LEBT/MEBT Upgrade and Effect on Emittance

D. Raparia

2008/12/05

Acknowledgements

J. Alessi, B. Briscoe, J. Fite, T. Lehn, A. Kponou, V. Lodestro, G. Omar, M. Okamura, J. Ritter, W. Shaffer, A. Zelenski

Why changes in LEBT/MEBT

ACCLERATOR	INTENSITY	EMITTANCE(n,95%)
SOURCE	$1.0\ 10^{12}$	$2\ \pi$
LINAC	$5.0\ 10^{11}$	$8\text{-}10\ \pi$
BOOSTER	$2.0\ 10^{11}$	$10\text{-}6\ \pi$ (Scraping)
AGS	$1.6\ 10^{11}$	$11\text{-}16\ \pi^{*}$
RHIC	$1.4\ 10^{11}$	$8\text{-}12\ \pi$

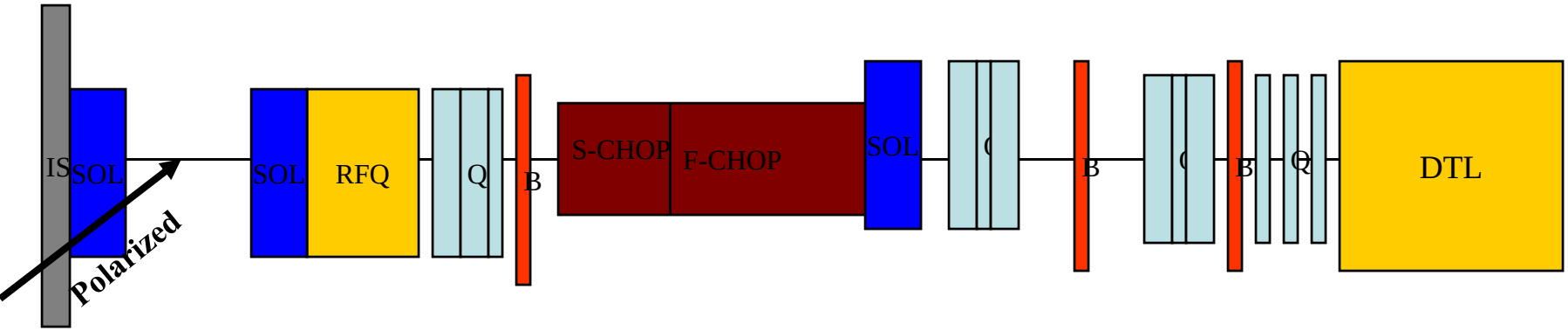
Is it intensity or emittance or both ?

- Source can give 2 times more intensity at cost of more frequent maintenance (Zelenski)
- Beam-Beam Limit $2.0\ 10^{11}$ (?)
- In Booster emittance is scraped

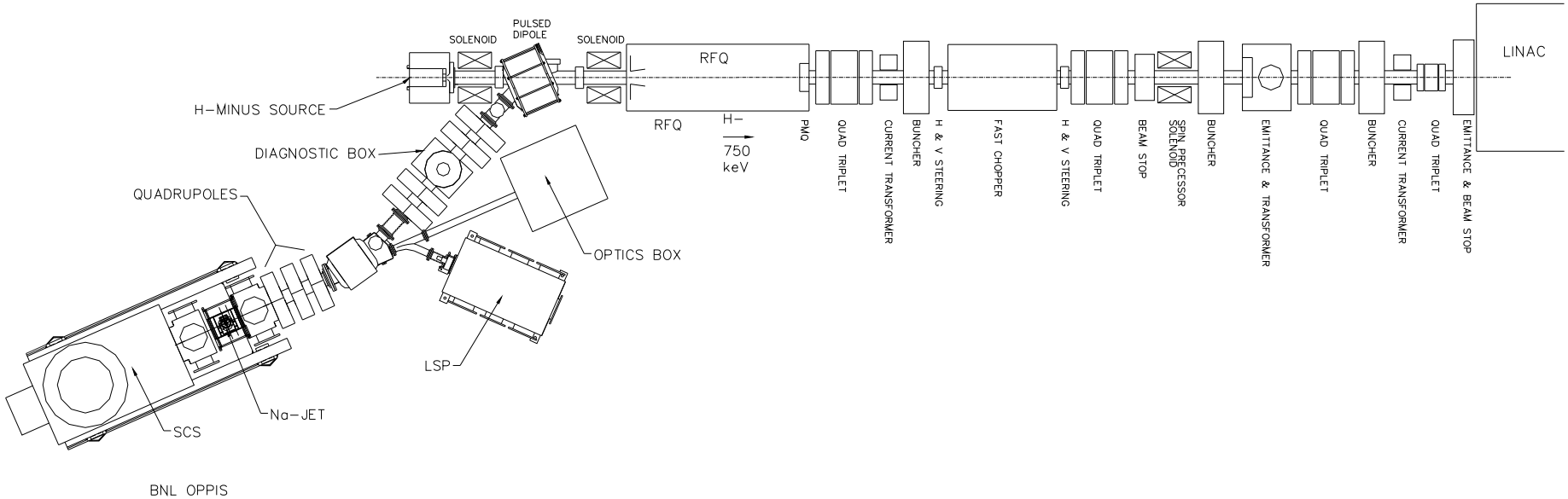
*5/11/06 H 11.4π V $16\ \pi$ with $1.6*10^{11}$

OLD MEBT

- Transverse: RFQ and DTL has FODO Lattices but MEBT has triplets to provide long drift space for chopper. Some quad are limited for maximum current
- Longitudinal: Focusing period in RFQ and DTL is about 6 cm ($\beta\lambda$=6.05 cm) where as in MEBT we have unevenly placed 3 bunchers in 7 meter. Beam is effectively completely debunched and lost all the advantage of RFQ bunched beam

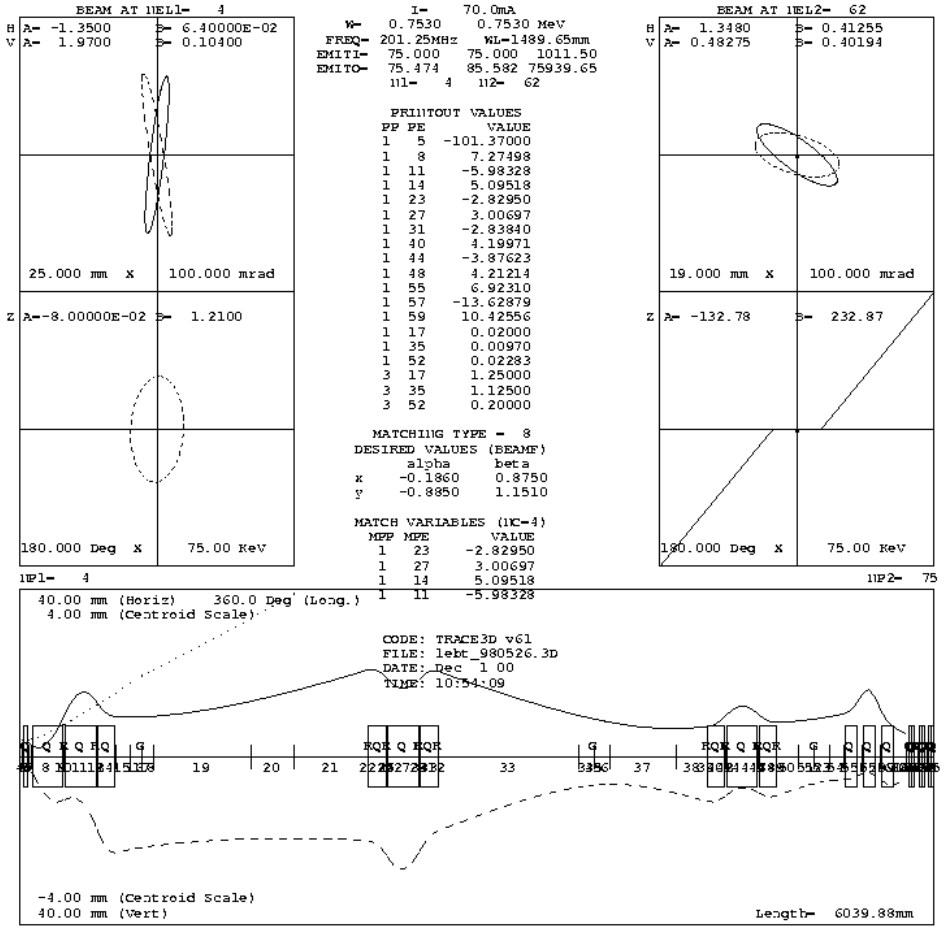


OLD LEBT & MEBT



BNL OPPIS

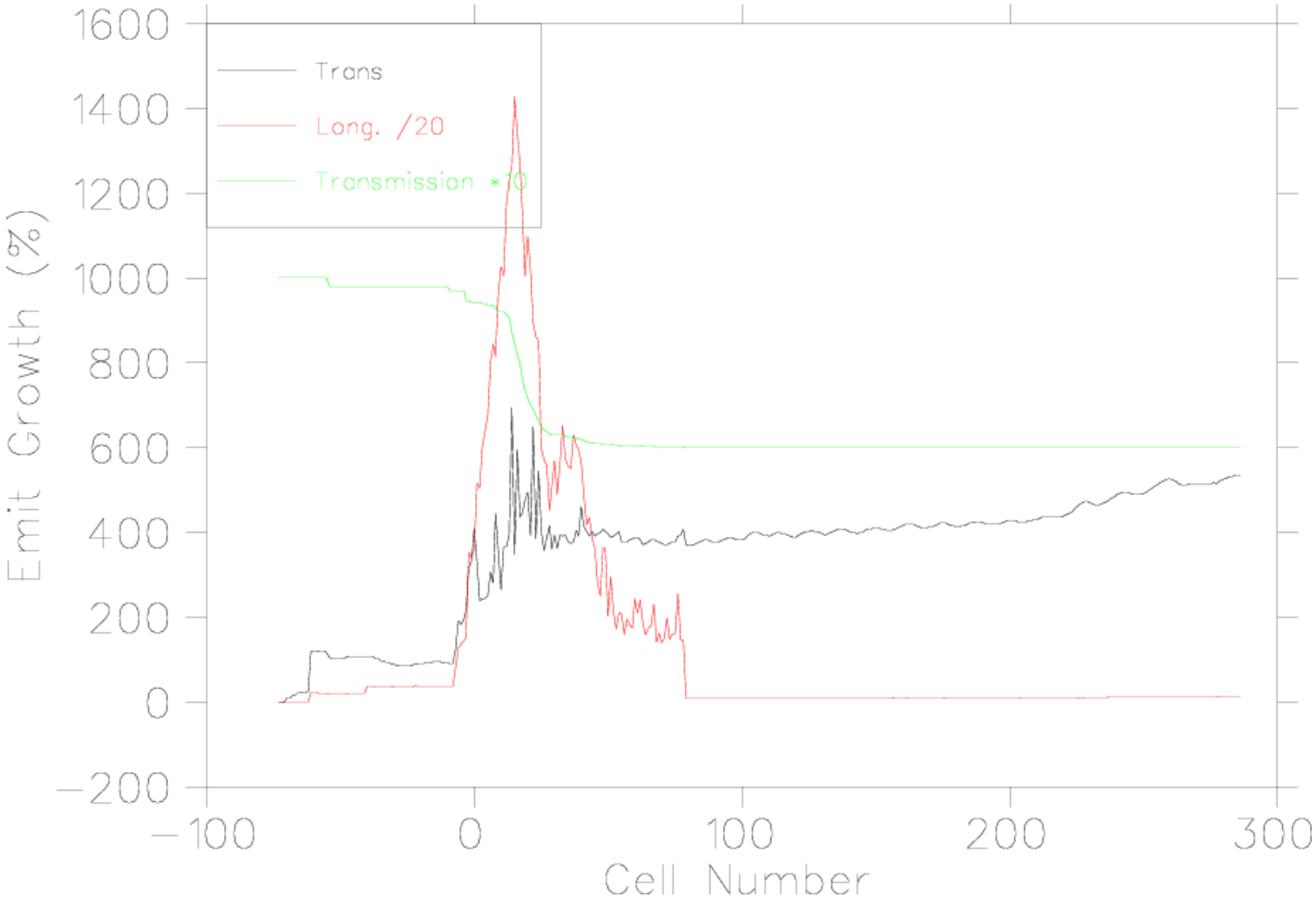
OLD MEBT TRACE OUTPUT

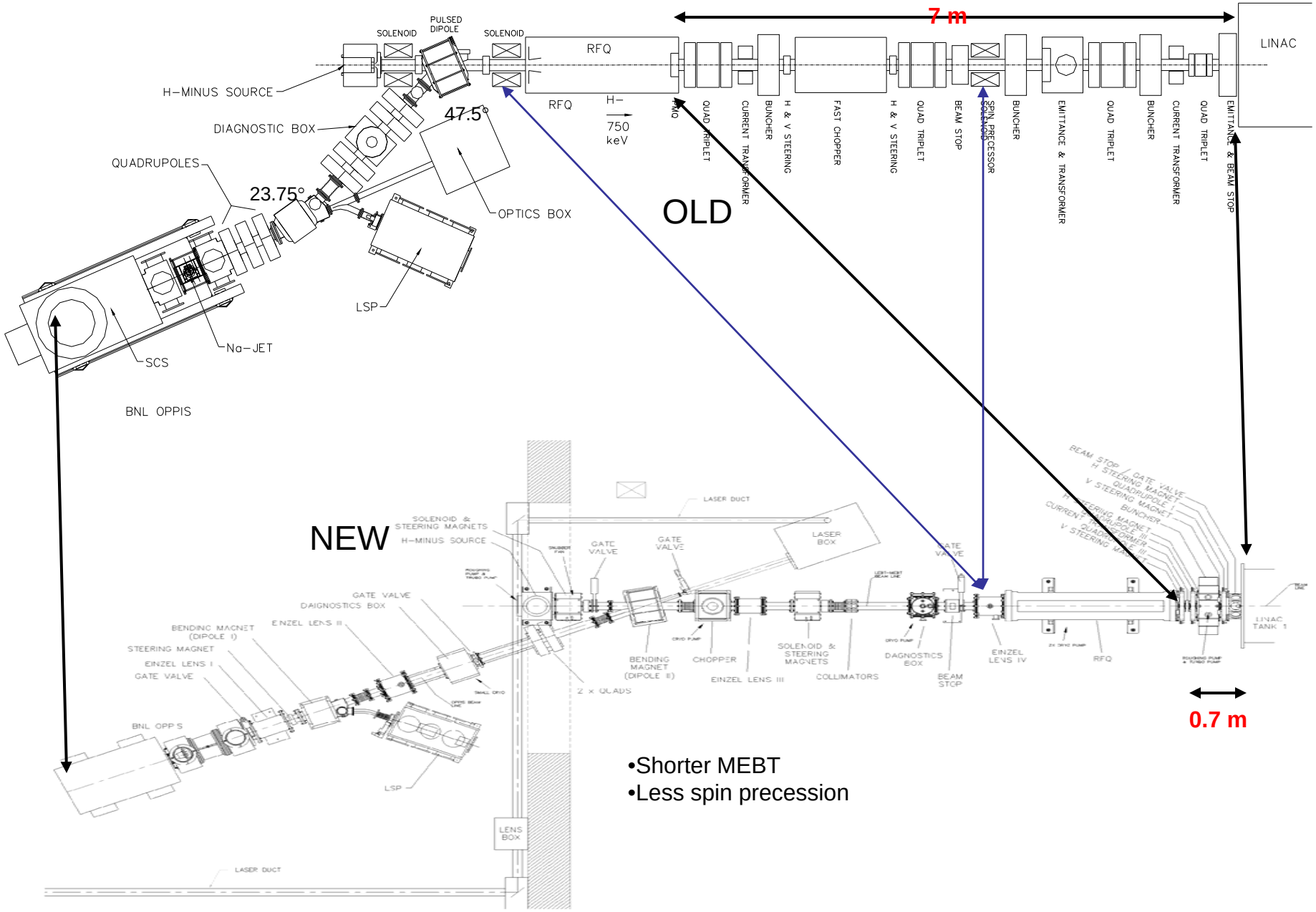


DTL

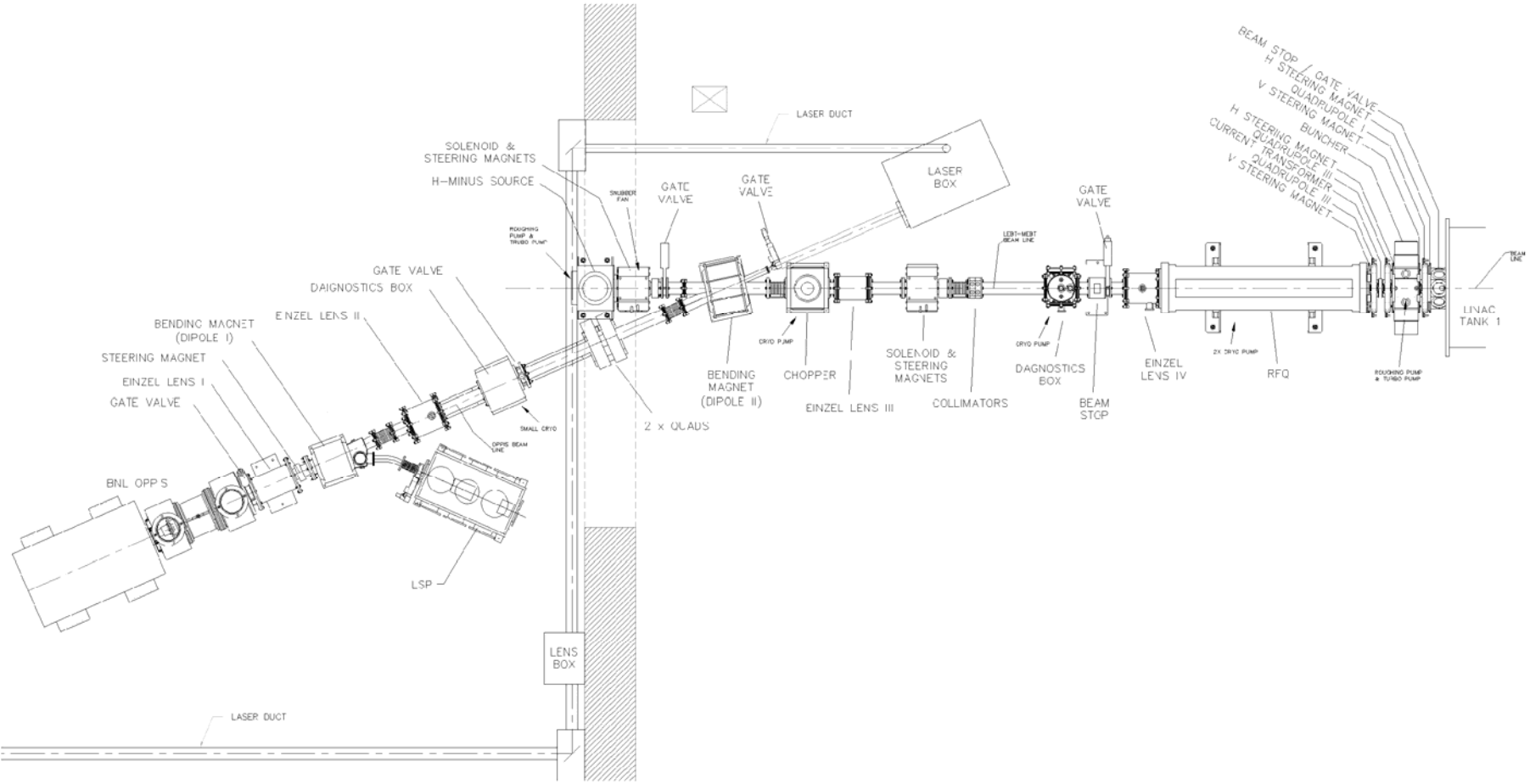
- Present transverse lattice is not matched tank to tank and when ever this is quad size changed, but after 35 years of operation present quad setting are optimize for maximum current. There should be a reason for it e.g misalignment calibration etc.
- Tank Phase and Amplitude set point are unknown
- Transverse emittance [(ex+ey)/2] growth is about 475% and longitudinal emittance growth is about 350%

OLD Emit. & Transmission



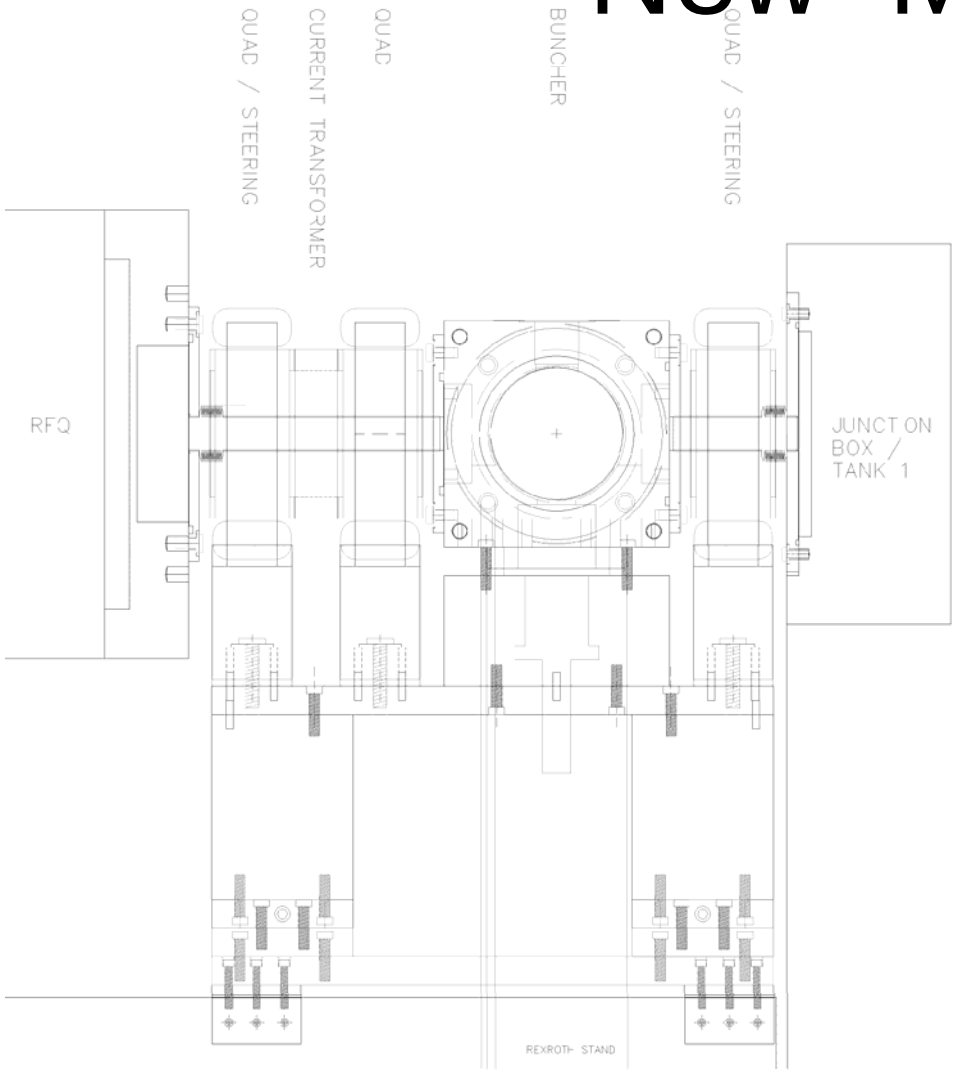


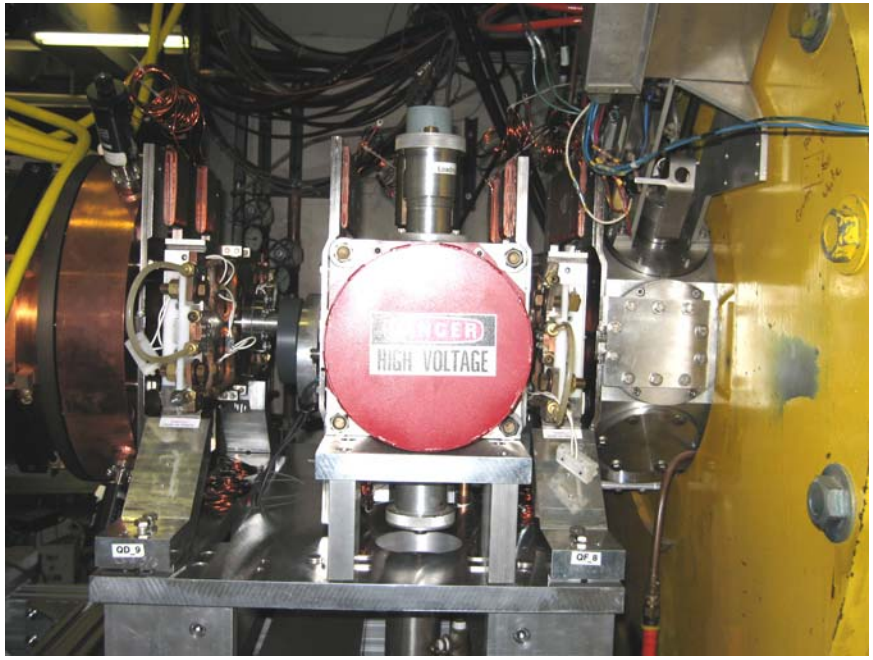
•Shorter MEBT
•Less spin precession



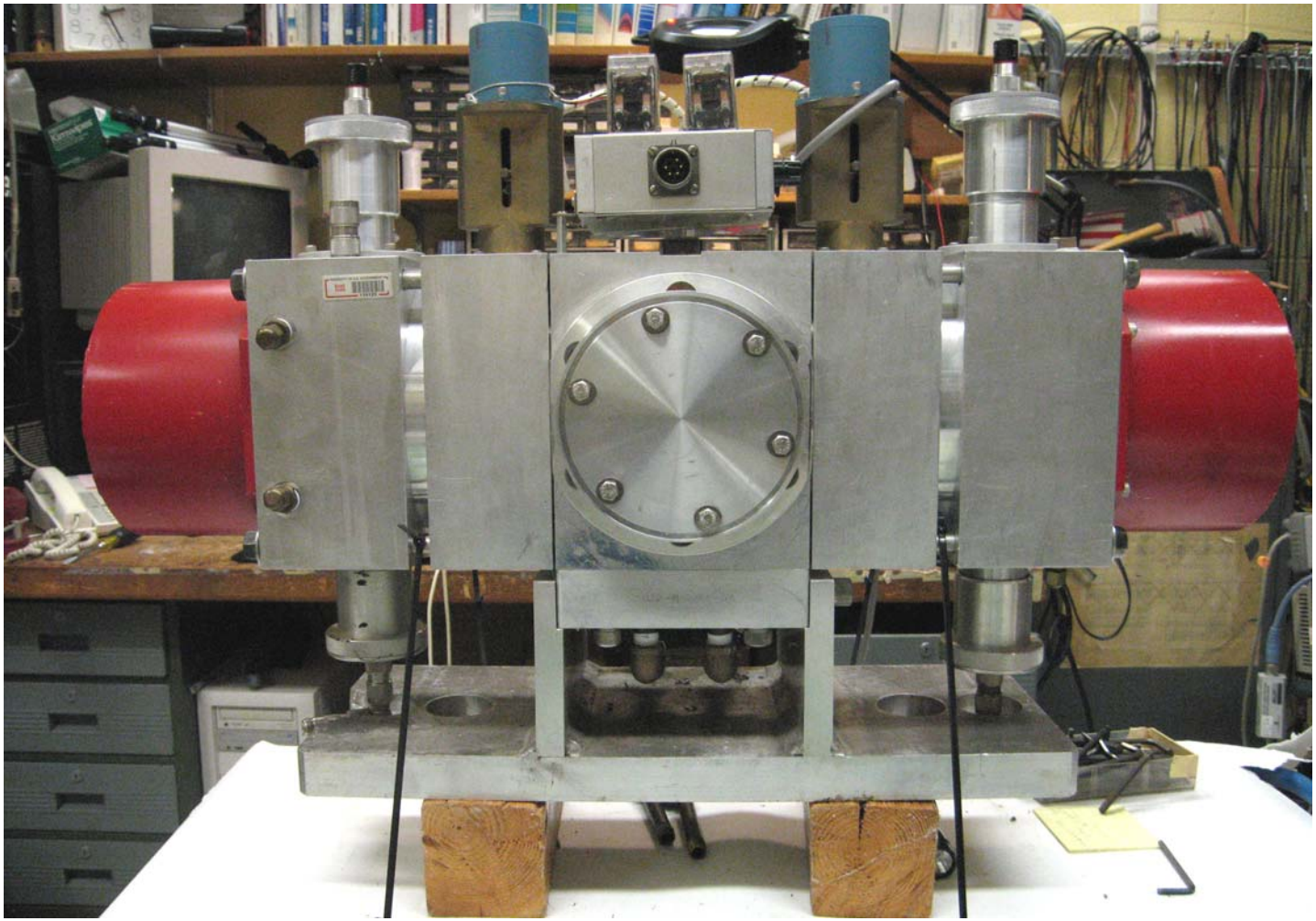
New LEBT & MEBT

New MEBT


QUAD / STEERING
CURRENT TRANSFORMER
QUAD
BUNCHER
QUAD / STEERING
RFQ
JUNCTION BOX / TANK 1
REXROTH STAND


HIGH VOLTAGE
QD 9
QF 8

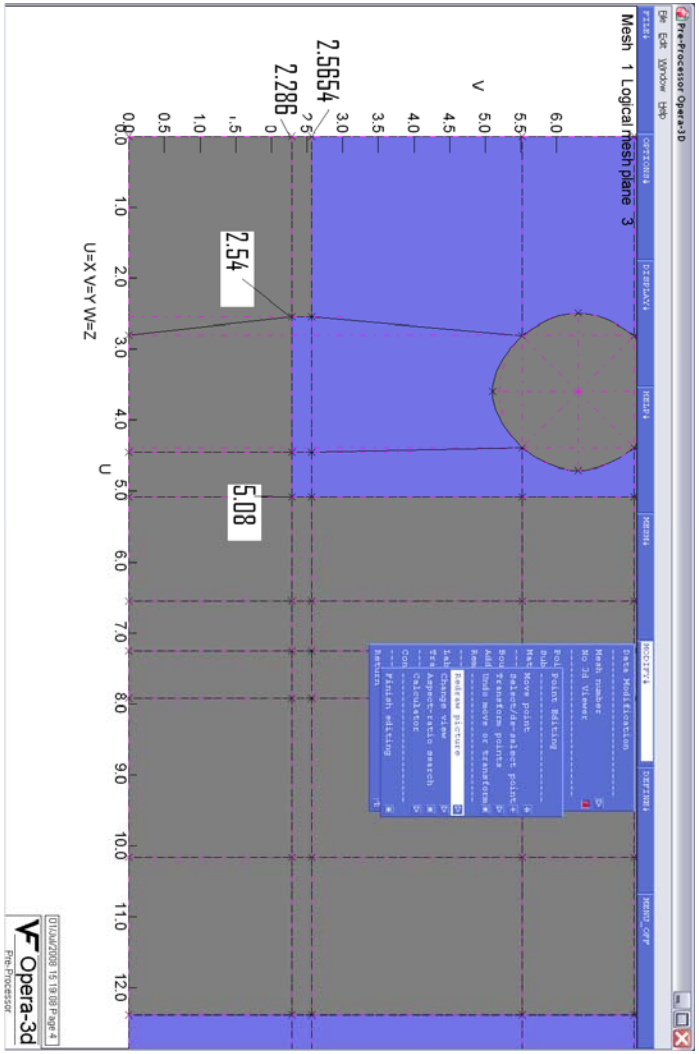
Modified Buncher



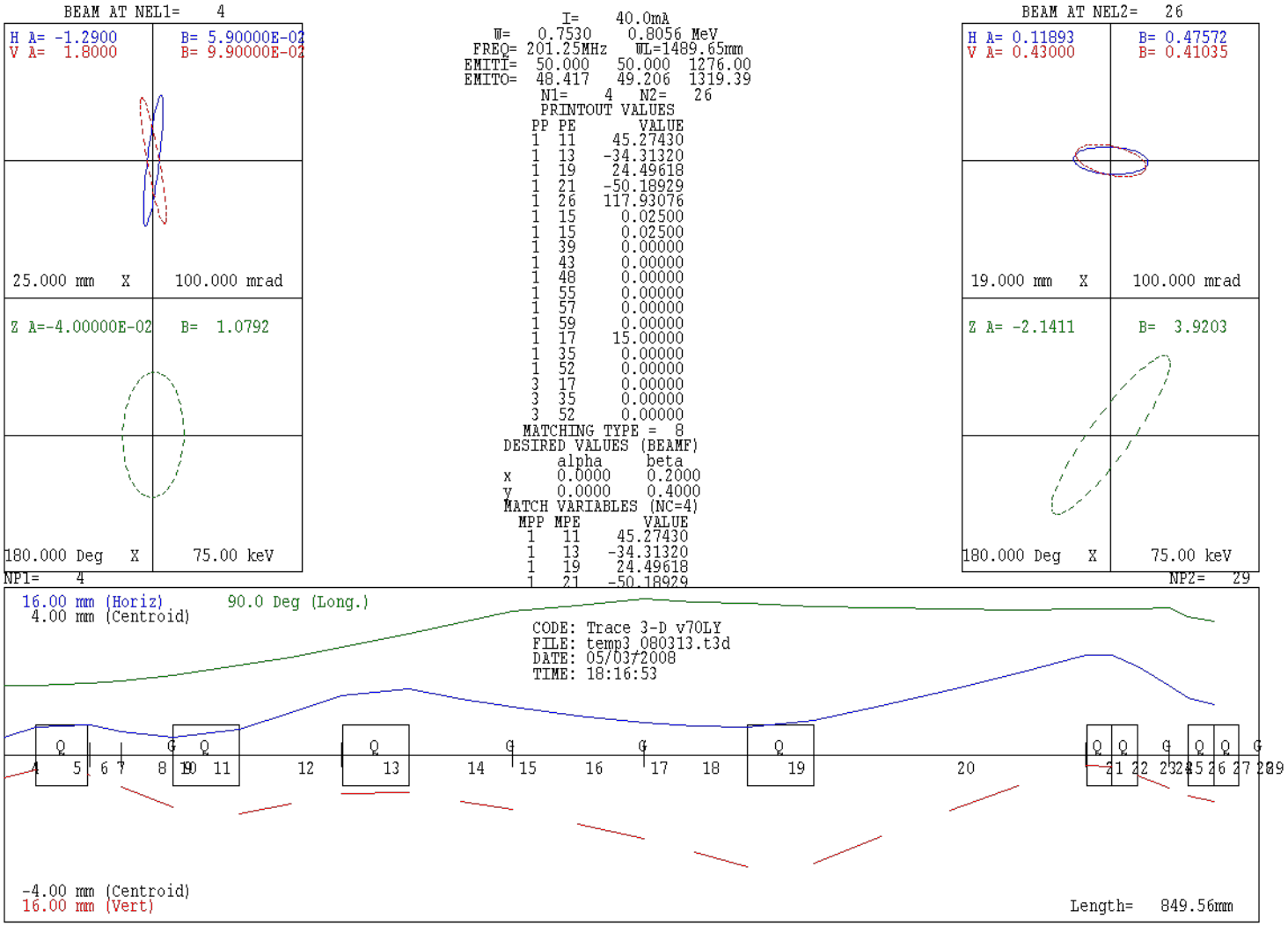
- Needed more (6 kW) power
- Available power 5 kW
- Combining two 5 kW
- Modification completed
- Test completed

New very thin steer

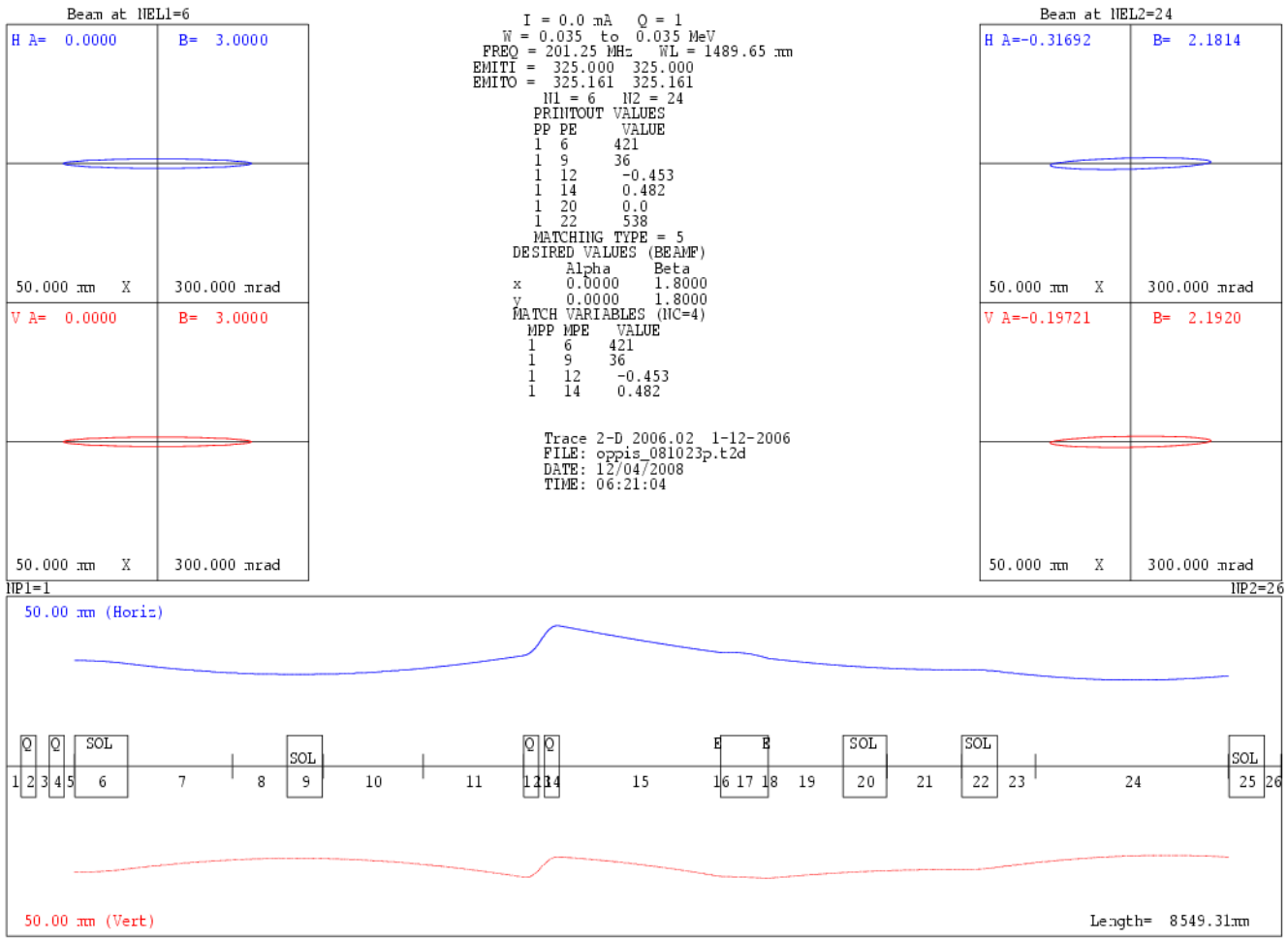
- Only 5 mm thick
- Bdl ~ 4000 G-cm



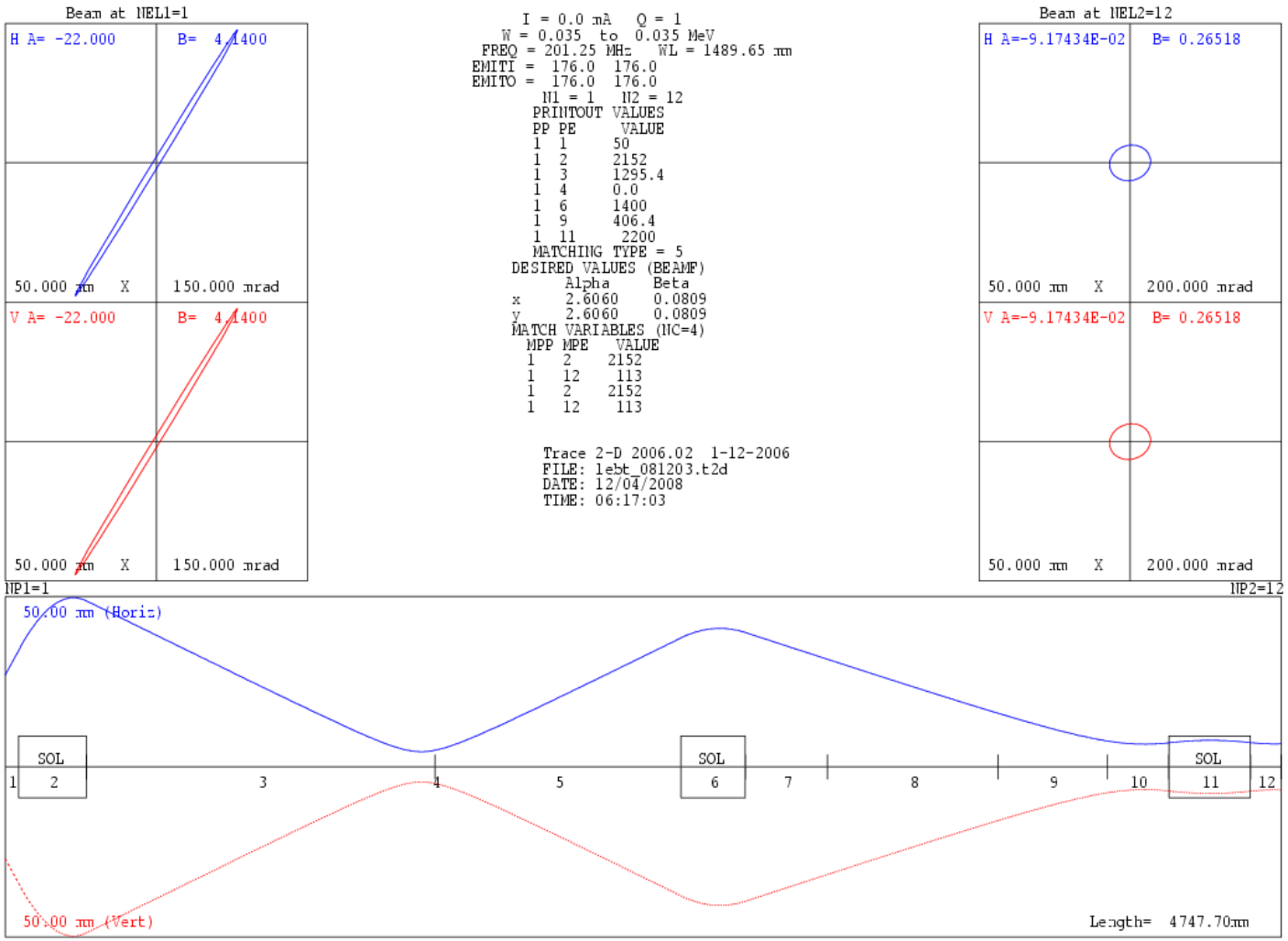
New MEBT


BEAM AT NEL1= 4
H A= -1.2900
V A= 1.8000
B= 5.90000E-02
B= 9.90000E-02
25.000 mm X
100.000 mrad
Z A=-4.00000E-02
B= 1.0792
180.000 Deg X
75.00 keV
NP1= 4
I= 40.0mA
W= 0.7530 0.8056 MeV
FREQ= 201.25MHz WL=1489.65mm
EMITI= 50.000 50.000 1276.00
EMITO= 48.417 49.206 1319.39
N1= 4 N2= 26
PRINTOUT VALUES
PP PE VALUE
1 11 45.27430
1 13 -34.31320
1 19 24.49618
1 21 -50.18929
1 26 117.93076
1 15 0.02500
1 15 0.02500
1 39 0.00000
1 43 0.00000
1 48 0.00000
1 55 0.00000
1 57 0.00000
1 59 0.00000
1 17 15.00000
1 35 0.00000
1 52 0.00000
3 17 0.00000
3 35 0.00000
3 52 0.00000
MATCHING TYPE = 8
DESIRED VALUES (BEAMF)
alpha beta
x 0.0000 0.2000
y 0.0000 0.4000
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 11 45.27430
1 13 -34.31320
1 19 24.49618
1 21 -50.18929
BEAM AT NEL2= 26
H A= 0.11893
V A= 0.43000
B= 0.47572
B= 0.41035
19.000 mm X
100.000 mrad
Z A= -2.1411
B= 3.9203
180.000 Deg X
75.00 keV
NP2= 29
16.00 mm (Horiz)
4.00 mm (Centroid)
90.0 Deg (Long.)
CODE: Trace 3-D v70LY
FILE: temp3_080313.t3d
DATE: 05/03/2008
TIME: 18:16:53
-4.00 mm (Centroid)
16.00 mm (Vert)
Length= 849.56mm

New LEBT for Polarized H^-

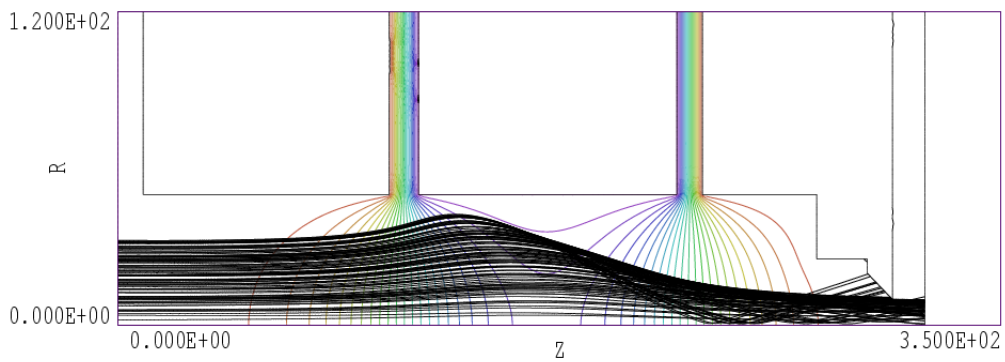


New LEBT for H^-



Einzel Lens Focusing

- Last summer Einzel Lens was tested for both polarized and high intensity sources
- Last month power supply was test for this lens

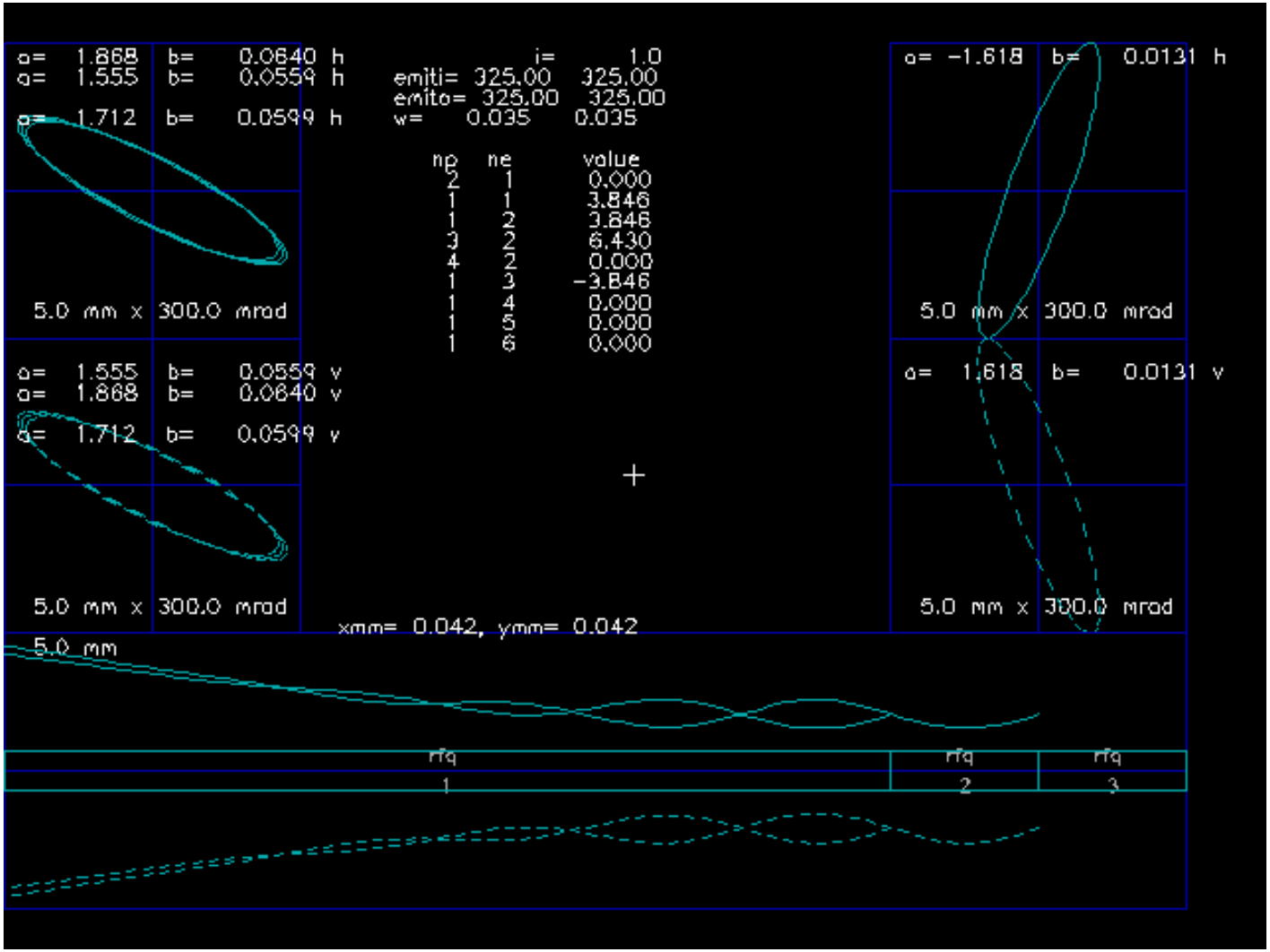



```
Total orbits:  100
Plotted range
  NOrbMin:    1
  NOrbMax:  100
Plot mode: ZR
Magnification: OFF
Orbit range
   XMin:  -4.178E+01
   XMax:   3.897E+01
   YMin:  -4.016E+01
   YMax:   3.810E+01
   ZMin:   3.100E-04
   ZMax:   3.200E+02
   RMin:   5.986E-01
   RMax:   4.247E+01
```

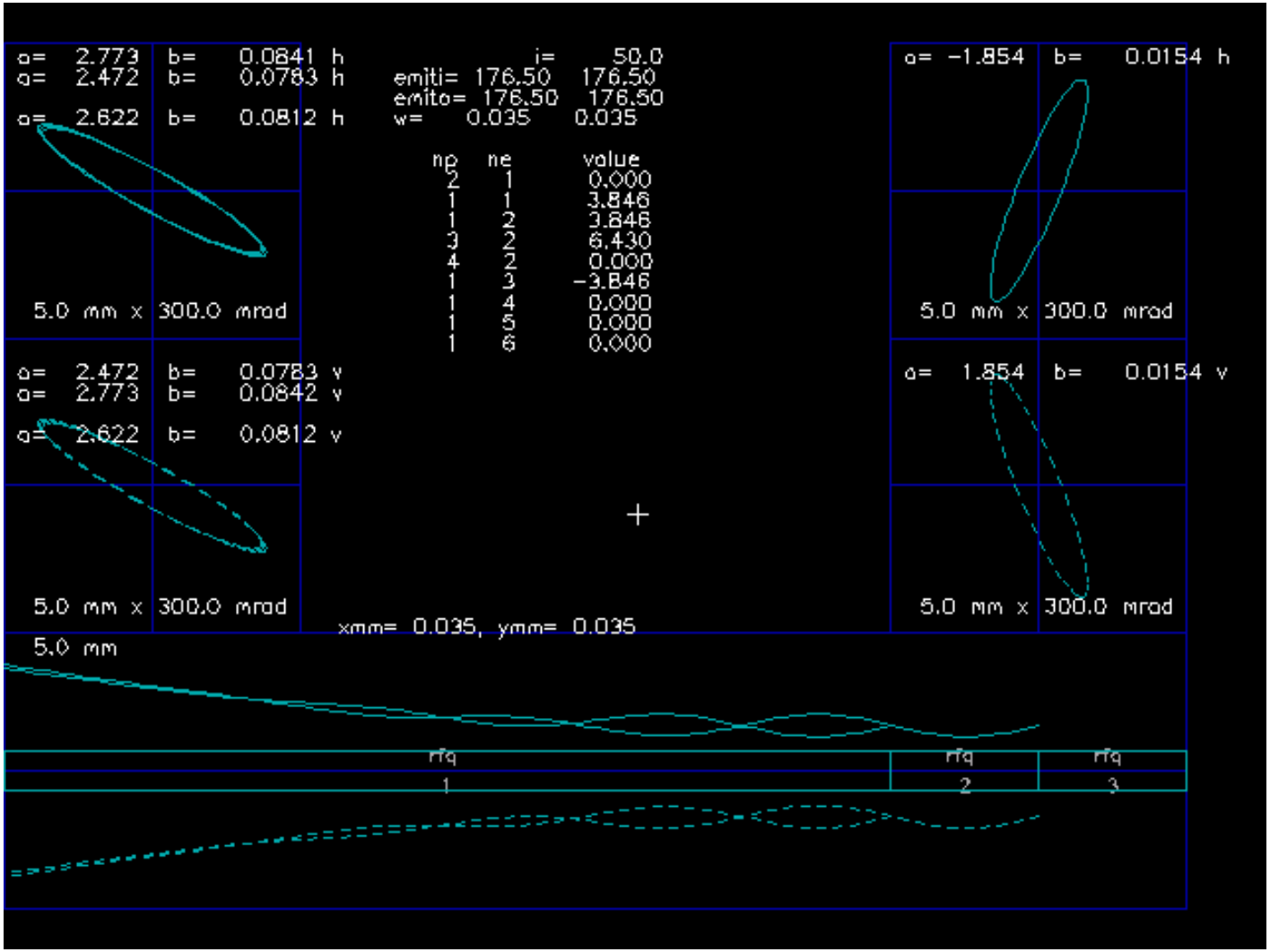
```
Plot type: Contour
Quantity: Phi

Minimum value:  -3.149E+0
Maximum value:   0.000E+0
   -2.887E+04
   -2.624E+04
   -2.362E+04
   -2.099E+04
   -1.837E+04
   -1.575E+04
   -1.312E+04
   -1.050E+04
   -7.873E+03
   -5.249E+03
   -2.624E+03
    0.000E+00
```

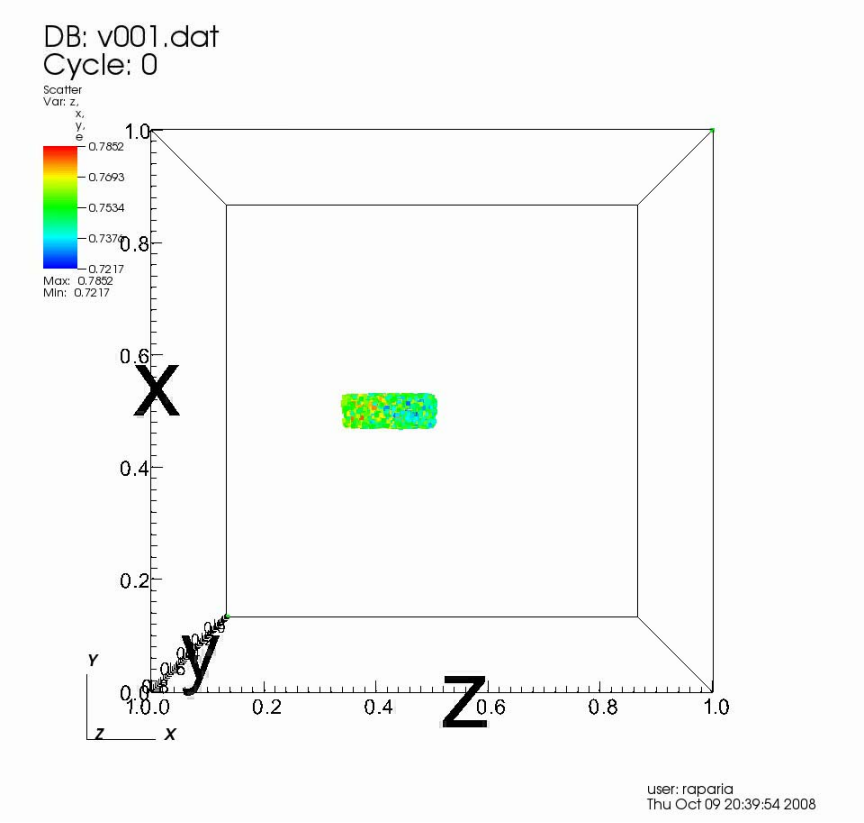
RFQ Acceptance for Polarized H^-

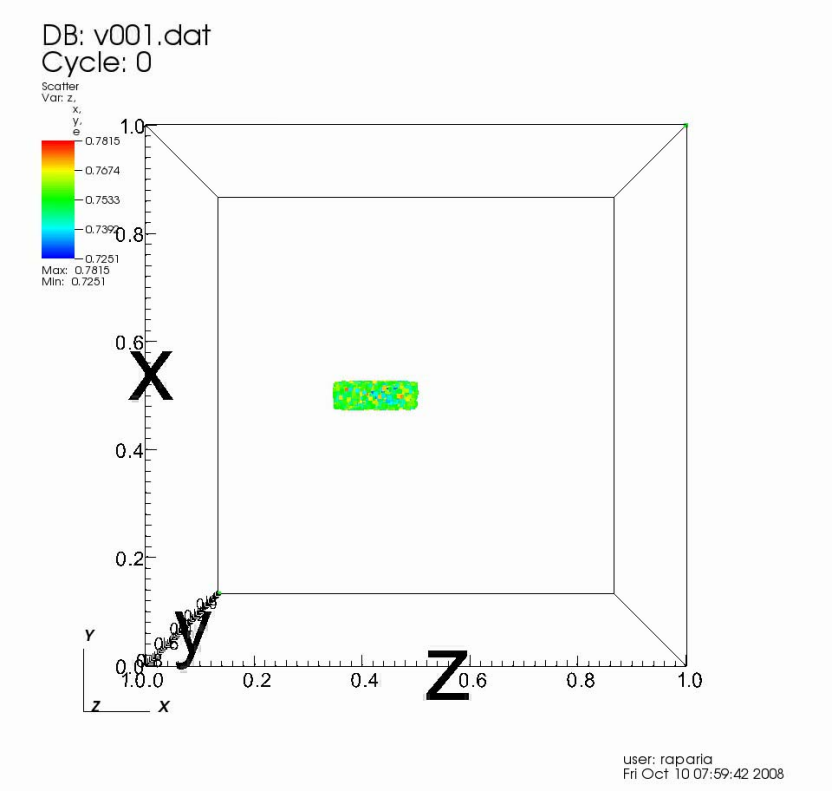


RFQ Acceptance for High Intensity H^-



Old and New


DB: v001.dat
Cycle: 0
Scatter
Var: z,
x,
y,
e
0.7852
0.7693
0.7534
0.7376
0.7217
Max: 0.7852
Min: 0.7217
1.0
0.8
0.6
0.4
0.2
0.0
1.0
0.2
0.4
0.6
0.8
1.0
X
y
Z
Y
Z
X
user: raparia
Thu Oct 09 20:39:54 2008


DB: v001.dat
Cycle: 0
Scatter
Var: z,
x,
y,
e
0.7815
0.7674
0.7533
0.7392
0.7251
Max: 0.7815
Min: 0.7251
1.0
0.8
0.6
0.4
0.2
0.0
1.0
0.2
0.4
0.6
0.8
1.0
X
y
Z
Y
Z
X
user: raparia
Fri Oct 10 07:59:42 2008

Caution out these Simulations

- No error are included
- Assume Phase & Amplitude ideal
- Real life expectation

	Emit growth x, z, trans
New MEBT	100% 100%, 100%

Expected Emittance After MEBT Upgrade

- **At end of linac**

  H 5 π mm mrad (N, 90 %)

  V 5 π mm mrad (N, 90 %)

- **At end of booster**

  assuming matched (we are matched),

  present booster lattice

  H 12 π mm mrad (N, 90 %), $\Delta\varepsilon_x$=7

  V 8 π mm mrad (N, 90 %), $\Delta\varepsilon_y$=3

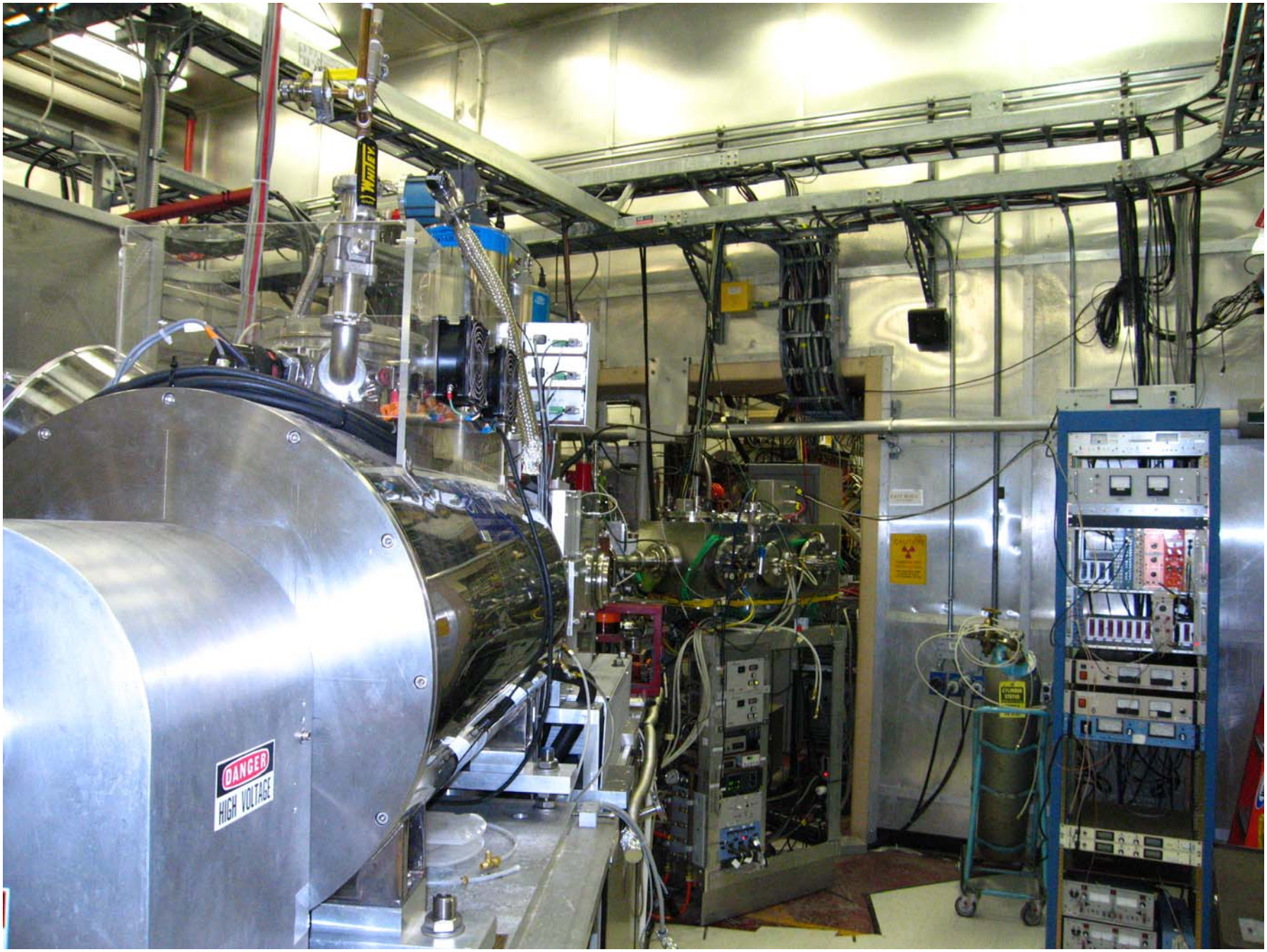
- With low beta lattice at injection (assuming matched)

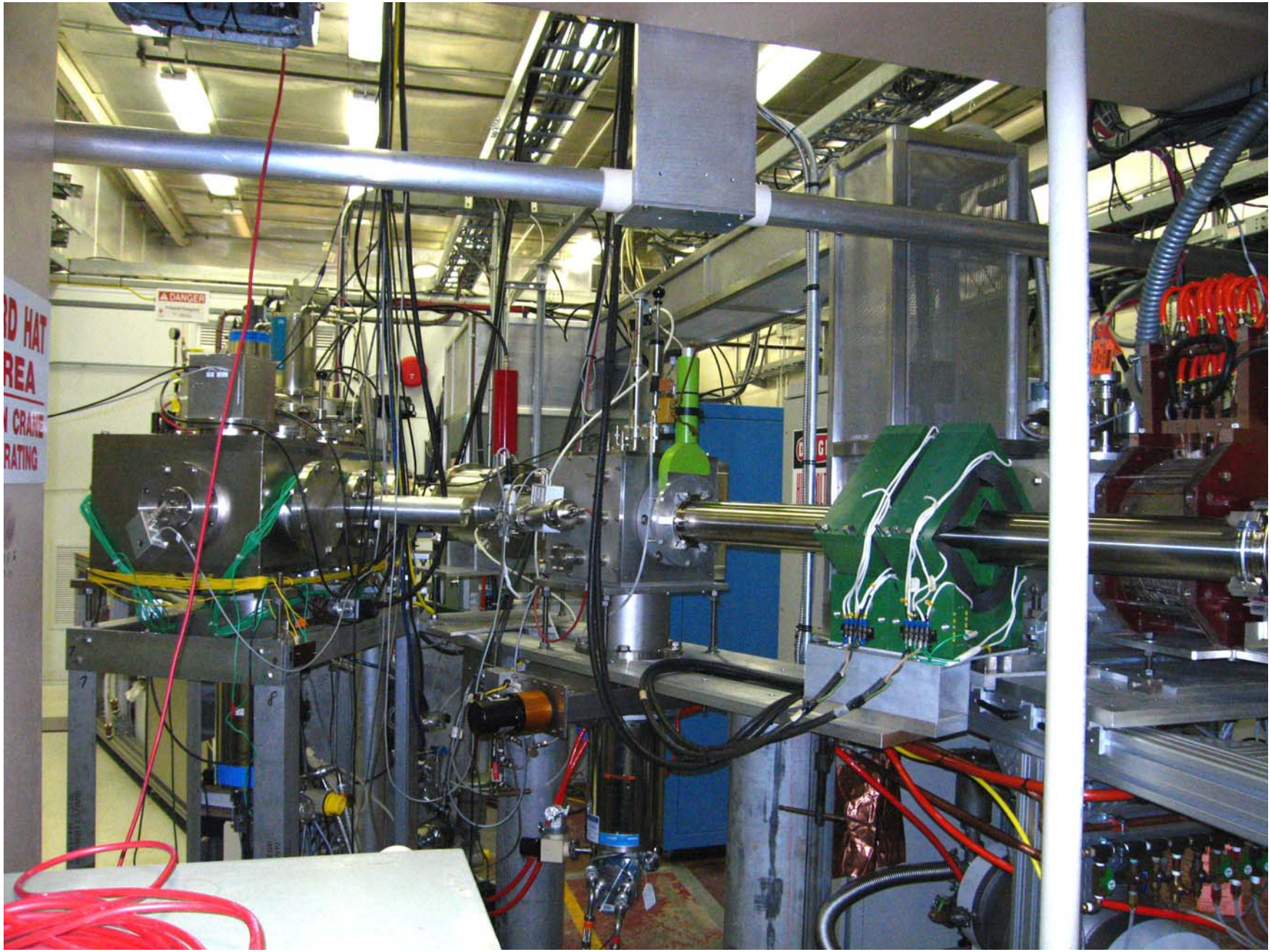
  H 8 π mm mrad (N, 90 %), $\Delta\varepsilon_x$=3

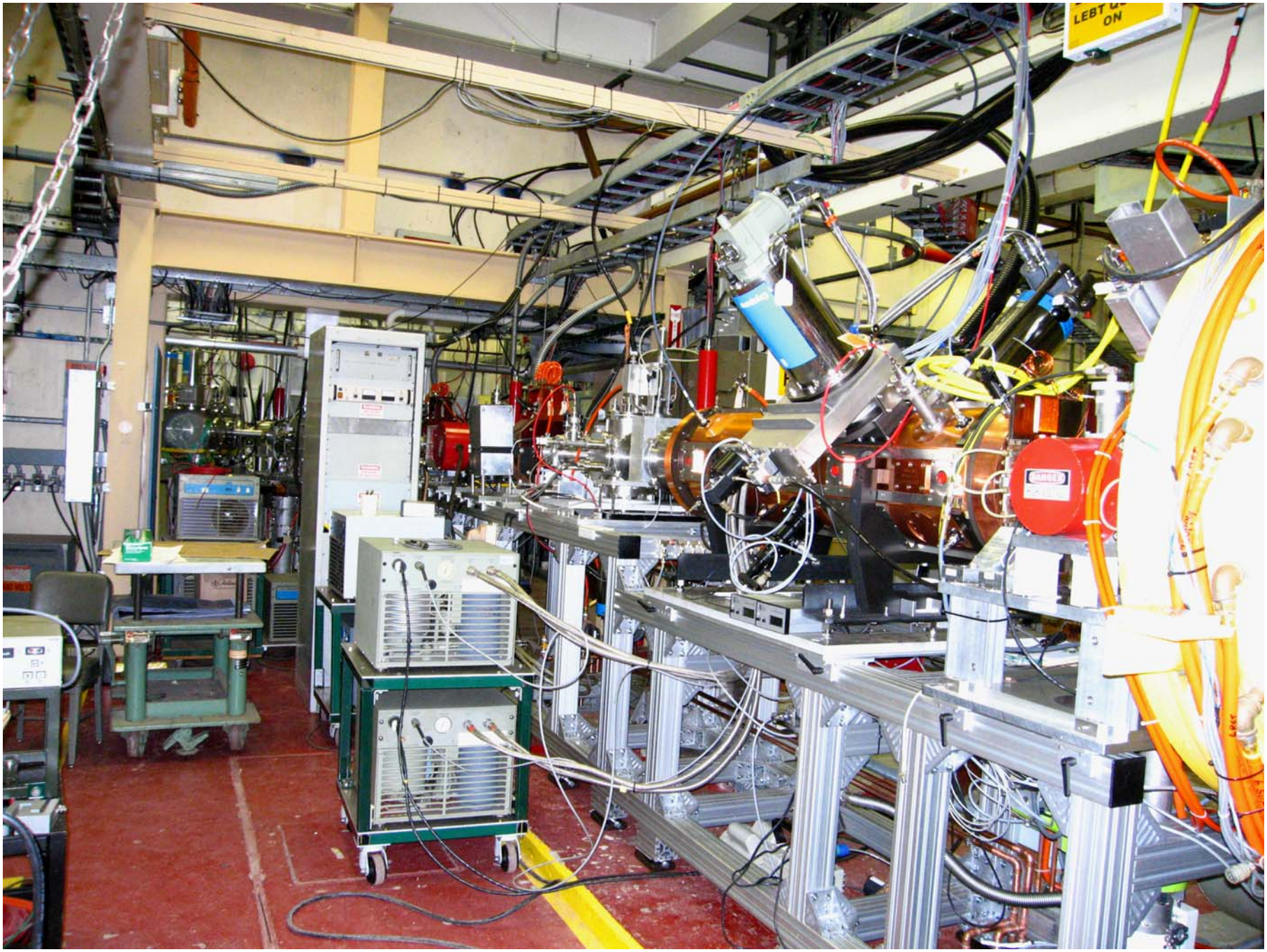
  V 7 π mm mrad (N, 90 %), $\Delta\varepsilon_y$=2

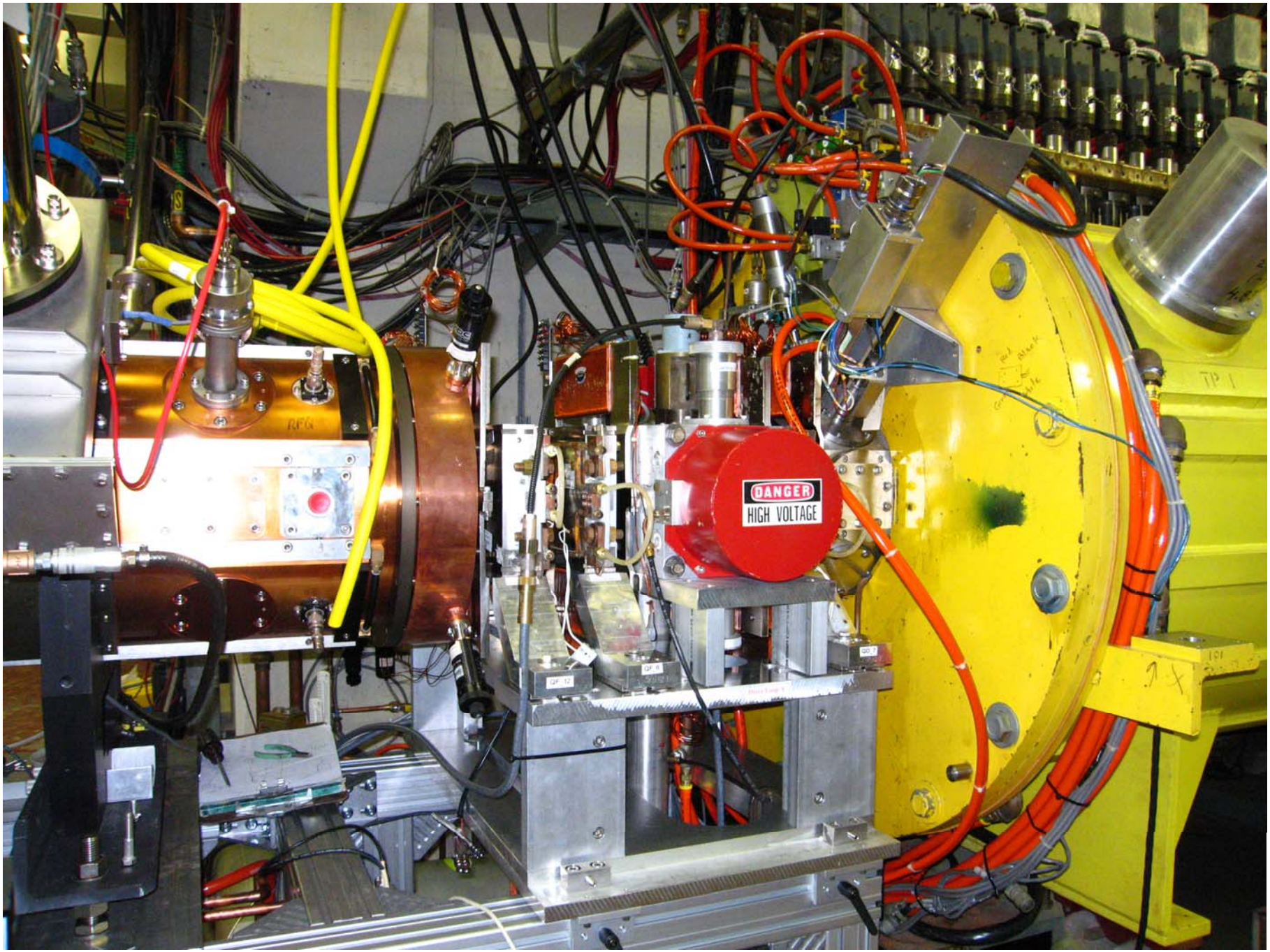
Note: To get to these emittances will involve learning curve

Status


DANGER
HIGH VOLTAGE


D HAT
REA
N CRANE
RATING
DANGER


LEBT
ON


DANGER
HIGH VOLTAGE

Status

- LEBT install and commissioned with both polarized and high intensity beam
- RFQ install and re-commissioned with polarized beam
- MEBT installed and system testing underway

  -water leak in quadrupole coil connection , water interlock

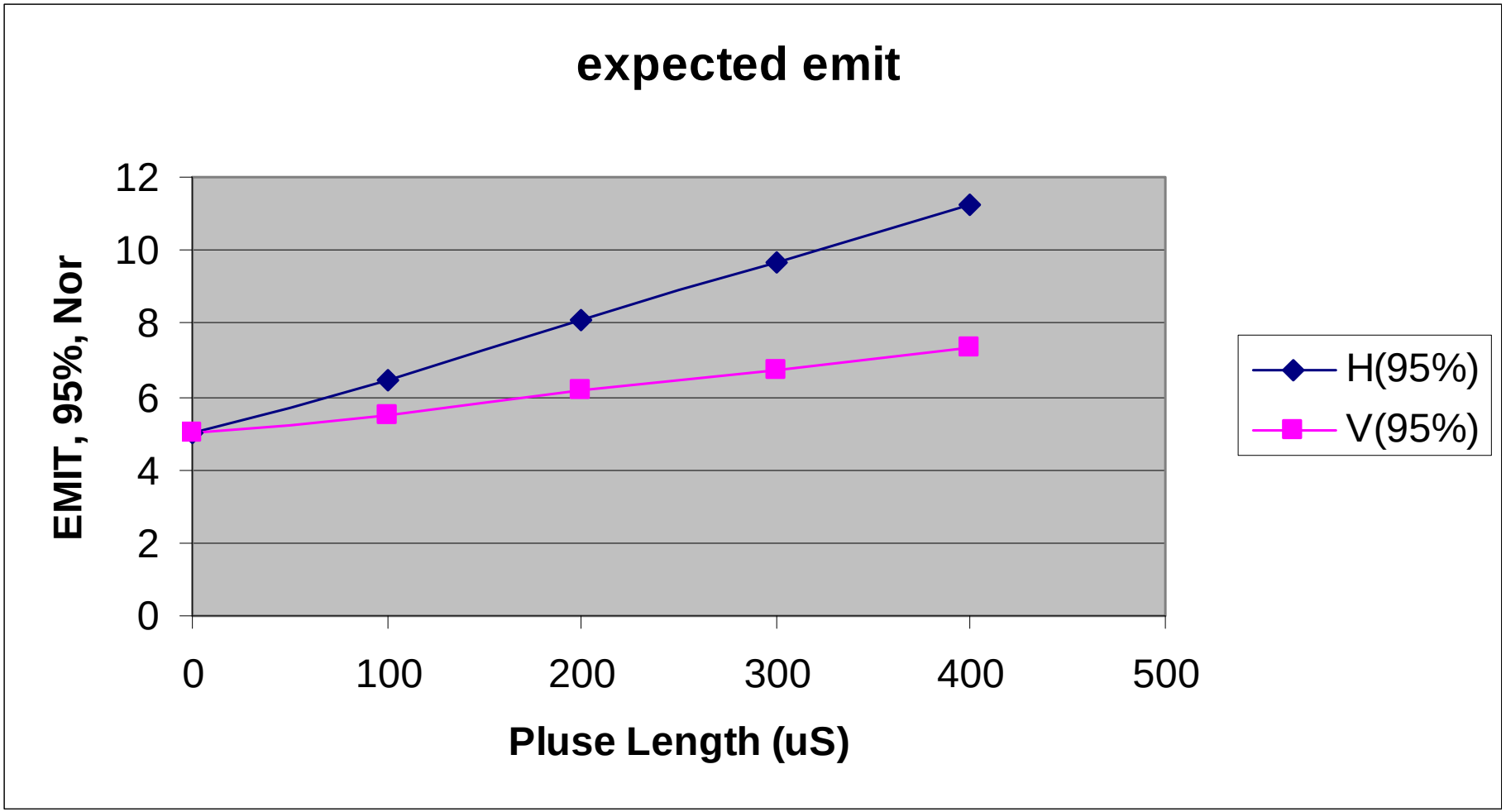
  -sparking in buncher coupling loop
- Could (will) send beam through MEBT today

Status: Beam Commissioning

- Polarized
  -LEBT: 100% transmission for both emittances (OPPIS solenoid on and off)
  -RFQ: Transmission >90% for solenoid off
  ~65% for solenoid on
  -DTL 200 MeV:

- High intensity
  - LEBT: >85 % Transmission (Optimization continue)
  -RFQ:
  -DTL 10 MeV:
  -DTL 116 MeV:

Expected Emit at BTA after MEBT Reconfiguration



Emittance Growth

Emittance growth due to multiple scattering

$$\Delta\varepsilon \equiv n\beta\theta^2$$

N=number of traversal: Pulse Length, Size, Painting Scheme

β= Beta function at foil: ring lattice, (matching etc)

θ= Scattering angle: Material of foil, Thickness

$$\sigma = 14.2z\frac{\sqrt{x/X_0}}{p\beta}[1 + 0.088\log_{10}\left(xz^2/X_0\beta^2\right)].$$

Emittance Growth

Emittance growth due to multiple scattering

$$\Delta\varepsilon \equiv n\beta\theta^2$$

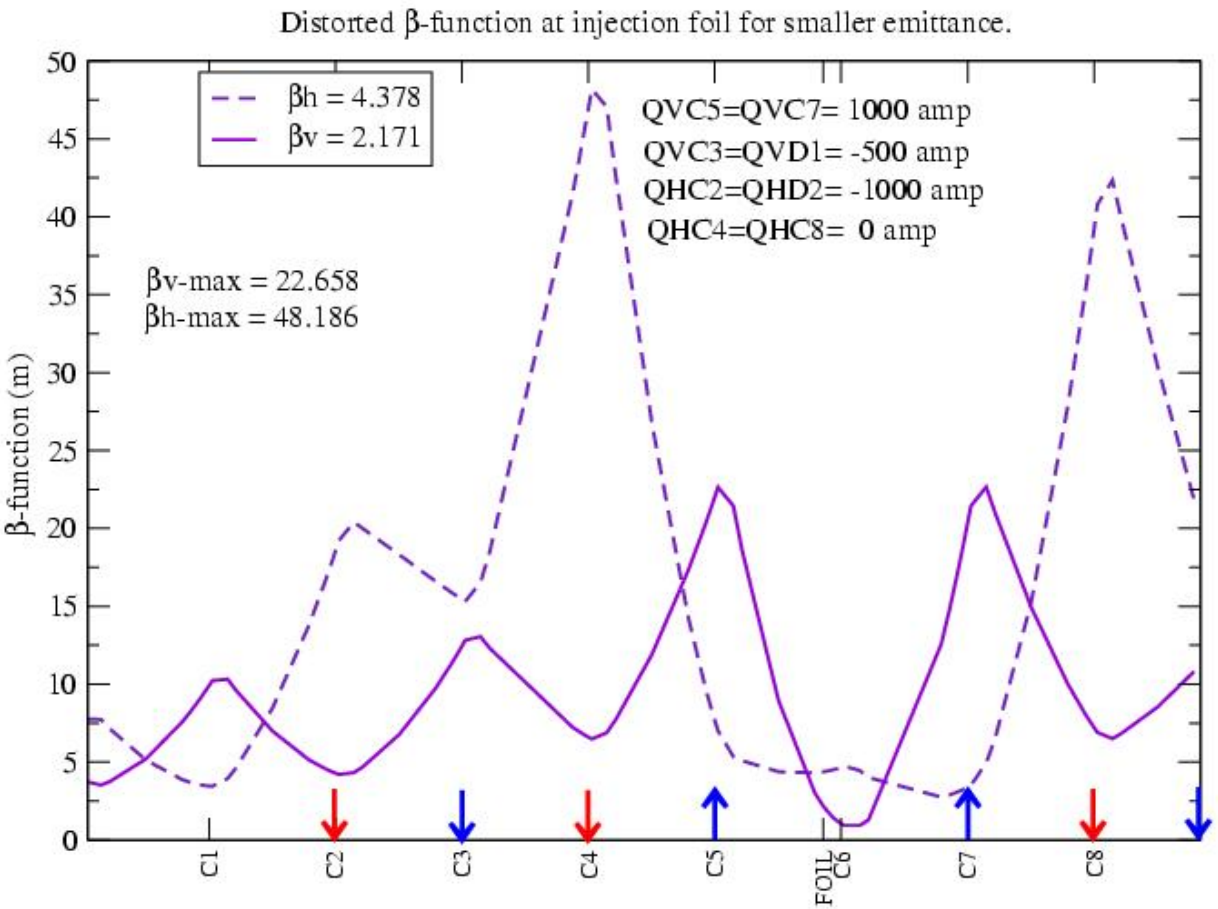
N=number of traversal: Pulse Length, Size, Painting Scheme

β= Beta function at foil: ring lattice, (matching etc)

θ= Scattering angle: Material of foil, Thickness

$$\sigma = 14.2z\frac{\sqrt{x/X_0}}{p\beta}[1 + 0.088\log_{10}\left(xz^2/X_0\beta^2\right)].$$

Modified Booster Lattice (1) (Kevin)



S1: (3 p.s.'s)

C5=C7=1000 A

C3=D1=-500A

C2=D2=1000A

$\beta_x = 4.4, \alpha_X = -0.162$

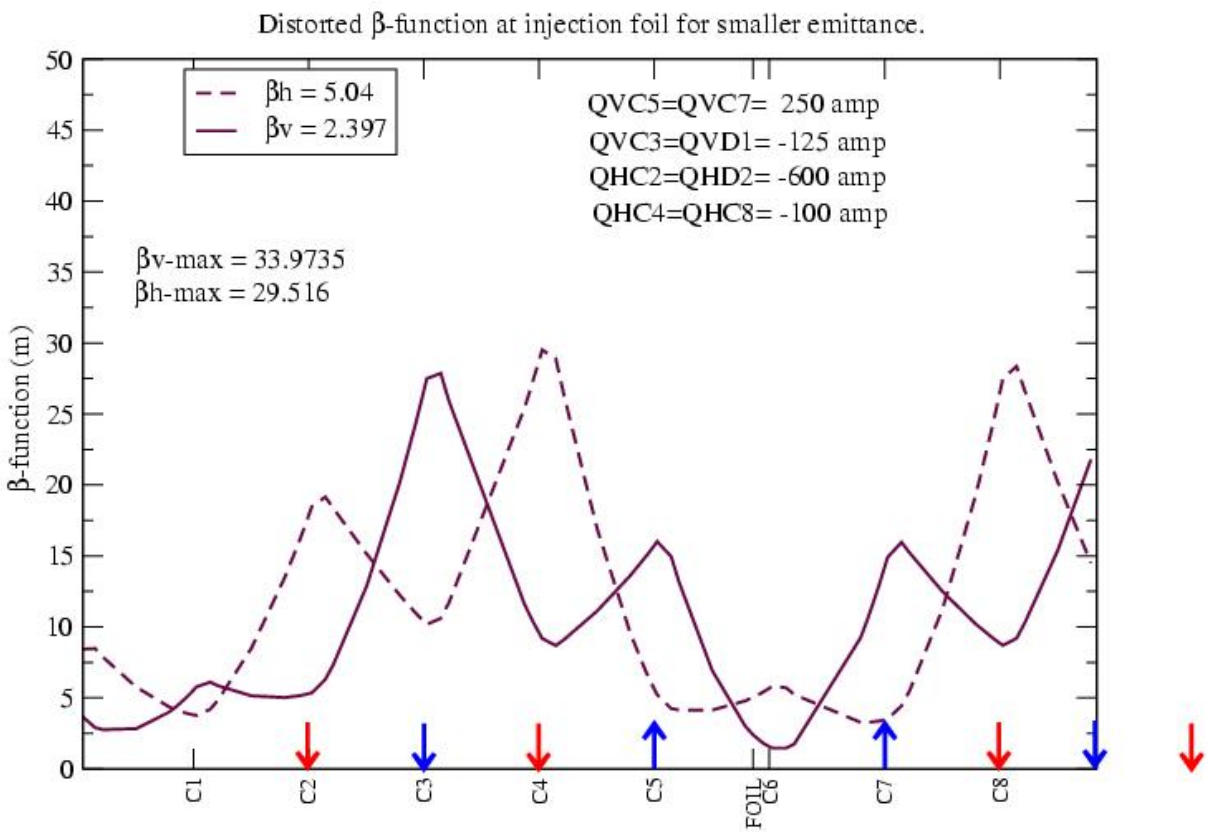
$\beta_y = 2.2, \alpha_Y = 1.326$

$\eta_X = 3.70$, $\eta'_X = 0.552$

$\beta_{x\text{-max}} = 48.2$
$\beta_{y\text{-max}} = 22.7$
horz. tune = 4.53
vert. tune = 4.64

GAMMA(TR)=4.57804

Modified Booster Lattice (2) (Kevin)



S3: (4 p.s.'s,
but not running as hard)

C5=C7=250 A

C3=D1=-125A

C2=D2=600A

C4=C8=-100

β_x = 5.0,α_X=-0.471

β_y = 2.4,α_Y=0.934

η_X=3.46, η'_X=0.515

$\beta_{x\text{-max}}$ = 29.5

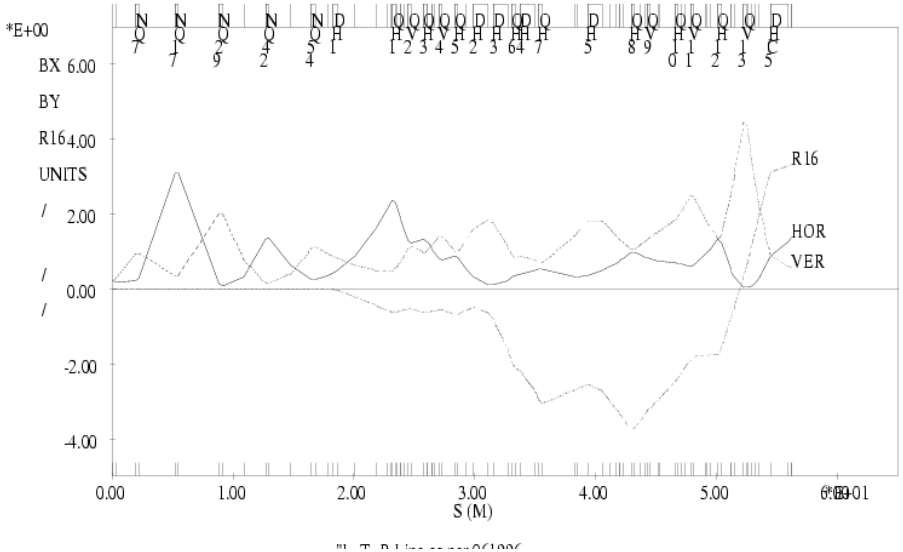
$\beta_{y\text{-max}}$ = 34.0

horz. tune = 4.57

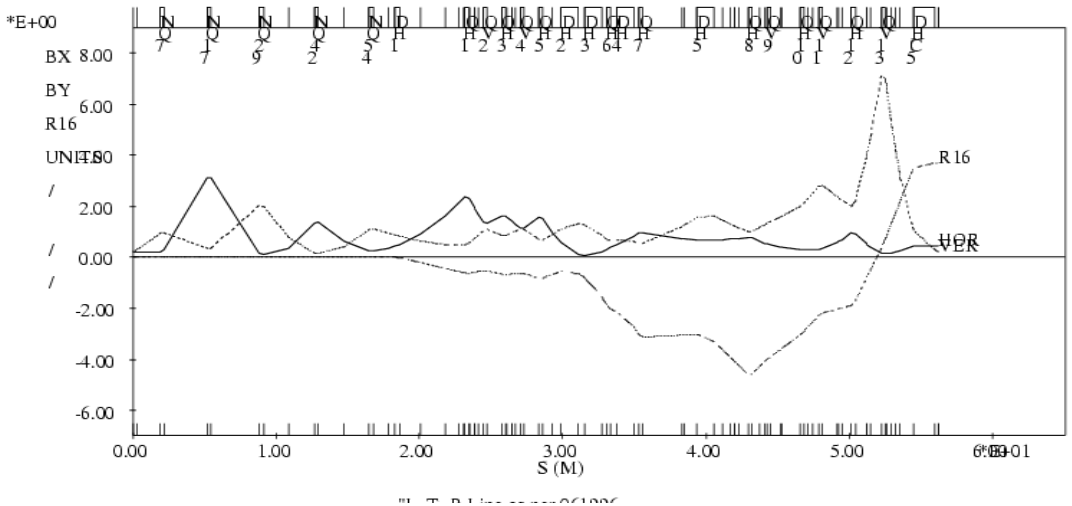
vert. tune = 4.53

GAMMA(TR)=4.665412

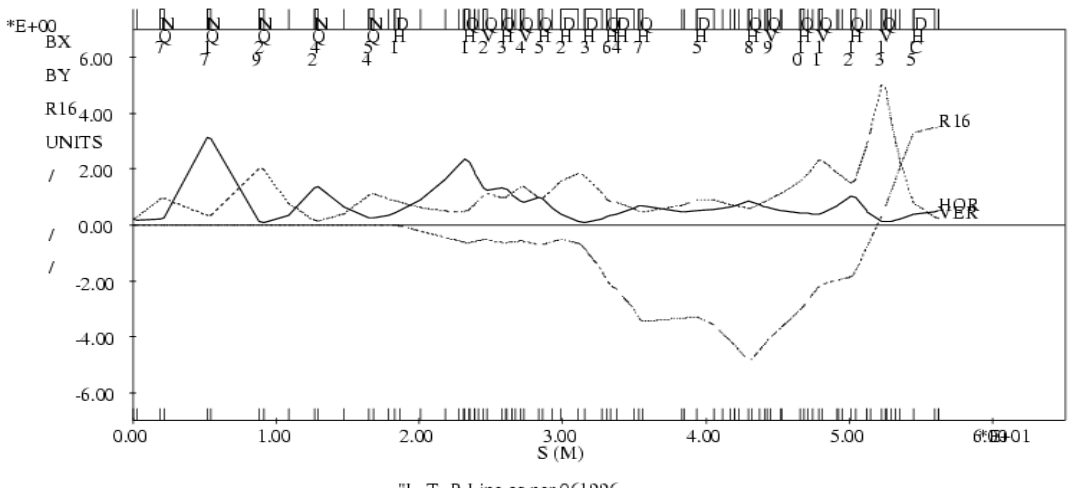
LTB Present


*E+00
BX
BY
R16
UNITS
/
/
/
6.00
4.00
2.00
0.00
-2.00
-4.00
R16
HOR
VER
0.00
1.00
2.00
3.00
4.00
5.00
S (M)

LTB Solution 1



LTB Solution 2



Quad Strengths

quad	matched	Solution 1	solution1/matched	Solution2	Solution2/matched
NQ7	-4.6925	-4.6925	1	-4.6925	1
NQ17	4.3355	4.3355	1	4.3355	1
NQ29	-2.8928	-2.8928	1	-2.8928	1
NQ42	3.4571	3.4571	1	3.4571	1
NQ54	-2.2782	-2.2782	1	-2.2782	1
QH1	2.93035	2.80274	0.956452301	2.91543	0.994908458
QV2	-2.85746	-3.16635	1.108099501	-2.85543	0.999289579
QH3	1.96379	2.00085	1.018871672	1.85166	0.942901227
QV4	-2.52254	-2.64051	1.04676594	-2.41835	0.958696013
QH5	3.12912	3.62238	1.157635374	3.12912	1
QH6	3.18358	2.81269	0.88349908	2.49616	0.784073276
QH7	2.30802	2.18032	0.94467119	2.23321	0.967586936
QH8	1.877848	1.87947	1.000863755	1.90001	1.011801807
QV9	-0.29106	-0.24365	0.837112623	-0.25894	0.889644747
QH10	0.48178	0.52203	1.083544356	0.48332	1.00319648
QV11	-1.98299	-1.67135	0.842843383	-1.97639	0.996671693
QH12	4.82538	4.392	0.910187384	4.38378	0.908483891
QV13	-4.13415	-4.44428	1.07501663	-4.33648	1.048941137