Beam Halo Studies

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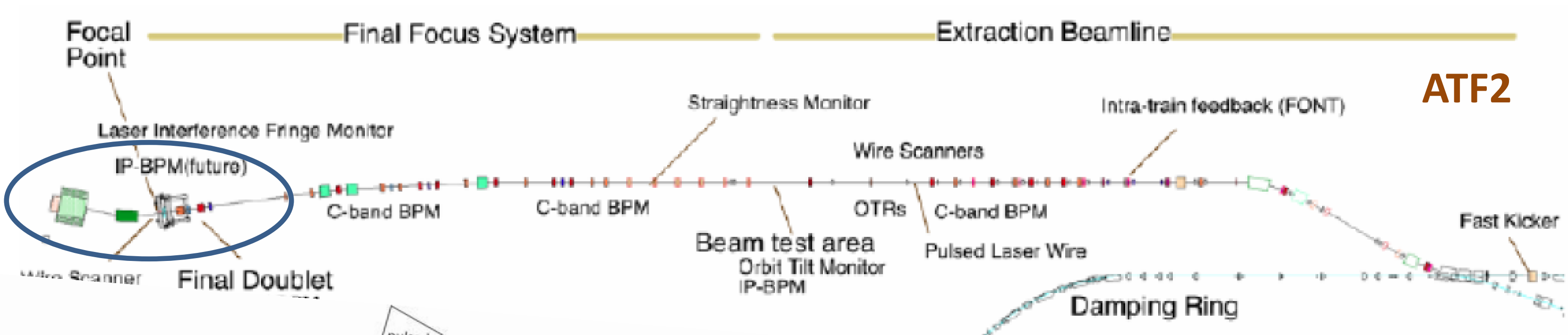
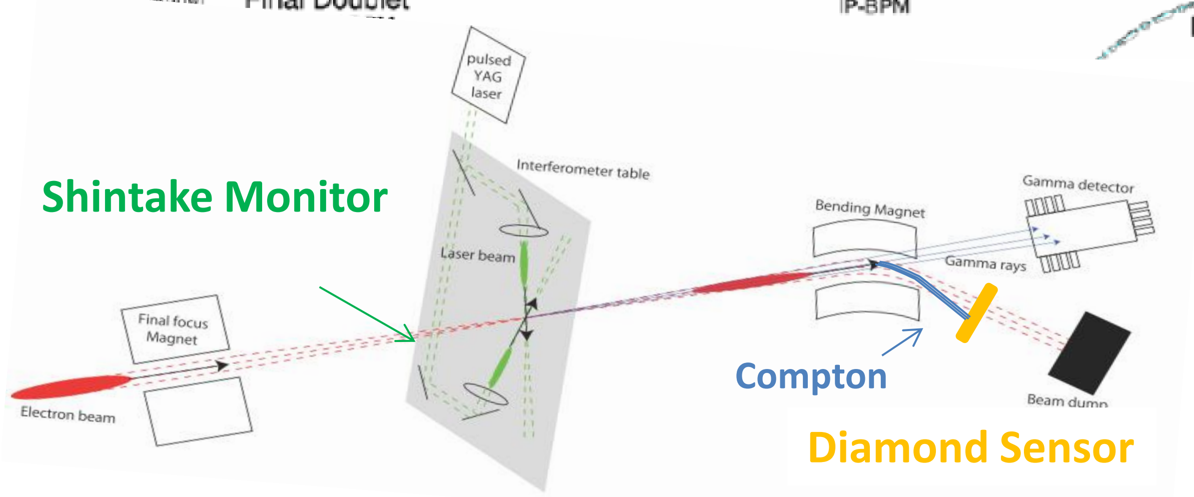
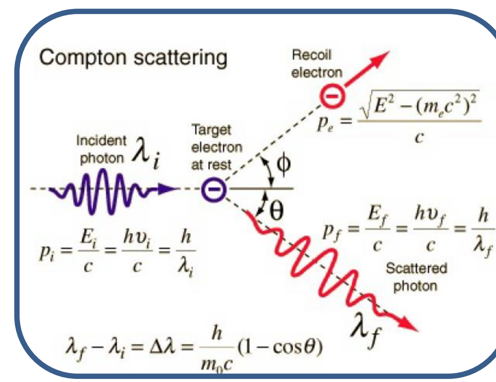
Introduction





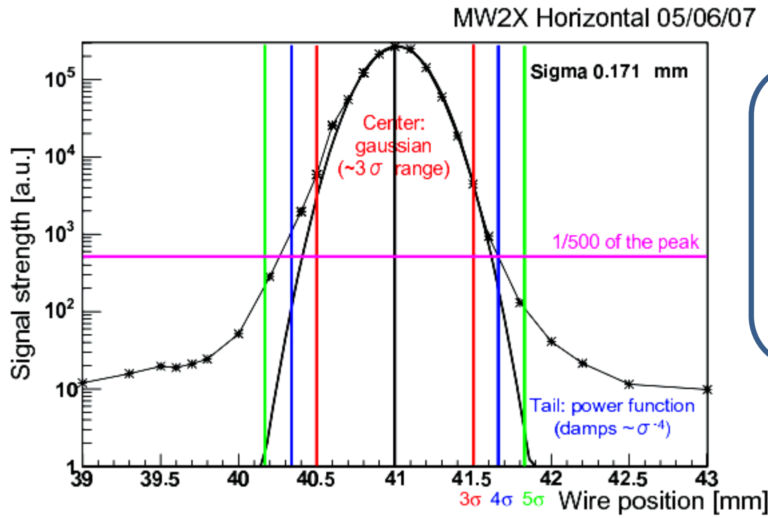


Motivations:

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

Halo Measurement Using Wire Scanners

Beam Halo Measurement



Halo Density

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

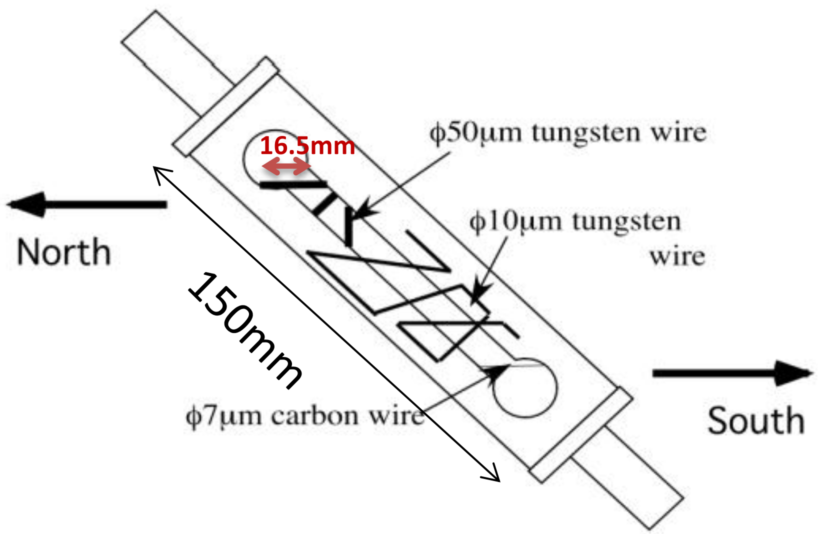
x-> the distance from the beam center as a unit of σ

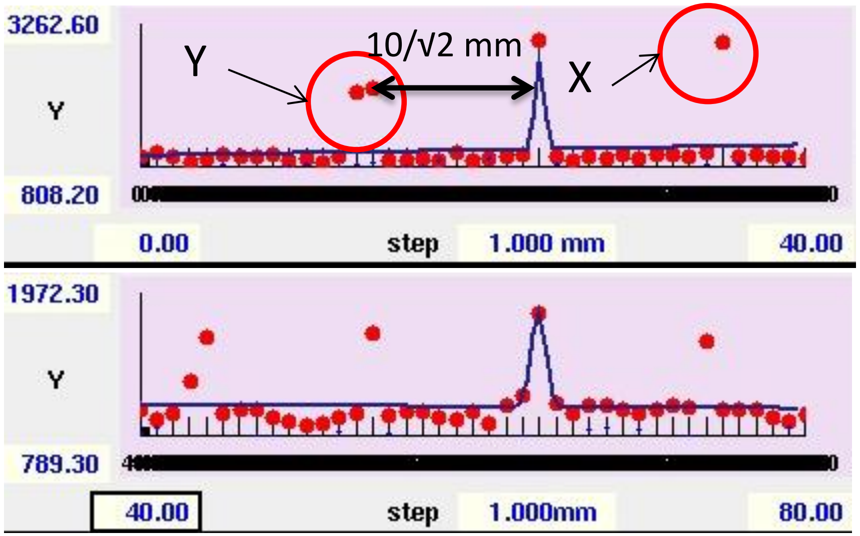
T. Suehara et al., "Design of a Nanometer Beam Size Monitor for ATF2", arXiv:0810.5467v1

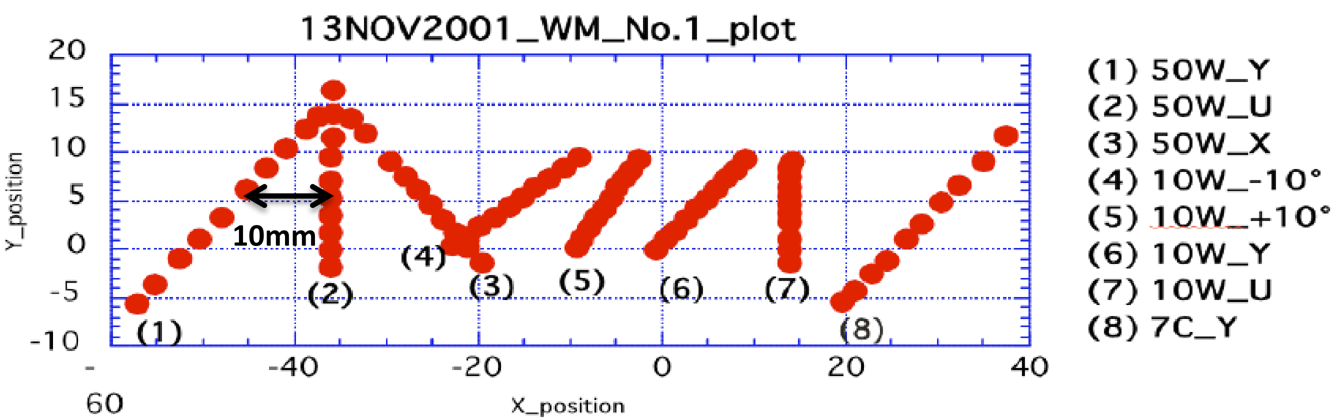
Energy spread of halo = ? Unknown;

- First beam halo measurements were done in ***2005*** using the wire scanners in the old extraction line -> need to be confirmed in the present ATF2 beam line;
- No energy halo measurement was performed before -> Energy spread of halo is unknown -> can be investigated by measuring halo distribution at the location of large dispersion (at extraction line and at B-Dump bending magnet).

Wire Scanner Structure







Distance between the center of the wires: ***10mm (10/√2 mm in beam direction)***

Possibility for Halo Measurement

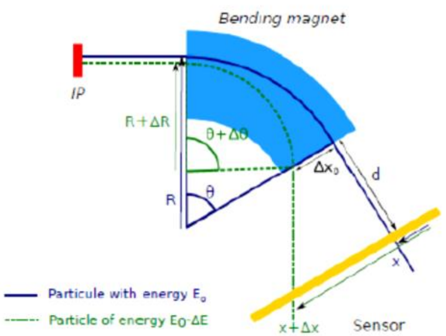
- **For MW2X we used 10 µm tungsten wire for Y and 50 µm tungsten wire for X; For Post-IP wire scanner we used 50 µm tungsten wires for both X and Y.**

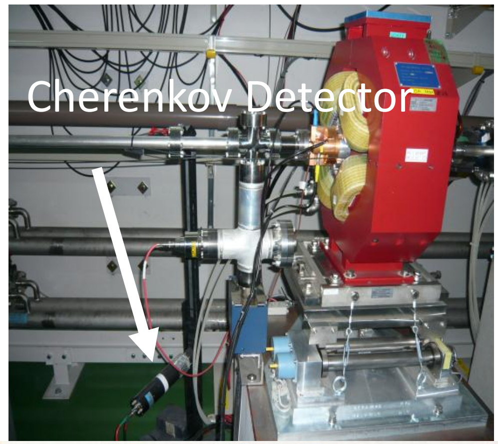
- **If we take the middle point between two peaks, then the maximum distance between two measurements using different wires is 5/√2 mm, which correspond to the following σ:**

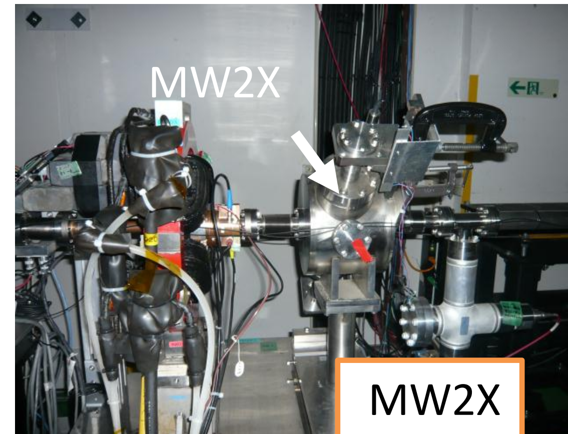
	Y-	Y+	X-	X+
MW2X	$-154\sigma_y$	$154\sigma_y$	$-41\sigma_x$	$41\sigma_x$
Post-IP wire scanner	$-30\sigma_y$ *	$11\sigma_y$	$-14\sigma_x$	$14\sigma_x$

*** There is no other wires on the left side of the first wire used for Y scan.**

Wire Scanners & Detectors



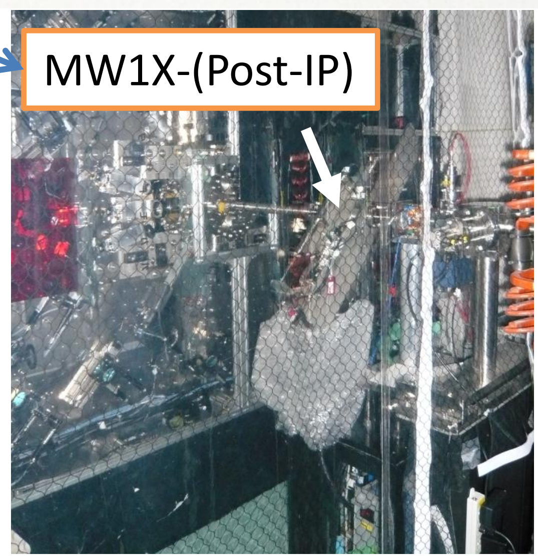




Diamond Detector

MW2X

MW1X-(Post-IP)

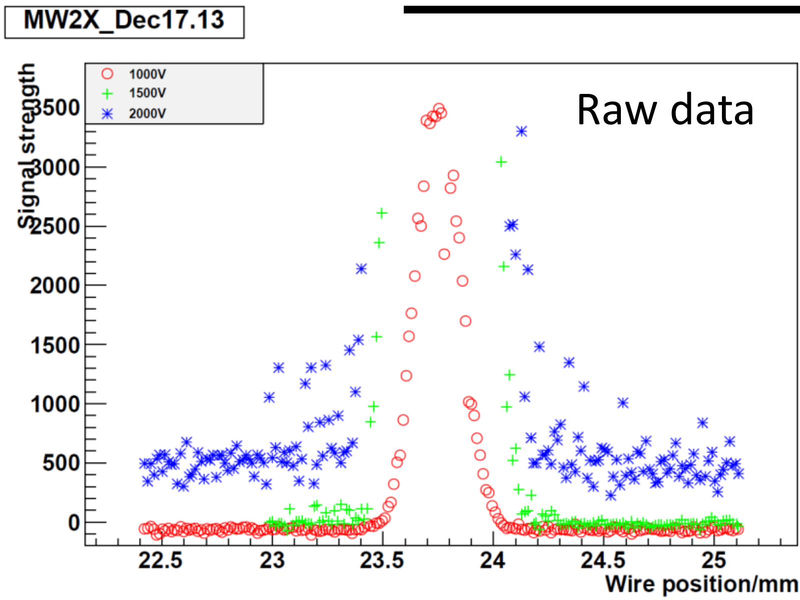


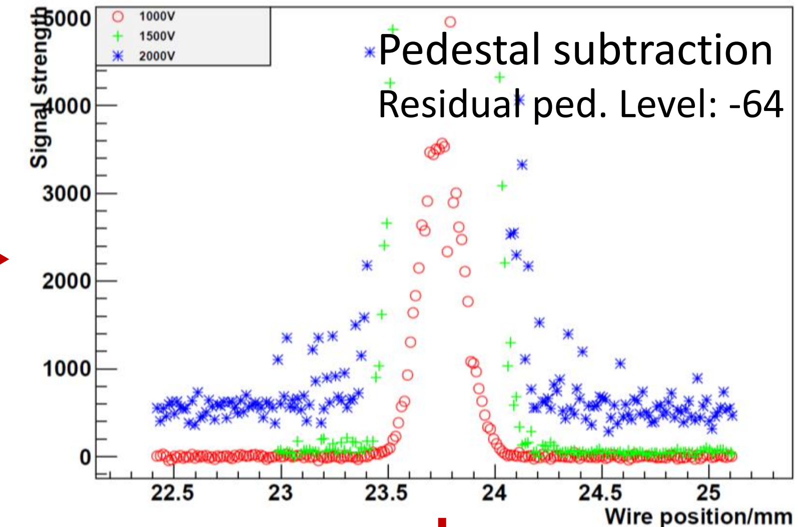
MW3X

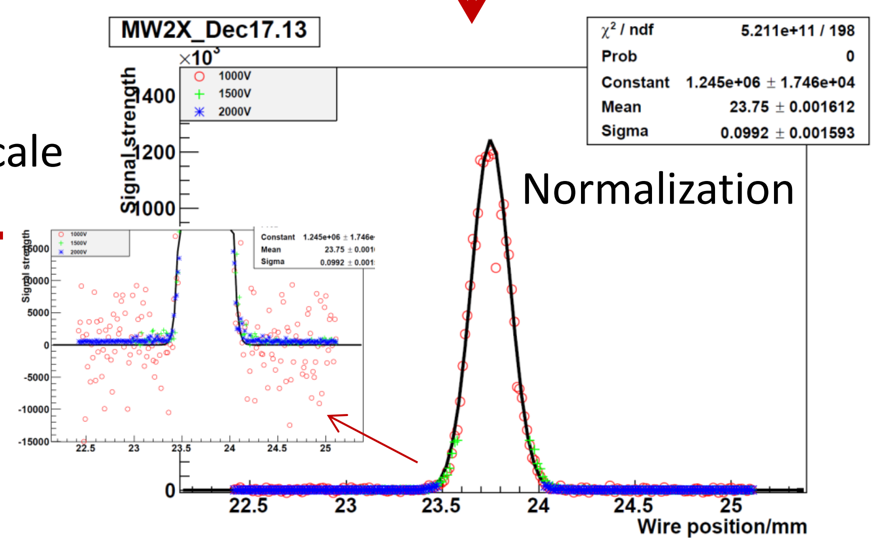
Halo Measurement @ ATF

- ✓ MW2X -> horizontal & vertical (energy halo)
- ✓ MW3X -> horizontal
- ✓ MW1X-(Post-IP) -> edge of cut on vertical halo

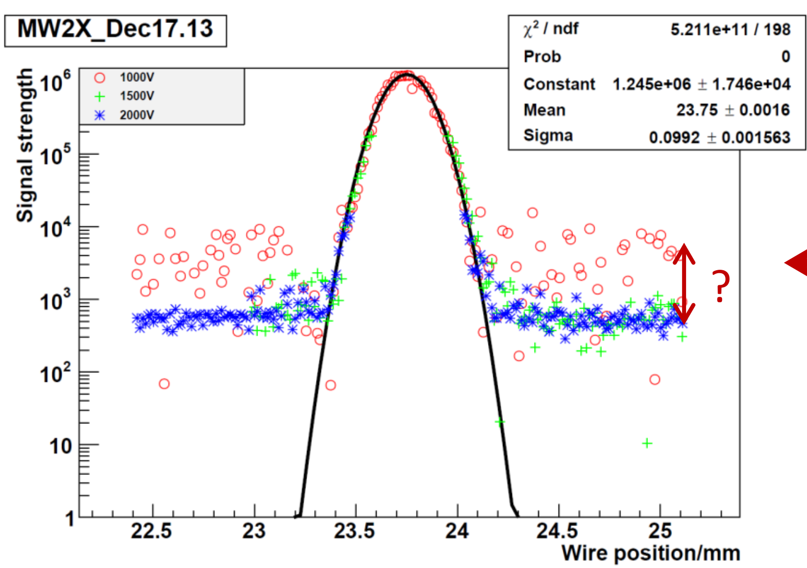
Data Analysis Process





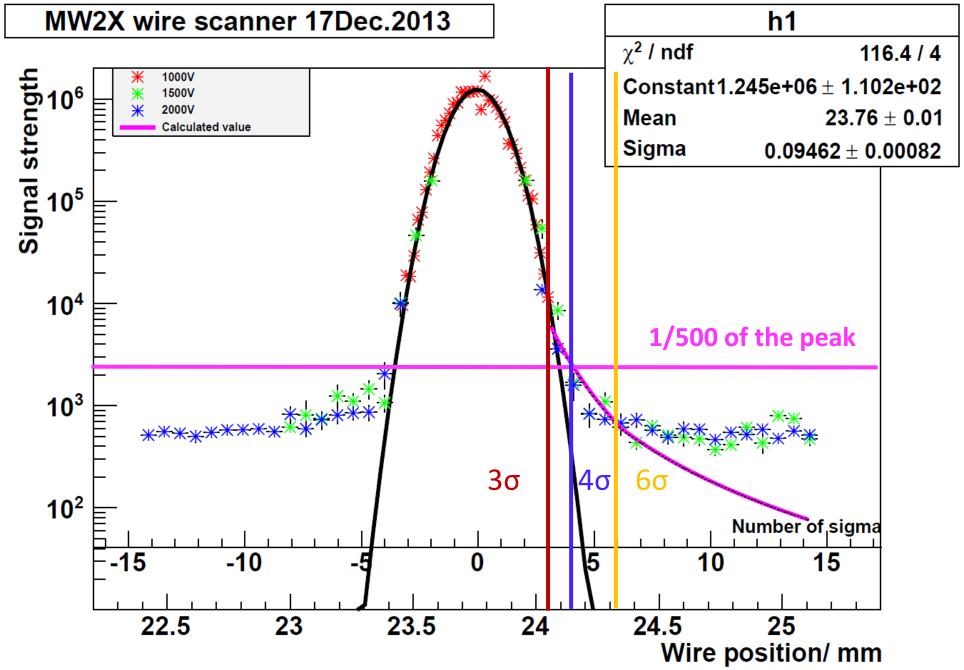


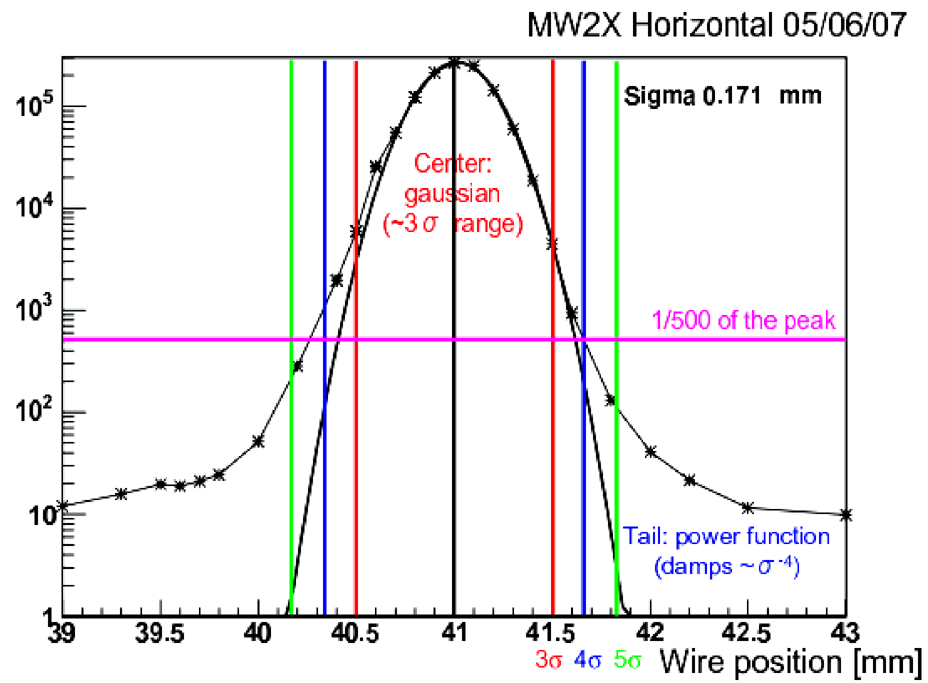
In log-scale



? Baseline for 1000V seems to be electronic noise (not reliable) *->Background @ 1000V under PMT sensitivity ?*

Comparison with data taken in 2005





$$\rho_{halo} = 1.02 * 10^{9} * z^{-3.5} \ (3 < z < 6)$$

$$\rho_{halo} = 1.70 * 10^{8} * z^{-2.5} \ (z > 6)$$

-> Calculated value: parameterization of beam halo

(initially done by Suerara-san and modified by Dou)

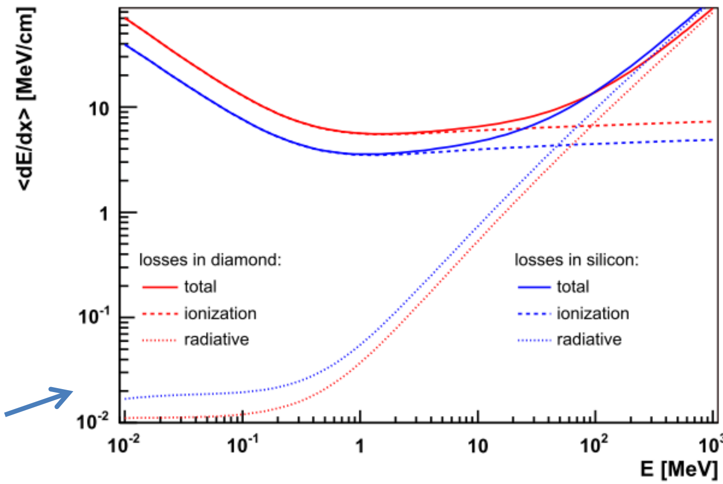
Preparation of diamond sensor for PHIL & ATF2

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})	1900	1500
Hole mobility (cm^3 V^{-1} s^{-1})	2300	500
Saturation velocity (μm ns^{-1})	141 (e^-) 96(hole)	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***

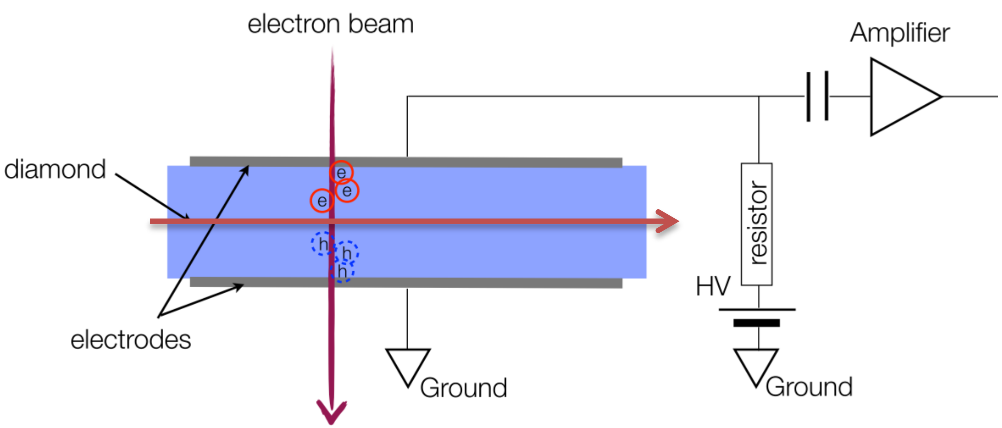


Energy loss of an electron in **diamond** & **silicon**

	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

High voltage side readout



GEOMETRIES

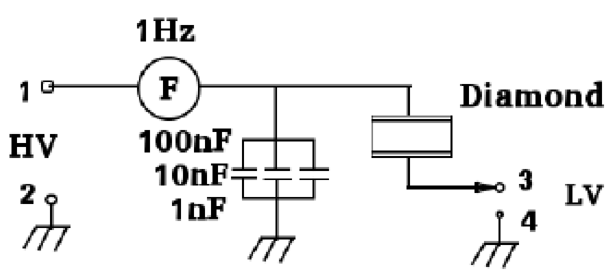
Diamond detectors:

- ***Pads : mm² x 500 µm***
- ***Strips & pixels***
- ***Membranes (→ 5 µm)***

Diamond type:

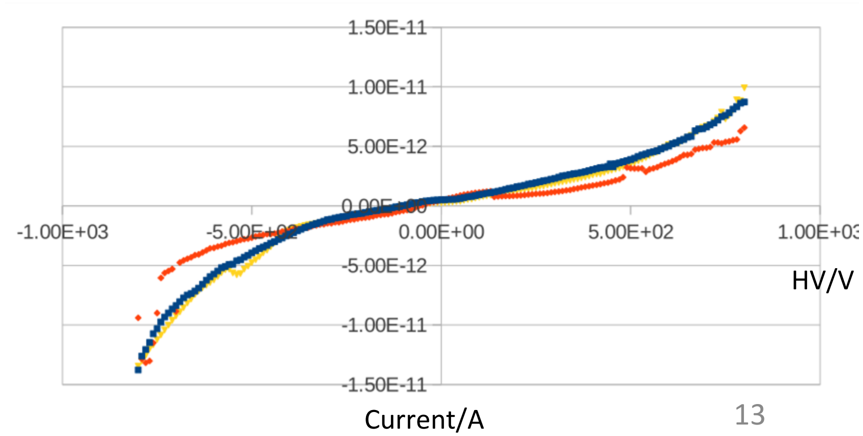
- ***Poly crystalline diamond***
- ***Single crystalline diamond***

Low voltage side readout



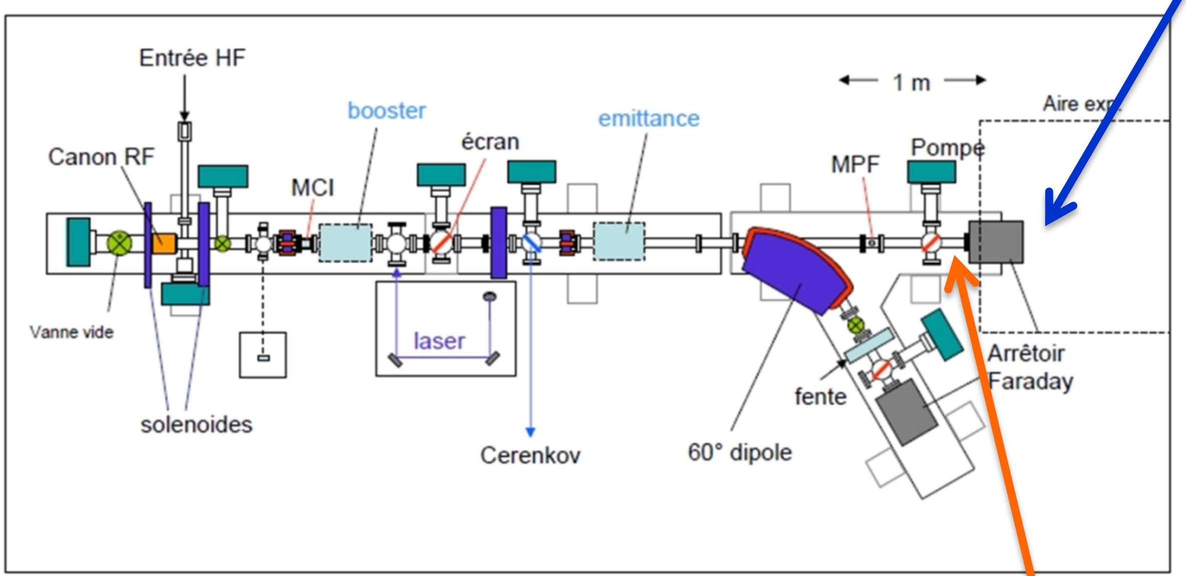
Charge created by 1MIP in diamond → 2.74 fC

Current Measurement



Diamond Detector Test @ PHIL

Test of fast remote readout (amplifier or attenuator +fast heliax coax cable) with particles at end of beam line, using existing single crystal 4.5x4.5mm CVD diamond pad sensor

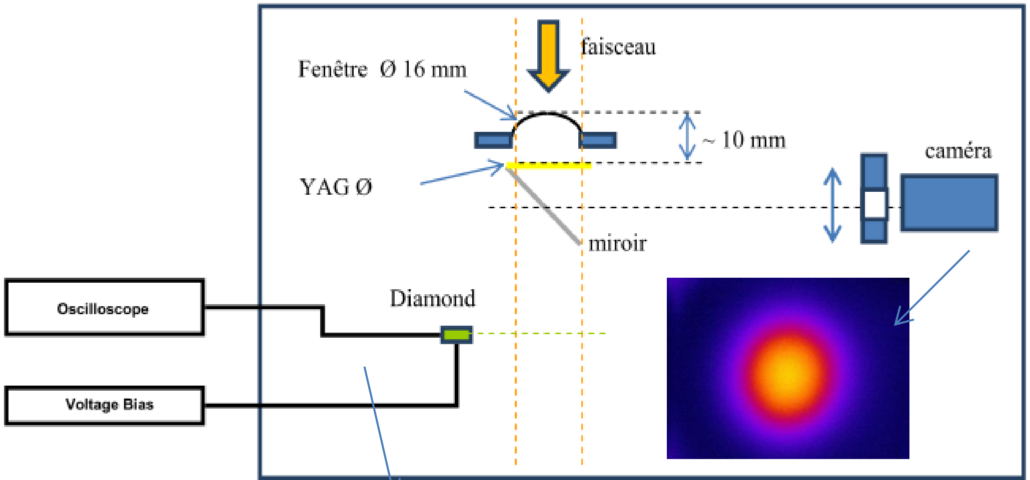


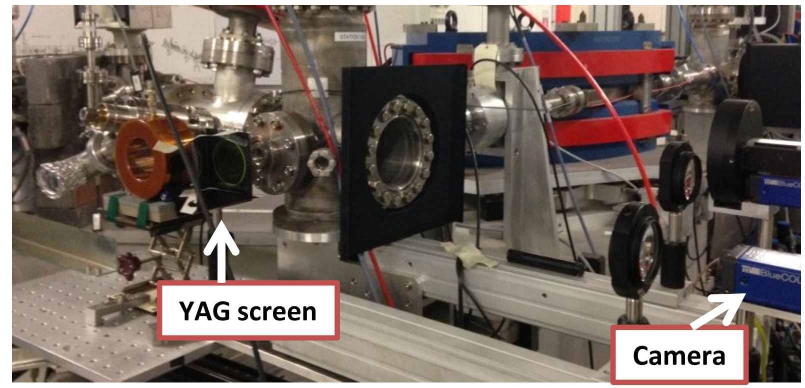
PHIL Electron Beam Parameters

- ✓Charge: 1pC-500 pC/bunch (1 bunch per RF pulse) ;
- ✓Duration of Charge: 7 ps FWHM;
- ✓Charge Stablility: < 2%;
- ✓Beam Energy: 3 to 5MeV;
- ✓Minimum Dispersion: < 1%;

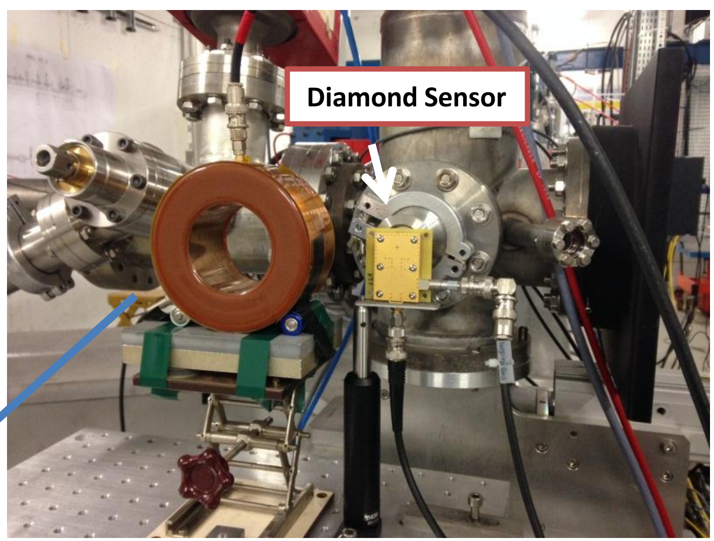
In-vacuum single crystal CVD diamond sensor with 4 strips (identical setups as for ATF2) -> test and diagnostic for PHIL

Experimental Setup @ PHIL

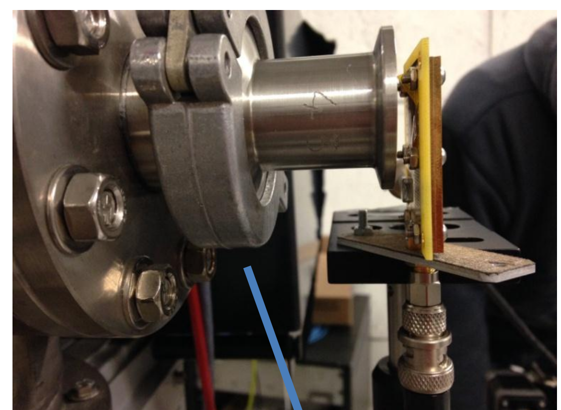




50 m HELIAX 1/2 coax cable+ 50 m HELIAX 1/4 coax cable



ICT3

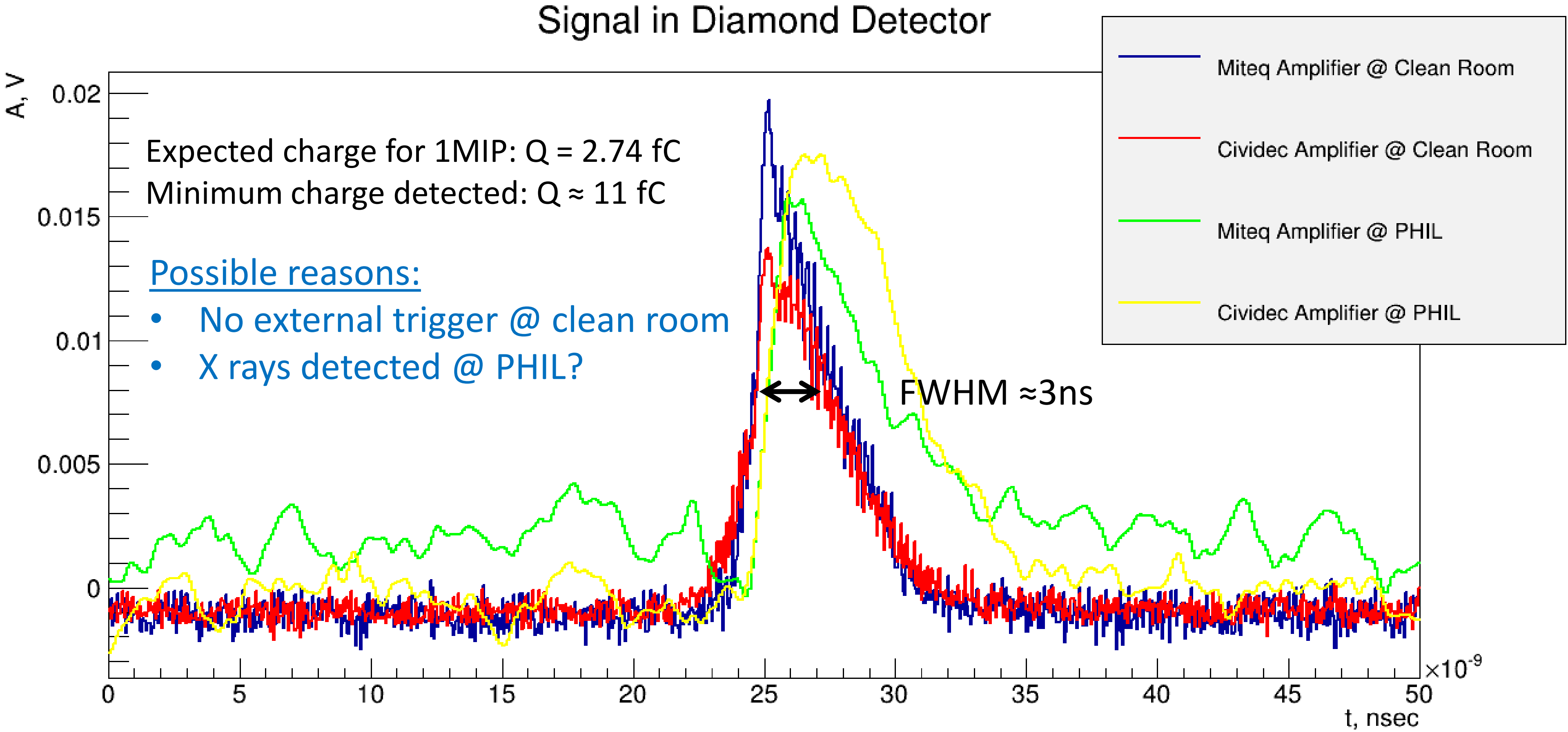


Collimator: R=1mm

Minimum Signal Detection

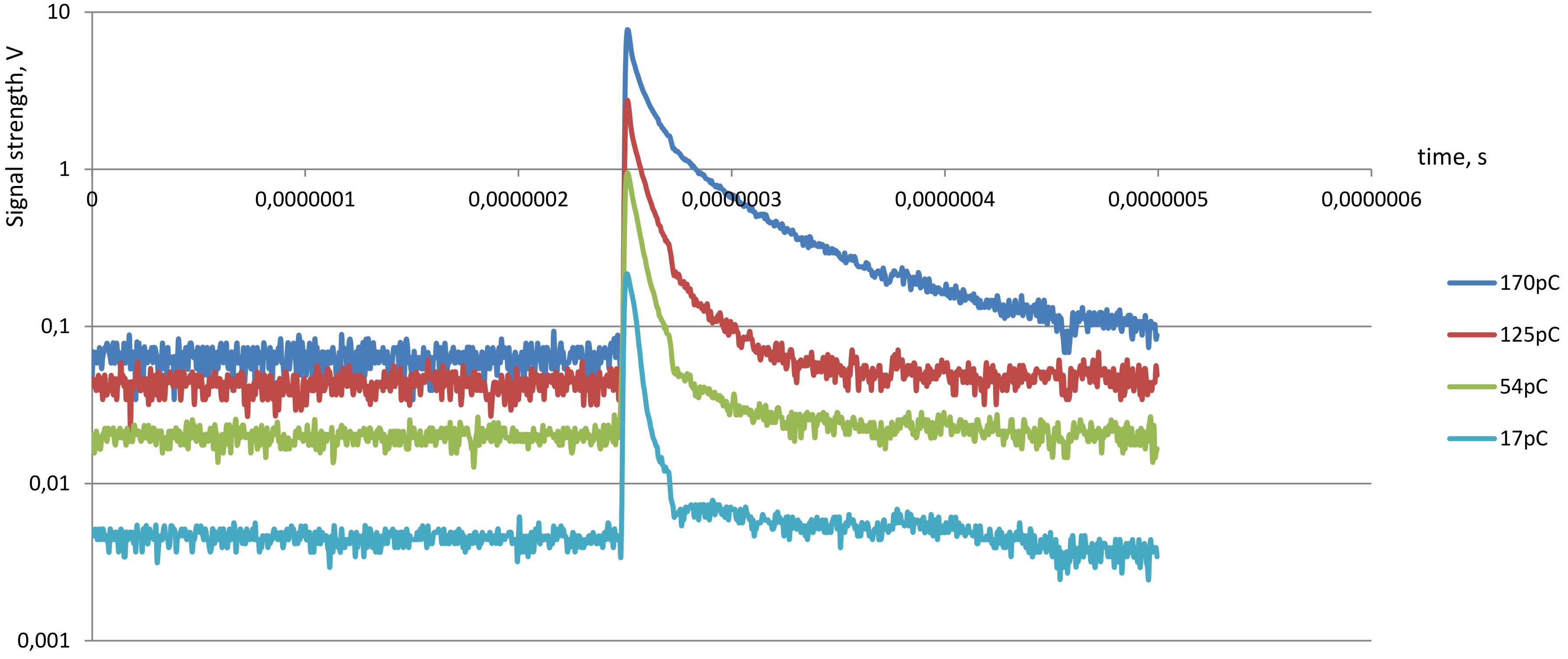
Signal @ Clean Room : averaged by 8 events
Signal @ PHIL : single event

$$^{90}\mathrm{Sr} \xrightarrow[0.55\ \mathrm{MeV}]{\beta,\ 27.7\mathrm{y}} {}^{90}\mathrm{Y} \xrightarrow[2.27\ \mathrm{MeV}]{\beta,\ 64\mathrm{h}} {}^{90}\mathrm{Zr}$$



Signal Form for Different Beam Charge

Without box and with 24dB attenuator and 2mm collimator, distance to exit is ≈4.5cm



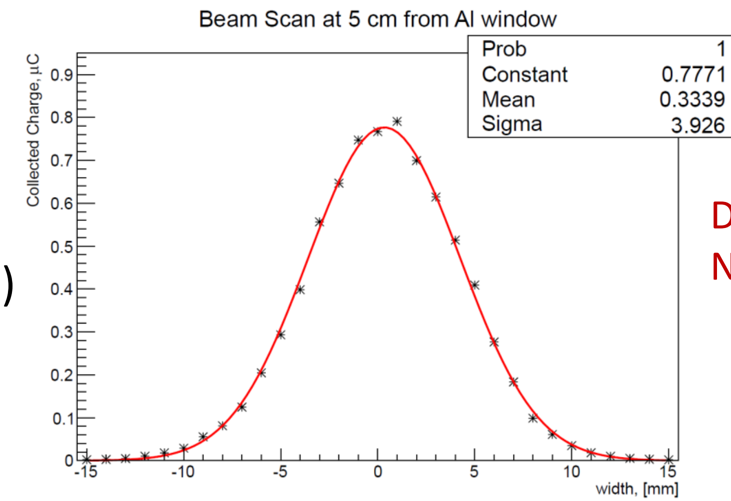
Beam Size Measurement

Diamond size : 4.5X4.5 mm

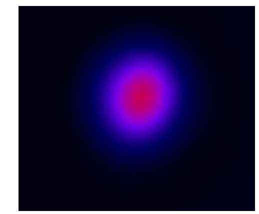
$\sigma_m{}^2 - (4.5/\sqrt{12})^2 = \sigma_{beam}{}^2$

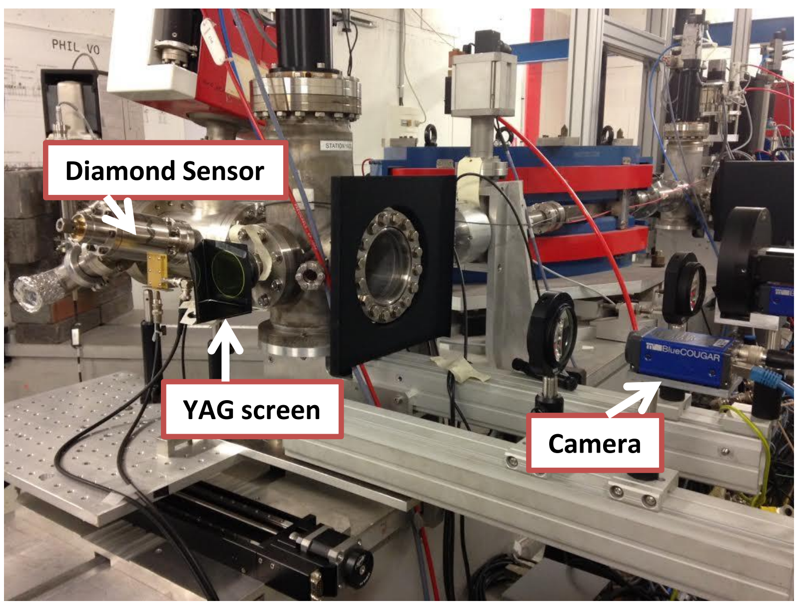
σ_m : measured beam size (fitted by gaussian)

σ_{beam} : horizontal beam size



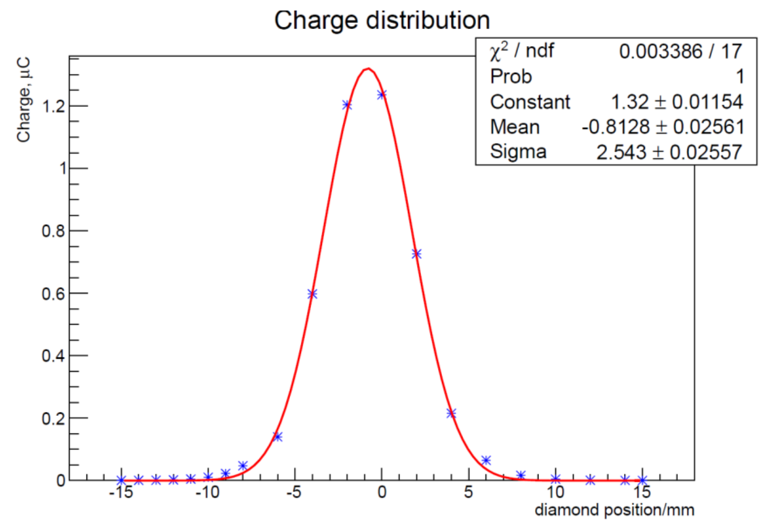
Data taken in Nov. 2013





σ_{beam} =3.7 mm

YAG screen measured beam size : 2.2 mm

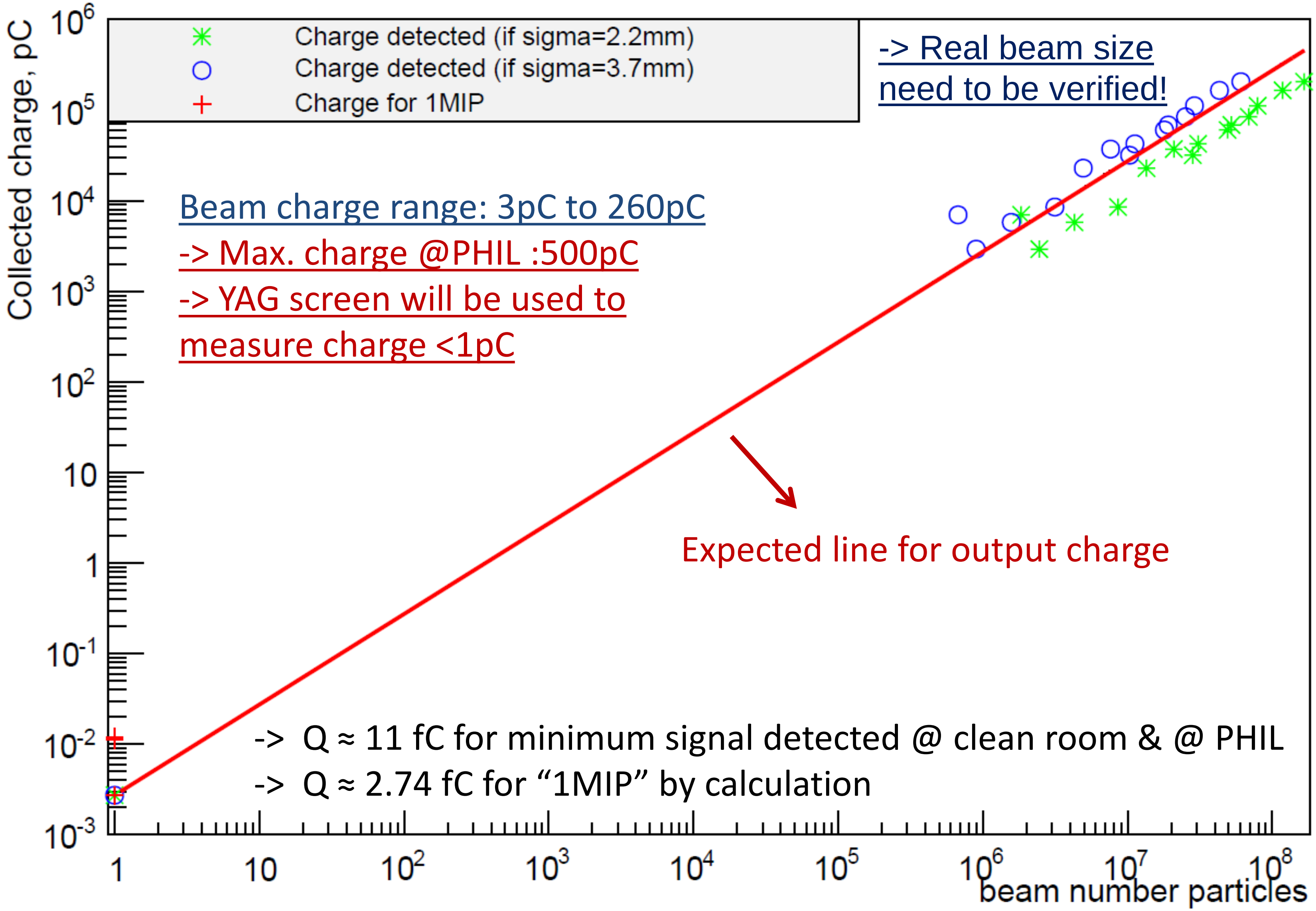


Data taken in Jan. 2014

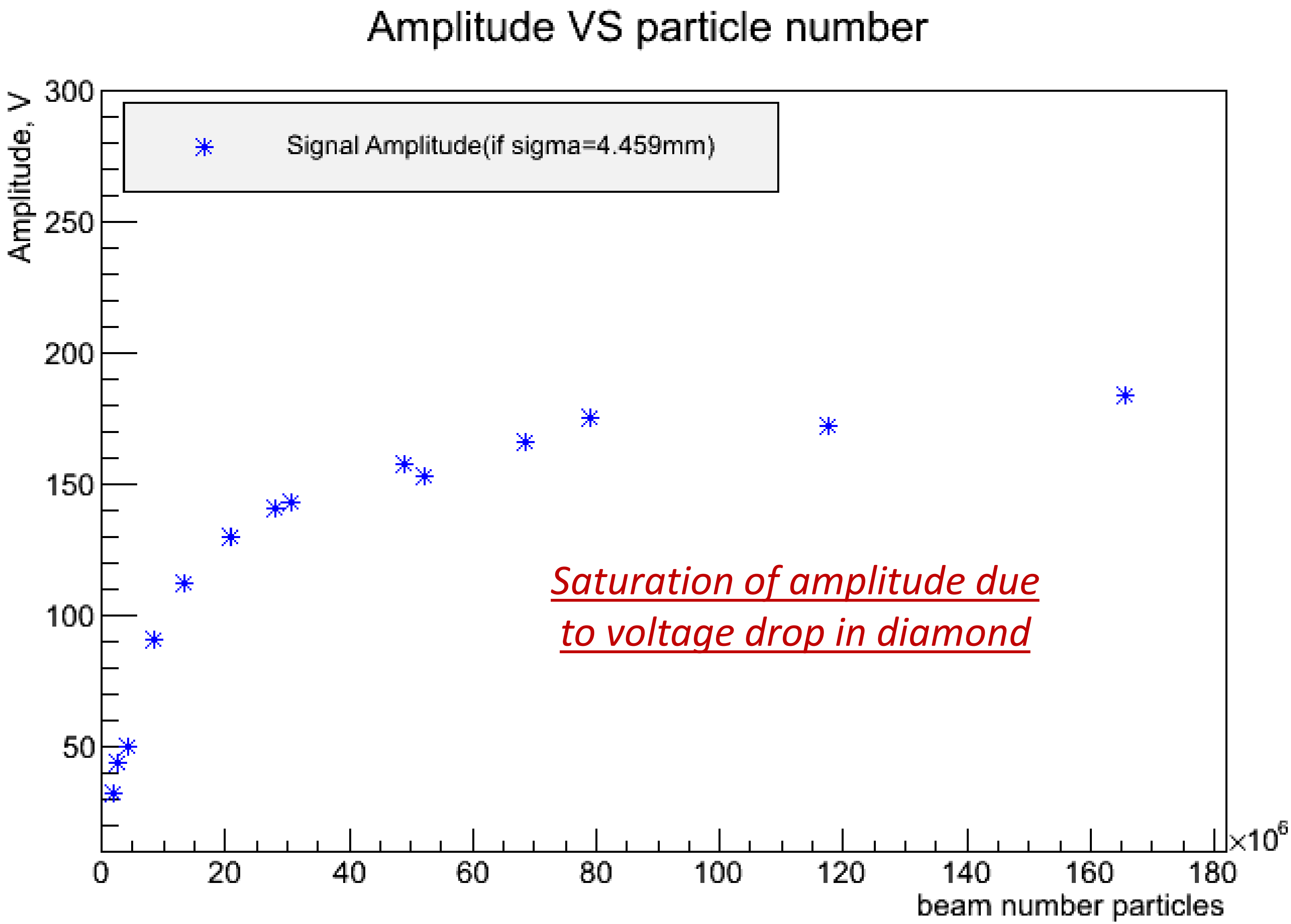
σ_{beam} =2.17 mm

YAG screen measured beam size :1.67mm

Linearity of Output Charge

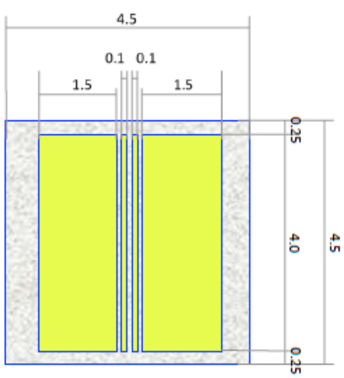


Saturation of Output Amplitude



Expected Signal Range @ ATF2

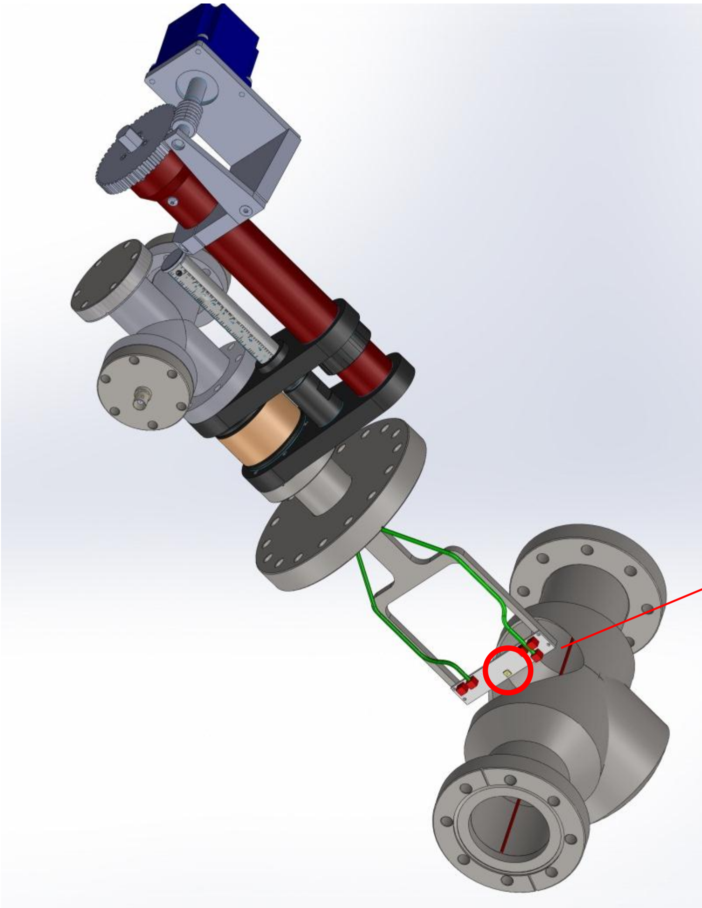
	Total #	Max. #/mm^2 @ Sensor	Charge signal/mm^2
Beam	10^{10}	$6.16*10^7$	1.6887μC
Halo ($\delta p/p_0$=0.01)	10^7	$1.14*10^4$	31.236pC
Halo ($\delta p/p_0$=0.0008)	10^7	$2.24*10^4$	61.376pC
Compton	28340	$5.2*10^2$	1.4284pC

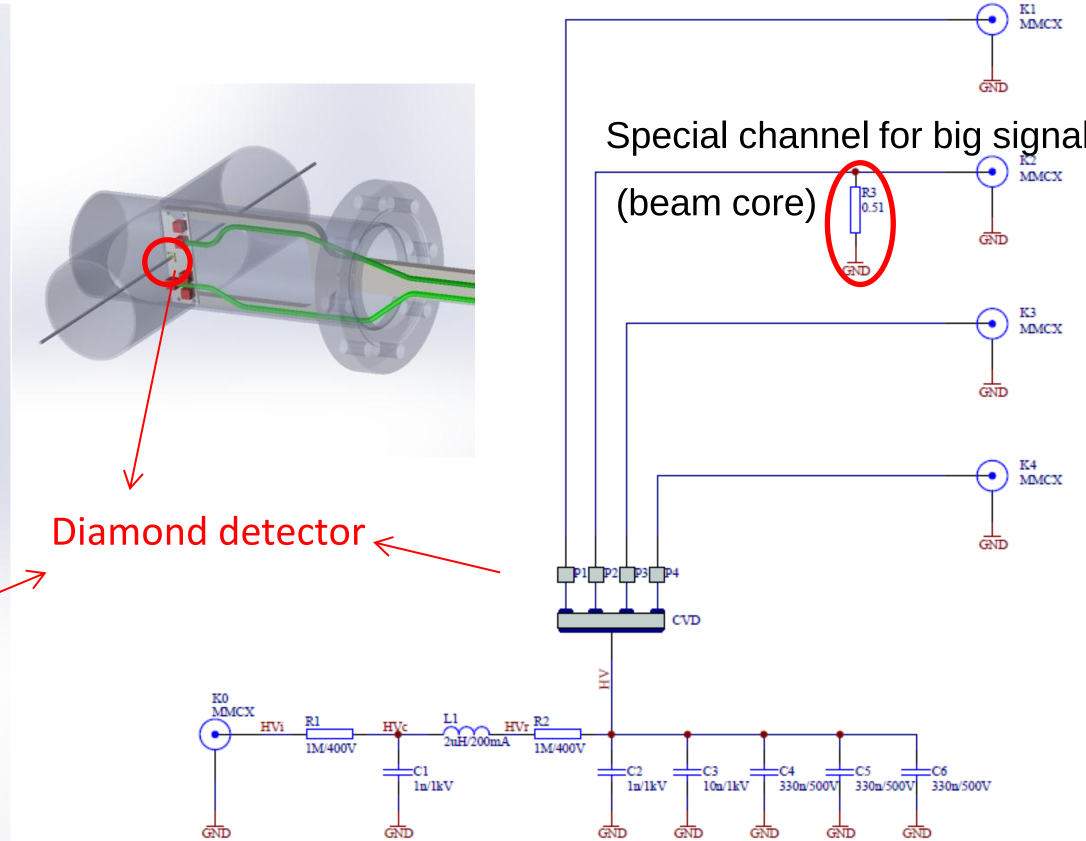


Tested signal ranged @ PHIL with 4.5X4.5mm^2 diamond pad
-> 11fC (with 40dB amplifier) to 1μC (with 12dB attenuator)

=> *New design* with 4 strips for diamond detector in vacuum

Design for Diamond Detector in Vacuum





Same "plug compatible" design for PHIL and ATF2: fabrication will be completed in April 2014 before testing in May-June at PHIL.

Summary and Future Plan

- Halo measurement at diagnostic section (extraction line) using MW2X wire scanner require *careful procedures for the data taking and analysis to combine data with sufficient dynamic range*; Measurements were done up to *$\pm 15\sigma_x$* and the results in 3σ to 6σ range fit reasonably with parameterizations determined using data taken in 2005, however *beyond 6σ the beam halo is covered by background;*

- Diamond detector will be installed after the B-Dump bending magnet to investigate the beam halo propagating mode;

- We have successfully detected a minimum signal of *1 electron by using 40dB amplifier* and a maximum signal of *10^8 electrons by using 24dB attenuator*.

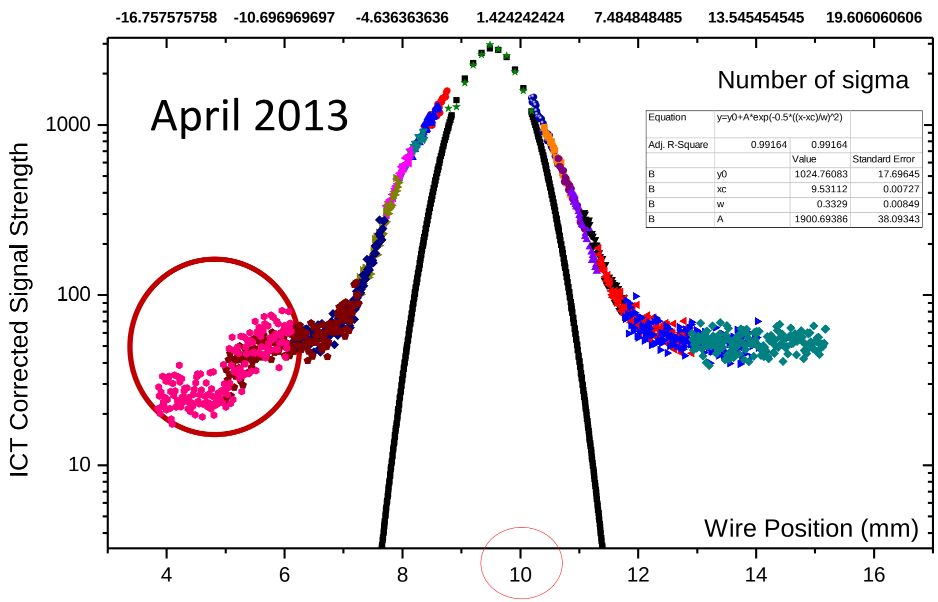
- Diamond detector tests @ PHIL show good linearity in output charge in *the range from 10^6 to 10^8 particles -> more tests are planned for larger range;*

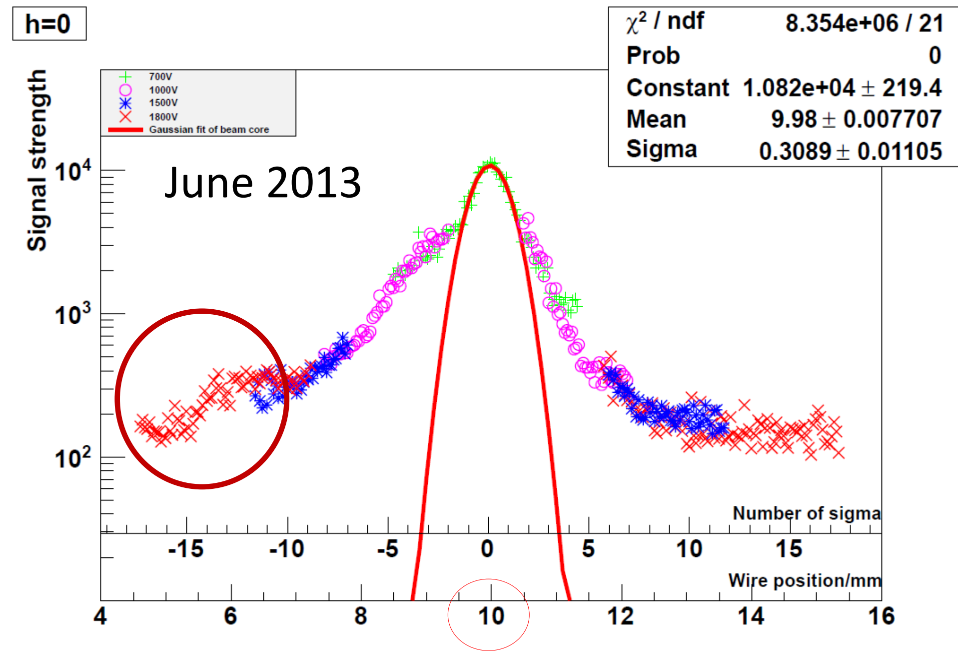
- Fabrication of diamond detector for vacuum *will be completed in April 2014 before testing in May-June at PHIL and installation at ATF2.*

Thank you for your attention !

Backup Slides

Halo Distribution at Post-IP

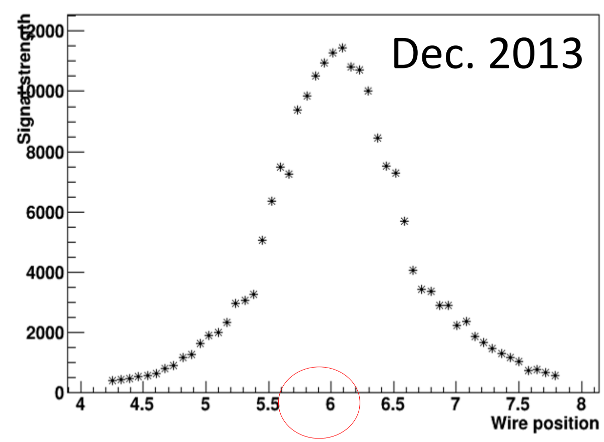




Edge of cutting almost at the same position -> -14σ

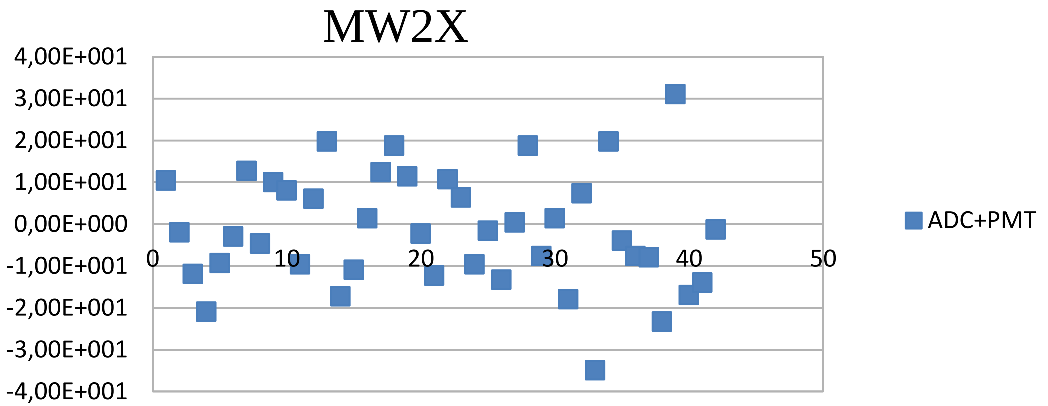
Beam Center Moved from 10mm to 6mm

→ Not able to see the edge on the left side again

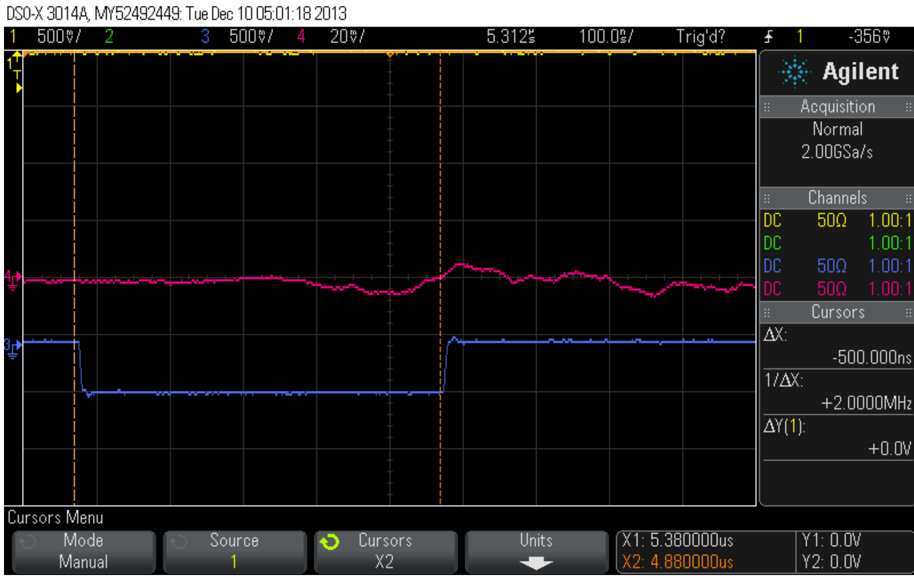


Signal Level Without beam

- By connecting the ADC with the PMT, we measured the signal level with data acquisition software → should be 0 without beam and without background?
- Signal level for MW2X: -1.4 (average)



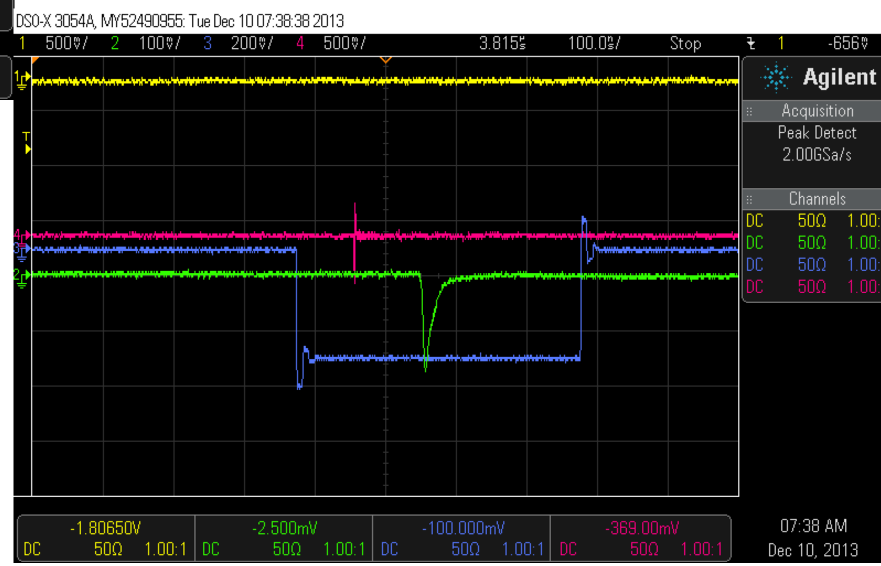
Gate Width and Signal Pulse



MW2X

gate width:500 ns

timing delay: ? ns

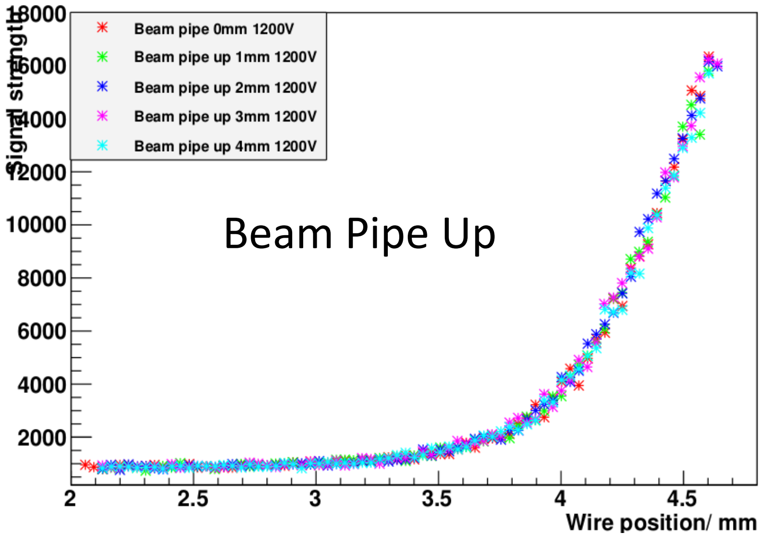


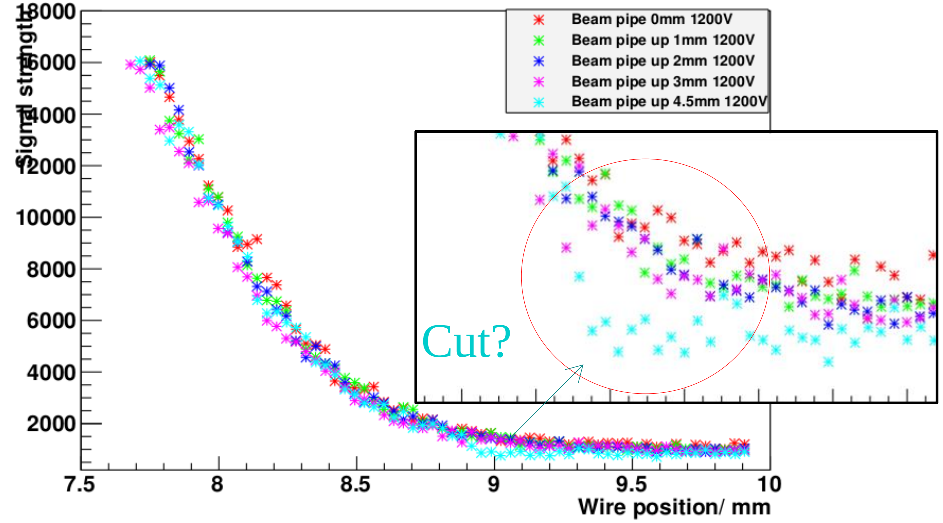
MW1X

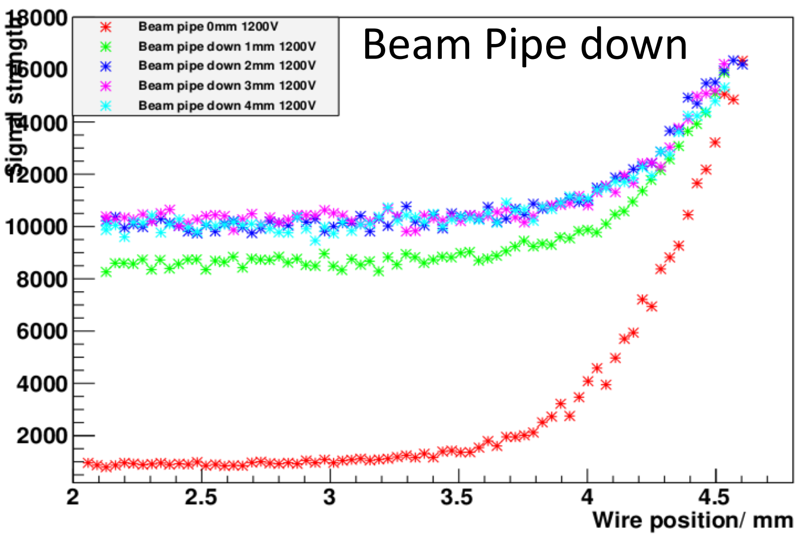
gate width:410 ns

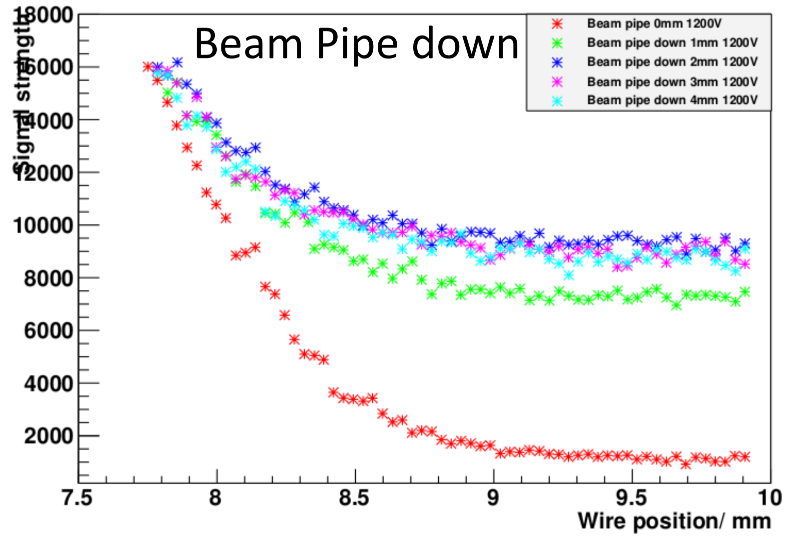
timing delay: 180 ns

Effect of Beam Pipe Movement on Beam Halo

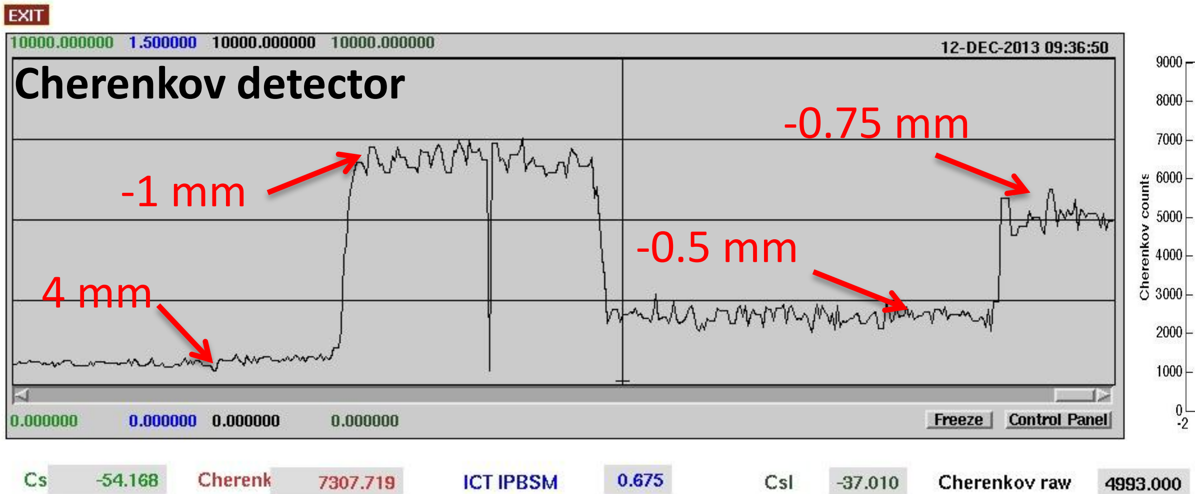


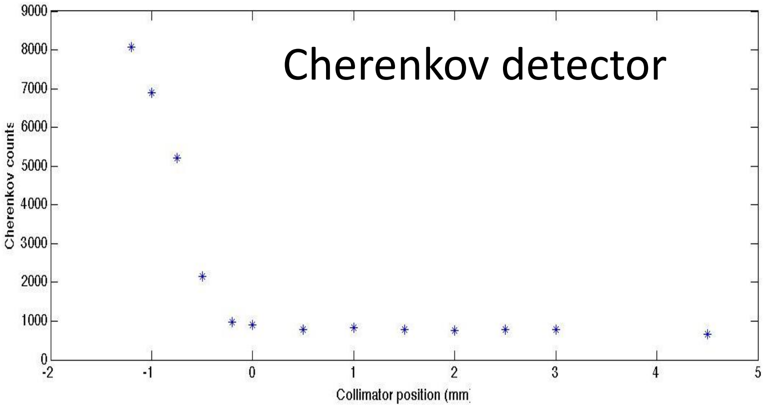


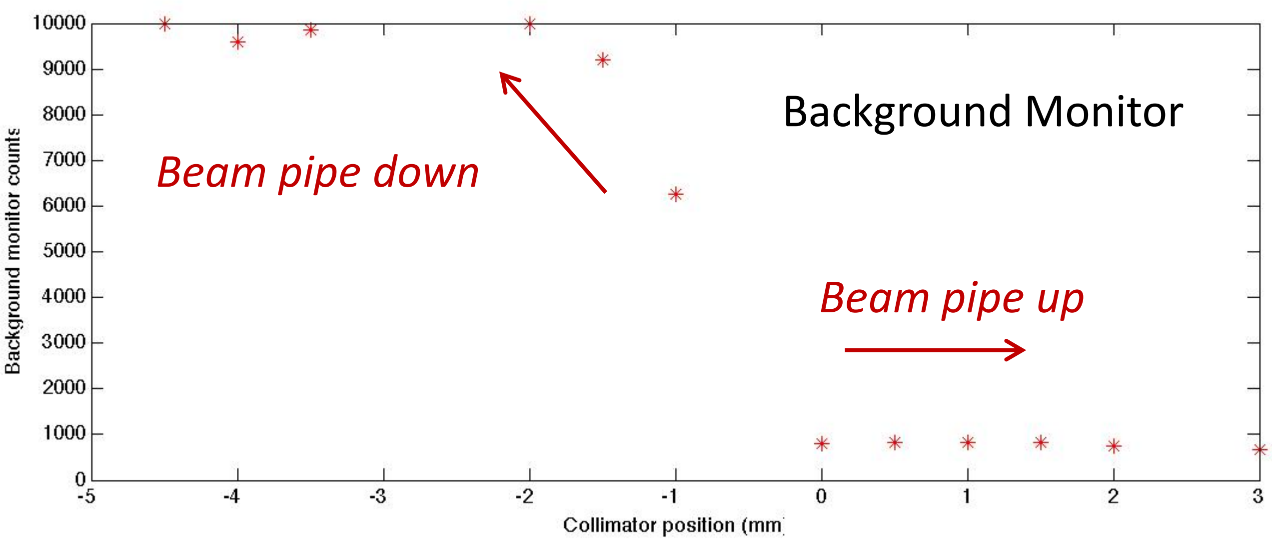




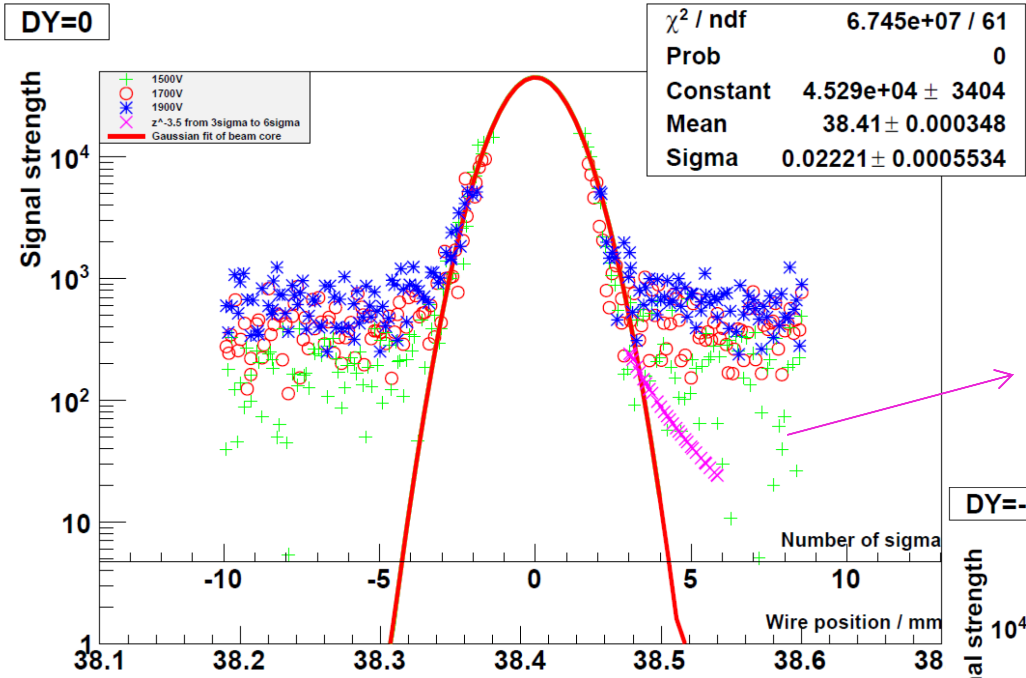
Effect of Beam Pipe Movement on Background





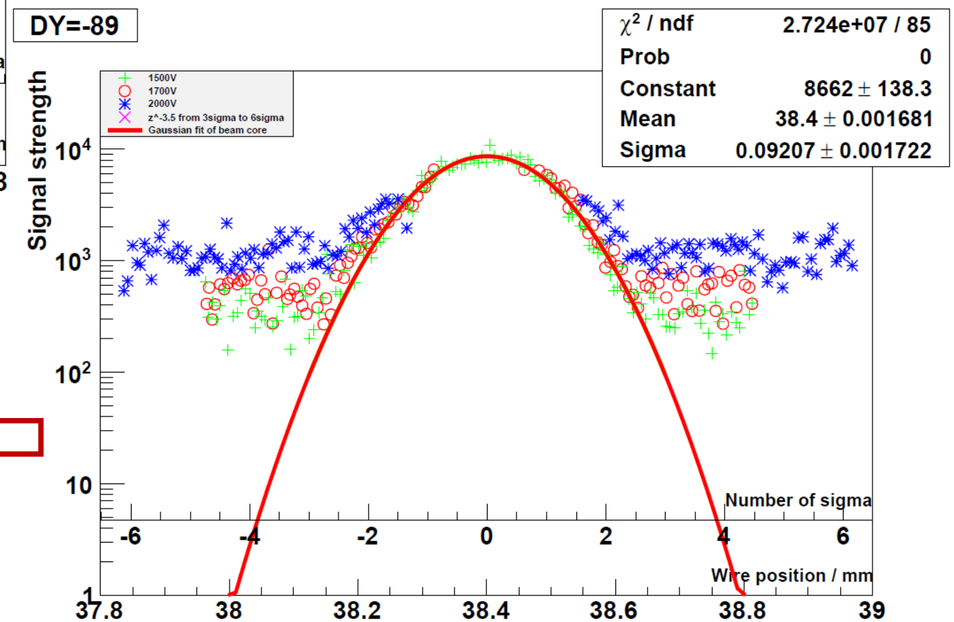


Energy Halo Measurement Using MW2X



Parameterization of beam halo (initially done by Suerara-san in 2005 and modified by Dou):

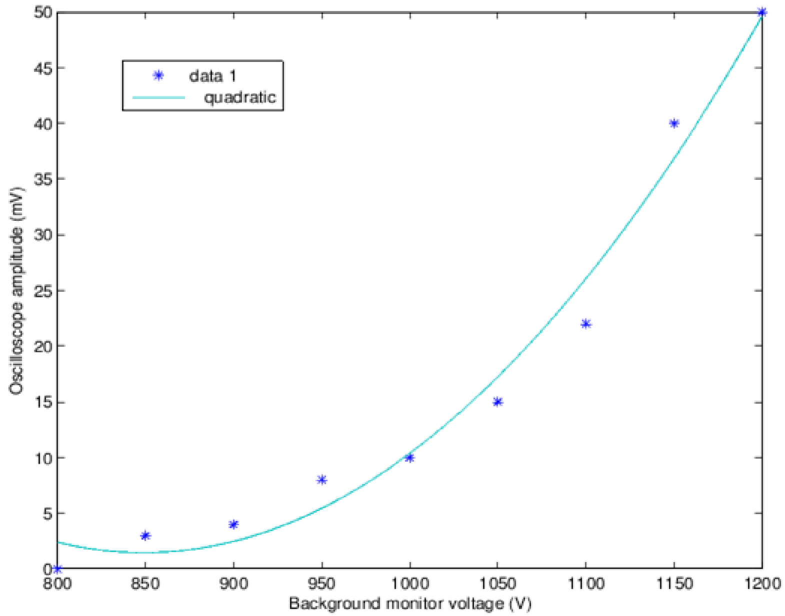
$$\rho_{halo} = 1.02 * 10^{9} * z^{-3.5} \ (3 < z < 6)$$



DY=0, Halo starts at ≈ 3 σ

DY=-89, Halo starts at < 2 σ

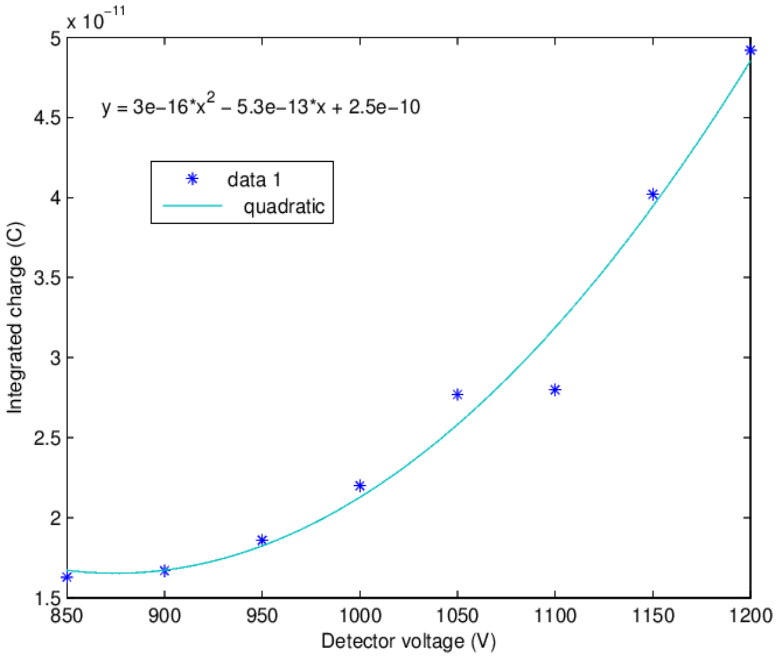
Dependence of Background on HV



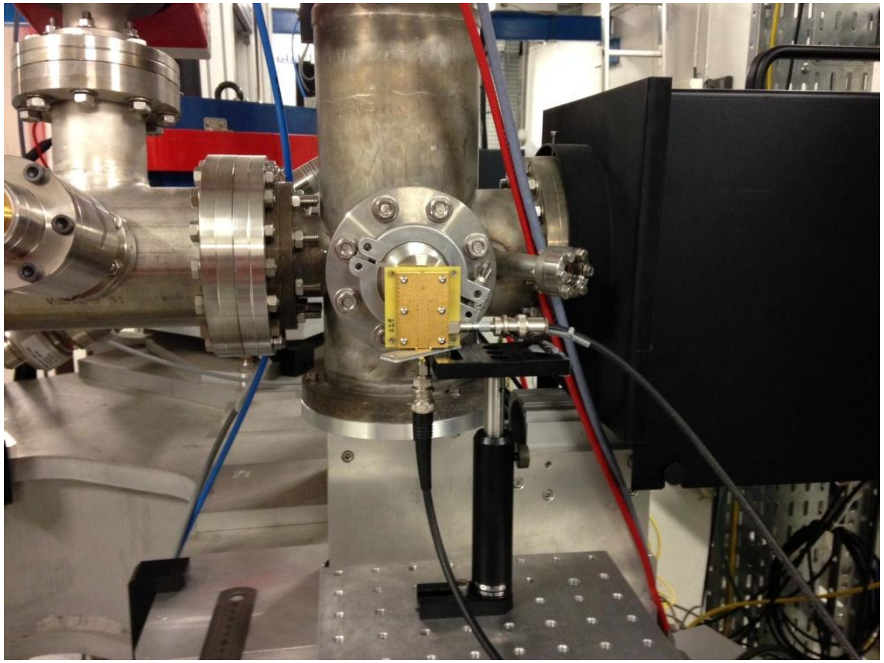
Data taken on Agilent Scope

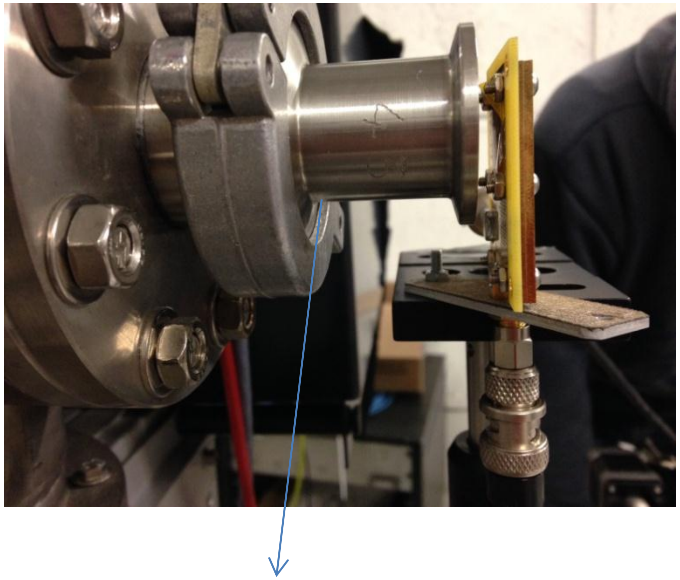
→ Amplitude vs HV

Charge vs HV ←



Measurement Procedure

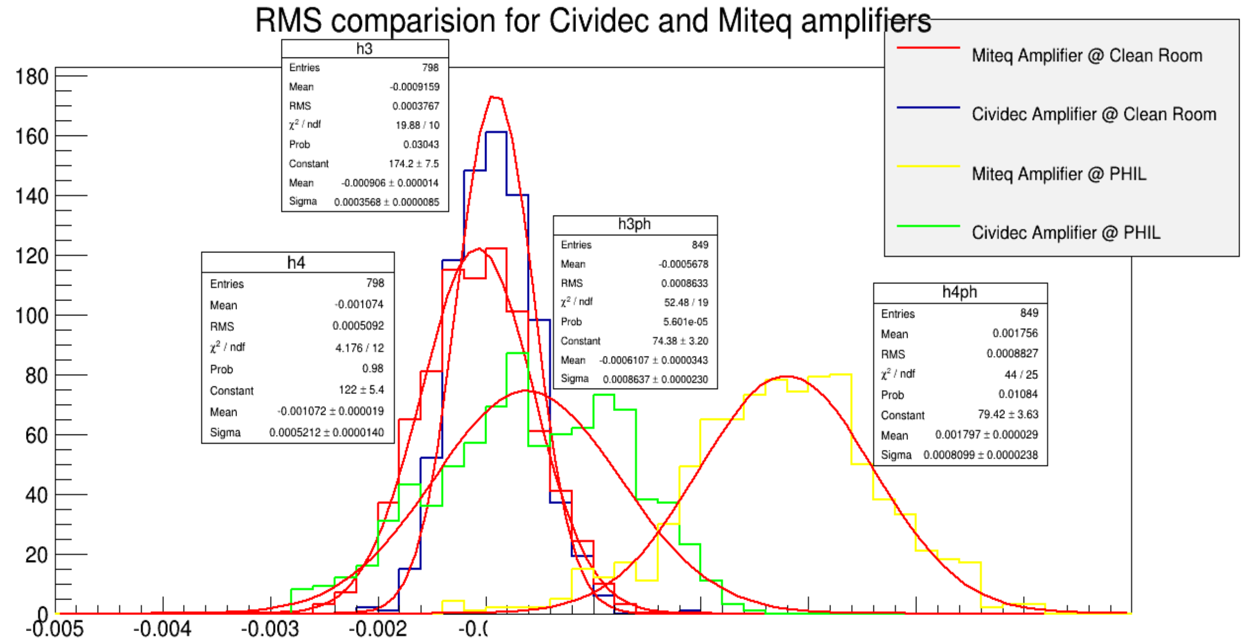




R=1mm collimator (L=4mm)

- Put the diamond detector at 4.5mm far away from the exit
- Scan the beam without collimator to measure the beam size
  -> for the calculation of # e^- hit on the diamond
- Add R=1mm collimator and steering the beam to the center of diamond
- Measure the beam charge at exit using ICT(from 1pC to 270pC)
- Read the signal strength (amplitude and area) using Agilent scope

Noise Analysis



CIVIDEC 40dB amplifier

MITEQ 20dB+20dB amplifier

	Miteq@CR	Cividec@CR	Miteq@PHIL	Cividec@PHIL
Noise Mean Value, mV	-1	-0.9	-0.6	1.8
Noise RMS, mV	0.51	0.38	0.88	0.86
Collected charge, fC	10.6	9.6	17.6	19.1
Signal Amplitude, mV	20	14	16	18
S/N ratio	41.2	39.2	18.8	18.8