Interaction of electron beam with dielectric wakefield structure at TTX beamline

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OUTLINE

- Introduction

-- Dielectric wakefield structures (DWS) and the applications

-- TTX beamline (Yingchao Du, Plenary MO2A)

- Researches at TTX

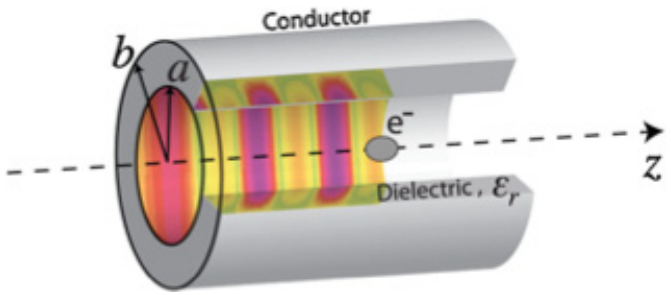
-- Experiment on wakefield THz radiation

-- Experiment on selectively THz excitation by bunch train

-- Experiment on collinear wakefield acceleration

- Summary

Dielectric wakefield structure (DWS)

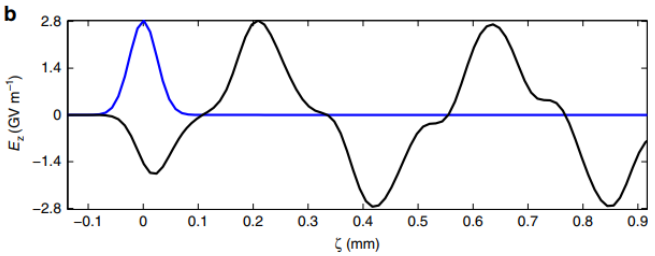


A. M. Cook, et.al., PRL 103, 095003 (2009)

- Slow wave structure
- Narrow band frequency with bandwidth~ 1%
- High gradient wakefield driven by e-beam

Gradient of wakefield：

$$E_z(z) \approx \frac{Q}{a^2} \cdot F(k, \sigma_z) \cdot \cos(kz)$$



B.D. O'Shea, et.al., nature communications,7,12763,2016

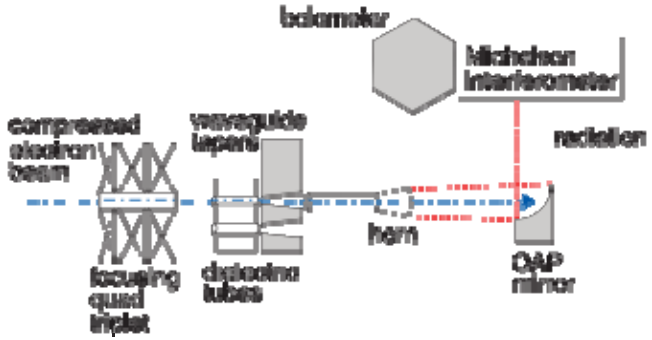
a: radius of DWS
Q: charge of drive beam
$F(k, \sigma_z)$: form factor of e-beam

$2a$~300 μm
Q~3 nC, σ_z~25 μm
E_{max}~2.8 GV/m

Application of DWS_1

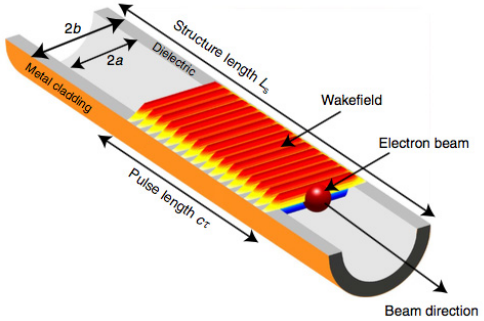
Applications of the wakefield

mJ-THz radiation source



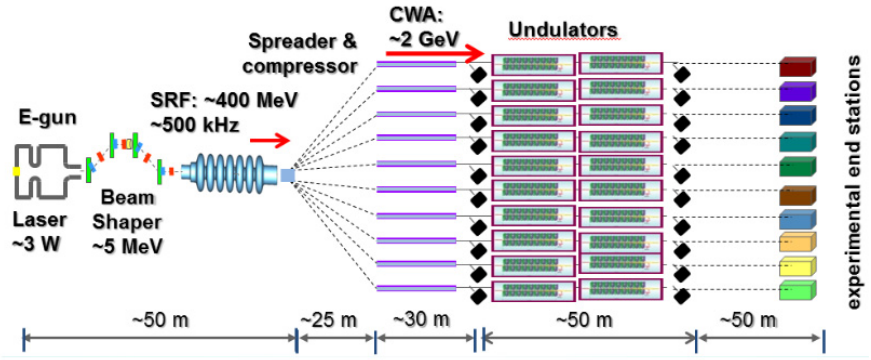
A. M. Cook, et.al., PRL 103, 095003 (2009)
S. Antipov, et.al., PRL 111, 134802 (2013)
G. Andonian, et.al., APL 98,202901 (2011)
M.C. Thompson, et.al, PRL 100, 214801 (2008)

GV/m wakefield accelerator



Collinear wakefield acceleration

B.D. O'Shea, et.al., nature communications,7,12763,2016



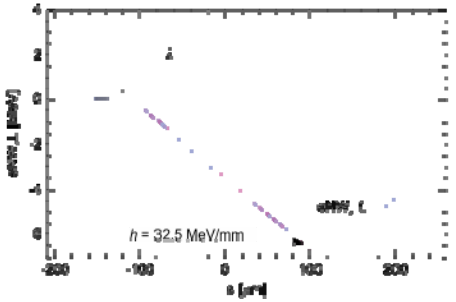
XFEL based on DWS

A. Zholents, et.al., FEL2014, FRB02,P 993-998

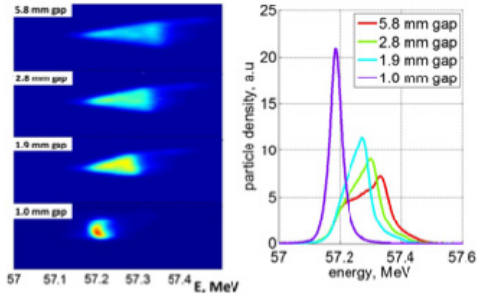
Application of DWS_2

Wakefield application on e-beam

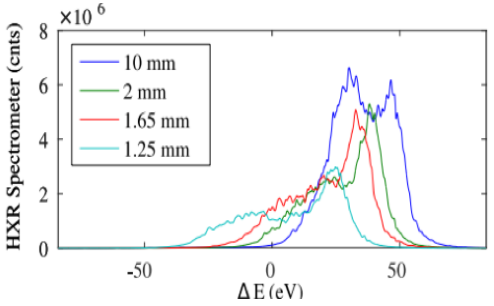
Dechirper



K.Bane, NIM. A 690, 106–110 (2012)

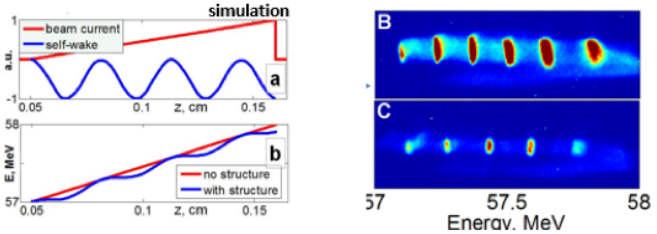


S. Antipov, et.al., PRL 112, 114801 (2014)

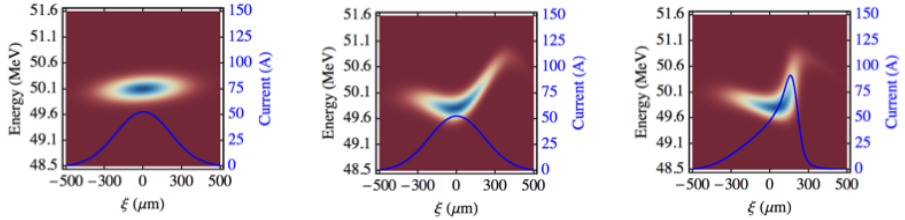


H.X Deng, et.al., PRL 113, 254802 (2014)

Bunching and shaping

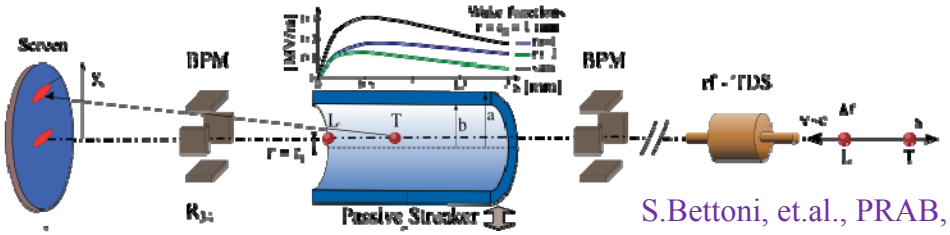


S. Antipov, et.al., PRL 108, 144801 (2012)



G.Andonian, et.al., PRL 118, 054802 (2017)

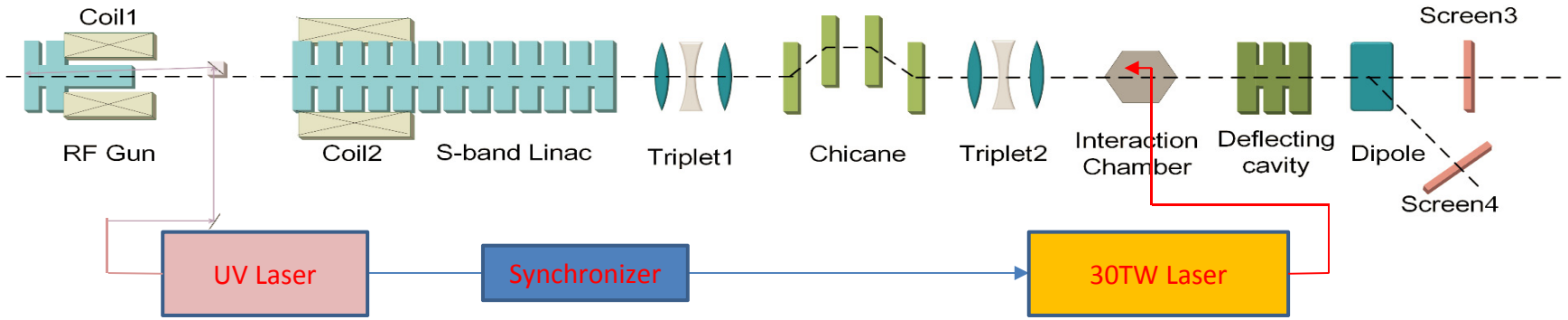
Passive deflecting cavity



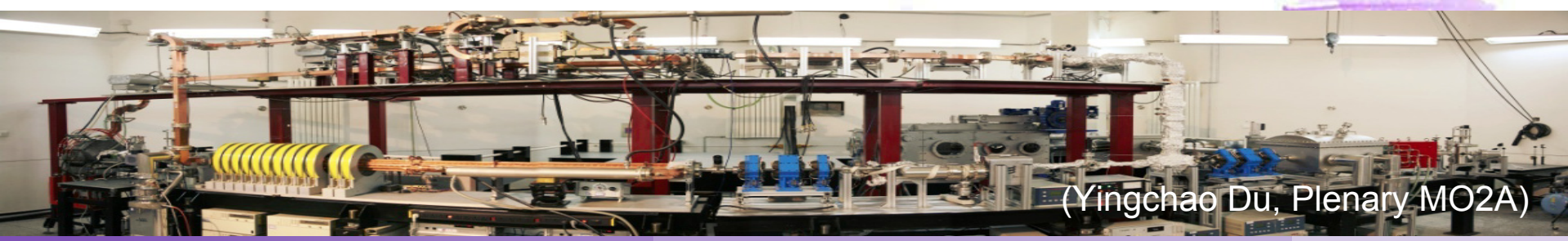
S.Bettoni, et.al., PRAB, 19, 021304 (2016)

TTX beamline_1

TTX: Tsinghua Thomson scattering X-ray Light Source



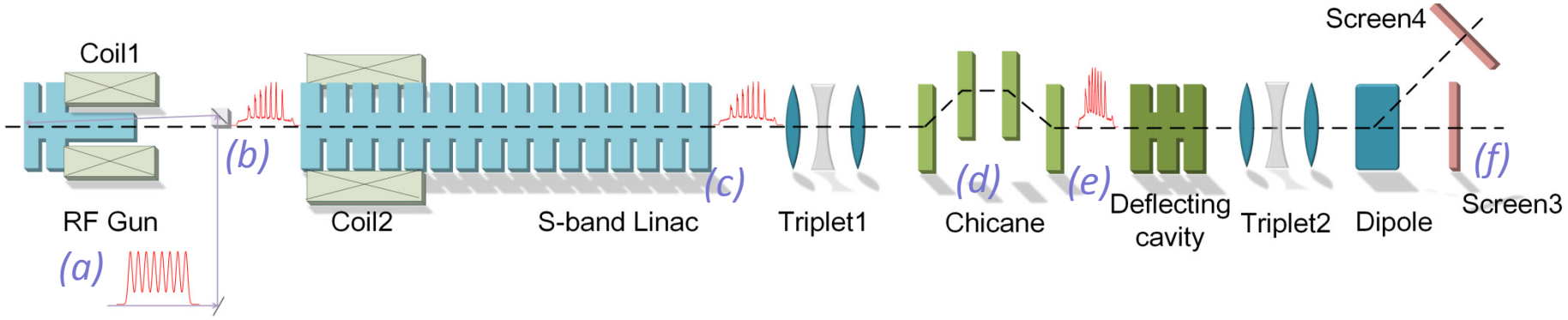
- ✓ 30TW laser system
- ✓ Bunch charge : a few pC ~ 1nC
- ✓ High gradient RF gun ~110MV/m (emittance: 0.8um ~500 pC)
- ✓ Beam energy up to 50MeV
- ✓ Beam radius ~100 um (rms)
- ✓ 4-dipole chicane for beam compression (rms bunch length: 300pC~100 fs)



(Yingchao Du, Plenary MO2A)

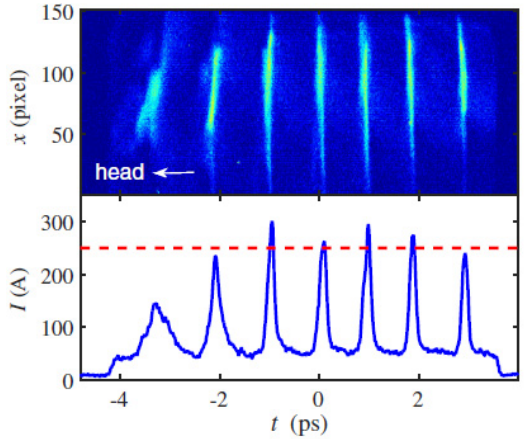
TTX beamline_2

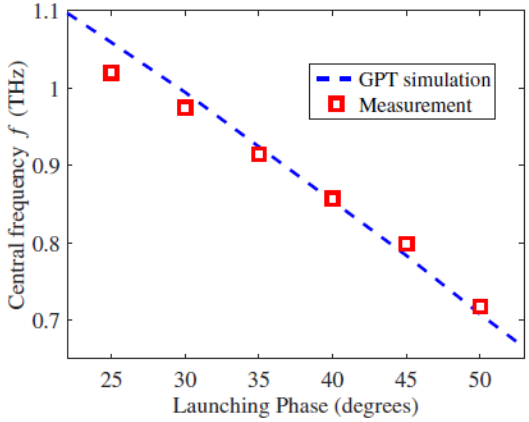
Bunch train generation based on nonlinear space charge oscillation

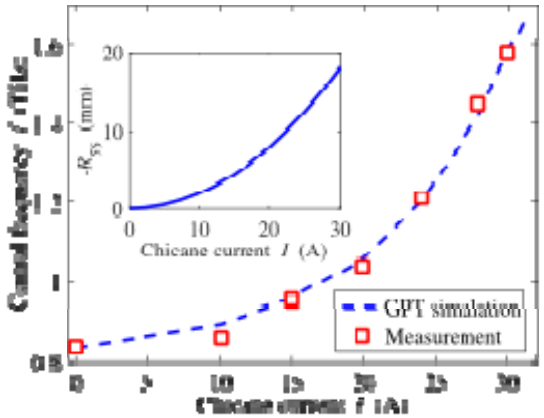


✓ (1) Large charge (~700pC) and high peak current (~300A)

✓ (2) Tunable uniform spacing from ~0.5THz to ~1.6 THz



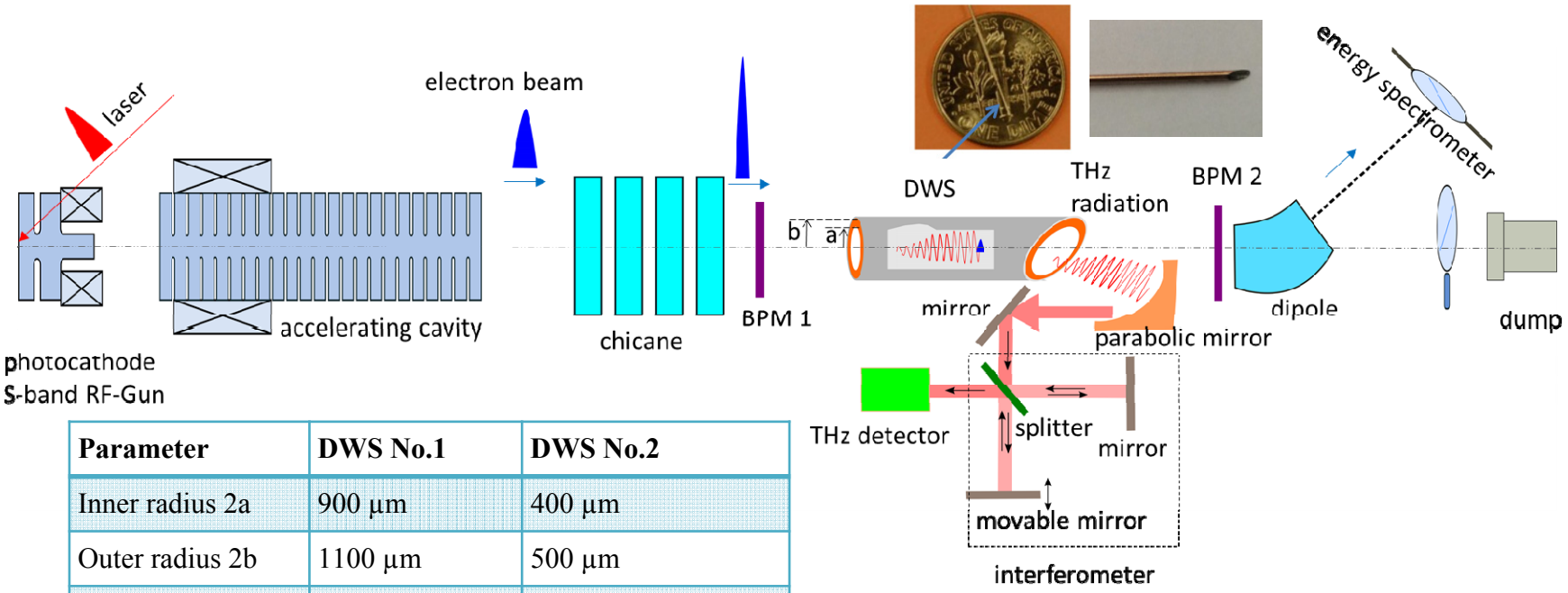




Z. Zhang, et.al., RPL 116, 184801 (2016)

Experiment on THz generation_1

Beamline setup



Parameter	DWS No.1	DWS No.2
Inner radius 2a	900 μm	400 μm
Outer radius 2b	1100 μm	500 μm
Frequency	0.3 THz	0.5 THz

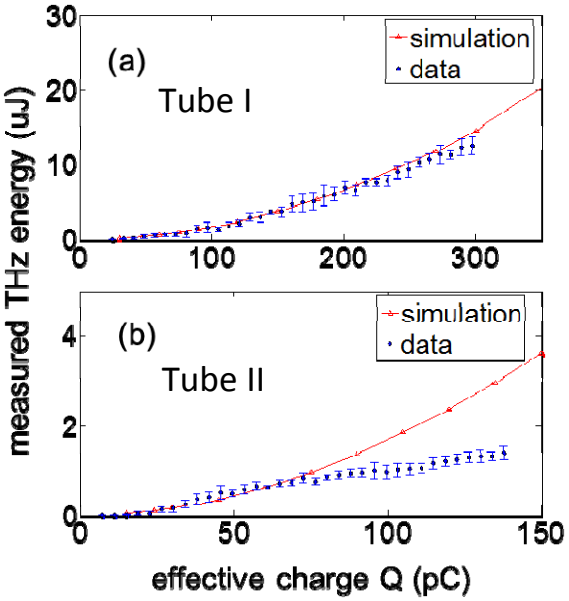
- ✓ Careful alignment and focus of the beam through DWS with ~400 μm diameter
- ✓ Coupler design with angle cut at the end of DWS for high efficiency extraction (>90%) of the THz radiation

S. Antipov, et. al., APL 109, 142901 (2016)

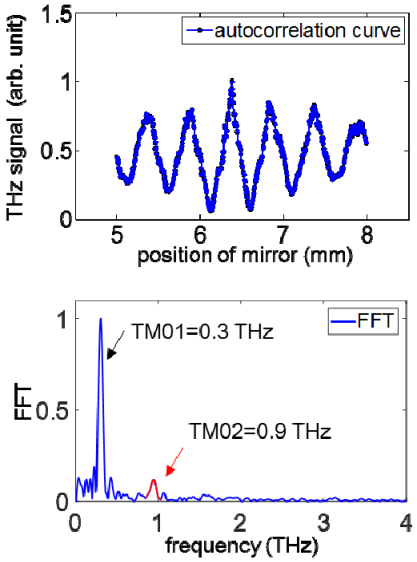
Experiment on THz generation_3

Experimental results

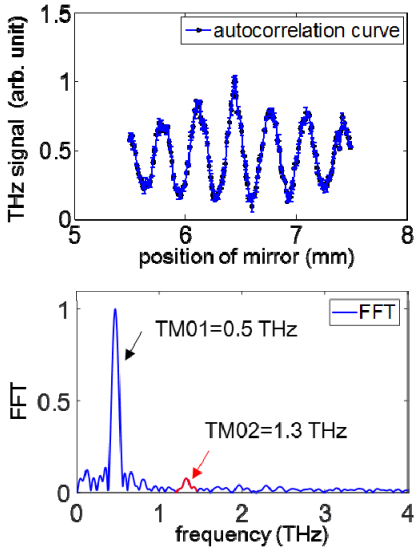
THz energy



THz spectrum



(a) Tube I



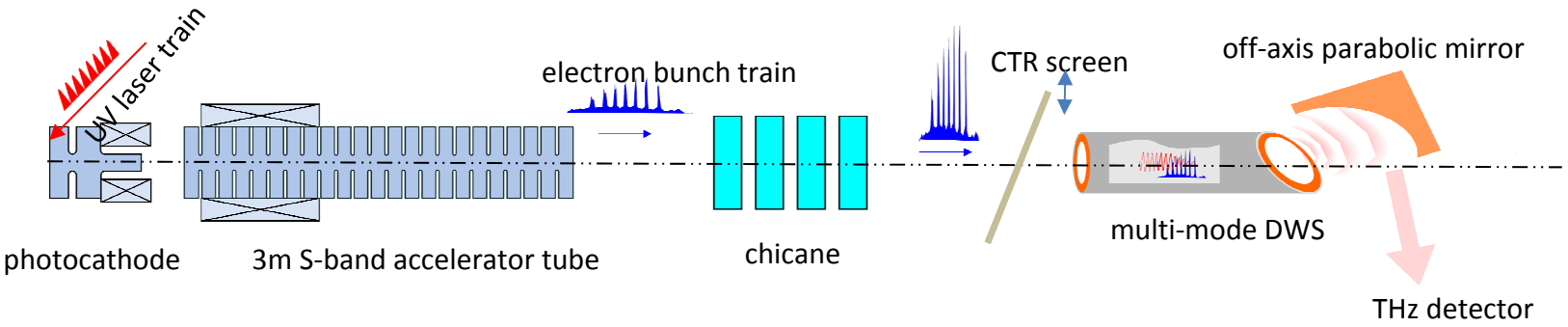
(b) Tube II

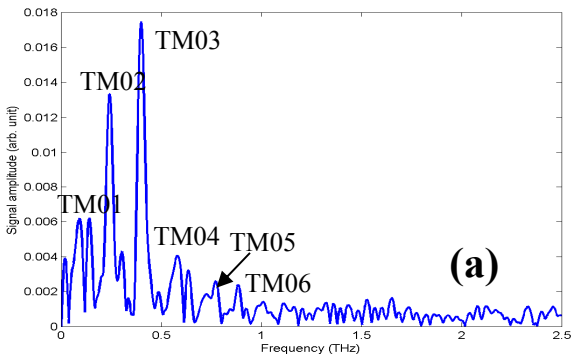
- ✓ Tens of μJ THz pulse energy has been measured with several hundred pC beam.
- ✓ Second order mode of the THz radiation is clearly seen with short drive beams

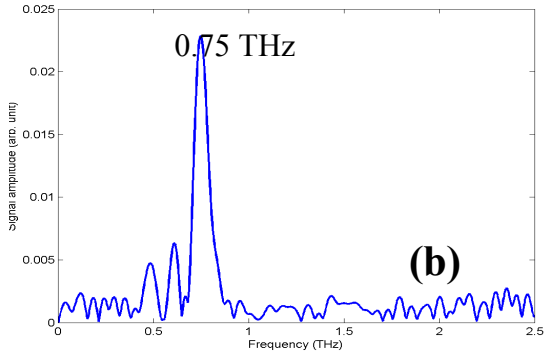
D. Wang, et.al., Rev. Sci. Instrum., 89, 093301 (2018)

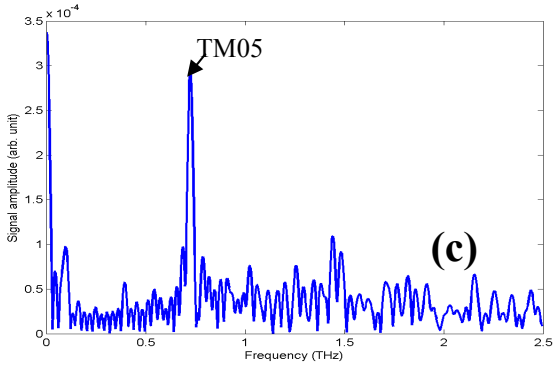
Experiment on selectively excitation

Excite multi-mode DWS by bunch train







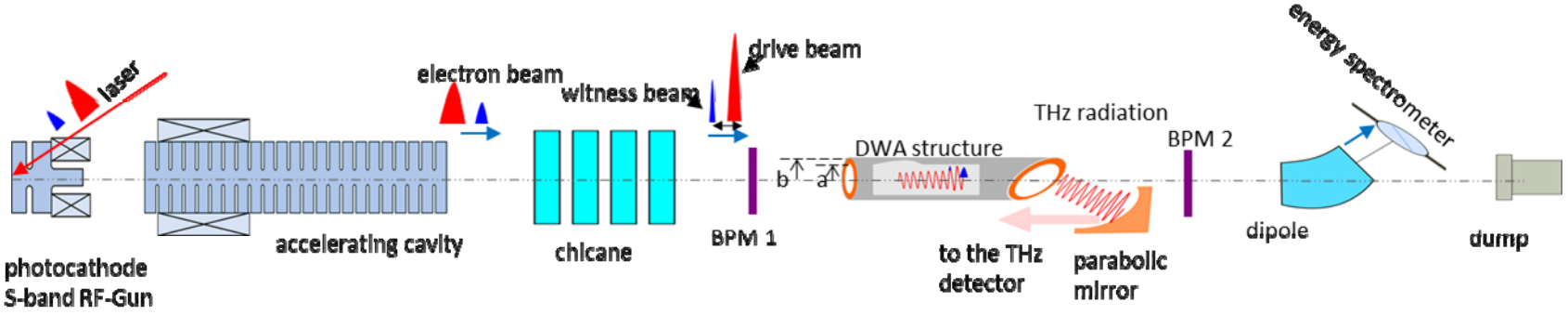


- ✓ (a) Multimode is clearly seen when multi-mode DWS is excited by single bunch
- ✓ (b) 0.75 THz bunch train based on NSCO is generated and measured via CTR
- ✓ (c) TM05 mode is resonantly excited (choose by) 0.75 THz bunch train

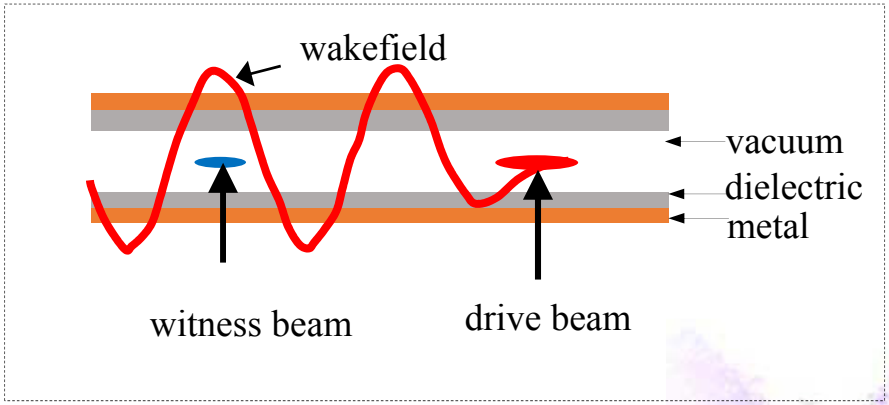
D. Wang, et.al. IPAC17, MOPVA 027 (2017)

Collinear wakefield acceleration_1

Beamline setup

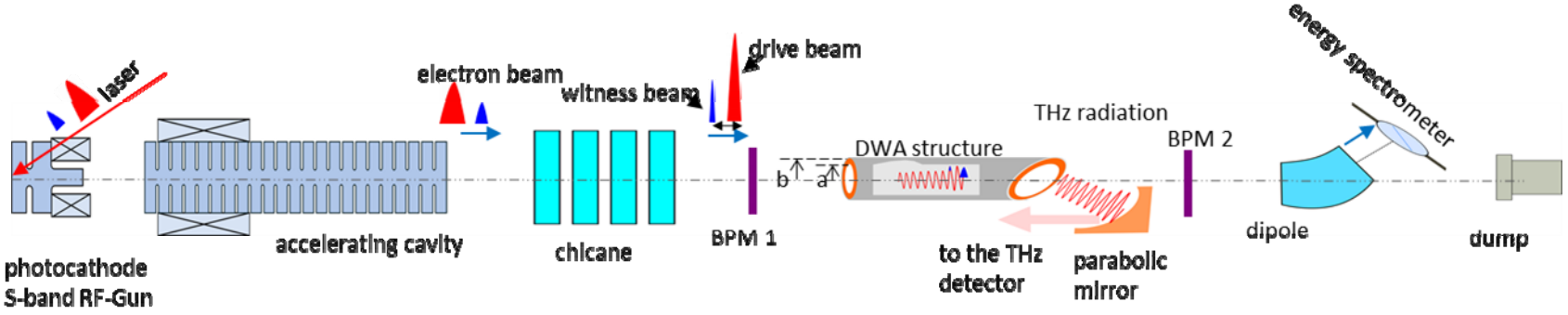


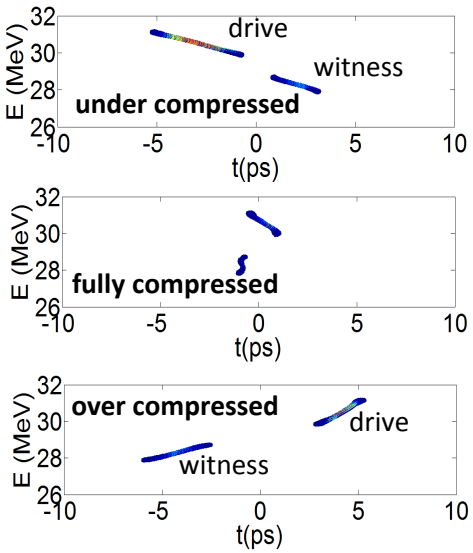
Collinear wakefield acceleration in DWS



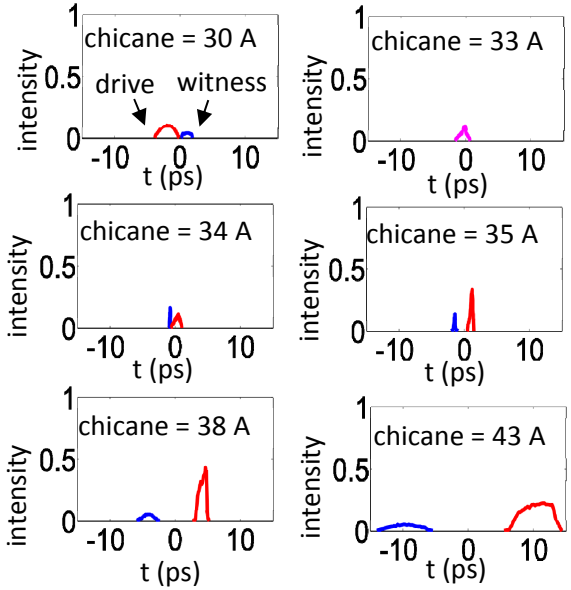
Collinear wakefield acceleration_2

Manipulate drive-witness beam pair with chicane

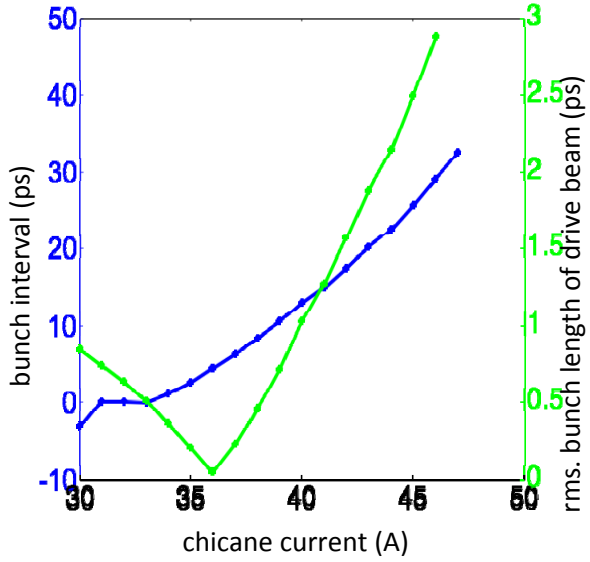




(a) phase space of beam pair



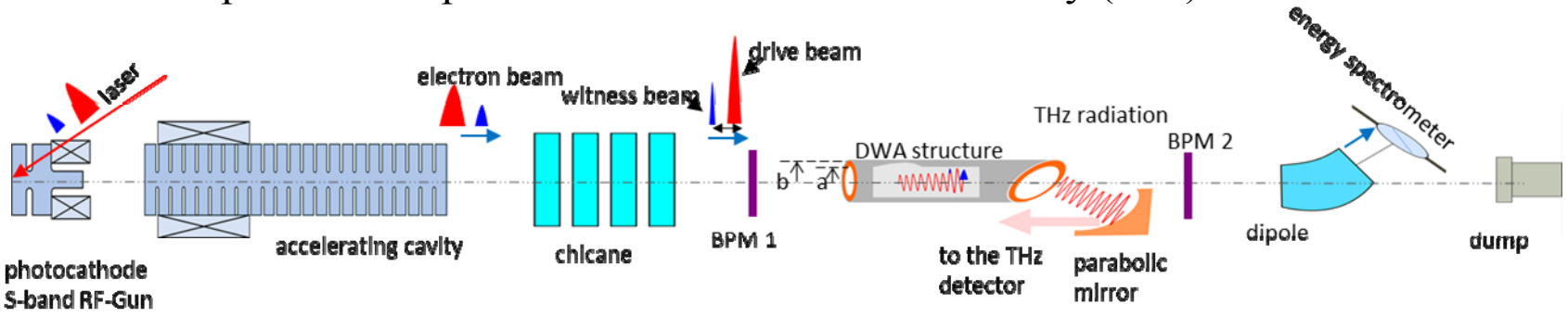
(b) longitudinal distributions

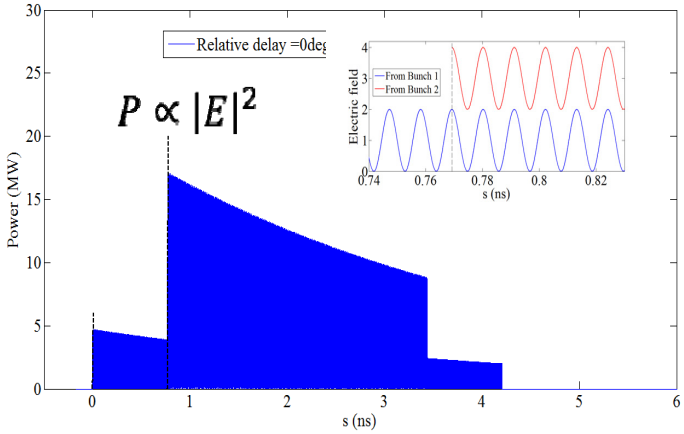


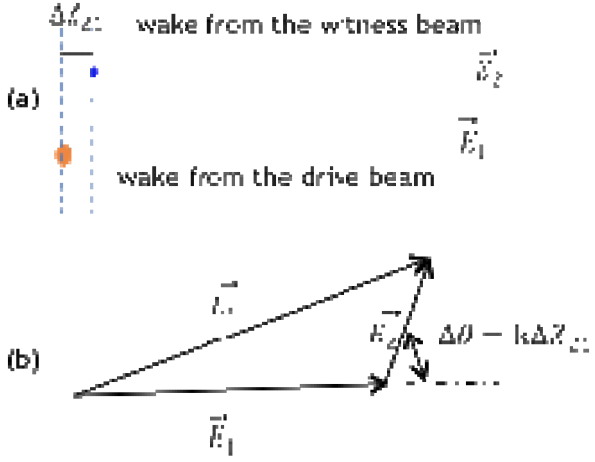
(b)bunch length and intervals

Collinear wakefield acceleration_3

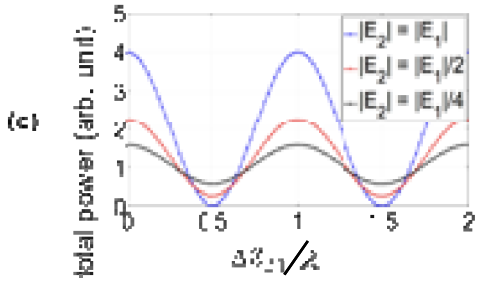
Map wakefield phase with two beam interferometry (TBI) method







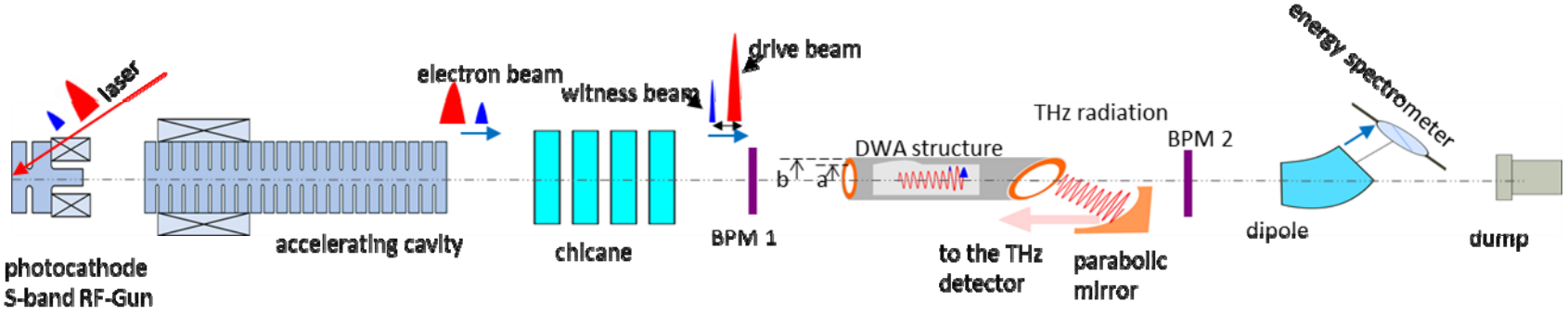
- ✓ Scan the delay of two bunches → Measure the total THz energy
- ✓ Peaks & Valleys in energy curve → Phase of maximum deceleration and acceleration



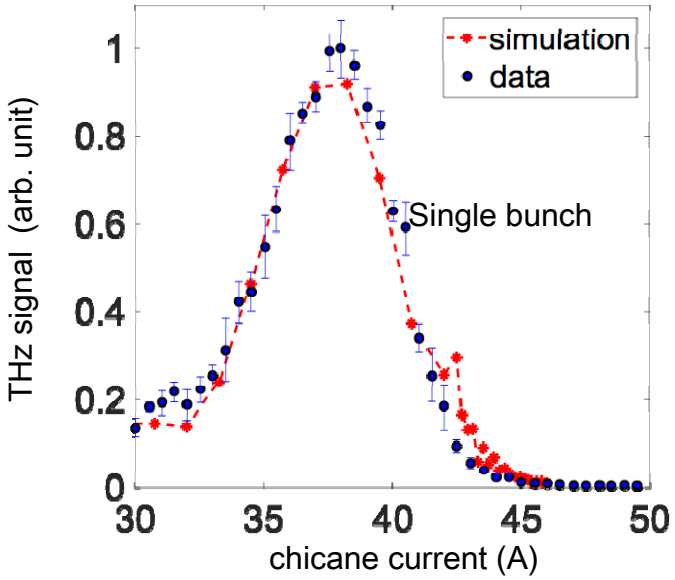
D. Wang, et.al. PRL 116,054801 (2016)

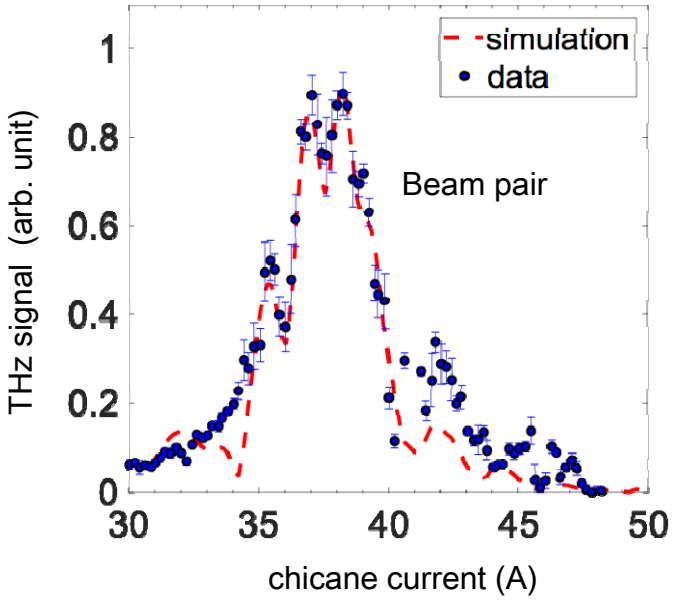
Collinear wakefield acceleration_3

Application of TBI at TTX



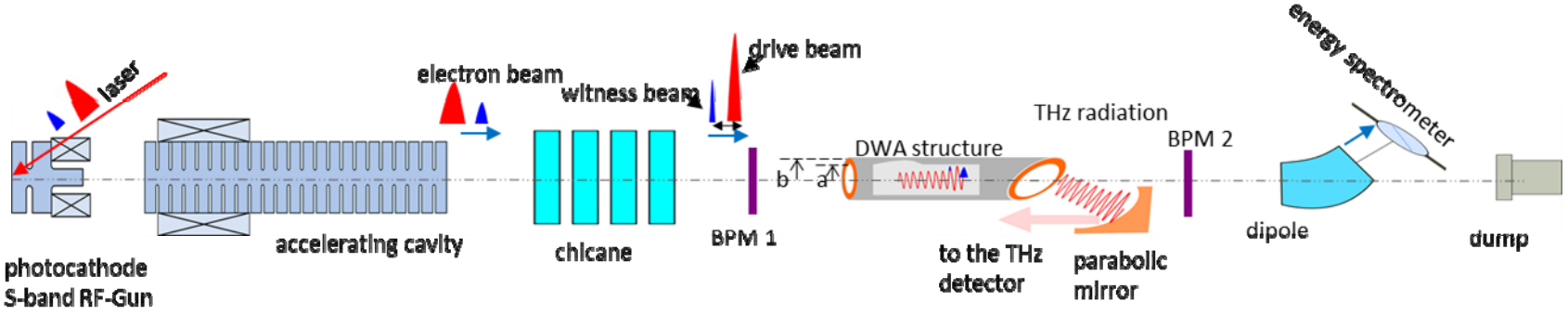
THz signal varies with the chicane current



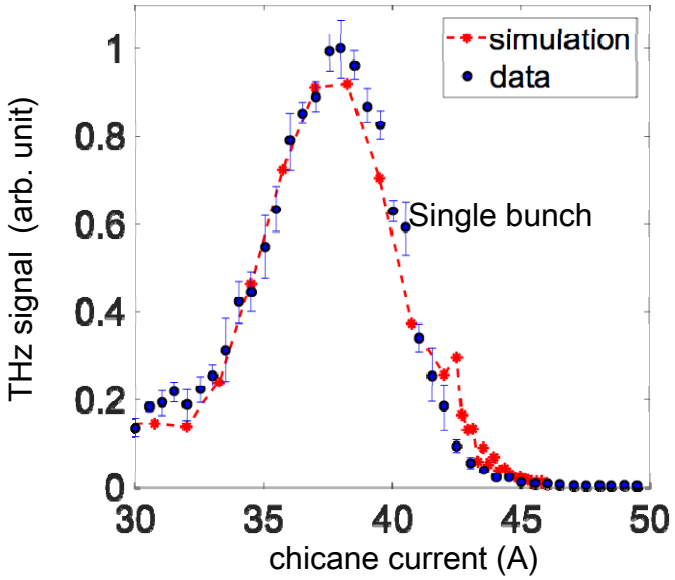


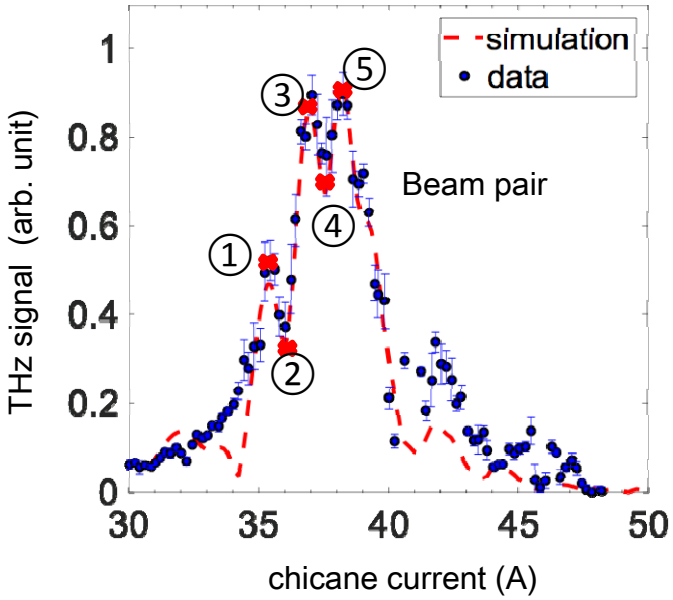
Collinear wakefield acceleration_3

Application of TBI at TTX



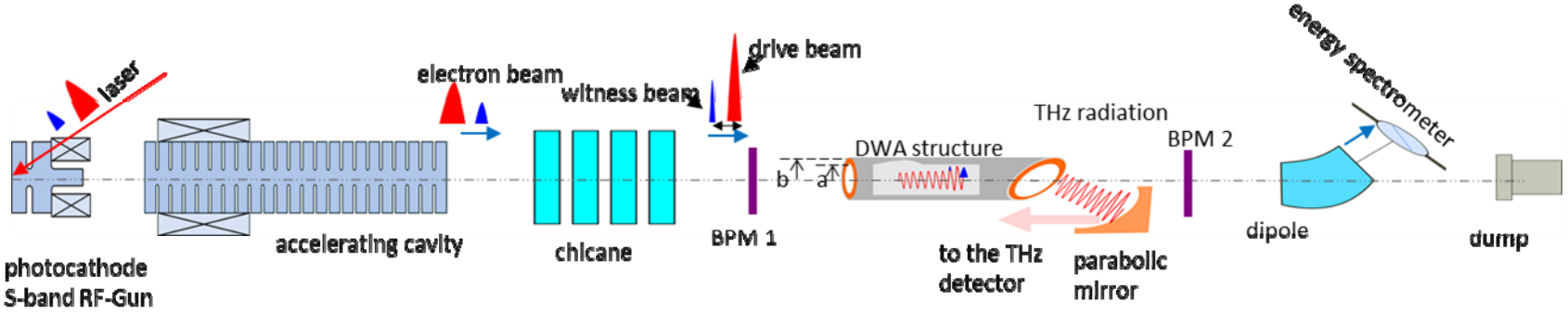
THz signal varies with the chicane current

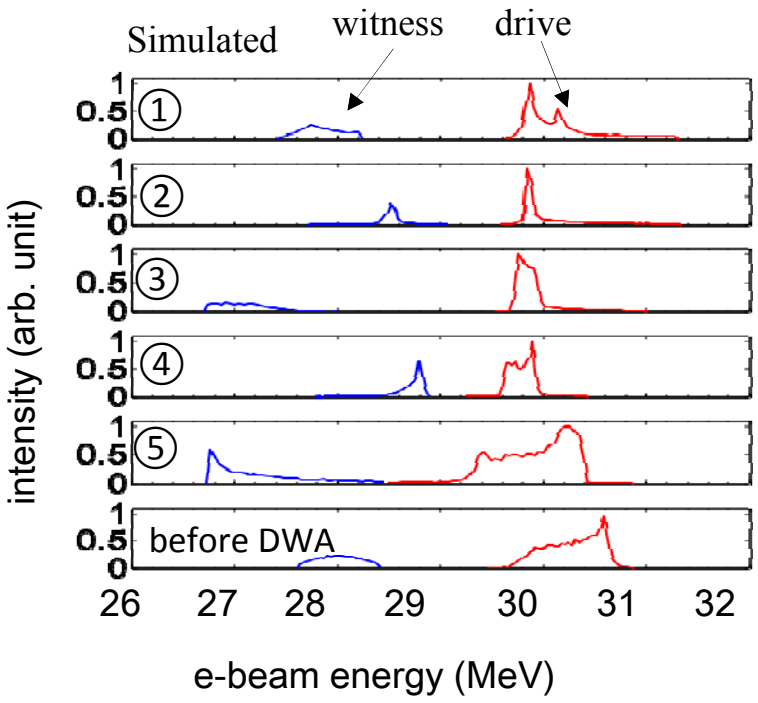


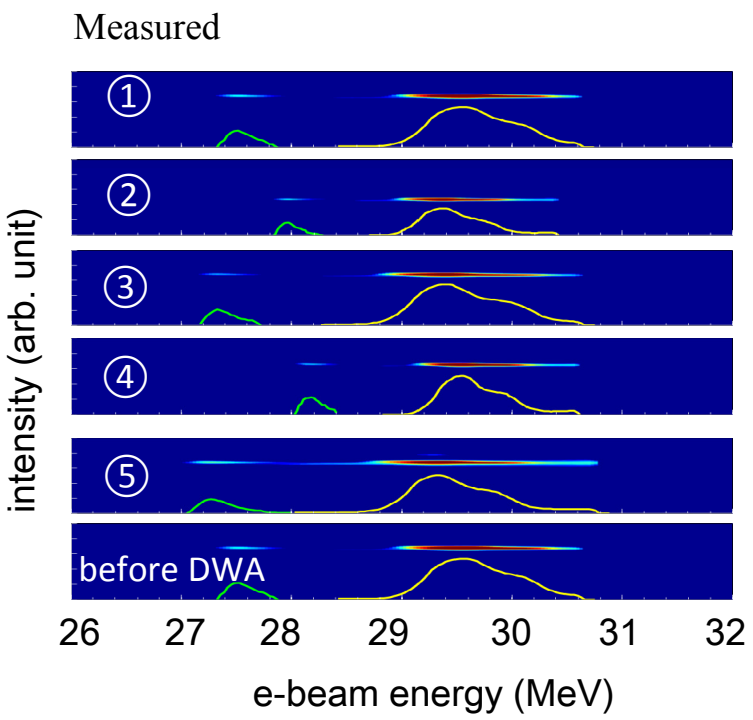


Collinear wakefield acceleration_4

Collinear acceleration results

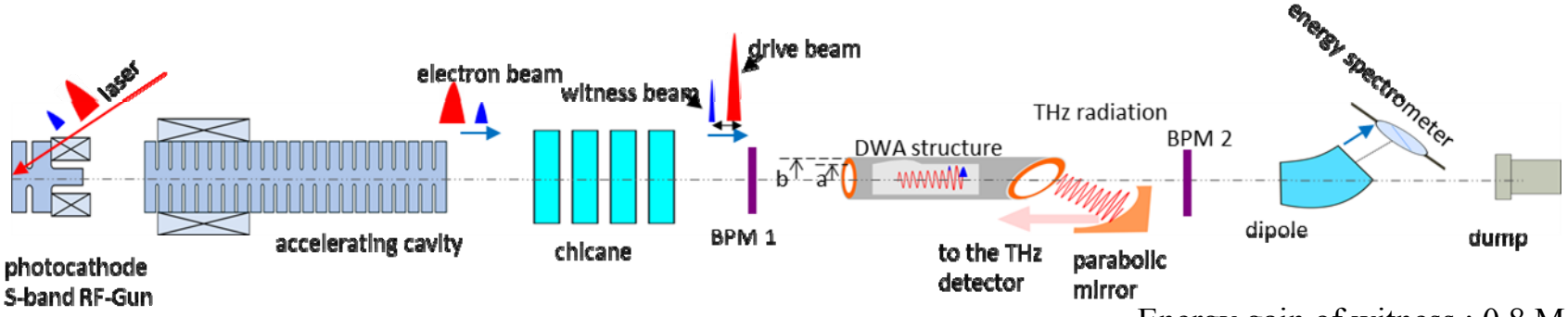






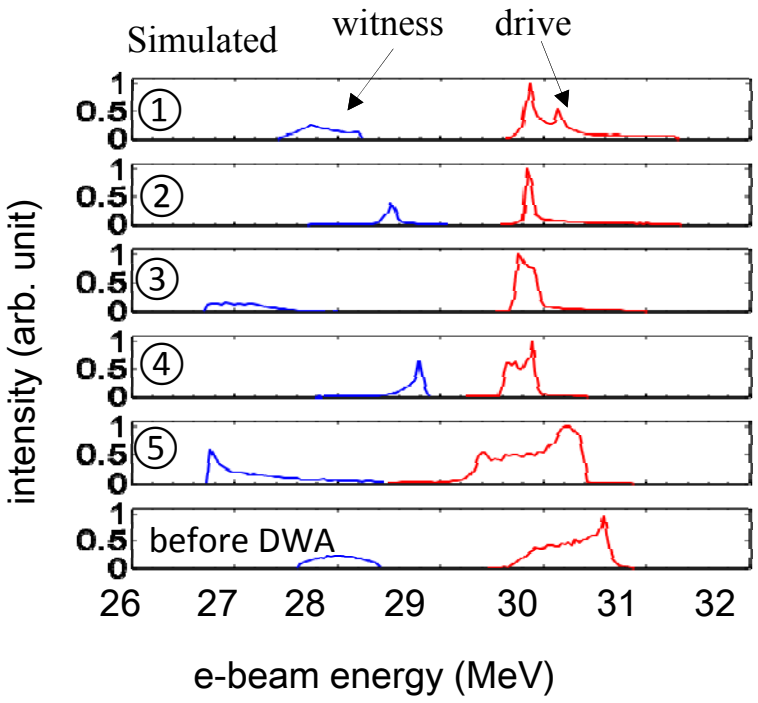
Collinear wakefield acceleration_4

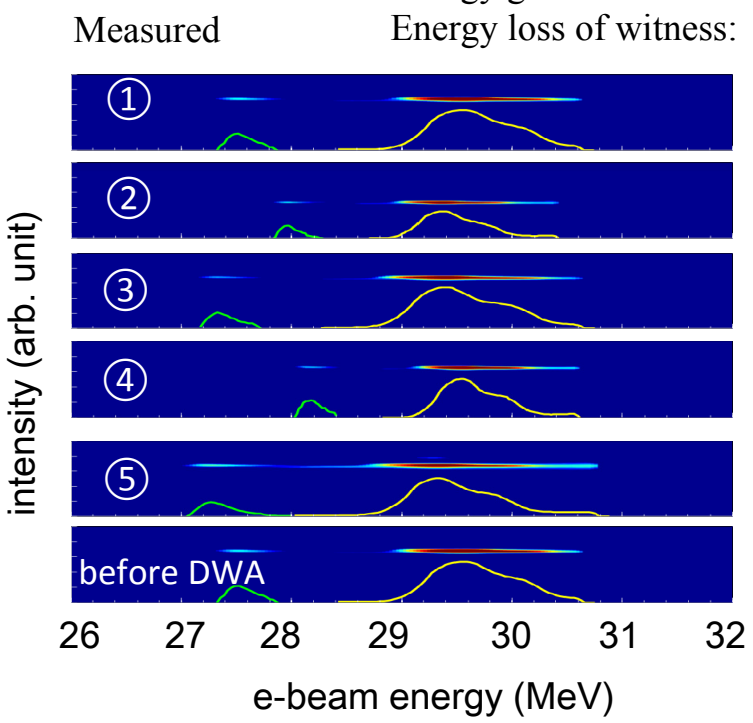
Collinear acceleration results



Energy gain of witness : 0.8 MeV

Energy loss of witness: 1.2 MeV





D. Wang, et.al. APL 111,174102 (2017)

Summary

✓ Dielectric wakefield structure find applications in fields such as radiation source, wakefield acceleration, e-beam manipulations

✓ We performed series of experiments on beam interaction with DWS at TTX

-- THz radiation experiment

-- Selectively excitation of THz by bunch train

-- Collinear wakefield acceleration with TBI method

✓ Plan

-- Beam manipulation with DWS at TTX (dechirp/ bunching/shaping/ ...)

-- Permanent magnet design for long DWS

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✓ Collaborators from JAI, Oxford, UK

Ivan V. Koloplev, Huibo Zhang, G. Doucas

✓ Collaborators from Argonne National Laboratory, US

THANKS!
COMMENTS & SUGGESTIONS