Recent results on hollow beam collimation

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Fermilab

LARP

Recent activity

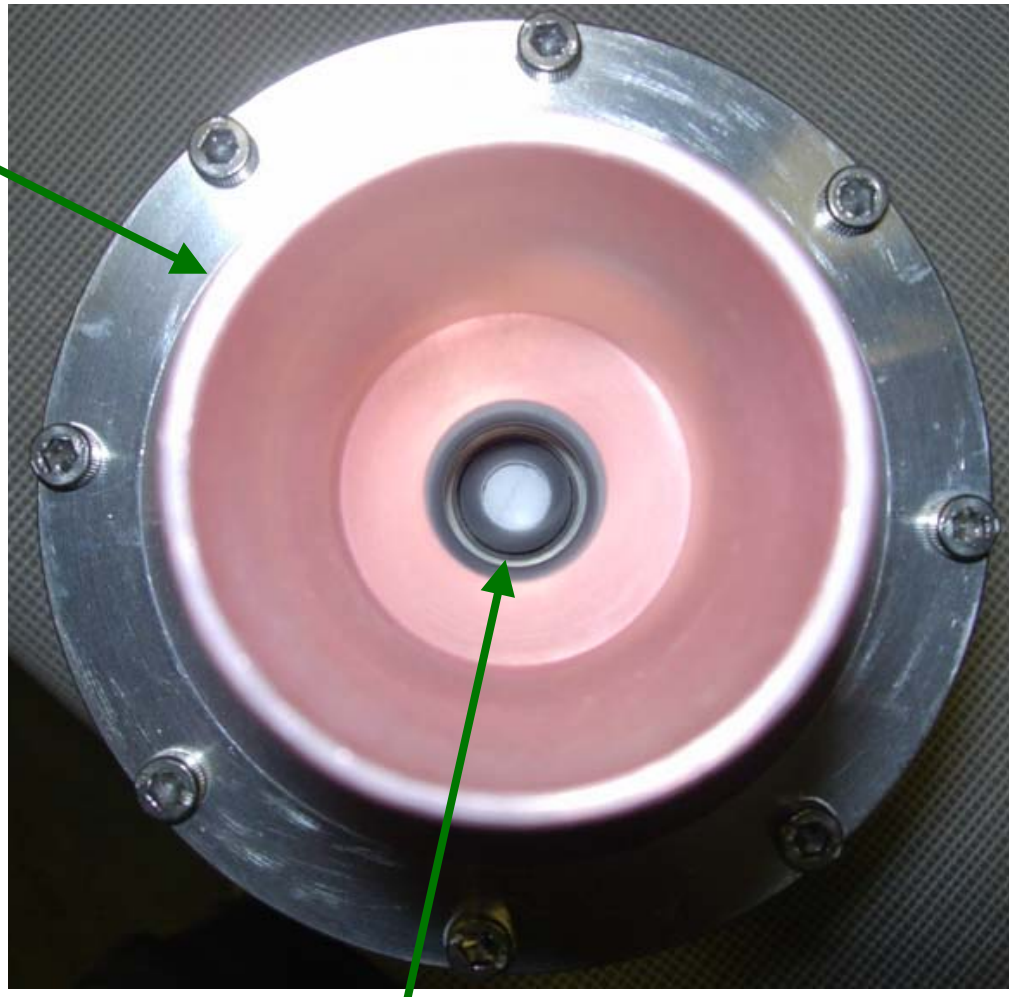
- At the test stand:
  - Studied time microstructure of hollow beam pulse *gs*
- In the Tevatron:
  - Aug 2-3: installed hollow gun in electron lens TEL2 *G. Kuznetsov, S. Sylejmani, gs*
  - Complete TEL2 test with e-beam before Tevatron start-up:

    BPMs, modulator, power supplies *J. Crisp, B. Fellenz, G. Kuznetsov, G. Saewert, J. Simmons, X. Zhang, gs*
  - Verified abort-gap cleaning effect (as TEL1 backup) *X. Zhang*
  - First dedicated studies Oct 13-14 (3 hrs) and Oct 27-28 (4 hrs): *A. Valishev, gs*
    - position/angle scans, beam alignment
    - effects of e-beam size, current and pulsing pattern on emittances, intensity and luminosity decay rates
    - dependence of losses on working point in pulsed mode
    - scraping mode with fixed e-beam and pbar/proton orbit bump

The 0.6-in hollow gun

Copper anode

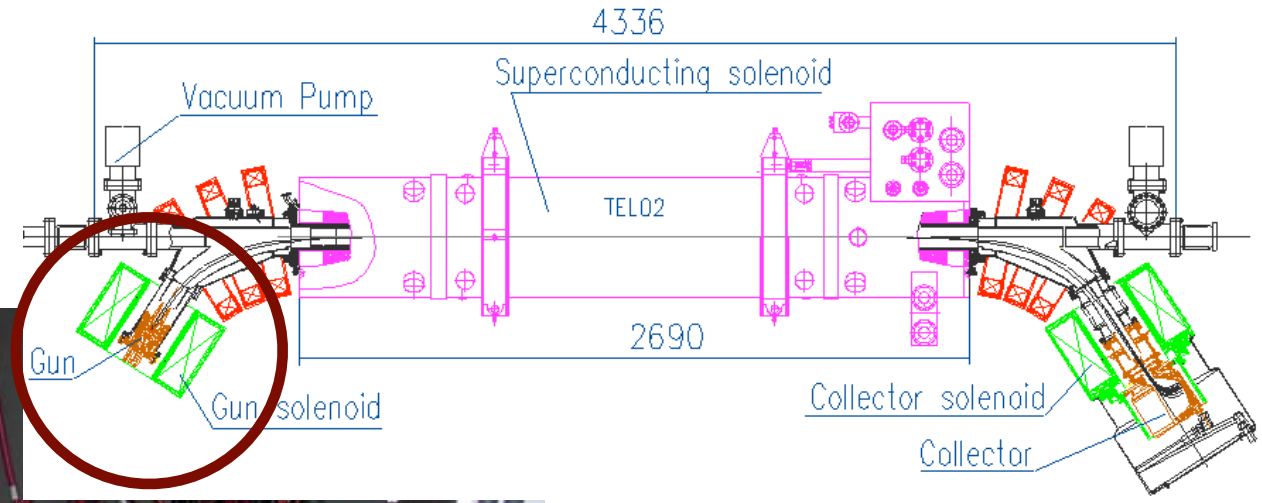
side view

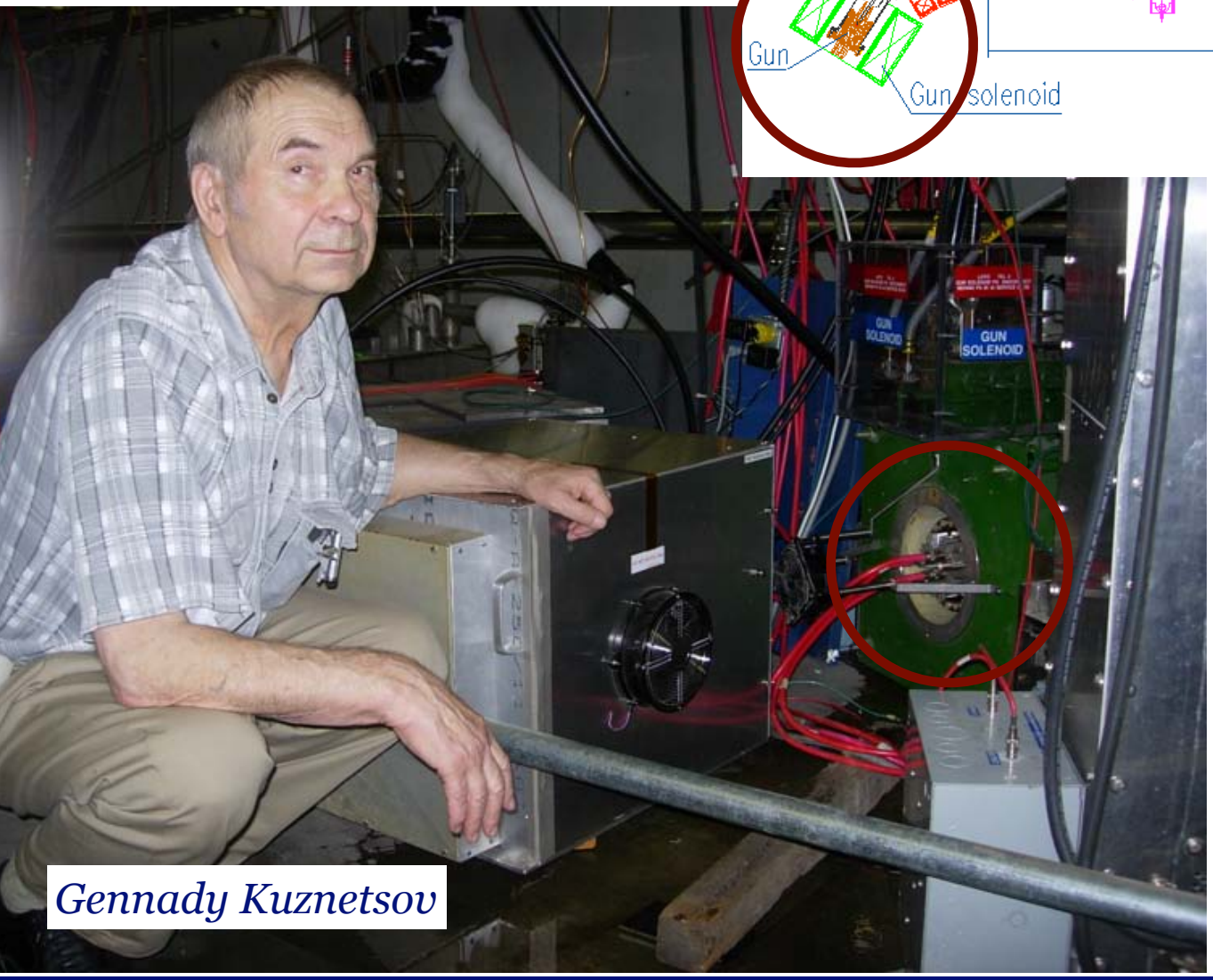


top view

Tungsten dispenser cathode
with convex surface
15-mm diameter, 9-mm hole

Hollow gun installed in the Tevatron (Aug 2)

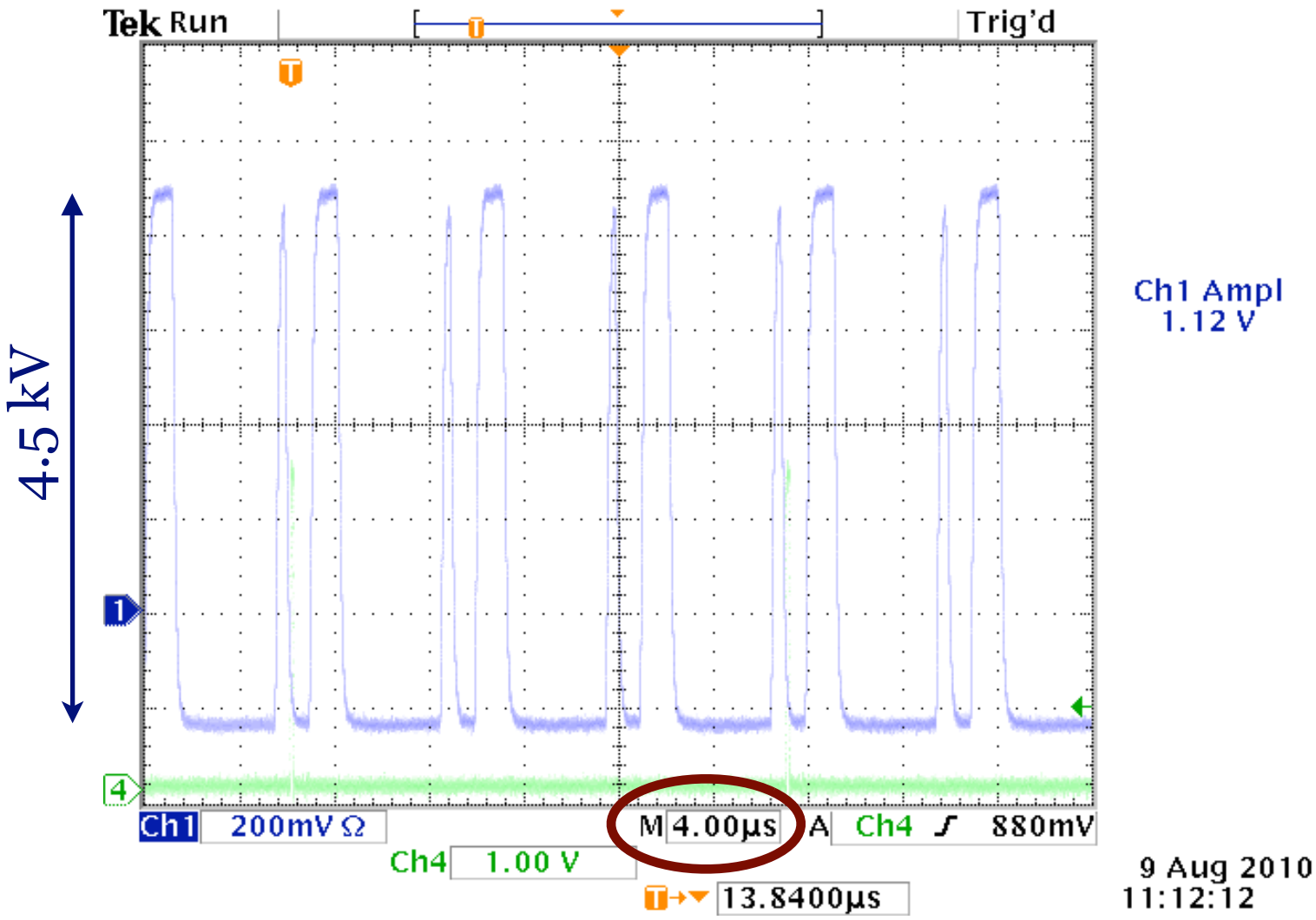




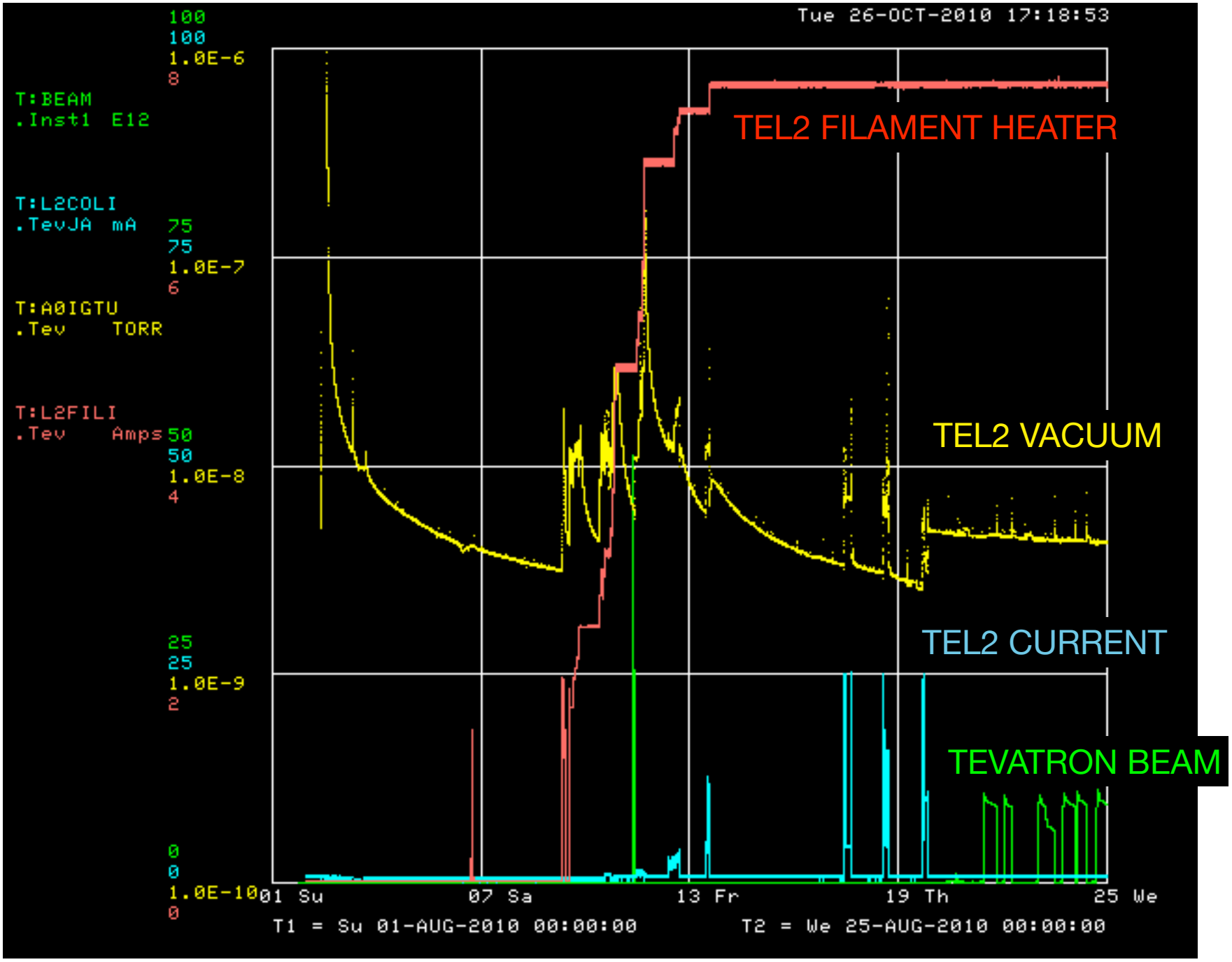
Gennady Kuznetsov

Modulator tests without e-beam

Replaced DC supplies in tunnel (out of spec, radiation damage?)
Modulator tested up to 4.8 kV at highest switching rate

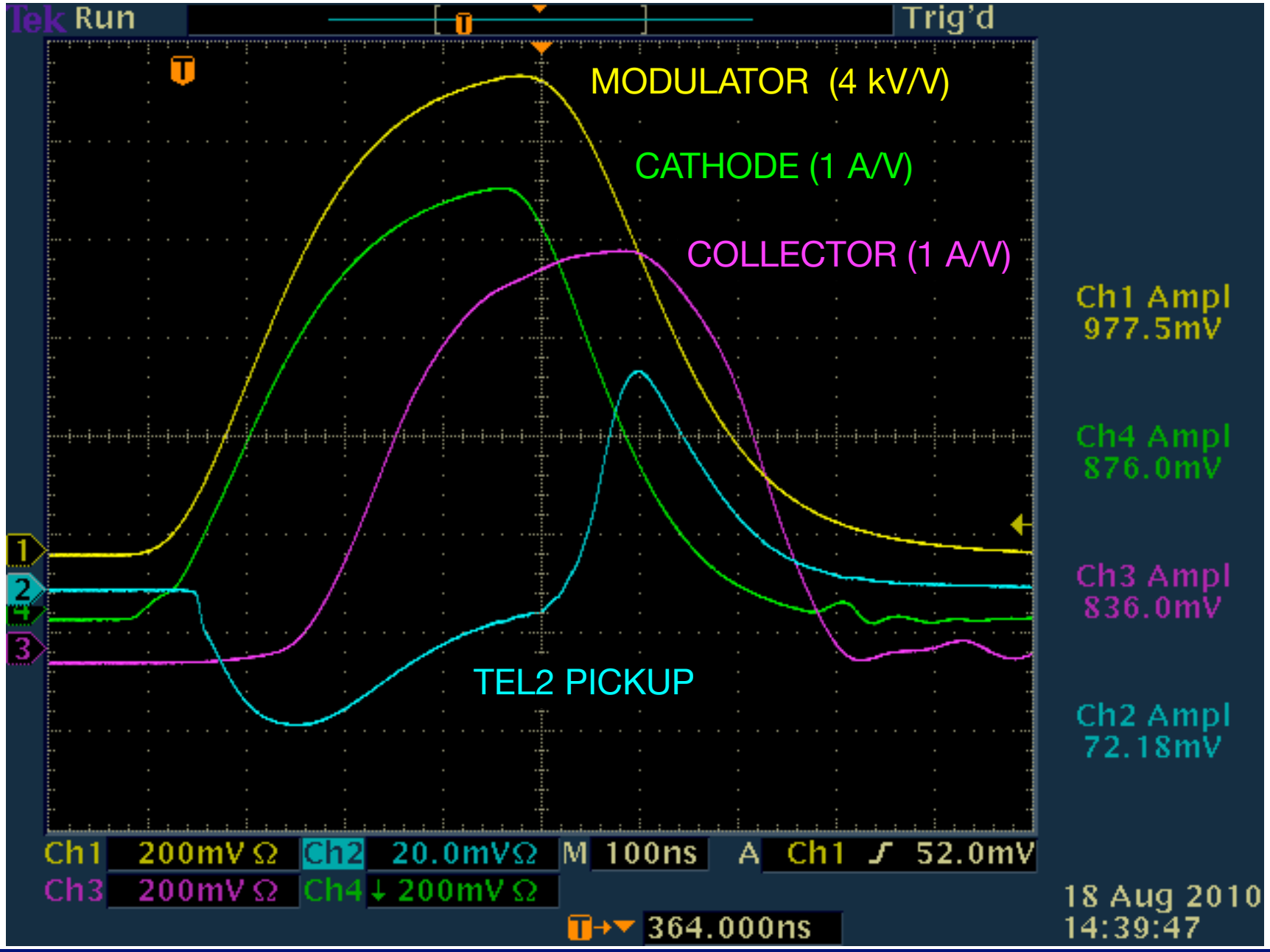


Vacuum recovery and filament heating



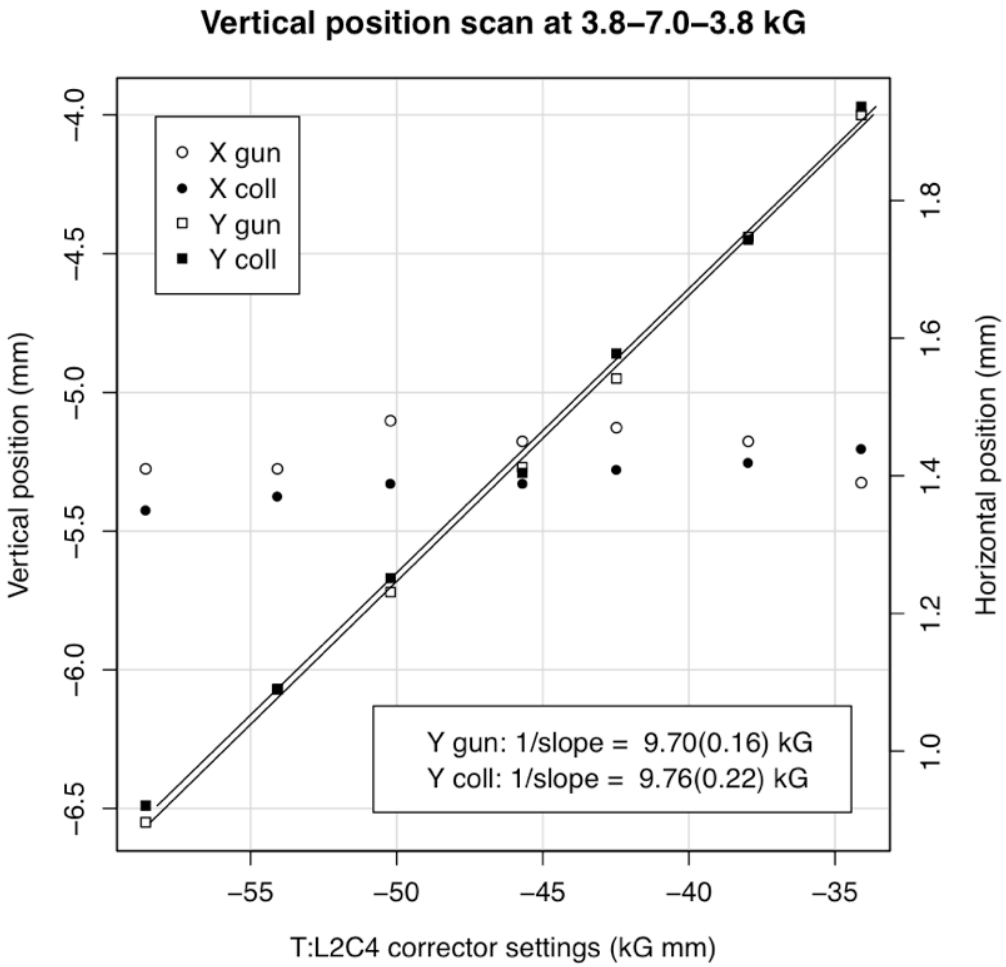
TEL2 checks before Tevatron start-up

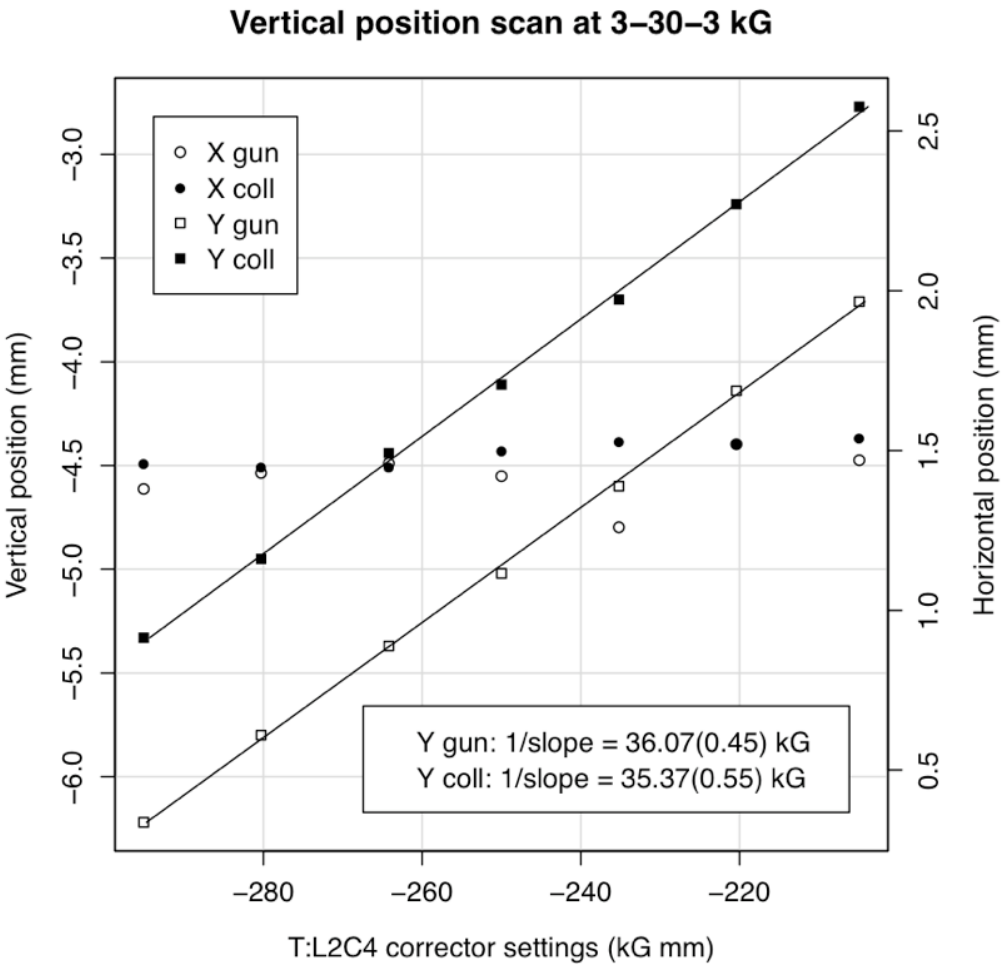
Shortest pulse:



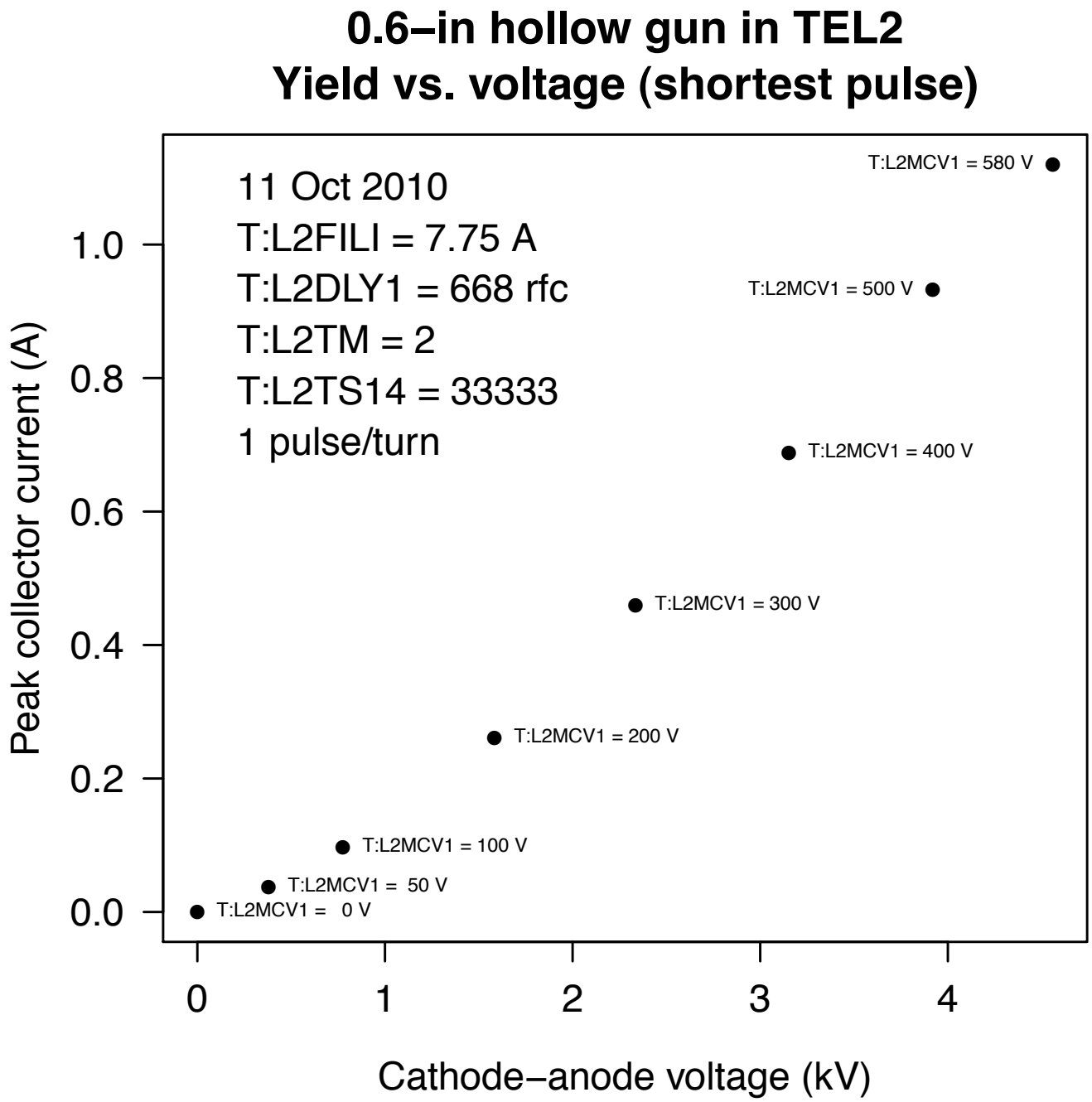
Corrector/BPM calibration vs. magnetic field

To change hole size for collimation, need to operate at different field ratios B_{gun}/B_{main}



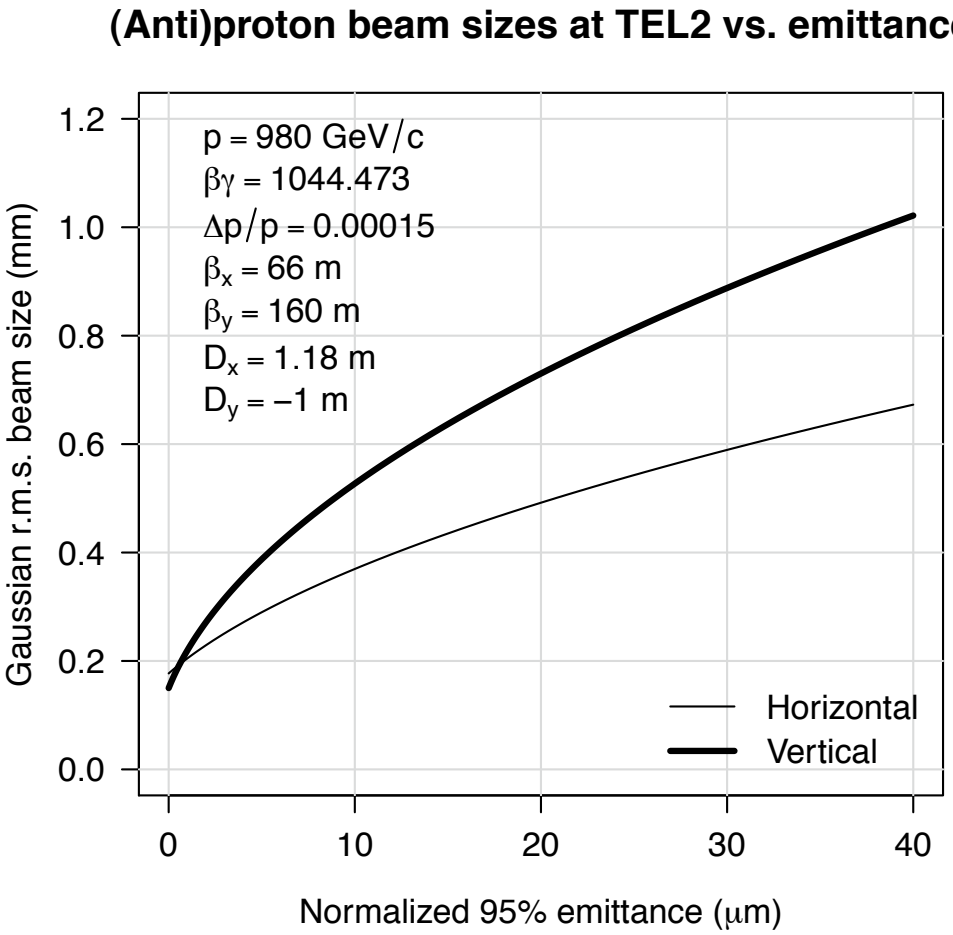


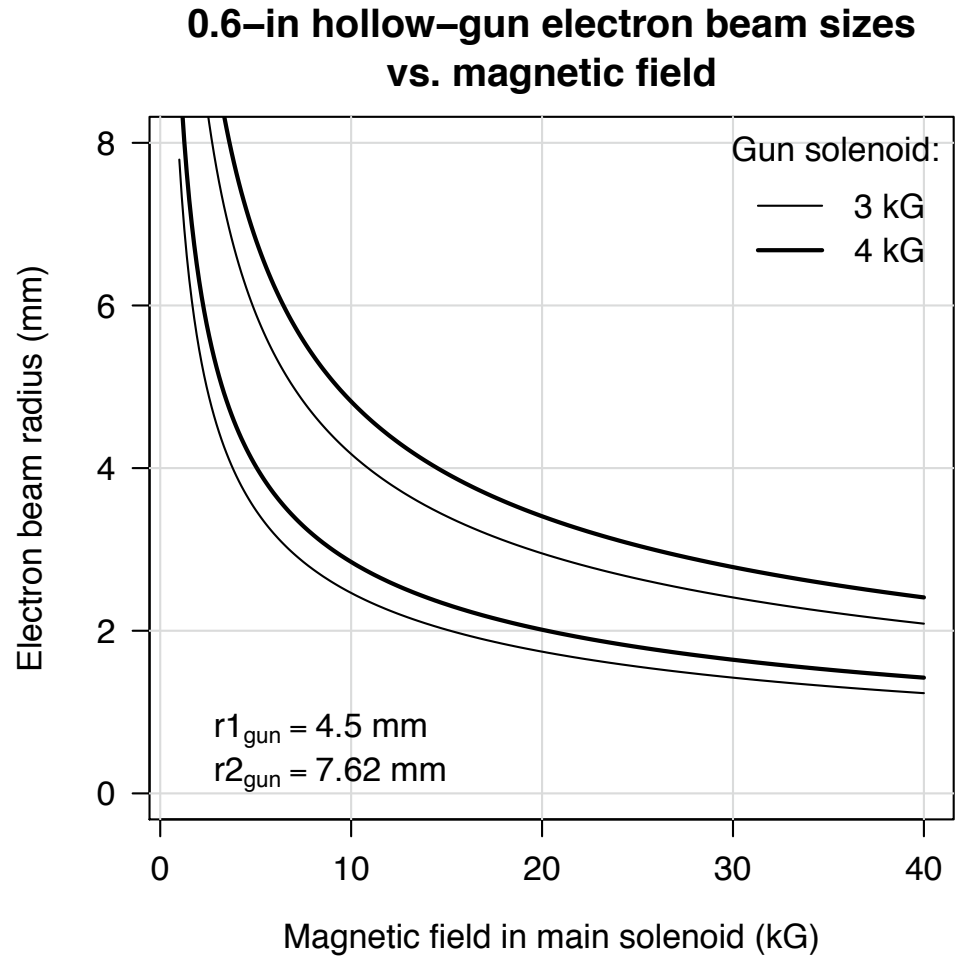
Hollow gun performance in TEL2 after cathode conditioning



First dedicated studies in the Tevatron at collisions

- Two end-of-store studies so far: Oct 13-14, store #8171 (3 hrs) and Oct 27-28, store #8210 (4 hrs)
- Goals:
  - Which studies are parasitical? Which ones need dedicated time?
  - How critical is the alignment with the present gun?
  - How large is the scraping effect on halo and core?
- Bunch-by-bunch observables:
  - Losses at collimators (not gated) and detectors
  - Intensities, luminosities, emittances, and their decay rates
- Factors:
  - e-beam position and angle, current (1.1 A max) / profile, size (about 3.5-5.0 σ_y), pulsing pattern (skip 0-9 turns)
  - machine working point: tunes and coupling

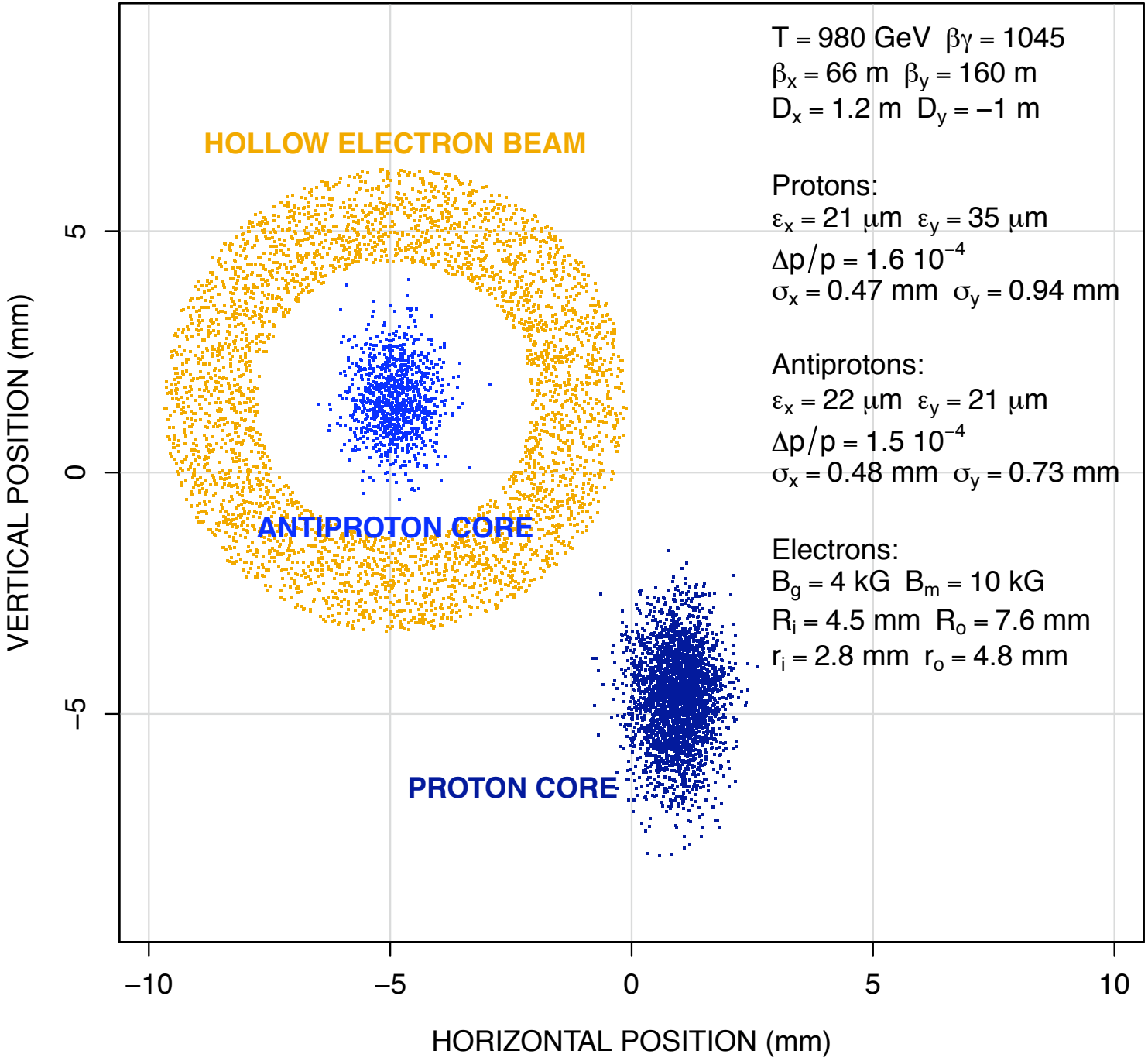




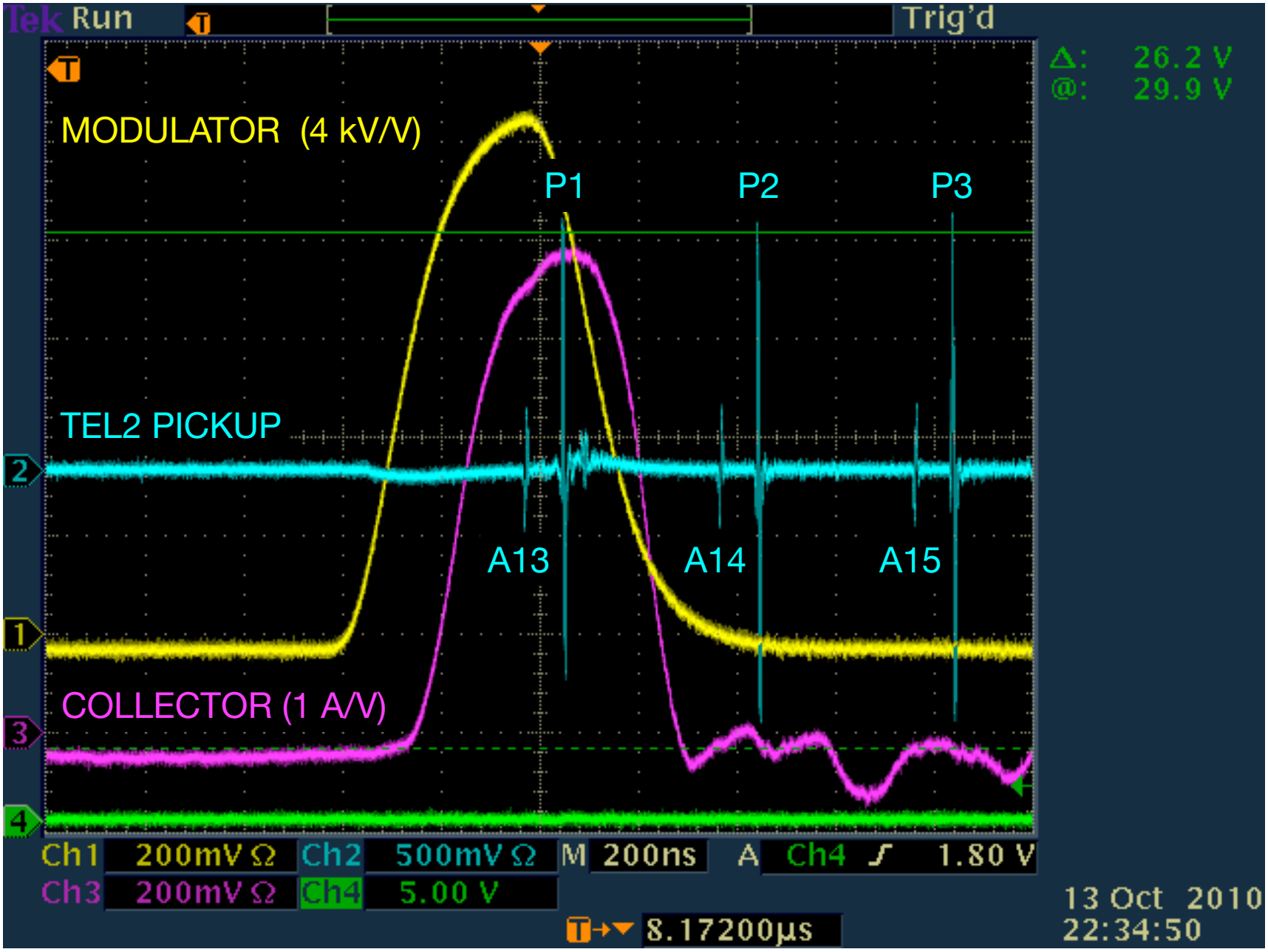
Chose to start with antiproton bunches:

- lower emittances and intensities, larger magnetic field ⇒ more stable
- in Tev lattice, TEL2 more similar to pbar collimator ⇒ better capture

Example of transverse beam profiles at TEL2



e-beam pulse synchronization with antiproton bunch



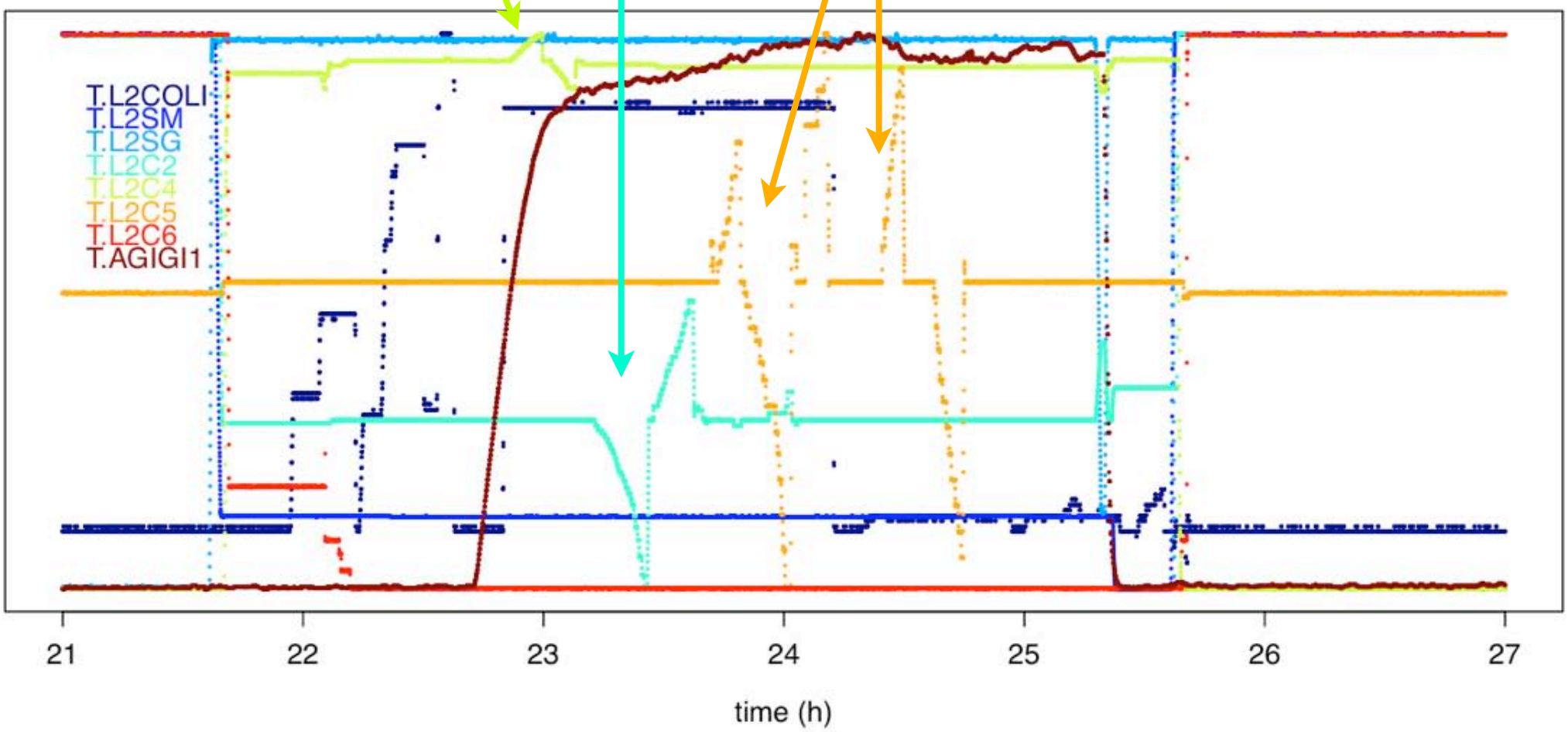
Oct 13-14 (store #8171) study overview

Pulse: 1 pulse/turn | 1 pulse/6 turns

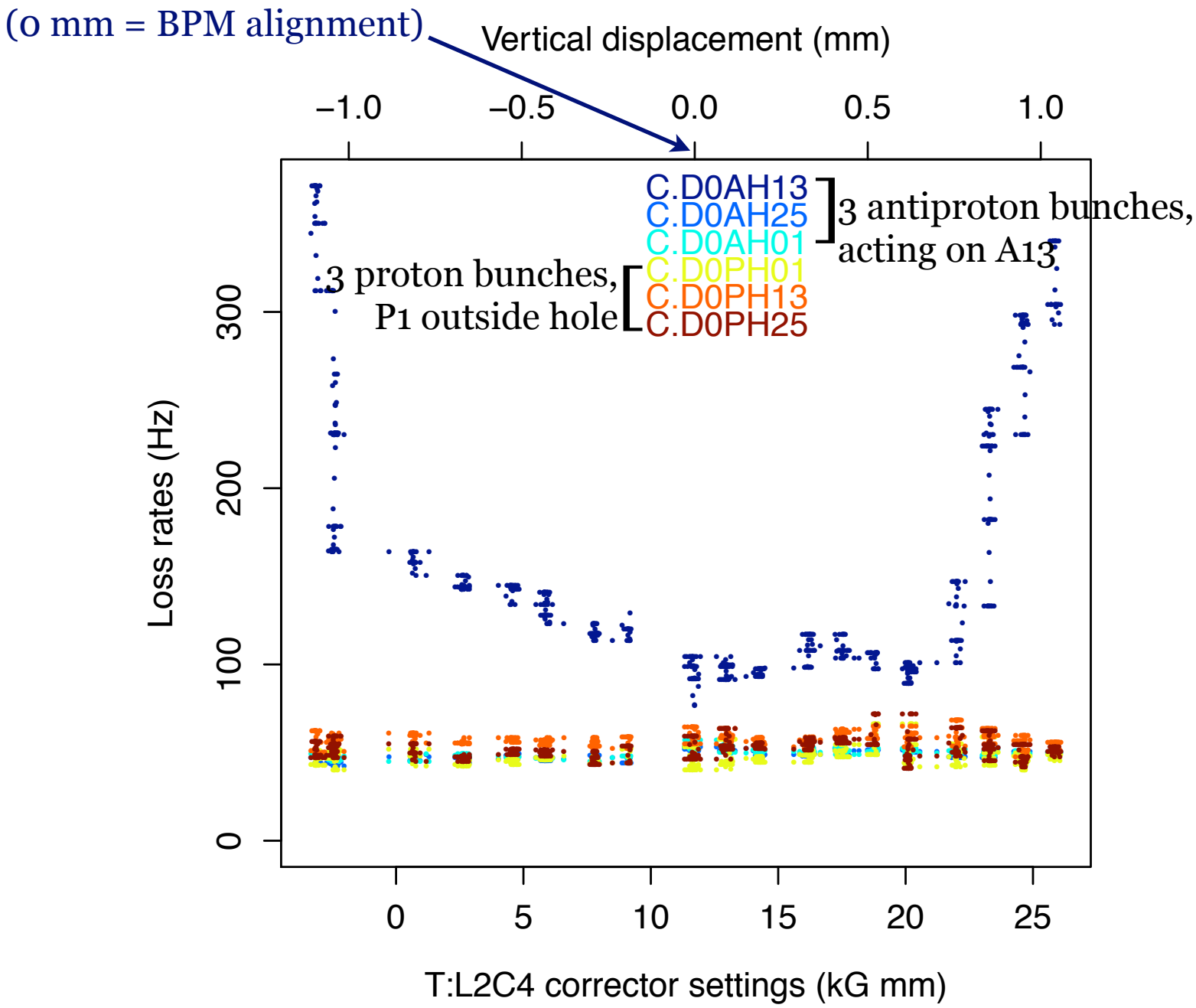
Bunch: A13 | A25

Hole radius: 4σ | 5σ | 3.5σ

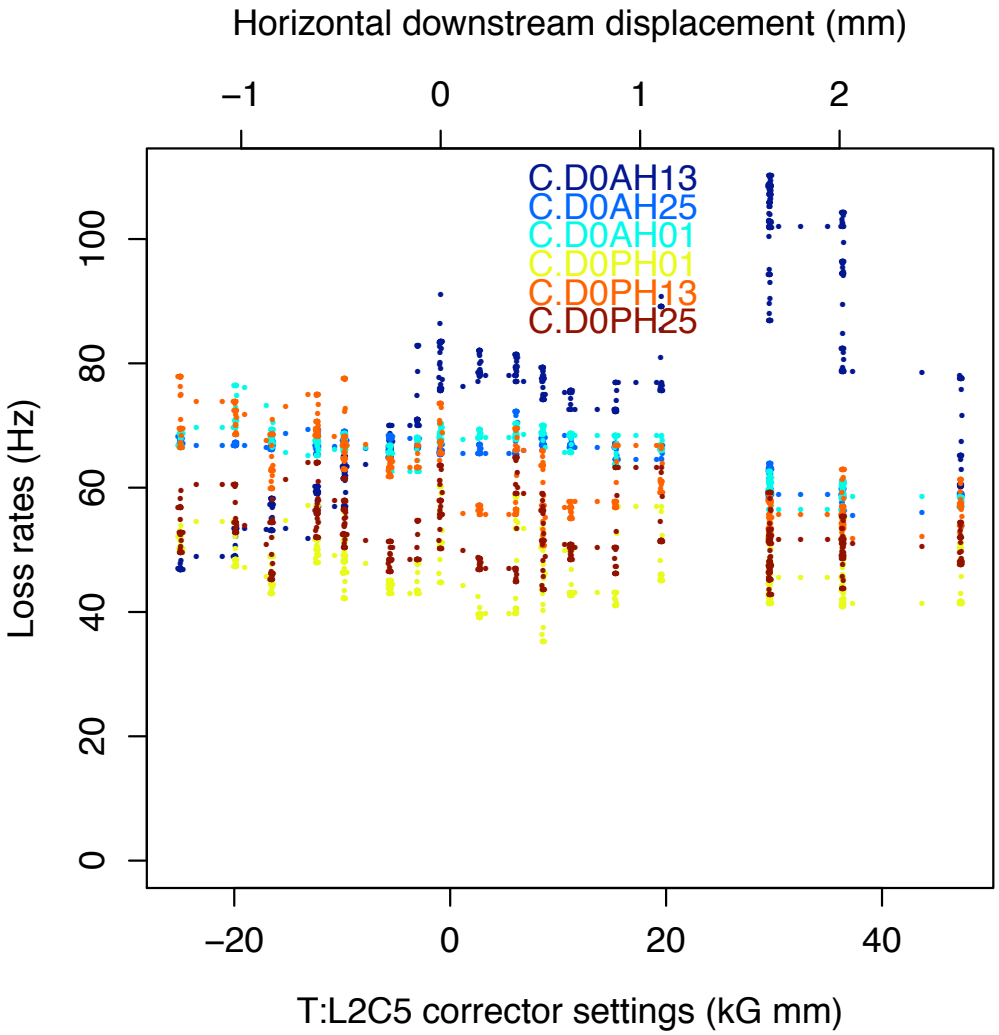
Alignment scans: V pos. H pos. H angle

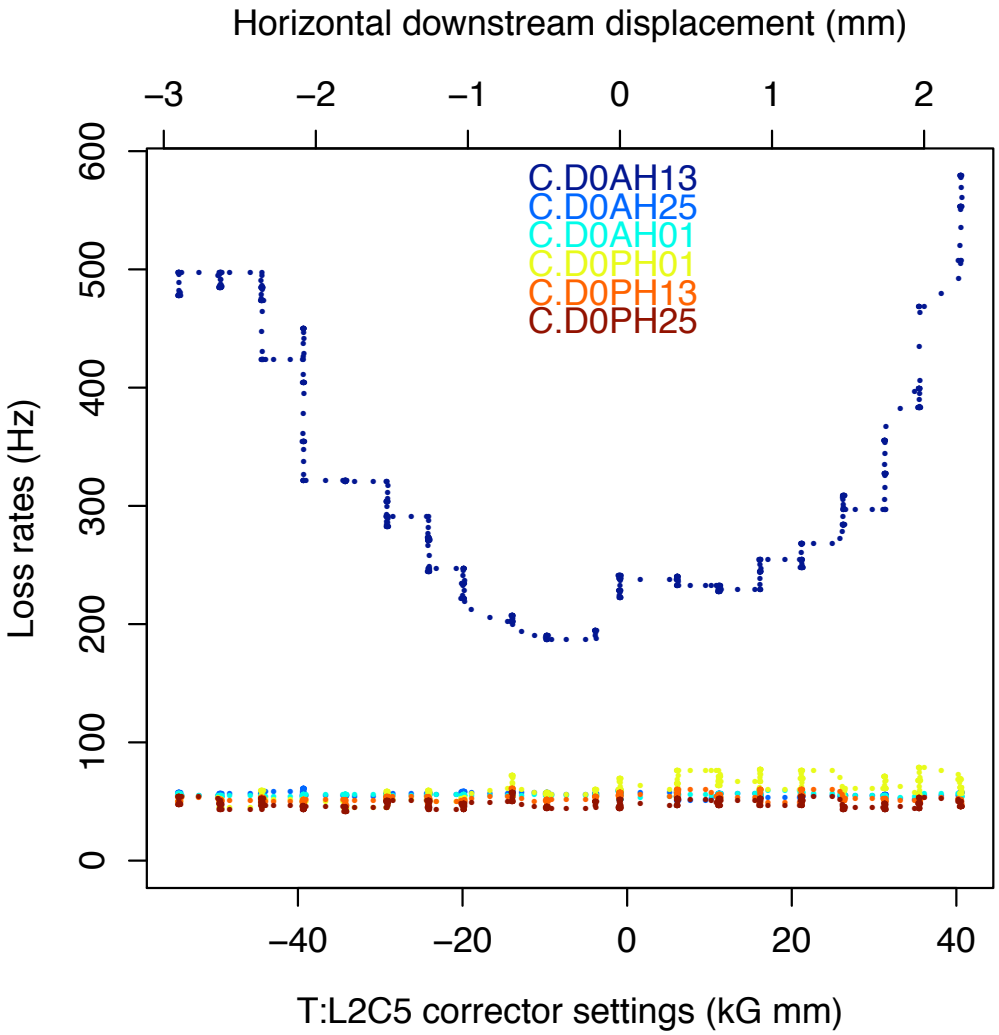


Bunch-by-bunch losses during vertical e-beam scan

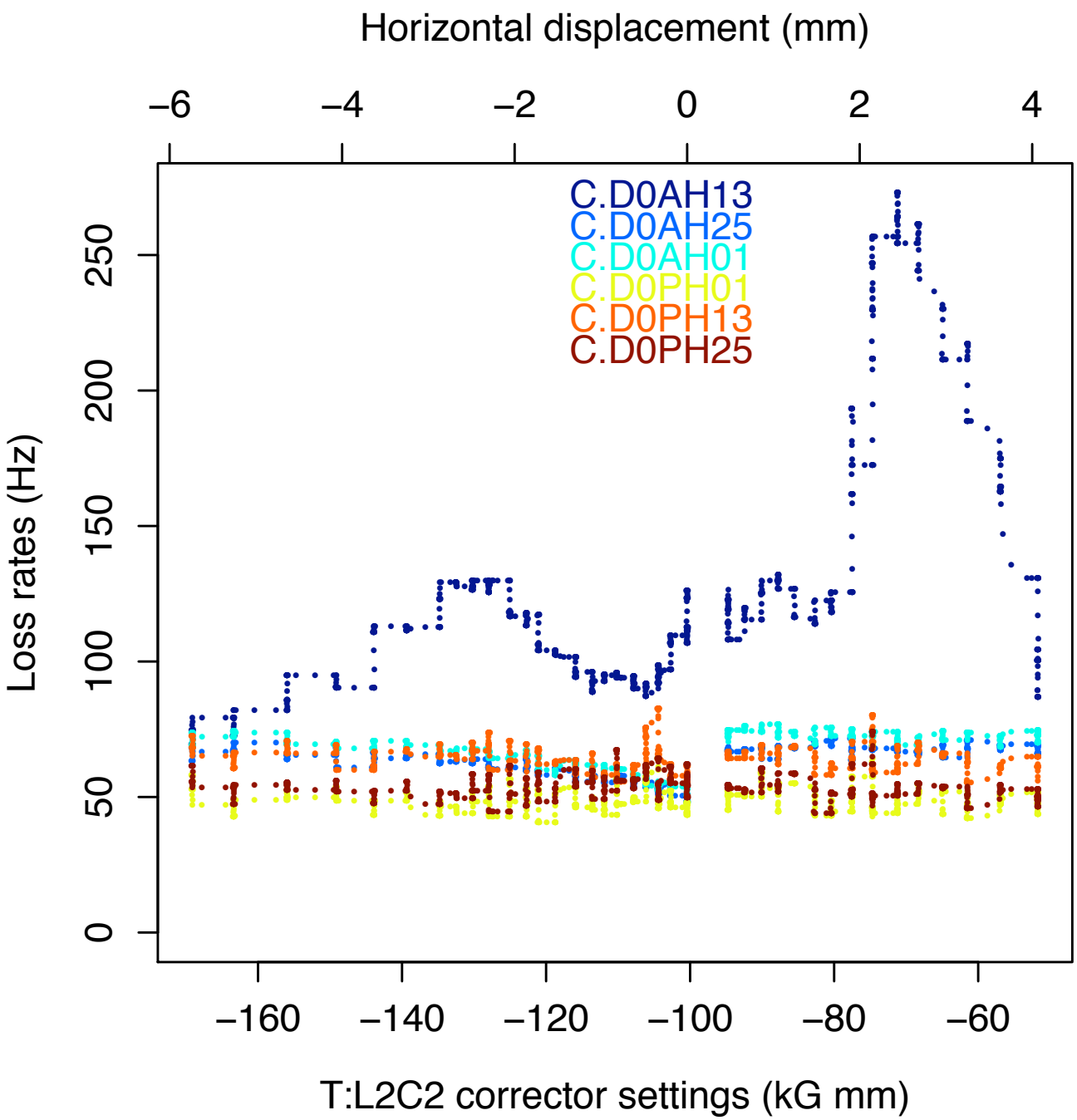


Horizontal angle scan: 1 pulse/turn vs. 1 pulse/6 turns

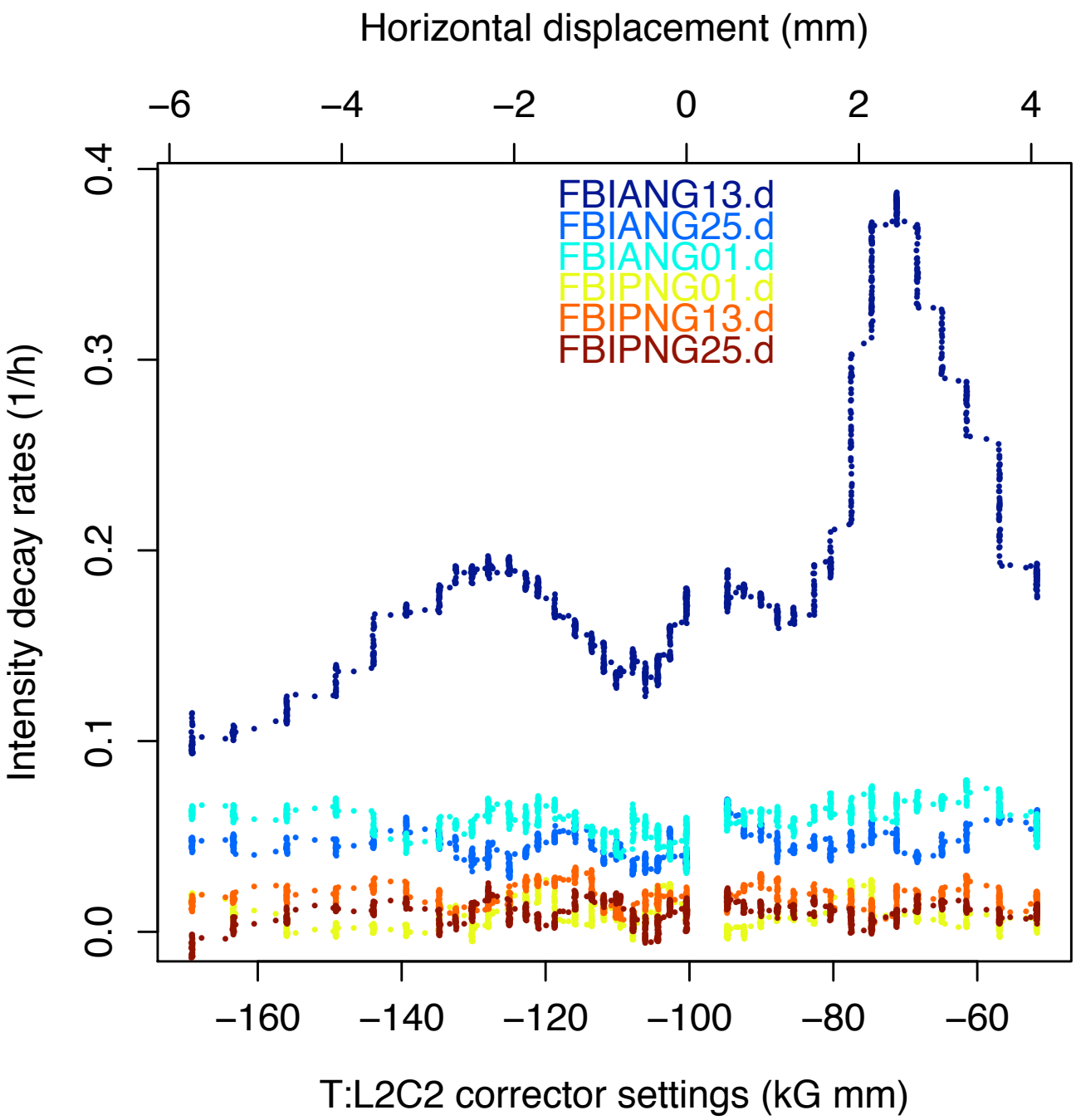




Losses during horizontal scan

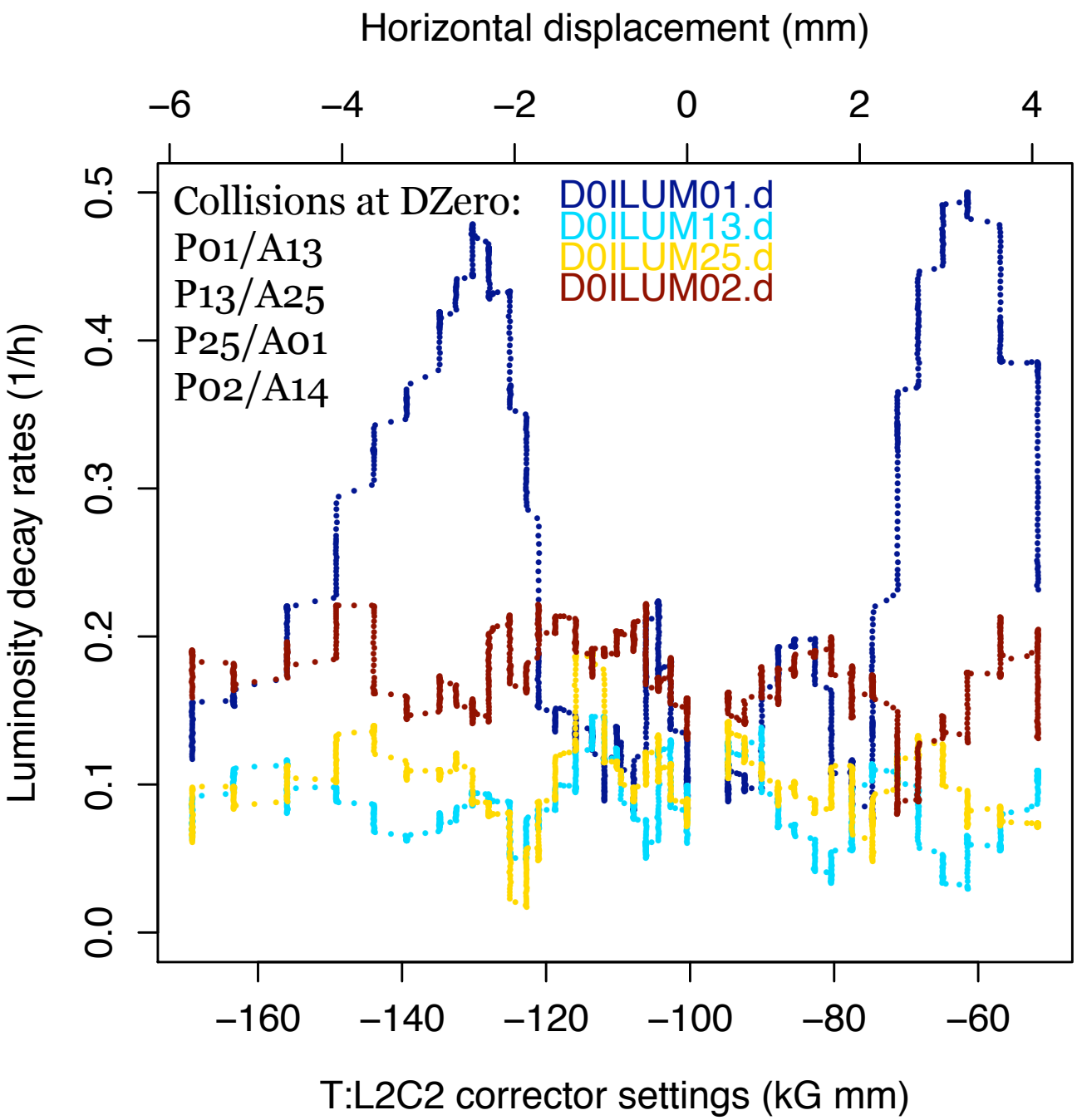


Intensity decay rates during horizontal scan



As expected, decay rate of bunch intensity closely follows losses.

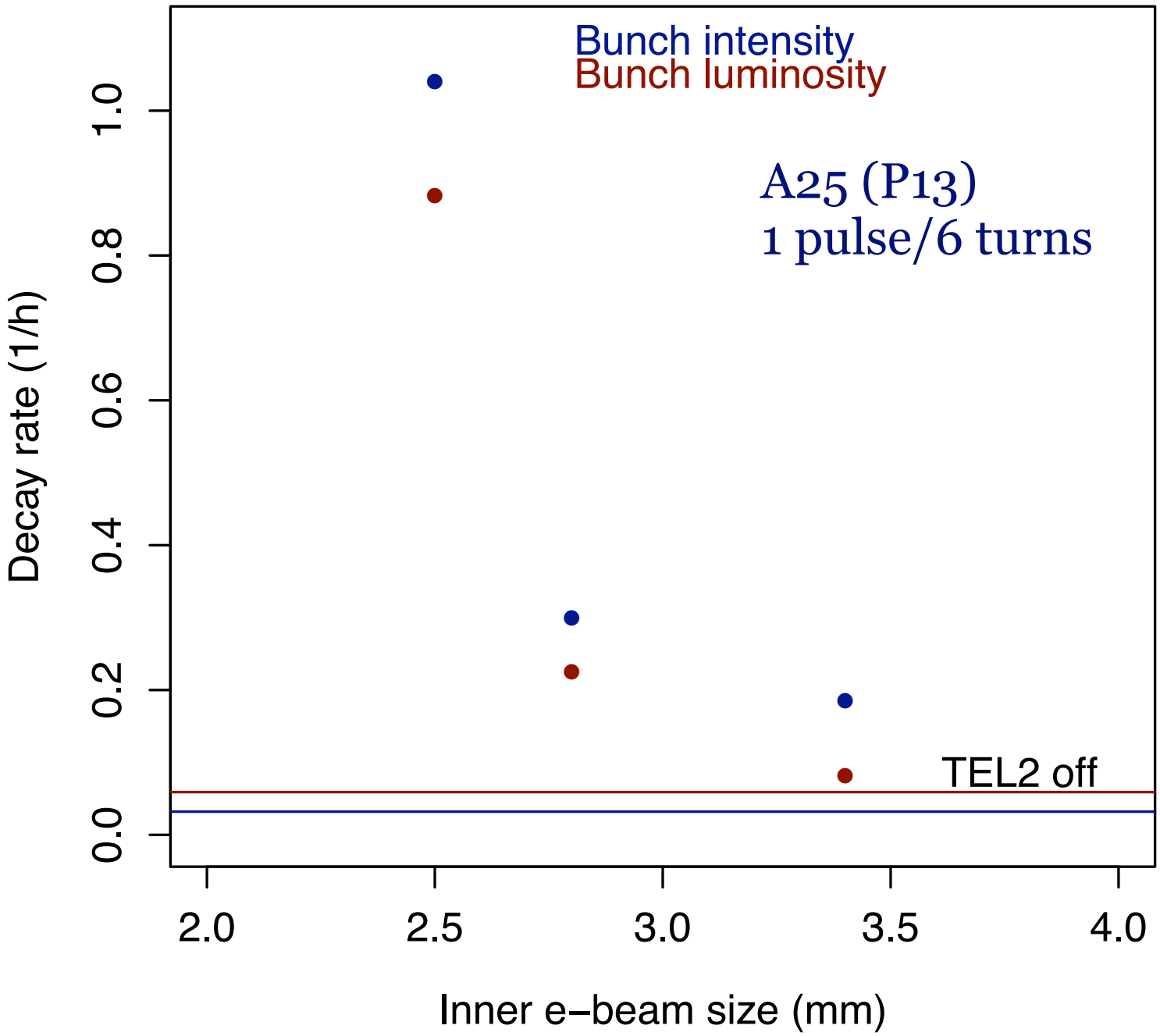
Luminosity decay rates during horizontal scan



But luminosity decay rate does not change when beams are aligned!

⇒ Scraping of halo without affecting core!?

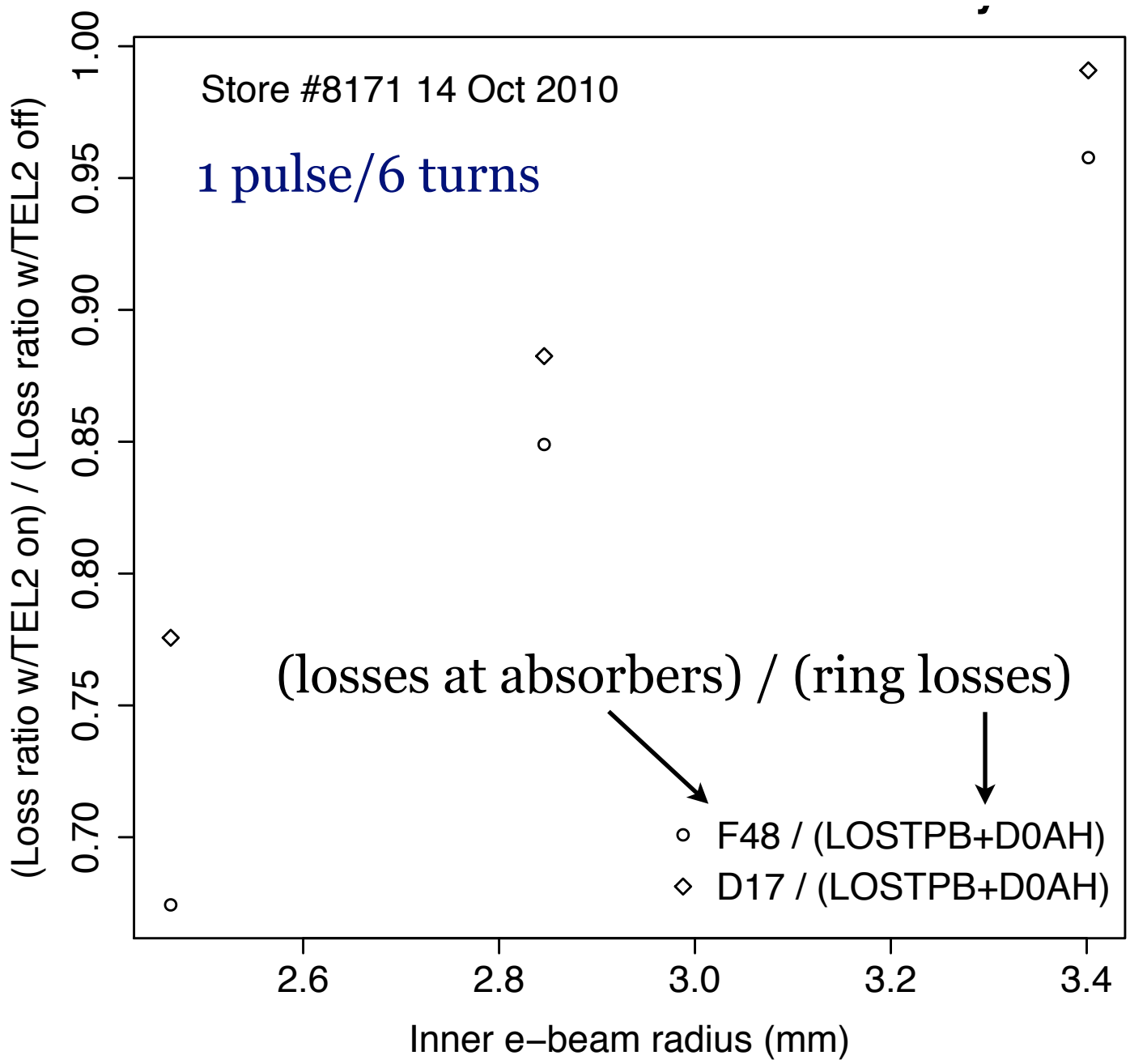
Intensity and luminosity decay rates vs. e-beam size



Collimation "efficiency" vs. e-beam size

In Tev lattice, TEL2 is not an ideal antiproton target.

Nevertheless, capture efficiency should be larger if scraping halo and lower when affecting core.



Preliminary results: first study

- Electron beam is not perfectly symmetric around axis (space charge, bends). This has not been a limitation so far.
- Aligned e-beam can be turned on 1 bunch parasitically.
- Effects on losses, intensities, emittances and luminosities are detectable.
- Pulsing every 6th turn (TEL1 abort-gap cleaning mode) is considerably more effective than every turn.
- Total losses can be increased with negligible effect on luminosity lifetime, i.e. there is halo scraping with no effect on core or an increase in specific luminosity.

Tevatron studies of Oct 27-28 (store #8210)

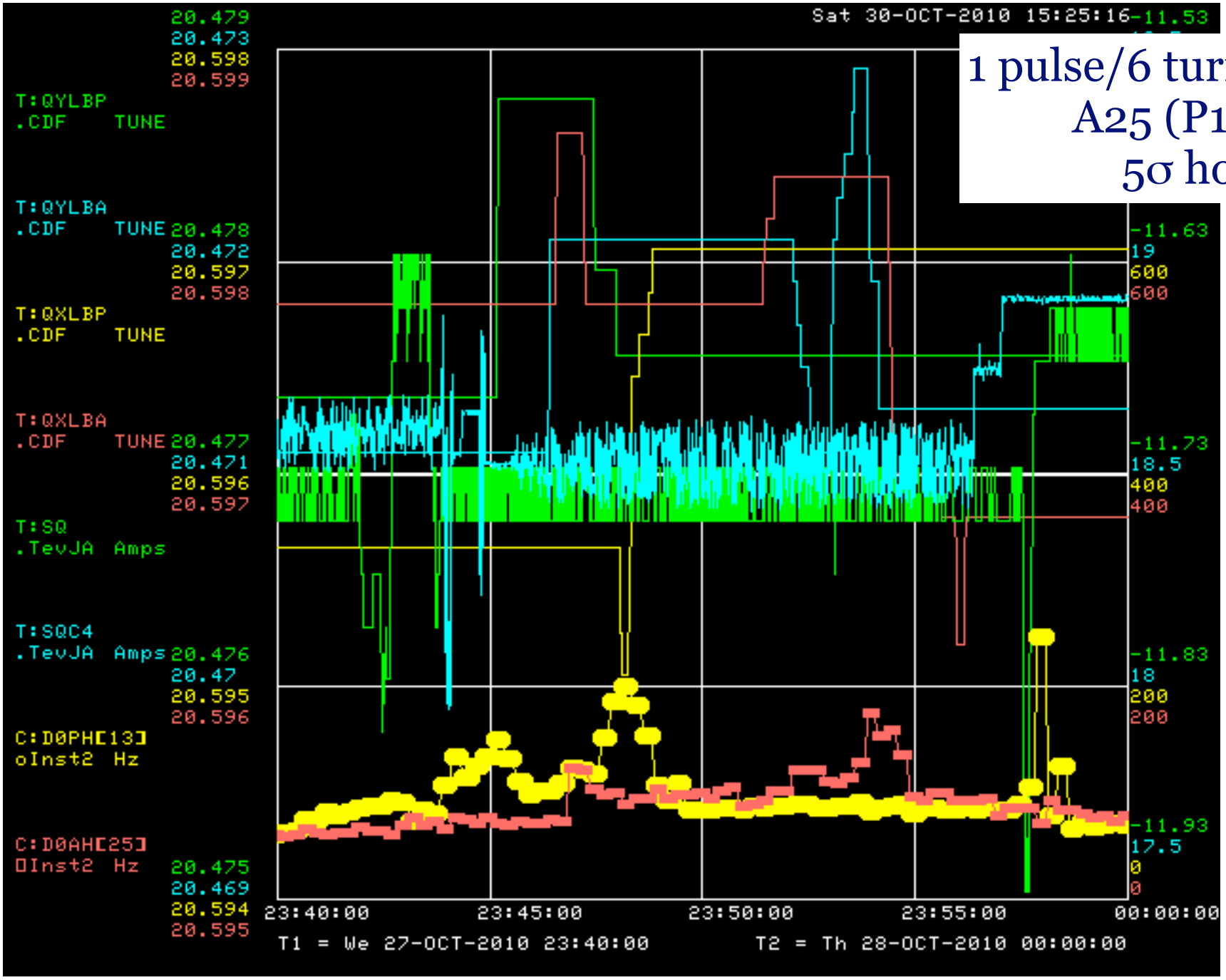
- Demonstration of parasitic operation acting on 1 bunch
- Effect of working point on losses
- Intensity and luminosity decay rates vs. e-current
- Vertical orbit bump with fixed e-beam

Losses vs. working point

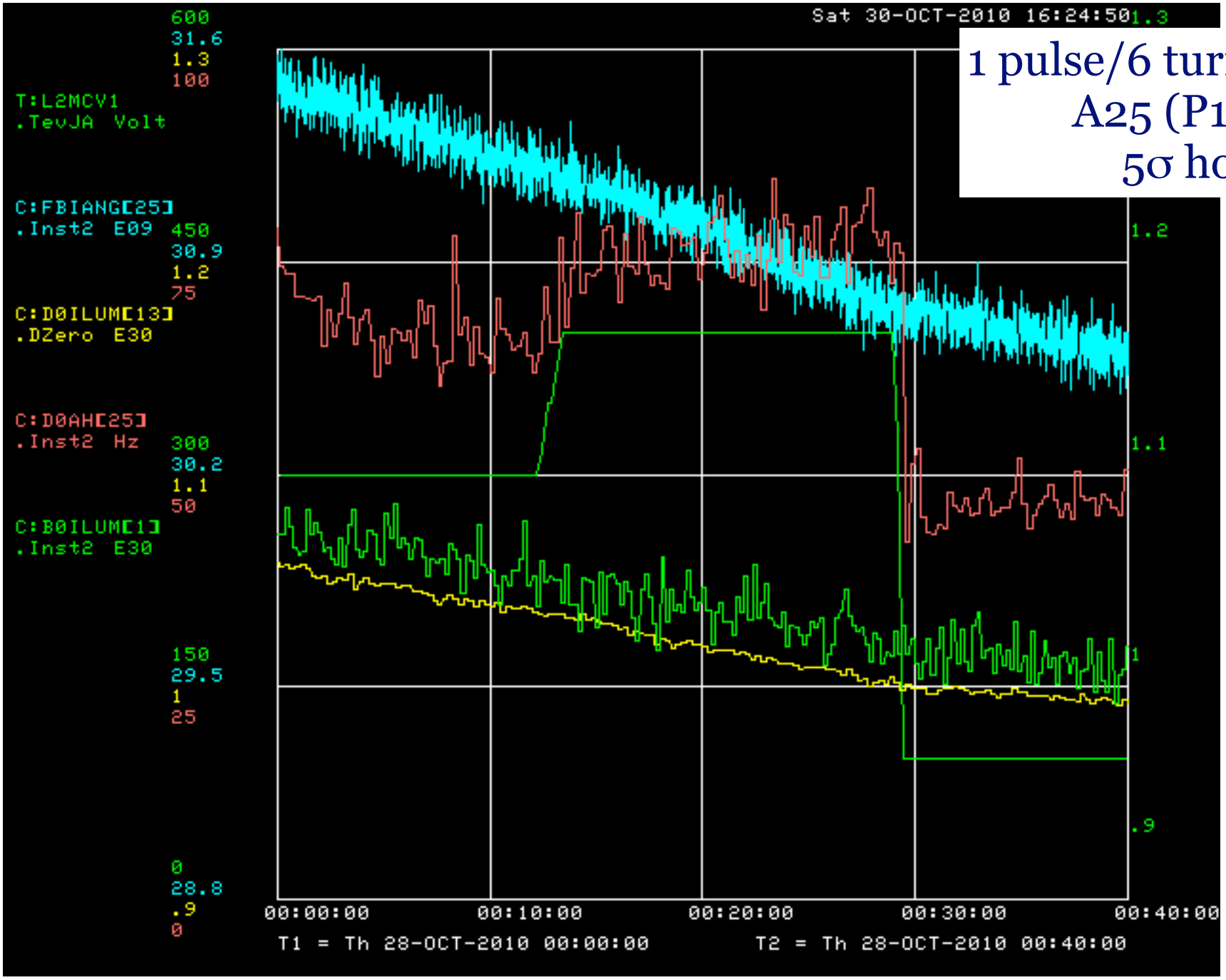
tune settings

coupling

losses

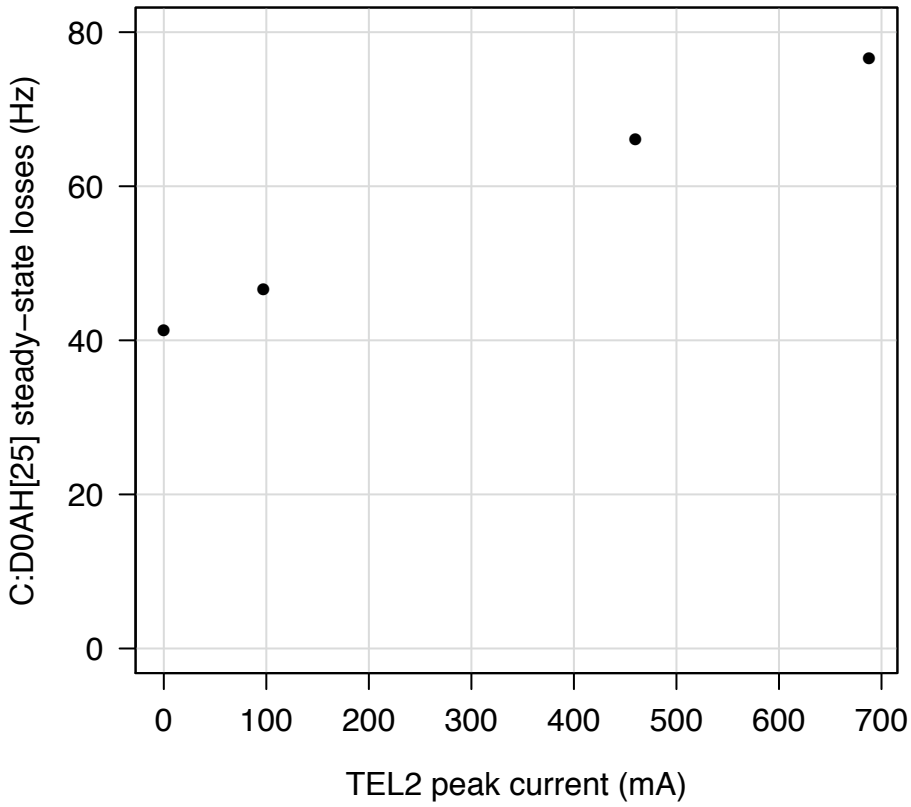


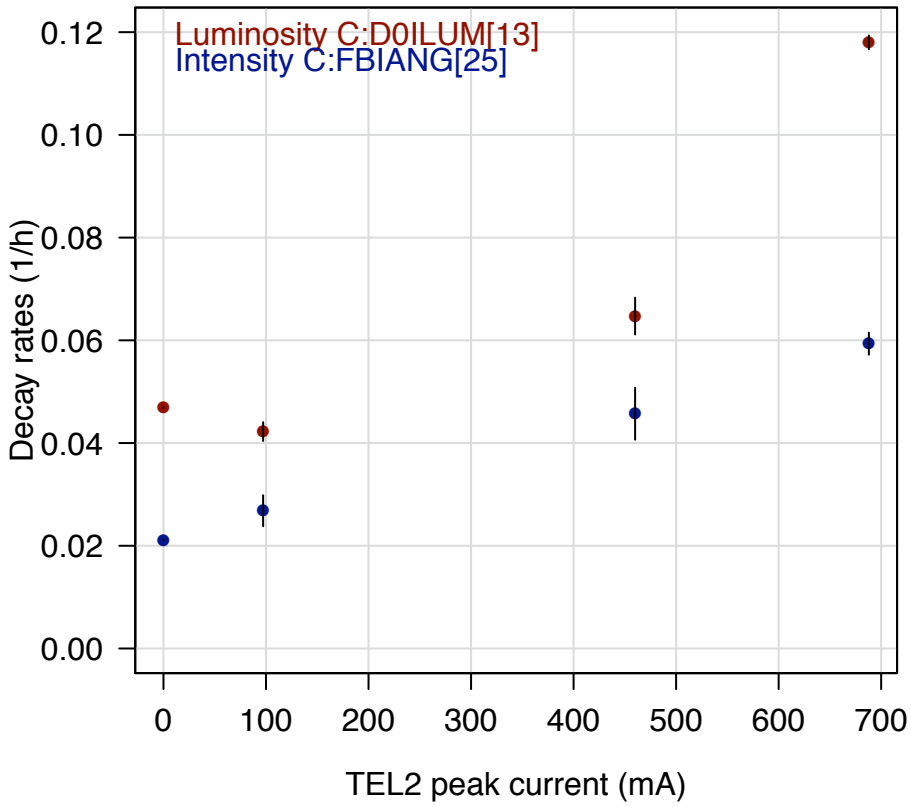
Intensity and luminosity decay rates vs. e-beam intensity



1 pulse/6 turns
A25 (P13)
5σ hole

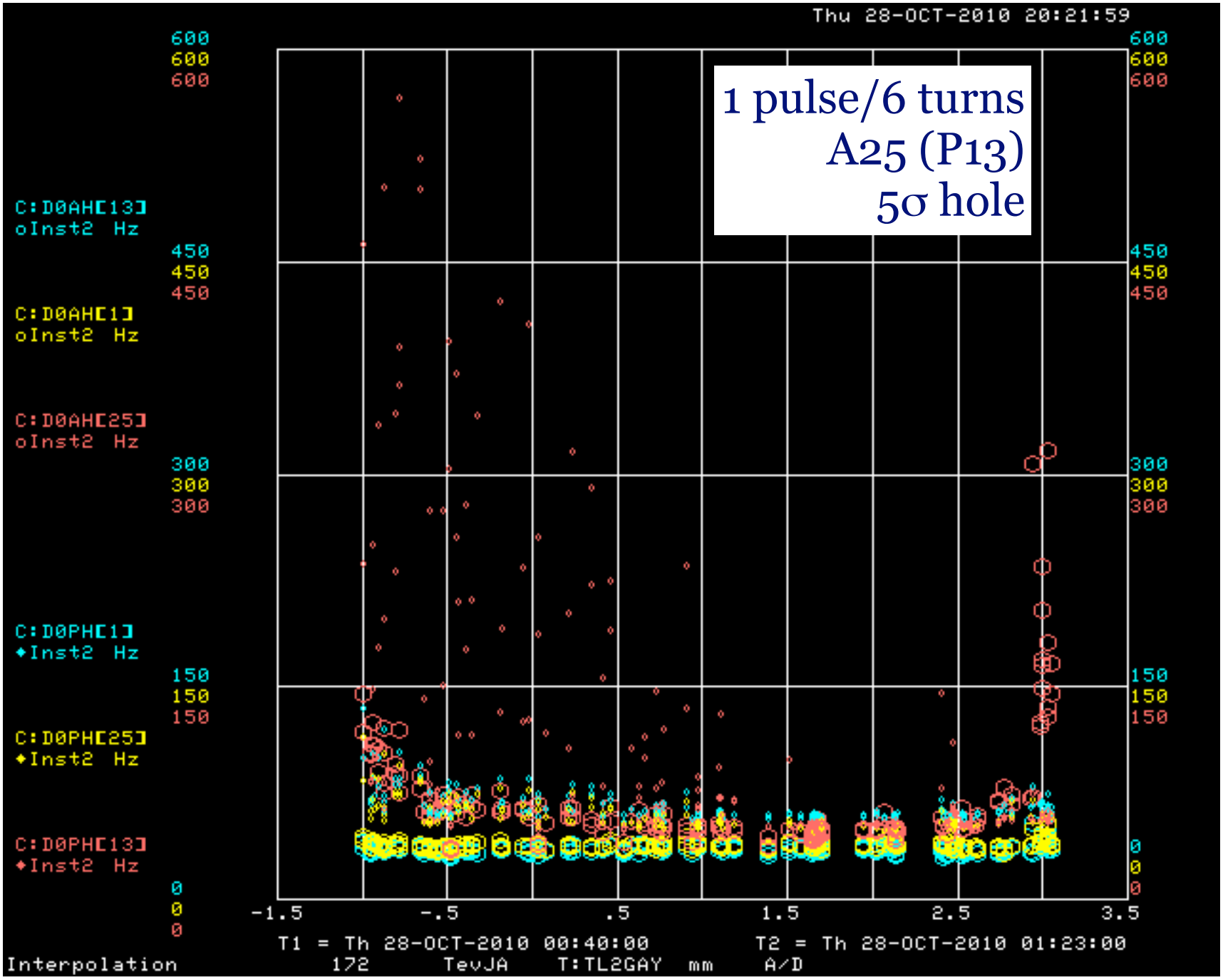
Intensity and luminosity decay rates vs. e-beam current





- Losses and intensity decay rates are proportional to e-current
- Growth of luminosity decay rates is slower
- Indication that scraping without affecting the core is possible

Vertical orbit bump, fixed e-beam



Preliminary results: second study

- When pulsing every 6th turn (TEL1 abort-gap cleaning mode) losses on affected antiproton bunch and on closest proton bunch are sensitive to the machine working point (tunes and coupling) and relative position.
- At the end of a store at least, a stable working point in pulsed mode could always be found.
- Acquired data in stable conditions for 3 e-current settings to quantify differential halo/core scraping.
- Changing (anti)proton orbit at TEL2 with fixed e-beam position is a viable scraping mode: bump is local and tunes are not affected.

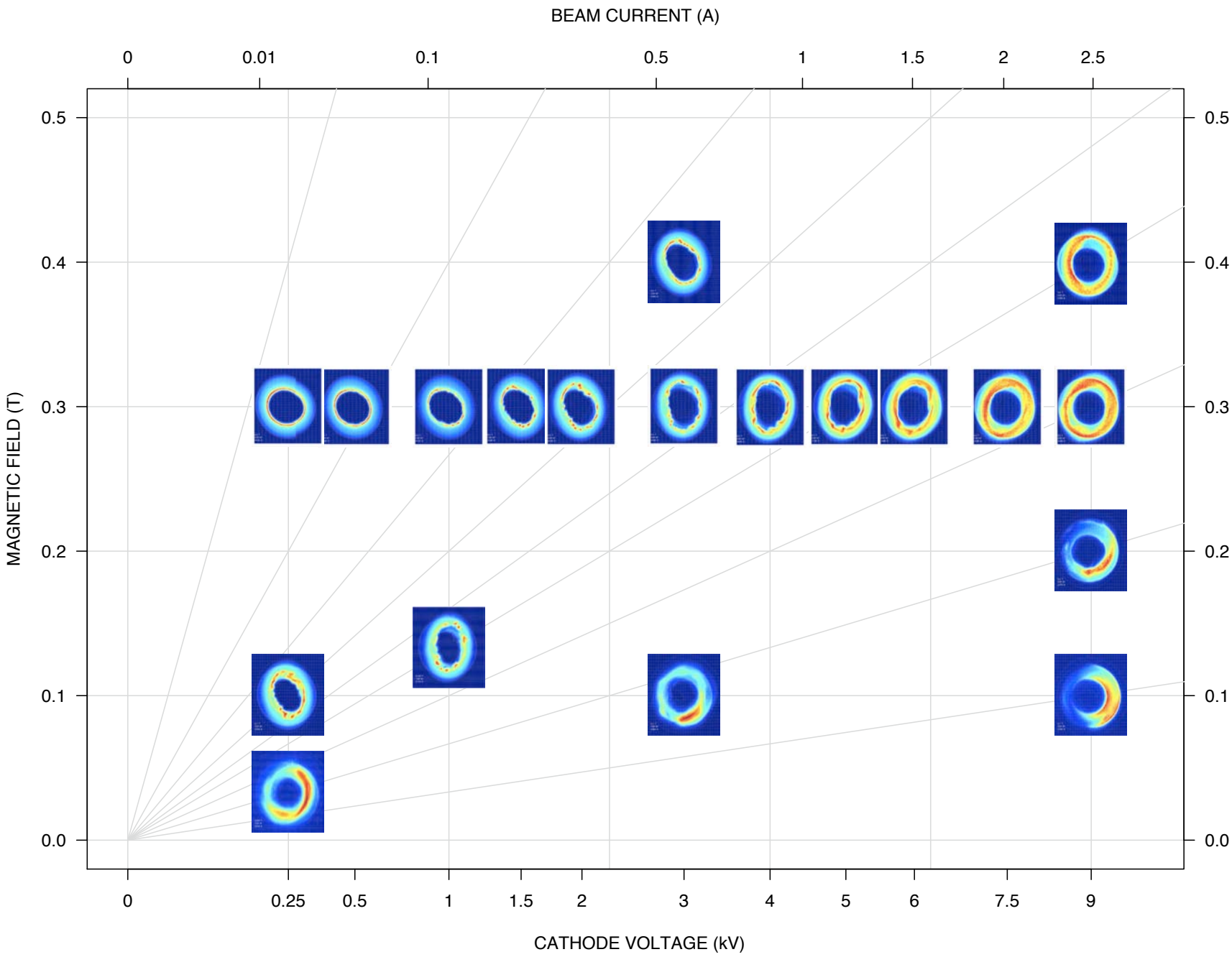
Outlook

- Open questions:
  - Operation at high intensity?
  - Pulsed mode necessary? If yes, stable working point exists?
  - Acting on more than one bunch?
  - Need to try with protons?
- Next steps:
  - Systematic study of observables vs. e-beam current/profile, size, pulsing pattern (mostly parasitical)
  - Collimator scans to directly measure effects on halo population (need dedicated study time)

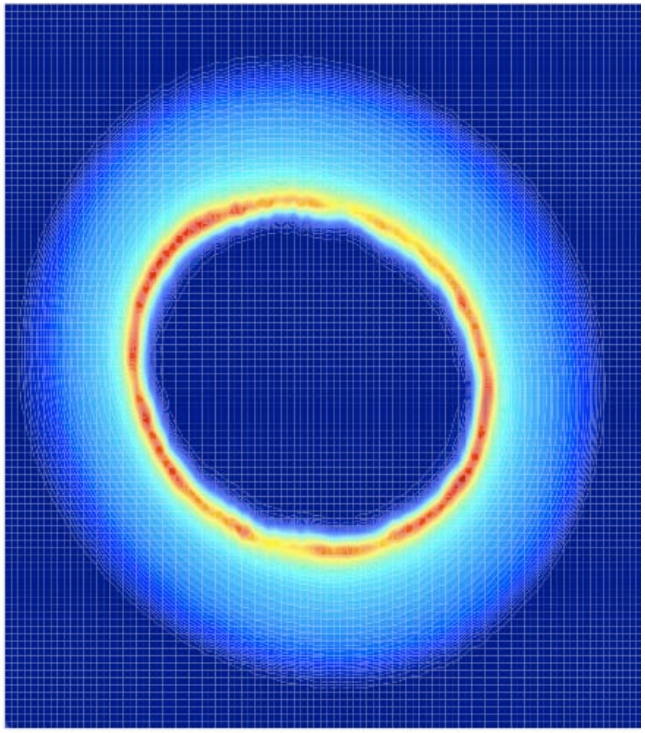
Thanks for your attention

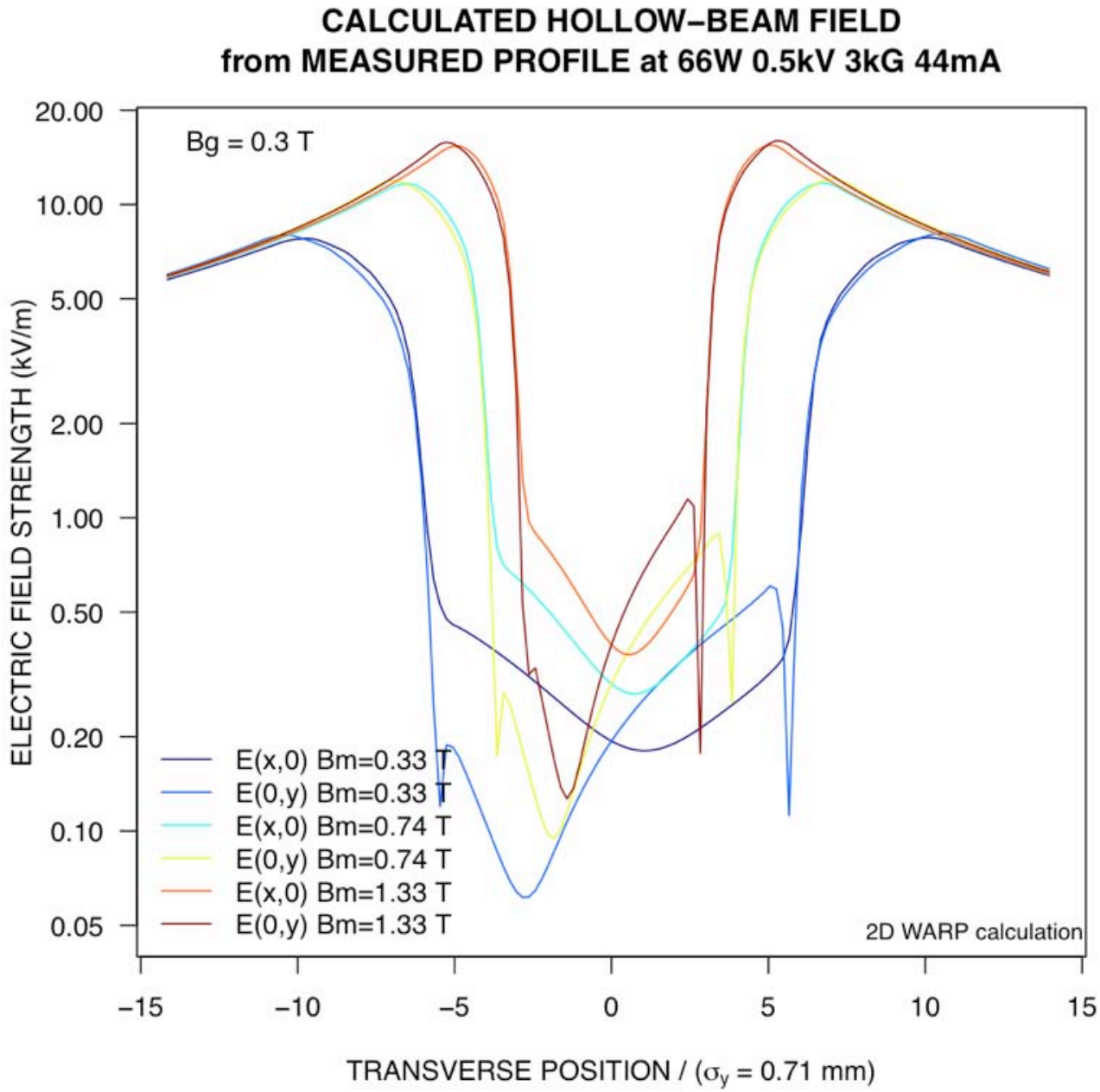
Backup slides

Measured hollow beam profile vs. current and field



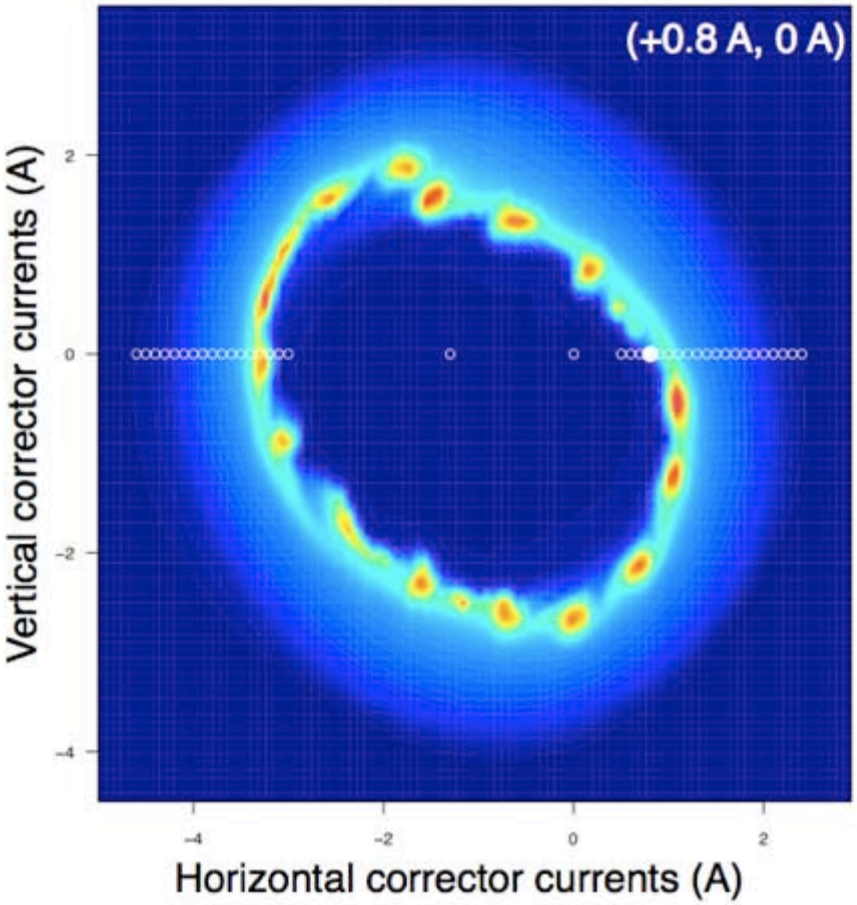
WARP calculation of electric fields from measured profiles

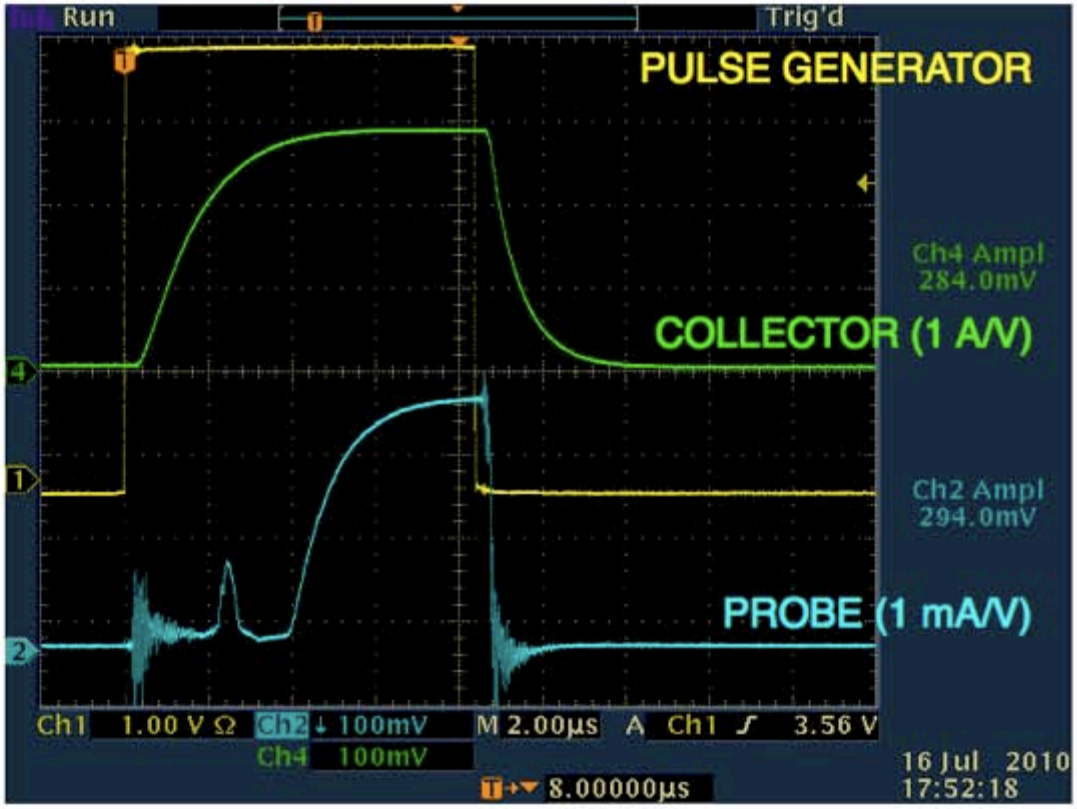




Hollow-beam pulse time structure

TIME MICROSTRUCTURE OF LOCAL CURRENT DENSITY
0.6-in hollow electron gun in TEL test stand, 16 July 2010





Vacuum: 2E-8 mbar
Filament heater: 7.75 A, 5.93 V
Solenoids: 3-4-1 kG (1797 A - 9650 A - 684 A)
Electron pulse: 2 kV, 8 µs width, 4 ms rep., 348 mA peak

→ http://home.fnal.gov/~stancari/hebc/time_structure_movie.gif

Convex cathode? Longitudinal space charge? Ions?