Diamond Detector Research at the University of Surrey

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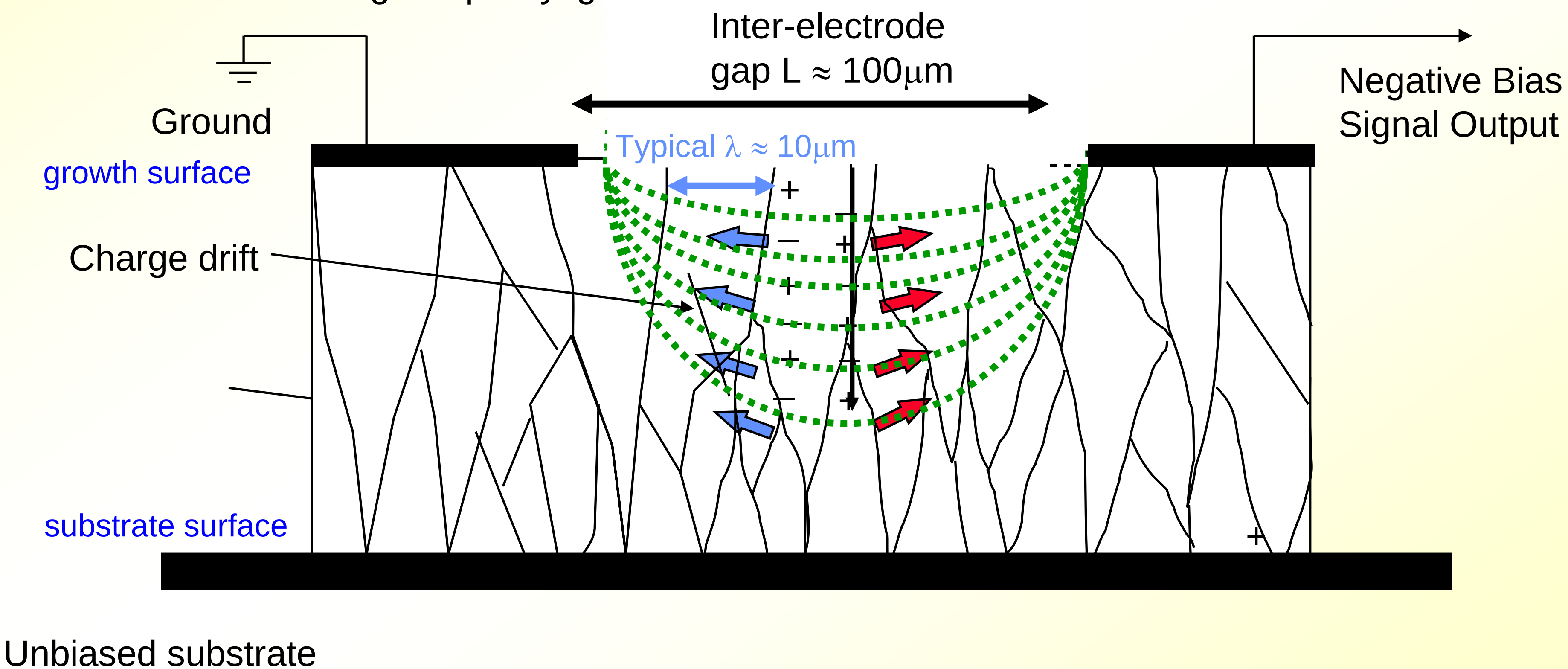
Polycrystalline CVD diamond

Polycrystalline CVD diamond has been extensively studied by CERN, nuclear physics, and other University groups.

Main commercial supplier is De Beers – now Element Six Ltd.

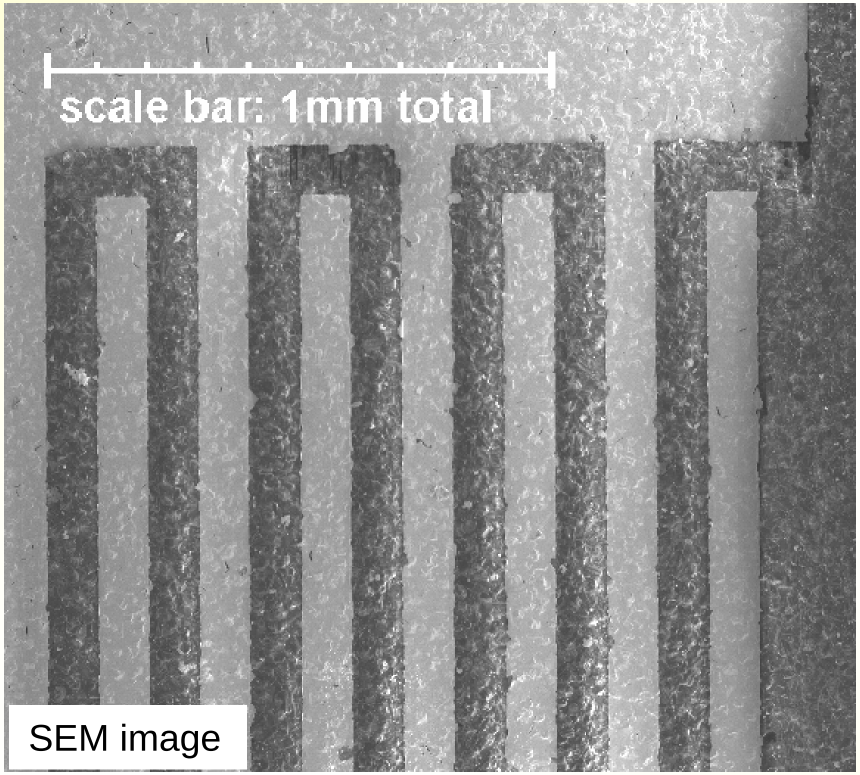
Free-standing diamond film, typical thickness 50 – 500µm, area 10x10mm upwards

We have studied performance of coplanar diamond devices, where the active layer is closer to the higher quality ‘growth’ surface.

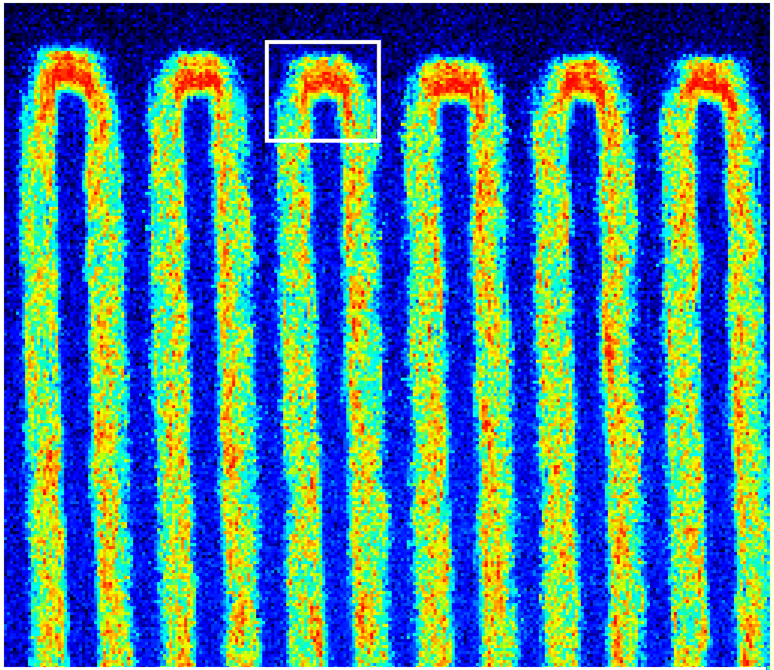


Ion Beam (IBIC) imaging with 2 MeV protons

Focused ion beam maps show 'hot spots' at electrode tips due to concentration of the electric field



SEM image

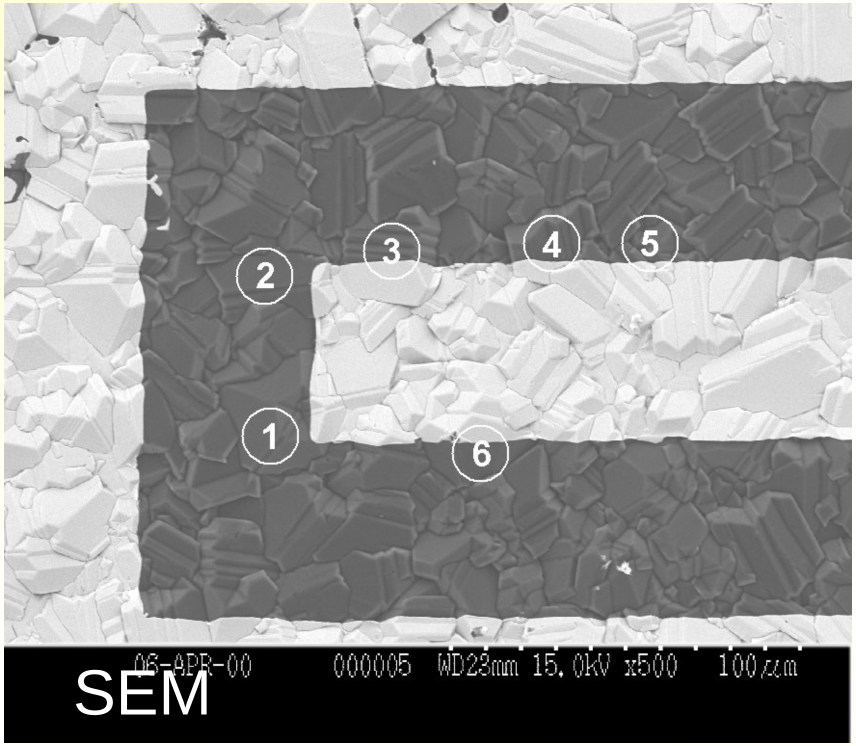


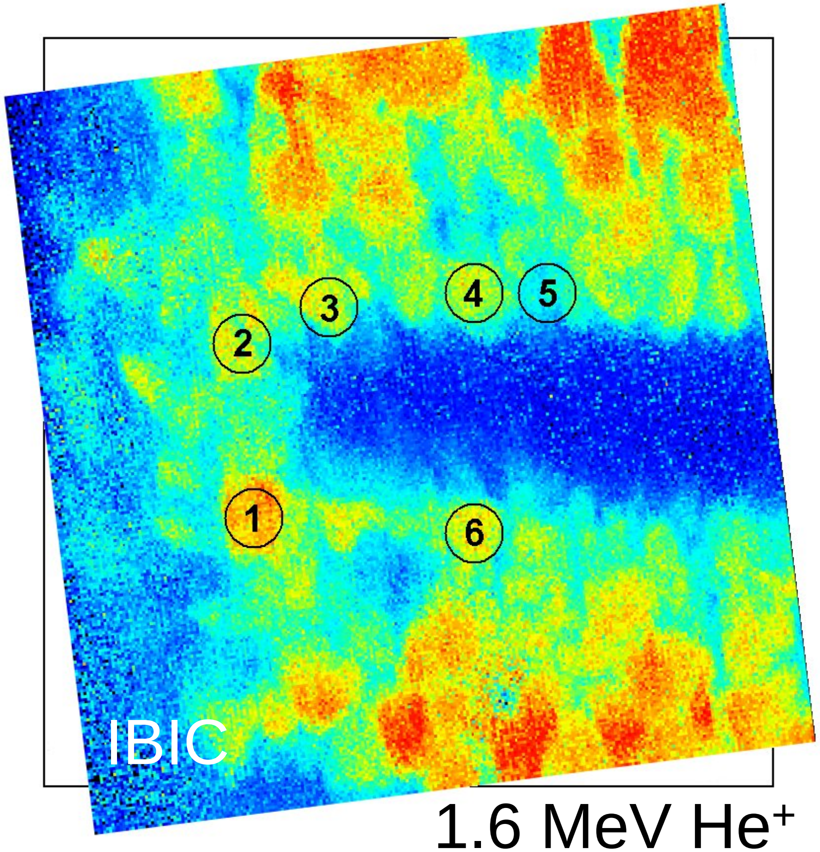
Ion beam map of signal amplitude (red = high, blue=low)

Poor charge collection under each electrode is due to reduced electric field typical of the coplanar electrode structure ⇒ not a useful device for spectroscopy

Correlation of SEM images with ion beam maps

Focused ion beams are used to correlate individual crystallite structures from SEM images with charge maps – maximum charge amplitude is observed from the largest crystallites



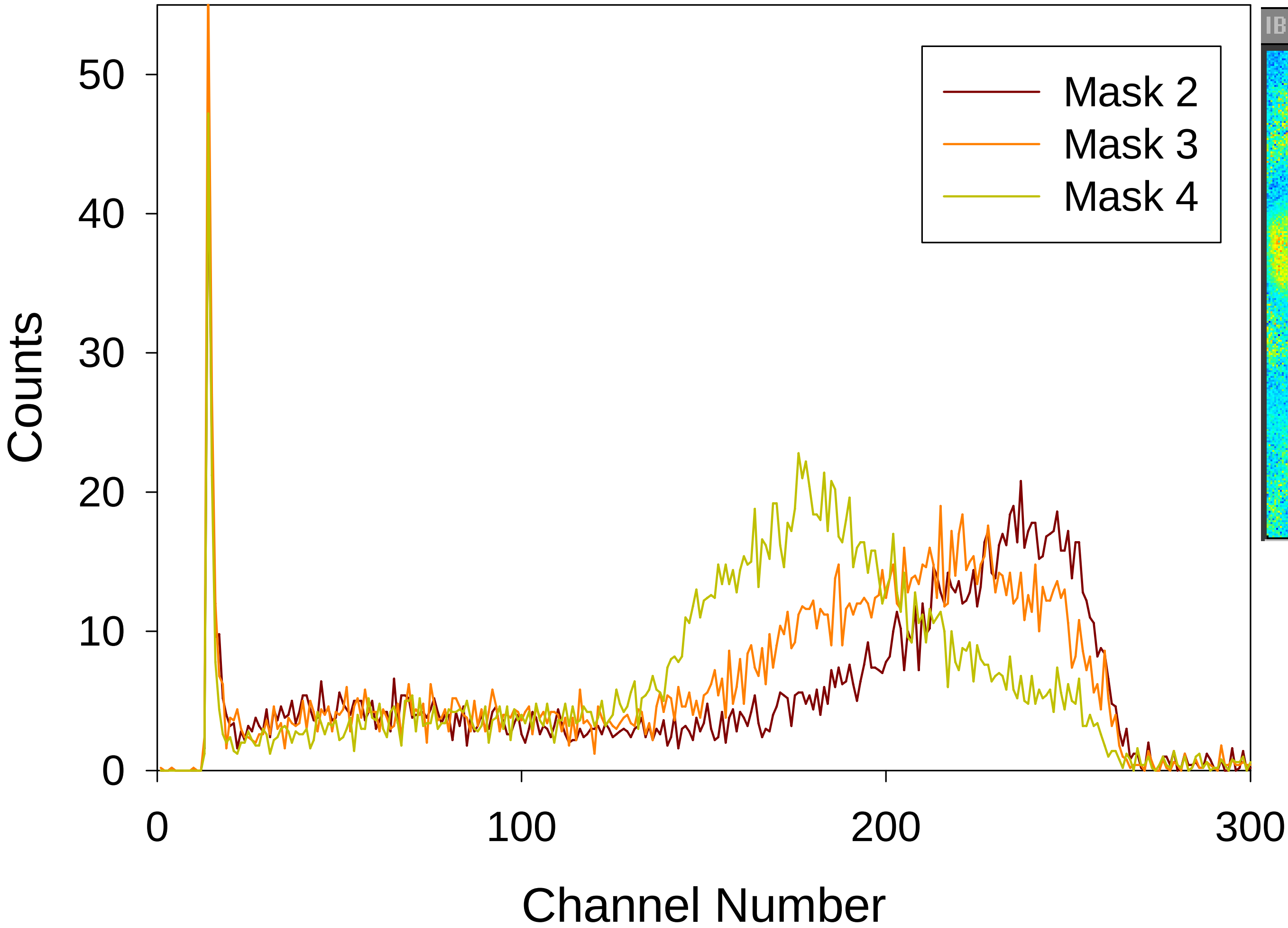


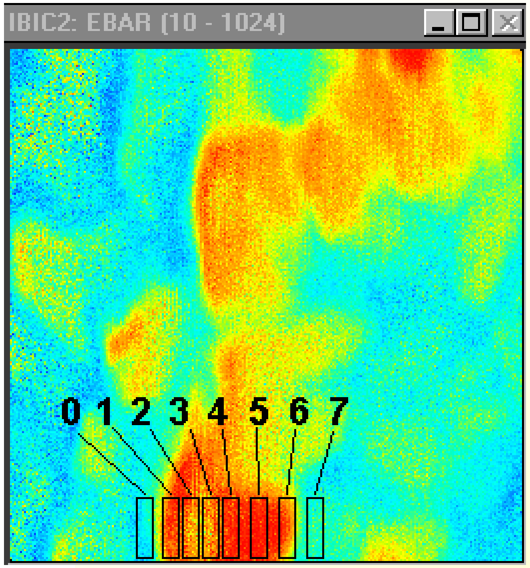
1.6 MeV He^+

PJ Sellin et al, Applied Physics Letters 77/6 (2000) 913-915

Pulse height spectra across a crystallite

Similar high resolution mapping can be used to study the variation of charge amplitude within different regions of a single diamond crystal

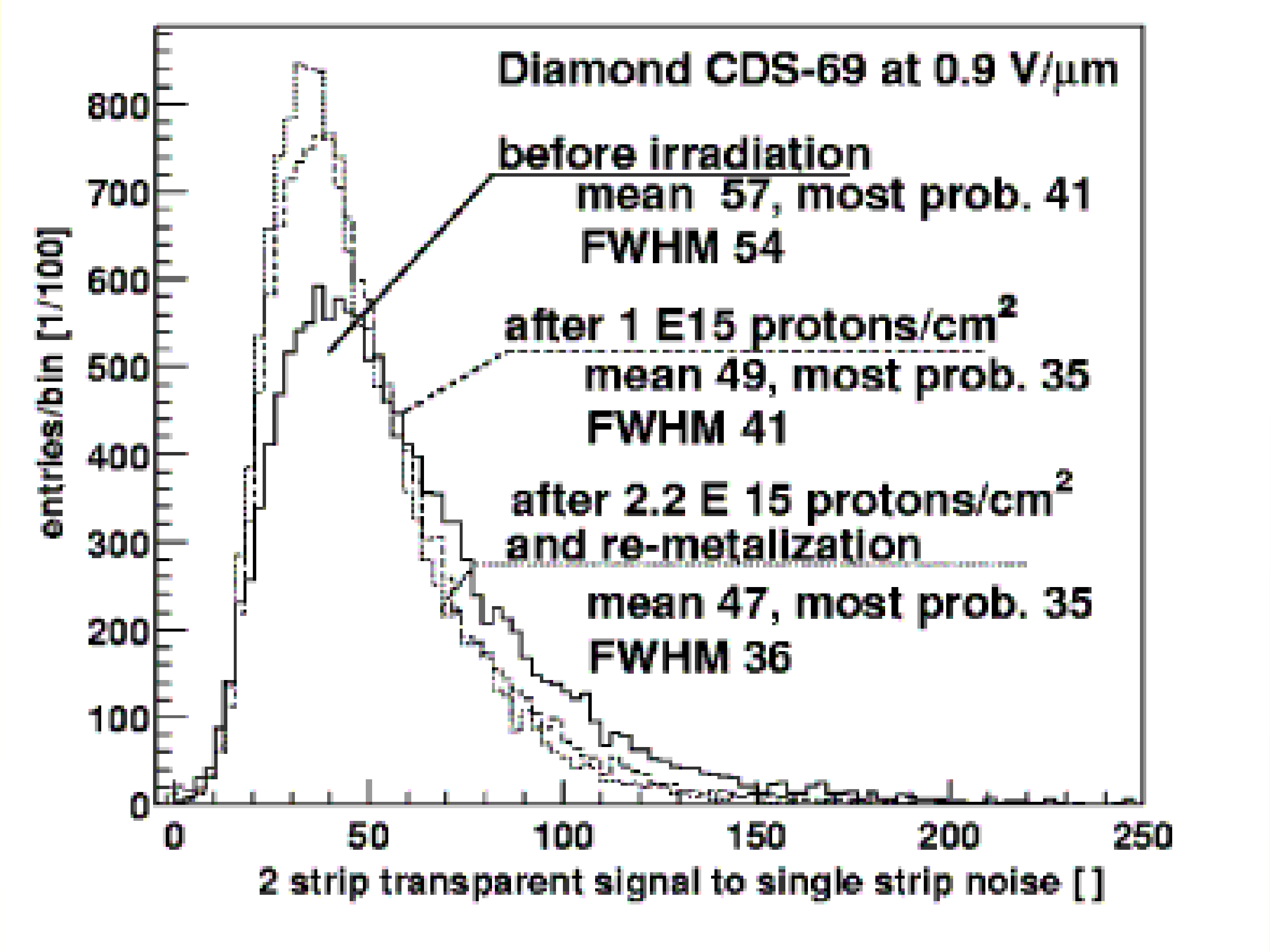




Regions 2 and 3 show the highest charge collection, and the best resolved peak.

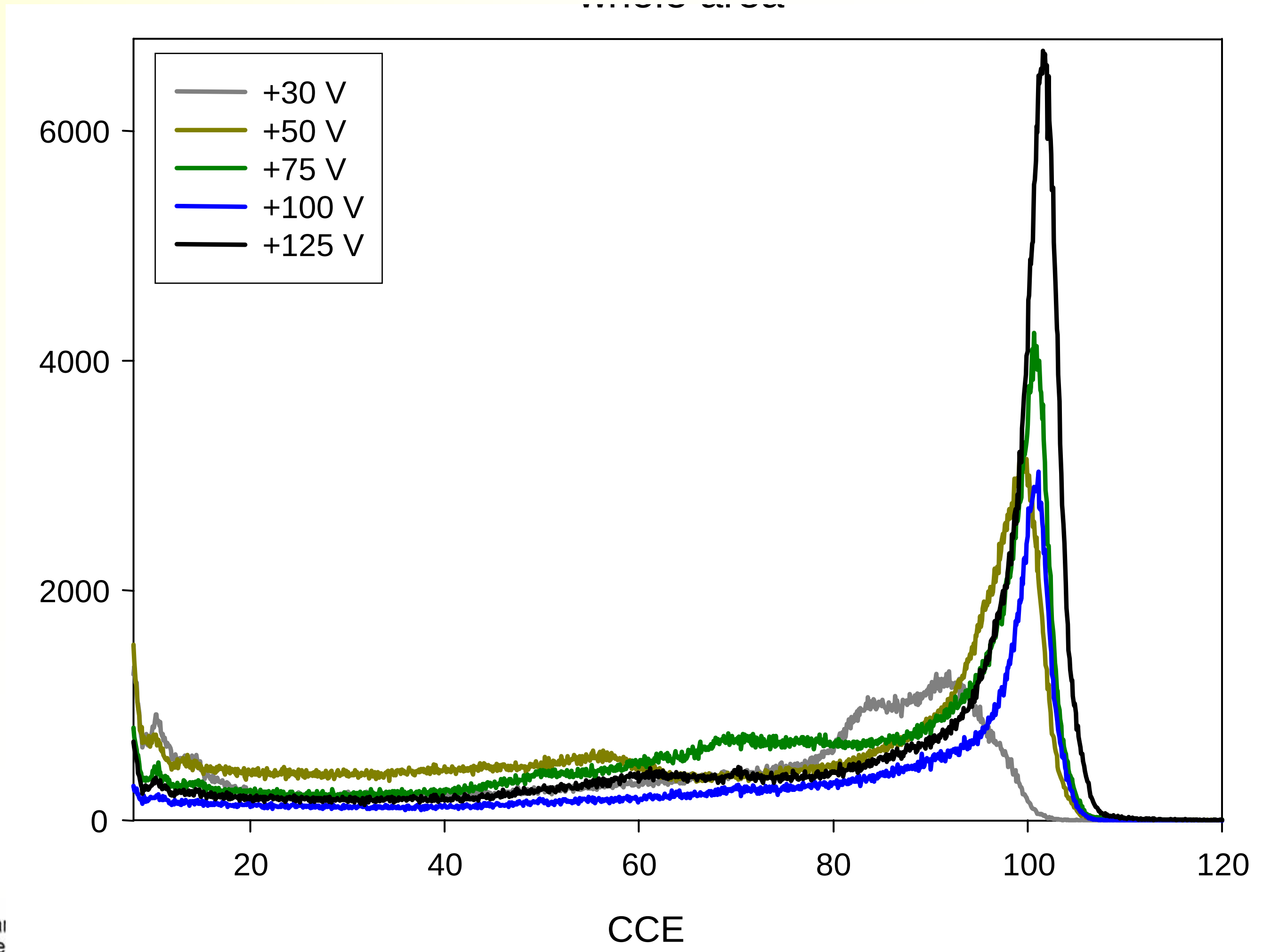
Radiation-hard diamond detectors at CERN

Minimum ionising particle (MIP) signal amplitude of polycrystalline CVD diamond, as a function of proton fluence (RD42):



100% charge collection from single crystal diamond

We have recently fabricated test devices from single crystal CVD diamond, which demonstrate excellent charge transport and 100% CCE. The material contains no grain boundaries over an area of 3x3mm.



Conclusions

- Polycrystalline CVD diamond devices have been extensively studied, with CCE values that are highly dependent on material quality and thickness.
- Free-standing polycrystalline material from 50 – 500μm thickness is now available, with areas of 10x10mm or higher.
- Element Six Ltd (De Beers) continues to be the dominant supplier of the best material.
- The CERN RD42 collaboration has demonstrated radiation hardness of diamond at $>2x10^{15}$ cm^{-2} for GeV protons.
- First measurements of single crystal diamond have demonstrated excellent response uniformity, minimal trapping effects, and 100% CCE.
- Surrey expects to work with Element Six in the next 2-3 years to develop single-crystal diamond devices of 5x5mm or larger.