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NORTHERN ILLINOIS CENTER FOR ACCELERATOR AND DETECTOR DEVELOPMENT

NIU

ERL cooler beam tests at the FAST facility

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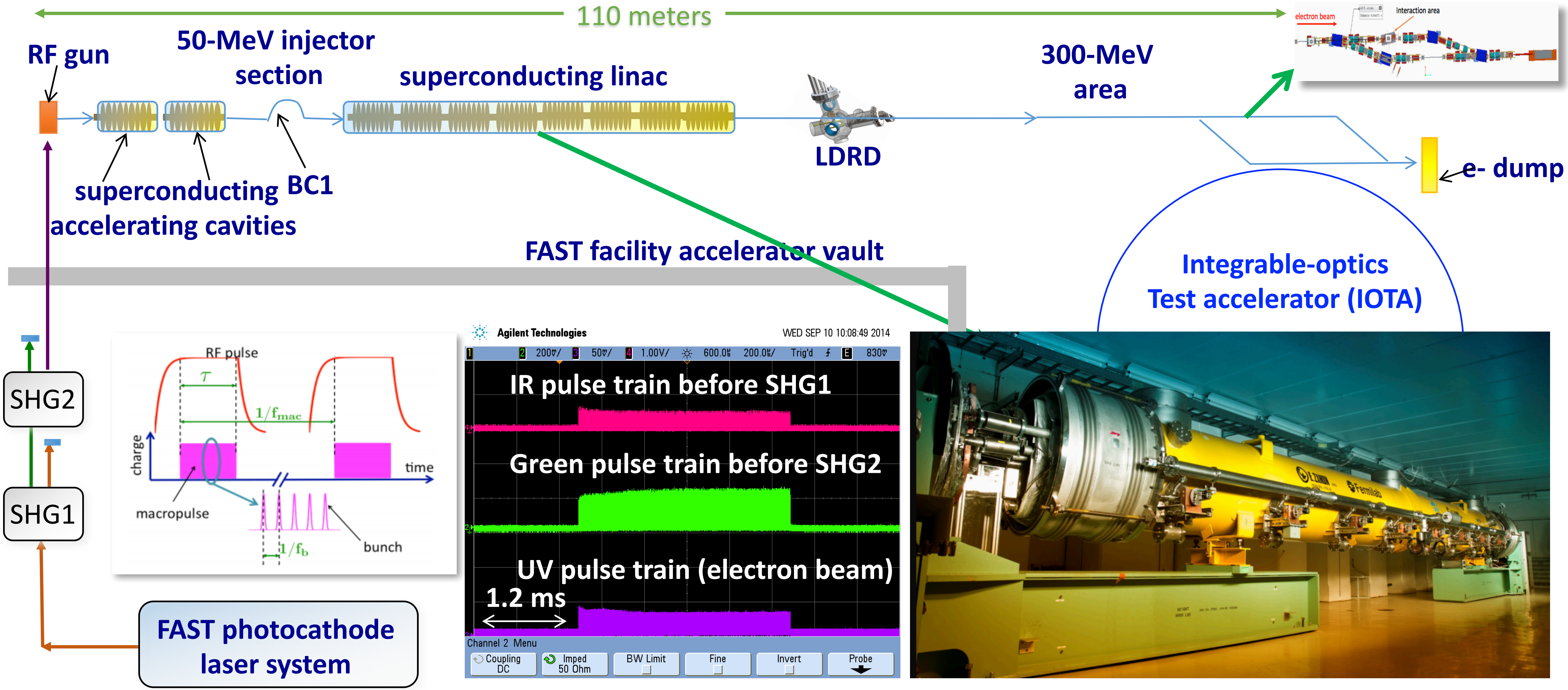
Introduction

- High-charge magnetized beam:
  - Production of high-charge (3.2 nC) magnetized beam
  - characterization of magnetization
  - Transport + manipulation over long beamline including use of locally non-symmetric optics
- High-current magnetized beams → understanding halo
  - Explore halo formation in magnetized beam using a long-dynamical range diagnostics (LDRD)
- New merger concept:
  - Tests of merger concept combining RF deflector and magnetic coil proposed by A. Hutton -- augmenting recent test at Cornell.

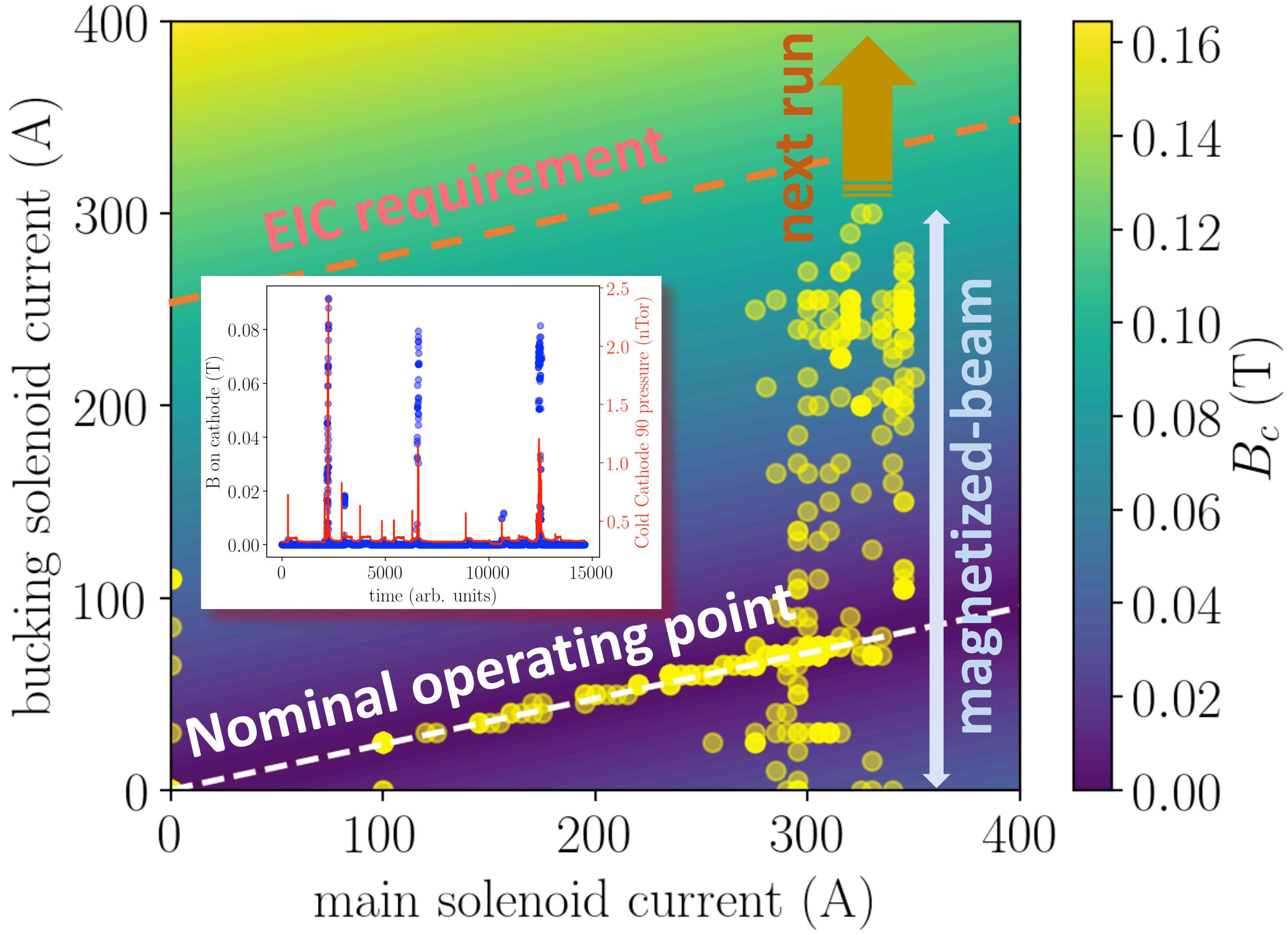
YEAR 1

YEAR 2

The FAST facility infrastructure



Relevance of FAST injector to EIC e- cooling



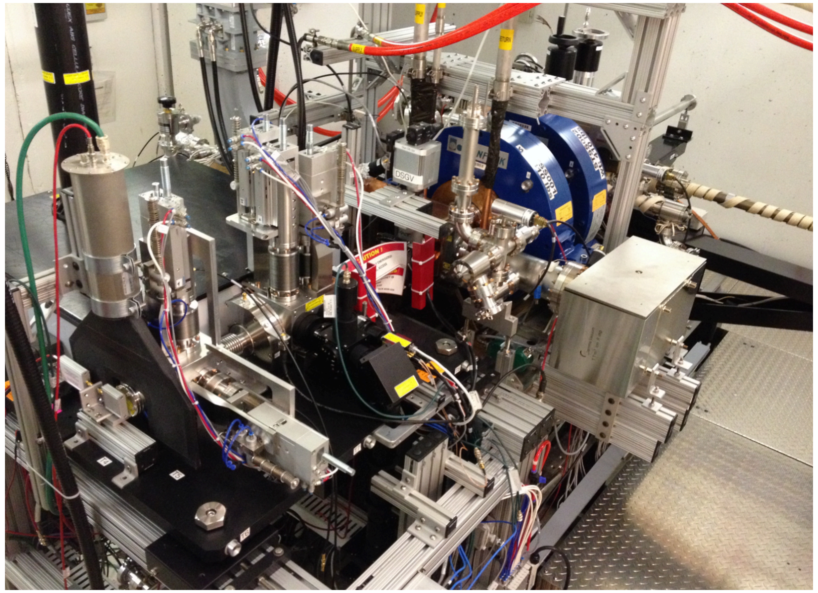
⬤ are data points from Winter-2017 run

parameter	JLEIC	FAST	units
energy	20-55	<50	MeV
bunch length	2	0.3*	cm
thermal emittance	<19	~1	µm
cathode spot rad.	2.2	~1*	mm
B-field on cathode	0.1	0.09	T
rms energy spread	0.03	0.1	%
Bunch charge	3.2	2*	nC

* Parameter can be varied

Magnetized beams in the FAST injector

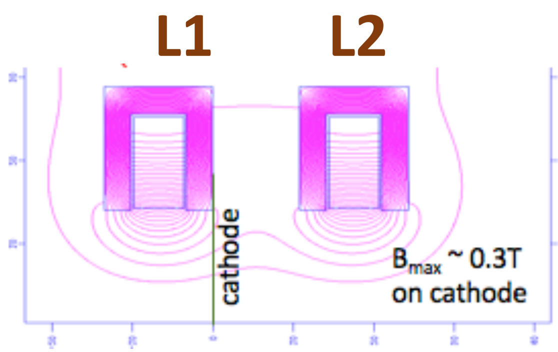
- The FAST injector includes
  - 1+1/2 RF gun
  - High quantum efficiency Cs_2Te photocathode
  - A symmetrical solenoid configuration can provides substantial field on cathode up to 0.15 T
- Magnetized beam is characterized by the *magnetization* parameter



$$\mathcal{L} = \frac{eB_c}{2mc}\sigma_c^2 \simeq 294 B_c[T]\sigma_c^2[m]$$

Laser-spot size on cathode

B field on cathode



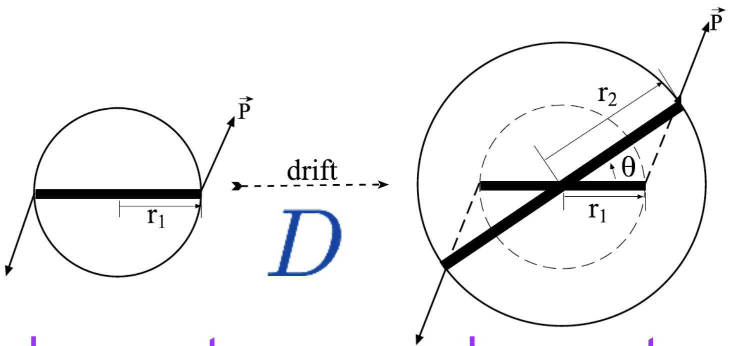
- Drift emittance is

$$\varepsilon_d = \varepsilon_+ \simeq 2\mathcal{L} \text{ (for JLEIC } \varepsilon_d \simeq 36\ \mu\text{m)}$$

Magnetized beams generation at FAST

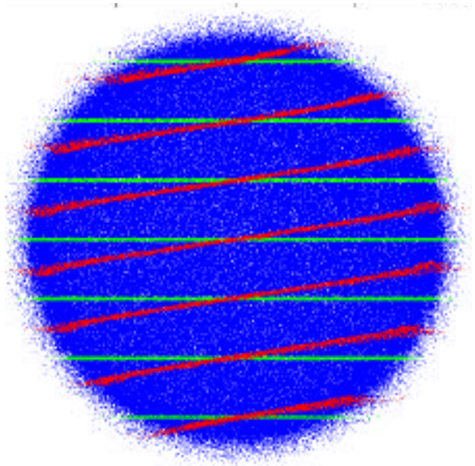
- During the winter 2017 run we did some *low-charge* (pC) magnetized beam
- Inferred the magnetization via measurement of the kinetic angular momentum

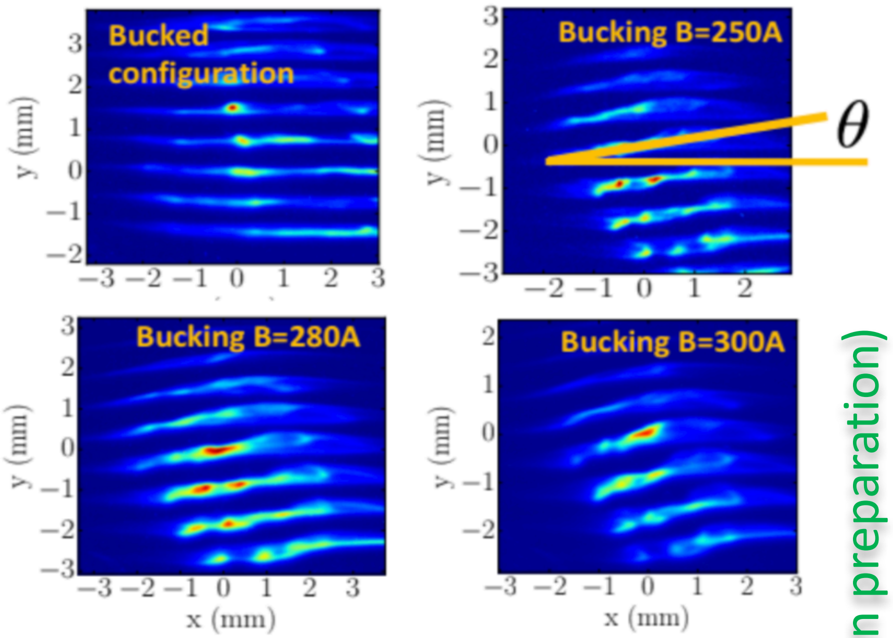
$$\mathcal{L}_n \equiv \gamma\mathcal{L} = \gamma\frac{\sigma_1\sigma_2\sin\theta}{D}$$

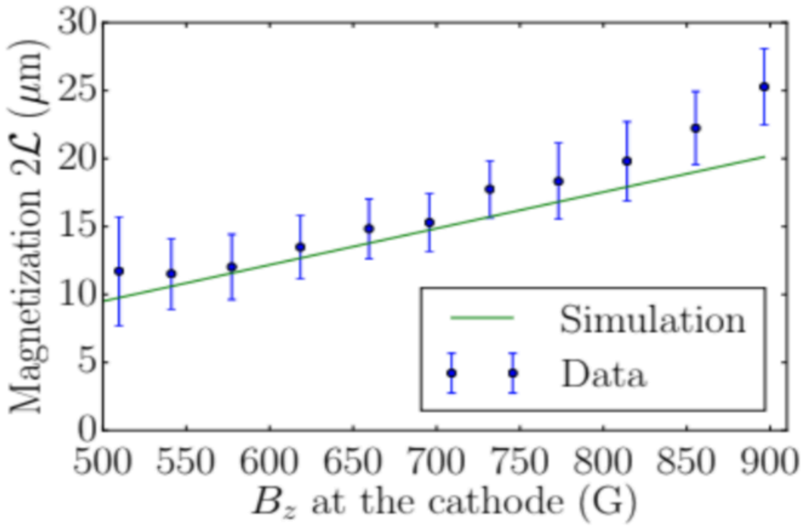


beam at slits

beam at observation point







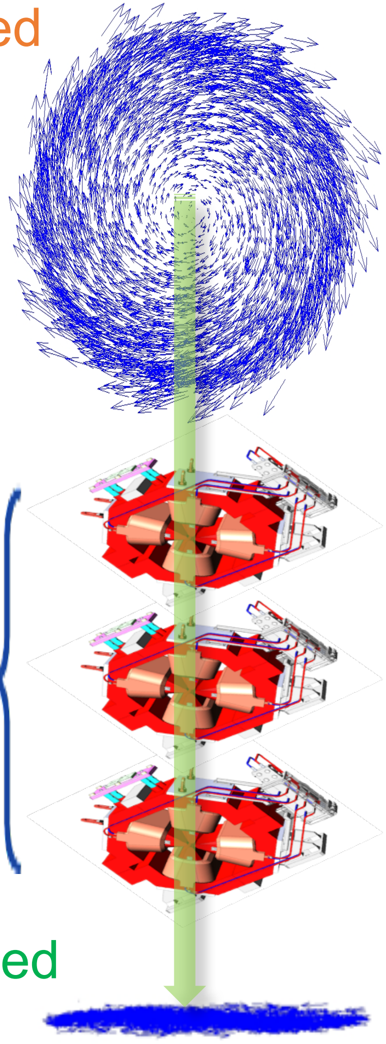
(A. Halavanau, in preparation)

Alternative measurement via decoupling

- A set of three quadrupole magnets can decoupled an incoming magnetized beam
- In the process the magnetized beam eigen-emittances are mapped into conventional transverse emittances

$$\varepsilon_{n,\pm} = \sqrt{(\varepsilon_{n,u})^2 + (\gamma\mathcal{L})^2} \pm \gamma\mathcal{L}$$

$$\begin{cases} \varepsilon_{n,+} = 2\gamma\mathcal{L} \ \text{(drift emittance)} \\ \varepsilon_{n,-} = \dfrac{(\varepsilon_{n,u})^2}{2\gamma\mathcal{L}} \end{cases}$$



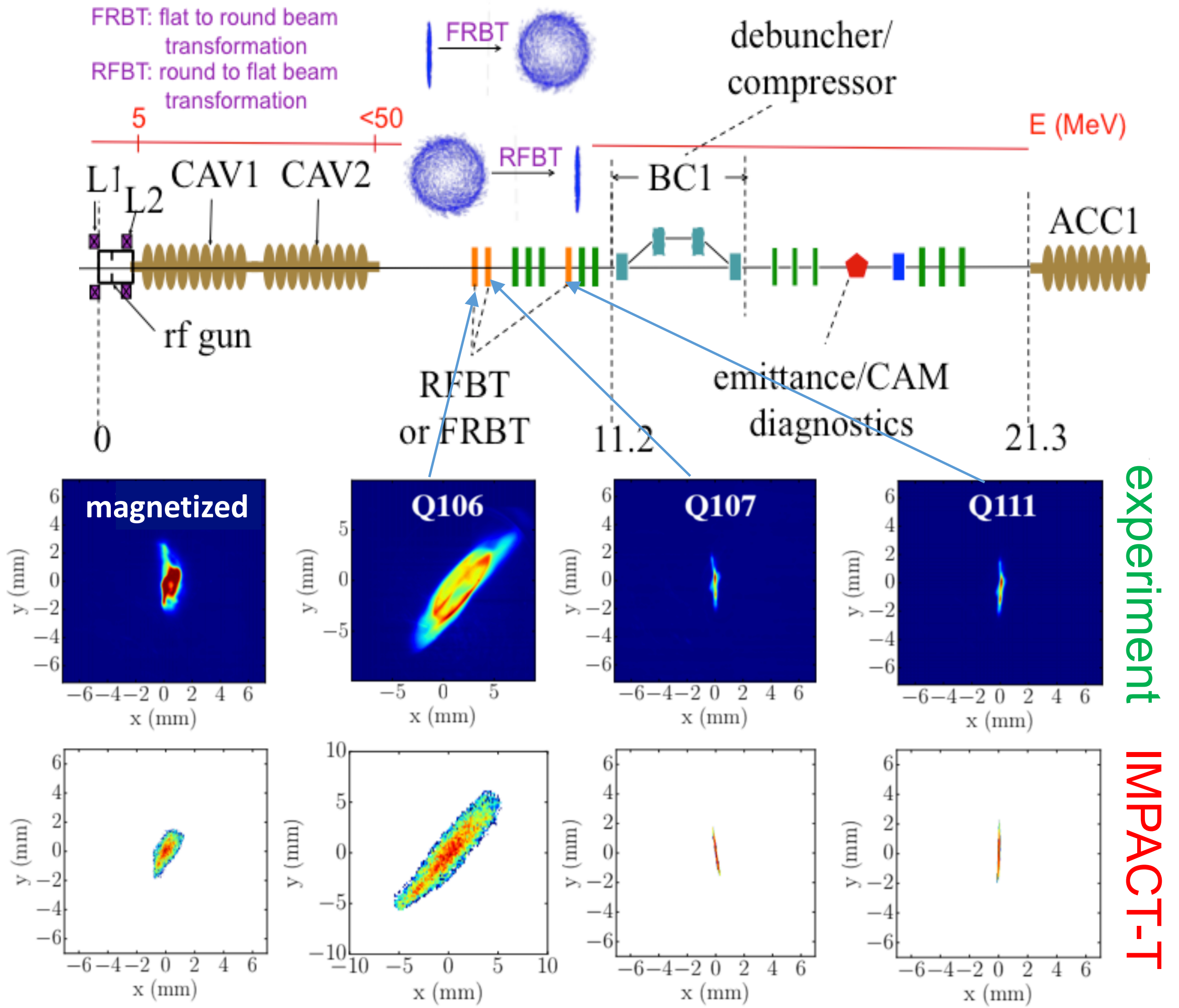
R. Brinkmann et al., PRSTAB 4, 053501 (2001)
Y. Derbenev, University of Michigan report UM-HE-98-04 (1998)

Decoupling into flat beams @ FAST (preliminary)

- Low charge experiment (pC) performed in Winter 2017
- Demonstrated flat-beam emittance repartition

Experimental results			
Norm. emit.	Vert. fb	Hor. fb	Units
ϵ_x	0.13 ± 0.03	12.7 ± 2.79	μm
ϵ_y	14.4 ± 3.17	0.17 ± 0.04	μm
ϵ_{4D}	1.37 ± 0.42	1.47 ± 0.49	μm
IMPACT-T simulations			
ϵ_x	0.08	17.7	μm
ϵ_y	18.0	0.10	μm
ϵ_{4D}	1.20	1.33	μm

$$\varepsilon_{4D} \equiv \sqrt{\varepsilon_{n,-}\varepsilon_{n,+}}$$

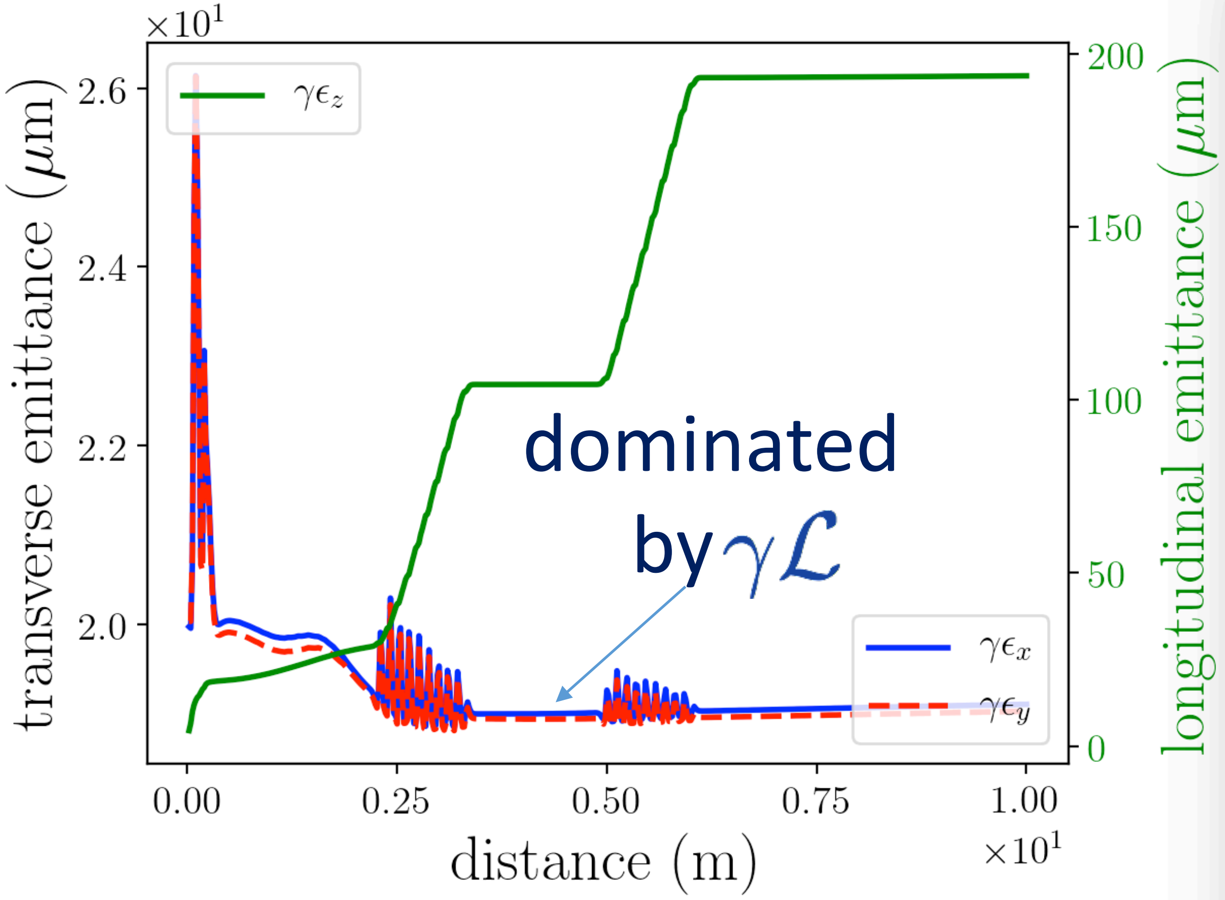


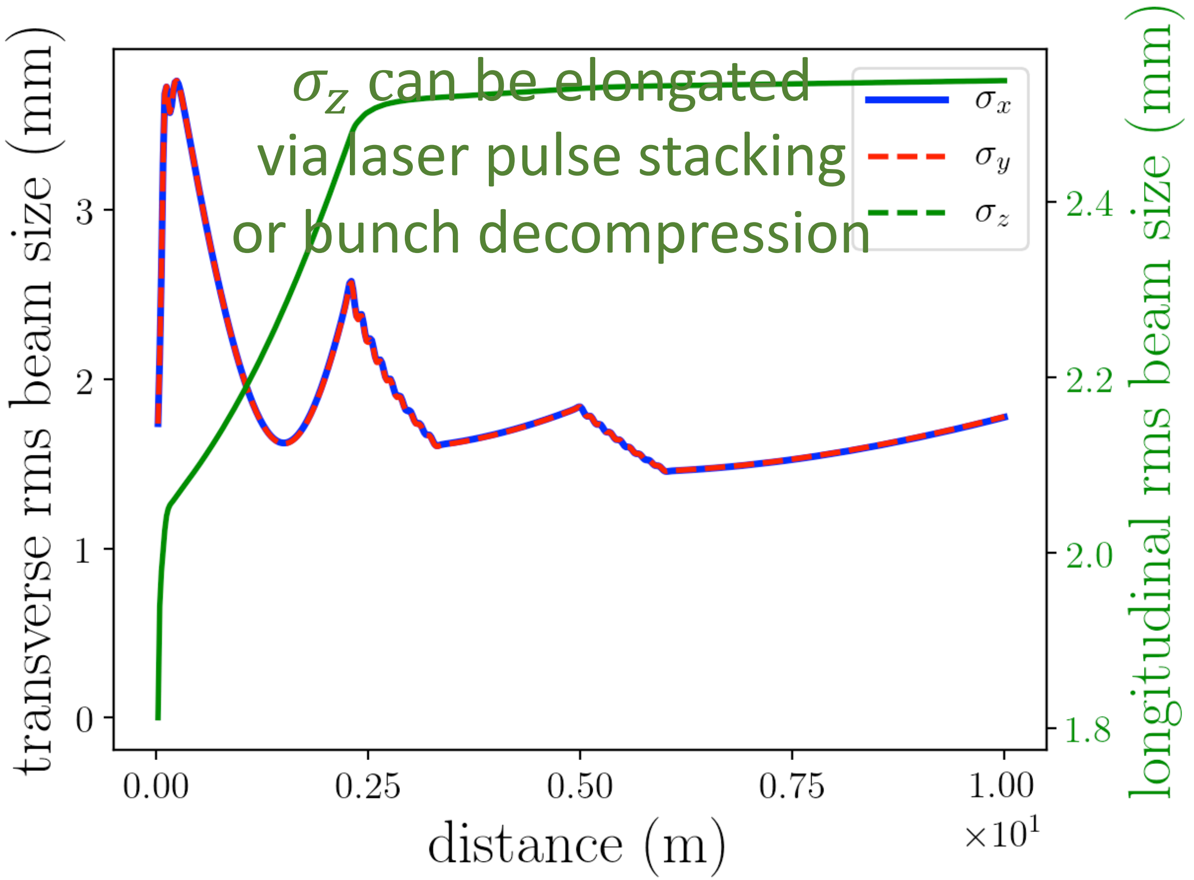
(A. Halavanau, in preparation)

Formation of high-charge magnetized beams I

- Simulation to demonstrate FAST photo-injector can produce JLEIC-like emittances (σ_c = 1.1mm, Q = 3.2 nC)

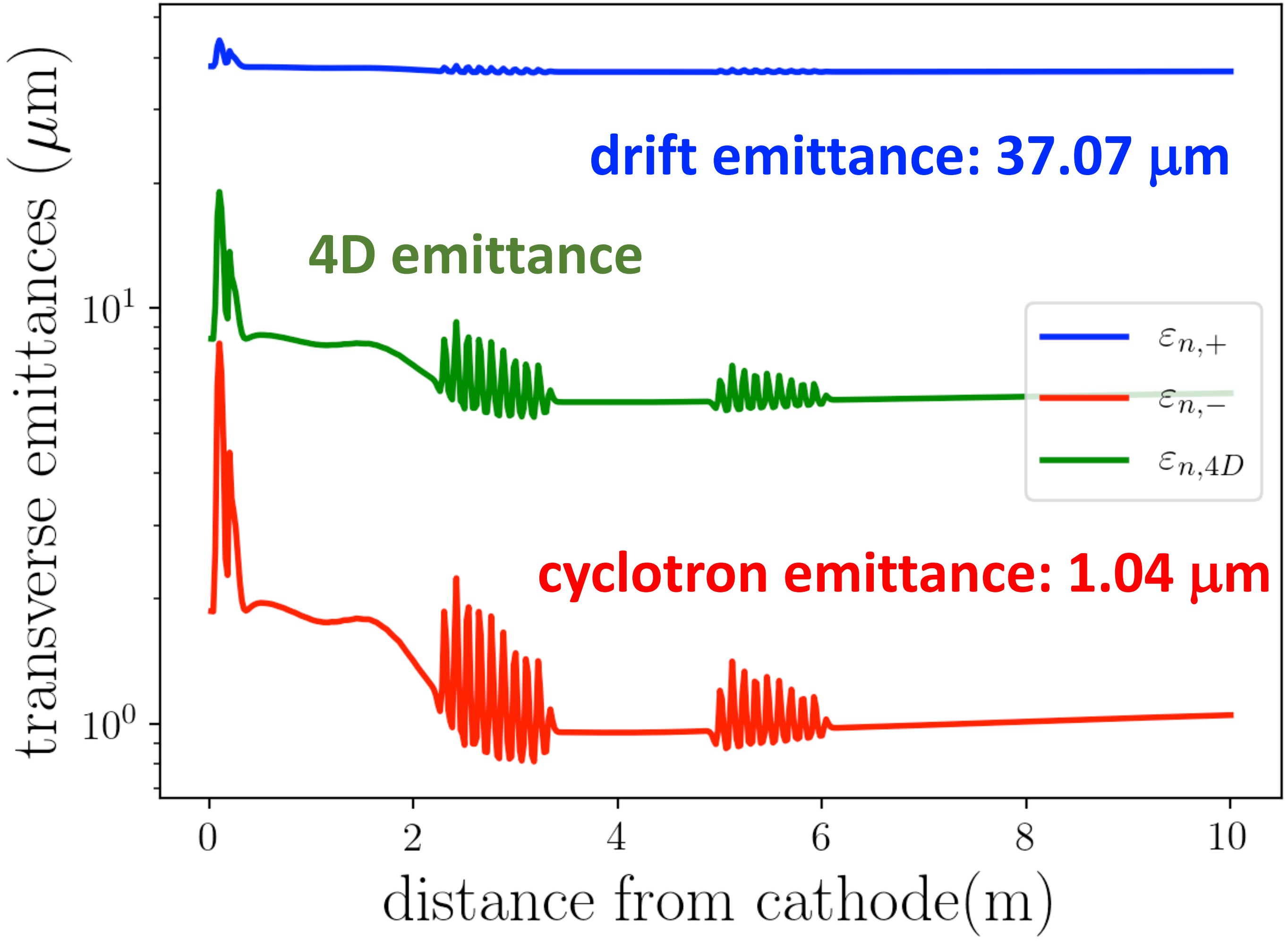
(run # 002787)





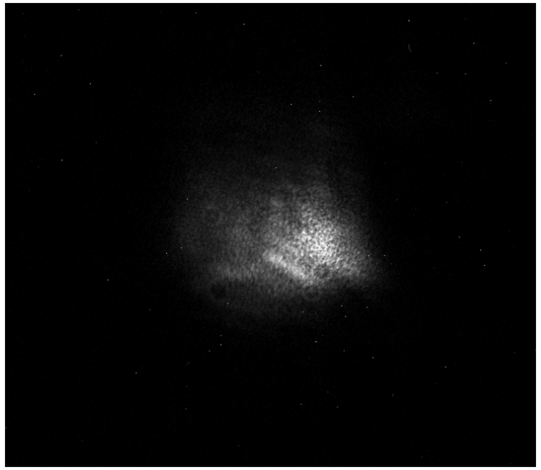
Formation of high-charge magnetized beams II

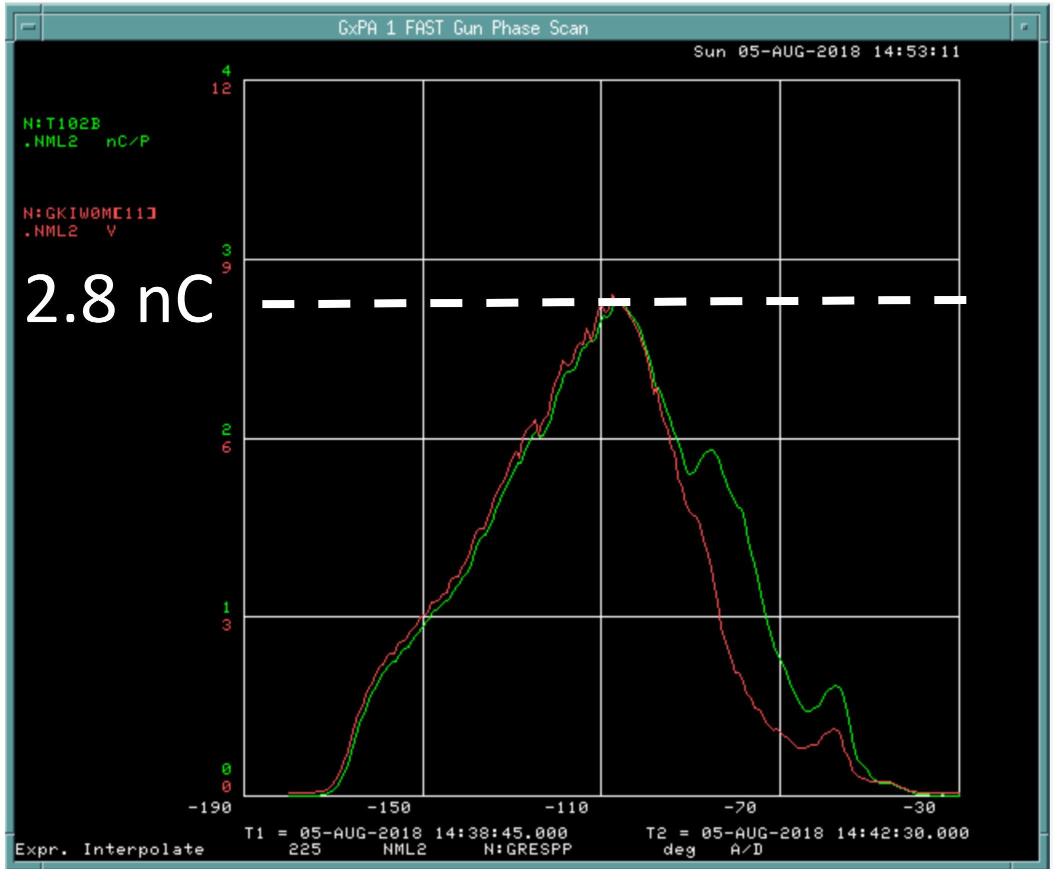
- Started with thermal emittance associated to Cs_2Te photocathode
- Eigen-emittance partition consistent with required value for JLEIC ERL cooler
- Magnetization at cathode is
$$\gamma\mathcal{L} \simeq 18.02\ \mu m$$
- Next step is to understand mapping to real conventiona emittance using RFBT



Going to higher charge

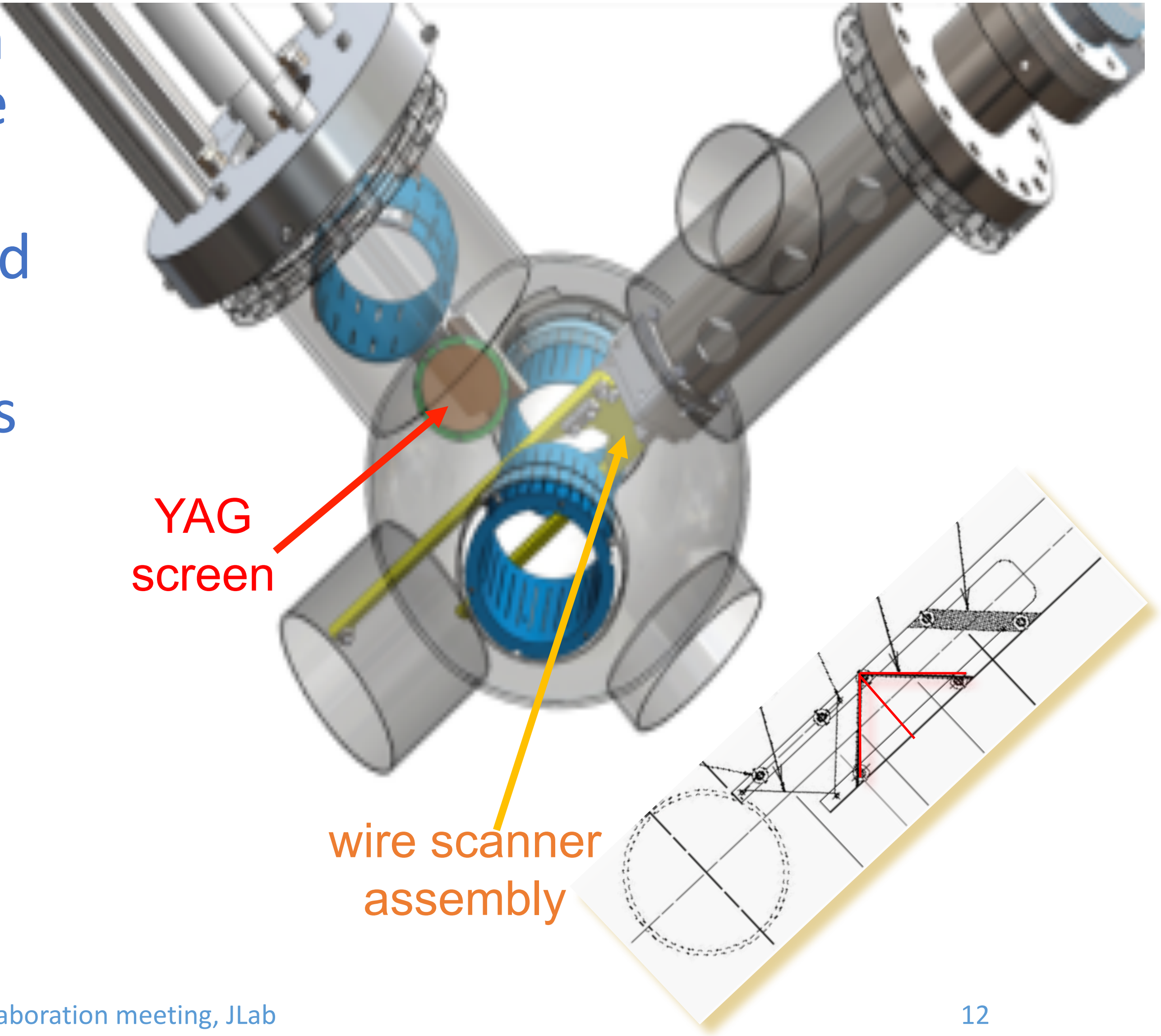
- Experiment on high-charge magnetized beam generation in preparation
- Some challenges being addressed:
  - Laser-distribution control (transverse + longitudinal if needed)
- So far up to 2.8 nC was produced (limited by the laser setting)





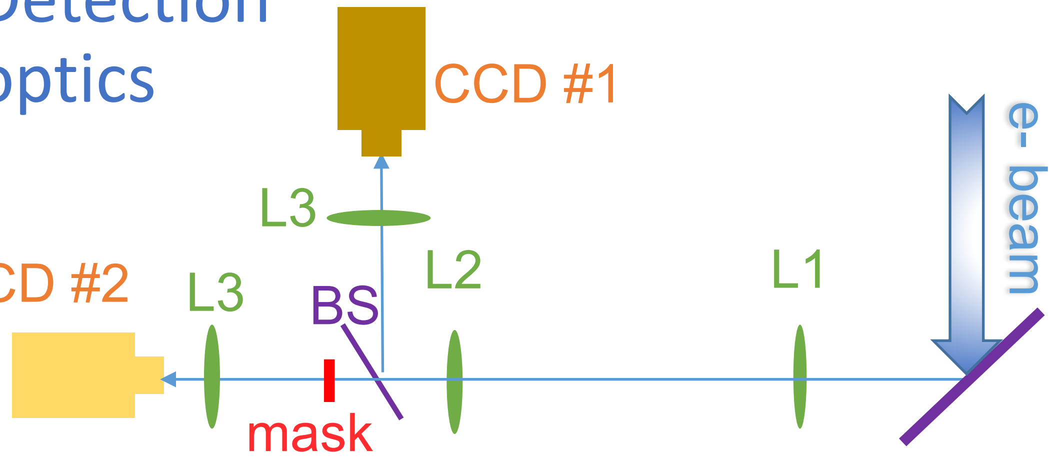
Halo formation in magnetized beams

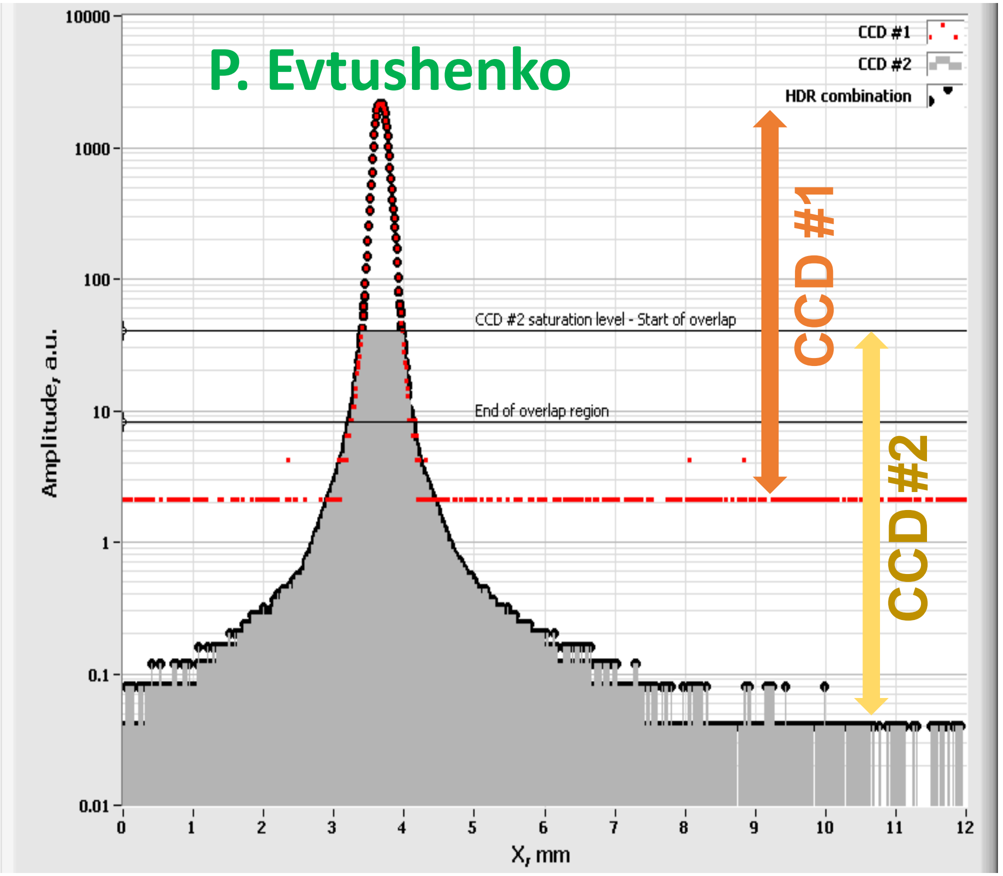
- Halo could cause beam loss which would ultimately limit the average current of the ERL cooler
- Various source of halo (some could be mimicked with laser shaping)
- Large-dynamical-range diagnostics developed at Jlab (P. Evtushenko and J. Gubeli):
    - Wire scanner with high-dynamical range electronic or PMT (measured projections only)
    - YaG:Ce screen with dual-sensor detection system.



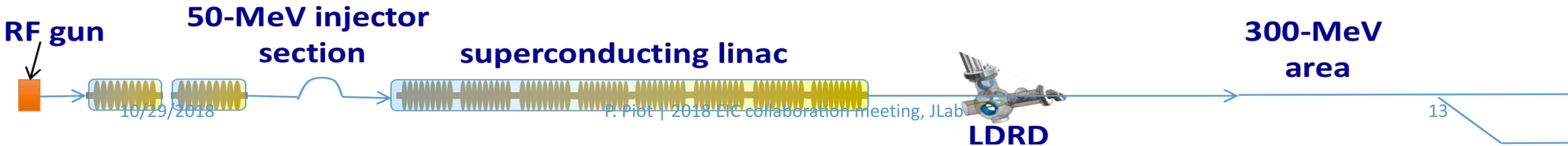
Measurement of halo at $\sim 10^{-6}$ fraction

- Detection optics



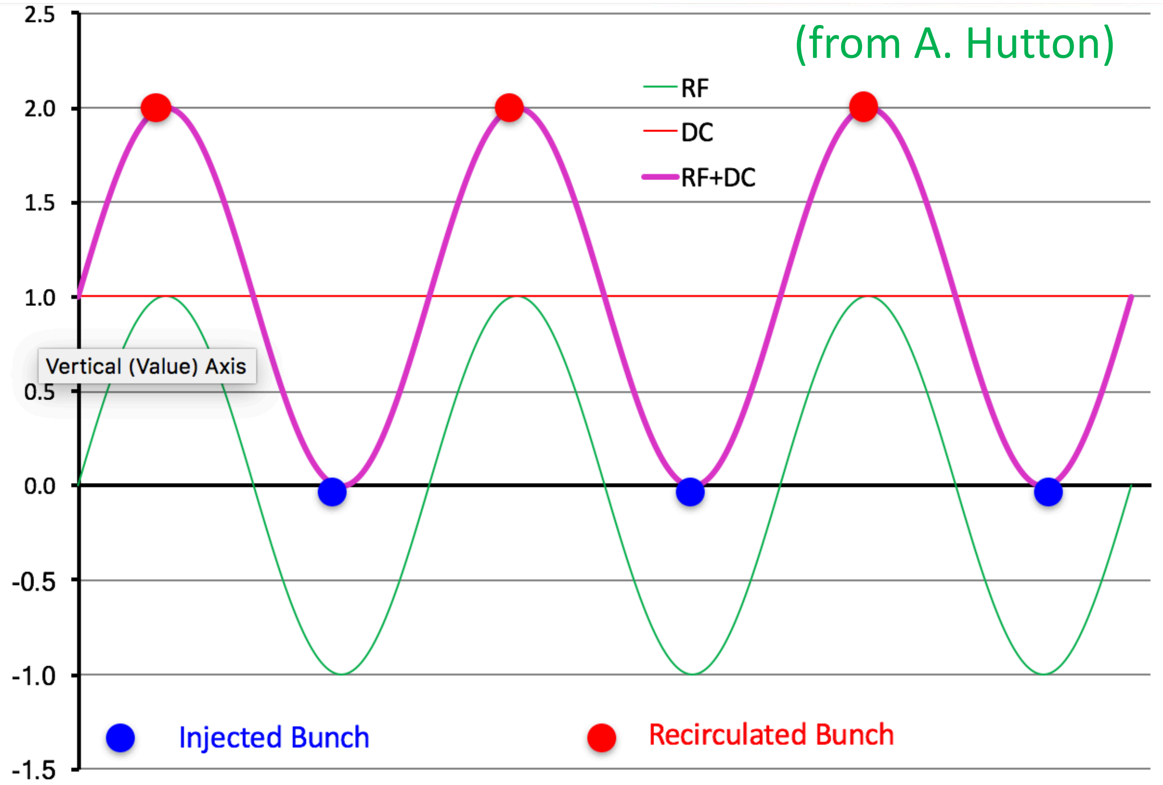


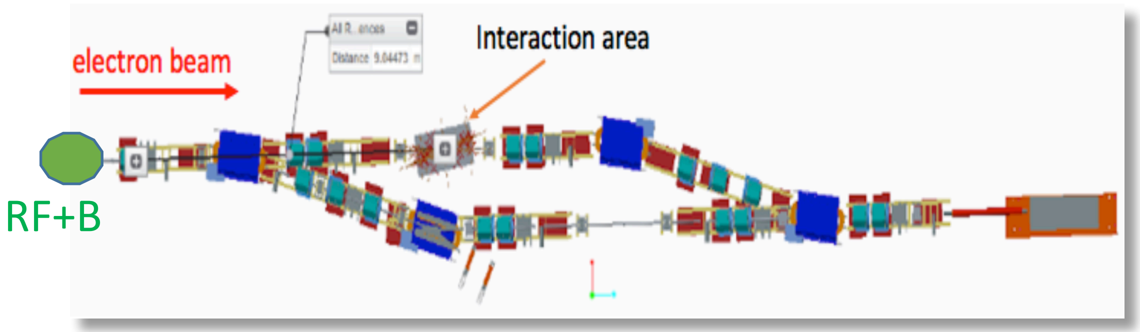
- Magnetized beam will be transported for 50-70 m and halo diagnosed
- Mapping of eigen-emittance will be done in 45-deg frame (w. normal quad)



Test of a new merger concept (during year 2)

- Straight merger concept (see talk by K. Deitrick):
  - RF deflecting cavity with superimposed magnetostatic fields.
  - Separation of injector and recirculated beam with angular separation sufficient for septum magnet.
- Preliminary tests done at Cornell
- Follow up tests at FAST:
  - beam degradation due to RF field
  - Impact on magnetization
  - Depending on location; RF cavity will also be used as a longitudinal phase space diagnostics





Summary

1. High-charge magnetized beam:
   a. Simulation of 3.2 nC magnetized beam with parameters consistent with JLEIC mostly done; need to understand limiting effects associated with mapping into conventional emittances (flat-beam transform).
   b. Simulations of transport of magnetized beams started.
   c. Beam experiment on magnetized beam formation & characterization in preparation.
2. High-current magnetized beams
   a. Possible locations for the LDRD identified, final locations to be selected based on simulations (1.b).
3. New merger concept
   a. planned in year 2, identified a 1.3-GHz power supply, location of experiment not yet decided.