Beam Monitoring using CVD Diamond Sensors

1. Signal collection in CVD diamond
2. The Current State of the art in Diamond sensors
3. Diamond beam monitors in large pion fluxes
4. Diamond monitors at PEP-II/SLAC
5. Progress on monitors for KEK

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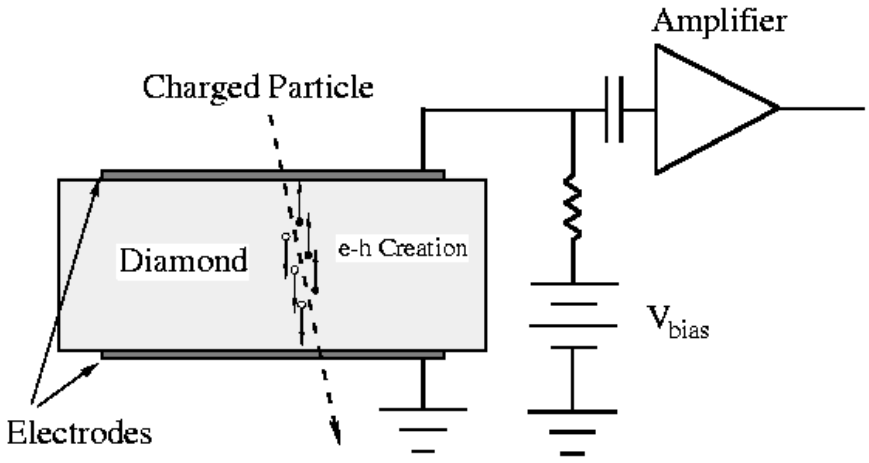
CVD Diamond Sensor Operating Principle

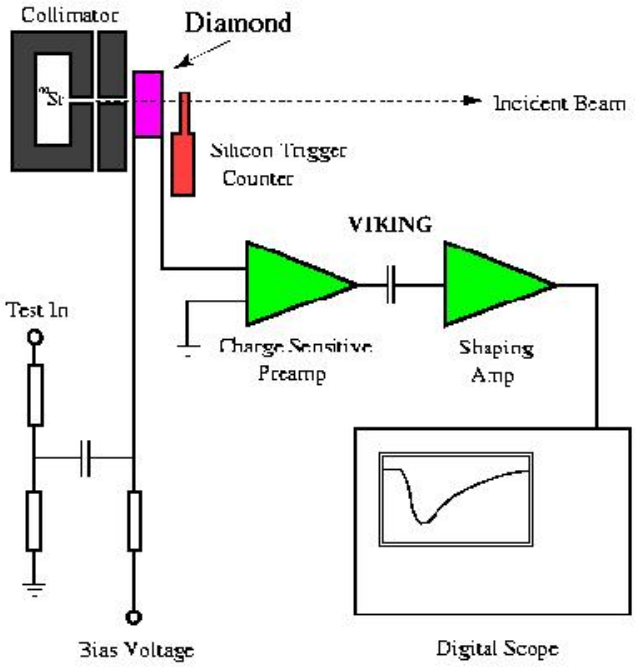
- Diamond sensor works like
  - A solid-state ionisation chamber



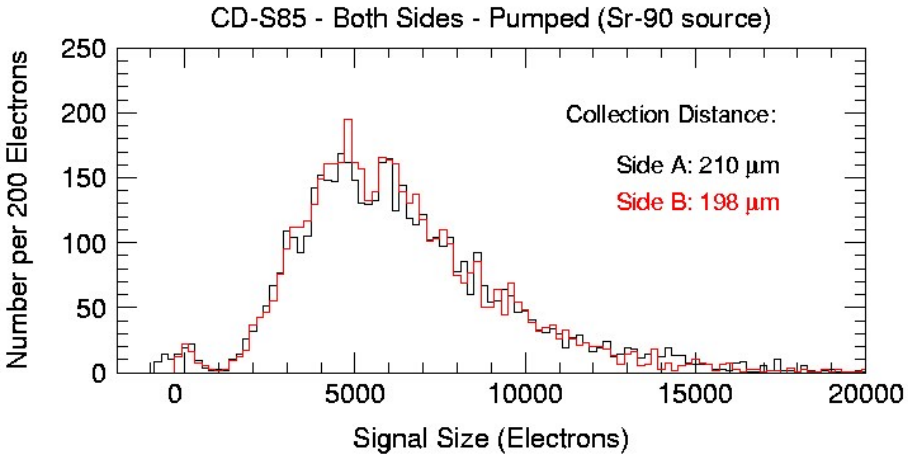
- Resistivity so high, leakage current typically pA
  - No need reverse biasing
  - No need to implant diodes etc.

Diamond Sensor Characterisation

- Characterise diamond sensors with bench-top setup
  - ^{90}Sr electrons $\frac{dE}{dx} \approx 1.08$ minimum ionising



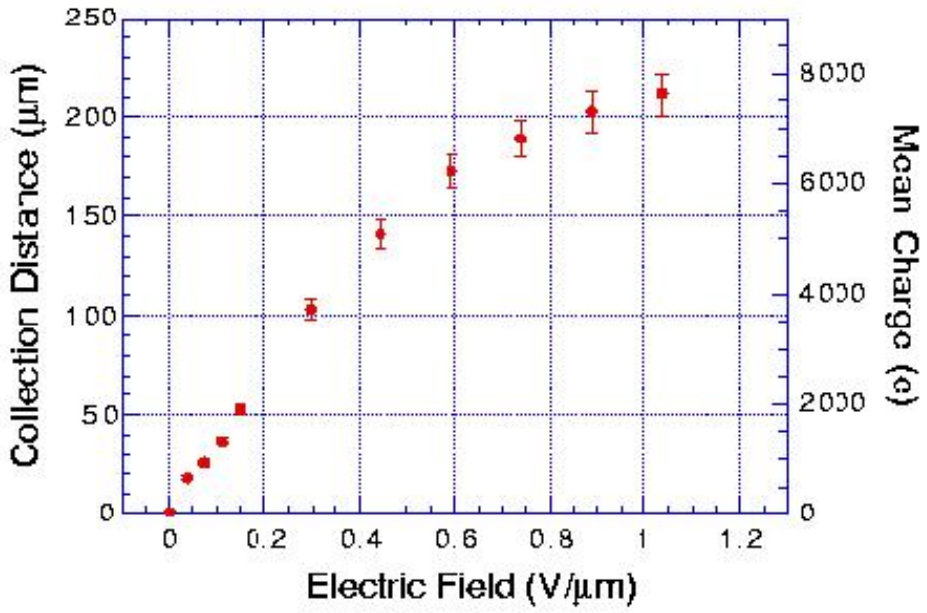
- Typical signals look like



- (Side A) +ve electric field, Side B) -ve electric field)

Signals Seen from Diamond Sensors

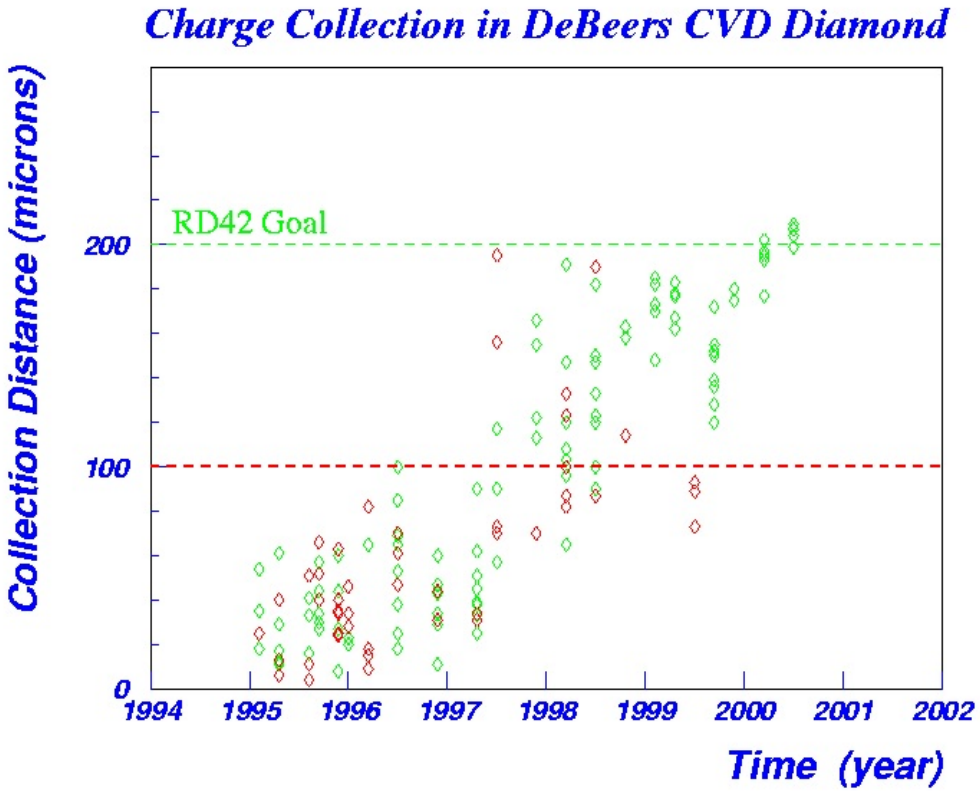
- The signal as a function of applied bias voltage



- Signal increases linearly (drift velocity $\approx E$)
- Approaching 1 V/μm carrier mobility $\approx 1/E$
  - Carrier velocity plateaus
  - Signal, due to image charge motion, saturates
- Typically operate diamond sensors at about 1V/μm
  - 300 to 400 V across 300 μm thick sensors

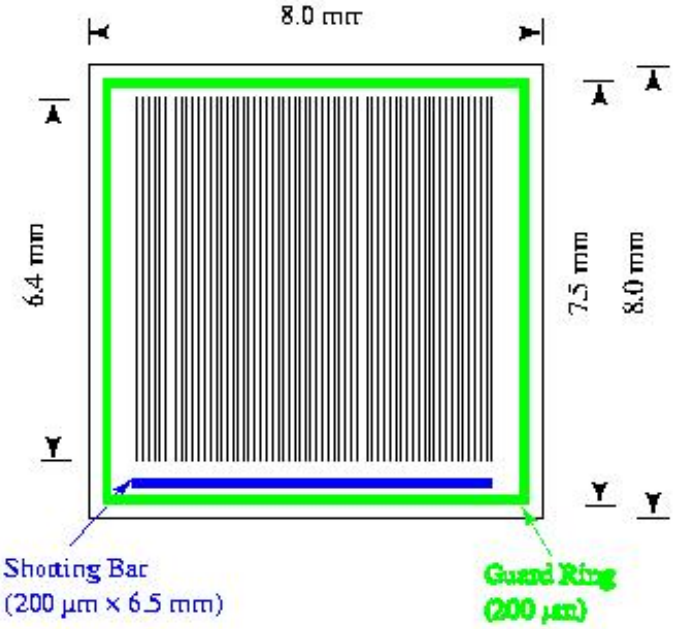
The RD42 Project at CERN

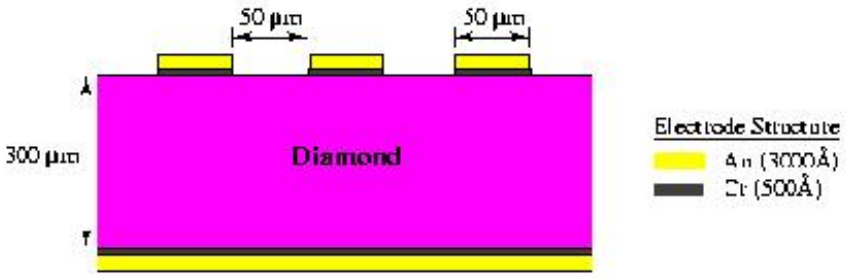
- RD42 established to demonstrate
  - CVD diamond sensors rad hard alternative for LHC MIP detectors
  - This resulted in a series of goals
    1. Signal sizes exceeding 7000 e for MIPs
    2. Radiation tolerance beyond 10^{15}/ cm^2
    3. Signal formation times of a ns
- We have met these goals



Particle Detector Prototypes

- A wide variety of particle detector protoypes
  - Strip trackers (ref: NIM A354, 318 (1995))



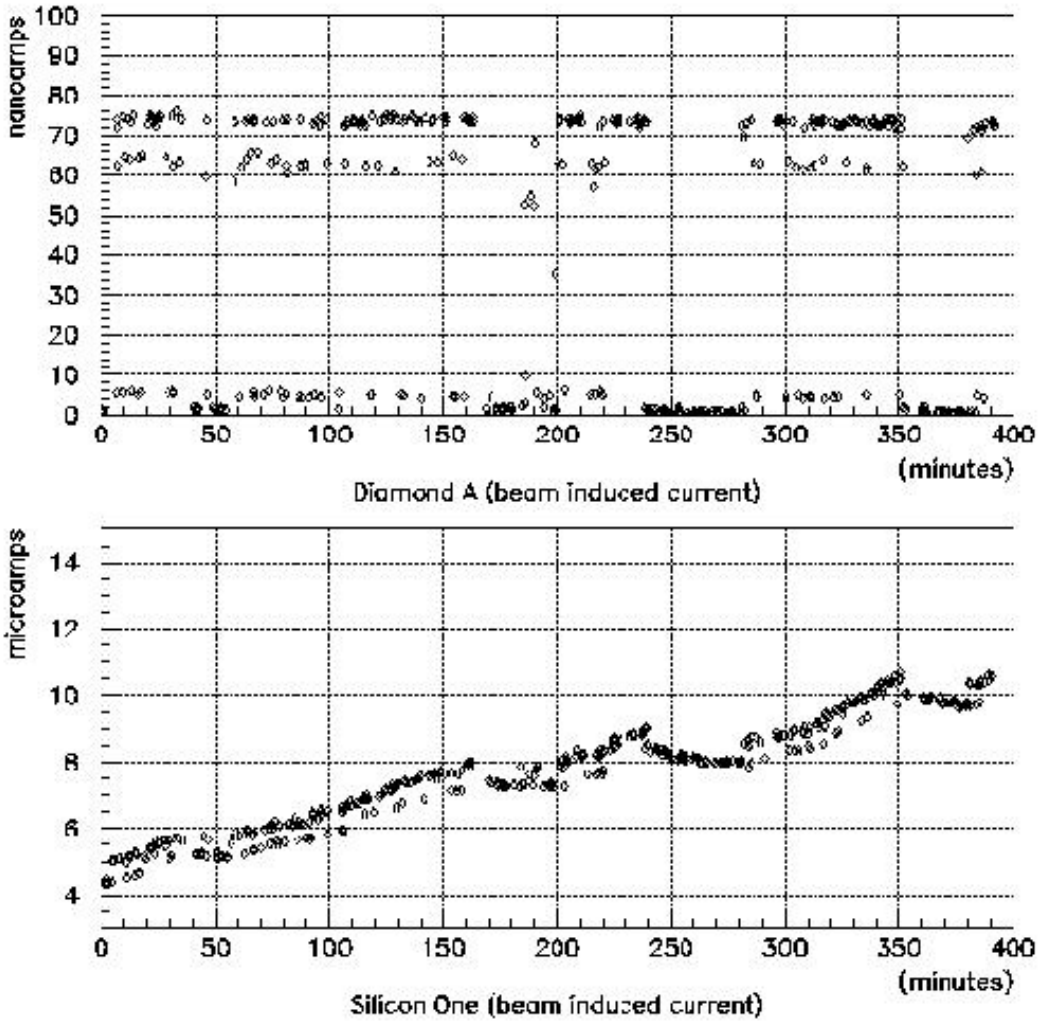


  - Bump-bonded hybridised pixel detectors (ref: NIM A436, 326 (1999))

- Reasonable efficiencies and position resolutions

Other Results from RD42

- Using state of the art samples in 1994
  - Irradiated samples to 3×10^{14} pions/cm^2
  - Involved beam fluxes of 10^7 pions/cm^2/s

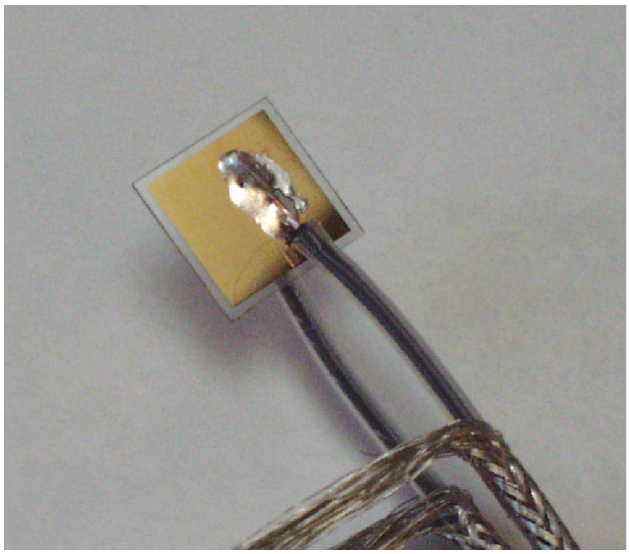


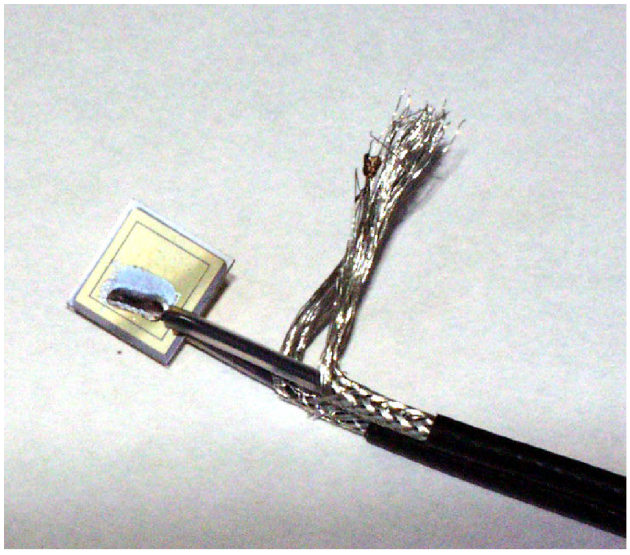
- Shows current in sensors during irradiation
  - Silicon: dominated by leakage due to damage
  - Diamond: proportional to pion flux

- Ref: CERN-PPE 95-173, submitted to NIM ...

Beam Monitors at PEP-II (Photos from H.Kagan, OSU)

- Have installed a series of CVD sensors around BaBar at PEP-II (Fall 2002)

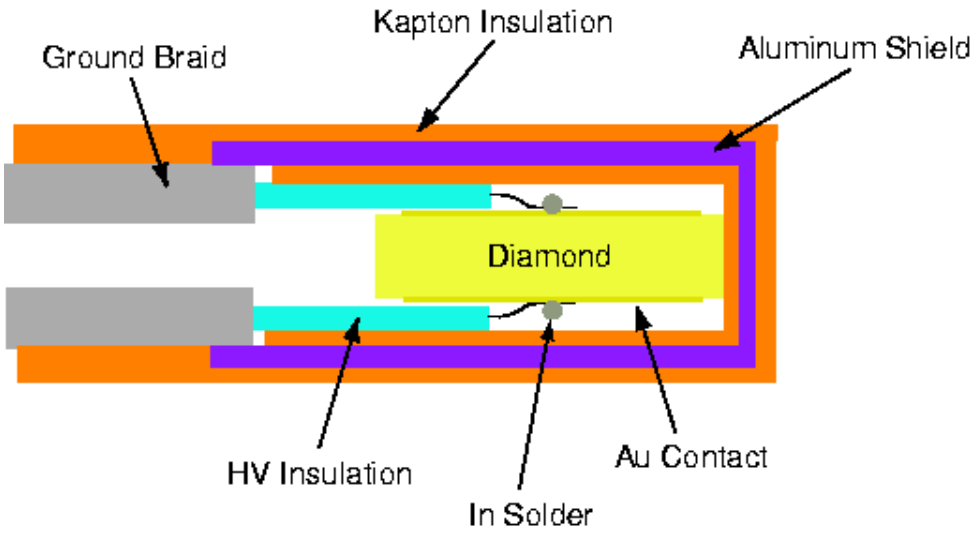




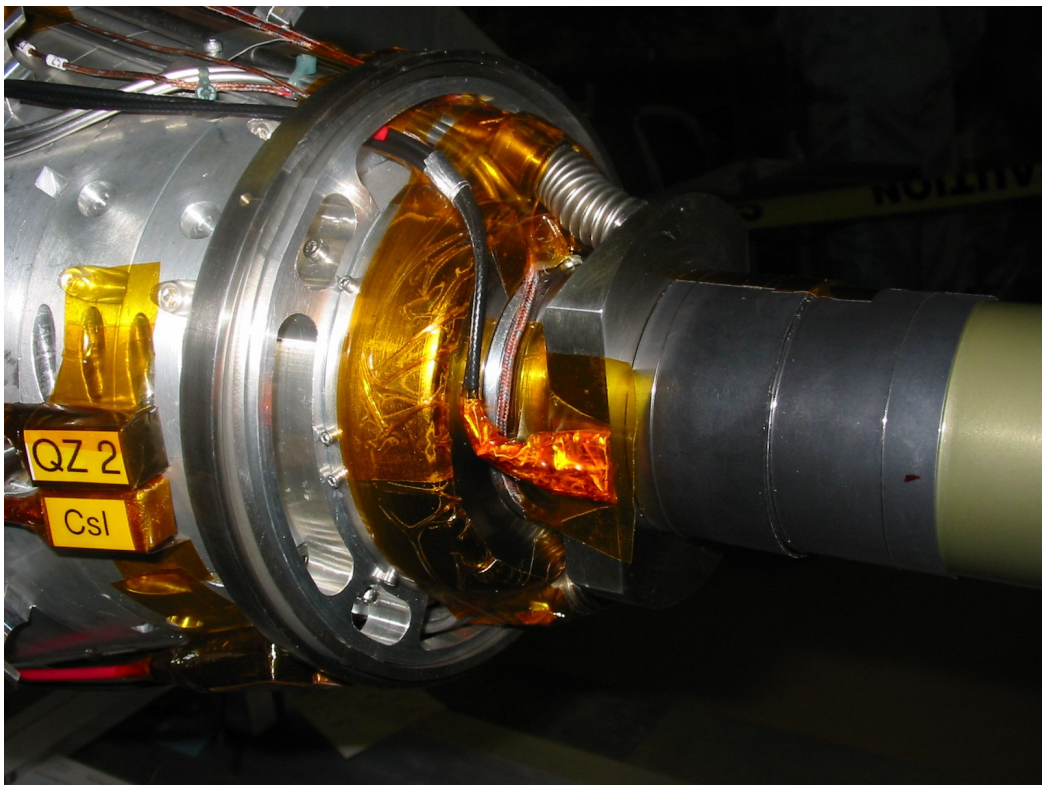
- Simple pad sensors

Beam Monitors in BaBar

- Schematic of monitor package

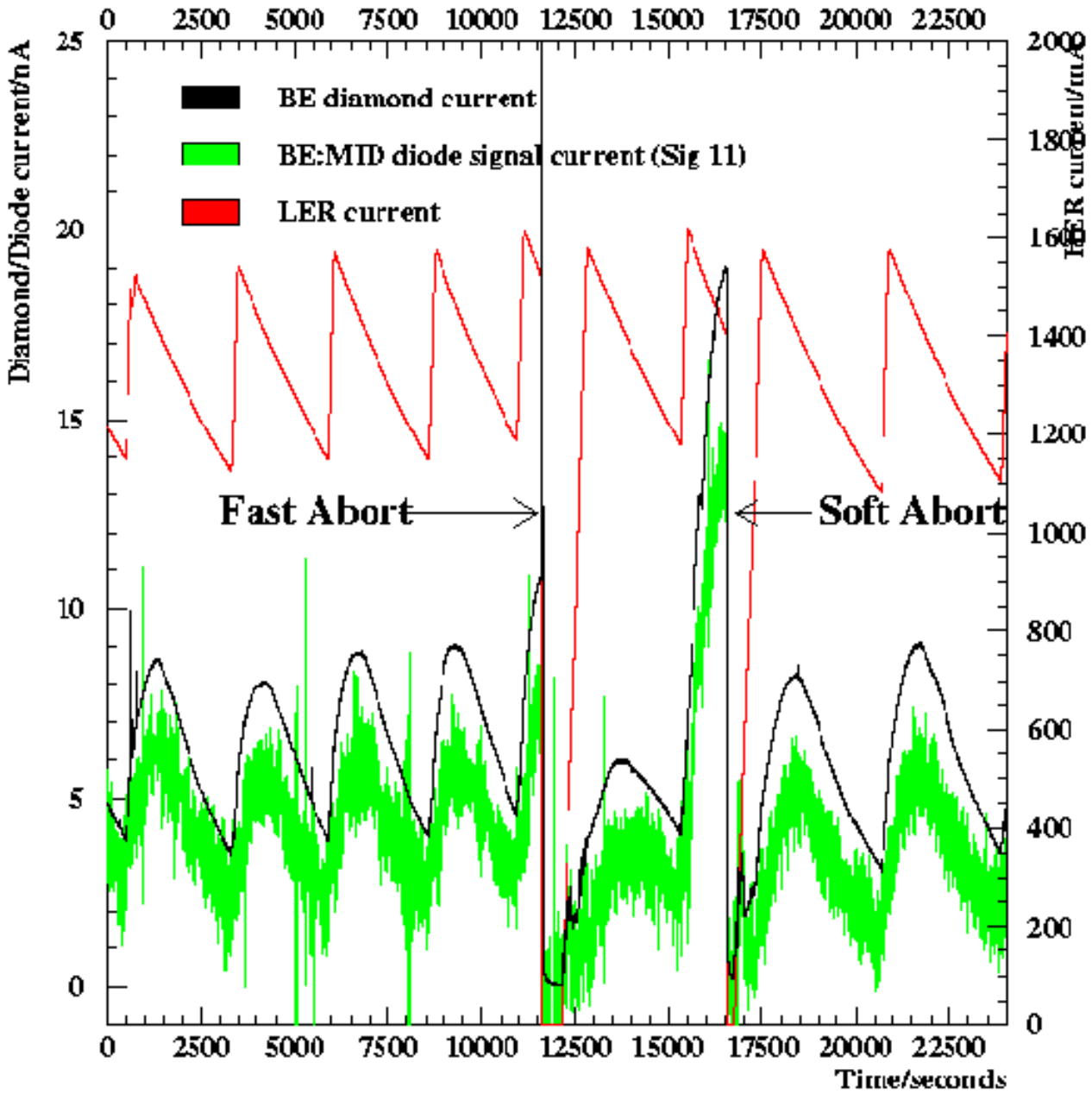


- And how they look near the BaBar IR



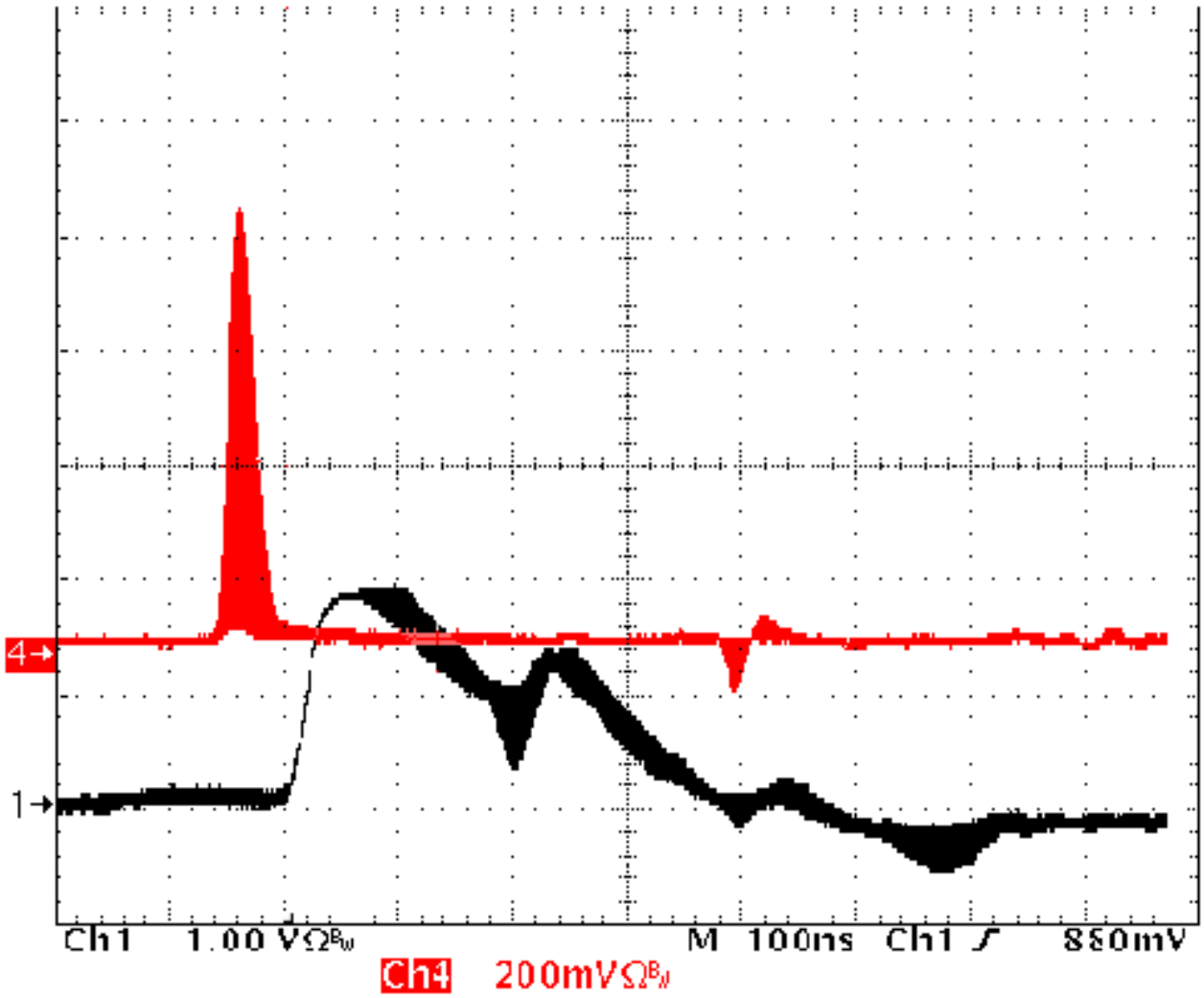
Steady Datataking from PEP-II

- Extended data taking period



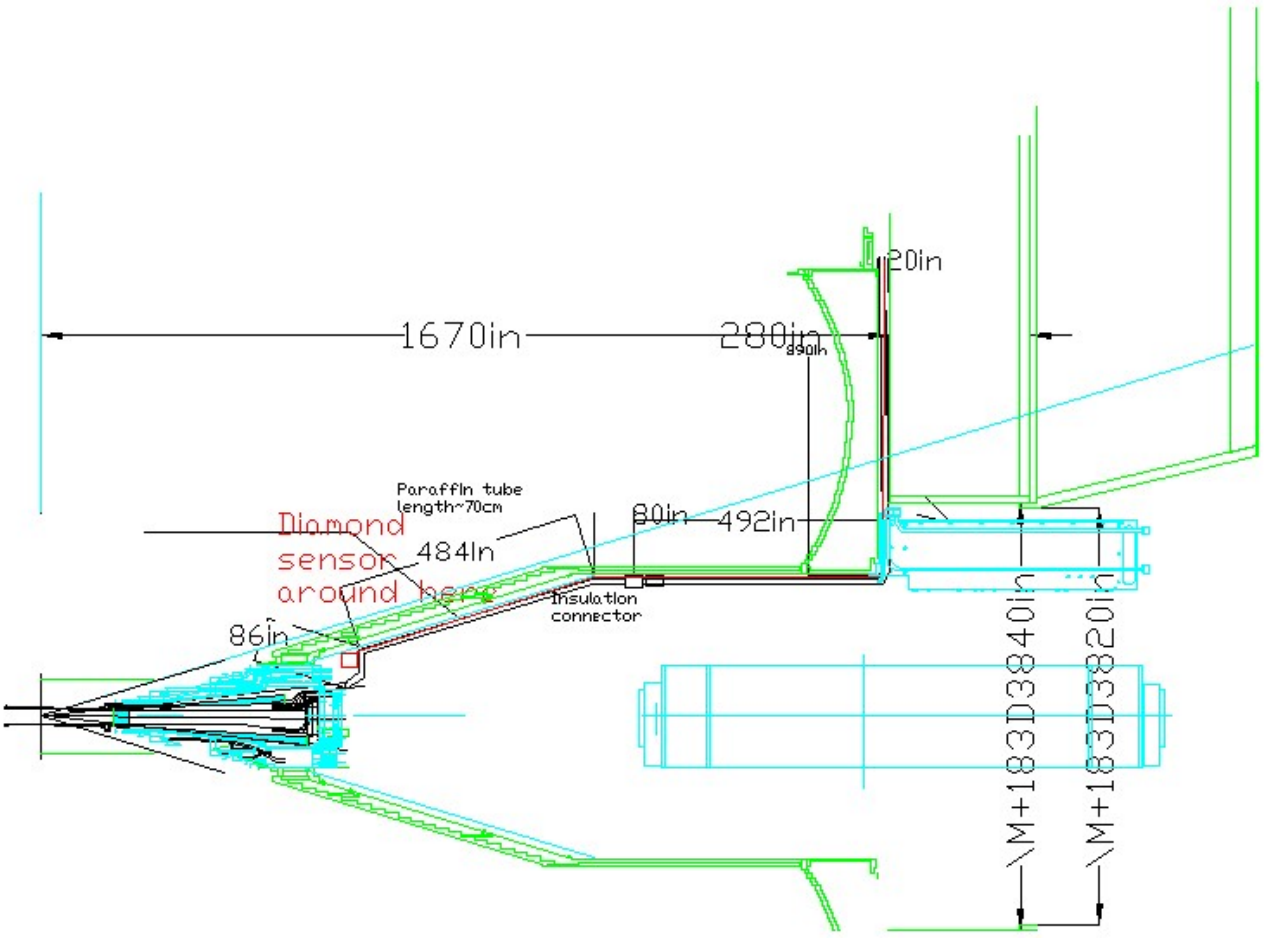
Fast Abort Signal at PEP-II

- Captured a beam abort on a digital scope
  - Red is diamond
  - Black is damaged silicon

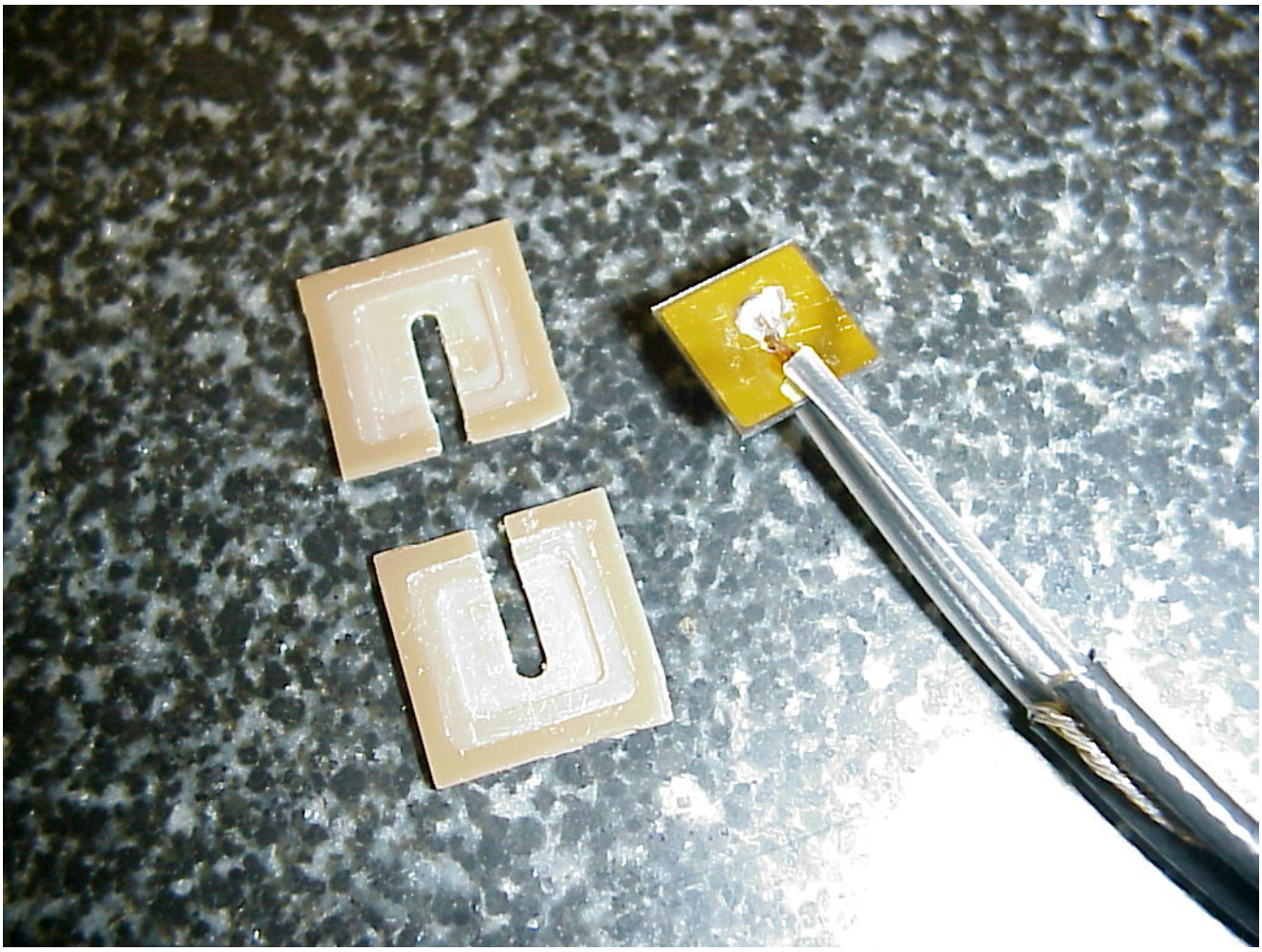


Location of Monitors in Belle

- Plan to install similar sensors in Belle



Packaging for Belle



A Finished Belle Monitor Package

Plans for Further Beam Monitoring

- Sensors installed around BaBar IR
  - Now working reliably
  - Tagging beam dumps triggered by silicon
  - Plans to install monitors elsewhere around ring
    - Learning about time-structure of PEP-II beams
    - Developing rad-hard time-sensitive readout
    - May install similar sensors in beam dump
- Install similar sensors at Belle/KEK in late August