CryoBLM Beam test – first results

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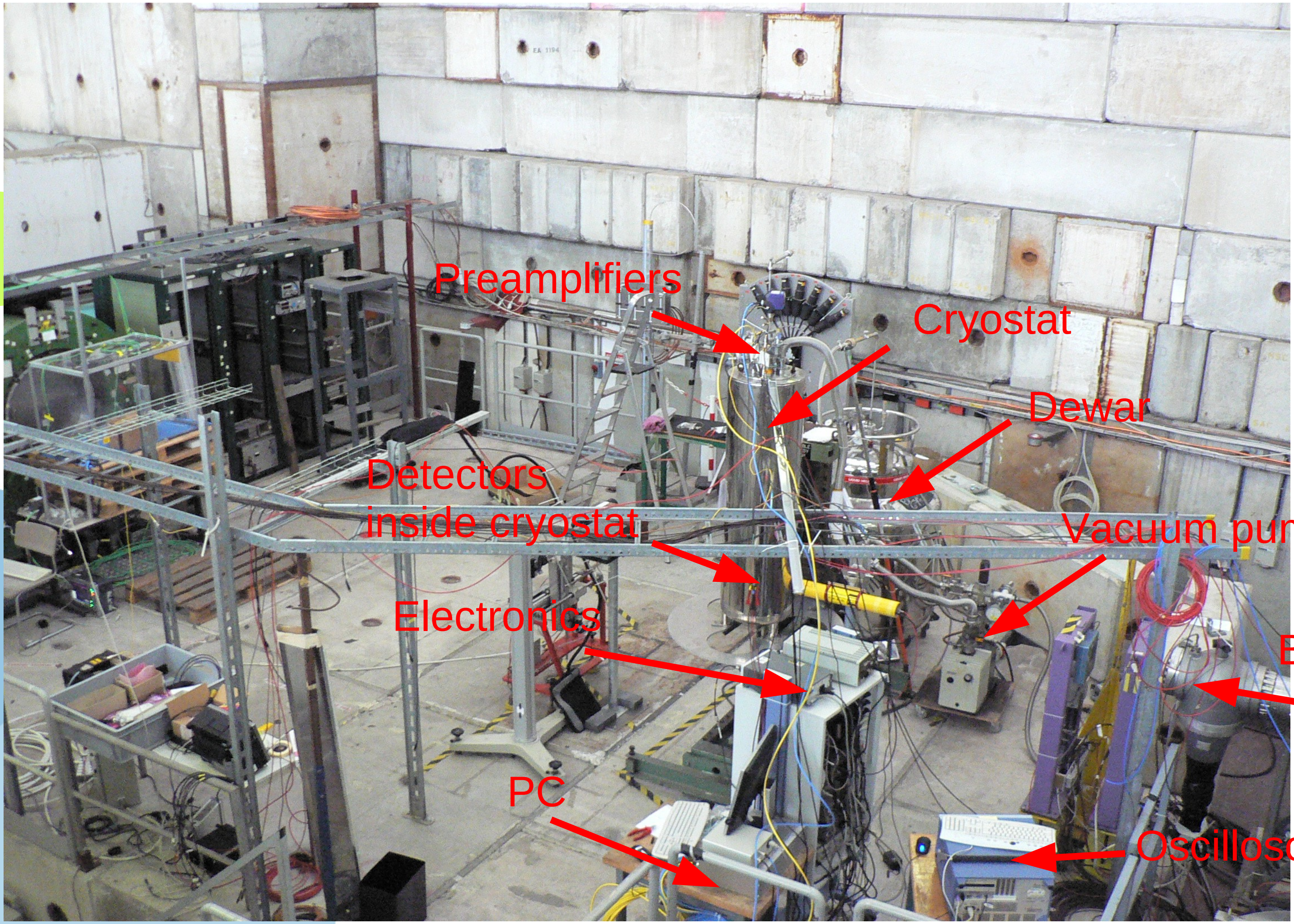
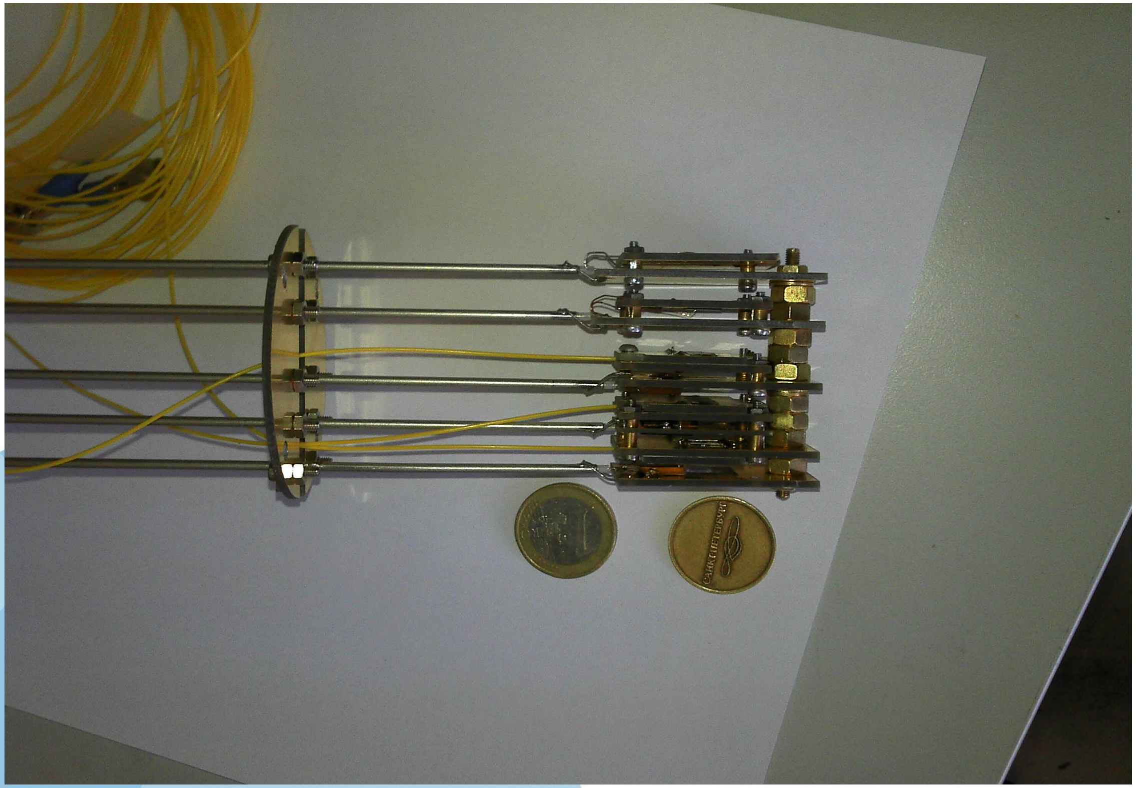
Outline

- Measurement setup
- Beam characteristics
- Signal estimations
- Single particle mode
  - Trigger level discussion
  - Diamond results
  - Si results
  - Comparison
- DC measurements
  - LHe chamber results
  - Diamond results
  - Si results
- General comparison (estimation, single particle and DC)
- Open questions and future measurements

Beam test area

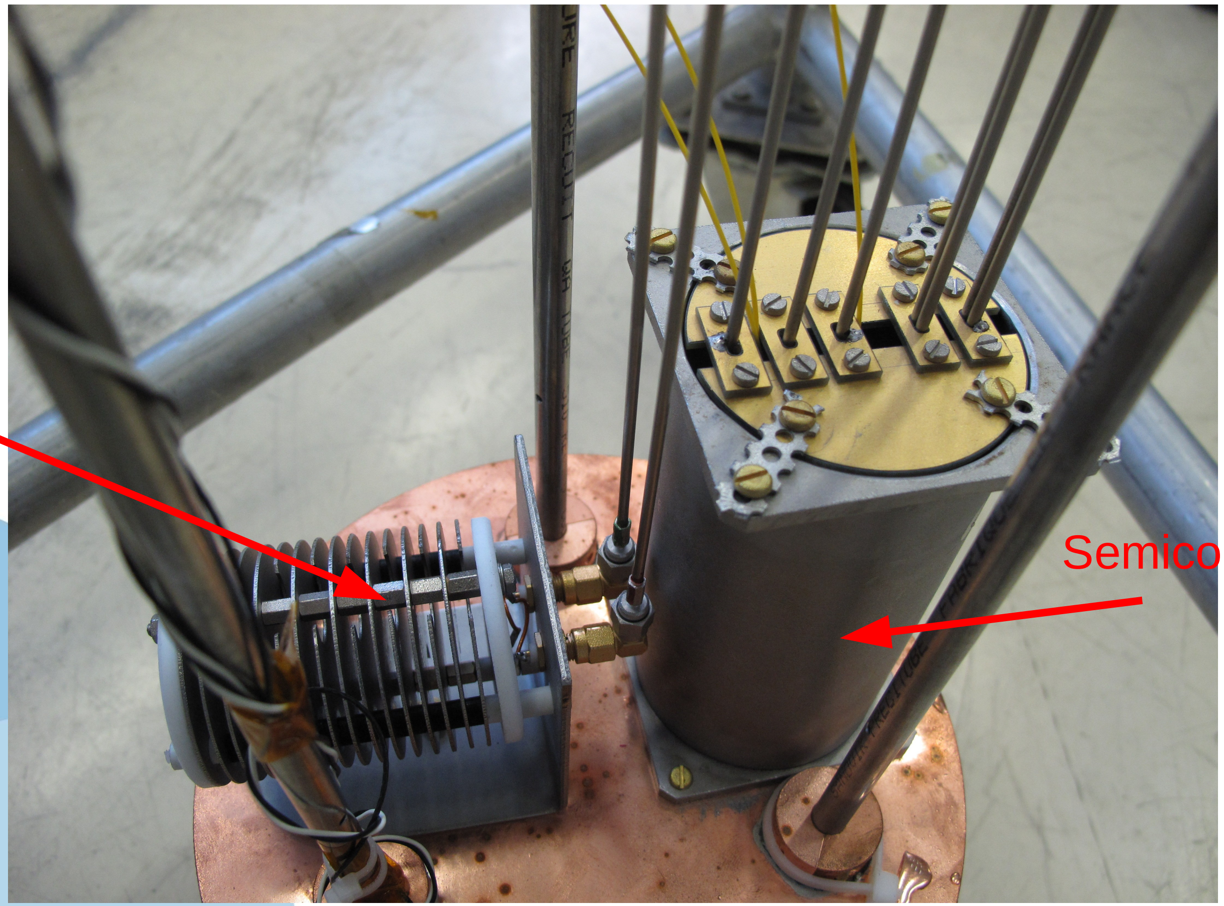


Semiconductors holder from Vladimir Eremin



- 4 Silicon detectors
- 1 single crystal diamond (sCVD)

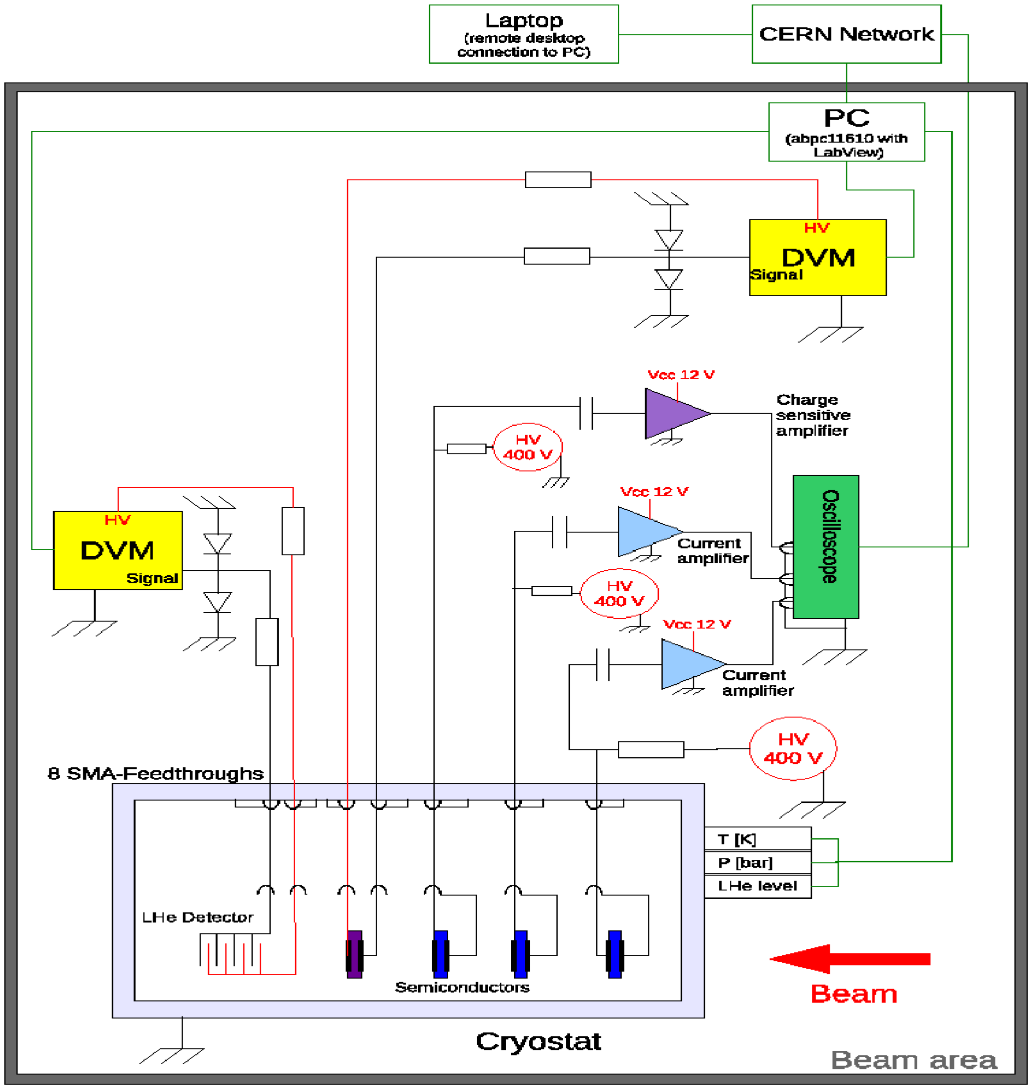
Inside cryostat - detectors



Inside cryostat

Cable length between detectors and preamplifiers ~ 1.5 m

Electronic setup general overview

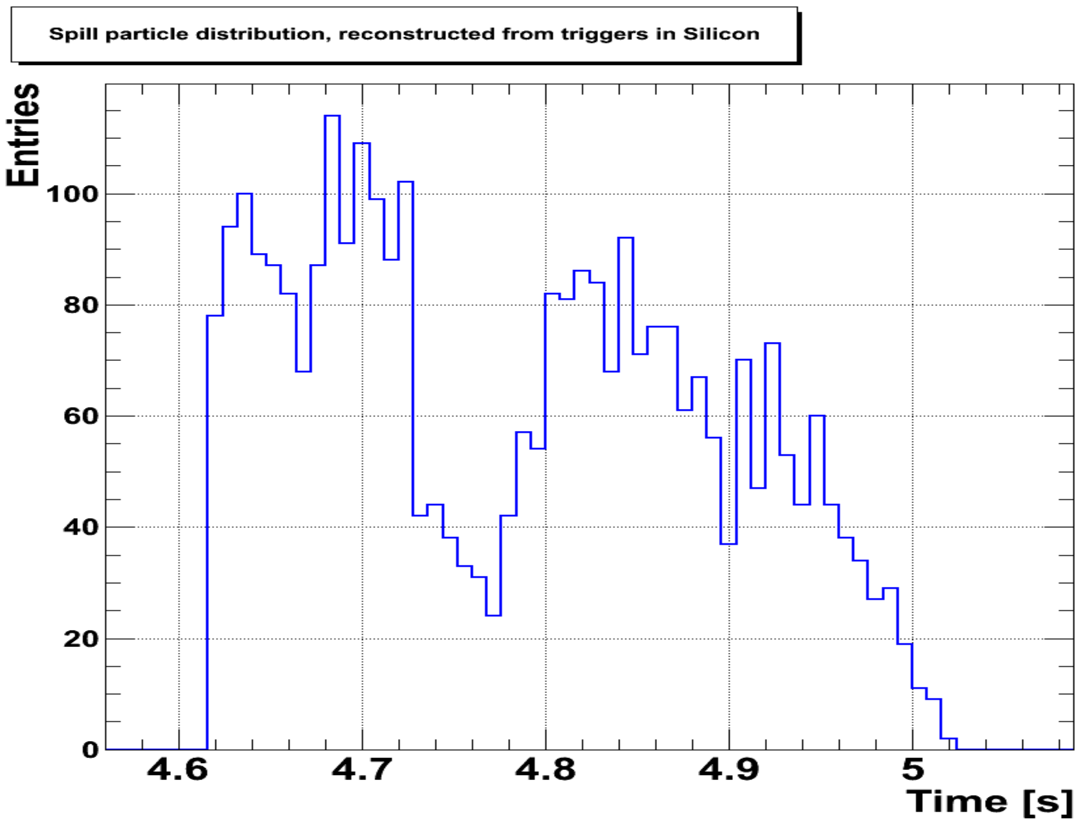


T9 Beam characteristics

- Beam generated by directing PS beam onto target
- Particles consist of positive pions, kaons and protons (dominating)
- 10 GeV/c particles
- Beam intensity 350 000 particles/spill
- Size at focus about 1 cm^2
- Spill duration of 400 ms (about 875 particles/ms)
- One spill every 45 s

- Practical advantages:
  - Close to cryolab
  - Enough space available for cryogenic setup
  - Fast beam stop and entering of radiation area possible

Beam characteristics
Spill shape



- Spill shape of one spill and about 3000 entries
- Adding more spills for better statistics and better average spill shape

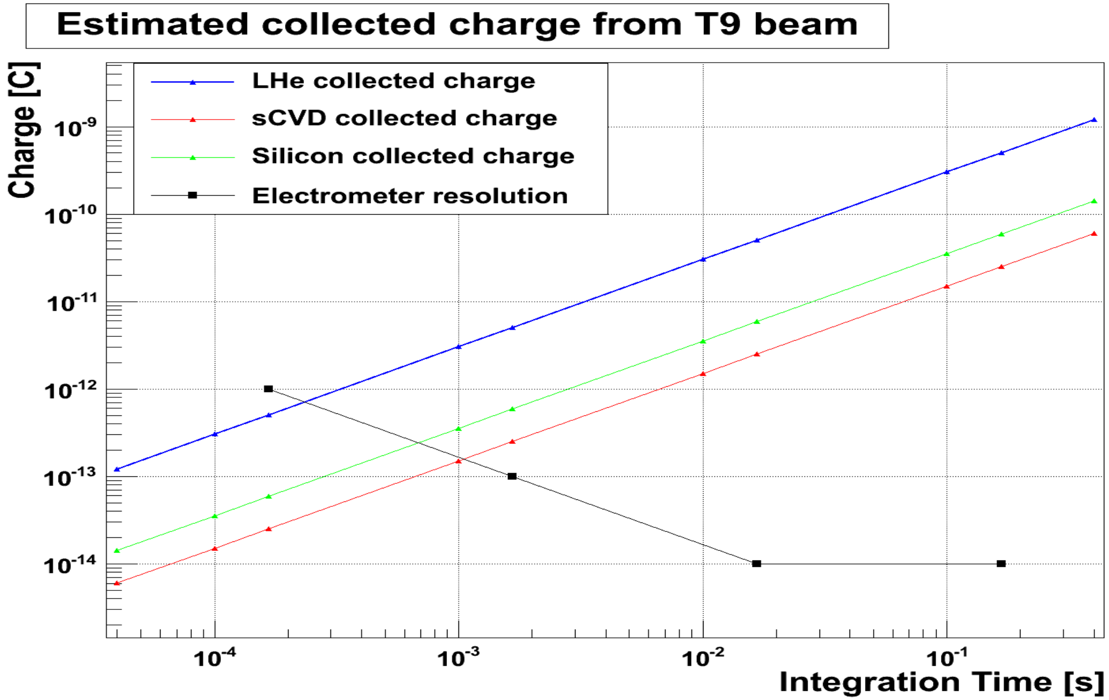
Signal Estimation

- Estimations done with:
  - Stopping power of material P_{stop}
  - Density of material ρ
  - Electron-hole Pair creation energy E_{pair}
  - Dimensions of detector (active area A_{active} and length l)
  - Beam characteristics (beam size A_{beam}, number of particles n_p and spill duration)
- Charge per particle:
  - Liquid helium: **12.2 fC**
  - sCVD: **3.79 fC**
  - Si: **5.68 fC**
- Charge per spill:
  - Liquid helium: **3.66 nC**
  - sCVD: **182 pC**
  - Si: **426 pC**

$$Q = \frac{P_{stop} \cdot \rho \cdot l}{E_{pair}}$$

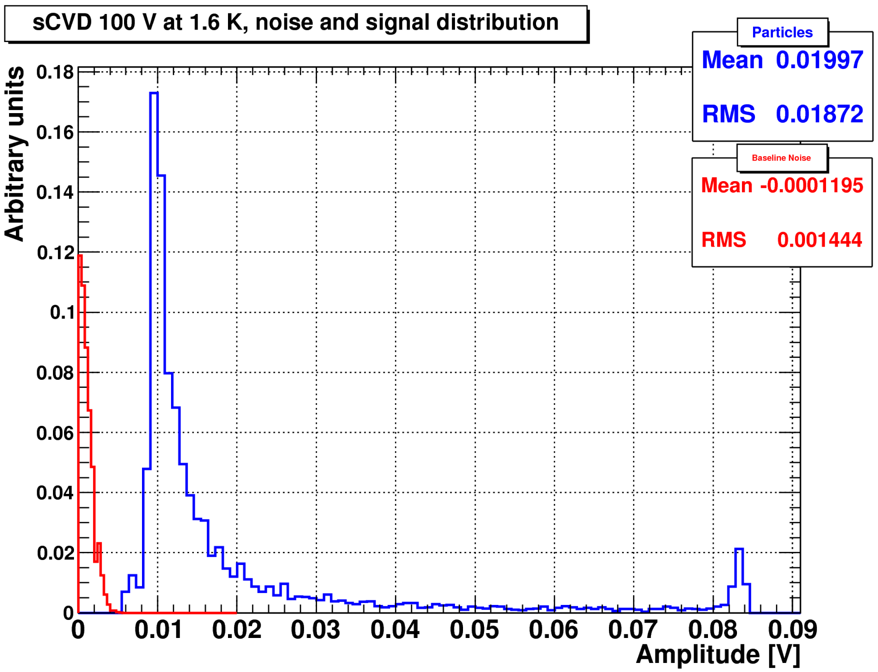
$$Q_{spill} = \frac{P_{stop} \cdot \rho \cdot l}{E_{pair}} \cdot n_p \cdot \frac{A_{active}}{A_{beam}}$$

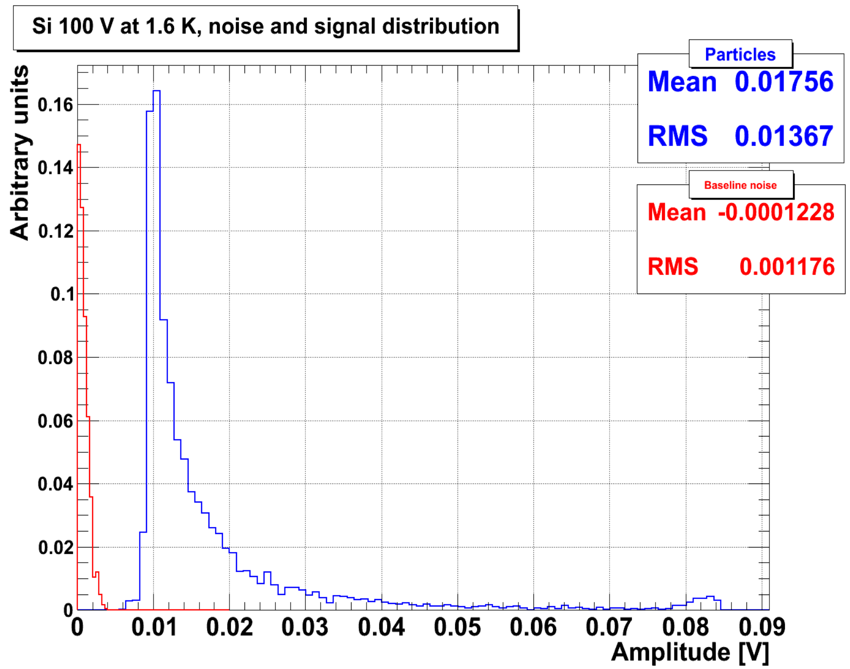
Signal Estimation
(Check done to see if signals measurable)



- Estimated currents from particles:
  - LHe chamber: **9.14 nA**
  - sCVD: **454 pA**
  - Si: **1.07 nA**

Noise and signal comparison through amplitude distribution



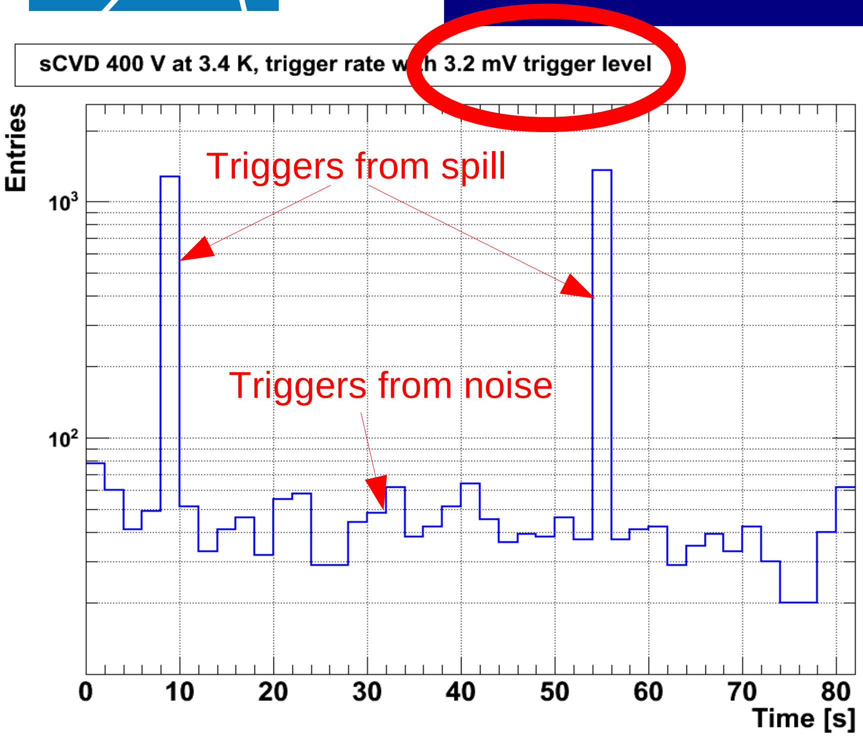


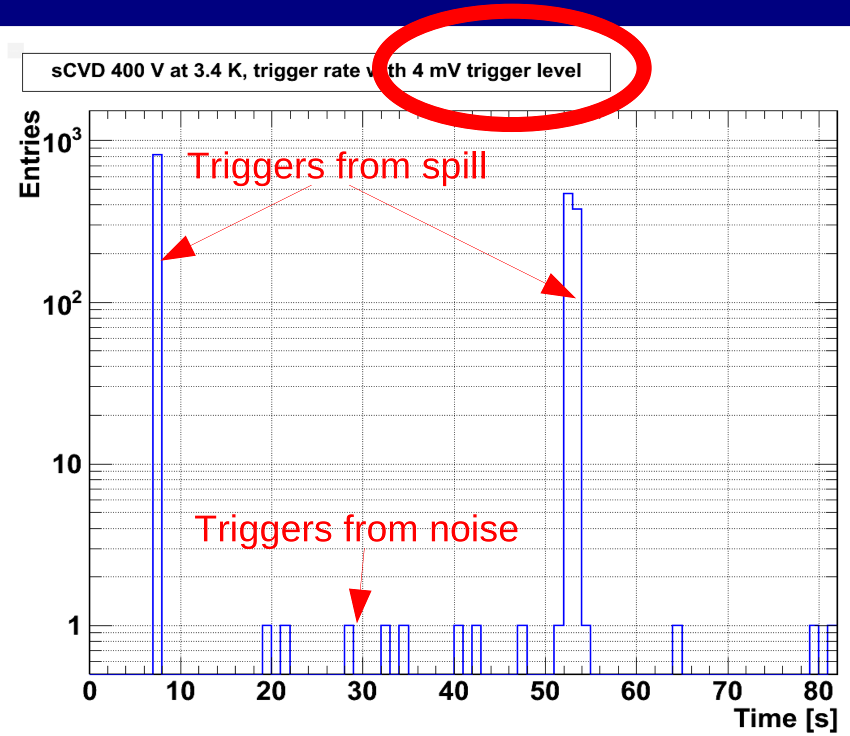
- 6 mV trigger (Trigger setting important)
- To compare with values from DiamondBLM:
  - Baseline noise RMS 0.4 mV
  - Particles mean: 16.9 mV

Triggering method on oscilloscope for single particle detection

- Goal: detect all particles and no noise
- Noise level is slightly different (depending on vibrations from vacuum pump, heat of the amplifier,...) two strategies for trigger level:
  - 6 mV over all measurements to enable comparison (Downside: loss of pulses from particles)
  - Optimisation of trigger for each measurement (Downside: less comparable)
- Solutions for future:
  - Analysing only pulses inside the spill
  - Use additional external trigger next time

Trigger level

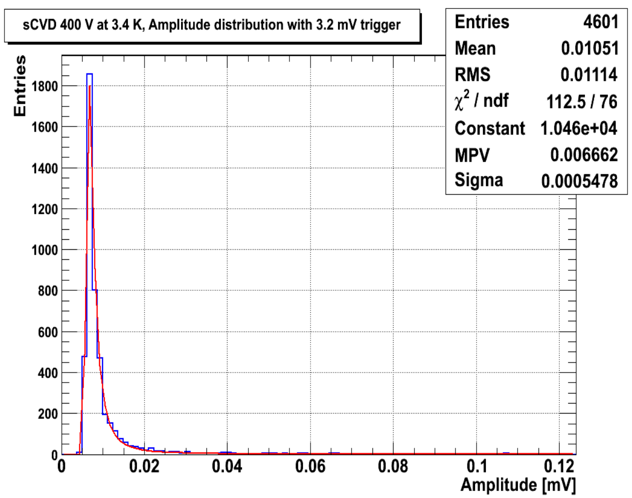


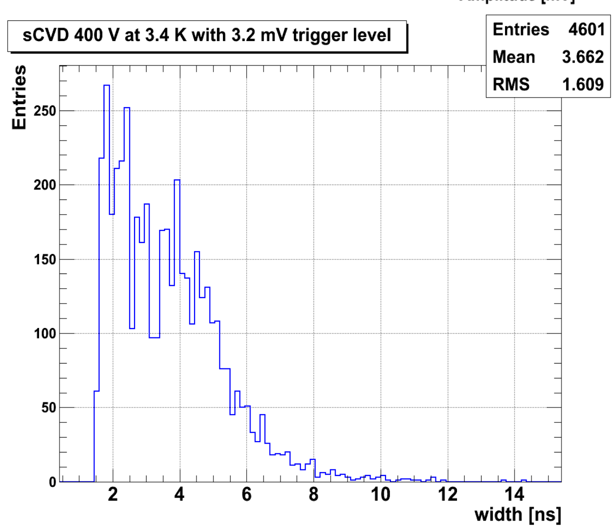


- With 3.2 mV trigger level about 30 % noise
- With 4 mV trigger lower noise rate, but also less particles detected from spill

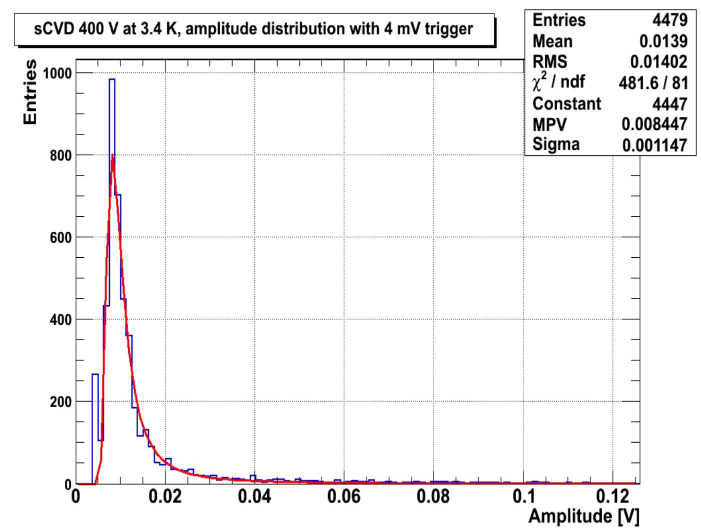
Trigger level
Comparison 3.2 mV and 4 mV level

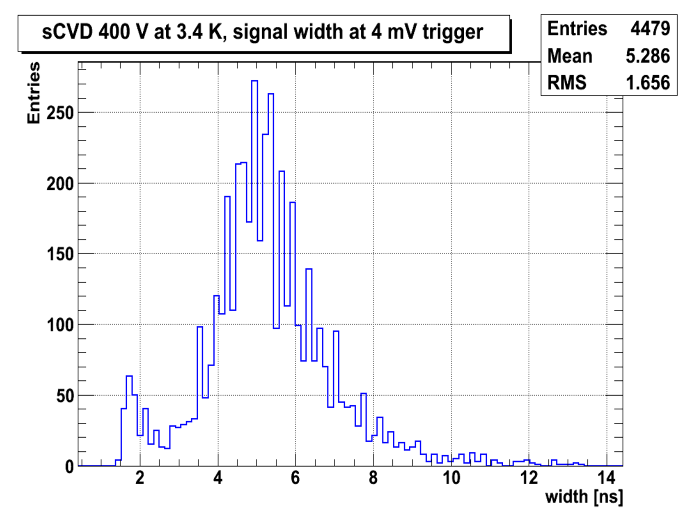
3.2 mV trigger



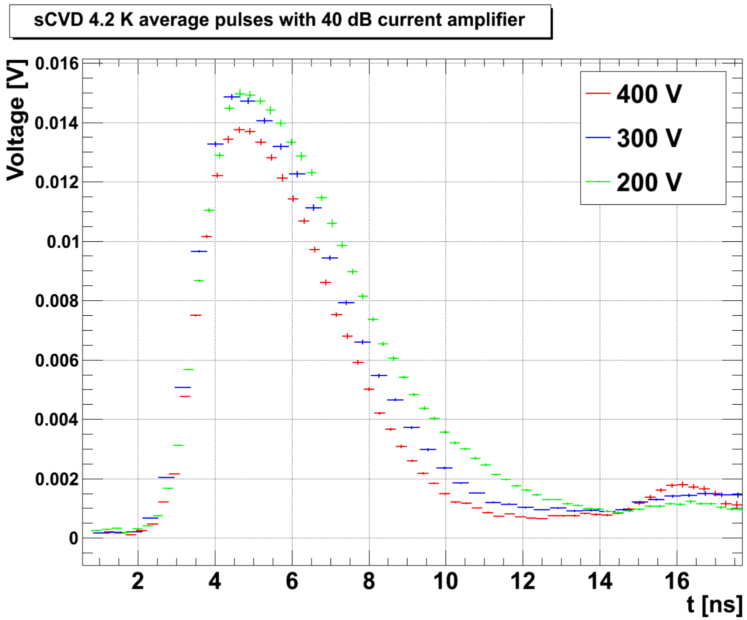


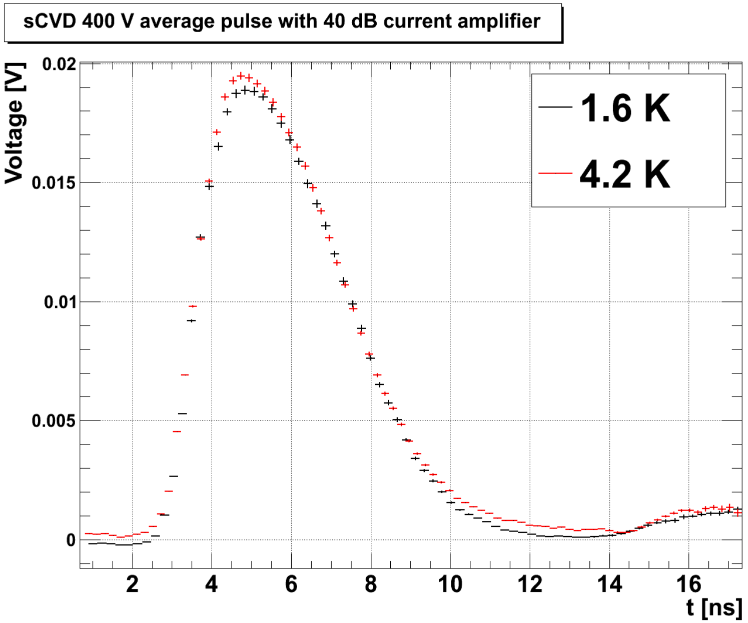
4 mV trigger





Diamond results
Single particle

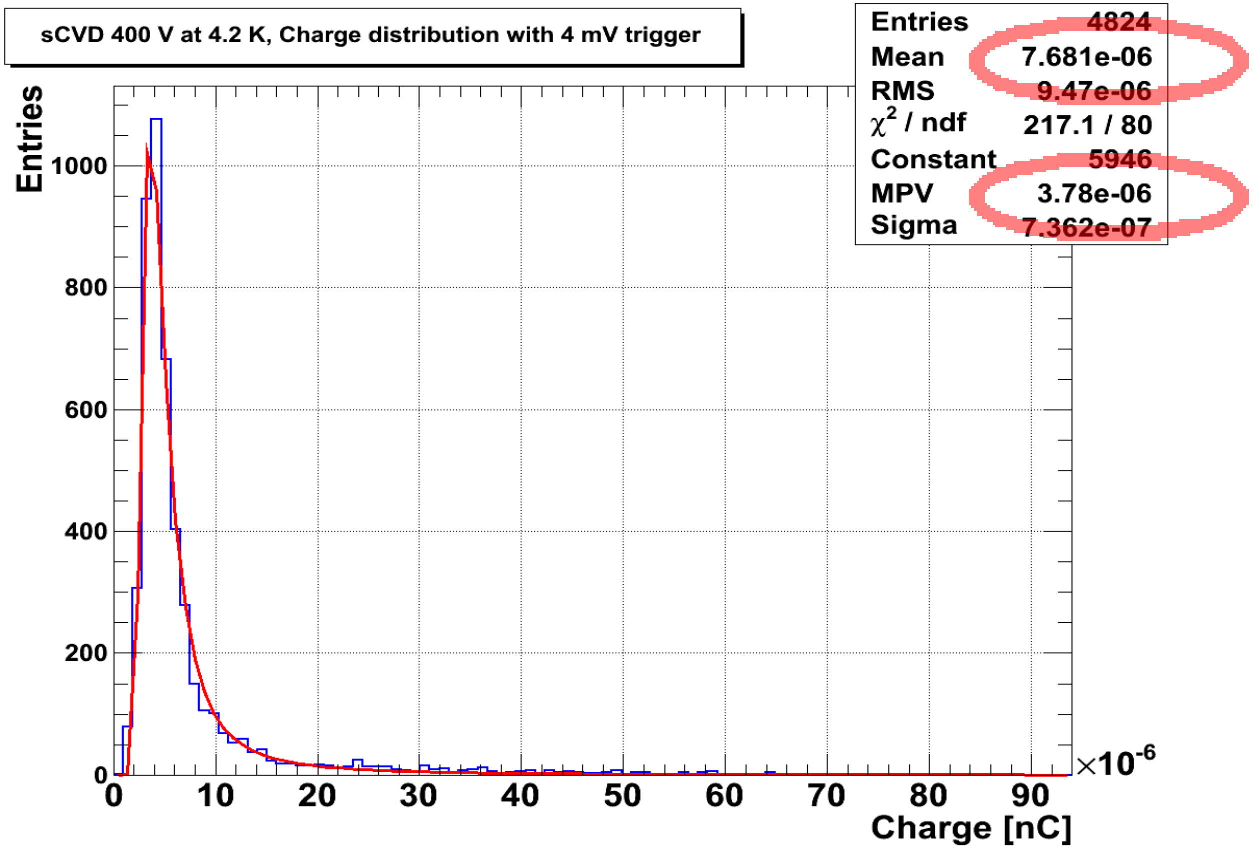




- With 4 mV trigger

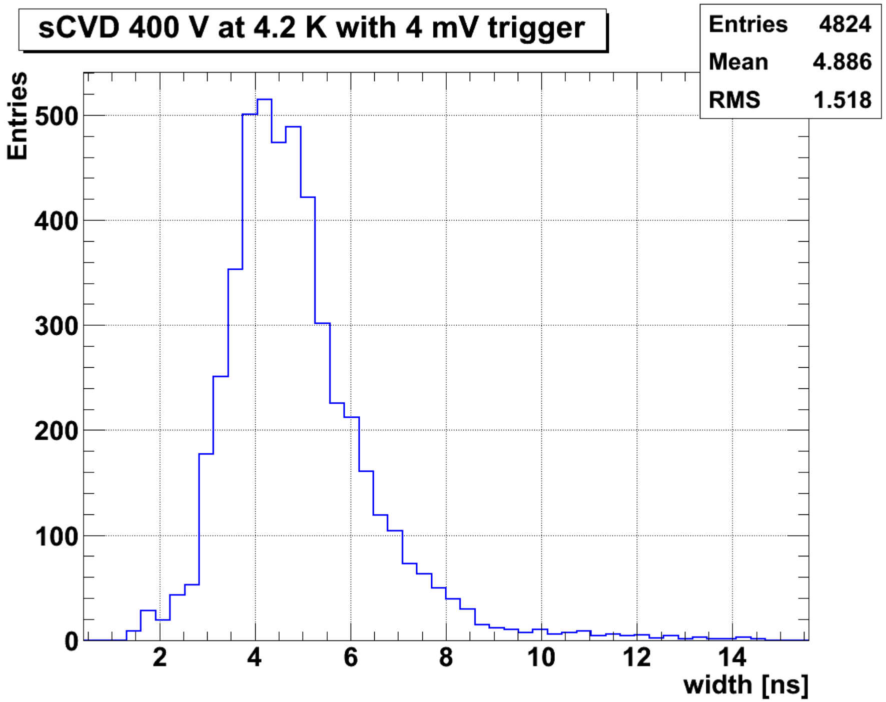
- With 6 mV trigger
- Only offset different
- Plot may be used as argument to make radiation hardness tests at 4.2 K only

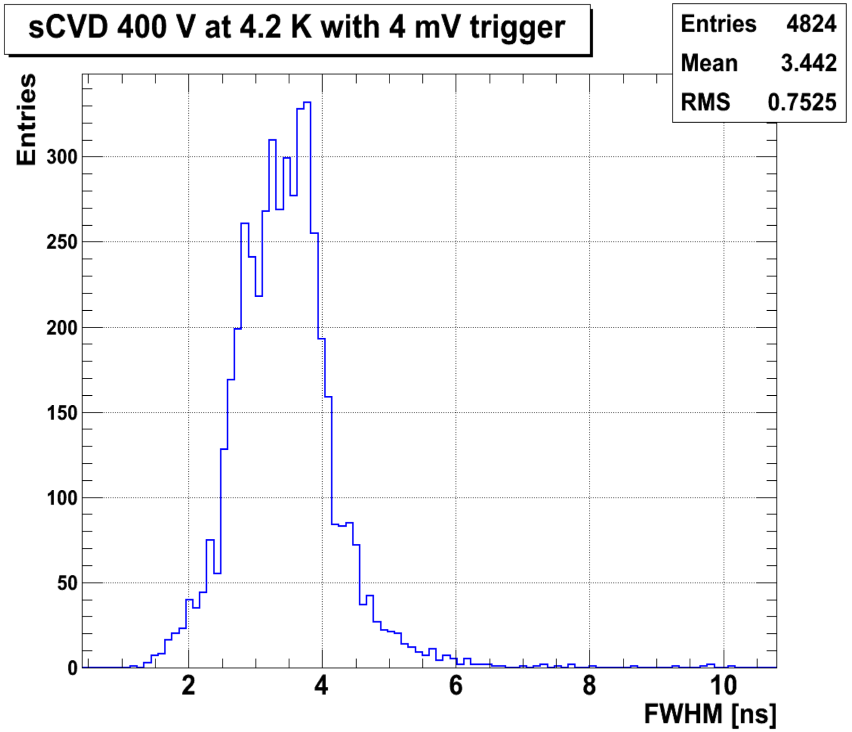
Diamond results 400 V
Single particle detection



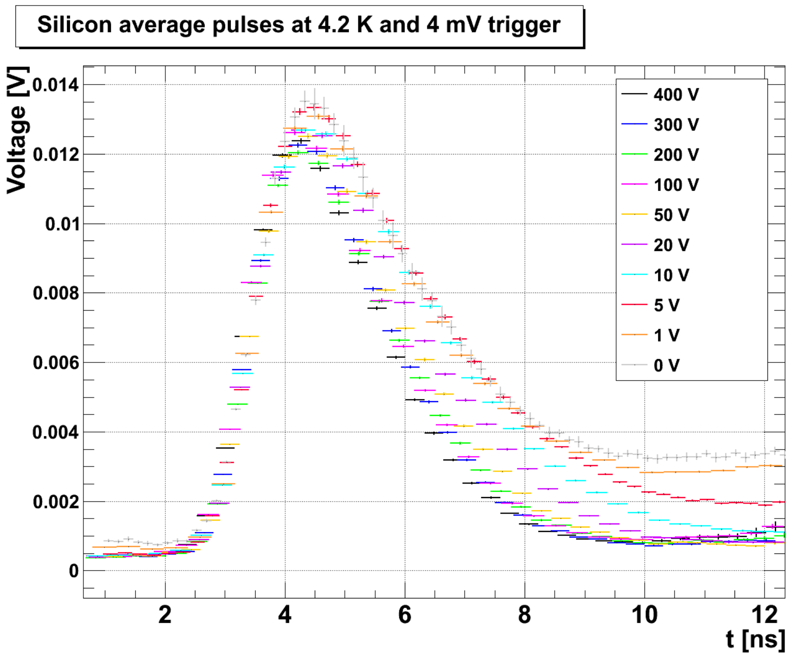
- Estimated: 3.79 fC

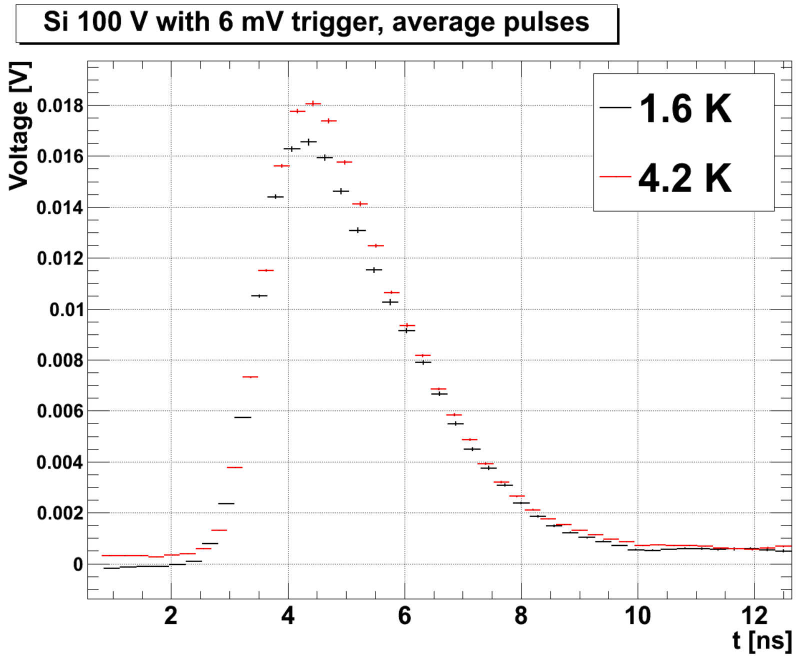
Diamond results 400 V
Single particle detection





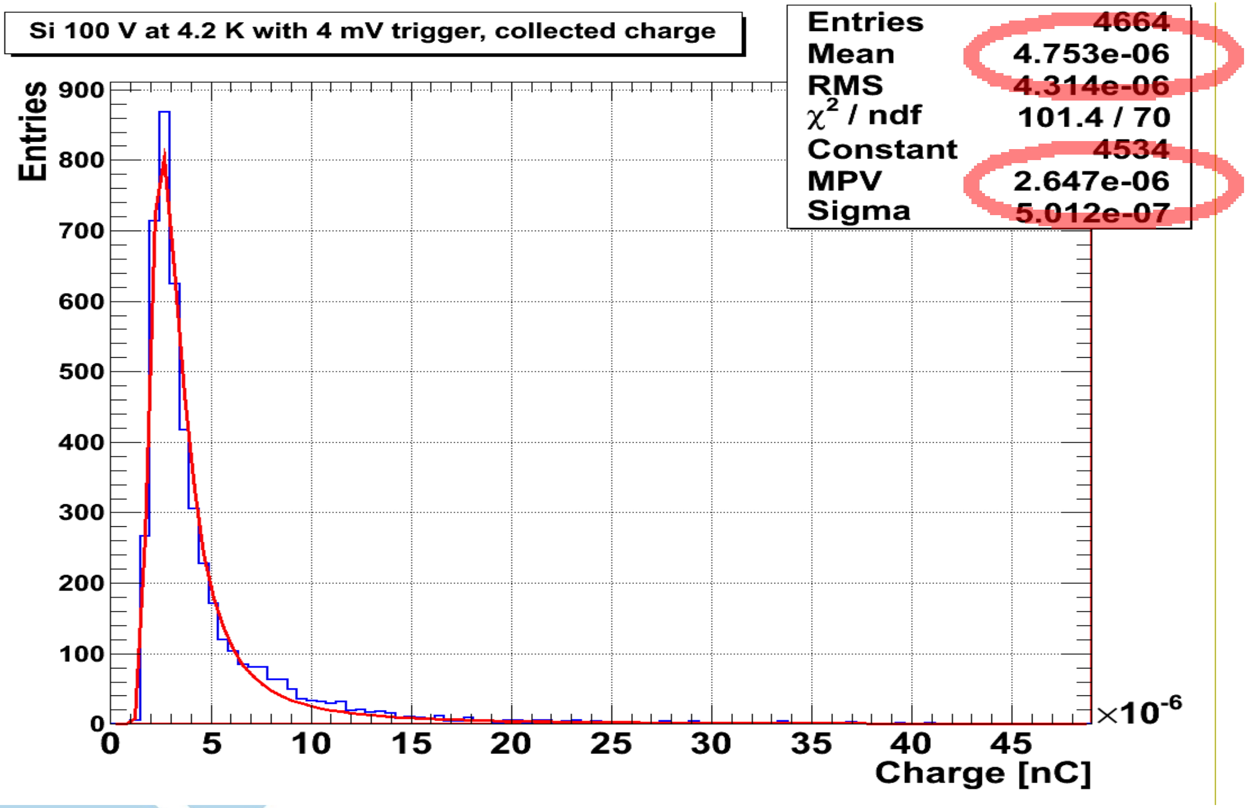
Silicon results
Single particle detection





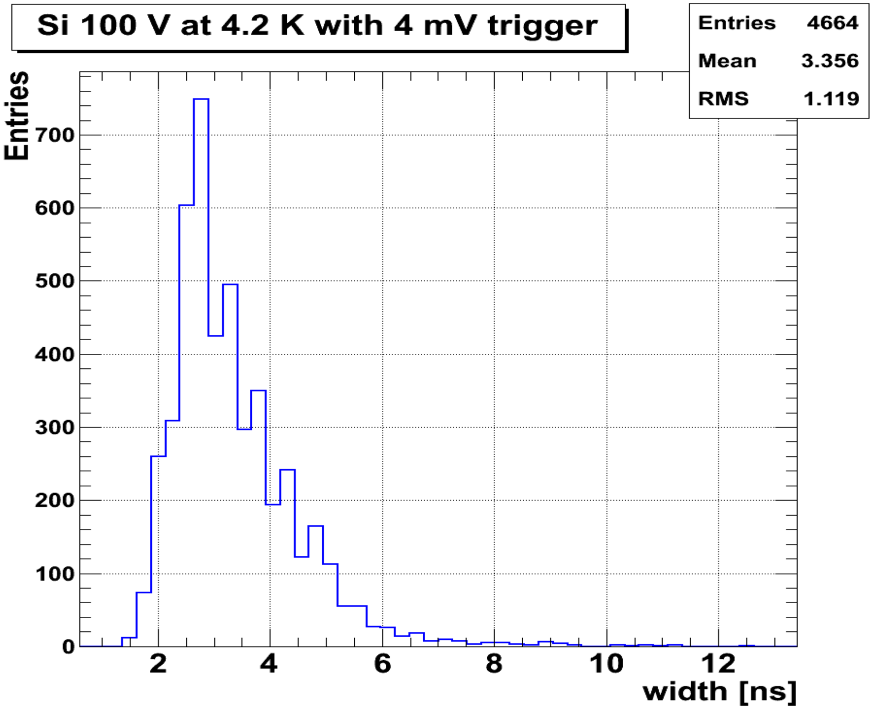
- Again no significant difference for Si between liquid and superfluid helium

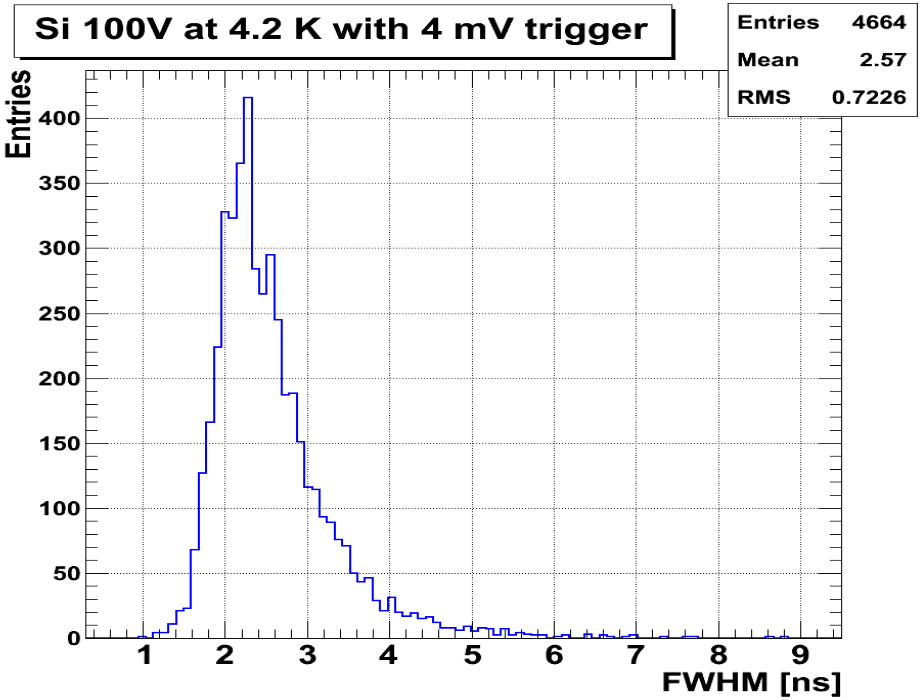
Silicon results
Single particle detection



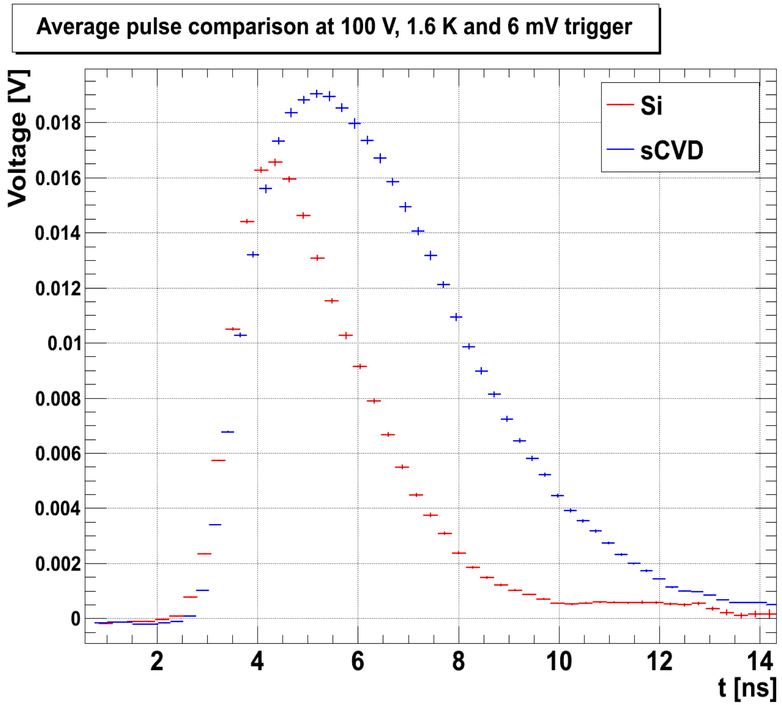
- Estimated: 5.68 fC

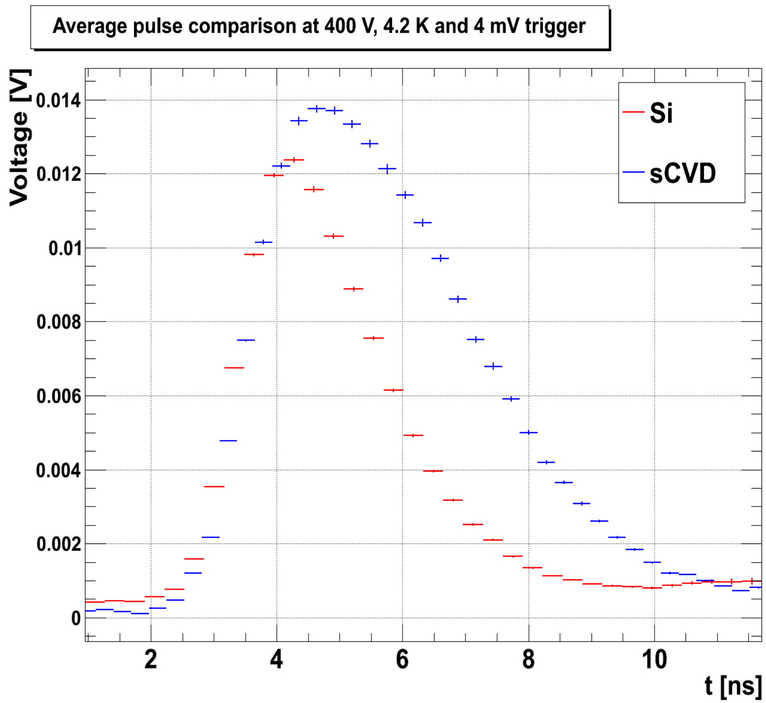
Silicon results
Single particle detection





Comparison sCVD and Si Single particle detection



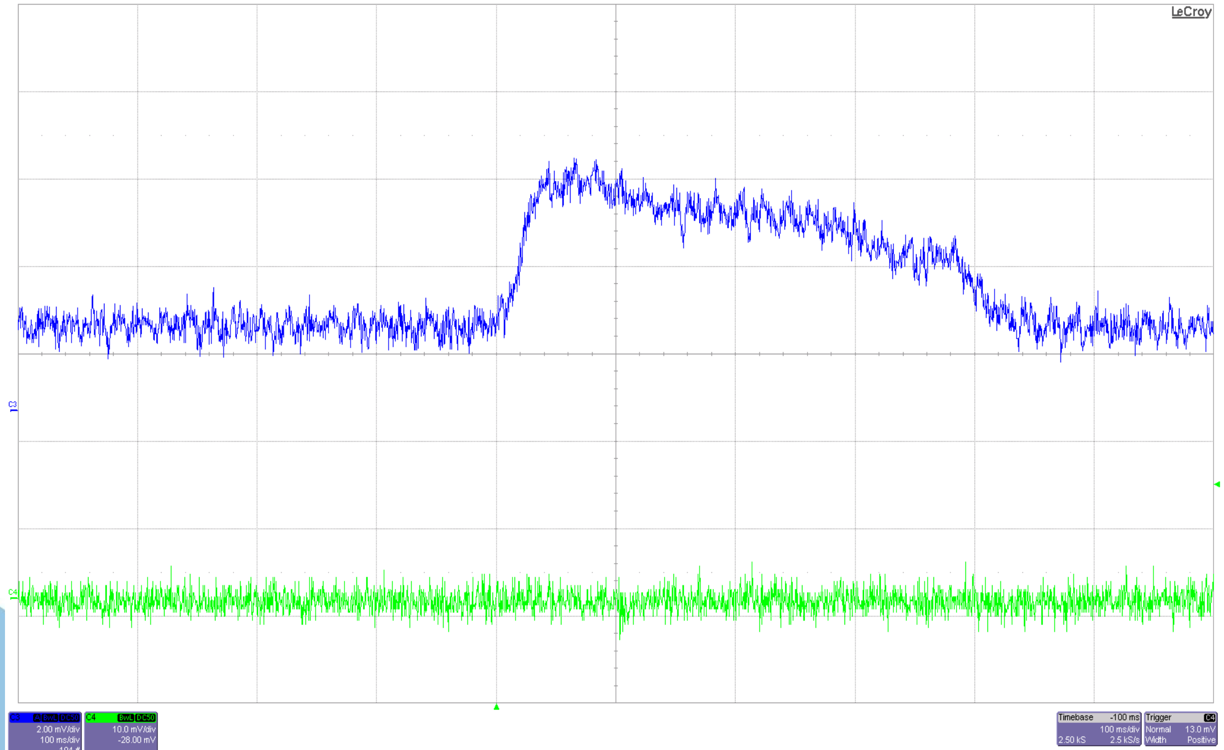


- In average per particle more charge from sCVD compared to Si (contradiction with estimations and DC measuremets)

LHe ionisation chamber
Fast read out

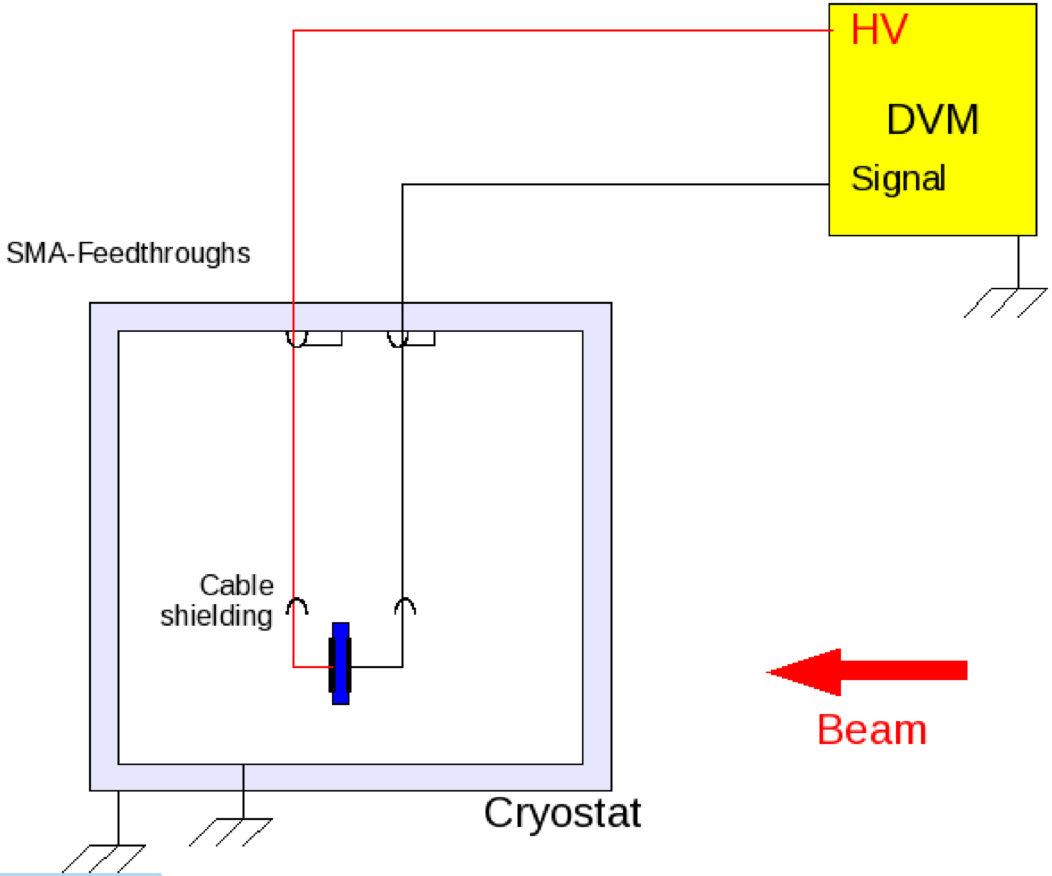
900 V

Superfluid 1.6 K



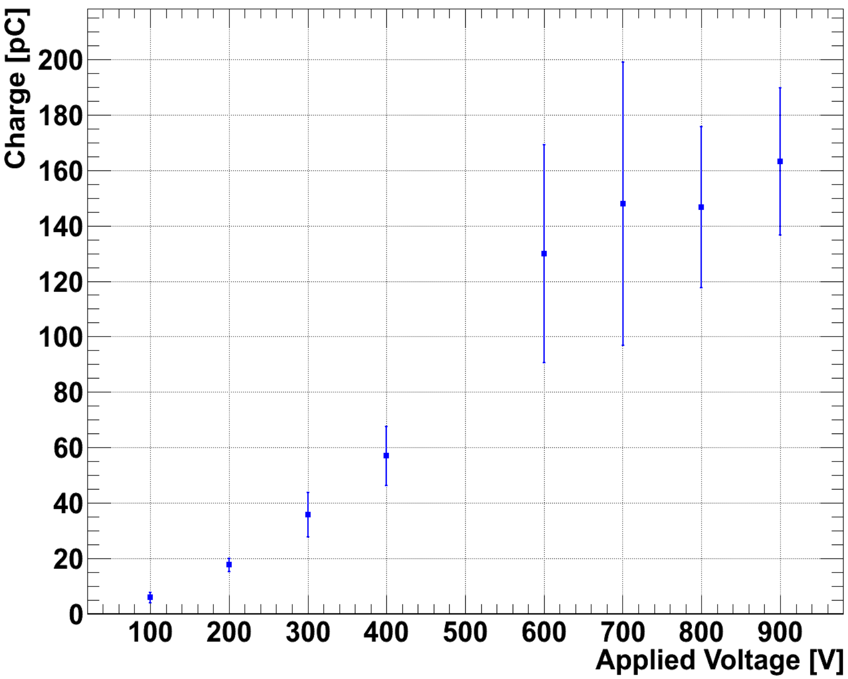
- Signal from whole spill
- Ion and electron mobility in superfluid about 0.02 $cm^2/V/s$ (extremely slow)

Electronic setup for DC measurements

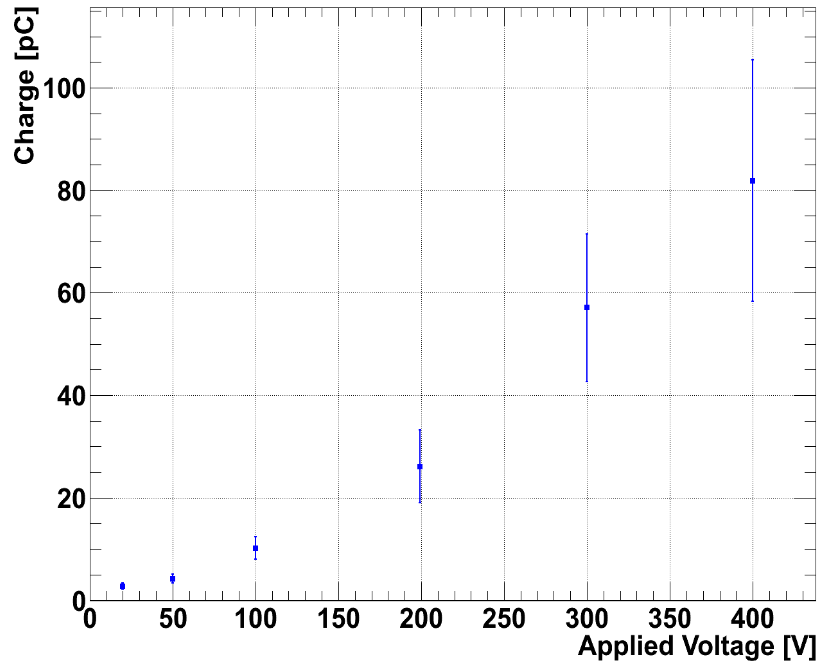


LHe chamber
Collected charge per spill

1.7 K



4.2 K

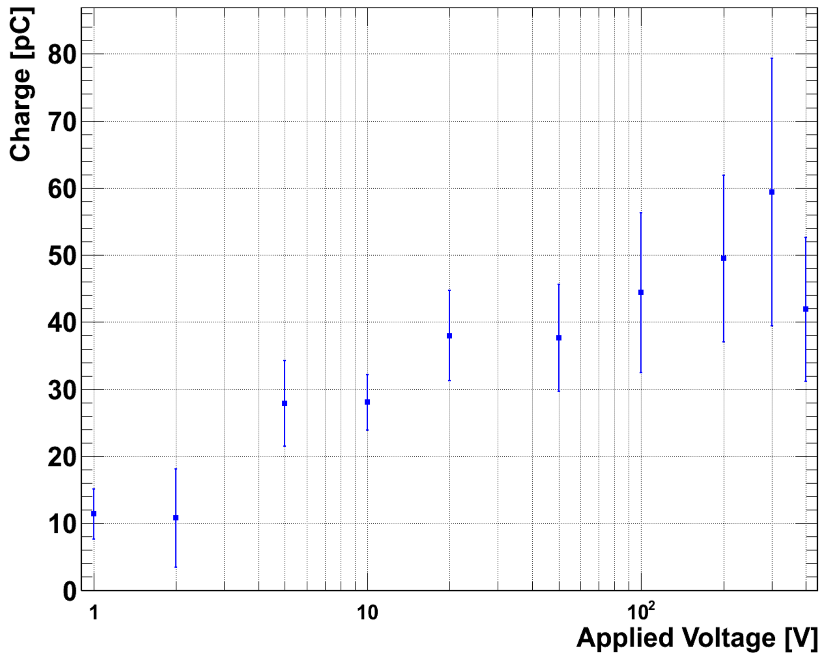


Above 400 V corona discharge

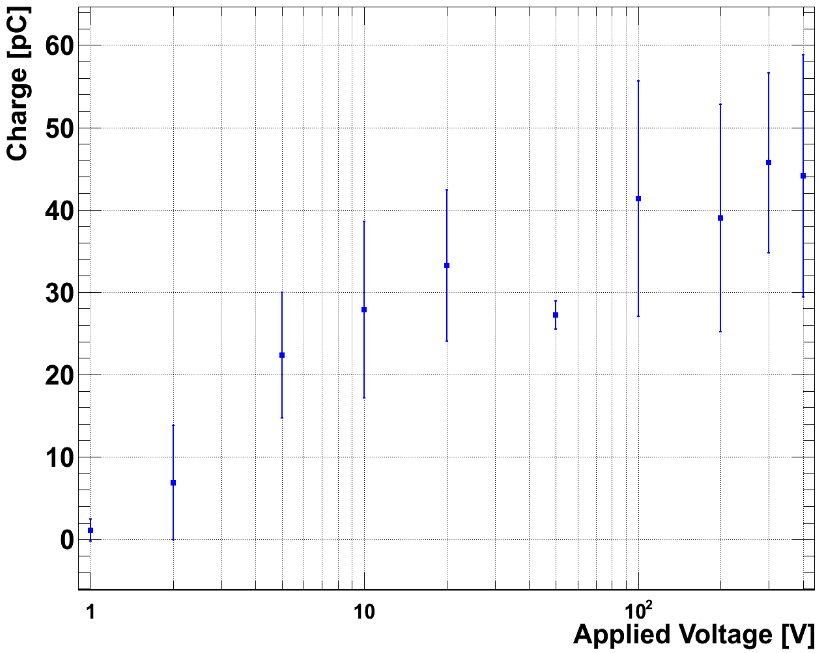
- Estimated charge per spill: 3.66 nC
- Apparently no efficient charge transport, due to slow mobility

sCVD
Collected charge per spill

1.6 K



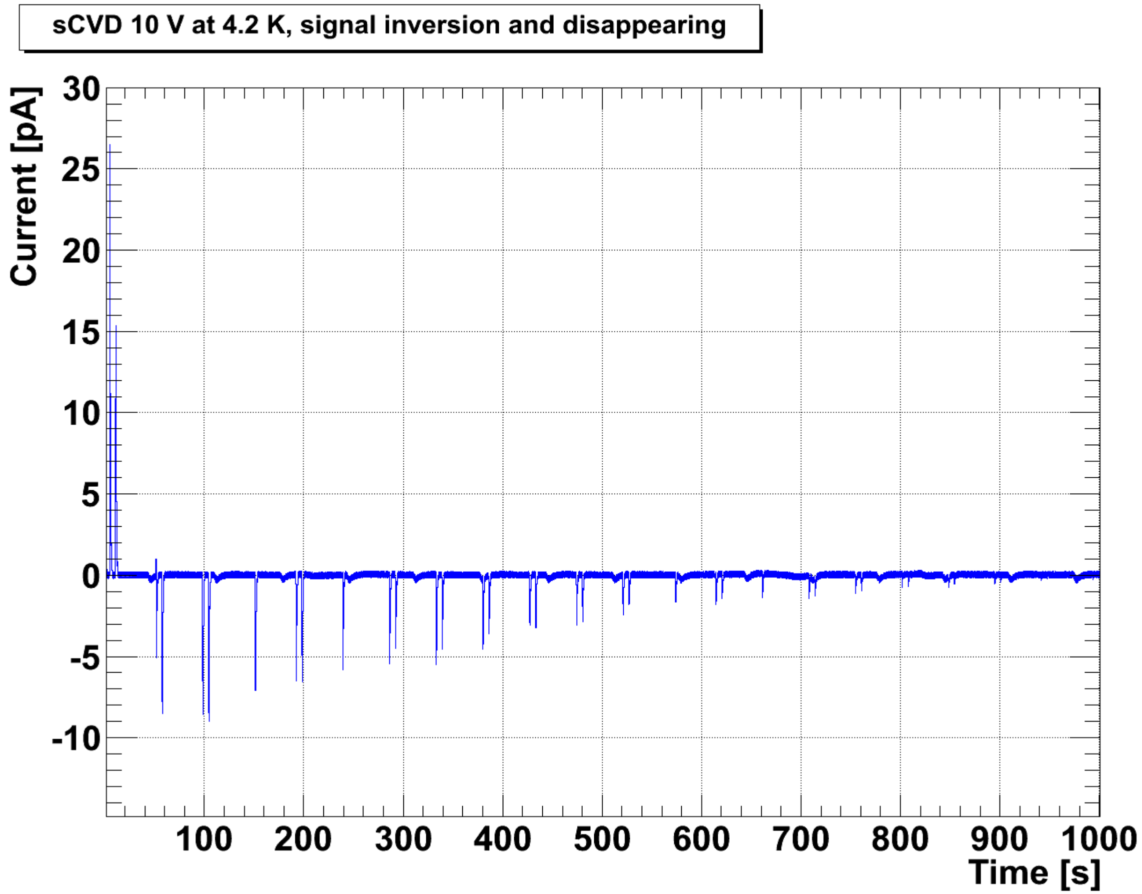
4.2 K



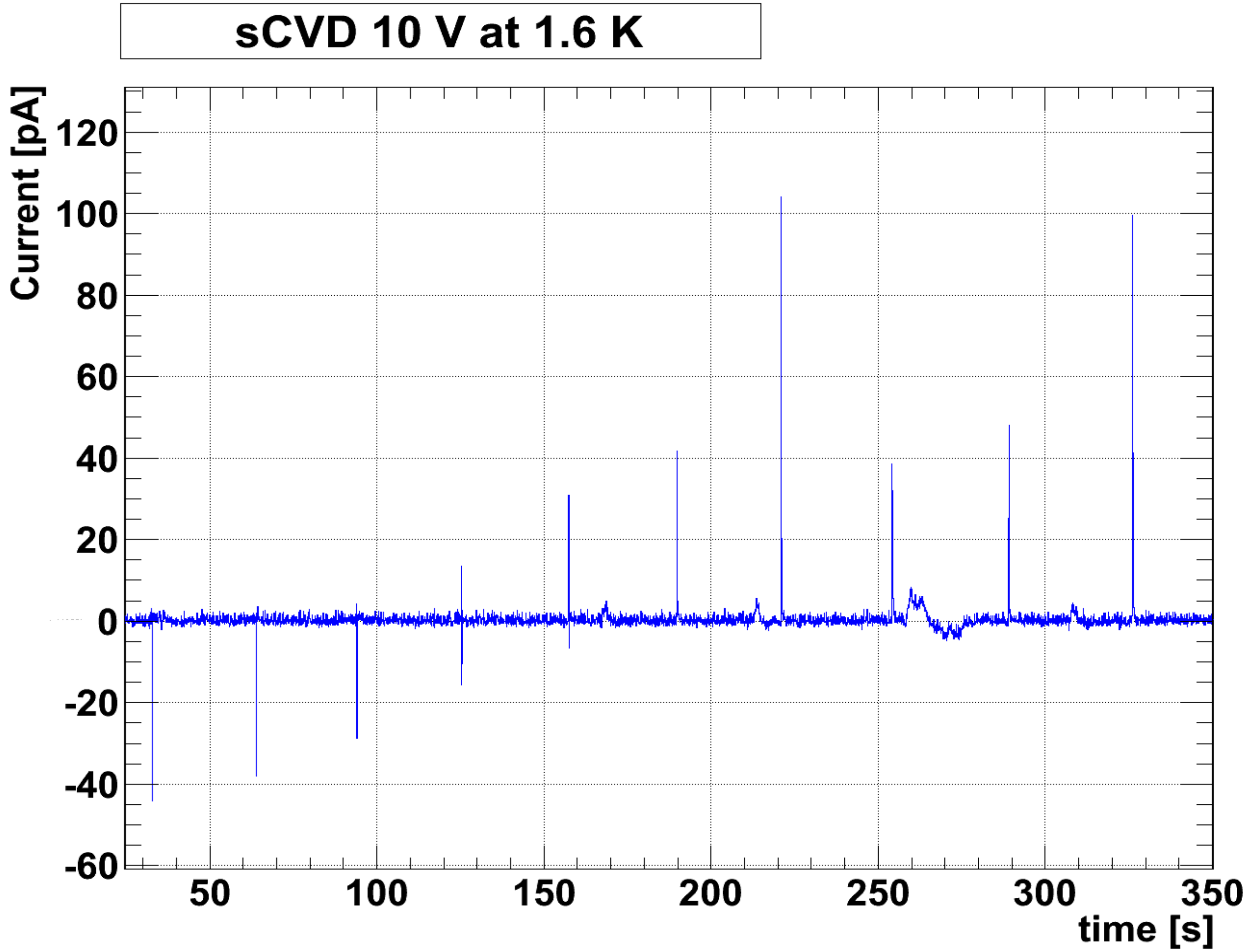
- Estimated charge per spill: 181 pC
- Measured about 45 pC (~ factor 4 less)
- Possible explanation for difference is slight misalignment

Beam test
sCVD signal disappearing

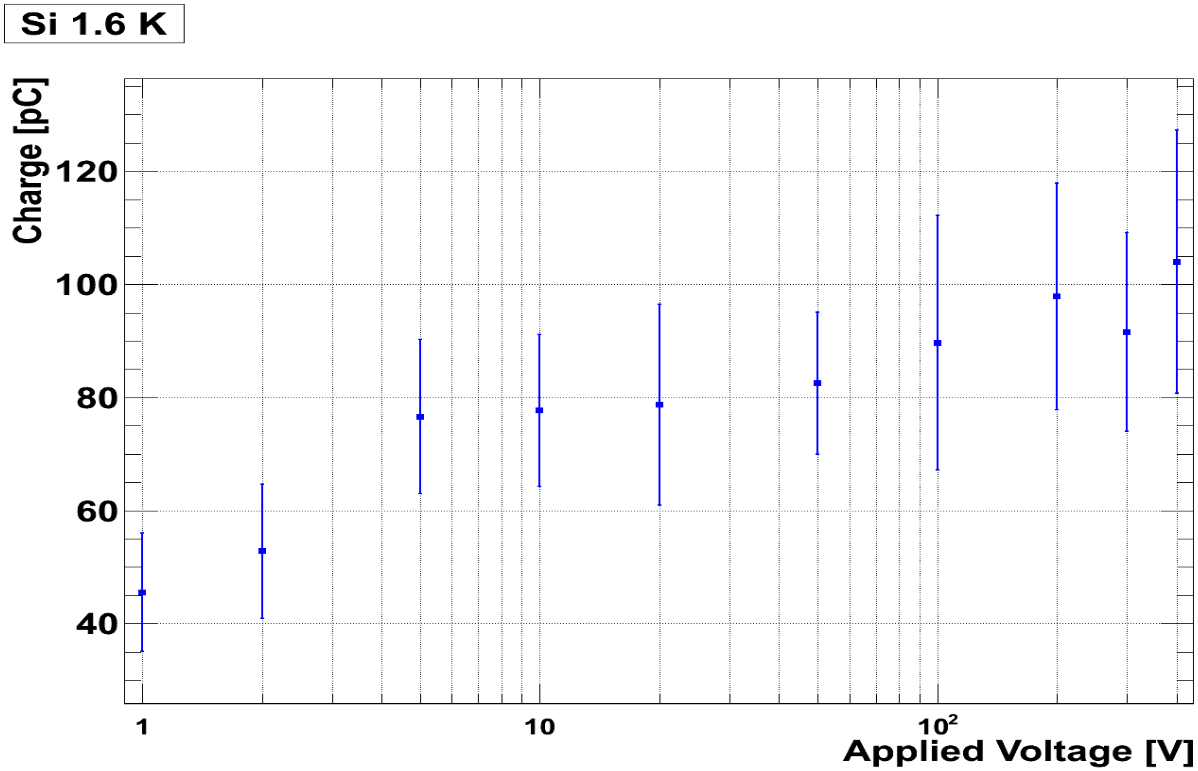
- Signal disappears after about 15 min



Beam test
sCVD signal inversion

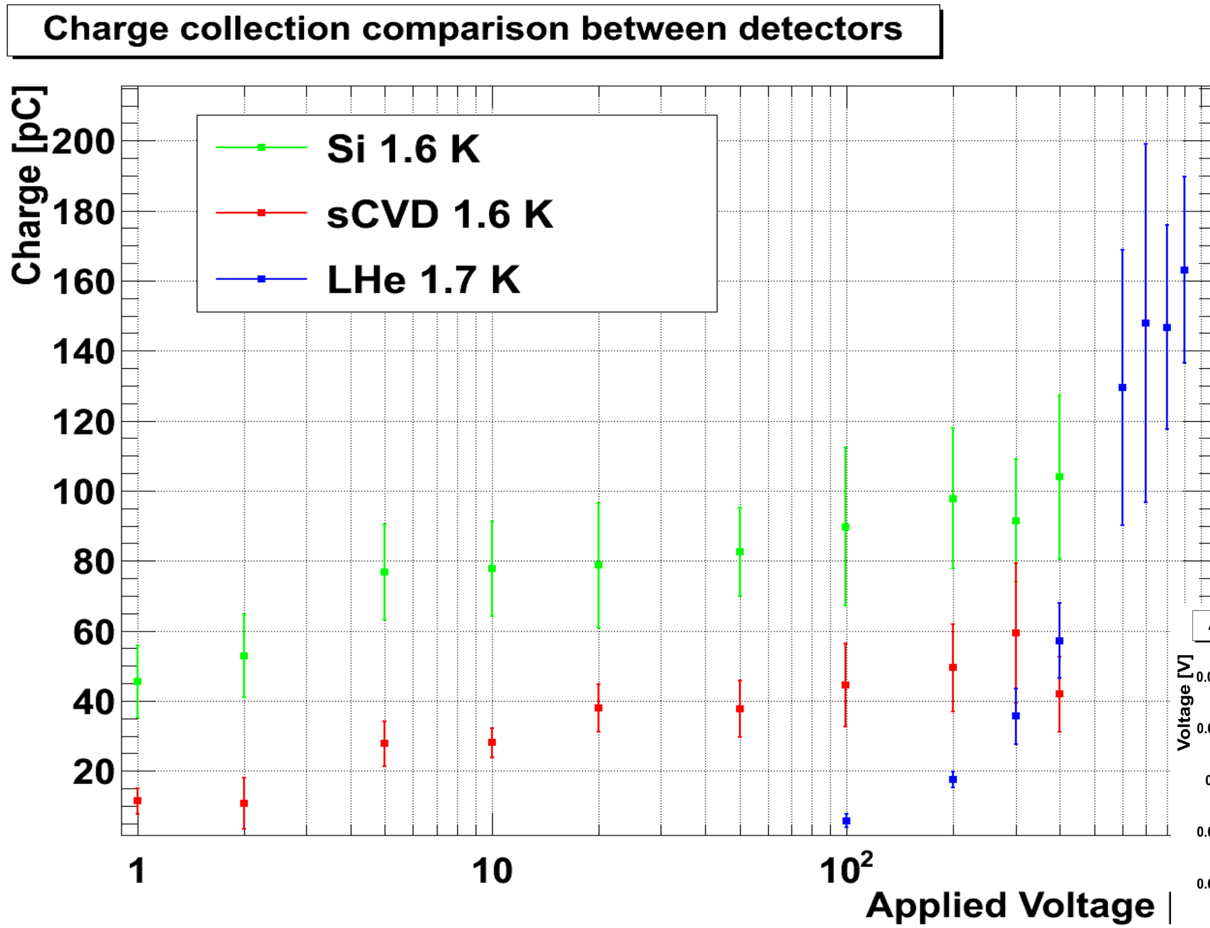


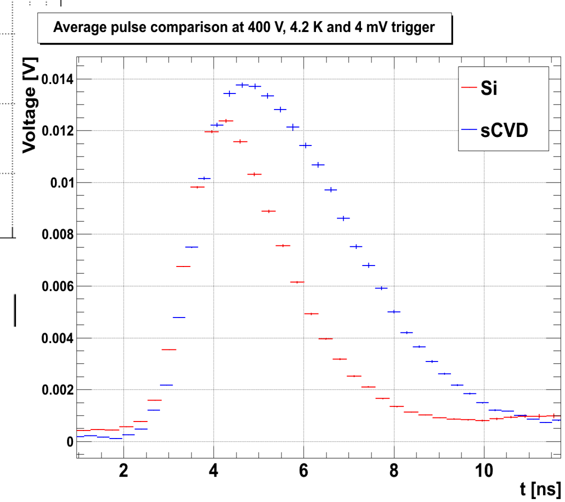
Beam test
Si collected charge



- Estimated charge per spill: 426 pC
- Measured about 100 pC (~ factor 4 less)
- Possible explanation for difference is slight misalignment (factor 4 for Si and sCVD strengthen this hypothesis)

Charge collection comparison Plots





Charge collection comparison Table

- Charge from single particle in fC:

	$Q_{estimated}$	$\langle Q_{single\ particle} \rangle$	$Q_{spill}/n_{p\ normalized}$
LHe	12.2	-	0.49
sCVD	3.79	7.68	0.80
Si	5.68	4.75	1.14

- Remarks:
  - Number of particles (normalized to detector size) going through semiconductors not exactly known (misalignment might be major source of disagreement)
  - Charge ratio: $$\frac{Q_{sCVD\,estimated}}{Q_{Si\,estimated}} \simeq \frac{Q_{sCVD\,spill\,normalized}}{Q_{Si\,spill\,normalized}}$$
  - In single particle measurements some low sCVD pulses might be lost due to trigger setting

Open questions LHe

- LHe response time (rise immediately?)
- Charge per spill disagreement between estimation and measurement? (No efficient charge transport)
- LHe Ion vs electron mobility, measurable in lab?
- LHe corona discharge, measurable in lab?
- LHe purity inside cryostat? (according to theory should be nothing due to suprafluidity)
- Linearity of response with respect to beam intensity
- Saturation level

Open questions Semiconductors

- Semiconductors radiation hardness
- Semiconductors leakage current measurable at 1.9 K and 4.2 K?
- Why is charge per particle higher for sCVD than for Si, but not charge per spill?
- Pre-amplifier into the cold?
  - + very low noise
  - - feasible&working in cold with radiation and B-field?
  - - more feed-throughs needed going into cryostat
- Semiconductors polarization at low temperatures (disappearing signal)
- Saturation levels

Conclusions

- All tested detectors work at superfluid helium temperatures
- Critical missing information:
  - Radiation hardness of semiconductors
  - Time response of LHe chamber
- Ongoing analysis of the beam test data
- In parallel further measurements foreseen in the laboratory:
  - Silicon (TCT) charge generation with laser and alpha source
  - sCVD (TCT) charge generation with alpha source

Acknowledgements
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