The Fermilab/NICADD photo-injector laboratory

- FNPL is a collaborative effort amongst several institutes and universities to operate a high-brightness electron photo-injector dedicated to fundamental and advanced accelerator R&D
- Main support comes from FNAL & North Illinois Center of Accelerator & Detector Development (NICADD)

- Collaborators includes:

U. of Chicago, U. of Rochester, UCLA,
U. of Indiana, U. of Michigan, LBNL, NIU,
U. of Giorgia, Jlab, Cornell University

DESY, INFN-Milano, IPN-Orsay
CEA-Saclay

- The present talk highlights of the **past five months** activities and present our short term plans.

The FNPL experiment

- **Since mid 90's:** FNAL operates a high brightness photo-injector (A0 now FNPL)

- Copy of FNPL was installed at TTF-1 (DESY) and supported SASE-FEL operation (100 nm)

Main beam parameters:

E= 16 MeV

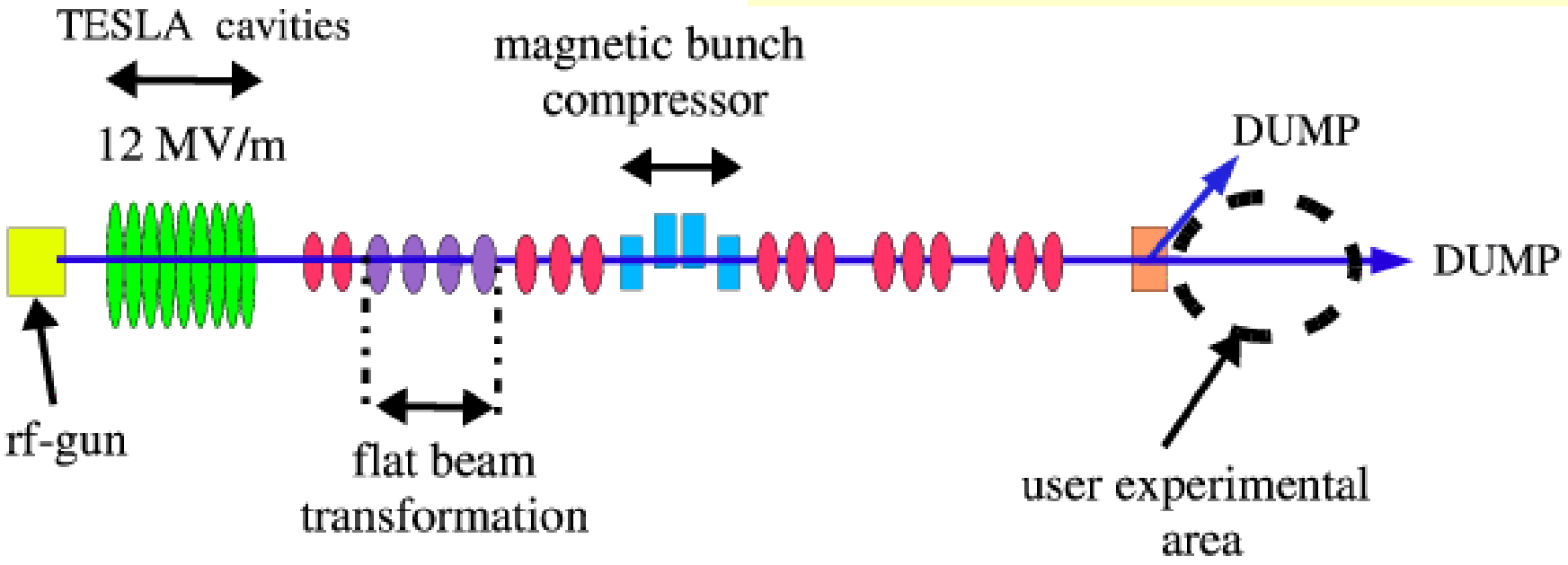
Q= 0 to 15 nC,

ε_T =3.7 mm-mrad (1 nC)

δp/p=0.25 % (1 nC)

I_{peak} = 75-330 A (BC off)

I_{peak} = 200-1700 A (BC on)



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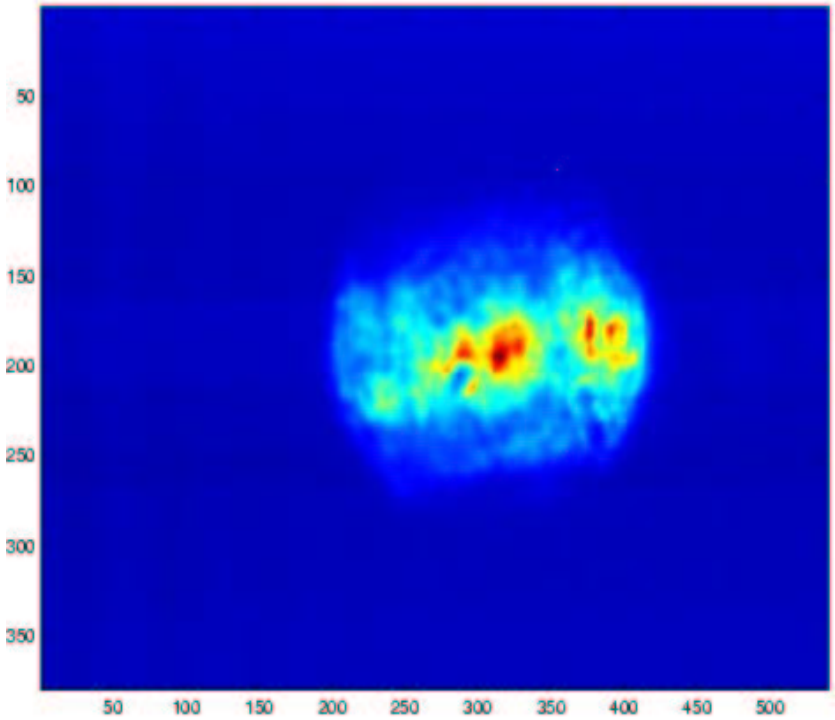
Activities since last AAC meeting (Nov. 2003)

- Continue on trying to improve experiment/modeling of the beamline (gun energy problem, laser two pulses experiment, round beam studies)
- Flat beam experiment/modeling/analytical work is on-going, our present purpose being to understand the round-to-flat beam transformation
- Continue working on beam diagnostics and control system improvement
- Completed taking data for the plasma acceleration experiment (NIU/UCLA): broke a new record of 130 MV/m accelerating
- Installed the plasma density transition trapping experiment (UCLA) is still in commissioning phase
- We now have a design (soon a drawing) for the short term upgrade

Main problems for the past five months

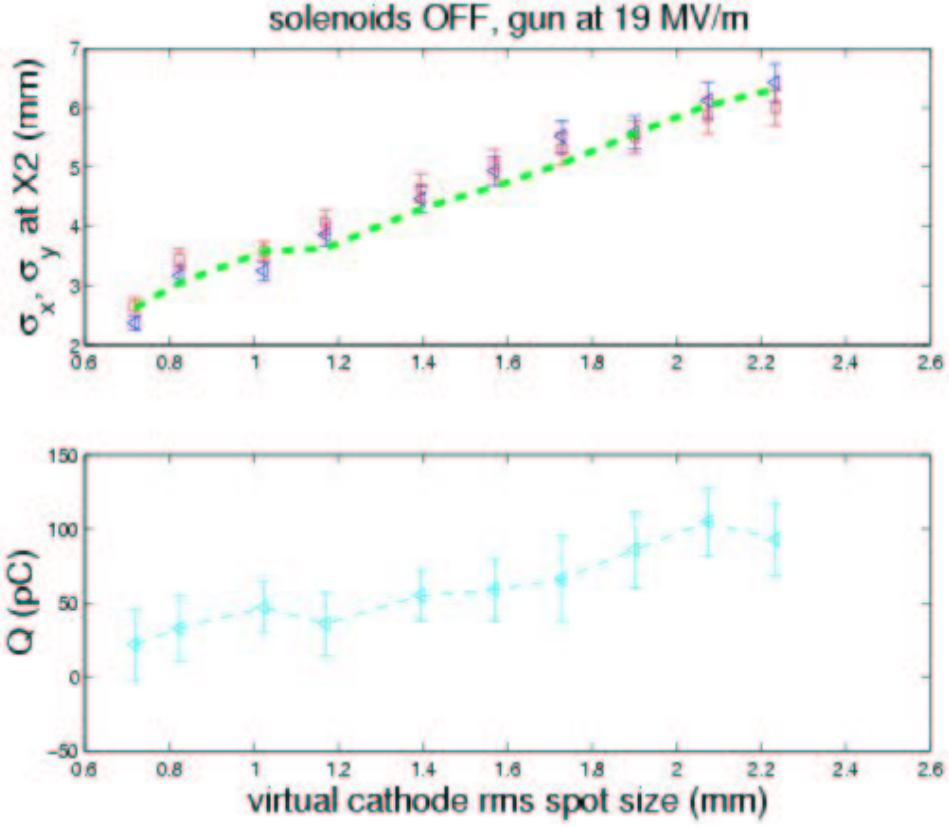
- We have reliability/reproducibility problems:
- several downtimes due to failure of various ancient cooling systems for photo-cathode laser and rf-gun e- source,
- failure of components of the modulator power supply for the 9-cell cavity klystron

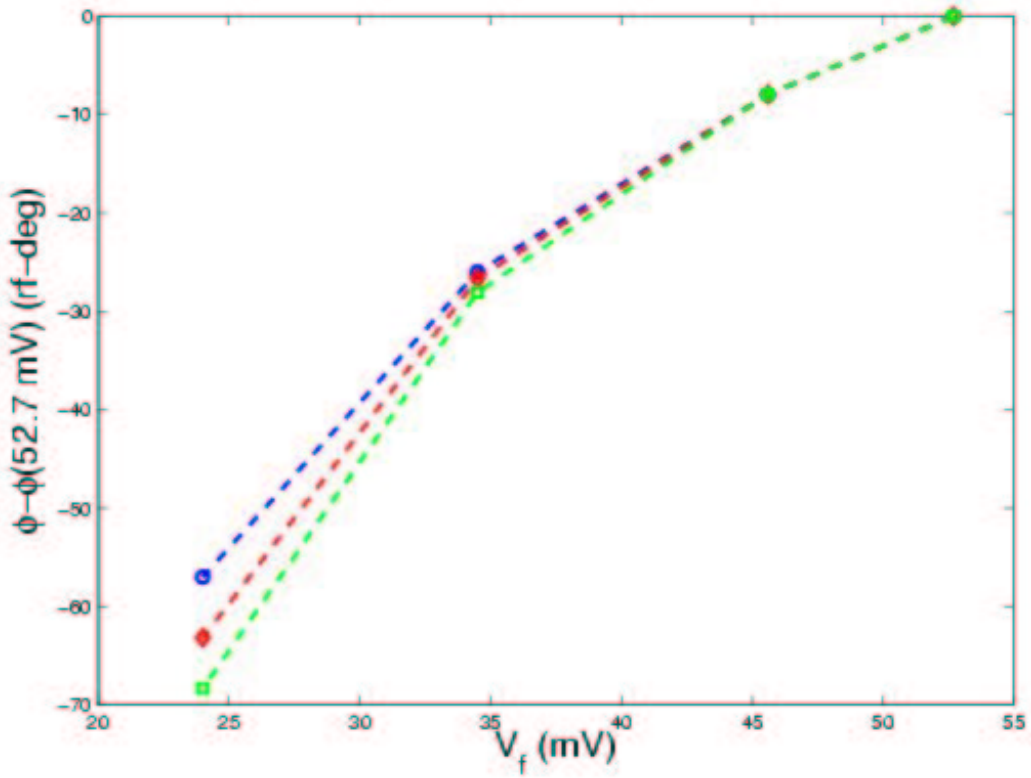
- Photo-cathode drive laser has problems (**we lost our laser expert**): non-uniformity of the transverse spot size on the cathode, day to day variation of oscillator "stable point" -- we are trying to improve the diagnostics of the laser system



Improving model + experimental conditions

- Found some problem with the rf-calibration of the gun, the maximum E-field on cathode is 35 MV/m and not 40 MV/m as previously thought





- Using TESLA cavity, we could measure the time-of-flight vs gun gradient
- We also found good agreement for spot sizes downstream of the gun versus laser spot

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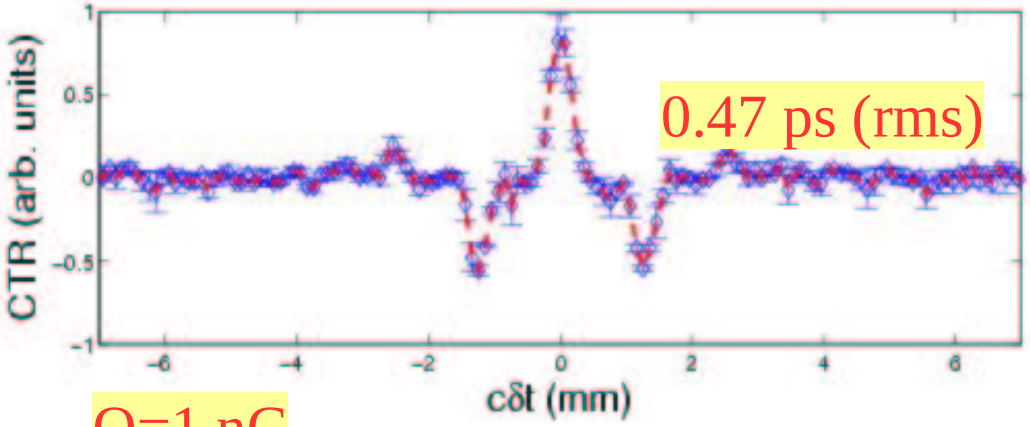
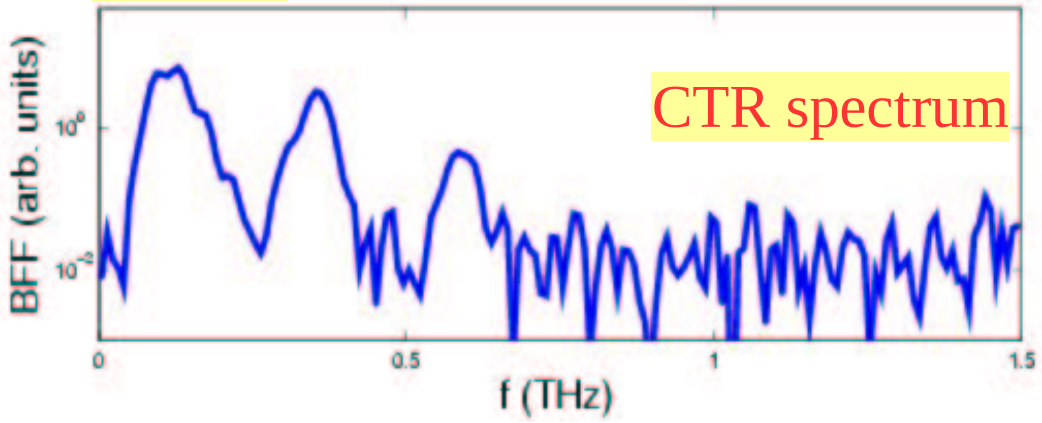
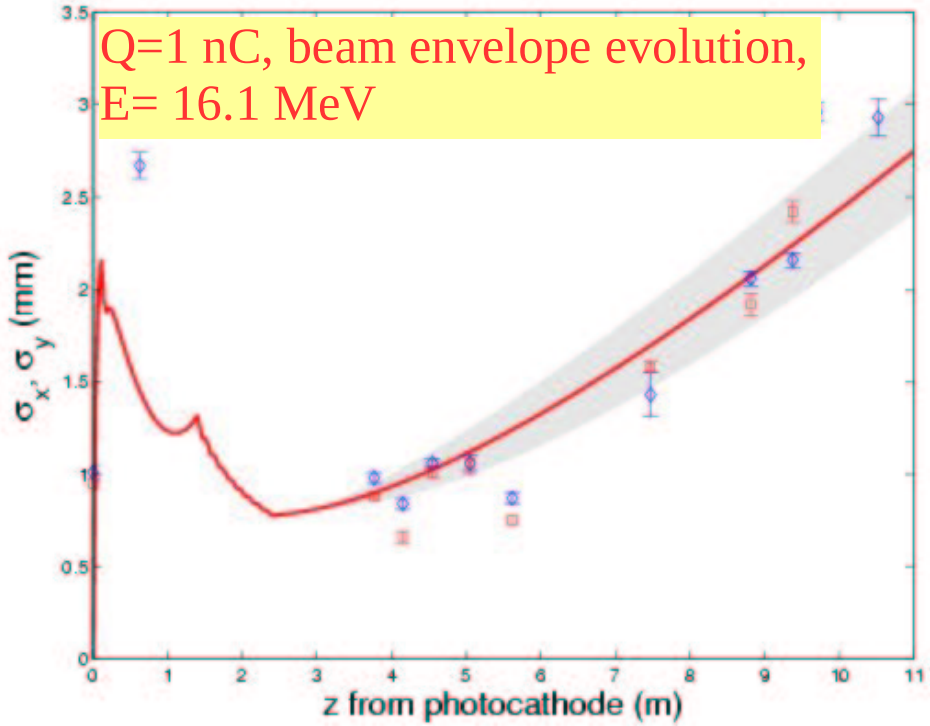
Improving model and instrumentation

- Experimental and numerical investigation of transverse and longitudinal dynamics of space-charge-dominated beams – benchmarking of different numerical models



Q=1 nC





- Bunch length measurement of sub-ps e- bunch using freq-domain analysis of coherent transition radiation
- Developed new control LINUX-based control system: various sub-system can now be controlled from a single PC

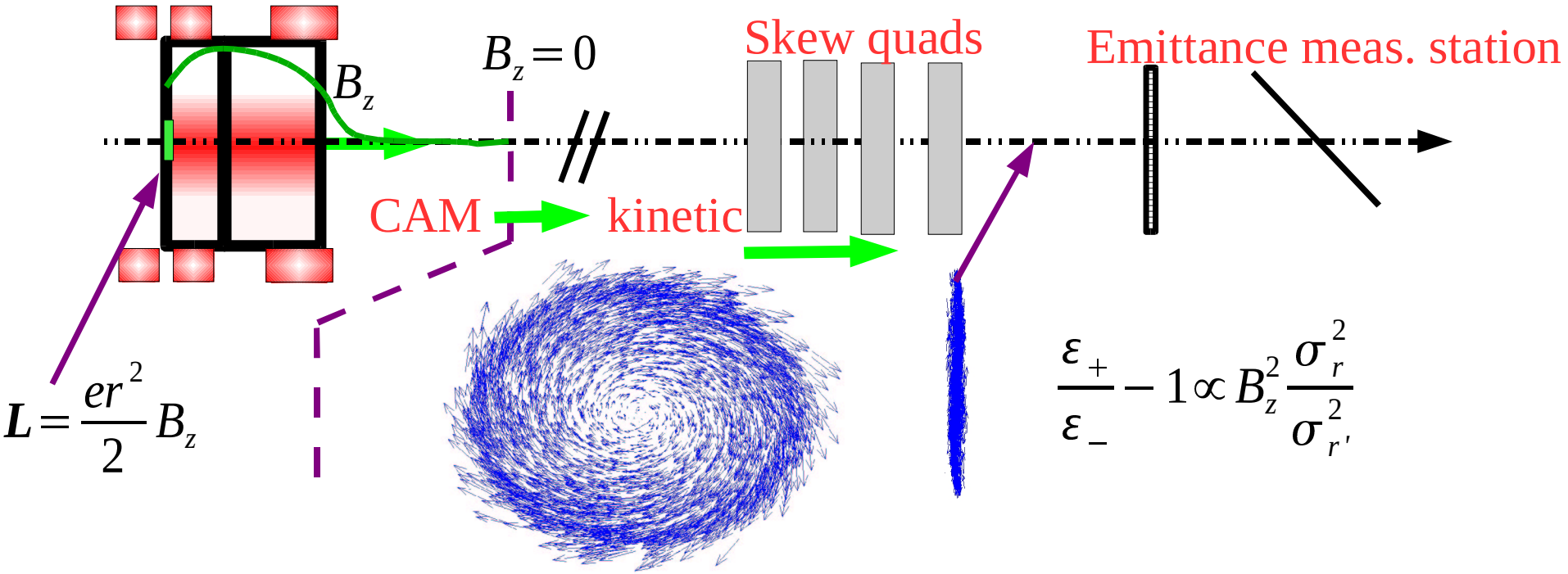
Photo-injector production of flat beams

1) Measure kinetic vs can. angular momentum.

2) Measure incoming 4x4 beam matrix

3) Set-up the transformation

4) Measure flat beam emittances



Plans: 1) check the flat beam emittance are given by $\varepsilon_\pm = \varepsilon \pm L$

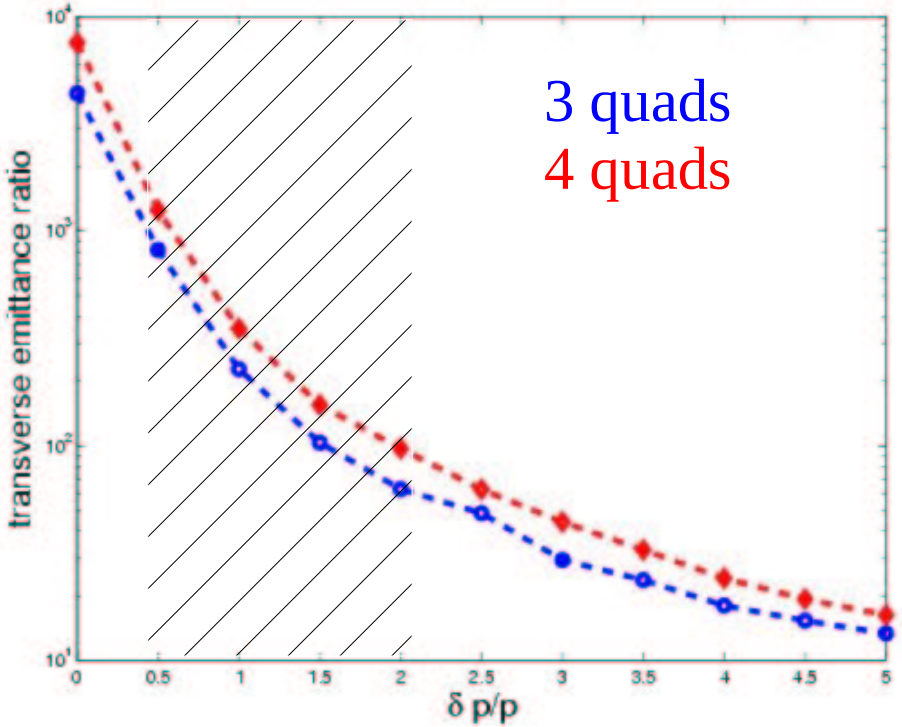
2) do parametric studies,

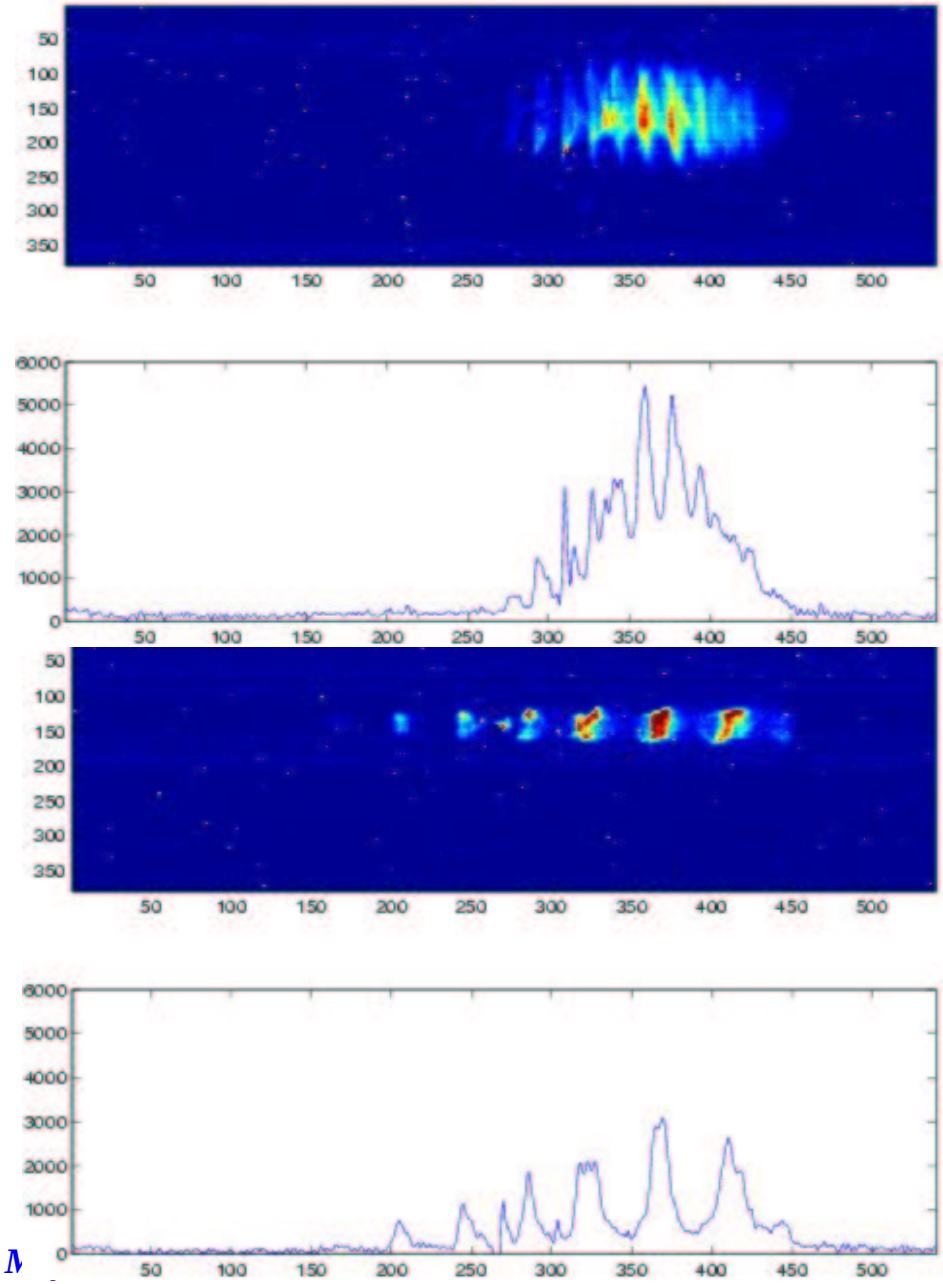
3) compressed flat beams

 (Grad. Stud. Y.-E. Sun, U of Chicago)

Photo-injector production of flat beams: progress report

- kinetic ang. Momentum vs CAM measured (now checking versus charge)
- work on improving diagnostics for transverse emittance measurement
- did numerical and analytical study of impact of energy spread on round-to-flat beam transformation

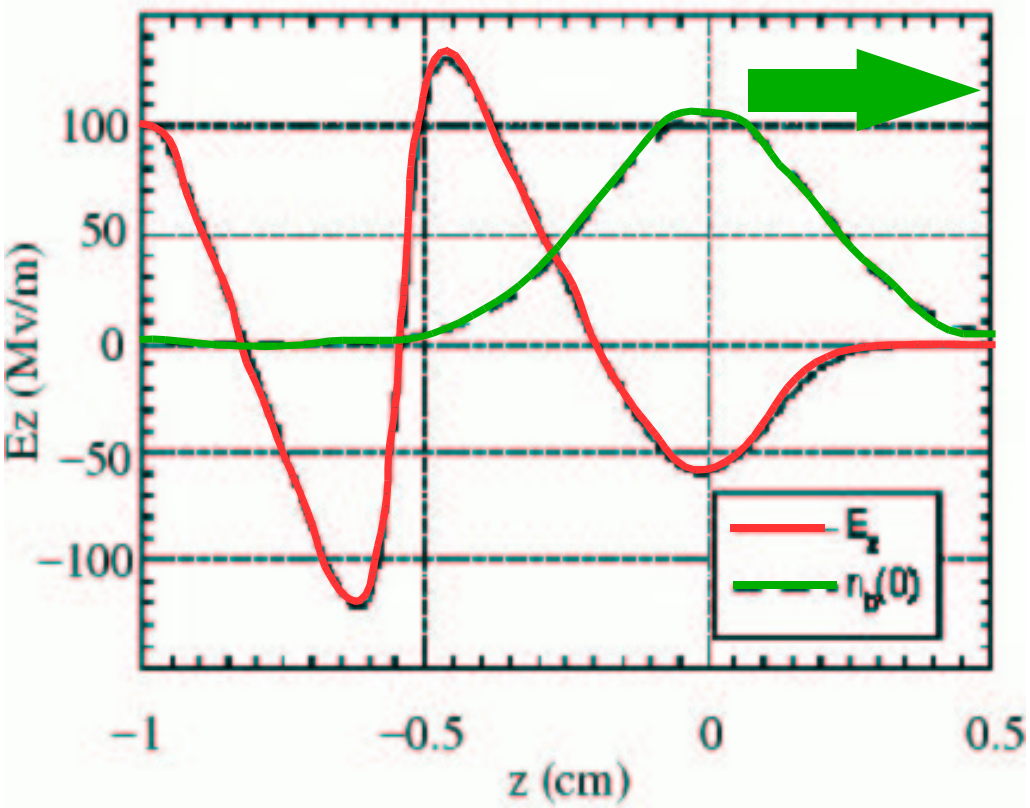




New results on Plasma-wakefield acceleration of electrons

- High current e- beam injected in a plasma induces density modulation
- Energy in the bunch is modified according to the induced wake-field

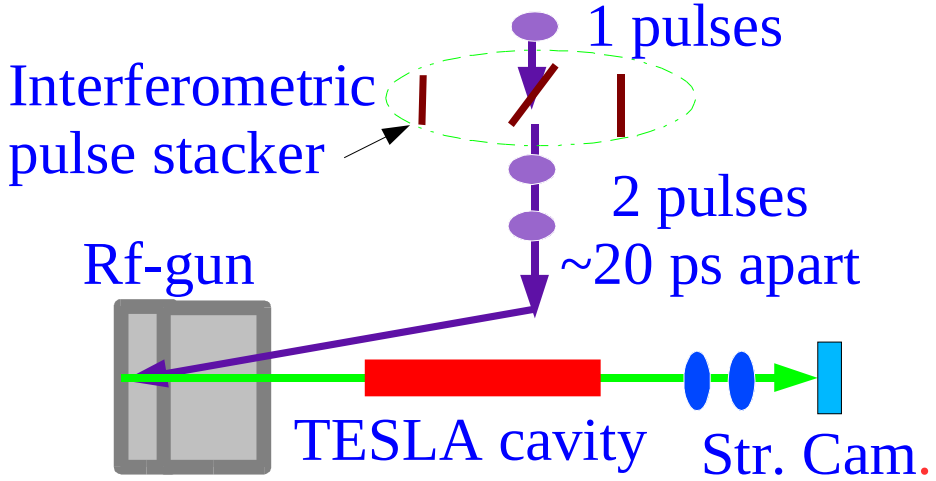
Achieved energy gradient of 130 MeV/m



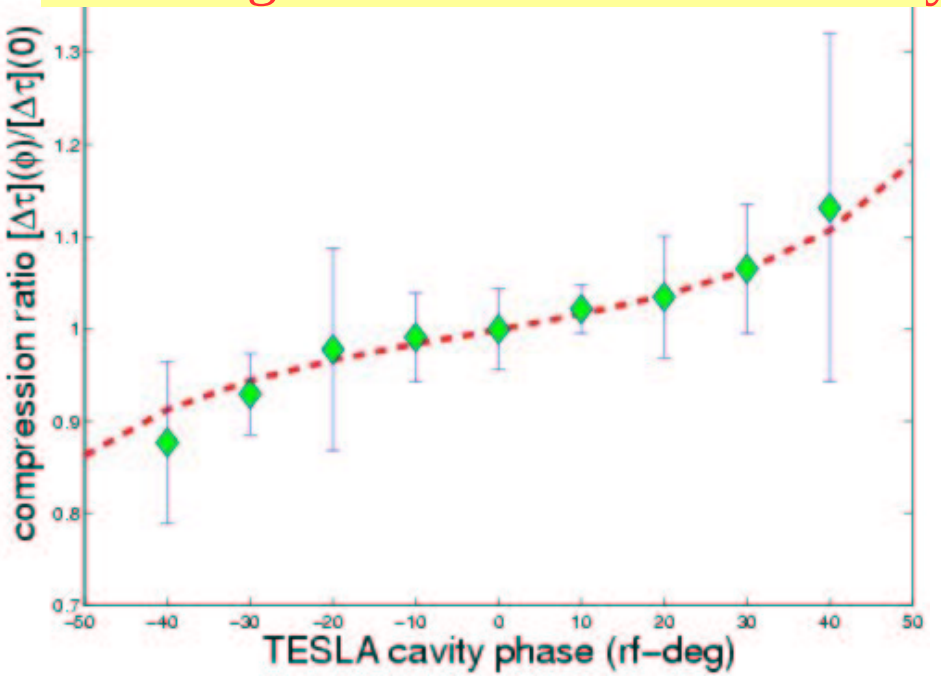
- A next set of experiments aims in sampling the plasma wake using a witness bunch following the drive beam at variable time delays

Two-marcroparticles experiment

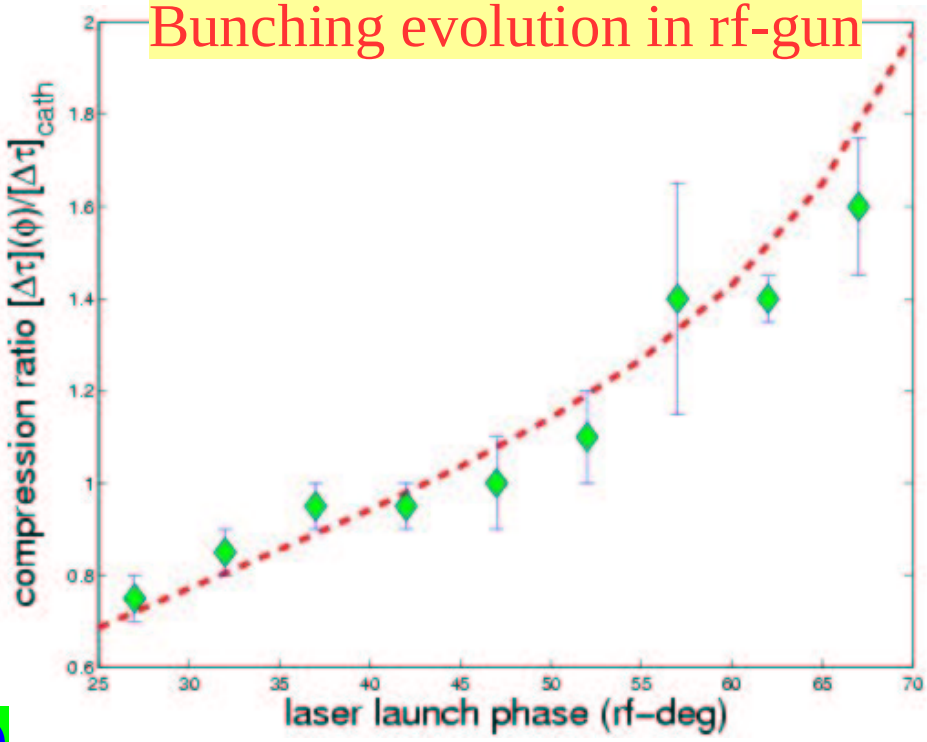
- Develop method to investigate the single-particle dynamics through the linac using two bunches within the same rf-bucket



Bunching evolution in TESLA cavity



Bunching evolution in rf-gun

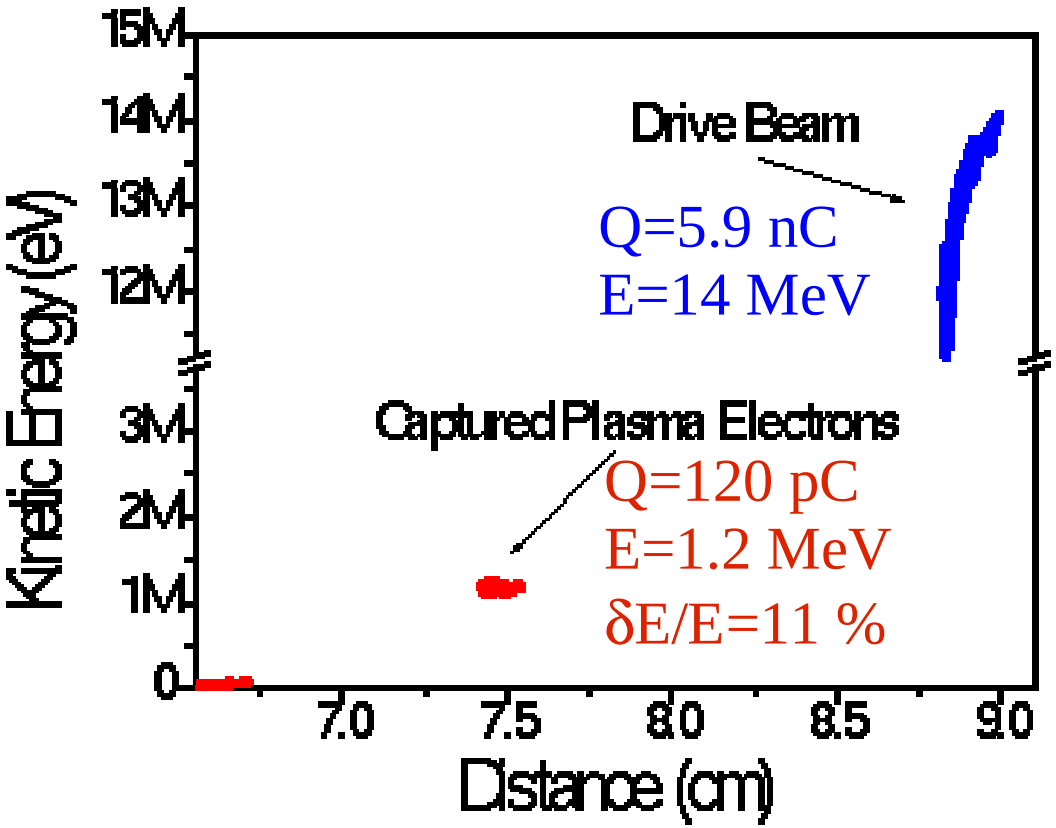


- Later extend to 4 macro-particles, and also study transverse beam dynamics

(Grad. Stud. R. Tikhoplav, U of Rochester)

Report progress on Plasma-wakefield generation of electrons

- Experiment was installed, commissioned, and ran regularly with beamtime of 1.5 days/a week
- The focus has been on the transport a 15 nC (compressed) beam up to the experiment with 100 % transmission, presently half of the charge is lost (chromatic effects + multiple scattering in an Al. Foil)

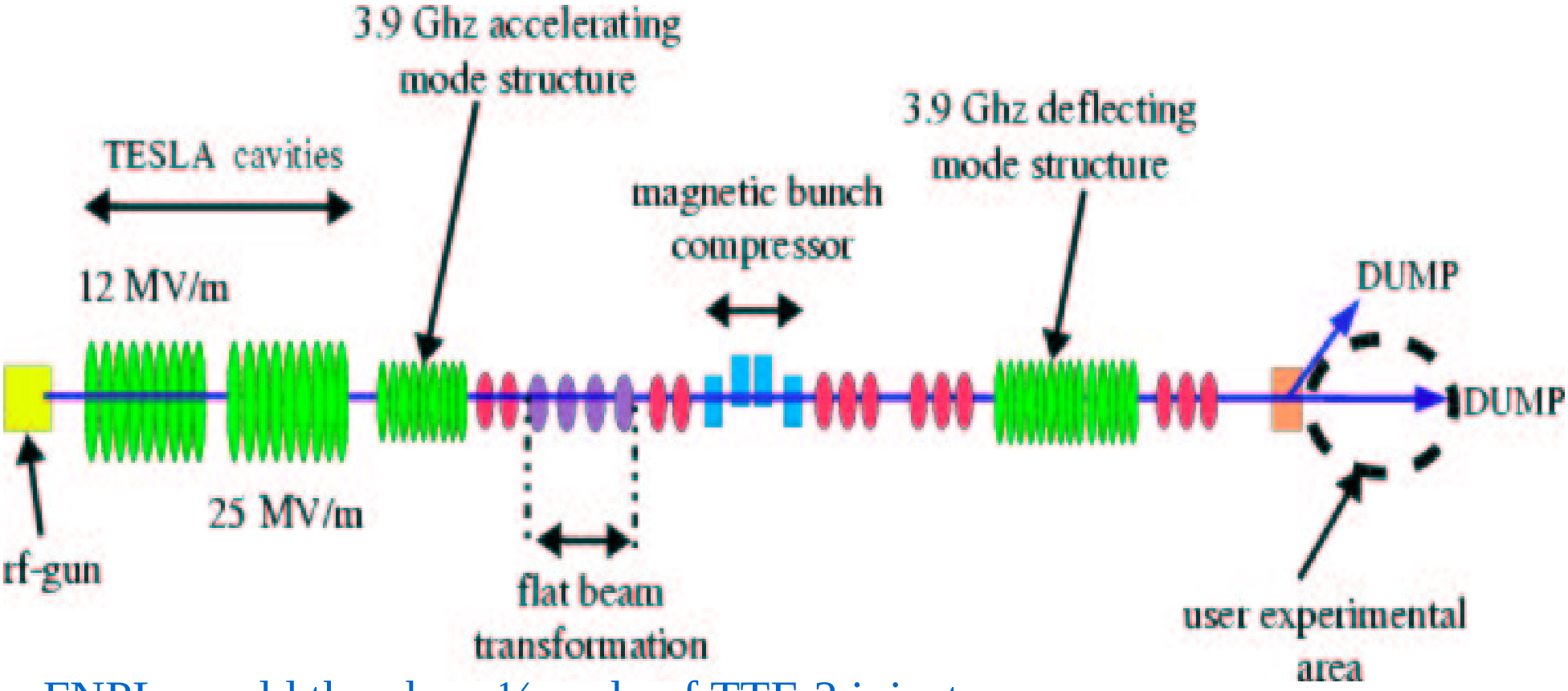


- Self-trapping mechanism based on rapid change in the wake-field wavelength at a steep transition in the plasma density
- Plasma electrons are dephased into an accelerating field of the plasma wake

(Grad. Stud. M. Thompson, UCLA)

FNPL upgrade

- DESY has offered to give a TESLA cavity (Grad.>25 MV/m)
- Proposed upgrade also incorporate the "CKM deflector" (3.9 GHz deflecting cavity) and eventually a 3.9 Ghz accelerating mode cavity being developed at FNAL in the context of TTF-FEL 2 accelerator



FNPL would then be a ¼ scale of TTF-2 injector

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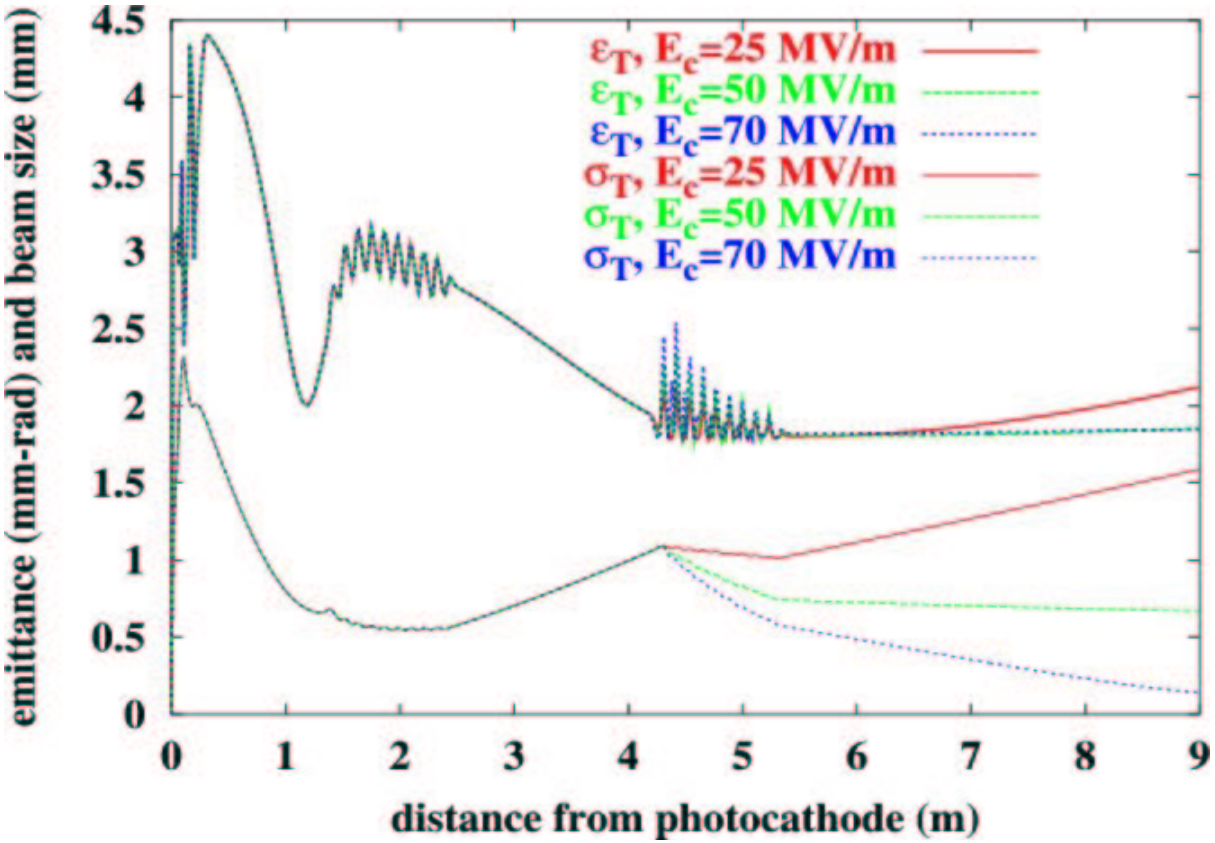
FNPL upgrade

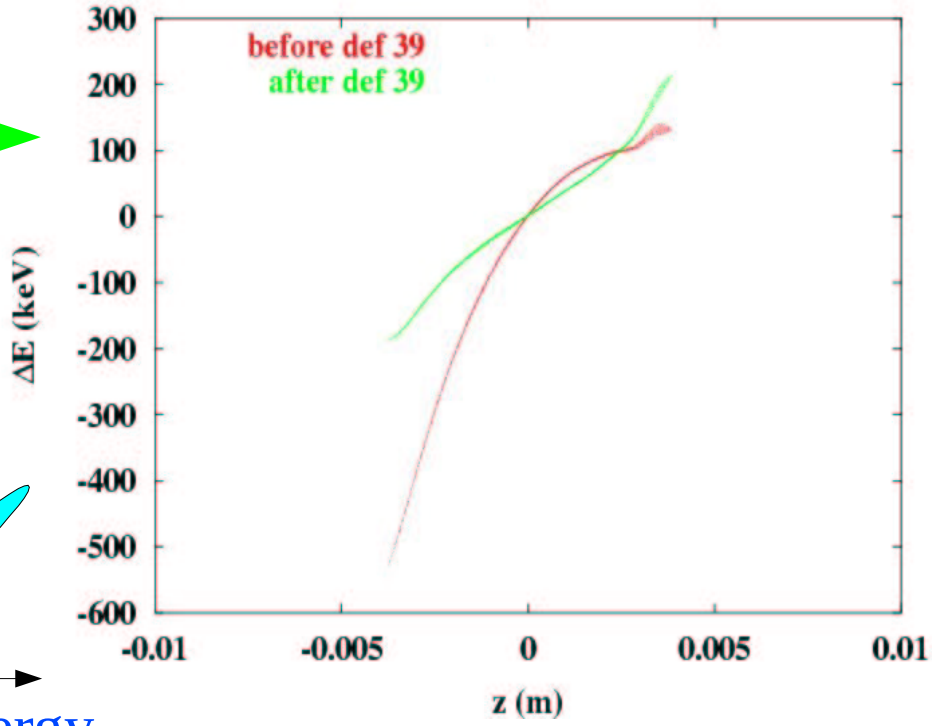


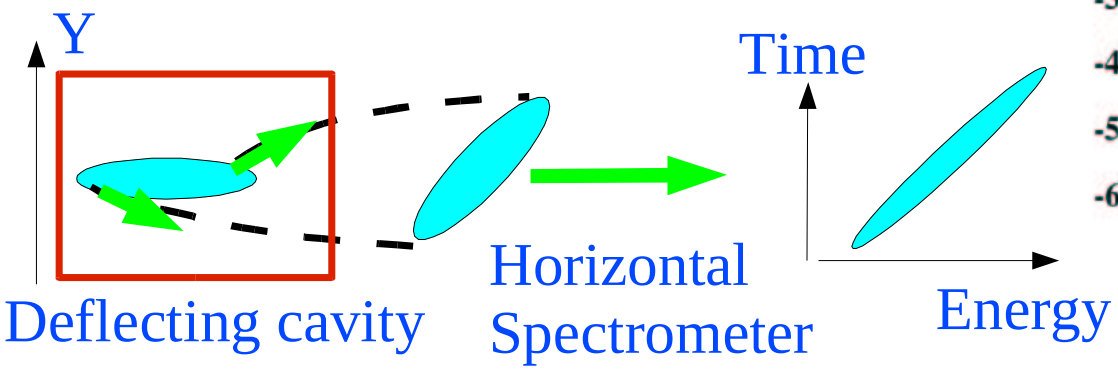
- Beam dynamics studies completed, now interacting with mechanical engineers
- Design report soon to be released

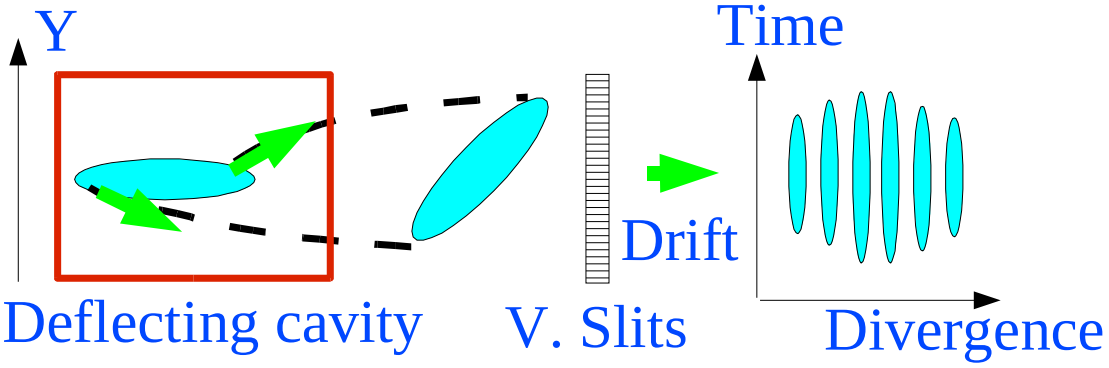
- **Deflecting 3.9 Ghz cavity** Installation at FNPL : characterization with beam, and beam diagnostics.
- **Accelerating 3.9 Ghz cavity** used for linearization of the longitudinal phase space to achieve high peak current.

Longitudinal phase space manipulation and diagnostics

- Test and optimization of the longitudinal phase space linearization scheme to increase the peak current downstream of a bunch compressor





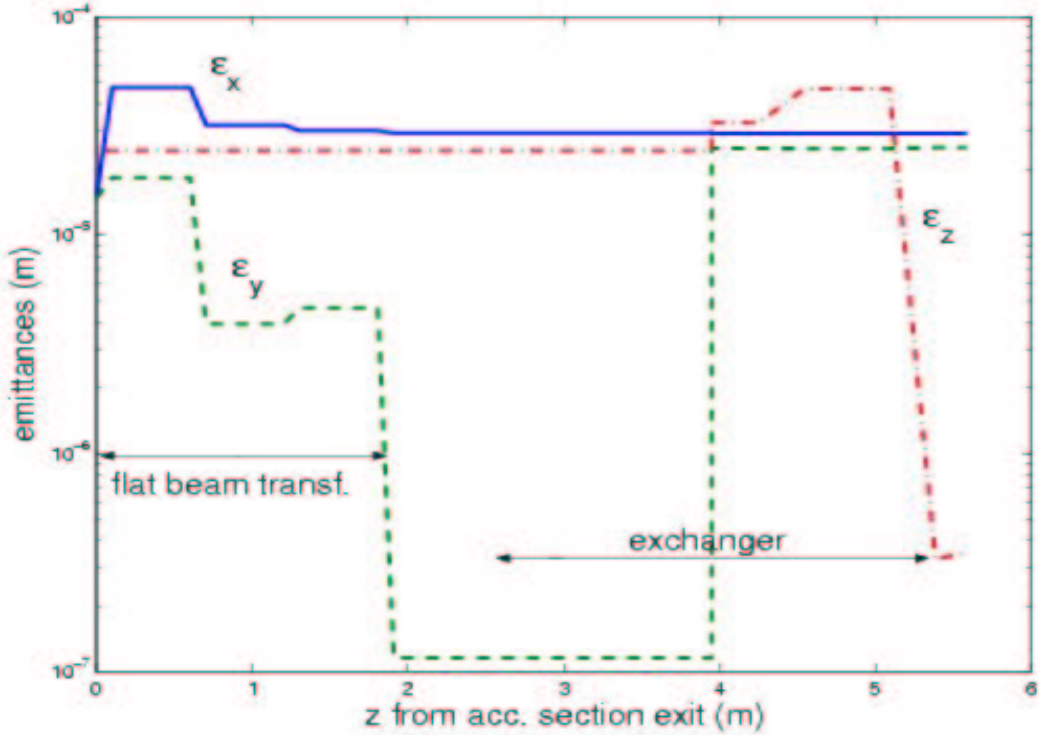


- Longitudinal and time-dependent transverse phase spaces measurements

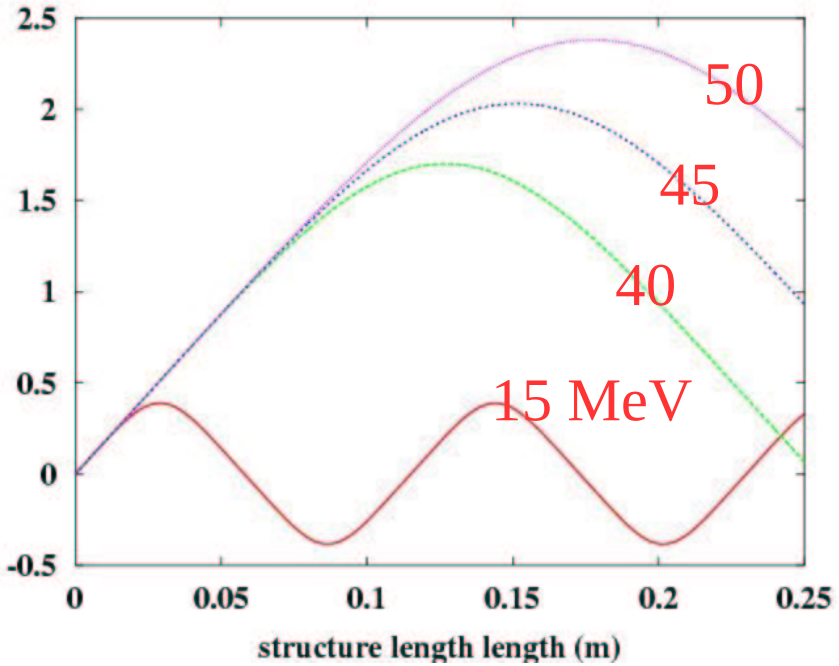
A PhD candidate from Rudgers U. will join our team to work on this topics

Possible other experiment at the upgraded FNPL

- Laser acceleration of electrons (we have a TM*010 laser ready)
- Possibility to demonstrate emittance exchange between horizontal and longitudinal phase spaces (suggestion at last AAC)



Laser acceleration: energy gain



- Smith purcell radiation source using flat beam
- Continue other advance accelerator activity (e.g. underdense plasma lens)

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Plans for next months, up to energy upgrade

- Up to the energy upgrade our plans are:
  - concentrate on flat beam production
    (grad. stud: Y.-E. Sun U. of Chicago)
  - take a set of round beam data both with short laser pulses, and long laser pulses (grad. stud R. Tikhoplav U. of Rochester)
  - complete the plasma density transition trapping experiment
    (grad. stud M. Thompson UCLA),
  - complete the plasma wake-field experiment using the drive/ witness beams method

- We will continue working on diagnostics, especially on a CW autocorrelator at the laser oscillator, and implementing the pulse stacking method to have plateau-distribution

- In parallel work on the upgrade project is on going

Contributors to the Physics program

Students:
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M. Thompson (UCLA)

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