Source foil design studies

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The SuperNEMO experiment

0νββ with calo-track technique @ LSM:

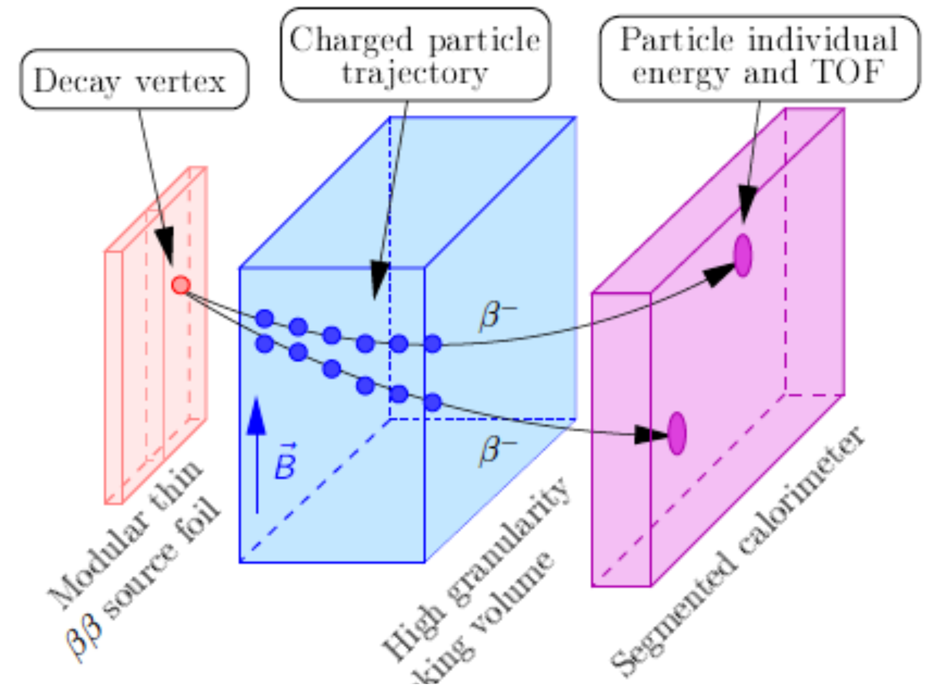
- Tracker + calorimeter + magnetic fiels: full kinematic
- Detector ≠ from ββ emitter: optimise isotope choice

Exploit a well known technique (NEMO3)

- Increase ββ emitter mass up to ~100 kg
- Improve detection technique and reduce background

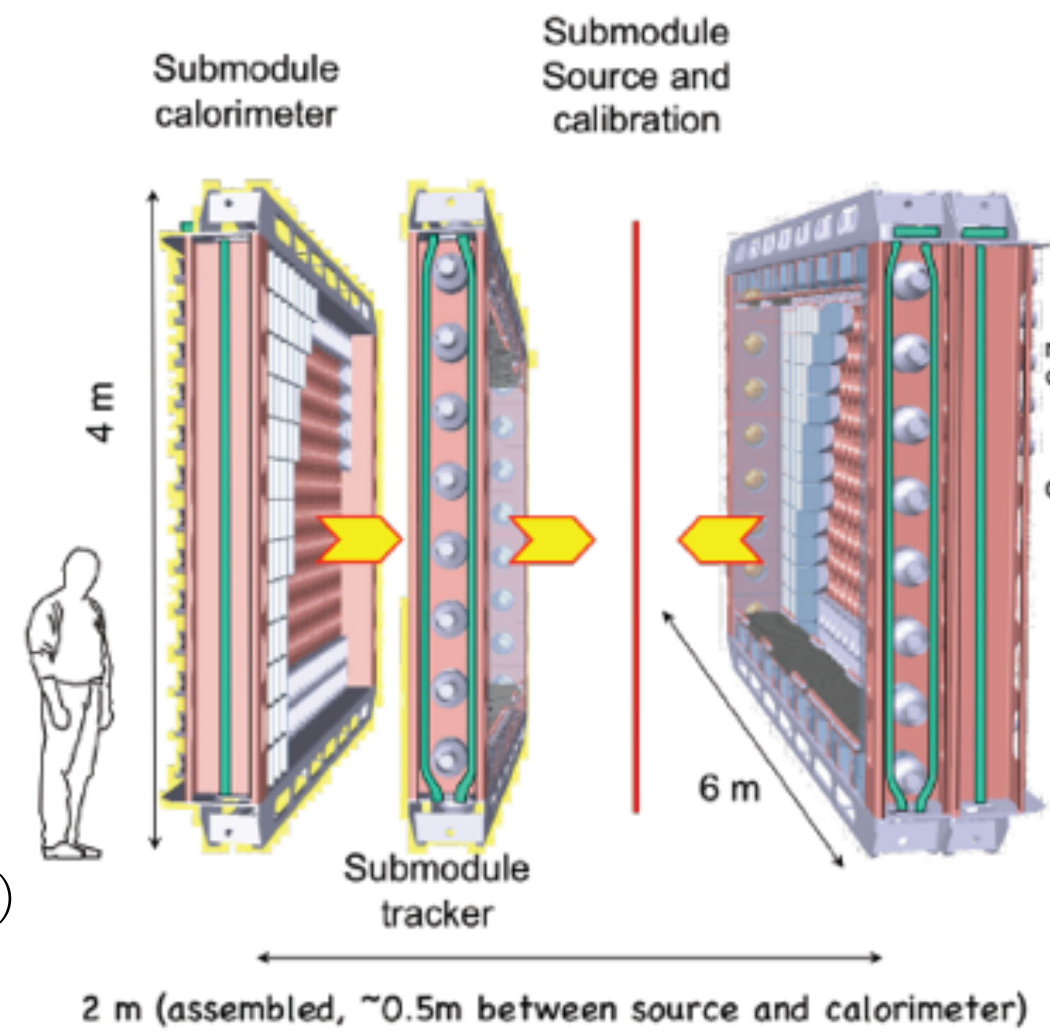
Goal: background free measurements in 5 years

- Improve current limits by factor ~100



The demonstrator module

- 1 module with 7 kg ^{82}Se
- Match SuperNEMO's radio-purity requirements
- Less than 0.2 background events in search region with in 3yrs
- Achieve competitive sensitivity:
  - NEMO3 (100Mo) in 4.5 months
  - By 2017: $T_{1/2}^{0\nu} > 6.5\times10^{24}$ yr



LAPP responsibilities:

- Produce half of the ββ foil sources for Demonstrator module (this talk)
- Slow control system development (next talk)

- Goal of the study
- Present general strategy
- Some useful figure of merits (FOM)
- Some preliminary results

Kick off

Goal of the study

Source foil design is **not completely frozen** yet:

- Foil geometry frozen (see ex. DocDB 2589 Marek)
- Sensitivity studies set some target values
  - Thickness, ^{208}Tl & ^{214}Bi max activity, others (?)
- No detailed foil composition yet ==> how do we produce it?

Let's have a **look at the details** and try to **come out with a proposal**:

- Which are those details?
- How to proceed?

A look to the detail

Starting from NEMO3 composite foil design

- ββ isotope mixed with Polyvinyl-Alcohol (PVA)
- 2 Mylar backing film for mechanical support

Few simple parameters come to mind:

(1) Foil thickness

(2) Fraction of PVA mix

(3) Type of mechanical support

  - Mylar backing films, central mesh, fishing wires

Keeping in mind target parameters already defined ==>

==> Let's define the design from scratch for SuperNEMO w.r.t

- **Detector performances:** dedicated MC studies (this work)
- **Production procedure:** dedicated R&D on going @ LAPP (but not only)

How to proceed

Let's start simple:

(1) Identify some figure of merits (FOM) related to detector performances

(2) Let's study how such FOM behave w.r.t. source parameters

(3) Come up with a preliminar proposal

In parallel : x-check feasibility with R&D test

In a next (future) step ==> detailed sensitivity study

From the technical point of view:

- MC simulation with **SN@ilWare** framework, legacy version:
  - Cadfael-0.2.3 ; Bayeaux-0.9.4 ; Falaise-0.2.1
  - Custom module to produce ROOT output (sncore ex05)

Figure of merits

(1) Study electron generated in source foil

- Distribution of electron energy loss ==> **Peak** and **FWHM**
- Total energy resolution

(2) Study alpha generated in source foil

- **Exit probability** of alpha produced in the foil
- ^{214}Bi background measurement

Later we could consider:

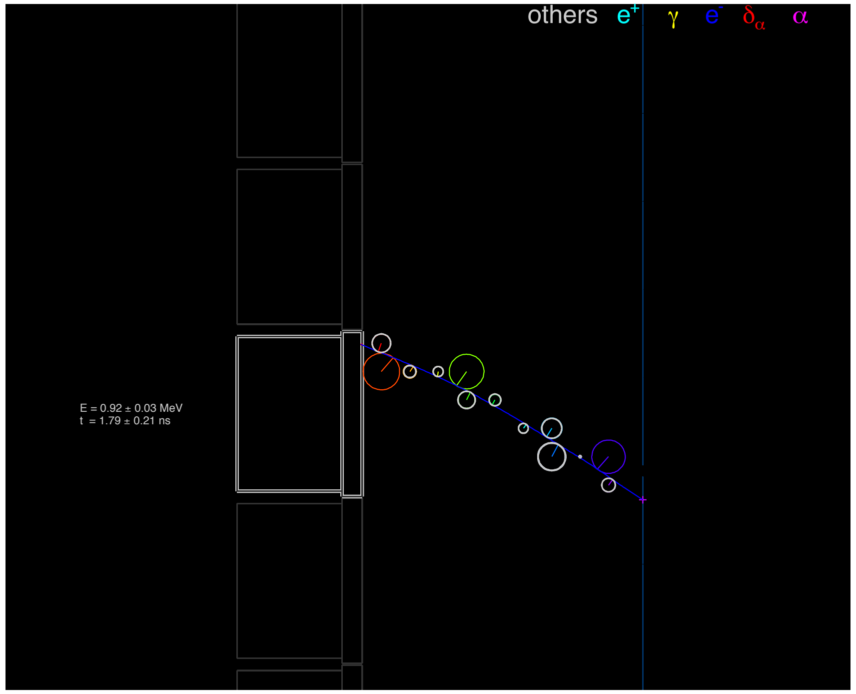
(3) bb0v detection efficiency (require a bit more elaborated study)

Events generation

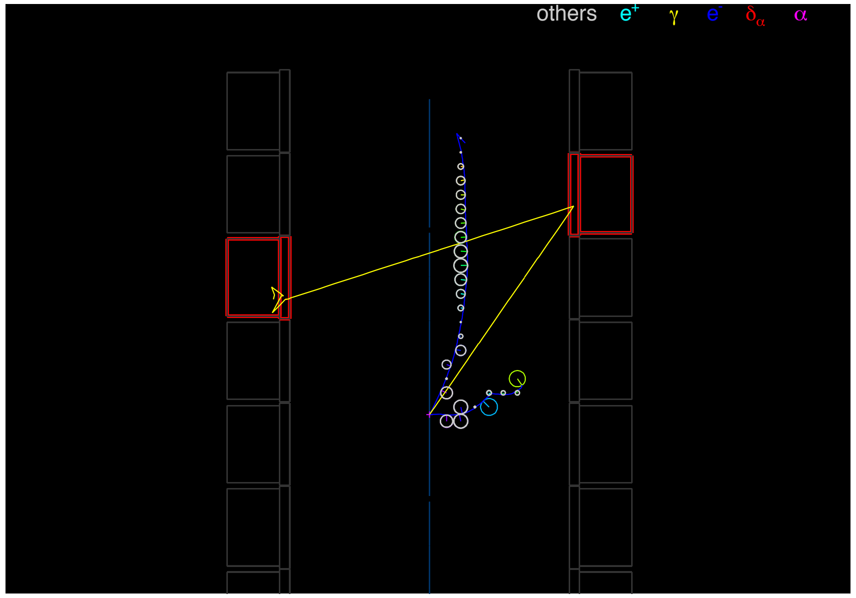
- Geometry: **config_2.0**
  - No Mylar backing film
  - Just Selenium mixed with 5 % Polyvinyl Alcohol
  - Target thickness: 50 mg/cm2 ==> 0.167 mm
- Vertex generator: **source_strips_bulks**
- Event generator:
  - **Electron_monokinetic:** 1 MeV, random momenta
  - **Alpha_monokinetic:** 7.7 MeV (^{214}Bi), random momenta
- Total number of event: 100k evt.

Electron energy loss

Selection criteria



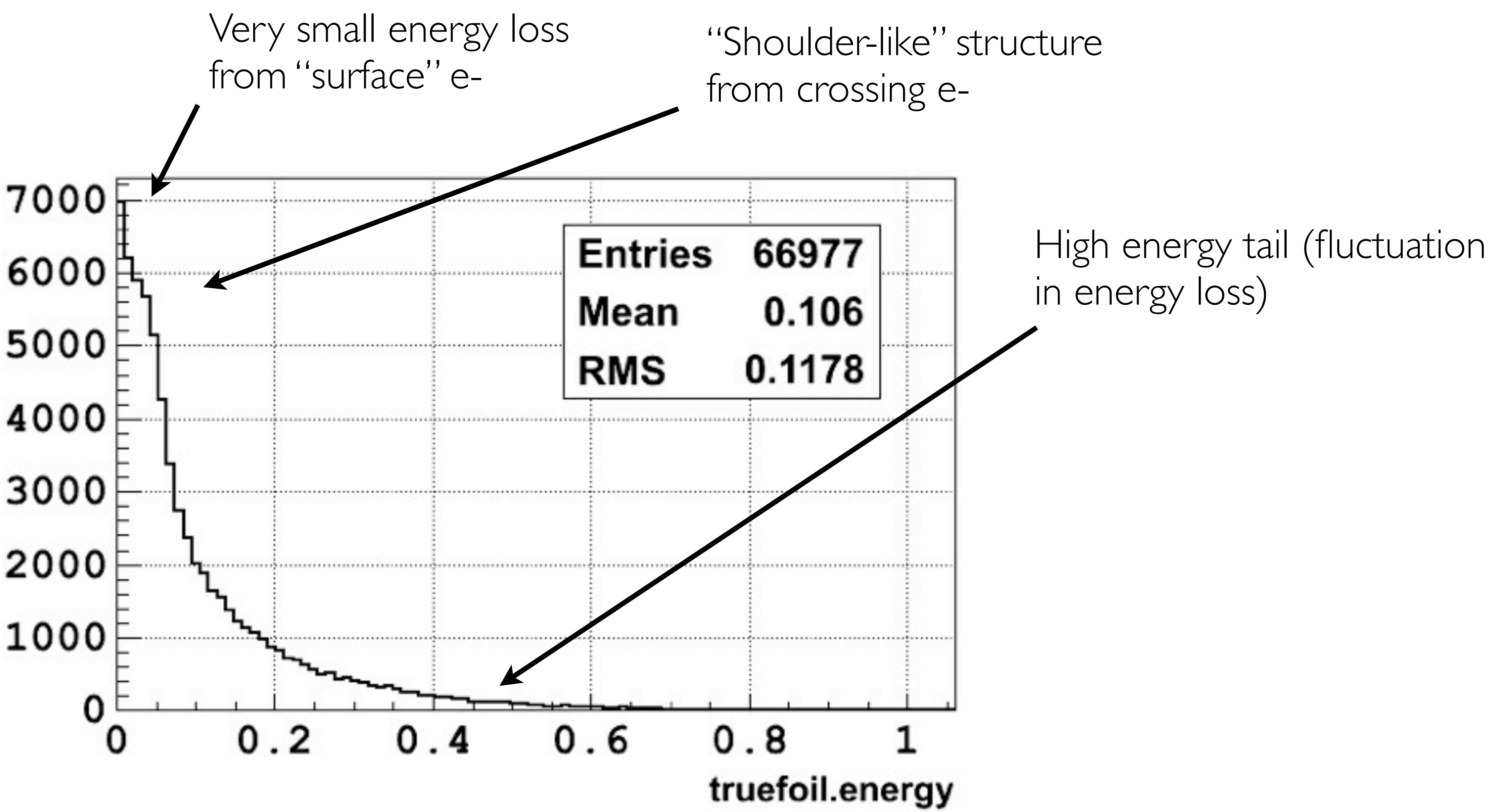
- Selection criteria:
  - One particle from the source ==> one hit in the main calo
  - Get rid of funny events
- Total number of evt. after selection: 66977 evt. (66%)



Check:

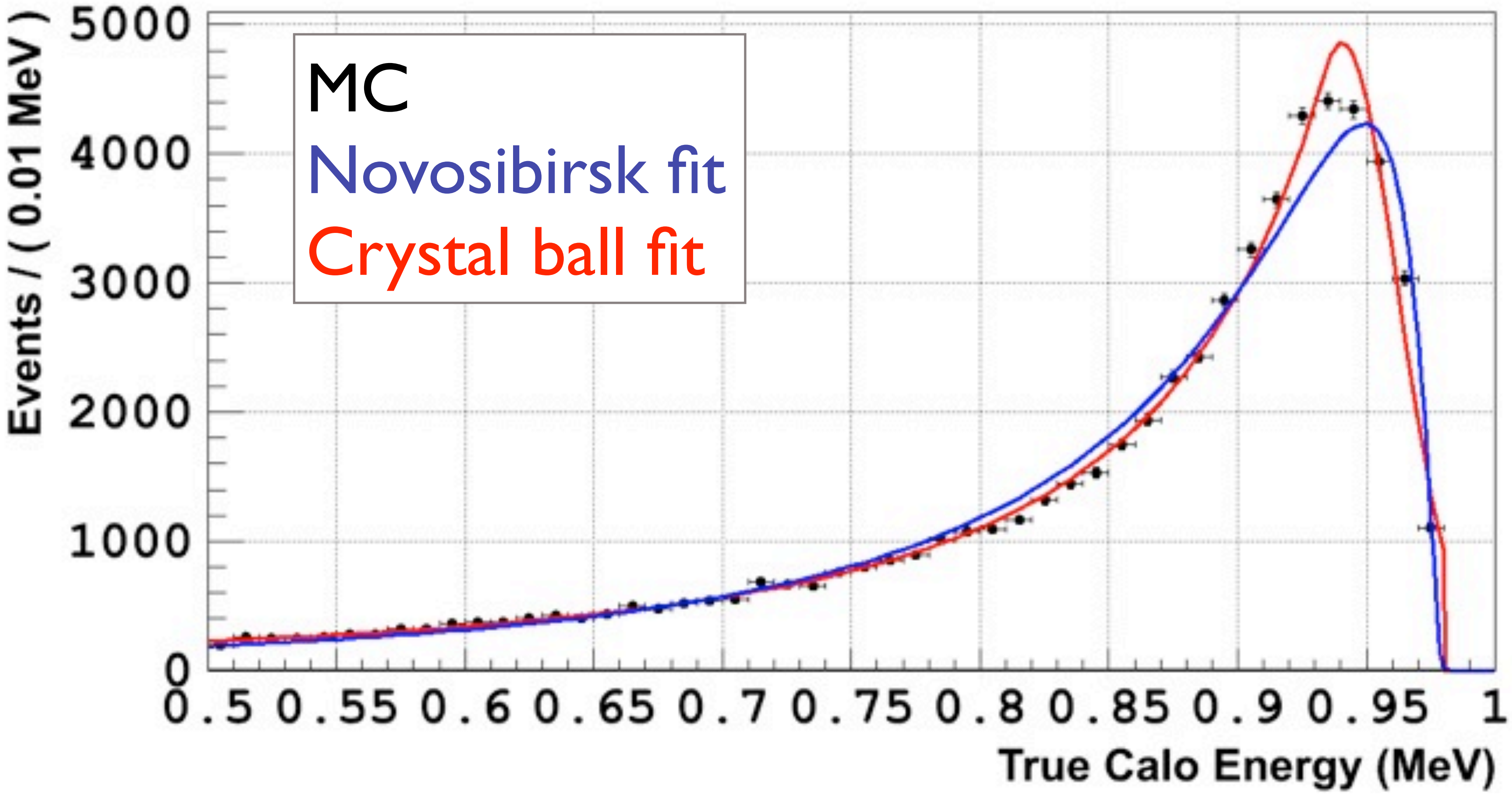
- True energy loss in foil source
- True energy loss in main calo
- Calibrated energy loss in main calo (resolution effects)

Electron energy loss in source



- Distribution not easy to characterise through Peak and FWHM

True energy in the calorimeter




```
 Floating Parameter    FinalValue +/-  Error
 --------------------  --------------------------
          CBS_alpha    3.3012e-01 +/-  7.18e-03
              CBS_n    2.1502e+00 +/-  6.05e-02
           CBS_peak    9.4048e-01 +/-  3.08e-04
          CBS_width    2.1740e-02 +/-  3.05e-04

Reduced chi2: 6.13506673248
```

```
 Floating Parameter    FinalValue +/-  Error
 --------------------  --------------------------
           NOV_peak    9.4911e-01 +/-  3.55e-04
           NOV_tail   -1.0939e+00 +/-  7.35e-03
          NOV_width    4.4778e-02 +/-  3.23e-04

Reduced chi2: 9.8176867036
```

- Convolution among E loss in source, tracker & scint. block
  - No calorimetric effect here, only fluctuation in energy loss
- Fit with two models:
  - **Novosibirsk**: gauss with exponential tail
  - **Crystal Ball**: gauss with power law tail

commonly used to models energy loss

- CB generally fits better (for this study)

Calibrated energy (resolution effect)

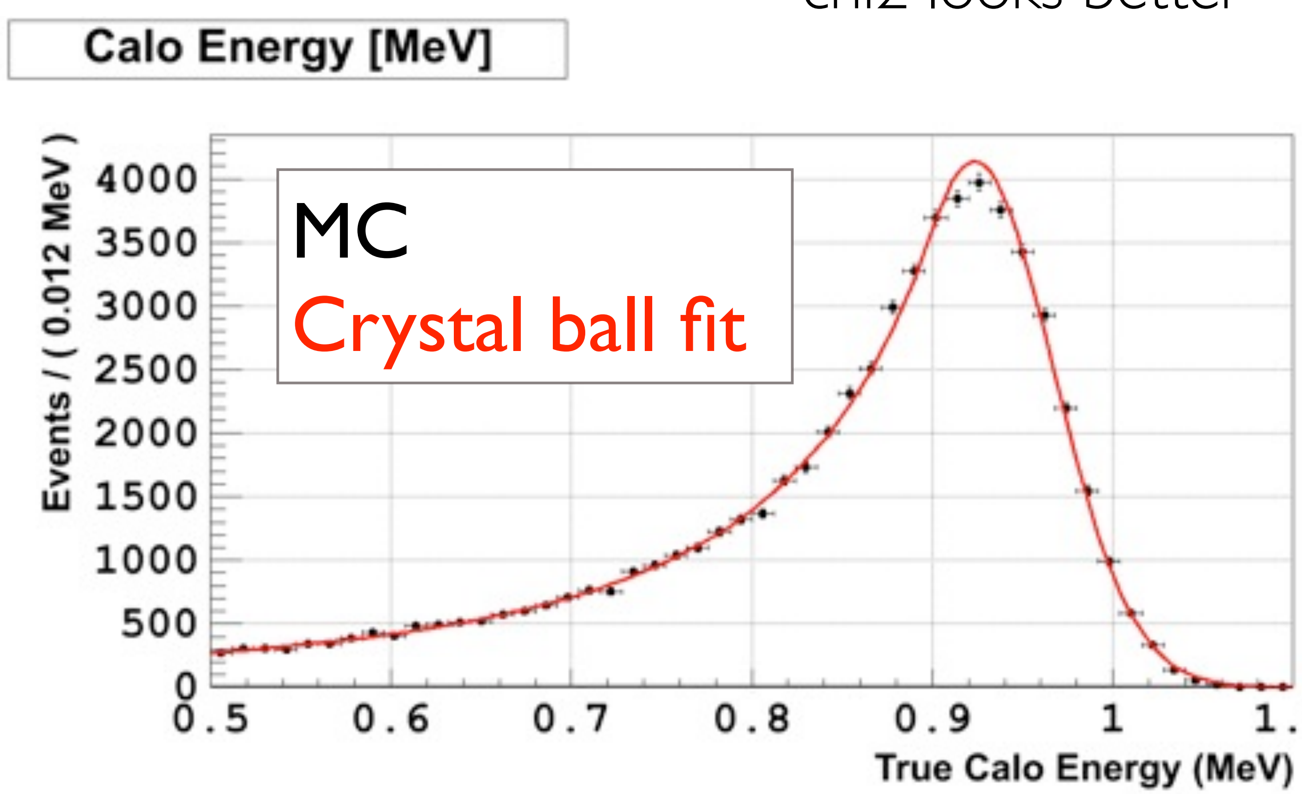
	Peak [MeV]	FWHM [MeV]	Resolution @ 1 MeV [%]
TRUE	0.940 +/- 0.001	0.051 +/- 0.002	**5.2 +/-0.2**
Calib.	0.923 +/ 0.001	0.103 +/- 0.002	**10.7 +/- 0.2**

Add 8 % gaussian spread (?)

```
Floating Parameter    FinalValue +/-  Error
--------------------  --------------------------
         CBS_alpha    5.0949e-01 +/-  1.01e-02
             CBS_n    2.3899e+00 +/-  1.03e-01
          CBS_peak    9.2326e-01 +/-  4.23e-04
         CBS_width    4.3732e-02 +/-  2.94e-04

Reduced chi2: 2.21700146943
```

chi2 looks better



Peak position decrease of ~17 keV: was it expected? (Light collection on PMT? QE?)

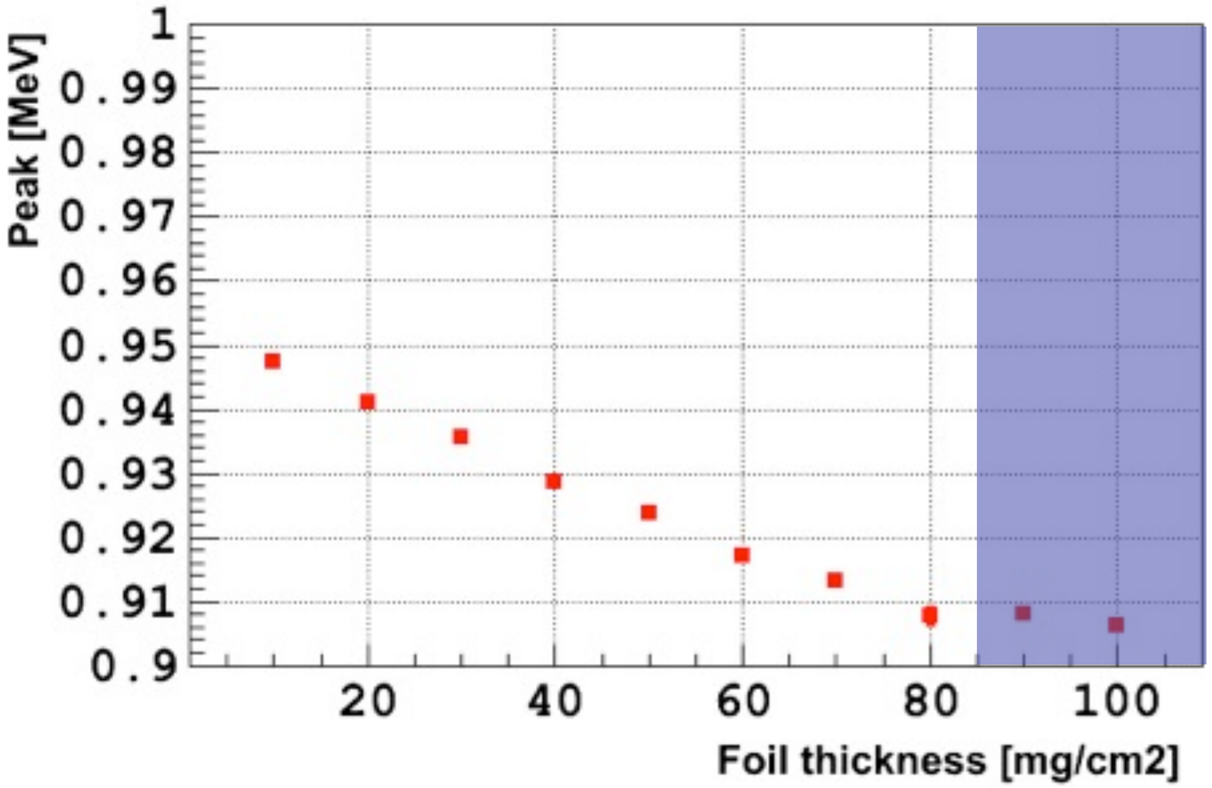
Subtracting 8% resolution in quadrature ==> 7.1% so about 2% higher than expected.

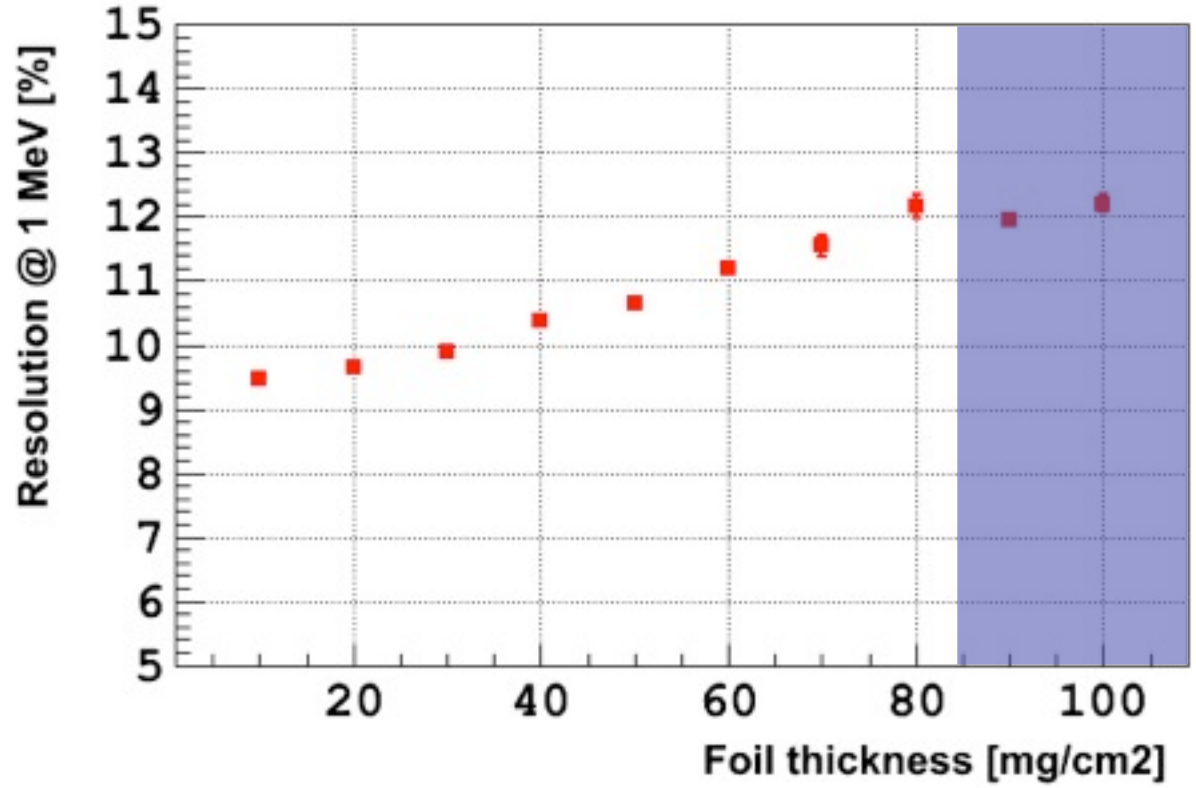
Something I'm not keeping into account? Something else?

Let's change the foil thickness

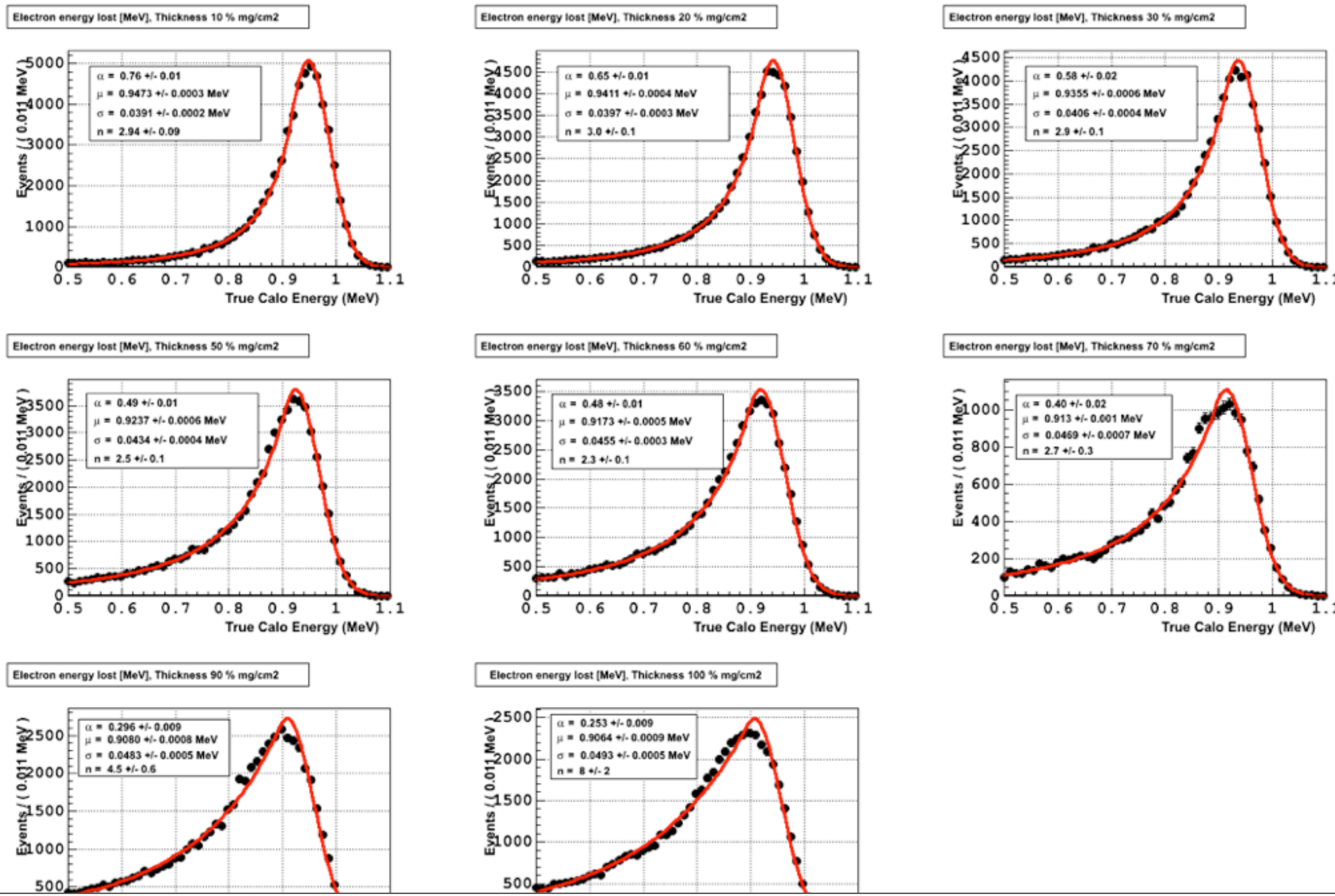
thickness	peak	100*fwhm/	chi2
[mg/cm^2]	[MeV]	[%]	
10	0.947	9.46	2.34
20	0.941	9.64	1.61
30	0.936	9.88	2.25
40	0.929	10.4	1.71
50	0.924	10.6	2.43
60	0.917	11.2	2.13
70	0.913	11.5	1.88
80	0.908	12.2	2.45
90	0.908	11.9	4.3
100	0.906	12.2	3.72

- Good fit except last two point
- Peak shift down ~40 keV
- Resolution decrease ~2.5 - 3 %





Let's change the foil thickness (fit results)

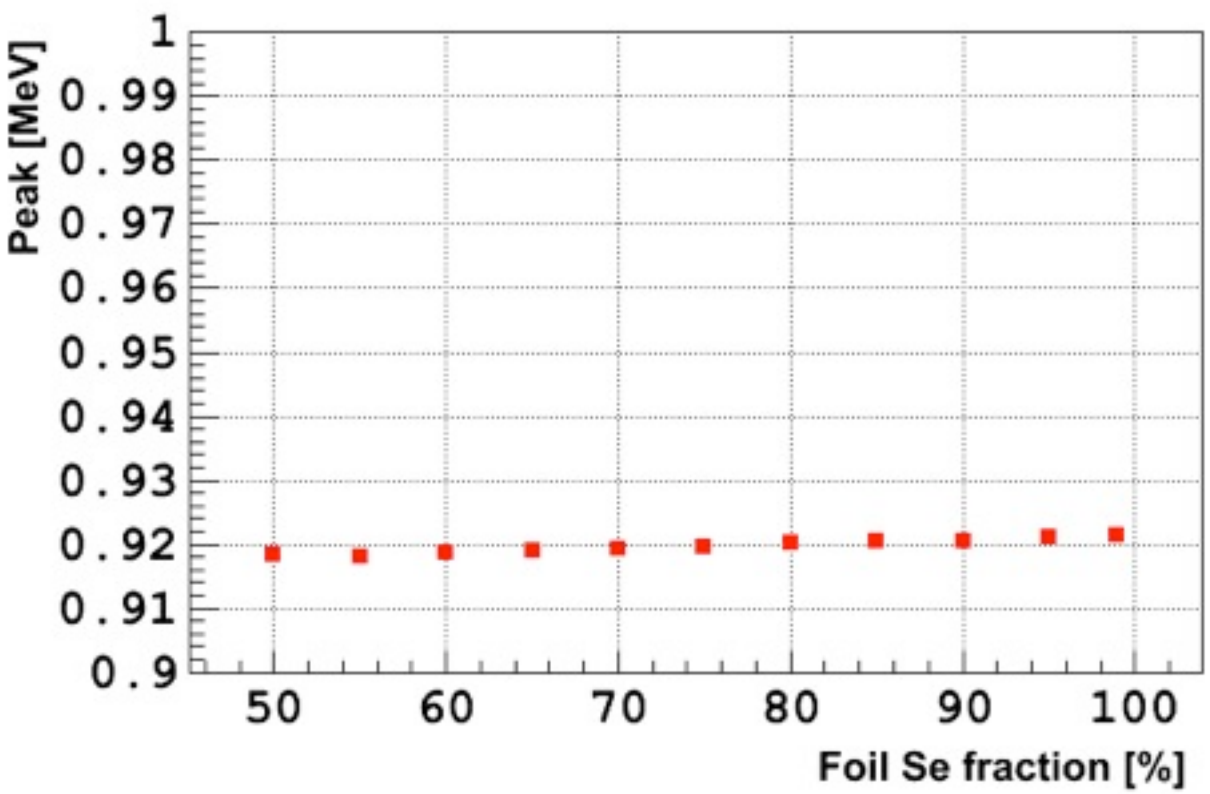


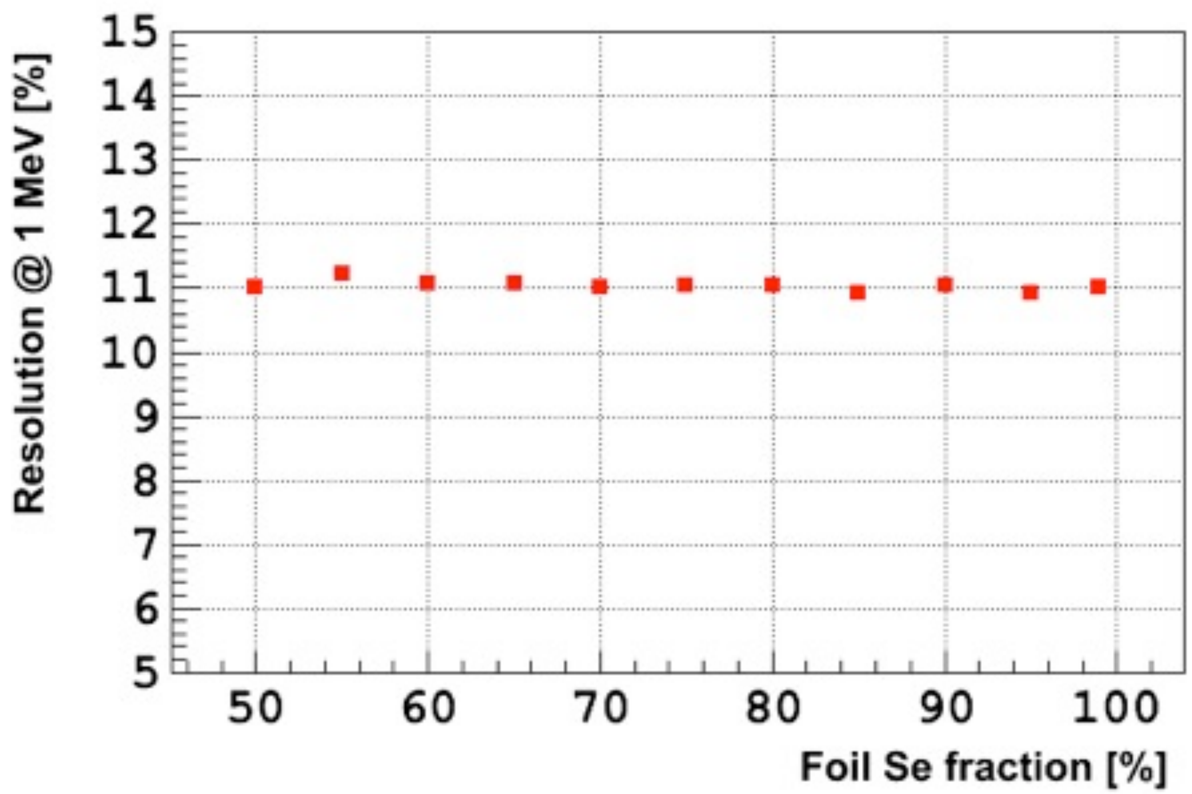
Let’s change the Se:PVA mix

[Se %] [MeV] [%]

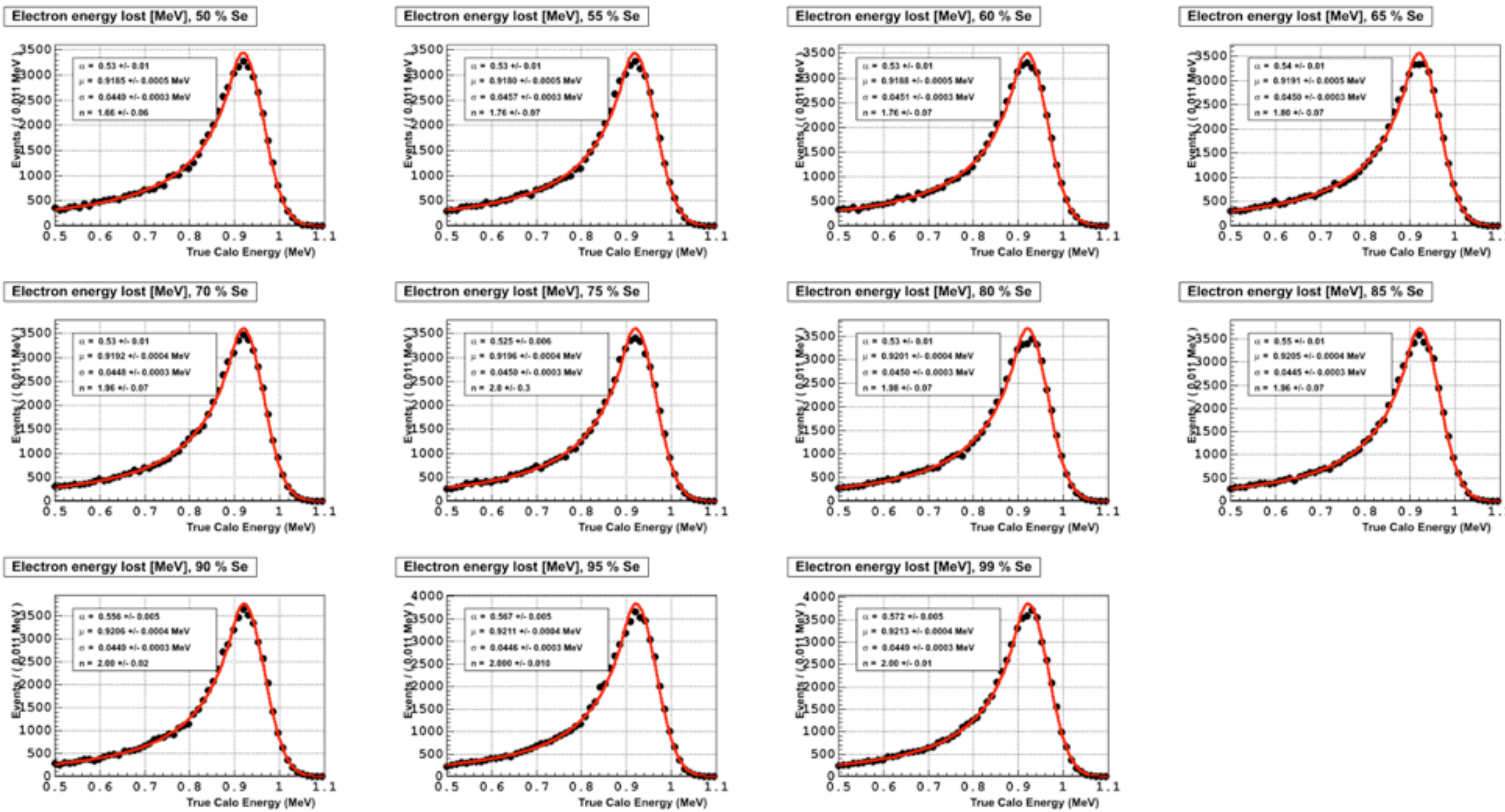
frac	peak	100*(2.35	chi2
50	0.9185	11.02	3.049
55	0.918	11.23	2.877
60	0.9188	11.09	2.497
65	0.9191	11.06	2.061
70	0.9192	11	1.909
75	0.9196	11.06	3.268
80	0.9201	11.05	2.946
85	0.9205	10.93	2.58
90	0.9206	11.03	2.601
95	0.9211	10.93	3.597
99	0.9213	11.02	2.091

- Change total Se mass fraction & ecompute other components:
  - Pure ^{82}Se & natural Se, assuming 3% contamination (Barabash)
  - PVA components (C, O, H)
- Very week dependence < 1 % variation





Let’s change the Se:PVA mix (fit results)



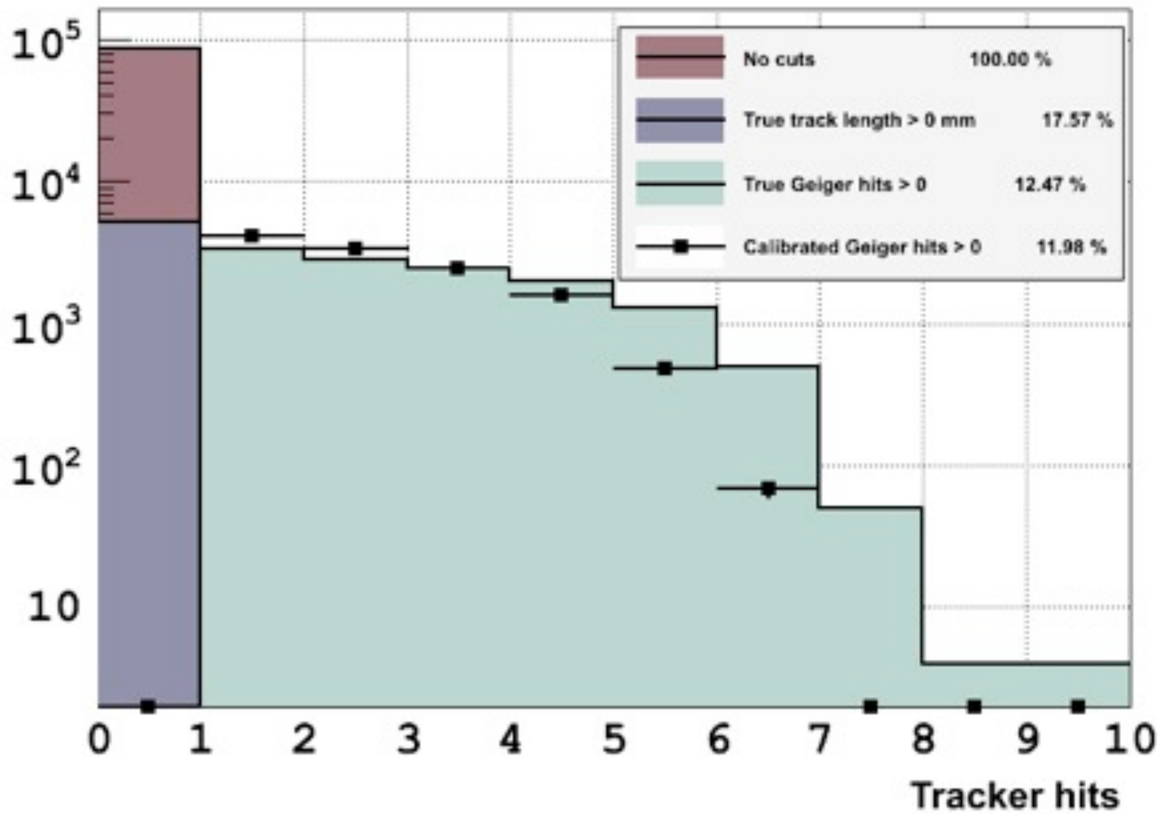
Alpha exit probability

Alpha exit probability from source foil

Alpha are identified trough their track length in the tracker gas

- Higher the exit probability
  - Higher the alpha detection efficiency
  - Better the measurement of internal ^{214}Bi contamination

Cut	Prob. [%]
No cuts	100
Track length in gas > 0 cm	17.57
True geiger hit > 0	12.47
Calibrated geiger hit > 0	11.98



For comparison:

- NEMO3 got ~16% alpha detection efficiency
- Order of magnitude is correct
- Expecting higher value (maybe just too simple study?)

Let's change the foil thickness

thickness [mg/cm^2]	100*n1/n0 [%]	100*n2/n0 [%]	100*n3/n0 [%]
10	71.2	55.4	53.8
20	43.2	30.5	29.3
30	28.4	20.1	19.3
40	21.6	15.3	14.7
50	17.6	12.5	12
60	14.2	10	9.62
70	12.4	8.77	8.4
80	10.6	7.63	7.32
90	9.54	6.82	6.55
100	8.49	6	5.75

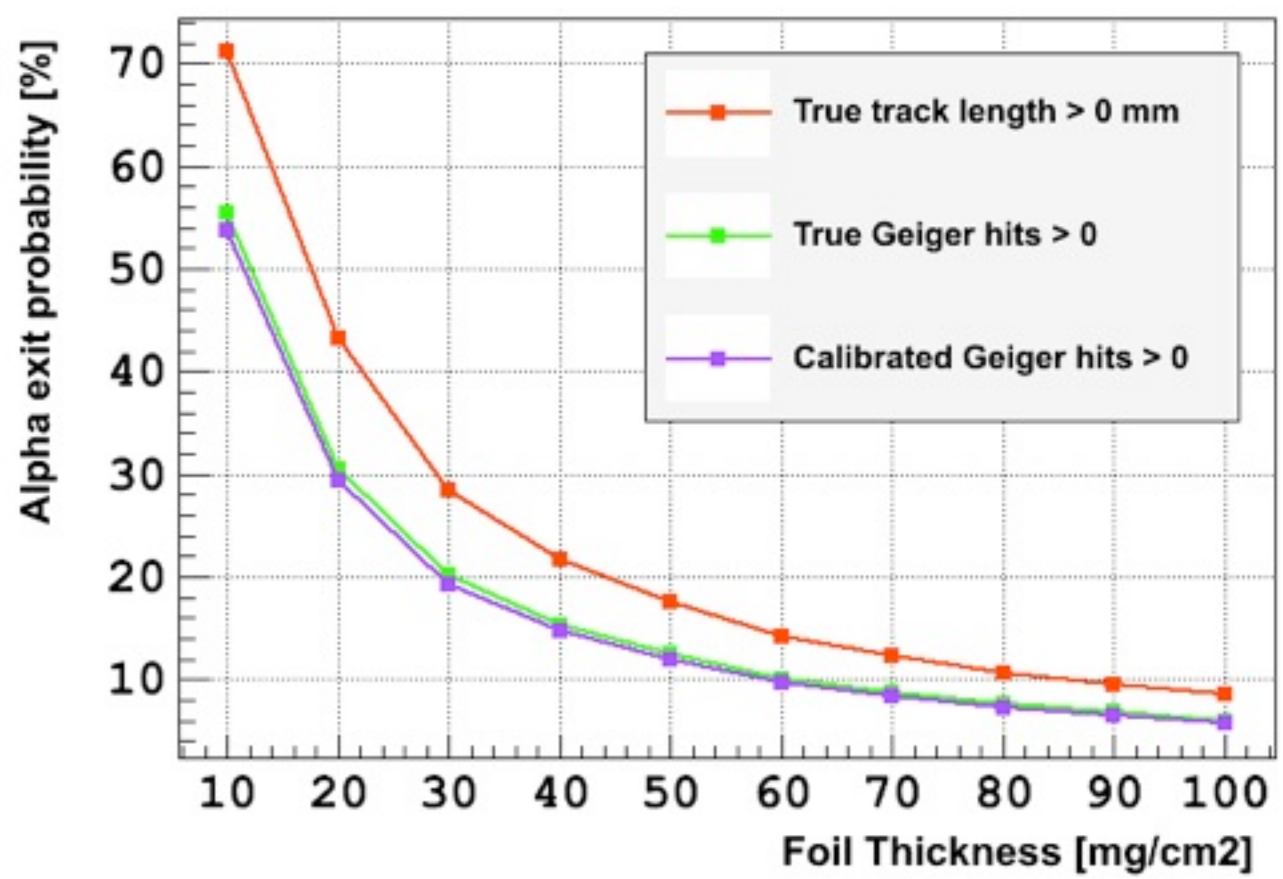
In the explored region:

- Alpha exit probability from ~55 % to ~5%
- 12 % for the target thickness

Keep in mind the current foil design:

- No mylar film
- 5 % PVA (while 20% is more likely)

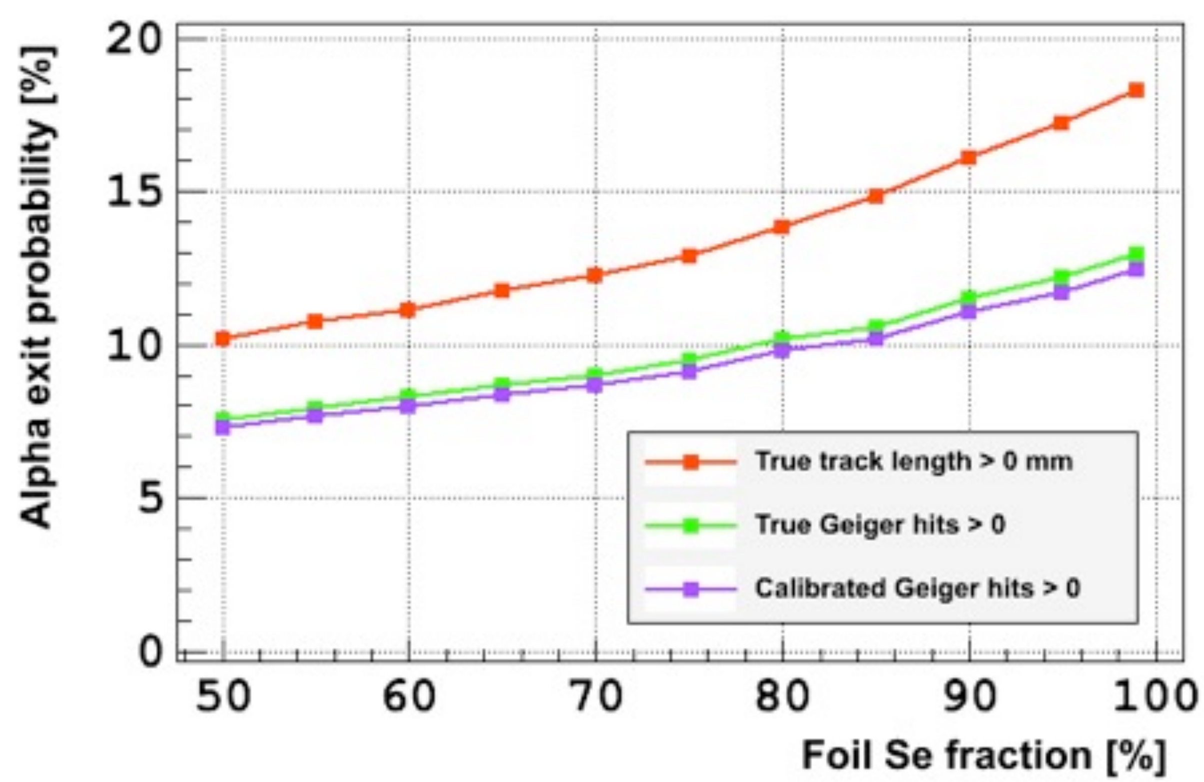
Values are "upper limit", ==> expected to lower down a bit



Let's change the Se:PVA mix

[Se %] frac	[%] 100*n1/n0	[%] 100*n2/n0	[%] 100*n3/n0
50	10.2	7.51	7.25
55	10.7	7.92	7.62
60	11.1	8.28	7.98
65	11.7	8.67	8.33
70	12.3	8.99	8.64
75	12.9	9.48	9.1
80	13.8	10.2	9.81
85	14.8	10.6	10.2
90	16.1	11.5	11
95	17.2	12.2	11.7
99	18.3	12.9	12.4

- Change total Se mass fraction & ecompute other components:
  - Pure ^{82}Se & natural Se, assuming 3% contamination (Barabash)
  - PVA components (C, O, H)
- Slight increase of exit probability ~ 5.5 %



- The foil source design in not frozen yet
  - Some details need to be investigated: foil composition, mechanical supports
- First very simple attempt in such direction
  - Use simple mono energetic particle gun
    - Concentrate on the detail of the detector response
  - Define few FOM related to the detector performance
    - Peak & FWHM of e- energy loss in calo (resolution)
    - Alpha exit probability from foil (Background detection efficiency)
  - Study such FOM w.r.t. source parameters: foil thickness, Se:PVA ratio

Conclusions

- Need to modify source geometry to include mechanical support:
  - Mylar backing film
  - Mesh backbone
  - Others (?)
- Investigate the effect of the multiple scattering on the particle exit probability (alpha and electron)
- Consider to keep into account the total mass of the bb isotope

Next steps