

Study of space charge dominated beams at the AWA rf photoinjector

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Outline

Facility Introduction

- Photoinjectors

- Ongoing Experiments

Simulations

- Code

- Optimization

Experimental Measurements

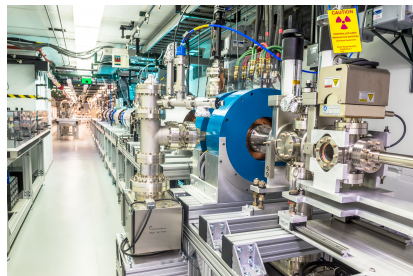
- Overview

- Beam Size Measurements

Argonne Wakefield Accelerator Facility

Two photocathode guns and accompanying linacs:

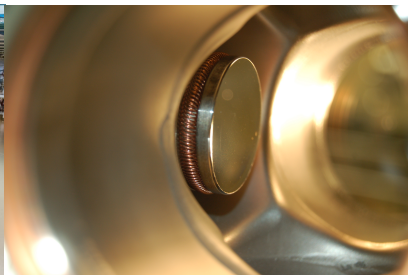
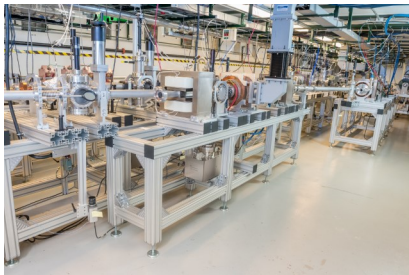
- **Drive Line:** Cs_2Te cathode, 6 linac cavities
 - Charge 0.1-100nC
 - Energy ≤ 65 MeV
- **Witness Line:** Mg cathode, 1 linac cavity
 - Charge 0.1-10nC
 - Energy ≤ 15 MeV



AWA Facility

Current experiments include:

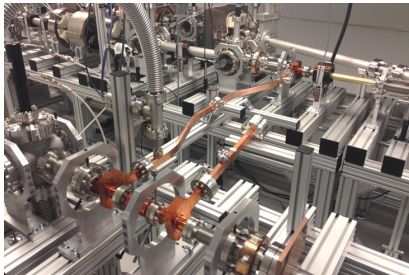
- Emittance Exchange (EEX)
- Electron Radiography Imaging (ERI)
- Cathode Studies



AWA Facility

Current experiments include:

- Two Beam Acceleration (TBA)
- Beam line design for TBA = my thesis
- Dielectric accelerating and decelerating structure tests



Code

OPAL-T:

<https://gitlab.psi.ch/OPAL/src/wikis/home>

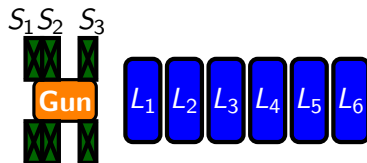
- Free, open source
- Developed at PSI, easy to work with developers
- Parallel (weak scaling)
- Features include 3D space charge and wakefields
- Can output data in beam or global reference frame

RF photoinjector benchmark:

<https://gitlab.psi.ch/OPAL/src/wikis/RFPhotoInjector>

Initial Optimization Goals at 40 nC

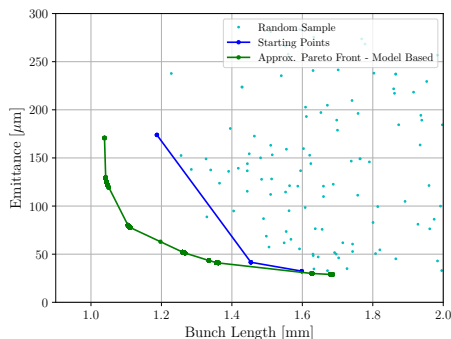
- Linac only, used BOBYQA algorithm
- Determine optimum settings for TBA experiments
- metrics = emittance & bunch length
- Varied 10 parameters:



Variable	Range	Unit
Solenoid Strength	$150 \leq S_3 \leq 440$	amps
Phase of Gun	$-40 \leq \phi_g \leq 40$	degrees
Laser Radius	$3 \leq R \leq 9$	mm
Laser FWHM	$2 \leq T \leq 10$	ps
Cavity Phase	$-40 \leq \phi_L \leq 40^1$	degrees

¹ $\phi_L = [\phi_{L_1}, \dots, \phi_{L_6}]$

Initial Optimization Results at 40 nC



Code verifies:

- Larger laser radius is always better
- Shorter laser pulse length \rightarrow shorter σ_z
- Longer laser pulse \rightarrow lower $\epsilon_{x,y}$
- Running off crest in linac mitigates energy spread out of gun

$$f(v, w) = w \bar{\epsilon}_x(v, z_1) + (1 - w) \bar{\sigma}_z(v, z_1)$$

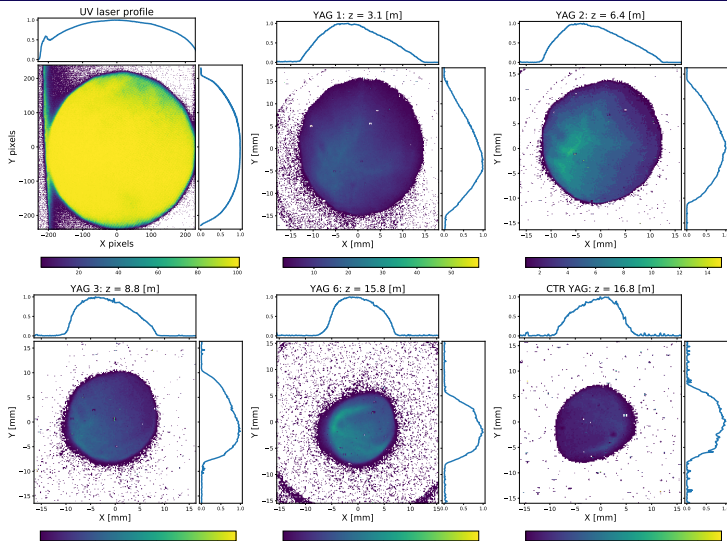
Overview

Took data exactly 2 weeks ago!

Tried to dial in machine settings based on simulations:

- Initial results did not match simulations - not a surprise
- Identified issues:
 - Energy lower than expected
 - Solenoid strength
 - Shot to shot charge fluctuation
- Adjusted settings to approach simulation values
- Took four types of data:
 - Energy measurements
 - **Beam size data - YAG screens**
 - Emittance - scanning slit
 - Bunch length - CTR (interferometer, and bolometer)

Beam Size Measurements

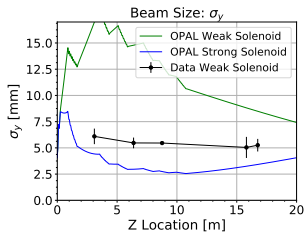
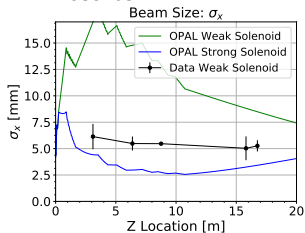


Hot spot on bottom left corner...origin laser?

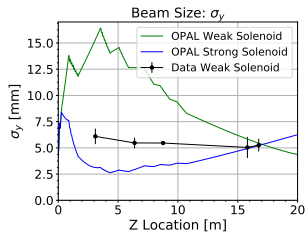
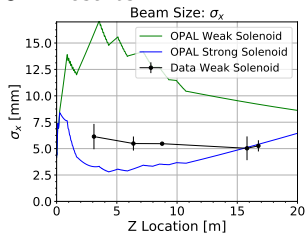


Beam Size Measurements

2D Results:



3D Results:



Summary

End Goal: Use simulations to optimize beam parameters.

- AWA beam line configuration is dynamic and variable
- Space charge drives the limitations for TBA experiments
- We need a set of tools to quickly optimize extremely different parameters
- Agreement between simulations and measurements should guide experiments

Thanks for your time!

