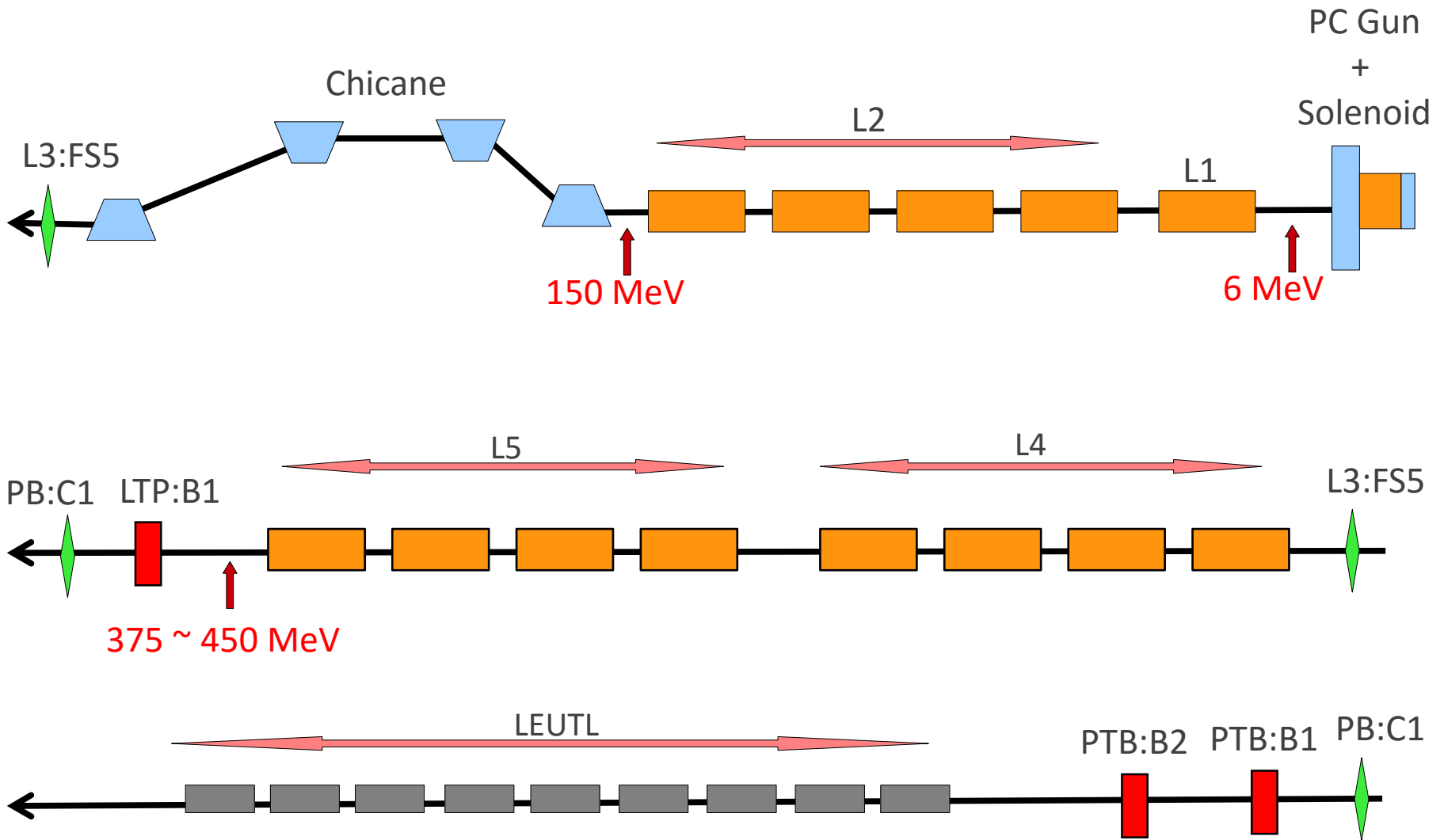


PC Gun Beam in APS Linac Simulations, Measurements and Operation Considerations

Y. Sun, J. Dooling, S. Pasky, A. Zholents

Nov. 11, 2015

APS LINAC



Beam Optimization

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

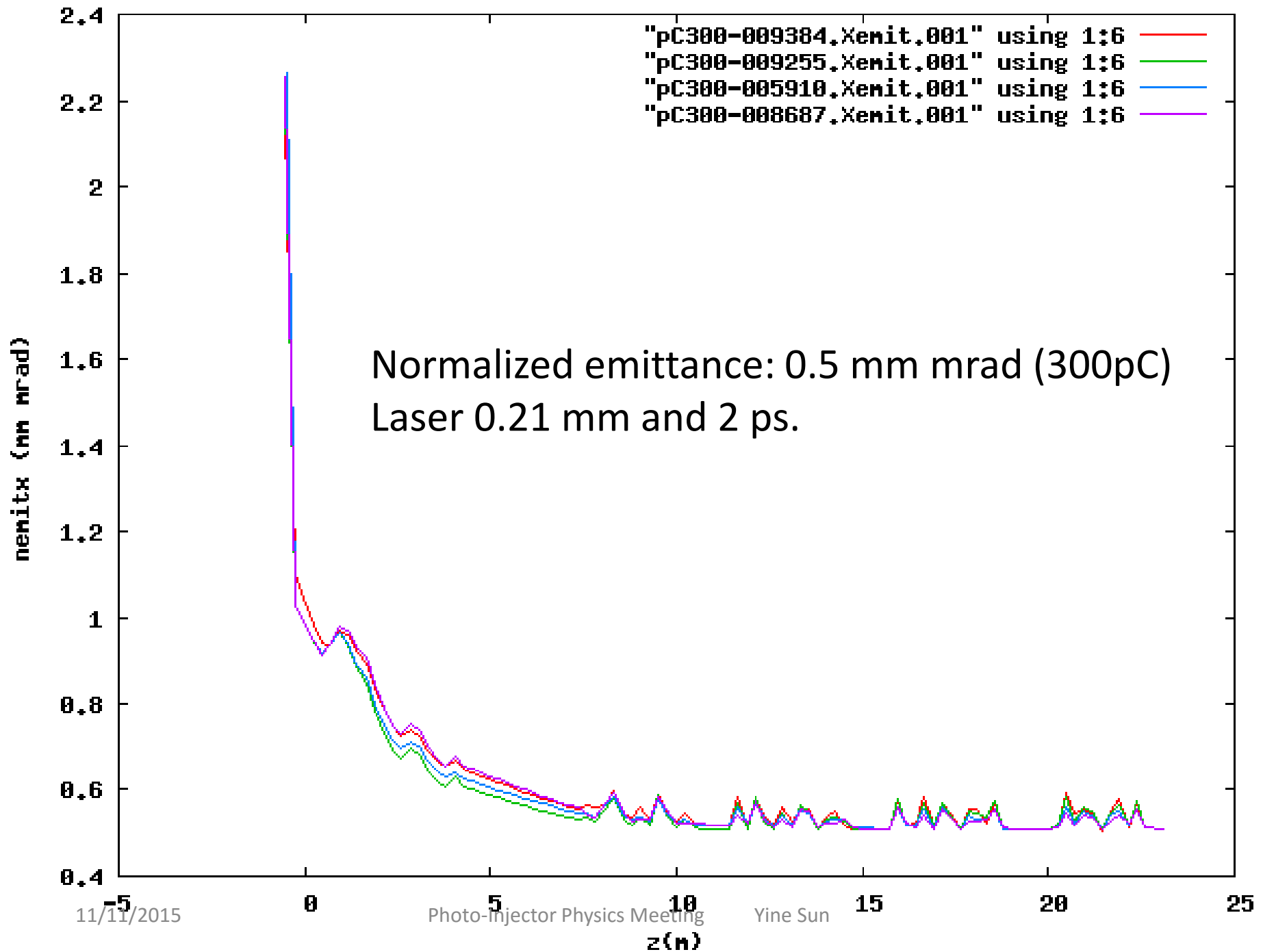
Energy: 150 MeV at chicane; minimum emittance

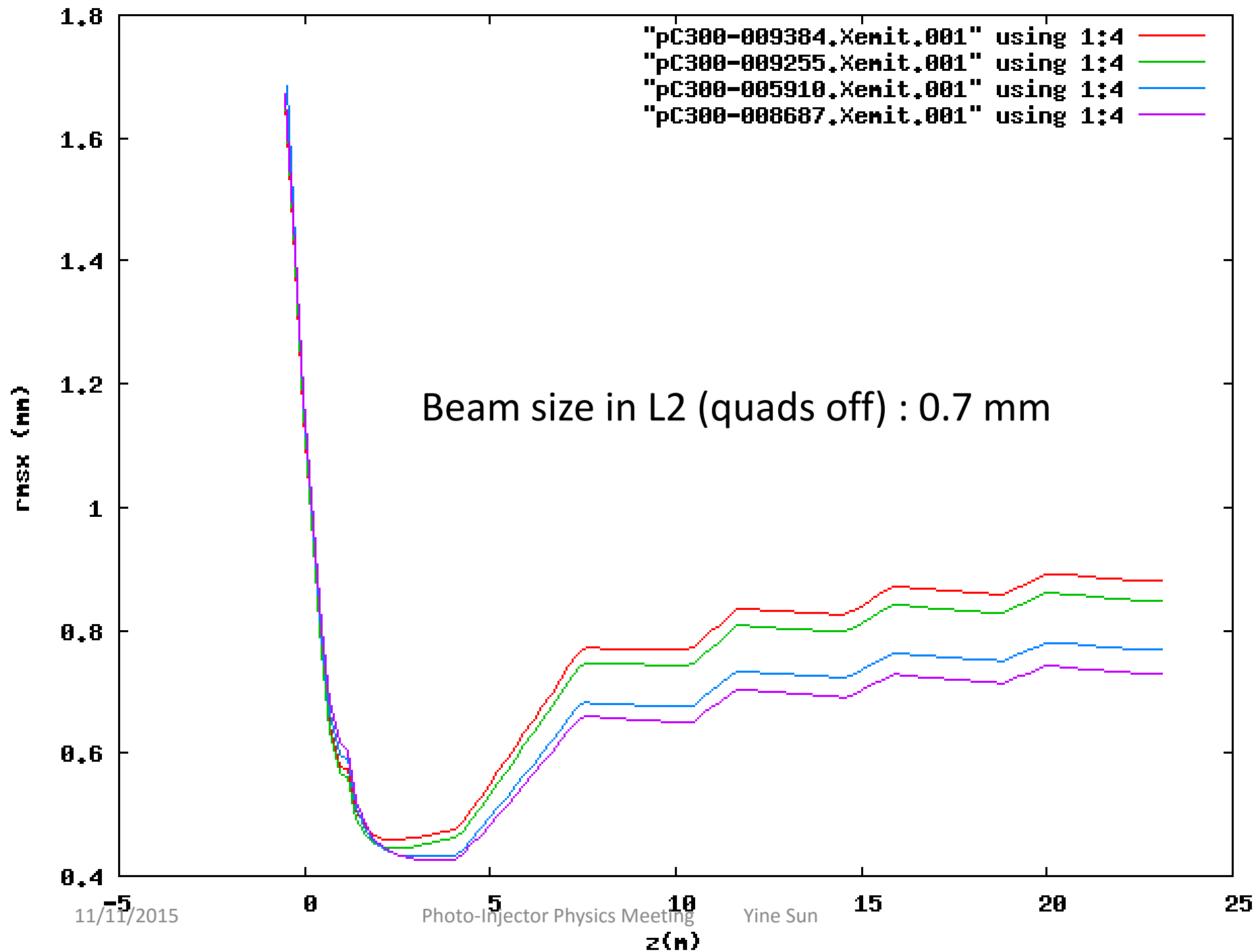
parameterName	lowerLimit	upperLimit	errorLevel	initialValue
spot	0.21	1.0	0.02	0.26
pulse	0.001	0.002	0.0002	0.0015
E1	-110.0	-100.0	1.0	-105.0
Phi1	-20.0	20.0	0.5	-4.029
E2	-15.0	-5.0	0.5	-9.0
Phi2	-10.0	10.0	0.5	-7.0
B1	0.2	0.315	0.01	0.23
E3	-15.0	-12.0	0.2	-14.1412
Phi3	-40.0	0.0	2.0	-19.0

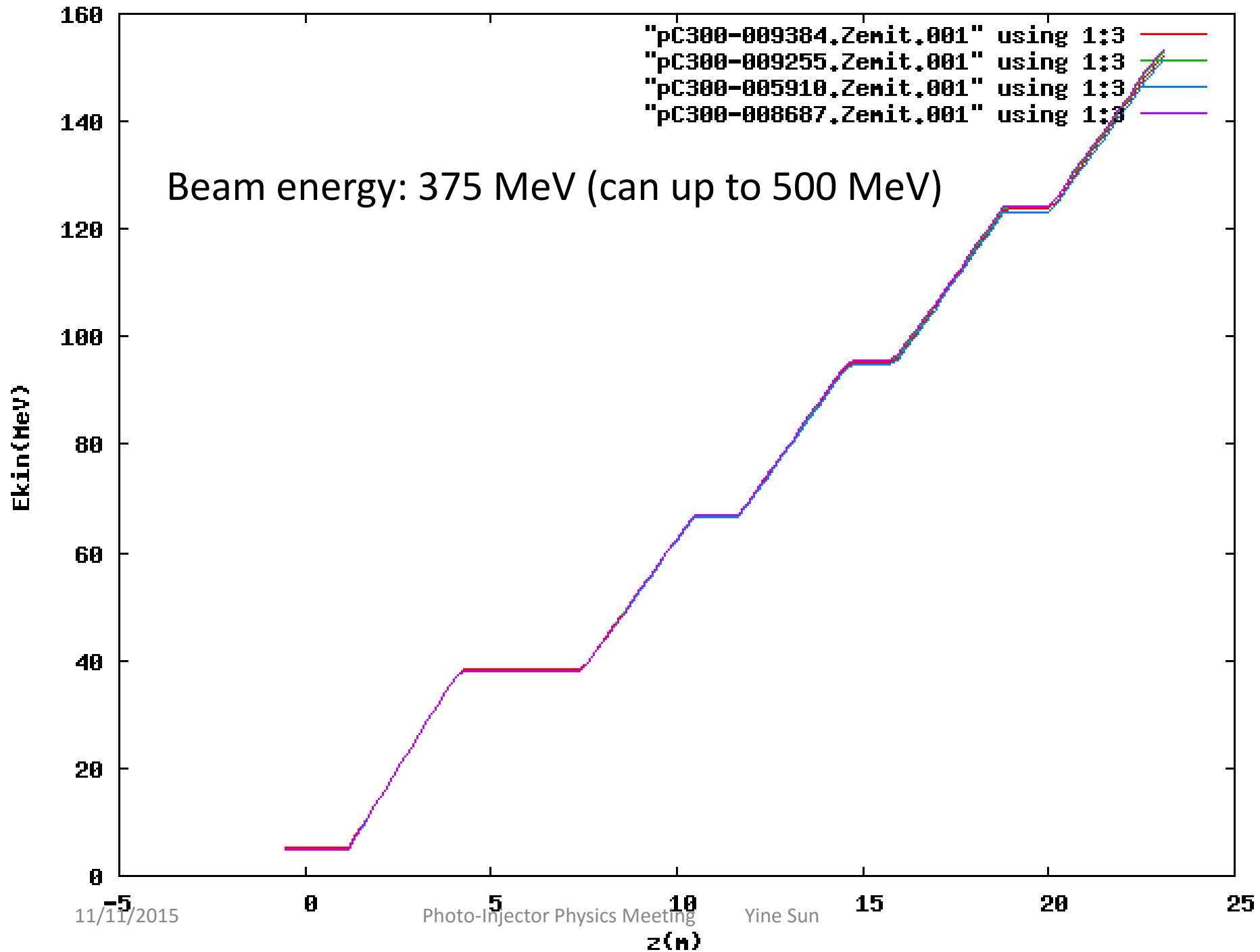
optimized machine
parameters

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

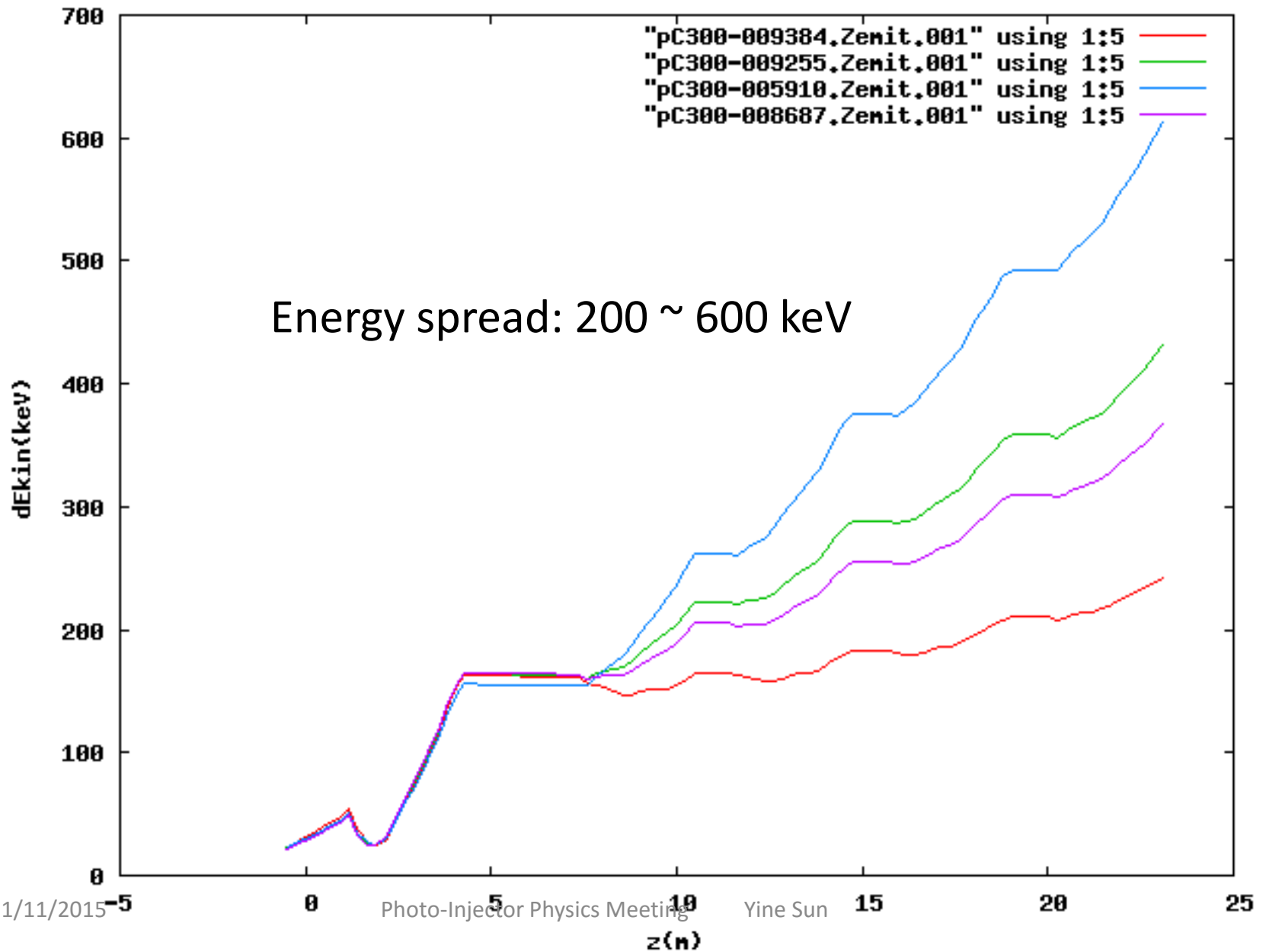




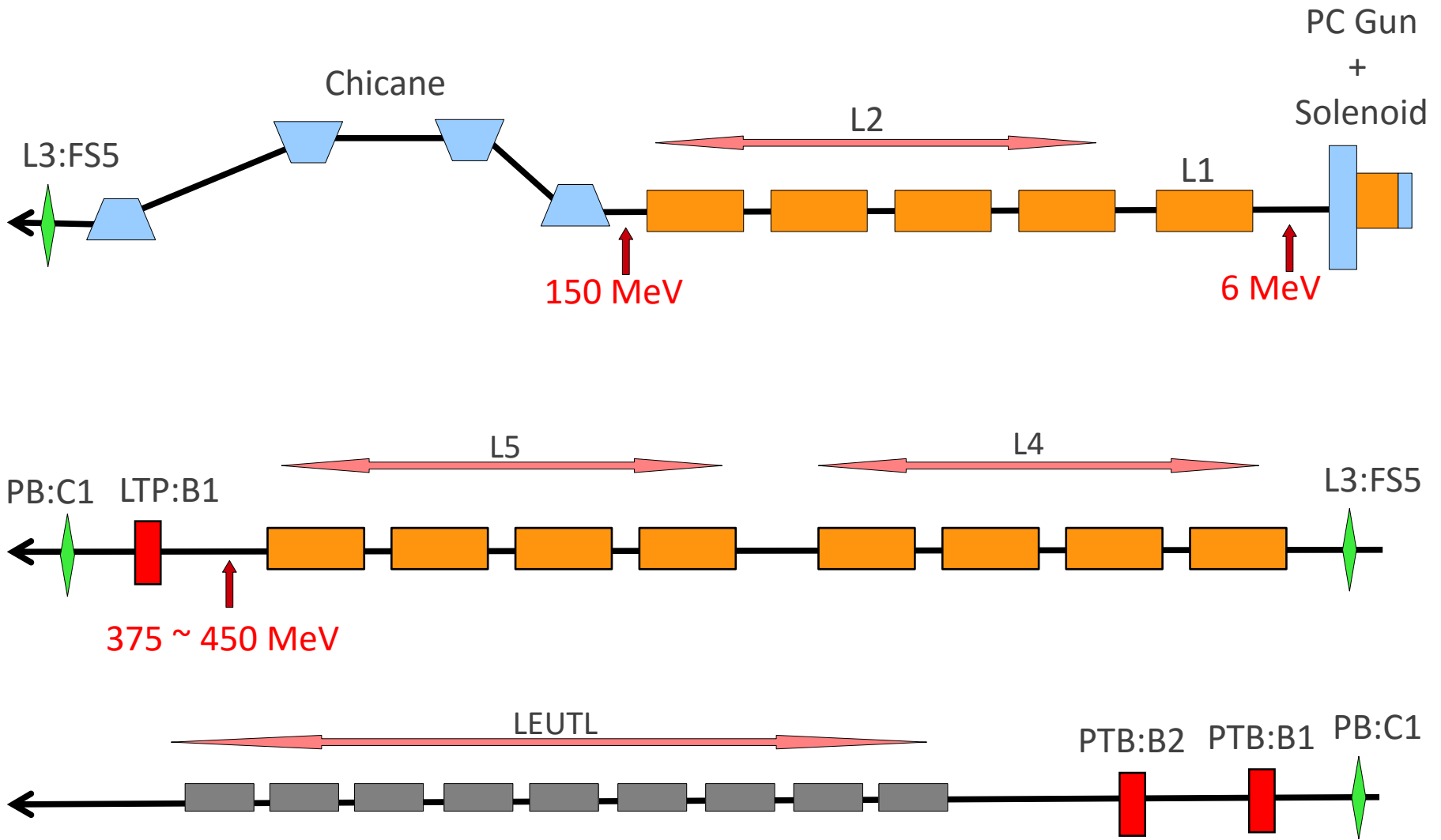




300 pC Optimization Results

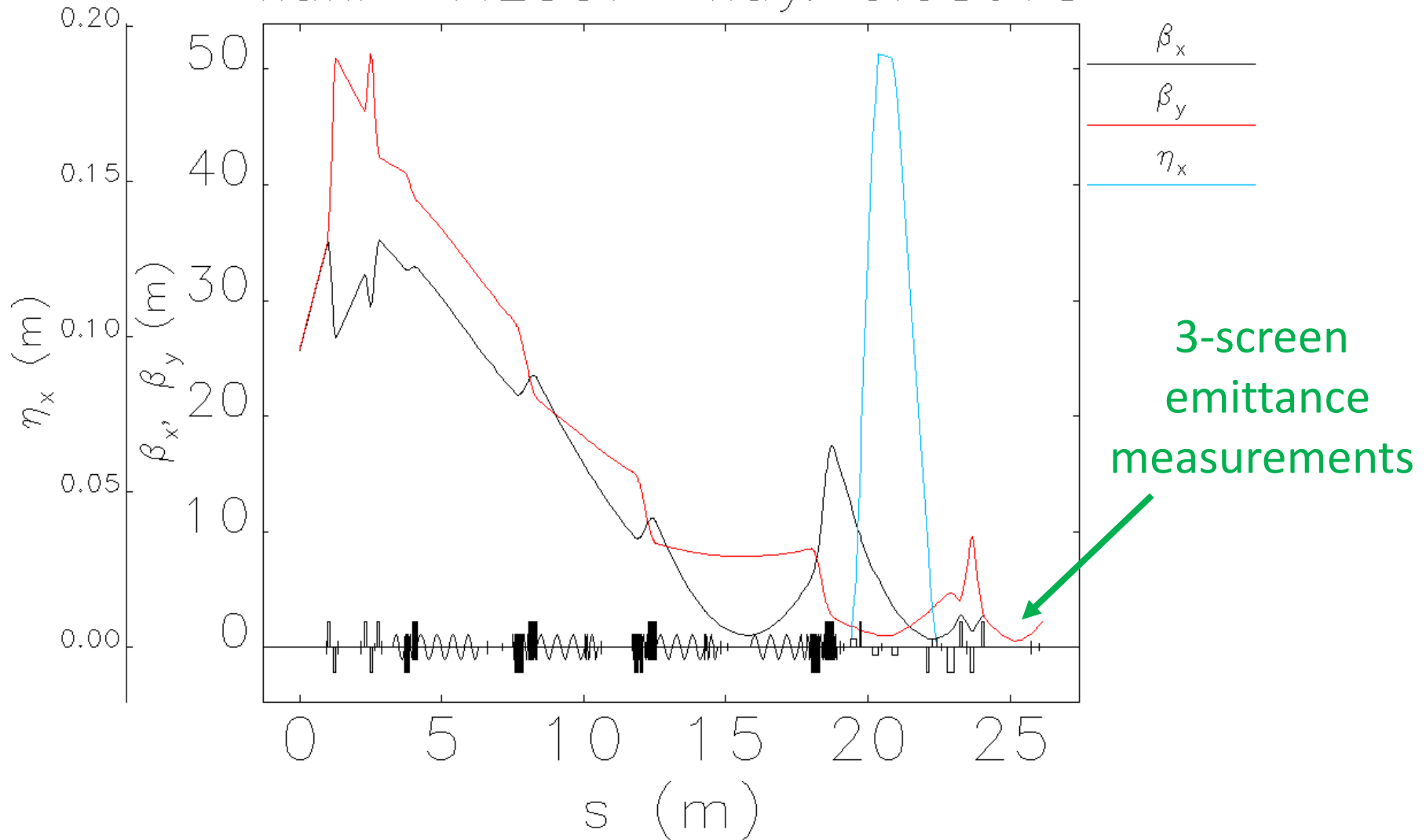


APS LINAC



ELEGANT matching through chicane

nux: 1.2507 nu_y: 0.98618

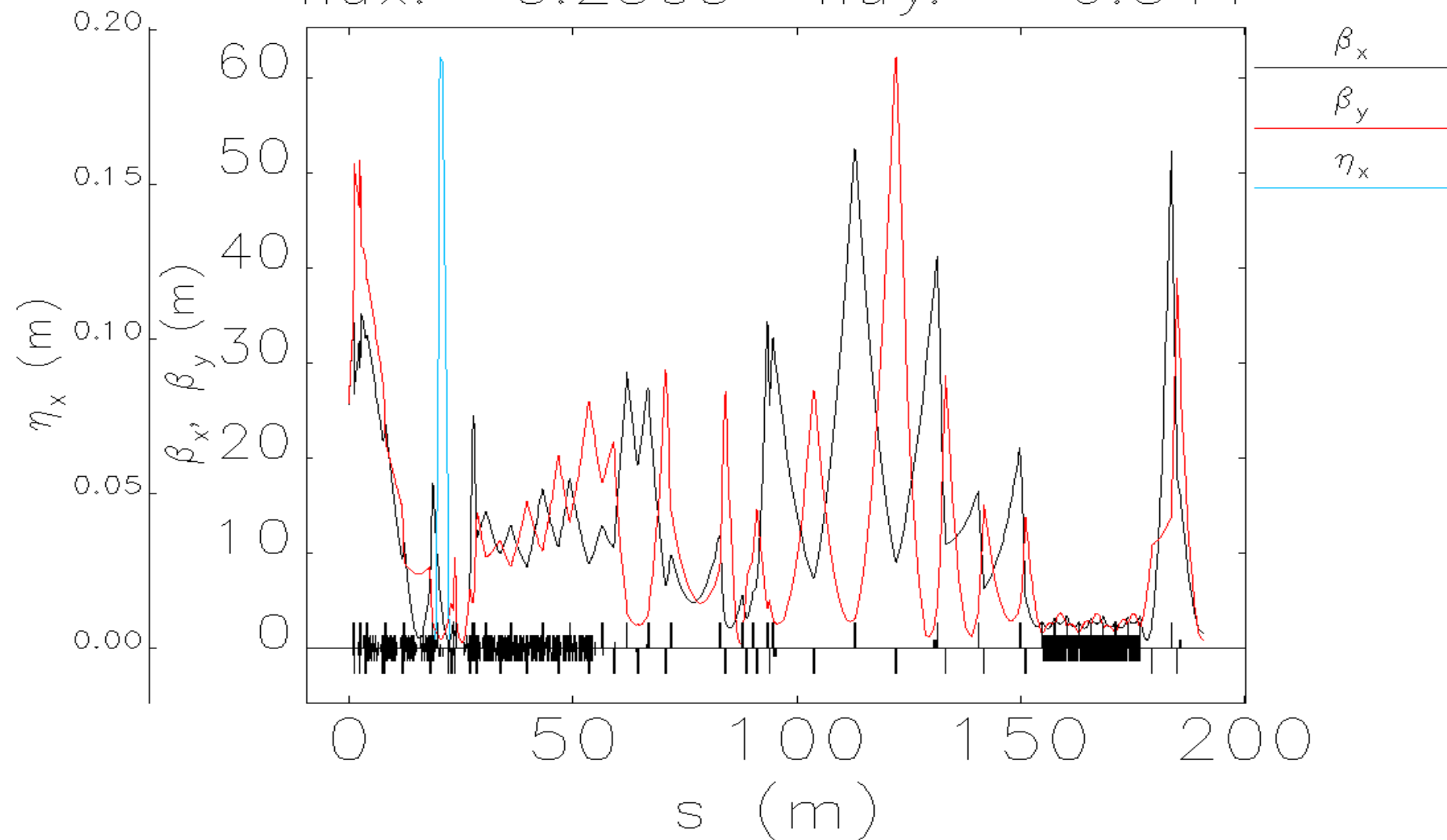


Twiss parameters for transverse

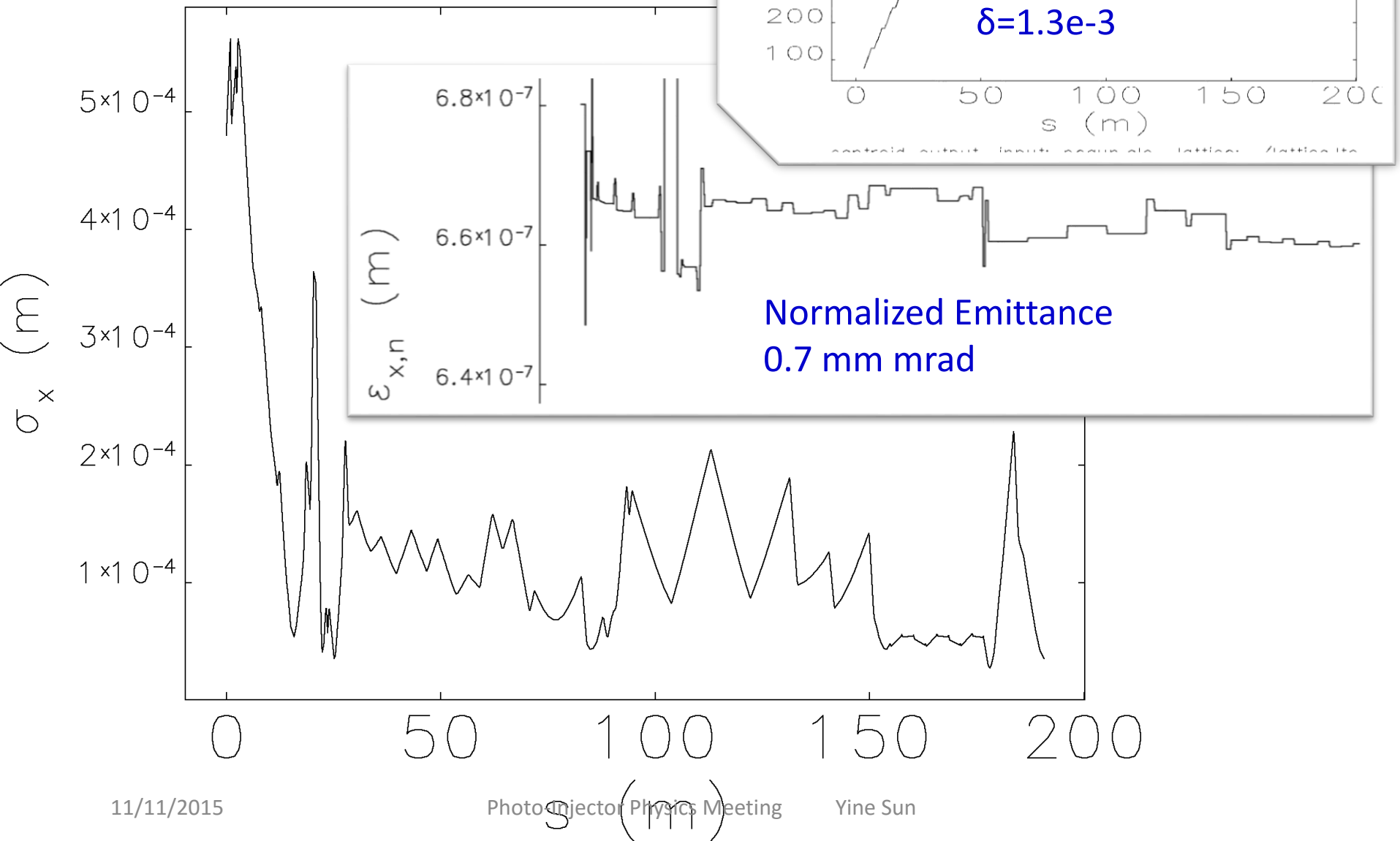


Lattice through Linac to LEUTL

nux: 5.2503 nuy: 6.3444



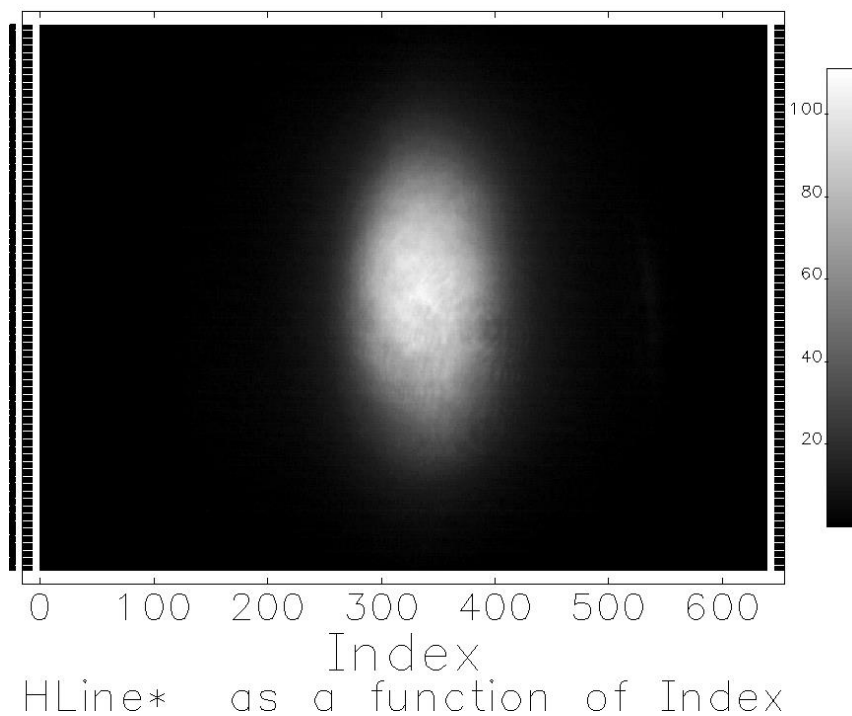
Beam Parameters: an example



Simulations Using Larger Laser Spot

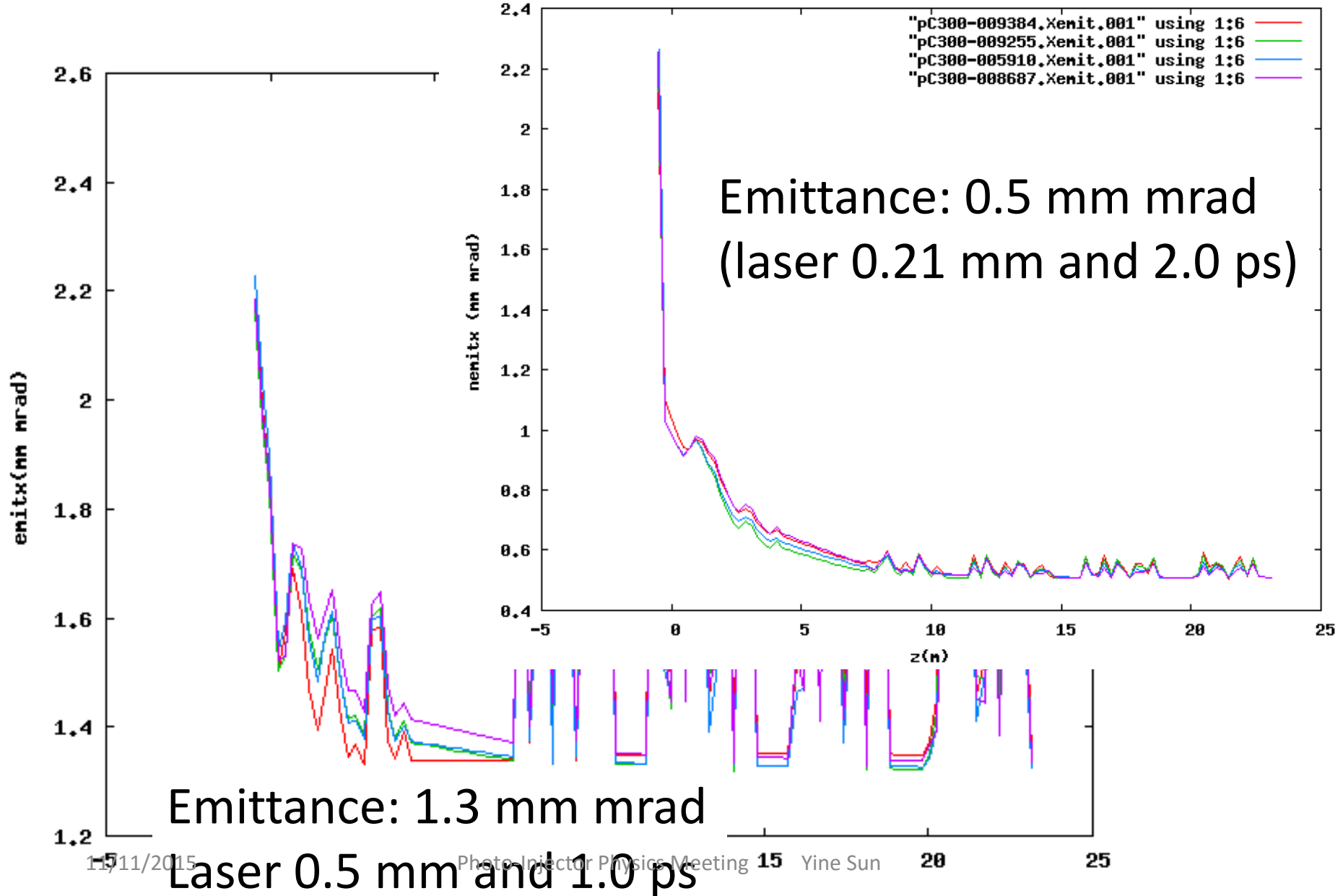
- Measured UV drive laser: $\sigma_x=0.481$ mm, $\sigma_y=0.875$ mm (Dooling);

Image from VirtualCathode

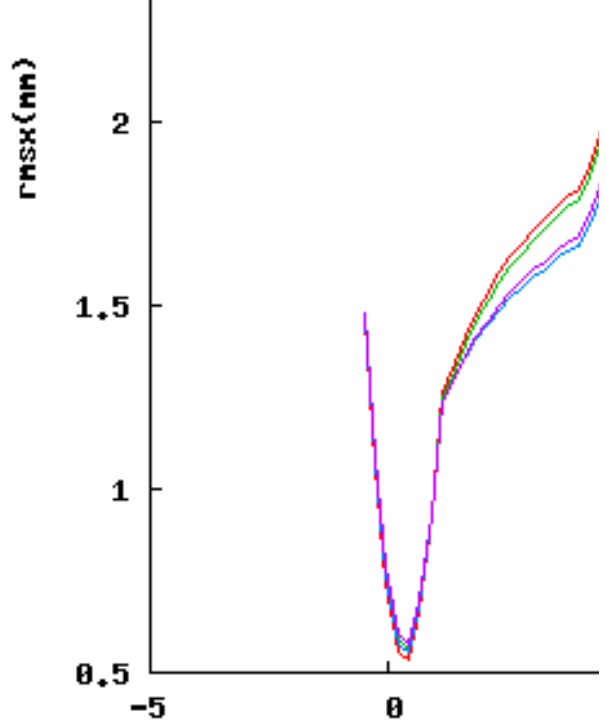
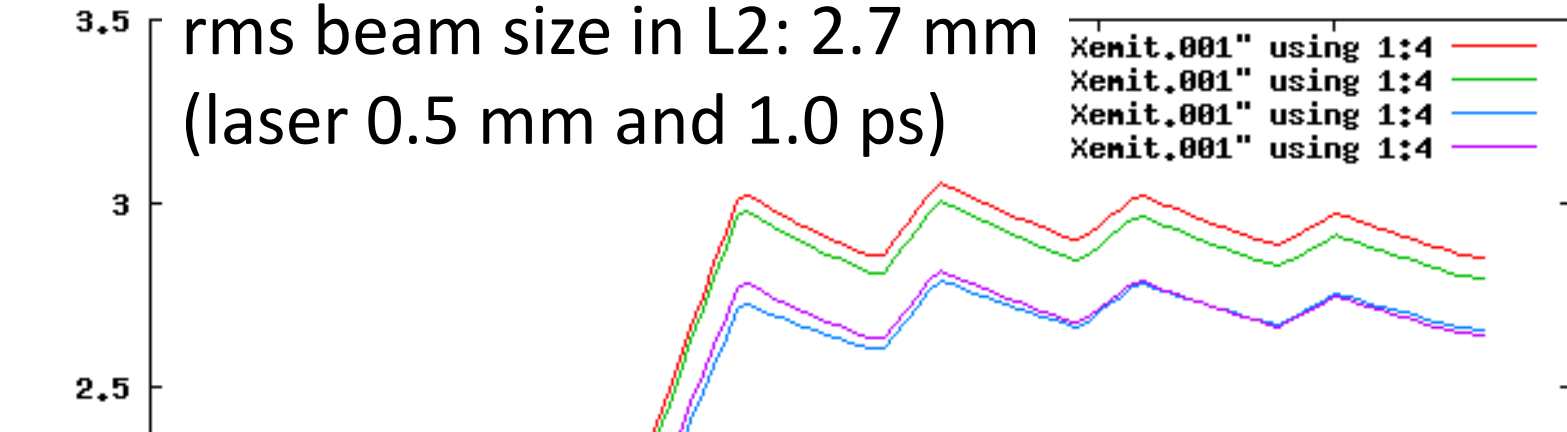


- In ASTRA optimization, set the lower limit of rms spot size to 0.5 mm. UV laser pulse range kept in (1.0 ~ 2.0) ps range.

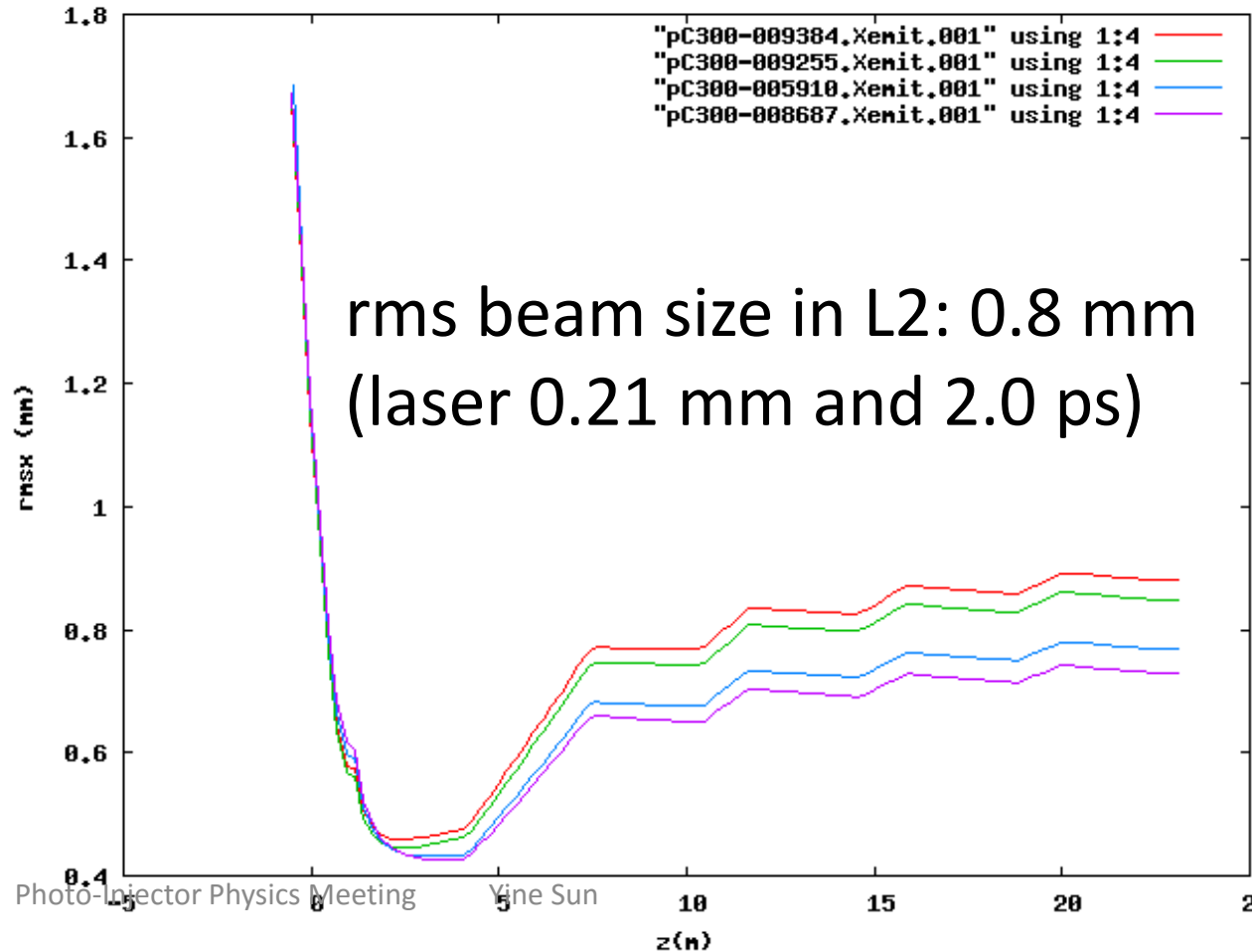
Optimization Results with Larger Laser



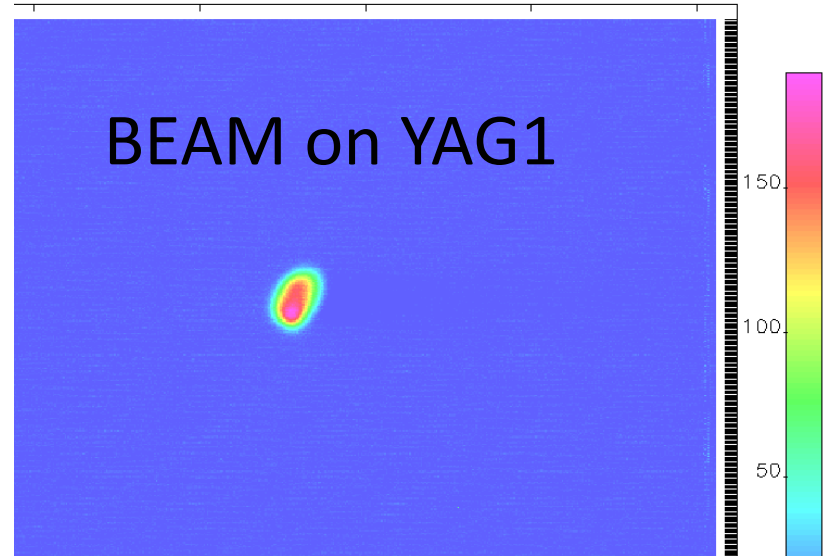
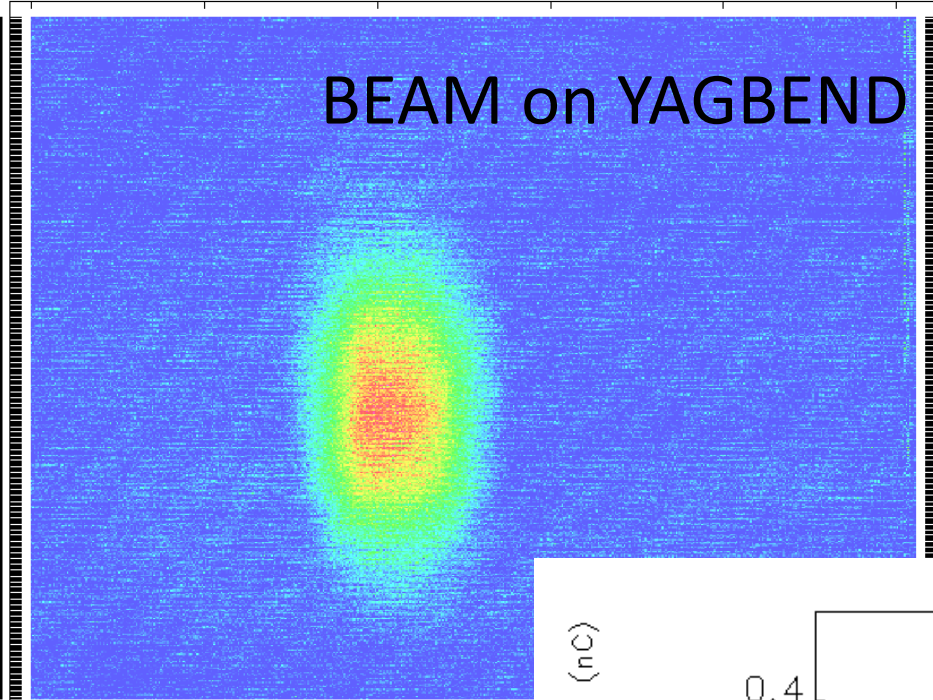
rms beam size in L2: 2.7 mm
(laser 0.5 mm and 1.0 ps)



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

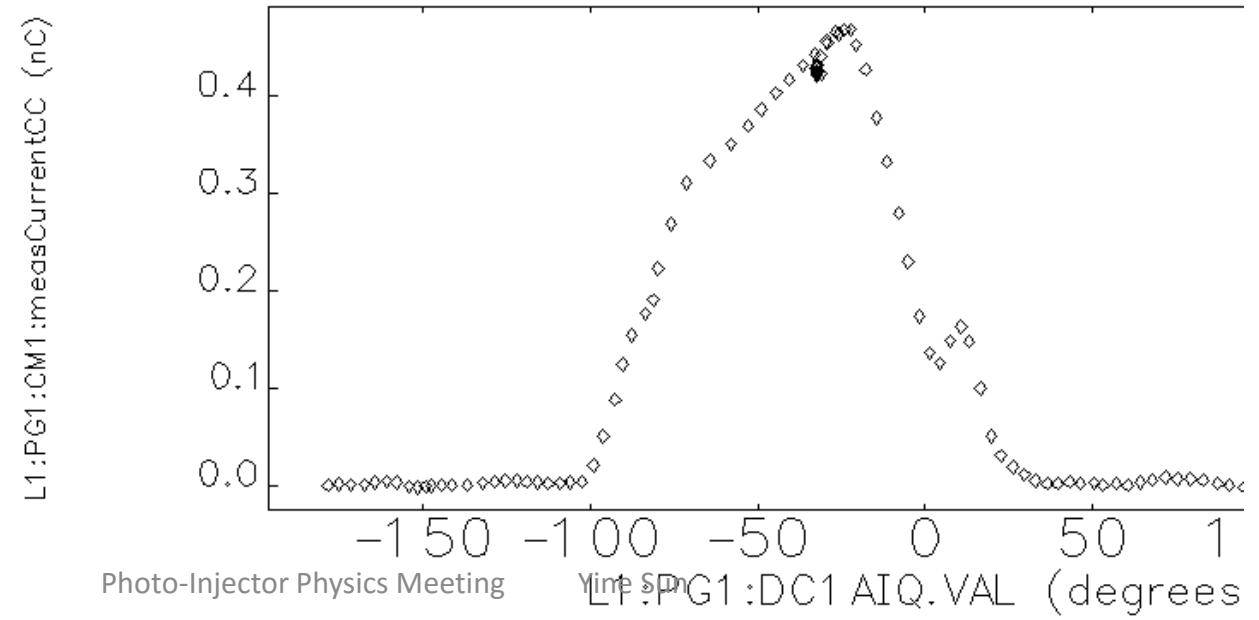


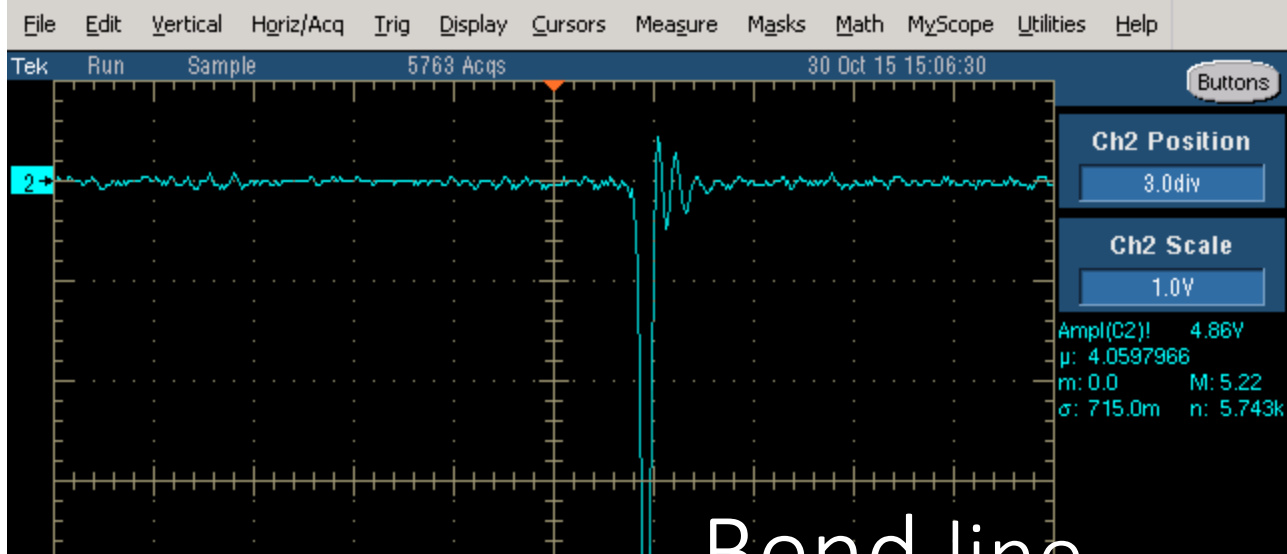
Measurements: PC Gun Beam in APS Linac



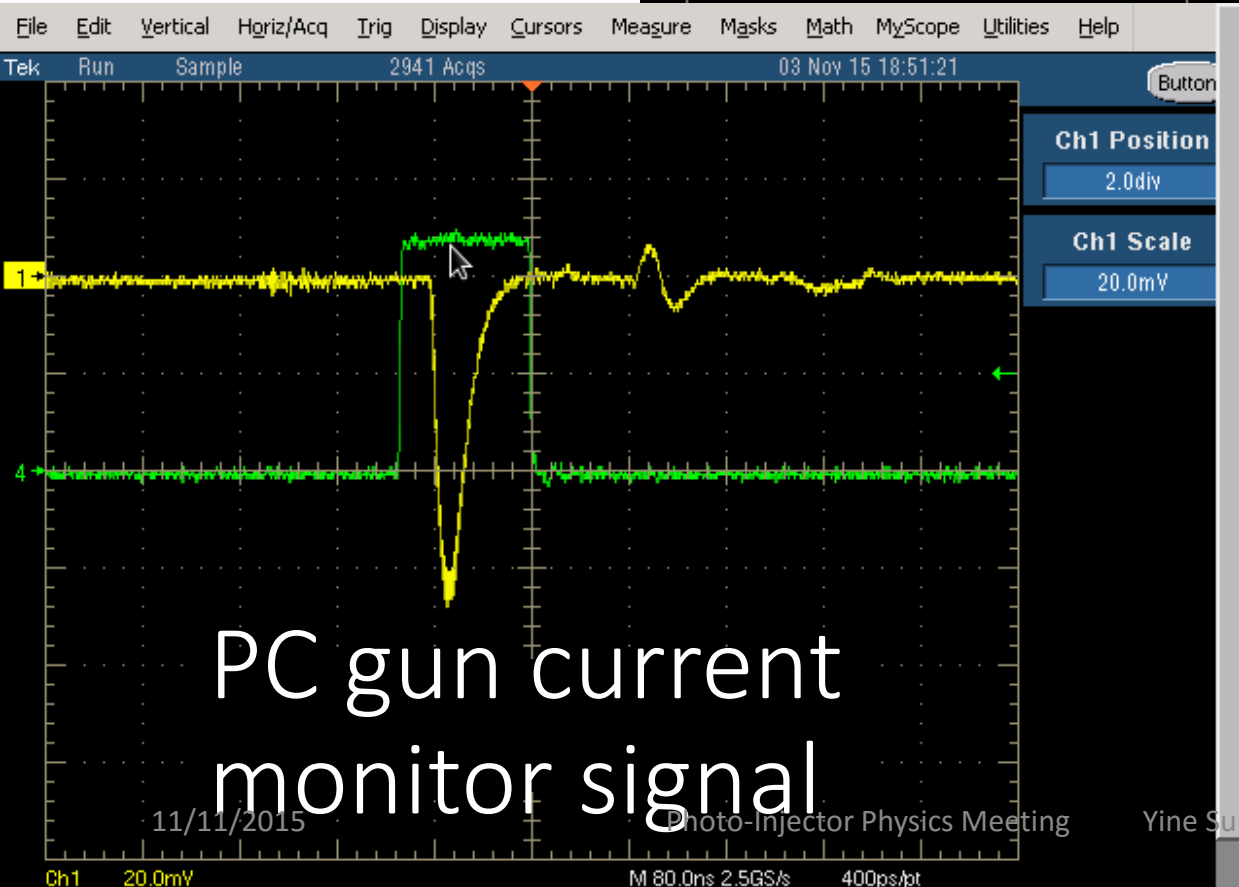
Maximum charge at 50 deg from zero crossing: 350pC

L3 Phase Setpoint versus Charge - S





Bend line
Faraday cup
signal



PC gun current
monitor signal

11/11/2015

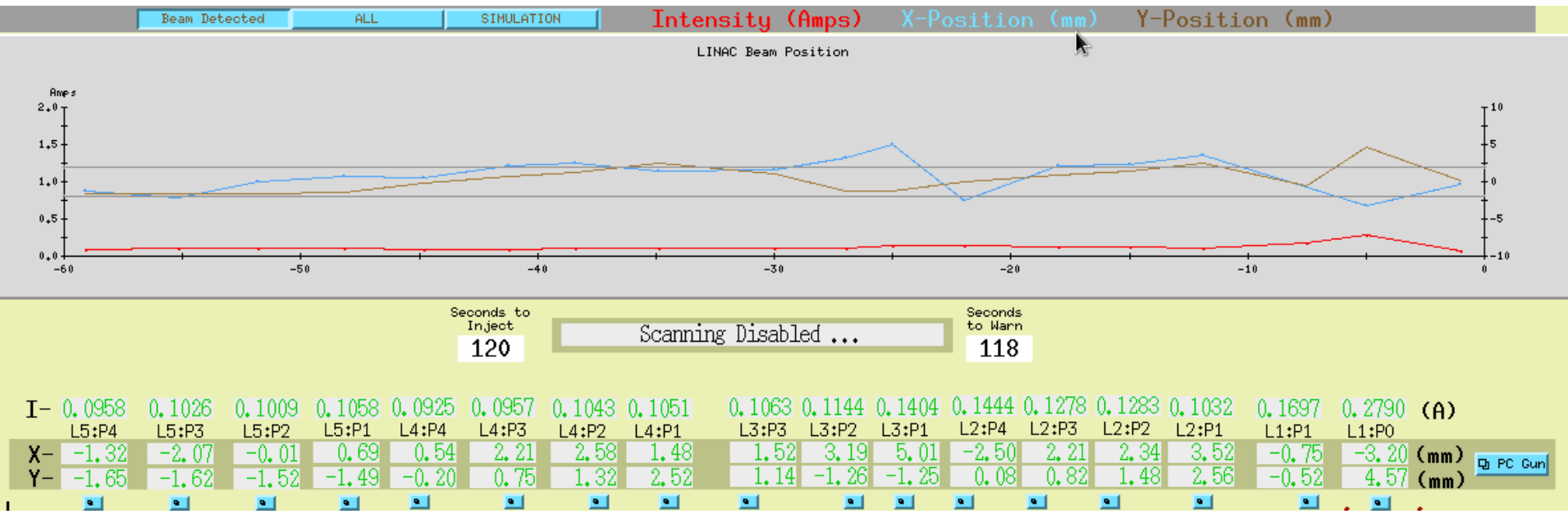
Photo-Injector Physics Meeting

Yine Sun

Ch1 20.0mV

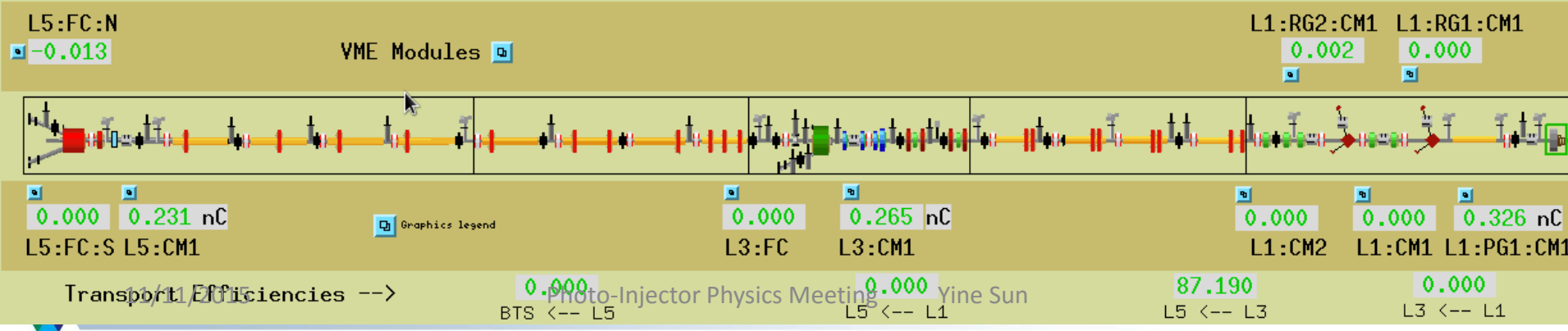
M 80.0ns 2.5GS/s 400ps/pt

First PC Gun Beam Trajectory Through Linac BPMs



Linac Current monitor Measurements

LINAC Current Monitors



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

Alcove

- LEUTL Tunnel
- BPM Displays
- Alcove vac: $5.7e-10$
- Beam dump vac: $1.1e-09$
- RAD Stop: Open

Booster Bypass

- BB-C4 (Closed)
- BB-C3
- BB-C2
- BB-C1 (Closed)
- BB-Dump

PTB

- PTB Vacuum
- PTB: B1, H3, Q6, V3, Q6, H4, Q7, V3, Q6, H3, B1

Par Bypass

- Optics
- Optics: $1.2e-09$, $1.1e-09$
- QBYPASS ADC: $3.5e-10$
- PB-C3, PB-C4, PB-C1
- DBL Stop: Closed

LTP

- LTP Details
- LTP: FL3, S5-C1, FS#10

LINAC

- LINAC Details
- FS#9

BB:Q2	0.0000	0.0018
BB:V1	-0.0000	-0.0027
BB:Q3	0.0000	0.0073
BB:H2	-0.0000	-0.0002
BB:Q4	0.0000	0.0000
BB:V2	-0.0000	-0.0031
BB:BM2	0.0000	0.0000
BB:Q5	0.0000	0.0000
BB:Q6	0.0000	0.0000
BB:H3	-0.0000	-0.0049

PTB:B1	136.4423	136.454
PTB:H3	-0.3500	-0.3487
PTB:Q6	6.2779	6.2556
PTB:V3	0.4400	0.4400
PTB:Q7	4.3050	4.2872
PTB:H4	0.7700	0.7681
PTB:Q8	0.3593	0.3520
PTB:V4	0.1500	0.1493
PTB:Q9	2.0102	2.0071
PTB:B2	128.0071	127.978

PB:Q1	0.0000	0.0000
PB:Q2	0.0000	0.0000
PB:V1	0.0000	-0.0057
PB:H1	0.0000	0.0167
PB:Q3	0.0000	0.0000
PB:Q4	0.0000	0.0000
PB:V2	0.0000	-0.0108
PB:H2	0.0000	-0.0053

LTP:Q10	0.9132	0.9154
LTP:V4	-0.1166	-0.1173
LTP:Q9	1.5993	1.5942
LTP:H4	1.1319	1.1292
LTP:Q8	1.8452	1.8420
LTP:Q7	1.4884	1.4724
LTP:V3	0.2652	0.2627
LTP:Q6	3.3267	3.3138
LTP:H3	-1.3500	-1.3468
LTP:B1	139.6920	139.721

066 05/03/2001

LEUTL Beamline

- XFD Controls
- XFD FEL Diagnostics
- Diagnostic Trigger: -5.000
- BD Field, BD Max T
- LU-C4, VUV-10, LS:BMHS:H2, LS:Q4
- LS:Q3, LS:Q4, LS:H2, LS:BM
- F:CM2, F:PM99, F:PM12, F:PM11, F:PM10, F:PM9, F:PM8, F:PM7, F:PM6, F:PM5, F:PM4, F:PM3
- Yag9, Yag8, Yag7, Yag6, Yag5, Yag4, Yag3, Yag2, Yag1, Yag0
- LU-C1, Laser Align, F:PM2, F:PM1
- V1, H1, Q2, Q1, LS: LS:
- BB-C4
- LA:PM1, LA:Q2, LA:Q1

LEUTL Tunnel Beam Power

Alcove

- Bypass >>
- BB-C4

Total:		
TO Undulators:		
THRU Undulators:		

LS:Q1		
LS:Q2		
LS:H1		
LS:V1		

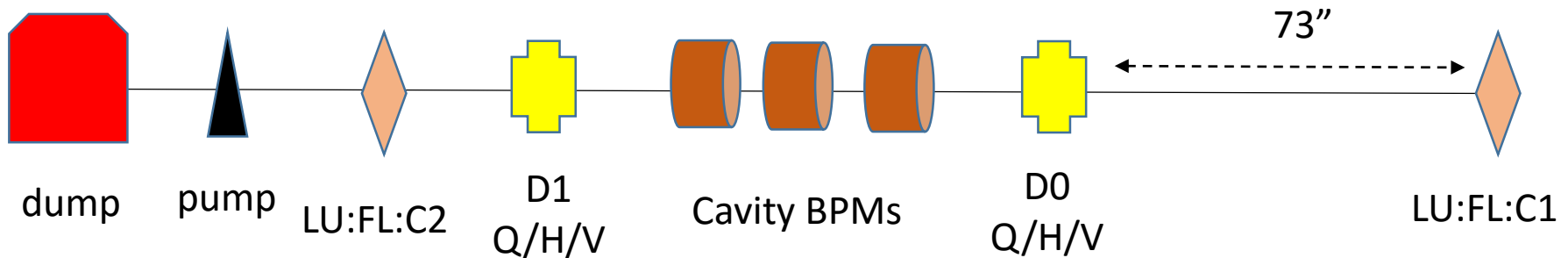
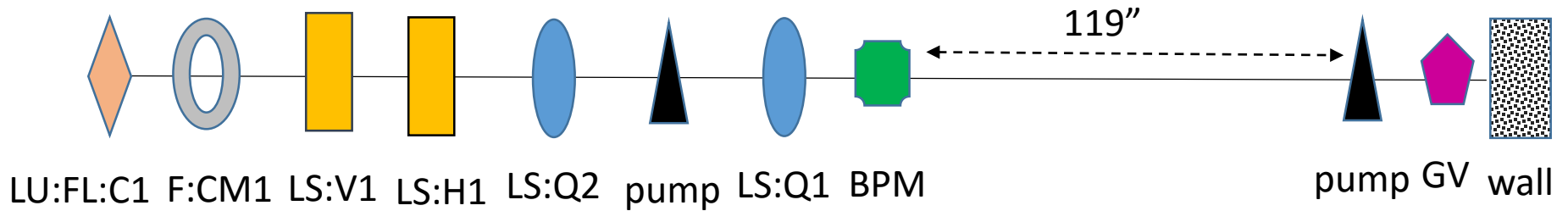
LA:Q1	0.000	0.000
LA:Q2	0.000	0.000

BB-C3 * Poke Flag label for detail screen

Power Supply On/Off Scripts

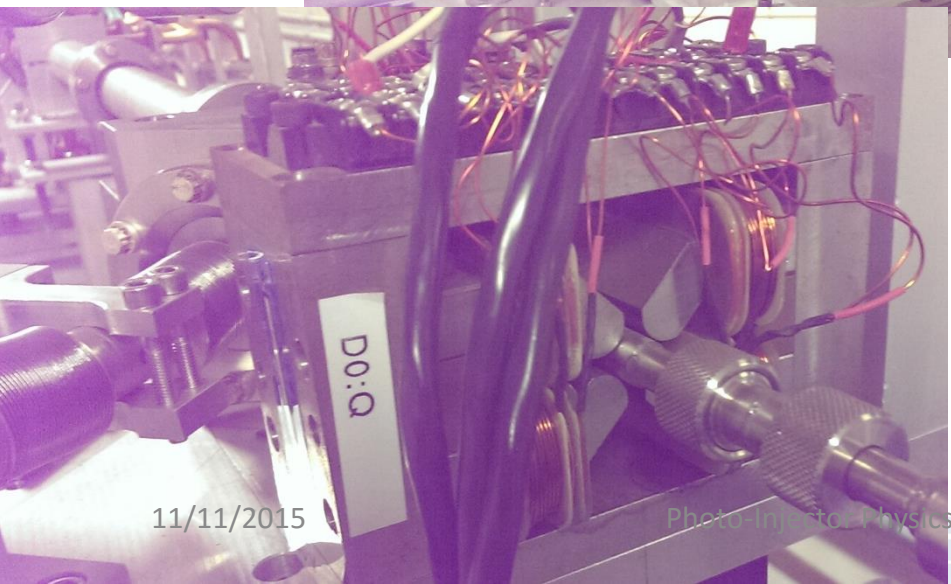
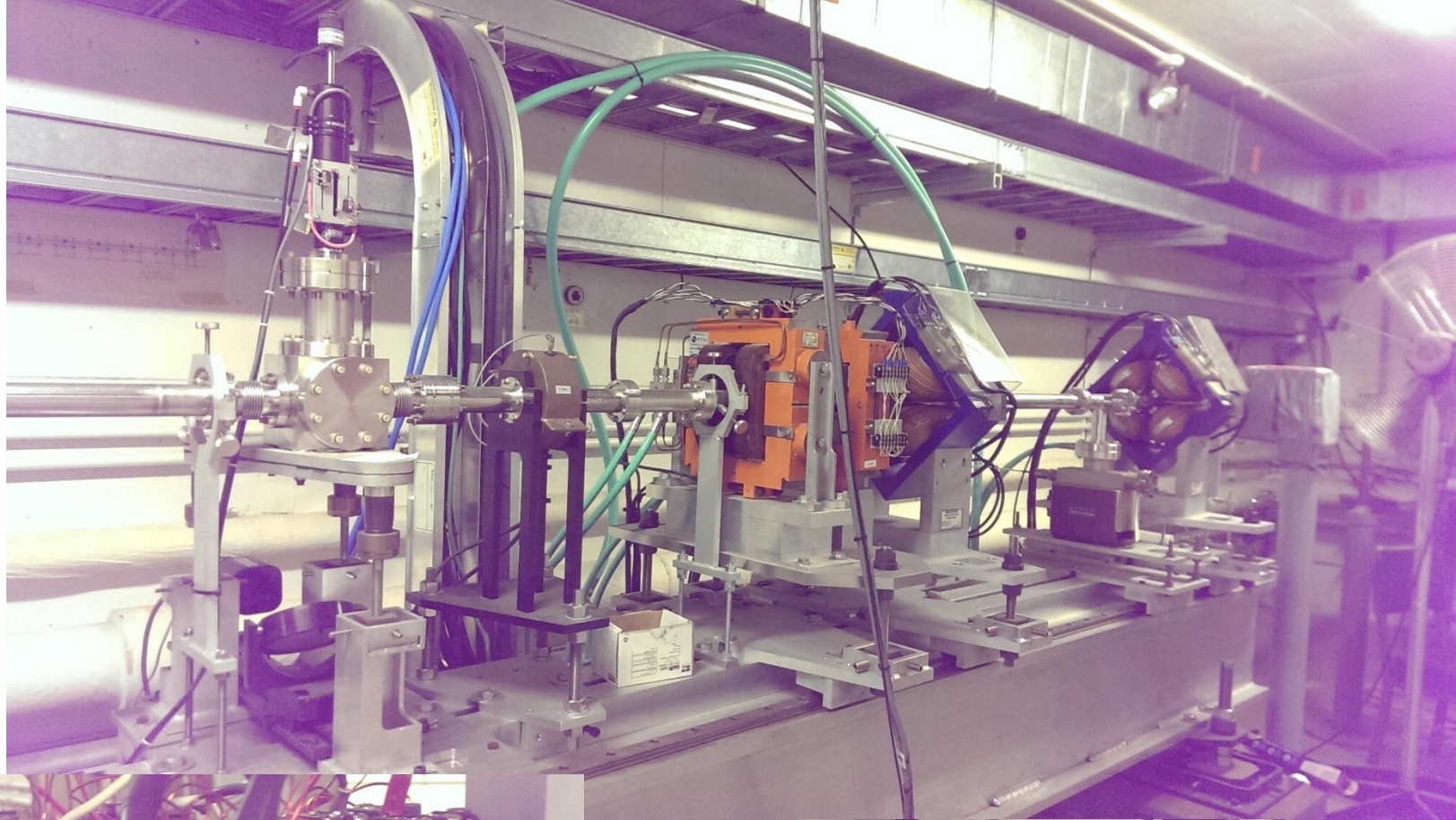
More PS Details

The LEUTL Tunnel



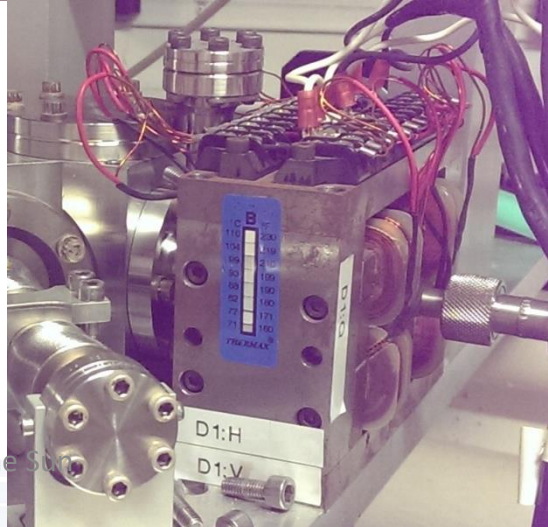
Installed quads: LS:Q1, LS:Q2; Two spares: LS:Q3,LS: Q4
Two steering magnets: LS:V1 and LS:H1

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

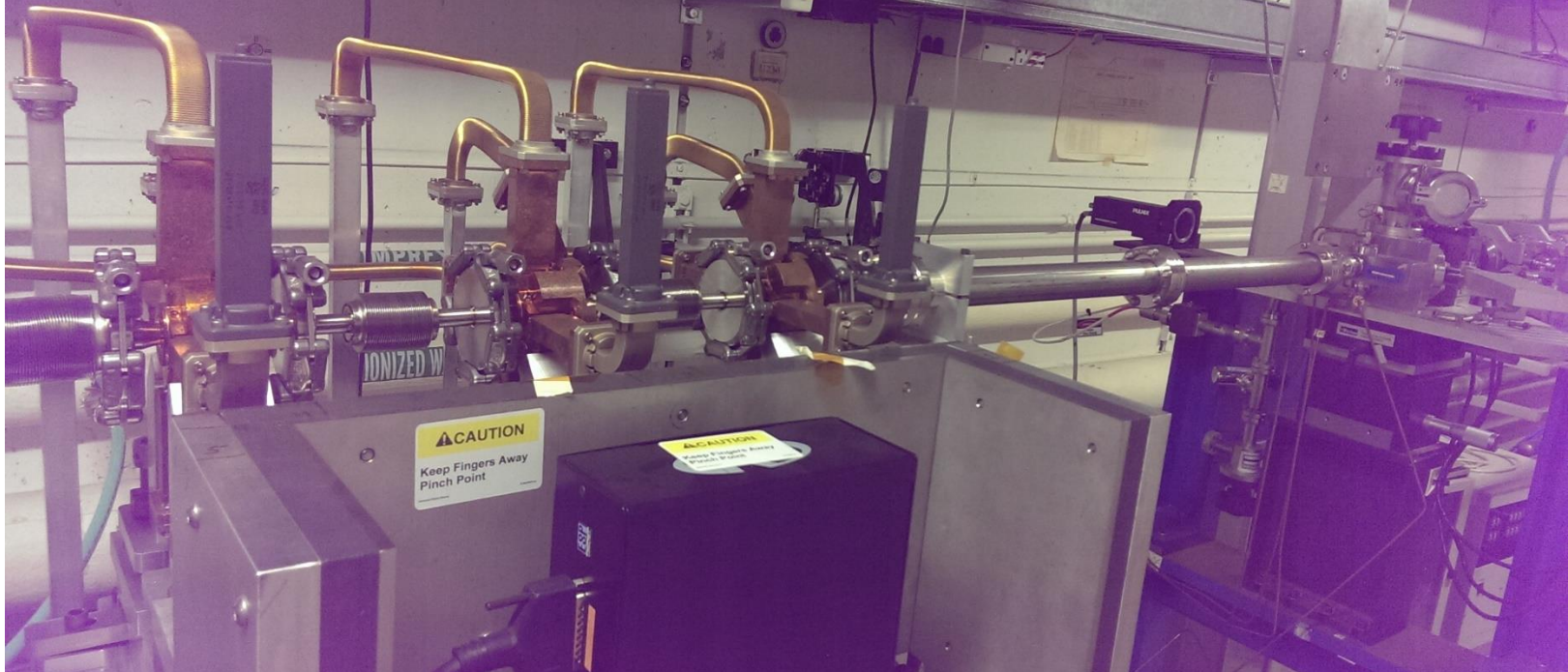


D0:
Q/H/V

D1:
Q/H/V



Cavity
BPM
1,2,3



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

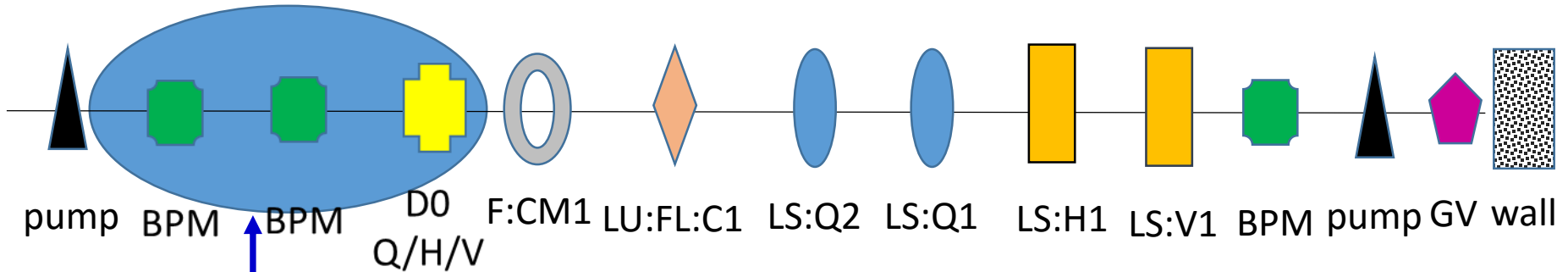
Not all magnets exists.
Not all existing magnets
have power supplies.

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

No controls.

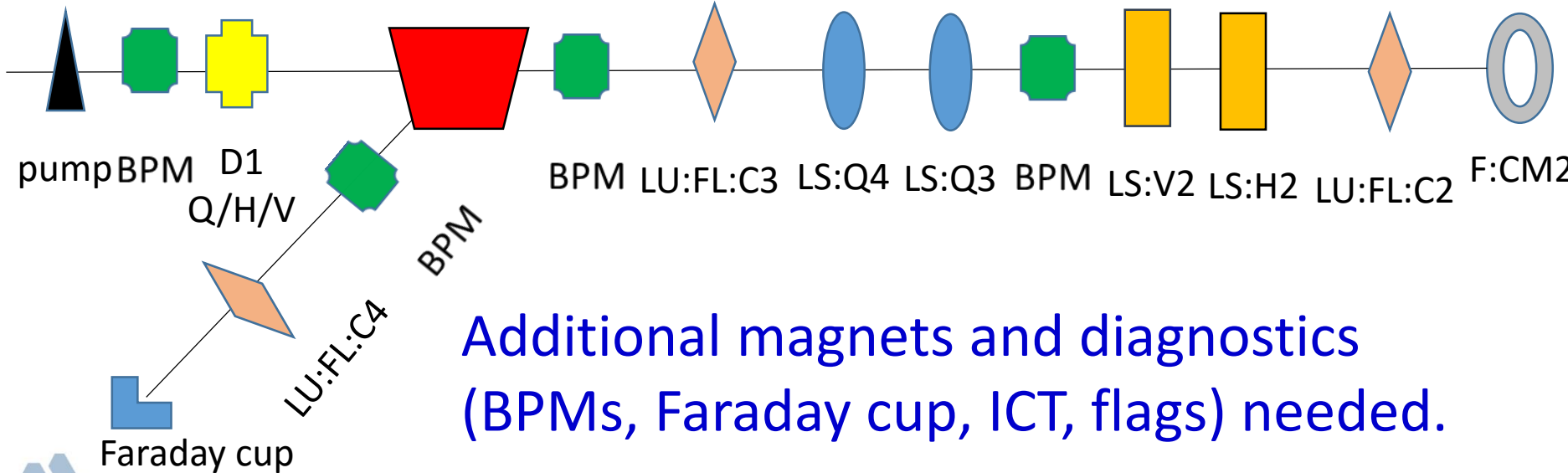


Revive the LEUTL Tunnel for accelerator physics



3~4 meter exp. area

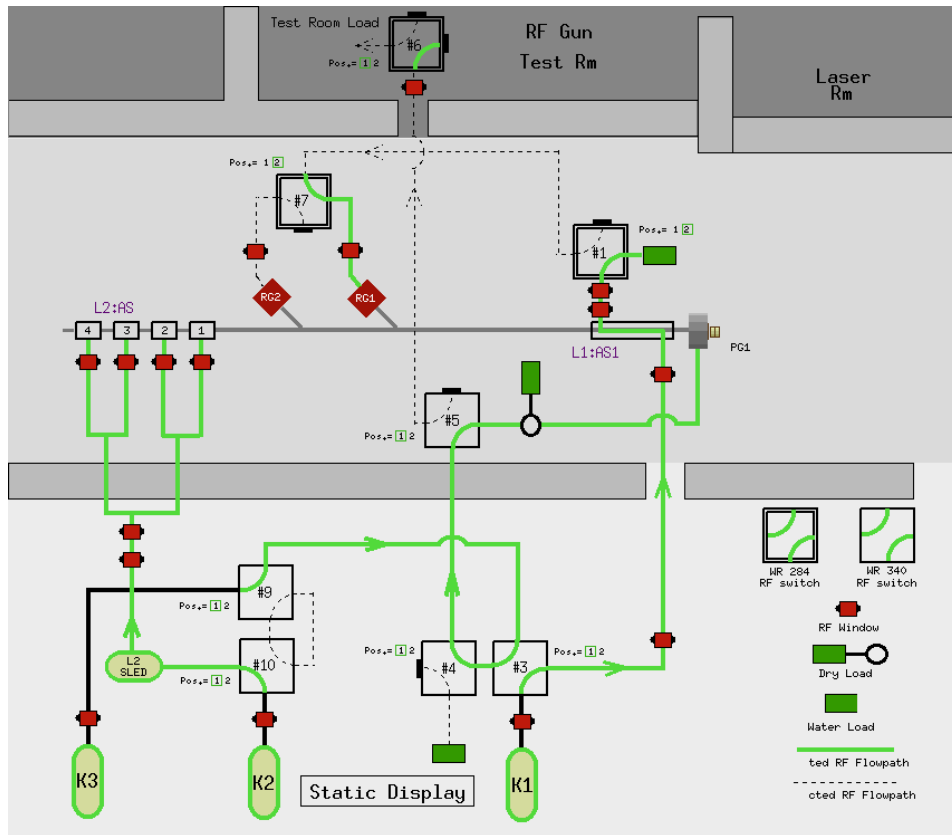
can be longer, for example to accommodate 5-dipole compressor demonstration, it will need to be >10m. More magnets and diag. will be needed for a useful longer beam line.



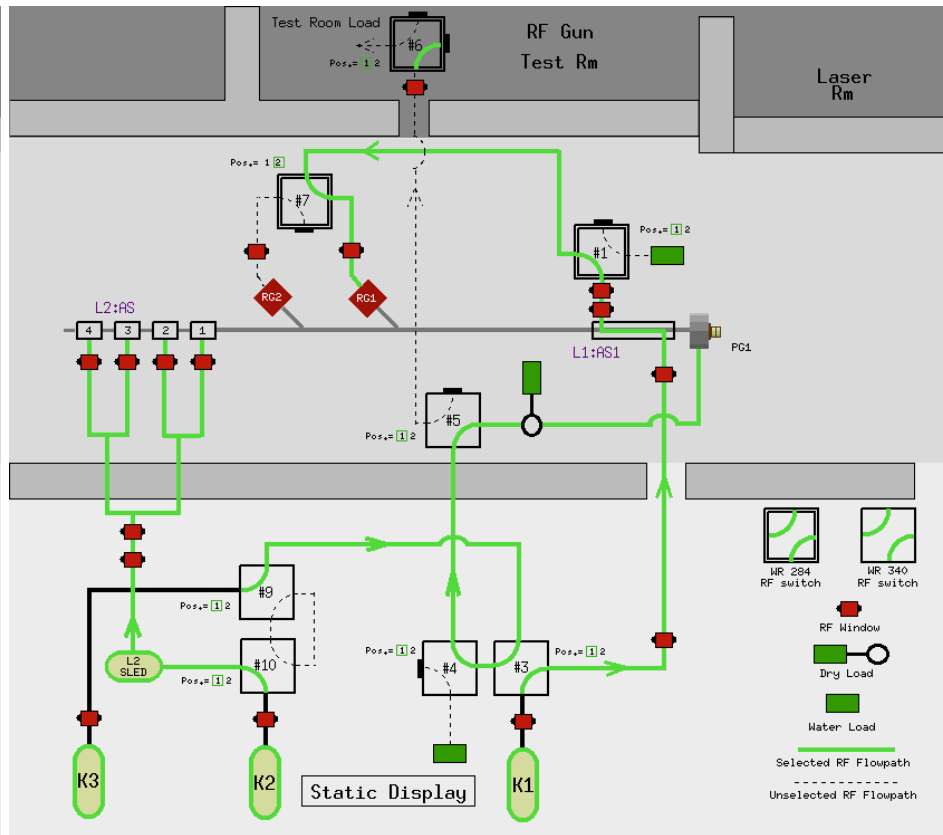
Additional magnets and diagnostics (BPMs, Faraday cup, ICT, flags) needed.

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

Gate Start	Gate Width		L1
-4.500	4.600	us	
Modulator Trigger Time (us)			
-10.000	-6.000	0.000	

	Gate Start	Gate Width
L1 Coarse	-4.500	4.60
RFG Gate	-2.030	1.050

L1 Timing Source Select

30	LI RF Rate
4	LI Beam (RFG)

PC Gun

Gate Start	Gate Width		L1
-2.030	1.050	us	
Modulator Trigger Time (us)			
-10.000	-6.000	0.000	

	Gate Start	Gate Width
L1 Coarse	-4.500	4.60
RFG Gate	-2.030	1.050

L1 Timing Source Select

30	LI RF Rate
2	LI Beam (RFG)

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

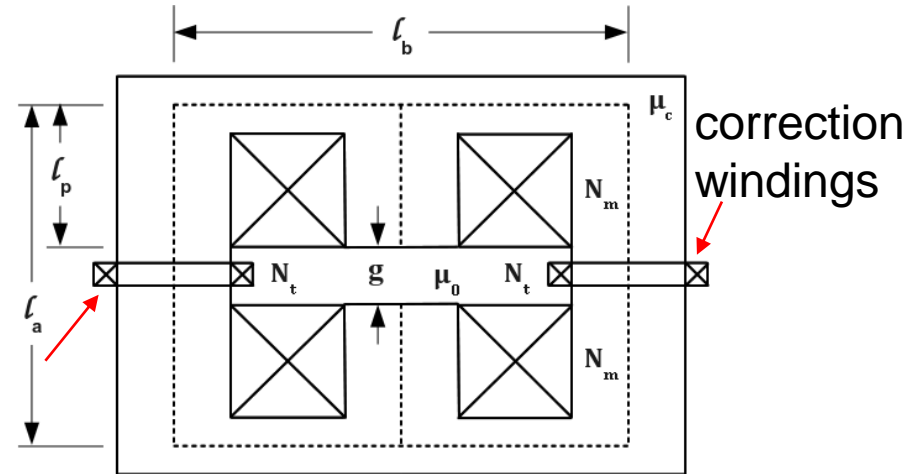
Also need to buck gun alpha magnet remnant fields.



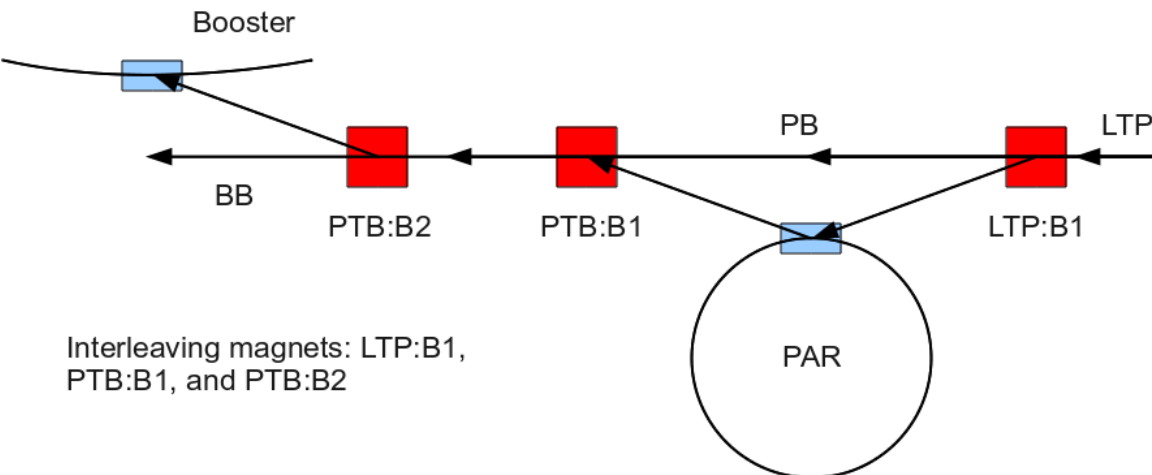
Interleaving dipoles require correction for injection to PAR/Booster and LEUTL (Dooling, Sereno)

possible solutions:

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



small corrector: $K_m=290 \text{ G}\cdot\text{cm}/\text{A}$
 $\ell_{\text{eff}}=0.985 \text{ cm}$



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.

