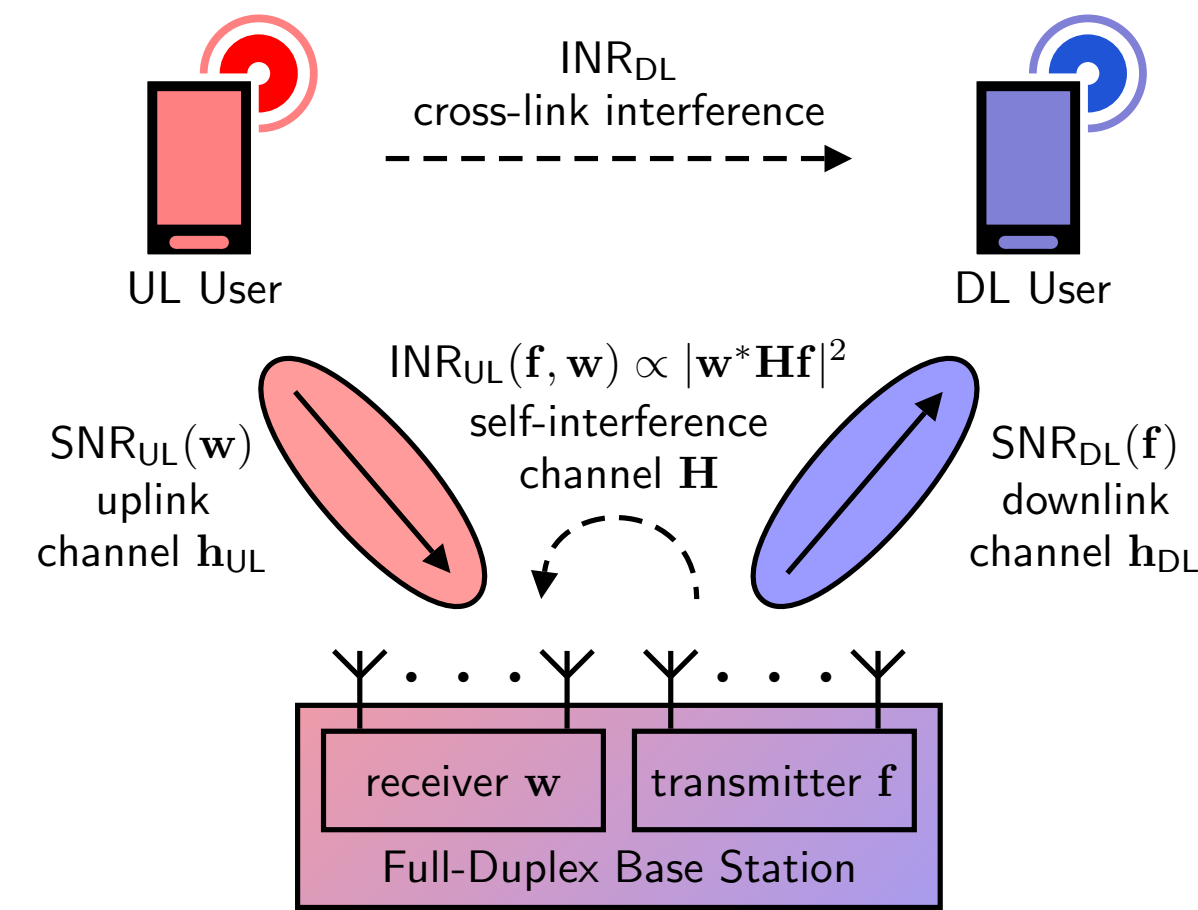


Full-Duplex System Model



A base station with an N_t -antenna transmit array (beam $\mathbf{f}$) and an N_r -antenna receive array (beam $\mathbf{w}$) serves one downlink and one uplink user at the same time and same frequency band:

$$\text{SNR}_{\text{DL}}(\mathbf{f}) = \frac{P_{\text{tx}}^{\text{BS}} |\mathbf{h}_{\text{DL}}^* \mathbf{f}|^2}{P_{\text{n}}^{\text{UE}}}, \quad \text{SNR}_{\text{UL}}(\mathbf{w}) = \frac{P_{\text{tx}}^{\text{UE}} |\mathbf{w}^* \mathbf{h}_{\text{UL}}|^2}{P_{\text{n}}^{\text{BS}}}$$

$$\text{INR}_{\text{UL}}(\mathbf{f}, \mathbf{w}) = \frac{P_{\text{tx}}^{\text{BS}} |\mathbf{w}^* \mathbf{H} \mathbf{f}|^2}{P_{\text{n}}^{\text{BS}}}, \quad \mathbf{H} = \sqrt{\frac{\kappa}{\kappa+1}} \bar{\mathbf{H}} + \sqrt{\frac{1}{\kappa+1}} \hat{\mathbf{H}}$$

- **Self-interference:** Transmit signal leaks onto receiver over the channel $\mathbf{H}$ [1]: static near-field $\bar{\mathbf{H}}$ plus time-varying reflections $\hat{\mathbf{H}}$.
- **Cross-link interference:** The uplink user interferes with the downlink user (INR_{DL}), independent of the base station beams.
- **Prior work** (STEER [2, 3]): Probe self-interference on candidate pairs near the aligned beams to pick a serving pair; each probe costs user airtime and repeats as users move.

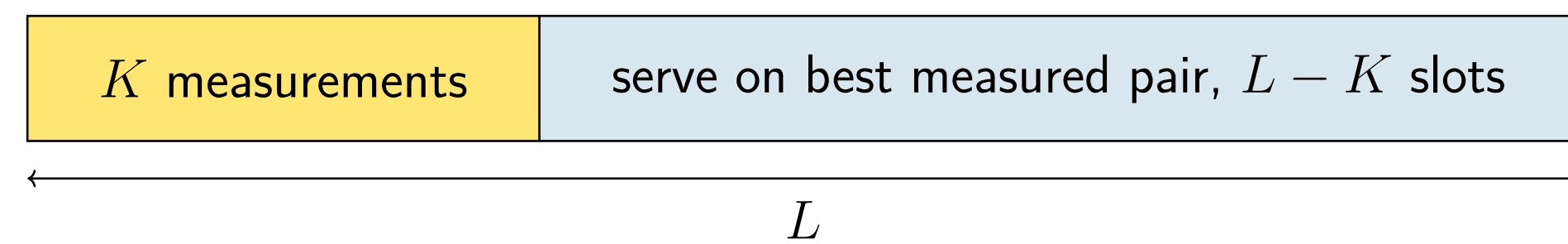
Metric and Problem Formulation

Metric: Sum spectral efficiency of a beam pair $(\mathbf{f}, \mathbf{w})$:

$$R(\mathbf{f}, \mathbf{w}) = \log_2 \left(1 + \frac{\text{SNR}_{\text{DL}}(\mathbf{f})}{1 + \text{INR}_{\text{DL}}} \right) + \log_2 \left(1 + \frac{\text{SNR}_{\text{UL}}(\mathbf{w})}{1 + \text{INR}_{\text{UL}}(\mathbf{f}, \mathbf{w})} \right)$$

- **Known** after beam alignment: SNR_{DL} , SNR_{UL} , INR_{DL} .
- **Unknown** unless measured: $\text{INR}_{\text{UL}}(\mathbf{f}, \mathbf{w})$ (one time slot defined as the time to collect a single probing measurement).

Trade-off: Each user pair is allocated L time slots:



Problem: Select the K probing measurements and serving pair:

$$\max_{\mathbf{f}, \mathbf{w}, K} \underbrace{\frac{L-K}{L}}_{\text{airtime left}} \cdot \underbrace{R(\mathbf{f}, \mathbf{w})}_{\text{sum rate}}$$

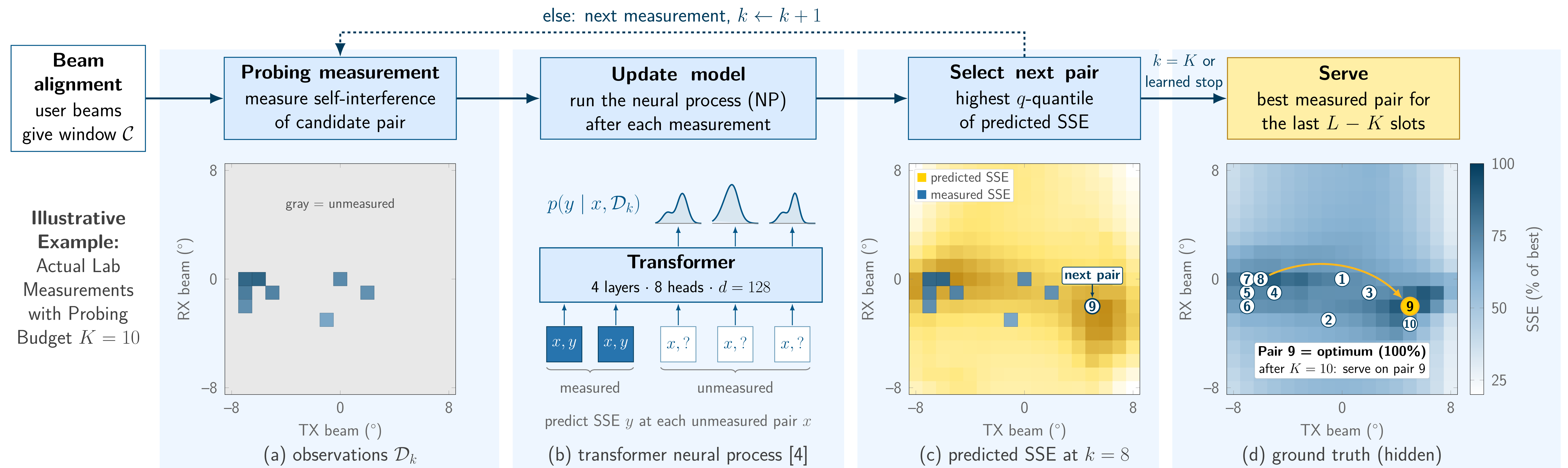
s.t. $(\mathbf{f}, \mathbf{w})$ is one of the K measured pairs

Candidate pairs must lie within $\pm\Delta\theta$ of the beams identified from beam alignment. $\rightarrow$ Ensures high SNR is maintained.

- **Option #1: Fixed budget:** K is chosen from L in advance.
- **Option #2: Variable budget (learned stop):** After each probe, a small head on the NP predicts the chance the best pair so far is $>5\%$ below optimal; stop once this predicted miss falls below $\delta(L)$.

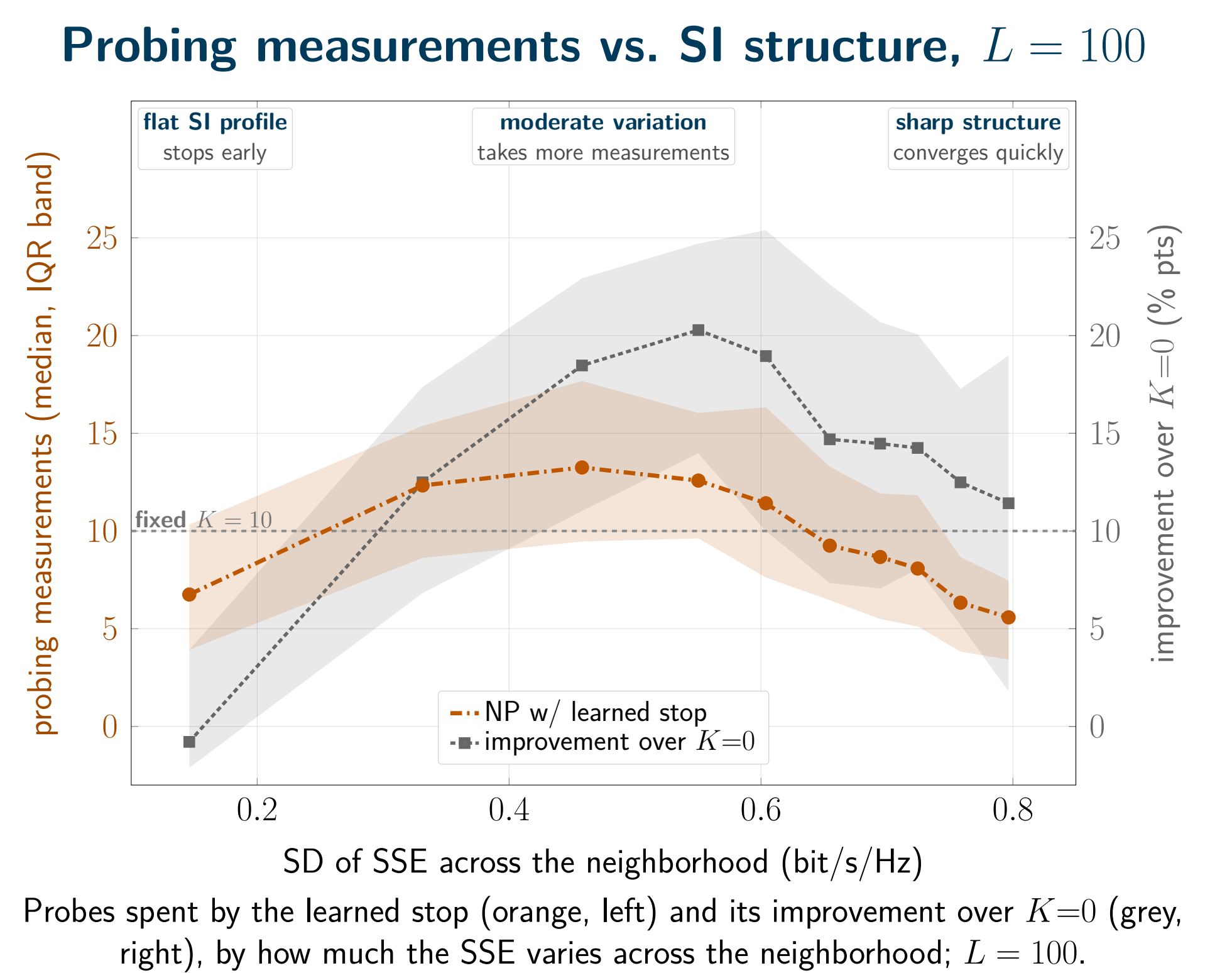
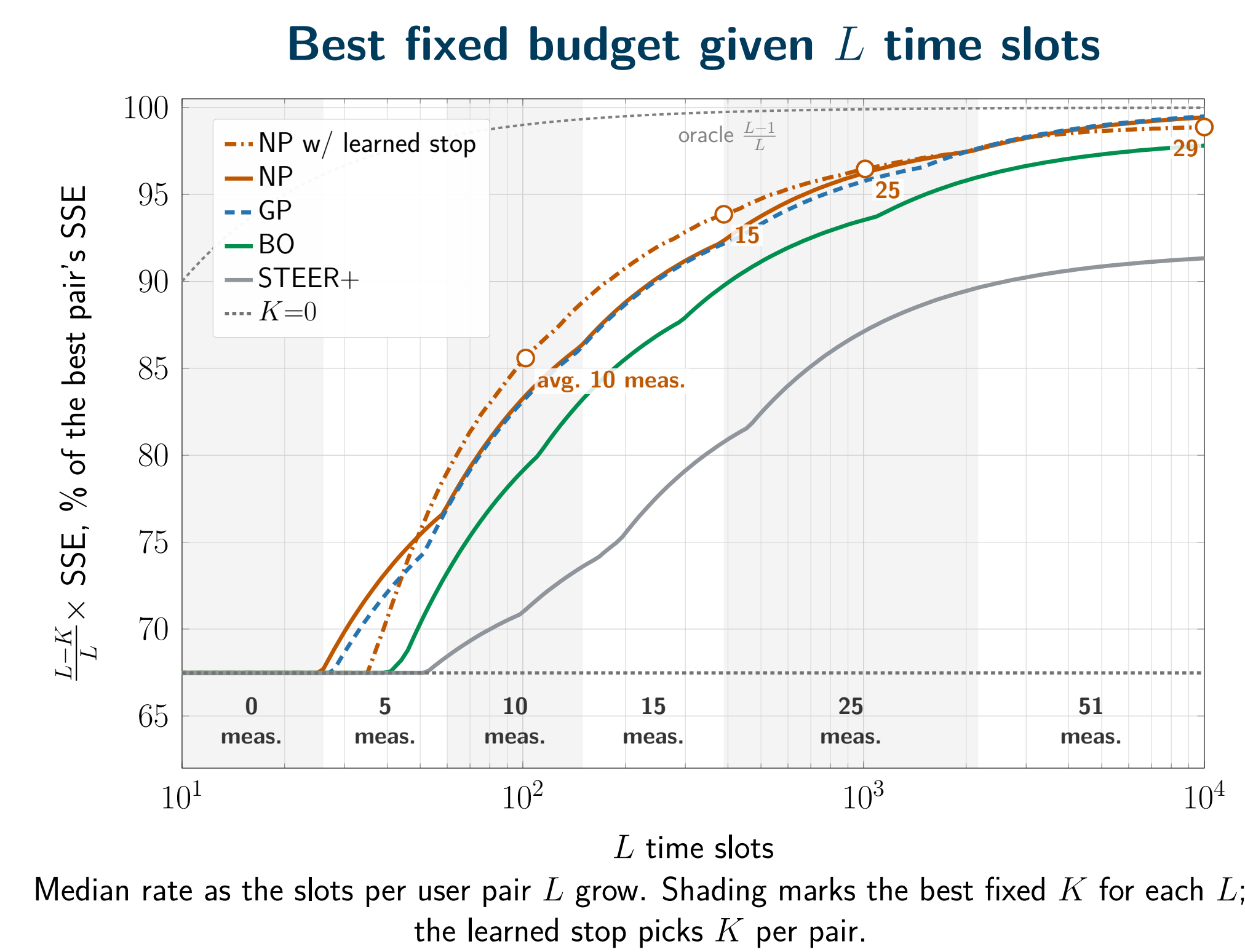
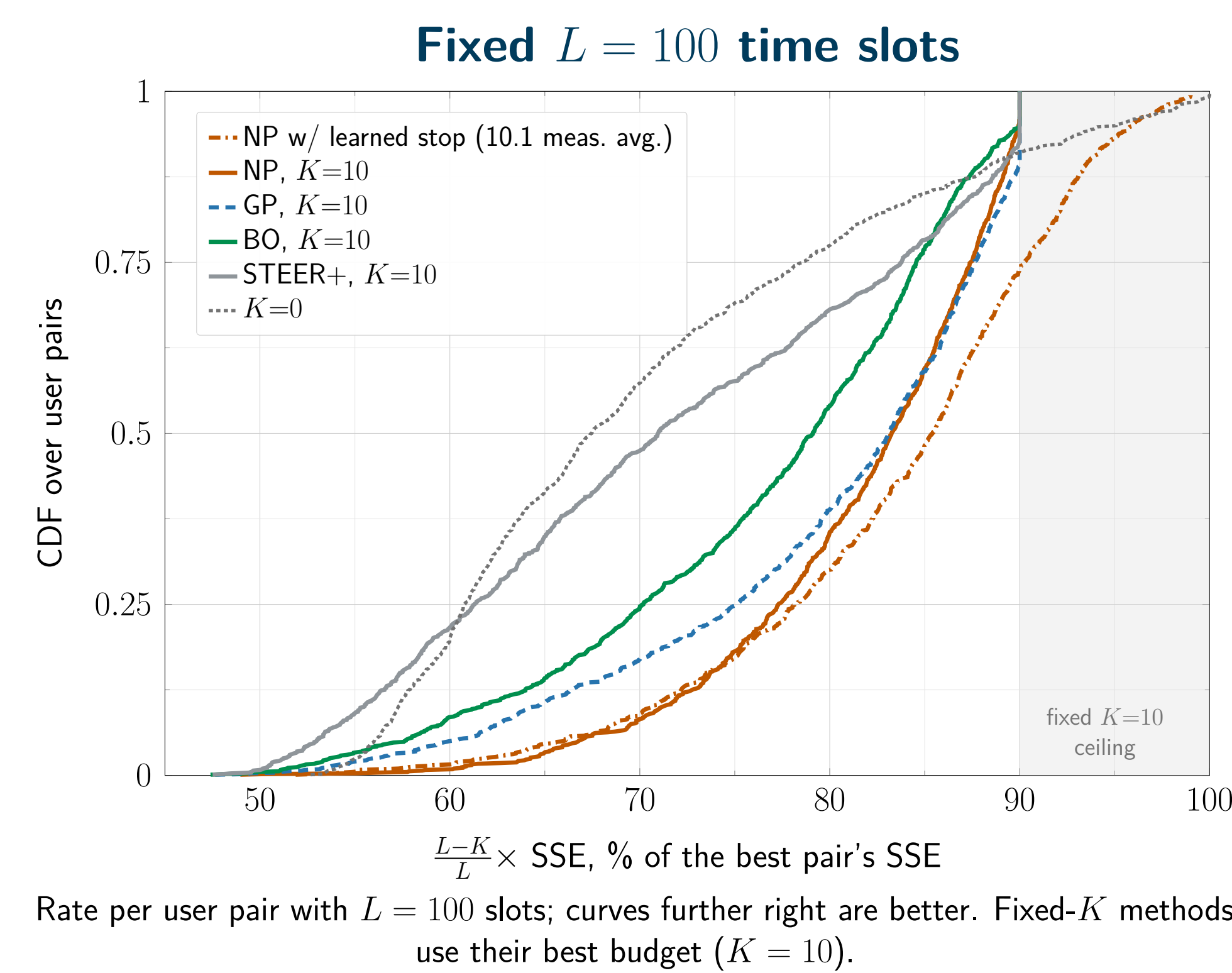
Goal: Maximize rate per time slot by balancing K against $R(\mathbf{f}, \mathbf{w})$.

Proposed Method: Sequential Probing and Beam Selection



Results

Compared against: STEER+ [3] (local search over pairs near the aligned beams), BO [5] (Bayesian optimization directly on measurements), and GP (our sequential refinement loop with a training-free Gaussian process surrogate in place of the NP).



Dataset

- **Source:** measured 28 GHz self-interference between the transmitter and receiver phased arrays of a full-duplex base station [1], the campaign used by STEER [2].
- **Neighborhoods:** 11,025 user pairs, each with $5^4 = 625$ candidate beam pairs (5×5 transmitter by 5×5 receiver, azimuth and elevation) around the aligned beams.
- **Measurements:** self-interference power (INR) only, one per probe.
- **Evaluation:** 1,000 neighborhoods on 10 receiver beams held out from training.

Future Steps

- **Finer codebooks:** overhead grows with K , not with the number of candidate pairs, so the same loop can search finer angular grids.
- **User mobility:** carry measurements across time to track moving users with fewer probes.
- **New arrays and sites:** test how well the NP transfers to other hardware and environments.
- **Online learning:** keep updating the NP from probes collected in deployment, so it adapts as the SI channel changes.

References

- [1] I. P. Roberts et al., Beamformed SI Measurements at 28 GHz, *IEEE Trans. Wireless Commun.*, 2022.
- [2] I. P. Roberts et al., STEER, *IEEE Trans. Commun.*, 2022.
- [3] I. P. Roberts et al., STEER+, *Asilomar*, 2023.
- [4] T. Nguyen and A. Grover, Transformer Neural Processes, *ICML*, 2022.
- [5] S. Yang et al., BO-Based Beam Alignment, *IEEE PIMRC*, 2022.