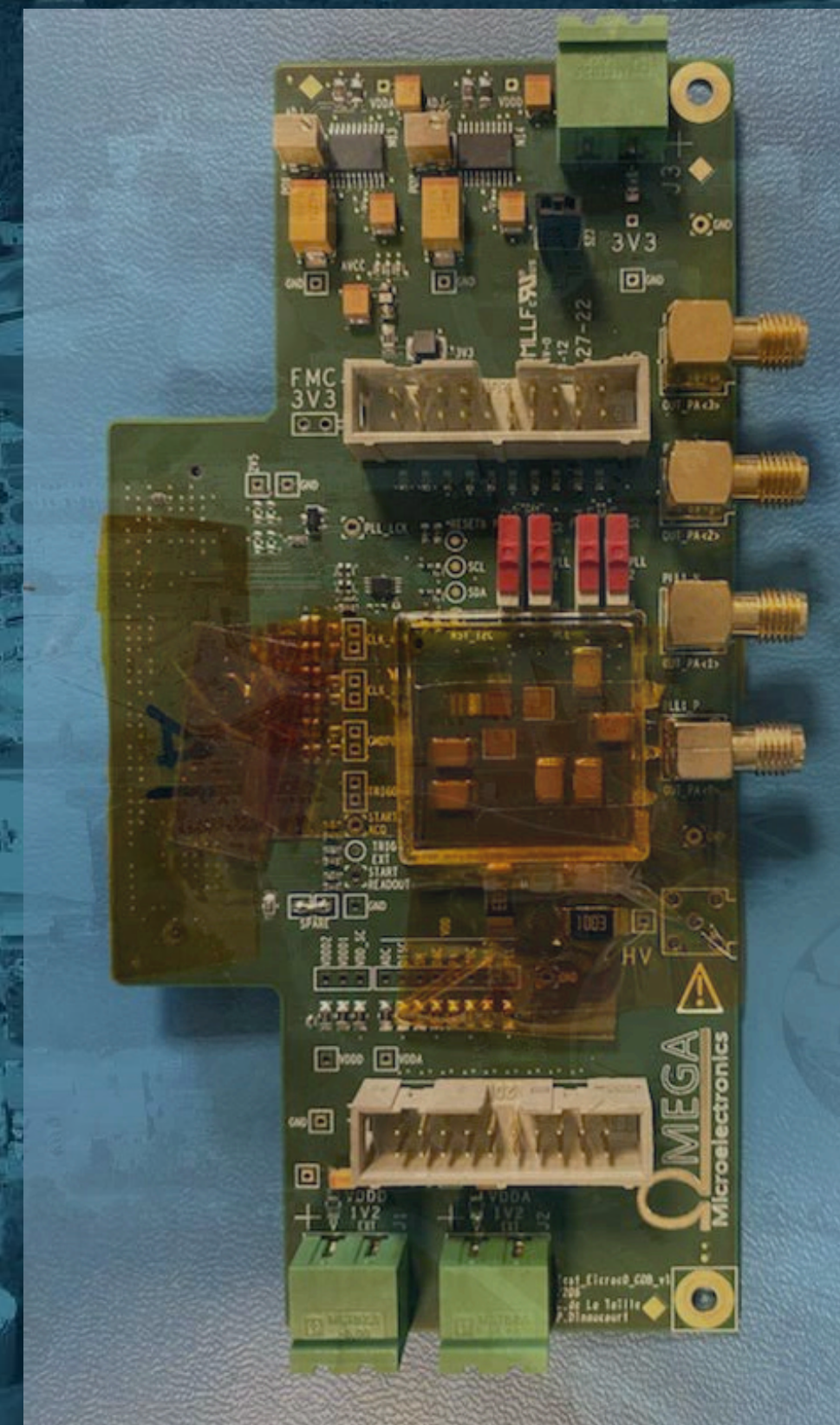


# Updates on EICROCO testing at BNL



Gabriele D'Amen (BNL),  
Hijas Farook (UNM)  
Alex Jentsch (BNL)  
Souvik Paul (SBU)  
Prashanth Sanmuganathan (BNL)  
Prithwish Tribedy (BNL)  
Alessandro Tricoli (BNL)

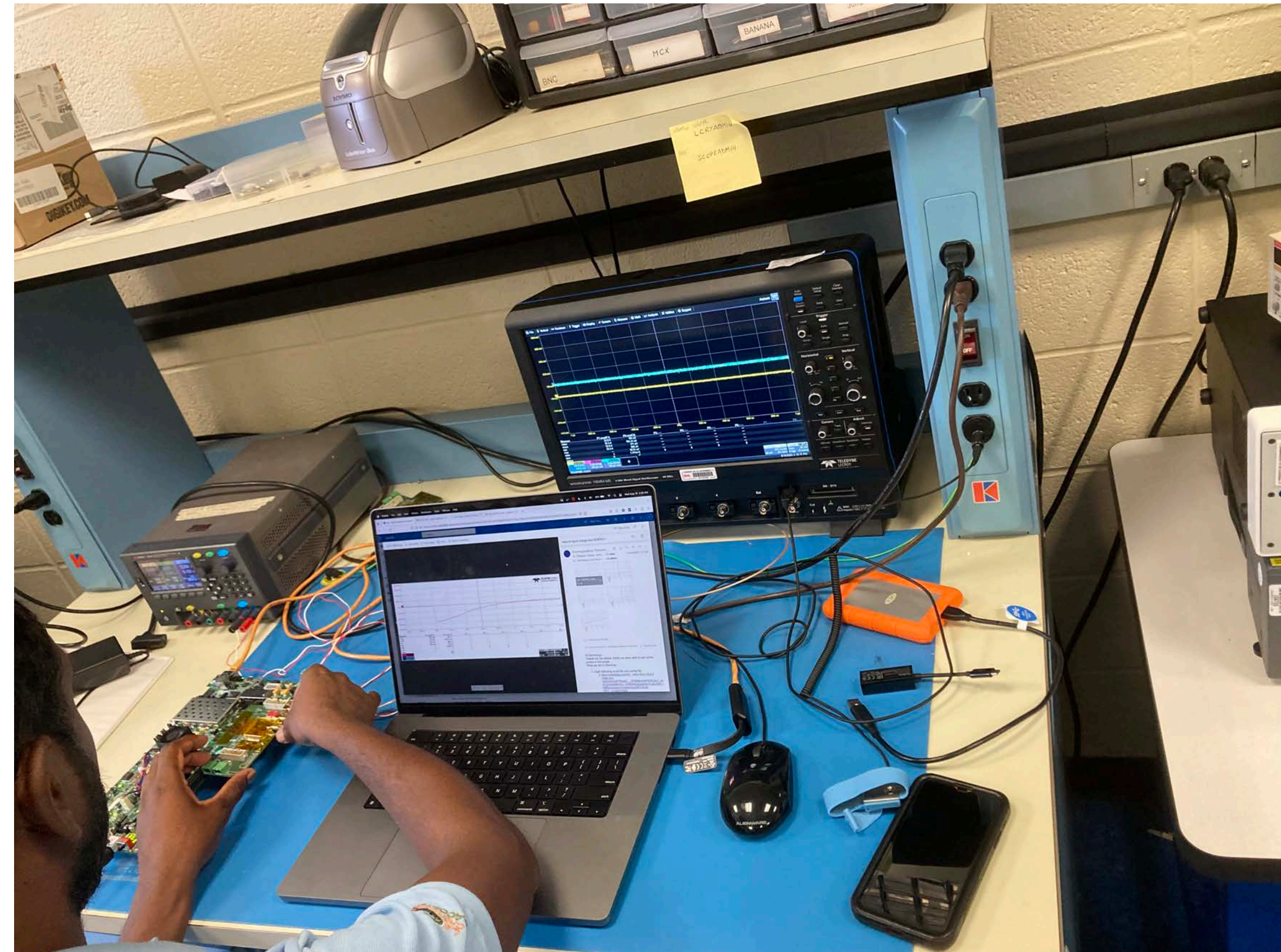
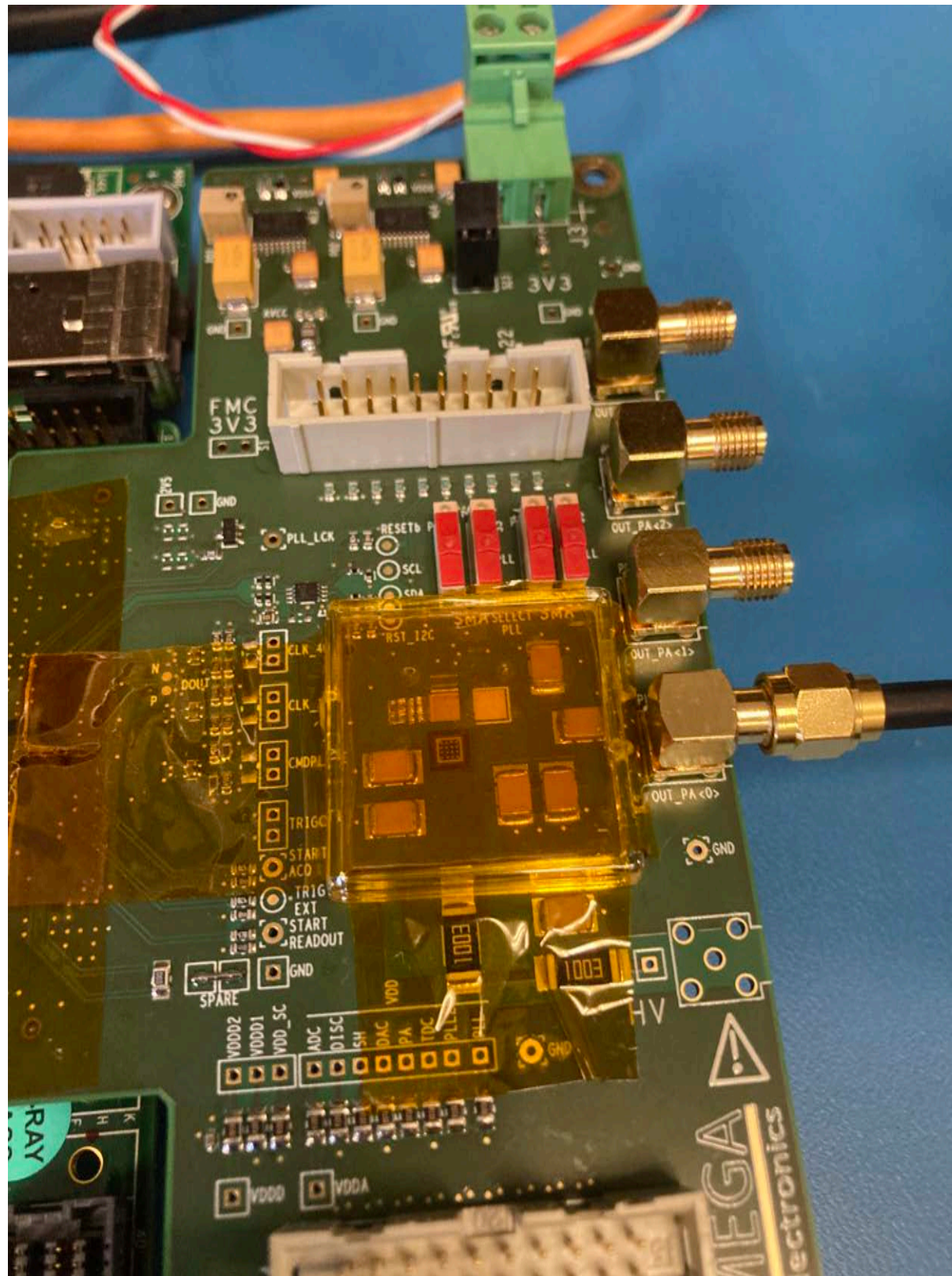




# EICROC0 test setup

Test setup

PCB board G1



Previous studies by Dominique et al (EICROC0 testing at IJCLab)

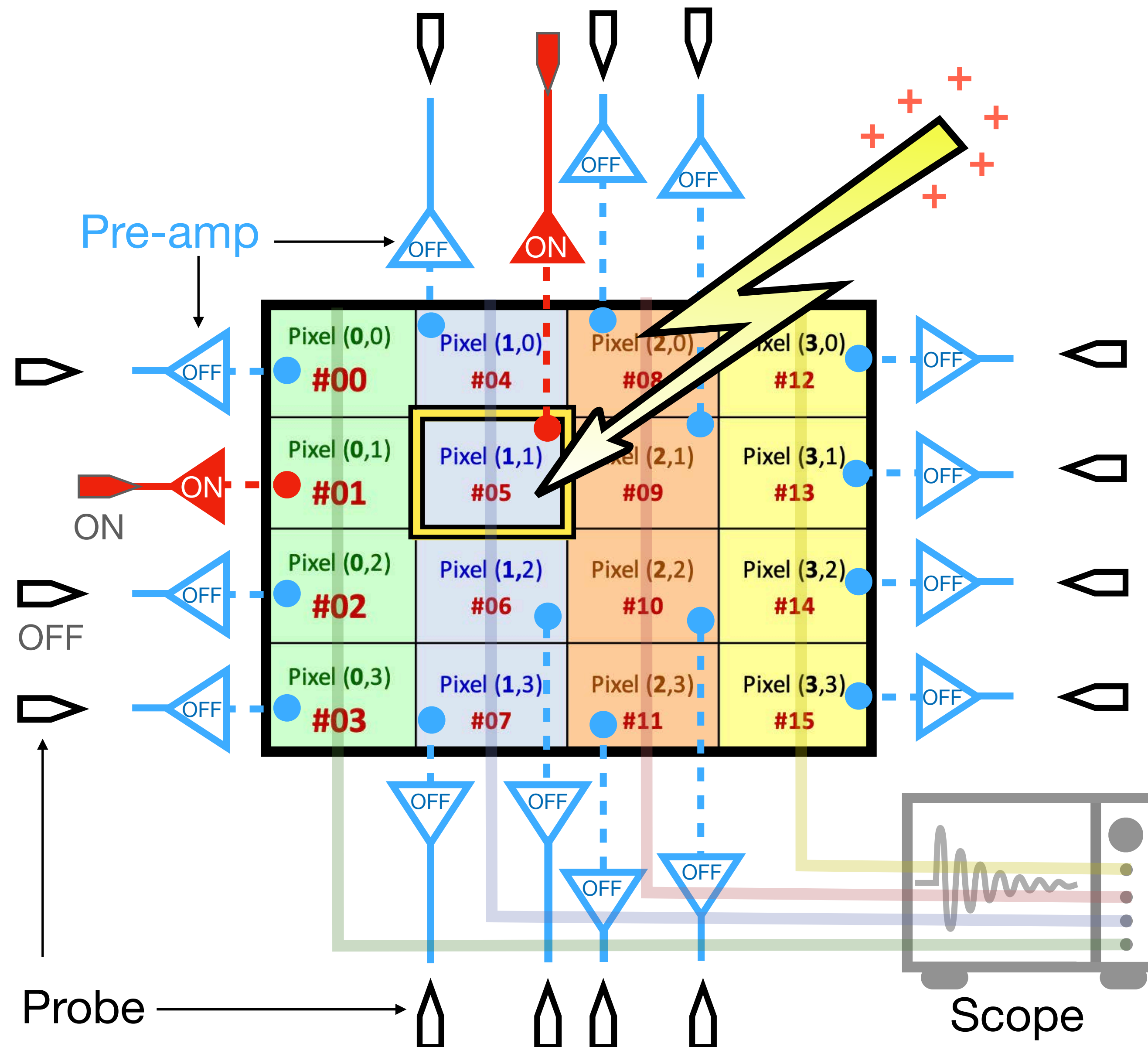
[https://indico.bnl.gov/event/19528/contributions/76533/attachments/47836/81223/EICROC0\\_Progress\\_report\\_eRD112\\_20230\\_06\\_06.pdf](https://indico.bnl.gov/event/19528/contributions/76533/attachments/47836/81223/EICROC0_Progress_report_eRD112_20230_06_06.pdf)

Previous studies at BNL (first experience with EICROC0, all-pixel response, charge injection, jitter)

[https://indico.bnl.gov/event/20429/contributions/80407/attachments/49672/84949/bnleicroc\\_testing\\_sep11.pdf](https://indico.bnl.gov/event/20429/contributions/80407/attachments/49672/84949/bnleicroc_testing_sep11.pdf)



# Our set up



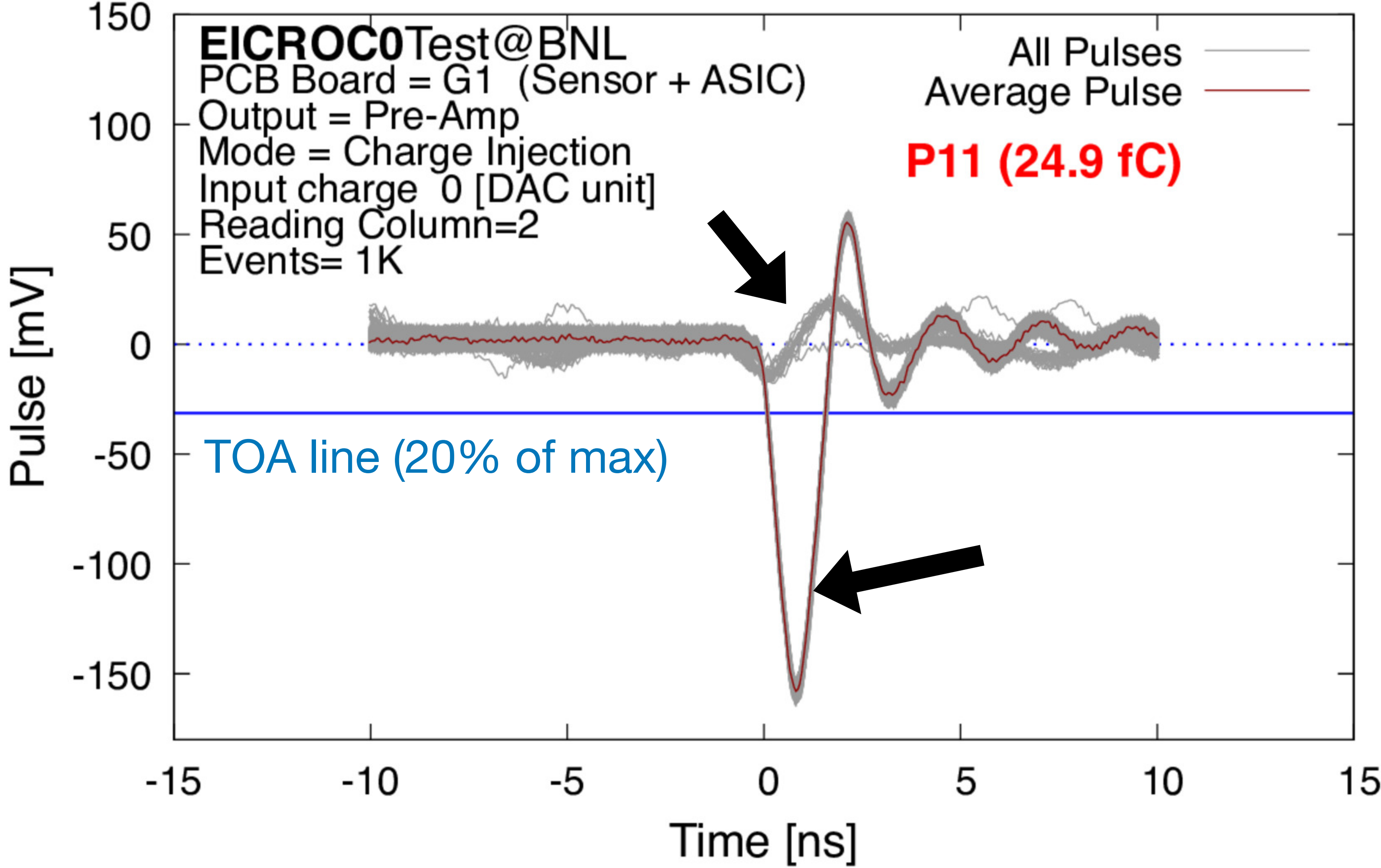
Options with our setup:

- There is no sensor, we only inject charge to individual pixel
- Pre-amp out of an entire column is read via a scope
- The probe and pre-Amp for each pixel can be turned on/off

We inject charge in a central pixel P(1,1) and study:

- Signal/background shape
- Response with charge injection
- Jitter of TOA
- Cross-talk with other pixels

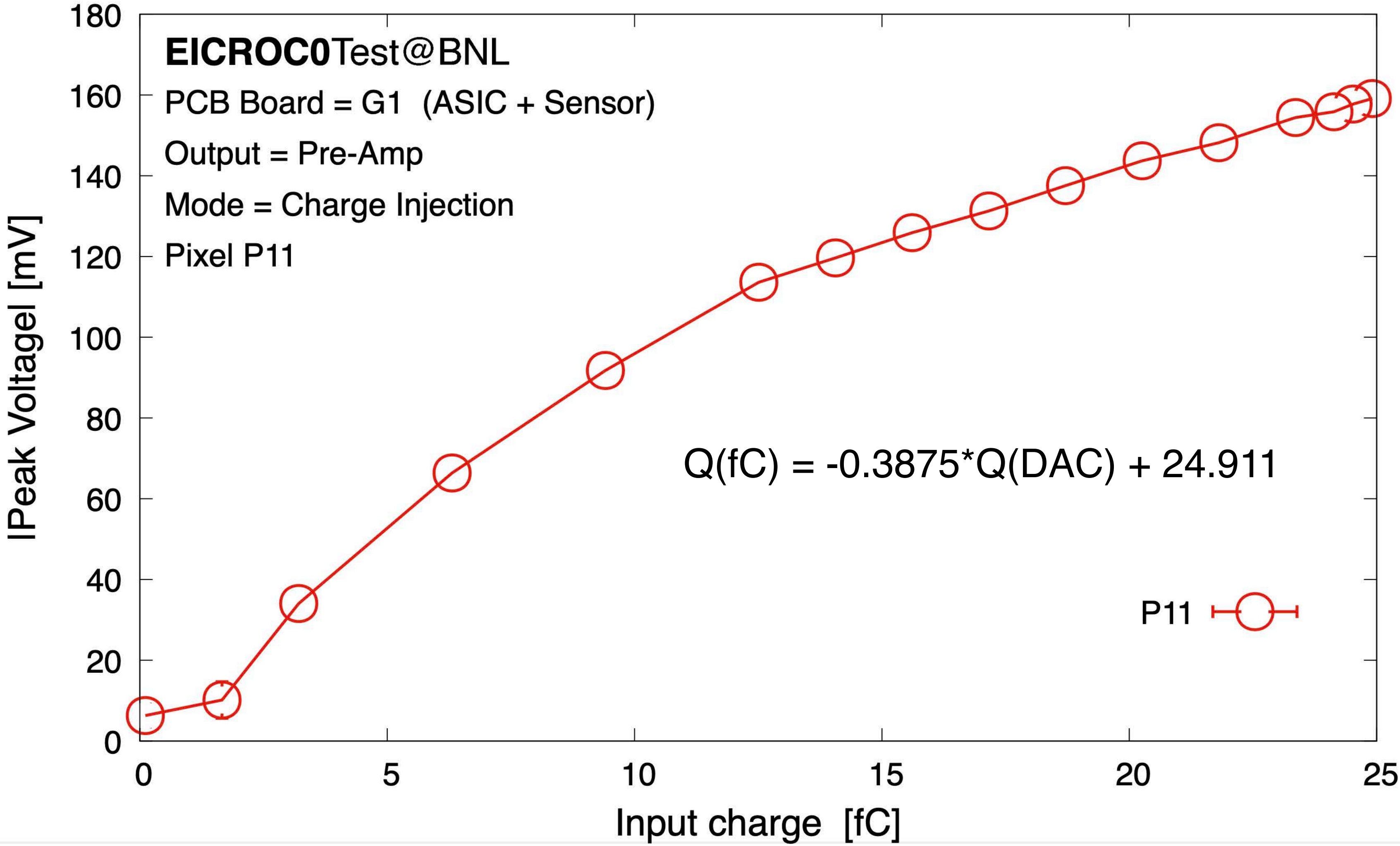
# Pre-Amp output amplitudes Pixel 11



|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |

Typical noise can be quantified to be below 20% of peak with 24.9 fC

# Pre-Amp output amplitudes Pixel 11

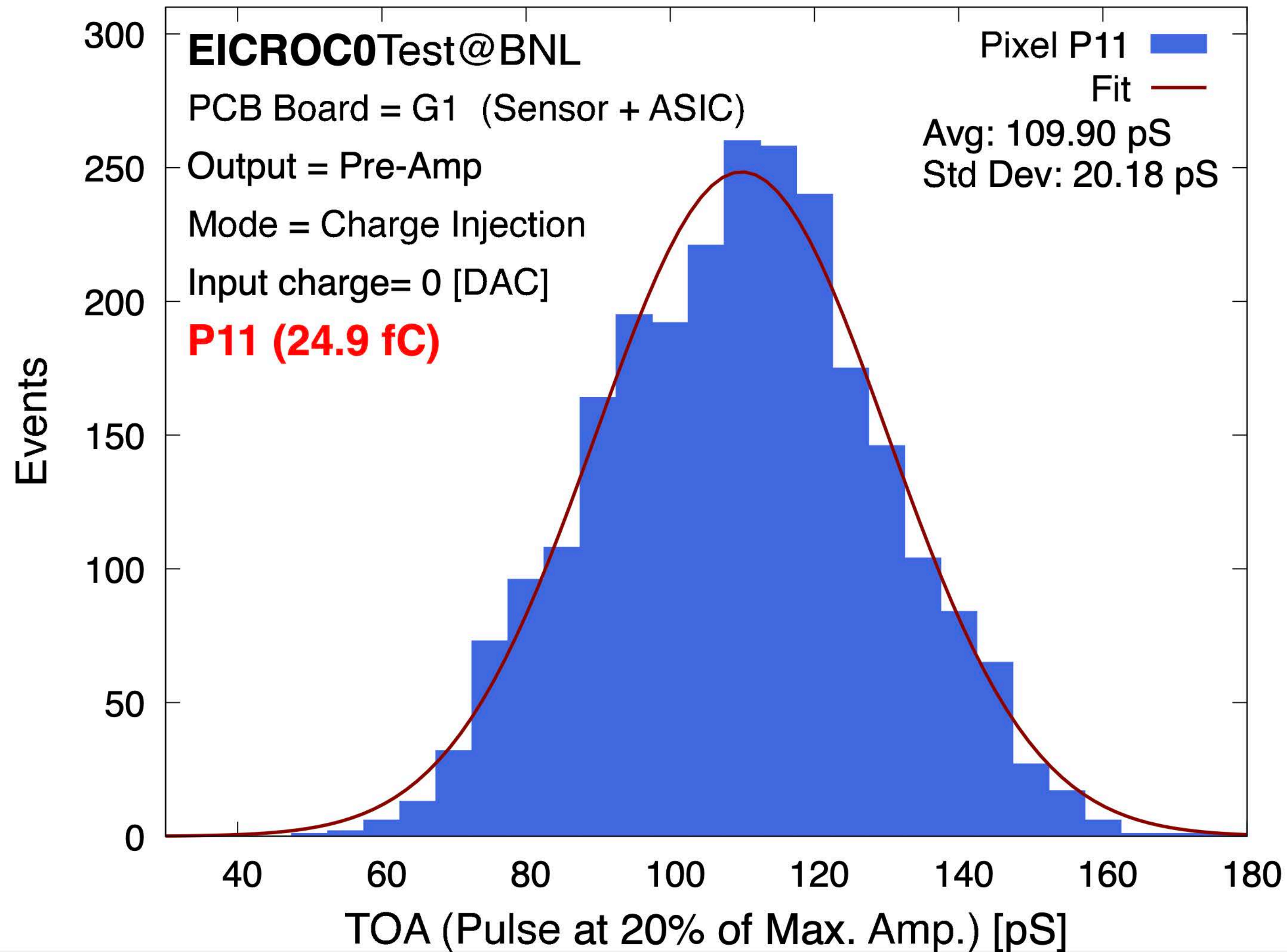


|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |

Absolute Max. Voltage vs Injected Charge show nonlinear trend



# Jitter Investigation for Time of arrival

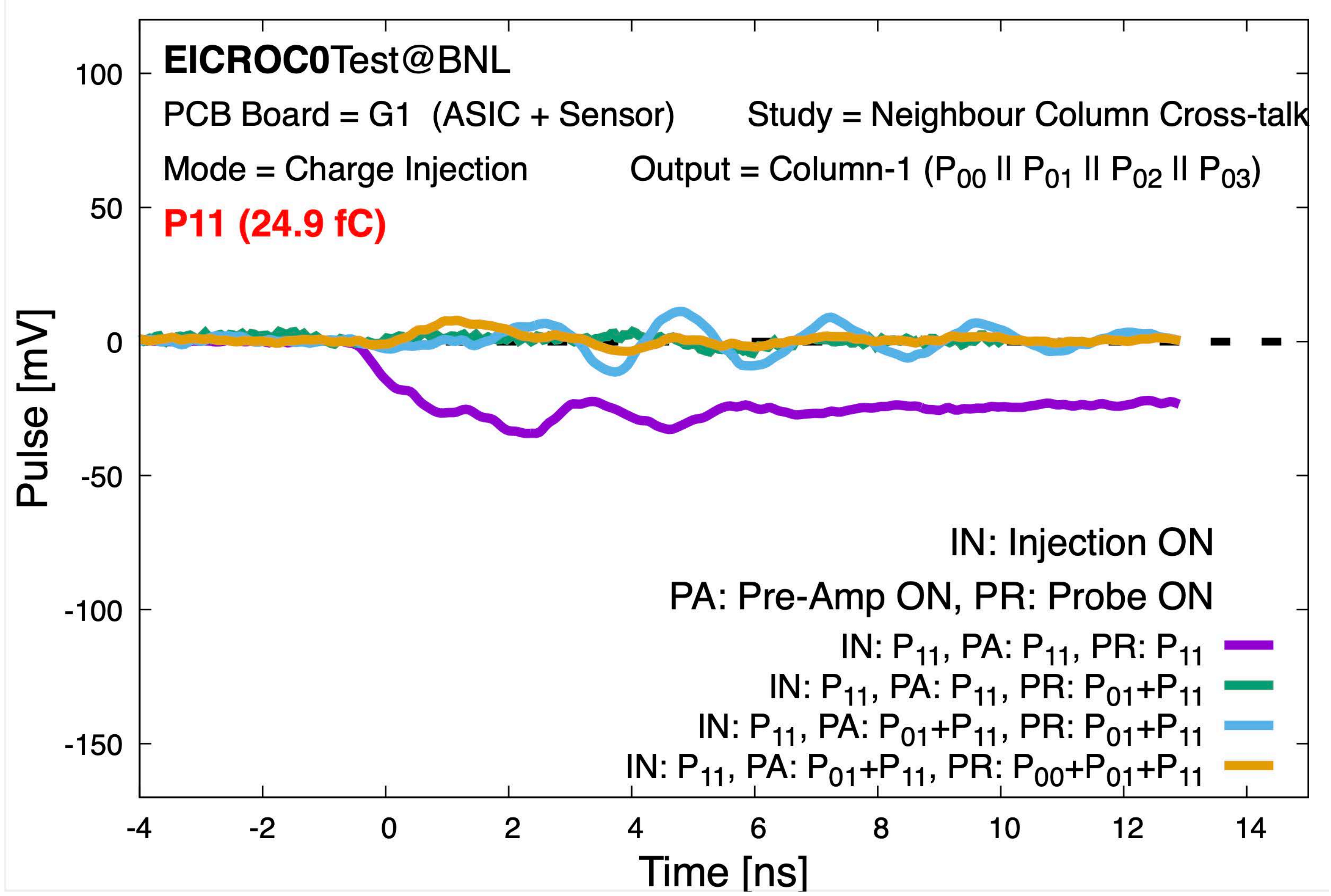


|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |

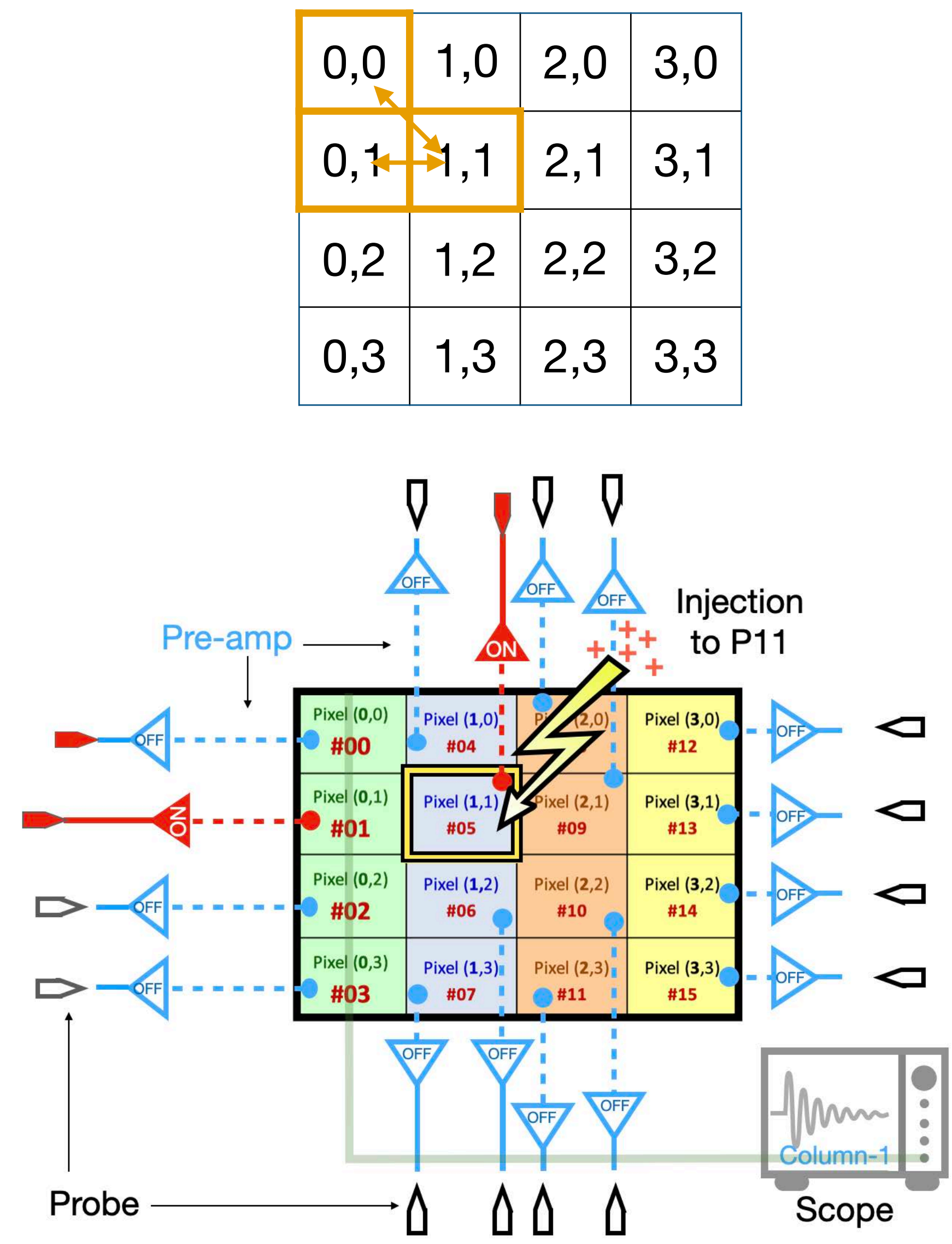
- Jitter is equivalent to  $\sigma$
- Mean Time of Arrival (ToA) sets the threshold for Constant Fraction Discriminator

Jitter of the TOA found to be about 20 pS

# Neighbor-column crosstalk (Reading Noise)

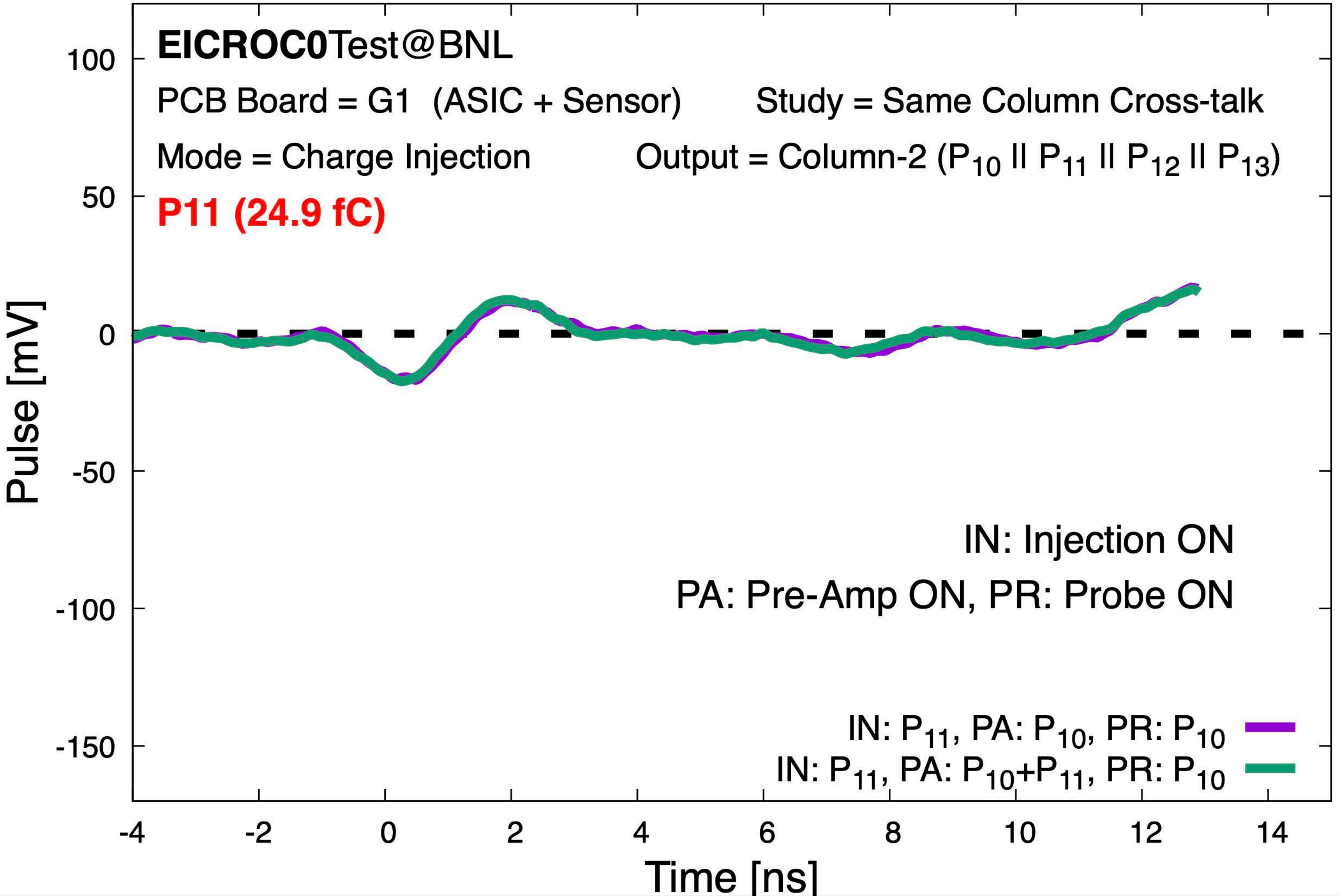


Turning another probe ON makes it disappear

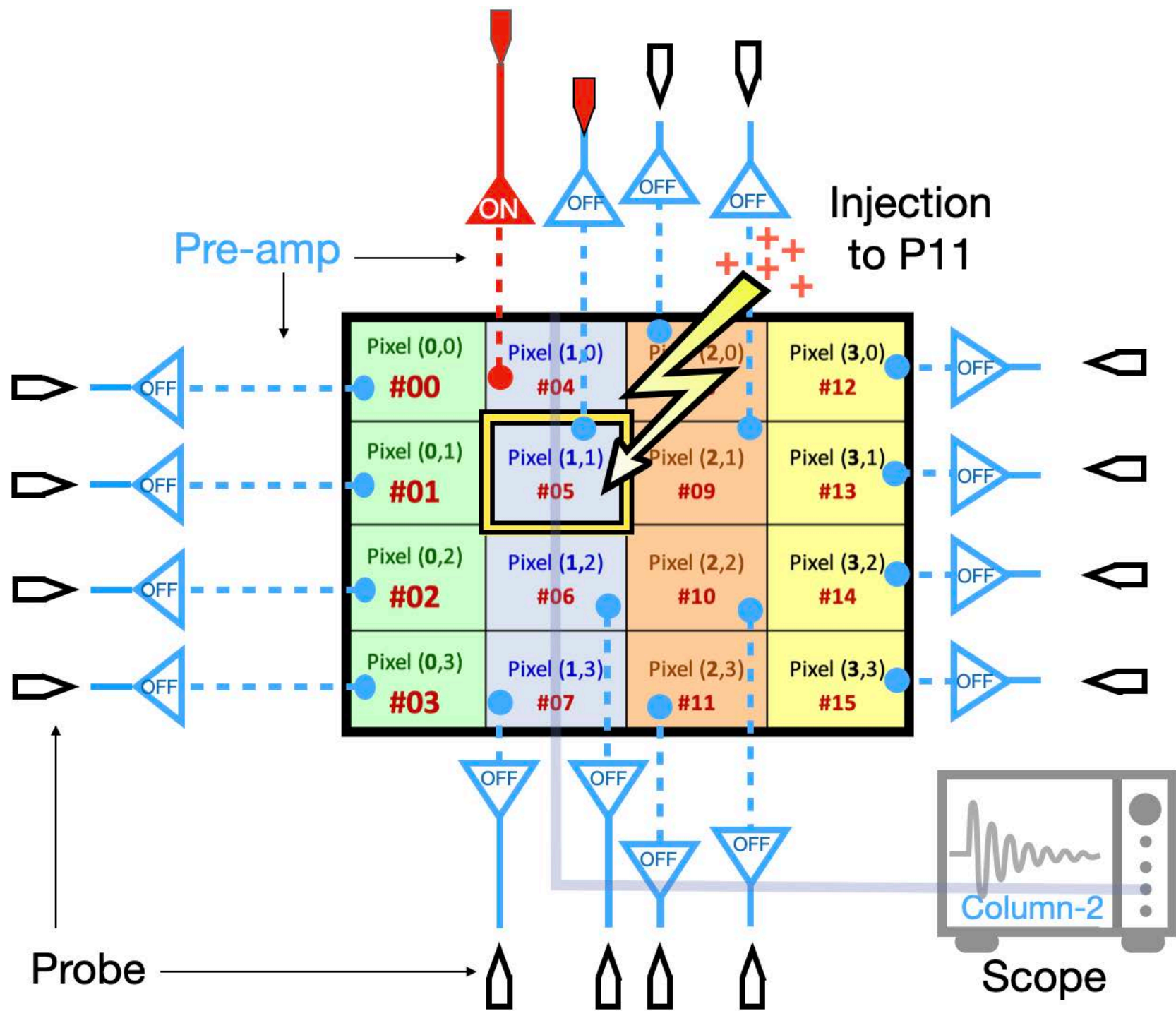




# Same-column crosstalk (Reading noise)



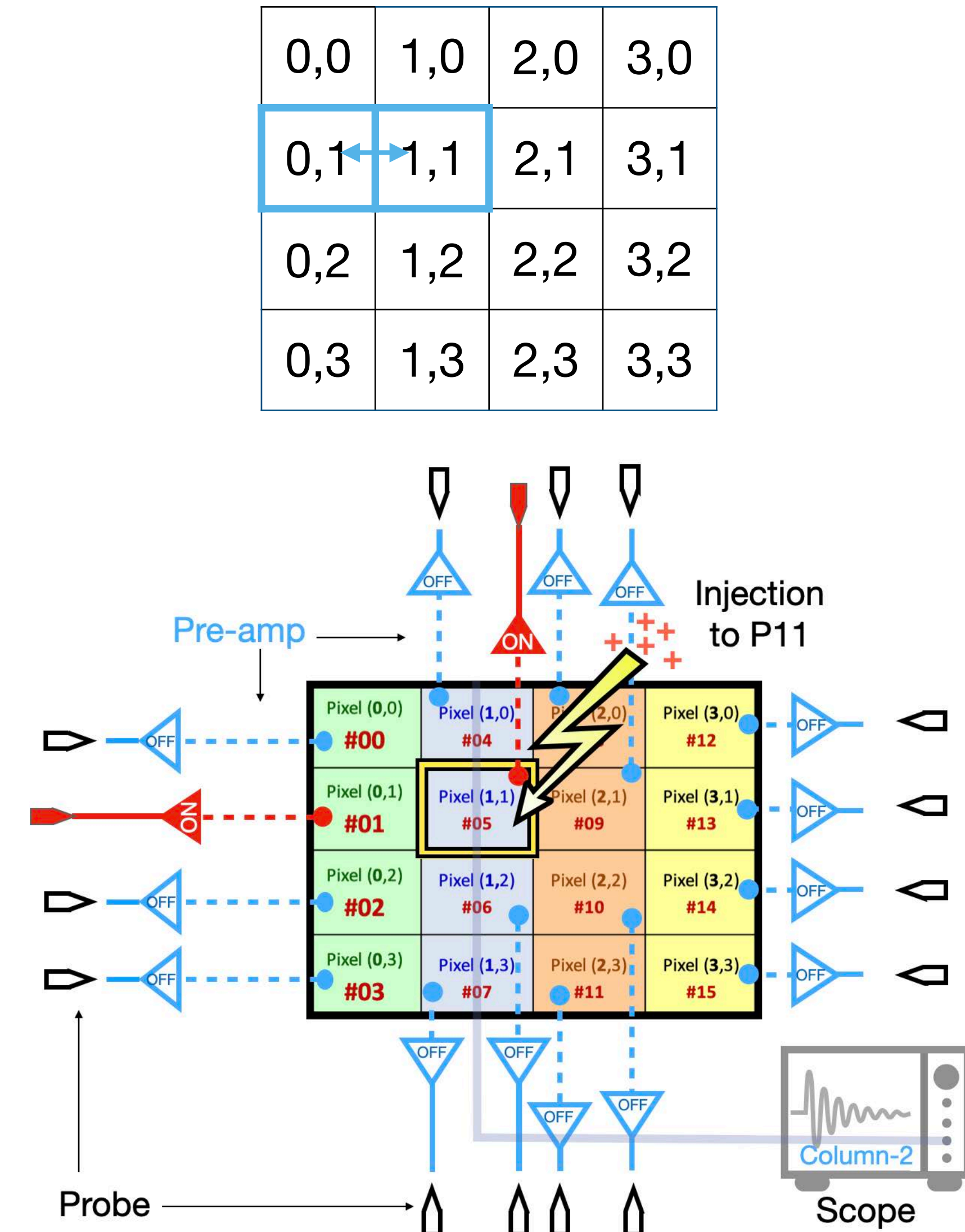
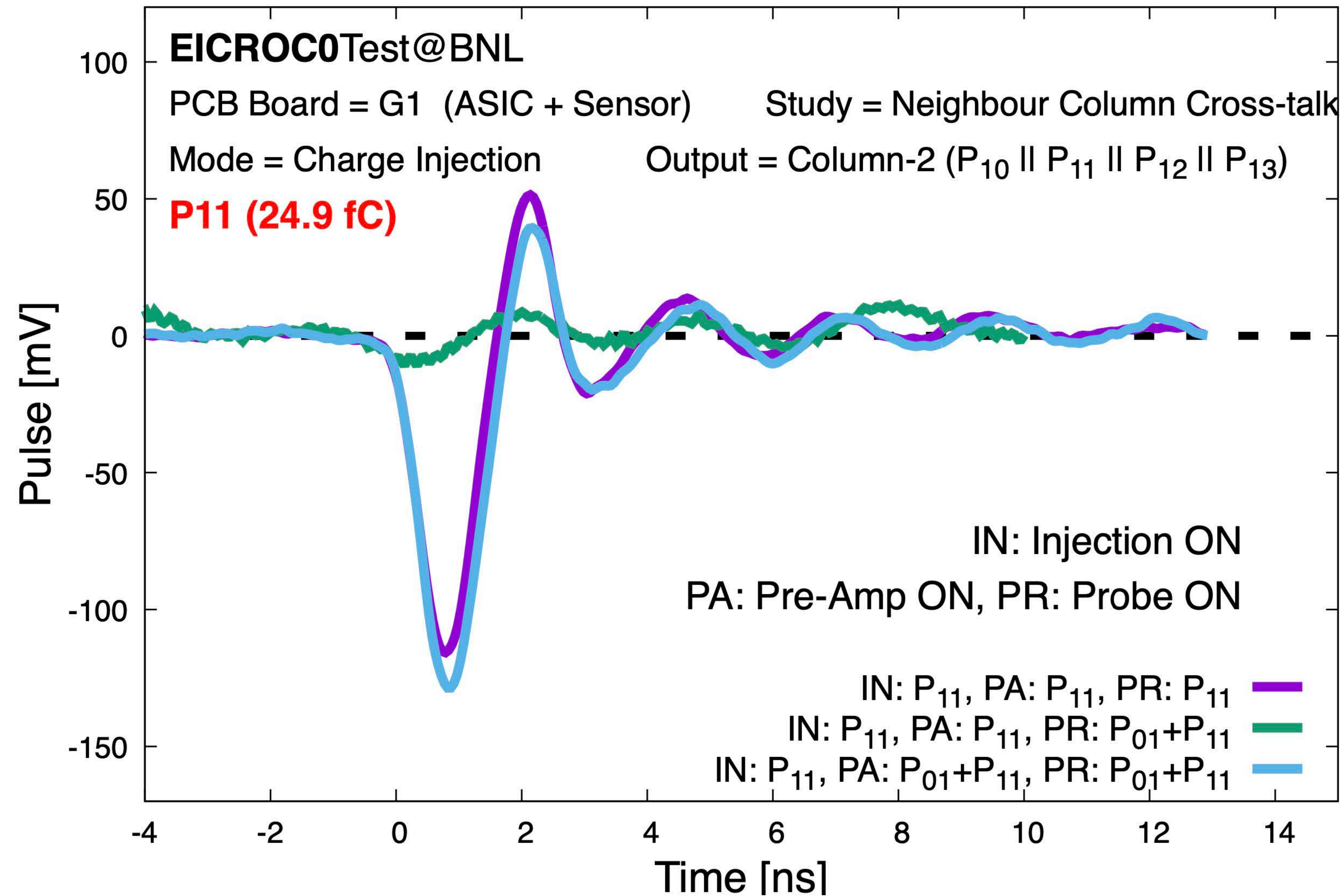
|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |



Noise remains if the PA in P11 is turned on

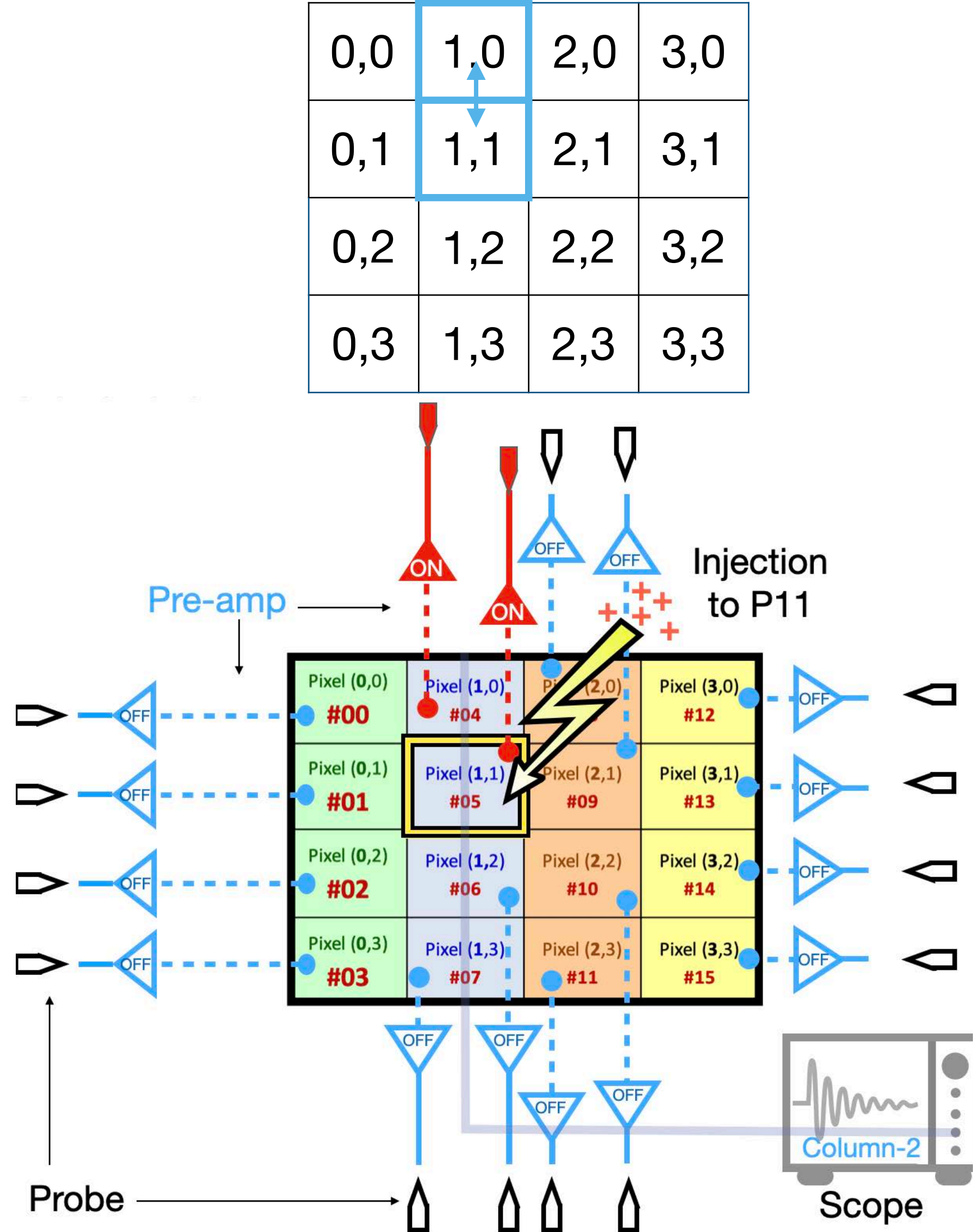
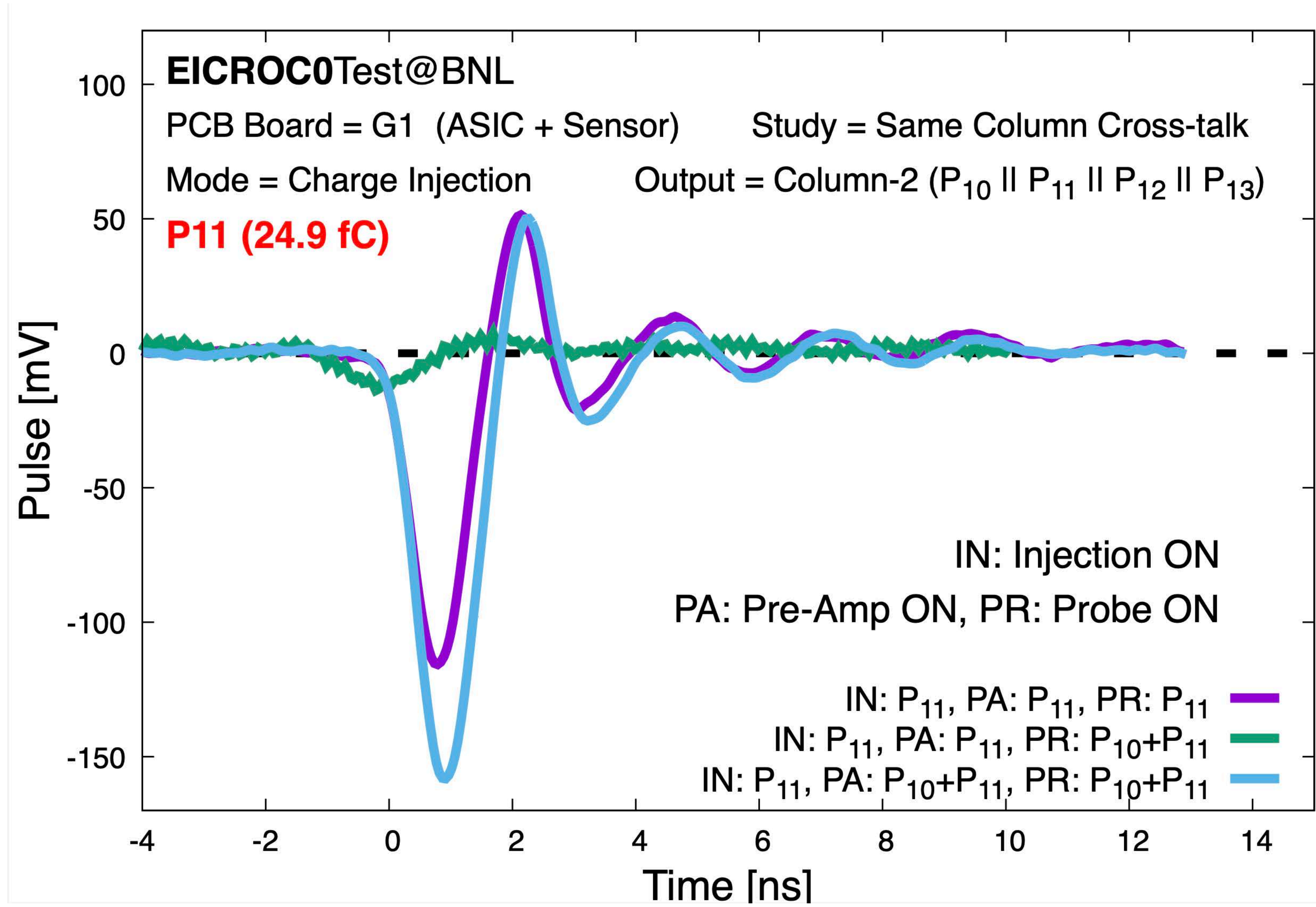


# Neighbour-column crosstalk (Reading Signal)





# Same-column crosstalk (Reading Signal)





# Summary

BNL EICROC0 set up wte studied the response of pixels with charge injection in a single pixel

- Performed some primary characterizations and replication of EICROCx developer's results
  - We see noise below 20% max peak.
  - We see a jitter of 20 pS
  - Cross talk study performed, due to the connections in the board, turning on a probe or PA from a neighbor pixel has impact on the signal and noise in a pixel

To Do:

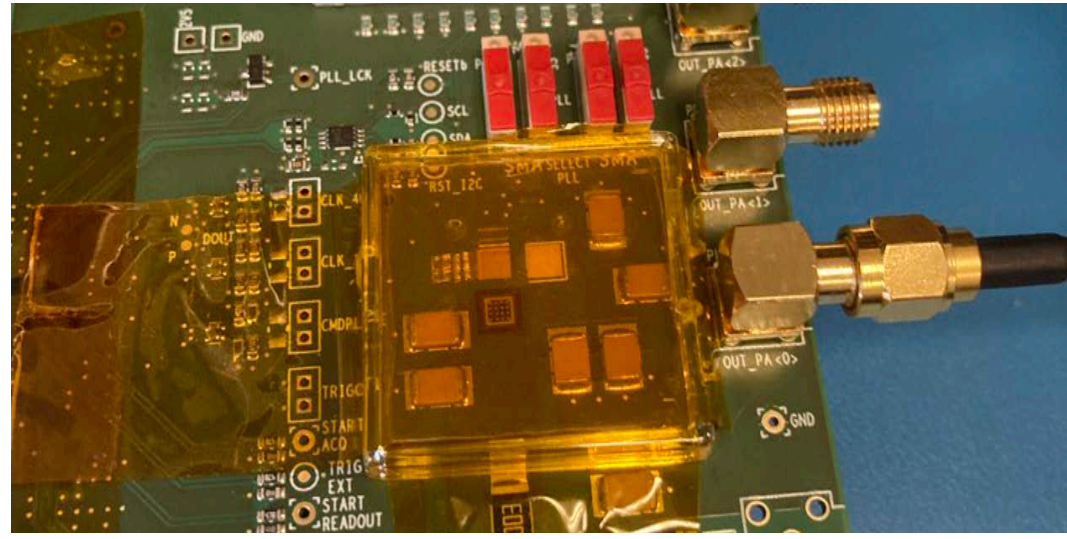
- Read the digitized output TDC/ADC, Pulse with clock ON/OFF
- Characterization with sensor using a source



**BACKUP**



# Pre-Amp output amplitudes: large charge



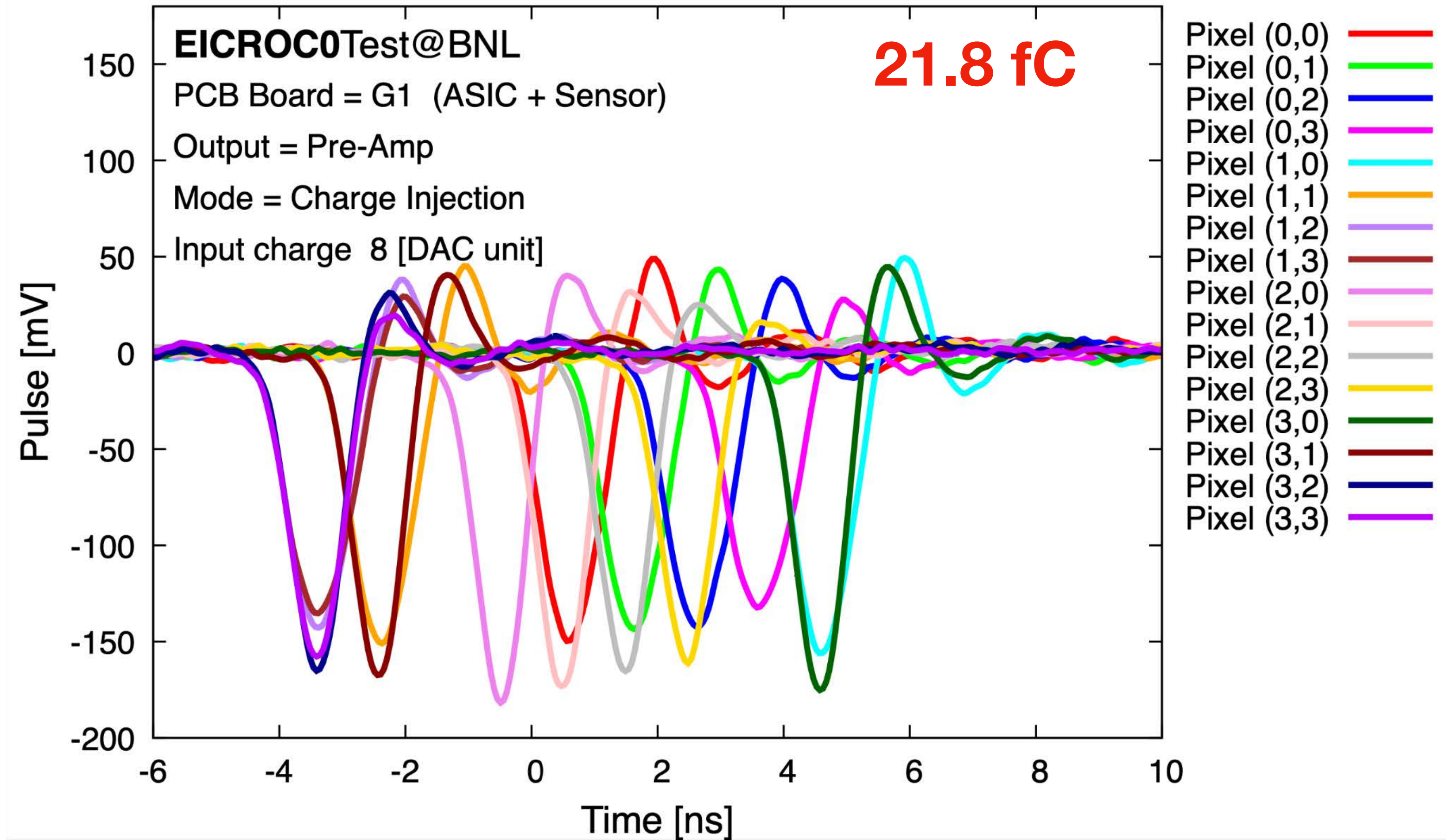
<P0>

| Pixel / Channel Mapping | Column 0           | Column 1           | Column 2           | Column 3           |
|-------------------------|--------------------|--------------------|--------------------|--------------------|
| Line 0                  | Pixel (0,0)<br>#00 | Pixel (1,0)<br>#04 | Pixel (2,0)<br>#08 | Pixel (3,0)<br>#12 |
| Line 1                  | Pixel (0,1)<br>#01 | Pixel (1,1)<br>#05 | Pixel (2,1)<br>#09 | Pixel (3,1)<br>#13 |
| Line 2                  | Pixel (0,2)<br>#02 | Pixel (1,2)<br>#06 | Pixel (2,2)<br>#10 | Pixel (3,2)<br>#14 |
| Line 3                  | Pixel (0,3)<br>#03 | Pixel (1,3)<br>#07 | Pixel (2,3)<br>#11 | Pixel (3,3)<br>#15 |

We inject charge into each pixel

We select the pixel we read in the column by setting bit-4 of register EN\_digprobe. Pixel (0,0) is only read in Column 0 and so on.

Input charge = 8 DAC = 21.8 fC



All the pixels perform as per expectations

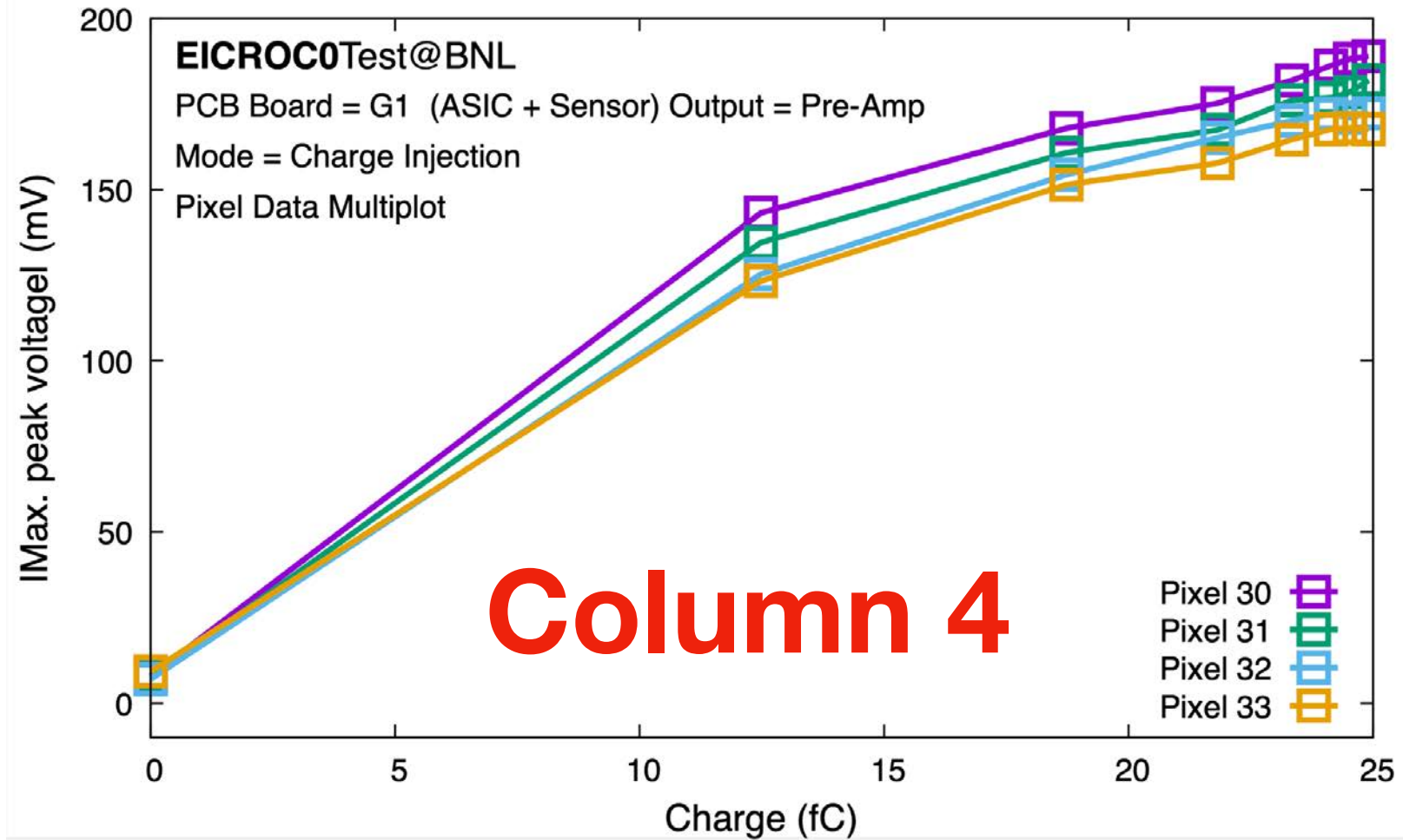
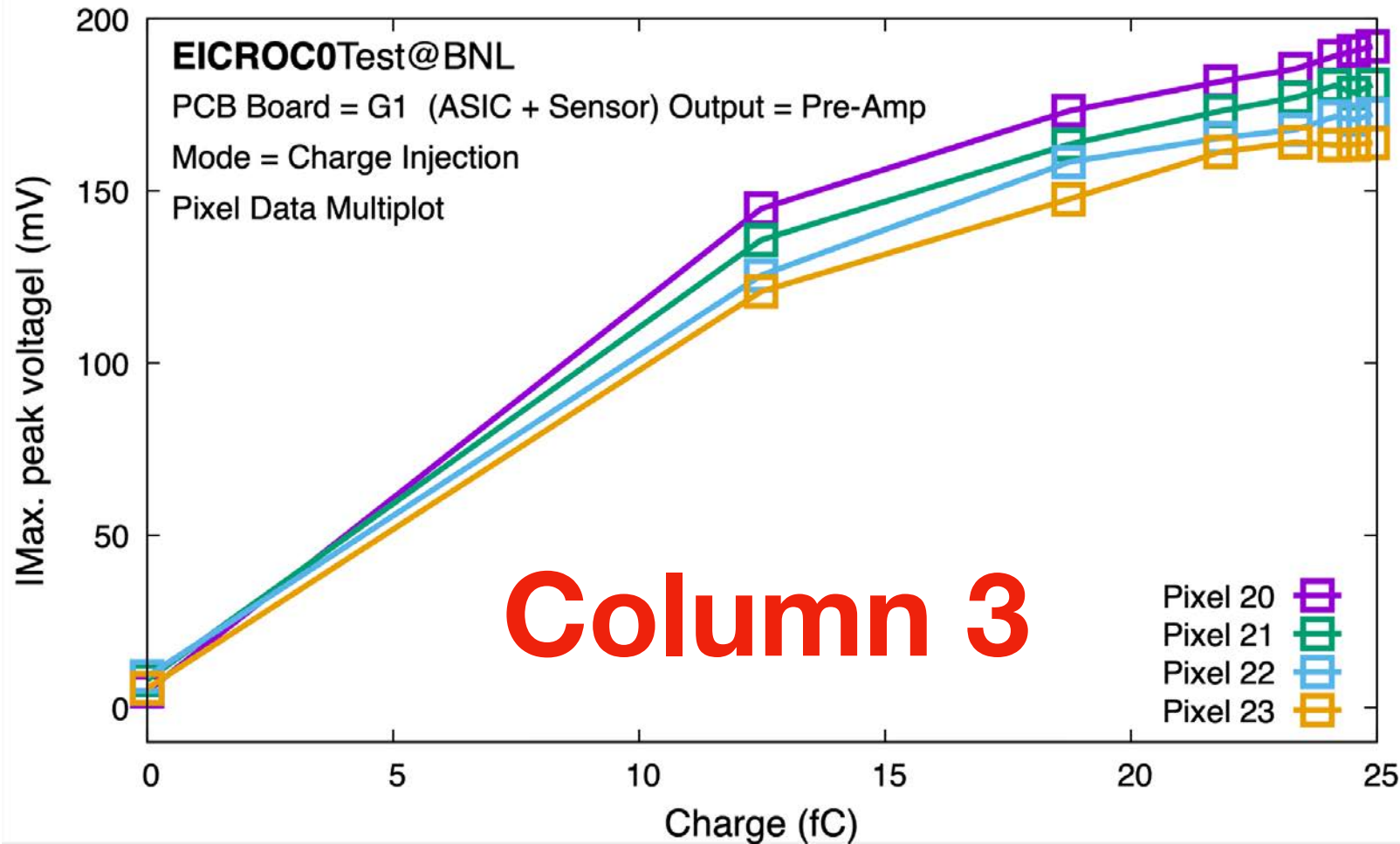
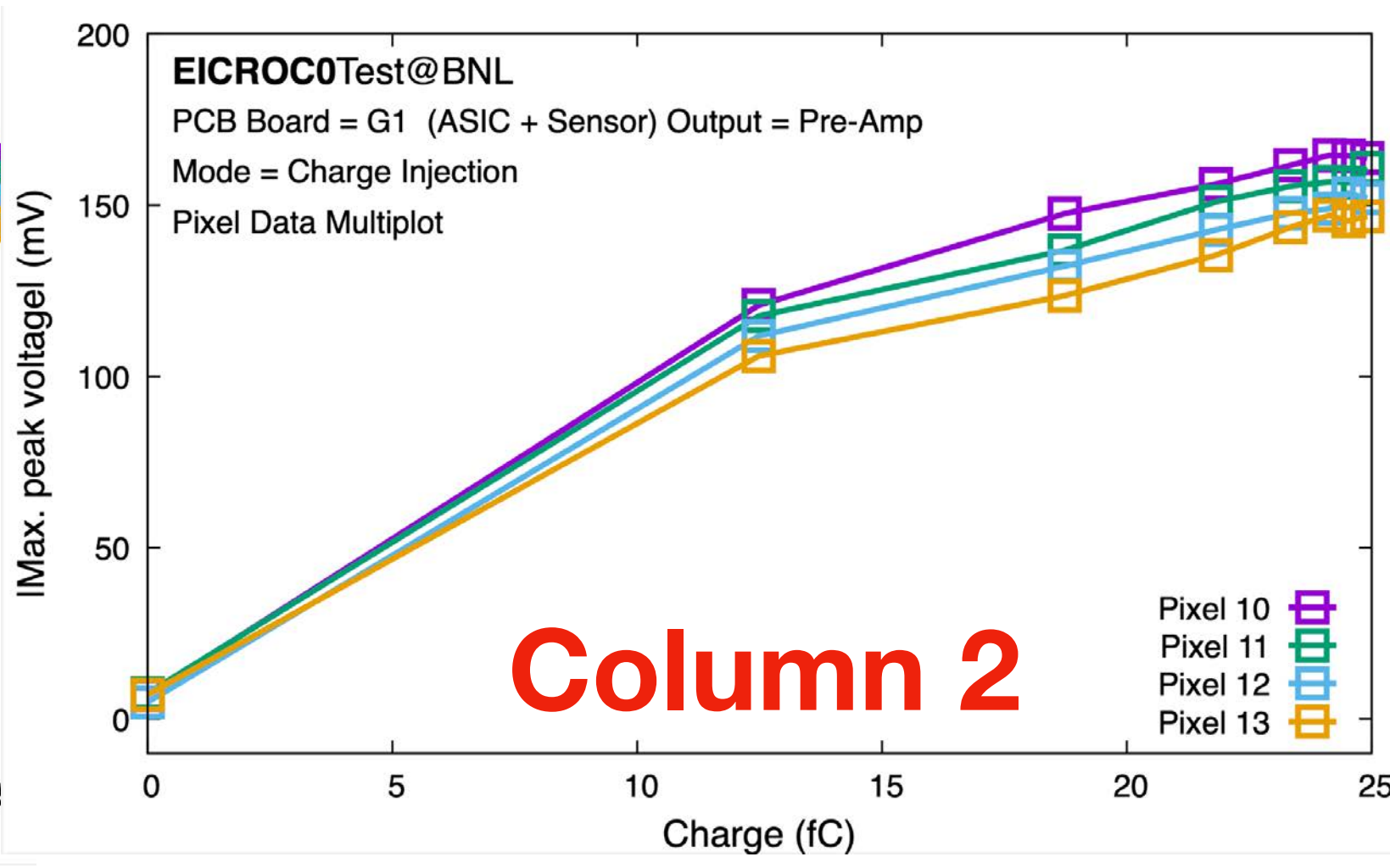
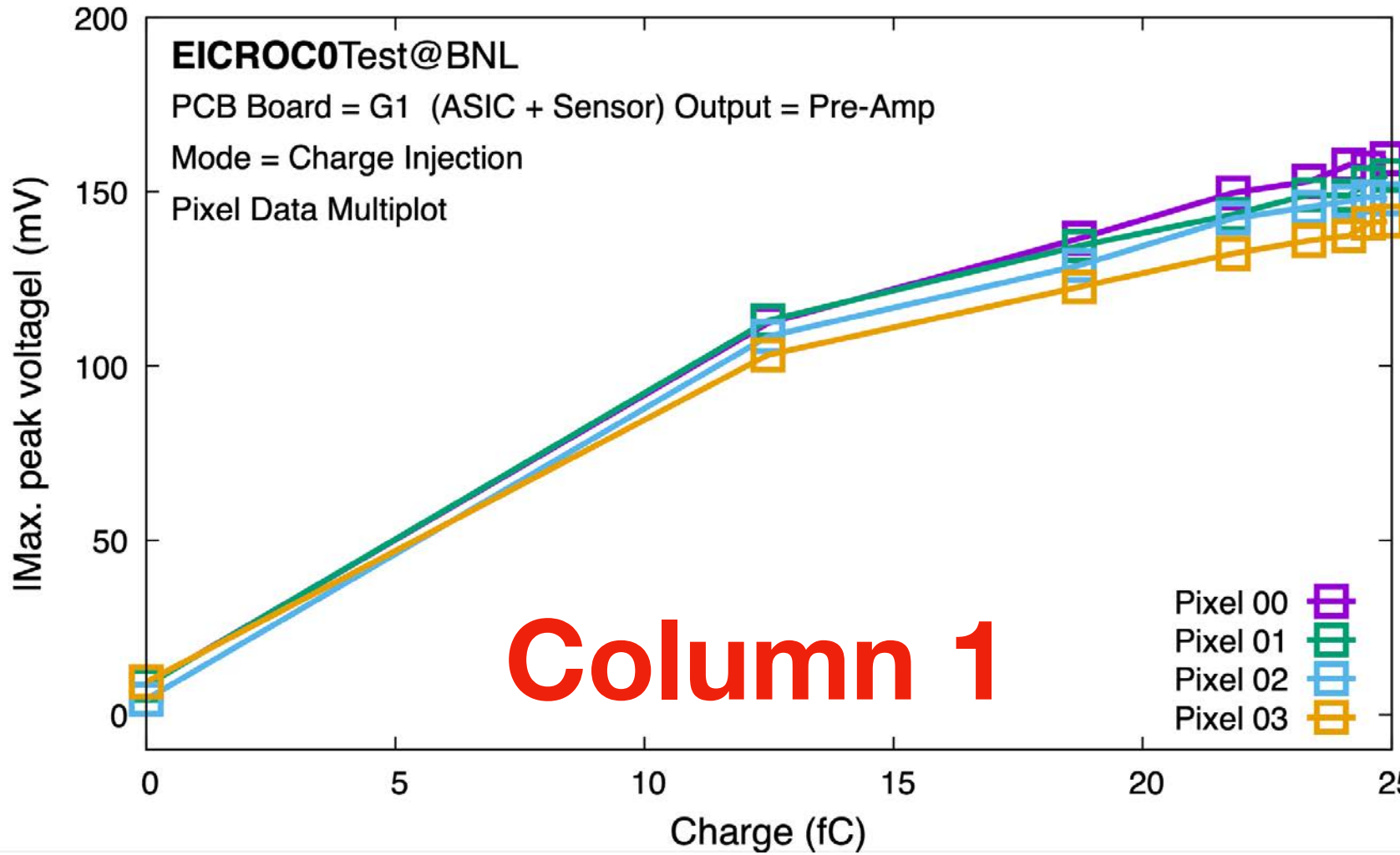


# Column-wise variation: Absolute max. amplitude

| Reg 0x20C dacb_pulser value | Tension [mV] | Charge [fC] |
|-----------------------------|--------------|-------------|
| 0                           | 249,1        | 24,91       |
| 1                           | 245,3        | 24,53       |
| 2                           | 241,4        | 24,14       |
| 4                           | 233,4        | 23,34       |
| 8                           | 218,2        | 21,82       |
| 16                          | 187,3        | 18,73       |
| 32                          | 124,8        | 12,48       |
| 63                          | 5,05         | 0,505       |

$Q \text{ [fC]} = C \text{ [fF]} \times U \text{ [mV]}$   
 $C = 100 \text{ fF}$

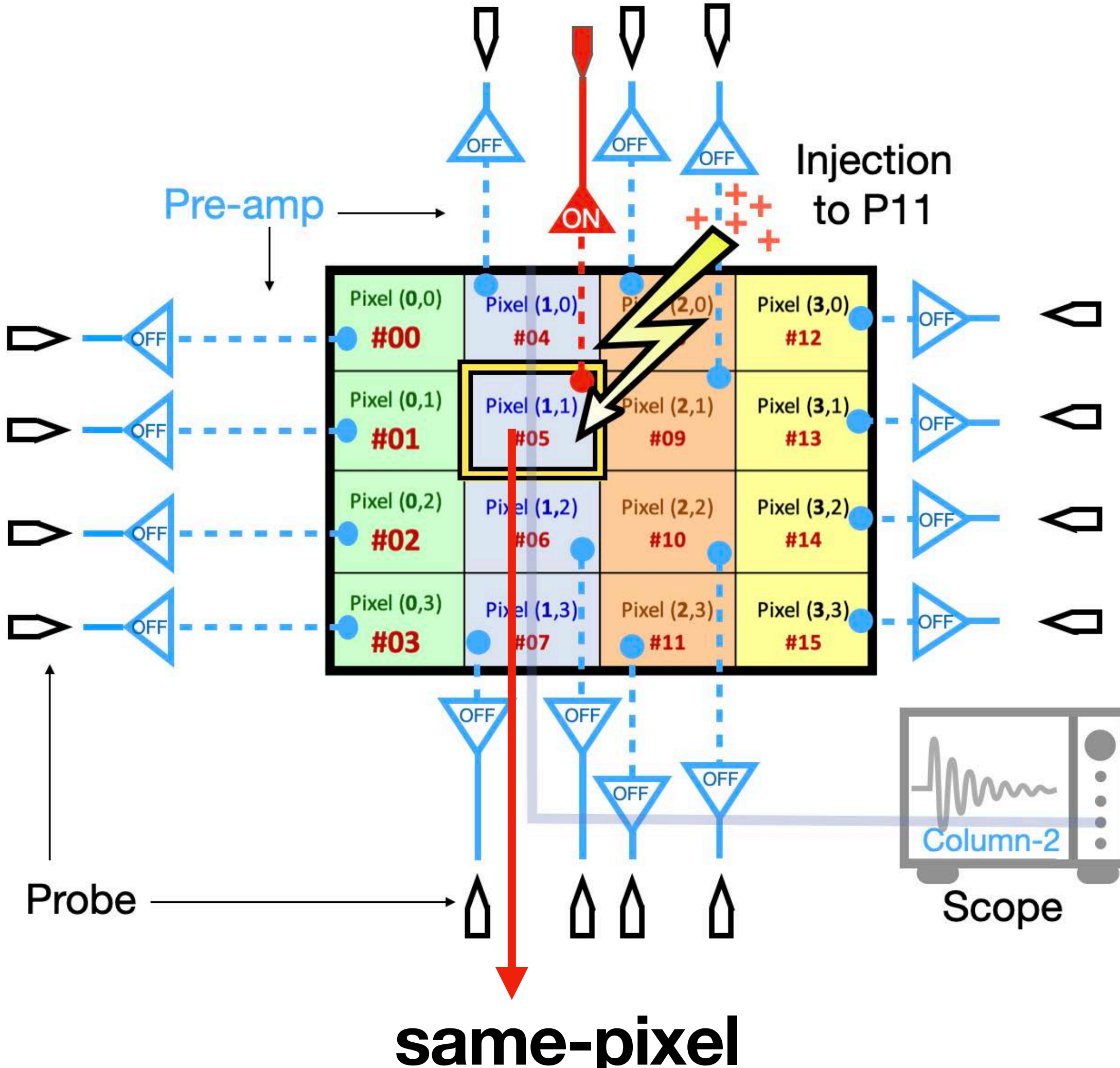
Non-linear behaviour in general.  
 For a given injected charge,  
 Columns 2 and 3 have greater  
 absolute maximum amplitudes  
 (of signal) in comparison to  
 Columns 0 and 1.



Correlated response as expected

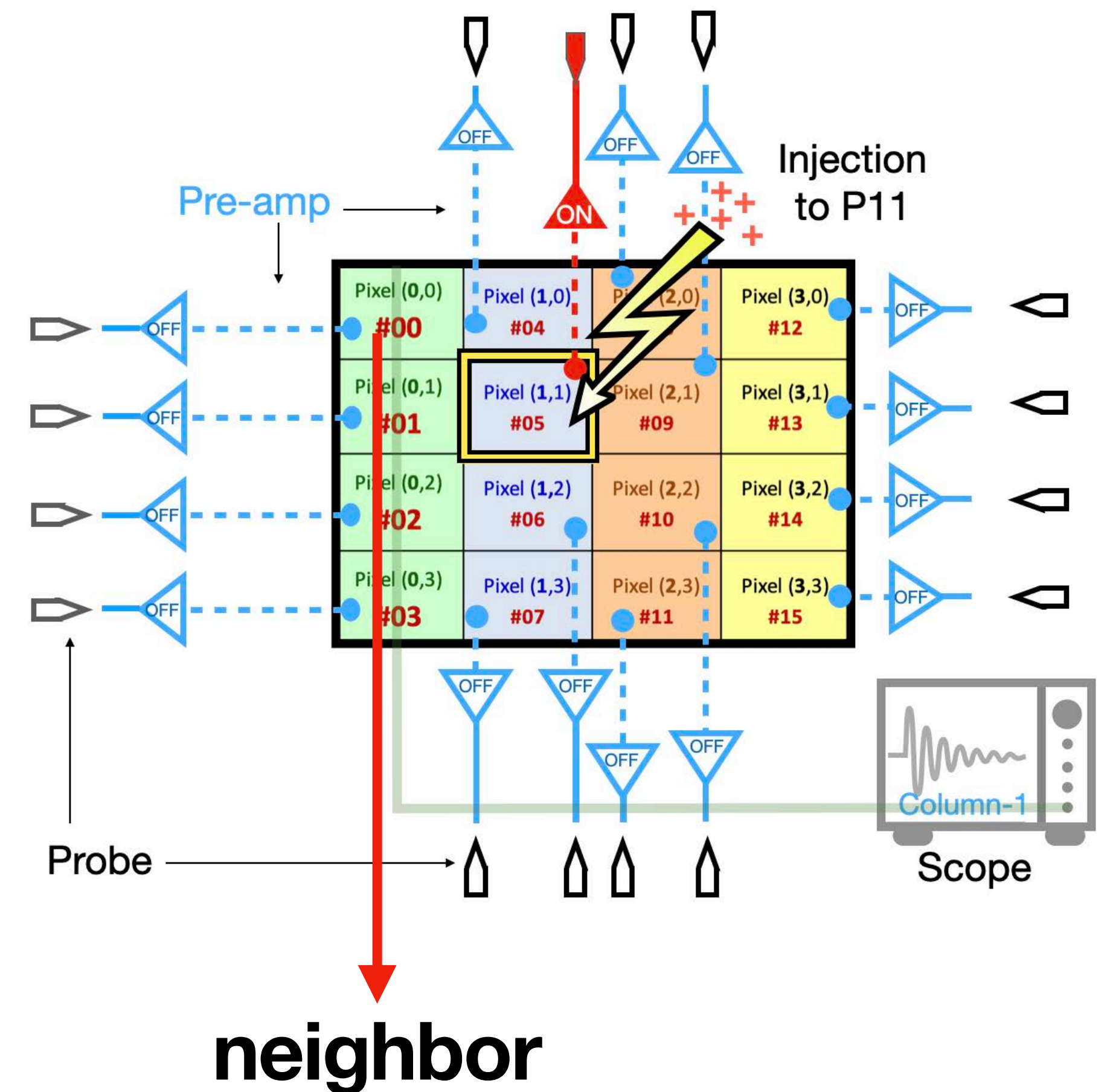


# Solo response of P11 (charge injected)



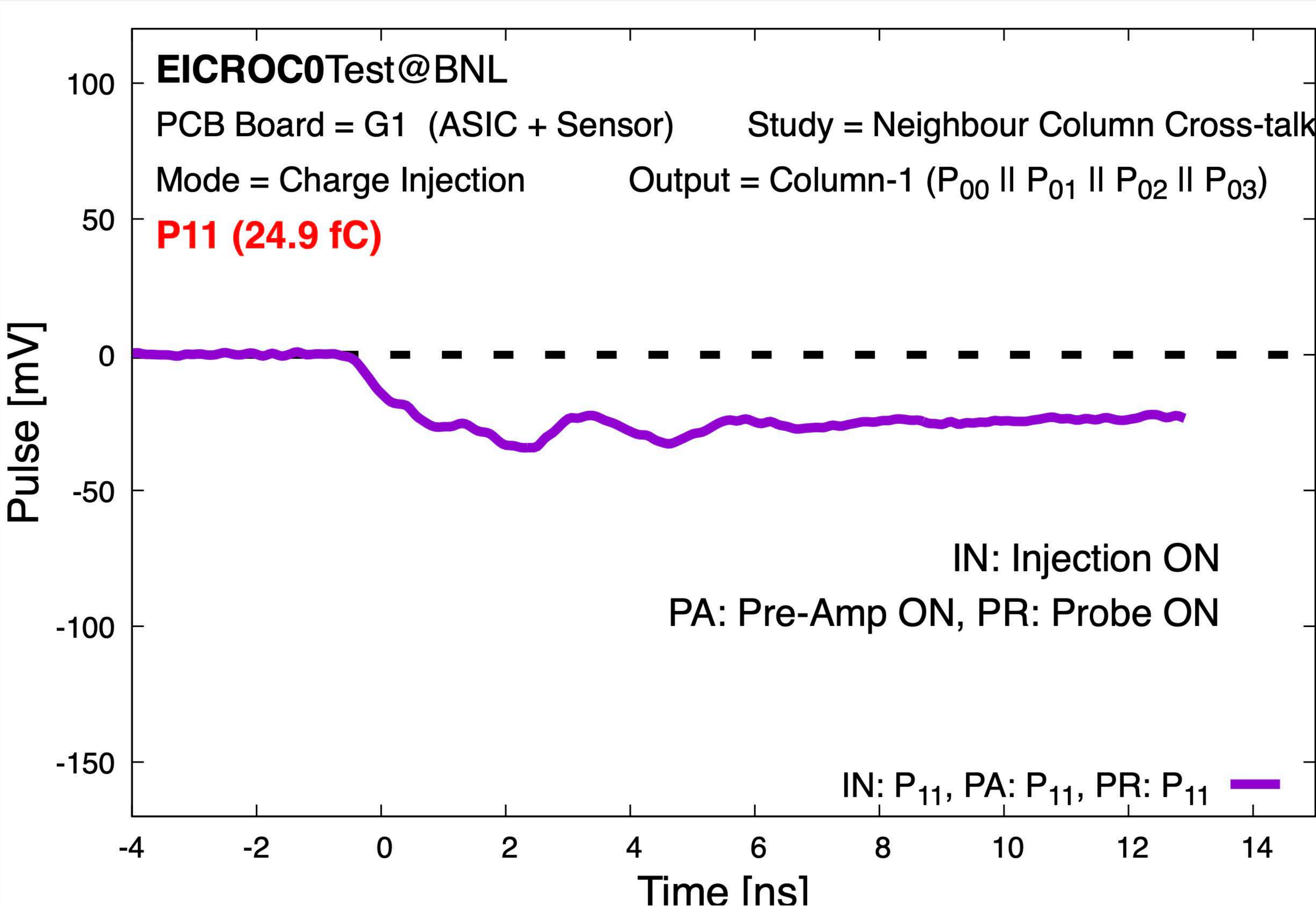


# How Cross-talk from pixel in different-column affect noise?





# Neighbor-column crosstalk (Reading Noise)

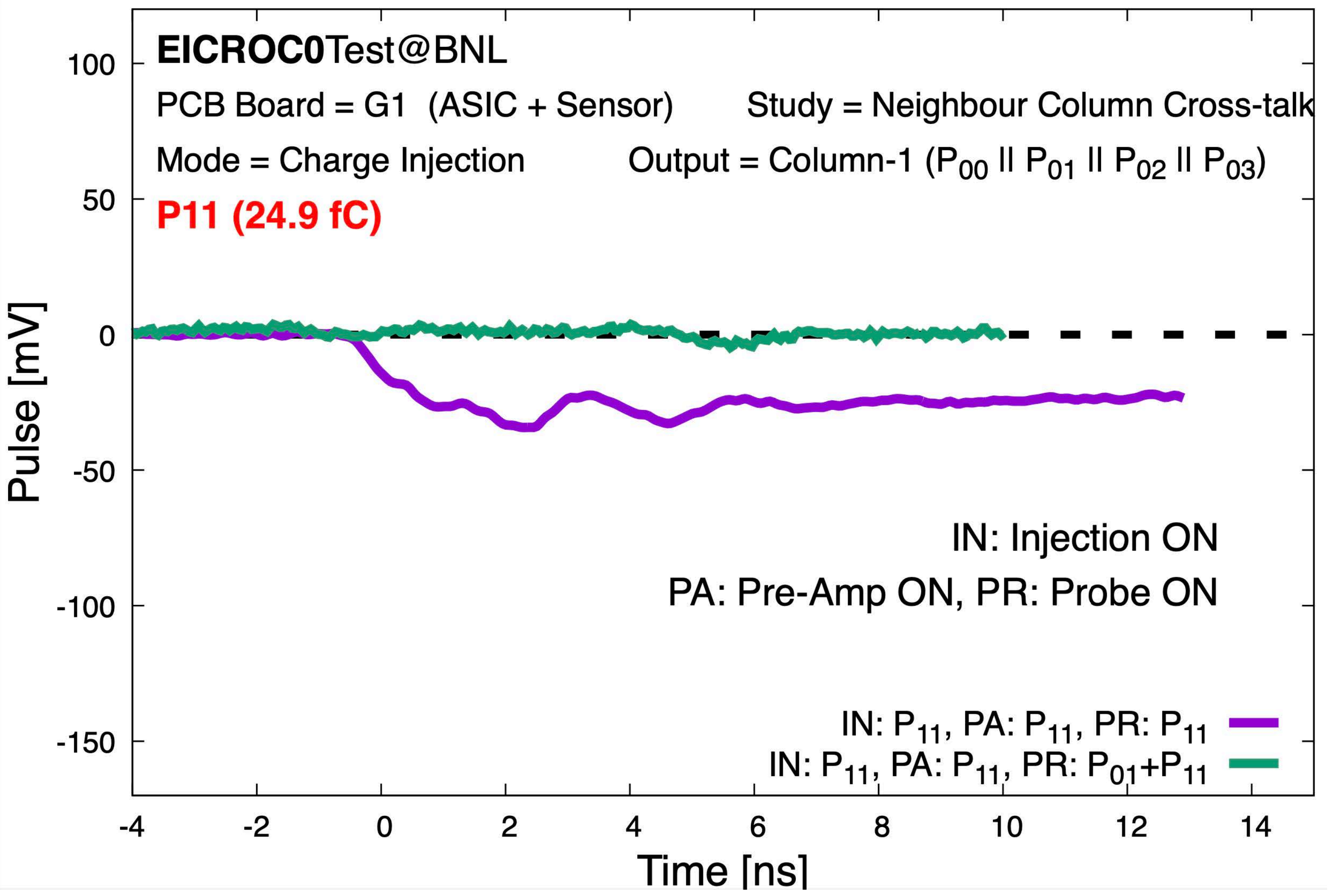


|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |

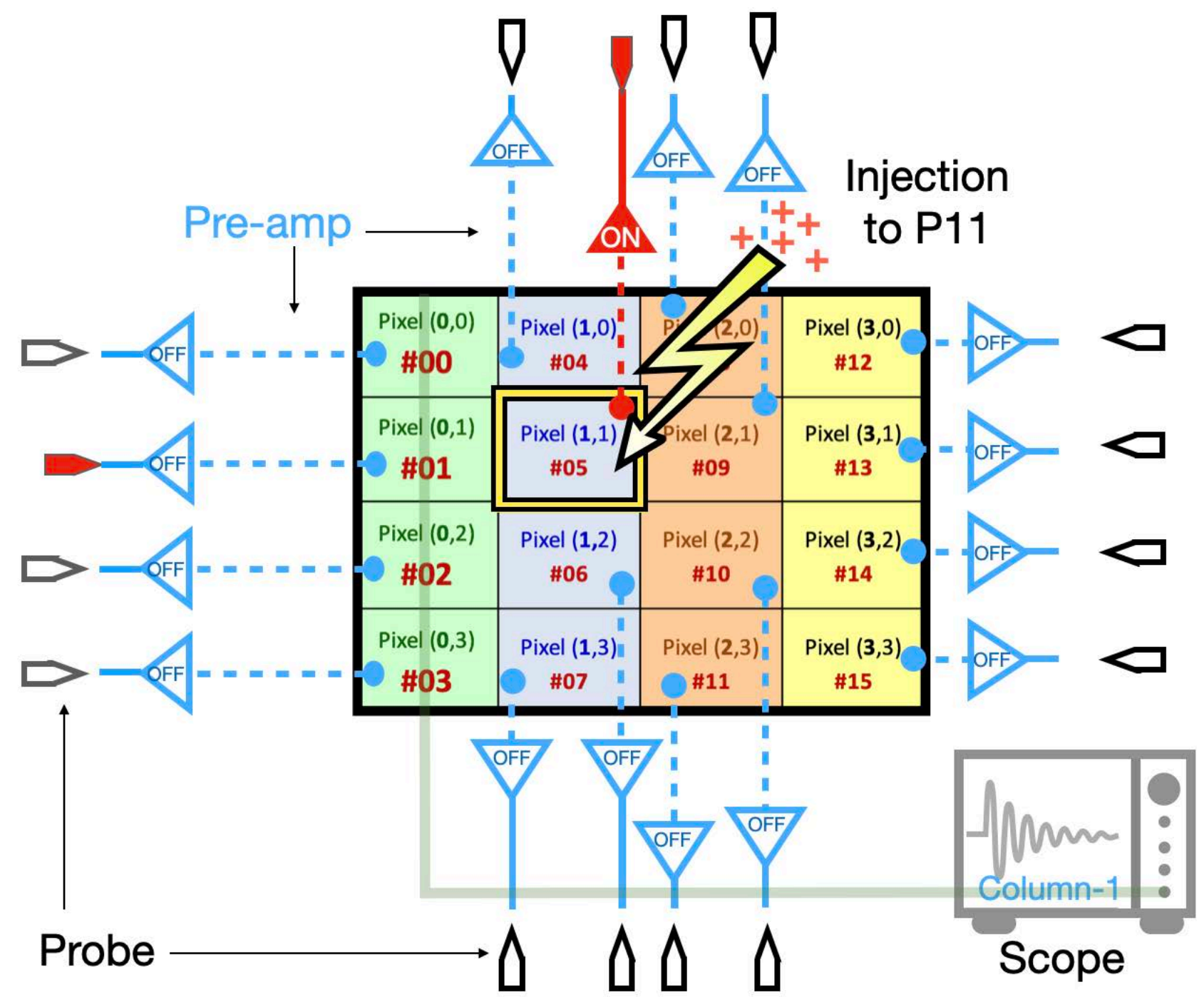
A pedestal like signal seen when the probes are not ON



# Neighbor-column crosstalk (Reading Noise)



|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |



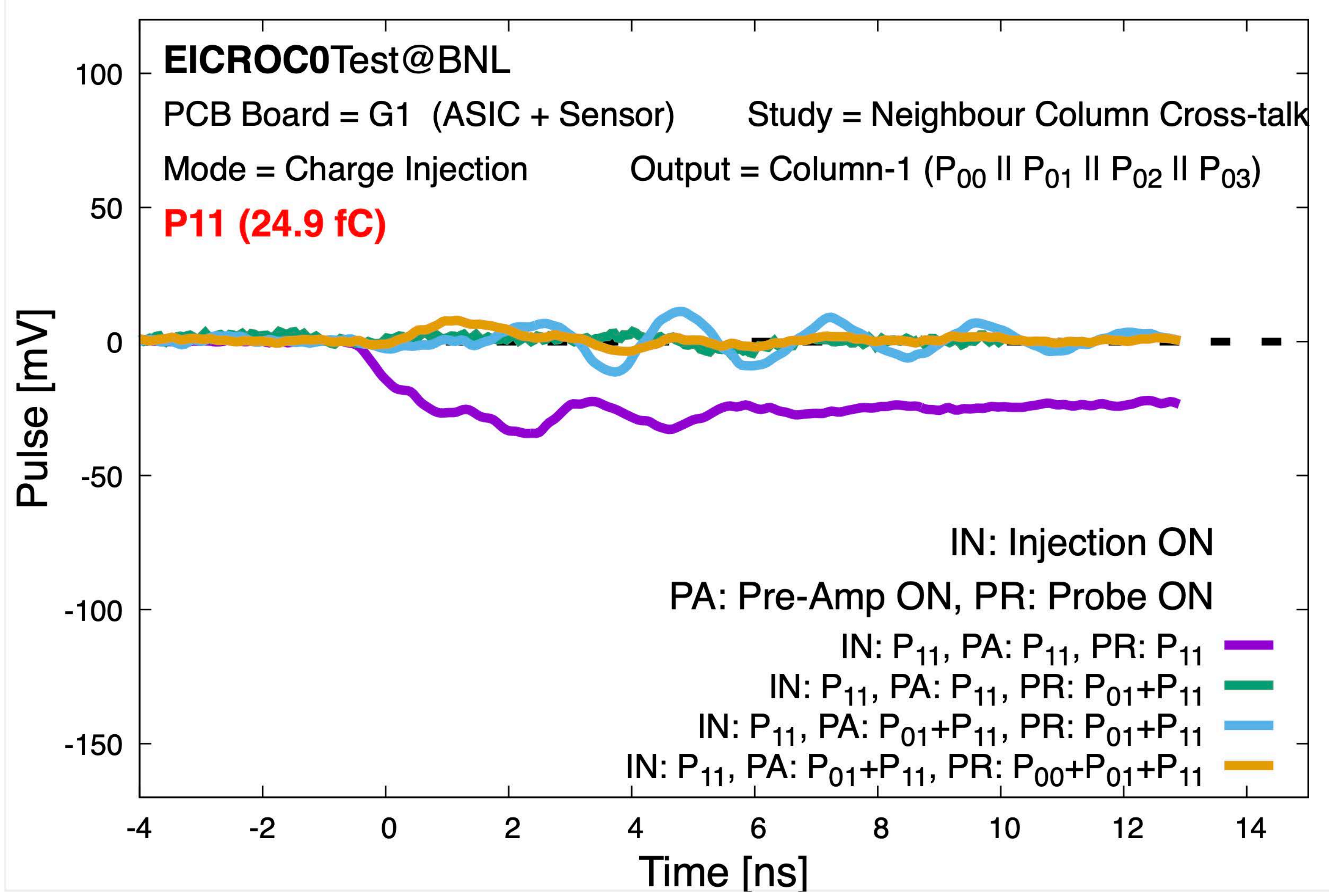
Turning the probe ON in P01 makes it disappear



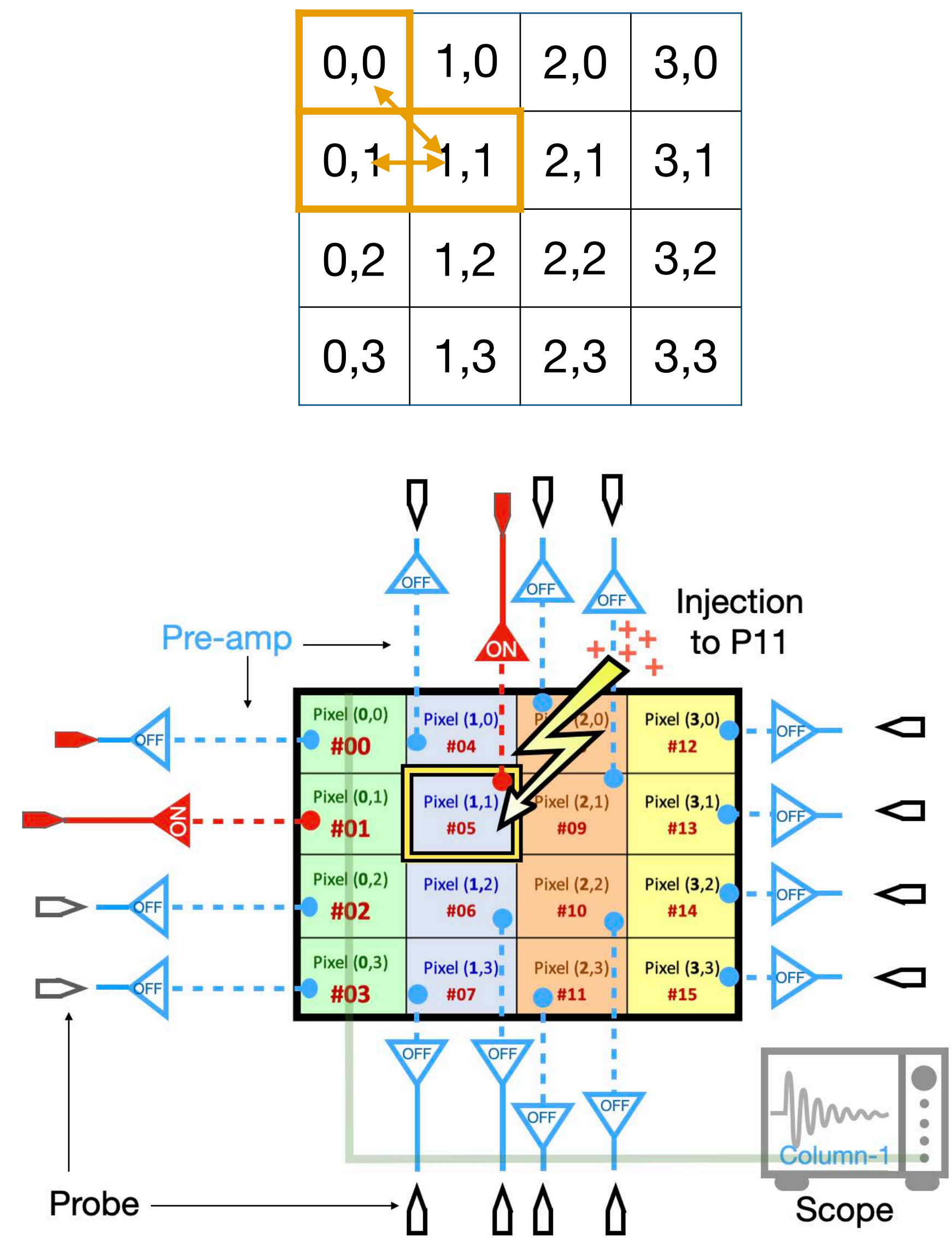




# Neighbor-column crosstalk (Reading Noise)



Turning another probe ON makes it disappear

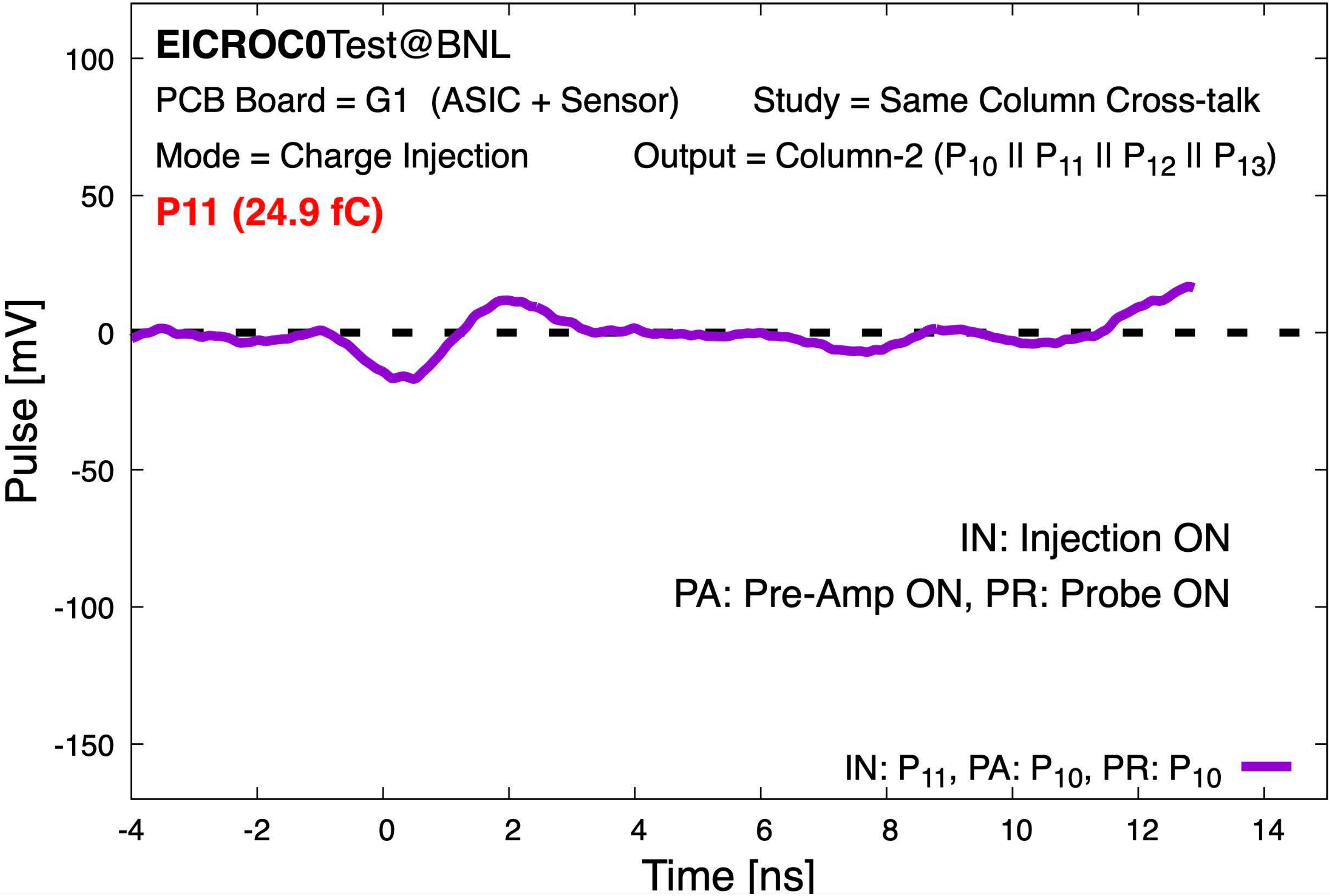




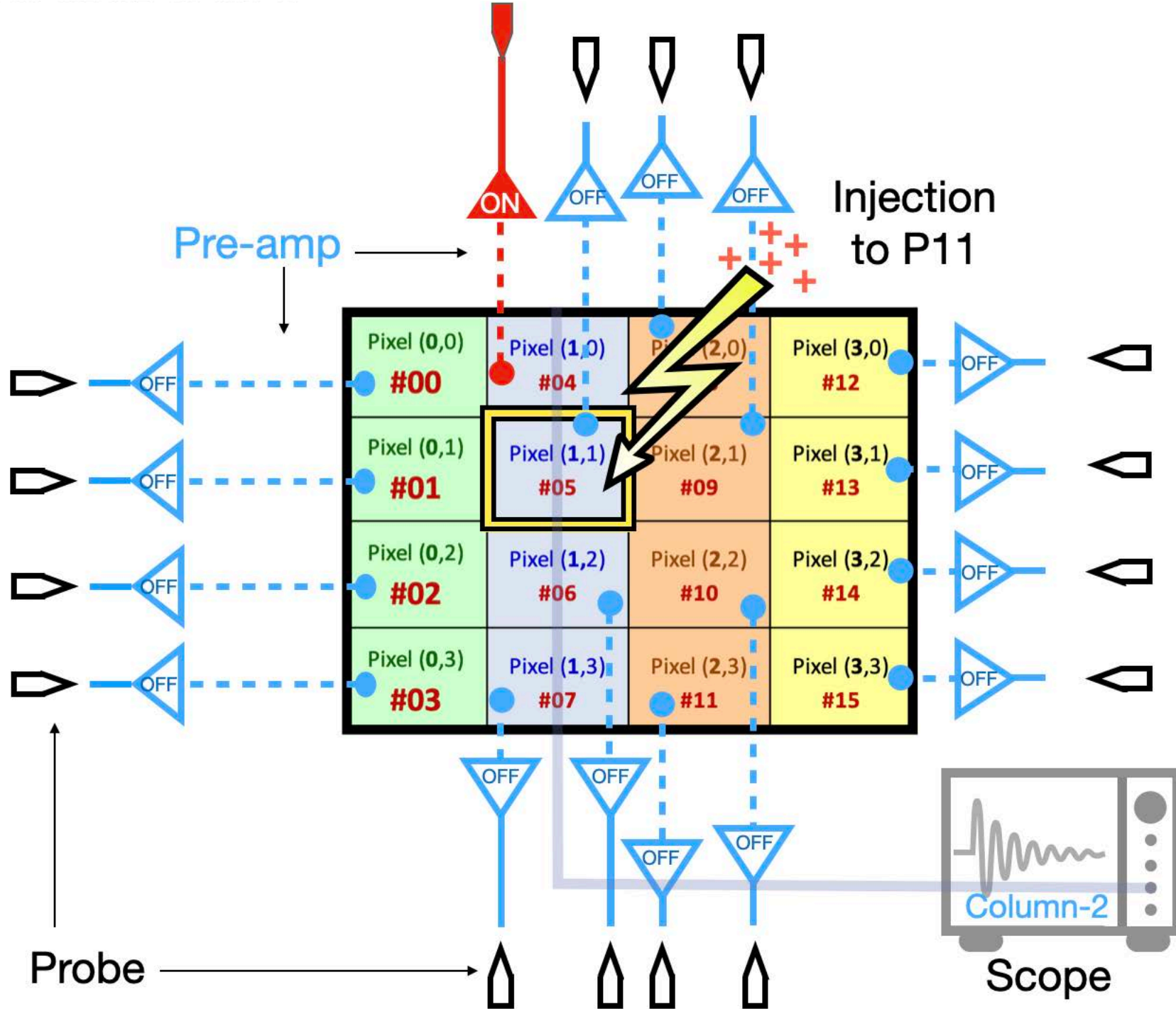




# Same-column crosstalk (Reading noise)



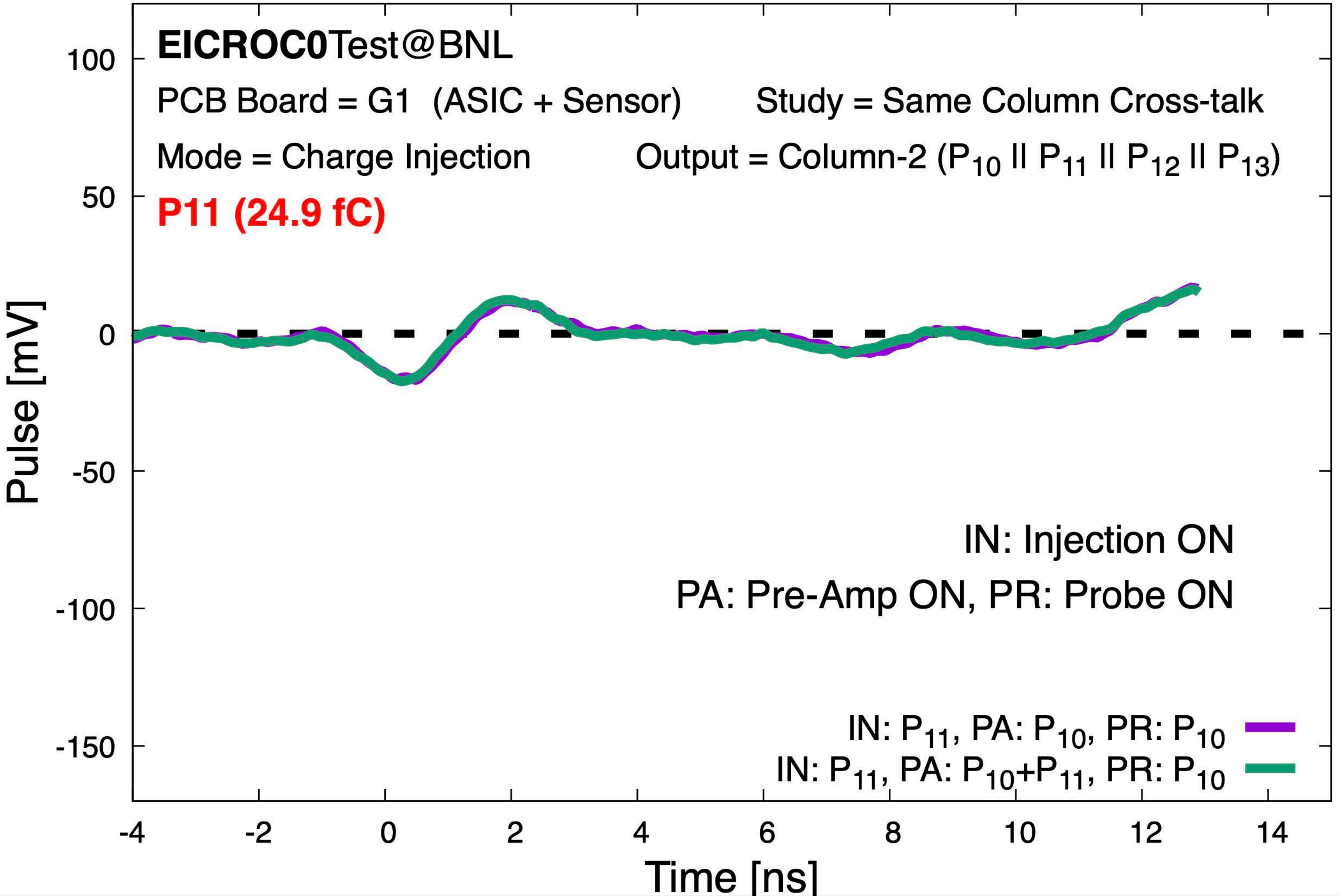
|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |



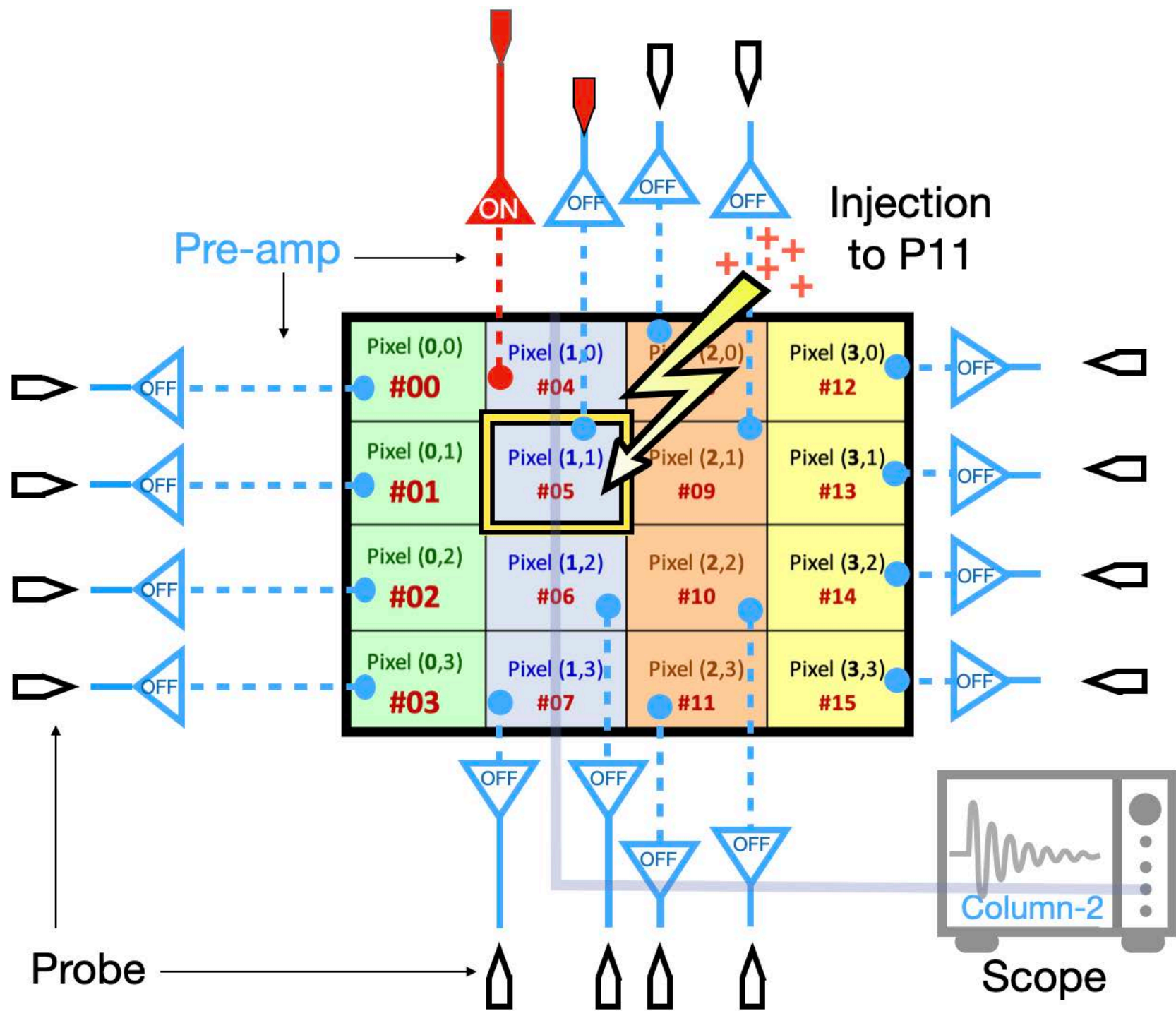
Noise seen if probe and PA are turned ON



# Same-column crosstalk (Reading noise)



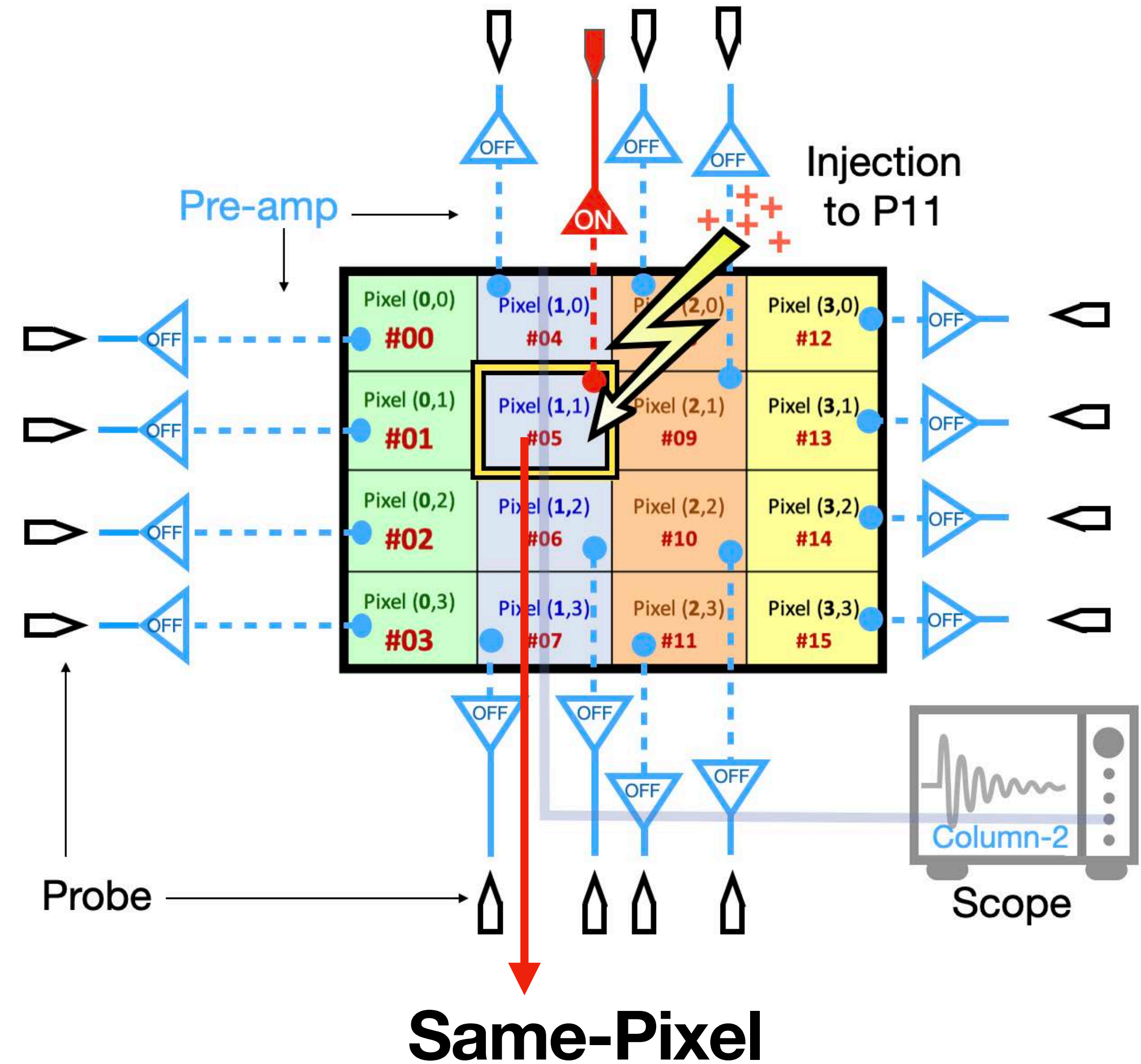
|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |



Noise remains if the PA in P11 is turned on



# Cross-talk from neighbor affect signal ?

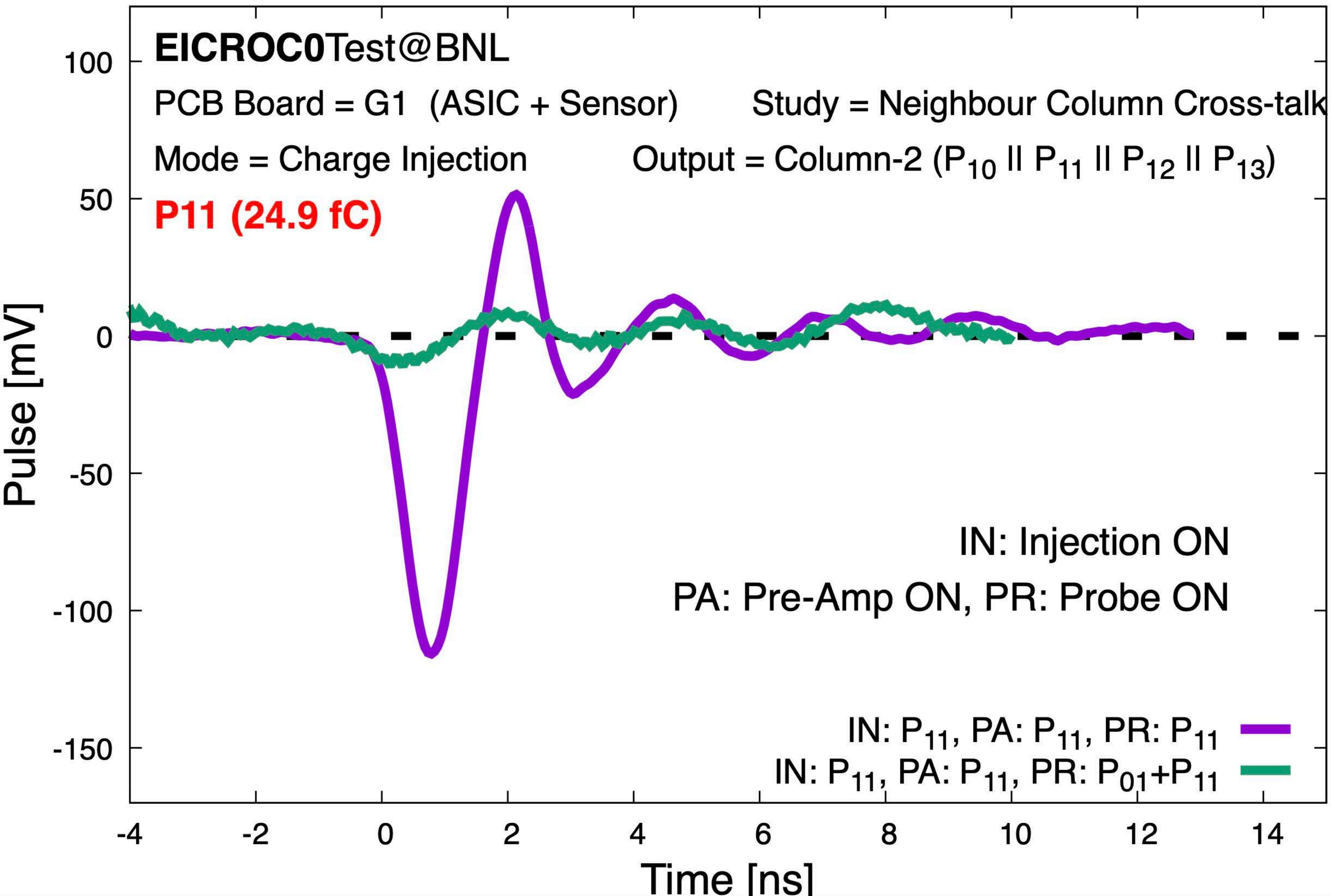




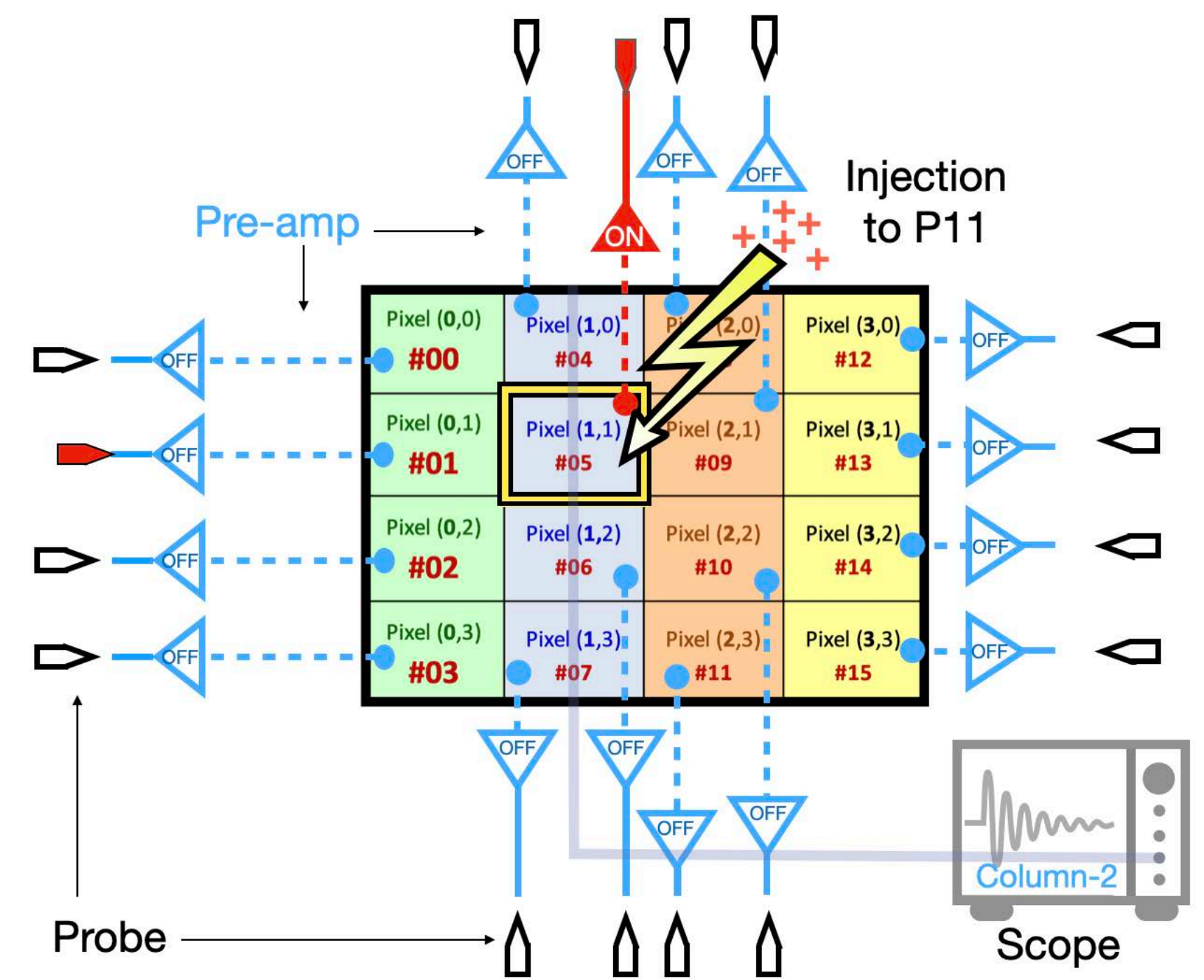




# Neighbour-column crosstalk (Reading Signal)

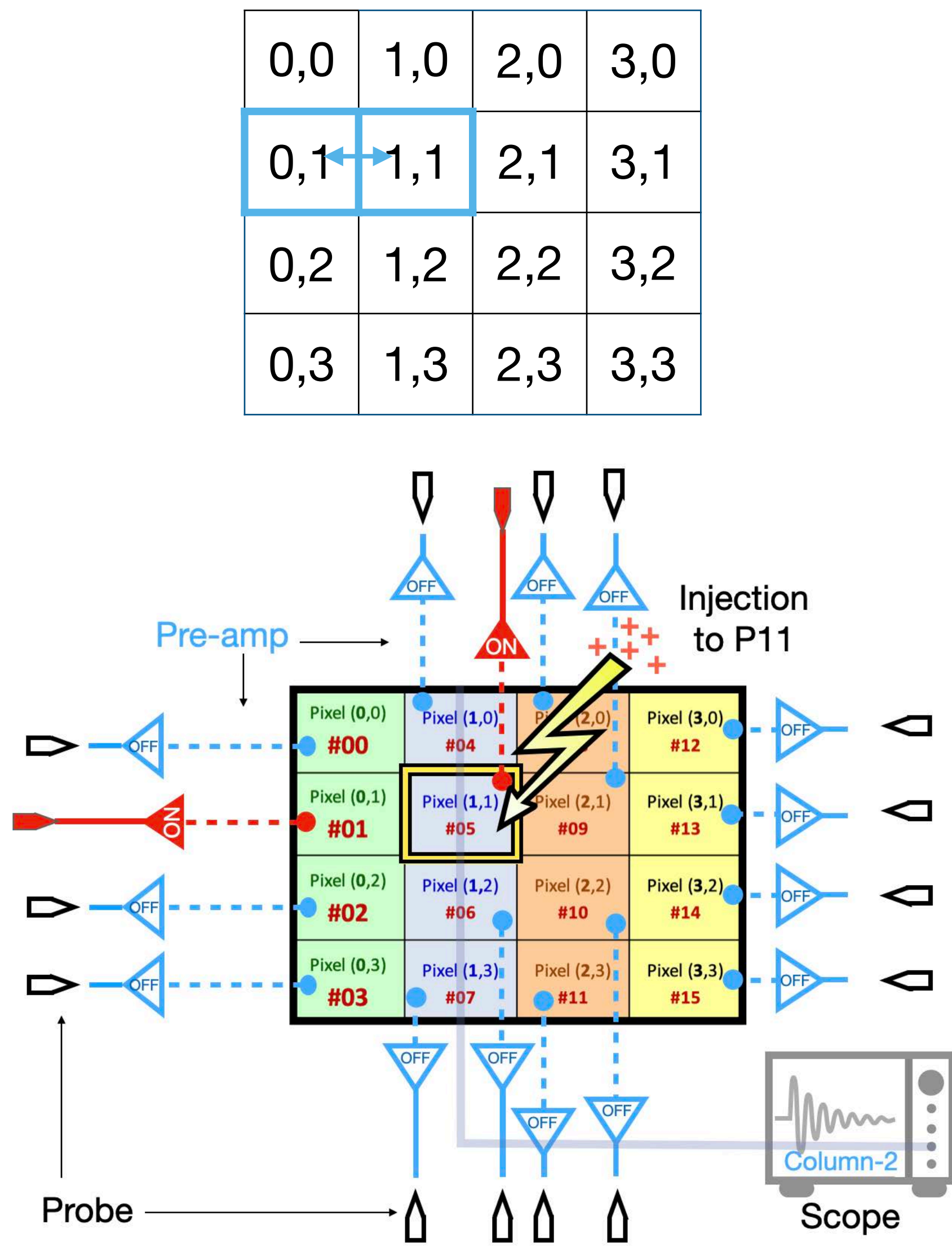
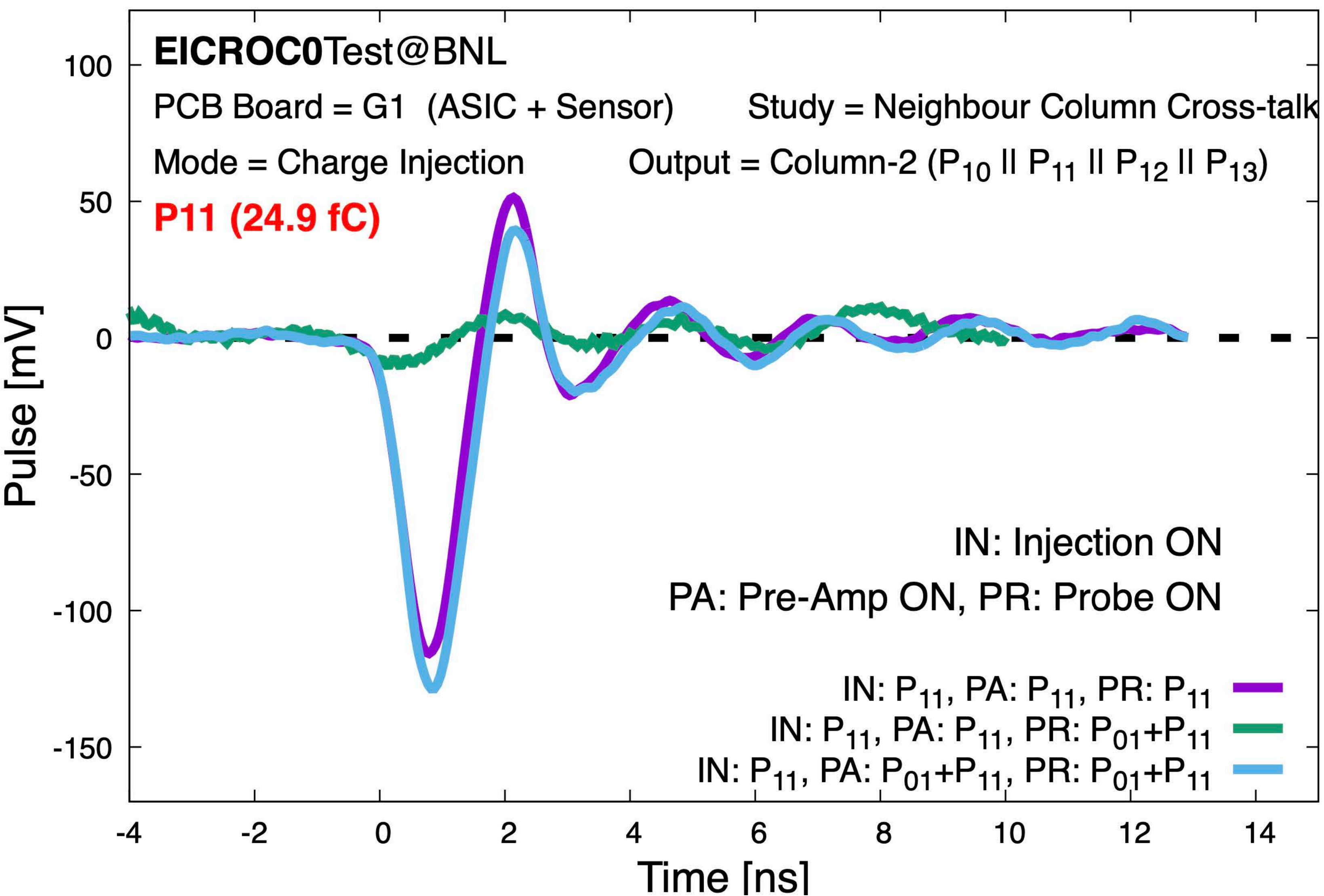


|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |



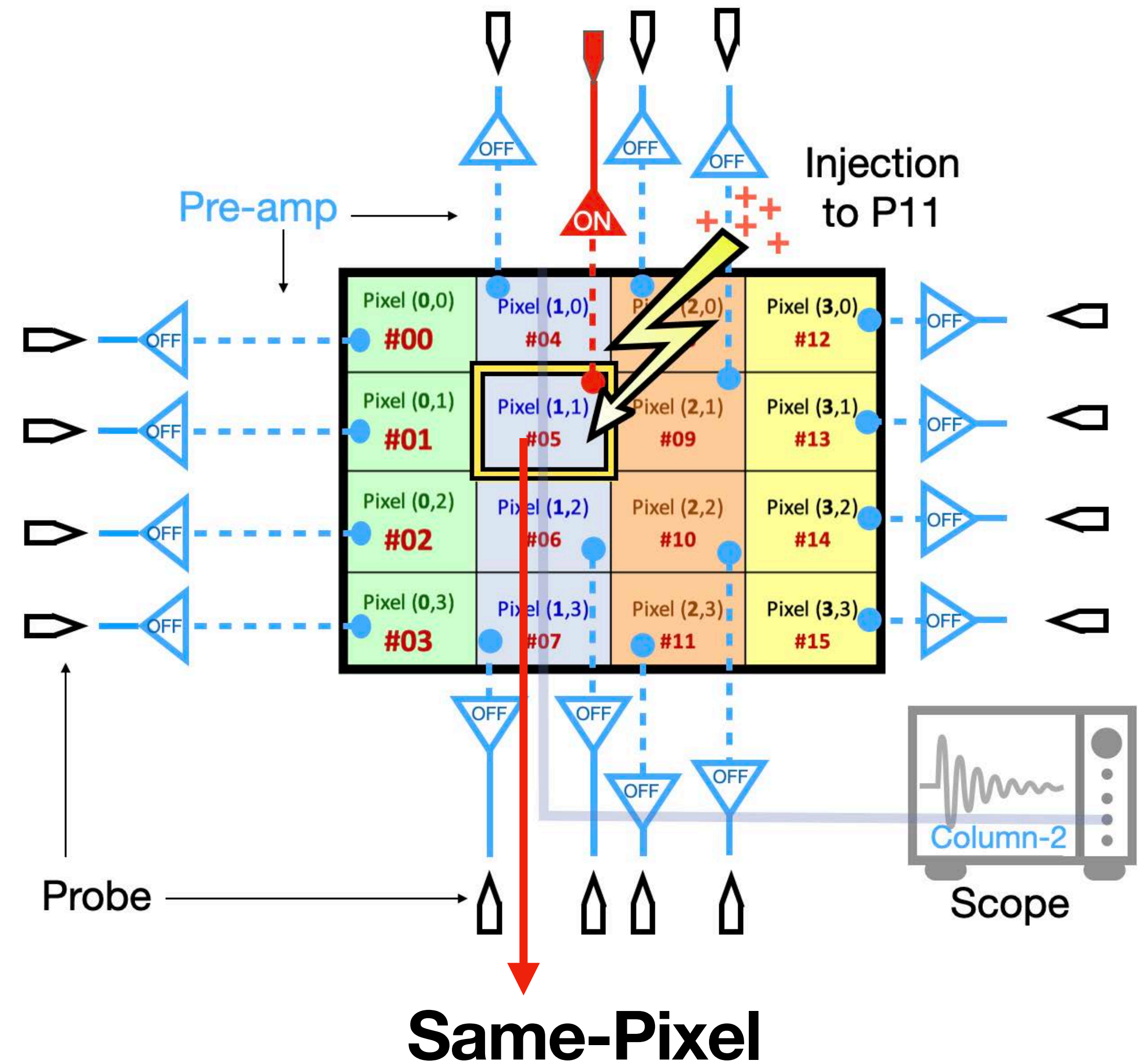


# Neighbour-column crosstalk (Reading Signal)



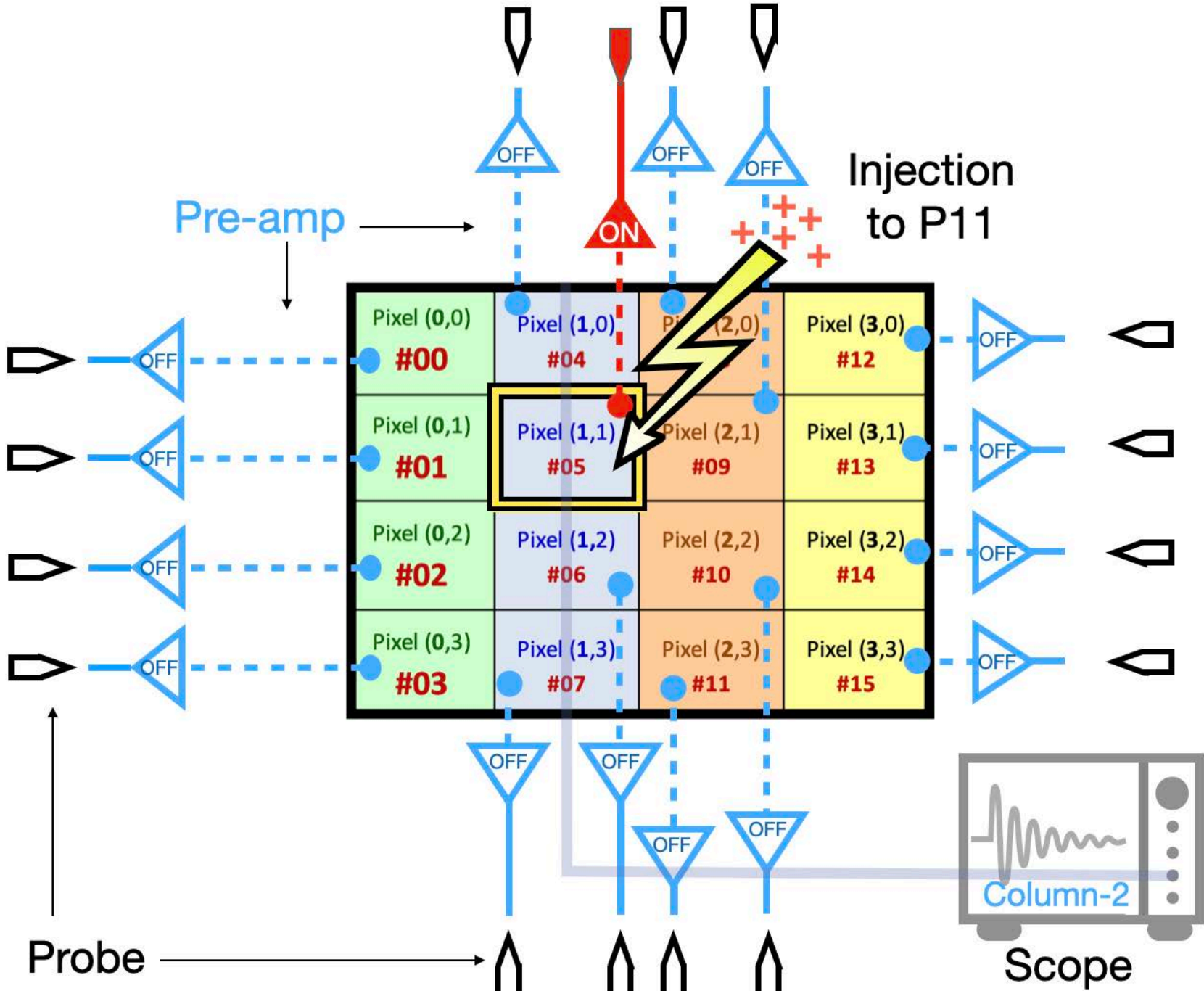
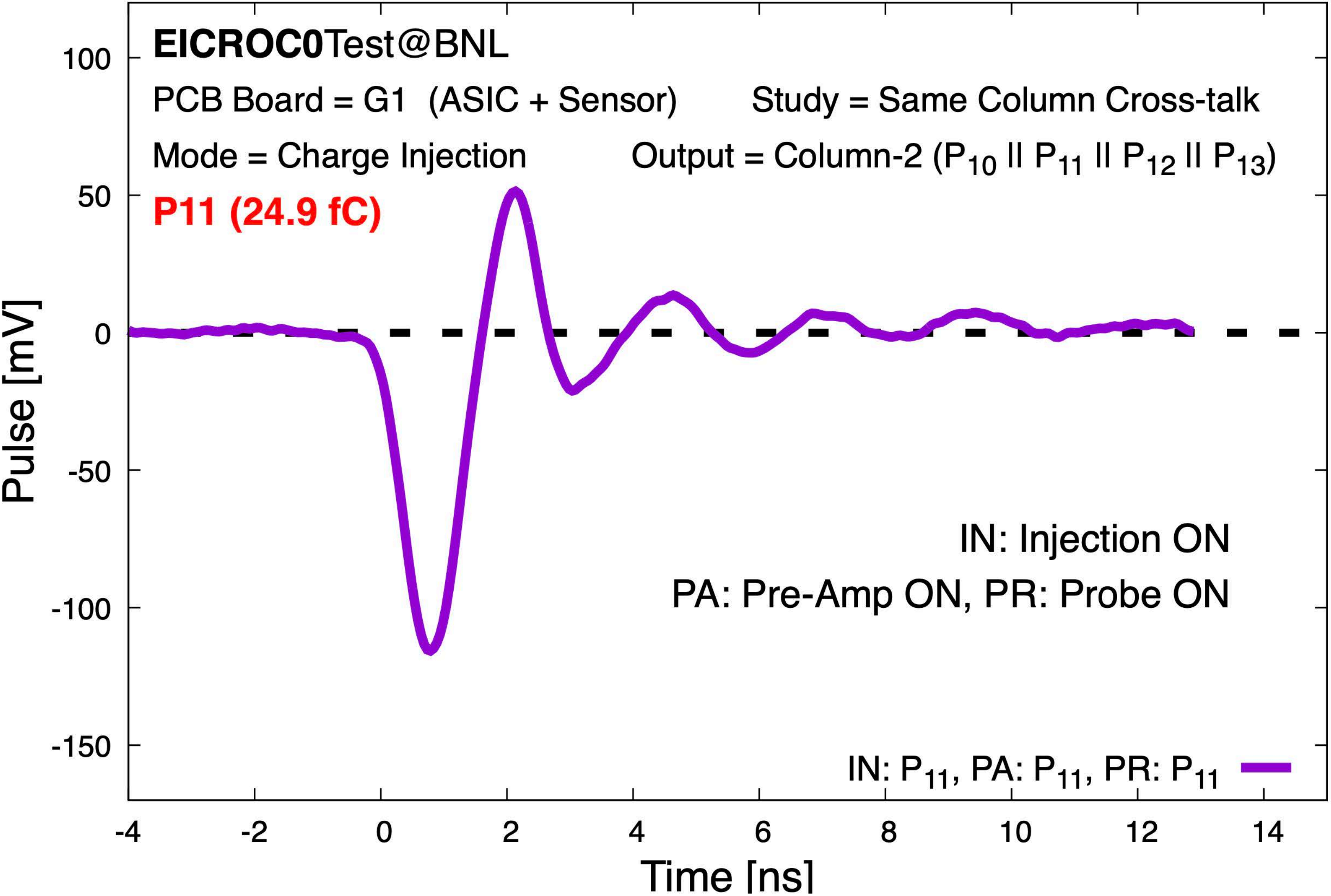


# How Cross-talk from same column affect signal ?



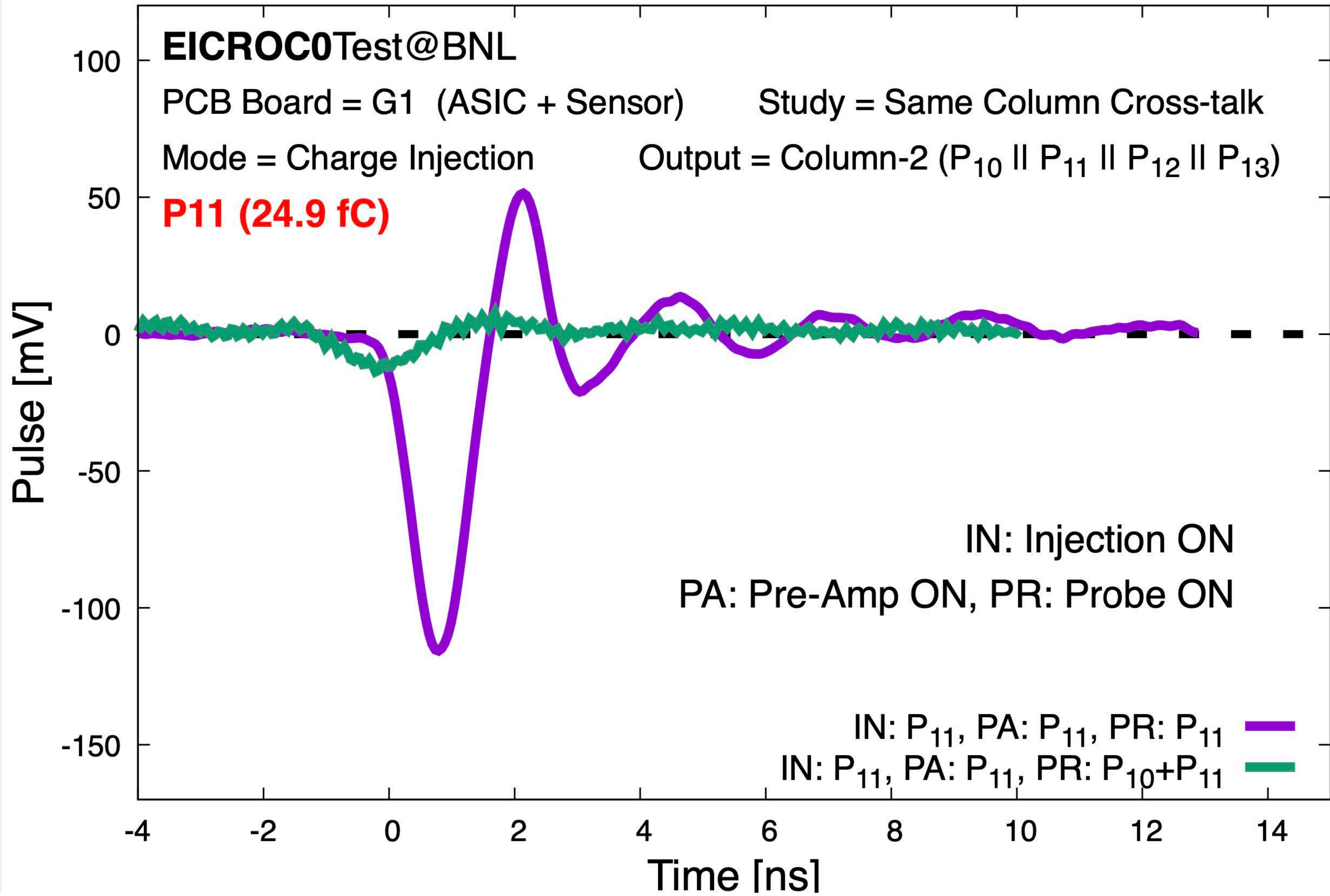


# Same-column crosstalk (Reading Signal)

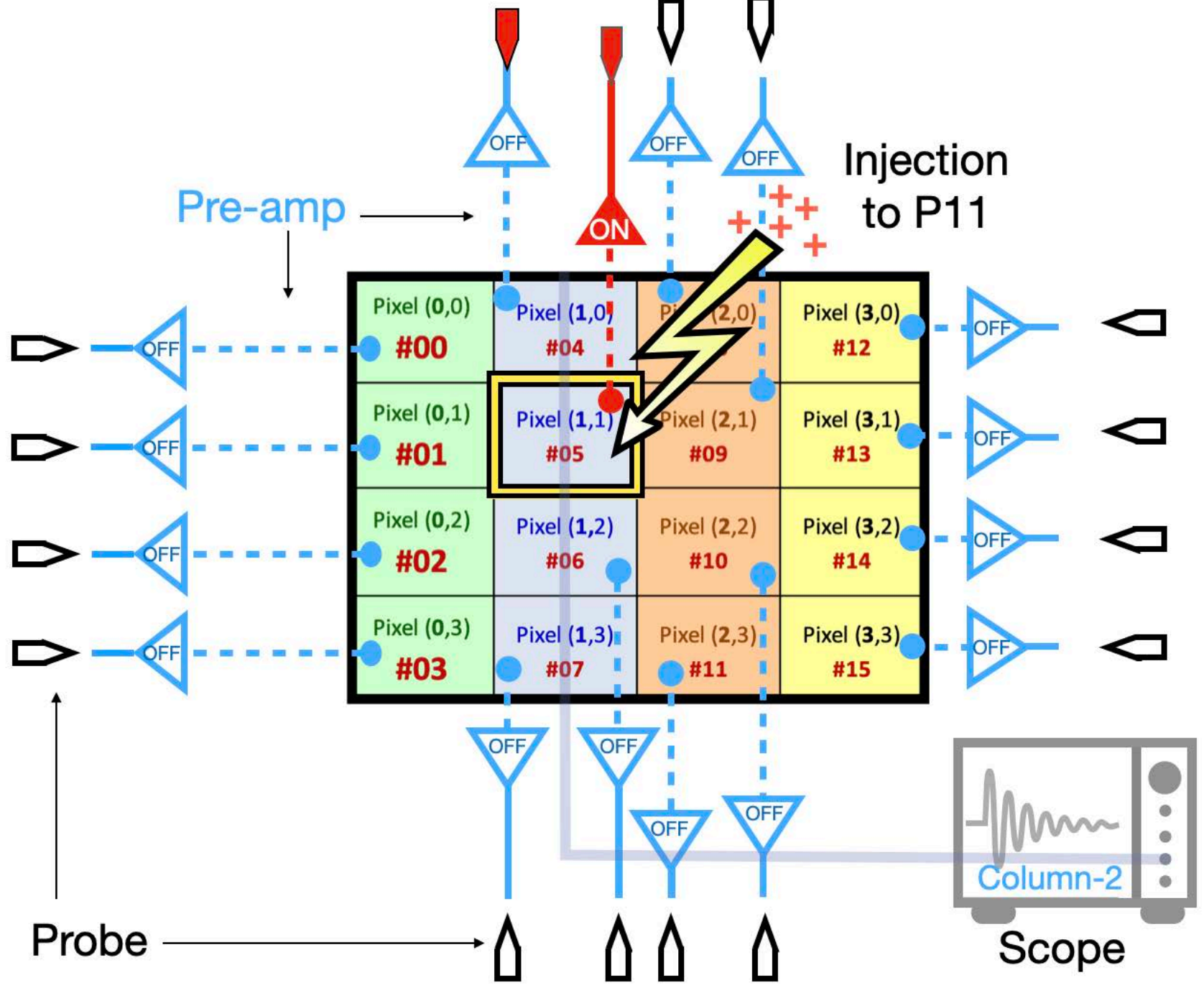




# Same-column crosstalk (Reading Signal)



|     |     |     |     |
|-----|-----|-----|-----|
| 0,0 | 1,0 | 2,0 | 3,0 |
| 0,1 | 1,1 | 2,1 | 3,1 |
| 0,2 | 1,2 | 2,2 | 3,2 |
| 0,3 | 1,3 | 2,3 | 3,3 |





# Same-column crosstalk (Reading Signal)

