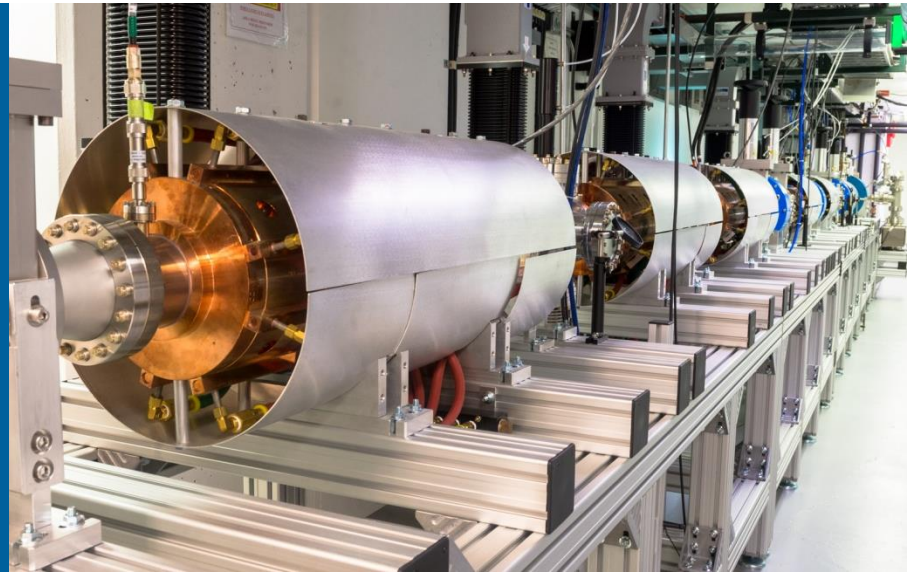
STATUS ON ARGONNE WAKEFIELD ACCELERATOR AND ITS EXPERIMENT



WEI GAI

FOR AWA GROUP AT ARGONNE NATIONAL LAB

CLIC Workshop, March 8, 2017

*with major contributions from Euclid Techlabs/Tsinghua University

OUTLINE

1. Accelerator R&D at ANL HEP
2. Facility and Experiments Highlights
3. Collaboration with External Users
4. Challenges and Future Plan

A PLATFORM FOR ADVANCES SCIENCES AND TECHNOLOGIES FOR FUTURE ACCELERATORS

Two beam acceleration for LC

Novel Acceleration Concepts

High Power RF (~ GW)

High Gradient Structures (GV/m)

Radiation sources GHz – THz

Advanced Beam Manipulation: EEX

Positron Sources for LC

ARGONNE WAKEFIELD ACCELERATOR (AWA)

ARGONNE WAKEFIELD ACCELERATOR (AWA) AND A LIST OF MAJOR ACCOMPLISHMENTS/HIGHLIGHTS

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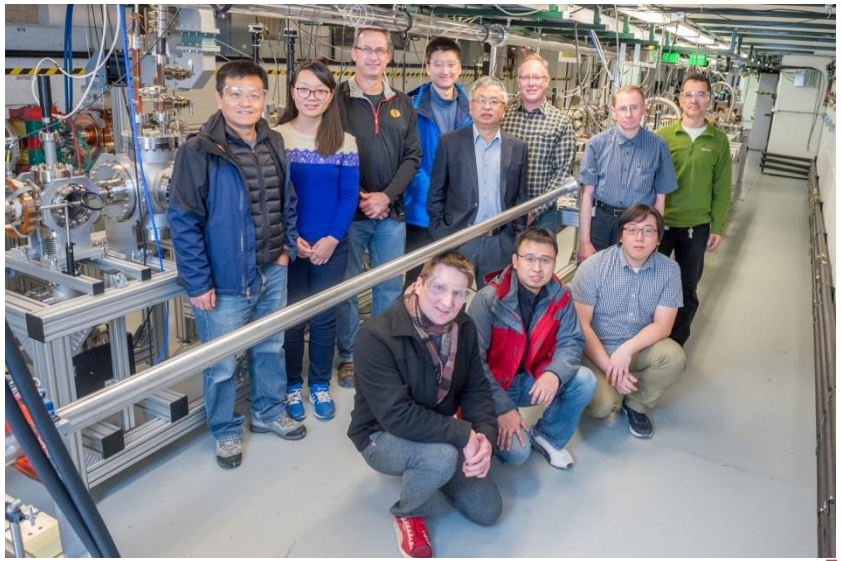
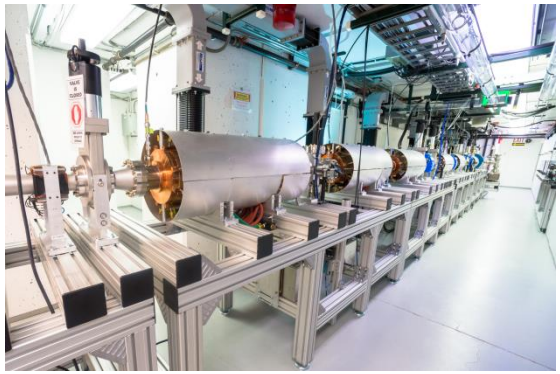
ARGONNE WAKEFIELD ACCELERATOR GROUP

- 6 scientific/engineering staffs
- 1 technician
- ~ 5 constant students from universities
  - 3 Ph.D. Graduated
  - 2 new students
- 4 Euclid Residents



AWA BEAMLINES



- single bunches
- bunch charge 0.05 to 10 nC

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

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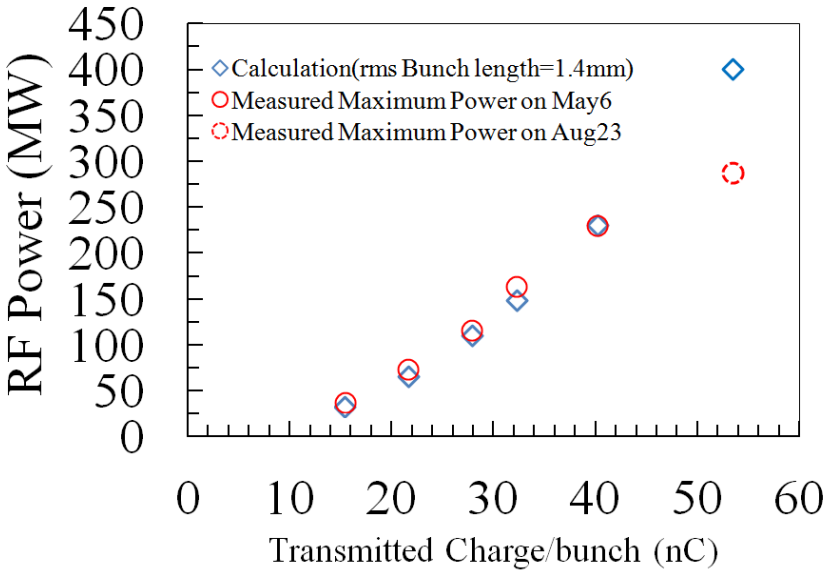
HIGHLIGHT OF ACCOMPLISHMENTS

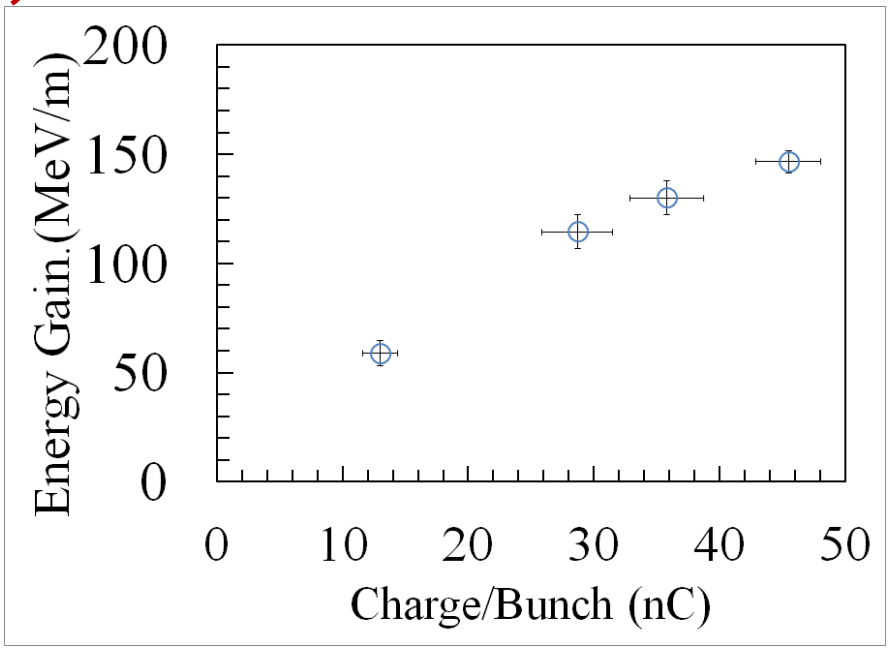
- 11.7 GHz TBA (see below,IPAC 16, plenary talk)
- Completed the phase I ILC positron target testing

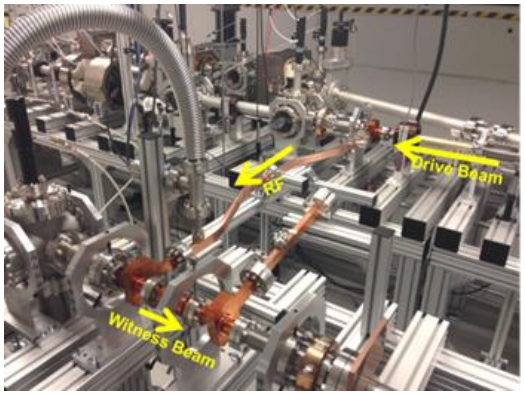
- 26 GHz TBA (on going, see below)
- Staging demonstration (see NAPAC 16, plenary talk))
- EEX demonstrated (IPAC oral, and AAC invited,)
- Hosted International Workshop on High Gradient 2016 at ANL

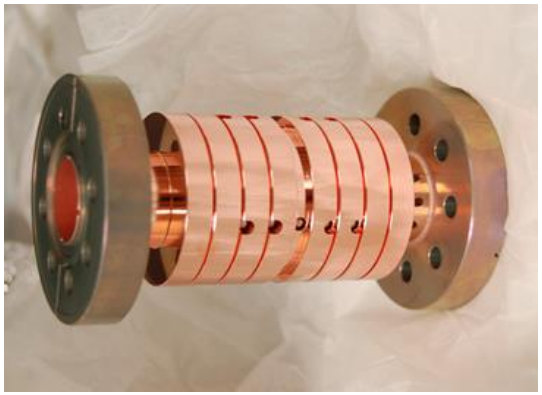
REPORT ON RECENT DATA FROM AWA

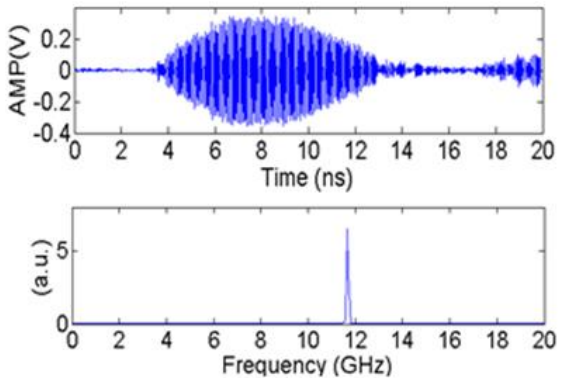
A. High gradient Two Beam Acceleration at 11.7 GHz Measured: ~ 150 MV/m, 300 MW measured*





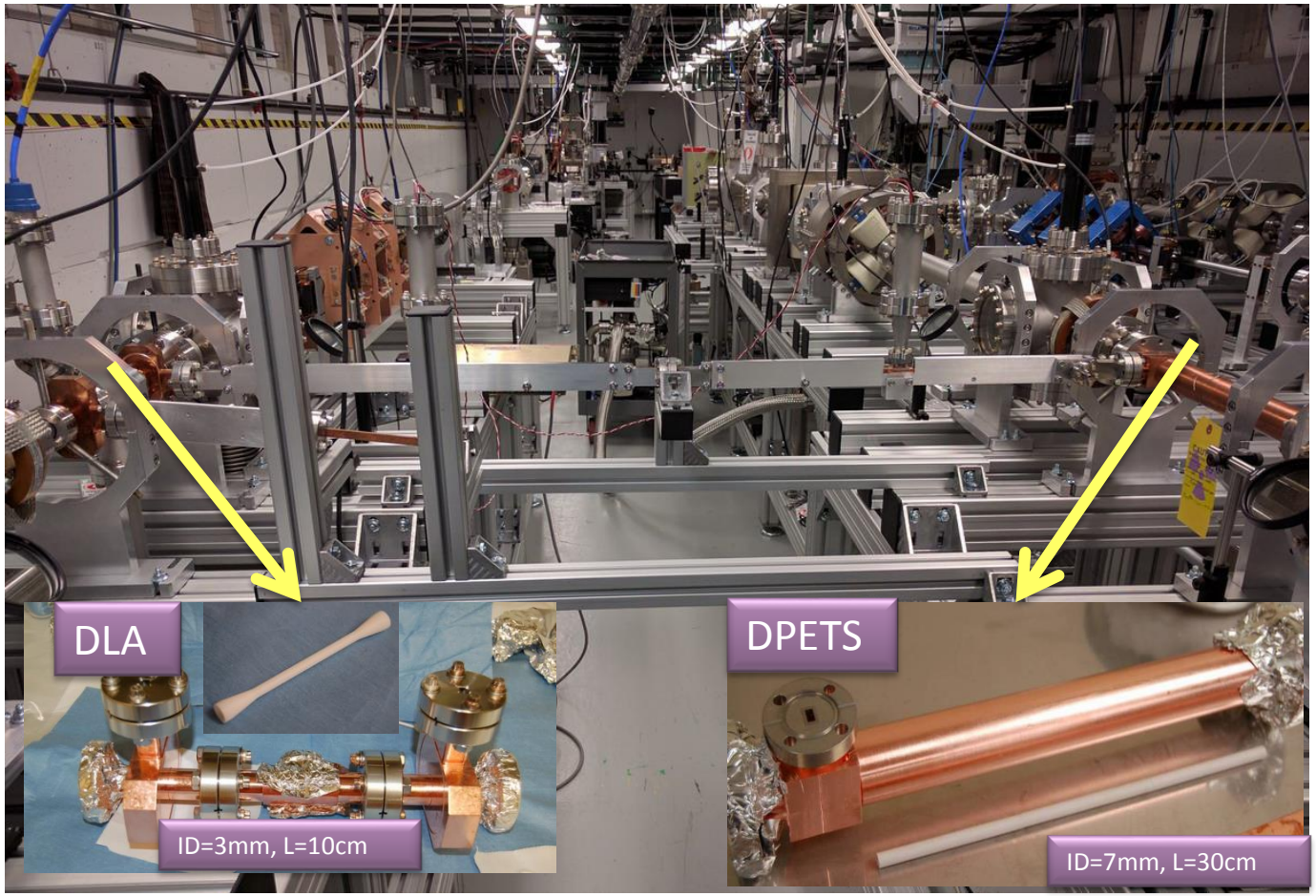






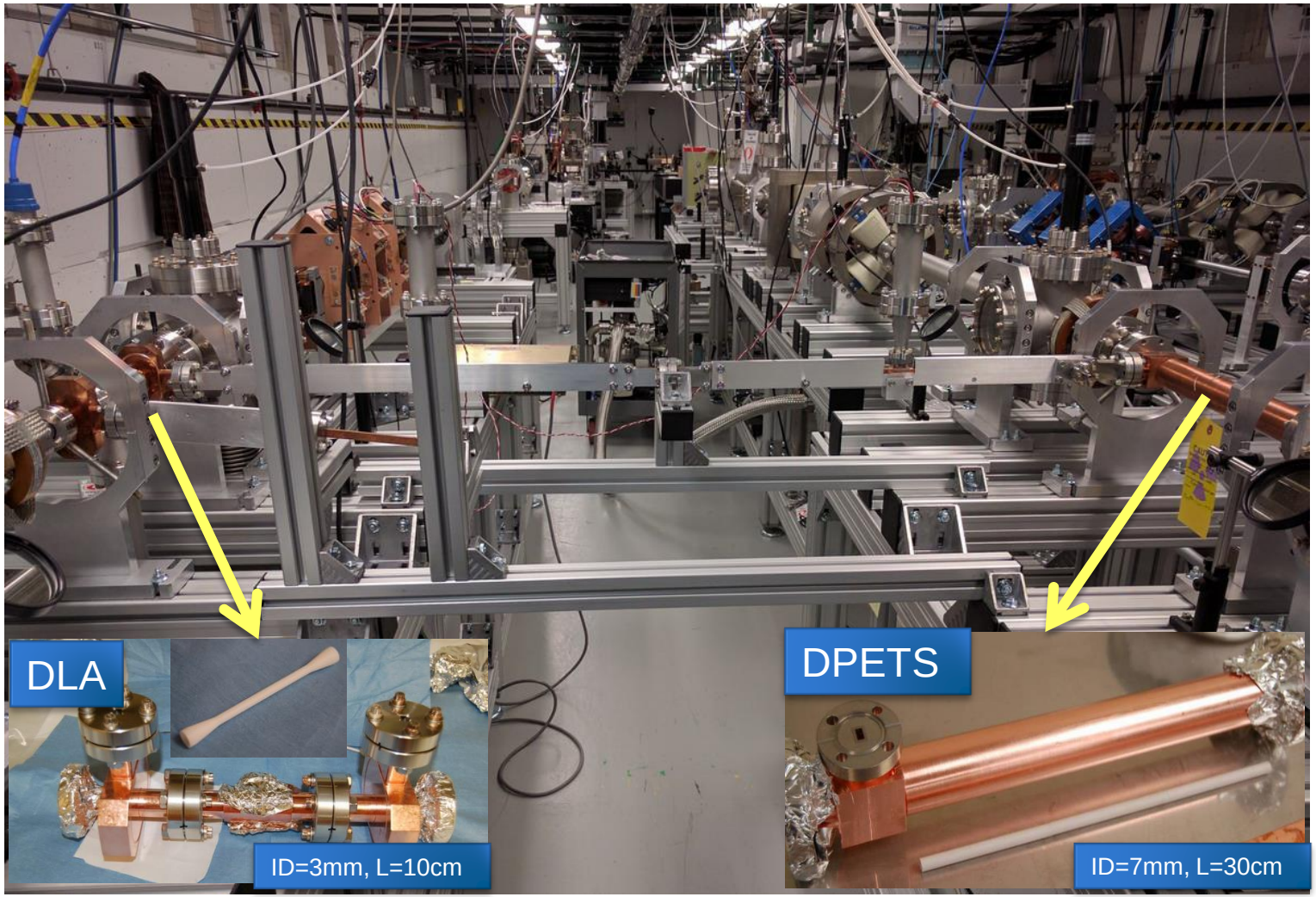
B. 26 GHz Two beam acceleration using dielectric structures for both power generation and acceleration:

(Dec. 2016~Now)



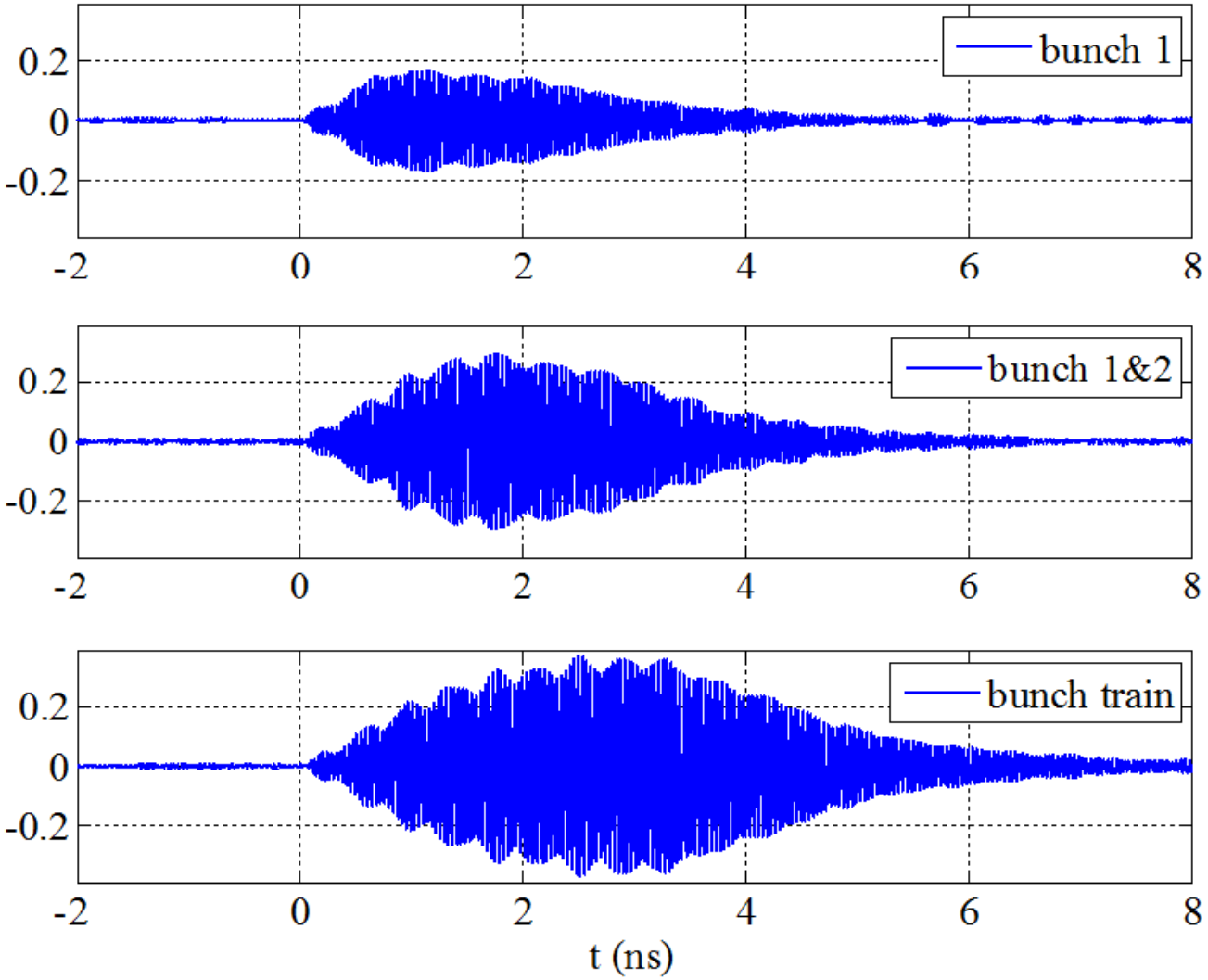
The 1st Full Dielectric Short Pulse TBA Test(26GHZ)

(Dec. 2016~Feb. 2017)



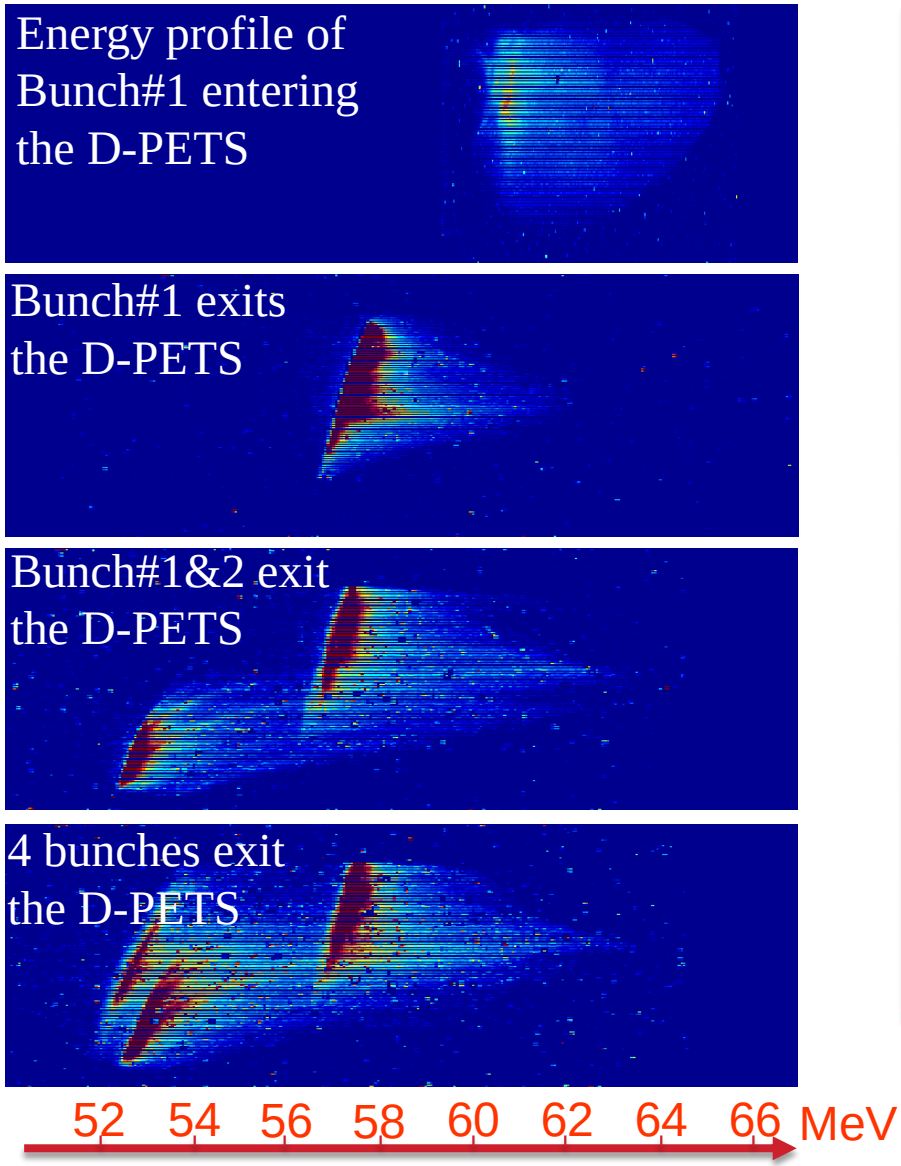
RF Pulse Out of The 26GHz Dielectric PETS

~160MW rf power output by a 4x22nC bunch train were measured (preliminary results; need to be confirmed from the final calibration).



Note: Insufficient sampling rate of the 50GHz scope attributed to the ripples.

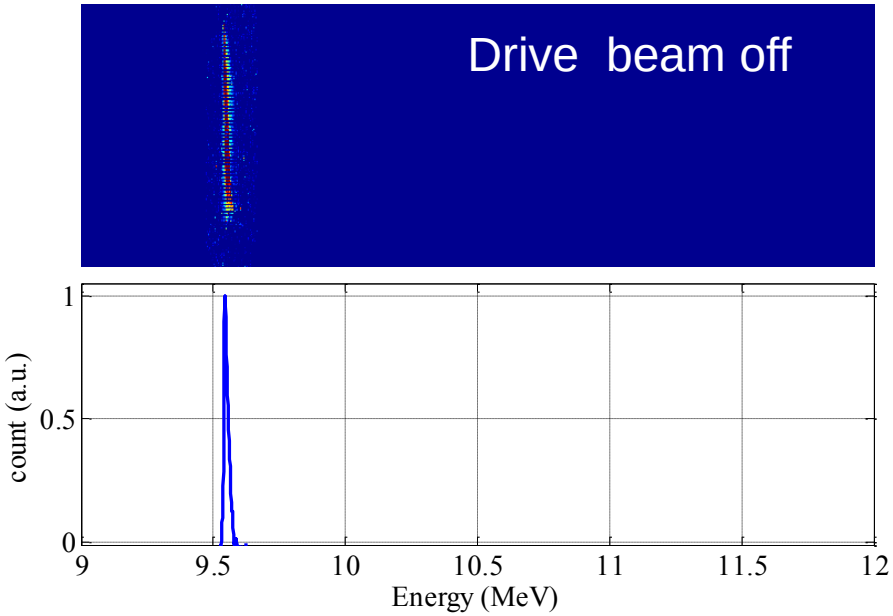
Drive Beam Deceleration In The 26GHz D-PETS

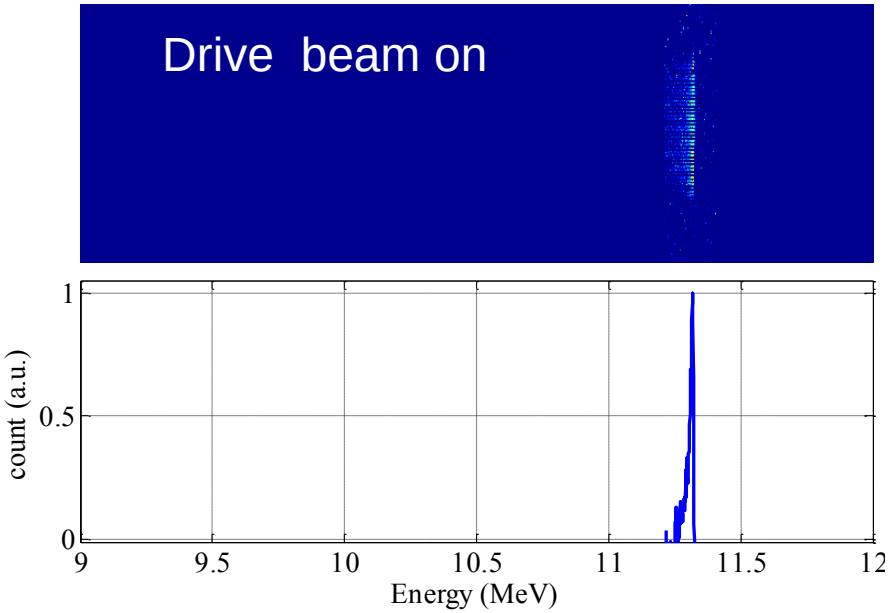


- ~4MeV deceleration was measured for each drive bunch which is aligned with ~160MW rf power output by a 4x22nC bunch train.

- Strong transverse kick occurred during the bunch train case resulting in Bunch #3 out of the energy spectrometer screen in the 4-bunch case (this prototyping D-PETS doesn't have transverse mode damping feature).

Main Beam Acceleration In The 26GHz Dielectric Accelerator

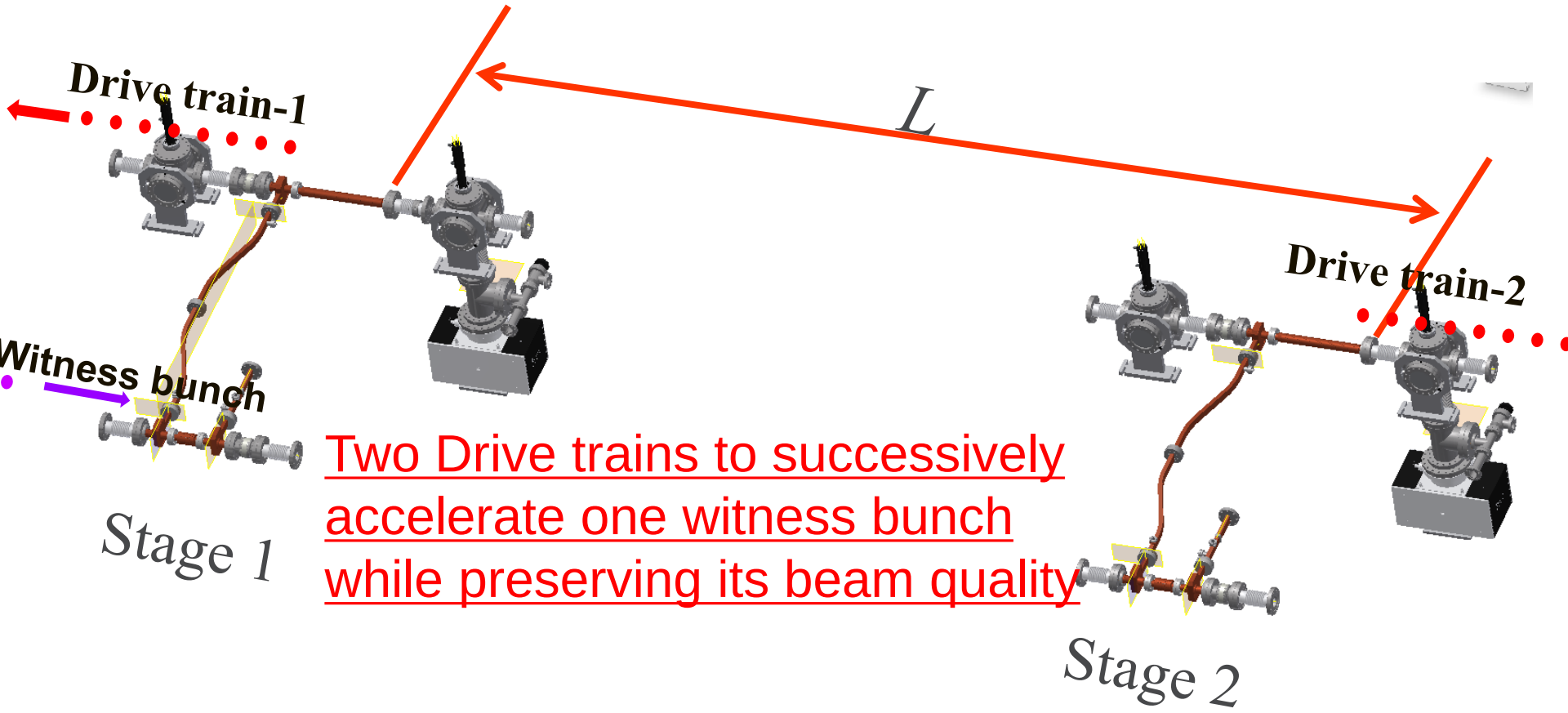




- ~1.8MeV acceleration of a 230pC witness beam transmitted through the dielectric accelerator, which is eqv. to ~50MV/m gradient.

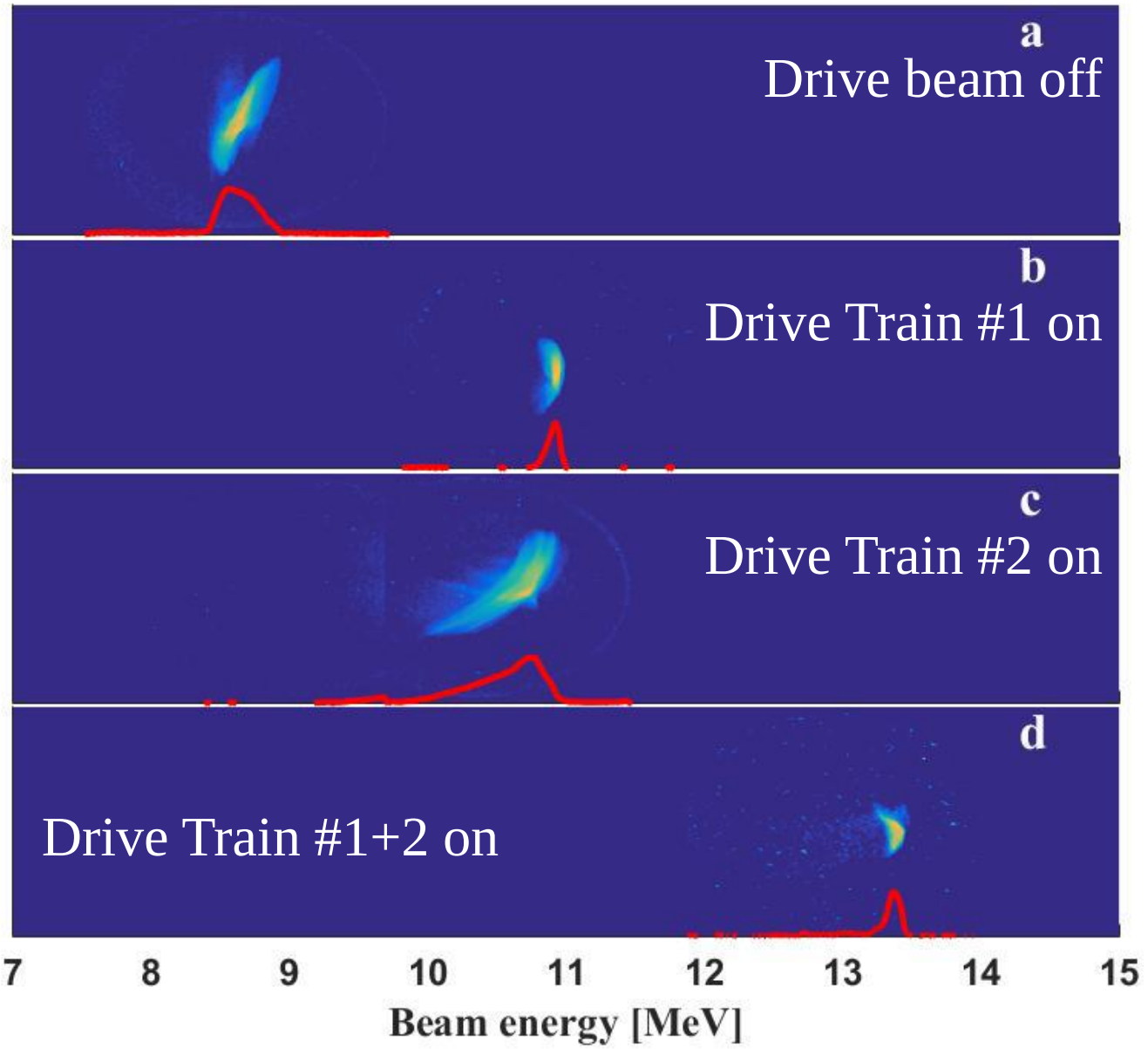
- Gradient is lower than the ideal case due to the combination of RF loss in the waveguide, miss-match of the phase advance, and inefficient rf coupling, etc.

C: STAGING FOR TWO BEAM ACCELERATION



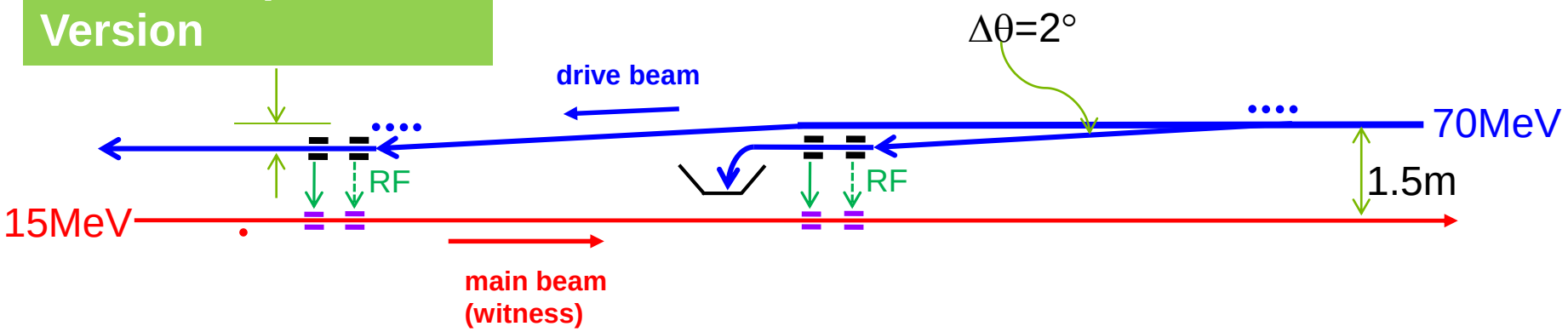
Two Drive trains to successively accelerate one witness bunch while preserving its beam quality

C: STAGING EXPERIMENT AT AWA



C: Complete STAGING DEMONSTRATION AT AWA Nicole Nevue's thesis

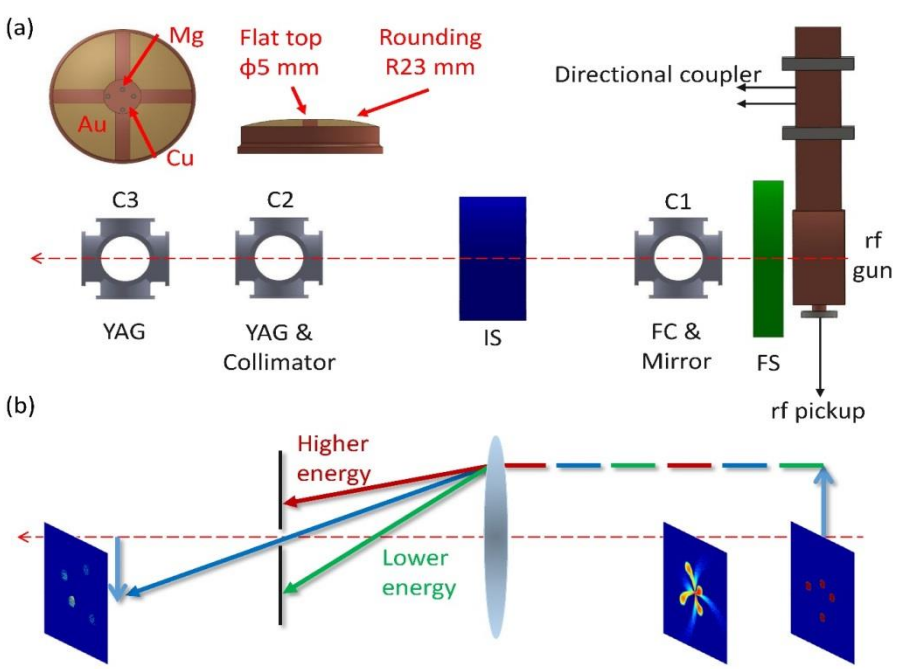
More Complete Version

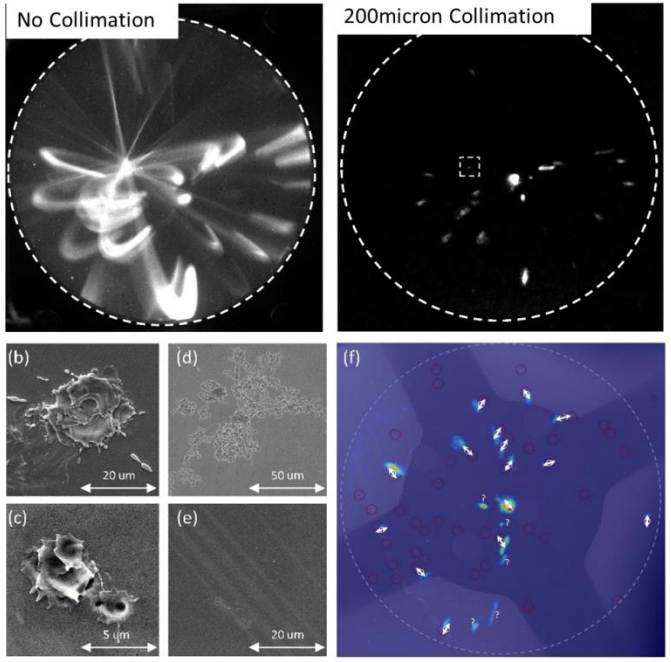


To be completed in FY 18

REPORT ON RECENT ACTIVITIES FOR EXTERNAL USERS

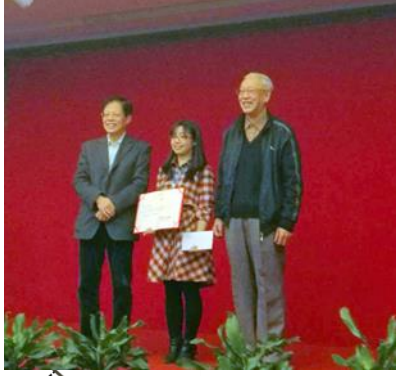
A. STUDIES OF FIELD EMISSION/RF BREAKDOWNS AT AWA (SLAC/Tsinghua U.)

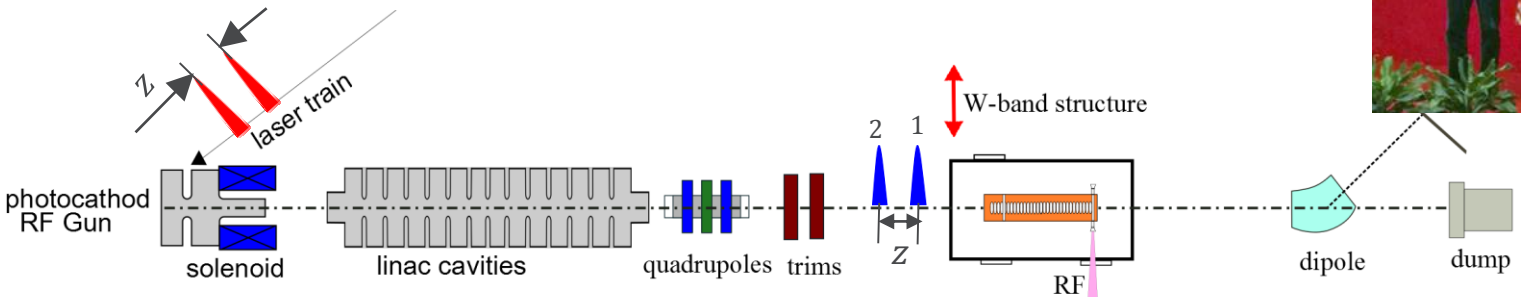




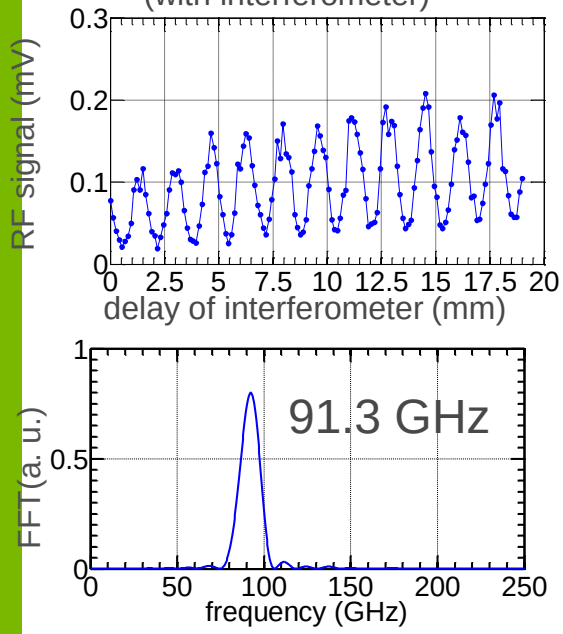
Sketch of the Dark current imaging beamline at AWA

D. W-BAND RF GENERATION WITH TWO ELECTRON BUNCHES (5 MW)



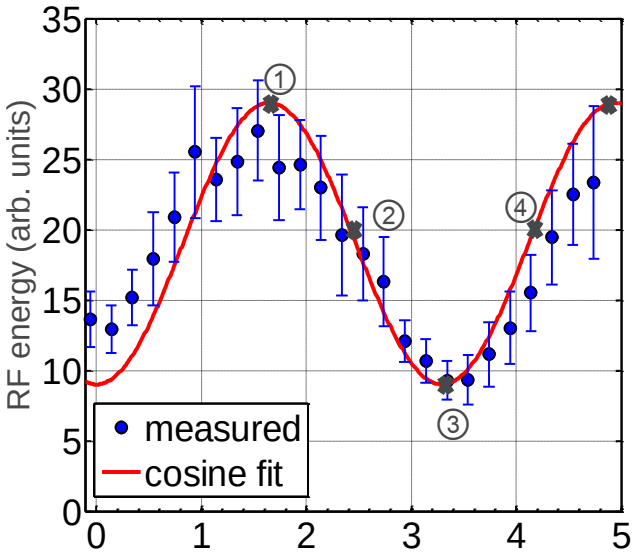


frequency measurement
(with interferometer)



(a)

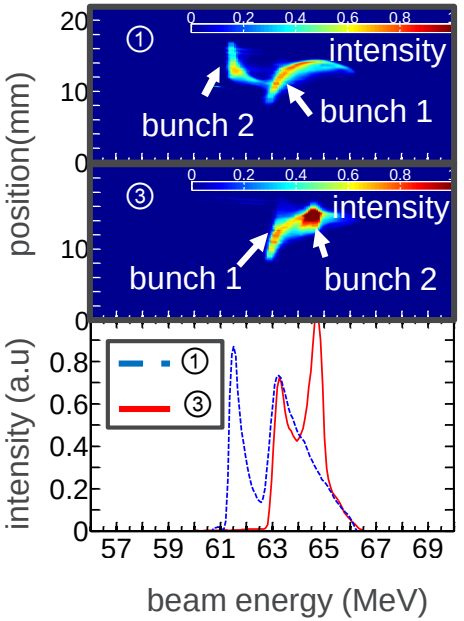
RF measurement vs. delay of bunch 2
(with energy meter)



$\Delta z = z - z_0$ (mm)

(b)

electron beam energy measurement
(on spectrometer)



(c)

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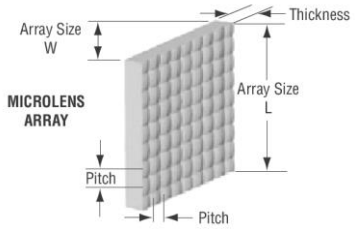
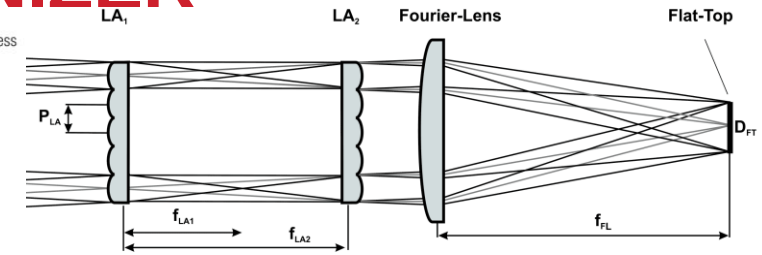
E. MICRO-LENS ARRAY (MLA) LASER HOMOGENIZER



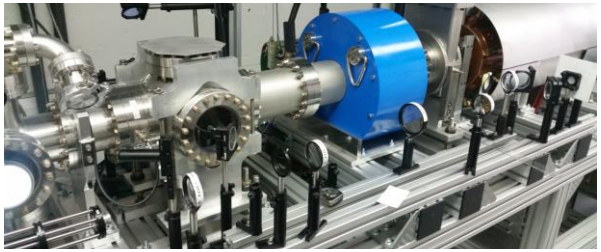


Resulting distribution can be flat-top or multi-beam

Joint collaboration with Northern Illinois University

MLA plate

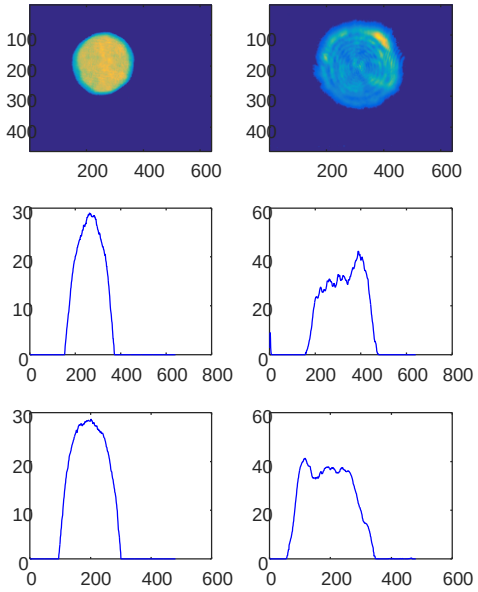
Layout for laser homogenizer



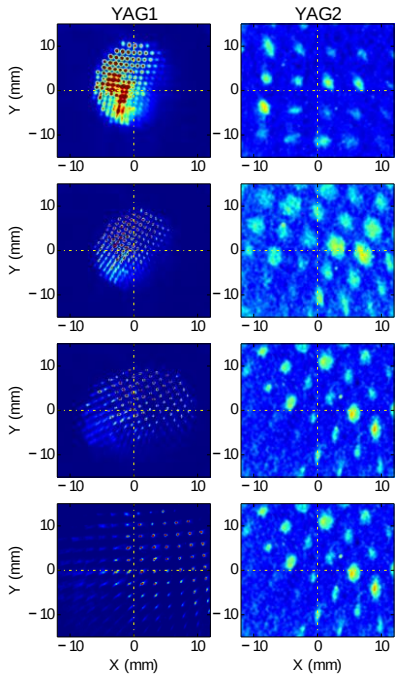
Optical transport requires custom imaging solution

Homogenized beam
More intensity!

Regular beam
clipped with iris



Multi-beam



Advantages of the MLA:

1) Flat-top homogenized laser spot
2) Reduction of beam emittance by factor of 3!
3) Multi-beam pattern generation
4) Available off-shelf!

Both beams were produced at 18/50 MeV

References:
FERMILAB-TM-2634-APC (arXiv:1609.01661), FERMILAB-CONF-16-460-APC (Proc. of NAPAC'16)

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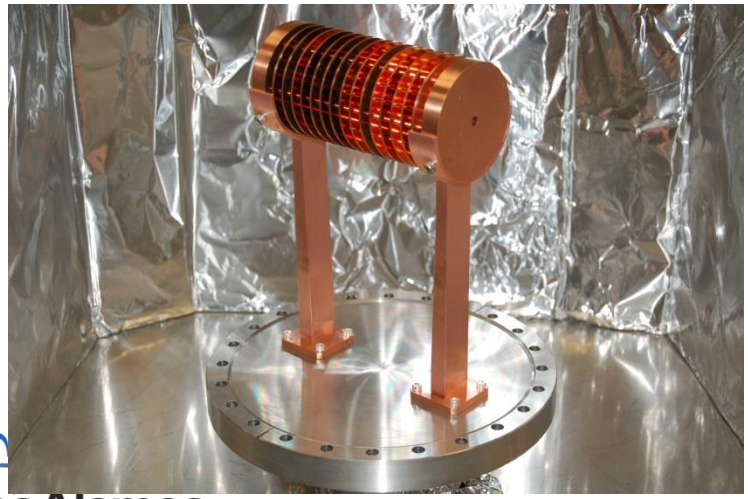
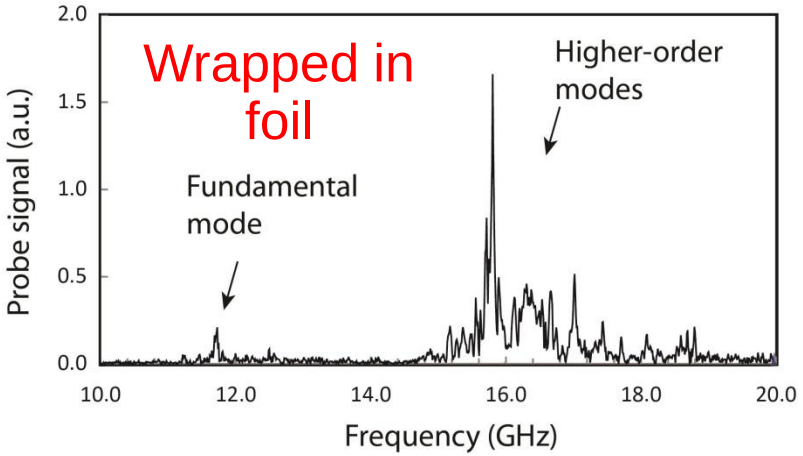
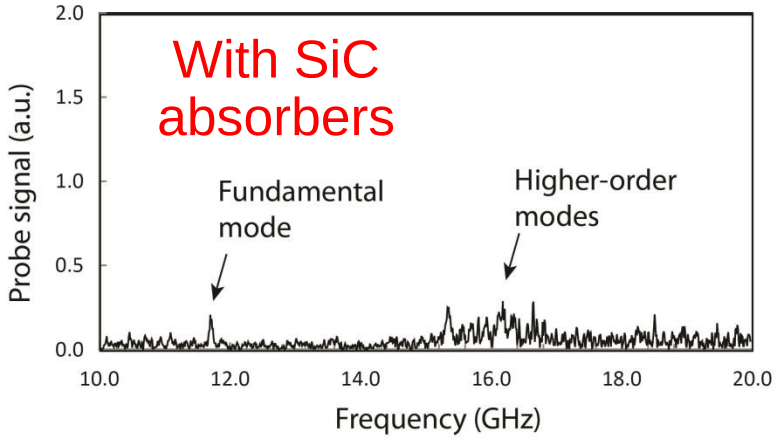
F. Wakefield measurements in an X-band PBG accelerating structure at AWA

- Open PBG structures with absorbers were demonstrated to have excellent higher order mode suppression properties.
- Future work: two-bunch experiments, demonstration of the wakefield acceleration.



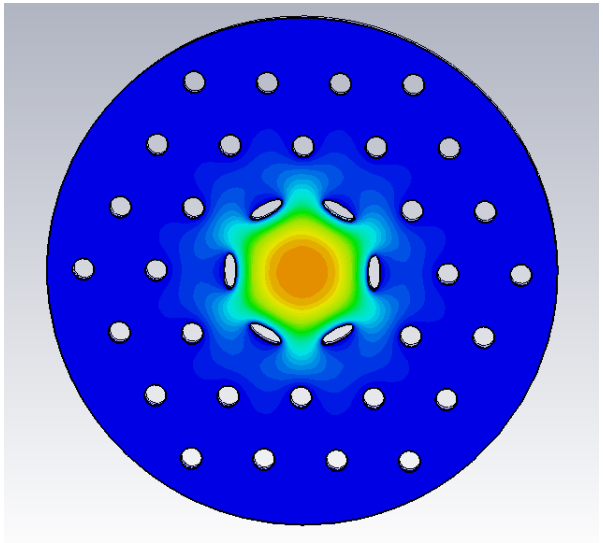




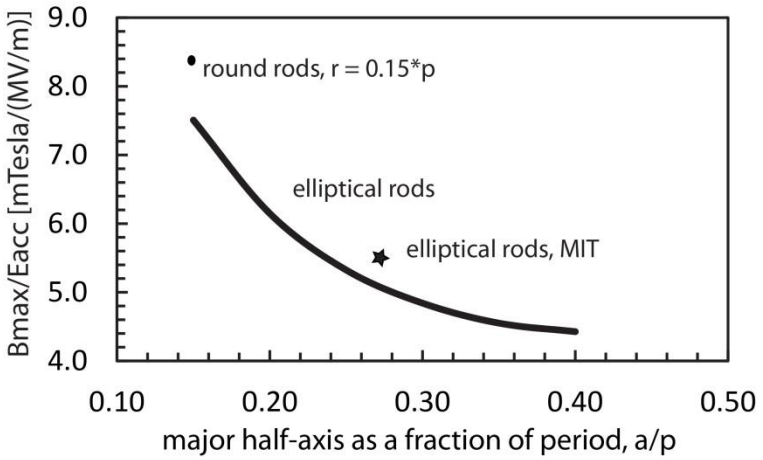
E.I. Simakov *et al.*, Phys. Rev. Lett. **116**, 064801 (2016).

F. Future work: X-band PBG accelerator with elliptical rods

The PBG cells with elliptical inner rods can have better wakefield suppression properties and go to higher gradients.

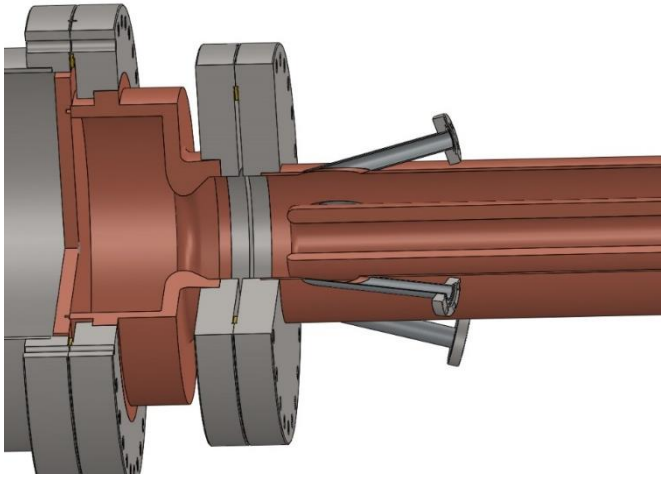


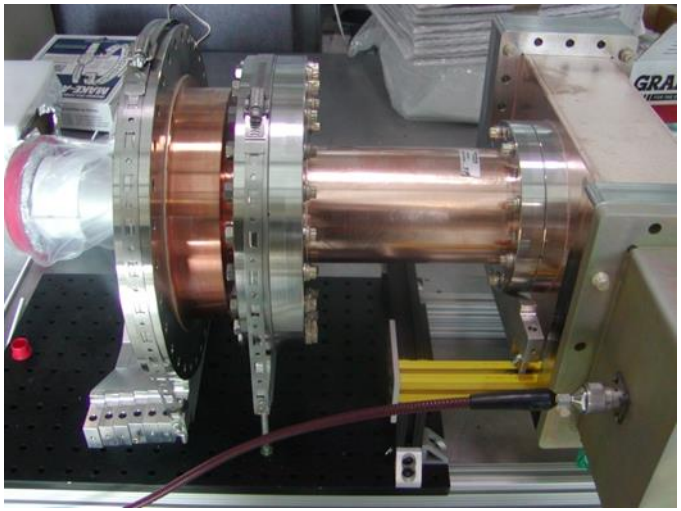
	Resonator with 6 elliptical rods	Resonator with round rods	MIT's PBG resonator with e-rods
$[r_s/Q]$	14.94 kΩ/m	13.8 kΩ/m	14.85 kΩ/m
B_{peak}/E_{acc}	5.3 mTesla/(MV/m)	8.4 mTesla/(MV/m)	5.6 mTesla/(MV/m)
E_{peak}/E_{acc}	1.98	2.13	2.07
Q_{diff} (HOMs)	130	212	431



G. High Gradient Test Cell for LANL (John Lewellen) at AWA

- Key features
  - on-axis, variable coupling
  - removable cathode backplane
  - modular design
- Implementation stages
  - Flat backplane, no cathode joint
  - Flat backplane, removable cathode
  - Field enhancing geometry
- Initial tune & coupling check completed, Preparing for assembled system leak check
- Final design of water manifold for temp. stabilization





NEXT STEPS (5 -10 YEARS)……

1) Maintaining core competences:
   - Enhancing the results, demonstrate collider type devices, such as power sources and gradients. 300 – 500 MV/m and 1 GW peak power in the range of 10 - 100 GHz range.
   - The research has to have relevance to the future of HEP LC, such as 300 – 1000 GeV CM e+ e- machines.

2) Improve facility:
   - Drive beam, higher charge, shorter length and lower emittance
   - Construct double EEX, can be used by external users.
   - Provide high power radiation sources (high power RF and THz), order of magnitude above current available sources from other places.
   - Complete the capabilities for Collinear plasma WF experiments,

NEXT STEPS (5 -10 YEARS)

- Beam conditioning and manipulations:
  - EEX
  - High brightness beam generation and characterization,
  - Diagnostics Development and testing
  - Applications:
- Electron interaction with materials,
  - Electron imaging for time and spatial resolved advanced high density mater studies
  - Compact Accelerators for HEP detector calibrations (example, 0.1 – 20 MeV electron, muon – e detector and so on)
  - Gamma rays, and e+

SUMMARY:

AWA HAS BEEN COMMISSIONED, WE WELCOME EXERNAL USERS FOR THEIR BEAM PHYSICS/ACCELERATOR PROJECTS.