

Guns  
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Simulations  
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Big Computers  
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# Guns and Codes

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# Outline

## Guns

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Photoinjectors

## Simulations

Codes

PIC Results

## Big Computers

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## Guns

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# What's a gun?

A few key parts are needed:

- Cathode (Source of particles)
- Focusing (usually solenoids)
- Vacuum (strict for electron machines w/ semiconductors)
- Accelerating field

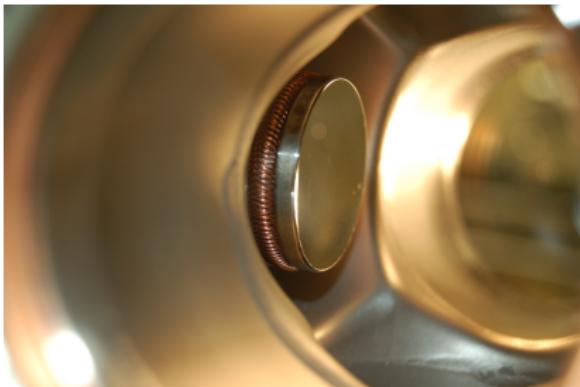


[https://www.lhc-closer.es/taking\\_a\\_closer\\_look\\_at\\_lhc/0.proton\\_source](https://www.lhc-closer.es/taking_a_closer_look_at_lhc/0.proton_source)

## Sources of particles: Cathodes

The particles have to come from somewhere:

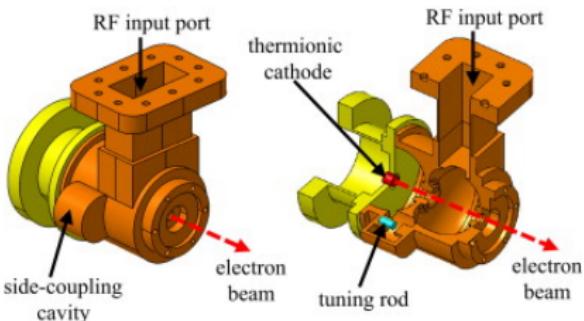
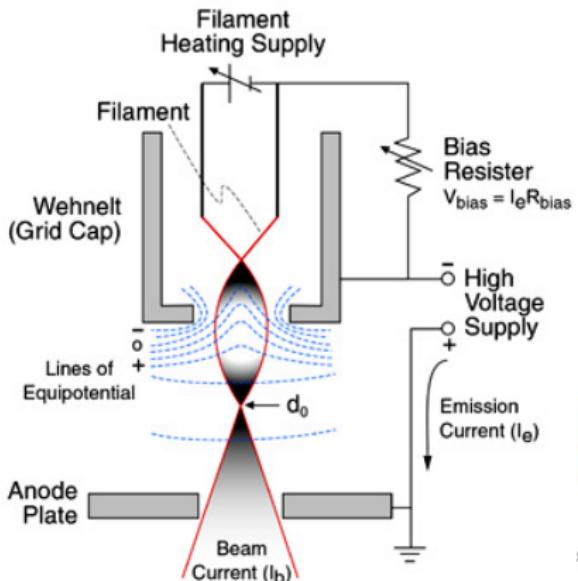
- metals and semiconductors
- gas
- filament



Source: AWA-ANL

# Thermionic Cathodes

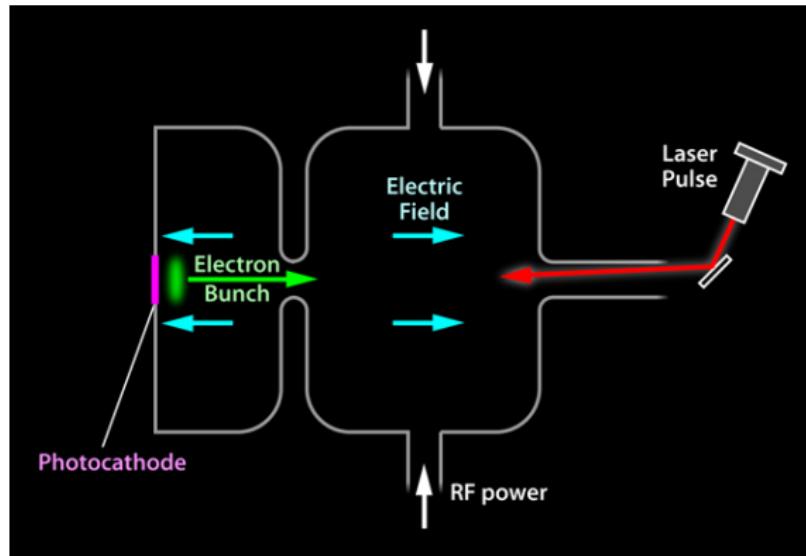
A filament is heated up until electrons are emitted.



Sources: <https://www.sciencedirect.com/science/article/pii/S0168900213014381#f0005>  
<https://nau.edu/cefns/labs/electron-microprobe/glg-510-class-notes/instrumentation/>

# Photocathodes

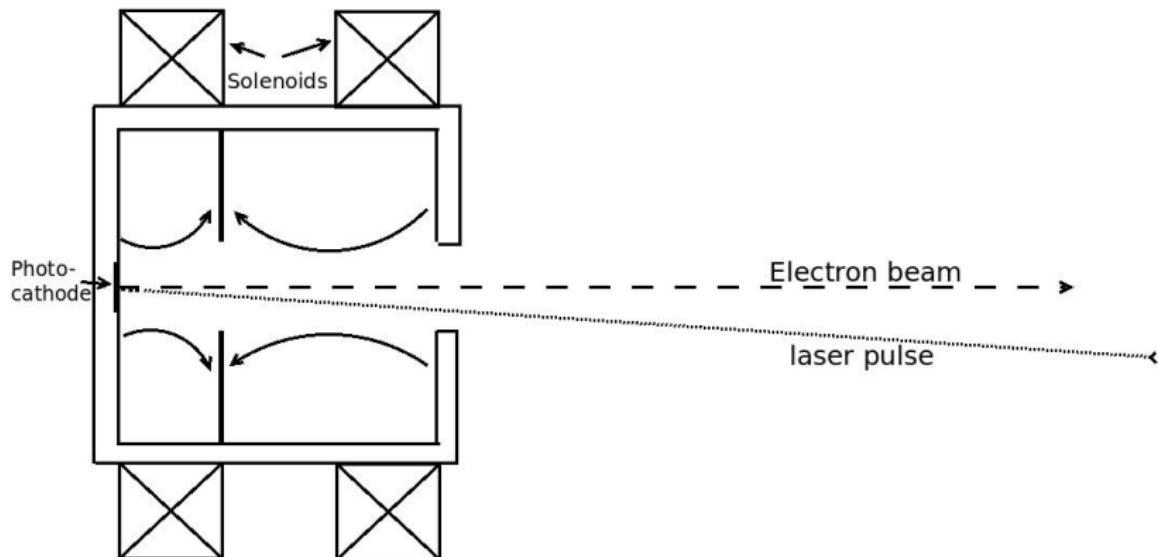
- Needs a laser
- Photoelectric effect



<https://phys.org/news/2013-02-black-gold-enabling-bright-high.html>

# AWA-ANL Gun

RF Photoinjector, 1.5 cell



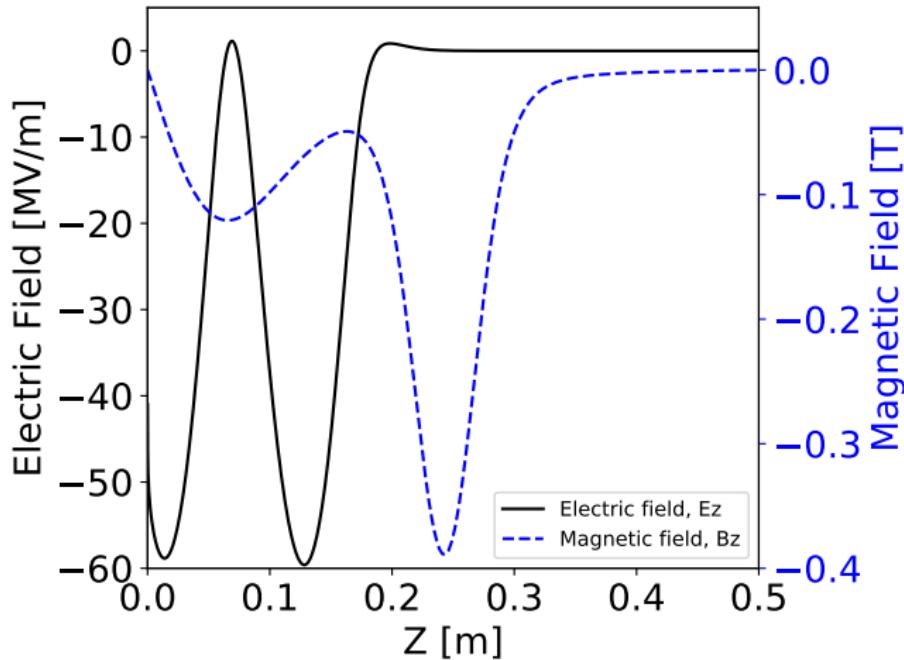
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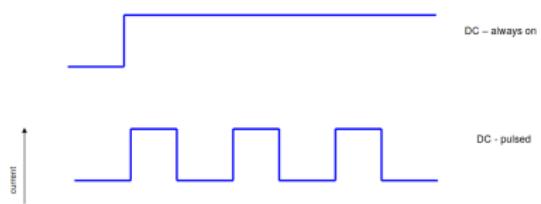
## AWA Gun fields



# Gun Types

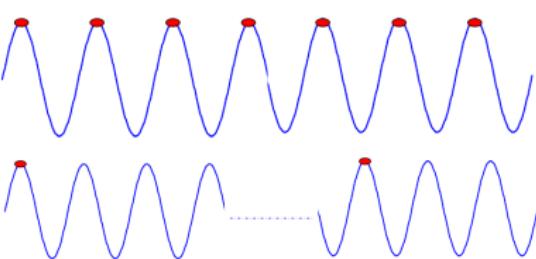
## DC Guns

- Bunch compression usually required



## RF Guns

- Energy chirp, but bunched



[https://www.classe.cornell.edu/~hoff/LECTURES/08S\\_688/08S\\_688\\_080225.pdf](https://www.classe.cornell.edu/~hoff/LECTURES/08S_688/08S_688_080225.pdf)

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# Simulations

Simulations give help with design and prediction of accelerators.  
Two main types of simulations:

- PIC: Particle in Cell
  - Model particles individually
- Envelope
  - Use matrices to look at envelope behavior

Historically, envelope codes were first. Now computing resources are good enough to use PIC in more situations.

## Some Envelope Codes

These codes do matrix multiplication, and use input beam parameters to find Twiss parameters around a beam line.

- MADX - <http://mad.web.cern.ch/mad/>
- Elegant (also a PIC code) -  
<https://beta.sirepo.com/elegant#/simulations>
- Accelerator Toolbox (AT) -  
<https://www.slac.stanford.edu/grp/ssrl/spear/at/>
- TRACE - [http://laacg.lanl.gov/laacg/services/  
download\\_trace.phtml](http://laacg.lanl.gov/laacg/services/download_trace.phtml)

# PIC Codes

PIC = Particle in Cell

Distribute particles on a grid and solve equations numerically.

- Particle-Particle Forces (space charge)
- E&M Forces
- Apertures

Draw some things on the board....

Meshes, particle push, etc.

## Some PIC codes for beam line modeling...

- Parmela -  
[http://laacg.lanl.gov/laacg/services/serv\\_codes.phtml](http://laacg.lanl.gov/laacg/services/serv_codes.phtml)
- ASTRA - <http://www.desy.de/~mpyflo/>
- GPT - <http://www.pulsar.nl/gpt/>
- OPAL - <https://gitlab.psi.ch/OPAL/src/wikis/home>
- Synergia - <https://web.fnal.gov/sites/Synergia/SitePages/Synergia%20Home.aspx>
- Bmad - <https://www.classe.cornell.edu/bmad/>
- G4beamline -  
<http://www.muonsinternal.com/muons3/G4beamline>
- WARP - <http://blast.lbl.gov/blast-codes-warp/>
- IMPACT - <http://blast.lbl.gov/blast-codes-impact/>

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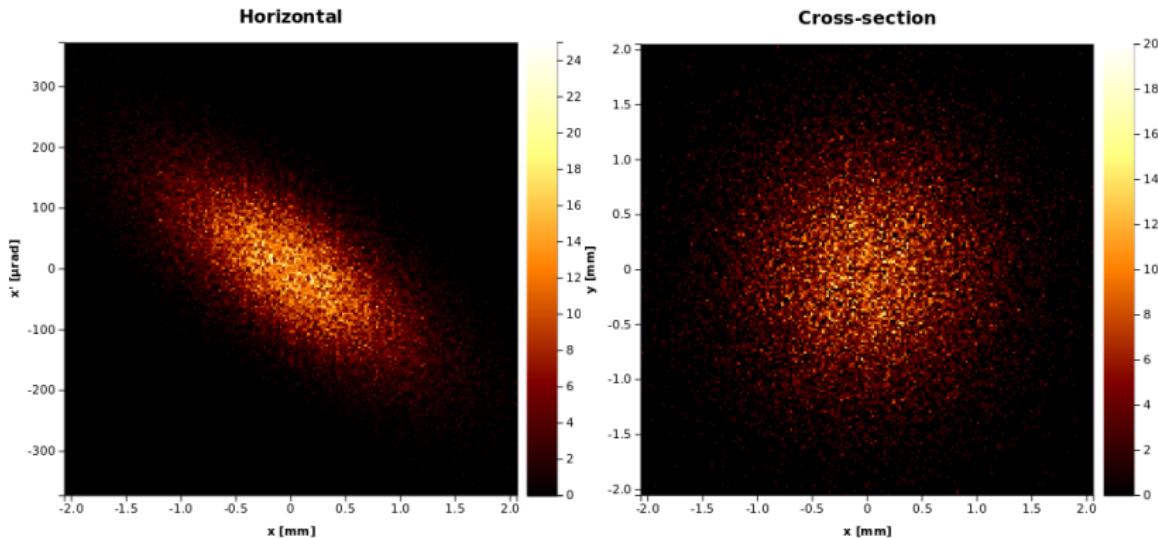


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## Some PIC Codes cont..

- Elegant (also a PIC code) -

<https://beta.sirepo.com/elegant#/simulations>

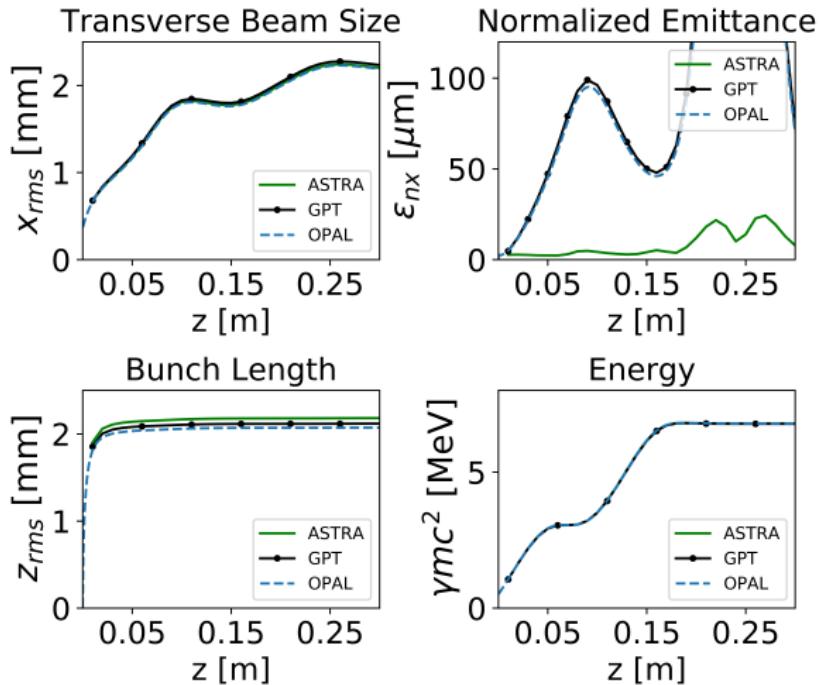


## PIC Code Comparison

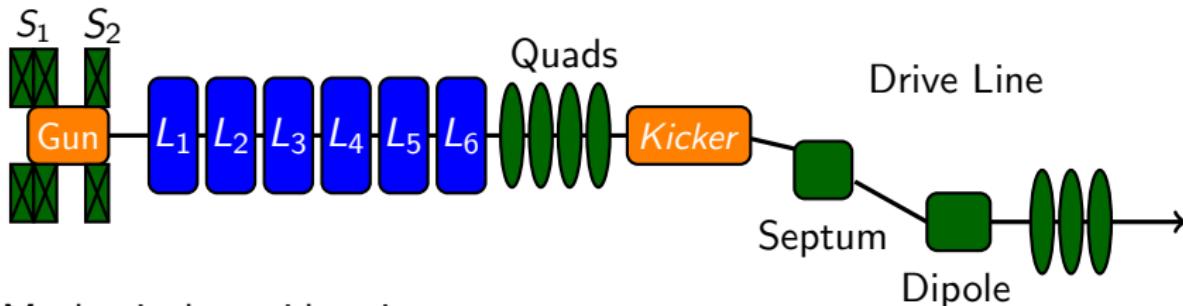
Feature	ASTRA	GPT	OPAL
Windows	✓	✓	✗
Mac	✓	✓	✓
Linux	✓	✓	✓
Open Source	✗	✗	✓
Parallel	✗*	✗*	✓
Autophase	✓	✗	✓
Adaptive Time Step	✗	✓	✗
3D Space Charge	✓	✓	✓
Wakefields	✓	✗*	✓
CSR	✗	✗*	✓

\* features available on request or in specific versions.

## PIC Results: Statistics, beam parameters w.r.t. bunch.



## Beam Line Modeling, High Charge



Mechanical considerations:

- 1m between kicker and septum
  - for separation  $\geq 50\text{mm}$  in septum.
- 1.8m between septum and dipole
  - for separation  $\geq 0.5\text{m}$  of beam lines.
- 15cm between quads for easy installation.
- 0.3m between quads and PETs for yag screen.

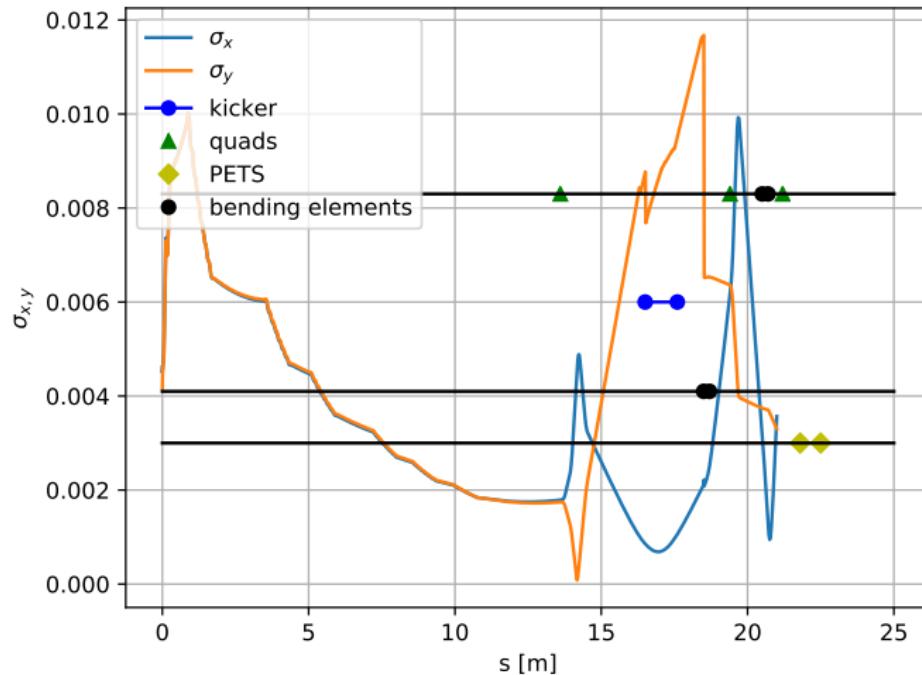
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PIC Results

## PIC Results: High Charge 40 nC



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PIC Results

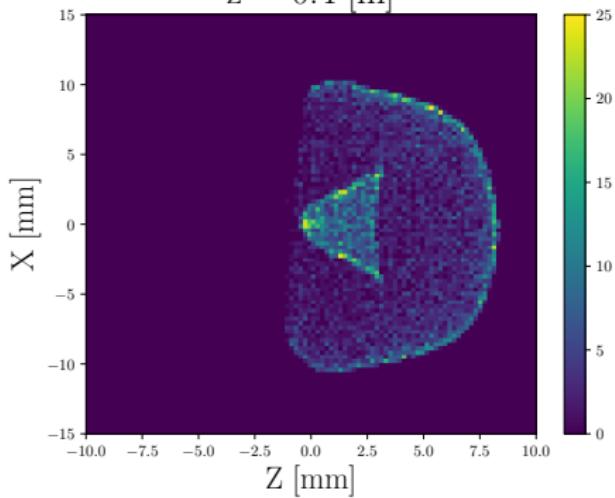
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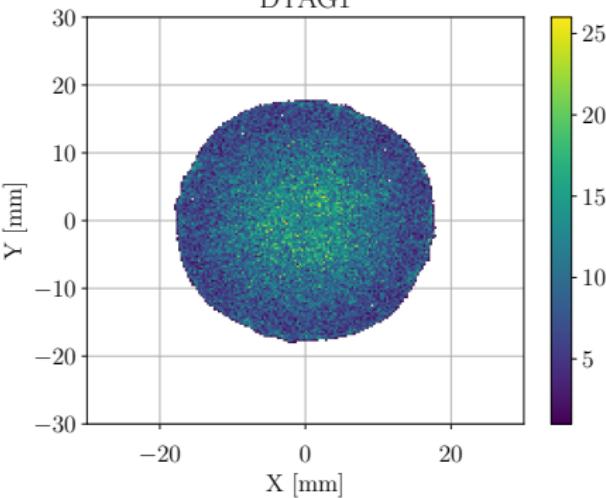
## PIC Results: Real Space

Longitudinal Distribution After Gun

$z = 0.4 \text{ [m]}$



$M=250$ , FWHM=1.5ps:  
DYAG1



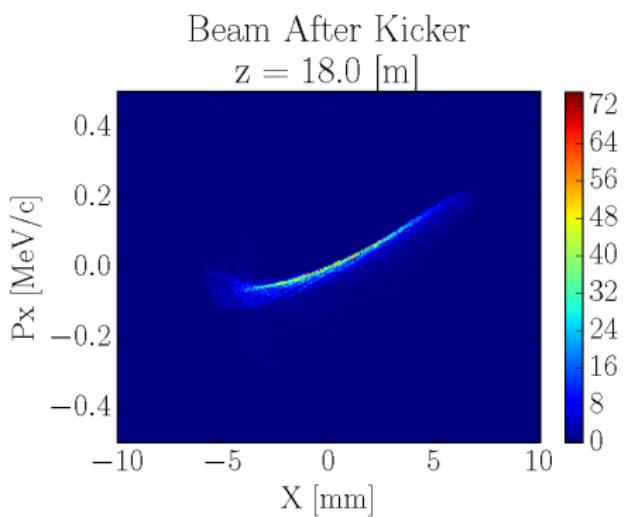
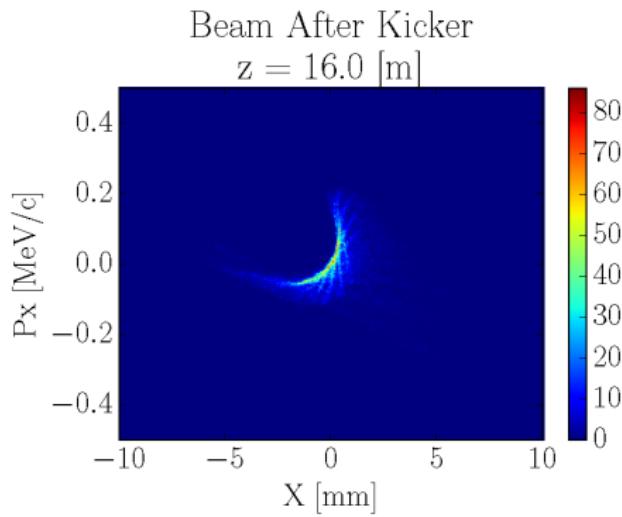
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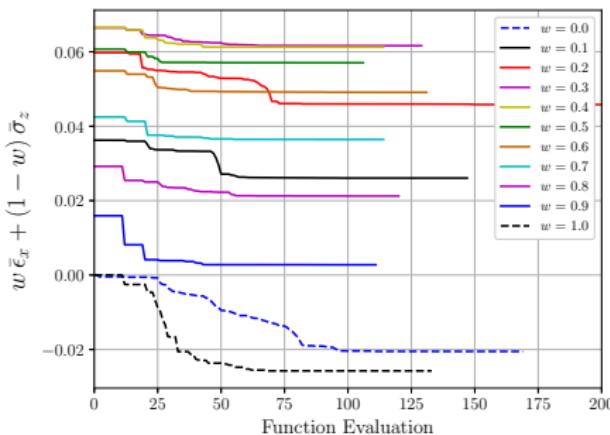
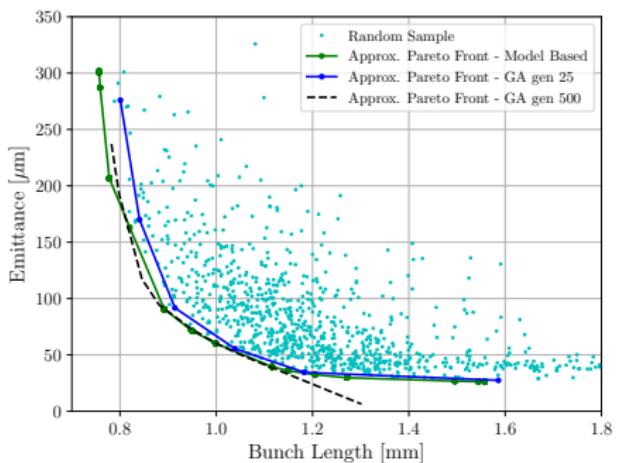
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## PIC Results: Phase Space



# Optimization

Accelerators have many free parameters: magnets, phases, dimensions, etc. Optimization is an alternative to brute force and hand tuning.



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## Computing resources available to you:

- LCRC-ANL: Bebop
- ORNL: Titan, Summit
- FNL: Local resources
- ALCF-ANL: Theta, Mira
- NERSC-LBNL: Edison, Cori
- ORNL: Titan, Summit



## Computer Jargon / typical hardware / software.

- Linux, KNL's
- slurm, torque, batch jobs

Let's do a demo? Sirepo and bebop.

```
nicole@nicole-XPS-13-9360:~$ ssh bebop
*****
* This machine accepts SSH public key only. +
* If you do not have a public key set up, you will not be able to login. +
*
* See http://www.lcrc.anl.gov/for-users/getting-started/ssh for more information. +
*****
Enter passphrase for key '/home/nicole/.ssh/bebop_key':
-----
          Notice to Users

This is a Federal computer system and is the property of the United States
Government. It is for authorized use only. Users (authorized or unauthorized)
have no explicit or implicit expectation of privacy.

Any or all uses of this system and all files on this system may be intercepted,
monitored, recorded, copied, audited, inspected, and disclosed to authorized
site, Department of Energy, and law enforcement personnel, as well as
authorized officials of other agencies, both domestic and foreign. By using
this system, the user consents to such interception, monitoring, recording,
copying, auditing, inspection, and disclosure at the discretion of authorized
site or Department of Energy personnel.

Unauthorized or improper use of this system may result in administrative
disciplinary action and civil and criminal penalties. By continuing to use
this system you indicate your awareness of and consent to these terms and
conditions of use. LOG OFF IMMEDIATELY if you do not agree to the conditions
stated in this warning.

-----
[neveu@beboplogin2 ~]$ █
```