Two-Beam-Acceleration Experiments at the Argonne Wakefield Accelerator Facility (AWA)

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Outline

- Mission and AWA approach
- Wakefield acceleration
- AWA facility
- Recent experiments

Mission

Studying the Physics and Developing the Technologies for Future HEP Accelerators (and possibly other applications).

Reasons for the mission (Challenges for Future HEP Linear Colliders):

- High gradient (~ hundreds MV/m) and High Impedance (high R/Q)
  - Requires new or alternative accelerating structures.
- High Power RF Sources (~ GW Scale)
  - Requires new type sources.
- Higher order mode damping
  - Requires beam breakup control.
- Positron acceleration
- Find pathway to LC / Higgs factory

The AWA Approach:
a Realistic Path to a Future HEP Machine

Short RF pulses

Shorter RF pulses are less likely to cause breakdown. The energy efficiency and structure bandwidth can be made appropriately high.

Advanced structures (e.g. dielectrics)

Dielectric materials are likely to withstand higher electric fields than metals, without arcing.

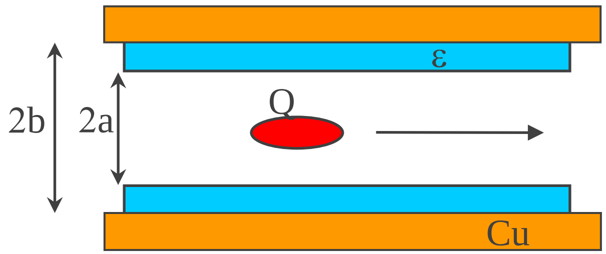
Structures that can accelerate electrons and also positrons

Since colliders are assumed to need electron beams and positron beams, we need to develop accelerating structures that can operate with either.

Schemes that allow for staging

Likely to need multiple stages to achieve desired energy. Need injection and precise control of the RF phase of multiple stages.

Wakefields in Cylindrical Dielectric Structures (a short Gaussian beam)



$$W_Z(z) \approx \frac{Q}{a^2} \exp\left[-2\left(\frac{\pi\,\sigma_z}{\lambda_n}\right)^2\right]\cos(kz)$$

$$\sigma_r = \left(\frac{\varepsilon_N}{\gamma}\beta\right)^{1/2}$$

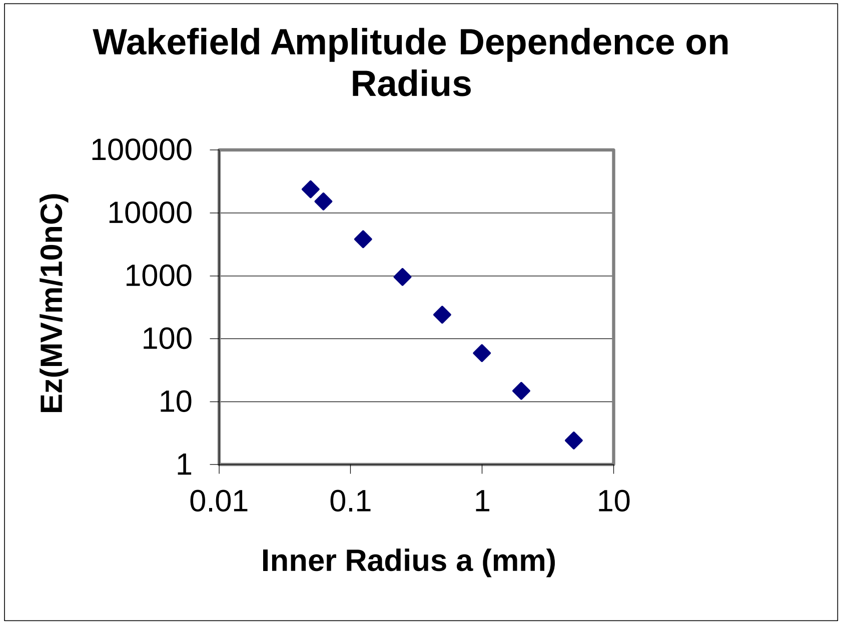
Key to the success:

→ superb drive beam & sensible structure design

- Energy ↑
- Charge ↑
- Bunch length ↓
- Emittance ↓

But, it is difficult to have high charge pass through small holes**!**

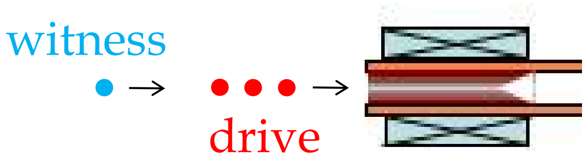
And at some point transverse wakefields become problematic.



Two Different Schemes

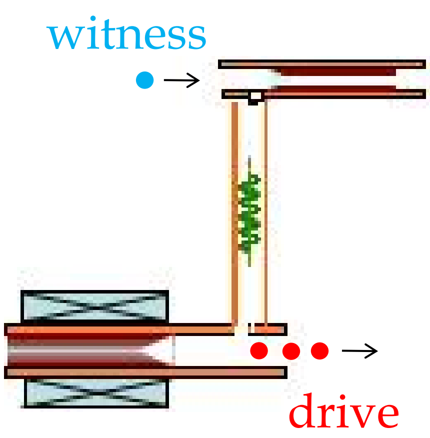
Collinear Acceleration

- Single wakefield structure
- No need for RF couplers
- Wide range of RF frequencies
- Easier to explore very high gradients at high frequencies
- Common transport optics for both beams (drive and witness) may create difficulties, especially for staging

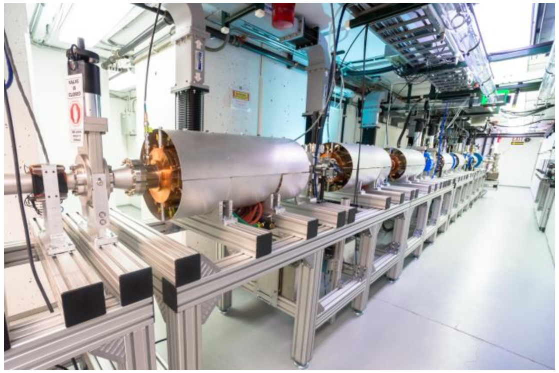


Two Beam Acceleration (TBA)

- Need for RF couplers on both structures
- Short RF pulses require broad bandwidth couplers
- Each structure can be optimized independently
- Independent beamline optics makes staging much simpler



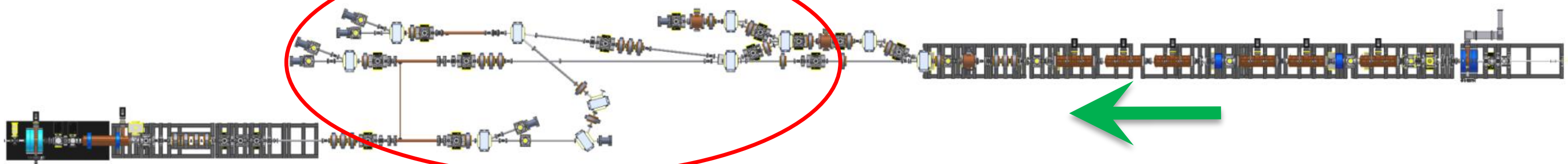
AWA Beamlines



experimental area

collinear & TBA

EEX & bunch compression



witness beam U-turn

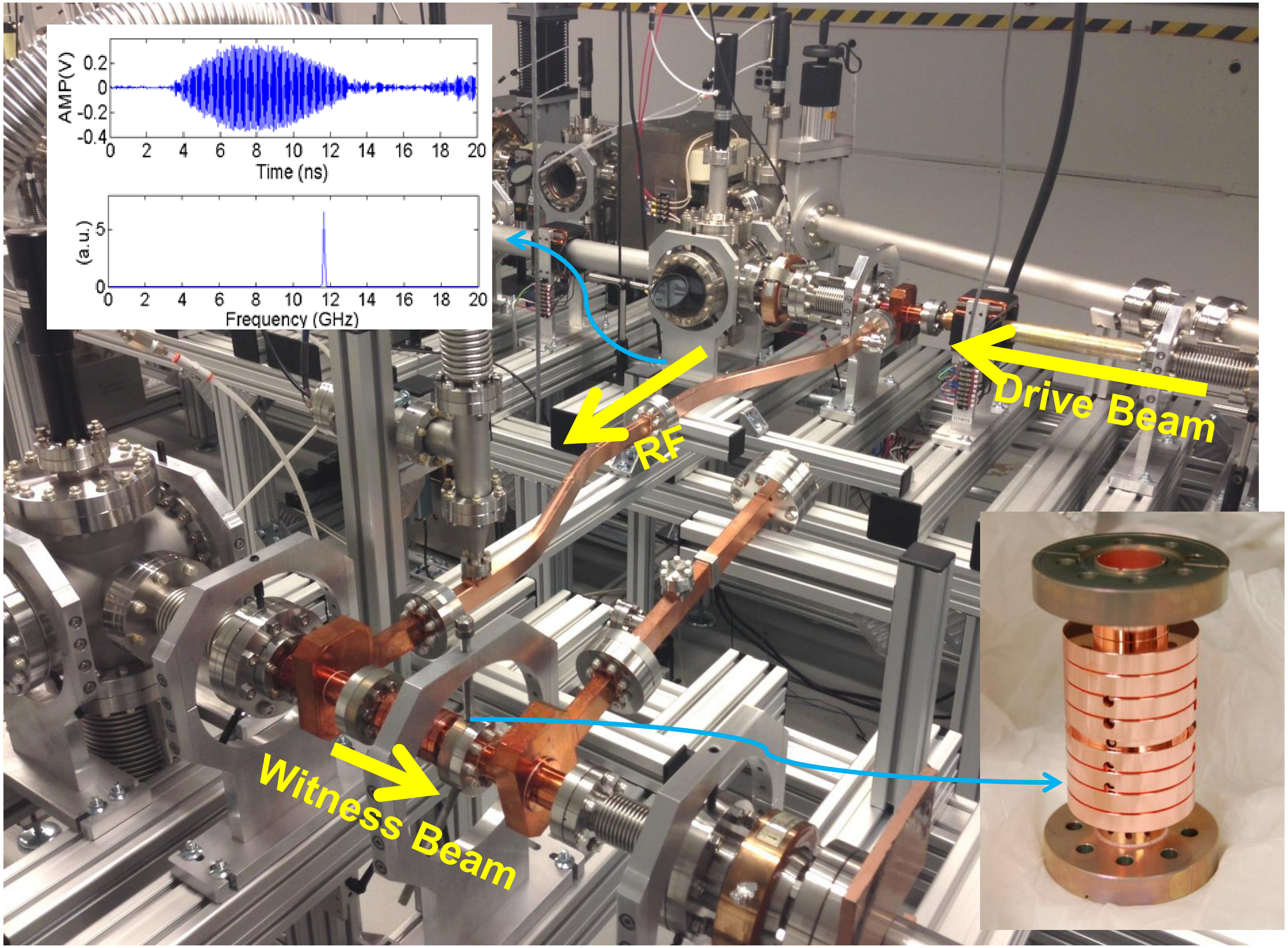
15 MeV witness beam

- single bunches
- bunch charge 0.05 to 60 nC

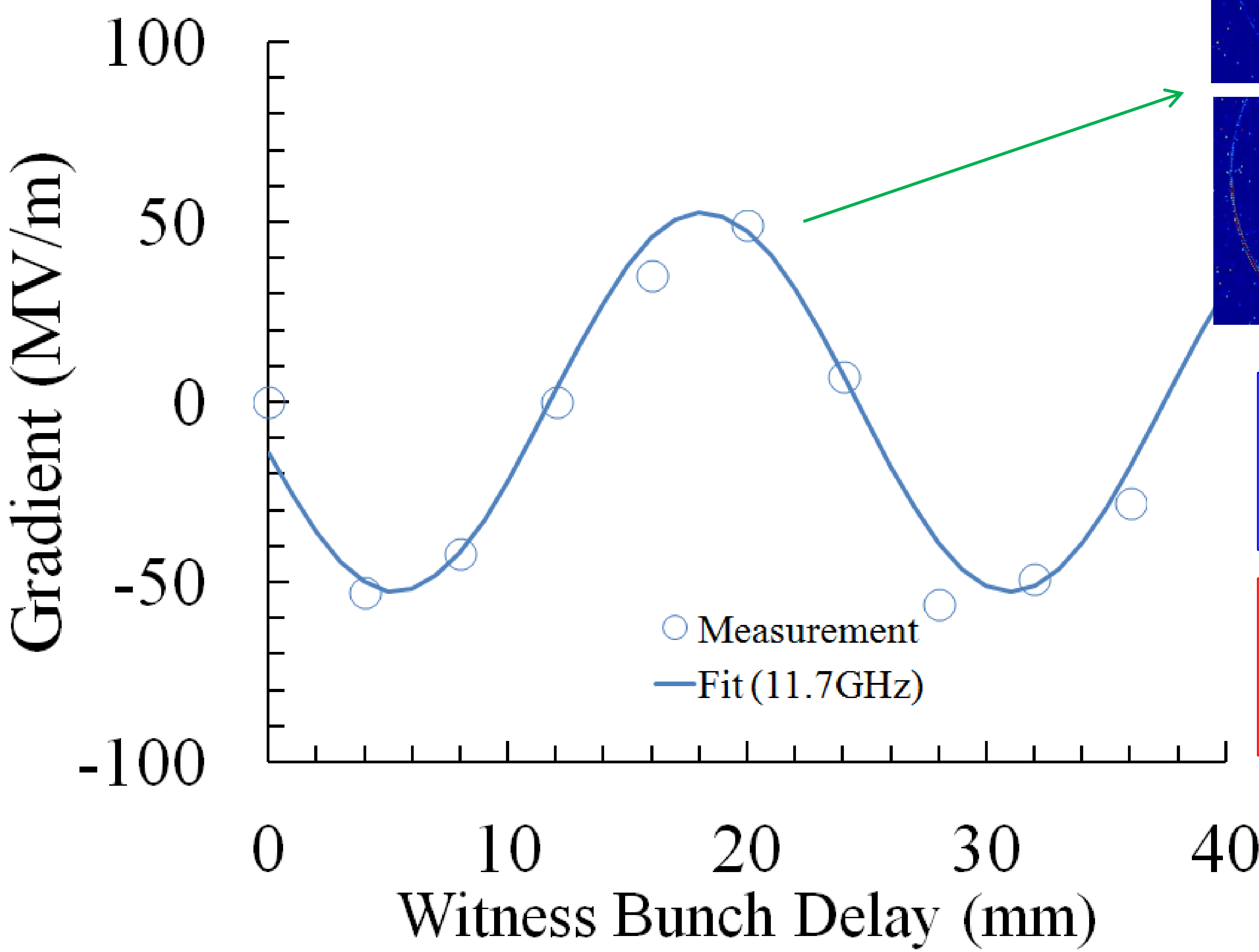
70 MeV drive beam

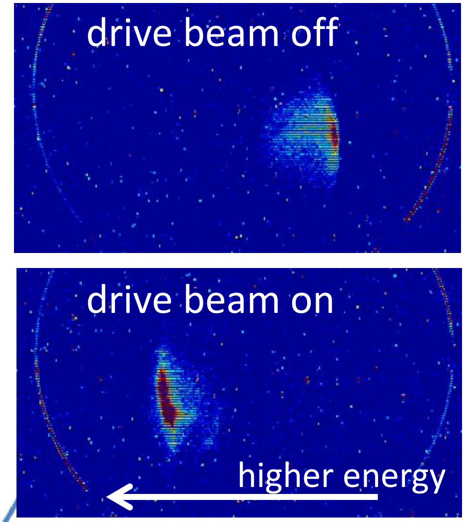
- bunch trains of up to 32 bunches
- Maximum charge in single bunch **100 nC**
- maximum charge in bunch train **600 nC**.

TBA setup
11.7 GHz iris loaded metallic structures



TBA Experiment at AWA
(preliminary results)





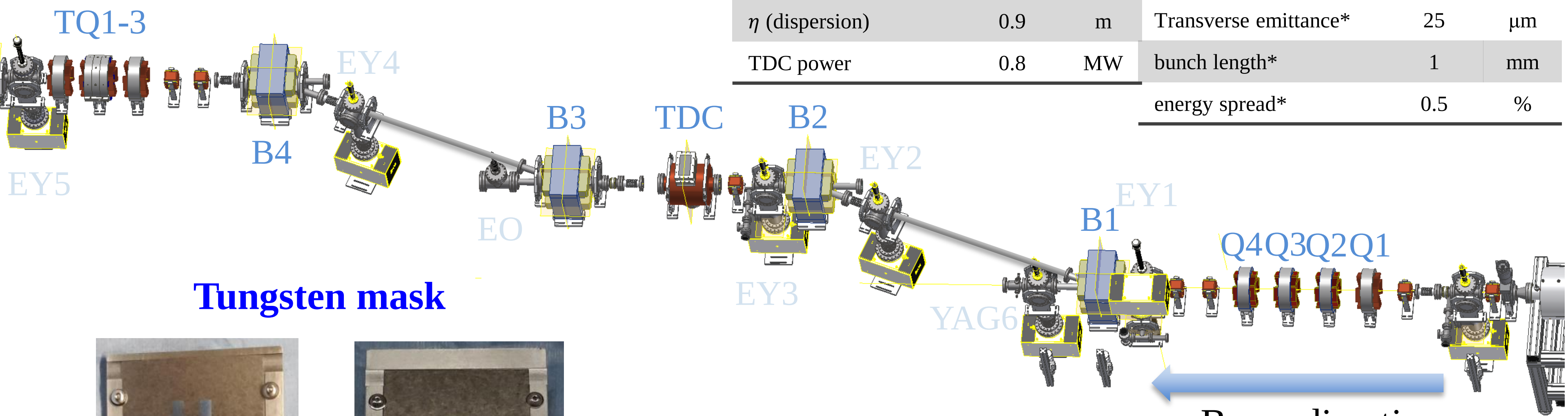
Witness beam:
8.5 ± 1.4 MeV
0.5 nC

Drive beam:
8 bunches
90 nC charge in train

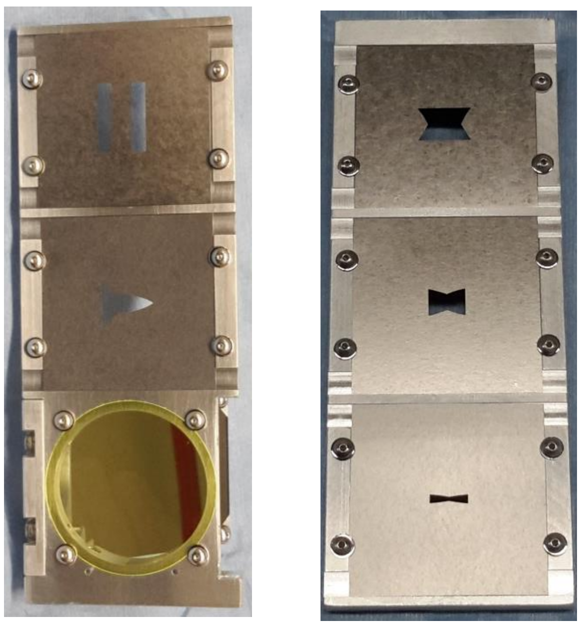
Emittance Exchange

Input beam parameter	Value	Unit
Incoming charge	4-6	nC
Beam energy	46.5	MeV
beam size at EY1	5	mm
Transverse emittance*	25	μm
bunch length*	1	mm
energy spread*	0.5	%

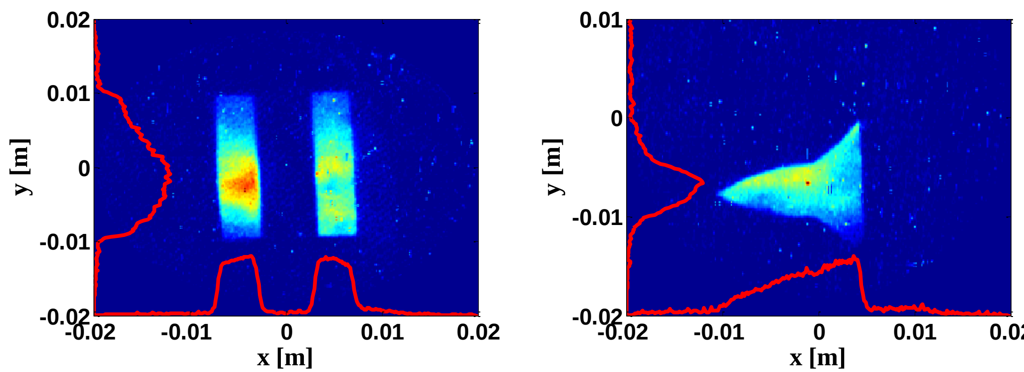
Beam line parameter	Value	Unit
Bending angle	20	deg
Dipole-to-Dipole	2.0	m
η (dispersion)	0.9	m
TDC power	0.8	MW



Tungsten mask

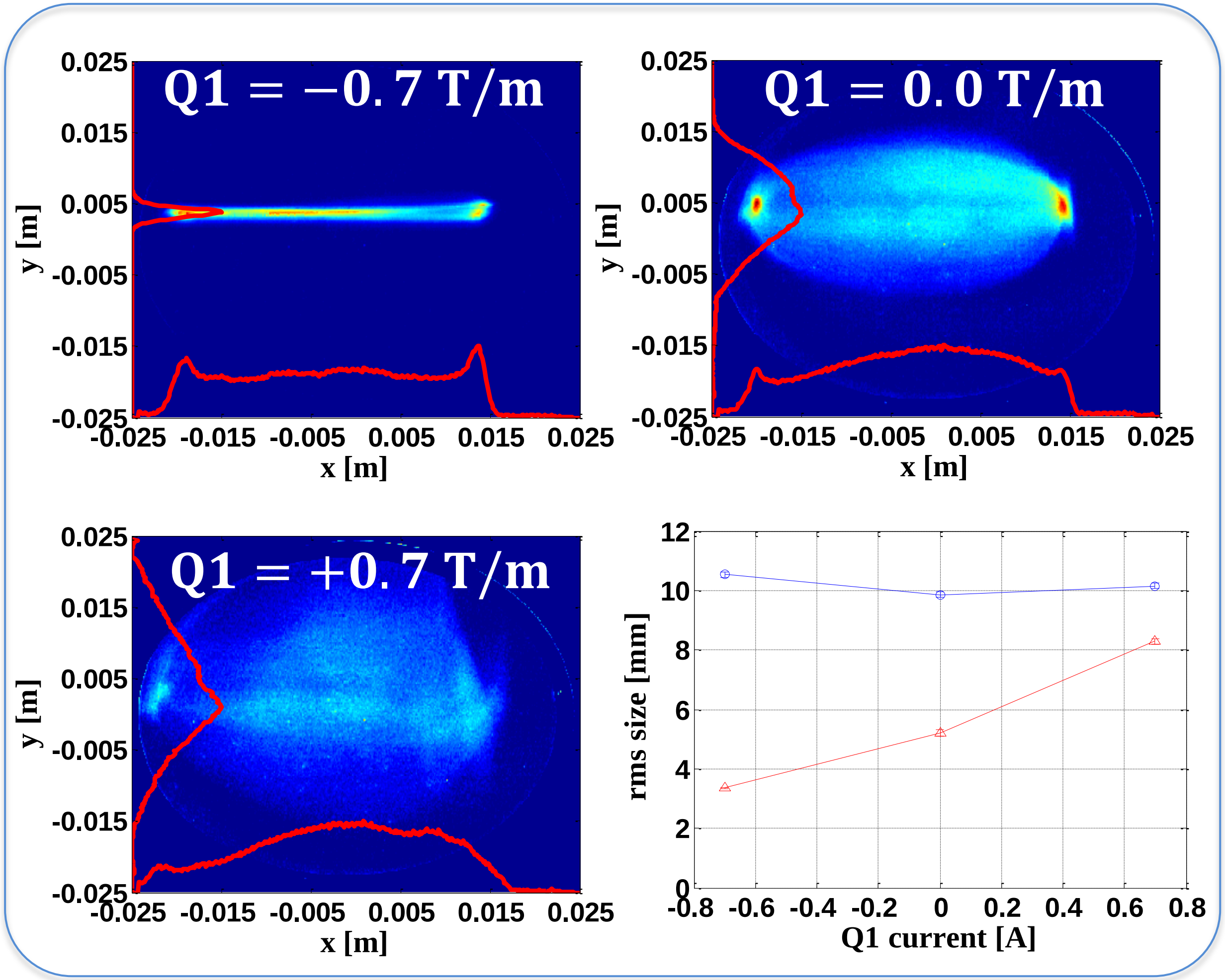


Transverse beam image and profile at YAG6

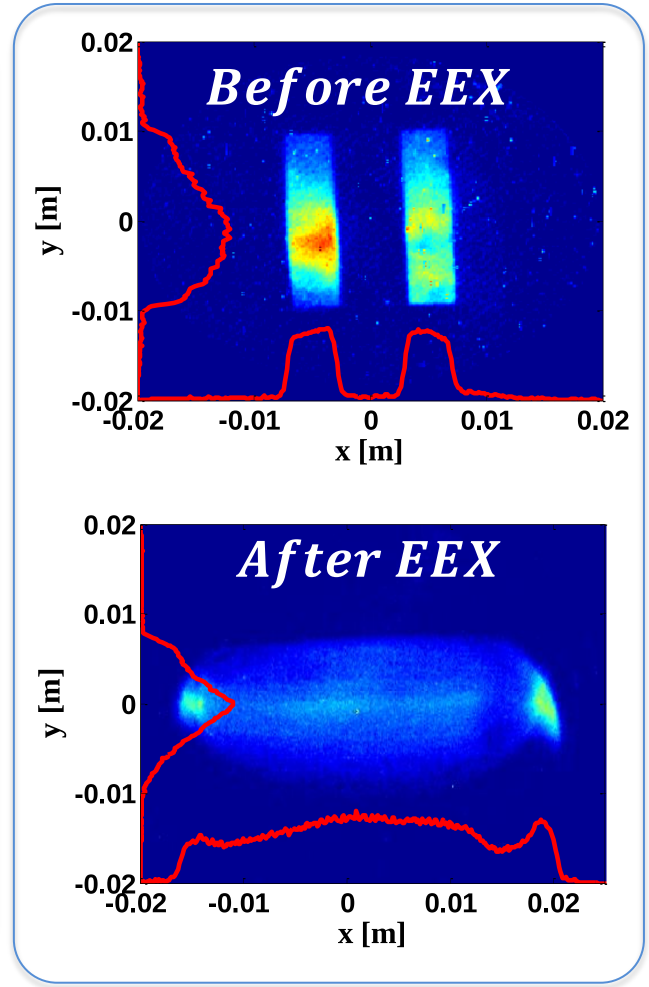


EEX Initial Measurements

Quadrupole scan



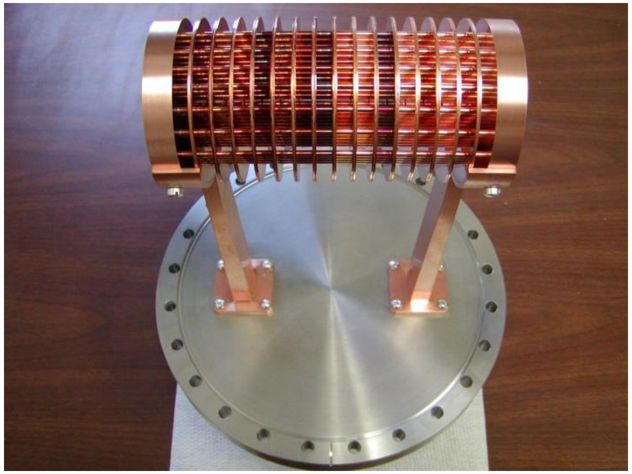
Property exchange



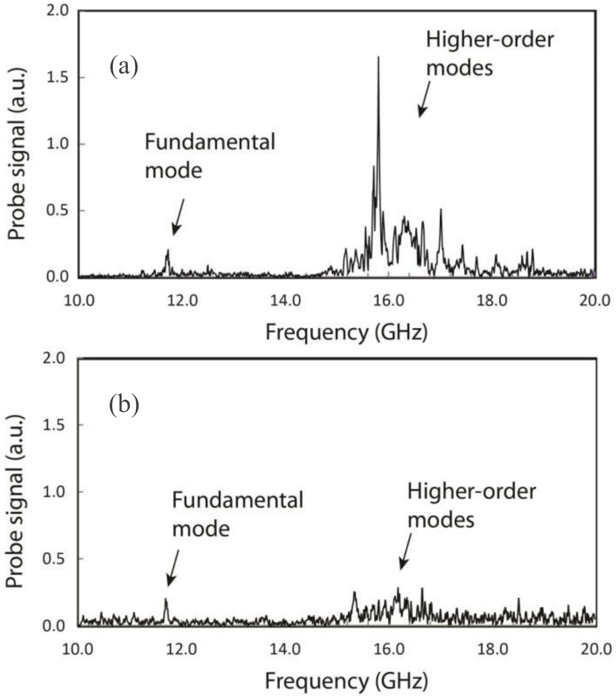
- Horizontal beam size remains constant while vertical beam size changes dramatically.
- Transversely separated two beam becomes single beam after the EEX.

EXPERIMENTAL STUDY OF WAKEFIELDS IN AN X-BAND PHOTONIC BAND GAP ACCELERATING STRUCTURE

Evgenya Simakov et al.

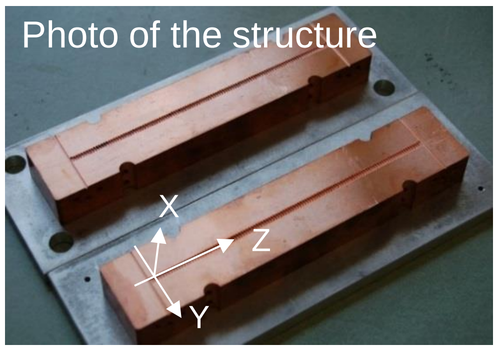


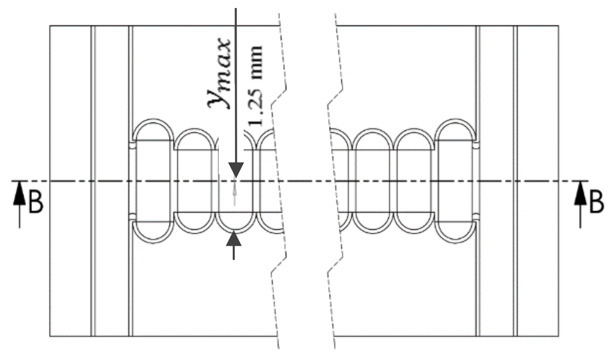
PBG structure

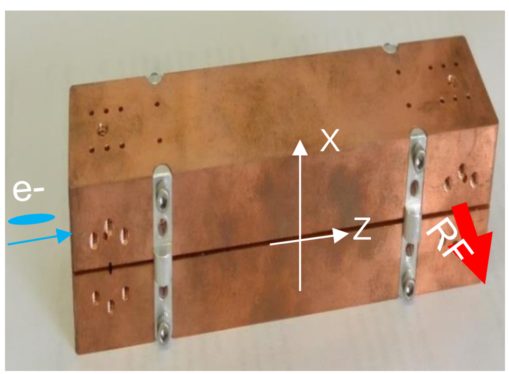


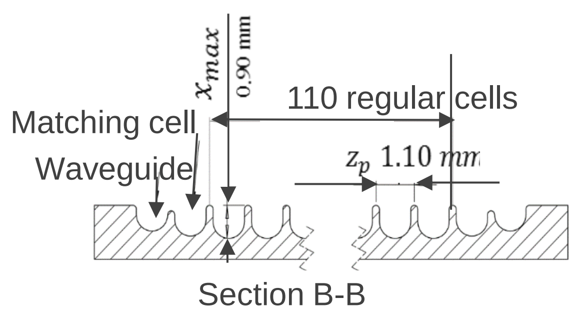
High Power RF Radiation at W-Band Based on Wakefields Excited by Intense Electron Beam

Two copper plates with periodic grooves make up the W-band PETS

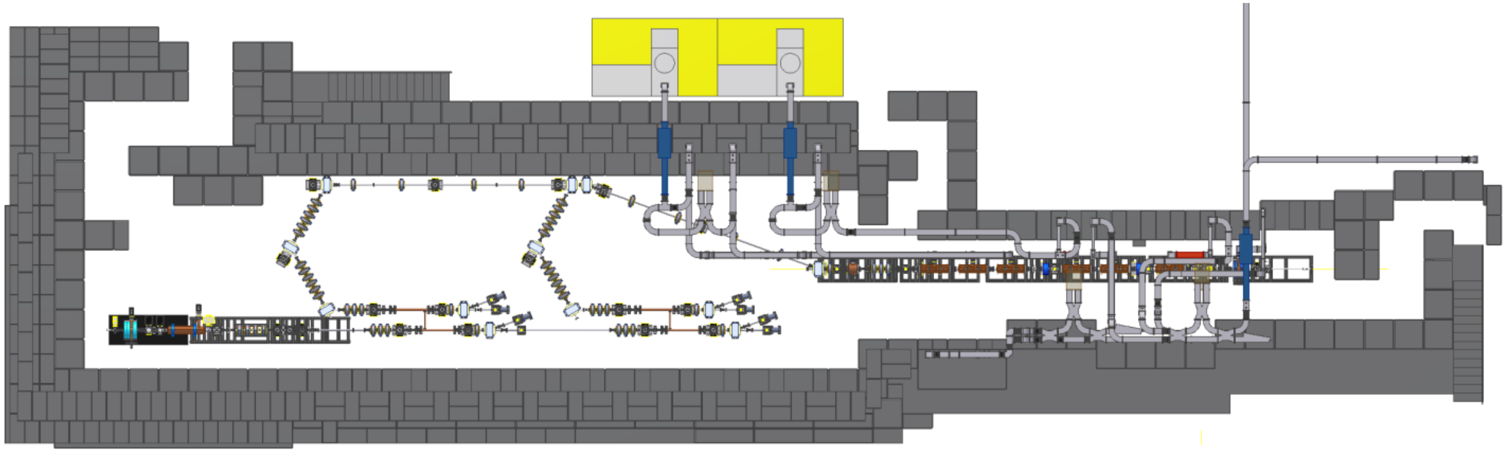


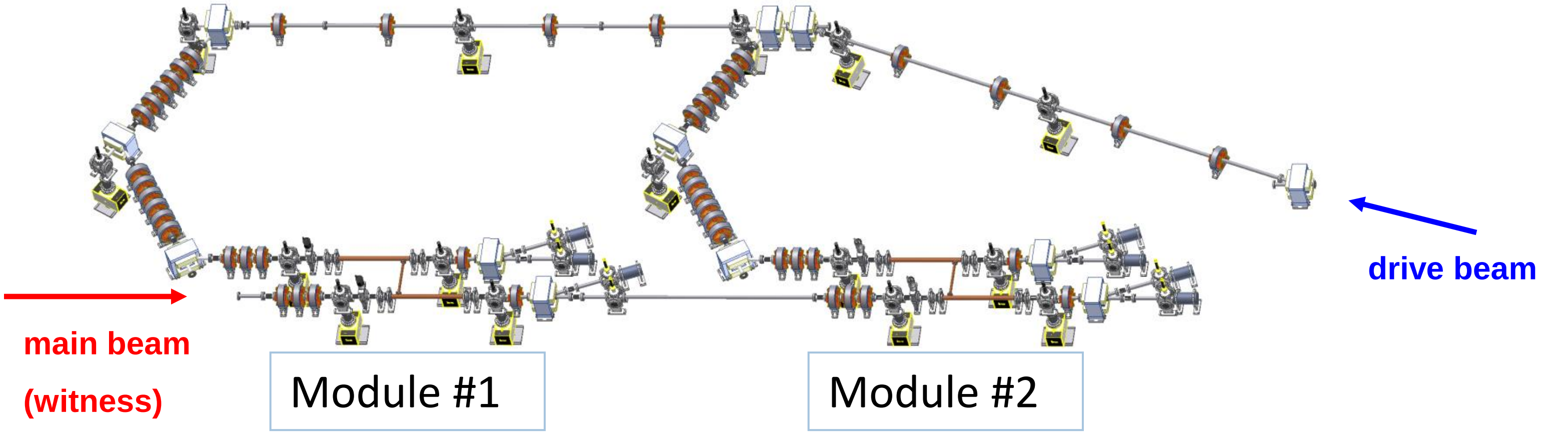




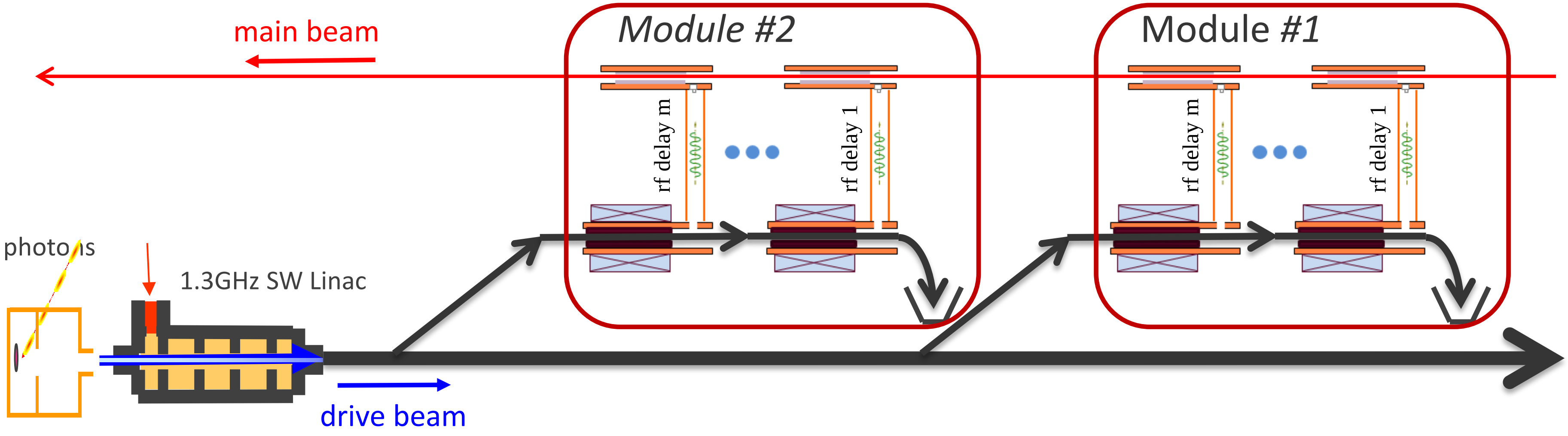


Staging: U-turn Option





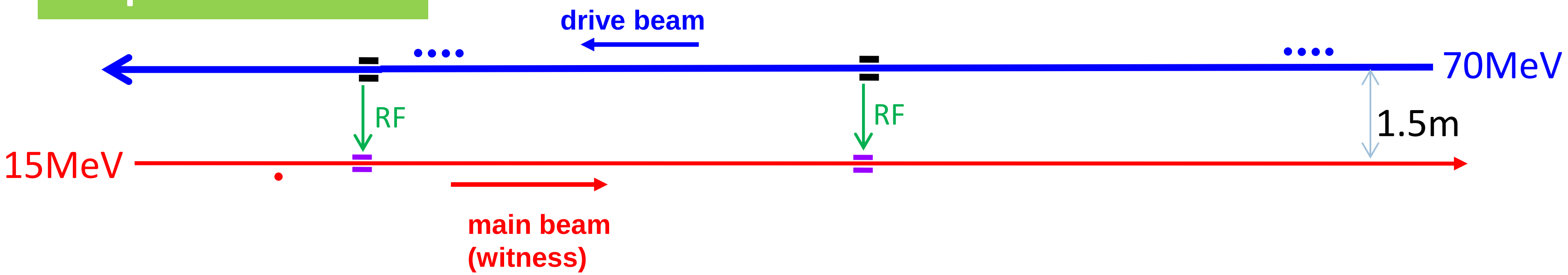
Staging:
using RF delay to obtain proper timing



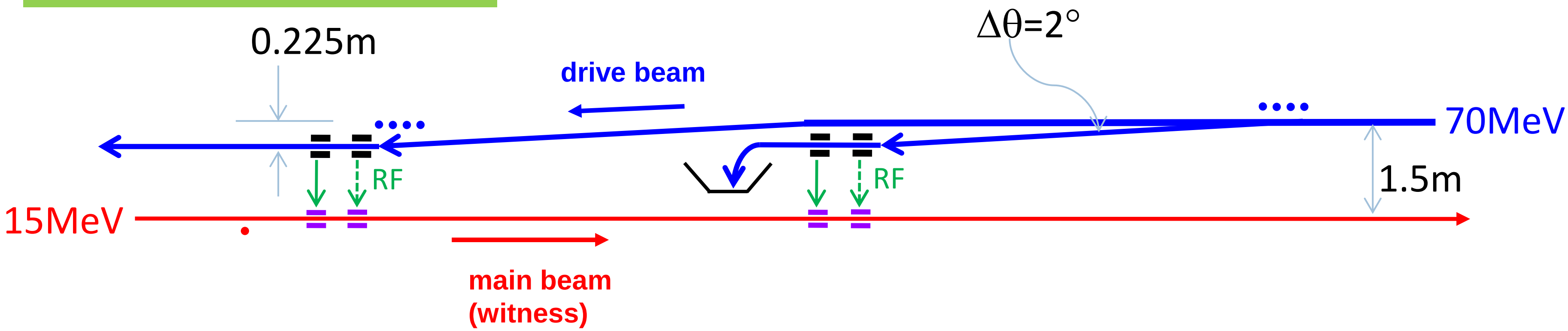
- Avoids 180° arcs (big, expensive, deleterious to beam quality)
- Shifts burden to RF delay lines (not trivial…)
- Maybe practical if number of structures inside each module is not too large

Staging Demonstration at AWA

Simplified Version



More realistic Version



Unique Capabilities of the AWA Facility

- Two independent linacs allow experiments with excitation and probing of wakefields
- Extremely high charge, short electron bunches
- Flexible and reconfigurable beamline switchyard to host various experiments

General Long Term Objectives

- High gradient excitation: **hundreds of MV/m** in long structures.
- Acceleration of witness beam: **~ 100 MeV**
- Higher RF power extraction: **~ GW level**
- Demonstration of staging schemes

Thank you for your attention!