

3D Diamond Detectors

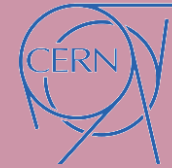
Presented by Iain HAUGHTON

Particle Physics
8th Trento Workshop
18.02.13

Collaborators



RD42



Overview

Motivation







Fabrication

Conducting Columns

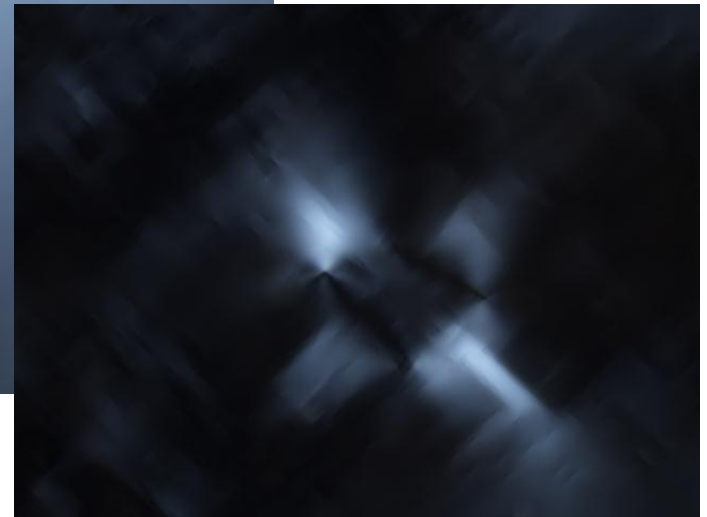
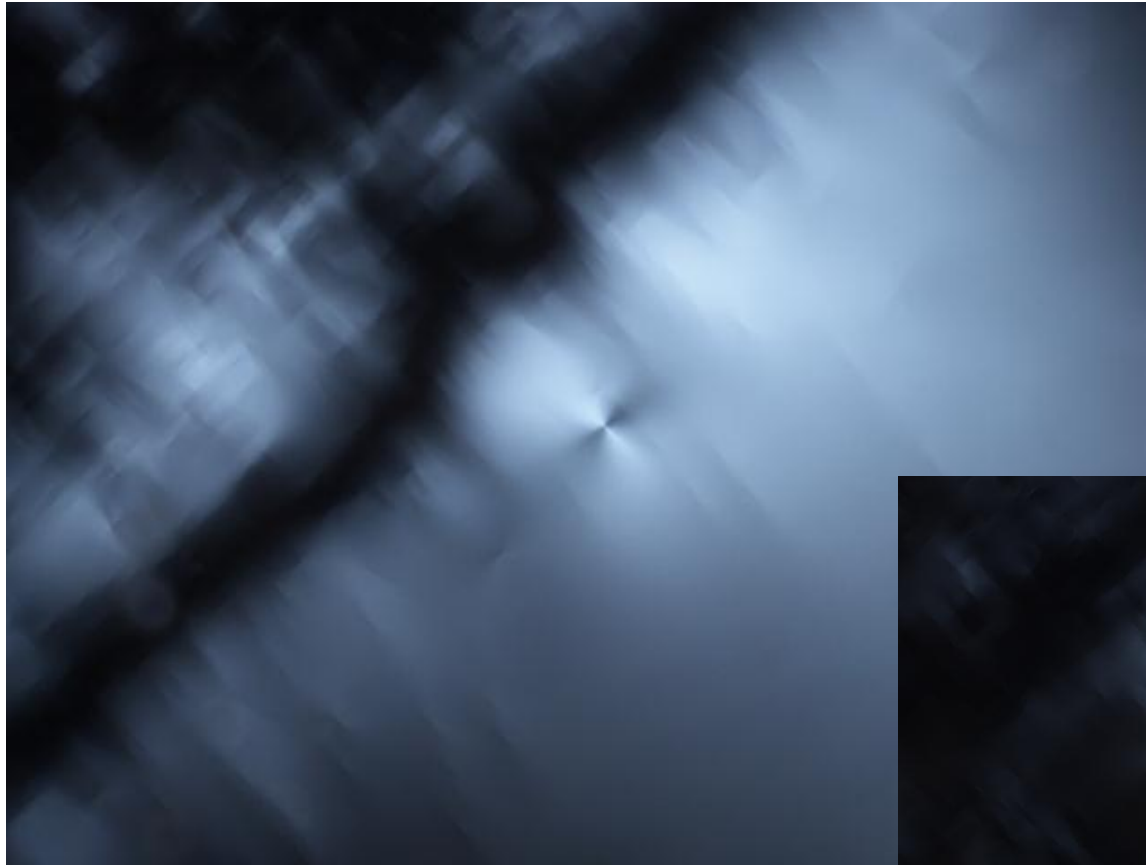
Testing

Conclusion

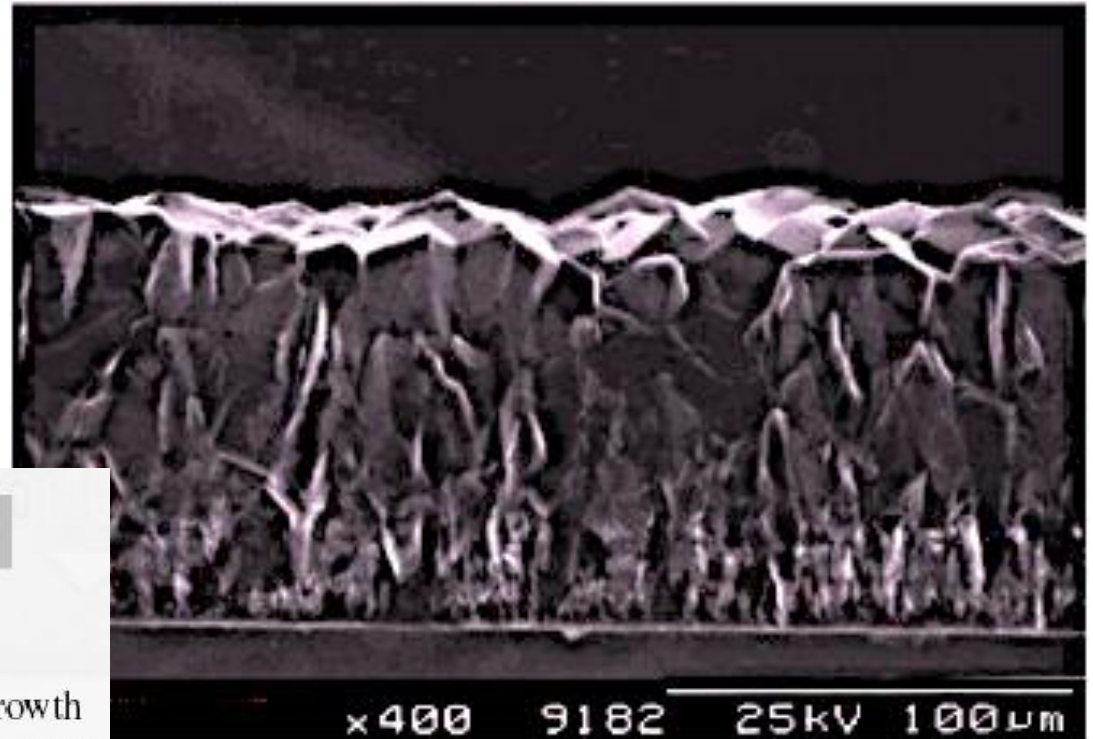
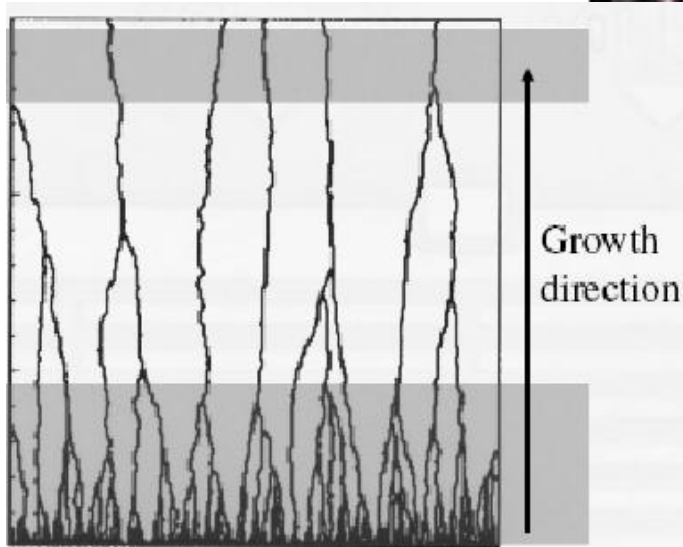
Why Diamond?

Advantages		Limitations
Band gap = 5.5 eV  Low leakage current		13.6 eV required to create e-h pair  Low signal
Dielectric constant = 5.7  Low capacitance		Single crystal samples small in size.
Breakdown field = 10^7 V/m  Operation at high voltage		Single crystal diamond is currently expensive.
Thermal conductivity $> 1800 \text{ cm}^{-1}\text{W}^{-1}$  Operation without cooling		
Displacement energy = 43 eV  Radiation tolerant		

Single Crystal Diamond

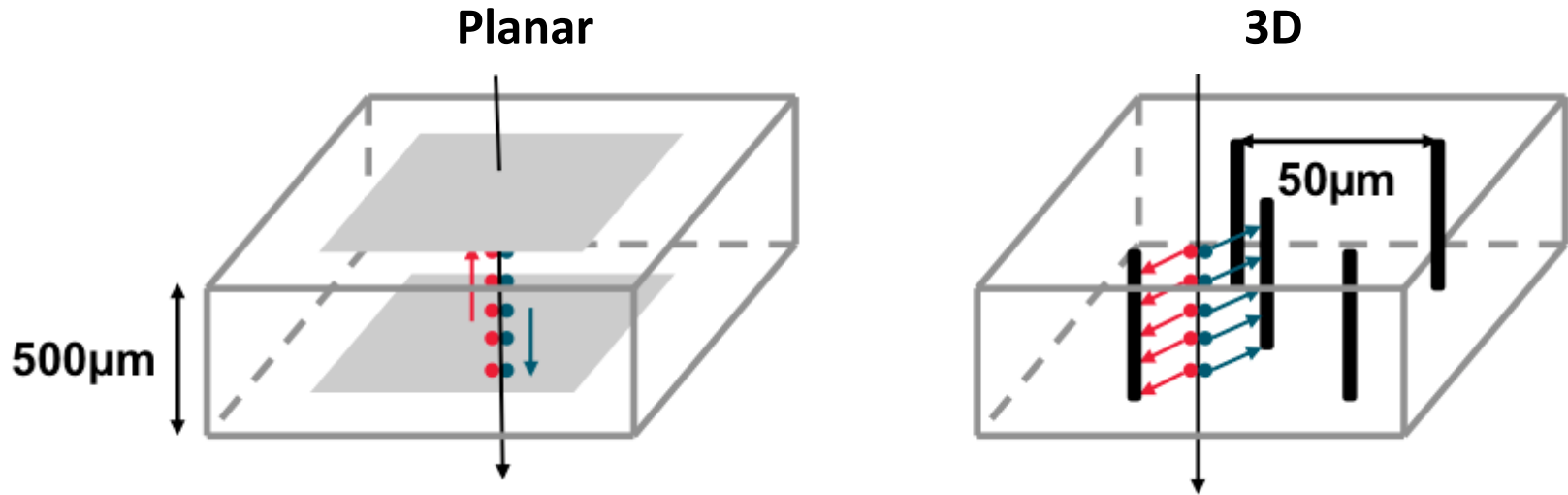


Polycrystalline Diamond



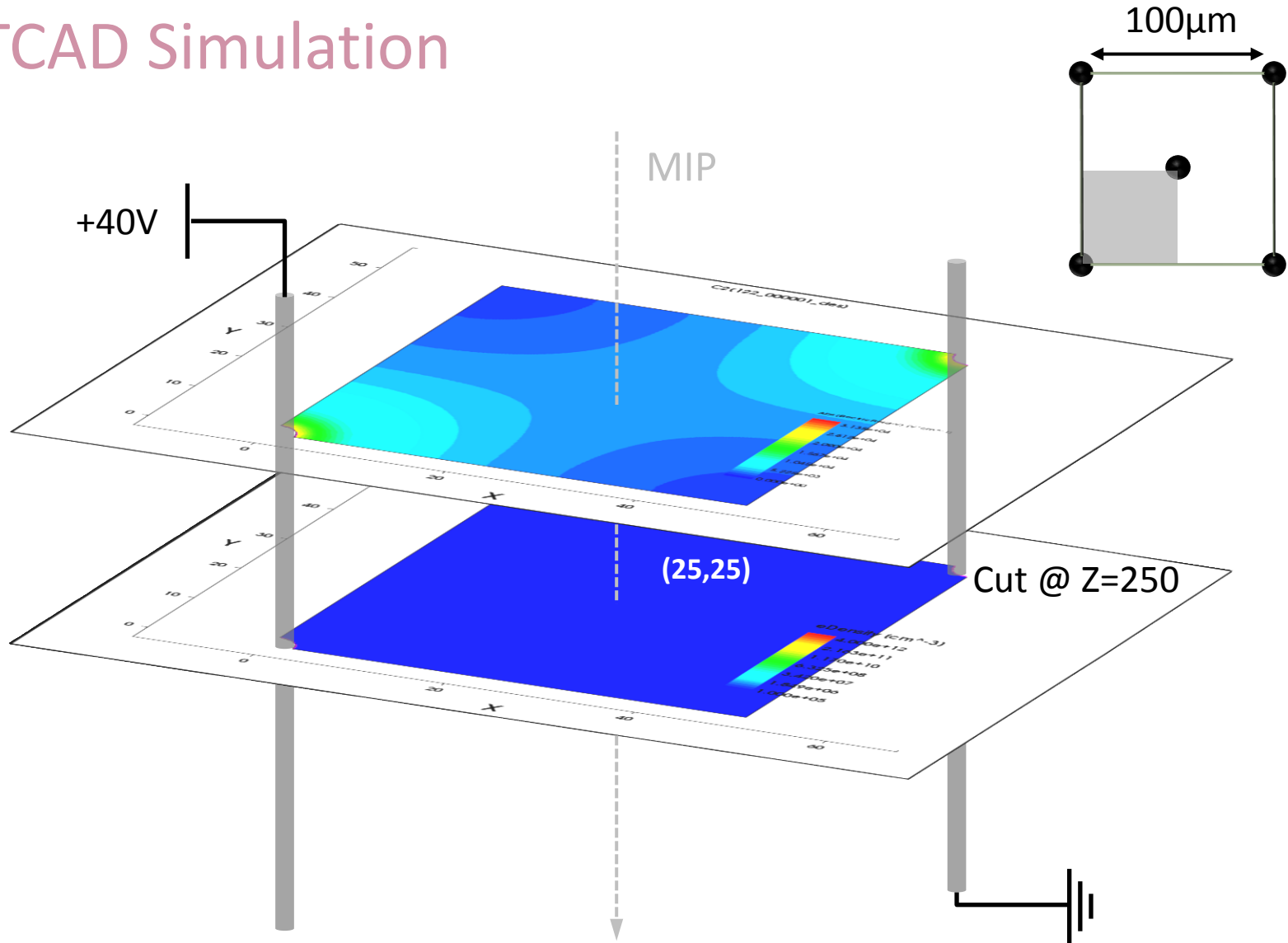
[1] P.W.May, DRM, V19, I5-6,p369-396, 2009

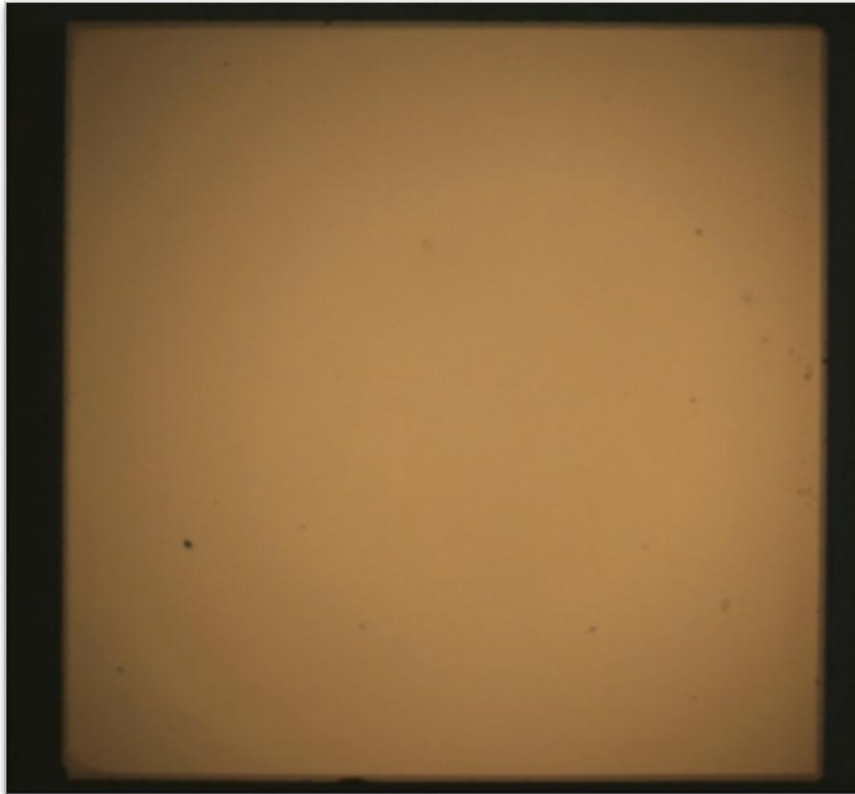
Why 3D?



Drift distance comparable to mean free path of charge carriers in irradiated diamond.

TCAD Simulation

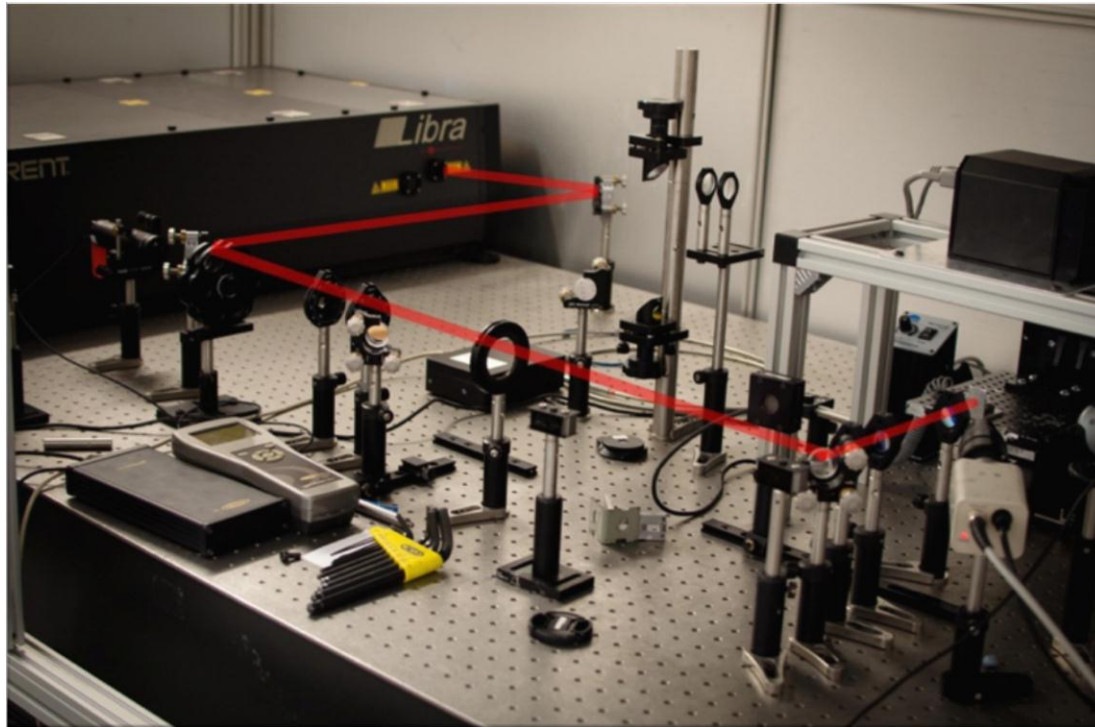




Surface
Treatment

Column
Drilling

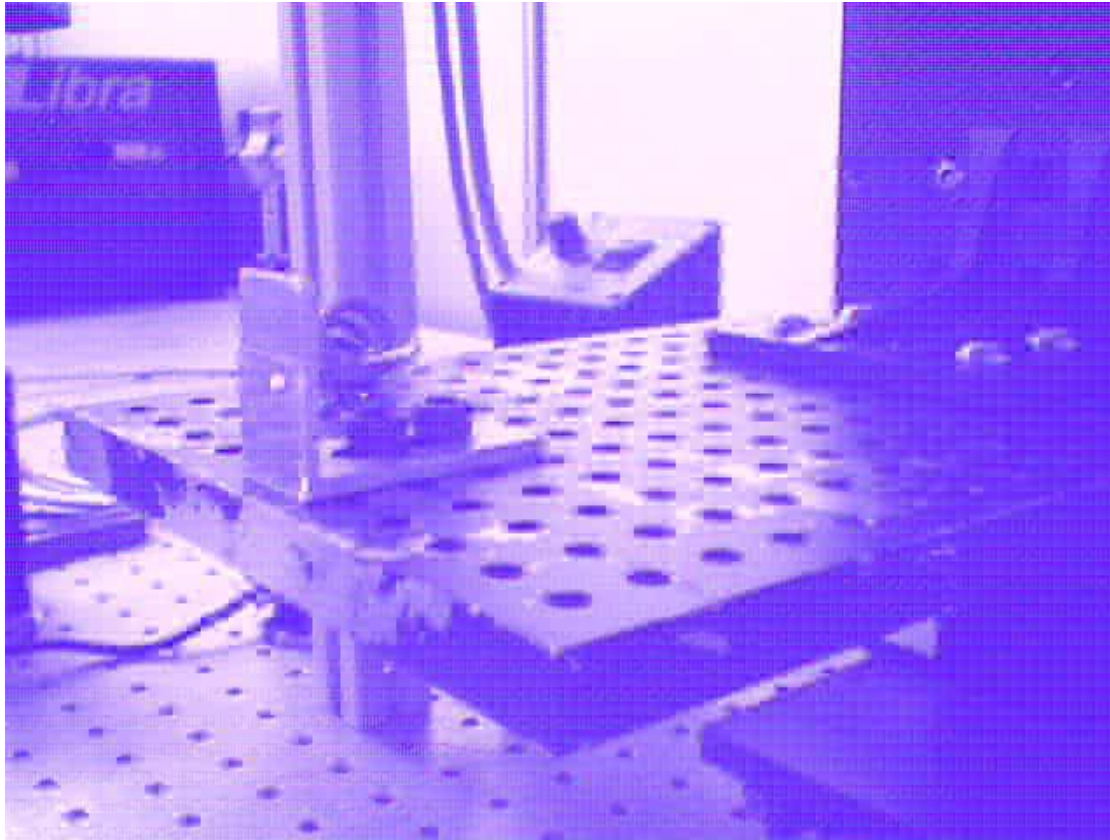
Metalising



Surface
Treatment

Column
Drilling

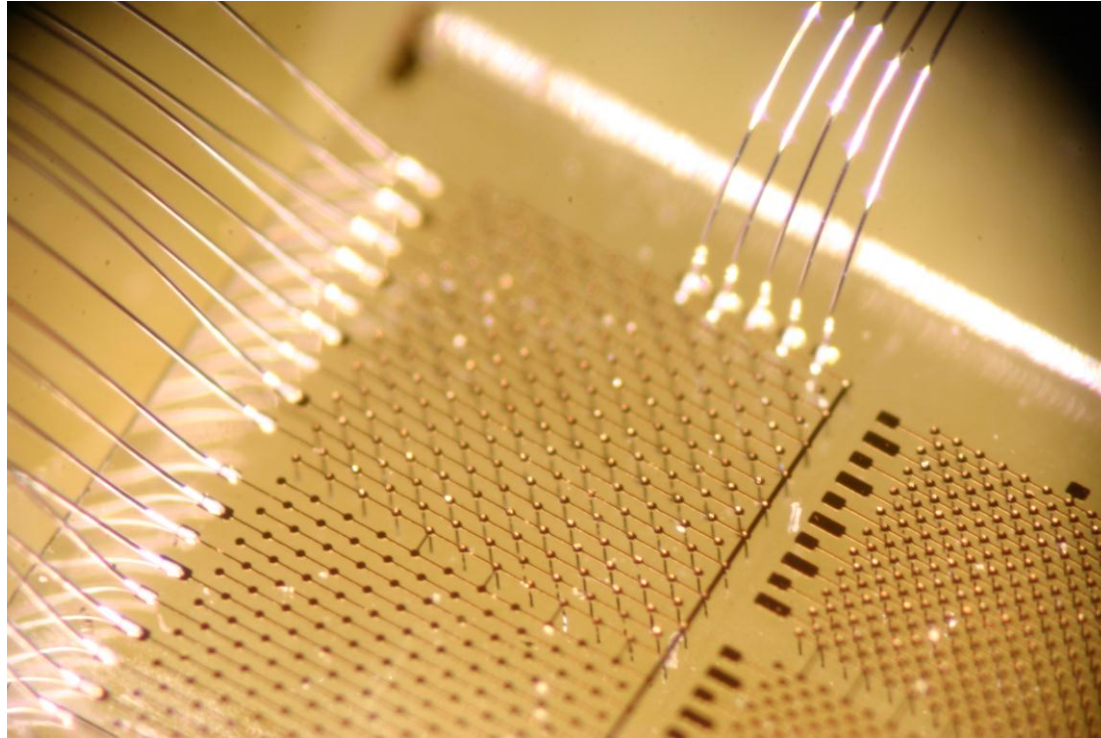
Metalising



Surface
Treatment

Column
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Metalising

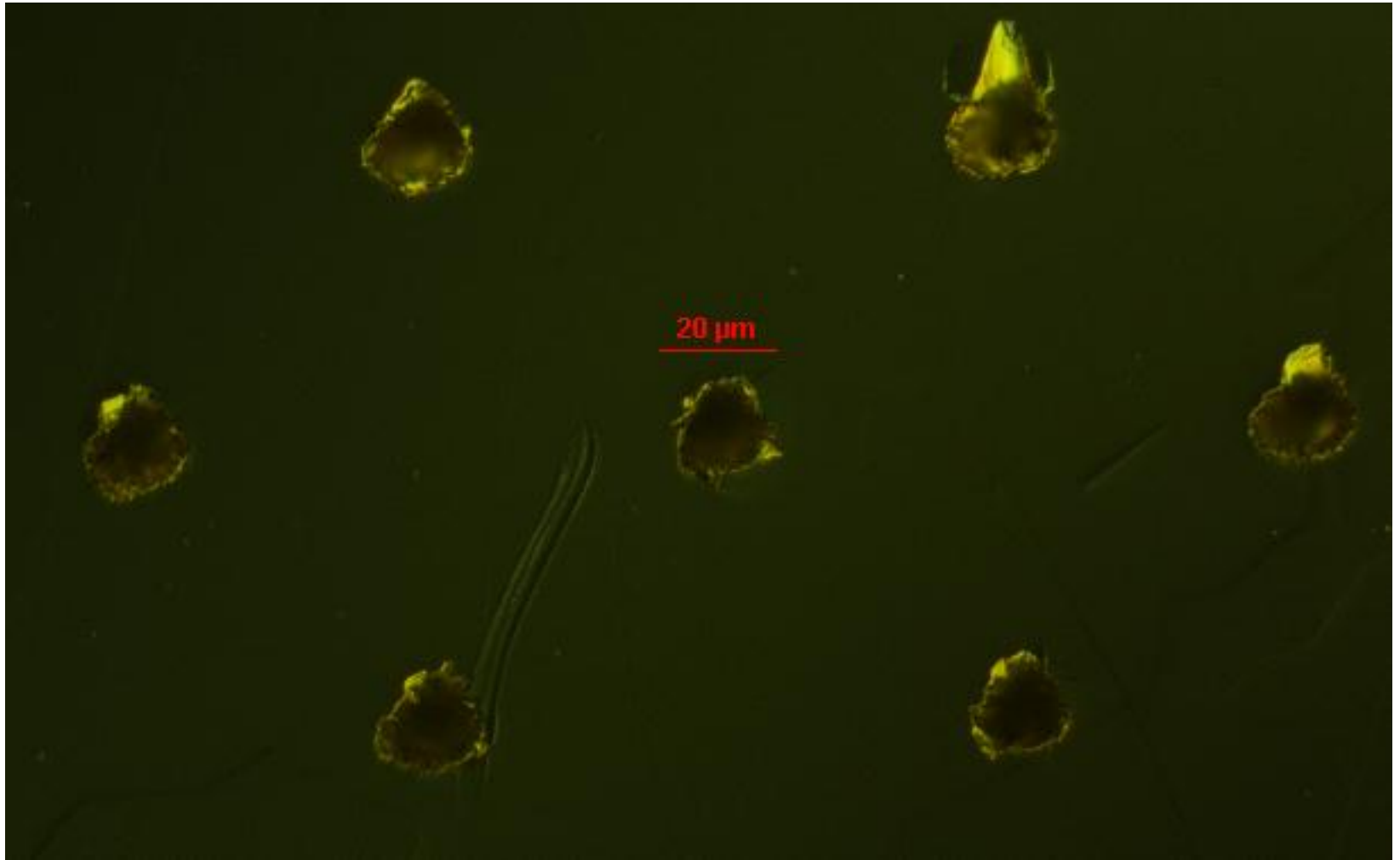


Surface
Treatment

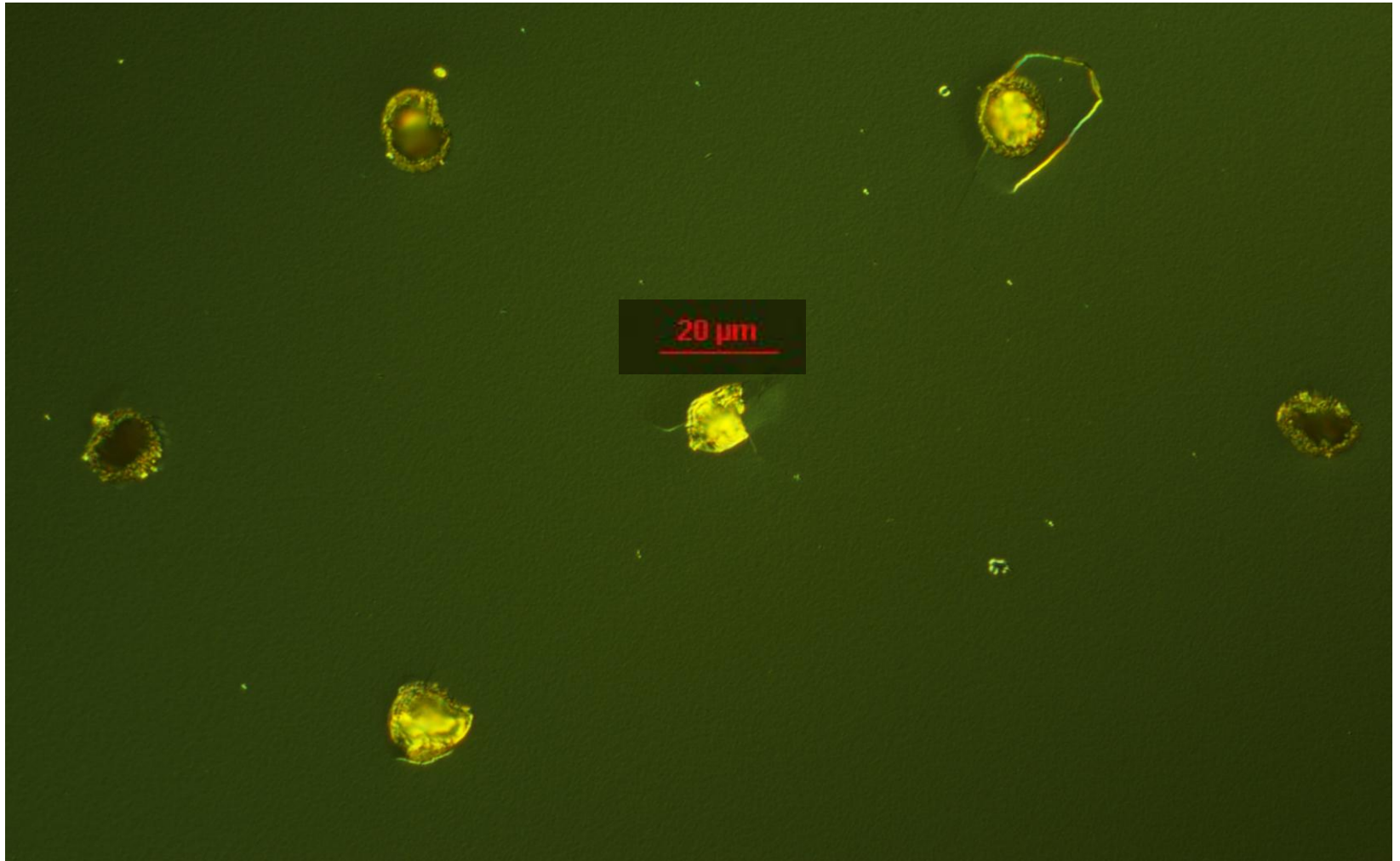
Column
Drilling

Metalising

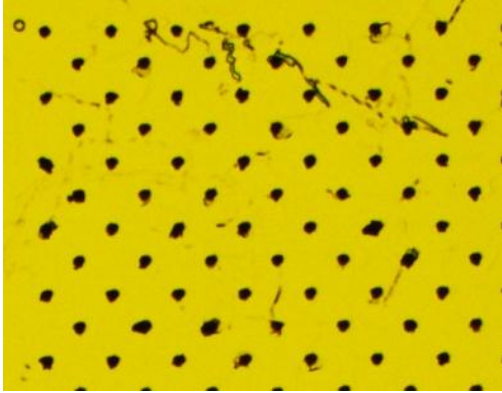
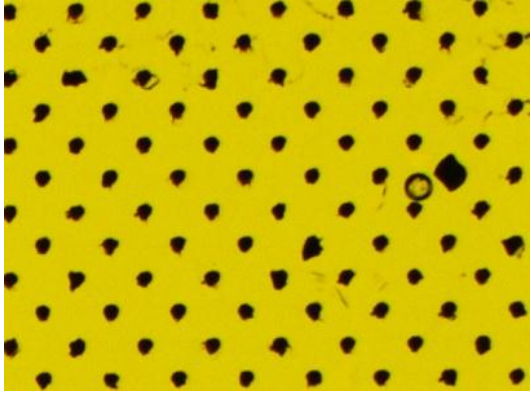
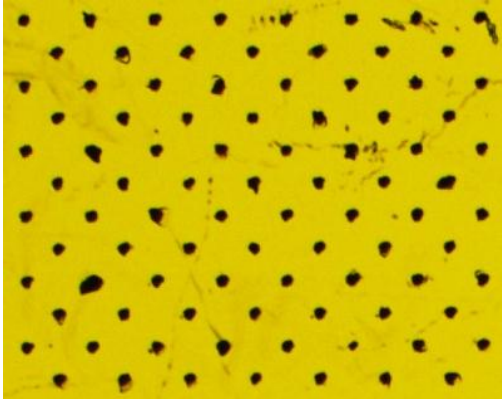
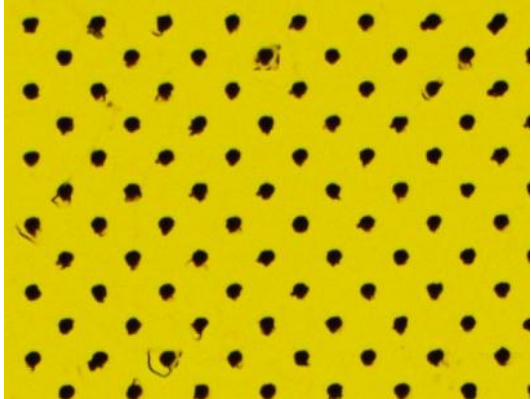
Seed Side




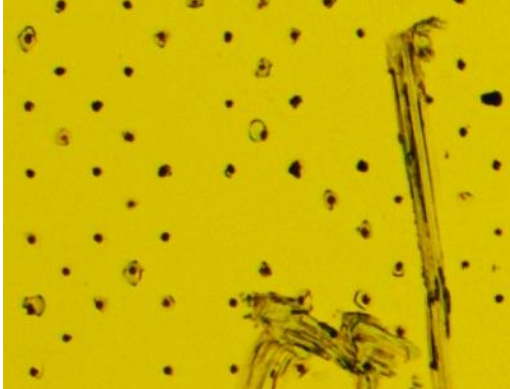
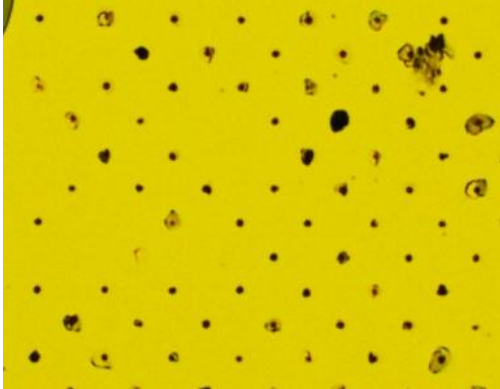
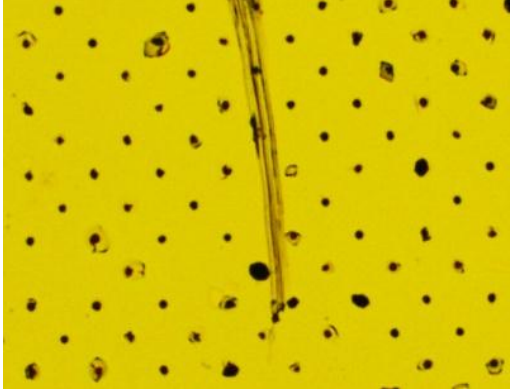
Exit Side



Seed Side

	Low Power	High Power
Low Speed		
High Speed		

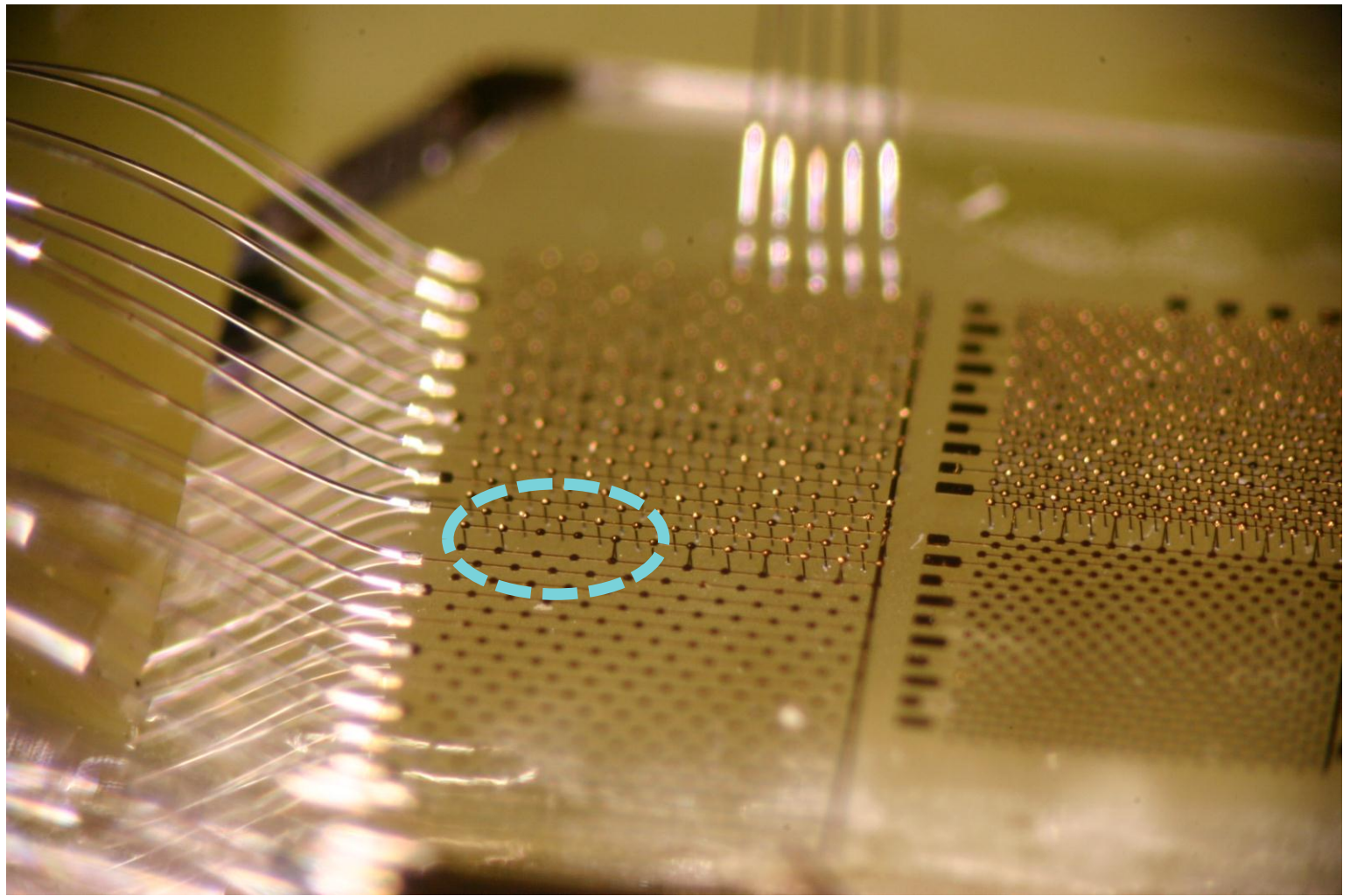
Exit Side

	Low Power	High Power
Low Speed		
High Speed		

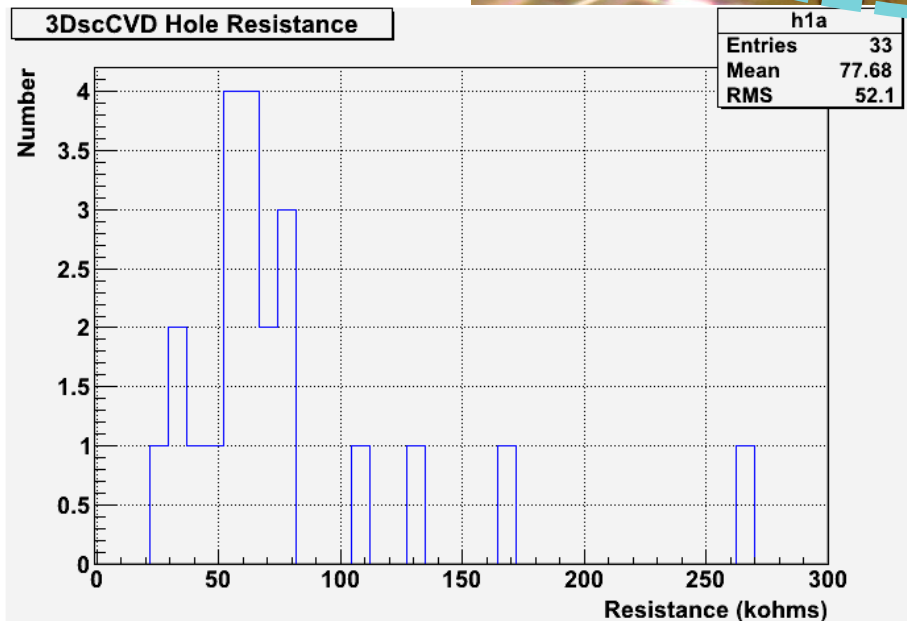
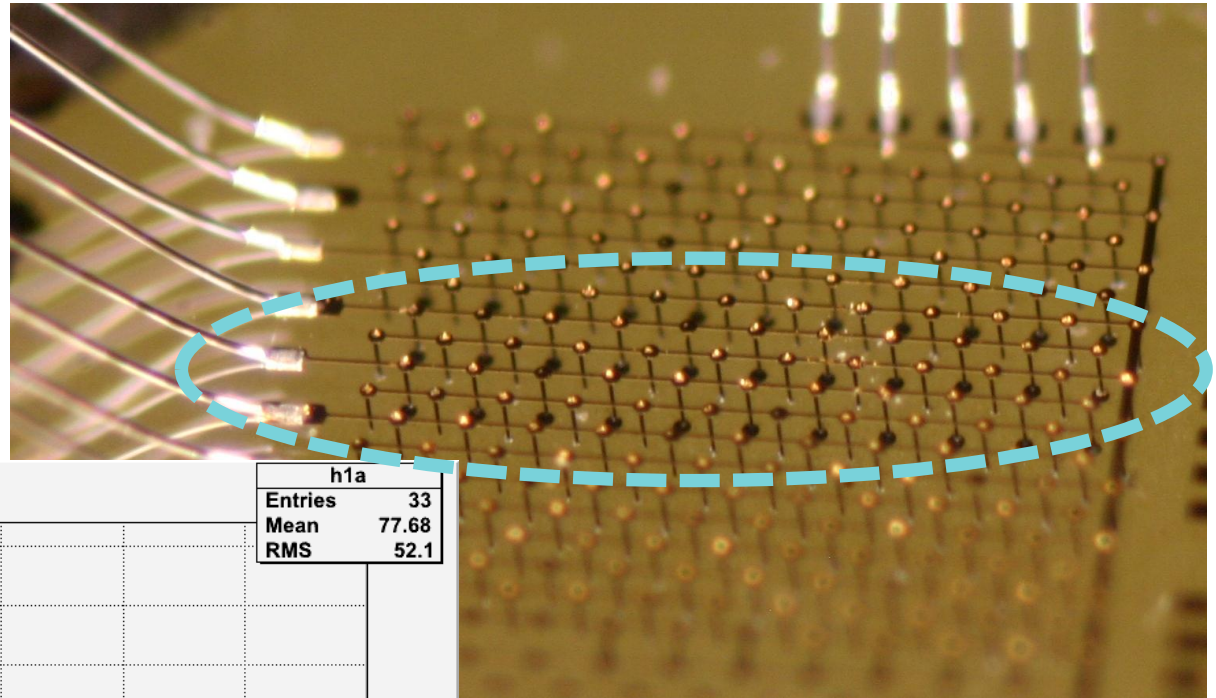
Column Success

	Low Power	High Power
Low Speed	92%	81%
High Speed	94%	89%

Missing Columns

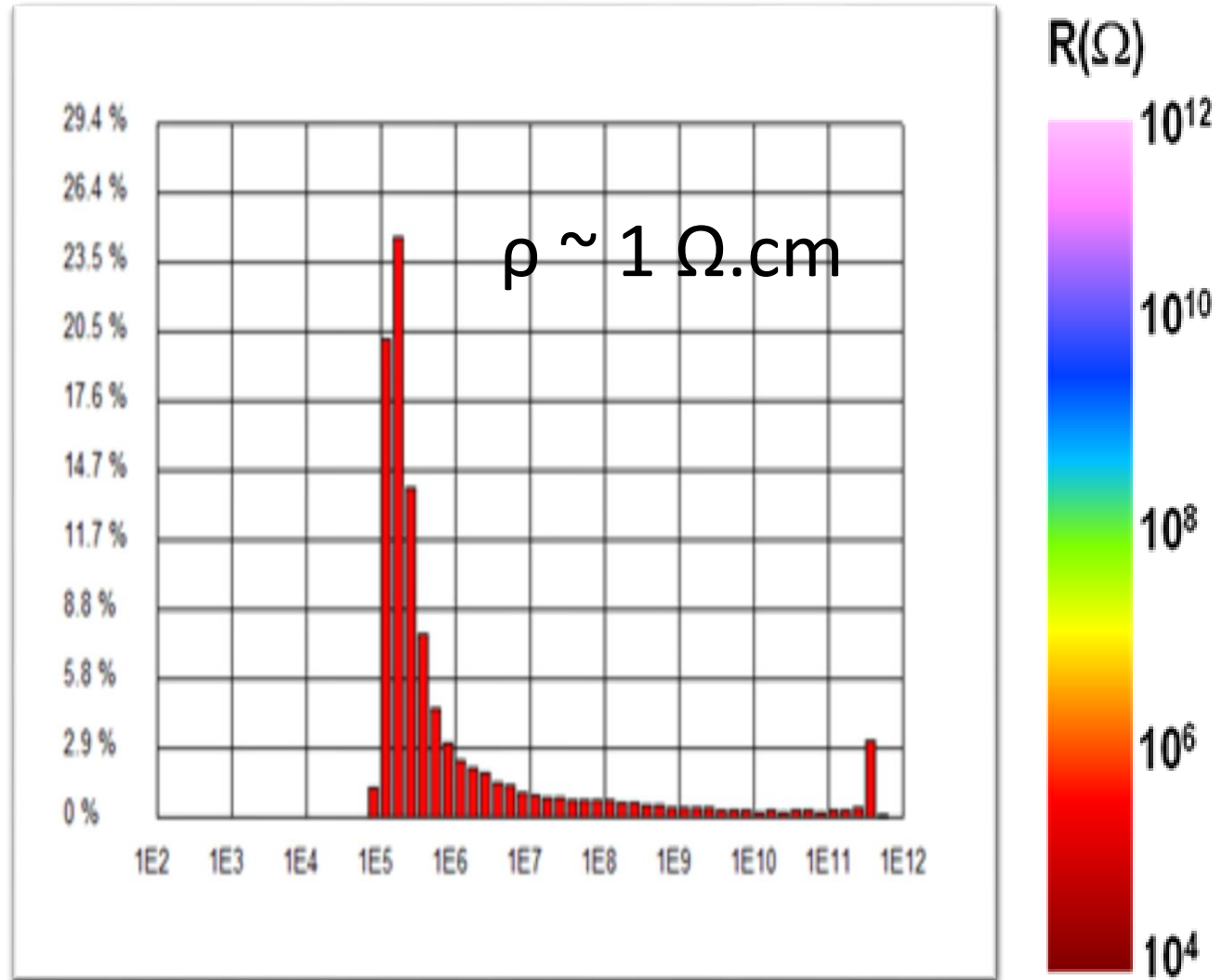


Column Resistance: Contact

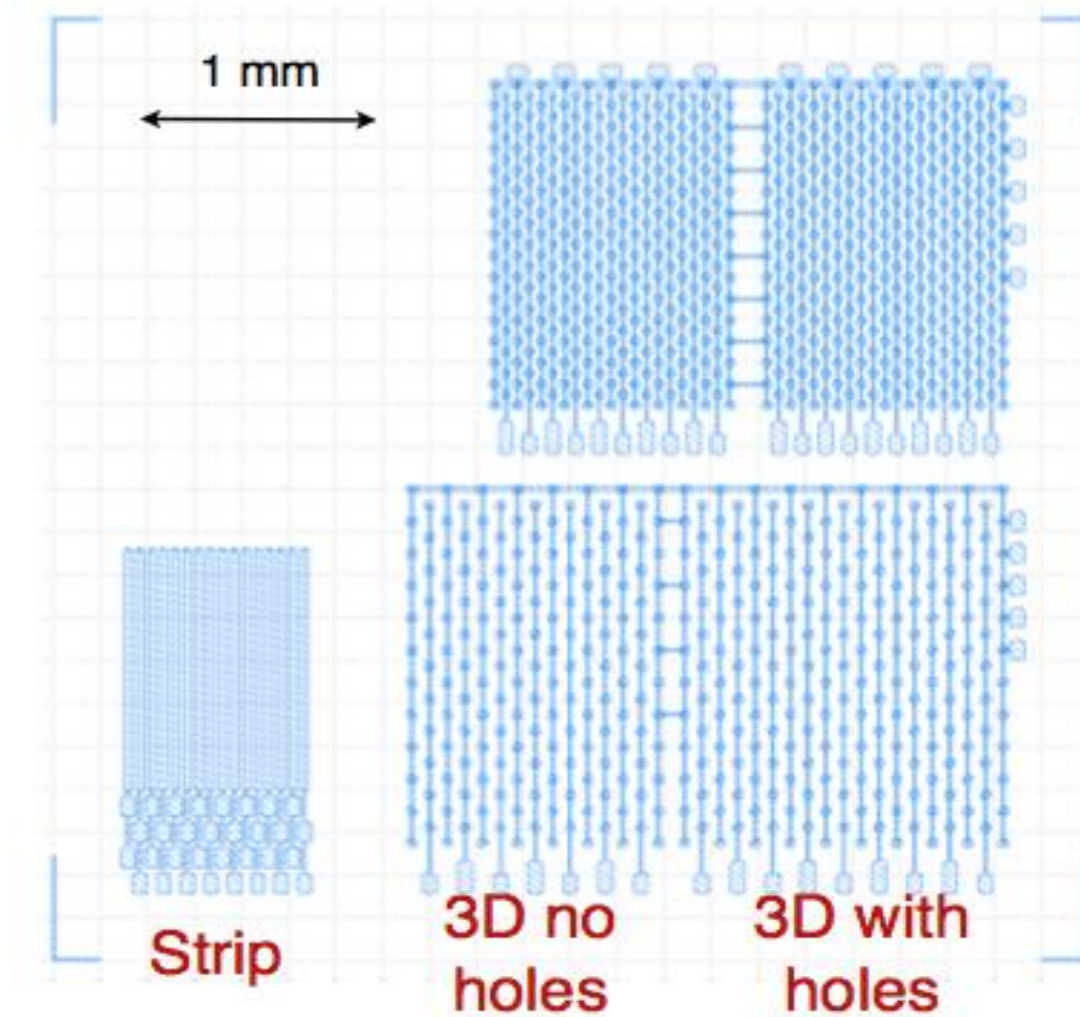


$$\rho \sim 1 \Omega \cdot \text{cm}$$

Column Resistance: AFM

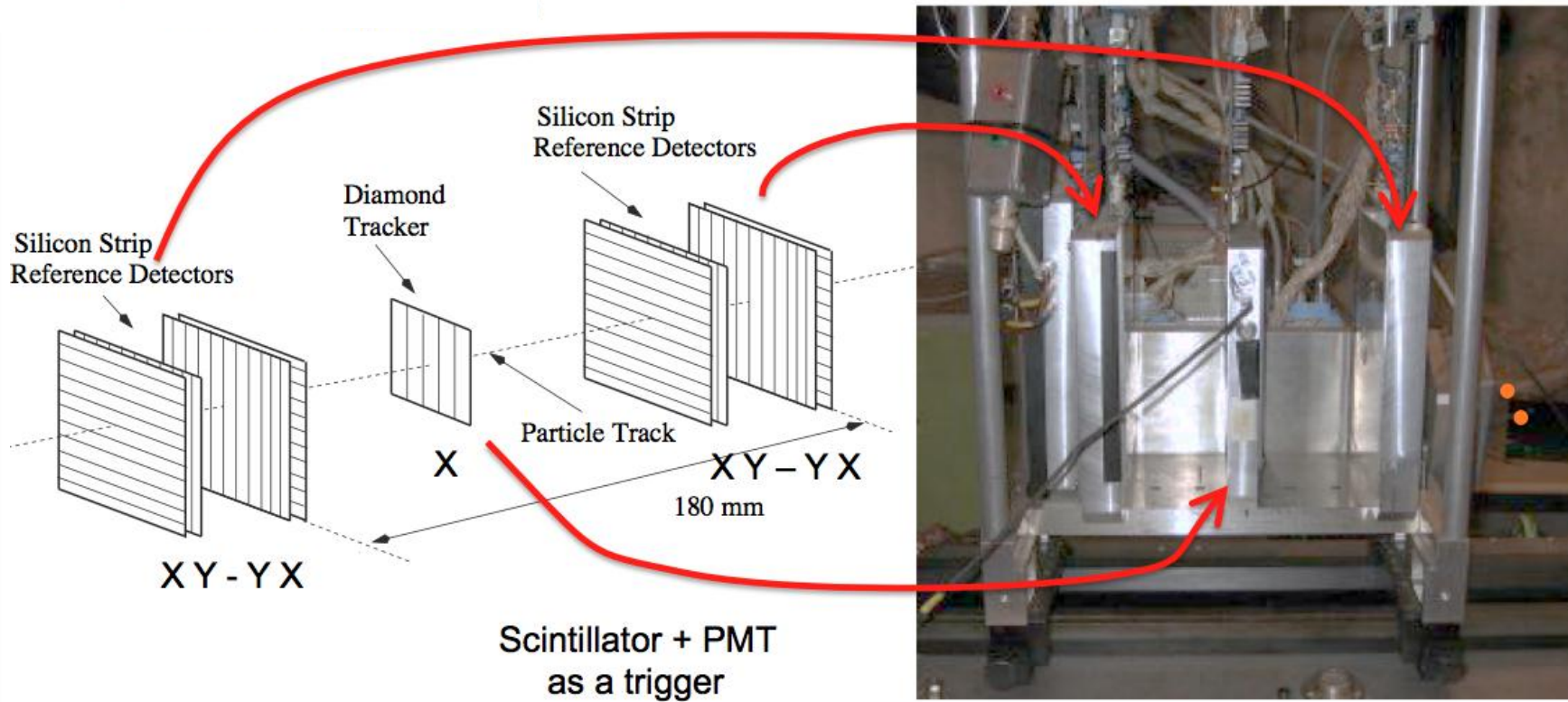


CERN Test beam

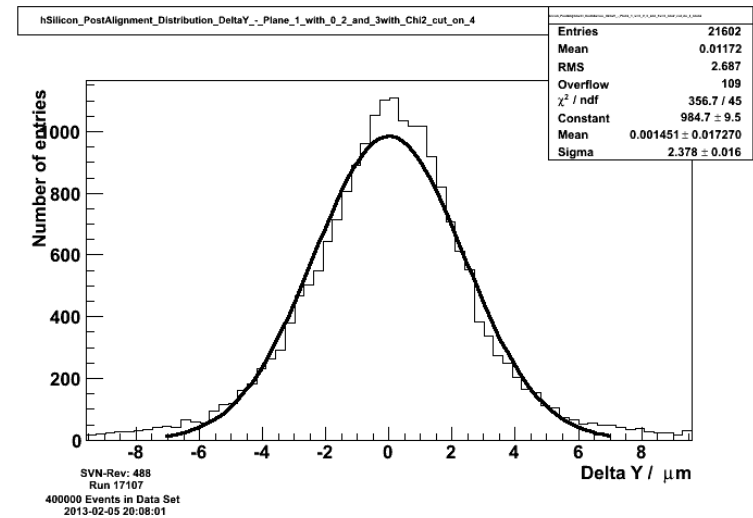
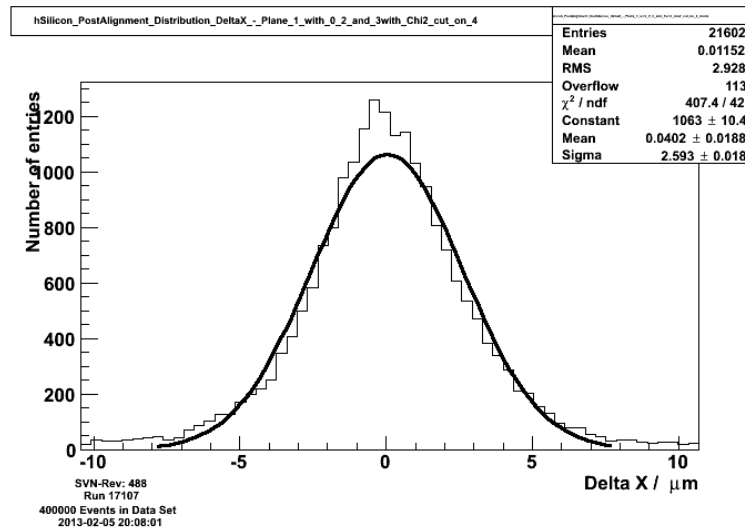
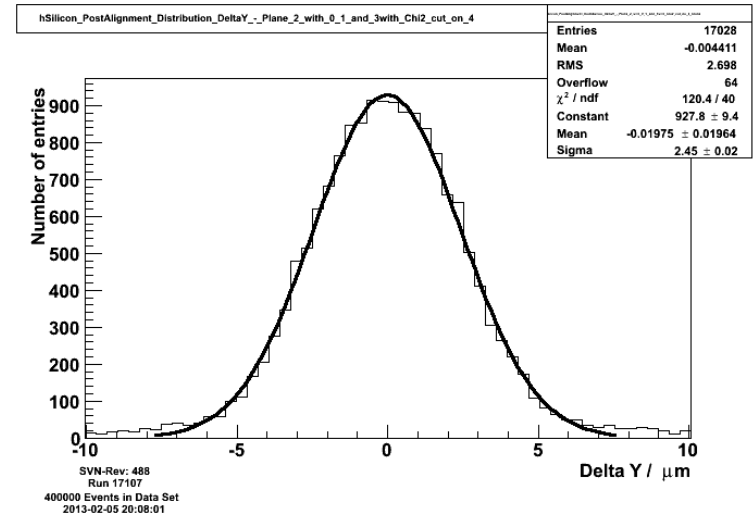
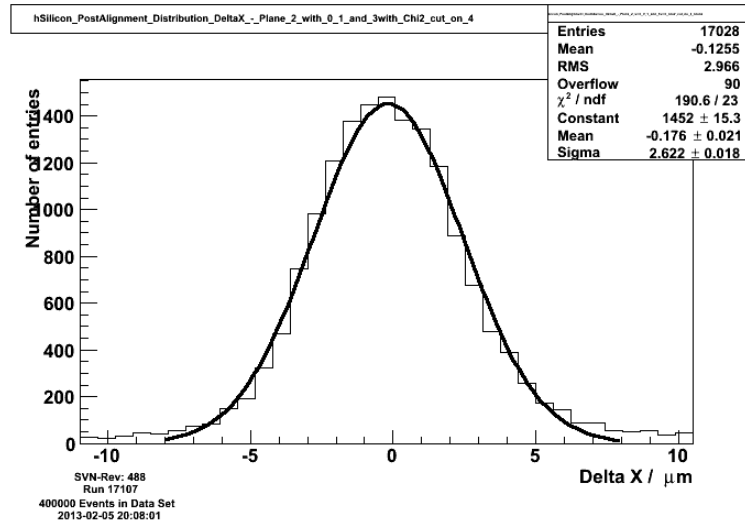


CERN Test beam

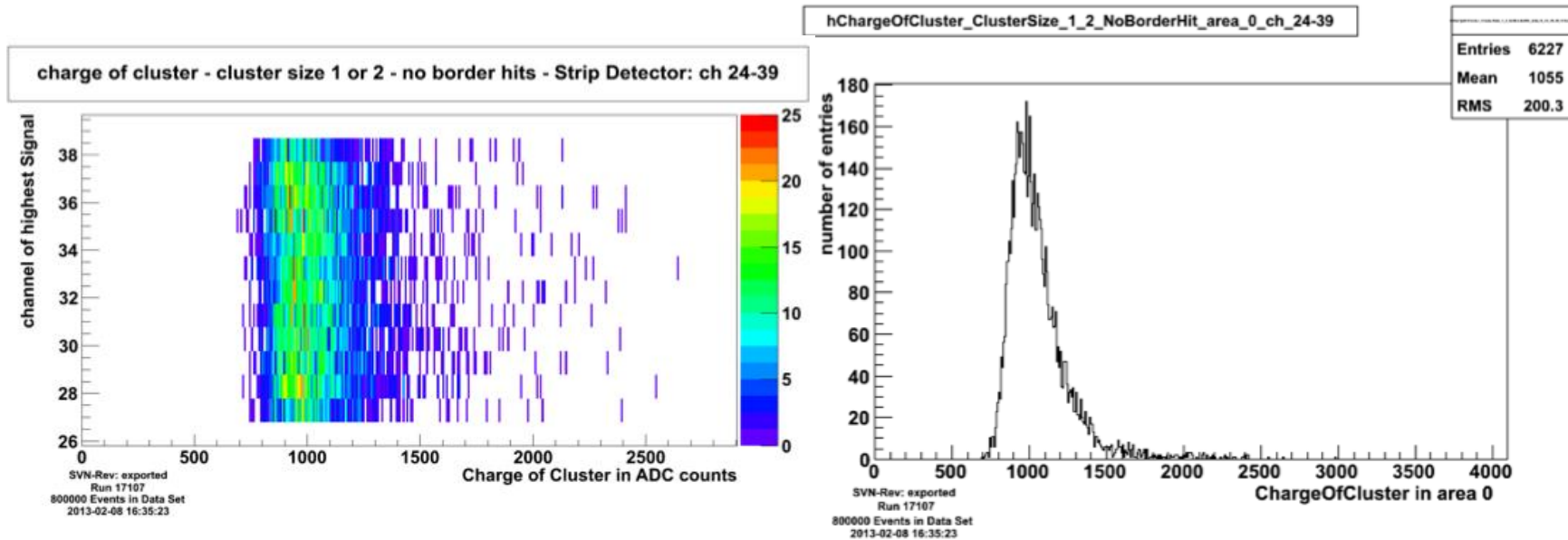
- Using Strasbourg strip telescope in H6A (NA – SPS) with 120 GeV protons.
- Require one and only one hit in each silicon plane.



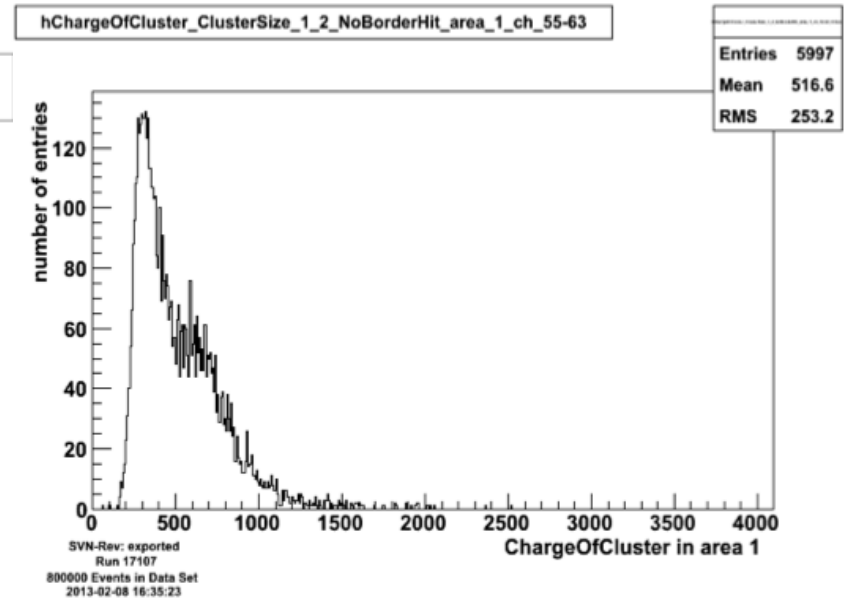
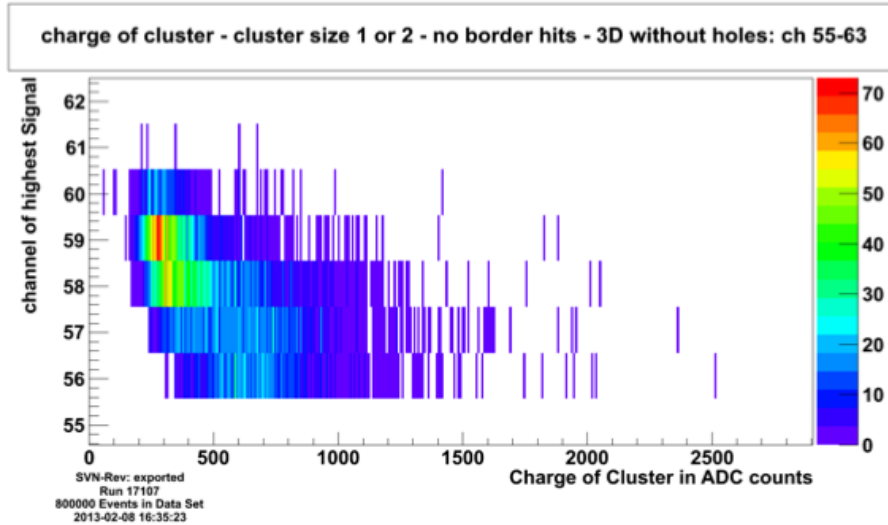
CERN Test beam



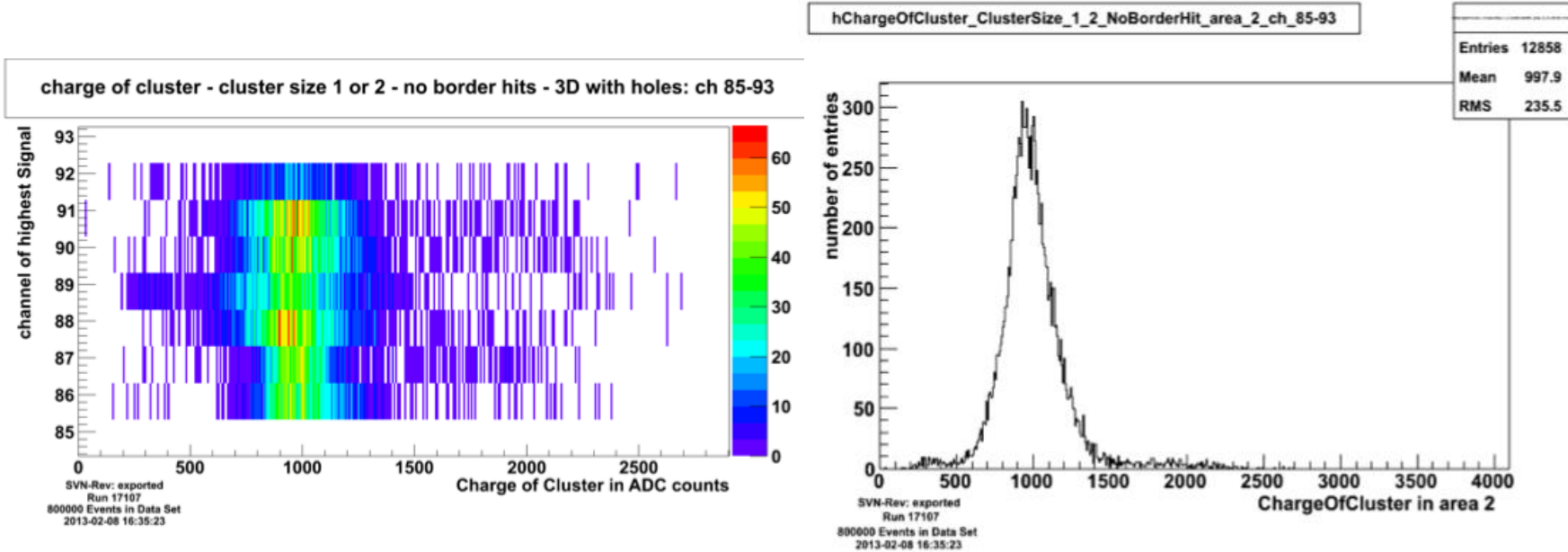
Strip Detector



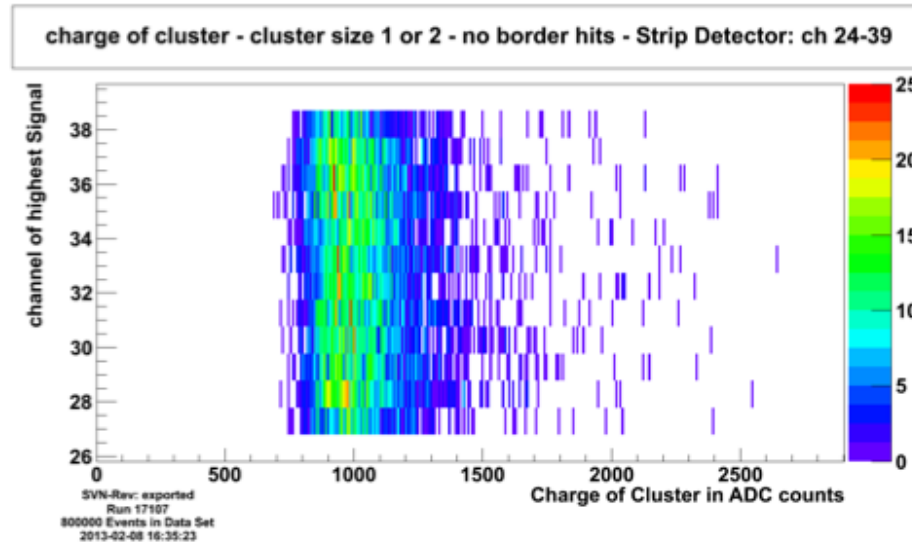
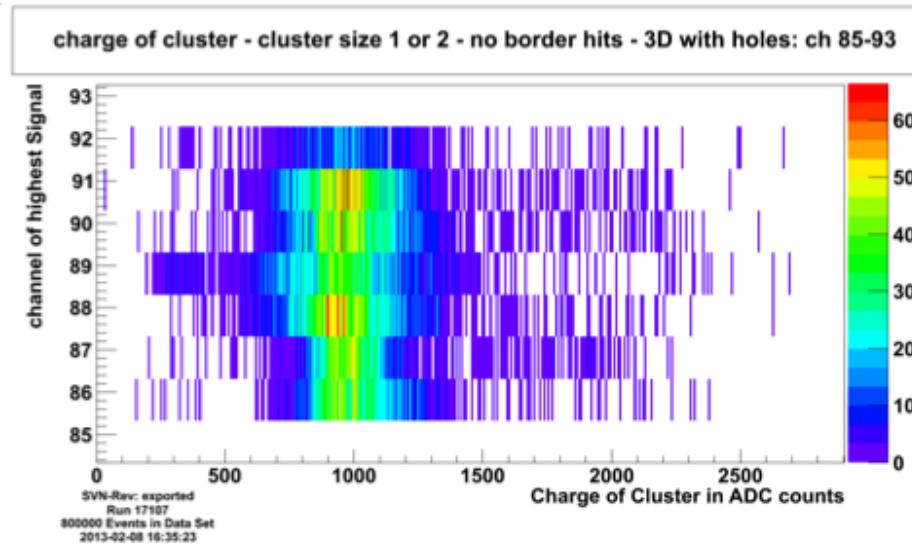
3D No Holes



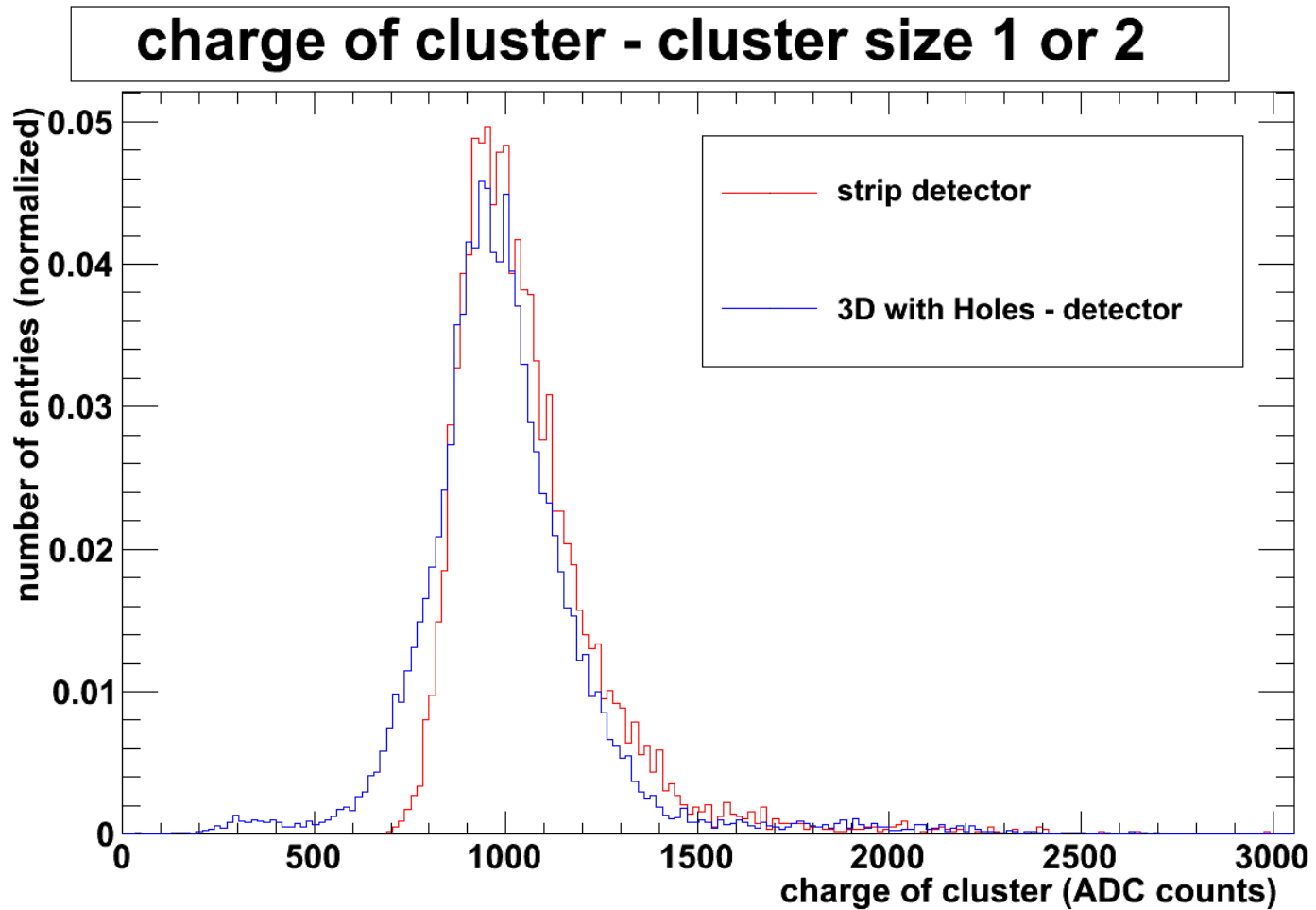
3D With Holes



Strip vs 3D



Strip vs 3D



Conclusion

- Produced conducting columns within diamond bulk.
- Achieved > 98% success rate in column drilling.
- Success in metalisation and column contact.
- Test beam results → columns collect > 95% charge.
- Regions of slightly lower charge collection
→ looking into with simulations.
- Radiation tests to be done.