Beam Condition Monitor for the CMS

BCM Group
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Beam Condition Monitor for CMS

Purpose

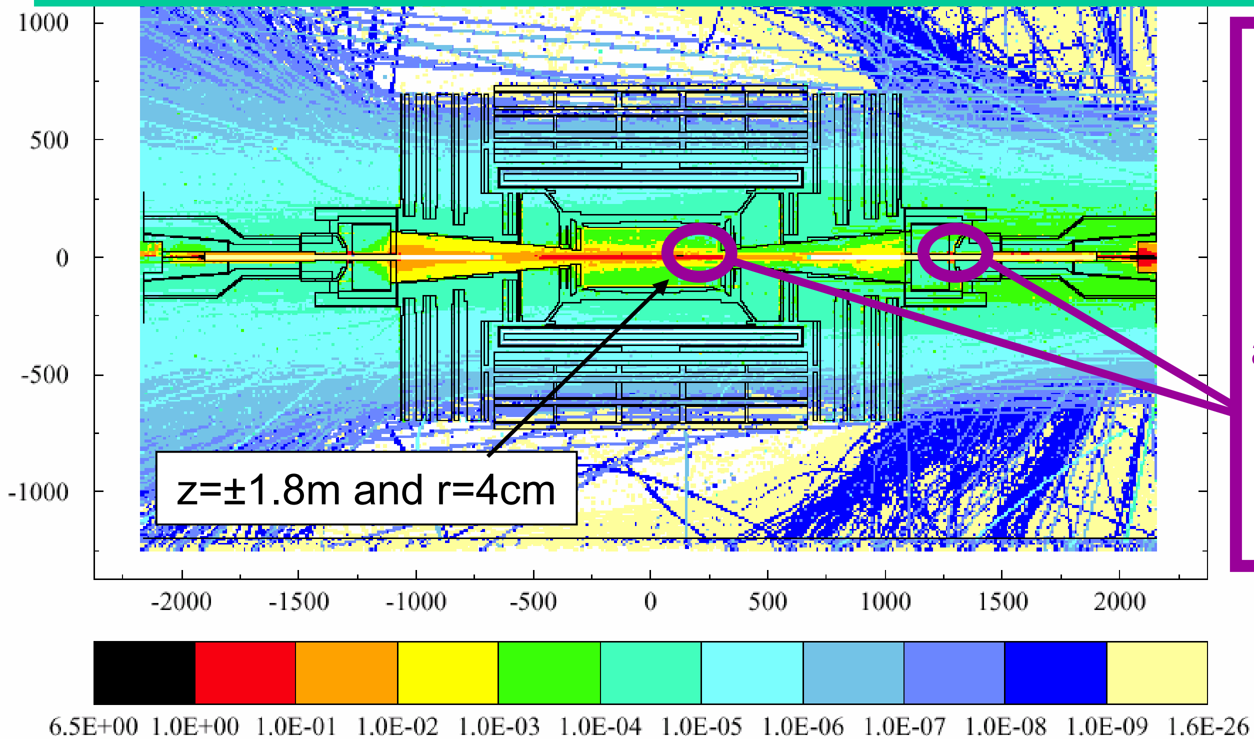
- The Beam Condition Monitor (BCM) has to provide online radiation monitoring within the CMS
- BCM forms part of the radiation monitoring system for equipment safety and radiation level/beam monitoring
- The BCM should be in addition to the LHC machine protection system and Beam Loss Monitors

BCM Issues

- Allows protection of equipment during instabilities/accidents
- Provides fast feedback to the machine for optimization of beam conditions
- Provides fast feedback to the machine for detection of adverse beam conditions
- Monitors the instantaneous dose during operation
- Provides input into LHC beam abort system (1 input/ experiment)

Accident Scenarios

Unsynchronised beam abort: ~10^{12} protons lost in IP 5 in 260ns



Beam condition monitors

Looking for increase over normal rate

Monitors to be within CMS and feed to machine interlock

Sensors to be placed in the Pixel volume and after the Forward calorimeter

- Sensors under investigation: Polycrystalline Diamond
  - Fast signal response
  - Radiation hardness
  - Minimal services required ie no cooling necessary

Evaluated using a fast extraction beam from the CERN PS at the T7 beamline (November 2003)

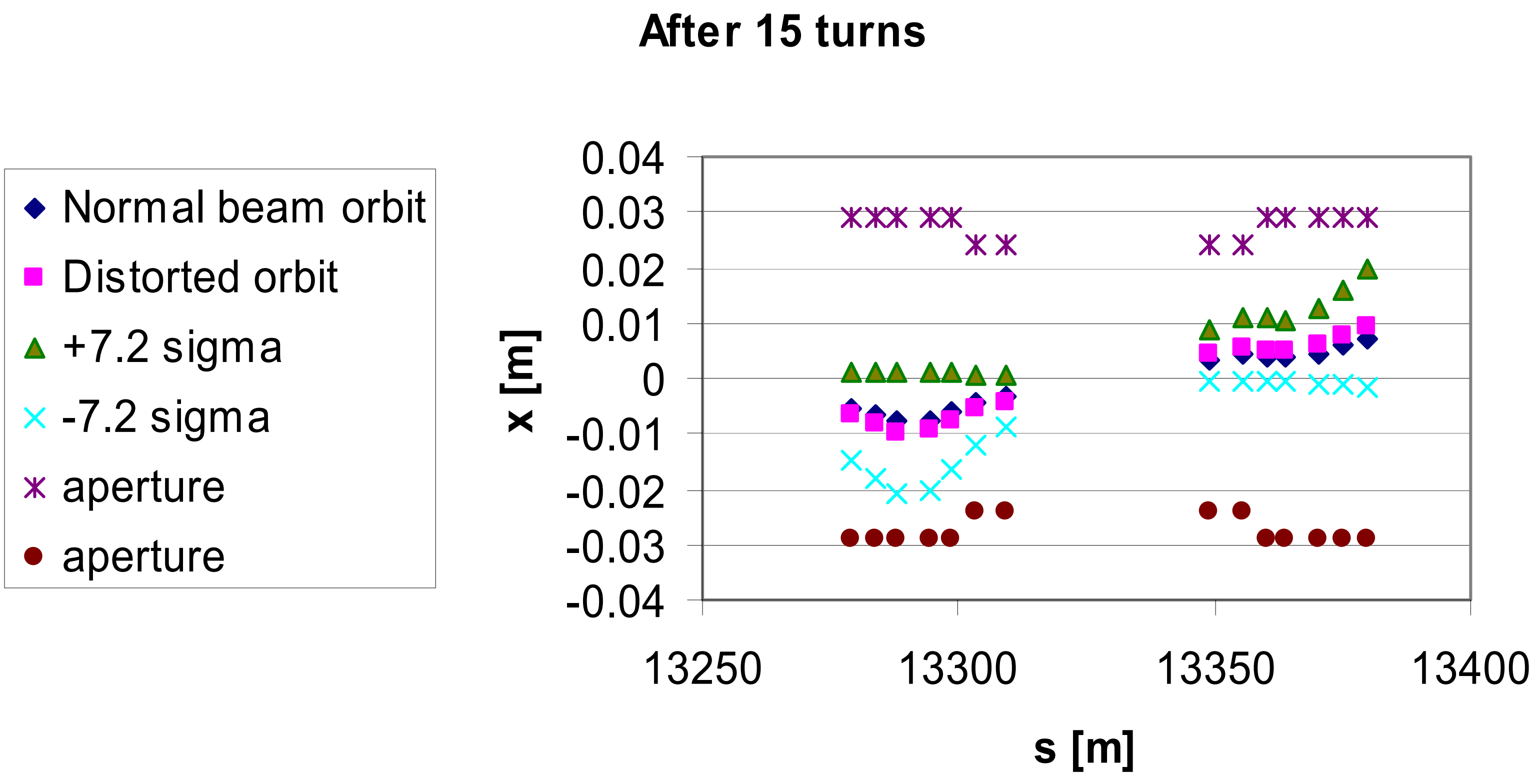
Beam Accidents
What are the timescales

List of machine-identified equipment failures

Name	Operation Mode	Loss Location	ΔT
D1 warm	Collision	Triplet/collimator	5 turns
Damper	Injection	Arc/triplet	6 turns
Warm quadrupoles	Any	Collimator	18 turns
Warm orbit corrector	Collision	Triplet/collimator	55 turns
RF	Any	Arc/triplet/septum	55 turns
D1 warm	Injection	Arc/triplet/collimator	120 turns

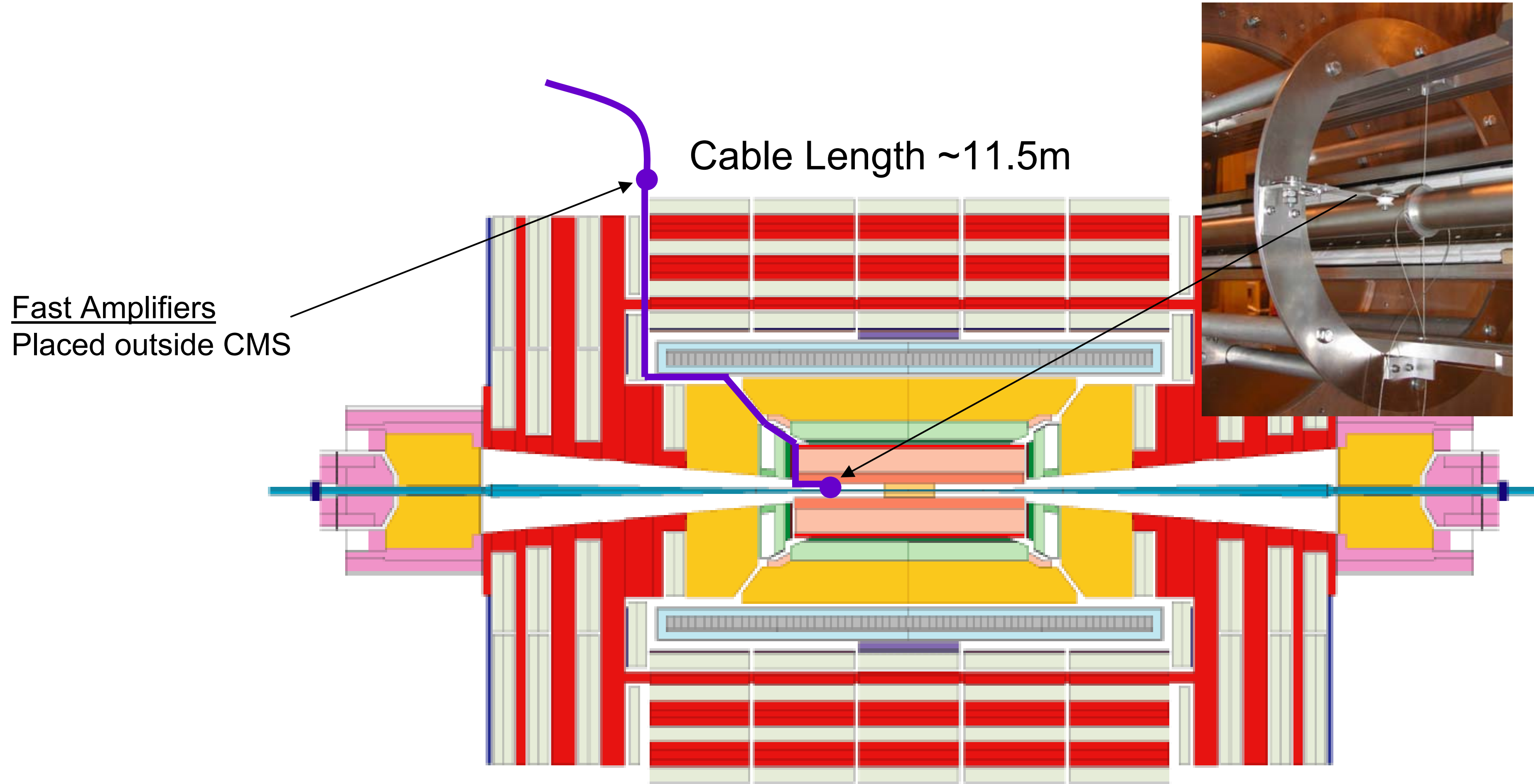
Fastest generic beam loss scenarios: ~ in 5 orbits ie ~ 500μs the beam is off by 3 sigma, this defines the response timescale of our system.

Beam Accidents
What are the timescales



A MAD simulation for a D1 failure (by V. Kain) will serve us to calculate the numbers of protons that will be lost per turn. Then a Fluka simulation can give us the dose per turn that will allow us to set the timescales and the thresholds.

Conceptual BCM layout



DCS

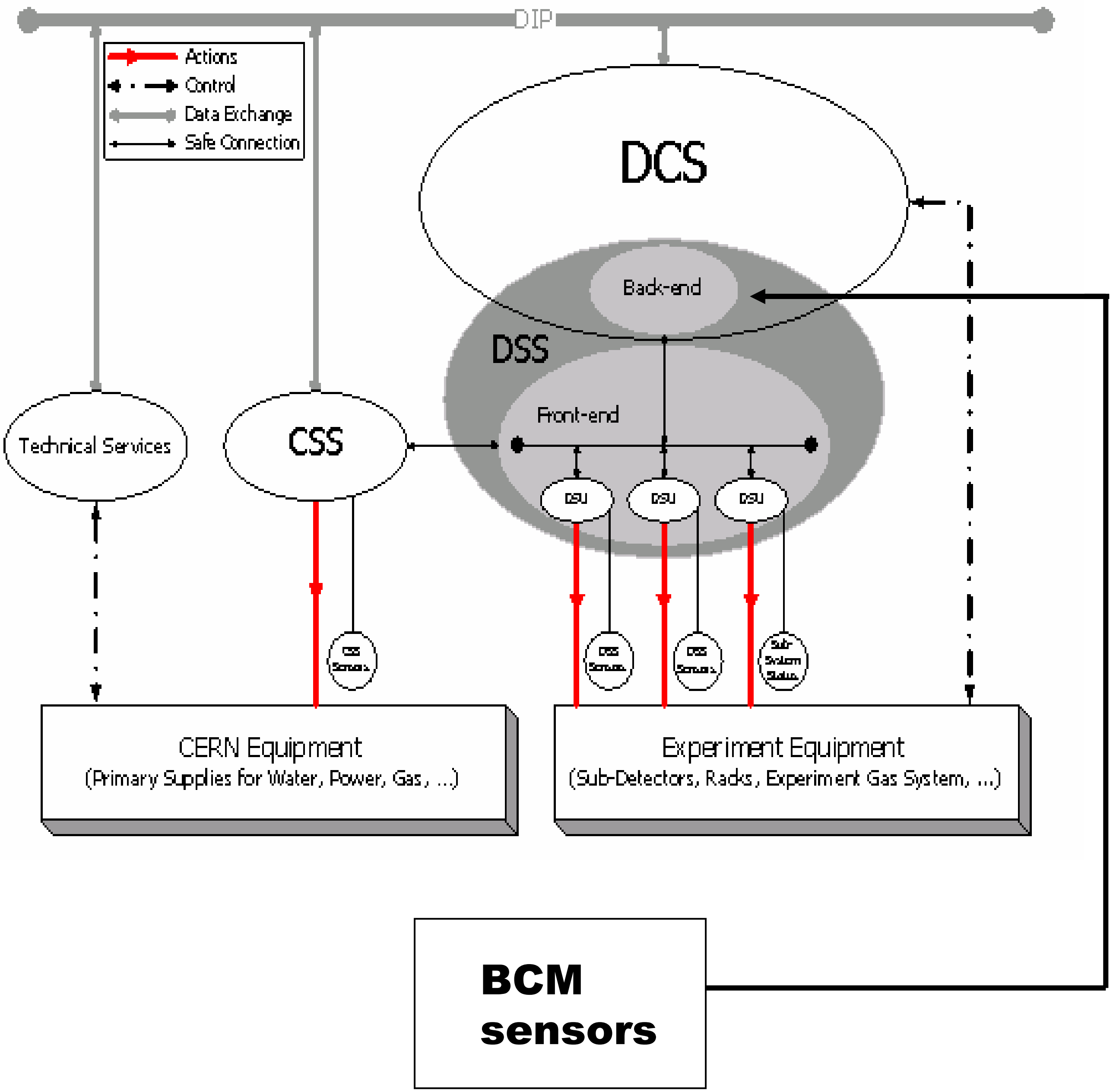
Monitoring and control of the detector

DSS

Safeguard of experimental equipment

BCM

- **Input into DSS.**
- Protect subdetectors from adverse beam conditions
- Redundant of the Beam Loss Monitors of the Machine

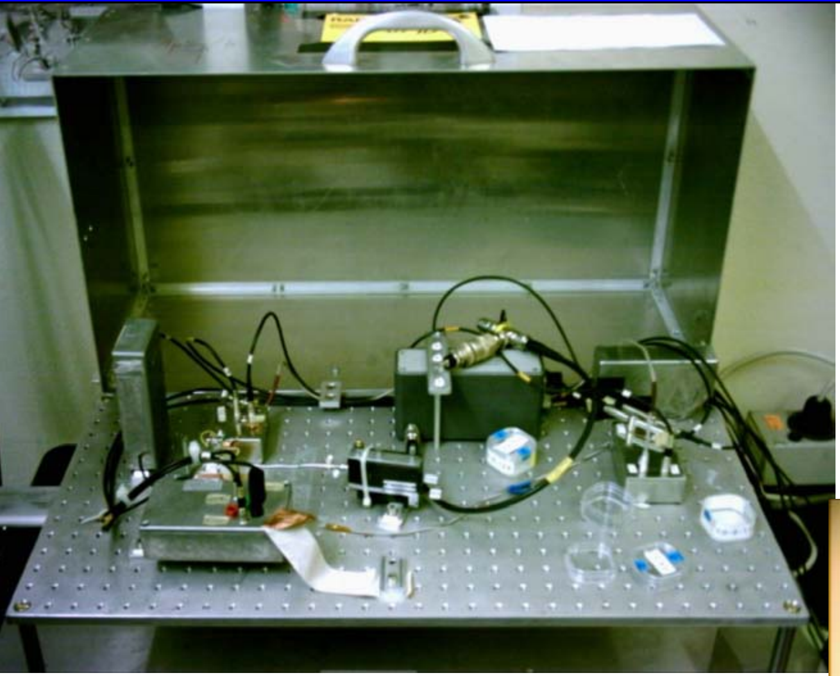


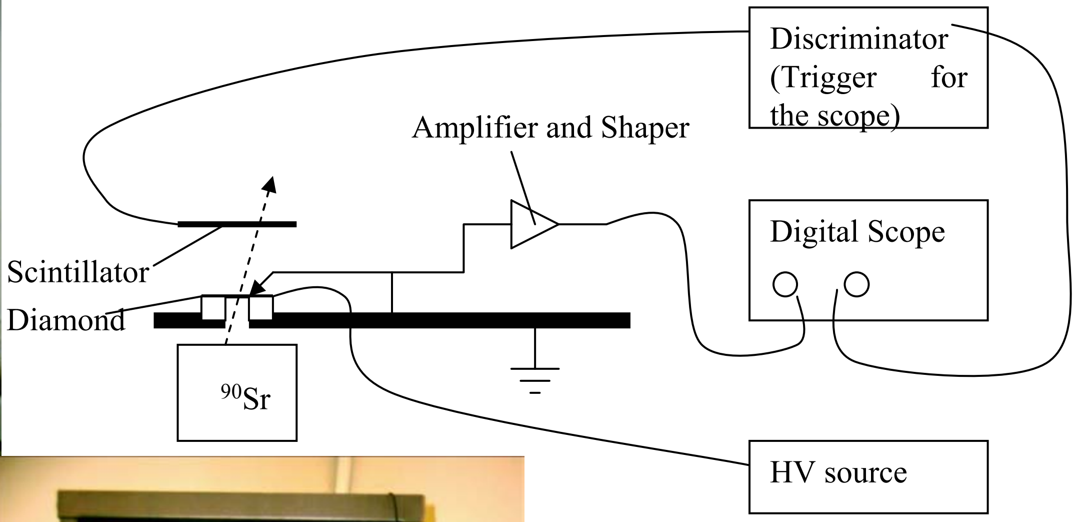
Diamond Characterization

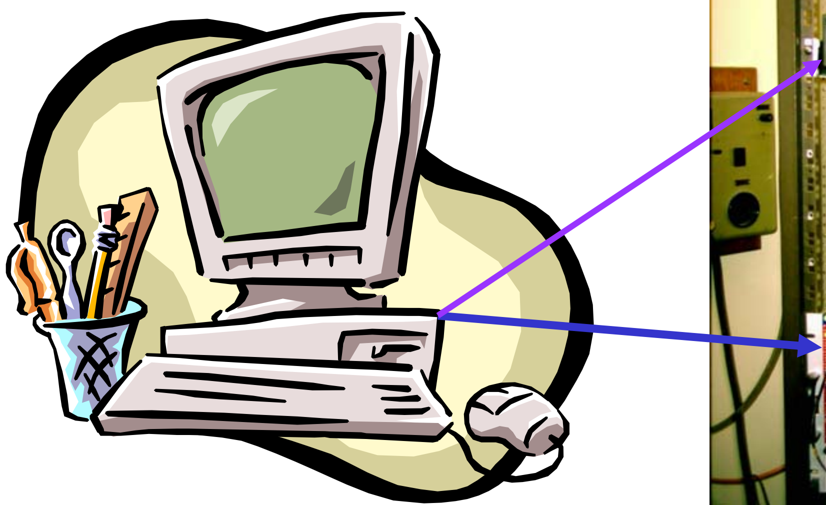
Measurements performed on diamonds:

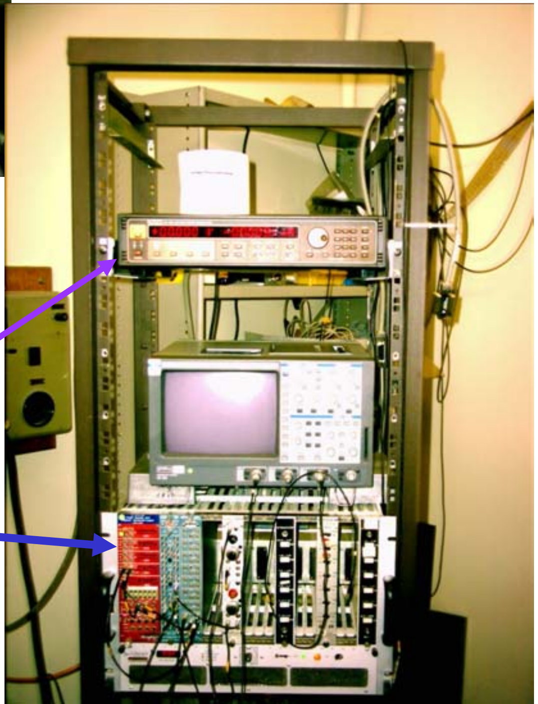
- I-V curve.
  - First quality check of the samples, metallisations.
  - To determine the electrical resistivity.
- Collection distance vs time.
  - Study of the pumping.
  - Charge collection distance at 1 V/ μm.
- Collection distance vs bias voltage.
  - Measurement of the charge collection distance at different electric fields.
  - Study of the radiation damage.
  - Study of the polarization.
- I-T curve.
  - Find the thermo-stimulated current peak. Number of traps.
  - Depumping of diamonds.

Diamond Characterization

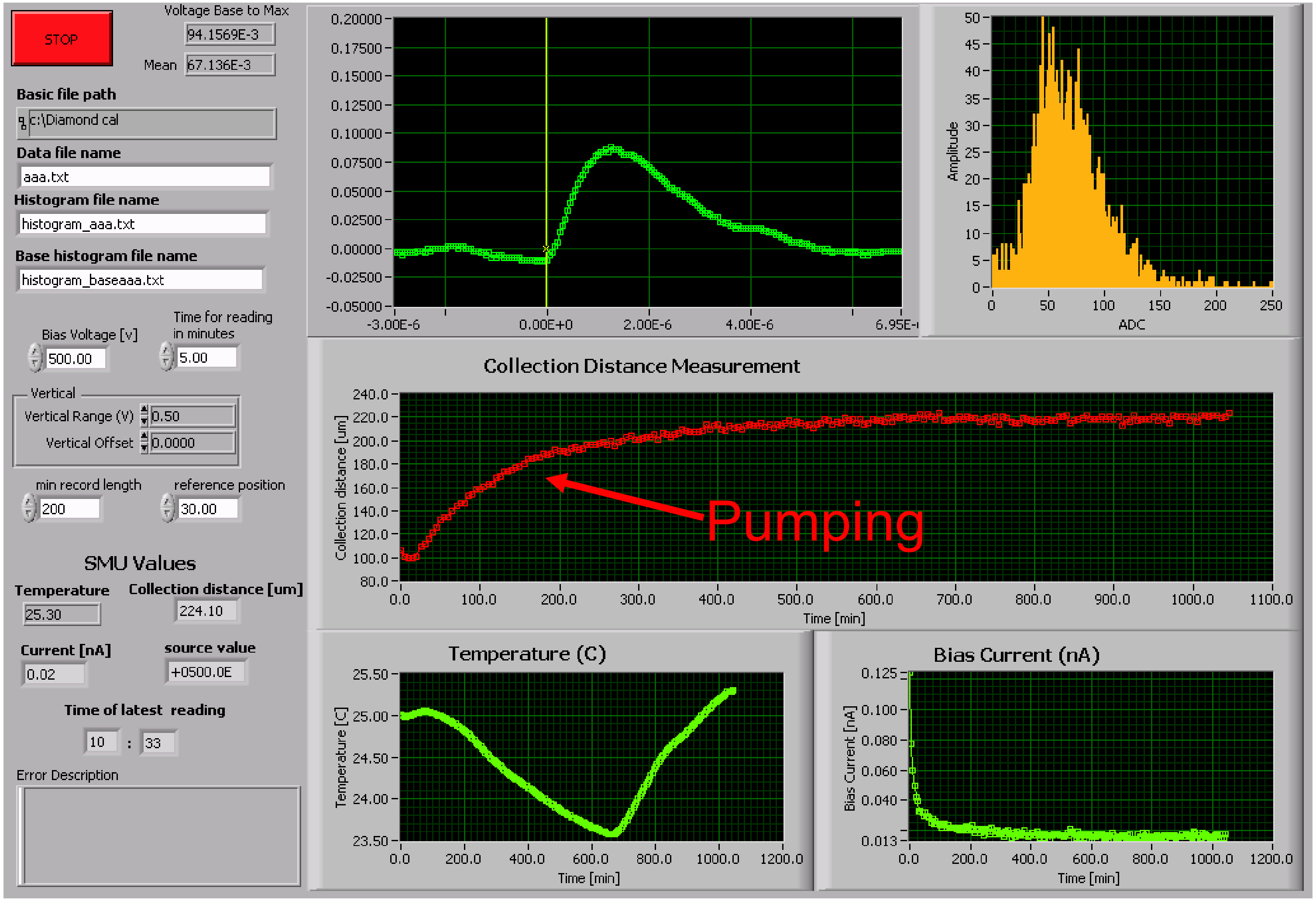








Diamond Characterization



The software gets the top value of the peak and deducts the average value of the base

Those values are averaged over a certain time (usually 5 min) for calculating the collection distance

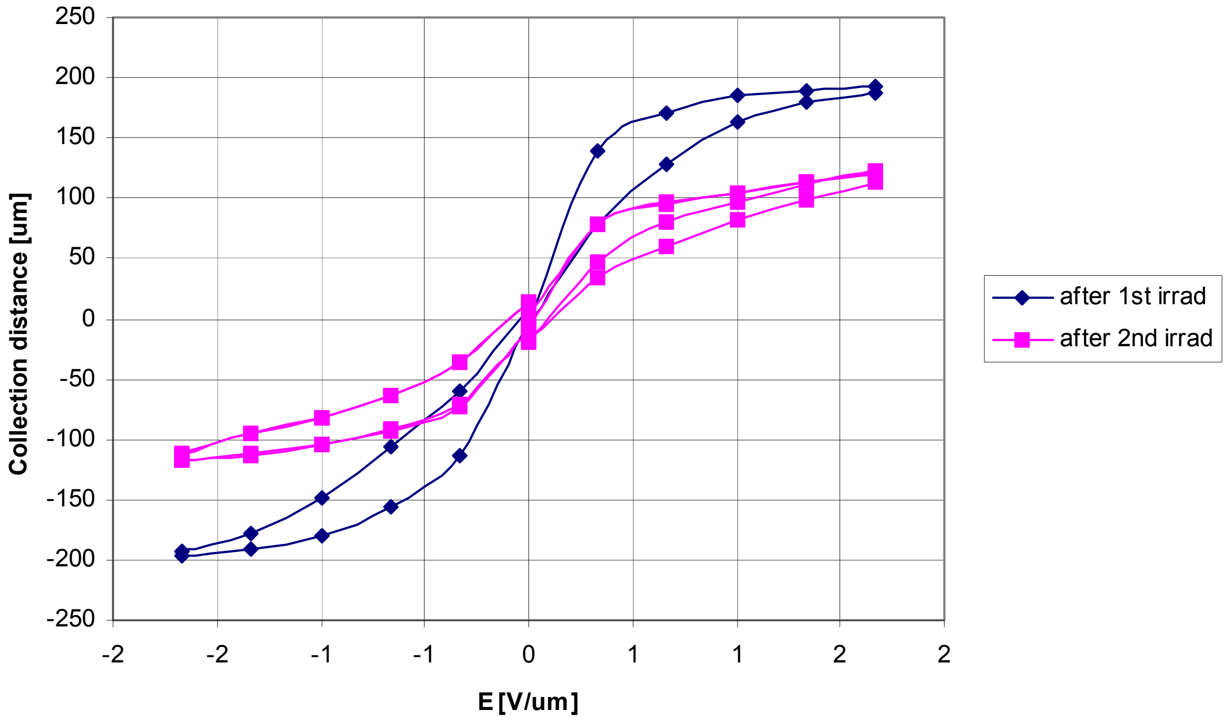
Study of the radiation damage

Collection distance vs electrical field for an irradiated diamond:

1st irradiation of 5E14 p/cm^2

2nd irradiation of 1E15 p/cm^2

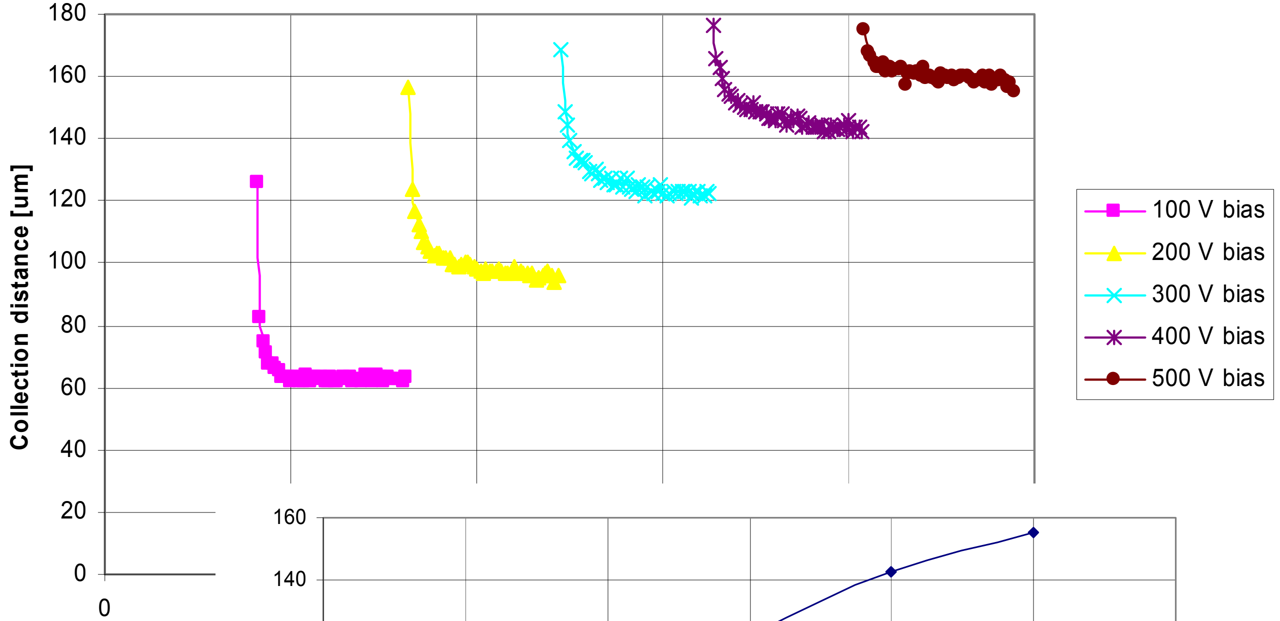
The hysteresis observed is due to a charge polarization effect.



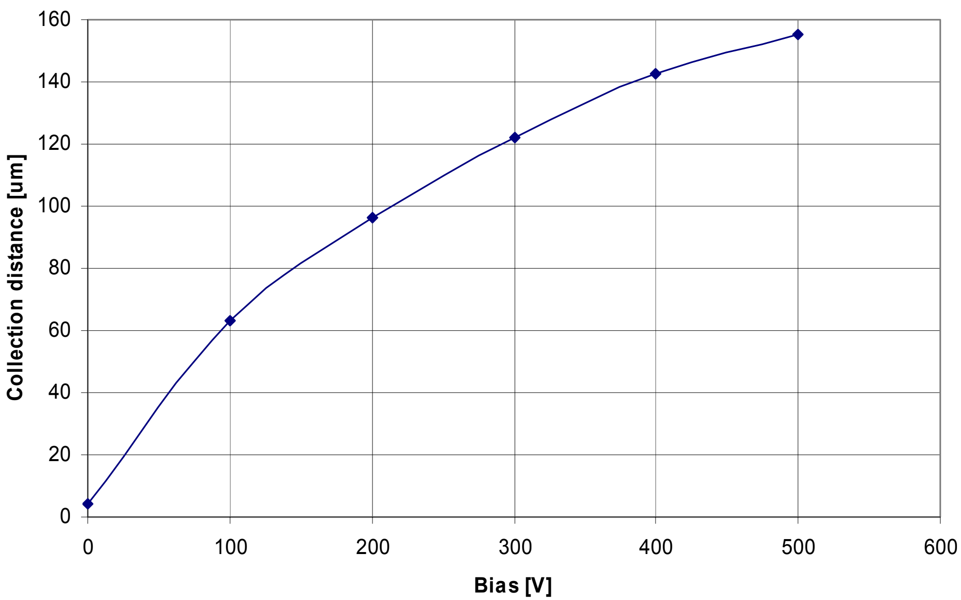
Measurement of the charge collection distance - Study of the polarization

Polycrystalline diamond presents a polarization effect every time a bias voltage is applied to it.

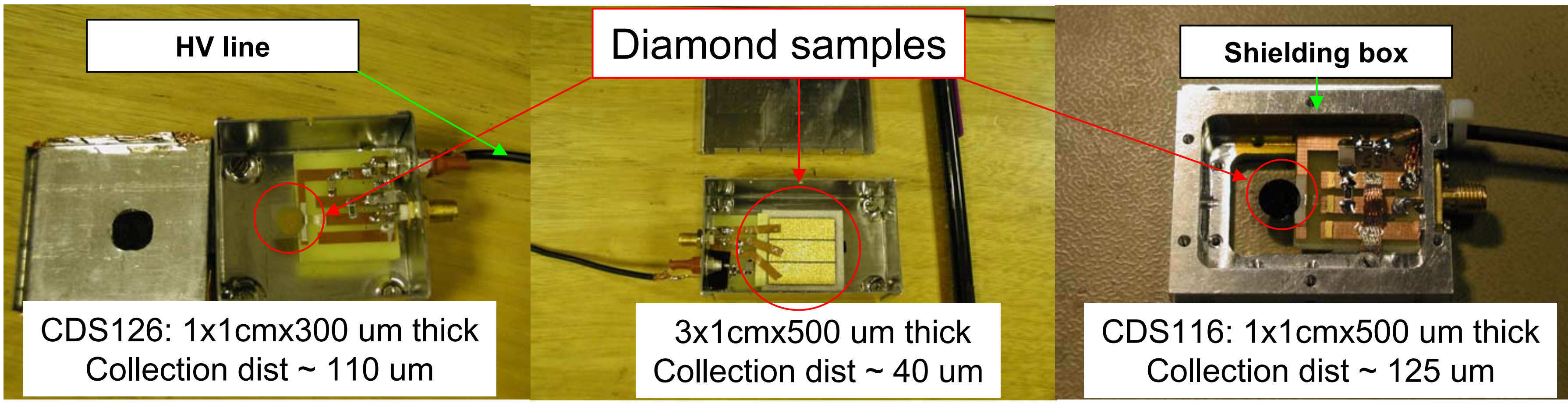
The polarization appears any time the bias is increased.



This graphic shows the “real” values of the collection distance (after polarization) at different electrical fields, after 4 hours.



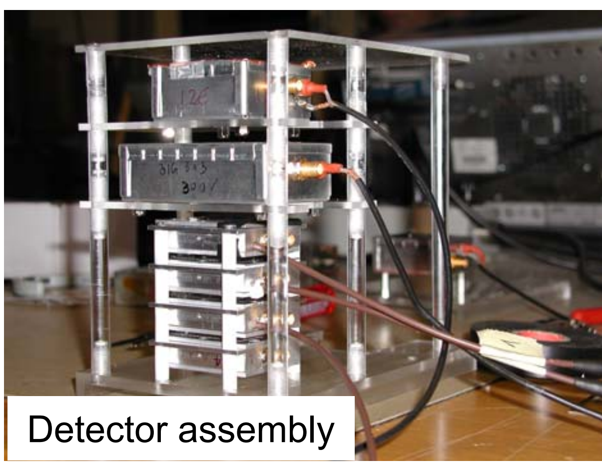
T7 Testbeam Hardware



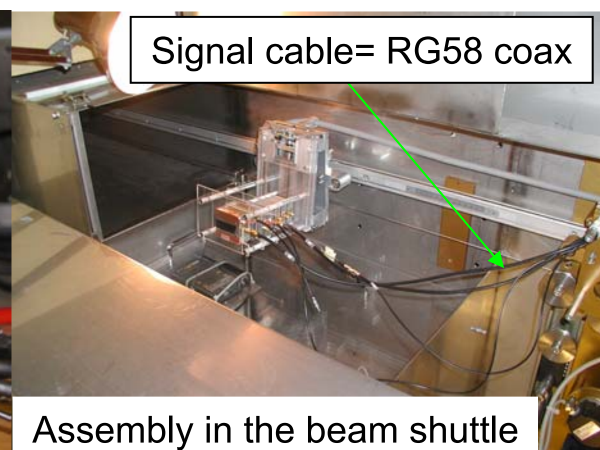
CDS126: 1x1cmx300 um thick
Collection dist ~ 110 um

3x1cmx500 um thick
Collection dist ~ 40 um

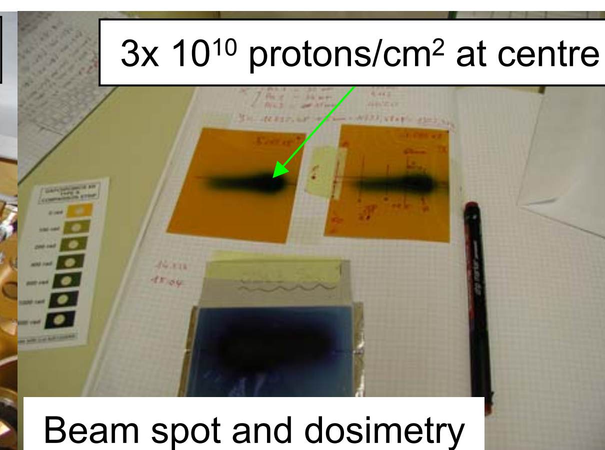
CDS116: 1x1cmx500 um thick
Collection dist ~ 125 um



Detector assembly

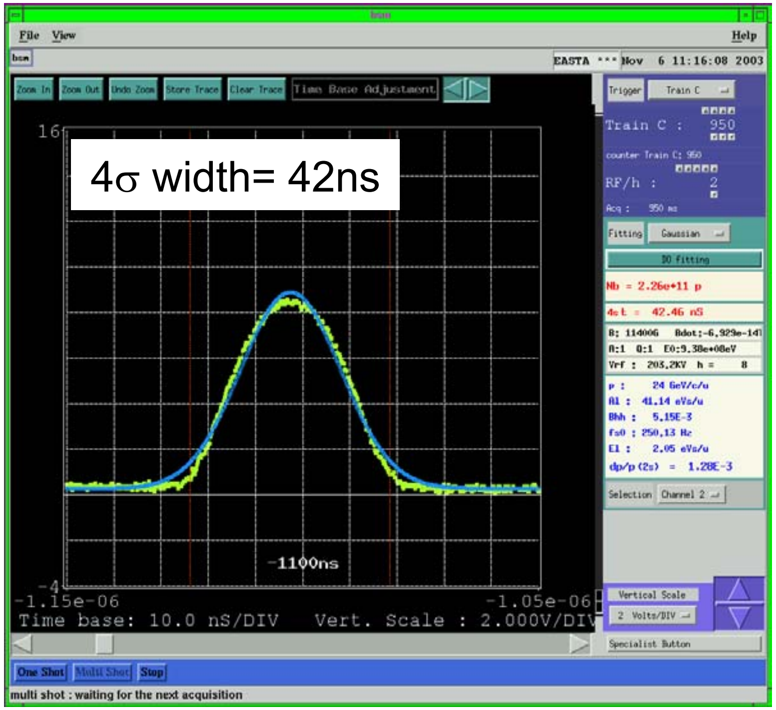


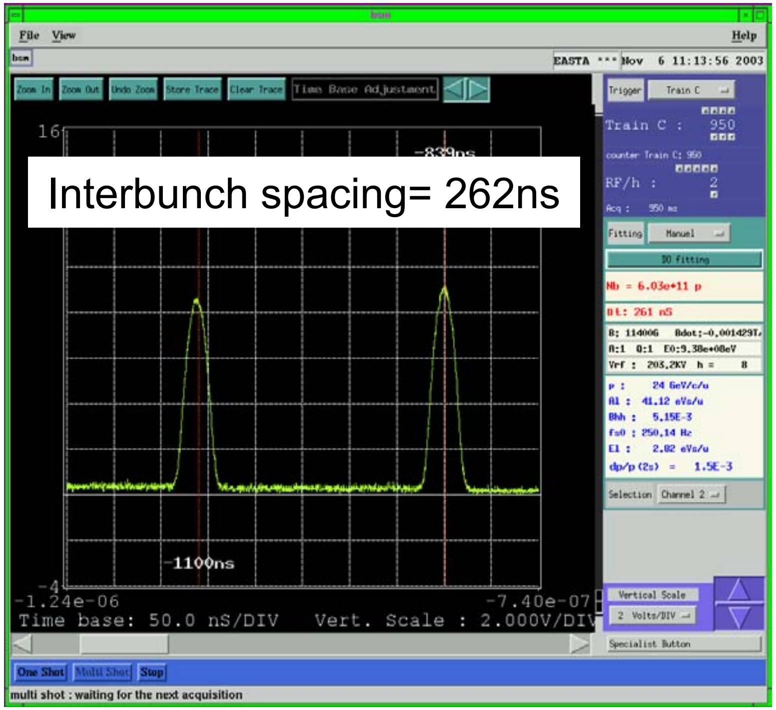
Assembly in the beam shuttle



Beam spot and dosimetry

November T7 Test beam: Fast extraction beam from the PS

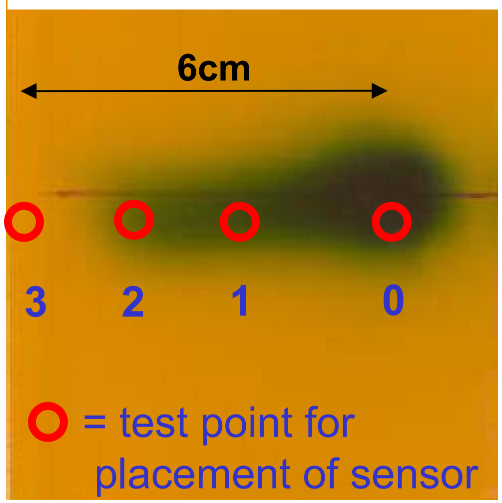


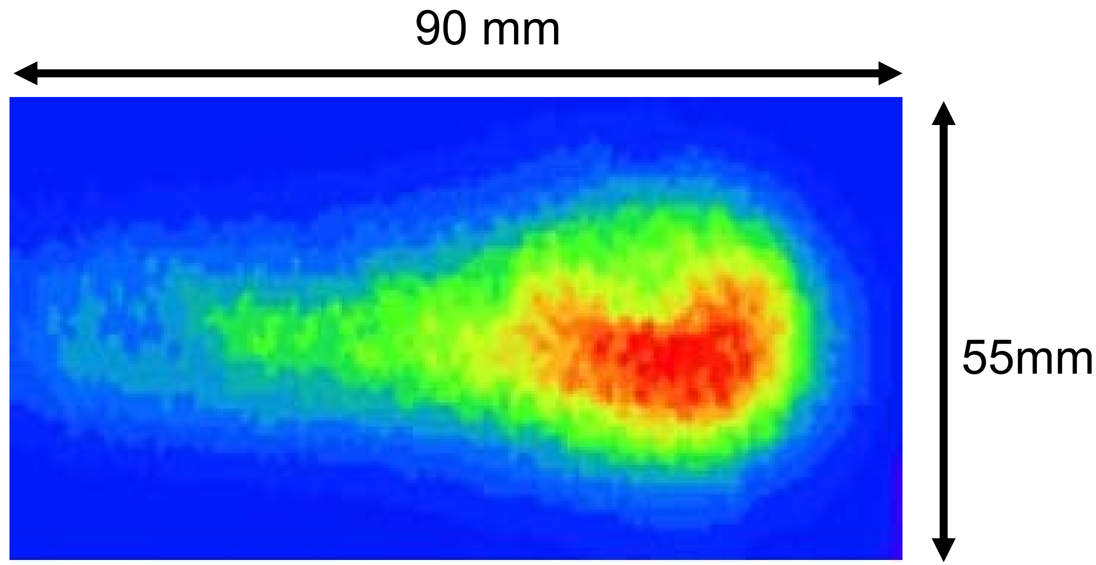


Beam intensity: 8×10^{11} protons per spill
Fluence: $\sim 3 \times 10^{10}$ protons/cm^2/spill at the centre of the beam spot
$\sim 1 \times 10^{8}$ protons/cm^2/spill in the halo

Beam profile

Film exposure of the beam after 40 bunches





Beam Profile as measures by OSL film
OSL =Optically Stimulated Luminesence

<u>Relative fluence levels</u>

Position 0 = 1.0
Position 1 ~ 0.4
Position 2 ~ 0.2
Position 3 ~ 0.01

mm	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
0	0.2	0.2	0.2	0.2	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.0
5	0.2	0.2	0.2	0.3	0.3	0.3	0.1	0.3	0.4	0.8	0.7	1.0	1.0	1.4	1.3	1.2	1.0	0.1	0.1
10	0.6	0.6	0.6	0.8	0.9	0.9	0.8	0.8	1.0	1.0	1.1	1.3	1.5	2.1	2.0	2.0	1.6	0.2	0.1
15	0.6	0.6	0.6	0.8	1.1	1.1	1.3	1.1	1.4	1.6	1.8	2.3	2.6	3.5	3.0	2.9	2.7	0.2	0.1
20	0.7	0.7	0.7	1.1	1.4	1.7	1.9	2.1	2.8	3.2	4.9	5.0	7.7	9.8	12.7	10.6	6.2	0.5	0.1
25	0.7	0.9	0.9	1.0	1.5	3.1	7.4	10.3	13.1	15.6	17.6	21.5	26.7	38.9	56.7	45.0	17.7	1.2	0.1
30	0.7	0.9	0.8	1.1	2.2	7.4	18.6	28.4	28.9	39.3	45.6	48.9	70.8	82.1	100	87.8	36.5	4.3	0.2
35	0.7	0.8	0.9	1.1	2.7	6.1	17.4	25.1	28.5	34.4	27.7	42.4	42.2	61.1	58.1	69.2	28.1	6.1	0.2
40	0.6	0.7	0.8	1.1	2.2	4.1	6.6	8.1	8.5	8.6	10.3	13.5	18.7	26.7	36.0	28.3	10.5	3.4	0.2
45	0.6	0.7	0.7	0.8	1.1	1.9	2.2	1.7	1.7	2.7	3.1	4.3	5.8	7.6	8.1	5.7	4.0	2.4	0.2
50	0.7	0.6	0.7	0.9	0.8	1.0	1.2	1.1	1.3	1.5	1.6	2.2	2.2	2.6	3.1	2.6	2.3	1.8	0.1
55	0.4	0.5	0.6	0.7	0.8	0.8	0.8	0.7	0.8	1.1	1.0	1.1	0.7	0.6	0.4	0.4	0.3	0.2	0.1

Dosimetry measurements

Beamspot Dosimetry

Used ^{24}Na for dosimetry on aluminum placed in the beam

Dosimetry done by Maurice Glaser and Federico Ravotti

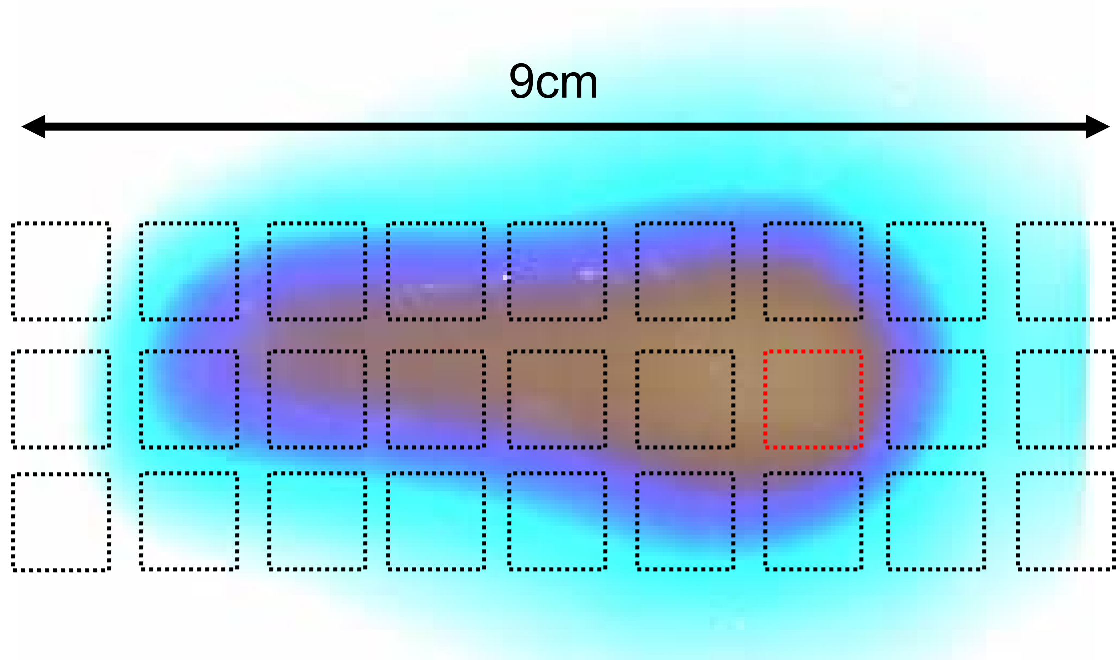
Result

Fluence at beam “centre” =

2.8×10^{10} protons/cm^2 ± 10%

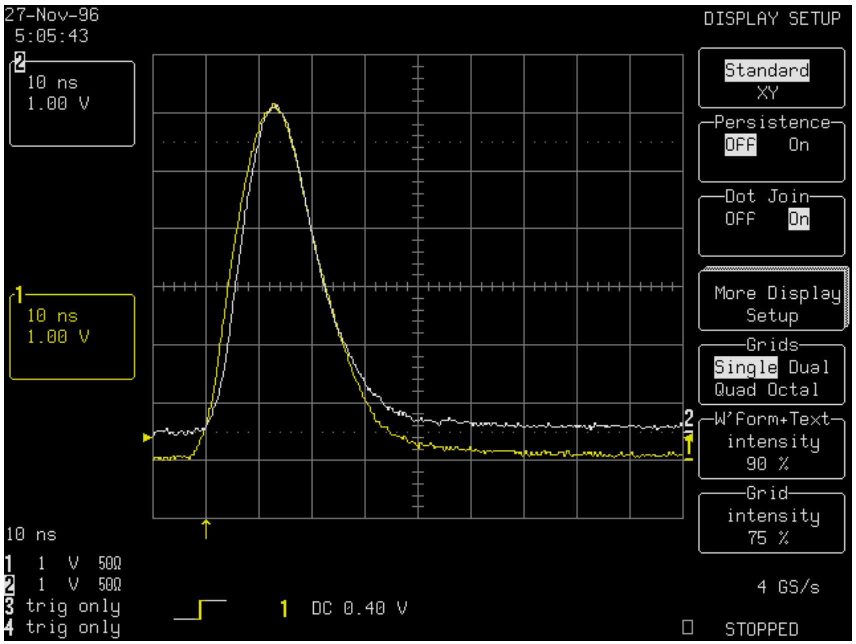
Mapping of beam spot

Consistency between the different films, the OSL, and the aluminum



Dosimetry Results from Grid of Aluminum samples: Relative variation %								
0.0	3.3	10.2	13.8	16.5	27.7	33.1	0.0	0.0
1.3	5.3	11.9	19.1	31.8	74.2	100.0	63.0	0.0
0.0	0.0	0.0	0.0	3.4	8.0	6.2	0.0	0.0

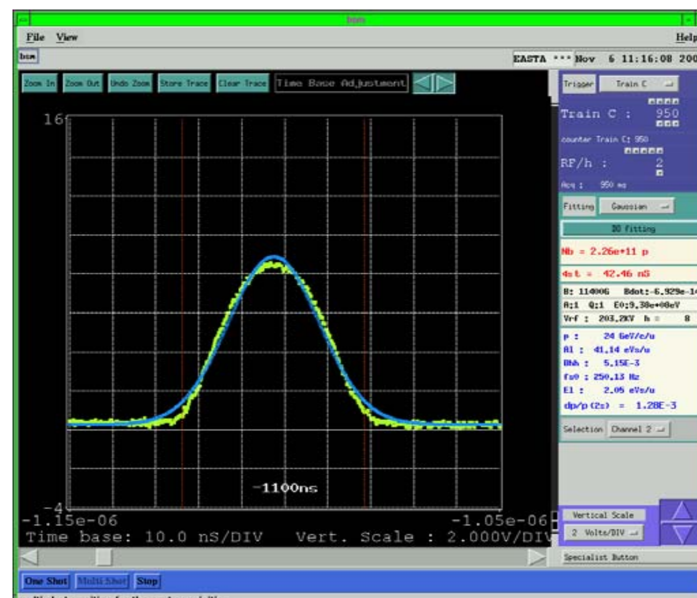
Single shots



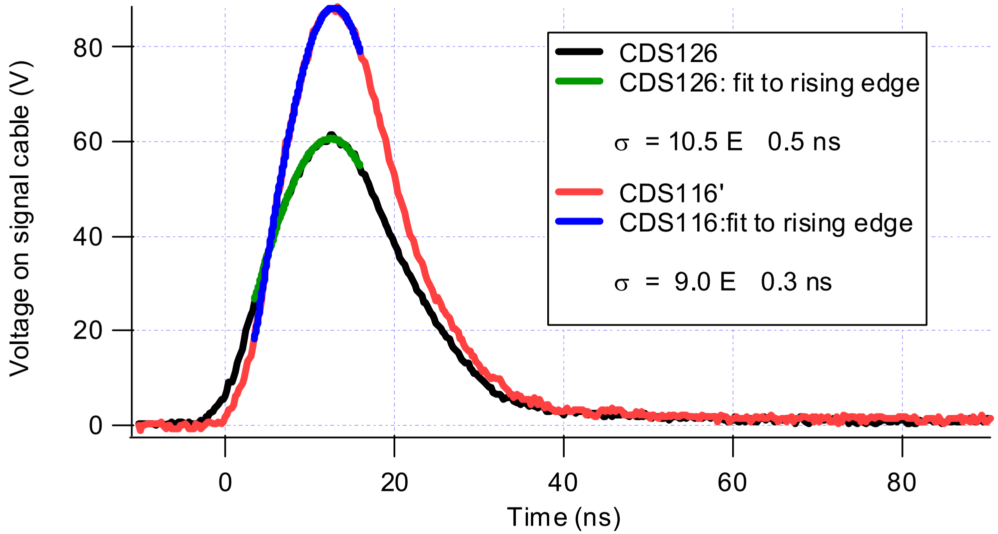
Single pulses from diamond

- Bias on Diamond = +1 V/ µm
- Readout of signal:
  - 16m of cable
  - no electronics
  - 20dB attenuation on signal cable (factor 10)

Almost identical to PS beam profile



Single shots: Details



Diamond Collection Distance

Diamond signal ~ collection distance

Collection distance (CDS116) ~125 μm

Collection distance (CDS126) ~110 μm

For std bias voltage of 1 V/μm

Area of pulse

- Proportional to current from a bunch.
- Use area to estimate bunch fluence.
  - Pulse area(CDS116@Pt 3) = 9.8×10^{7} p/cm^2
  - Pulse area(CDS126@Pt 3) = 8.7×10^{7} p/cm^2
- Fair agreement with dosimetry results
  - Dosimetry(Al, @ Pt 3) = 2.2×10^{8} p/cm^2

Diamond Collection Distance

Signals from sensors are large

- V_max (CDS116) = 88 volts => 1.76 Amps into a 50 Ohm load
- V_max (CDS126) = 61 volts => 1.22 Amps into a 50 Ohm load

Time response

Fit Gaussian to leading edge of pulses

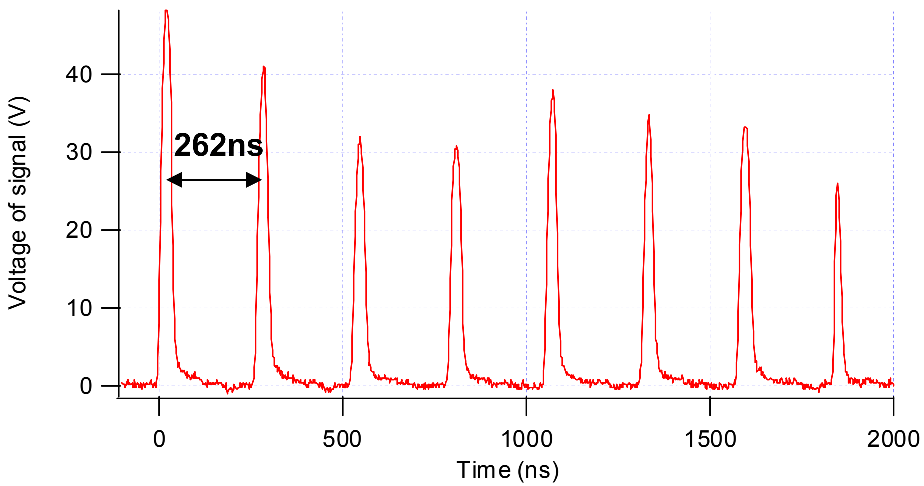
σ (CDS126) =10.5 ± 0.5 ns

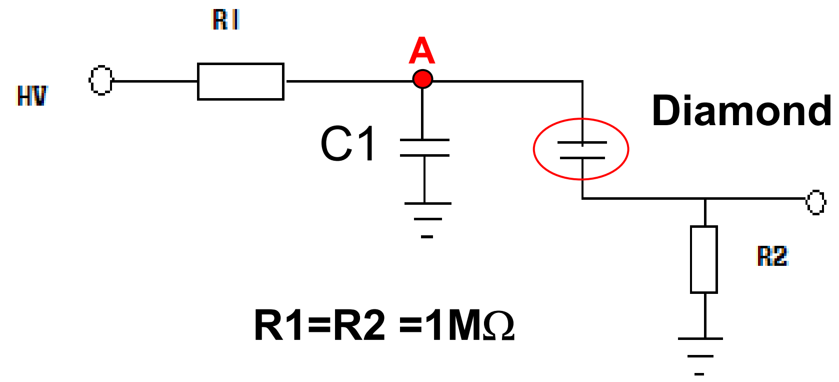
σ (CDS116) = 9.0 ± 0.3 ns

Comparable to σ(PS)=10.5 ns with ~6% distortion from the signal cable

=> No problem with extracting timing structure from sensors on 16 m coax cable

Multiple Bunches





C1 acts as a reservoir capacitor

=>The larger the value the longer the bias field on the can be maintained.

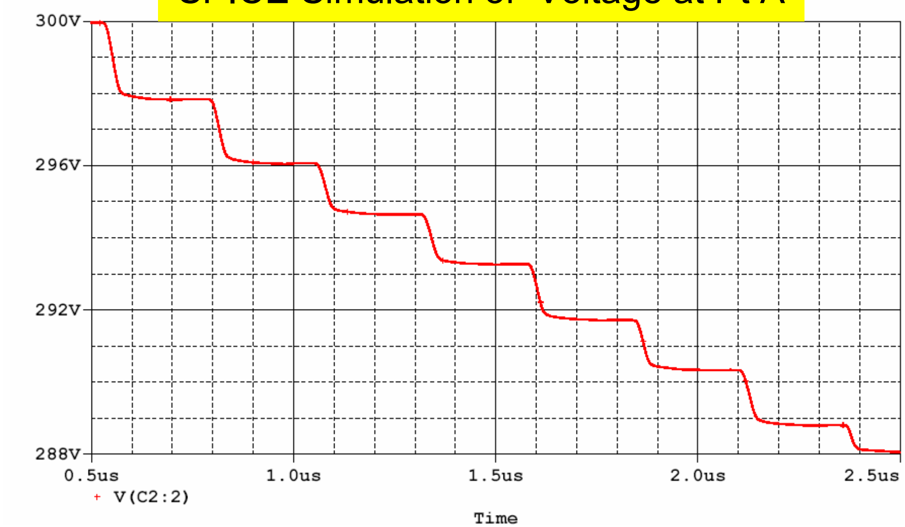
C1(CDS126)=15 nF

C1 is sufficiently large to maintain bias across the diamond for the 8 bunches.

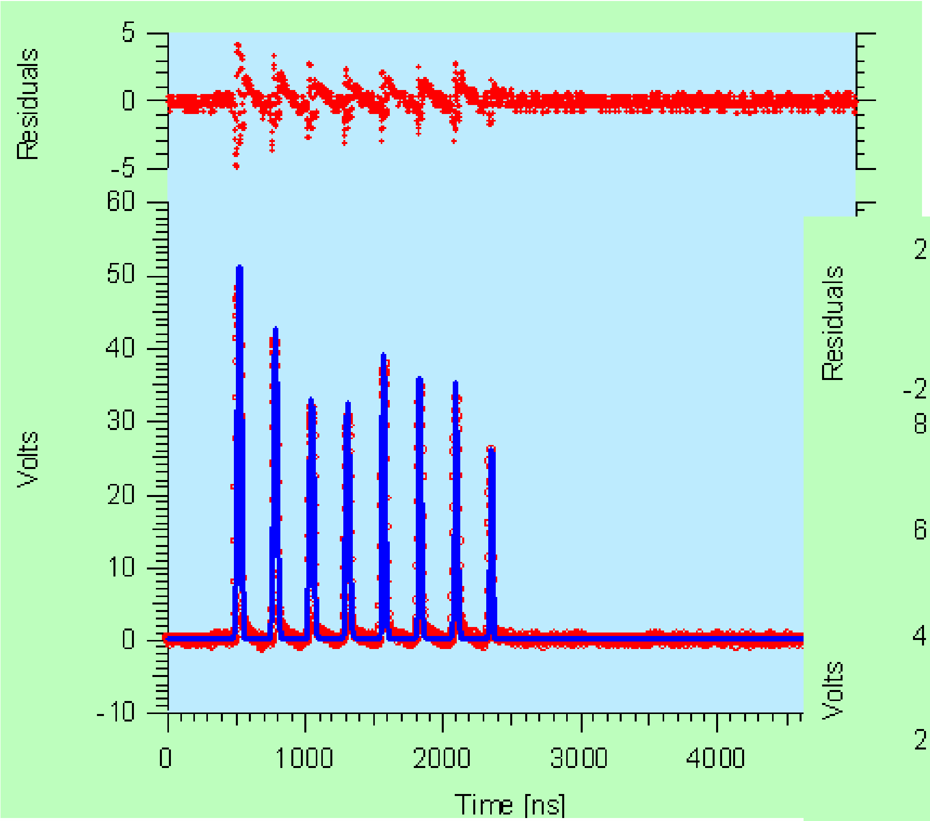
C1R1 time constant ~15 ms

⇒ recharge of C1 is slow compared to bunch structure

SPICE Simulation of Voltage at Pt A

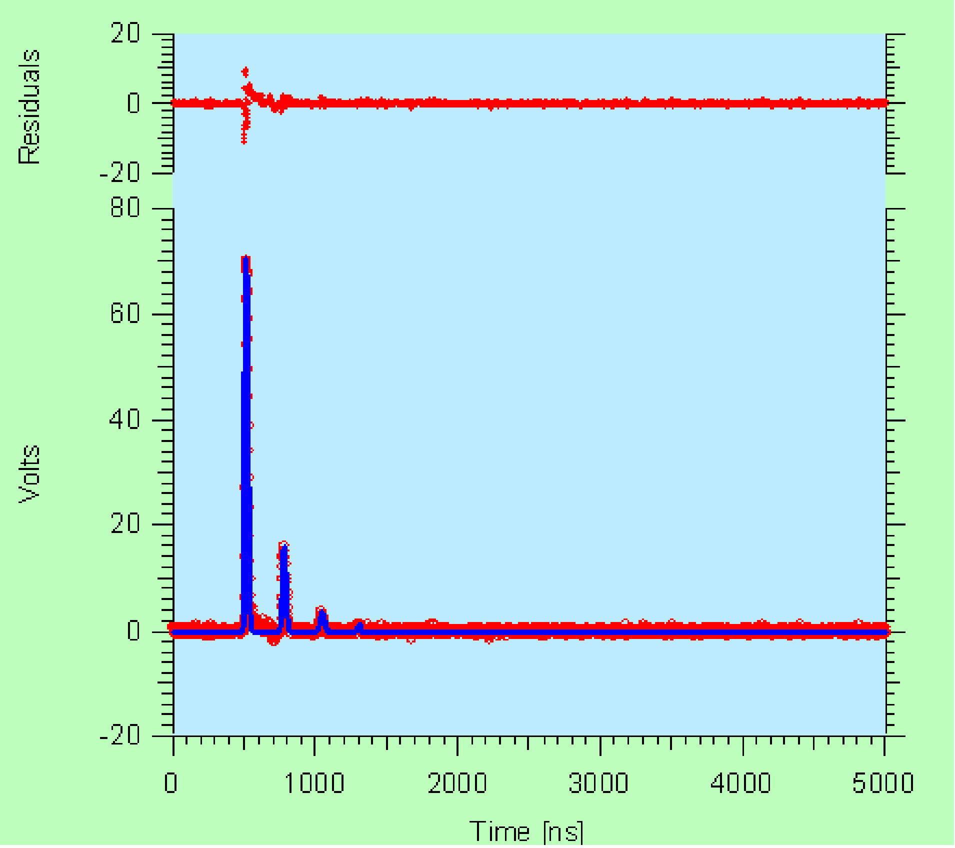


Multiple Bunches



CDS126 (110 µm @ 300V). The integration of the gaussian fit for the first peak gives a value of **9.05x10⁷p/cm²**

CDS116 (125 µm @ 500V). The integration of the gaussian fit for the first peak gives a value of **1.2x10⁸p/cm²**



Conclusions

- An automatic setup for measuring diamond characteristics has been developed.
- This setup allows detailed studies of diamond polarization effects.
- Diamonds are able to withstand intense beam.

Next Steps

- Finish analyzing the data that we have from the November testbeam:
  - Data taken is for the “worst case” scenario
- Build a prototype BCM (sensors+ electronics + decision logic)
  - Reduce signal to noise so to clearly see MIPs
- Continue with the characterization of diamonds
- May 04: Return to the East Hall for dedicated fast extraction beam
  - Intensity: 10^3 to 10^6particle/cm^2
  - Test prototype electronics
  - Evaluate BCM threshold-response time