Test of Diamond Sensors at PHIL

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LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

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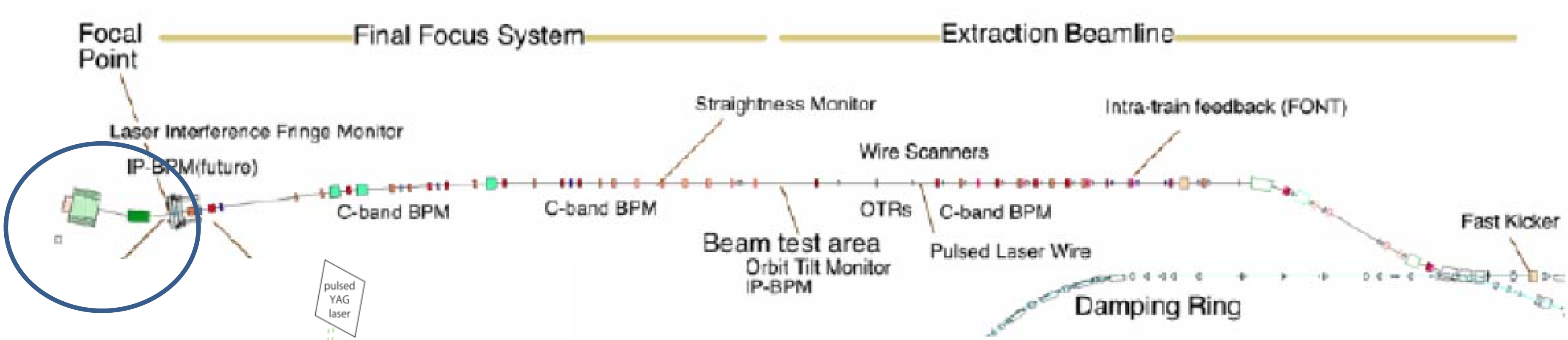
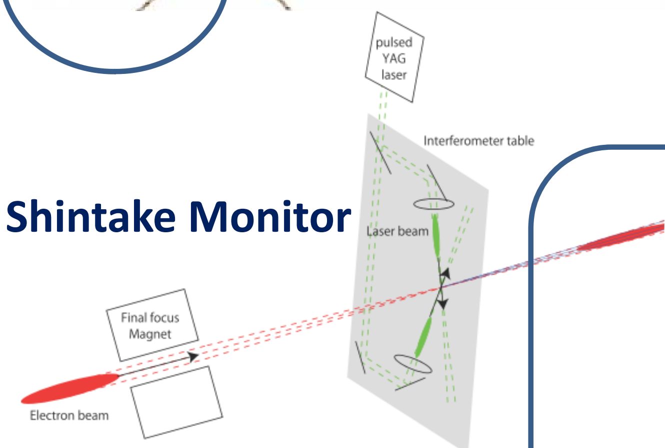
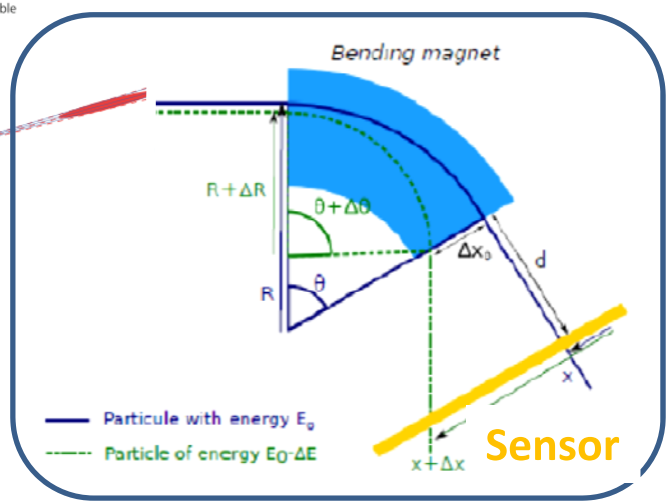
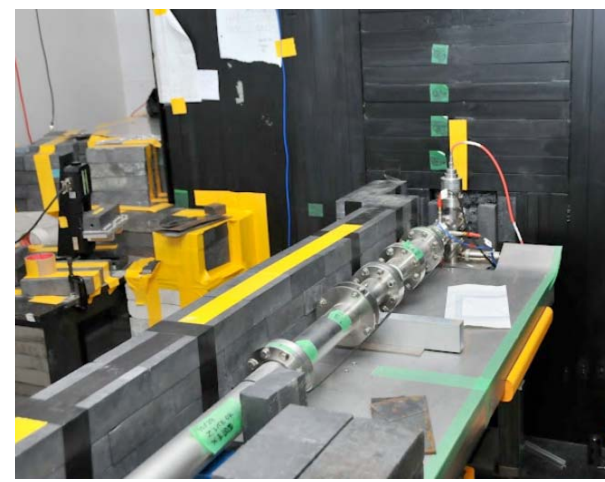
ATF2 & Beam Halo Measurement



Shintake Monitor







Motivations:

- ***Beam halo transverse distribution unknown → investigate halo model***
- ***Probe Compton recoiled electron→ investigate the higher order contributions to the Compton process***

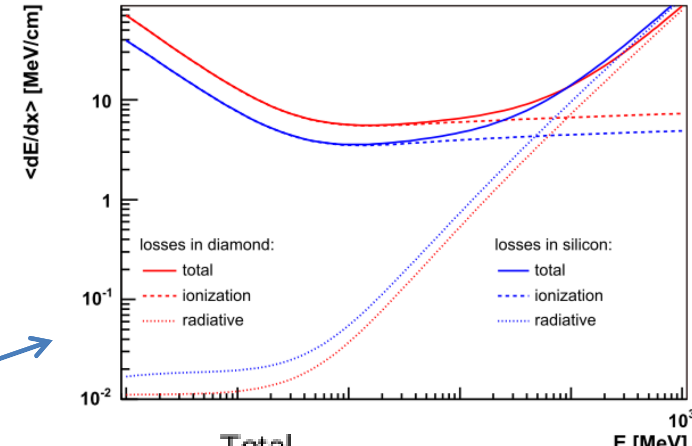
Diamond Detector Characteristics

Property	Diamond	Silicon
Density (g m^{-3})	3.5	2.32
Band gap (eV)	5.5	1.1
Resistivity (Ω cm)	>10^{12}	10^5
Breakdown voltage (V cm^{-1})	10^7	10^3
Electron mobility (cm^3 V^{-1} s^{-1})	1800	1500
Hole mobility (cm^3 V^{-1} s^{-1})	1200	500
Saturation elocity (μm ns^{-1})	220	100
Dielectric constant	5.6	11.7
Neutron transmutation cross-section(mb)	3.2	80
Energy per e-h pair (eV)	13	3.6
Atomic number	6	14
Av.min.ionizing signal per 100 μm (e)	3600	8000

ADVANTAGES

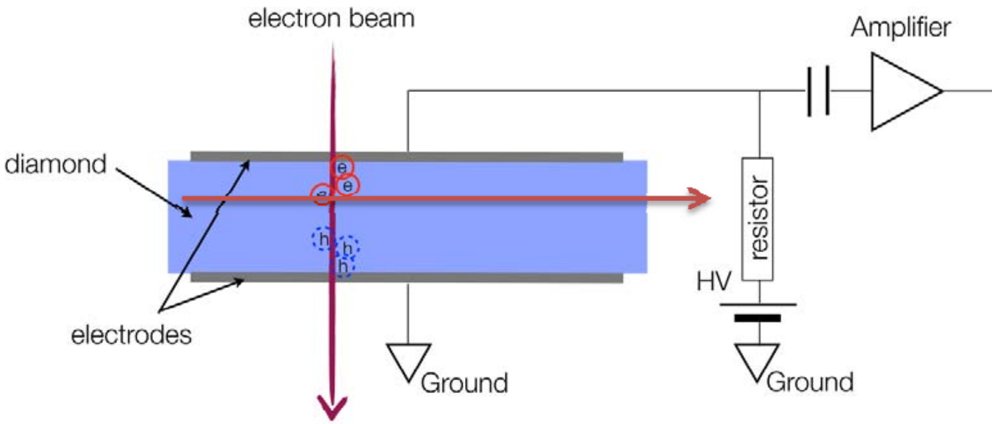
- ***Large band-gap ⇒ low leakage current***
- ***High breakdown field***
- ***High mobility ⇒ fast charge collection***
- ***Large thermal conductivity***
- ***High binding energy ⇒ Radiation hardness***
- ***Fast pulse ⇒ < 1 ns***

Energy loss of an electron in **diamond** & **silicon**

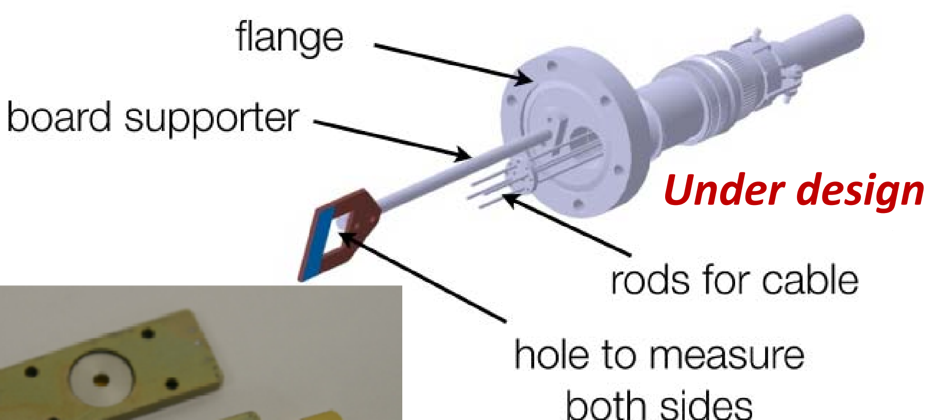


	Kinetic Energy MeV	Collision Stp. Pow. MeV cm2/g	MeV/cm	Radiative Stp. Pow. MeV cm2/g	MeV/cm	Total Stp. Pow. MeV cm2/g	MeV/cm
PHIL →	3.00E+000	1.59E+000	5.60E+000	3.56E-002	1.25E-001	1.63E+000	5.73E+000
ATF2 →	1.30E+003	2.09E+000	7.36E+000	2.96E+001	1.04E+002	3.17E+001	1.11E+002

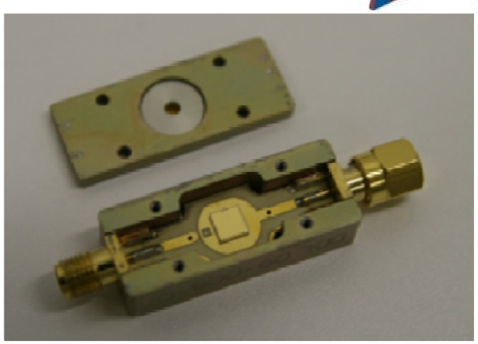
Diamond Detector Characteristics



Charge created by 1MIP in diamond → 2.74 fC



Under design

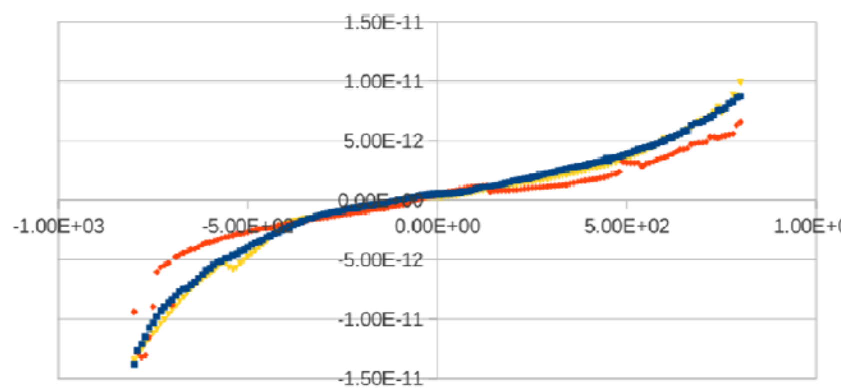


Diamond detectors

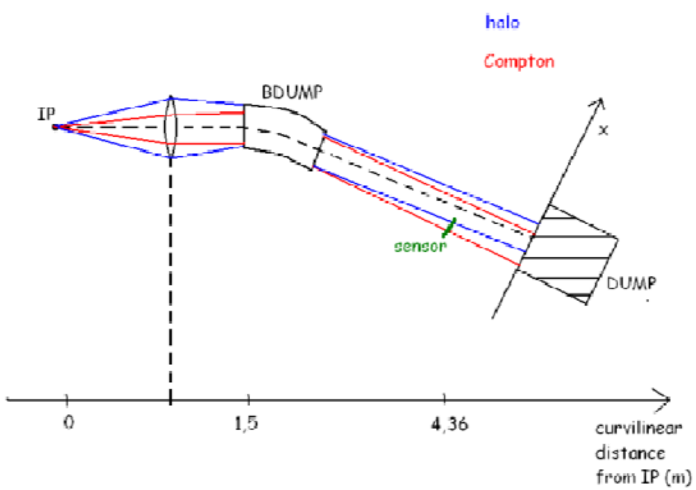
Configurations:
- ***Pads : mm^2 x 500 μm***
- ***Strips & pixels***
- ***Membranes (→ 5 μm)***
- ***Orthogonal/ Parallel orientation***

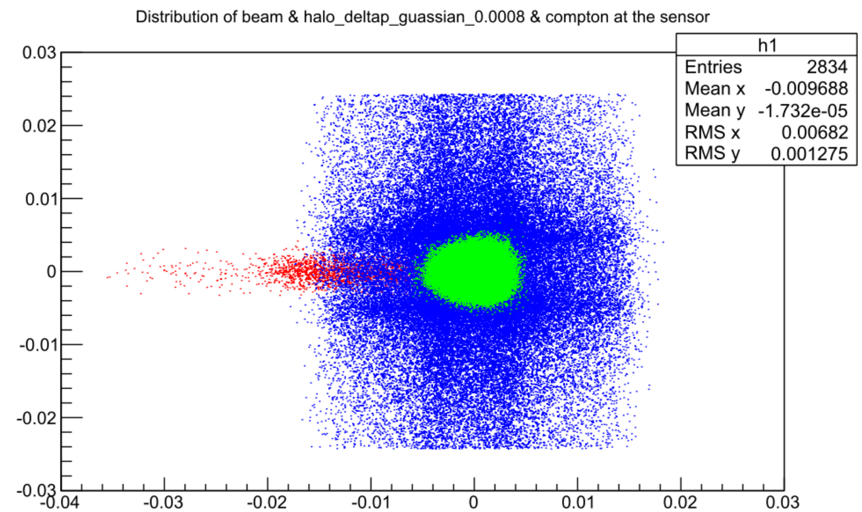
Types:
- ***Poly crystalline diamond***
- ***Single crystalline diamond***

Current Measurement



Mad-X Simulation Results for Beam & Halo & Compton Signal @ Sensor

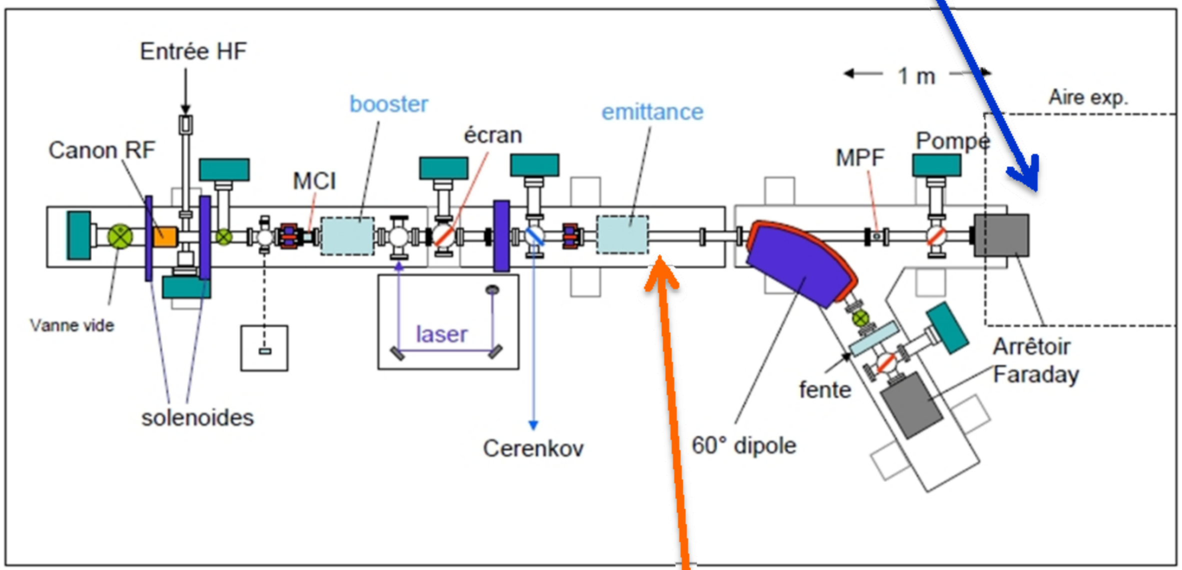




	Total Number (in simulation)	Total Number (in experiment)	Min.～Max. Number/mm^2 @ Sensor	Charge signal/mm^2
Beam	10^5	10^{10}	$6163*10^5$	$1.6887*10^{-6}$C=1.6887μC
Halo ($\delta p/p_0$=0.01)	10^5	10^7	$114*10^2$	$3.1236*10^{-11}$C=31.236pC
Halo ($\delta p/p_0$=0.0008)	10^5	10^7	$224*10^2$	$6.1376*10^{-11}$C=61.376pC
Compton	2834	28340	3*10～52 *10	82.2fC～1.4284pC

Diamond Detector Test @ PHIL

Test of fast remote readout (fast heliax coax cable + ASIC) with particles at end of beam line, using existing single crystal 4.5x4.5mm CVD diamond pad sensor



ATF2 in-vacuum 2x2mm single crystal CVD diamond sensor profile scanner -> test and diagnostic for PHIL

PHIL Electron Beam Parameters
(given by ***Hugues Monard***)

- ✓**Charge: 10 pC-250 pC/bunch (1 bunch per RF pulse) ;**
- ✓**Duration of Charge: 7 ps FWHM;**
- ✓**Charge Stablility: < 2%;**
- ✓**Maximum Energy: 3MeV;**
- ✓**Minimum Dispersion: < 1%;**
- ✓**Beam Size -> ?**

Expected Signal @ PHIL

- Charge created by 1MIP in diamond : 2.74 fC;
- Charge @ PHIL: 10 pC-250 pC/bunch (1 bunch per RF pulse)
- Signal pulse length of diamond: t=1ns;

Minimum charge obtained from PHIL (in case all the electrons hit on the diamond):

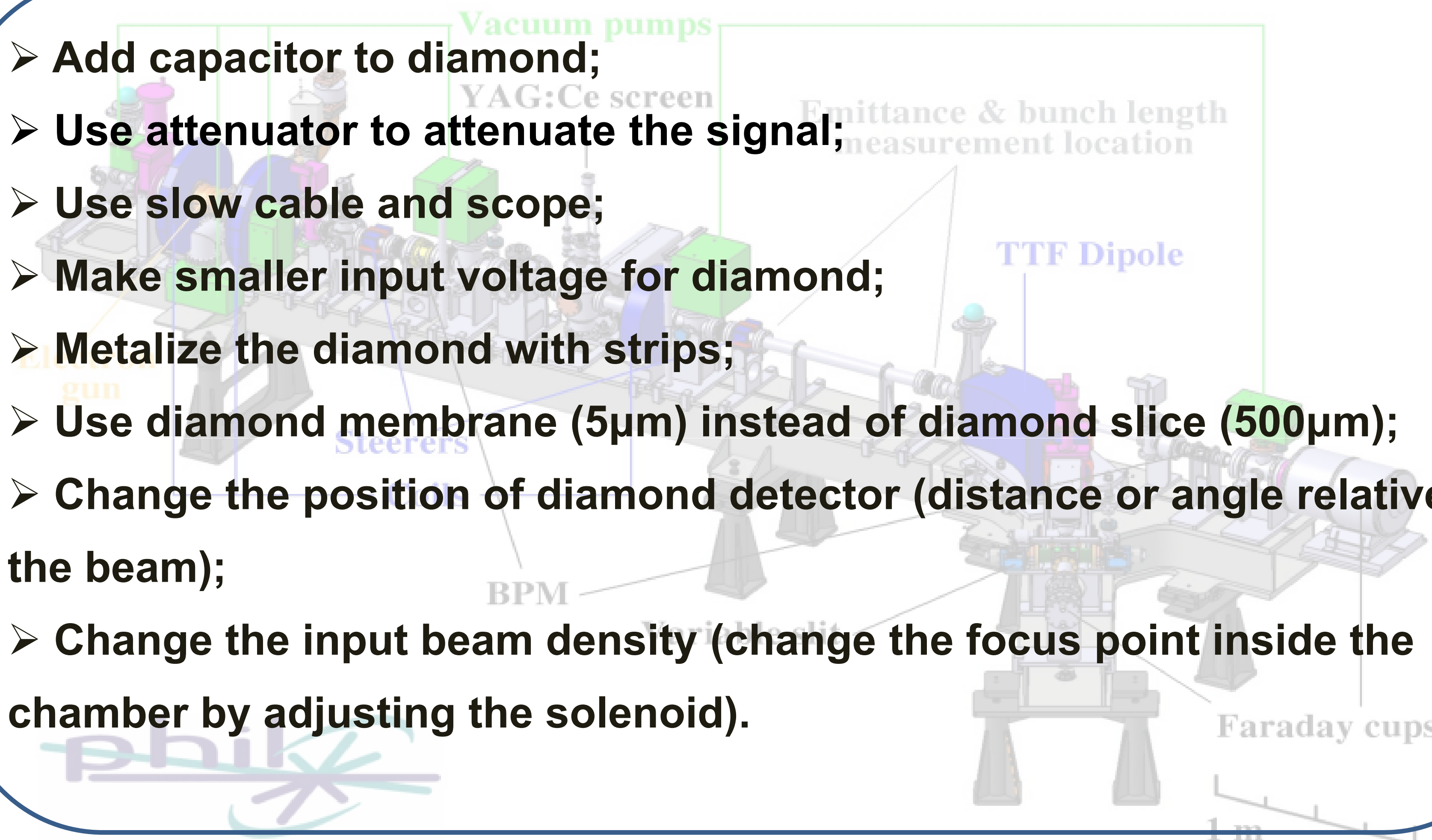
$$Q = \frac{2.74\times10^{-15}\times10\times10^{-12}}{1.6\times10^{-19}} = 1.71\times10^{-7}\,C = 0.171\mu C$$

Convert the charge into voltage:

$$V = R\times I = \frac{R\times Q}{t} = \frac{50\times1.71\times10^{-7}}{10^{-9}} = 8550V$$

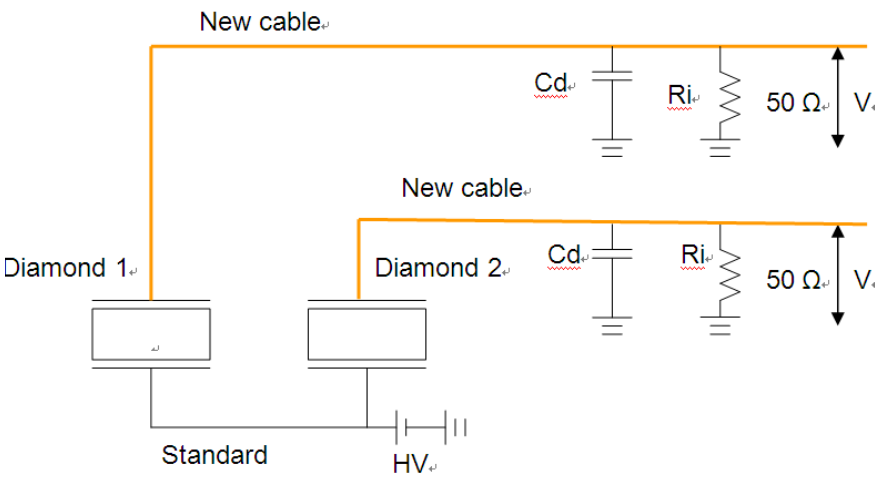
Too Large!

Different Ways to Reduce the Signal



- Add capacitor to diamond;
- Use attenuator to attenuate the signal;
- Use slow cable and scope;
- Make smaller input voltage for diamond;
- Metalize the diamond with strips;
- Use diamond membrane (5μm) instead of diamond slice (500μm);
- Change the position of diamond detector (distance or angle relative to the beam);
- Change the input beam density (change the focus point inside the chamber by adjusting the solenoid).

Electronics Setup



Agilent DSO6104L Fast Sampling Oscilloscope

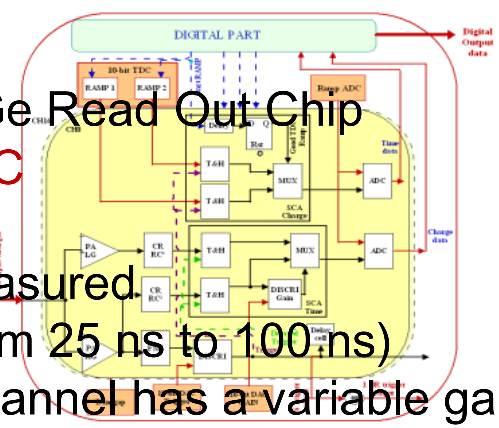
- 1 GHz analog bandwidth and up to 4 GSa/s sample rate
- 8 bit vertical resolution (extensible to 12 bits)
- 4-channel Agilent 6000L Series
- Maximum input : 400 V pk
- BNC connector used

Cable length: 25 m to 50 m (measured by *Jean-Noel Cayla*)

Cable Type
LDF4-50A, HELIAX 1/2 "
LDF1-50, HELIAX® 1/4 "
Connector R185A.216.020 ECO 7/16 1/2"
Connector ECO 7/16 1/4"

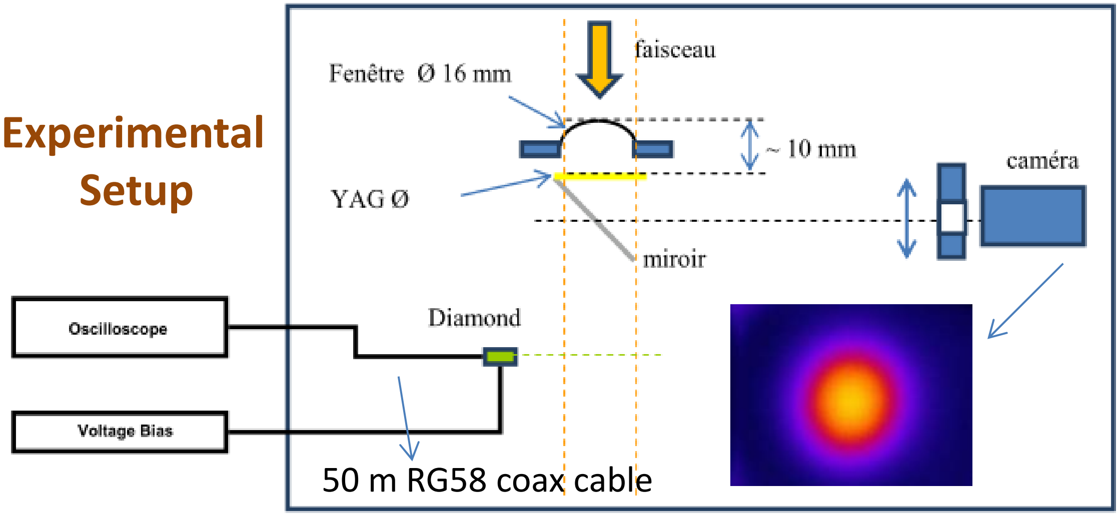
PARISROC2

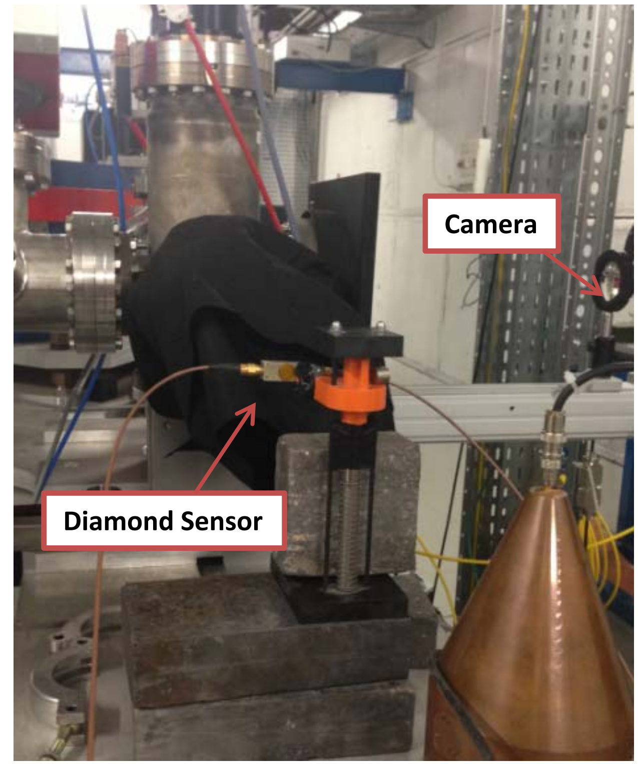
- Photomultiplier Array Integrated in SiGe Read Out Chip
- Charge dynamic range: 50 fC to 200 pC
- Self triggering and ADC integrated
- Both charge and time data can be measured
- Shaper with variable shaping time (from 25 ns to 100 ns)
- 16 independent channels and each channel has a variable gain

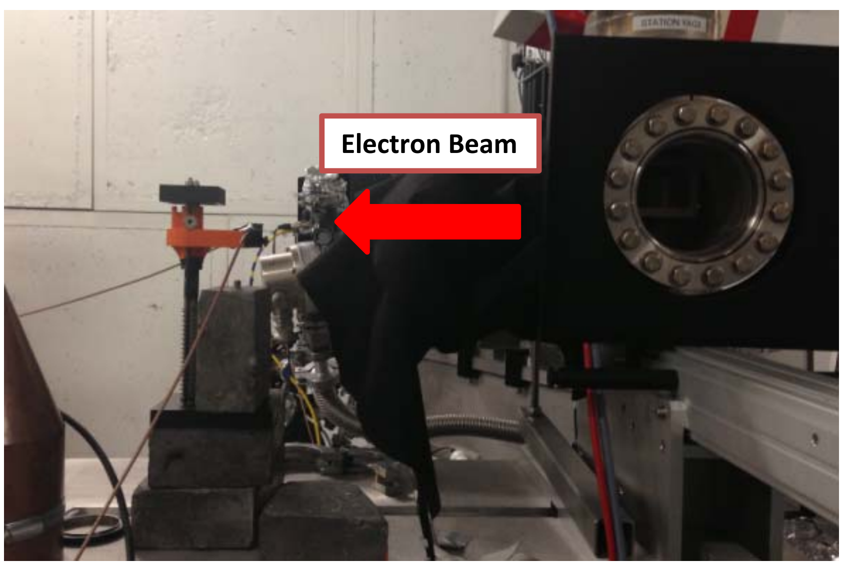


First Test @ PHIL

Experimental Setup

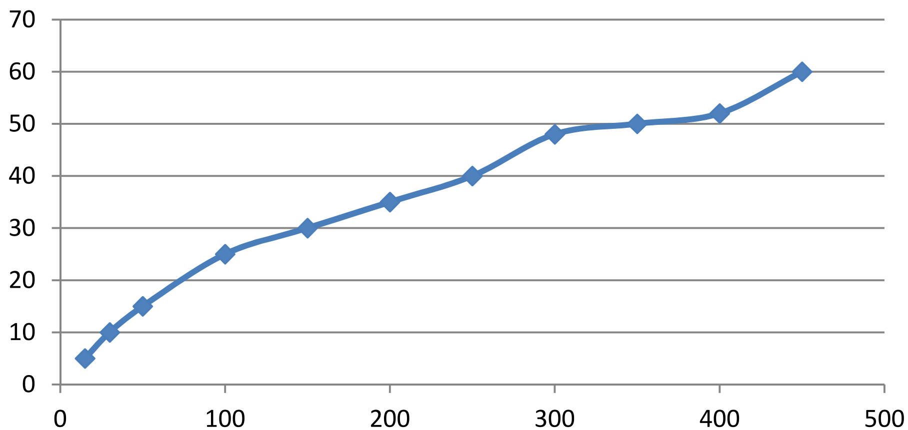




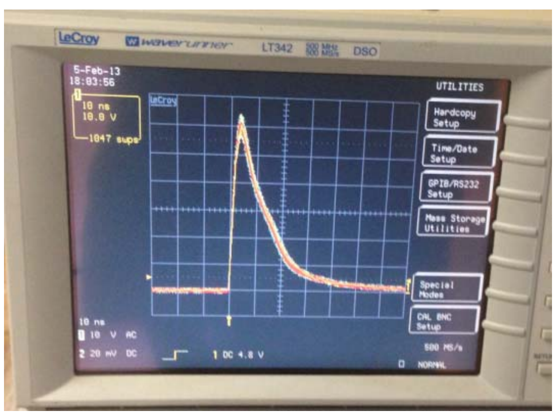


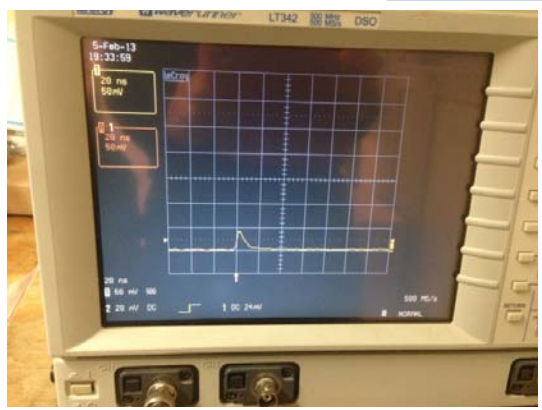
First Test Results @ PHIL

Amplitude @ sensor VS Bias voltage



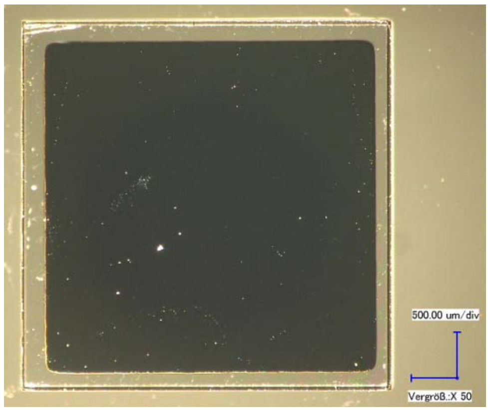
Filter	Total Charge	Amplitude @sensor
100%	180pC	65V
62%	130 pC	55V
31%	95pC	45V
3%	14pC	7V
0.1%	≈0.1pC?	40mV



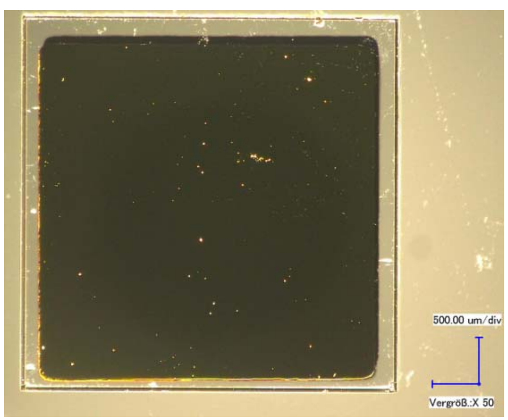


Minimum signal?
Number of electrons?
Attenuation of cables?
Charge collection efficiency?
Calibration?

IV Measurement for New Samples

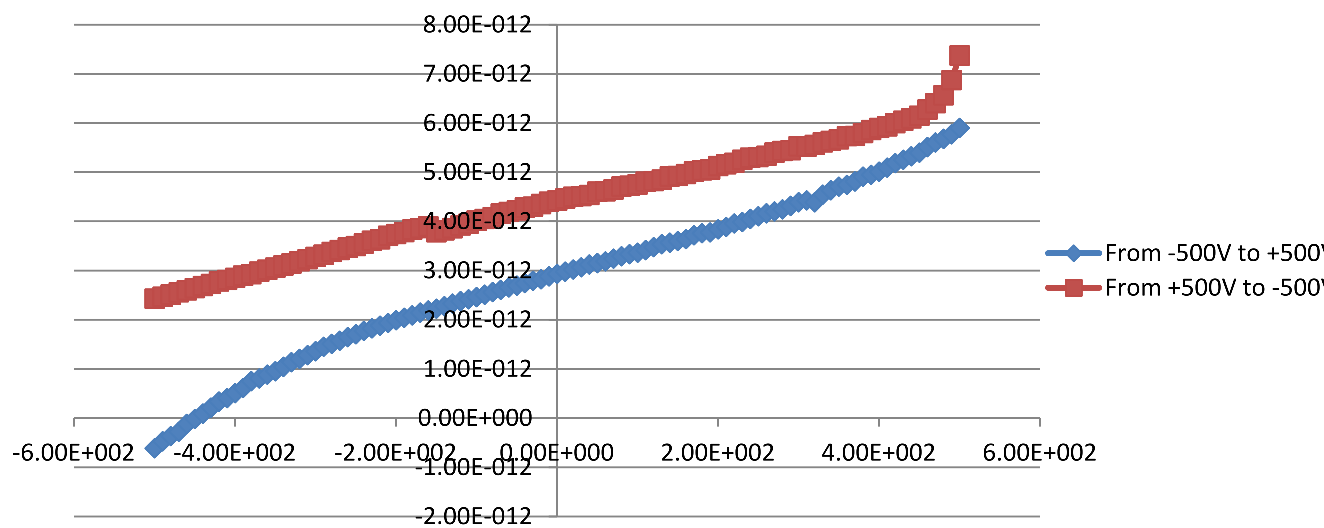


metallised_Al100nm



metallised_TiPtAu

Metallization	Sample N°	Surface	Thickness
Al	641-2	4.11x4.11mm2	529-533µm
	655-3	4.11x4.12mm2	512-521µm
TiPtAu	641-5	4.11x4.11mm2	528-530µm
	655-5	4.11x4.12mm2	518-525µm



Dark current level is a few pA

Summary and Future Plan

- **The charge obtained from PHIL (from 0.17μC to 4.25μC) is very close to the charge created by the ATF2 beam (1.6887μC/mm^2);**
- **To calibrate the halo and Compton measurement results we will also need to use the diamond detector to measure the beam itself, with an attenuator; the beam intensity will also be measured by other existing instruments;**
- **We can reduce the signal by changing the input beam density and changing the position of diamond detector (distance or angle relative to the beam) and also the signal can be attenuated by high bandwidth attenuator or the diamond bias voltage can be reduced;**
- **Measure signals from diamond sensors using the PHIL beam and a set of fast Agilent 1 GHz bandwidth / 4 GHz sampling oscilloscopes;**
- **Test diamond sensors using PARISROC II by reducing the signal.**

⇨ **Finally install the diamond sensor @ ATF2**
→ measure the beam halo and Compton → before the end of 2013

Thank you for your attention !