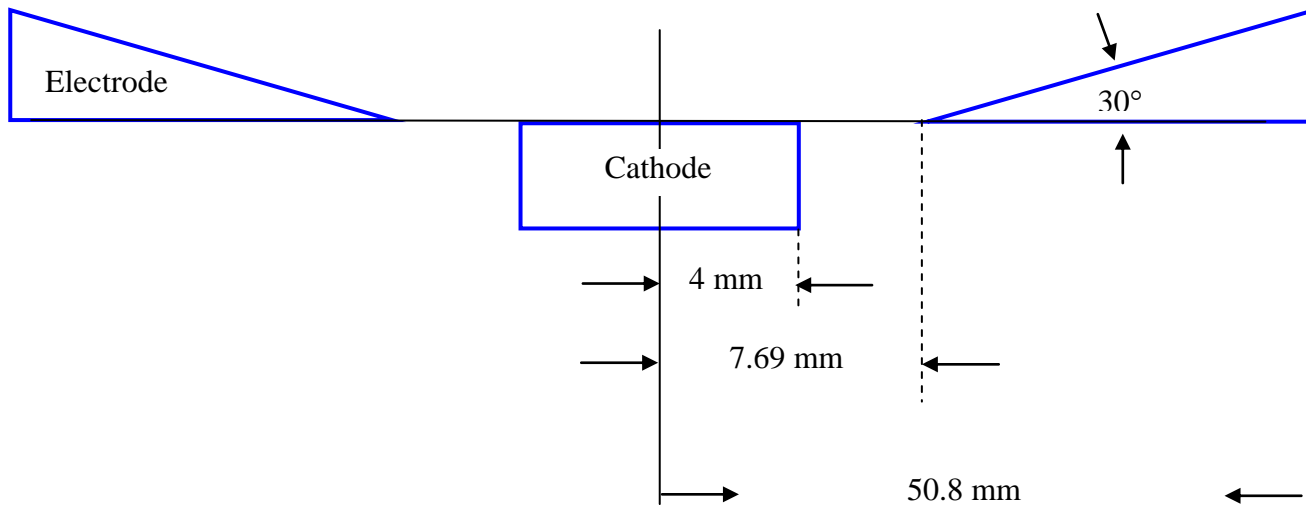


## LEBT Optimization Based on “Final<sup>1</sup>” Gun Geometry

Previous results:

- 4 mm cathode showed advantage in RF voltage and bunching efficiency, with tolerable emittance increase.
- 32°/36° electrode angle comparison showed mild focusing dependence but both were acceptable, indicating wide range of operable angle values.
- Geometry used for final beam test consistent with fabrication specs:



From initial gun test there was observation of over-focusing at existing Pierce angle (32°?). This partly motivated the reduced angle, especially considering lower bunch charge operations.

⇒ Previous optimization results showed a pretty tolerant LEBT to this parameter.

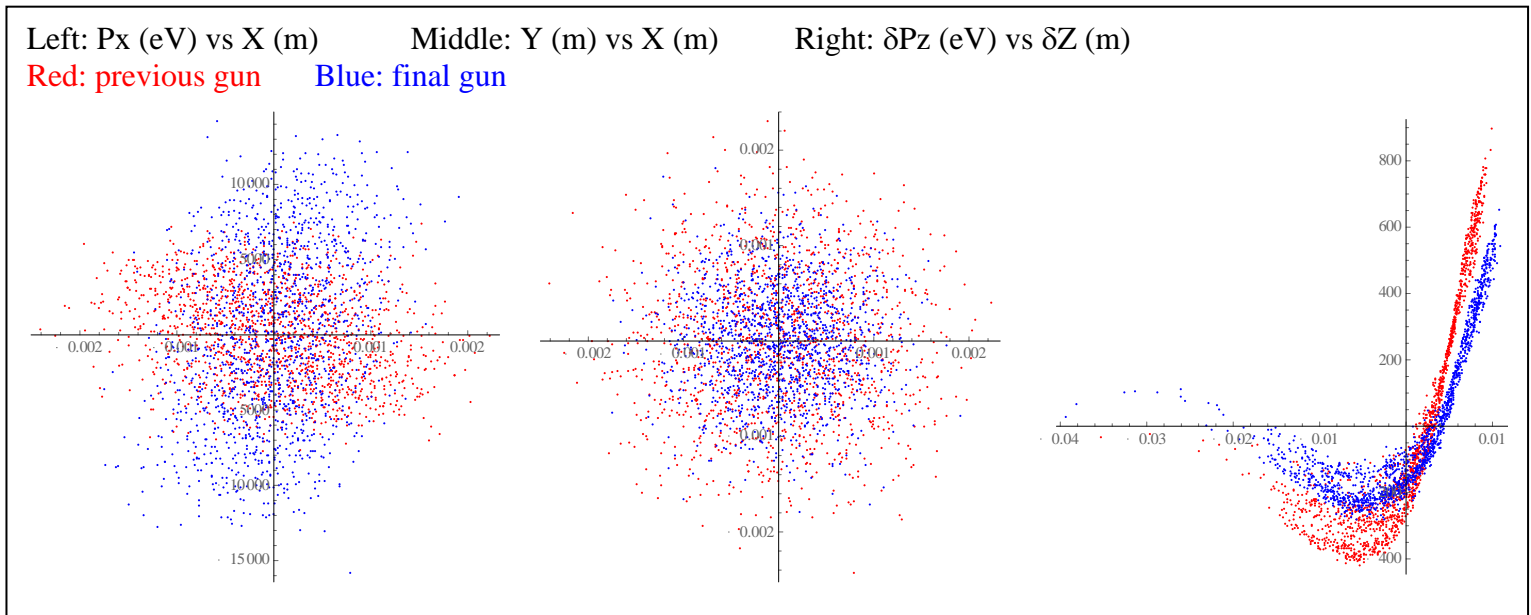
⇒ Relative ease to adjust this angle after real experimental results are available allows setting this initial value based on existing incomplete information. It is not clear beam simulation can accurately pinpoint the optimal Pierce angle to  $\pm 2^\circ$  level.

<sup>1</sup> i.e., that is to be fabricated for the 300 keV gun.

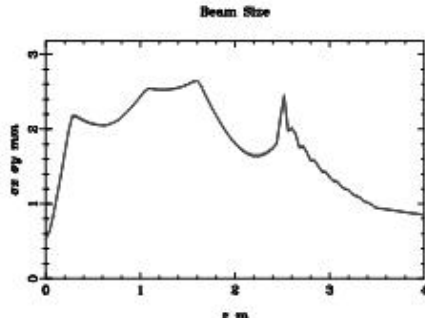
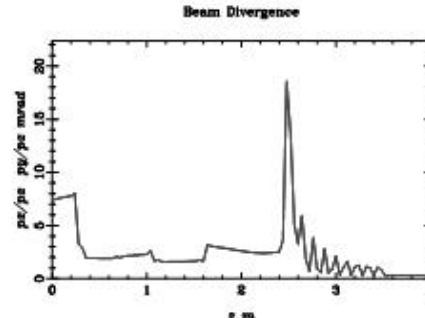
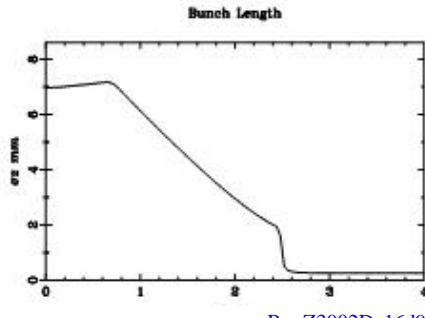
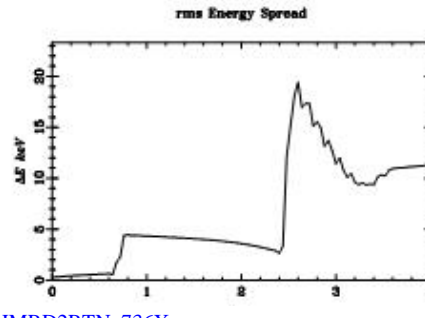
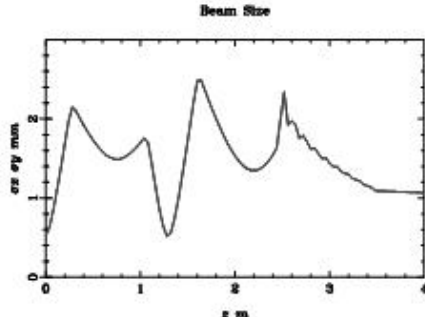
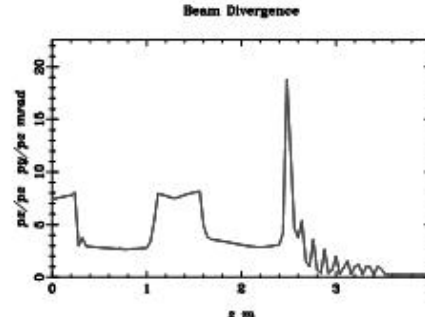
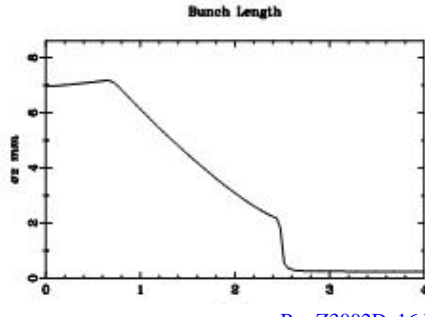
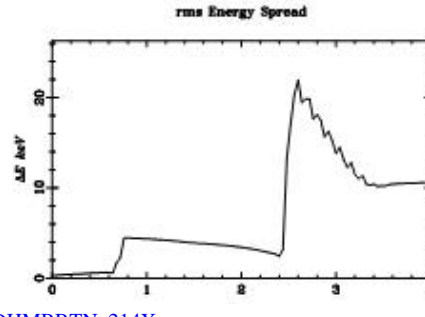
- Transversely beam is slightly divergent out of the gun due to the decreased Pierce angle, but this was also seen before when cathode size was increased.
- Longitudinal variation may come from cathode size increase (with impact on RF and cutoff voltages). More shallow RF grid waveform resulted in smaller longitudinal emittance, and in turn better bunching.

Comparing beam parameters out of various gun configurations at 14.9 cm from the cathode (In all cases 1500 particles are used in GPT simulation)

All $\pm 16^\circ$ conduction angle	34° electrode 3 mm cathode	30° electrode 4 mm cathode
$\sigma_x$ (mm)	0.787182	0.570367
$\sigma_y$ (mm)	0.776627	0.56441
$\sigma_z$ (mm)	6.21775	7.13112
$\sigma_{x'}$ (mrad)	4.99729	9.34588
$\sigma_{y'}$ (mrad)	5.02724	9.32535
$\sigma_{z'}$ ( $10^3 \delta P_z / P_z$ )	0.518149	0.361966
$\sigma_E$ (keV)	0.253408	0.177023
$\epsilon_{x^N}$ (mm-mrad)	4.67908	6.29036
$\epsilon_{y^N}$ (mm-mrad)	4.64347	6.22209
$\epsilon_{z^N}$ (m-eV/c)	1.21472	1.15234
$\alpha / \sqrt{\beta \gamma}$	-0.261692	0.28839
Bunch charge (pC)	16	16

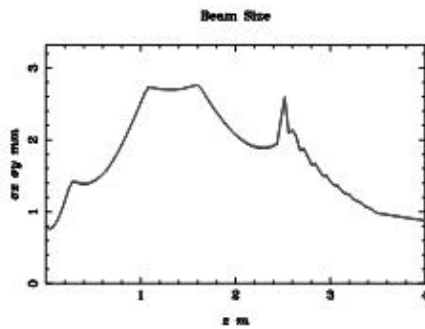
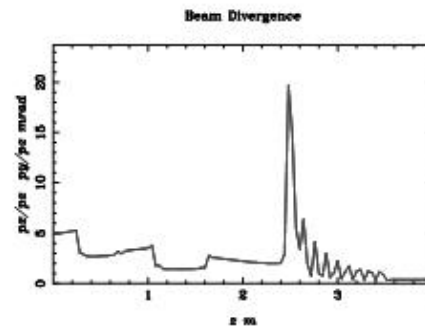
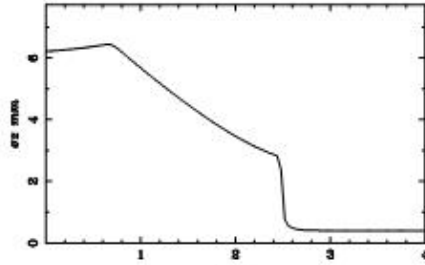
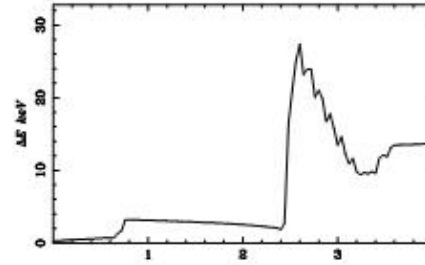
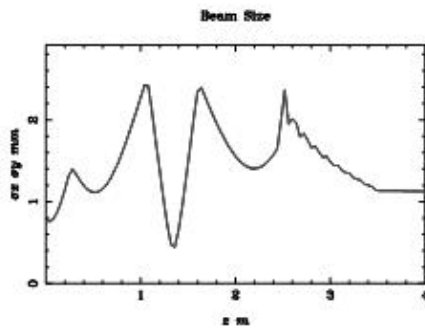
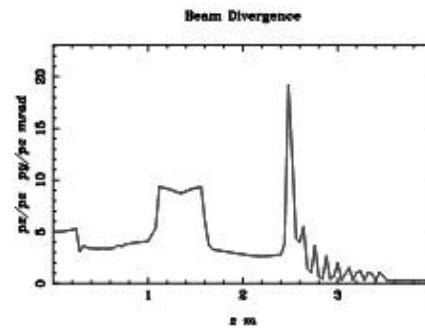
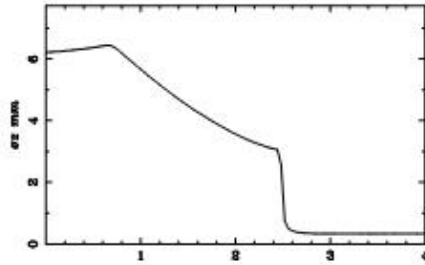
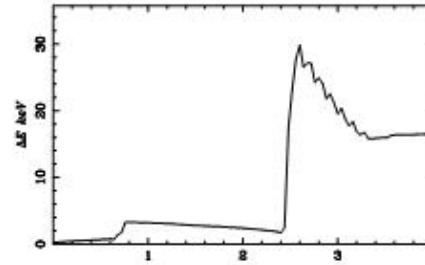


Original Gun Field (Parameters?):

	Solenoid Strength	Cavity Phase <sup>2</sup> & Amplitude	Left: RMS $\sigma_x$ (mm); Right: RMS $\sigma_x'$ (mrad)	
Weak Focus	384.528 G	0.4405 MV/m		
	173.386 G	-88.93°		
	211.698 G			
	20.00 MV/m			
		5.7935°		
			RunZ3002Da16d95GDHMRD2RTN_736X	
Strong Focus	418.695 G	0.4500 MV/m		
	453.359 G	-85.27°		
	412.437 G			
	20.00 MV/m			
		3.9060°		
			RunZ3002Da16d95GDHMRRTN_214X	

<sup>2</sup> Phase relative to maximum gain point determined by Astra at cavity entrance.

Previous Gun Field (Feb. 2011; 34° electrode, 3 mm cathode):

	Solenoid Strength	Cavity Phase <sup>3</sup> & Amplitude	Left: RMS $\sigma_x$ (mm); Right: RMS $\sigma_x'$ (mrad)			
Weak Focus	382.822 G	0.3840 MV/m				
	221.786 G	-104.88°				
	192.065 G					
	20.00 MV/m	5.1127°				
Strong Focus	435.114 G	0.3923 MV/m				
	442.582 G	-104.85°				
	433.402 G					
	20.00 MV/m	2.8866°				

RunZ3002Da16d95 GDHMRD3RTNG\_2046X

RunZ3002Da16d95 GDHMRRTNG\_937X

<sup>3</sup> Phase relative to maximum gain point determined by Astra at cavity entrance.

Final Gun Field (June 2011; 30° electrode, 4 mm cathode):

	Solenoid Strength	Cavity Phase <sup>4</sup> & Amplitude	Left: $\epsilon_x$ (mm-mrad); Middle: RMS $\sigma_x$ (mm); Right: RMS $\sigma_x'$ (mrad)		
Weak Focus <sup>5</sup>	382.293 G	0.462311 MV/m		RunZ3002Da16d95MODGDHMRD2RT_2069X	
	157.243 G	-95.7901°			
	229.498 G				
		20.00 MV/m			
		3.77092°			
Strong Focus	397.811 G	0.430661 MV/m		RunZ3002Da16d95MODGDHMRRT_2693X	
	400.945 G	-104.787°			
	421.100 G				
		20.00 MV/m			
		4.3975°			

<sup>4</sup> Phase relative to maximum gain point determined by Astra at cavity entrance.

<sup>5</sup> Alternative solution: [RunZ3002Da16d95MODGDHMRD3RT\\_1139](#), with RF phases closer to strong focusing and most of the other optimized cases.

## Observations

- 4 mm cathode and resulting emittance increase does not significantly affect meeting design specs in LEBT.
- 30° Pierce angle expectedly led to more divergent beam into LEBT. However the latter is seen to be able to accept beam coming from a wide range of Pierce angles.
- Beam size at the first solenoid determines maximum beam size and it can no longer be well below 3 mm RMS, but still within 3 mm spec.
- Reduced demand on solenoid strengths in LEBT (accompanying larger beam size)
- Other beam characteristics and tuning parameters are close to previous cases.

4 mm cathode seems a clear advantage. LEBT is sufficiently robust to take the 30° Pierce angle within its acceptance range. Experimental data is critical in eventual fine tuning of this parameter.

# Addendum

New 9-cell cavity field (V. Zvyagintsev 2011-10-12) with final Gun Field:

	Solenoid Strength	Cavity Phase <sup>6</sup> & Amplitude	Left: $\epsilon_x$ (mm-mrad); Middle: RMS $\sigma_x$ (mm); Right: RMS $\sigma_x'$ (mrad)		
Weak Focus <sup>7</sup>	382.001 G	0.445476 MV/m			
	160.694 G	-101.811°			
	244.460 G				
		20.00 MV/m			
		6.19253°			
Strong Focus <sup>8</sup>	397.64 G	0.417995 MV/m			
	419.295 G	-104.947°			
	410.485 G				
		20.00 MV/m			
		1.4976°			

RunZ3002Da16d95MODGDHMRD3RTNV\_1064X

RunZ3002 Da16d95MODGDHMRRTNV\_948X

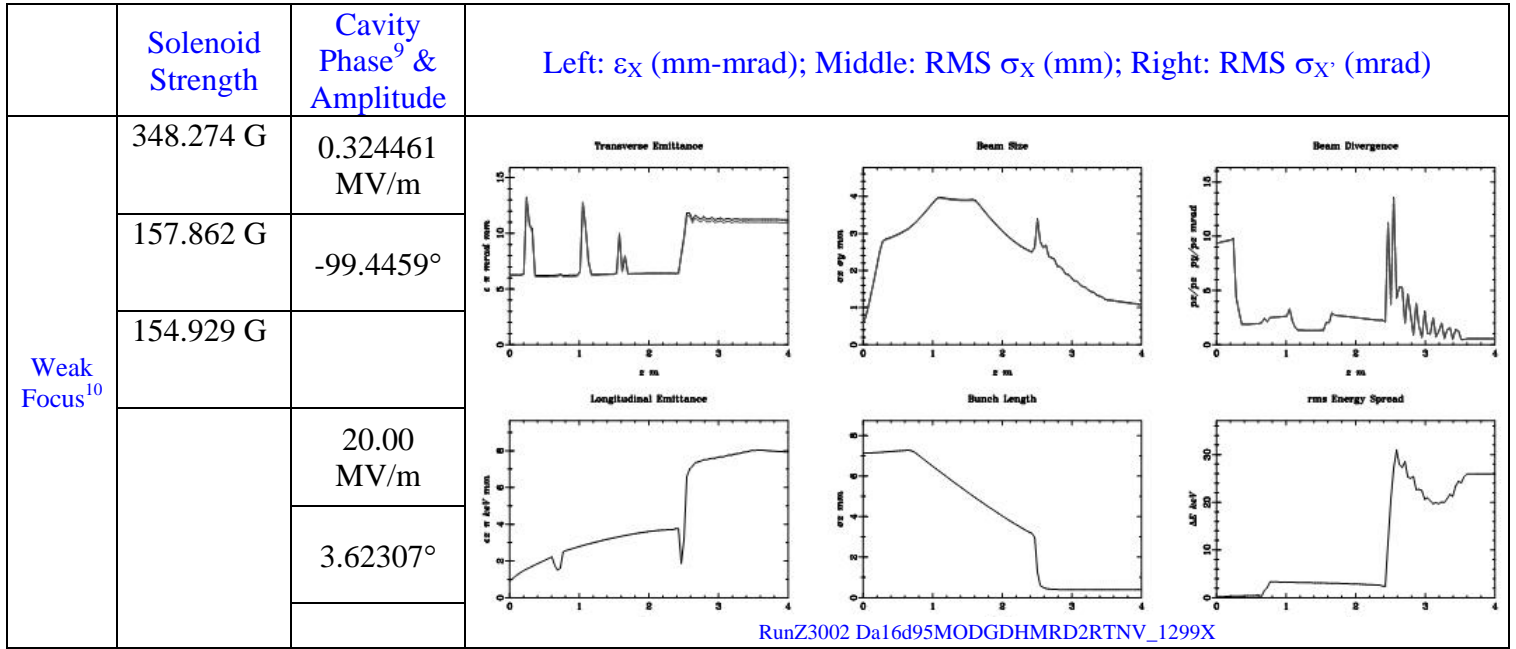
<sup>6</sup> Phase relative to maximum gain point determined by Astra at cavity [entrance](#).

<sup>7</sup> Interesting alternative solution: [RunZ3002Da16d95MODGDHMRD2RTNV\\_2525](#), with even smaller size and slightly different characteristic.

<sup>8</sup> Interesting alternative solution: [RunZ3002Da16 d95MODGDHMRRTNV\\_1441/1965/2273/2892](#), with smaller size but stronger solenoids.

These solutions also represent different tradeoff between bunch length and momentum spread. The baseline case has the smallest  $\sigma_z$  but larger  $\sigma_p$ .

Low divergence solution ( $\sigma_{X'} \approx 1$  mrad after 2<sup>nd</sup> solenoid)



- Observed different longitudinal beam behavior with the newly modeled 9-cell (vs Tesla 9-cell used in Astra runs so far). It is sufficiently visible to call for a re-optimization of the ELBT/VECC solutions. One immediate justification is that previously optimized RF parameters resulted in sub-optimal beam dynamics when directly applied to the new field map, preventing reliable conclusion for coupler kick study based on GPT.
- Essentially strong and weak focusing solutions with the same characteristics as before can be identified, with visibly different RF parameters for both the buncher and the ICM. These new parameters are expected to produce better matched results for the GPT studies.
- A special “low divergence” optics is also identified, with  $\sigma_{X'}$  down to 1 mrad level after the 2<sup>nd</sup> solenoid at the expense of  $\sigma_X \approx 4$  mm. This may provide a using tuning scenario for longitudinal space characterization. Note the buncher is also weaker than usual to reduce defocusing.

<sup>9</sup> Phase relative to maximum gain point determined by Astra at cavity entrance.

<sup>10</sup> Alternative solution: [RunZ3002Da16d95MODGDHMRD2RTNV\\_386](#).