

Pulsed-Beam Capability for the D-Pace ES-4 Emittance Scanner

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D-Pace, Inc.



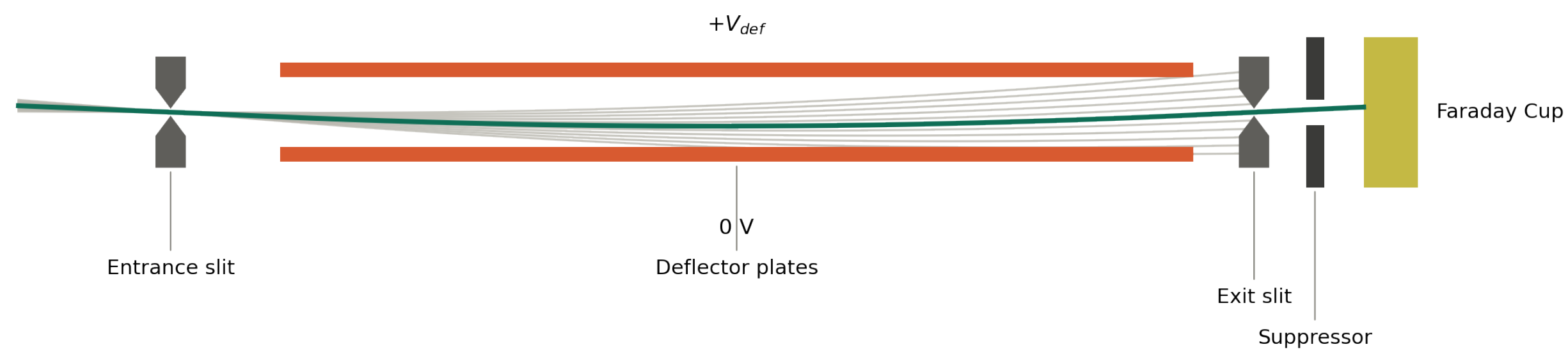
MOTIVATION

Reduce “Ghost” Signals Suppresses ghost-electron artifacts in emittance data	Pulsed Beams and Slice Emittance Resolves how phase space evolves within a single pulse
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How Allison-Type Scanners Work

- A narrow entrance slit lets ions at position x enter the probe
- A pair of deflection plates with voltage Vdef sets the trajectory
- The narrow exit slit ensures only ions with the selected x' exit the scanner and reach the Faraday cup
- Faraday-cup current is measured, giving I(x,x')
- Sweeping the deflection plate voltage sweeps the deflection angle
- Stepping the position of the probe, and repeating this process lets one measure the entire phase-space, with fine resolution

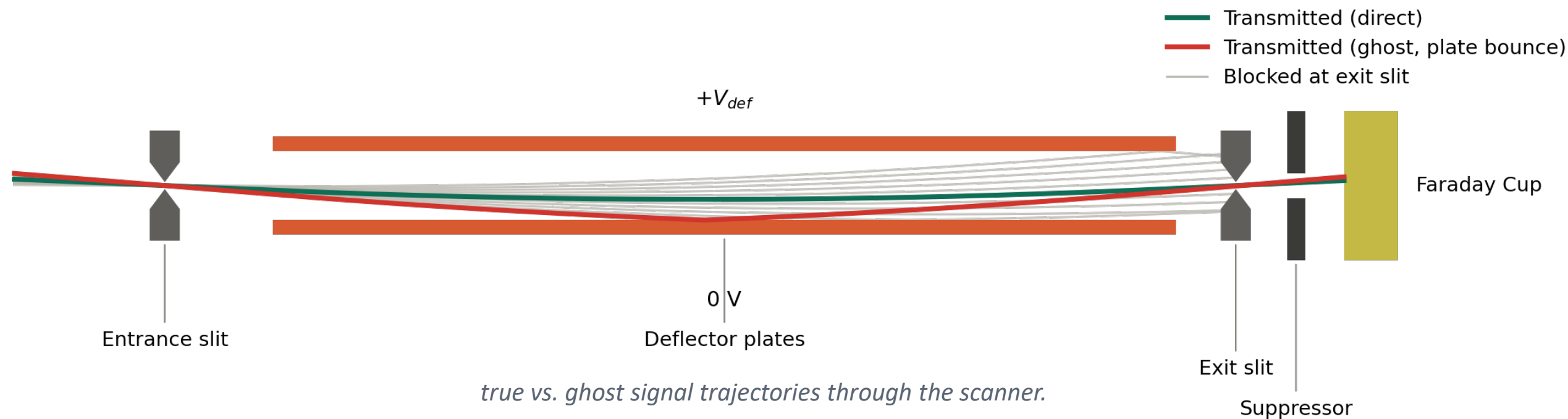
$$x' \approx V_{def} L / (2 \cdot d \cdot U_{beam})$$



Scanning x and Vdef gives I(x,x'), and thereby emittance and Twiss parameters (α, β, γ).

Ghost Signals

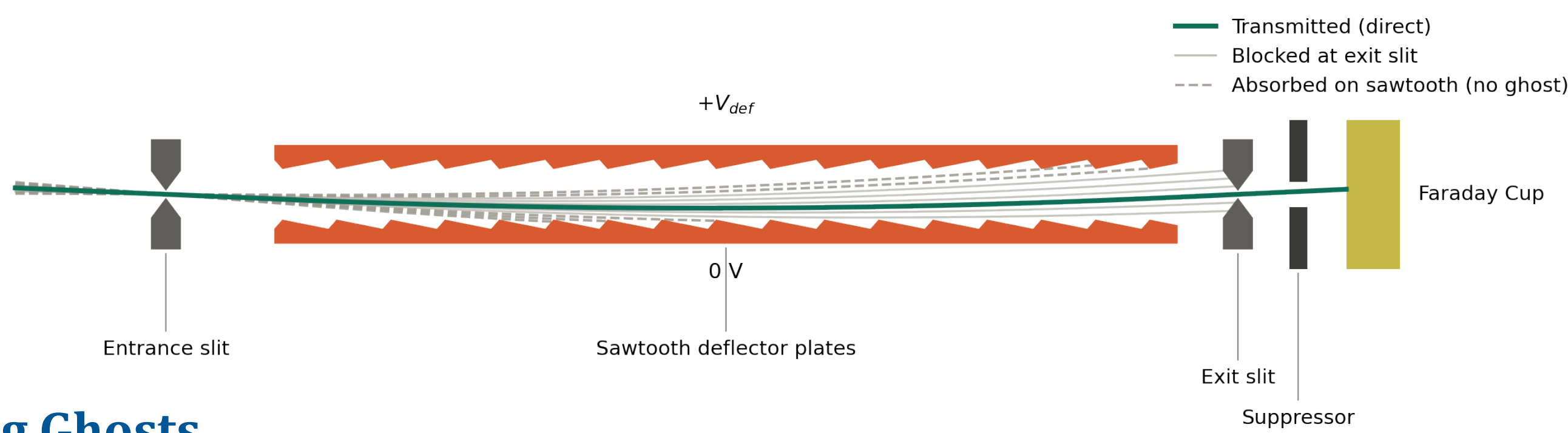
- Beamlets with certain entrance angles will collide with the deflector plate rather than the exit slit, sometimes with grazing incidence
- Grazing incidence favors backscattering over implantation
- Primary ions reflect off the surface while retaining most of their forward (beam-axis) momentum
- These primary ions can sometimes reach the exit slit resulting in a spurious “ghost” signal
- Ghost signals correlate with the real phase-space and appear as an offset region at large trajectory angles, biasing emittance estimates



true vs. ghost signal trajectories through the scanner.

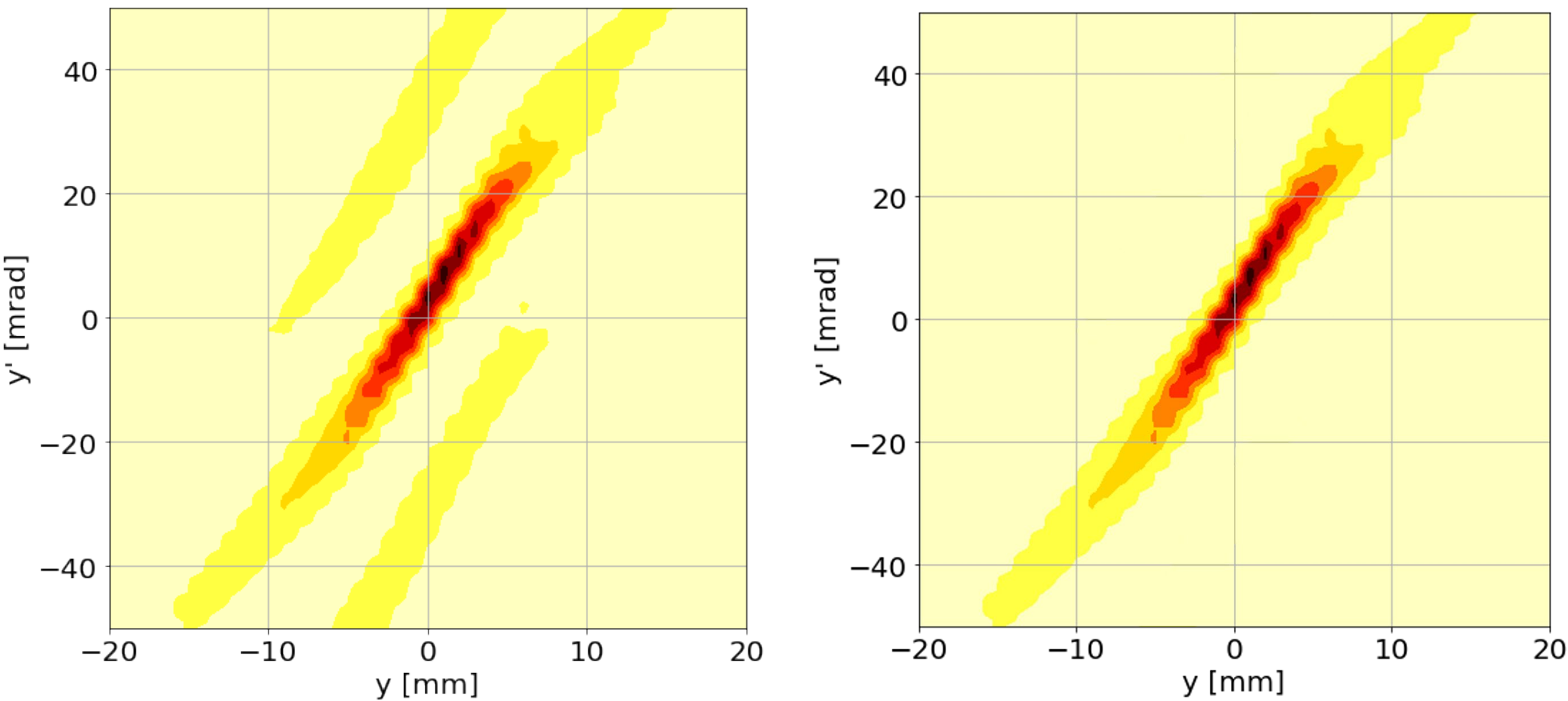
Saw-Tooth “Anti-Ghosting” Deflection Plates

- Staircase-cut plates replace the flat face with steep 70° risers, so ions that used to hit at grazing angles now strike nearly normal to the local surface.
- Near-normal impact favors implantation over backscattering, so primary ions stop in the plate instead of reflecting back toward the exit slit.
- Step angles are sized to the scanner's max impact-angle range, greatly reducing ghost signals
- This idea was first proposed by Stockli et al. [1]



Busting Ghosts

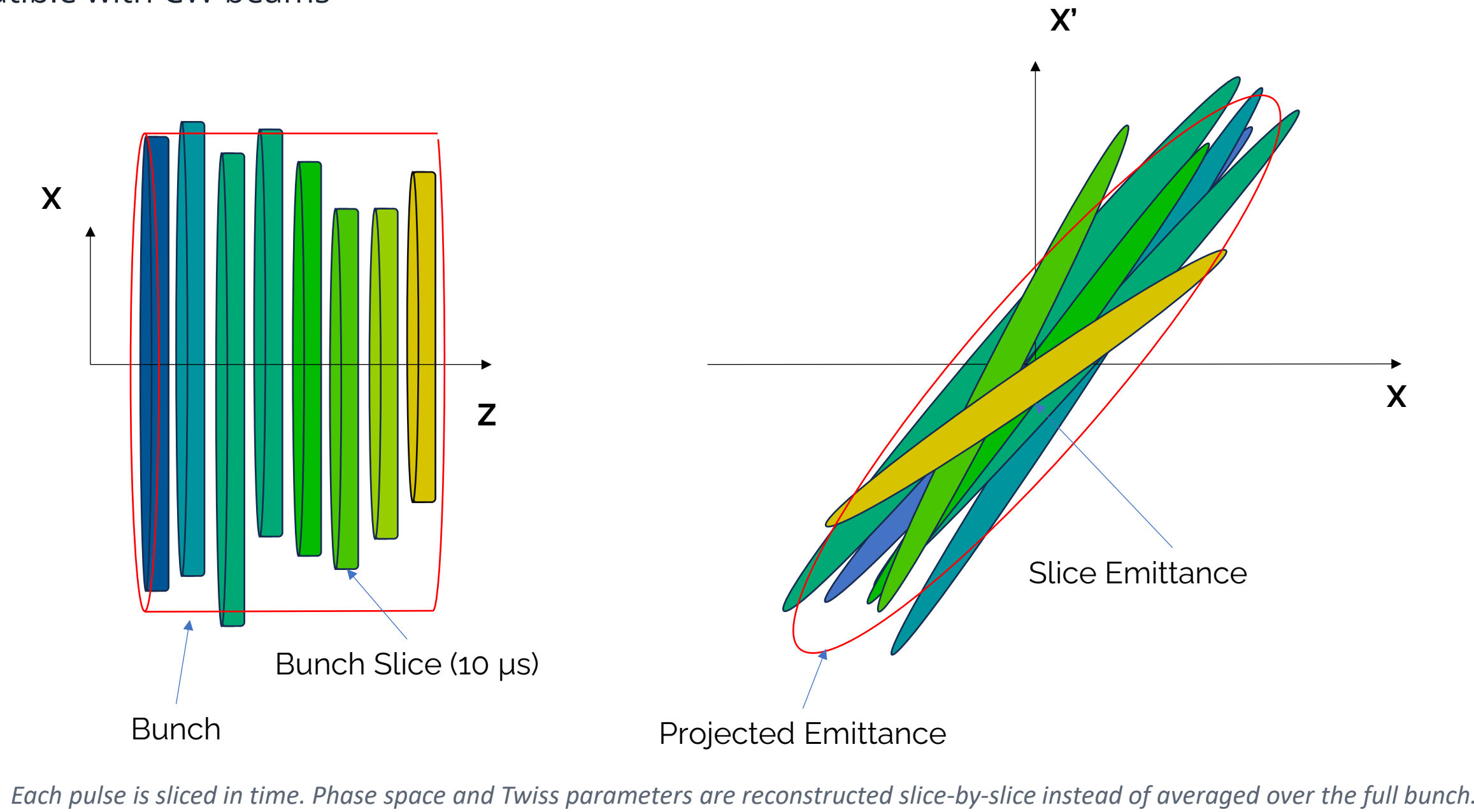
- The left image shows a typical scan of our H- source, with flat deflection plates
- Image on the right shows the same beam, instead measured with the sawtooth “anti-ghosting” plates
- Below results are from simulation



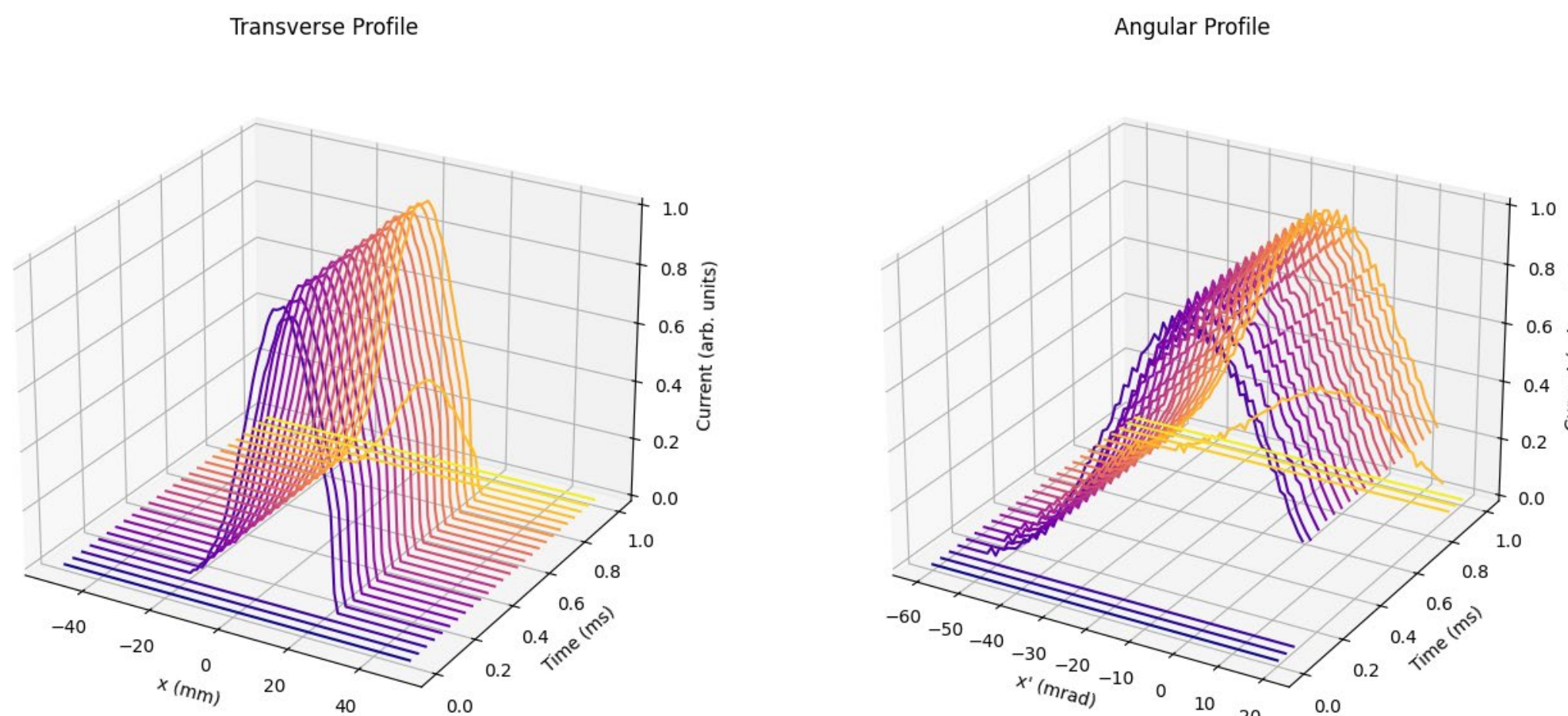
Synchronized Pulsed Acquisition

The upgraded control system now times acquisition to the pulse structure, in two modes:

- **Time-resolved** — windows as fine as 10 μs, showing phase-space over time within a single pulse
- **Averaged** — a conventional, CW-style measurement over the full pulse, giving the projected emittance
- Still fully compatible with CW beams



Each pulse is sliced in time. Phase space and Twiss parameters are reconstructed slice-by-slice instead of averaged over the full bunch.



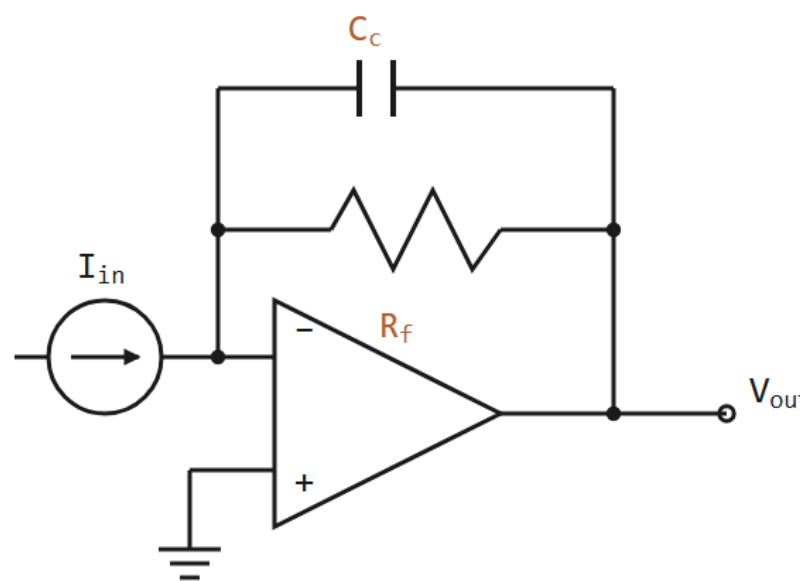
Integrating over the slices gives the transverse and angular profile of a bunch over time

Picoammeter Front-End Design

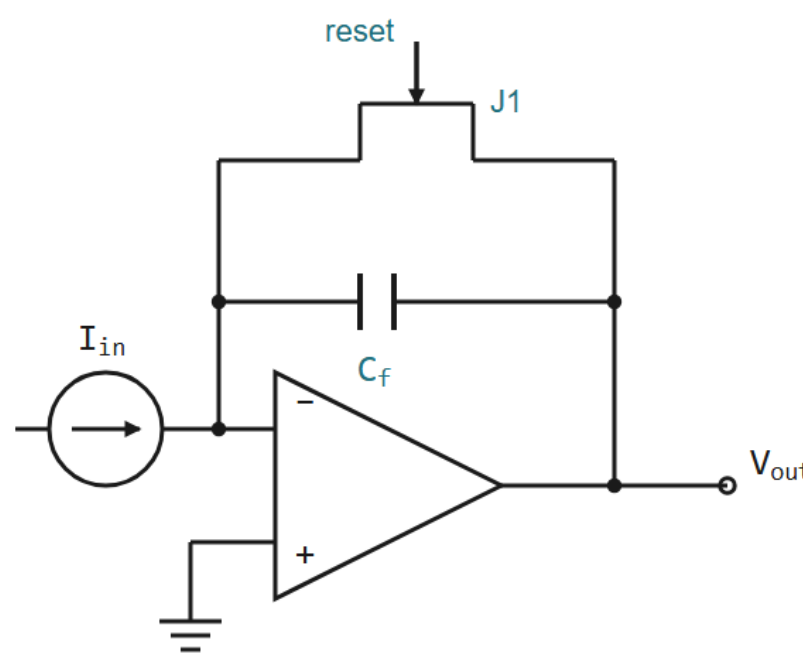
The Faraday-cup current is digitized by a D-Pace-designed charge-integrating picoammeter, giving I(x,x',t)

Capacitive vs. Resistive Transimpedance Amplifier

Resistive TIA



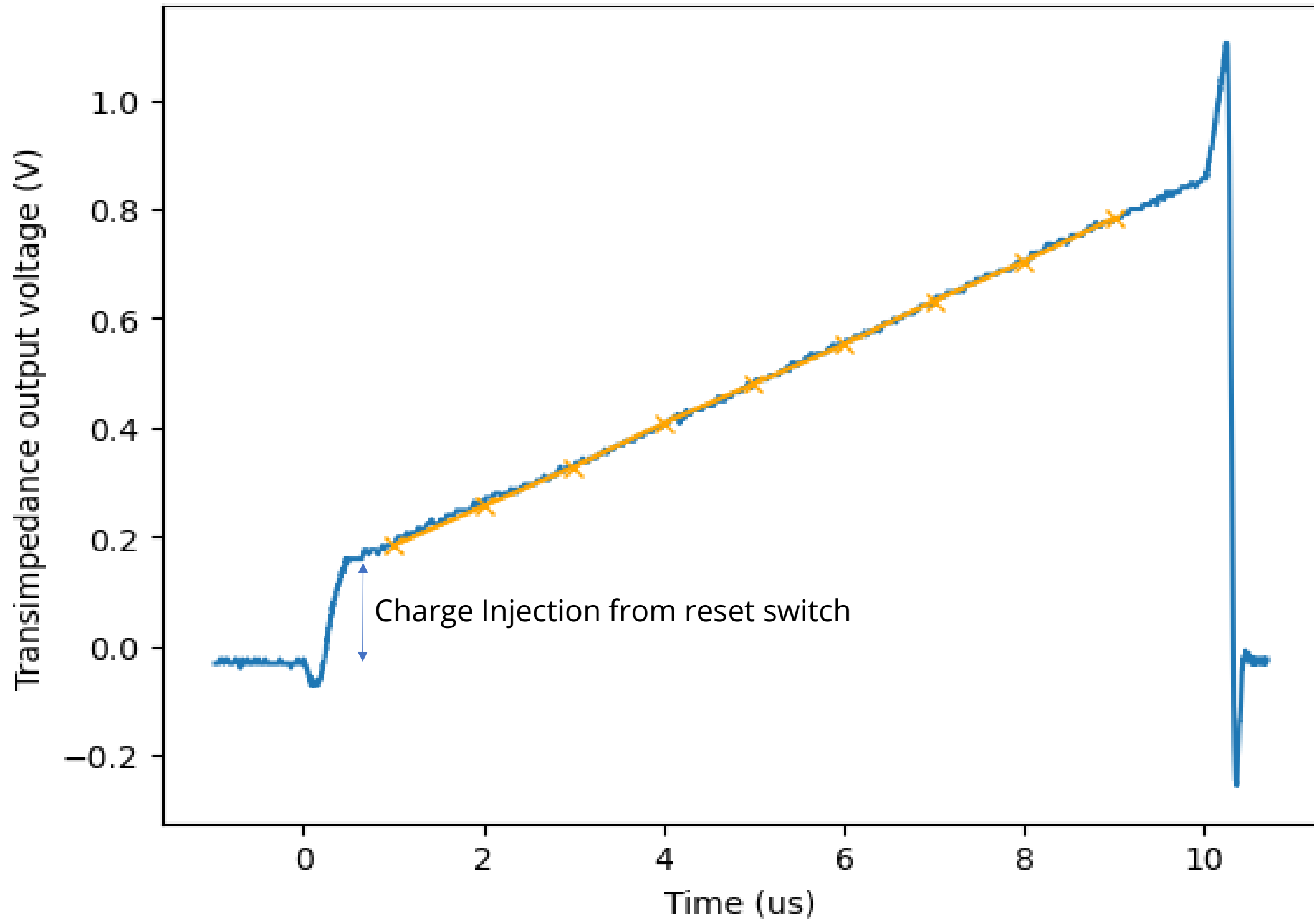
Capacitive TIA (integrator)



- A resistive TIA's noise scales as √Rf, so a bigger feedback resistor looks quieter, but the same Rf sets a pole with the parasitic capacitance, f3dB ≈ 1 / (2π · Rf · Cf): more sensitivity costs speed
- Charge integration avoids that trade-off. Beam current charges a feedback capacitor, Q = ∫ I dt = CV, with gain set by 1 / Cf instead of Rf
- An ideal capacitor adds no thermal noise, so the noise floor is set by op-amp input noise and reset-switch resistance, preserving pA–nA sensitivity without sacrificing bandwidth
- Pulse timing runs on an STM32 High-Resolution Timer running at 480 MHz, synchronized to the source trigger, allowing for no more than roughly 4 ps jitter

Charge Injection Mitigation and Ramp Sampling

- Charge Injection occurs due to fast rising edges on the reset switch coupling into the feedback capacitor via the switch's gate-drain capacitance
- We reduce the effect of charge injection by beginning sampling after the transient has finished
- A linear regression on the ramp samples extracts the slope of V(t), which, when scaled by the feedback capacitance, gives the average current over the pulse
- This averages down sample-to-sample noise across every point, rather than relying on just the endpoint samples, giving a more accurate current estimate than a simple two-point measurement.



Outlook

The upgraded ES-4 delivers slice-resolved emittance data from pulsed beams while redesigned deflection plates suppress the ghost signals that once corrupted phase-space measurements.

10 μs
slice-resolved
acquisition

No Ghosts
Anti-ghosting deflection plates
eliminate ghost signals

19"
rack-mount,
EPICS-ready

CW and Pulsed
no hardware changes
for CW vs. pulsed

References: [1] Stockli, Martin P., et al. "Ghost signals in Allison emittance scanners." *AIP Conference Proceedings*. Vol. 749. No. 1. AIP, 2005.