ETH zürich

# Development of bump bonding process for pixelated diamond sensors

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# Overview

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- Preliminary results with $^{90}$Sr source on pixel hybrid detector
- Future plans
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# Detailed process description

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6. RIE
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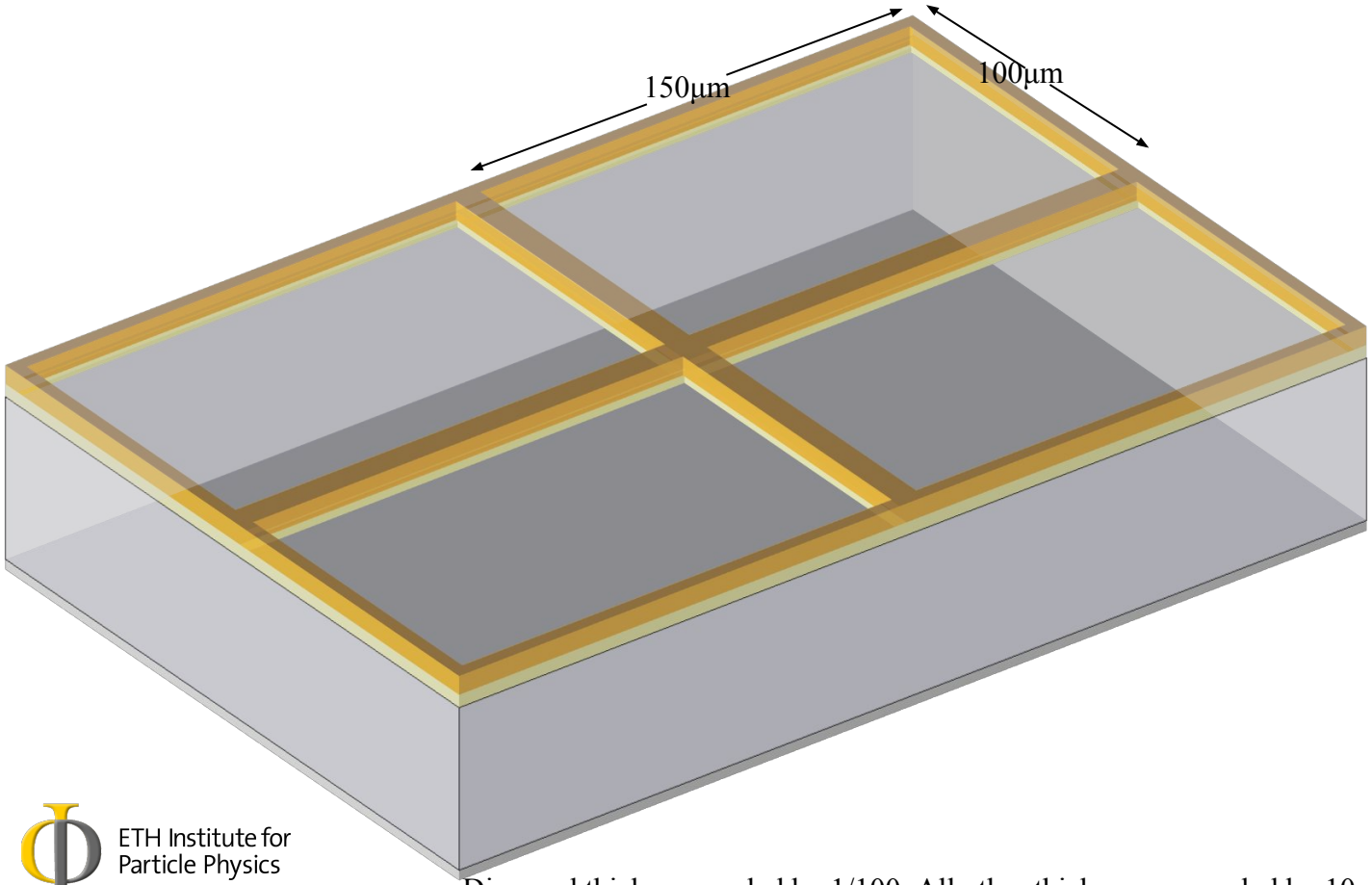
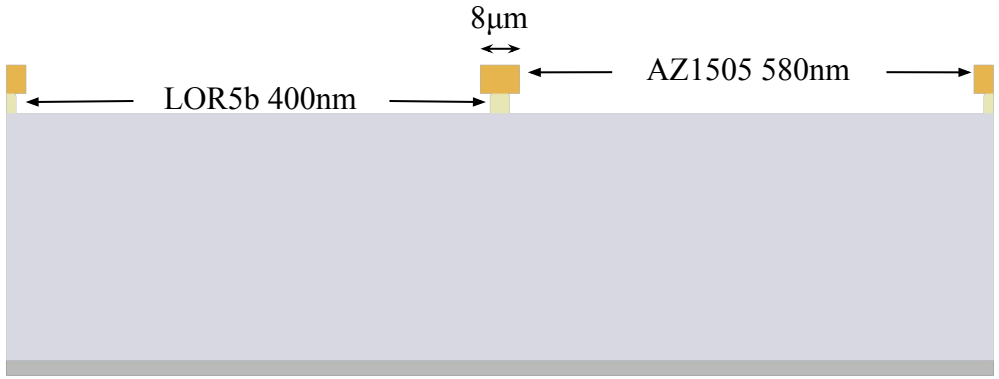
10. Indium mask
11. Indium evaporation
12. Indium lift-off
13. Reflow
14. Flip-chip and second reflow

# Detailed process description

## 1. Pixels metallization mask




Diamond thickness scaled by 1/100. All other thickness are scaled by 10

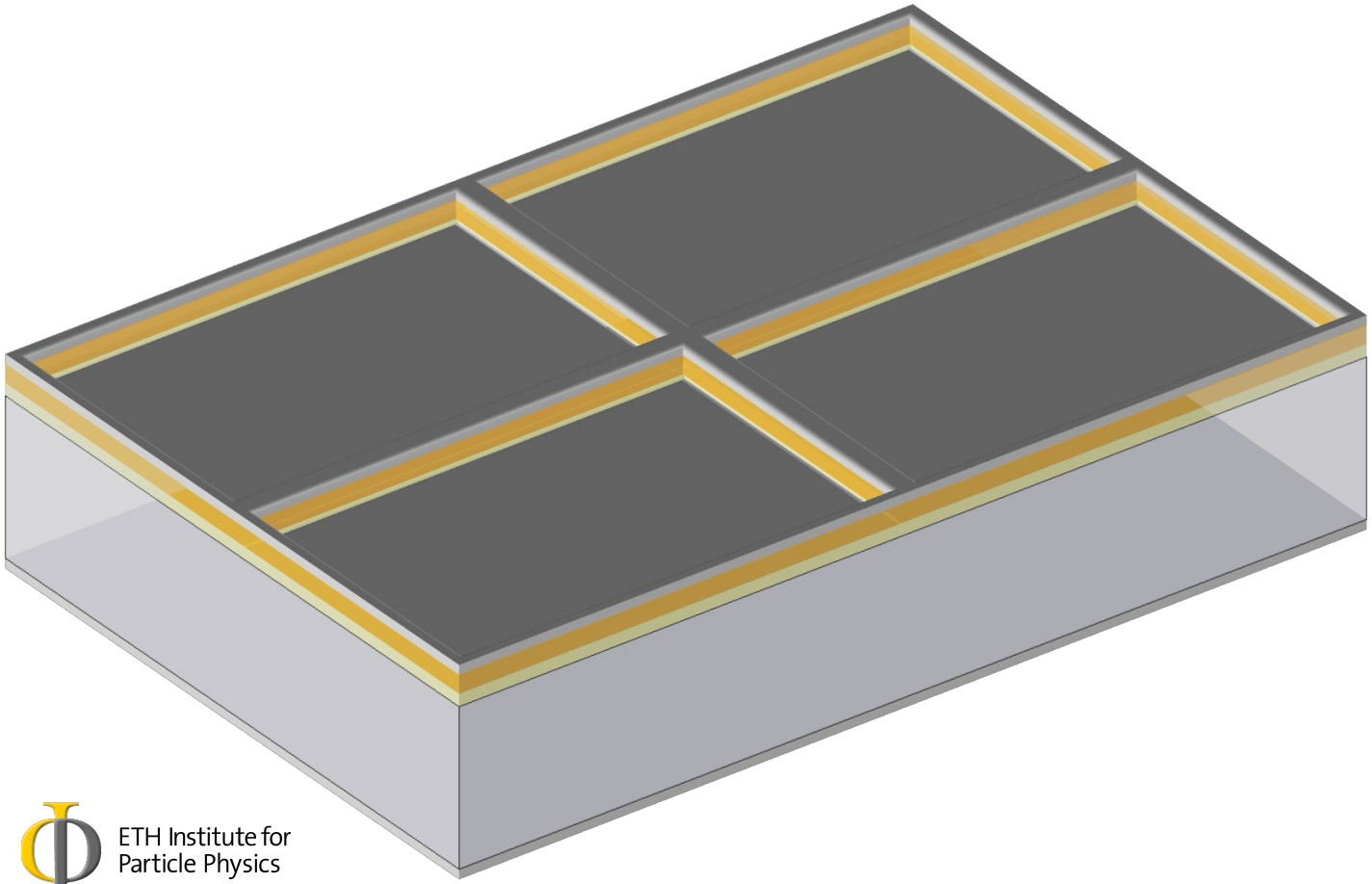


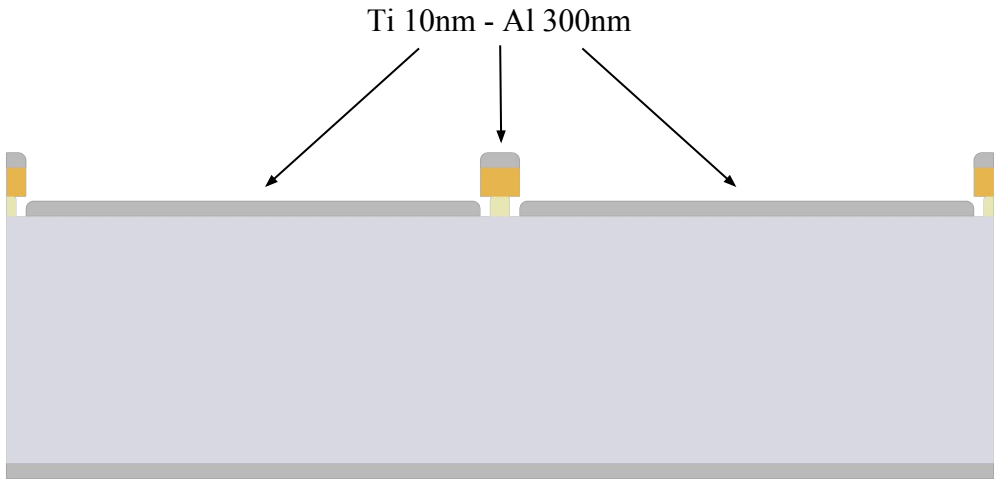

Slice view. Diamond thickness scaled by 1/100. All other thickness are scaled by 10

- Positive photoresist lift-off mask (400nm LOR5b - 580nm AZ1505)
- 8µm clearing between pixels

# Detailed process description

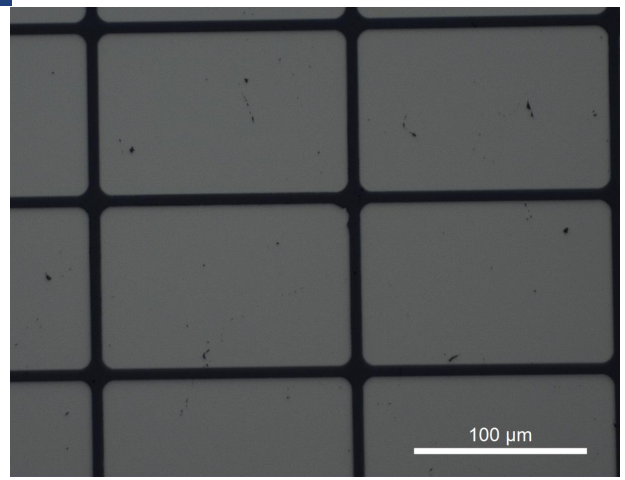
2. Metal deposition (sputtering or evaporation)



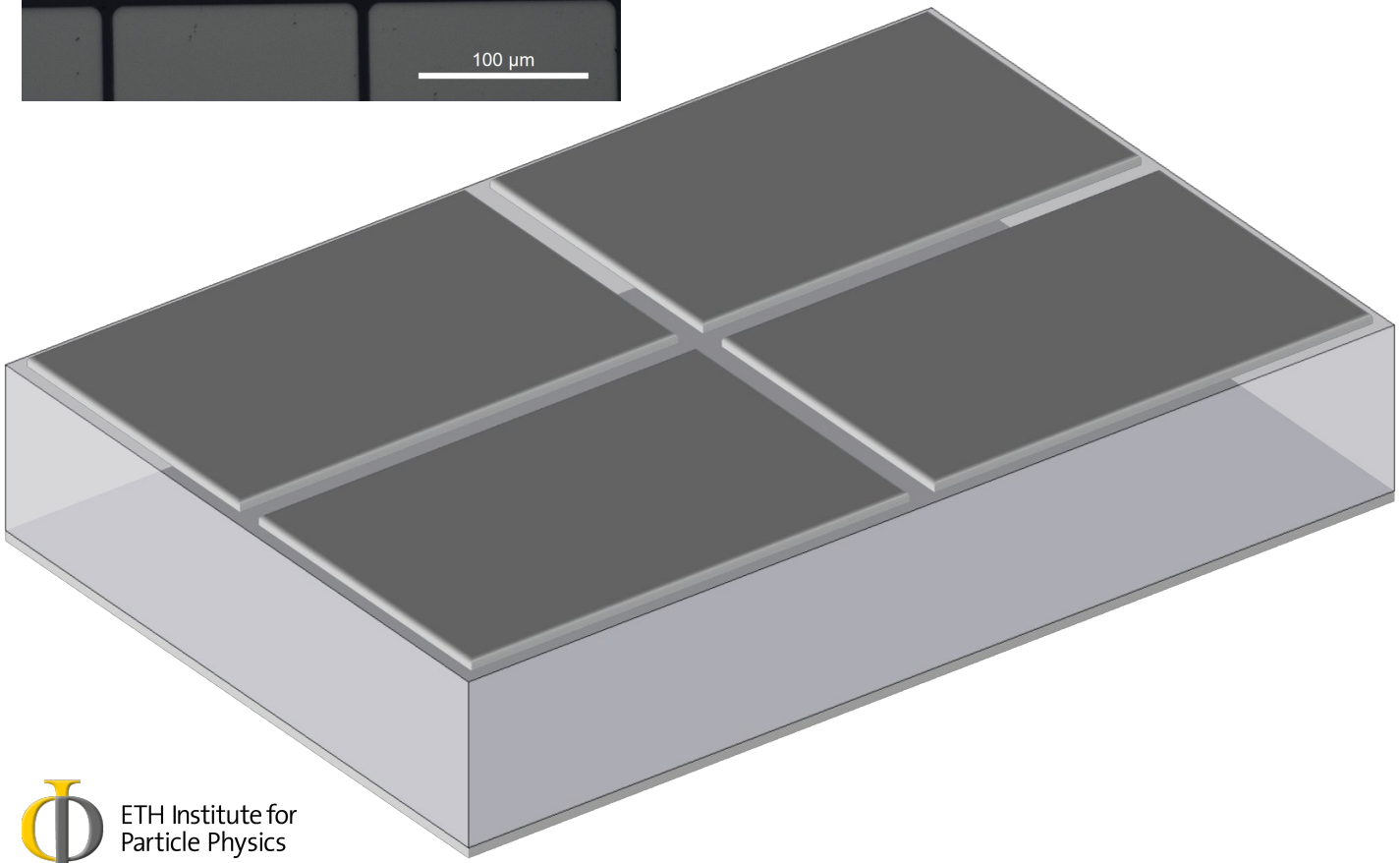



- Deposition of 10nm of Ti and 300nm of Al

# Detailed process description



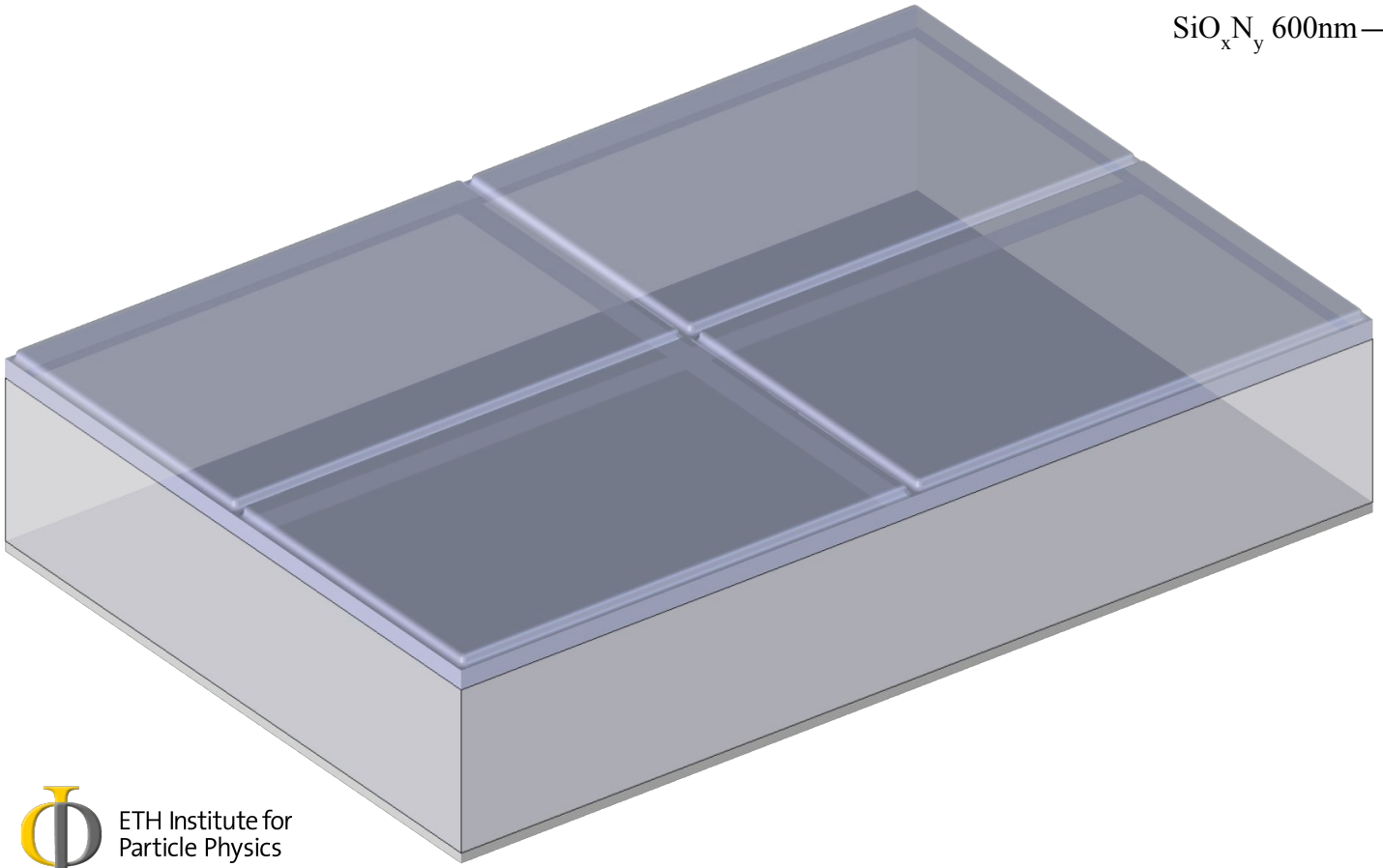

## 3. Metal lift-off and annealing



- Metal lift-off through solvents
- Anneal with Ar for 4 minutes at 400°C to ensure carbide bindings (C-Ti)

# Detailed process description

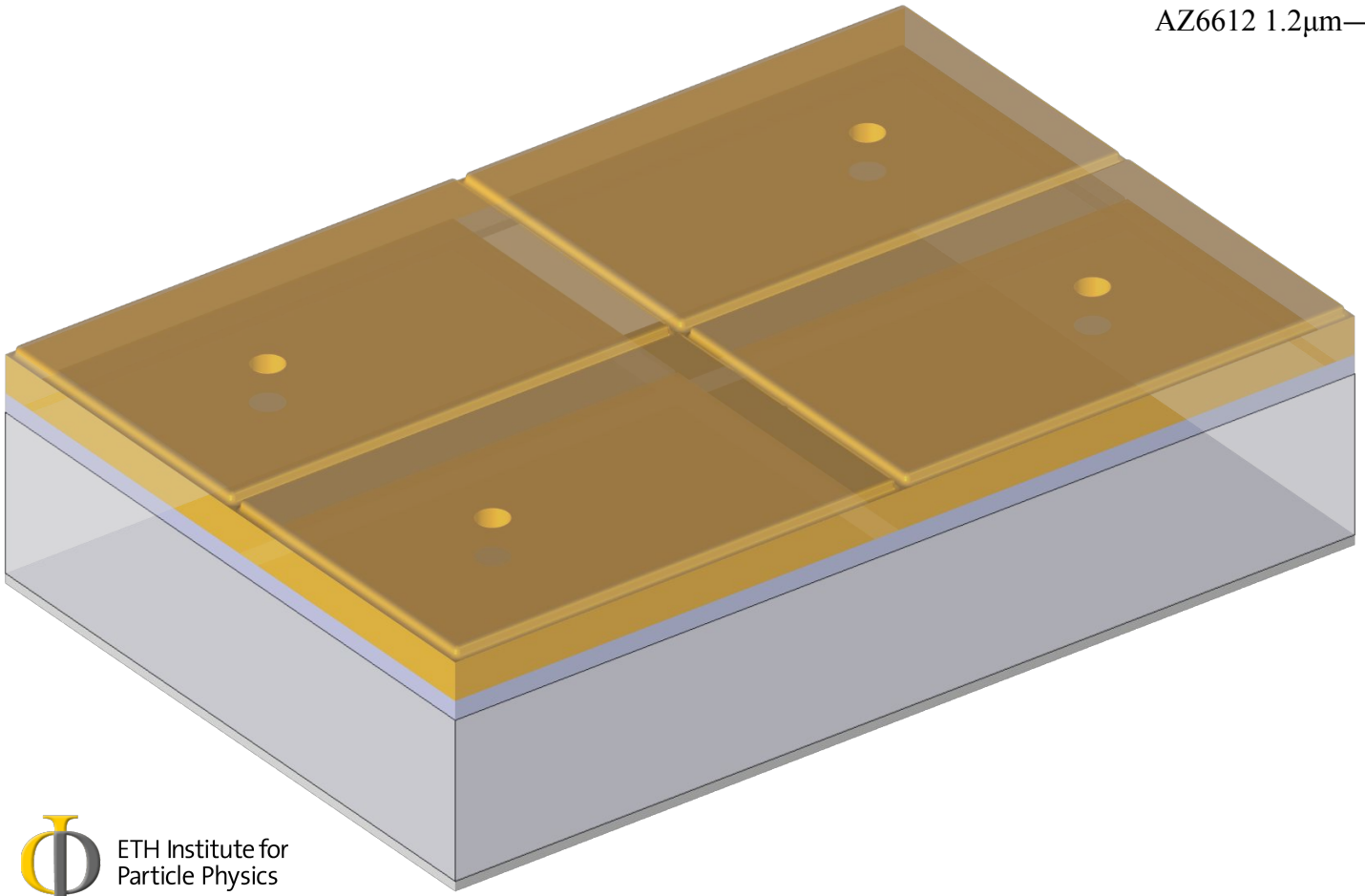
## 4. $SiO_xN_y$ passivation layer deposition with peCVD

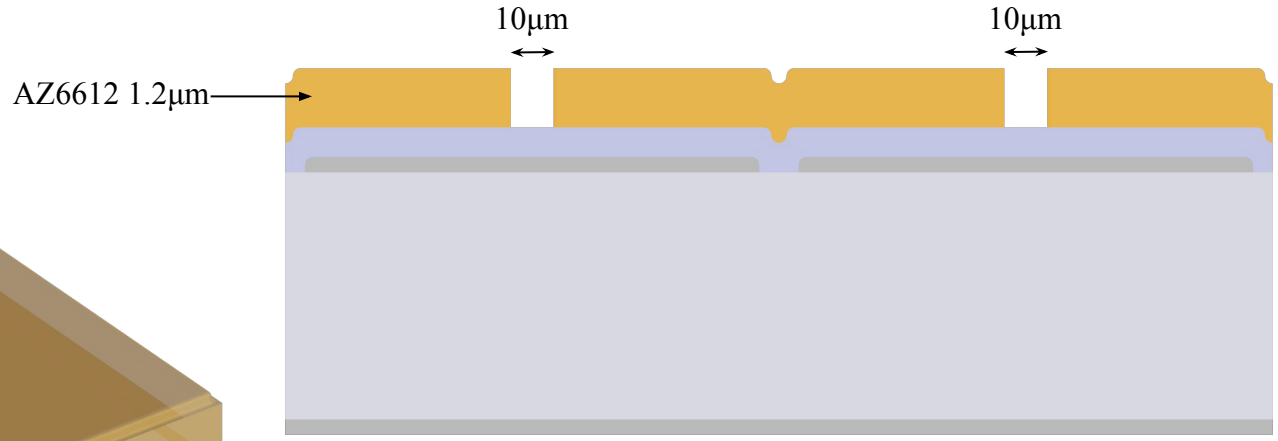



- 600nm $SiO_xN_y$ formation with low stress peCVD film deposition

# Detailed process description

## 5. RIE mask

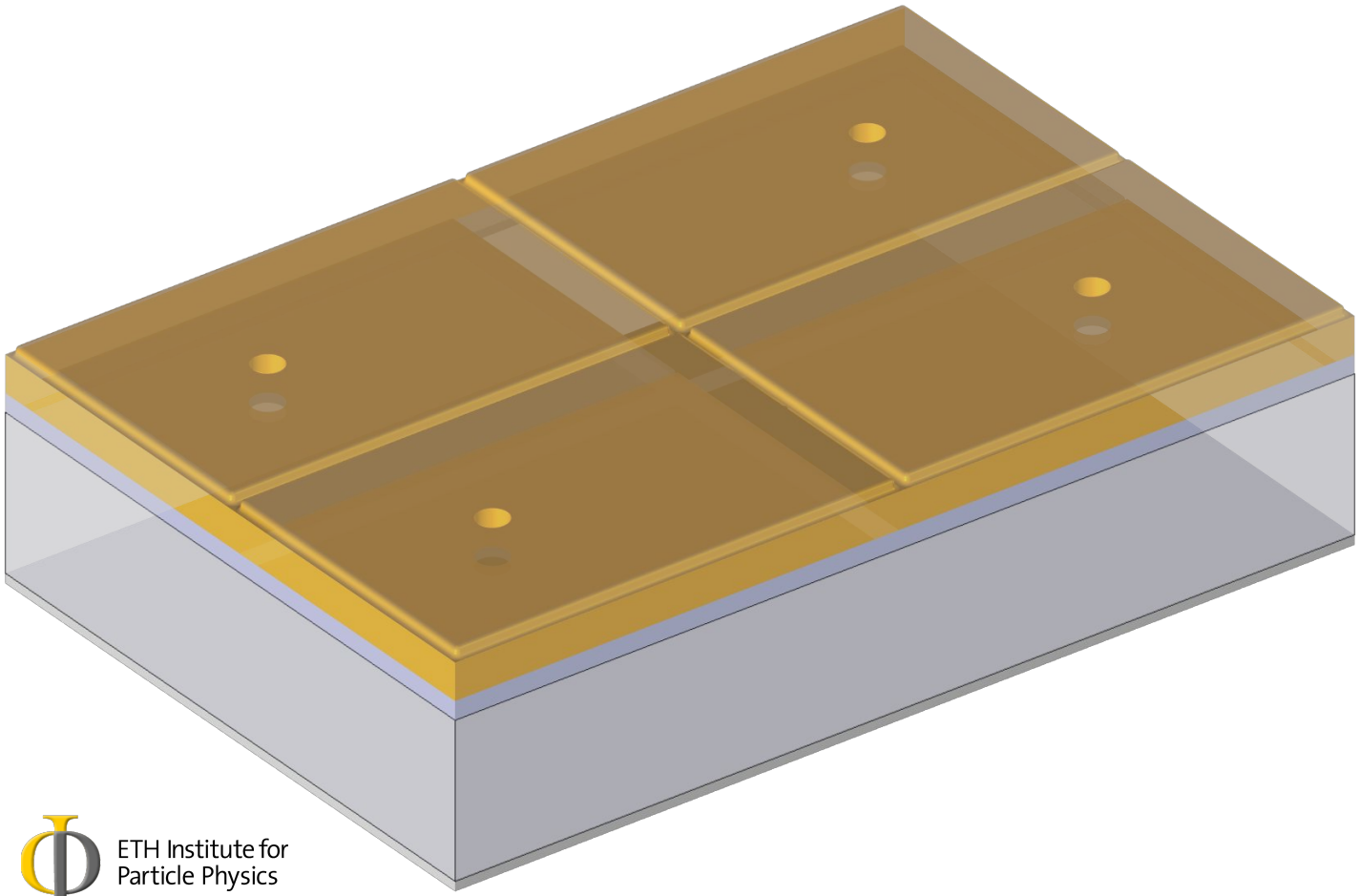





- Positive photoresist mask (1.2µm AZ6612)
- Holes of ⌀10µm

# Detailed process description

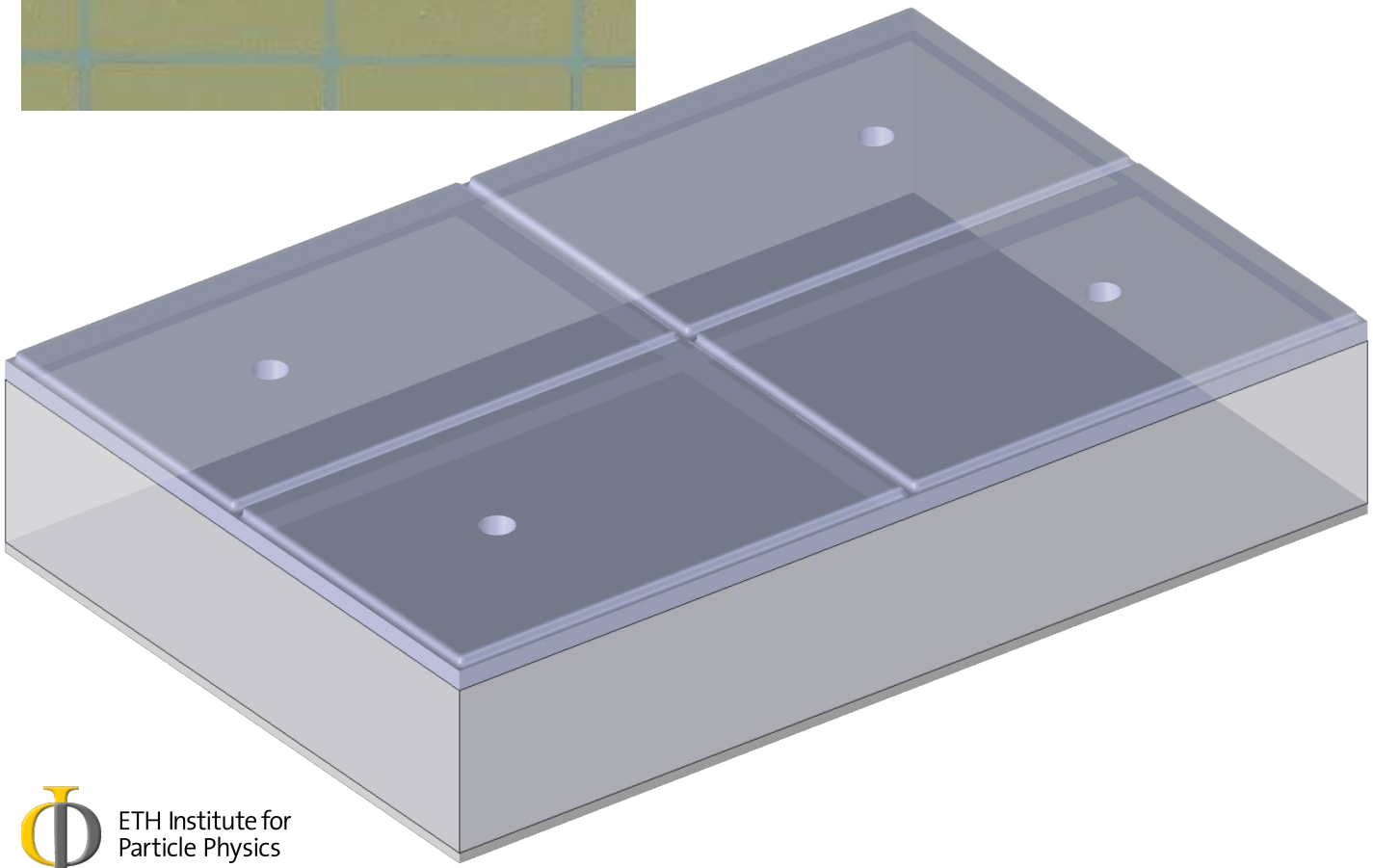
## 6. RIE



- Reactive Ion Etching with $CHF_3$ through all the $SiO_xN_y$ layer until metallization layer is reached

# Detailed process description

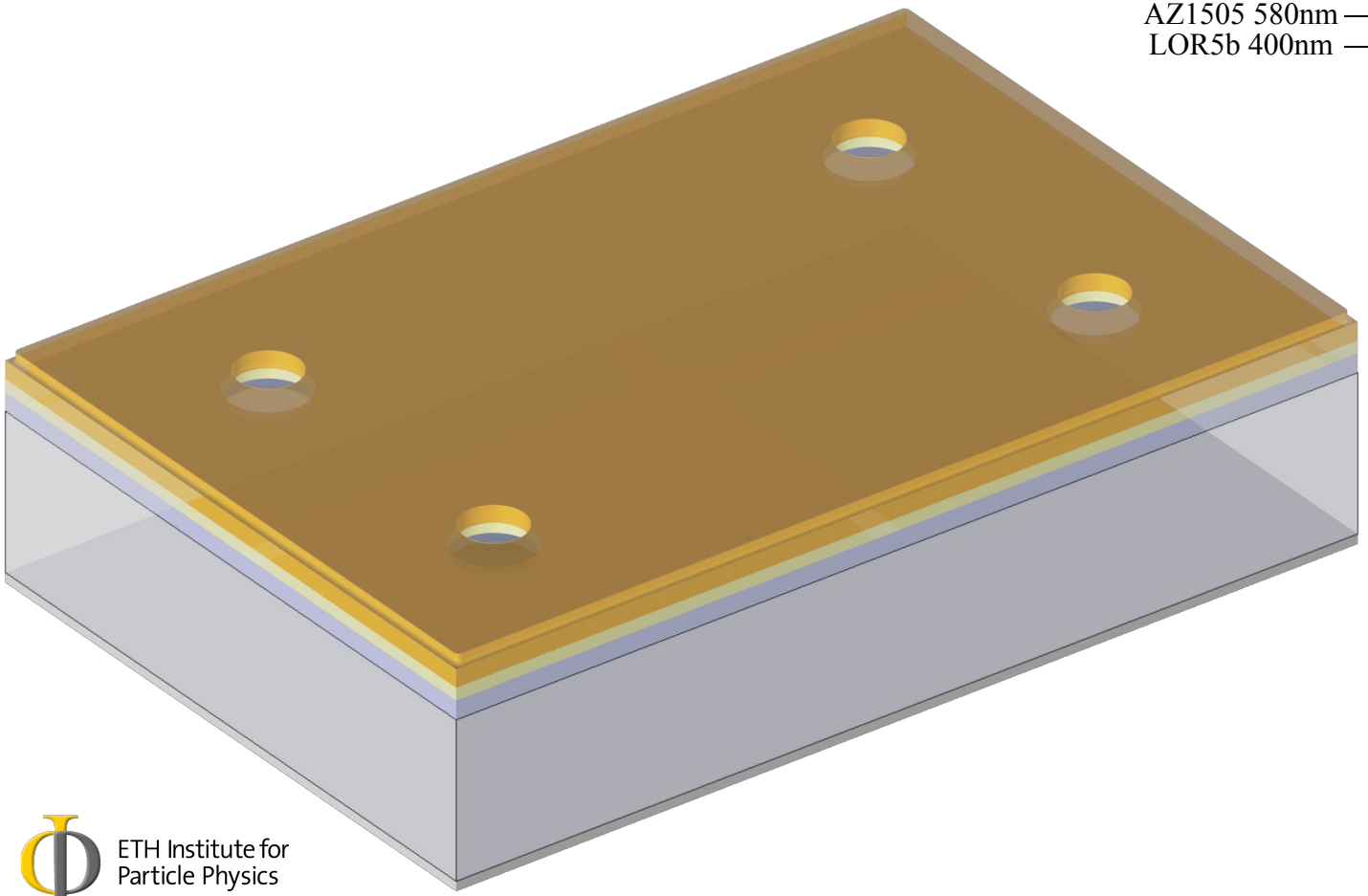
6. Detector after RIE and stripping

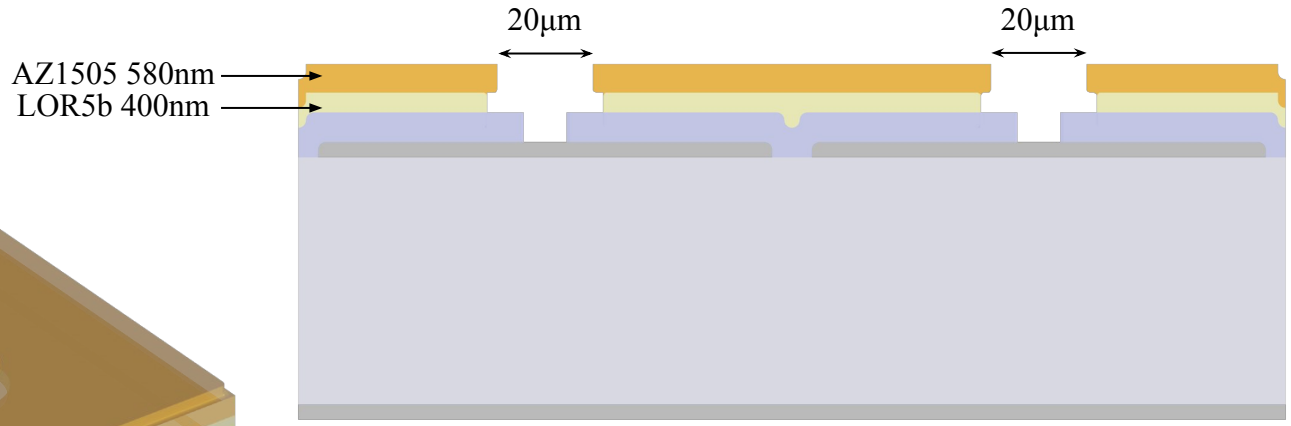


- Reactive Ion Etching with $CHF_3$ through all the $SiO_xN_y$ layer until metallization layer is reached

# Detailed process description

## 7. Ubm mask

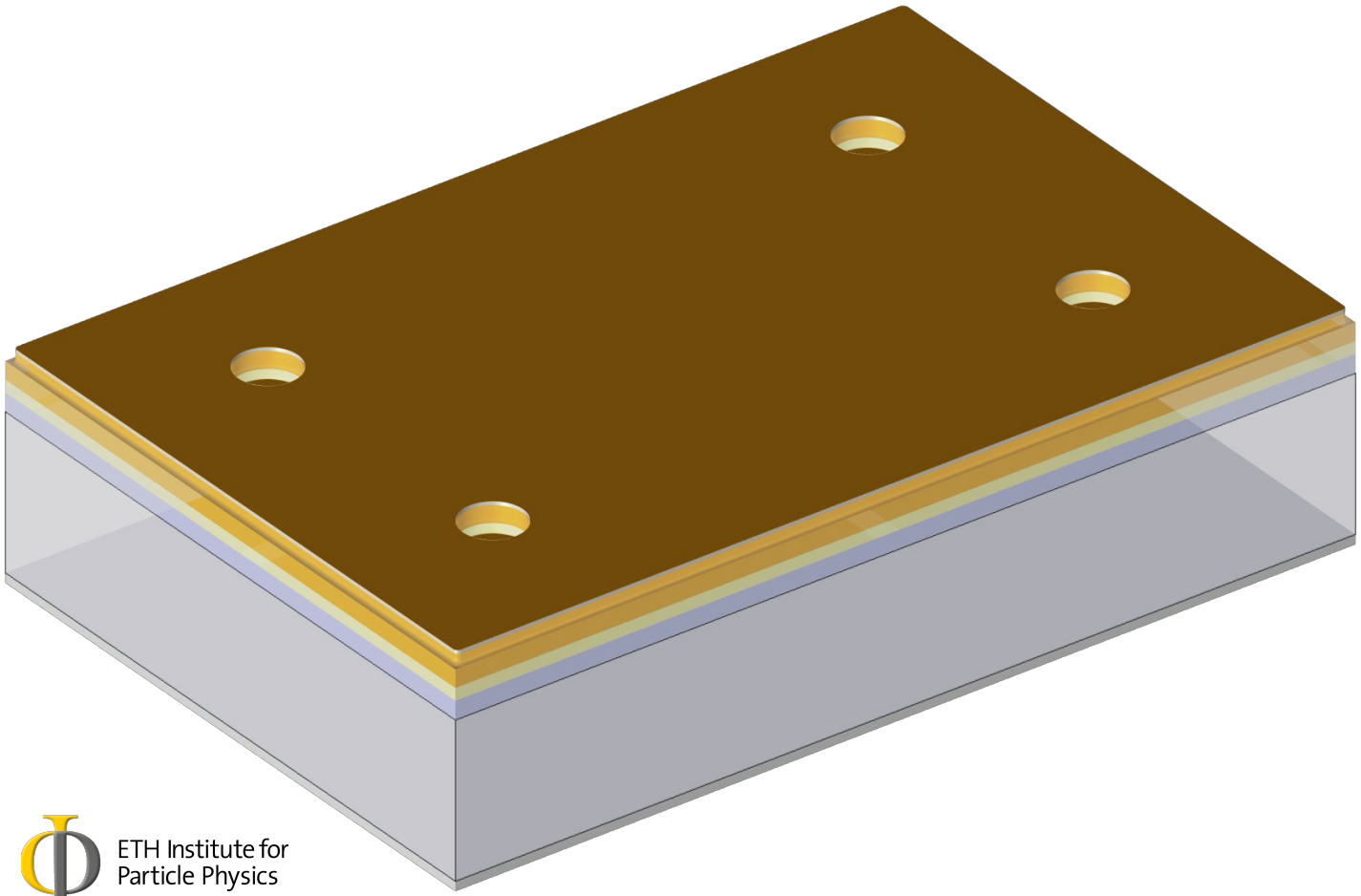


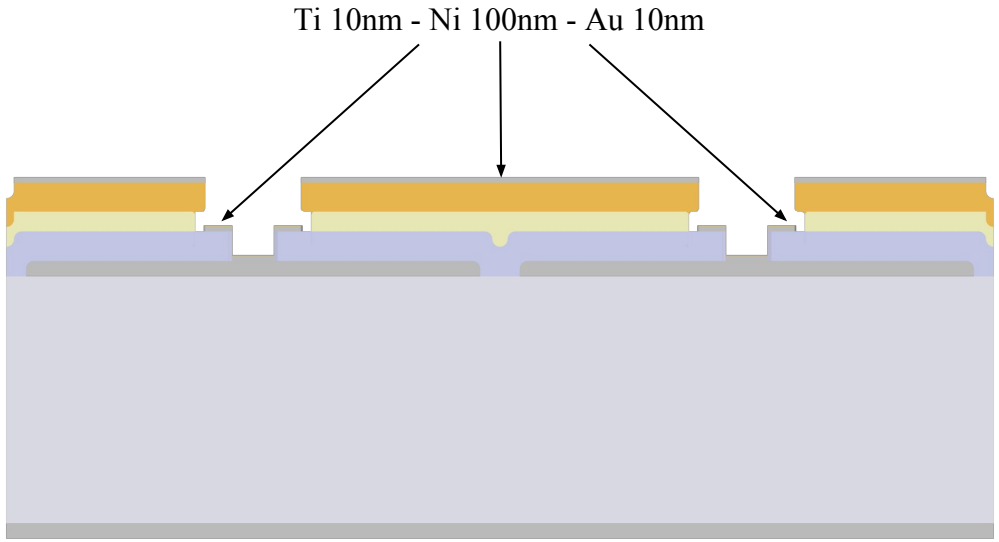



- Positive photoresist lift-off mask (400nm LOR5b - 580nm AZ1505)
- Holes of ⌀20µm

# Detailed process description

## 8. Ubm evaporation

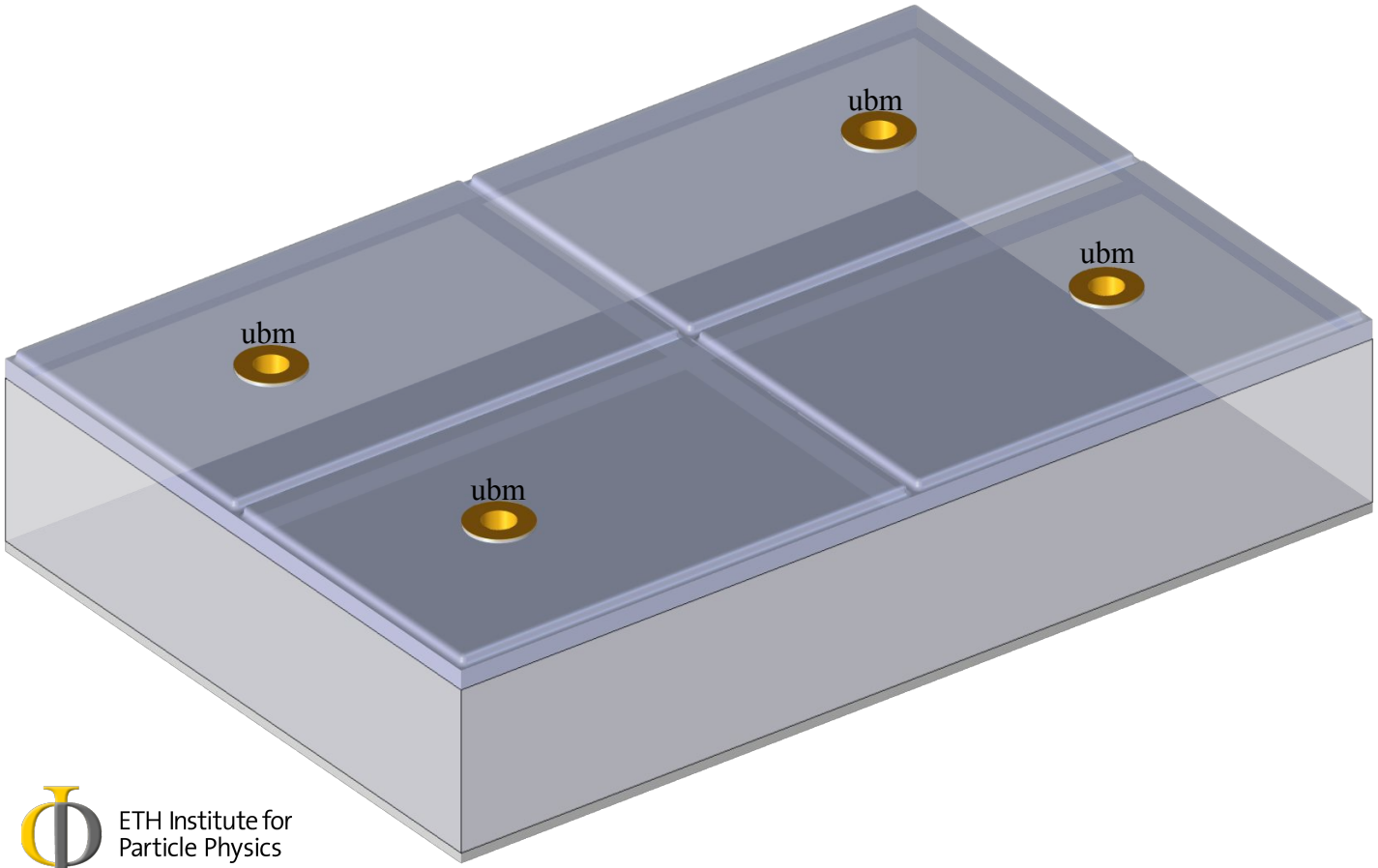





- Evaporation of 10nm Ti, 100nm Ni and 10nm Au for under-bump-metallization (ubm)

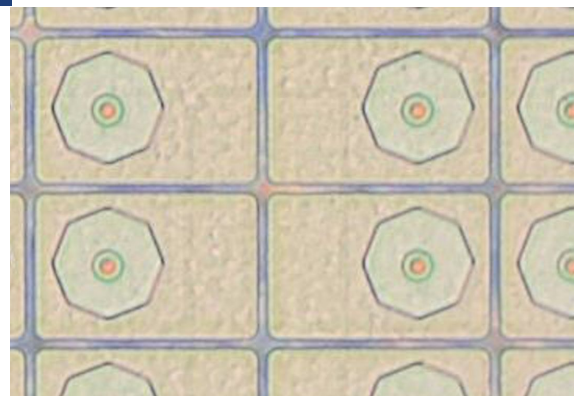
# Detailed process description

## 9. Ubm - Metal lift-off

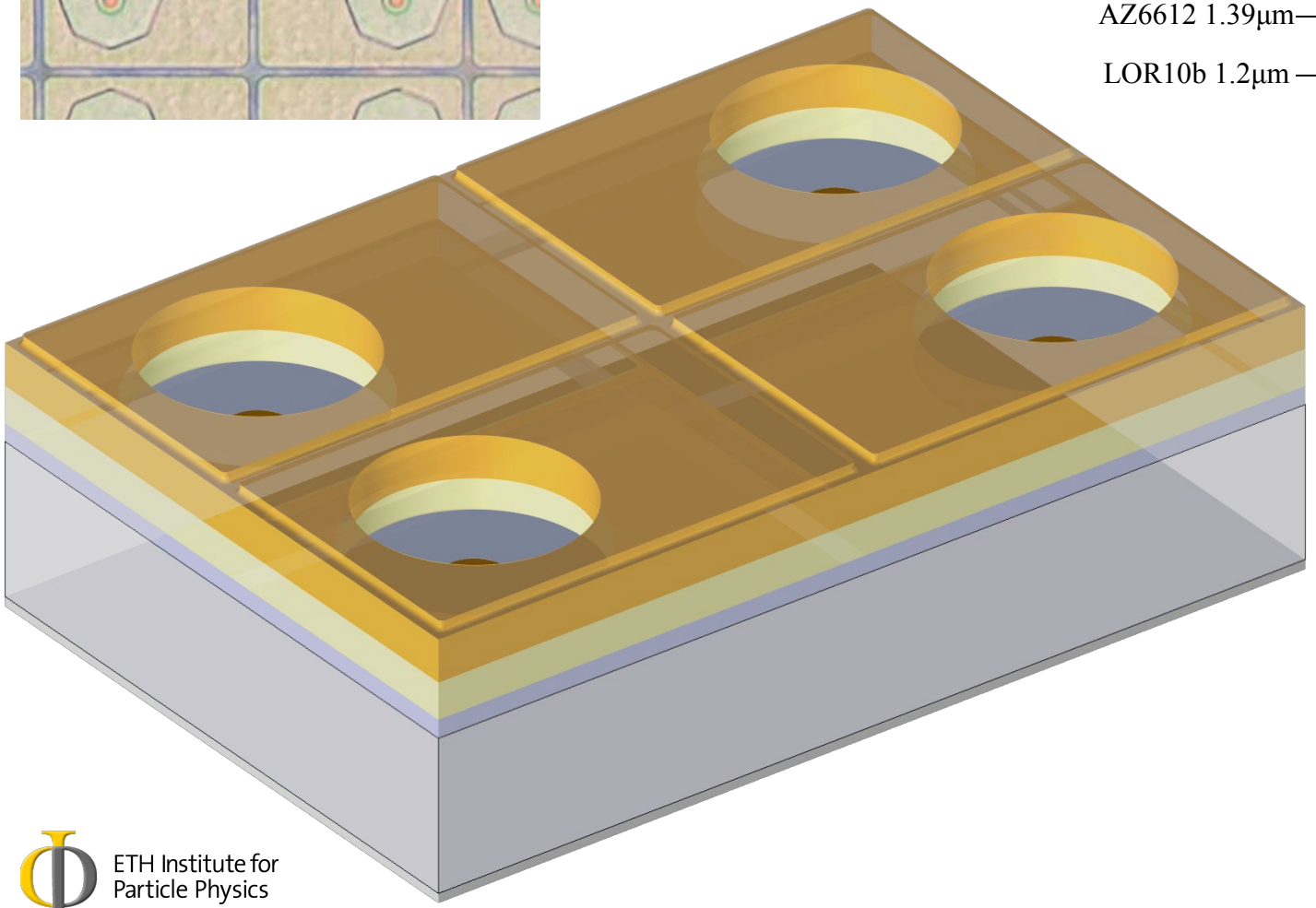


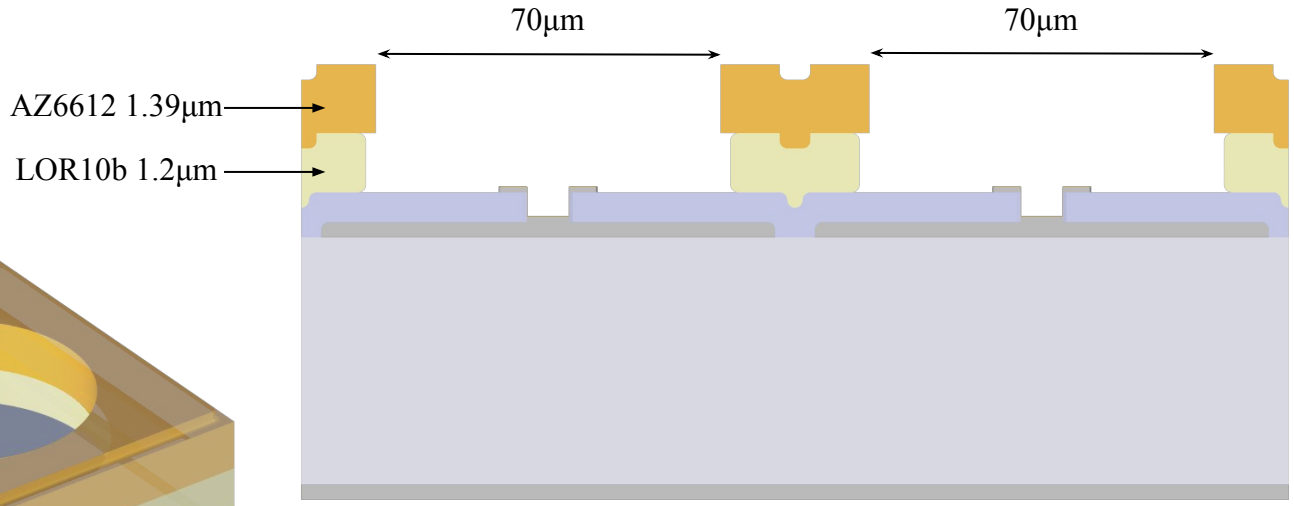

- Metal lift-off through solvents

# Detailed process description



## 10. Indium mask

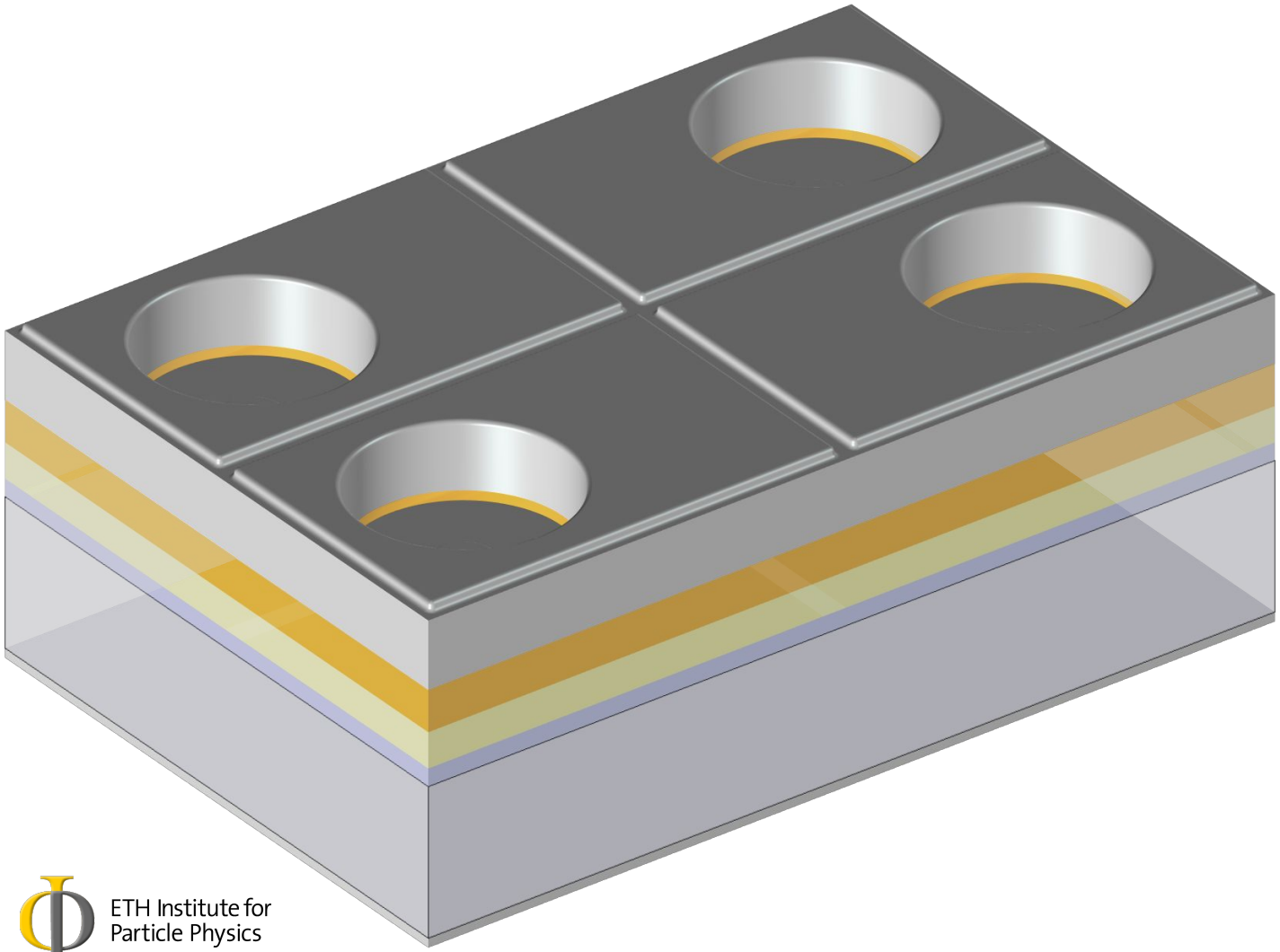


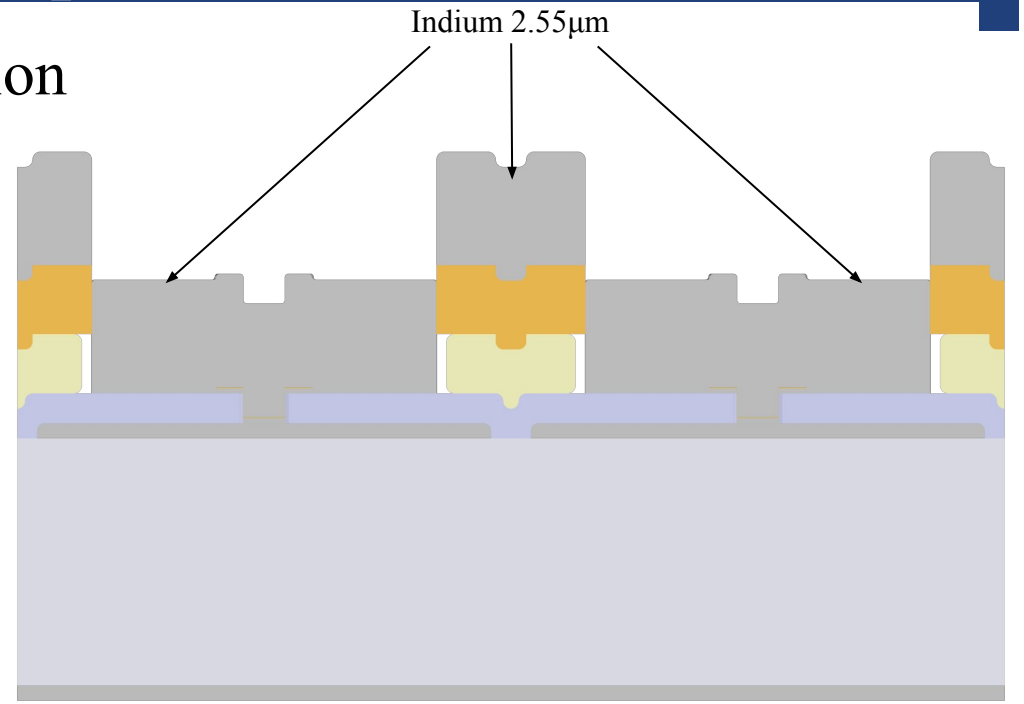



- Positive photoresist lift-off mask (1.2µm LOR10b - 1.39µm AZ6612)
- Holes of ⌀70µm

# Detailed process description

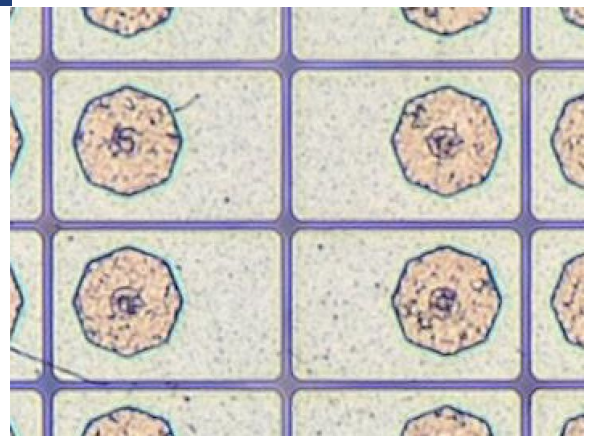
## 11. Indium evaporation



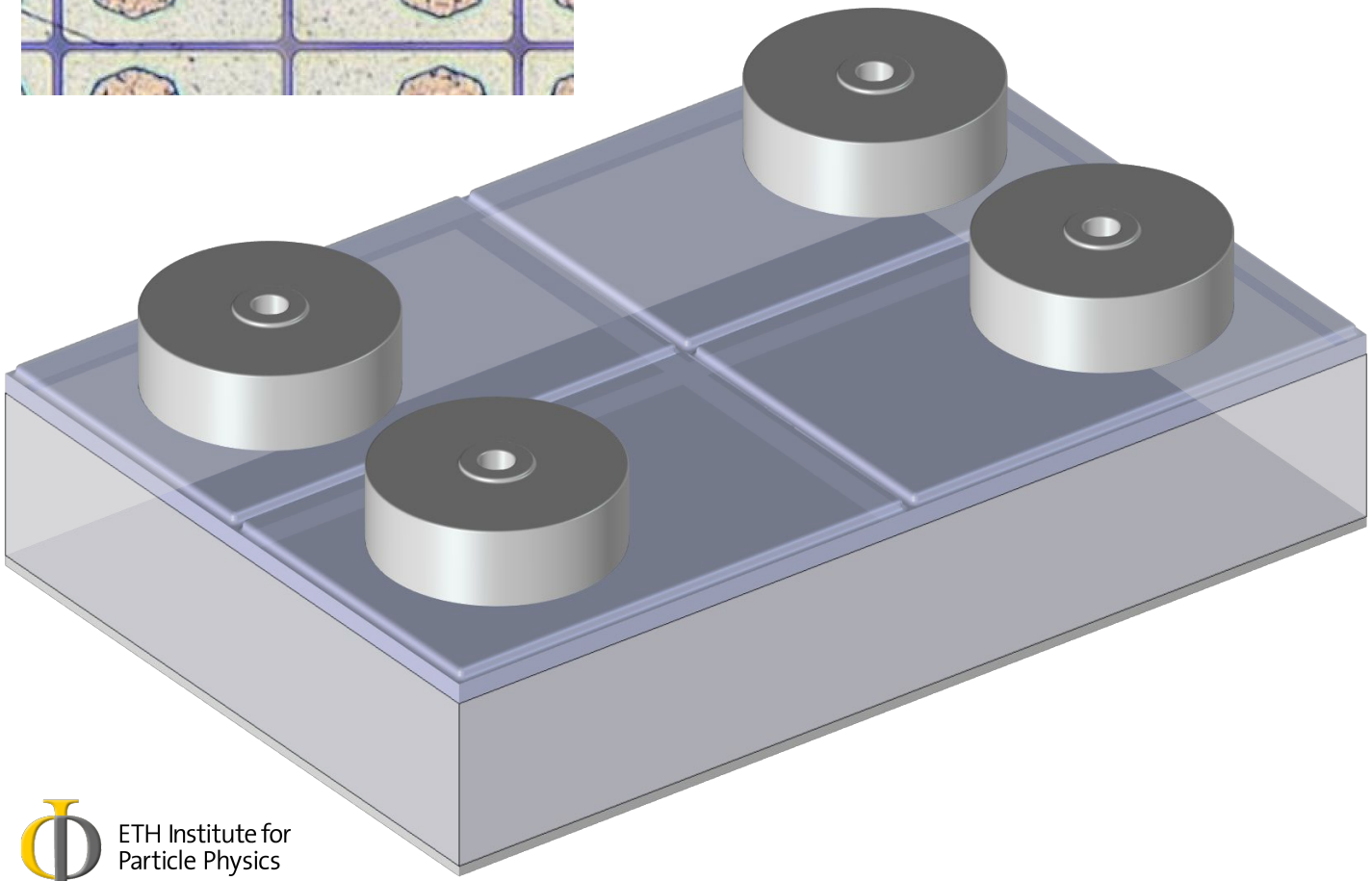


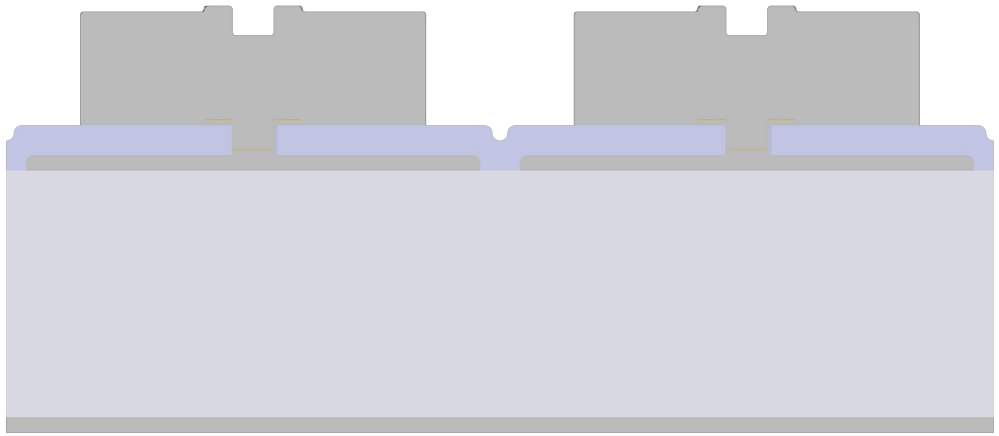

- Evaporation of 3gr of In (~2.55µm)

# Detailed process description



## 12. Indium lift-off

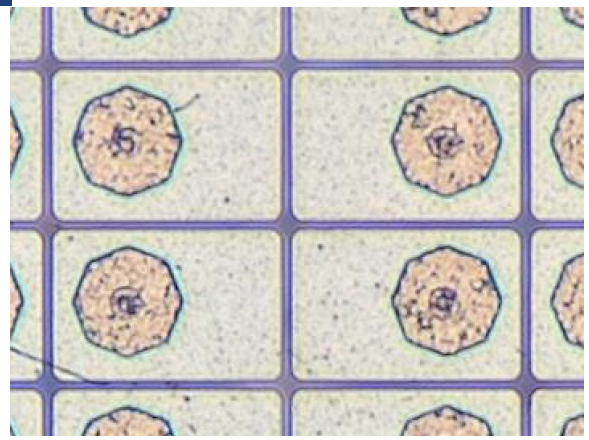


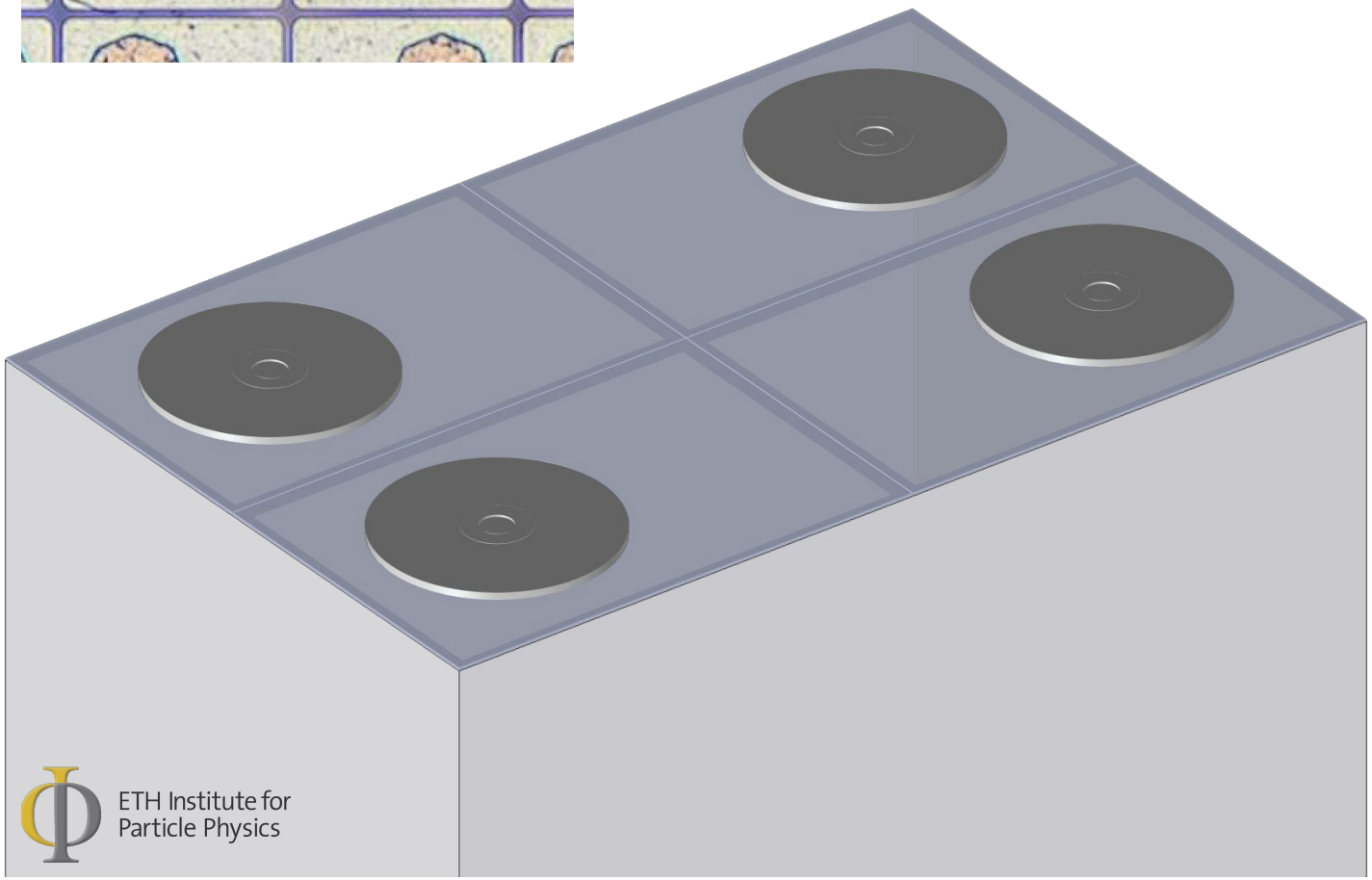


- Metal lift-off through solvents

# Detailed process description

12. Indium lift-off (on a 1:1 scale)

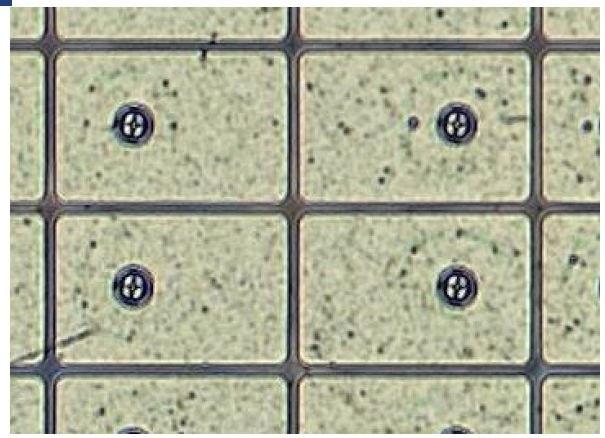


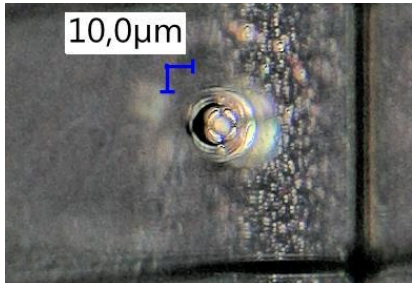


- Metal lift-off through solvents

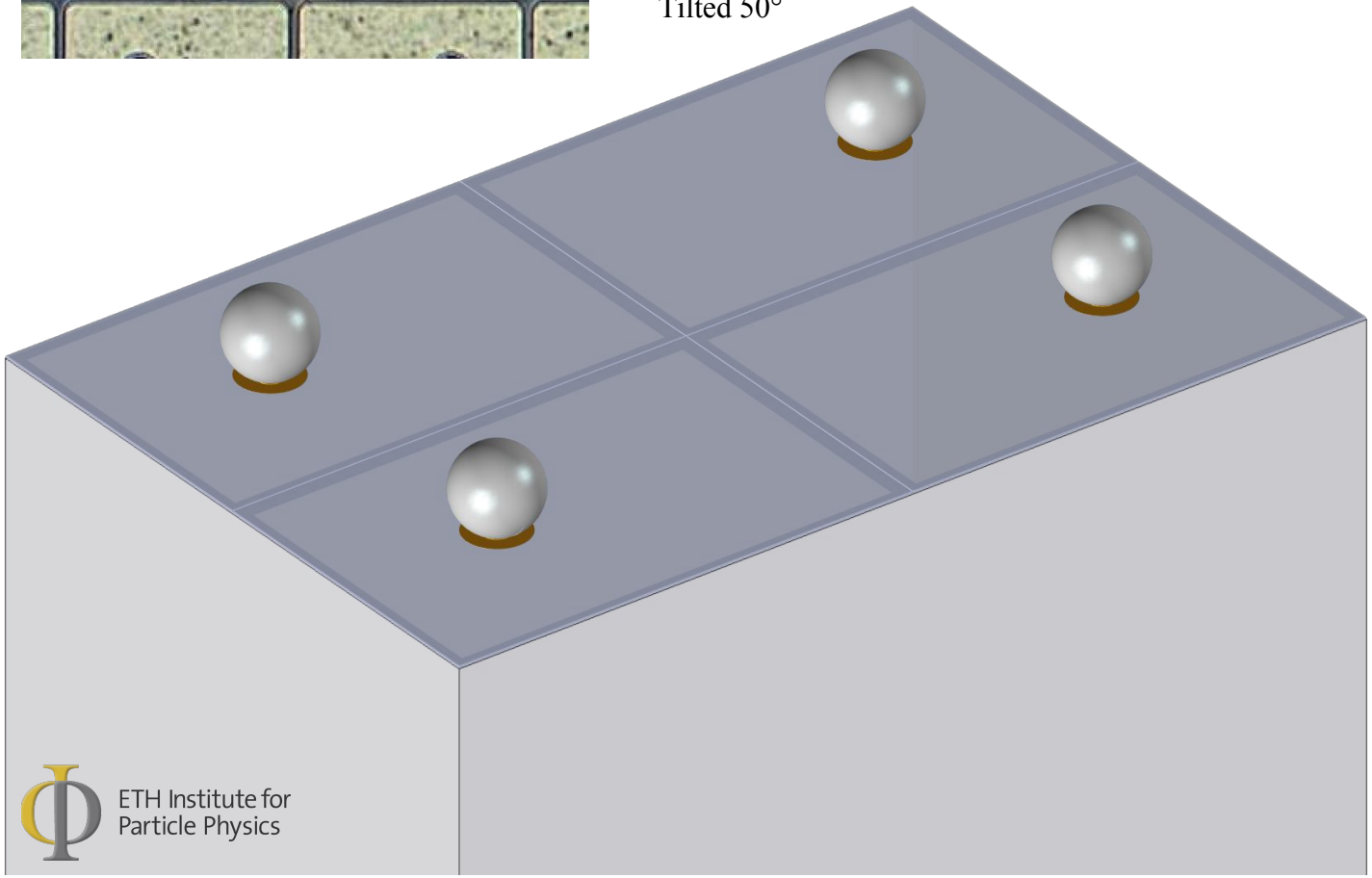
# Detailed process description

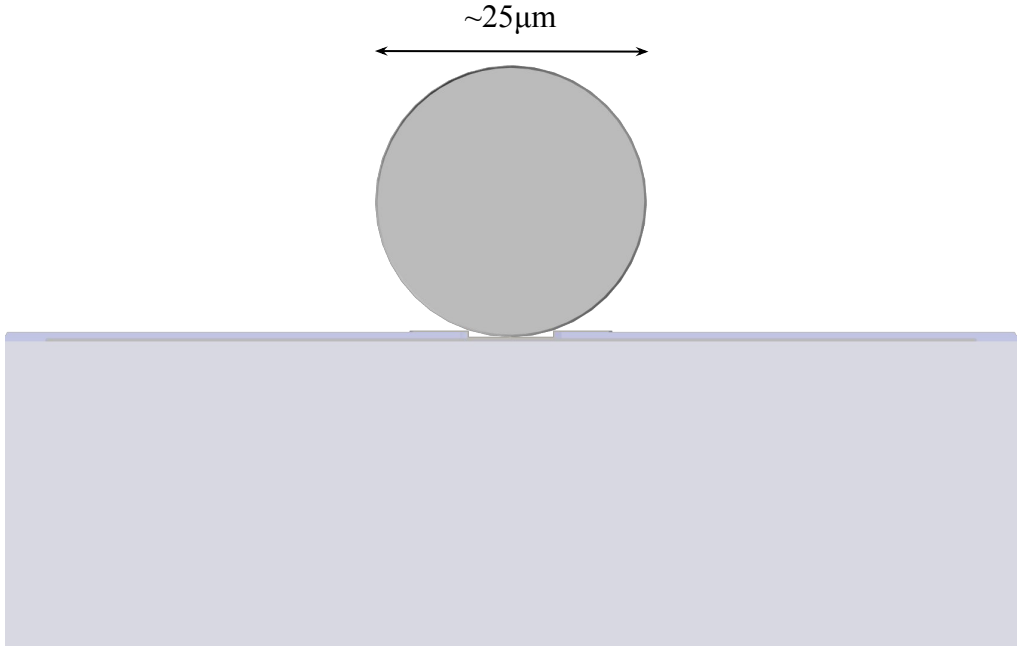
## 13. Reflow






Tilted 50°

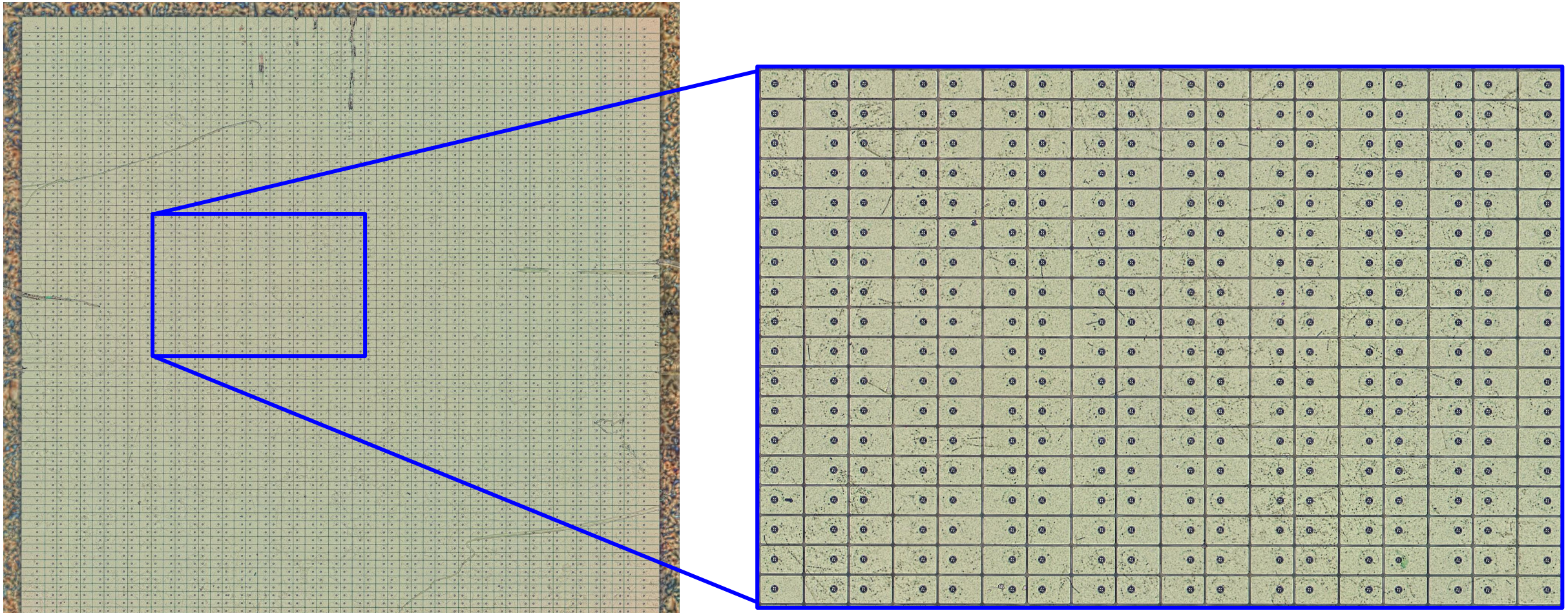





- 2 step reflow process - maximum temperature of ~200°C
- Bumps formation of ⌀~25µm

# Detailed process description

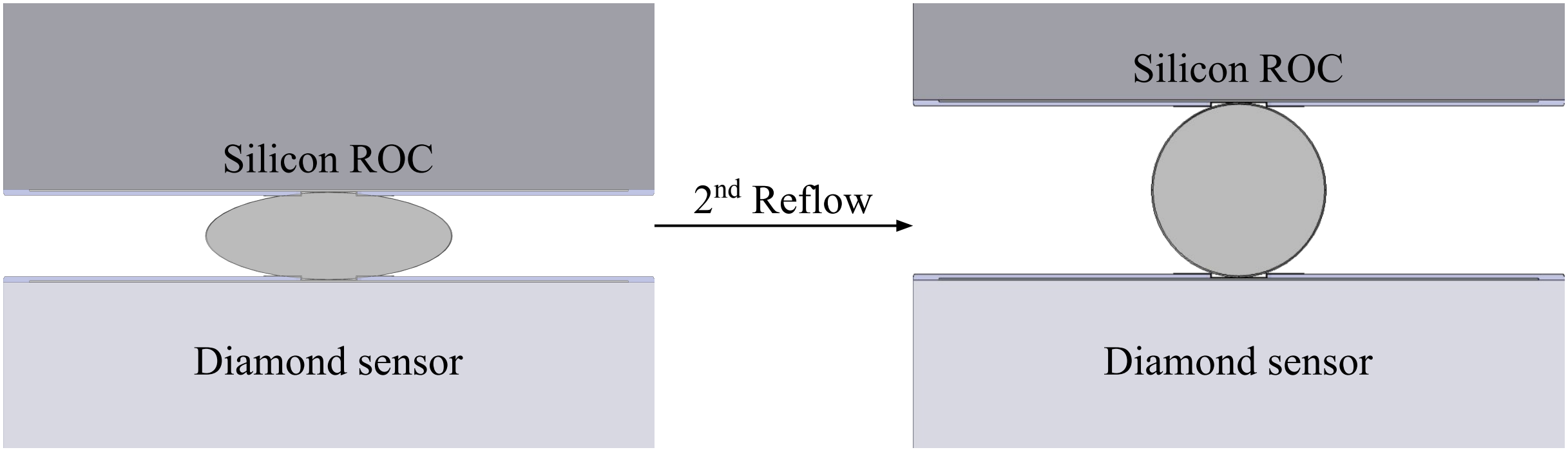
## 13. Pixel sensor prototype after 1st reflow



- 4150 out of 4160 bumps were correctly formed (yield of 99.8%)

# Detailed process description

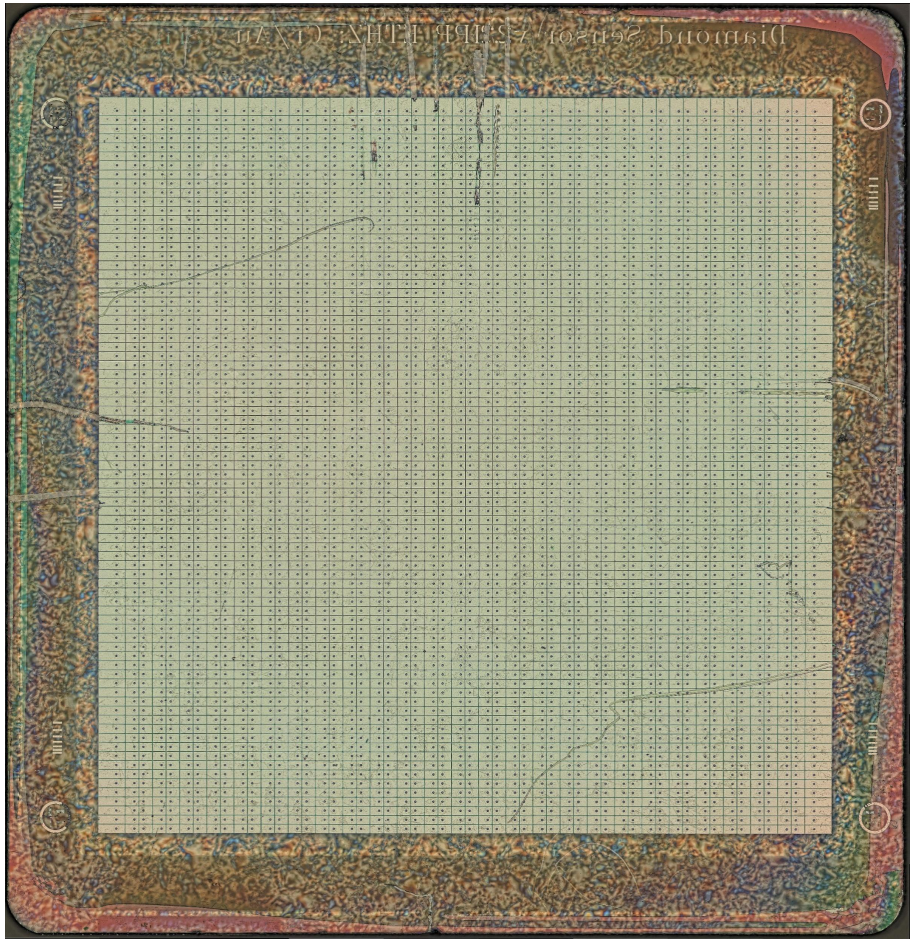
## 14. Flip-chip and second reflow

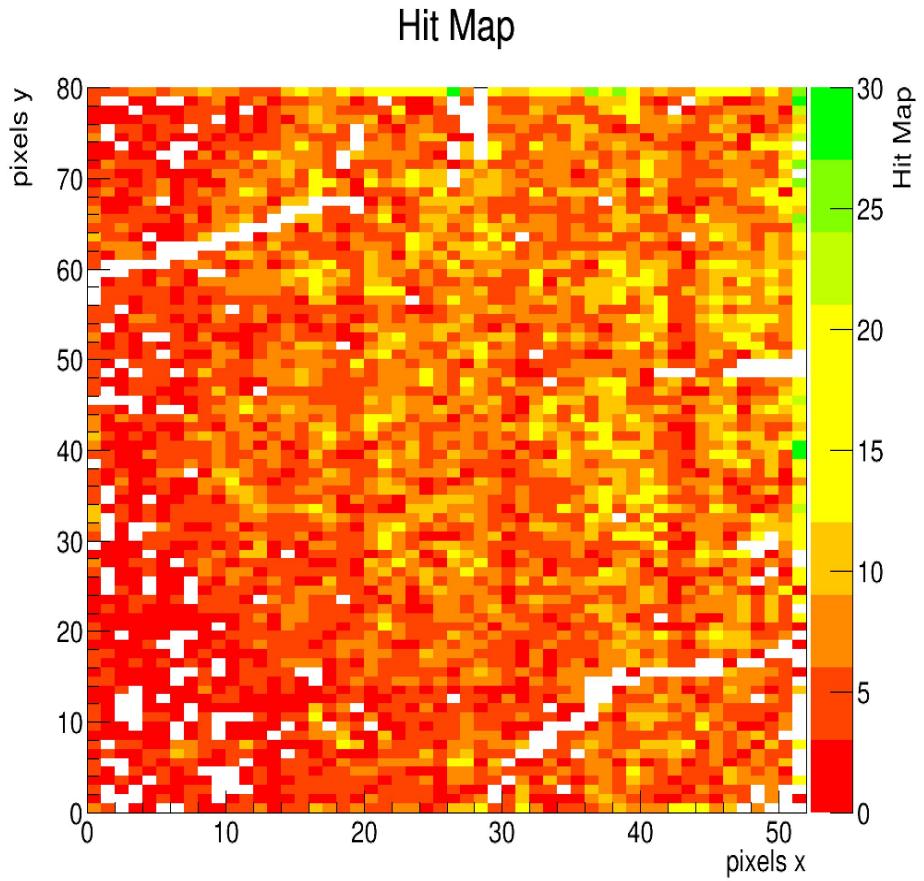



- Silicon ROC pressed with ~4 kg (~9 mN per bump) on the bumps attached to the sensor
- Second reflow to homogenize the bump-bonding over the chip and correct for slight misalignments

# Preliminary results with $^{90}$Sr source on pixel hybrid detector

## Hit map results with $^{90}$Sr source



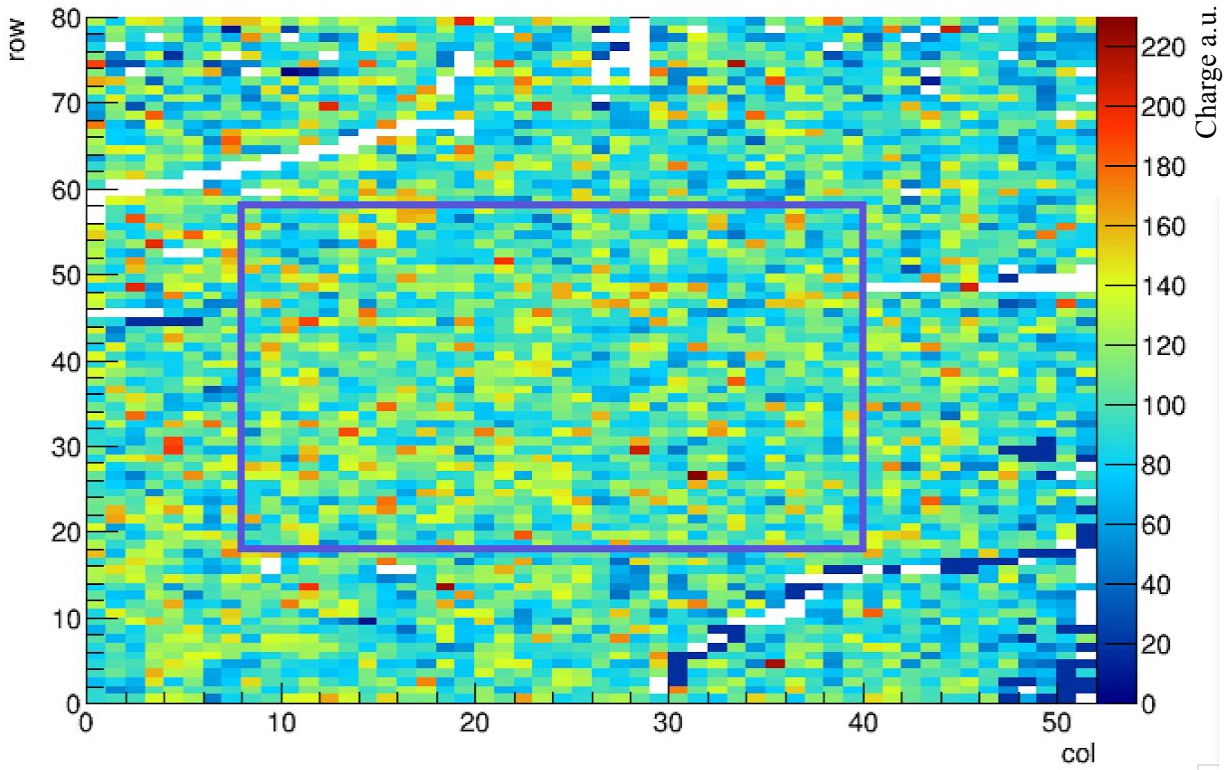



- 90Sr source test shows no hits (right) in the regions where there are tweezer marks during the fabrication process (left)

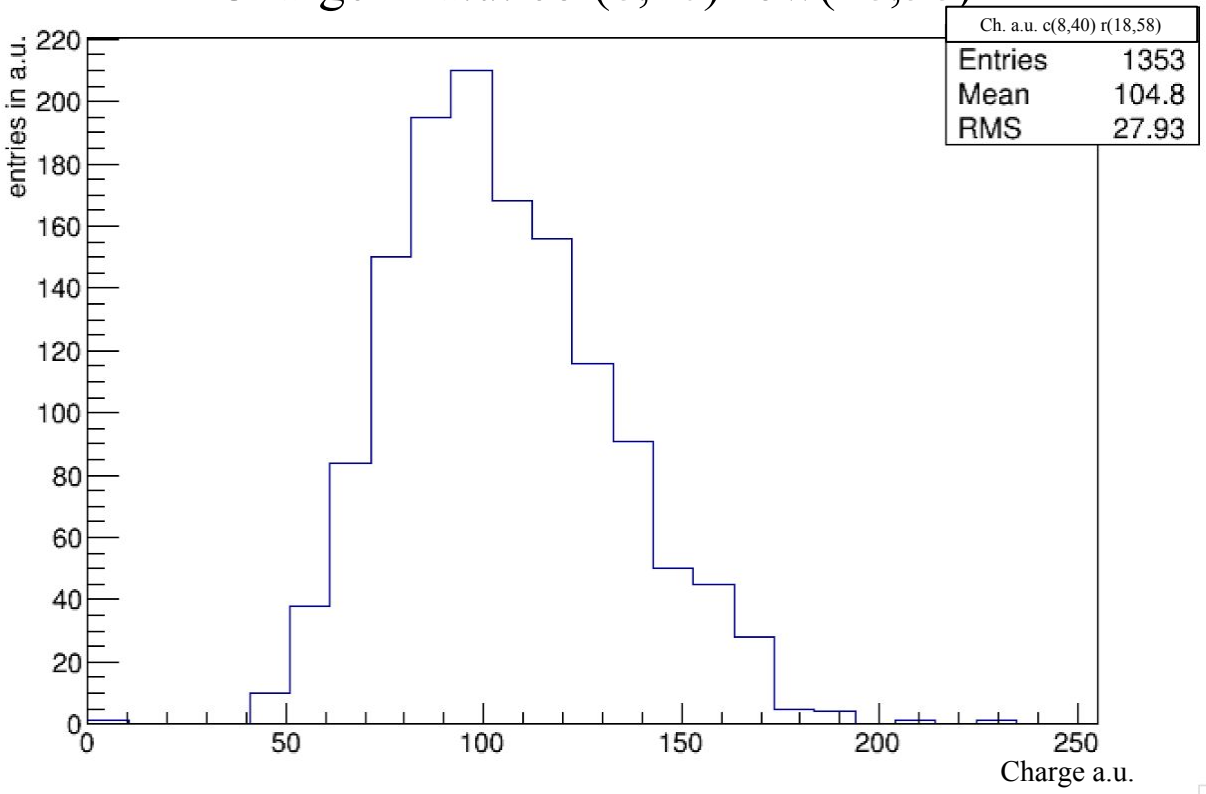
# Preliminary results with $^{90}$Sr source on pixel hybrid detector

## Charge map with $^{90}$Sr source

Charge in a.u.




Charge in a.u. col(8,40) row(18,58)




- Charge map using $^{90}$Sr source and hits obtained with a random trigger
- The ROC was calibrated with a threshold of ~1700e

# Future plans

- A light-tight mechanical setup is being created which enables the detectors to be pumped before taking measurements
- Trigger with scintillator
- Do clustering analysis
- Fabricate more prototypes and calibrate them
- Test the prototypes in a test beam (e.g. at PSI)

# Conclusions

- A full fabrication recipe has been developed to fabricate pixelated diamond sensors to couple with silicon ROC (i.e. CMS layer 2 chip)
- A correct bump formation was achieved with a yield of 99.8% over 4160 bumps
- Fabricated prototypes were successfully calibrated and tested with $^{90}$Sr source
- Cluster analysis and pumping are needed to be able to have obtain good measurements of the detector and to calibrate it
- A simpler bump-bonding recipe was developed which could work on future 3D diamond devices

# Acknowledgments


BRNC
Binnig and Rohrer Nanotechnology Center

- IBM Zürich cleanroom and staff for supplying their facilities, equipment and knowledge to do all the processes before the indium evaporation

PAUL SCHERRER INSTITUT
PSI

- PSI CMS group for lending the indium processing machines and their knowledge on indium bump-bonding procedures