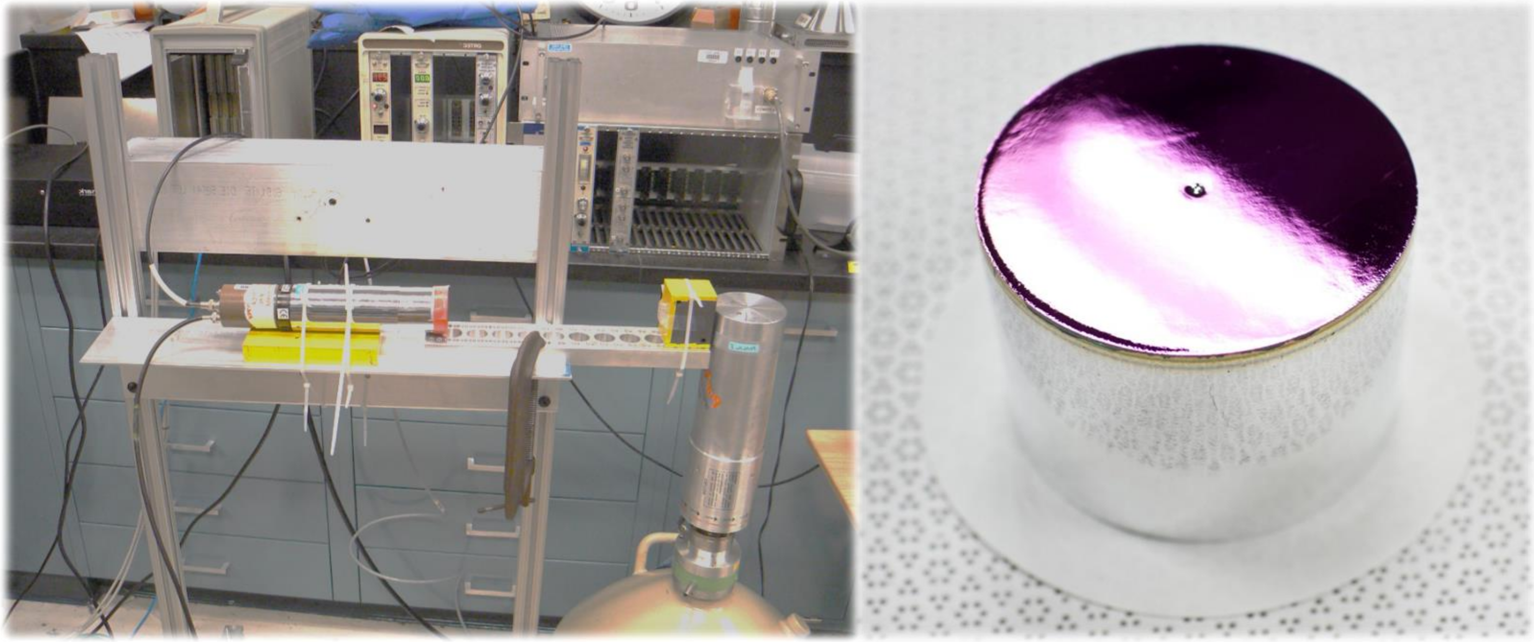
Pulse shape studies with ultra high purity point contact detectors



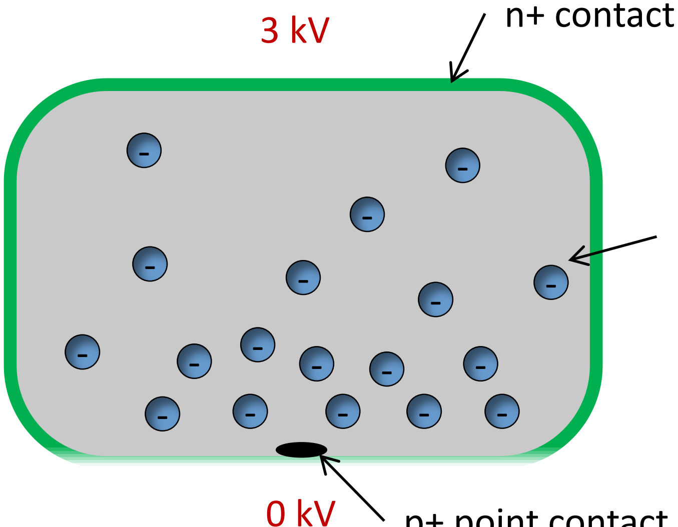
Alexander Hegai, Susanne Mertens, David Radford

for the Majorana Collaboration

Outline

- P-type Point Contact Detectors
- Ultra high purity crystals
- Impact on pulse shape parameters

P-type Point Contact Detector



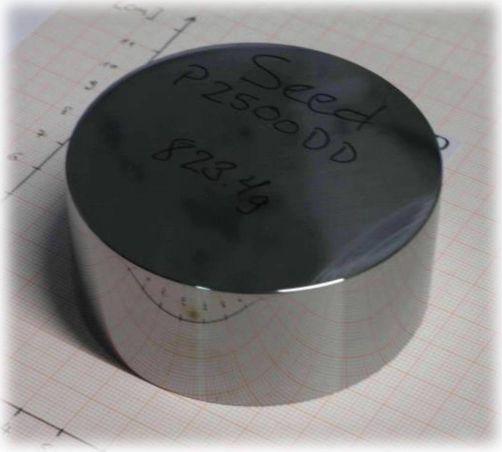
3 kV

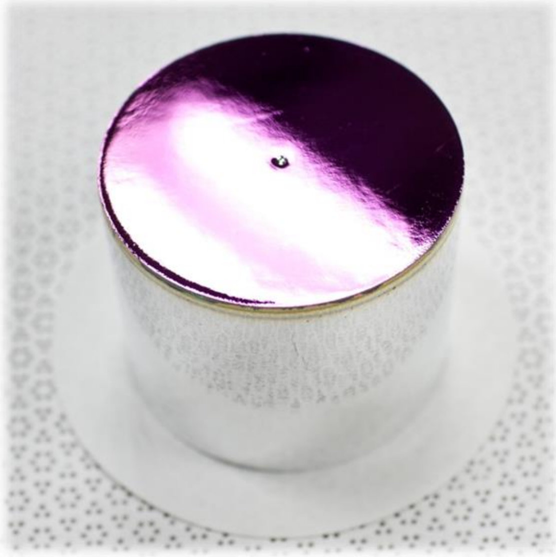
n+ contact Li diffused

p-type material

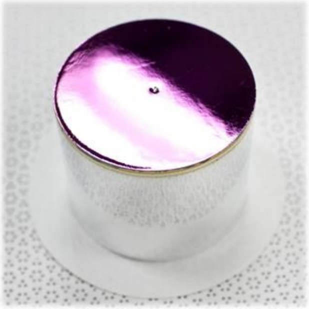
0 kV

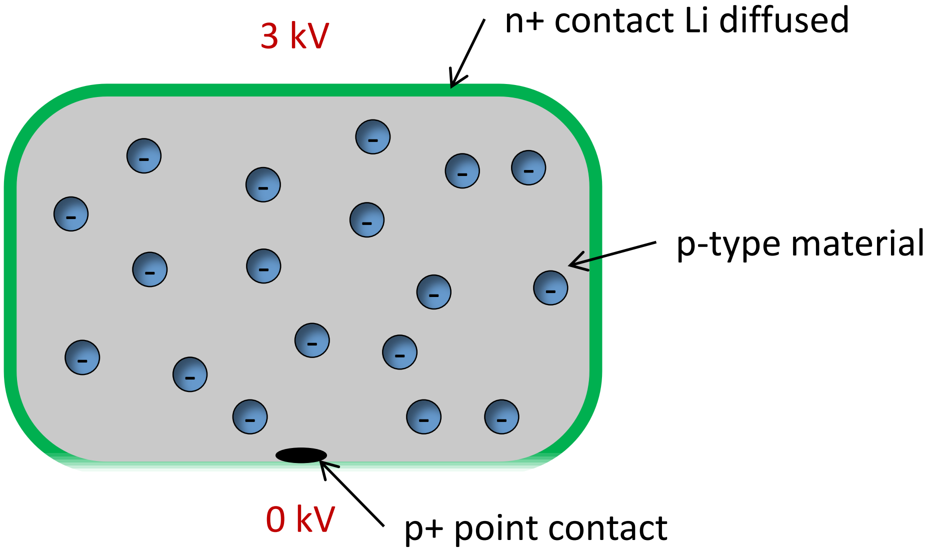
p+ point contact





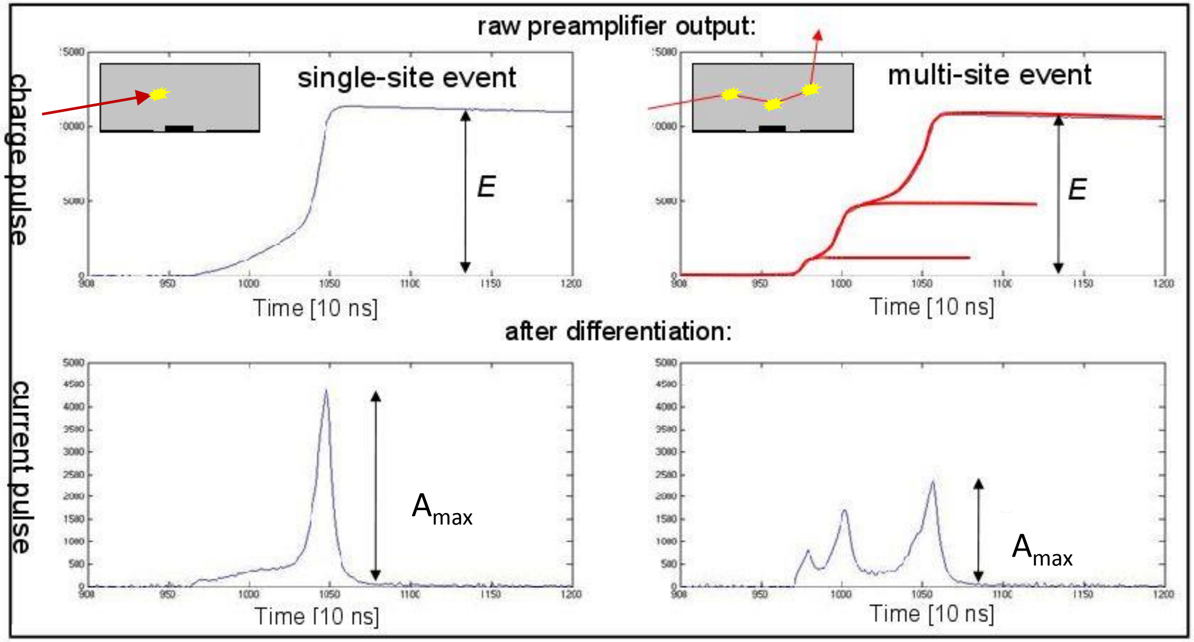
P-type Point Contact Detector

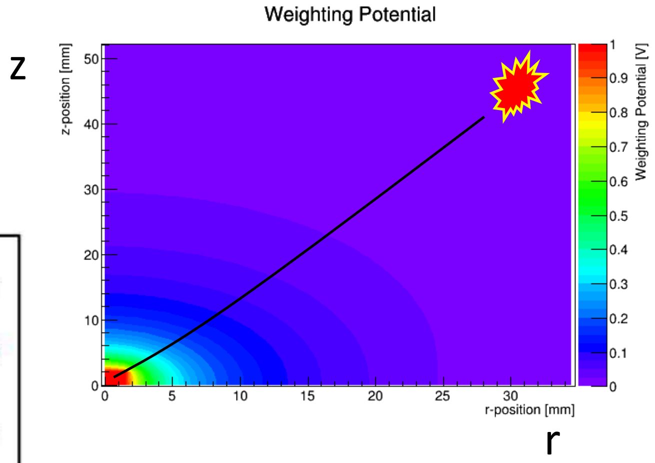




- 1 signal cable
  → less background
- Small p-contact
  → low capacitance
  → less noise
- Thick dead layer
  → less alpha and beta events

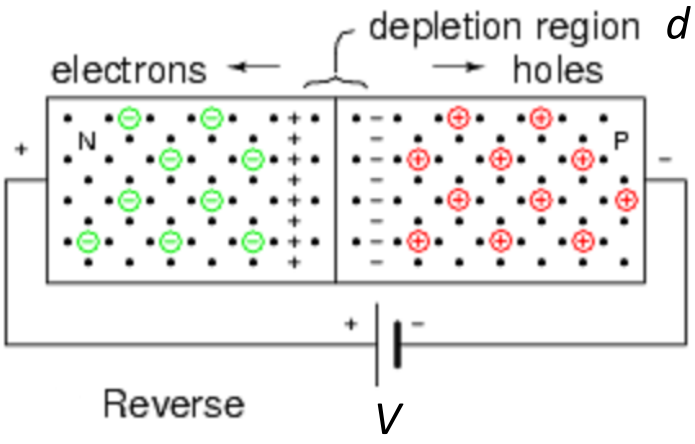
P-type Point Contact Detector





Easy and reliable distinction between singe- and multi-site events with A/E method

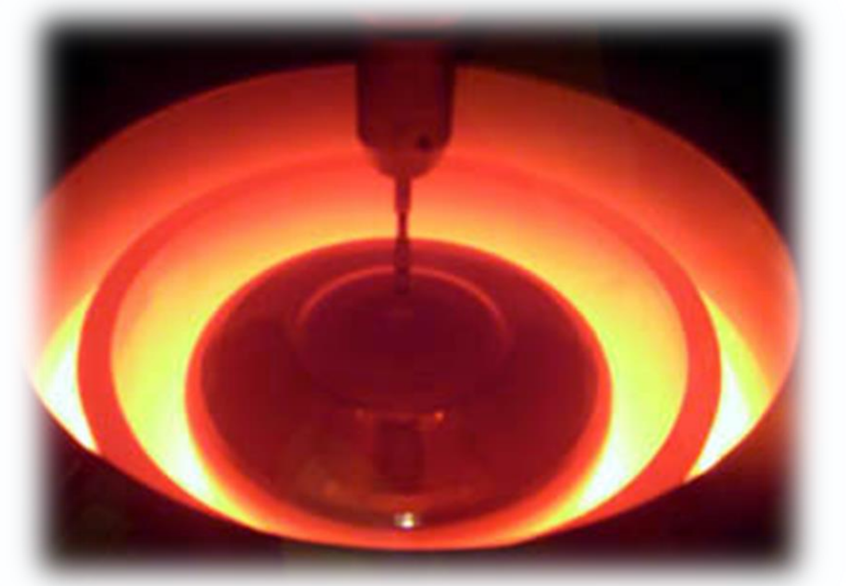
Advantages of high purity PPC



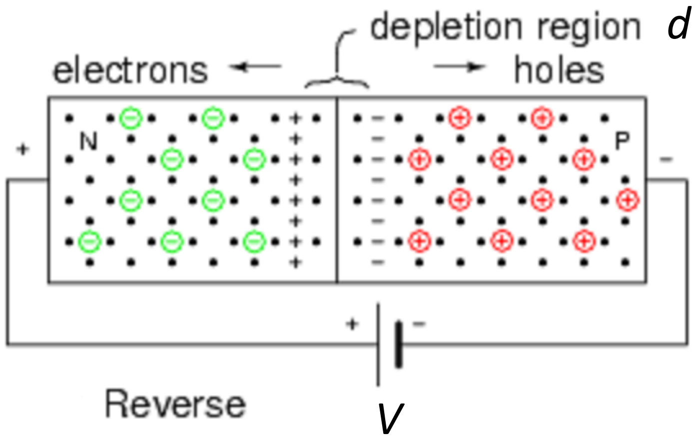
$$d \cong \left(\frac{2\epsilon V}{eN}\right)^{1/2}$$

→ $V \sim N$

N=*net impurity number*
ϵ =*dielectric constant*
e= elementary el. charge



Advantages of high purity PPC



$$d \cong \left(\frac{2\epsilon V}{eN}\right)^{1/2}$$

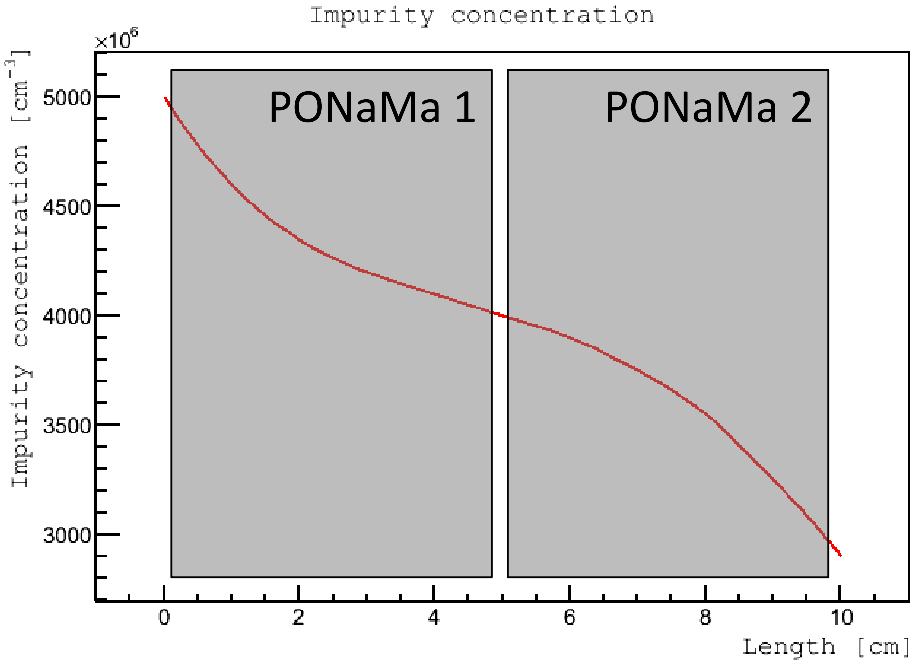
$\rightarrow V \sim N$

N=net impurity number
ϵ =*dielectric constant*
e= elementary el. charge

- Lower bias voltage
- Bigger detectors
- Smaller surface to volume ratio

PONaMa

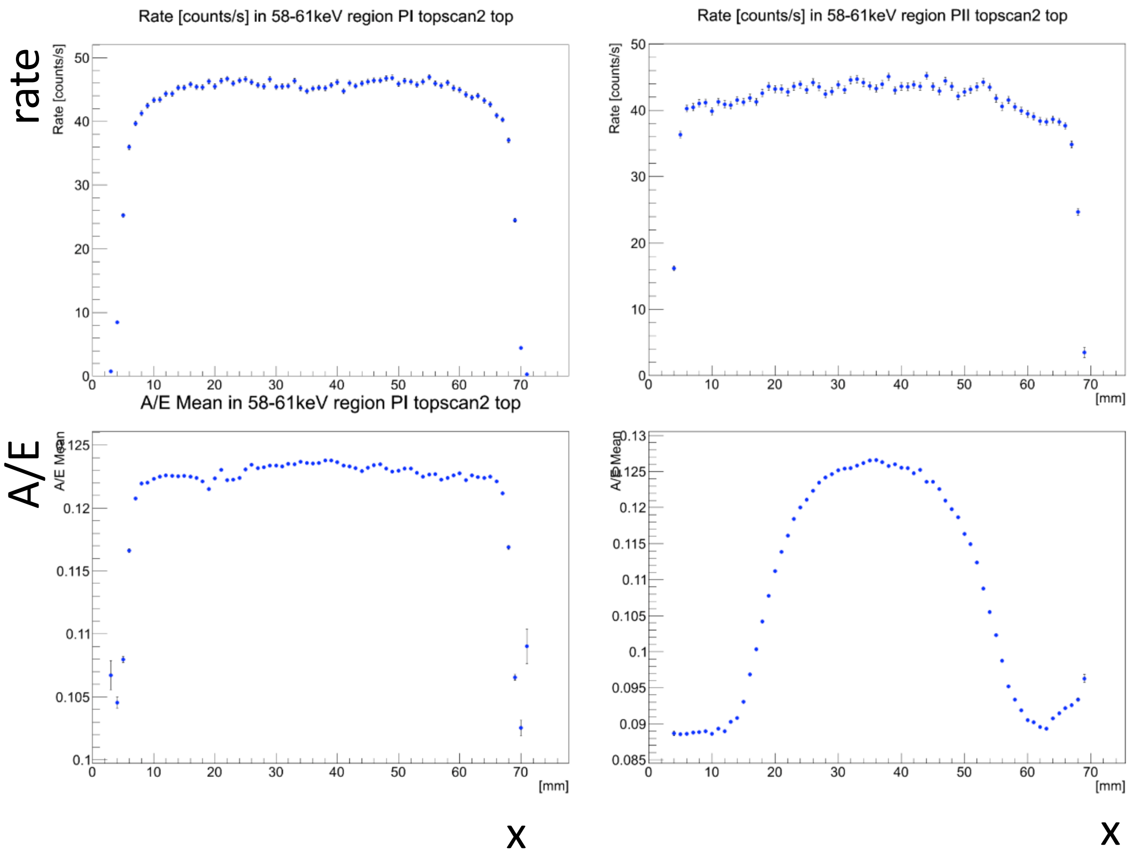
PPC from **O**RTEC made from **Na**tural **Ma**terial



PONaMa radial scan

PONoMa I

PONoMa II

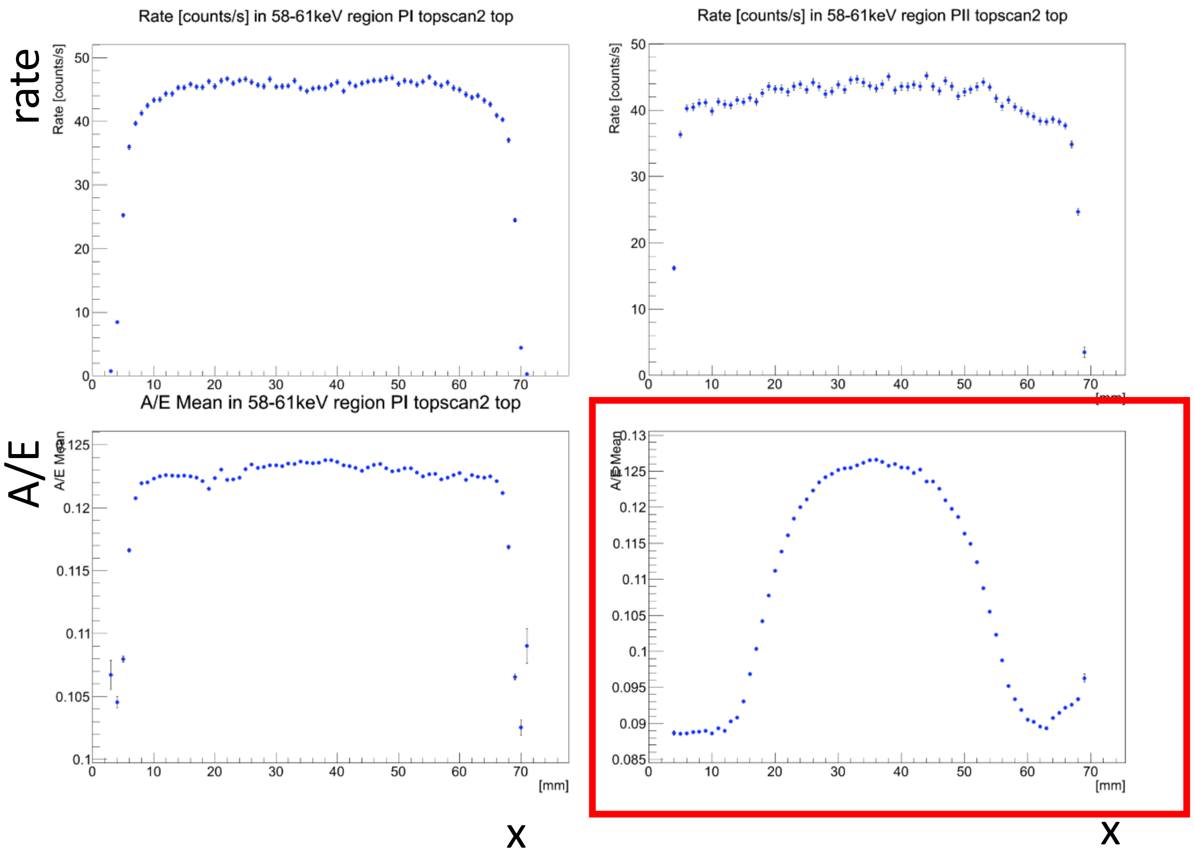


- ^{241}Am source 59.5 keV
- 1mm steps

PONaMa radial scan

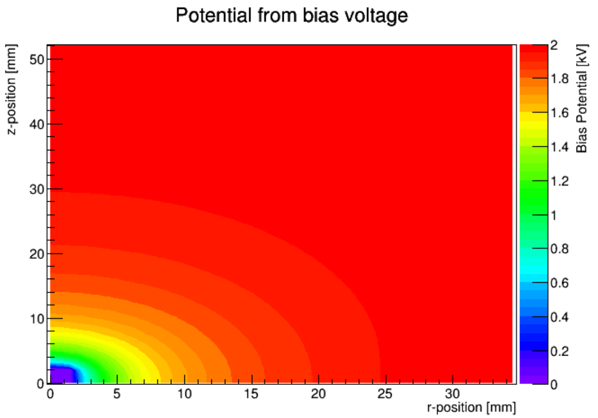
PONoMa I

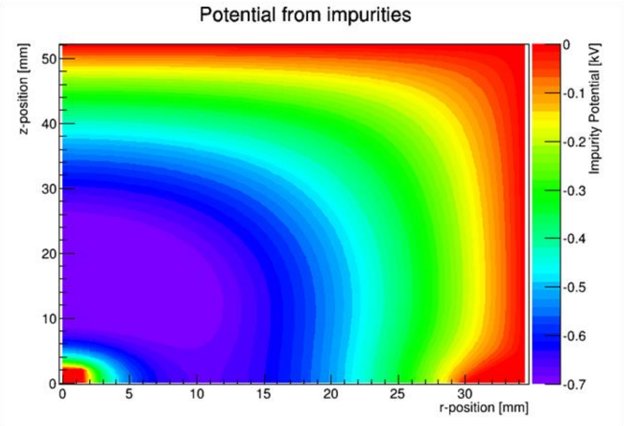
PONoMa II

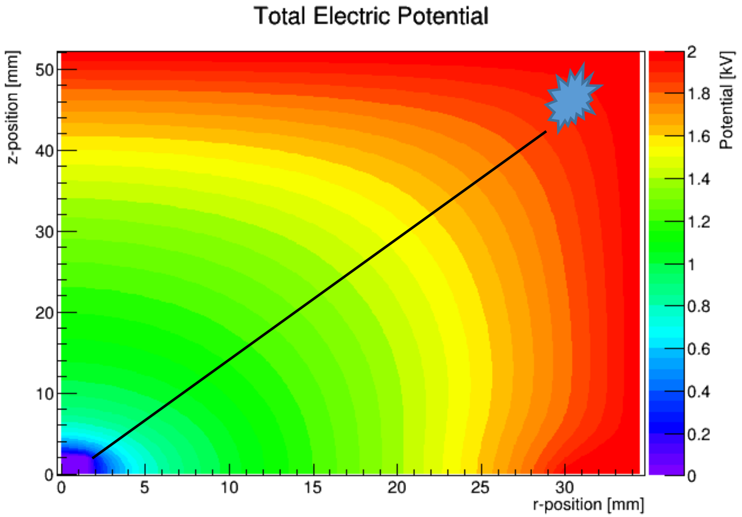


- ^{241}Am source 59.5 keV
- 1mm steps

PONaMa I electric field


Potential from bias voltage

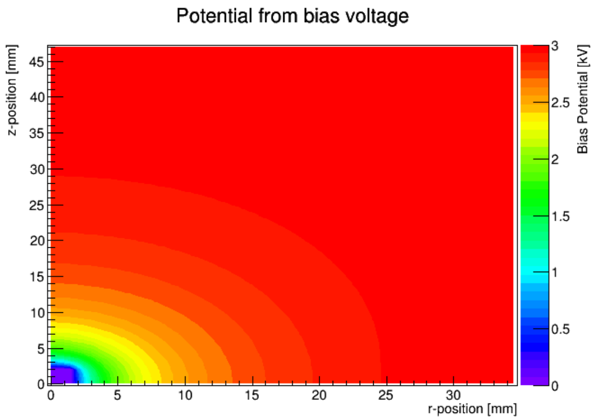

Potential from impurities

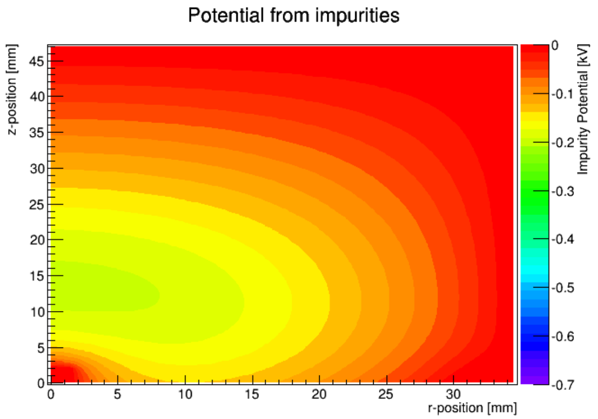

Total Electric Potential

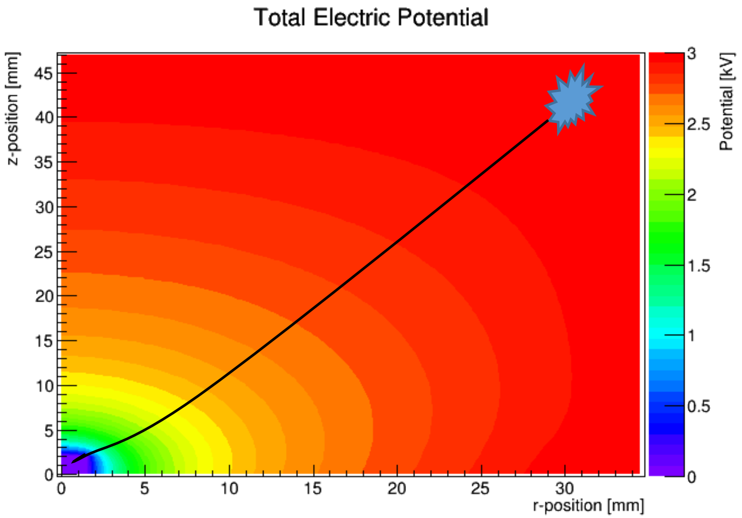
- Impurity gradient predominant for the field gradient in the corners

→ Responsible for the transport of the charge cloud towards the point contact

PONaMa II electric field





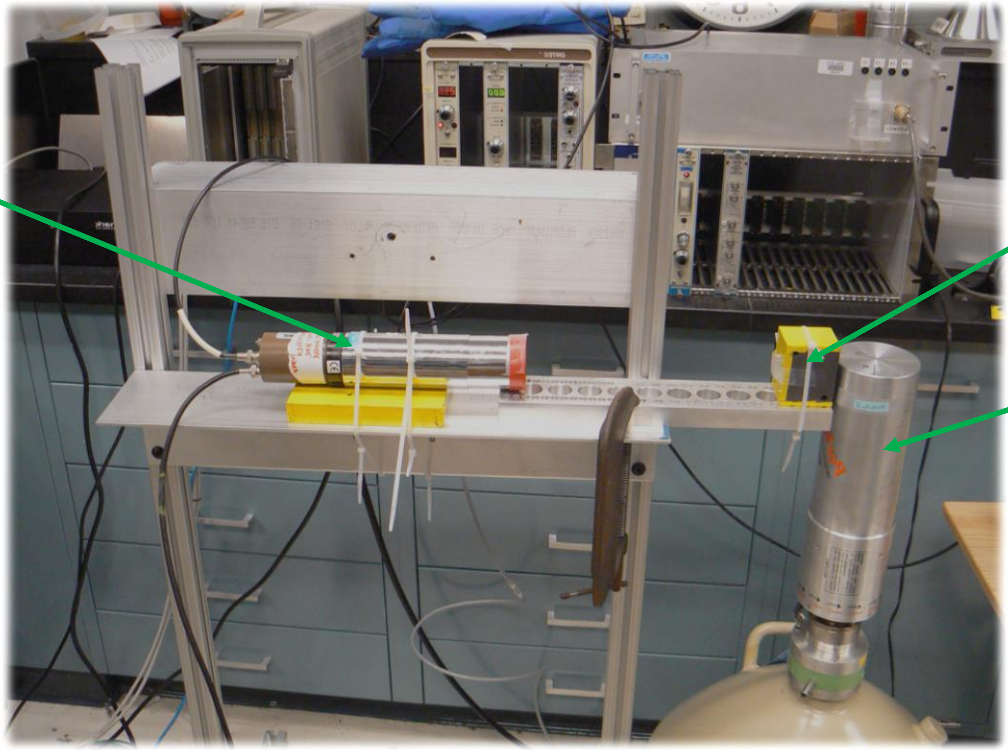


- Low impurity gradient leads to small drift in the corners

→ smaller maximum current at point contact

→ degraded A/E parameter (hypothesis)

Drift time measurements

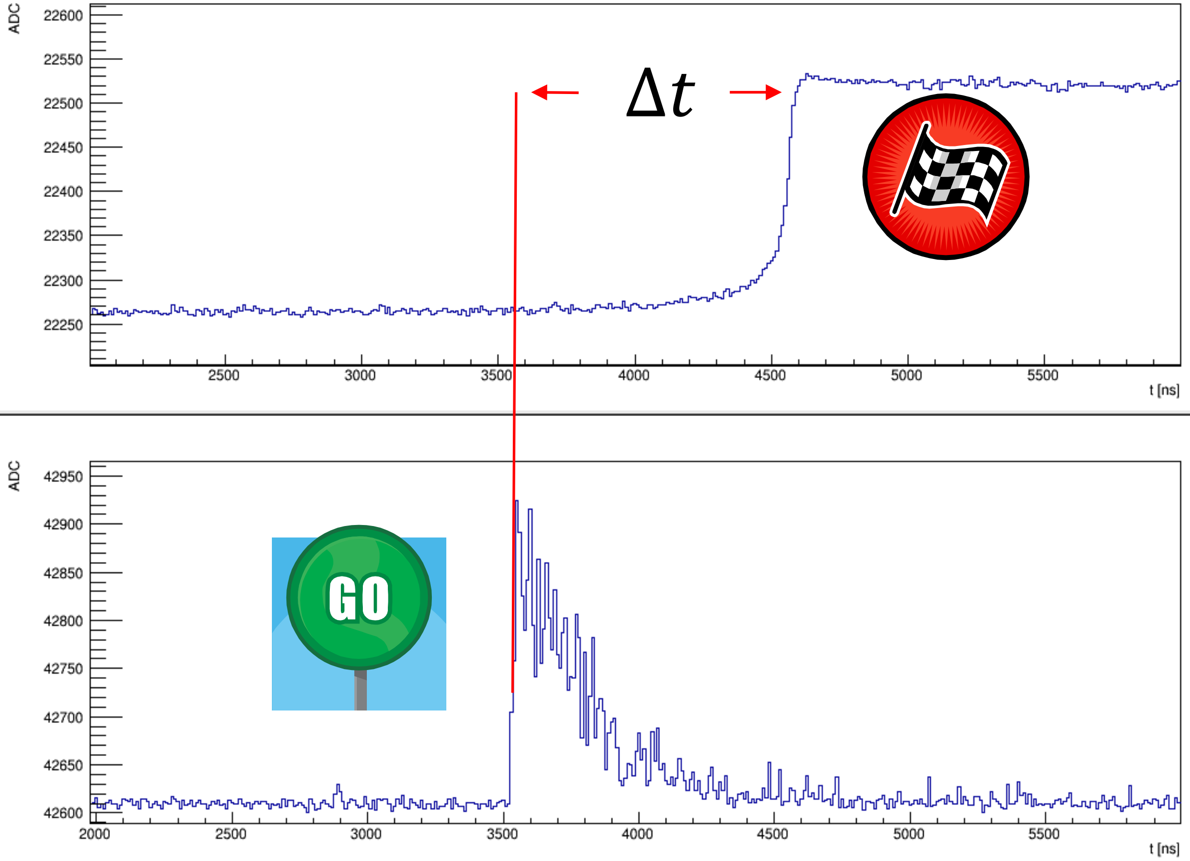


NaI+PMT

collimated ^{22}Na-source

PONaMa

Drift time measurements

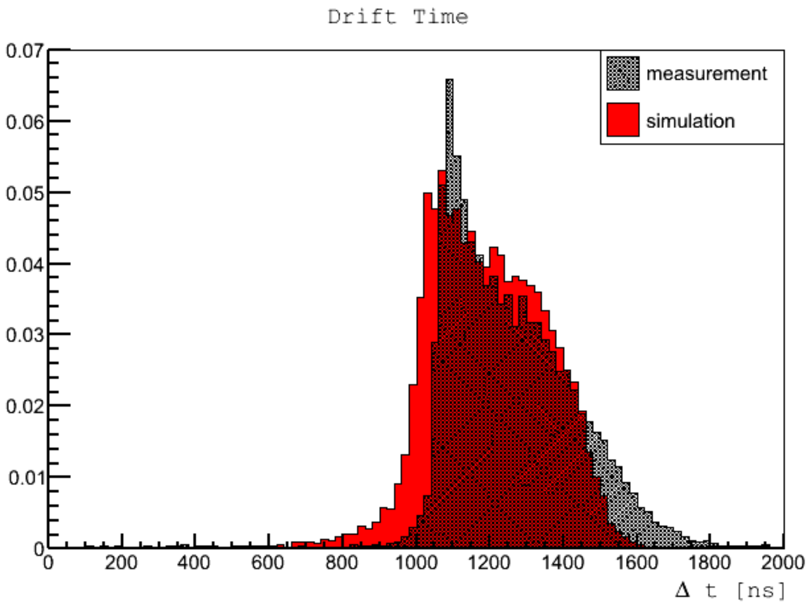


PONoMa

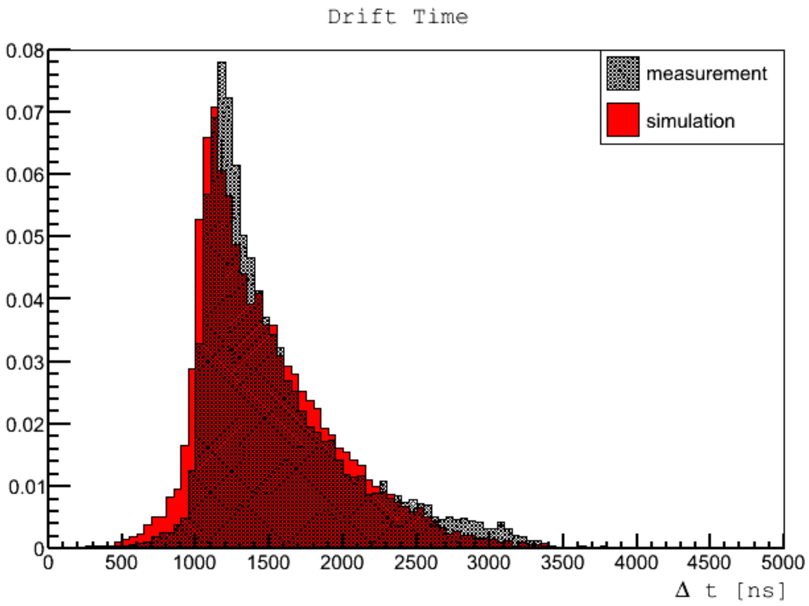
NaI+PMT

Drift time

PONoMa I

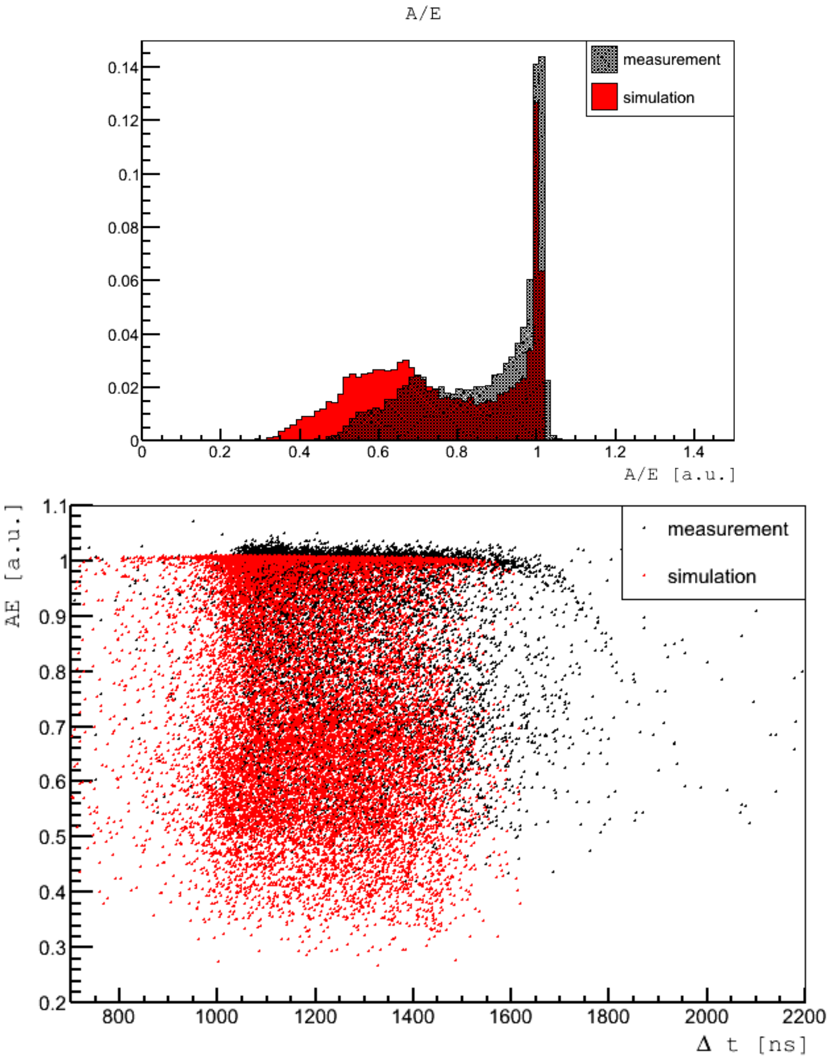


PONoMa II

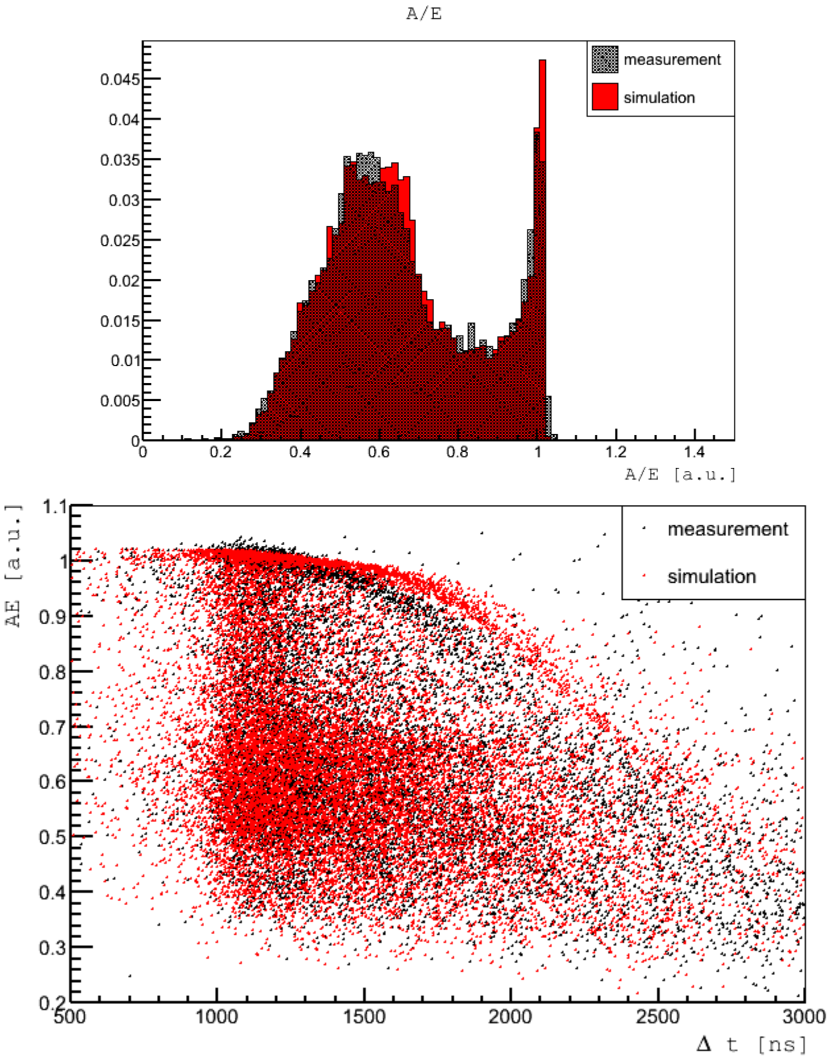


A/E vs drift time

PONoMa I



PONoMa II

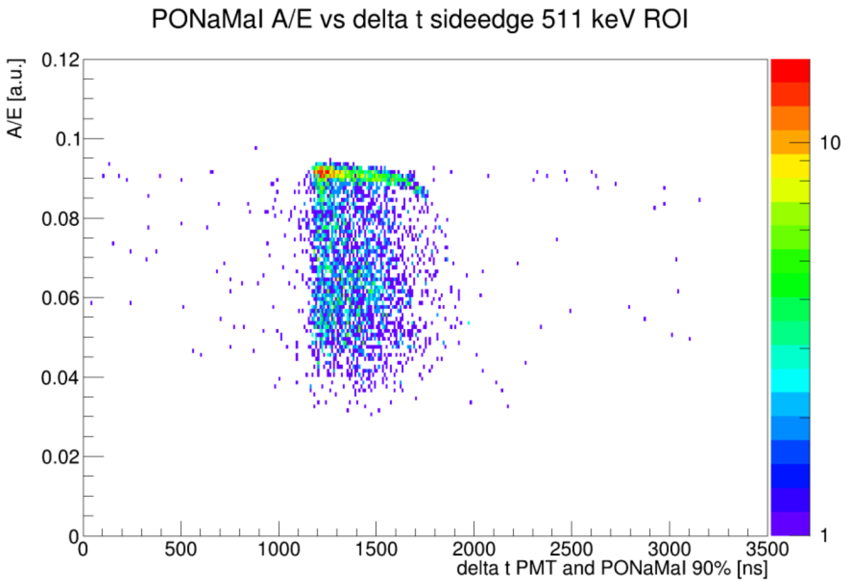


Conclusion

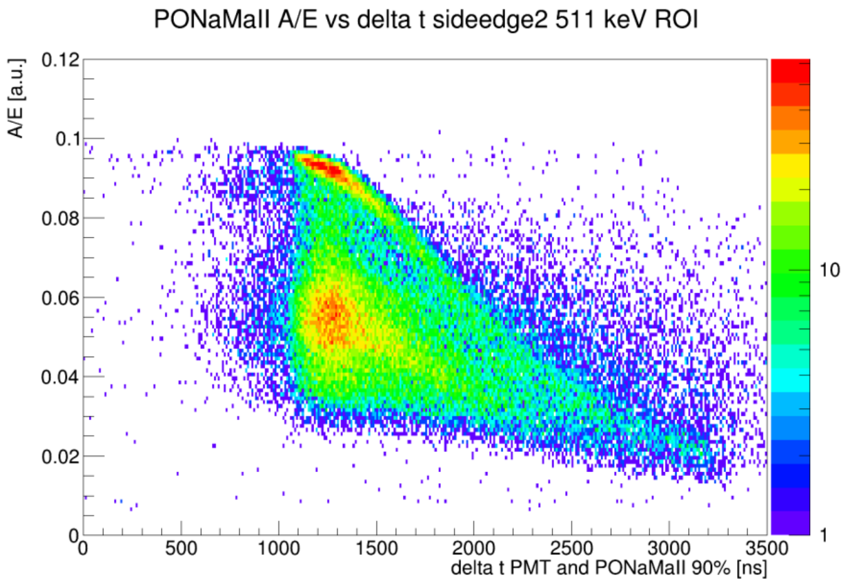
- PPC detectors allow an easy and robust single- vs multi-site discrimination
- Ultra high purity crystals are needed to produce large detectors with an acceptable bias voltage
- An impurity gradient that is too shallow leads to pulse shape discrimination degradation

backup

PONoMa I



PONoMa II



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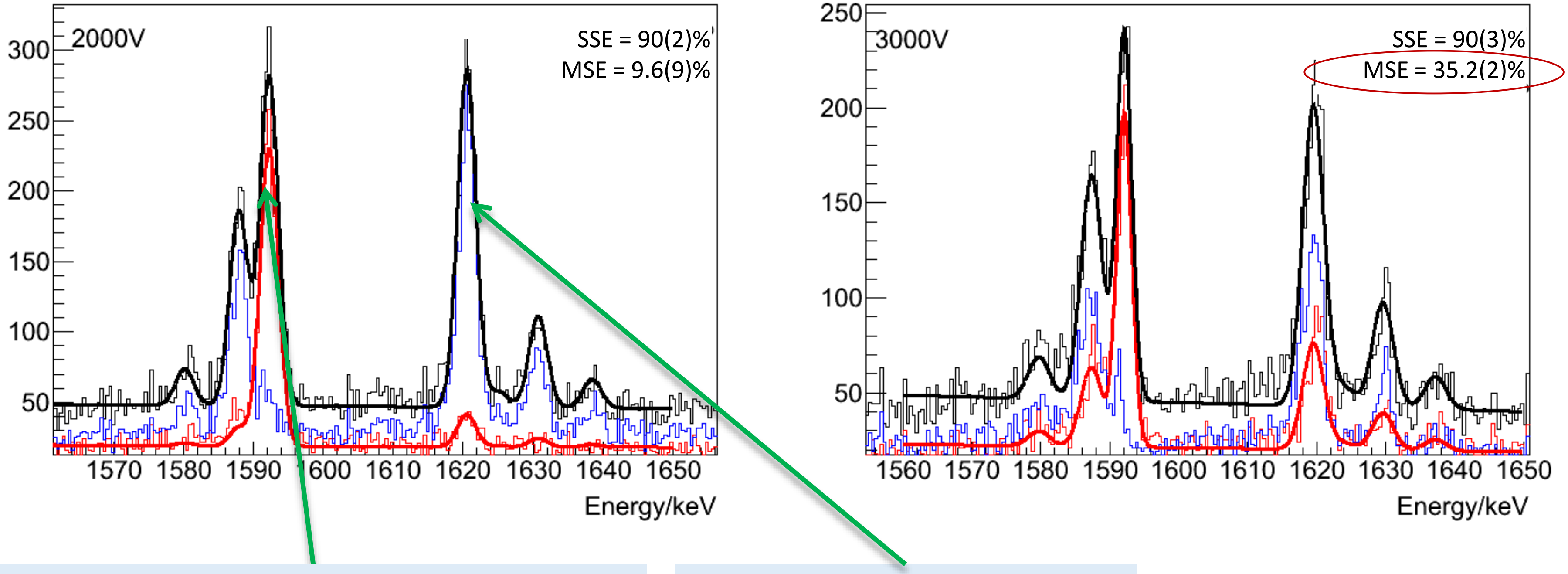
PSD performance based on A/E cut

PONoMa I

PONoMa II



Single-site event:
(Double escape peak of Thallium)

Multi-site events:
(Actinium)

backup

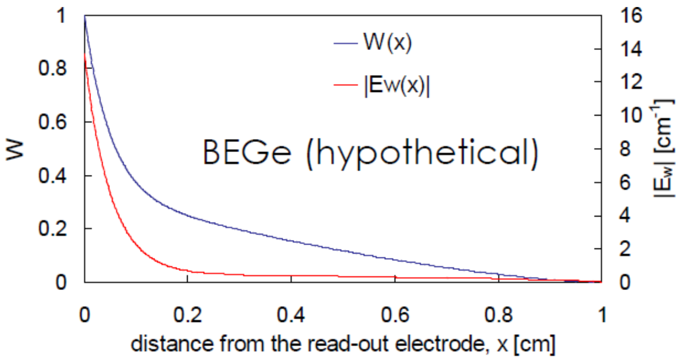
Pulse formation

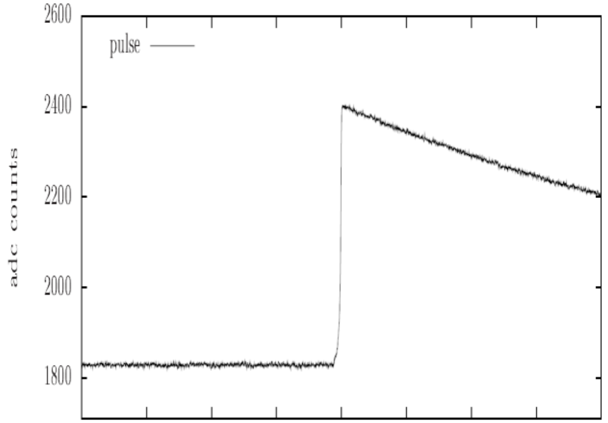
- Shockely-Ramo theorem: The induced charge Q on the read-out electrode is given by:

$$Q = -q * W(\vec{r})$$

$W(\vec{r})$ is the weighing potential of the charge q at the position $\vec{r}$, it represents the electrostatic coupling between the charge q and the read-out electrode

- The signal is the sum of the induced charge by the holes and electrons





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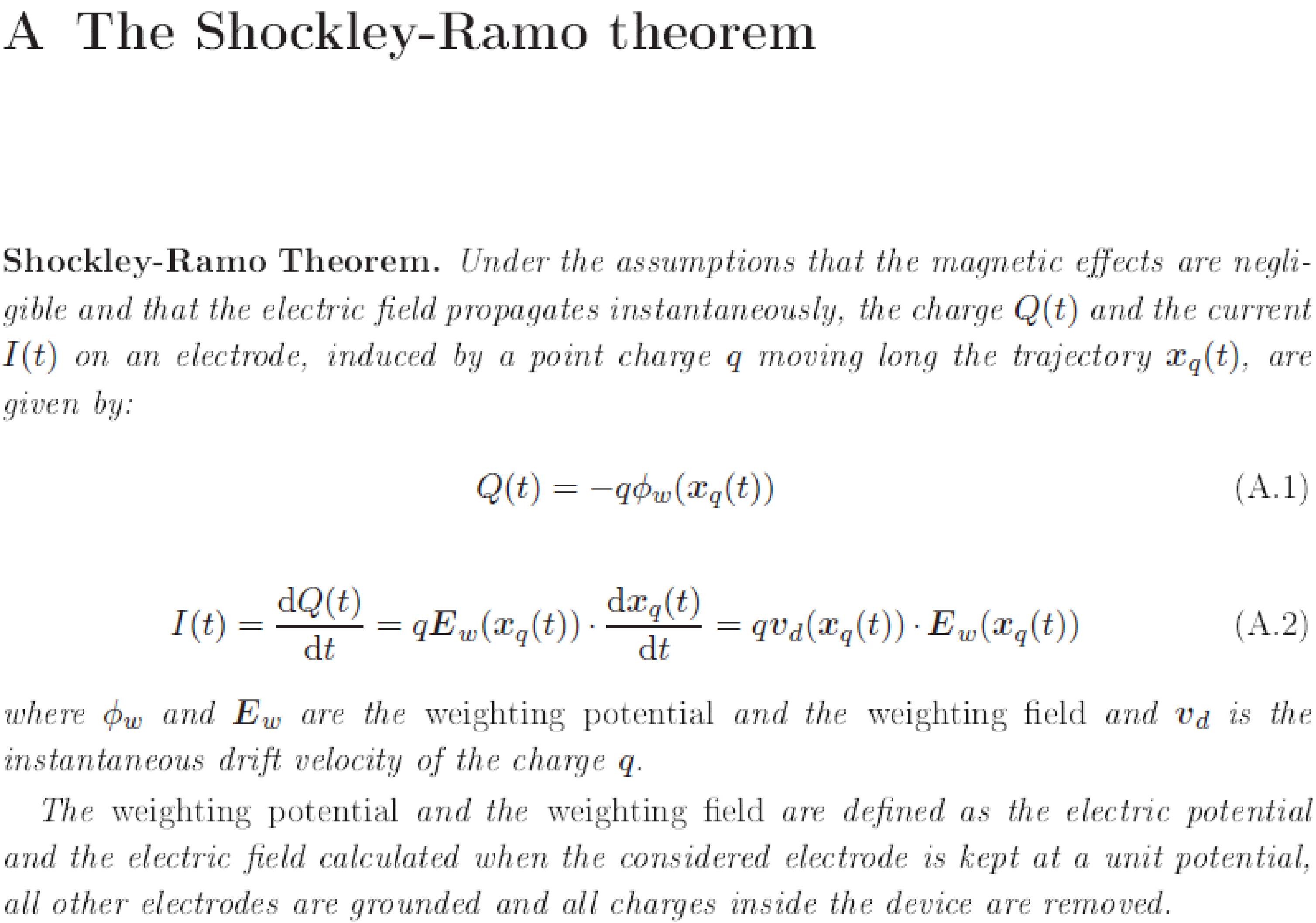

A The Shockley-Ramo theorem

Shockley-Ramo Theorem. *Under the assumptions that the magnetic effects are negligible and that the electric field propagates instantaneously, the charge* $Q(t)$ *and the current* $\boldsymbol{I}(t)$ *on an electrode, induced by a point charge* $\boldsymbol{q}$ *moving long the trajectory* $\boldsymbol{x}_q(t)$, *are given by:*

$$Q(t) = -q\phi_w(\boldsymbol{x}_q(t)) \tag{A.1}$$

$$\boldsymbol{I}(t) = \frac{\mathrm{d}Q(t)}{\mathrm{d}t} = q\boldsymbol{E}_w(\boldsymbol{x}_q(t)) \cdot \frac{\mathrm{d}\boldsymbol{x}_q(t)}{\mathrm{d}t} = q\boldsymbol{v}_d(\boldsymbol{x}_q(t)) \cdot \boldsymbol{E}_w(\boldsymbol{x}_q(t)) \tag{A.2}$$

where ϕ_w *and* $\boldsymbol{E}_w$ *are the* weighting potential *and the* weighting field *and* $\boldsymbol{v}_d$ *is the instantaneous drift velocity of the charge* $\boldsymbol{q}$.

The weighting potential *and the* weighting field *are defined as the electric potential and the electric field calculated when the considered electrode is kept at a unit potential, all other electrodes are grounded and all charges inside the device are removed.*