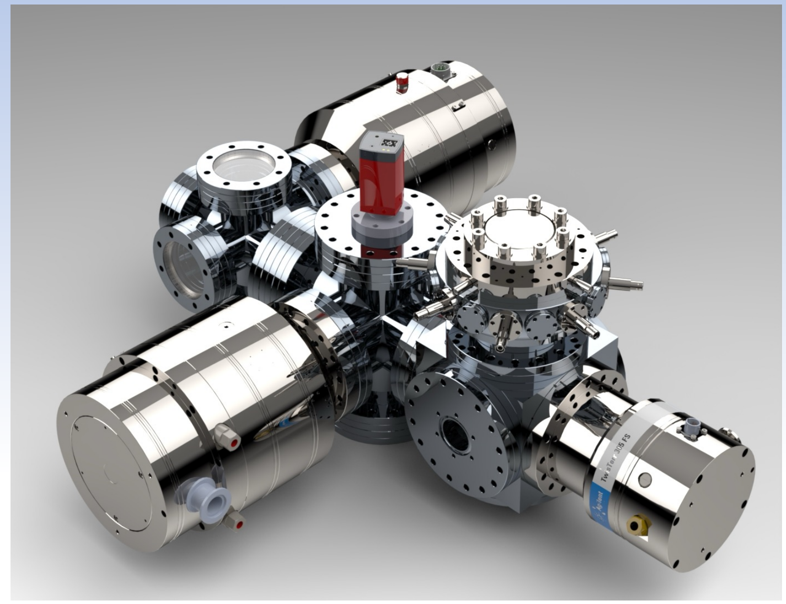
E-322:
Gas Sheet Viewscreen Progress Update

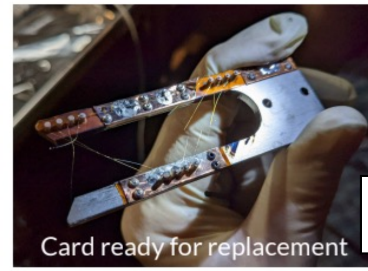


G. Andonian
FACET–II User Meeting
October 17-19, 2023
SLAC

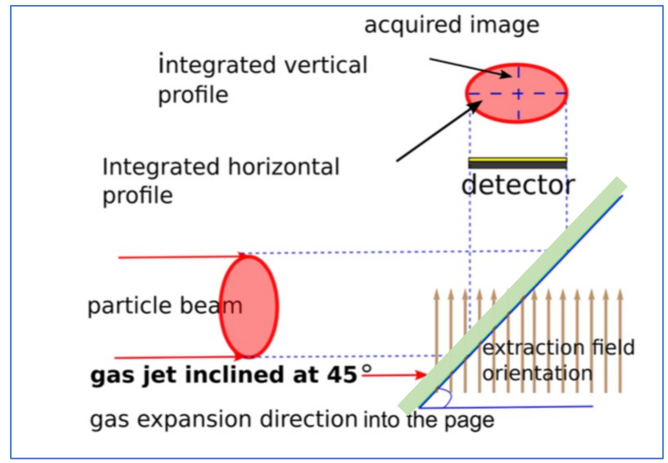
UCLA SLAC radiasoft UNIVERSITY OF LIVERPOOL RadiaBeam

Background

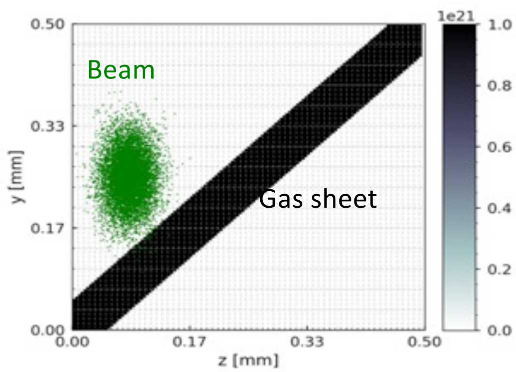
- High-intensity beams present unique challenges in transverse profile diagnostics
- Single-shot, regenerative diagnostic for FACET-II
  - Non-destructive
- "Gas sheet ionization viewscreen"
  - Generate a gas sheet, or "curtain" w/ nozzles and beam skimmers
  - FACET e-beam ionizes neutral gas
  - Ions imaged by an "ion microscope"
  - Resolve high-intensity beams with reconstruction algorithm



"Consumable diagnostics"
M. Hogan



Y. Hashimoto, et al, Proc. PAC 2001, Chicago, USA (2001)
V. Tzoganis, et al, *PRAB* **20**, 062801, 2017



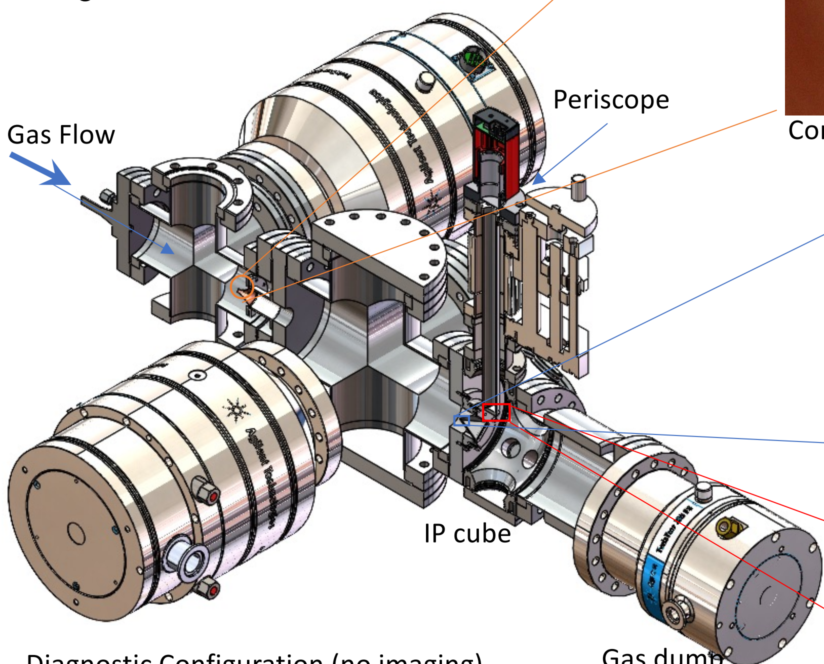
Main science goal: Test Gas Sheet Viewscreen at FACET-II
- Compare to available diagnostics at 'lower' intensity
- Use at highest intensity as online viewscreen

Status

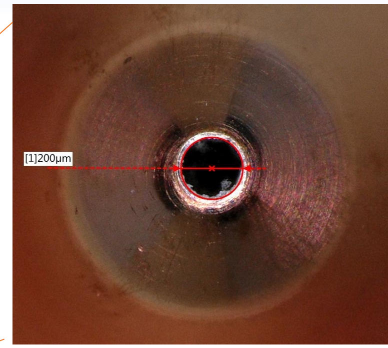
- Experiment E-322: offline progress since last meeting
  - Bench top tests for gas curtain
  - Electrostatic column PS for imaging upgraded
  - Beam tests with low charge at UCLA Pegasus shows GSM results in a reduced geometry
  - Need to solve a few engineering issues to make it FACET-II compatible
    - remote control

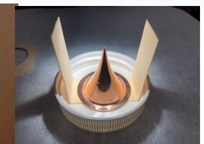
Gas Sheet Generation on bench

- Benchtop tests (from 2020-21)
  - “fast” valve + nozzle (40-400μs, < kHz)
  - Fast recovery of vacuum after gas sheet operation (N_2)
  - various skimmer sizes (200μm → 4mm)
- Vacuum recovery at Hz rep rate
- Agrees w/ Molflow simulations

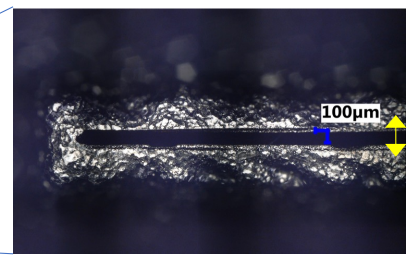


Diagnostic Configuration (no imaging)



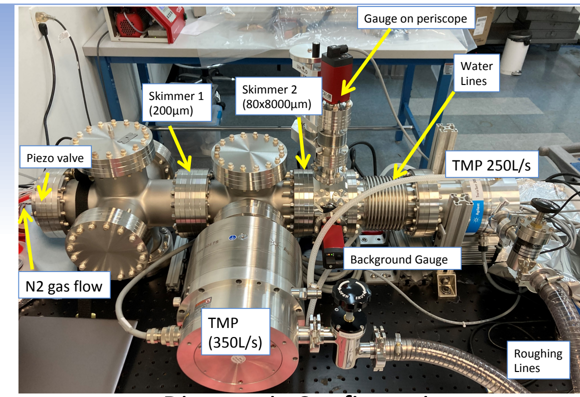


Conical skimmer

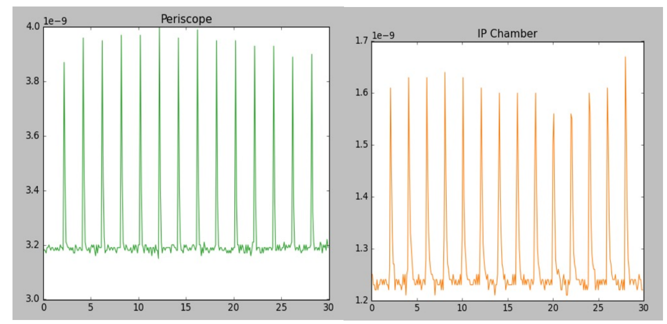


‘Shaper’ (rectangular 100μm x 8mm)

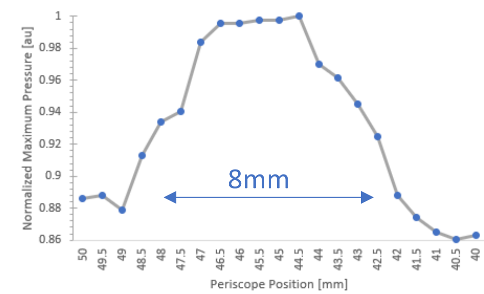
1mm “Bulldozer” Collector



Diagnostic Configuration



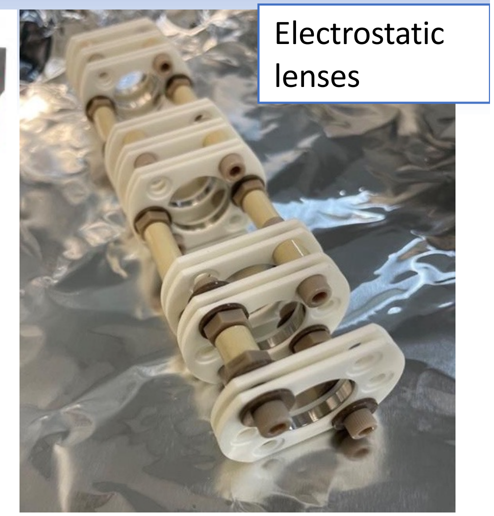
Vacuum Readings @ 0.5 Hz

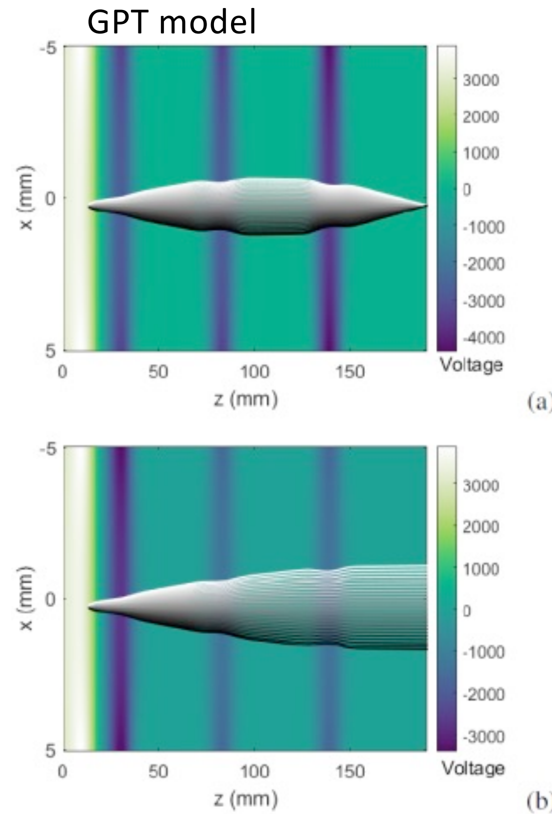


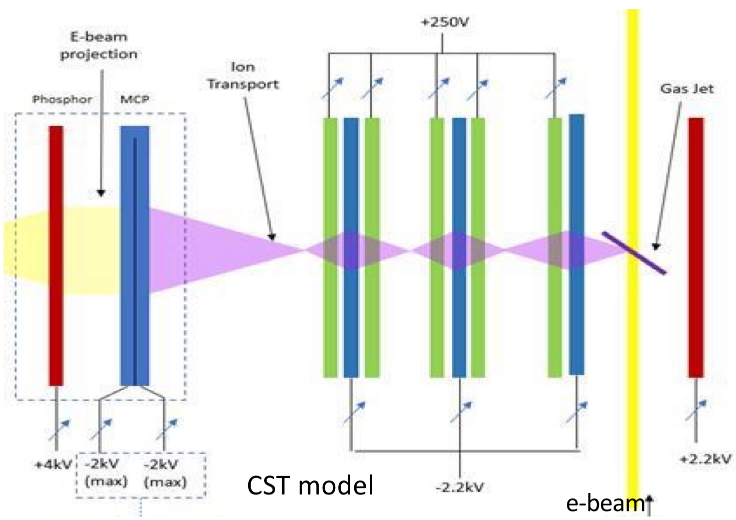
Gas Profile at Diagnostic

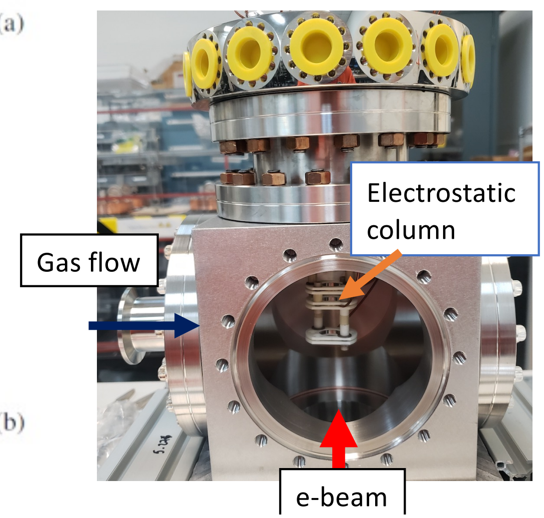
Ion Extraction Column - Design

- Transport and magnify generated ion beam to Micro-Channel Plate (MCP) detector
- Simulated fields and ion beam transport in CST, GPT
- Fine-tune magnification imaging ability with ions from laser field ionized gas
- Design magnification: 4x
- Individual controllable lenses offer flexibility
  - Velocity mapping mode
  - Electron detection







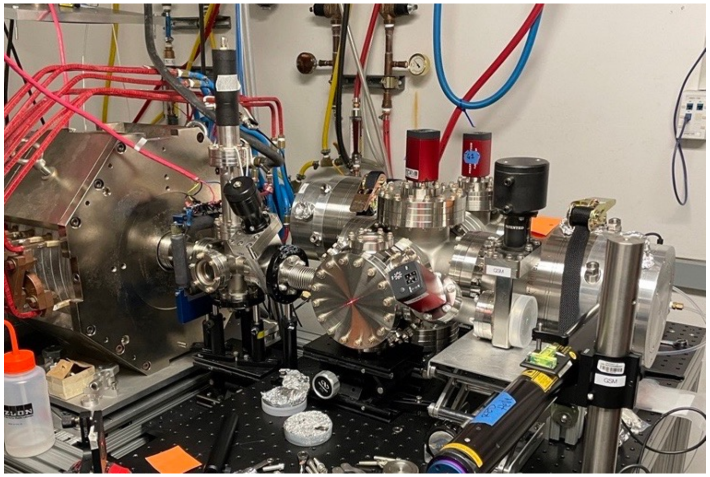


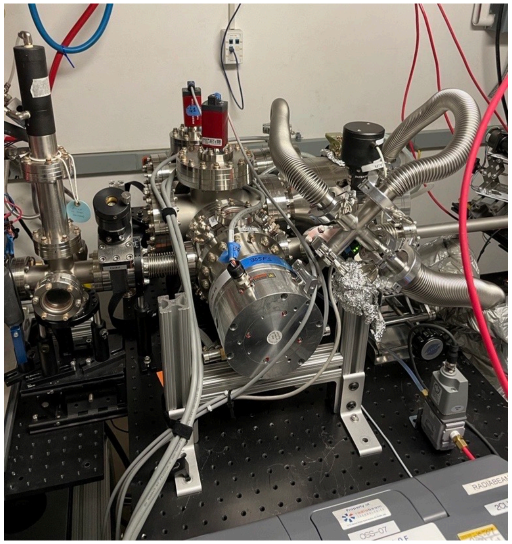
Commissioning at UCLA

- UCLA Pegasus beamline (E_b = 7 MeV)
  - Validate results with well-diagnosed beams
  - Impact ionization gives beam footprint
  - Resolvable on MCP/phosphor
- Status
  - Ion microscope tested on dedicated laser stand prior to beamline install
  - Installed on beamline, vacuum <E-9
  - Tests w/ e-beam but simplified gas delivery setup

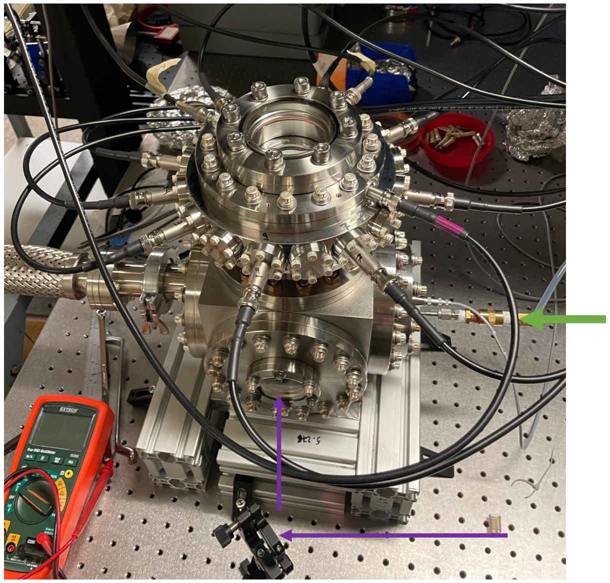
Pegasus Beam
$\sigma_x = \sigma_y$ = 40 µm
σ_z = 200 µm
Q = 0.1nC

Gas Sheet
n_{N2} = ~10^{13} cm^{-3}
L_{N2} = 3 mm





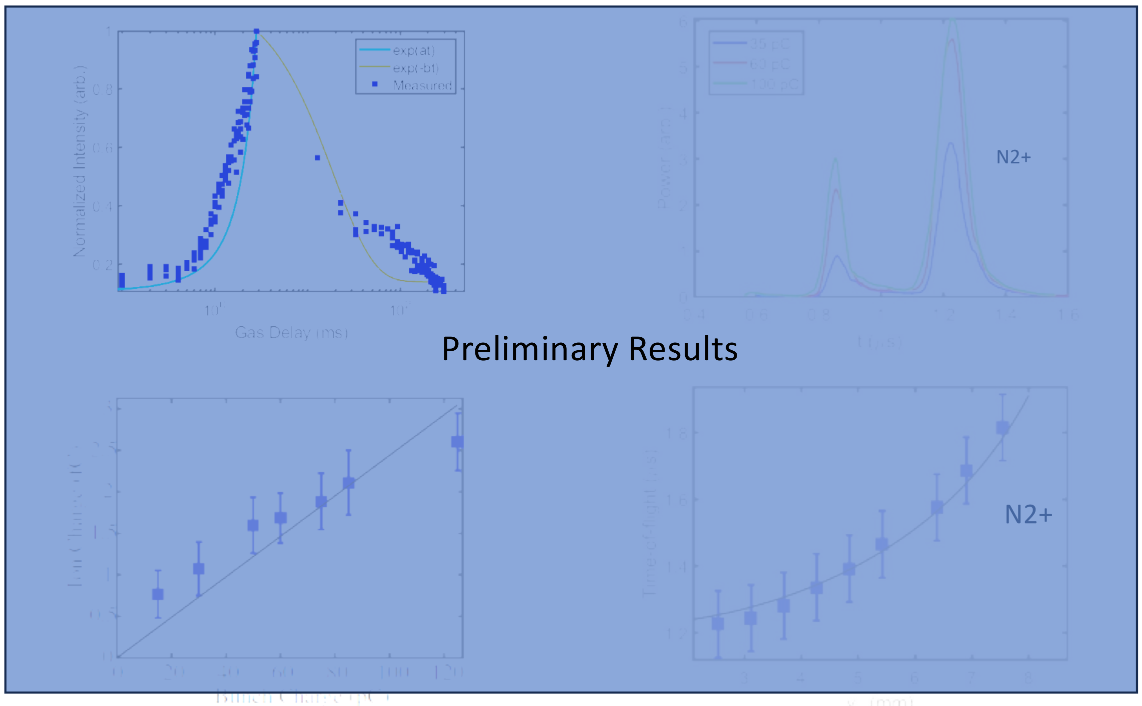
GSM at Pegasus

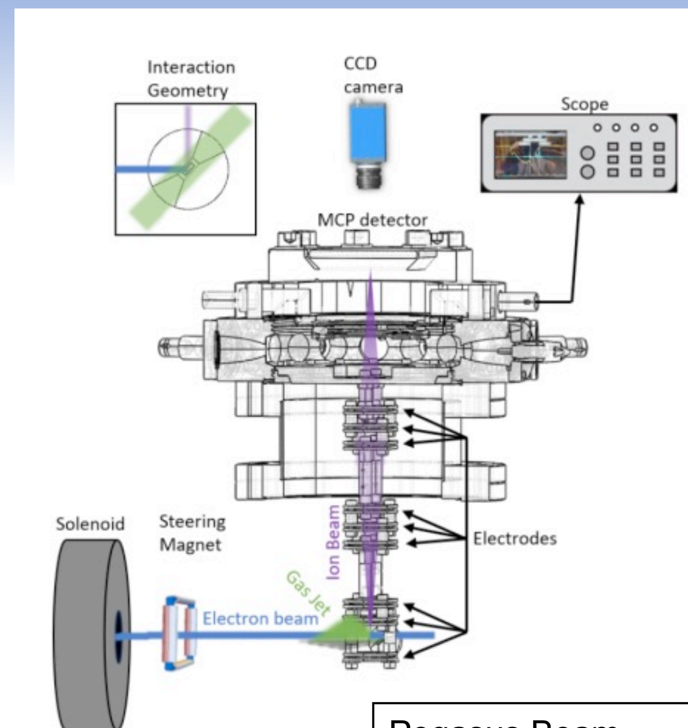


Microscope Commissioning w/ laser

Commissioning at UCLA Pegasus

- Two main outputs:
  - ion MCP image + oscilloscope trace
- Time-of-arrival gives q/m for ions.



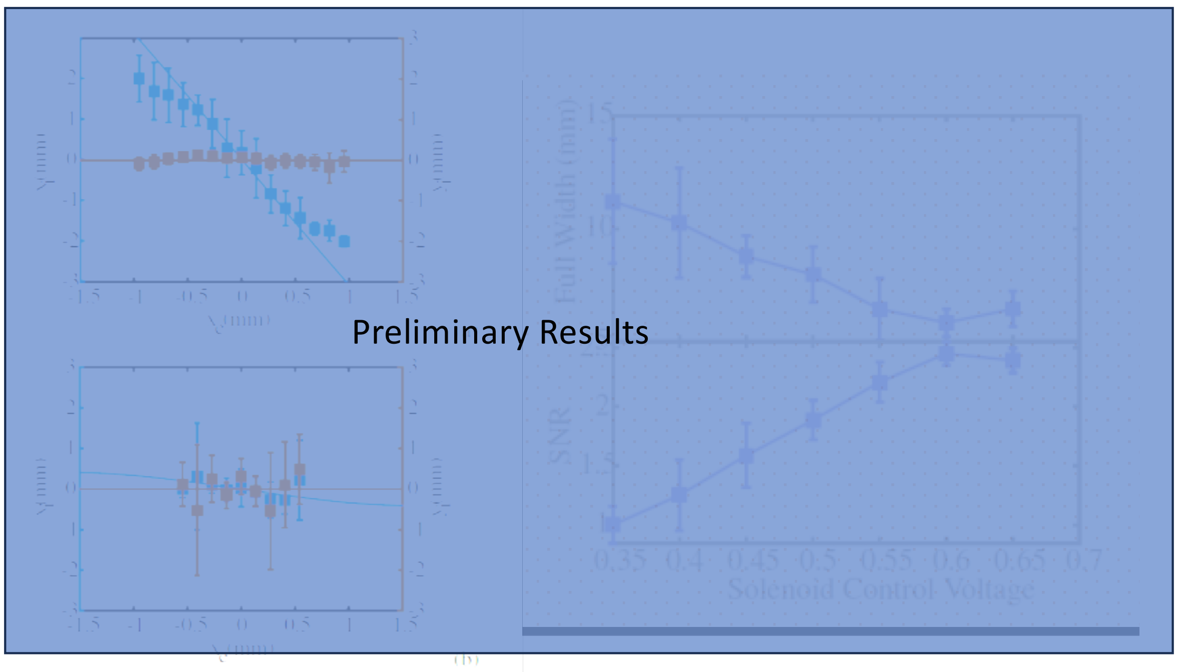


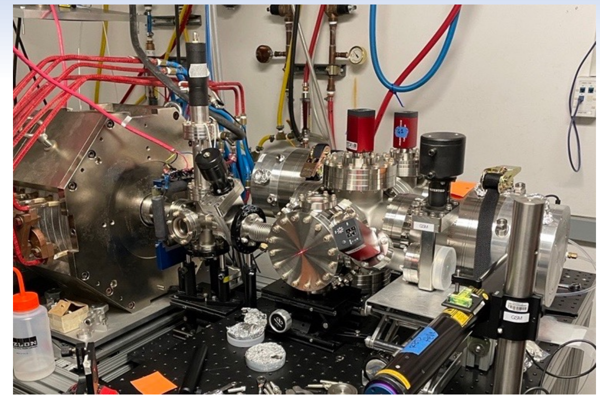
Pegasus Beam
$\sigma_x = \sigma_y = 40\ \mu m$
$\sigma_z = 200\ \mu m$
Q = 0.1nC

Gas "Sheet"
$n_{N2} =\sim 10^{13}\ cm^{-3}$
$L_{N2} = 3\ mm$

Imaging and transverse profile results

- Skimmer removed -> gas jet, not 45 degree curtain.
  - Only one dimension is relevant
- Set up lenses for imaging (M = 4)
- Velocity mapping configuration also demonstrated
- Vary solenoid and measure transverse spot size





GSM installed on Pegasus beamline

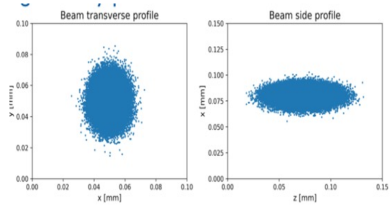
Ionization yield increase due to overlap between input beam and gas jet

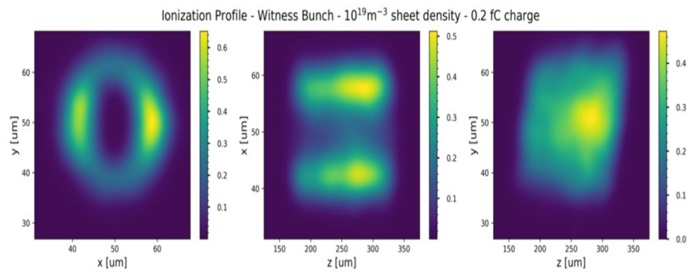
Field ionization contribution minimal in this setup, but will be important for FACET-II.

Ionization Dynamics - FACET II

Configuration 1: drive/witness

Q = 0.5nC
σ_x= 5µm,
σ_y = 7.5µm,
σ_z = 14µm



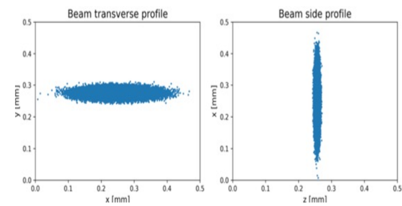


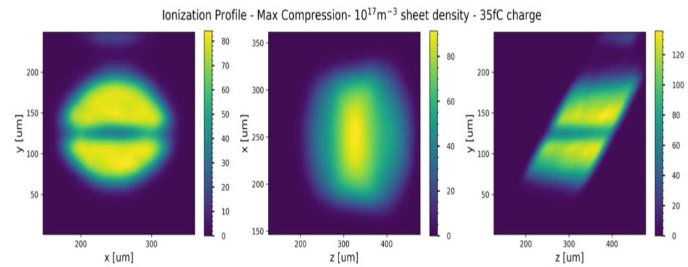
N_2 gas sheet
Density = 10^{19}m^{-3}
Thickness = 150µm
Q_{ions} = 0.2 fC (10^3 ions)

- Lower end of acceptable statistics
- High gain MCP
- Thicker gas sheet?

Configuration 2: max compression

Q = 1.4 nC
σ_x = 49µm,
σ_y = 8.5µm,
σ_z= 3.5µm





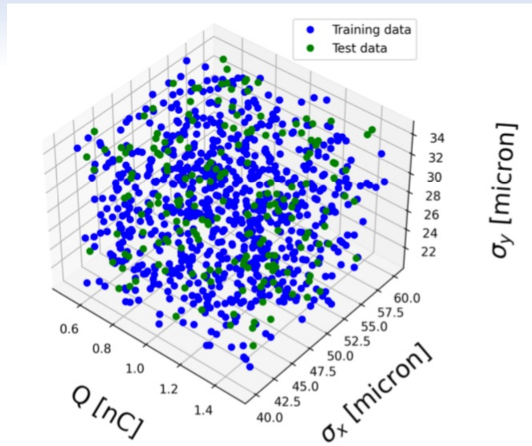
N_2 gas sheet
Density = 10^{17}m^{-3}
Thickness = 150µm
Q_{ions} = 35 fC (>10^5 ions)

- Substantially larger yield
- Reduced densities
- flexibility
- Gas sheet tunability

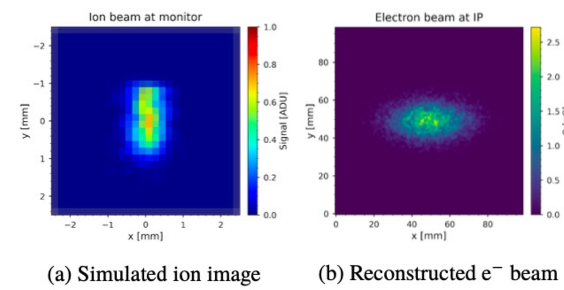
WARP simulations: Field ionization at high beam intensity

Profile Reconstruction

- Test data for surrogate model (WARP)
  - Variances in Q, σ_x, σ_y, σ_z, n_p
- Simulated ion image is used as input to a convolutional neural network (CNN) for reconstruction
- Robust performance of CNN
- Further enhancement when constraints enforced (e.g. from experimental measurements)



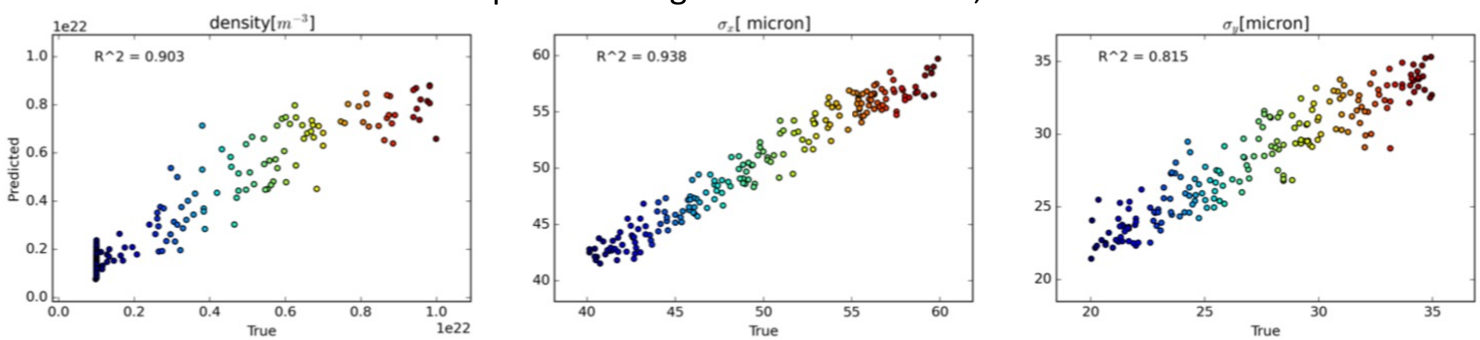
3D parameter space



(a) Simulated ion image (b) Reconstructed e^- beam

Sample reconstruction

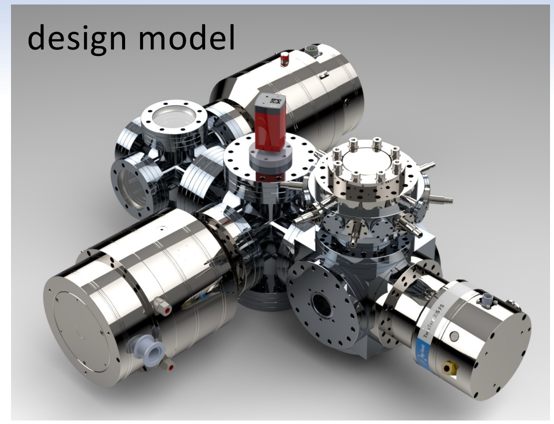
Performance plots: surrogate model vs truth, and relative R^2 values

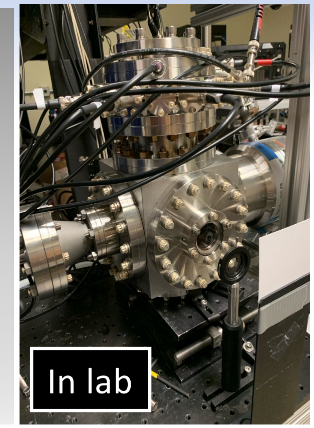


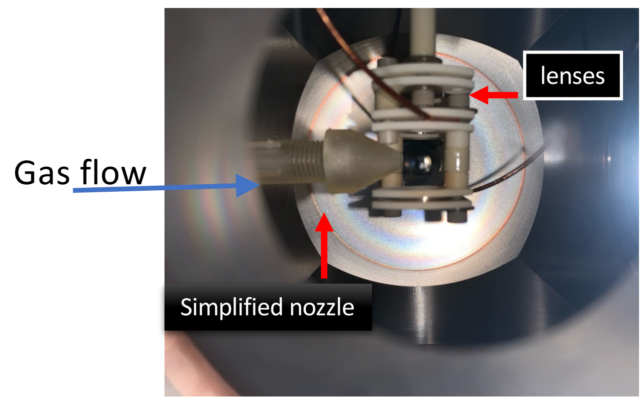
Reconstruction algorithm trained to deconvolve field-ionization profile information

Next steps for FACET-II

- Resetting of electrostatic lenses
  - Accidental charging takes long time to dissipate
  - May be solved by switching polarities
- Timing of $N2^+$ vs $N2^{++}$ / N+
  - focusing depends on q/m so both species will convolute
  - need to gate for one species
- Power supply location in tunnel
  - Local shielding?
- Gas sheet revitalization
  - Used simplified gas delivery
  - Turbo pumps may need service ($)
- Revisit simulations as new FACET-II parameters become available
  - Magnification



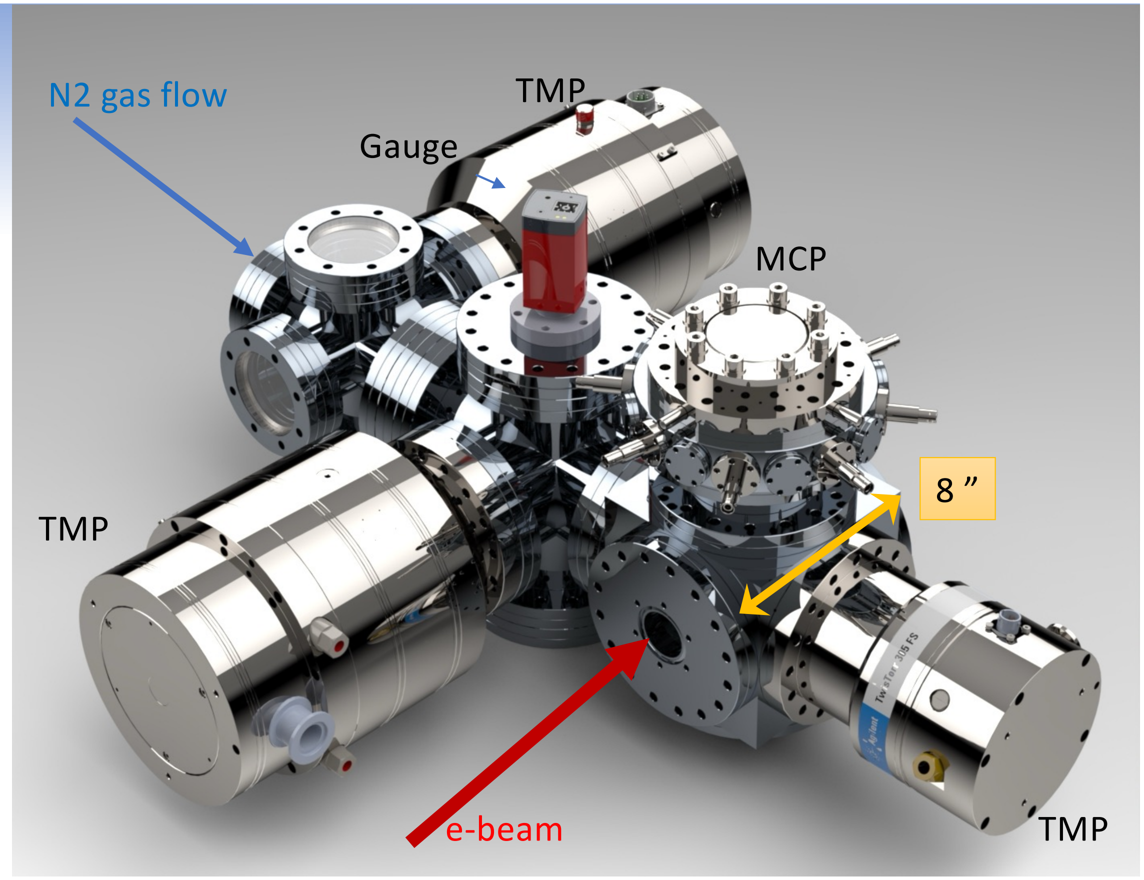




Need to address these items **before** FACET-II installation, with FACET group in design review

Experimental layout

- Space requirements: ~1m from wall
- Gas jet:
  - N2 bottle, Low voltage PS for regulators
- TMPs need water + power
  - Logic for turn-on order
  - Can be oriented any direction
- "Flange-flange" distance: **8 inches**
- Possible to run in semi-parasitic mode depending on location



Gas Sheet Viewscreen is adaptable to any of the FACET beam configurations

Summary

- First commissioning of single-shot, ion microscope based, gas-sheet monitor successful at Pegasus lab in UCLA
  - Impact ionization dominated
  - Single-shot, non-destructive measurement of charge and transverse profile
  - Gained operational experience
- Some engineering needed to adapt to FACET-II, then ready for experiments
  - Profile monitor for multi-kA beams
  - Field ionization contribution

Acknowledgements:
N. Burger, T. Hodgetts, D. Gavryushkin, J. Penney, A.L. Lamure, N. Norvell, M. Ruelas (RadiaBeam),
A. Diaw, N. Cook, C. Hall (RadiaSoft),
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P. Denham, D. Garcia, P. Musumeci, A. Ody, M. Yadav (UCLA),
C. Welsch (Univ. Liverpool)

This work supported by Grant No. DE-SC0019717

Thank you!

Back up slides

Publications/Students

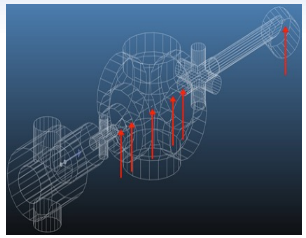
- N. P. Norvell, G. Andonian, T. J. Campese, A. L. M. S. Lamure, M. Ruelas, A. Y. Smirnov, N. M. Cook, J. K. Penney, and C. P. Welsch, “Gas Sheet Ionization Diagnostic For High Intensity Electron Beams,” Proceedings IPAC 2021, pp. 489–491, Sep. 2021.
- M. Yadav, P. Manwani, J. B. Rosenzweig, G. Andonian, O. A. Ö. Apsimon, C. P. Welsch, N. M. Cook, A. Diaw, C. C. Hall, and N. P. Norvell, “Gas Sheet Diagnostics Using Particle In Cell Code,” Proceedings of IPAC2022, pp. 410–413, Jul. 2022.
- N. M. Cook, A. Diaw, C. C. Hall, G. Andonian, N. P. Norvell, and M. Yadav, “Electron Beam Phase Space Reconstruction From A Gas Sheet Diagnostic,” Proceedings of IPAC2022, pp. 414–417, Jul. 2022.
- N. Burger, G. Andonian, T. Hodgetts, D. Gavryushkin, N. Norvell, N. Cook, C. Welsch, M. Yadav, P. Denham, P. Musumeci, A. Ody, “Experimental Characterization Of Gas Sheet Transverse Profile Diagnostic” Proceeding NA-PAC 2022, #THZE4 (2022)

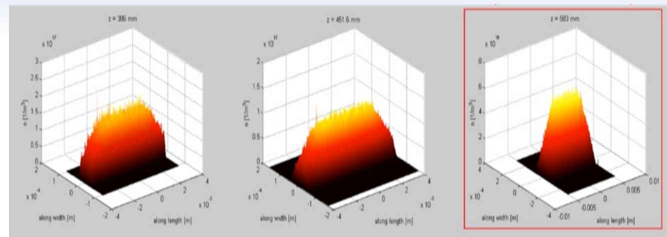
Students: P. Denham (UCLA) from Pegasus Lab

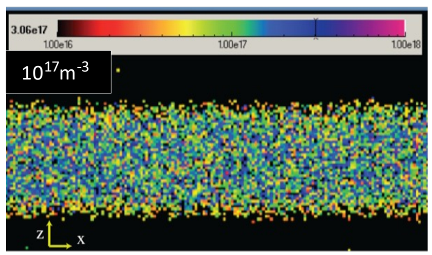
Gas Sheet Generation - Design

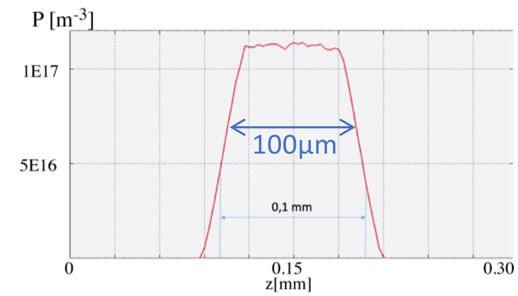
Optimization of gas density profile: (Molfow+)

- Example to study effect of skimmer size/shape/locations
- Compact design to maintain distribution at IP



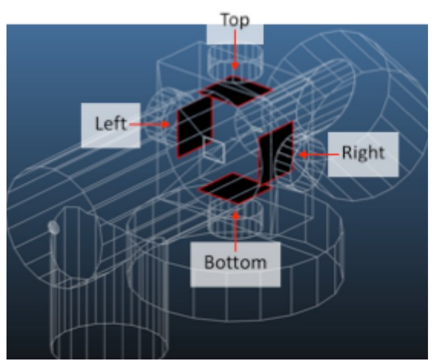






Differential pumping: (Molflow+)

- Strict UHV requirements determine pump speed and placement



Vacuum levels near IP (mbar)

	Min	Max	Av
Top	1,66E-09	4,49E-09	3,14E-09
Bottom	1,65E-09	4,13E-09	2,64E-09
Left	2,09E-09	4,54E-09	3,20E-09
Right	1,73E-09	4,50E-09	3,19E-09