KILC12

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Joint ACFA Physics / Detector Workshop and GDE meeting on Linear Collider

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

April 24, 2012

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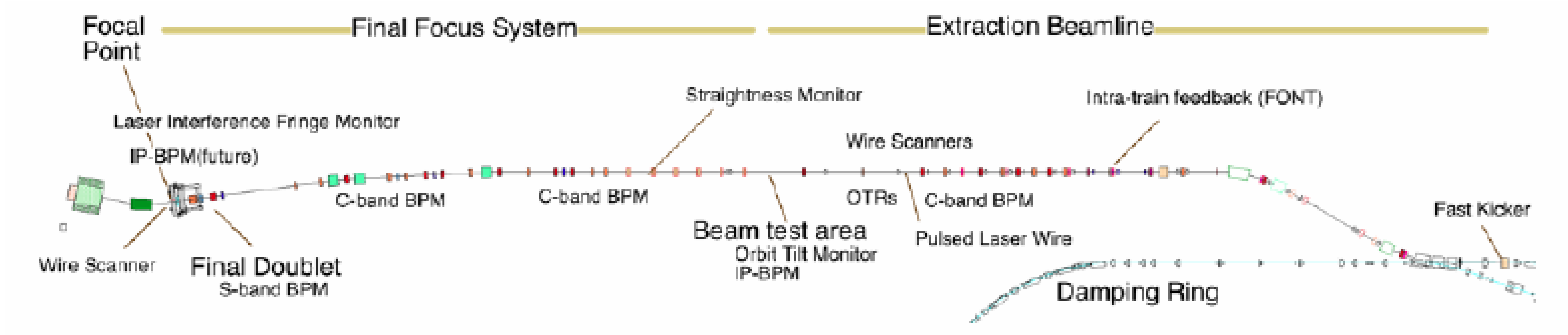
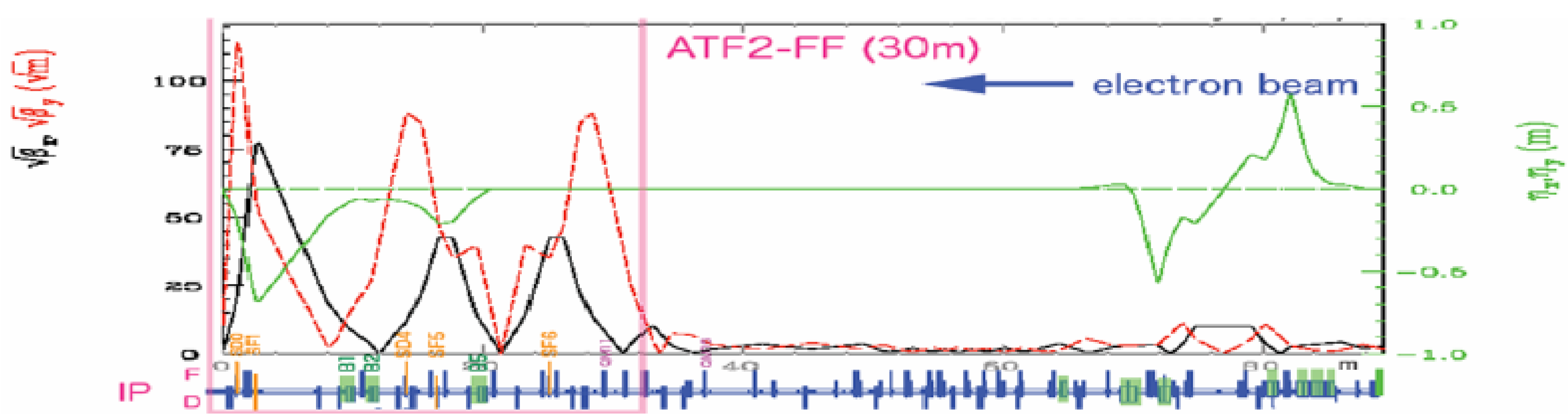
- Introduction of ATF2 and Shintake beam size monitor
- Measurement of beam halo and Compton recoil electron spectrum
- Introduction of diamond sensor
- Prototype design of diamond detector
- IV measurement of diamond sensor
- Summary and Plan

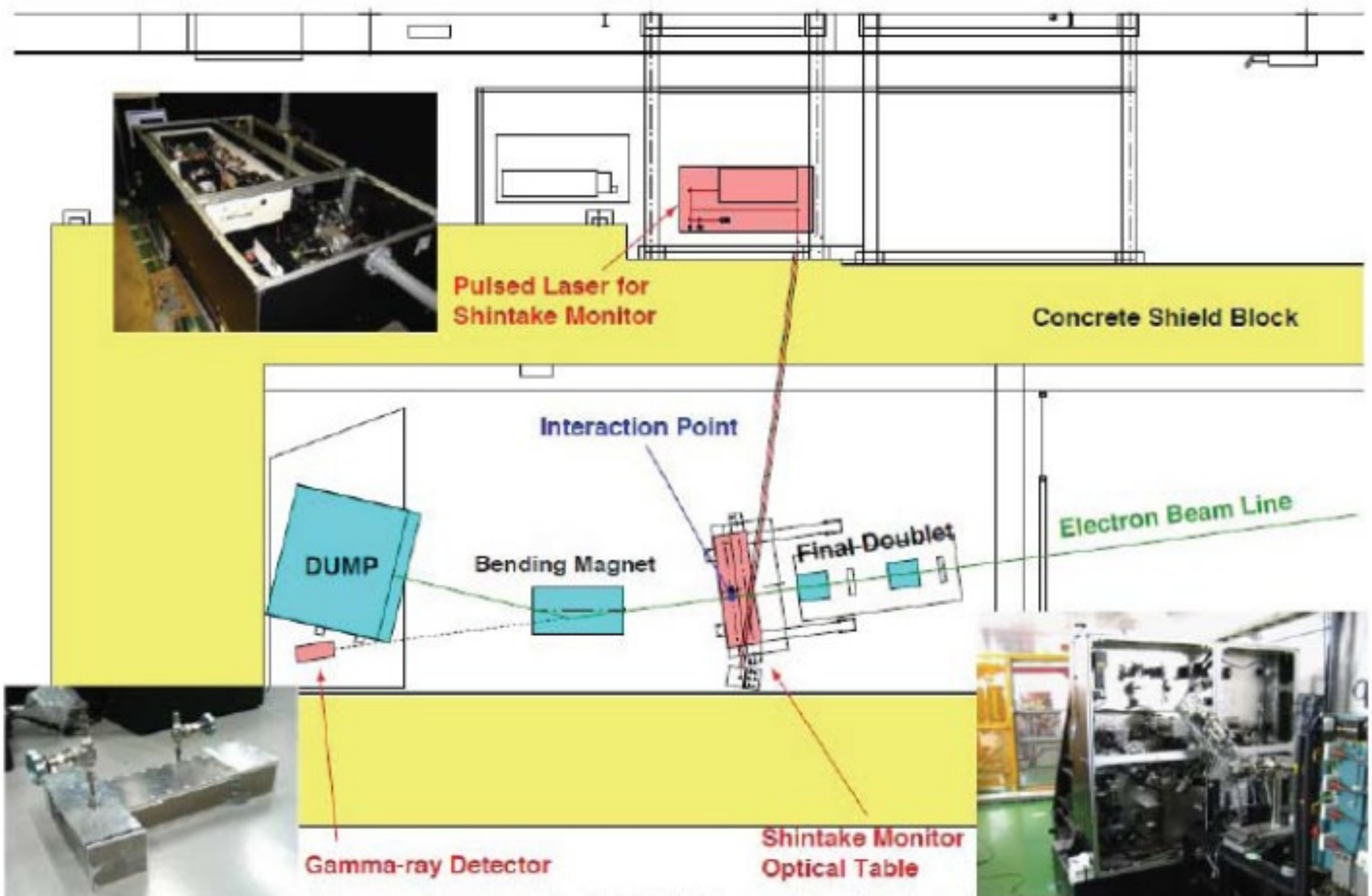
ATF2 operation & instrumentation R&D



2nd order telescope *fine tuning of local errors*	Match optics into FF *buffer section for input errors*	DR extraction *setup, stability*

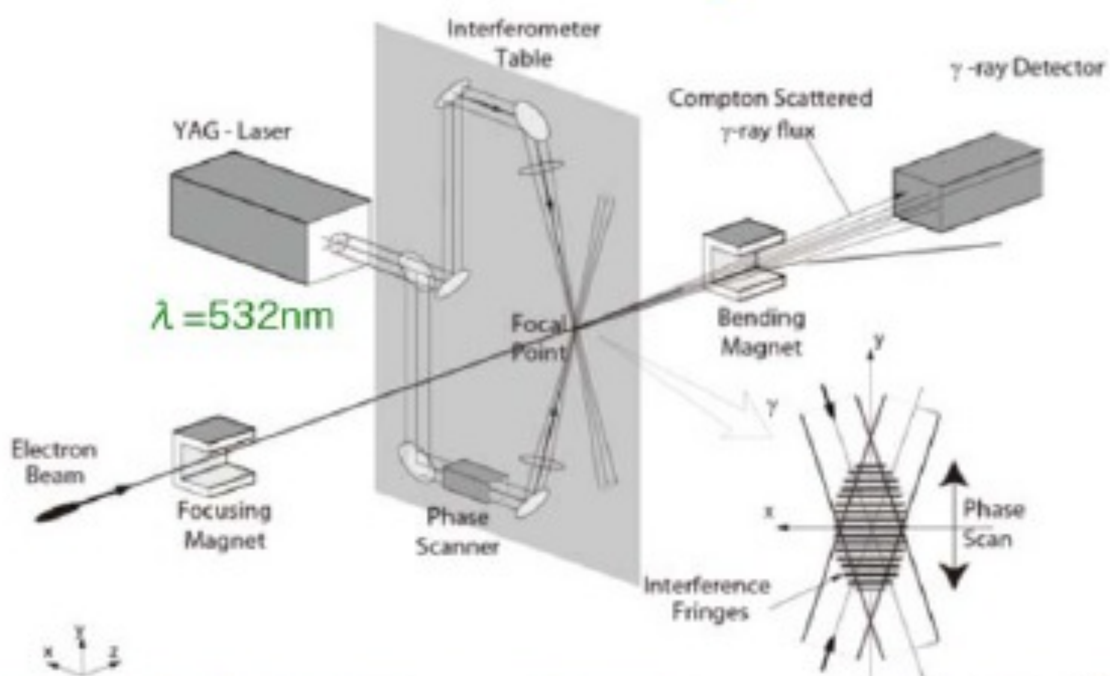


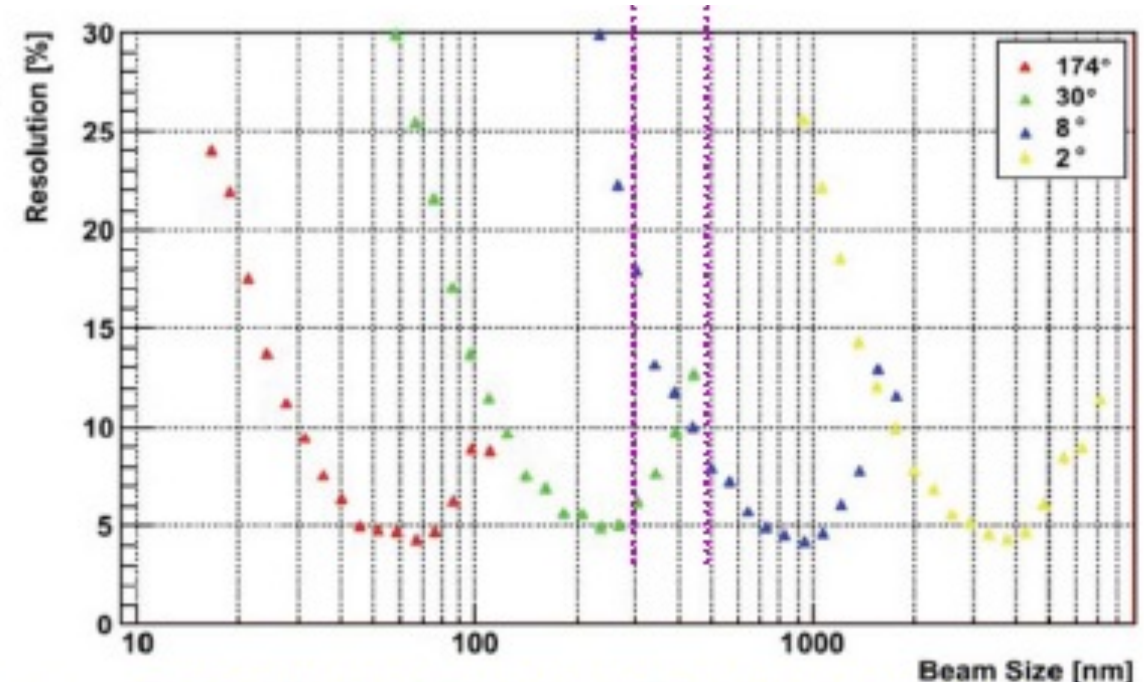
Shintake beam size monitor at IP



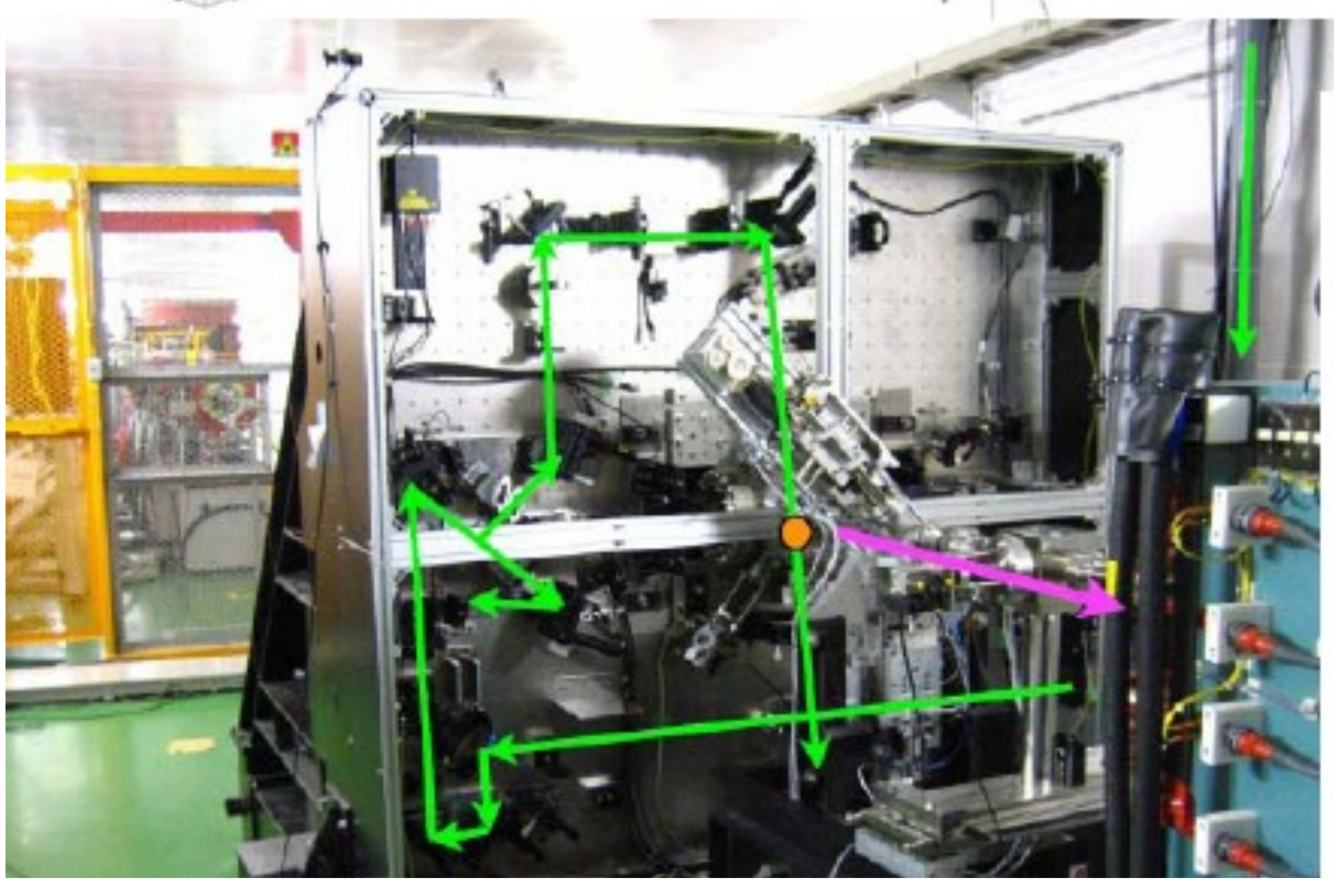
Layout around ATF2 Interaction Point

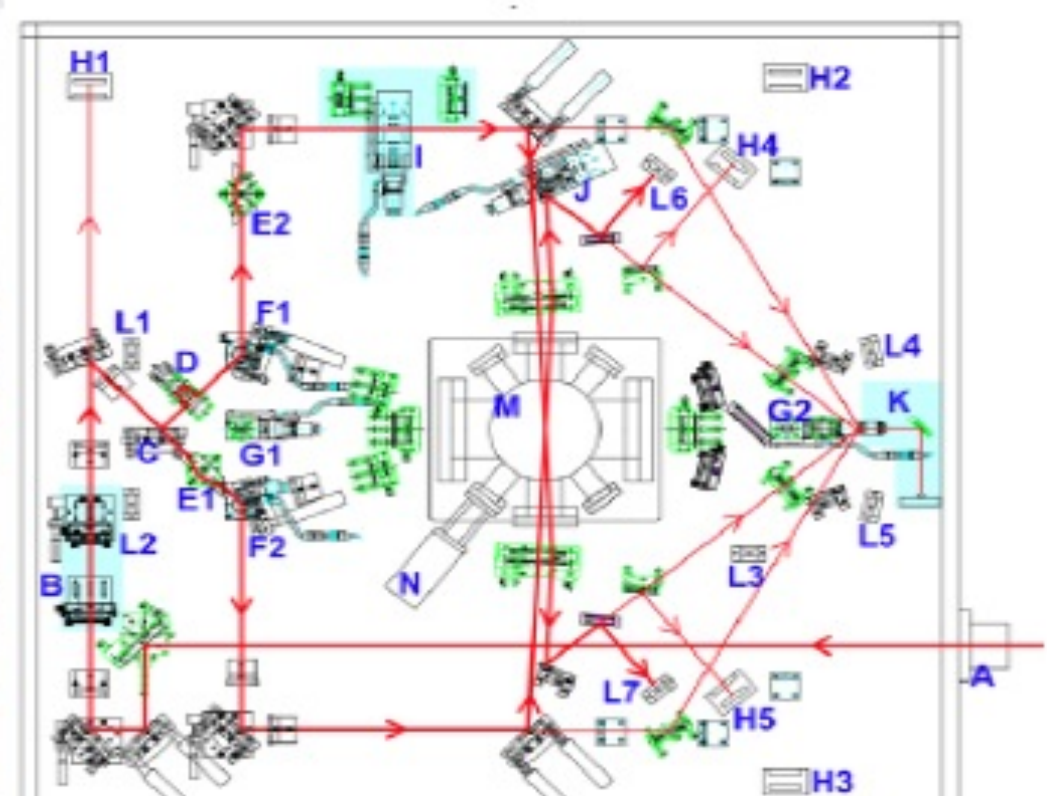
Shintake beam size monitor at IP





Sensitivity ranges of crossing angles



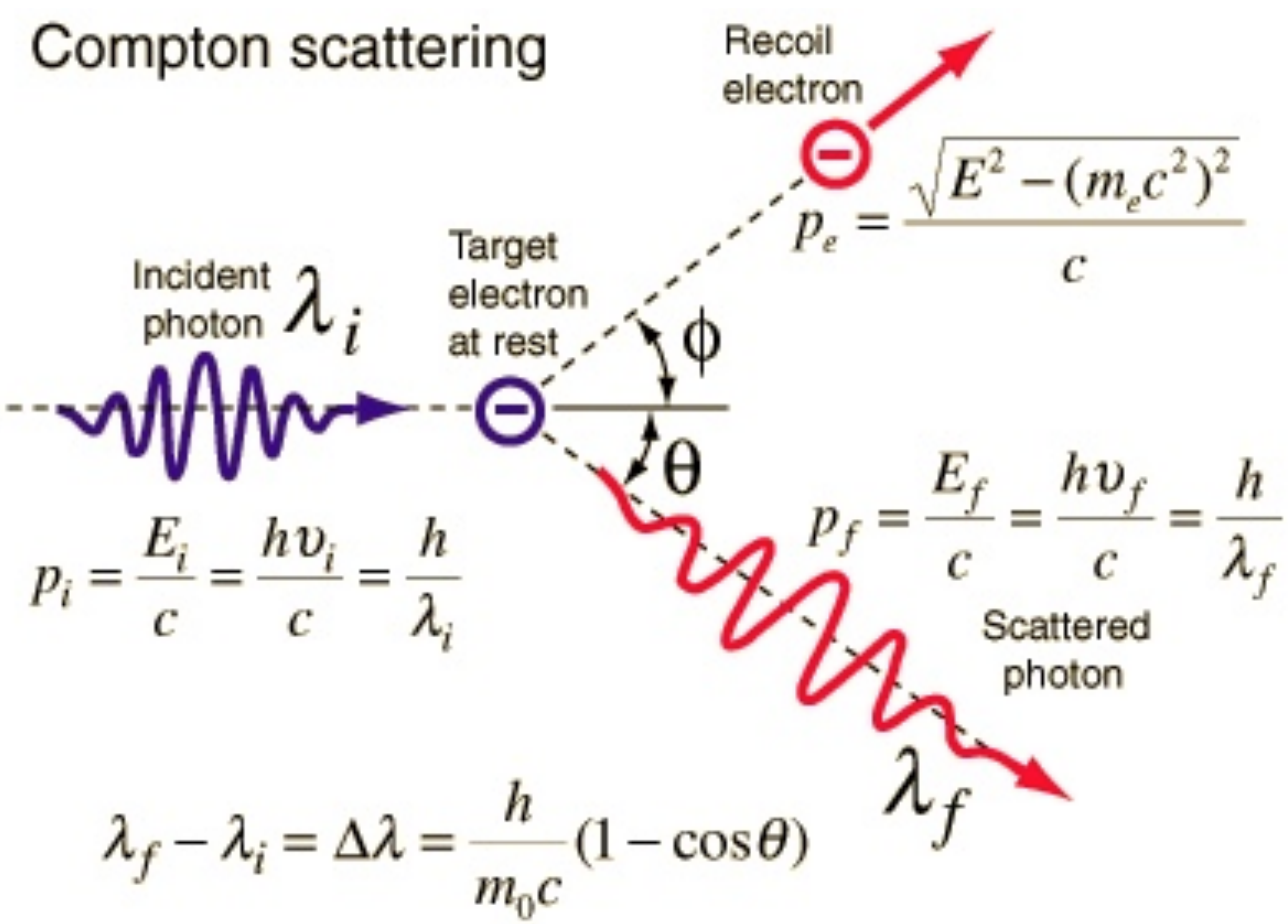


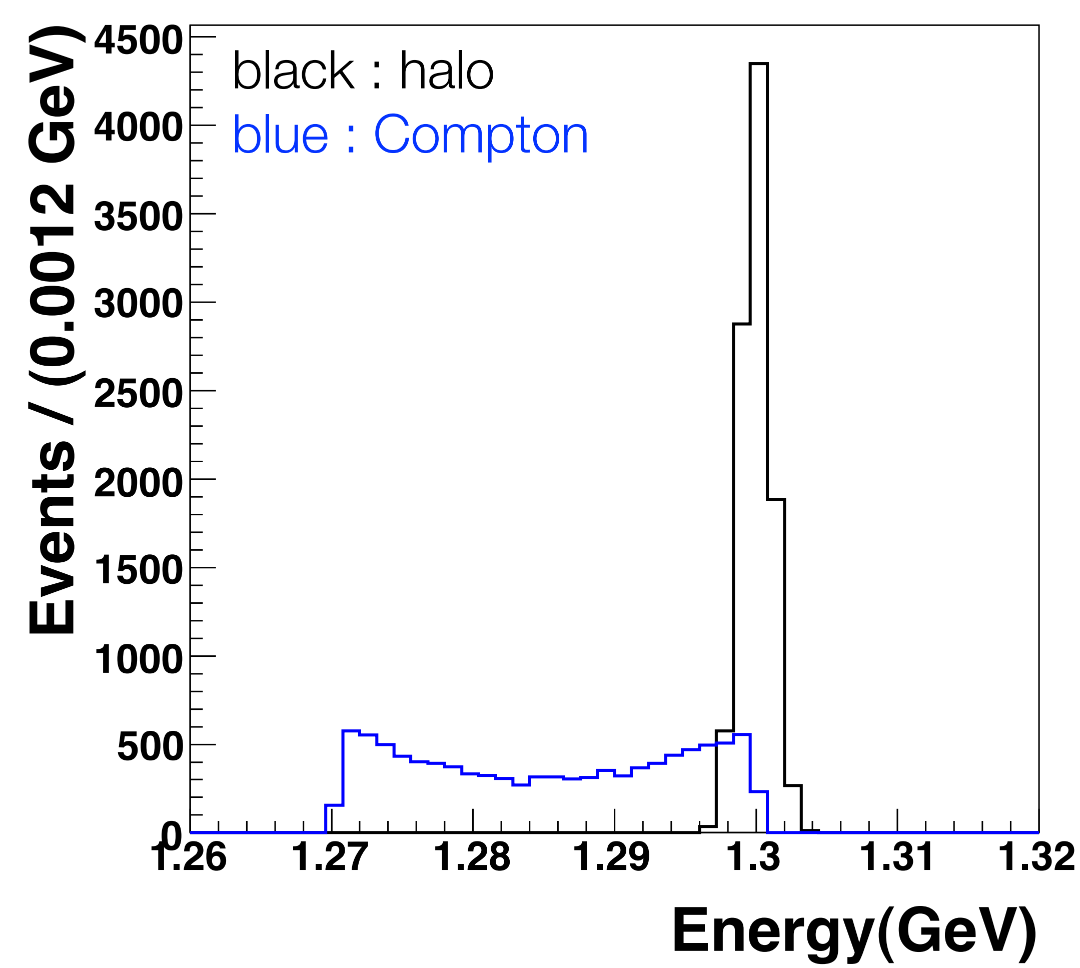
Measurement of beam halo and Compton recoil electron spectrum

- 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 recoil electron spectrum

- What is Compton recoil electron 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

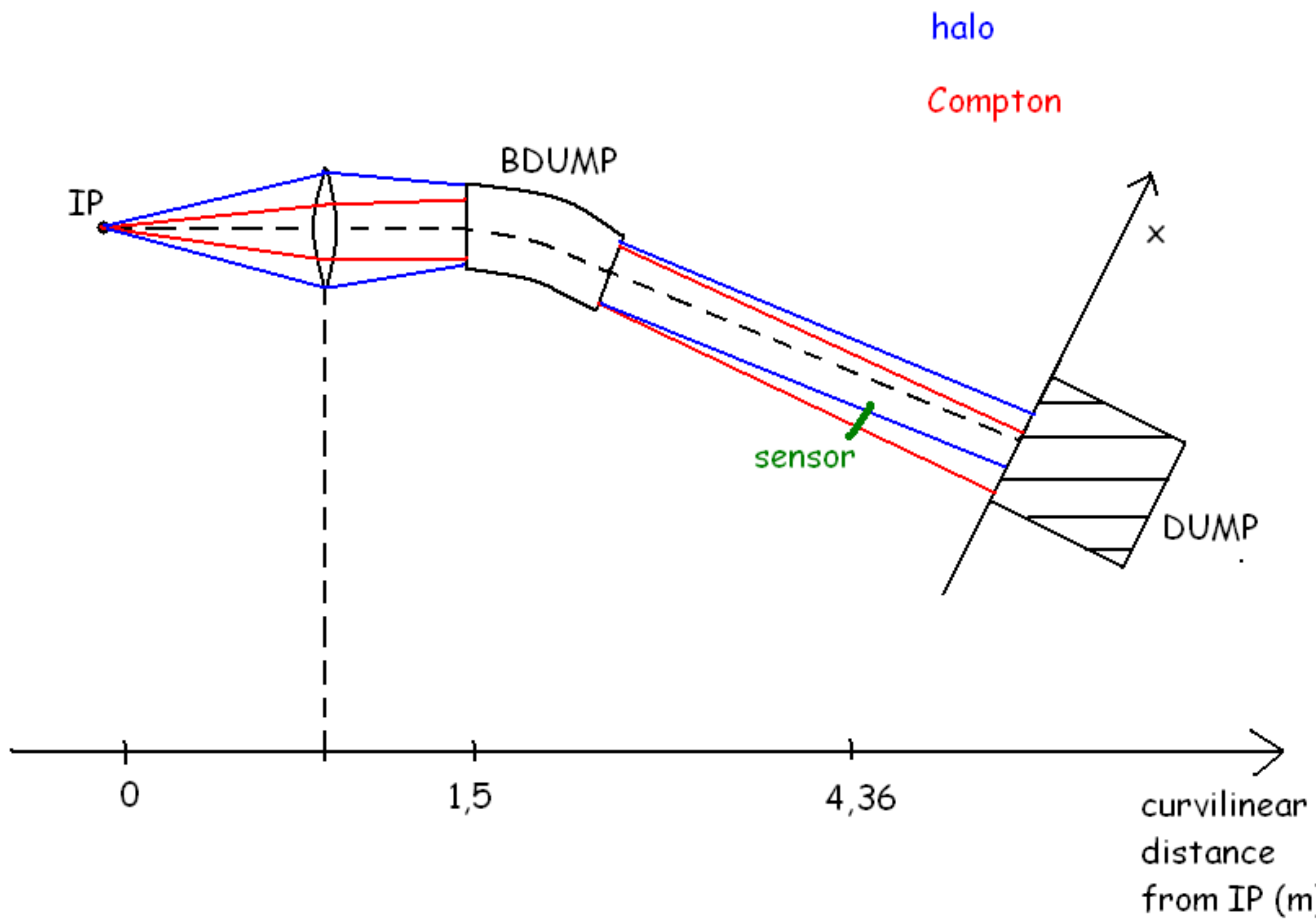




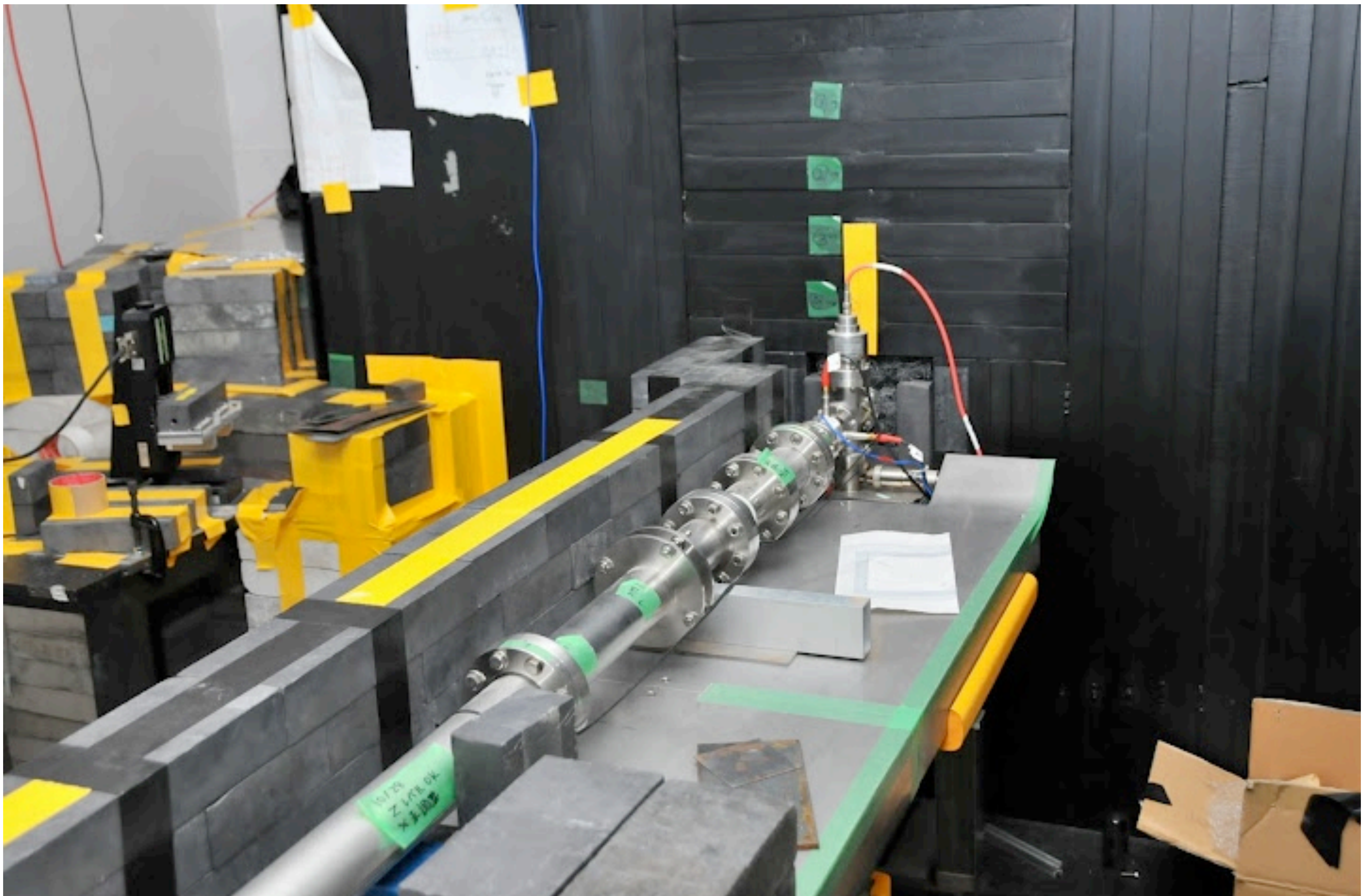
* The plot is one of MAD simulation results

Measurement of beam halo and Compton recoil electron spectrum

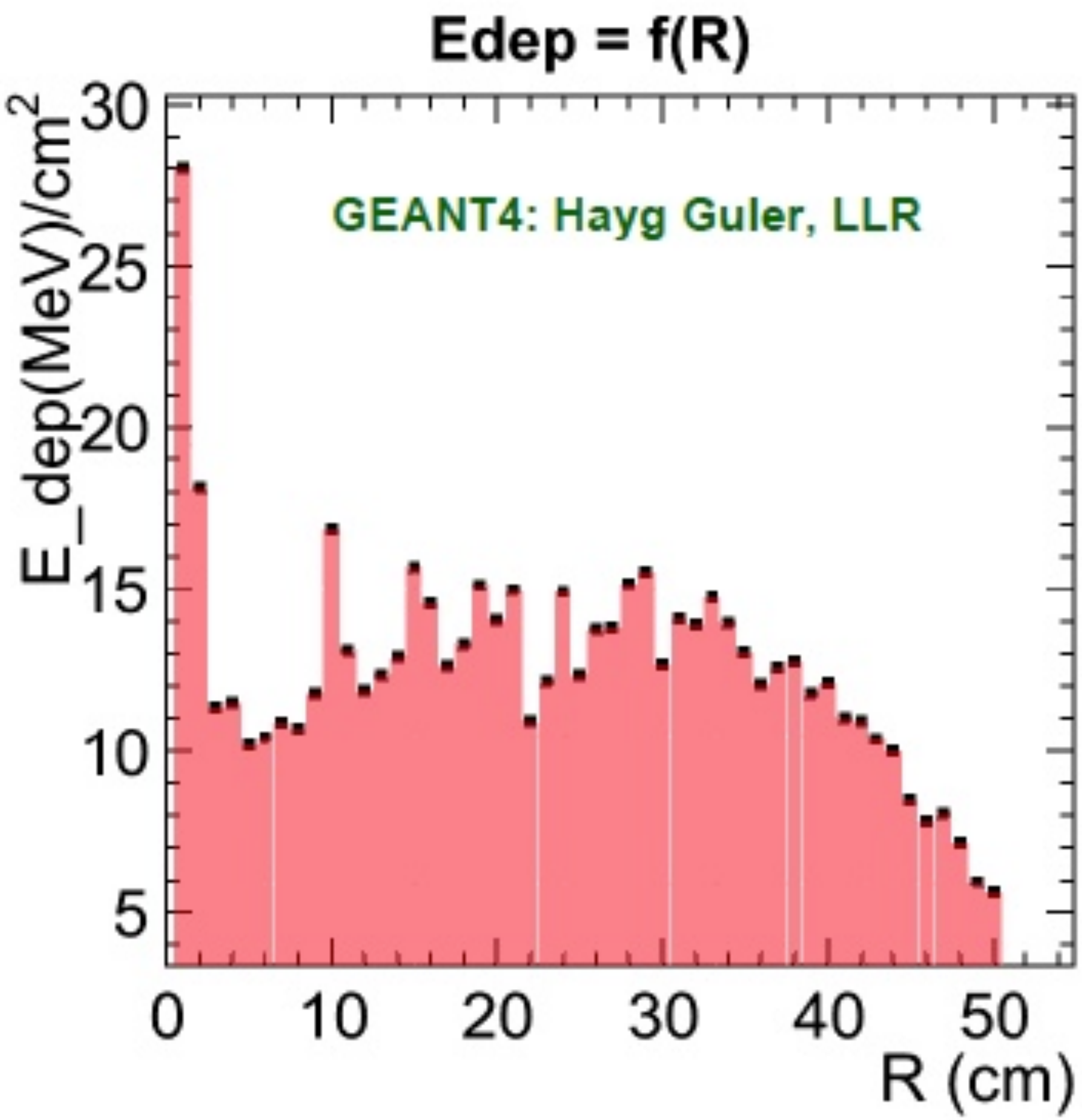
- Illustrative layout



Measurement of beam halo and Compton recoil electron spectrum



Measurement of beam halo and Compton recoil electron spectrum



Expected radiation dose near beam dump

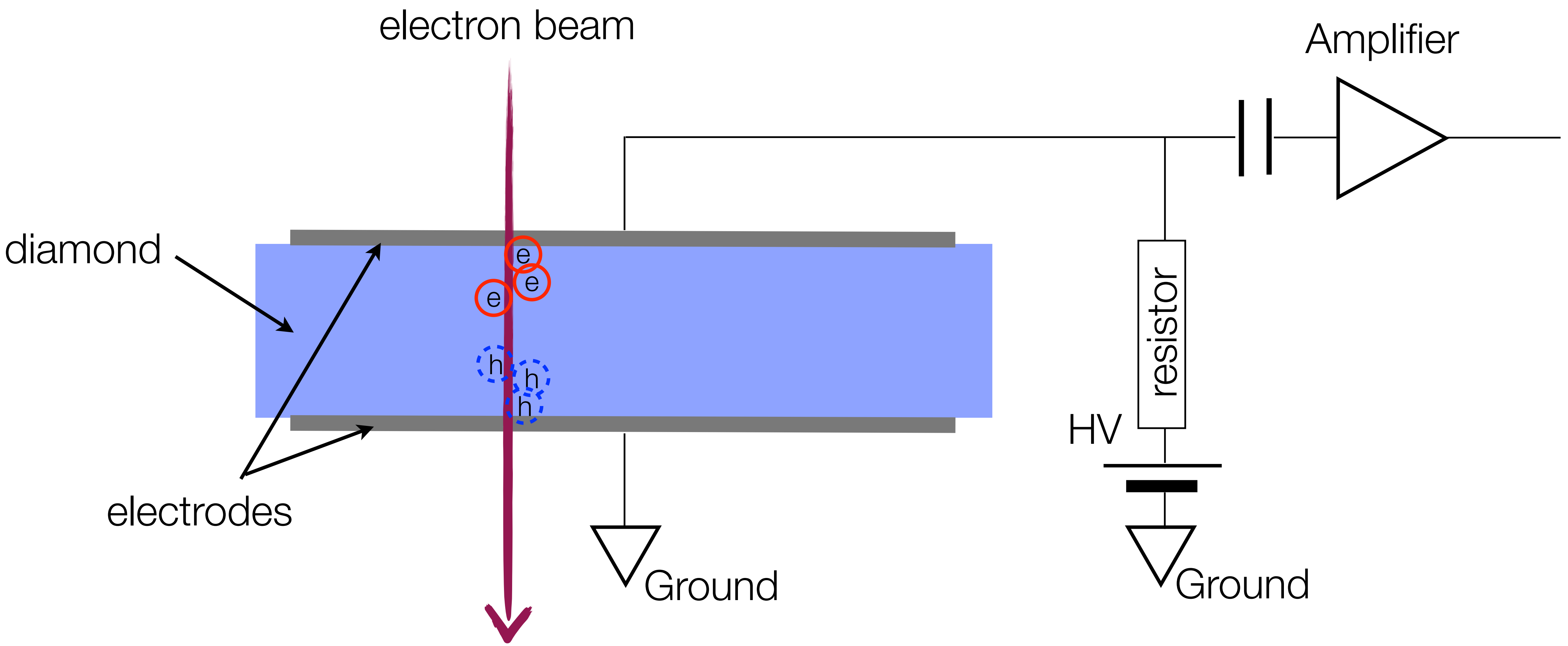
preliminary

- 500 µm thick Si sensor 2 m from dump
- For 10^{10} beam electrons incident on dump
  - deposition from neutron backscattering
    ➔ 0.25×10^{-4} Gy/pulse or 300 Gy/year
  - deposition from 107 halo electrons
    ➔ 0.3×10^{-2} Gy/pulse or 25 kGy/year
- Tolerance for CVD diamond > 1 MGy

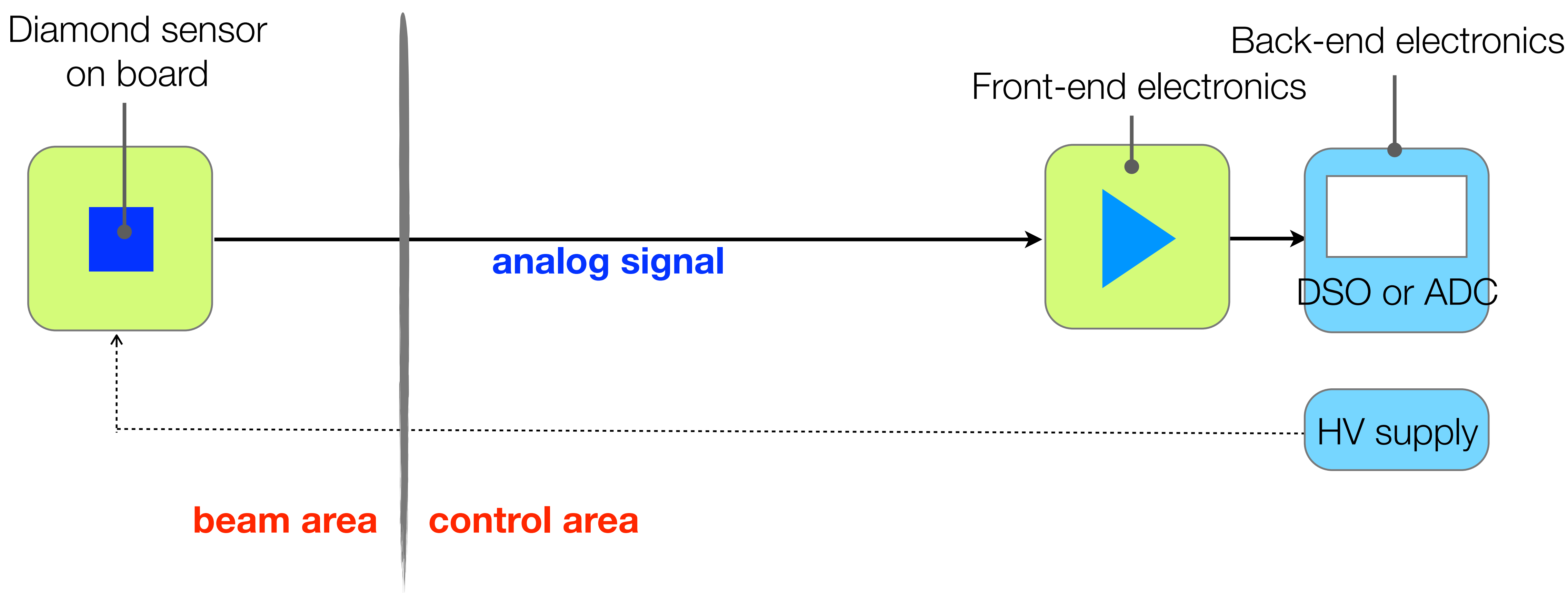
Characteristics of Diamond

Property	Silicon	Diamond	Advantage	Disadvantage
Atomic number	14	6	• close to the soft human tissue ➔ radiation dosimetry • minimize particle scattering and absorption ➔ tracking detector	small cross section for high energy X-rays or γ-rays ➔ poor detection efficiency
Density (gm^{-3})	2.32	3.5		
Band gap (eV)	1.1	5.5	• windowless operation • low noise at high temperature	
Resistivity (Ωcm)	10^{5}	$>10^{12}$	no needed reverse bias	
Electron mobility ($cm^3V^{-1}s^{-1}$)	1500	1800	fast signal collection	
Hole mobility ($cm^3V^{-1}s^{-1}$)	500	1200		
Saturation velocity ($\mu m\ ns^{-1}$)	100	220	high speed and high count rate operation ➔ can be a application on high event rate environment ➔ low pile-up	
Dielectric constant	11.7	5.6	small capacitance	
Neutron transmutation cross-section (mb)	80	3.2	radiation hardness	
Energy per e-h pair (eV)	3.6	13		small signal
Average minimum ionizing signal per 100 μm (e)	8000	3600		

Operational principle of Diamond

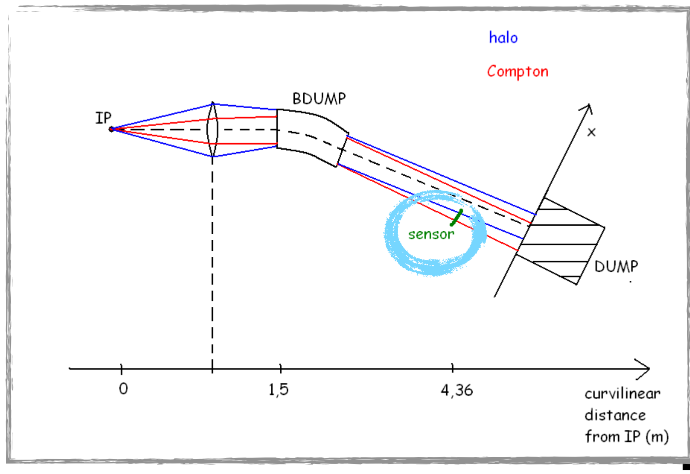


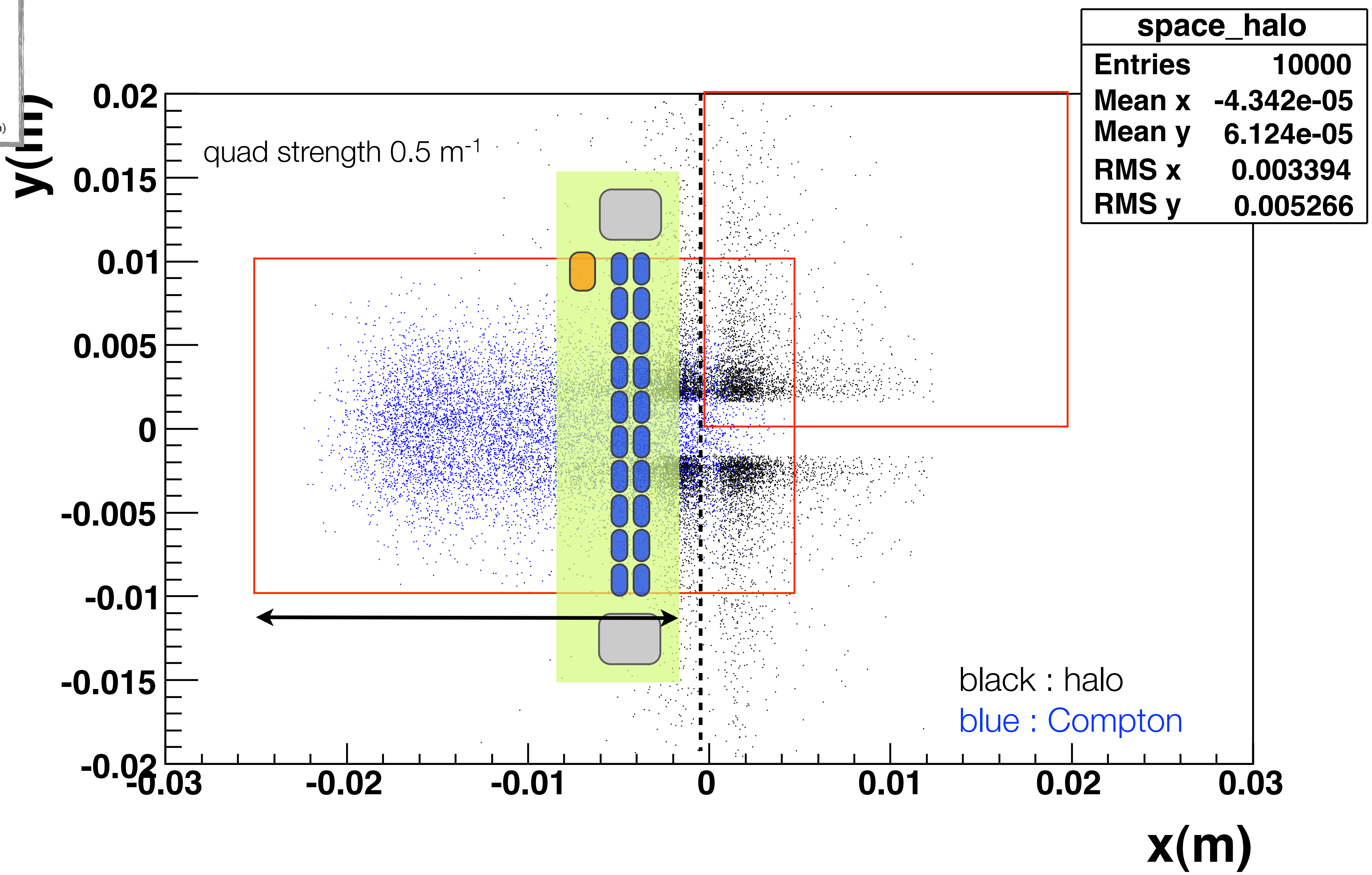
Prototype design of Diamond detector



- Diamond sensor consists only a few channel
- The post-IP region is scanned by the diamond sensor module
- The readout electronics is placed at control area (The distance between diamond sensor and electronics is about 50 m)
- PARISROC2 and DSO6104L are considered as front-end and back-end electronics, respectively

Prototype design of Diamond detector





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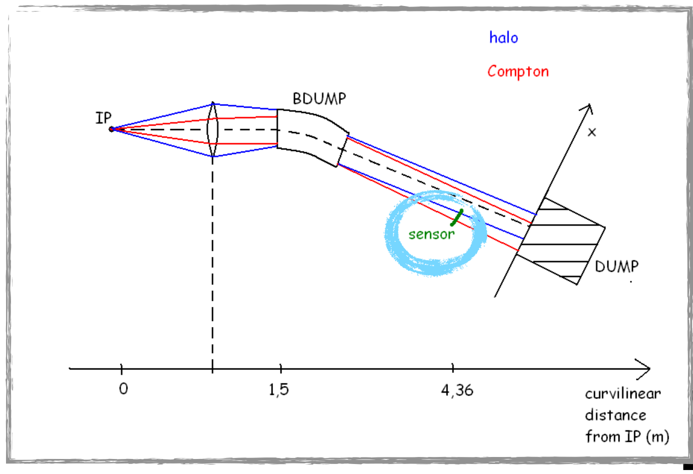
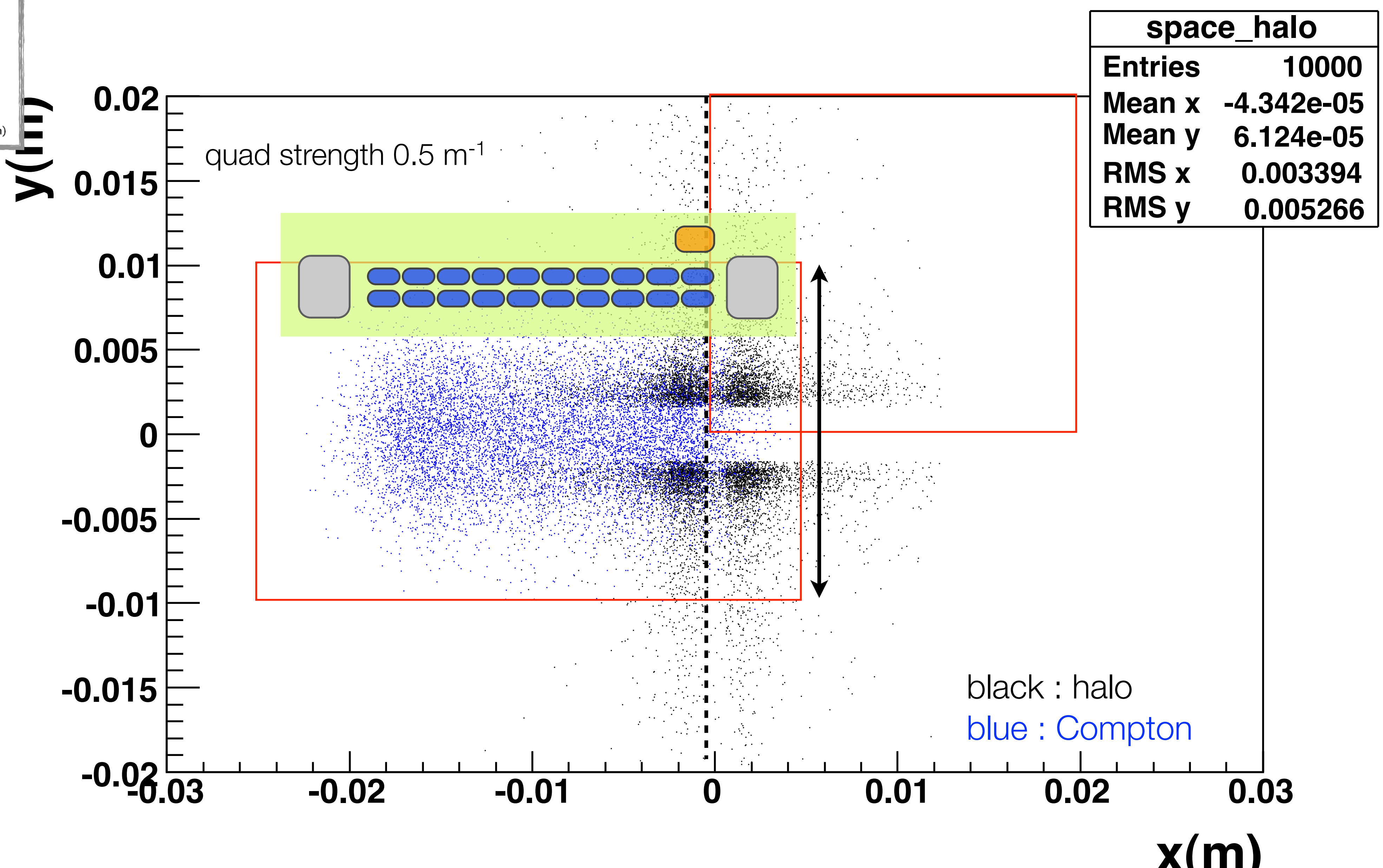
Prototype design of Diamond detector





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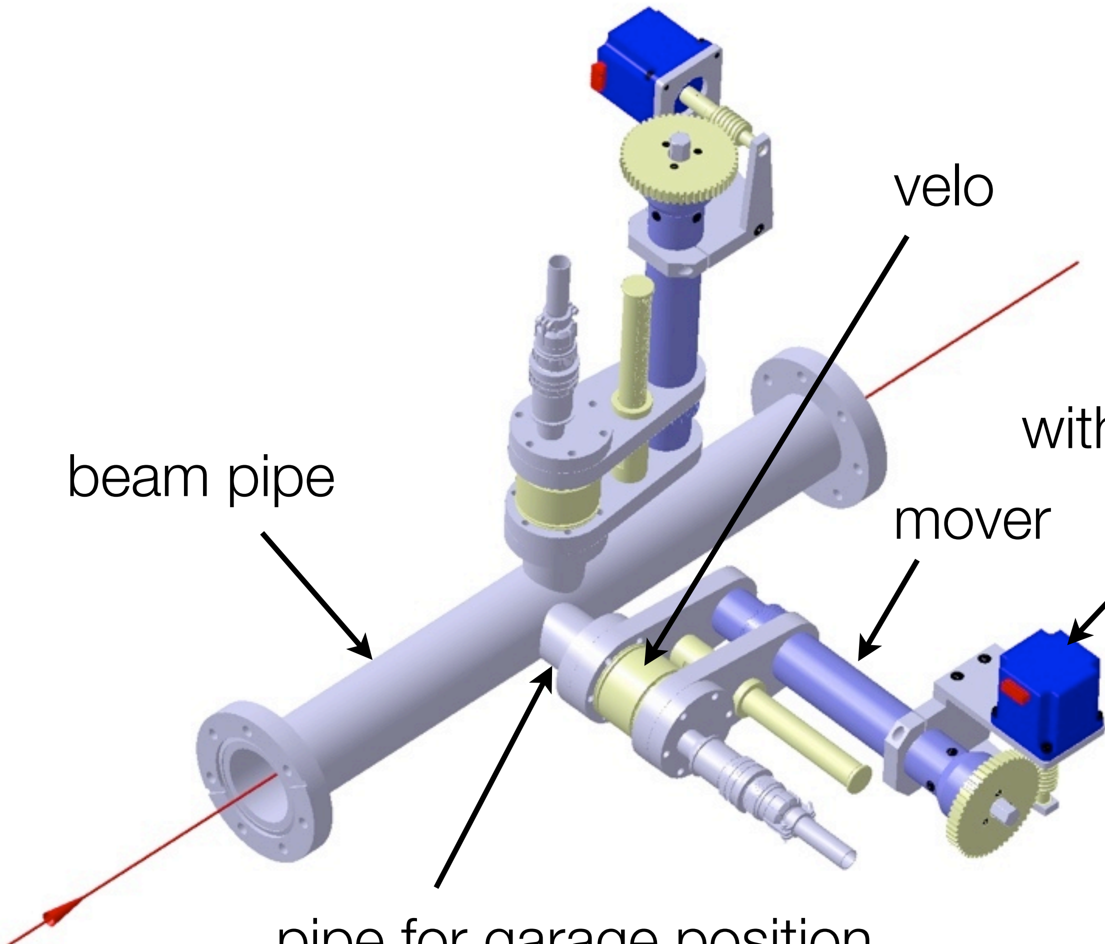
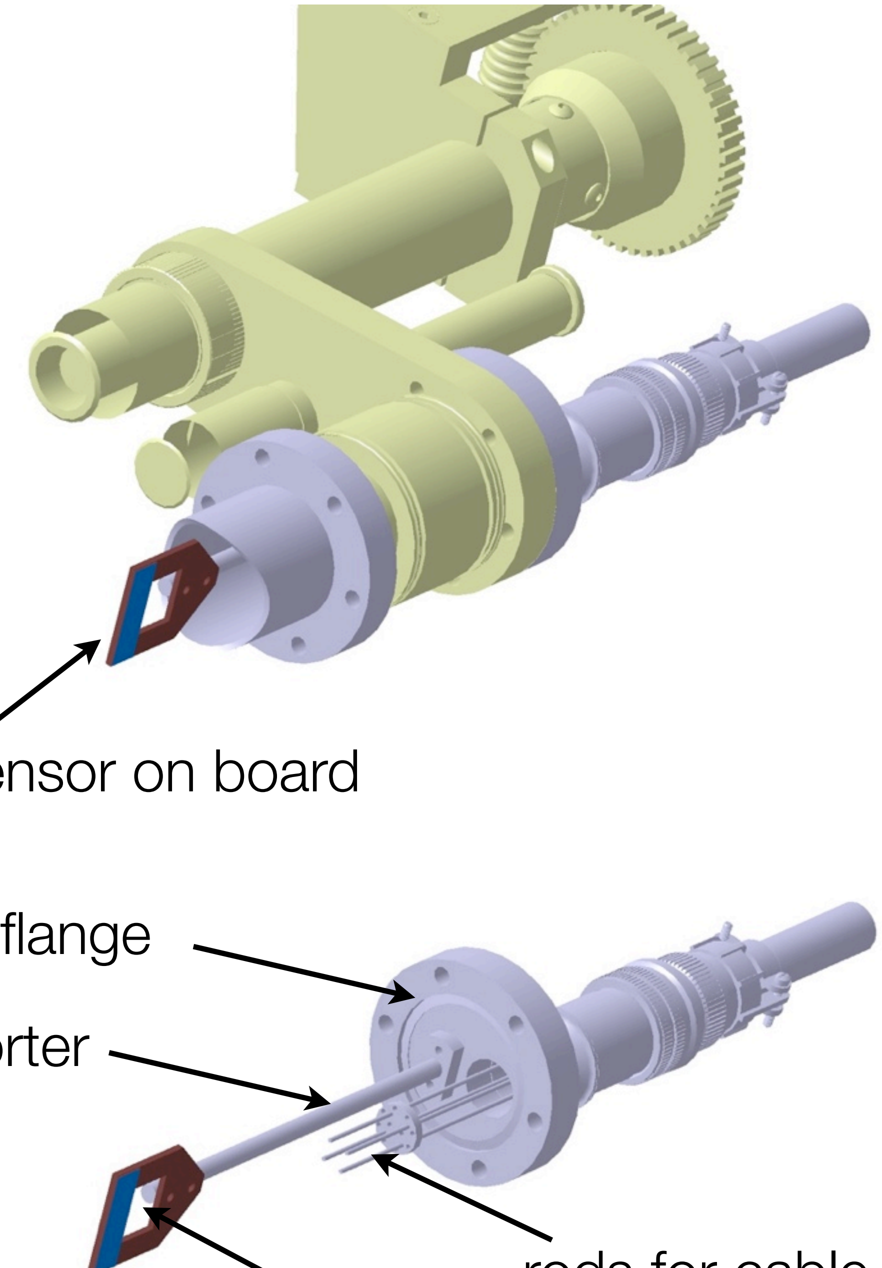
Prototype design of Diamond detector: Mechanics





Many thanks to M. Frederic Bogard

Prototype design of Diamond detector: Dynamic range

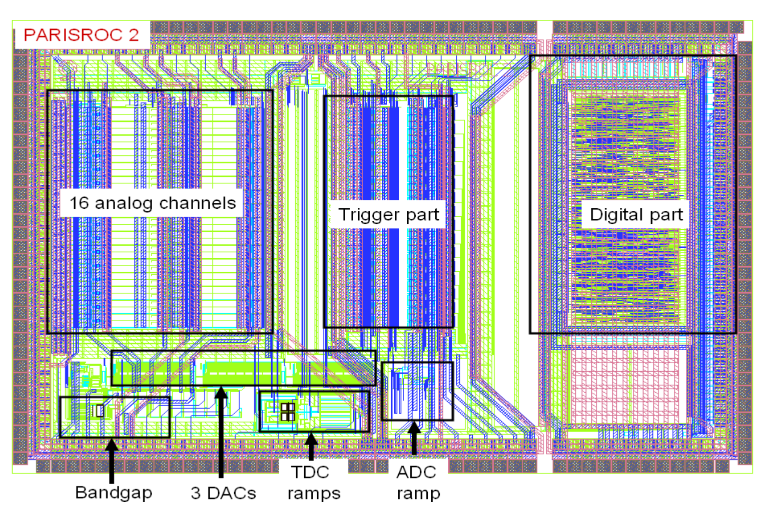
- The size of charge signal is calculated with number of events multiplied by charge of 1 MIP
  - 1 MIP corresponds for 2.74 fC (500 μm thick and CCE ≥ 95% diamond assumed)
- Very huge signal and too wide dynamic range
- But, repetition rate is a few Hz (1.5 Hz ~ 6 Hz)

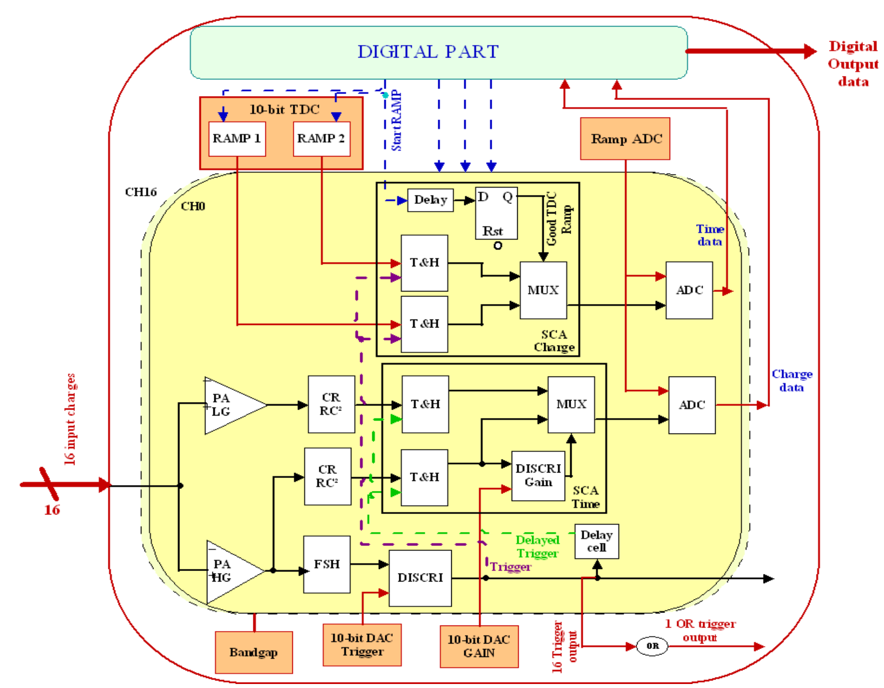
	Size of Diamond sensor	
	1×20 mm^2	2×20 mm^2
intrinsic spatial resolution*	0.29 mm	0.58 mm
charge signal of **halo**	**3 pC< charge < 365 pC**	3 pC < charge < 550 pC
charge signal of **Compton**	**8 fC< charge < 2 pC**	0.01 pC < charge < 5 pC

* pitch / $\sqrt{12}$, in here pitch is assumed to be a length of one side

Prototype design of Diamond detector: Front-end electronics

- 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: 50 fC 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





Prototype design of Diamond detector: Front-end electronics

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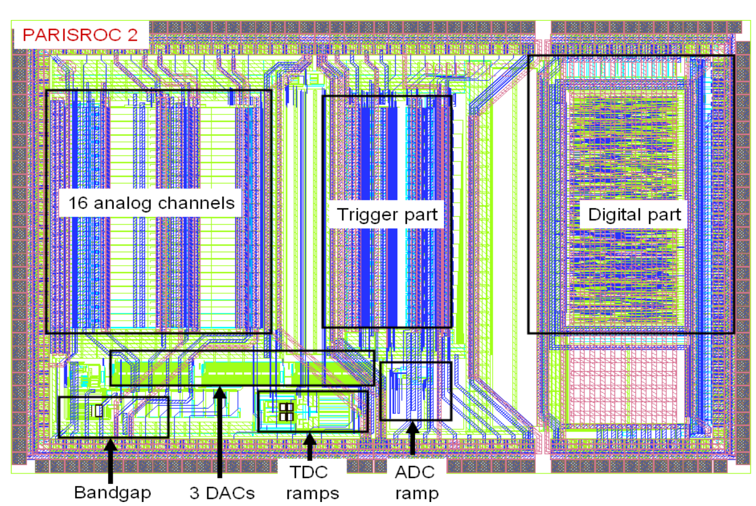
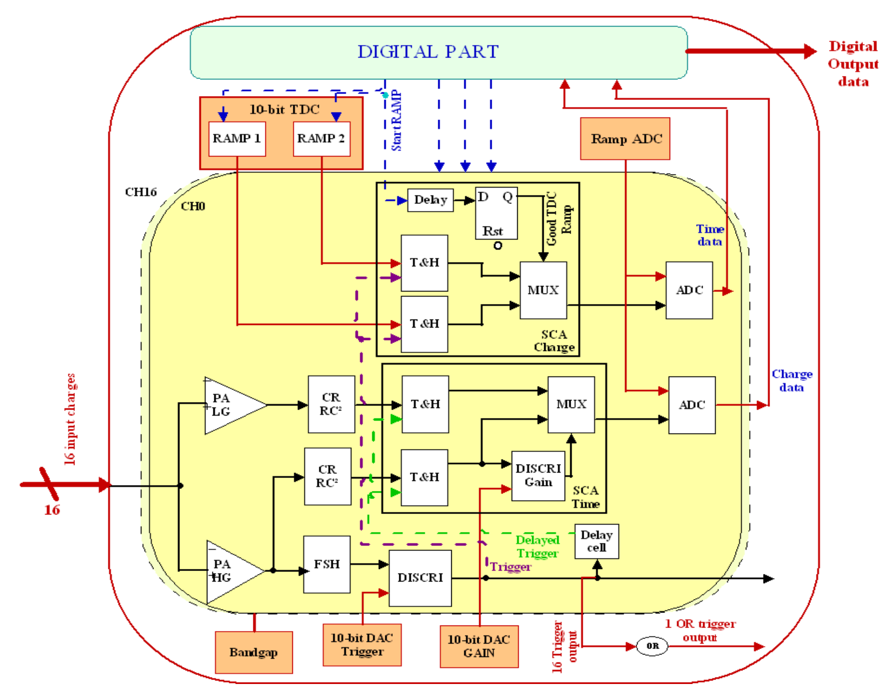
  - Photomultiplier Array Integrated in SiGe Read Out Chip
  - 16 independent channels and each channel has a variable gain ➔ cover the large input dynamic range
  - Charge dynamic range: 50 fC to 100 pC → can be expanded up to 500 pC
  - Shaper with variable shaping time (from 25 ns to 100 ns)
  - Self triggering and ADC integrated
  - Both charge and time data can be measured





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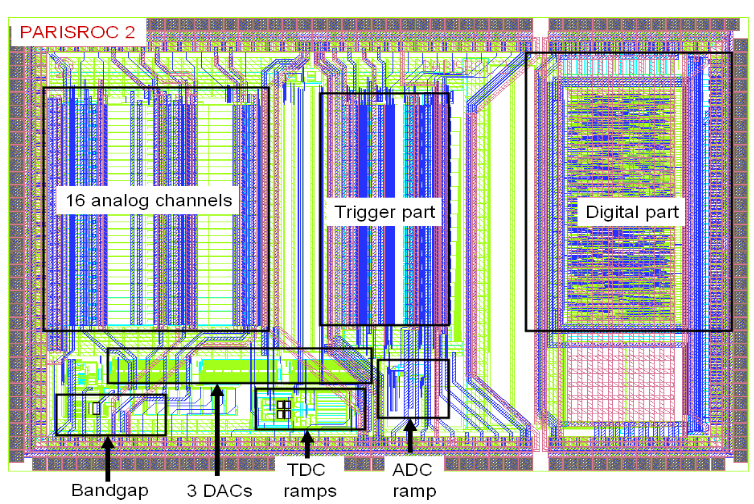
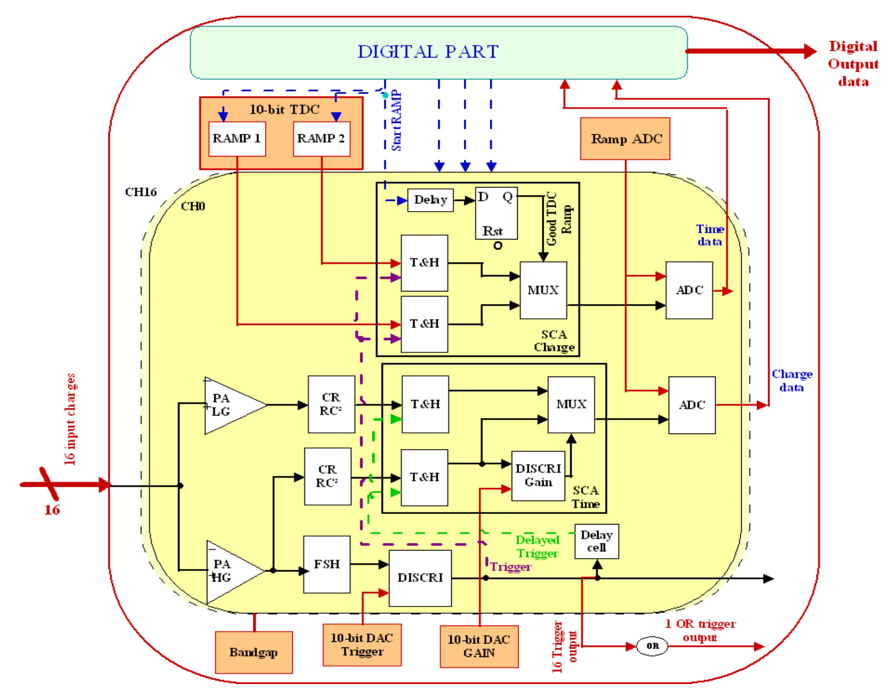
  - Both charge and time data can be measured

can be expanded up to 500 pC

can not be changeable
another amplifier needed





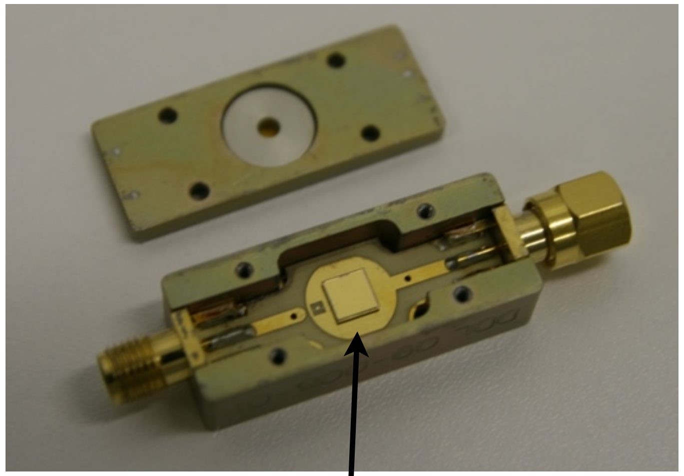
Prototype design of Diamond detector: Back-end electronics

- 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 already integrated at LAL and KEK, respectively
- Understanding both systems ➔ Adapting for our diamond detector

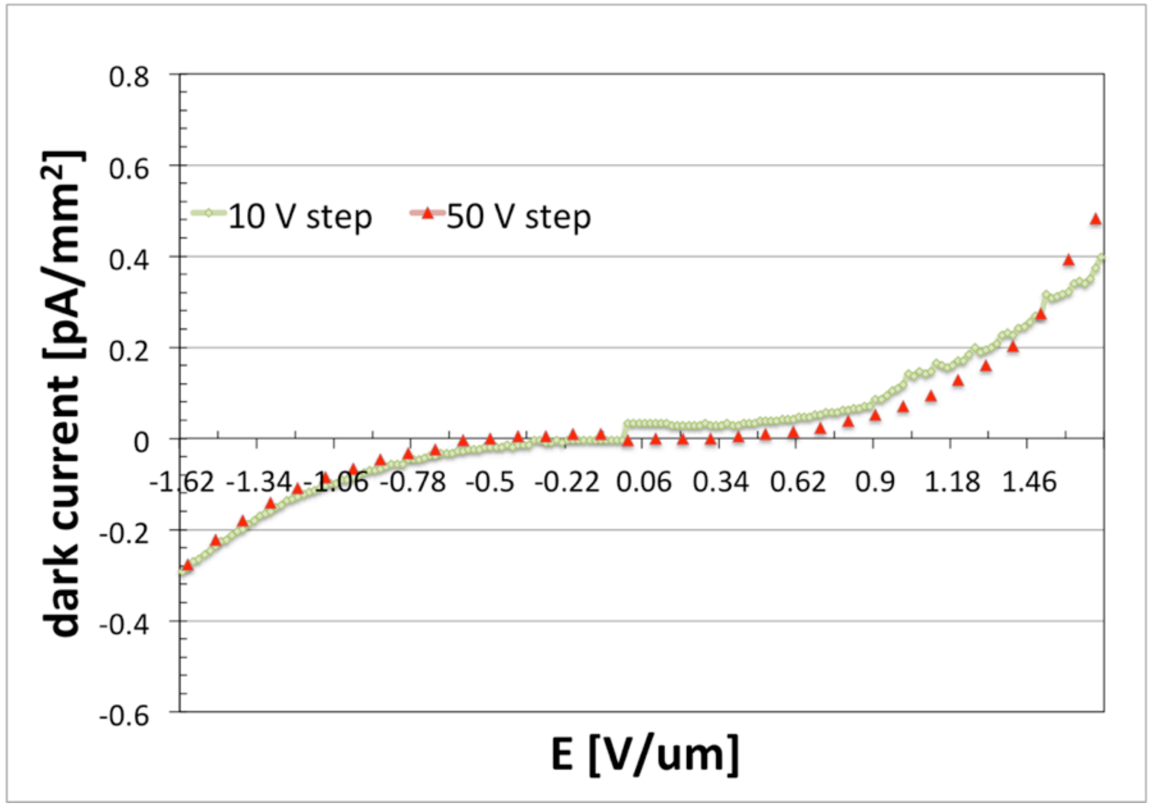
IV measurement of Diamond pad sensor

- There are a several aspect to characterize the diamond sensor such as <u>the current voltage characteristic</u>, charge collection, and timing properties



4.6 × 4.6 mm^2 single crystalline diamond pad

- 4.6 × 4.6 mm^2 and 500 μm thick single crystalline diamond pad sensor
- Dark current is measured with Keithley 6517B electrometer for difference bias voltage
- Dark current level is a few pA at 1 V/μm
- Other characteristics will be proceeded



Summary and Plan

- Single crystal CVD diamond sensor is chosen for beam halo and Compton recoil electron measurements
- 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
- Diamond and readout electronics is in designing and studying

- Now we have a single pad diamond sensor from UK company
- Understanding of diamond sensor and PARISROC2 ASIC chip
- Prototype diamond detector : Aim to first do beam tests in ATF diagnostic area : end of 2012