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Dynamic characterization of the ARCADIA passive pixel arrays: a comparison between simulation and experimental data

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on behalf of the ARCADIA collaboration

ARCADIA

Advanced Readout CMOS Architectures with Depleted Integrated sensor Arrays

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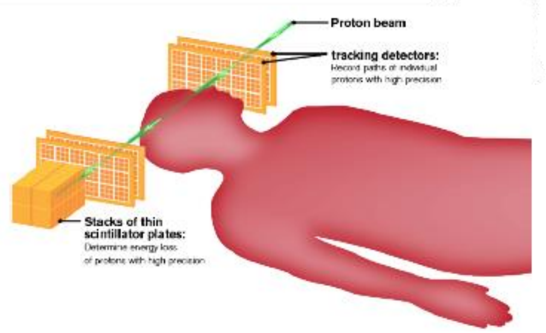
Outline

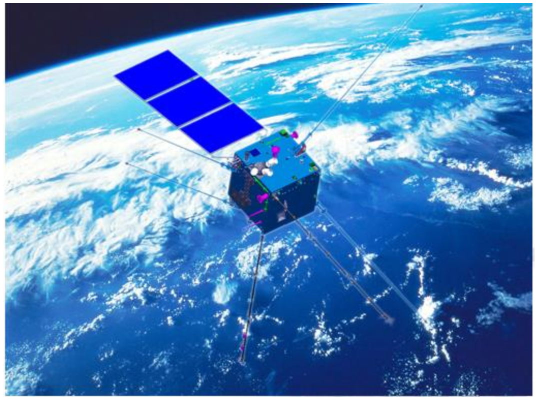
1) Sensor concept
2) Passive pixel arrays
3) Electrical characterization
4) Laser characterization
5) Conclusions

ARCADIA Project

- Fully depleted MAPS
- Target applications:
  - medical imaging (e.g. PCT)
  - particle detection on satellites
  - HEP experiments

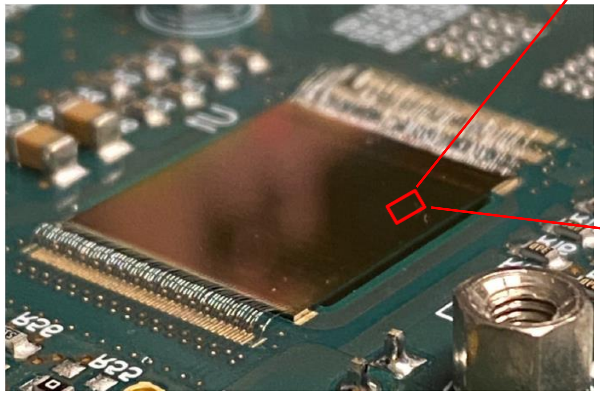


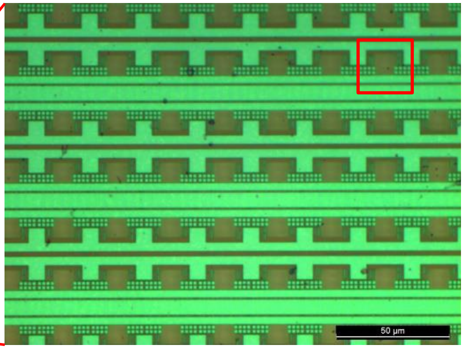
Piero Giubilato



CSES-01
http://cses.roma2.infn.it

Andrea Paternò, Vertex 2021
ARCADIA MD1 chip

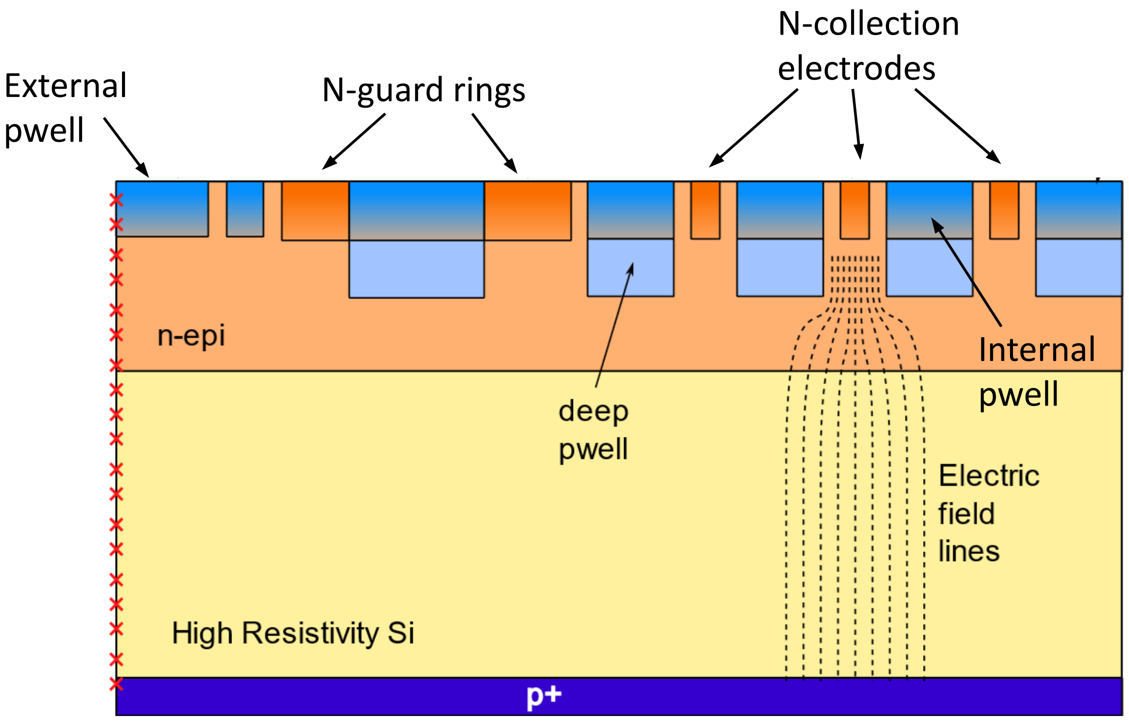




MD1 chip micrograph

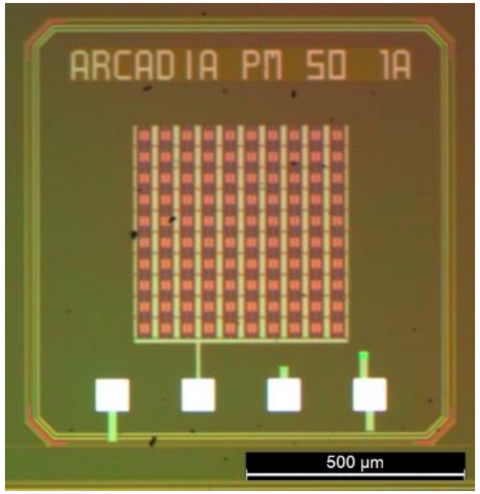
- Main Demonstrator (MD1) with sensor array composed of 512x512 pixels with 25µm pixel pitch
- Embedded analog and digital frontend electronics

Sensor concept



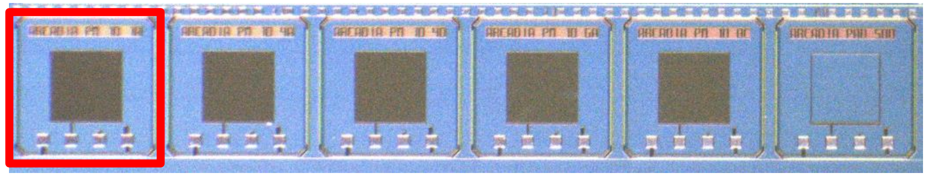
- Produced with commercial CMOS 110nm process (LFoundry)
- High resistivity silicon substrates
- N-type epitaxial layer to delay the onset of the punch through
- Operation in full depletion condition
- Independent frontside and backside bias electrodes

ARCADIA Test Structures

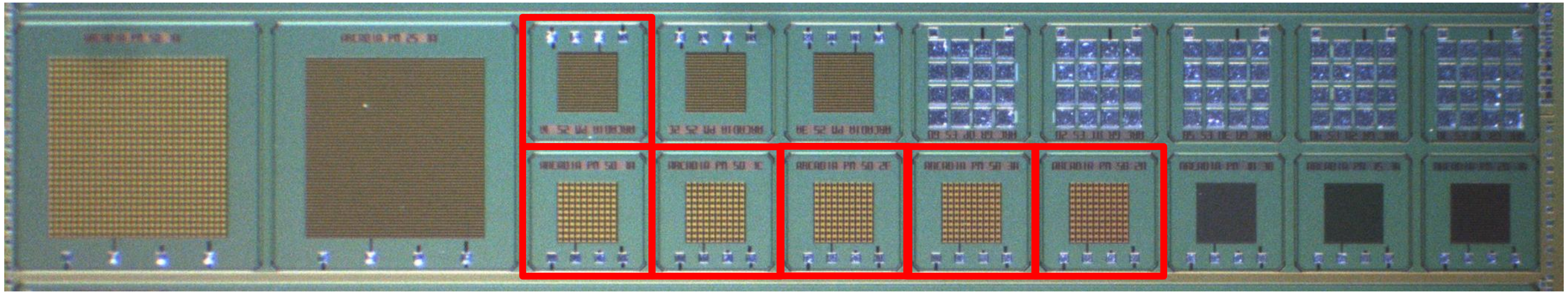


- Chip frontside electrodes
  - External pwell
  - N-type sensor nodes
  - Internal pwell
  - N-guard rings

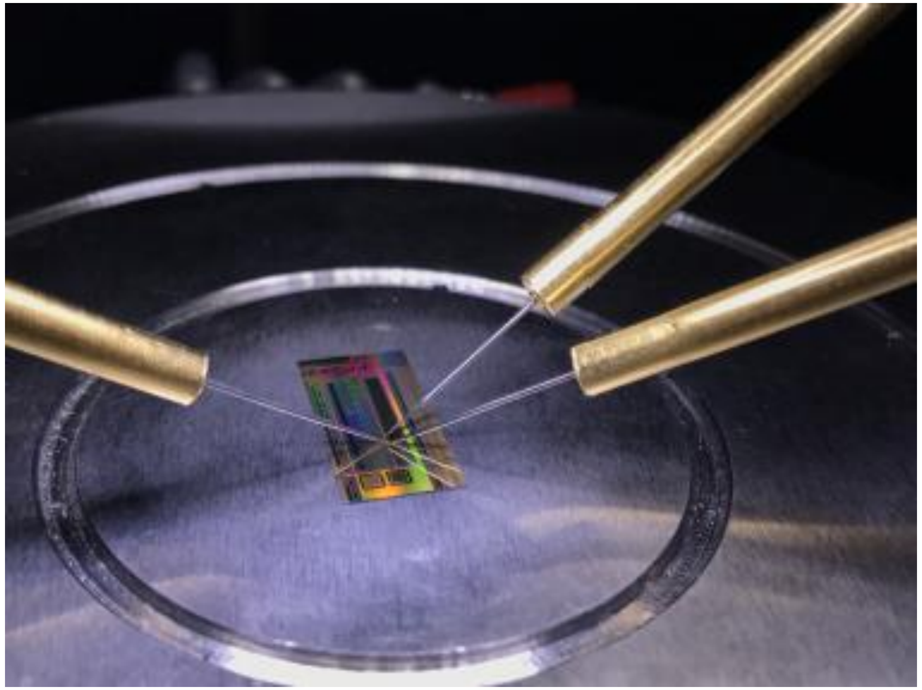
- Passive TS chip 2
  - 10µm pixel matrix



- Passive TS chip 1
  - 50µm pixel matrices
  - 25µm pixel matrix

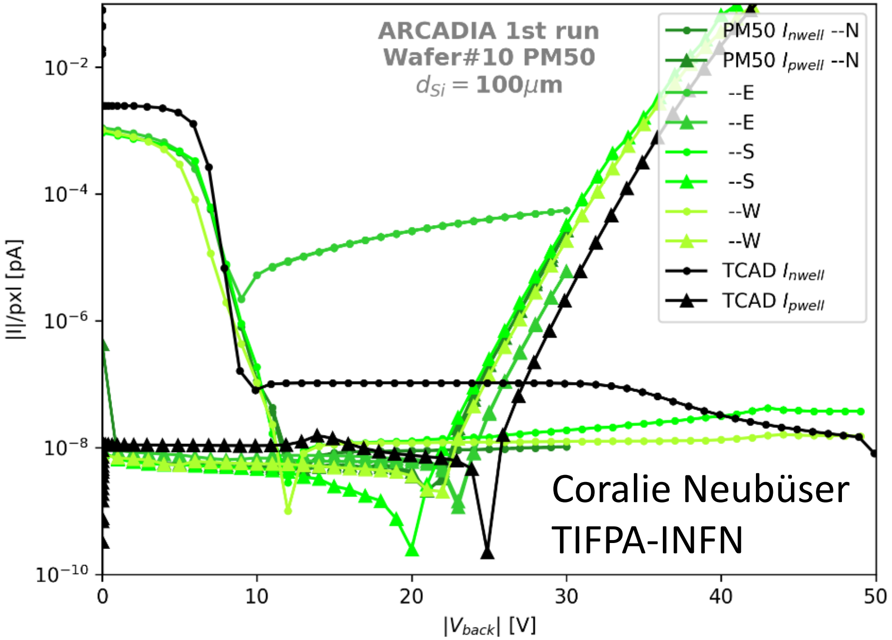


Electrical characterization



Coralie Neubüser, TIFPA-INFN

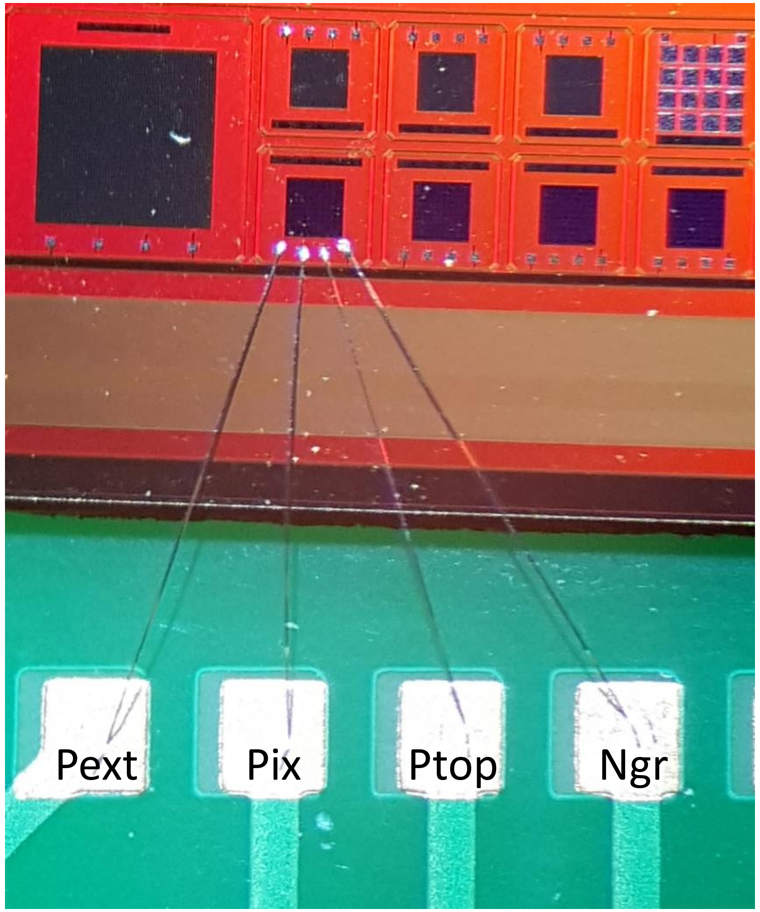
- IV measurements to extract V_{depl} and V_{PT}
- CV measurements to determine C_{pix}
- Both frontside and backside bias are properly working
- Samples with active thickness 48, 100 and 200µm



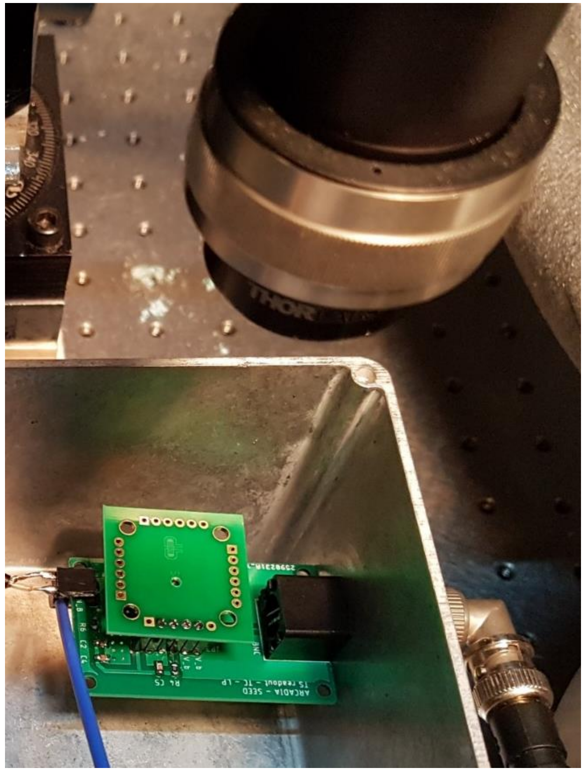
Coralie Neubüser TIFPA-INFN

	C_{pix}	
t_{act}	100 µm	
V_n	0.8 V	1.2 V
Pix 50 1A	23.7 fF	18.4 fF
Pix 50 2F	9.6 fF	8.9 fF
Pix 50 3A	23.1 fF	20.9 fF
Pix 25 1A	6.1 fF	4.9 fF
Pix 10 1A	4.4 fF	3.9 fF

Biasing scheme & Laser setup

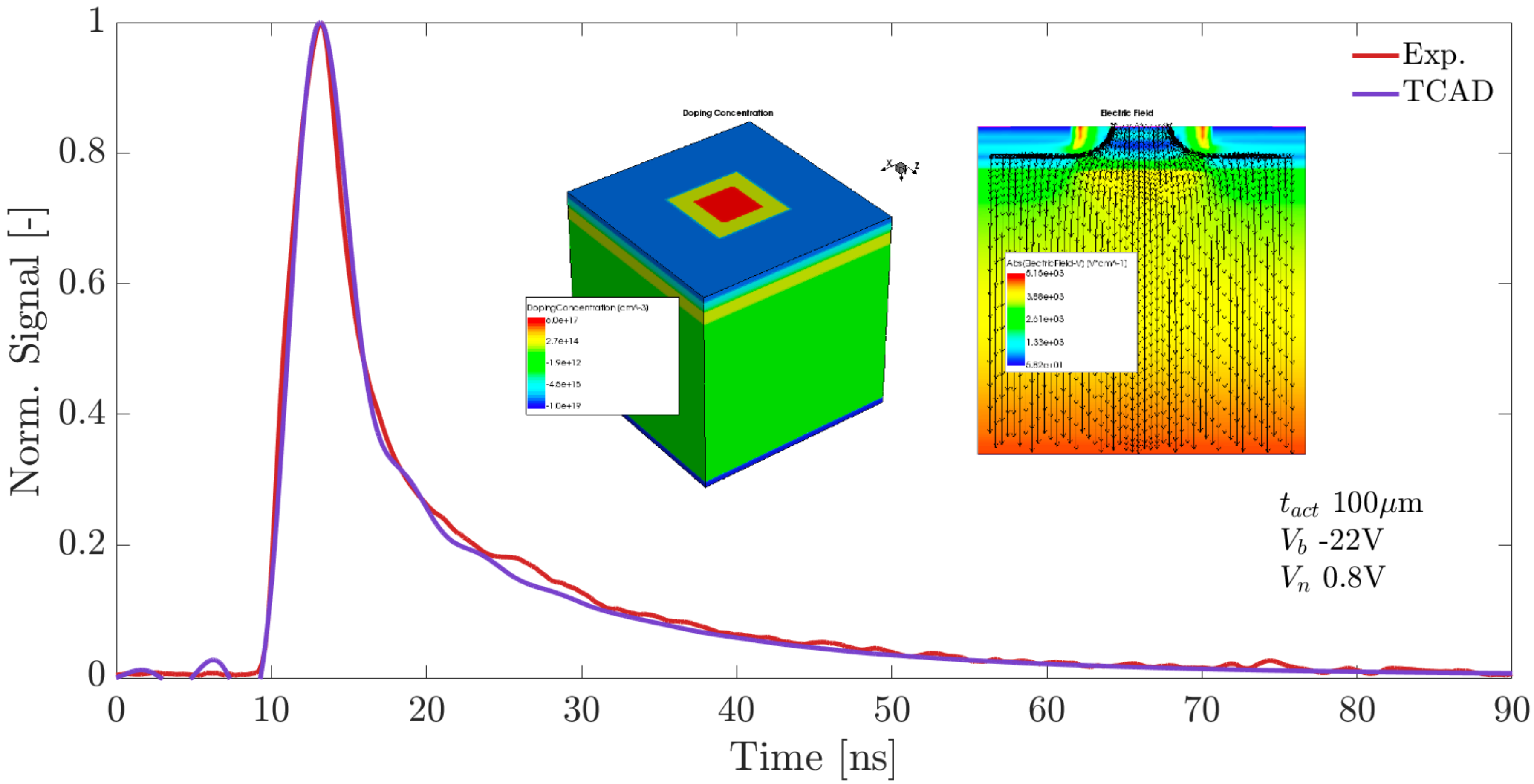


- Negative voltage bias applied to Pext electrode
- $V_{pix} = V_n = 0.8V$
- $V_{Ngr} = V_n$
- $V_{Ptop} = 0V$



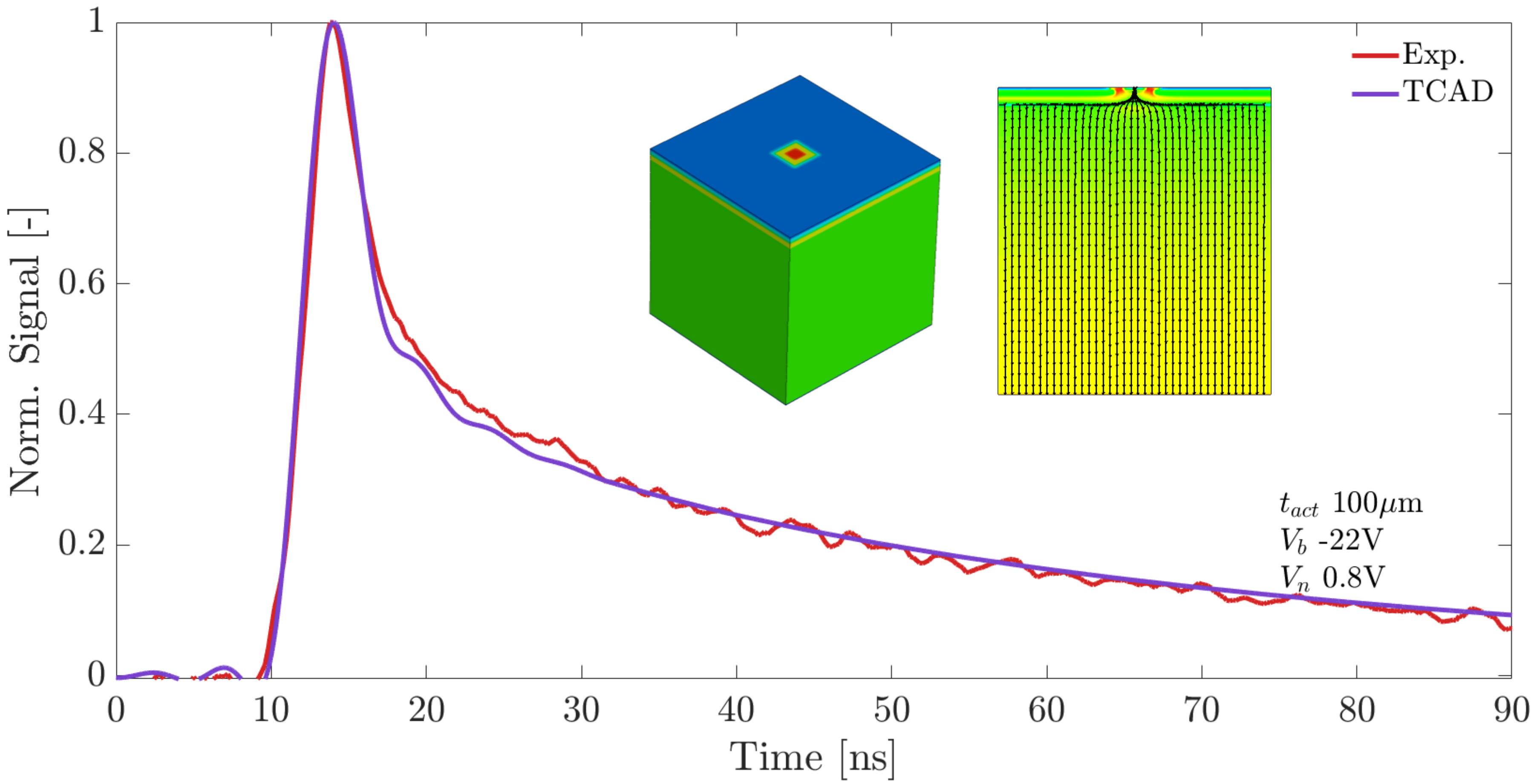
- Red laser (660nm) with 350ps pulse at FWHM
- Infrared laser (1060nm) with < 100ps pulse at FWHM (Alphalas)
- External commercial amplifier with 1GHz bandwidth

IR laser - PM 50 standard layout (1A)



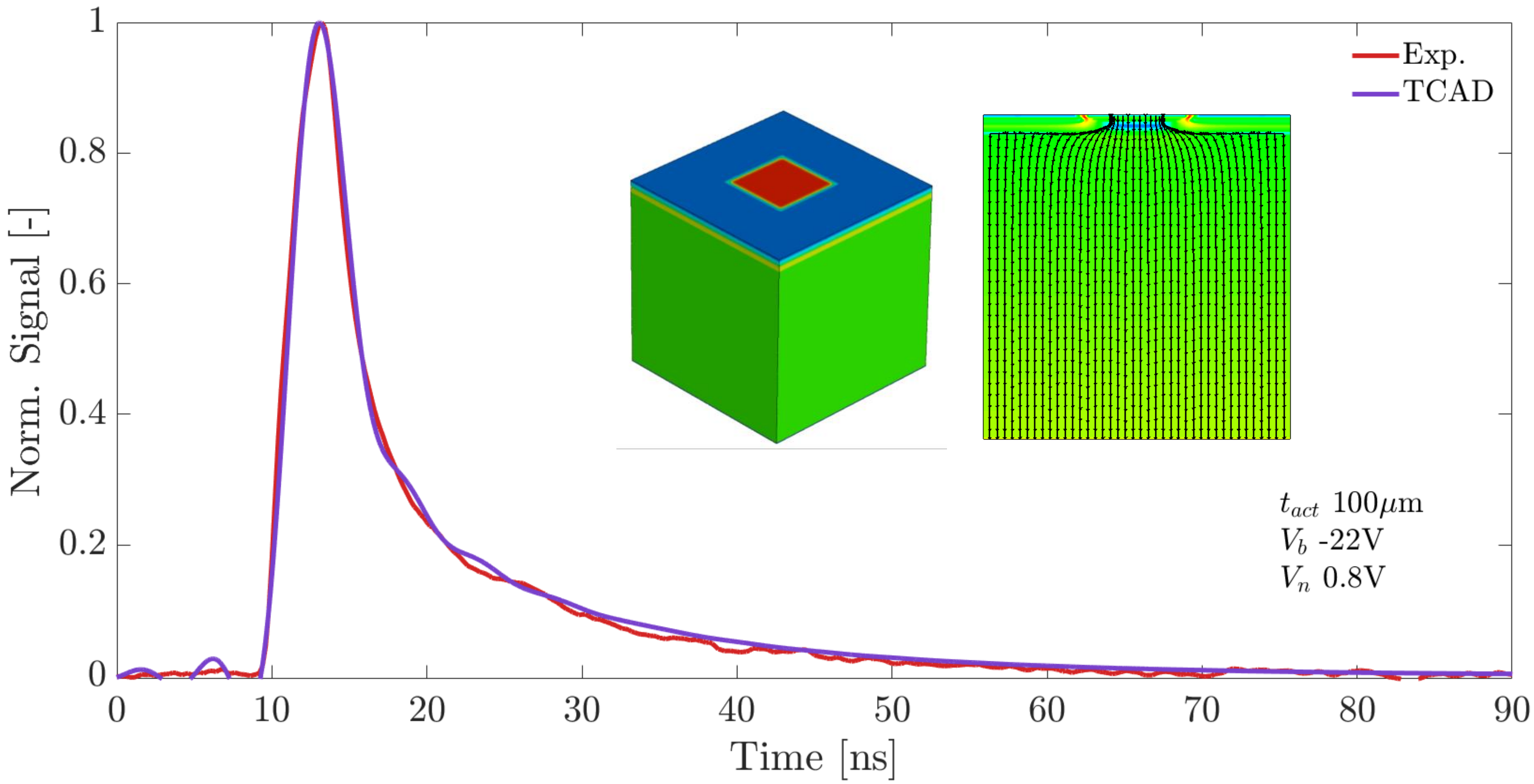
- t_{si} 100 μm
- Frontside bias
- Backside illumination with unfocused IR laser spot
- Reference pixel layout for 50µm pixel arrays

IR laser - PM 50 minimum C layout (2F)



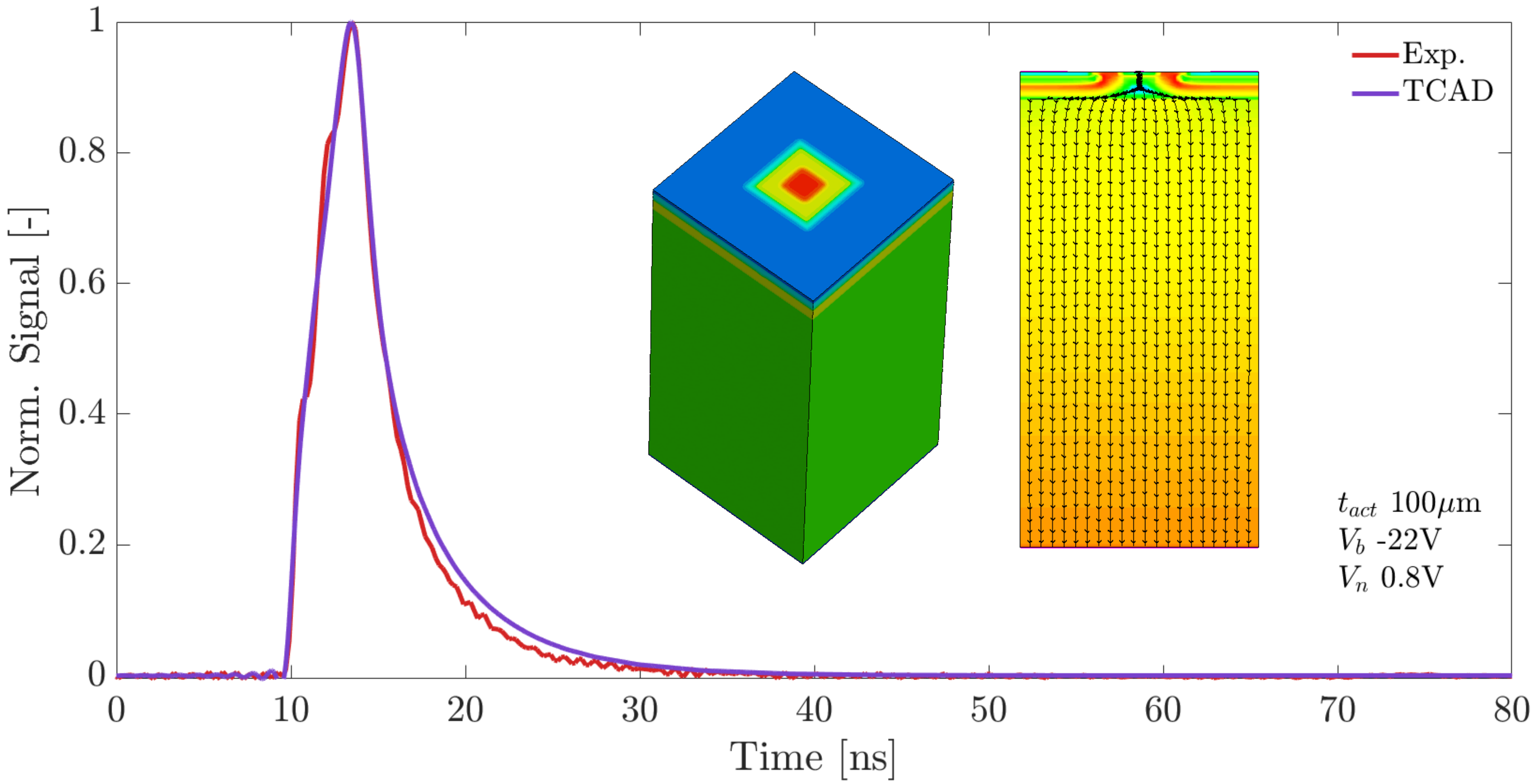
- t_{si} 100 μm
- Frontside bias
- Backside illumination with unfocused IR laser spot
- Minimum capacitance layout for 50µm pixels
- Slowest signal
- t_{95} around 110 ns

IR laser - PM 50 fastest layout (3A)



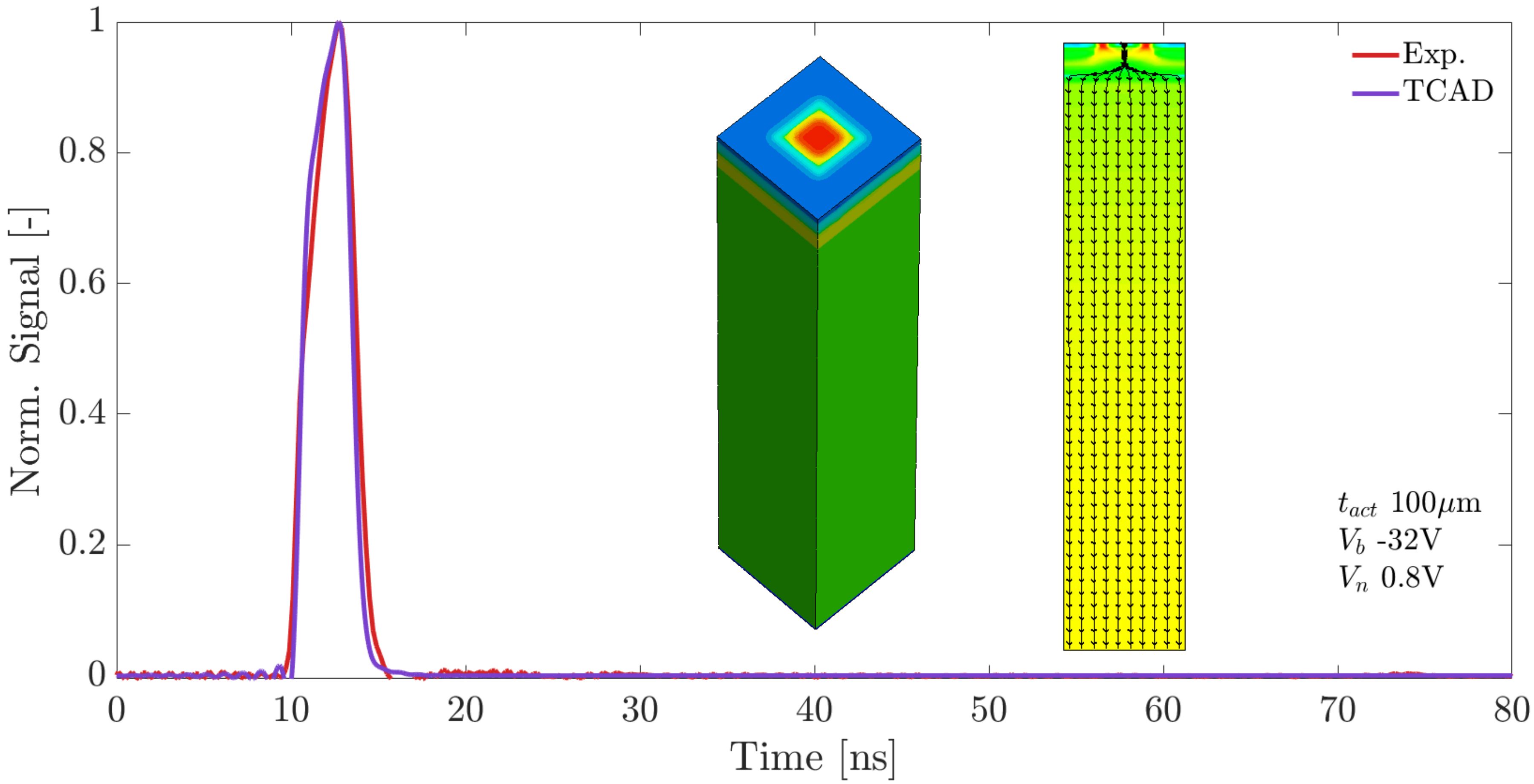
- t_{si} 100 μm
- Frontside bias
- Backside illumination with unfocused IR laser spot
- Fastest signal for pixel matrices with 50μm pitch

IR laser - PM 25 standard layout (1A)



- t_{si} 100 μm
- Frontside bias
- Backside illumination with unfocused IR laser spot
- Faster signal w.r.t. pixel arrays with 50µm pixels

IR laser - PM 10 standard layout (1A)



- t_{si} 100 μm
- Frontside bias
- Backside illumination with unfocused IR laser spot
- Pixel matrix with the fastest charge collection

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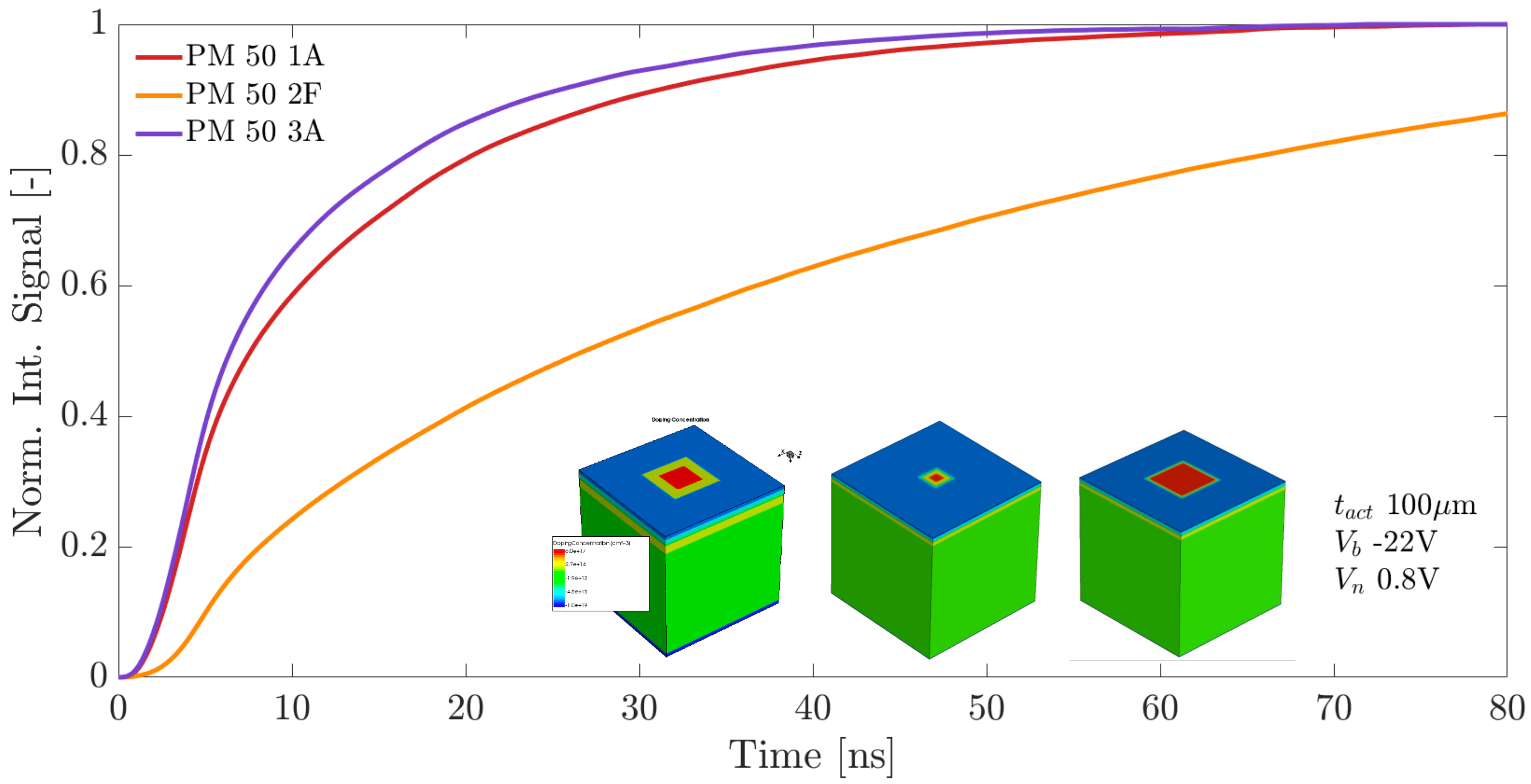
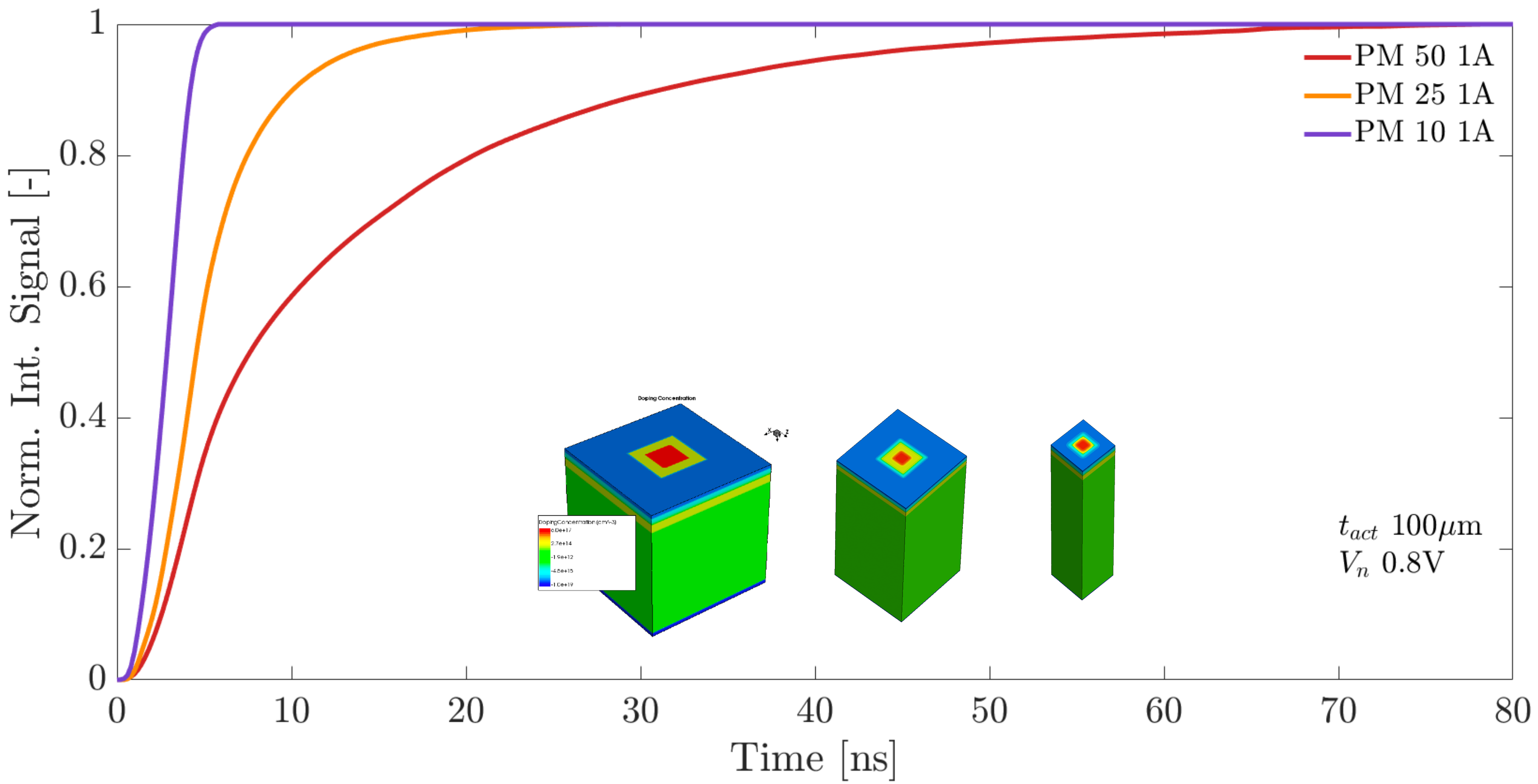
IR laser - Signal integrals cfr. pixel layout



- Faster charge collection for larger sensor nodes as well as smaller pwell
- $t_{50} < 7$ns in the best case

PM	t_{50} (ns)	C_{pix} (fF)
50 1A	7.8	23.7
50 2F	27	9.6
50 3A	6.6	23.1

IR laser - Signal integrals cfr. pixel pitch



- Faster charge collection for decreasing pixel size
- t_{50} around 3ns for a pixel size of 10µm

PM	t_{50} (ns)	C_{pix} (fF)
50 1A	7.8	23.7
25 1A	4.6	6.1
10 1A	3	4.4

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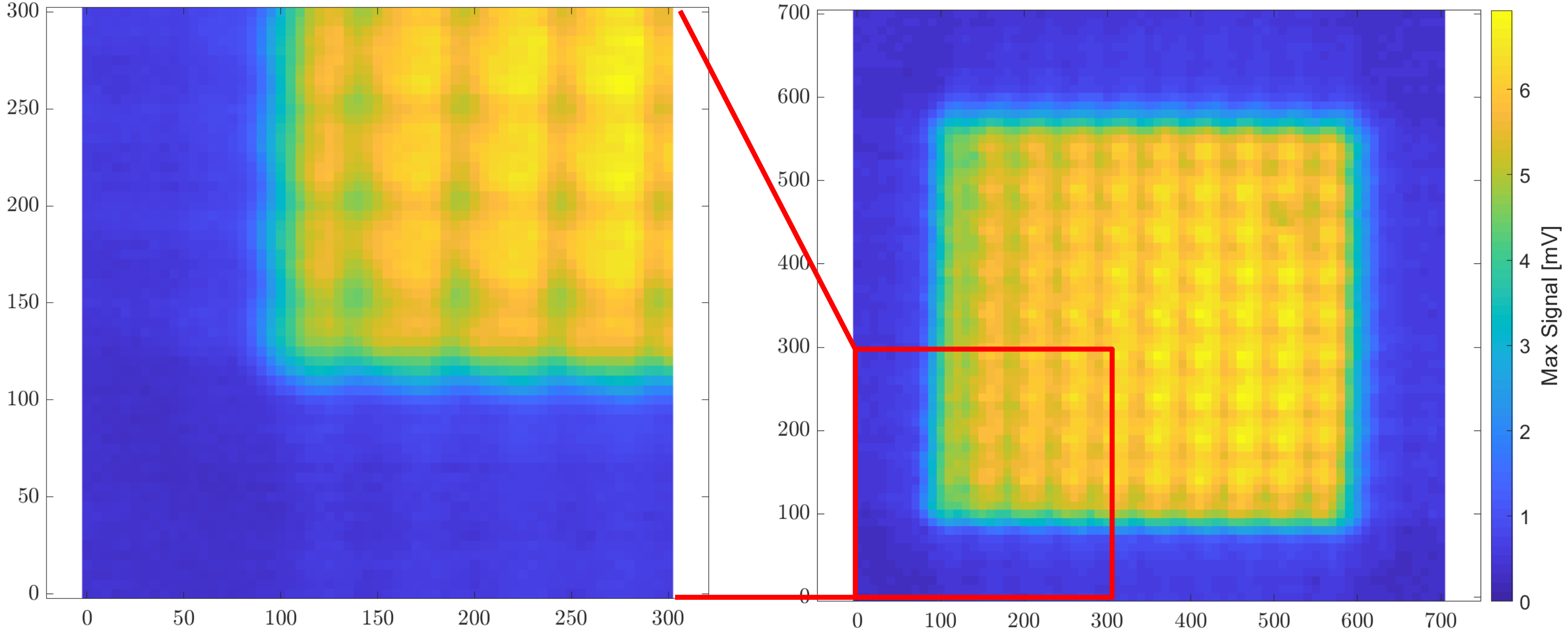
IR laser scan - PM 50 2A

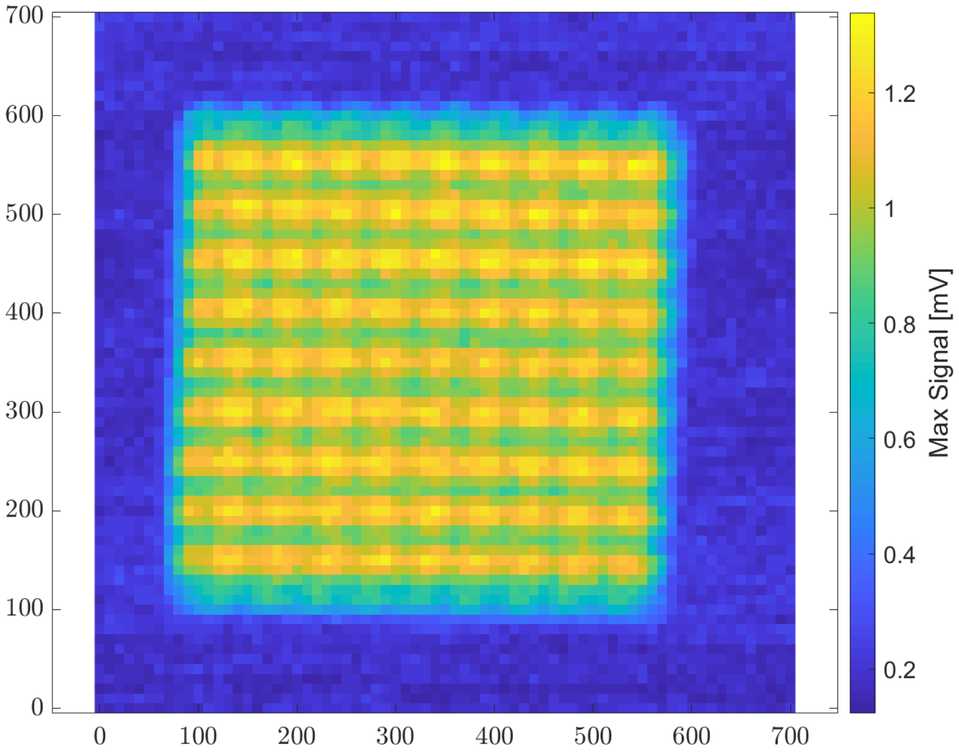


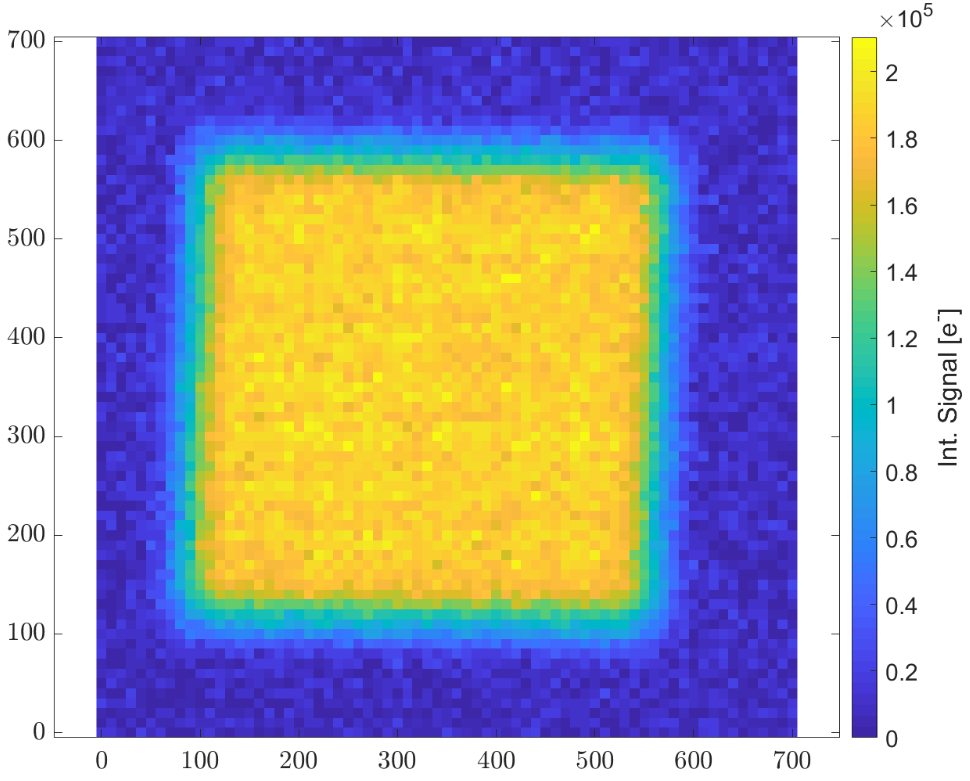
5µm motor step

10µm motor step

- $V_n = 0.8V$
- $V_{bias} = -22V$
- Focused IR laser spot
- Signal amplitude dependance on the laser spot position
- Laser light partially back-reflected by frontside metals

Red laser scan - PM 50 2F





- $V_n = 0.8V$
- $V_{bias} = -22V$
- Focused laser spot
- Uniform charge collection within the matrix area

10µm motor step

Conclusions

- IV curves show that the sensors work properly with $V_{PT} > V_{depl}$
- Faster charge collection with smaller pixel pitches, smaller pwell width and larger collection electrodes as properly predicted from simulations
- Trade off needed in the pixel layout to minimize the pixel capacitance and optimize the charge collection speed
- t_{50} in the order of 3ns for the pixel array with 10µm pixels with t_{act} of 100µm
- Samples from 1st engineering run (mid 2021), 2nd engineering run (just received), 3rd engineering run submission (mid 2022)

The ARCADIA collaboration

F. Alfonsi, G. Ambrosi, A. Andreazza, E. Bianco, G. Balbi, S. Beolè, M. Caccia, A. Candelori, D. Chiappara, T. Corradino, T. Croci, M. Da Rocha Rolo, G. F. Dalla Betta, A. De Angelis, G. Dellacasa, N. Demaria, B. Di Ruzza, A. Di Salvo, D. Falchieri, M. Favaro, A. Gabrielli, L. Gaioni, S. Garbolino, G. Gebbia, R. Giampaolo, N. Giangiacomi , P. Giubilato, R. Iuppa, M. Mandurrino, M. Manghisoni, S. Mattiazzo, C. Neubüser, F. Nozzoli, J. Olave, L. Pancheri, D. Passeri, A. Paternò, M. Pezzoli, P. Placidi, L. Ratti, E. Ricci, S. B. Ricciarini, A. Rivetti, H. Roghieh, R. Santoro, A. Scorzoni, L. Servoli, F. Tosello, G. Traversi, C. Vacchi, R. Wheadon, J. Wyss, P. Zuccon

Thank you for your attention!