The first results on cryogenic semiconductor detectors for advancing the LHC beam loss monitors

Presented by

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on behalf of
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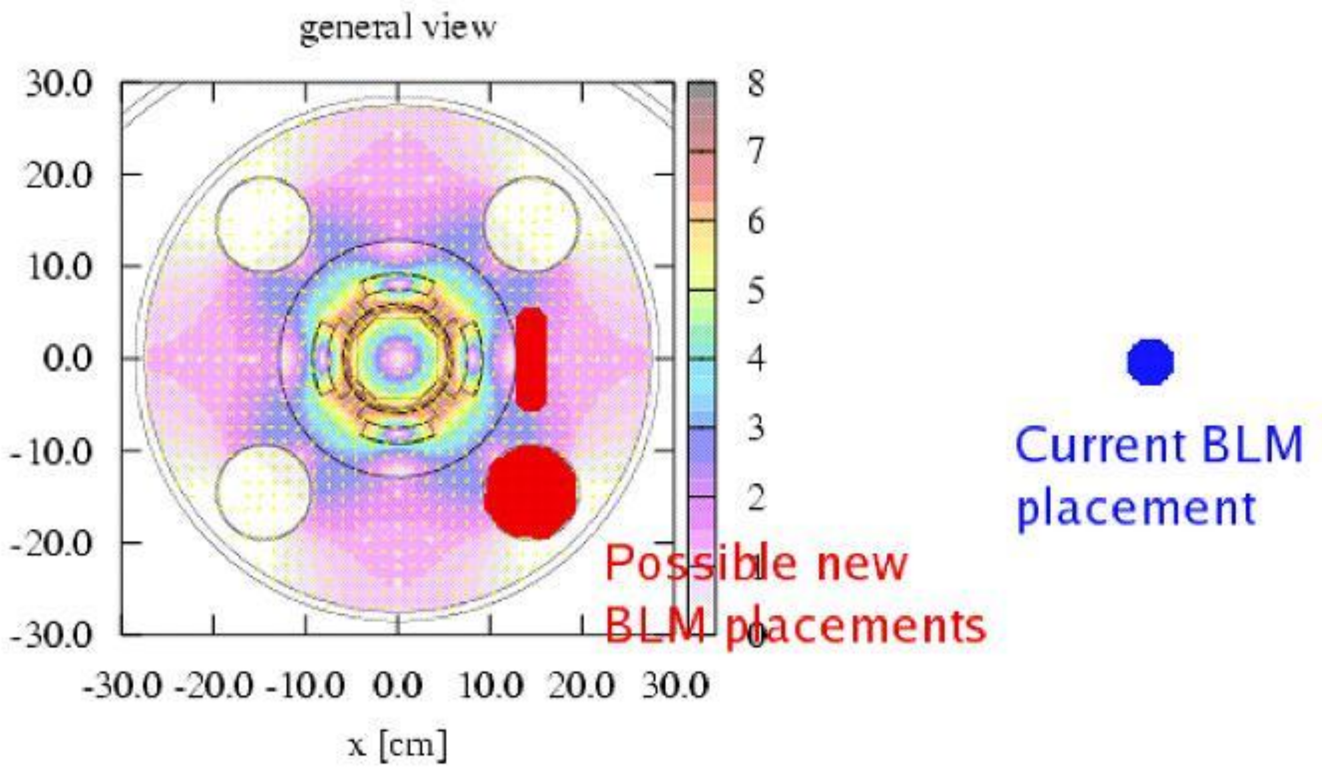
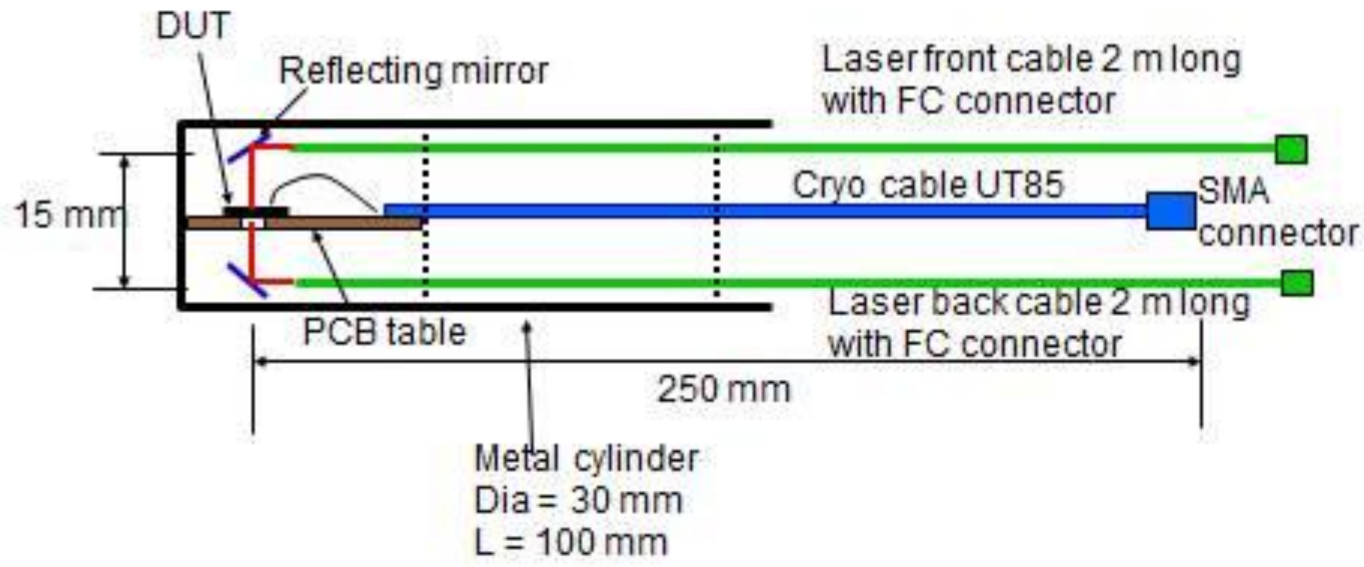
RIMST (Zelenograd)
BE-BI-BL, Cryo lab., and RD39 (CERN) teams

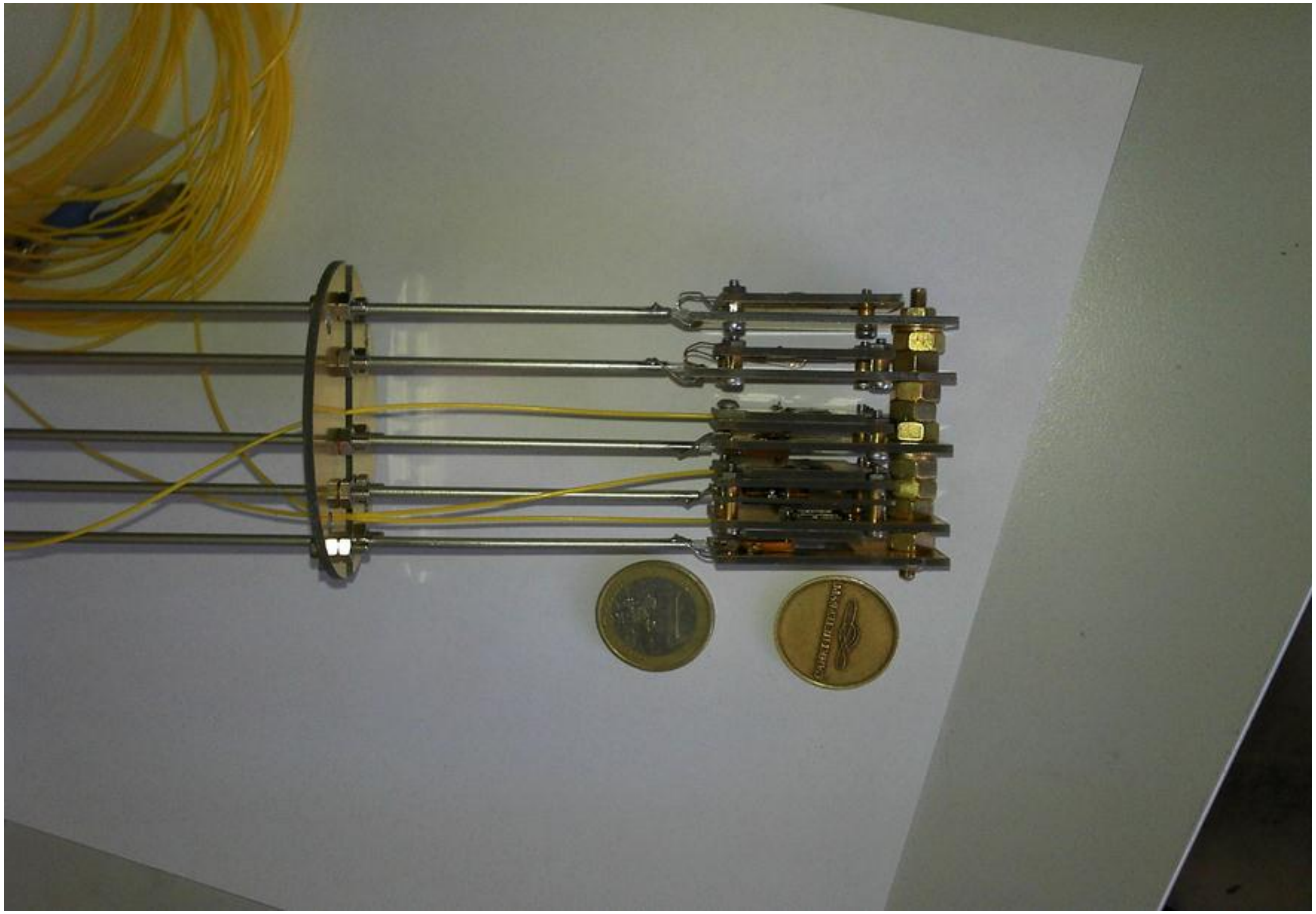
The new BLM arrangement



TCT cryogenic module



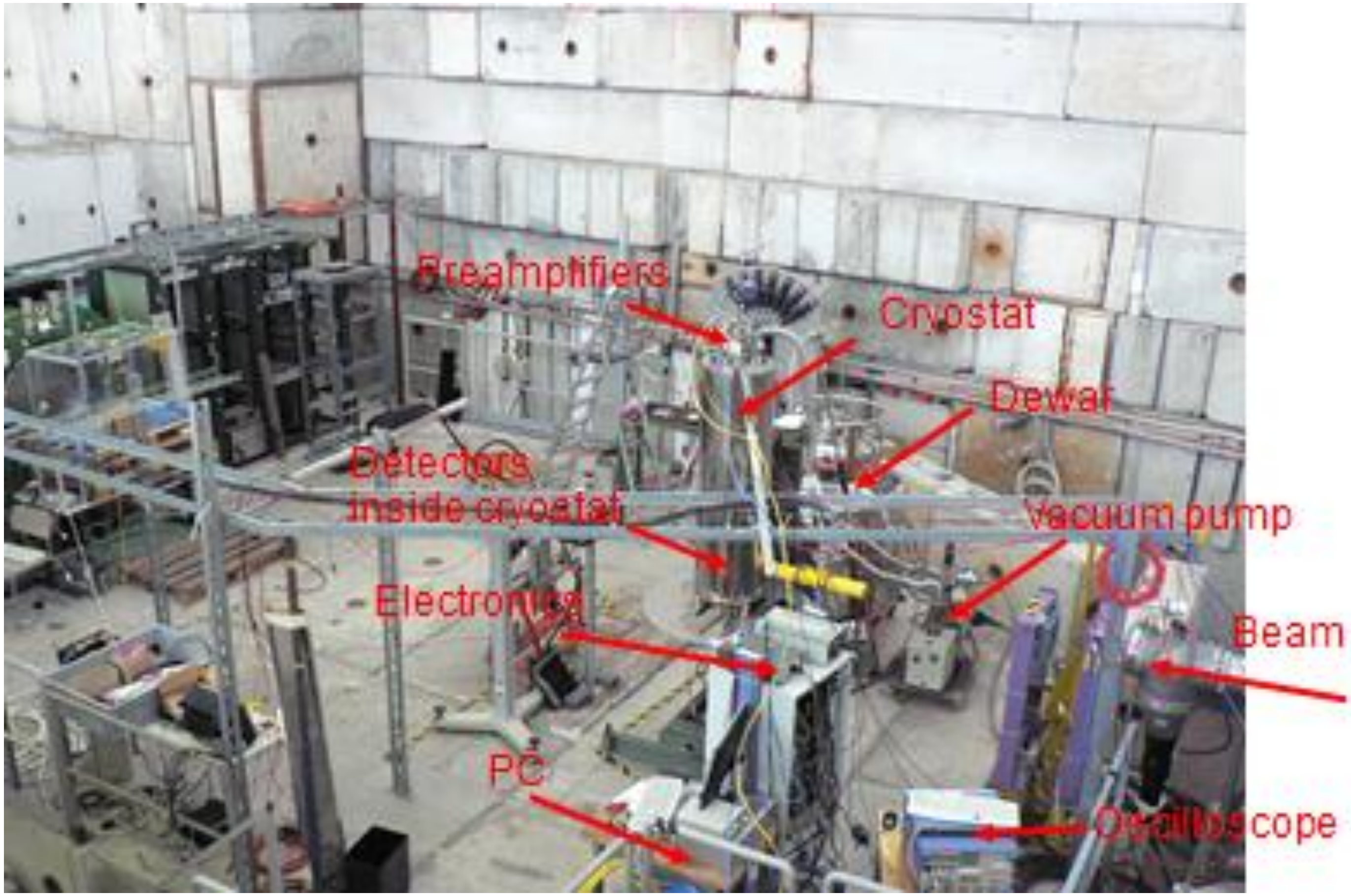
Arrangement with 5 cryogenic modules



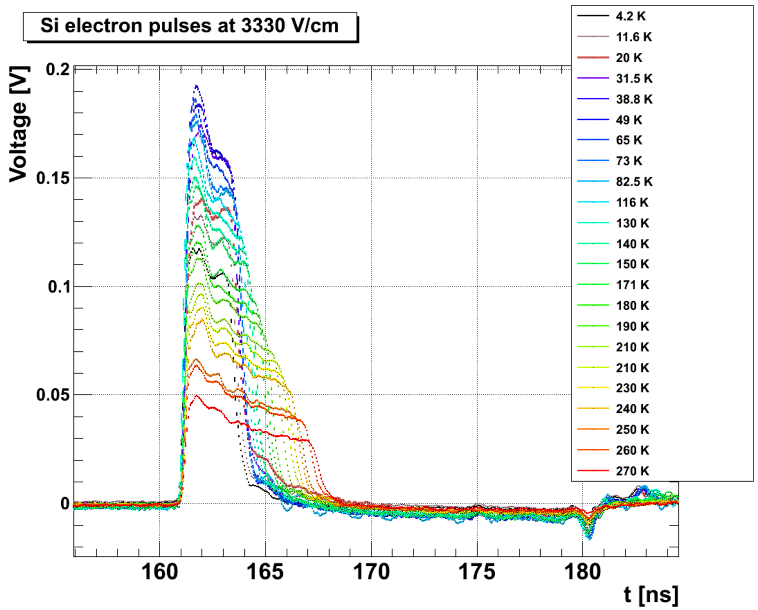
Inside the cryostate

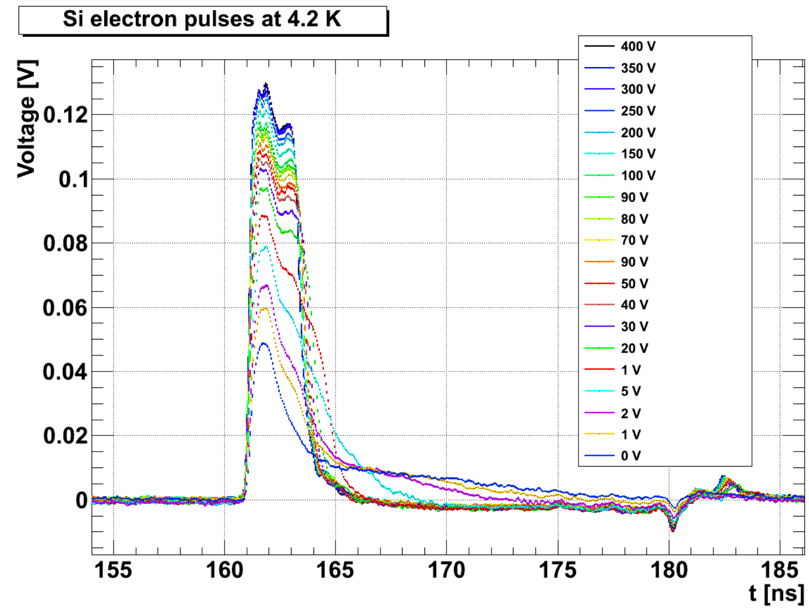
Cryostat

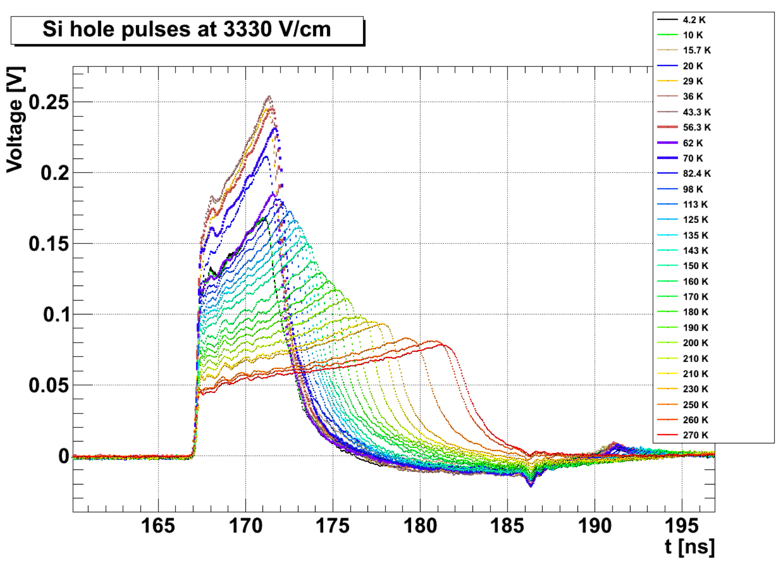
The beam test area

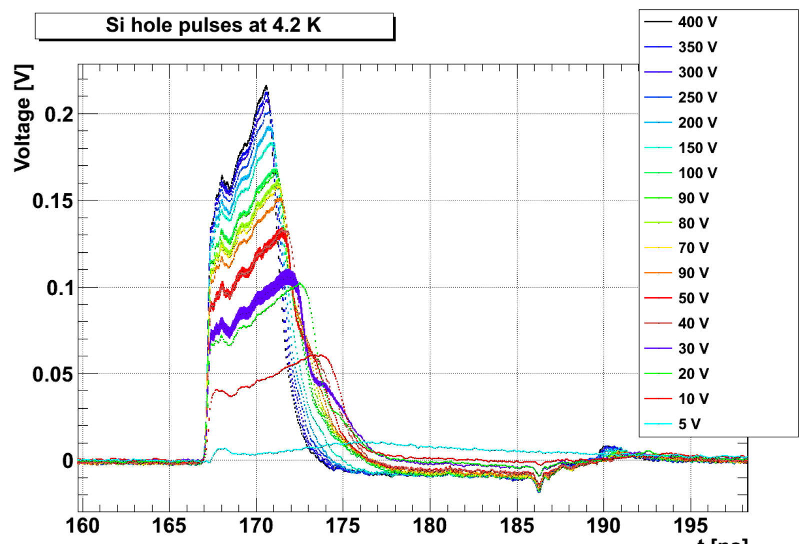


Charge collection









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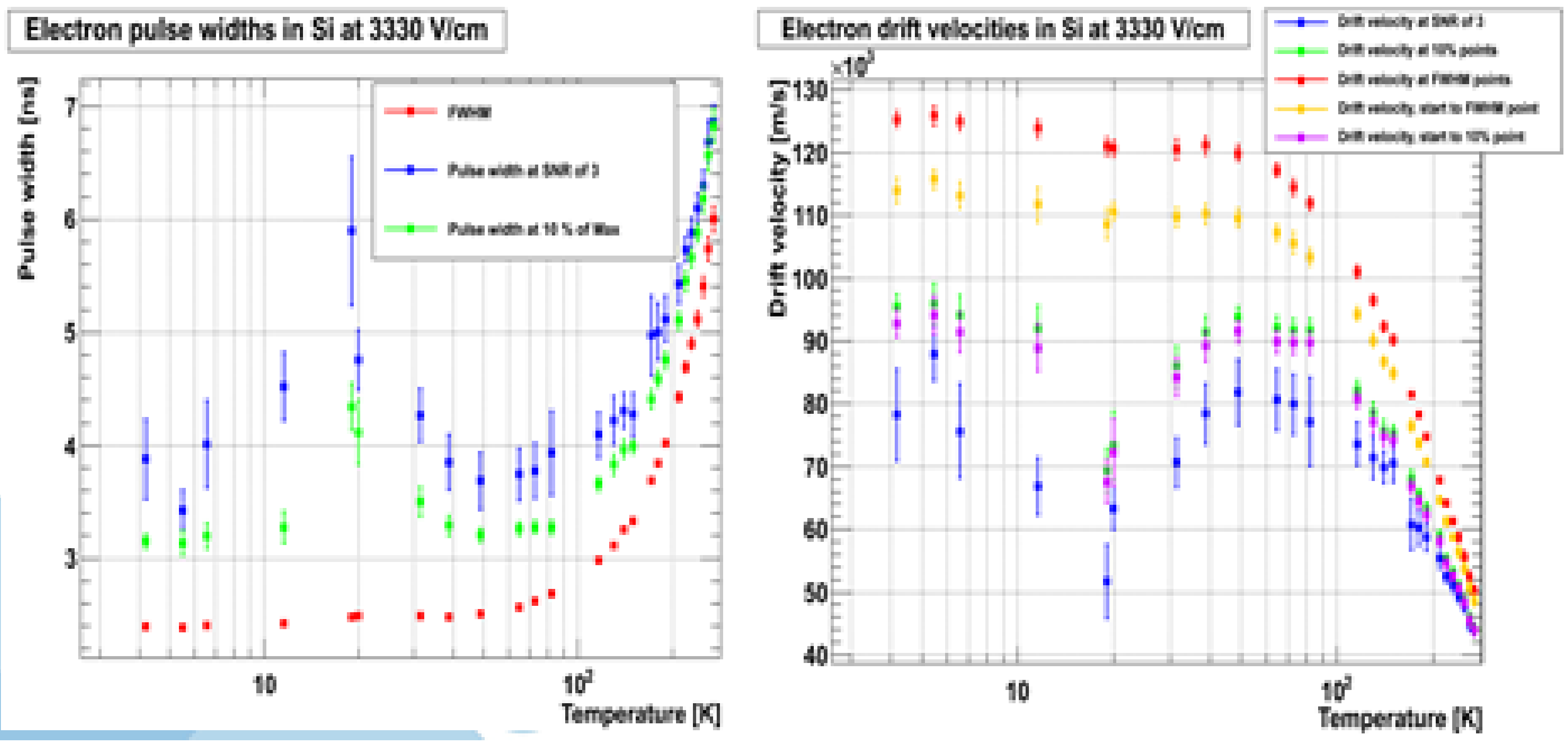
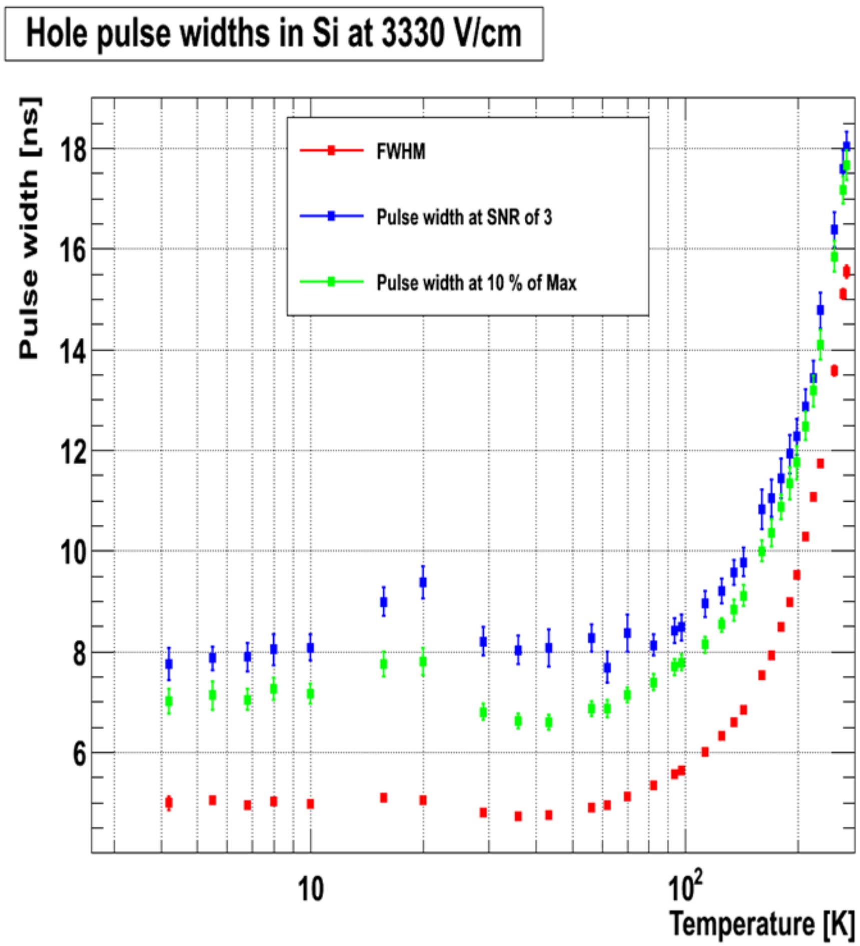
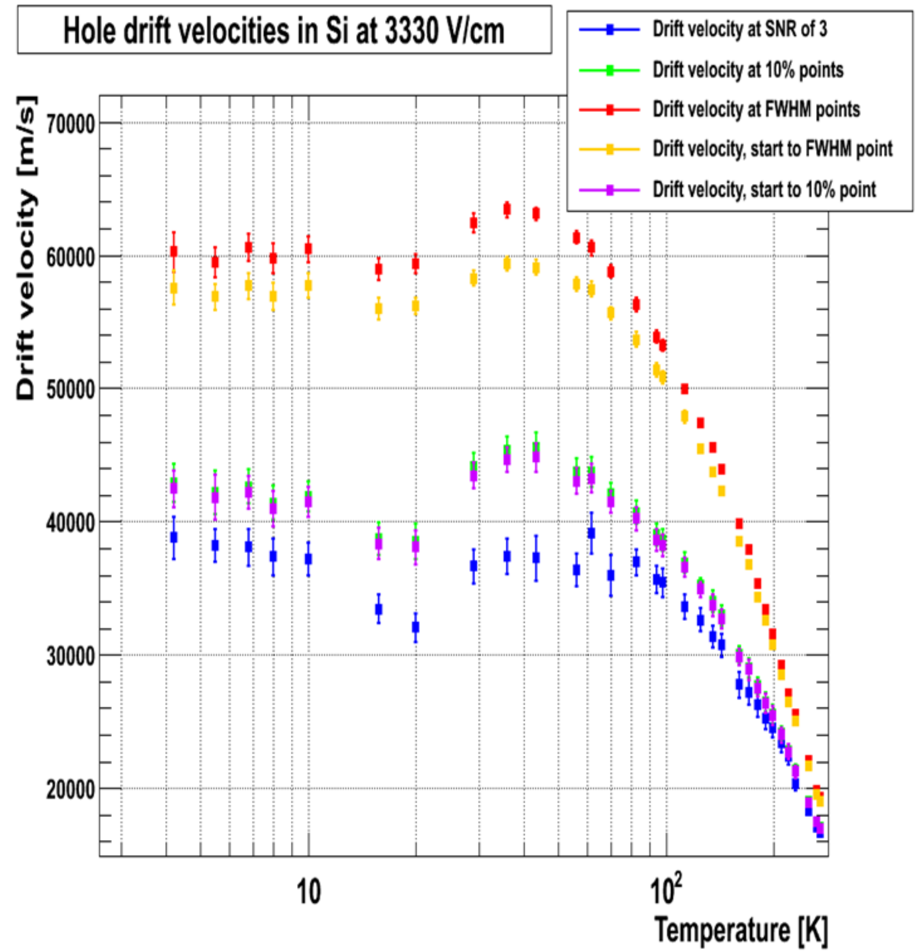
Electron collection



Hole drift velocity





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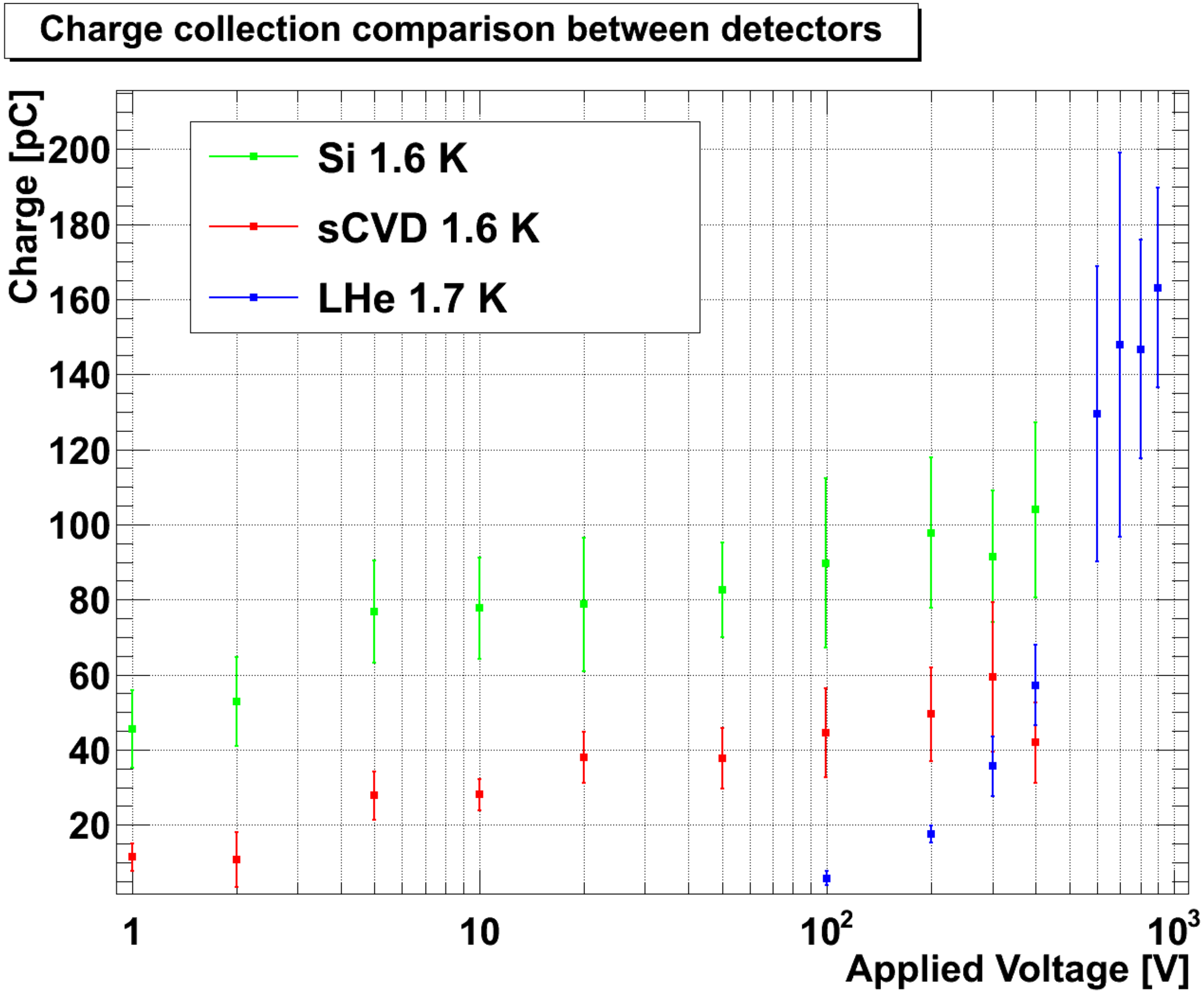
Collected charge in Silicon and Diamond detectors



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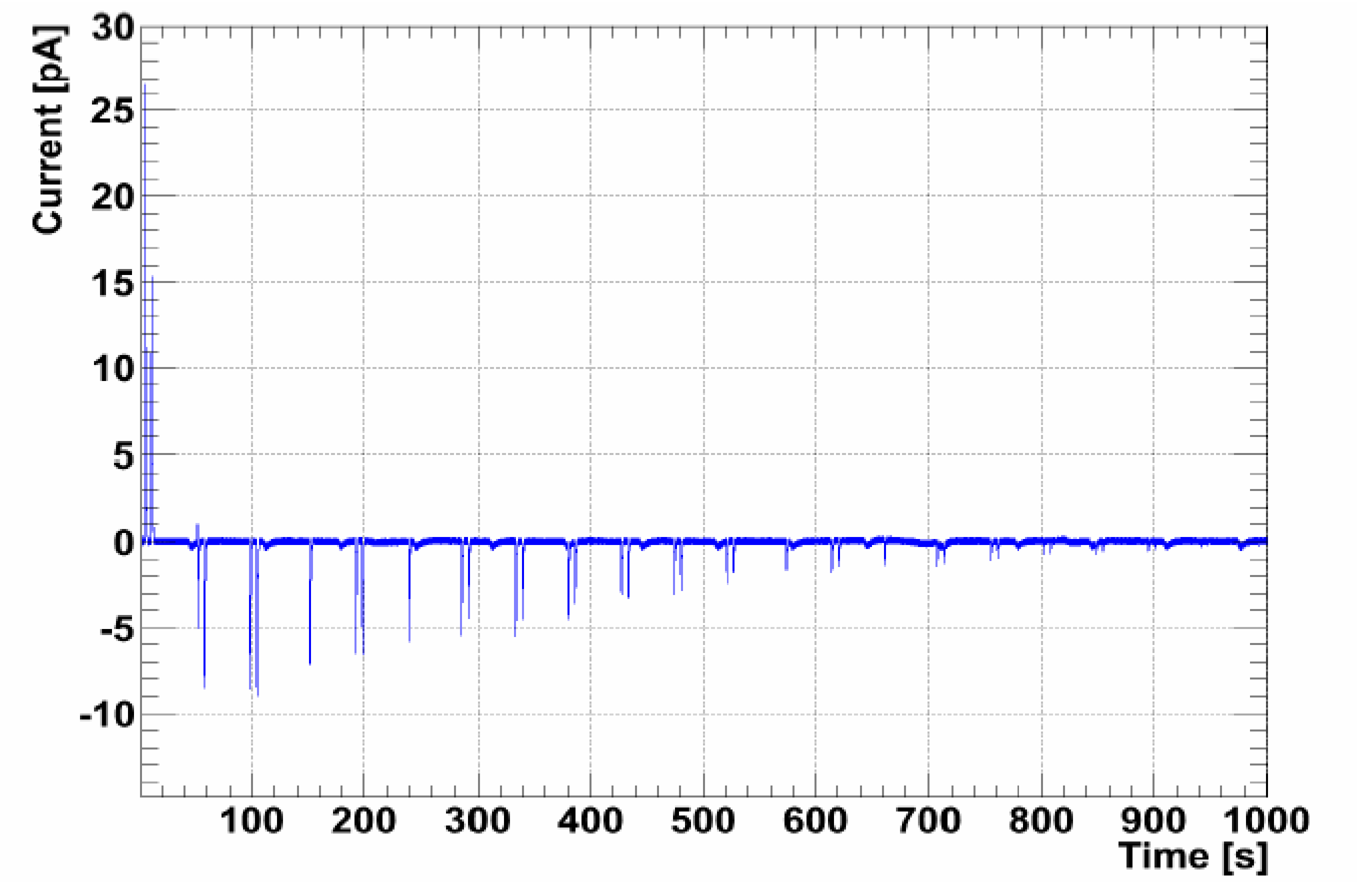
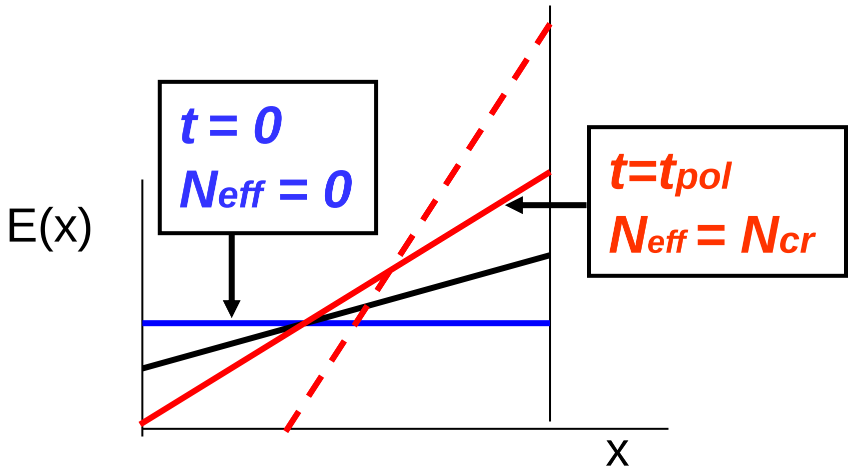
Sc diamond detector polarization



Polarization time in diamond

- The polarization criteria



Detector at:

Vb = 1000V
W = 500um
Ncr = 1e12 cm-3
ncr = Ncr x W = 1e11cm-2

Polarization by trapping:

MGA (2.7eV)

σtr =1e-15cm2, Ntr=1e15 cm-3)

RT

Trapping time = 1e-7c

Detrapping time = 1e35 c

Collection time = 1e-8 s

Polarization time (estimation)

R = 1e6 MIP cm-2 c-1

1MIP – 1e4 pairs

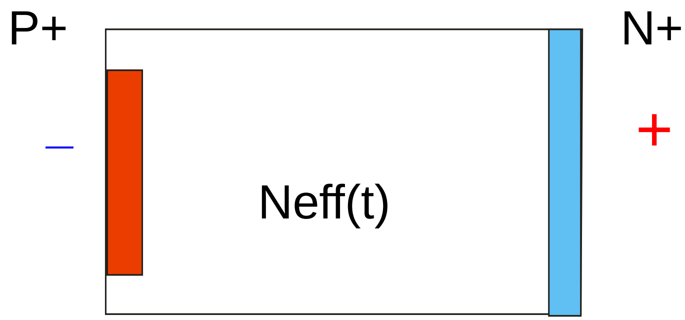
CCE = 0.9

n_{tr} = 1e4x(1-CCE)xR = 1e9 cm-2 c-1

$t_{pol} = n_{cr} / n_{tr}$ = **100 c**

More details on polarization:
B.Dezillie, et al. NIM A 452, 2000,p.440

Electric field evolution in detectors under bulk polarization

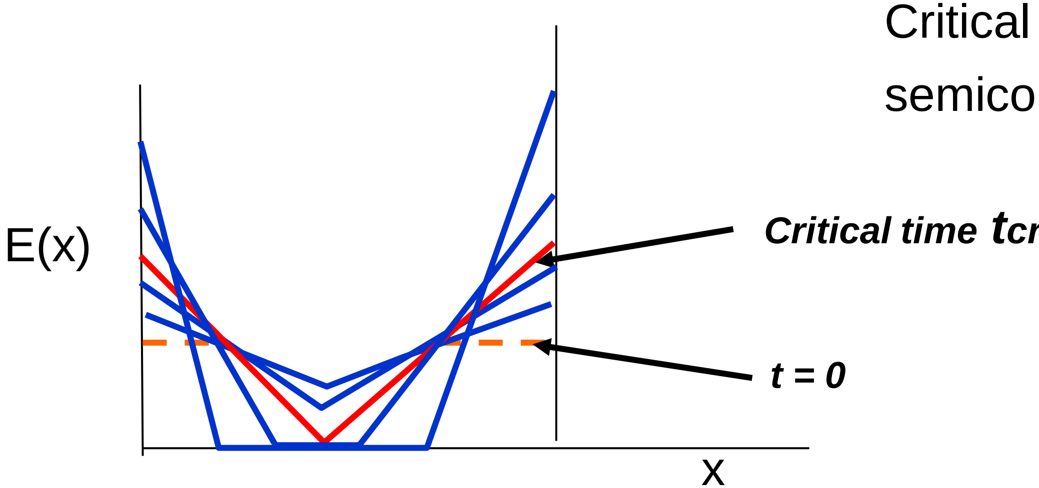


$t_{pol} = C*V / \{I*(1-CCE)\}$

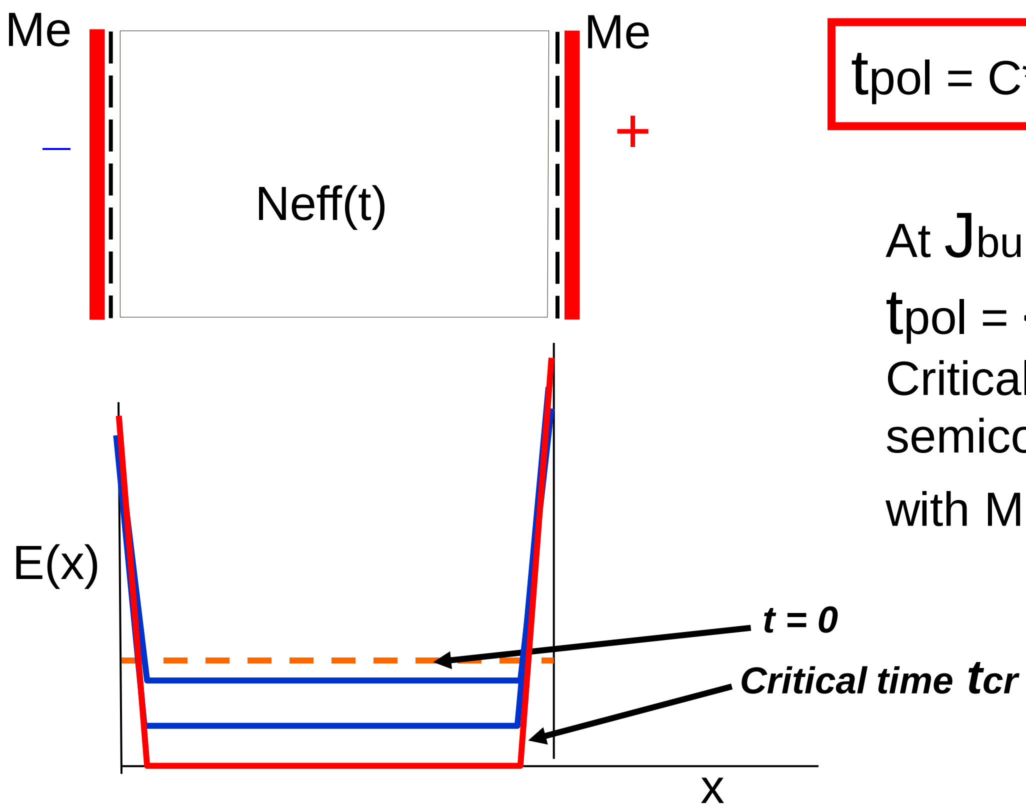
At J_{bulk} = 1e-9 A/cm2

t_{pol} = < 1000c !!!!

Critical for deep level rich semiconductors



Electric field evolution in detectors under charge accumulation at the contacts



$t_{pol} = C*V / \{I*(1-CCE)\}$

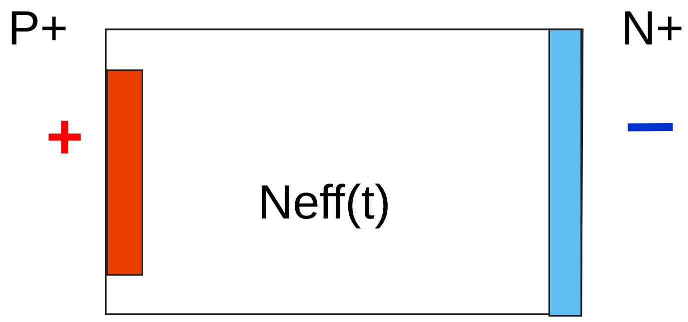
At J_{bulk} = 1e-9 A/cm2

t_{pol} = < 1000c !!!!

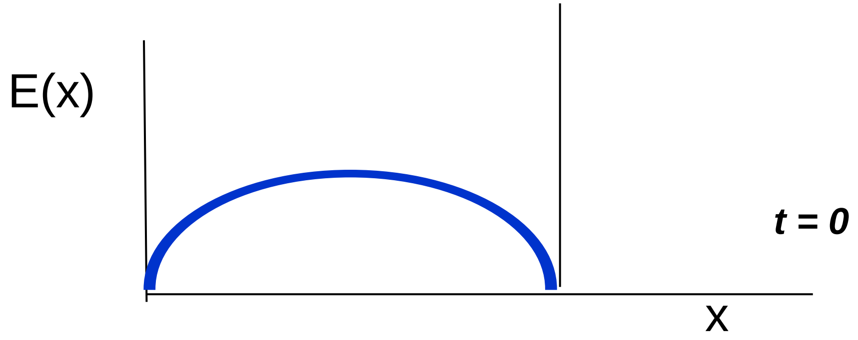
Critical for the wide band semiconductor detectors

with M-S-M structure

Double side injection structures as a possible solution

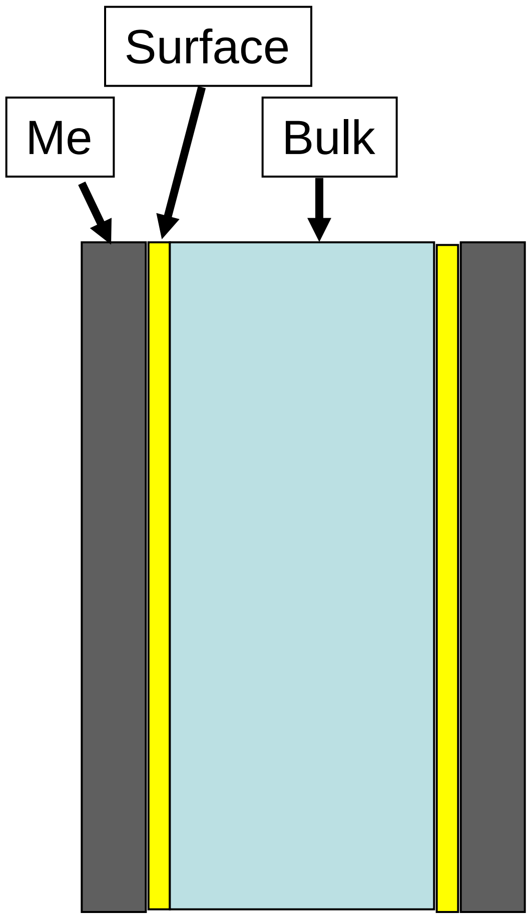


$E(n+) = E(p+) = 0$

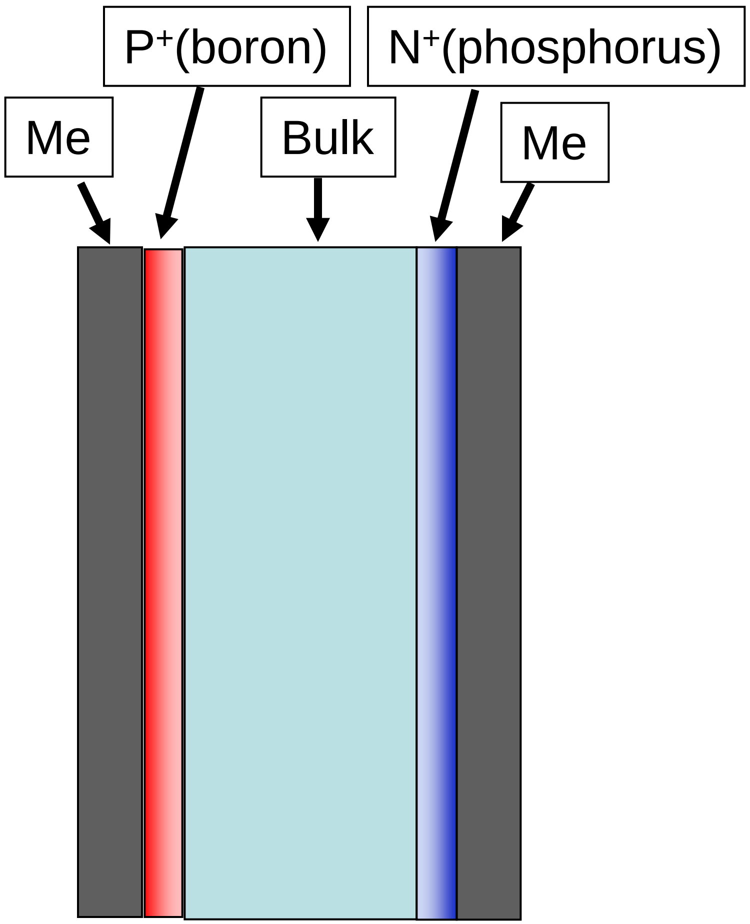


Critical condition:
Injection at cryogenic temperatures.
The best candidate – silicon P-I-N structure with **higly doped contacts.**

Comparison of Surface-barrier and P-I-N detectors

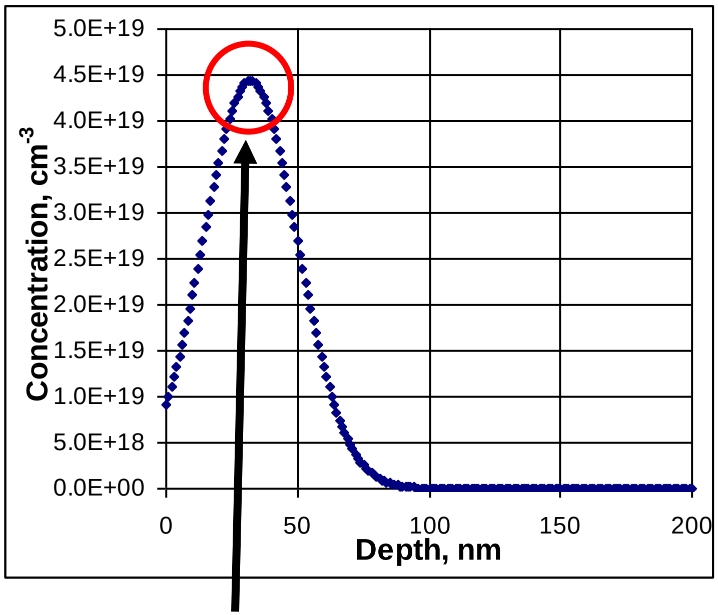


S/B detector
or M-S-M

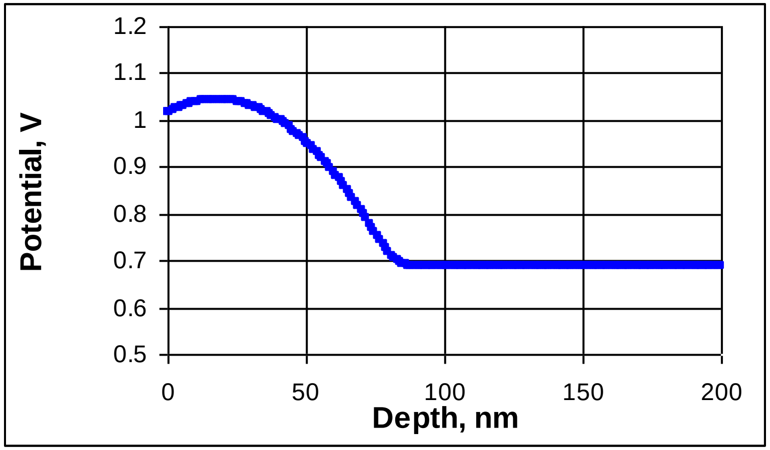


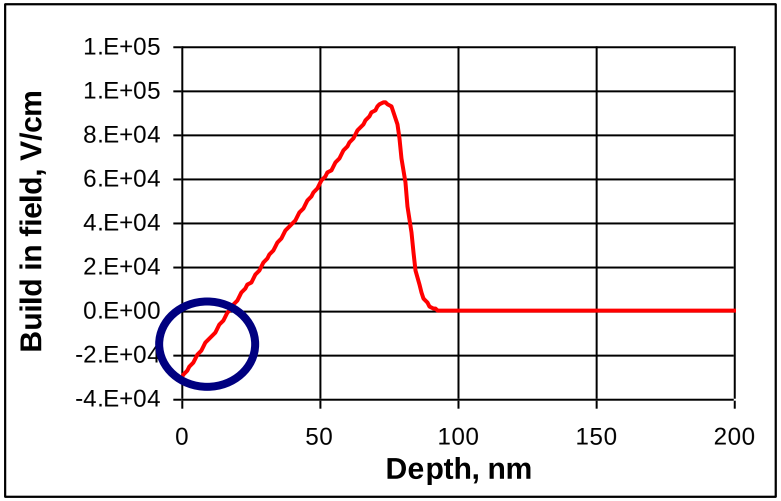
P-I-N

Electric field and potential at the detector entrance window



Degenerate Silicon
Si=Me





Conclusions

- Polarization could be a major drawback for Diamond and Silicon detectors operated at high counting rate at very low temperatures.
- The possible solution for Silicon detectors is a P-I-N structures with thin and abrupt highly doped contacts.
- For Diamond detectors the solution is not evident.
- The modules with optimized P-I-N structures must be studied with MIP's laser simulator and in test beams of 2012.

Thank you for your attention