Status of post-IP diamond sensor project for beam core and halo measurements

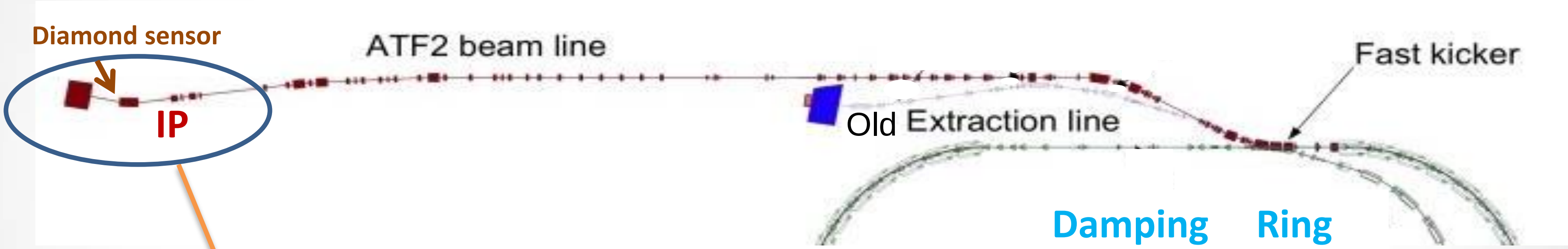
S. Liu, P. Bambade, F. Bogard, P. Cornebise, V. Kubytskyi, C. Sylvia, A. Faus-Golfe, N. Fuster-Martínez, T. Tauchi, N. Terunuma

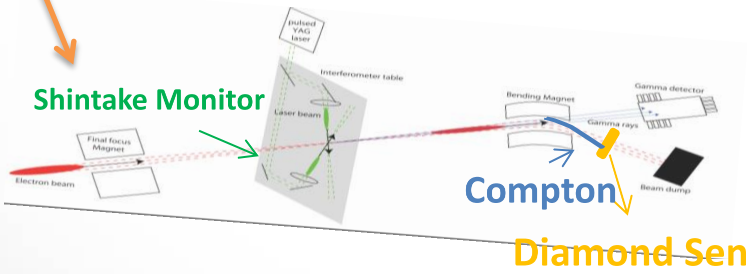
ATF2 Project Meeting, 24 Feb. 2015

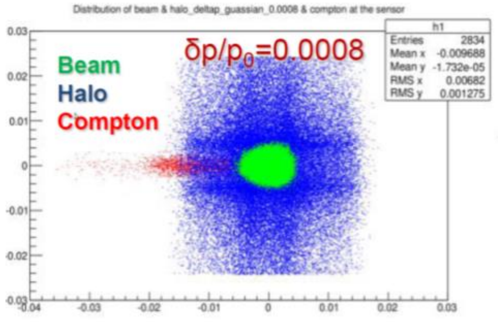
Outlines

- Motivations
- Post-IP Diamond Sensor (DS)
- Characterization of DS
  - Upper limit
  - Lower limit
- Measurements using DS
  - Beam Core
  - Beam Halo
- Conclusions & Prospects

Motivations







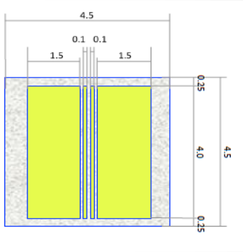
- ➢ ***Beam halo transverse distribution unknown → investigate halo model***
- ➢***Probe Compton recoil electron (prepare future investigations of higher order contribution to Compton process)***

Diamond Sensor with large dynamic range

Expected signal @ATF2 : 10 ->10^8 e^- required!

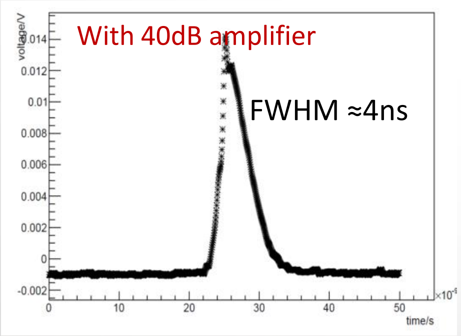
	Total N	Min.～Max. N/mm² @ DS	Charge signal/mm²
Beam	10^{10}	6.2×10^8	1.7μC
Halo	10^7	1.1×10^4～2.2×10^4	31.2pC～61.4pC
Compton	28340	30～5.20×10^2	82.2fC～1.4pC

4.5mm X 4.5mm X 500μm

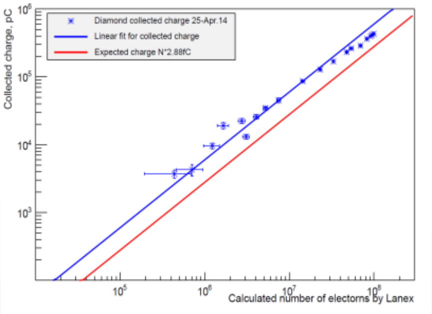


Charge generated by 1 MIP for 500 μm diamond (with 100% CCE): 2.88 fC

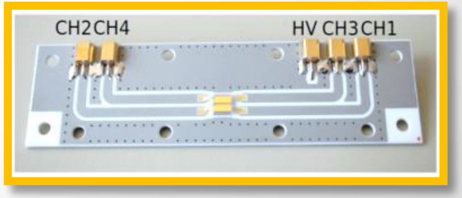
1 e^- tested with ^{90}Sr source



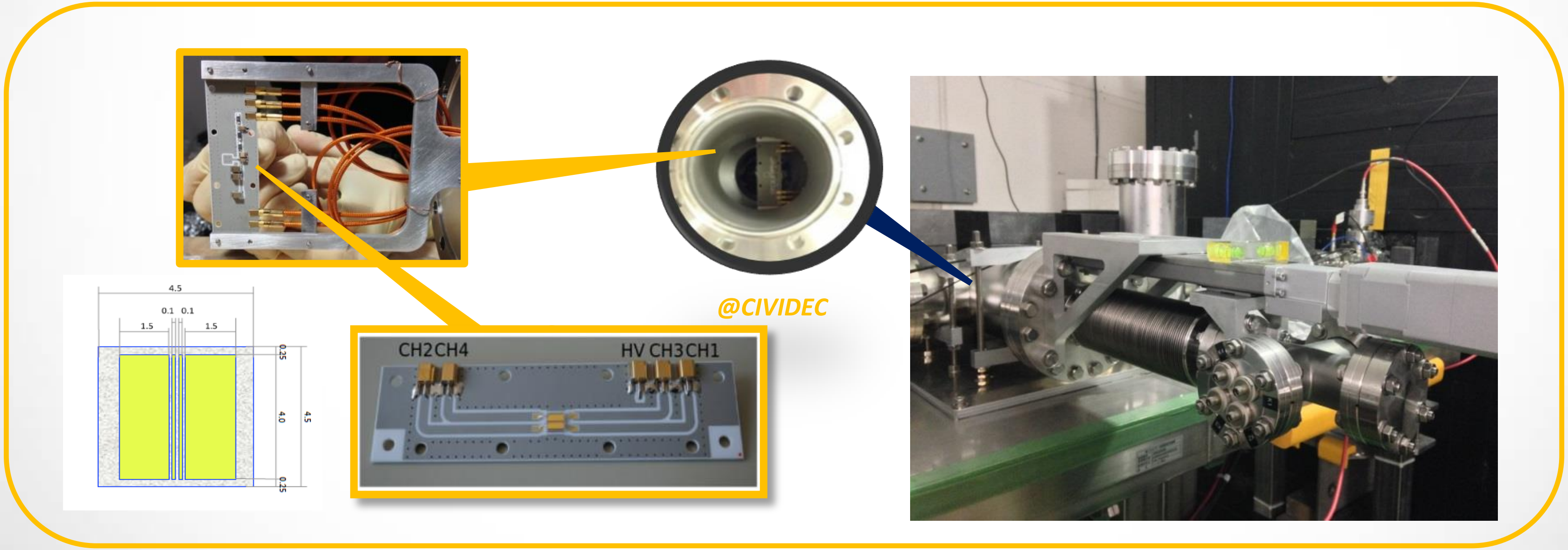
10^5 ->10^8 e^- tested at PHIL in air



In vacuum DS designed for ATF2

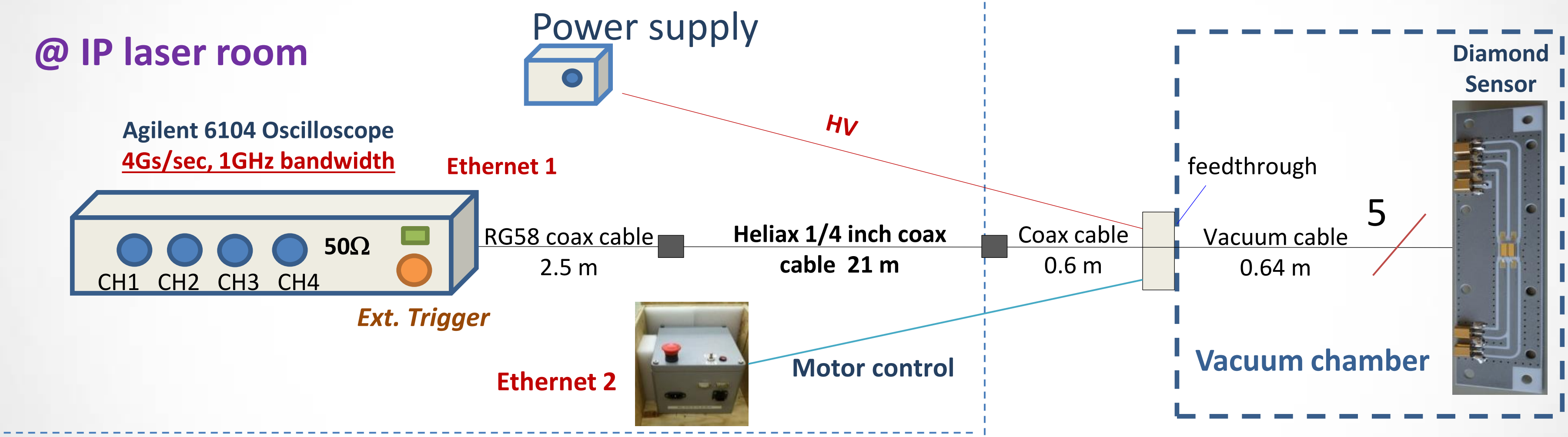


In vacuum Post-IP DS



- The first Diamond Sensor is installed horizontally at ATF2 in Nov. 2014
- A second unit will be installed vertically in 2015 for vertical halo measurements

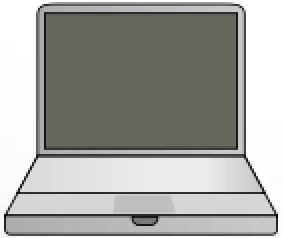
Data Acquisition System



@ Control room

Data acquisition using Matlab

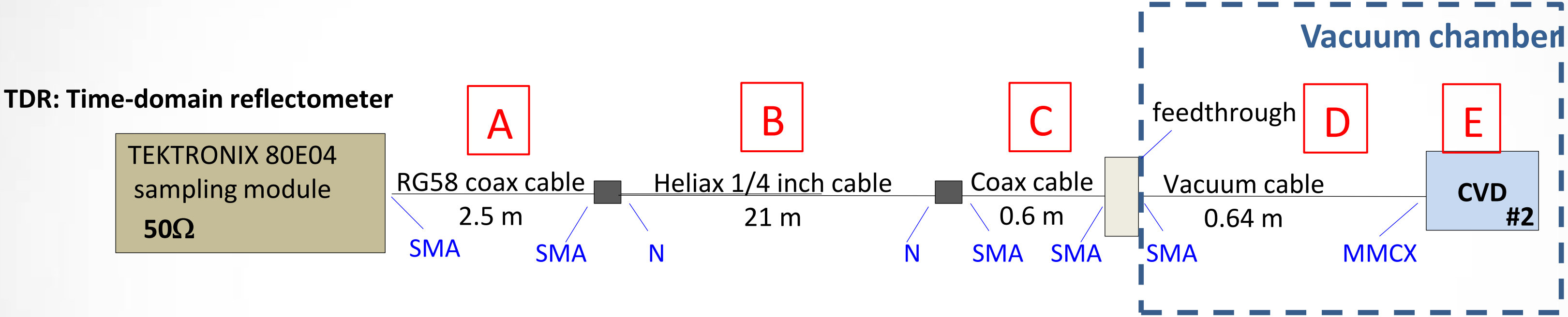
PC

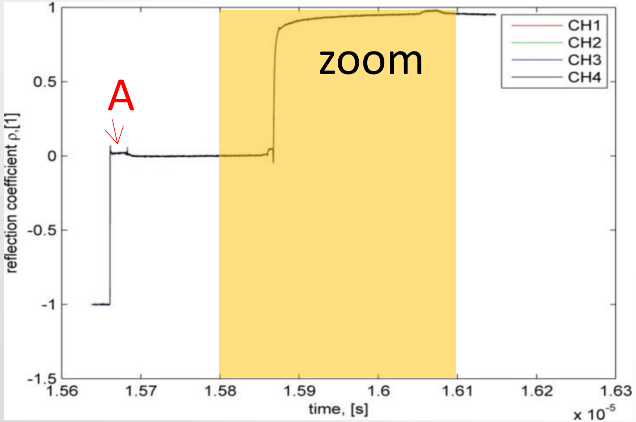


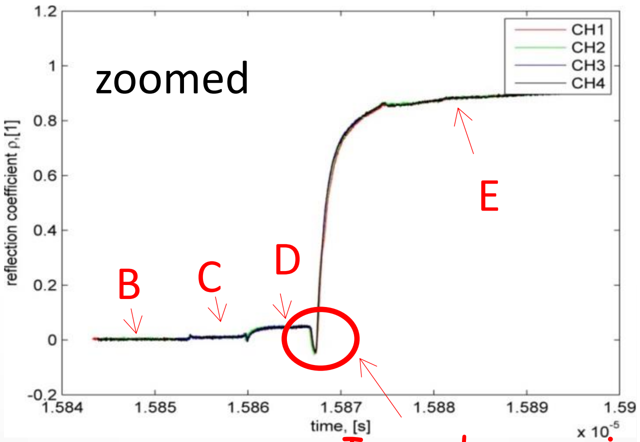
Ethernet 3

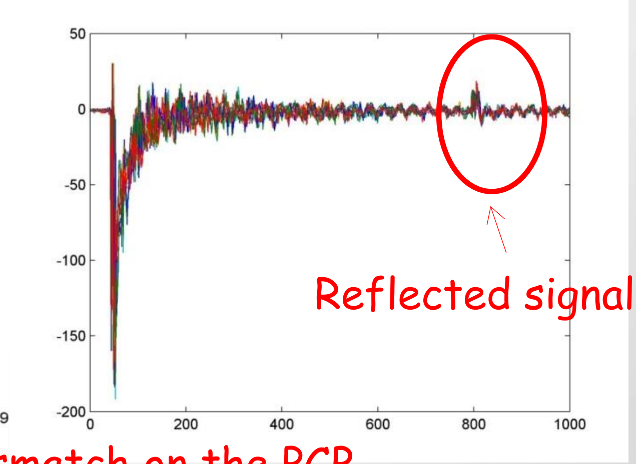
Tests of the system were done with beam at PHIL (photoinjector beamline at LAL) in Oct. 2014 before installation at ATF2

System Impedance Matching



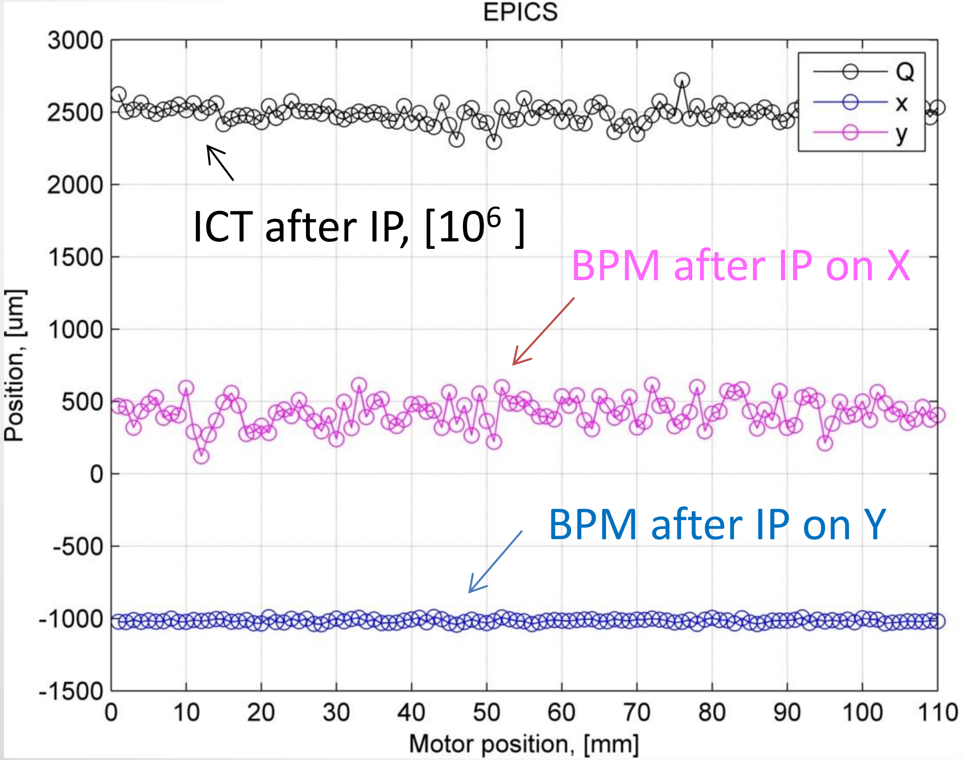






Impedance mismatch on the PCB

Information from ICT and BPMs

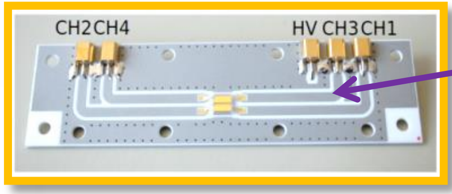


- ICT correction and beam position jitter (4-6 µm) can be taken into account in data analysis
- We read the data from Epics via SSH, but it is possible to use Labca to get data directly from Matlab
- In the future we can also input data from DS to the Epics system

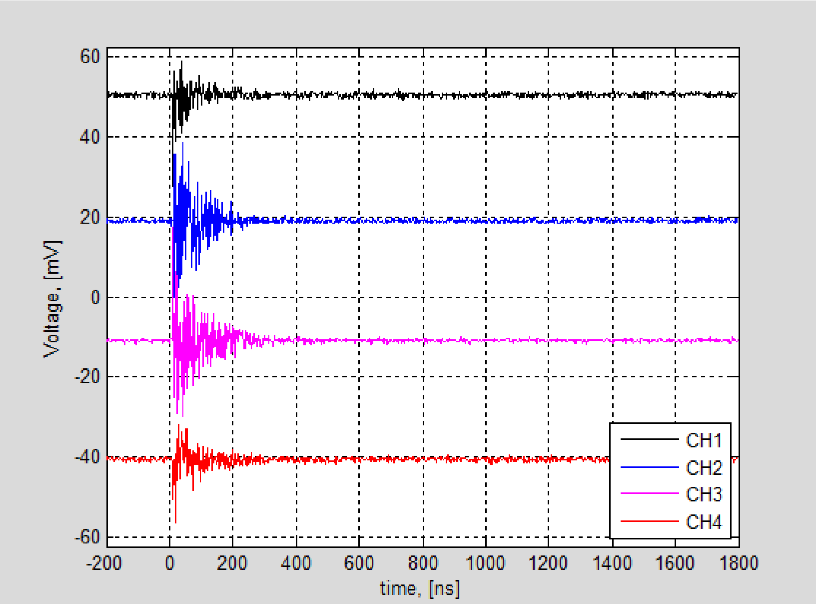
Characterization of Diamond Sensor (DS)

- Lower limit of DS : pick-up study
- Higher limit of DS : linearity study

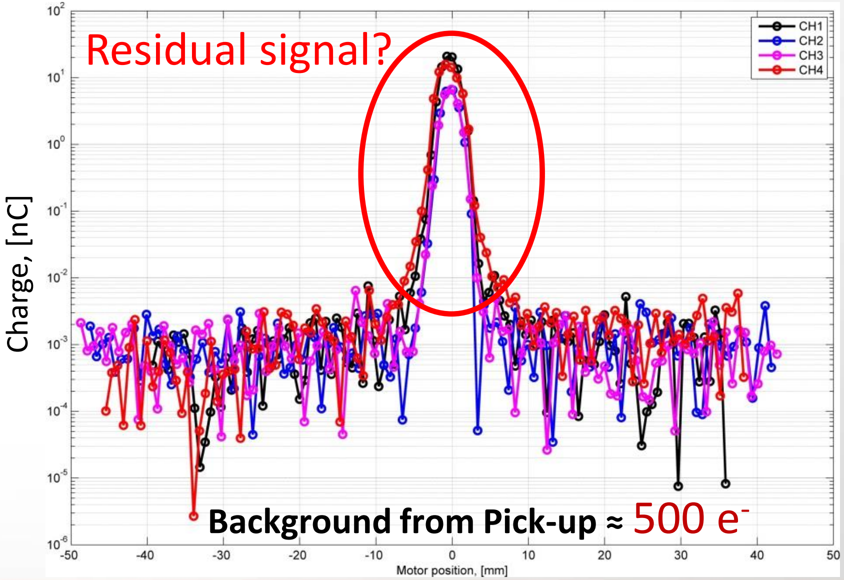
Signal Pick-up Study



Signal pick-up by the strip lines on the PCB was observed as the PCB is not shielded



Pick-up scan w/o applying HV on DS



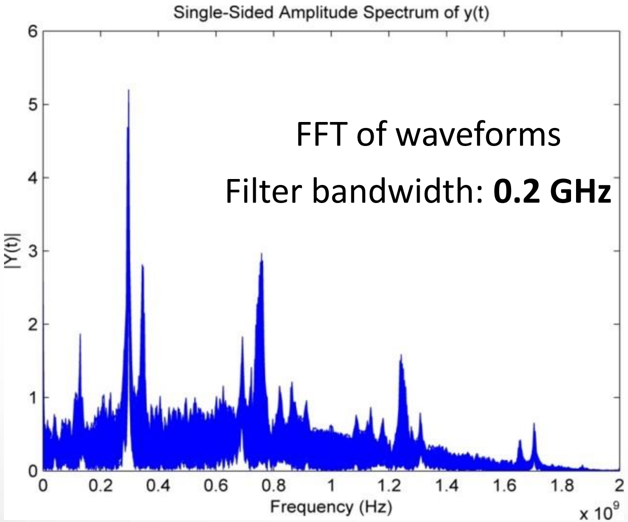
Signal Pick-up Study

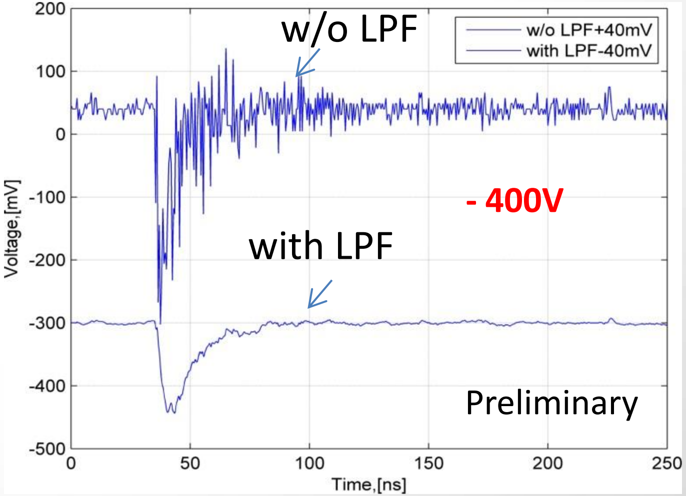
Effects:

- Prevent us to see the real waveform (not able to see the small signal of backscattered particles from DUMP)
- Increased the background level (systematic error) for beam halo and Compton signal measurement

Solutions:

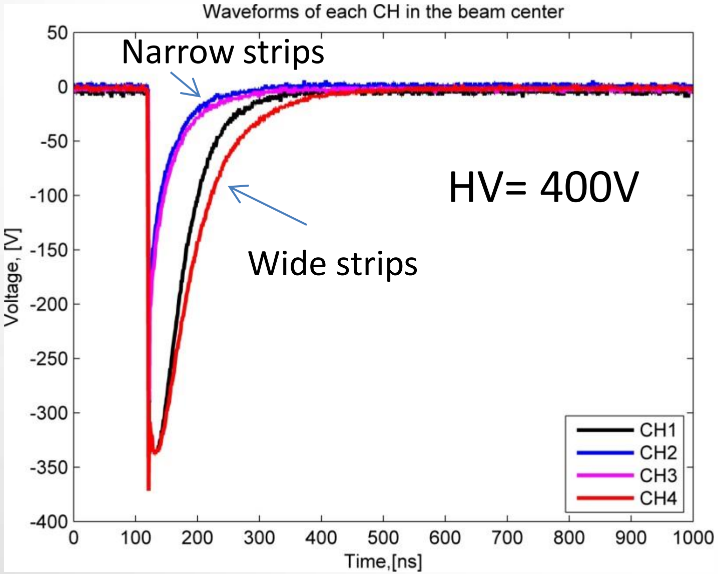
- Low Pass Filter (LPF) in data analysis
- Shielding of PCB

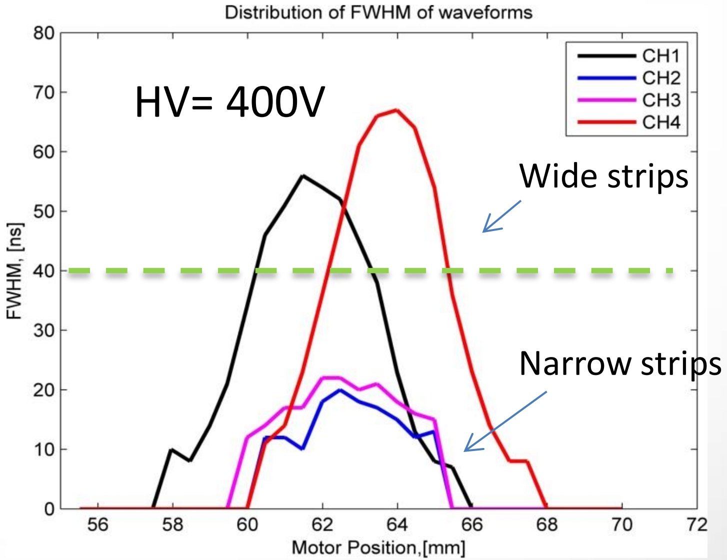




Charge Collection Time

- Decreased E in DS due to voltage drop on the 50Ω -> longer charge collection time needed





Typical life time of e^-h pairs:

$\tau_{e,h} \approx 40$ ns

- Modeling of diamond sensor signal formation in extreme conditions

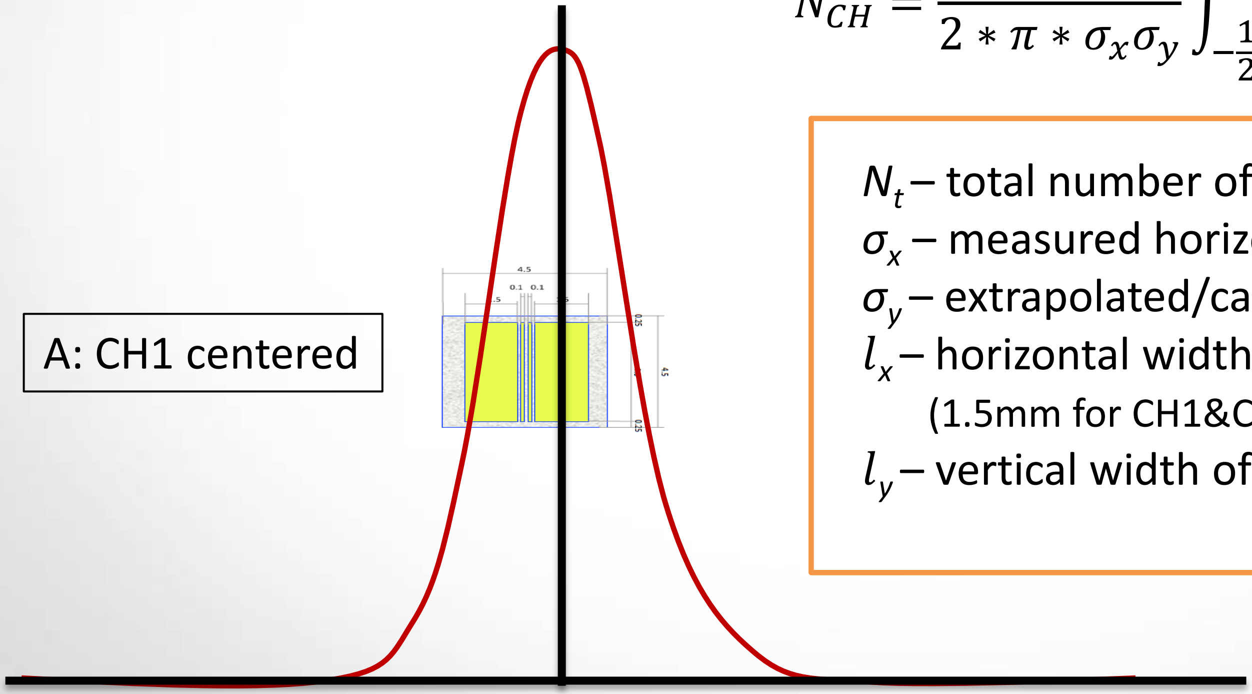
-> presentation of V. Kubytskyi

Linearity of DS Response

Number of e⁻ intercepted on each channel:

$$N_{CH} = \frac{N_t}{2 * \pi * \sigma_x \sigma_y} \int_{-\frac{1}{2}l_x}^{\frac{1}{2}l_x} e^{-\frac{x^2}{2*\sigma_x^2}} dx \int_{-\frac{1}{2}l_y}^{\frac{1}{2}l_y} e^{-\frac{y^2}{2*\sigma_y^2}} dy$$

A: CH1 centered



N_t – total number of e⁻

σ_x – measured horizontal beam size

σ_y – extrapolated/calculated vertical beam size

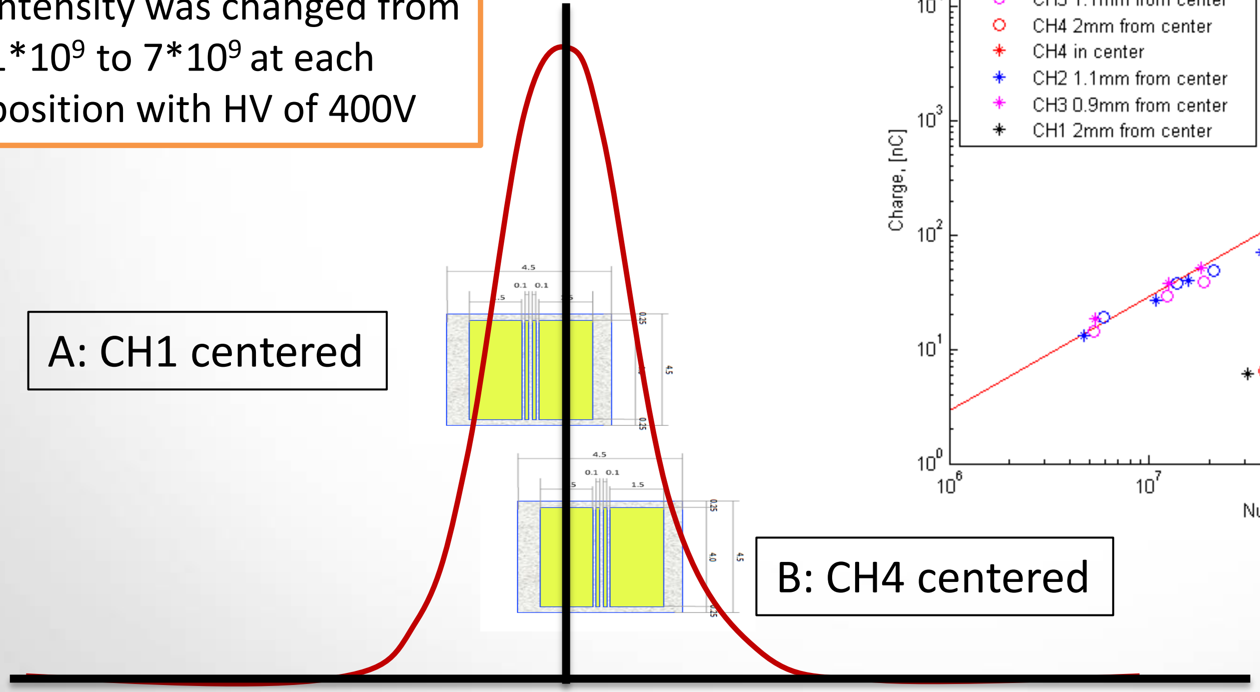
l_x – horizontal width of each channel

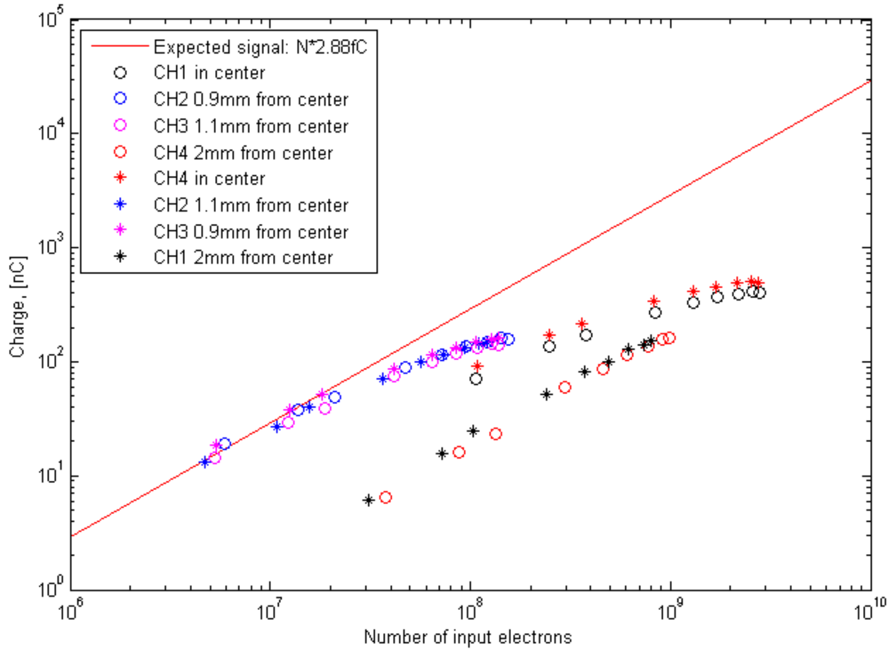
(1.5mm for CH1&CH4 and 0.1 mm for CH2&CH3)

l_y – vertical width of each channel (4mm)

Linearity of DS Response

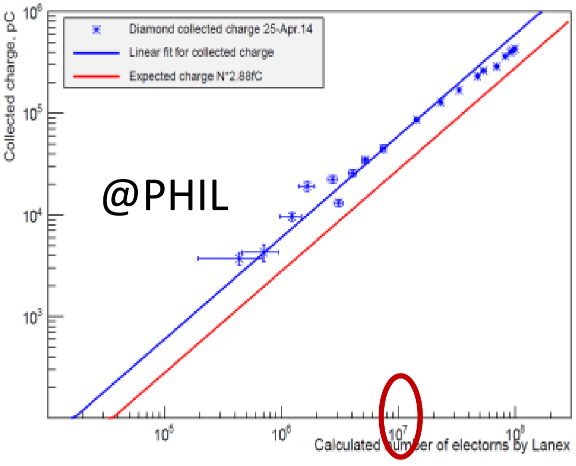
The DS was positioned at location A and B, the beam intensity was changed from $1*10^9$ to $7*10^9$ at each position with HV of 400V



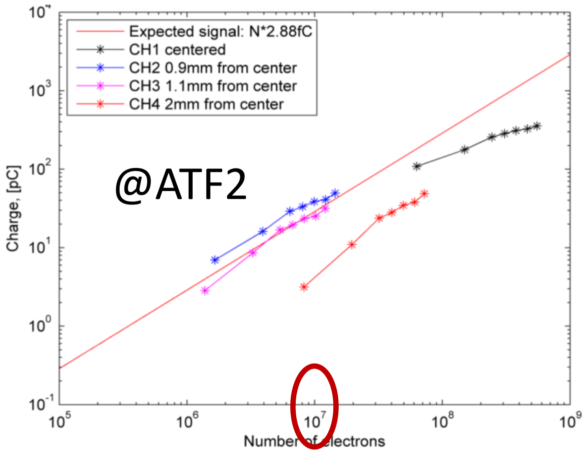


Linearity of DS Response

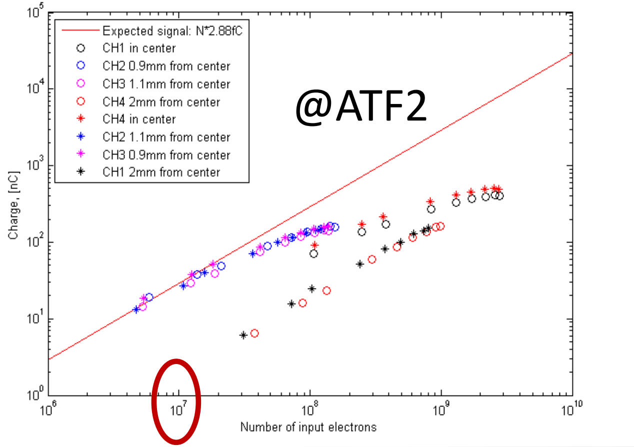
Tests in Air @PHIL (25-04-2014)



BX100BY1000 Optics (20-12-2014)



BX10BY0.5 Optics (12-12-2014)

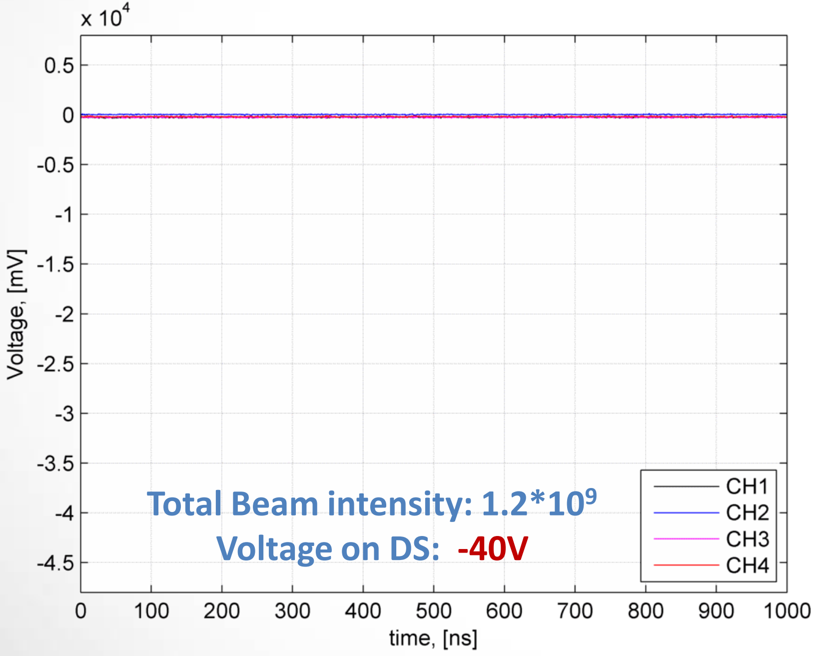


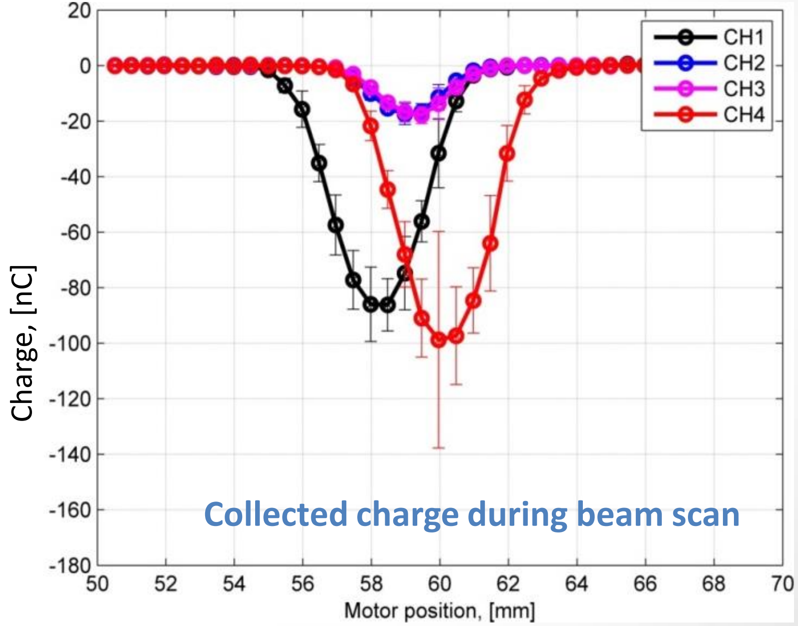
- **Linear response up to 10^7 is confirmed**
- **CH1 and CH4 has different behavior in the beam core and away from beam core -> might due to capacitive coupling (under investigation)**

Measurements Using DS

- Beam core measurement
- Beam halo measurement

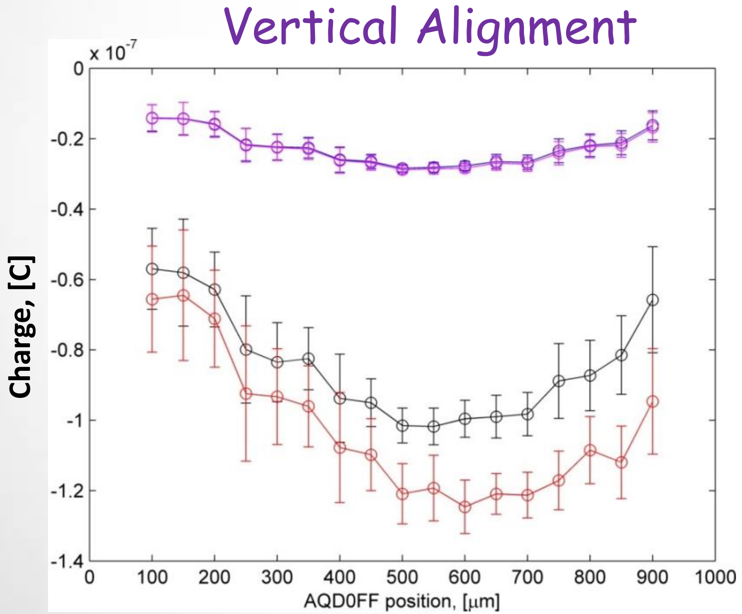
Waveforms and Integrated Charge during Scan



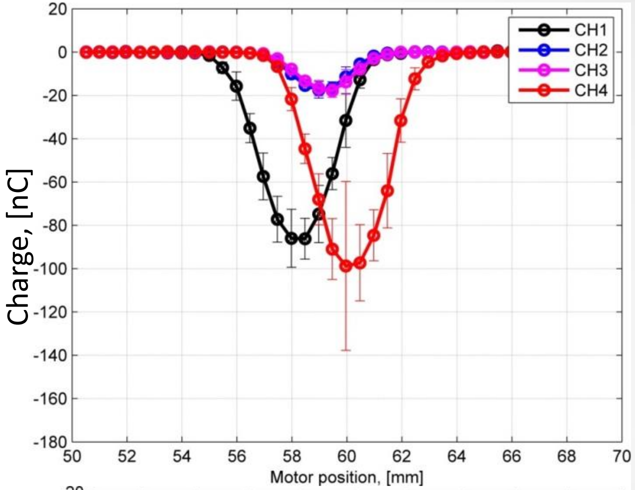


- The beam core is scanned by DS by applying low voltage
- The charge of waveform at each position is integrated to get the distribution

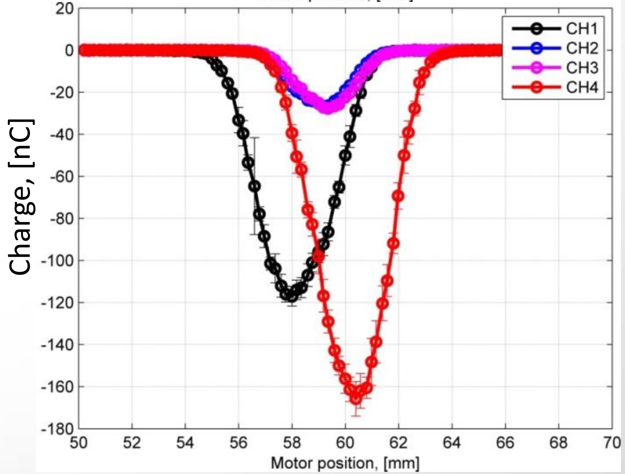
Beam Core Scan



Before Alignment



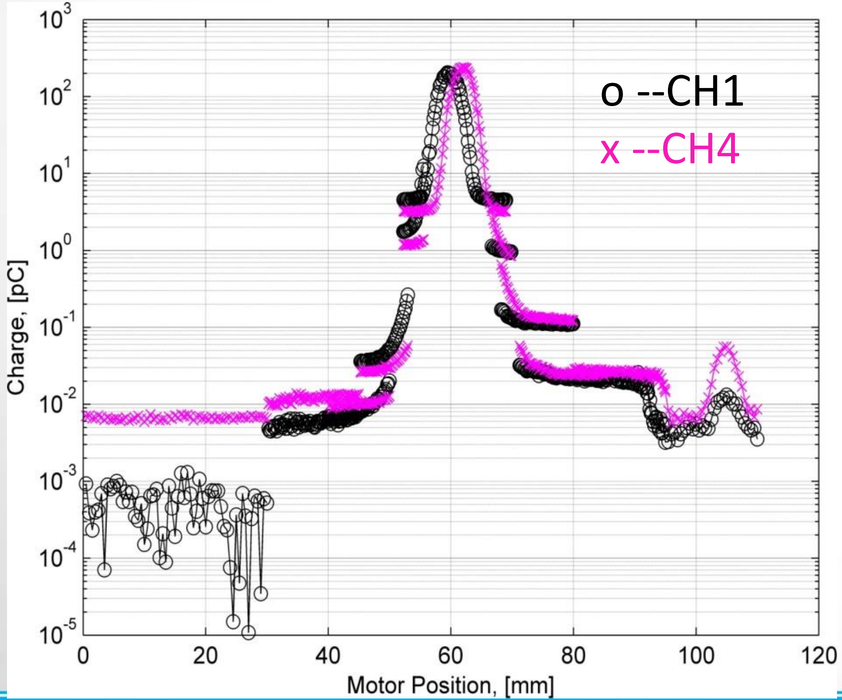
After Alignment



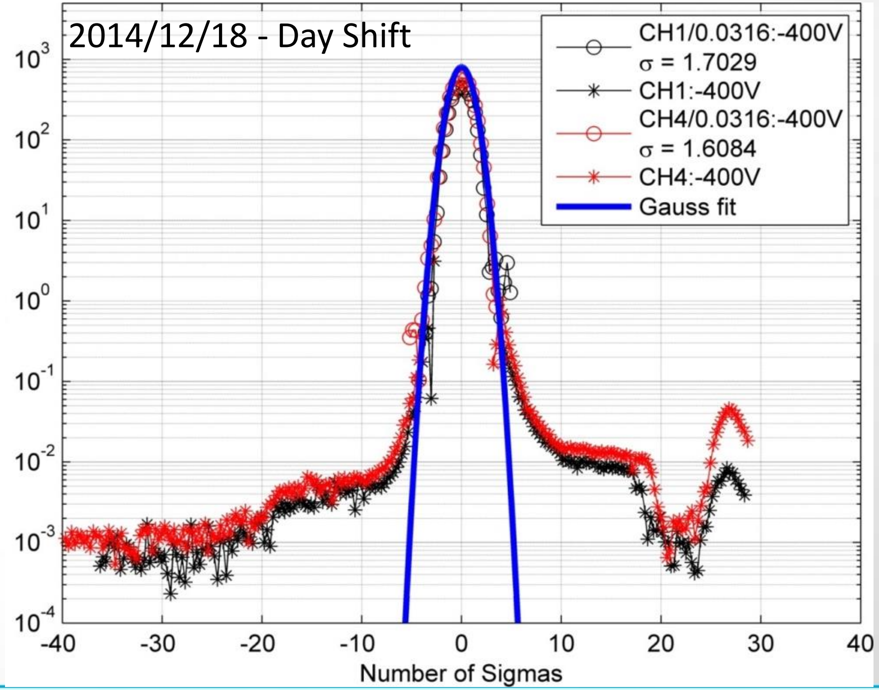
We move the AQD0FF magnet mover vertically to find the max. charge collected on DS

Scope Vertical Range (VR) Setting

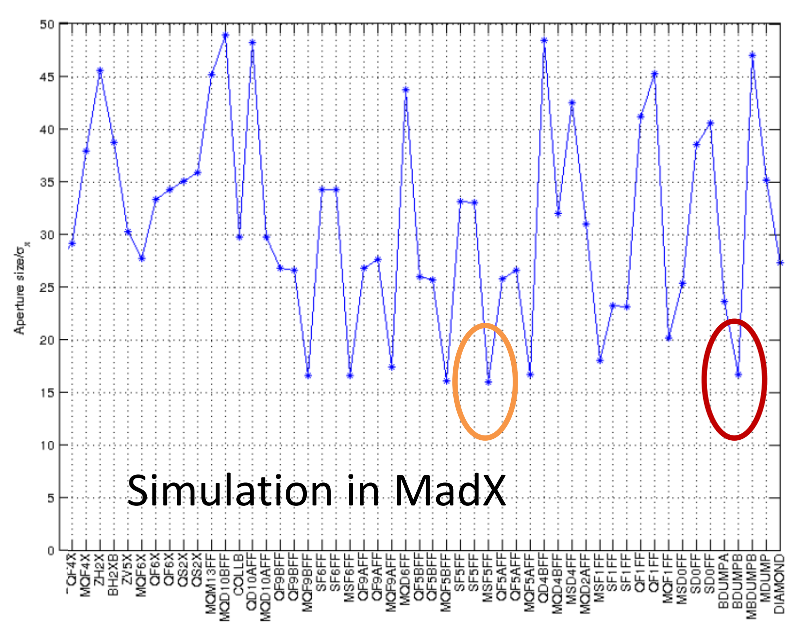
Set VR Manually:
<u>Change VR at each range</u>

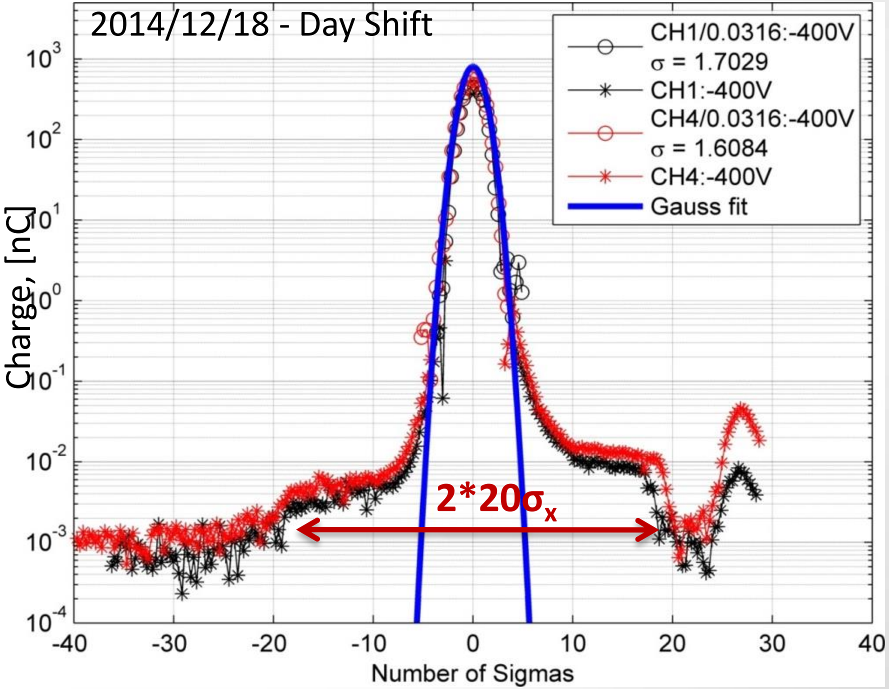


Set VR Automatically:
<u>Change VR at each point</u>



Cut of Beam Halo



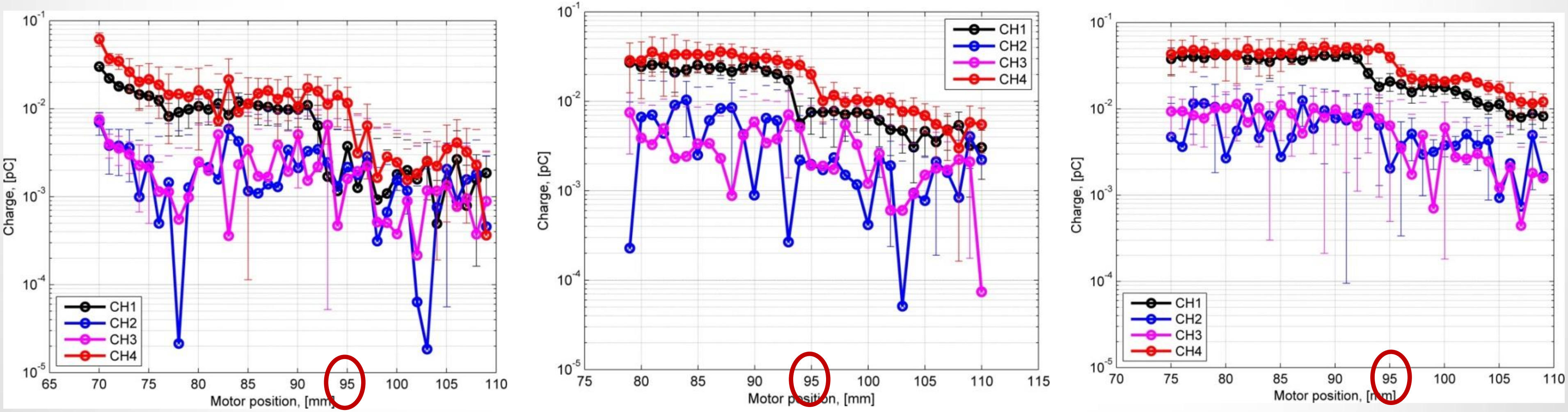


	Horizontal cut by apertures, [σ_x]		
	MSF5FF	BDUMPB	DS
BX10BY0.5	16.01	16.70	27.26

which one corresponds to the cut measured at DS location?

Cut of Beam Halo

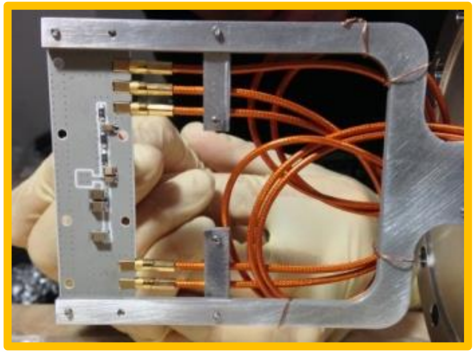
BDUMP Strength increasing



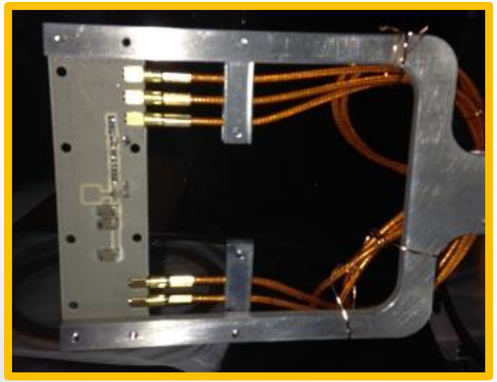
Change BDUMP bending magnet strength, the edge of cut doesn’t change, it stays at around 95mm-> Cut of beam halo should be given at the BDUMP exit

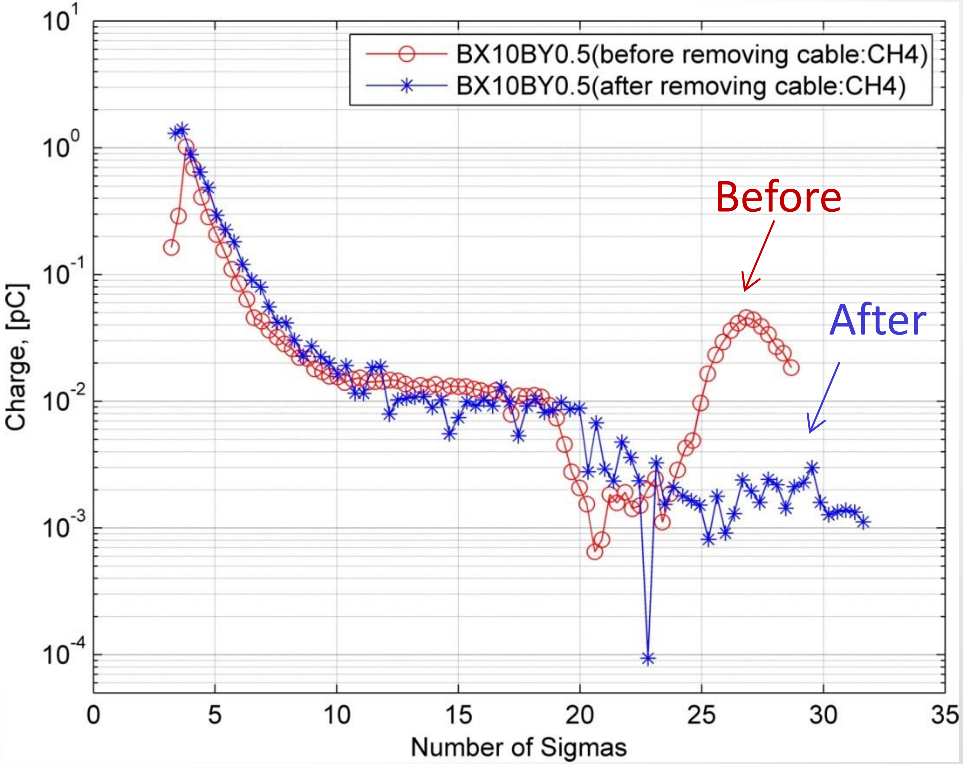
Issue with cables

Before fixing

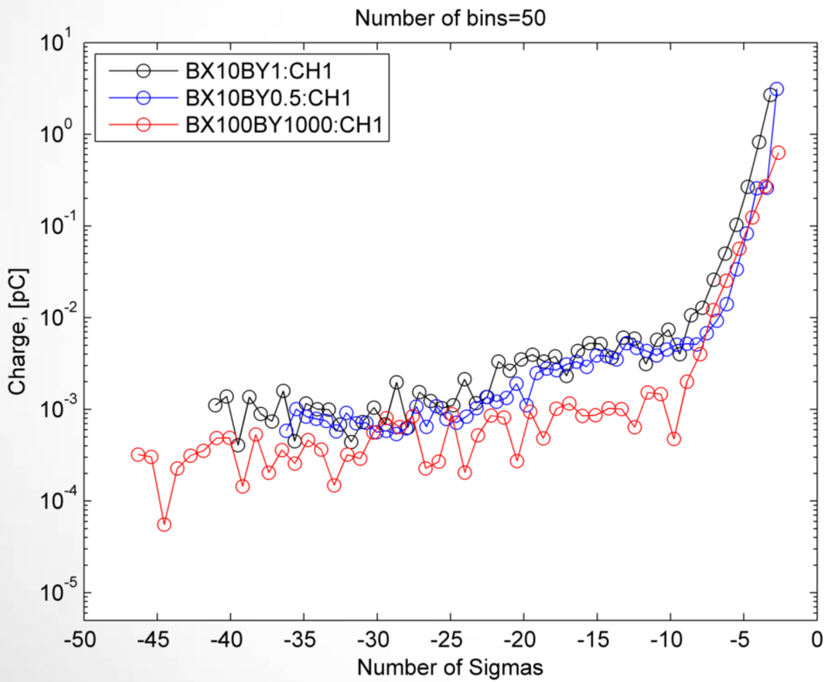


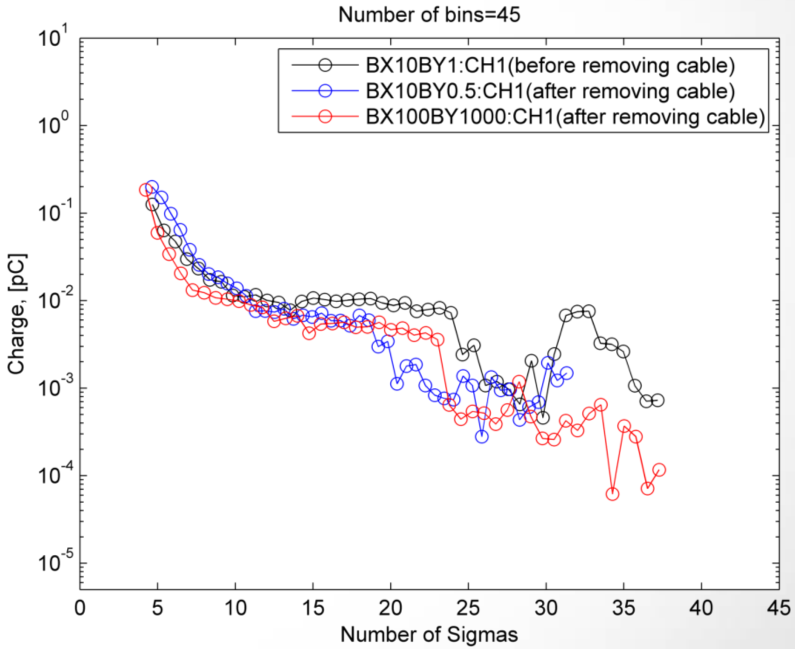
After fixing





Beam Halo Distribution for Different Optics





- **No obvious change observed in the horizontal beam halo distribution between BX10BY1 and BX10BY0.5 optics**
- **For BX100BY1000 optics, beam halo is less than other optics**

Upgrade Aspects for DS

- Temperature probes on the PCB
- Shielding for EM pickup
- Avoid impedance mismatch on the PCB
- Fixing of in vacuum cable to reduce background
- Dealing with coax cable outgasing to enable usage in very strict vacuum conditions
- Simulation of charge collection in diamond, preparing our own diamond sensors at LAL

Conclusions and Prospects

❑ DS with large dynamic range

- Lower limit: 10^2 of pick up level
  - ➢ LPF in data analysis
  - ➢ Shielding of PCB
- Upper limit: linear range up to 10^7
  - ➢ Use narrow strips for beam core measurement
  - ➢ Can be increased by adding smaller resistor (<50 Ohm)
  - ➢ Signal in non linear range can be calibrated

❑ Beam core and halo measurement

- ➢ Horizontal beam core and halo measurement with 10^6 dynamic range achieved
- ➢ Beam halo distribution were compared for different beam optics
- ➢ 2nd unit of DS (with upgrades) will be installed vertically in *April 2015*
- ➢ Further study to check the possibility of measuring Compton recoil electrons is ongoing

Thank you!

Back up …

Main Goal for 2014 Run

Commission and characterize DS

November Run (5 shifts)

- **Pick-up study**
- Study of correlation between DS, ICT and BPM data
- Beam core and halo scan with different HV
- Background study (background signal from cables observed)
- **Vertical alignment (VA)** applied
- Tests of auto vertical range setting

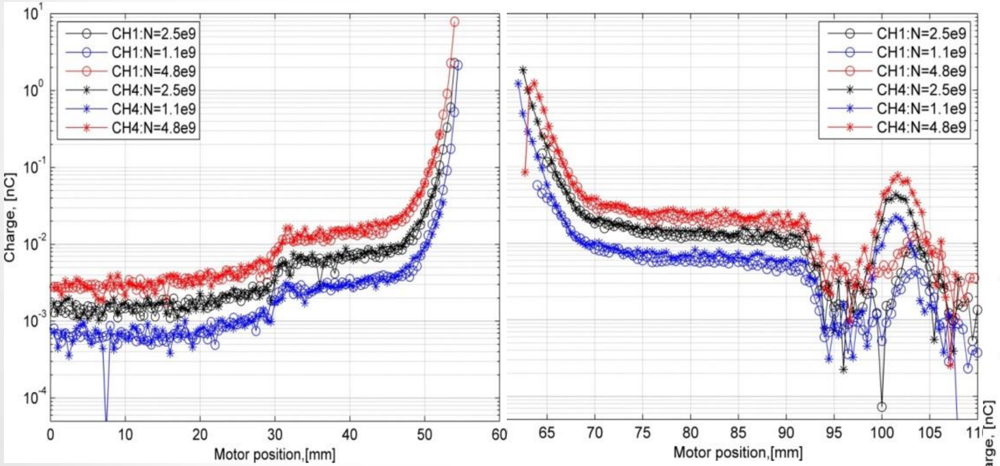
Initial measurement of horizontal beam halo distribution

December Run (6 shifts)

- **Charge Collection Efficiency (CCE) study** with attenuators(with different HV)
- **Beam halo scan for different beam intensity** ($1.1*10^9$,$2.5*10^9$,$4.9*10^9$)
- **Beam halo scan for different beam optics**
- Study the background from cables
- Study the cut of beam halo by upstream apertures
- First try to measure Compton recoil electrons

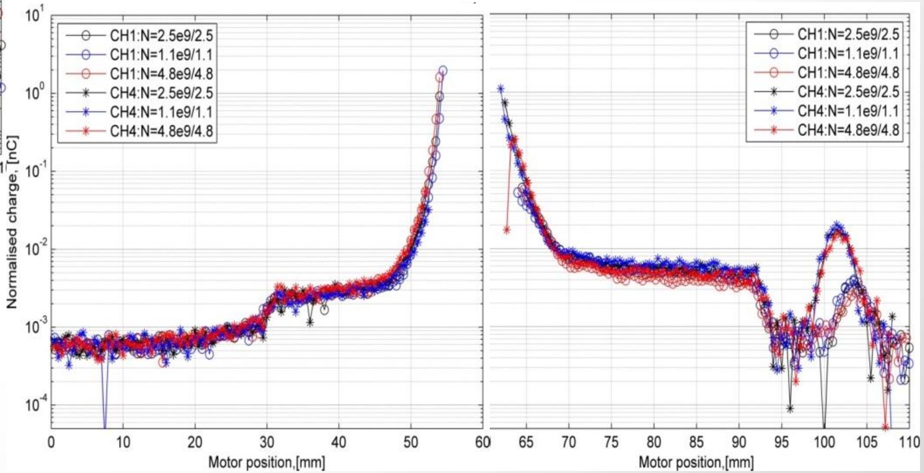
Beam Halo Distribution for Different Beam Intensity

Before Normalization



Measurements were done for BX10BY0.5 optics with N= 1.1*10^9,2.5*10^9,4.9*10^9

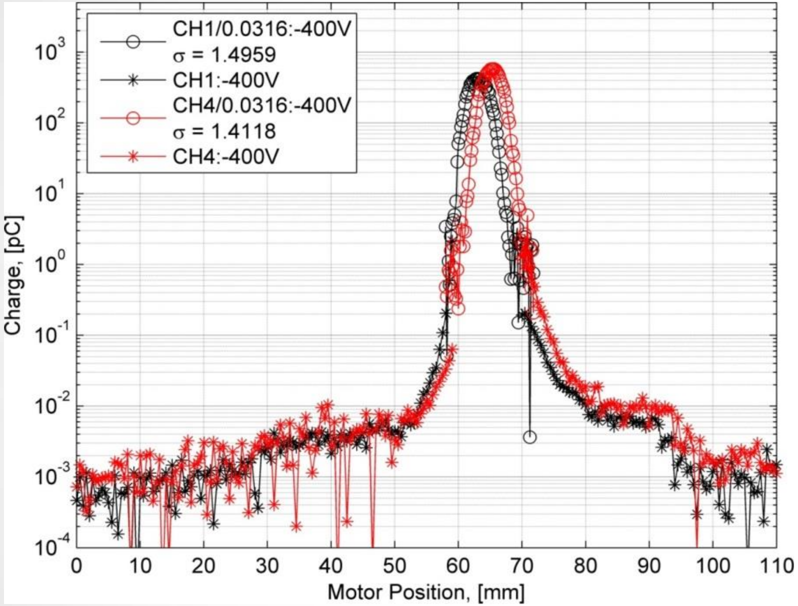
After Normalization



- No change in horizontal beam halo distribution was observed

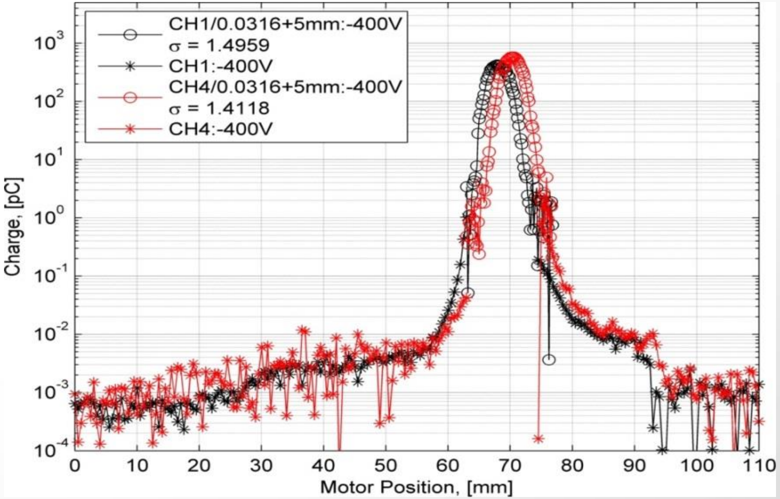
-> We expect to see the changes on the vertical beam halo distribution

Cut of Beam Halo

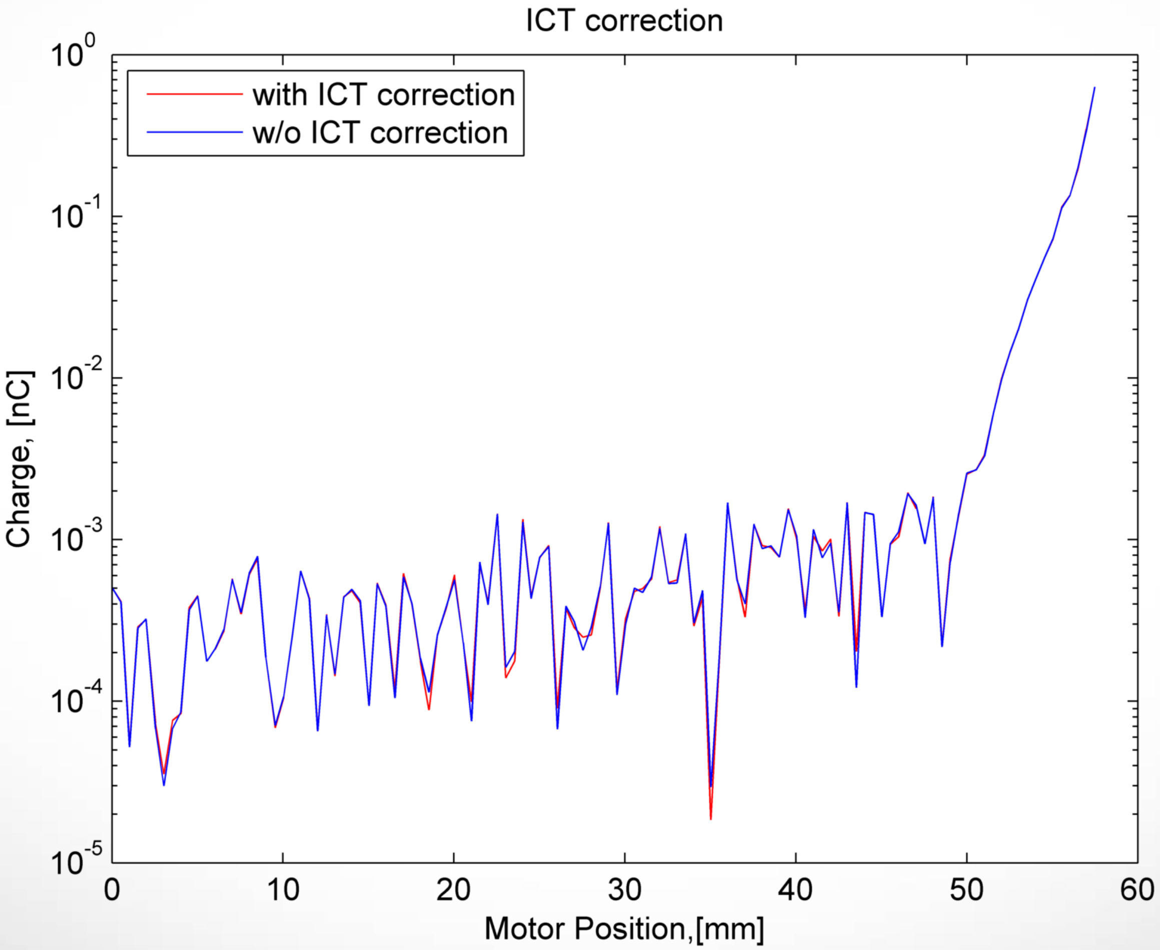


QF9AFF horizontal: 0 mm

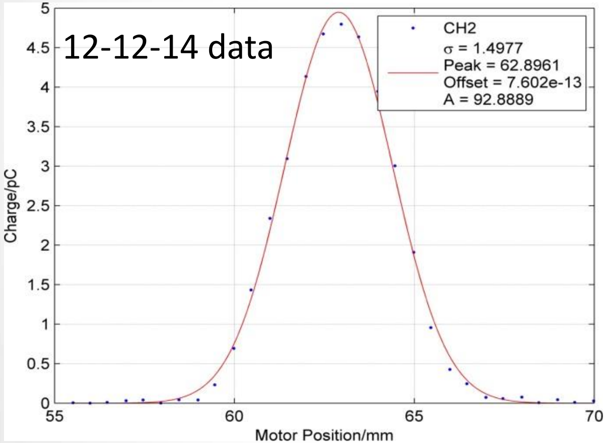
QF9AFF horizontal: -3 mm

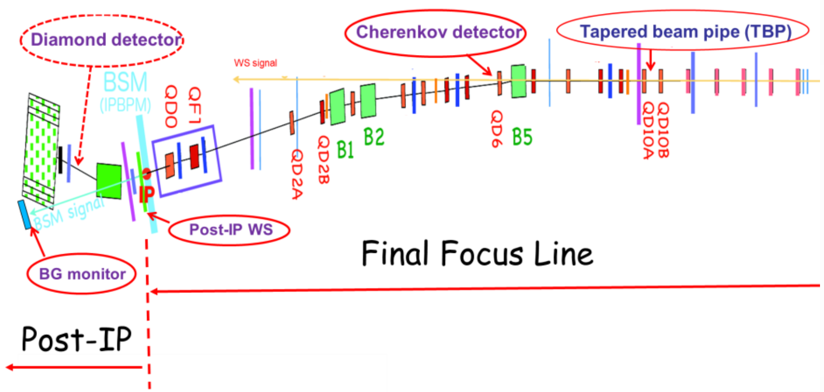


Change beam horizontal positon at QF9AFF, the edge of cut still stays at around 95mm on HE side


ICT correction
with ICT correction
w/o ICT correction
Charge, [nC]
Motor Position,[mm]
10^0
10^-1
10^-2
10^-3
10^-4
10^-5
0
10
20
30
40
50
60

Beam Size Verification

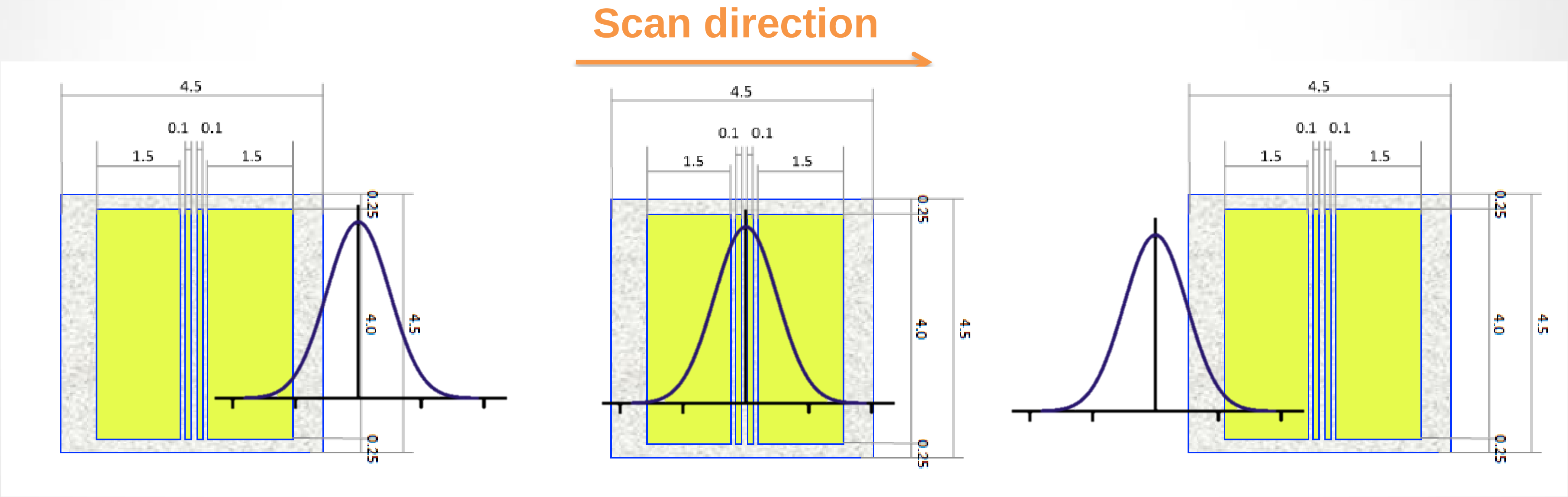




Vertical beam size is extrapolated from the Post-IP WS measured beam size

	BX10BY0.5 (12-12-14)	
	σ_x (m)	σ_y (m)
Post-IP WS calculated	1.564e-04	2.892e-04
Post-IP WS measured	2.174e-04	5.57e-04
DS calculated	1.394e-03	1.787e-03
DS expected	1.938e-03	3.442e-03
DS measured (CH2)	1.498e-03	Non

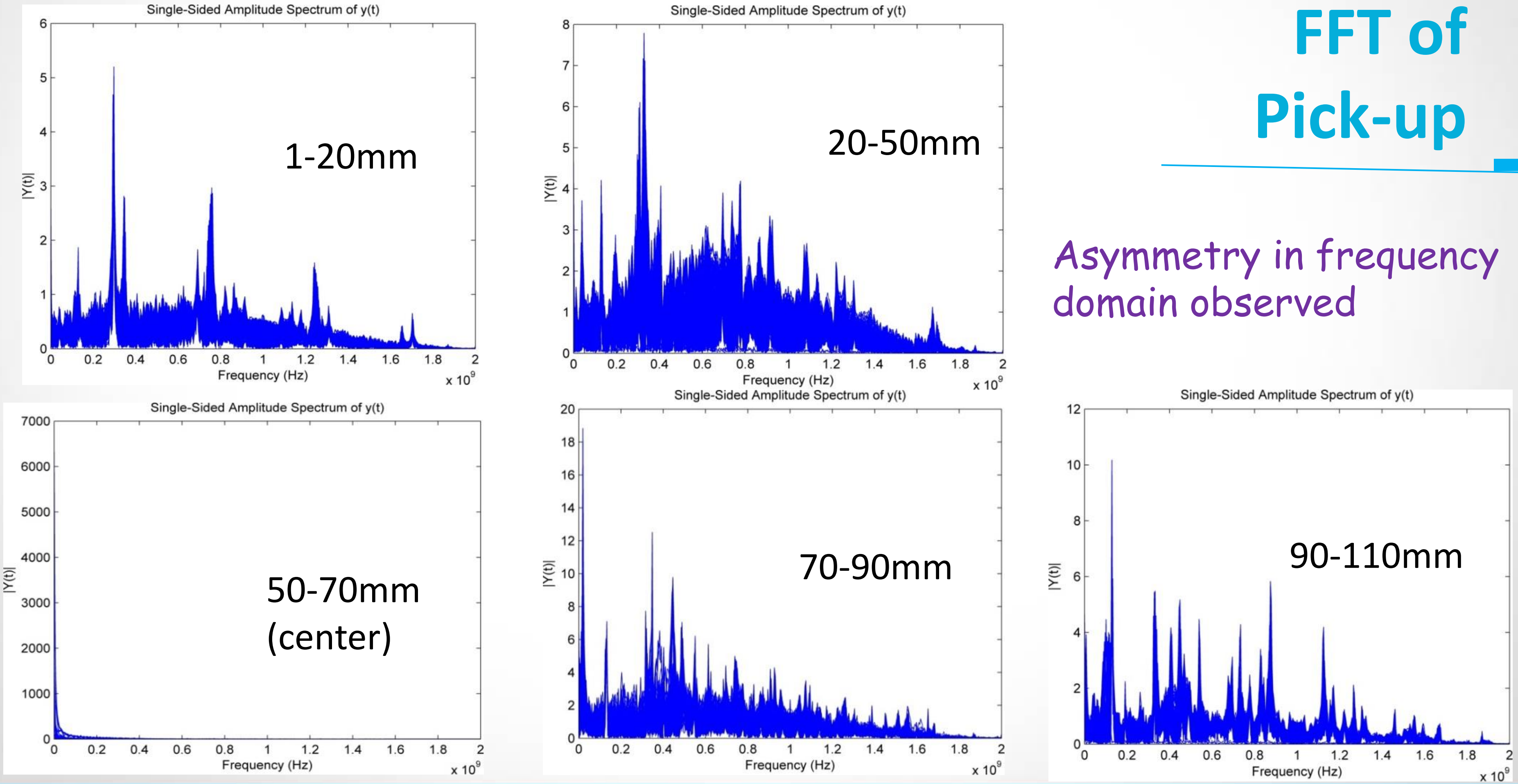
Beam Core Scan



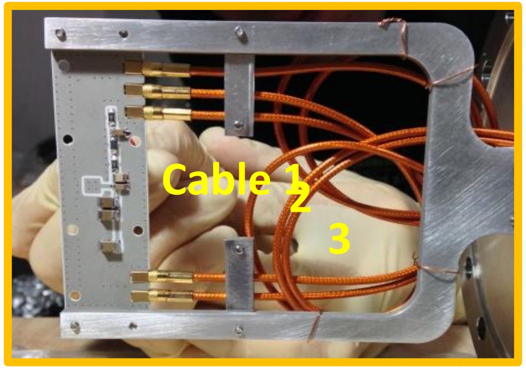
- Signal at each channel is a convolution of beam (Gaussian) with strip (rectangular shape)
- Fit function: F(d1,a1,b1,s1) = d1+a1*(**erf**(((x+0.75-b1)/(sqrt(2)*s1)))-**erf**(((x-0.75-b1)/(sqrt(2)*s1))))

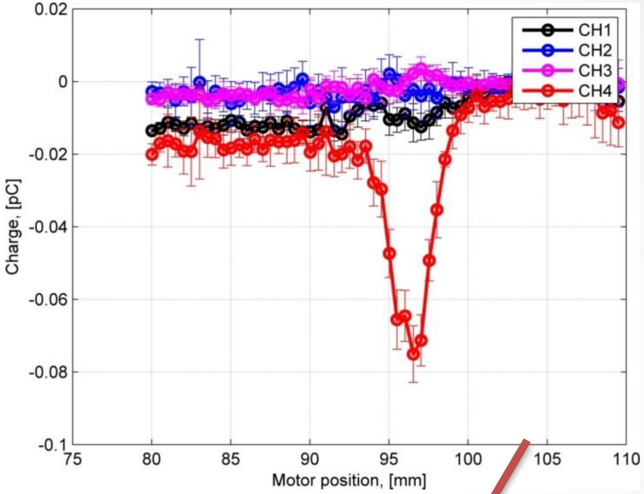
FFT of Pick-up

Asymmetry in frequency domain observed

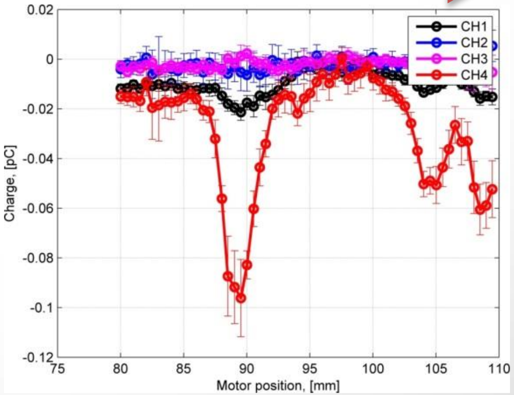


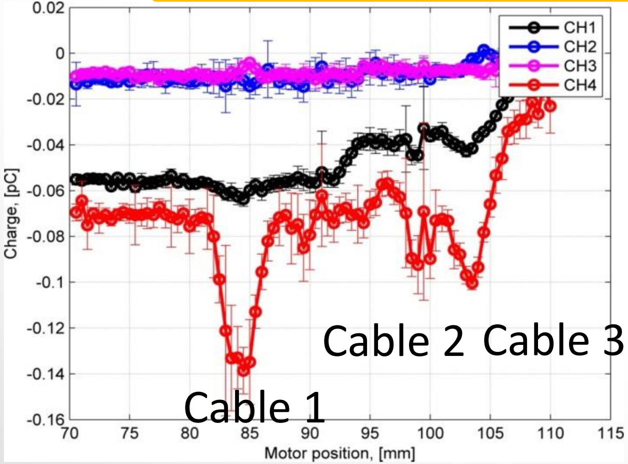
Background from cables



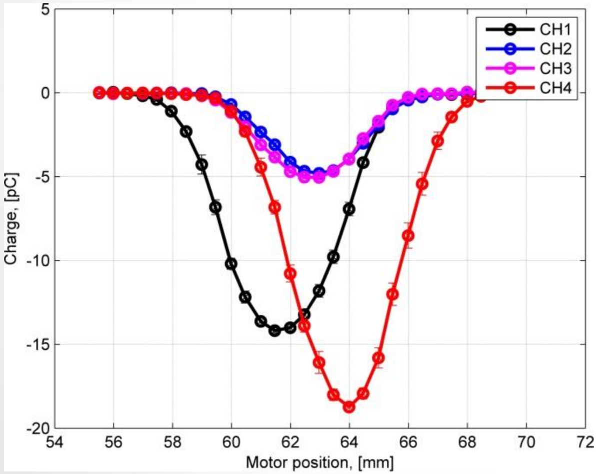


Move the beam step by step





Expected signal (400V)

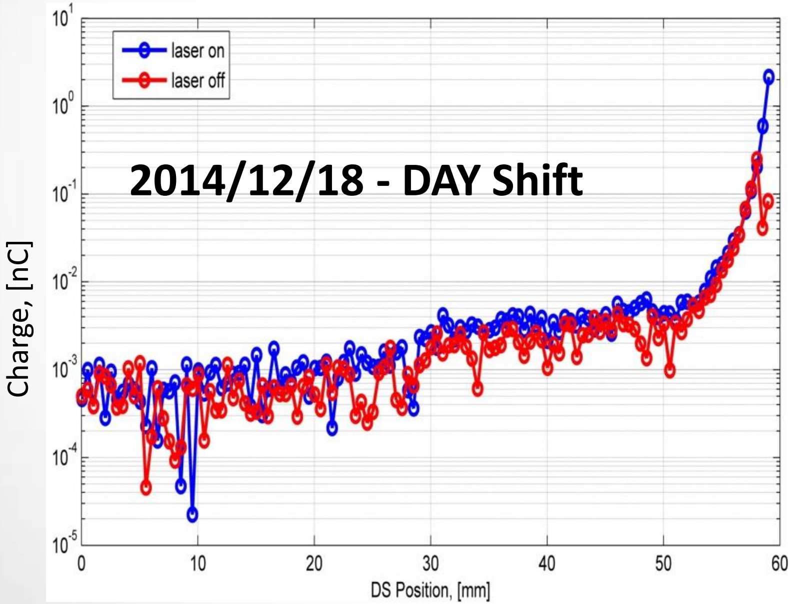


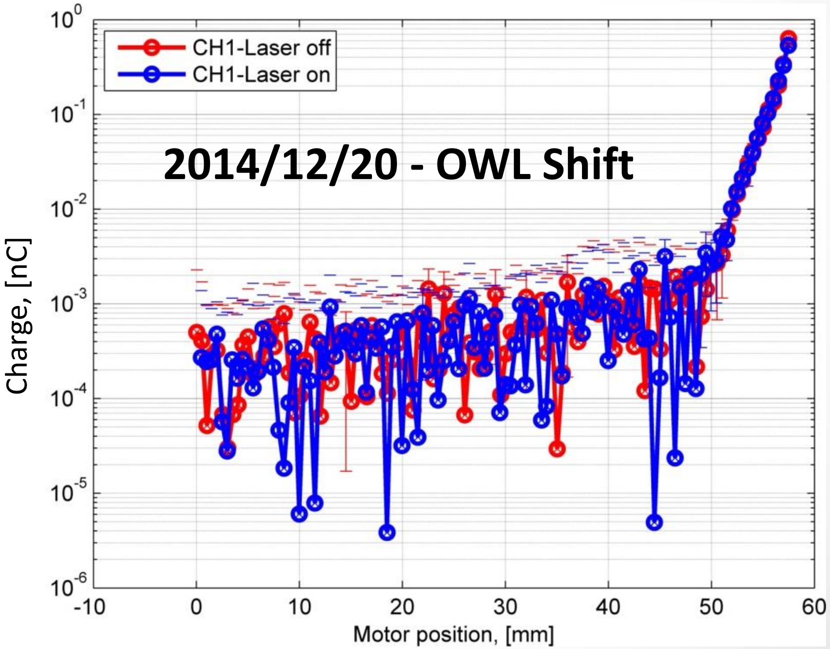
	CH1	CH2	CH3	CH4
Measured σ_x	1.70 mm	1.49 mm	1.53 mm	1.61 mm
Ratio of collected e-	13.34%	1.04%	1.02%	14.07%
Expected full charge (3fC/MIP)	1.88µC	147.21nC	143.68nC	1.98µC
Max. charge collected	442.72nC	151.79nC	158.11nC	600.8nC
Corresponding CCE	23.55%	101%	101%	30.35%

Data taken with 30dB attenuator
Total e- number: $4.8*10^9$

Scan_Run60_12-12-2014_143616_core_400V

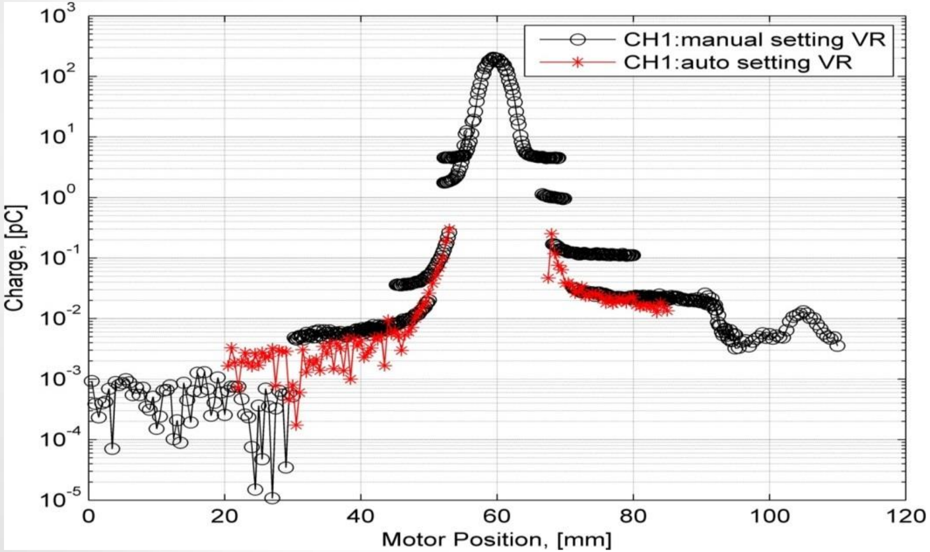
COMPTON RECOIL ELECTRONS STUDY

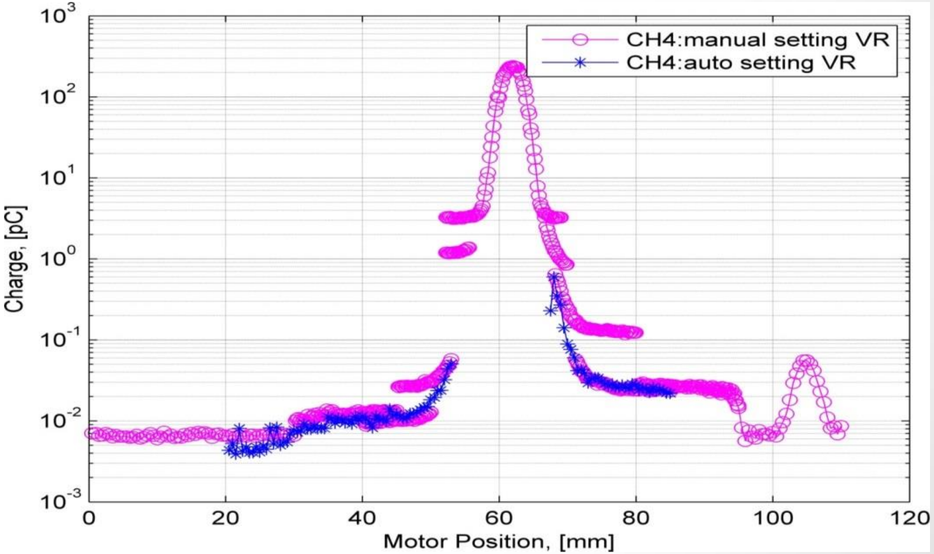




- Perform simulations in CAIN and Mad-X for different optics
- Compare the estimated signal level with the background/pick-up signal level

Scope Vertical Range Setting





- The sensitivity of DS to beam halo depends on the resolution of scope, which can be adjusted by changing the vertical range (VR);
- We have tried to set the VR manually and automatically by program.