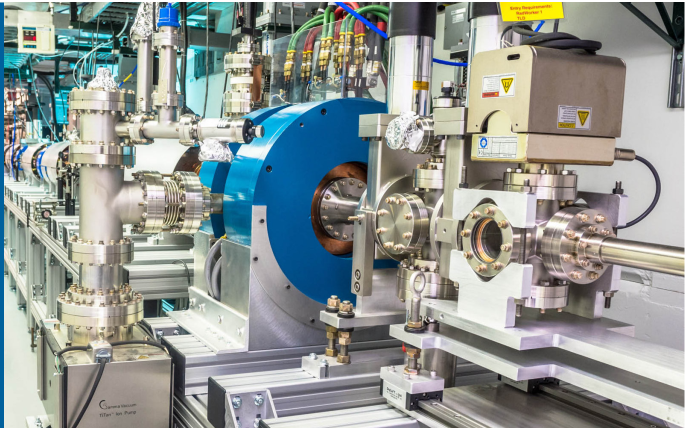
PROGRESS REPORT ON AN X-BAND HIGH-GRADIENT PHOTOINJECTOR

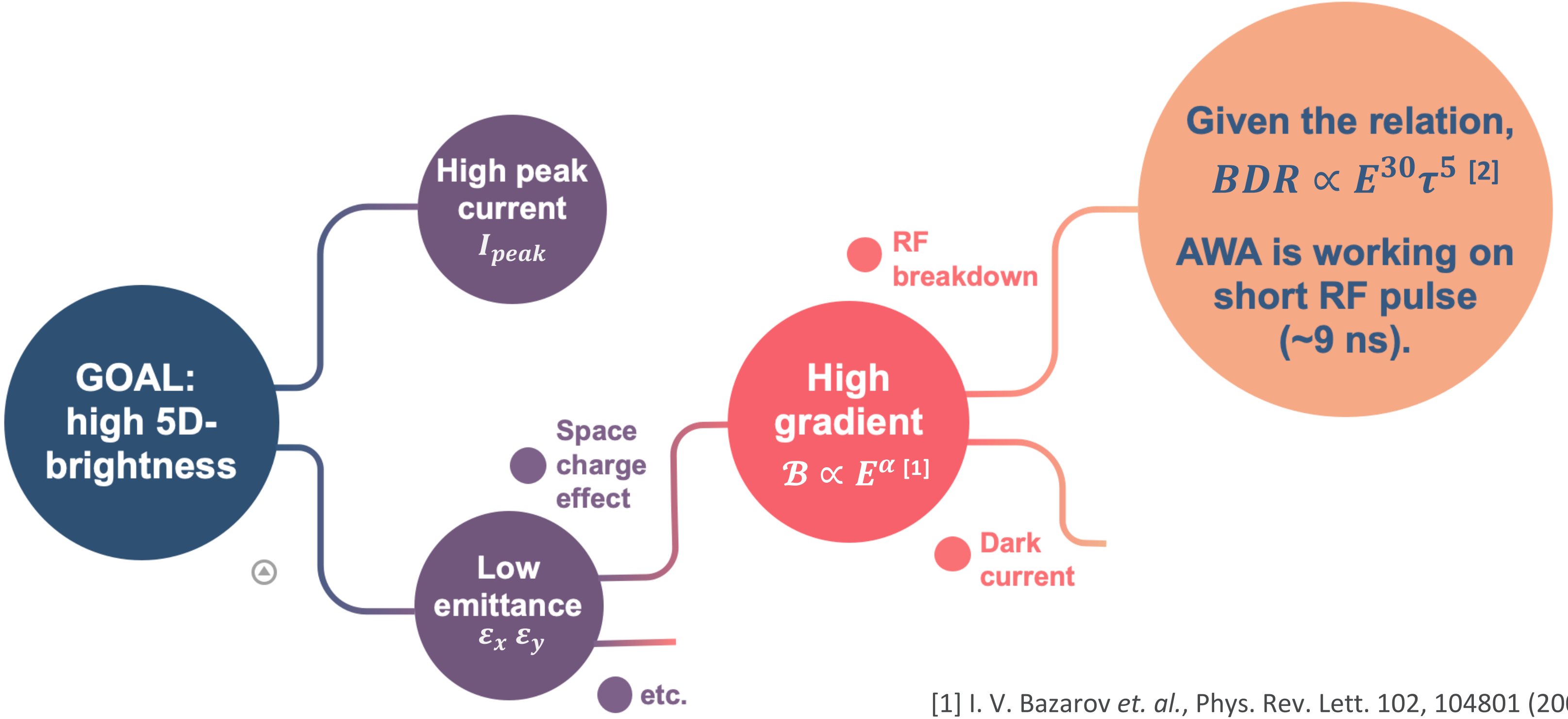


GONGXIAOHUI CHEN
on behalf of joint efforts from AWA, Euclid Techlabs and NIU

08/08/2022

OUR APPROACH TO HIGH BRIGHTNESS

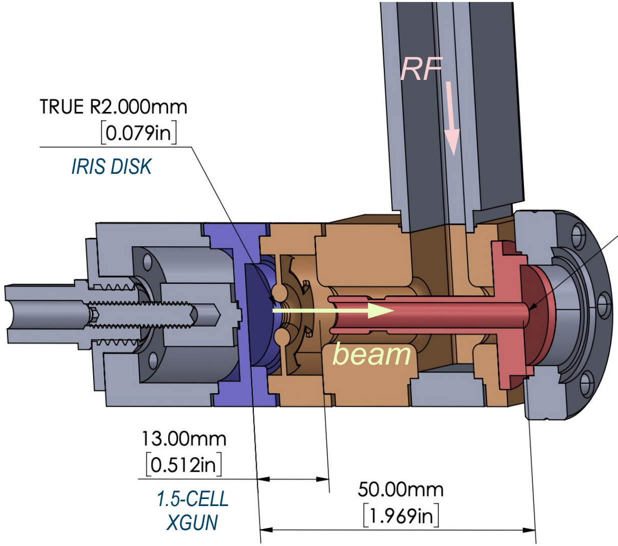
Motivation

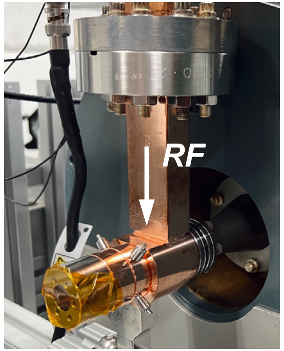


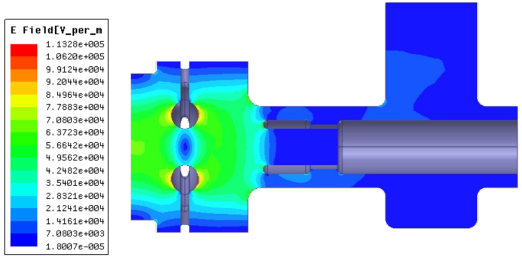
[1] I. V. Bazarov *et. al.*, Phys. Rev. Lett. 102, 104801 (2009).
[2] A. Grudiev *et. al.*, Phys. Rev. ST-AB, 12, 102001 (2009).

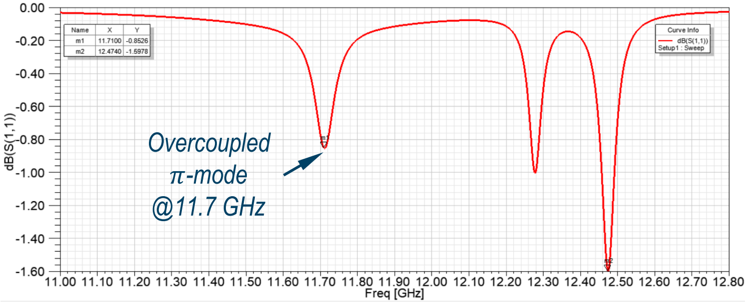
SHORT PULSE XGUN DESIGN

- X-band 1.5-cell rf gun (Xgun)
- Operate on π-mode @11.7 GHz
- Strongly over-coupled
  - Short fill-time
- Cathode is the Cu backwall of the Xgun cavity





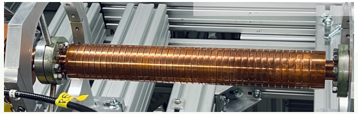


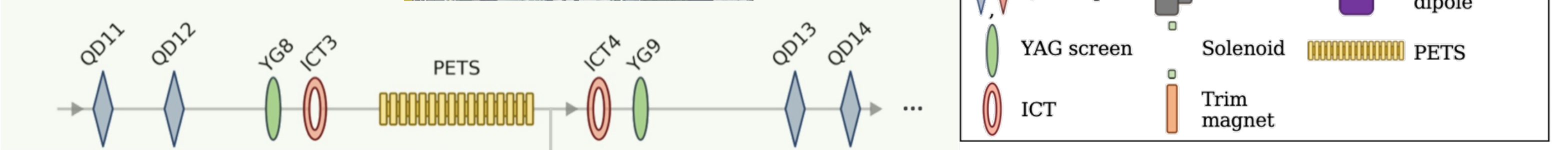


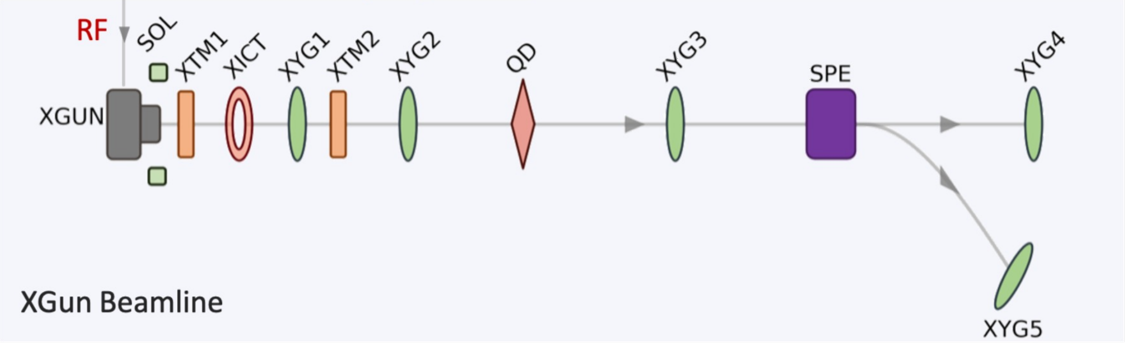
BEAMLINE FOR THE 1ST BEAM TEST

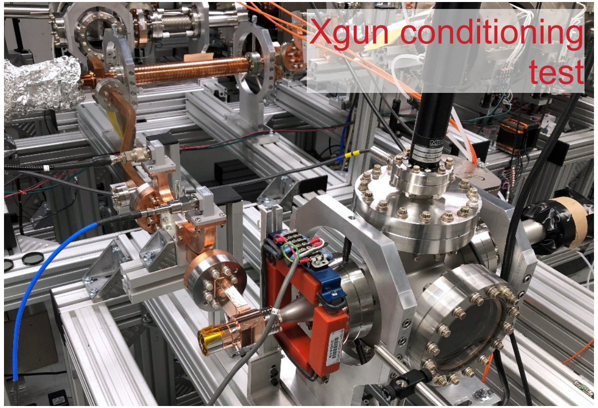
Nov. 2021

PETS [1]





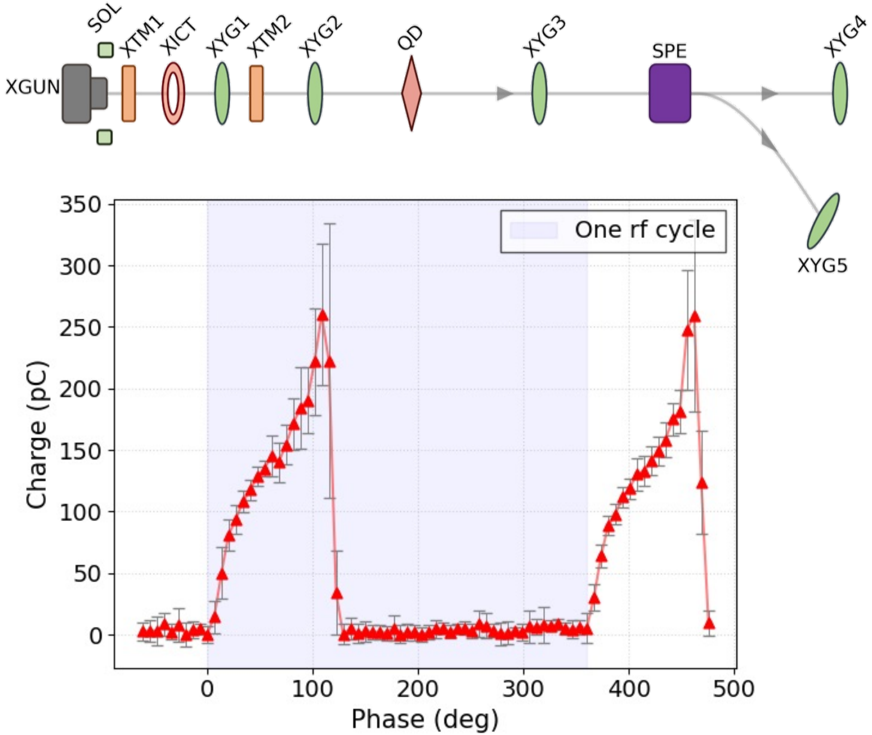




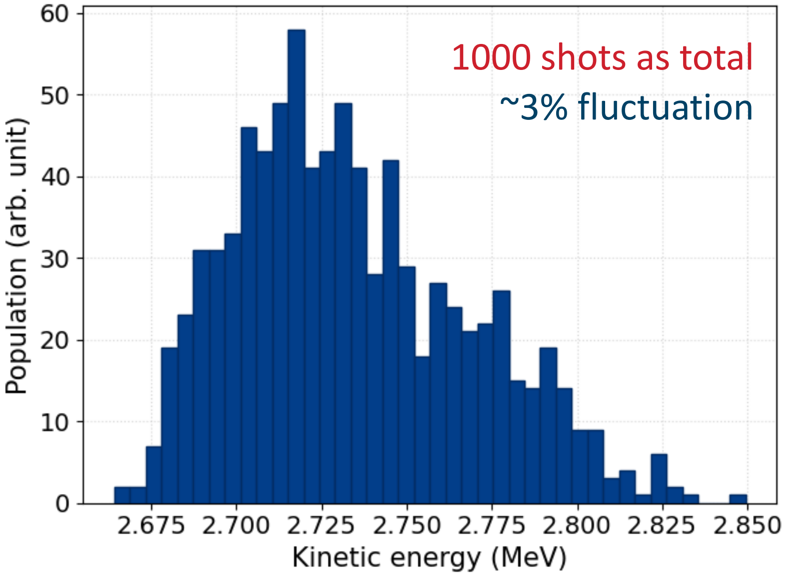
- Gun conditioned to high gradient (Nov. 2020)
  - achieved 350 MV/m within 70k pulses [2]
- Beam energy characterization

[1] J. Shao *et. al.*, doi:10.18429/ JACoW-IPAC2019- MOPRB069 (2019)
[2] W.H.Tan *et. al.,* arXiv:2203.11598v1 (2022)

BEAM ENERGY CHARACTERIZATION



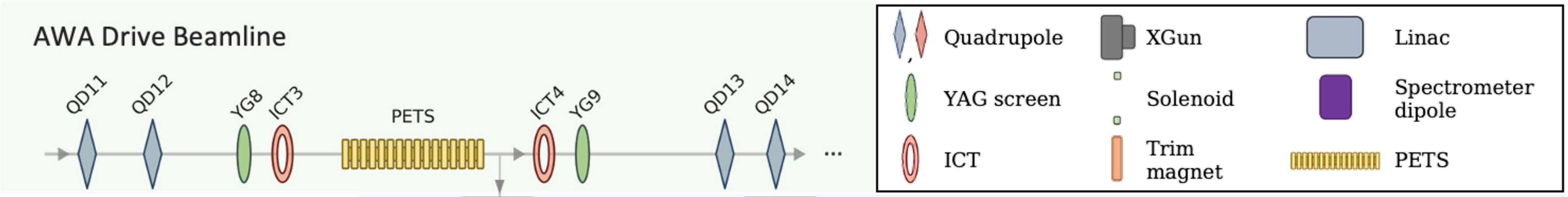
- Xgun phase scan @340 MV/m

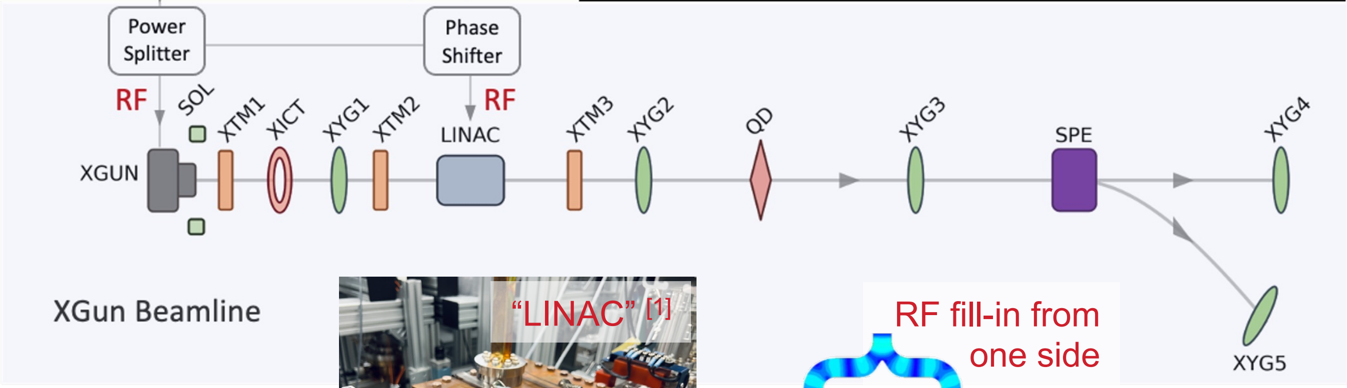


- Energy measured by the spectrometer dipole
- ~3% fluctuation, likely due to the drive charge instability.
- Max achieved gradient is **388 MV/m** from the beam energy measurement

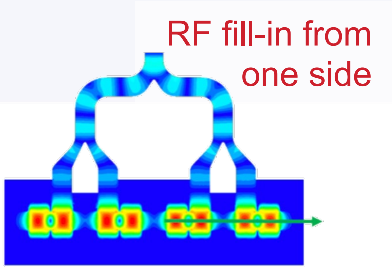
BEAMLINE FOR THE 2ND BEAM TEST

With linac installed; July 2022





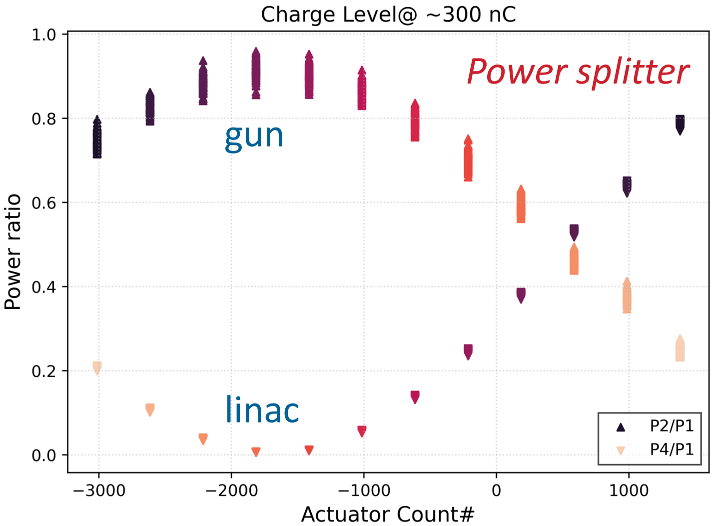
- Beam energy characterization with LINAC
- Preliminary emittance measurement at low gradient

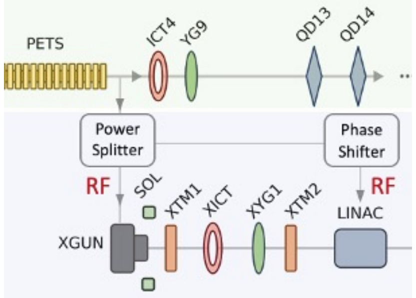


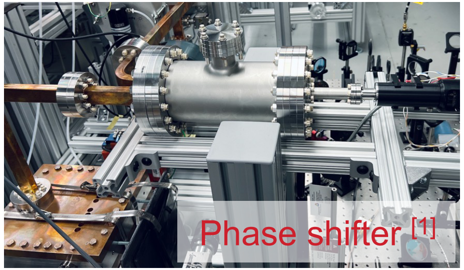
[1] S. Antipov *et. al.*, doi:10.18429/ JACoW-IPAC2021-MOPAB152 (2021)

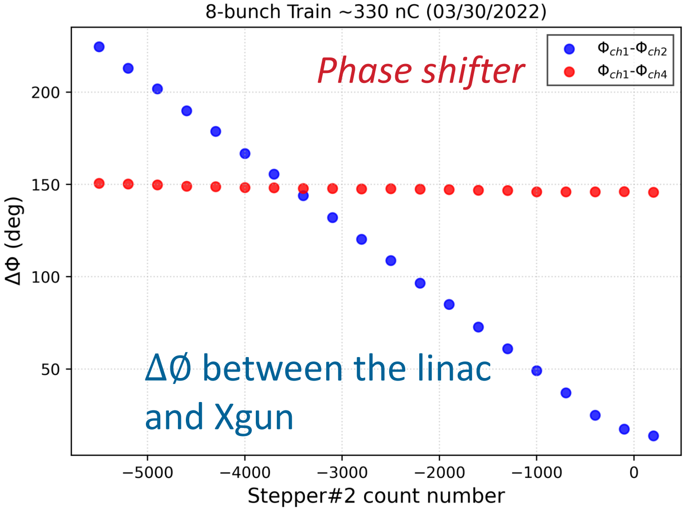
POWER SPLITTER AND PHASE SHIFTER TEST

March 2022









- Both components were tested with high power
- Power splitter:
  - 0-100% power variation
- Phase shifter:
  - >180 deg phase shift

[1] Sergey Kuzikov *et. al.,* doi:10.18429/JACoW-IPAC2022-MOPOMS013 (2022)

PRELIMINARY EMITTANCE MEASUREMENT

July 2022

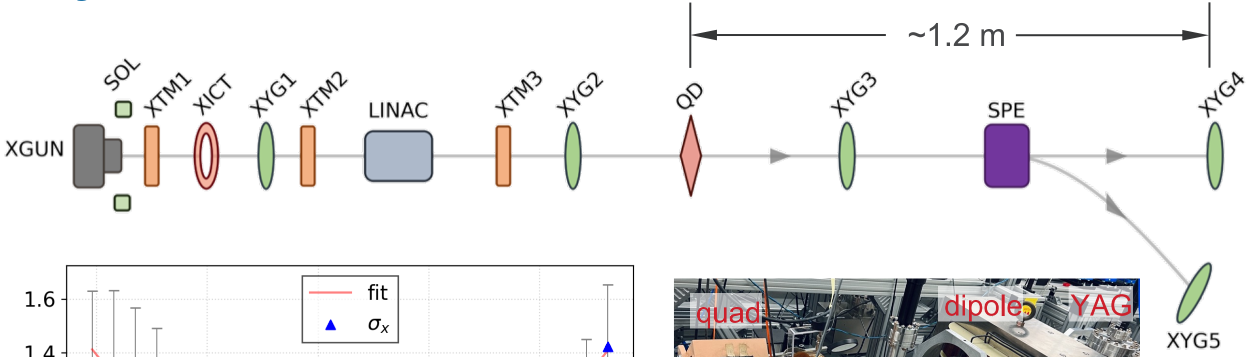
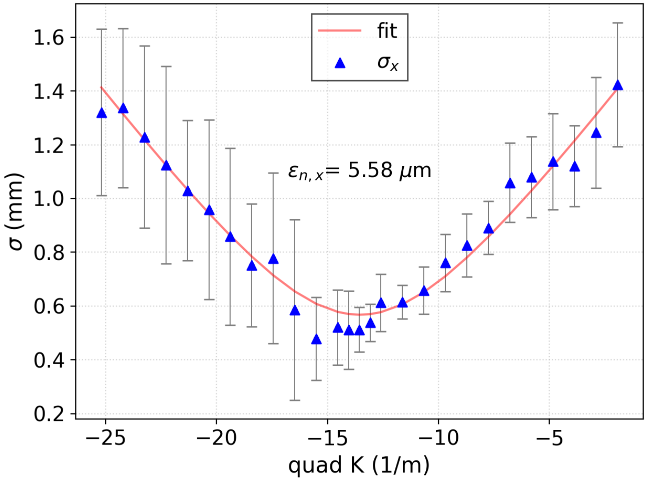
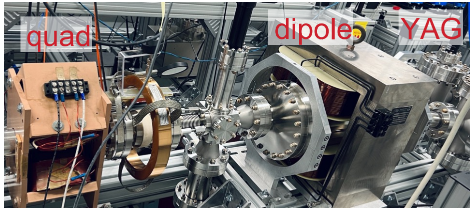
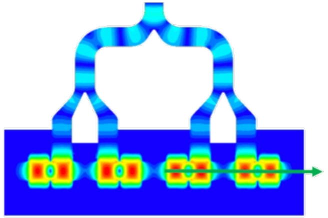


Table 1: List of the operating parameters

Parameter	Value	Unit
Laser σ_x	0.189	mm
Laser σ_y	0.234	mm
Laser bunch length (FWHM)	300	fs
Xgun peak E-field	280.0±3	MV/m
Xgun phase [1]	31.8	degree
Bunch charge	44.9±10	pC
Solenoid B-field	0.202	T
Linac peak field	86.9±2	MV/m







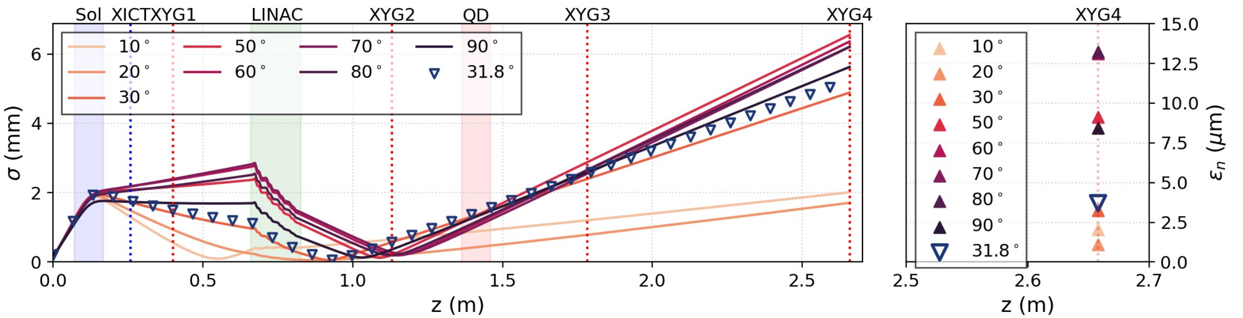
- Emittance was measured by quad scan:
  - $\varepsilon_{n,x} = 5.58\ \mu m$
  - $\varepsilon_{n,y} = 11.26\ \mu m$ (due to geometry asymmetry of the linac)
  - Kinetic energy: 5.9 MeV
- This is a preliminary test. Xgun was not operated at optimized parameters.

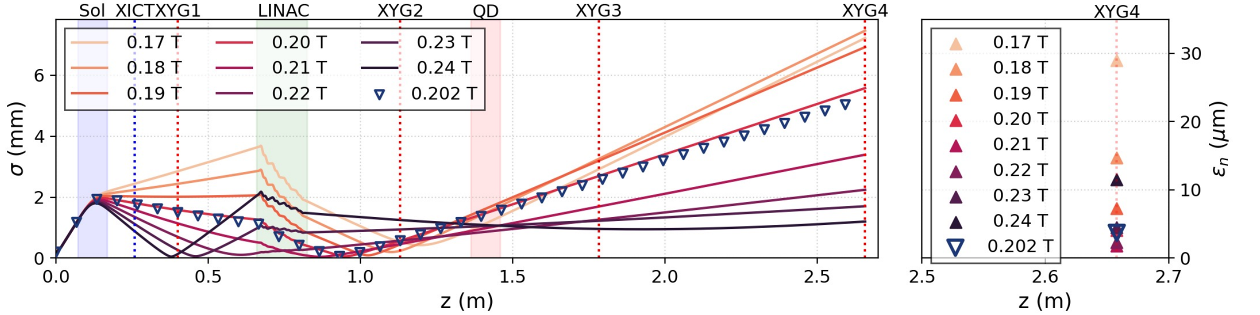
COMPARISON WITH SIMULATIONS

- Based on all real operating params., ε_{sim}~3.7 μm close to ε_{mea}~5.6 μm.
- Possible factors causing emittance growth:
  - laser spot size
  - laser pulse length
  - Xgun launching phase
  - solenoid field
  - linac gradient

Table 2: List of simulation parameters

Parameter	Sim. set#1	Sim. set#2
Laser $\sigma_{x,y}$	0.2 mm	0.2 mm
Bunch charge	45 pC	45 pC
Xgun peak E-field	280 MV/m	280 MV/m
Xgun phase [2]	10° to 90°	31.8°
Solenoid B-field	0.202 T	0.17 T to 0.24 T
Linac peak field	86.9 MV/m	86.9 MV/m





- At current gradient and configuration (non-ideal linac), emittance can be improved to 1 μm by carefully tuning the Xgun phase and the solenoid strength.

CONCLUSION

- A program to develop a high brightness photoinjector based on short-pulse RF is underway as collaboration between ANL, Euclid, and NIU.
- Recent developments:
  - High gradient achieved ~400 MV/m
  - Beam energy characterized
  - Preliminary emittance measured at limited resources (re-purposed linac, solenoid, etc.)
- Future plans:
  - Upgrade the laser system to carefully shape and diagnose the laser distribution and control its transverse size.
  - Add an OPA (optical parametric amplifier) to match the wavelength to the effective work function (compensate for the Schottky effect).
  - A new linac (with cylindrical symmetry) is designed and under construction.
- This source will serve as an injector for an 0.5 GeV accelerator for a linear-collider module demo and also to support research on the compact FEL.

BIG THANKS TO OUR TEAM!

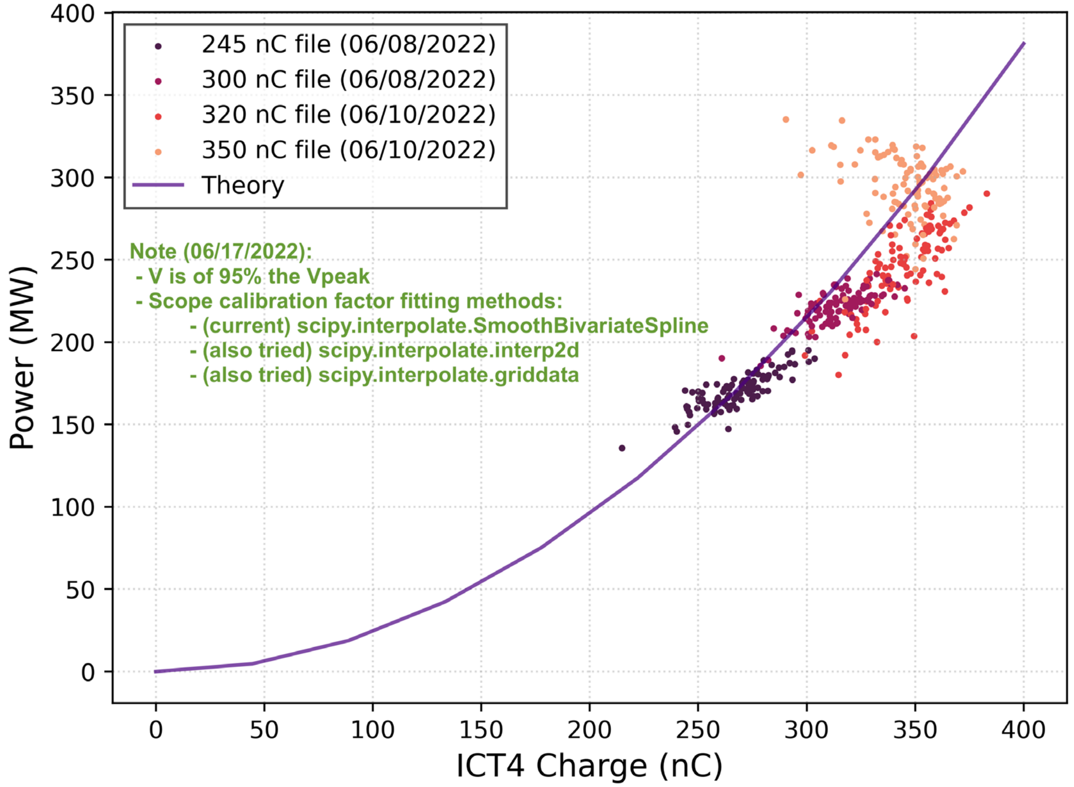
Scott Doran (AWA)
Seongyeol Kim (AWA)
Wanming Liu (AWA)
John Power (AWA)
Charles Whiteford (AWA)
Eric Wisniewski (AWA)
Gwanghui Ha (was at AWA, now at NIU)
Jiahang Shao (was at AWA, now at IASF)

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

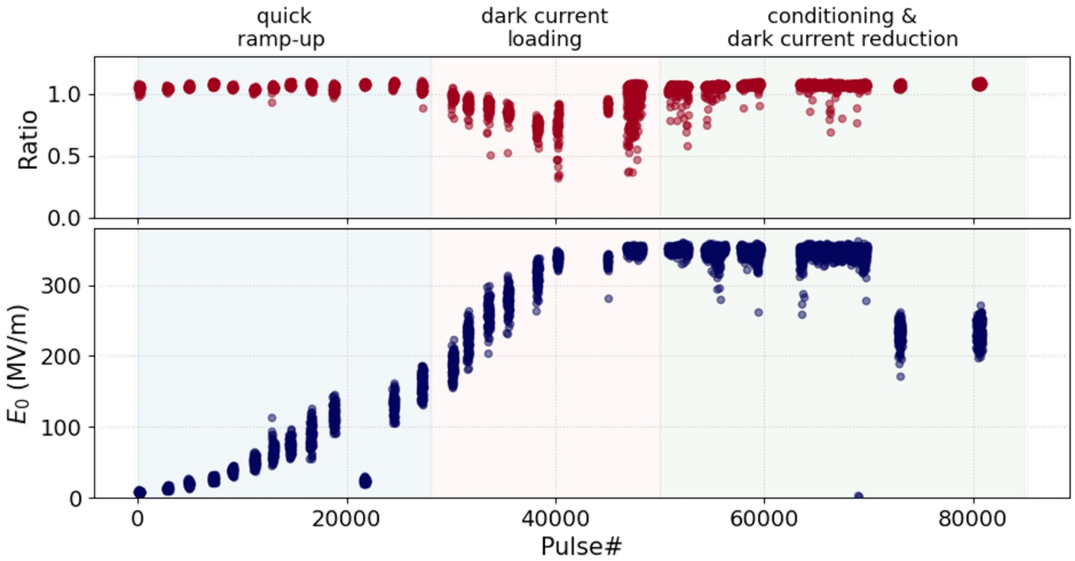
Xueying Lu (NIU / AWA)
Philippe Piot (NIU / AWA)
Wei Hou Tan (NIU)

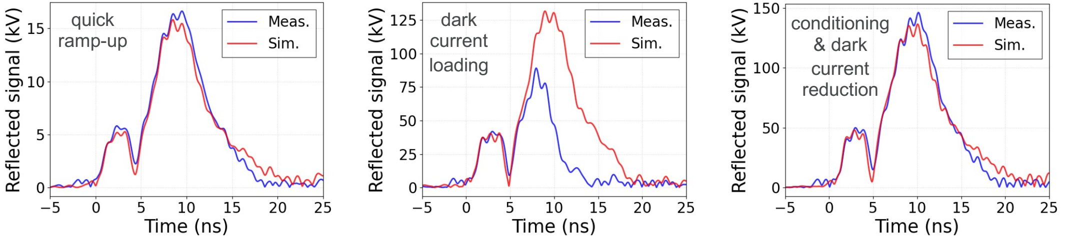
BACKUP

EXTRACTED POWER VS. AWA DRIVE CHARGE



GUN RF CONDITIONING





Quick information:

- Conditioning process is fairly quick.
- Achieved 350 MV/m within 80k pulses.
- No observable dark current after conditioning.

* Reflection signal was measured from a directional coupler.

LASER FOR EMITTANCE MEAS.

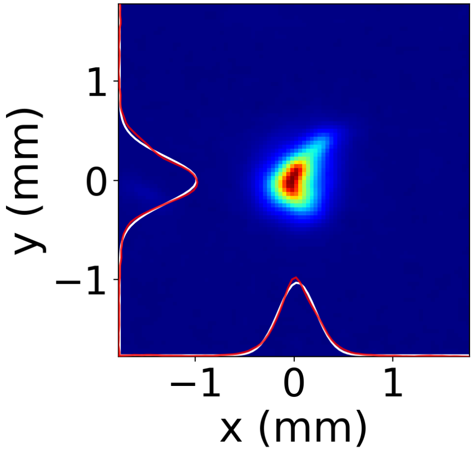


Table 1: List of the operating parameters

Parameter	Value	Unit
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Laser σ_y	0.234	mm
Laser bunch length (FWHM)	300	fs