Resonant Excitation of Plasma Wakefields in the Linear Regime

(Nonlinear Regime, Y. Fang, MOP158)

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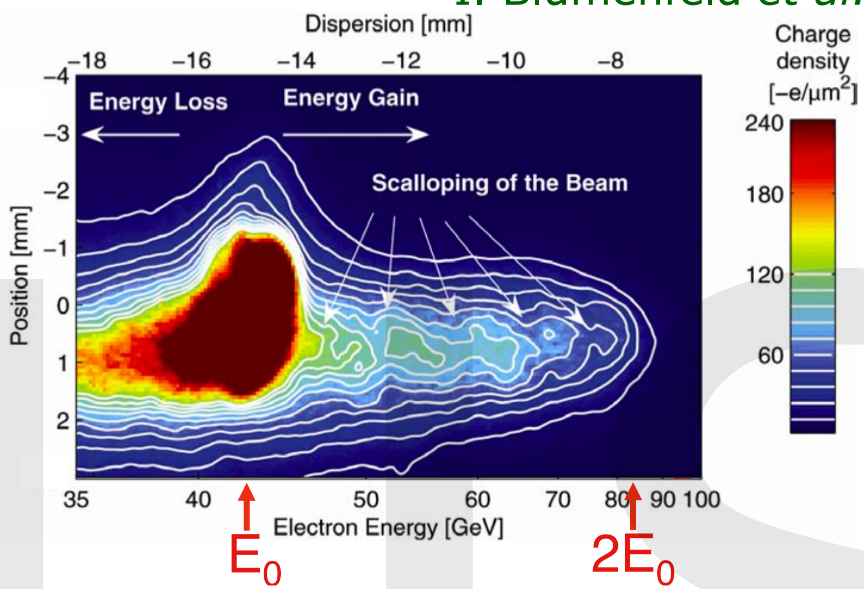
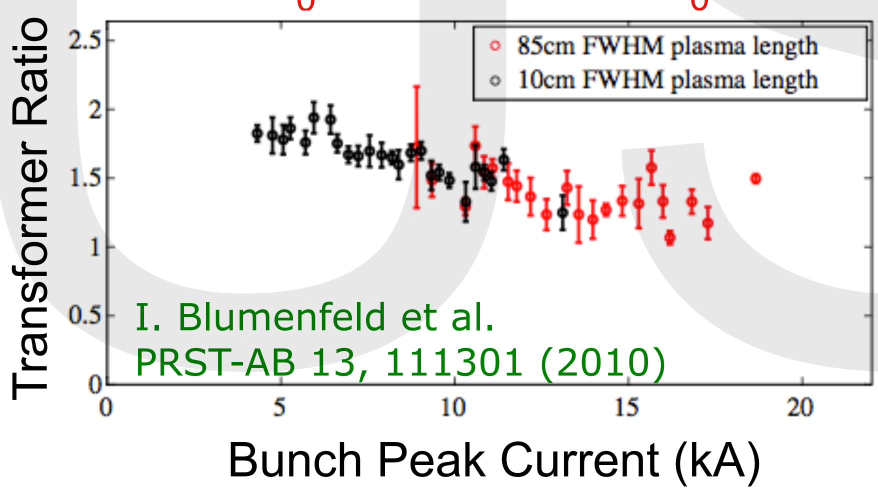
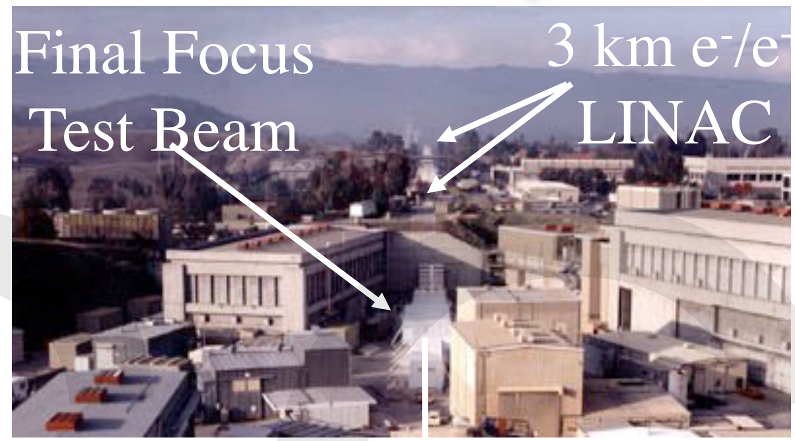
e^- ENERGY DOUBLING

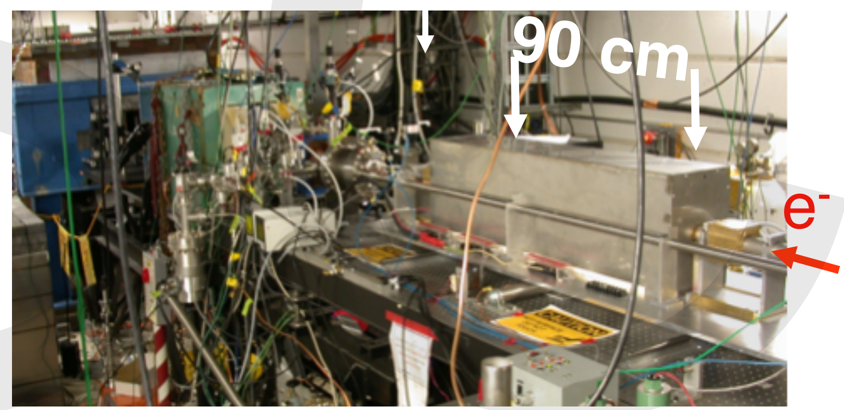
I. Blumenfeld *et al.*, Nature 445, 2007





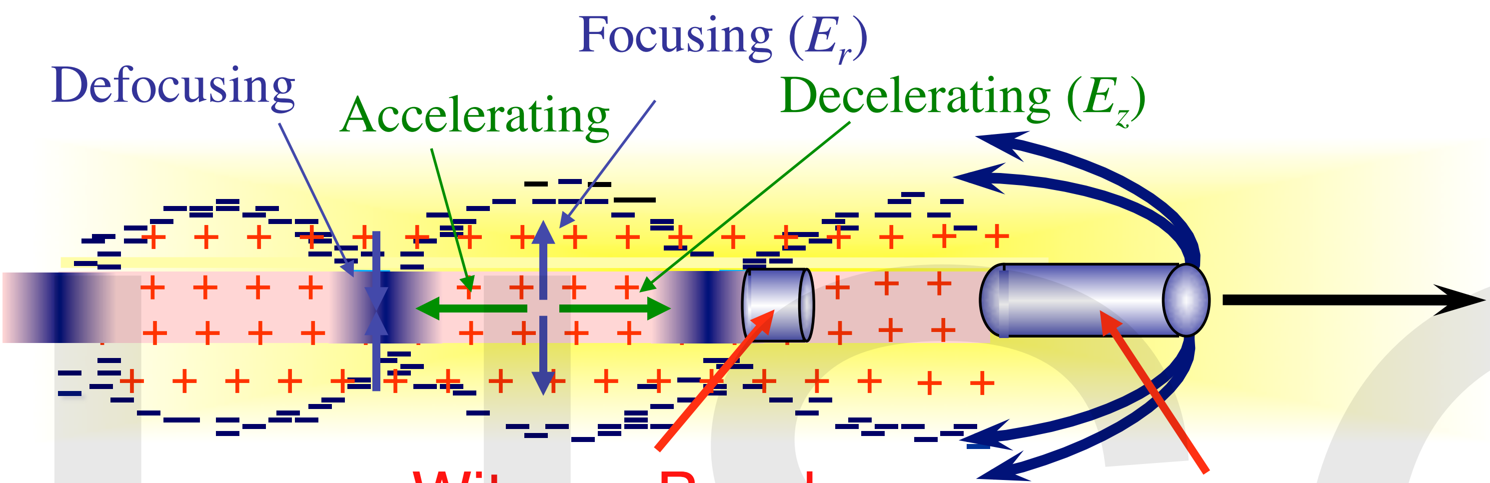
E_0=42 GeV

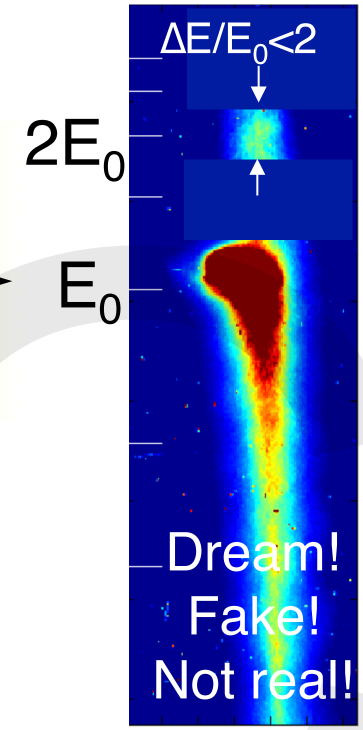




- Energy doubling of e^- over L_p≈85 cm, 2.7x10^{17} cm^{-3} plasma
- Unloaded gradient ≈52 GV/m (≈150 pC accel.)
- $R=E_a/E_d$≈1.5

2-BUNCH PWFA





- Really important experiment! (psychologically)
- Witness bunch: lower charge (*N*), good emittance, shorter
  beam loading for *ΔE/E*<<1
- New facility: FACET@SLAC for 25GeV PWFA accelerator module
  M.J. Hogan et al., New J. Phys. 12, 055030 (2010) & Next talk!
- Large transformer ratio for >>E_0 gain
  R.J. England, MOP088
- Low energy physics experiments

MULTIBUNCH PWFA

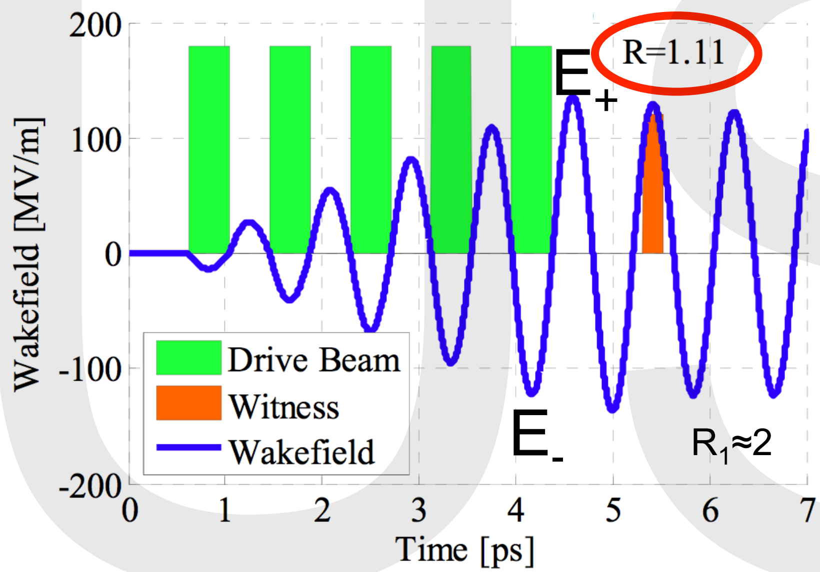
Transformer Ratio: $R = E_+ / E_-$ Energy Gain: $\leq RE_0$

σ_r=125 μm, n_e=1.8x10^{16} cm^{-3}, λ_p=250 μm

E_0: incoming energy

Q=30 pC/bunch, Δz=250 μm≈λ_p

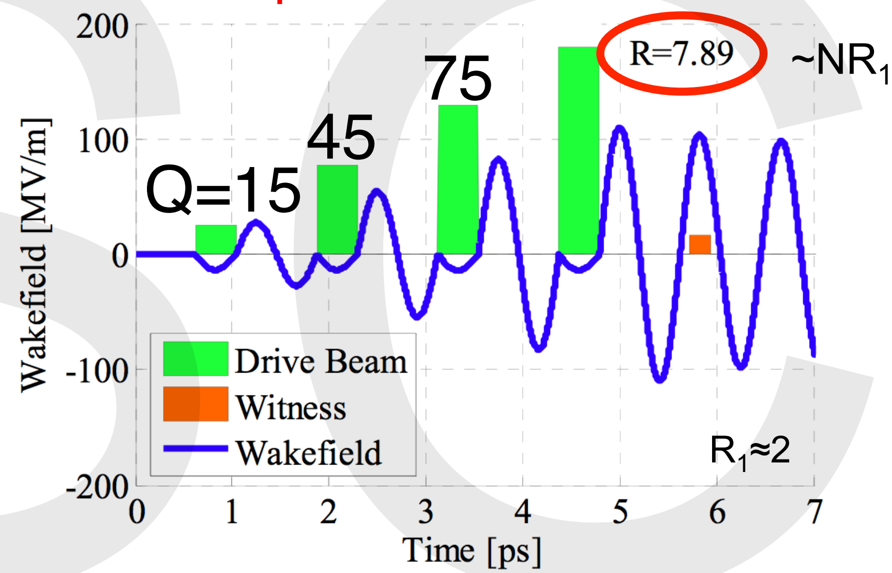
Bunch Train



Kallos, PAC'07 Proceedings

Δz=375 μm≈1.5λ_p

Ramped Bunch Train*



*Tsakanov, NIMA, 1999

- Linear (2D) theory for n_b<<n_e!
- R=7.9 => add 8 times the incoming energy in a single PWFA stage!
- Must generate train at picosecond time scale

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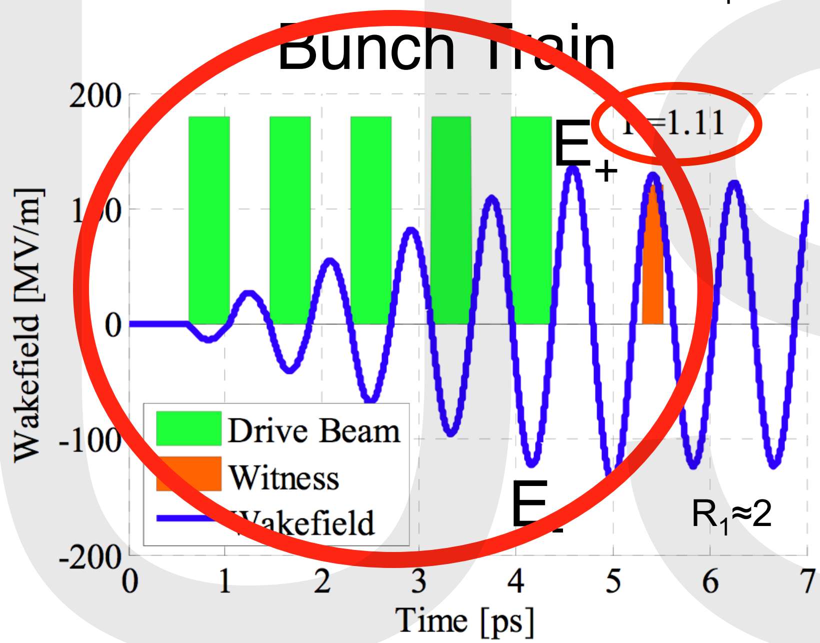

Kallos, PAC'07 Proceedings

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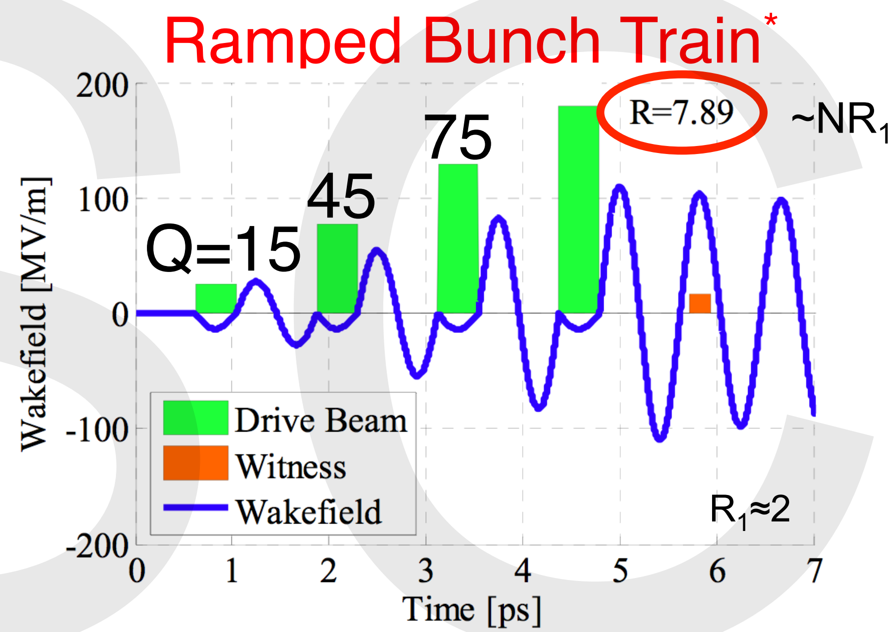

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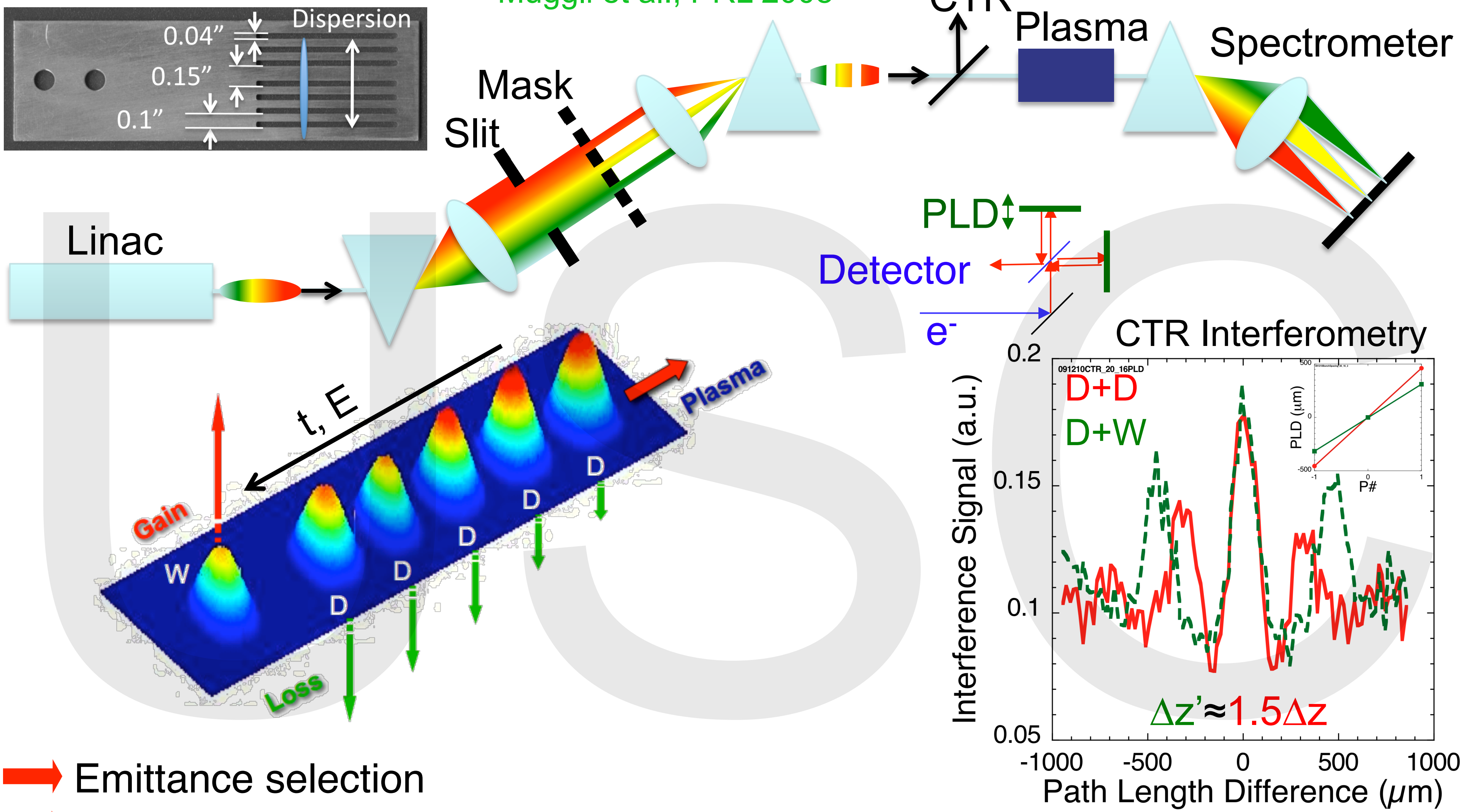
Multibunch Source-Masking

Muggli et al., PRL 2008



- Emittance selection
- Can choose the chirp, W at high energy
- Choose microbunches spacing and widths with mask and beam parameters: N, Δz, σ_z, Q

USC

Plasma Source

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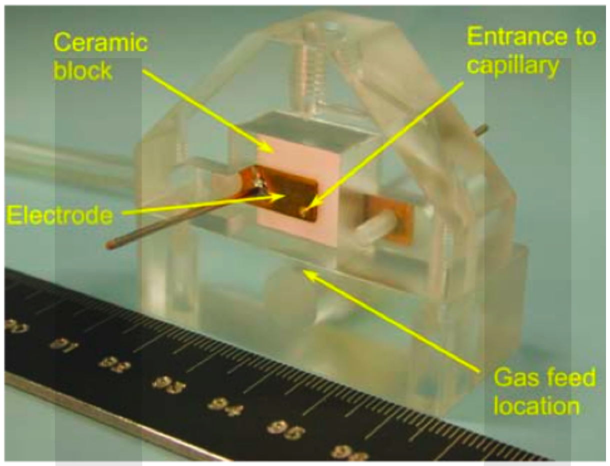
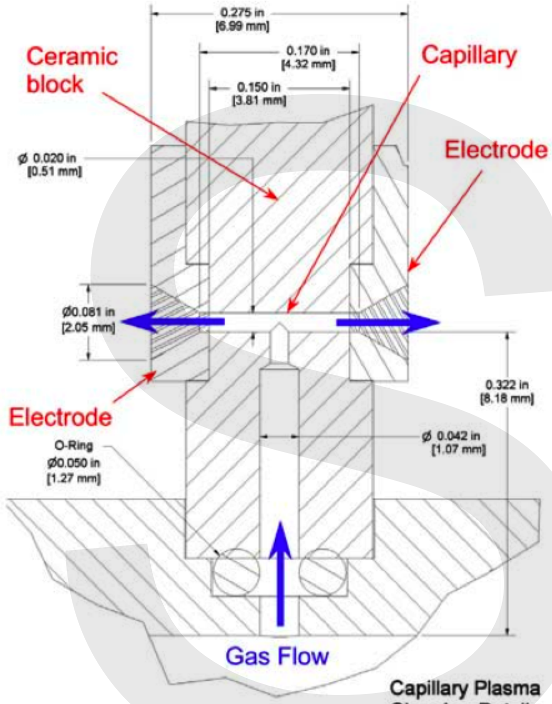
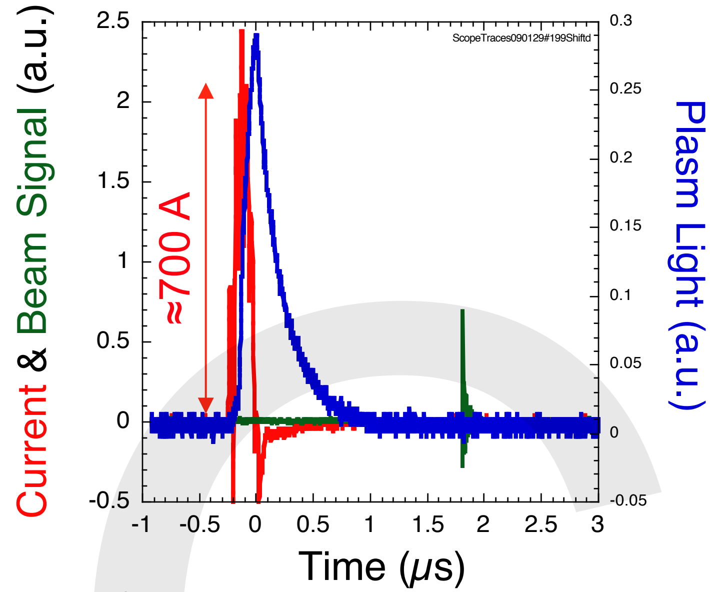
H_2-puff Capillary Discharge

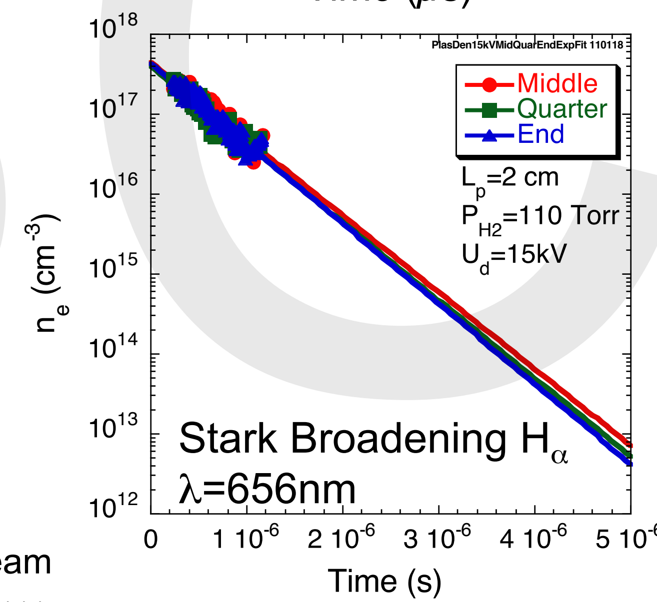
Kimura, AAC'06 Proceedings





Capillary Plasma Chamber Details





- U=15kV, P_{H2}=100Torr
- Plasma density n_e controlled through $\tau_{discharge-beam}$
- n_e fit and extrapolation $n_e(\tau) \cong 4.3\times10^{17} cm^{-3} e^{-\tau/444ns}$

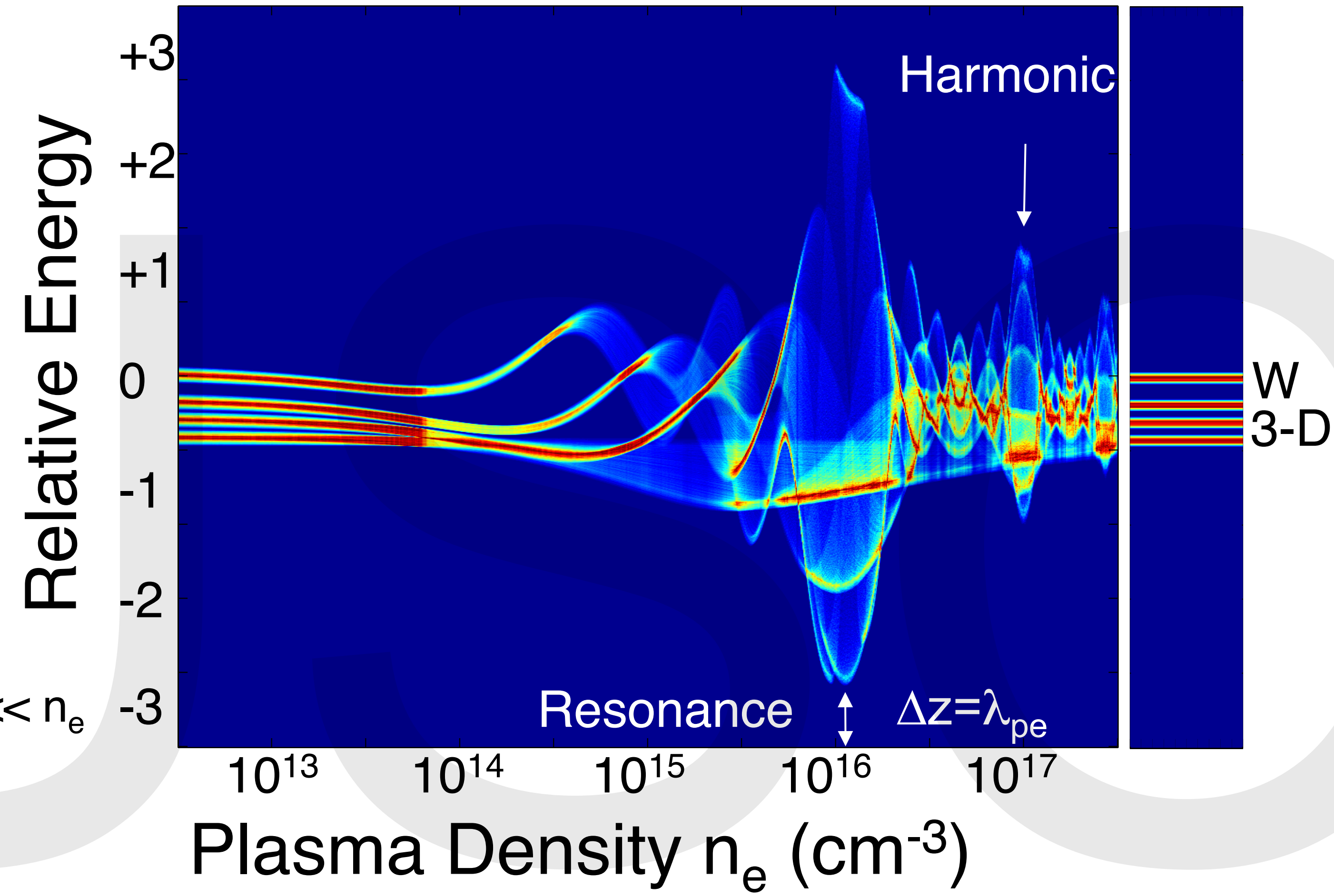
L_p≈2cm

ENERGY CHANGE

Linear calculation (2D): microbunches with equal charge

Experimental Parameters:

E_0=59 MeV
σ_r =100 um,
Δz=284 μm,
d=142 μm
$\Delta z'$=426 μm
Q_{tot}=140 pC
N_d=3D+W
Q_b=35 pC
L_p=2 cm
$n_b \approx 4\times10^{13}$cm^{-3} << n_e
Linear Regime!



- Resonant excitation of wakefield is the main feature
- Chirp such that W enters with highest energy
- $n_{e,\ res} \approx 1.4\times10^{16}$ cm^{-3}

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ENERGY CHANGE

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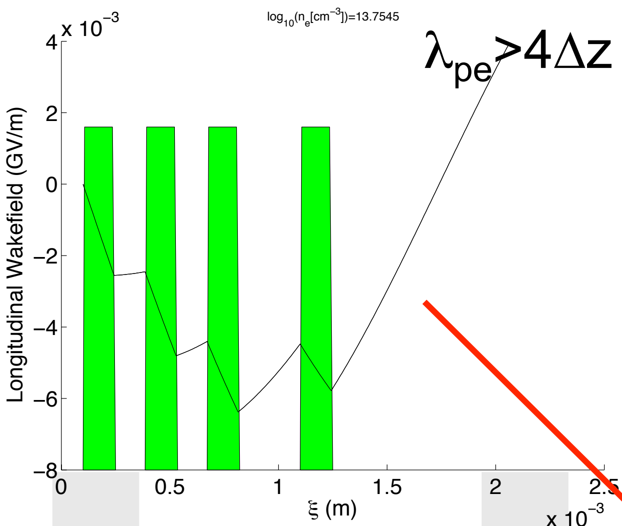

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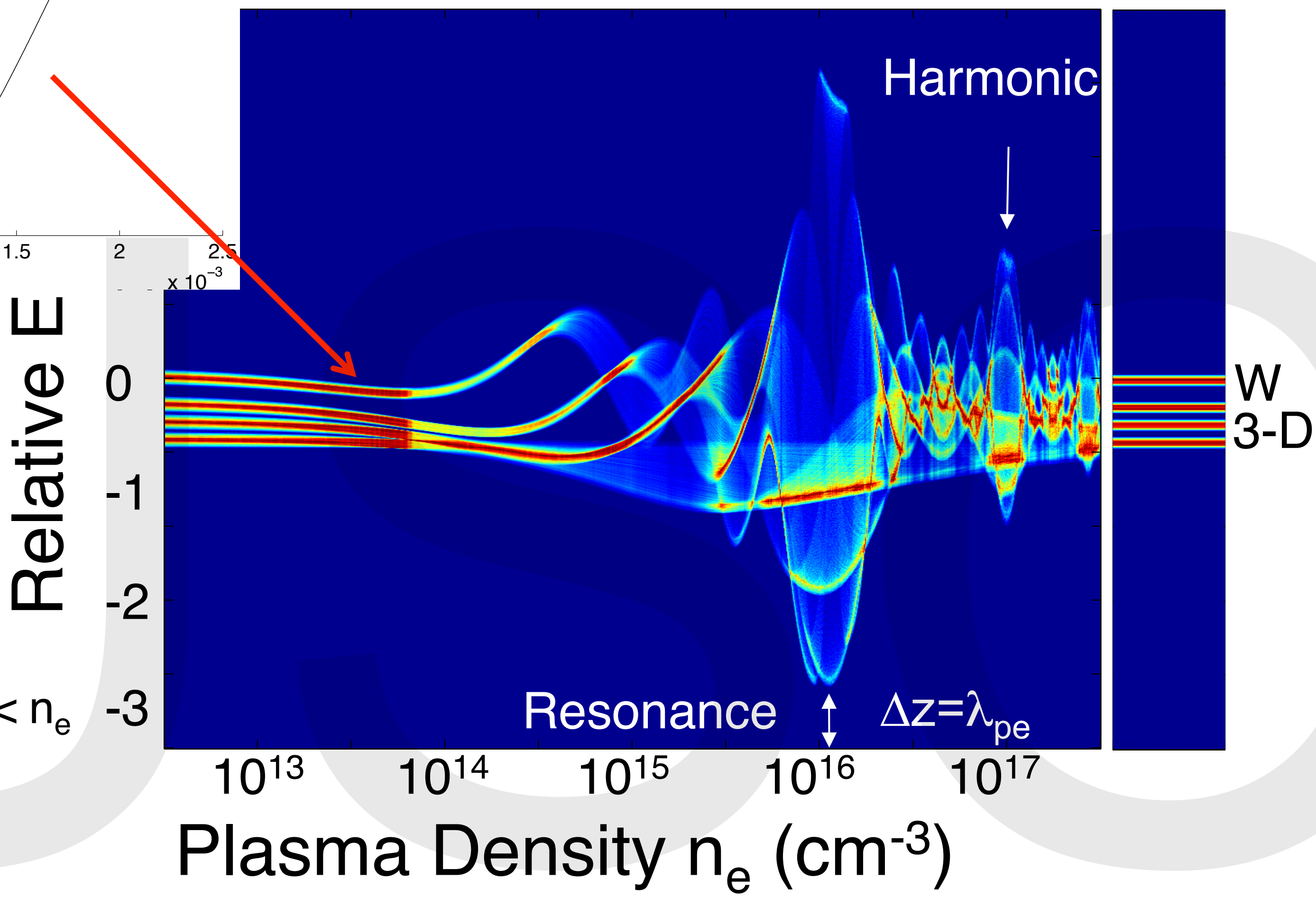

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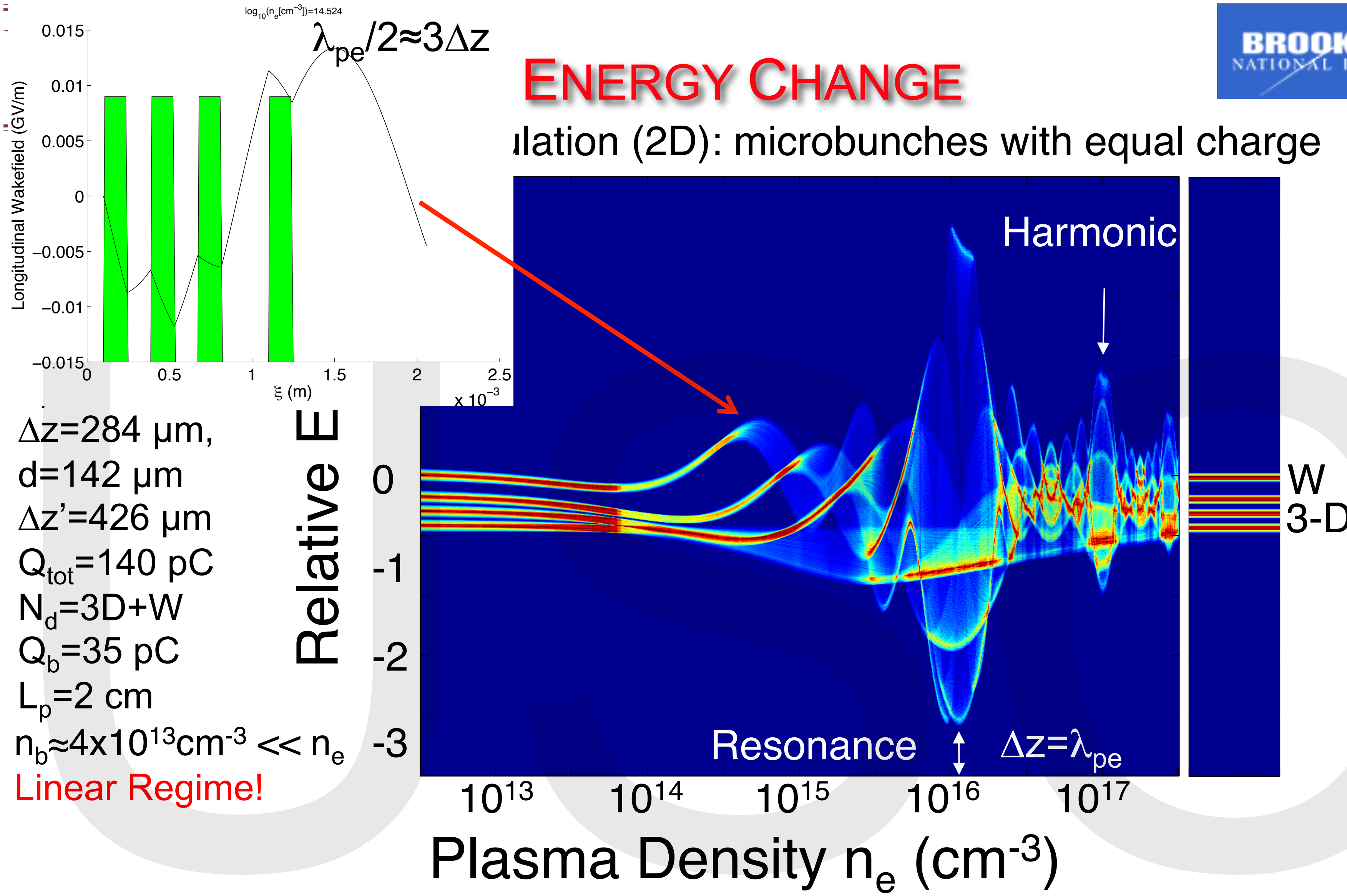

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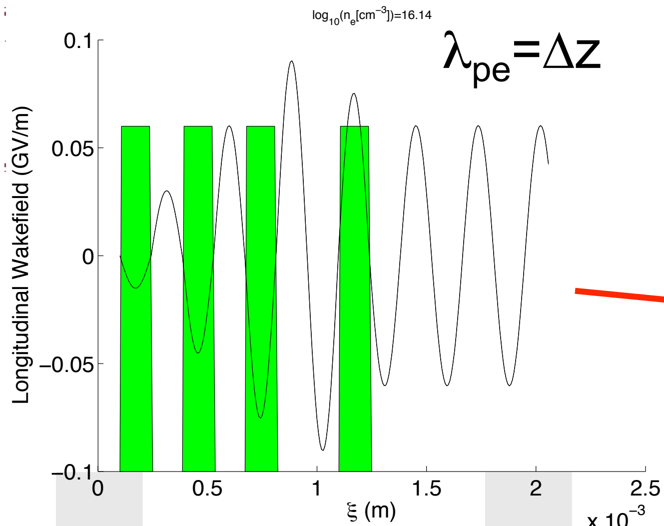

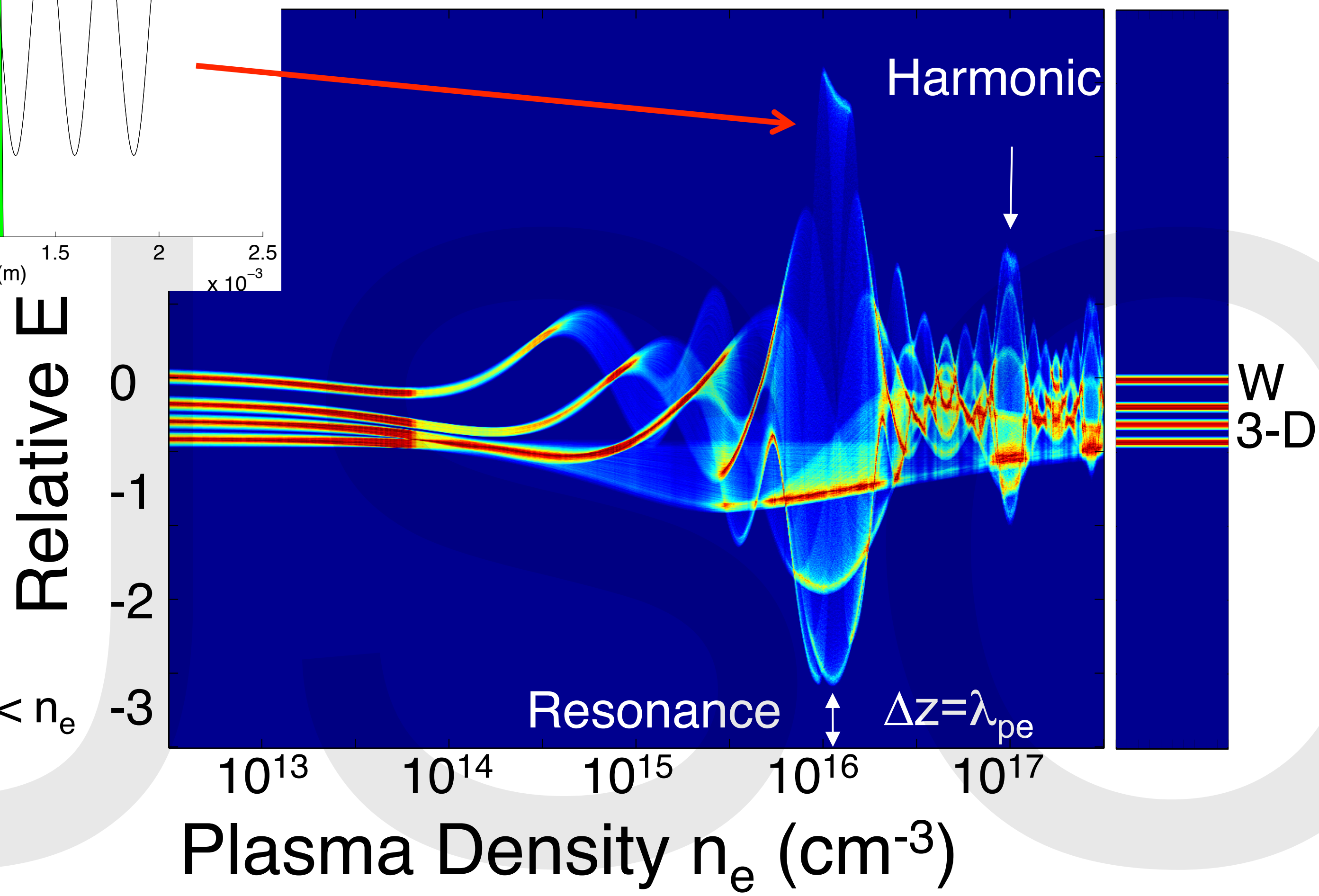

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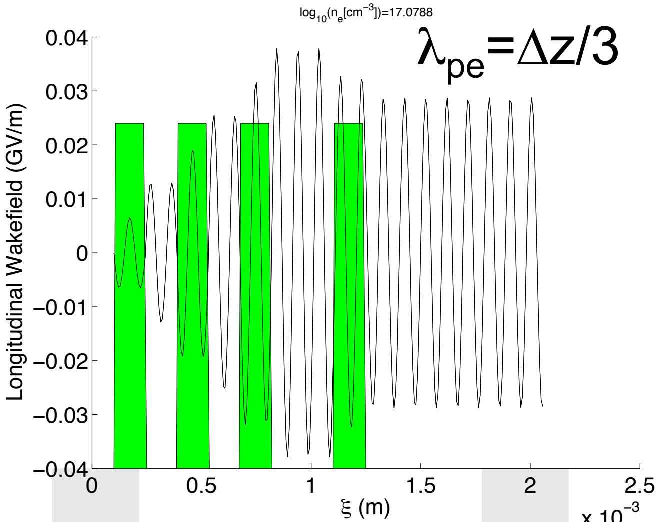

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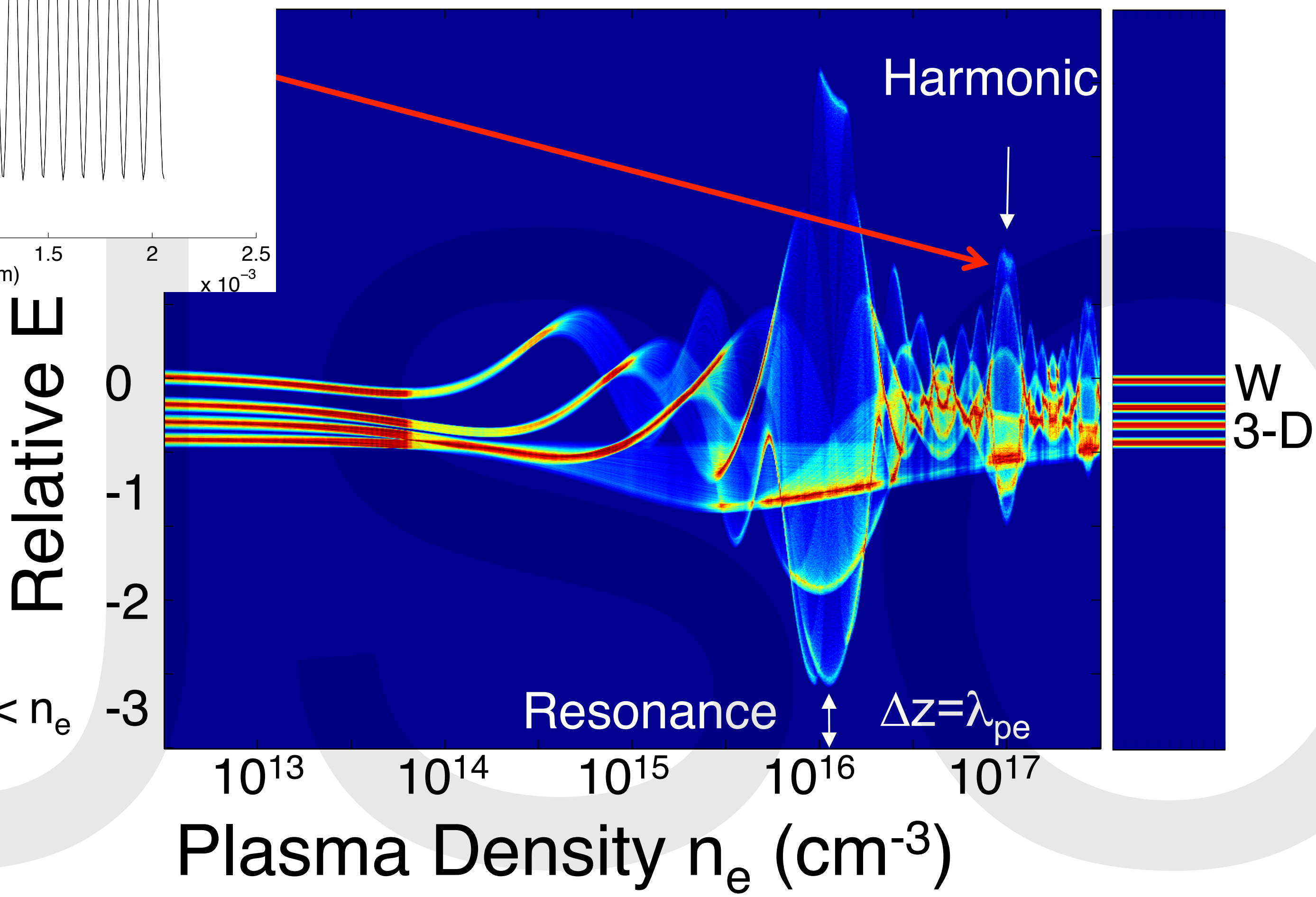

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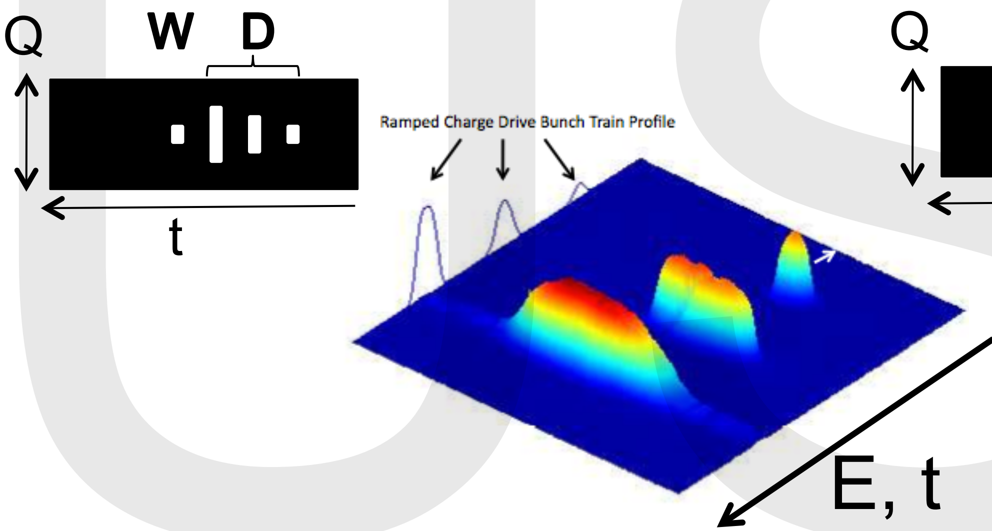
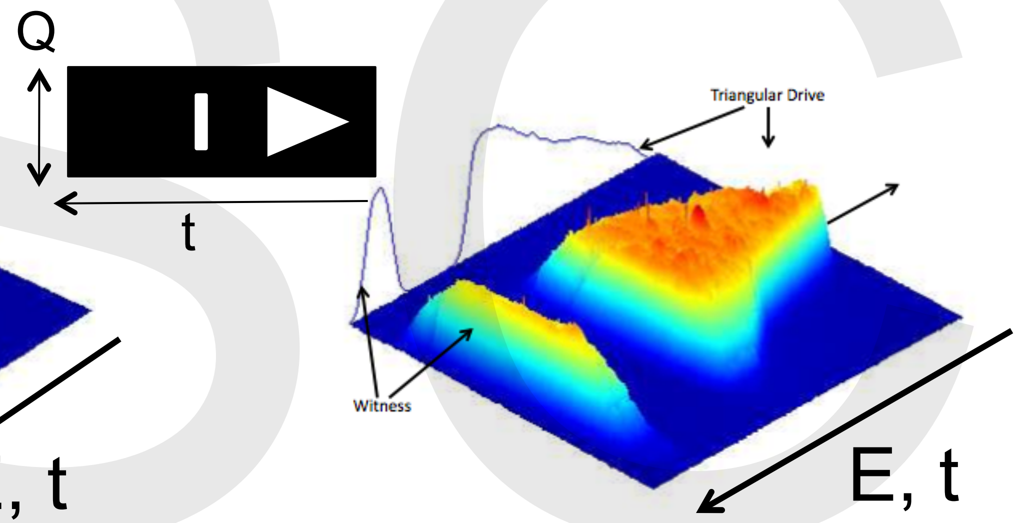
OTHER LOW ENERGY EXPERIMENTS

- Experiments have clearly shown resonant excitation of plasma wakefields
- Large transformer ratio PWFA
  - Ramped bunch train
  - Triangular bunch

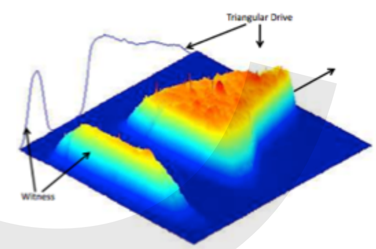




- Visualization of wakefields with FDH (R. Zgadzaj, M. Downer, U. Texas)
- Application to THz dielectric loaded accelerator (DLA) G. Andonian MOP057
- Access to nonlinear regime with tight focusing (Y. Fang, MOP158)

SUMMARY & CONCLUSIONS

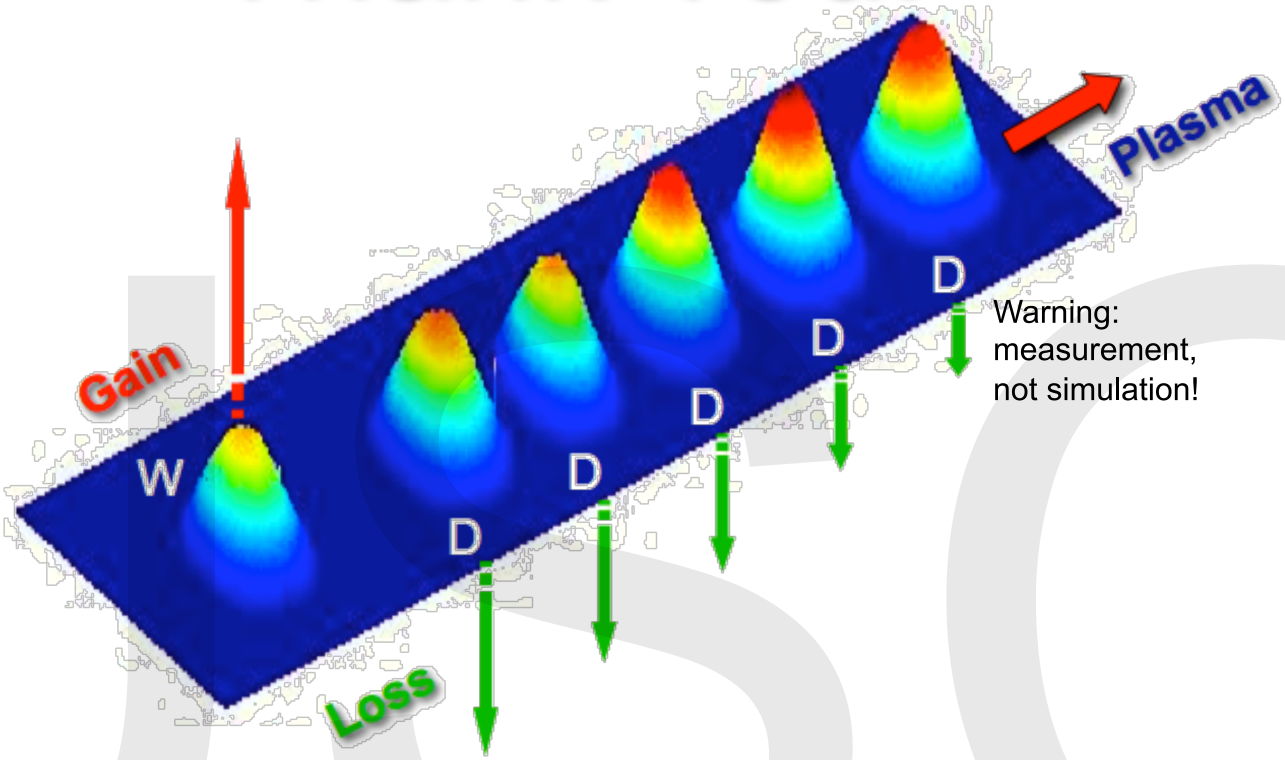
- Can add >$2E_0$ with drive bunch train and large transformer ratio
- First step: resonant excitation of PWFA
- Developed a masking technique to tailor bunch train
- Resonance observed in experiments, $\lambda_{pe} \approx \Delta z$, as expected
- Vary n_e from 10^{14} to 5×10^{17} cm^{-3}, i.e. f_{pe} from 100GHz to 7THz
- Masking technique can also tailor the charge (RBT, triangular, …)
- Low energy physics experiments as test bed (FACET, …)



Next:

- PWFA transformer ratio
- Access non linear regime of PWFA, large transformer ratio?
- Application to dielectric loaded accelerator (DLA), CSR suppression, …

Thank You!



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