CVD Diamond Sensors for the Beam Calorimeter of the ILC

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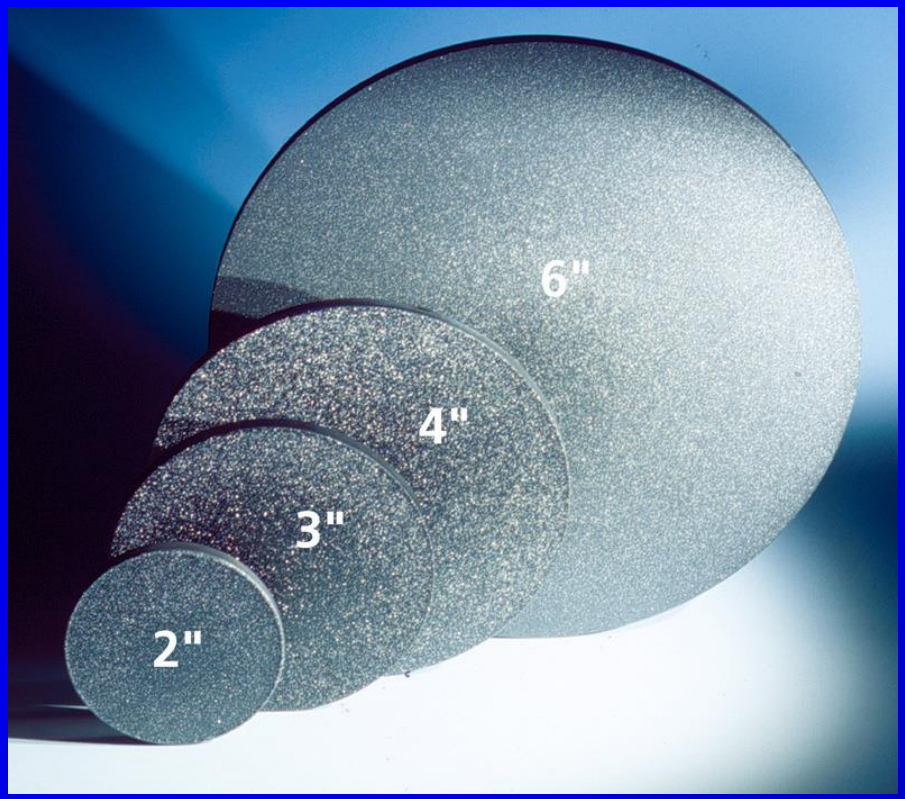
FCAL Collaboration Workshop

TAU, September 18-19, 2005

Outline

- Prototyping activities on diamond sensors:
  - FAP7 series from Fraunhofer IAF
  - E6_4p remetallized and CCD vs dose
  - FAP5
- Summary & outlook

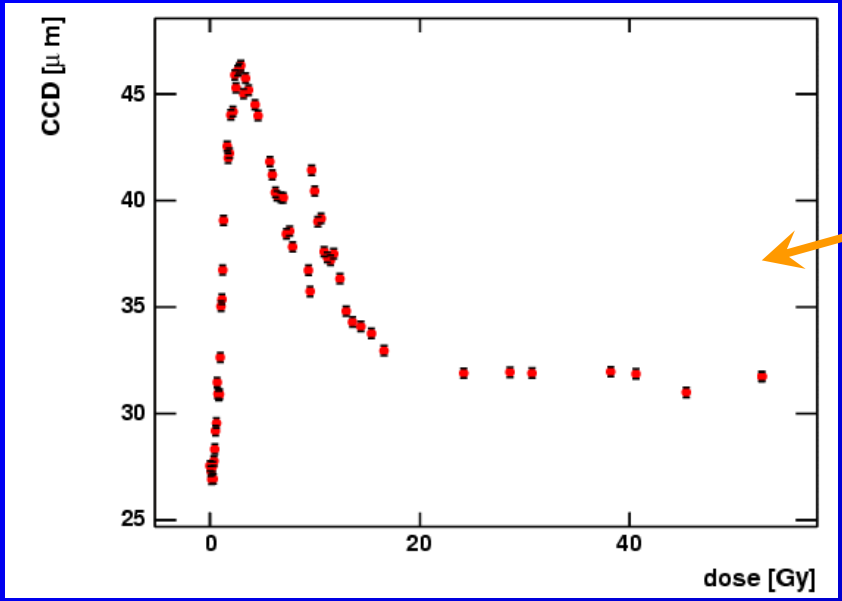
pCVD Diamond Production



polycrystalline CVD diamond wafer
(Photo: IAF)

Single crystal CVD diamonds are not (yet) available on wafer scale.

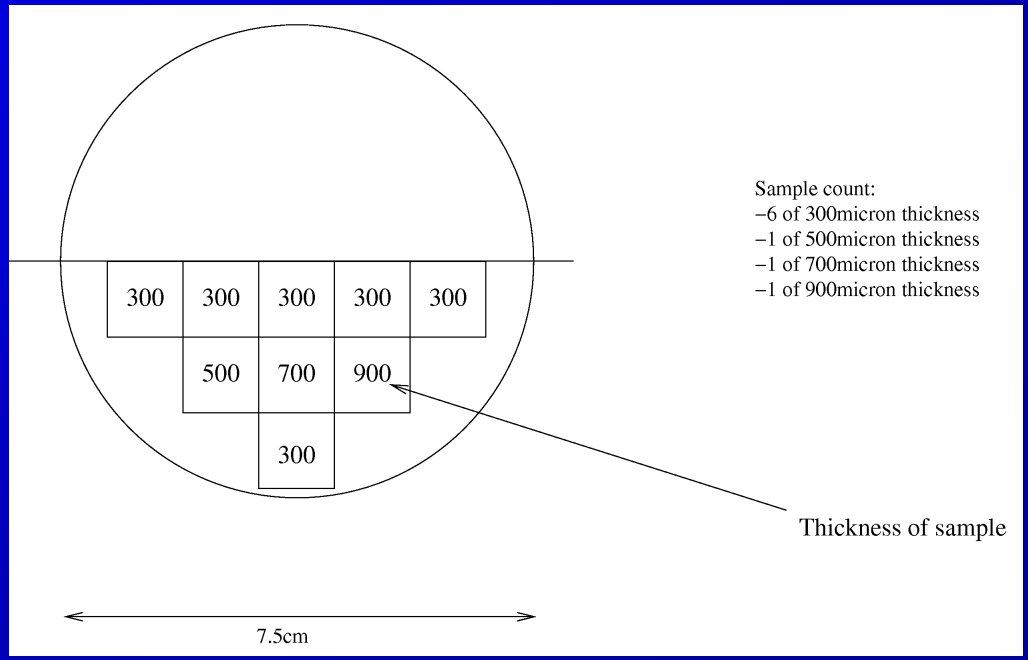
Investigation of FAP7 series



FAP6

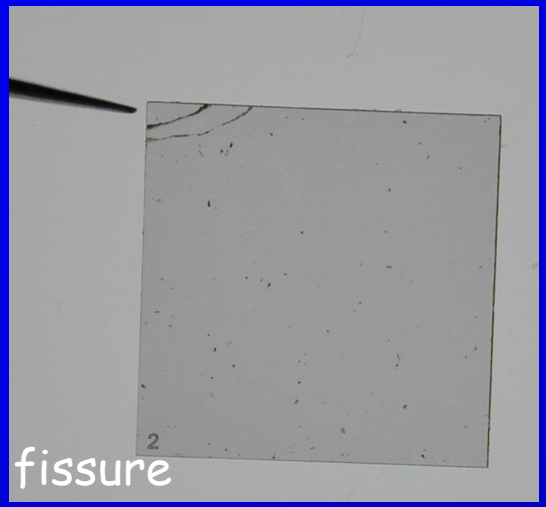
In 2004 we got a promising sensor from Freiburg, FAP6.

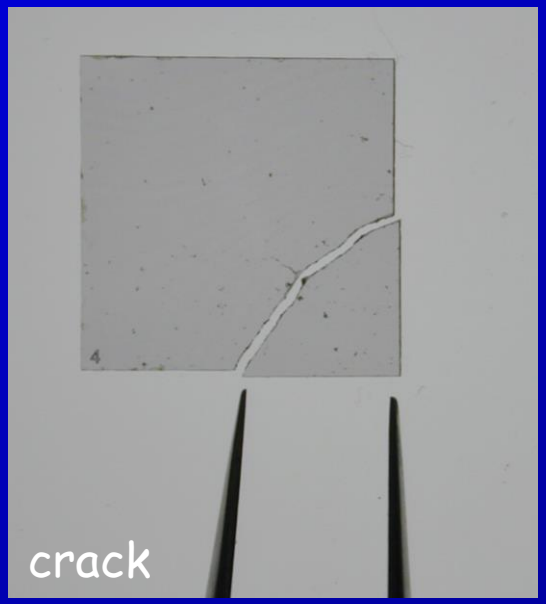
A batch of samples from the same wafer, with comparable performance, was ordered.
The aim was to investigate:
- different thicknesses
- different radii/wafer positions



The issues (1)

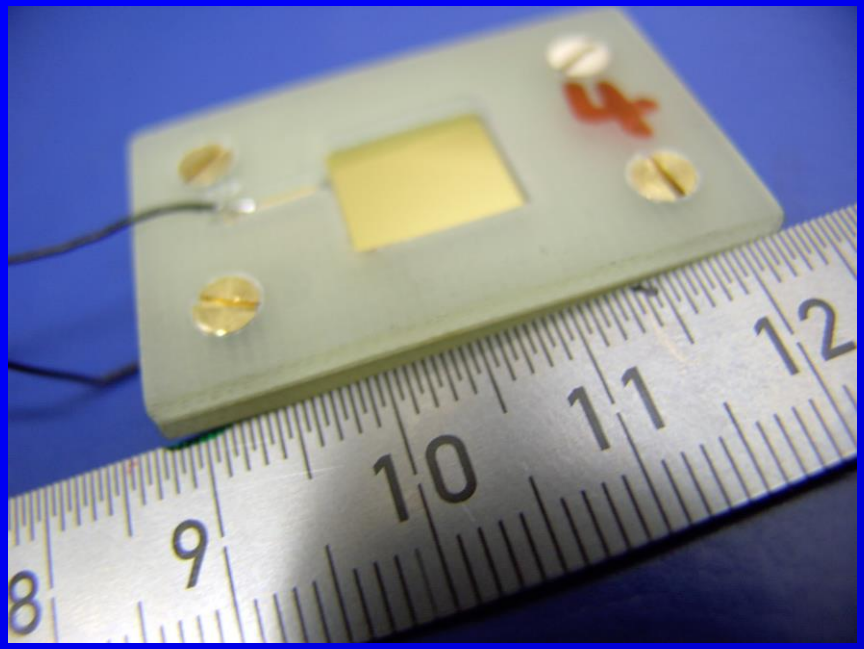
- Lost samples during the thinning procedure
  - Thinning procedure for singulated samples.
  - High amount of material to be removed.
  - Polycrystalline samples.

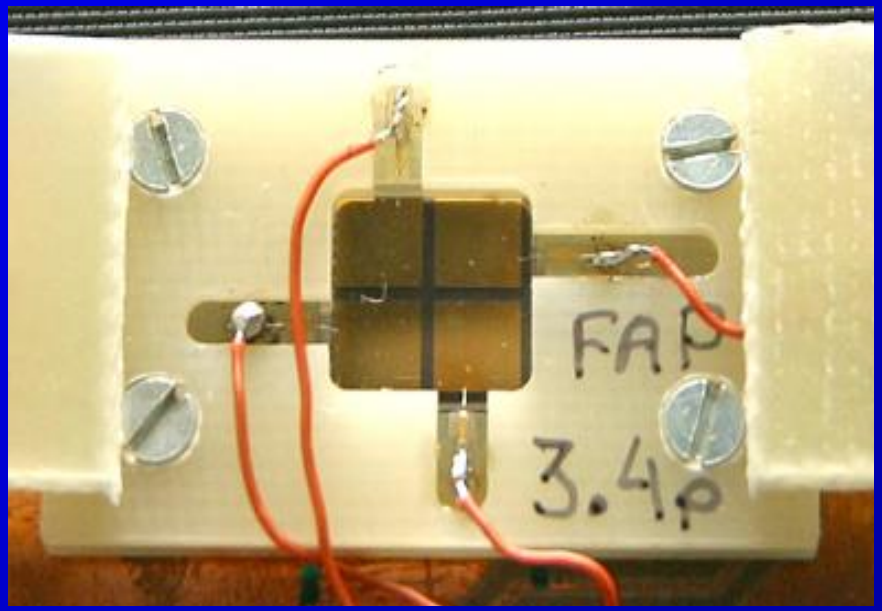




- If possible metallization was shrinked or number of pads reduced.
- Replacement sensors were produced. => Total of 11 samples!

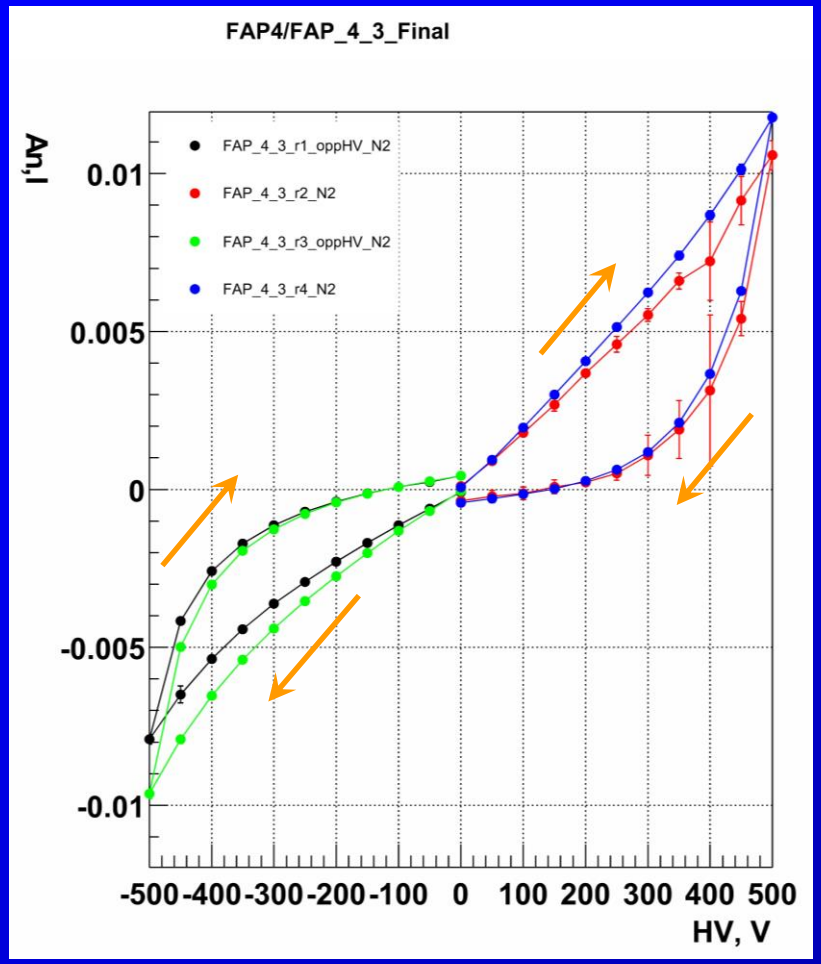
Diamond Prototyping



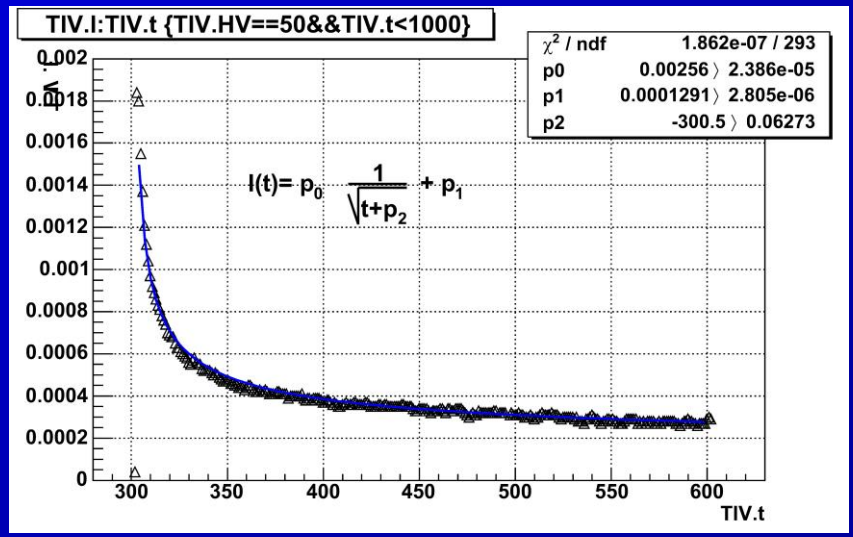


Diamond size: 12x12 mm^2
Metallization: 100 nm Ti + 200 nm Pt + 500 nm Au
usually four segments

IV Behavior

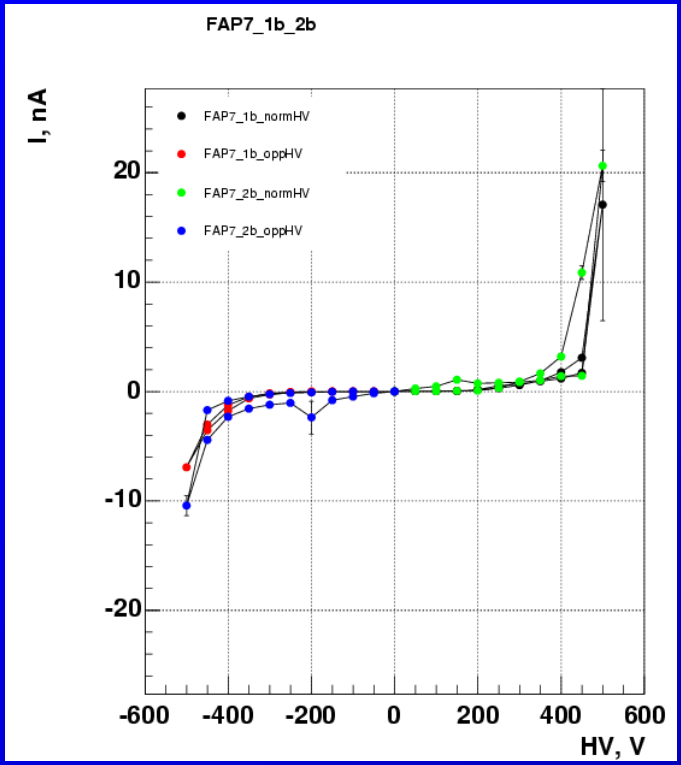


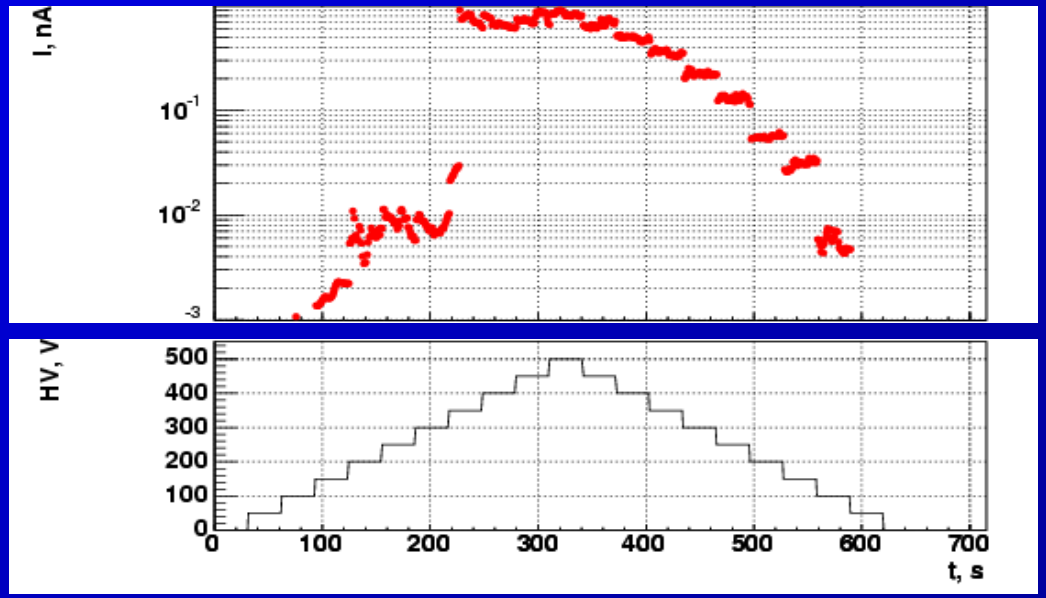
- IV behavior: ohmic for ramping up/down, hysteresis
- Current ~pA
- I = I(t) ~1/sqrt(t) - dependence



The issues (2)

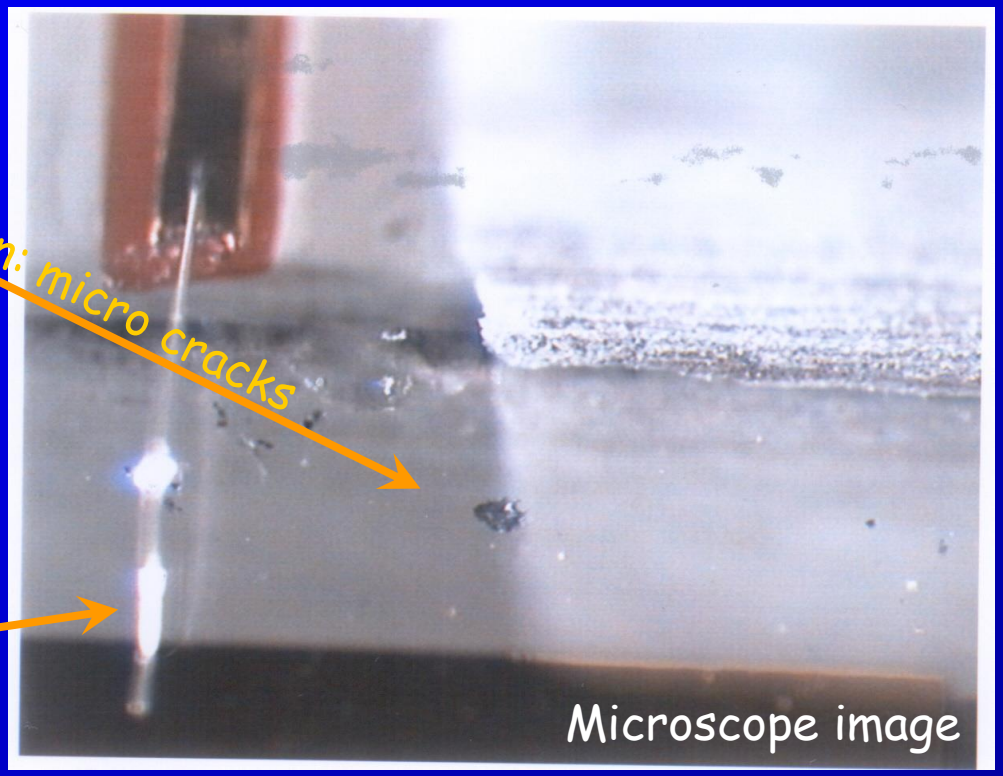
- Large currents in most of the samples of the FAP7 series (8 out of 11).
- These currents originate in single pads.





Origin of isolated breakthroughs

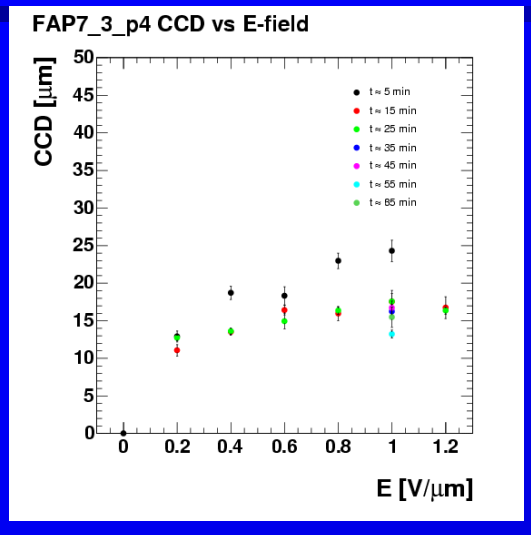
Possible explanation: micro cracks

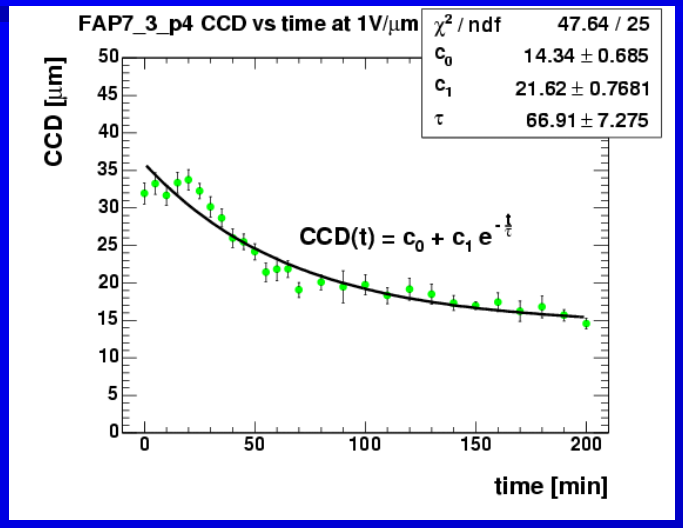


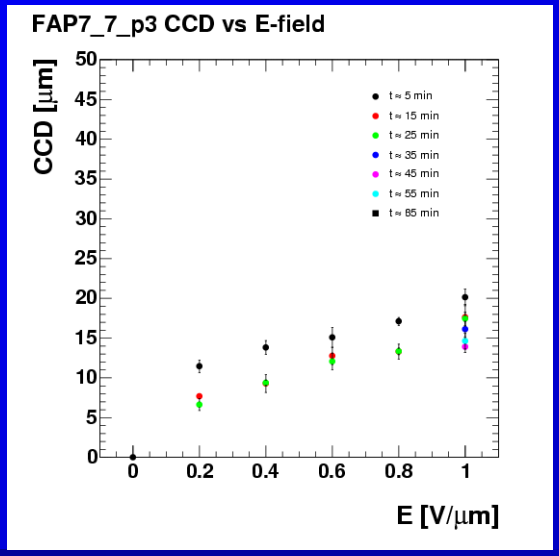
Good: Wire bonding is now reliable.

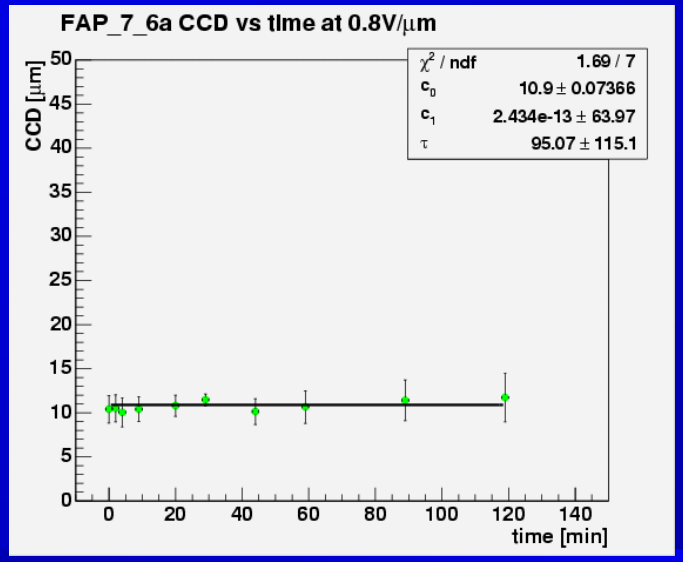
Most of the samples have micro cracks IN their crystal bulk.
IAF: The number of micro cracks increases with wafer thickness and radius on the wafer.

CCD Performance of FAP7 batch







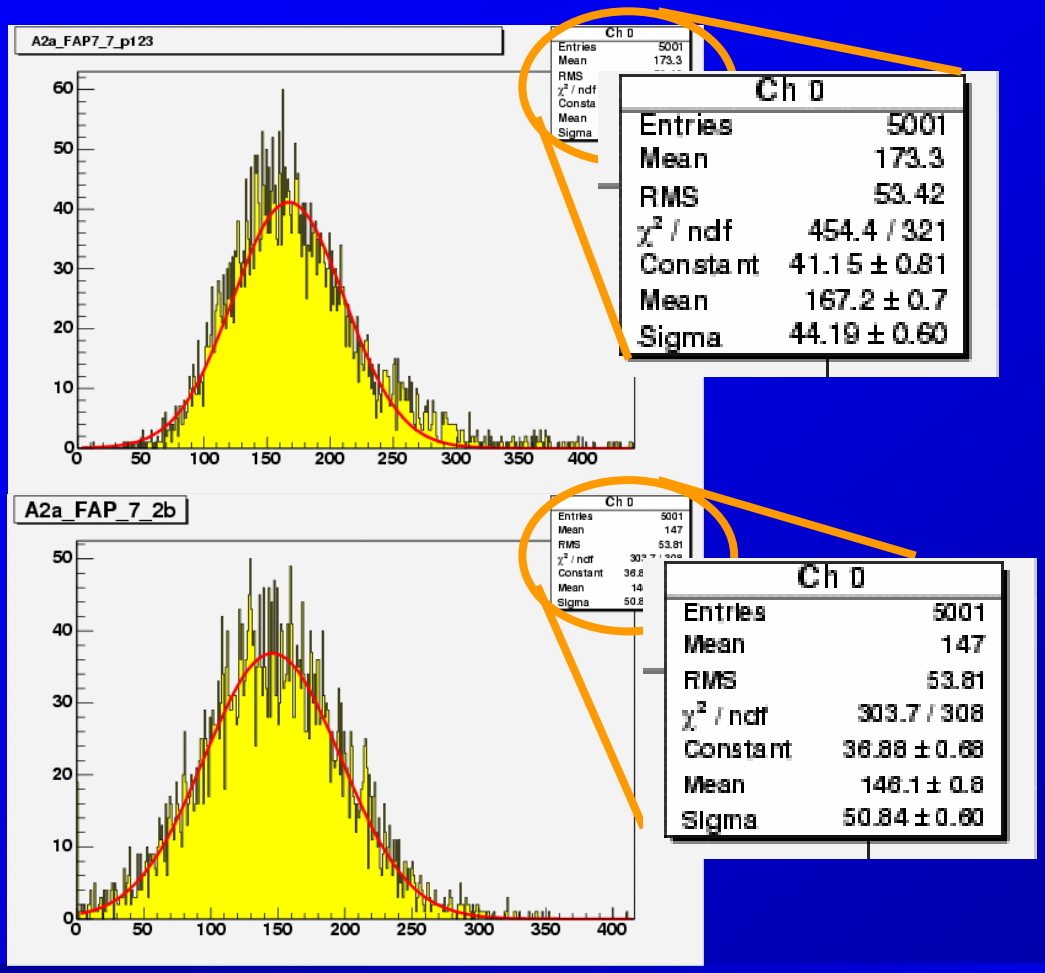


CCD performance of all diamonds from FAP7 is poor, but a signal can still be extracted.

In principle, this would be no problem for the BeamCal, but....

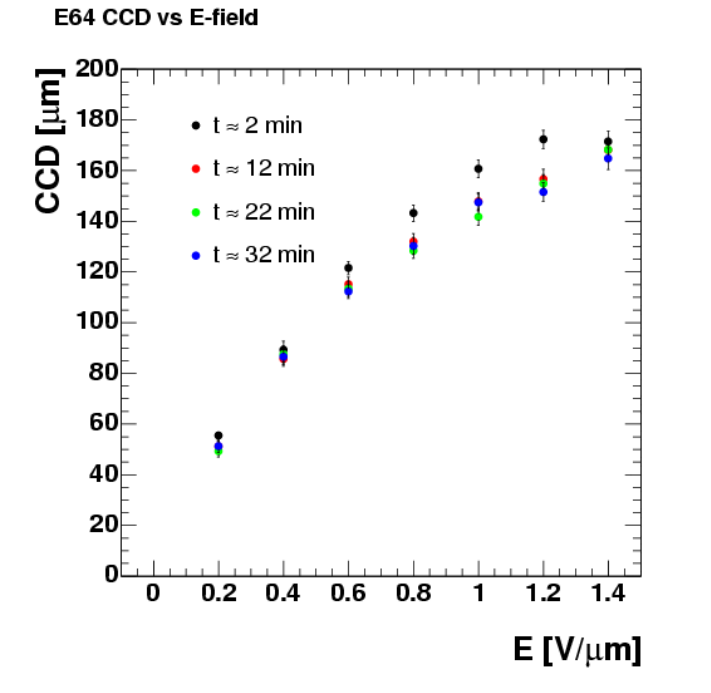
The issues (3)

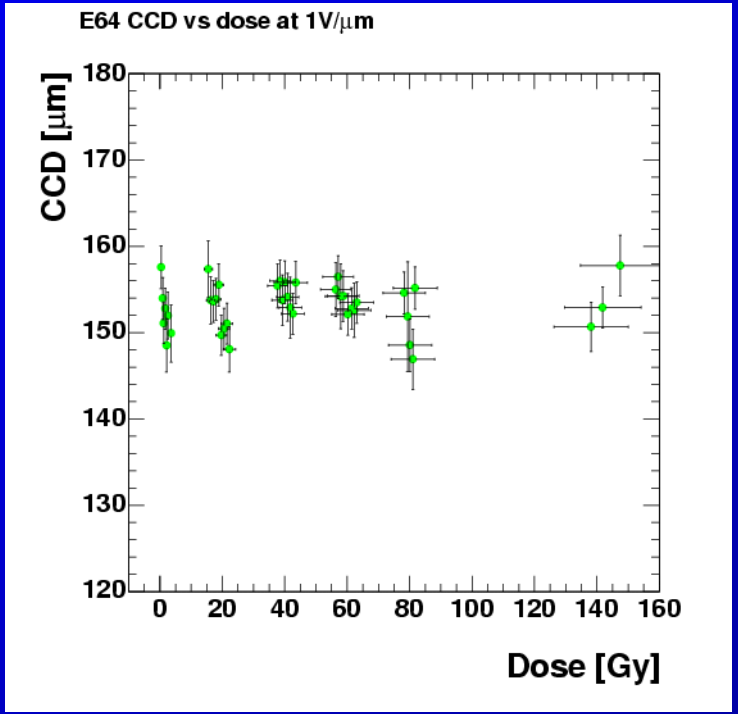
Major problem: CCD vs Dose behavior of the FAP7 samples.



Decrease of signal and increase of noise after ~ 3 Gy.
This is accompanied with increasing current.
The behavior is similar for at least 3 FAP7 samples.

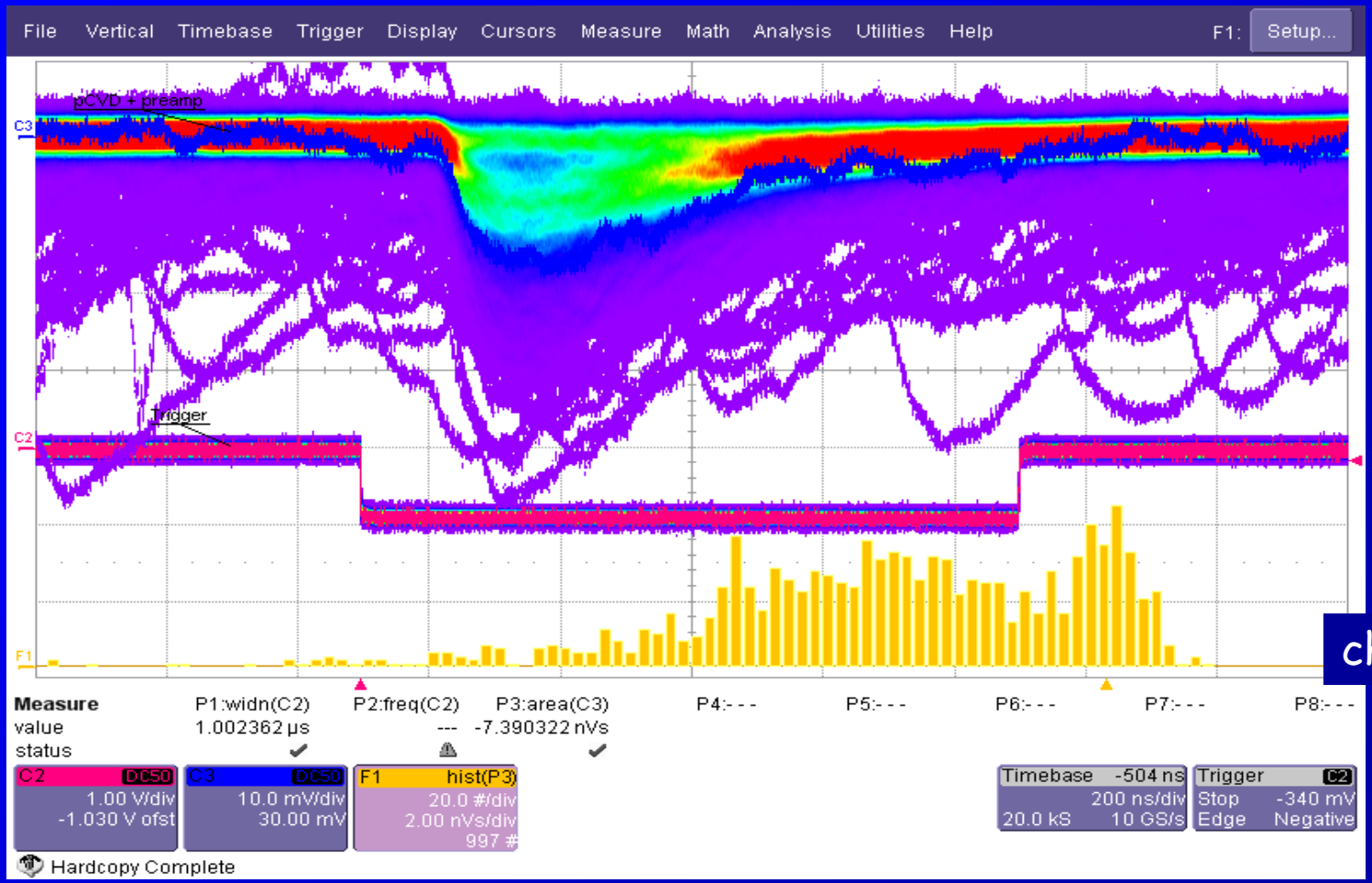
Some Good News - E6_4p





Element 6 sample was remetallized and shows good performance and is stable under irradiation.

E6_4p Signal

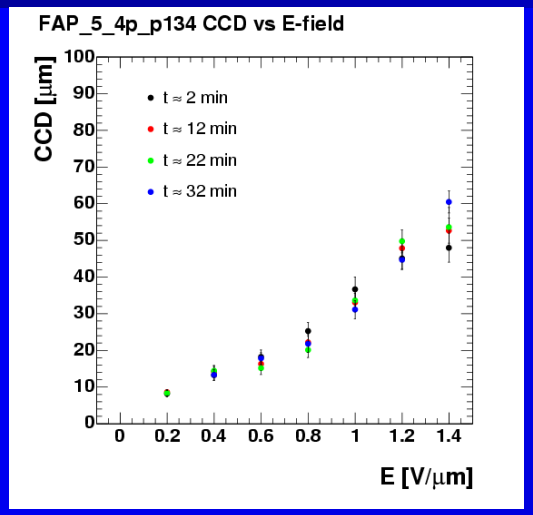


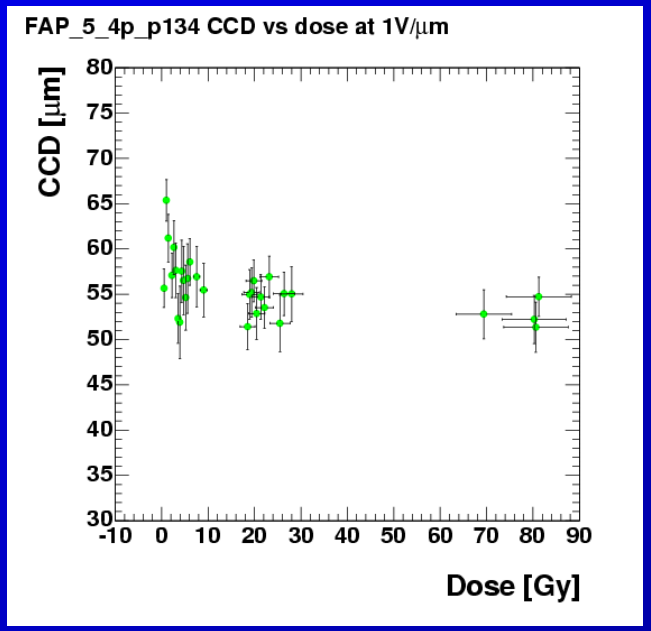
signal (~1000)

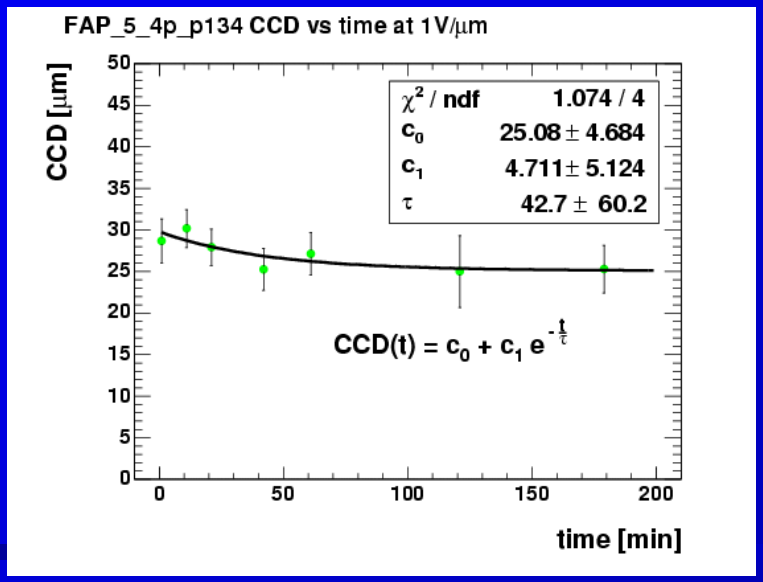
trigger

charge histogram

2nd Good Sample from IAF - FAP5







Also FAP5 is stable under irradiation.
The efficiency is not very high, but it would be sufficient for BeamCal.
Need more samples like this from IAF.

Summary

- FAP 7 batch was not very successful.
  - Thinning problems.
  - Micro cracks and current breakthroughs.
  - CCD vs Dose behavior unsatisfactory.
- Element 6 samples have the best performance.
  - Metallization seems to be of minor importance atm..
- IAF has produced two good samples for us with stable behavior under irradiation.

Outlook

- Need more samples from IAF. FAP5 and 6 are a good starting point...but this was the case before FAP7 batch.
- Avoid thick wafers (~1 mm) to achieve less micro cracks and reliable thinning procedure.
- IAF promised to deliver new samples in October.
- Starting to look into single crystal diamonds. Will get a sample in the next weeks...it's from Element 6.
- Continue to investigate FAP7 batch of sensors.