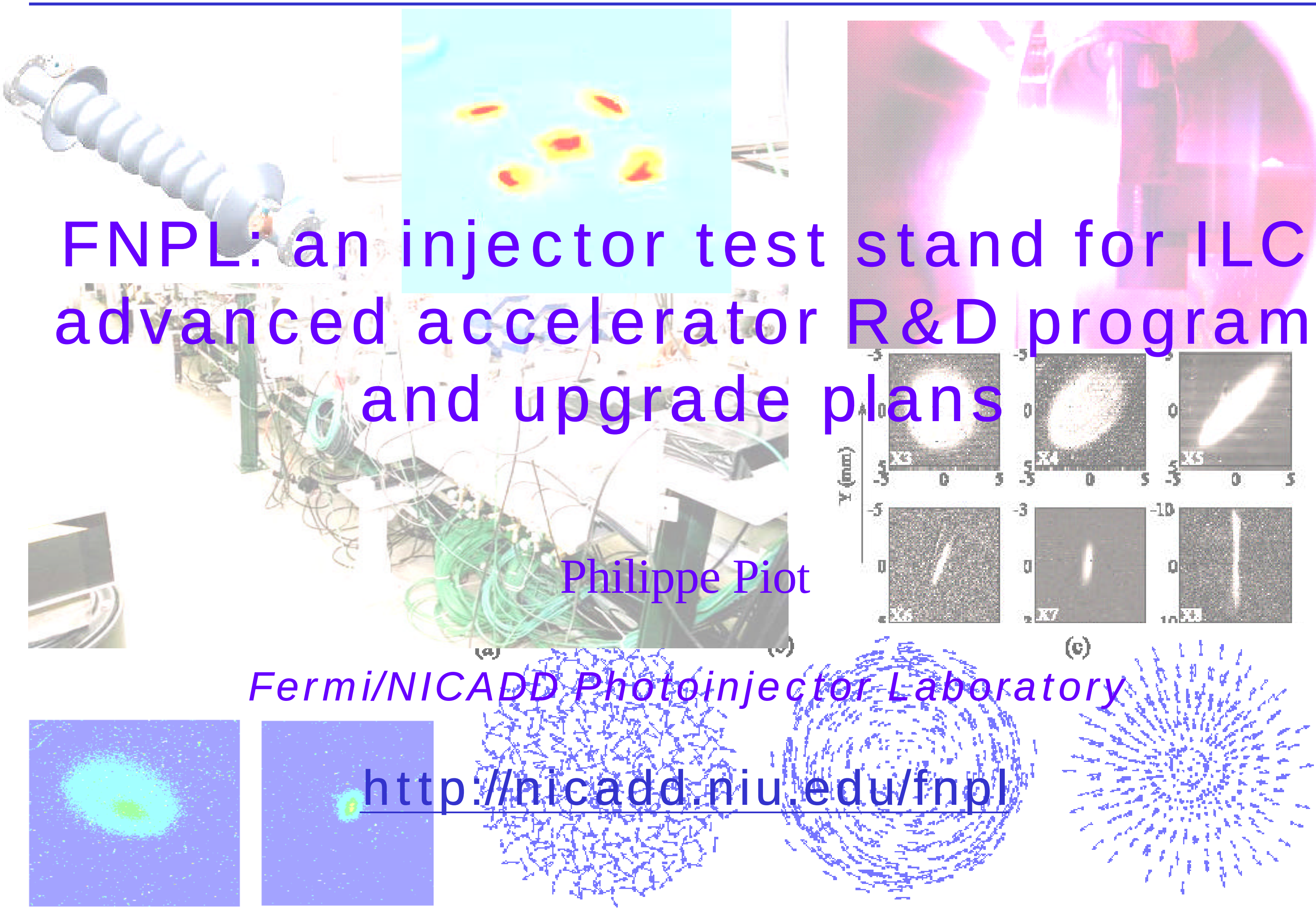
FNPL: an injector test stand for ILC advanced accelerator R&D program and upgrade plans



Philippe Piot

Fermi/NICADD Photoinjector Laboratory

http://nicadd.niu.edu/fnpl

Outline

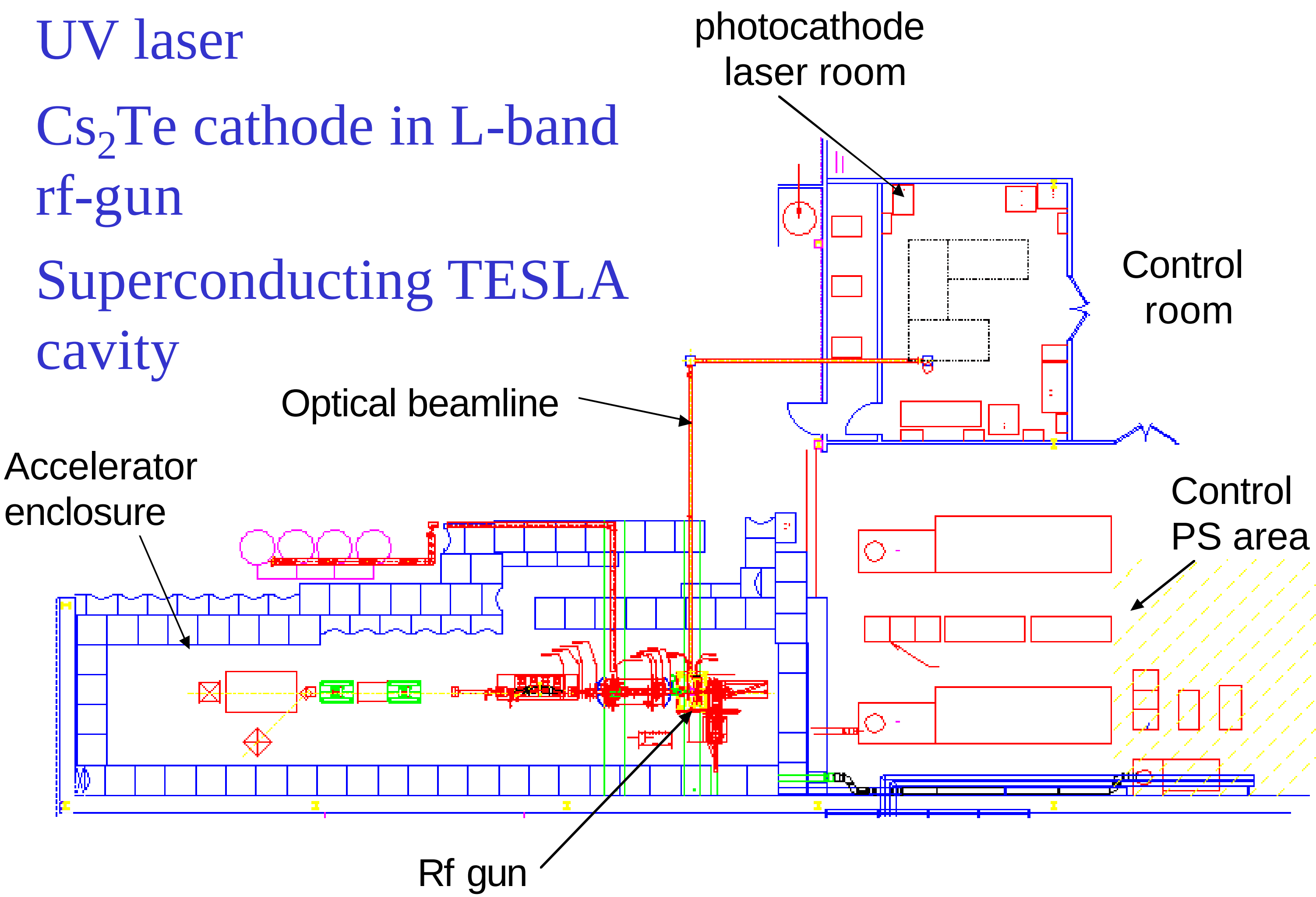
- Introduction
- Present activities:
  - Beam physics
  - Advanced accelerator R&D
  - ILC-related studies
- Upgrade plans
- Conclusions & plans

Introduction

- 2 Injectors built in 1992 by FNAL/DESY with contributions from IN_2P_3 (Orsay), INFN (Milano), UCLA, …
- 1 installed in at DESY TTF-1 (1st POP for UV SASE-FEL)
- 1 installed at FNAL in A0 building: FNPL
- FNPL is used for beam physics and advanced accelerator R&D
- FNPL is foreseen to serve as an e- injector for SMTF

Overview of FNPL infrastructure

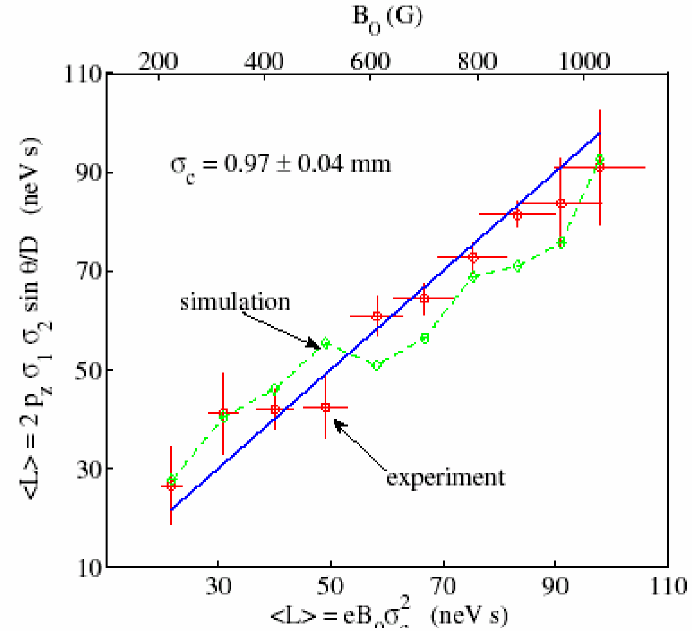
- UV laser
- Cs_2Te cathode in L-band rf-gun
- Superconducting TESLA cavity

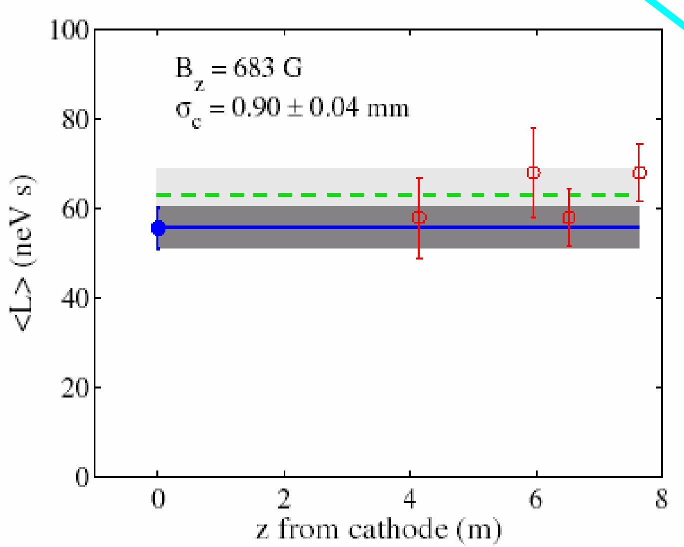


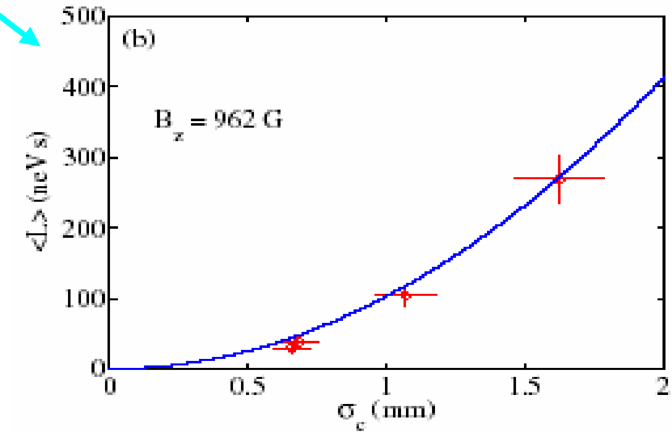
Angular-momentum-dominated beams

- Photoinjector production of AM-dominated beam for e- cooling, flat beam production
- Check scaling law:

$$\langle L \rangle = eB\sigma_c^2$$

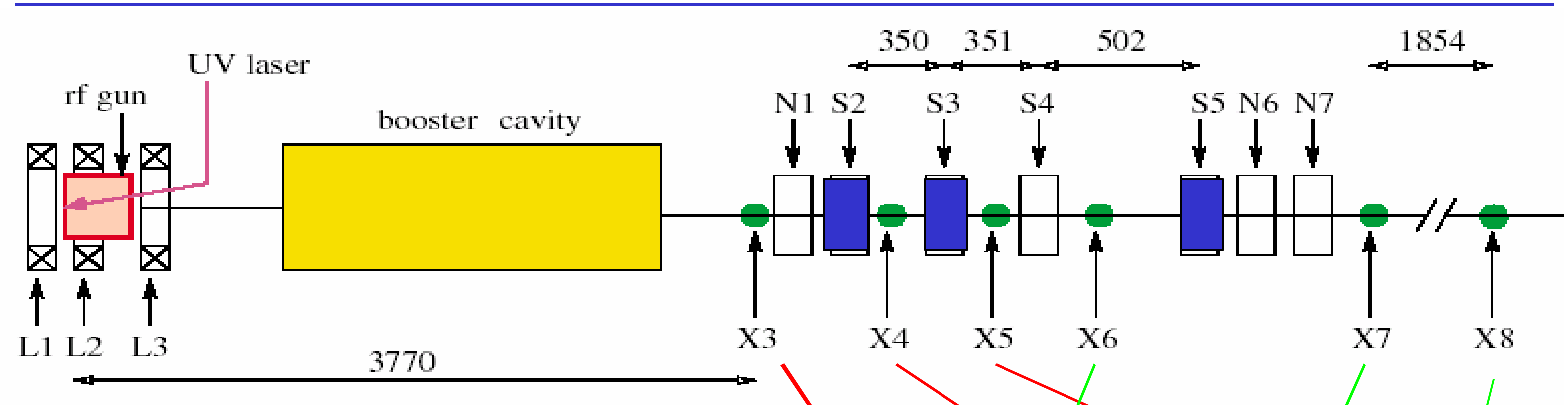




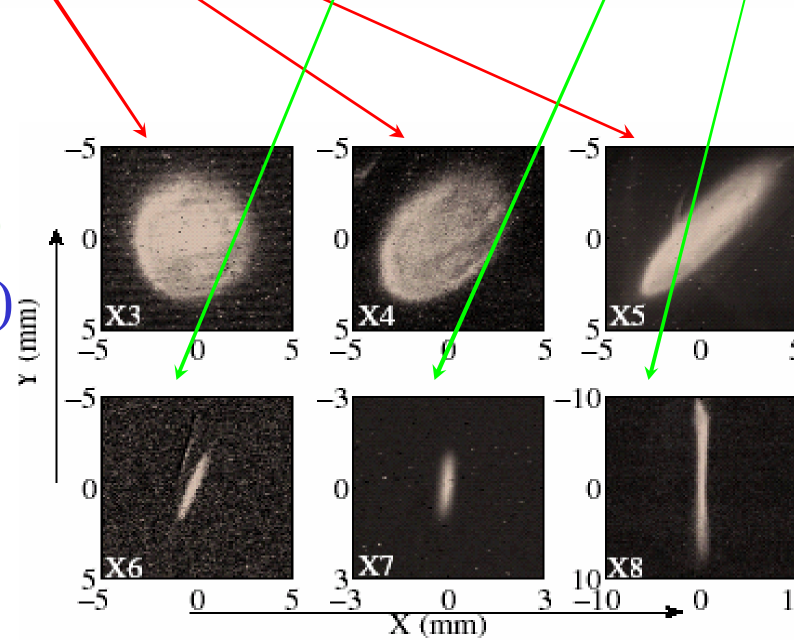


Y.-E Sun et al. (U. of Chicago / FNAL /Berkeley)

Production of flat beams

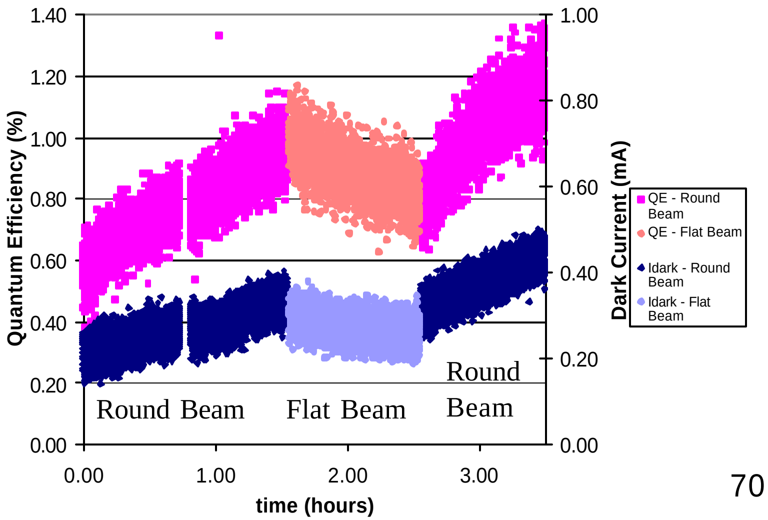


- Use a 3 skew quadrupoles ⇨ torque ⇨ removes L_z
- 1st POP in 99 **(D. Edwards et al)**
- Feb 2005, achieved (95% rms) e_x / e_y = 100±5 (=41/0.41)
- Further optimizations with new photocathode drive laser (using stacked pulses)

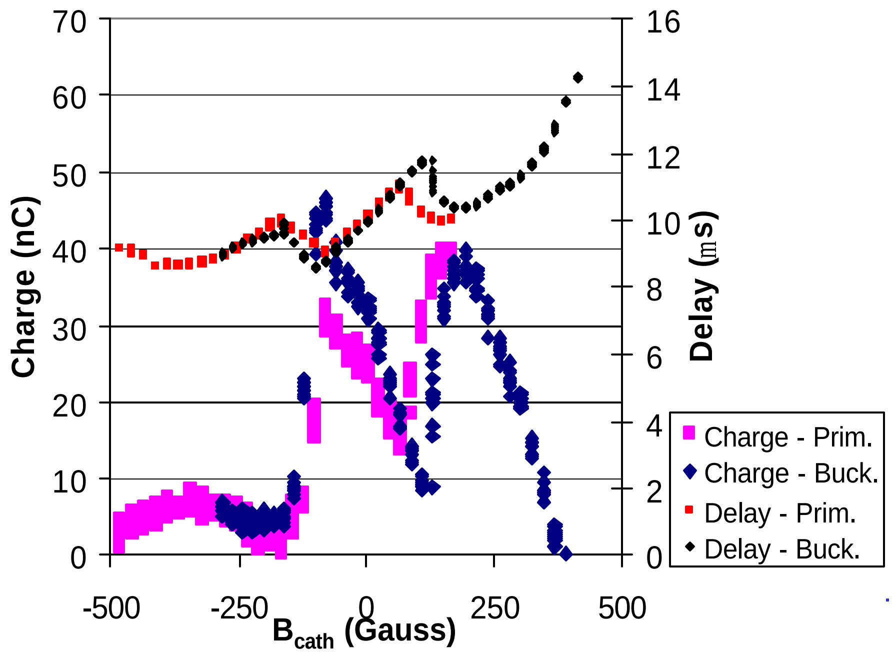


Y.-E Sun et al. (U. of Chicago / FNAL/Berkeley)

Photo-emission & dark current studies



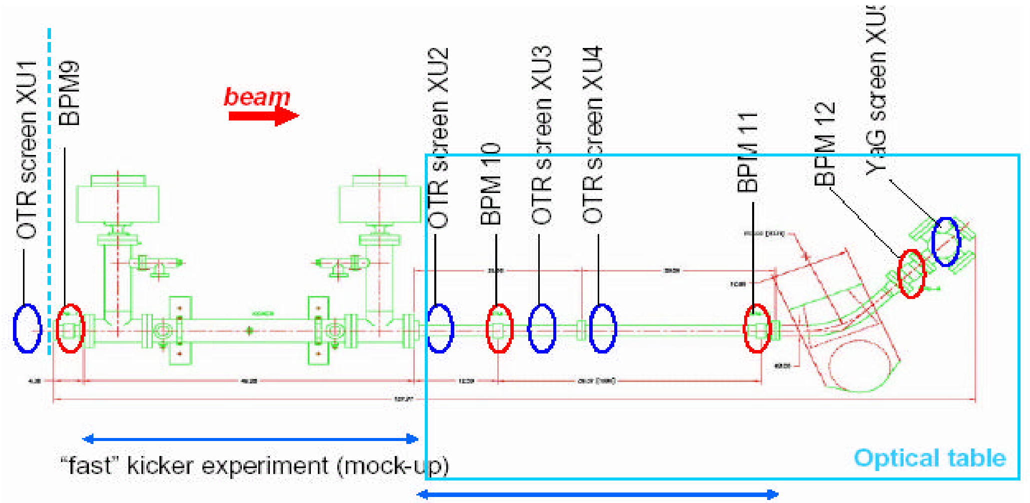
- Dependence of QE and dark current on gun solenoid settings
- QE + dark current increase when B-field on cathode is zero (round beam settings)

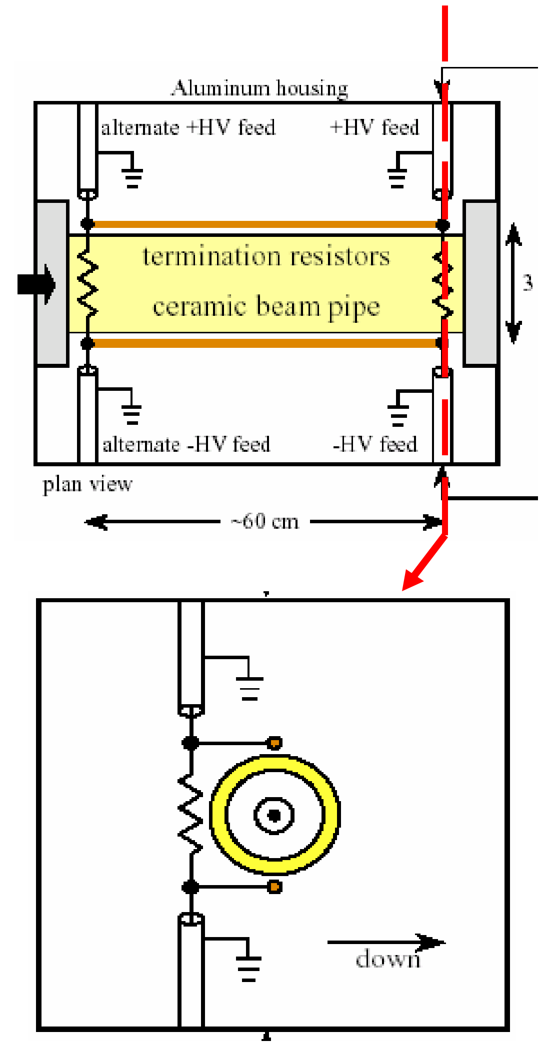


- Intricate relation between observed effects on QE/dark current and rf-multi-pacting during rf pulse turn-on/off

R. Fliller III, W. Hartung (FNAL/MSU)

Fast-kicker tests for ILC damping ring

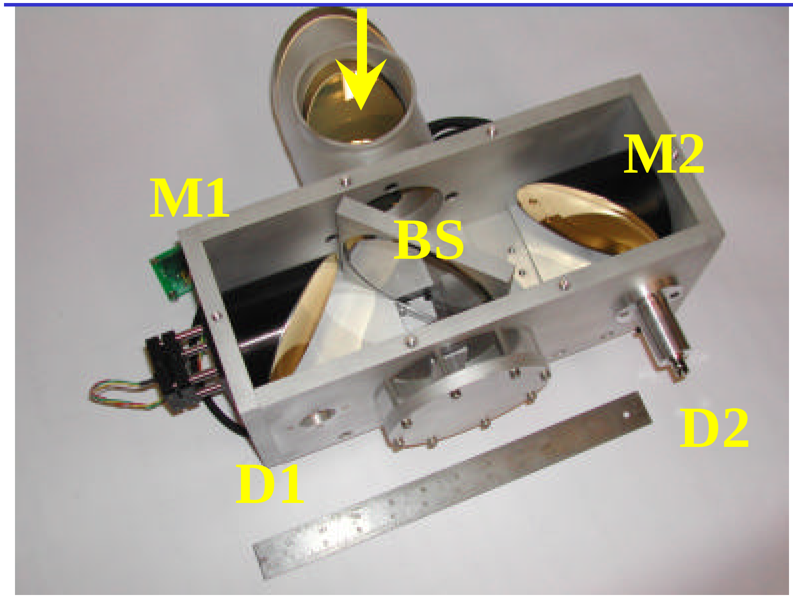


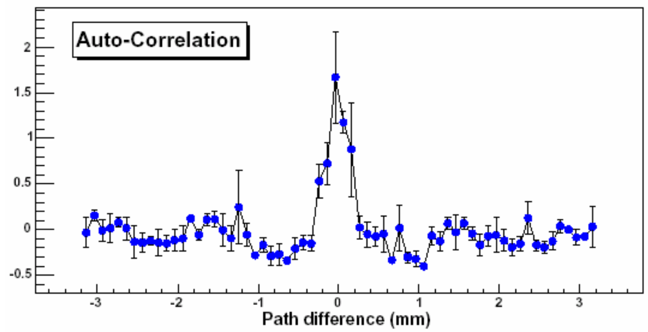


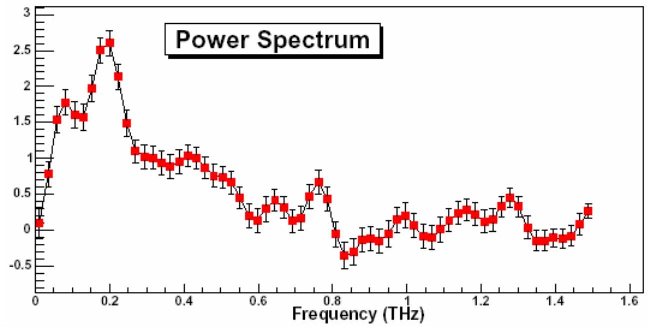
- R&D on fast kicker aimed to shorten ILC damping ring
- Beam-based measurement of kick rising time will be done at FNPL
- Phase I (installed): mockup experiment using transmission-line kicker ⇨ test of pulser + measurement methods
- Phase II: install a prototype fast kicker

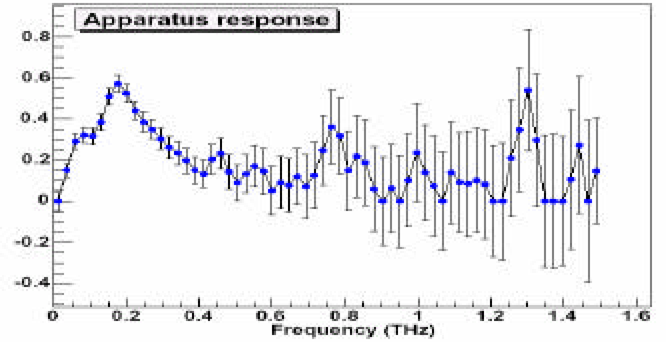
G. Gollin et al. (UI @ Urbana Champaign + FNAL + Cornell)

Bunch-length diagnostics with coherent radiation









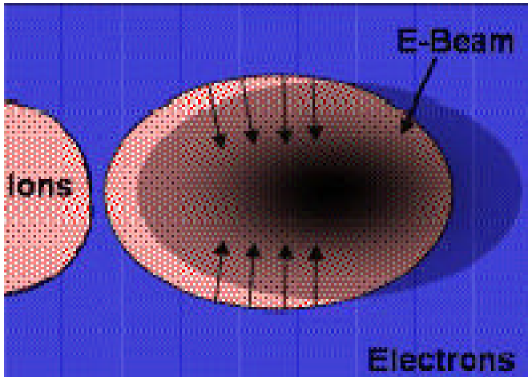
- CTR autocorrelation

$$\frac{d^2W}{dwd\Omega} \propto \left[N + N(N-1)|\Lambda(w)|^2\right]$$

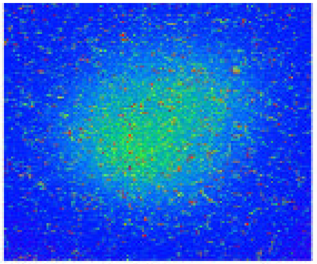
- Many limitations for sub-mm bunch (FIR detectors, diffraction, …) being investigated at FNPL

D. Mihalcea U. Happek et al. (NIU & U. of Georgia)

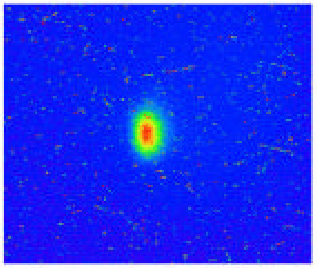
Plasma focusing in under-dense regime



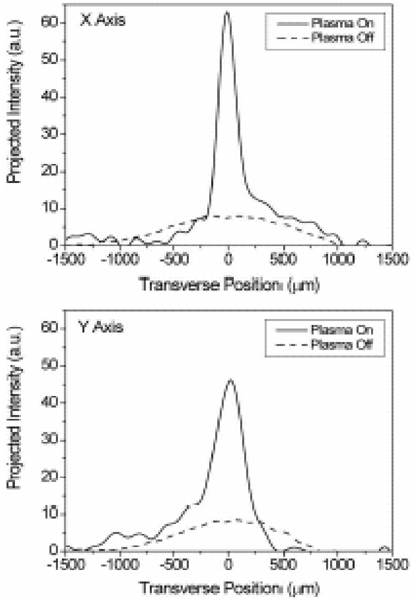
- Uses electrostatic forces to focus beam in both directions
- $B' = \dfrac{e n_p}{2 e_0 c} \approx 3 \times 10^{-11} n_p$ [T/m]
- De-magnified by a factor 22

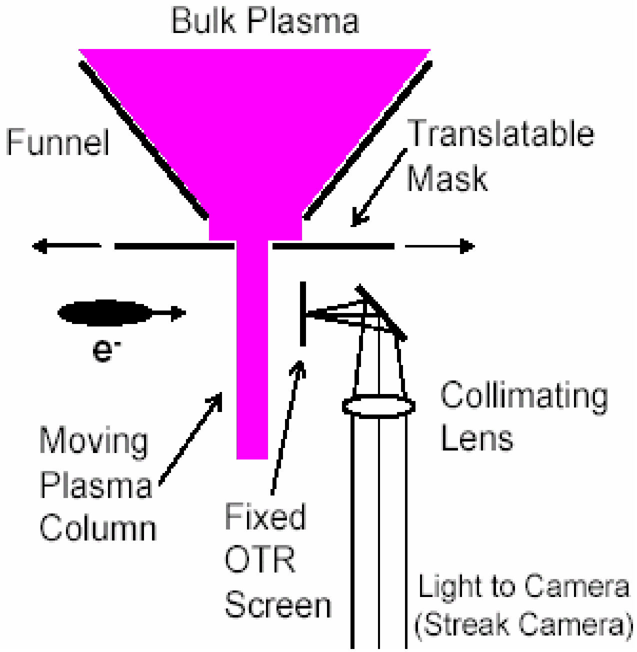


Unfocused - 5 electron pulses



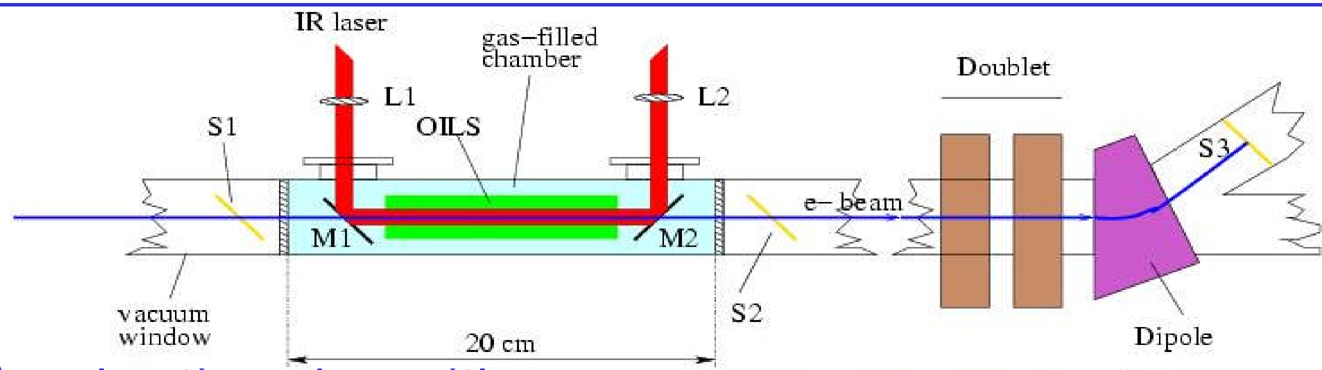
Focused - 1 electron pulse



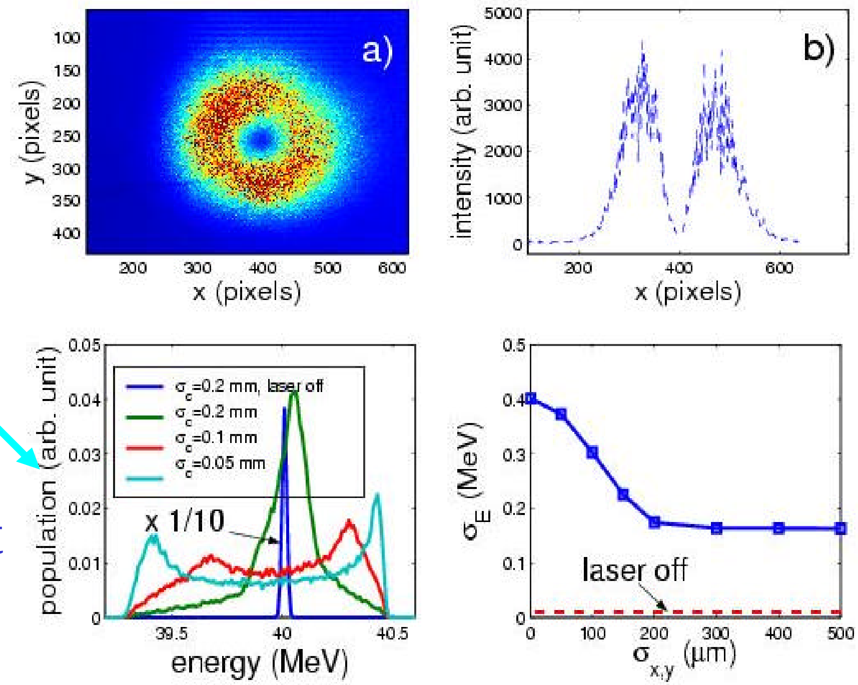


M. Thompson et al. (UCLA)

Inverse Cerenkov acceleration (ICA)



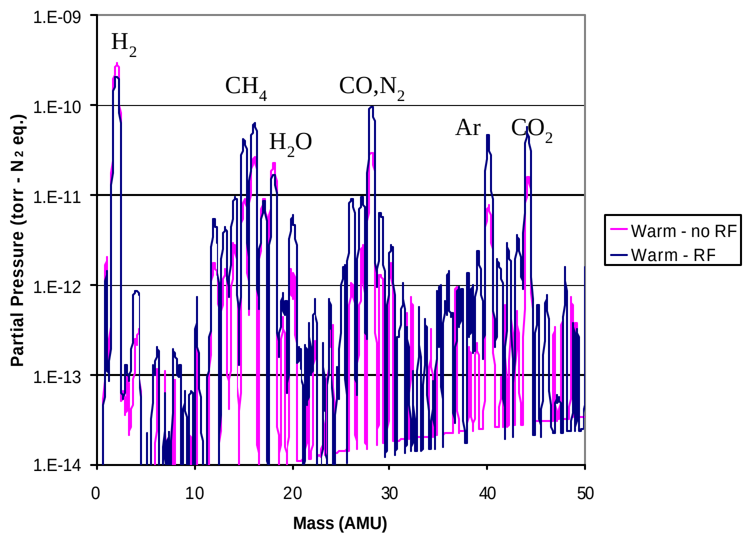
- Acceleration of e- with a radially polarized laser
- Produced TM^{*}_{01} mode
- investigated experiment feasibility at E=40 MeV
- ICA will produce micro-bunched beam at 1 μm
  ⇨ possible use of these short pulses in other experiment
- **Need 40-50 MeV e- beam!**



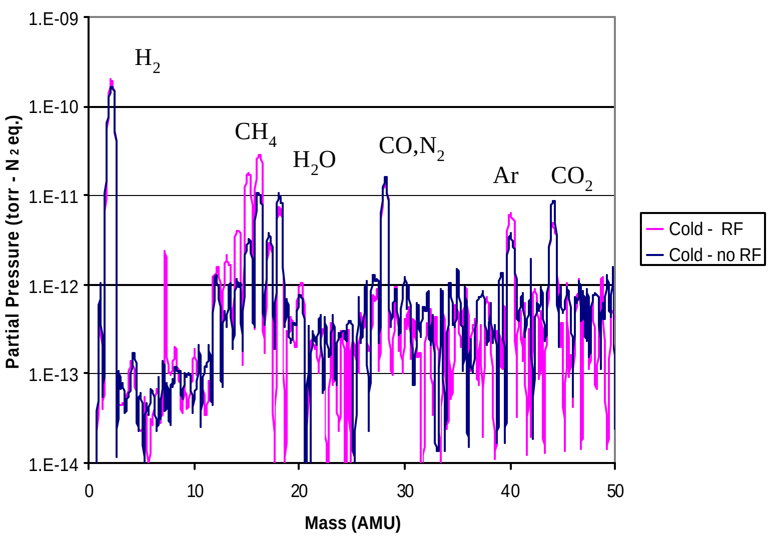
R. Tikhoplav et al. (U. of Rochester / FNAL)

R&D toward polarized e- source for ILC

- Need to operate GaAs cathode in rf-gun
- GaAs requires P~10^{-12} Torr in DC guns
- Cool rf-gun with N_2 to lower equilibrium pressure



An RGA spectrum with and without RF in a room temperature gun. All of the gases in the system, save hydrogen, are outgassed when RF is applied to the gun.

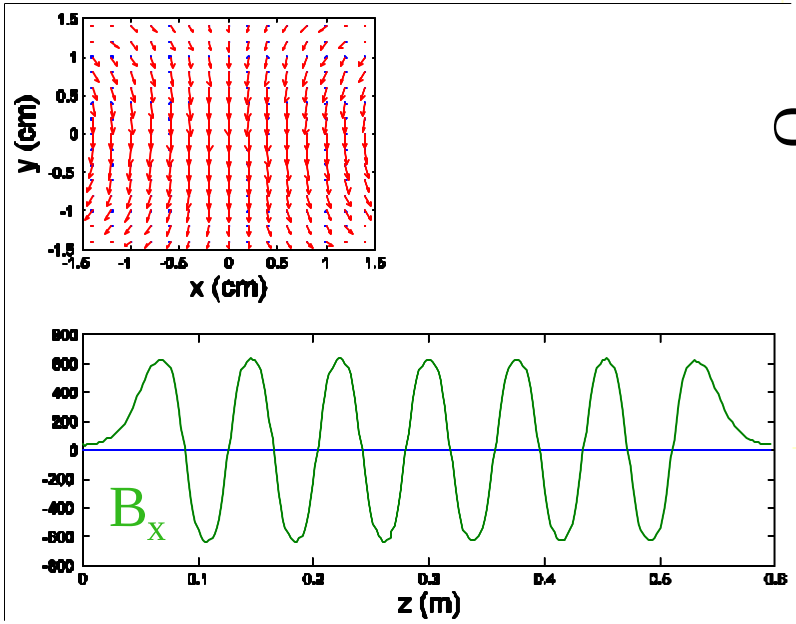


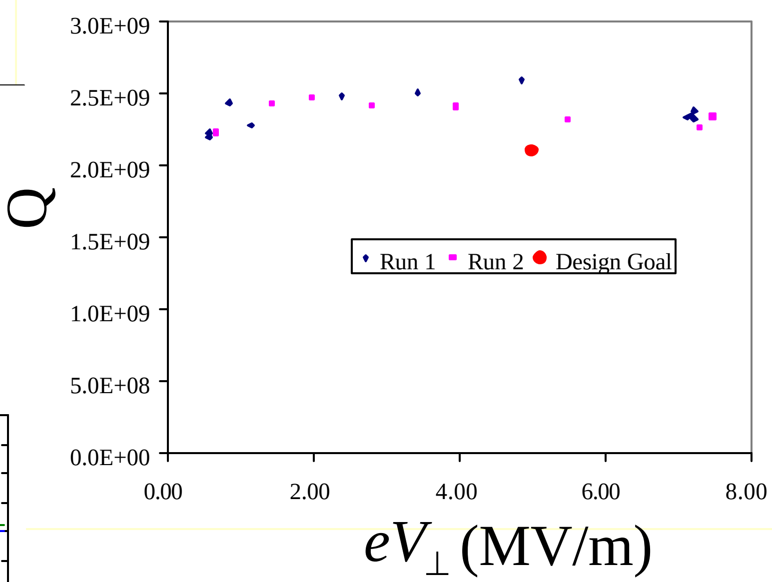
An RGA spectrum with and without RF in a gun cooled to 92 K with liquid Nitrogen. Only methane and argon noticeably increase with RF applied.

R. Fliller III, (FNAL); SBIR with AES

R&D on 3.9 GHz Deflecting cavity

- SCRF TM_{110} mode cavity developed for CKM exp.
- Can be used as bunch length diagnostics
- Crab cavity?



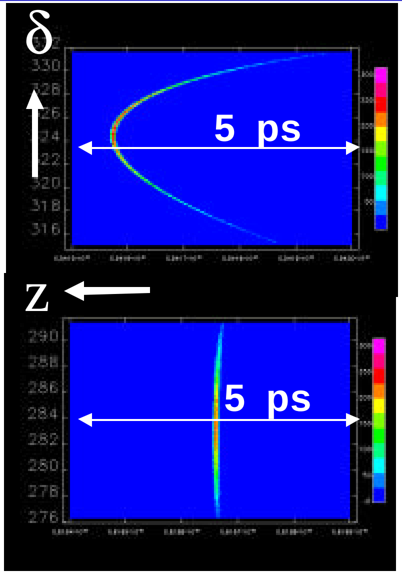


L. Bellantoni, T. Koeth et al. (FNAL/U. of Rutgers)

R&D on 3.9 GHz accelerating mode cavity

- SCRF TM_{010} mode cavity developed for linearization of (z,d)

- Applications to many project: FEL-drivers operating at 1.3 GHz, post damping ring BC for ILC



SOMETHING FROM N. SOLYAK or L. BELLANTONI?

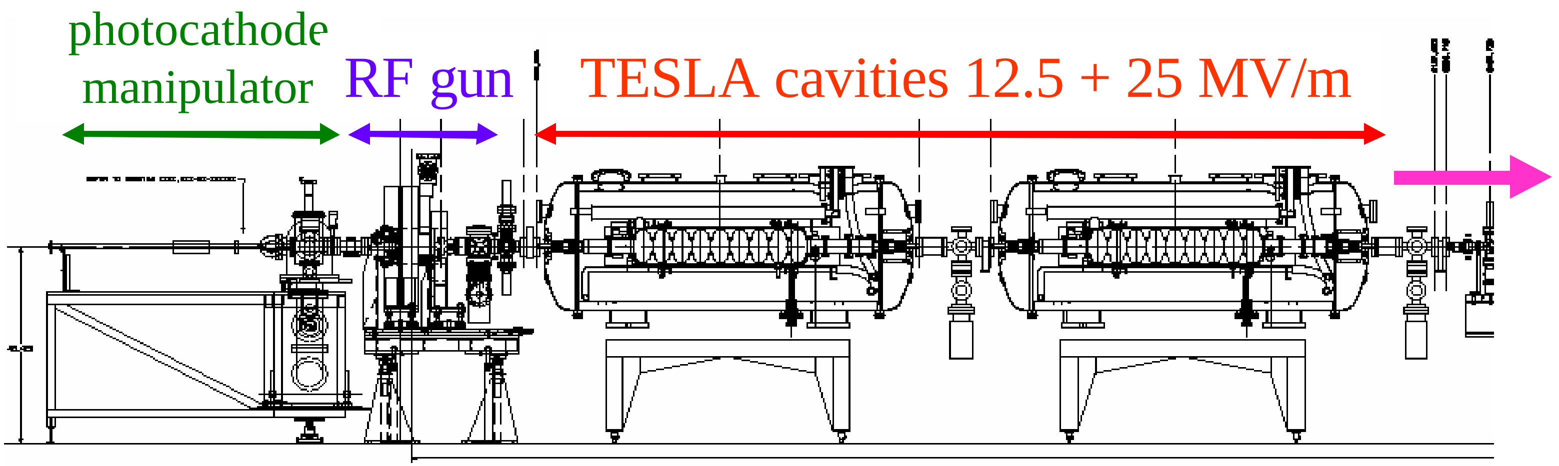
N. Solyak T. khabiboulline et al. (FNAL/DESY)

Upgrade plans for FNPL

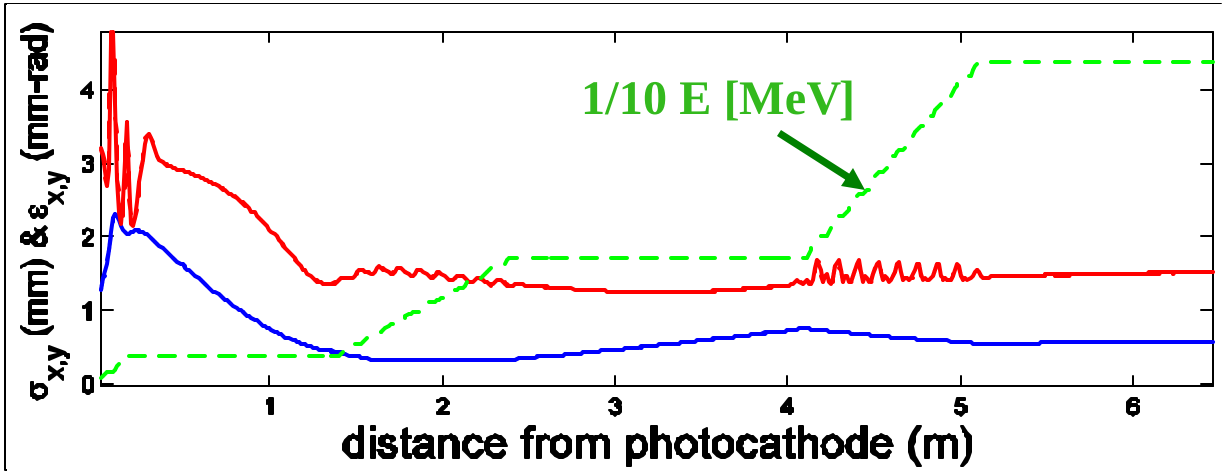
- Main motivation for upgrade: higher energy; beam more rigid + less subject to space charge forces $O(\gamma^{-2})$
- In the upgrade process some problems with the present beamline will be addressed (e.g. bunch compression)
- Recycle present beamline
- Staged upgrade:
  - Phase I (starts in Jan 2006): install 2nd cavity + new downstream beamline that still fits in the present A0 bunker (FNPL upgrade @ A0)
    ⇨ possible test with beam of 3.9 GHz cavities
    ⇨ beam physics
  - Phase II (in SMTF building): re-optimize injector for ILC parameters integrate the two 3.9 GHz cavities in the injector design
    ⇨ continue beam physics and adv. acc. R&D
    ⇨ provide a 40-50 MeV e- injector for SMTF
  - In parallel: continue upgrading the photocathode drive-laser and develop a cylindrical-symmetric rf-gun

Overview of FNPL upgrade @ A0

- Generation and acceleration section

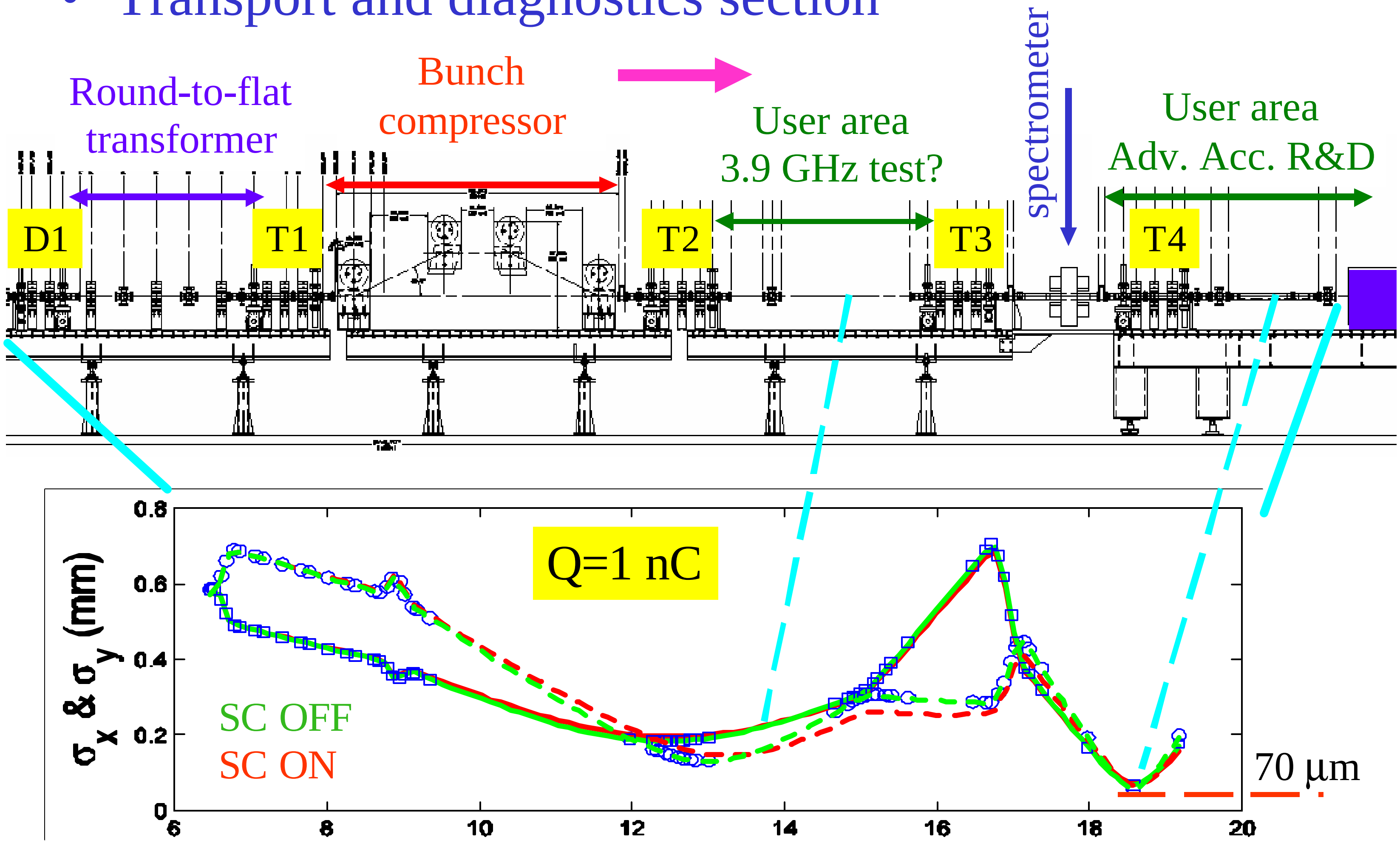


Q=1 nC



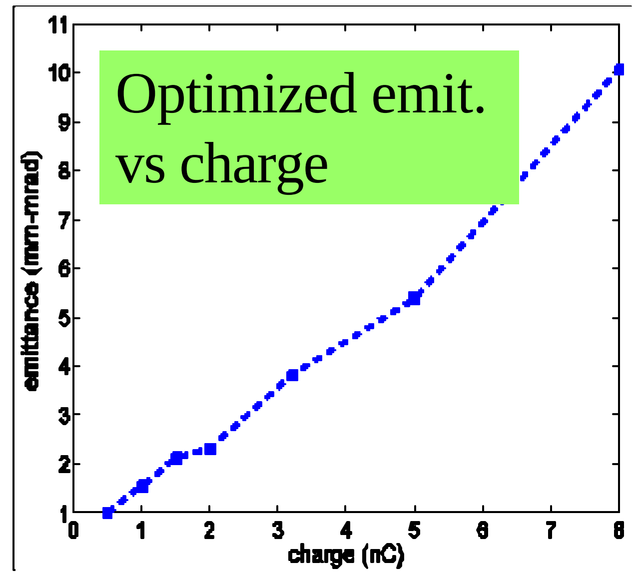
Overview of FNPL upgrade @ A0

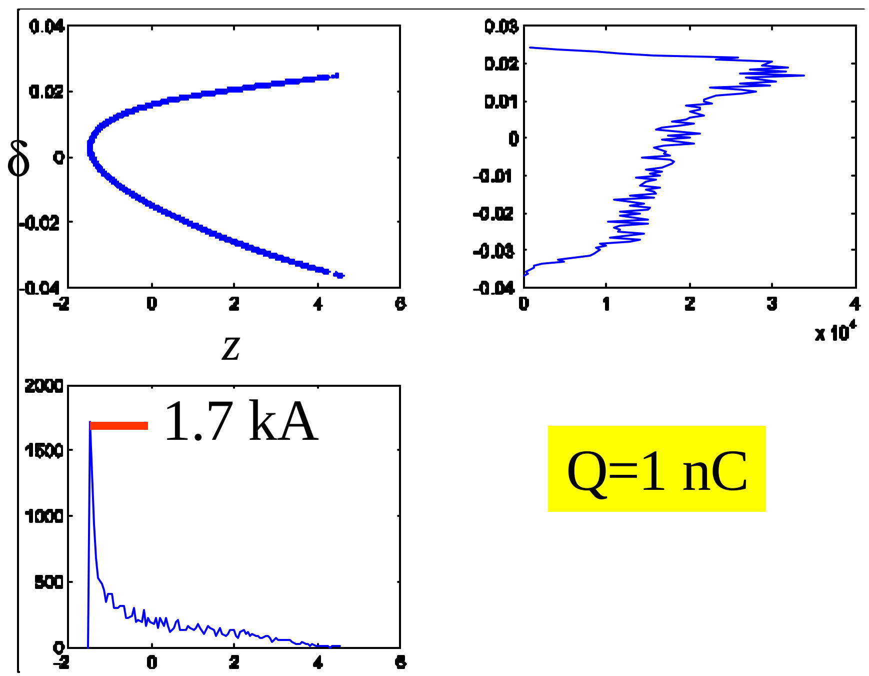
- Transport and diagnostics section



FNPL upgrade @ A0: ILC parameters

- Generation of 3.2 nC with $\gamma\varepsilon$< 5 mm-mrad possible
- Bunch compression ⇨ high $\hat{I}$ ⇨ wakefield, HOM studies

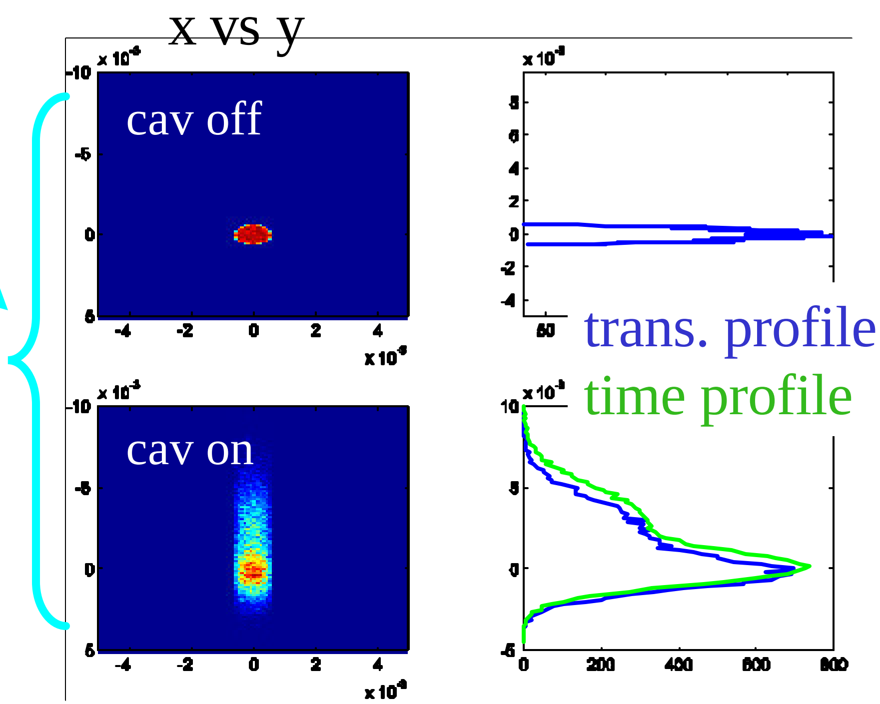




- w/o 3rd harm section (w long cathode laser) BC is nonlinear
- Easy to get σ_t close to ILC specs

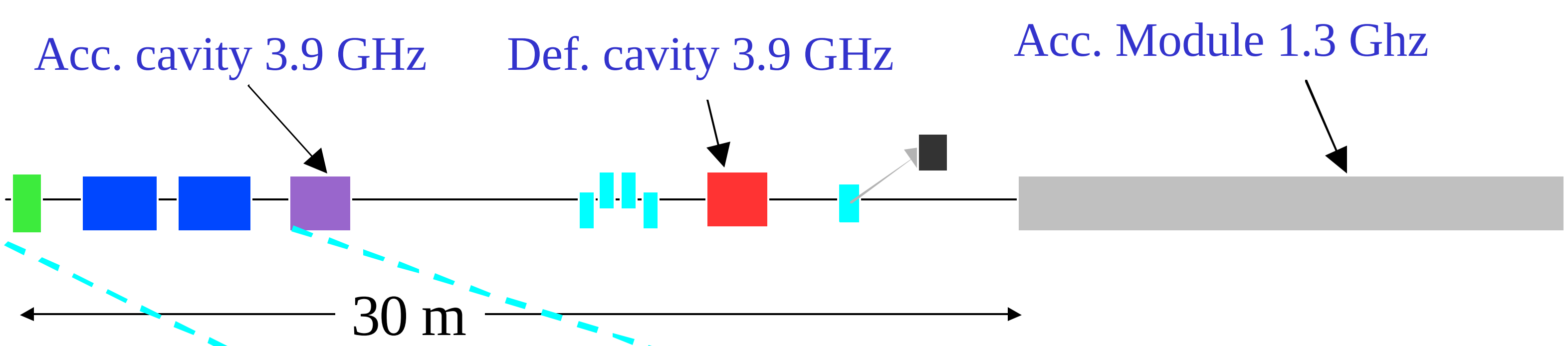
FNPL upgrade @ A0: 3.9 GHz cavities tests

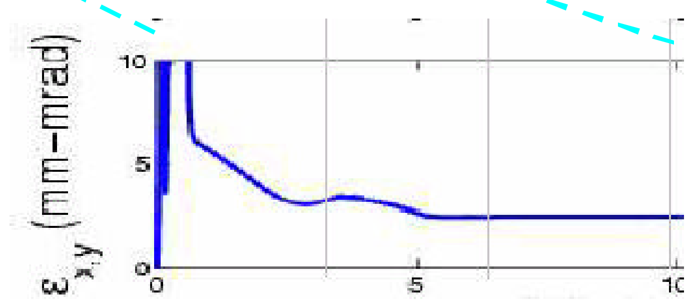
- Ideally would like to install both 3.9 GHz cavities in FNPL; not possible due to space constraints
- But still can do relevant tests for each cavity
- Test of TM_{110} cavity to measure bunch length after BC (simulations using 3D field from HFSS)
- Test of TM_{010} cavity to lower energy spread when 1.3 GHz section operated on crest



Overview of FNPL @ SMTF

- Re-locate FNPL at SMTF location
- re-optimize distance between rf-gun and 1st cavity
- integrate both 3.9 GHz cavities in the accelerator (if proper HOM-damping possible for deflecting cavity)

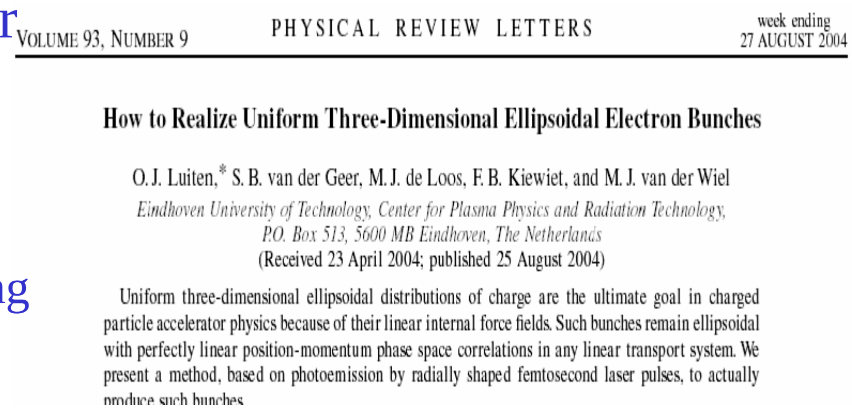




Assumed a flat-top photo-cathode laser
Q=3.2 nC
2.5 mm-mrad

Important needed R&D

- A key component in the injector is the **photocathode laser**
  - new oscillator (diode pumped) installed at FNPL (May 2005)
  - Current work aims at (1) producing uniform time-distribution (2) improving IR? UV quadrupling
  - The amplification chain is obsolete ⇨ upgrade to diode-pumped amplification
- **RF-gun R&D** is needed:
  - cylindrical-symmetric rf-gun (similar to DESY and BESSY)
  - mixed frequency guns (SLAC) [FNPL will have both 1.3 and 3.9 GHz sources]



VOLUME 93, NUMBER 9 PHYSICAL REVIEW LETTERS week ending 27 AUGUST 2004

How to Realize Uniform Three-Dimensional Ellipsoidal Electron Bunches

O. J. Luiten,* S. B. van der Geer, M. J. de Loos, F. B. Kiewiet, and M. J. van der Wiel

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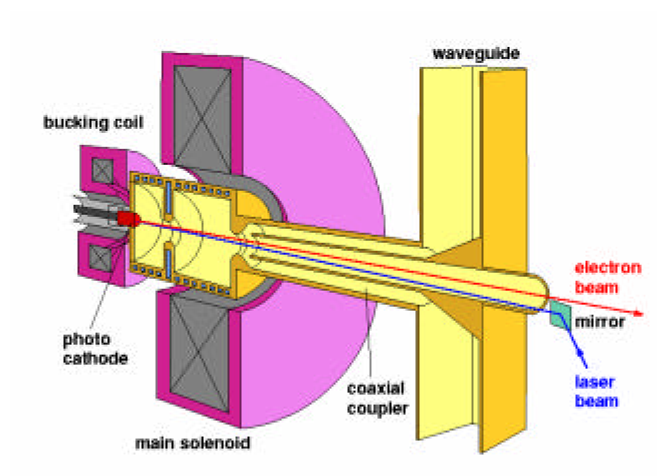
(Received 23 April 2004; published 25 August 2004)

Uniform three-dimensional ellipsoidal distributions of charge are the ultimate goal in charged particle accelerator physics because of their linear internal force fields. Such bunches remain ellipsoidal with perfectly linear position-momentum phase space correlations in any linear transport system. We present a method, based on photoemission by radially shaped femtosecond laser pulses, to actually produce such bunches.



Conclusion +plans

- Continue current activities up to early 2006:
  - Further optimization of flat beam
  - Beam dynamics study of beam parameters for different laser time profile (uniform vs Gaussian)
  - New diagnostics: OTRI, test of new OTR radiator, TOF measurements, EO-imaging
- Early 2006 install 2nd cavity
  - optimize beam parameters at 40-50 MeV
  - HOM measurements?
  - Laser acceleration experiment in user area?
- Later in 2006:
  - Modify bunch compressor
  - install CKM cavity (need 3.9 GHz rf-system integrated)