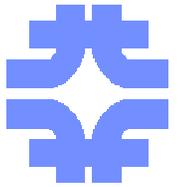




# The Fermilab/NICADD photo-injector laboratory

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- FNPL overview
- Improving model and instrumentation
- Recent results from plasma wake field acceleration
- Longitudinal dynamics studies using a two-particles experiment
- Plasma density transition experiment
- Photo-injector production of flat beams
- Future plan: FNPL energy upgrade to 40-50 MeV

➤ 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:

$E = 16 \text{ MeV}$

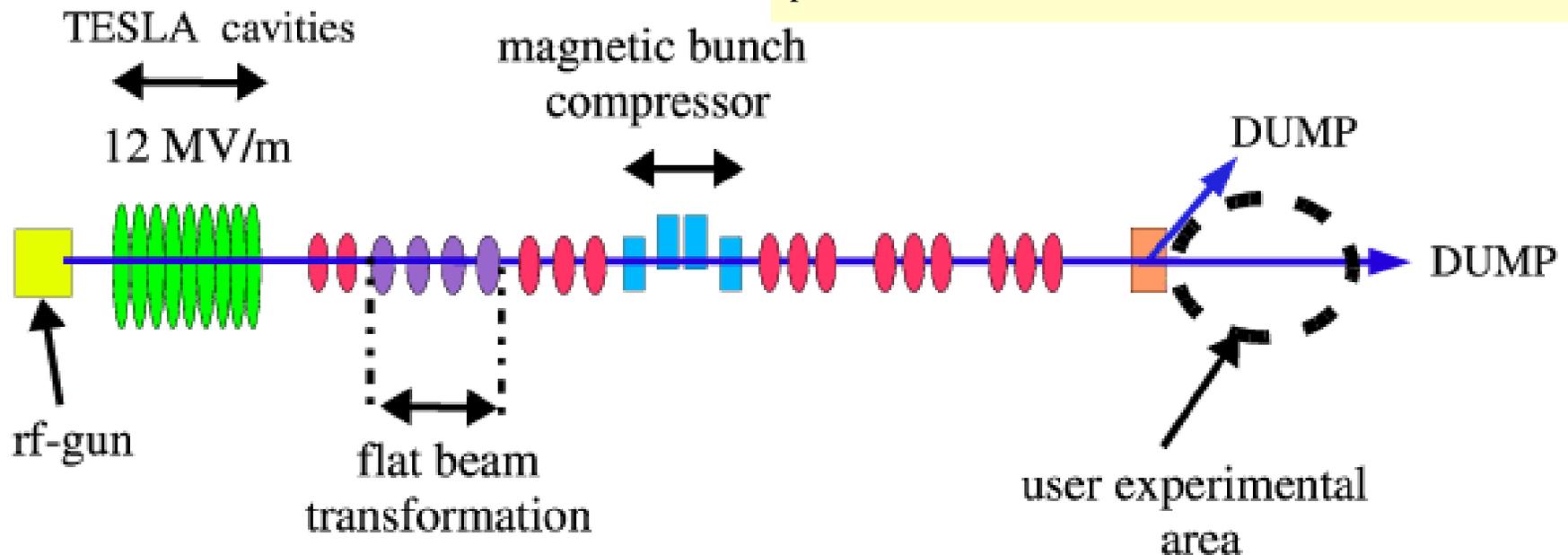
$Q = 0 \text{ to } 15 \text{ nC}$ ,

$\varepsilon_T = 3.7 \text{ mm-mrad (1 nC)}$

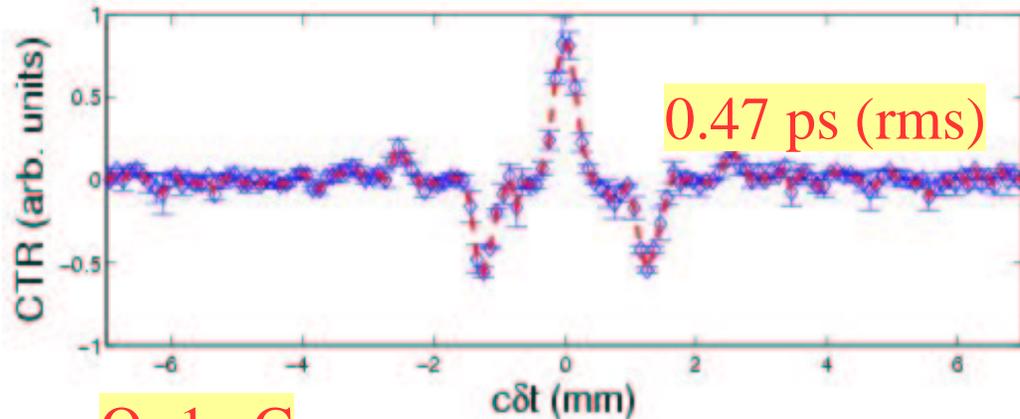
$\delta p/p = 0.25 \%$  (1 nC)

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

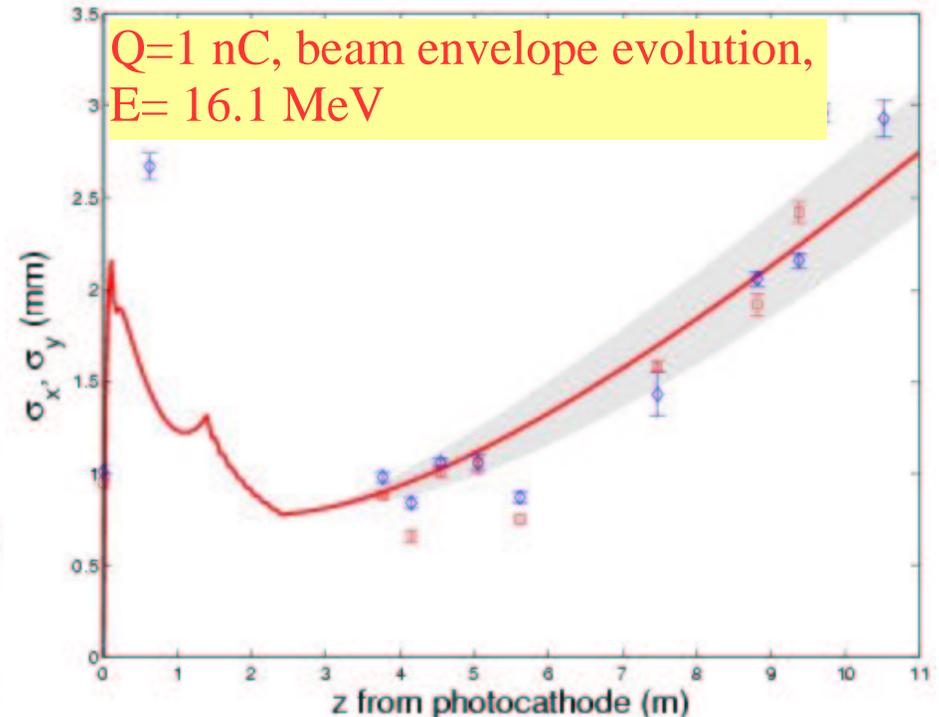
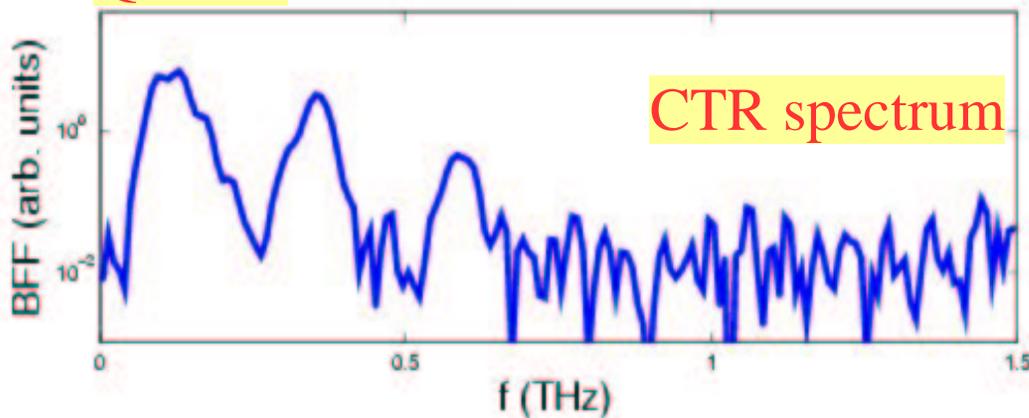
$I_{\text{peak}} = 200\text{-}1700 \text{ A (BC on)}$



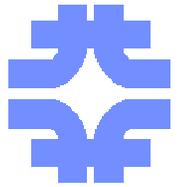
➤ Experimental and numerical investigation of transverse and longitudinal dynamics of space-charge-dominated beams – benchmarking of different numerical models



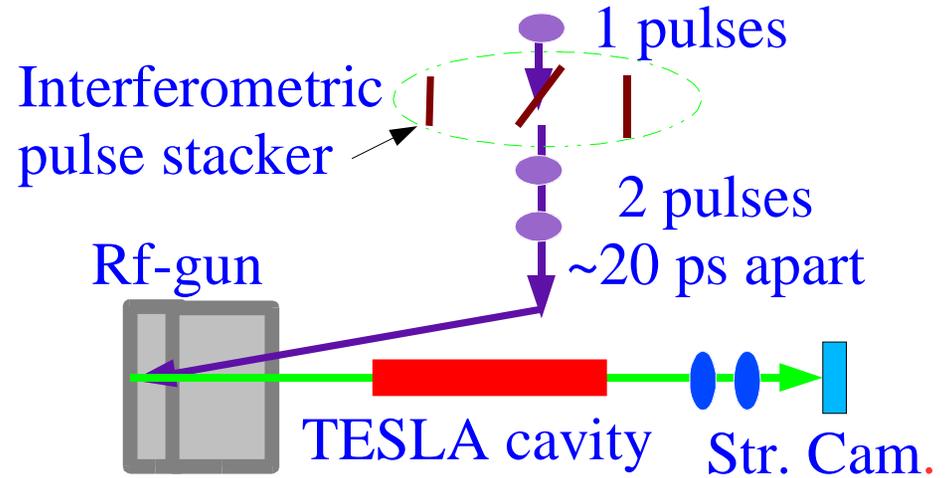
Q=1 nC



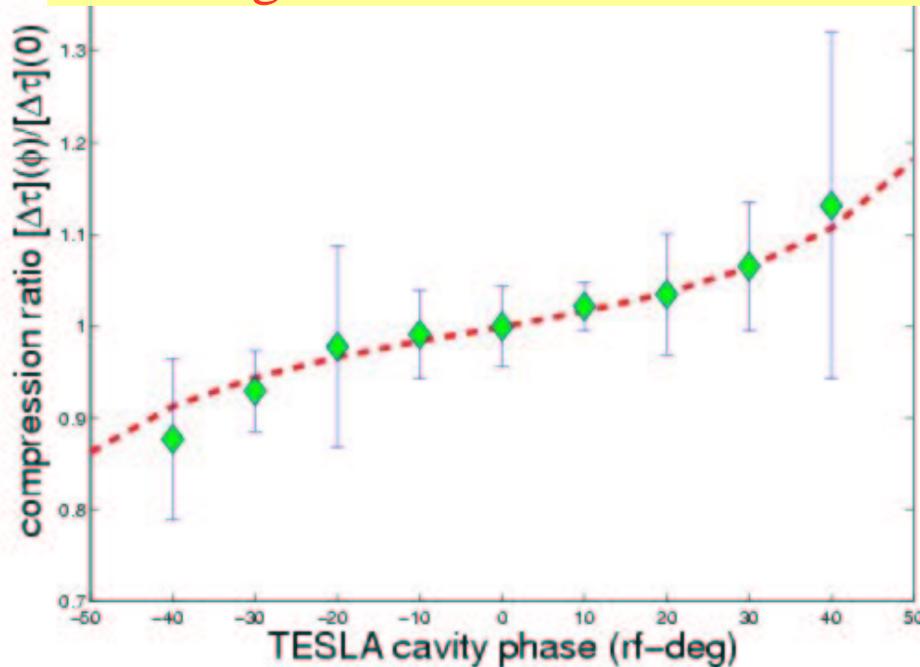
➤ Bunch length measurement of sub-ps e- bunch using freq-domain analysis of coherent transition radiation



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

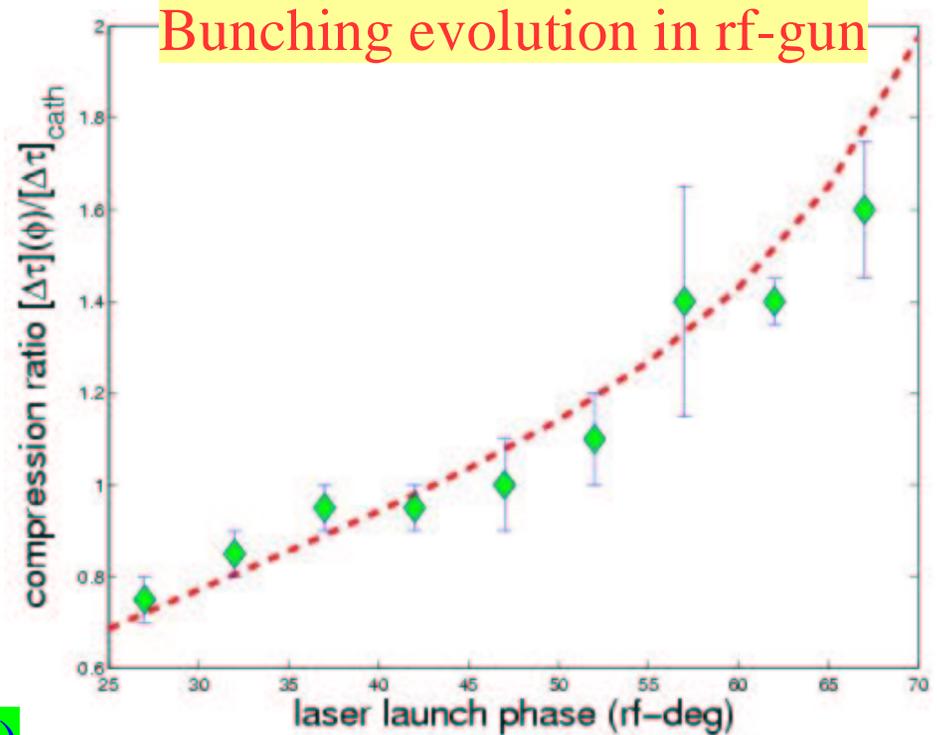


Bunching evolution in TESLA cavity



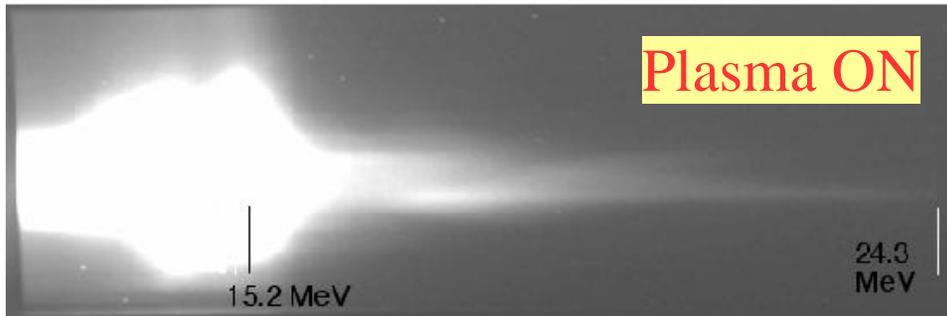
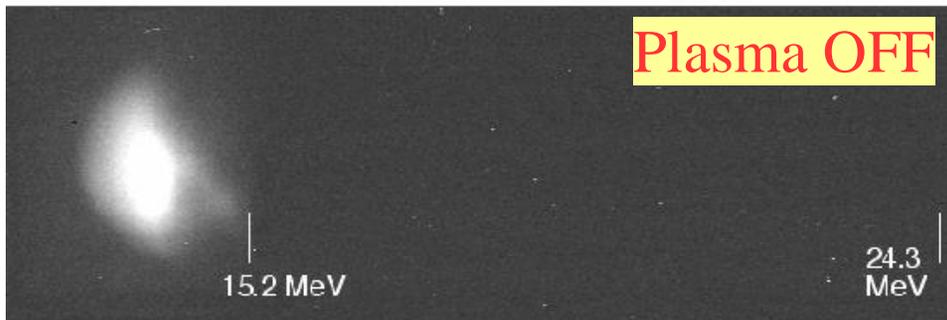
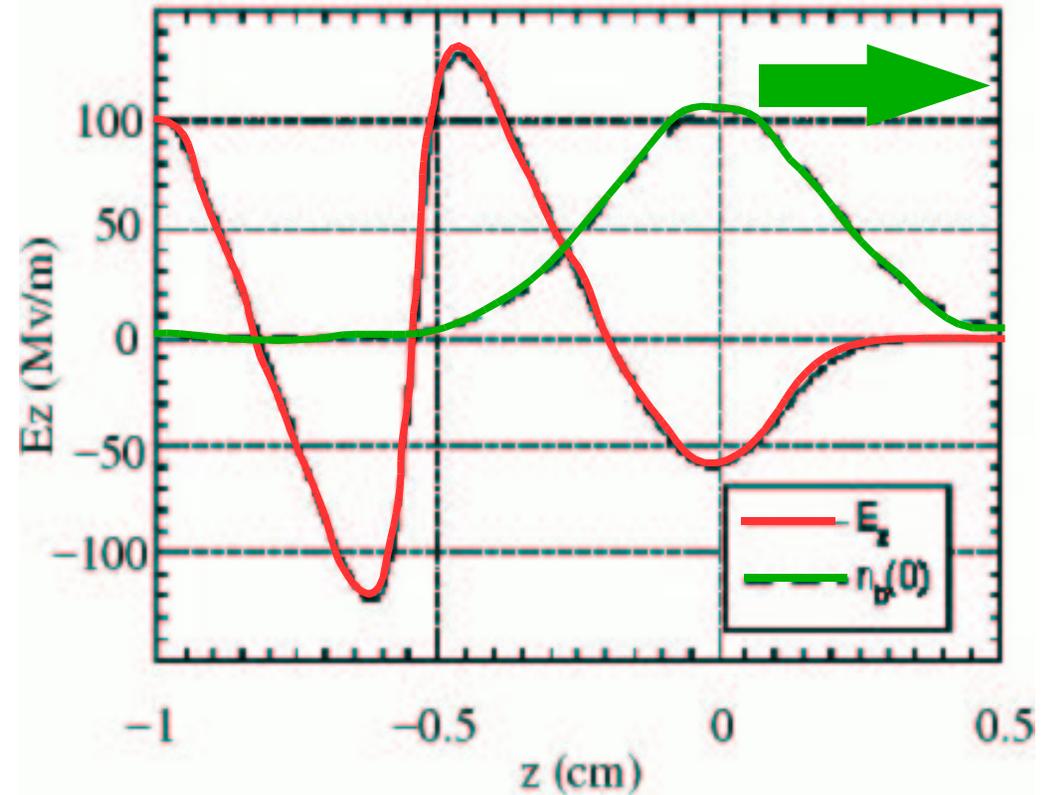
➤ Later extend to 4 macro-particles, and also study transverse beam dynamics

Bunching evolution in rf-gun



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

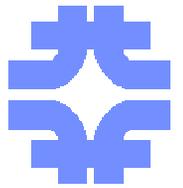
**Achieved energy gradient of 130 MeV/m**



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

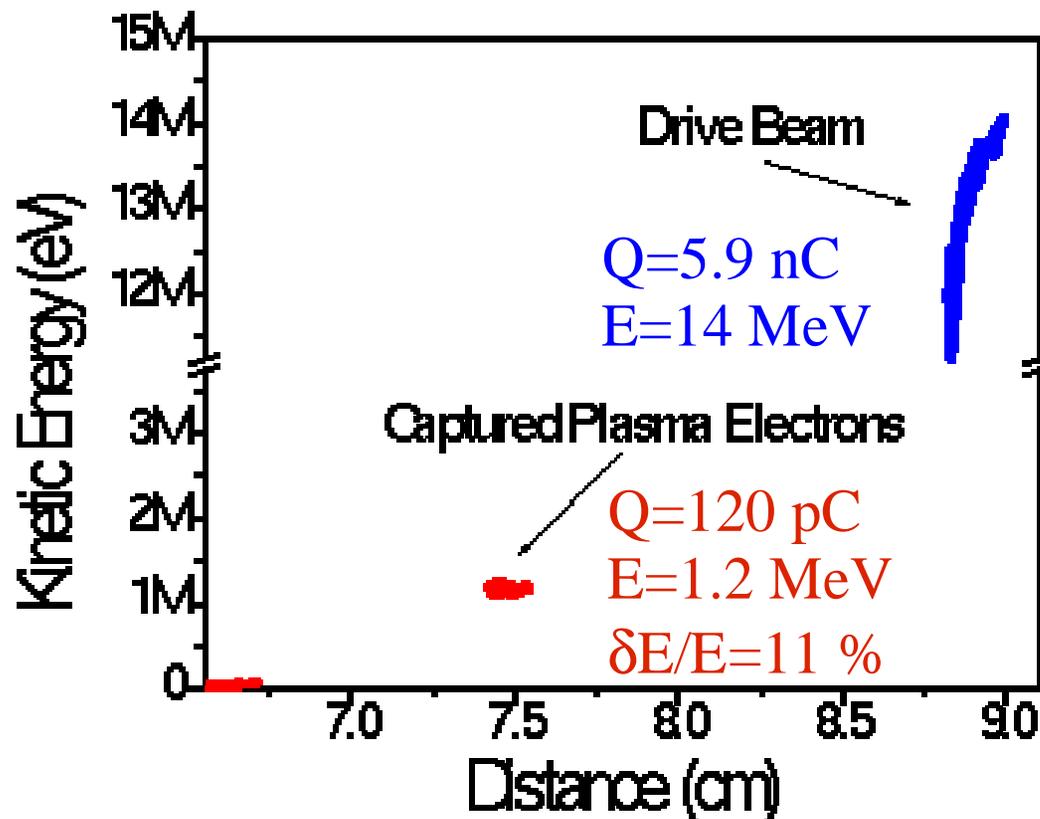
(See WG talk from N. Barov)

# Plasma density transition experiment



➤ 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



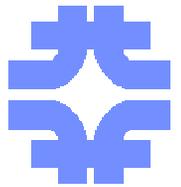
➤ Experiment was installed, commissioned, and ran regularly experiment still on-going

➤ The focus has been on the transport a 15 nC (compressed) beam up to the experiment with 100 % transmission

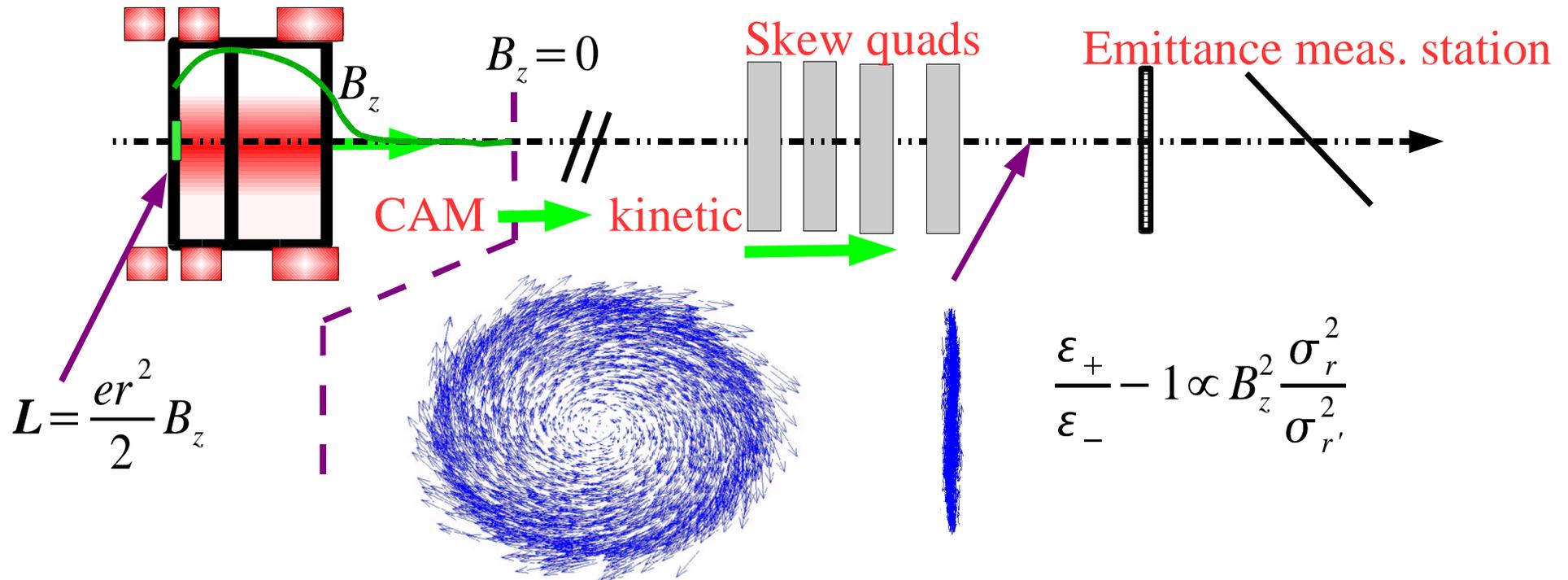
➤ The experimental set-up will also be used for underdense plasma lens experiment

(M. Thompson, UCLA)

# 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

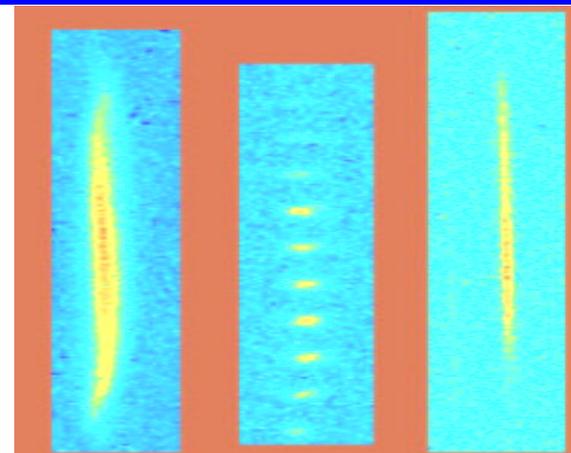
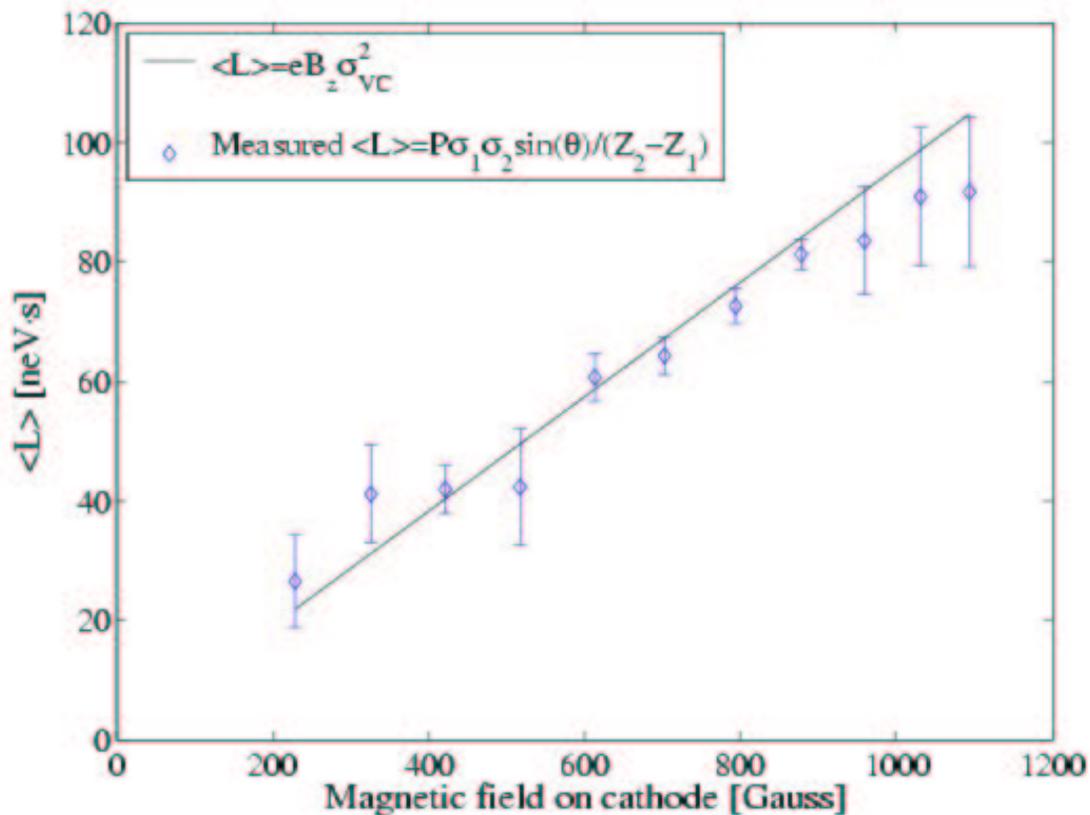


(Grad. Stud. Y.-E. Sun, U of Chicago)

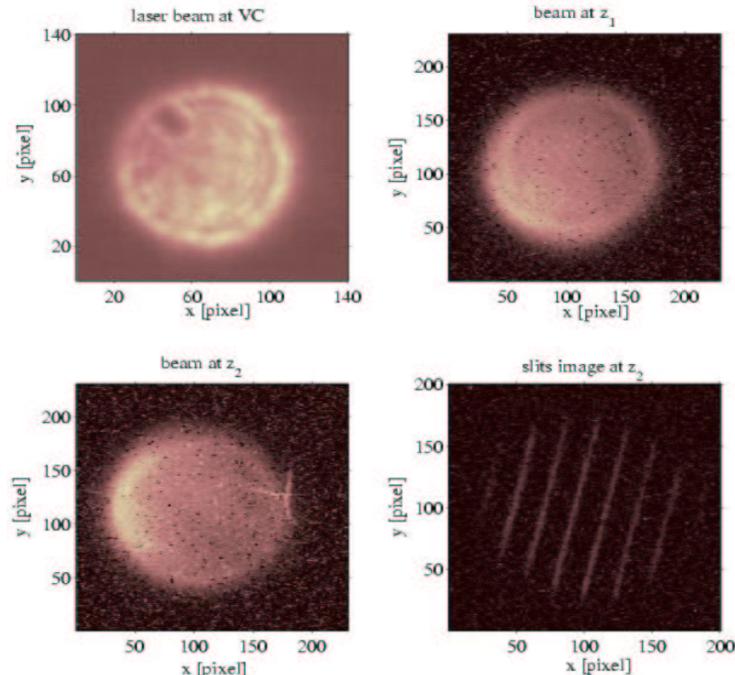
# Photo-injector production of flat beams: progress report



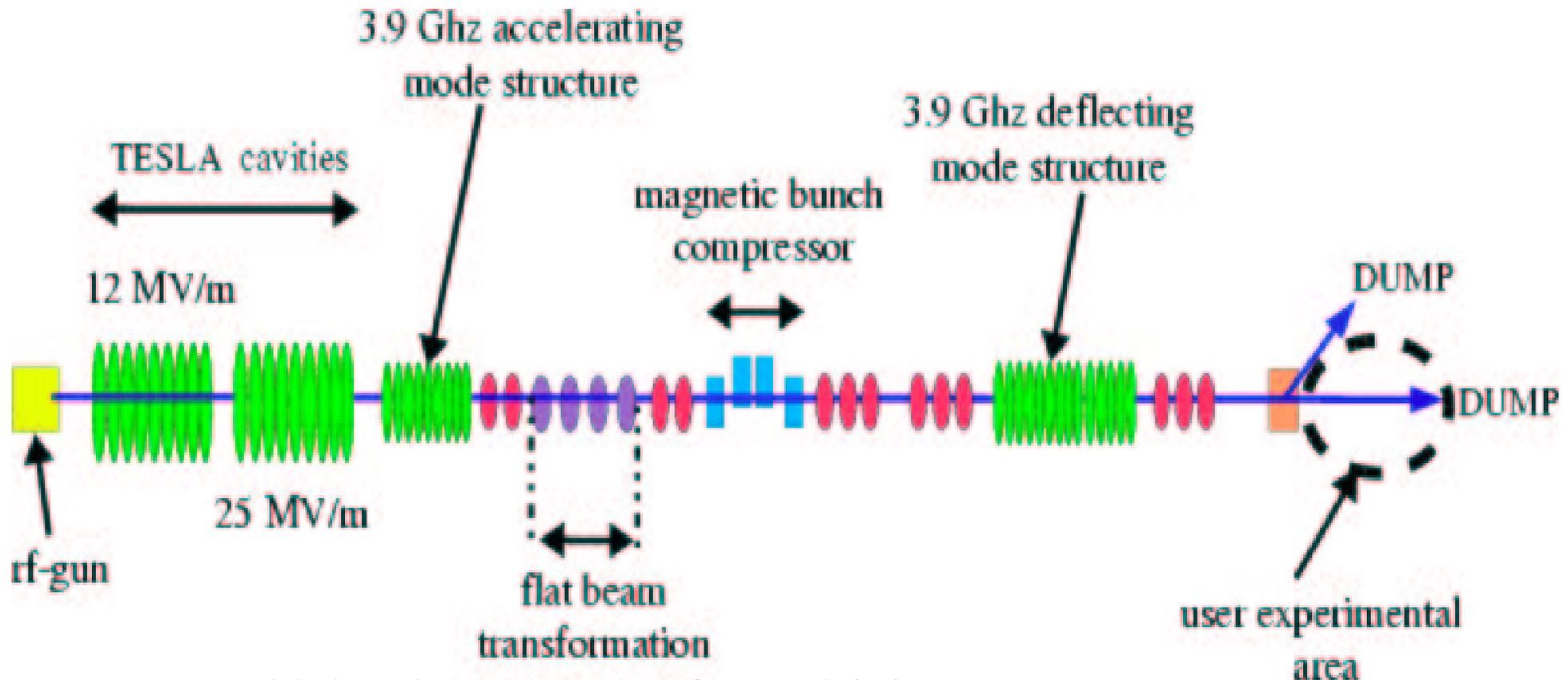
- Proof-of-principle experiment done
- Measured emittance:  $\frac{\epsilon_y}{\epsilon_x} = 45/0.9 \simeq 50$
- Now working toward emittance ratio  $> 100$



SPOT YMS XMS



- 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



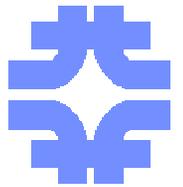
FNPL would then be a 1/4 scale of TTF-2 injector

*P. Piot, AAC workshop (Stony Brook, June 2004)*



# Contributors to the Physics program

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