Investigation of Beam Halo at ATF2

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- **General Study of Beam Halo**
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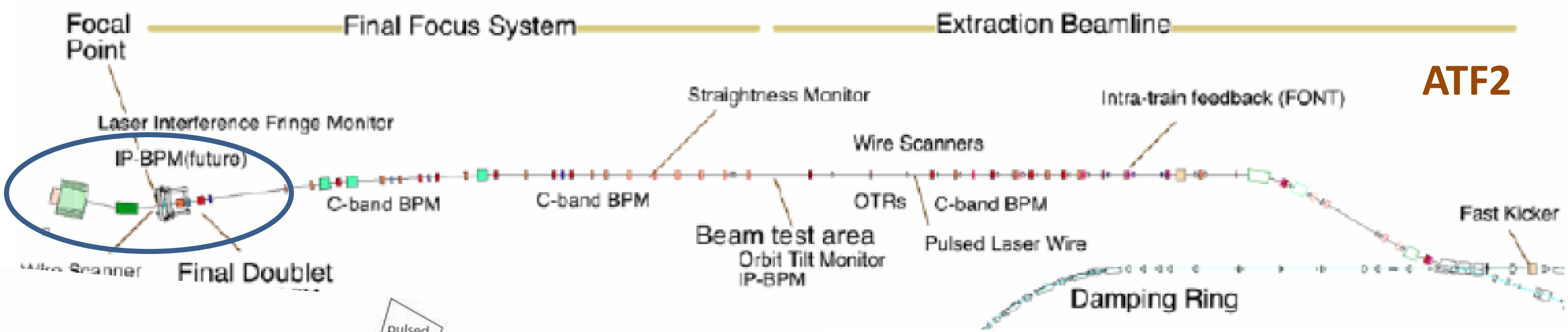
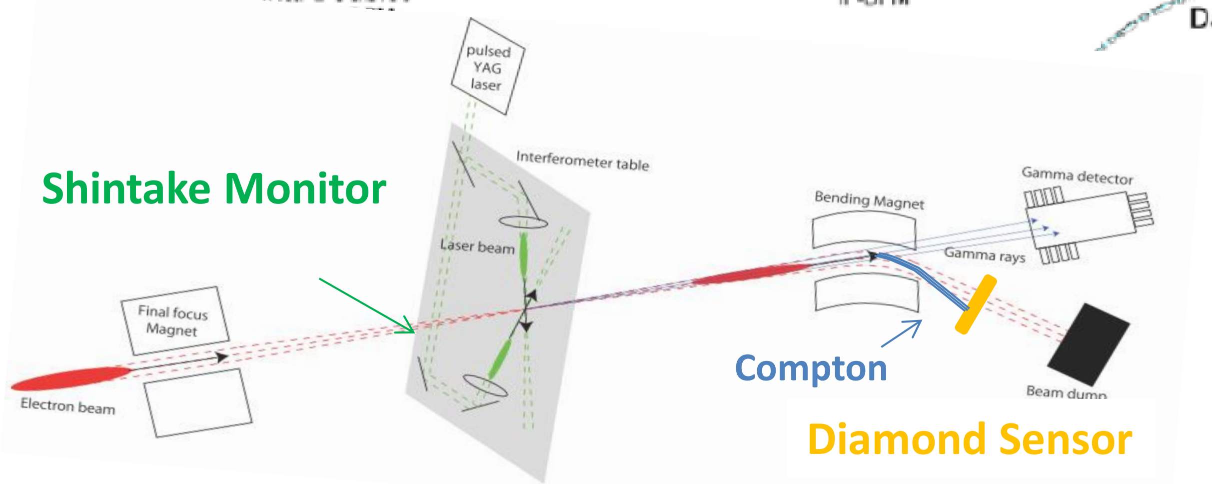
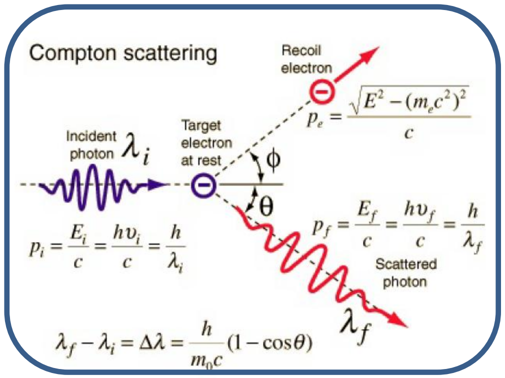
- **Summary and Future Plan**

Introduction







Motivations:

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

General Study of Beam Halo

Theory
- Beam Halo Generation -> D. Wang, T. Demma

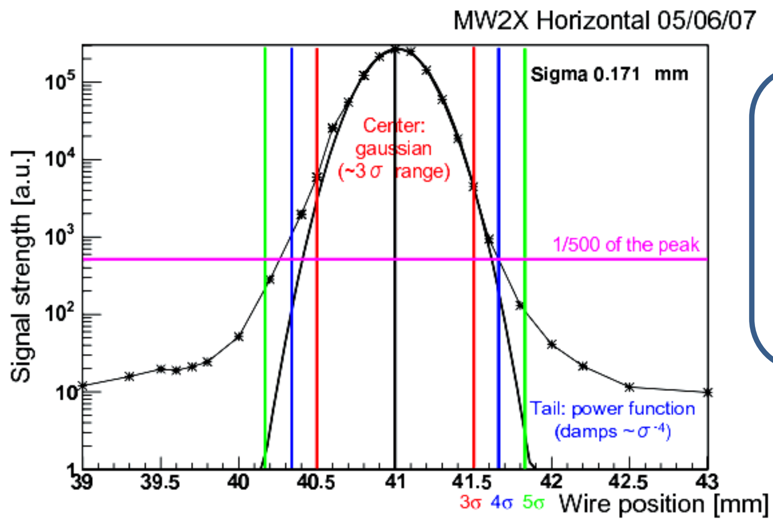
Simulation
- MAD-X Simulation -> Halo Collimation->@LAL & IFIC
- GEANT4/BDSIM Simulation -> I. Khvastunov

Instrumentation
- Diamond Detector R &D

Experiment
- Diamond Test @ PHIL
  - In air
  - In vacuum
- Halo measurement @ATF2
  - Wire Scanners
  - Diamond Detector

Beam Halo
Measurement & Collimation

Beam Halo Measurement



Halo Density

$$\rho_{h1} = 2.2 \times 10^9 \times x^{-3.5} \quad \text{(horizontal and vertical until 6 } \sigma\text{)}$$
$$\rho_{h2} = 3.7 \times 10^8 \times x^{-2.5} \quad \text{(vertical outside 6 } \sigma\text{)}$$

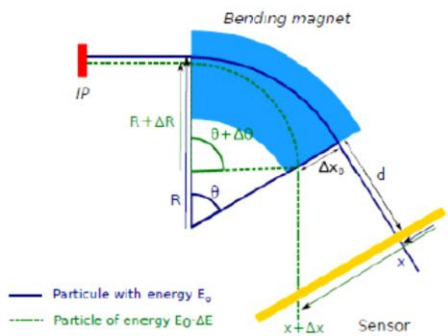
x-> the distance from the beam center as a unit of σ

T. Suehara et al., "Design of a Nanometer Beam Size Monitor for ATF2", arXiv:0810.5467v1

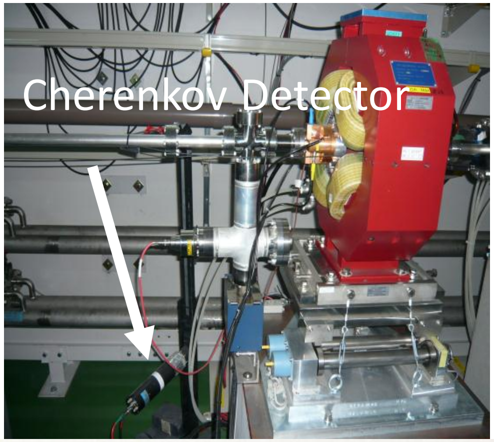
Energy spread of halo = ? Unknown;

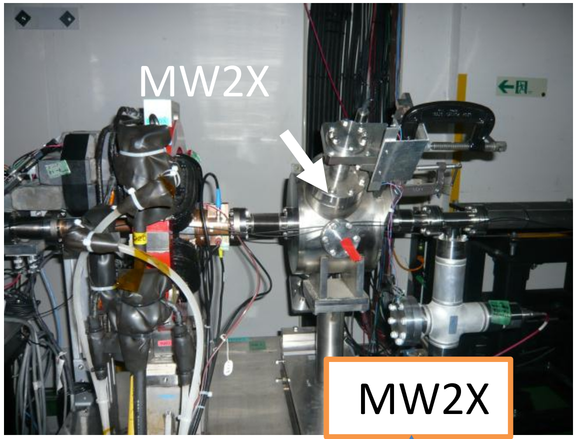
- First beam halo measurements were done in ***2005*** using the wire scanners in the extraction line -> need to be updated for present beam optics;
- No energy halo measurement was performed before -> Energy spread of halo is unknown -> can be investigated with wire scanners by measuring halo distribution by changing the vertical dispersion in the diagnostic section.

Wire Scanners & Detectors

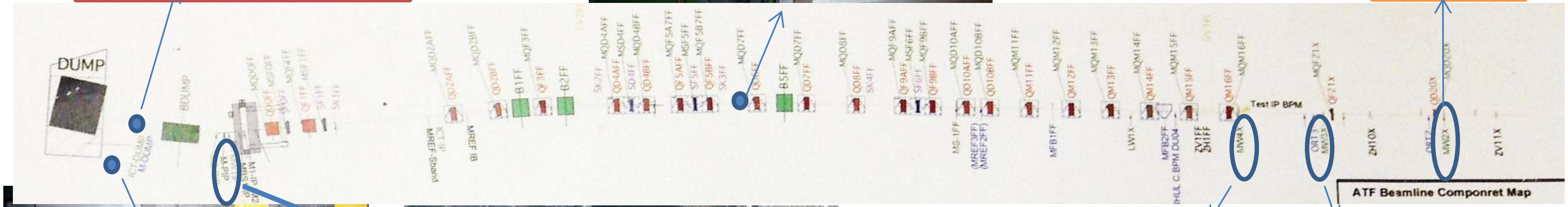


Diamond Detector

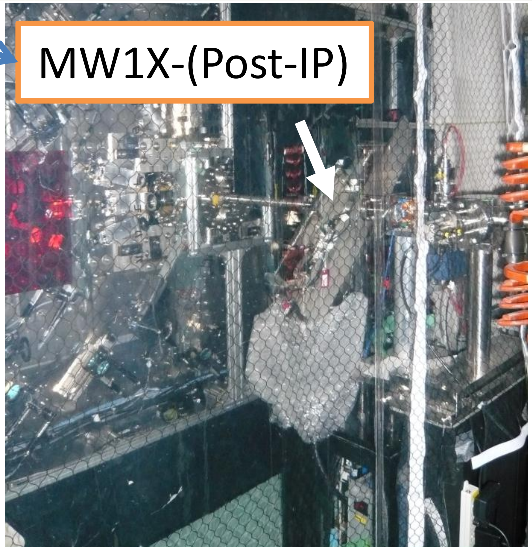




MW2X



MW1X-(Post-IP)



MW4X

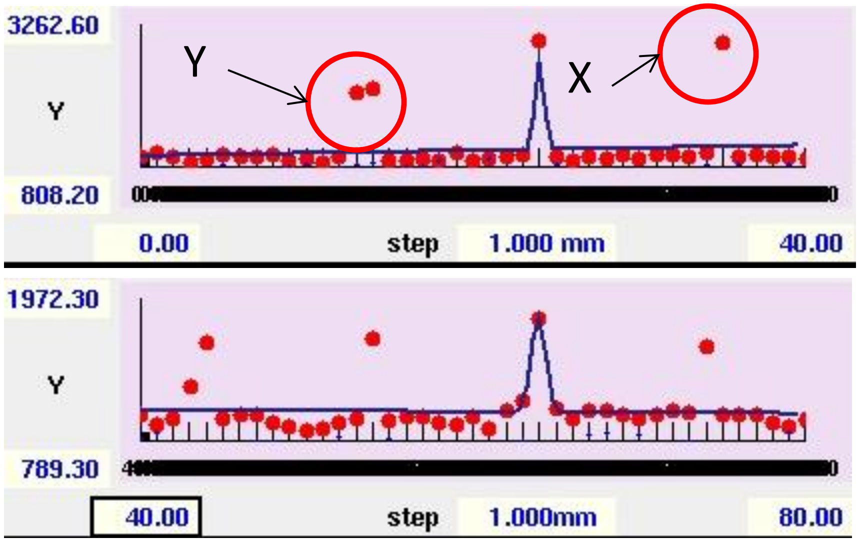
MW3X

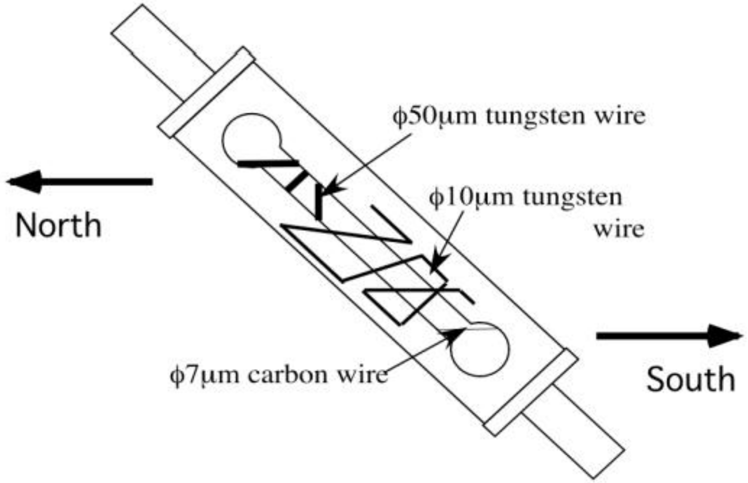
2013 April Run @ ATF

- ✓ MW2X
- ✓ MW3X
- ✓ MW1X-(Post-IP) -> Initial data analysis

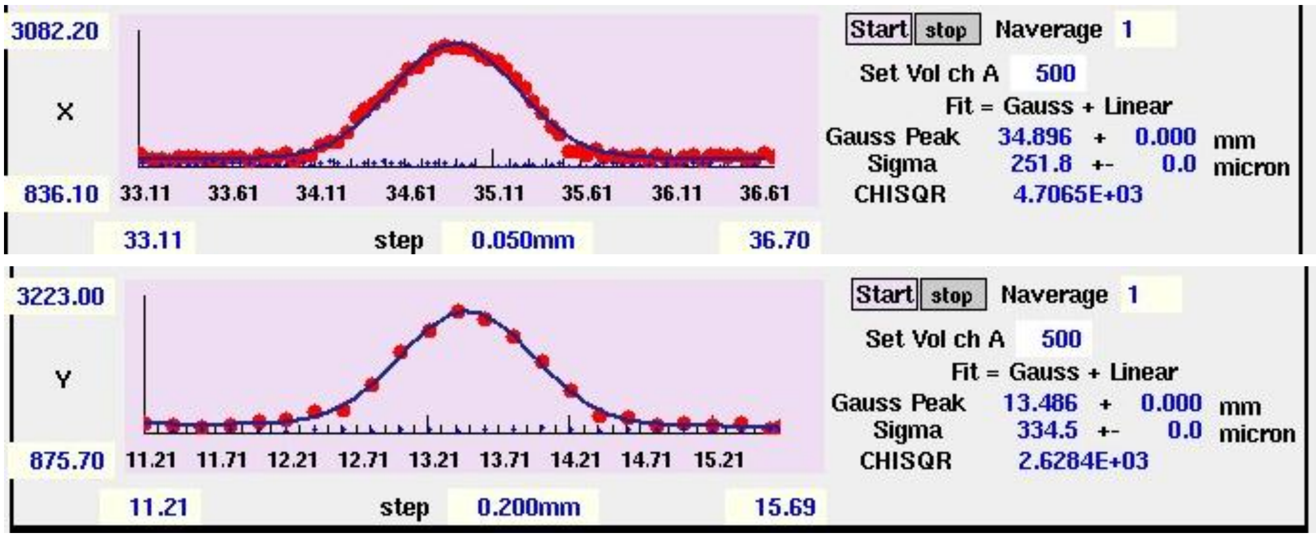
MW1X-Post IP Wire Scanner

Step 1： Overall Scan to find wire position

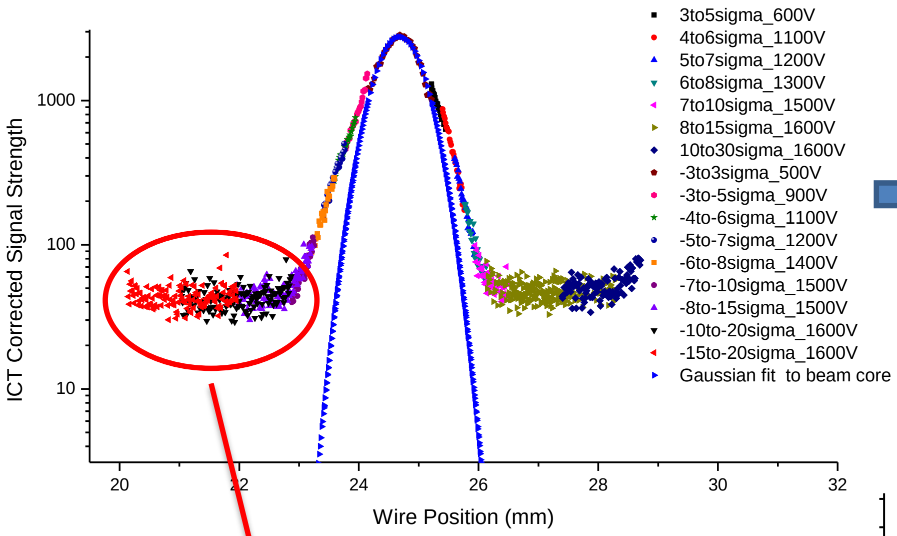




Step 2： X & Y Scan to get Gaussian Peak and sigma



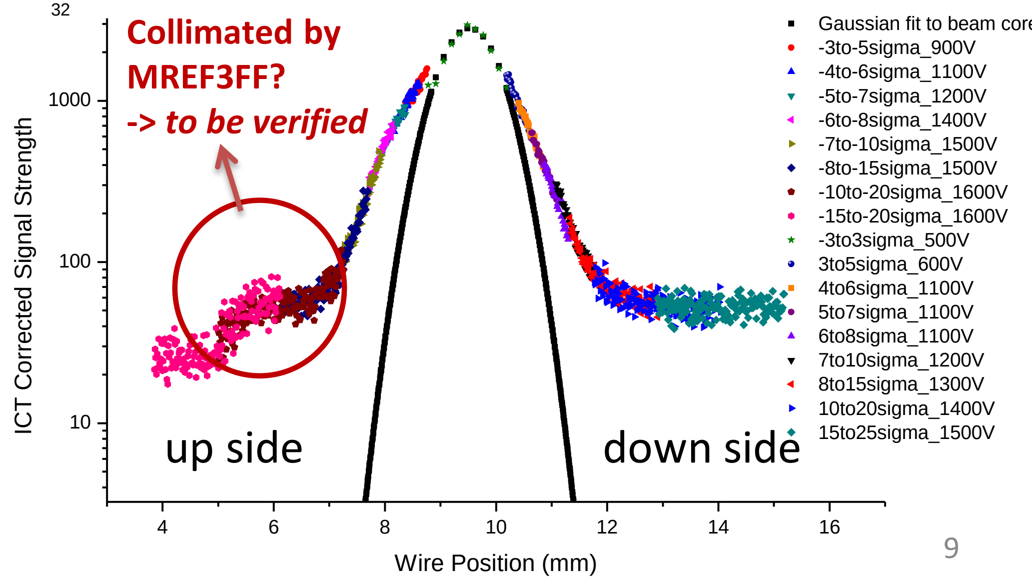
Beam Distribution After Normalization



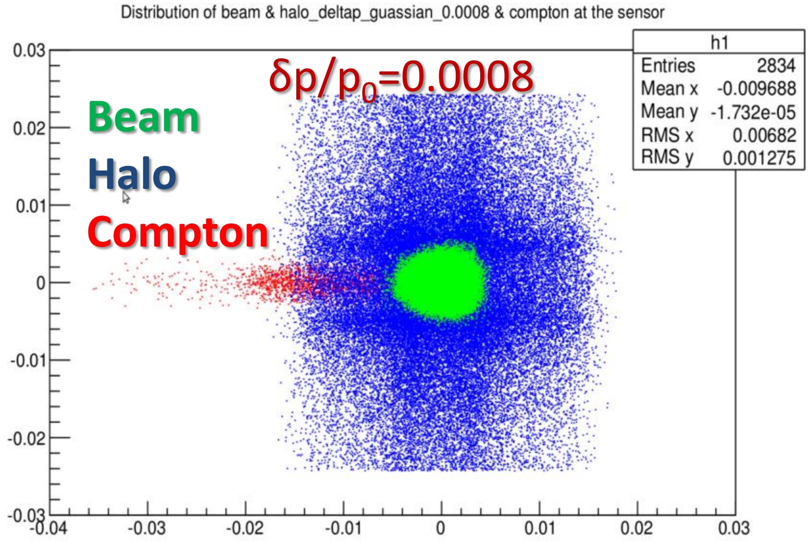
Horizontal beam

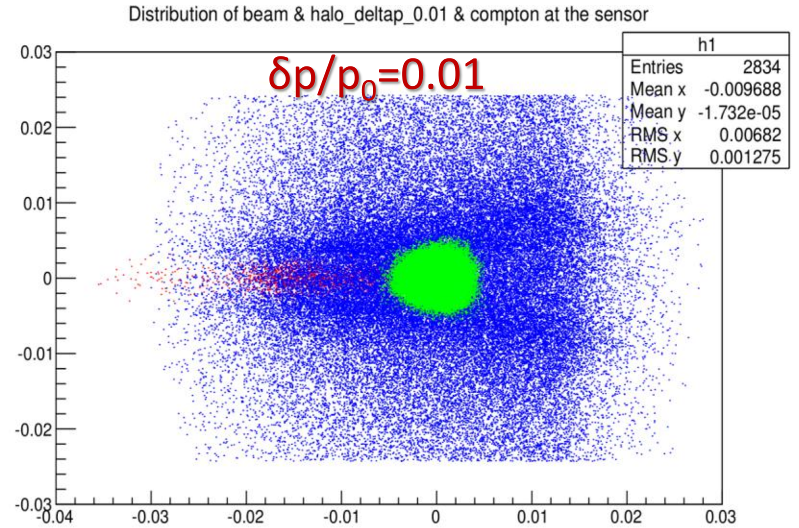
Halo+Pedestal+Background?

Vertical beam



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



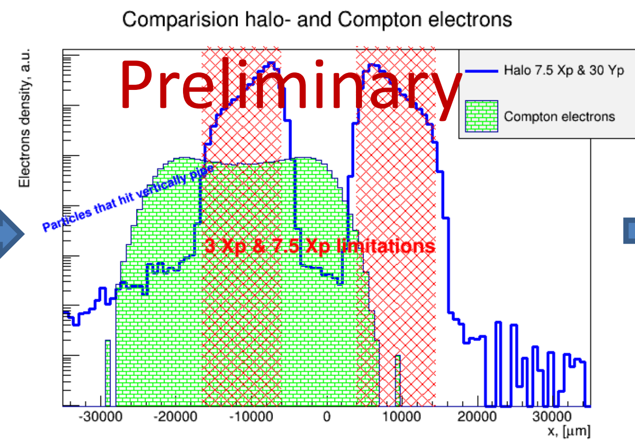


	Total Number (in simulation)	Total Number (in experiment)	Min.～Max. Number/mm² @ Sensor	Charge signal/mm²
Beam	10^5	10^{10}	$6163*10^5$	$1.6887*10^{-6}$C=1.6887μC
Halo ($\delta p/p_0$=0.01)	10^5	10^7	$114*10^2$	$3.1236*10^{-11}$C=31.236pC
Halo ($\delta p/p_0$=0.0008)	10^5	10^7	$224*10^2$	$6.1376*10^{-11}$C=61.376pC
Compton	2834	28340	3*10～52 *10	82.2fC～1.4284pC

Halo Collimation

Vertical Halo

Hit BDUMP → may re-generate halo of off-momentum beam particles;

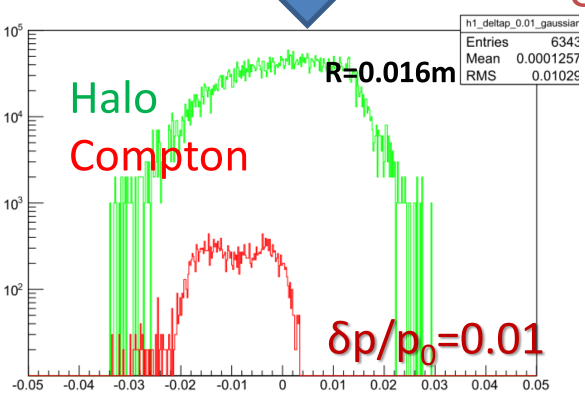


→ Betatron collimation needed

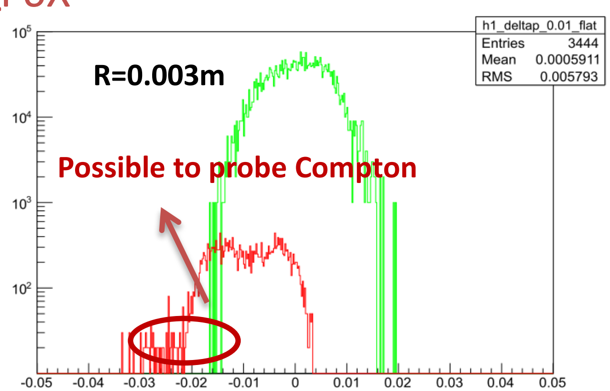
Horizontal Halo

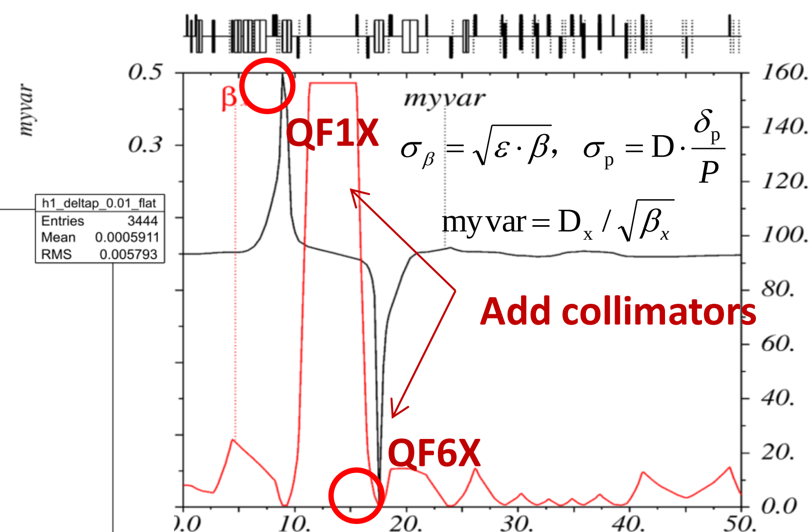
May cover the Compton signal especially in case of large initial energy spread.

→ Energy & betatron collimation needed



QF6X





Diamond Detector R&D

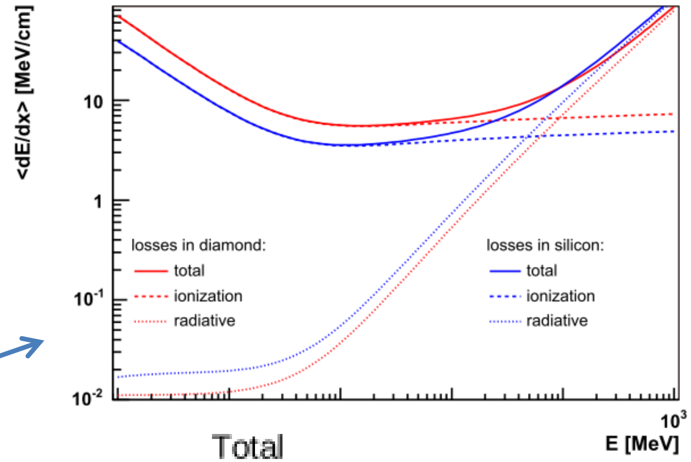
Diamond Detector Characteristics

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

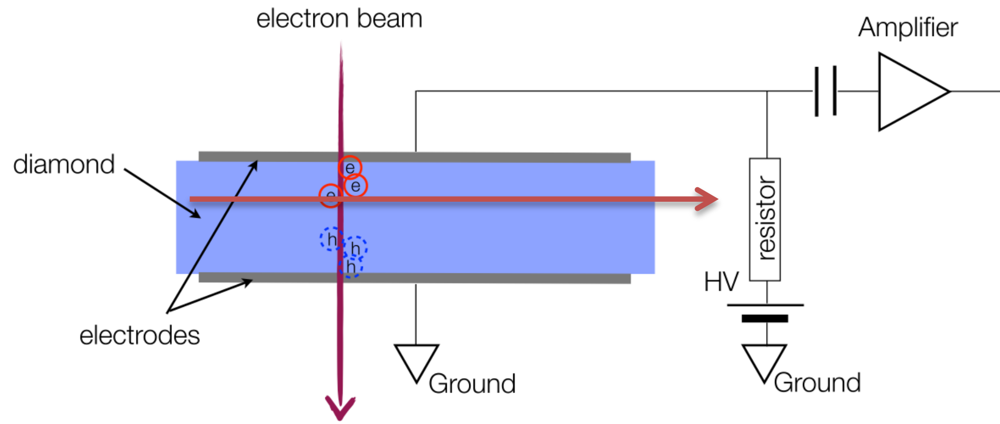
- ***Large band-gap ⇒ low leakage current***
- ***High breakdown field***
- ***High mobility ⇒ fast charge collection***
- ***Large thermal conductivity***
- ***High binding energy ⇒ Radiation hardness***
- ***Fast pulse ⇒ < 1 ns***

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



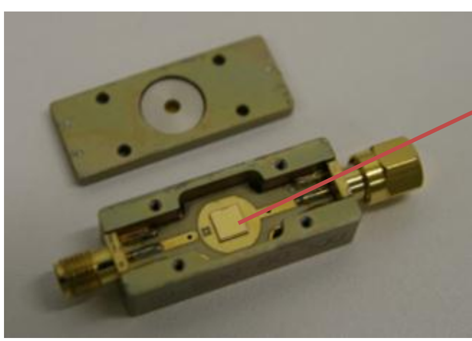
Charge created by 1MIP in diamond → 2.74 fC

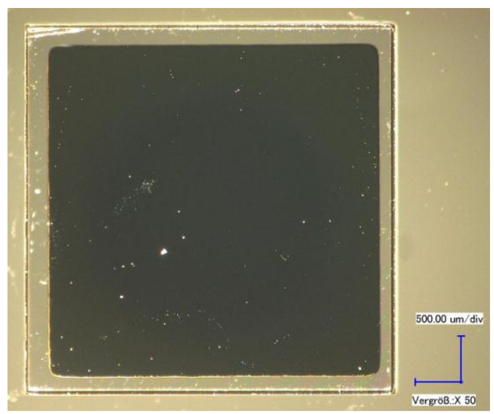
Diamond detectors

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

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

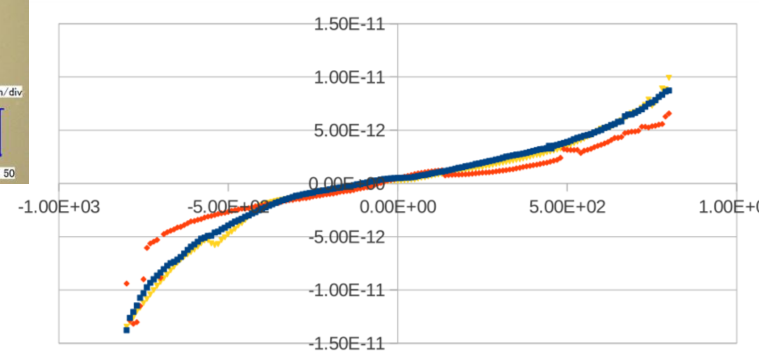
Metallised with
Al or Ti/Pt/Au(100nm)



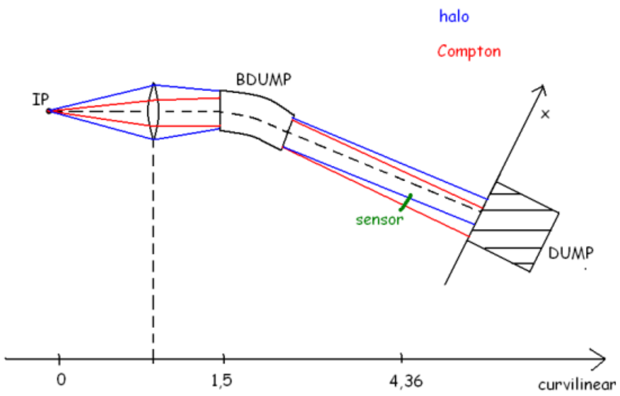


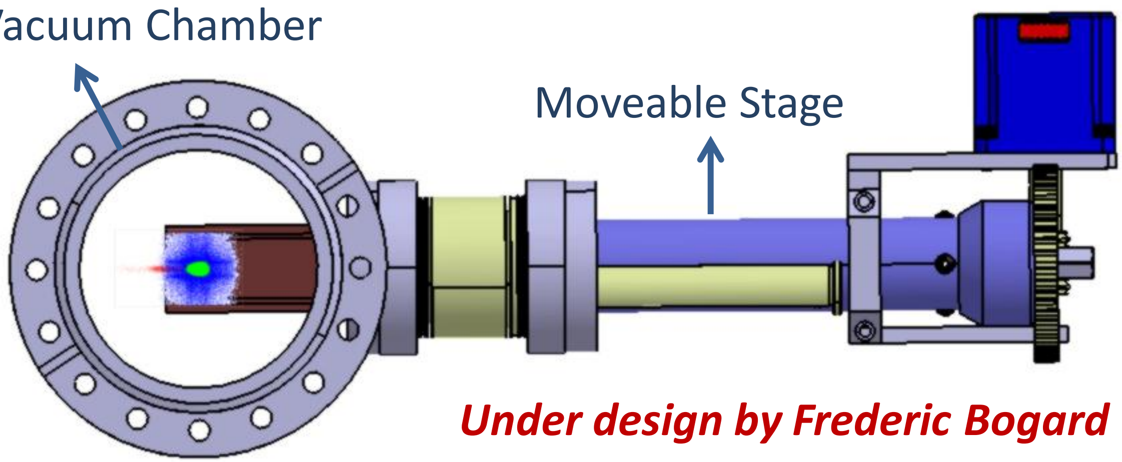
Surface: 4.5X4.5mm^2

Dark Current Measurement

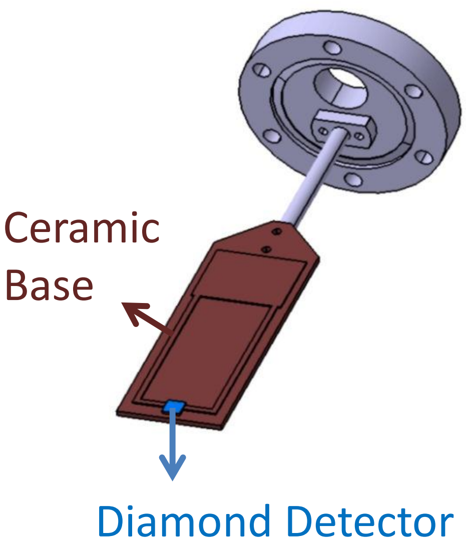


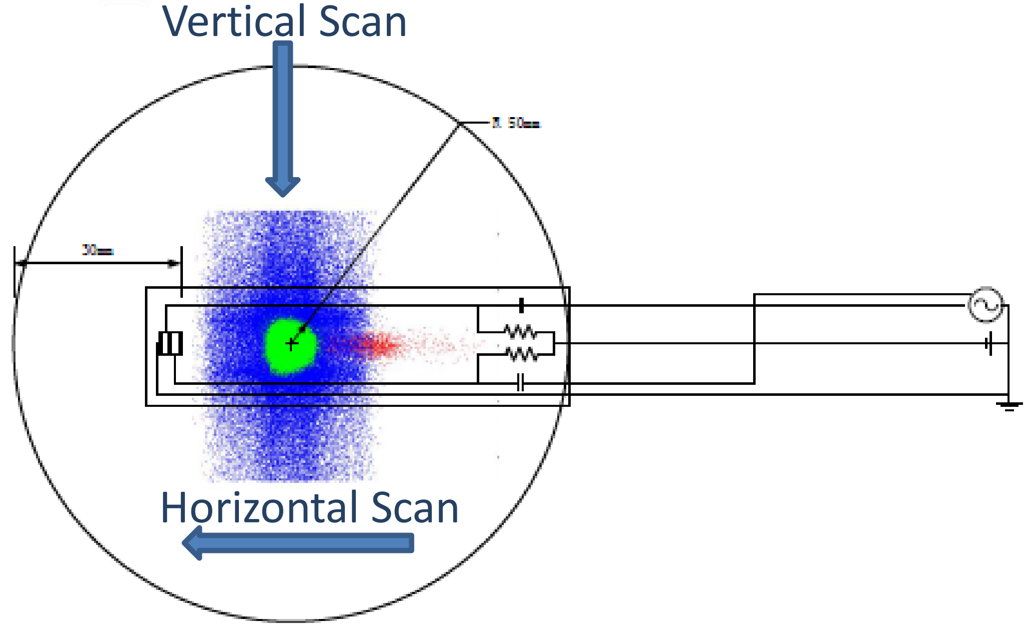
Detector Holder Design





Under design by Frederic Bogard

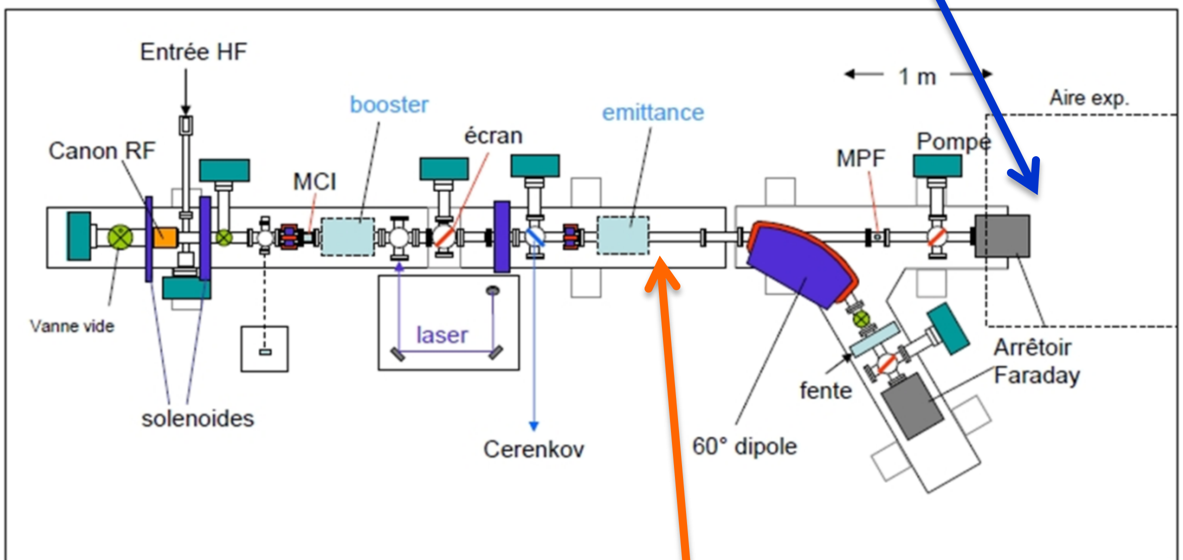




Diamond Detector Test @ PHIL

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



In-vacuum single crystal CVD diamond sensor profile scanner -> for PHIL diagnostic

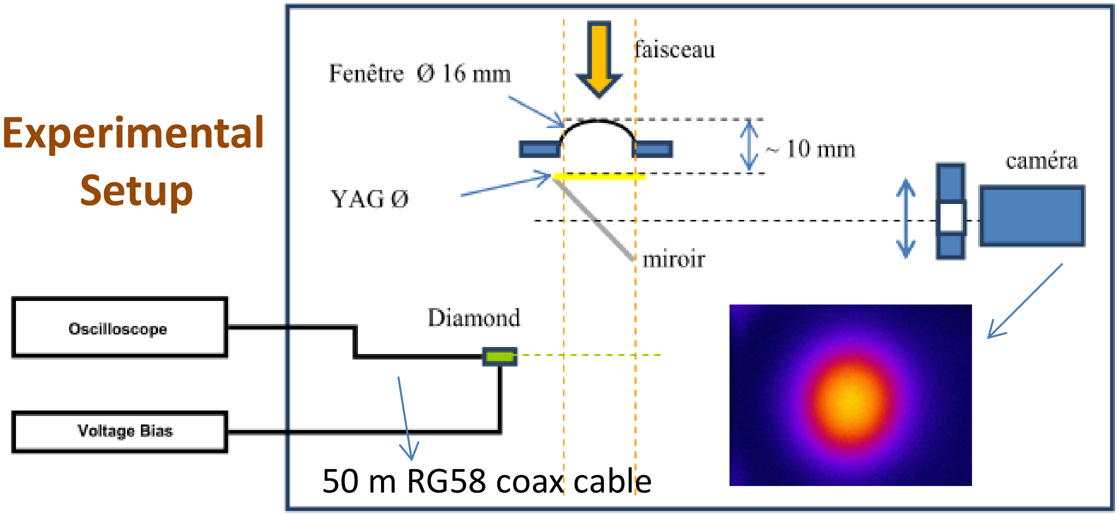
PHIL Electron Beam Parameters

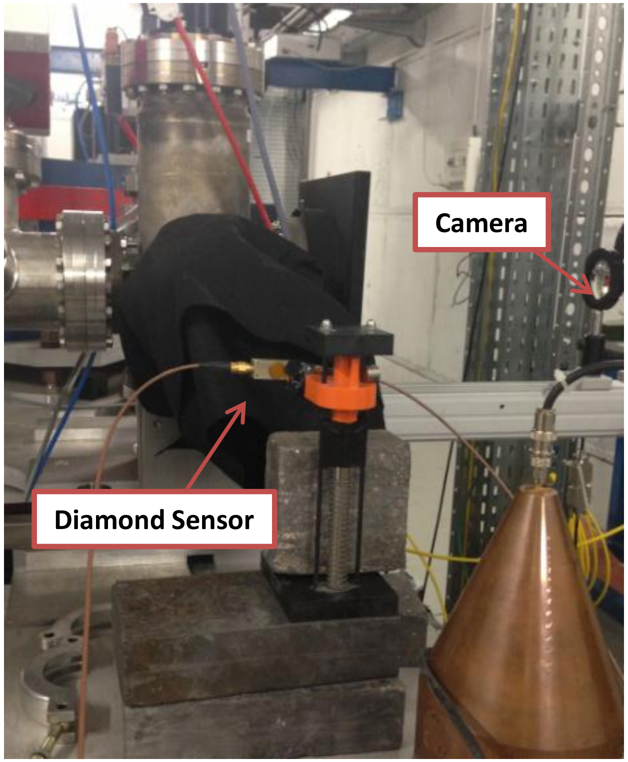
(given by ***Hugues Monard***)

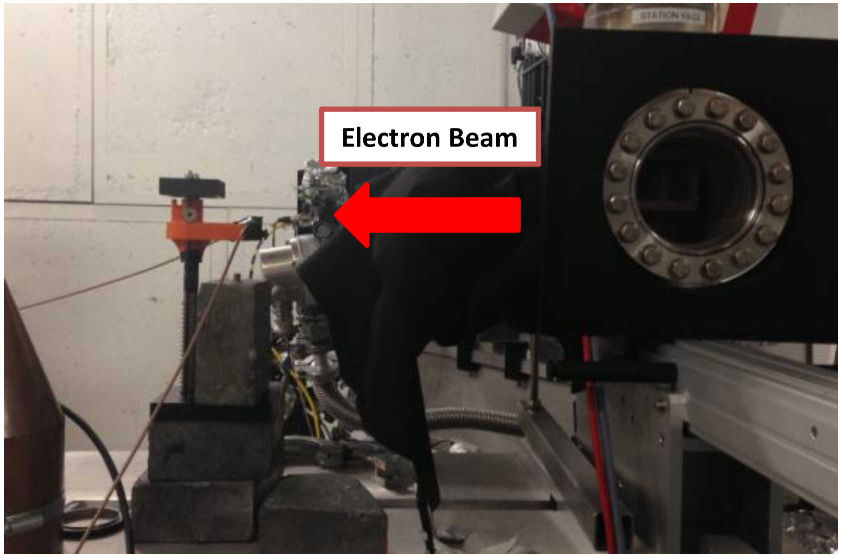
- ✓**Charge: 10 pC-250 pC/bunch (1 bunch per RF pulse) ;**
- ✓**Duration of Charge: 7 ps FWHM;**
- ✓**Charge Stablility: < 2%;**
- ✓**Maximum Energy: 5 MeV;**
- ✓**Minimum Dispersion: < 1%;**
- ✓**Beam Size -> ?**

First Test @ PHIL

Experimental Setup



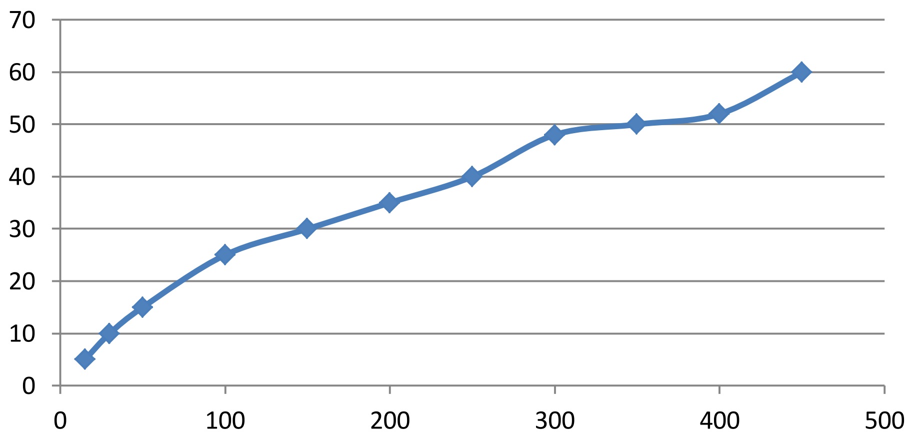




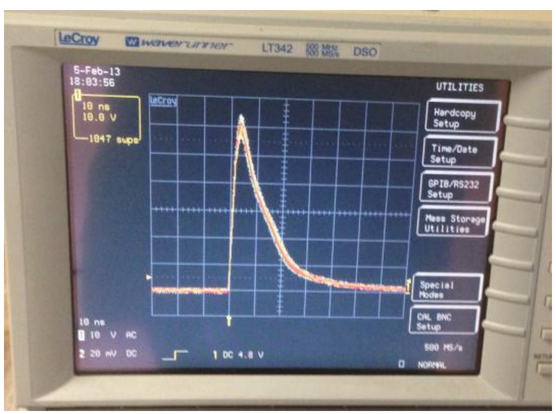
Performed on 08.02.2013

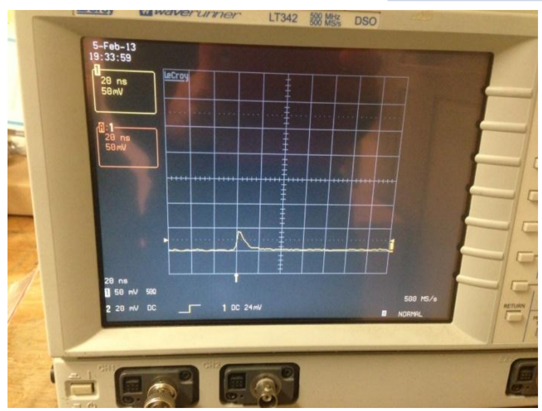
First Test Results @ PHIL

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





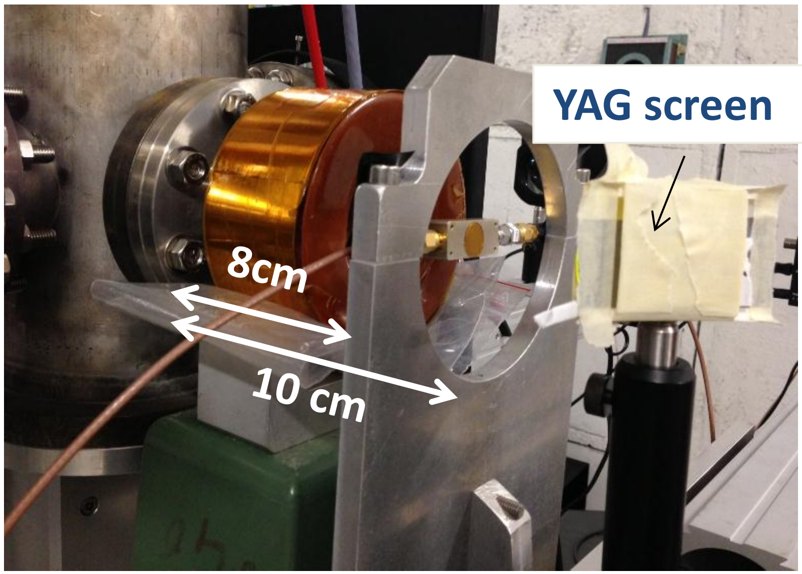
Minimum signal
Number of electrons
Attenuation of cables
Charge collection efficiency
Calibration

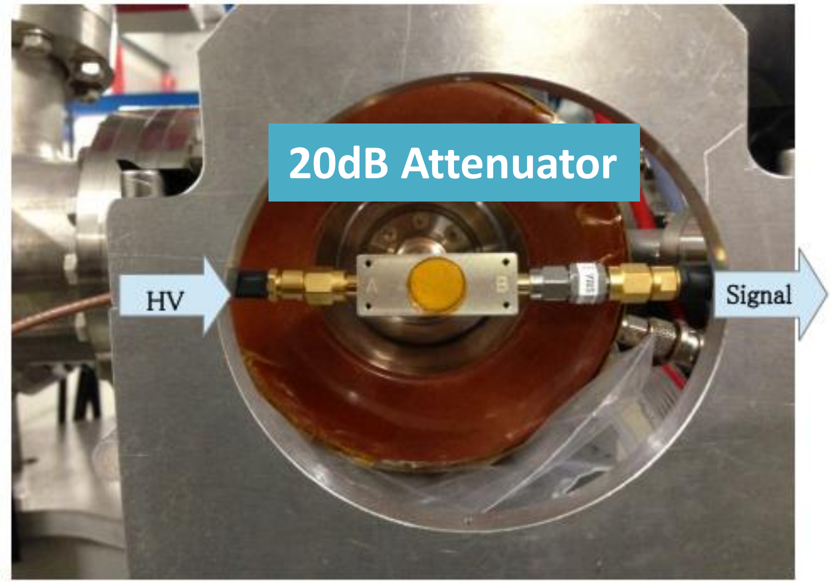
Second Test @ PHIL

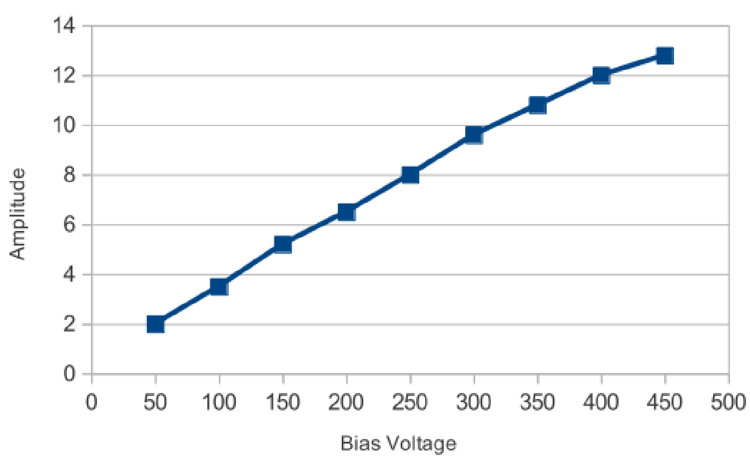
Beam Energy : 3 MeV;   Beam Size: σ ≈ 4.5 cm

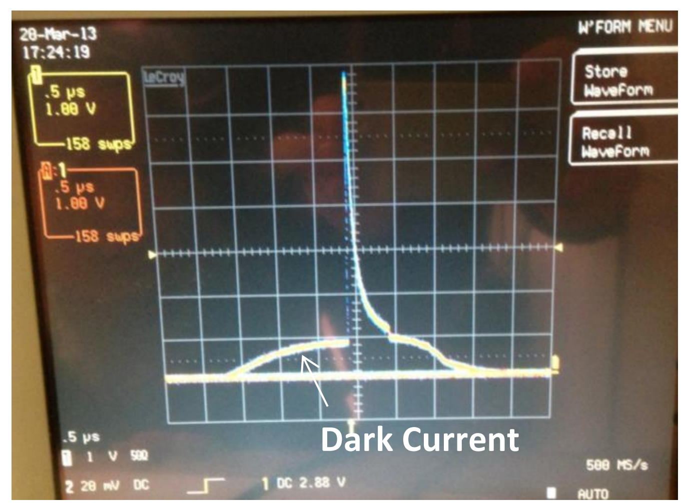
Beam Charge: 33 pC (measured at ICT 1, obtained using a 10% filter on the laser)

Performed on 20.03.2013









Summary

- We can investigate halo propagating model by measuring the beam halo using diamond sensor;
- We probably need to cut the beam halo signal to probe the Compton spectrum. Betatron collimation may be needed for both horizontal and vertical planes as well as energy collimation for horizontal plane (collaboration with IFIC);
- First tests of diamond sensor @ PHIL;
- First measurements of halo at ATF2.

Future Plans

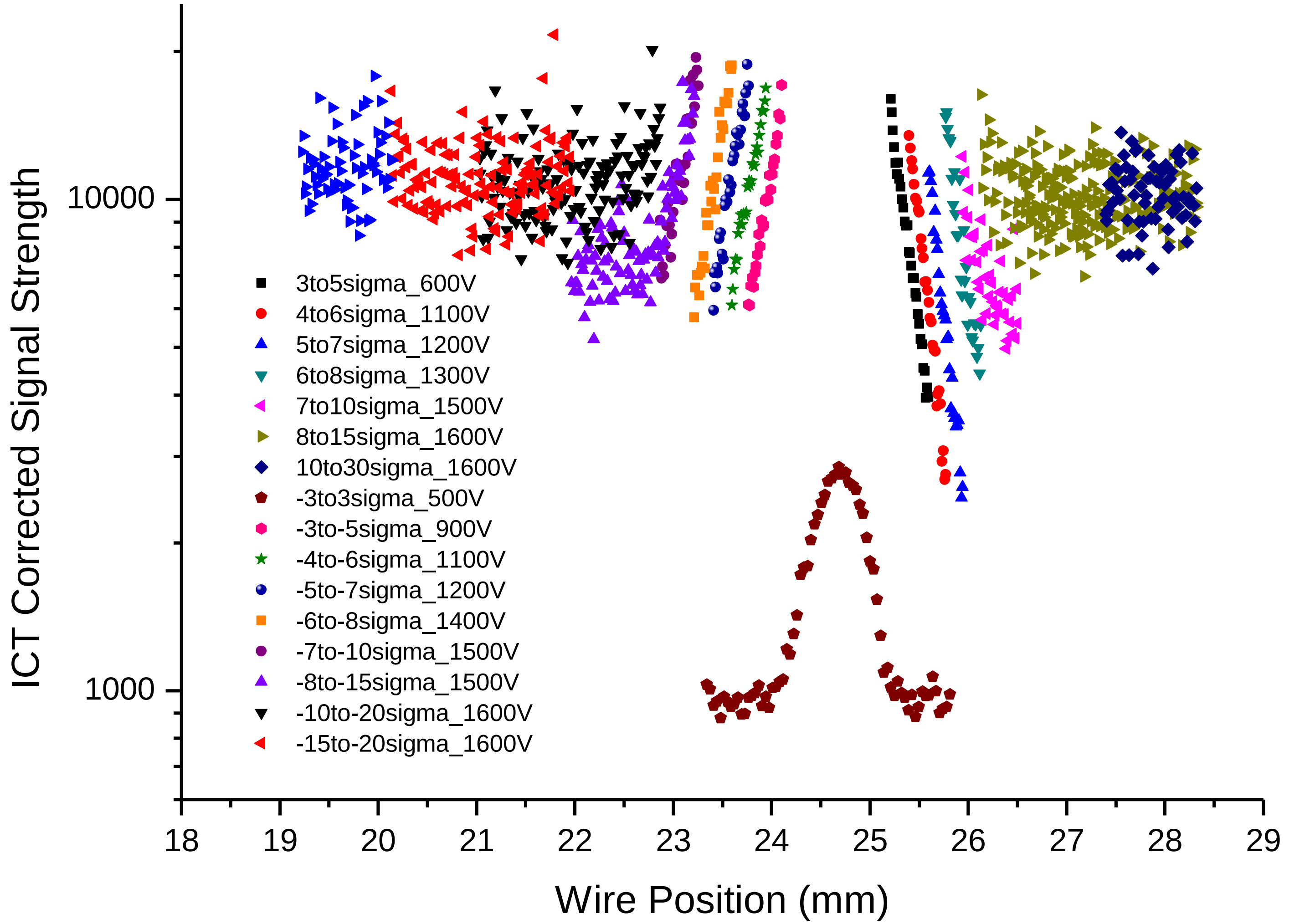
- Continue data analysis for the ATF2 halo measurement using wire scanners;
- Energy halo measurement using wire scanners at ATF2 in *June* (by S. Bai);
- Investigation of halo generation theory (by D. Wang and T. Demma);
- BDSIM-GEANT4 simulation for beam halo regeneration study (by I. Khvatunov)
- Calibrate the readout of diamond sensor using Sr source in *June*;
- Finish the design of in vacuum detector and detector holder, install and test in air @ PHIL before *December*;

→ Install the diamond sensor @ ATF2 in *2014*

Thank you for your attention !

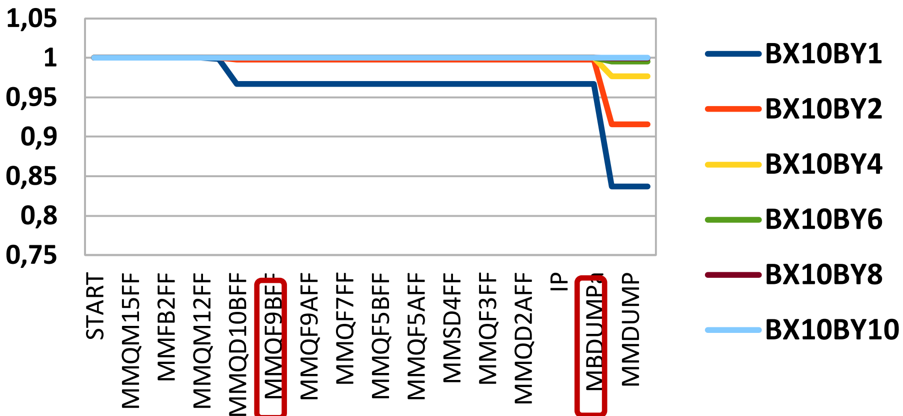
Backup Slides

Beam Distribution Before Normalization

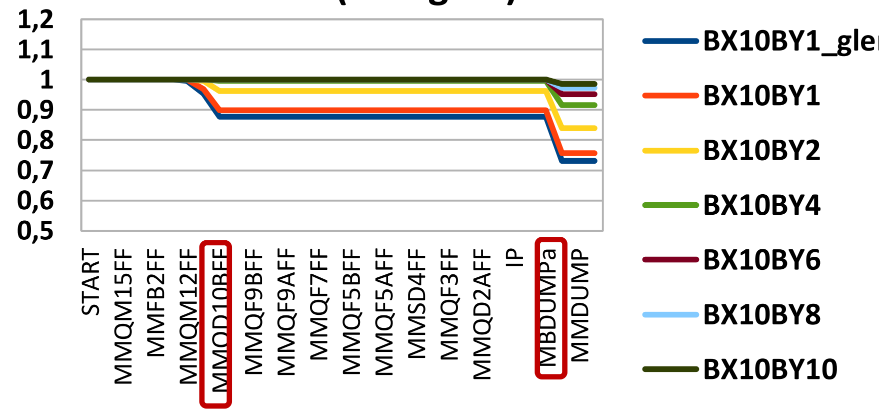


Change the beta_y*

Ratio of halo (40 sigma) loss on Y axis



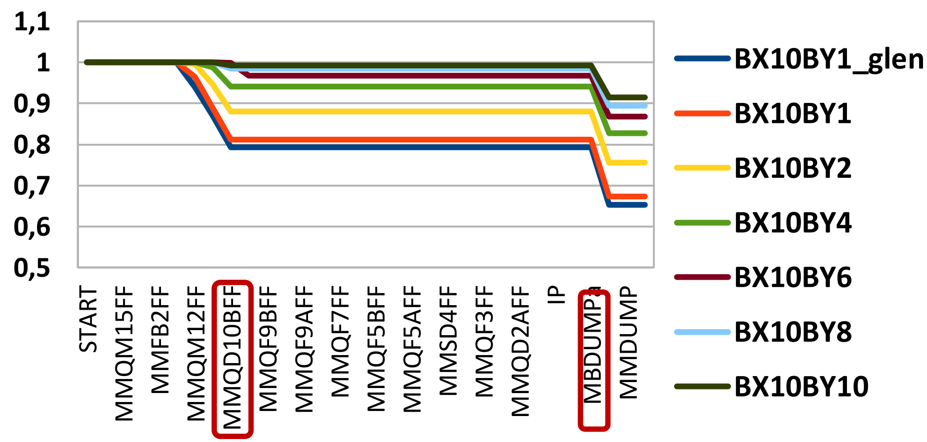
Ratio of halo (60 sigma) loss on Y axis



Almost no halo loss at BDUMP for BX10BY10

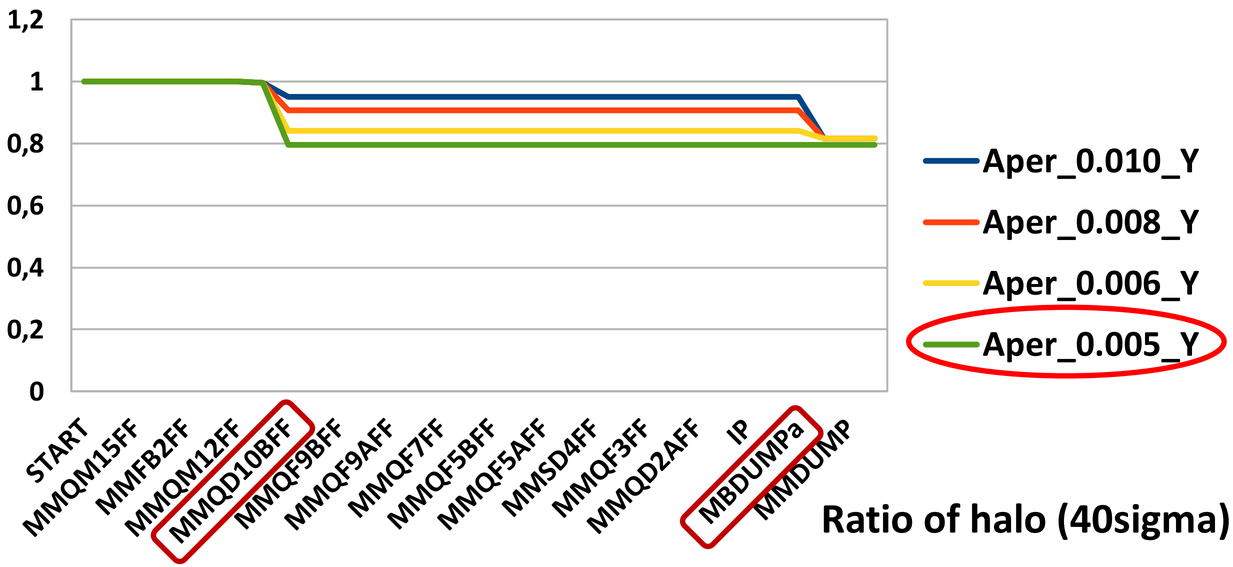
Larger beta_y* can reduce vertical halo hitting BDUMP beam pipe

Ratio of halo (100 sigma) loss on Y axis



Vertical Collimation at QD10

Ratio of halo (40sigma) loss on Y axis with deltap_0.0008

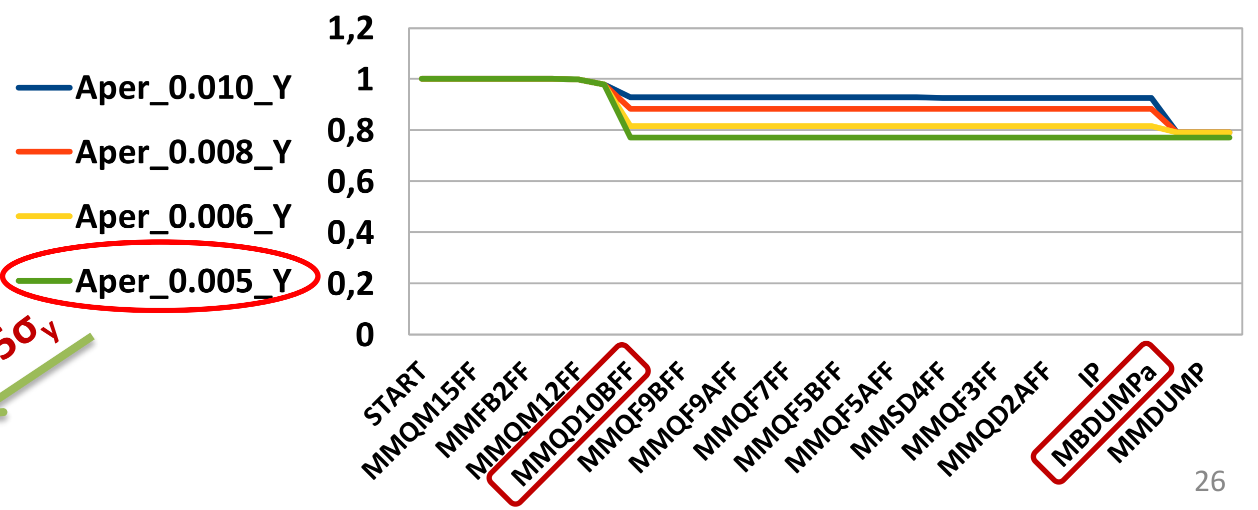


Initial Aperture Size:

R=0.01m

Ratio of halo (40sigma) loss on Y axis with deltap_0.01

No halo loss at BDUMP



$15\sigma_y$

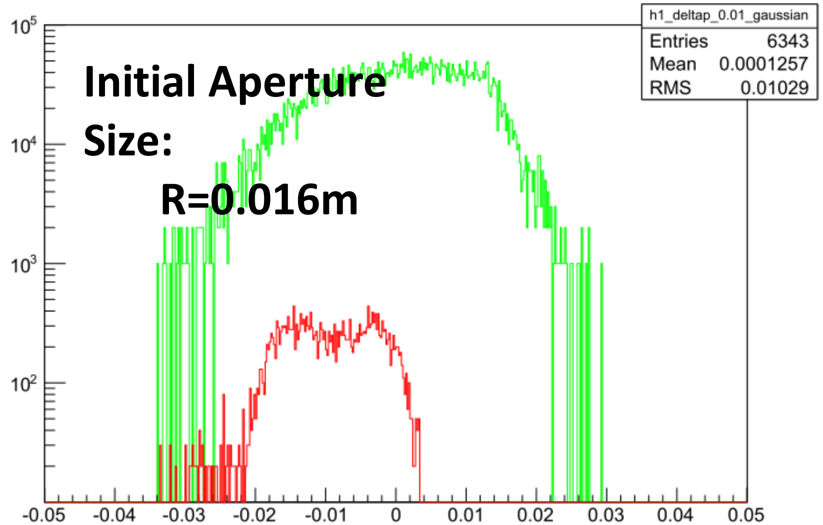
Vertical Beam Size @ QD10:

σ_y =0.3336mm

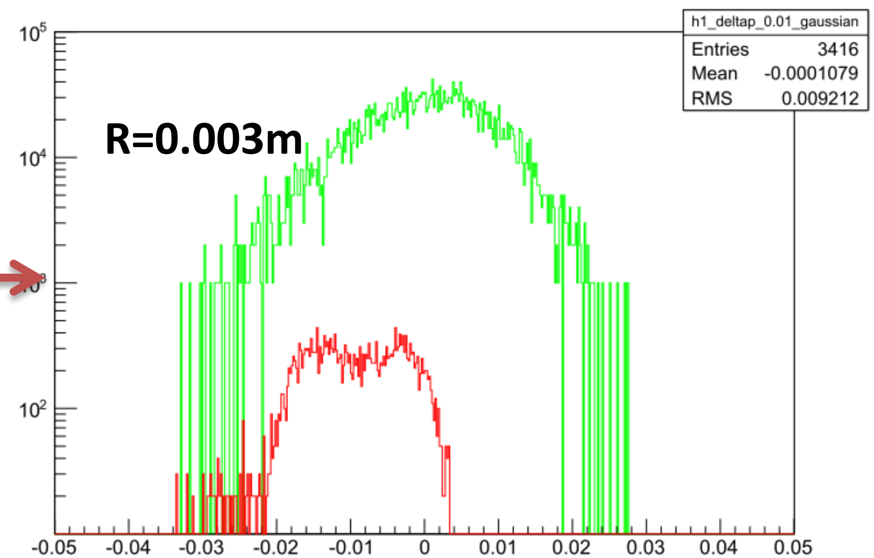
Horizontal Collimation at QF1X

Energy Spread:

Flat deltap= 0.01



Compton still covered by halo



Horizontal Collimation at QF6X

Energy Spread:

Flat deltap= 0.01