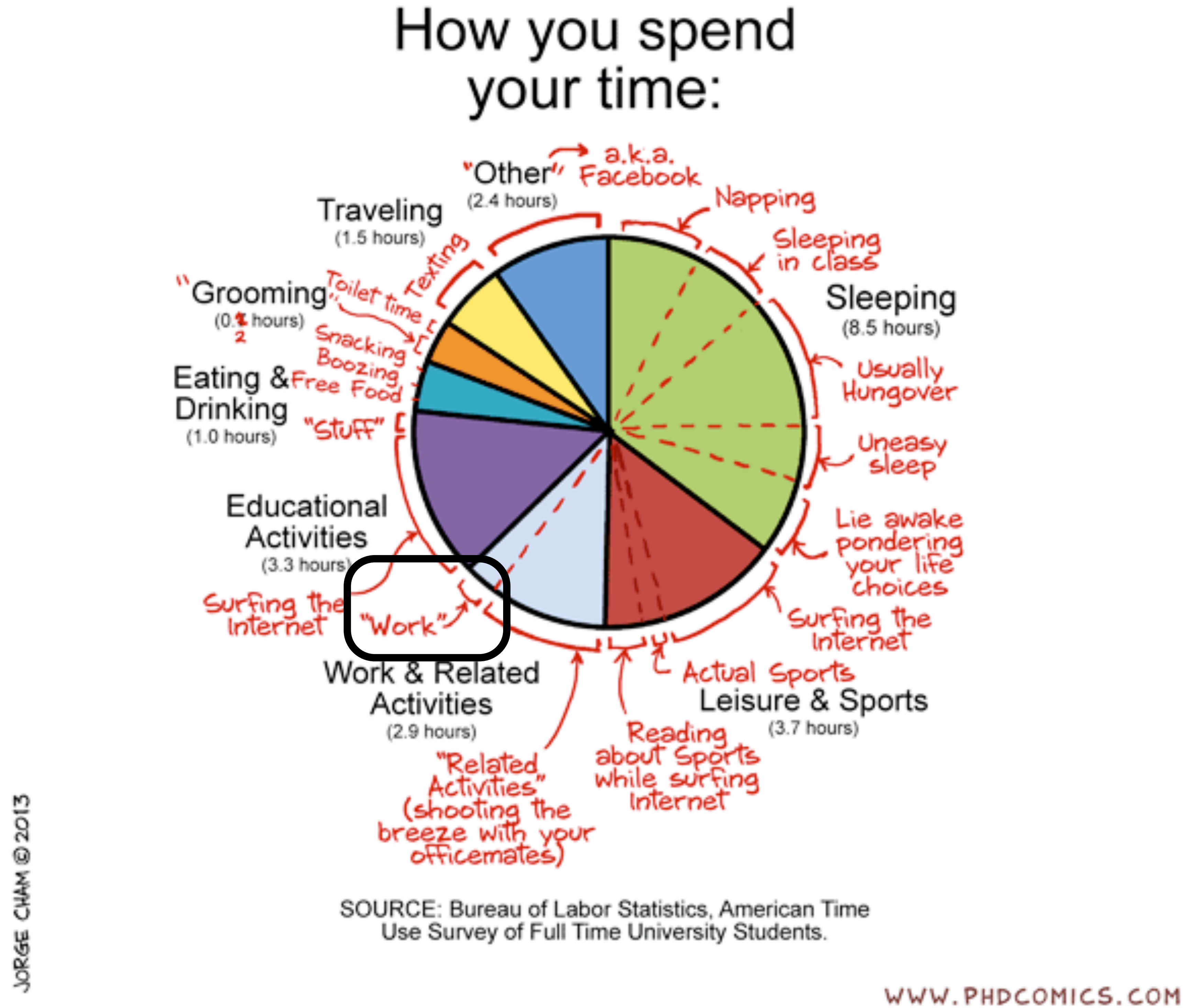


Alberto Remoto

remoto@in2p3.fr

Laboratoire d'Annecy-le-vieux de Physique des Particules

Introduction

Target: study and optimise foil source design

Fist step:

- Simple but flexible framework design (Geant4 stand-alone)
- Identify important source parameters:
    - **Mean energy loss**
    - **RMS energy loss**
    - Backgrounds

Second step:

- Integrate in SuperNEMO offline code
- Convolve with detector response
- Sensitivity studies

Similar studies has been done in 2007 (Vladimir Vassiliev, UCL, DocDB 433-v1) but details on source parameters are not specified...

Start from scratch, focusing on accurate source design

Details on foil materials

```
Thickness: 130 um
PVA fraction: 0.2
Surface Density: 50 mg/cm2
Density: 3.86 g/cm3
Material: Foil Source    density:  3.860 g/cm3   RadL:    3.716 cm   Nucl.Int.Length:   32.510 cm   Imean: 231.803 eV
Element: PureSe 82 (Se)    Z = 34.0    N =   82.0    A =  81.92 g/mole
---> Isotope: Se_82    Z = 34    N =  82    A =  81.92 g/mole    abundance: 100.00 %
 ElmMassFraction:   80.00 %  ElmAbundance  23.51 %

Element: H (H)    Z =   1.0    N =    1.0    A =    1.01 g/mole
---> Isotope:     H1    Z =  1    N =   1    A =    1.01 g/mole    abundance:  99.99 %
---> Isotope:     H2    Z =  1    N =   2    A =    2.01 g/mole    abundance:   0.01 %
 ElmMassFraction:    1.83 %  ElmAbundance  43.71 %

Element: C (C)    Z =   6.0    N =   12.0    A =   12.01 g/mole
---> Isotope:    C12    Z =  6    N =  12    A =   12.00 g/mole    abundance:  98.93 %
---> Isotope:    C13    Z =  6    N =  13    A =   13.00 g/mole    abundance:   1.07 %
 ElmMassFraction:   10.91 %  ElmAbundance  21.86 %

Element: O (O)    Z =   8.0    N =   16.0    A =   16.00 g/mole
---> Isotope:    O16    Z =  8    N =  16    A =   15.99 g/mole    abundance:  99.76 %
---> Isotope:    O17    Z =  8    N =  17    A =   17.00 g/mole    abundance:   0.04 %
---> Isotope:    O18    Z =  8    N =  18    A =   18.00 g/mole    abundance:   0.20 %
 ElmMassFraction:    7.26 %  ElmAbundance  10.93 %
```

Input parameters

Computed by G4

Foil material

Flexible geometry:

- Foil dimension (cm)
- **Thickness (mg/cm)**
- **PVA fraction**
- **Other parameter derived from above (density, ...)**
- Next step: add fishing wires (foil mechanical support)

Detail particle gun

Particle gun:

- 1 MeV Electron in the source center -> "See" only 1/2 Thickness
- Perpendicular direction w.r.t foil

Next step -> more clever gun: random position in the foil and random direction

Standard EM list:

- Gamma:
  - Photoelectric effect
  - Compton scattering
  - Gamma conversion
  - Pair production
- Electron & Positron:
  - Multiple scattering
  - Ionisation
  - Bremmsstrahlung

Min Cut: 1 um (default ~1 mm)

dE/dx binning 12x10 (default 12x7)

Pure Se

Thickness

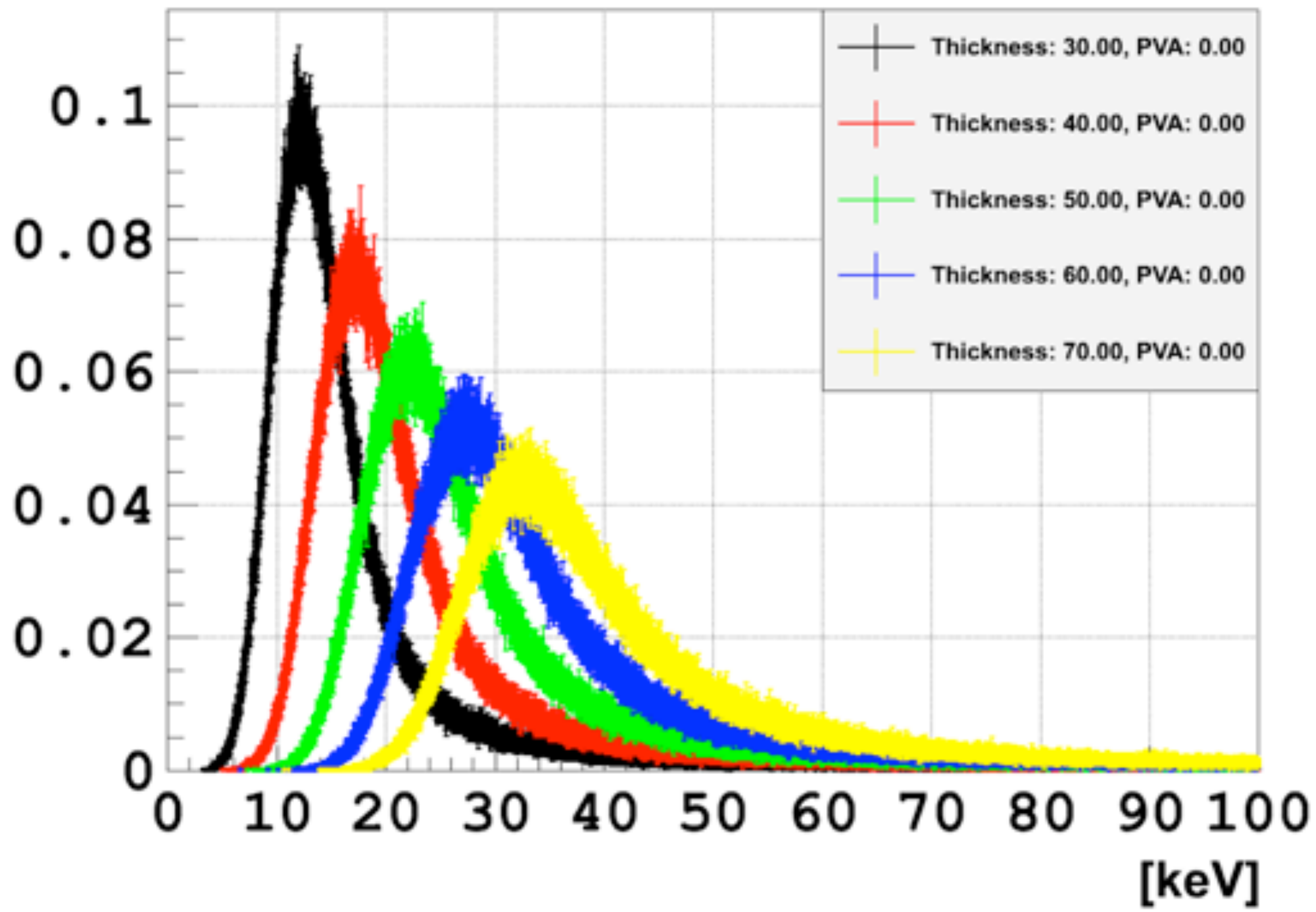
Linear Thickness

Surface density [mg/cm2]	Volume density [mg/cm3]	Thickness [um]	PVA f [--]	Mean E loss [keV]	Mean dE/dx [keV/mg/cm2]
30.00	4500.00	66.67	0.00	16.73 +/- 10.57	1.12 +/- 0.70
40.00	4500.00	88.89	0.00	22.60 +/- 12.02	1.13 +/- 0.60
50.00	4500.00	111.11	0.00	28.55 +/- 13.08	1.14 +/- 0.52
60.00	4500.00	133.33	0.00	34.50 +/- 13.74	1.15 +/- 0.46
70.00	4500.00	155.56	0.00	40.52 +/- 14.18	1.16 +/- 0.41

Mean value

RMS

Simple calculation



By increasing foil thickness:

- Rather constant dE/dx as should be
- **Increase** mean energy loss
- **Increase** mean energy loss RMS

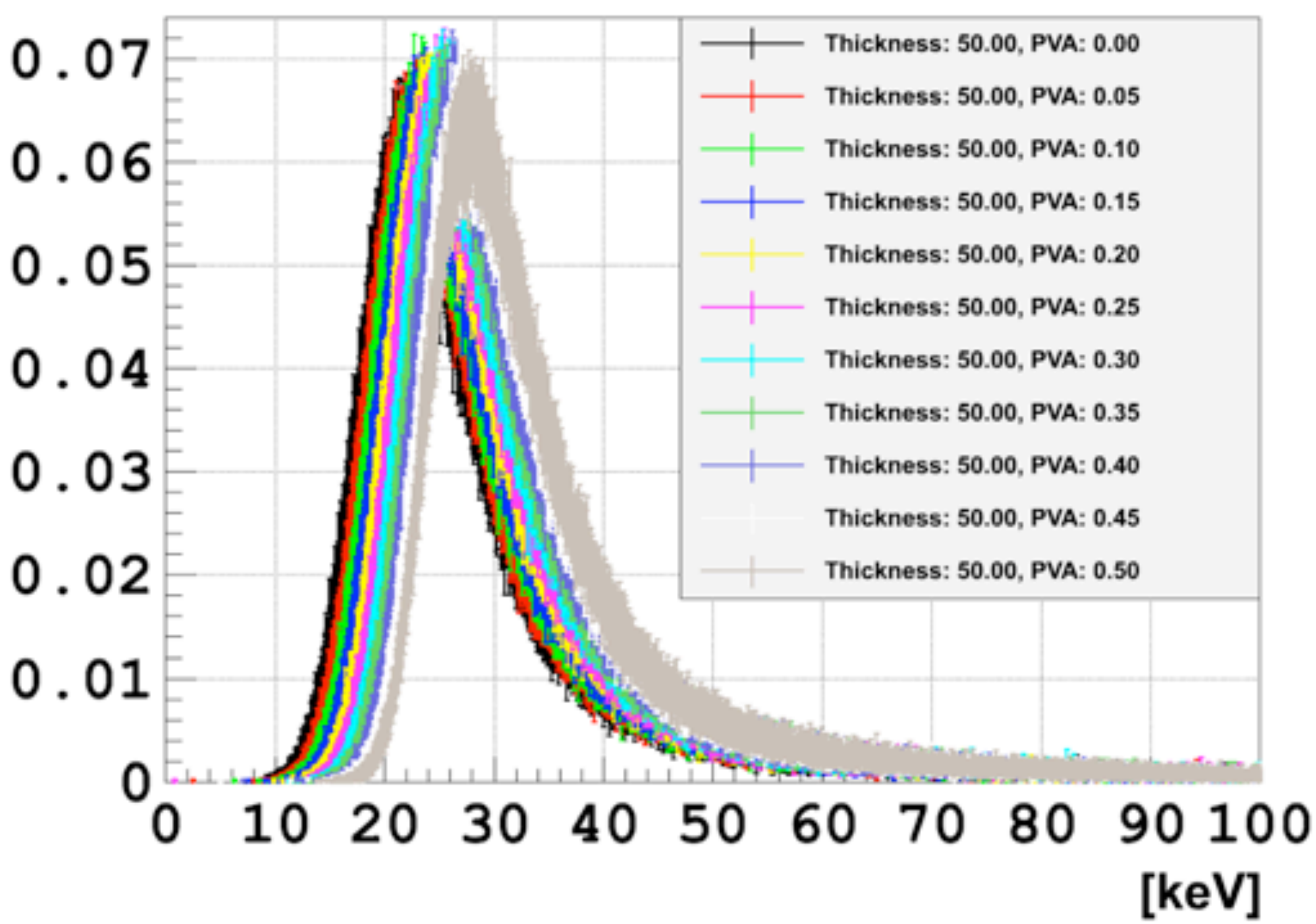
PVA/Se mix

I'm decreasing fraction of Se

Thickness

Linear Thickness

Surface density [mg/cm2]	Volume density [mg/cm3]	Thickness [um]	PVA f [--]	Mean E loss [keV]	Mean dE/dx [keV/mg/cm2]
50.00	4500.00	111.11	0.00	28.55 +/- 13.08	1.14 +/- 0.52
50.00	4340.00	115.21	0.05	29.11 +/- 12.90	1.16 +/- 0.52
50.00	4180.00	119.62	0.10	29.69 +/- 12.80	1.19 +/- 0.51
50.00	4020.00	124.38	0.15	30.31 +/- 12.75	1.21 +/- 0.51
50.00	3860.00	129.53	0.20	30.94 +/- 12.67	1.24 +/- 0.51
50.00	3700.00	135.14	0.25	31.54 +/- 12.60	1.26 +/- 0.50
50.00	3540.00	141.24	0.30	32.15 +/- 12.53	1.29 +/- 0.50
50.00	3380.00	147.93	0.35	32.82 +/- 12.57	1.31 +/- 0.50
50.00	3220.00	155.28	0.40	33.40 +/- 12.45	1.34 +/- 0.50
50.00	3060.00	163.40	0.45	34.04 +/- 12.43	1.36 +/- 0.50
50.00	2900.00	172.41	0.50	34.67 +/- 12.39	1.39 +/- 0.50

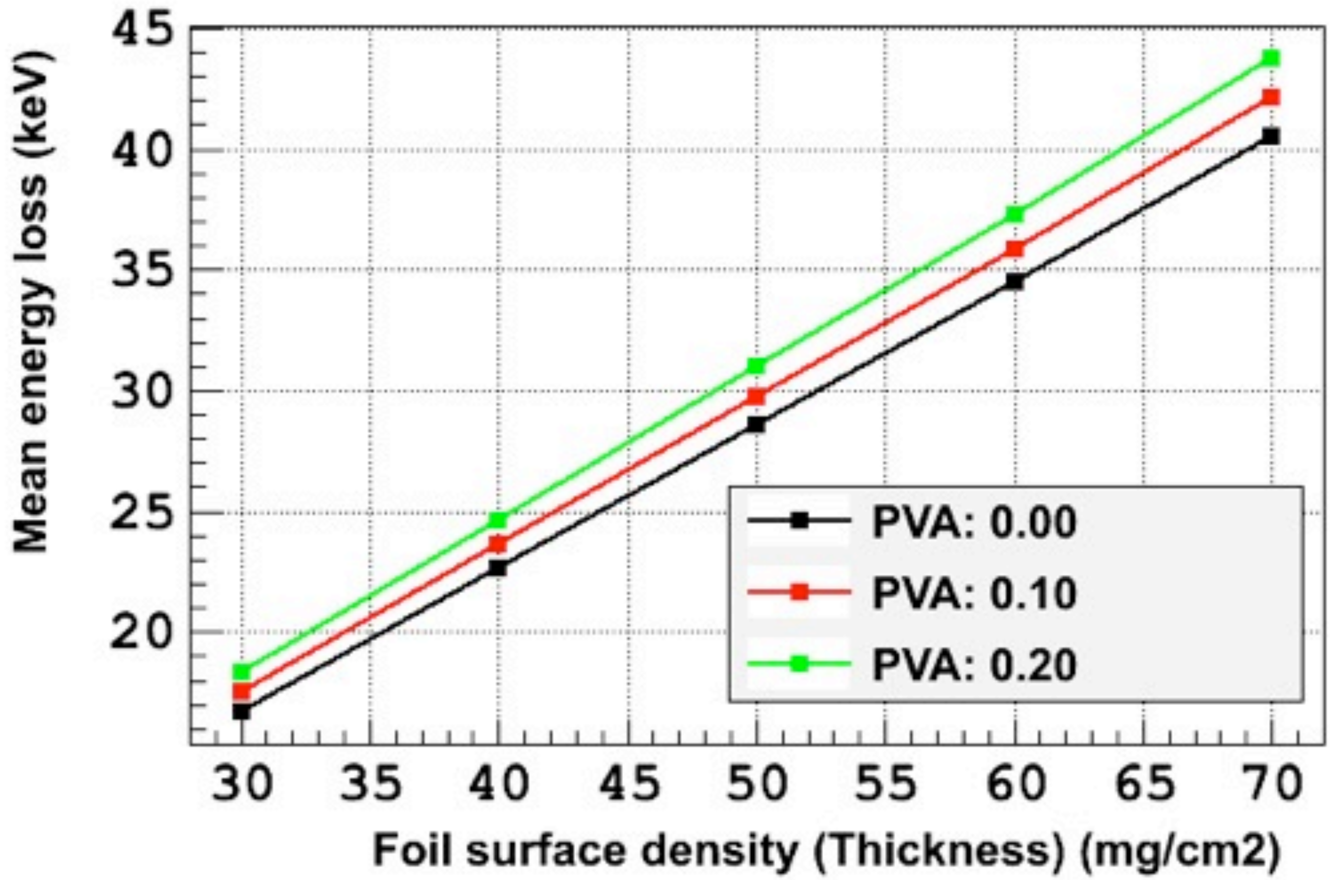


	I (eV)	Z/A
Se	348.0	0.41
PVA	69.7	0.54
Mix @ 10 %	76.6	0.42

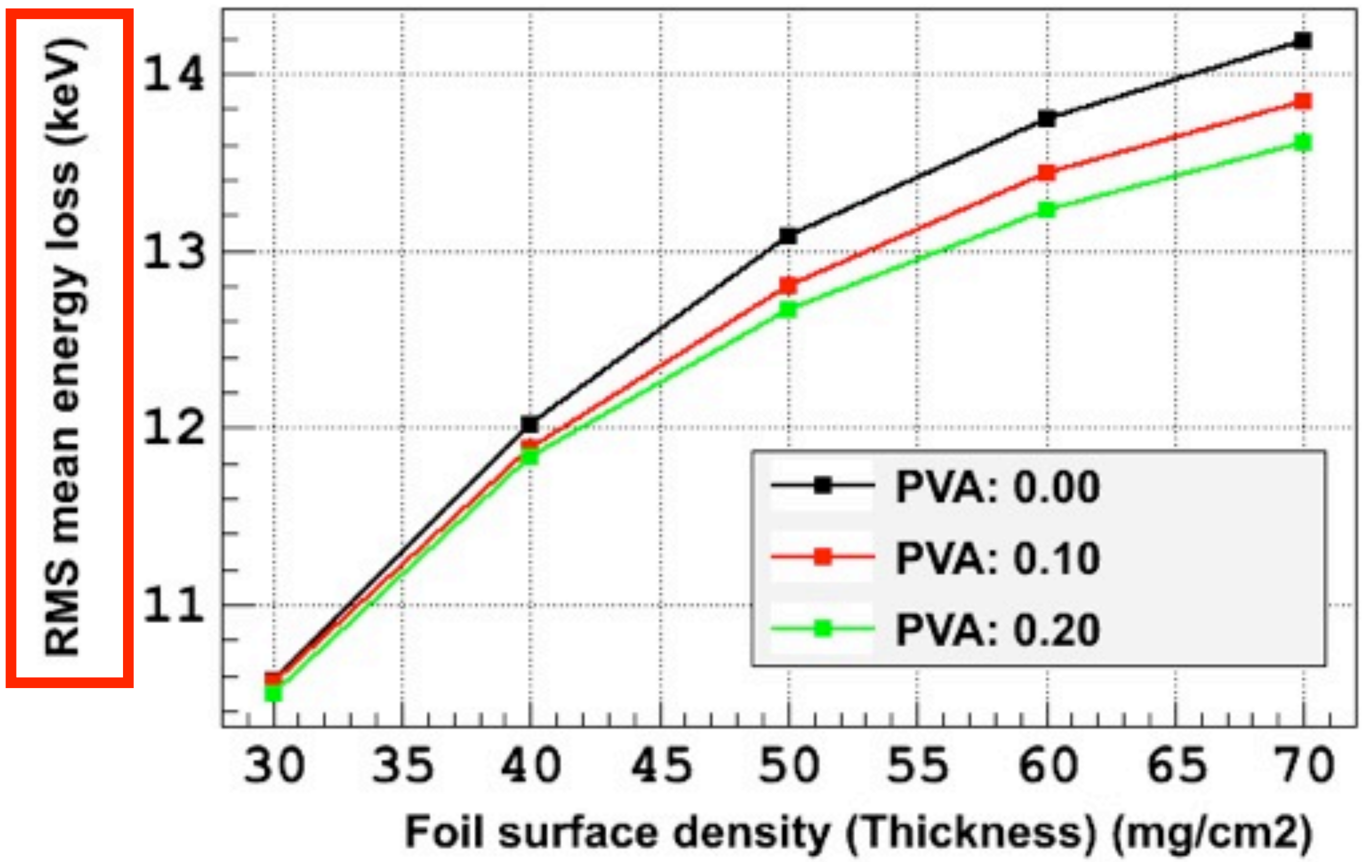
By adding PVA:

- **Increase** dE/dx (**increase** Z/A ?)
- **Increase** mean energy loss
- **Decrease** mean energy loss RMS (?)

Energy loss vs thickness



impact energy measurement



Most important parameter (?)

impact on energy resolution

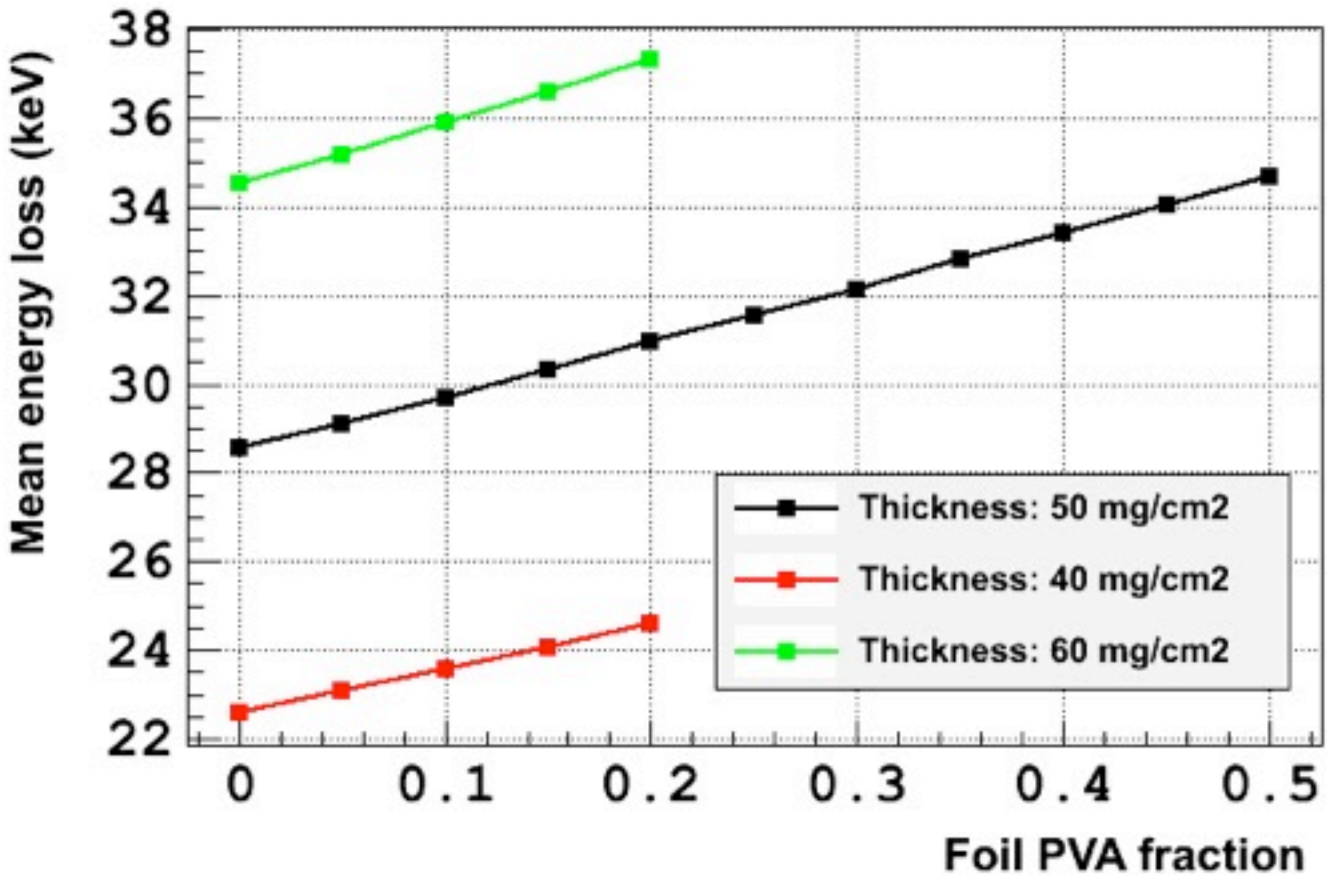
$\langle E_{RMS}/T \rangle \approx$ a-b Ln(T)

I should consider FWHM

$\Delta E_{foil} \approx$ 1.2 -1.3 % @ 50 mg/cm²

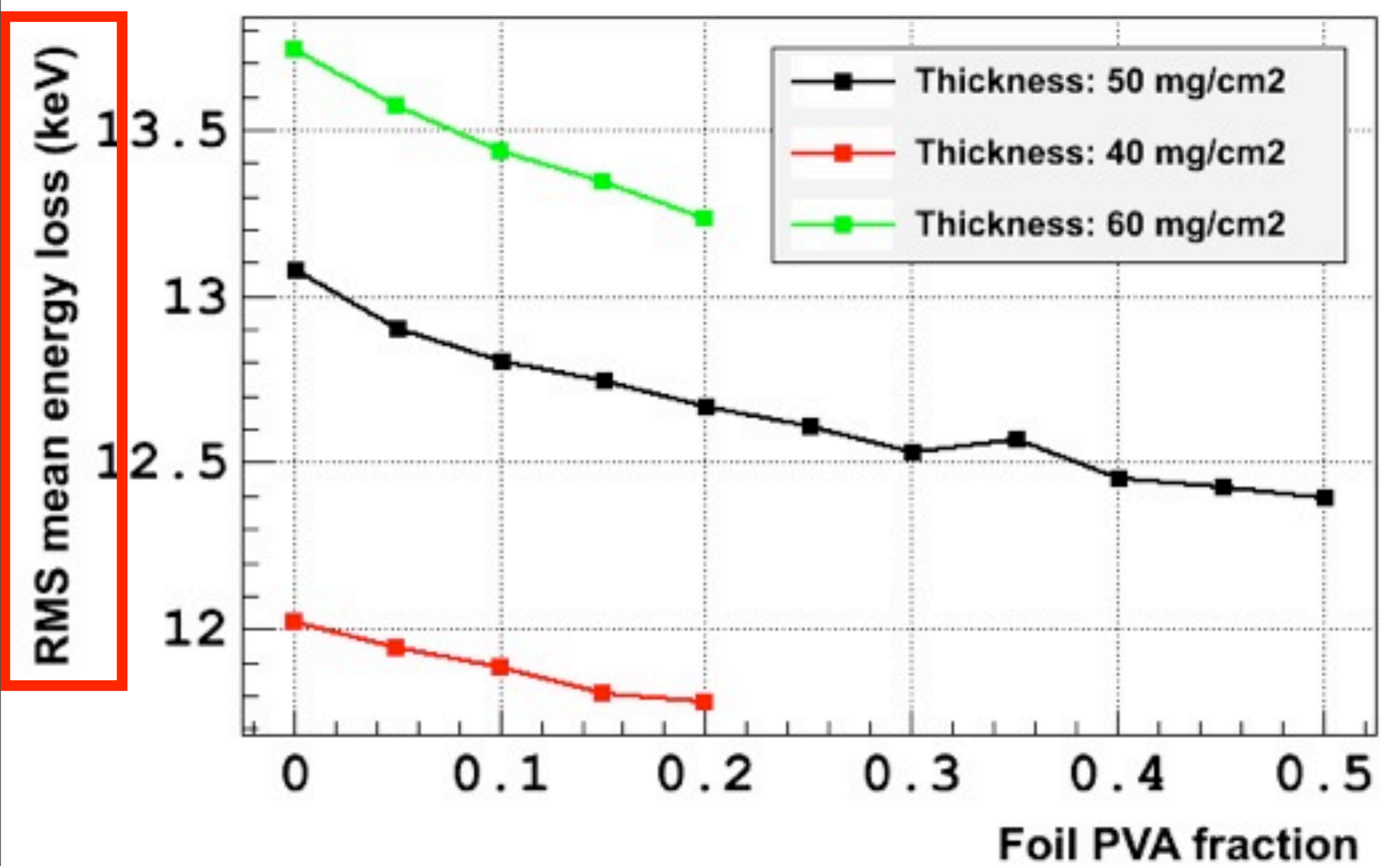
Expected to increase when considering e- in the whole foil volume with random direction....

Energy loss vs PVA fraction



T [mg/cm²]	⟨dE/df$_{PVA}$⟩ [keV/0.01]
40	**0.9**
50	**1.2**
60	**1.4**

Most important parameter (?)
impact on energy resolution



$\Delta E_{foil} \approx$ 1.2 - 1.4 % @ 10 % PVA

Expected to increase when considering e- in the whole foil volume with random direction....

Expected to get worse when considering background: more material more background?

Summary

That's it for the moment, but let's go through next steps:

- Particle gun: event randomly generated in the whole source with random direction
- Foil geometry: add fishing wires
- Analysis:
  - Mean energy loss and RMS from fit of the distribution
  - Secondary production probability (towards backgrounds studies)?
- Energy RMS most important parameter identified up now → impact on calorimetric energy resolution!

What about other parameter?

Background make signal worse → impact the sensitivity

- Some background depends from the foil
- Internal foil contamination on Bi & Tl
- External radon surface contamination
- Gamma conversions, Moller scattering, fast neutrinos, ..

High rapidity and good energy resolution helps

Which the impact of foil design and composition?

Needs dedicated background generators?

- At some point probably better converge with SuperNEMO code