Optical and electrical characterization of Cadmium Telluride (CdTe) X-ray pad detectors

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HSTD11 & SOIPIX2017, Okinawa

Alex Winkler

Thursday, December 14th, 2017, Session 12 – 4, ID 173

Team

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Finland

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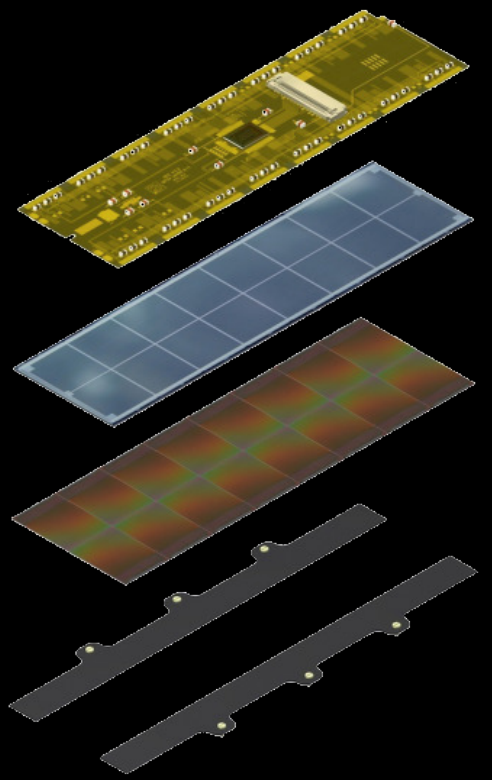
Croatia

Particle Physics to the people

Particle Physics to the people

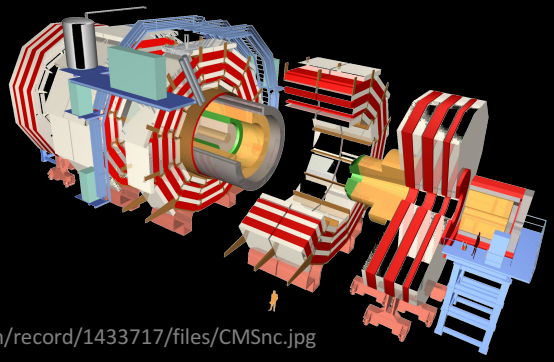
- CMS pixel upgrade work
- Detector research for HL-LHC and other detector applications
- Emphasize efforts of developing detectors for medical imaging
  - Use HEP developments + effective detector materials
  - Ultra low dose imaging
  - BNCT



https://ars.els-cdn.com/content/image/1-s2.0-S0168900216300493-gr1.jpg

Particle Physics to the people

- Medical imaging want same thing as HEP:
  - Faster, smaller detectors
  - More pixels
  - Higher bandwidth
  - More information = spectrum/ pixel (photon counting)
  - Radiation hardness



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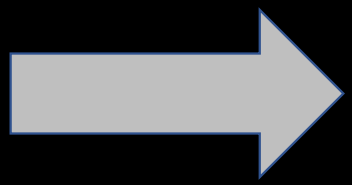

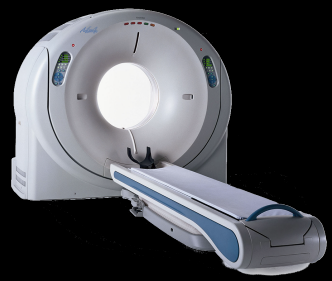

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Particle Physics to the people

Detectors need to work:

- Efficient = high stopping power (calorimeter) → Si out
- RT operation → Ge out
- Large volumes/ bulk detectors → GaAs out
- CdTe/ CdZnTe (CZT)

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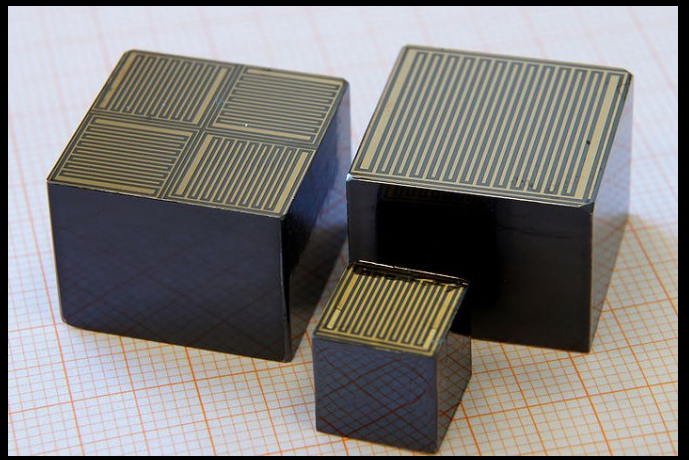
- CdTe/ CdZnTe (CZT)
  - High Z_{eff} = 50
  - Large bandgap → RT operation
  - High resistivity (10^9 – 1.5 10^{10} Ωcm)
    → several cm thick detectors possible
  - Reasonably developed



https://www.lngs.infn.it/images/ricerca/cobra/large_detectors.jpg

CdTe/ CZT, but?

- … is not Si!
  - Brittle, toxic
  - Chip scale processing
  - Not temperature stable (processing < 140°C)
  - Not every chemical works

Details in Ms. Gädda's poster (P21) and PSD11 proceedings.

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    - → Act like deep level defects
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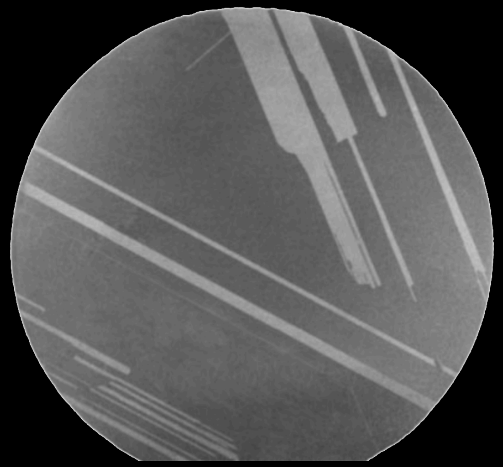

DOI: 10.1109/TNS.2002.803882

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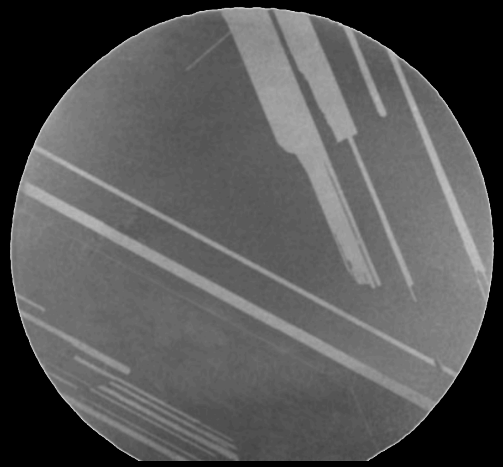

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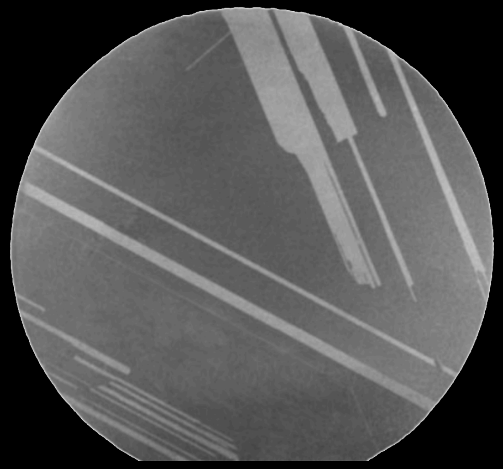

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Precipitates as key

- Precipitates dictate detector performance
  - Number
  - Size
  - Distribution
- Need to predict detector performance before production
- HOW?

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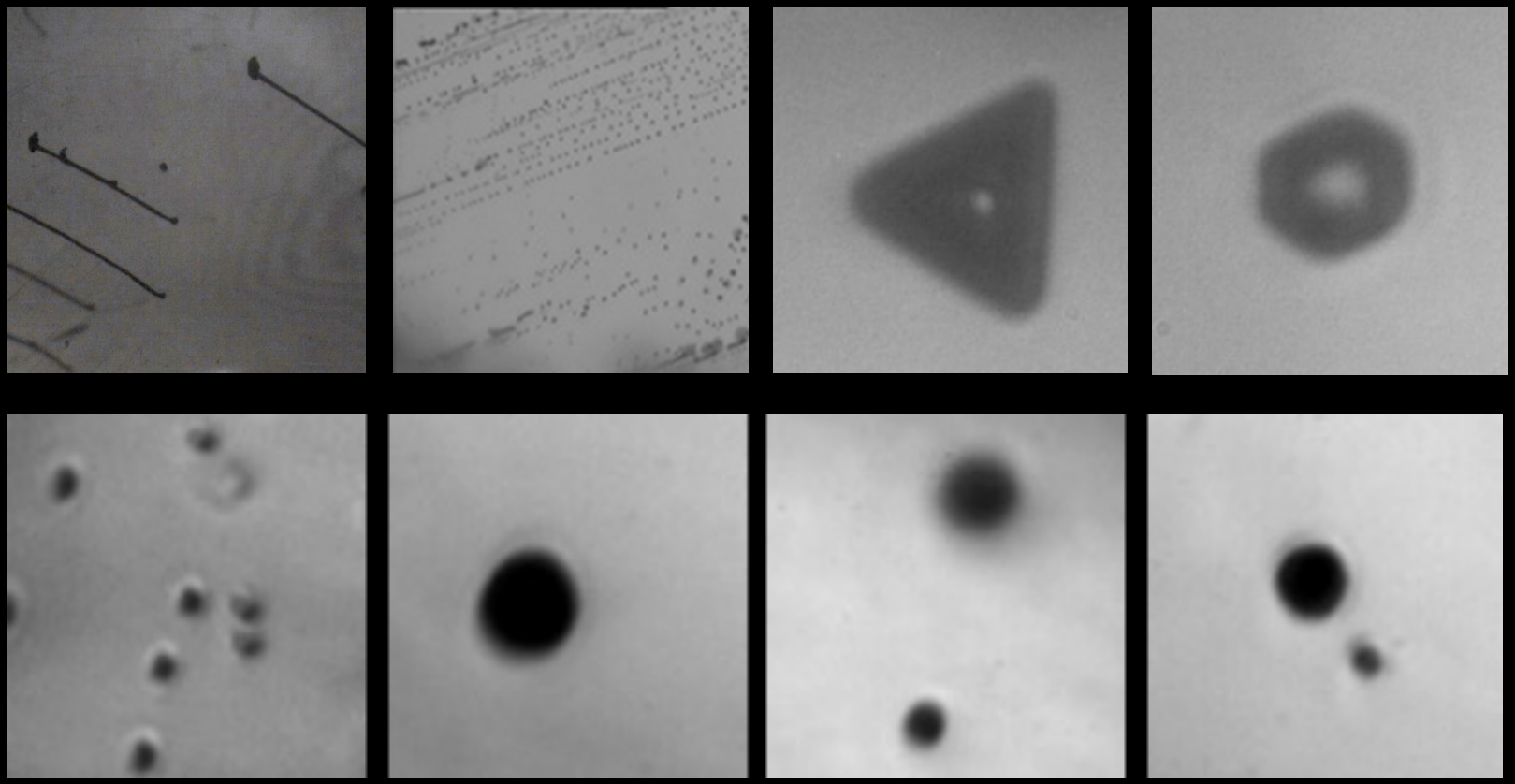
→ IR microscope mapping

IR mapping



IR mapping

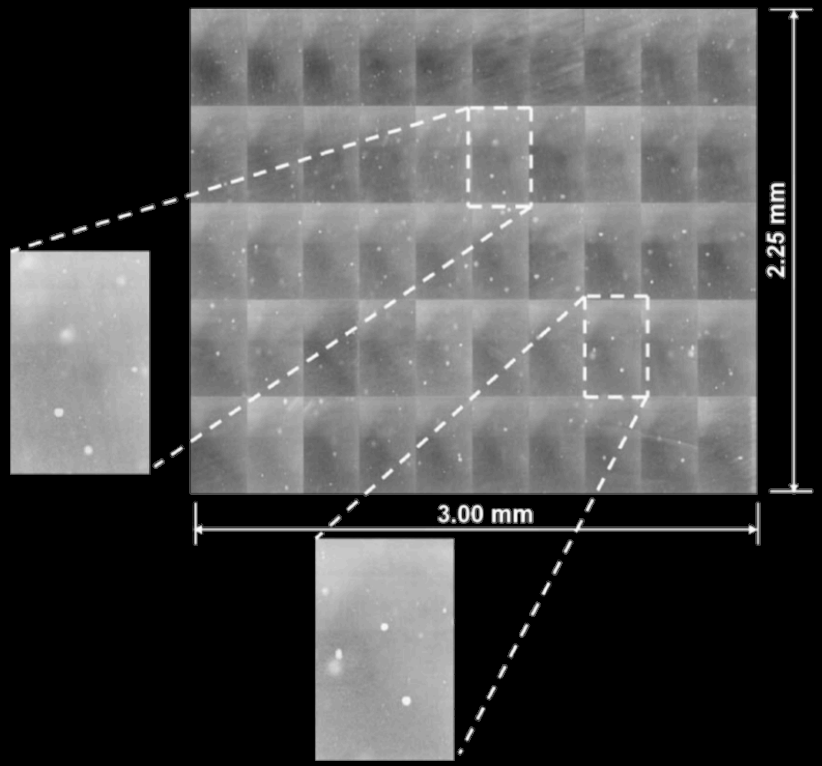


FIG. 3. IR microscope images of CZT1 at 10× magnification.

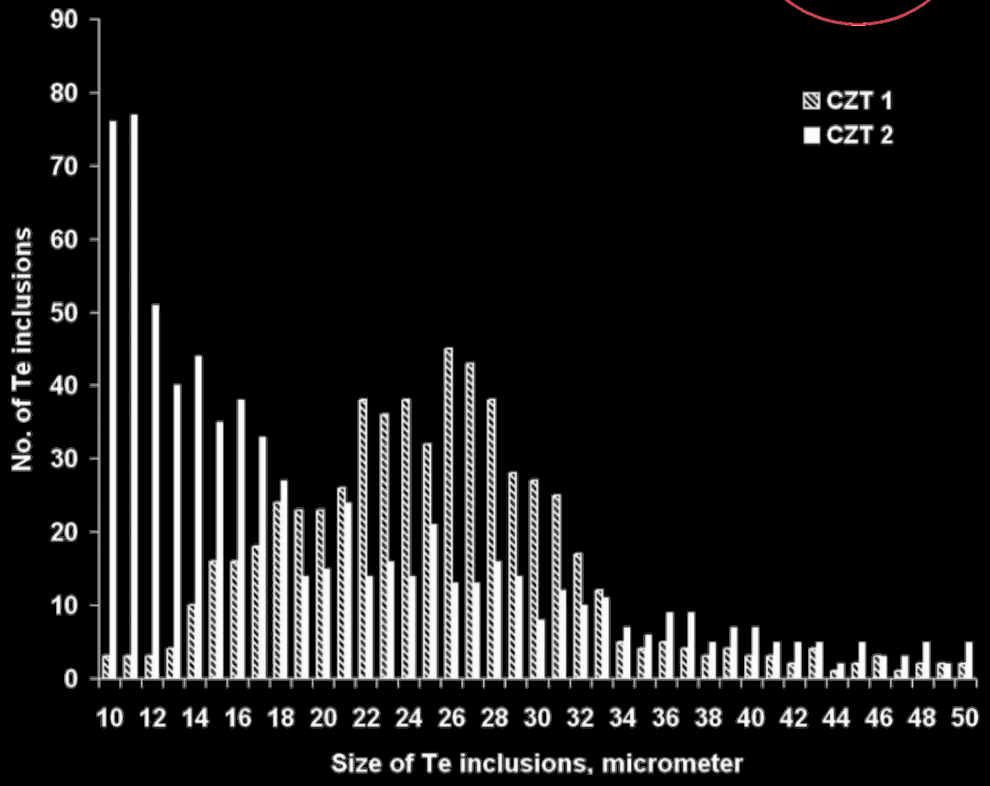
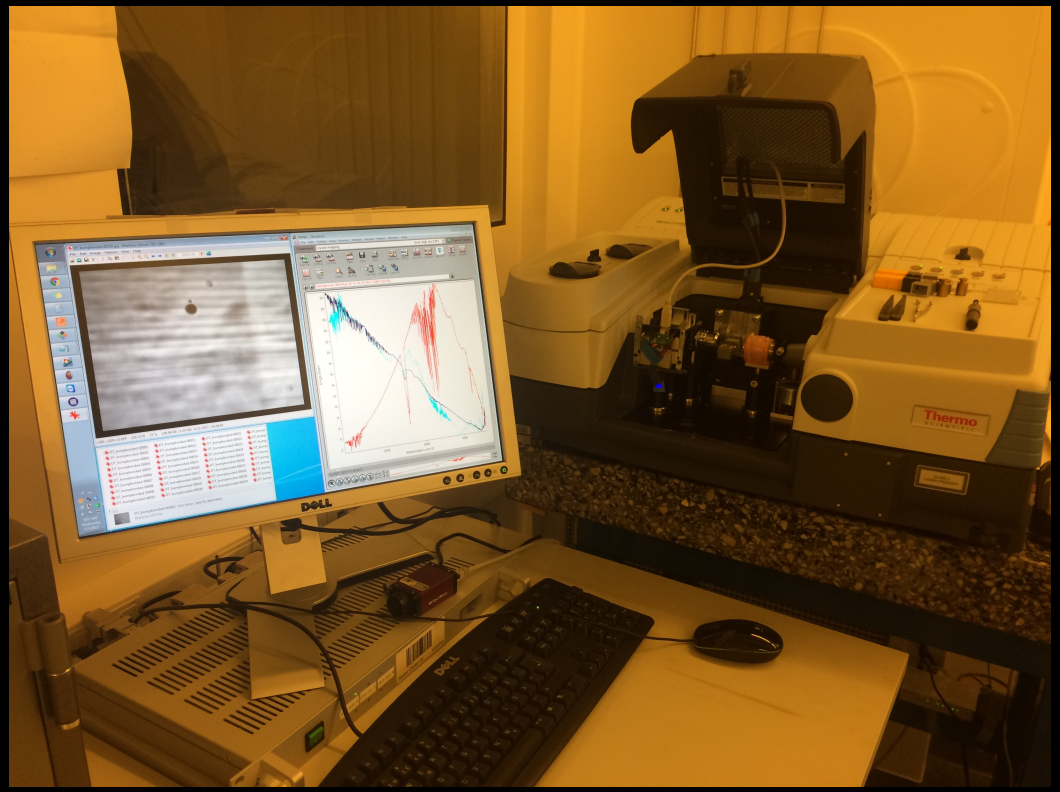


FIG. 5. Histogram of the Te inclusion size distribution in CZT1 and CZT2.

Adapted from Tepper et al. DOI: 10.1063/1.2967726

3D IR characterization (HIP)

- 3D IR microscope
- High resolution (≈ 210/170 µm)
- Precipitates close to diffraction limit ≈ 1µm



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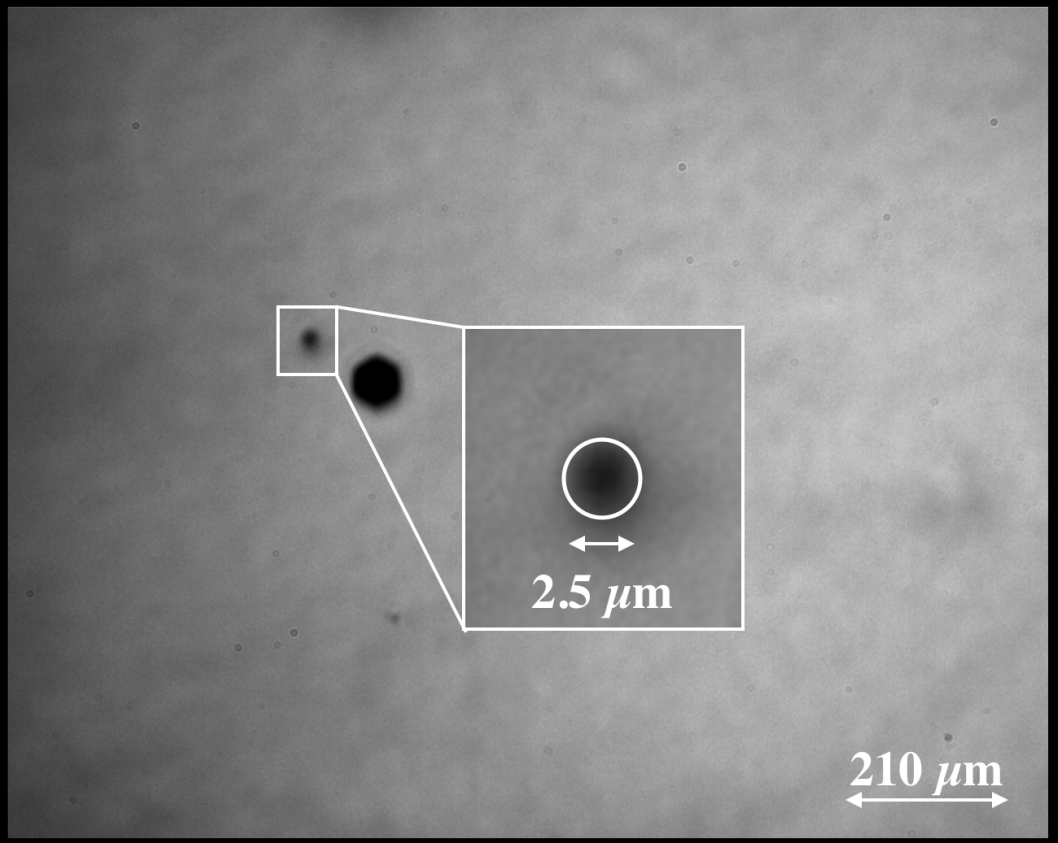
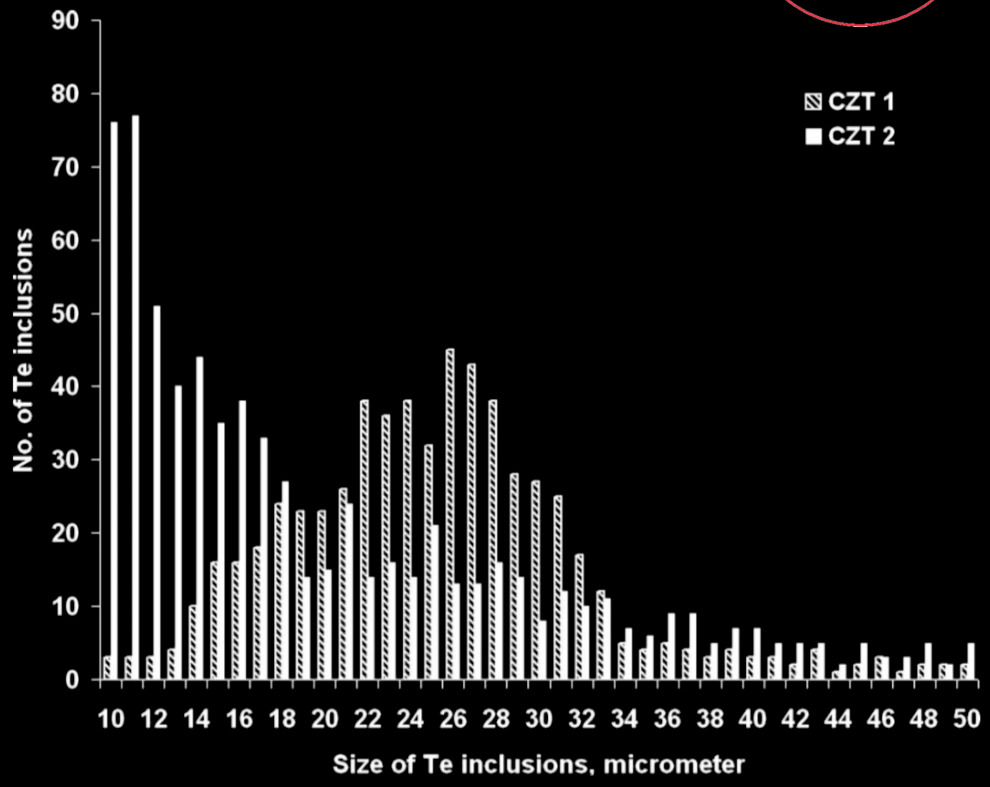
- 2/3D maps of precipitates distribution



3D IR characterization (HIP)

- Scanned a few hundred crystals
- Confirm Tepper results: smaller precipitates more present
- In CdTe most precipitates are <5 µm size



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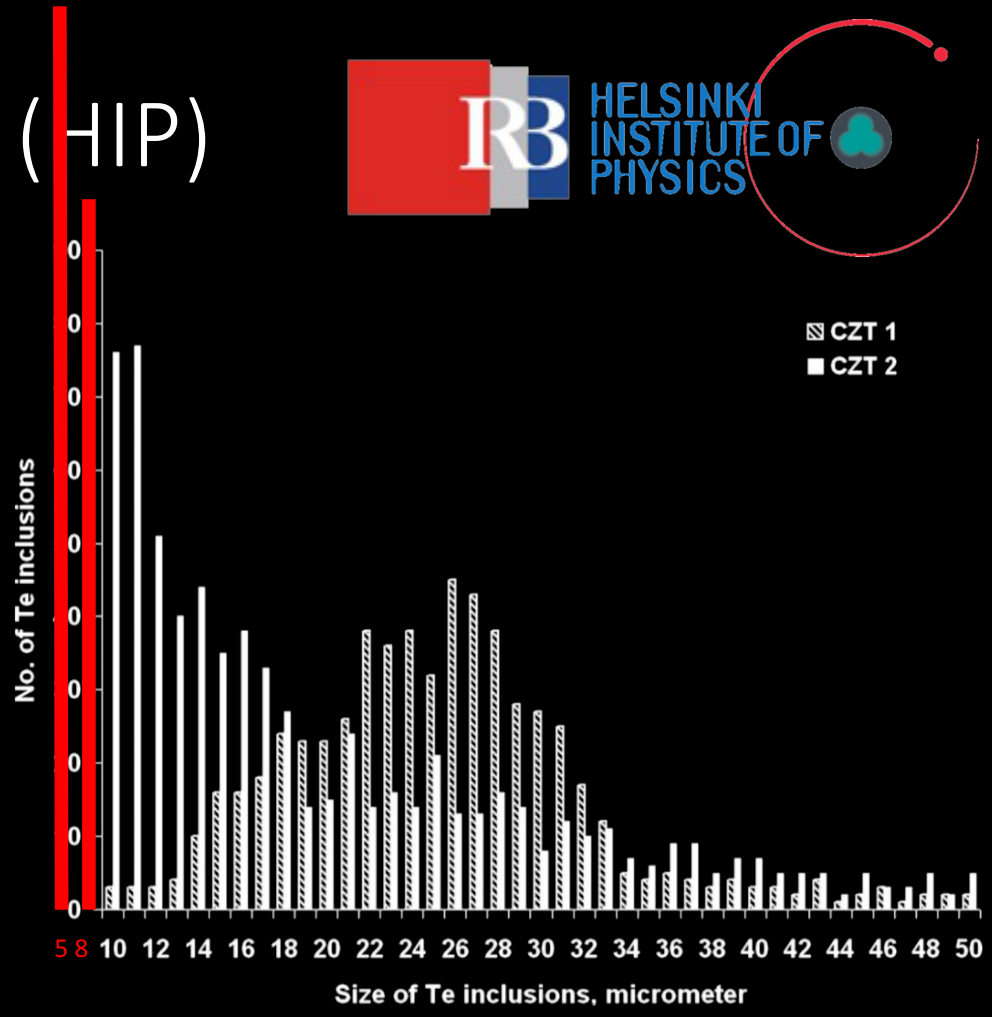

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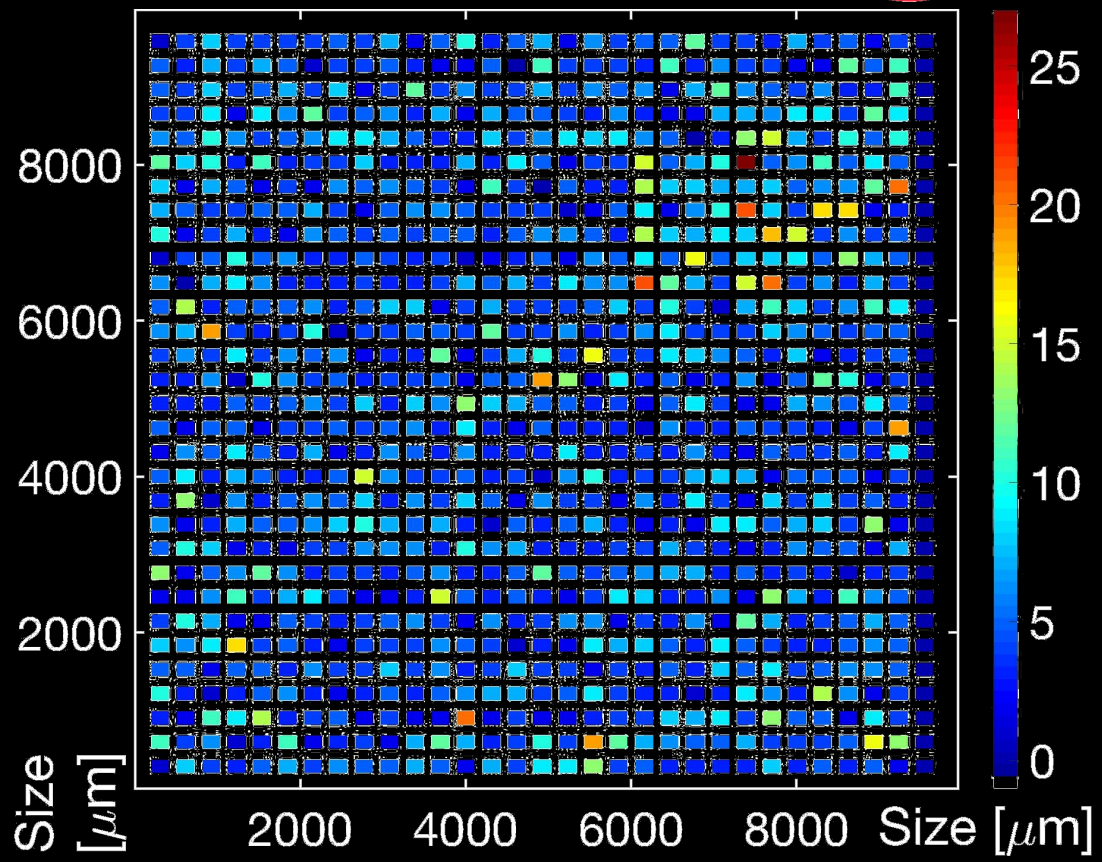
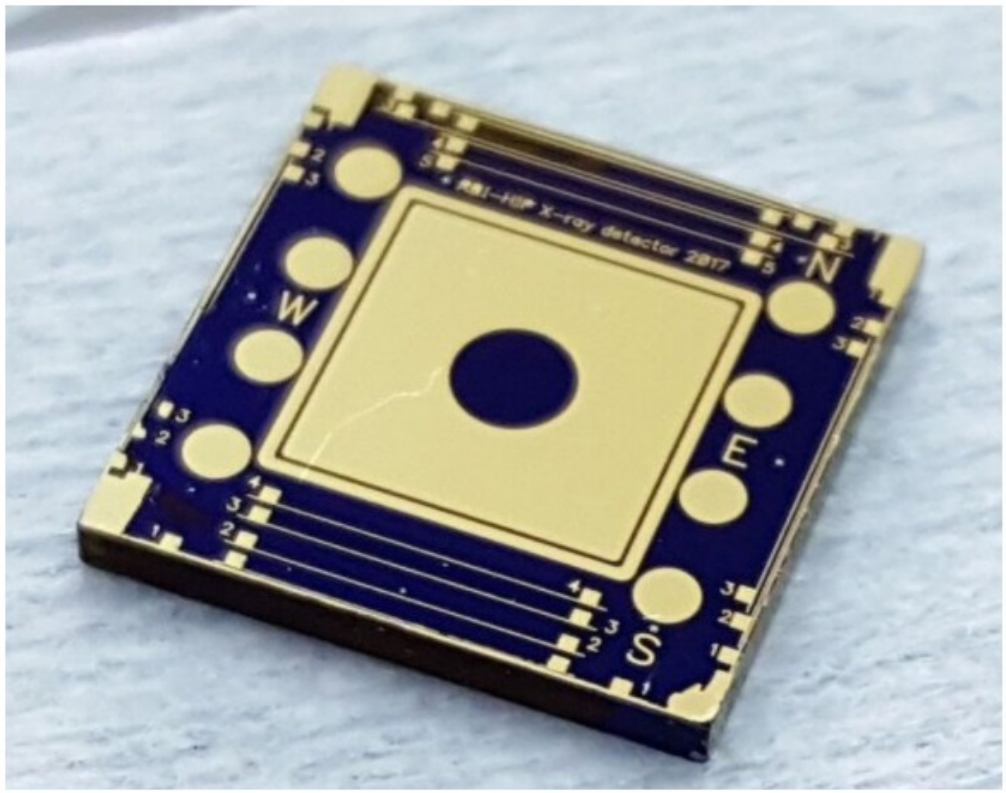


CdTe pad detector



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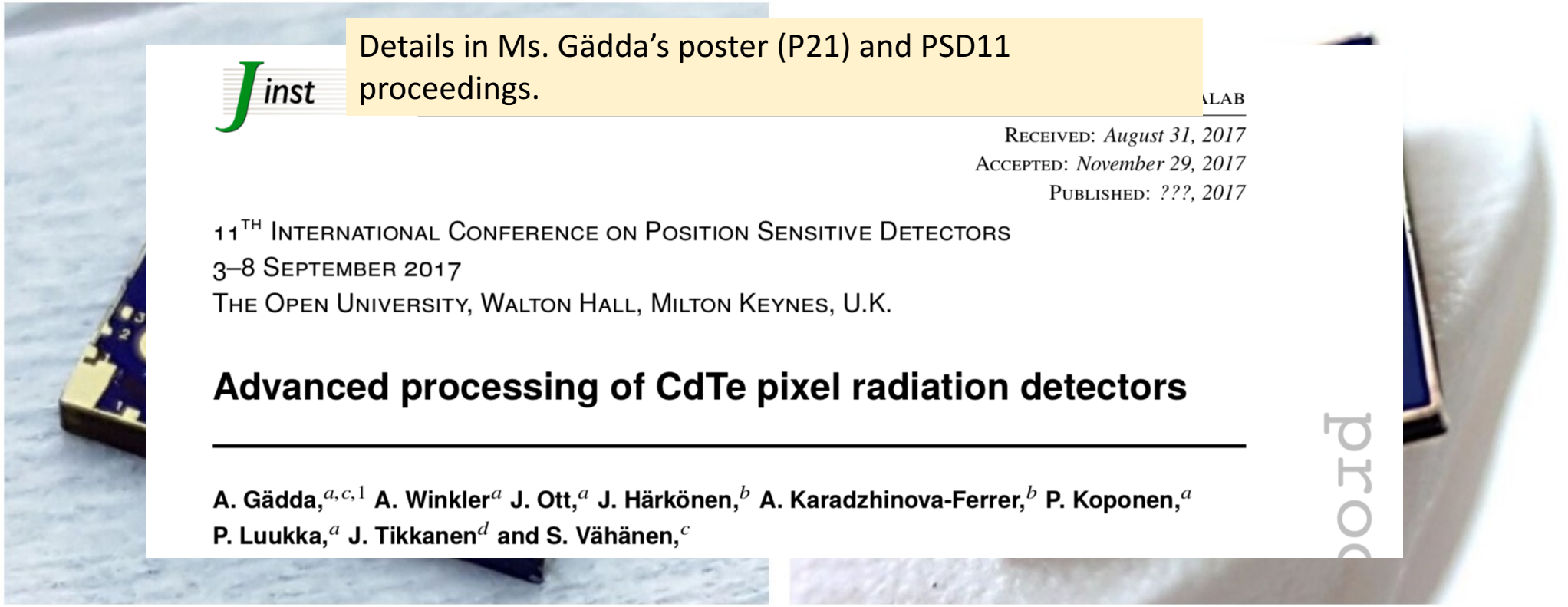

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...LAB

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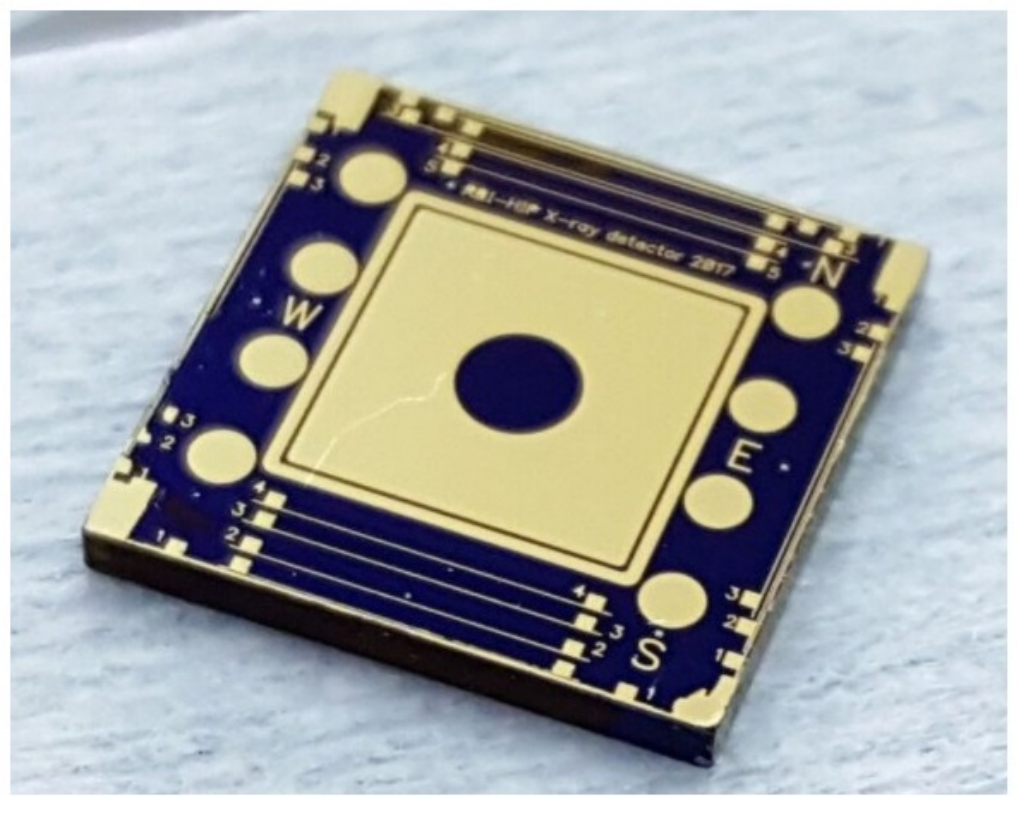
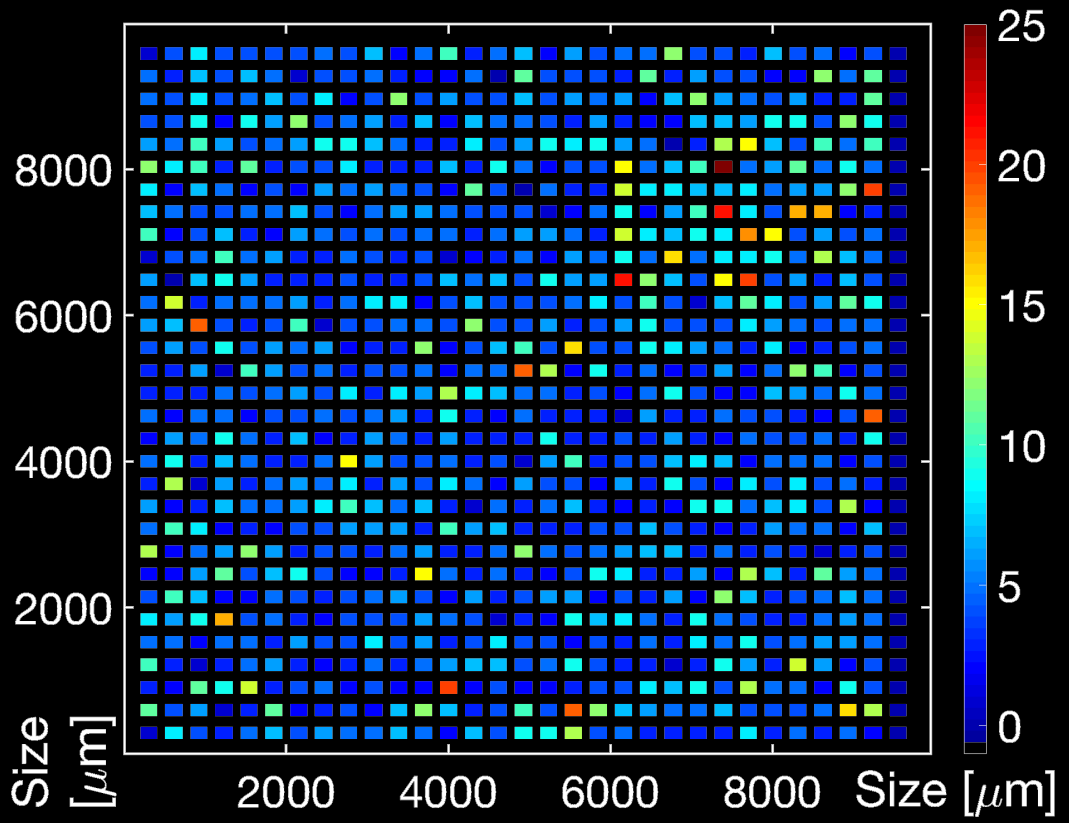
3–8 SEPTEMBER 2017
THE OPEN UNIVERSITY, WALTON HALL, MILTON KEYNES, U.K.

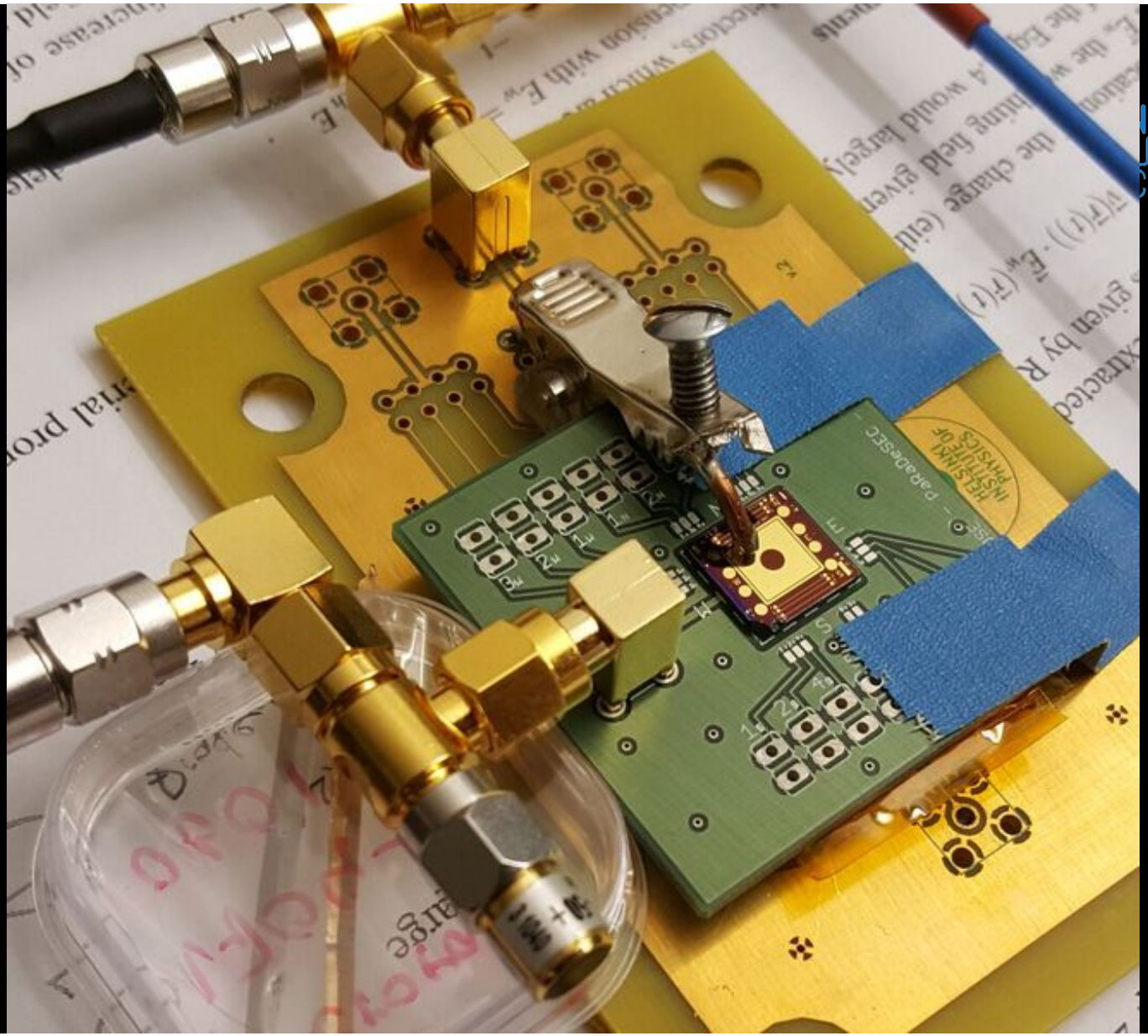
Advanced processing of CdTe pixel radiation detectors

A. Gädda,[a,c,1] A. Winkler[a] J. Ott,[a] J. Härkönen,[b] A. Karadzhinova-Ferrer,[b] P. Koponen,[a] P. Luukka,[a] J. Tikkanen[d] and S. Vähänen,[c]

CdTe pad detector



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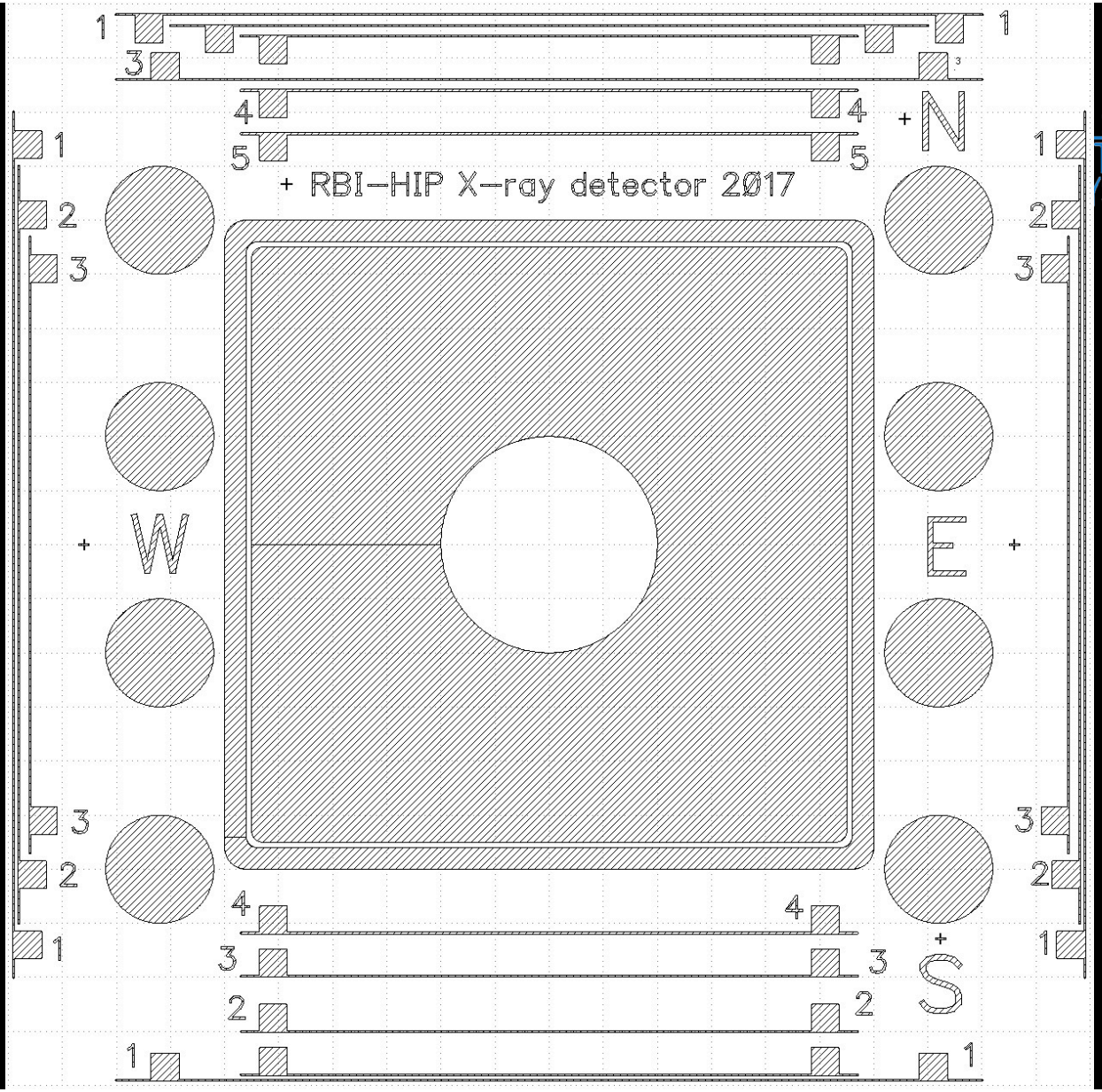
RBI–HIP X–ray detector 2017
N
W
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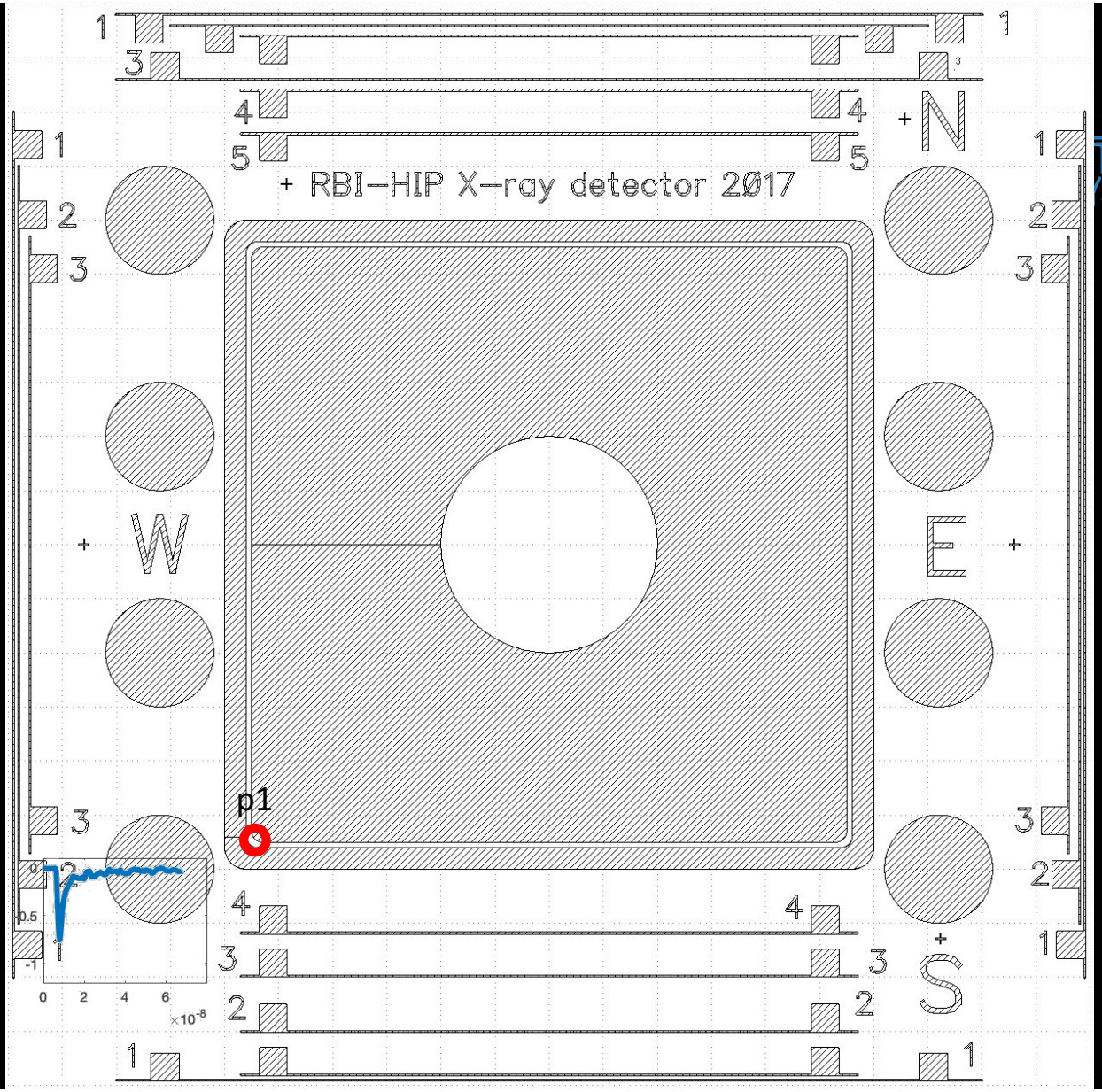
RBI–HIP X–ray detector 2017
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p1
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2
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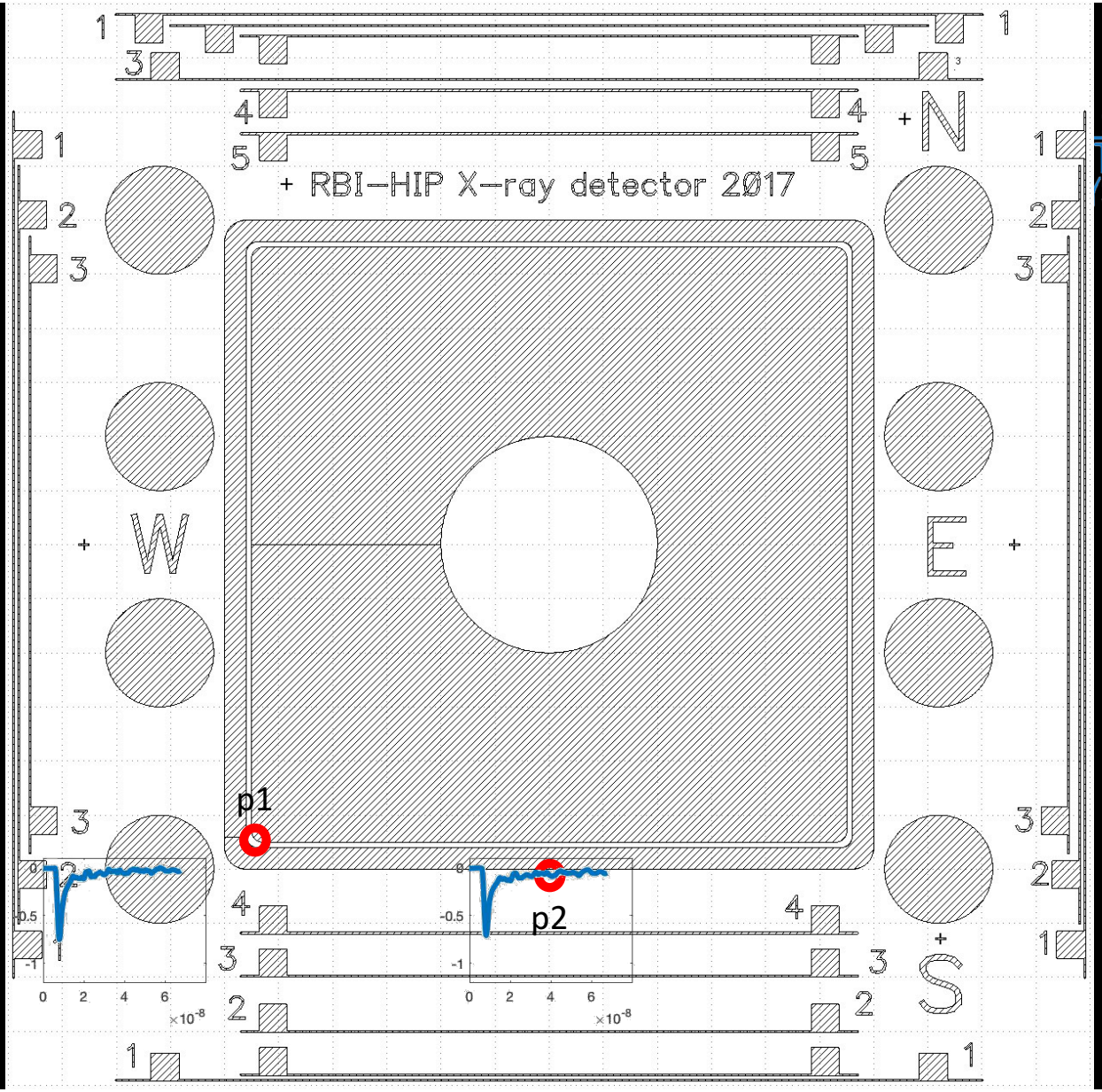
6
×10^-8
0.5
-1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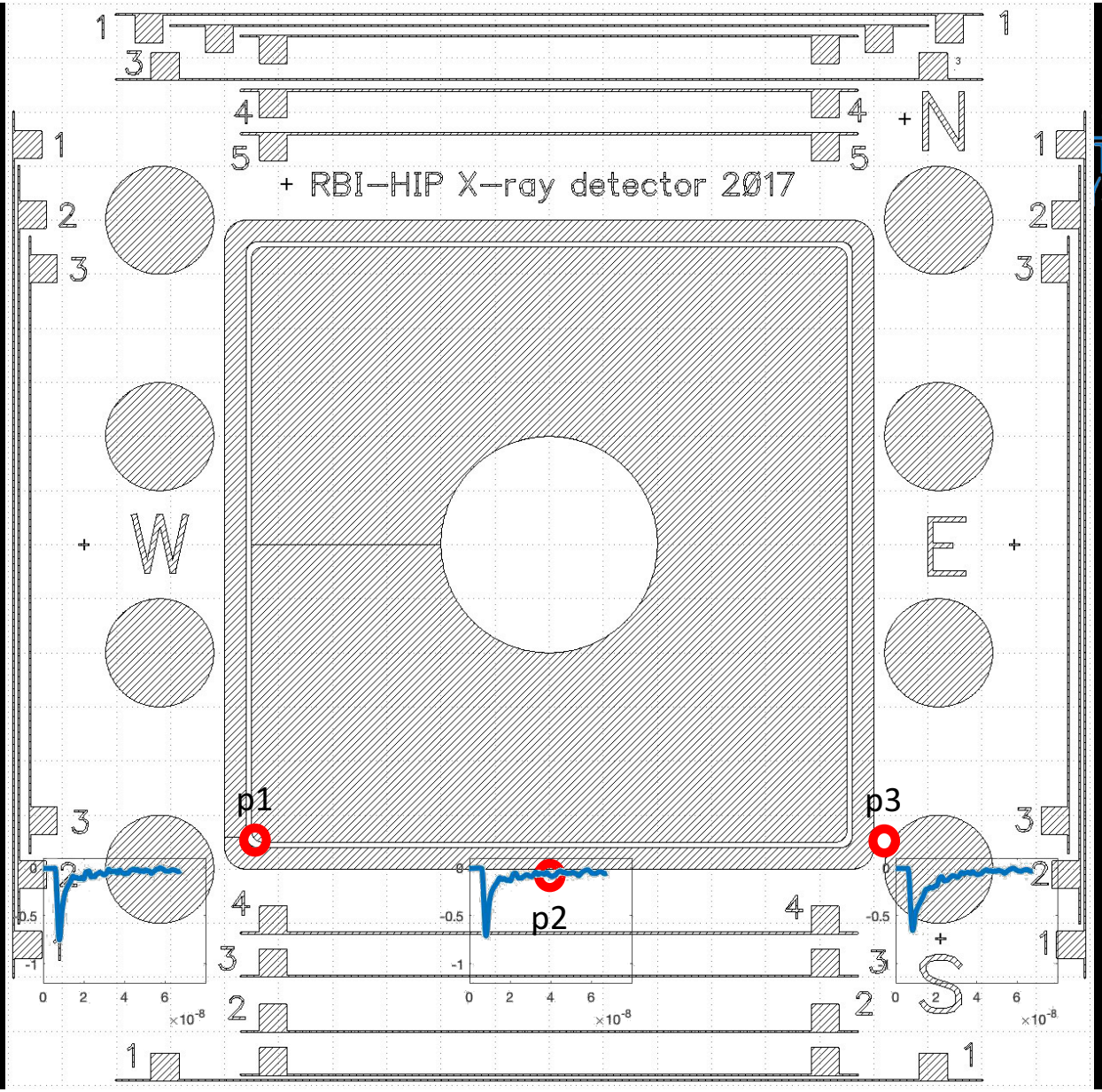
E
S
p1
p2
×10^-8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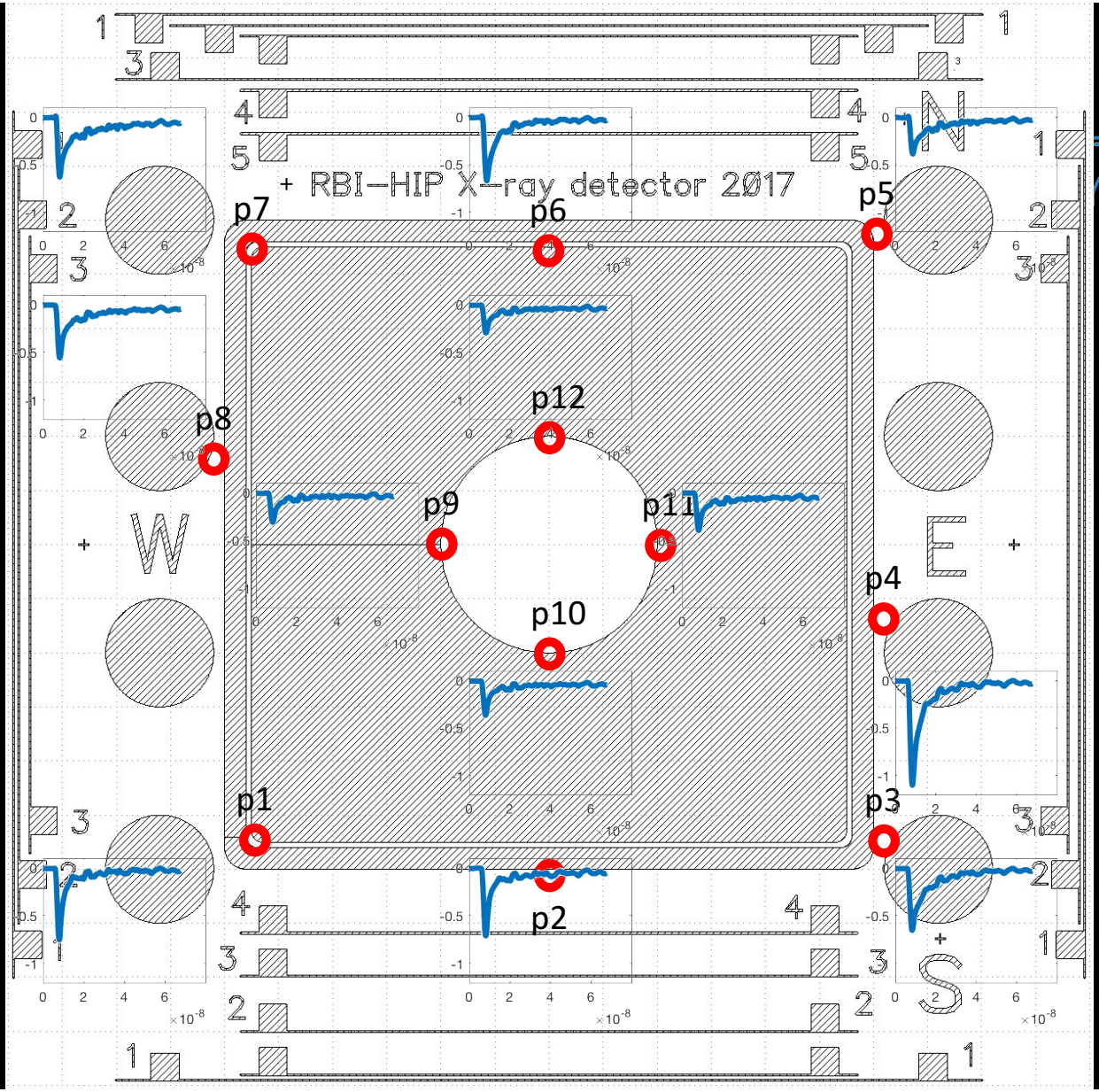
N
W
E
S
p1
p2
p3
×10^-8


+ RBI–HIP X–ray detector 2017
p7
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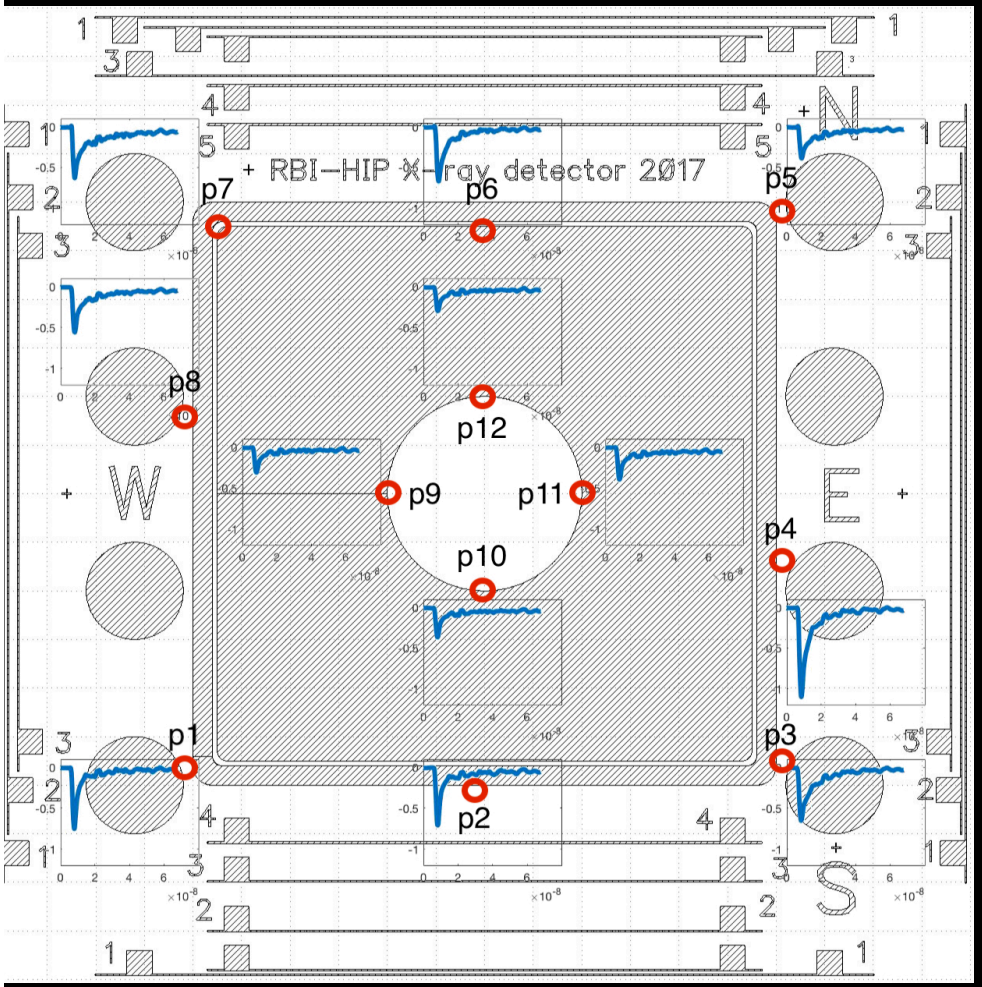
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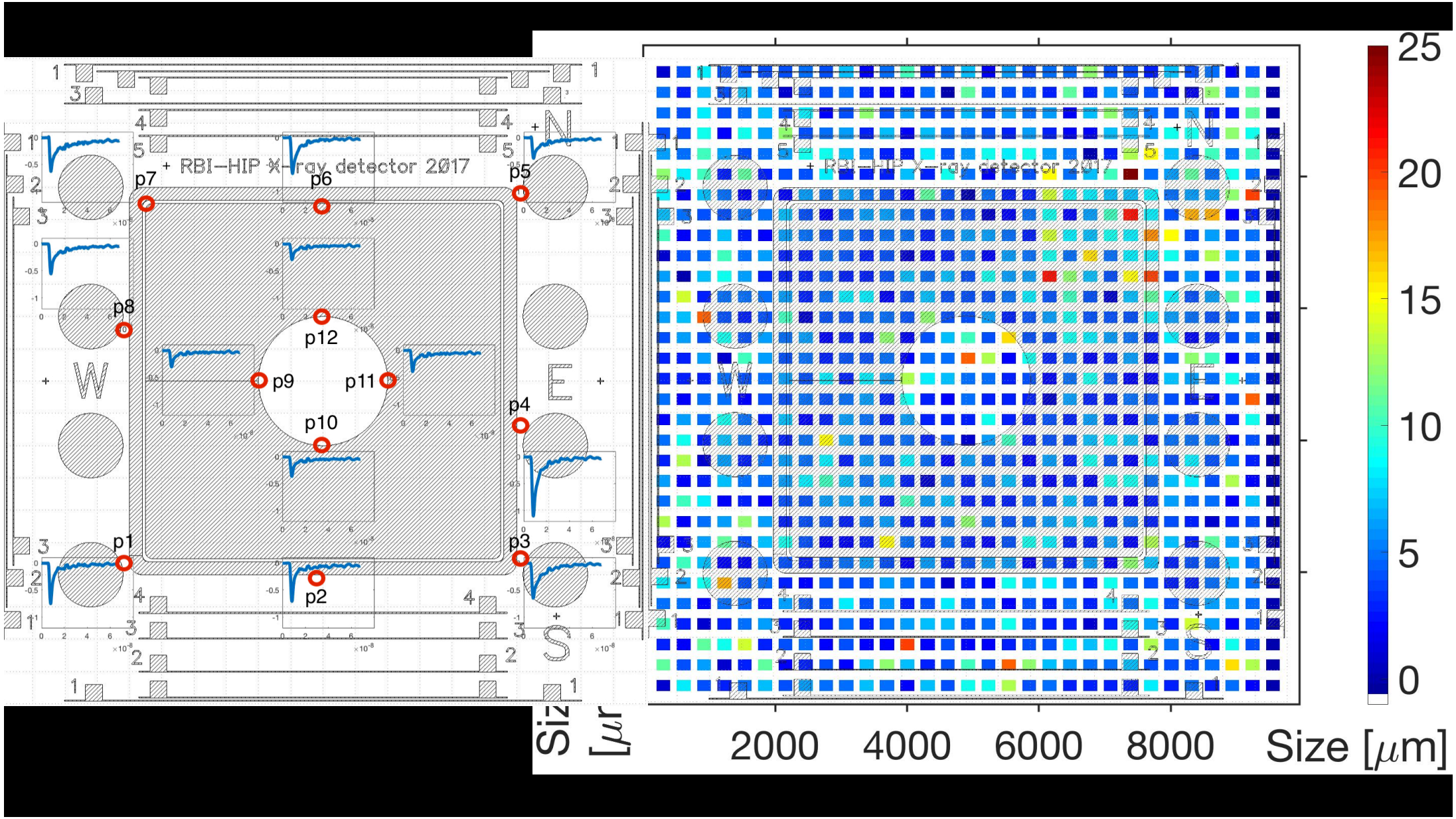
RBI–HIP X-ray detector 2017
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p4
p5
p6
p7
p8
p9
p10
p11
p12
N
W
E
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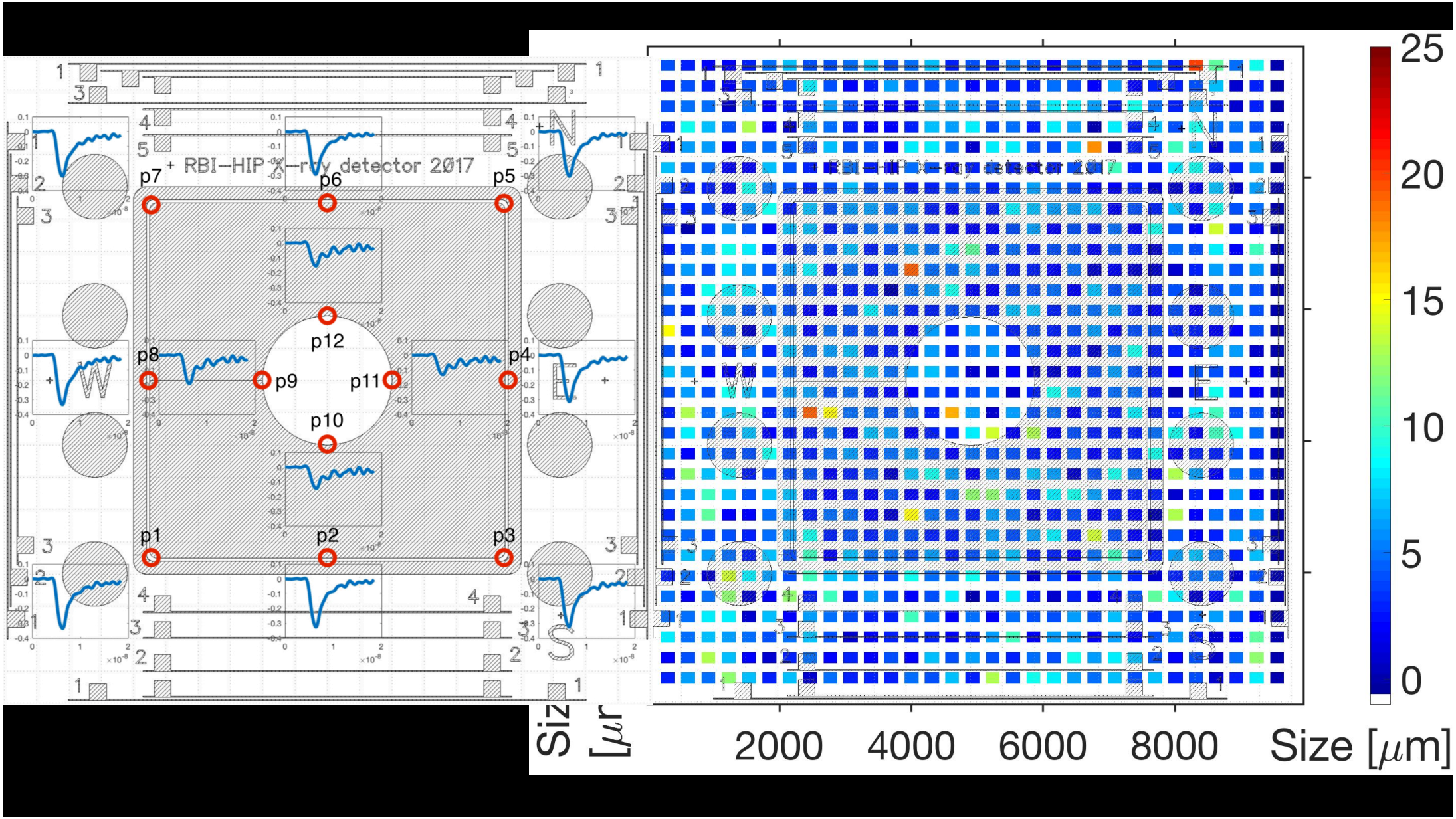
RBI–HIP X-ray detector 2017
2000
4000
6000
8000
Size [μm]
25
20
15
10
5
0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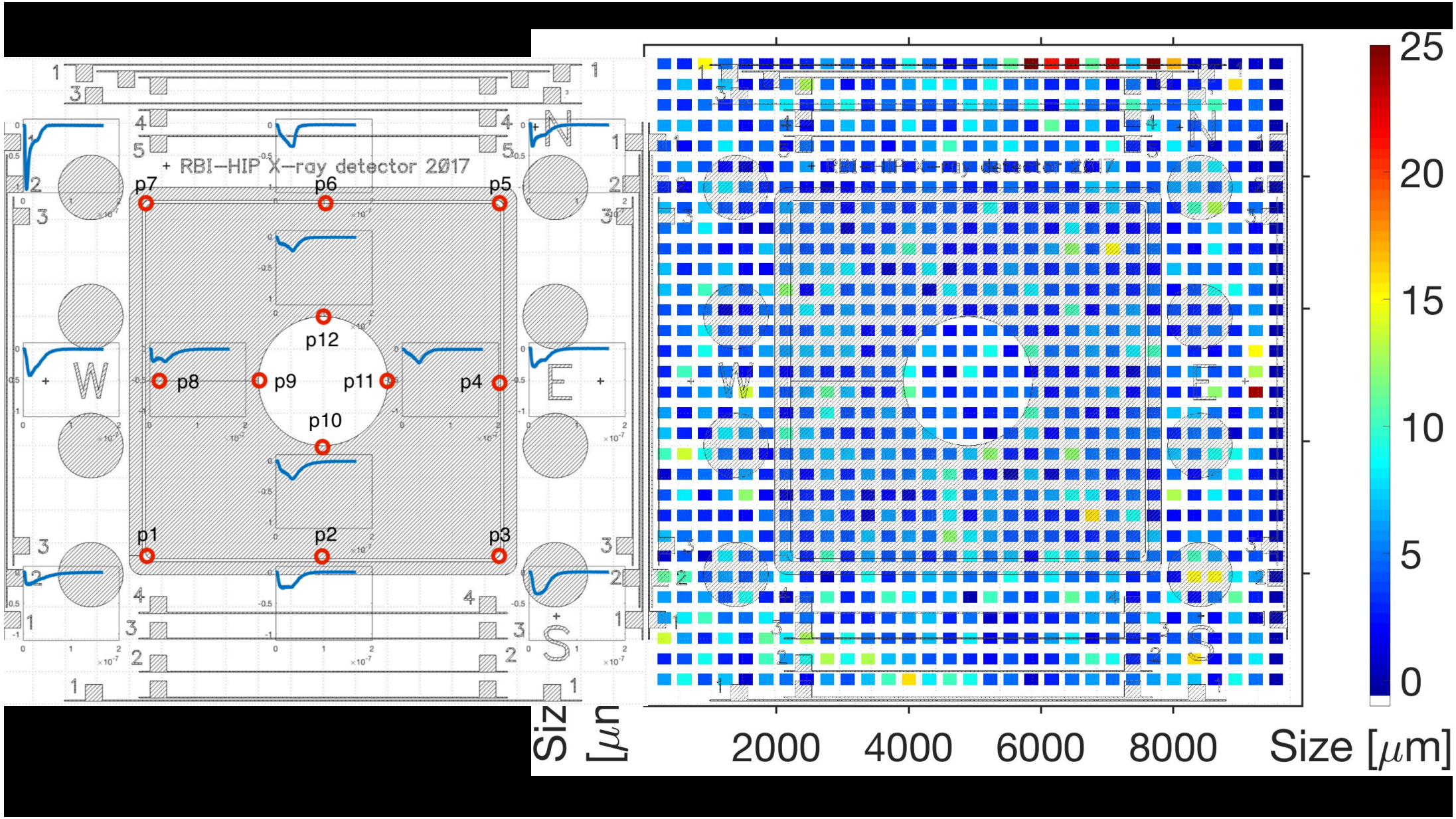
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Conclusions & Outlook

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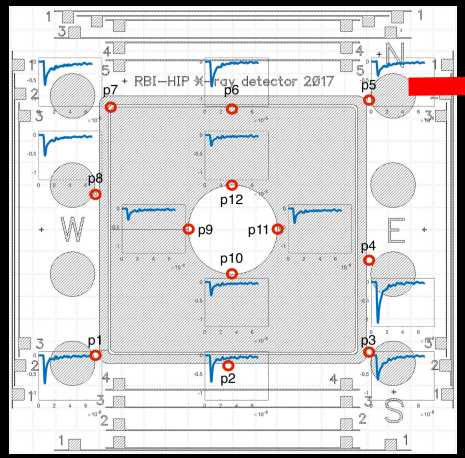
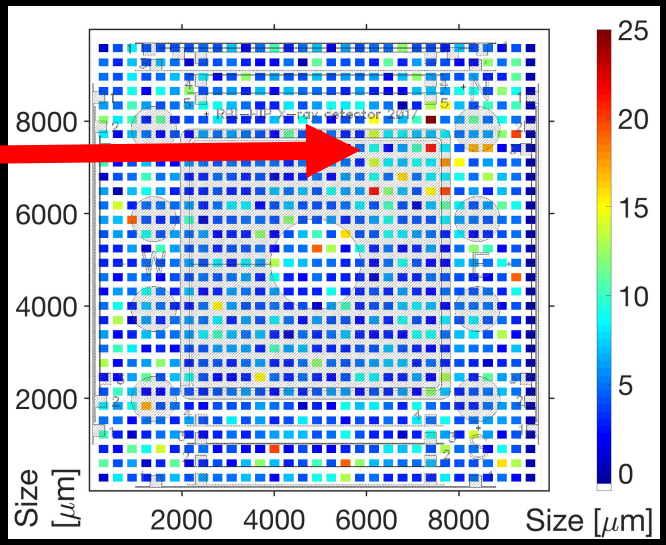
- IR: correlation of CCE map and defect map





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- Based on defect map → “panel mosaic”