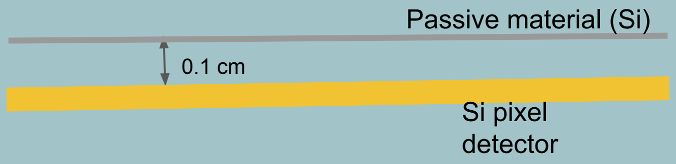
Spatial resolution study

Summary

5 Feb 2020

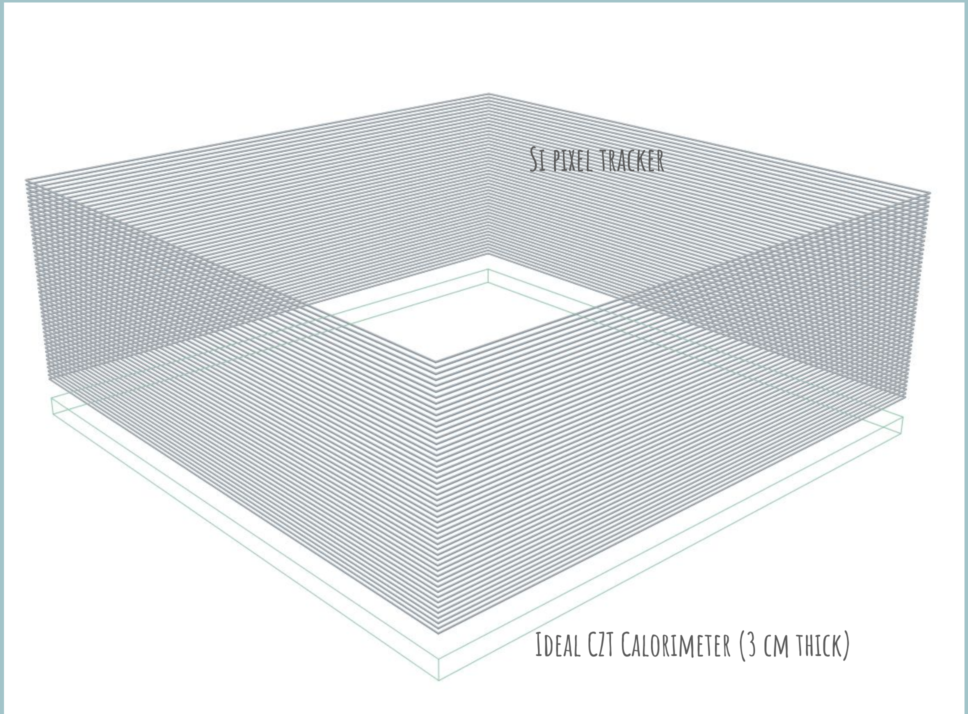
The **basic geometry** is composed of
- 50 layers (1mx1m) of voxel detectors - 1 cm separation
- ideal calorimeter (very fine voxelization)
- passive material on top of each tkr layer - 0.1 cm separation



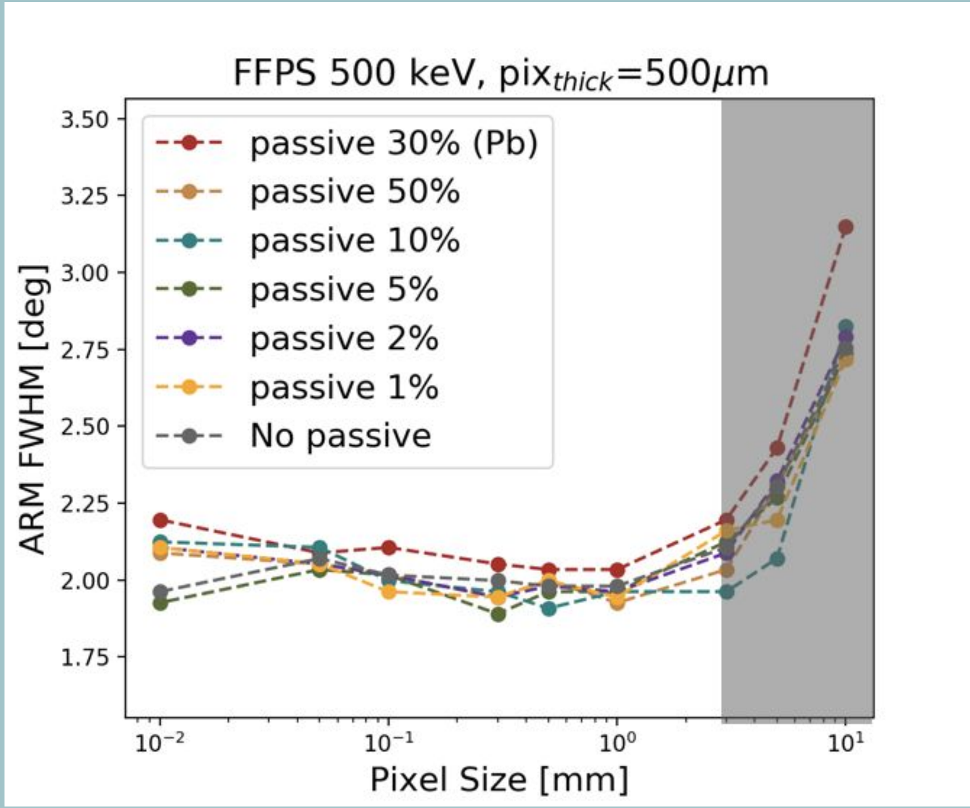
Tested parameters:
- Voxel size:
  * 10 mm
  * 5 mm
  * 3 mm
  * 1 mm
  * 0.5 mm
  * 0.3 mm
  * 0.1 mm
  * 0.05 mm
  * 0.03 mm
  * 0.01 mm
- Si thickness:
  * 500 um

- passive material:
  * 0%
  * 1%
  * 2%
  * 5%
  * 10%

We want to test the different configurations for different energies:
  * 100 keV
  * 200 keV
  * 300 keV
  * 1000 keV

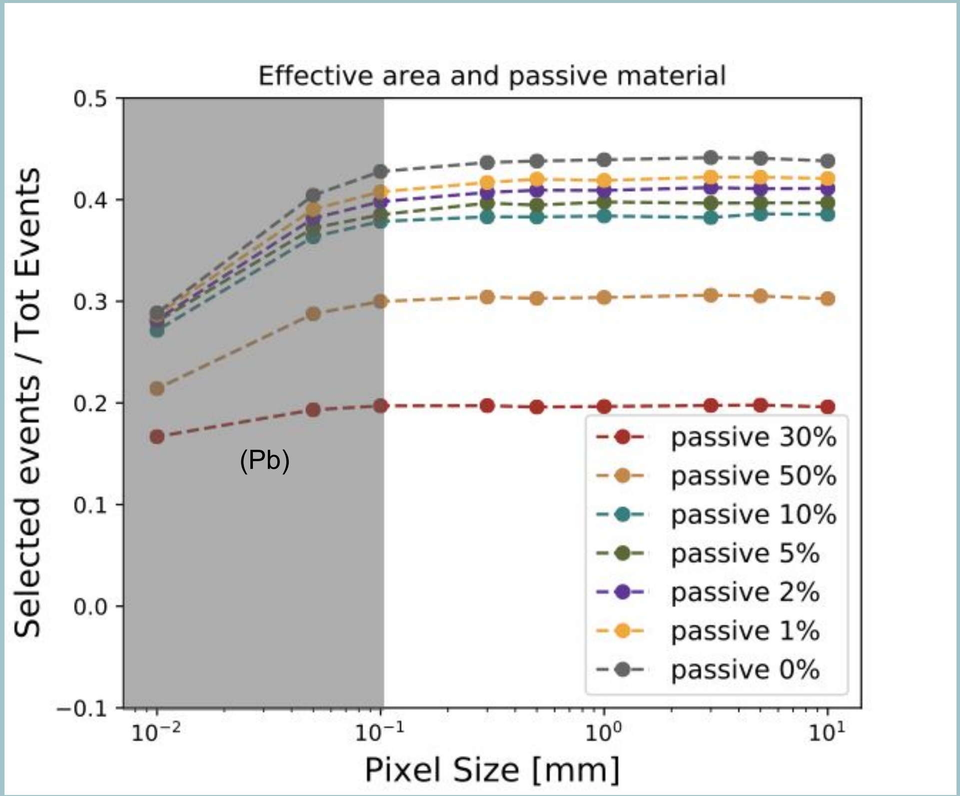


Passive materia and pixels size



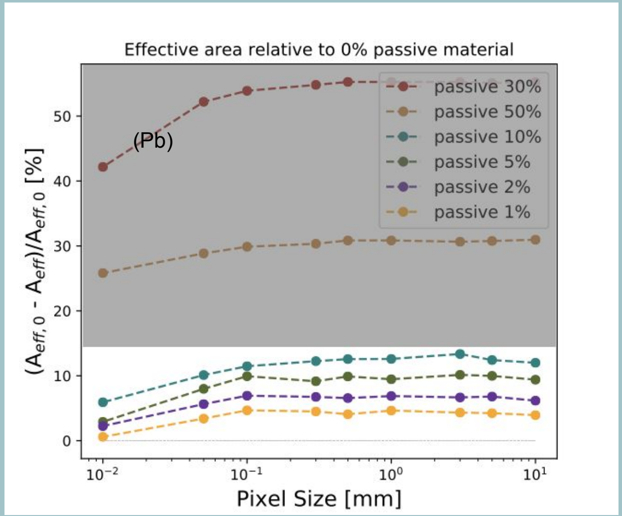
Loss in the spatial resolution when pixels are too large (Apix > 3 mm2)

Effective Area and passive material



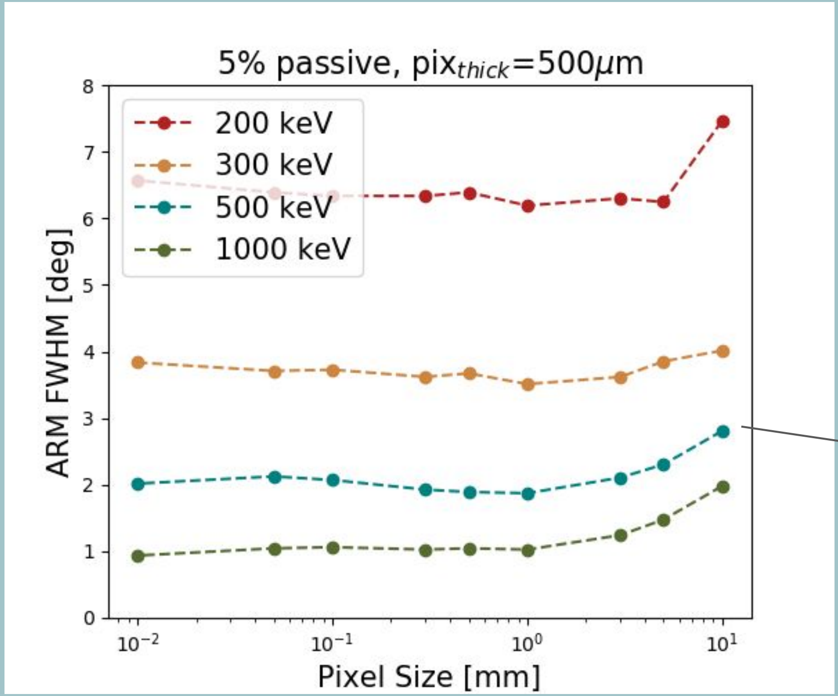
Loss in the effective area for small pixels:

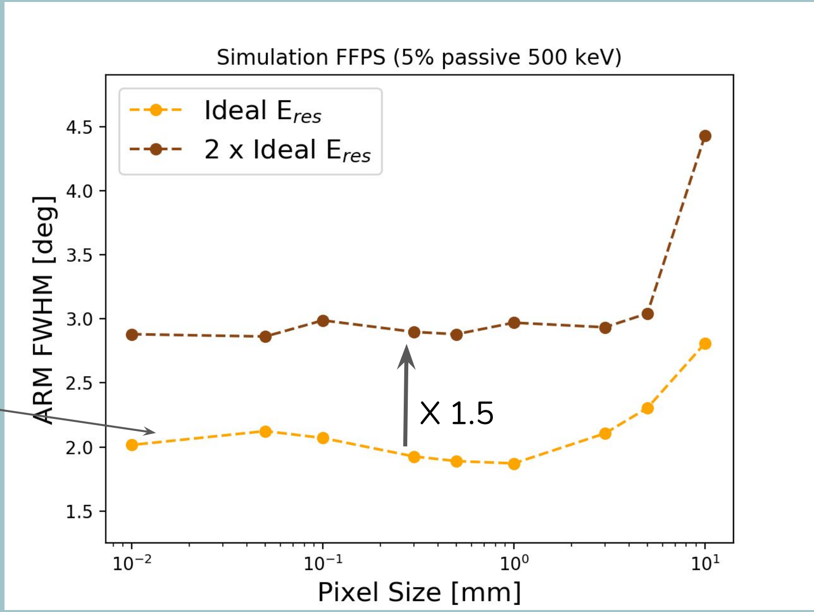
- Too small energy loss to trigger a signal in a pixel



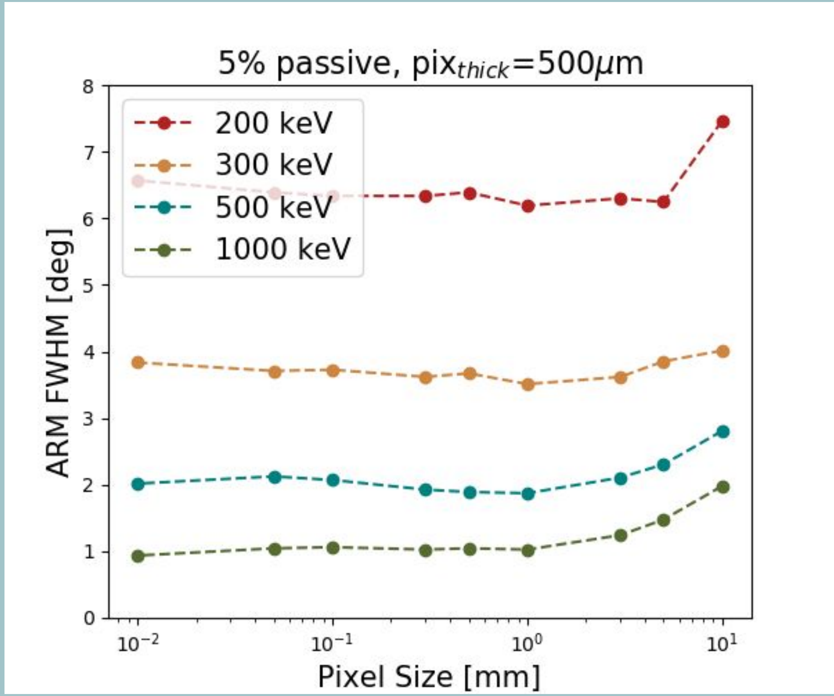
ARMs as a function of energy @ 5% passive

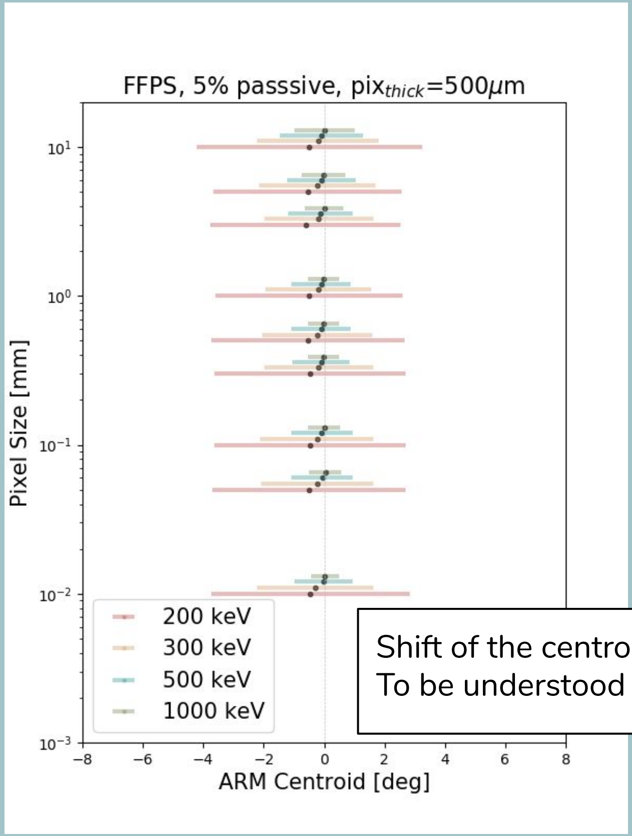
DSiPix.EnergyResolution Gauss 662 662 4.25 // (->8.5)
DSiPix.EnergyResolution Gauss 122 122 2.2 // (->4.4)





ARMs as a function of energy @ 5% passive





Shift of the centroid for low energies.
To be understood at some point...

Some numbers

$100\ um^2 < Pix_{size} < 3\ mm^2$
Passive material (Si) < 10%
Minimum simulated energy of AMEGO-like instrument > 200 keV

To do

- Dynamic range of each pixel
- Passive material study at 200 keV
- Try different thicknesses (ATT: the passive is defined with respect to that parameter, ok?)
    a. 300 um, 700 um (500 done)
- Good pixel yield: add a percentage of dead pixels in the simulations (select one case for the other parameters)
-

I can work on this after Feb 19, but if you need something urgently let me know.

Spatial resolution study

Simulations to determine the pixel size

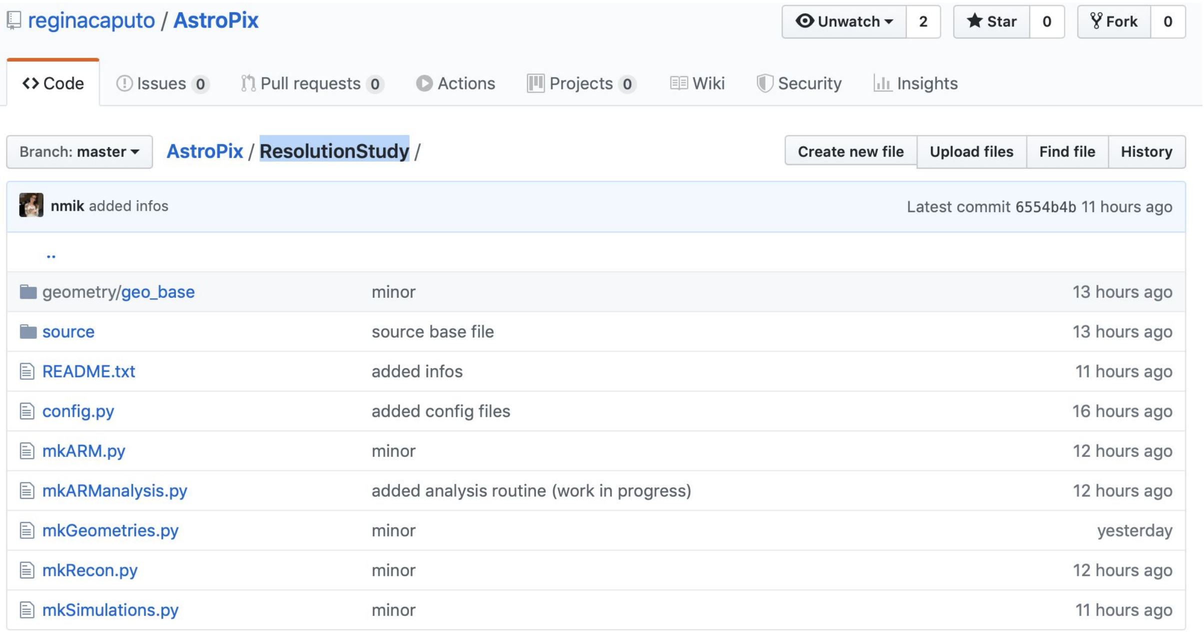
Astropix Meeting 12/4/19

Working space: github repository

https://github.com/reginacaputo/AstroPix

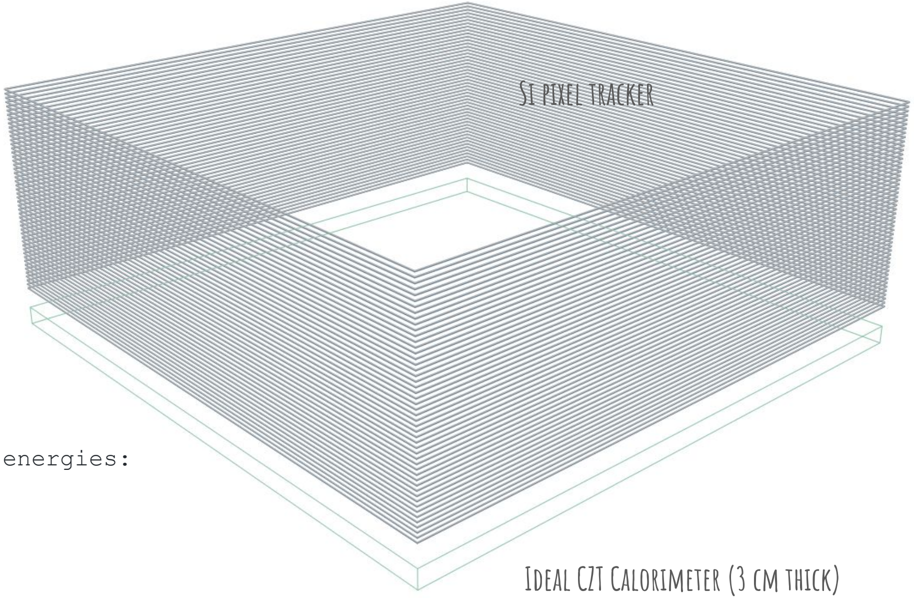
Branch: master

Folder: ResolutionStudy



README.txt

```
This study aims to define the ideal pixel size for the AstroPix project.

The basic geometry is composed of
    - 50 layers (1mx1m) of voxel detectors - 0.1 cm separation
    - ideal calorimeter
    - (passive material on top of each tkr layer)

We want to build a routine to build and test different geometries changing some parameters:
   - Voxel size:
             * 10 mm
             * 5 mm
             * 3 mm
             * 1 mm
             * 0.5 mm
             * ... (enough to see the plateau)
   - Si thickness:
             * 300 um
             * 500 um
             * 700 um
   - passive material:
             * 1%
             * 2%
             * 5%
             * 10%

We want to test the different configurations for different energies:
             * 100 keV
             * 662 keV
             * 1000 keV
```

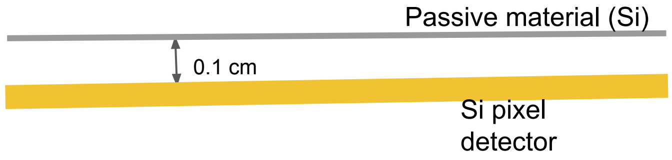


README.txt

```
Description of the files:
-------------------------

 * config.py -> where we declare the parameters we want to study

 * mkGeometries.py -> builds all the geometry configurations starting from base files
located in the geometry/geo_base/ folder.

 * mkSimulations.py -> Creates .source files from a base file located in the source/ folder
and produce a sh file with the list of the commands to run the simulations (for now the
simulations have to be run manually).

 * mkRecon.py -> Runs the reconstruction of the events with revan (according to the
configuration file declared in the config file).

 * mkARM.py -> Takes the revan output and produces .root files with the ARM histograms.

 * mkARManalysis.py -> Runs analysis routine.



How to run the routines:
------------------------

 >>> python mkGeometries.py -c config.py
 >>> python mkSimulations.py -c config.py -sim True
 >>> python mkRecon.py -c config.py
 >>> python mkARM.py -c config.py --show True
 >>> python mkARManalysis.py -c config.py
```

Config.py

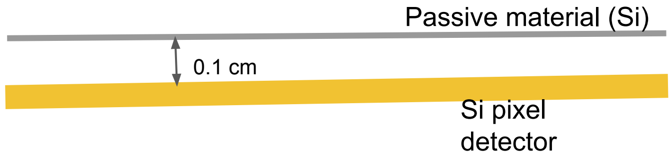
```
PASSIVE = [0.01, 0.02, 0.05, 0.1]
THICKNESS = [300, 500, 700] #um
VOXELSIZE = [10, 5, 3, 1, 0.5, 0.3, 0.1, 0.05, 0.01] #mm
ENERGY = [100, 662, 1000] #keV

GEO_BASE = 'geometry/geo_base/AstroPix_base.geo.setup'
DET_BASE = 'geometry/geo_base/AstroPix_base_prop.det'
SRC_BASE = 'source/FarFieldPointSource_base.source'

REVAN_CFG = 'source/FFPS.revan.cfg'
MIMREC_CFG = 'source/FFPS.mimrec.cfg'
```



Defines the pixel size (assumed squares)

Config.py

```
PASSIVE = [0.01, 0.02, 0.05, 0.1]
THICKNESS = [300, 500, 700] #um
VOXELSIZE = [10, 5, 3, 1, 0.5, 0.3, 0.1, 0.05, 0.01] #mm
ENERGY = [100, 500, 1000] #keV

GEO_BASE = 'geometry/geo_base/AstroPix_base.geo.setup'
DET_BASE = 'geometry/geo_base/AstroPix_base_prop.det'
SRC_BASE = 'source/FarFieldPointSource_base.source'

REVAN_CFG = 'source/FFPS.revan.cfg'
MIMREC_CFG = 'source/FFPS.mimrec.cfg'
```

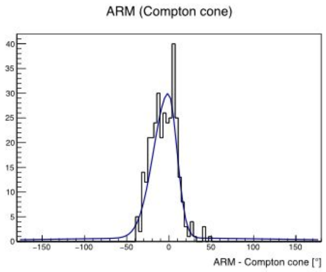


Defines the pixel size
(assumed squares)

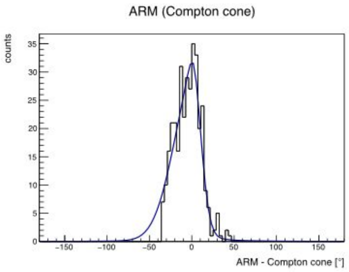
Angular Resolution Measure (ARM)

WE WANT TO ESTIMATE THE ARM AS A FUNCTION OF THE PIXEL SIZE (FOR THE DIFFERENT GEOMETRY CONFIGURATIONS VARYING THE PIXEL THICKNESS, % OF PASSIVE MATERIAL, AND FOR ENERGIES TESTABLE IN LAB)

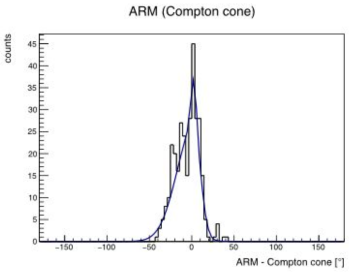
10mm



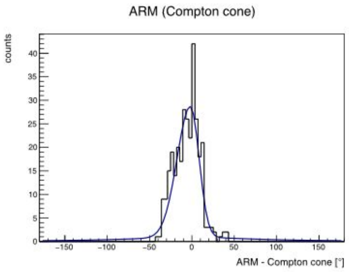
5mm



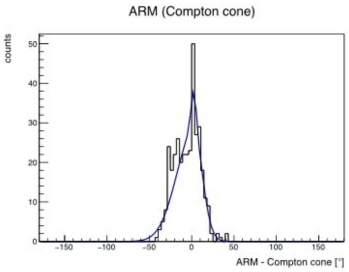
3mm

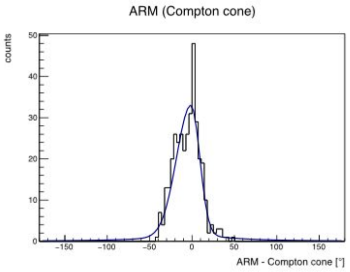


1mm

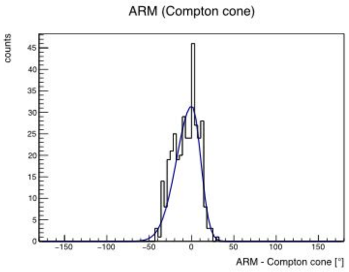


0.5mm

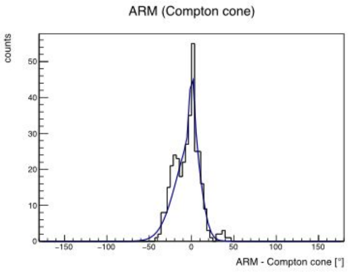




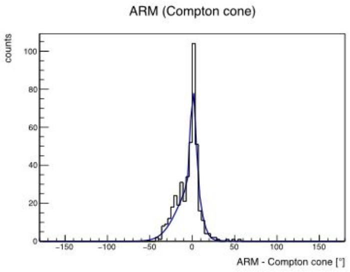
0.3mm



0.1mm

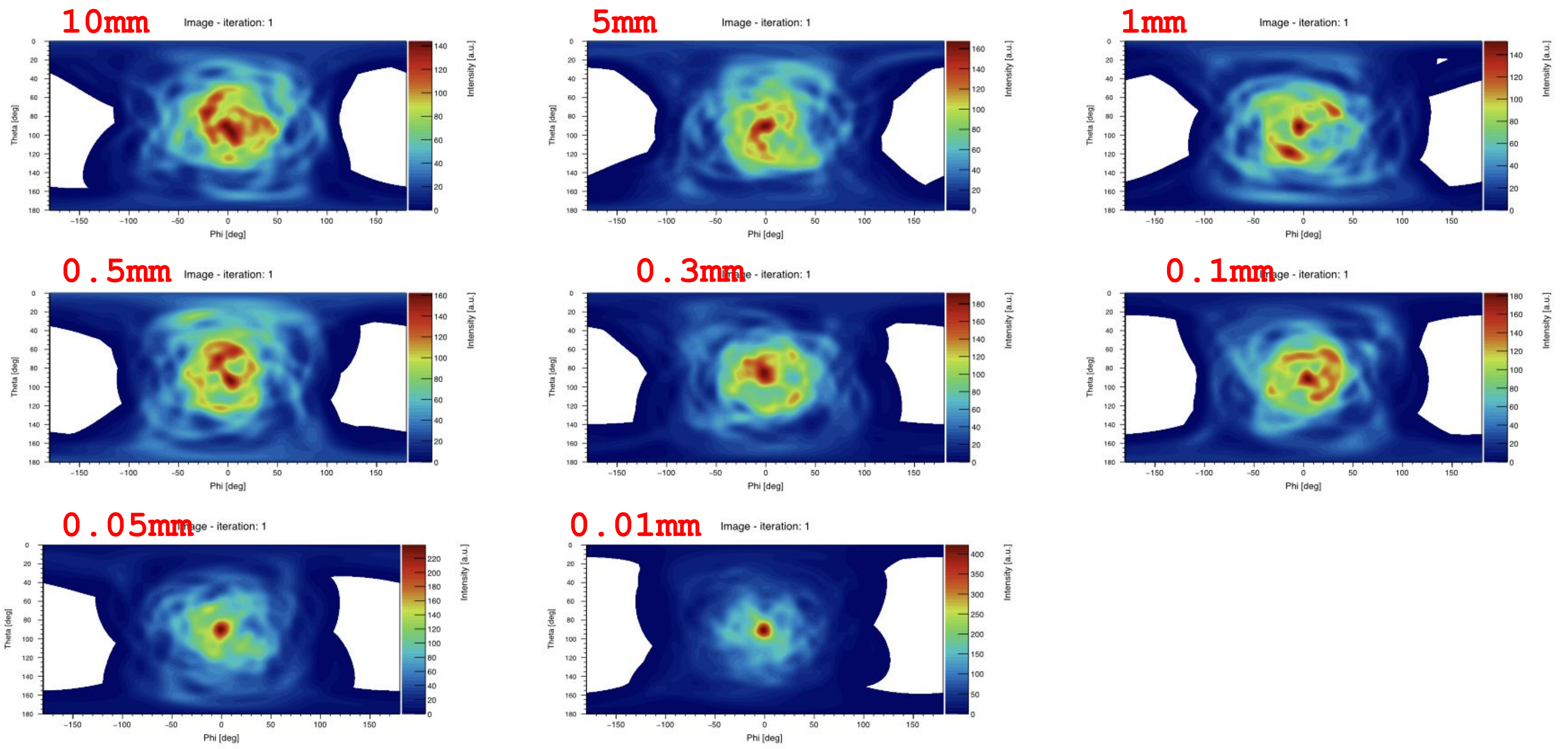


0.05mm



0.01mm

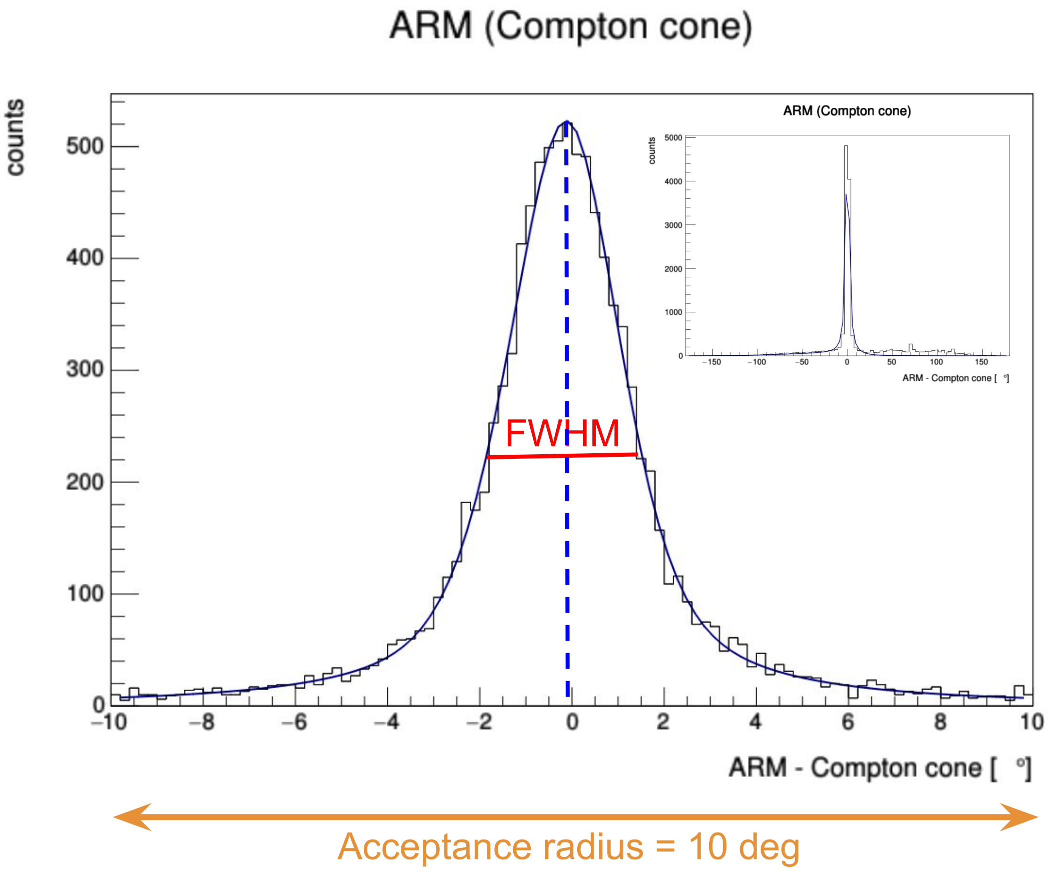
Image reconstruction (source = FarFieldPointSource)



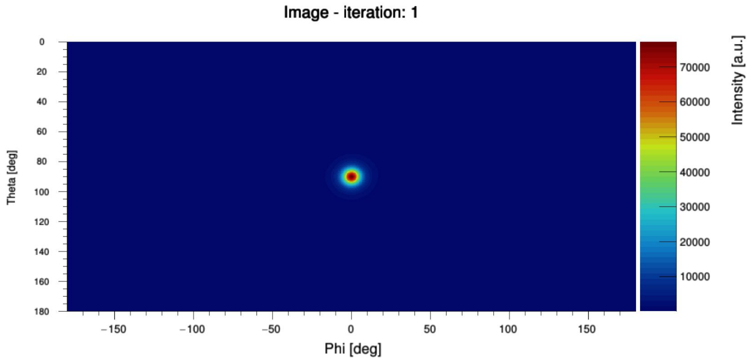
After reviewing the *mimrec* config file

Astropix Meeting 12/18/19

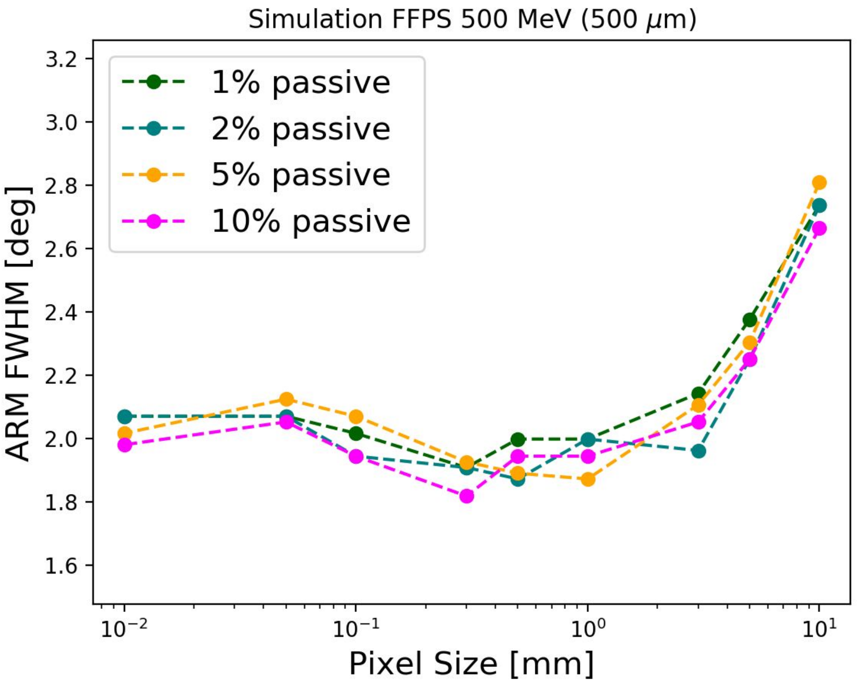
ARMs analysis

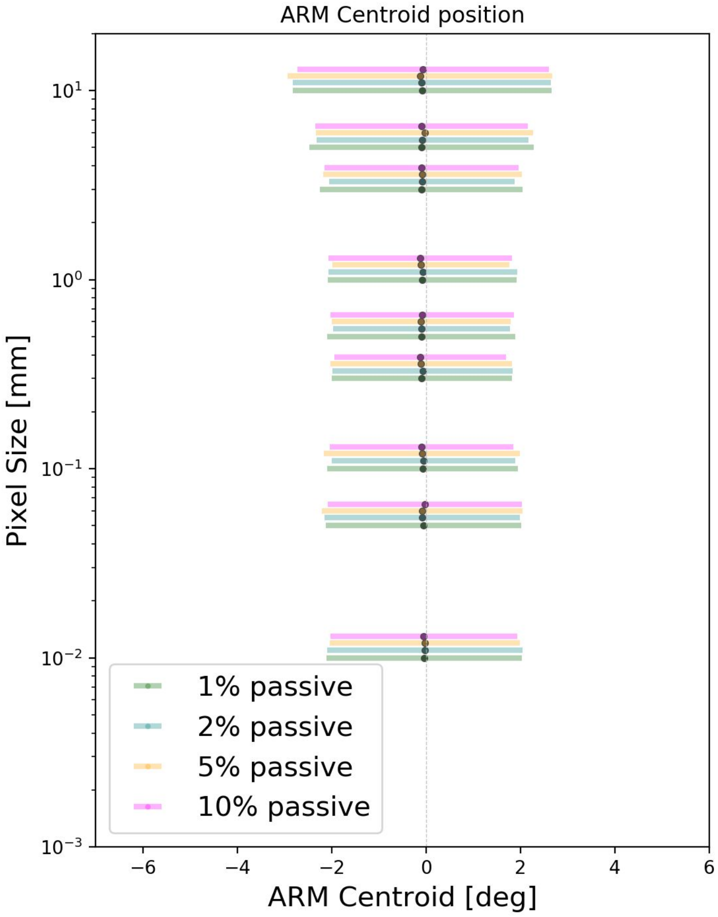



```
Statistics of ARM histogram and fit
***********************************

Analyzed Compton and pair events:         15713
Compton and pair events in histogram:     10115 (64.3734%)

RMS:                                      2.53623 deg

Total FWHM of fit (not of data!):        2.96992 deg
Maximum of fit (x position):             -0.124236 deg
(1-sigma uncertainty: -0.170549 deg ... -0.0763816 deg)
with maximum 523.247 cts
```

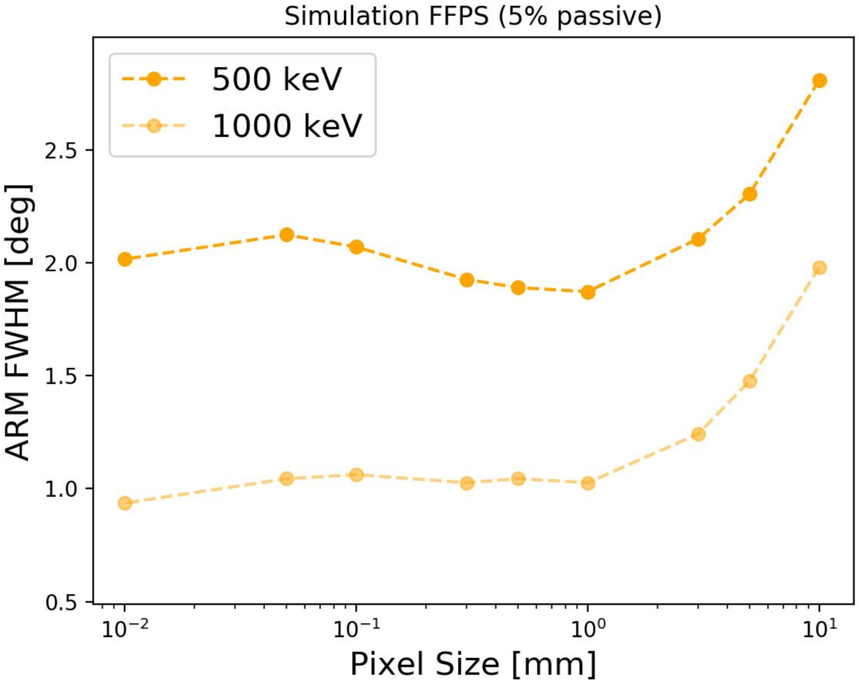


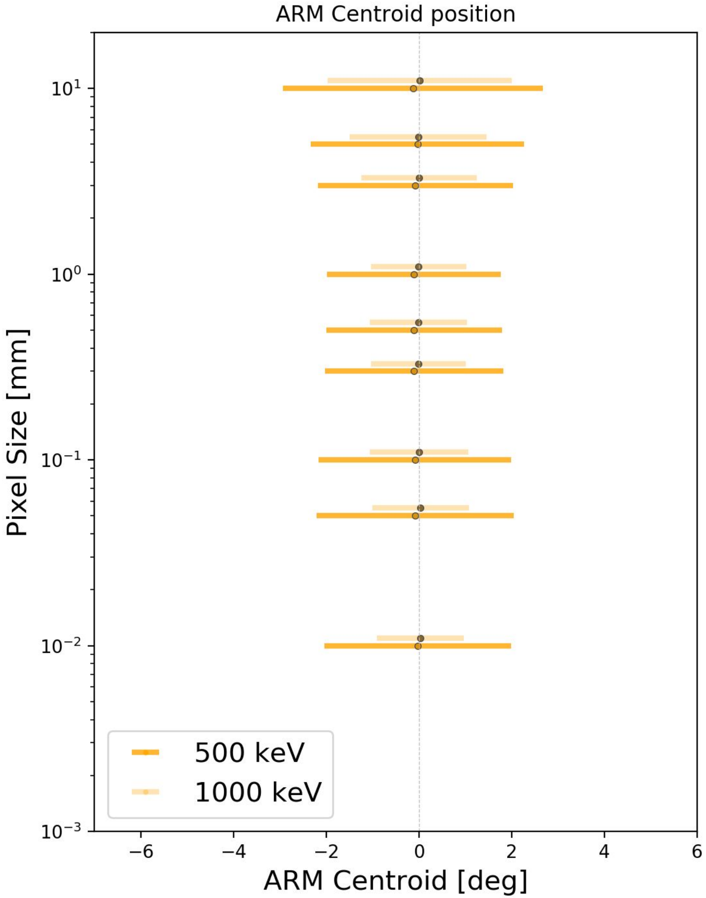
ARM as a function of passive % @ En=500keV





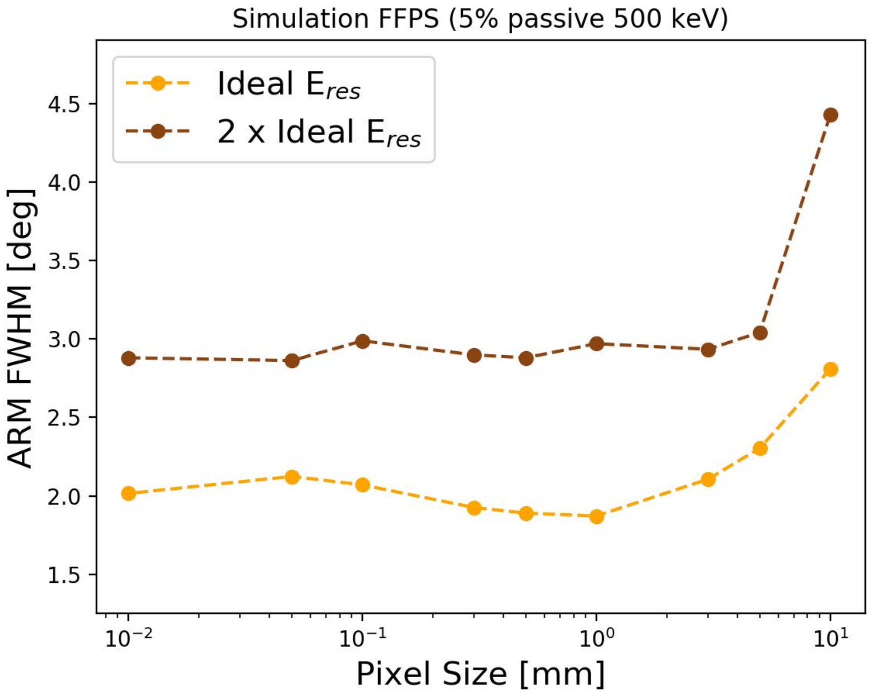
ARMs as a function of energy @ 5% passive

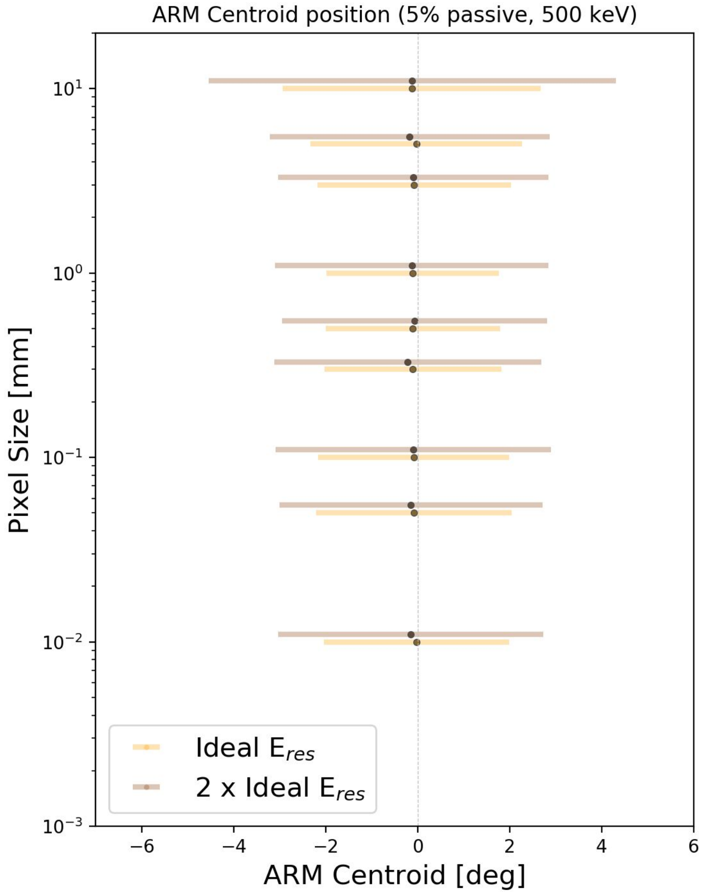




ARMs - worst energy res (X2) - 5% passive - 500keV

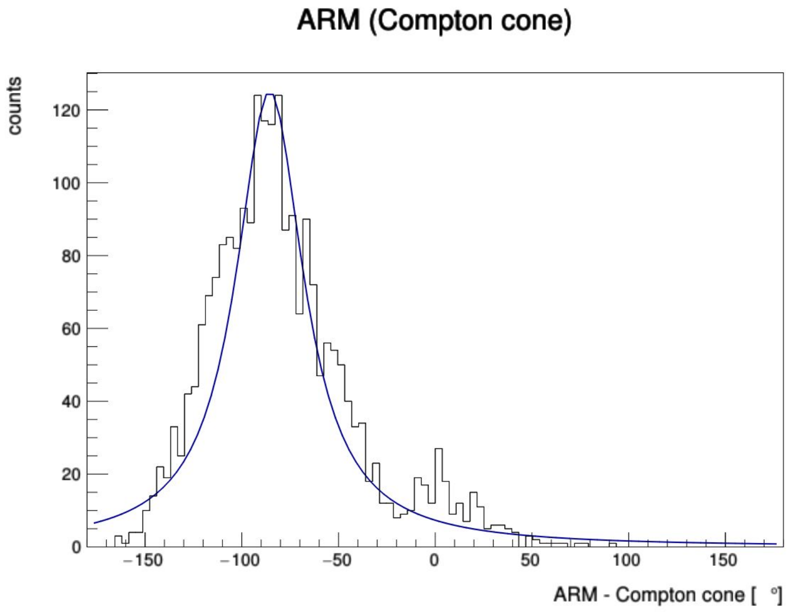
DSiPix.EnergyResolution Gauss 662 662 4.25 // (->8.5)
DSiPix.EnergyResolution Gauss 122 122 2.2 // (->4.4)

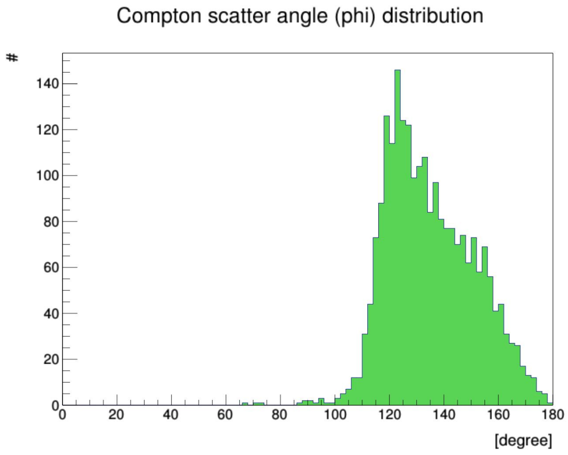


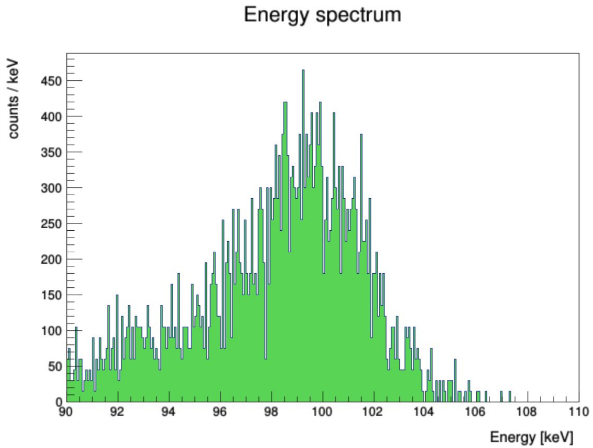


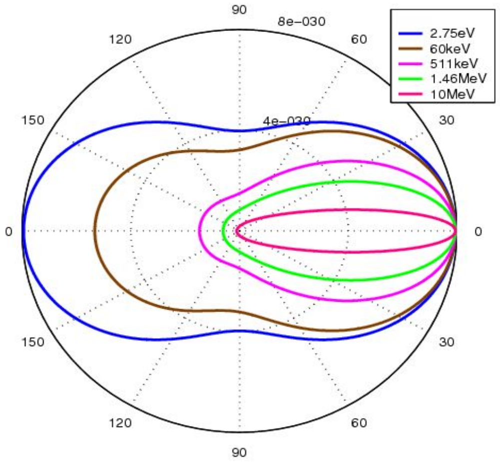
The strange case of the simulations @ 100 keV

Total FWHM of fit (not of data!): 42.6714 deg
Maximum of fit (x position): -85.5513 deg









The strange case of the simulations @ 100 keV

```
Event statistics for all triggered (!) events:
  Number of events .......................................  22488 (100.000%)
  Number of events, which passed event selections ........   2920 (
12.985%)
  Reconstructable events .................................  22488 (100.000%)
       Single-site  ......................................      0 (  0.000%)
       Compton  ..........................................   2915 ( 12.962%)
           Decay  ........................................      0 (  0.000%)
       Pair  .............................................      0 (  0.000%)
       Muon  .............................................      5 (  0.022%)
       PET . .............................................      0 (  0.000%)
       Multi  ............................................      0 (  0.000%)

Rejection reasons for not reconstructable events:
  Event consists of nothing but one track ................  16503
  Track is not valid .....................................    110
  Electron direction is not valid ........................     96
  Comptel type with incompatible kinematics ..............   2859
    Total ................................................  19568
```

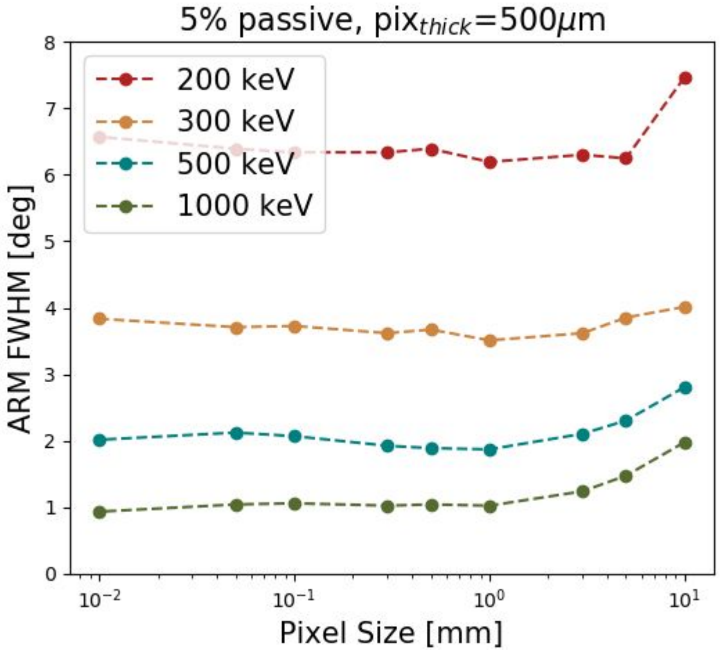
After meeting on 12/18/19

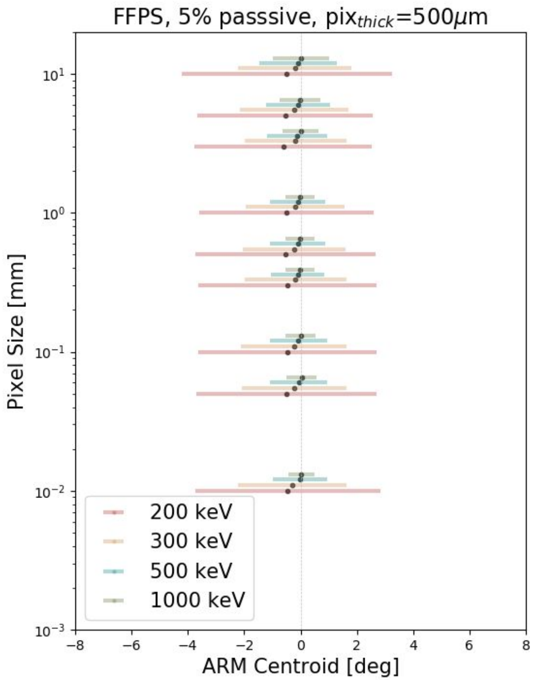
Astropix Meeting Jan. 2020

ARMs as a function of energy @ 5% passive

For ideal energy resolution!
DSiPix.EnergyResolution Gauss 662 662 4.25
DSiPix.EnergyResolution Gauss 122 122 2.2

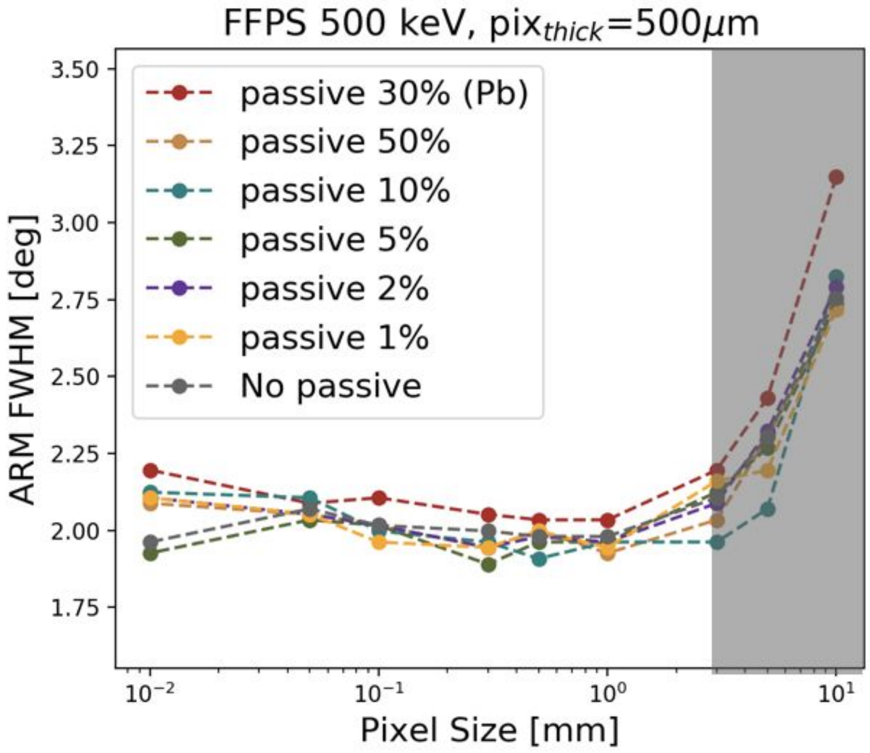
(see slide 13 for worse energy resolution case)





ARMs FWHM

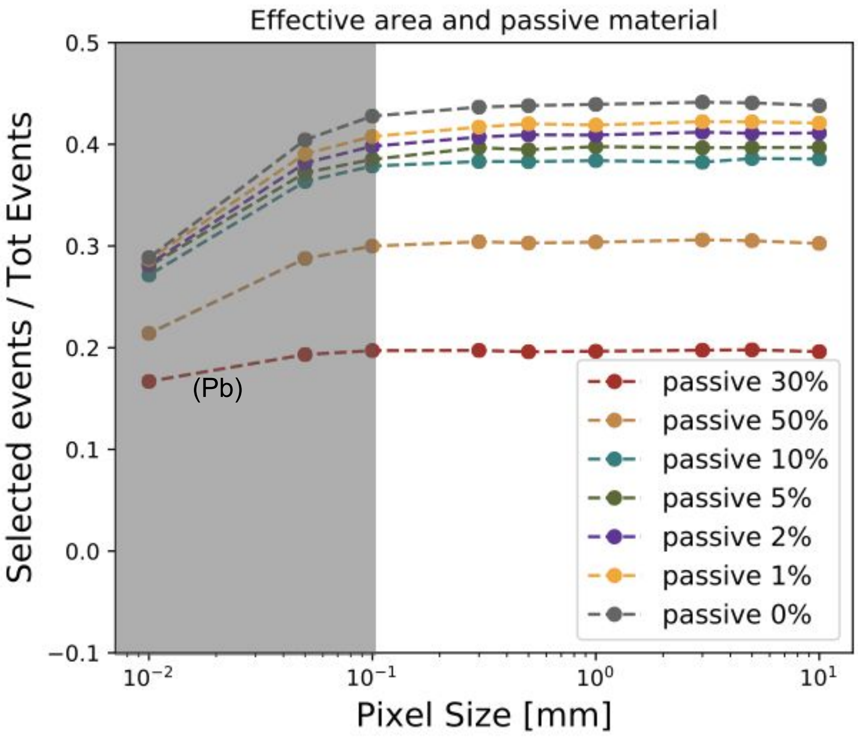
Loss in the spatial resolution when pixels are too large (Apix > 3 mm2)



Effective Area and passive material

Loss in the effective area for small pixels:

- bad reconstruction due to non-optimized algorithm?
- Too small energy loss to trigger a signal in a pixel?

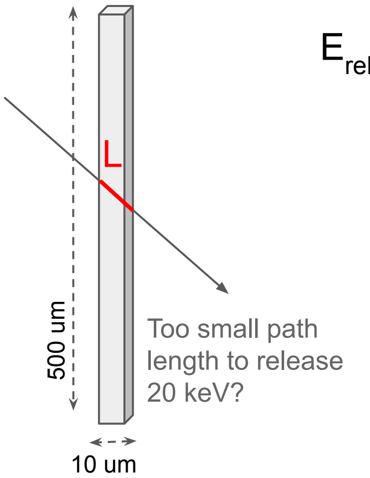


Effective Area and passive material

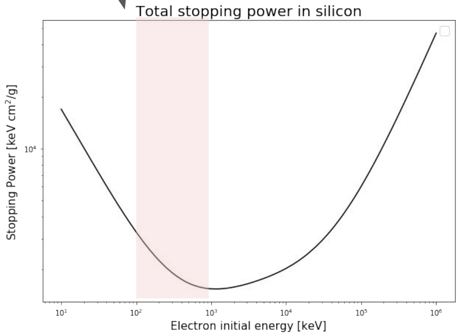
Loss in the effective area for small pixels:

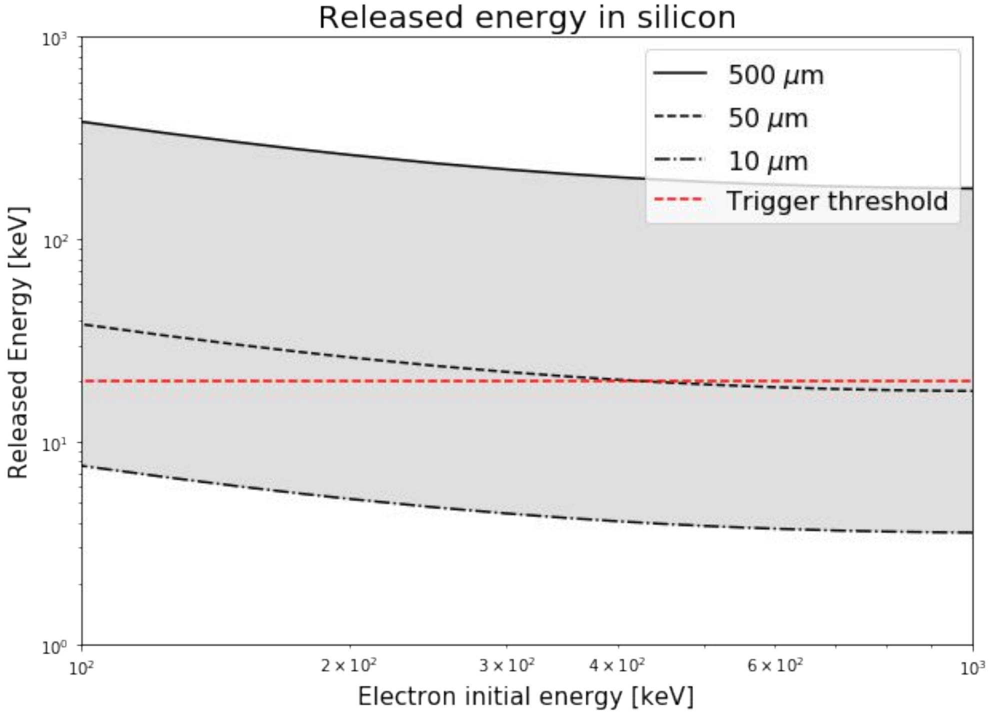
- bad reconstruction due to non-optimized algorithm?
- Too small energy loss to trigger a signal in a pixel?

DSiPix.TriggerThreshold 20



E_{rel}[keV] = SP[keV cm^2/g]*L_{Si}[g/cm^2]

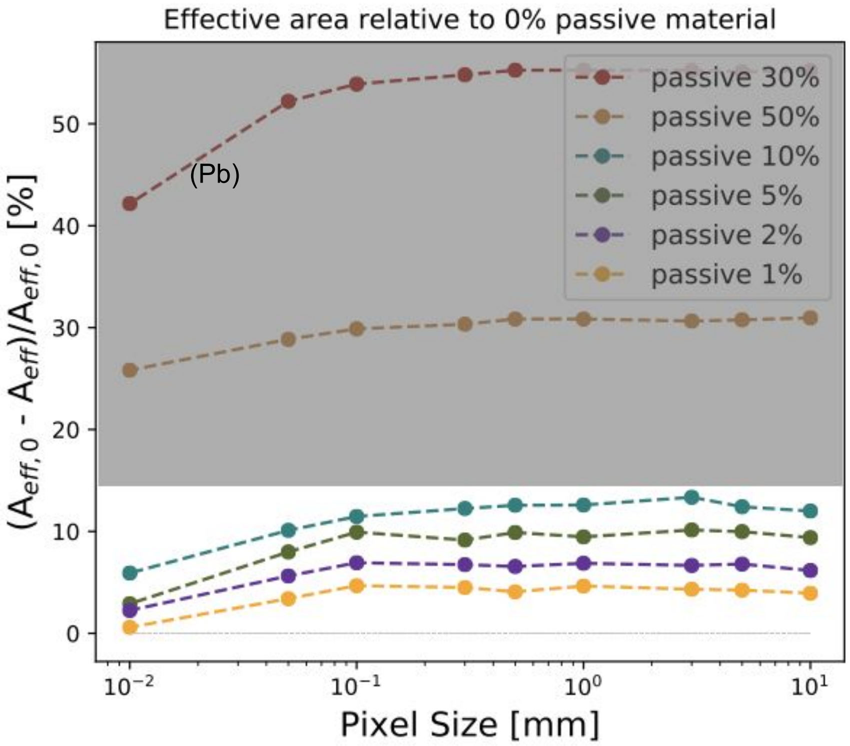




https://physics.nist.gov/PhysRefData/Star/Text/ESTAR.html

Effective Area relative to the “No passive material” case

Compared to the case w/o passive material:
- up to 10% (Si) passive material the loss in effective area stays below 15%



Conclusions - parameters optimization

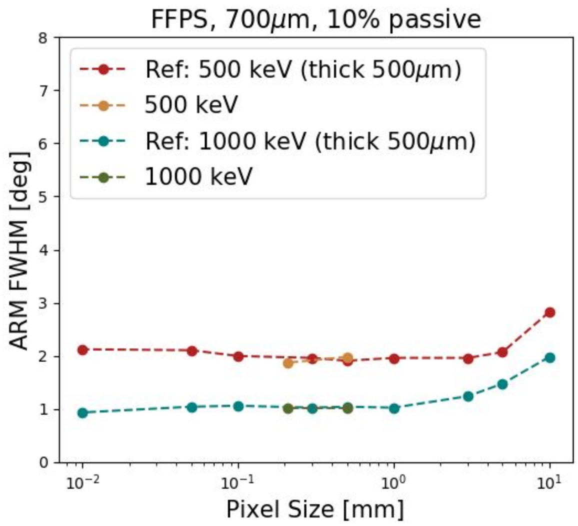
$100\ um^2 < Pix_{size} < 3\ mm^2$

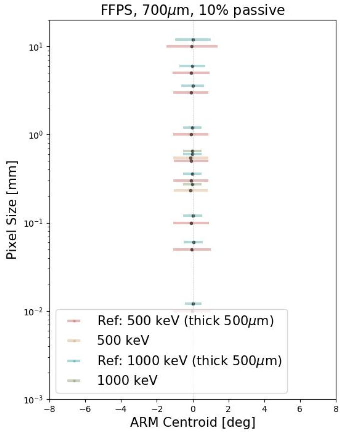
Passive material (Si) < 10%

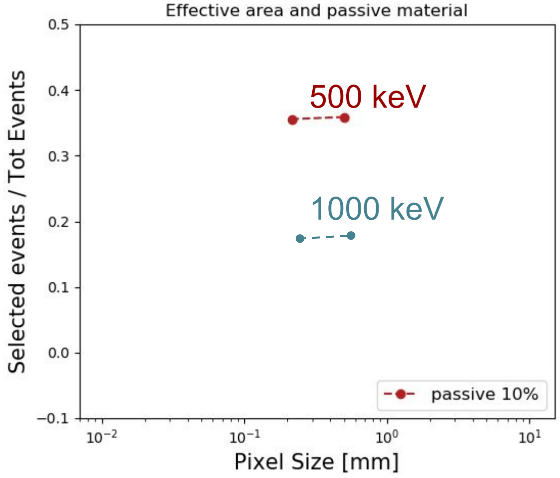
Minimum energy > 300 keV

After meeting on 02/18/20

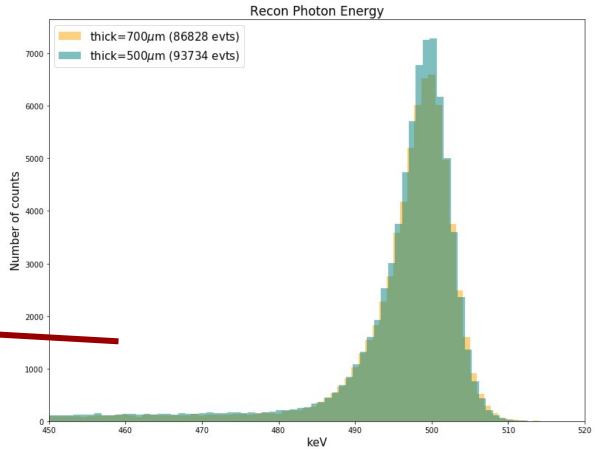
Thicknesses tests

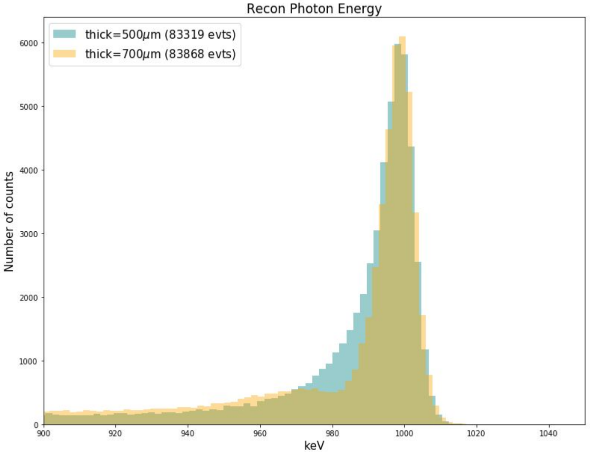






Comparison between 500um and 700 thick pixels (both 0.5x0.5 mm and 10% passive material, with simulated FFPS @ 500keV/ 1000keV)





Passive material study @ 200keV