RD39 Status Report 2010

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http://rd39.web.cern.ch/RD39/

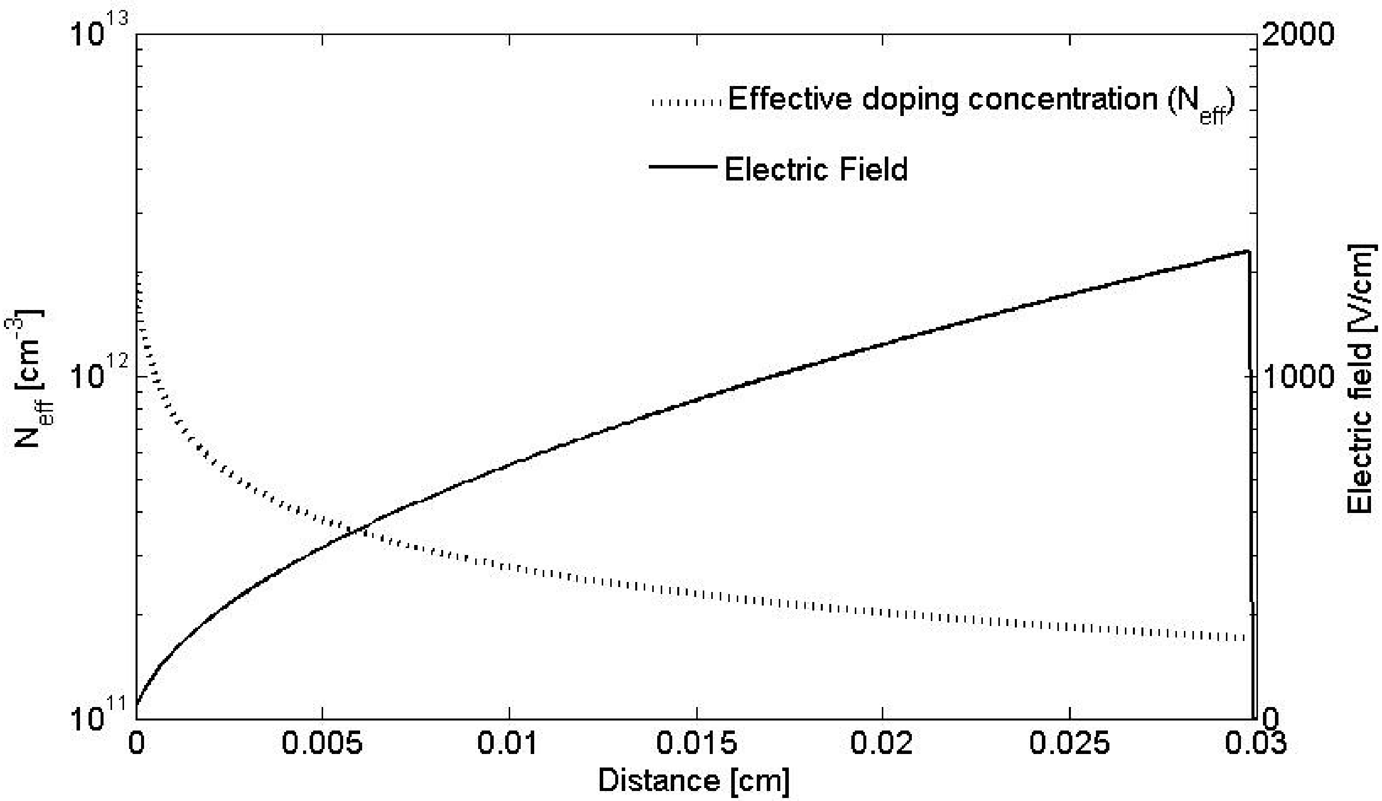
Outline

- **Principle of Charge Injected Detector (CID)**
- **Summary of previous planar CID test beam results.**
- **New 3D-Trench-CID**
- **Proposed new cryogenic project --- LHC beam loss monitor**
- **Summary**

Charge Injected Detector (CID) –Operational Principle

The electric field is controlled by charge injection, i.e. charge is trapped but not detrapped at "low" temperature

$$\tau_{trapping} = \frac{1}{\sigma_{e,h} v_{th} N_t} \qquad \tau_{detrapping} = \frac{1}{\sigma_{e,h} v_{th} e^{\frac{-E_t}{kT}}}$$



Electric field is extended through entire bulk regardless of irradiation fluence.

Electric field is proportional to square of distance E(x)~√x

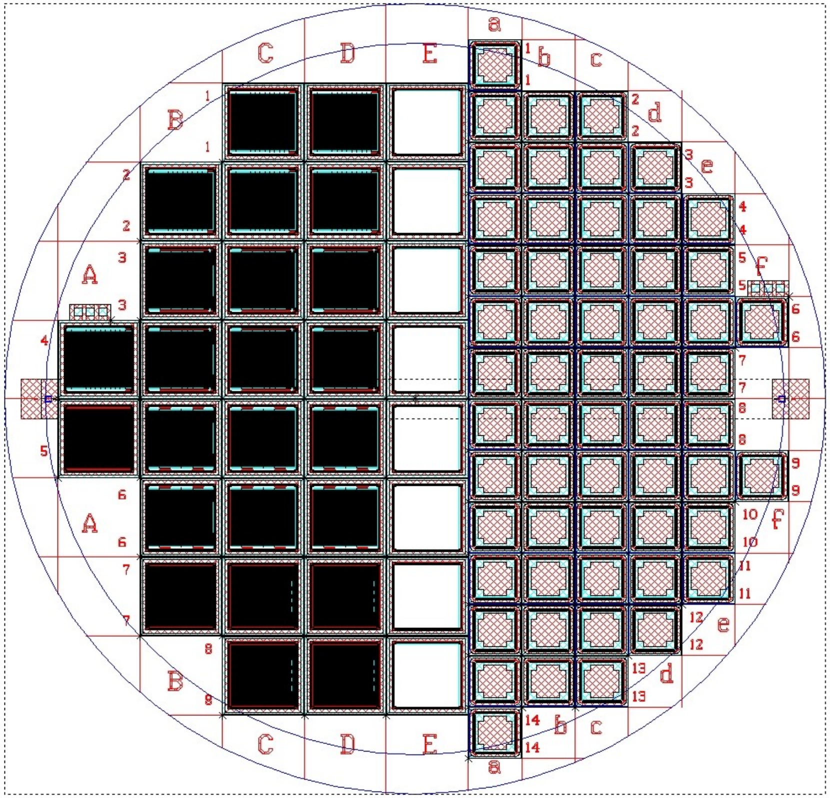
Detector is "fully depleted" at any bias or irradiation fluence

The trapping is reduced by injection

New strip detectors for CID studies

Substrate	Thickness [µm]	Resistivity [kΩcm]	Design
Fz-P	300	5-10	N-P-N
Fz-N	300	5-10	P-N-N
Fz-N	600	5-10	P-N-N
Fz-N	300	5-10	P-N-P
Fz-N	600	5-10	P-N-P
Fz-N	300	2-4	P-N-P

Purpose is to study how the charge injection influences on detector performance



For test beam studies good quality reference modules are needed (done in Nov 2010)

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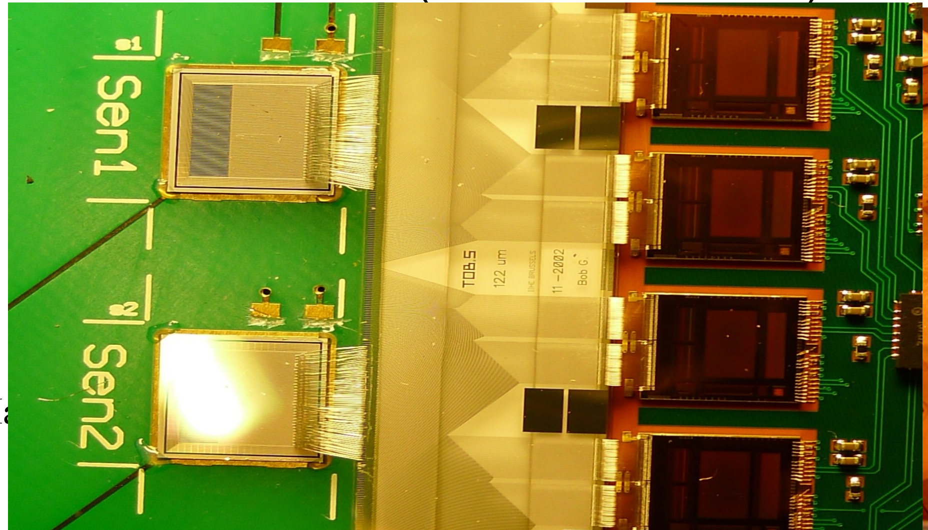
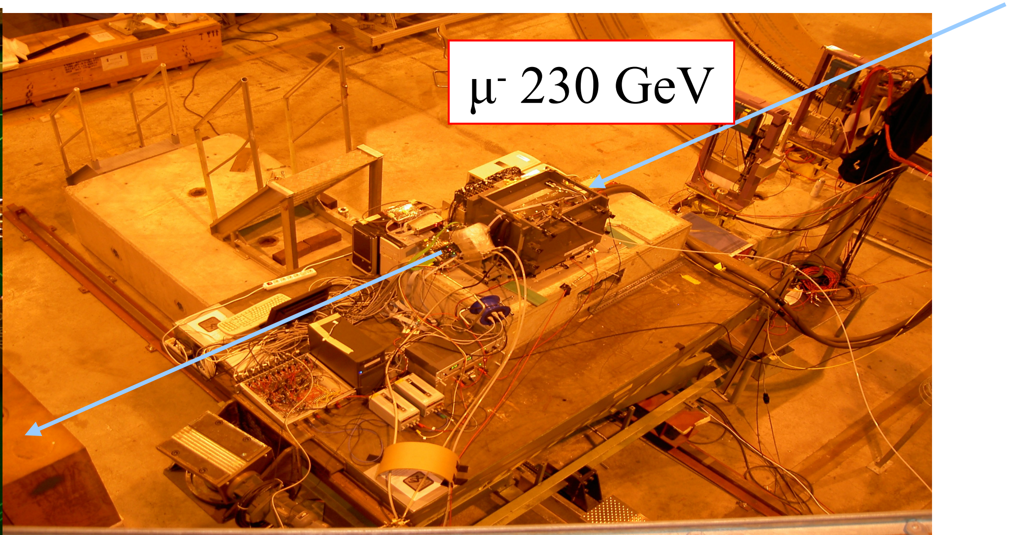
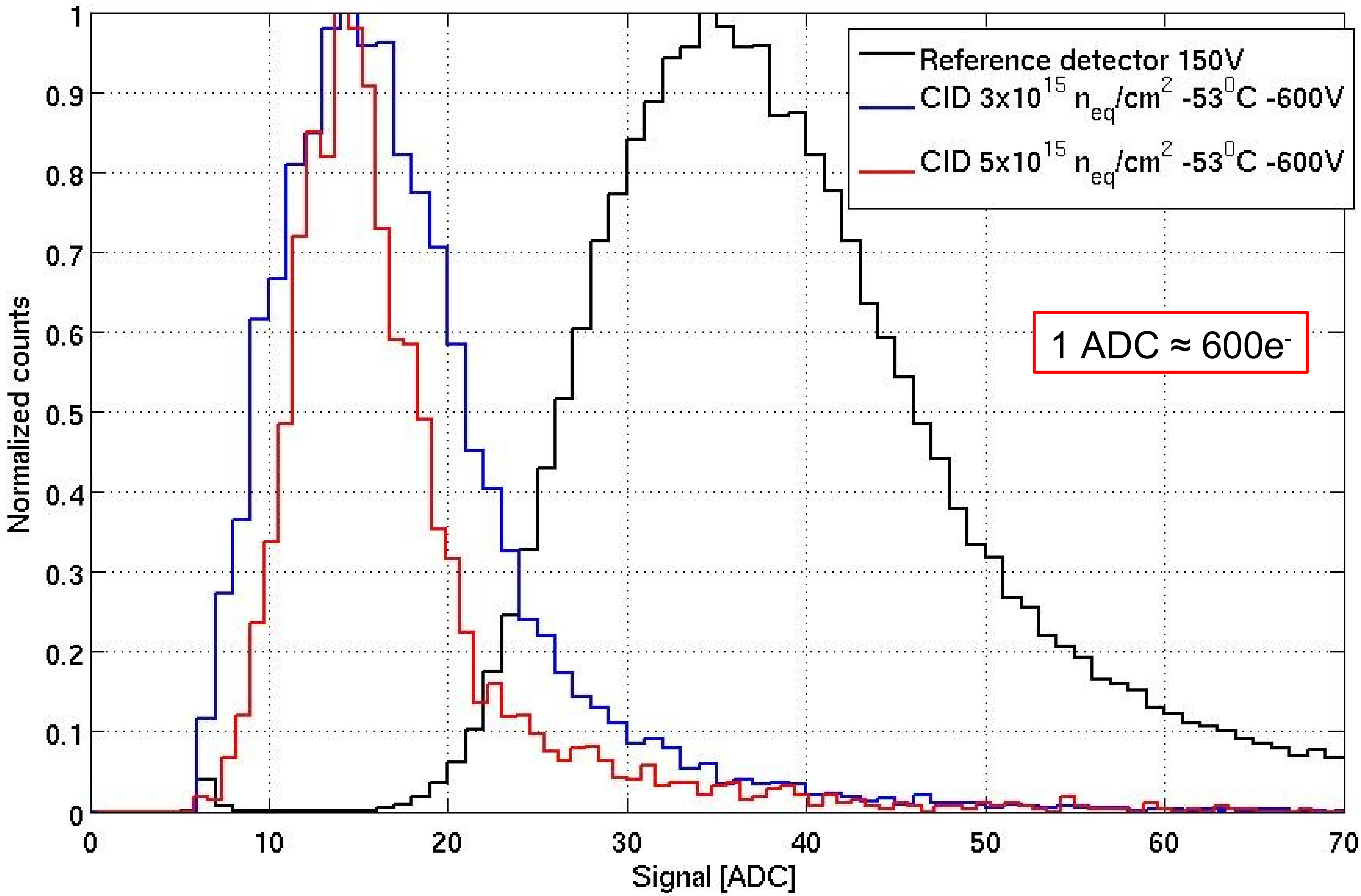
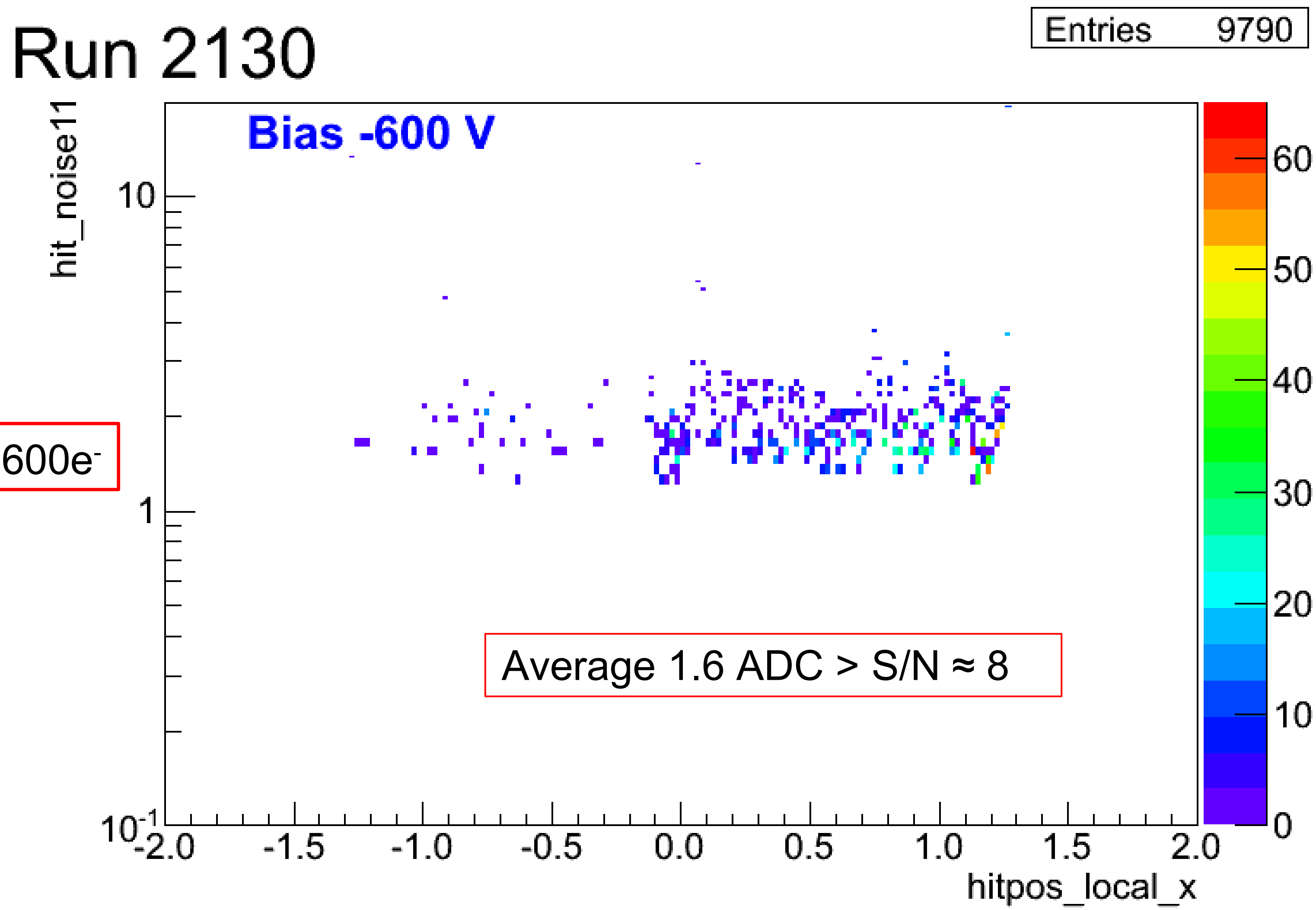




Summary plot of planar MCZ CID results



$5\times10^{15}\ n_{eq}/cm^2$ results -Noise



1 ADC ≈ 600e-

Average 1.6 ADC > S/N ≈ 8

3D-Trench Electrode detector at CID mode --- New CERN RD39 Rad-Hard Detector Initiative

More efficient charge injection to fill the traps

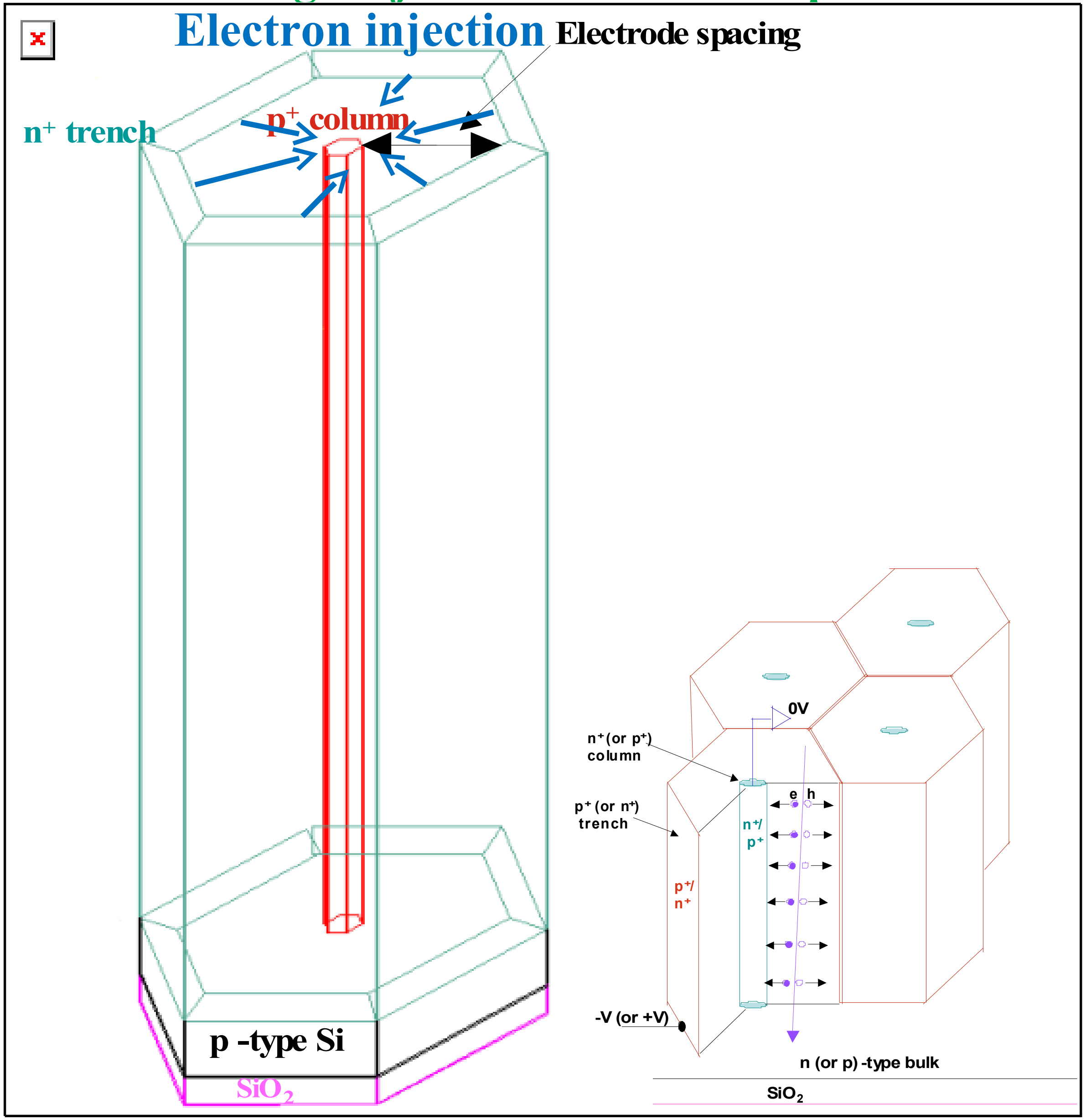


Fig. 1 Schematics of a single cell and array of a concentric type ICDA with outer ring junction (ICDA-ORJ)

Independent-Coaxial-Detector-Array (ICDA):

No cross talks between cells

3D-Trench-Electrode Detector
ICDA: Independent-Coaxial-Detector-Array
Zheng Li, 15th CERN RD50 Workshop, CERN, 11-18-2009

BNL US patent pending (61/525,756)
PCT filled on 10/15/2010 (PCT/US2010/52887)

Cylindrical geometry used for the simulation for 3D-Trench CID

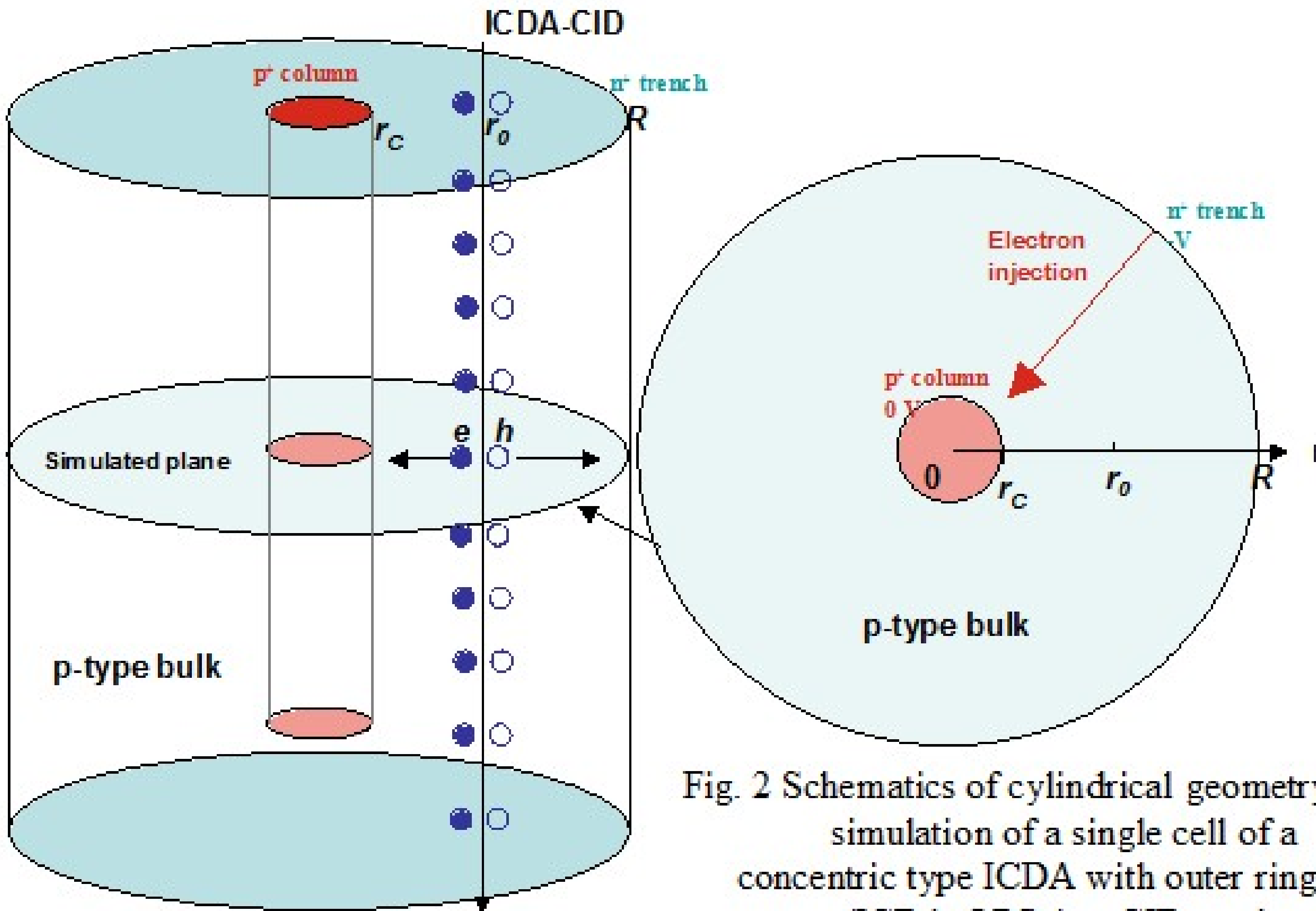
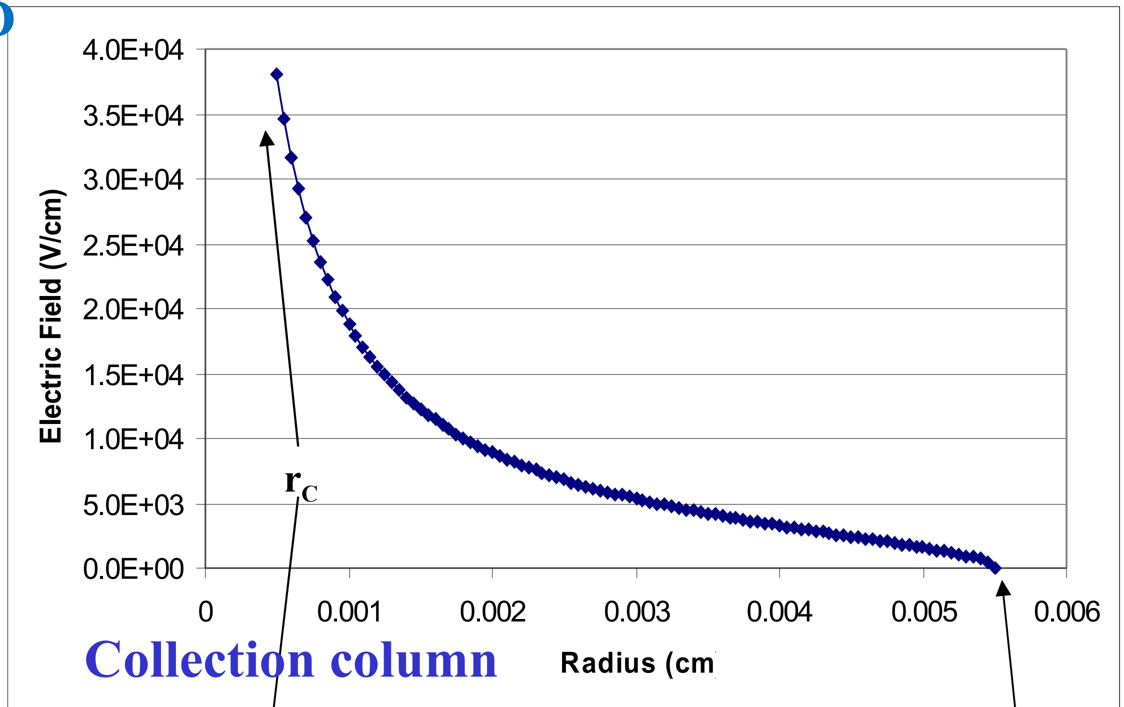


Fig. 2 Schematics of cylindrical geometry for the simulation of a single cell of a concentric type ICDA with outer ring junction (ICDA-ORJ) in a CID mode

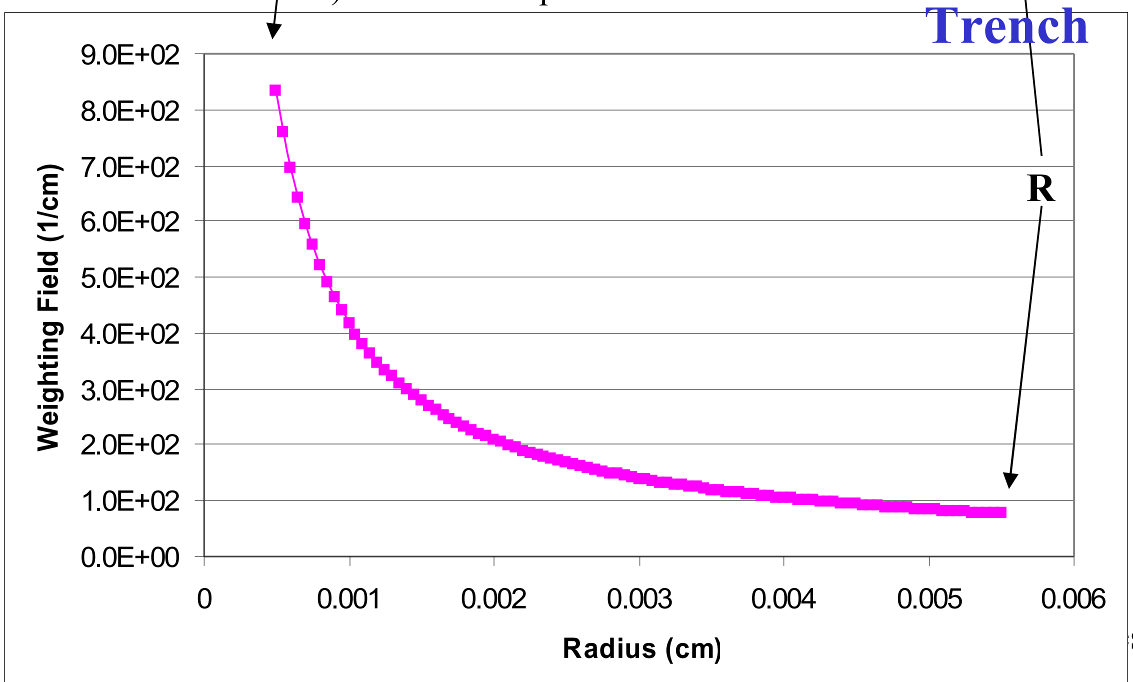
Electric field and weighting field profiles in a 3D-Trench CID



a) Electric field profile

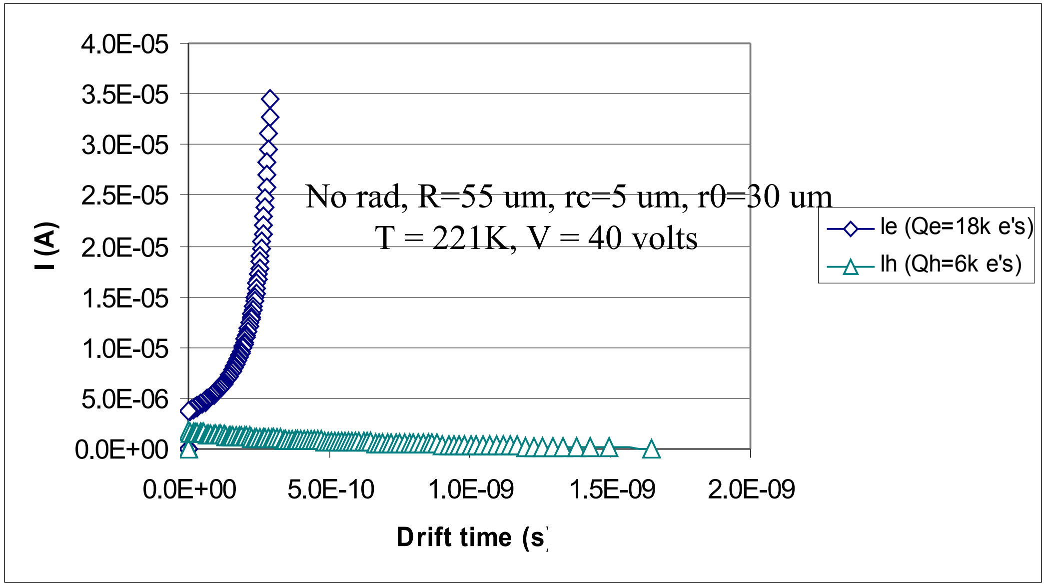
Similar shapes

Trench



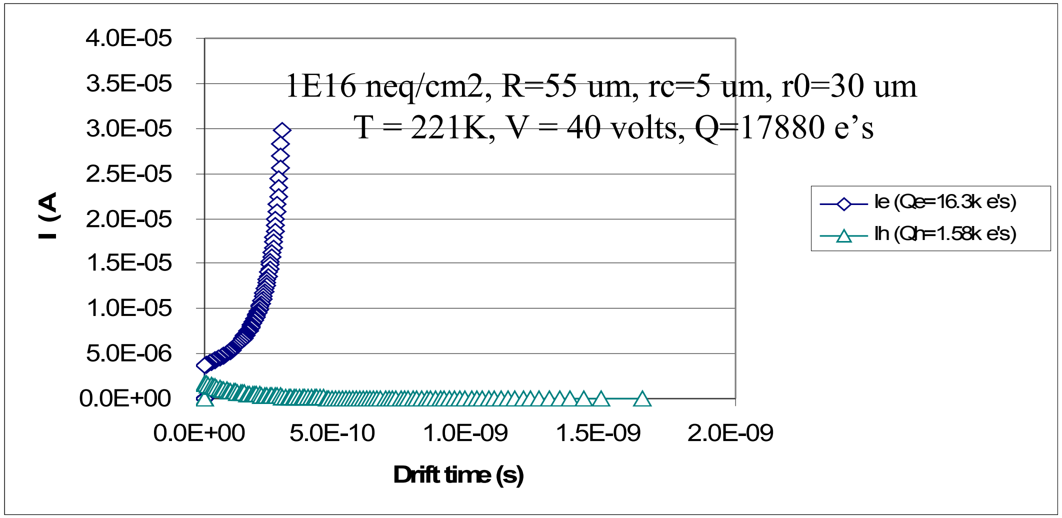
b) weighting field profile

Electron and hole current shapes induces by a MIP for a non-irradiated 3D-Trench CID



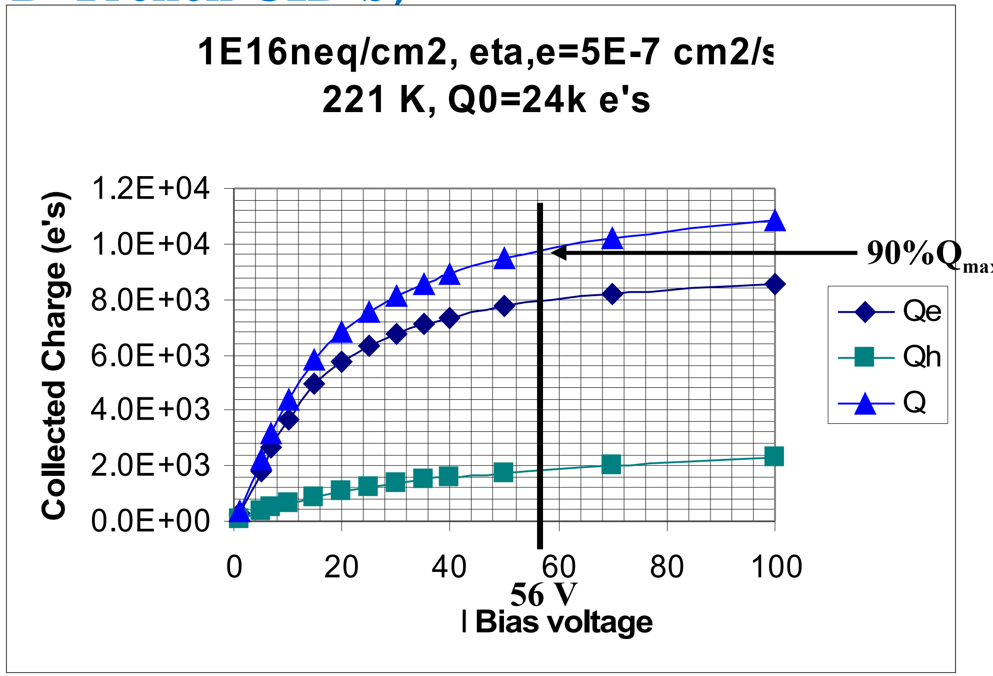
Total collected charge mostly contributed by electrons due to weighting field

Electron and hole current shapes induces by a MIP for an irradiated 3D-Trench CID

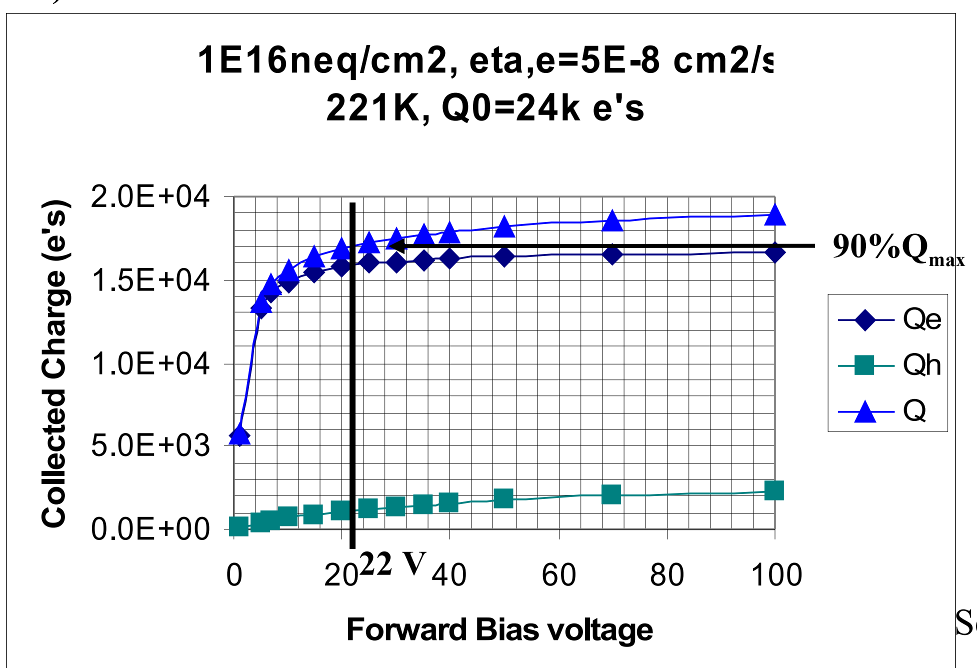


Total collected charge almost all contributed by electrons due to Weighting field and trapping

Total collected charge vs. bias voltage for a 3D-Trench detector a) and a 3D-Trench CID b)



a) Non-CID mode

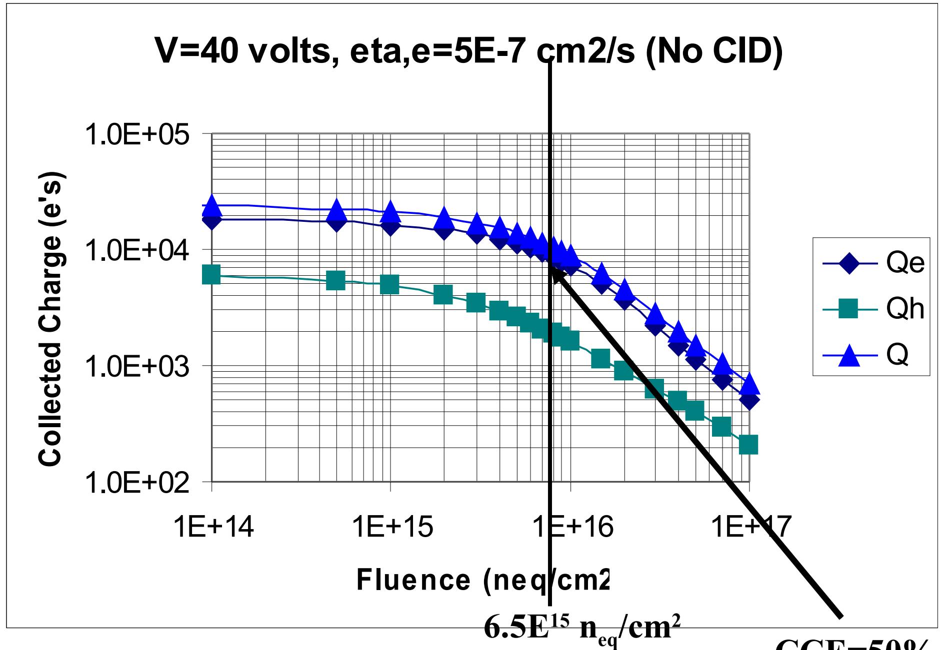


b) CID mode

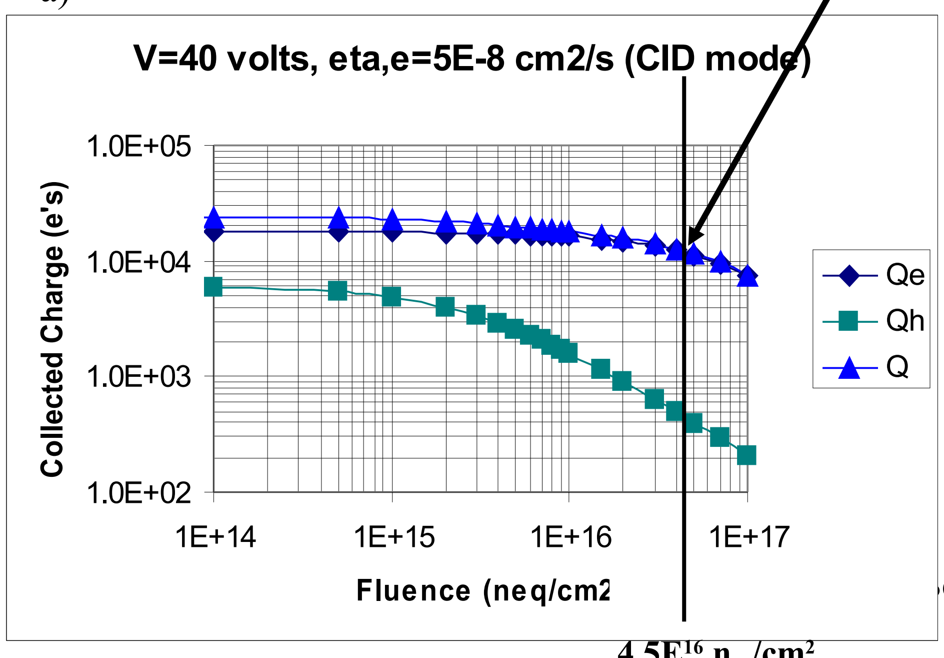
$$\frac{1}{\tau_t} = \eta_0 \cdot \Phi_{n_{eq}} :$$

Total collected charge in a 3D-trench CID is much more, and at much less Bias voltage

Total collected charge vs. fluence for a 3D-Trench detector a) and a 3D-Trench CID b)



a)

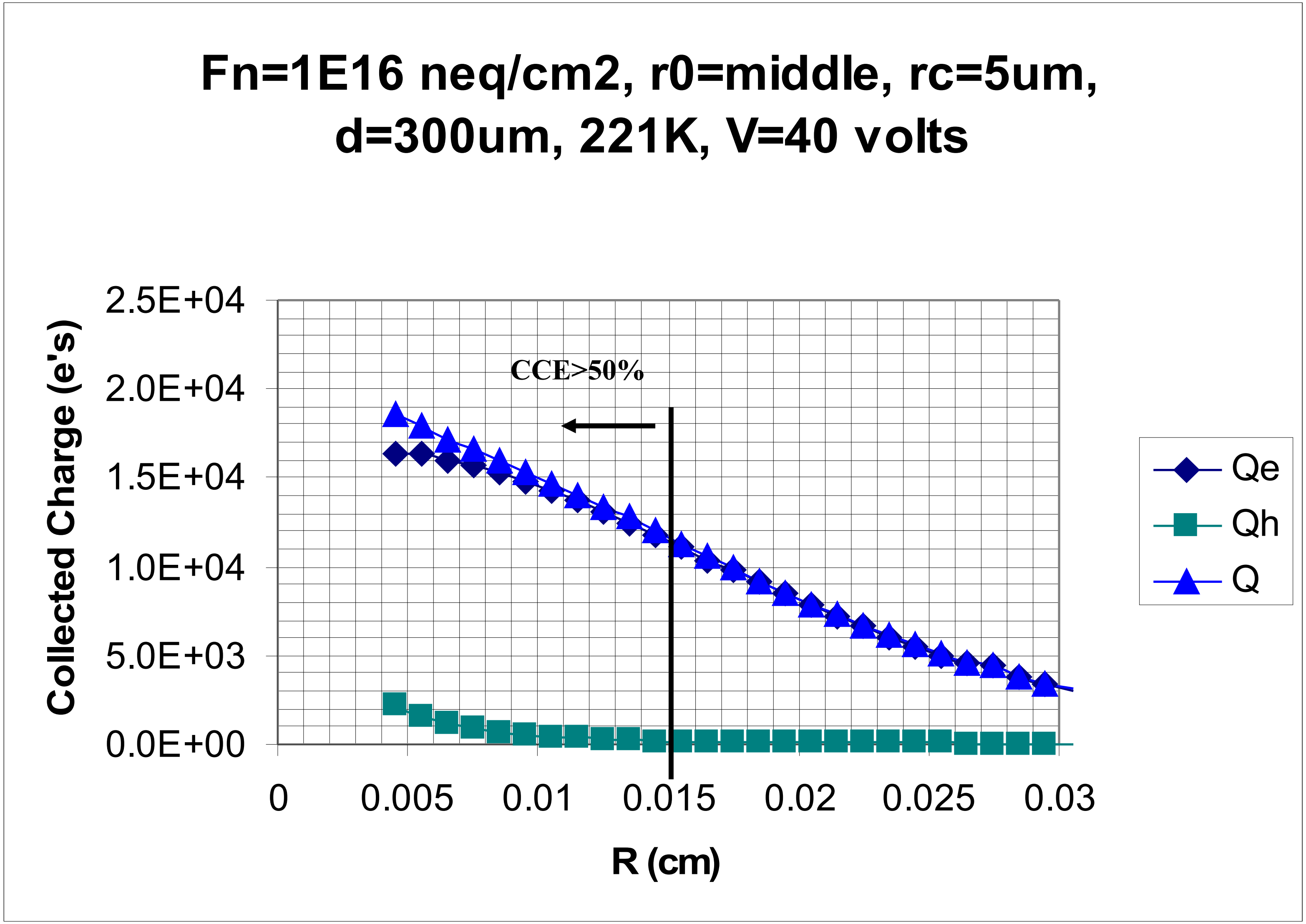


b)

For the same CCE, the fluence range in 3D-Trench CID can be 6 times higher than standard 3D-Trench detector

For planar CID, CCE is about 30% at 1×10^{16} n_{eq}/cm^2

CCE dependence on R (trench radius) in a 3D-Trench CID

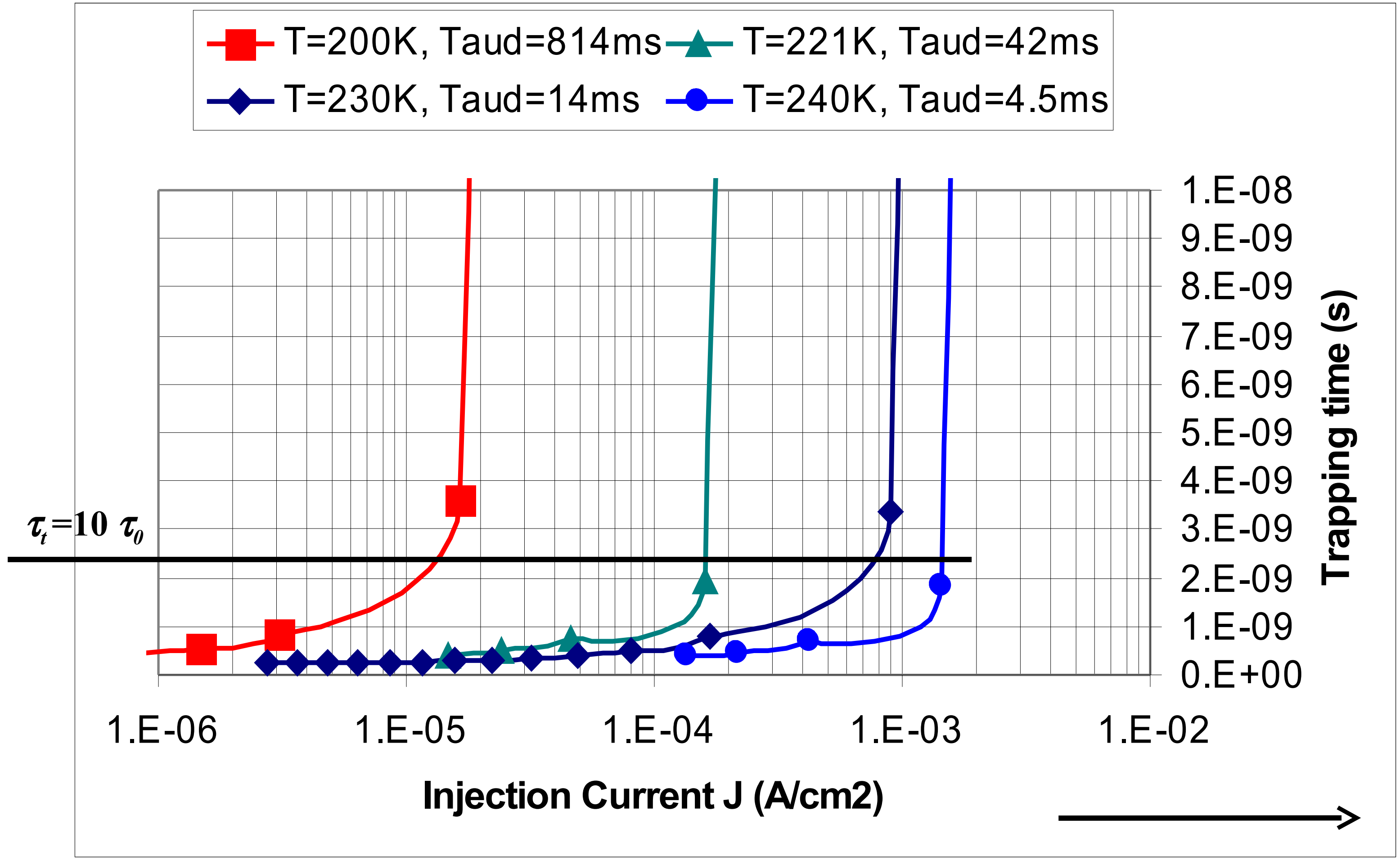


For R < 150 μm, CCE>50%

Charge injection induced reduction in trapping (increase in trapping time)

Dependence on Temp

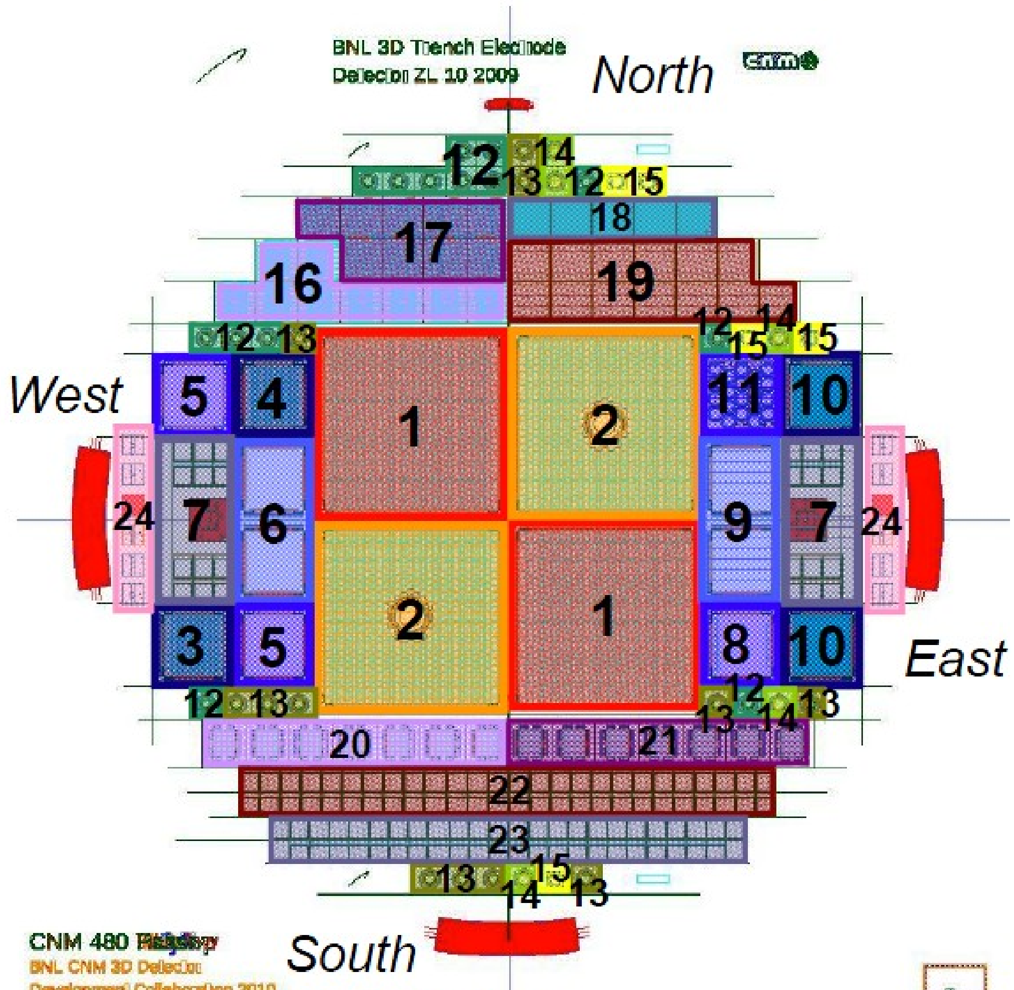
$N_T = 0.5 * \Phi_n$, $\Phi_n = 1.0 \times 10^{16}$ cm^{-2}, $E_t = 0.53$ eV, $\sigma = 1.0 \times 10^{-13}$ cm^2, $\tau_{t0} = 0.23$ ns



The higher the temp, the more the injection needed

Fabrication of the first prototype batch of BNL 3D-Trench-Electrode detectors are under way in CNM of Spain (Giulio Pellegrini), completion expected in summer 2011

CNM480 – trenched detectors for BNL (Zheng-Li)

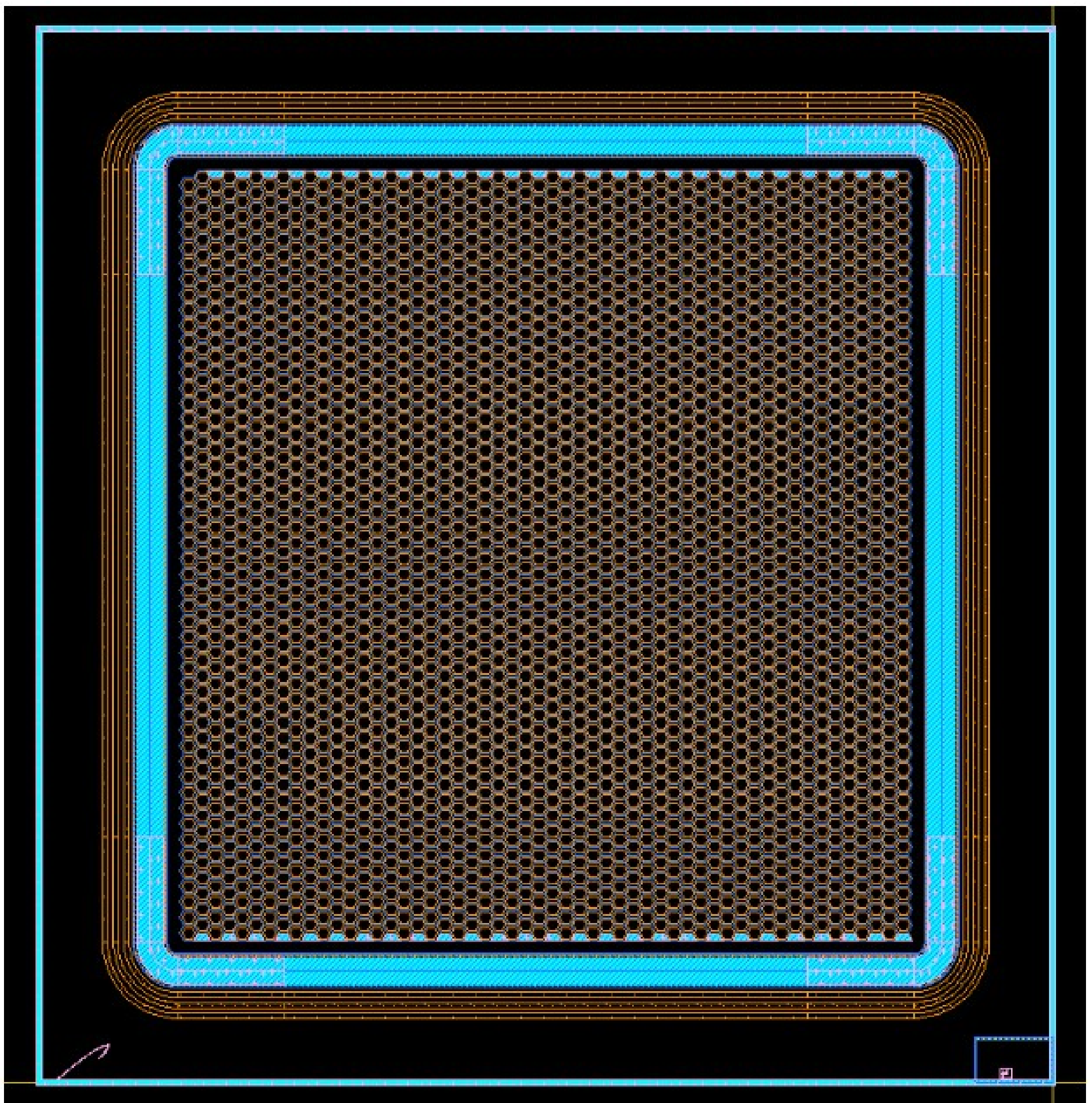


Mask with inverted color for clarity

Ref.	Name	Qty
1	3D_TRENCH_PIXEL_HEX_R500_0	2
2	3D_TRENCH_PIXEL_HEX_R500_1	2
3	3D_TRENCH_PIXEL_HEX_R500_2	1
4	3D_TRENCH_PIXEL_HEX_R500_7	1
5	3D_TRENCH_PIXEL_HEX_R80_70	2
6	3D_TRENCH_PIXEL_SQU_R212_7	2
7	3D_TRENCH_PIXEL_SQU_R212_1	4
8	3D_TRENCH_PIXEL_CIR_R300_7	1
9	3D_TRENCH_STRIPIXEL_SQU_R2	2
10	3D_TRENCH_STRIPIXEL_REC_16	2
11	3D_TRENCH_DRIFT_CIR_R500_1	1

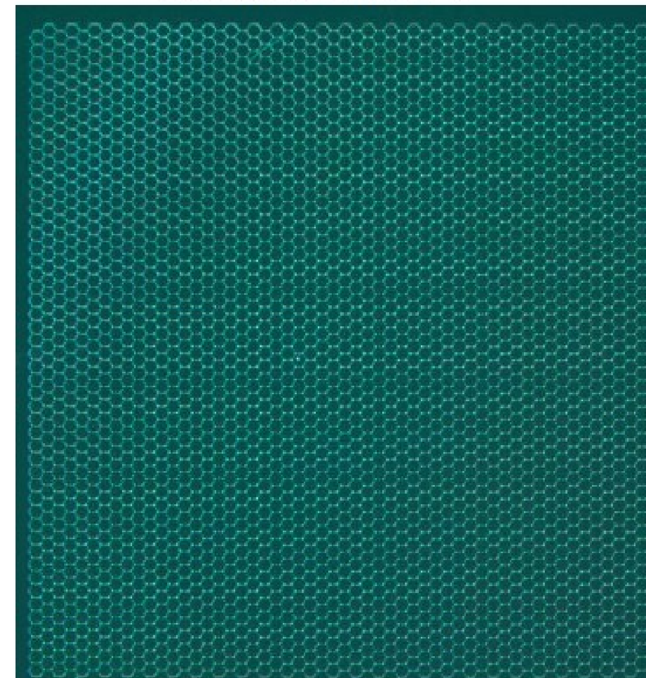
One example:
Hexangular type, R = 80 µm, 49x54 array

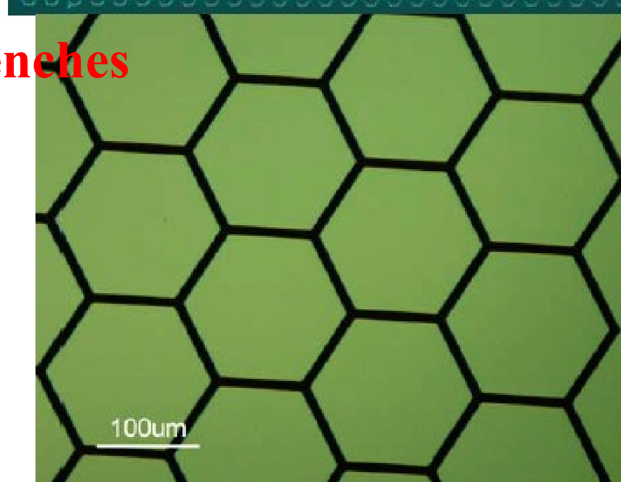
Design



Etched trenches

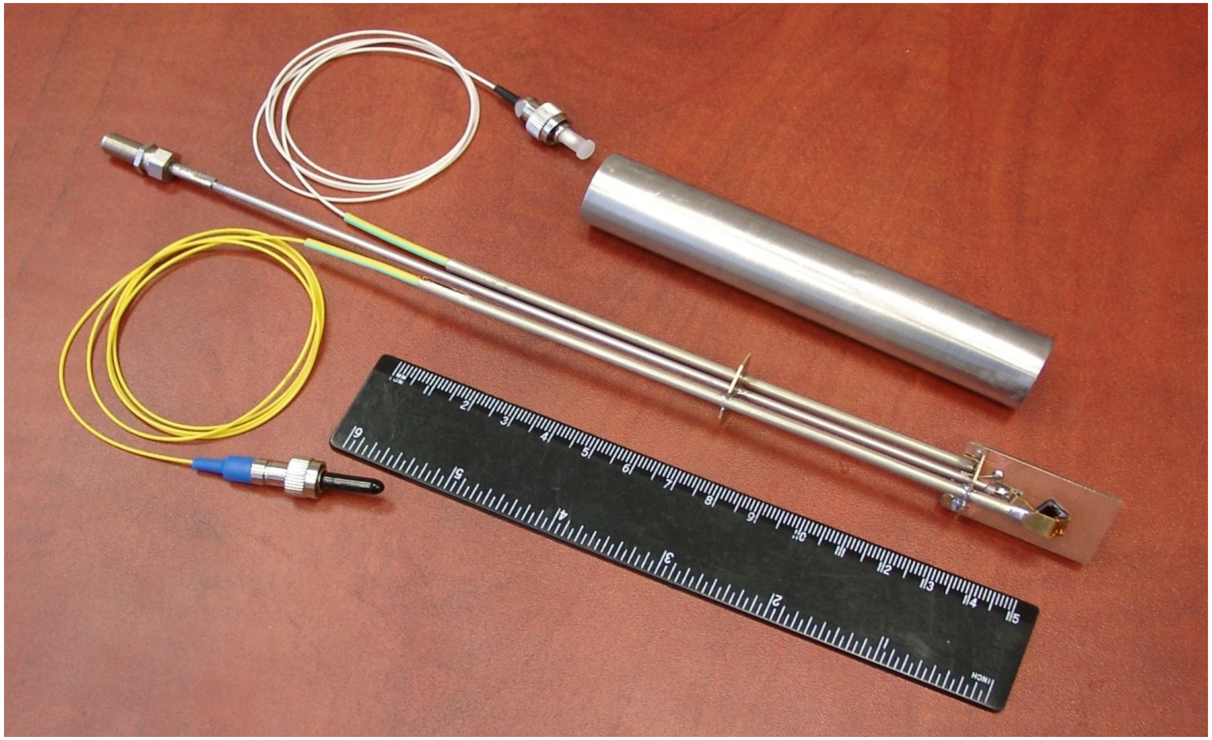
Pics from run5645





Proposed new cryogenic detector projects

- LHC Beam Loss Monitor



- Must operate at LHe temperature
- Must be radiation hard
- Probably operates in CID mode

Ongoing testing with RD39 cryogenic TCT (alpha source and laser)

Beam Loss Monitor prototype for testing

Summary

- New planar CID strip detectors with various configurations and thickness have been designed and made, and reference detectors have been beam tested
- New 3D-Trench-CID detectors have been extensively modeled and simulated;
- The CCE of these 3D-Trench-CID detectors are predicted to be much higher at much less bias voltages;
- the first prototypes of 3D-Trench-CID detectors are being made, and will be tested this coming year;
- The work for the proposed new cryogenic project --- LHC beam loss monitor has now being under way.