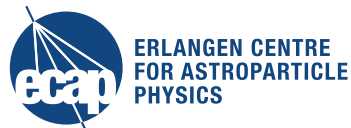


# Development of solid xenon detectors for low-background experiments

ERLANGEN CENTRE  
FOR ASTROPARTICLE  
PHYSICS

**Michael Wagenpfeil**, M. Filipenko, T.  
Gleixner, J. Yoo, G. Anton, T. Michel  
TIPP June 4th 2014

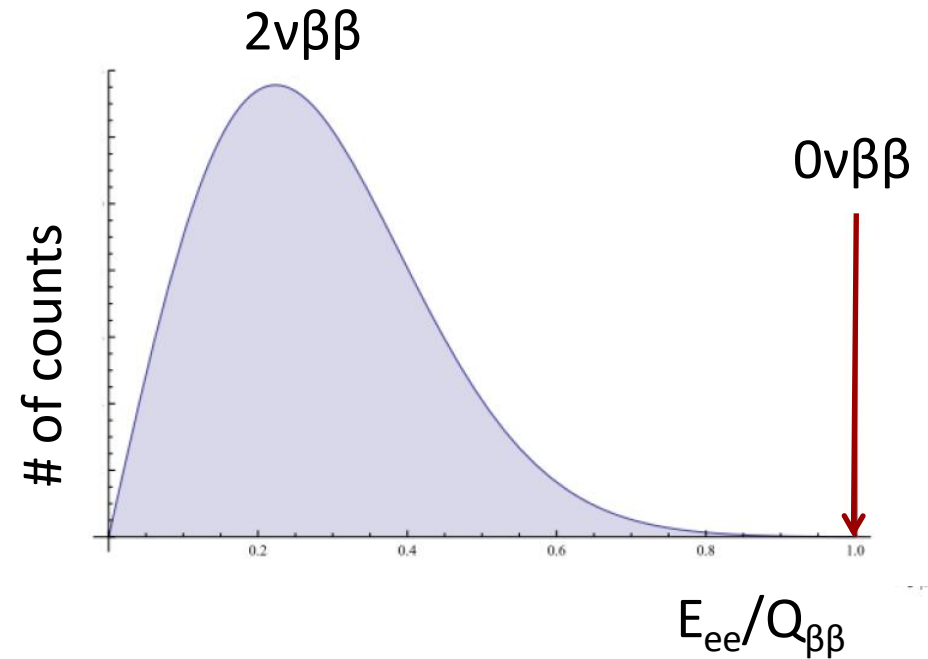
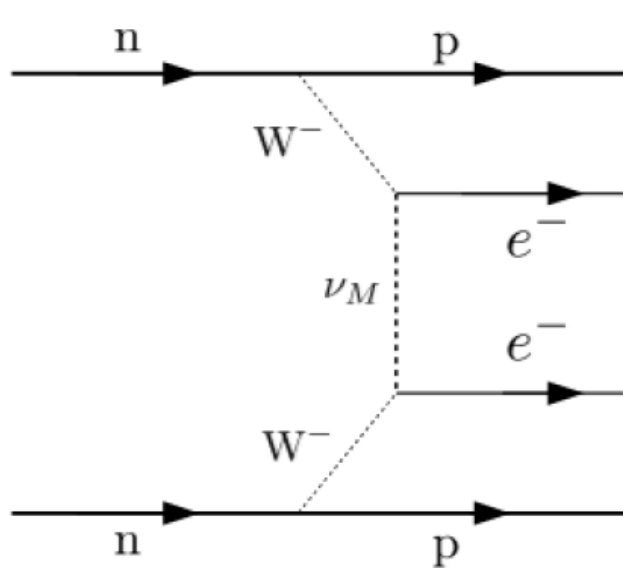
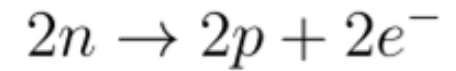


# Outline

- Motivation: Neutrinoless double beta decay
- Particle tracking in pixelated semiconductor detectors
- Solid xenon detector - concept
- Outlook

# Motivation

Neutrinoless double beta decay ( $0\nu\beta\beta$ )



$$T_{0\nu} > 2 \cdot 10^{25} a$$

# Motivation

## Neutrinoless double beta decay ( $0\nu\beta\beta$ )

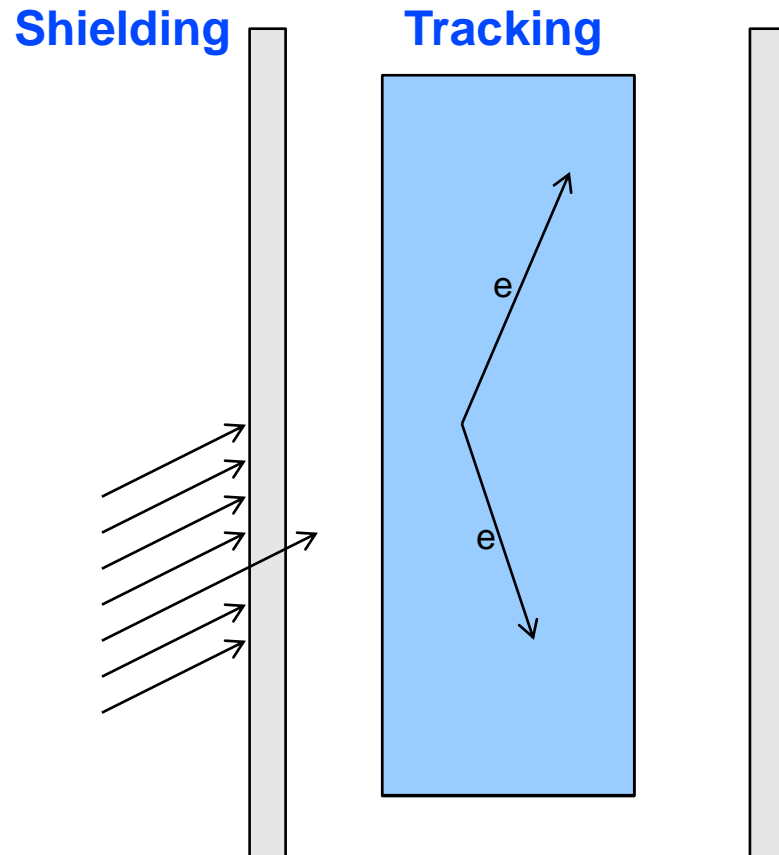
### Consequences:

- The Neutrino (a Lepton!) is a Majorana particle (Physics beyond SM)
- Measurement of the effective neutrino mass

$T_{0\nu} > 2 \cdot 10^{25} a$      $\rightarrow$  Major problem: background suppression

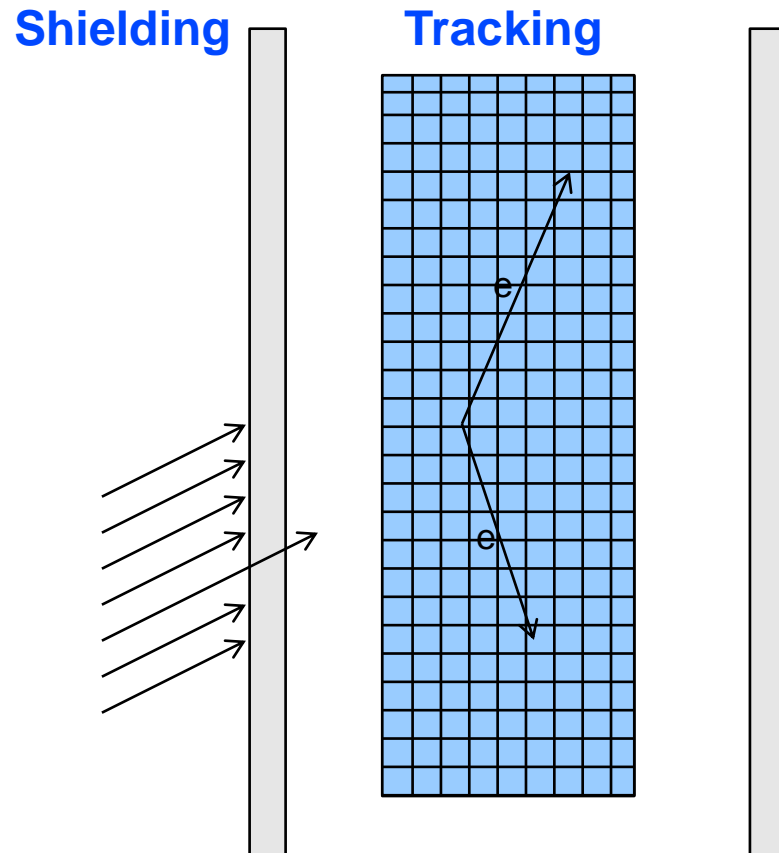
# Tracking

What is the principle?



# Tracking

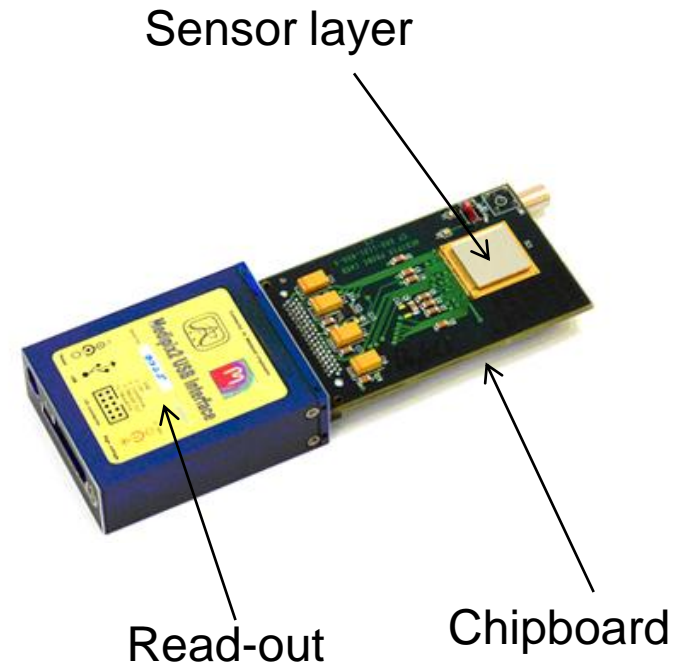
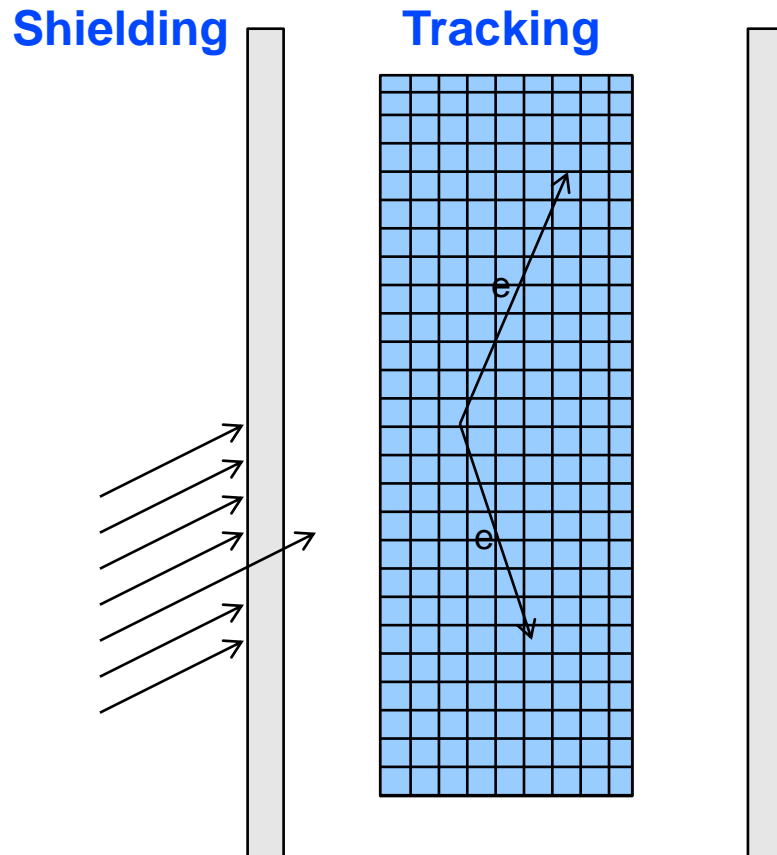
What is the principle?



Decay material = Sensor material

# Tracking

What is the principle?

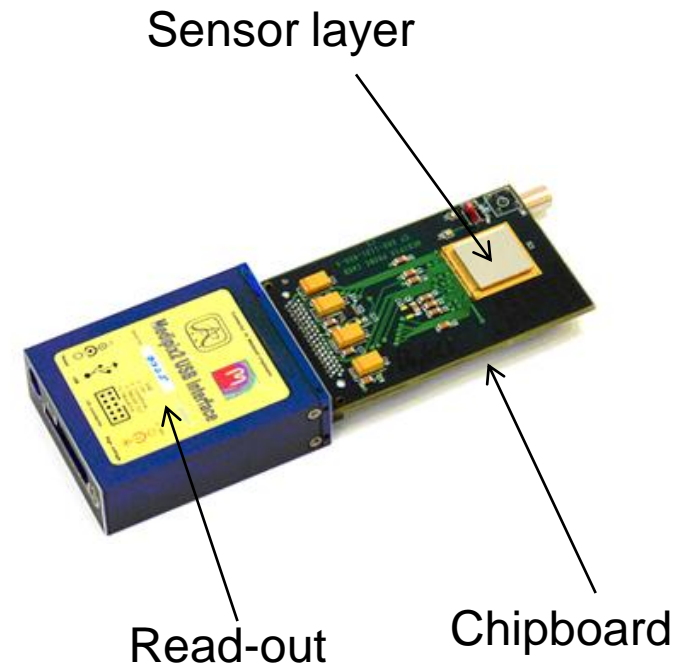


Decay material = Sensor material

# Tracking

## The Timepix detector

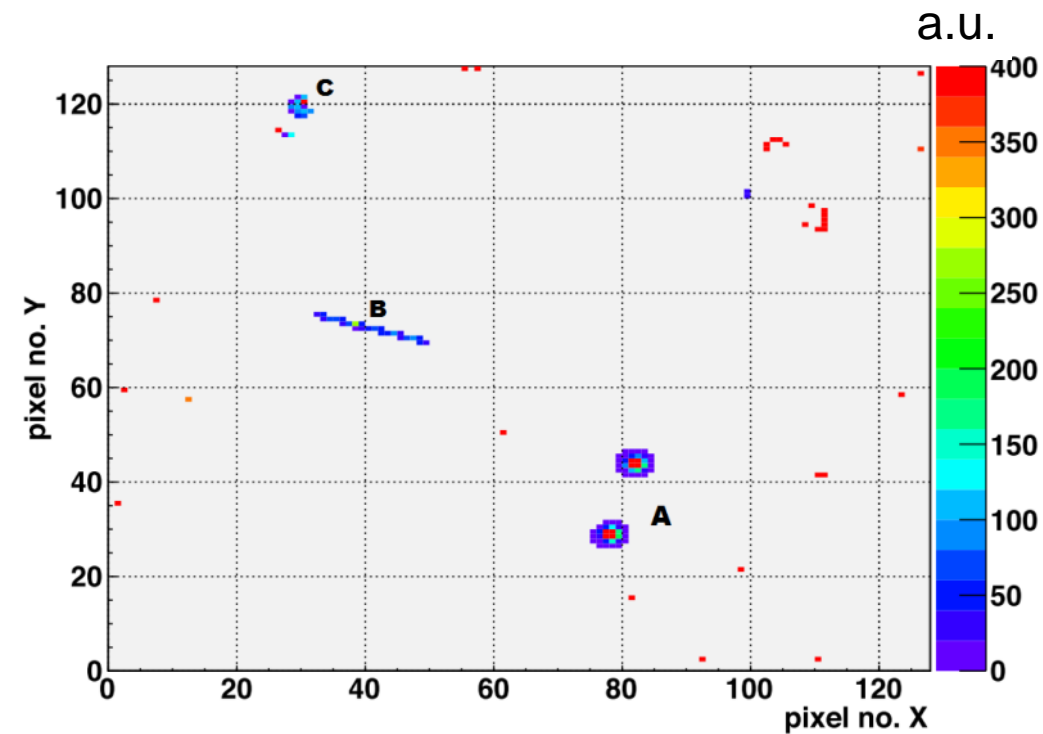
- Pixelated semiconductor X-ray Imaging Detector
- Facts:
  - Si or CdTe Sensors
  - 256 x 256 pixels per chip
  - 55 $\mu\text{m}$ , 110  $\mu\text{m}$  or 220  $\mu\text{m}$  pixelsize
  - Energy measurement for each pixel
  - Threshold limit at about 5 keV





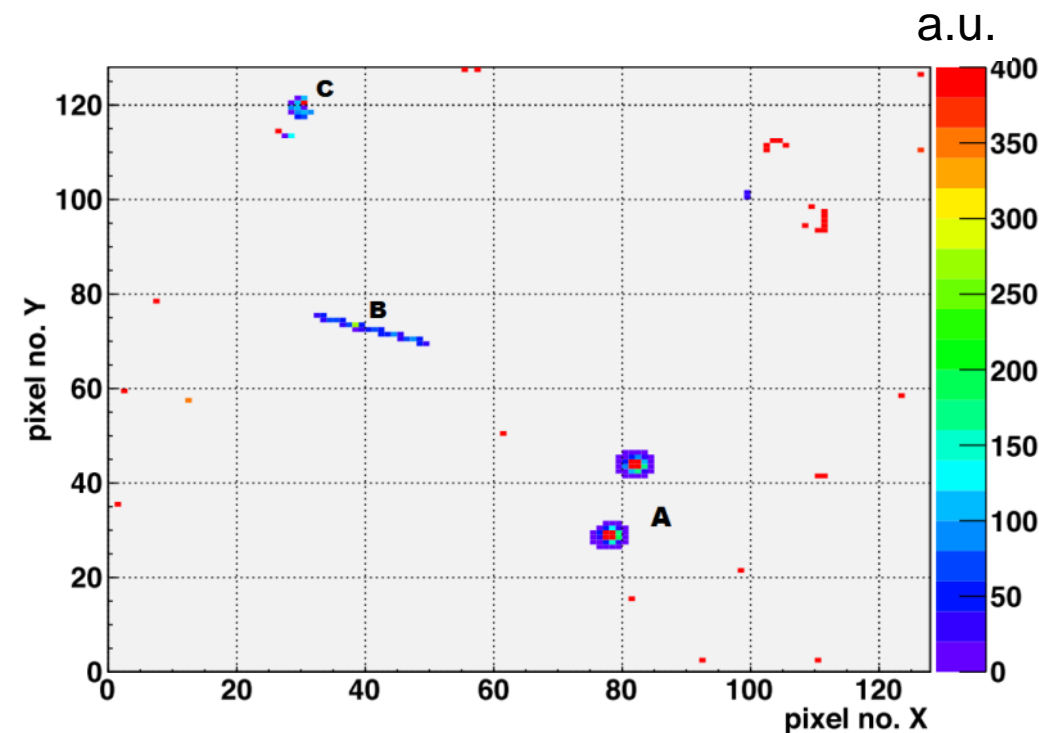
# Tracking

## Background suppression

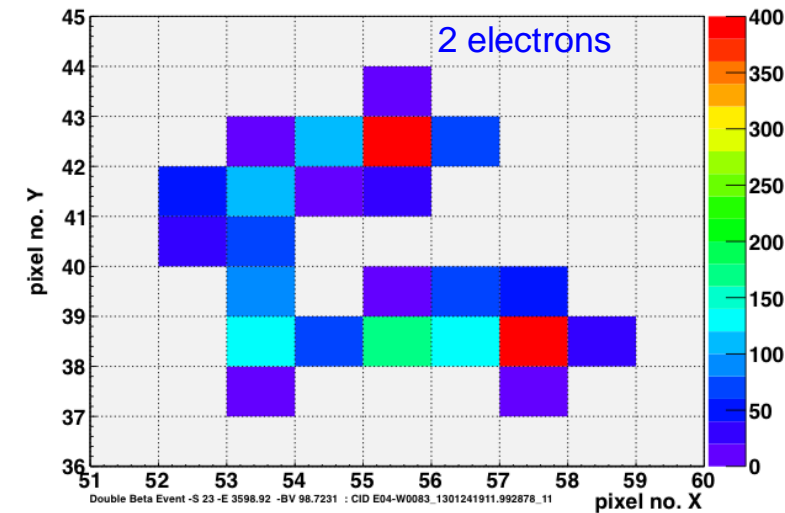
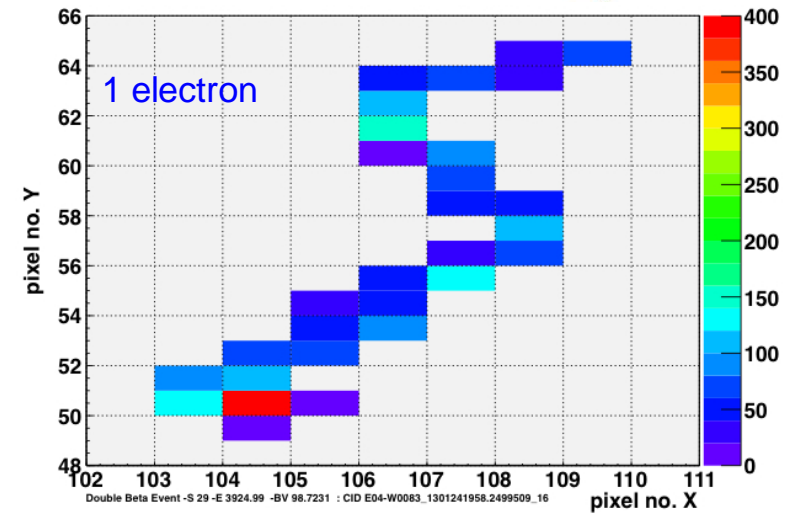


# Tracking

## Background suppression



The  $\beta$  vs.  $\beta\beta$  identification works –  
but not good enough!

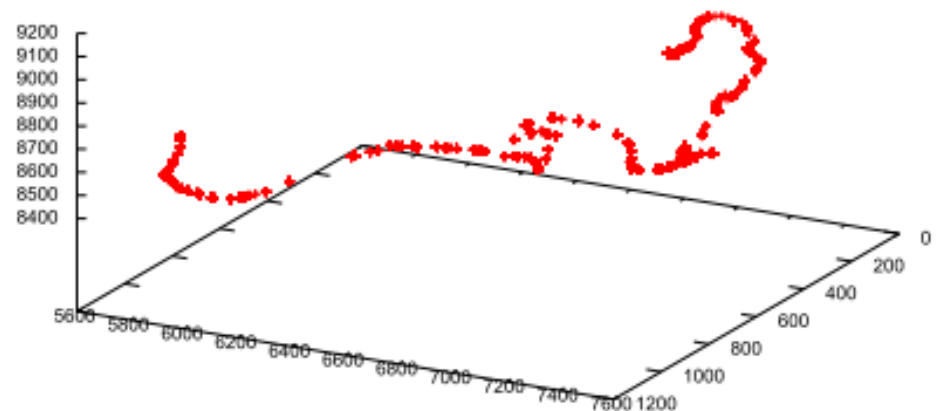
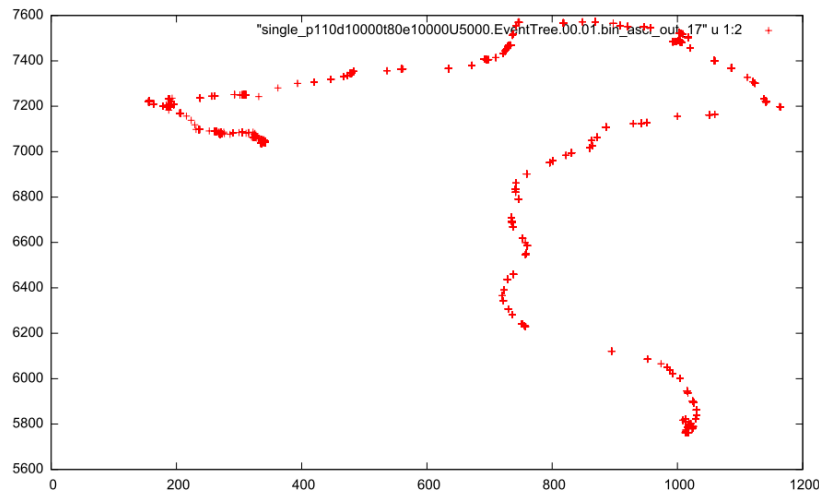


M. Filipenko, T. Gleixner, **EPJ-C**, 73:2374

# Tracking

## What have we achieved so far?

- Tracking is a valuable tool for background rejection
- 3D tracking is desirable (TPC)
- Pixelated semiconductor detectors are difficult to scale up



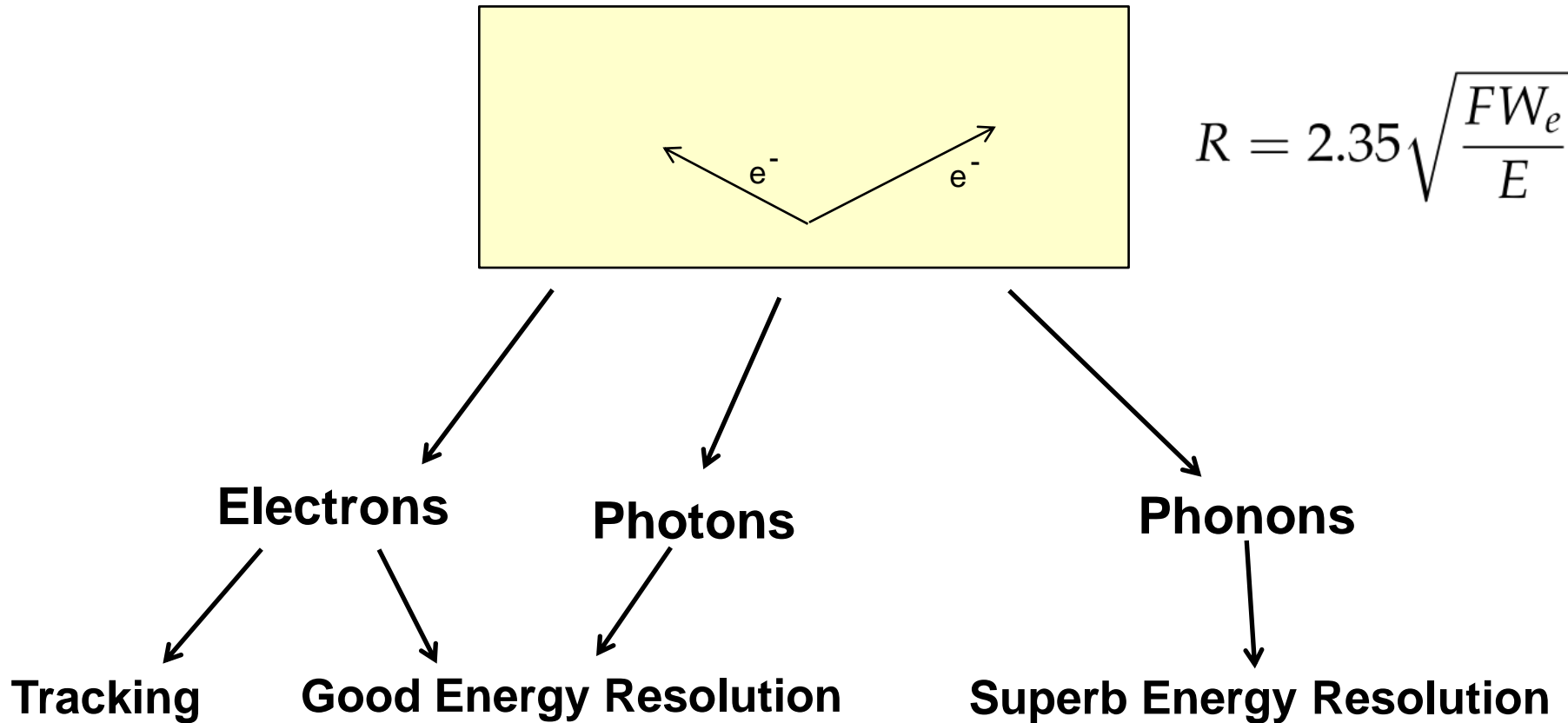
# sXe detector

## Why Xenon?

- Inert gas
- Long electron drift distance
- Xe-136 is a  $\beta\beta$ -isotope
- Easy to enrich and to scale up in mass
- No beta-emitting isotopes
- Q-value of about 2.5 MeV

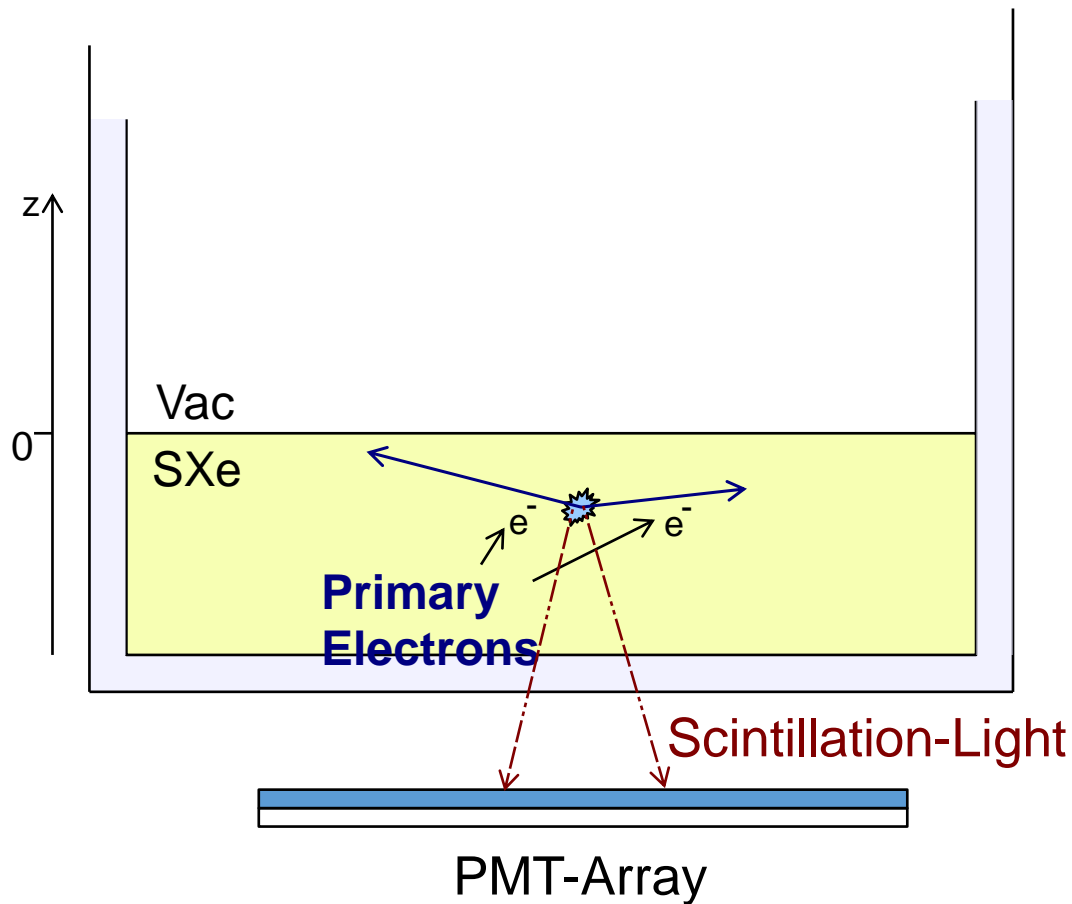
# sXe detector

Why solid?



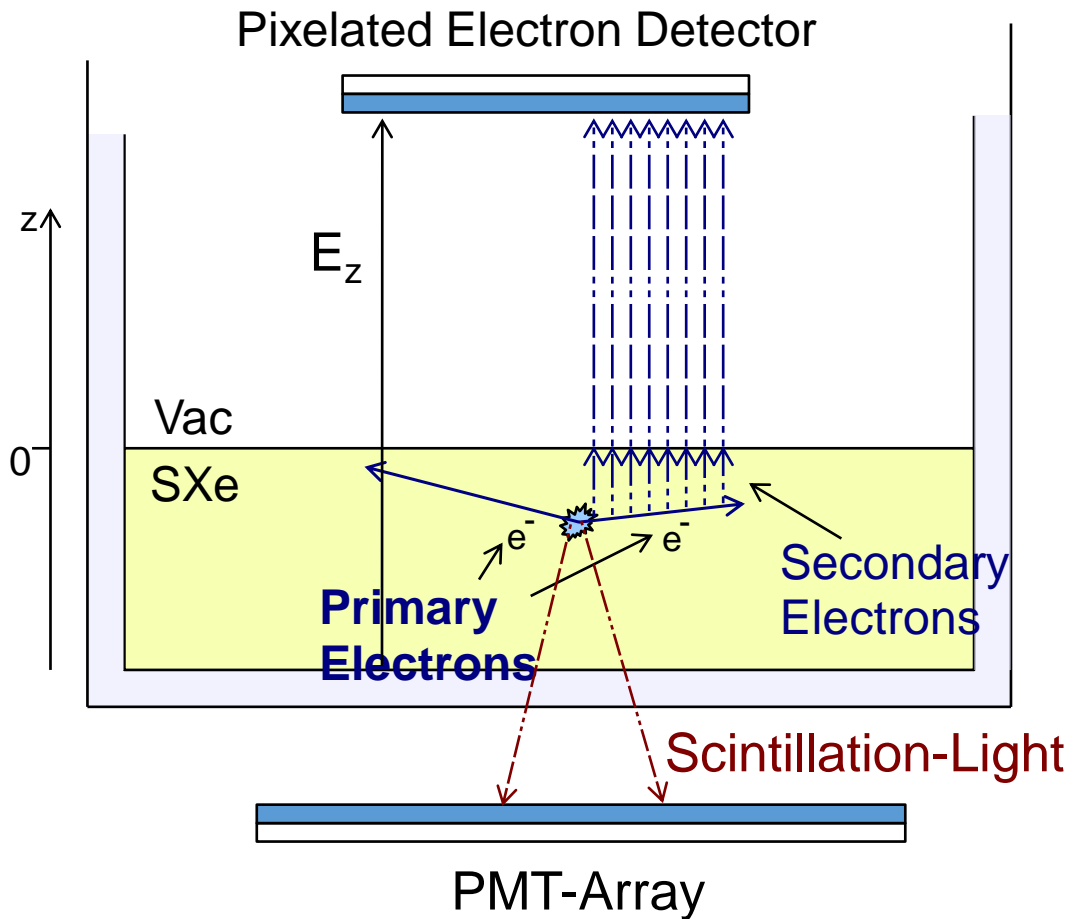
# sXe detector

## Principle



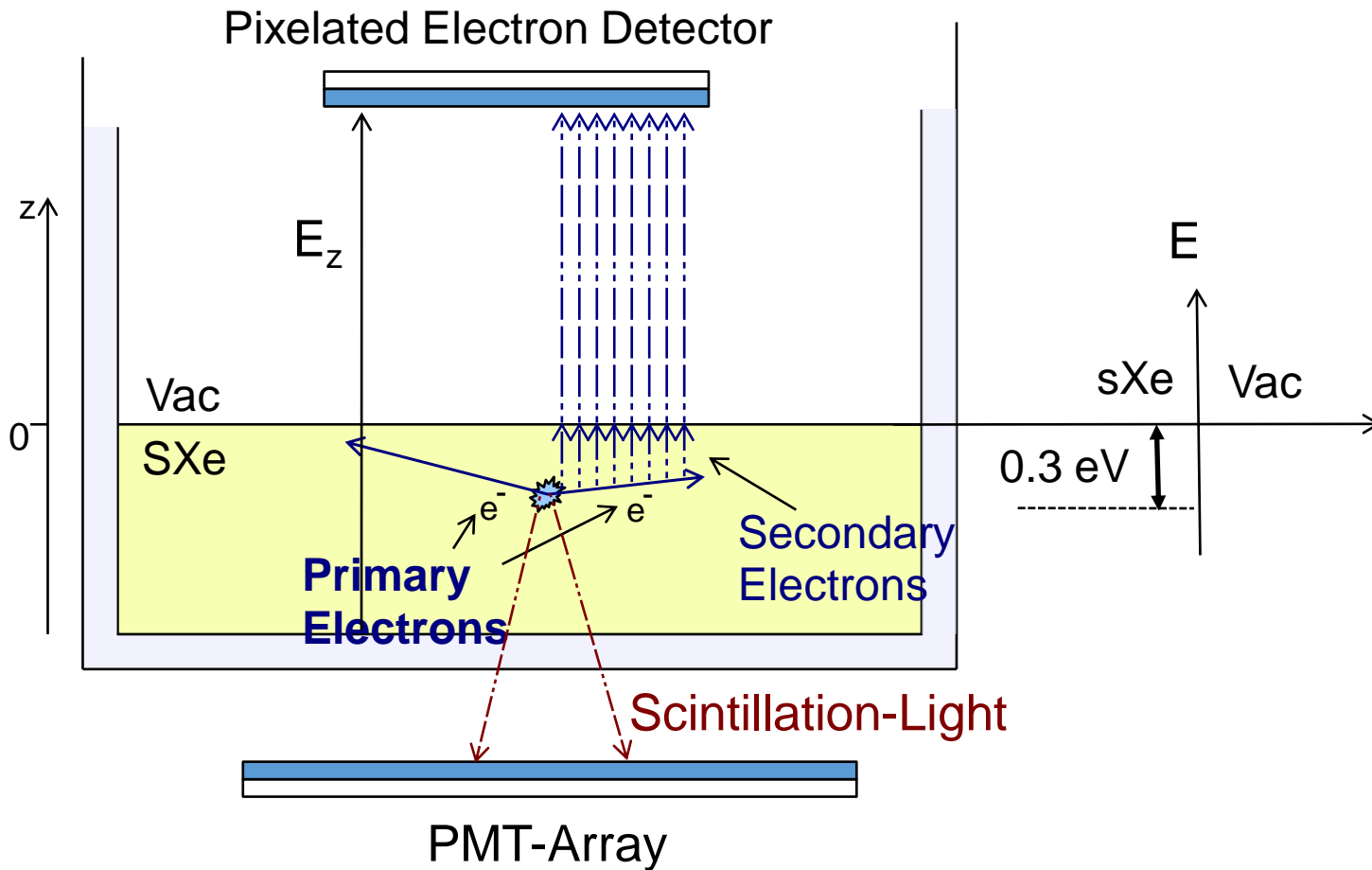
# sXe detector

## Principle



# sXe detector

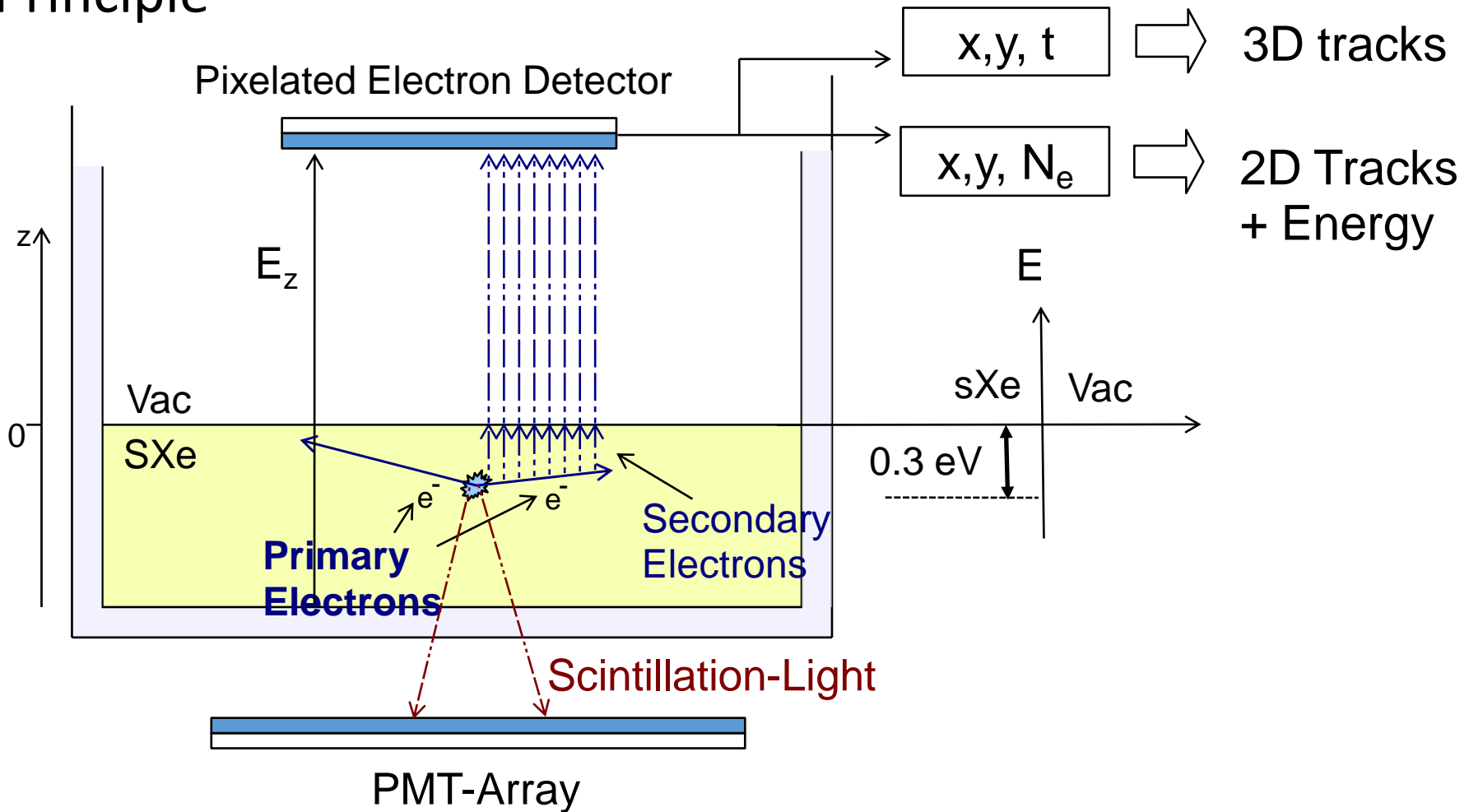
## Principle





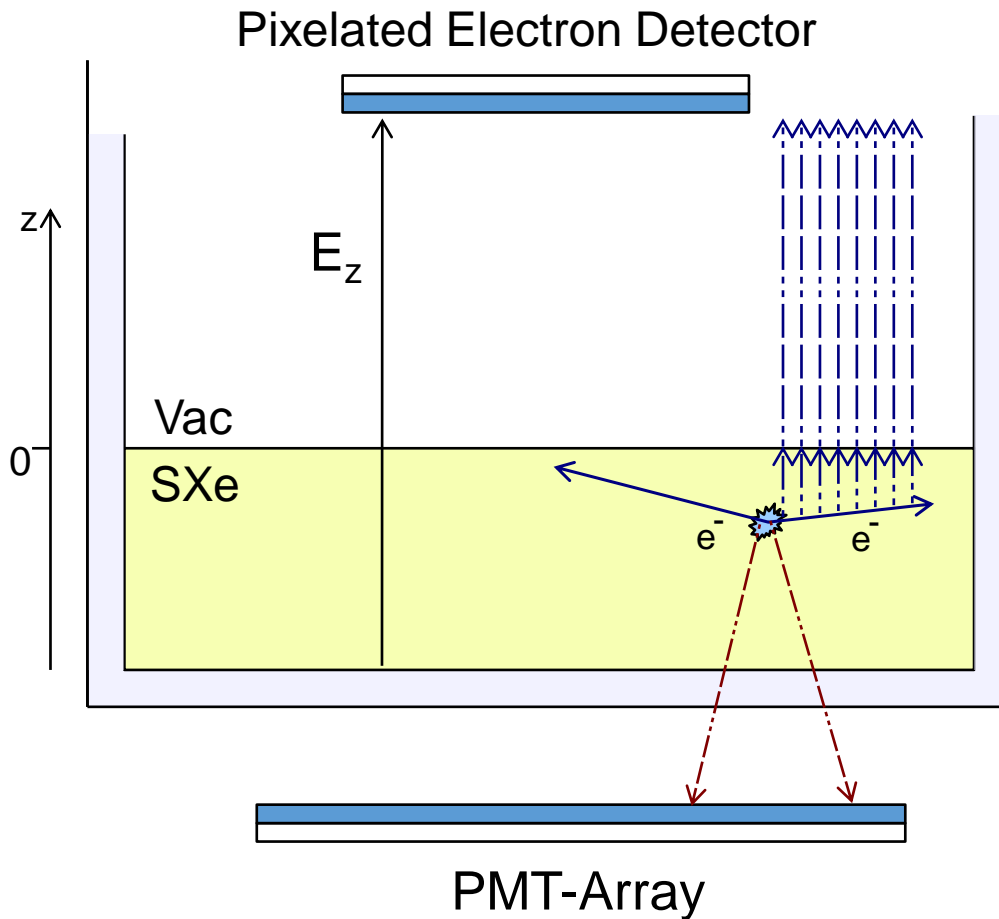
# sXe detector

## Principle



# sXe detector

## Principle

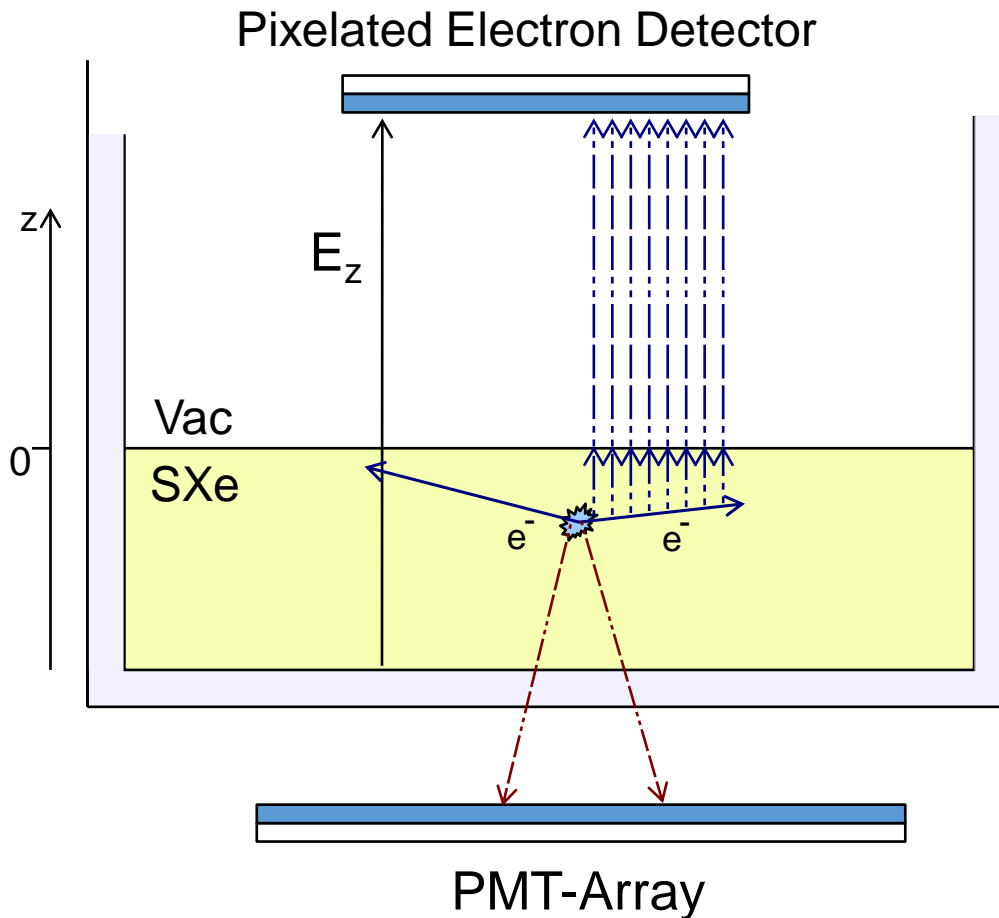


## Problems:

- small sensor size (14x14mm)

# sXe detector

## Principle

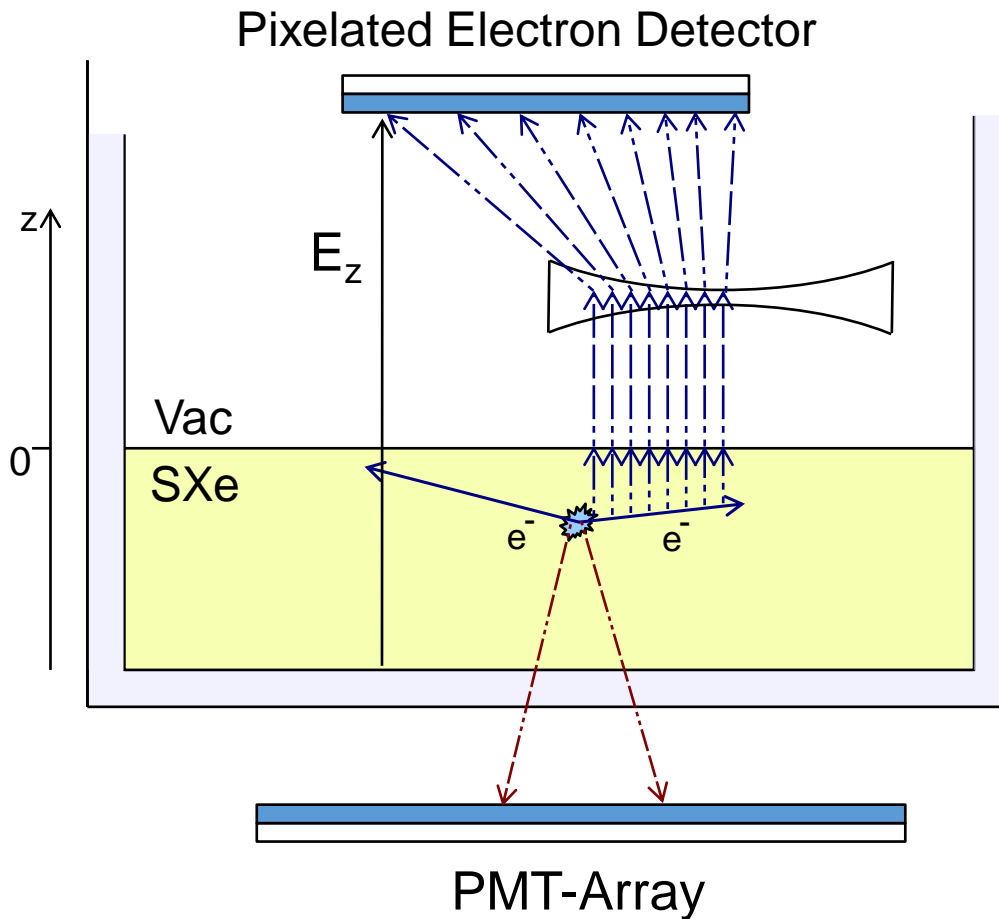


## Problems:

- small sensor size (14x14mm)
- short tracks (2mm)

# sXe detector

## Principle

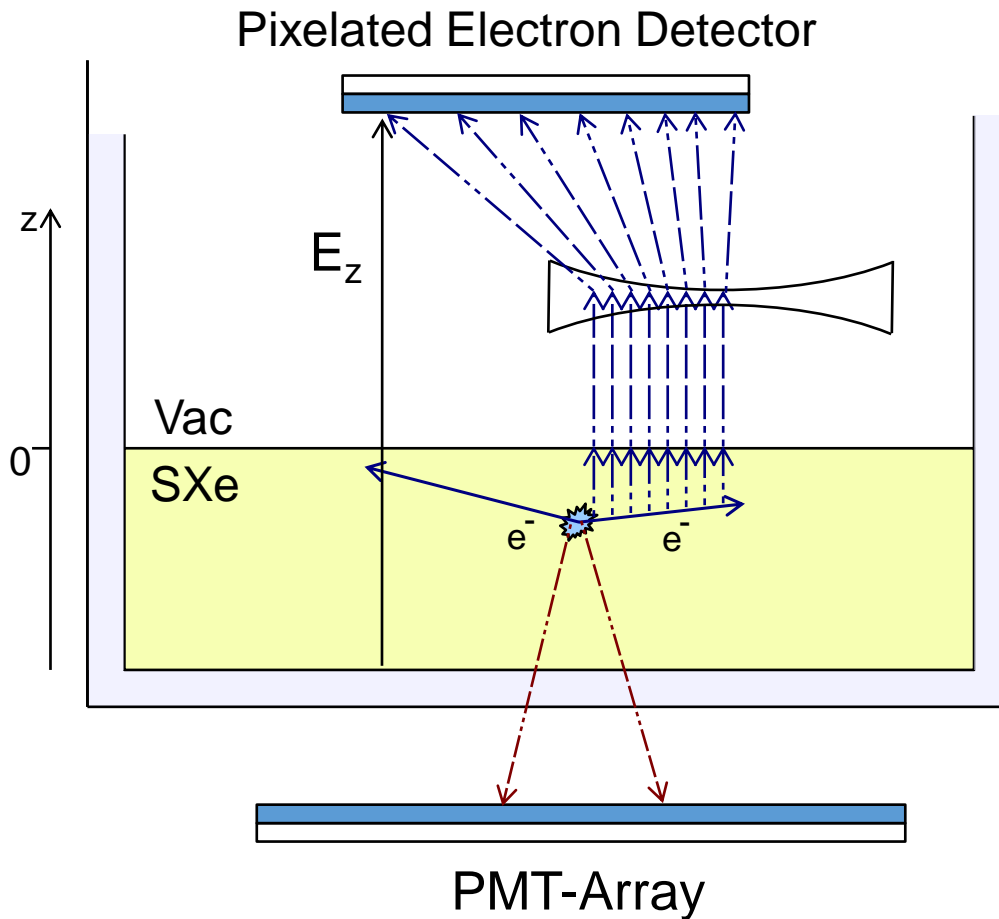


## Problems:

- small sensor size (14x14mm)
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# sXe detector

## Principle

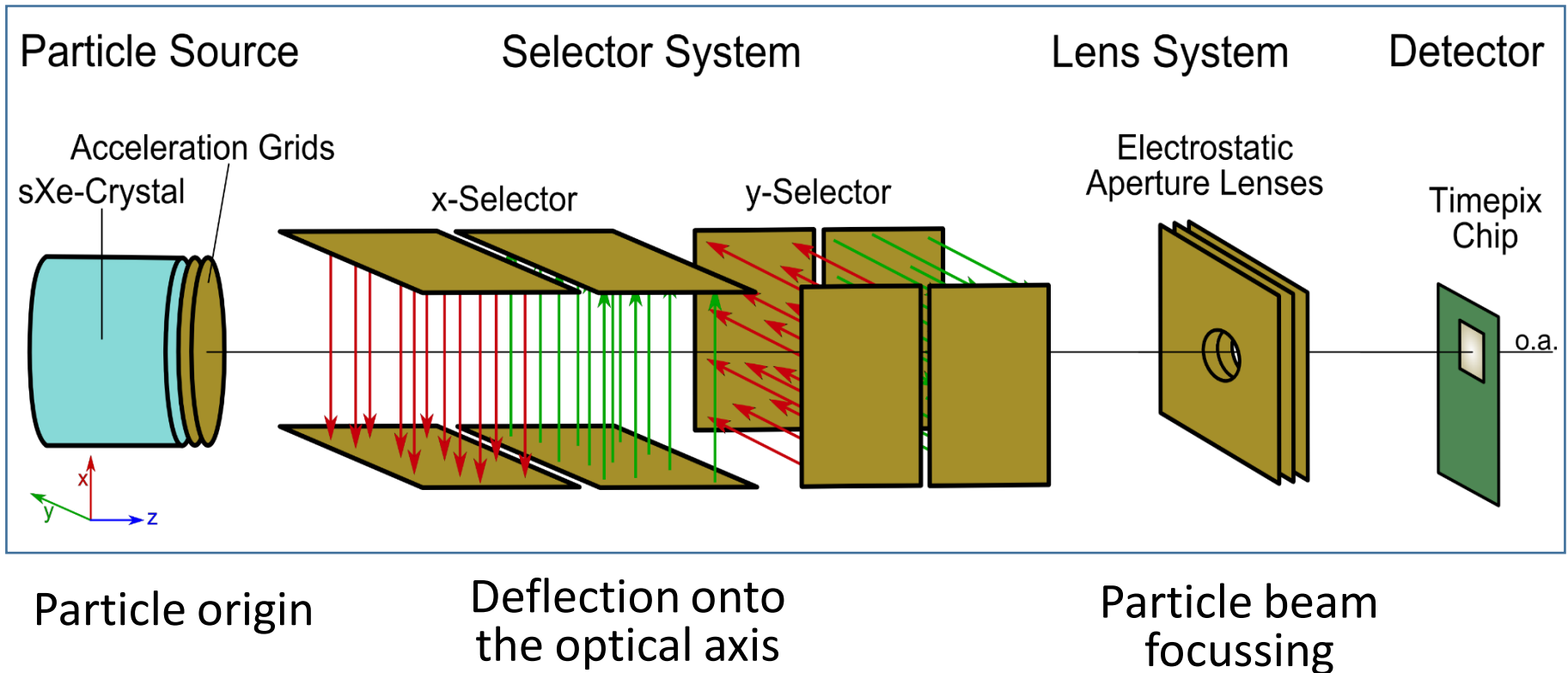


## Problems:

- small sensor size (14x14mm)
  - short tracks (2mm)
- electron optic system

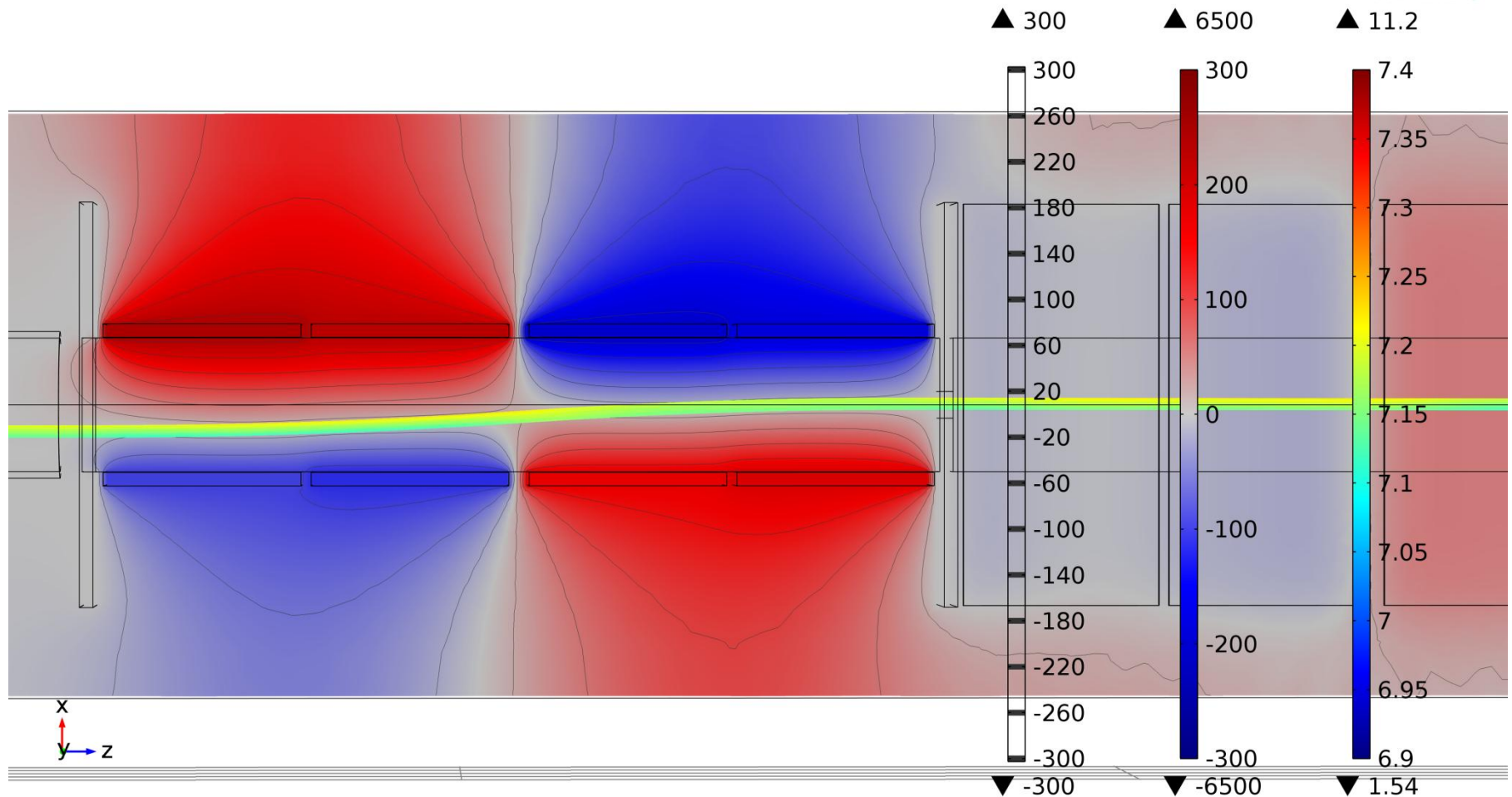
# sXe detector

## Principle of the electron optic system



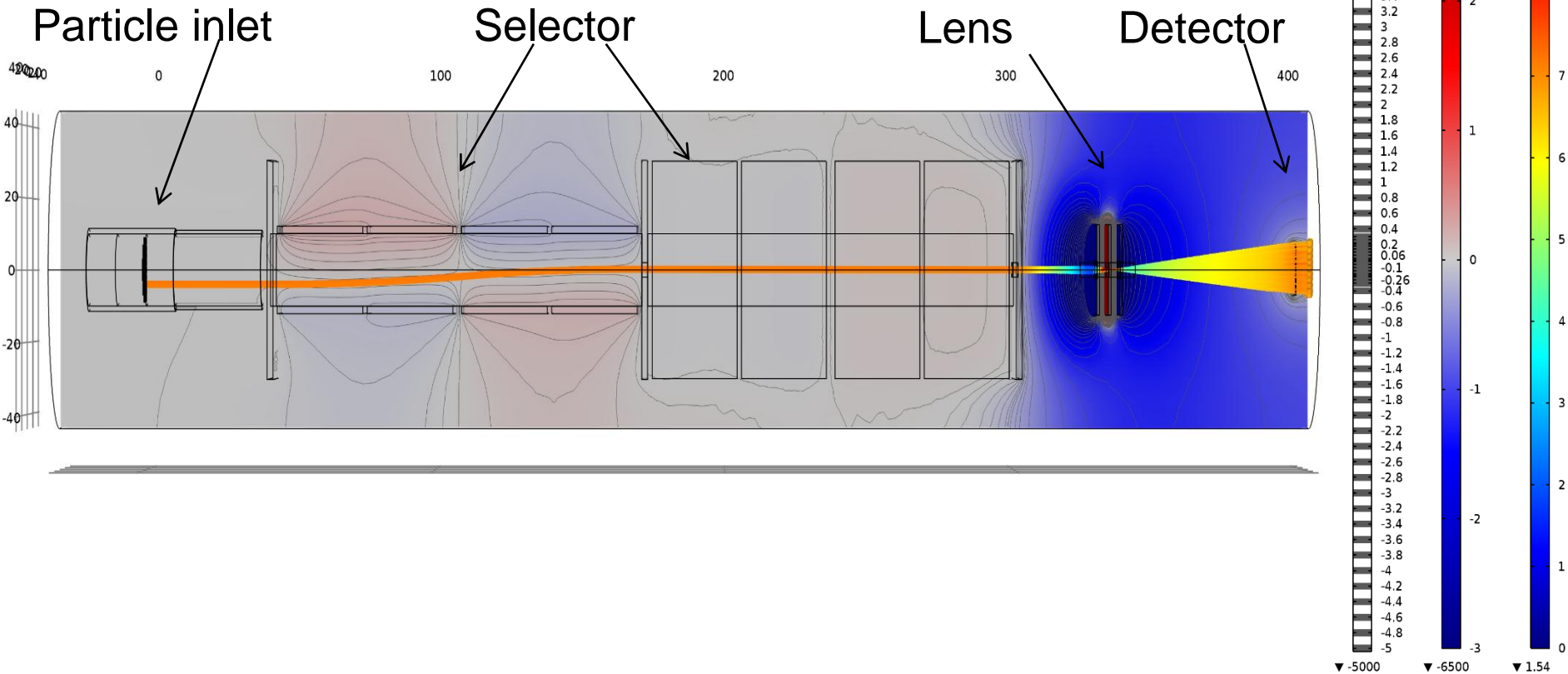
# sXe detector

## Simulation of the electron optic system



# sXe detector

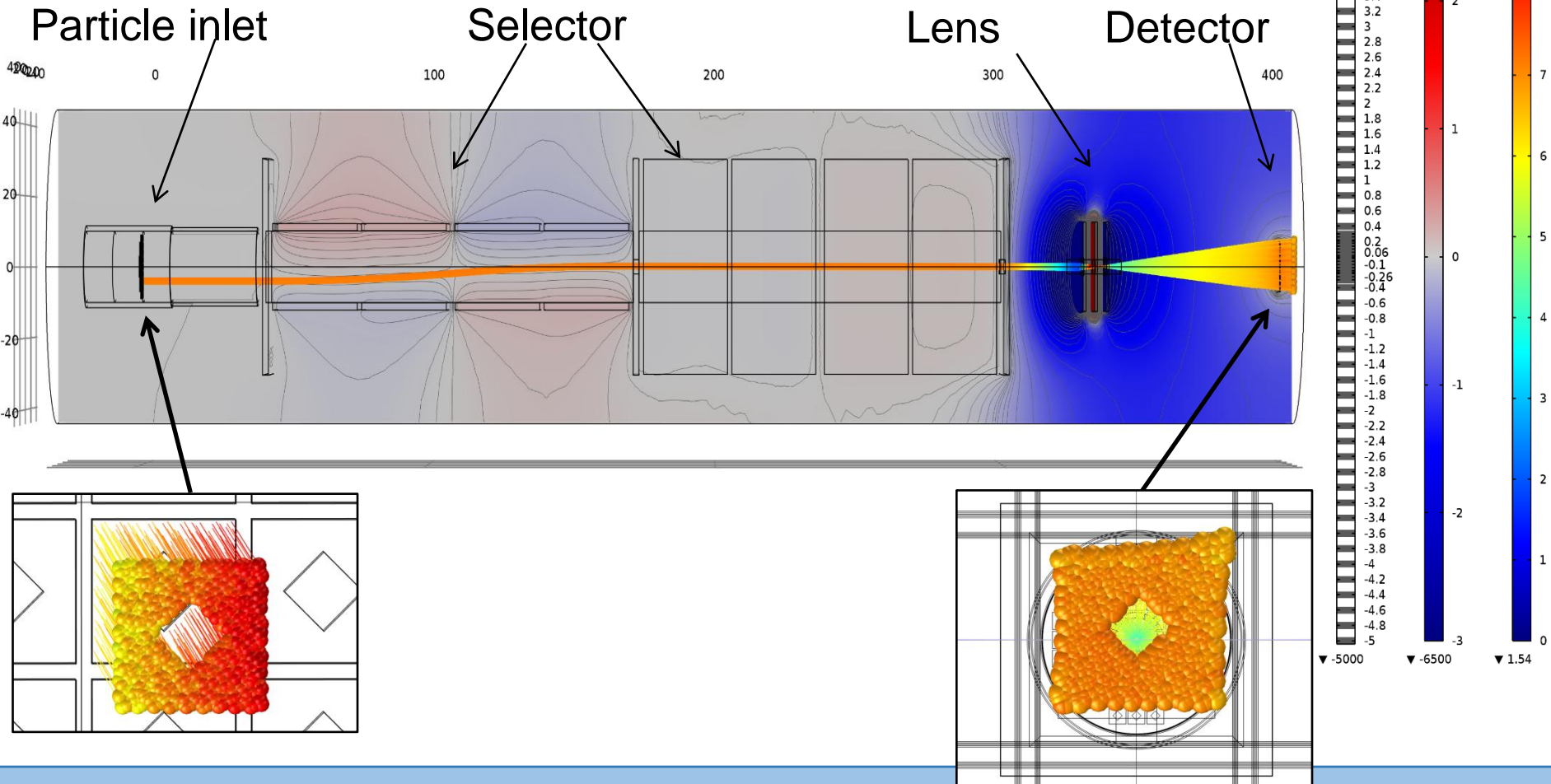
## Simulation of the electron optic system





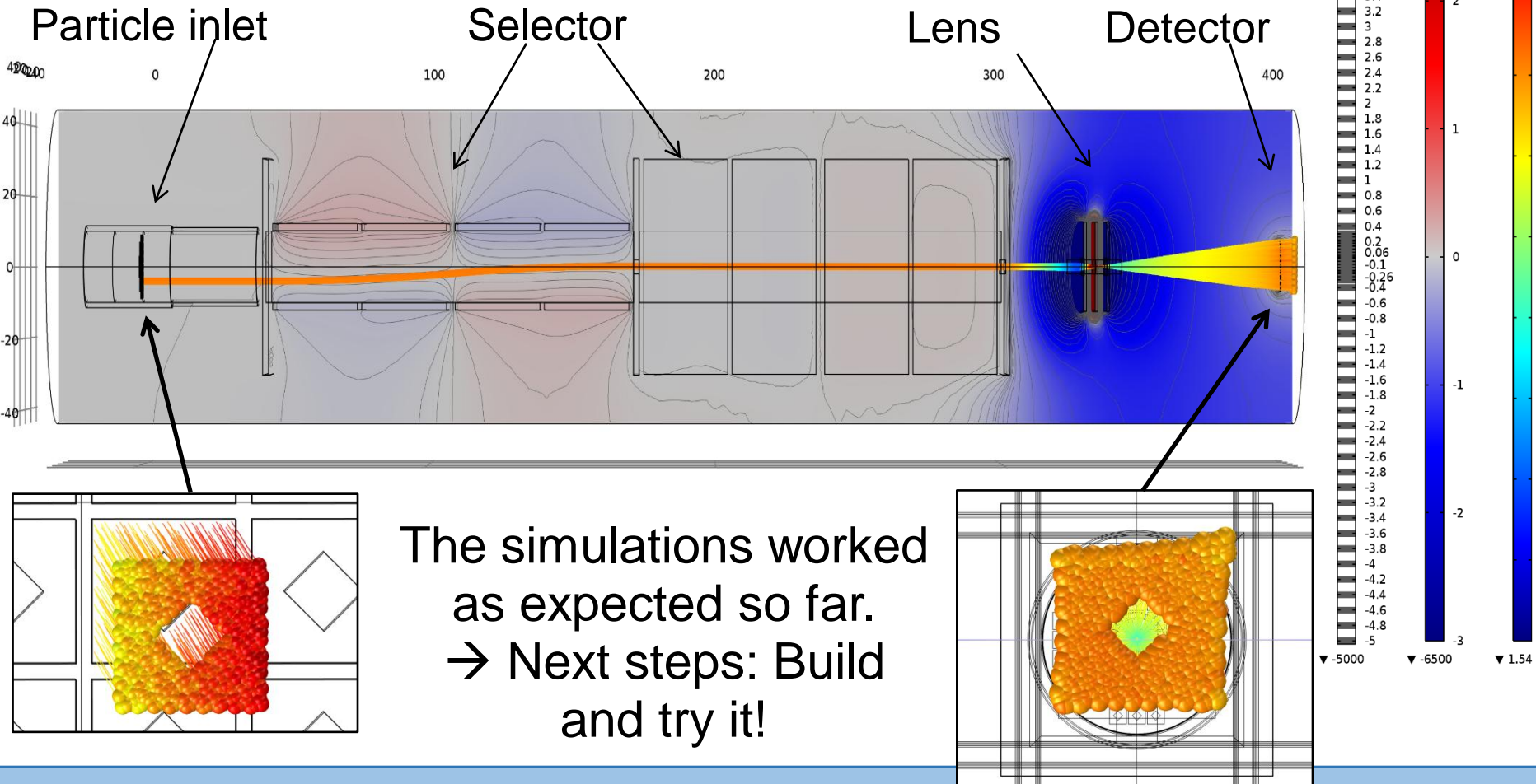
# sXe detector

## Simulation of the electron optic system



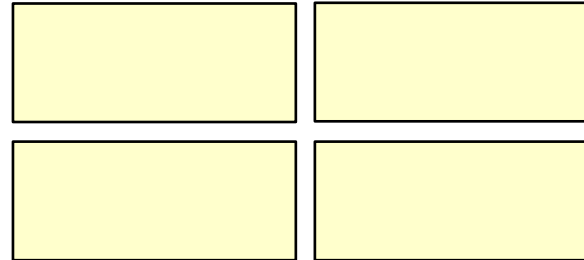
# sXe detector

## Simulation of the electron optic system



# Outlook

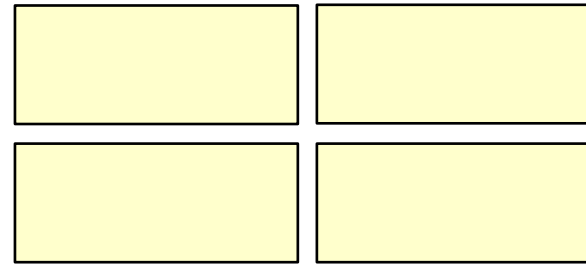
## The big plan



Large mass of SXe  
divided into smaller  
detection blocks

# Outlook

## The big plan

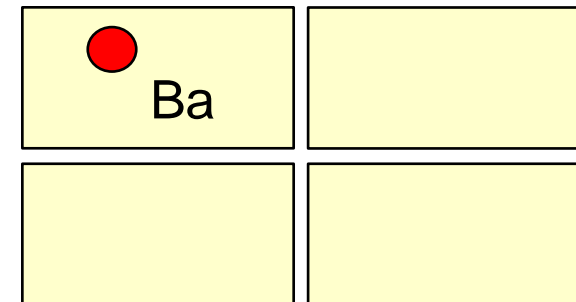
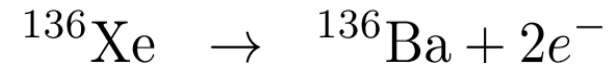
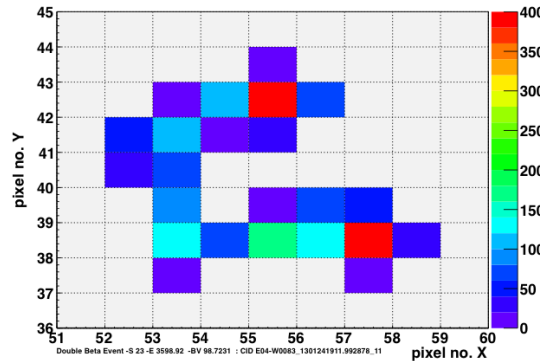
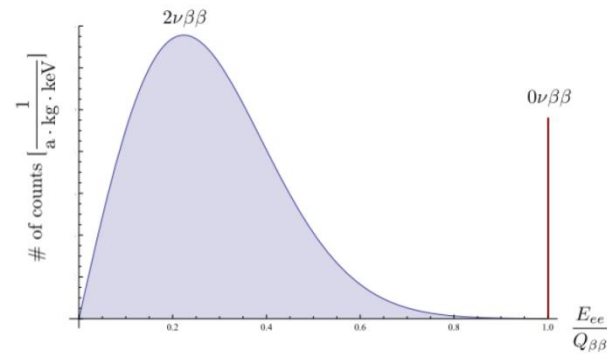


Large mass of SXe  
divided into smaller  
detection blocks

### I. Energy Signature

### II. Tracking Signature

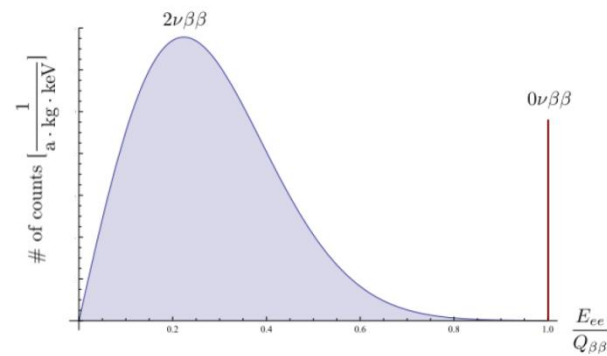
### III. Barium Tagging



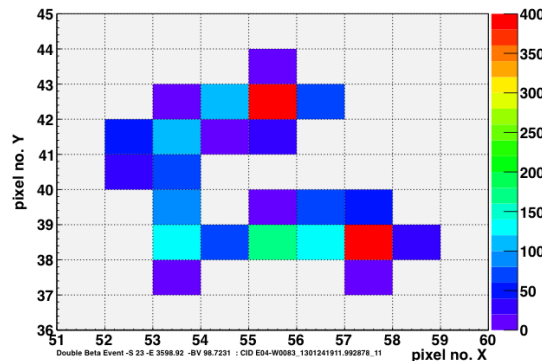
# Outlook

- Solid xenon detectors could be used for various low background experiments!
- Recent results are presented in the following talk by M. Filipenko.

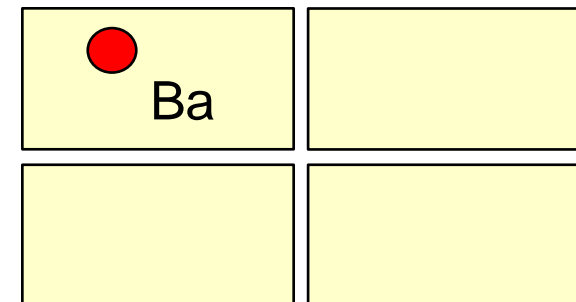
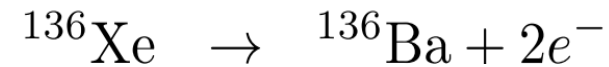
## I. Energy Signature



## II. Tracking Signature



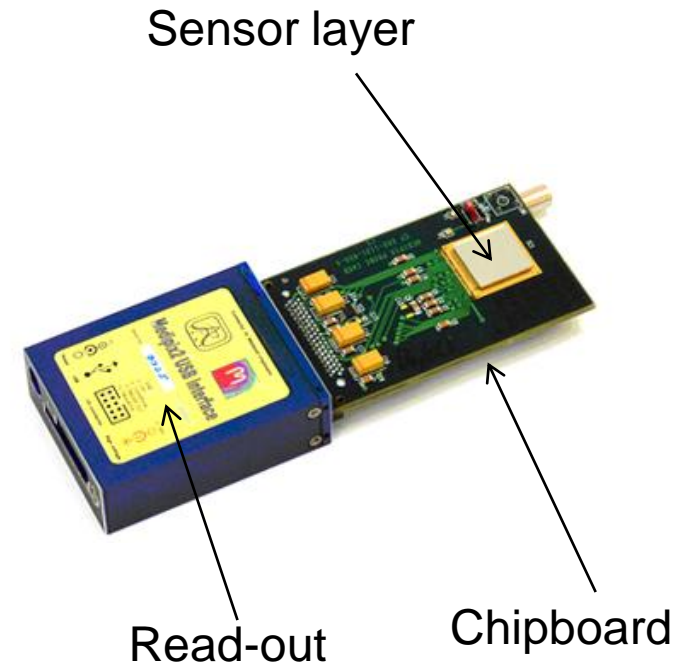
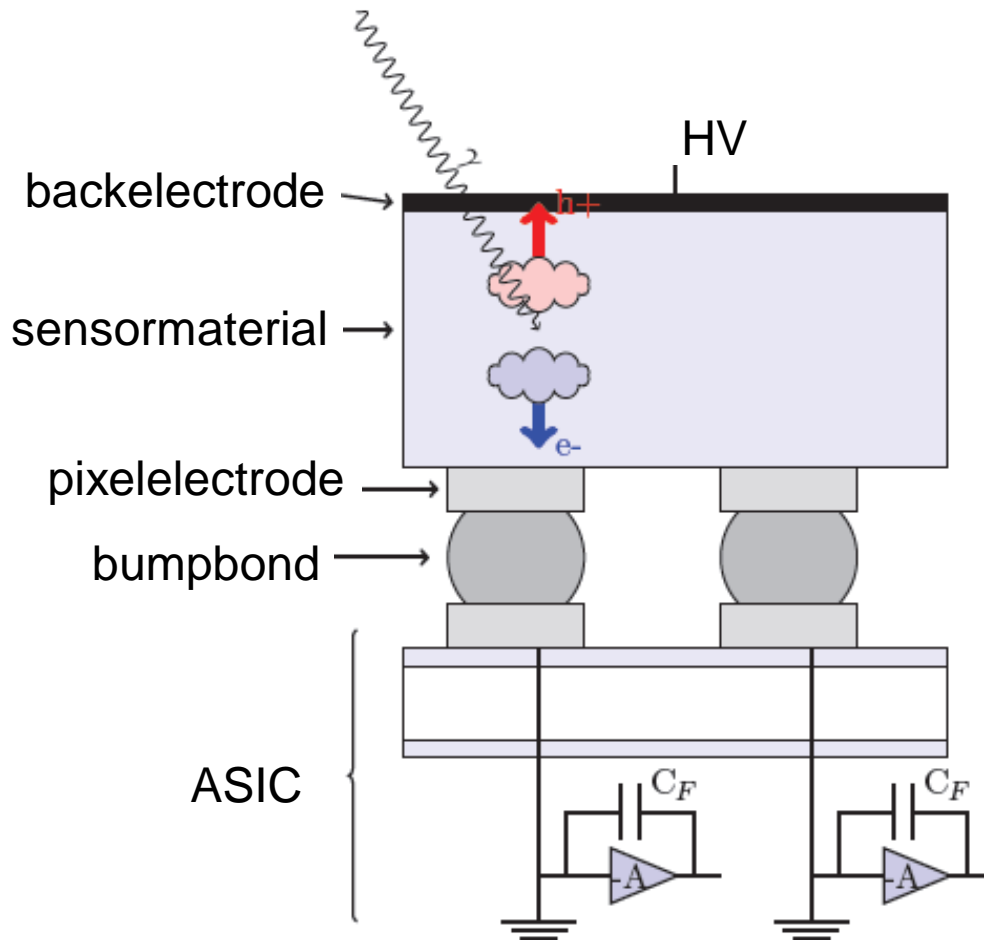
## III. Barium Tagging



# Backup

# Tracking

## The Timepix detector

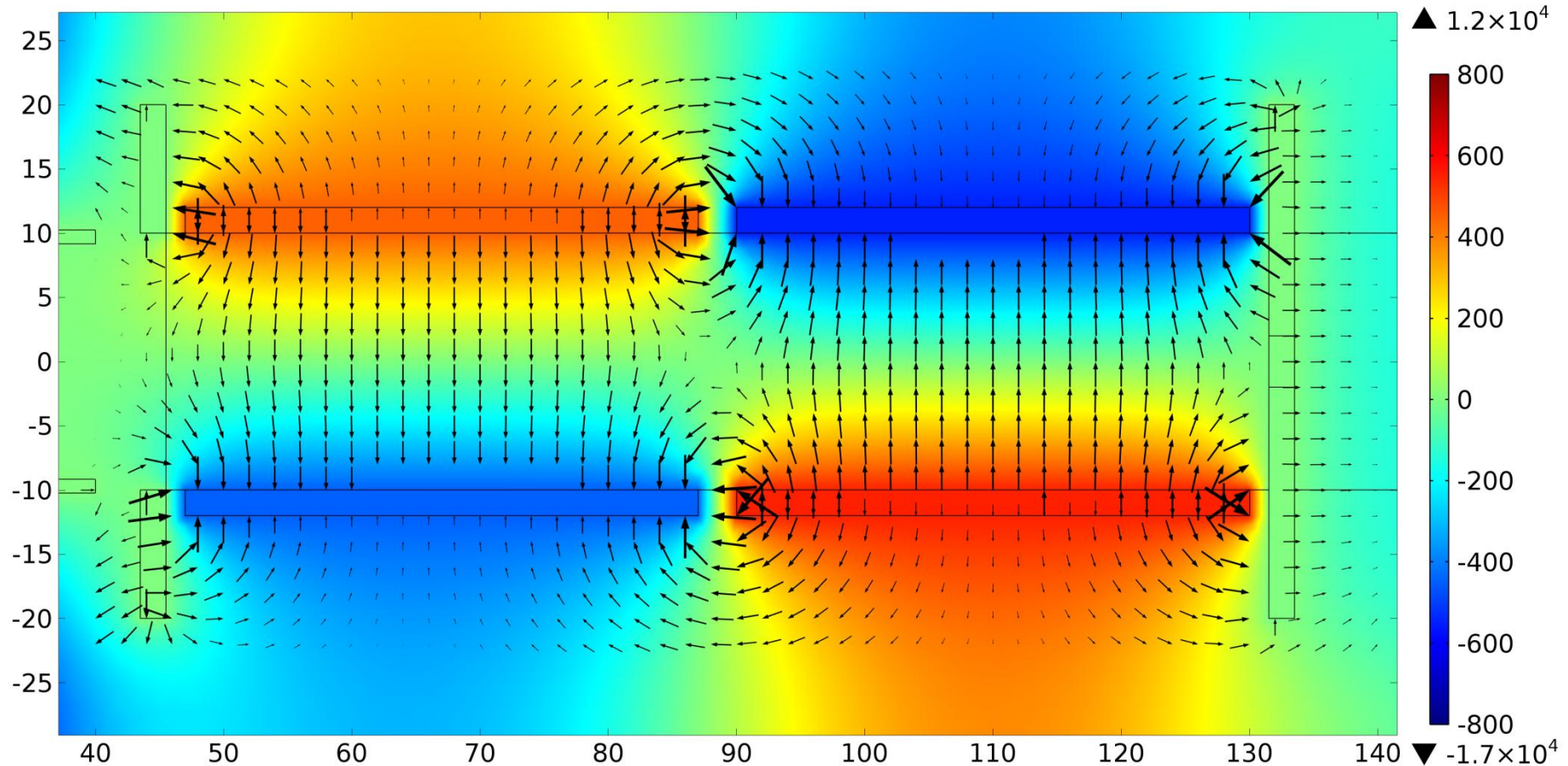


From E. Guni (Dissertation '12)



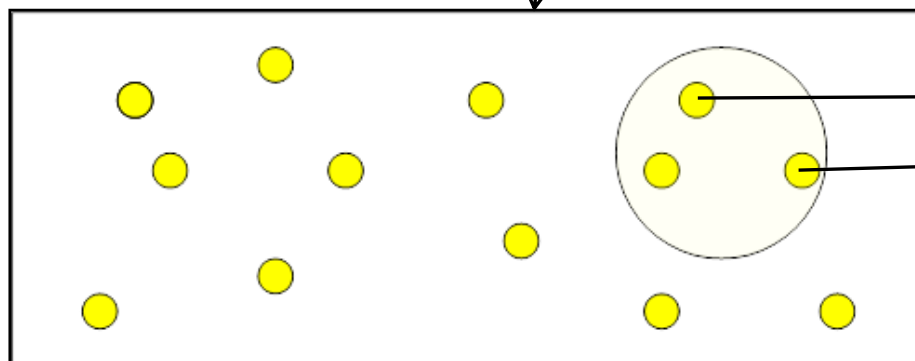
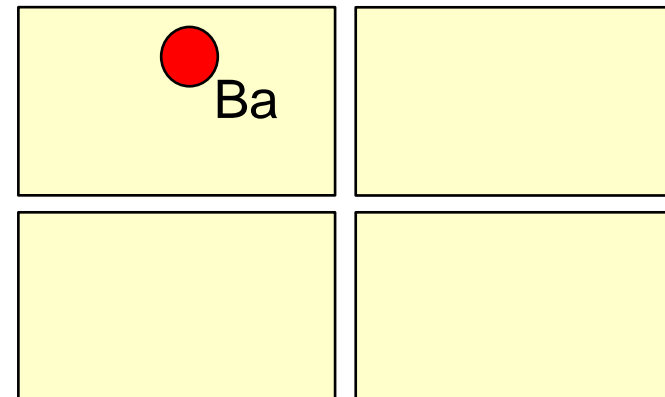
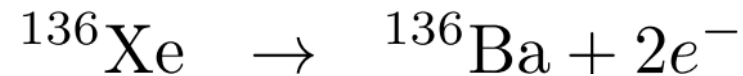
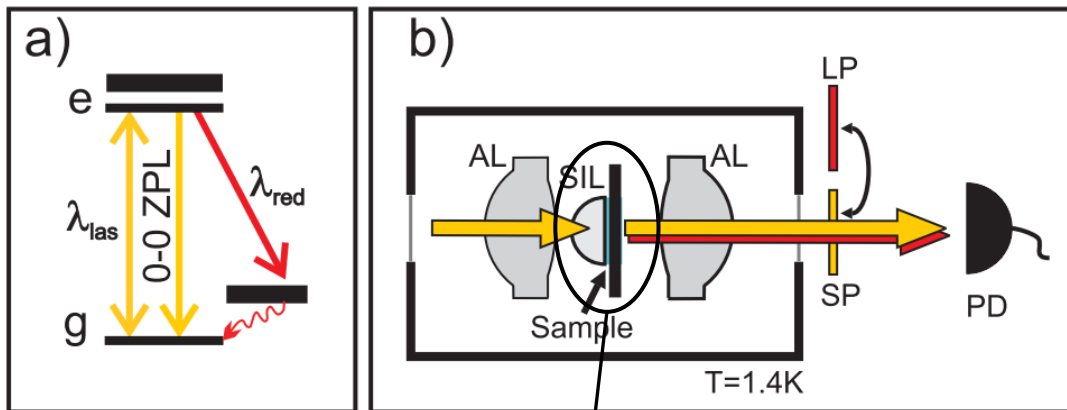
# sXe detector

## Simulation of the electron optic system

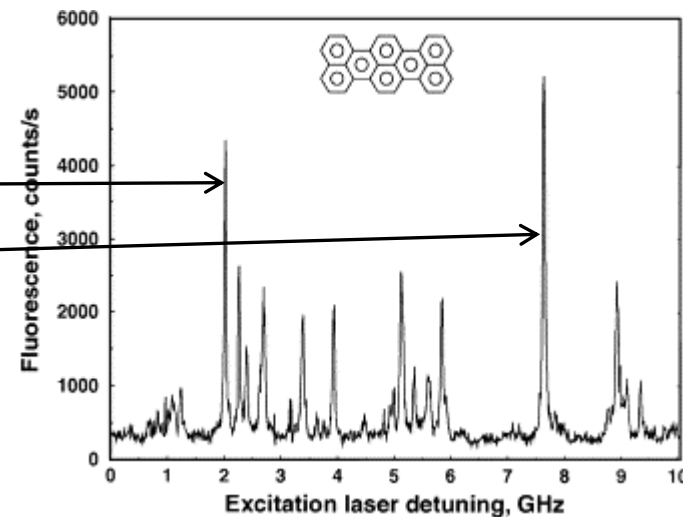




# Ba-Tagging



Sample thickness: about 500 nm



Taken from JLu: K. Rebane '02,  
DOI 10.1016/S0022-2313(02)00455-6