ATLAS Beam Abort System Using CVD Diamond Sensors

1. Signal collection in CVD diamond
2. The state of the art in Diamond sensors
3. Diamond monitors at e^+e^- B factories
4. Application to LHC
5. Proposal of the ATLAS-Canada group

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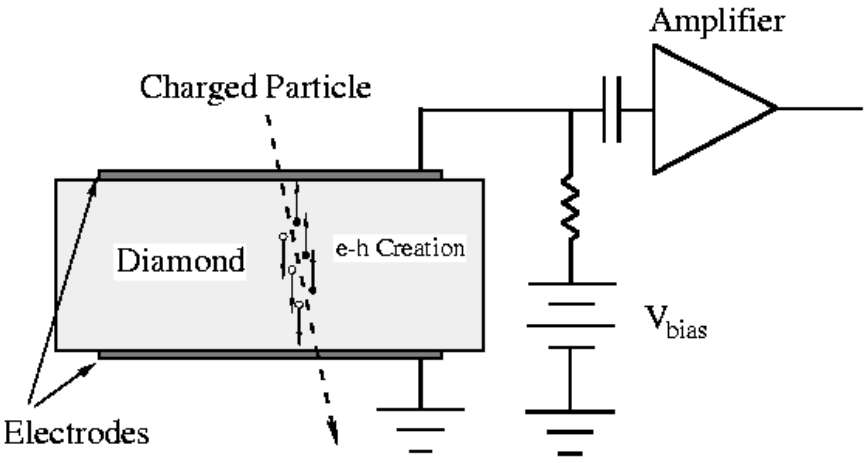
ATLAS-Canada/Toronto
November 5, 2003

CVD Diamond Sensor Operating Principle

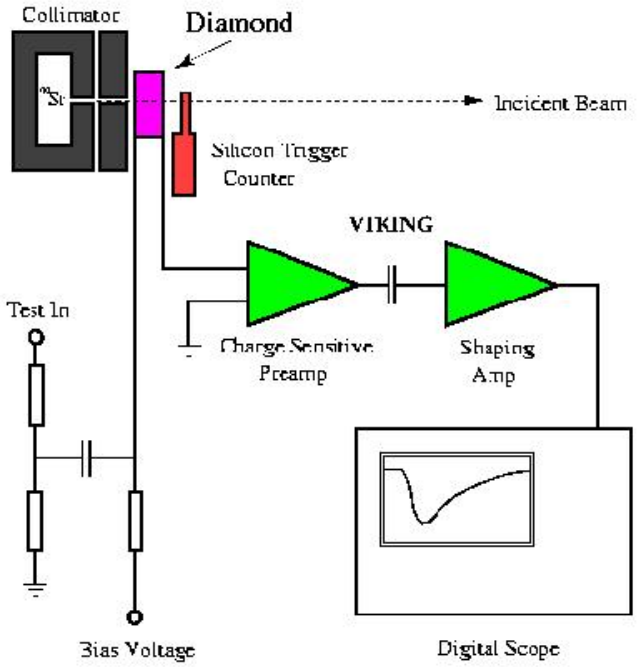
- Diamond sensor works like
  - A solid-state ionisation chamber



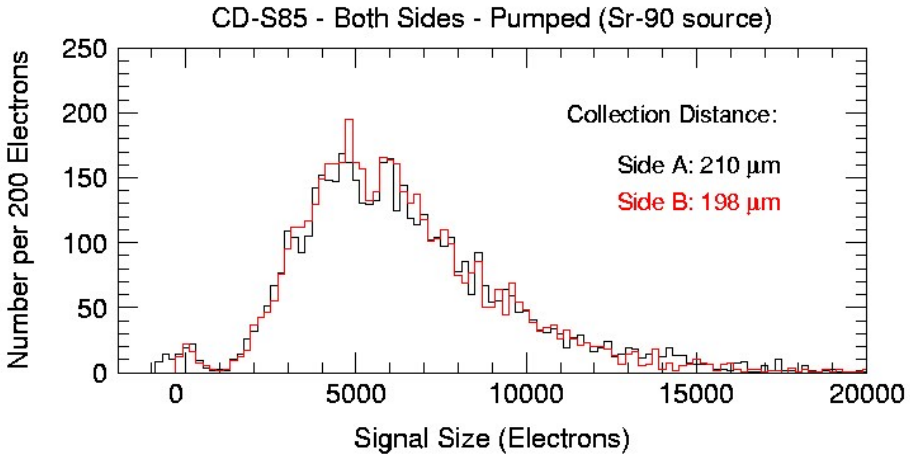
- Resistivity so high, leakage current typically pA
  - No need reverse biasing
  - No need to implant diodes etc.

Diamond Sensor Characterisation

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



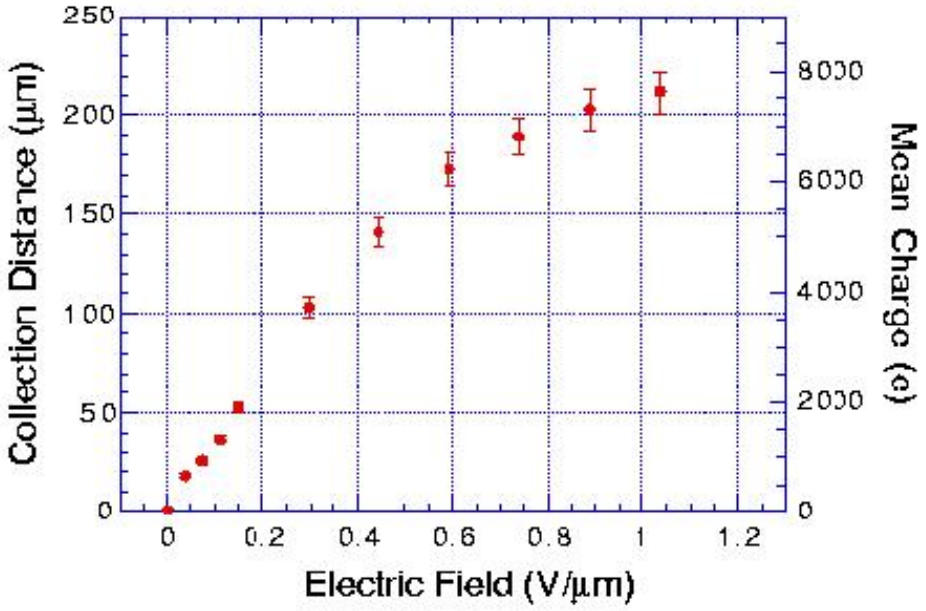
- Typical signals look like



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

Signals Seen from Diamond Sensors

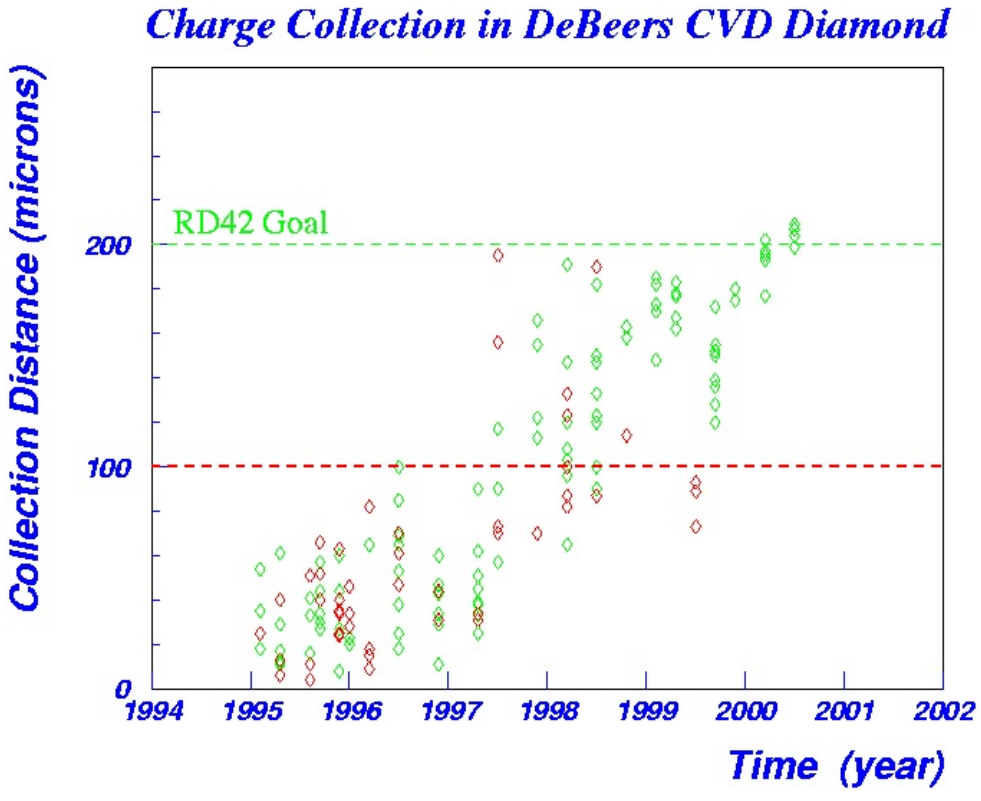
- The signal as a function of applied bias voltage



- 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

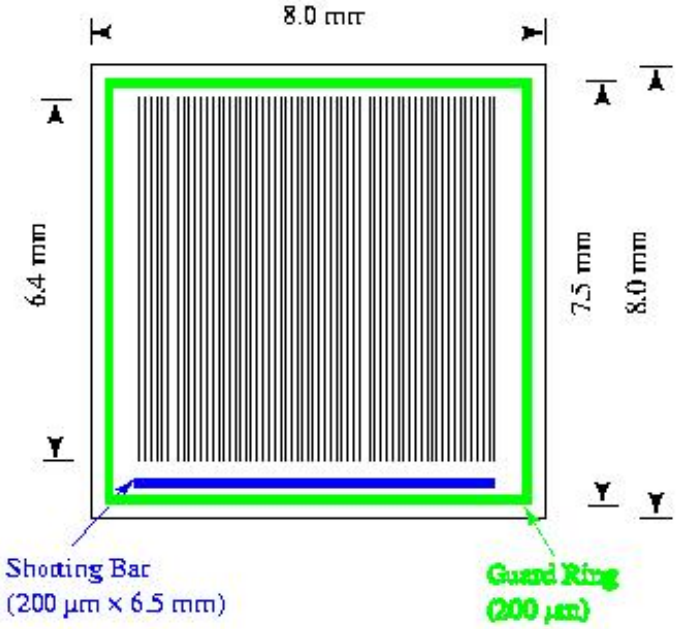
The RD42 Project at CERN

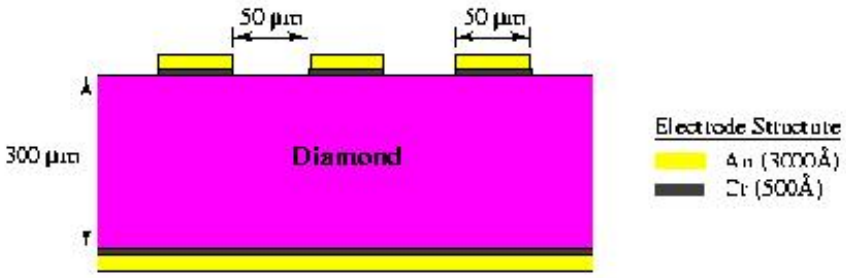
- RD42 established to demonstrate
  - CVD diamond sensors rad hard alternative for LHC MIP detectors
  - This resulted in a series of goals
    1. Signal sizes exceeding 7000 e for MIPs
    2. Radiation tolerance beyond 10^{15}/ cm^2
    3. Signal formation times of a ns
- We have met these goals



Particle Detector Prototypes

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



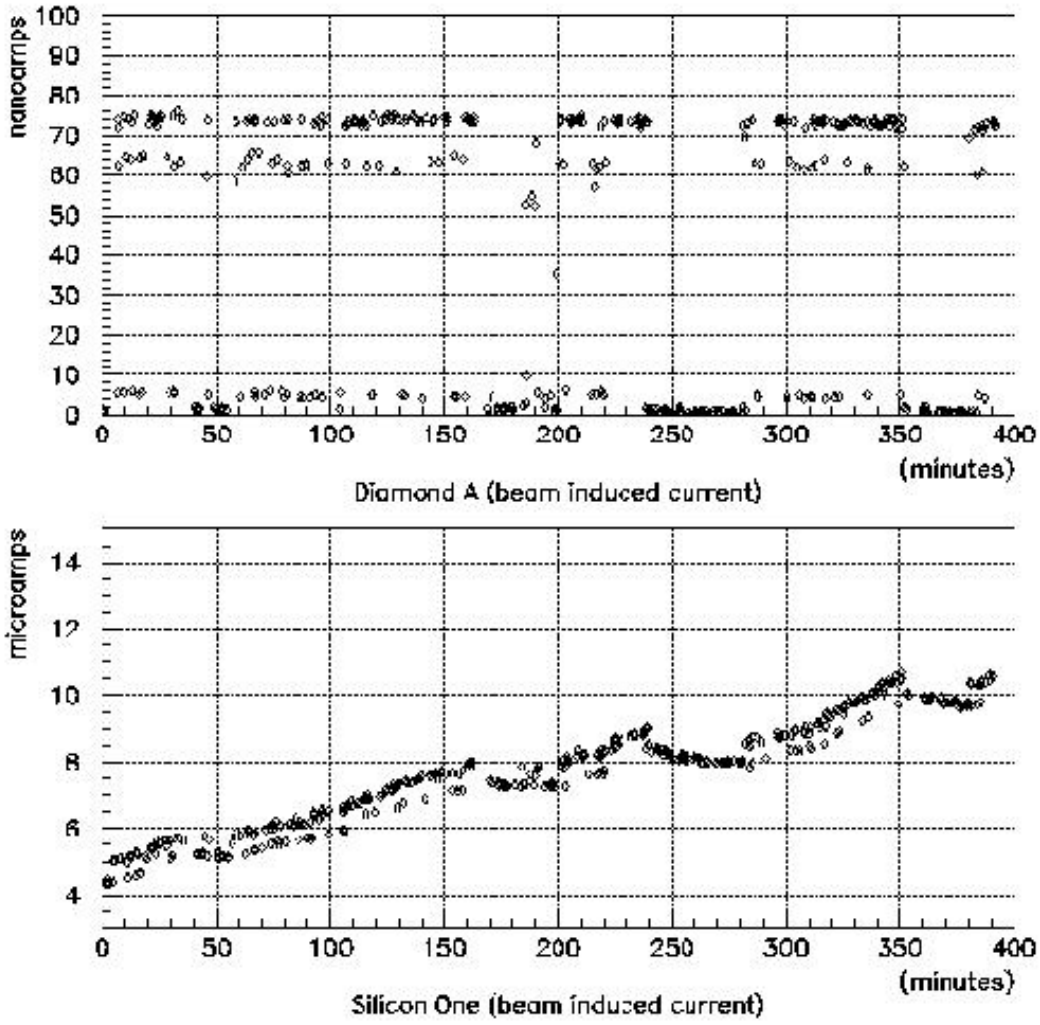


  - Bump-bonded hybridised pixel detectors (ref: NIM A436, 326 (1999))

- 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

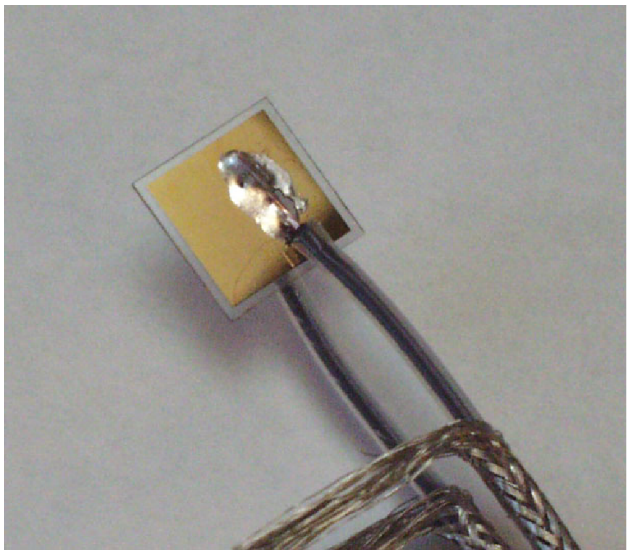


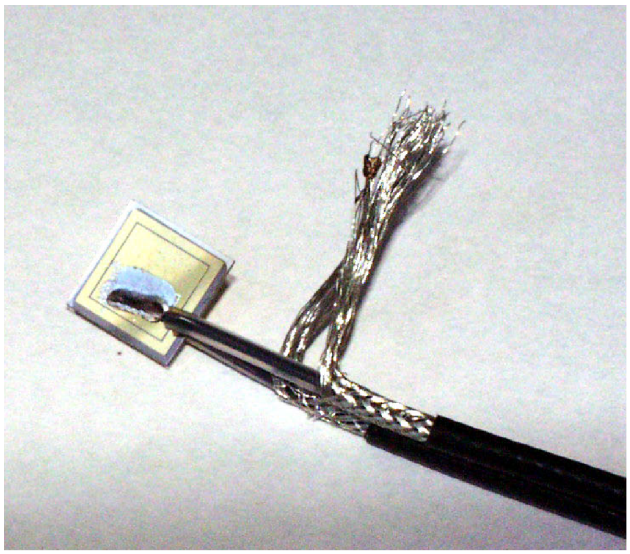
- Shows current in sensors during irradiation
  - Silicon: dominated by leakage due to damage
  - Diamond: proportional to pion flux

- 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)

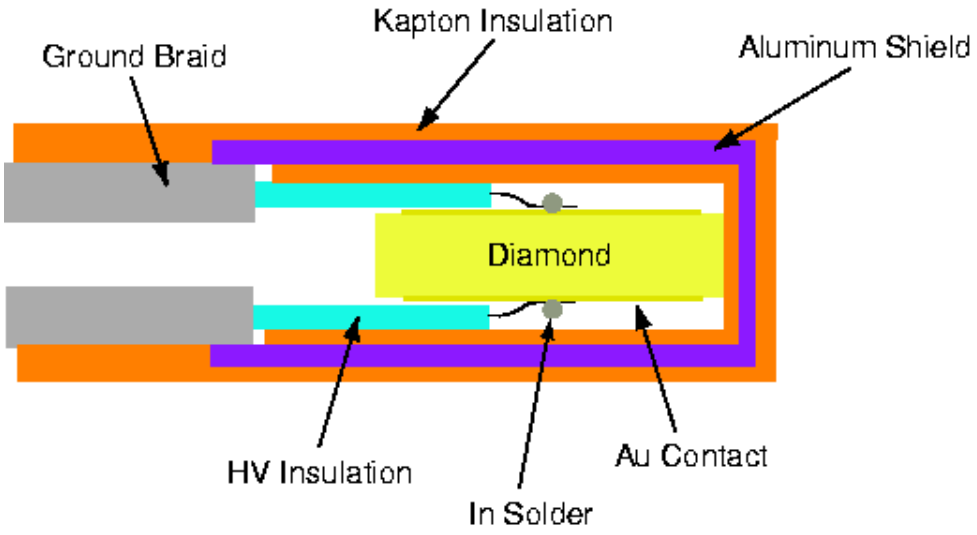




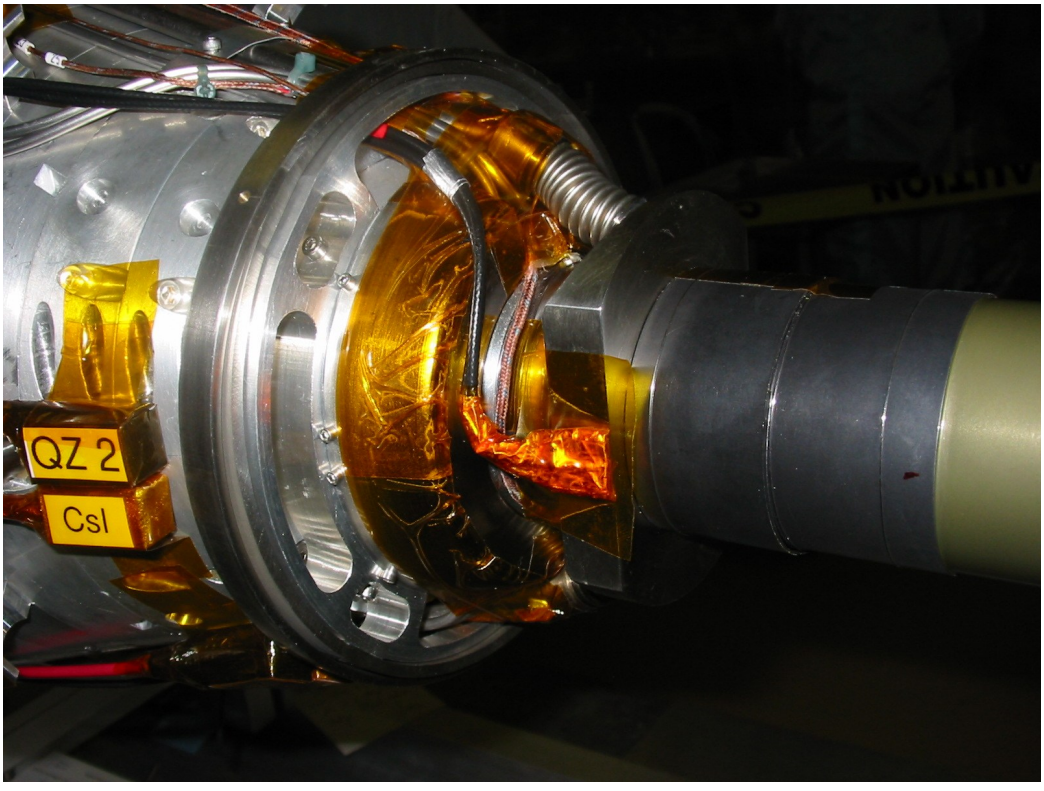
- Simple pad sensors

Beam Monitors in BaBar

- Schematic of monitor package

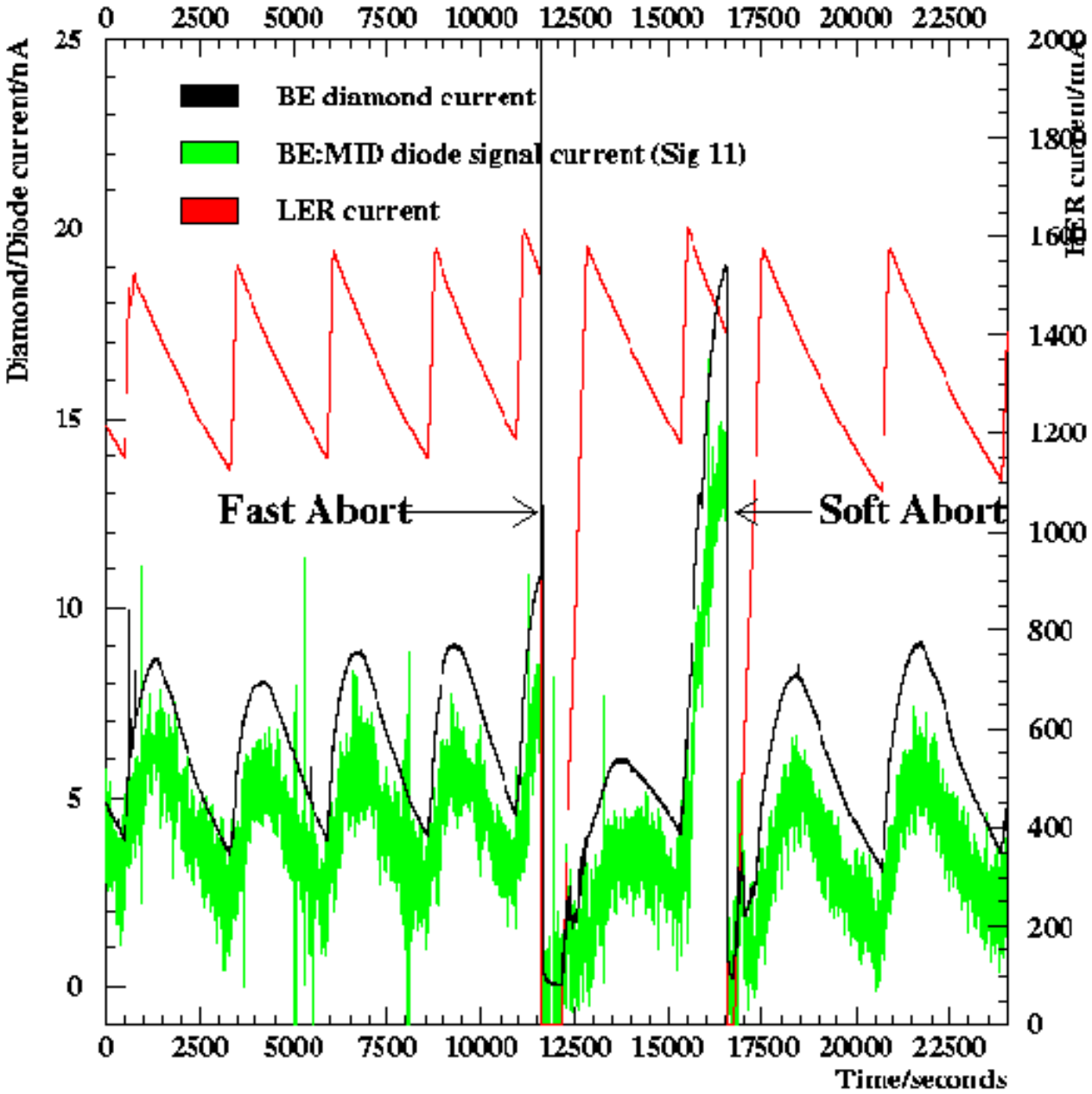


- And how they look near the BaBar IR



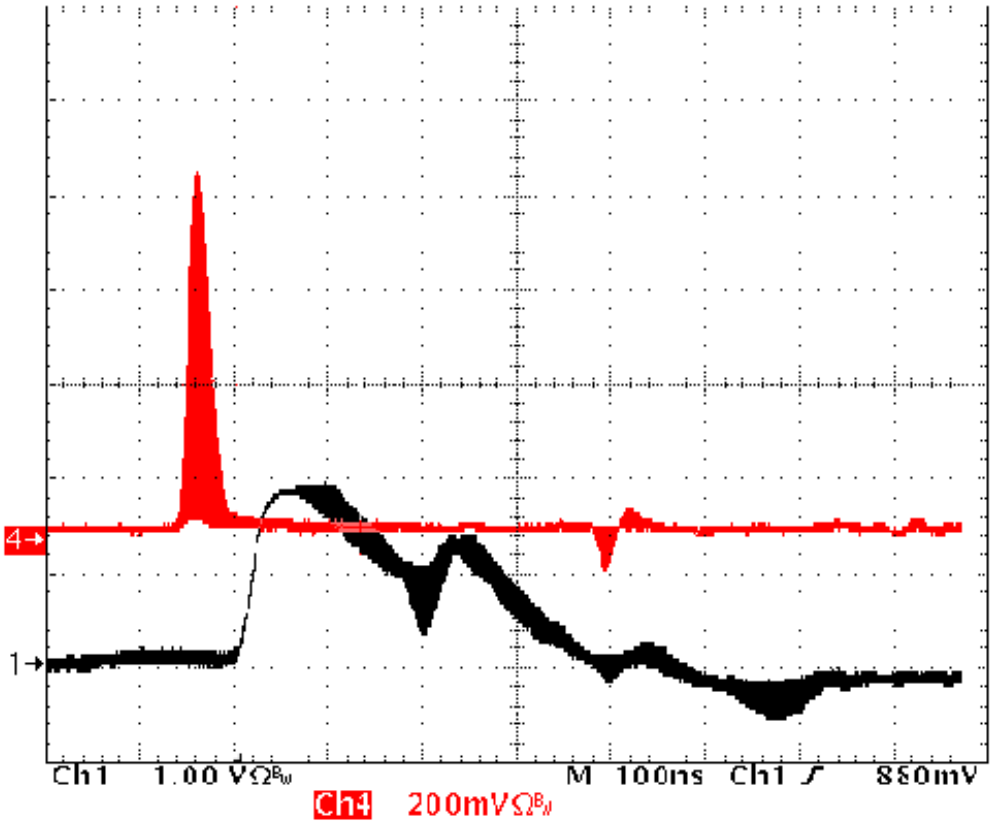
Steady Datataking from PEP-II

- Extended data taking period



Fast Abort Signal at SLAC

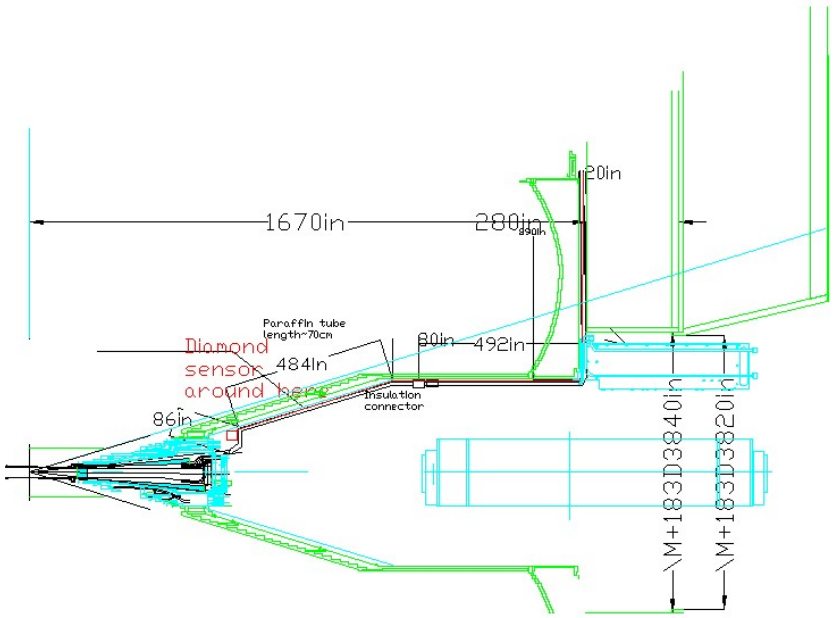
- Captured a beam abort on a digital scope
  - Red is diamond
  - Black is damaged silicon

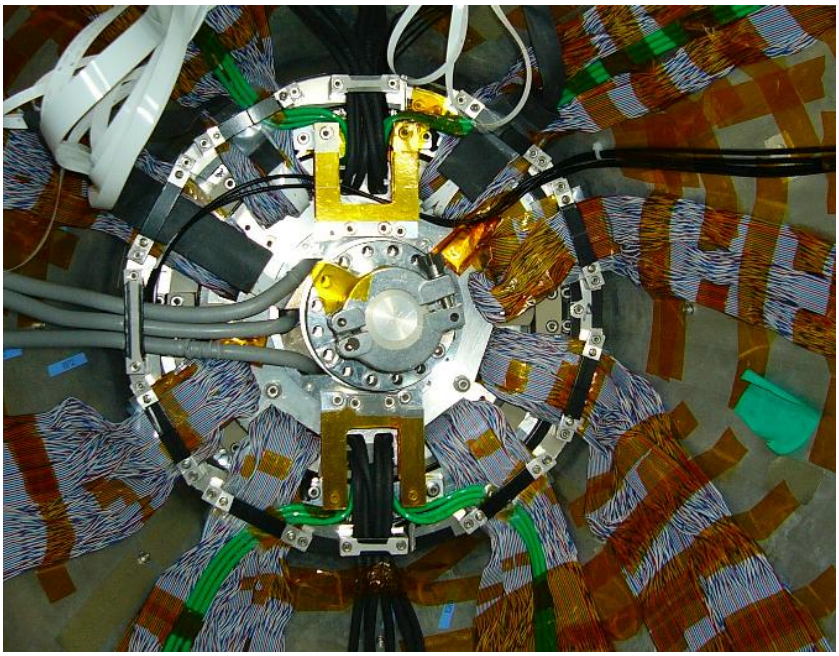


- Could use fast signal for single turn abort
  - Requires rad-hard, on-sensor electronics
  - Not proposed here

Installation at KEK/Belle

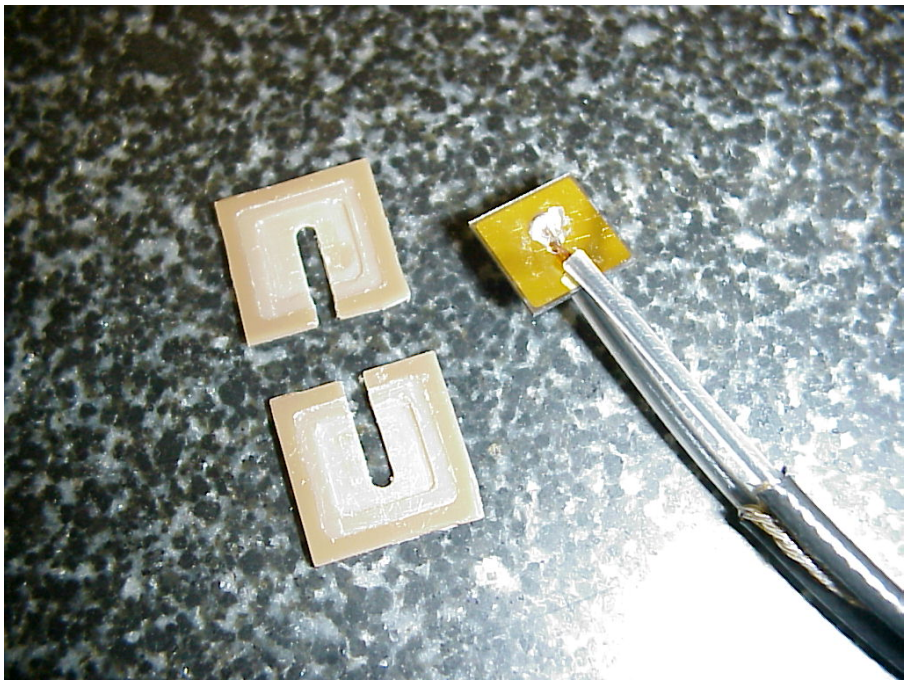
- Have installed similar sensors in Belle





- Now preparing readout electronics
- Install those later this year

Packaging for Belle



Applications at the LHC

- CMS exploring similar installations at the LHC

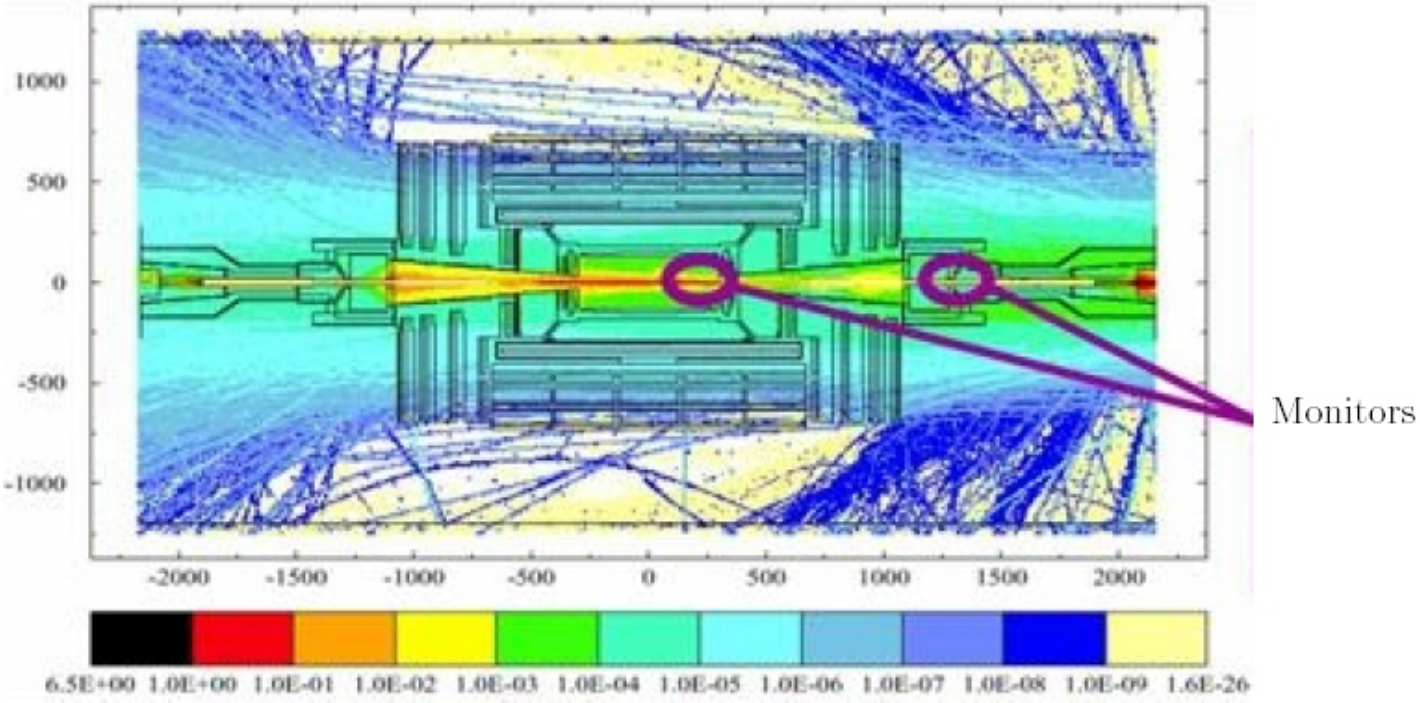


Figure 16: Simulation of a Beam Accident in CMS.

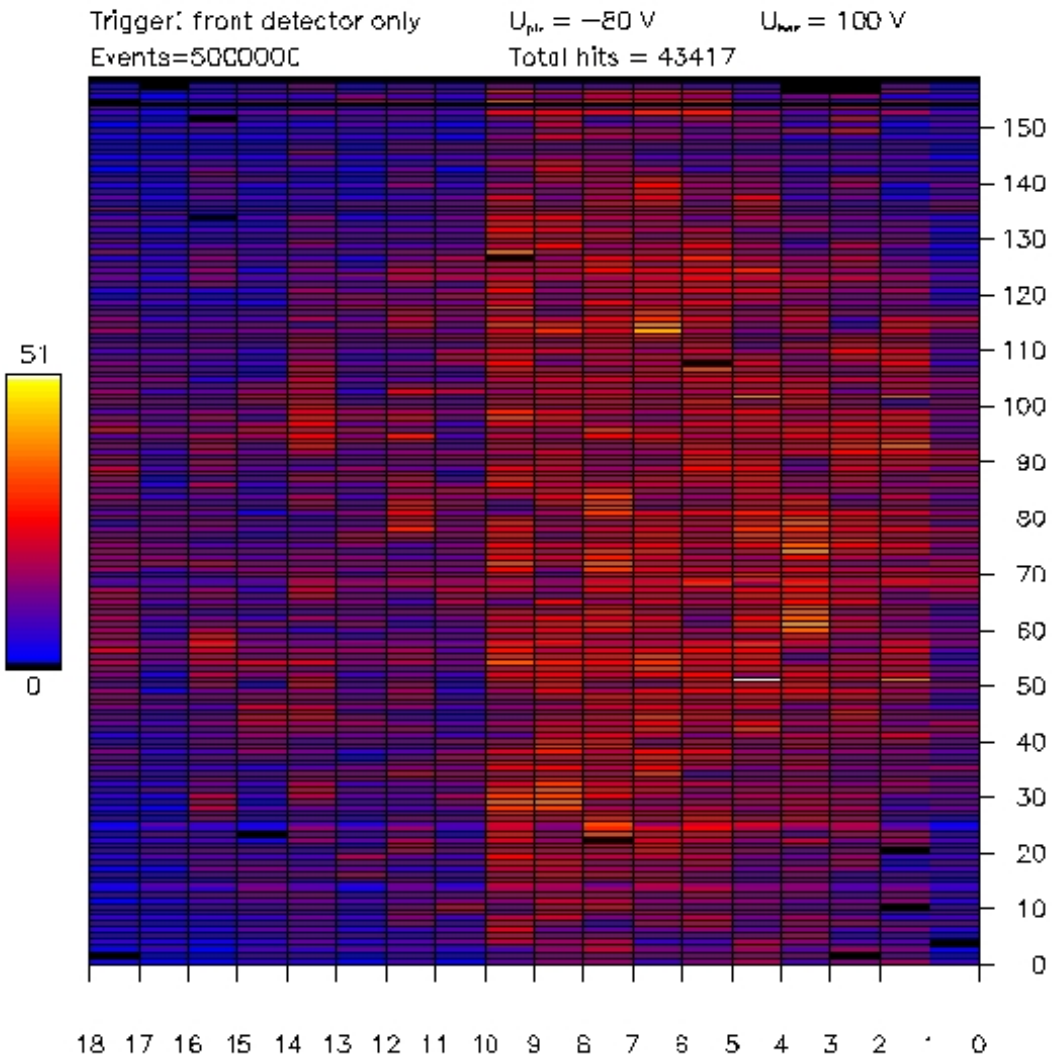
- Beam-test underway this week at CERN
  - Using 25ns beam in the CERN North Area
  - Simulate fast beam lost
  - Study fast abort signals
- Total dose at LHC more of an issue
  - Need to push rad-hardness further than RD42
  - Request support to do this

The Proponents

- This proposal is being led by
  - The Université de Montréal
    - Georges Azuelos, Claude Leroy, Jean-Pierre Martin (faculty)
    - P.A. Delsart (research associate)
    - C. Lebel (PhD), S. Charron (MSc) (students)
  - The University of Toronto
    - William Trischuk (faculty)
    - K. Vincent (technical staff)
    - 1/2 research associate (t.b.a.)

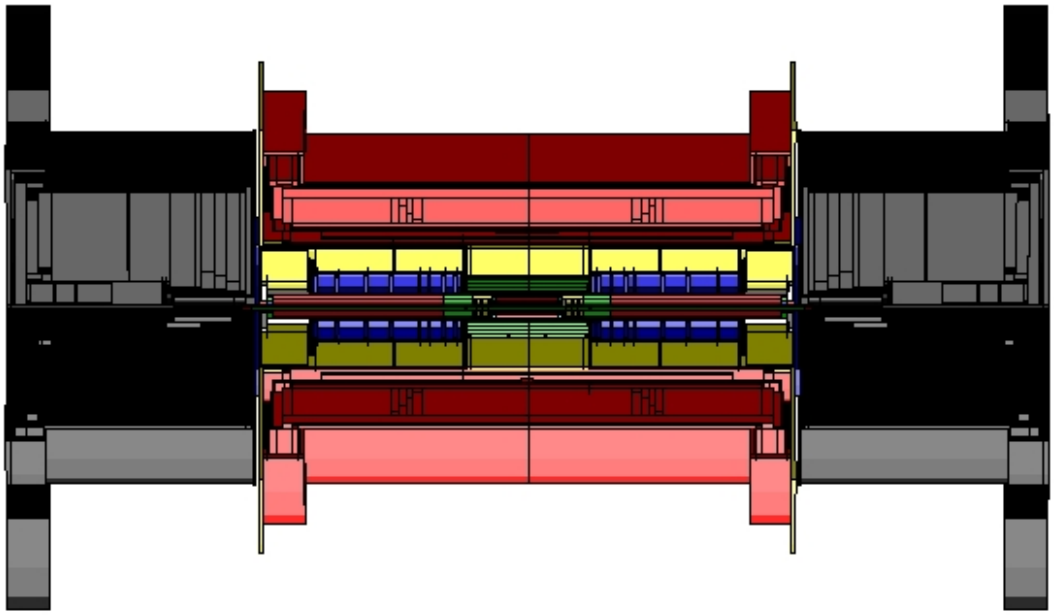
Previous Work in the ATLAS Inner Detector

- Solid state detector characterisation stations exist
  - In Toronto
    - Characterising CVD diamond using ^{90}Sr β
    - An ATLAS Pixel testbench
  - In Montréal
    - An ATLAS Pixel testbench
      - ^{106}Ru source image on pixel prototype



The Canadian Group's Expertise

- Canadian group has
  - Experience in radiation tolerance of materials
    - using protons up to 12 MeV at Montréal
    - Up to 24 GeV at the CERN-PS
    - Neutrons at Dubna
    - Studying activation of inner detector volume



- Have expertise to develop beam abort system
  - Sampling monitor currents at 1 MHz
  - Send fast signal to accelerator
  - On abort, save last N thousand samples

ATLAS View of this Proposal

- This work has fallen through the cracks in ATLAS
  - No serious effort along these lines yet
  - Have been studying this option for 6 months
  - Formally requested to look at this
    - By ATLAS Inner Detector project leader

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From: <steinar.stapnes@cern.ch>
To: <william@physics.utoronto.ca>
Cc: "'Richard Hawkings'" <Richard.Hawkings@cern.ch>,
    "'Heinz Pernegger'" <heinz.pernegger@cern.ch>,
    "'Marzio NESSI'" <Marzio.Nessi@cern.ch>
Subject: Radiation monitors
Date: Thu, 9 Oct 2003 16:27:31 +0200

We are looking for groups who can follow this,
communicate/follow with the CMS work, take
responsibility for the ATLAS parts, bring in
resources, etc. In fact, concerning the diamonds
progress looks good.

How is the funding and resource situation for
you now?  Is there any chance?

Best regards,

     Steinar
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Funds Requested

Equipment	2004-05	2005-06	2006-07
Prototype Sensors	15,360		
Metalisation	3,000	2,500	2,500
Packaging	2,000	2,000	500
Irradiation time	8,000	8,000	
Electronics development	8,000		
Support Mechanics for ATLAS			2,000
Production sensors		7,680	15,360
Production electronics		20,000	2,000
Cabling			8,000
Total Requested from NSERC	**$36,360**	**$40,180**	**$30,360**

ATLAS Beam Monitoring Proposal

- Prepare to install eight sensors around ATLAS IR
  - Test radiation hardness of material (2004-05)
  - Improve packaging/cabling (2005)
  - Beam abort/loss monitor electronics (2004-2006)
  - Acquire/assemble/install final sensors (2006)
- Ready for ATLAS commissioning in early 2007