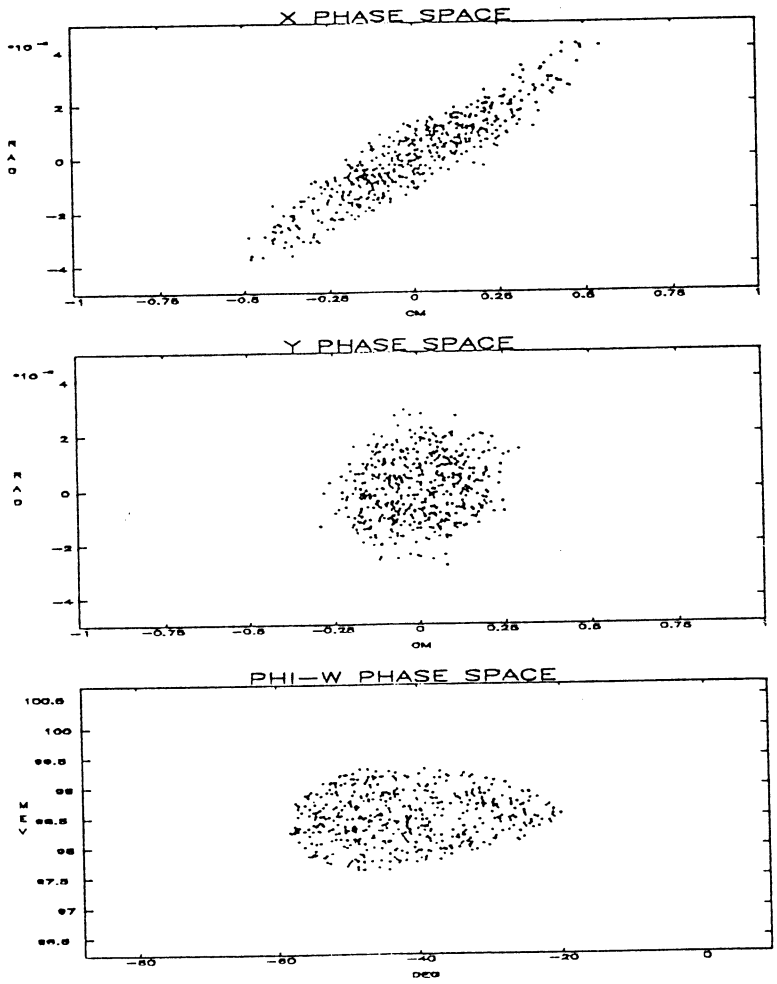
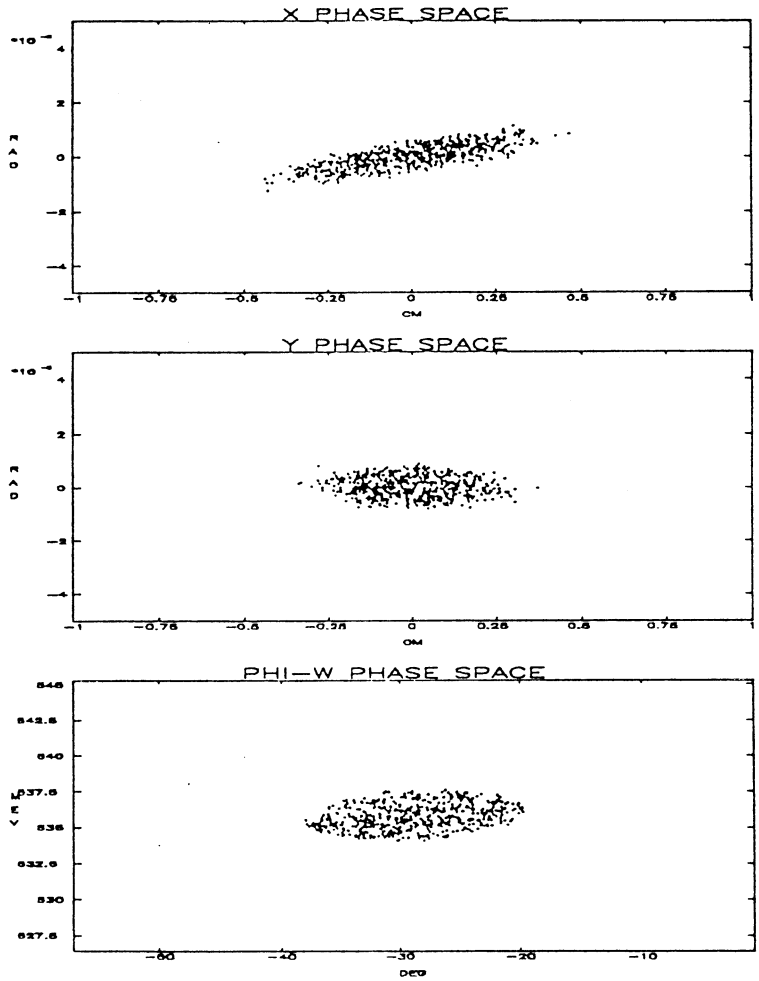
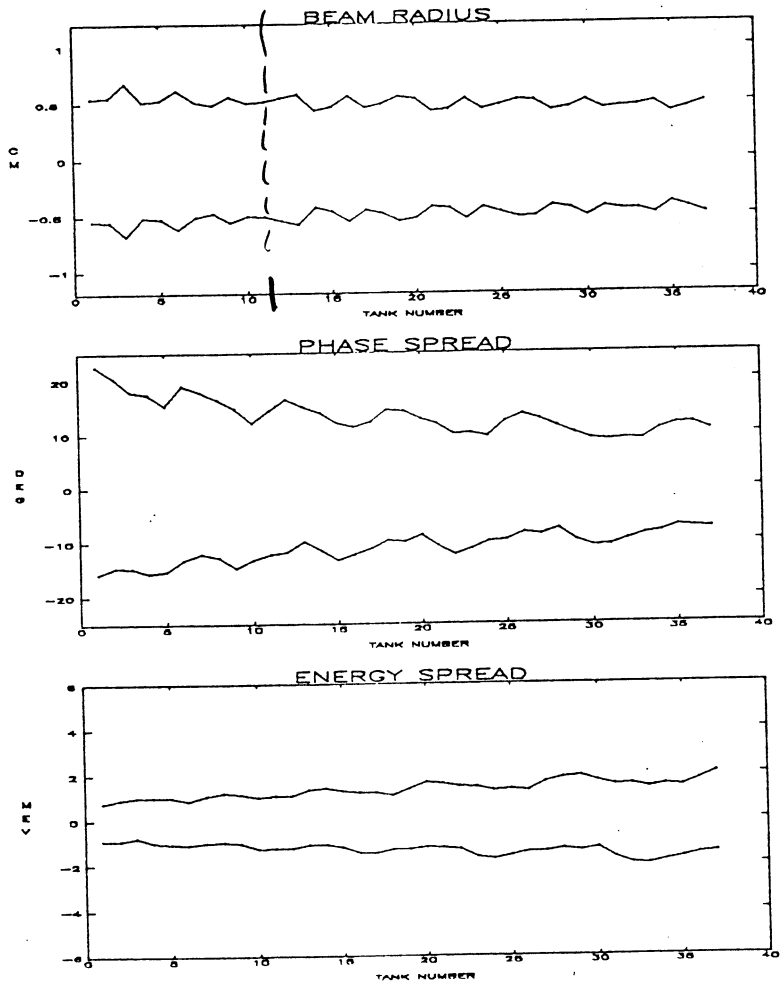
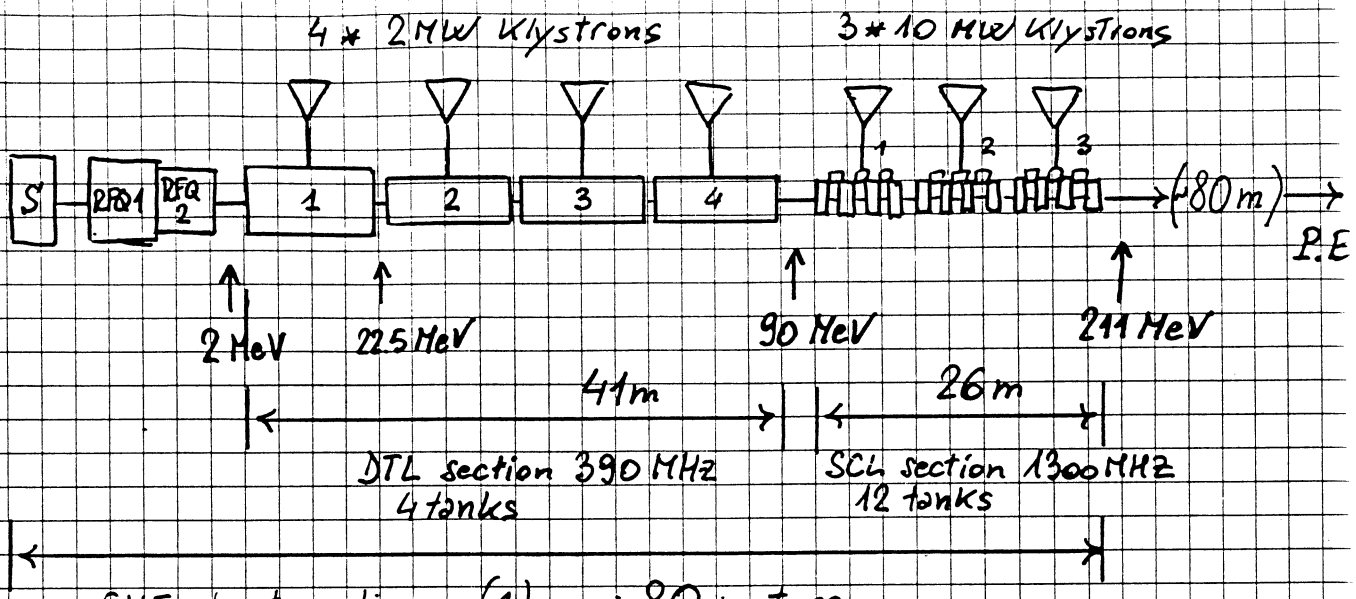

X PHASE SPACE
Y PHASE SPACE
PHI—W PHASE SPACE
CM
DEG


X PHASE SPACE
CM
Y PHASE SPACE
CM
PHI—W PHASE SPACE
DEG


BEAM RADIUS
MM
TANK NUMBER
PHASE SPREAD
DEG
TANK NUMBER
ENERGY SPREAD
MEV
TANK NUMBER



	DTL	SCL 1	SCL 2 (upgrade to 535 MeV)	
Energy	2 → 90	90 → 211	211 → 535	MeV
Frequency	390	1300	1300	MHz
# of klystrons	4	3	6	
# of tanks	4	12	24	
# of cells	216	304	816	
Peak power	7.1	23.4	46.5	MW
Acc. field E.T	~2.4	~4	~5.8	MV/m
Synchr. phase	-45° → -25°	-28°	-28°	
Transit time	0.73 → 0.88	~0.85	~0.85	
Shunt imped.	28 → 51	36 → 46	46 → 49	MΩ/m
Mean beam rad.	~2.7	~6	~5	mm
Bore radius	6 → 8	12	12	mm

83 meters needed for the upgrade

COST OF THE "NEW" LINAC

From "EHF Red Book":

DTL { structure 25 MDM → 0.34 MDM/m
RF 20 MDM → 2.5 MDM/unit = 1.25 MDM/MeV

SCL { structure 35 MDM → 0.12 MDM/m
RF 35 MDM → 2.19 MDM/unit = 0.22 MDM/MeV

Source, RFQs, chopper 7 MDM

122 MDM

"New" linac 211 MeV

DTL { structure 0.34 MDM * 41 m = 14 MDM
RF 2.5 MDM * 4 units = 10 MDM
⇒ 24 MDM (≈ 1/2)

SCL { structure 0.12 MDM * 26 m = 3.1 MDM
RF 2.2 MDM * 3 units = 6.6 MDM
⇒ ≈ 10 MDM

Overall 211 MeV linac cost (7 + 24 + 10) MDM = 41 MDM

Upgrade to 535 MeV (SCL):

Structure 0.12 MDM * 83 m ≈ 10 MDM
RF 2.2 MDM * 6 units ≈ 13 MDM
⇒ 23 MDM

+ 40% installation cost ~ 25 MDM