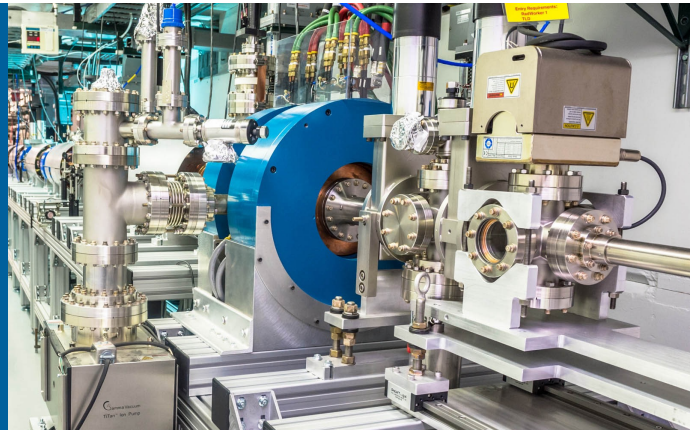
PROGRESS REPORT ON AN X-BAND ULTRA-HIGH GRADIENT PHOTOINJECTOR



GONGXIAOHUI CHEN
on behalf of joint efforts from AWA, Euclid Techlabs and NIU

10/03/2023

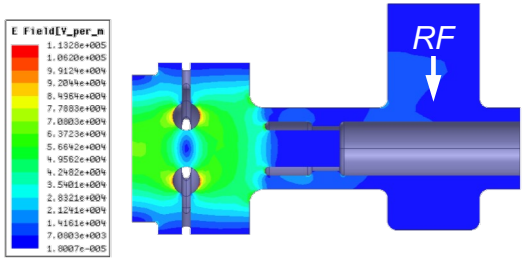
OUTLINE

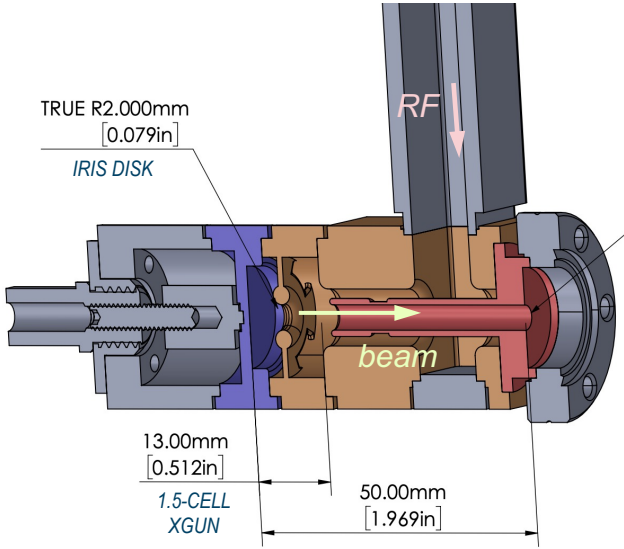
- Introduction to the X-band photogun (Xgun)
- High power rf conditioning test of Xgun
- Introduction to AWA drive beamline and Xgun beamline
- Some highlights of Xgun beam test
  - Energy characterization at a high gradient
  - Schottky studies *(fresh data)*
- Future: design of next generation Xgun

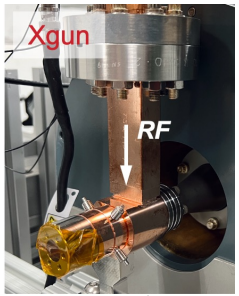
SHORT PULSE XGUN DESIGN

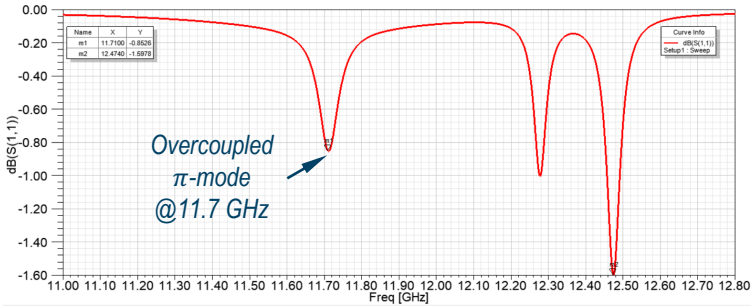
Brief introduction

- X-band 1.5-cell rf gun (Xgun)
- Operate on π-mode @11.7 GHz
- Short rf pulse (9 ns) operation
- Strongly over-coupled
  - Short fill-time
  - Q_load≈180
- Cathode is the copper backwall of the Xgun cavity

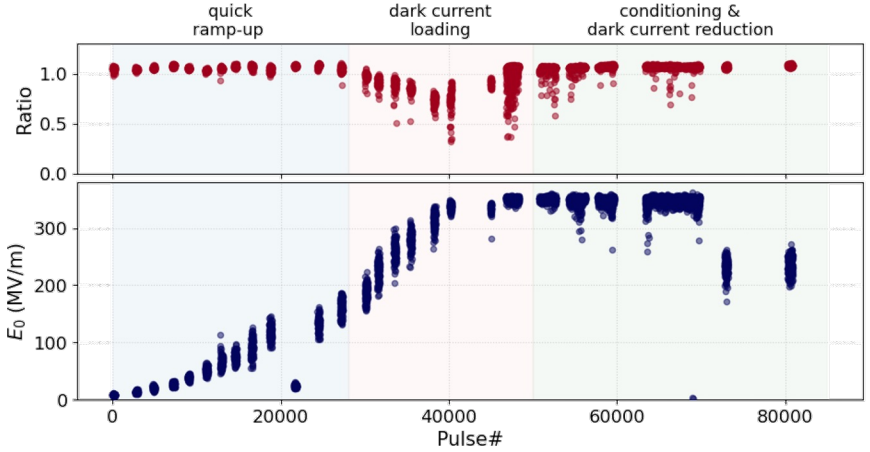


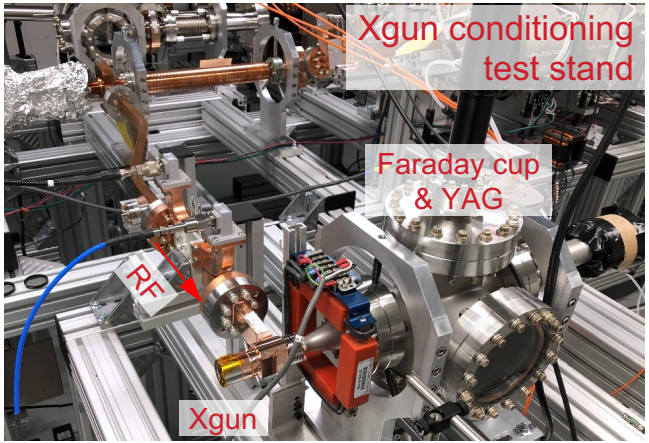


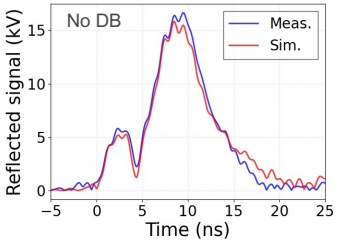


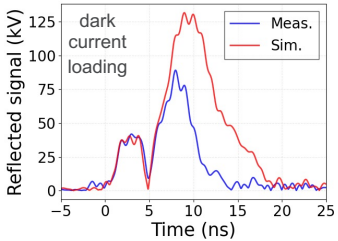


INITIAL RF CONDITIONING OF XGUN









- $Ratio = \frac{V_{ref\_meas}}{V_{ref\_sim}}$
- Conditioning process is quick.
- A dark current loading region observed.
- No observable dark current after conditioning.
- Achieved 350 MV/m within 70k pulses [1].

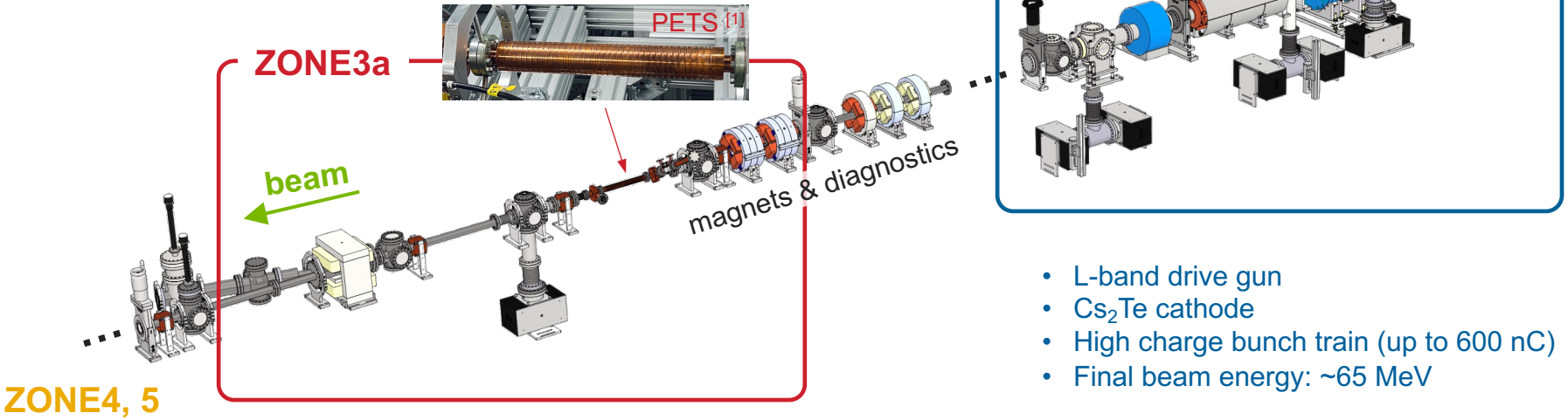
[1] W.H.Tan *et. al.,* Phys. Rev. Accel. Beams 25, 083402, August 2022 (2022)

INTRODUCTION TO AWA BEAMLINES

- Main drive beamline (deliver high charge bunch train)
- Xgun beamline (powered by drive beamline)

INTRODUCTION TO AWA DRIVE BEAMLINE

- Fully re-configurable
- Currently have a metallic Power Extraction and Transfer Structure (PETS) installed



- L-band drive gun
- Cs_2Te cathode
- High charge bunch train (up to 600 nC)
- Final beam energy: ~65 MeV

[1] J. Shao *et. al.*, doi:10.18429/ JACoW- IPAC2019- MOPRB069 (2019)

INTRODUCTION TO AWA DRIVE BEAMLINE

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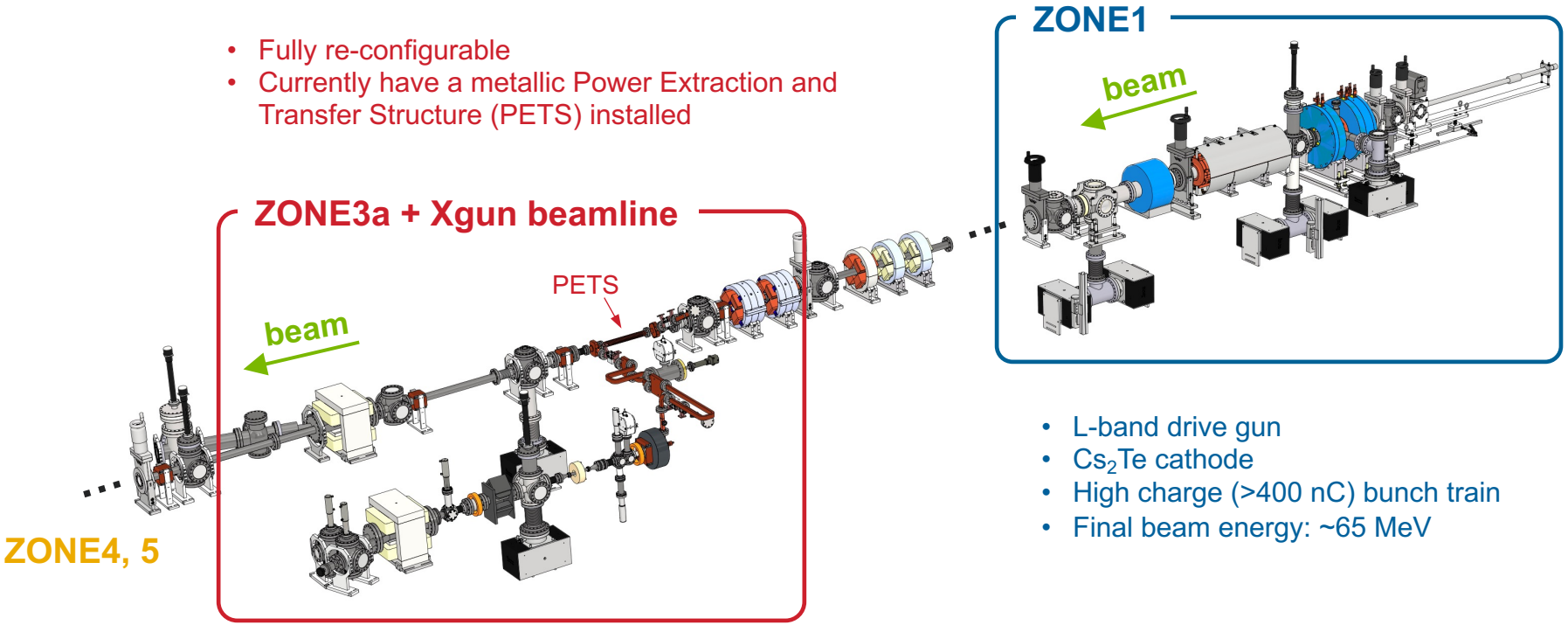
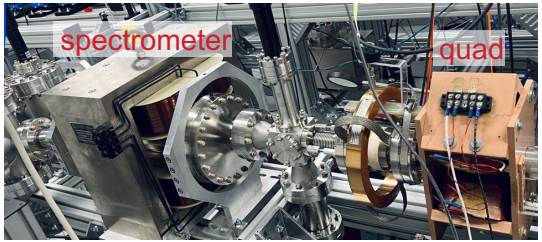
- Currently have a metallic Power Extraction and Transfer Structure (PETS) installed



- L-band drive gun
- Cs_2Te cathode
- High charge (>400 nC) bunch train
- Final beam energy: ~65 MeV

XGUN BEAMLINE
current configuration

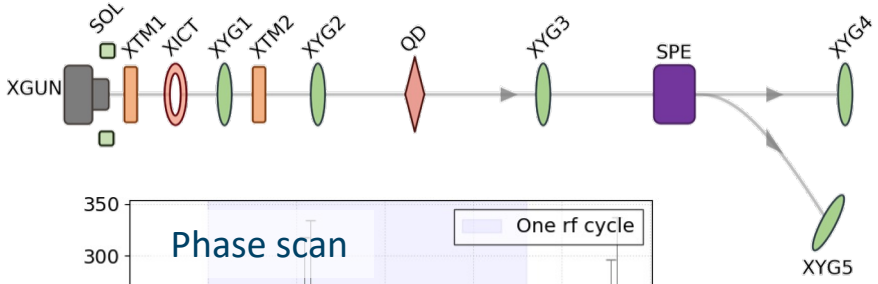


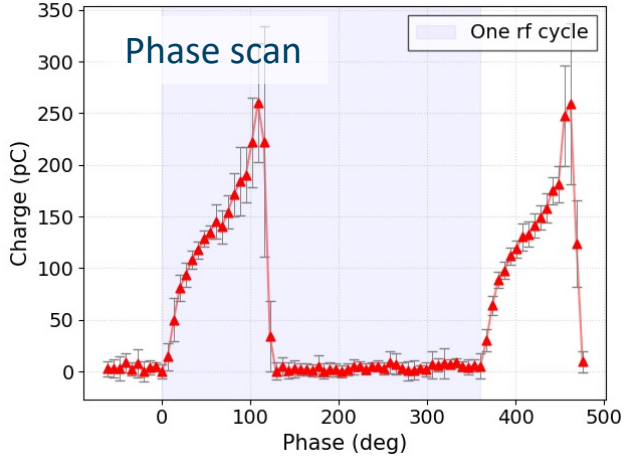
HIGHLIGHTS OF THE BEAM TEST

- Beam energy characterization
- Cathode studies on fundamentals of photoemission (on-going):
  - Schottky scans @ different Xgun gradients
  - More coming…

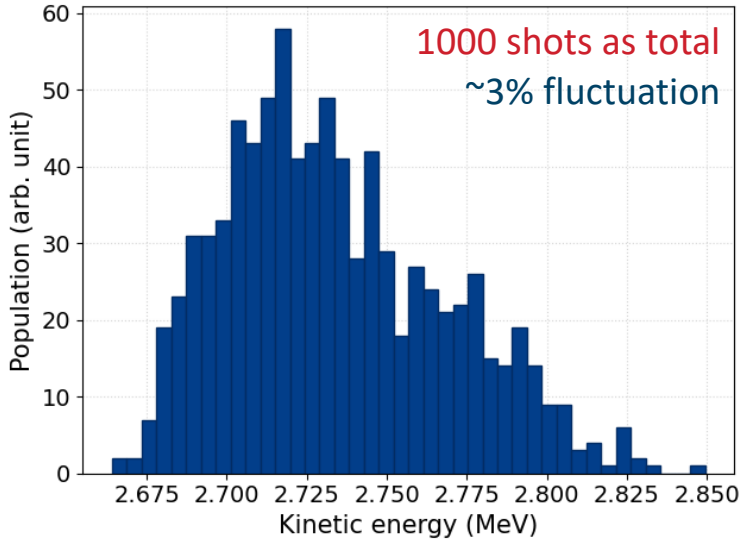
BEAM ENERGY CHARACTERIZATION

1st beam test





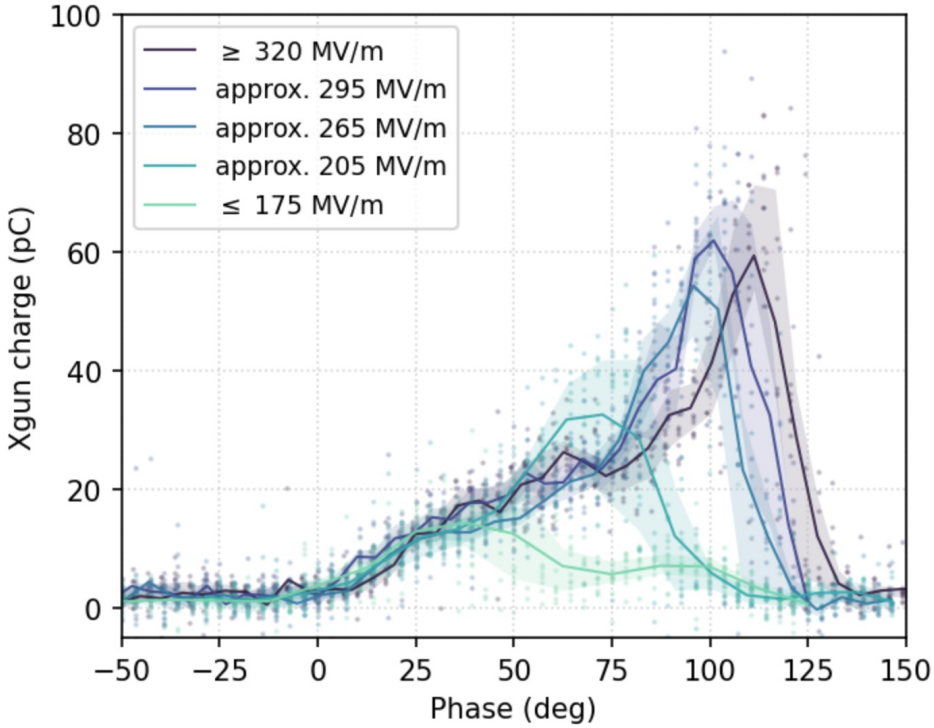
- Xgun phase scan @**340 MV/m**
- Evidence of strong Schottky effect



- Energy measured by the spectrometer dipole
- ~3% fluctuation, likely due to the drive charge instability and laser RF phase jitter in the drive linac.
- Max achieved gradient is **388 MV/m** from the beam energy measurement

SCHOTTKY STUDIES

Phase scan @ different gradients (fresh data!)



Goal: understand Schottky effect over a wide range of gradient on the cathode surface.

- Fresh experimental data.
- Solenoid strength was adjusted to achieve highest charge capture.
- Will need to compare the measured data with the simulations.

More results are coming!

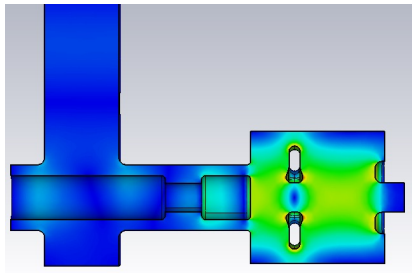
FUTURE WORK:
DESIGN OF NEXT GENERATION XGUN

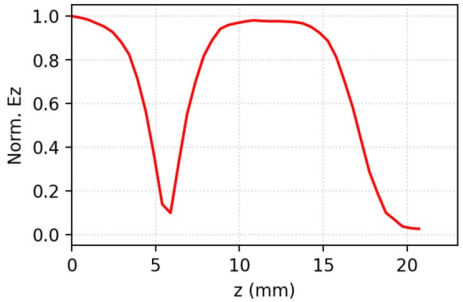
NEW XGUN DESIGNS

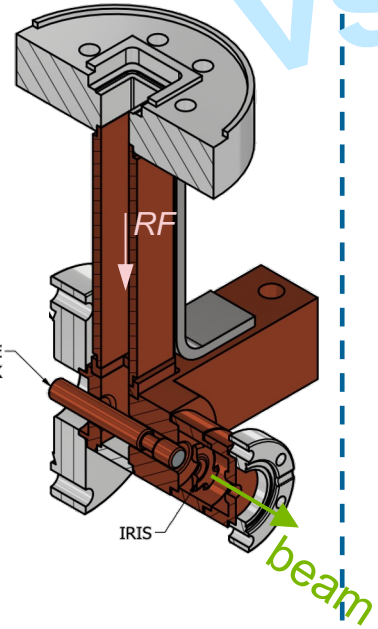
1.5 cell vs. 2.5 cell (?); with removeable cathode

New Xgun is designed by Sergey Kuzikov and Ernie Knight at Euclid TechLabs.

1.5 cell

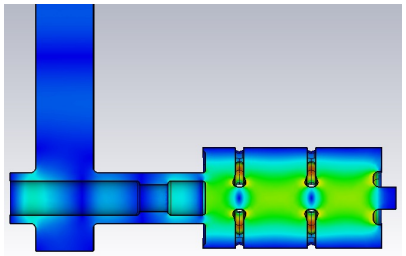


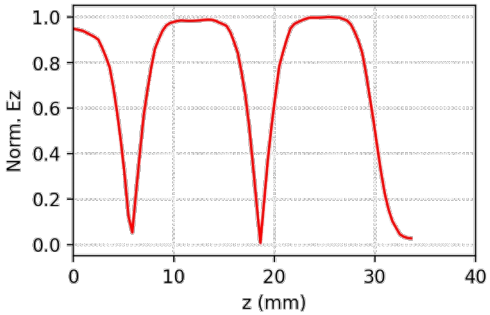


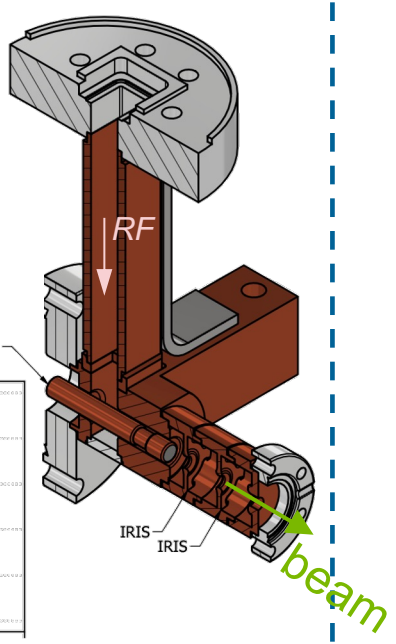


vs.

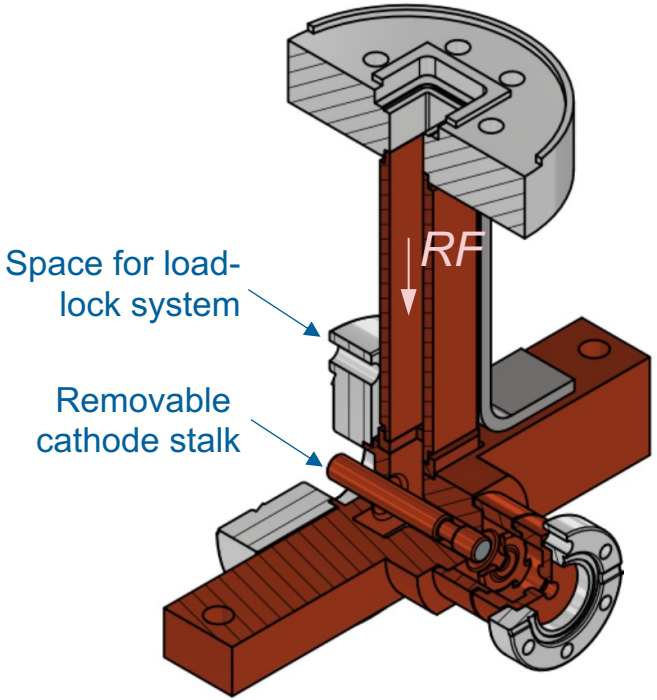
2.5 cell

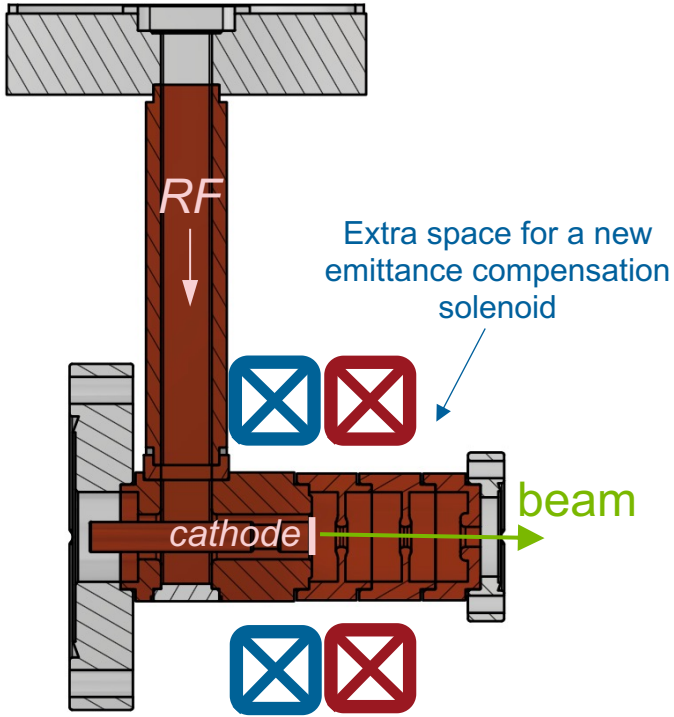






NEW XGUN + NEW SOLENOID





New Xgun is designed by Sergey Kuzikov and Ernie Knight at Euclid TechLabs.

CONCLUSION

- Characterized parameters of Xgun, include:
  - High gradient ~400 MV/m
  - Beam energy 2.7 MeV
- Cathode studies has begun:
  - Preliminary phase scans at different gradients have been performed.
  - More results are coming.
- New designs of the Xgun have been proposed, aims to include:
  - Removable cathode stalk for different cathode materials
  - Load lock system
  - A new emittance compensation solenoid

BIG THANKS TO OUR TEAM!

Scott Doran (AWA)
Seongyeol Kim (AWA)
Wanming Liu (AWA)
John Power (AWA)
Charles Whiteford (AWA)
Eric Wisniewski (AWA)
Gwanghui Ha (now at NIU)
Jiahang Shao (now at IASF)

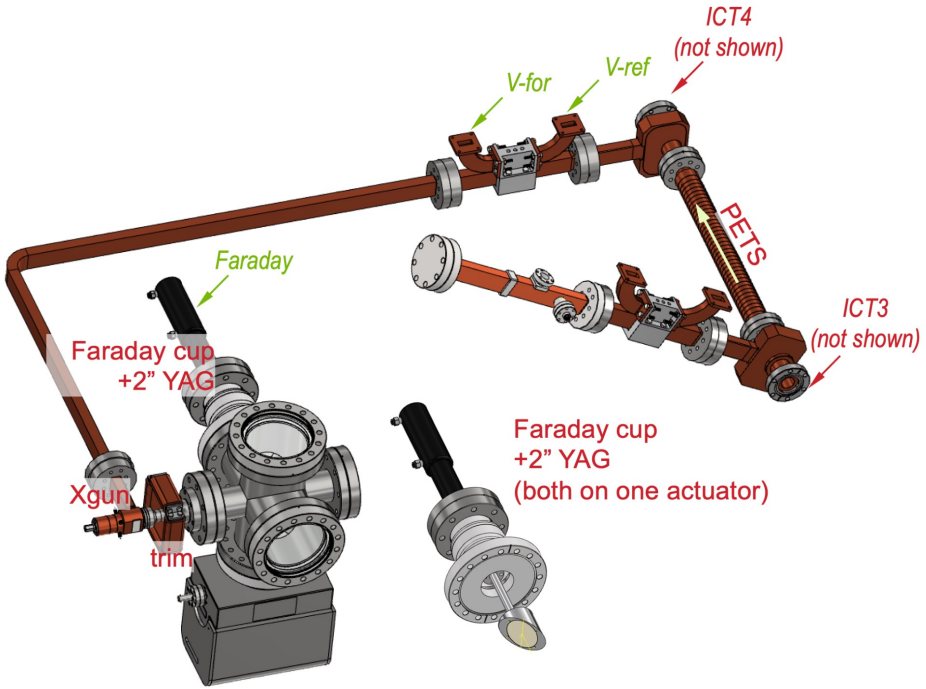
Chunguang Jing (Euclid Techlabs / AWA)
Ernie Knight (Euclid Techlabs)
Sergey Kuzikov (Euclid Techlabs)
Pavel Avrakhov (Euclid Techlabs)
Sergey Antipov (now at PALM Scientific)

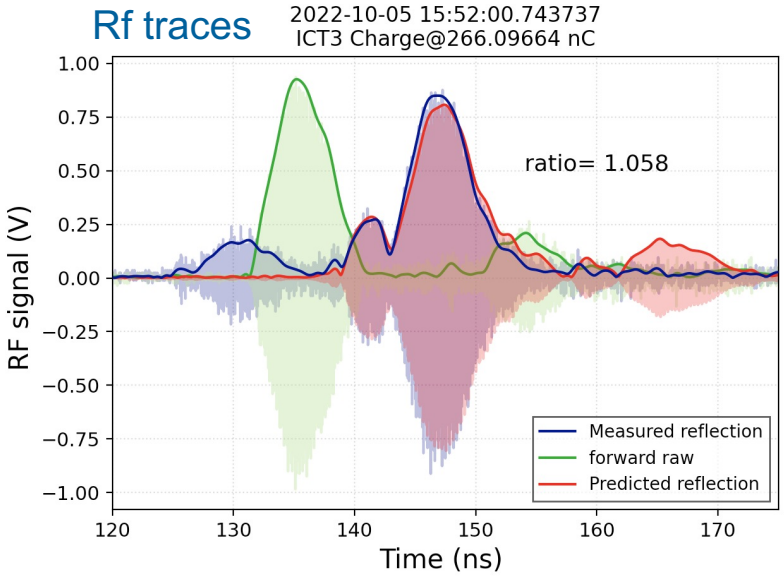
Emily Frame (NIU)
Xueying Lu (NIU / AWA)
Philippe Piot (NIU / AWA)
Wei Hou Tan (now at SLAC)

BACKUP

XGUN DAMAGE TEST

Oct. 2022 - Xgun high power test/re-conditioning





XGUN DAMAGE TEST

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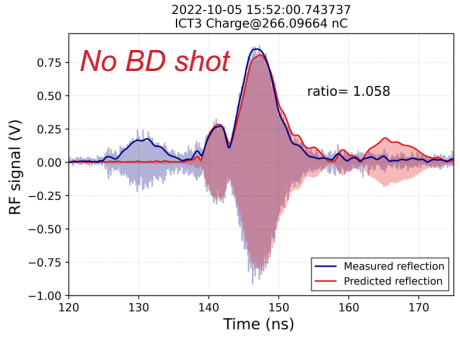

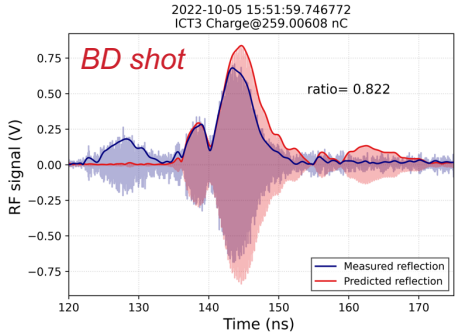

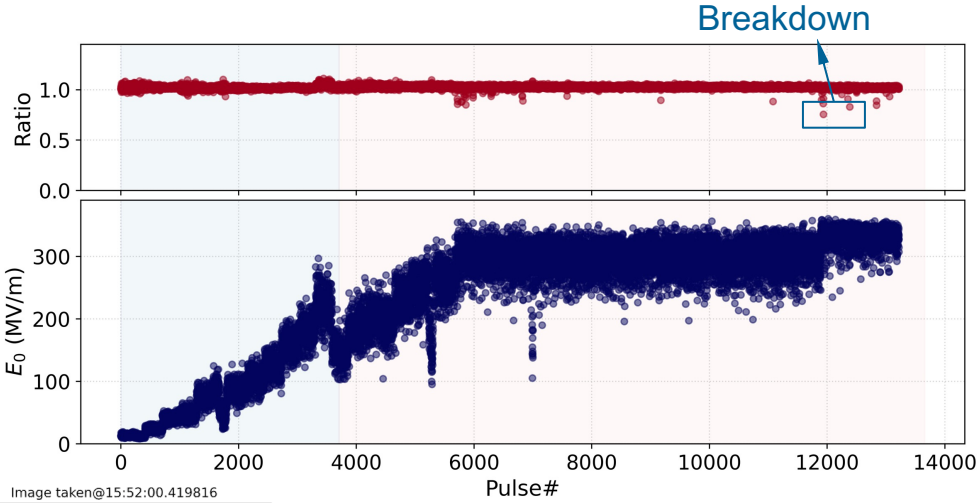

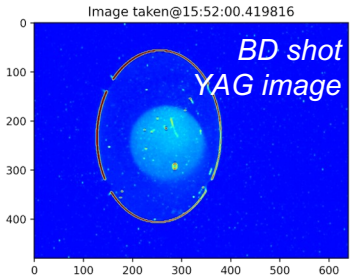

- $Ratio = \frac{V_{ref\_meas}}{V_{ref\_sim}}$

XGUN DELAY STAGE