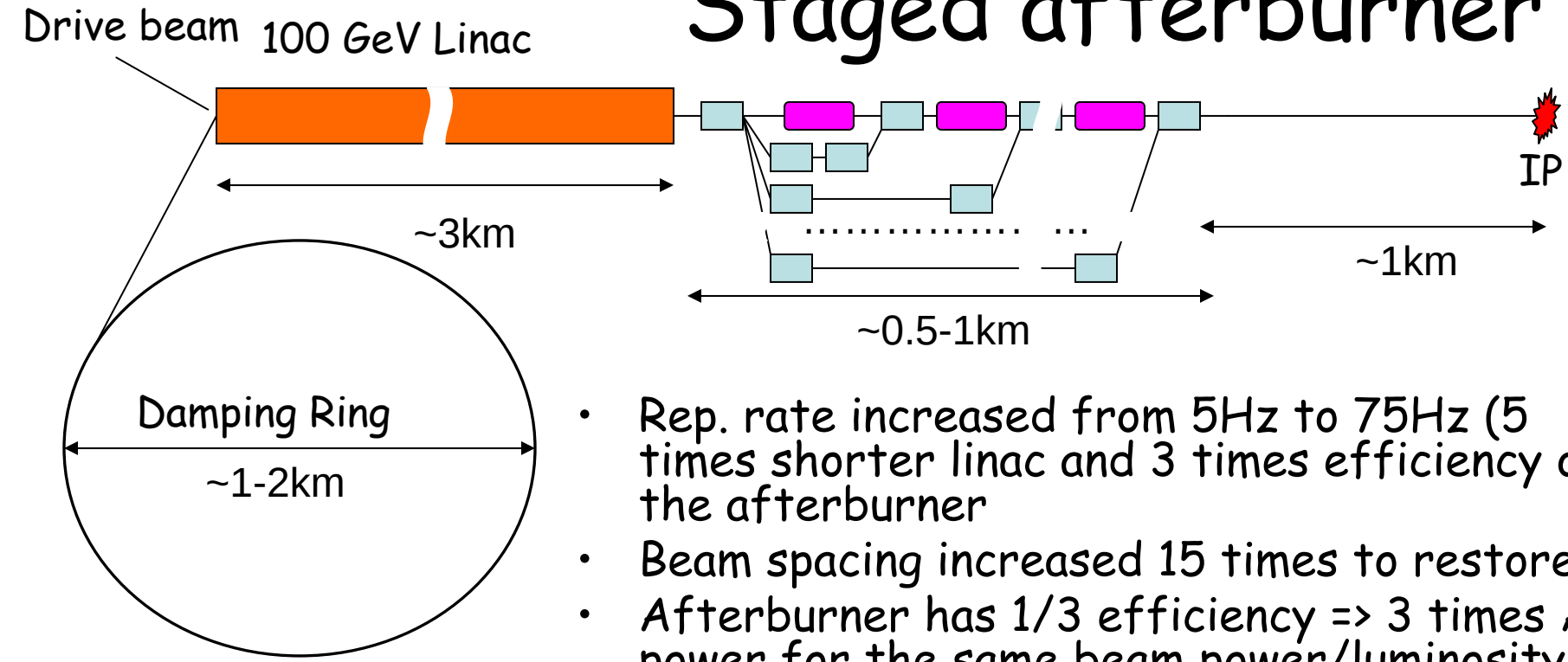
Working Group 4: e-Beam Driven Accelerators

Group-Leaders: V. Yakimenko (BNL), R. Ischebeck (SLAC)

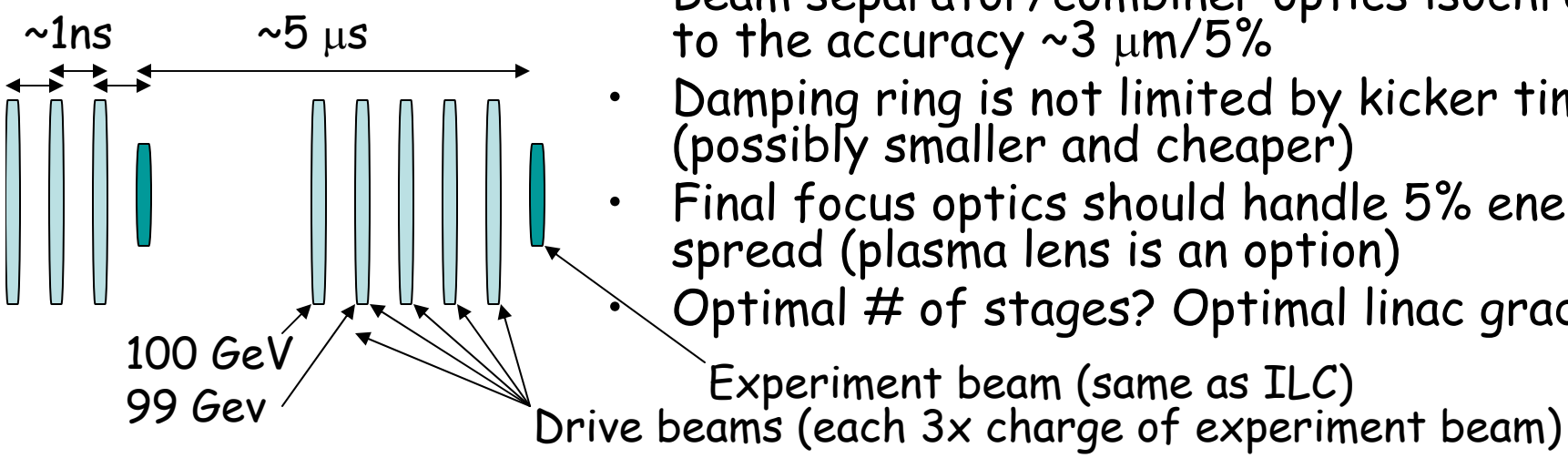
Staging of PWFA to produce 1 TeV c.m.

- (AAC2004 proposal:) Use energy doubler: 250 GeV -> 500 GeV
- Start with 100 GeV beam, go to 500 GeV in four to five stages
  - Similar to what was demonstrated by E-167
- Go from 100 to 500 GeV with a shaped beam in one step
  - Relies on higher transformer ratio
  - Needs experimental verification
  - Use multiple beams to replace shaped beam?
- Advantages of multiple stages
  - No head erosion
  - Circumvent hosing
    - Chengkun's simulation
  - Feedback and control
- Advantages of single stage
  - Simpler synchronization
  - Shorter, no need for isochronous beam splitters/combiners

Staged afterburner



- Rep. rate increased from 5Hz to 75Hz (5 times shorter linac and 3 times efficiency of the afterburner
- Beam spacing increased 15 times to restore RF
- Afterburner has 1/3 efficiency => 3 times AC power for the same beam power/luminosity
- Beam separator/combiner optics isochronous to the accuracy ~3 μm/5%
- Damping ring is not limited by kicker timing (possibly smaller and cheaper)
- Final focus optics should handle 5% energy spread (plasma lens is an option)
- Optimal # of stages? Optimal linac gradient?



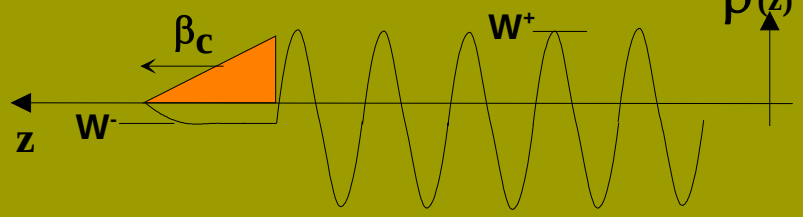
Alexei Kanareykin, Transformer Ratio Experiment

Pulse Shaping and Bunch Train

Dielectric tube

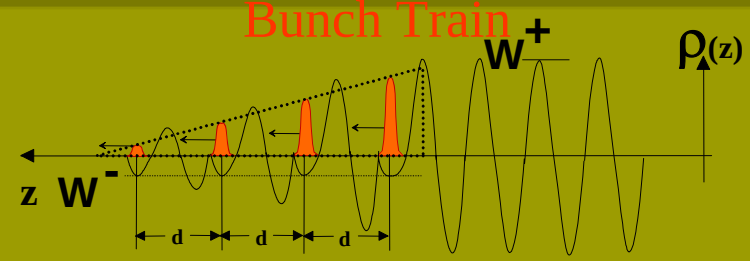
Copper housing

Scheme I---Single Ramped (Triangular) Bunch



Reference: Bane et. al., IEEE Trans. Nucl. Sci. NS-32, 3524 (1985)

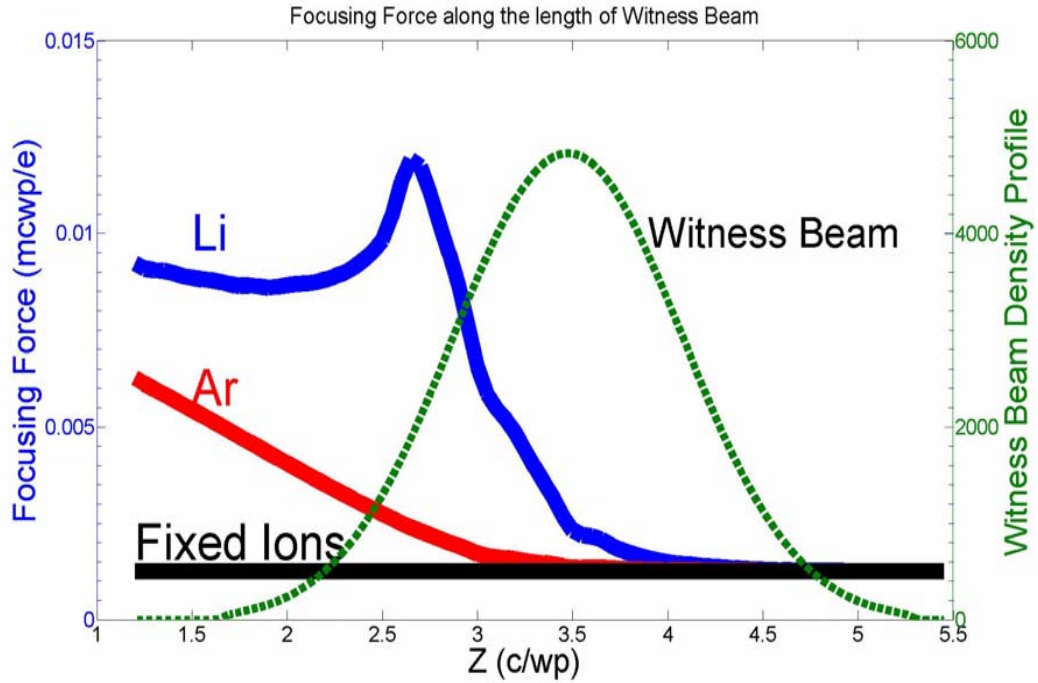
Scheme II---Ramped Bunch Train



Reference: Schutt et. al., Nor Ambred, Armenia, (1989)

E-Tech

Ion Motion Jamie Rosenzweig, Reza Gholizadeh



- The witness beam in the ILC design is so dense that ions collapse completely on the time scale of the beam
- A simple extension of the SLAC experiment is not applicable.

- While Lithium completely collapses before it reaches the tail, Argon's increase in Focusing Force is still acceptable

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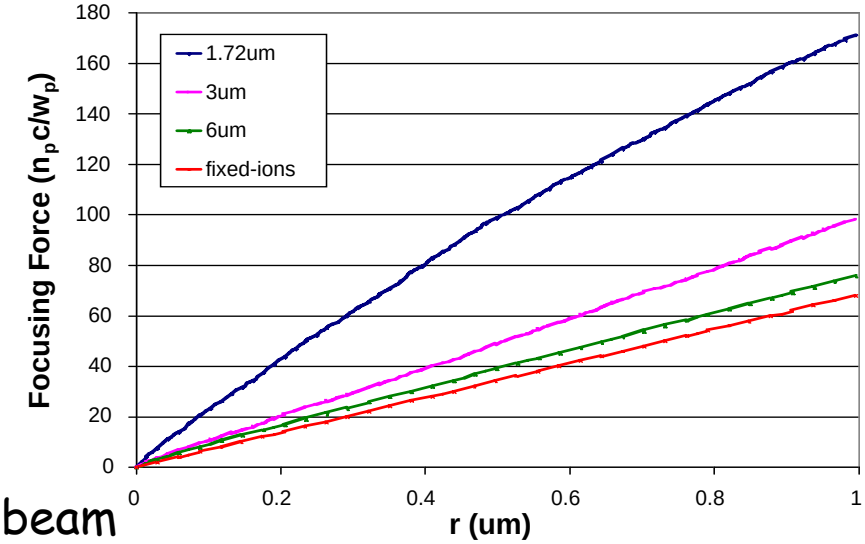
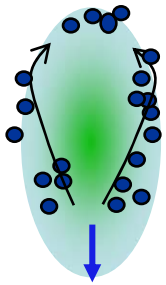
Ion Motion



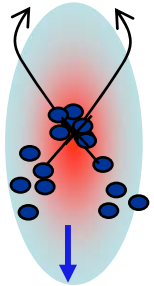
- Look into
  - Synchrotron radiation
  - Multiple ionization
  - Nuclear scattering
- Solutions
  - Larger emittance of the drive beam
  - Are there better knobs?
    - Larger mass (*A*) ions?
  - More revolutionary directions
    - Hollow plasma fiber (already needed for positrons)
    - Try vastly different beam parameters?
      - Scaling is "unnatural", beam charge too big? We need to look…
- **Might need completely different LC-consistent parameter set**

Chris Clayton: Differences between Electron and Positron Wakes

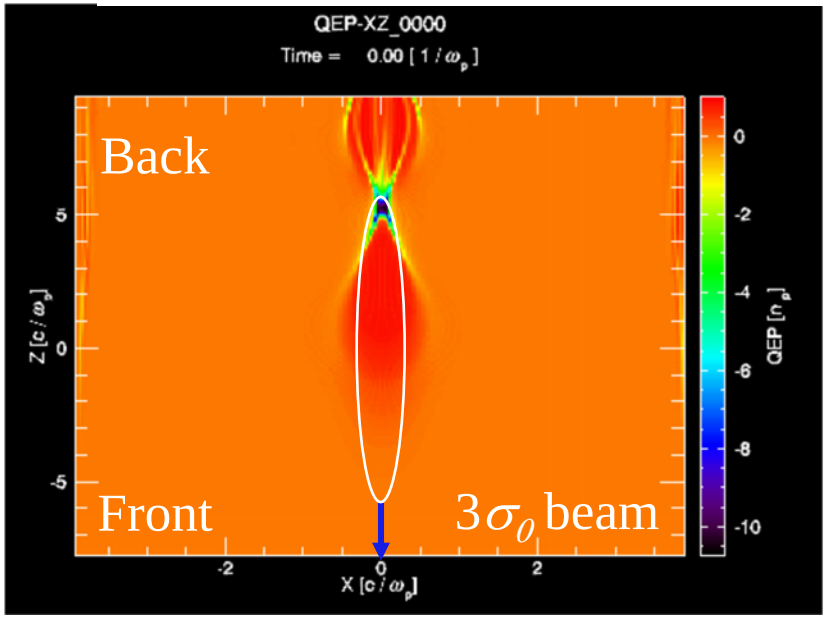


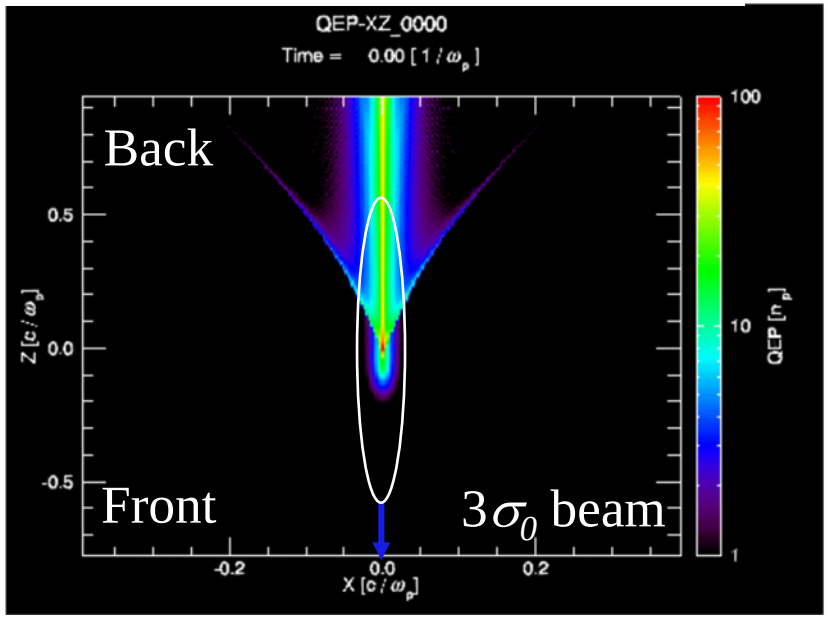
Electron case: "Blow-out"

Positron case: "Flow-In"



x, z slices of the plasma density in nonlinear regime (n_b>>n_e)

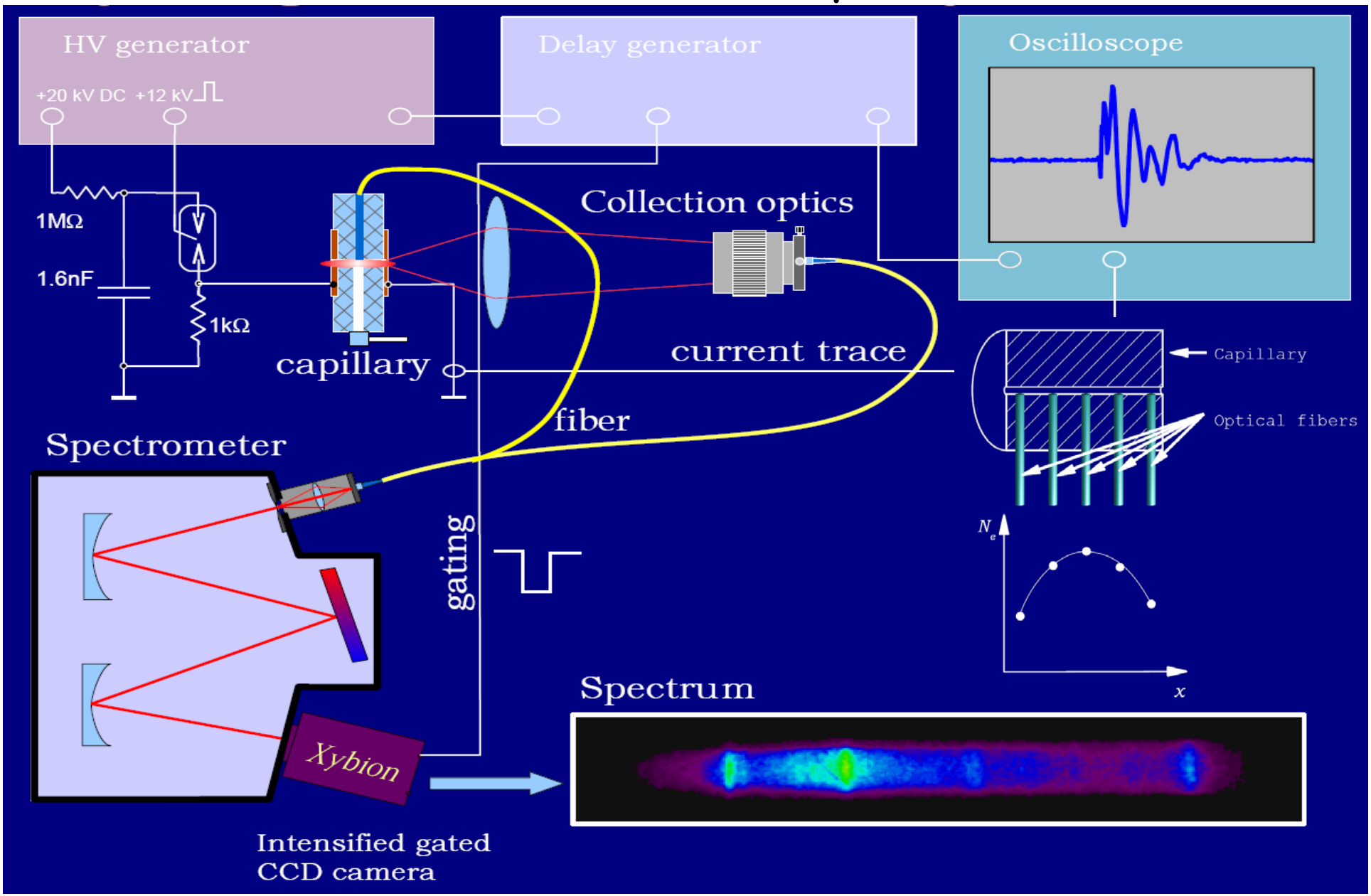




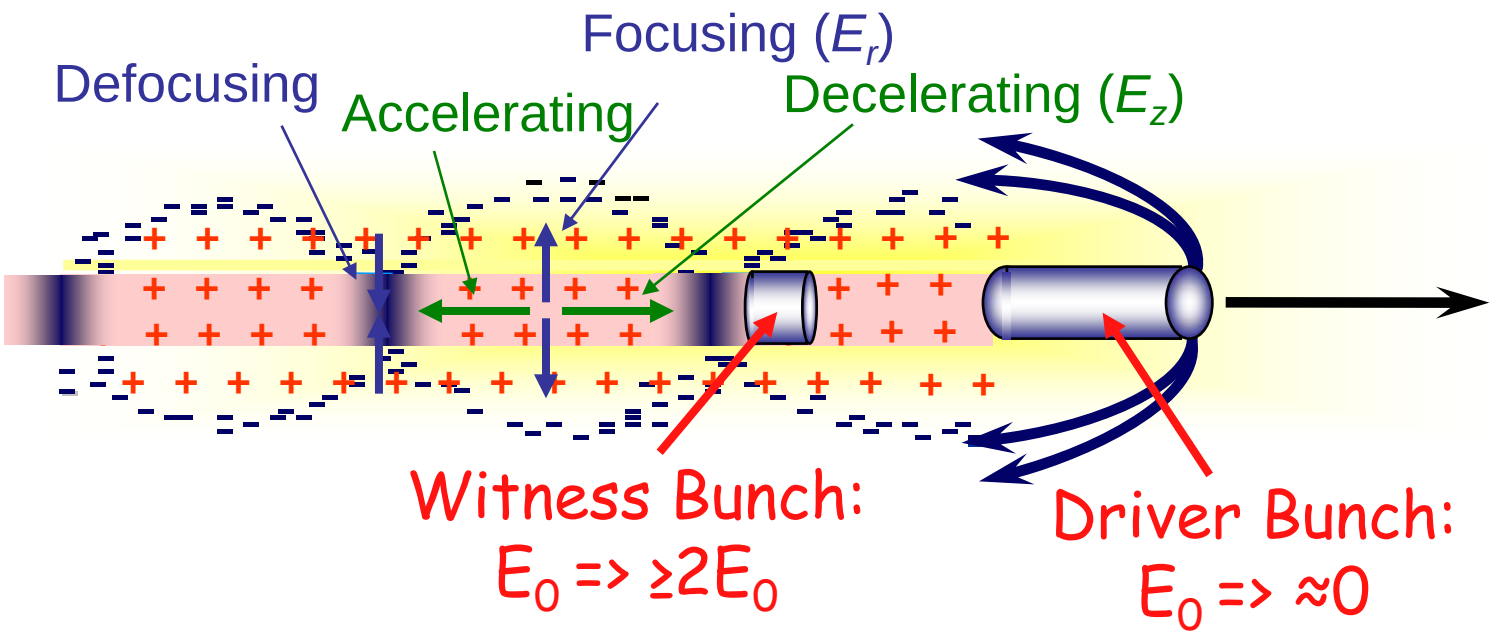
- Uniform focusing force $F_\perp(r,z)$
- $F_\perp(r,z)$ limited to $n_i = n_e$(bkgnd)
- Self-similar evolution

- Non-uniform focusing $F_\perp(r,z)$
- $F_\perp(r,z)$ NOT limited by n_e(bkgnd)
  n_e(in beam) ~ 20-30 X n_e(bkgnd)
- NOT self-similar evolution.

Daniil Stolyarov, Time resolved plasma density measurements in capillaries



2-Bunch PWFA



- Driver bunch: high-charge (3N), modest emittance, shaped?
- Witness bunch: lower charge (N), good emittance

beam loading for $\Delta E/E \ll 1$

Challenges:

-bunches with suitable parameters:

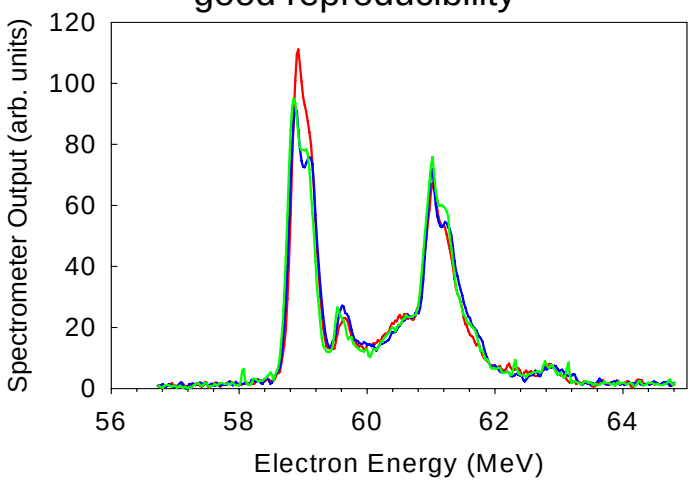
-timing between the two bunches

-bunch length

Wayne Kimura: STELLA-LW Program Update

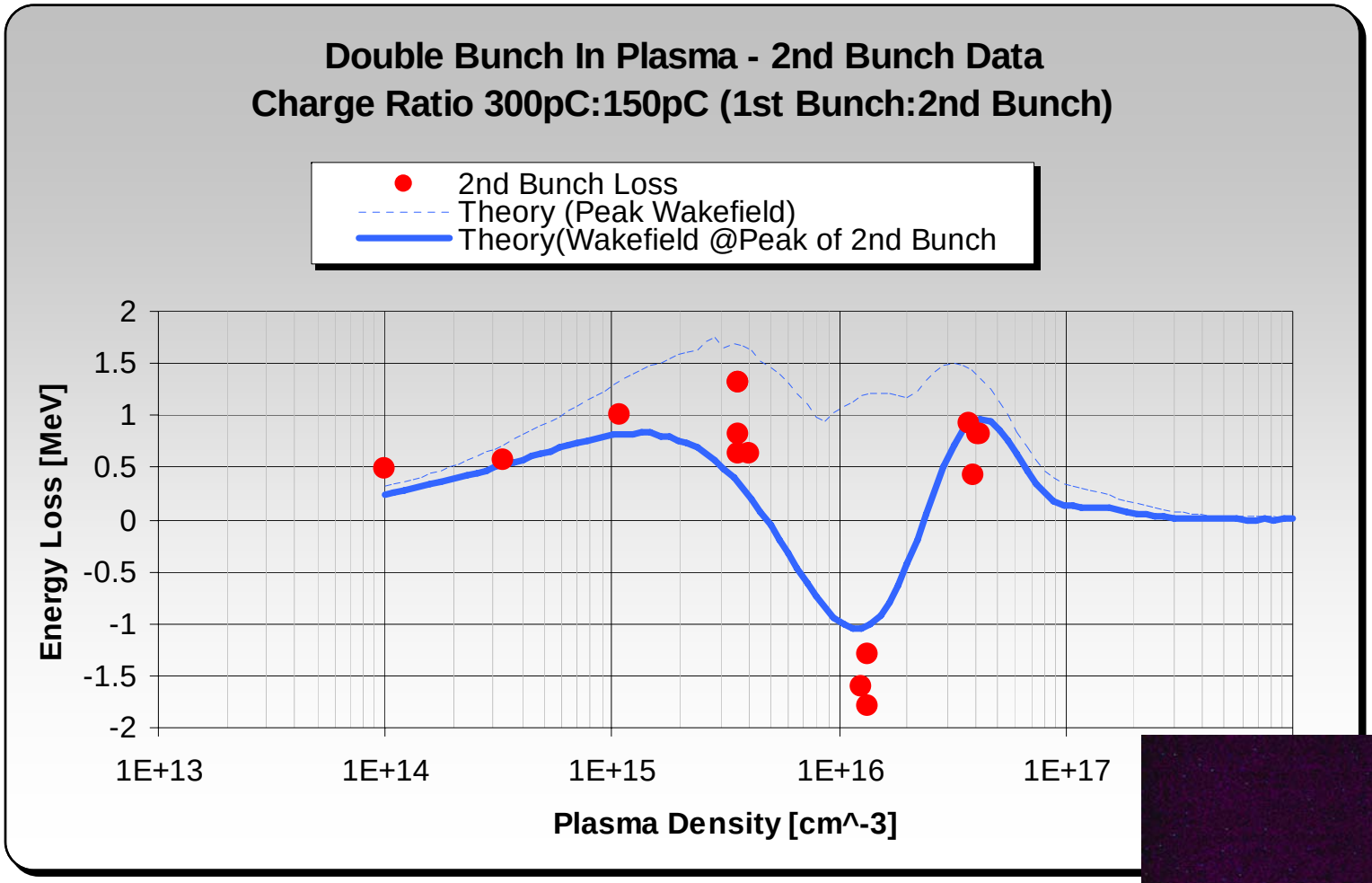
- Update on seeded SM-LWFA experiment
  - Demonstrated wakefield formation using double-bunch *e*-beam seeds
    - Observed interference effects between seed wakefields
    - Can block one seed to enable single-seed wakefield generation
  - Also observed energy gain of witness electrons following seeds
- Update on pseudo-resonant LWFA experiment
  - Additional modeling confirms minimum 3 TW laser peak power needed
  - ATF CO_2 laser now produces 1 TW
  - ATF upgrading laser systems to permit reaching 3 TW in ~12 months

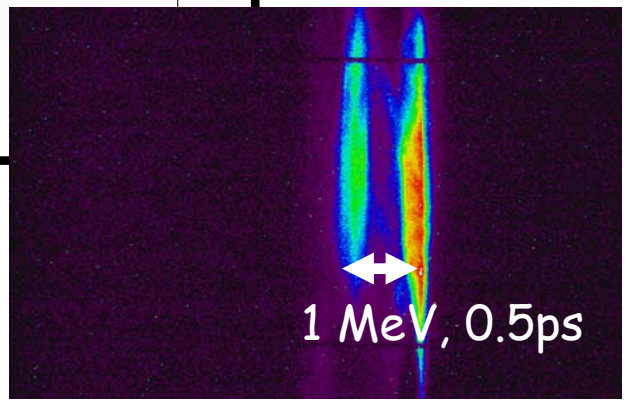
Overlap of three different shots shows good reproducibility



Themos Kallos: Double Bunch Experiment at ATF

The 2nd Bunch samples the wakefield of the first

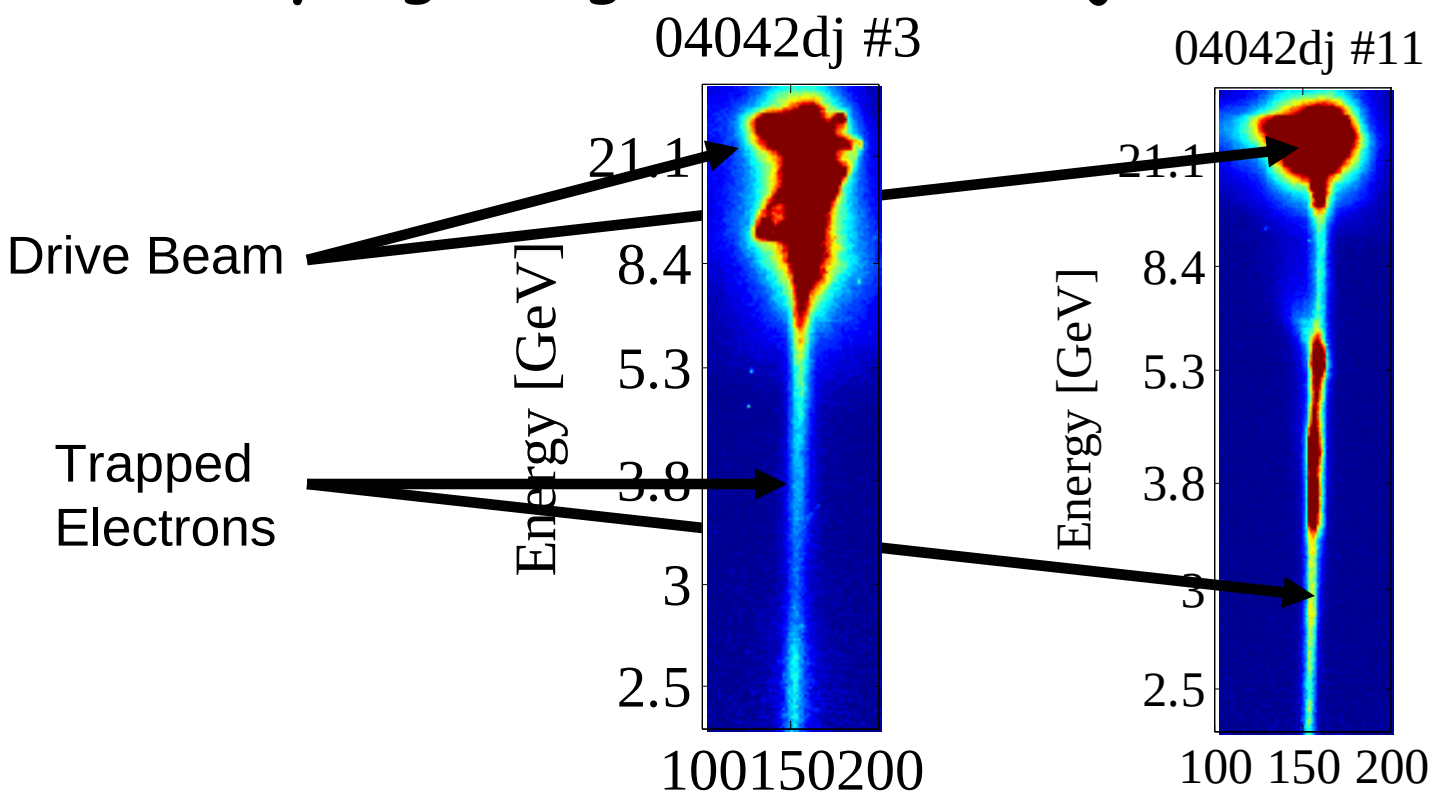


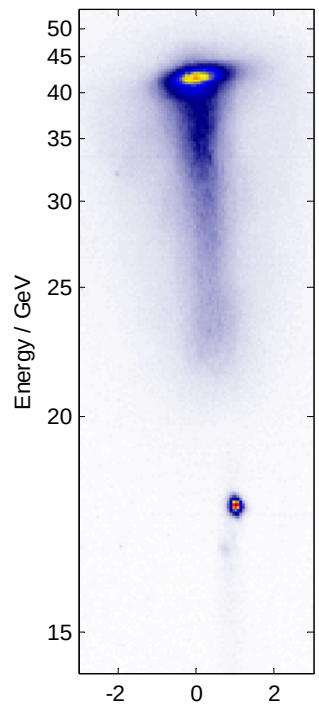


- A step in the right direction

Neil Kirby, E. Oz : Trapped Electrons in the SLAC E-167 Experiment

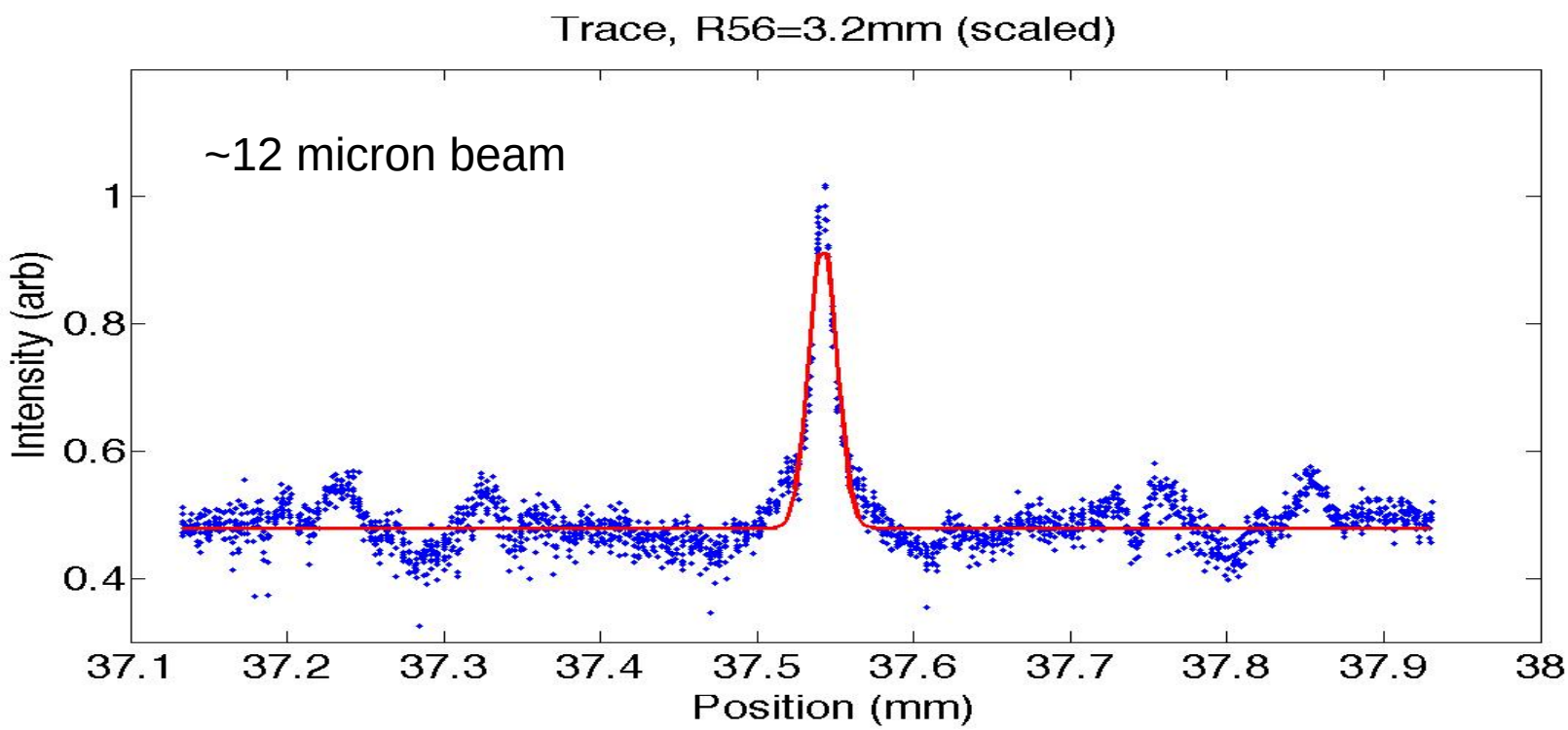
- Trapped electron show up as narrow transverse features that extend from at least 2 GeV to 10's of GeV.
- **Small size of trapped particles hints to the preservation of a small emittance**
- **Very high brightness beam injector ?**



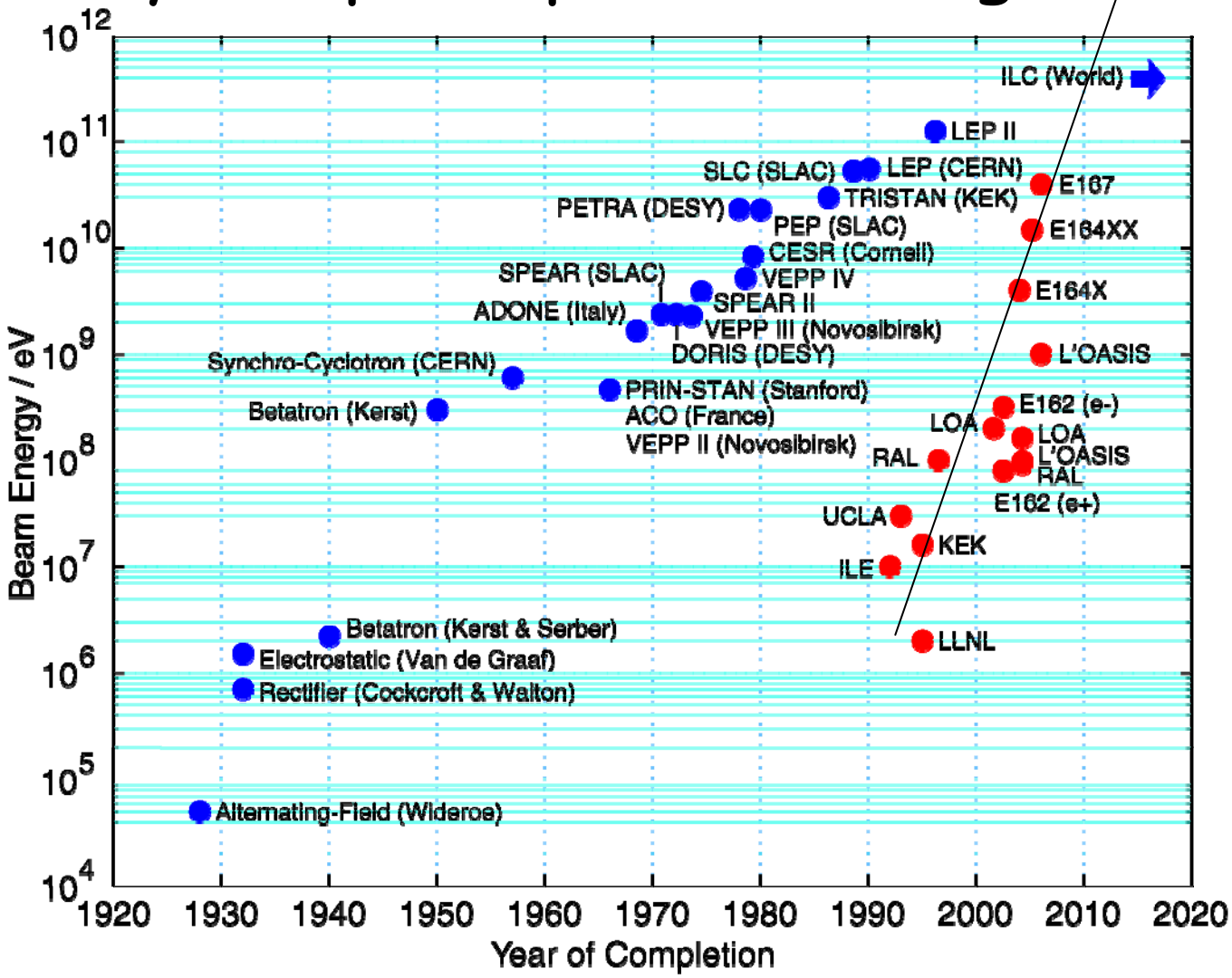


Ian Blumenfeld, Cameron Geddes, Themos Kallos, Wayne Kimura: Femtosecond Bunch Diagnostics

- We need to measure bunches of 5…30um
- Michelson interferometer for THz radiation is one possibility (Necessary to confirm by complementary information)
- Single-shot techniques are needed (possibly EO)
- Simultaneous measurement of multiple harmonics of CTR was used to characterize sub-5-micrometer bunches



Needed Experiments

- Two-bunch experiment
  - Demonstrate generation and control of drive and witness beam with suitable parameters
  - Precise time-of-flight transport optics for staging
- Positron acceleration
  - Accelerate positrons
  - Compare to simulations (Miaomiao Zhou)
- Ion motion
  - Direct study of ion energies at the experiment at ATF
  - Study ion collapse in a plasma lens experiment
  - Experiments with plasma of heavier ions
  - Plasma capillaries (hollow plasma channels)

Many Challenges ahead
Many Skeptics proven wrong