PC Gun Beam in APS Linac
Simulations, Measurements and Operation Considerations

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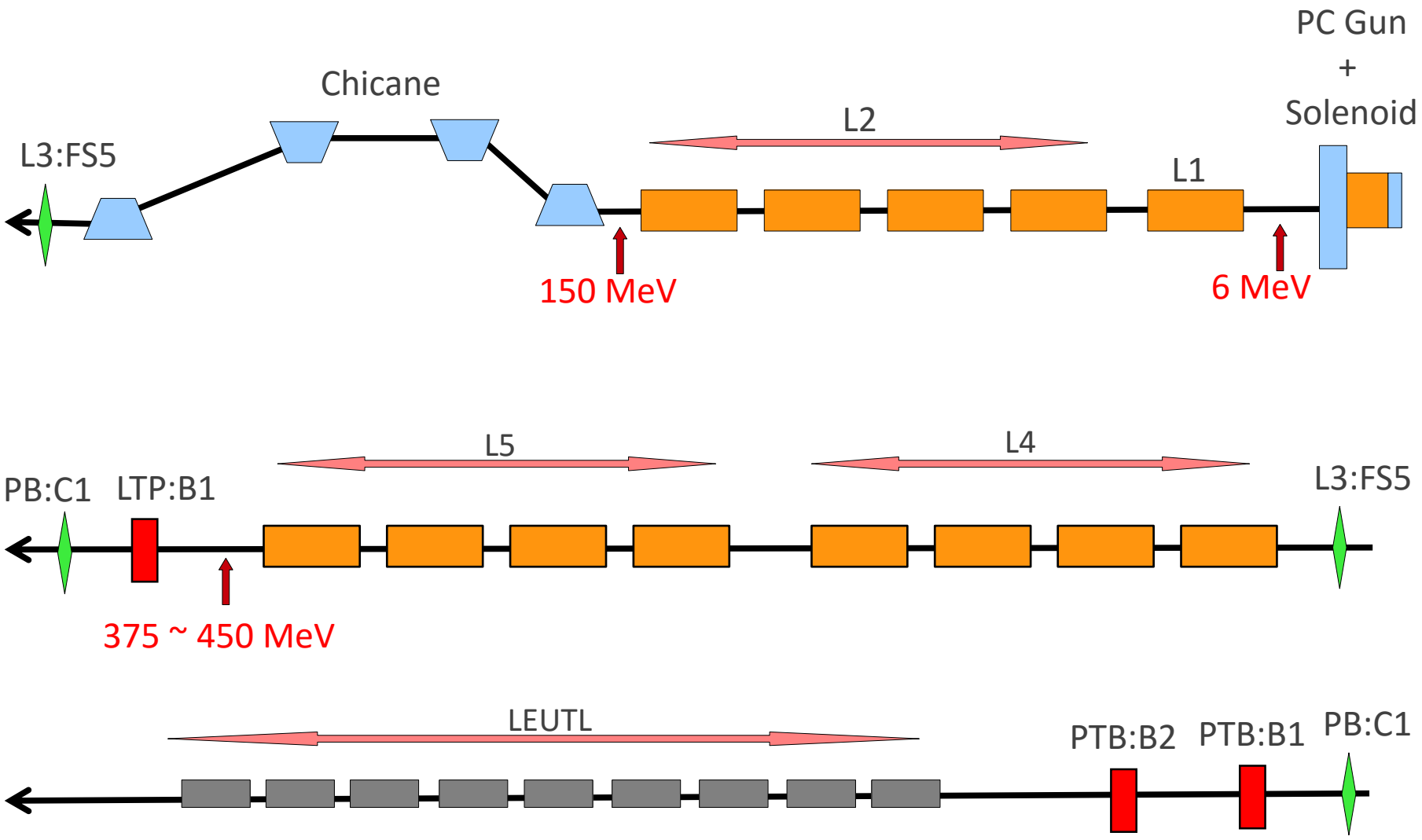
Nov. 11, 2015

U.S. DEPARTMENT OF ENERGY | Office of Science

APS LINAC


PC Gun
+
Solenoid
Chicane
L2
L3:FS5
L1
150 MeV
6 MeV
L5
L4
PB:C1
LTP:B1
L3:FS5
375 ~ 450 MeV
LEUTL
PTB:B2
PTB:B1
PB:C1

Beam Optimization

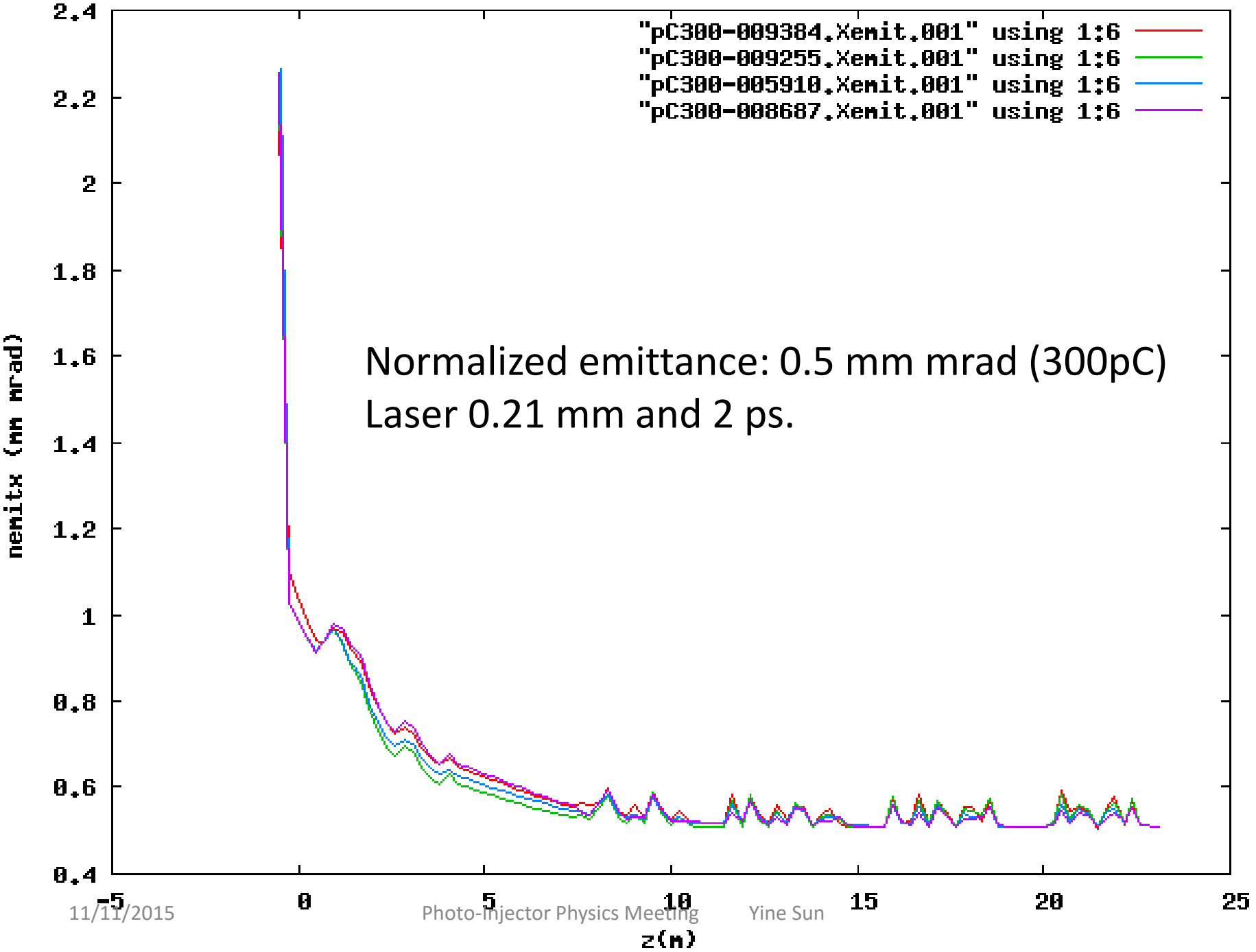
cathode -> the center of the waveguide of L1:AS1=1883 mm

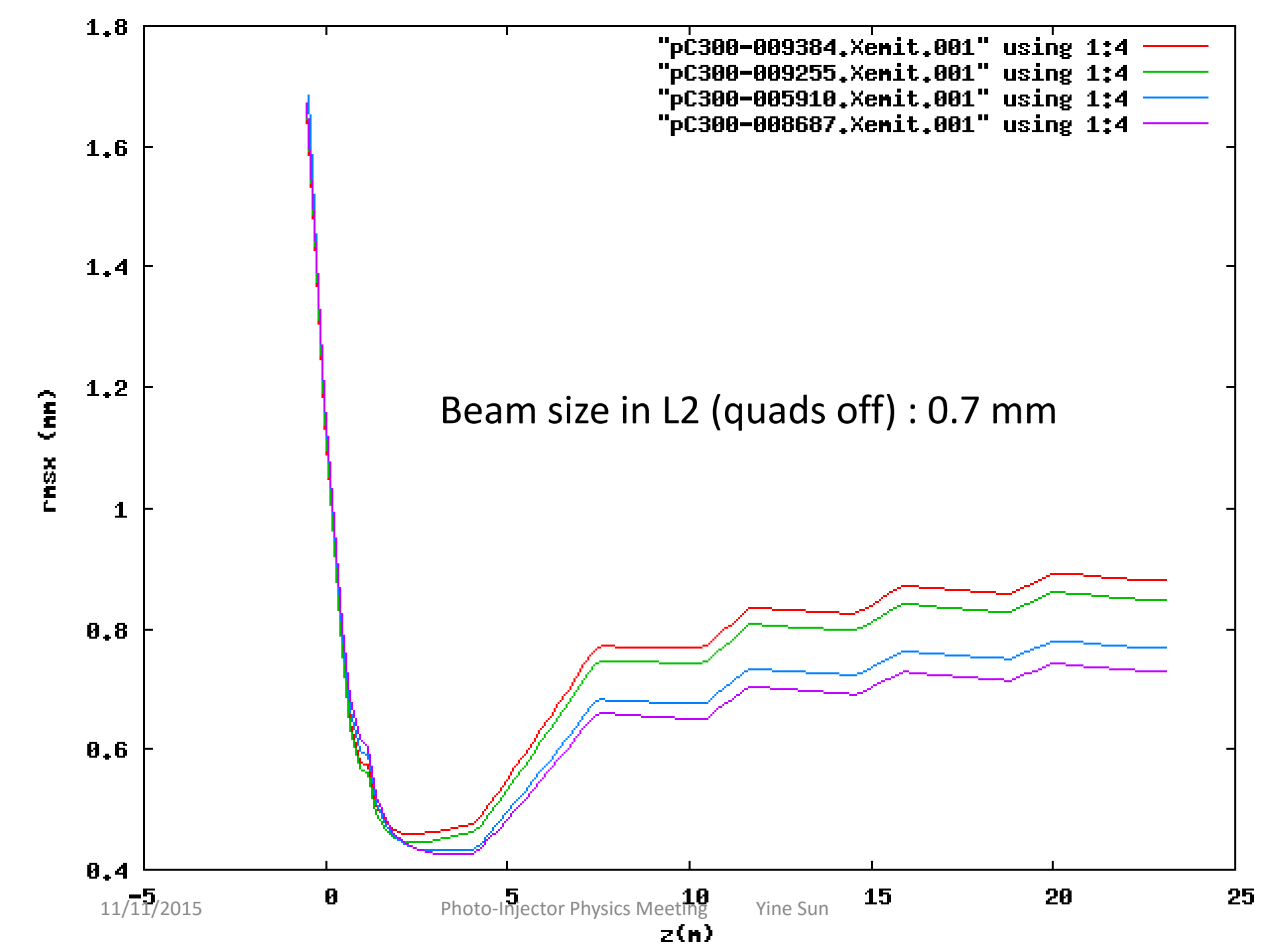
Energy: 150 MeV at chicane; minimum emittance

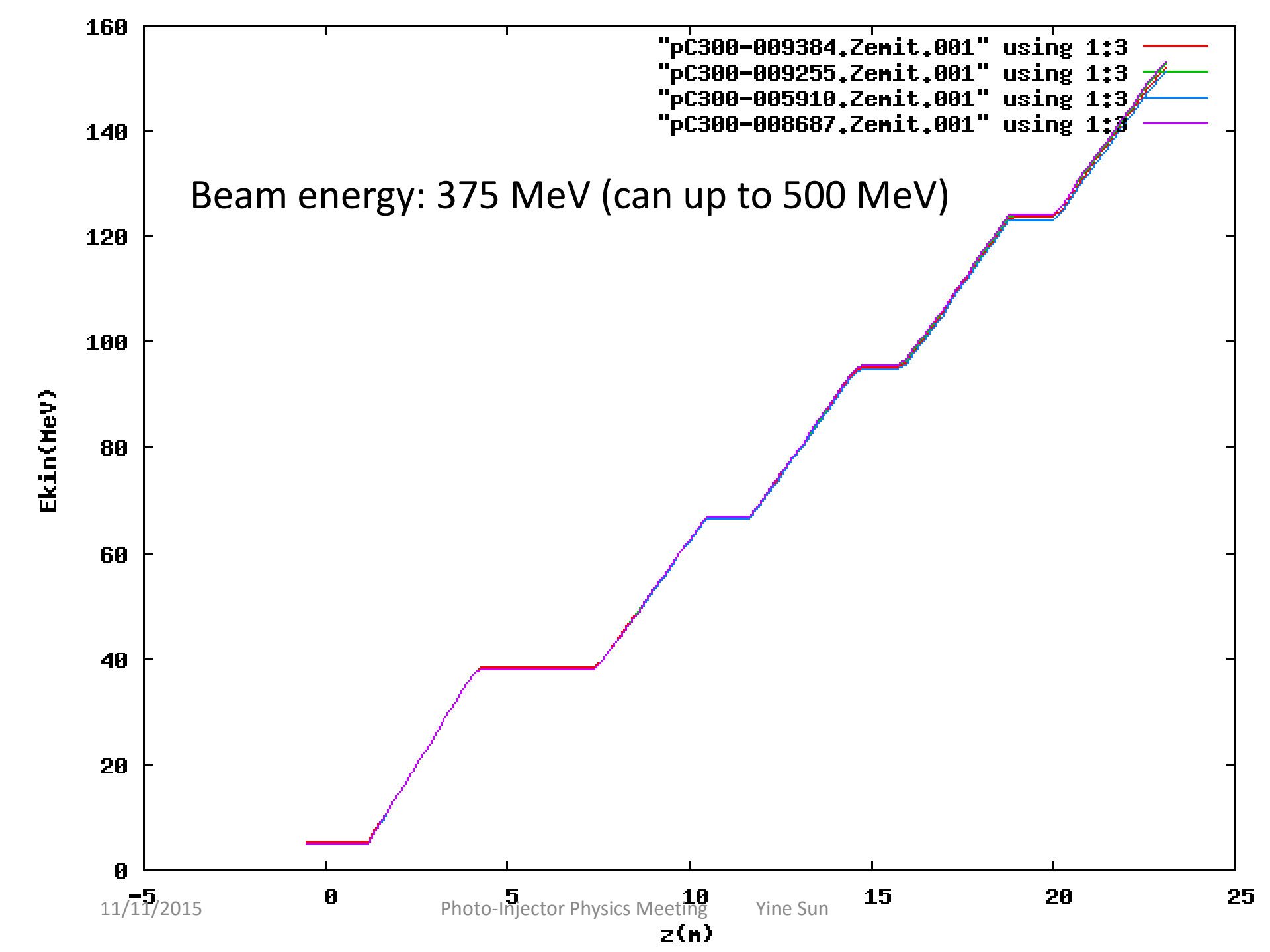
parameterName	lowerLimit	upperLimit	errorLevel	initialValue
spot	0.21	1.0	0.02	0.26
pulse	0.001	0.002	0.0002	0.0015
E1	-110.0	-100.0	1.0	-105.0
Phi1	-20.0	20.0	0.5	-4.029
E2	-15.0	-5.0	0.5	-9.0
Phi2	-10.0	10.0	0.5	-7.0
B1	0.2	0.315	0.01	0.23
E3	-15.0	-12.0	0.2	-14.1412
Phi3	-40.0	0.0	2.0	-19.0

optimized machine parameters

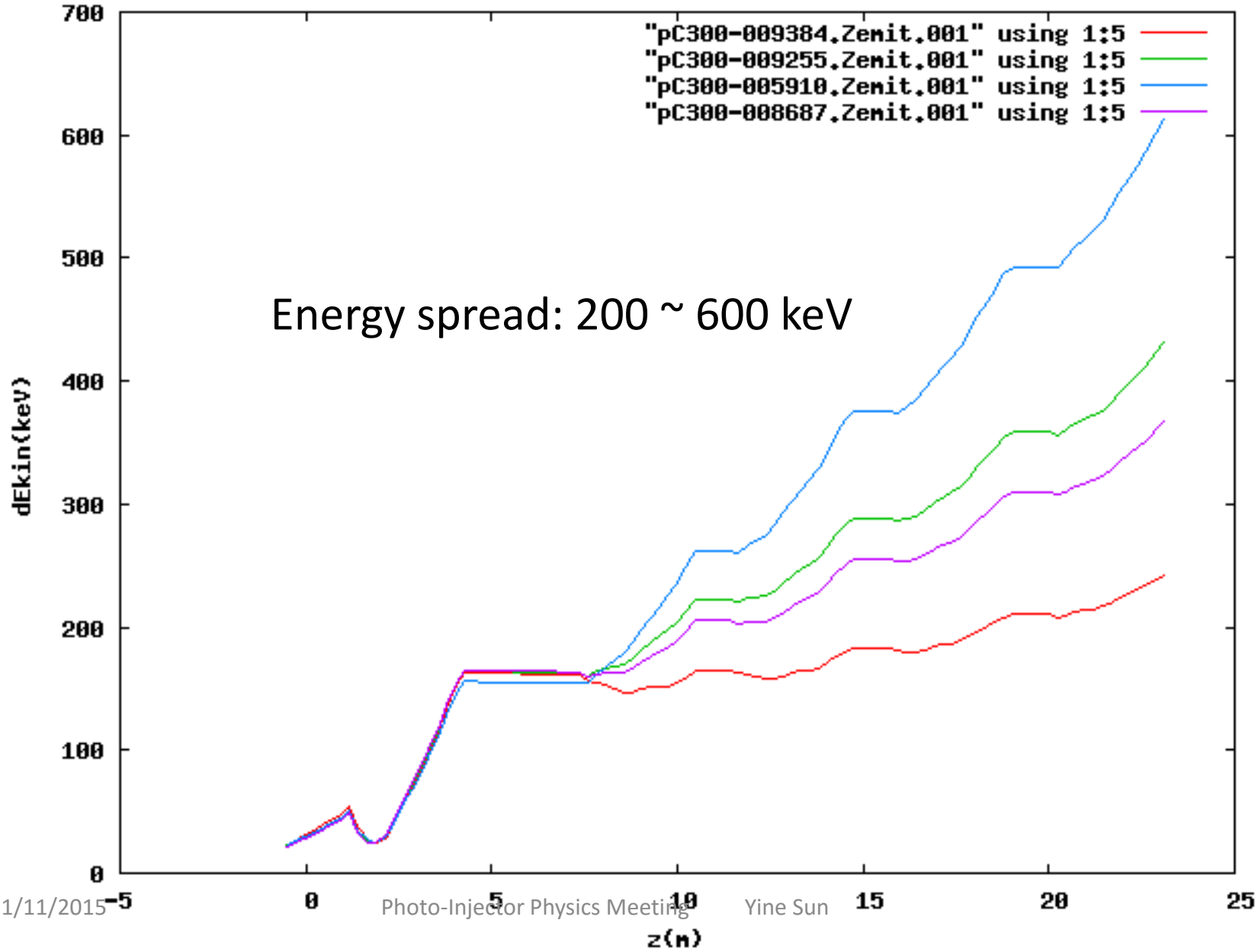
rms UV length	2	ps
rms UV size	0.21	mm
solenoid current	157 ~ 160	A [@0.001532 T/A]
max. gun gradient	105 ~ 108	MV/m


"pC300-009384.Xemit.001" using 1:6
"pC300-009255.Xemit.001" using 1:6
"pC300-005910.Xemit.001" using 1:6
"pC300-008687.Xemit.001" using 1:6
Normalized emittance: 0.5 mm mrad (300pC)
Laser 0.21 mm and 2 ps.
nemitx (mm mrad)
z(m)
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
-5
0
5
10
15
20
25

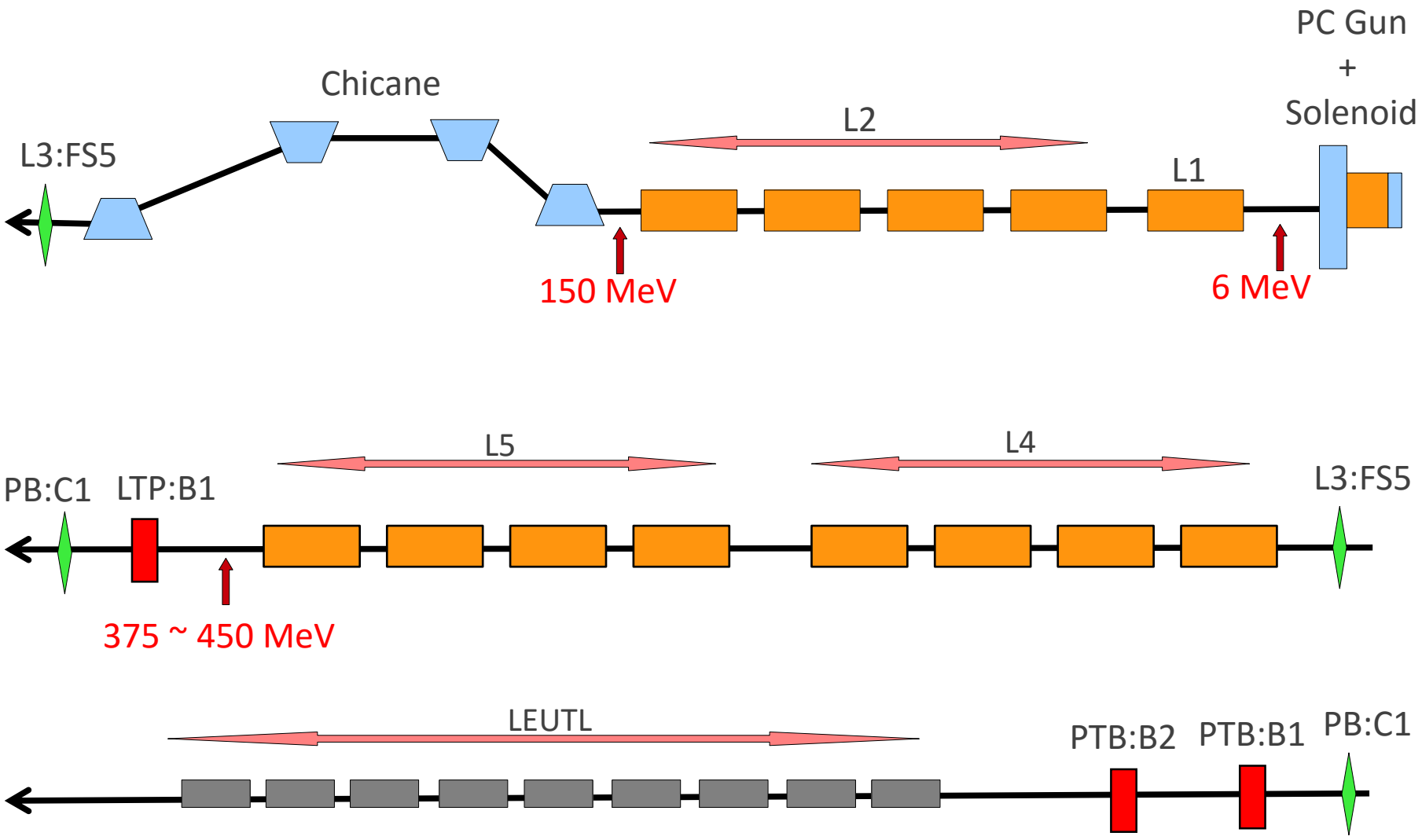

"pC300-009384.Xemit.001" using 1:4
"pC300-009255.Xemit.001" using 1:4
"pC300-005910.Xemit.001" using 1:4
"pC300-008687.Xemit.001" using 1:4
Beam size in L2 (quads off) : 0.7 mm
rmsx (mm)
z(m)
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
-5
0
5
10
15
20
25


"pC300-009384.Zemit.001" using 1:3
"pC300-009255.Zemit.001" using 1:3
"pC300-005910.Zemit.001" using 1:3
"pC300-008687.Zemit.001" using 1:3
Beam energy: 375 MeV (can up to 500 MeV)
Ekin(MeV)
z(m)
0
20
40
60
80
100
120
140
160
-5
0
5
10
15
20
25

300 pC Optimization Results



APS LINAC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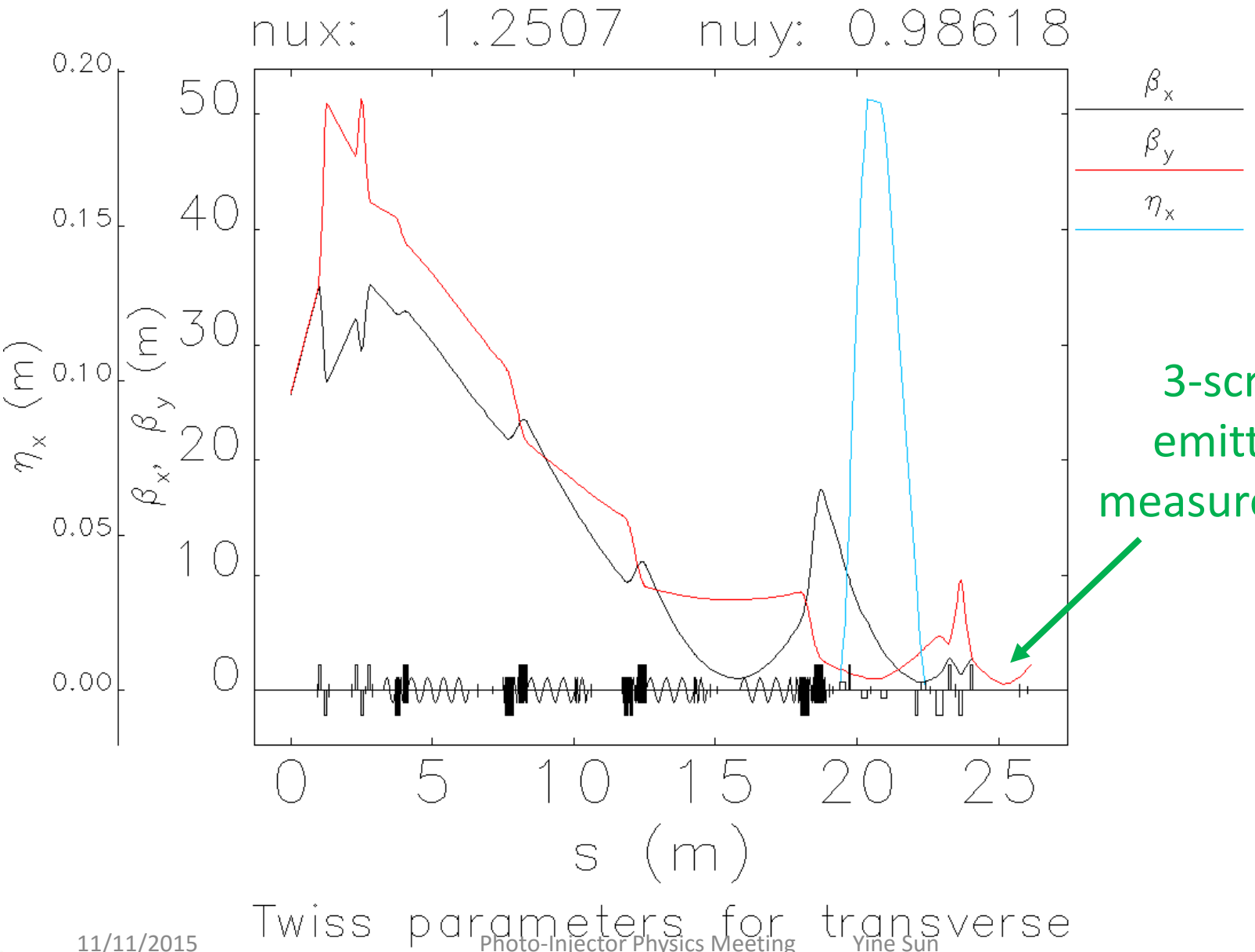
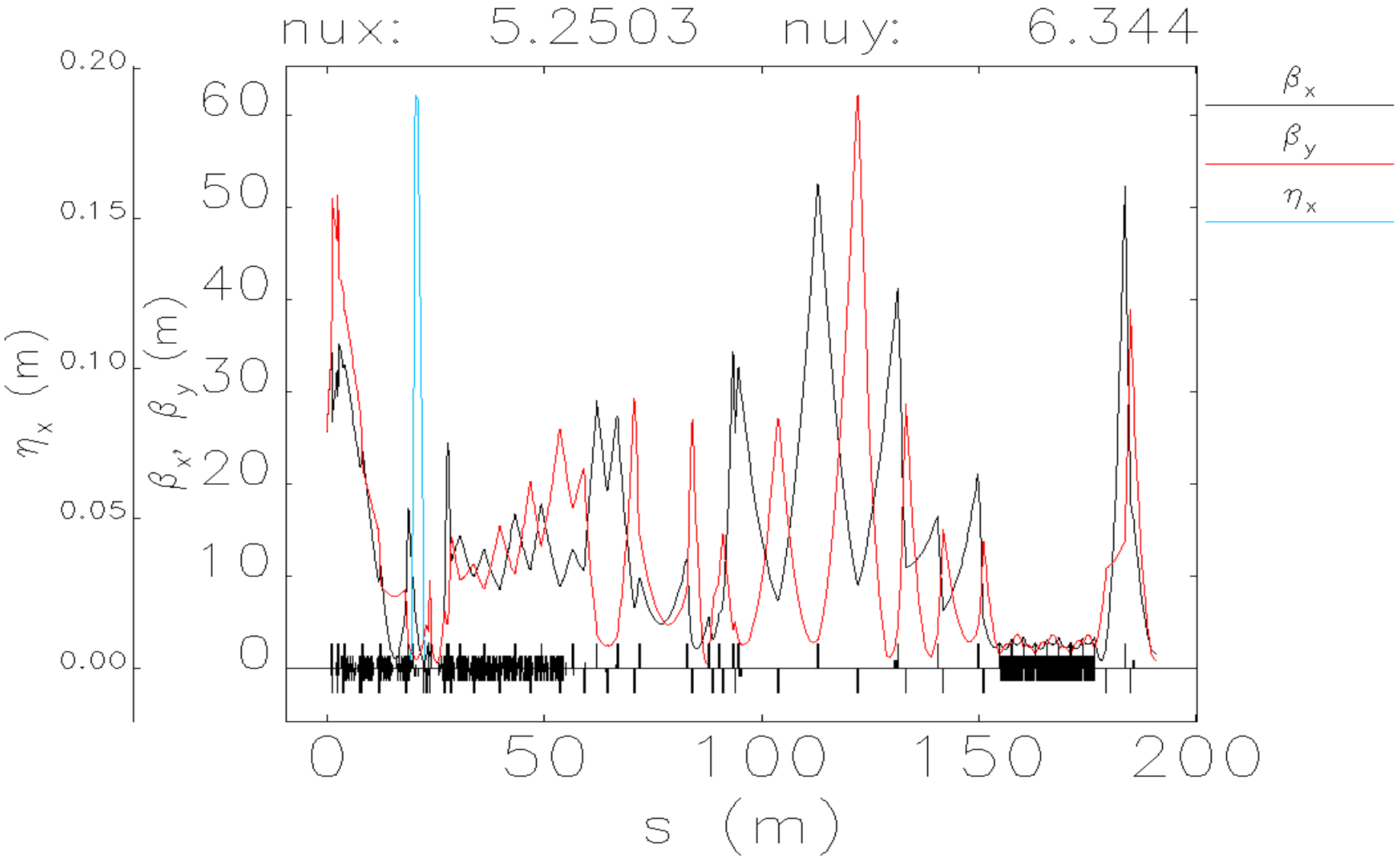
L4
PB:C1
LTP:B1
L3:FS5
375 ~ 450 MeV
LEUTL
PTB:B2
PTB:B1
PB:C1

ELEGANT matching through chicane

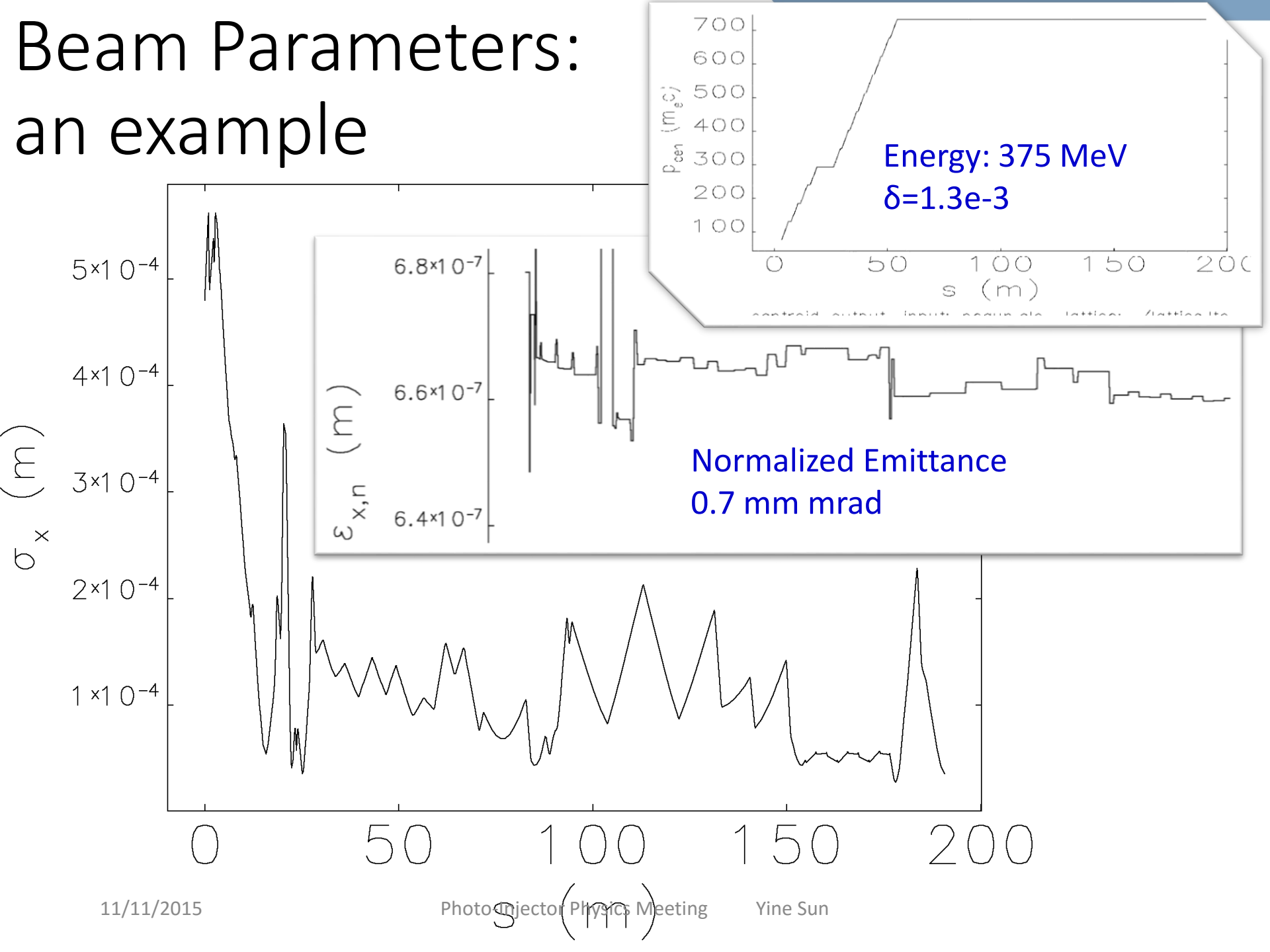


3-screen emittance measurements

Lattice through Linac to LEUTL

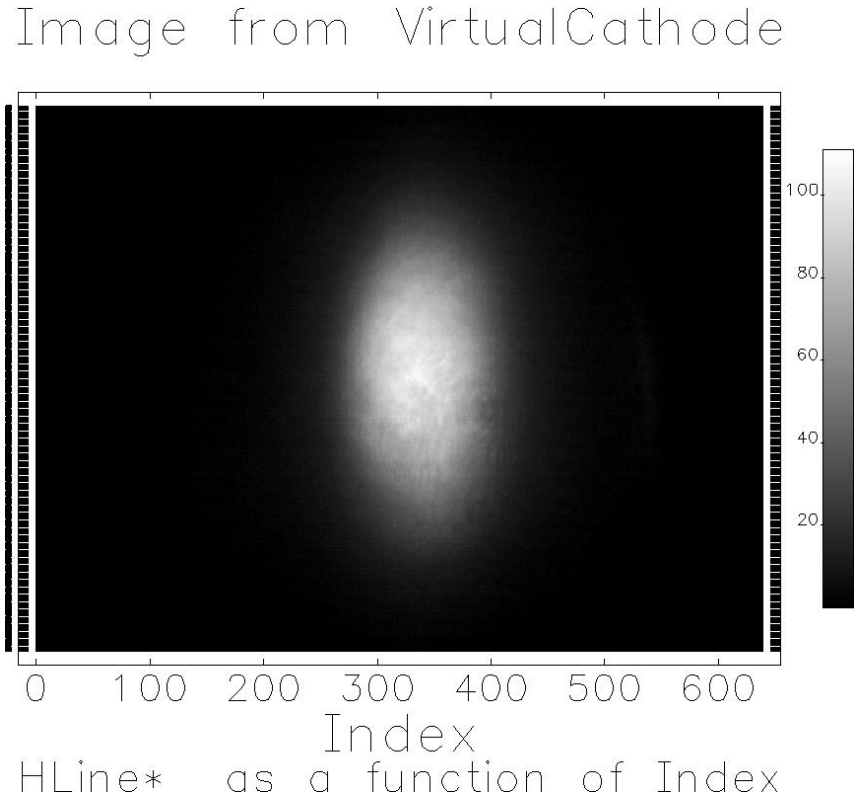


Beam Parameters: an example



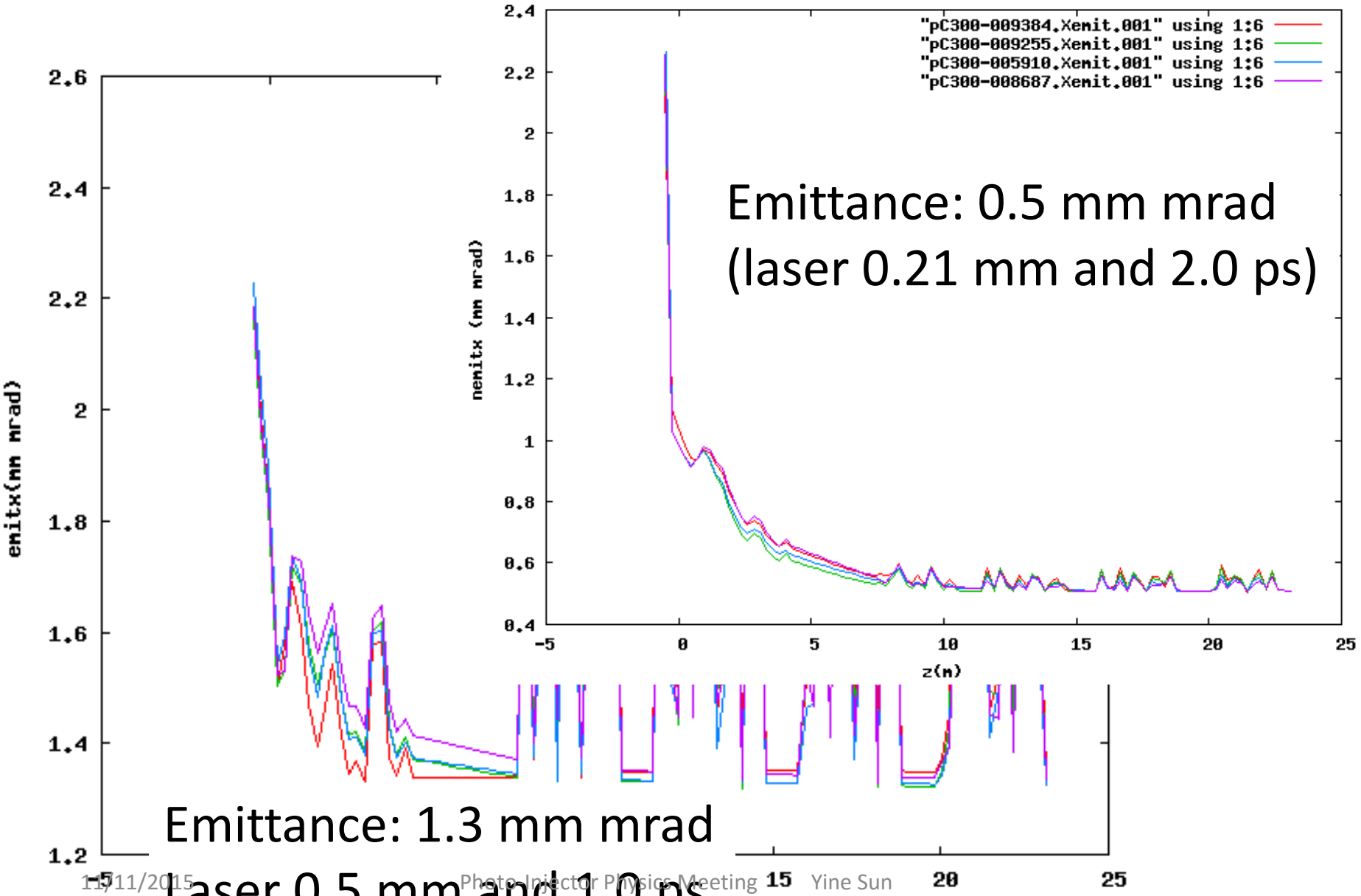
Simulations Using Larger Laser Spot

- Measured UV drive laser: σx=0.481 mm, σy=0.875 mm (Dooling);

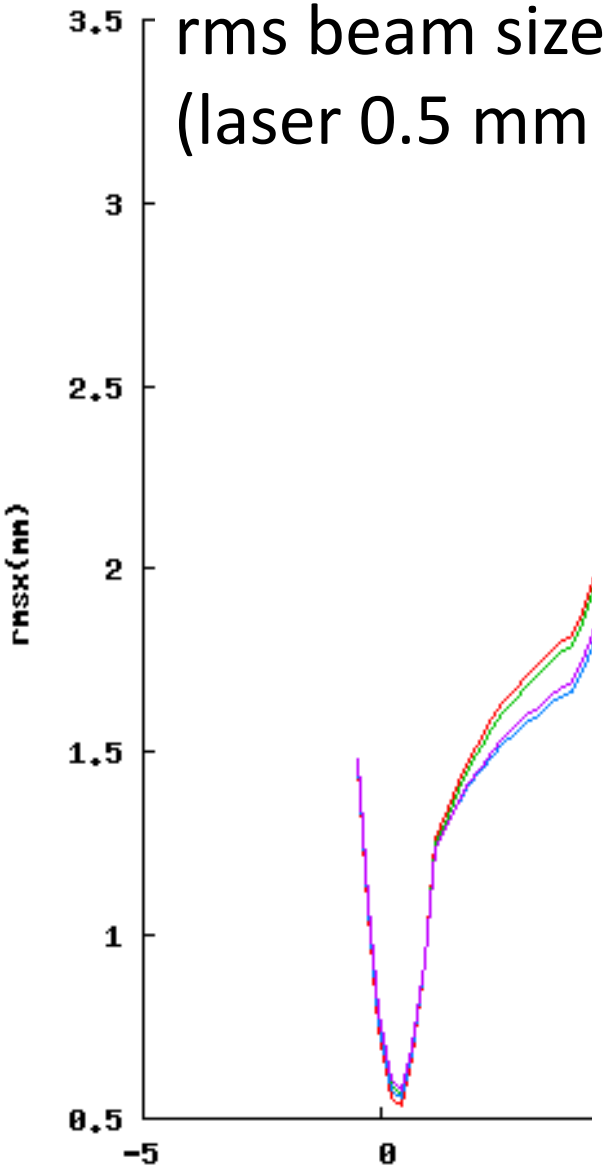


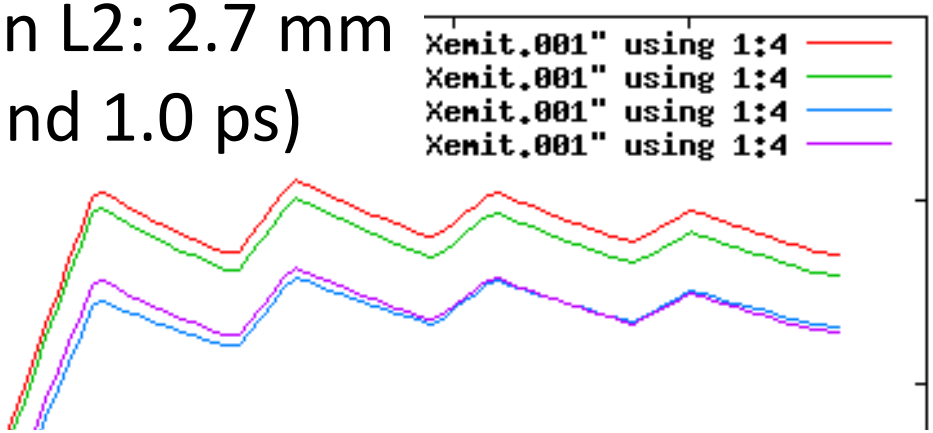
- In ASTRA optimization, set the lower limit of rms spot size to 0.5 mm. UV laser pulse range kept in (1.0 ~ 2.0) ps range.

Optimization Results with Larger Laser

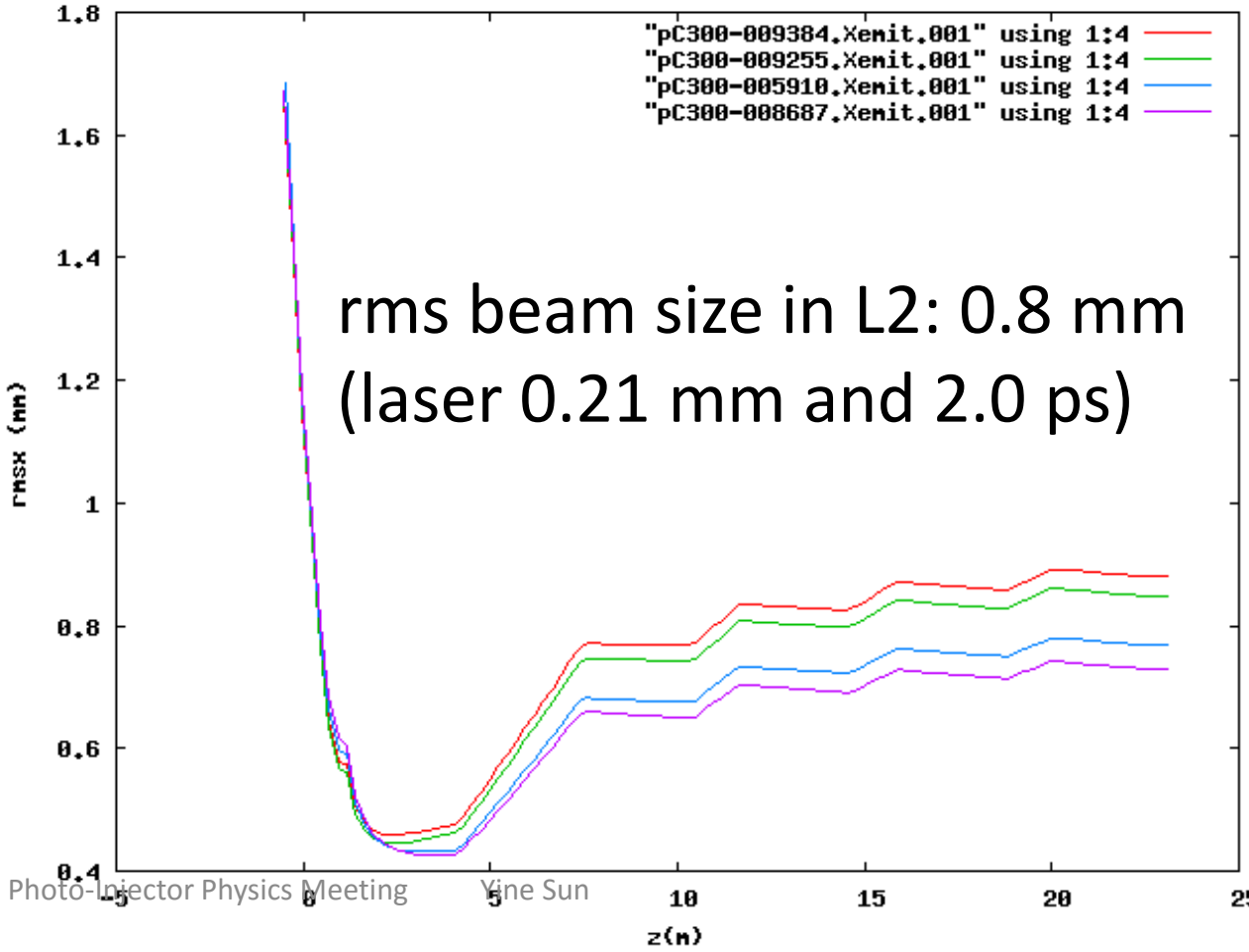


rms beam size in L2: 2.7 mm
(laser 0.5 mm and 1.0 ps)

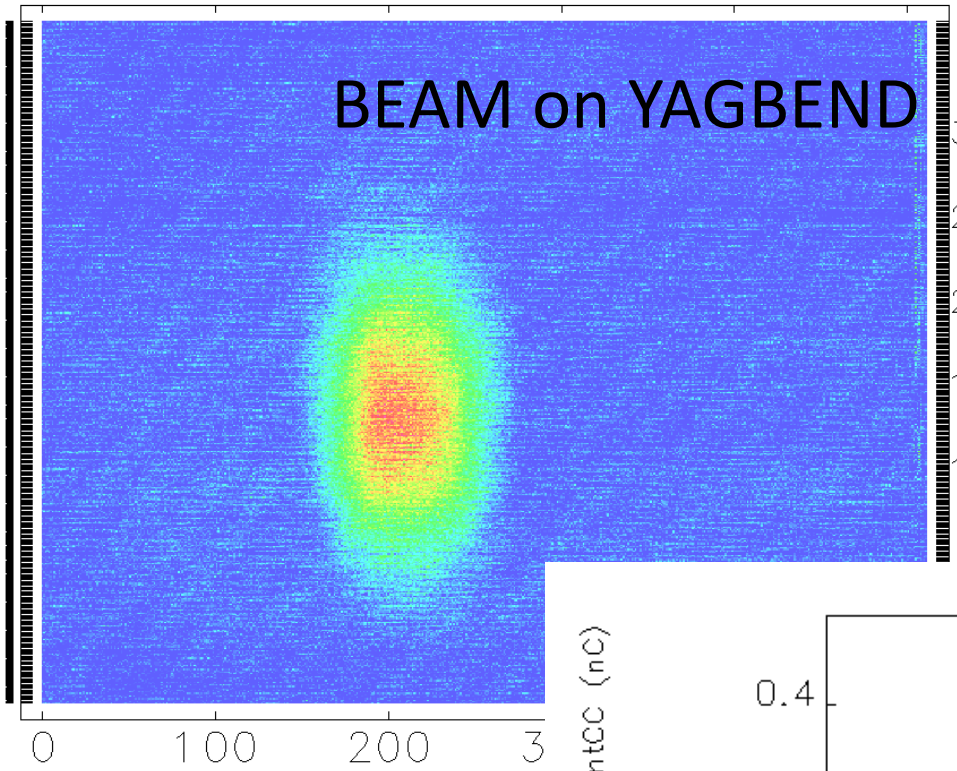


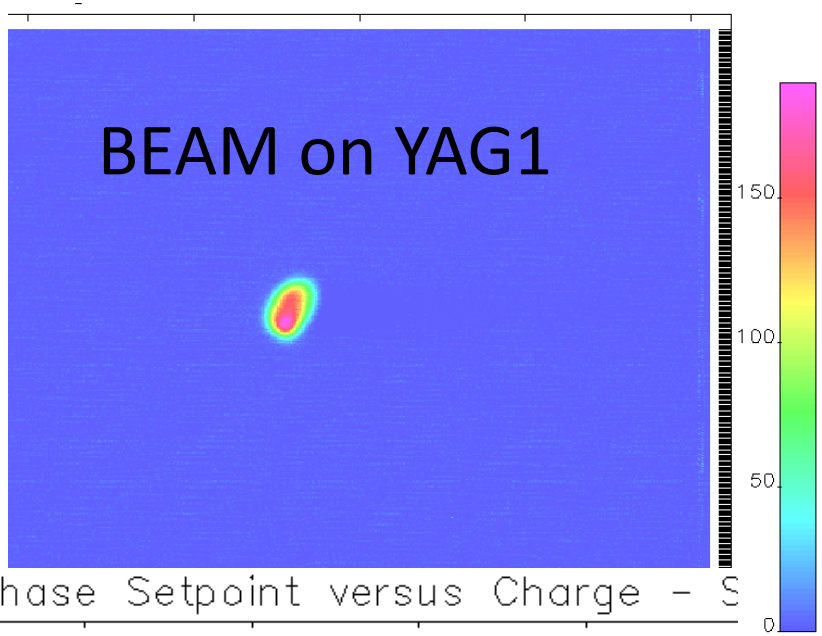


rms beam size in L2: 0.8 mm
(laser 0.21 mm and 2.0 ps)

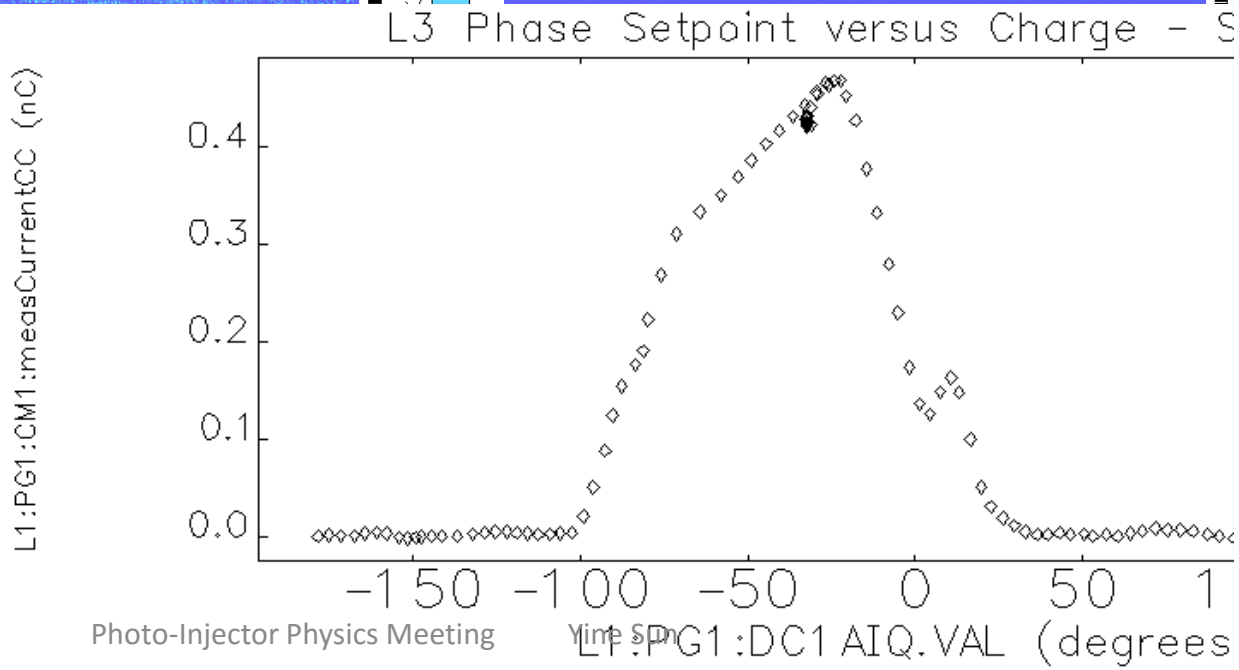


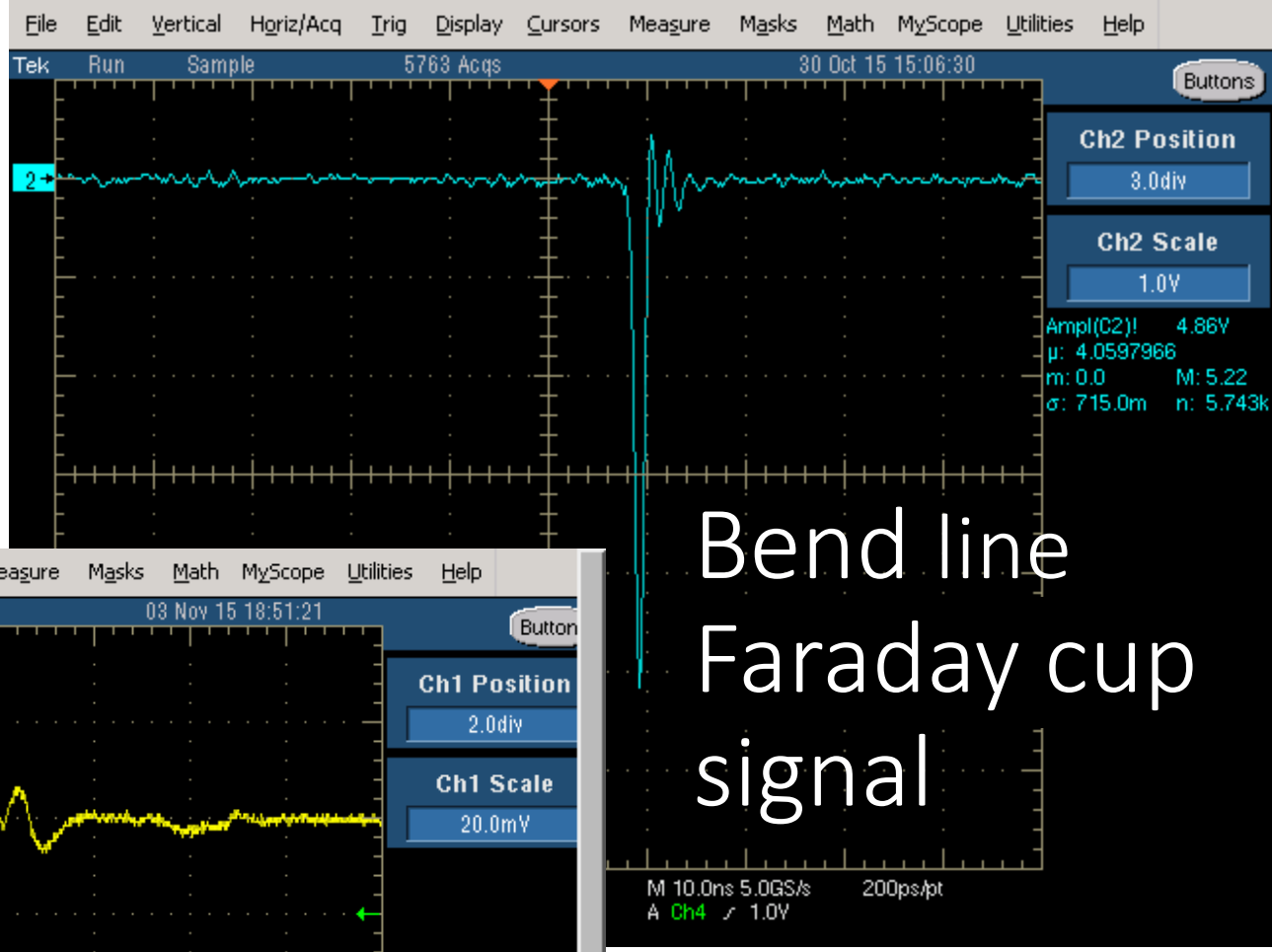
Measurements: PC Gun Beam in APS Linac



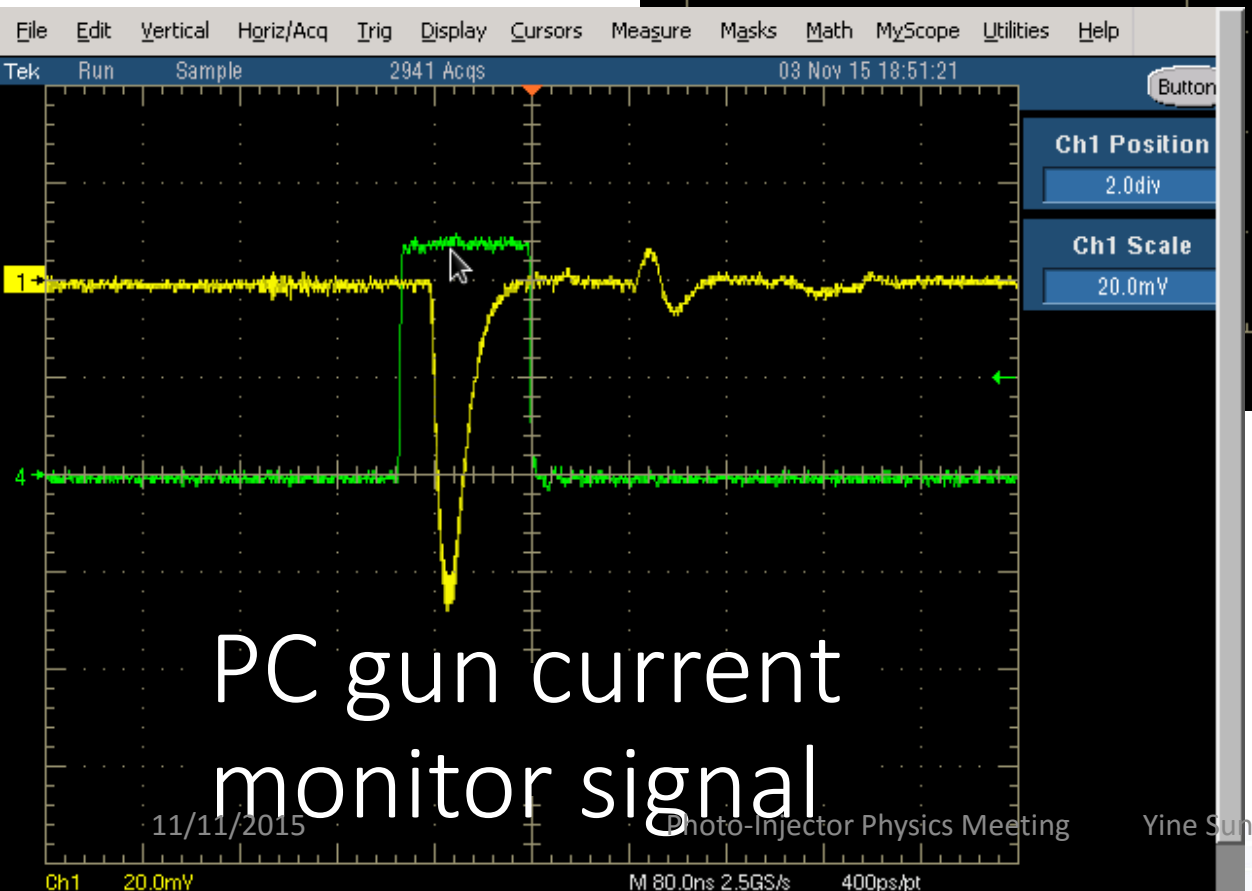


Maximum charge at 50 deg from zero crossing: 350pC



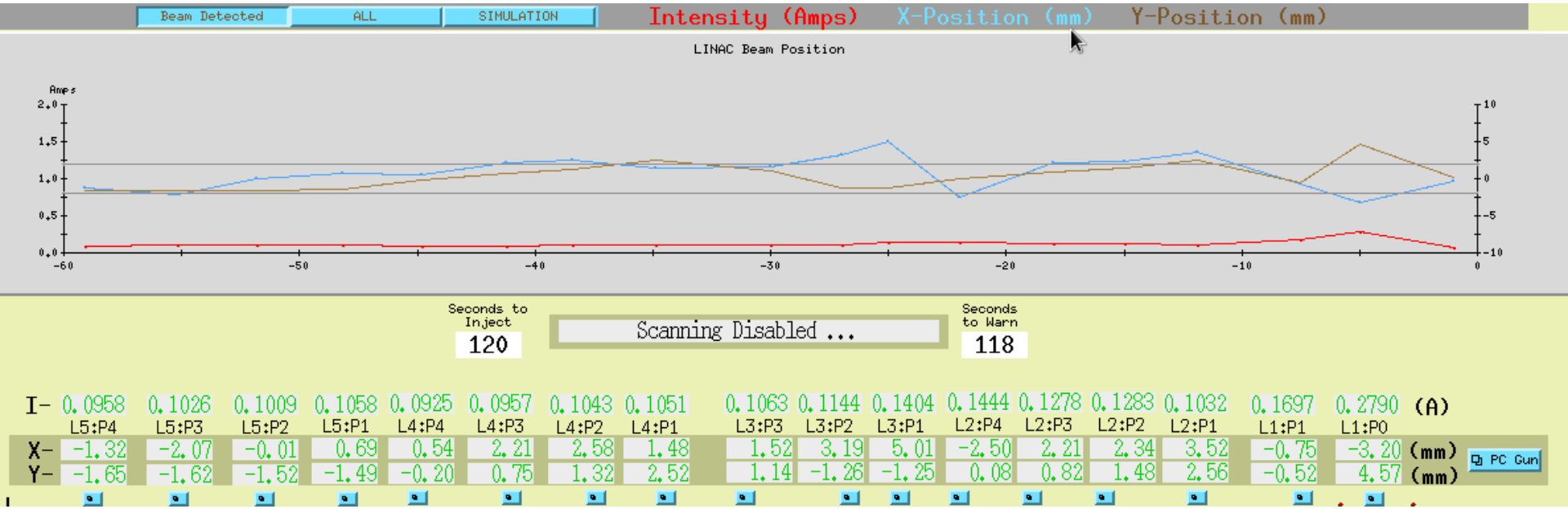


Bend line Faraday cup signal

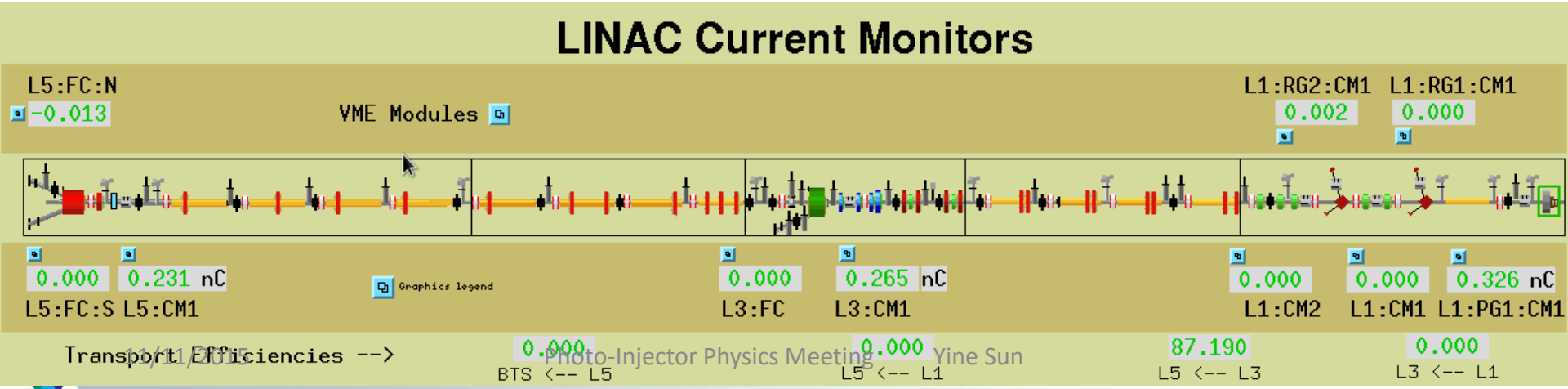


PC gun current monitor signal

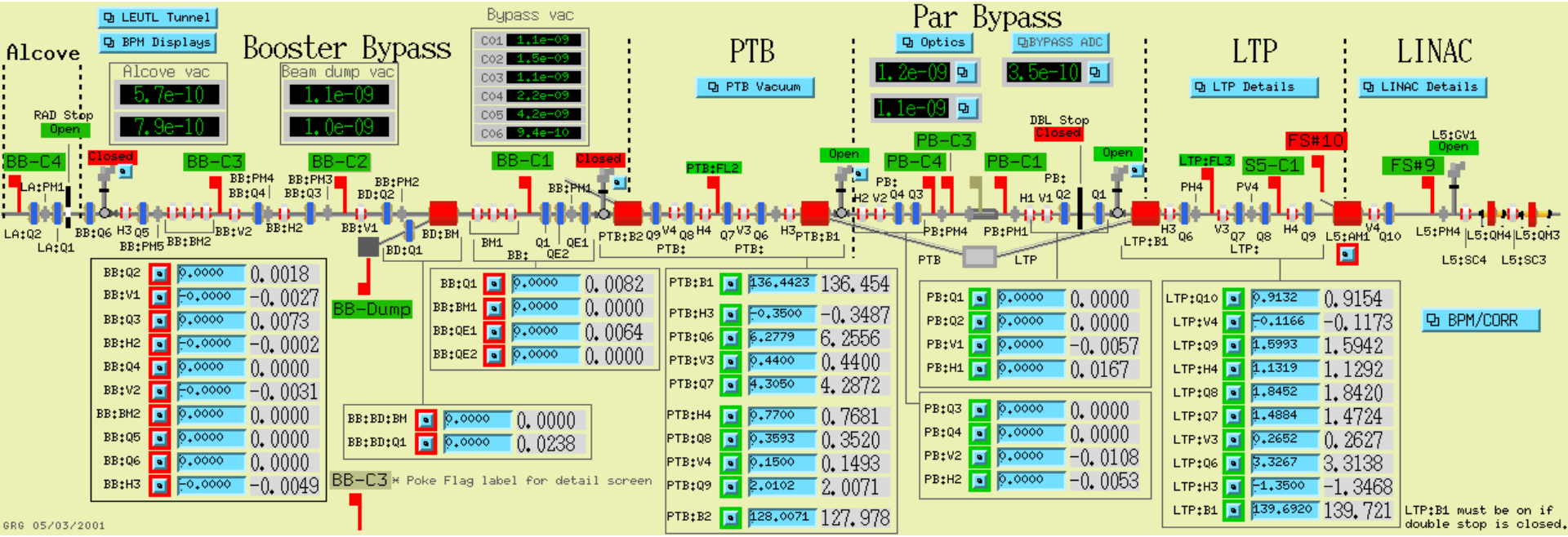
First PC Gun Beam Trajectory Through Linac BPMs

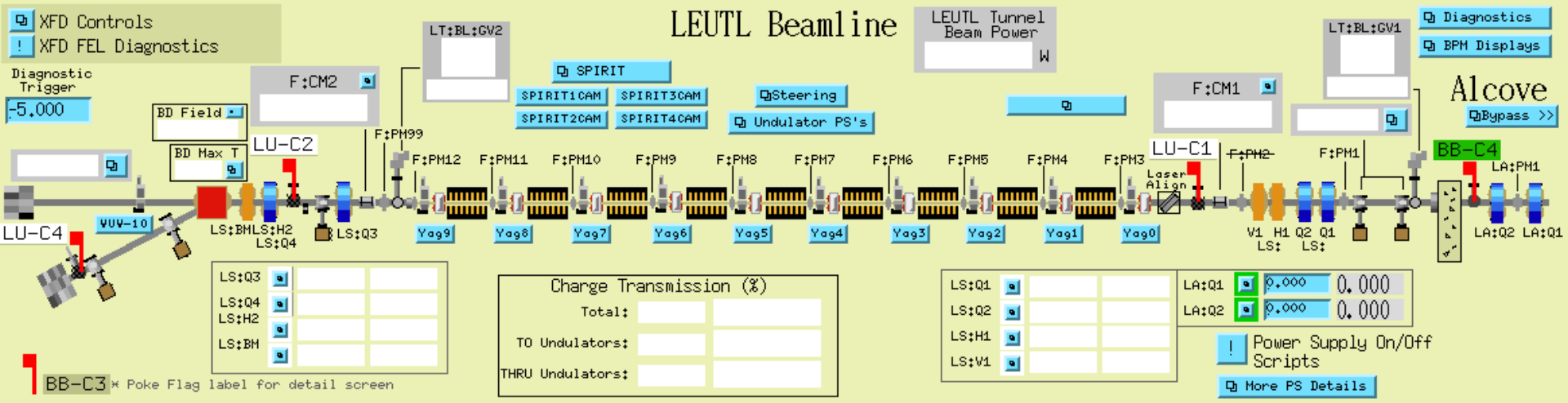


Linac Current monitor Measurements

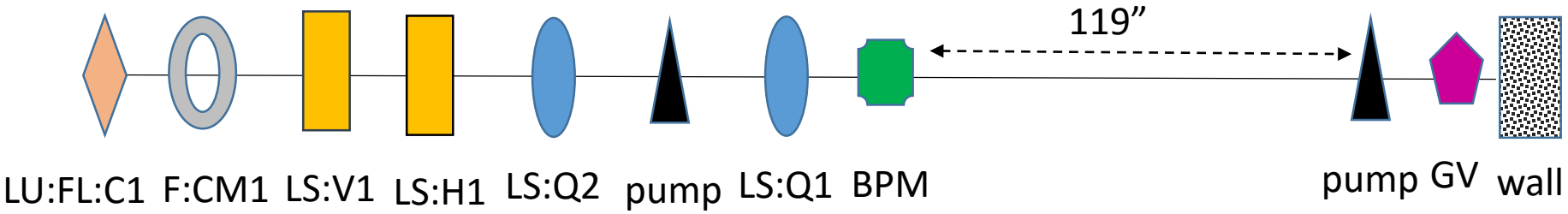


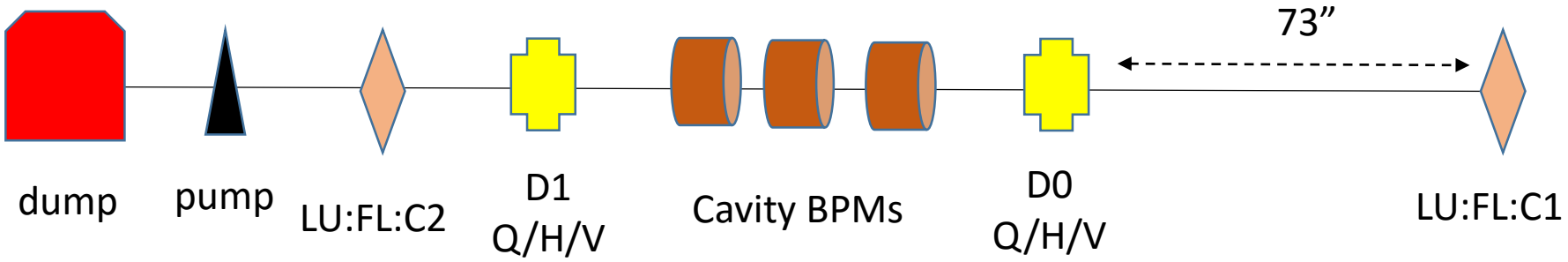
Beyond APS Linac: LTP→PB → PTB → BB → Alcove → LEUTL





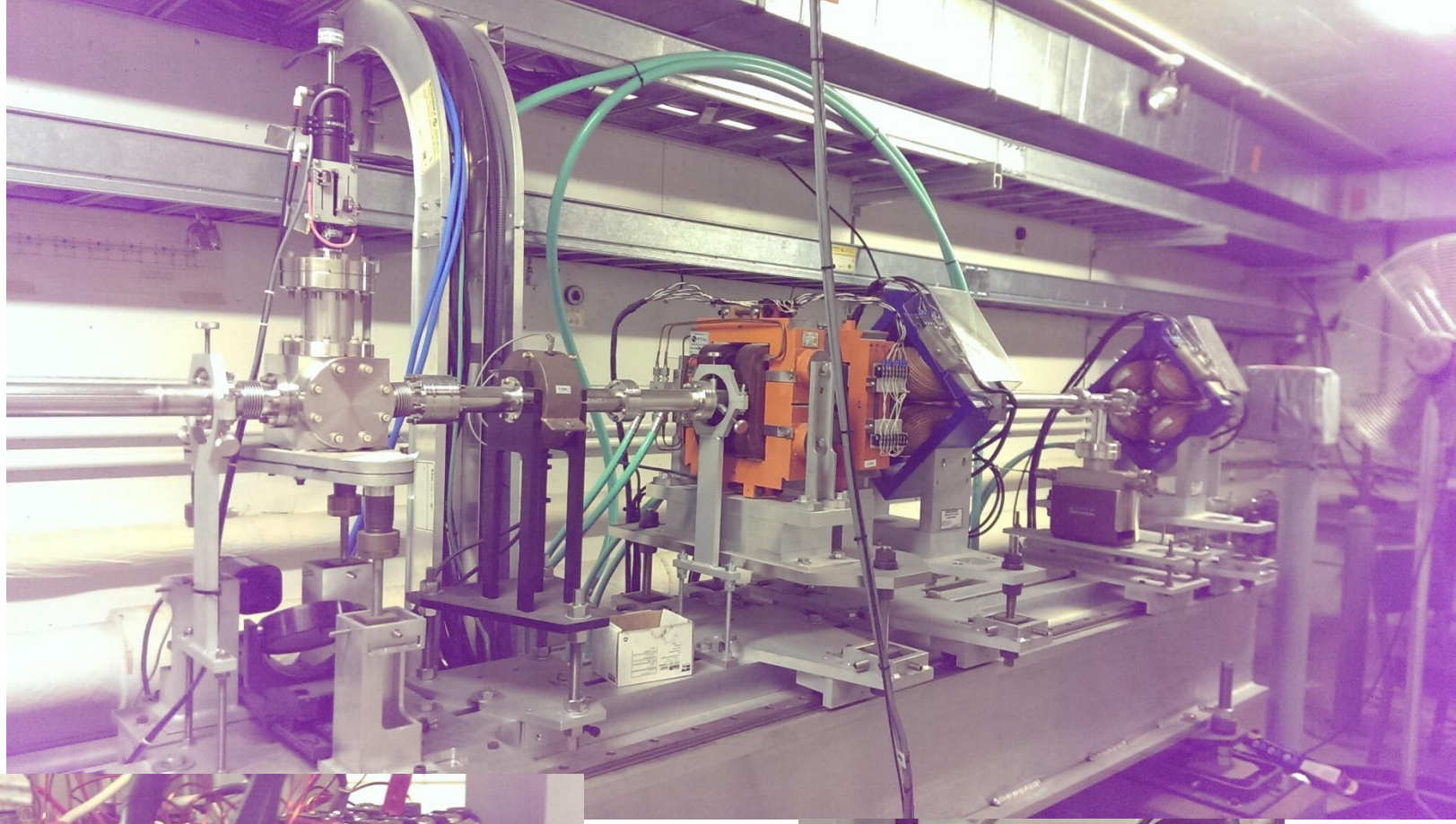
The LEUTL Tunnel





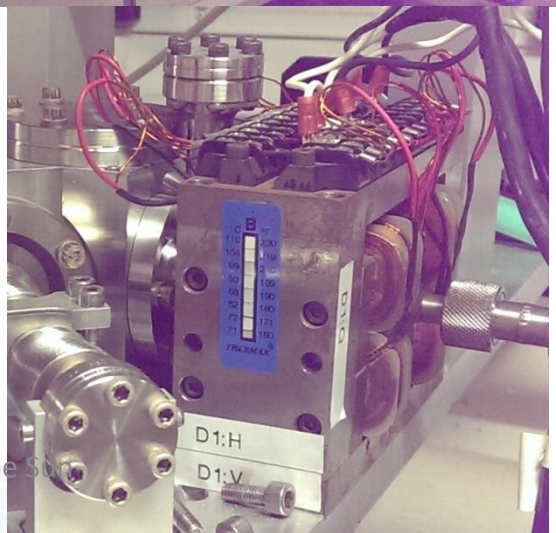
Installed quads: LS:Q1, LS:Q2; Two spares: LS:Q3,LS: Q4
Two steering magnets: LS:V1 and LS:H1

LS:Q1,
LS:Q2,
LS:H1,
LS:V1
F:CM1
LU:FL:C1

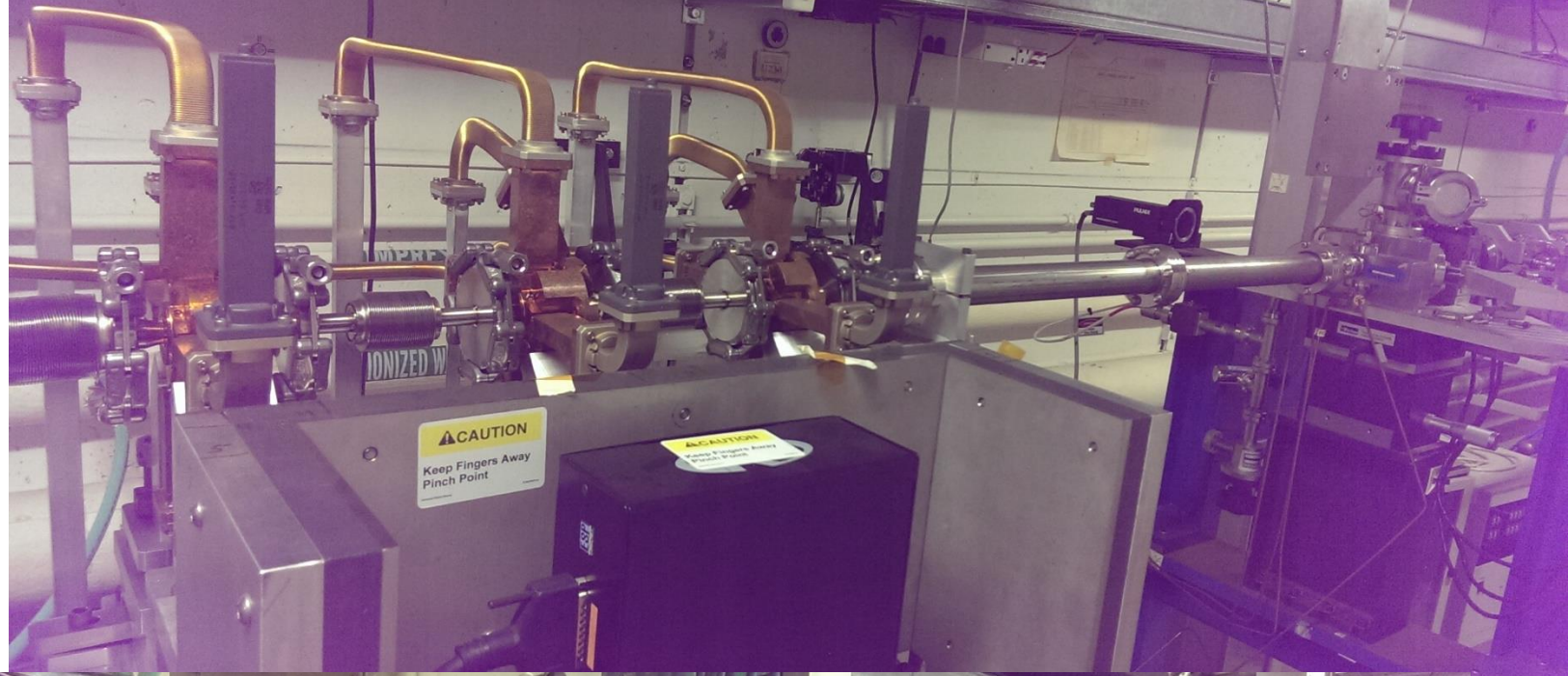


D0:
Q/H/V

D1:
Q/H/V



Cavity BPM 1,2,3



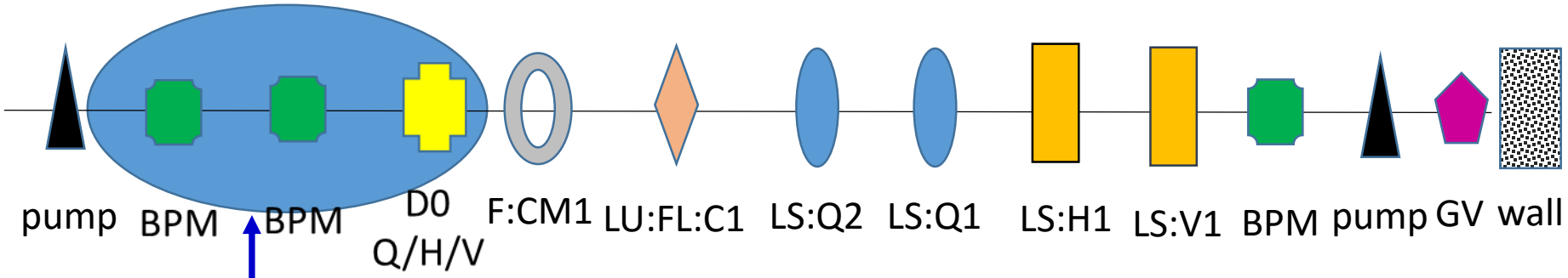
Spare Mags: LS:(Q3,Q4,H2,BD)

Not all magnets exists. Not all existing magnets have power supplies.

Existing power supply for
Three quads: LS:Q1, LS:Q2; LS:Q3
Three steering magnet: LS:H1/V1, LS:H2

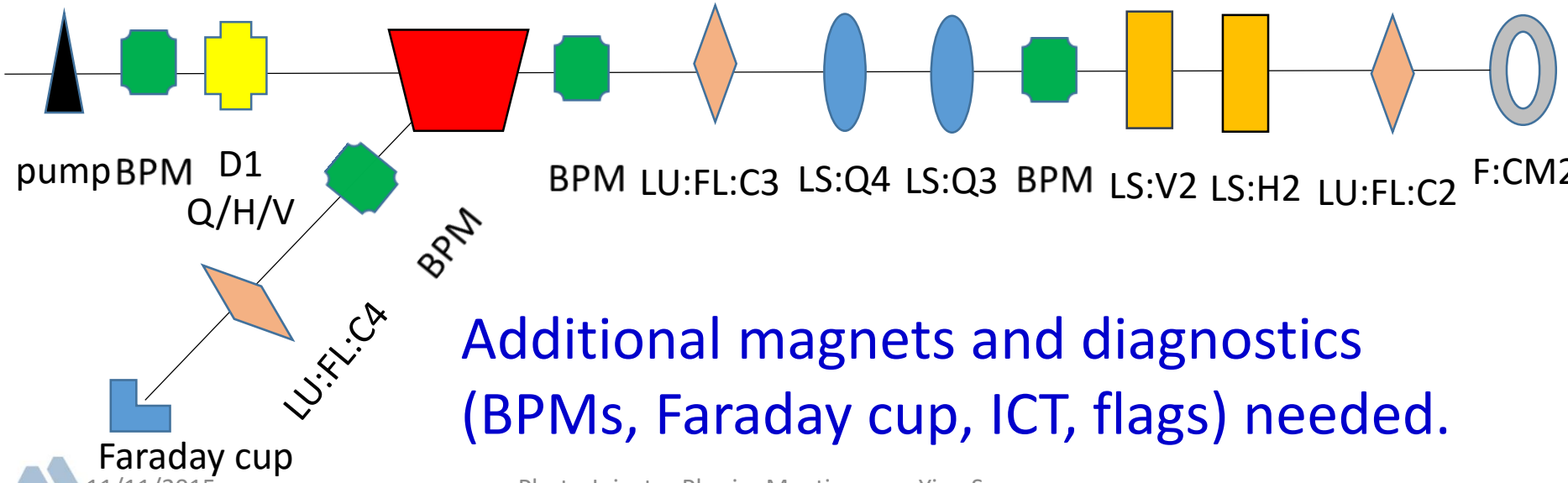
No controls.

Revive the LEUTL Tunnel for accelerator physics



3~4 meter exp. area

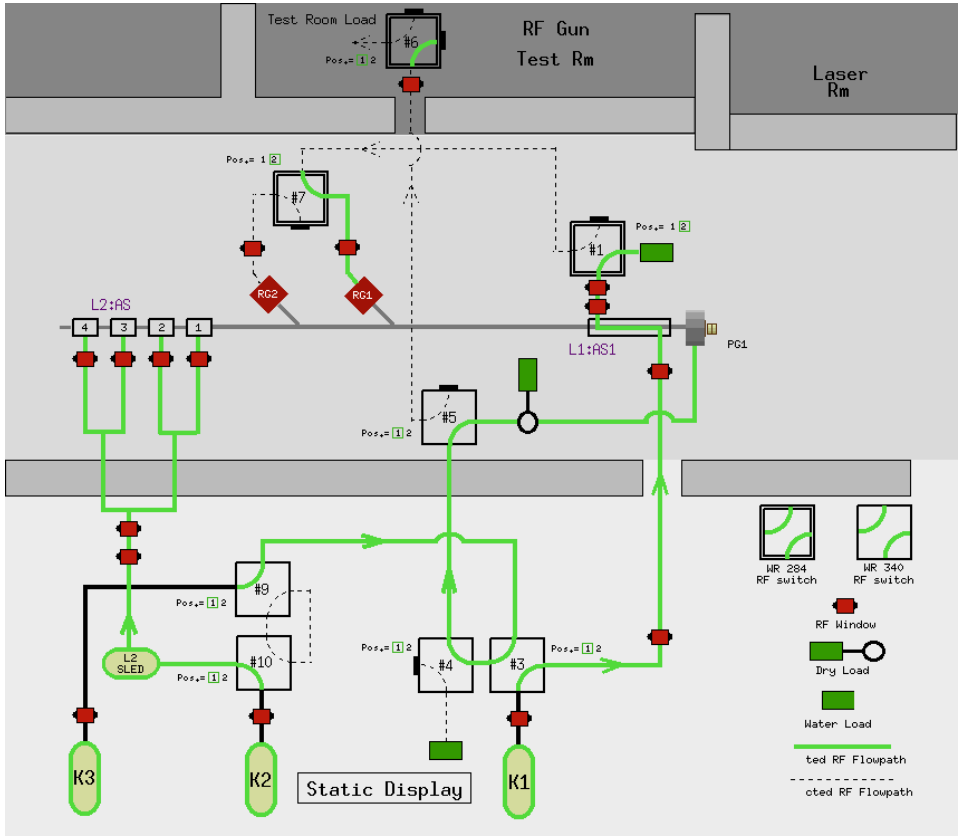
can be longer, for example to accommodate 5-dipole compressor demonstration, it will need to be >10m. More magnets and diag. will be needed for a useful longer beam line.



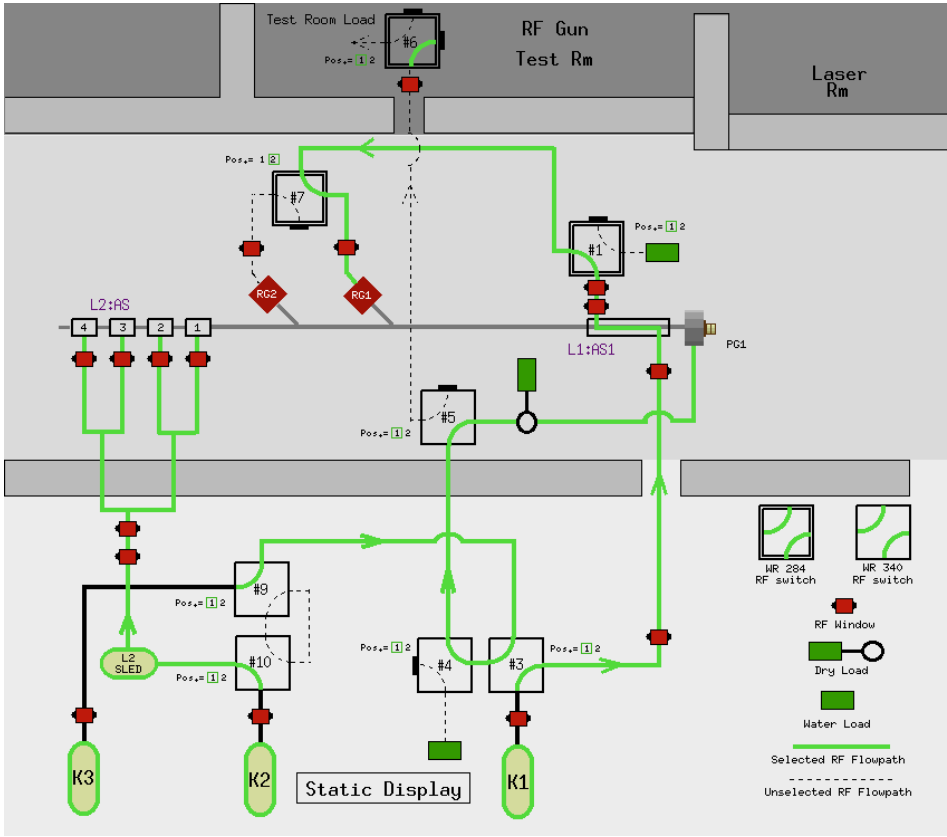
Additional magnets and diagnostics (BPMs, Faraday cup, ICT, flags) needed.

LEUTL/PAR Interleaving Operations

K1 RF switch changes (Pasky)



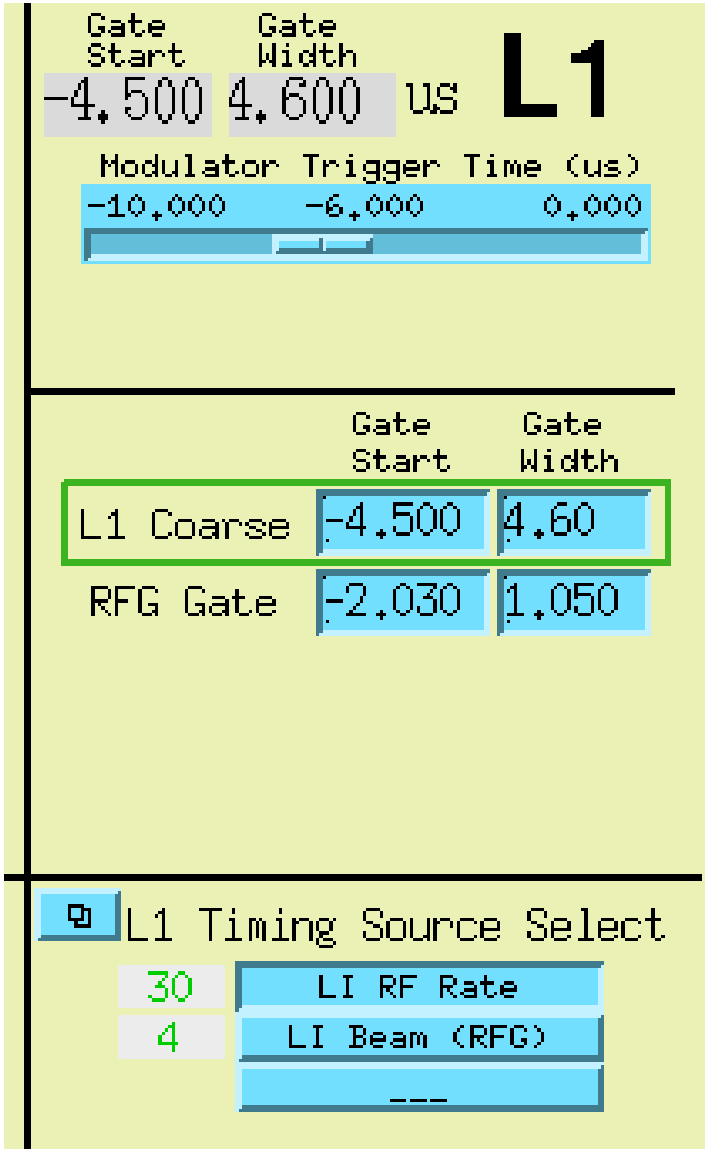
PC Gun



RG1

Best solution is to add a dedicated RF source for the therimionc rf guns - -decouple the rf sources for L1:AS1 and thermionic rf guns.

L1 RF Timing / RF Power Level Changes



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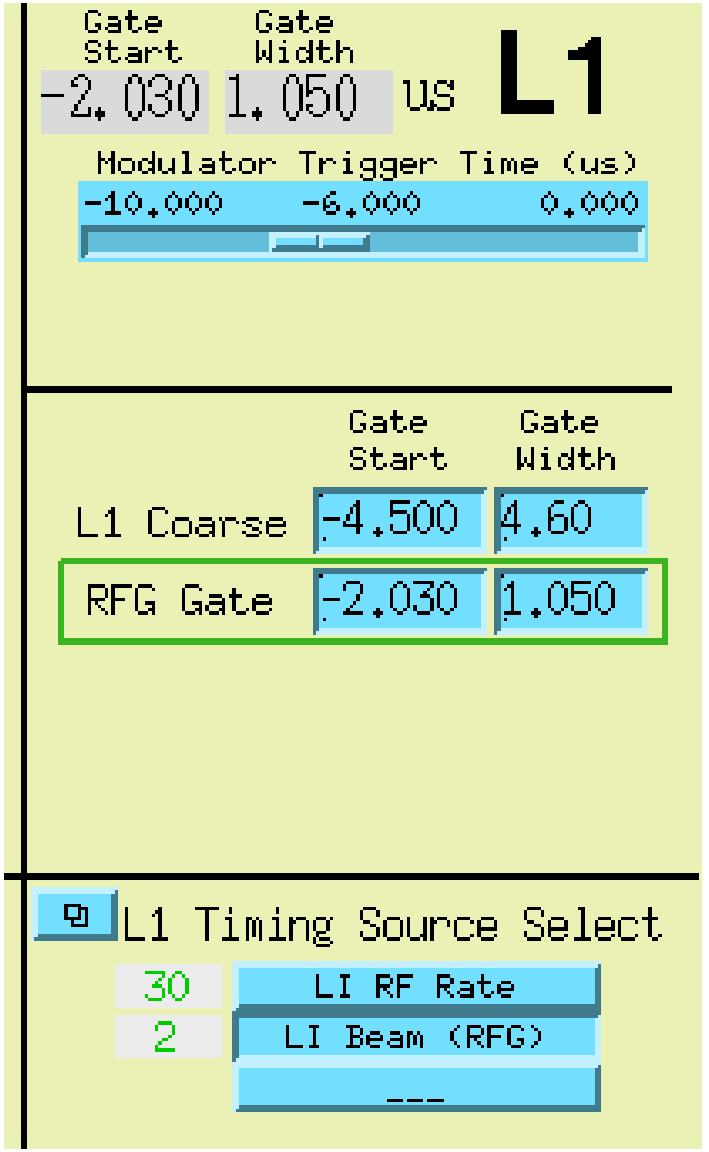


RG1

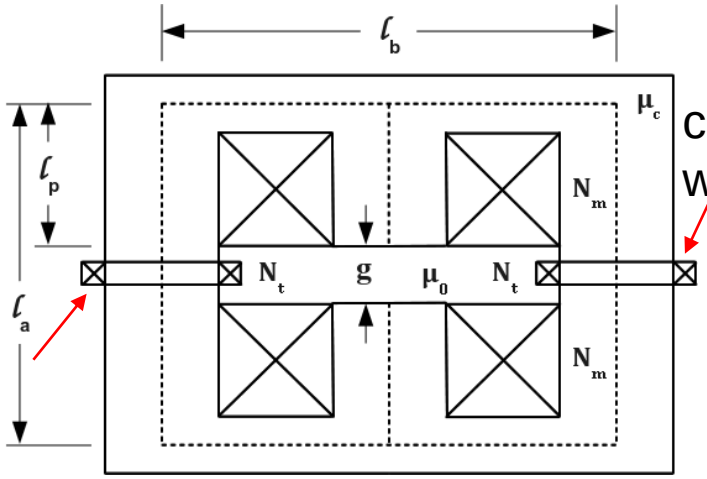
Interleaving Dipole Magnet Remnant Fields (Dooling, Sereno)

- LTP:B1, PTB:B1,PTB:B2
- pulsed dipole phys. length: L=39.9 cm (15.72”)
- Measured remnant field: B_{rem}=8.5-8.8 G
- B_{rem}L=340-350 G-cm
- elegant lattice file:home/helios/oagData/linac/lattices/lattice-2001-1012-matrix.lte-01.002

Also need to buck gun alpha magnet remnant fields.

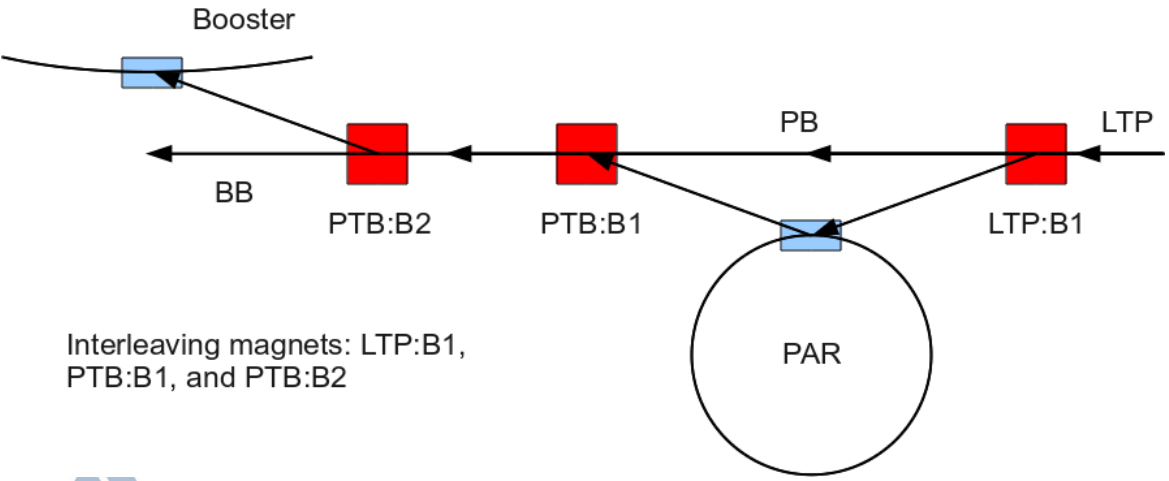
Interleaving dipoles require correction for injection to PAR/Booster and LEUTL (Dooling, Sereno)

- possible solutions:
  - add correction windings to the dipoles (AOP-TN-2013-054)
  - use small corrector windings
  - employ feedback on existing correctors

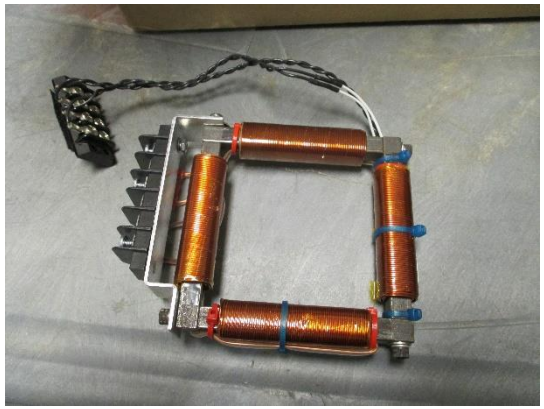


correction windings

small corrector: Km=290 G•cm/A
leff=0.985 cm



Interleaving magnets: LTP:B1, PTB:B1, and PTB:B2



Beam Lattice

- Different quadrupole settings for thermionic gun and PC gun beams;
- First experimental test of PC gun beam transportation through linac using thermionic (RG2) LTP system reference files shows acceptable beam transportation from L2 to L5. Beam is not matched at L3 screen emittance measurement flags and no injection into PAR;
- Match PC gun beam using magnets seen only by beam to linac;
- Reduce drive laser size for smaller beam size in the linac; experimentally test PC gun lattice setup files shown in the simulations;
- Check thermionic gun beam transportation to PAR using the PC gun lattice files.

Other Issues

- Timing
  - we successfully adjusted PC gun RF and laser timing such that the PC gun beam and thermionic gun beam arrives at L1:P1 at the same time.
  - Linac/PAR timing: thermionic gun injection into PAR every two seconds during top up. PC gun beam off every two seconds – easiest will be close laser shutter when thermionic gun kicker is turned on.
- BESOCM
- ACIS
  - three gun gate valves – instead of only one allowed to be open, we need two of these valves open for interleaving: PC gun gate valves + one of the two thermionic gun valve.