Report of the 1st Experiment Run of Vacuum Laser Acceleration at ATF

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Outline

- Scheme of Vacuum Laser Acceleration (VLA) with Capture and Acceleration Scenario (CAS)
- Simulation based on expected e-beam and laser beam at ATF
- Experiment setup and e-beam tuning
- Data acquisitation and status of analysis

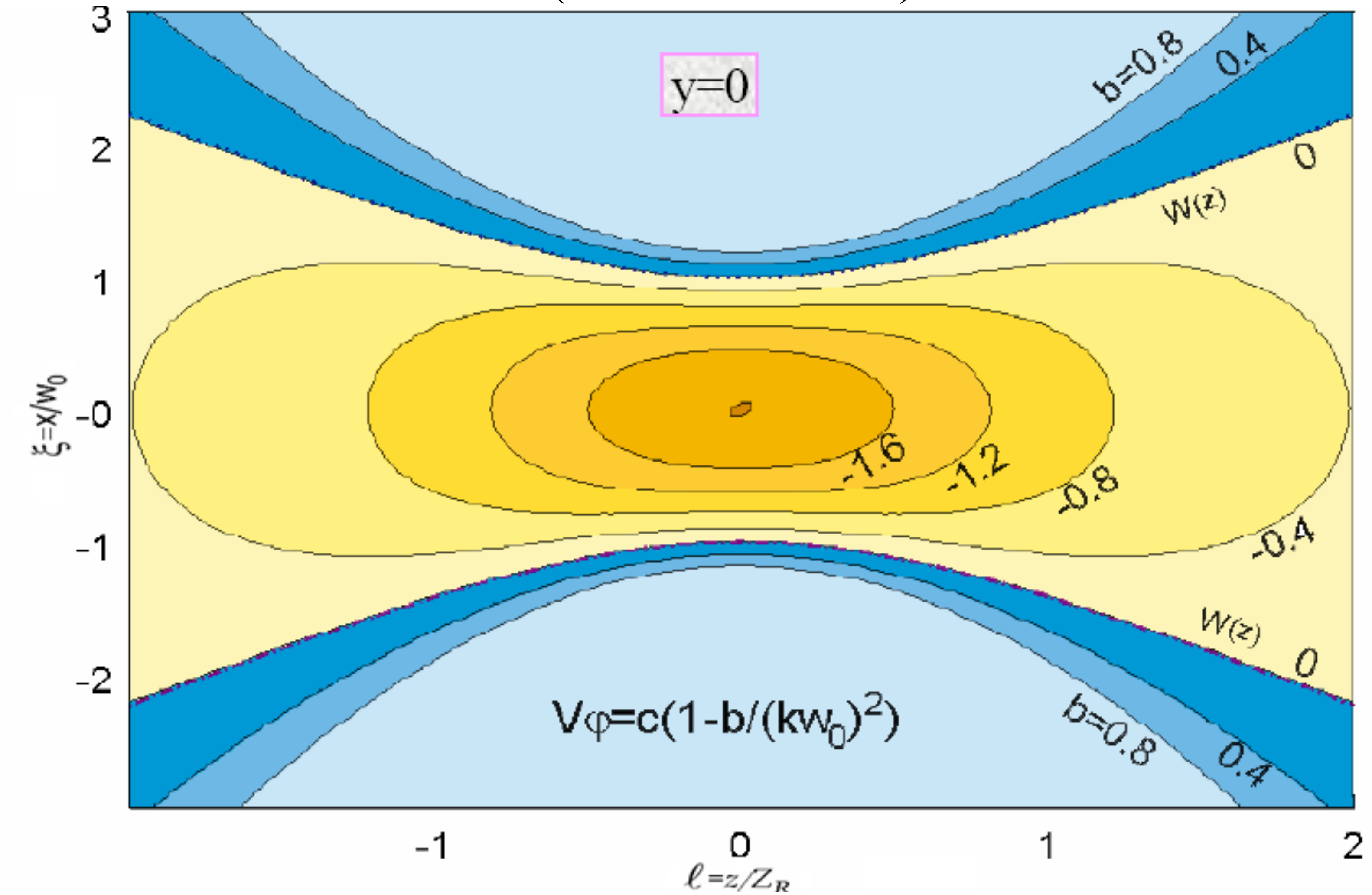
Principle of Vacuum Laser Acceleration

- **Lawson-Woodward theorem**: in the plane wave phase velocity V_φ >c, the electrons may experience the acceleration and deceleration phases alternately. Net energy gain is zero.

- **VLA (Vacuum Laser Acceleration)**: in a tightly focused laser, the diffraction not only changes the intensity distribution of the laser, but also its phase distribution, which results in V_φ <c in some areas. Thus, in some special regions, which overlaps features of both strong longitudinal electric field and low laser phase velocity, electrons can receive high energy gain from the laser.

Contour of Phase Velocity in a Tightly Focused Laser

(Gaussian beam)



Acceleration Channel

$V_\varphi < c$

Intense E_z

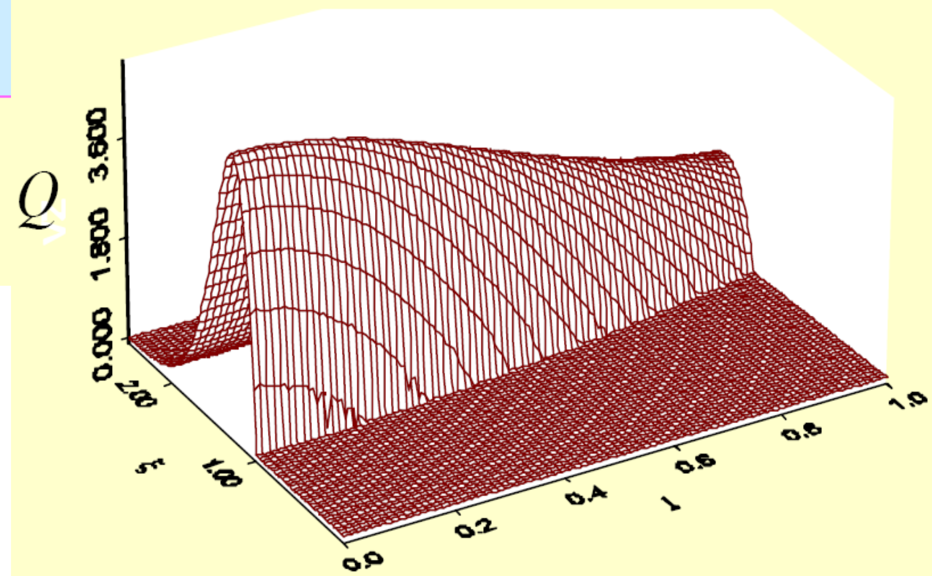
=> **Overlap region : good for acceleration**

Quality factor:

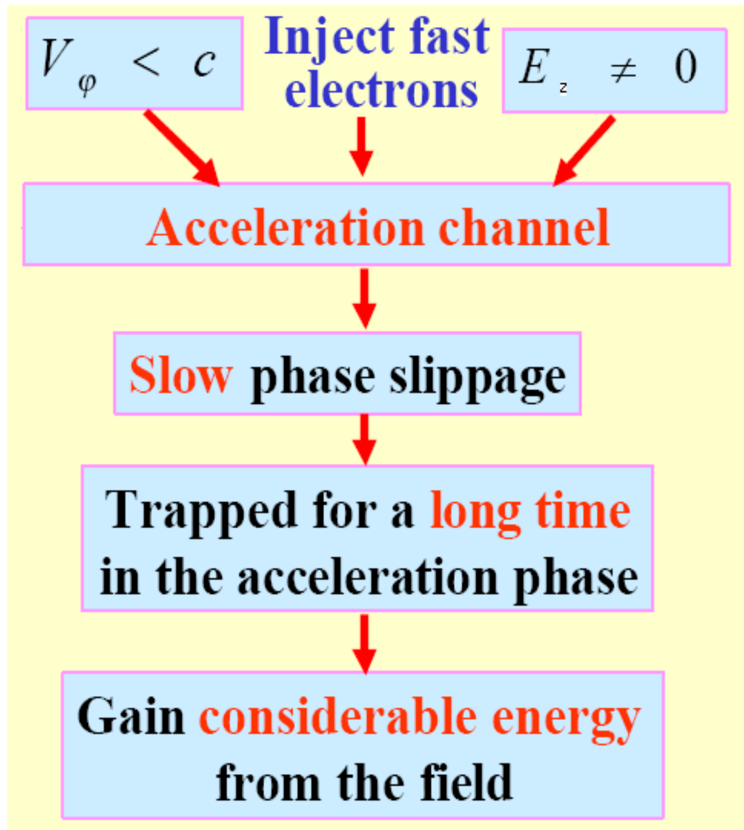
$$Q = h(V_{\varphi m}) \frac{x}{w(z)} \exp\left\{ -\frac{x^2 + y^2}{w(z)^2} \right\}$$

$$h(v_{\varphi m}) = 1, \quad v_{\varphi m} < c$$
$$\qquad\quad 0, \quad v_{\varphi m} > c$$

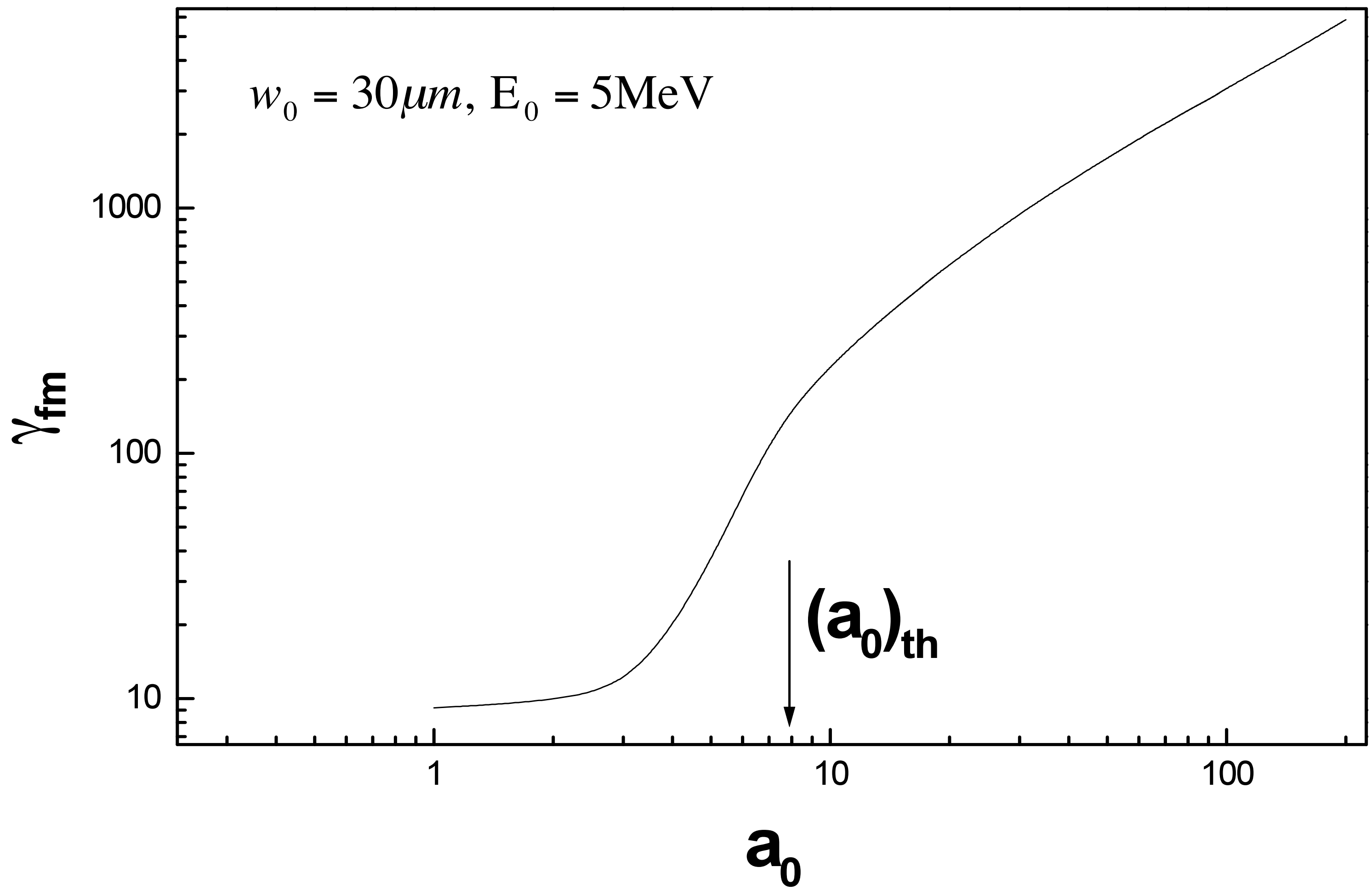
Acceleration channel (y=0)



Capture and Acceleration Scenario



Final Energy Changes as a Function of a_0



Expected e-beam and Laser Beam at ATF

Electron Beam:

Usually ATF's electron beams run at 40MeV to 70MeV. The e-beam energy can be tuned to 20MeV.

CO_2 Laser System:

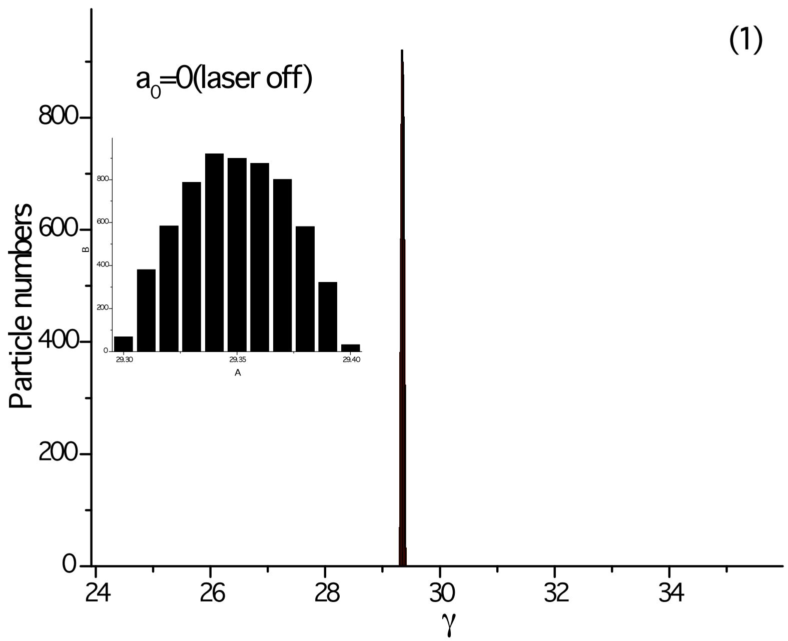
The laser pulse is 5ps and peak energy is 5J.

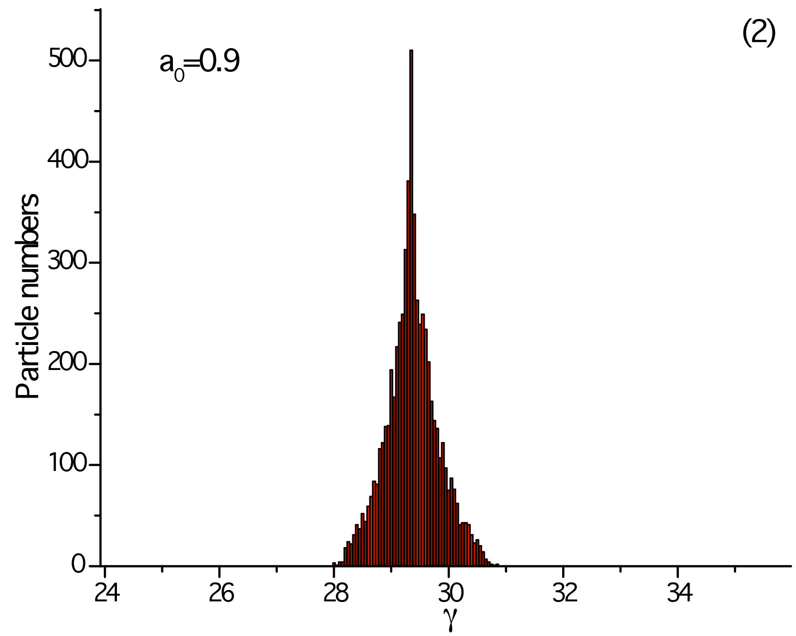
ATF's current e-beam and CO_2 laser do not reach the requirement of optimal VLA-CAS. However, our simulation shows that we still can perform proof-of-principle experiment of VLA at ATF.

E-beam Energy Spread from VLA

CO_2 Laser: spot size – 30 μm, pulse length – 5 ps, energy – 5 J

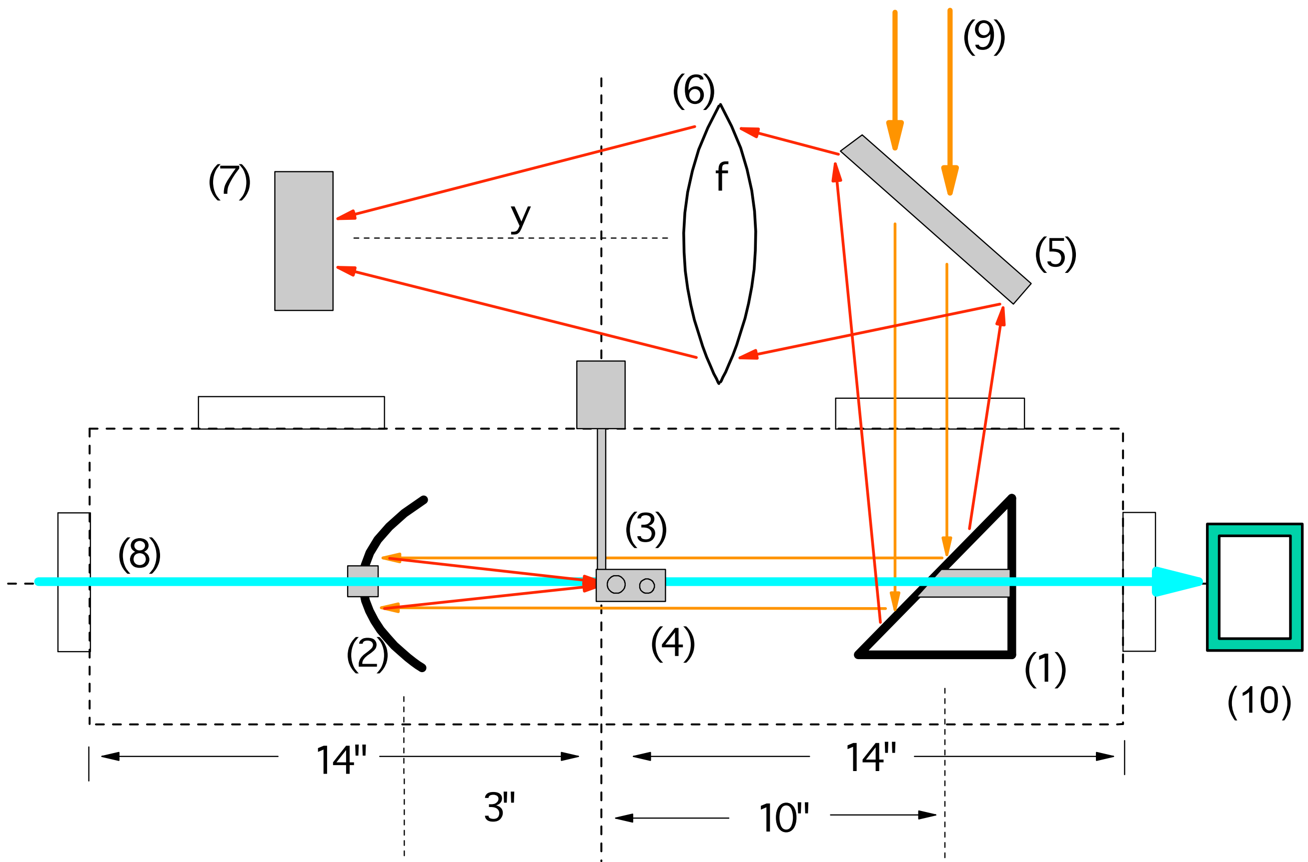
E-beam: initial Energy – 15 MeV, initial energy spread – 0.1%, beam size – 200 μm, initial emittance – 1 mm•mrad





Energy spread is changed from 0.1% with laser-off to around 1% with laser-on

Schematic of Experiment Setup



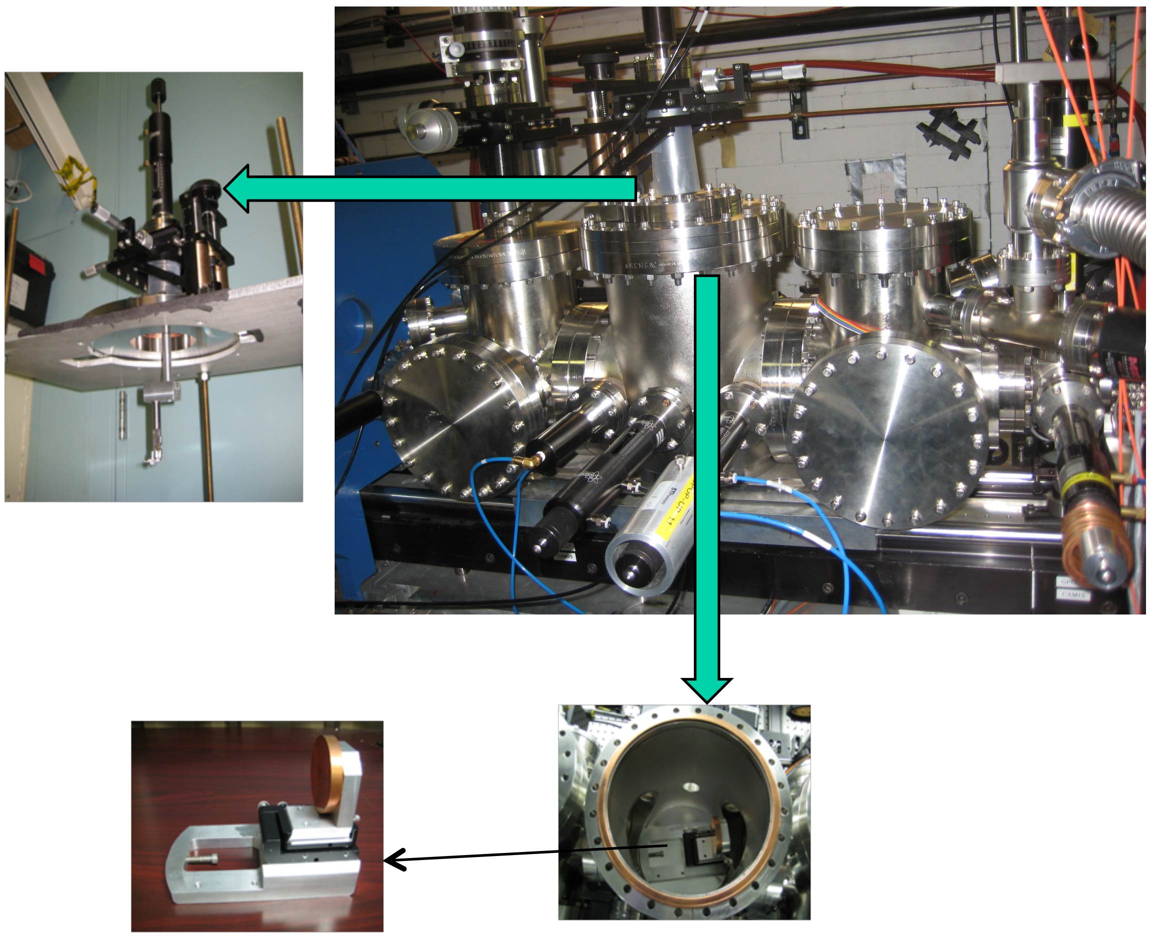
1. Flat mirror (GPOP 10)
2. Parabolic mirror (GPOP 8)
3. Pinhole (GPOP 11)
4. Germanium (GPOP 12)
5. 45^0 Beam splitter

6 & 7. setup for detector

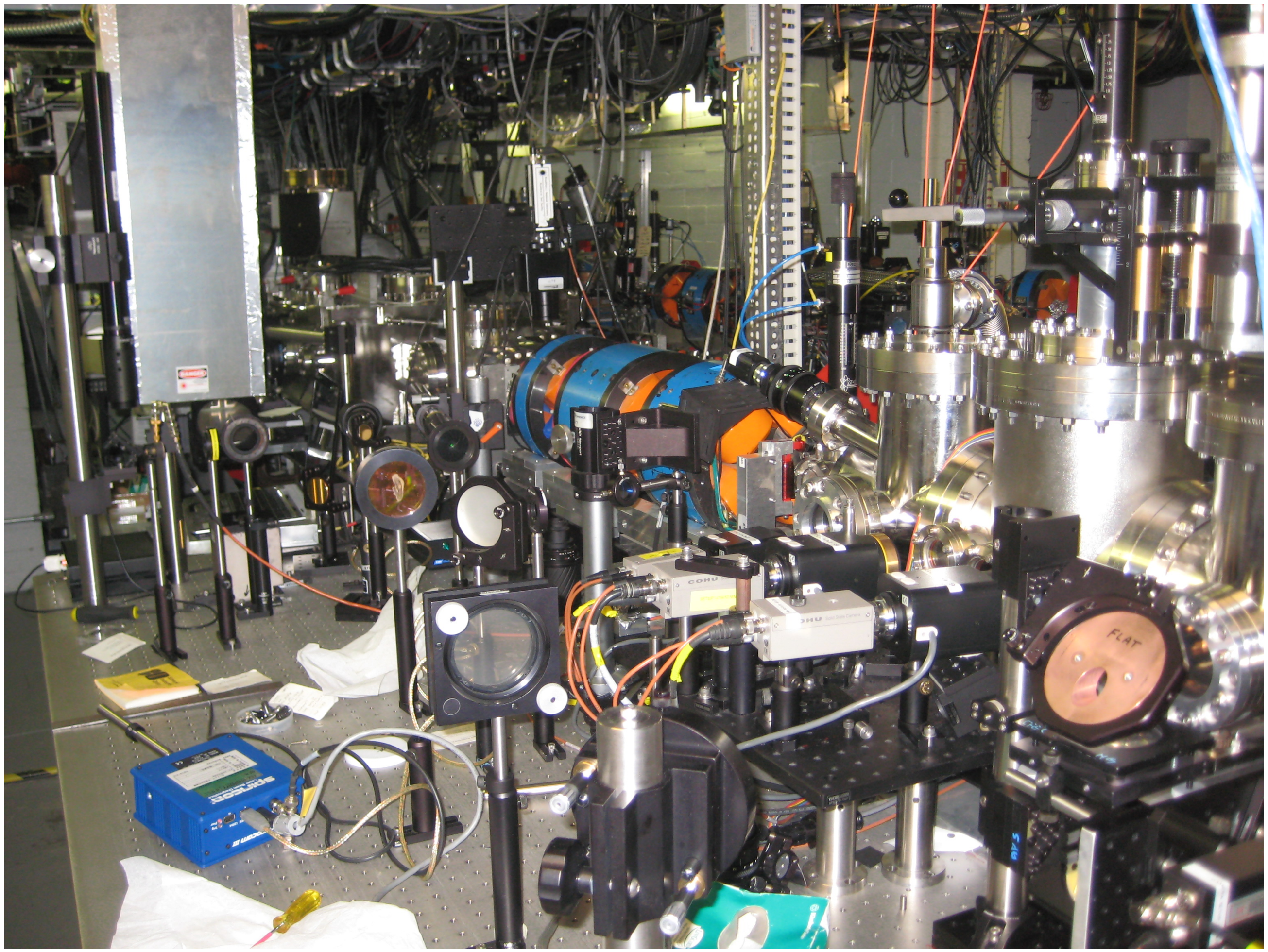
8. e-beam
9. Laser
10. 90^0 – high resolution dipole spectrometor

Experiment Setup

(Compton Chamber, Beam Line 1, Experimental Hall)



Laser Alignment and Diagnostic



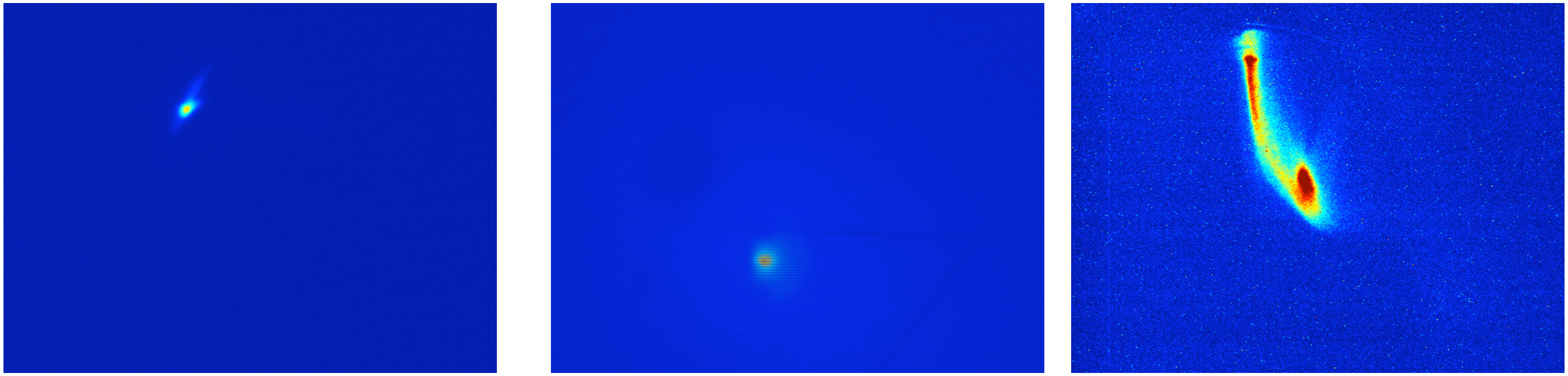
Example of Some Setup Activities

1st run (Feb. 13-Mar. 2, 2012)

1. Open flange (with target);
2. Replace salt windows;
3. Install Ge target;
4. Align beamline HeNe;
5. Align internal mirrors with beamline HeNe;
6. Set external optics, align local HeNe's (Green& Red);
7. Set diagnostic optics and Pyrocam;
8. Set CO2, see in diagnostic leg;
9. Put detectors and Joulemeter, see singals for synchronization;
10. Put main flange back and align pinhole;
11. Vacuum pump.
12. Measure expected delays on Scope;
13. Check HeNe alignment, mark BPMS;
14. Check CO2 signals and alignment on pinhloe;
15. Synch. Test;
16. Full Power Shots.

Preparation of e-beam

Beam focused at GPOP8. σx=184μm, σy=217μm
Charge at Spectrometer ~20pC
Pinhole transmission 15%~20%
Spectrometer resolution = 40keV (30 pixel sharp peak rising to half height)
Energy spread ~350-400 keV at 20 MeV beam (1.8%-2%)



GPOP 8 (left), GPOP 11-Pinhole (middle), Spectrometer (right)

Data Acquisition and Status of Analysis

- We took 30 laser power shots. Among them, 20 shots reach the maximum power around 3 Joule and their e-beam images at the spectrometer with laser-on and laser-off are recorded.
- We believe there is a signal from the experiment and we are working on the simulation with actual laser intensity and e-beam parameters during our experiment.
- We hope to complete the simulation and submit a paper later this summer.
- The VLA-CAS channel could be useful for LASER Fusion and we have discussed with NIF about this.

Thank You!