Integrated Modeling Tool for Electron-Beam based Ion-Sources (EBIS)*

Phase II: 8/8/12 – 2/7/16

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EBIS Modeling tools (**PBGUNS, CHASER** and **EBIS-PIC**)
     Charge-Breeding Modeling tools
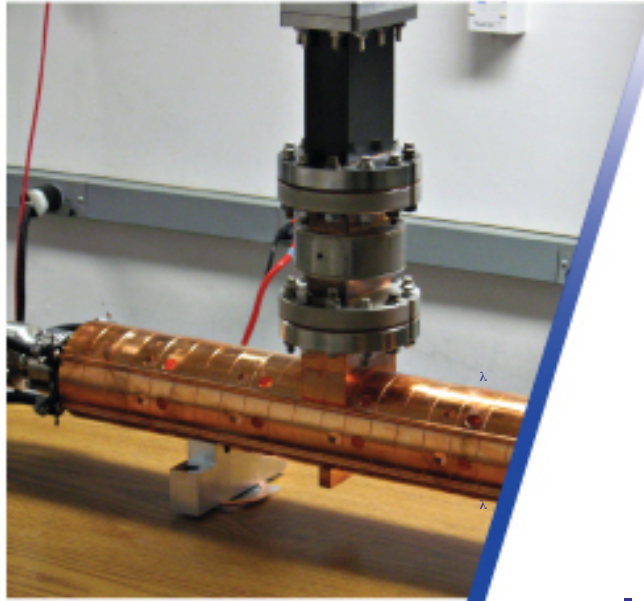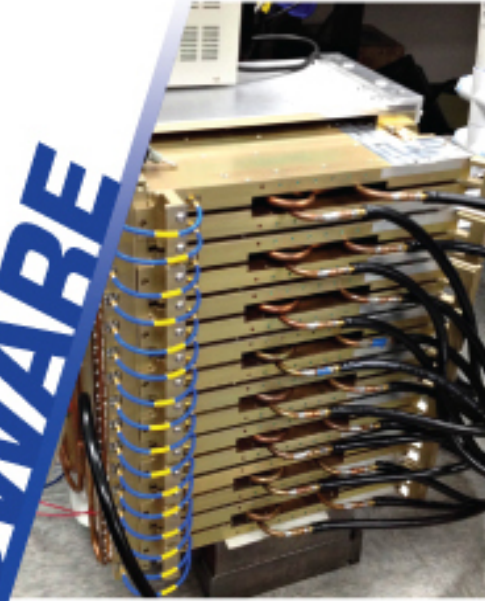   Injection and Extraction

Highlights of Recent Progress

Summary

FAR-TECH, Inc. Management and Facility
(Fusion and Accelerator Research)

- **Located in San Diego, CA**

- **Founded in 1994, to pursue fusion and accelerator related science and technology.**

- **Core staff of about 10 PhDs Physics/Engineering**

- **Facility:**
  - **Linux cluster**
  - **RF, UHV, laboratory and assembly**

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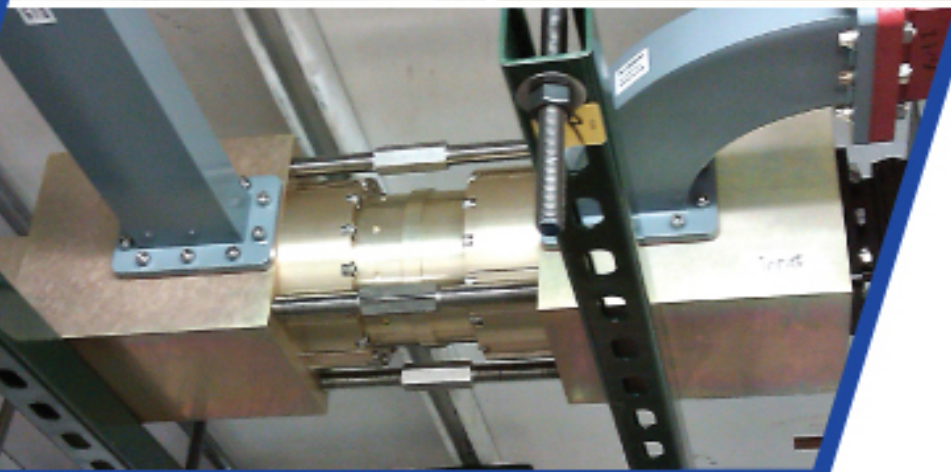
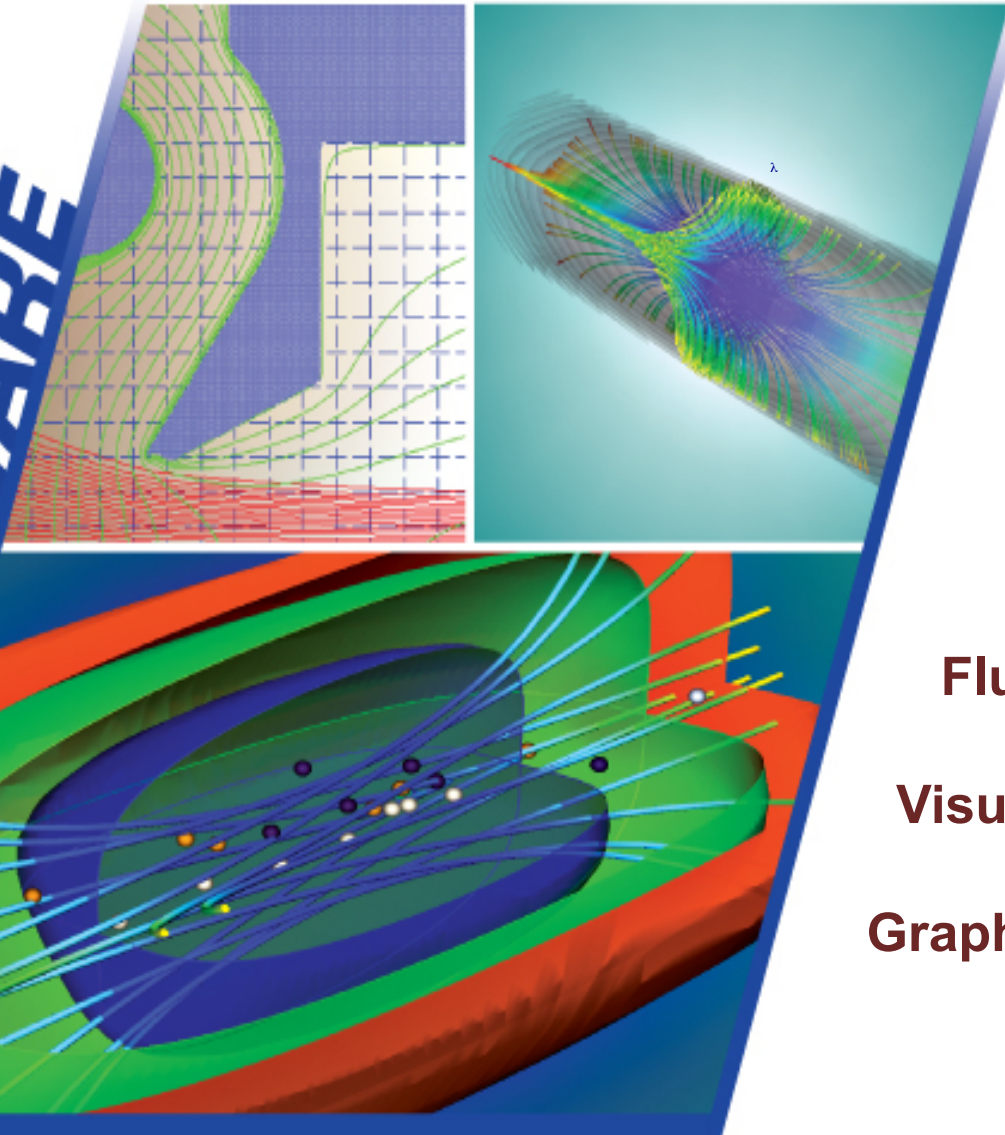**Linac Systems:**

Structure

RF source

Integration

Beam Instrumentation

Solid State Amplifier

Modeling tools for:
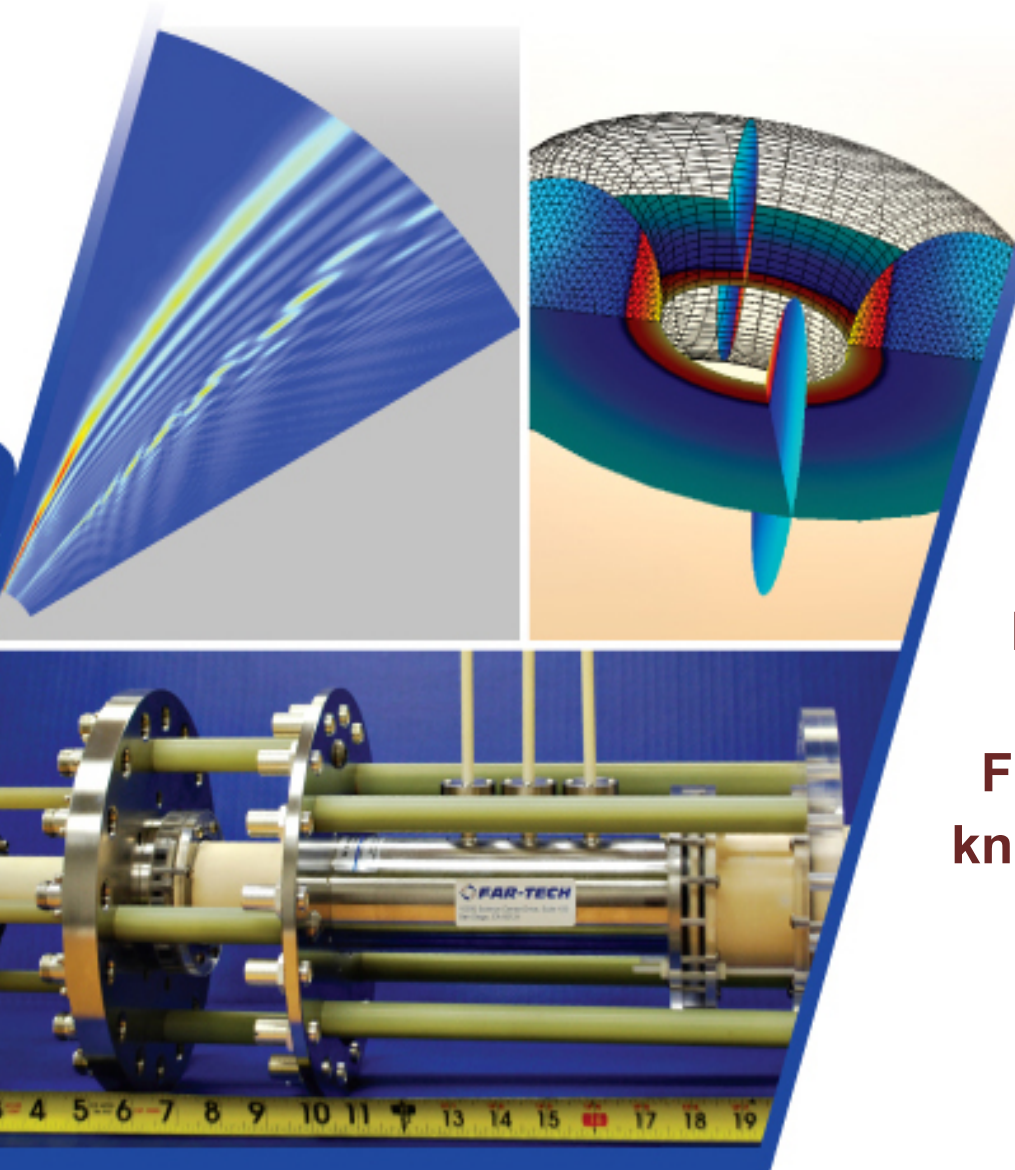
λ **Plasma**

λ **Beam**

Ion source

Fluid & PIC Simulations

Visualization

Graphical User Interface

New technique

New devices

New diagnostics

Fundamental knowledge discovery

Project Overview
Integrated Modeling Tool for Electron-Beam based Ion-Sources (EBIS)

**Project period**: 8/8/12 – 2/7/16 (no-cost extension)

Goal: Develop a numerical tool to help current operation of EBIS and new design.

NP Relevance: EBIS is a leading technology for HCIs which are needed for NP studies. Our modeling tool helps optimize current device operations and will assist the design of future devices. Extremely important for RIBs as experimental trial-and-errors must be minimized.
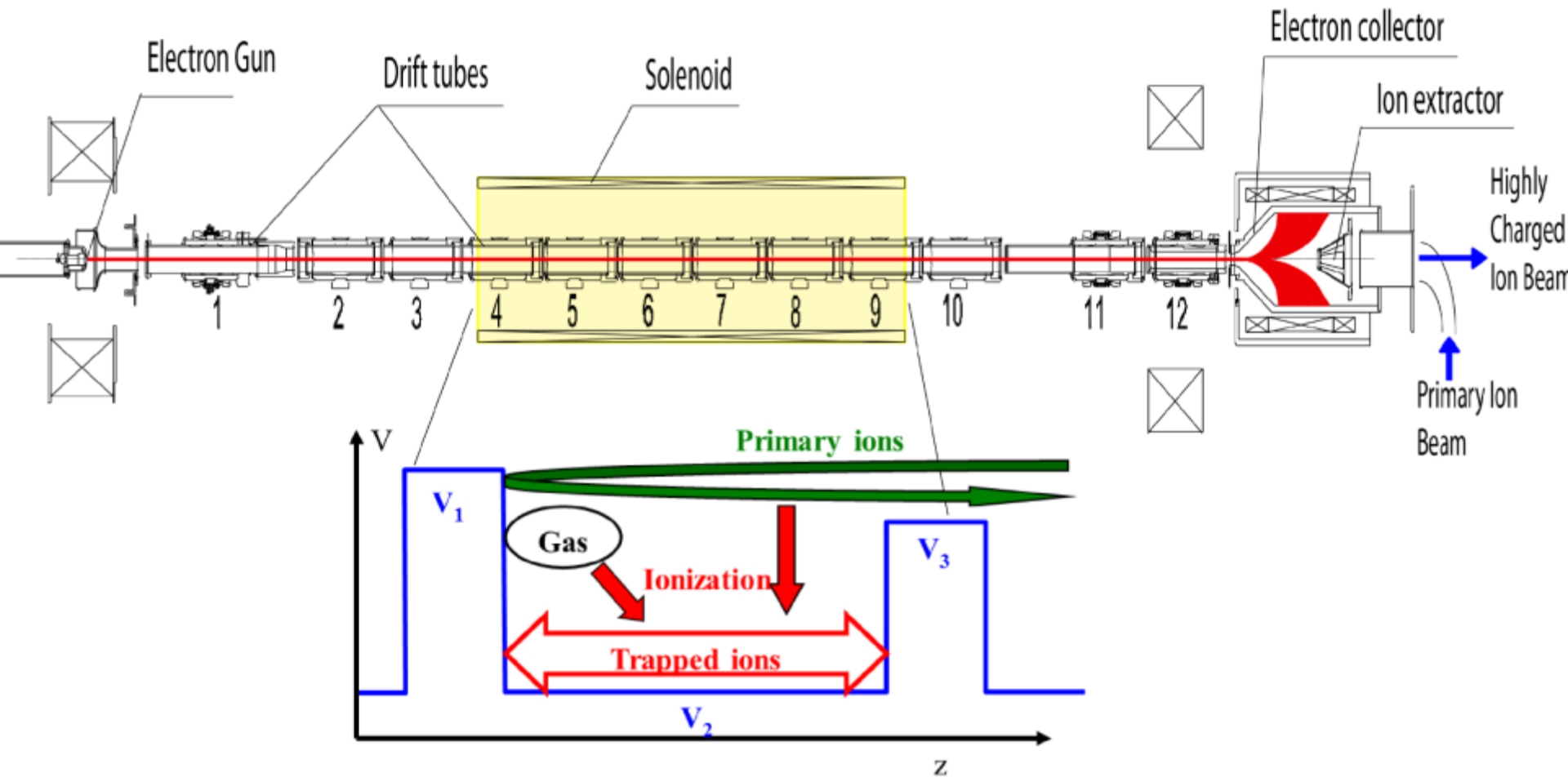
Status: Most of the objectives are met.

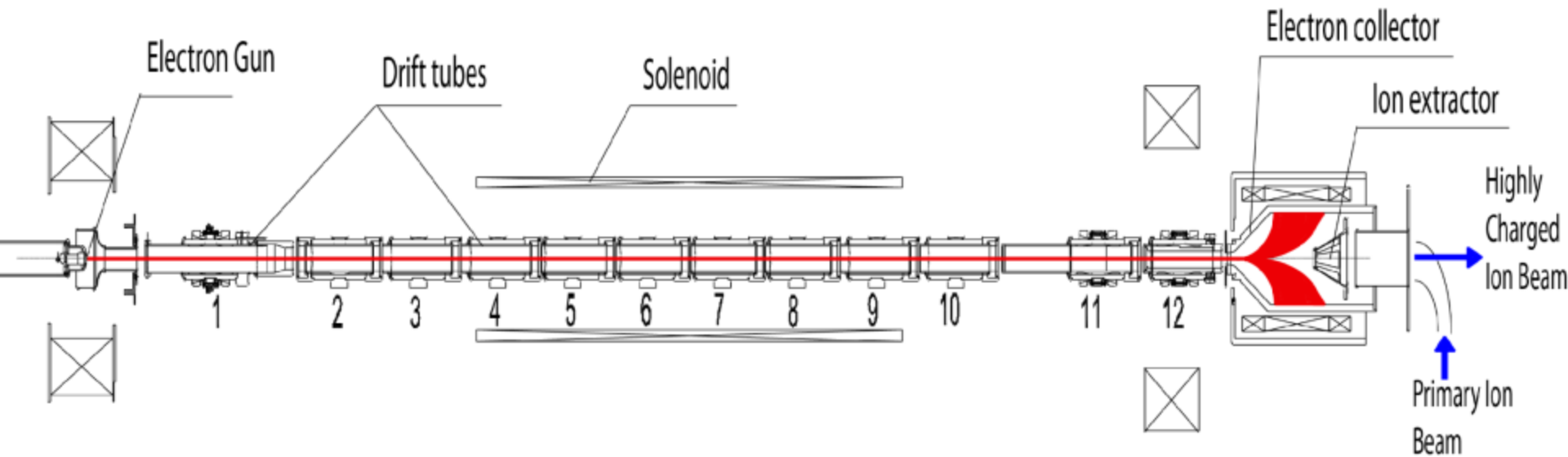**Remaining work**: Finalization with more validation, speedup and GUI

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Brief description of EBIS

Radial potential
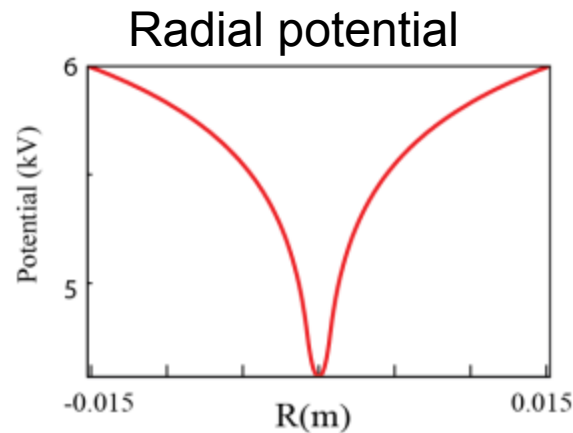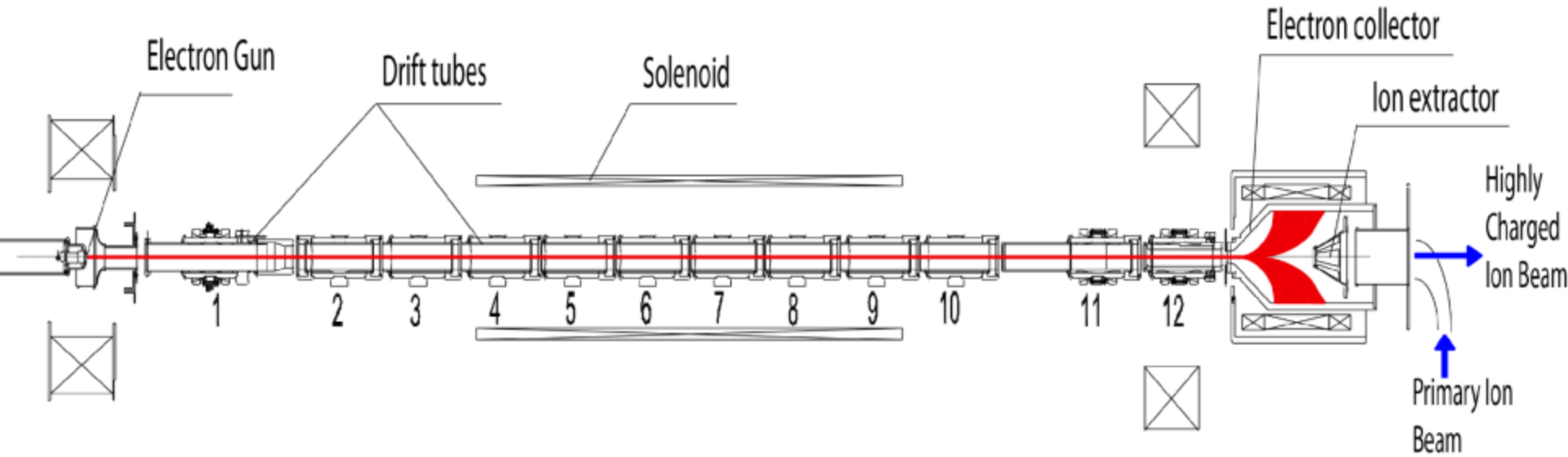
Brief description of EBIS

Optimization of EBIS Performance

How to enhance trapping efficiency?
How to enhance charge-breeding efficiency (RIBs)?
How to maximize the overlap of the primary ion beam (typically +1) with the electron beam?

How to create large extracted ion beam current?

…Depends on electron density, energy, injected ion energy and emittance, and so on.

EBIS Simulation has many numerical challenges:

Multi scale modeling:

electron dynamics time << ion dynamics

radial dimension << axial dimension

electron beam radius << device radius
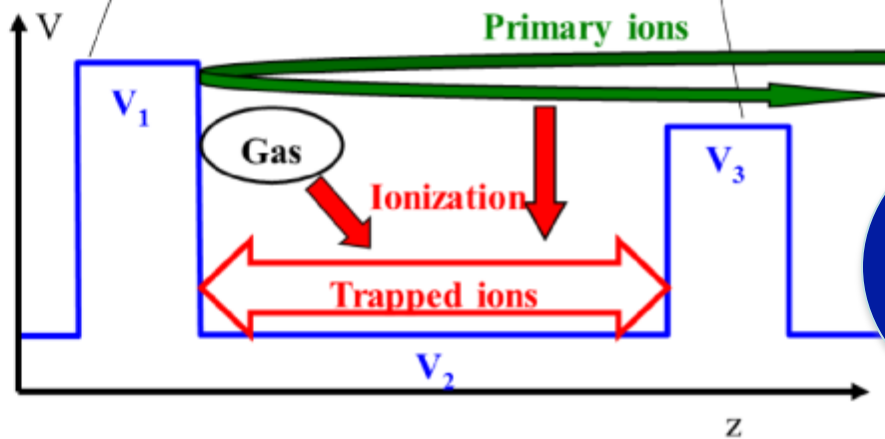
Charge breeding:
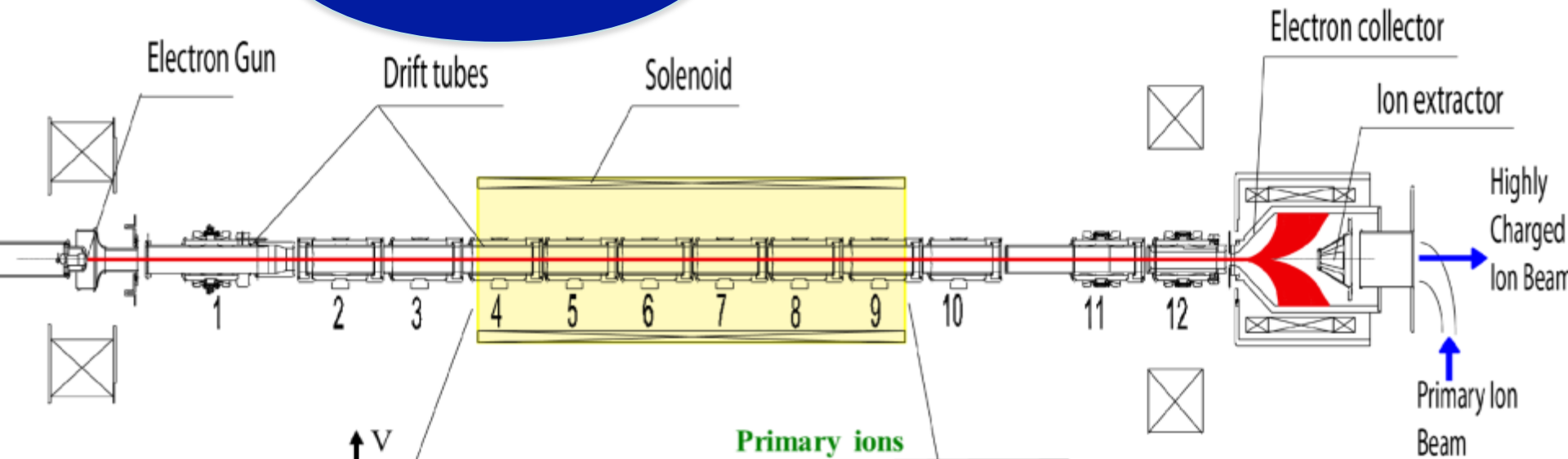
produces multi-species

long confinement

multi physics components required

Required CPU time is extensive.

**MODULARIZE SIMULATIONS IN SECTIONS
LOWER DIMENTIONAL TOOL WHEN APPROXIMATION VALID**

**PBGUNS for e-beam**

EBIS-PIC for charge breeding

EBIS-PIC modeling

**Electron and ion space charge modeled self-consistently.**

Important atomic processes are included via Monte Carlo collision algorithm. They include:

- **- Ionization**
- **- Charge exchange and recombination**
- **- Radiative recombination**
- **- Coulomb collisions of primary ions with electrons, amongst primary ions, and with neutral gas ions**

Charge breeding models in lower dimensions

Primary Ion beam
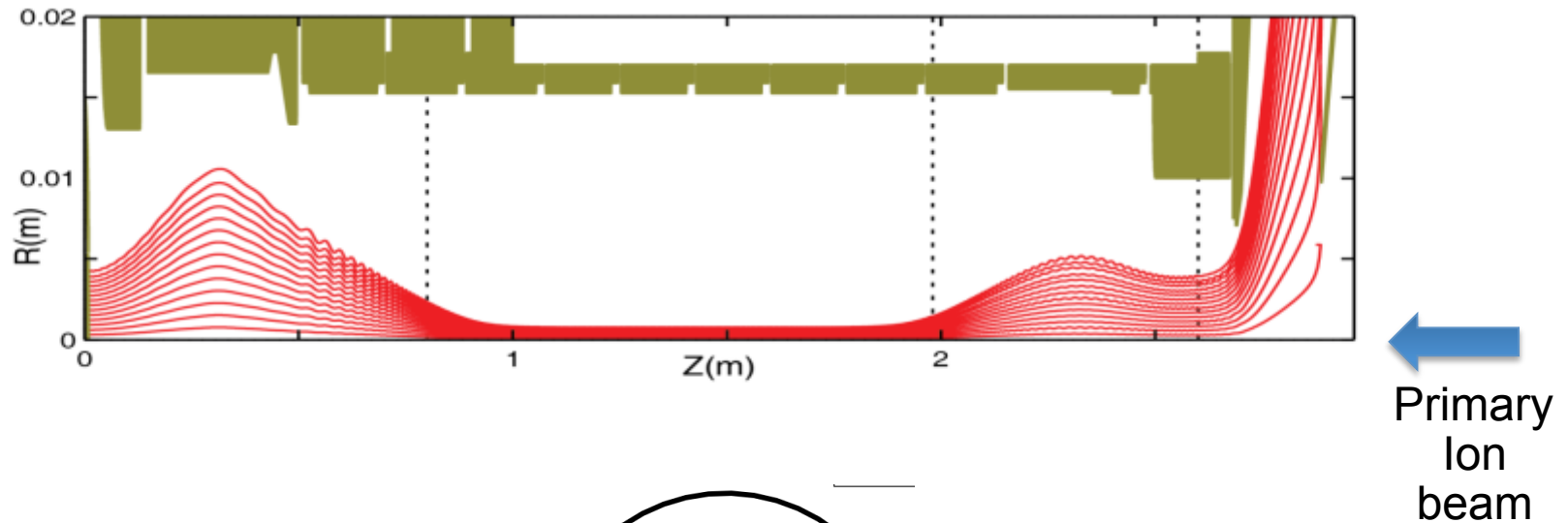
Need to consider required CPU time
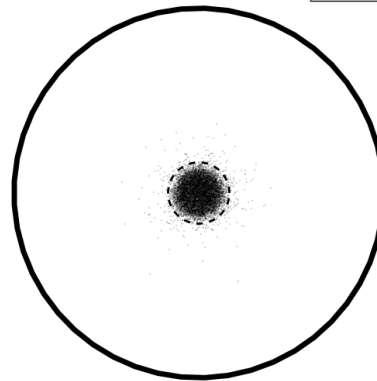
CHASER - 0D

EBIS-PIC - 1D

EBIS-PIC - 2D

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Radial dependence alone (1D) can provide significant info needed for EBIS design and experiments

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=> Space-charge self-consistent simulation is needed

$\Rightarrow$ **EC-PIC (Energy conserving -PIC) removes grid-heating problem, and can perform space-charge self-consistent PIC simulations with a relatively small number of numerical particles.**
Allows PIC-simulations less CPU-intensive even for highly-neutralized regime, where unrealistically large number of numerical particles are needed in standard PIC.

Highlights of Recent Progress

Improved model with 0D charge state model – CHASER

Improved algorithm for EBIS-PIC 1D model –
**Can simulate neutral regime and longer breeding time**

Simulation of ion Injection, charge breeding and extraction can be modeled using PBGUNS and EBIS-PIC 1D and 2D
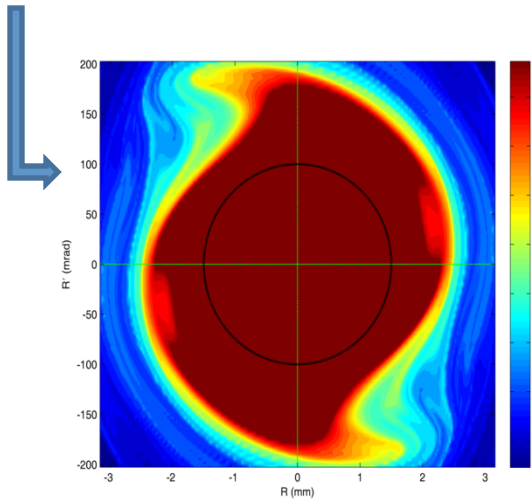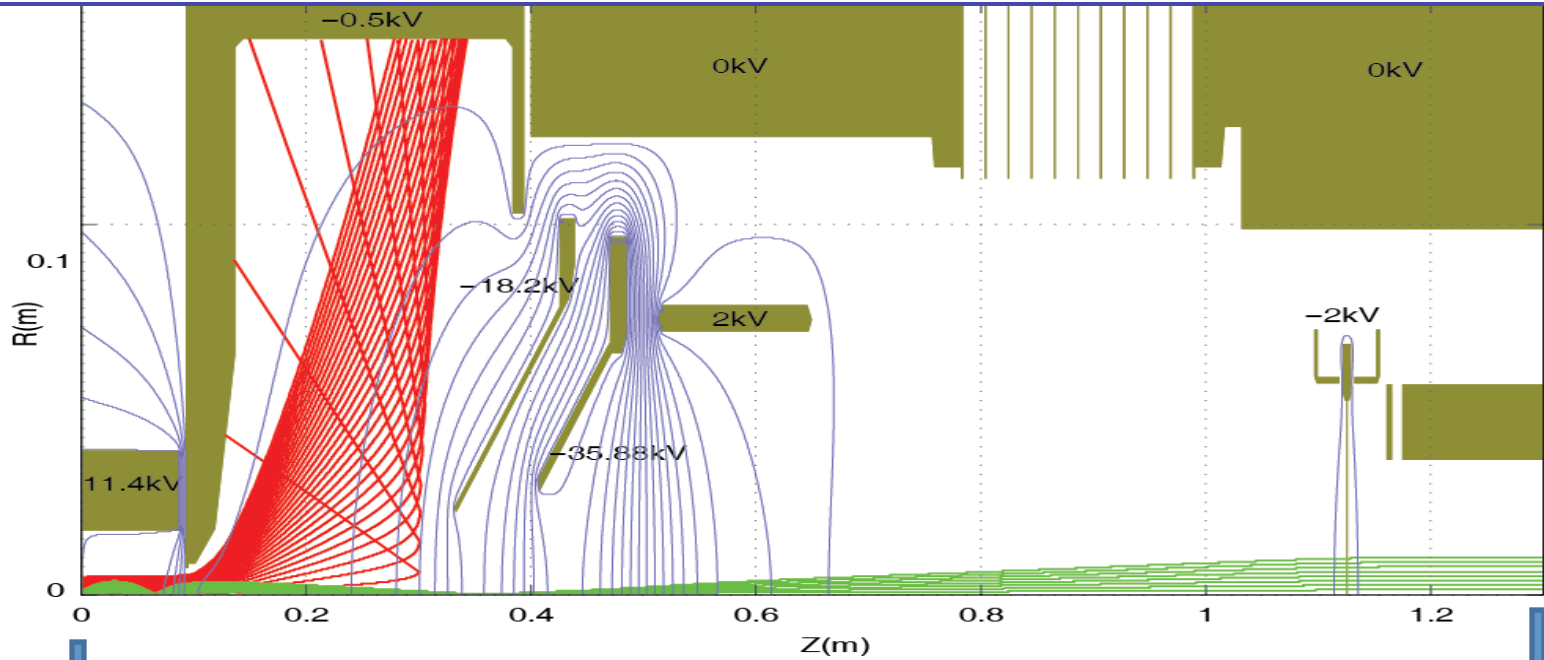
Experimentally relevant parameter study possible

GUI for EBIS-PIC is in progress

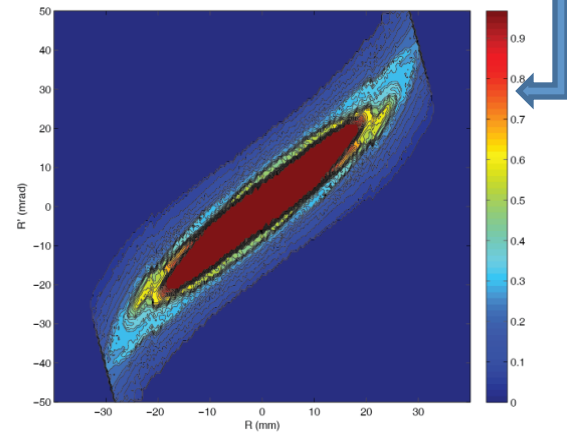# Neutral regime simulation : CSD and radial profiles and dynamics simulated by EC EBIS-PIC

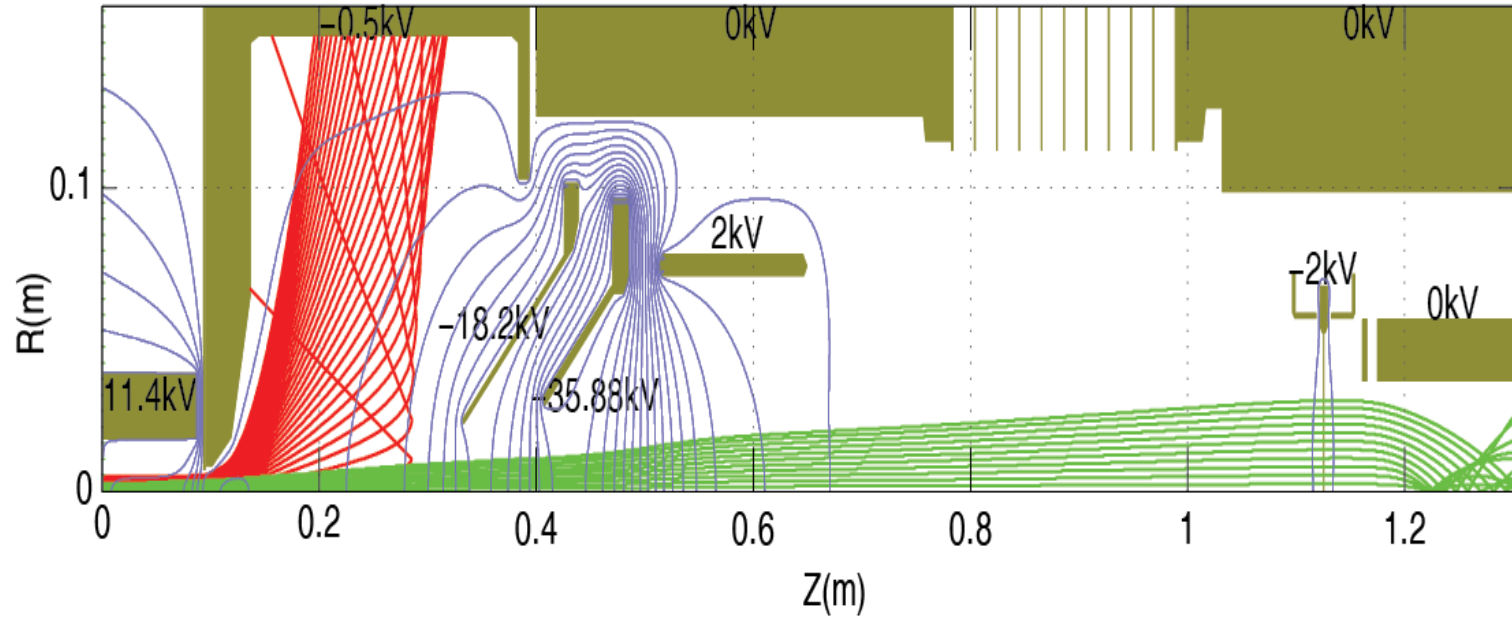Cs^{1+} beam: $I_{electron\ beam} = 7.5A$
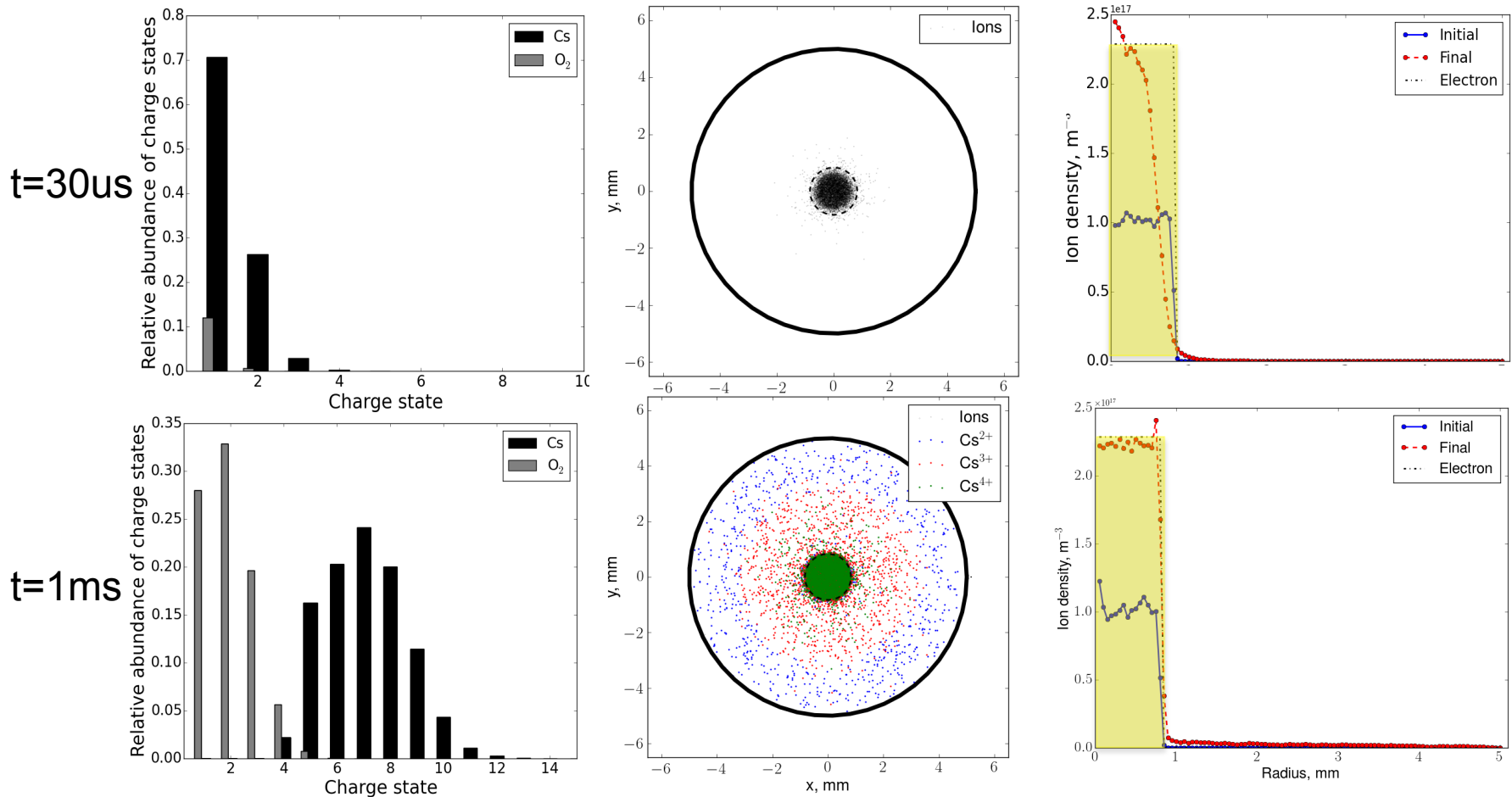
Ion injection simulation possible (PBGUNS + EBIS-PIC 2D)

Acceptance at two positions
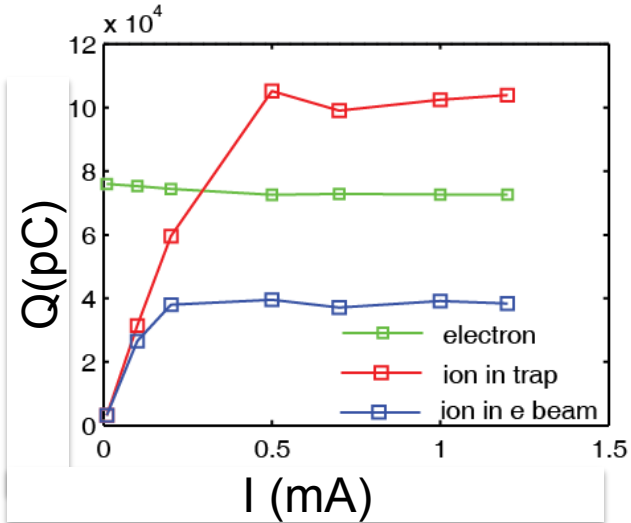
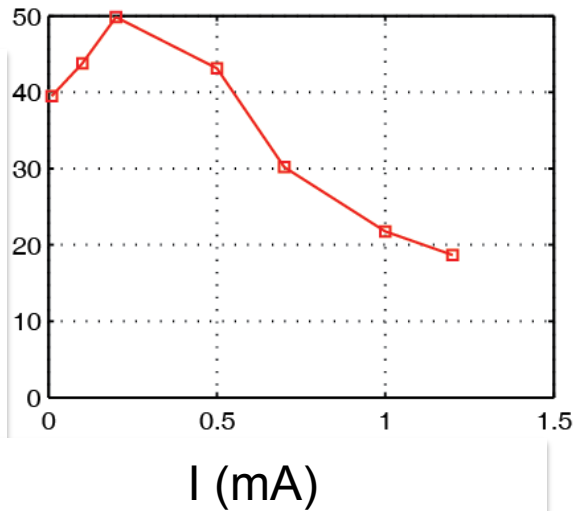# Self-consistent extraction simulation possible: PBGUNS
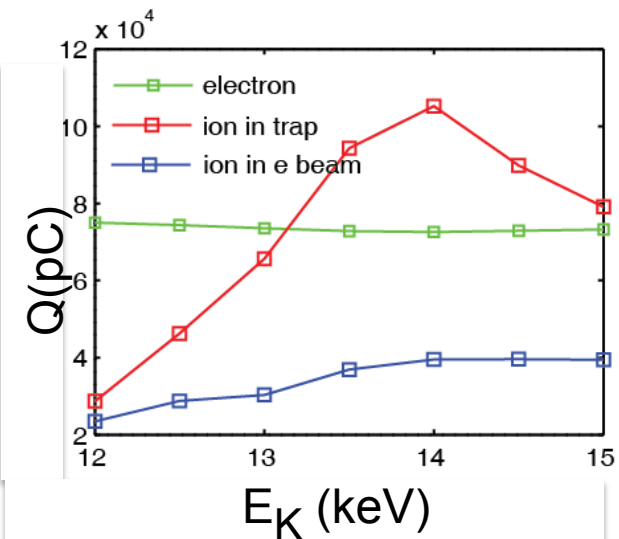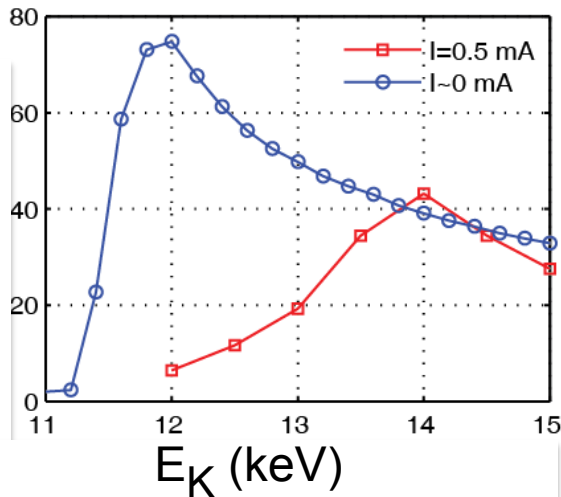

Au 32+ extraction simulation:

Parameter study is possible:
eg, Ion Trapping Efficiency and Charges vs Input Ion Current

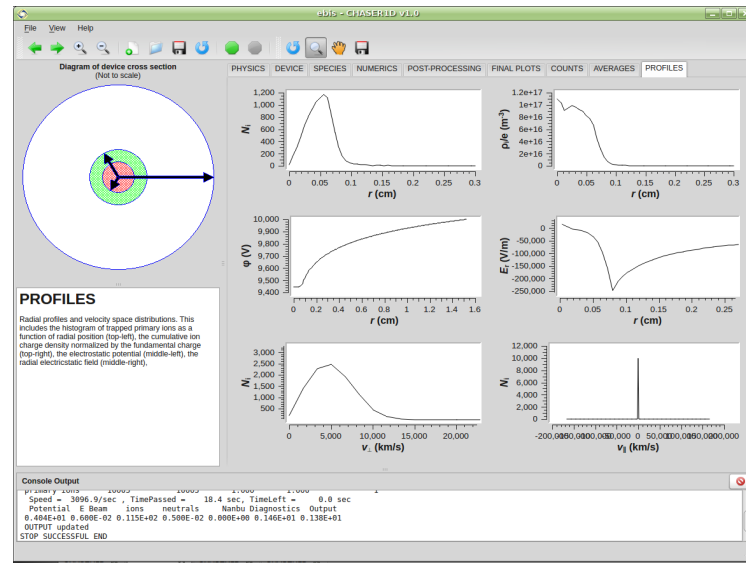# GUI developed for CHASER and EBIS-PIC 1D (shown below)
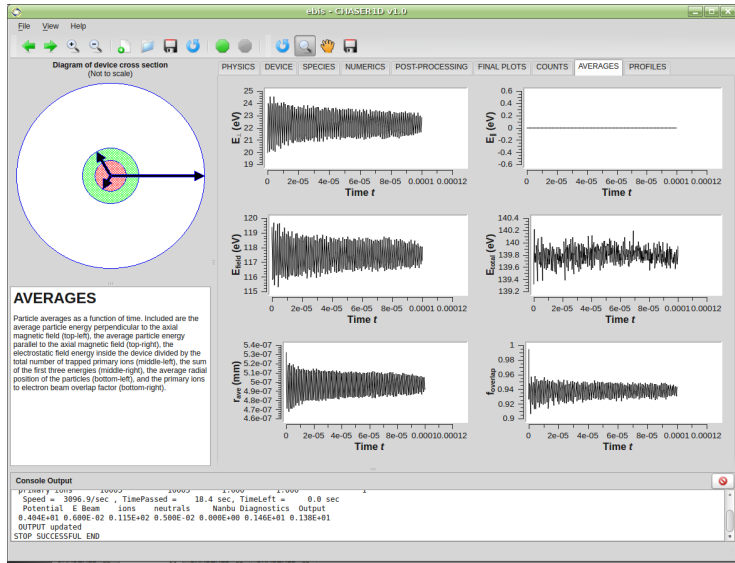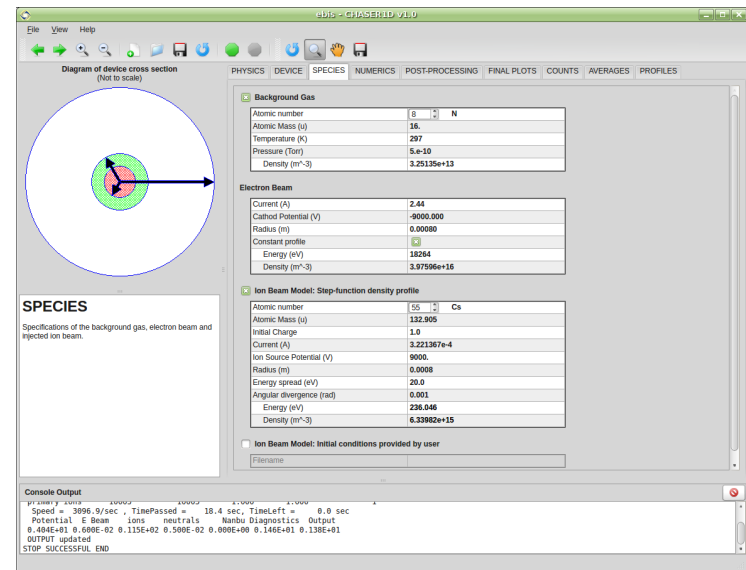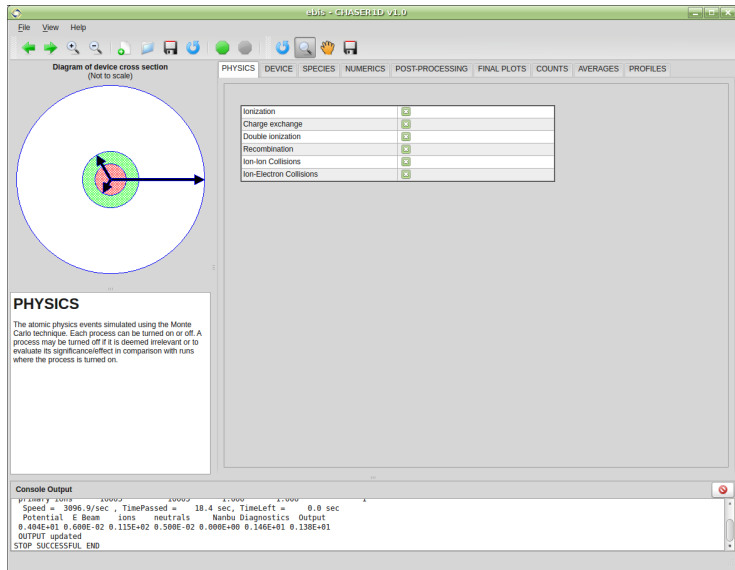
Summary: EBIS Simulation Procedures
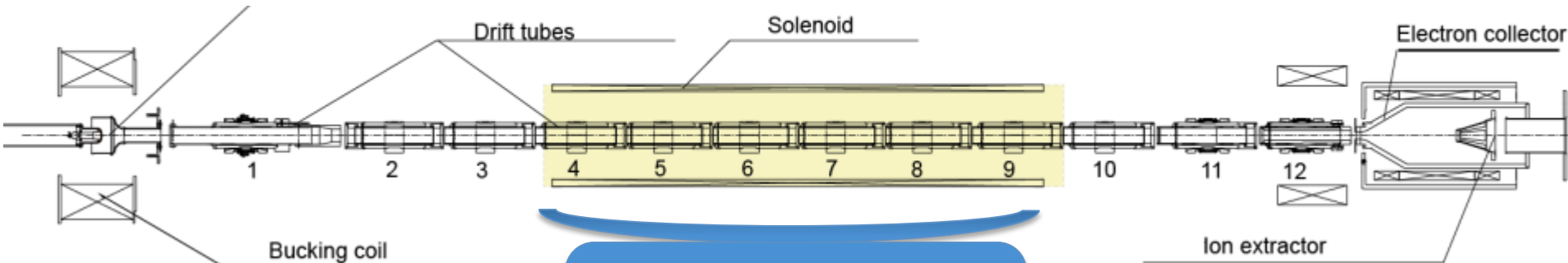
1. Electron beam:
PBGUNS

1D (r) geometry
1D fields
2D particle pusher

2D (r,z) geometry
2D fields
3D particle pusher

3. Charge Breeding:
EBIS-PIC 2D for a short time,
until ions become
approximately uniform in z,
then **EBIS-PIC 1D**(r)

2. Ion injection:
EBIS-PIC 2D (r,z)

4. Ion Extraction:
PBGUNS

Summarizing, FAR-TECH's EBIS modeling tool consists of:

PBGUNS (particle beam gun simulation code) :
   Most 2D beams can be simulated.
   Input parameter GUI with geometry viewing

CHASER: Charge State Estimator (0D) – good basis as a start
   Freeware: request to support@far-tech.com

EBIS-PIC:
   1D – long time charge breeding (> tens of ms)
   2D – short time charge breeding (< tens of ms)

PBGUNS
Version 5.1
Particle Beam Gun Simulations

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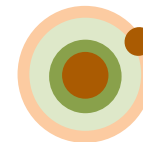http://www.far-tech.com/pbguns

CHASER v1.0

CHASER, the CHArge State EstimatoR, simulates the time
Evolution of charge states of ions in charge breeders.

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www.far-tech.com/chaser

EBIS-PIC

EBIS-PIC simulates
Ion charge breeding

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