Button response map and gain calibration

Antoine

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Beam position accuracy

We use look-up tables (maps) to reconstruct the beam position non-linearly

How well the maps describe reality affects:

- ✗ accuracy on beam position (and differential position)
- ✗ precision on gain calibration

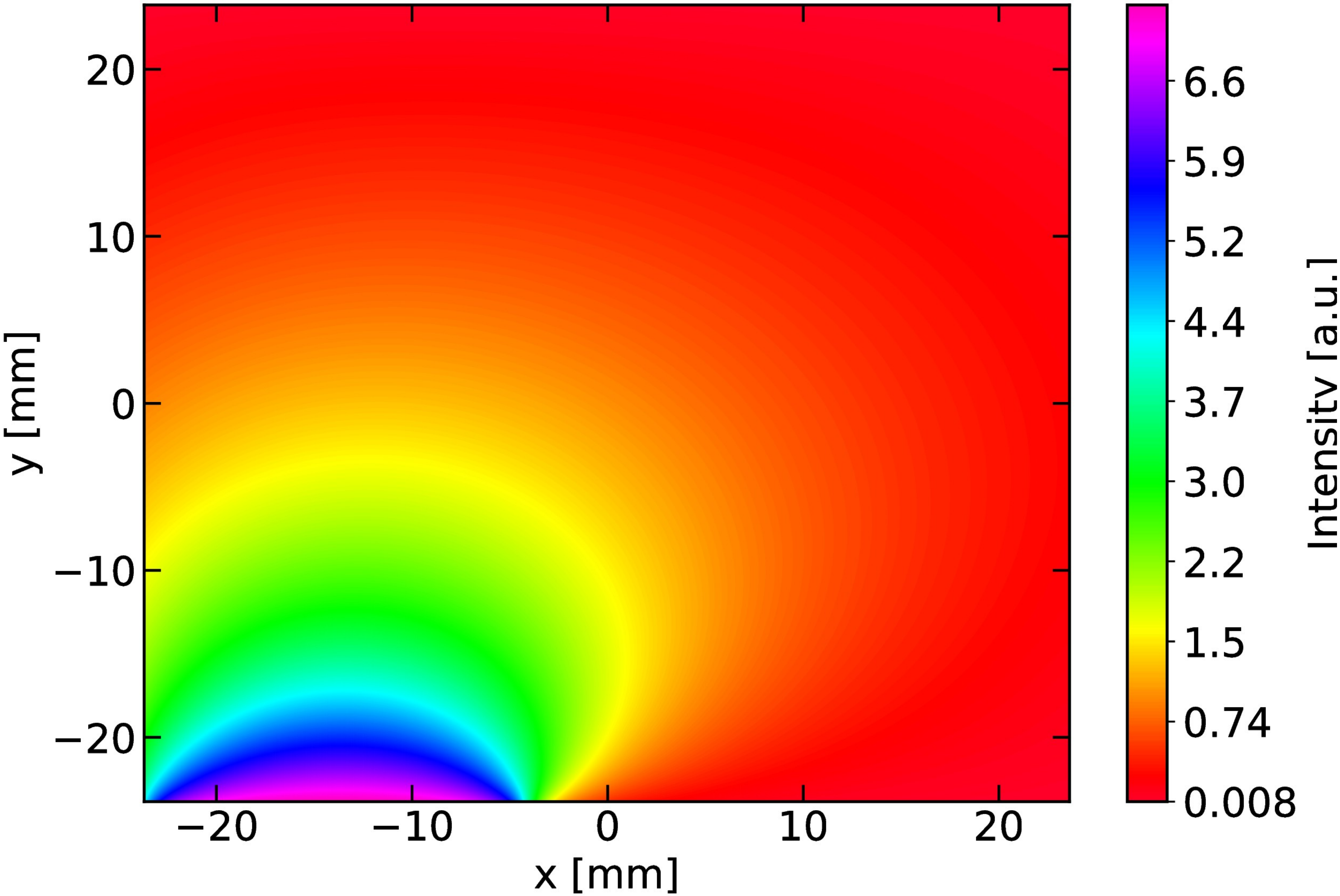
For the past many years we have been using maps generated using Poisson's equation (2D static approach)

Let's simulate the map using CST studio to incorporate 3D dynamic effects calculating time domain wakefield simulation

Note: this work is the revival of previous work that stalled couple years ago (see [0], [1], [2])

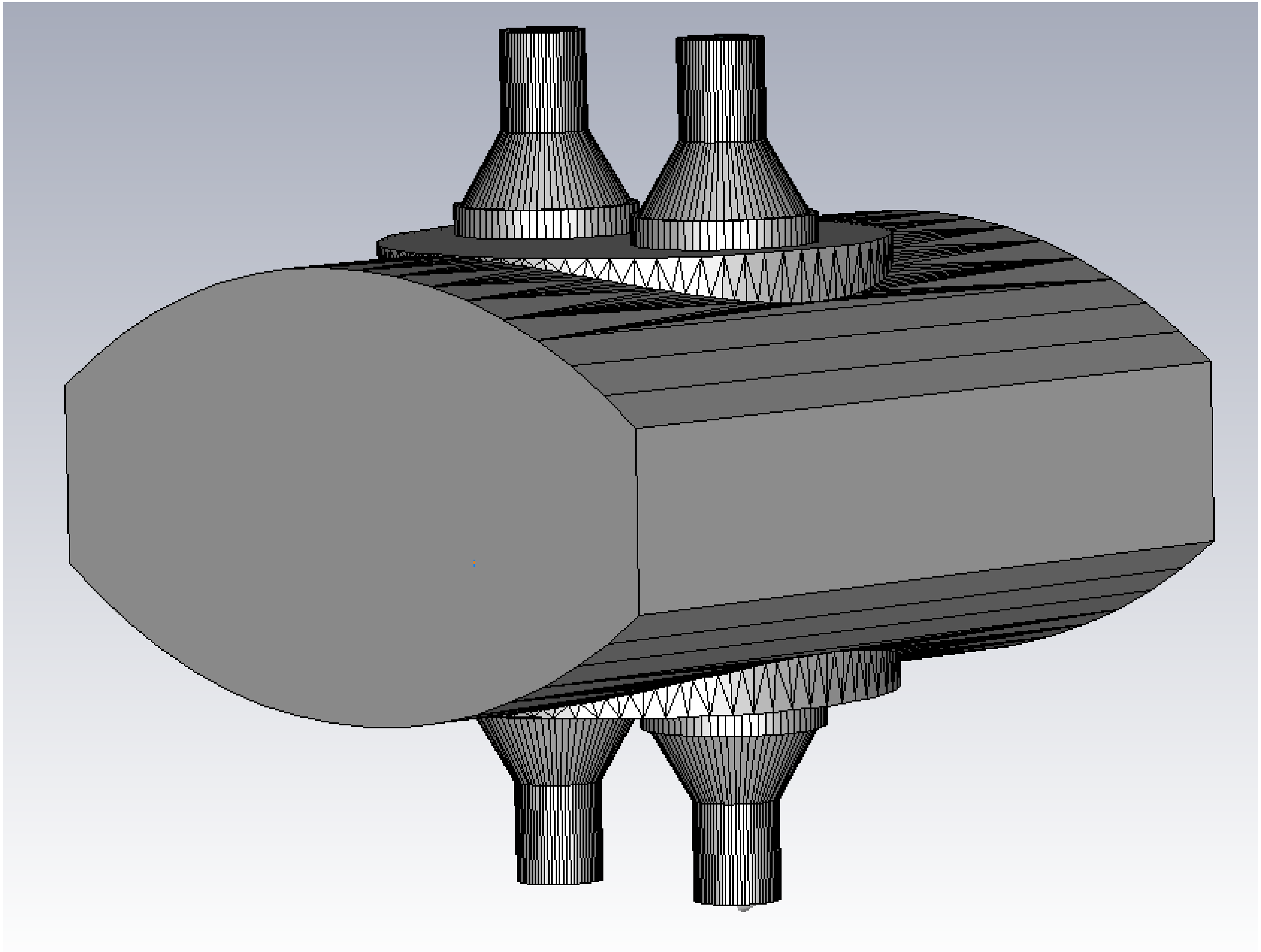
Nonlinear button response (North Arc)

Our standard map obtained solving  's equation (2D static)

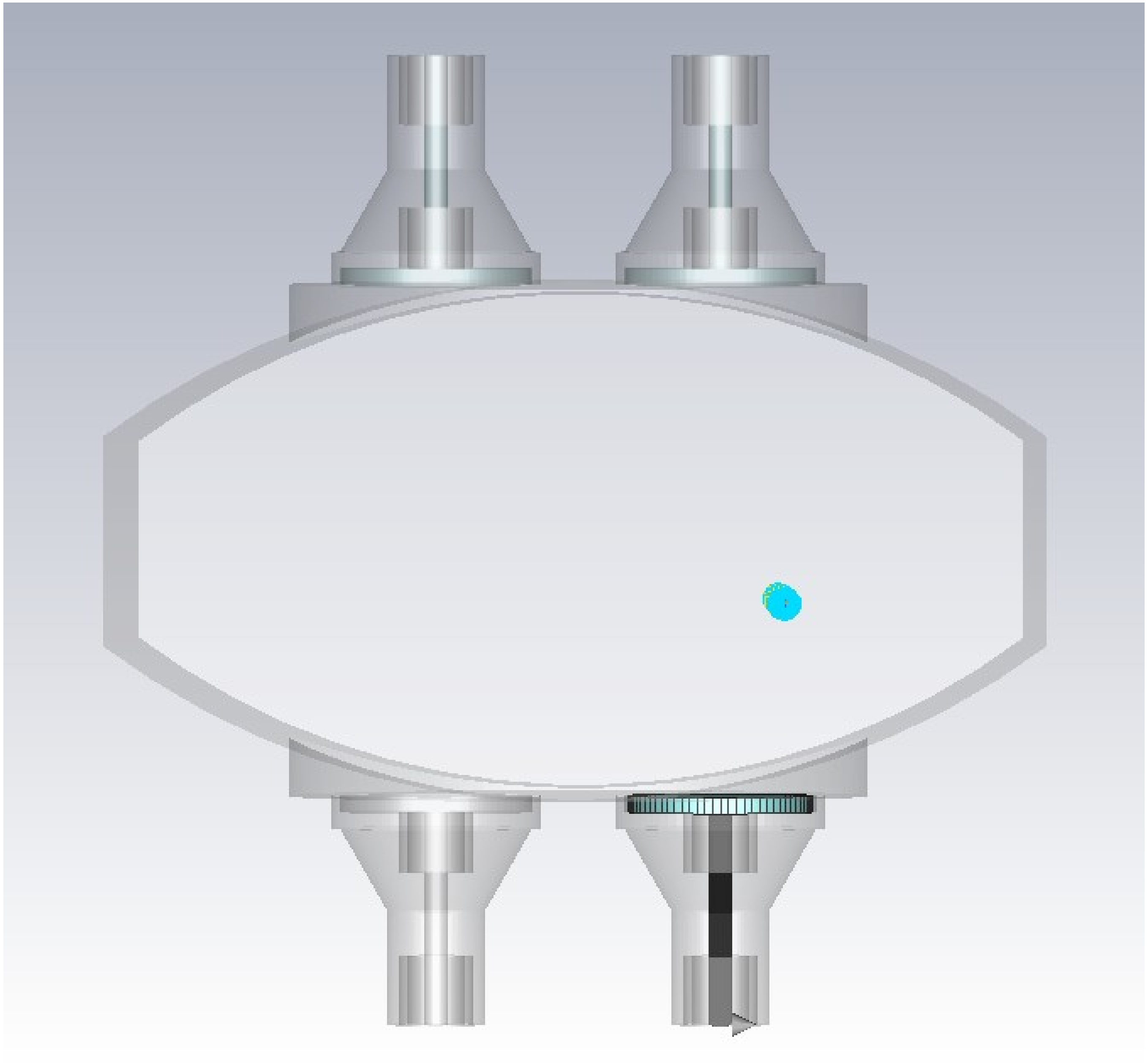


cubic interpolation, unity scaled at (x, y)=(0, 0)

3D dynamic map with CST studio

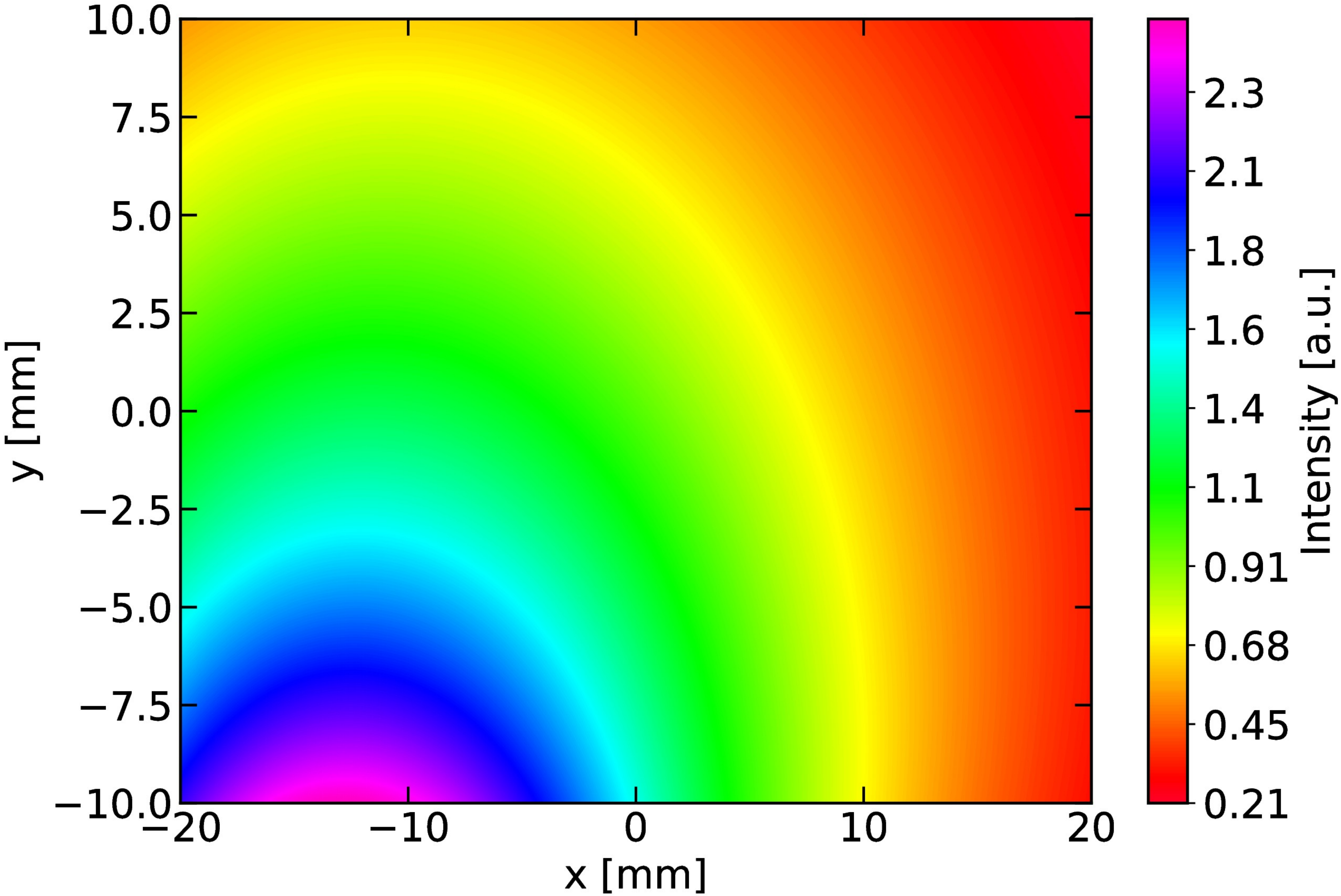


3D dynamic map with CST studio



3D dynamic map with CST studio

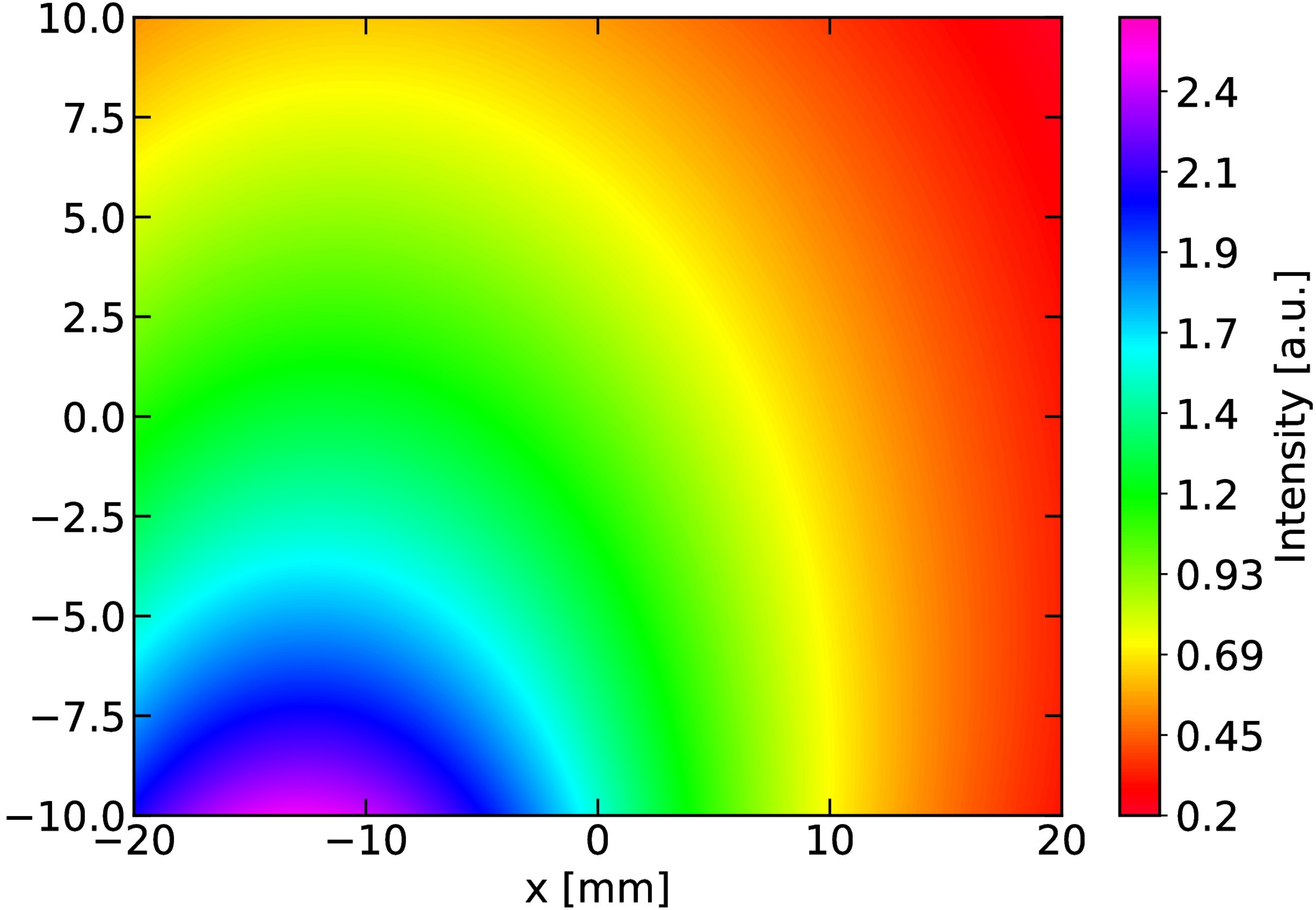
Time domain wakefield simulation gives us the following map:



cubic interpolation, unity scaled at (x, y)=(0, 0)

2D static map with Poisson

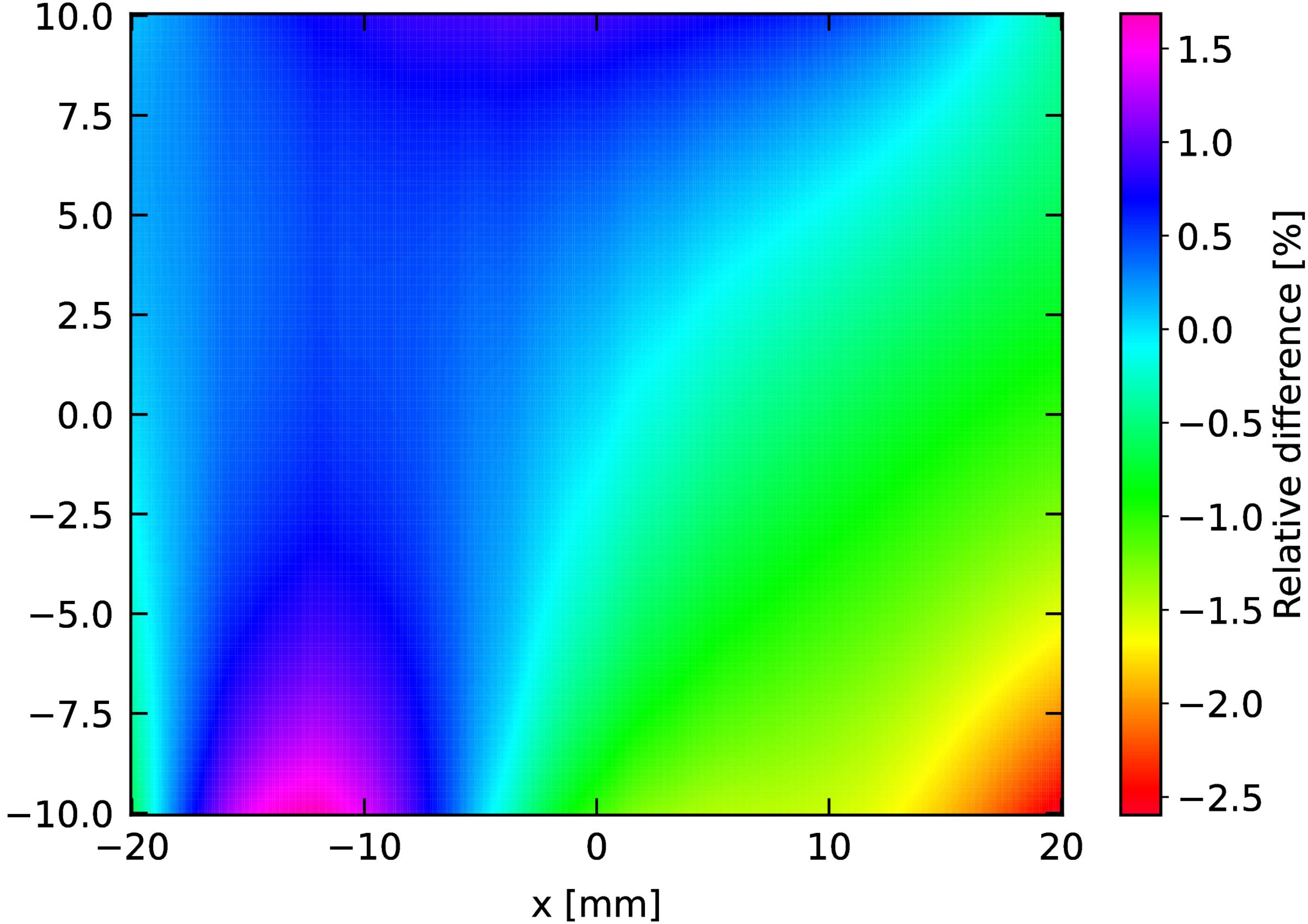
Our standard map obtained solving 's equation (2D static)



cubic interpolation, unity scaled at (x, y)=(0, 0)

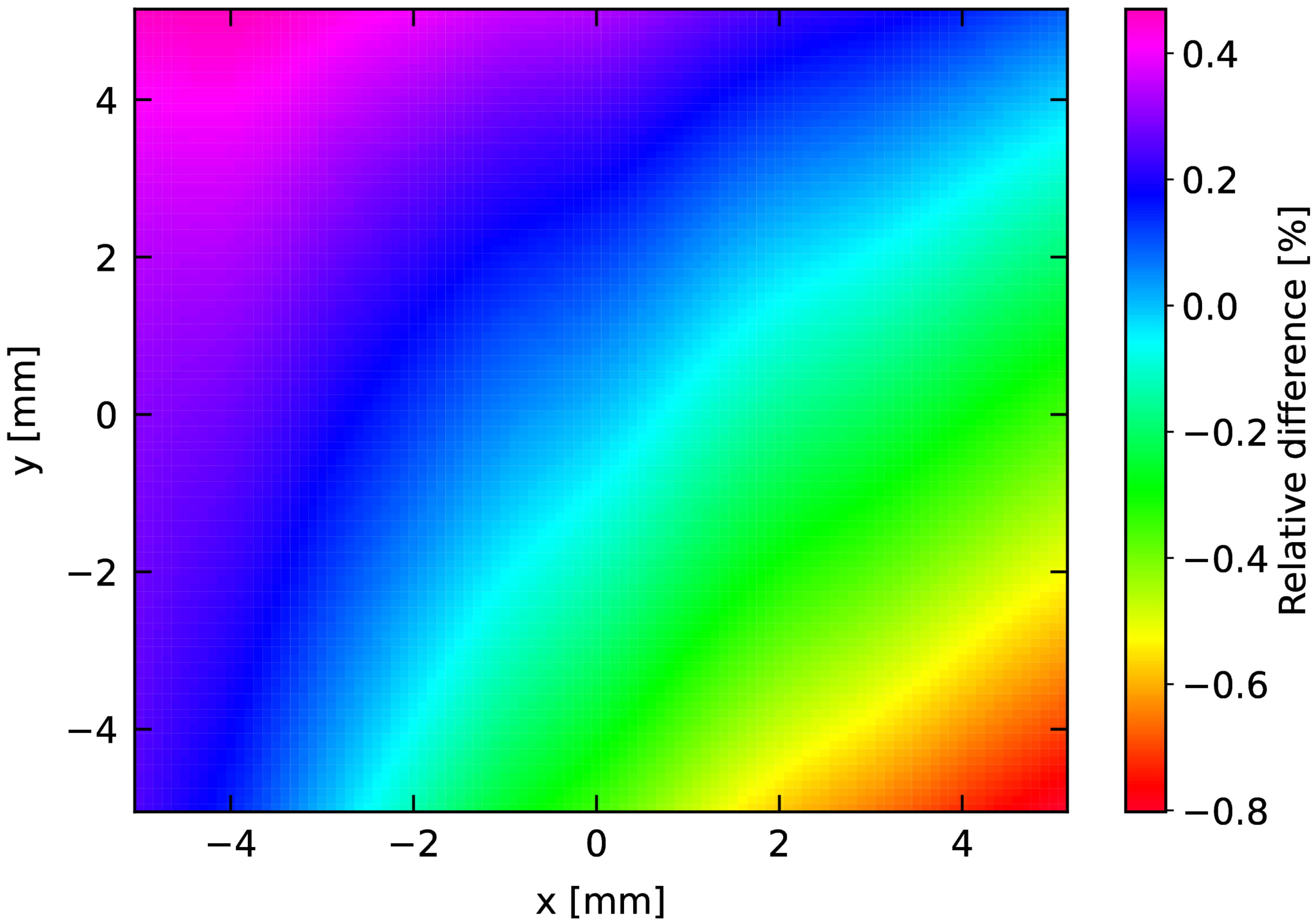
Map difference

Poisson vs 3D dynamic maps, both map normalized at (x, y) = (0, 0)



Map difference

Poisson vs 3D dynamic maps, both map normalized at (x, y) = (0, 0)



9-point grid MC pseudo-experiments

Use the Poisson response map to generate button amplitudes corresponding to the 9 (x, y) beam positions

The reference button amplitude at (x,y)=(0,0) is ~16,000 ADU:

Precision:

- ✗ assume perfect precision (very good in data from averaging 262k turns)
- ✗ only limiting factor is using integer amplitudes (mimics real-life)

Gains:

- ✗ random gain (Gaussian w/ sigma = 3%) applied to each button

Generate 1,000s of pseudo-experiments:

- ✗ 1 pseudo-experiment ≡ 9 (x,y) positions, 36 button amplitudes, 4 gains

Pseudo-datasets

Two pseudo-datasets (1,000s of pseudo experiments) as of now for the 9-point grid scenario

Shuffling (x, y) positions:

- ✗ random reference position: $x \in [-5, 5]$ mm, $y \in [-5, 5]$ mm
- ✗ grid points separation starts at 2 mm but each point is given:
  - ➢ a random displacement: $x \in [-1, 1]$ mm, $y \in [-0.5, 0.55]$ mm

Shuffling (x, y) position + timing offset:

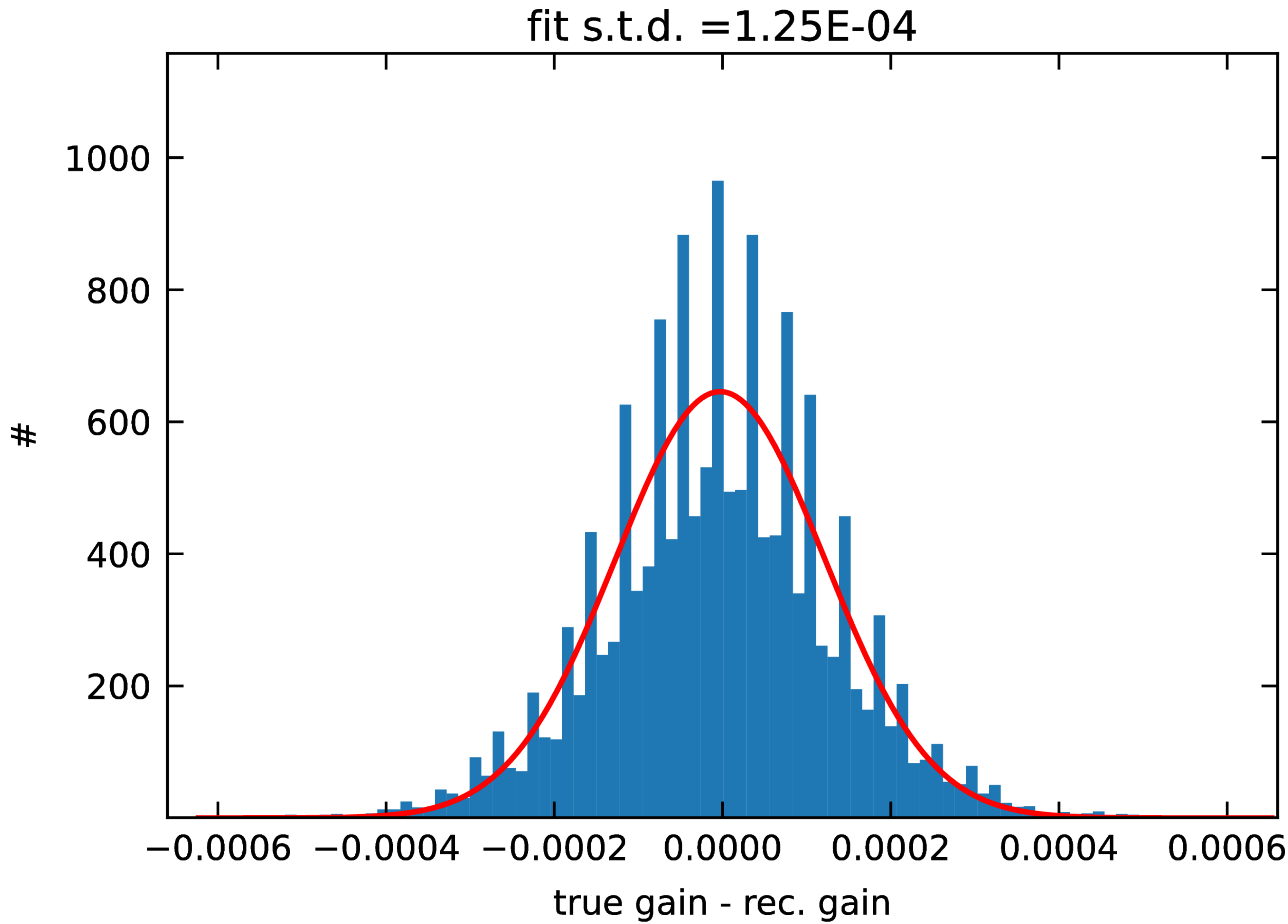
- ✗ add a random timing offset to each button:
  - ➢ timing offset $\in [-20, +20]$ ps → apply button scaling using cosine approximation to the peak of the waveform

Gain reconstruction

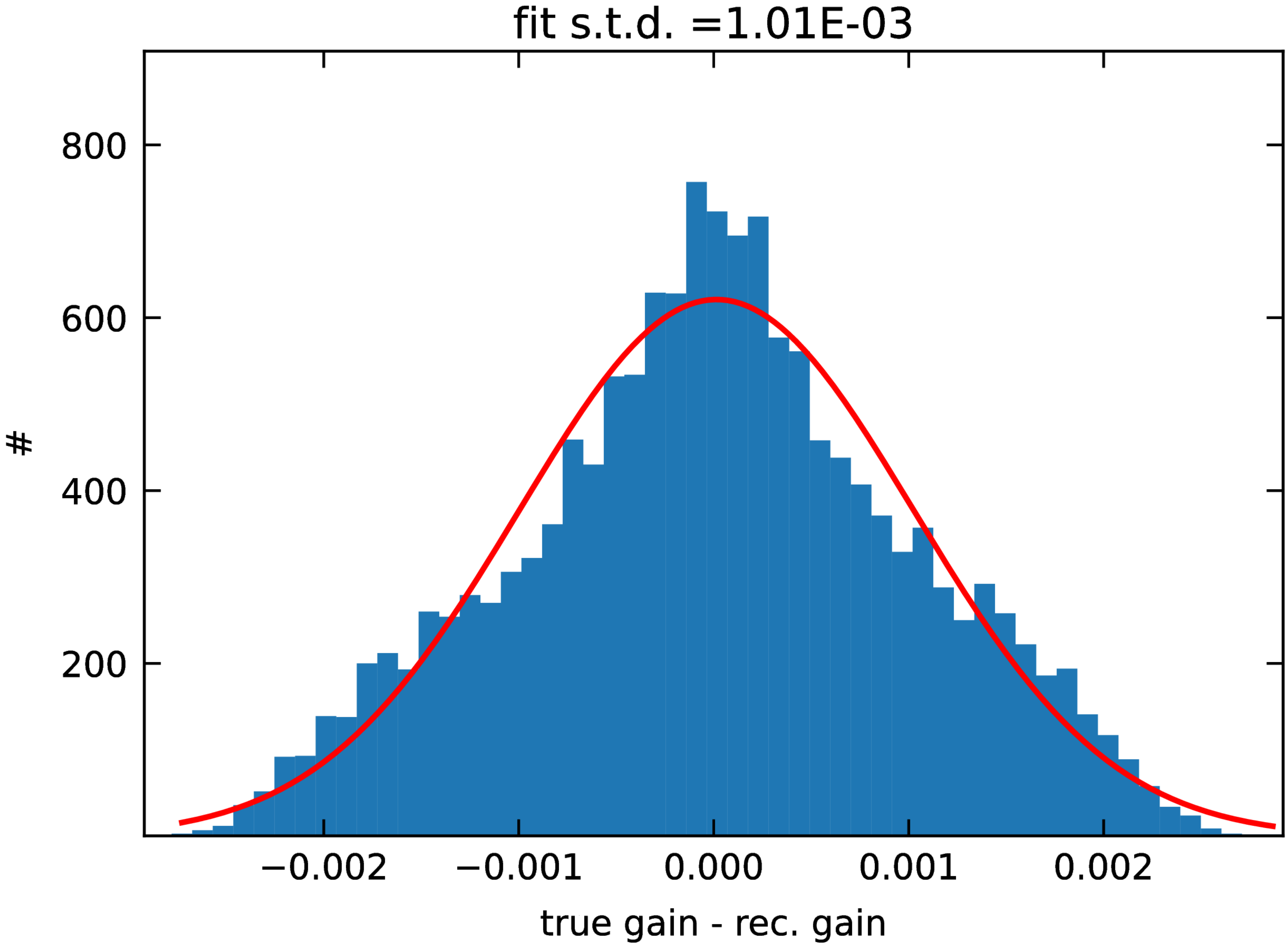
Moved from fitting 3 gains to fitting the 4 gains

After fitting the 4 gains, normalize values to gain 1 to make it easier to compare true and reconstructed values

Shuffling (x, y) positions:



Shuffling (x, y) + timing offset



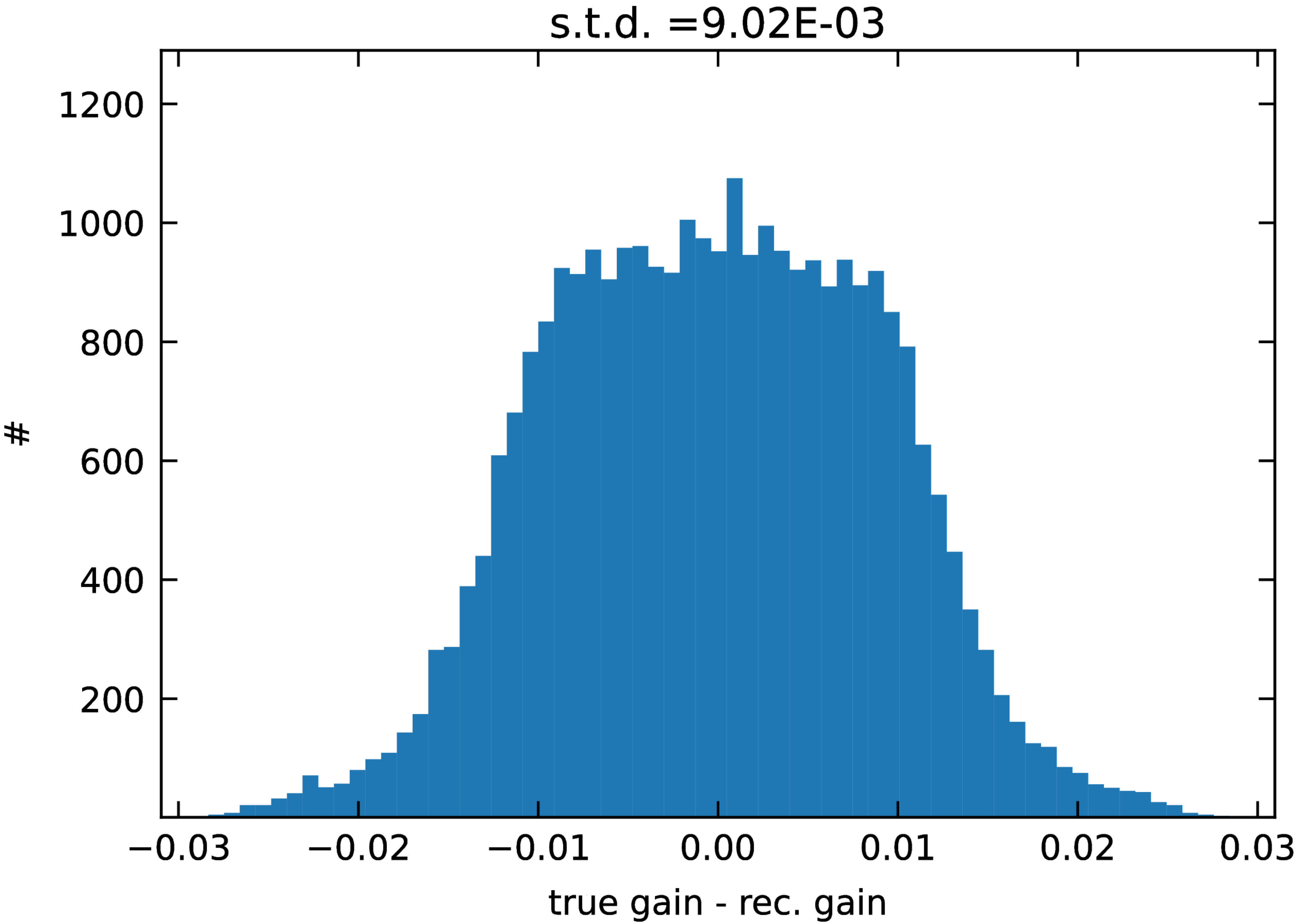
Effect from button response map?

What if our Poisson response map is different enough from reality? Given 4 buttons, difference can be cumulative if not symmetric around (x, y) = (0, 0).

On top of the other effects, added to Monte Carlo:

- ✗ use new 3D dynamic response map to generate button amplitude
- ✗ use standard Poisson map to reconstruct (x, y) and the gain

Shuffling (x, y) + timing offset + response map



Outlook

Percent-level difference in response map leads to percent-level degradation of the gain reconstruction precision → % difference is what we see in data from comparing datasets

If different datasets have different (x, y) beam positions, we could be seeing a precision limitation due to the Poisson map not being close enough to the real button response.

Easy to test in data: use new map to reconstruct gains

Machine Study

Back-to-back shift start with a cold machine for the first shift: can the gain calibrations change from warm-up effect or orbit position?

- ✗ evening shift (last shift of the night):
  - ➢ at 0.5 mA collect several identical shaker datasets
  - ➢ at 0.5 mA collect several identical shaker datasets retiming everytime
  - ➢ at 0.5 mA collect couple identical 9-point grid datasets (time only once)
  - ➢ repeat at 125 mA

- ✗ next morning shift (first shift of the day after overnight conditioning):
  - ➢ repeat 125 mA data collection : hot vs cold gains ?
  - ➢ at 0.7 mA, change orbit and repeat data collection

Note: orbit correction ON or OFF?

Additional materials

Placeholder