Beam Halo Measurement using Diamond Sensor at ATF2

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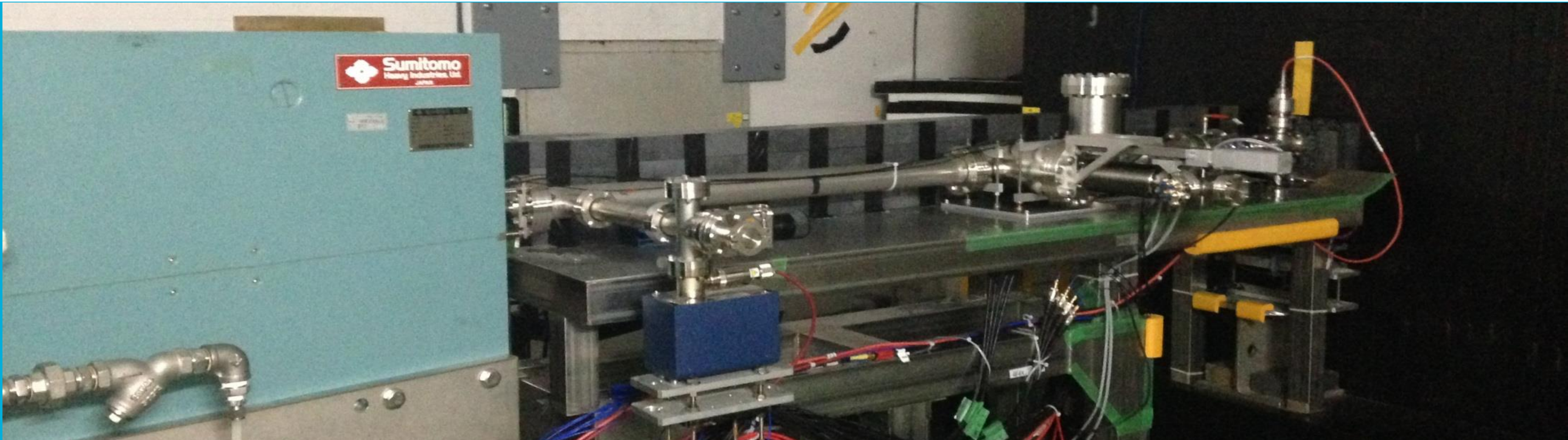
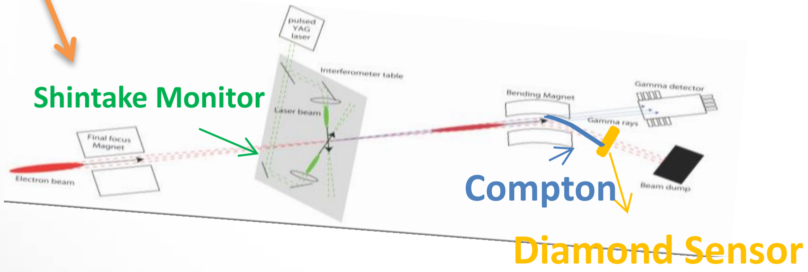
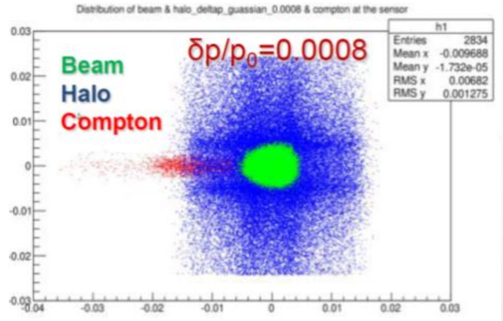


Outlines

- Motivations
- Issues of beam halo @ATF2
- Main Goals for 2014 Run @ ATF2
- Characterization of Diamond Sensor
- Beam Halo Measurements
- Conclusions and Prospects

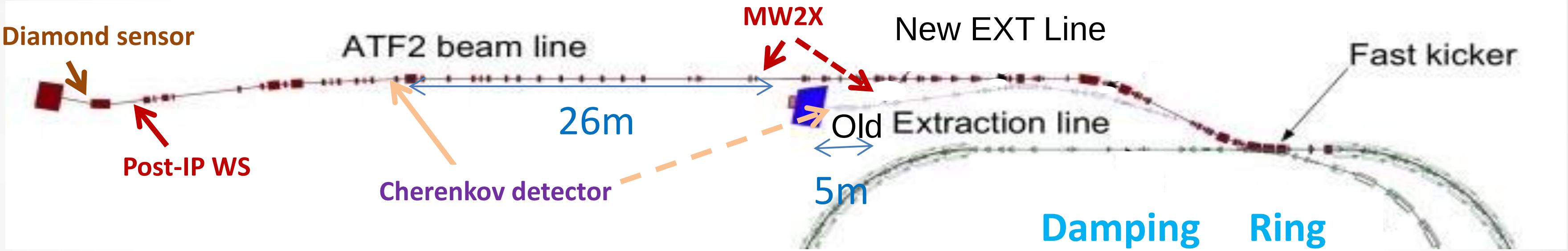
Motivations



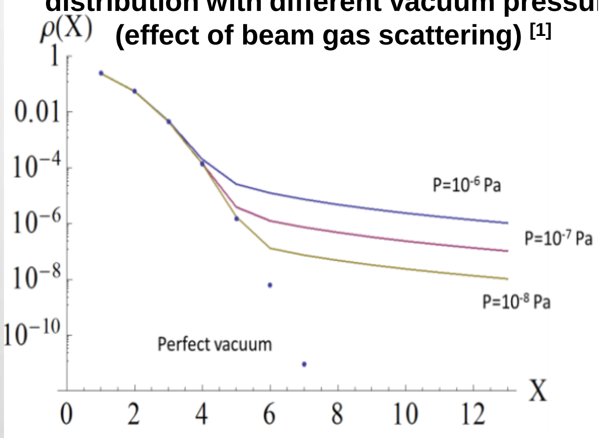


- ➢ ***Beam halo transverse distribution unknown → investigate halo model***
- ➢***Probe Compton recoil electron (prepare future investigations of higher order contribution to Compton process)***

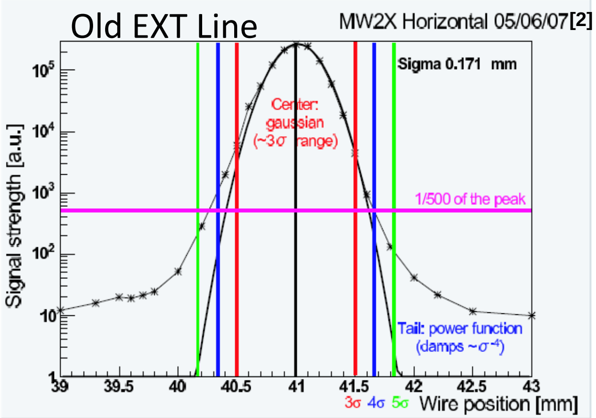
Issues of Beam Halo @ATF2



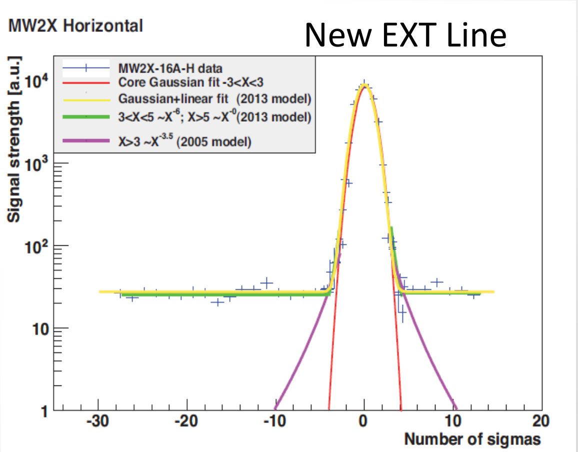
Analytical estimation of horizontal beam halo distribution with different vacuum pressure (effect of beam gas scattering) [1]



[1] D. Wang et al., arXiv:1311.1267v2(2014)



[2] T. Suehara et al., arXiv:0810.5467v1(2008)

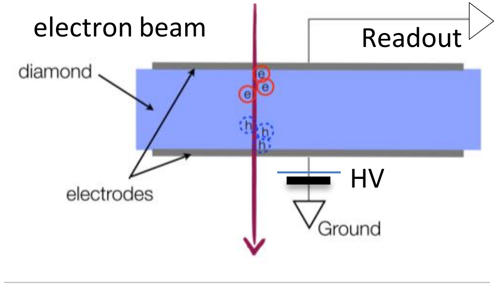


[3] S. Liu, N. Fuster et al., ATF-14-01 report

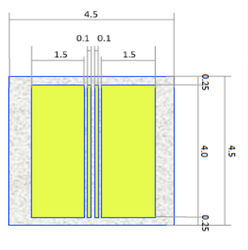
Diamond Sensor (DS) Characteristics

ADVANTAGES

- ***Large band-gap⇒low leakage current***
- ***High breakdown field***
- ***High mobility⇒Fast pulse (several ns)***
- ***Large thermal conductivity***
- ***High binding energy⇒Radiation hardness***

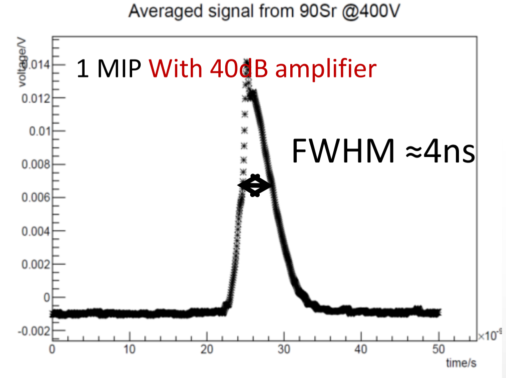


Charge generated by 1 MIP for 500 µm diamond (with 100% CCE): 2.88 fC



4.5mm X 4.5mm X 500µm

Dynamic range: 1 ->10^8 e^-



	Total N	Min.～Max. N/mm² @ DS	Charge signal/mm²
Beam	10^{10}	6.16×10^8	1.6887µC
Halo	10^7	1.14×10^4～2.24×10^4	31.236pC～61.376pC
Compton	28340	30～520	82.2fC～1.4284pC

Wire Scanner

Signal: Bremsstrahlung photons

Dynamic range limited by:

- Background level
- 14 bit ADC counts
- PMT high voltage

Background sources:

- Beam halo hitting the beam pipe
- Beam halo hitting another wire

Data Taking :

- Difficult to combine data
- Difficult to avoid beam position jitter

Diamond Sensor

Signal: *Ionized e- hole pairs*

Dynamic range:

⇒ 1 ～ >10^8 e^- (adding amplifier or attenuator)

Possible background:

- *Beam halo hitting B-Dump bending magnet*

⇒ can be collimated by collimators upstream

-> N.Fuster's talk

- *Back-scattered neutrons from dump*

⇒ slow neutrons can be separated in time

- *Bremsstrahlung photons*

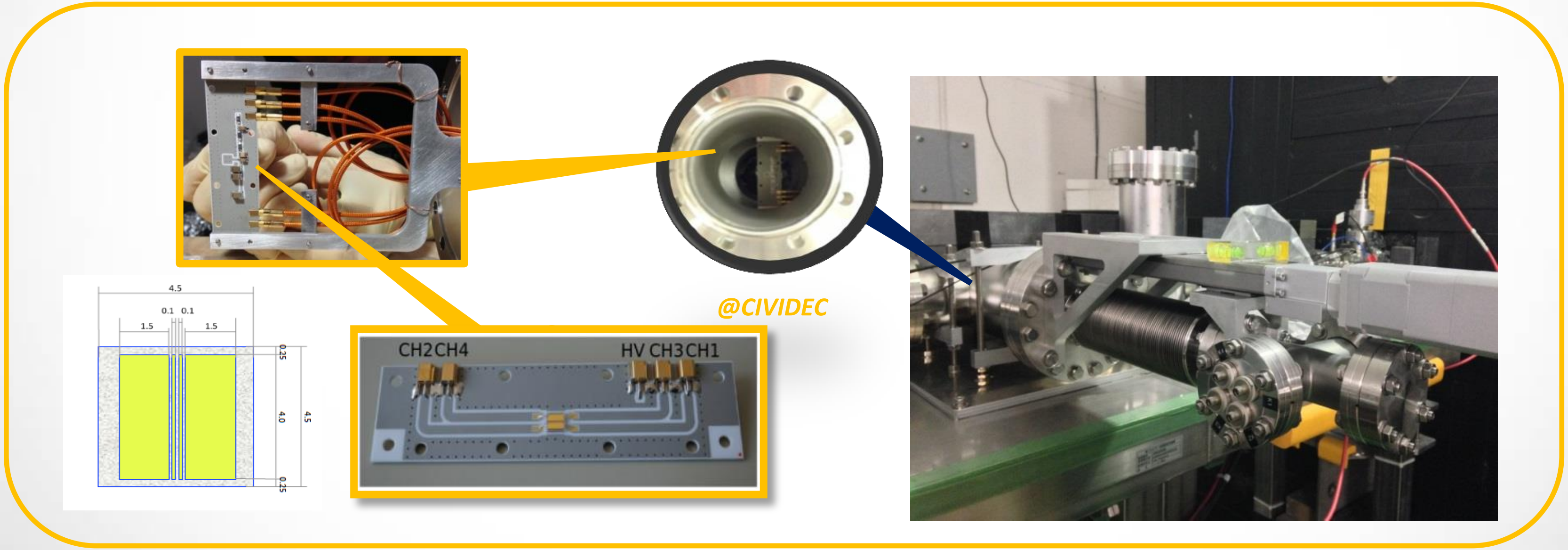
⇒ can be neglected?

Data Taking :

- *Different channel for beam core and halo*

⇒ possible to do overall scan

In Vacuum Diamond Sensor @ATF2

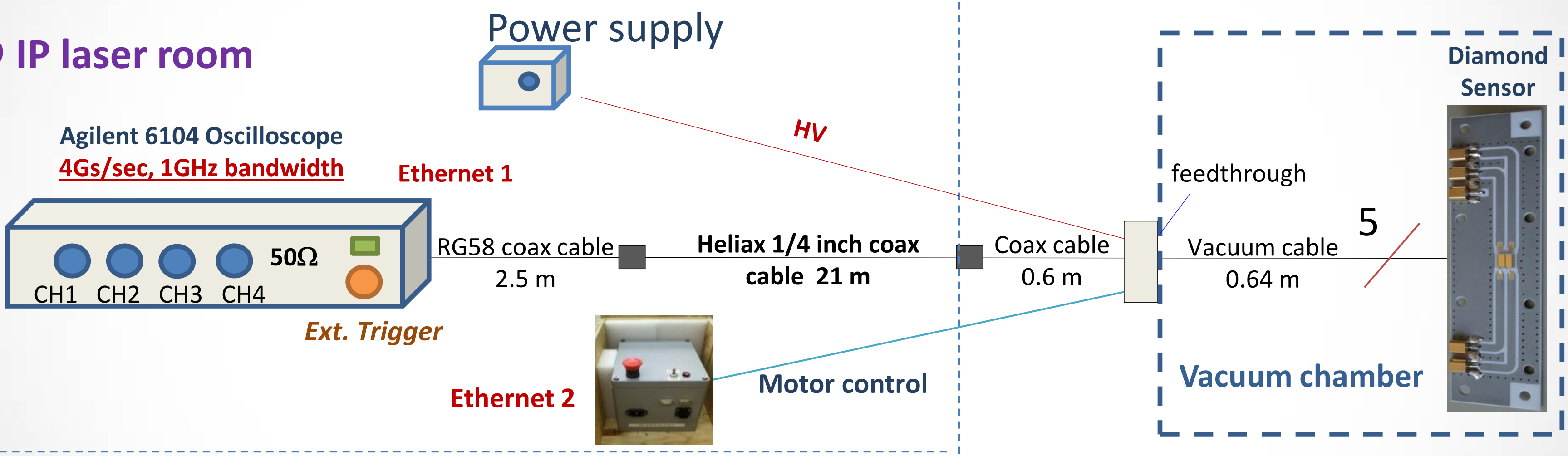


- The first Diamond Sensor is installed horizontally at ATF2 in Nov. 2014
- A second unit will be installed vertically in 2015 for vertical halo measurements

Data Acquisition System

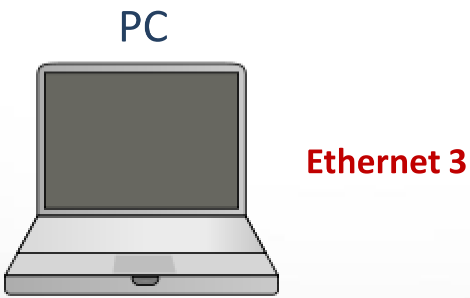
@ IP laser room

@ Post-IP



@ Control room

Data acquisition using Matlab



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

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

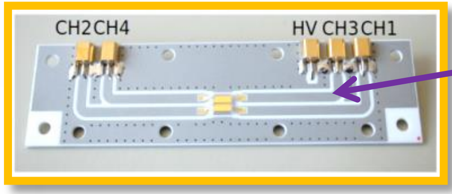
December Run (6 shifts)

- **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

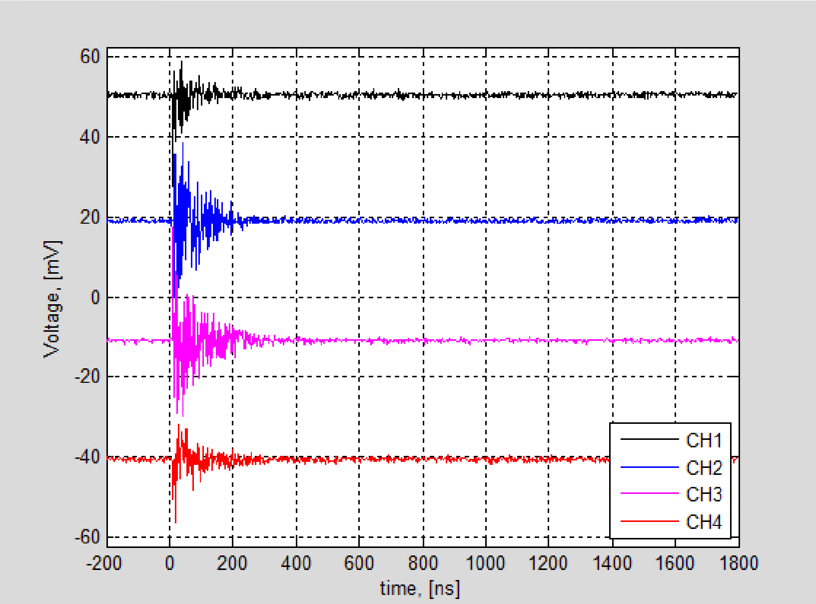
Characterization of Diamond Sensor (DS)

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

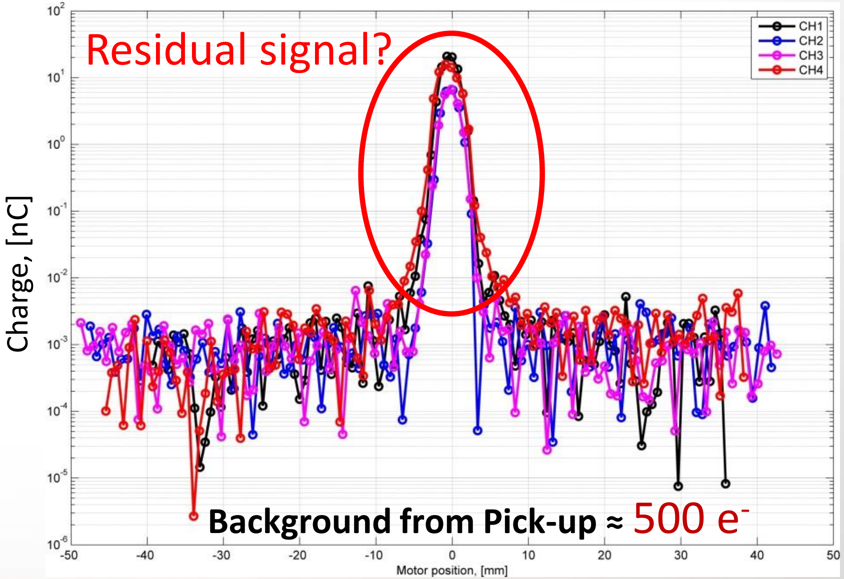
Signal Pick-up Study



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

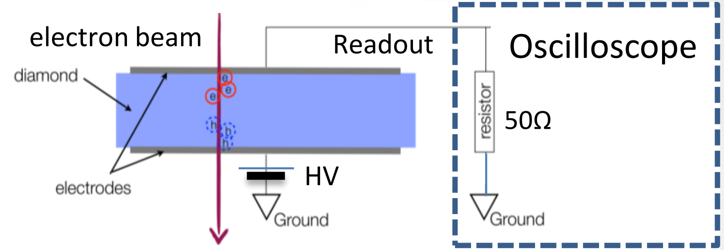


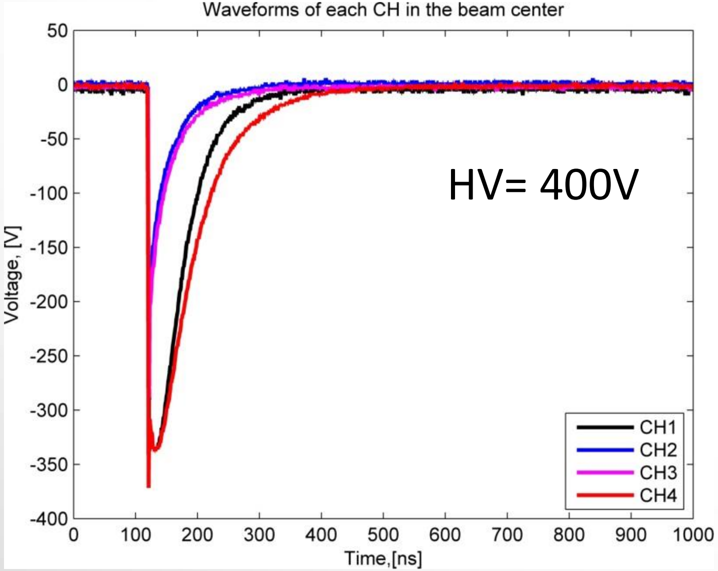
Pick-up scan w/o applying HV on DS

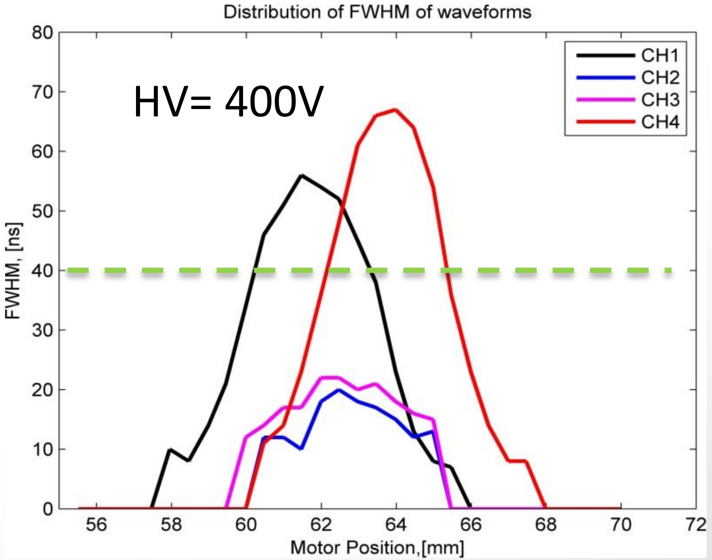


Charge Collection Efficiency

- Charge collection efficiency (CCE) depends on the "effective" bias voltage (EBS) on DS
- EBS = applied HV – voltage drop on the 50Ω



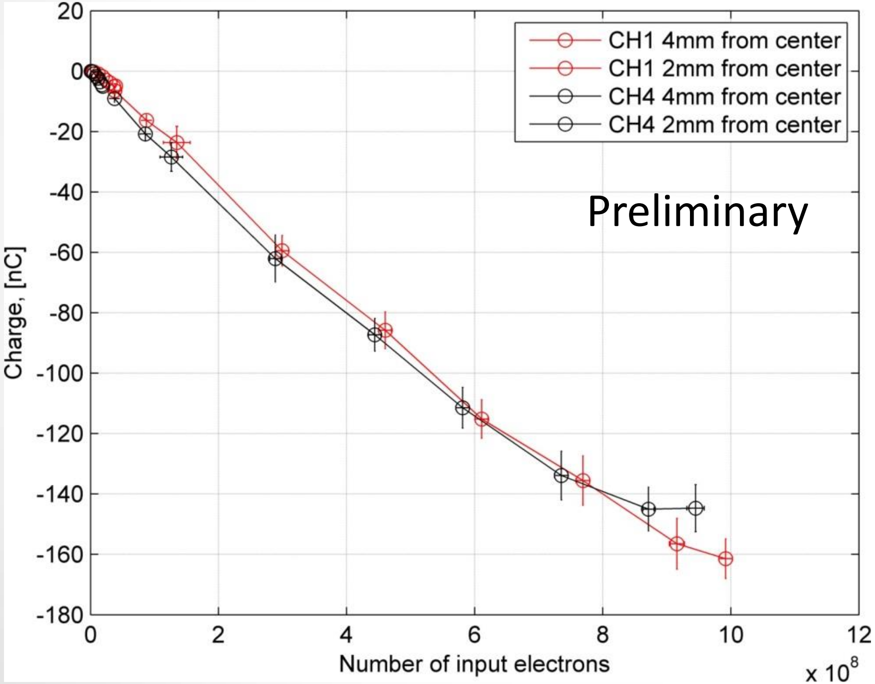


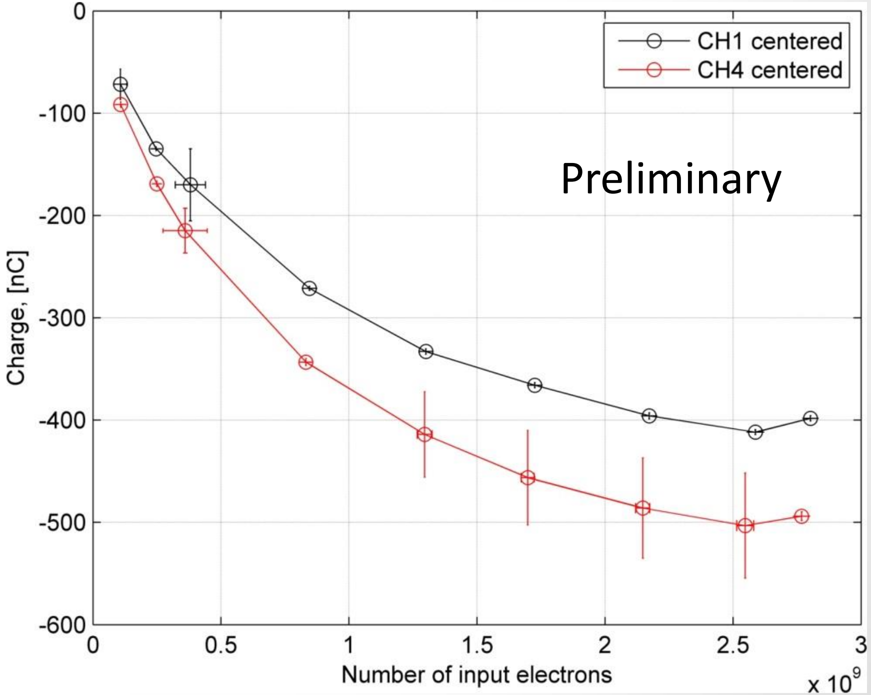


Typical life time of e^-h pairs:

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

Linearity of DS Response



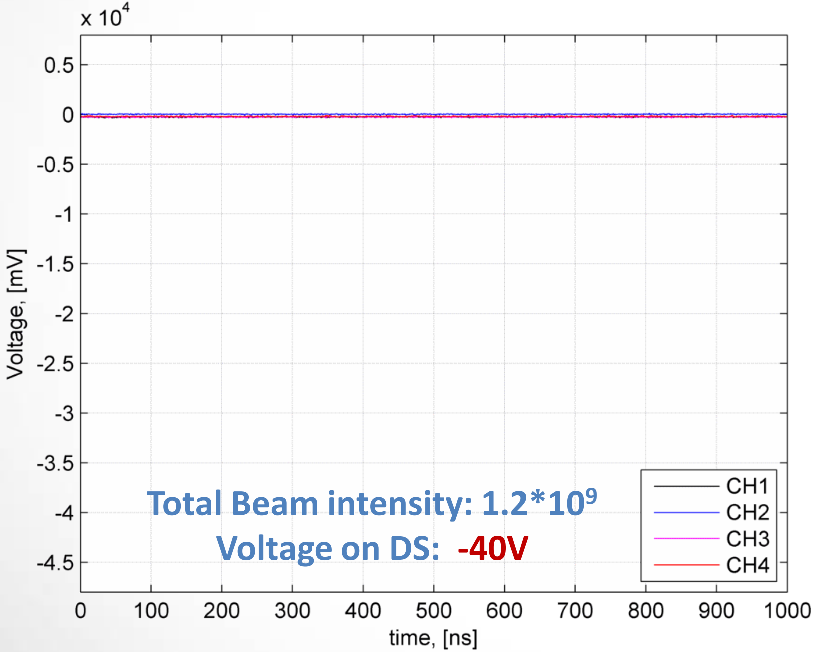


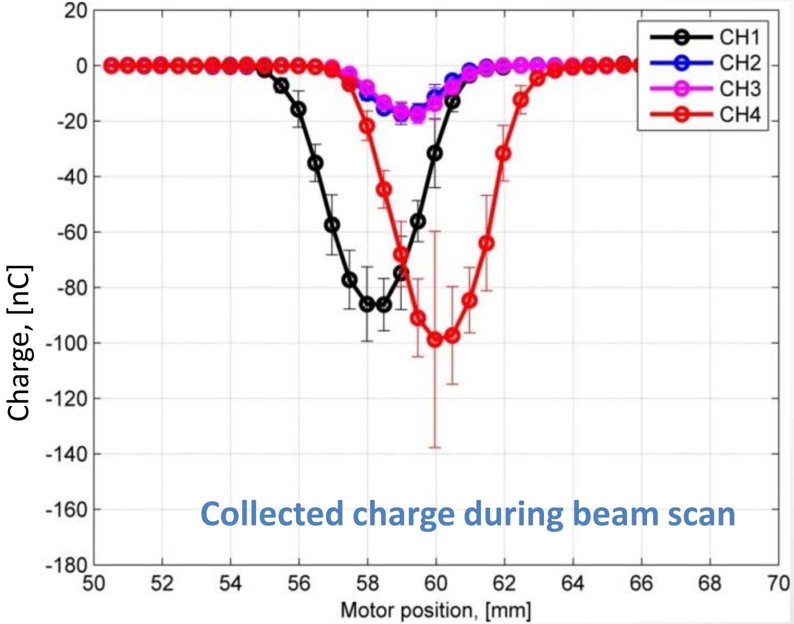
- Response is linear when the voltage drop is not significant
- In the beam core we observed an obvious non-linear response due to large voltage drop

Beam Halo Measurements

- Beam core scan and beam core distributions
- Beam size verification
- Beam halo scan and beam halo distributions

Waveforms and Integrated Charge during Scan

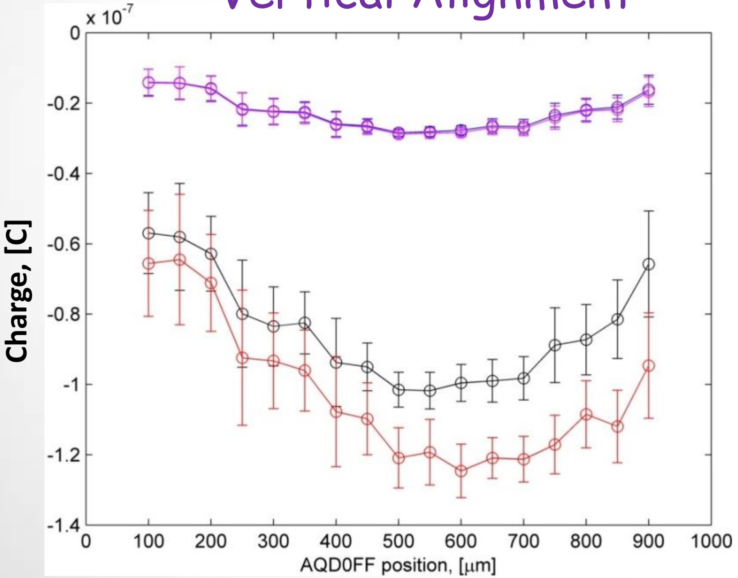




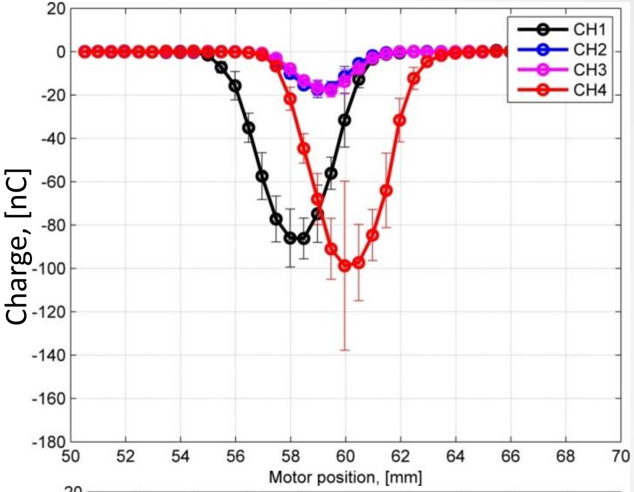
- The beam core is scanned by DS by applying low voltage
- The charge of waveform at each position is integrated to get the distribution

Beam Core Scan

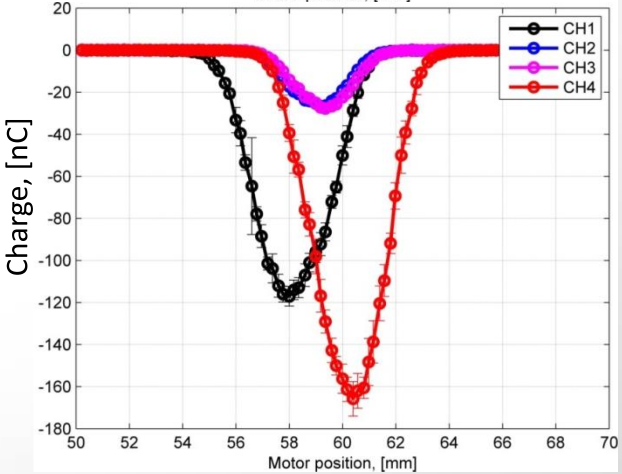
Vertical Alignment



Before Alignment

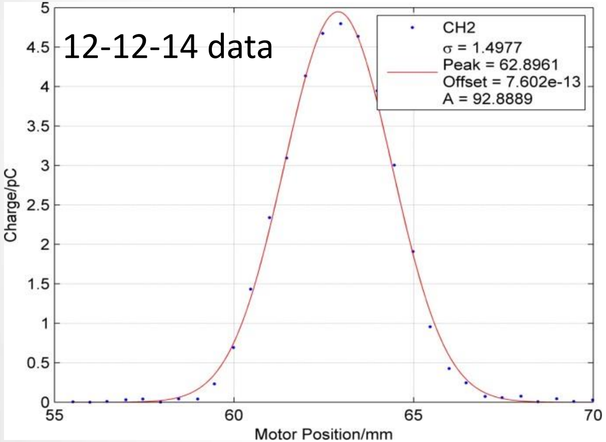


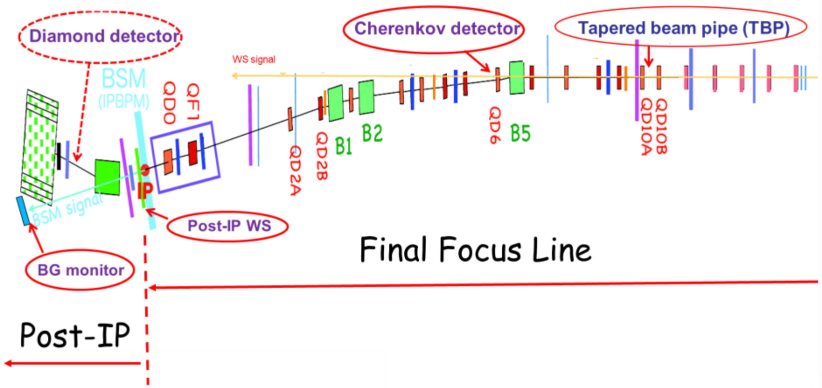
After Alignment



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

Beam Size Verification



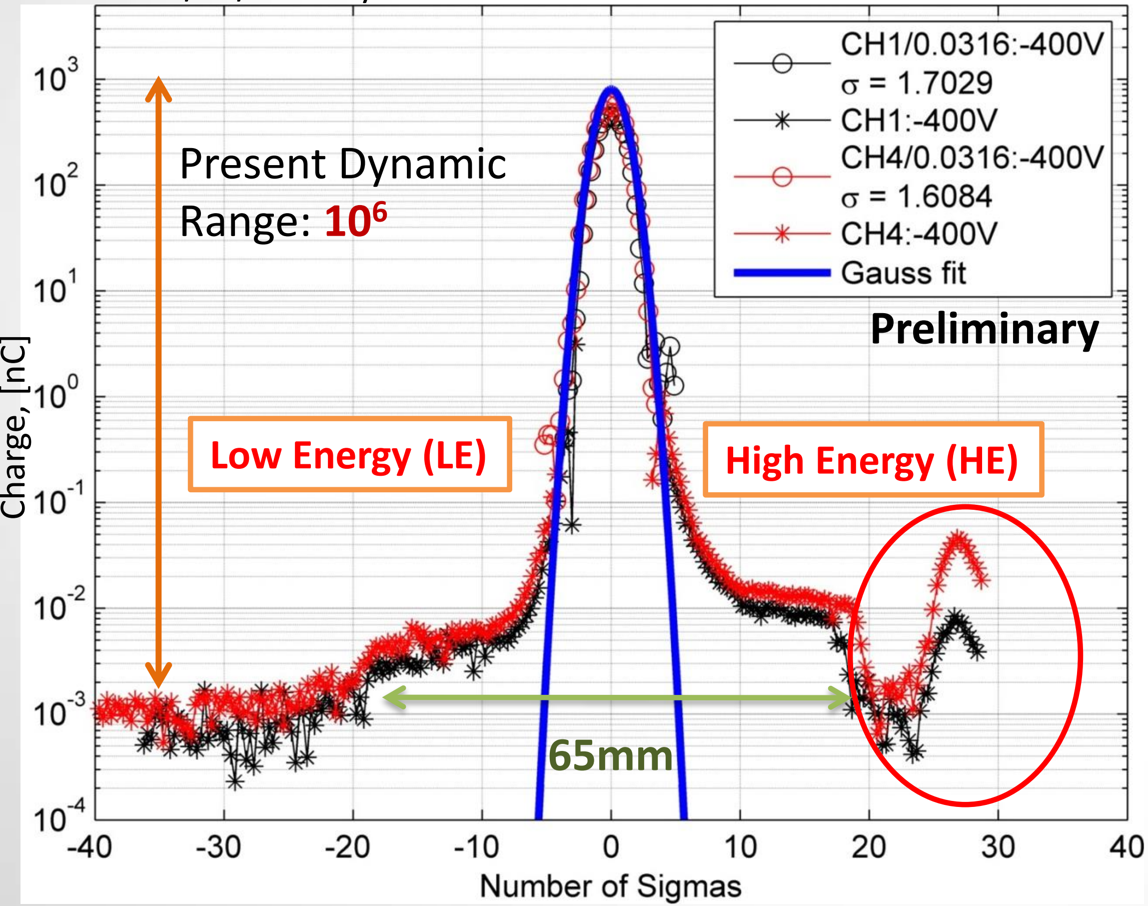


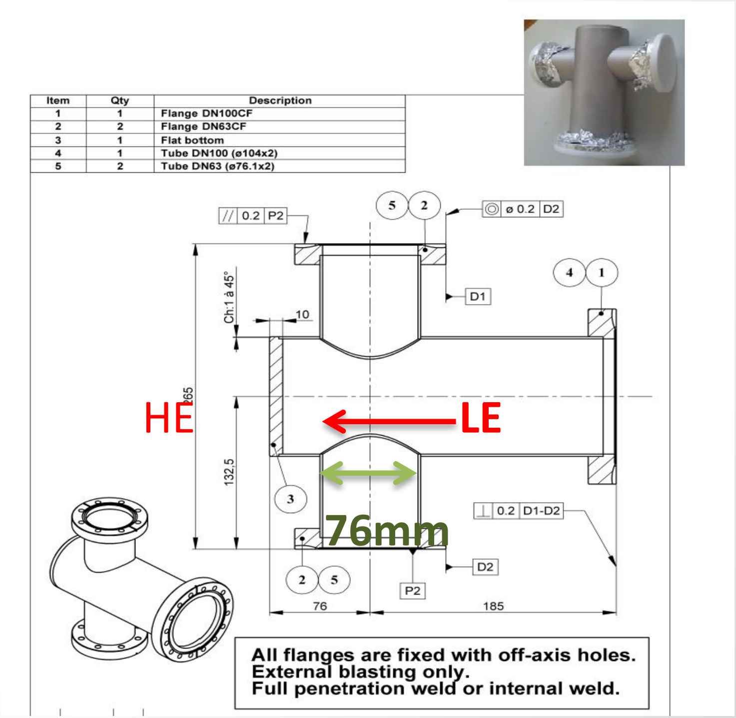
Vertical beam size is extrapolated from the Post-IP WS measured beam size

	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 Halo Scan

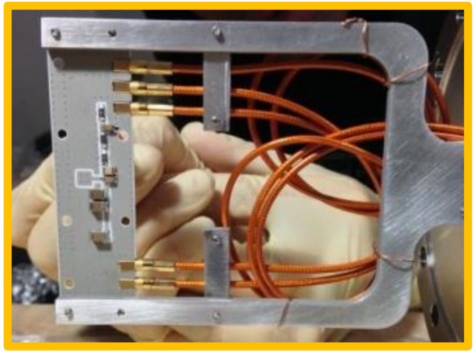
2014/12/18 - Day Shift



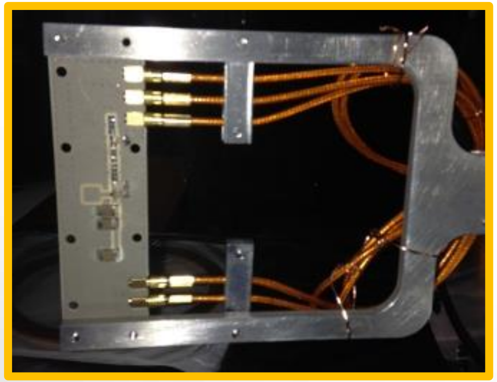


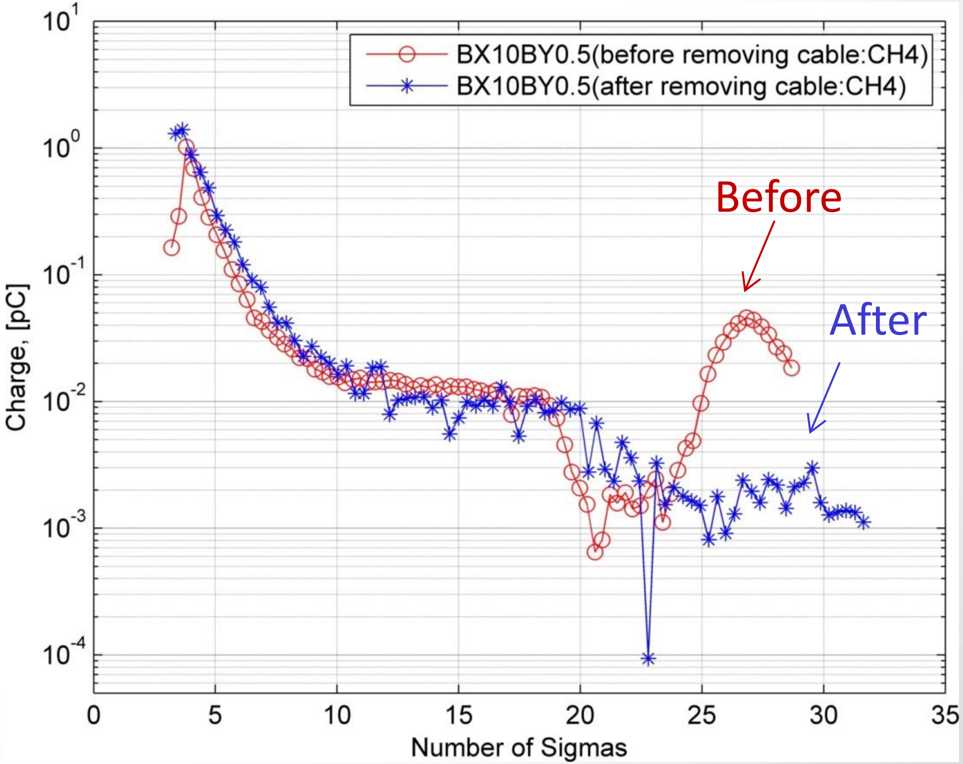
Issue with cables

Before fixing



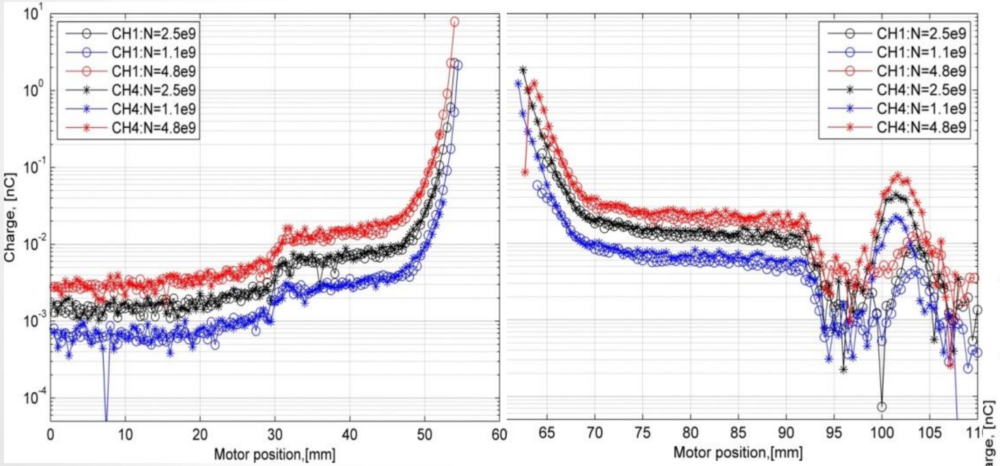
After fixing





Beam Halo Distribution for Different Beam Intensity

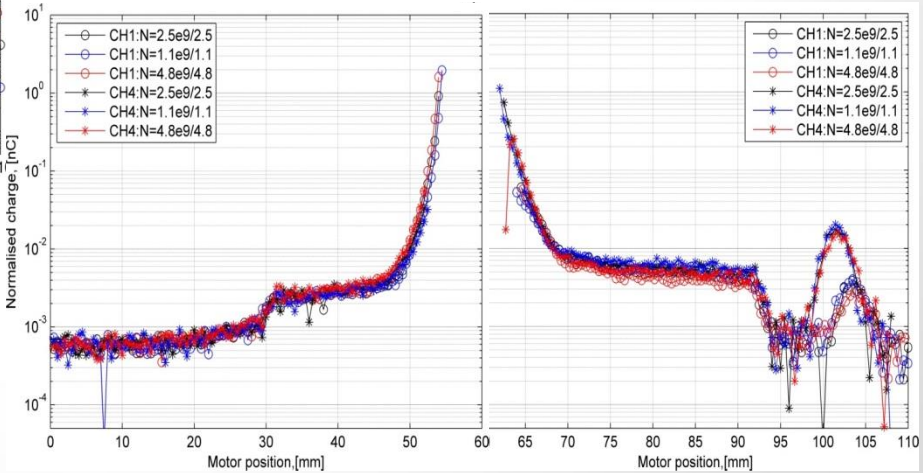
Before Normalization



Measurements were done for BX10BY0.5 optics with

N= 1.1*10^9,2.5*10^9,4.9*10^9

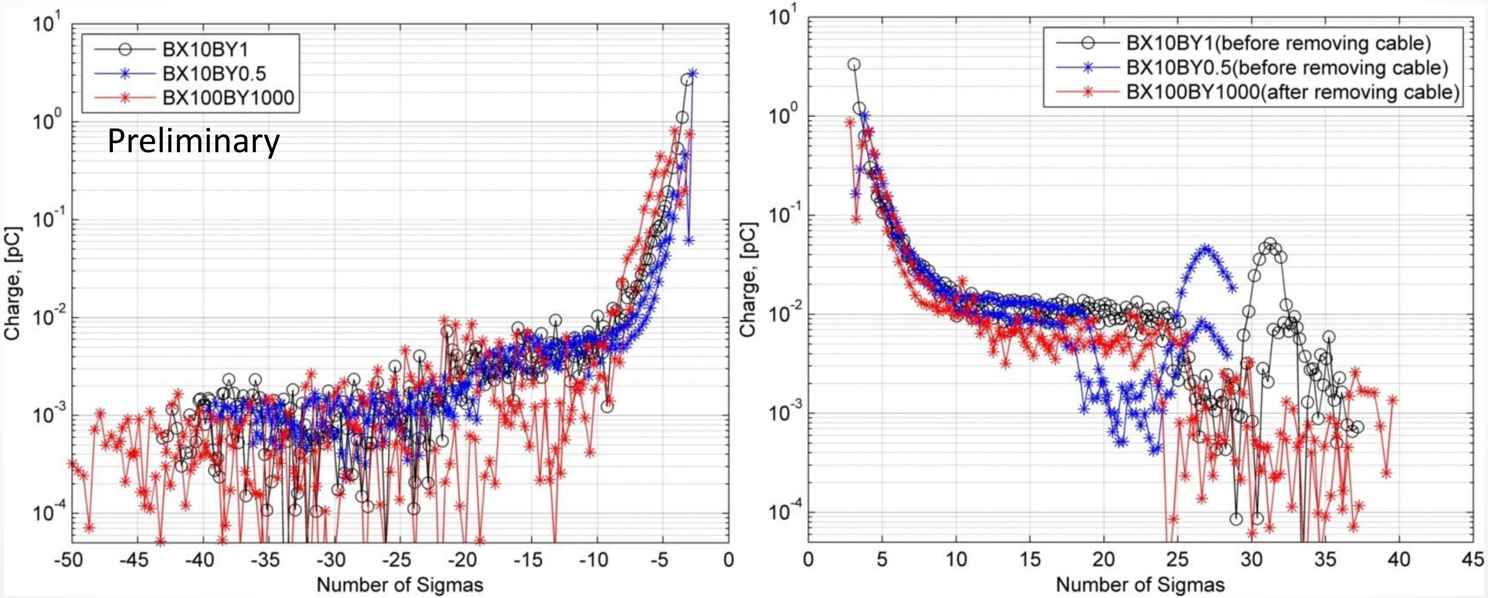
After Normalization



- No change in horizontal beam halo distribution was observed

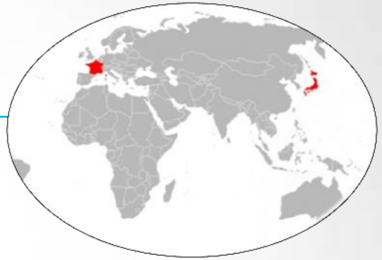
-> We expect to see the changes on the vertical beam halo distribution

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 seems less than other optics -> binning is needed**

Conclusions and Prospects



In Nov. and Dec. Run at ATF2 we performed:

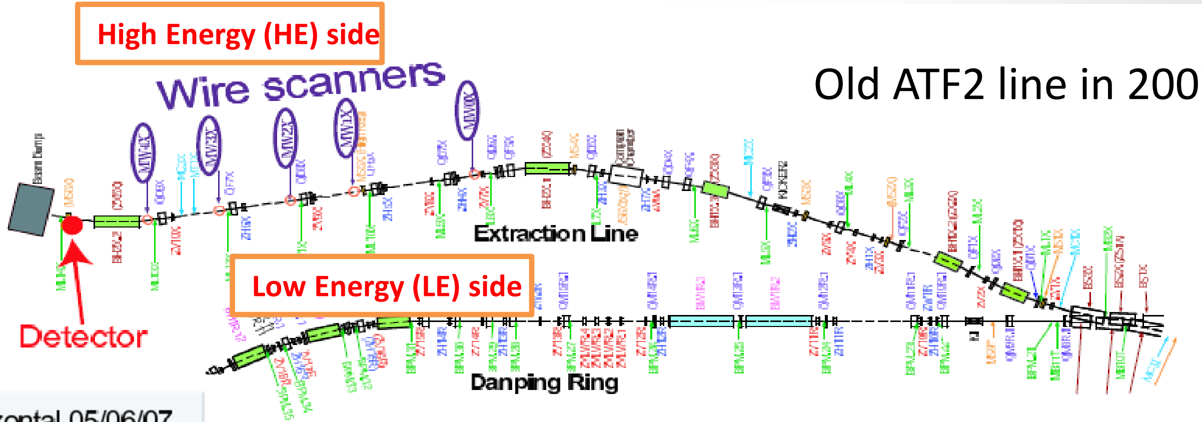
- ✓ Studies to characterize the in vacuum DS performance
- ✓ Initial measurements of horizontal beam halo distribution

- We can use DS to scan both the beam core and beam halo with a dynamic range of 10^6 (from $5*10^2$ to $5*10^8$ e^-) with a 30dB attenuator *-> saturation of charge collection will be studied in detail-> improvements on the PCB (shielding etc.) will further improve the dynamic range*
- Horizontal beam halo distribution was measured *-> will be compared with the measurements done in 2013 using the Post-IP WS -> will be useful to see effects from collimators soon to be installed*
- Asymmetry of horizontal beam halo distribution was observed -> *origin of this asymmetry will be studied*
- Dependence on beam intensity and beam optics will be checked for the vertical beam halo distribution using the 2^{nd} unit of DS -> will be installed in April 2015
- *Further study to check the possibility of measuring Compton recoil electrons is ongoing*

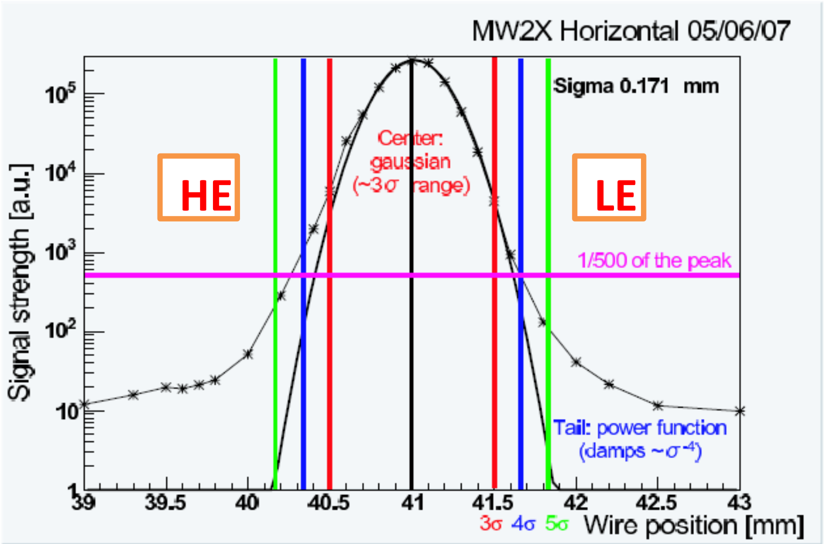
Thank you!

Back up …

Asymmetry of Horizontal distribution

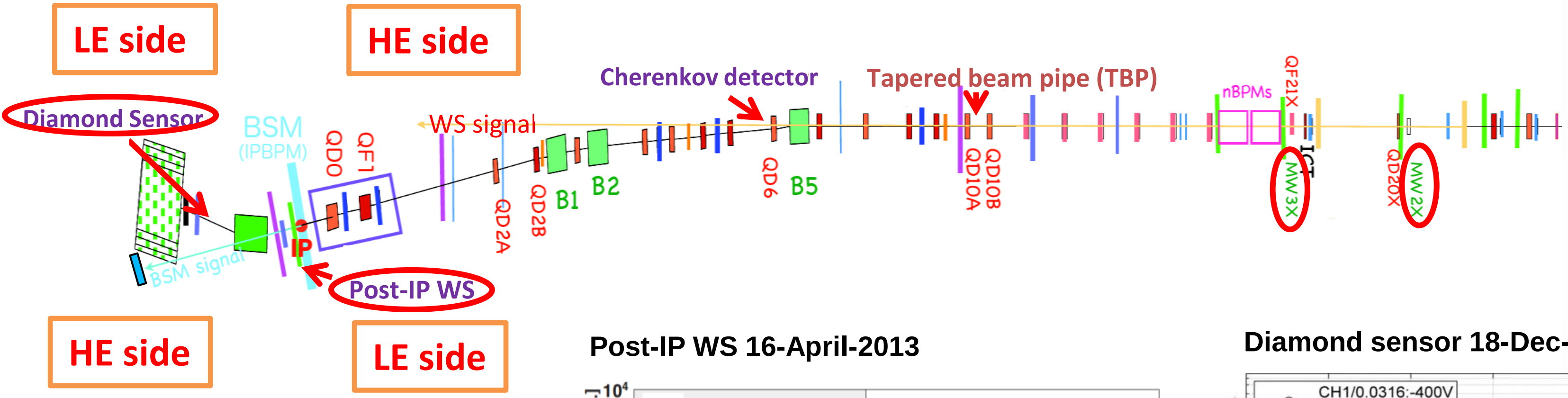


Old ATF2 line in 2007

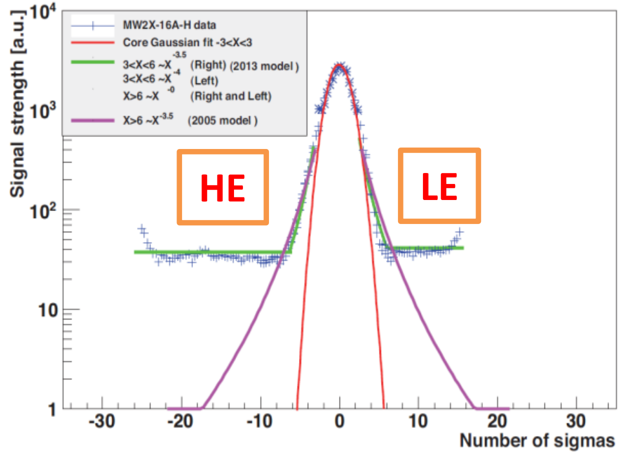


We can see the asymmetry of horizontal beam halo distribution from the data taken in 2007

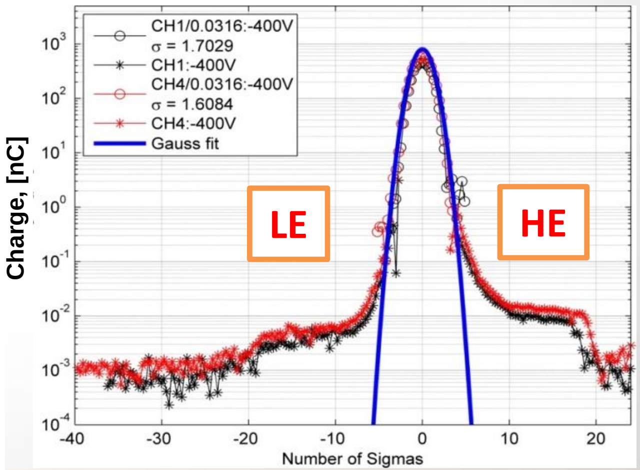
Asymmetry of Horizontal distribution



Post-IP WS 16-April-2013



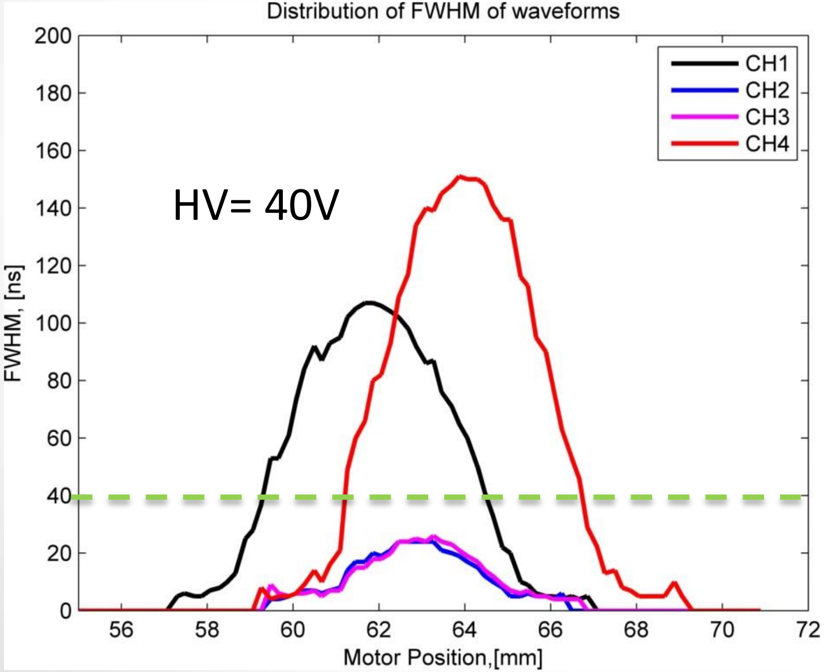
Diamond sensor 18-Dec-2014

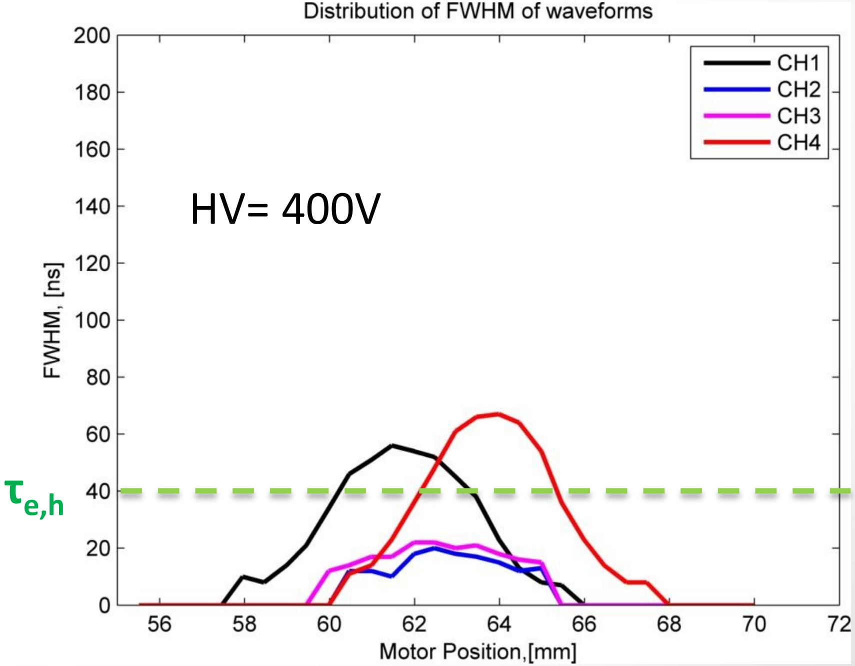


This asymmetry was observed also in the data taken in 2013 using Post-IP WS and in 2014 using DS

Signal FWHM distribution

Typical life time of e-h pairs[1] : $\tau_{e,h} \approx 40$ ns



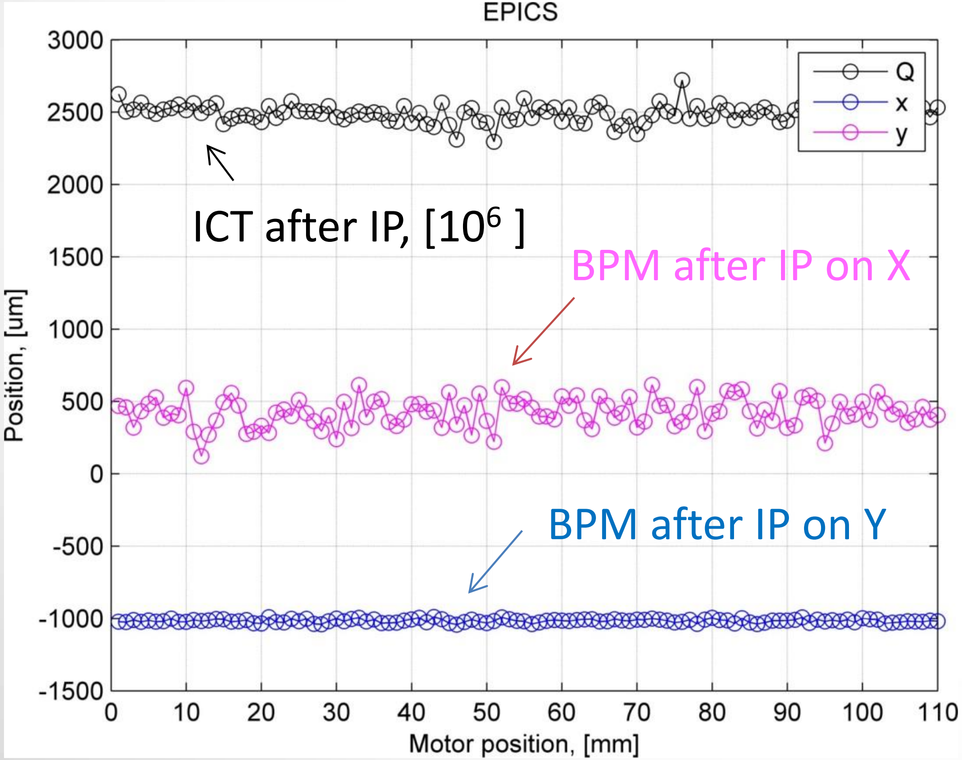


Hecht formula: $CCE^{[2]} = \frac{\tau_{e,h}}{t_{tr}}\left(1 - e^{-\frac{t_{tr}}{\tau_{e,h}}}\right) = (\mu\tau_{e,h}V/d^2)[1 - e^{-d^2/\mu\tau_{e,h}V}]$

[1] H. Pernegger et al., J.Appl.Phys. 97, 073704(2005)

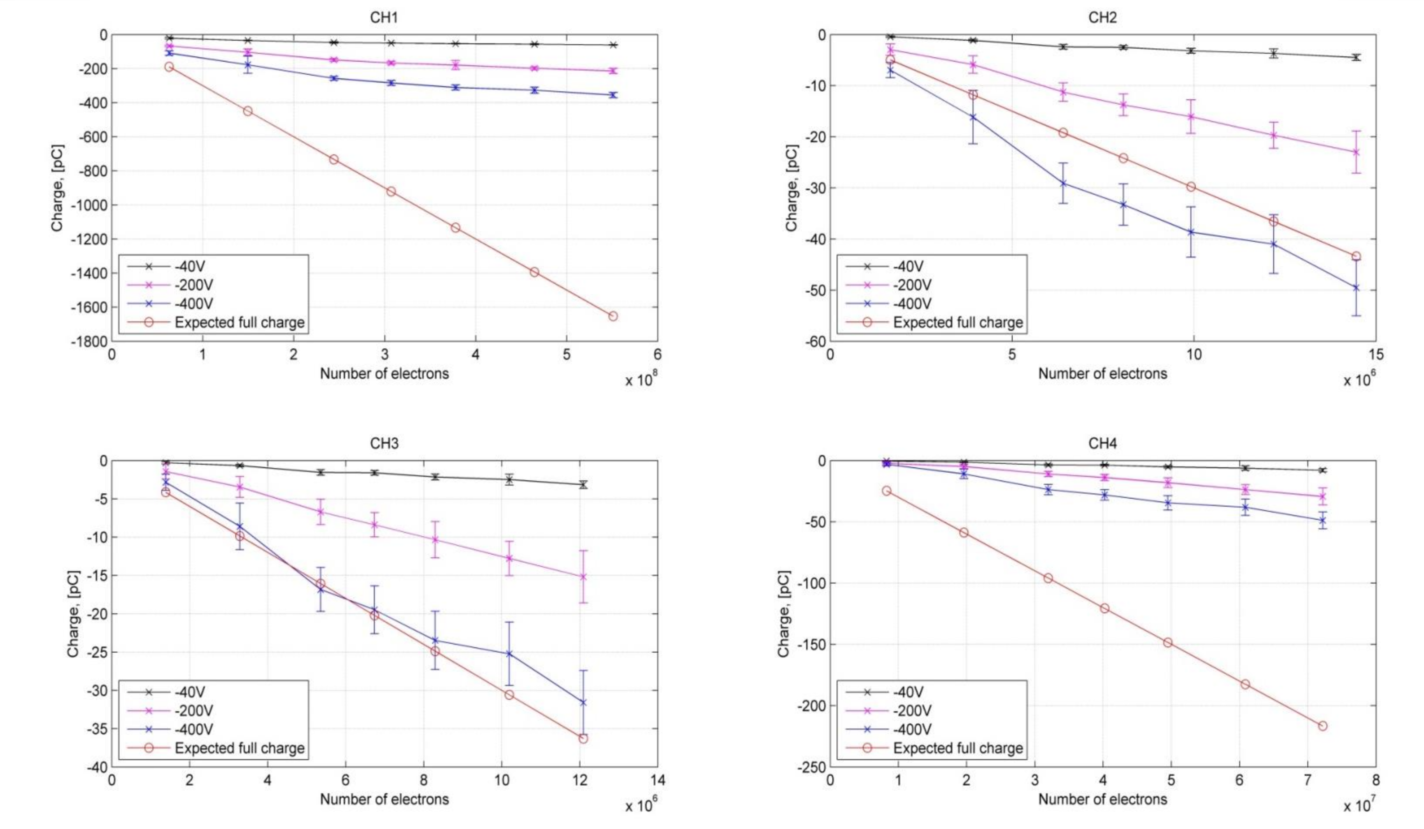
[2] M. Pomorski et al., phys. Stat. sol. (a) 203, No. 12 (2006)

Information from ICT and BPMs



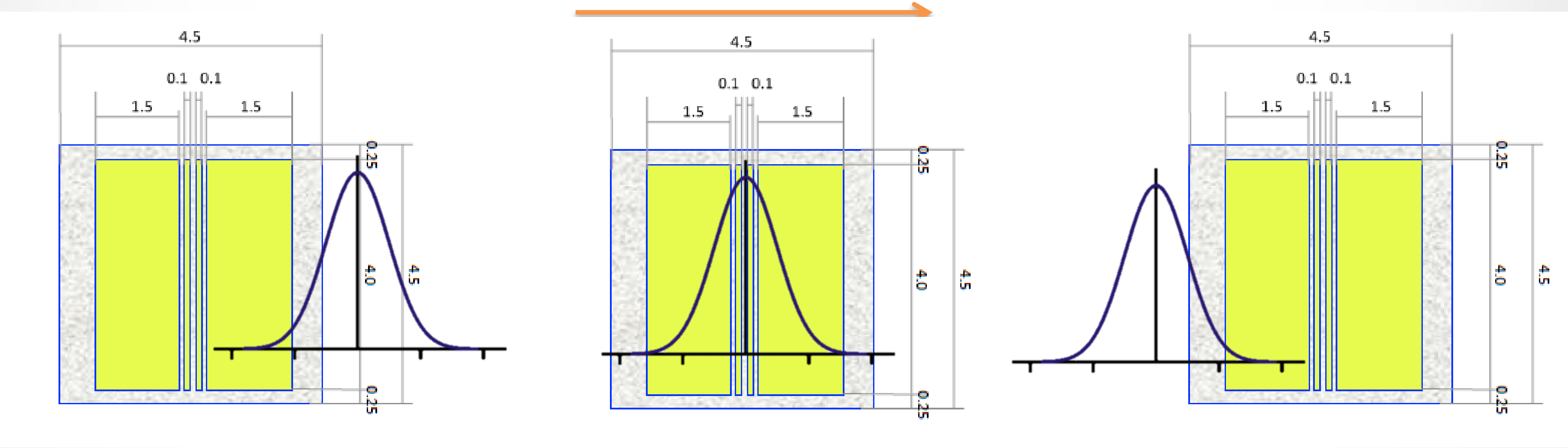
- ICT correction and beam position jitter (4-6 µm) can be taken into account in data analysis
- We read the data from Epics via SSH, but it is possible to use Labca to get data directly from Matlab
- In the future we can also input data from DS to the Epics system

Charge Collection Efficiency



Beam Core Scan

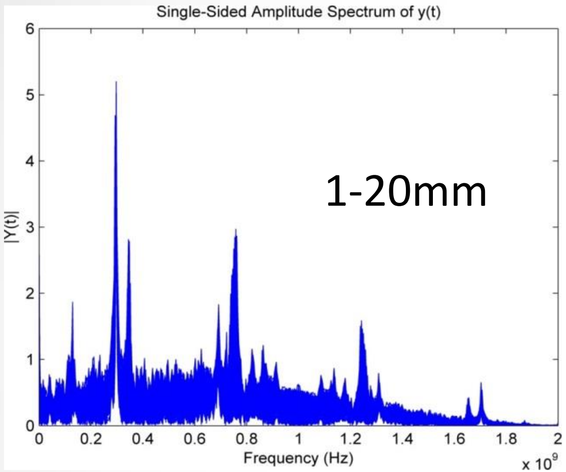
Scan direction

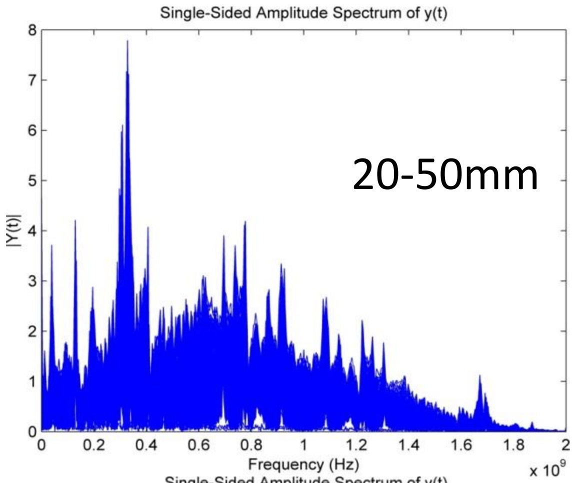


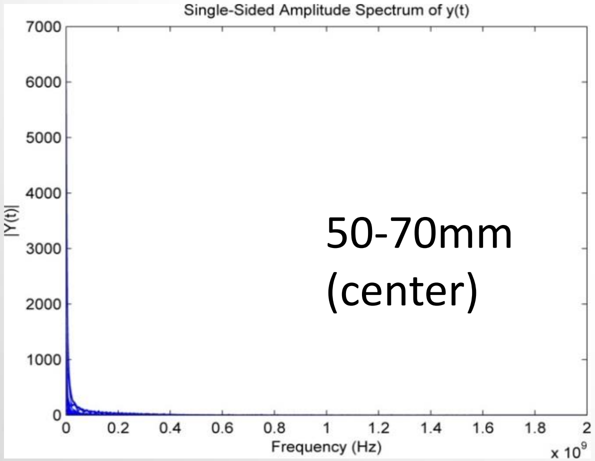
- Signal at each channel is a convolution of beam (Gaussian) with strip (rectangular shape)
- Fit function: F(d1,a1,b1,s1) = d1+a1*(**erf**(((x+0.75-b1)/(sqrt(2)*s1)))-**erf**(((x-0.75-b1)/(sqrt(2)*s1))))

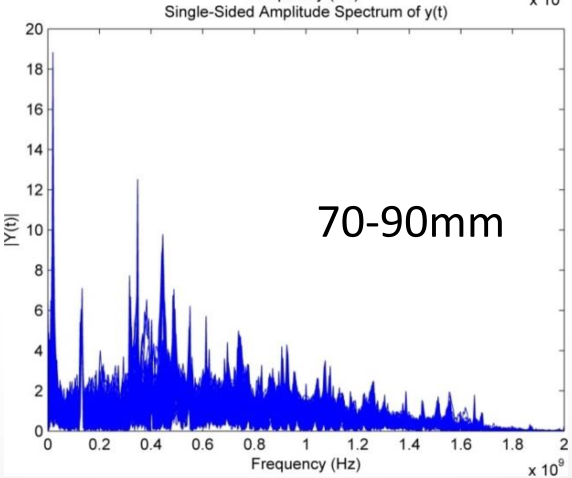
FFT of Pick-up

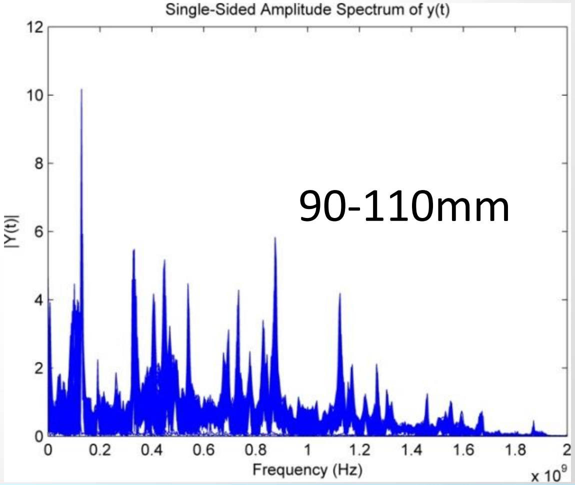
Asymmetry in frequency domain observed



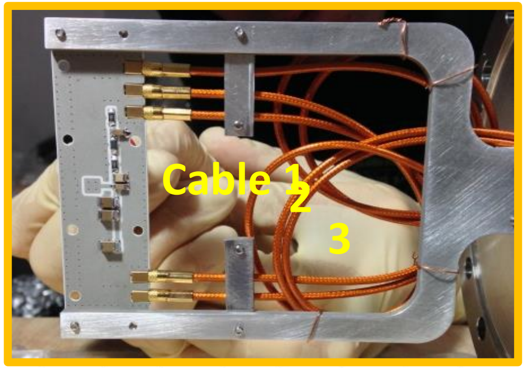


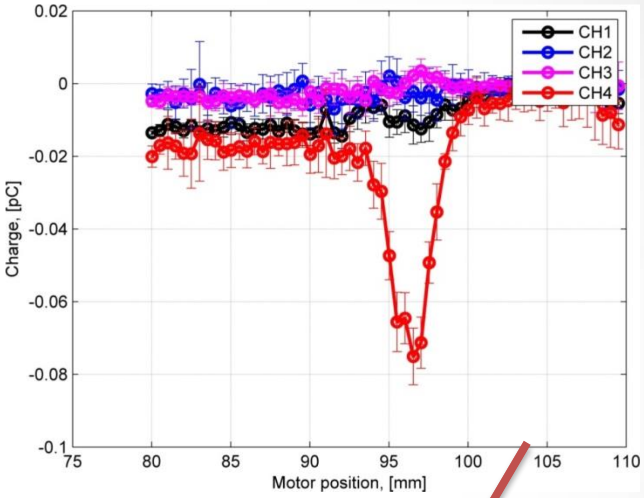




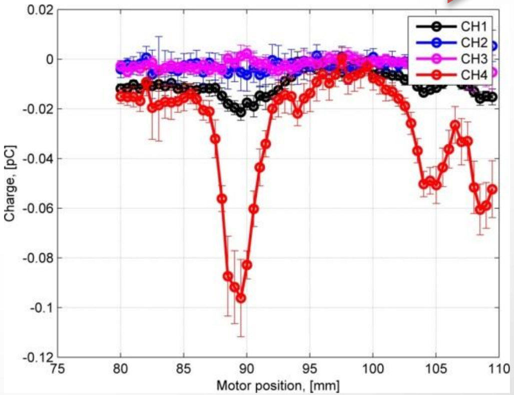


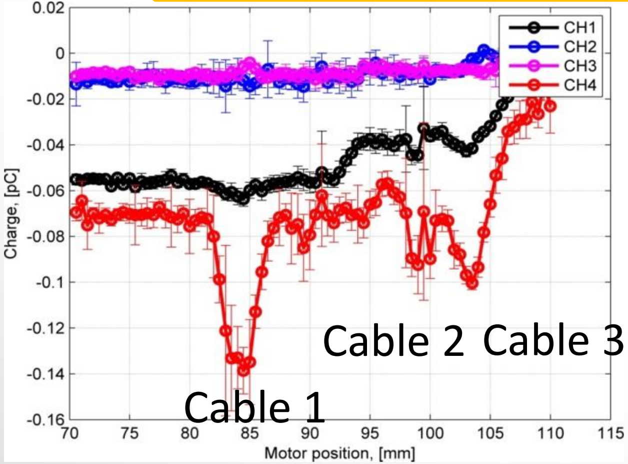
Background from cables



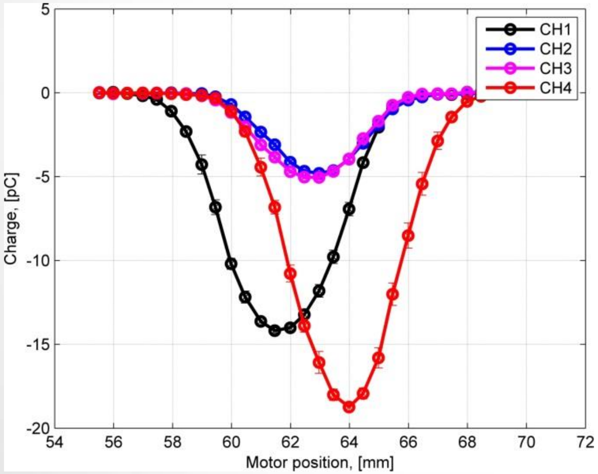


Move the beam step by step





Expected signal (400V)

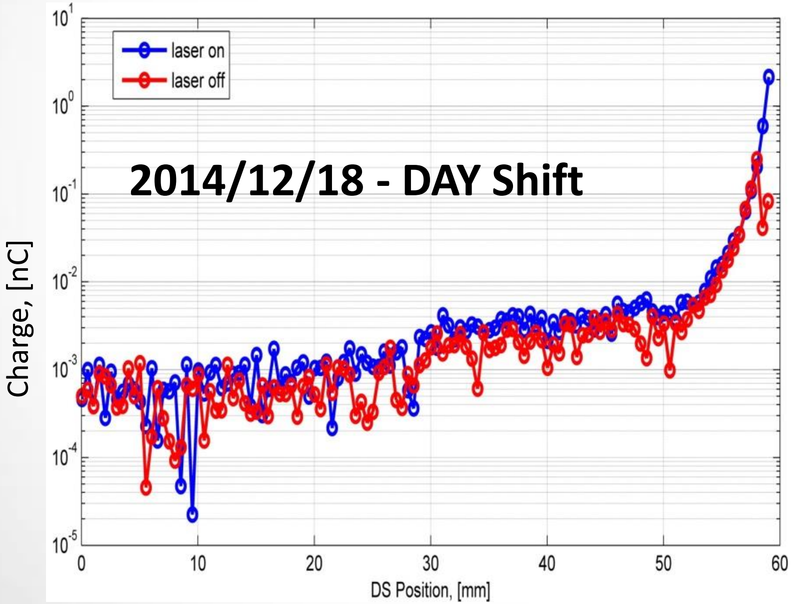


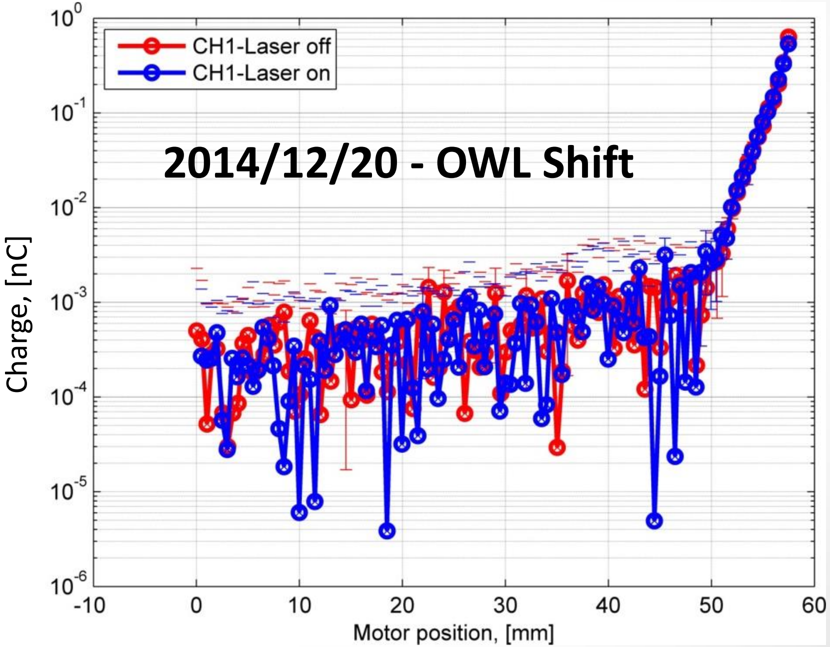
	CH1	CH2	CH3	CH4
Measured σ_x	1.70 mm	1.49 mm	1.53 mm	1.61 mm
Ratio of collected e-	13.34%	1.04%	1.02%	14.07%
Expected full charge (3fC/MIP)	1.88µC	147.21nC	143.68nC	1.98µC
Max. charge collected	442.72nC	151.79nC	158.11nC	600.8nC
Corresponding CCE	23.55%	101%	101%	30.35%

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

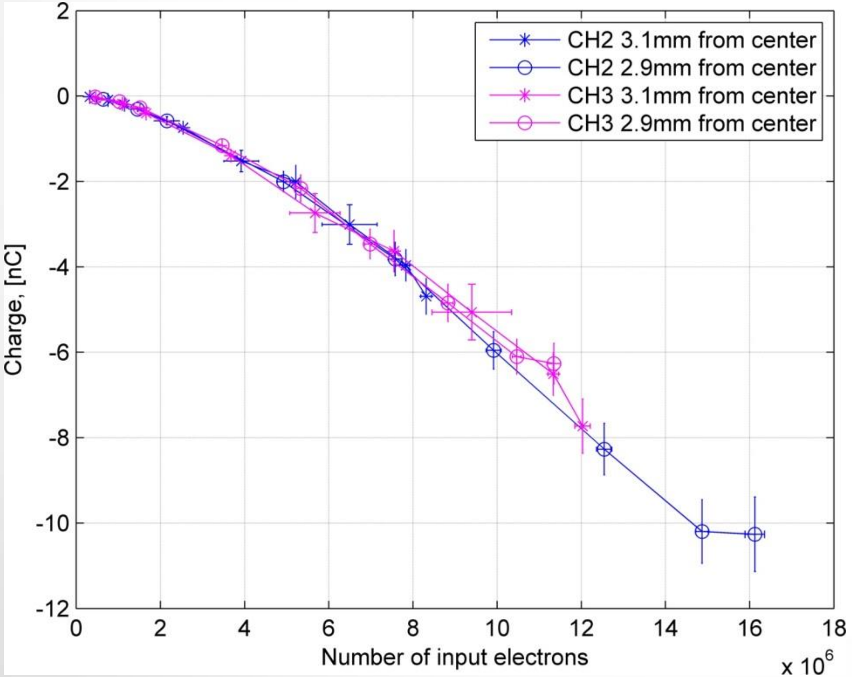
Scan_Run60_12-12-2014_143616_core_400V

COMPTON RECOIL ELECTRONS STUDY

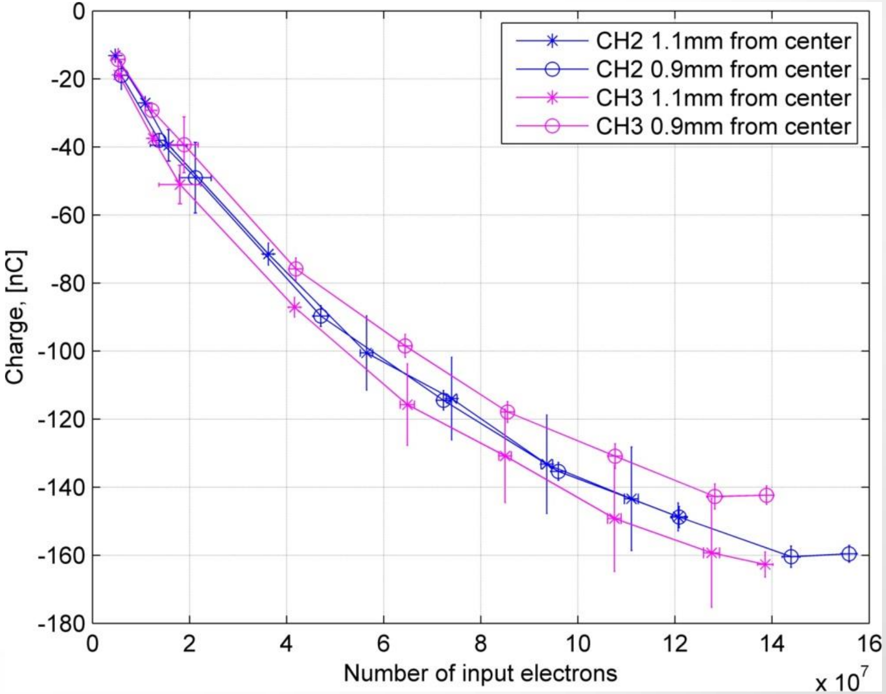




- Perform simulations in CAIN and Mad-X for different optics
- Compare the estimated signal level with the background/pick-up signal level



CH2 3.1mm from center
CH2 2.9mm from center
CH3 3.1mm from center
CH3 2.9mm from center
Charge, [nC]
Number of input electrons
x 10^6



CH2 1.1mm from center
CH2 0.9mm from center
CH3 1.1mm from center
CH3 0.9mm from center
Charge, [nC]
Number of input electrons
x 10^7