Wakefield Acceleration and Phase Space Manipulation at the Argonne Wakefield Accelerator Facility (AWA)

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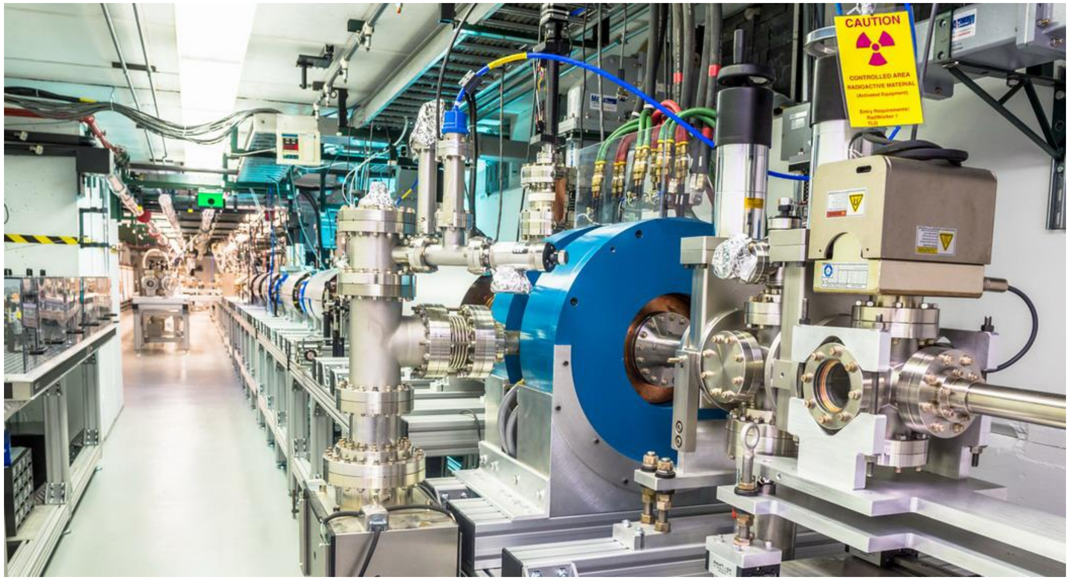
Outline

- AWA facility and its capabilities
- Two beam acceleration (TBA)
- Phase space manipulation
- Collinear wakefield acceleration with shaped bunches
- Electron radiographic imaging (ERI)
- Cathode test-stand

The AWA Facility:
A Flexible Testbed for Accelerator R&D

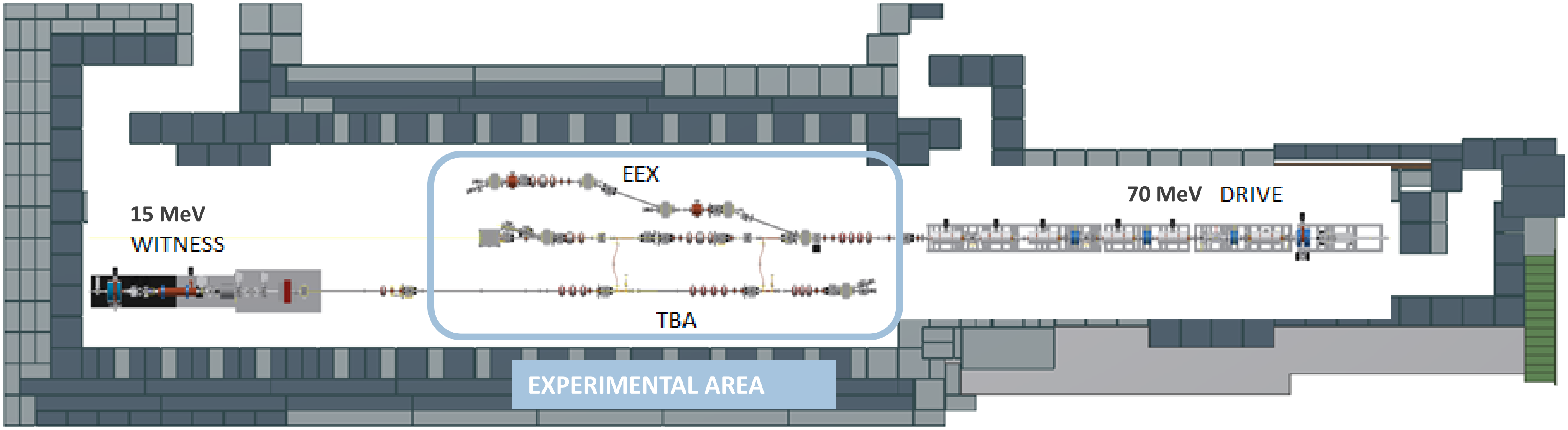


Mission:

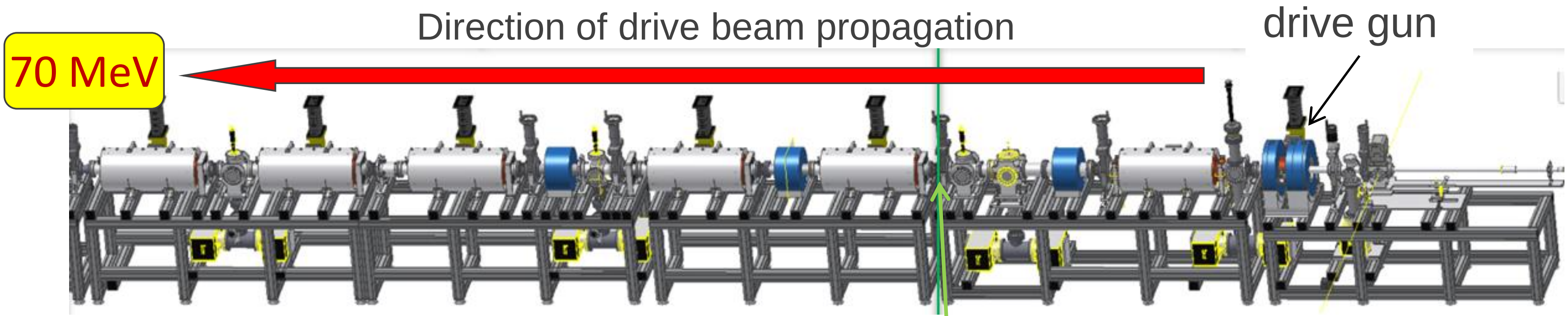
Studying the Physics and Developing the Technologies for Future Advanced Accelerators (primarily for HEP but also for other applications).

Main focus of research at AWA

- Beam driven wakefield acceleration
  - High intensity electron beam
  - Development of novel wakefield structures
- High power RF generation
- Phase space manipulation (bunch shaping)
- Novel applications



Drive linac: High Charge Measurements

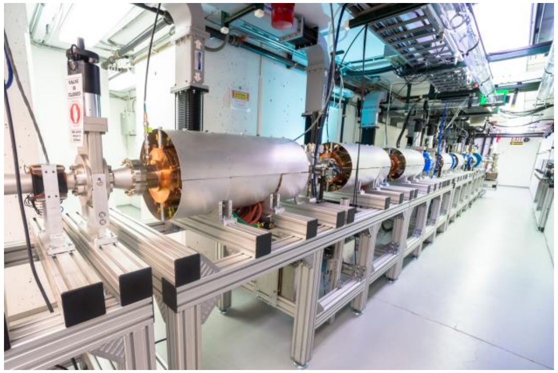


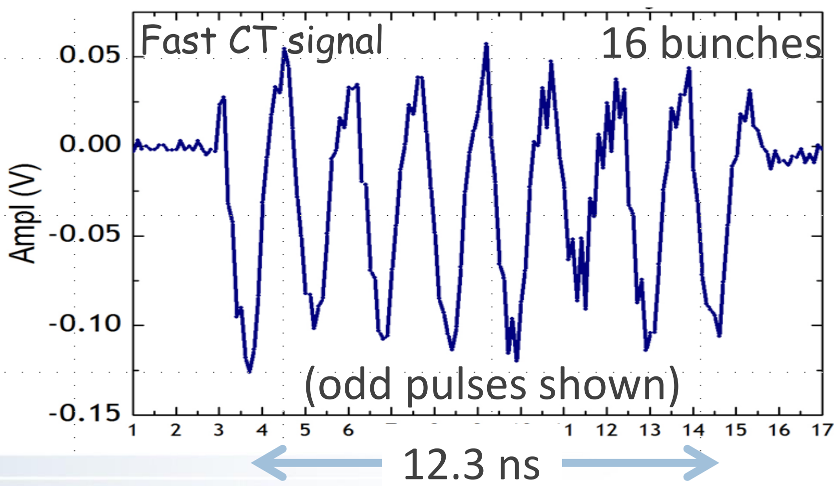
- Single bunch operation
  Q = 0.01-100 nC

- Bunch train operation
  Options of 2, 4, 8, 16, 32 bunches,
  with maximum charge in the train of about
  200 to 600 nC

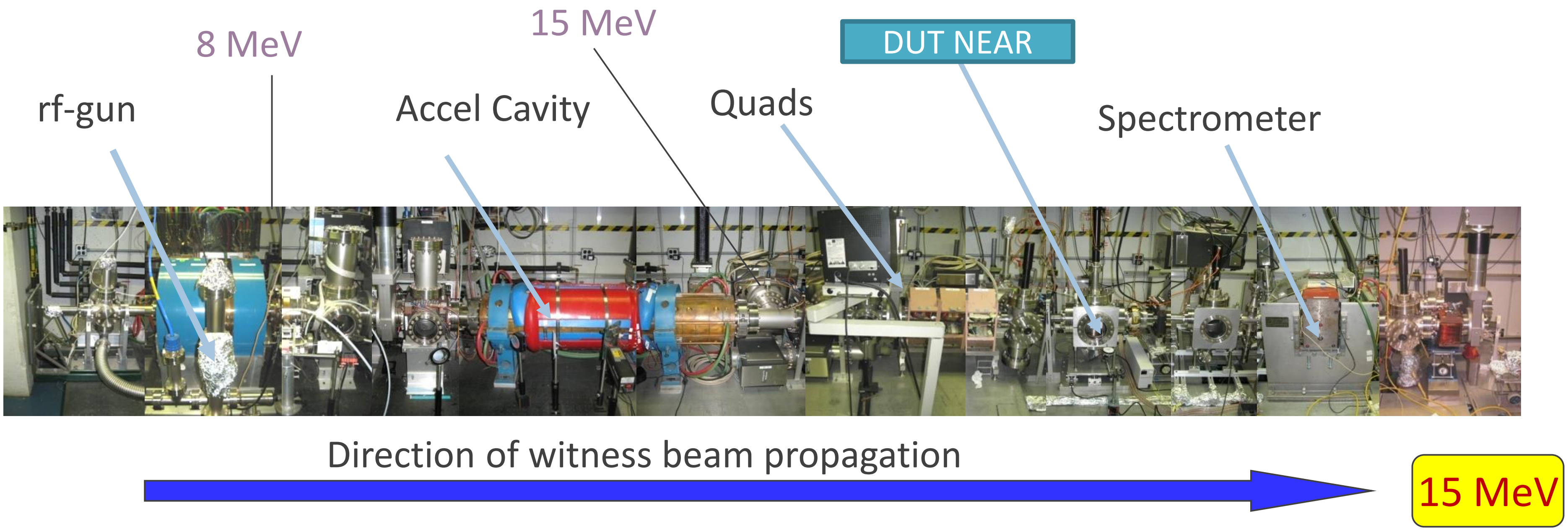
- **Drive RF photocathode Gun**
  - Cs_2Te photocathode
  - 248 nm laser
  - E_z = 85 MV/m

Variable duration = 6 – 12 ns





Witness Linac



- **Witness RF photocathode Gun**
  - Mg photocathode
  - 248 nm laser
  - E_z = 85 MV/m

Single bunch operation

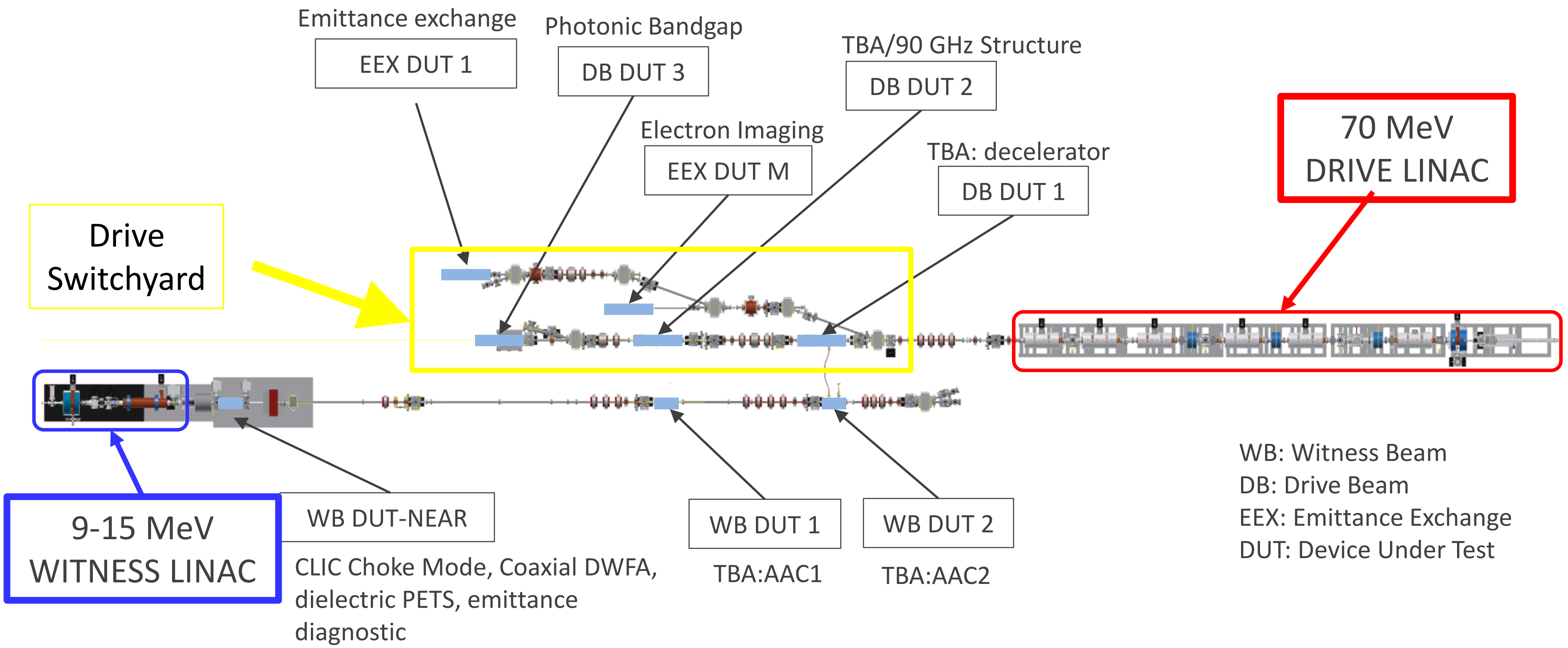
Q = 0.01-100 nC

Bunch train operation

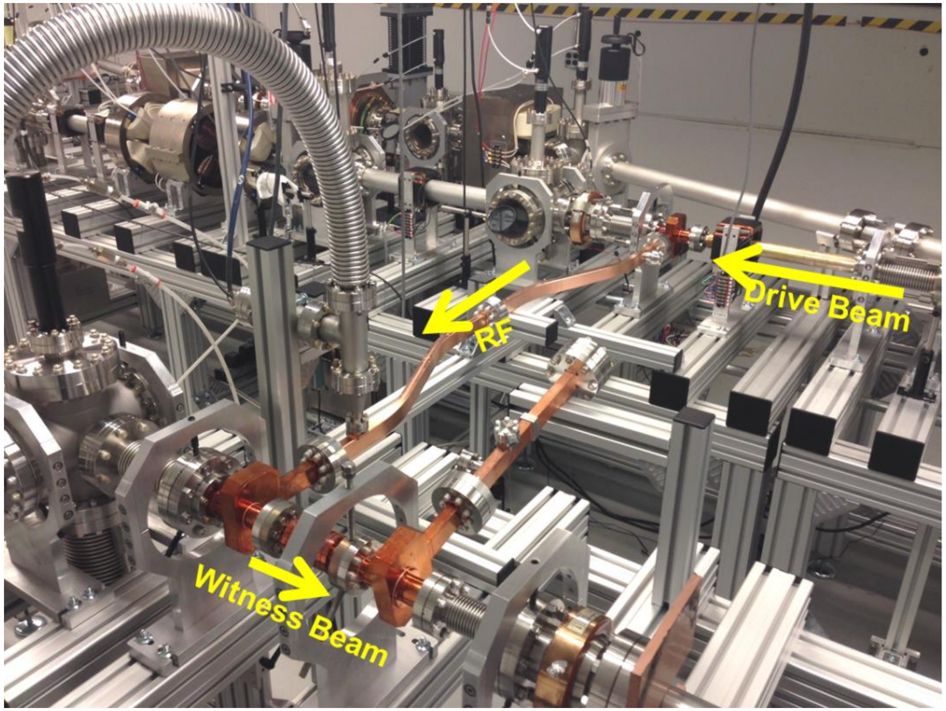
Possible, with a total charge of about 80 nC

AWA Beamlines

Flexible and reconfigurable, with multiple experimental areas

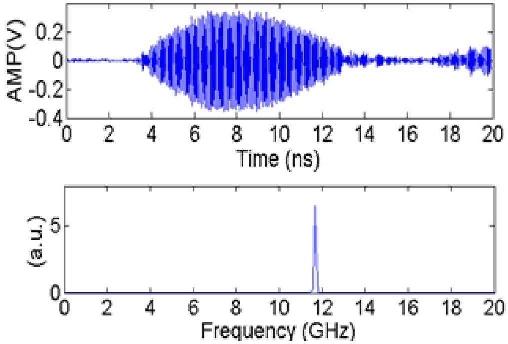


TBA experiment
11.7 GHz iris loaded metallic structures



Decelerating structure:
2π/3 mode
35 cells + coupling cells
0.22c group velocity

Accelerating structure:
2π/3 mode
3 cells + coupling cells
0.014c group velocity

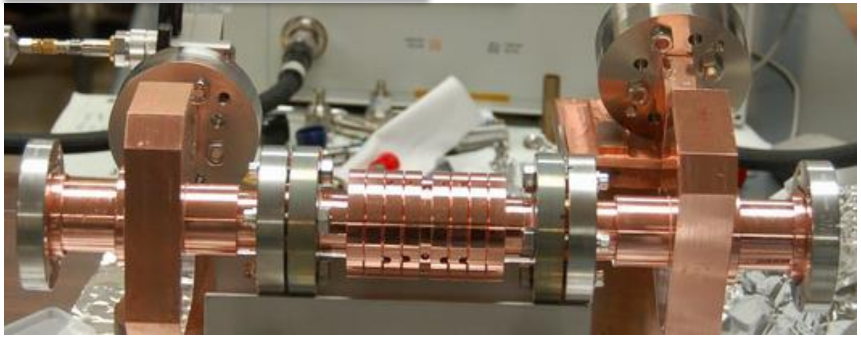


Structures used in the TBA/Staging Experiment

Power Extractor

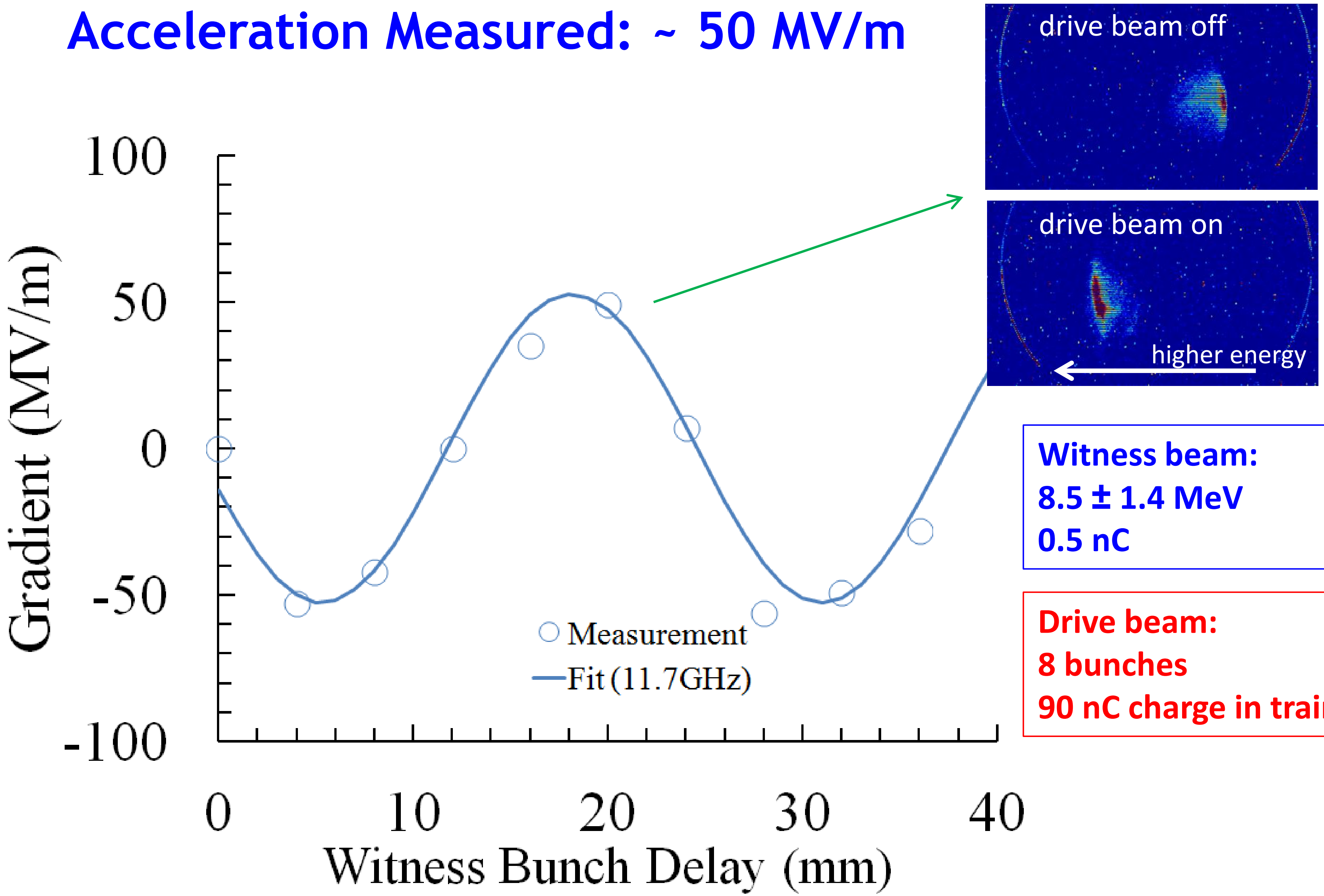
	Value
Freq.	11.7GHz
Mode	2pi/3
Aperture	17.6mm
Length	30cm
Passing Charge	8 x 20nC
Power	55MW

Accelerator



	Value
Freq.	11.7GHz
Mode	2pi/3
Aperture	6mm
Length	3cm
Input power	50MW
Gradient	100MV/m

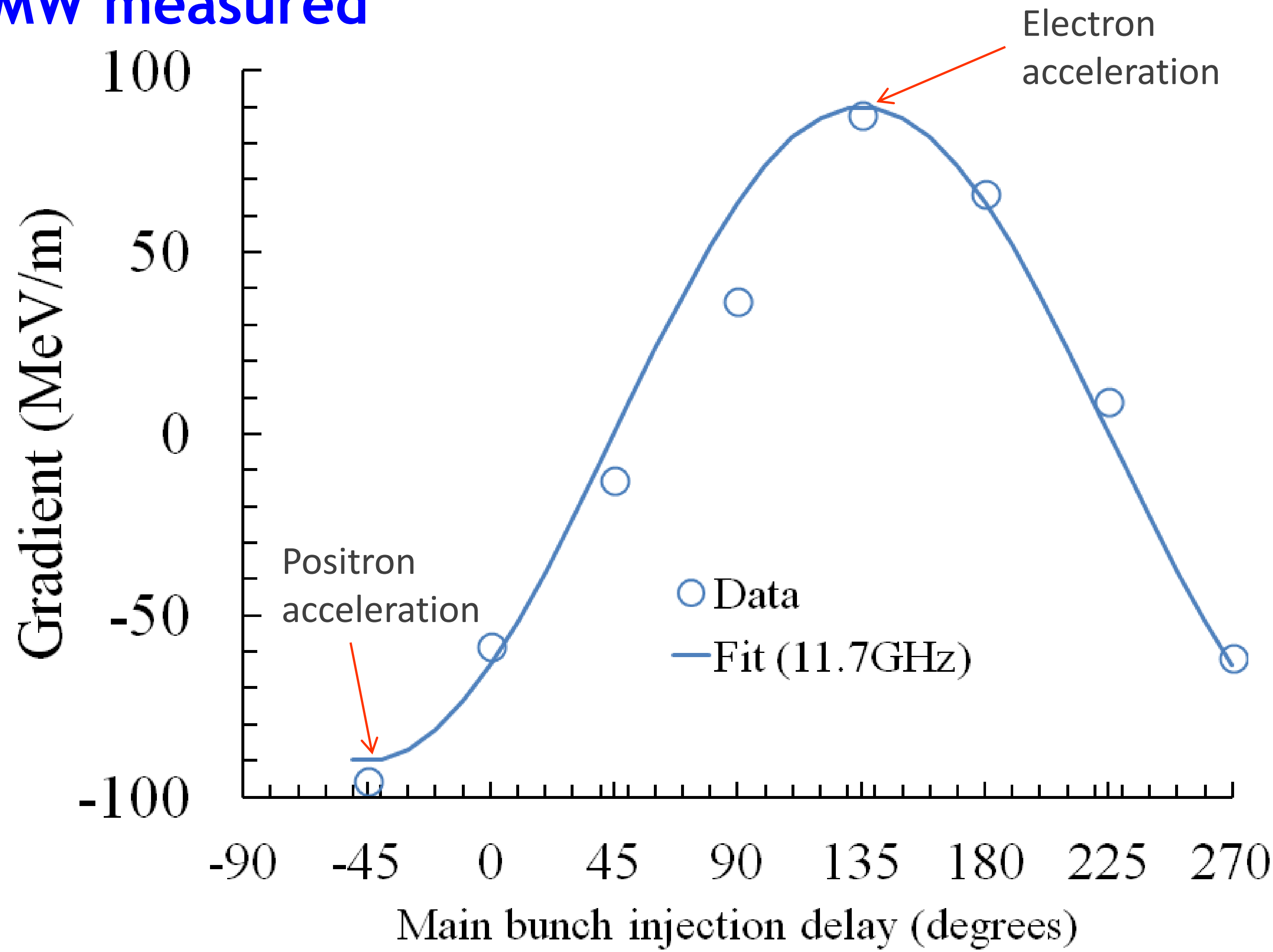
TBA data
Acceleration Measured: ~ 50 MV/m



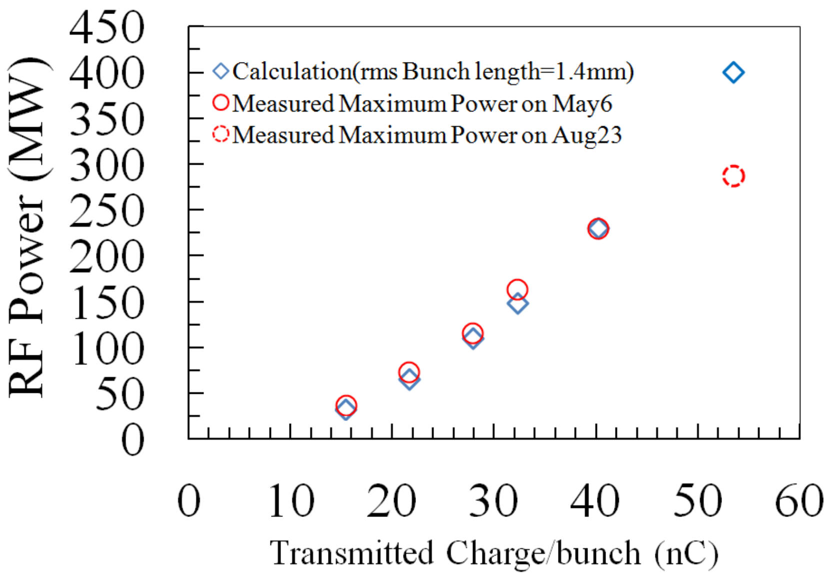
Witness beam:
8.5 ± 1.4 MeV
0.5 nC

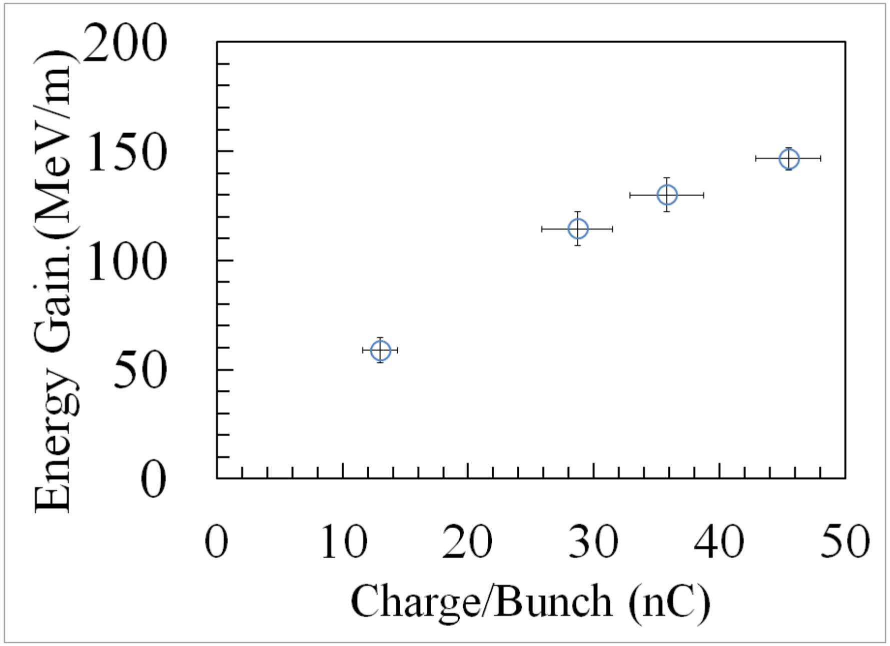
Drive beam:
8 bunches
90 nC charge in train

TBA data
Acceleration Measured: ~ 90 MV/m
80 MW measured



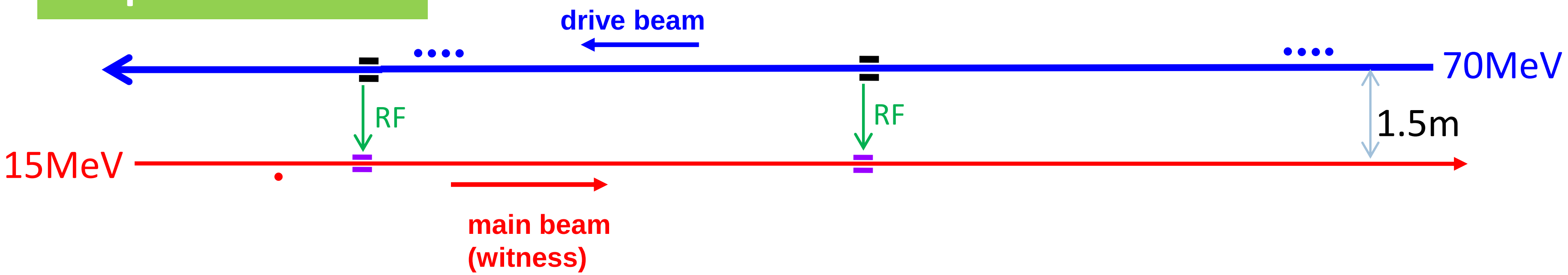
TBA data
Acceleration Measured: ~ 150 MV/m
300 MW measured



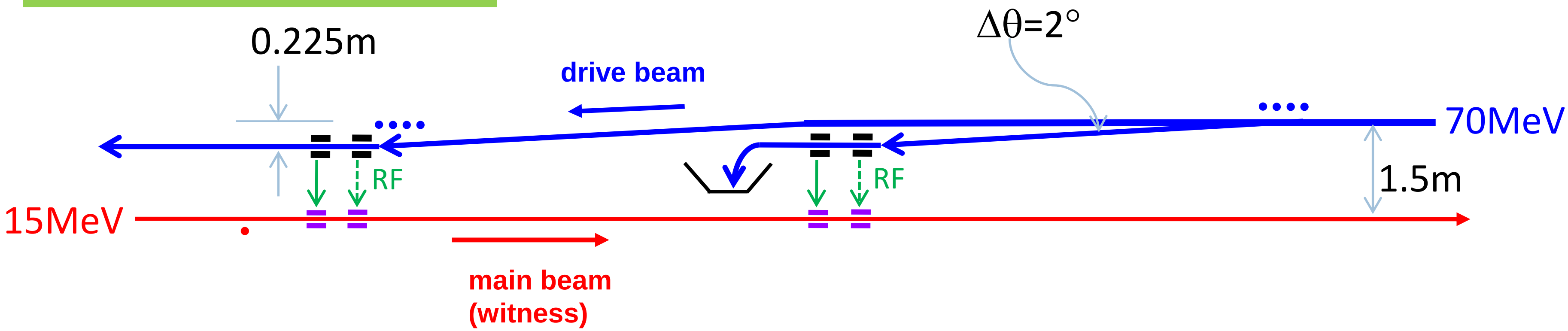


Staging Demonstration

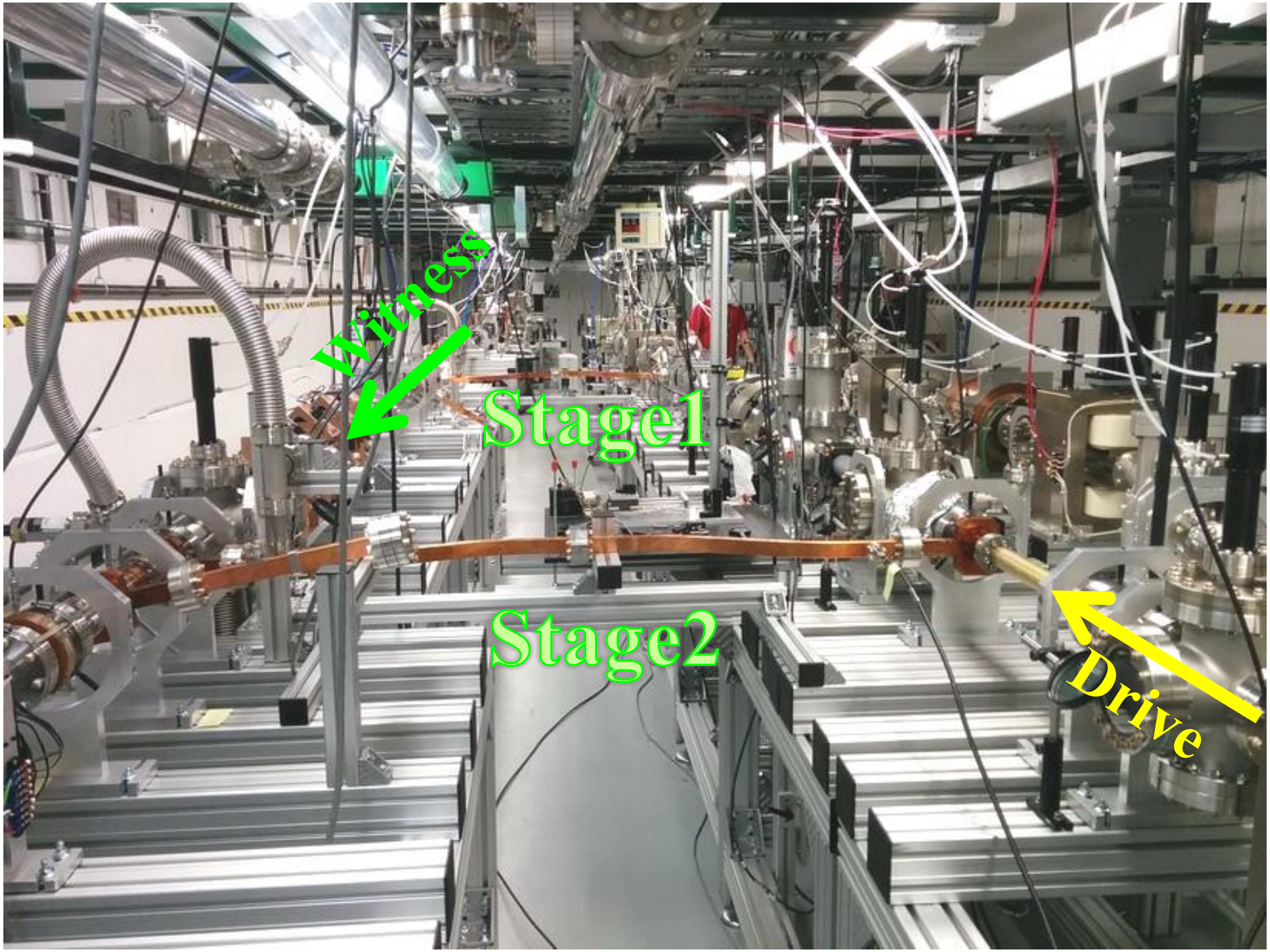
Simplified Version



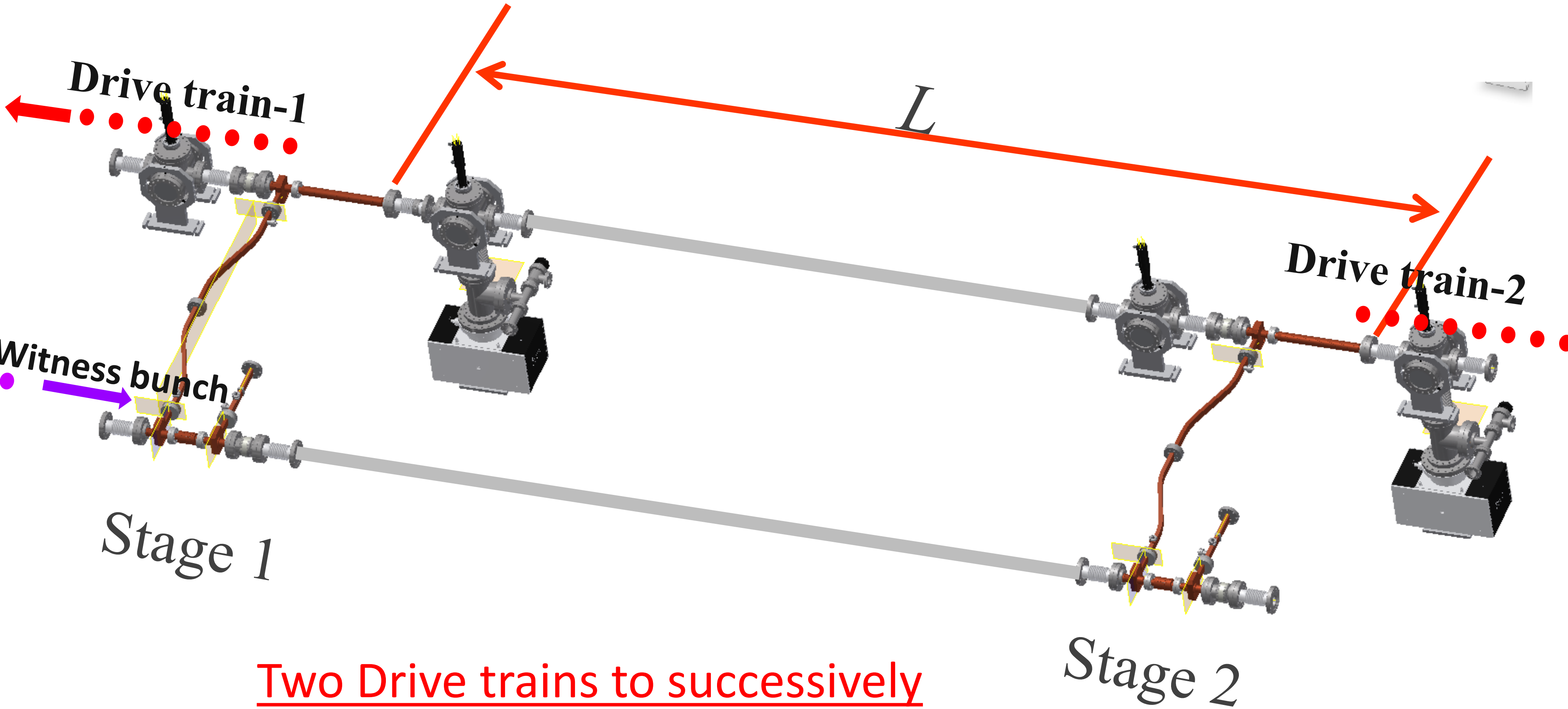
More realistic Version



Staging Demonstration at AWA

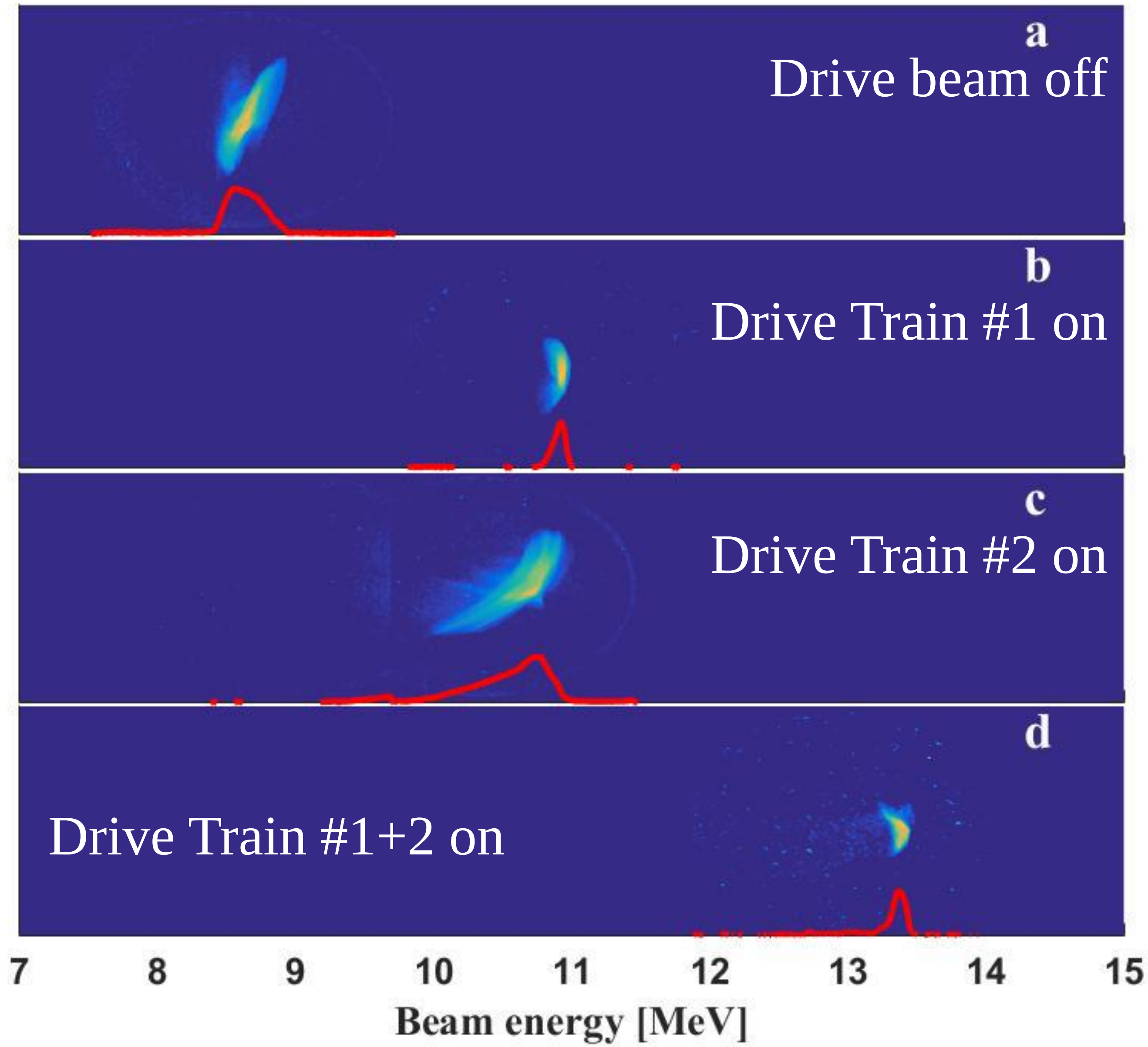


Timing Required for Staging Experiment



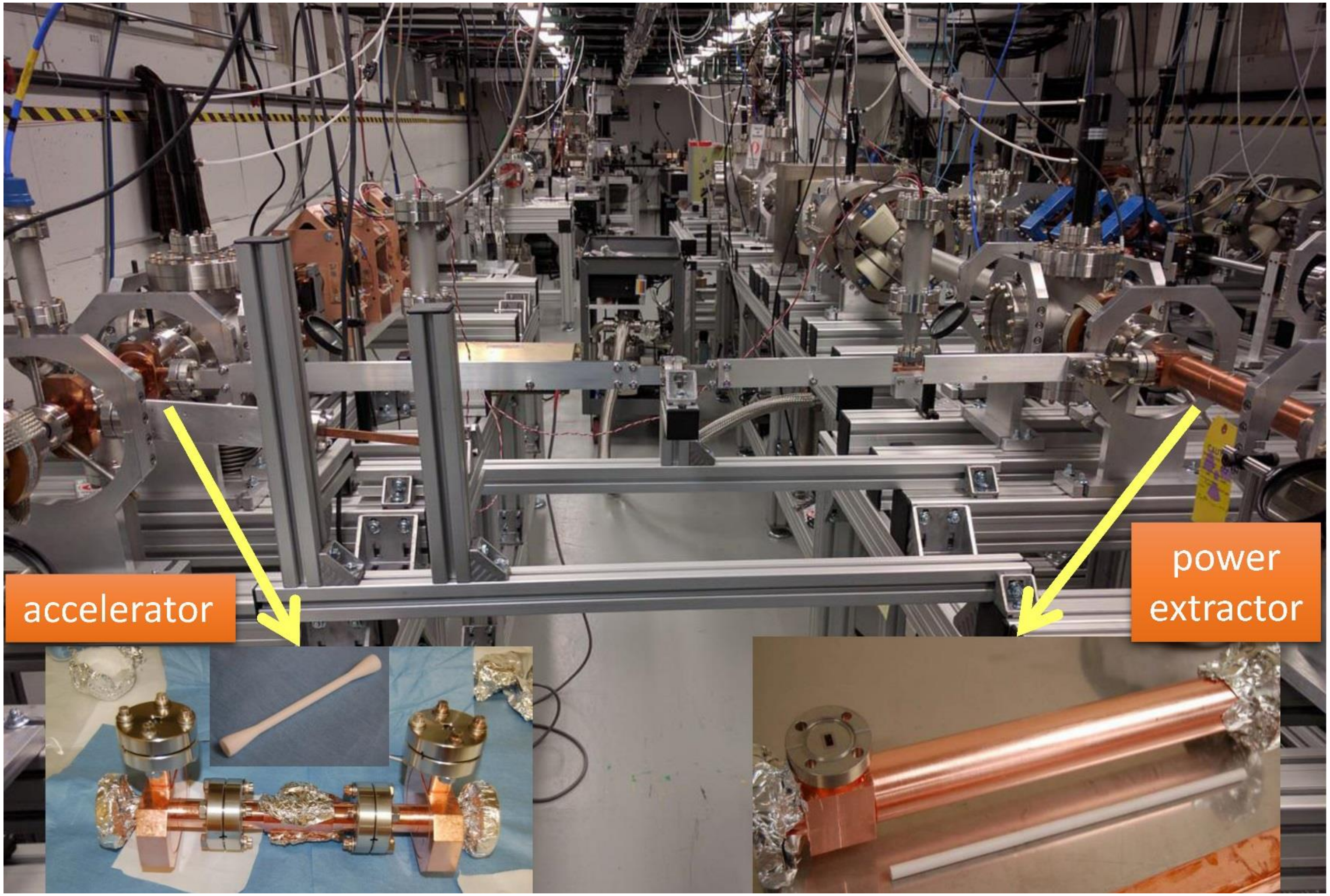
Two Drive trains to successively accelerate one witness bunch while preserving its beam quality

Staging Experiment at AWA

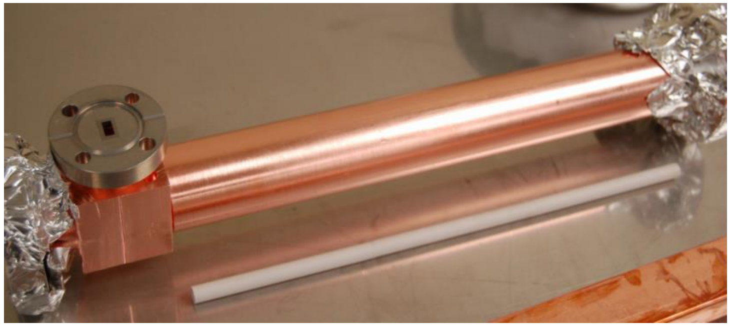


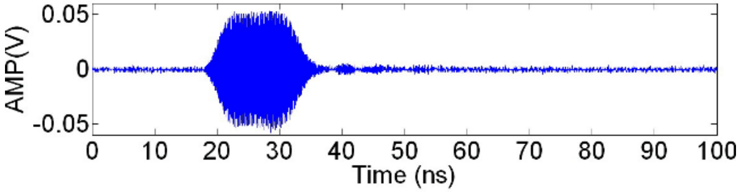
26 GHz dielectric TBA

- **Experimental setup**



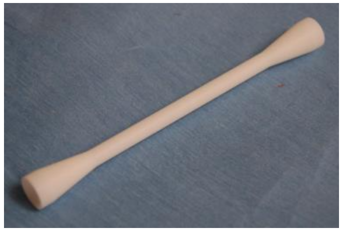
26 GHz Structure Parameters: Power Extractor





Dielectric ID / OD	7 mm / 9.068 mm
Dielectric constant	6.64
Length	30 cm
V_g / c	0.25
R/Q	9.79 kΩ/m
BW_{3dB} of coupler	120 MHz
Bunch charge	25 nC
Peak gradient	84 MV/m

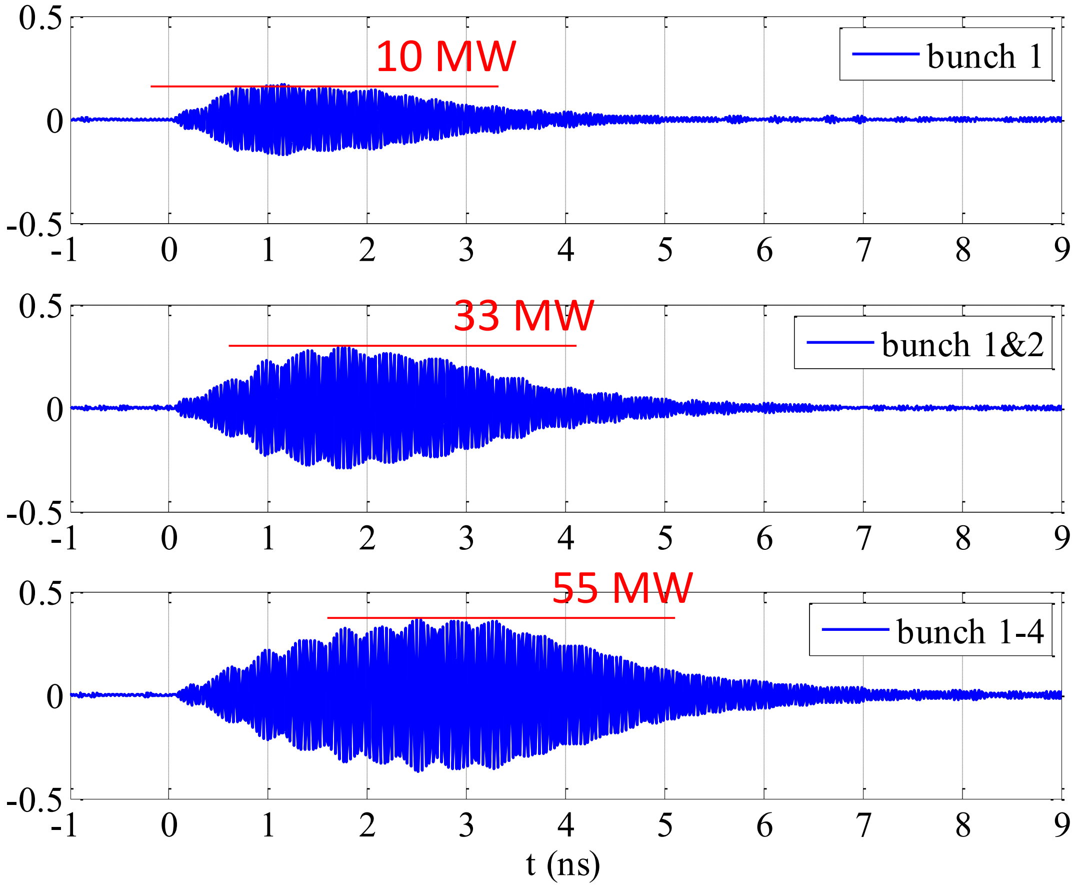
26 GHz Structure Parameters: Accelerator



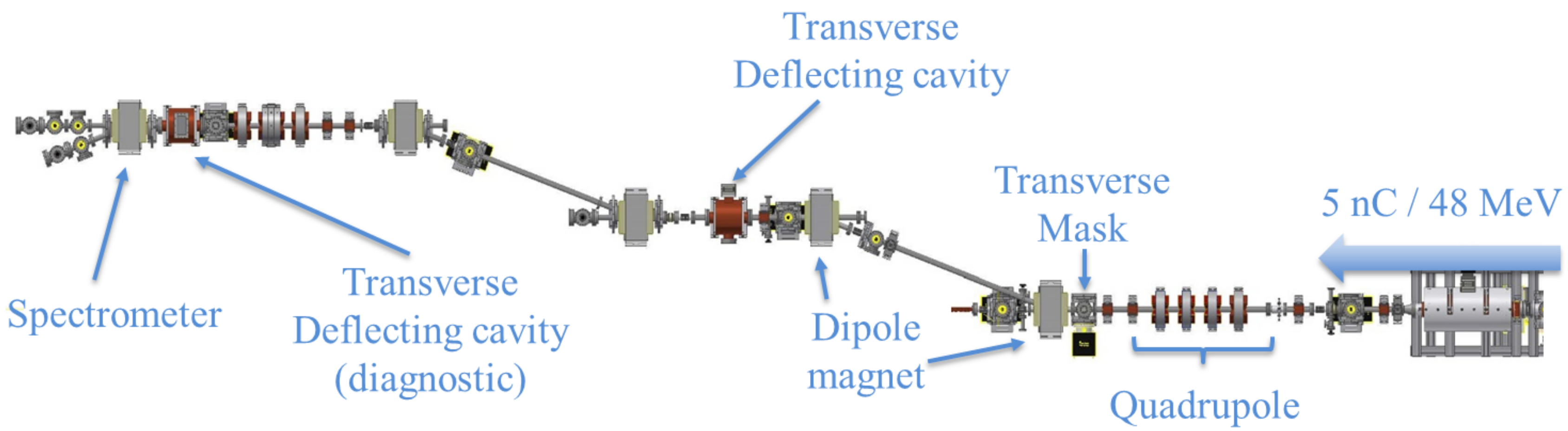
Dielectric ID / OD	3 mm / 5.025 mm
Dielectric constant	9.70
Length	10 cm
V_g / c	0.11
R/Q	22 kΩ/m
Q (loss tan = 10^{-4})	2295
Shunt impedance	50.4 MΩ/m
Input power	300 MW
Gradient	150 MV/m

26 GHz dielectric TBA

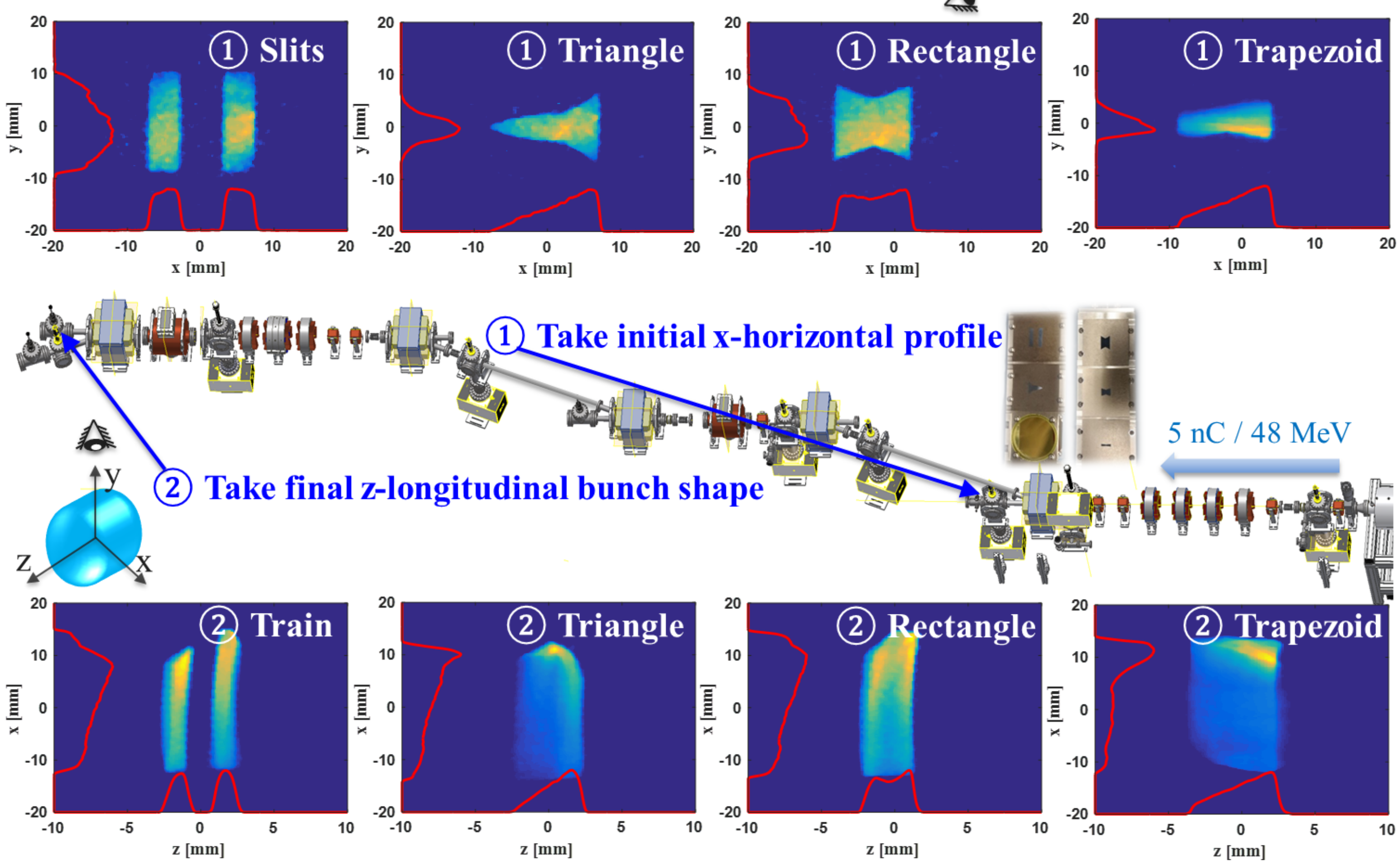
- **Power generation**
  - 55 MW 26 GHz power generated by 4-bunch train, 20 nC per bunch



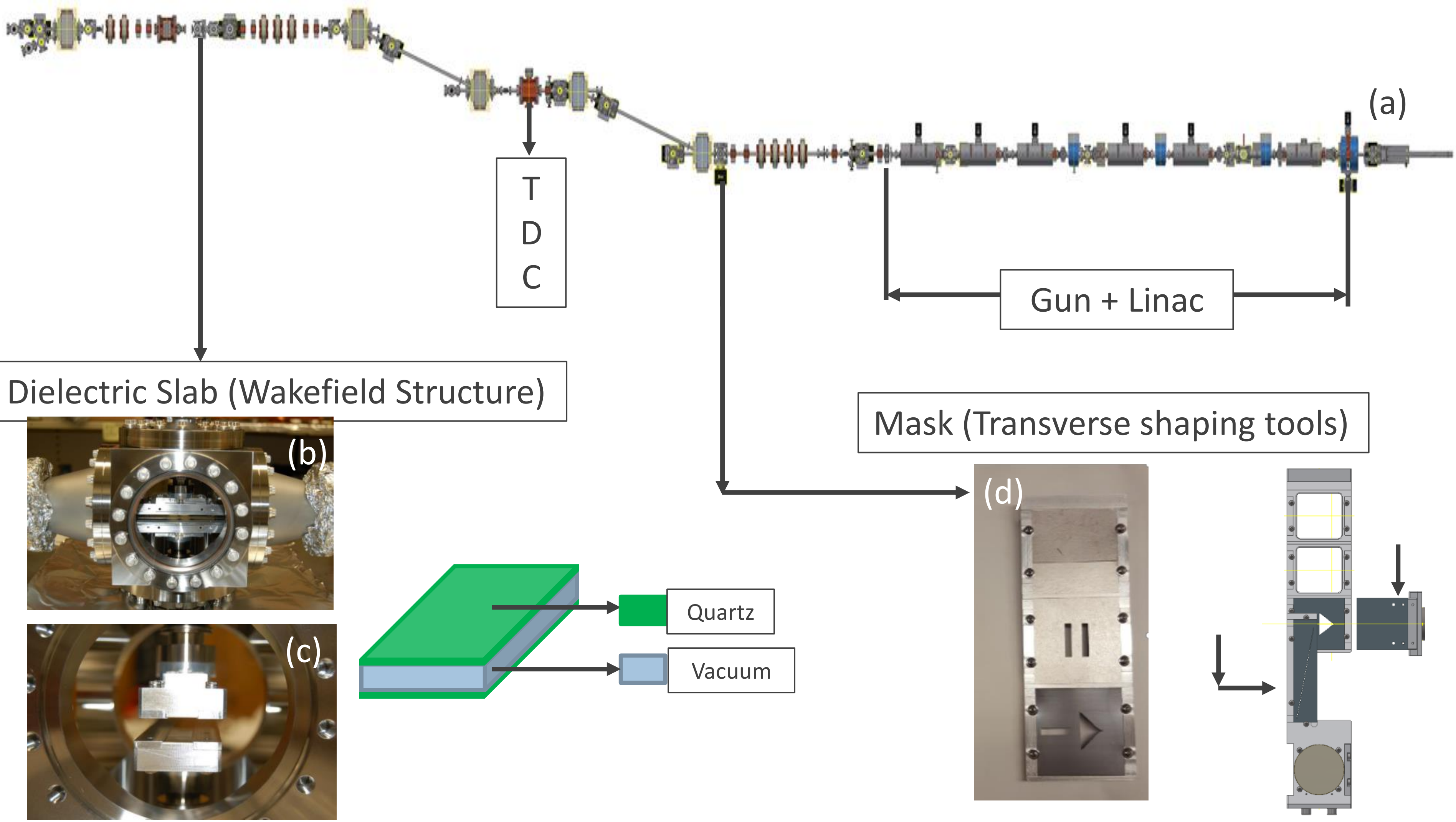
Emittance Exchange Beamline



Single EEX: Demonstration of longitudinal bunch shaping



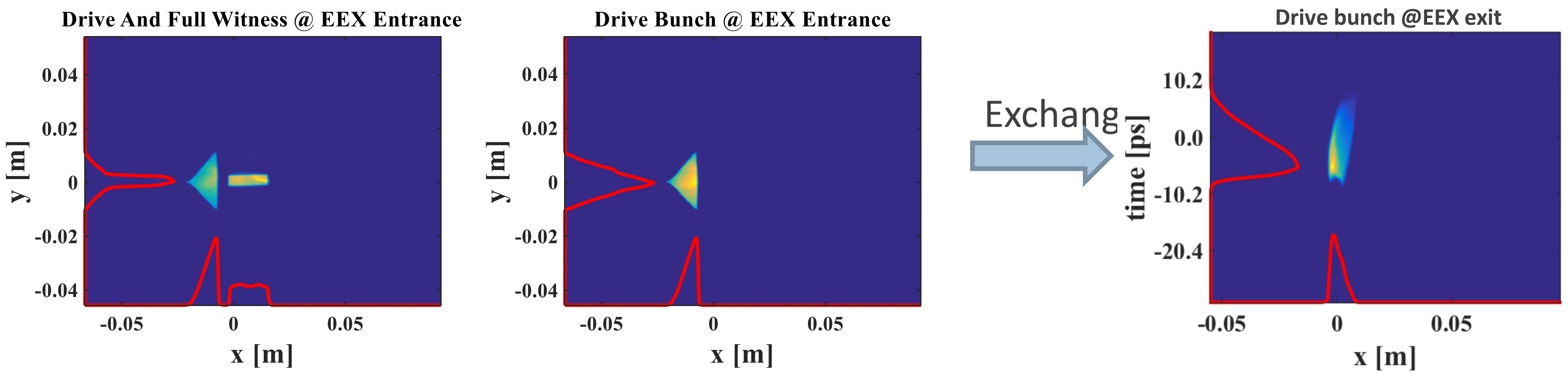
Collinear Wakefield Experiment with EEX Shaped bunches



Shaping of bunches for Collinear Wakefield Experiment

Shaping the beam transversely at the EEX Entrance

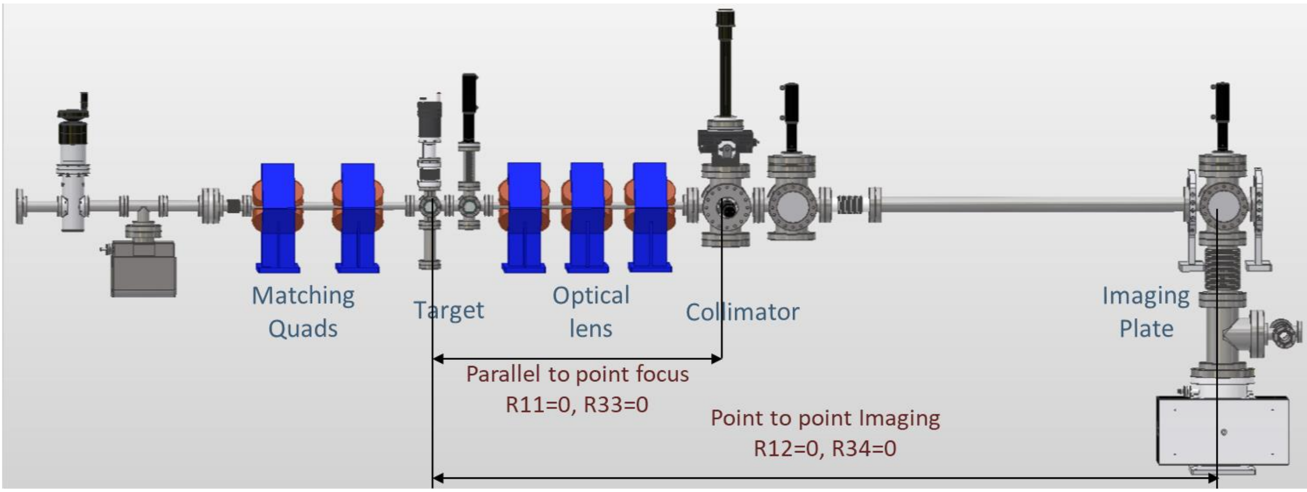
Longitudinal Profile Measured by TDC



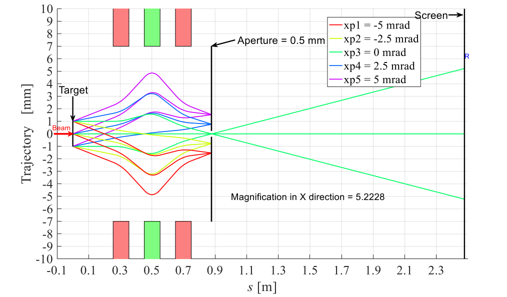
Drive bunch charge : $2.08^{+0.26}_{-0.18}\ nC$

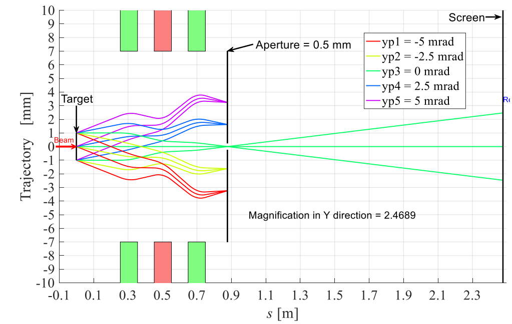
Full Witness bunch charge: $1.06^{+0.17.}_{-0.14}\ nC$

Electron Radiographic Imaging (ERI)



46 MeV, 5 mm collimator



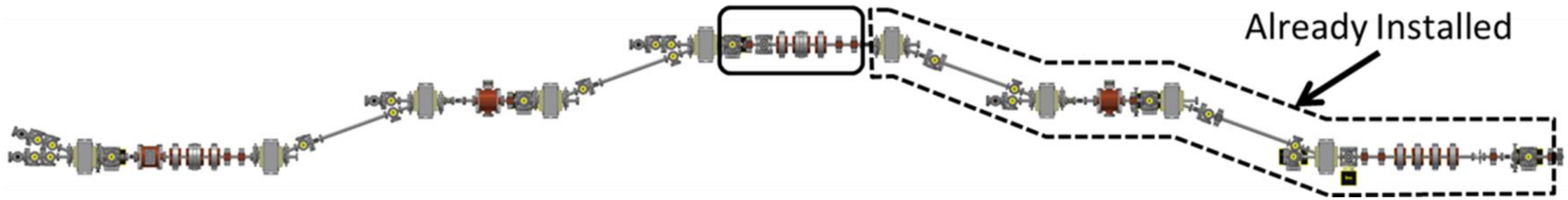


Future Activities

Experiments are planned in the topics of:

- TBA staging with kicker and septum
- Collinear wakefield acceleration in planar and cylindrical structures
- Plasma wakefield acceleration using the double emittance exchange beamline
- Bunch compression, CSR studies, THz generation

Double Emittance Exchange Beamline



Argonne Cathode Test-stand (ACT) at awa

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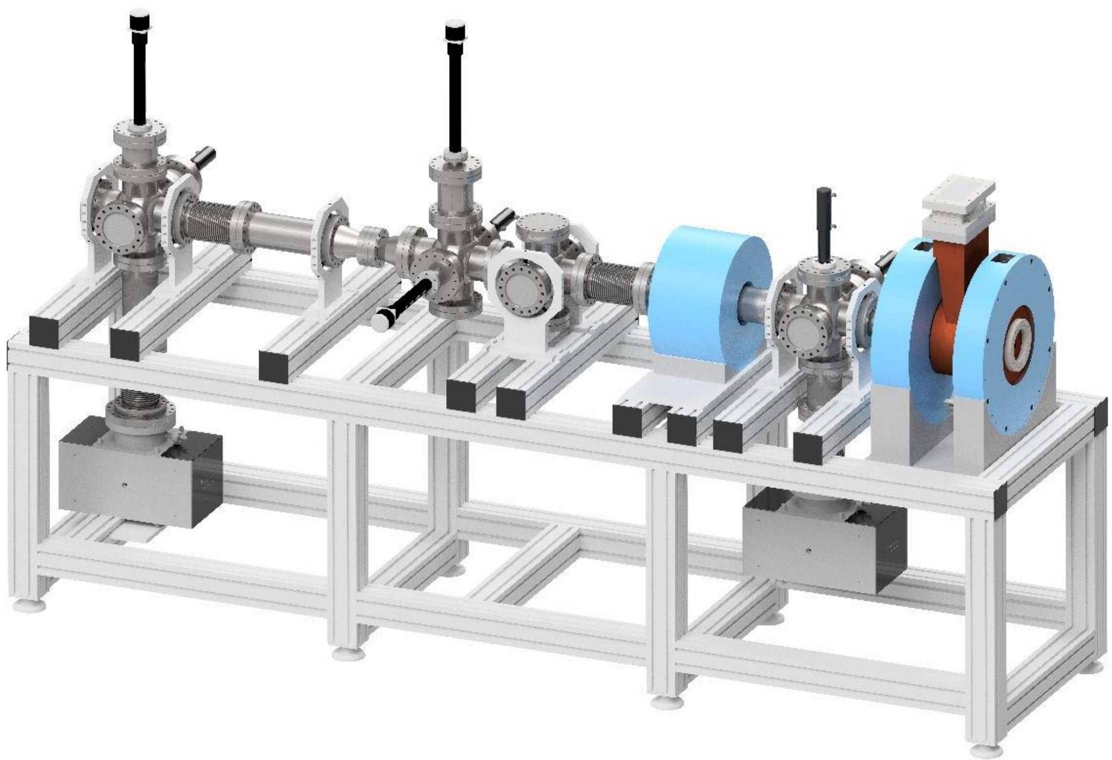
Argonne Cathode Test-stand (ACT) at awa

- **Ongoing upgrade (will be completed in 2017.11)**



- **Special measureable parameters**

  - rf breakdown location

  - Field emission location

Argonne Cathode Test-stand (ACT) AT AWA

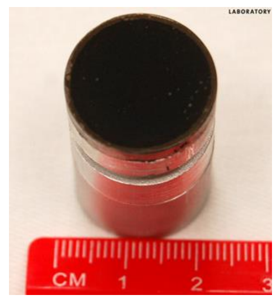
Argonne NATIONAL LABORATORY

- **The detachable cathode (20 mm in diameter)**
  - Convenient to test cathodes with different shape/finishing/material
  - Has attracted many collaborators and users

flat

- FE evolution (AWA)
- FE in static magnetic field (LBNL)

UNCD



- FE from UNCD (Euclid Techlabs)

Nb/Mg

- FE from superconducting material (IIT)

pin

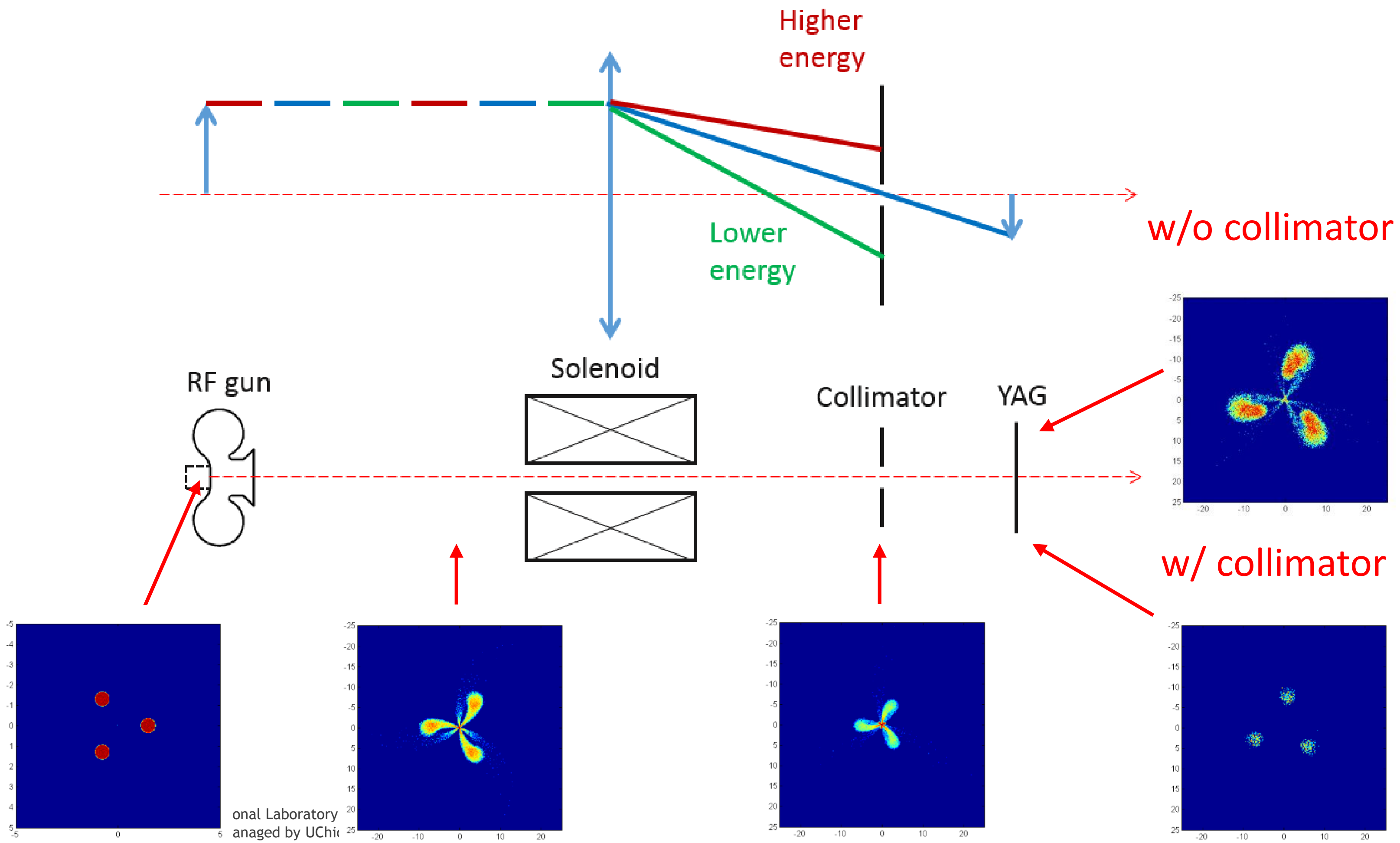
- Ultrahigh surface field (AWA&SLAC)
- FE dependence on stored energy (AWA&SLAC)

new shape

- Dark current imaging (AWA&Tsinghua)

Argonne Cathode Test-stand (ACT) AT AWA

- **Dark current imaging system**
  - Key component to study the origin and properties of field emitters
  - Use collimator to select electrons for high resolution



Experiments at ACT
- dark current imaging

- **In-situ observation**

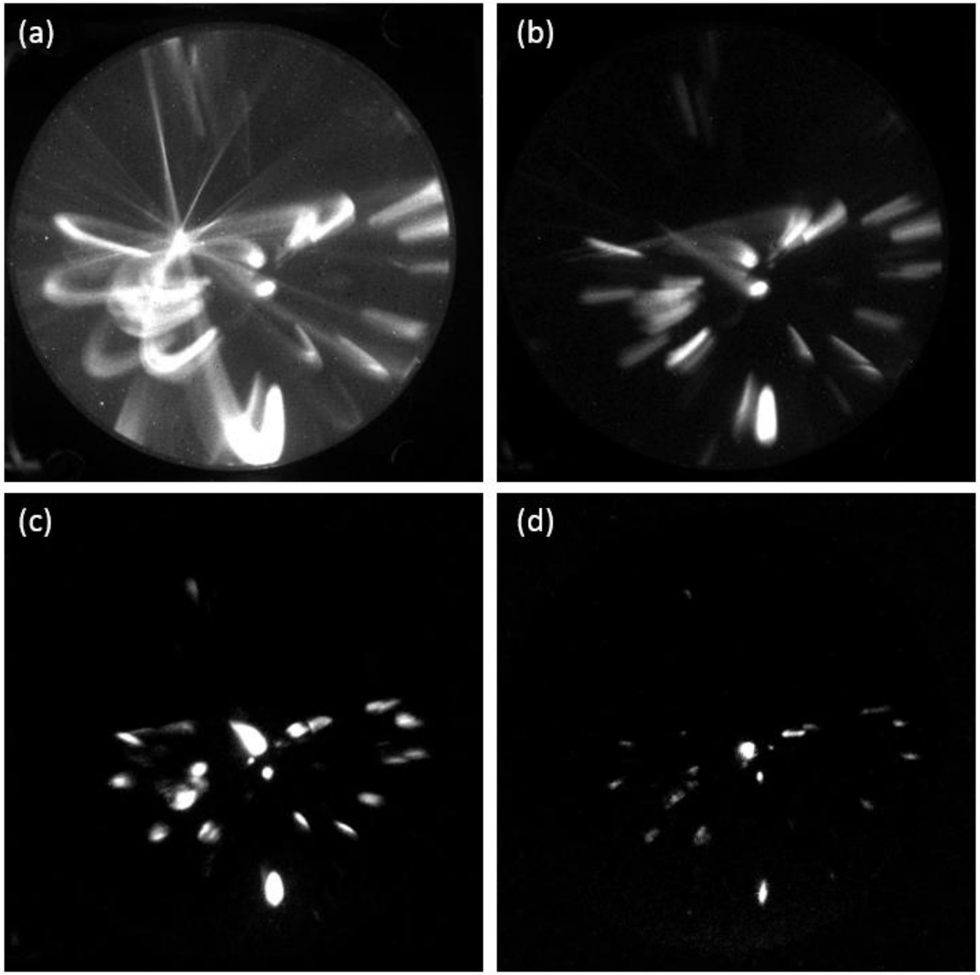
  - ~100 µm resolution, non-uniform distribution of field emitters

No aperture
20 shots

Φ 8 mm
20 shots

Φ1 mm
100 shots

Φ 0.2 mm
100 shots



Thank you for your attention!