The Fermilab/NICADD photoinjector laboratory

P. Piot on the behalf of the FNPL team

- **Beam dynamics associated to high-brightness electron beams**
  - beam manipulations: flat beam generation, bunch compression
  - diagnostics R&D
  - polarized rf-gun-based electron sources
- **Advanced accelerator Physics**
  - plasma-based acceleration
  - plasma-based electron source
  - (laser-based acceleration)
- **Future plans**
  - energy upgrade
  - installation of a deflecting and accelerating 3.9 Ghz cavities

More details in this afternoon poster session

NICADD= North Illinois Center for Accelerator and Detector Development

Overview and experimental capabilities

- 16 transverse profiles monitors,
- 3 slit-based emittance measurement stations,
- Streak camera (1 ps resolution),
- 8 electromagnetic beam position monitors,
- Frequency-based bunch length measurement (CTR interferometry),
- Accelerator can be remotely operated (e.g by teams at LBNL, DESY, MSU)

Main beam parameters:

E= 16 MeV

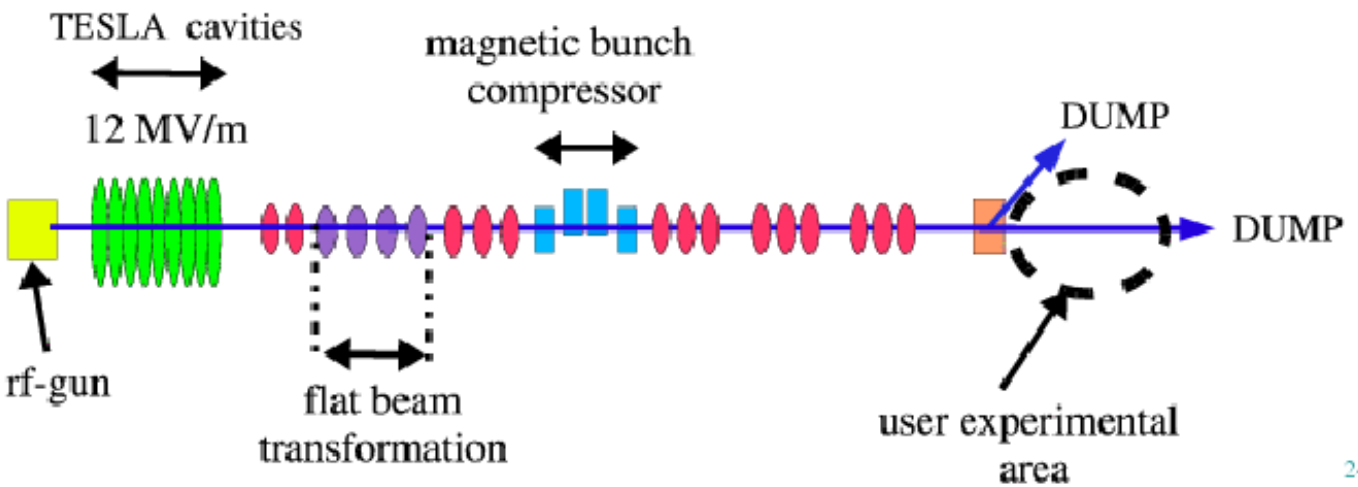
Q= 0 to 20 nC,

ε_T =3.7 mm-mrad (1 nC)

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

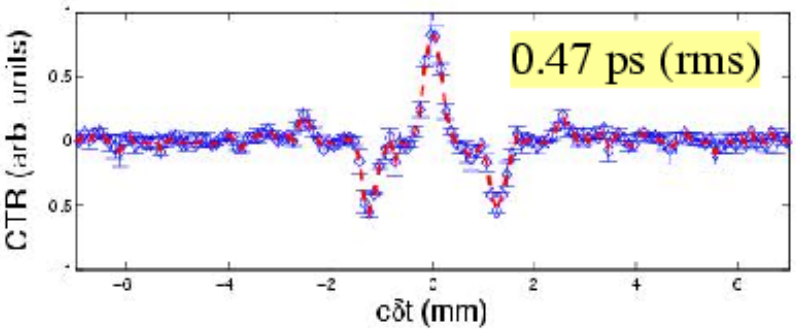
I_{peak} = 75-330 A (BC off)

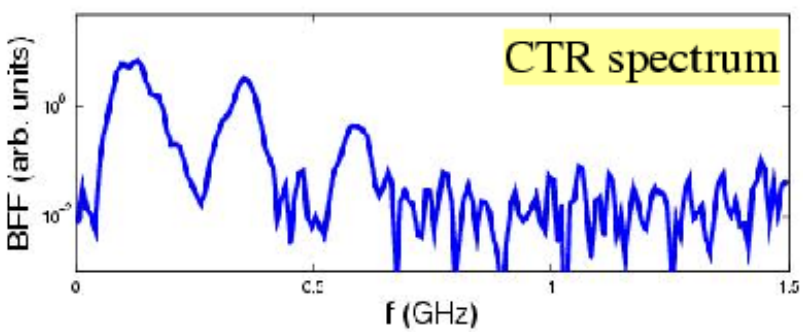
I_{peak} = 200-1700 A (BC on)

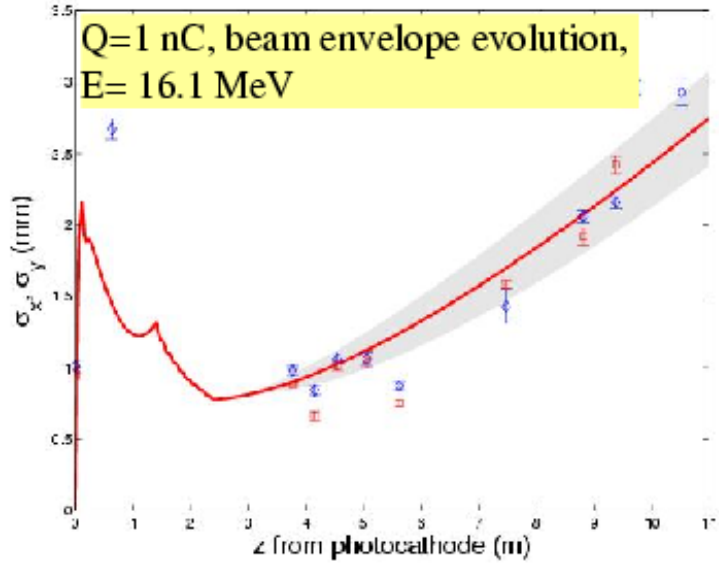


High brightness beam studies and associated diagnostics R&D

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

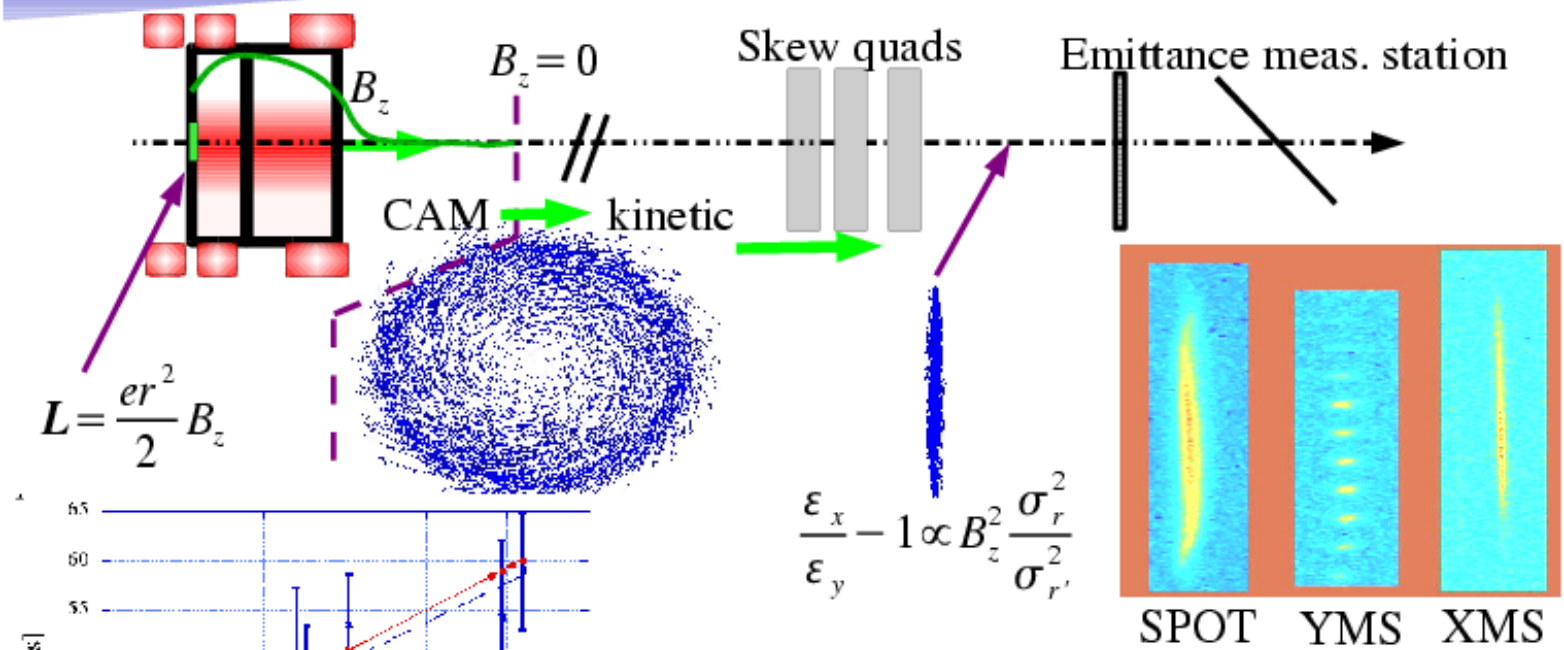


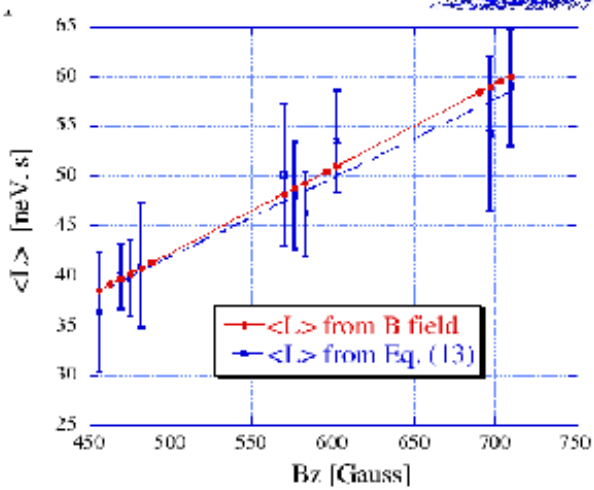




- Bunch length measurement of sub-picosecond electron bunch using frequency-domain technique based on coherent transition radiation
- Future plans include the use of electro-optical sampling for a time-domain bunch length measurements

Photo-injector production of flat beams

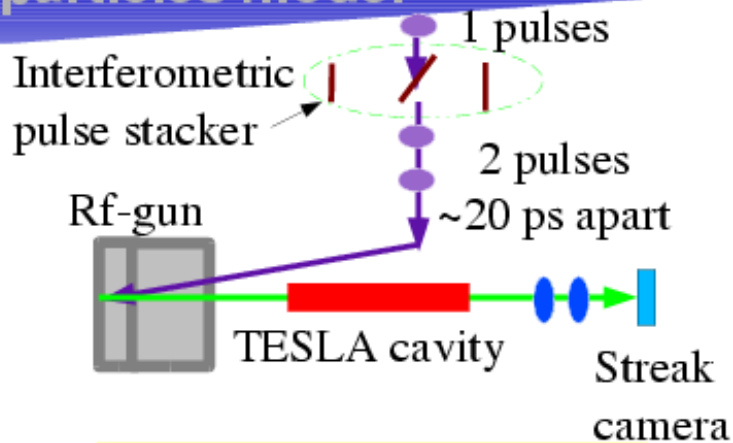




- Proof-of-principle experiment done
- Measured emittance: $\frac{\varepsilon_y}{\varepsilon_x} = 45/0.9 \simeq 50$
- Now working toward emittance ratio > 100

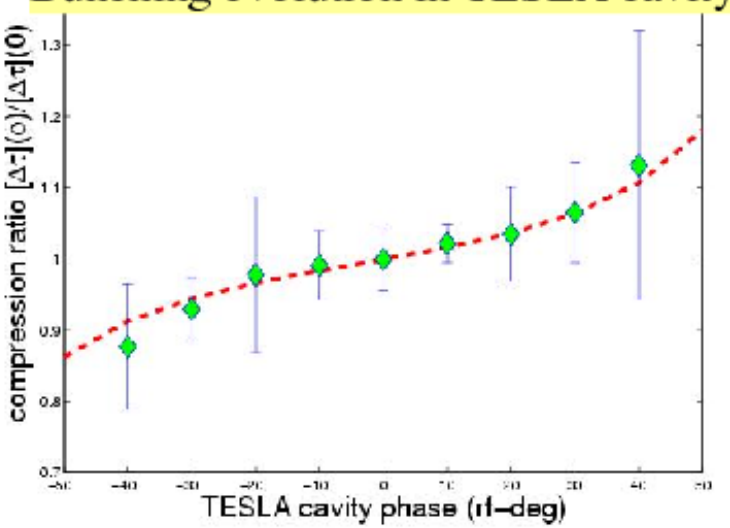
(Grad. Stud. Y.-E. Sun, U of Chicago)

Investigation of longitudinal beam dynamics using a two macro-particles model

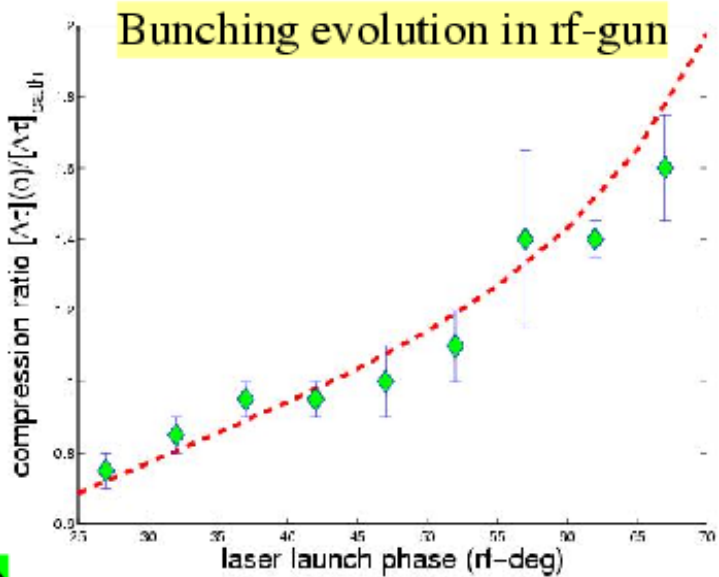


- Develop method to investigate the single-particle dynamics through the linac using two bunches within the same rf-bucket

Bunching evolution in TESLA cavity



Bunching evolution in rf-gun



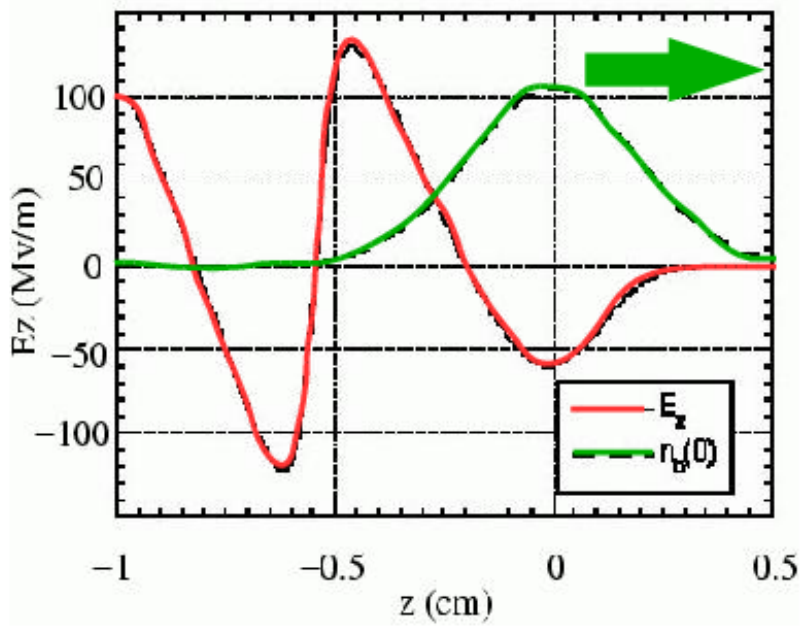
- Later extend to 4 macro-particles, and also study transverse beam dynamics

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

Plasma wakefield acceleration

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

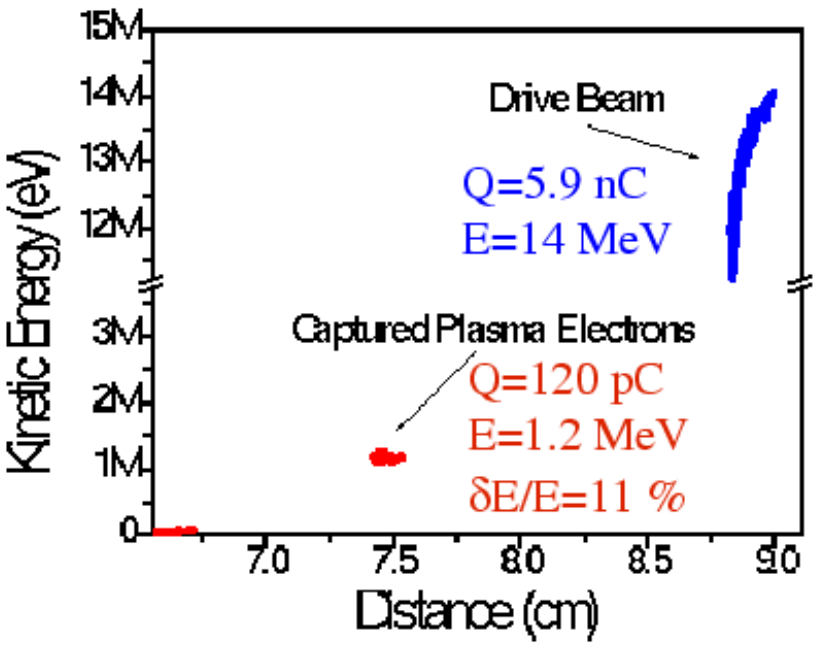
Achieved energy gradient of 130 MeV/m

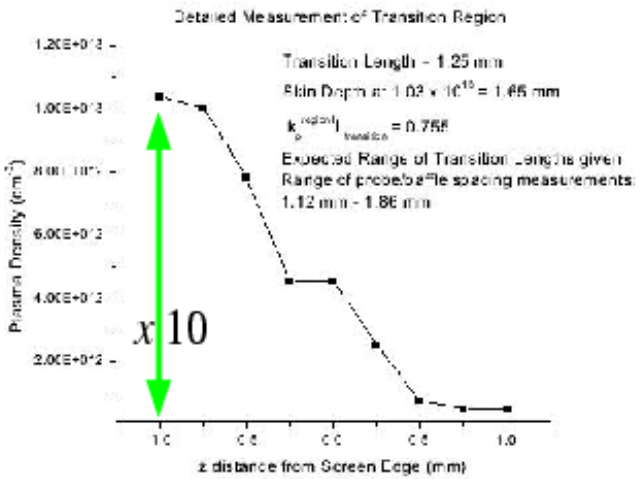


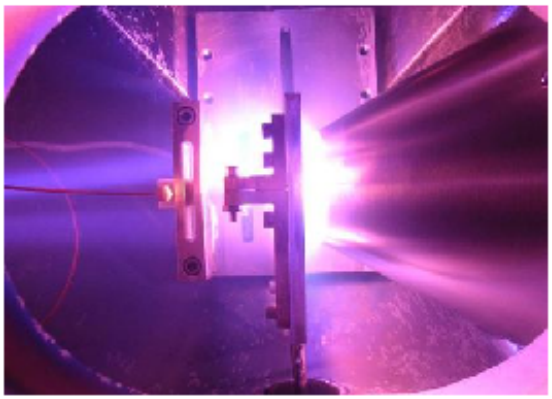
- A next set of experiments aims in sampling the plasma wake using a witness bunch following the drive beam at variable time delays

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



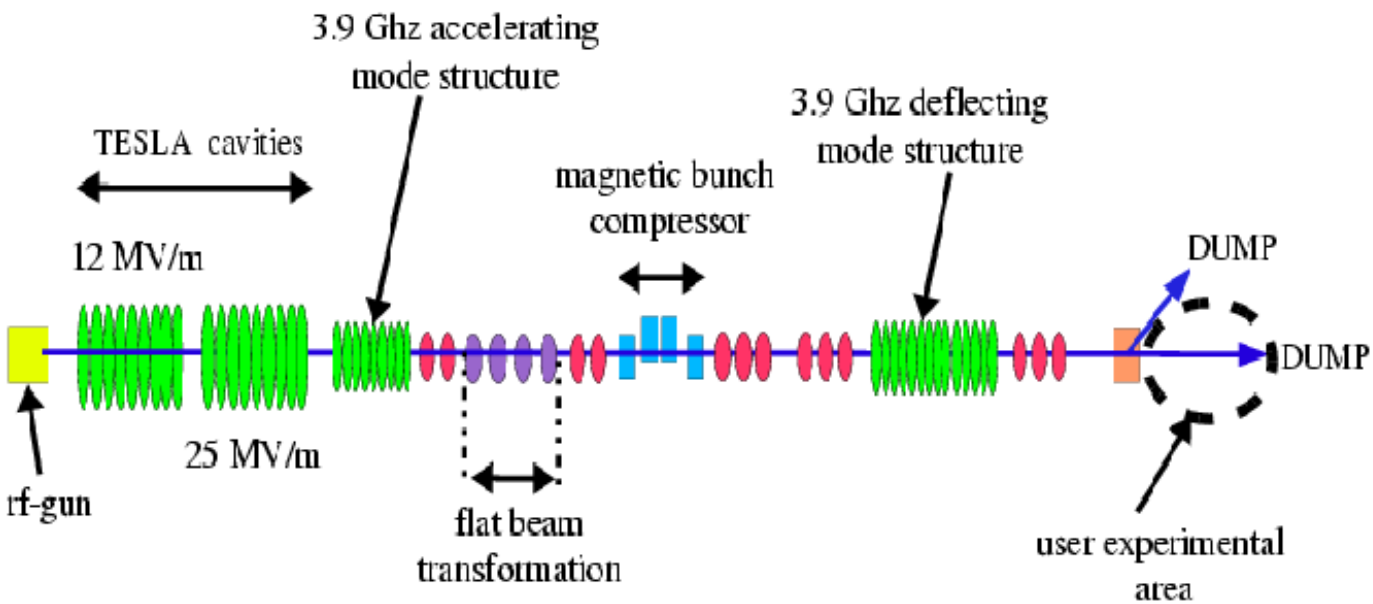




(Grad. Stud. M. Thompson, UCLA)

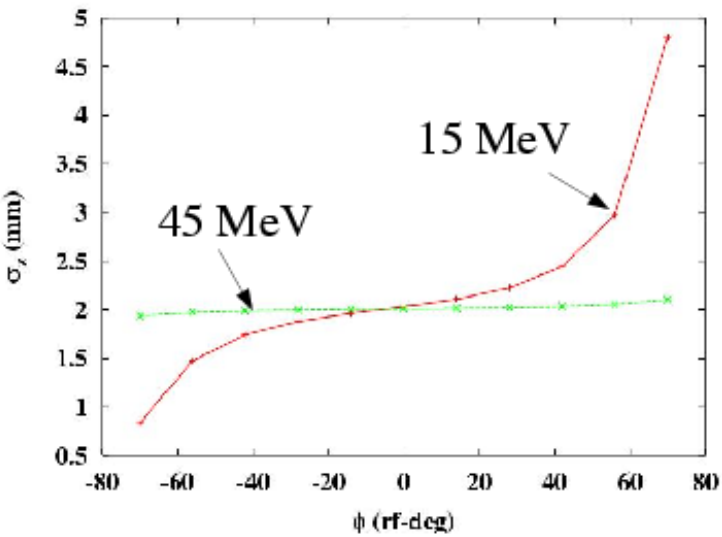
FNPL upgrade

- 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 a 3.9 Ghz accelerating mode cavity both 3.9 Ghz cavities are being developed at FNAL.

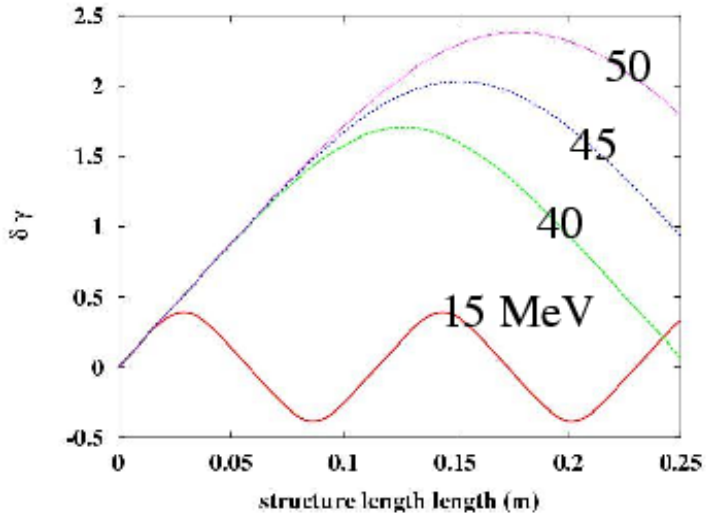


Advantages of a higher energy

- Beam less space-charge-dominated
  - better control of beam envelope
- "Rigid" longitudinal beam dynamics
  - rf-based longitudinal phase space measurements possible



Laser acceleration: energy gain

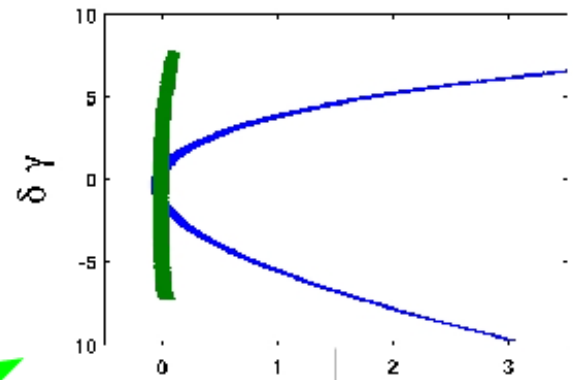


- Laser acceleration experiment:
  - phase slippage between e- and laser field less important

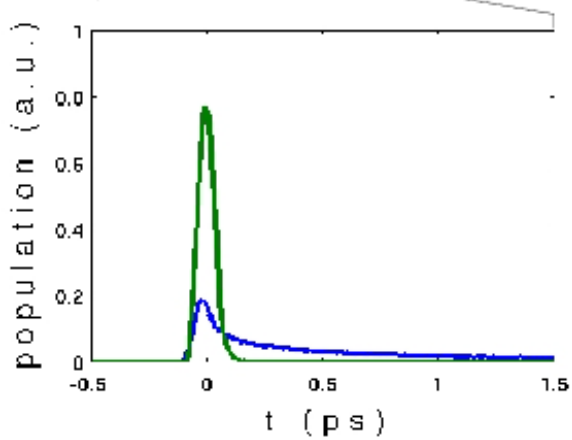
Use of the 3.9 Ghz cavities

- ***Deflecting cavity*** developed for CKM experiment. Other possible applications: crab-crossing technique, rf-separator, and beam diagnostics.
- Installation at FNPL : characterization with beam + provide beam diagnostics.

- ***Accelerating cavity*** used for linearization of the longitudinal phase space to achieve high peak current (applications to LUX proposal at BNL, TESLA VUV/X-Ray FELs, TESLA post-damping ring bunch compressor).
We will be able to test the "linearization" concept at FNPL.



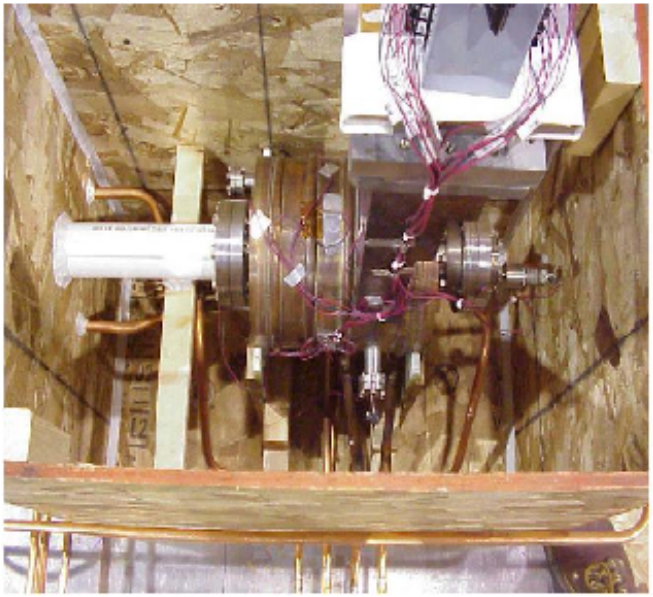
(z,δγ) after magnetic compression

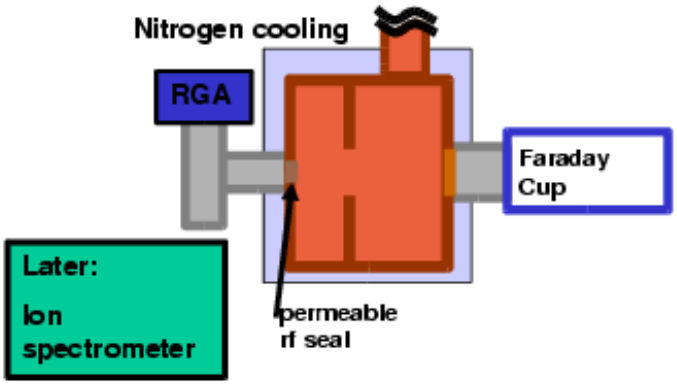


Charge density after compression

R&D for polarized electron source

- To fully take advantage of the possibility to generate flat beams with an rf-gun in LC, demonstration of beam polarization needed
- Polarized e- beams are produced using GaAs photo-cathodes, which requires a high vacuum quality $<10^{-12}$ Torr
- Investigate the use a cryogenic nc cavity to lower equilibrium temperature





- Demonstrate $<10^{-12}$ Torr
- Measure flux and energy of ions and electrons hitting the cathode
- Long term goal being to operate a GaAs cathode in an rf-gun

Our plan with the present set-up

Beam dynamics associated to high brightness e-beams:

- Presently, continue improving the modeling of our experiment (via a series of parametric studies) and our "macroparticle experiment" to study single-particle dynamics
- The flat beam study will resume very soon, with the goal of reaching a transverse emittance ratio of more than 100
- Continue working on instrumentation R&D

Advanced Accelerator Physics:

- The UCLA experiment is on-going, still in the commissioning phase, first results are expected with a few weeks from now
- The NIU/UCLA experiment will then be resumed with emphasis on trying to measure the wakefield dependence using a pump/probe beams set-up

Our plan with the upgraded facility

Beam dynamics associated to high brightness e-beams:

- On-going effort of modeling and understanding the dynamics of space-charge-dominated beam
- Generation of compressed flat beams without spoiling emittance ratio
- Continue working on instrumentation R&D: the deflecting mode cavity will provide a unique diagnostic for probing the time dependence of parameters within the bunch (so-called slice parameters)
- Possibility to demonstrate emittance exchange between the longitudinal plane and one of the transverse plane

Advanced Accelerator Physics:

- Smith-Purcell radiation source (in discussion with Jlab)
- In vacuum laser acceleration using an open-iris structure (laser has been developed at FNPL by collaborator from Rochester)
- Continue/improve plasma wakefield acceleration experiments
- And more fun to come...

The FNPL *Scuderia*

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