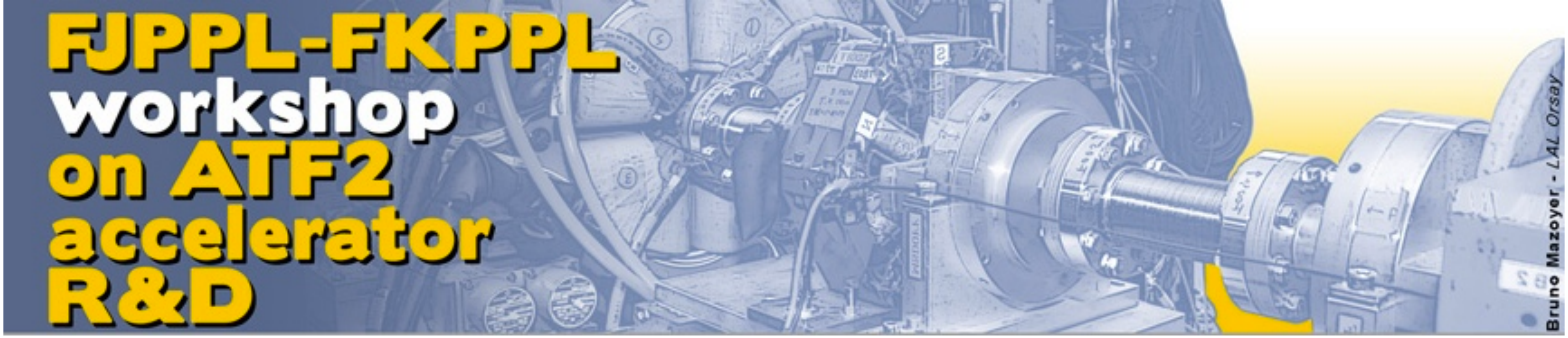

Measurement of Beam halo and Compton electron recoil spectrum after the IP of ATF2

March 20, 2012

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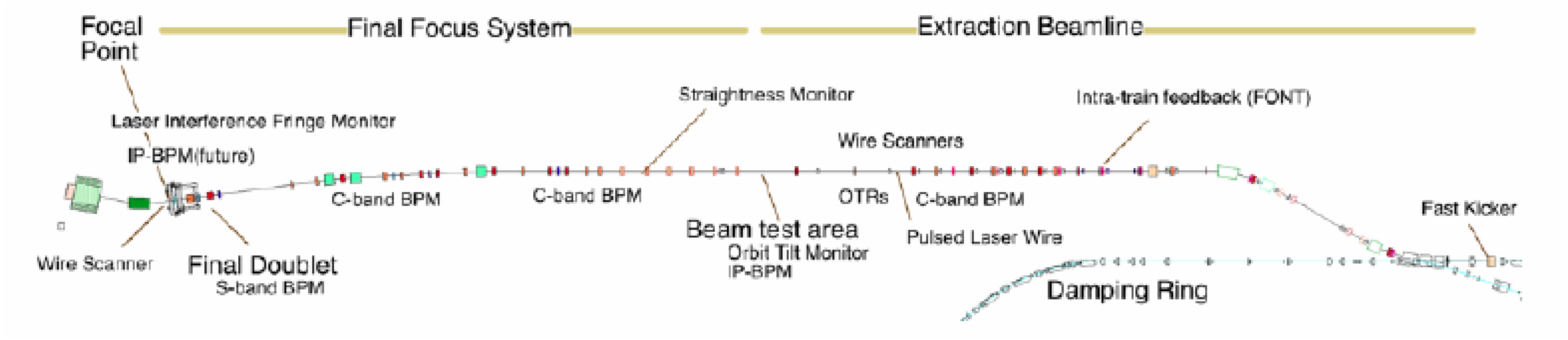
Laboratoire de l'Accélérateur Linéaire

Contents

- Introduction of ATF2 and Shintake beam size monitor
- Measurement of beam halo and Compton electron recoil spectrum
- Results of MAD simulation
- Design of diamond detector
- Summary and Plan

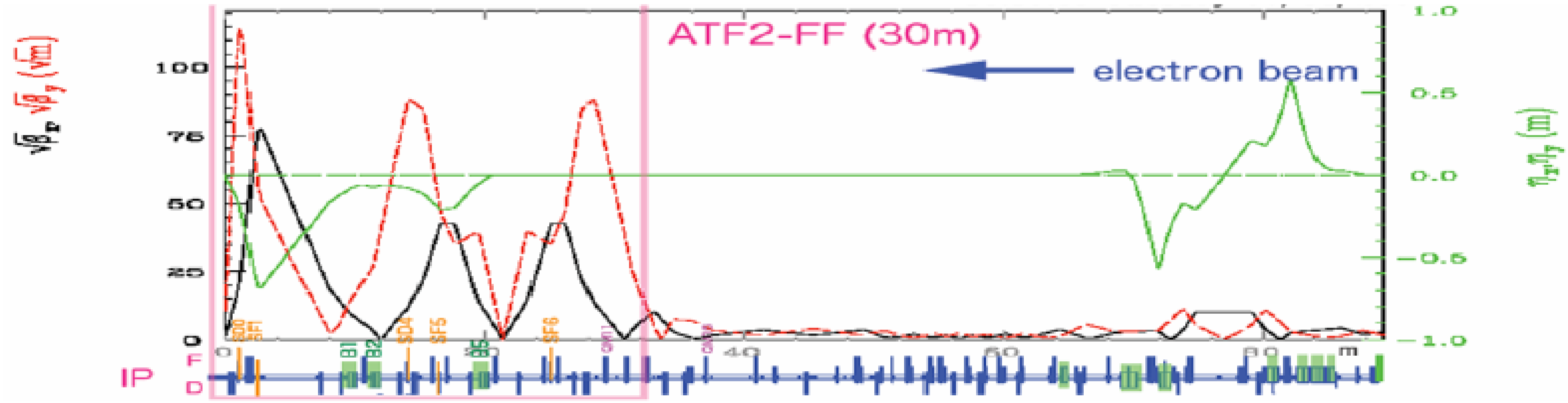
ATF2 operation & instrumentation R&D



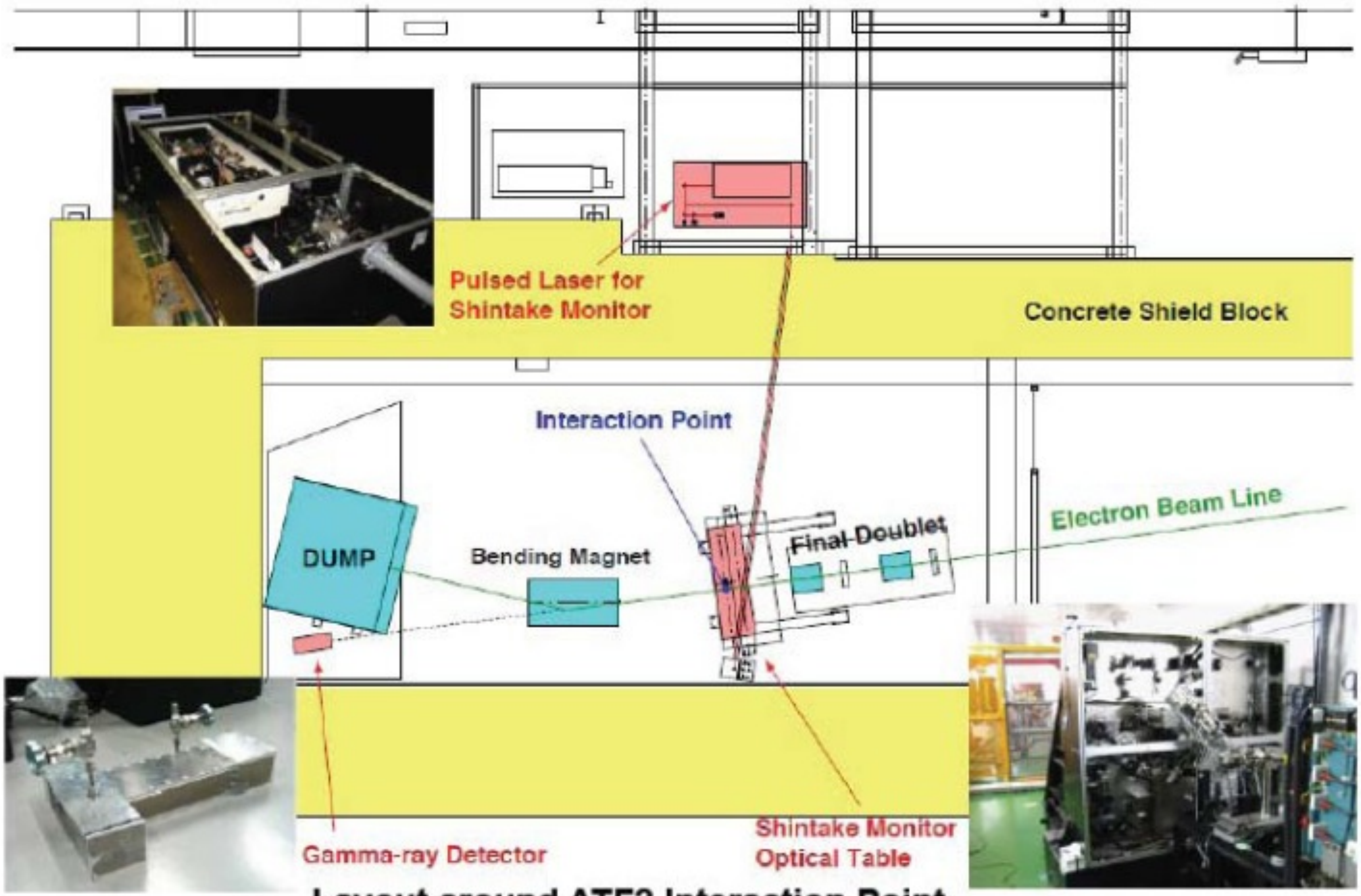
2nd order telescope
fine tuning of local errors

Match optics into FF
buffer section for input errors

DR extraction
setup, stability

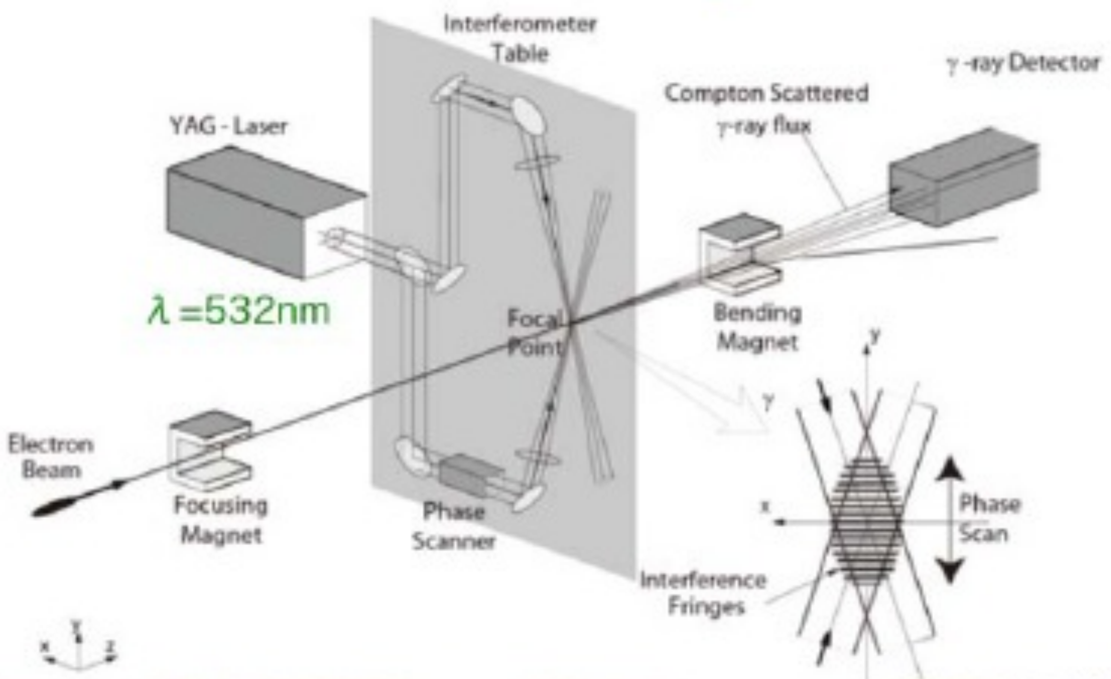


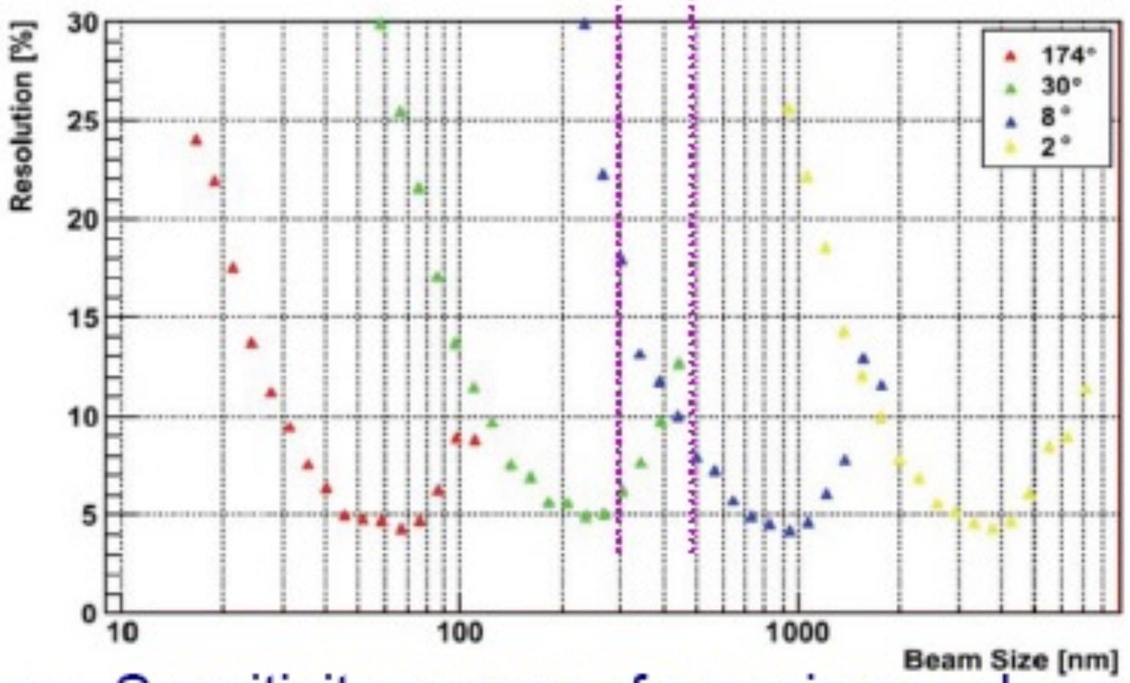
Shintake beam size monitor at IP



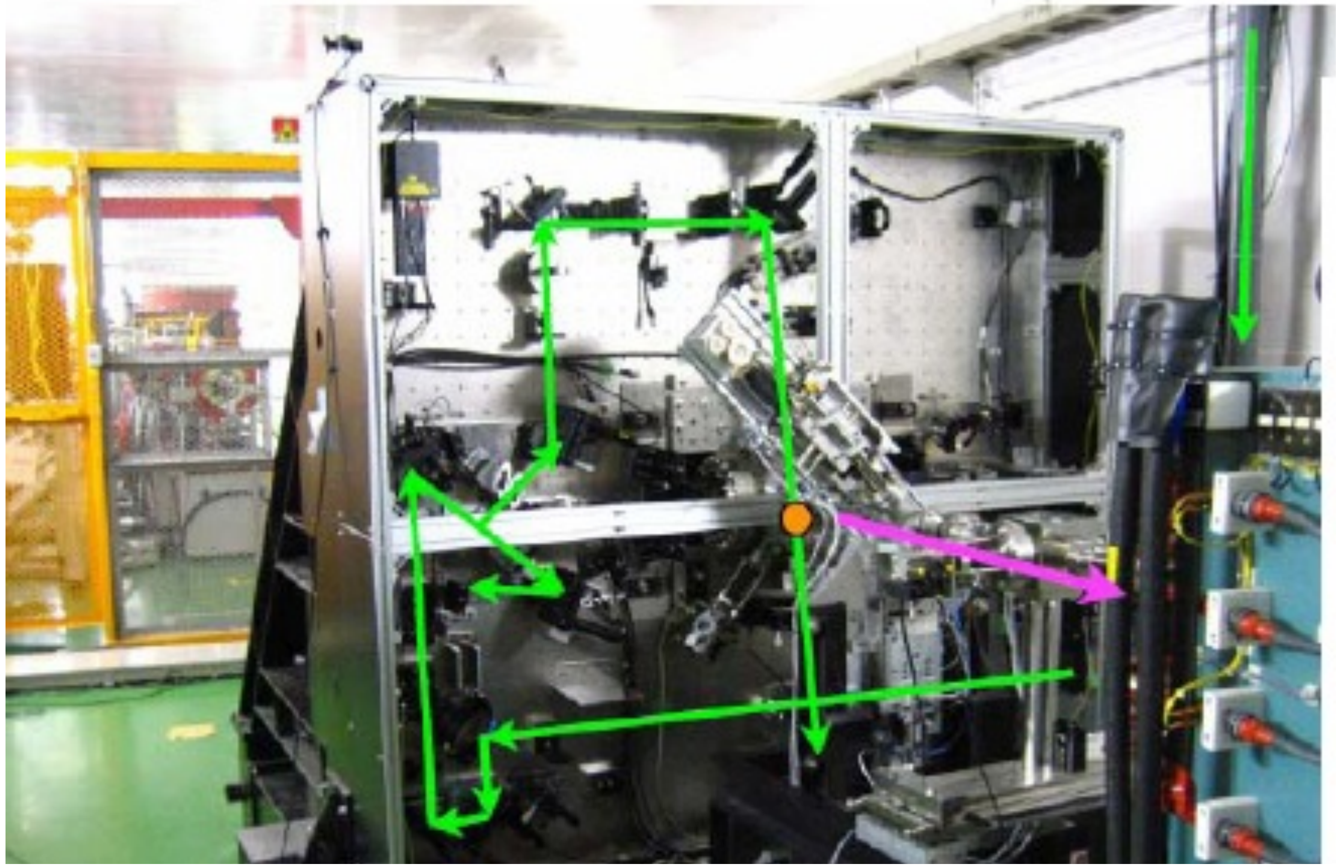
Layout around ATF2 Interaction Point

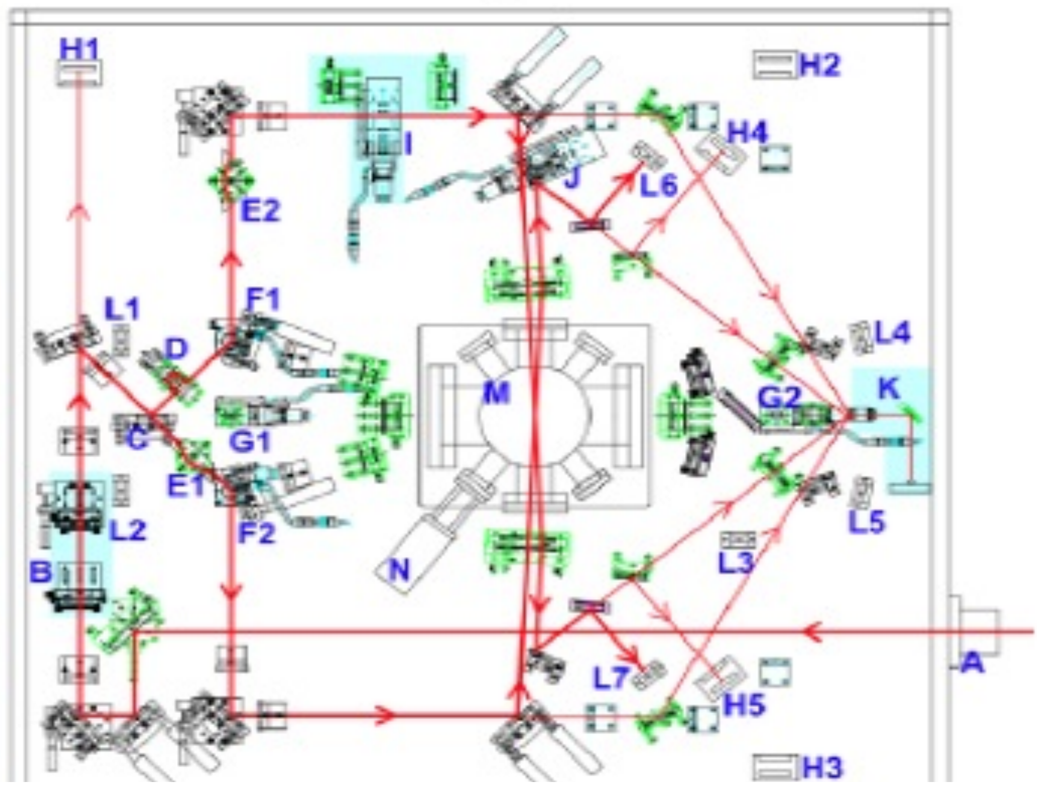
Shintake beam size monitor at IP





Sensitivity ranges of crossing angles





Measurement of beam halo and Compton electron recoil spectrum

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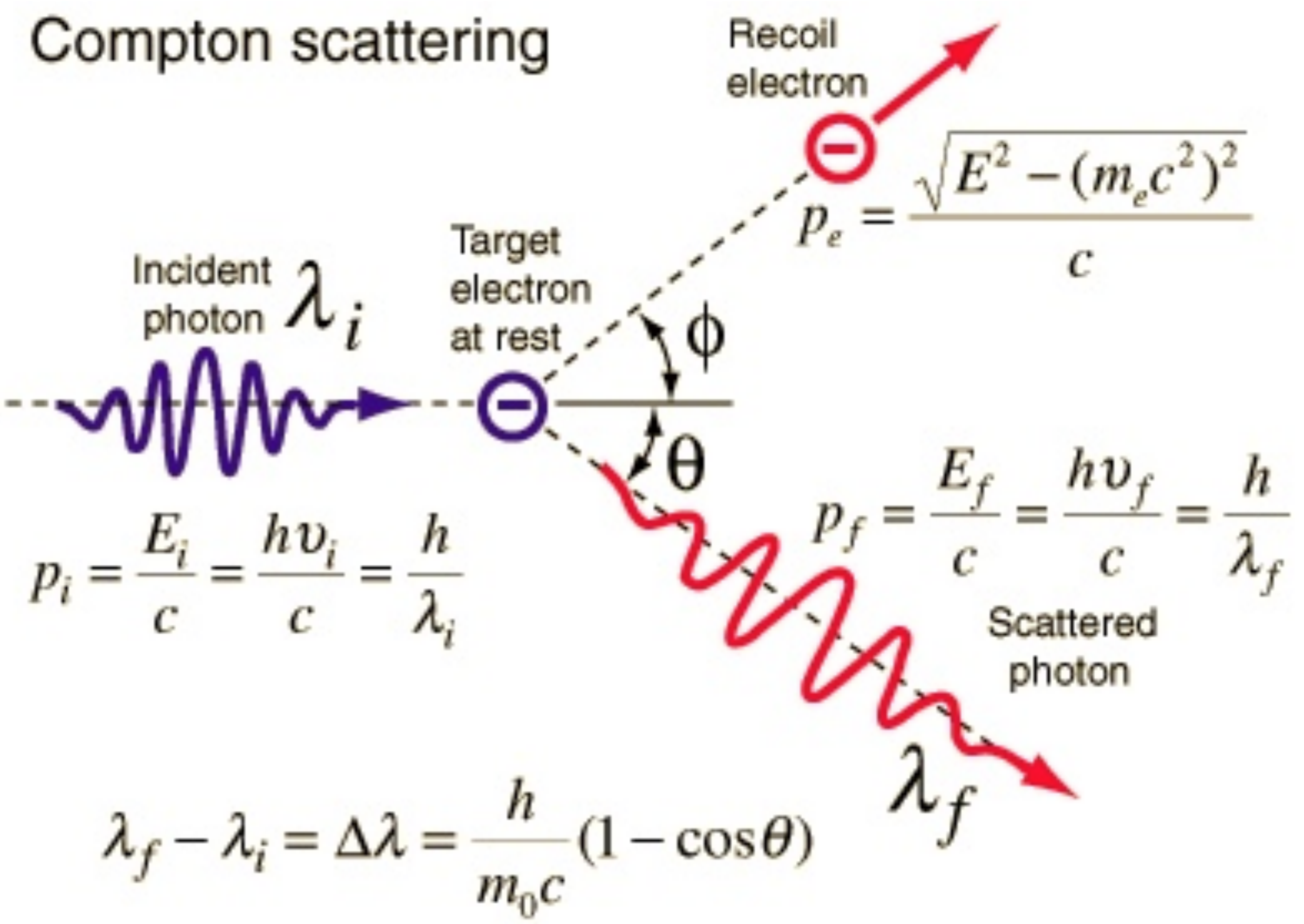
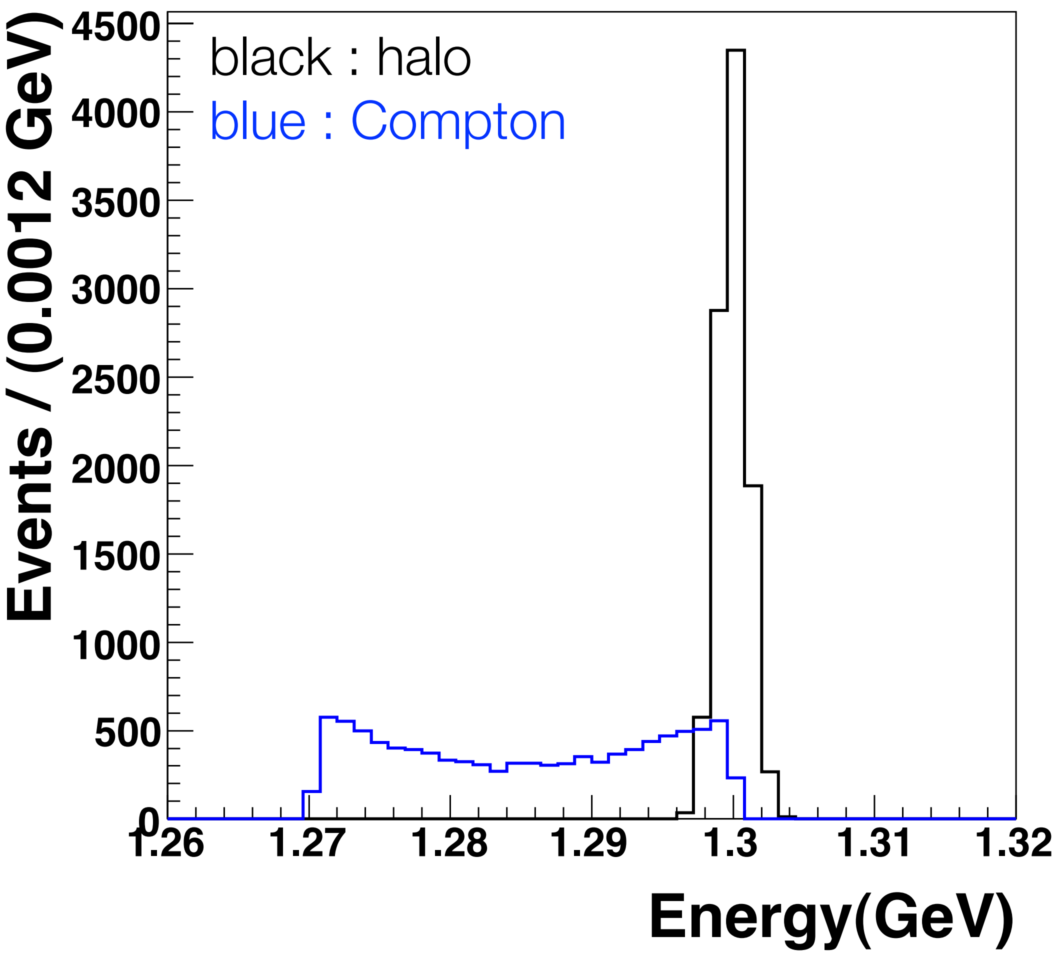
- What is beam halo?
  - major issue for IR backgrounds at many colliders, e.g. future linear colliders, B factories, and also ATF2
  - halo population poorly known, involves various mechanisms :
    dark current, wake-fields, non-linearity, multiple intra-beam Coulomb scattering, scattering off residual beam gas and thermal photons, very low Pt t-channel physics processes, ...
  - control of halo via collimation / optics essential to enable the most aggressive optics configurations for luminosity performance
- Motivation for measurements at ATF2
  - previous measurements in 2007 in old EXT line
  - halo transport in ATF2 and direct probe of tails in IP angular spread
  - investigation of halo modeling / comparing with measurements
  - check possibility to probe Compton electron recoil distribution during IP-BSM operation

Measurement of beam halo and Compton electron recoil spectrum

- What is Compton electron recoil spectrum?
  - When the beam size is measured at IP with Shintake monitor, electron beam is scattered by photon and a little part of their energy is transported to the photon

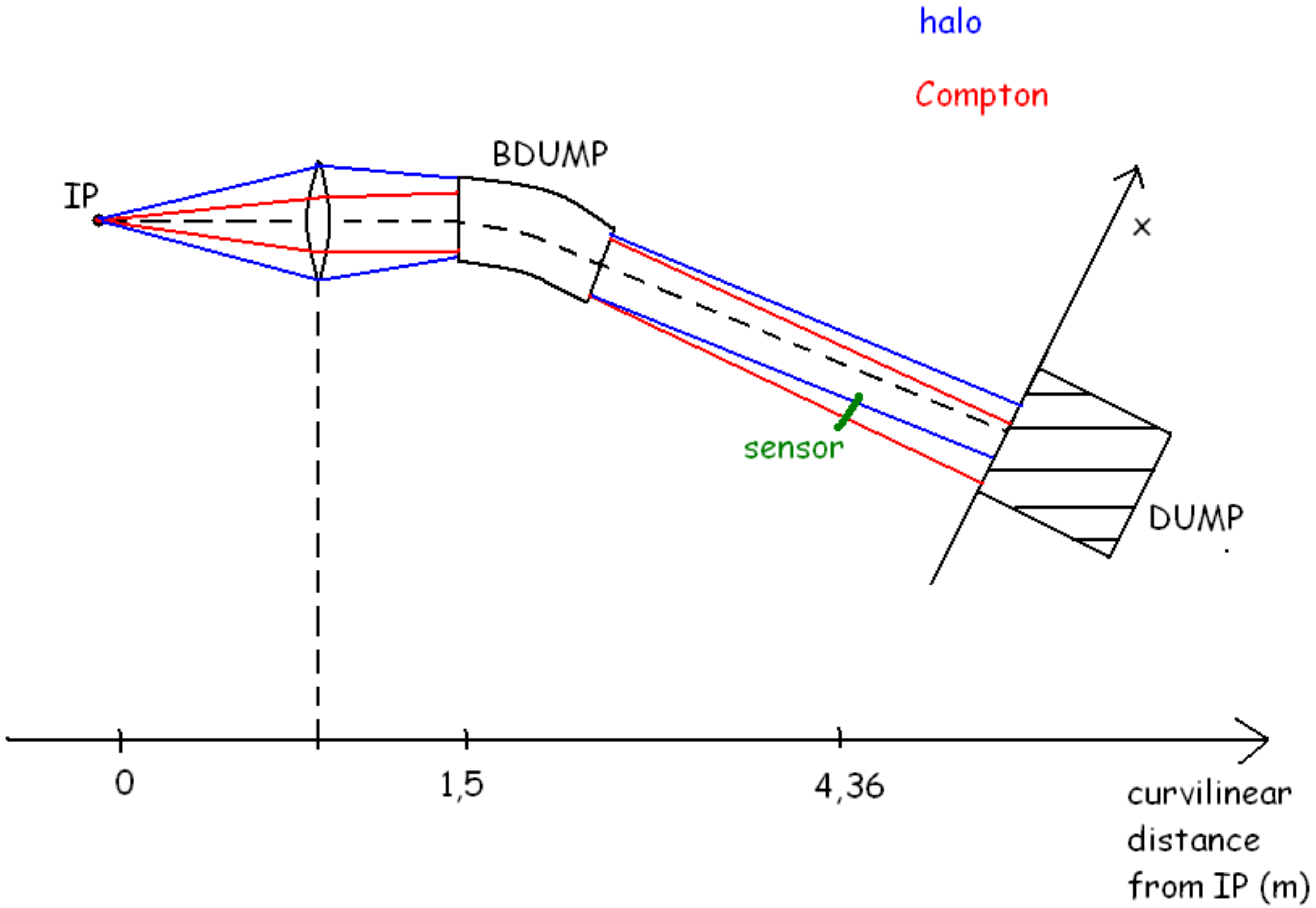


$$\lambda_f - \lambda_i = \Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

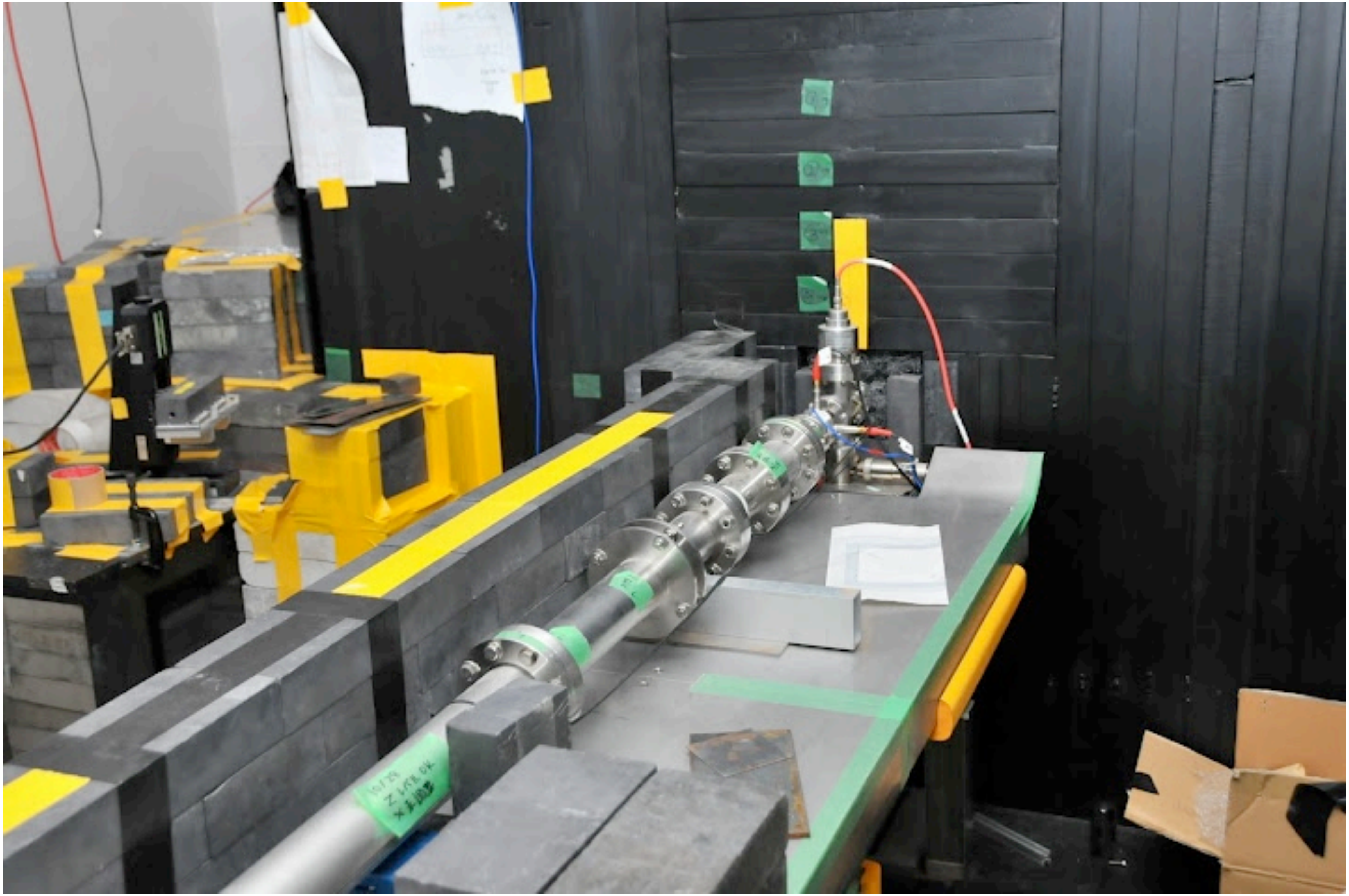


Measurement of beam halo and Compton electron recoil spectrum

- Illustrative layout



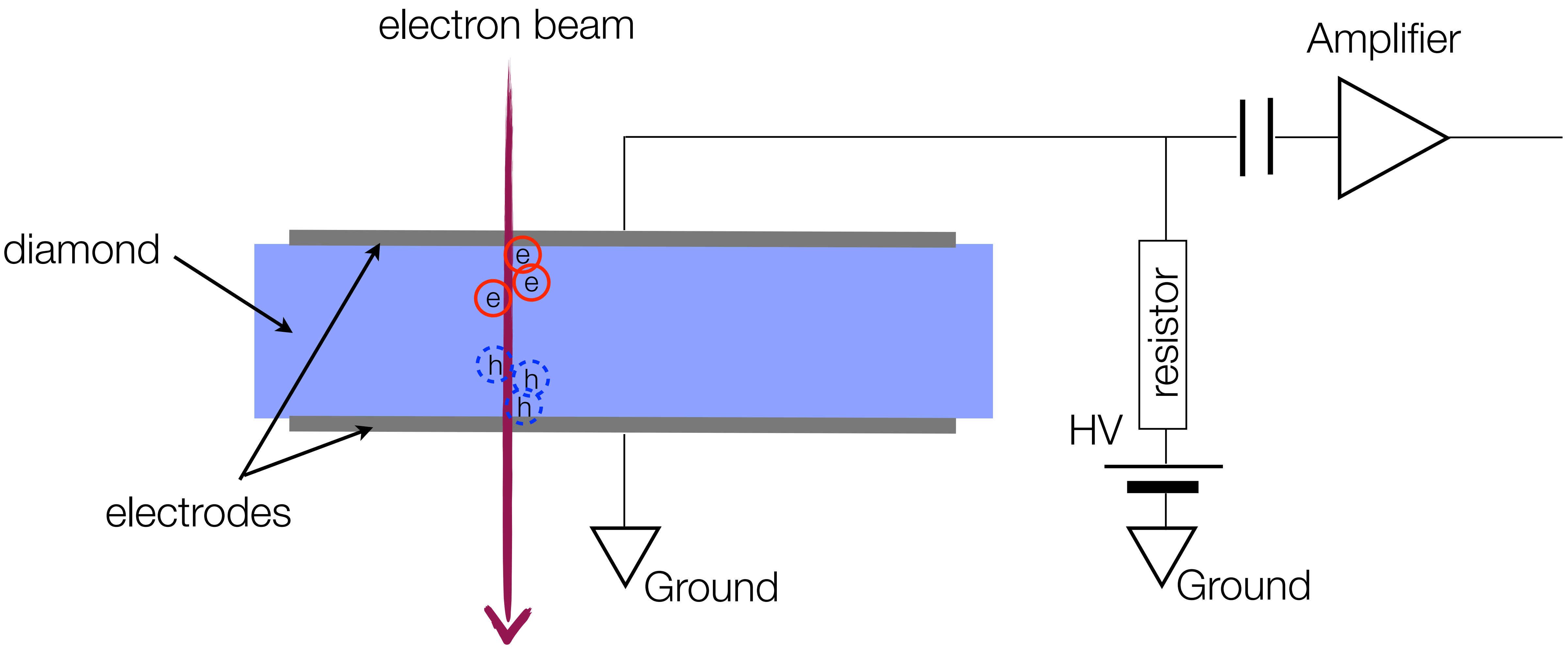
Measurement of beam halo and Compton electron recoil spectrum



Diamond sensor : characteristics

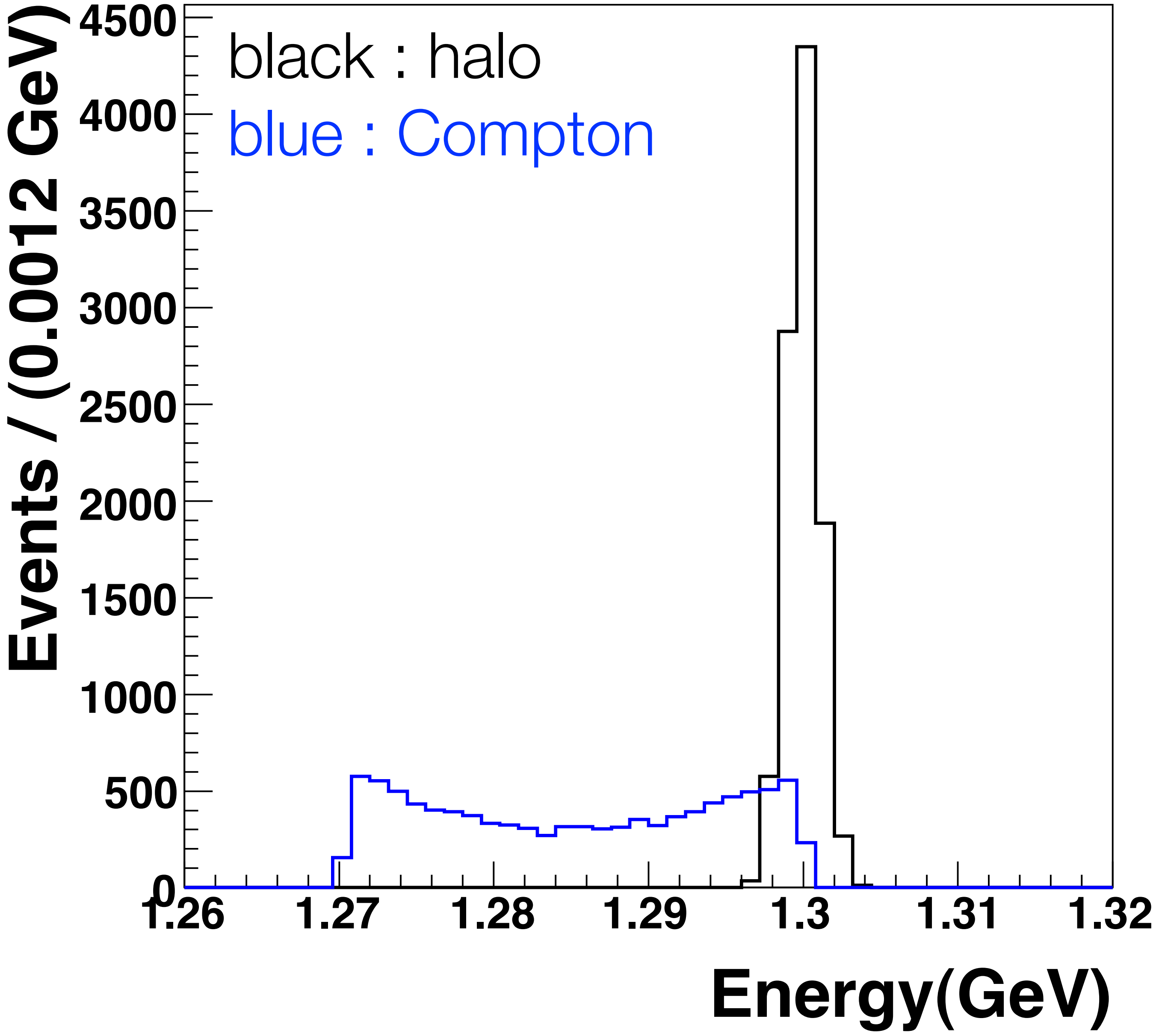
Property	Diamond	Silicon
Atomic number	6	14
Density (gm^{-3})	3.5	2.32
Band gap (eV)	5.5	1.1
Resistivity (Ωcm)	>10^{12}	105
Electron mobility (cm^{3}V^{-1}s^{-1})	1800	1500
Hole mobility (cm^{3}V^{-1}s^{-1})	1200	500
Saturation velocity (μm ns^{-1})	220	100
Dielectric constant	5.6	11.7
Neutron transmutation cross-section (mb)	3.2	80
Energy per e-h pair (eV)	13	3.6
Average minimum ionizing signal per 100 μm (e)	3600	8000

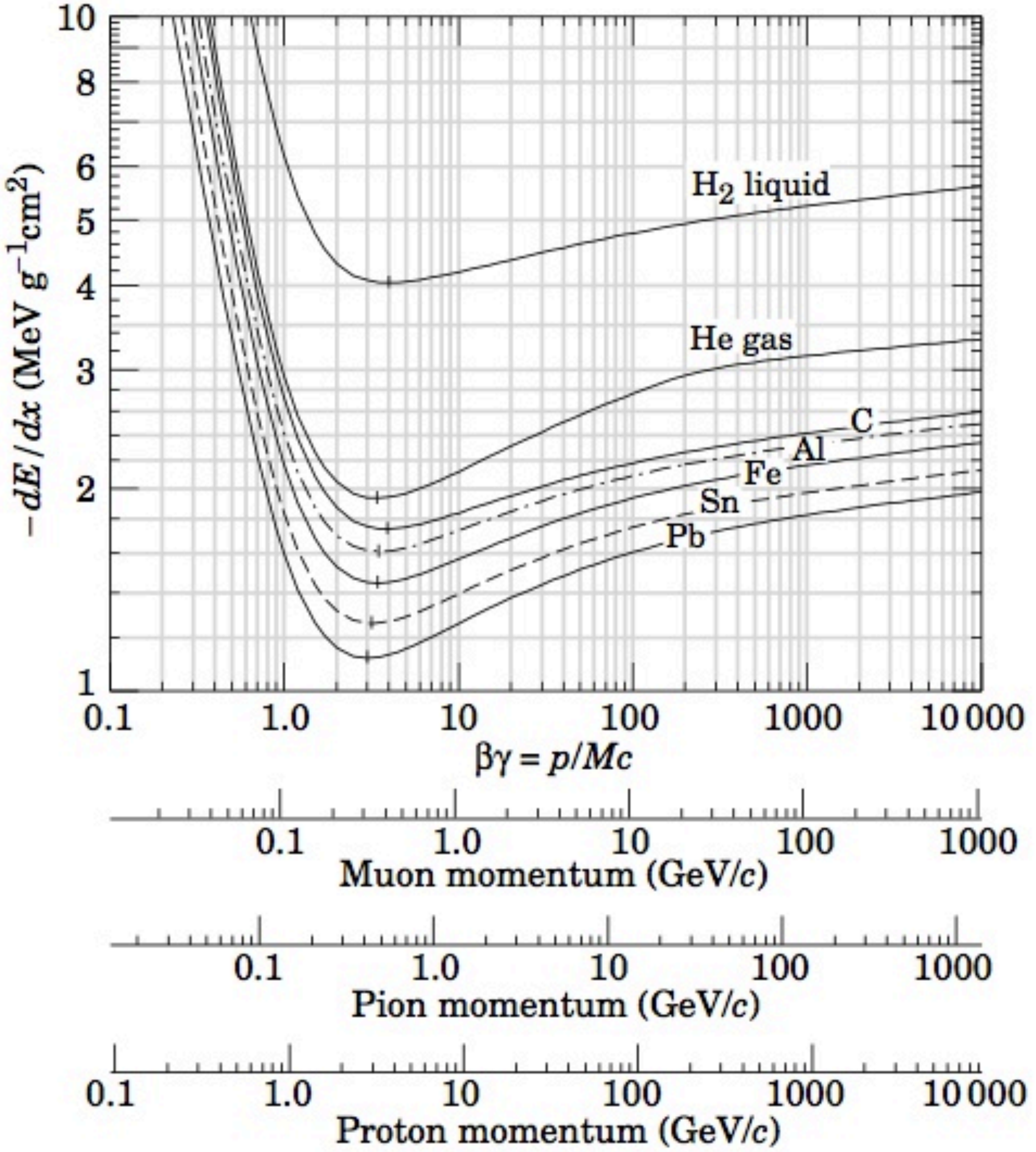
Diamond sensor : operational principle



Results of MAD simulation : Energy

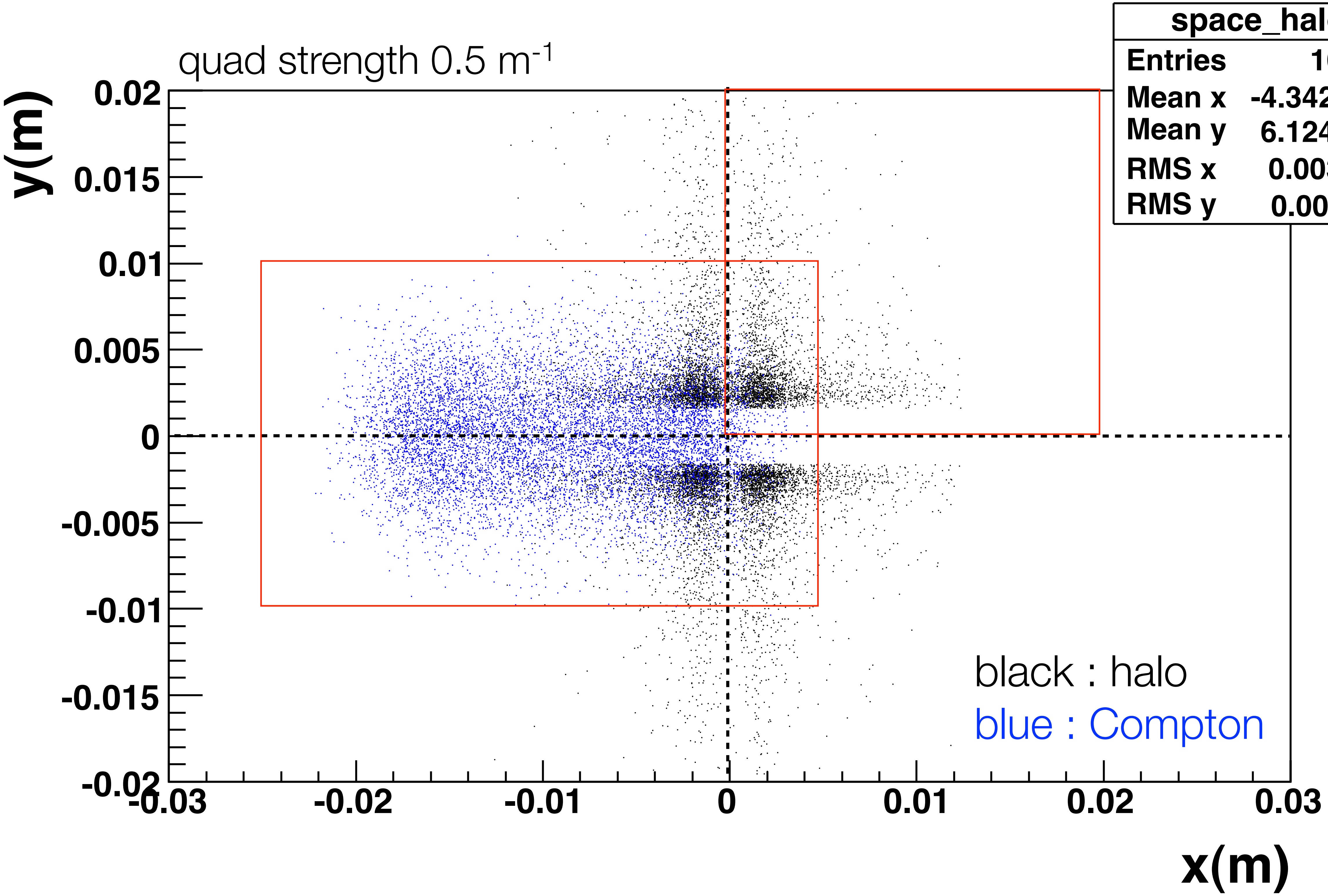
quad strength 0.5 m^{-1}





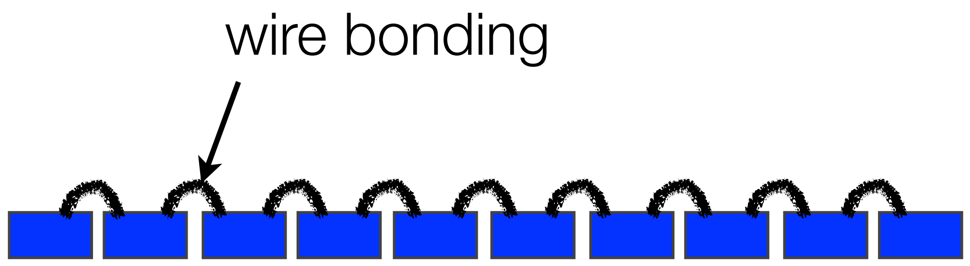
- Whole events could be consider as a MIP from the simulation result

Results of MAD simulation : Position

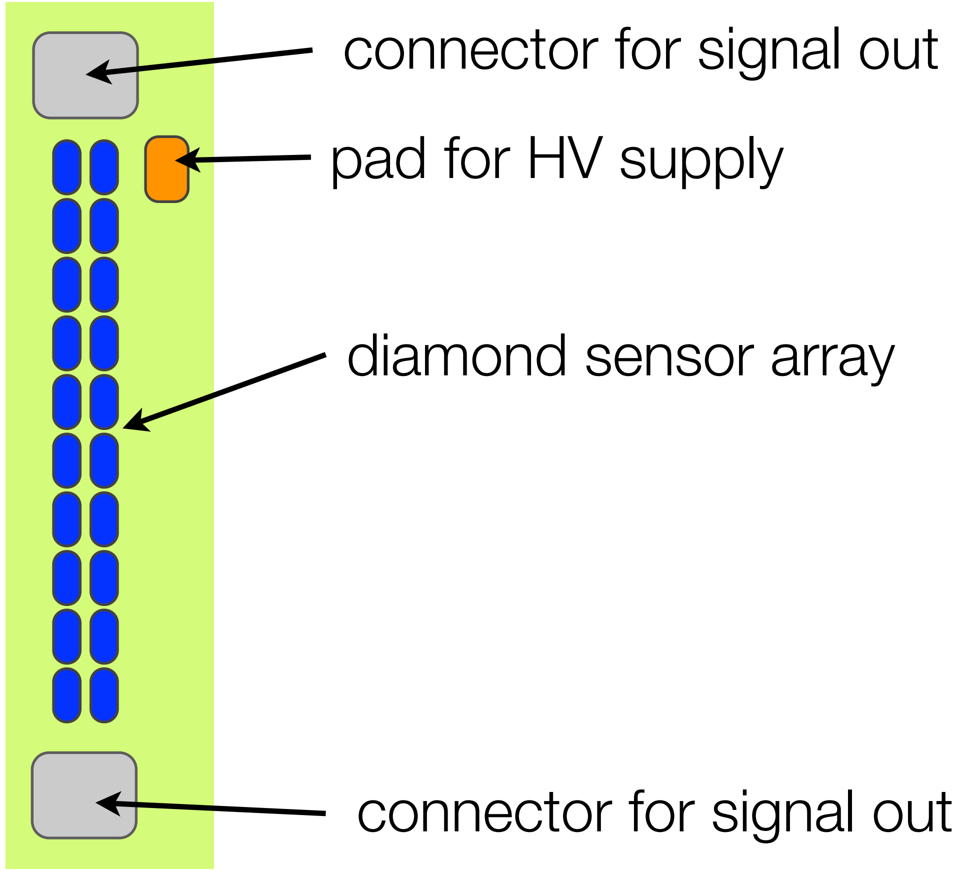


Design of diamond detector : diamond sensor

- Single crystal diamond sensor has a limit in size. The maximum size is 4.6 × 4.6 mm^2
- Prototype design
  - 2 × 10 array diamond pad sensor
  - the size of one pad is 2 × 2 mm^2 or 1 × 2 mm^2
  - the diamonds in column are connected by wire bonding
  - number of readout channel is two

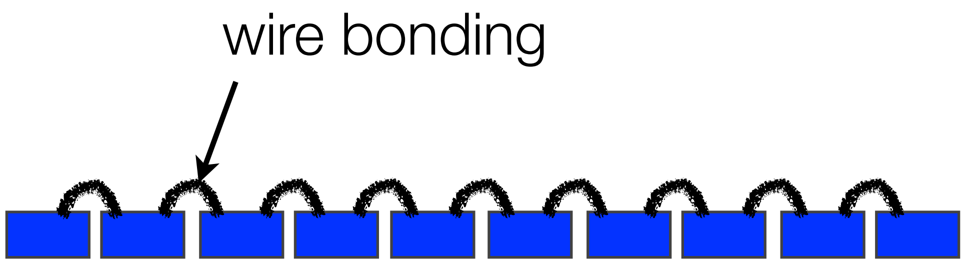


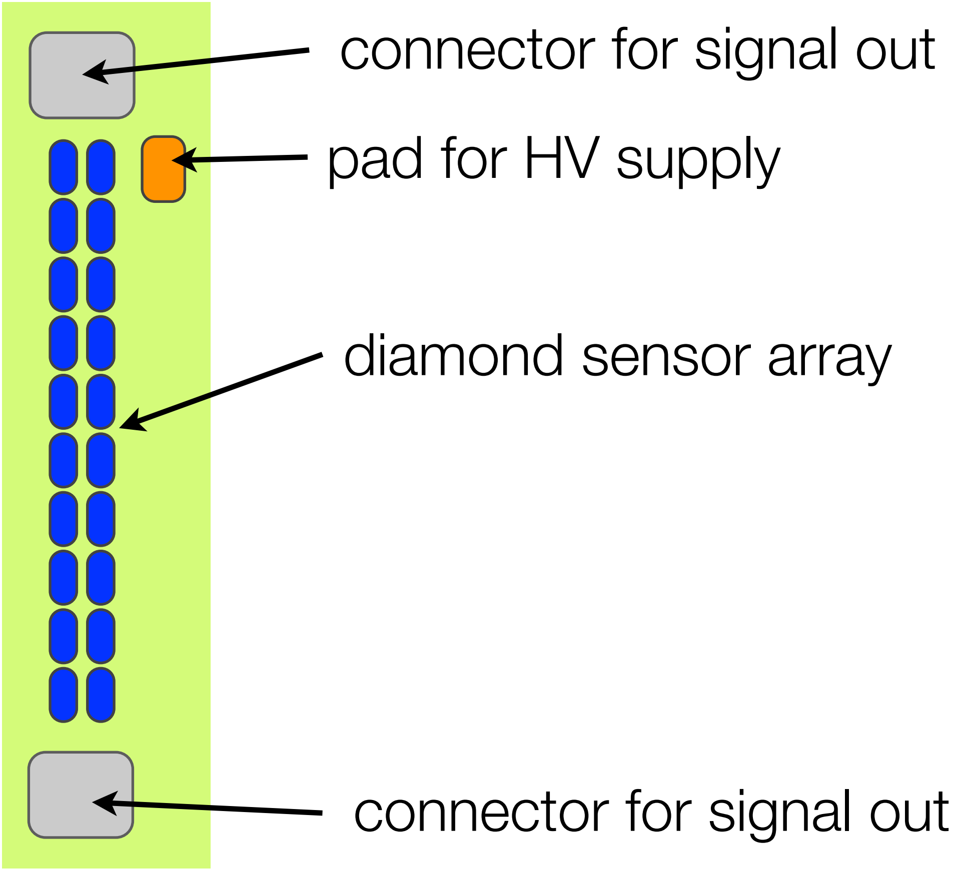
This is a sketch not final design ➔



Design of diamond detector : diamond sensor

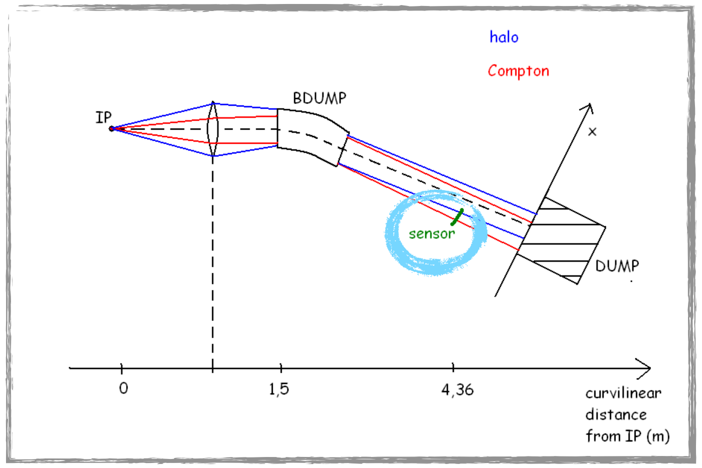
- Single crystal diamond sensor has a limit in size. The maximum size is 4.6 × 4.6 mm^2
- Prototype design
  - 2 × 10 array diamond pad sensor ➔ two channel diamond strip sensor
  - the size of one pad is 2 × 2 mm^2 or 1 × 2 mm^2
  - the diamonds in column are connected by wire bonding
  - number of readout channel is two

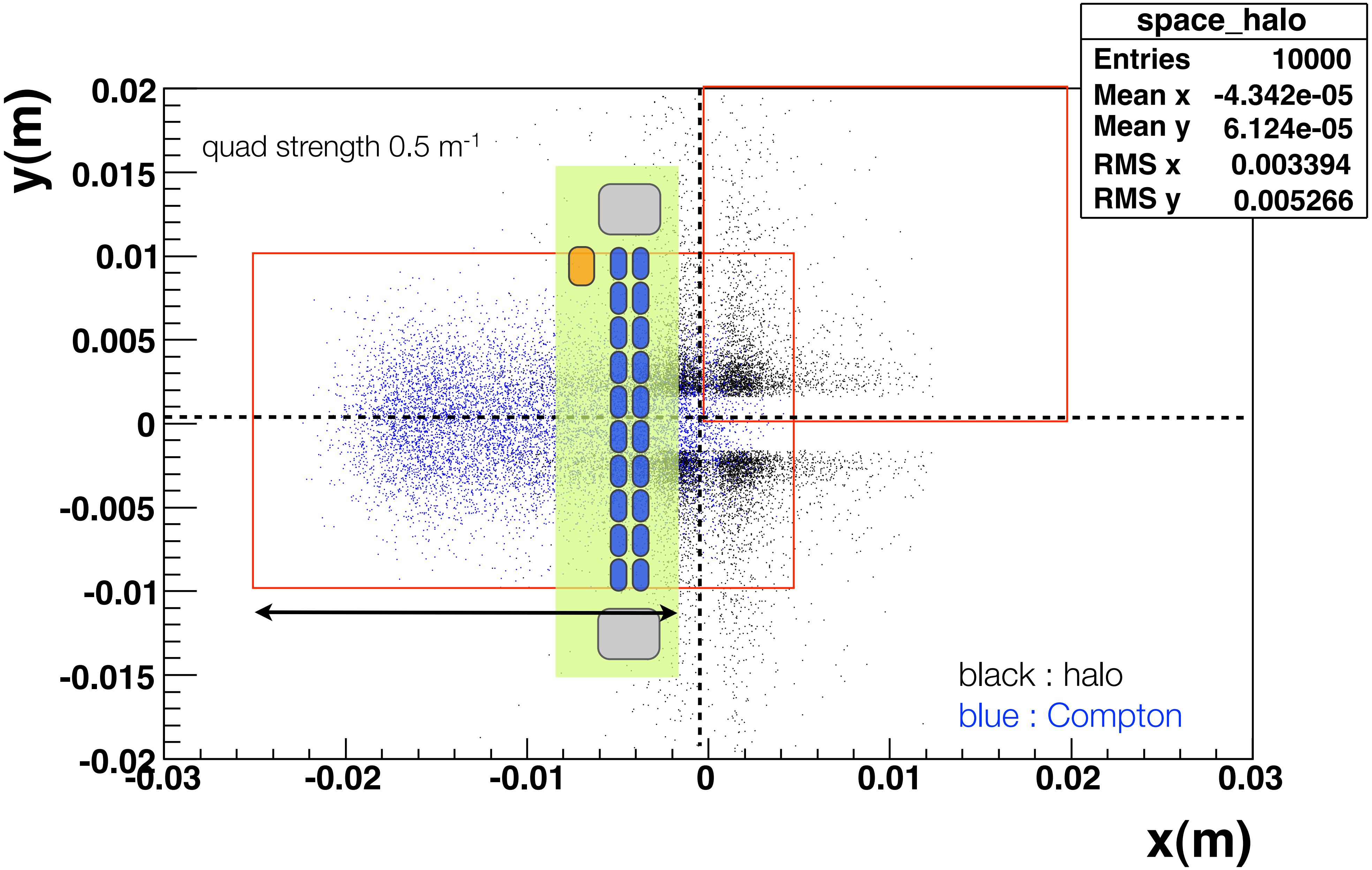




This is a sketch not final design ➔

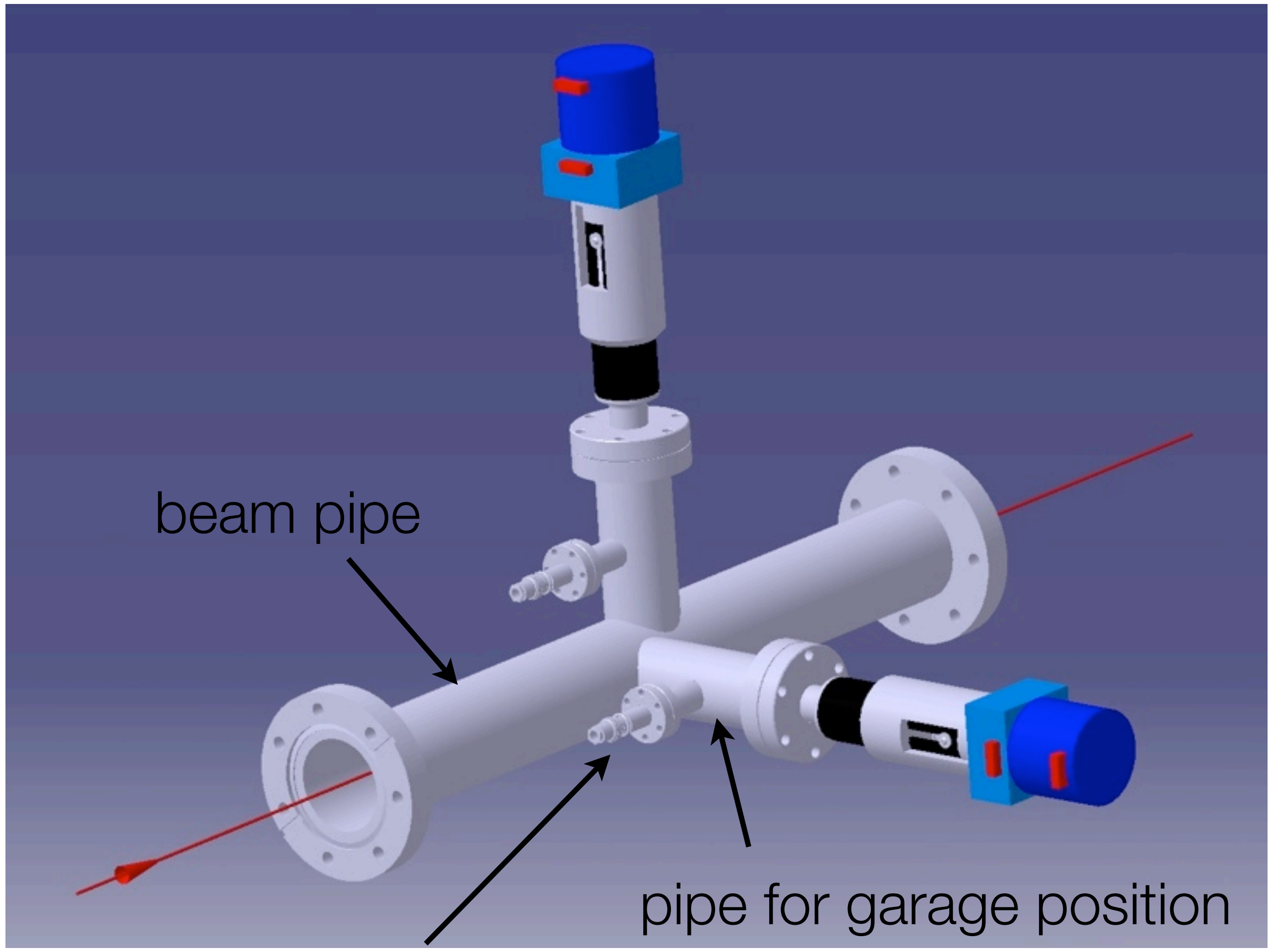
Design of diamond detector : diamond sensor





- The post-IP region is scanned by the diamond sensor module
- There is a probability to change the pad size of diamond and the number of channel

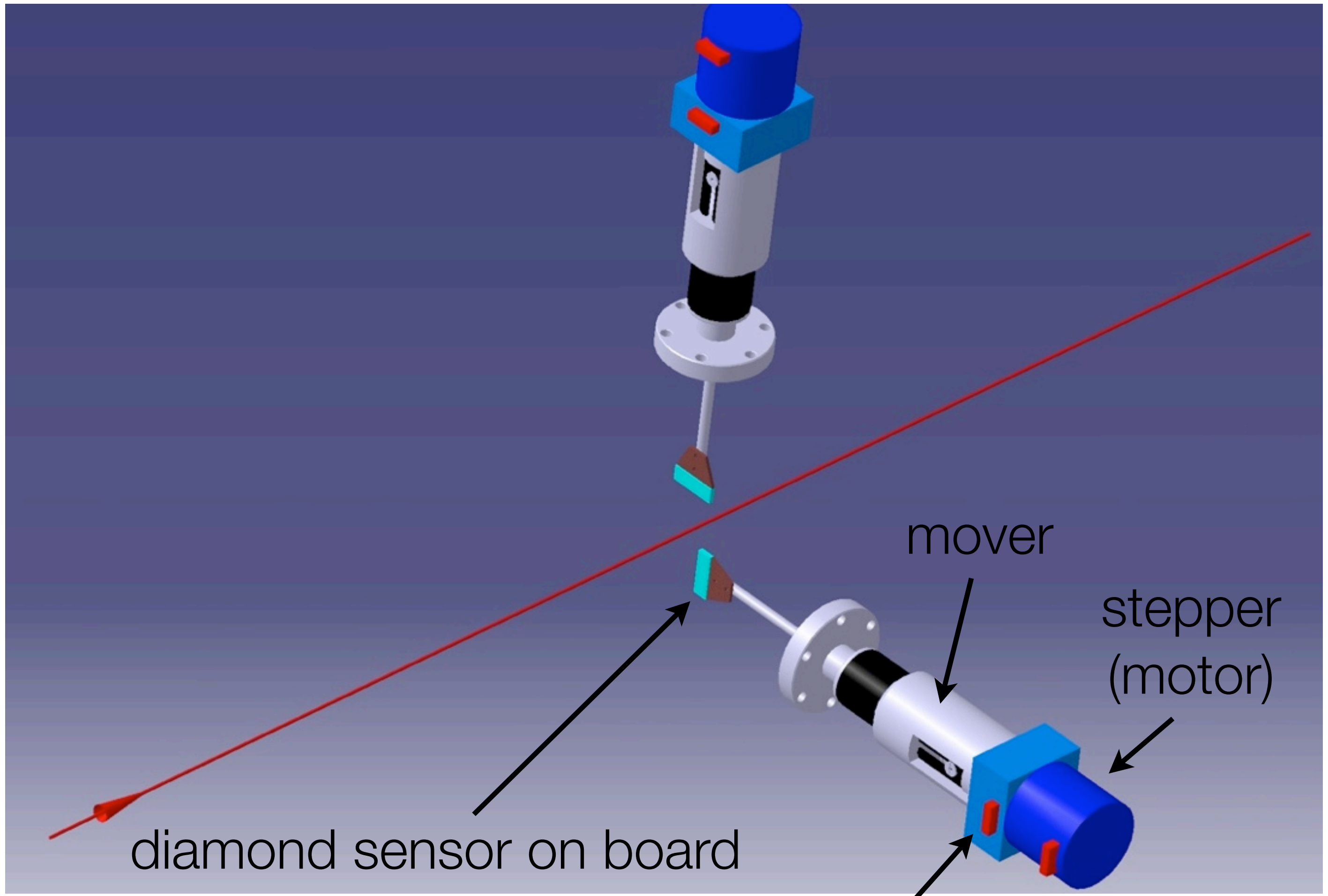
Design of diamond detector : mechanics



beam pipe

pipe for garage position

feed through

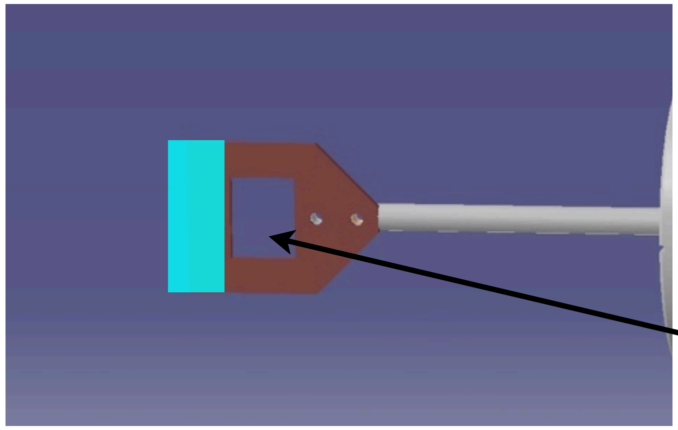


mover

stepper (motor)

diamond sensor on board

feedback



hole to measure both sides

Many thanks to M. Frederic Bogard

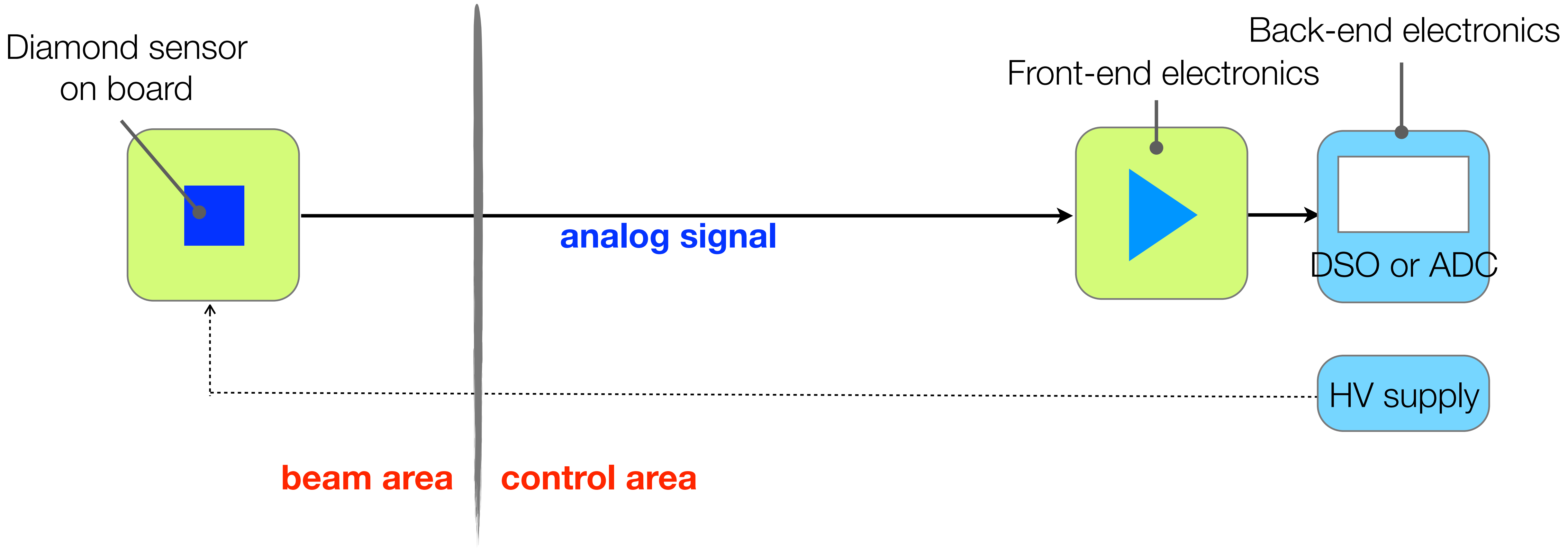
Design of diamond detector : size of signals

- The size of charge signal is calculated with number of events multiplied by charge of 1 MIP
  - 1 MIP corresponds for 2.74 fC (500 μm thick and CCE ≥ 95% diamond assumed)
  - The position distribution of page 13 divides into the area of diamond strip and the number of events for each area is obtained
- Very huge signal and too wide dynamic range
- But, repetition rate is a few Hz (1.5 Hz ~ 6 Hz)

	Size of Diamond sensor	
	1 × 20 mm^2	2 × 20 mm^2
intrinsic spatial resolution*	0.29 mm	0.58 mm
charge signal of **halo**	**3 pC< charge < 365 pC**	3 pC < charge < 550 pC
charge signal of **Compton**	**8 fC< charge < 2 pC**	0.01 pC < charge < 5 pC

* pitch / √12, in here pitch is assumed to be a length of one side

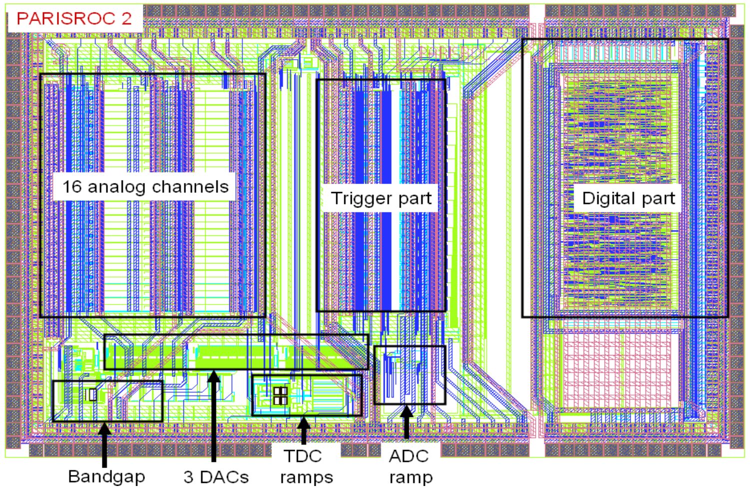
Design of diamond detector : signal readout

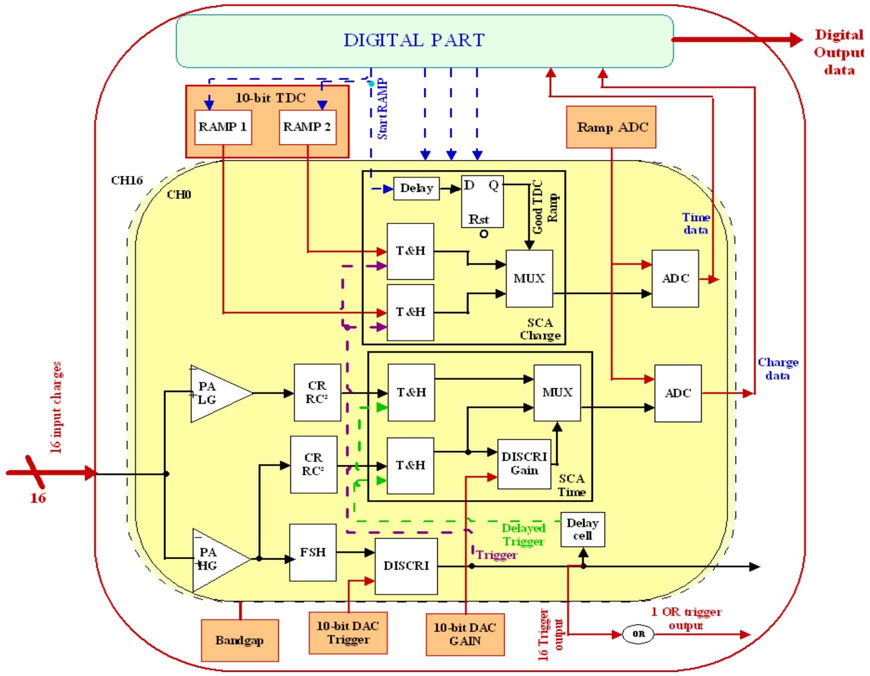


- The readout electronics is placed at control area
- The distance between diamond sensor and electronics is about 50 m
- PARISROC2 and DSO6104L are front-end and back-end electronics, respectively

Design of diamond detector : signal readout

- Front-end electronics : PARISROC2
  - Photomultiplier Array Integrated in SiGe Read Out Chip
  - 16 independent channels and each channel has a variable gain
    ➔ cover the large input dynamic range
  - Charge dynamic range: up to 100 pC
  - Shaper with variable shaping time (from 25 ns to 100 ns)
  - Self triggering and ADC integrated
  - Both charge and time data can be measured





Design of diamond detector : signal readout

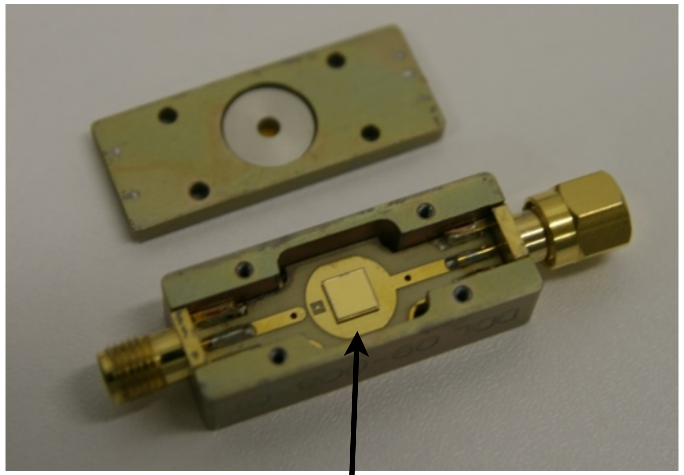
- Back-end electronics : DSO6104L
    - 4-channel Agilent 6000L Series Low-Profile Oscilloscopes
    - 1 GHz analog bandwidth and up to 4 GSa/s sample rate
    - 8 bit vertical resolution (extensible to 12 bits)
    - Maximum input : 400 V_{pk}
    - BNC connector used

- The DAQ system for PARISROC2 and DSO6104L are integrated at LAL and KEK, respectively
- Understanding both systems ➔ Adapting for diamond detector

Summary and Plan

- Single crystal CVD diamond sensor is chosen
- We have a huge charge signal and wide dynamic range
- The repetition rate is a few Hz (1.5 Hz ~ 6 Hz)
- Mechanics design shows some progress
- Readout electronics is in design

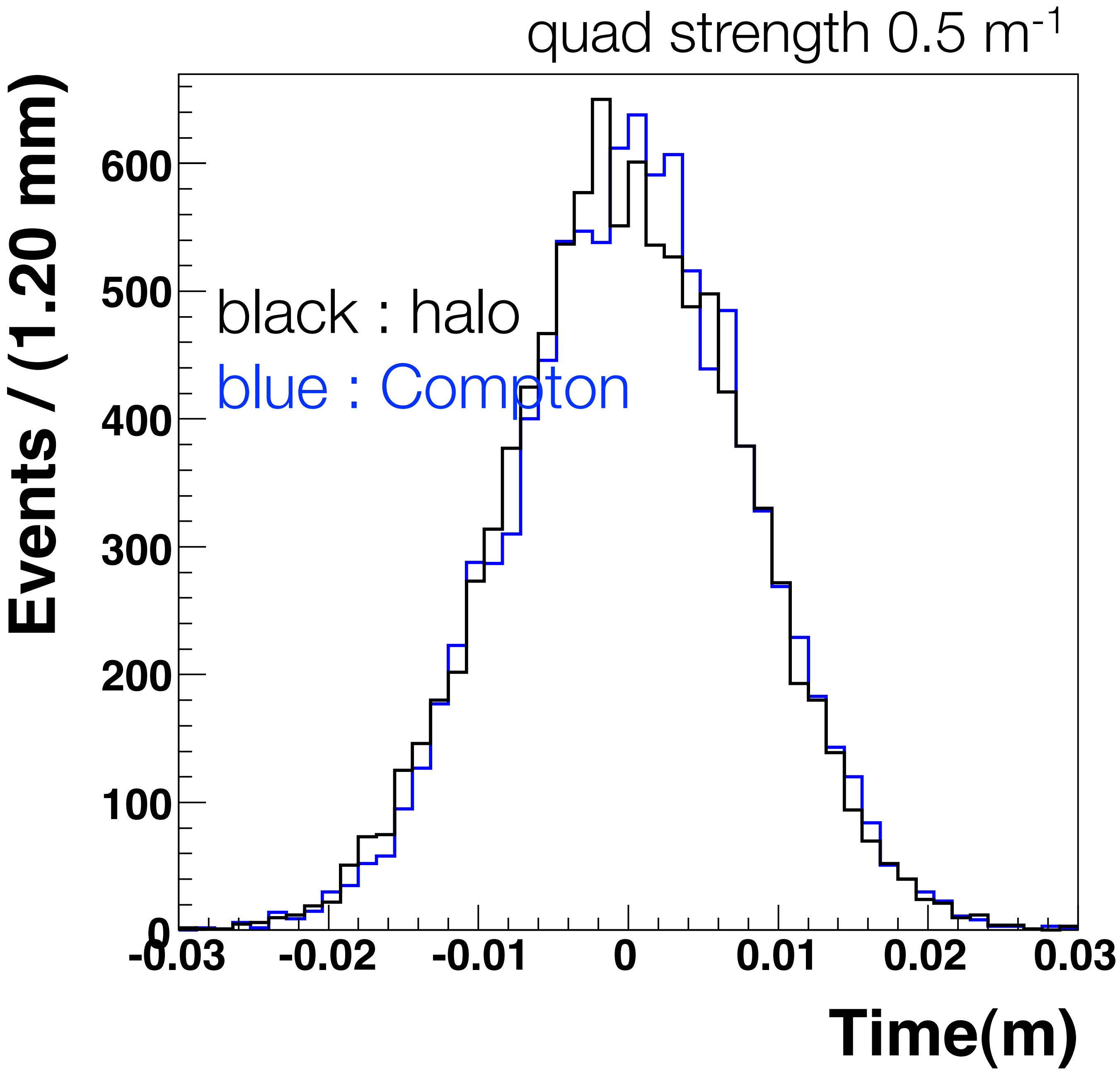
- Now we have a single pad diamond sensor from UK
- Understanding the signals from diamond sensor
- Prototype design: diamond sensor, electronics, mechanics
  - Lab. test at LAL
  - Detailed simulation
- Aim to first do beam tests in ATF diagonostic area : end of 2012



$4.6 \times 4.6\ \mathrm{mm}^2$ single crystalline diamond pad

Backup Slides

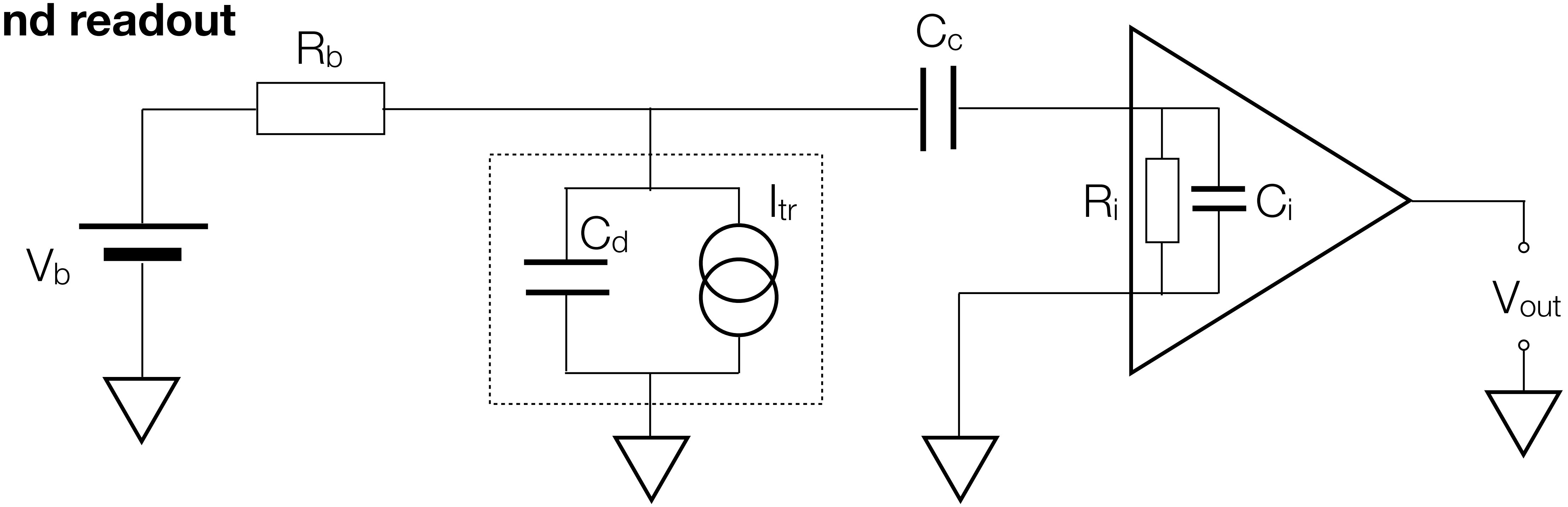
Results of MAD simulation : Time



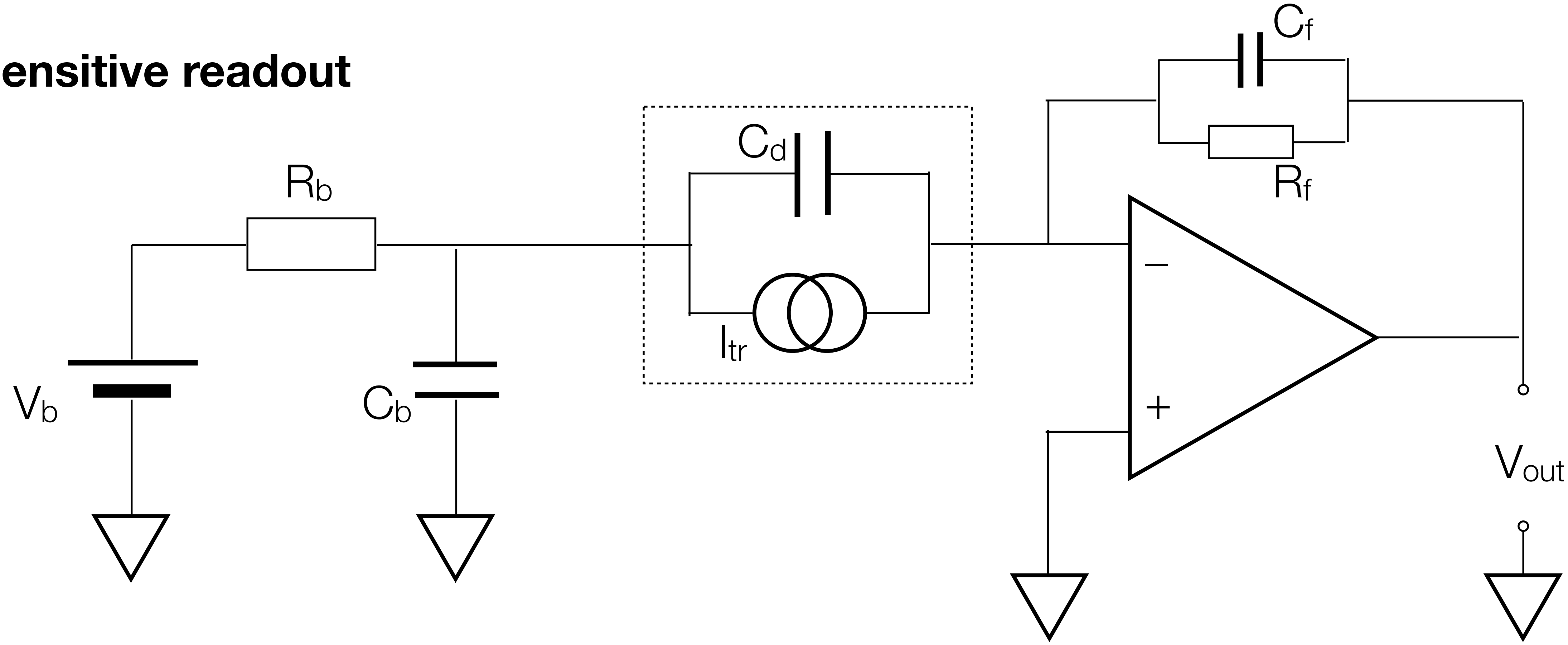
- The distributions are fitted by Gaussian function
- Halo
  - mean : -1.55×10^{-4} m
  - sigma: 8.02×10^{-3} m
- Compton
  - mean : 2.97×10^{-4} m
  - sigma: 7.92×10^{-3} m
- The sigma value is about 8 mm, which is consistent with a bunch length

Schematics of the most used connection circuits for charged particle detection

(a) broadband readout

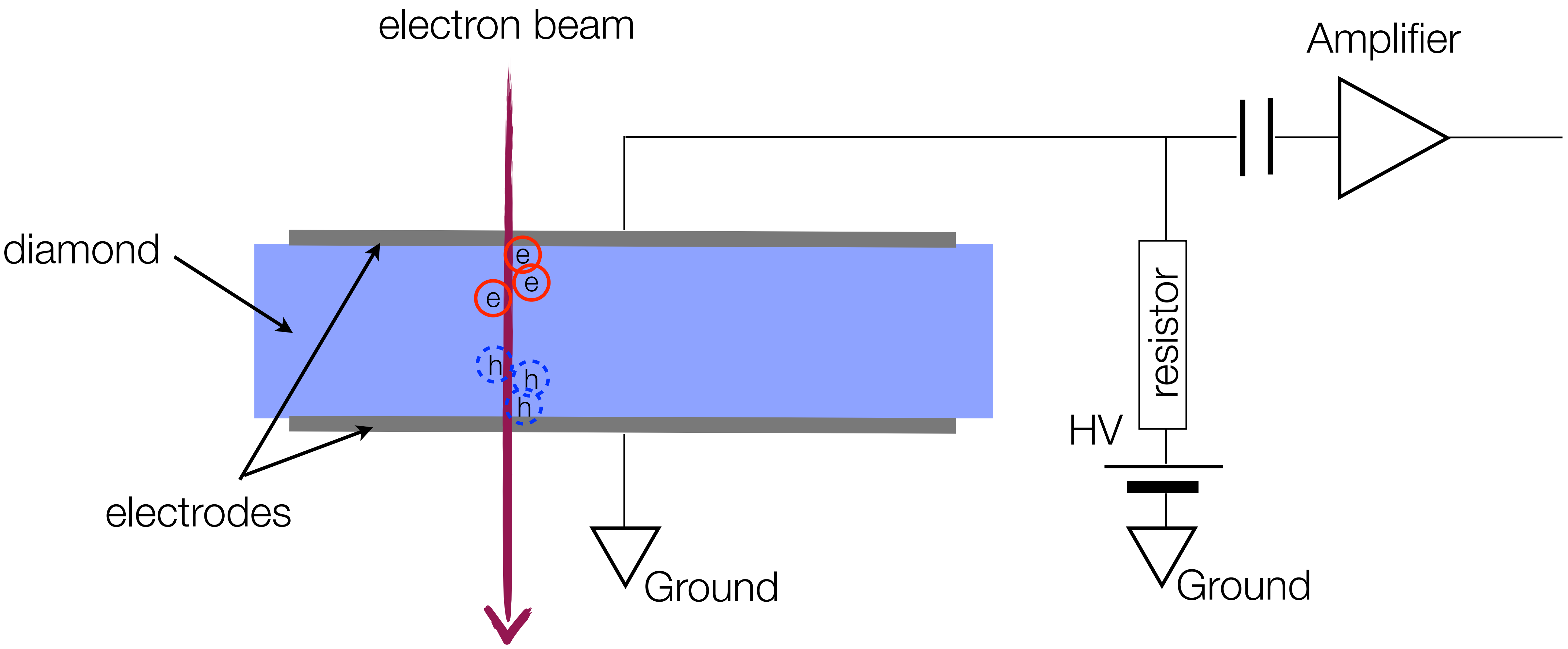


(b) charge-sensitive readout



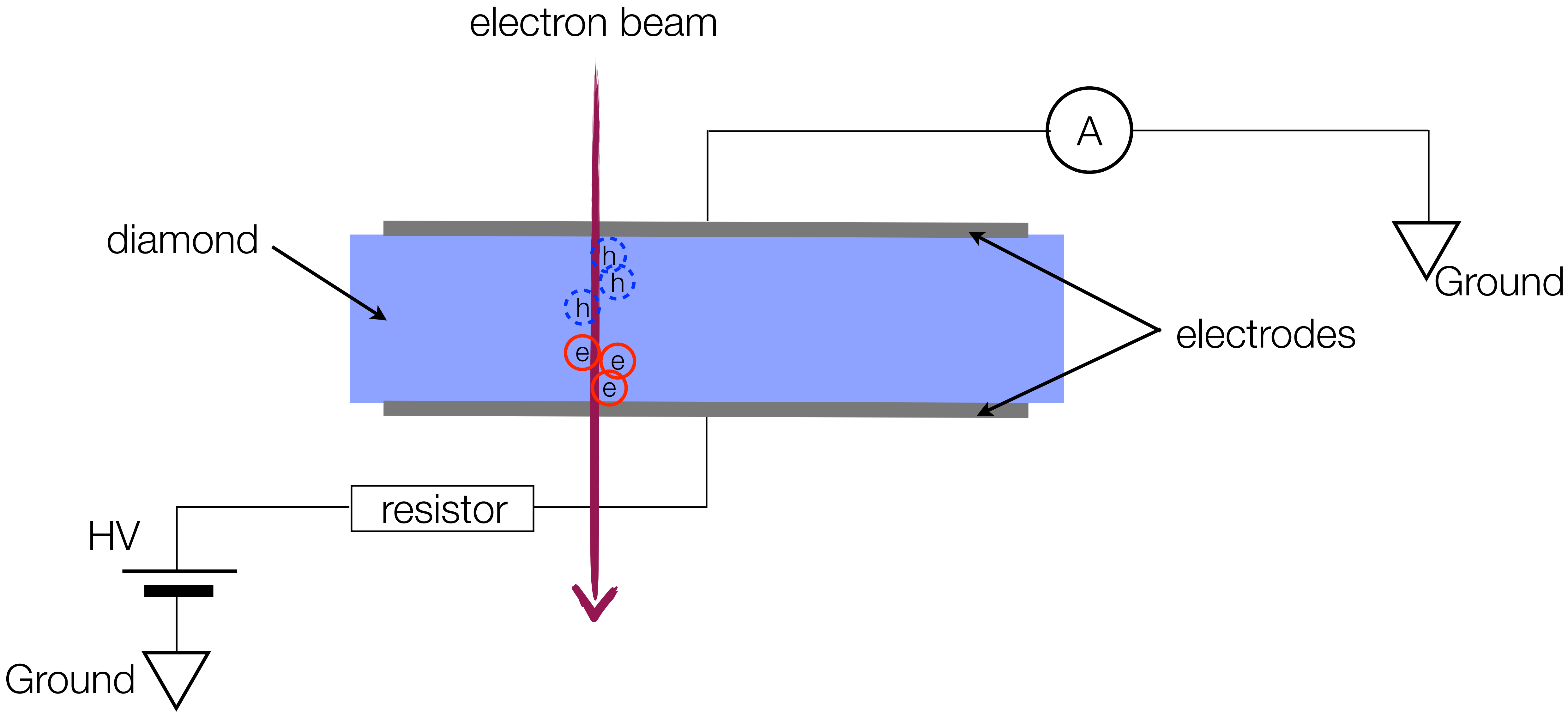
Diamond sensor : operational principle

(a) broadband readout



Diamond sensor : operational principle

(b) charge-sensitive readout



How many charge created when 1 MIP passing

- 500 µm thick and CCE ≥ 95% diamond
- 3600 × 5 × 0.95 = 17100 e-
- 17100 × 1.602 × 10^{-19} C
  = 27394 × 10^{-19} C
  = 2.74 fC

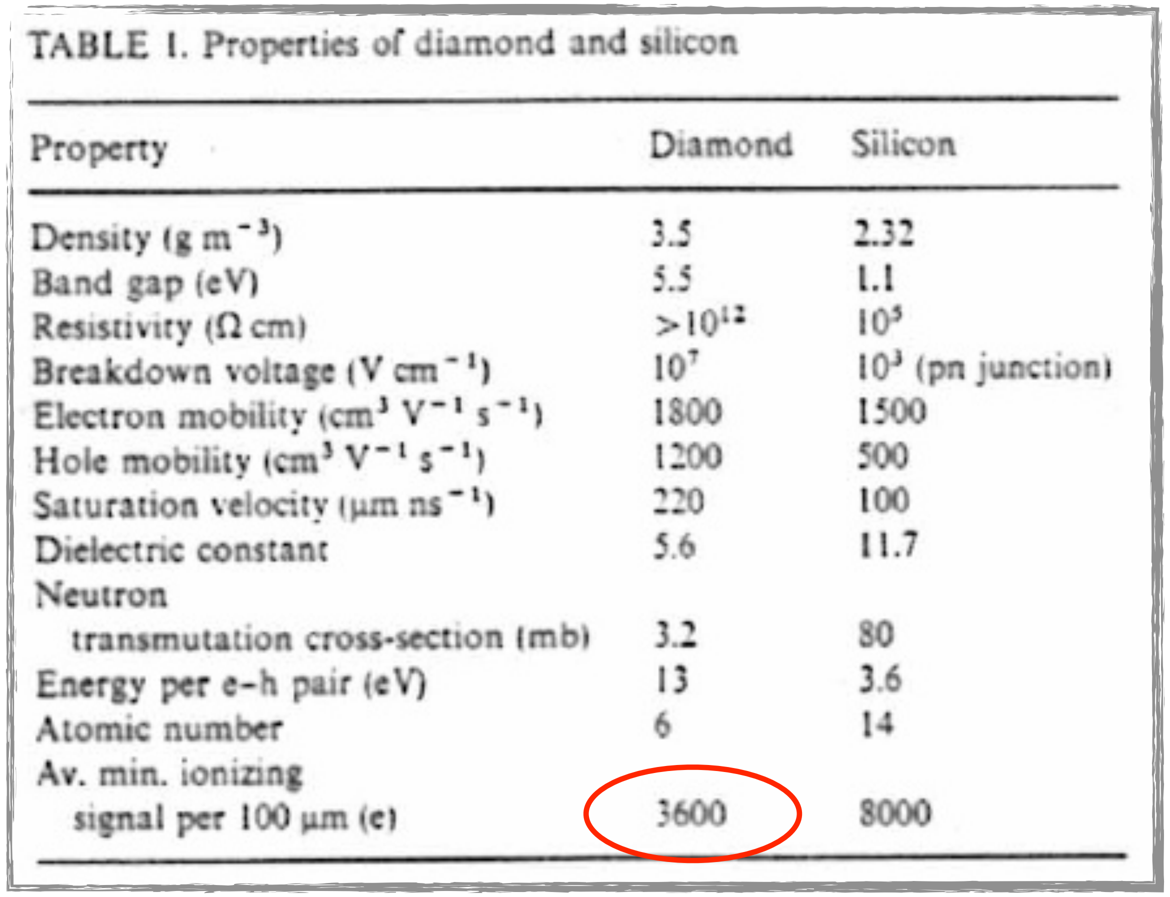


TABLE I. Properties of diamond and silicon

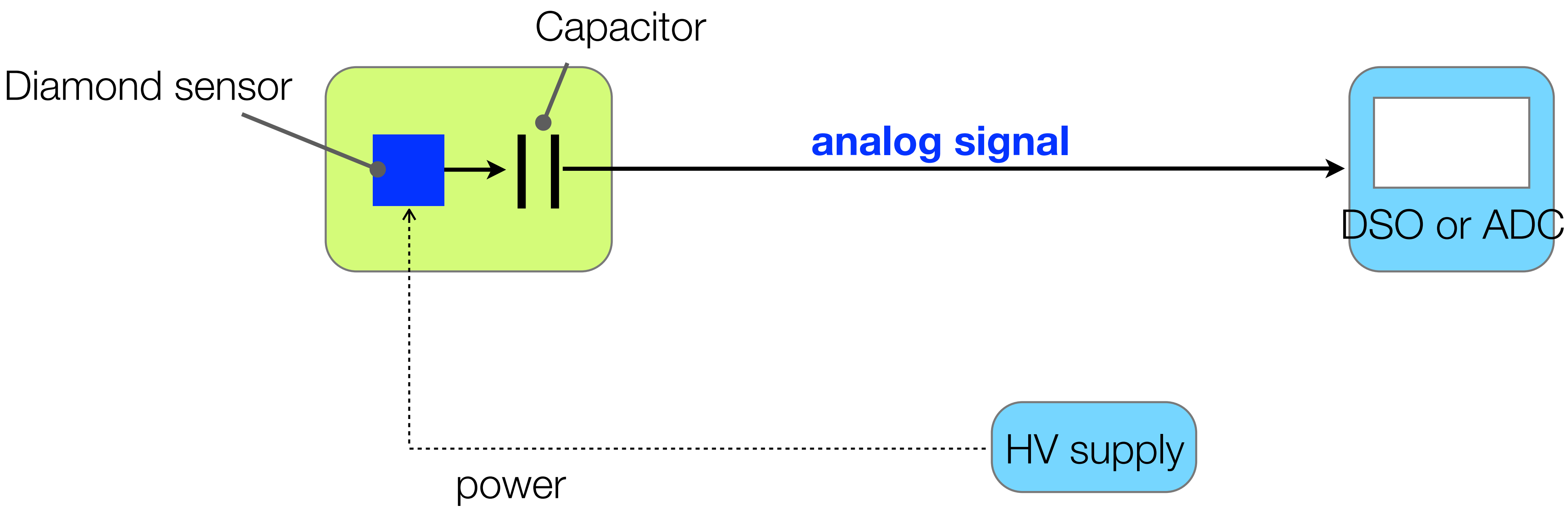
Property	Diamond	Silicon
Density ($g\ m^{-3}$)	3.5	2.32
Band gap (eV)	5.5	1.1
Resistivity (Ω cm)	$>10^{12}$	10^5
Breakdown voltage ($V\ cm^{-1}$)	10^7	10^3 (pn junction)
Electron mobility ($cm^3\ V^{-1}\ s^{-1}$)	1800	1500
Hole mobility ($cm^3\ V^{-1}\ s^{-1}$)	1200	500
Saturation velocity ($\mu m\ ns^{-1}$)	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

“Diamond radiation detectors”, D. R. Kania, et al., Diamond and Related Materials 2 (1993) 1012-1019

Design of diamond detector : signal readout

- Charge can be converted by capacitor or amplifier
- The readout electronics is placed far away from diamond sensor

case0



Capacitor

Diamond sensor

analog signal

DSO or ADC

HV supply

power

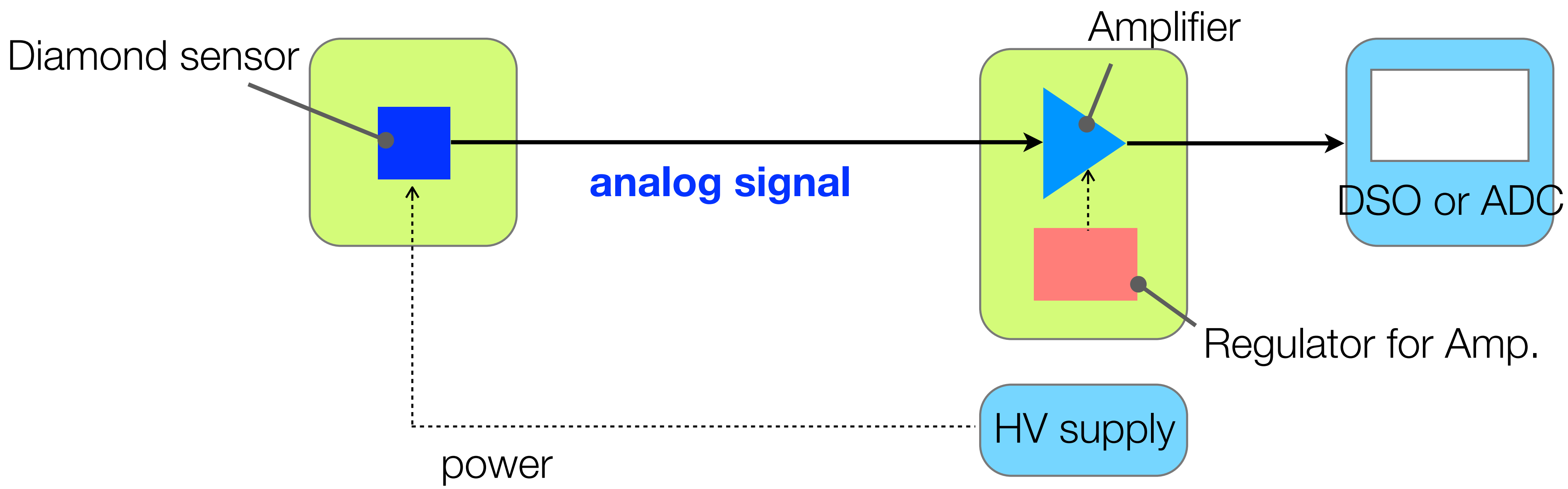
halo nC pF = kV nC nF = V

Compton pC pF = V pC nF = mV

When we use a big capacitor, time and noise are OK? And amplifier or shaper is needed?

Design of diamond detector : signal readout

case1



Diamond sensor

analog signal

Amplifier

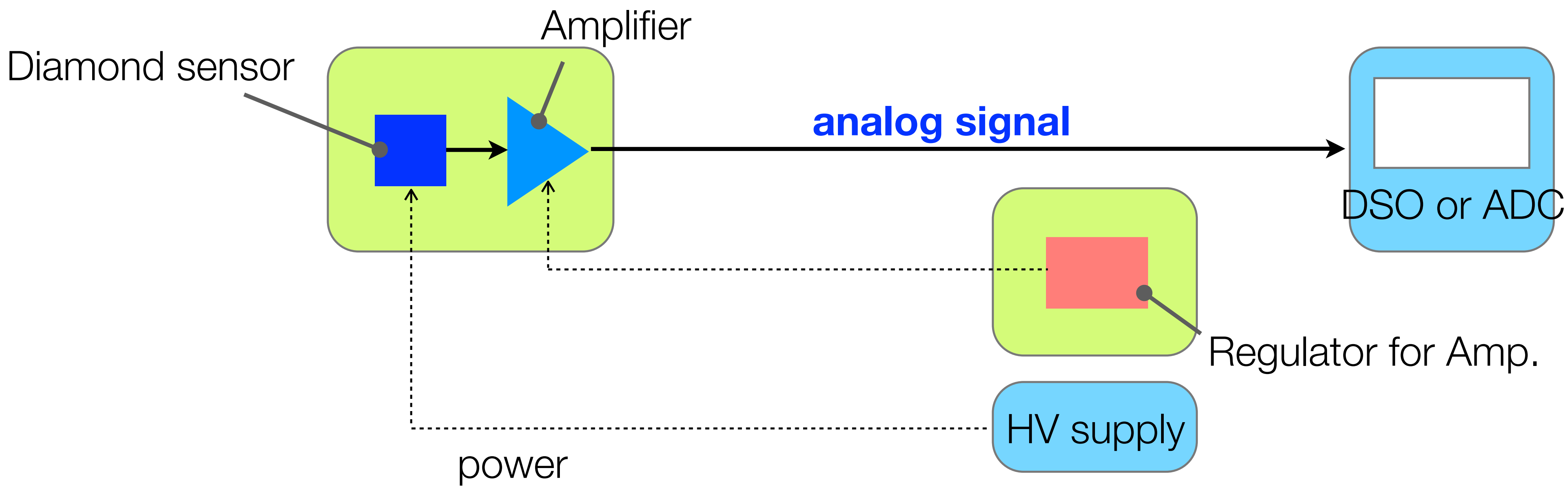
DSO or ADC

Regulator for Amp.

HV supply

power

case2



Diamond sensor

Amplifier

analog signal

DSO or ADC

Regulator for Amp.

HV supply

power