Advanced Accelerator R&D at Brookhaven Accelerator Test Facility

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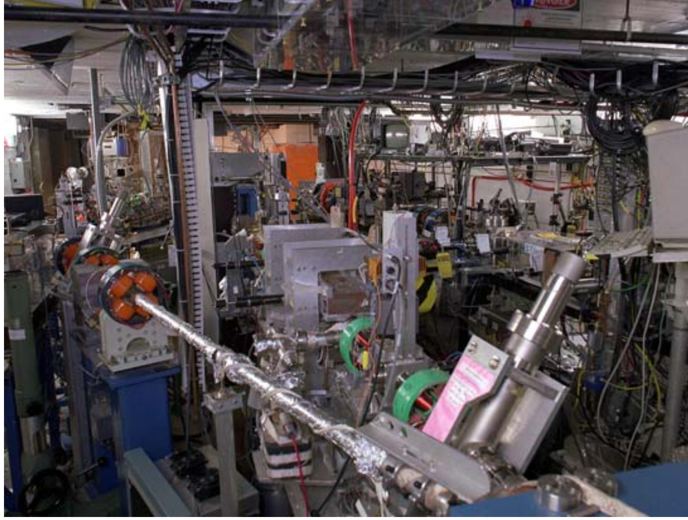
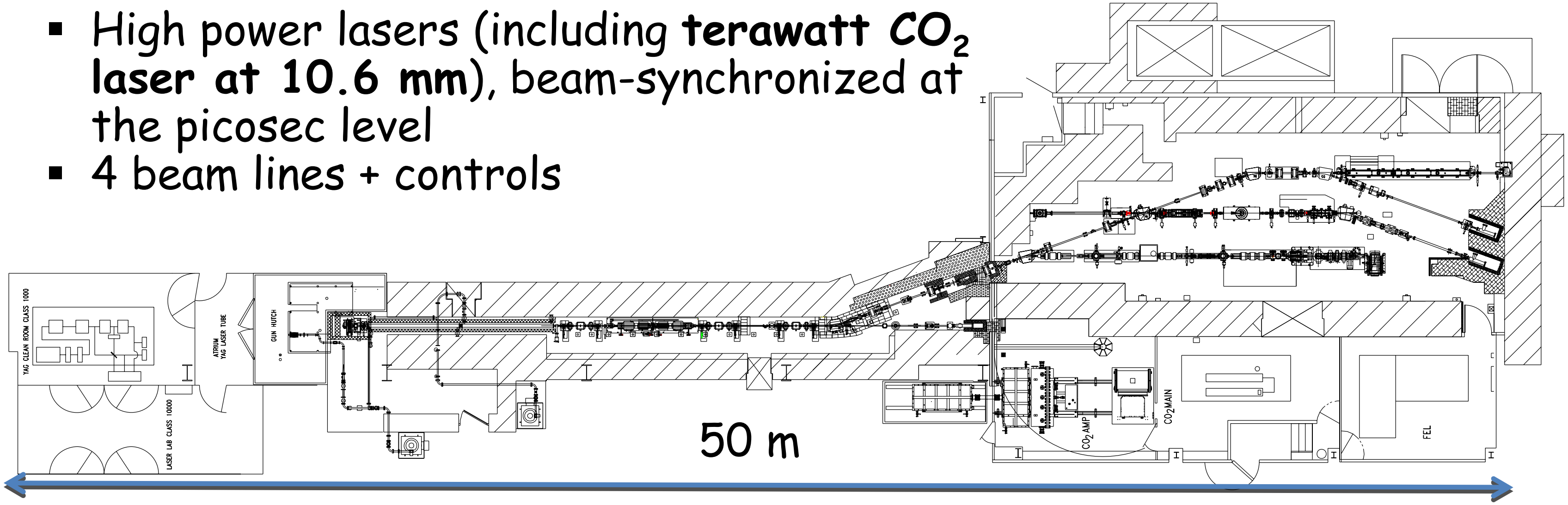
September 24, 2012

Accelerator Test Facility



The ATF is a proposal-driven, advisory committee reviewed USER FACILITY for long-term R&D of the Physics of Beams.

- The ATF features:
  - A High brightness electron gun
  - A 85 MeV Linac
  - High power lasers (including **terawatt CO_2 laser at 10.6 mm**), beam-synchronized at the picosec level
  - 4 beam lines + controls



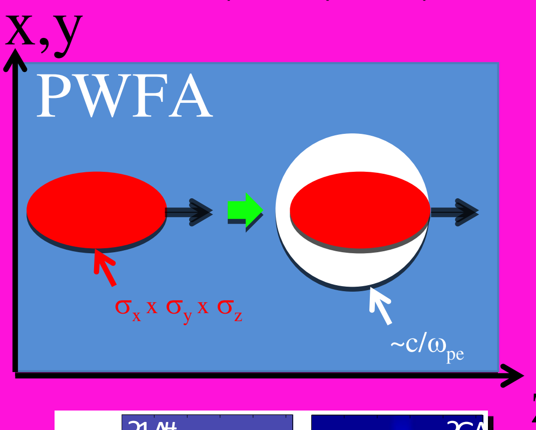
ATF is about:

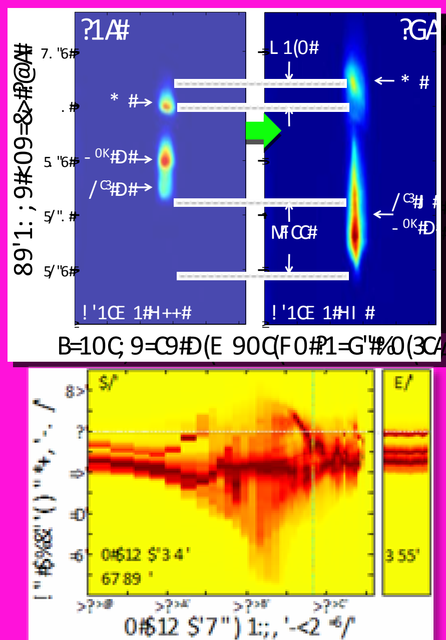
- high brightness sources;
- advanced diagnostics;
- novel ways of acceleration

Three Regimes of Charged Particle Beam - Plasma Interaction

Plasma Wakefield Accelerator

$\sigma_z \leq c/\omega_{pe}$, $\sigma_{x,y} < c/\omega_{pe}$

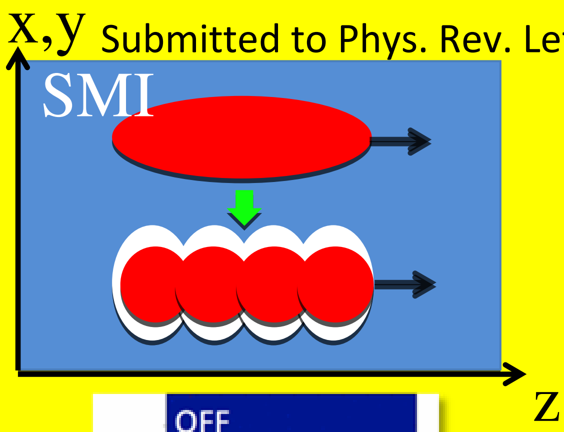


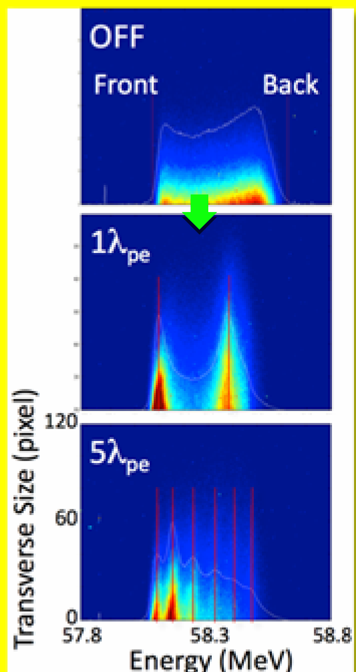


Self-Modulation Instability

$\sigma_z >> c/\omega_{pe}$, $\sigma_{x,y} < c/\omega_{pe}$

Submitted to Phys. Rev. Lett.

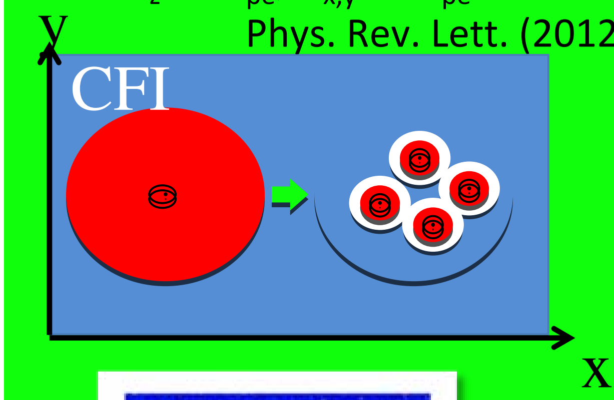


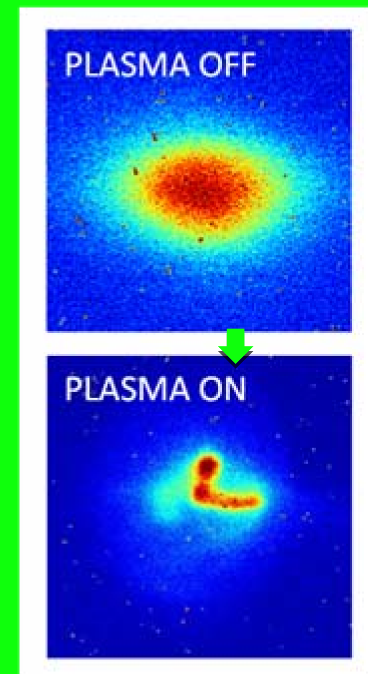


Current Filamentation Instab.

$\sigma_z \leq c/\omega_{pe}$, $\sigma_{x,y} < c/\omega_{pe}$

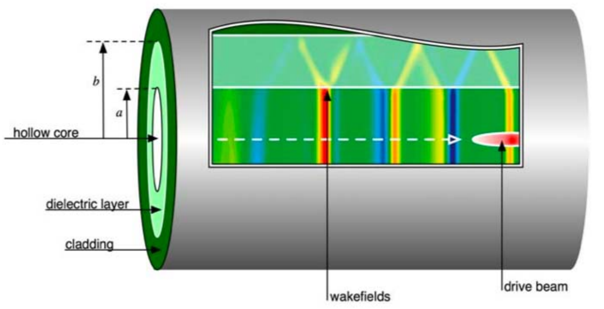
Phys. Rev. Lett. (2012)

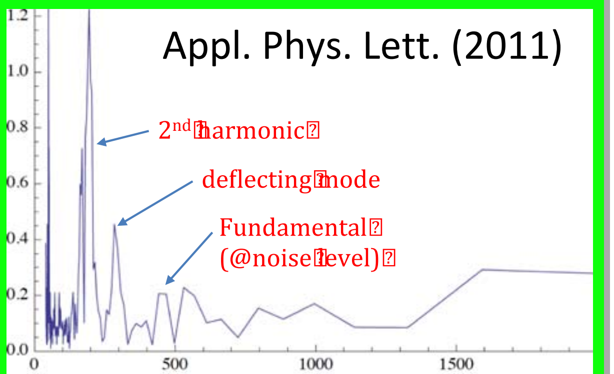




Dielectric Wakefield Accelerators

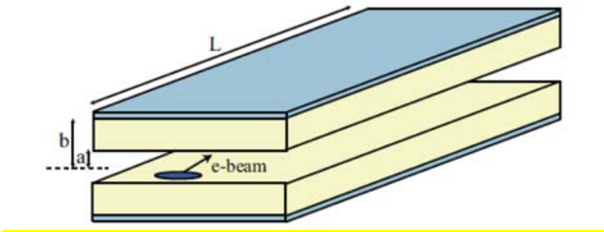
Mode analysis: THz radiation generation:



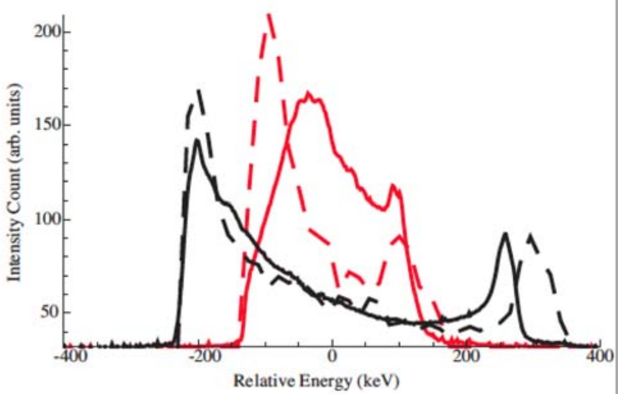


Frequency spectrum

Slab geometry



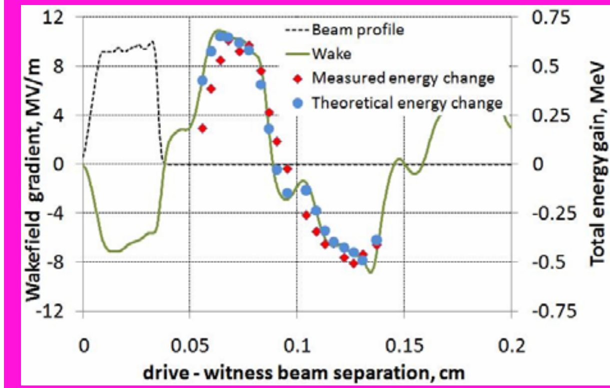
Phys. Rev. Lett. (2012)



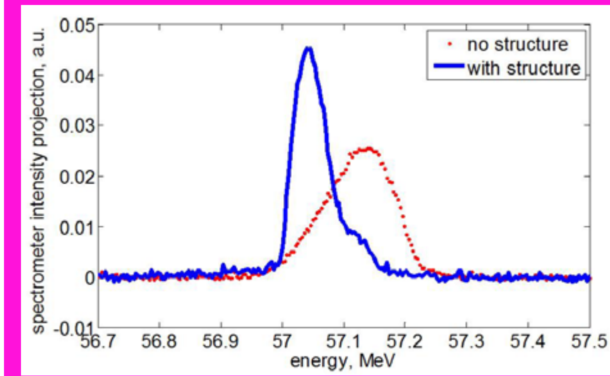
Momentum spectra: observed (solid) and simulated (dash)

Two beam accelerator

Appl. Phys. Lett. (2011)



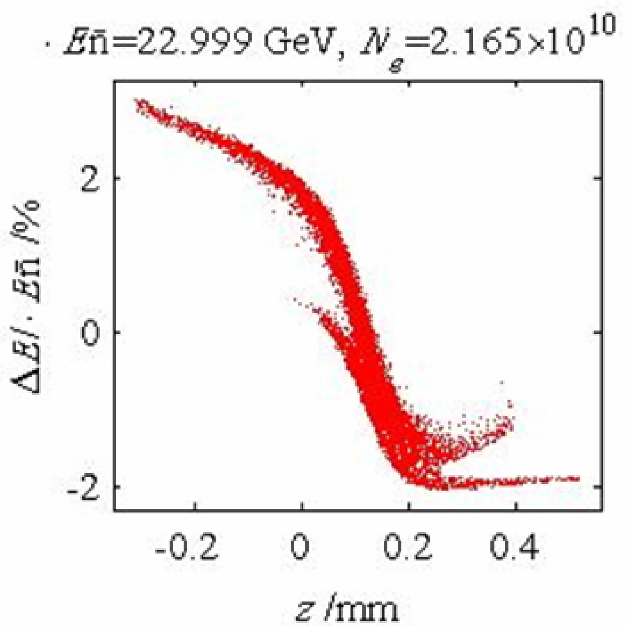
Energy chirp correction



Phys. Rev. Lett. (2012)

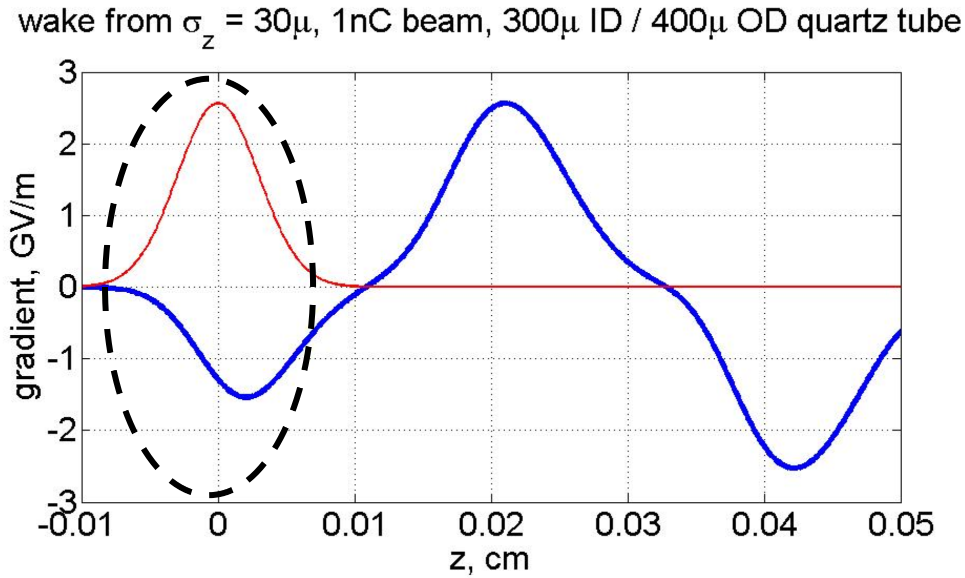
Energy chirp correction example

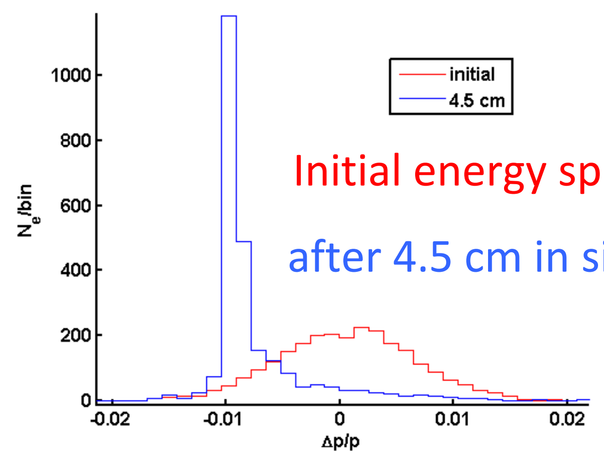
FACET beam



From M. Hogan, J. England (SLAC)

- Passive device (beam self-action)
- Can be tunable
- Ex. FACET 5% spread → 0.75% using a 5cm device



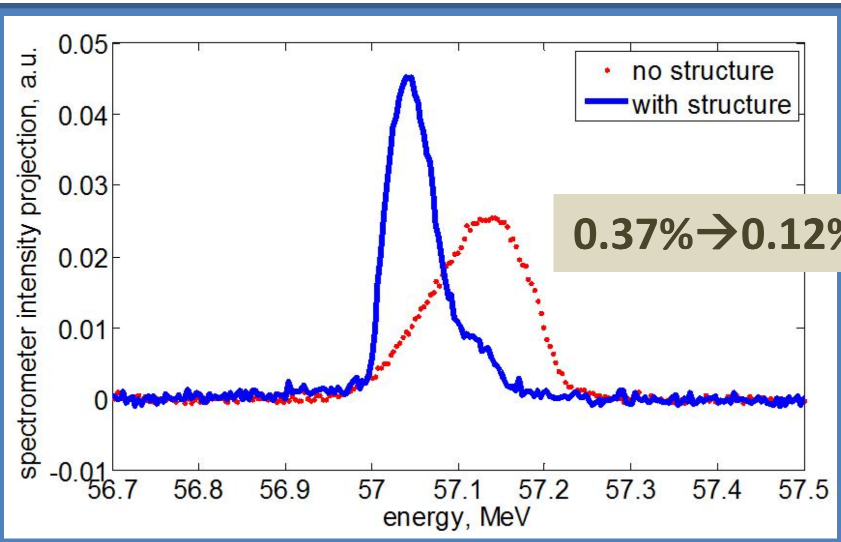


Initial energy spread

after 4.5 cm in silencer

Energy chirp correction demonstrated ATF

measurement



0.37%→0.12%

Limited by spectrometer resolution

Beam transmission

SS housing tubes

Quartz tubes (ε = 3.8)

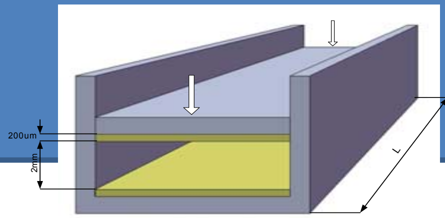
(Gold sputtered)

Sizes (ID / OD):

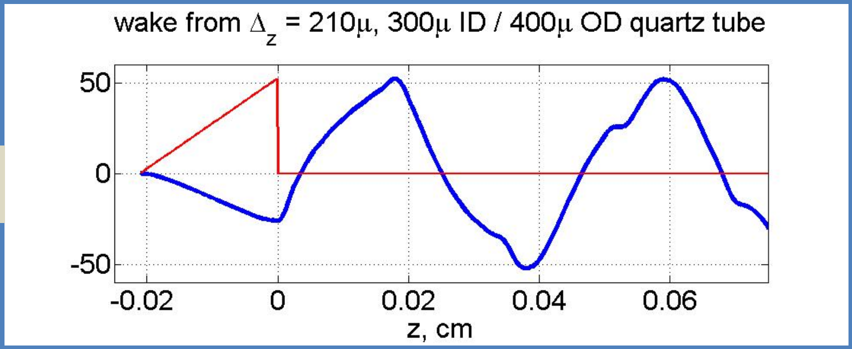
1”, 200 x 330 μ

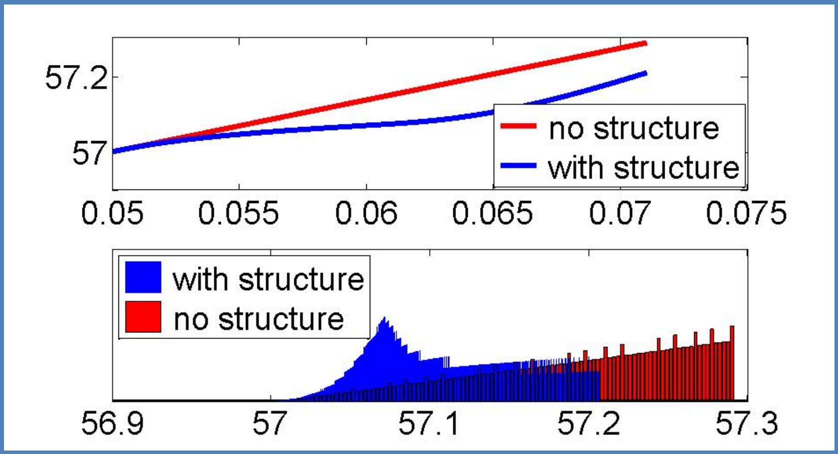
1”, 300 x 400 μ

2”, 400 x 550 μ



simulation

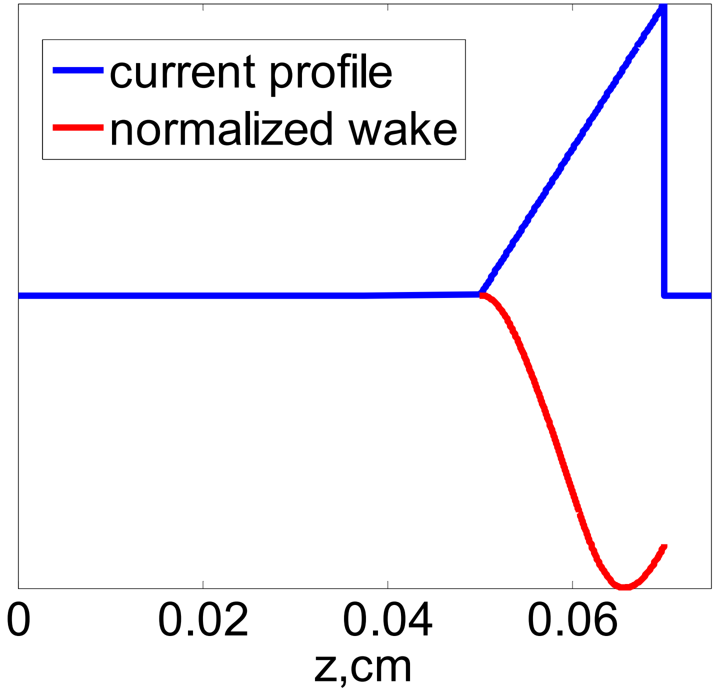


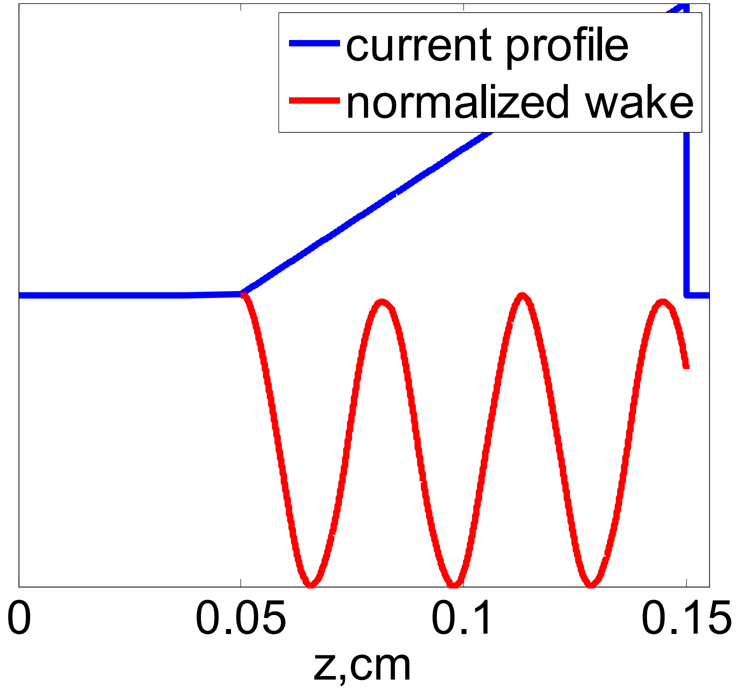


Linear chirp correction / energy modulation

S. Antipov et al. Phys. Rev. Lett. 108, 144801 (2012)

Self-wake energy modualtion



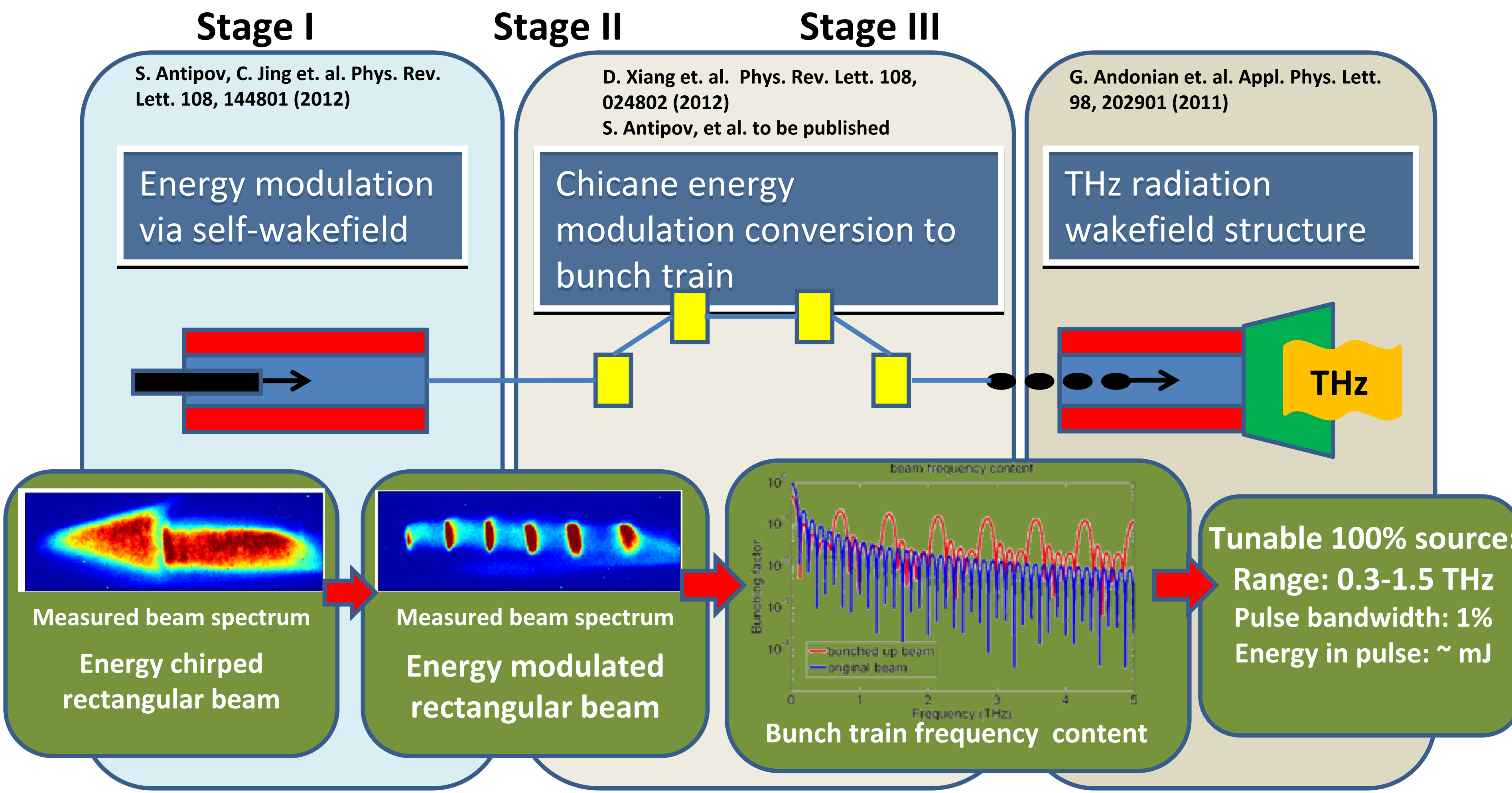


Chirp correction

Energy modulation

Antipov et al. Phys. Rev. Lett. (2012)

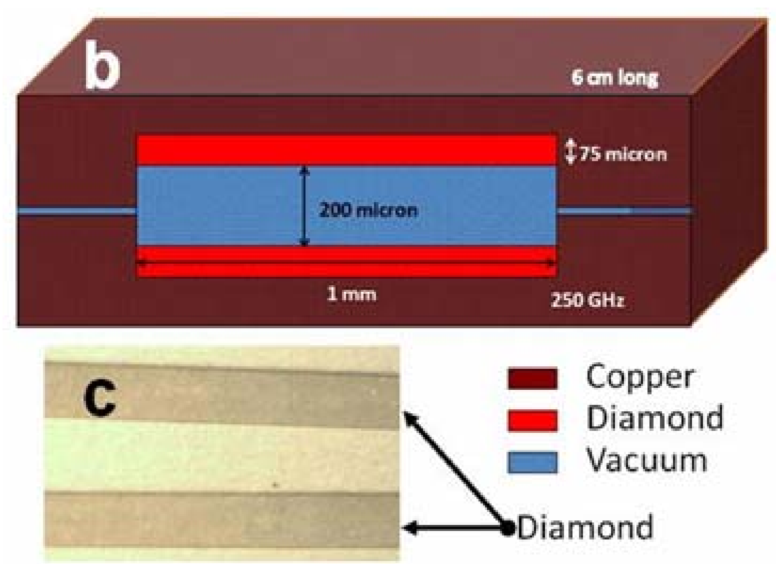
High power beam-based THz source

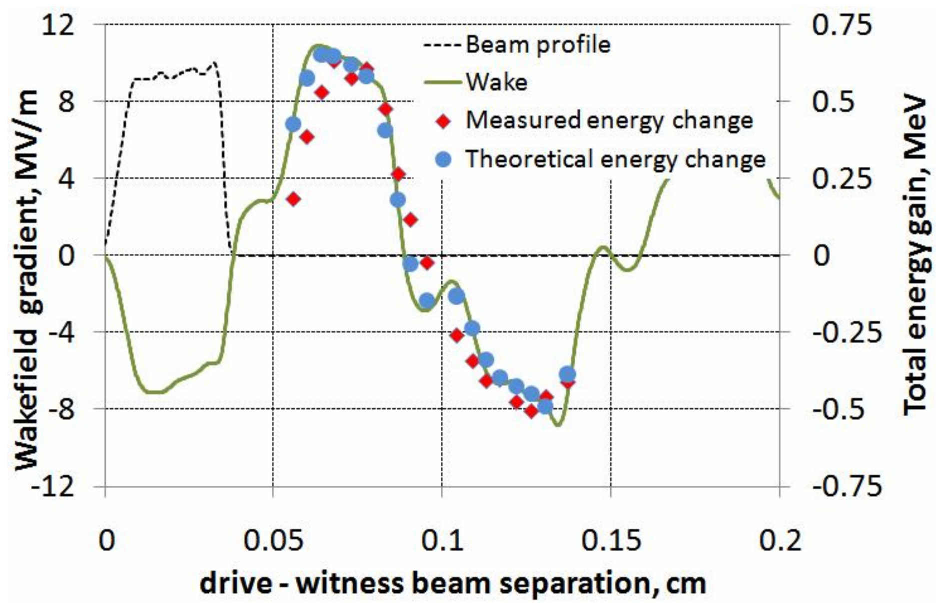


Flexible: each step has a tuning range

S.Antipov et al. Phys. Rev. Lett. (2012)

Wakefield Mapping of a Diamond Slab Structure at BNL/ ATF

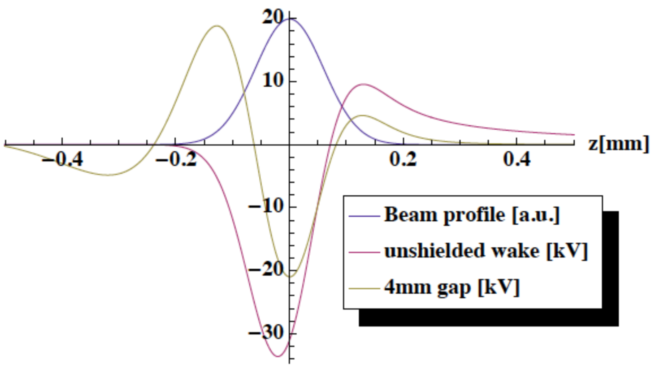


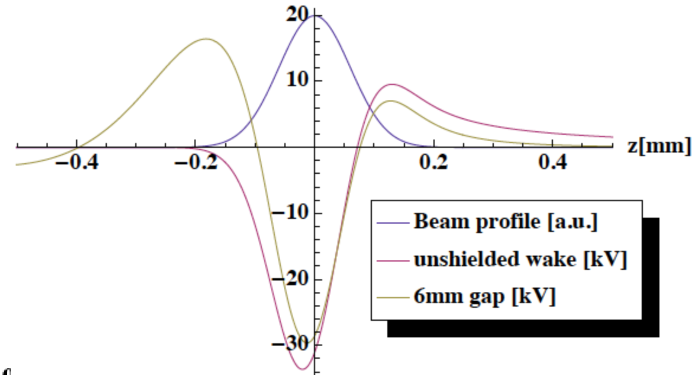


- 1st wakefield mapping experiment in THz regime (June 2011).
- 1st wakefield acceleration observed in THz regime.
- S. Antipov, *et al, App. Phy. Lett. March* 2012.

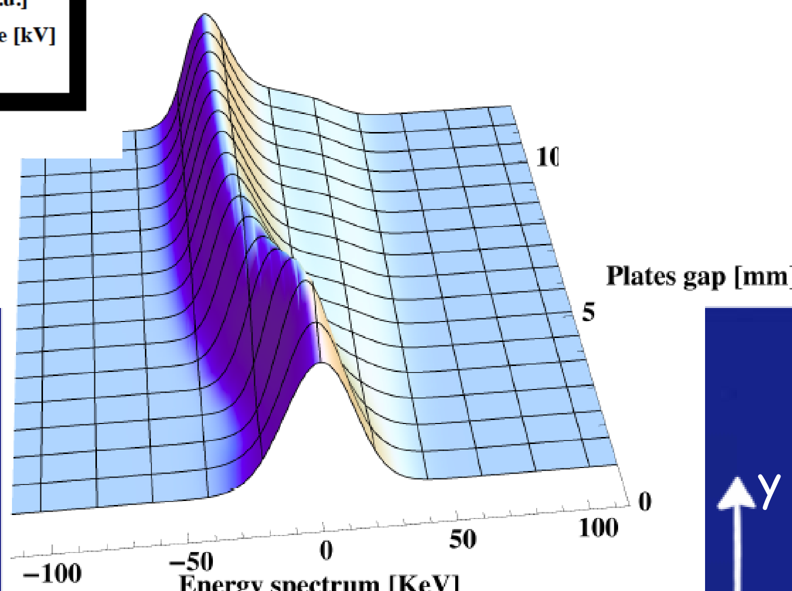
Suppression of Energy loss due to CSR

- Good agreement between theory and experiment was seen in our experiment as well in prior experiments
- Beam with no correlated energy chirp (0.3ps long) was used in this measurement

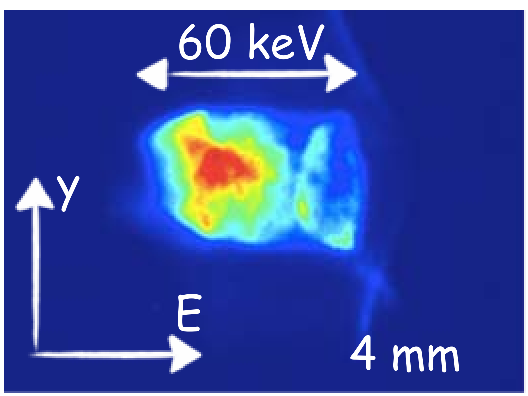


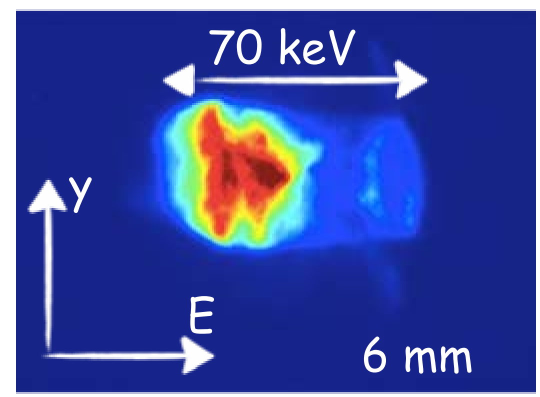


Energy spectrum plates at 4 mm gap



Energy spectrum plates at 6 mm gap

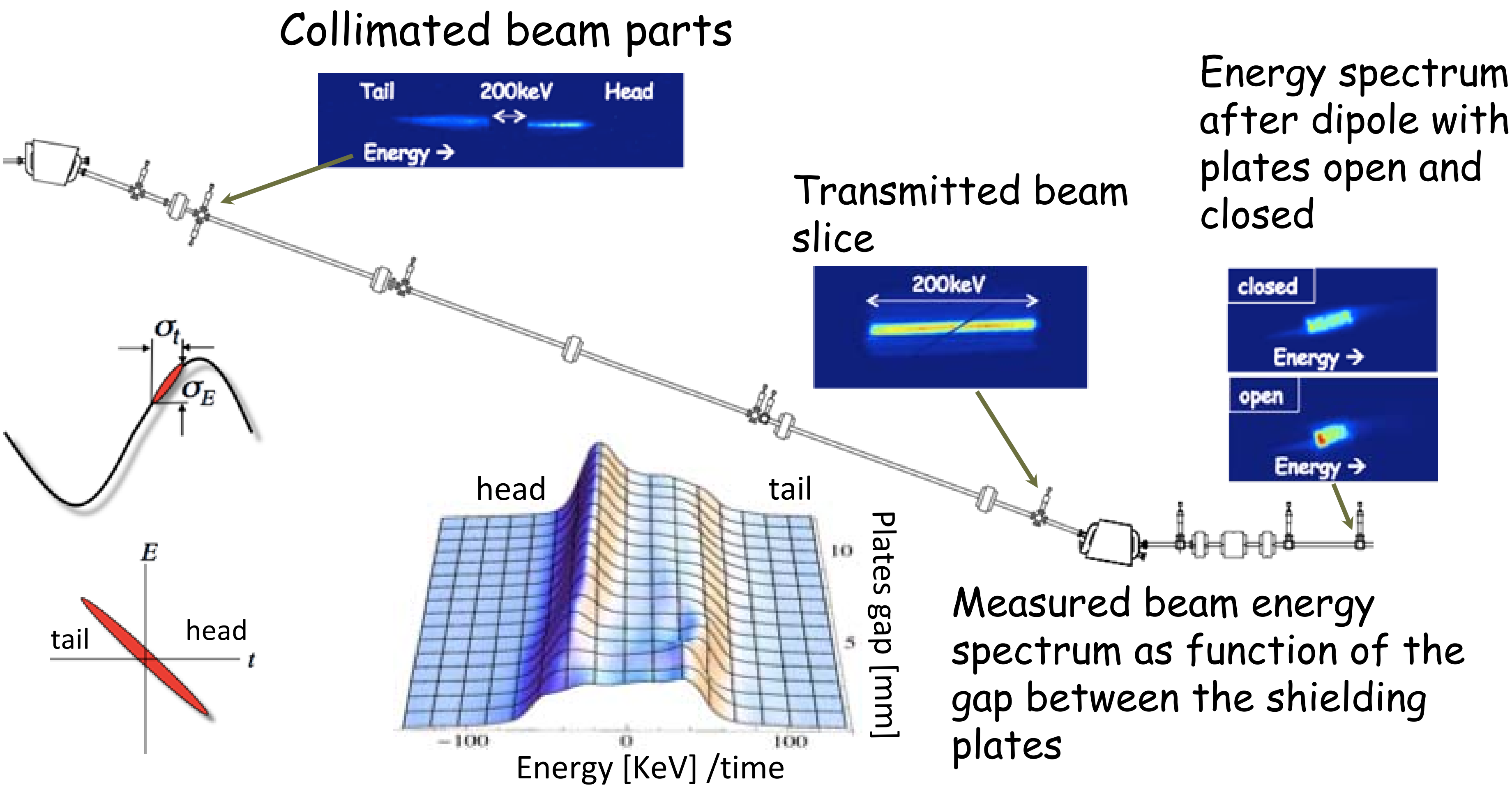




"Smarter" beam manipulation

Phys. Rev. Lett. (2012)

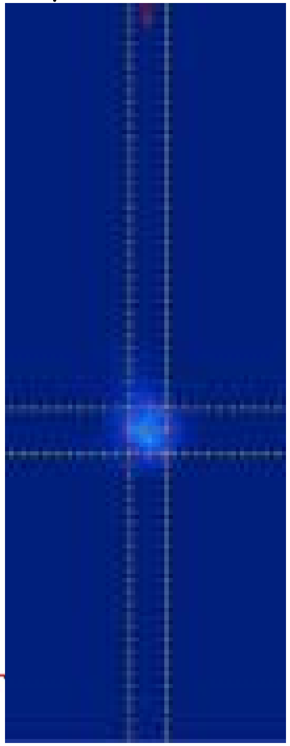
- Used for experiments:
  - Extremely stable chirped beam to characterized ~10^{-5} energy variation (CSR suppression studies)

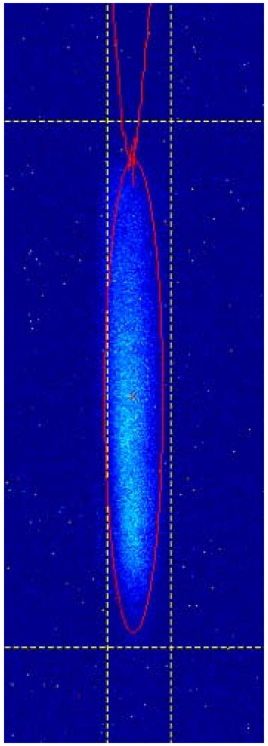


µbeam

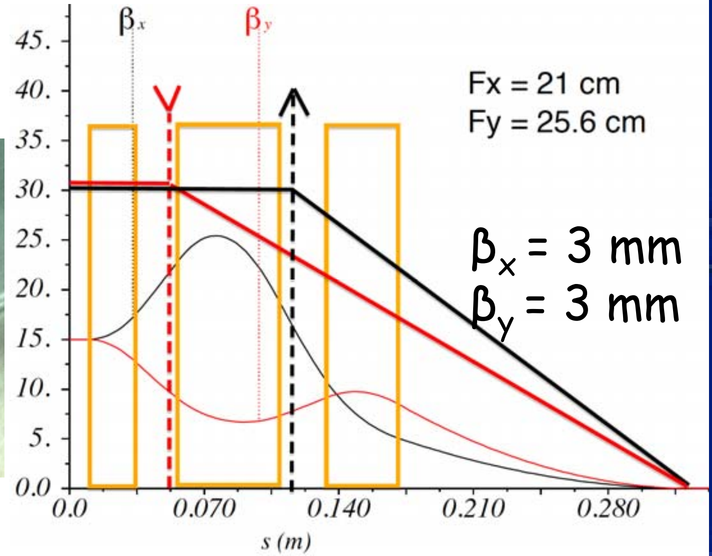
σ_x = 6 µm
σ_y = 6 µm

σ_x = 7 µm
σ_y = 115 µm

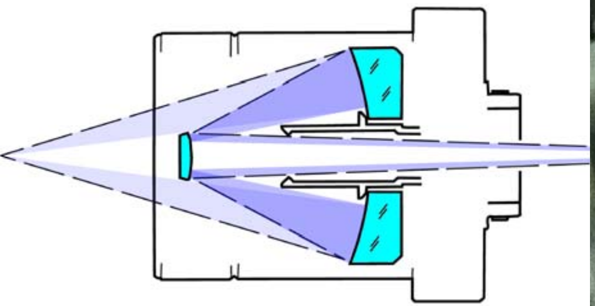




PMQ triplet set to have equivalent to thing lens matrix

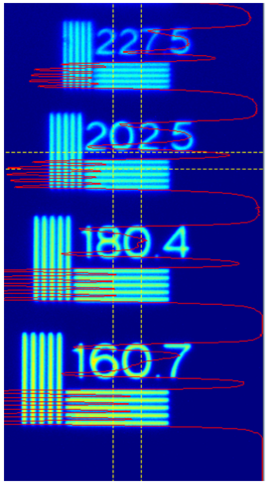


Reflective objective



optical resolution:
1.25 µm

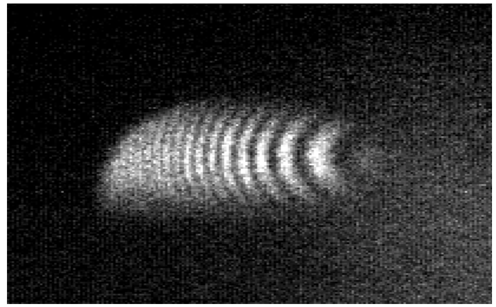
calibration:
0.63 µm/pix



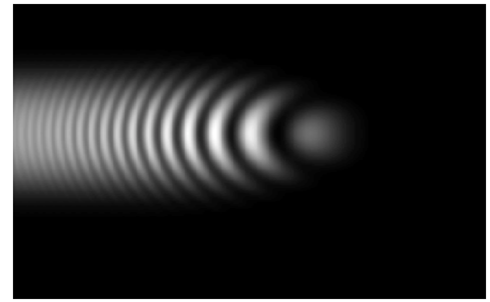
Single shot emittance measurement with interference of edge radiation

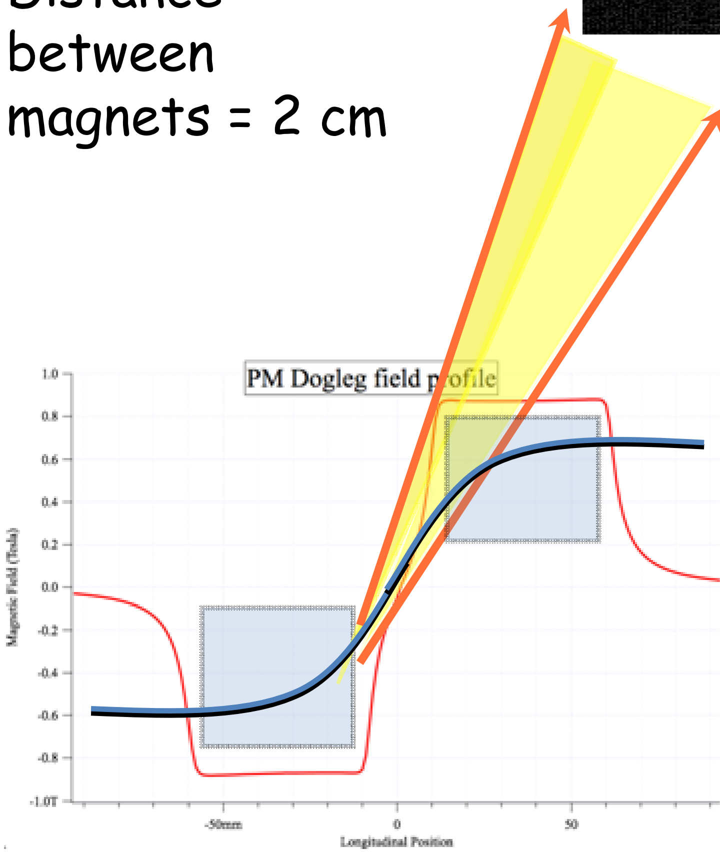
Dogleg magnets:
Mag. field = 0.9 T
Length = 5 cm
Distance between magnets = 2 cm

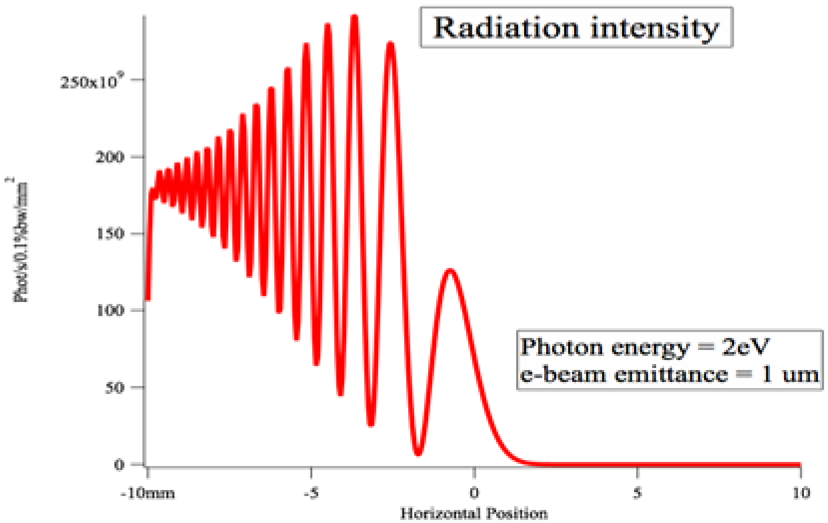
Real light



Simulation

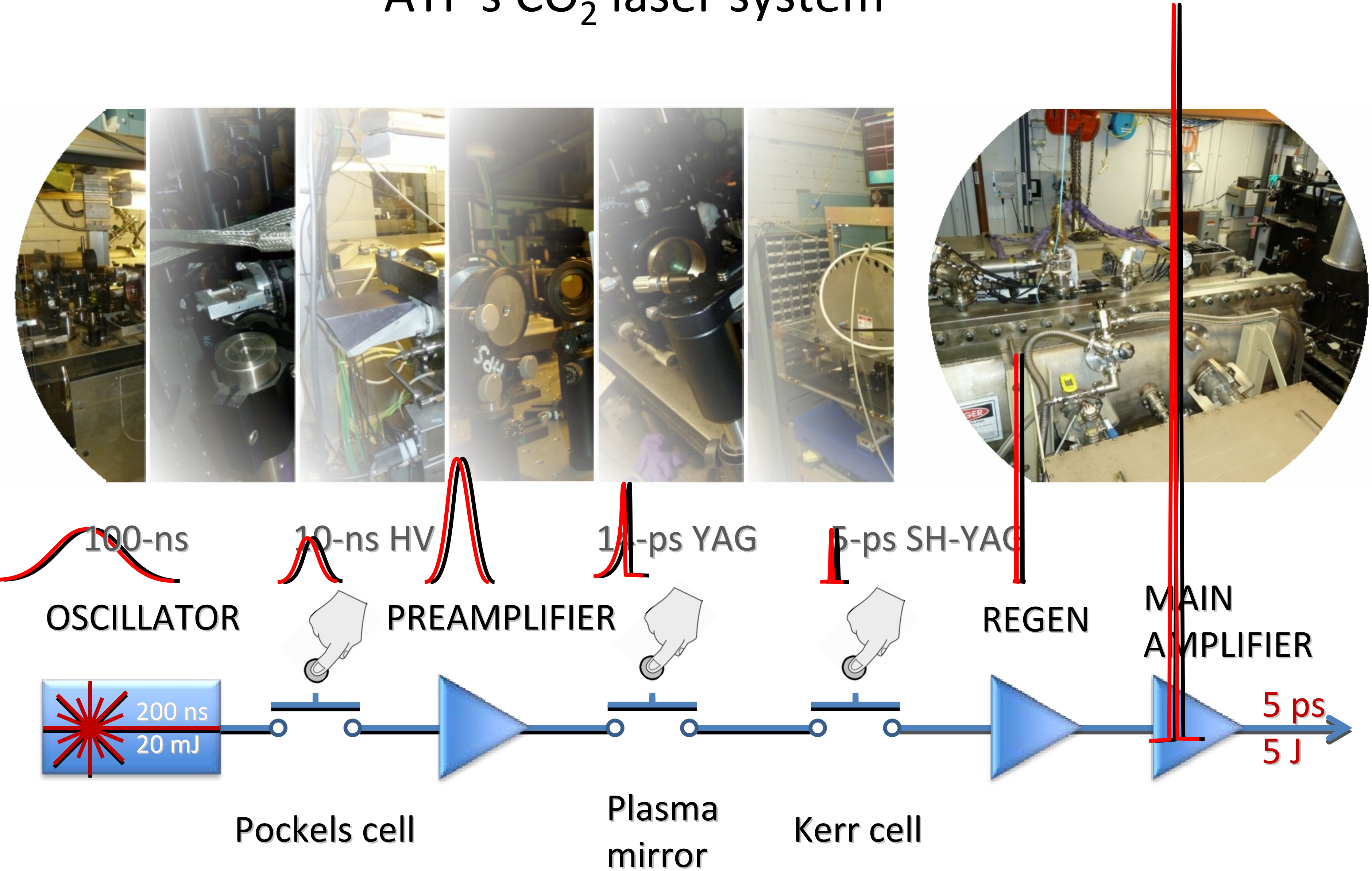




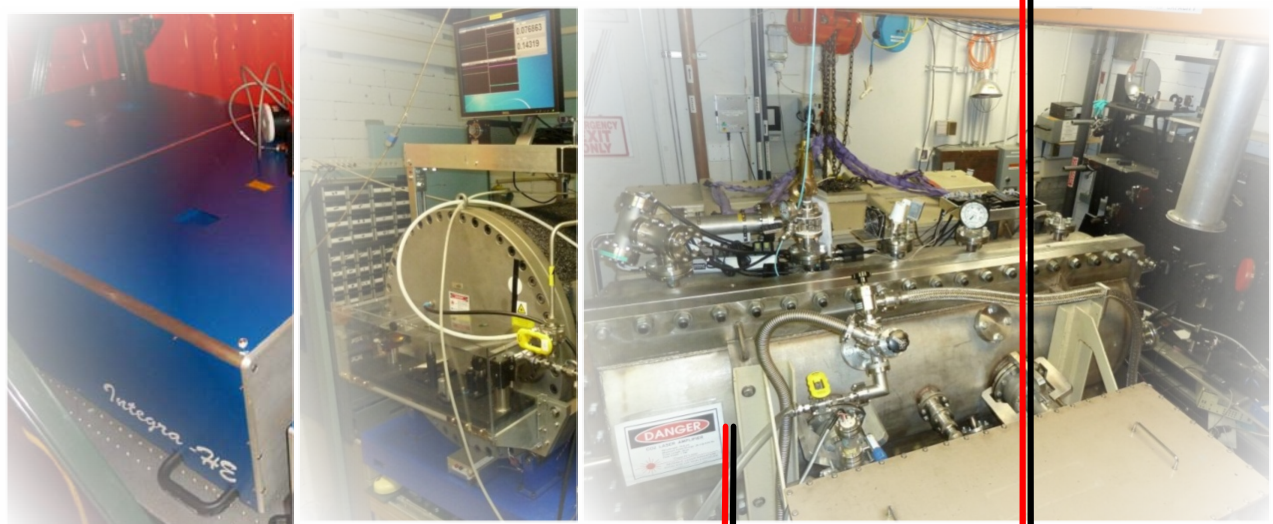


Beam:
E = 64 MeV   Q = 500 pC
dE/E = 2E-4 ε_N = 1.9 μm

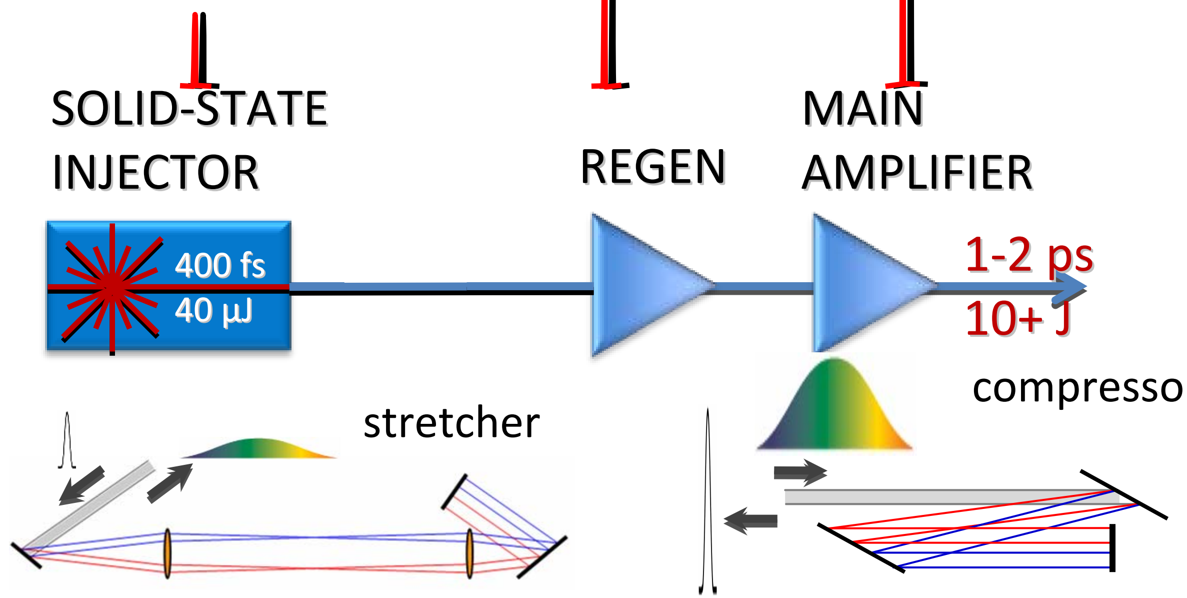
ATF's CO_2 laser system



Solid-state injector



- SIMPLICITY & RELIABILITY
- SHORT PULSE
- HIGH PULSE ENERGY
- HIGH CONTRAST
- BETTER ENERGY EXTRACTION

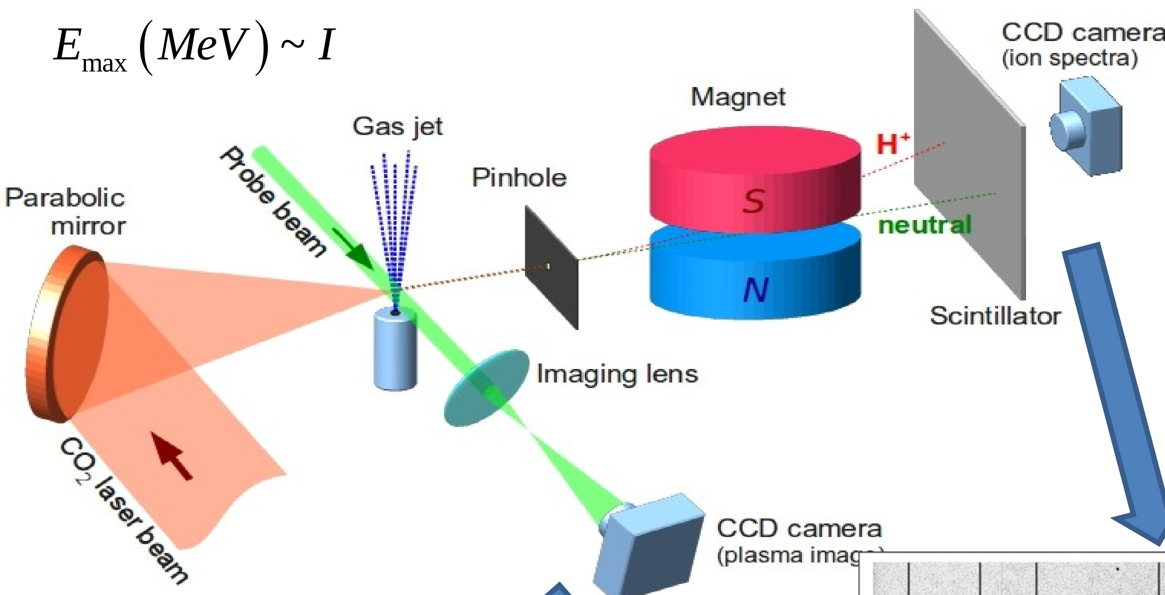


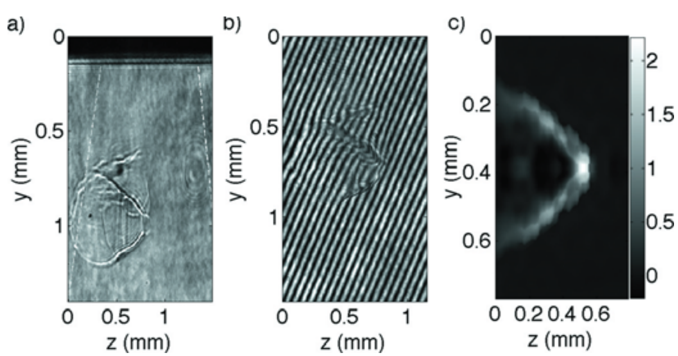
Monoenrgetic ion beam by Radiation Pressure Acceleration

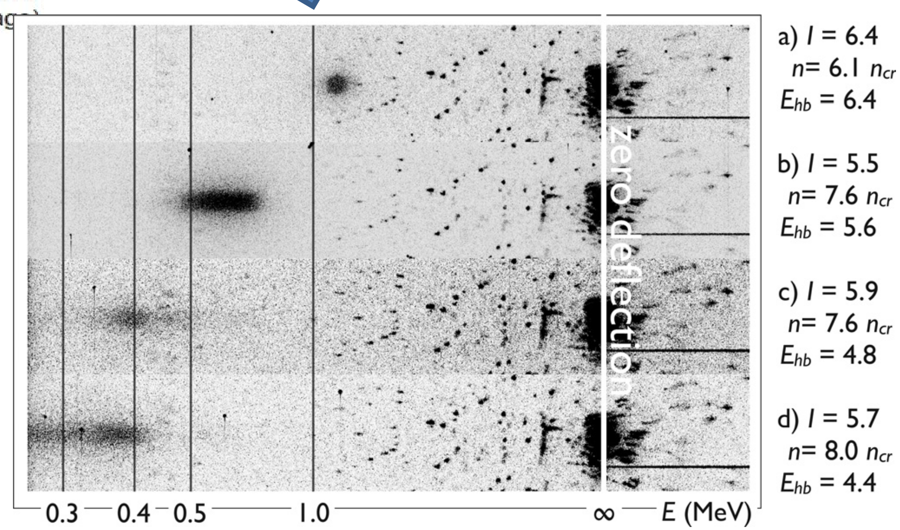
Phys. Rev. Lett. (2011).

$$E_{\max}\left(MeV\right) \sim I$$

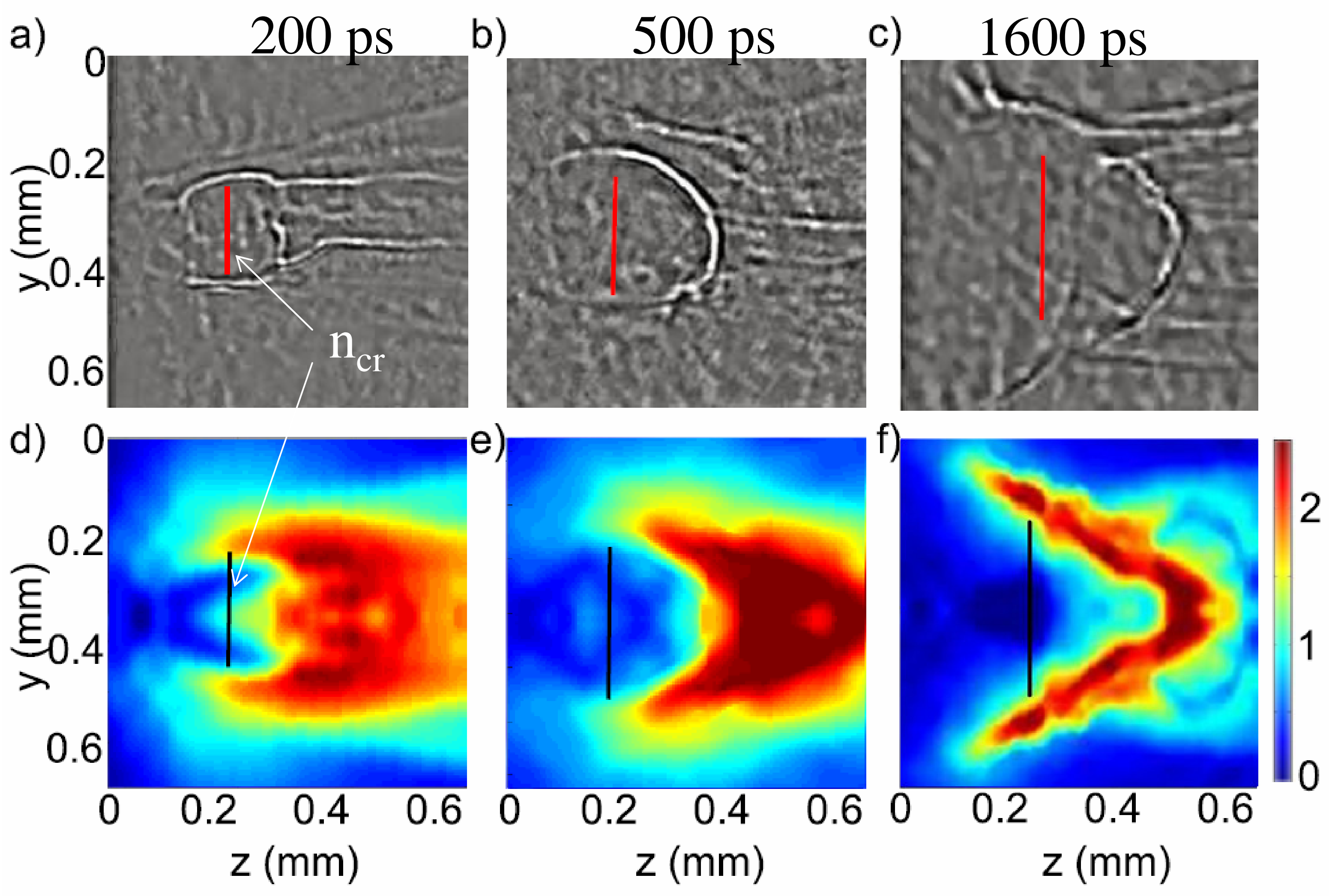
A monoenergetic proton beam is observed from the interaction of a short-pulse infrared laser with a gas jet target.







Measuring shock velocity



Conclusion:

- Very busy times at ATF: Activity doubled in last 3 years (publications, active experiments, new proposals, students …)
  - 22 students,
  - 25 experiments,
  - ~6 Phys. Rev. X publications in 2011, 8 in 2012
  - …
- There are more ideas then time or space…