Exciting News from Diamond-on-Iridium Sensors

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CARAT

Advanced Diamond Detectors

GSI

Helmholtz Zentrum für
Schwerionenforschung

MC PAD

OUTLINE

ELECTRICAL CHARACTERIZATION of DIA-ON-IR; DoI-DETECTOR CHARACTERISTICS in 2010

- INTRODUCTION
- DESCRIPTION of THE MEASUREMENTS: I_{IND}; Q_C
- TCT SIGNALS – Charge Transport; Internal Field; $\sigma_i(t)$
- ALPHA SPECTROSCOPY – Crystal Structure; CCE; $\delta E/E$
- SUMMARY and Preliminary Conclusions
- CHARACTERIZATION – Next Steps

CONTRIBUTING

DETECTOR LABORATORY

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- Michael Träger
- EBe

ACCELERATOR HF GROUP

- Peter Moritz

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UNIVERSITY OF AUGSBURG

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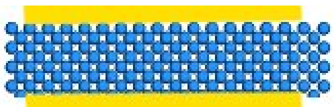
- Martin Fischer
- Stefan Gsell
- Matthias Schreck
- Christian Stehl

INTRODUCTION

TESTED DOI SAMPLES in 2010



FREESTANDING

A = (3.5 x 3.5) mm^2

both sides polished

METALLIZATION

Ti/Pt/Au (50/50/100)nm

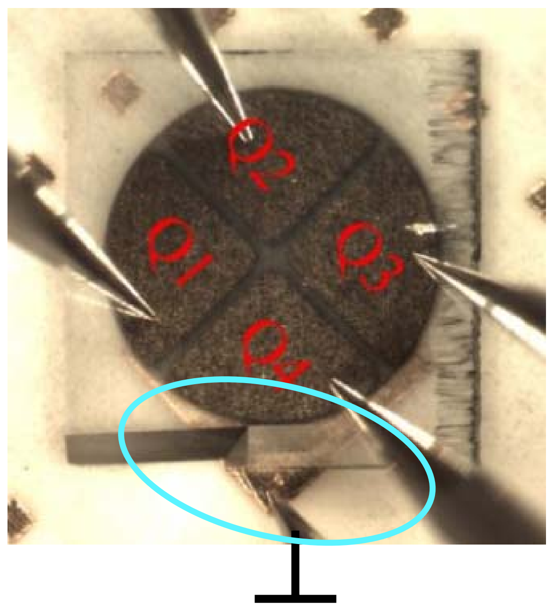
annealed (500 ^{o}C)

4Q-motif (growth-s.);

solid electrode (nucl.s.)

MFDIA-886-1, d = 290μm

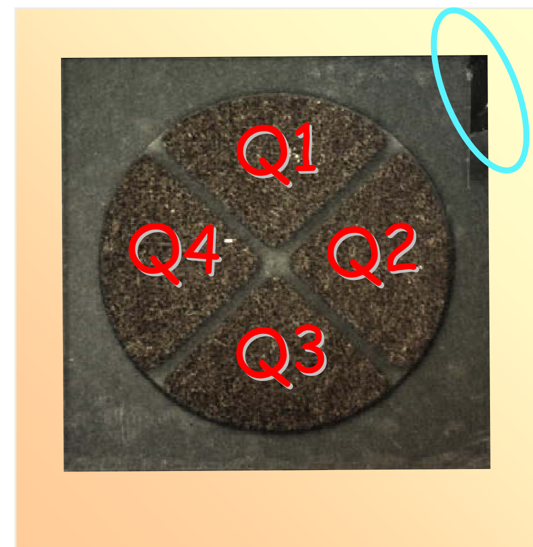
(July 2010)



ground electrode

MFDIA-886-2, d = 320μm

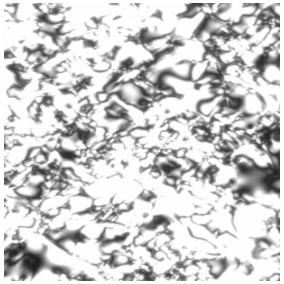
(July 2010)



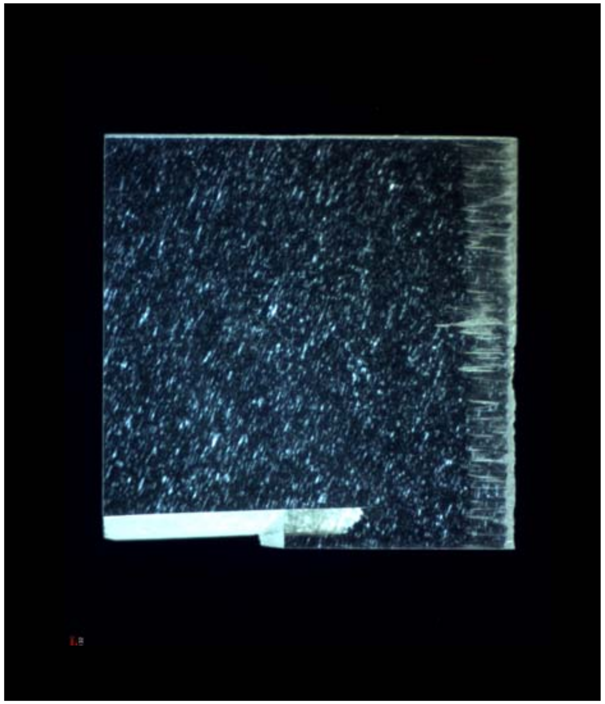
INTRODUCTION

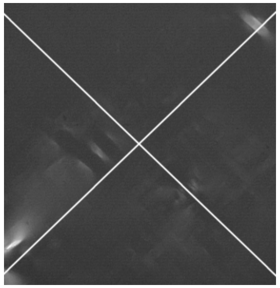
BIREFRINGENCE IMAGES

MFDia-886-1, d = 290μm, MFDia-886-2, d = 320μm,



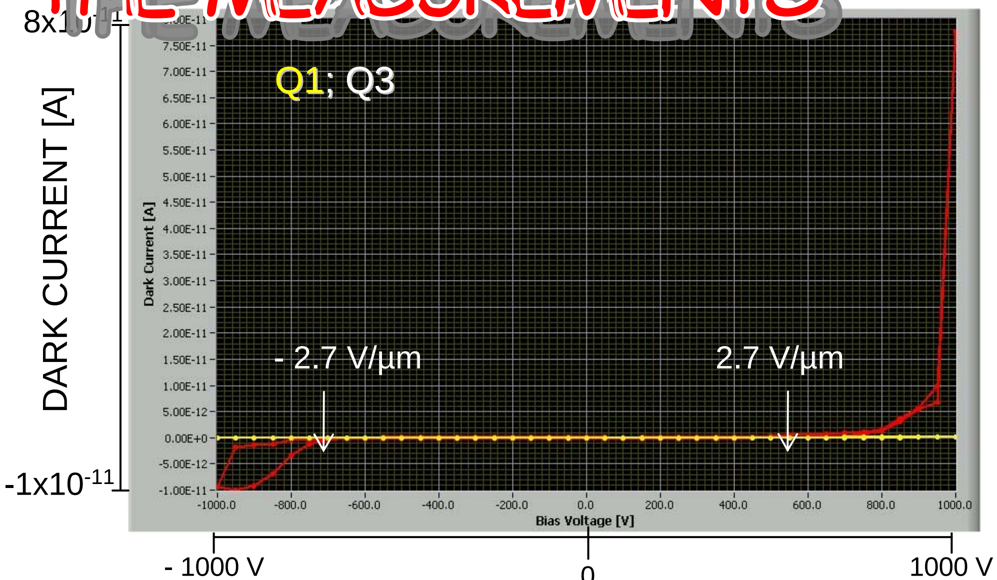
PC: Dia-on-Si

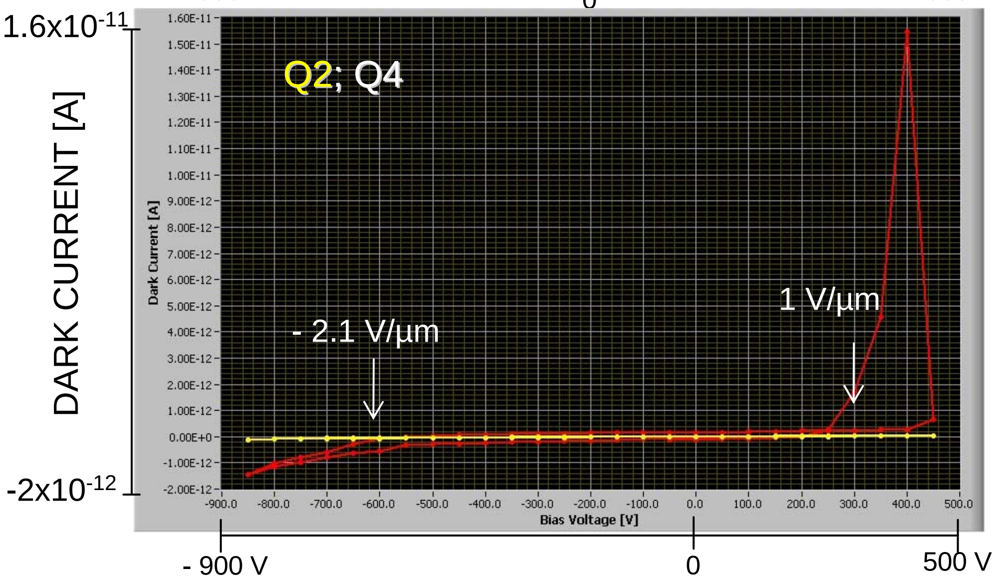




Dia-on-Dia

THE MEASUREMENTS

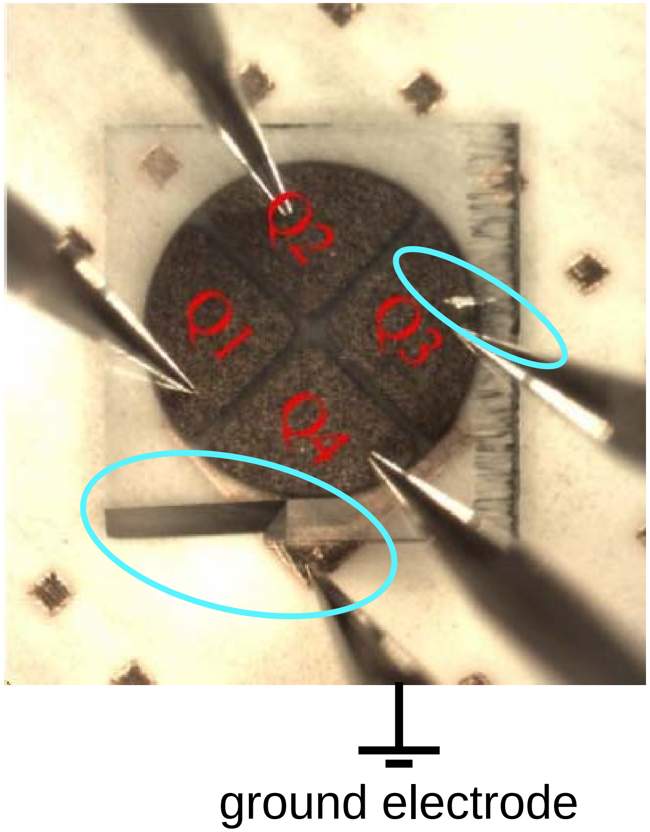




BIAS VOLTAGE [V]

IV CHARACTERISTICS

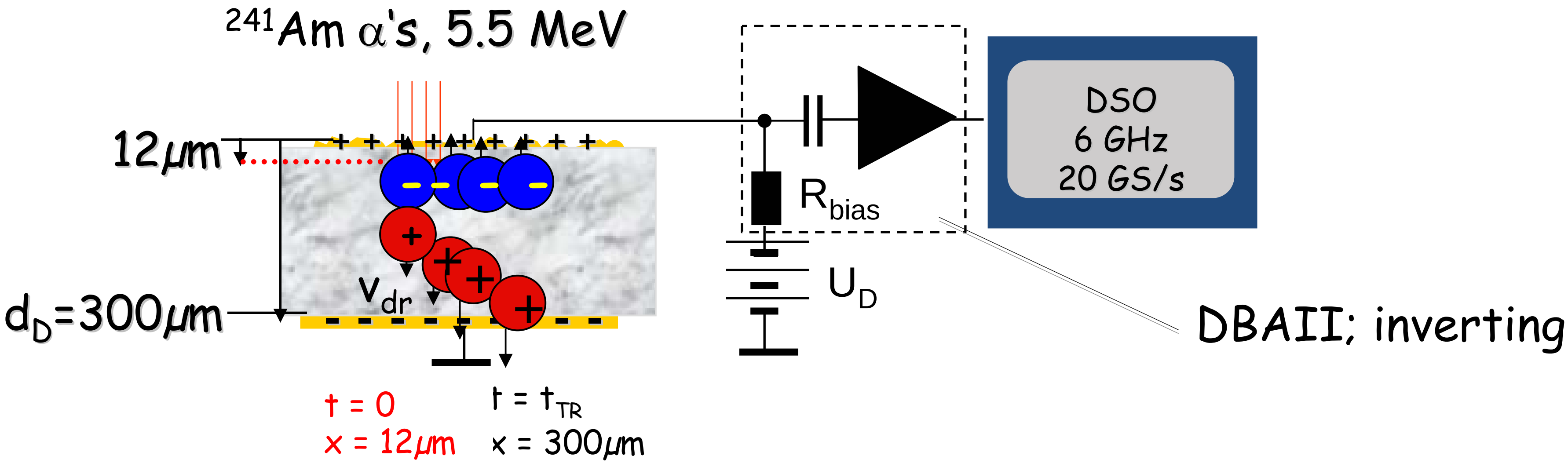
CS-886-1, d = 290µm
(2010)

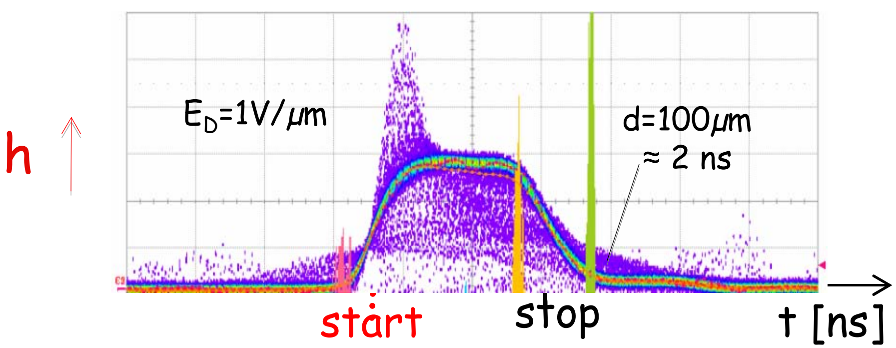


THE MEASUREMENTS

SINGLE-CARRIER DRIFT MODE: LOW IONIZATION

a) IDEAL CASE: CONSTANT E_D and COMPLETE DRIFT





a) DRIFT VELOCITY and MOBILITY:

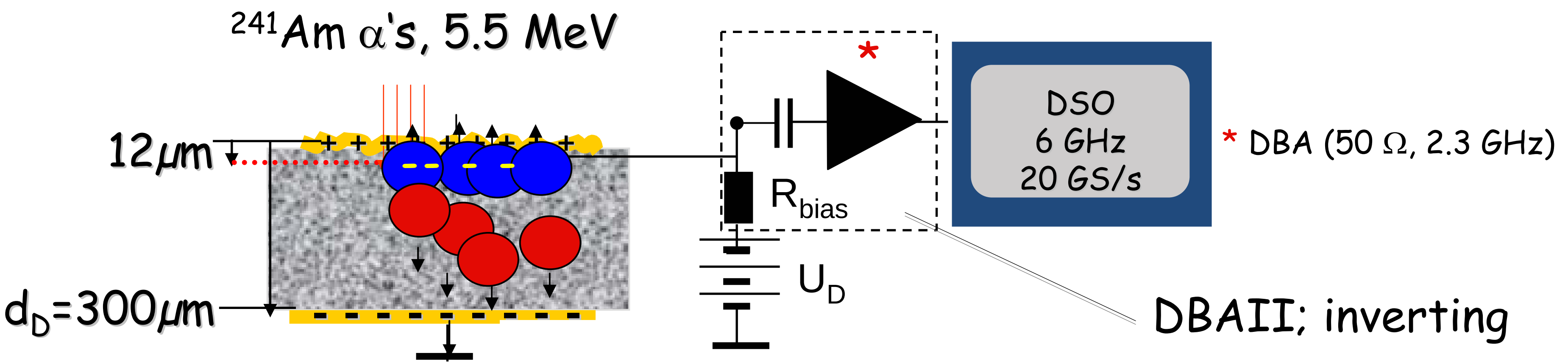
$$\Rightarrow v_{dr}(E_D)_{e,h} = d_D / t_{TR}(E_D)$$

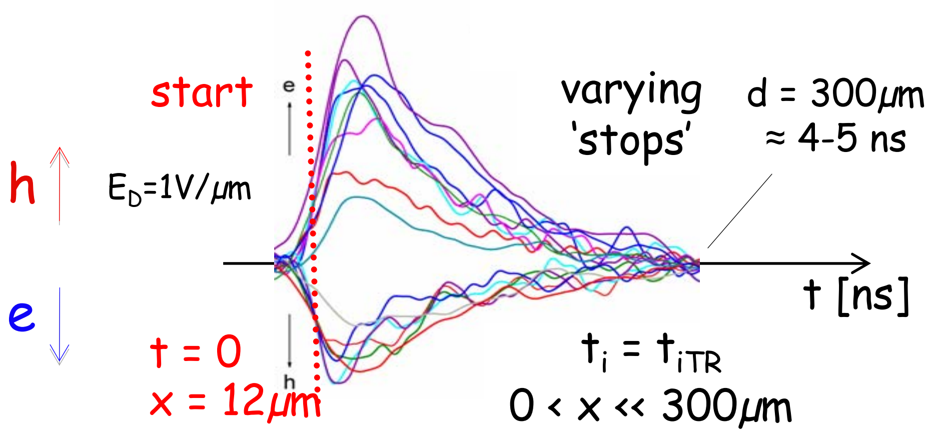
$$\mu_{dr}(E_D)_{e,h} = v_{dr}(E_D)_{e,h} / E_D$$

THE MEASUREMENTS

SINGLE-CARRIER DRIFT MODE: LOW IONIZATION

b) PRESENCE of TRAP CENTRES and FIXED SPACE CHARGE

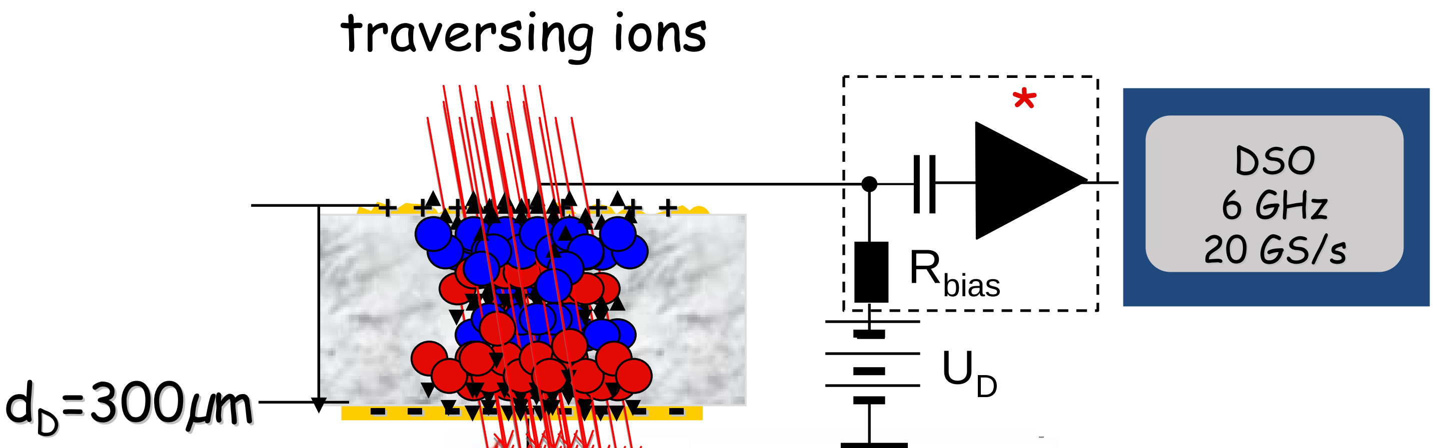




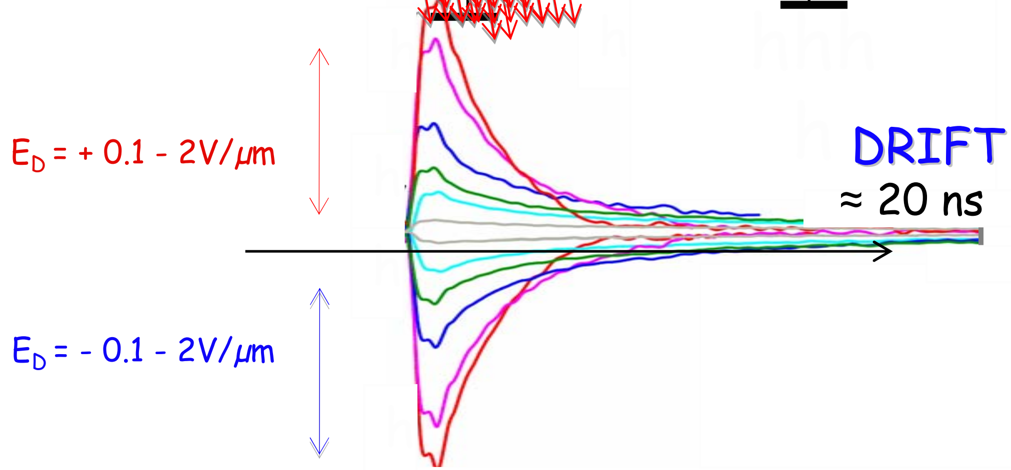
⇒ b) ESTIMATION of LIMITS

$LL < v_{dr}(E_D)_{e,h};\ \mu_{dr}(E_D)_{e,h};\ \tau_{e,h} < UL$

DUAL-CARRIER DRIFT MODE: HIGH IONISATION



* DBA (50 Ω, 2.3 GHz)



DRIFT VELOCITIES and MOBILITIES

- ⇒ non accessible
- ⇒ shorter t_{TR}
- ⇒ longer relaxation time

THE MEASUREMENTS

SIGNAL PROCESSING: INDUCED CURRENT/COLLECTED CHARGE

$$I_{tr}(t,E)=\frac{Q_G\cdot v_{dr}(E)_{e,h}}{d_D}\cdot\left(1-e^{(t/\tau_{eff}-t/\tau_{e,h})-(t/R_iC)}\right)=\frac{Q_C(E)}{t_{tr}}\cdot\left(1-e^{-t/R_iC}\right)$$

$$Q_G=\frac{\Delta E}{\varepsilon_{Dia}};\quad v_{dr}=\mu(E)\cdot E_D;\quad \tau_{eff}=\frac{\varepsilon\varepsilon_0}{e\mu_{e,h}N_{eff}}\propto\frac{t_{tr}V_{bias}}{ed^2\left|N_{eff}\right|};\quad life-\tau;\quad I_0=amplitude$$

BROADBAND

$Q_C \propto$ BB-Signal Area:

$$I_{tr}(t,E)=I_0\cdot\left(1-e^{-t/R_iC}\right)$$
$$0\le t\le t_{tr}$$

CHARGE-SENSITIVE

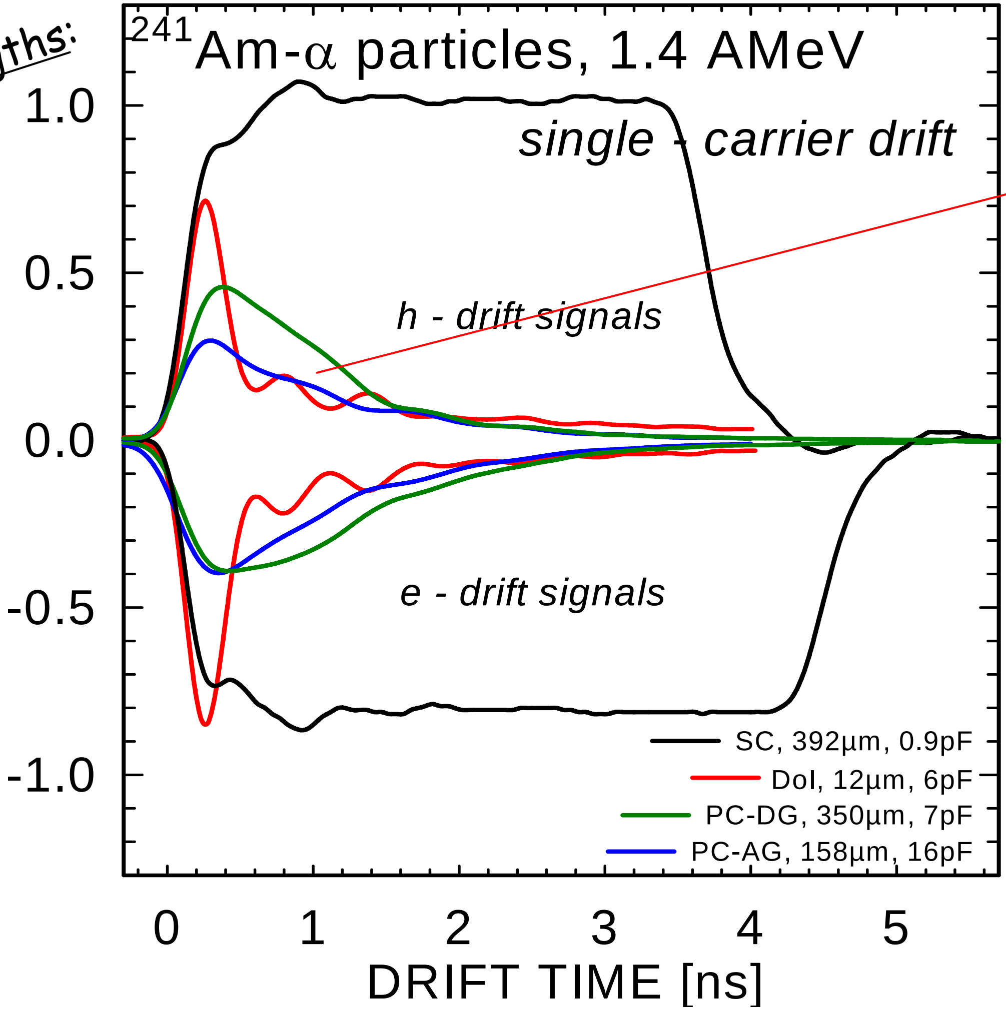
$Q_c \propto$ CS-Peak Amplitude:

$$U_{peak}(E)=\frac{\int I_{tr}(t,E)\,dt}{C_f}=\frac{Q_C(E)}{C_f}$$

TRANSIENT CURRENT SIGNALS

TCT with α-particles 2009

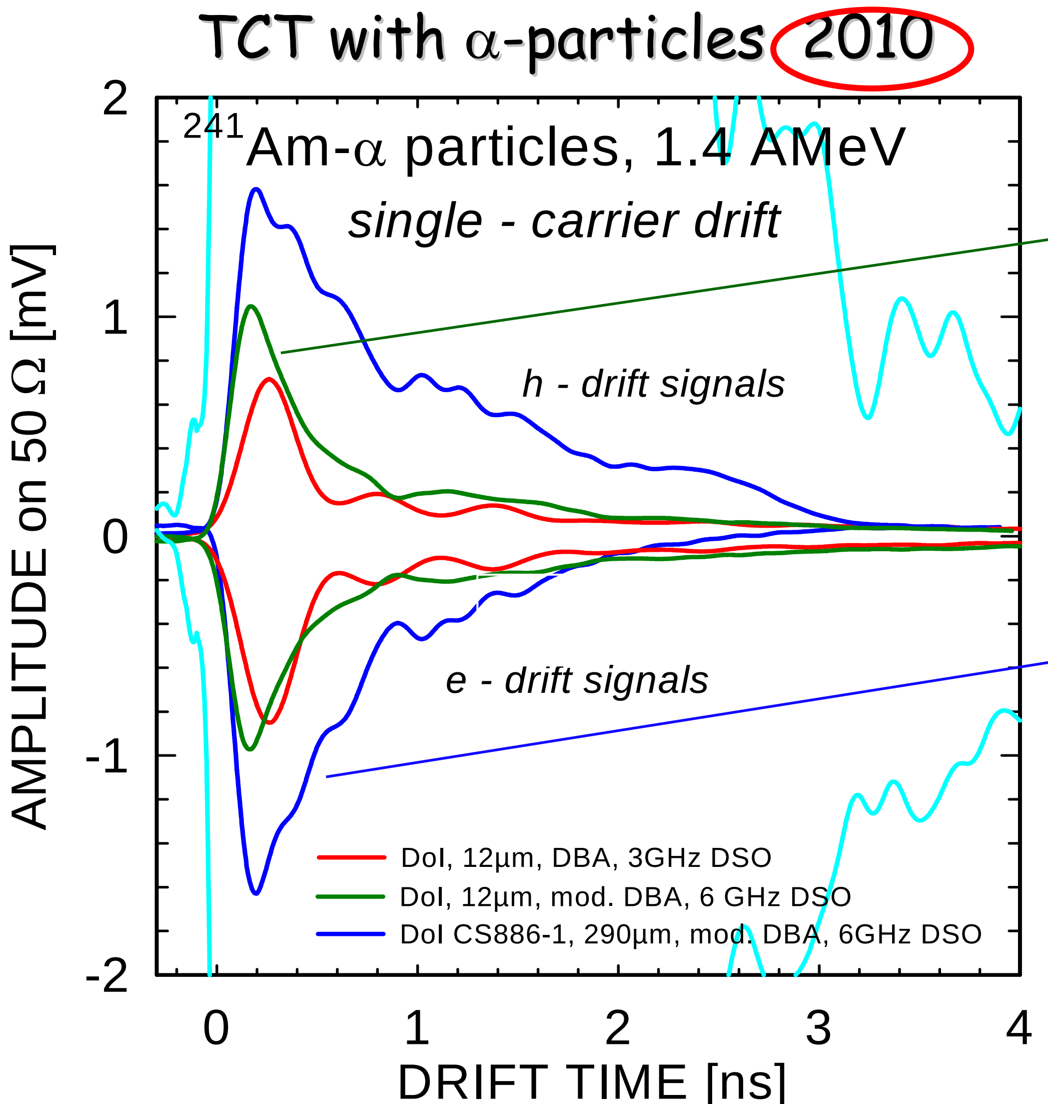
ATTENTION
max. poss. drift lengths:
SC: 390µm
PC-DG: 350µm
PC-AG: 160µm
DOI: 12µm



first indication of DBA (50Ω, 2.3GHz) problems characterizing Dia-on-Ir signals !

DBA modified for 3.4GHz

TRANSIENT CURRENT SIGNALS



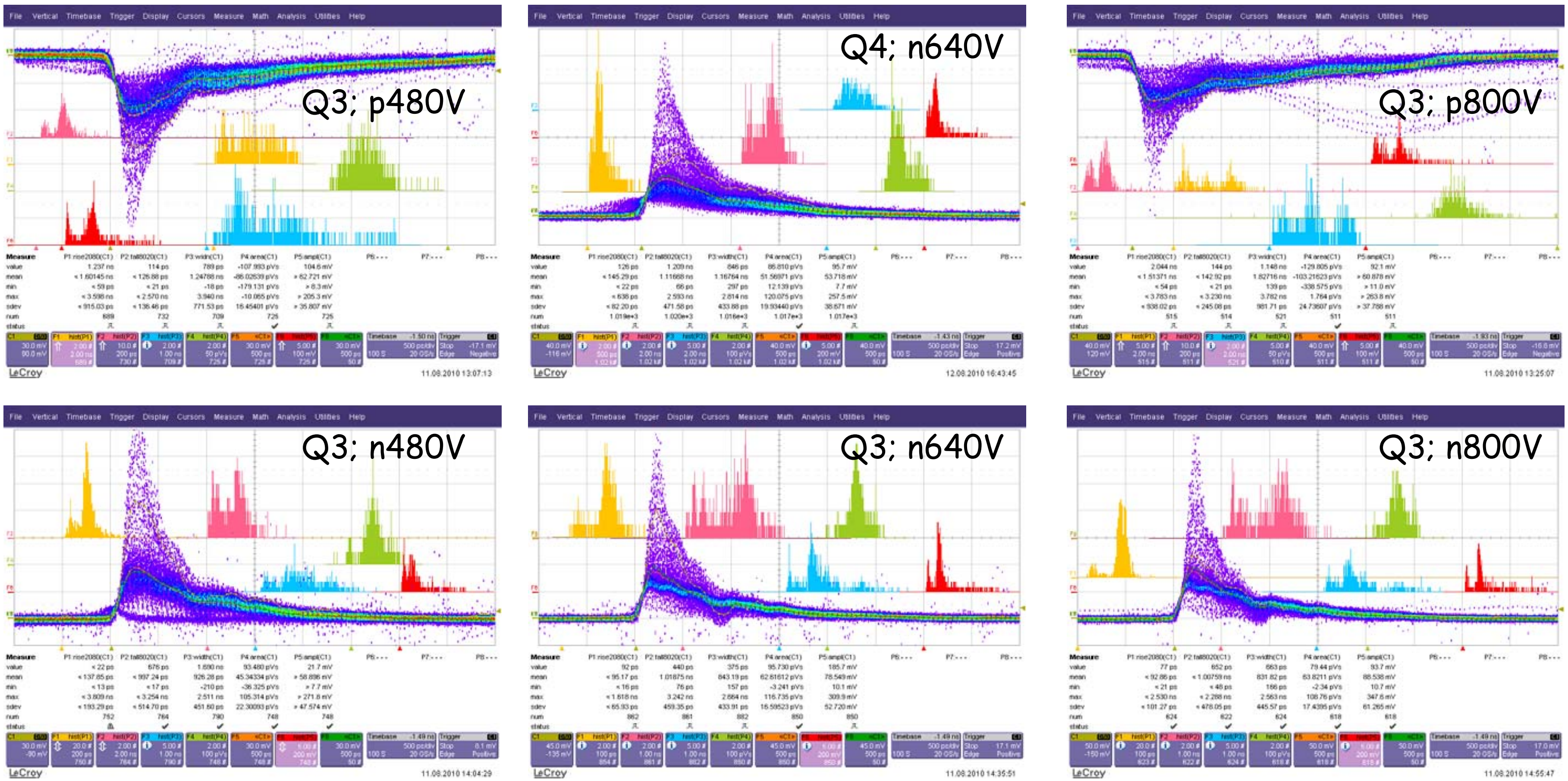
effect of mod. DBA and 6GHz DSO

effect of better DOI

TRANSIENT CURRENT SIGNALS

MFDIA886-2: TCT with α-particles 11.8.2010 'pumped'

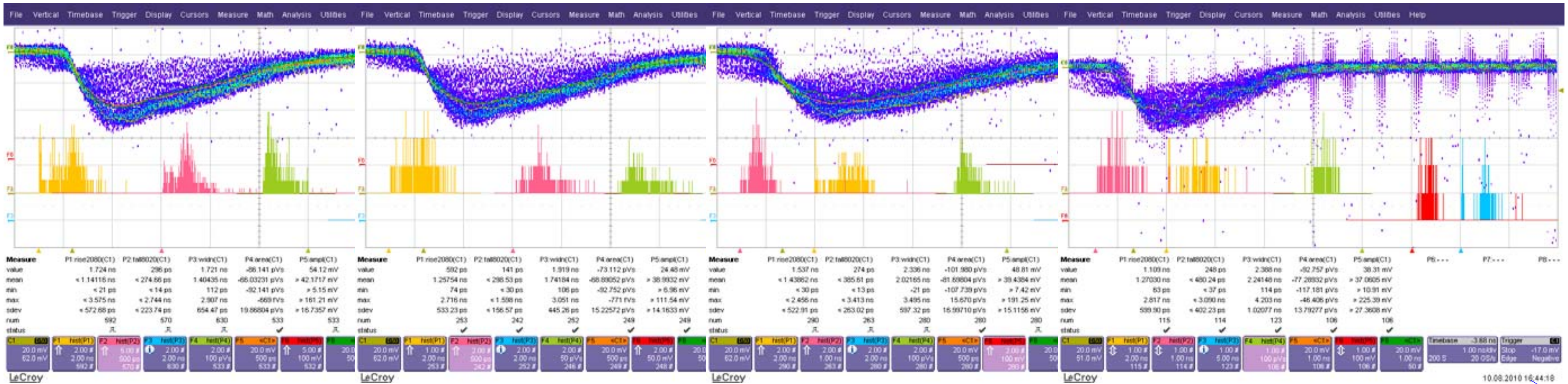
mod. DBA; 6GHz DSO; non-inverting



500ps/div

MFDIA886-2; Q1 'pumped' Positive Bias

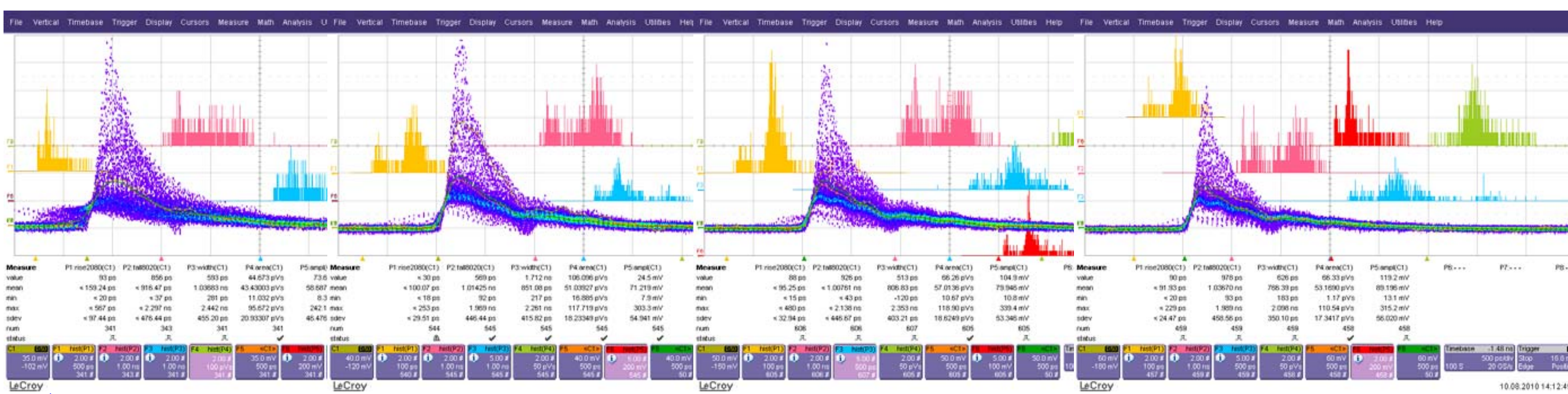
320 480 640 800 [V]



1.40 1.72 2.02 2.24 FWHM [ns]

MFDIA886-2; Q2 'pumped' Negative Bias

- 320 - 480 - 640 - 800 [V]

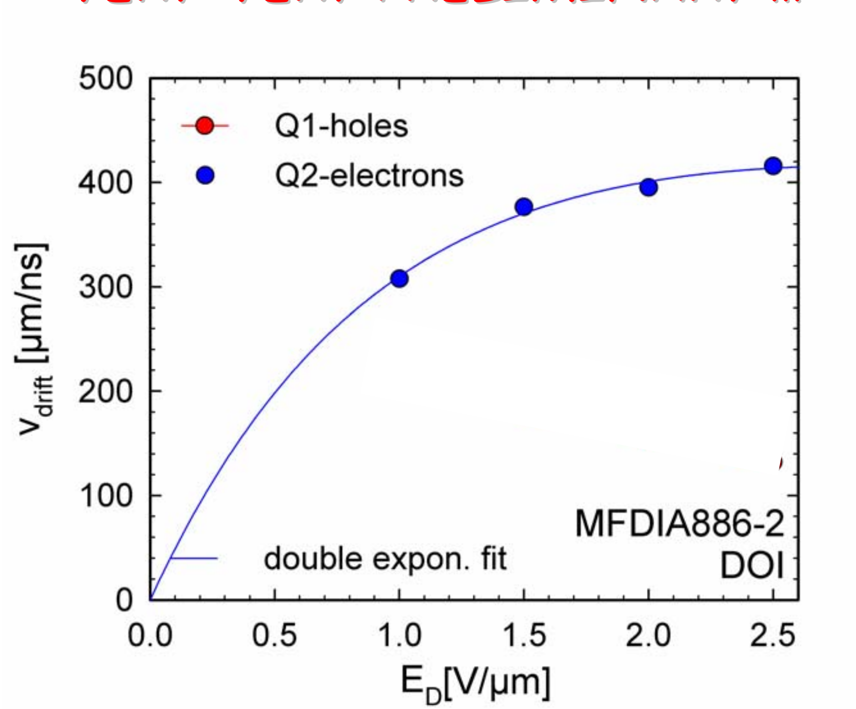


FWHM [ns] 1.04 0.85 0.81 0.77

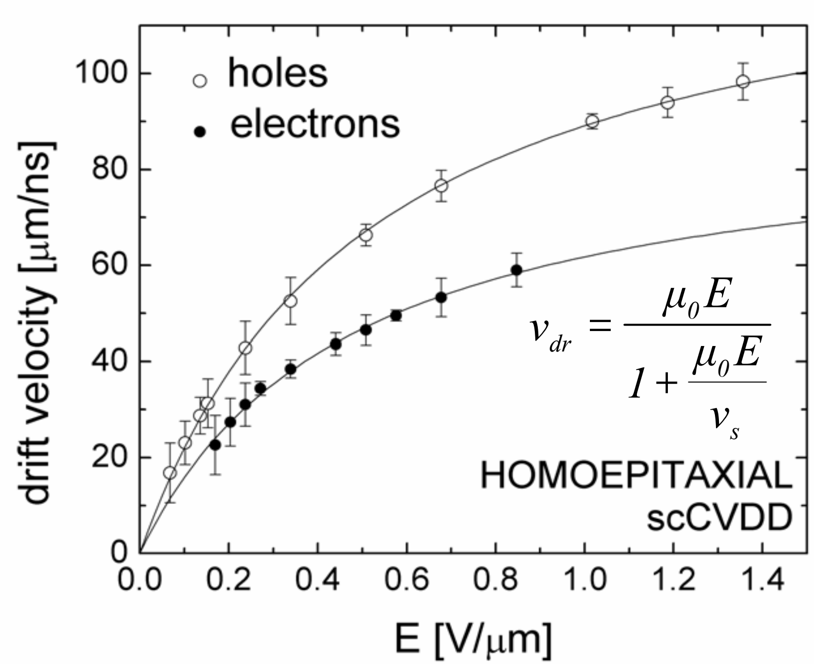
TRANSIENT CURRENT SIGNALS

TAKE TCT SIGNALS for SERIOUS and EXTRACT CHARGE DRIFT PARAMETERS

VERY-VERY PRELIMINARY !!!



M. Pomorski, PhD Thesis



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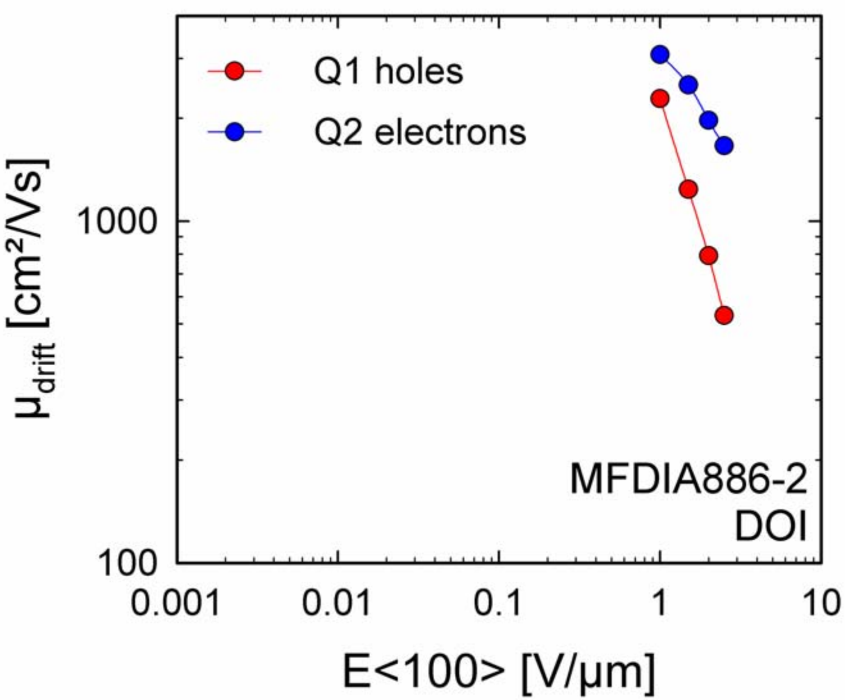
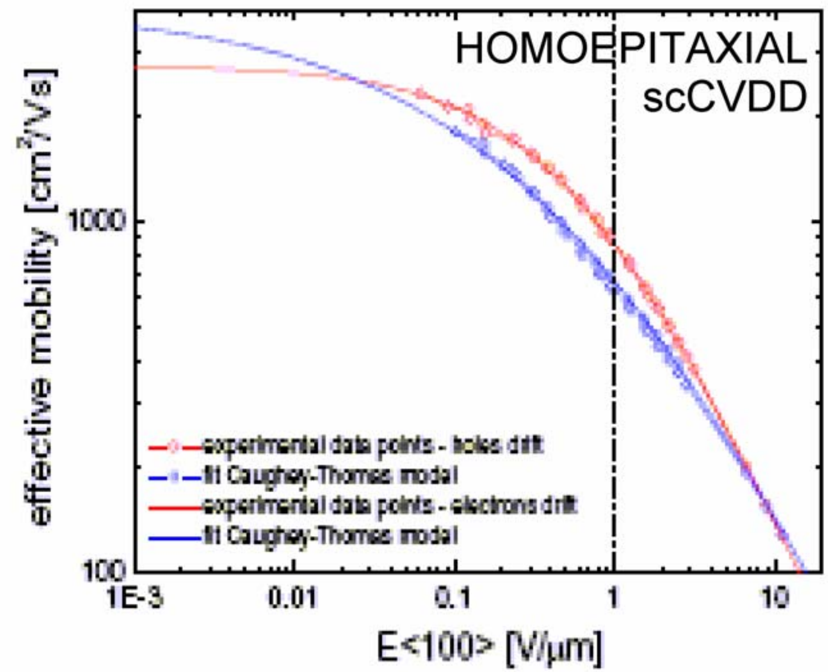
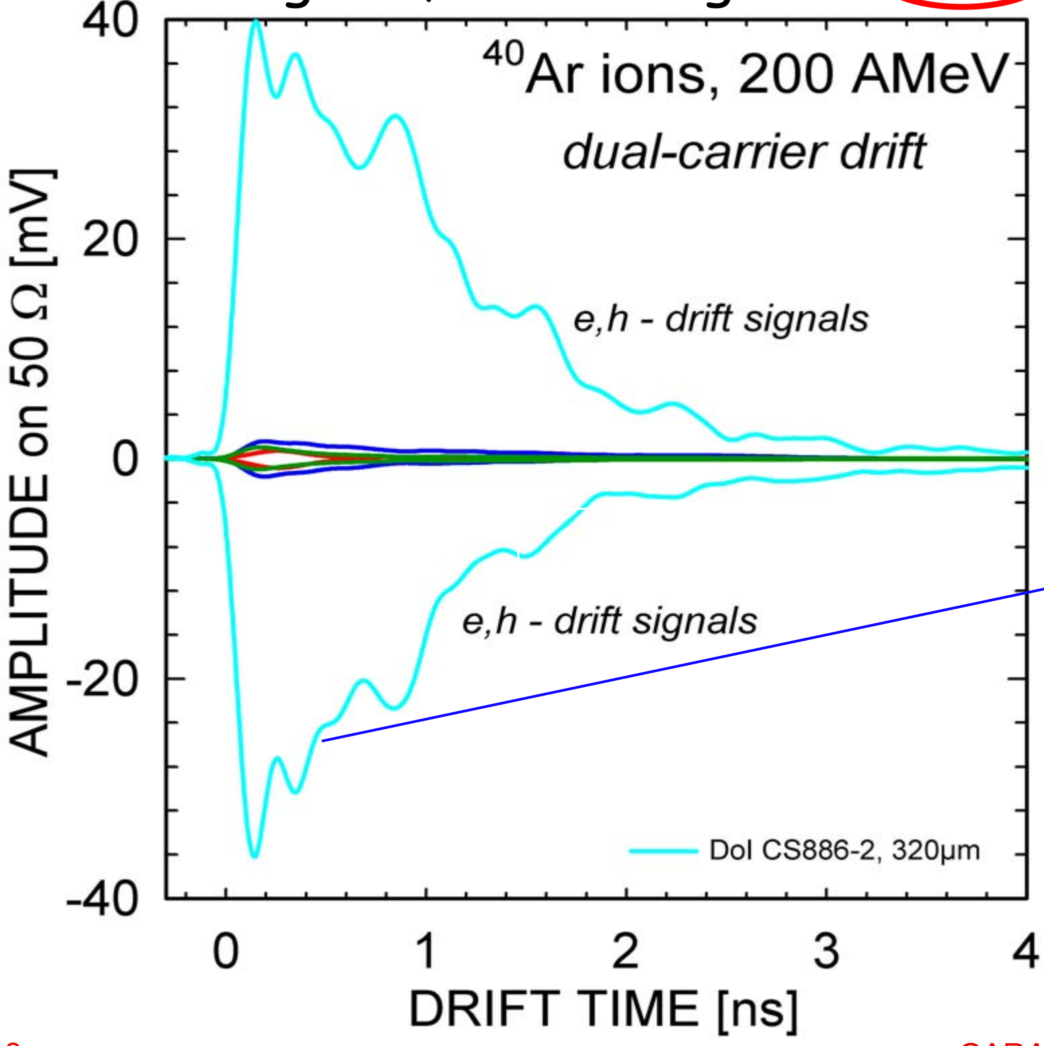


M. Pomorski PhD Thesis



TRANSIENT CURRENT SIGNALS

TC signals, traversing ions 2010



mixing of discrete life/drift times

?

NO !

imperfections

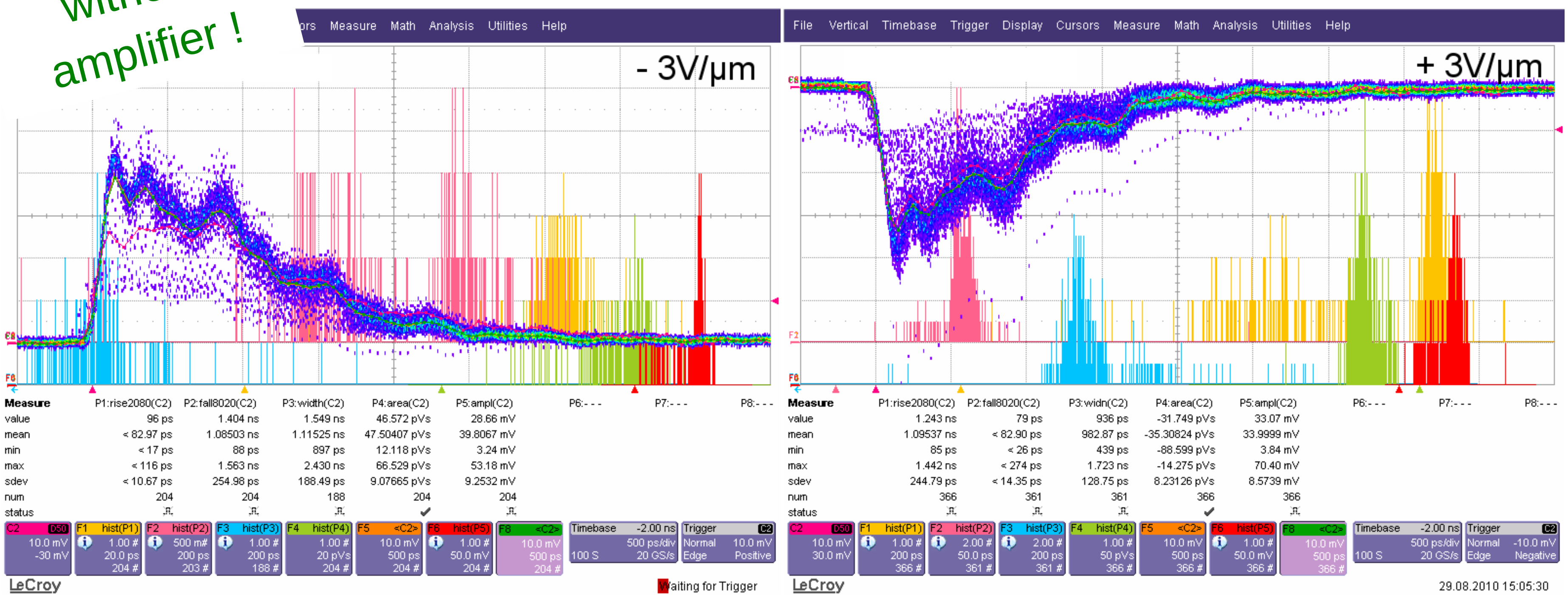
of the beam-test setup

TRANSIENT CURRENT SIGNALS

BEAM TESTwith ^{40}Ar, 200AMeV; 6MHz/spill=4s

ORIGINAL TC SIGNALS RECORDED by REMOTE CONTROLLED DSO, 6GHz BW, 20GS/s

without amplifier !



Fast uniform rise time; good S/N ratio ➔ expecting good $\sigma_i = \sigma_N / (dV/dt)$

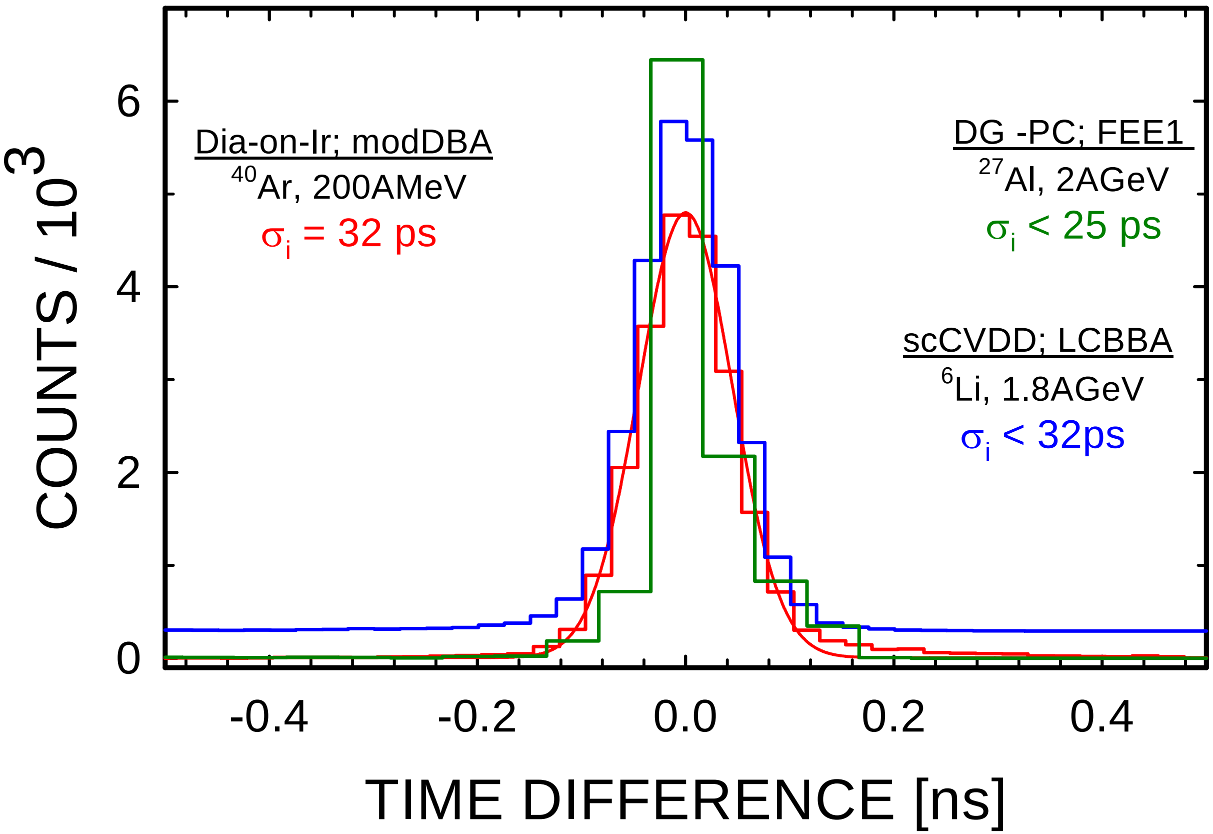
FWHM ~ 1.3 ns ➔ RateC = 700 MHz/detector channel

TIME RESOLUTION

BEAM TESTwith ^{40}Ar, 200AMeV; 6MHz/spill=4s

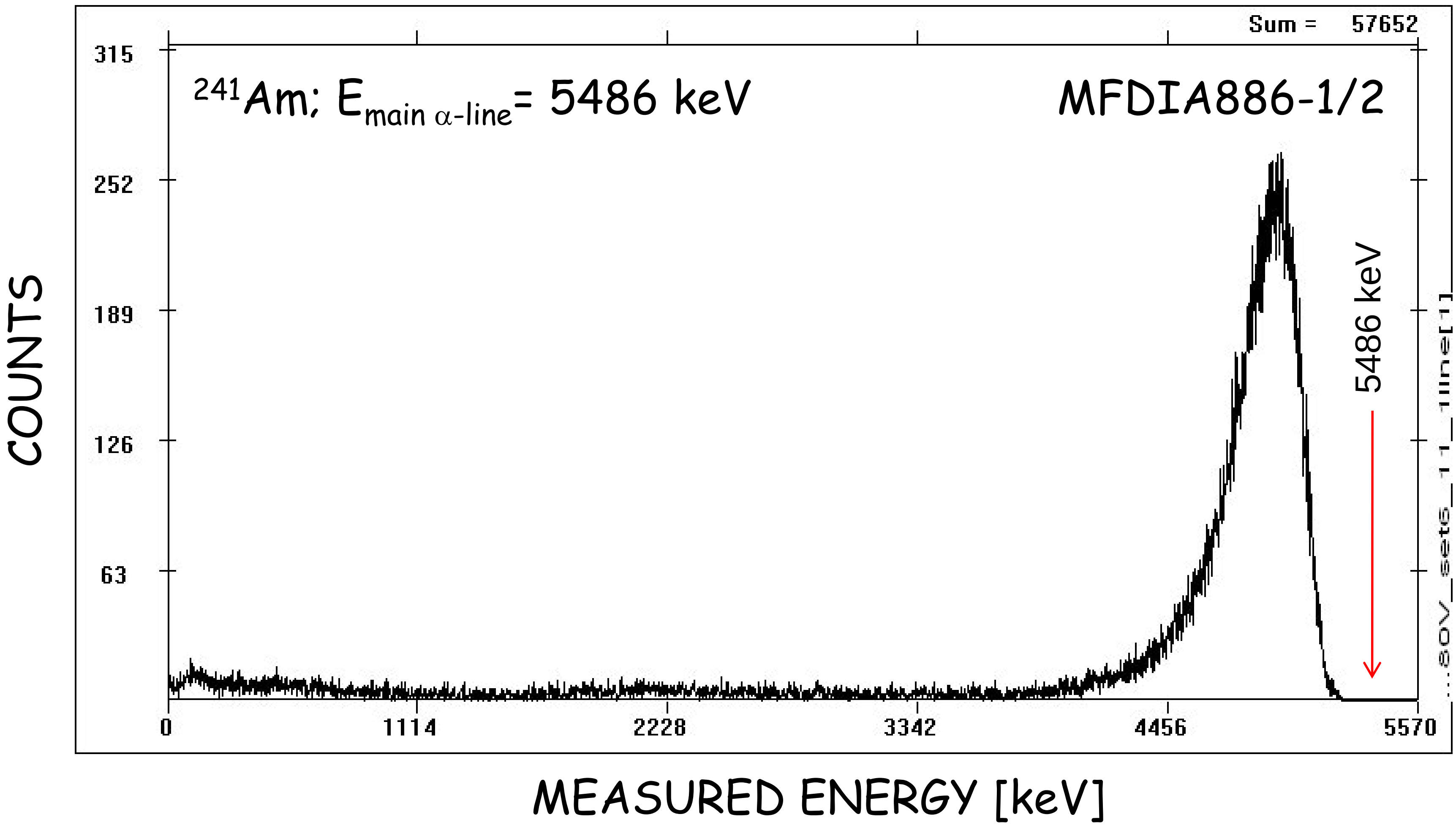
INTRINSIC TIME RESOLUTION of DoI SAMPLES
COMPARED TO sc- and pcCVDD detectors

non corrected for σ_N



CHARGE COLLECTION – CRYSTAL HOMOGENEITY

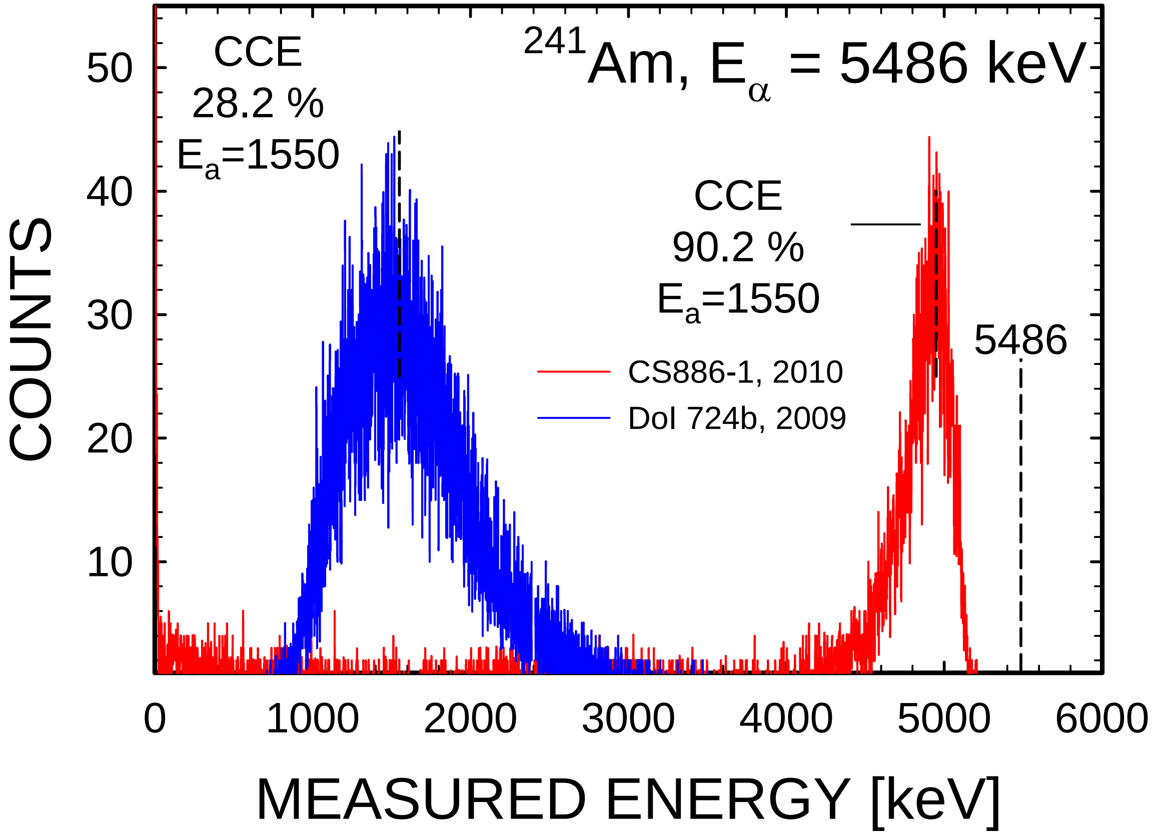
α – SPECTROSCOPY using CSTA2 preamps (U. Bonnes, TUD)



CHARGE COLLECTION - CRYSTAL HOMOGENEITY

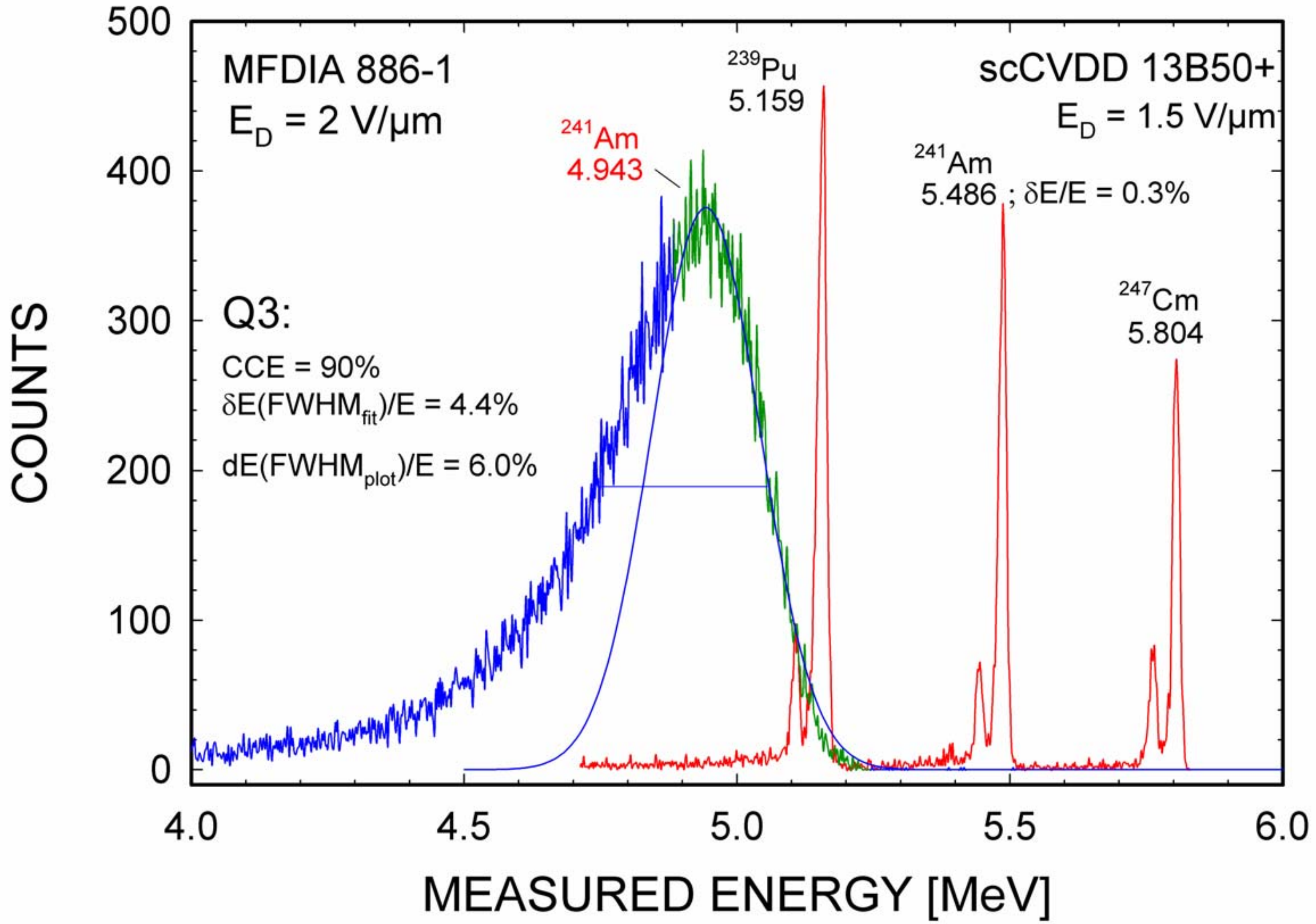
MFDia724b, d = 12μm (2009)

MFDia886-1, d= 290μm (2010)



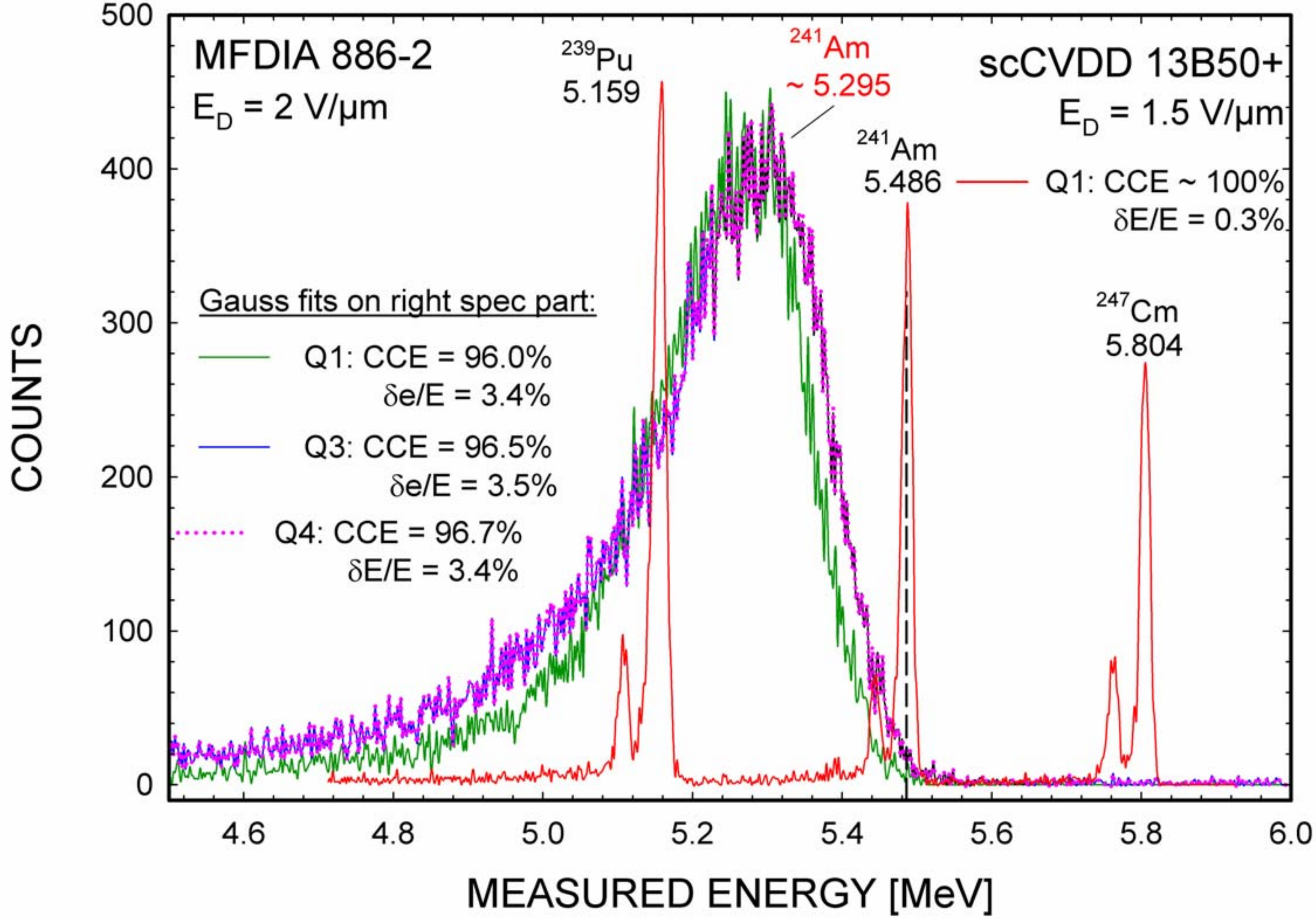
CHARGE COLLECTION – CRYSTAL HOMOGENEITY

MFDia886-1_Q1 (2010)



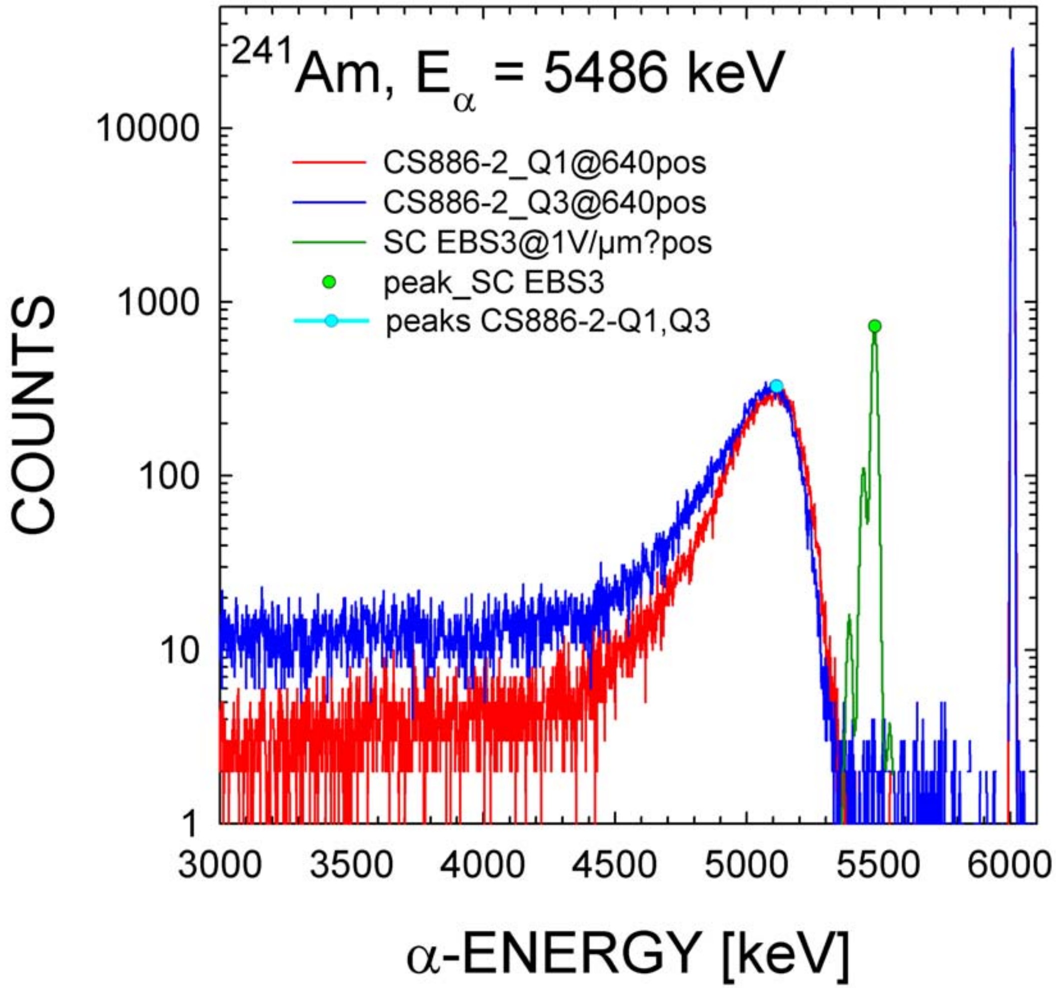
CHARGE COLLECTION - CRYSTAL HOMOGENEITY

MFDia886-2_Q1,Q3,Q4 (2010)



CHARGE COLLECTION - CRYSTAL HOMOGENEITY

MFDia886-2_Q1,Q3 (2010) comp. to a thick scCVDD (390μm)



SUMMARY AND PRELIMINARY CONCLUSIONS

- Low dark conductivity; order of 10^{-13} – 10^{-12} A
- 'Narrow' TCT signals of fast rt << 80 ps; 0.5 < FWHM < 2.4 ns

  corresponding to (preliminarily!!) very high v_{dr} values;

  e-v_{drmax} = 415 μm/ns and e-μ_{dr}(1V/μm) ~ 3080 cm^2/Vs (!!)
- CCE_α; ~ 90% - 97%
- Intrinsic time resolution; σ_i = 25 ps
- Energy resolution; $\delta E/E \approx$ 3 - 4%

CVD-DOI is a DEFECTIVE SINGLE CRYSTAL DIAMOND MATERIAL

THE SHORT CHARGE DRIFT COMBINED WITH A HIGH CCE

IS PRESENTLY NOT WELL UNDERSTOOD!!

DOI CHARACTERIZATION – NEXT STEPS

- Systematic analysis of TCT signals: FWHM vs. E_D
- $CCE(E_D)$ vs. T_{TR} (E_D) to estimate mean $\tau_{e,h}$
- NEW MEASUREMENTS applying/removing shortly HV

  (proposal Christoph Nebel)
- ....any other proposal is also welcome ......