The ATLAS Beam Conditions Monitor

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for the ATLAS BCM Group

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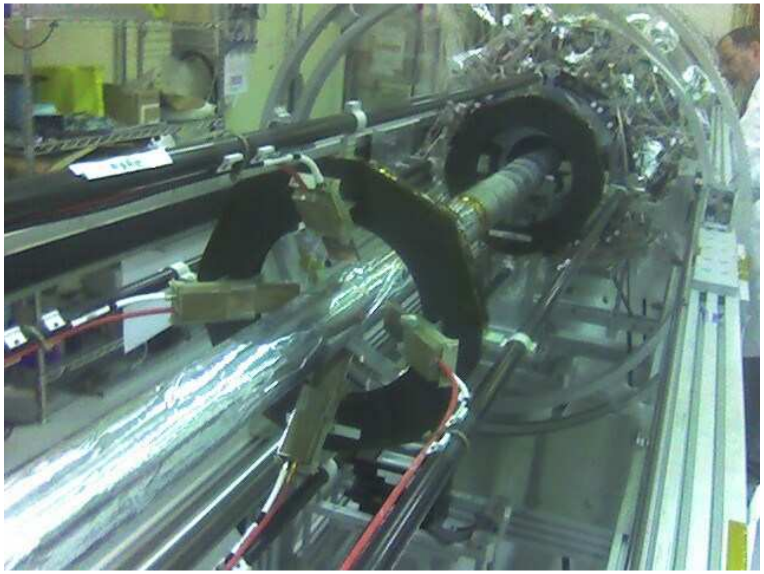
Outline of the Talk

- **Introduction**
- **Diamond Modules**
- **Testbeam Results**
- **Summary**



The ATLAS BCM Collaboration

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[3] *The Ohio State University, Columbus, OH, U.S.A.*
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Small group in ATLAS → 15 Participants

Diamond BCM detectors already in BaBar, Belle, CDF, ATLAS

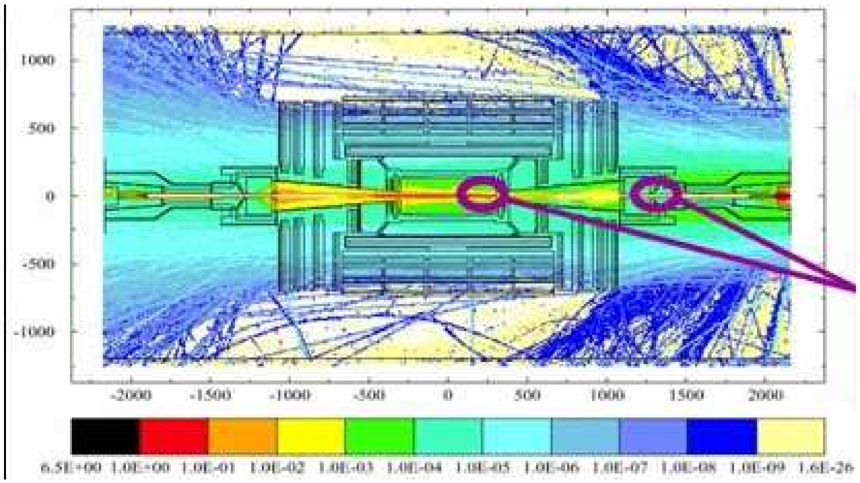
Planned for DESY, CMS, ALICE, LHCb

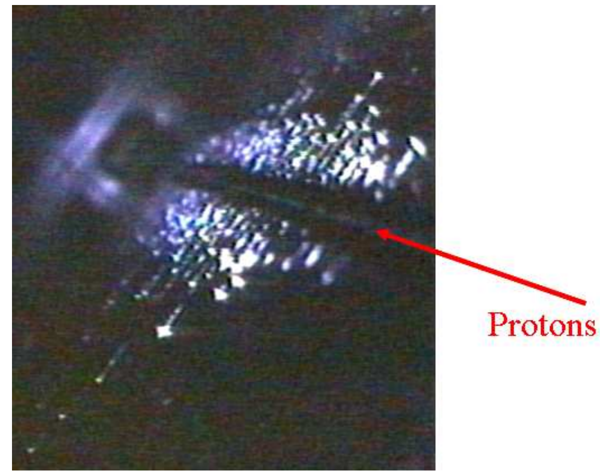
Motivation: Beam Condition Monitoring

→ Radiation monitoring crucial for Si operation/abort system

→ Abort beams on large current spikes

→ Measure calibrated daily and integrated dose





Style:

- DC current or Slow Readout (ms-μs)
- Requires low leakage current
- Requires small erratic dark currents
- Allows simple measuring scheme

- Examples: BaBar, Belle, CDF

- Single Particle Counting (ns)
- Requires fast readout (GHz range)
- Requires low noise
- Allows timing correlations

- Example: ATLAS

Motivation: Beam Condition Monitoring

Look for a Material with Certain Properties:

- Radiation hardness (no frequent replacements)
- Low dielectric constant → low capacitance
- Low leakage current → low readout noise
- Good insulating properties → large active area
- Room temperature operation, Fast signal collection time → no cooling

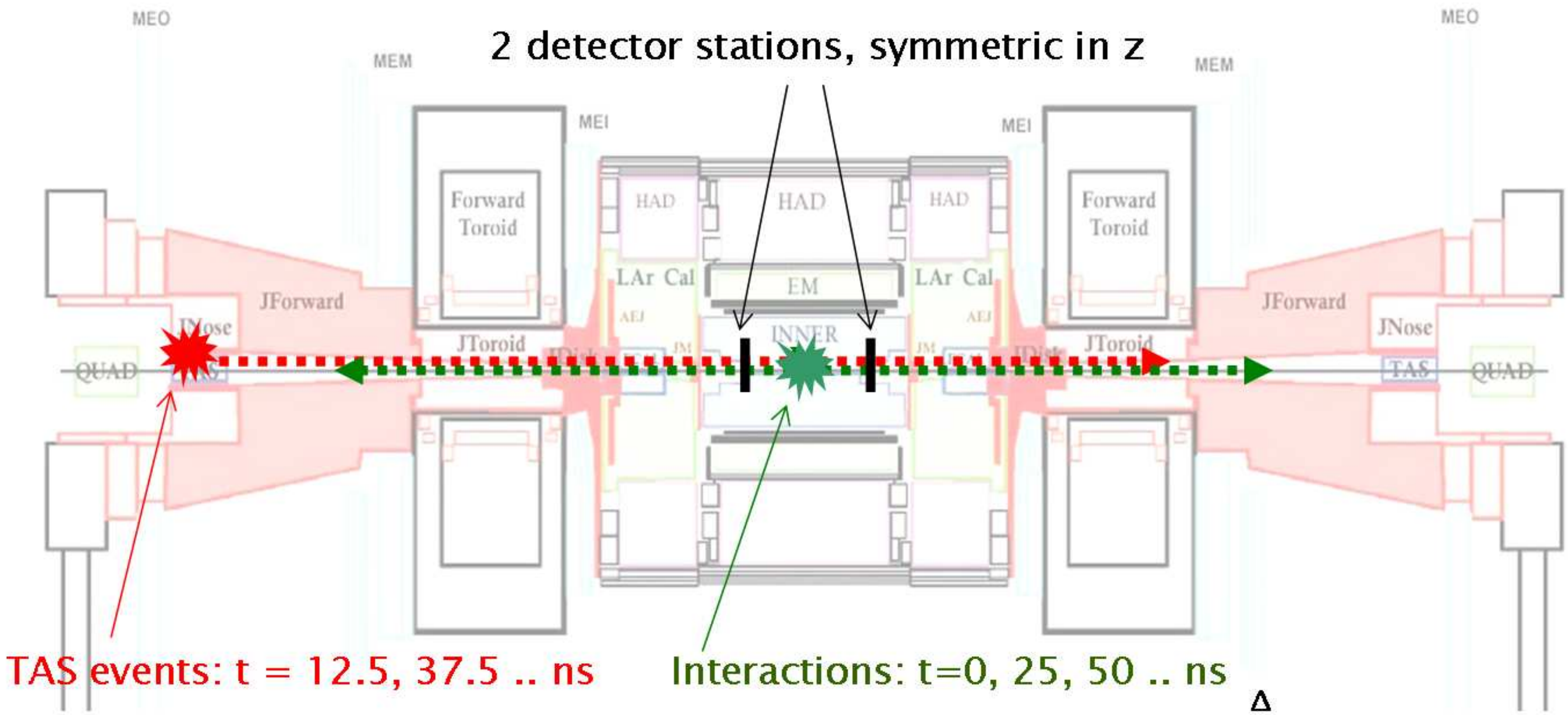
Presented Here:

- Polycrystalline Chemical Vapor Deposition (pCVD) Diamond
- ATLAS pCVD diamond Beam Conditions Monitoring system

References:

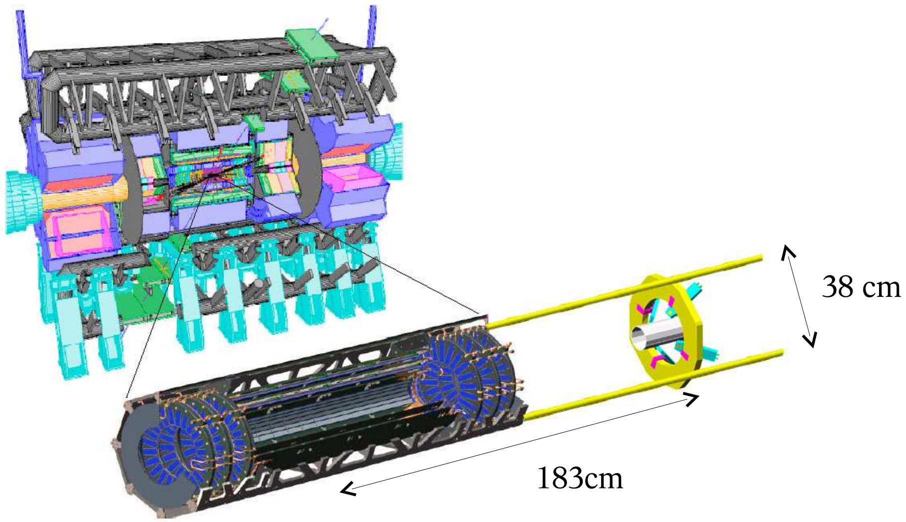
- *RD42* → http://rd42.web.cern.ch/RD42
- *ATLAS BCM* → https://twiki.cern.ch/twiki/bin/view/Atlas/BcmWiki
- *Diamonds supplied by and in collaboration with Element Six Ltd.*

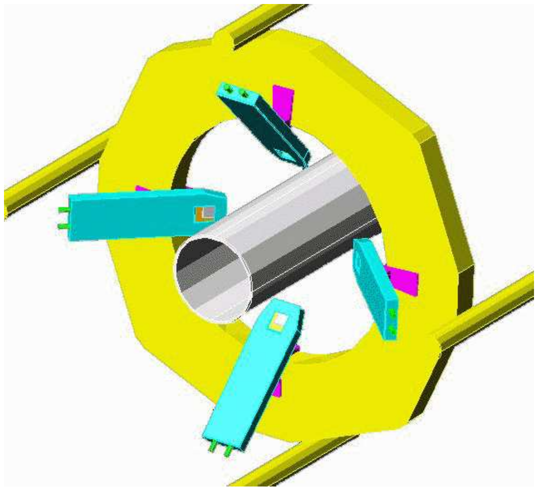
Idea: Time of flight measurement to distinguish collisions from background

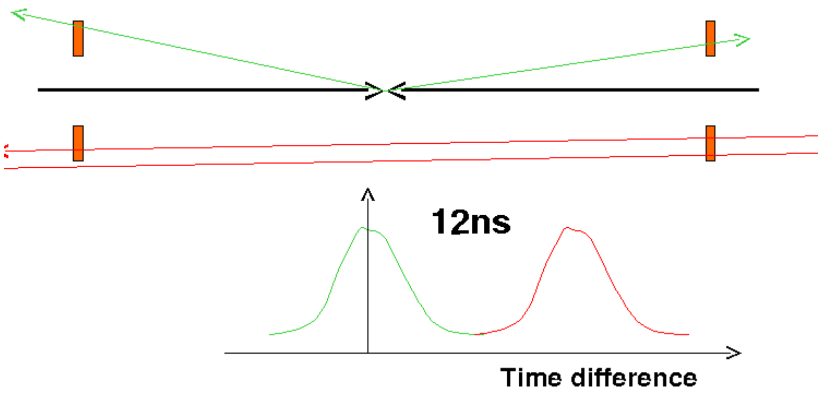


- Detectors placed at $z = \pm$ 1.9m and r = 55mm ($\eta \sim 4.2$, Δt = 12.3ns)
- Detectors must be able to withstand ∼50Mrad in 10yrs
- Detectors plus electronics must have excellent time resolution (∼1ns rise time, 2-3ns pulse width, 10ns baseline restoration)

Design: Inside the ATLAS Beam Pipe Support Structure (BPSS)

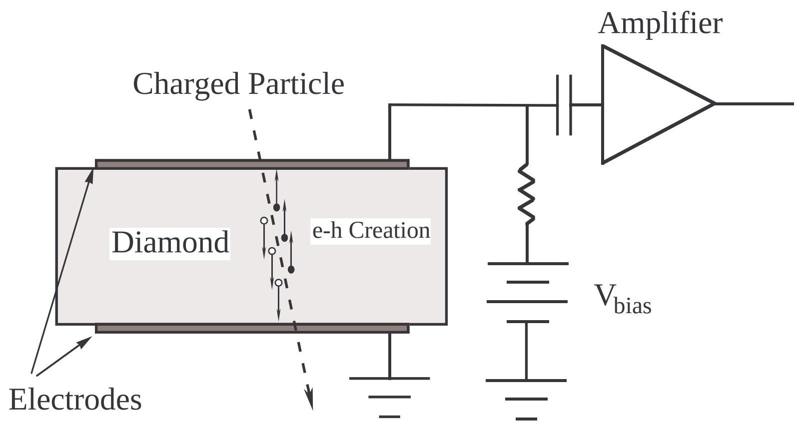


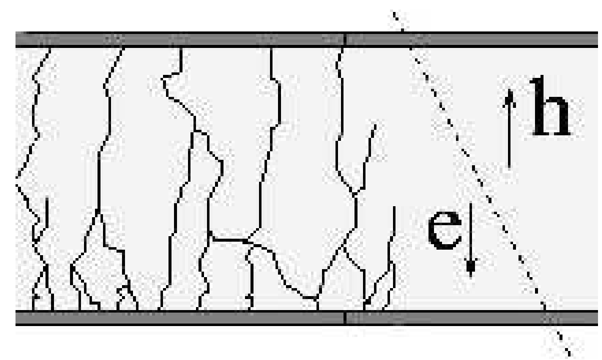




Detectors Constructed with Diamond:

Signal formation





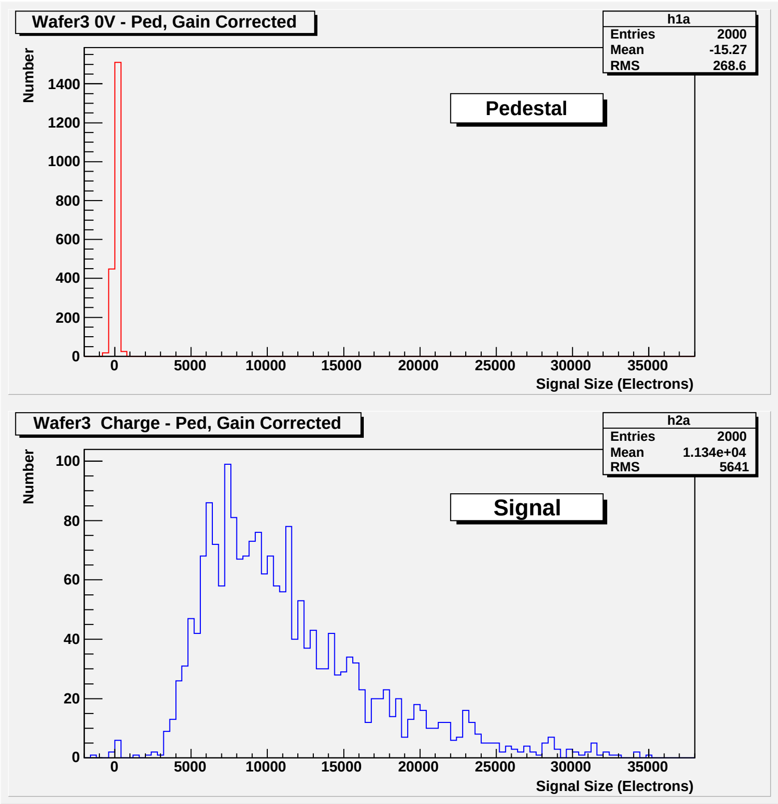
- $Q = \frac{d}{t} Q_0$ where d = collection distance = distance e-h pair move apart
- $d = (\mu_e \tau_e + \mu_h \tau_h) E$
- $d = \mu E \tau = v\tau$

  with $\mu = \mu_e + \mu_h \rightarrow v = \mu\ E$

  and $\tau = \frac{\mu_e \tau_e + \mu_h \tau_h}{\mu_e + \mu_h}$
- $I = Q_0 \frac{v}{d}$

Latest Material: pCVD Diamond Measured with a ^{90}Sr Source

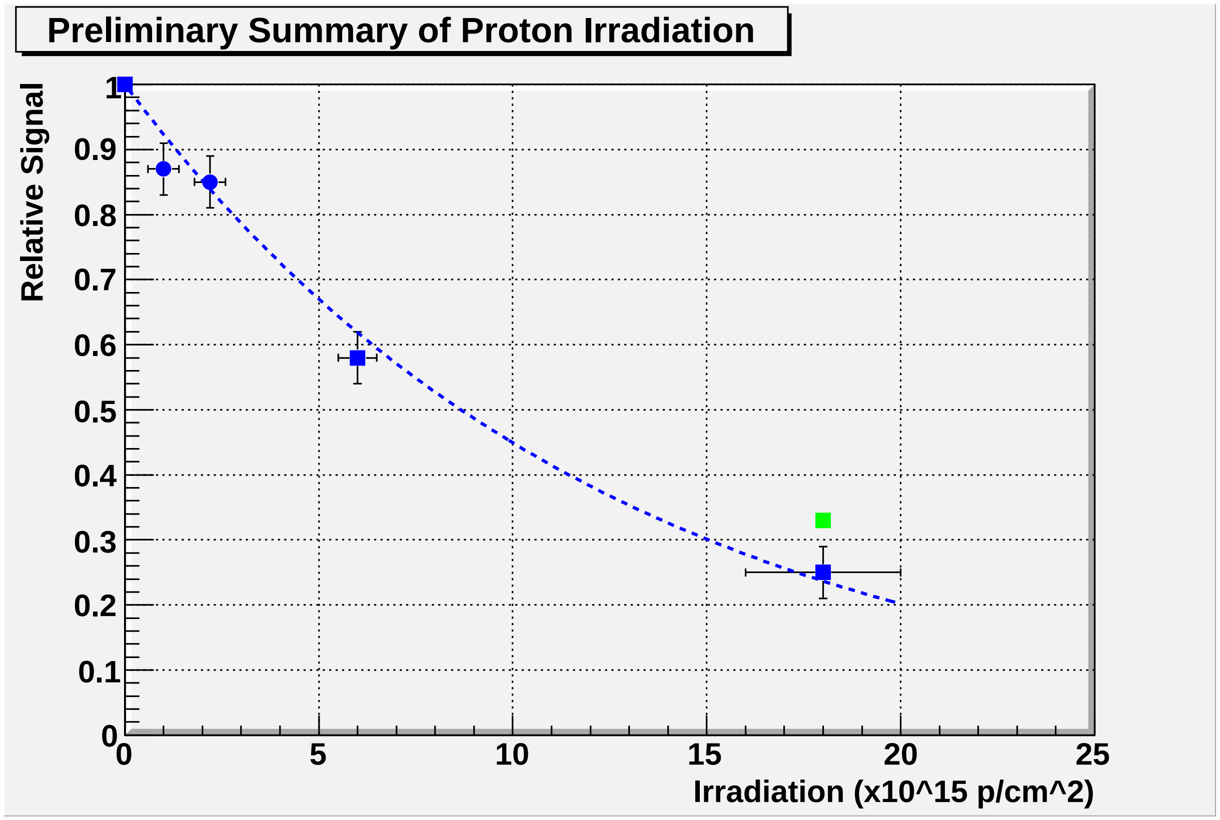
- Contacts on both sides - structures from μm to cm
- Usually operate at E=1-2V/μm
- Test Procedure: dot $\rightarrow$ strip $\rightarrow$ pixel on same diamond!



- Q_{MP} = 8500-9000e
- Mean Charge = 11300e

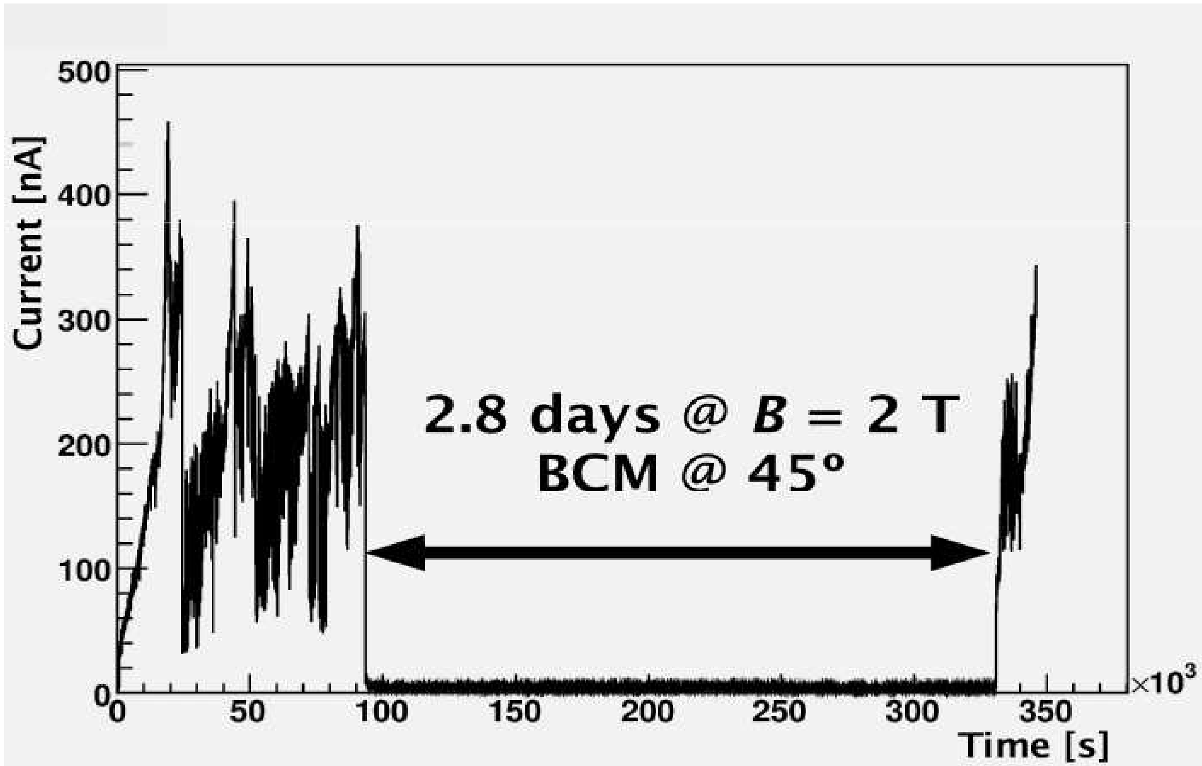
- Source data well separated from 0
- Collection Distance now ≈ 300μm
- Most Probable Charge now ≈ 9000e
- 99% of PH distribution above 4000e
- FWHM/MP ≈ 0.95 — Si has ≈ 0.5
- This diamond available in large sizes

Proton Irradiation Studies:



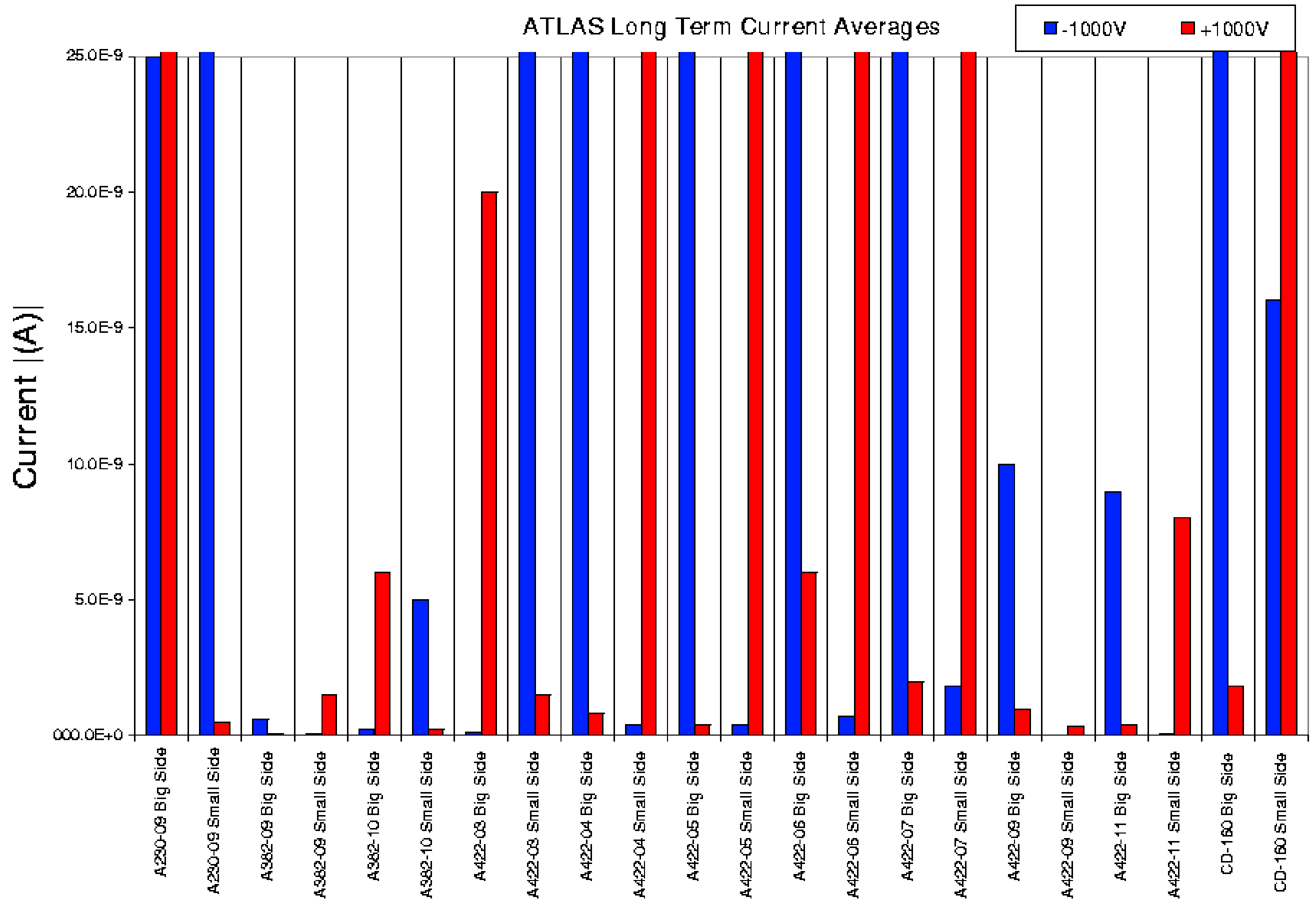
Summary of proton irradiation results for pCVD diamond at E=1V/μm and E=2V/μm (green square) after 1.8×10^{16} p/cm^2 ($\sim$500Mrad)

Erratic Dark Currents:



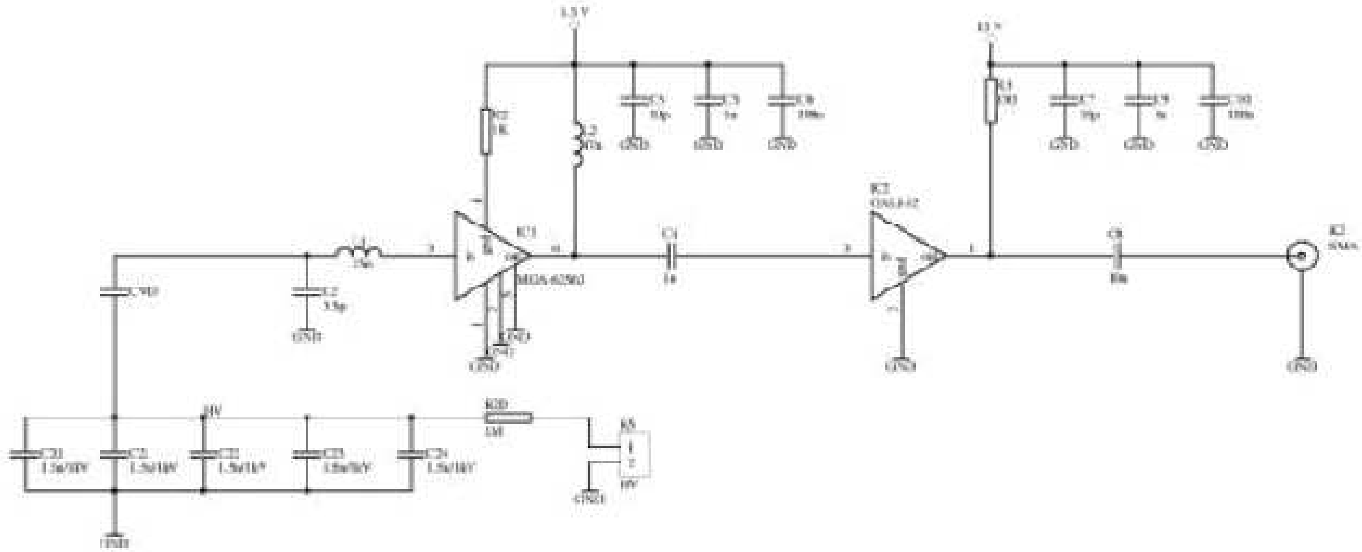
- First observed in BaBar.
- Can be large but reduced significantly in 0.5T or greater B field.
- Should not be a problem for particle counting.

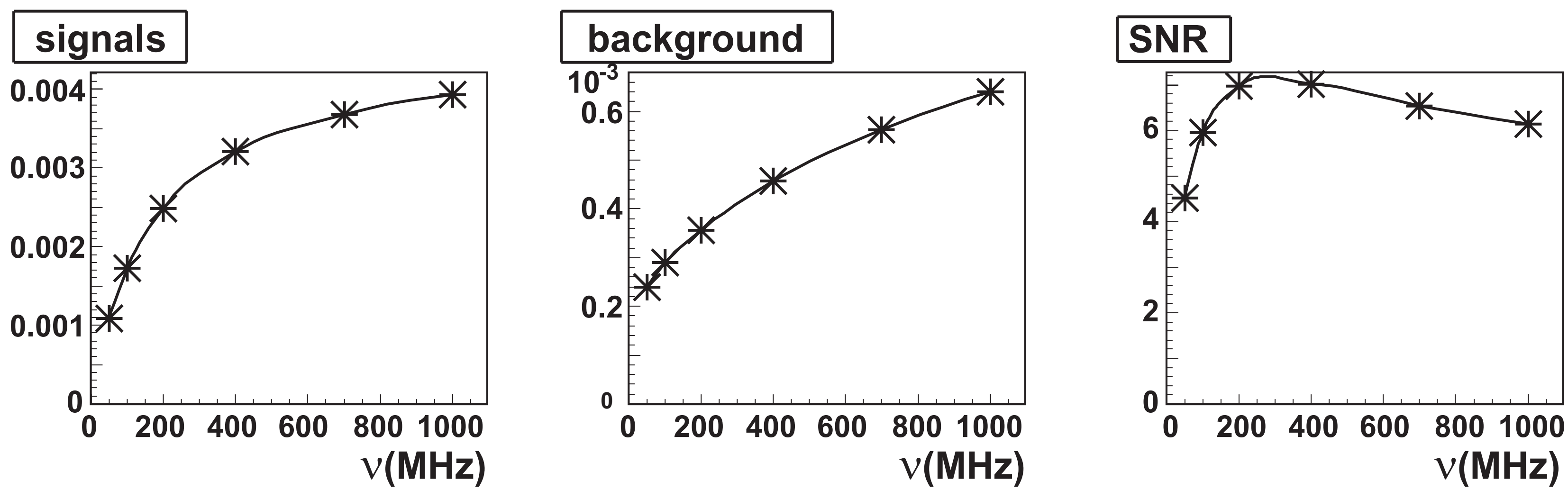
Leakage Currents at 1000V:



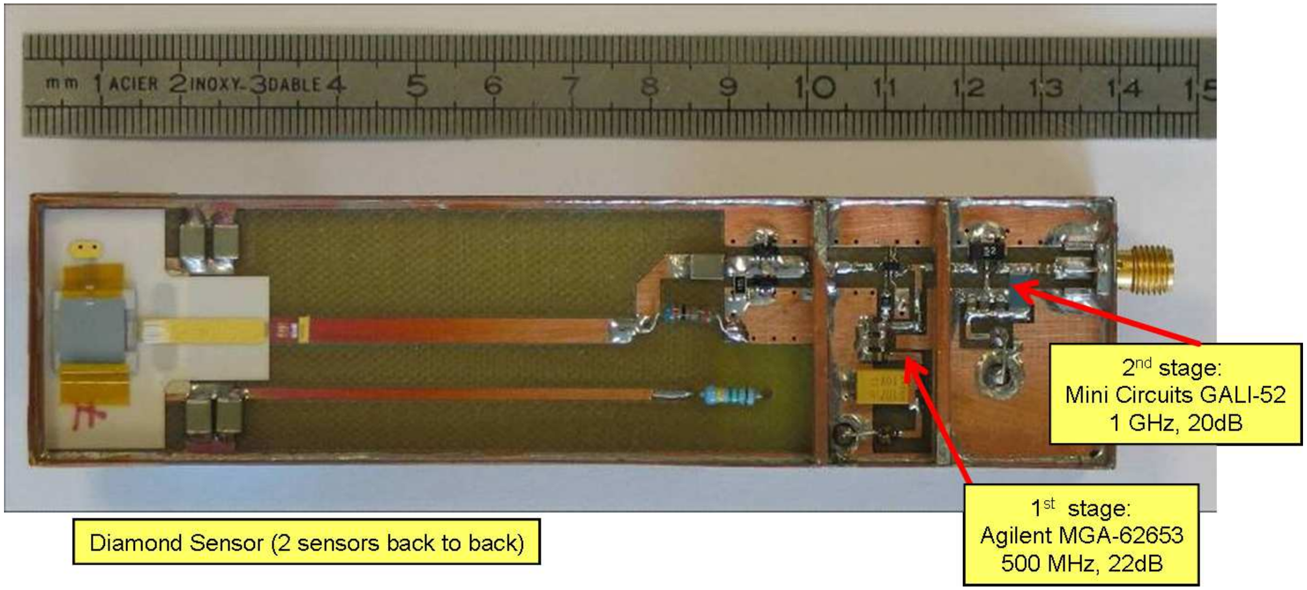
- Scale of leakage currents is small.
- Leakage currents have an orientation.

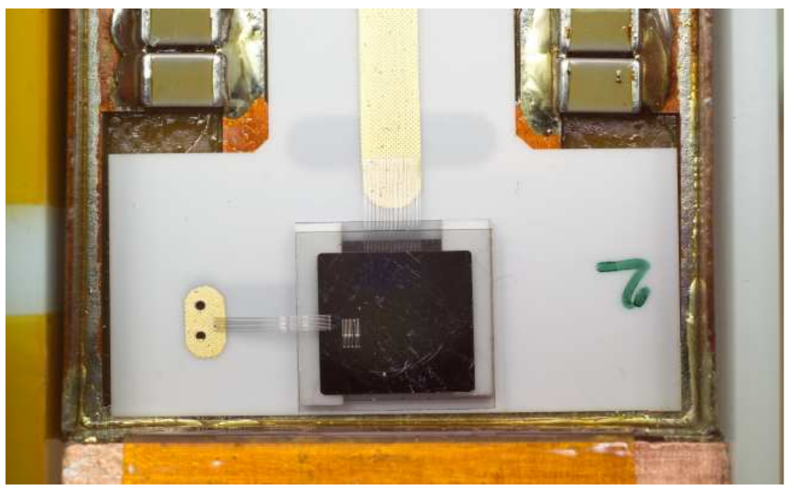
Frontend Amplifiers:



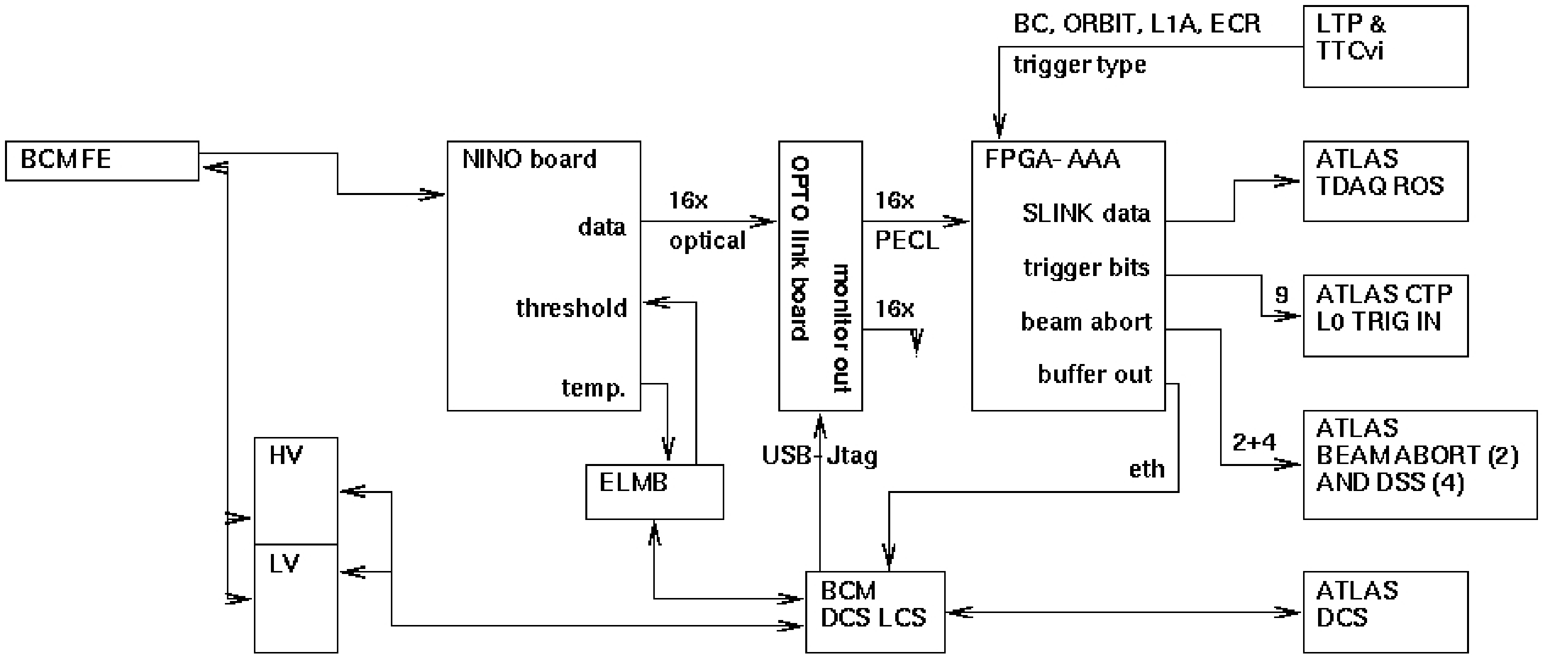


Mechanical Assembly:



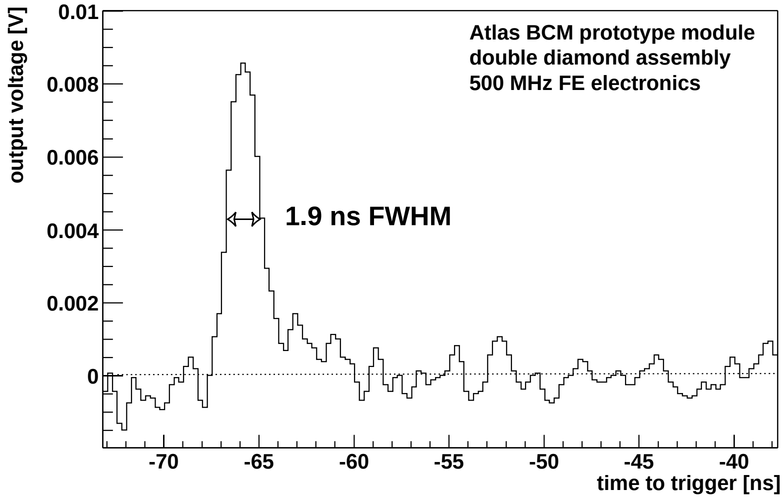


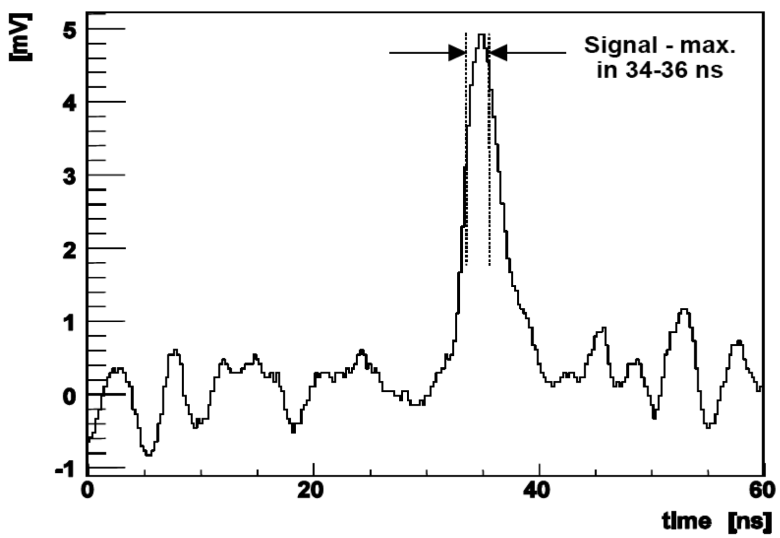
Backend Electronics:



- NINO provides trigger Time and Time Over Threshold

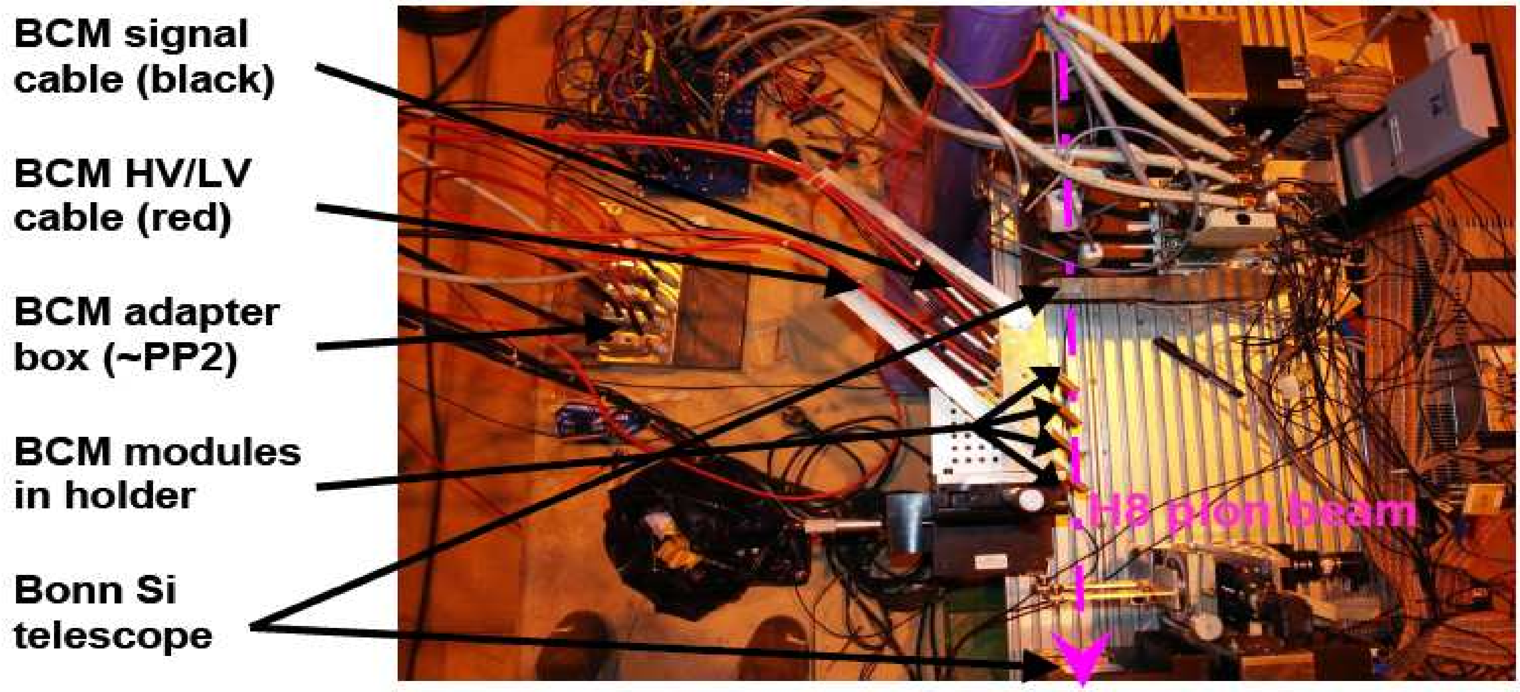
MIP Pulses:


Atlas BCM prototype module
double diamond assembly
500 MHz FE electronics
1.9 ns FWHM
output voltage [V]
time to trigger [ns]

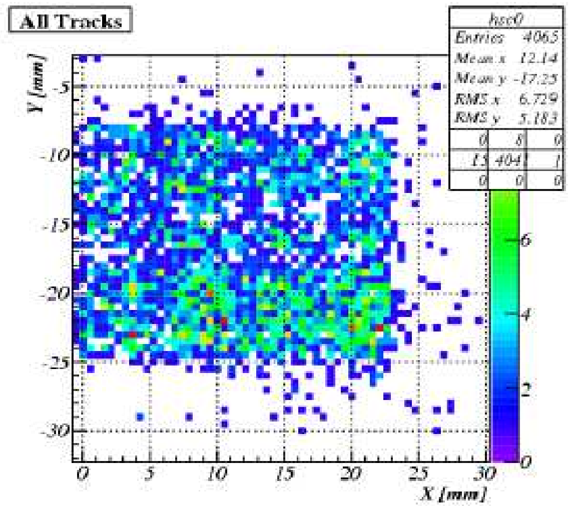

Signal - max.
in 34-36 ns
[mV]
time [ns]

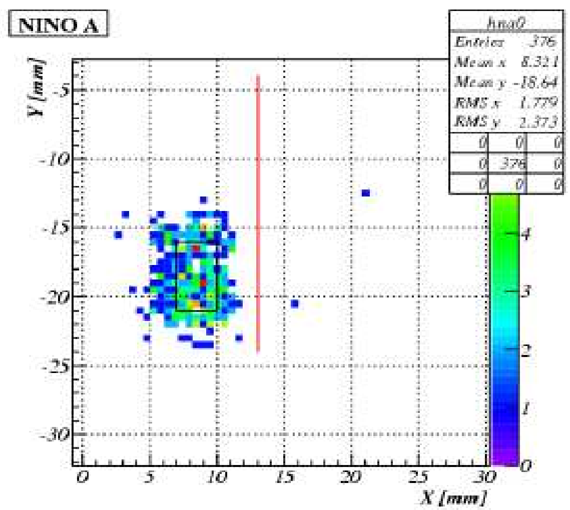
Beam Test Results

Testbeam Setup:

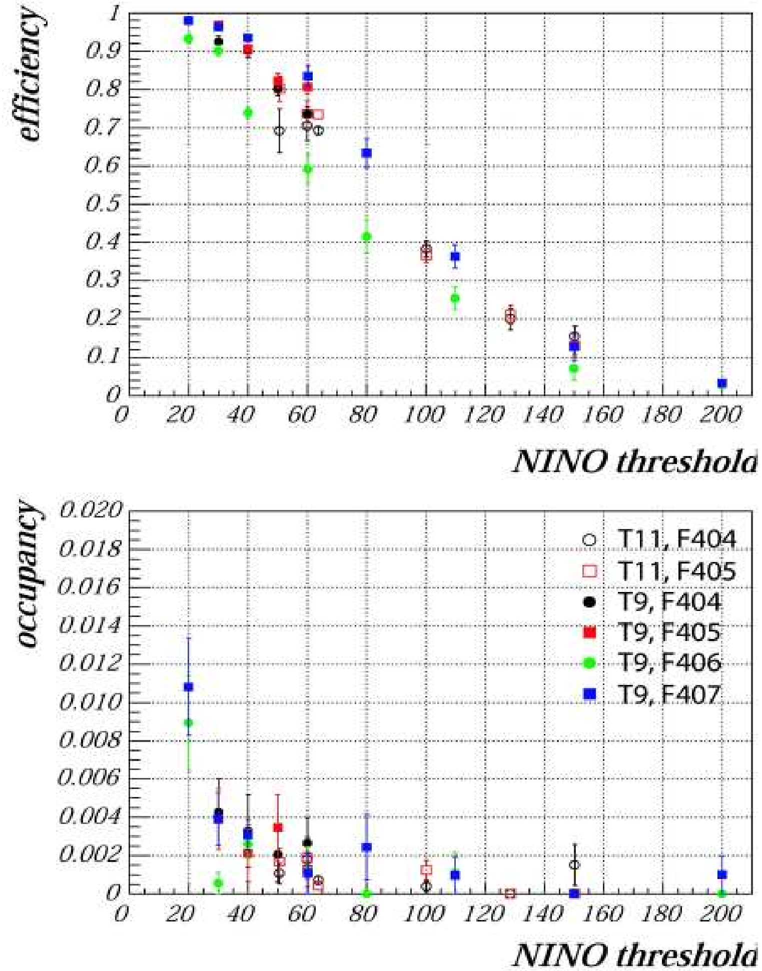


Hitmap:

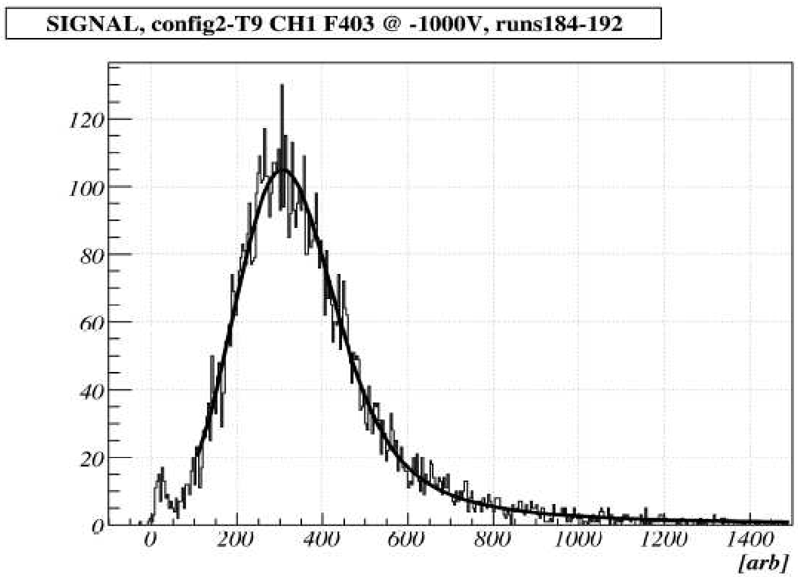

All Tracks
hsc0
Entries 4065
Mean x 12.14
Mean y -17.25
RMS x 6.729
RMS y 5.183
Y [mm]
X [mm]

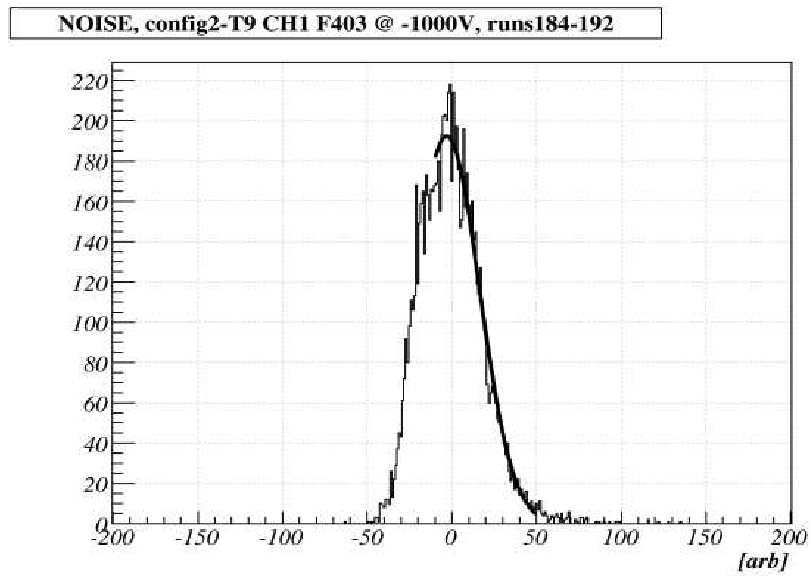

NINO A
hna0
Entries 376
Mean x 8.321
Mean y -18.64
RMS x 1.779
RMS y 2.373
Y [mm]
X [mm]

Efficiency and Occupancy:



Signal and Noise:

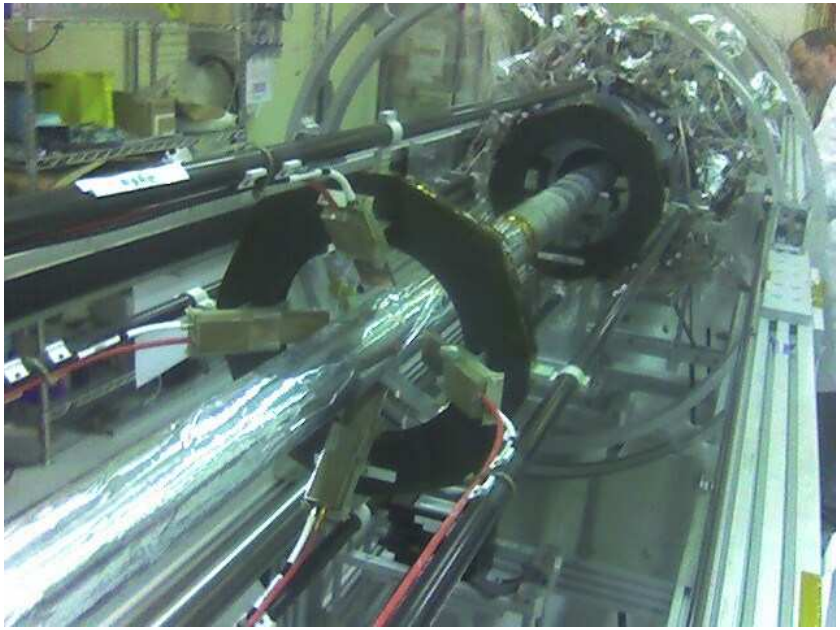


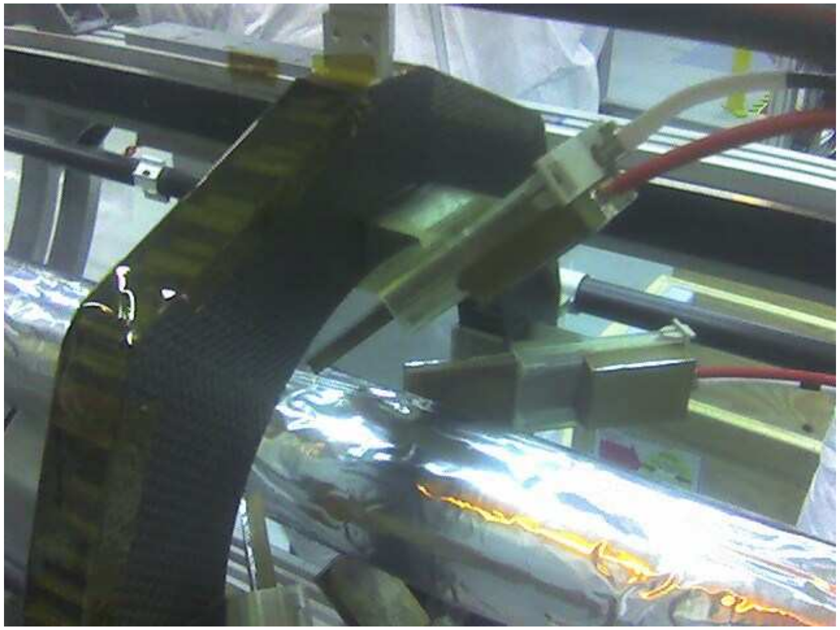


- Signal is 271 ADC counts; Noise is 20 ADC
- Measured S/N = 13.5±2

Present Status

Installation:



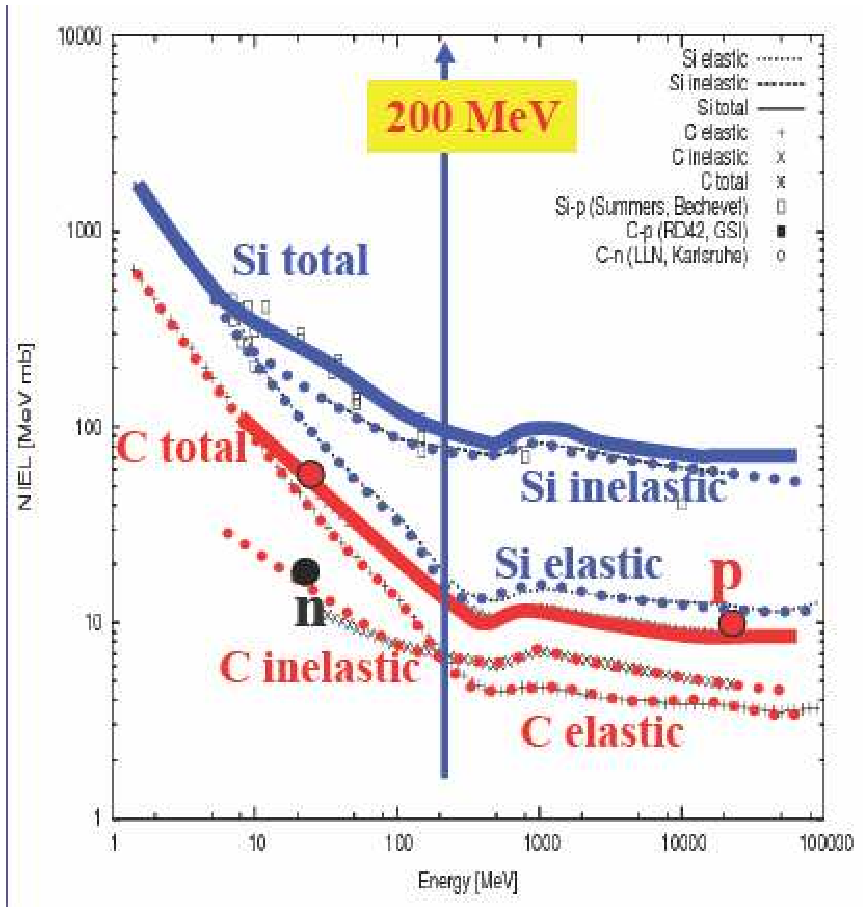


Summary

- **The ATLAS BCM system was constructed using pCVD diamond**
  - 2 diamonds are used in a back-to-back configuration
  - the assembly is tilted at 45^o
- **Testbeam results indicate an operable system**
  - S/N $\sim$ 13/1
  - Efficiency/Occupancy operating point determined
- **The ATLAS BCM System meets all of the design specs**
  - S/N $\sim$ 10/1
  - Risetime $\sim$ 1-2ns
  - Pulse width $\sim$ 3ns
  - Baseline Restoration in ¡10ns
  - Efficiency/Occupancy reasonable
- **BCM Status**
  - ATLAS diamond BCM installed in January 2007
  - Application of diamond successful in BaBar, CDF
  - A secondary (redundant) system for ATLAS is being discussed similar to CDF

Additional Transparencies

Irradiation Results and NIEL:



- Data for Diamonds seems to follow NIEL.
- At all energies diamond more radiation hard than silicon.

The CDF Diamond Radiation Monitors:

Photo of CDF Prototype Devices

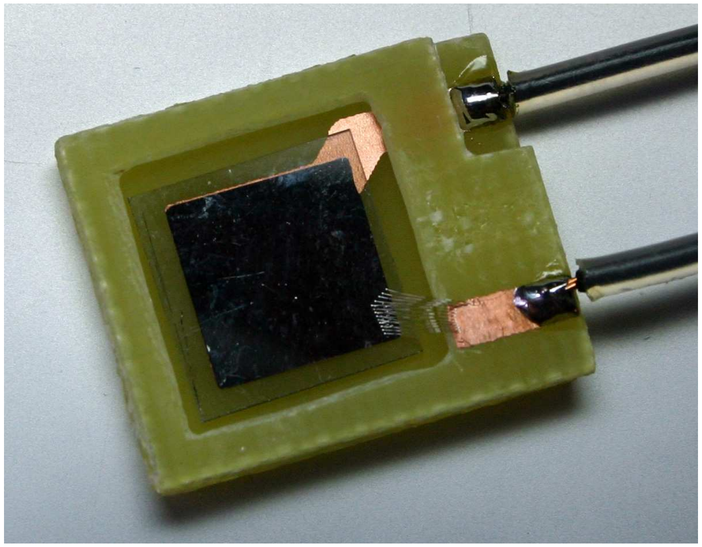
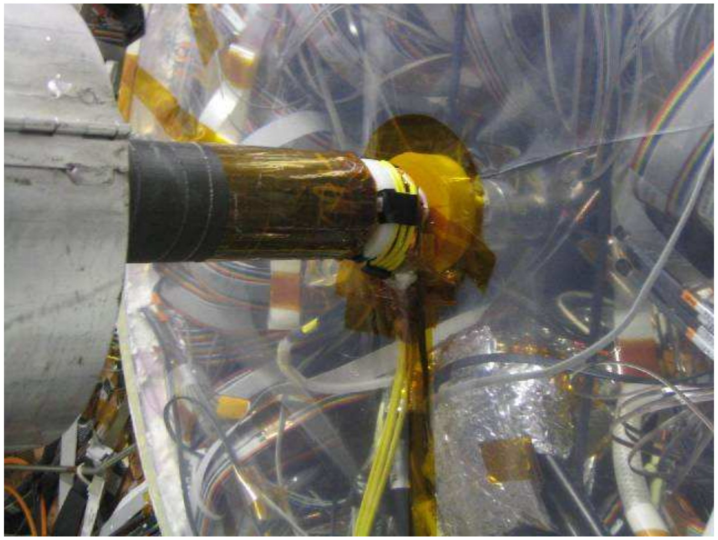
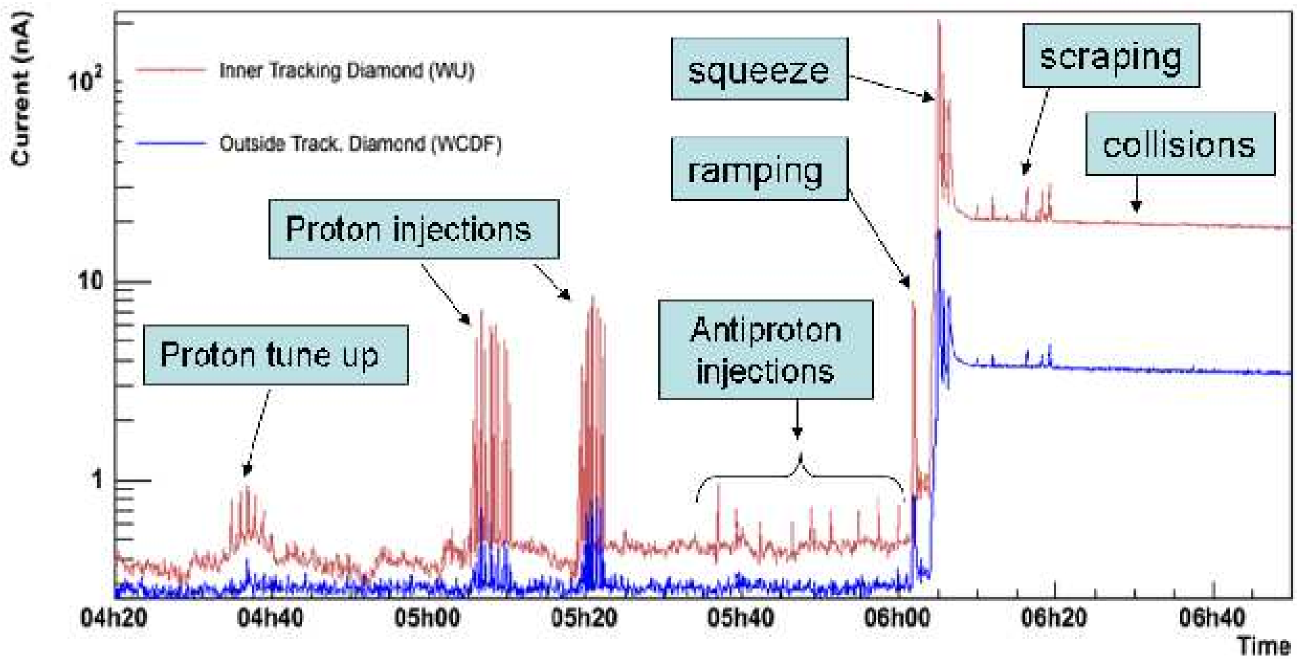


Photo of Installed CDF Device



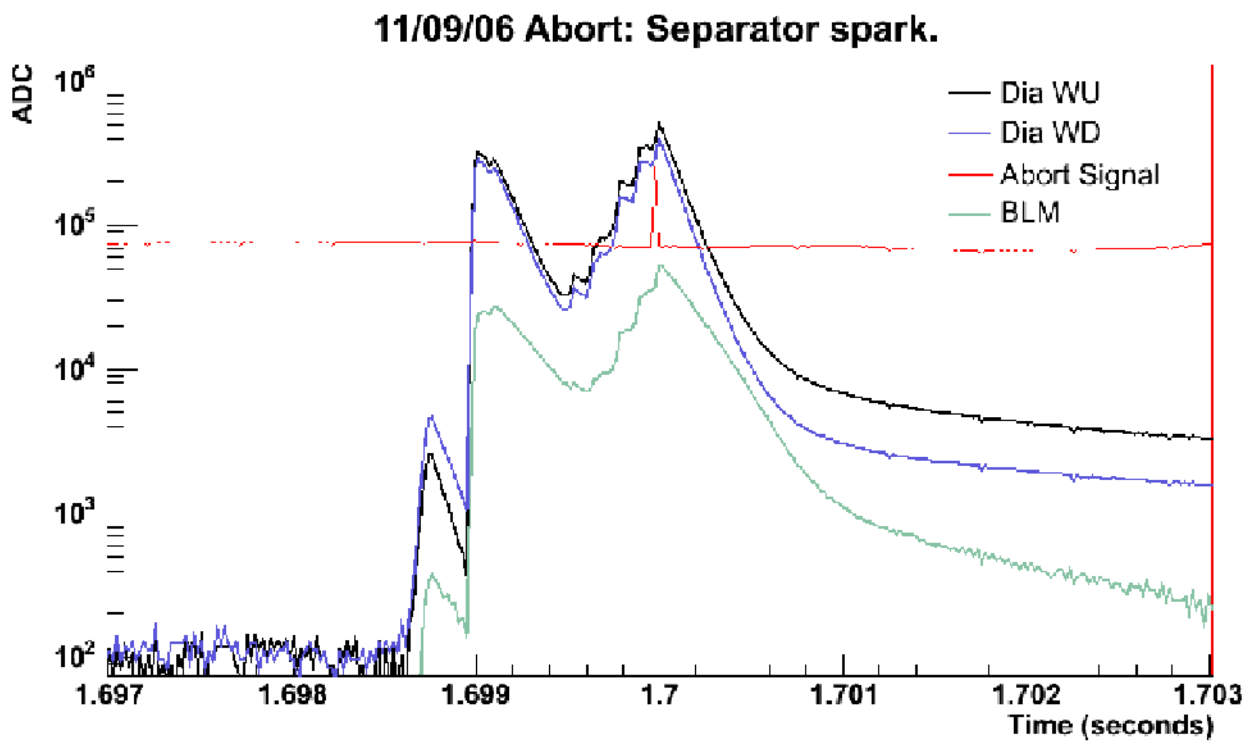
- The installed CDF device has thirteen diamonds
- Eight inside CDF - four per side
- Five outside the experiment at calibration stations near Beam Loss Monitors (BLM's)

Data Taking in CDF:



- *Two diamonds operating in CDF since Fall 2004.*
- *Full system installed - June 2006!*
- *Inside detector is the place to be by an order of magnitude!*

Beam Abort in CDF:



- *Both diamonds respond quicker than BLM and abort signal.*