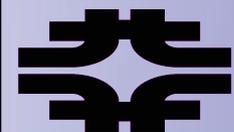


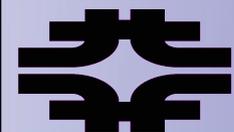
# *Linac Frontend Upgrade Report*

C.Y. Tan  
8 Dec 2010  
Proton Source Retreat

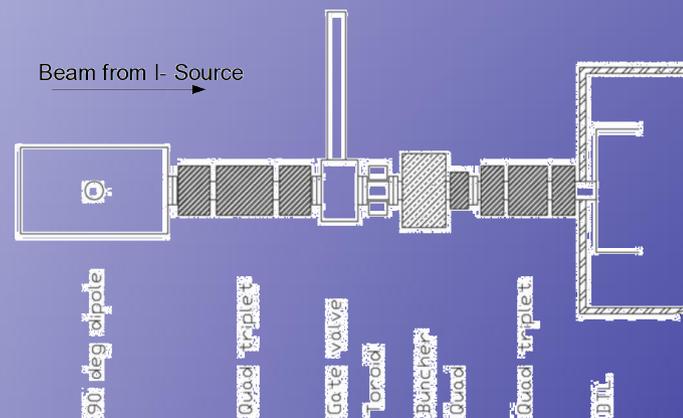
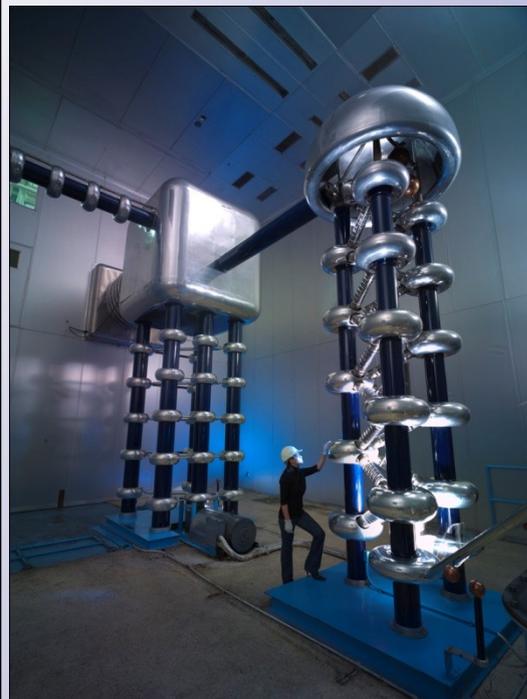


# People *(Additional Help – Needed/Requested)*

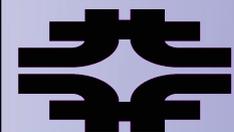
- ◆ AD people:
  - ◆ W. Pellico (head of proton source), C.Y. Tan, J. Lackey, D. Bollinger, K. Duel, R. Riley, V. Scarpine.
- ◆ TD people:
  - ◆ G. Velez, V. Kashikhin, A. Makarov
- ◆ Thanks to BNL pre-injector group
  - ◆ J. Alessi, D. Raparia, M. Okamura, V. Lodestro.



# Present Injector – Vintage 1968 Hardware



- Magnetron Source
  - 35 keV ribbon beam
  - Current about 50-60mA
- Cockcroft Waltons
  - 750keV
  - Current about 45 - 55 mA
- MEBT section
  - Quads and buncher before Tank 1
  - Dipole to accommodate another H- source + Cockcroft Walton



# Reasons for Upgrade

- ◆ The components are getting harder to maintain
  - ◆ Critical personnel have retired.
  - ◆ Components getting harder to find and replace
    - ◆ Critical failure of I- column in early 2010 which required a rebuild.
- ◆ As system ages, more time and attention required to maintain reliability of system.
- ◆ Going to RFQ system should increase beam quality and system reliability.
  - ◆ Very good results from BNL when they switched from Cockcroft-Walton to RFQ system. Done in 1989. (21 years late to the party)

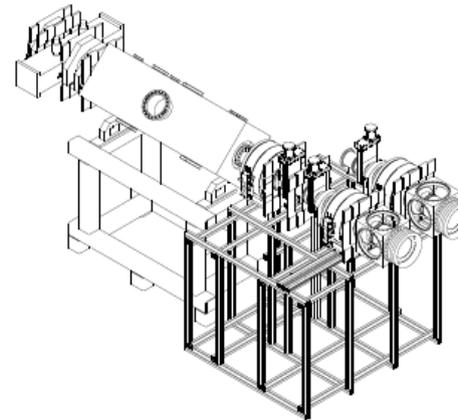
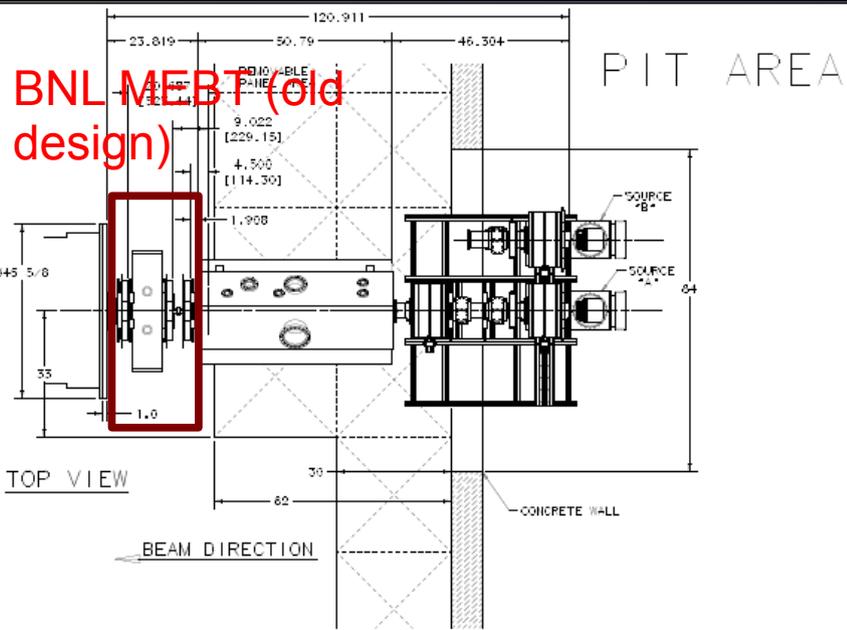


# Objectives

- ◆ This is not an R&D project
- ◆ Copy as much as possible from an existing injector
  - ◆ BNL injector is used as basis of design.
- ◆ Use as much as possible existing infrastructure, technology and expertise.
  - ◆ Convert slit magnetron source to round magnetron source
    - ◆ BNL style source. Very good reliability and performance > 90mA at 500 us, more than 6 months before any change required.
    - ◆ 750keV RFQ 60mA 200MHz (not technology limited)
- ◆ Better performance
  - ◆ At least 10-15% improvement in efficiency to Booster.
- ◆ Support future operations – Nova, Mu2E, MicroBooNE, G-2, RunIII

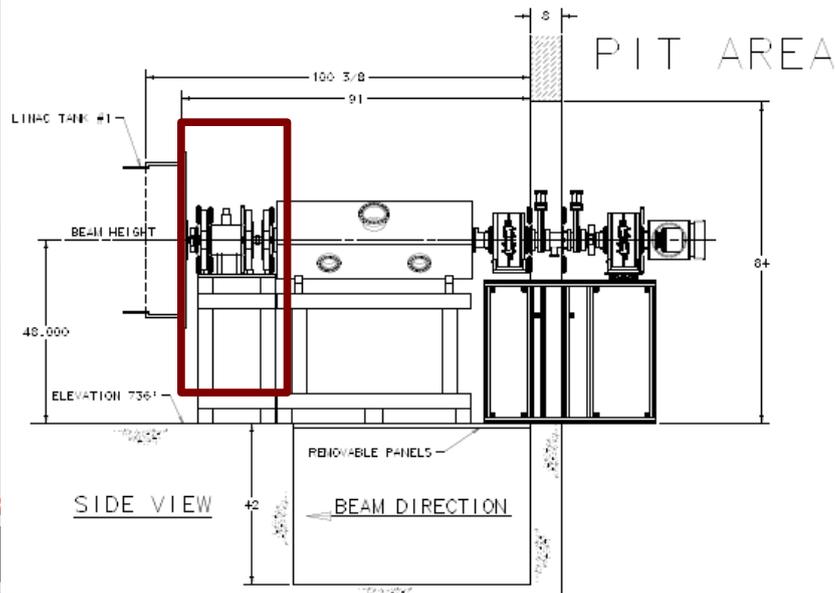


# Overall Mechanical Design



## PREACCELERATOR PRELIMINARY LAYOUT

NOVEMBER 16, 2010



UNLESS OTHERWISE SPECIFIED		ORIGINATOR	
DESIGNER	DATE	DESIGNER	DATE
CHECKED	DATE	CHECKED	DATE
1. OPEN ALL SHIP ENDS		APPROVED	
2. DO NOT SCALE DIMENSIONS		USER ONLY	
3. HIGHLIGHTING DIMENSIONS		DATE	
4. USE ALL LOCAL UNITS		DATE	
5. DIMENSIONS U.S. UNITS		DATE	
<b>FERMI NATIONAL ACCELERATOR LABORATORY</b> UNITED STATES DEPARTMENT OF ENERGY			
SCALE	DRAWING NUMBER	SHEET	PE
CREATED WITH	GROUP	1 OF 1	

# Why Round(Dimple) Source

BNL improvements in magnetron power efficiency

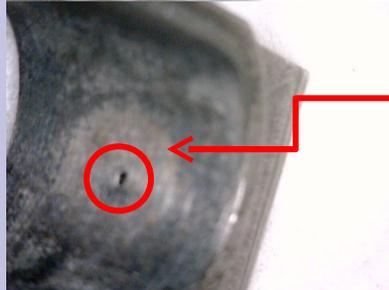
Cathode	H- (mA)	Arc I (A)	Arc V (V)	Pwr effic (mA/kW)	Lifetime (months)
Slit/flat	50	150	150	2.2	N/A
Slit /grooved	50	50	150	6.7	N/A
Circular/dimpled	100	10	150	67	6-9 months

FNAL magnetron power efficiency

Cathode	H- (mA)	Arc I (A)	Arc V (V)	Pwr effic (mA/kW)	Lifetime (months)
Slit/flat	50	150	150	2.2	N/A
Slit /grooved	50	50	120	8.3	3.5 (average)

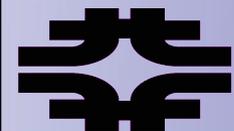


Cathode material blocking the cesium inlet opening in anode

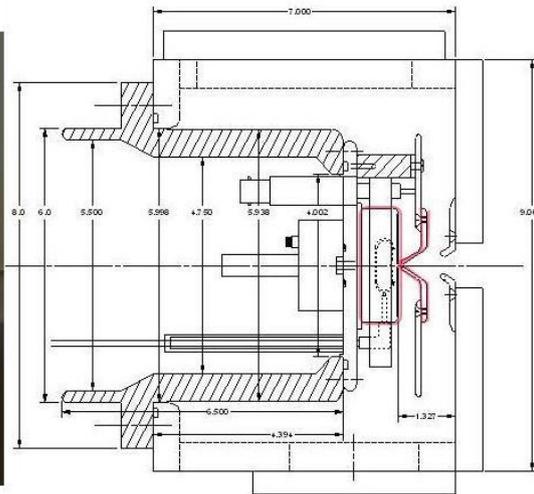
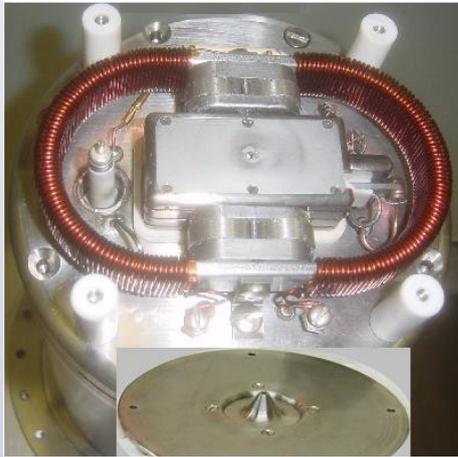


New anode showing cesium inlet

We have to run high arc currents ~ 50A in order to get 50mA+ of H- out of the source for Linac operations. This causes increased cathode erosion and reduced source lifetime. BNL needs only 10A of arc current to get 100mA of H- beam current. Their cathode erosion is greatly reduced which leads to longer source lifetimes.

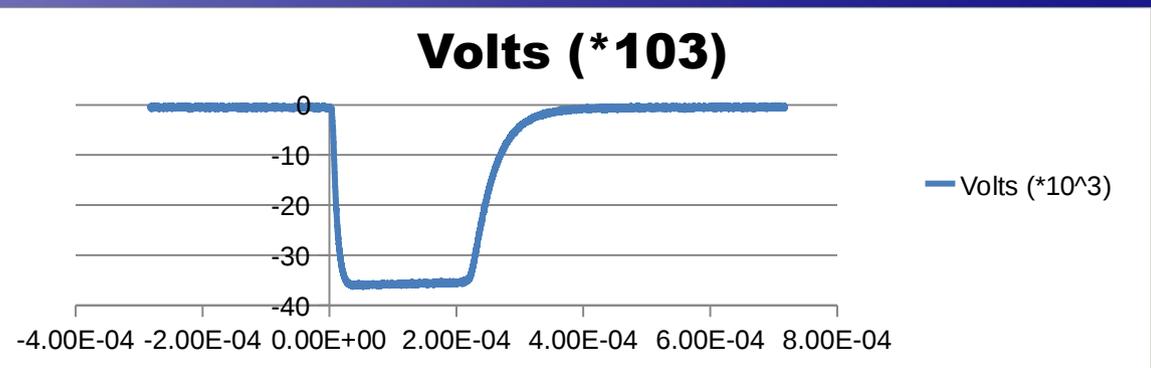


# The H- Test Source



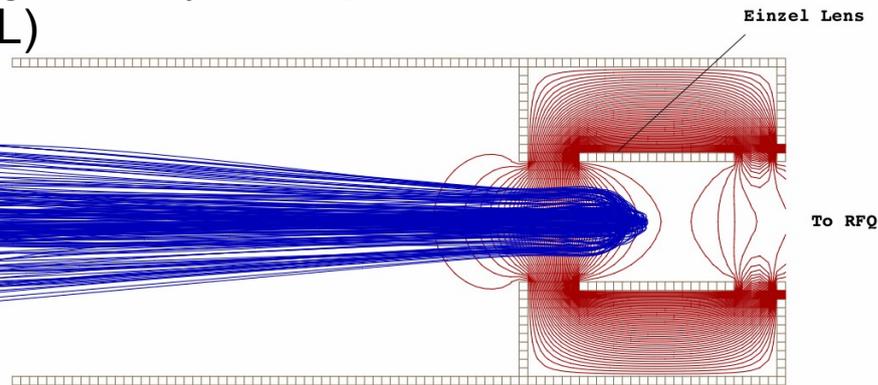
H- source test source (modified from HINS) source at 35keV

- 40mA at extraction
- Wrong cone.
- Should get 90mA at 35kV extraction.

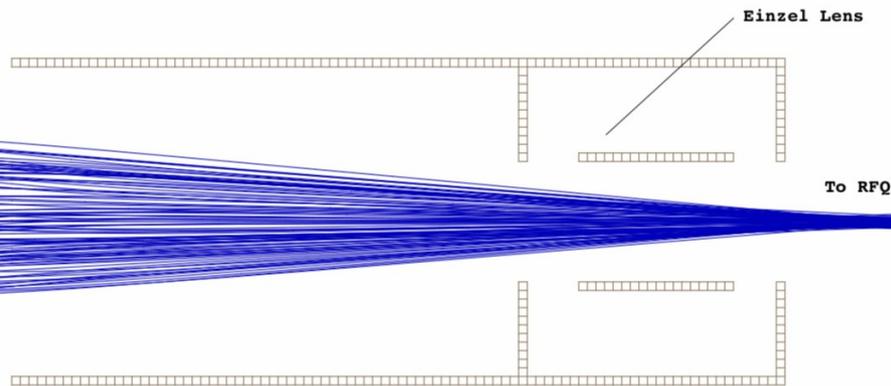


# Chopper

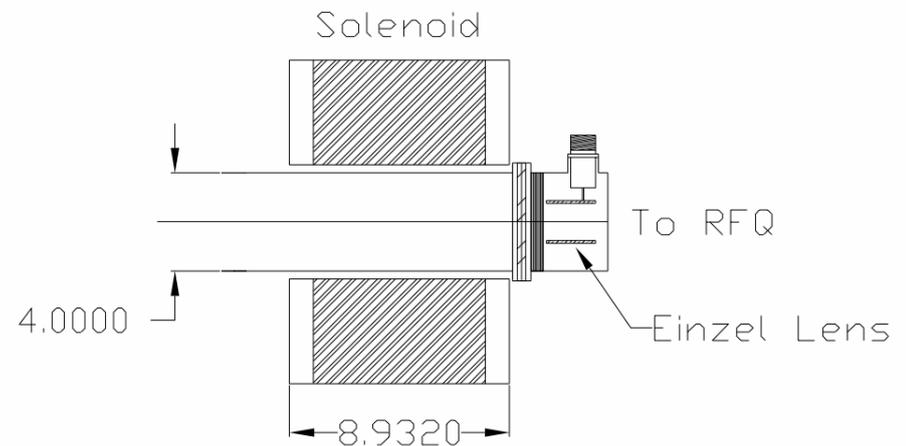
Suggested by D. Raparia  
(BNL)



Einzel Lens On at -36kV



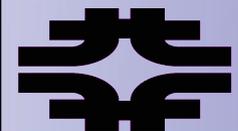
Einzel Lens Off



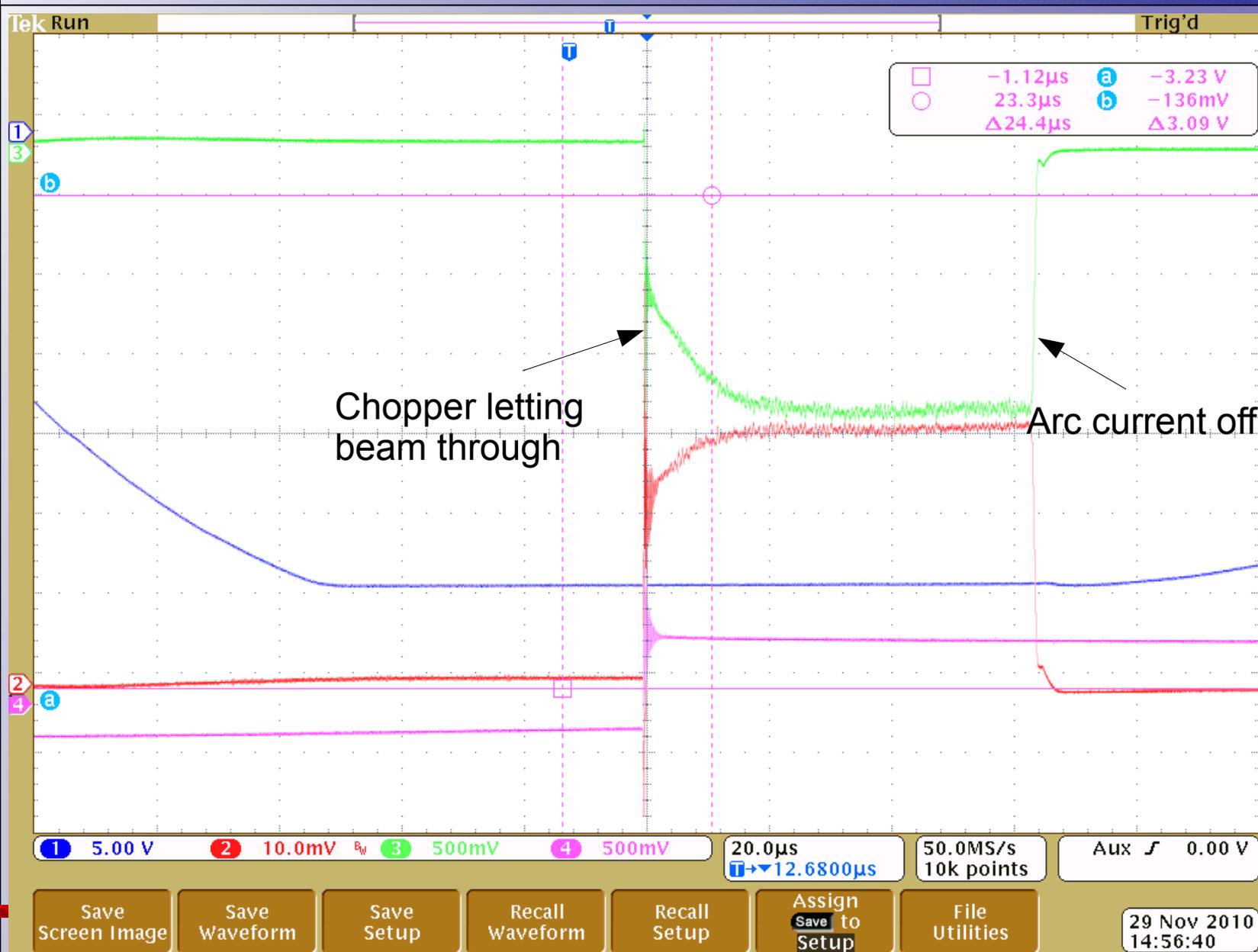
Preliminary experiments have shown that Einzel lens will not spark at 37kV with or without H-

Reason for chopper

- Want rise/fall time of H- < 1us.
- Want control of length of pulse.
- Want to neutralize the LEBT before chopping.



# First results



Green: Faraday cup

Red: toroid

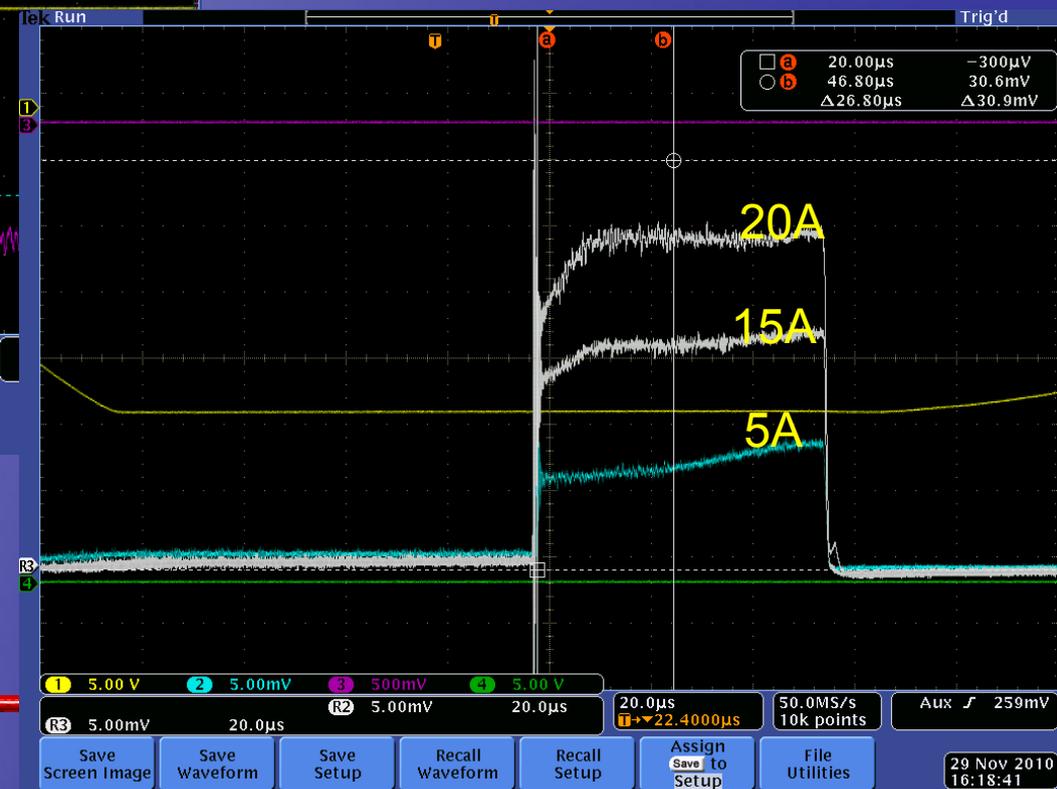
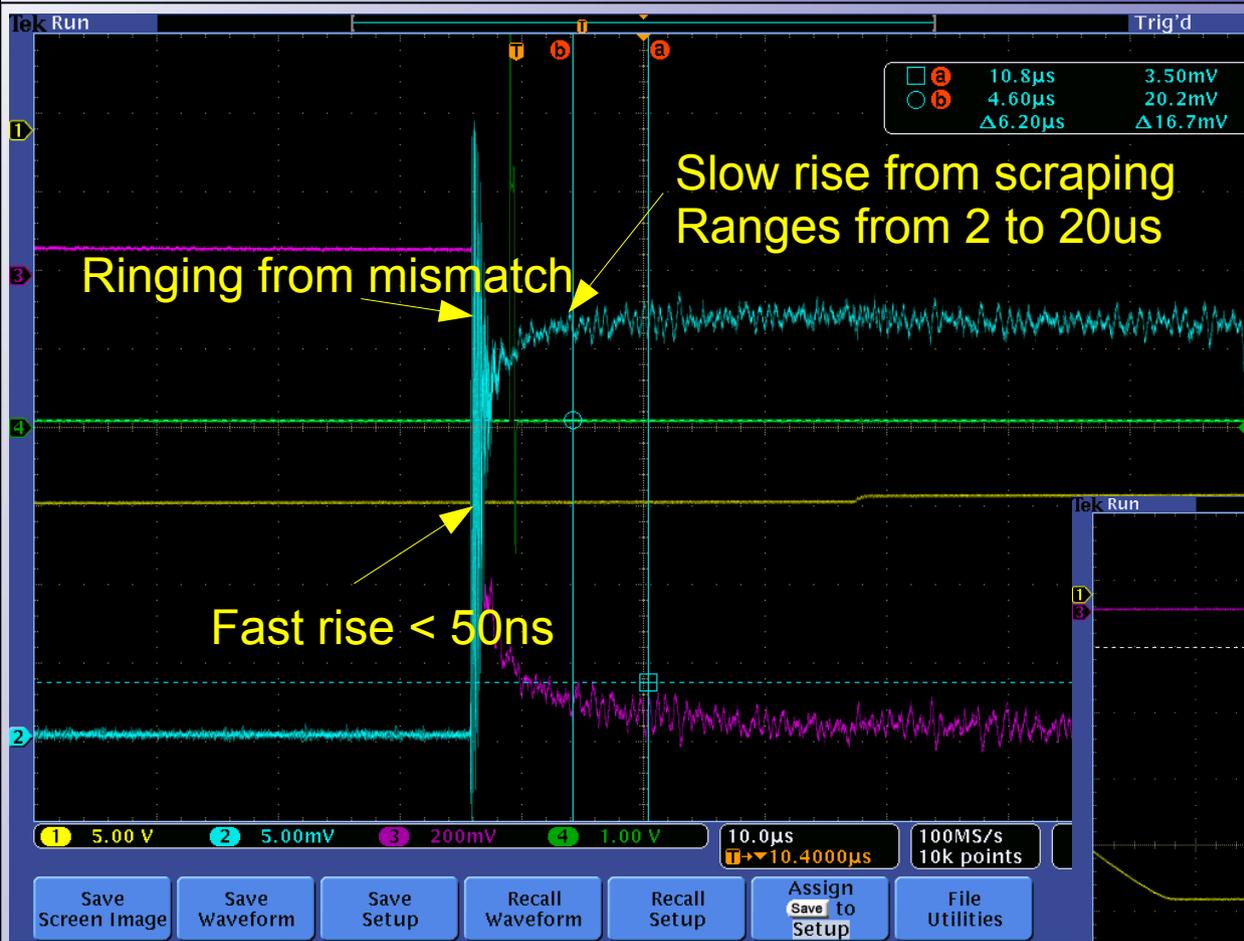
Blue: Extractor voltage

Magenta: chopper pulser

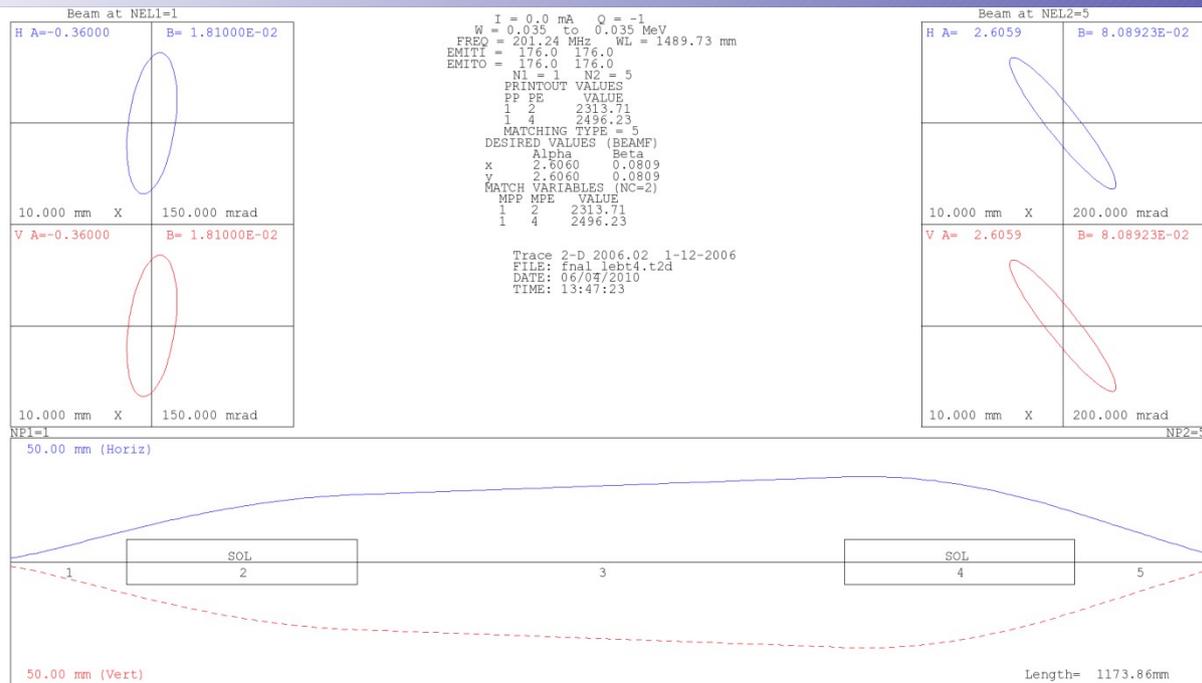
16 averages



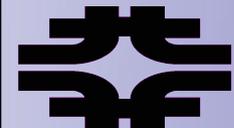
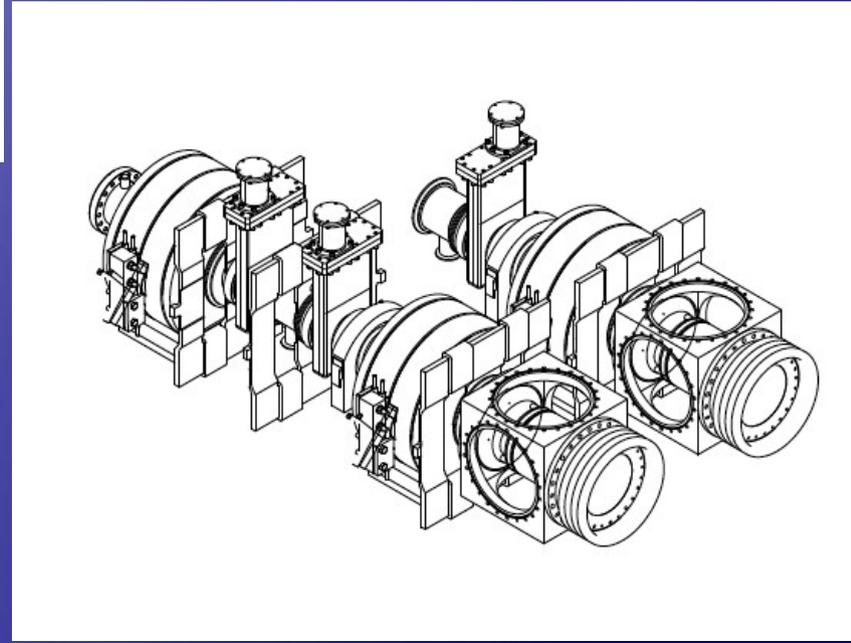
# Zoomed in view



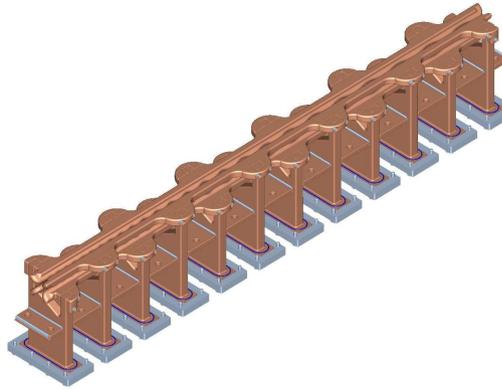
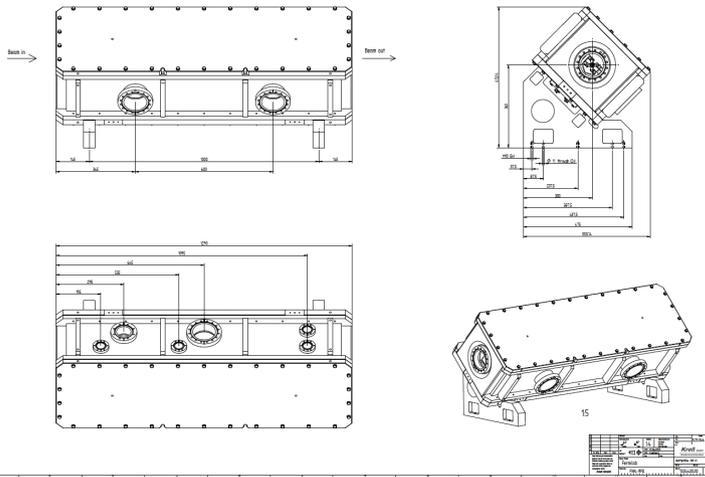
# LEBT



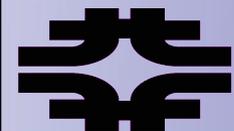
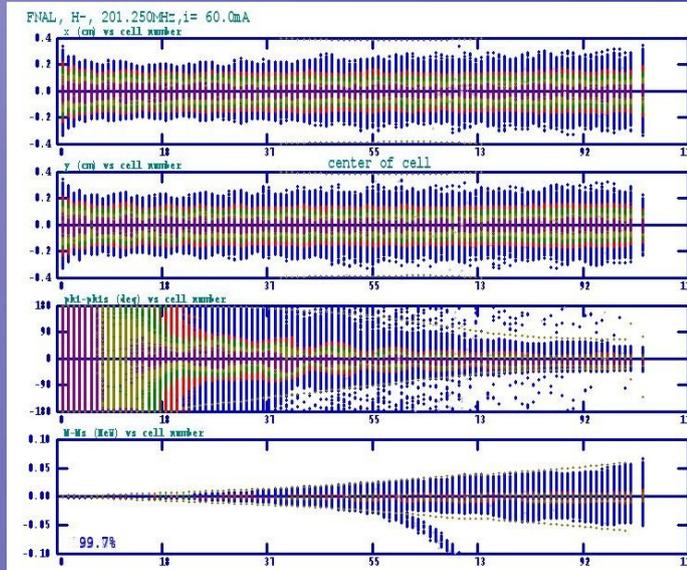
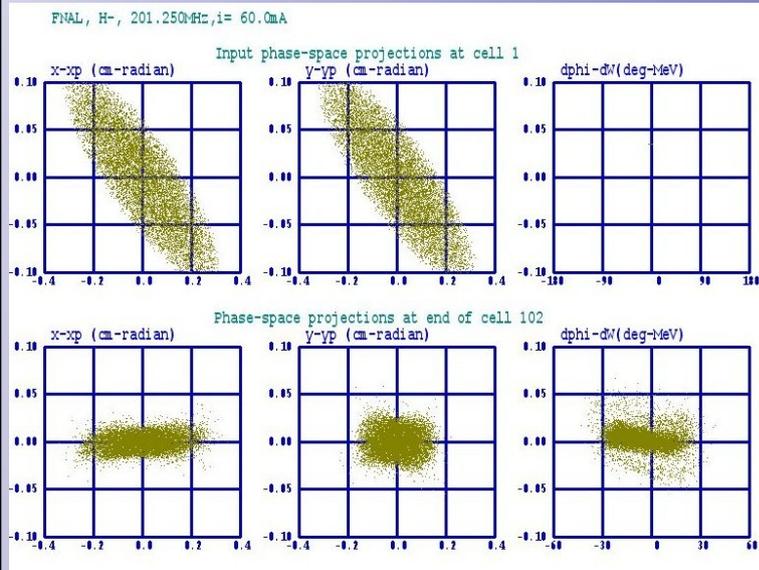
- LEBT < 1.2 m long
- 2 sources for reliability.
- Will probably use Xe gas neutralization of H-
- Solenoids are being built right now. Delivery expected by early 2011.



# RFQ



- 750keV RFQ.
- 60mA beam current
- 1.3m long.
- Rod design.
- Alwin Schempp designer
- Expected delivery, early 2011



# RFQ Params

60mA beam

Input:  $\alpha = 1.5$ ,  $\beta=5.1$  cm/rad  $\epsilon=210$  pi mm mrad

Output:

$$\alpha_x = -0.18, \beta_x = 12.5 \text{ cm/rad}, \epsilon_x \text{ (rms norm)} = 0.37$$

$$\alpha_y = 0.07, \beta_y = 5.5 \text{ cm/rad}, \epsilon_y \text{ (rms norm)} = 0.35$$

$$\alpha_z = 0.21, \beta_z = 1170 \text{ deg/MeV}, \epsilon_z \text{ (rms unnorm)} = 0.14 \pi \text{ MeV deg.}$$

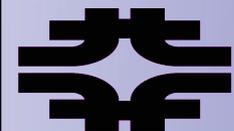
## 2.0 BAISC OPERATING SPECIFICATIONS

Operating Frequency	201.25 MHz
Frequency Tuning Range	+/- 100KHz (slug tuning range)
Input Energy	35 KeV
Output Energy	750 KeV
Repetition Rate	15 Hz
Design Beam Current	60 mA
Pulse Length	up to 100 us
Input Transverse Emittance	$0.3 \pi$ mm-mrad RMS Normalized
Output Transverse Emittance	$0.3 \pi$ mm-mrad RMS Normalized
Output Longitudinal Emittance	< 50 KeV deg Normalized 6sigma
Input Twiss Parameters*	$\alpha_x = \alpha_y$ , $\alpha_x = \alpha_y$ equal within +/-10%
Output Twiss Parameters*	Need to be developed and checked
Acceleration Efficiency	>95% @ full beam current
Power Consumption	100 kW + Beam Power
Sparking Rate	< $10^4$ sparks/pulse @ design power
Vacuum Pressure (Operating)	< $3 \times 10^{-7}$ torr @ design power
X-Ray Emission	< 5mrem/hr @ 1foot
Expected Lifetime	20 years

# *RFQ Tank Waiting to be Copper Plated*



“Grooves” are an artifact of compression. Not there in real life.

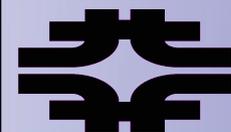


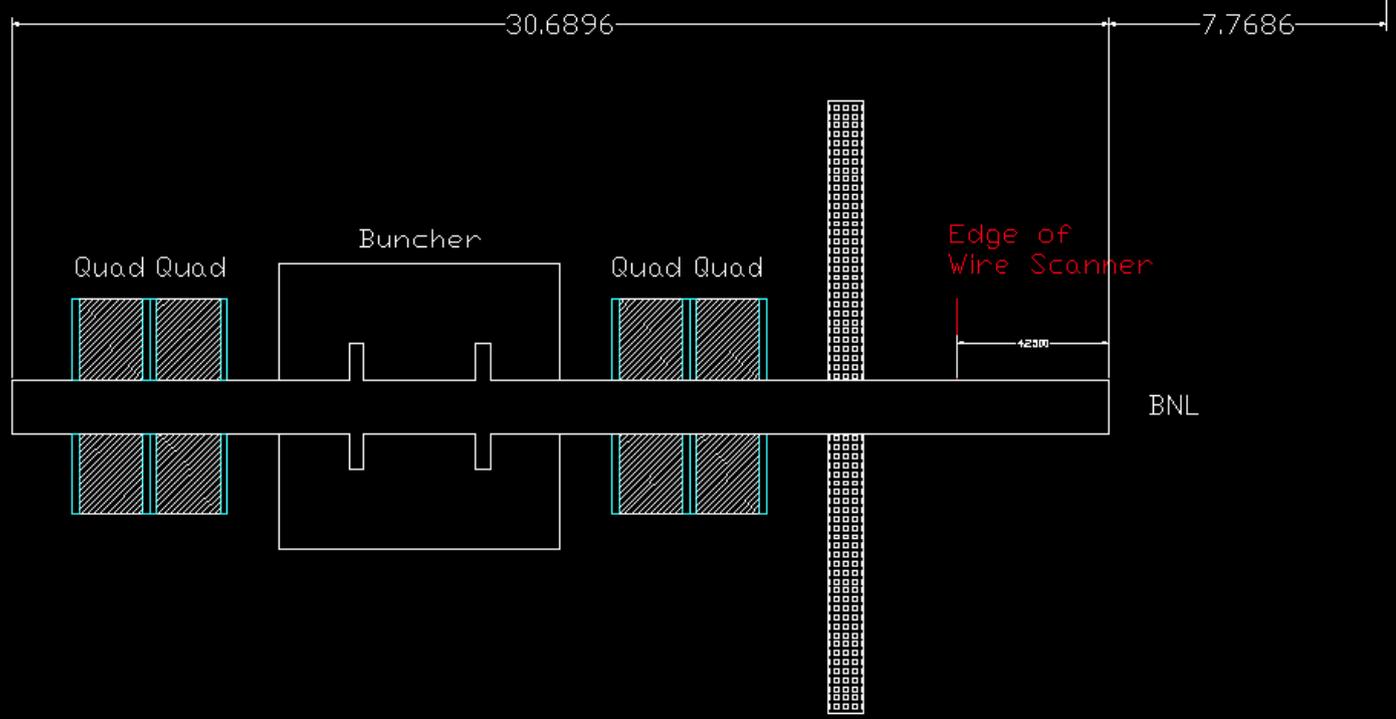
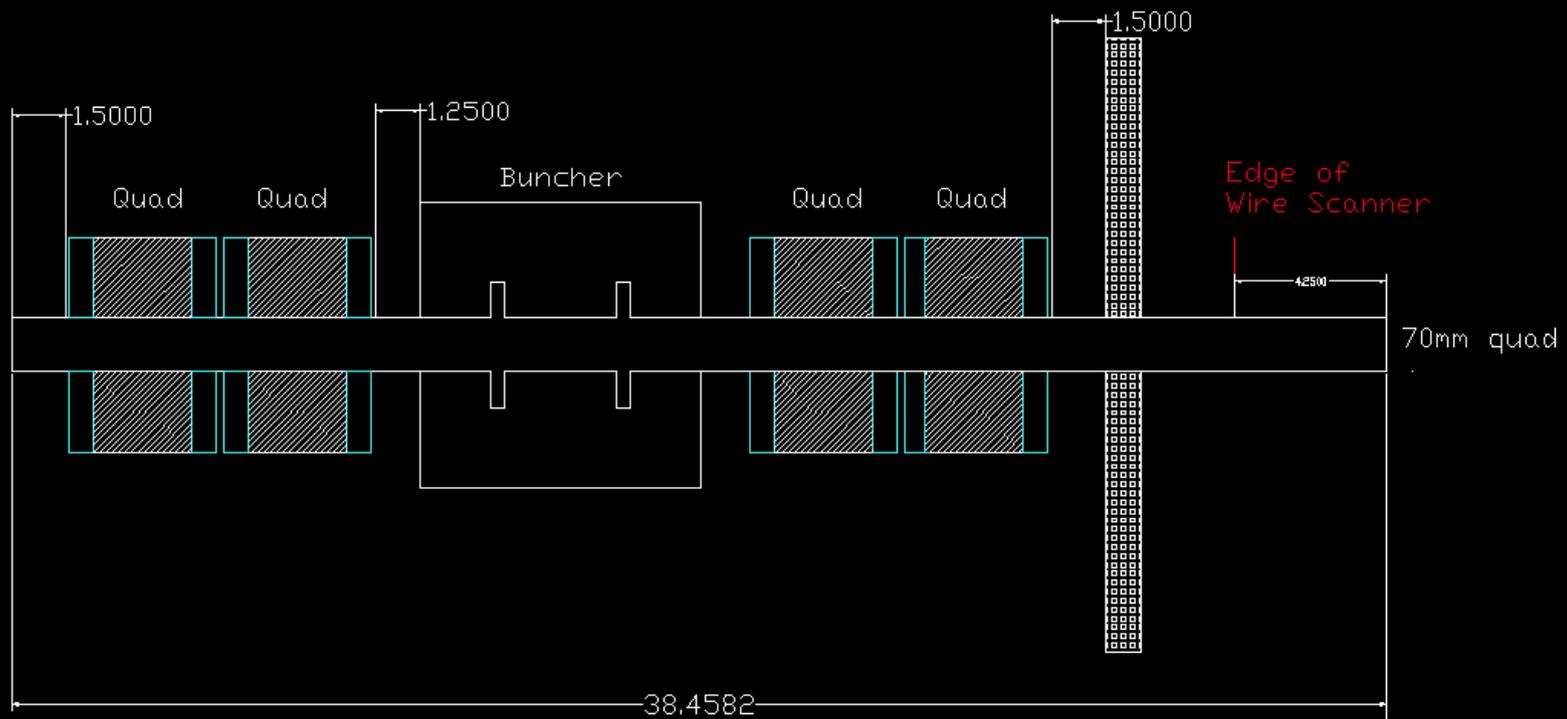
Fermilab,  
P.O. Box 500  
Batavia, IL 60510

# MEBT

The beam is approximately round coming out of the RFQ

- Use doublets to focus the beam before and after buncher
- Must be very short from BNL experience
- Use some of BNL's design
- Quads are a problem because they run very hard.
  - 2 designs available
    - BNL quads are 45mm (~55 physical length)
      - » Don't know whether can run at our rep rate of 15Hz
    - FNAL quads are 70mm (105mm physical length) but includes dipole correctors
    - Both give comparable capture at the end of Tank 1
    - Note: work is being done at TD to shorten the quads to ~55 physical length.





# MEBT Quad Strengths

## FNAL doublets

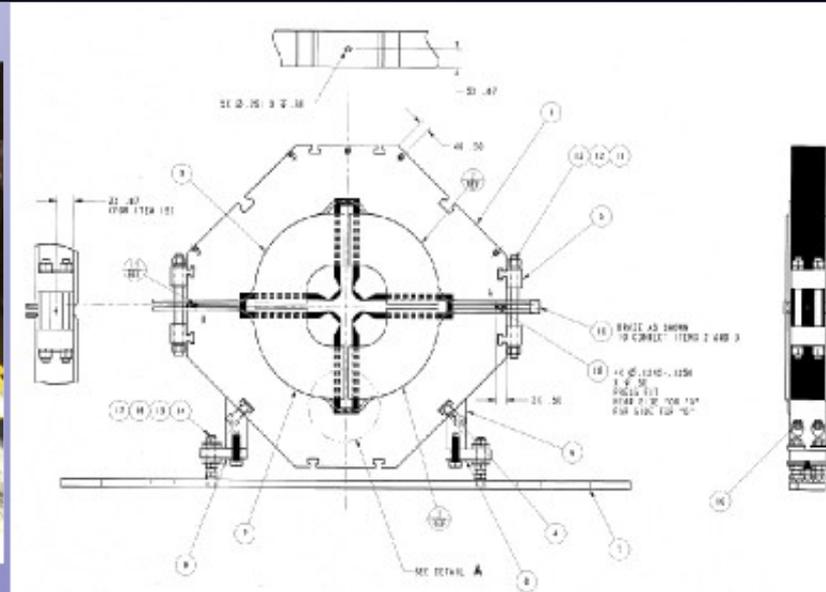
- Quad1: 26.8 T/m
- Quad2: 22.9 T/m
- Quad3: 17.6 T/m
- Quad4: 16.7 T/m

## BNL doublets

- Quad1: 54.0 T/m
- Quad2: 47.3 T/m
- Quad3: 40.3 T/m
- Quad4: 37.9 T/m

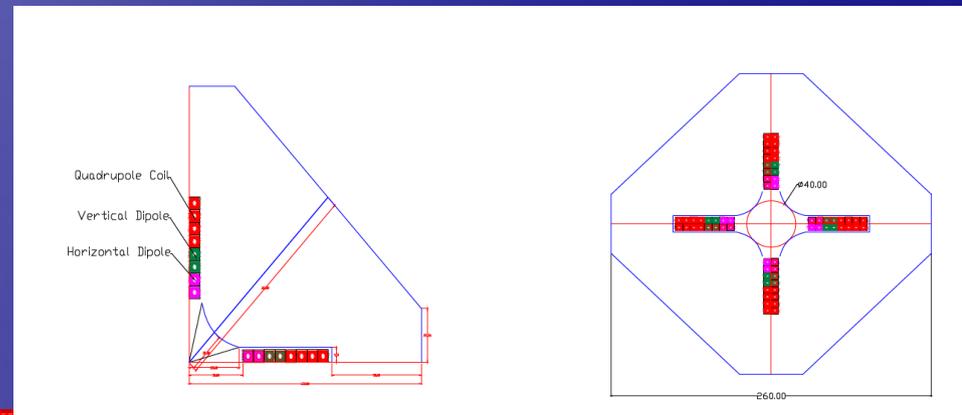
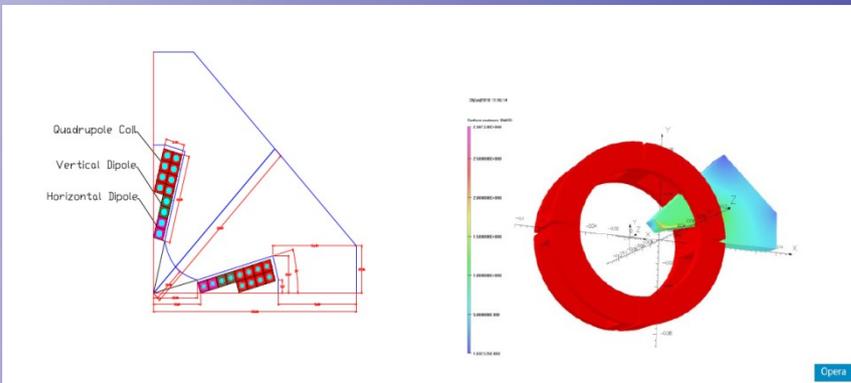


# MEBT Quads



BNL style

FNAL style



# Buncher

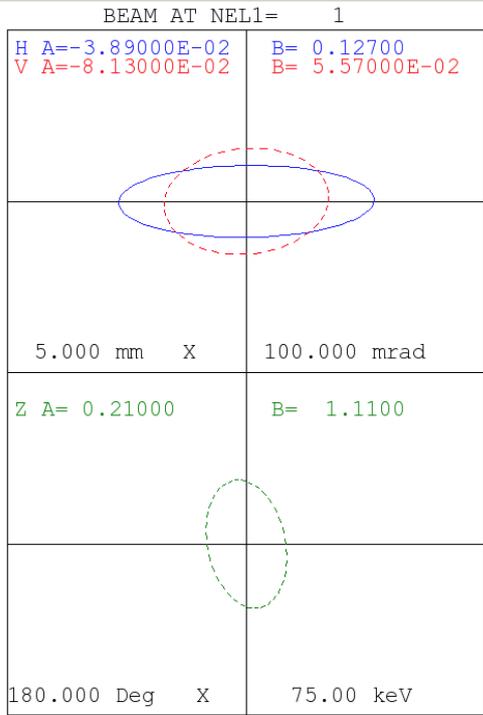


Pictures from  
BNL. Thanks to  
M. Okamura.



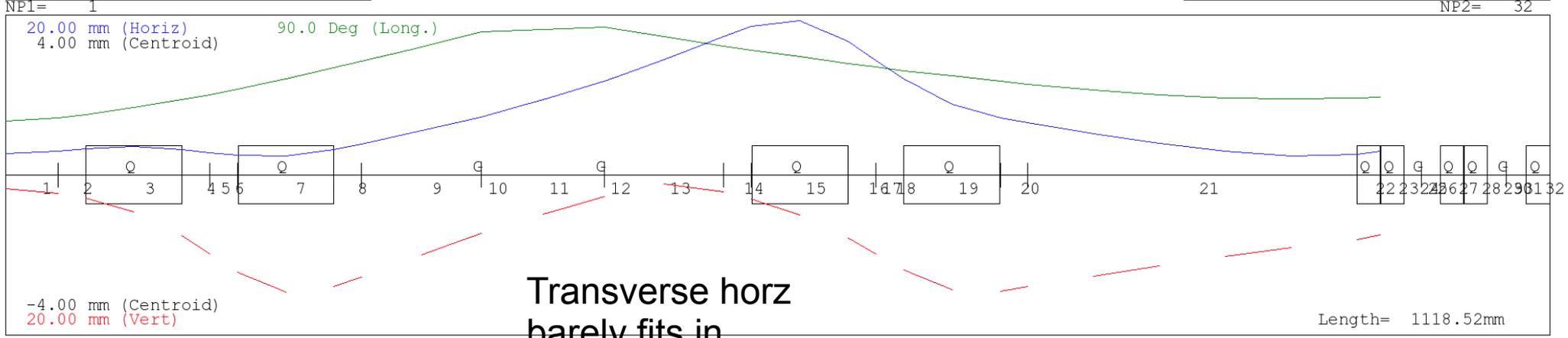
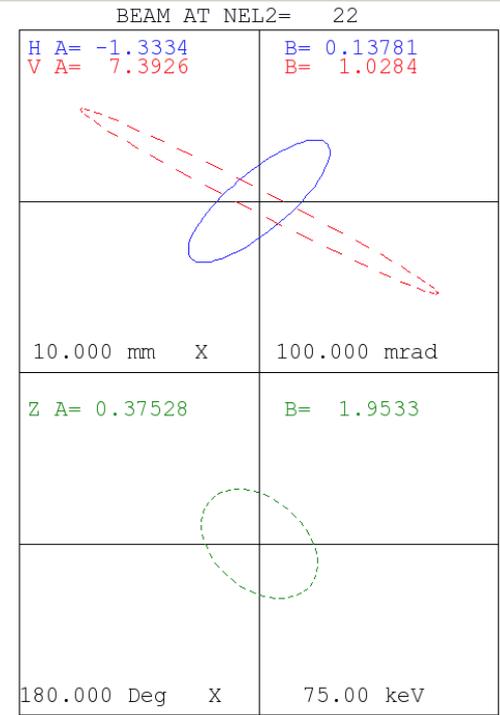
# FNAL Trace3D

TRACE 3D --- INTERACTIVE BEAM TRANSPORT PROGRAM 11/17/2010 VERSION 69ly file fnal\_doublets.t3d



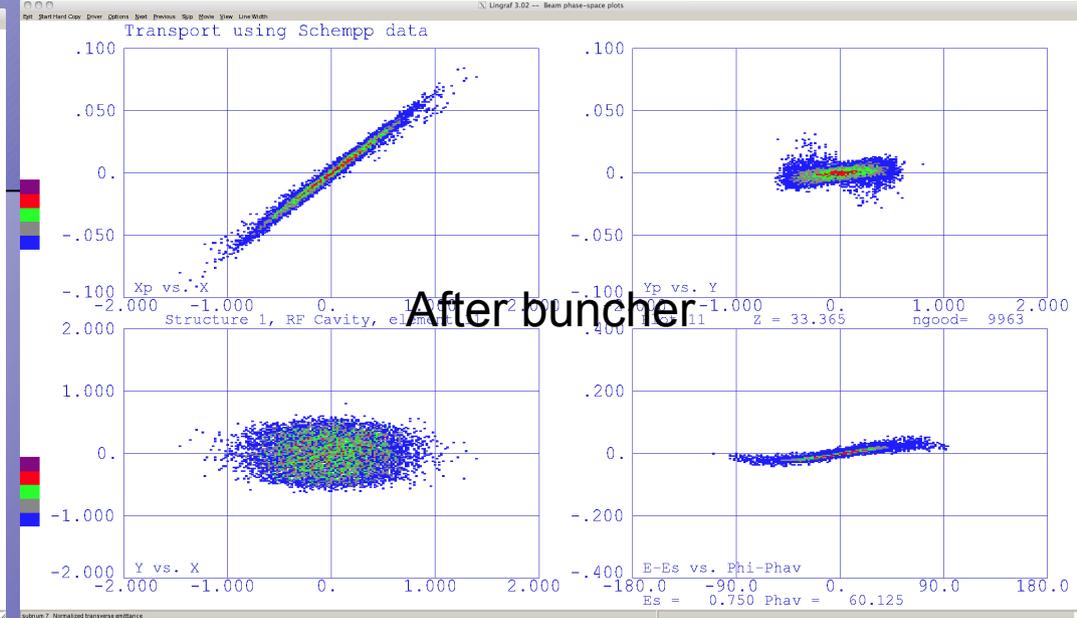
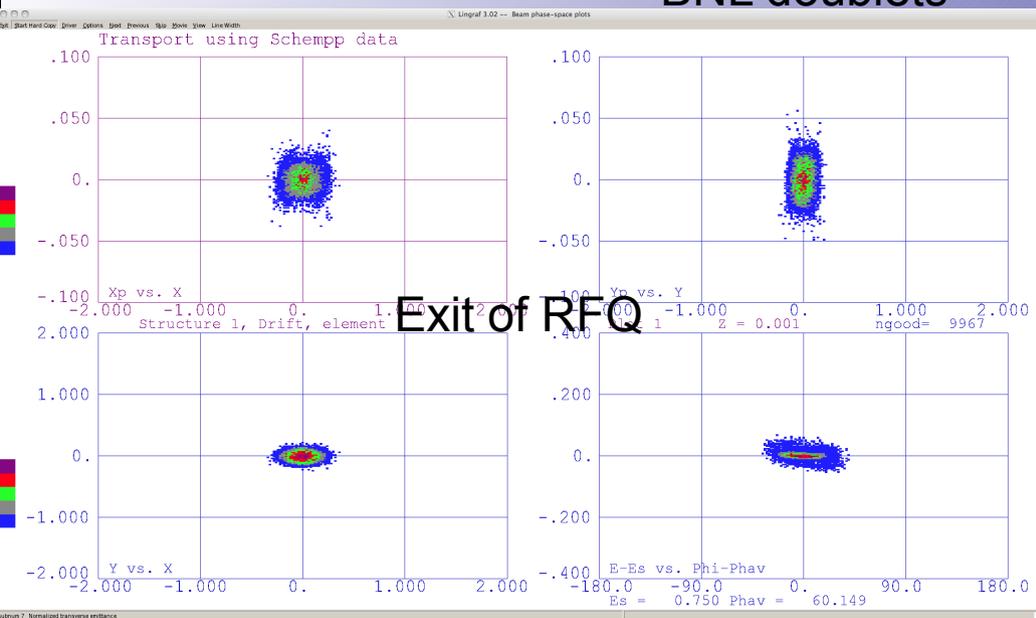
```

I= 60.0mA
W= 0.7500 0.7500 MeV
FREQ= 201.25MHz WL=1489.65mm
EMITI= 56.850 53.400 840.00
EMITO= 63.876 54.343 983.26
N1= 1 N2= 22
PRINTOUT VALUES
PP PE VALUE
1 2 20.00000
1 4 20.00000
1 6 20.00000
1 10 0.03598
MATCHING TYPE = 8
DESIRED VALUES (BEAMF)
alpha beta
x -0.7901 0.1502
y 0.7495 0.1045
MATCH VARIABLES (NC=4)
MPP MPE VALUE
1 3 -26.80310
1 7 22.86306
1 15 -17.60756
1 19 16.73034
    
```

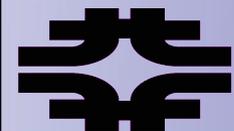
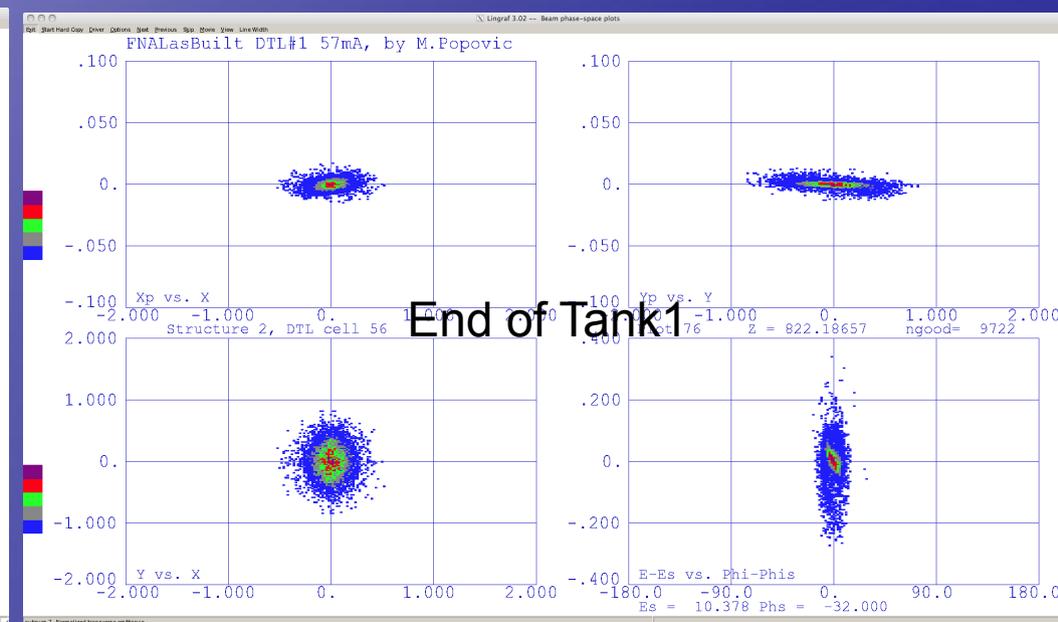
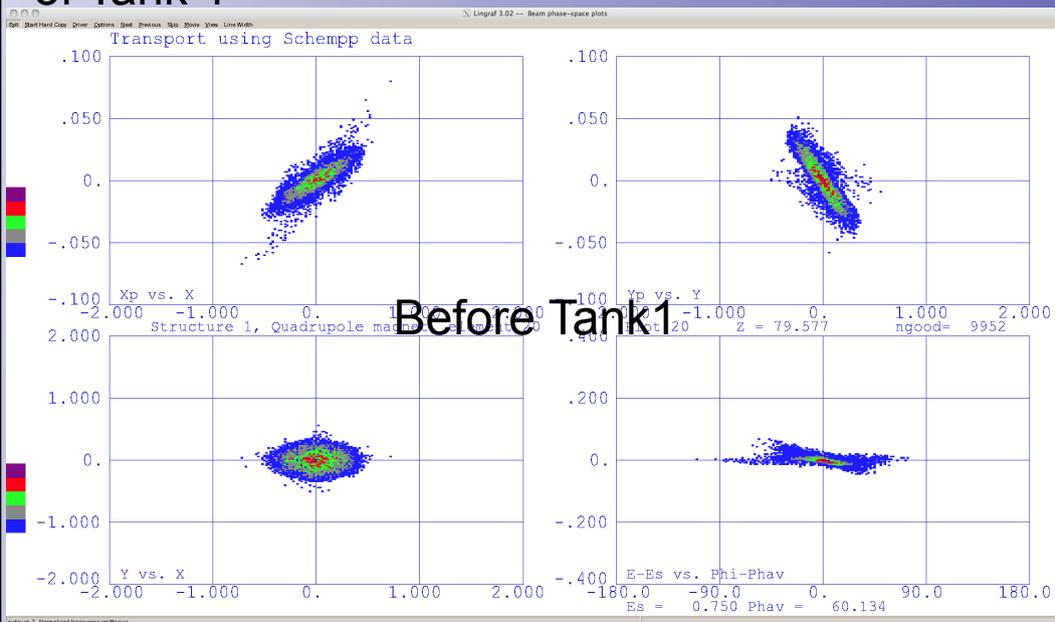


Transverse horz  
barely fits in  
beampipe

# BNL doublets

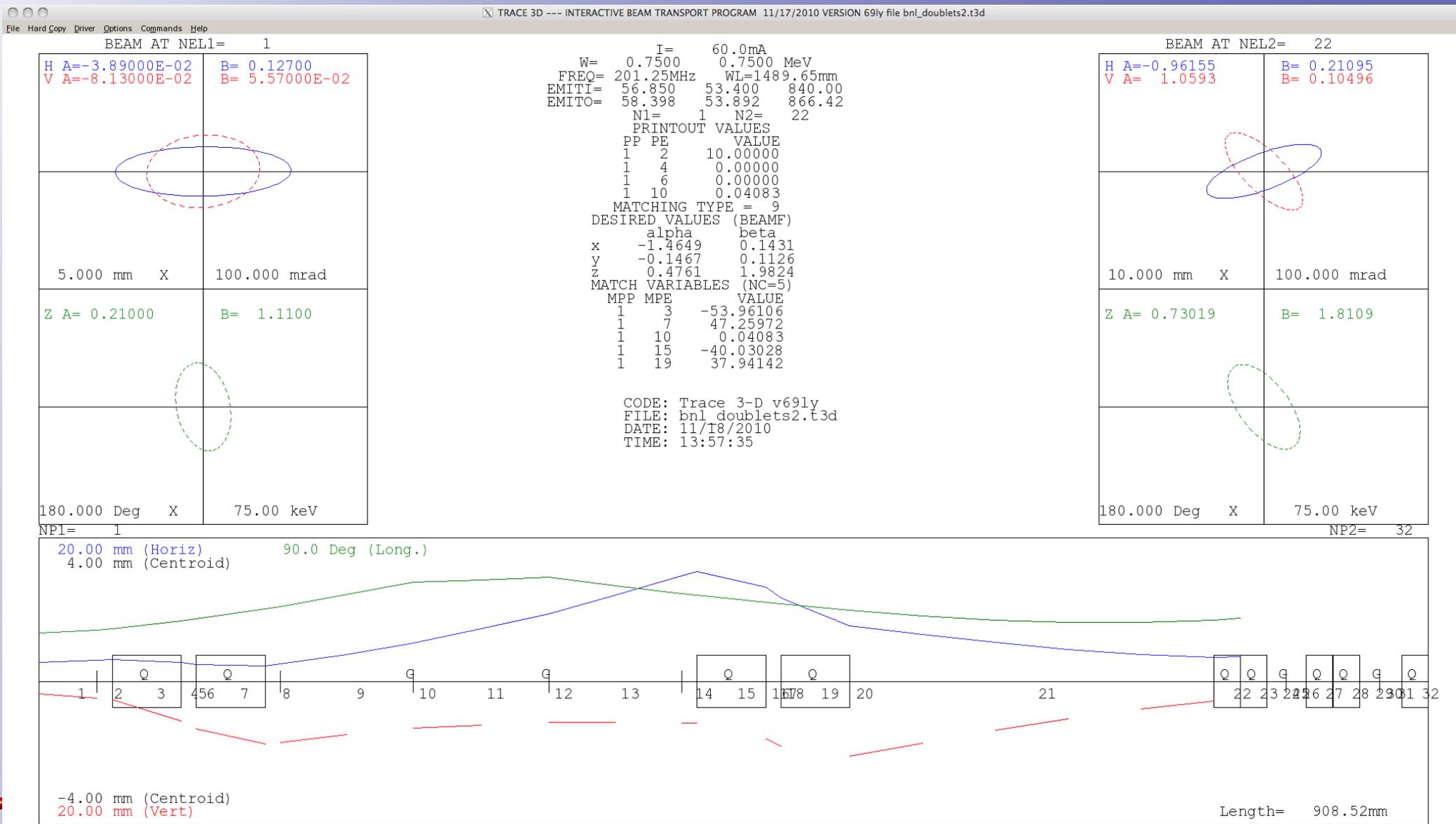


Capture is 97.5% at end of Tank 1



Fermilab,  
P.O. Box 500  
Batavia, IL 60510

# BNL Trace3D



# Conclusion

- ◆ Goal is to complete testing of injector before the shutdown of 2011.
- ◆ Installation will probably take 3 months in 2012.
- ◆ Lots of things to do before then
  - ◆ Complete commissioning of the H- source
  - ◆ Test Einzel lens as chopper.
  - ◆ Check and condition buncher.
  - ◆ Check and condition RFQ
  - ◆ Have test stand ready for beam test
  - ◆ Build and complete solenoids.
  - ◆ Build and complete quadrupoles.
    - ◆ Choice has to be made between BNL and FNAL quads

