Test beam results of graphene radiators studies

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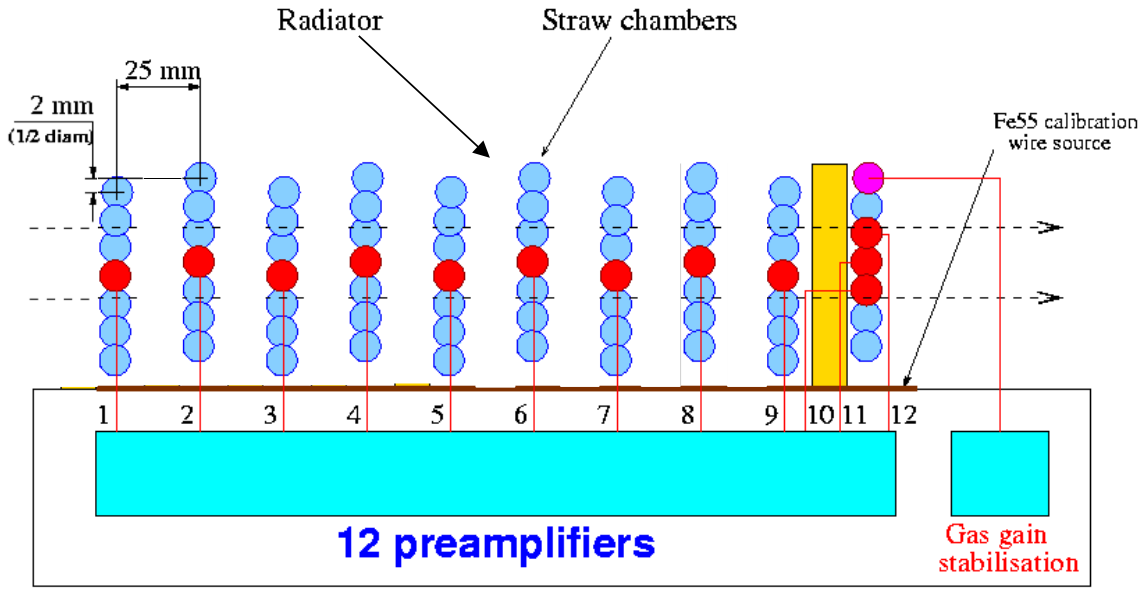
1. PE radiator with one graphene monolayer: we see an effect!?
2. 5 detector-radiator layers: why no difference between PP-Gr radiators?
3. Graphene paper of different thickness: do we see an effect?
4. Graphene material analysis results: what is an impact of oxygen on the results?
5. Discussion

Straw set-up with one radiator set for Graphene studies

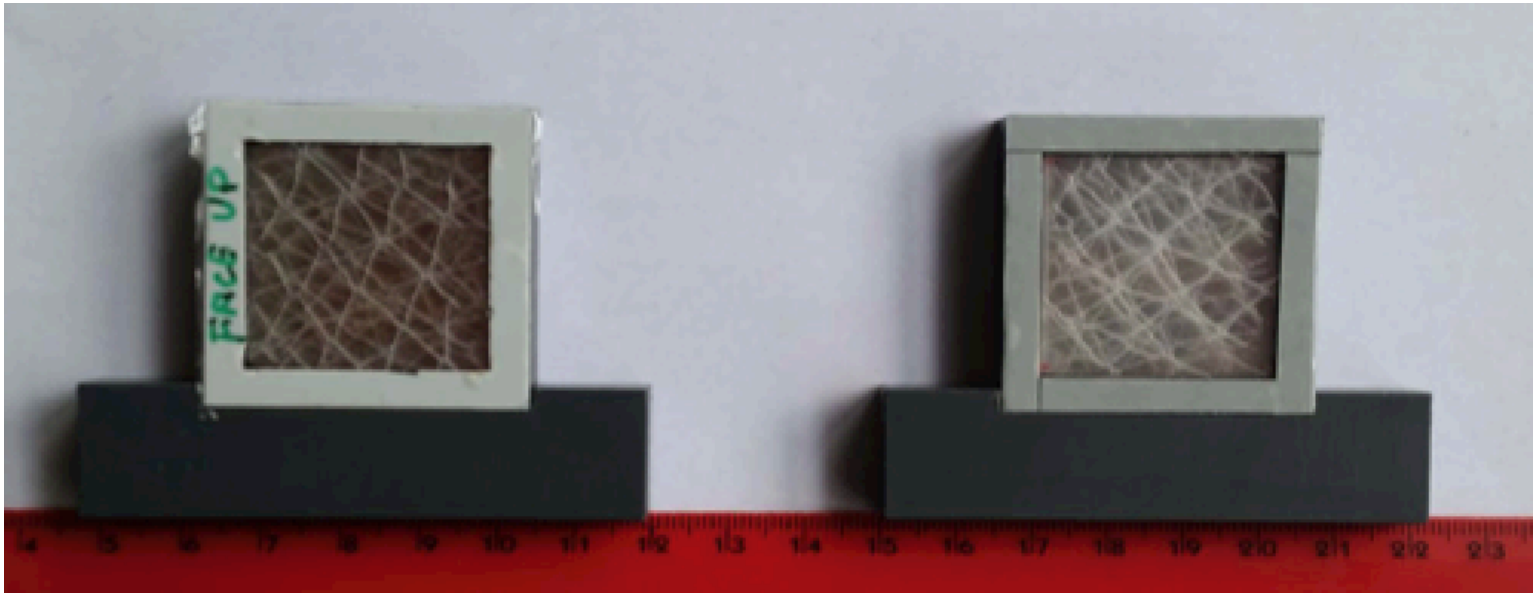


Single module radiator tests

- Polyethylene - PE (10 mm 41 foils 12.5 μm thick)
- Polyethylene with graphene layer- PEGr (same as above)
- Polyethylene with graphene layer reversed- PEGr_rev (same as above)
- Grapene paper radiator 1 foil, 2 foils 3 foils (8mm, 36 layers)

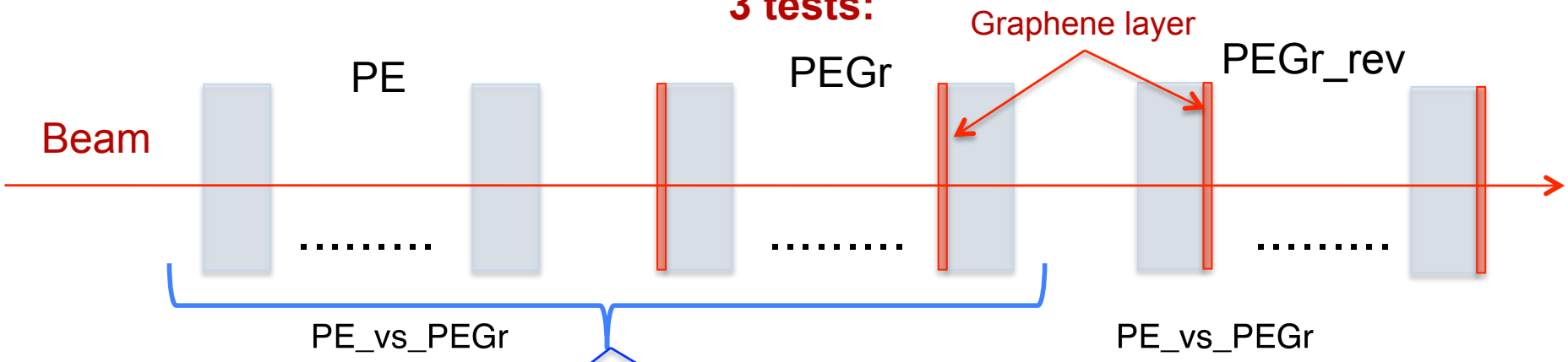
Polyethylene radiator with 1 grahene monolayer.

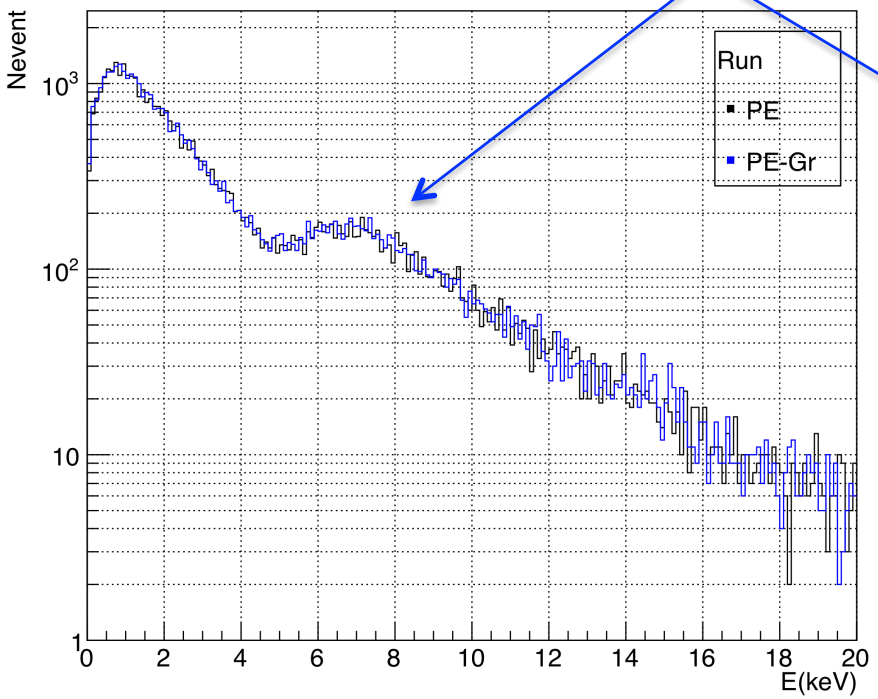
Polyethylene radiator with one graphene monolayer



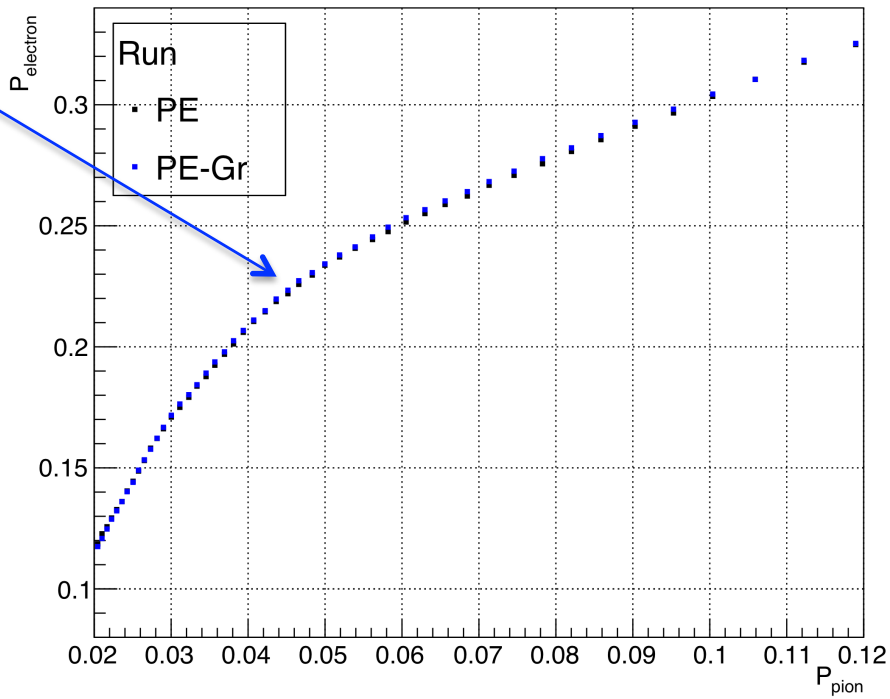
- 41 polyethylene foils of 12.5 μm thick
- ~240 μm gap between foils
- 39 folis have a mono-layer of graphene on one side
- The first and last foil without graphene

Polyethilene radiator with 1 monolayer of grahene



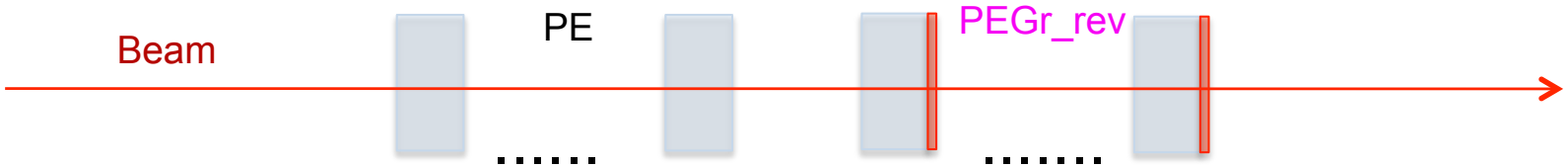


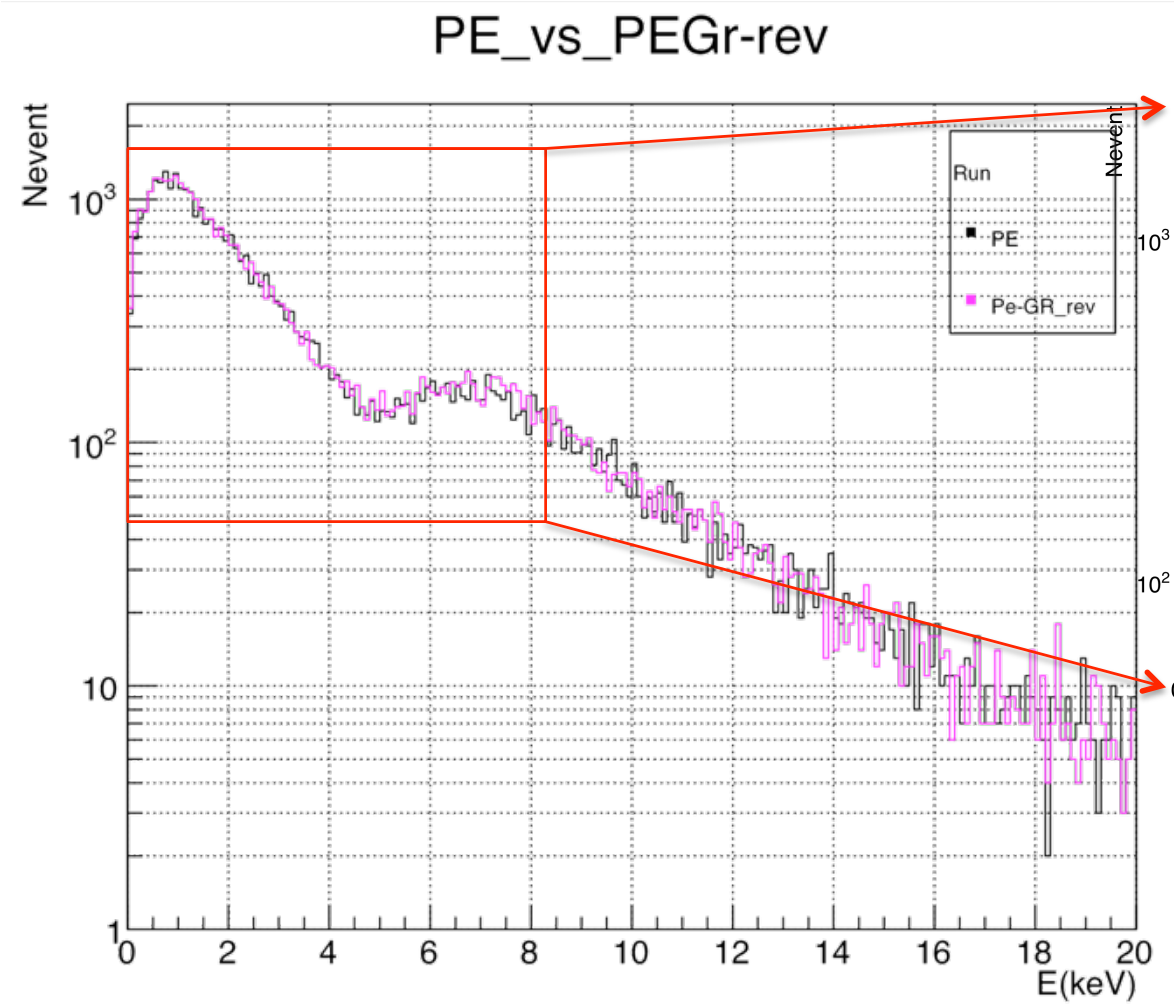
Comparison of differential dE/dX+TR spectrums of PE and PEGr radiators.

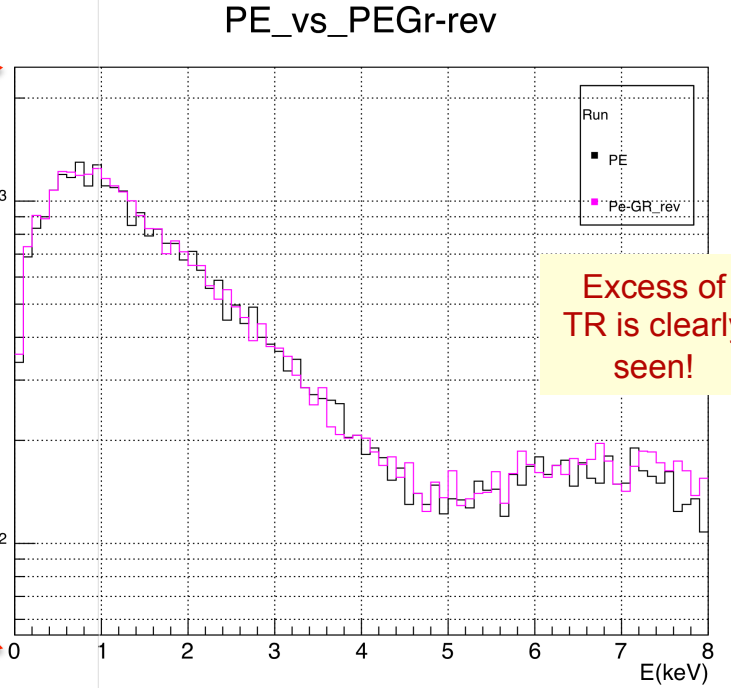


Probability to exceed threshold for electrons (P_e) VS probability to exceed threshold for pions (P_π) for PE and PEGr radiators.

Polyethilene radiator with 1 monolayer of grahene





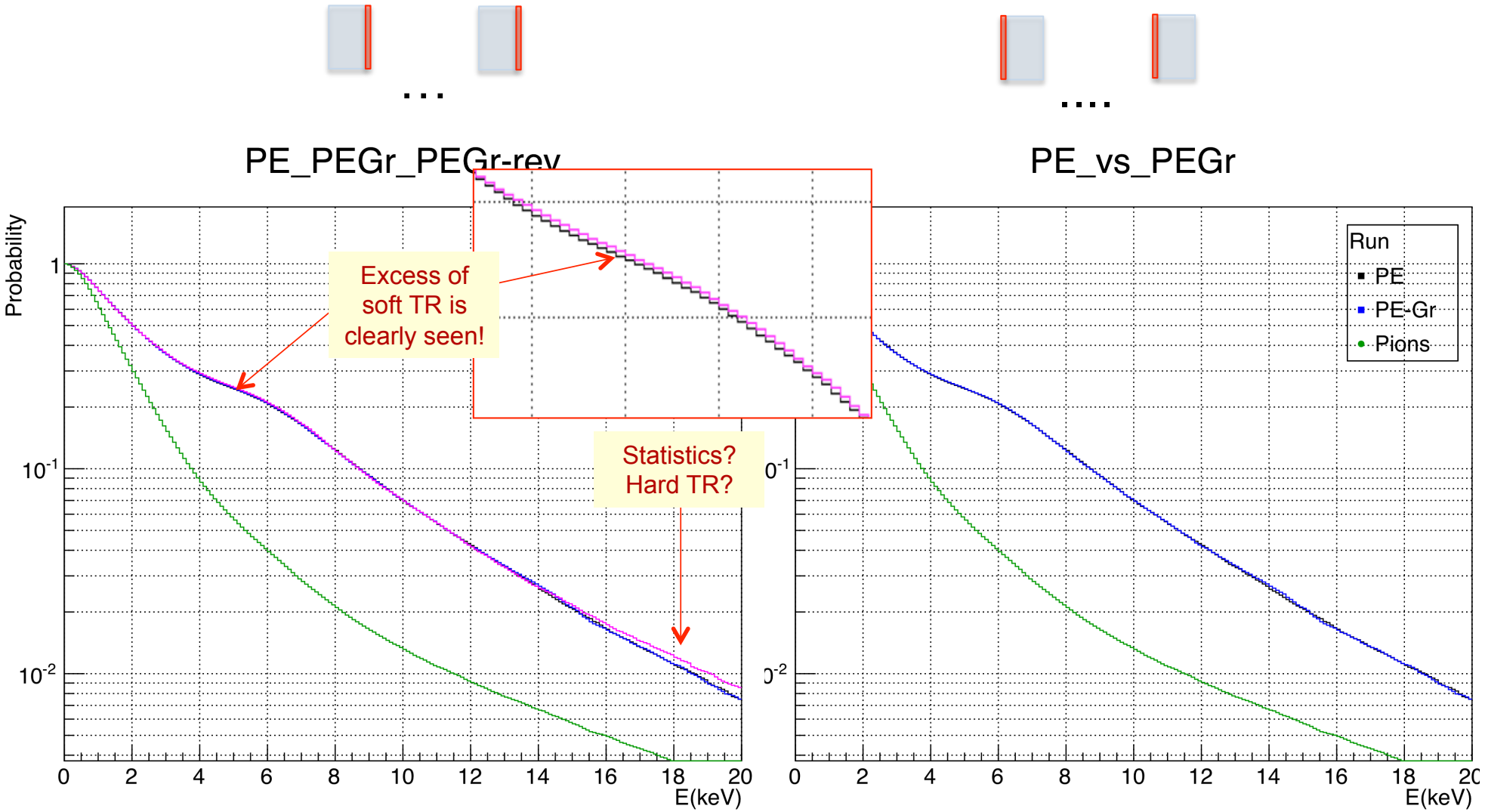


Excess of TR is clearly seen!

NOTE that spectrum shifted a bit to larger X-ray energies!

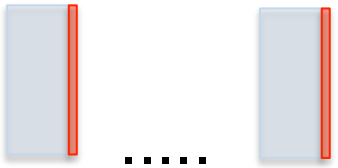
Comparison of differential dE/dX+TR spectrums of PE and PEGr_rev radiators.

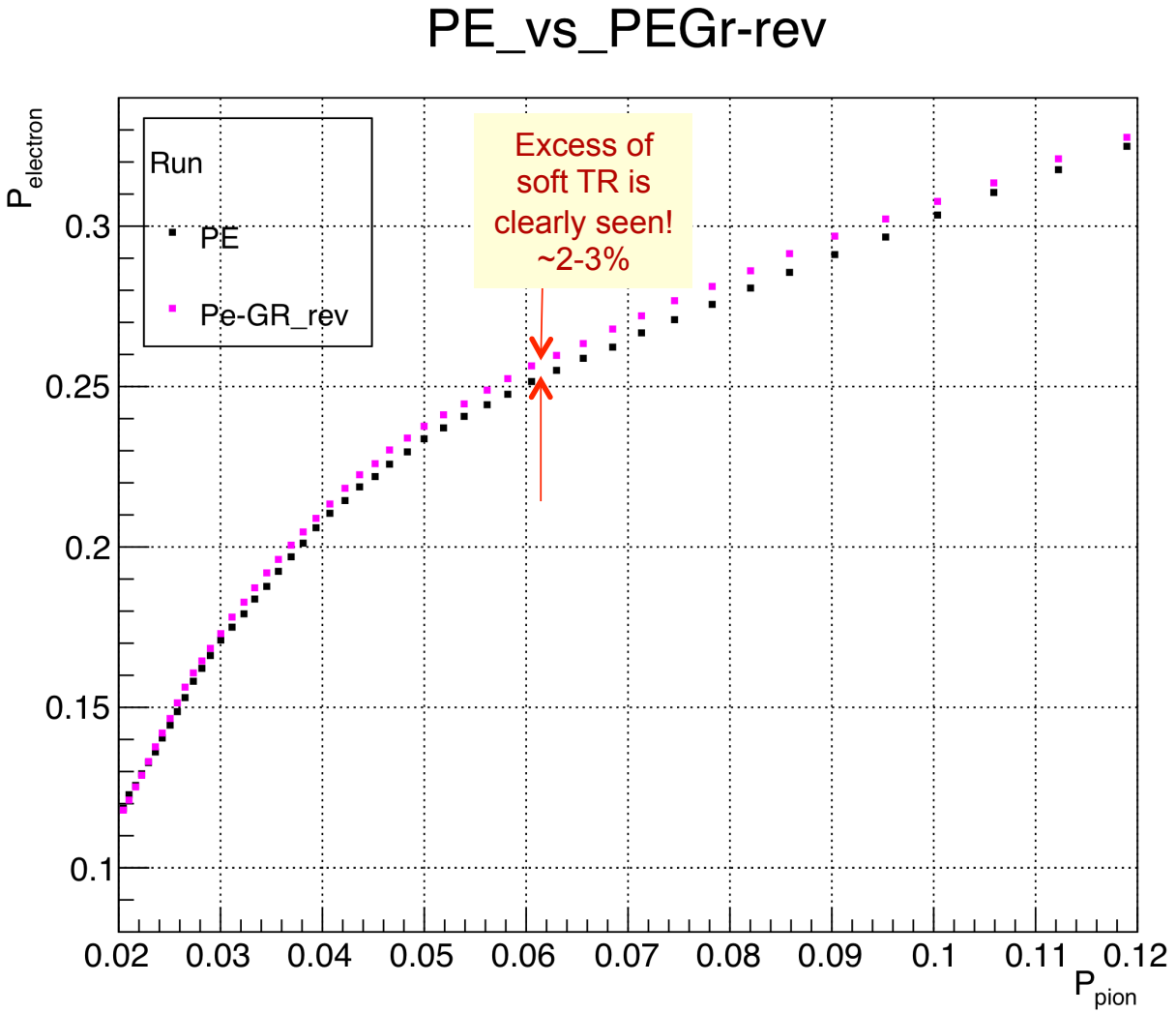
Polyethilene radiator with 1 monolayer of grahene



Probability to exceed threshold for electrons (P_e) VS probability to exceed threshold for pions (P_π) for PE and PEGr_Rev radiators (left)) for PE and PEGr (right) .

Polyethilene radiator with 1 monolayer of grahene





Probability to exceed threshold for electrons (Pe) VS probability to exceed threshold for pions (Pp) for PE and PEGr_rev radiators.

Is this is a effect of graphne layer?
If yes, is it connected to Graphene properties?

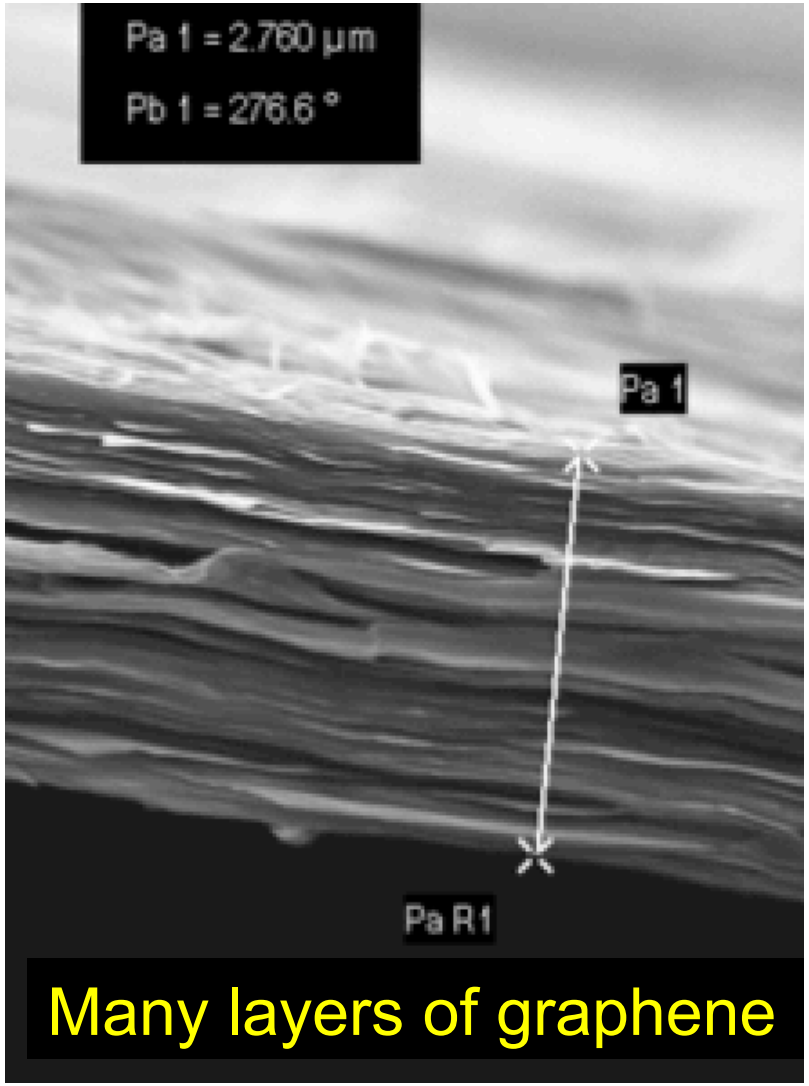
Statements and questions:

- *In the soft part of the spectrum (6-8 keV) the effect is statistically significant.*
- *At TR range >15 keV excess may have statistics origin.*
- *If the effect we see comes from graphene layer why only one orientation.*
- *Is this effect related to graphene properties or I can be attributed to the conductivity of the graphene layer.*
- *What tests can be performed to understand the results?*

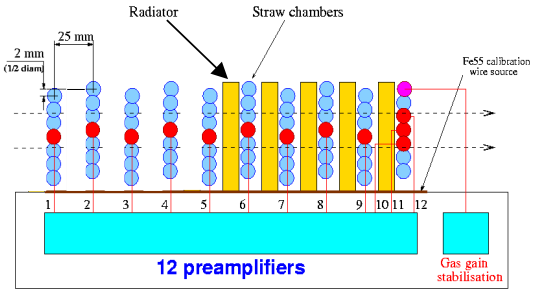
What can be done to verify the results?:

- *Try to produce the same type of radiator with 3 graphene layers.*
- *Produce the same type of radiator with 200 A^{o} of Al.*
- *Repeat the tests with larger statistics.*
- *Simulate the effect of a surface conductivity.*

Graphene paper tests.



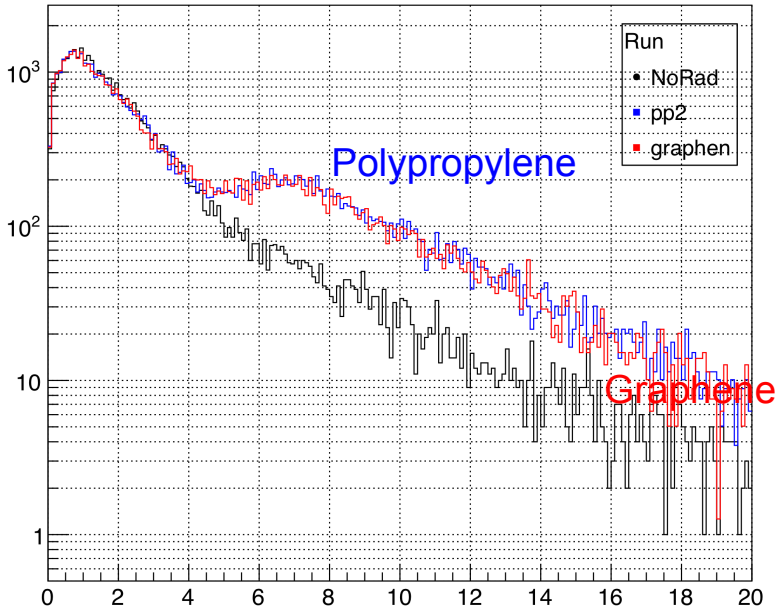
Test I: 5 modules of Graphene paper radiators comparison of 5 modules of PP radiator.



Graphene: 36 foils of ~10 μm (two graphene paper foils of 5 μm thick) separated by 230 μm mesh spacers.

PP: 36 foils of ~14.5 μm polypropylene separated by 225 μm mesh spacers.

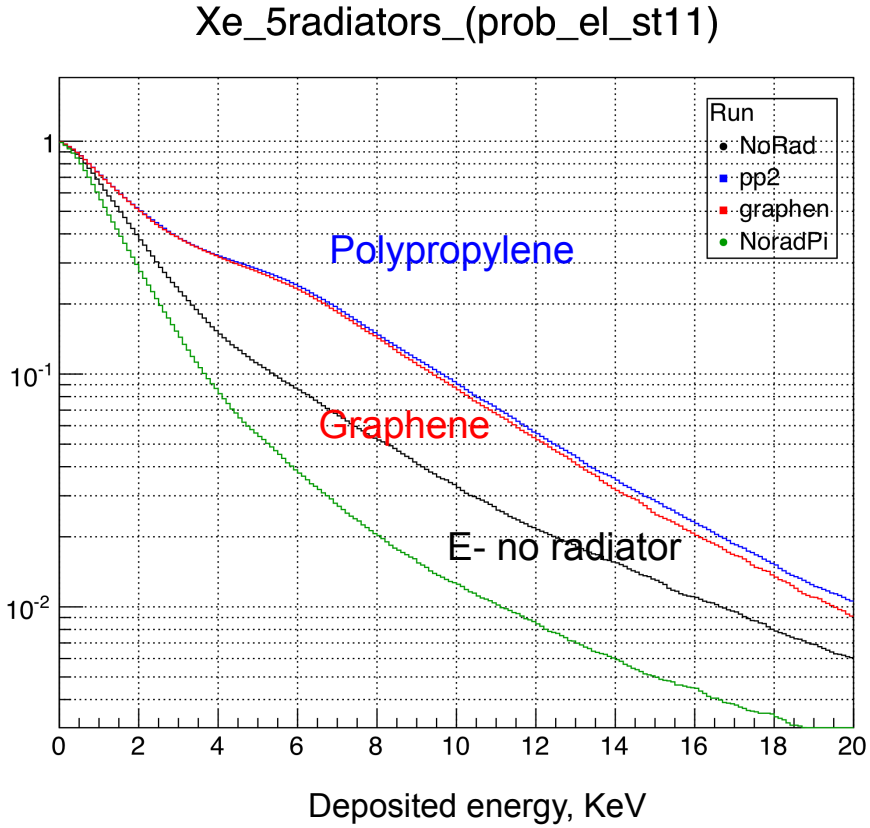
Xe_5radiators_(el_st11)

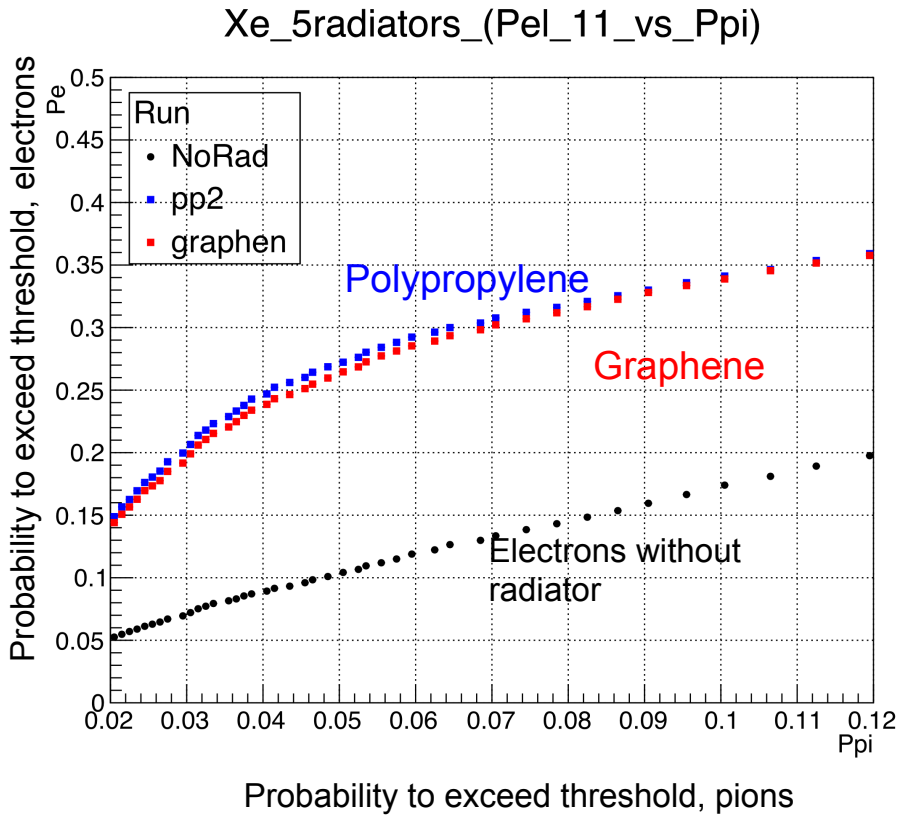


Differential dE/dX+TR spectrums of PP2 and graphene paper radiator (5 modules)

Integral spectrums for:

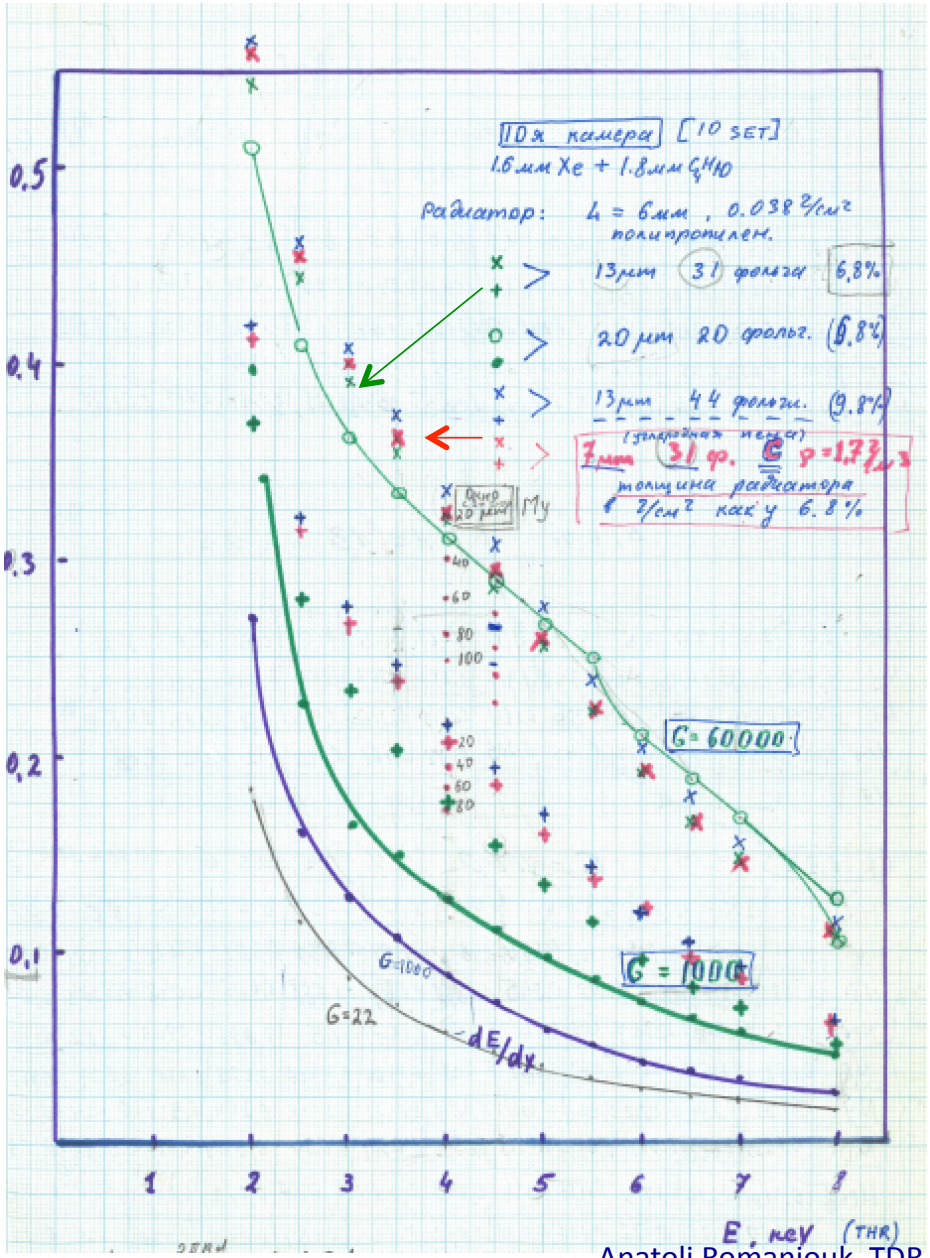
- Polypropilene film
- Graphene papere
- No Radiator





- TR from 5 graphene modules is less than from polypropylene radiators.
- Preliminary estimates showed that this is expected if these radiators would have no “grapgene effect”.

Almost 30 year old picture



Old Simulations:

- 31 foils, 13 μm PP
- 31 foils of 7 μm C of 1.7 g/cm^3

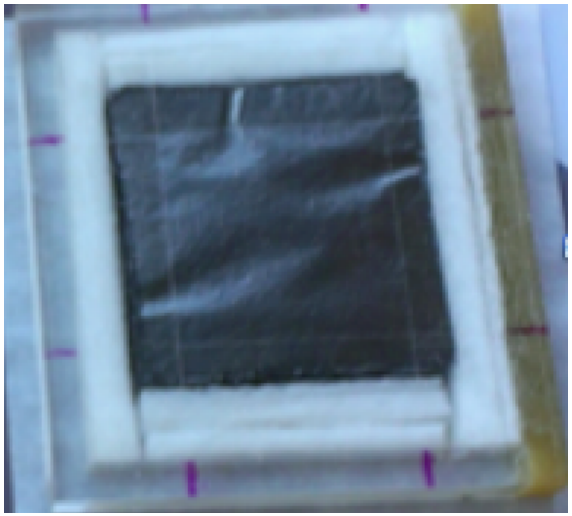
Test beam :

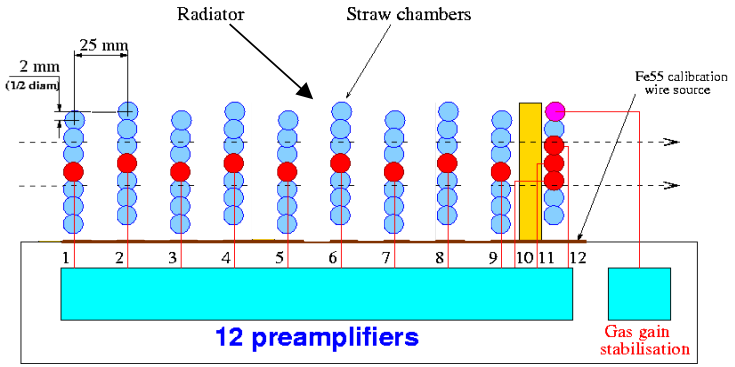
- 36 PP of 14.5 μm
- Compared to Graphene paper 10 μm C of ~ 2 g/cm^3

More TR expected from C-radiator!

NOTE: spectrums are very close to each other!

Test II: Graphene paper foil thickness





The same setup as for PE radiator.

Radiators: 8 mm thick 36 graphene paper layers (230 μm gap between layers).

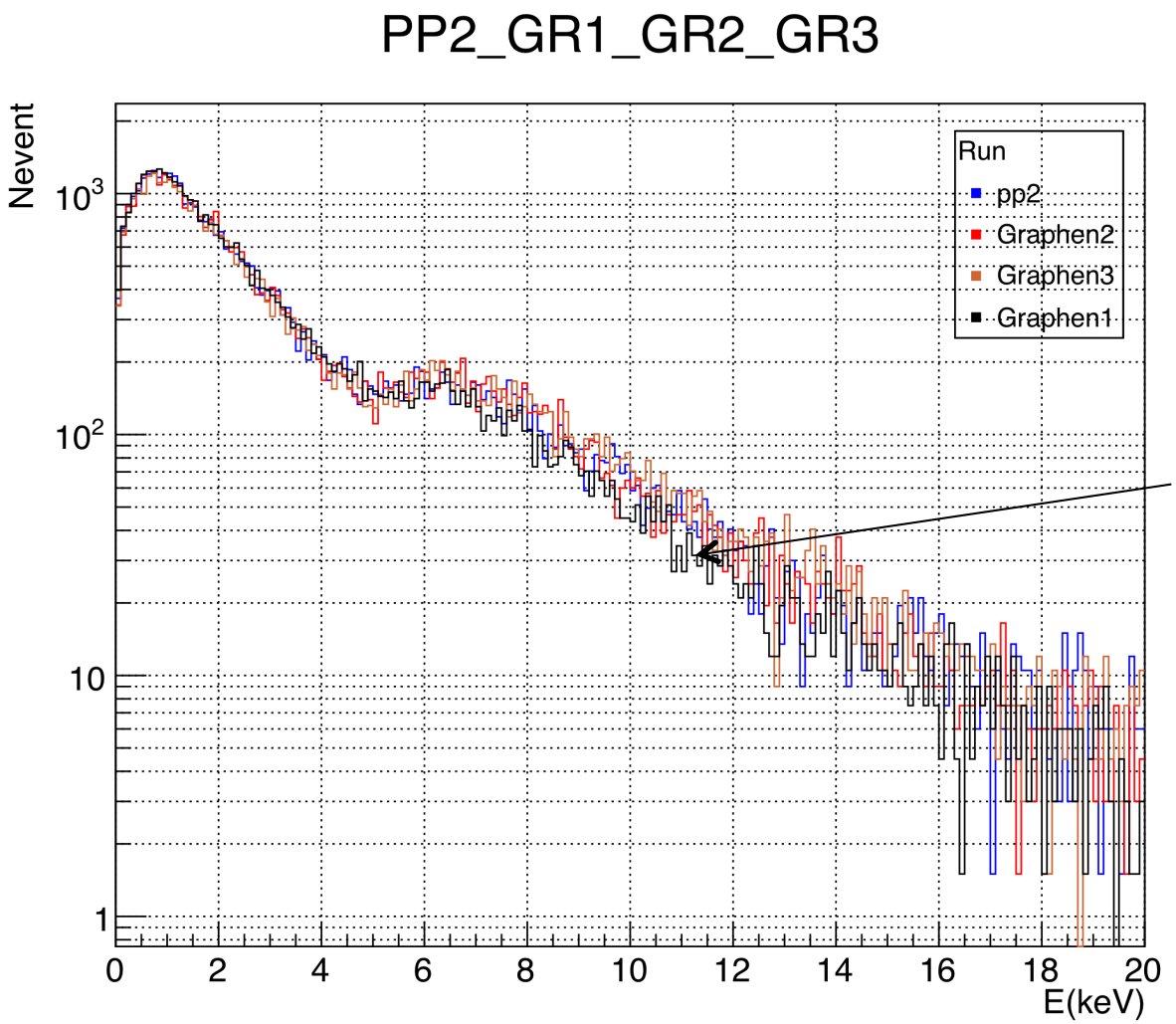
3 configurations:

- 1 graphene paper layer contains **1** grehene foil (GR1)
- 1 graphene paper layer contains **2** grehene foils (GR2)
- 1 graphene paper layer contains **3** grehene foils (GR3)

One foil is ~5 μm thick.

For comparison a polypropylene radiator with foil thickness of 14.5 μm (PP2) with the same structure was used.

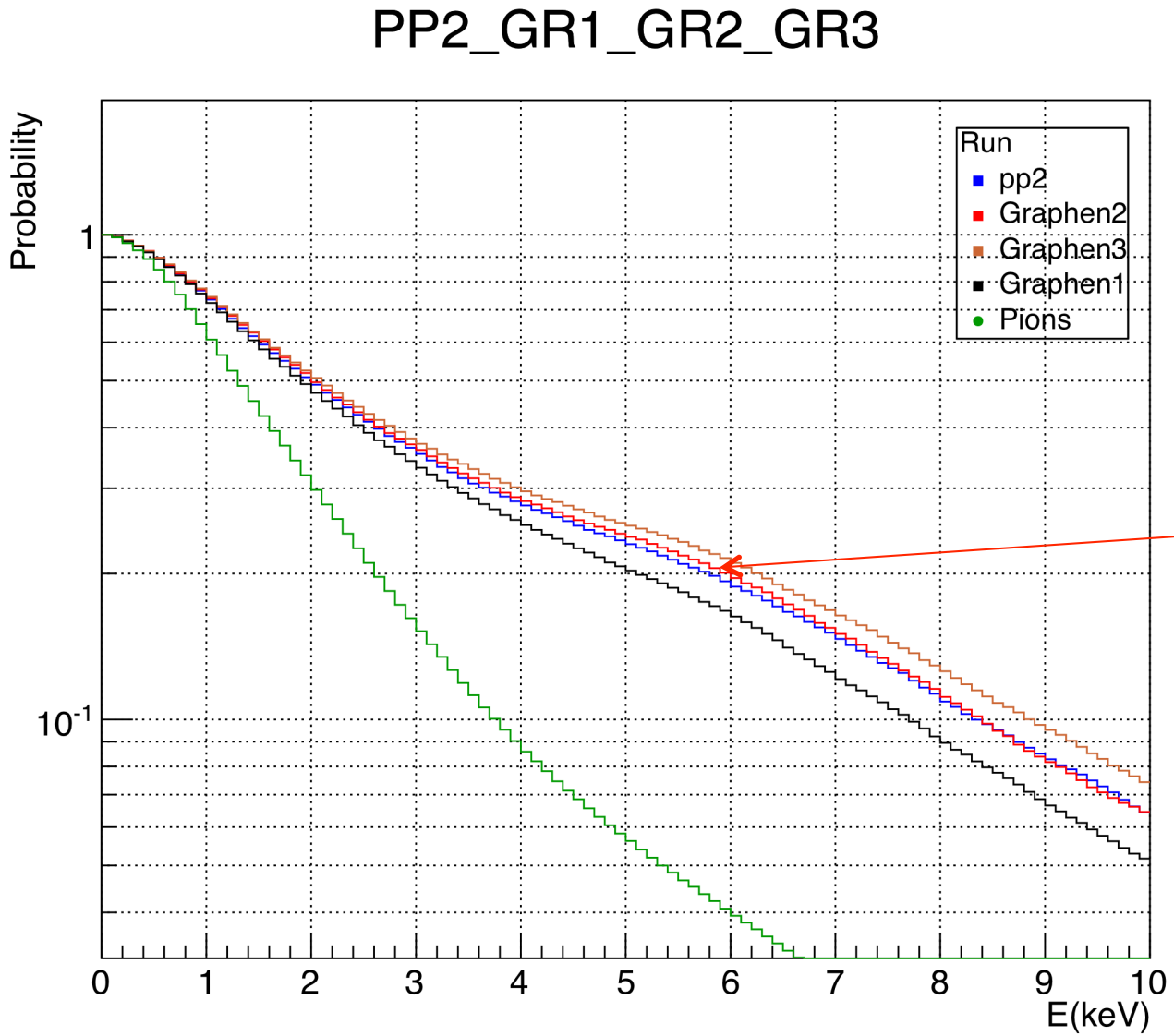
Test II: Graphene paper foil thickness



As expected 5 μm graphene layer produces soft TR spectrum.

Differential dE/dX+TR spectrums of PP2 and different graphene paper radiators

Test II: Graphene paper foil thickness

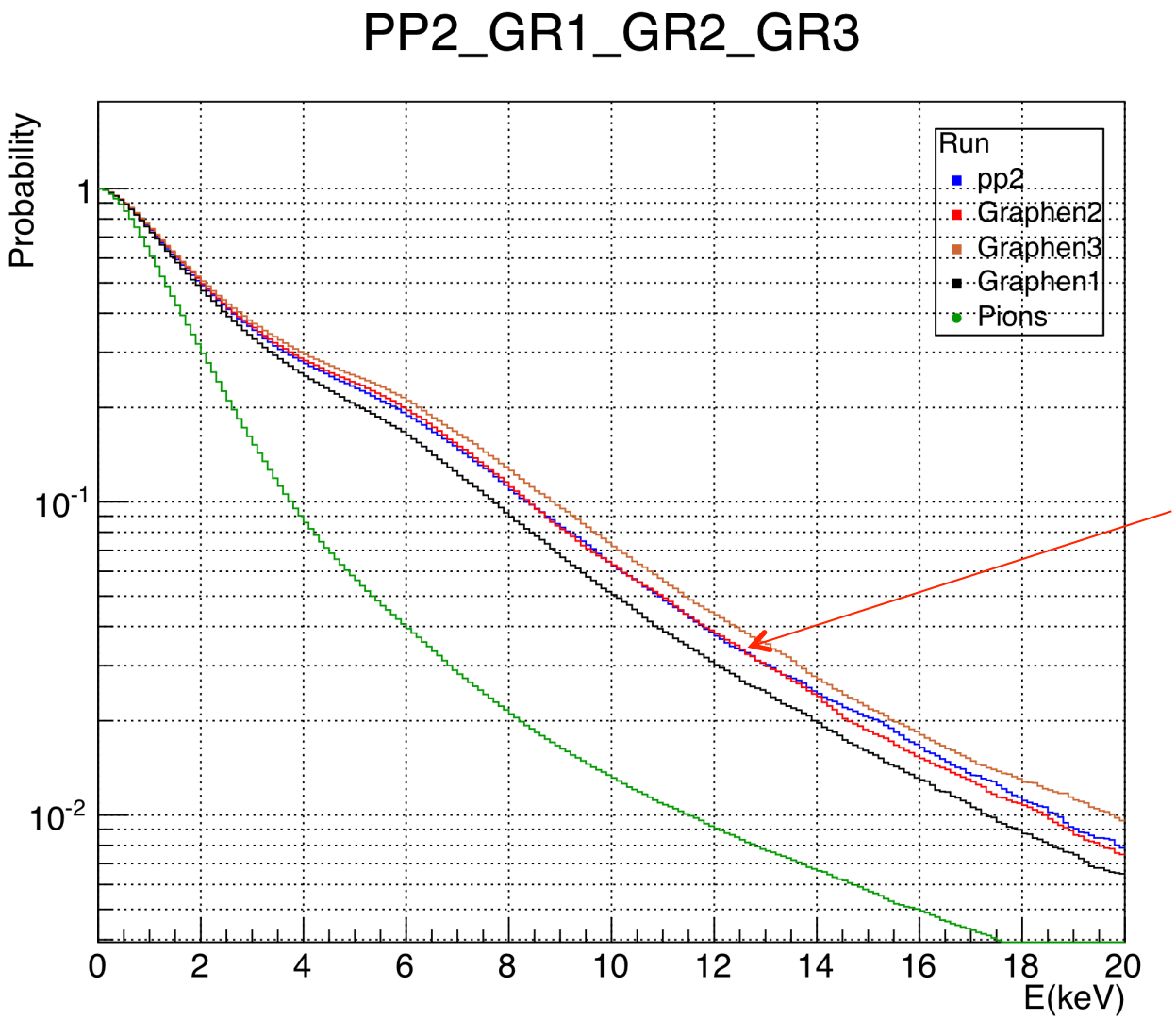


Integral dE/dX+TR spectrums of PP2 and different graphene paper radiators

Radiator with 2 foils of 5 μm graphene produces more TR in soft region than PP2 foil radiator.

From graphene radiator softer spectrum observed!

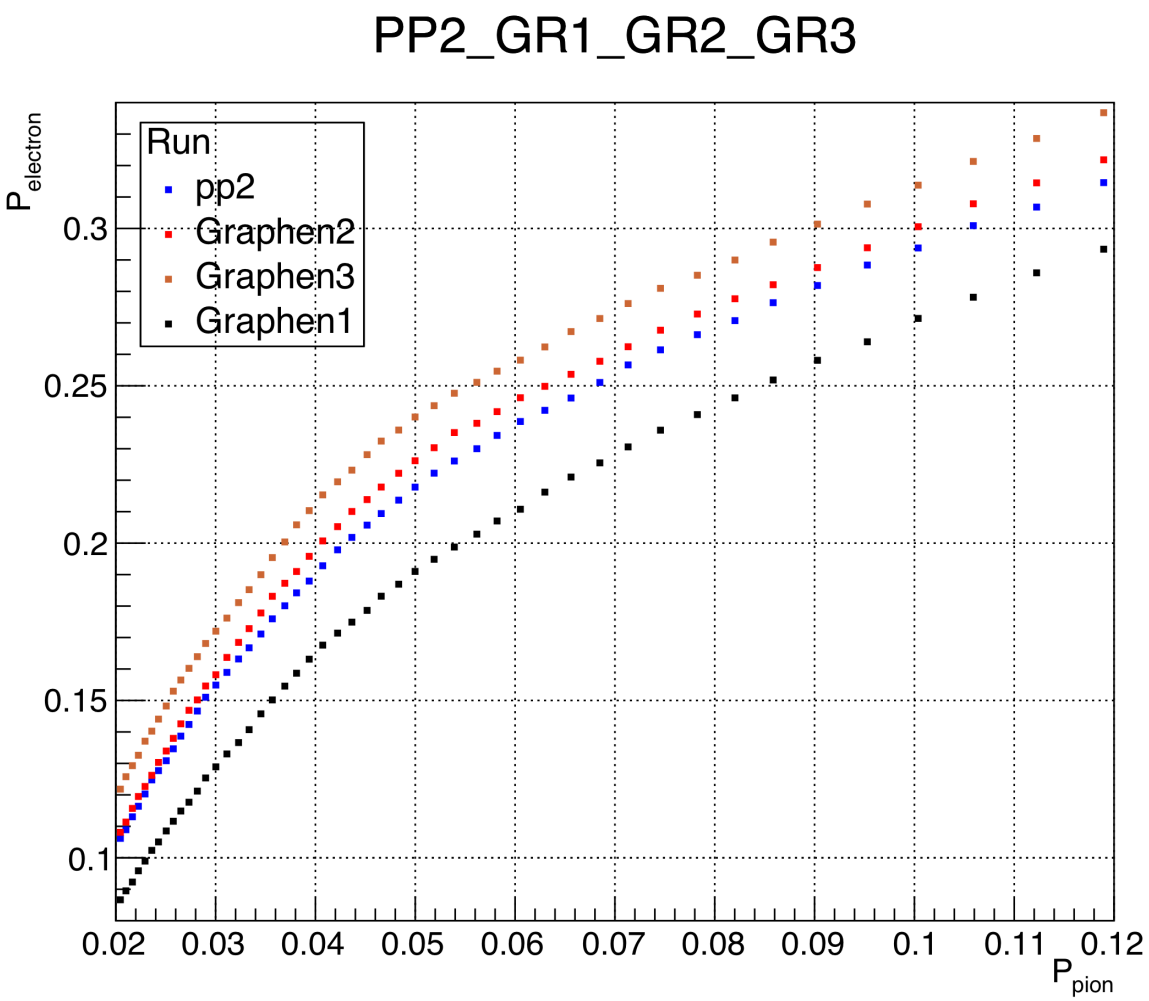
Graphene paper test



Integral dE/dX+TR spectrums of PP2 and different graphene paper radiators

Radiator with 2 foils of 5 μm graphene produces same or less amount of high energy TR than polypropylene foil radiator.

Graphene paper test

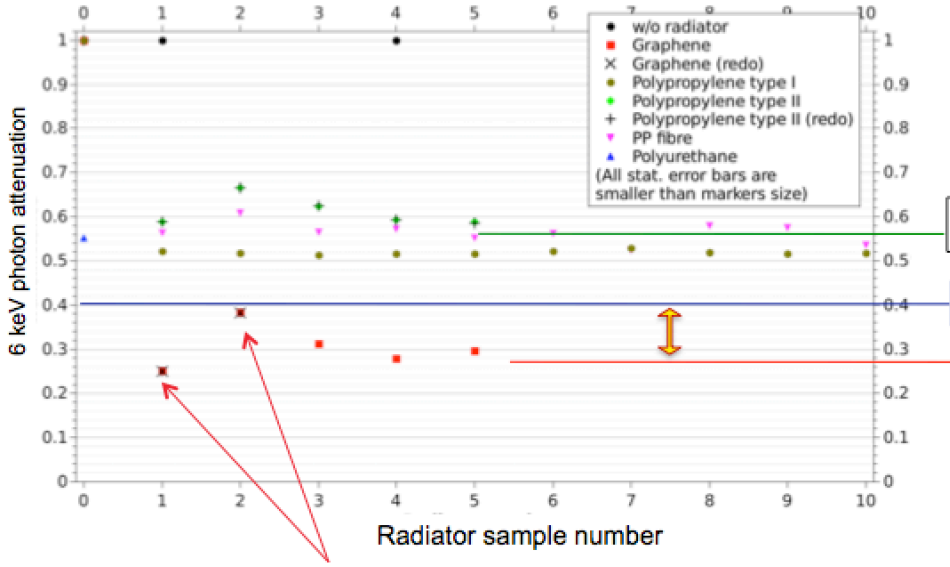


Probability to exceed threshold for electrons (P_e) VS probability to exceed threshold for pions (P_π) for graphene and polypropylene radiators.

We see that TR yield is larger for graphen radiator with layer thickness staring from 9-10 μm.

We shell expect better performance of the detector with graphene than with polypropylene radiator.
But we did not see this!

6 keV photon attenuation for different radiators.



PP2 radiator

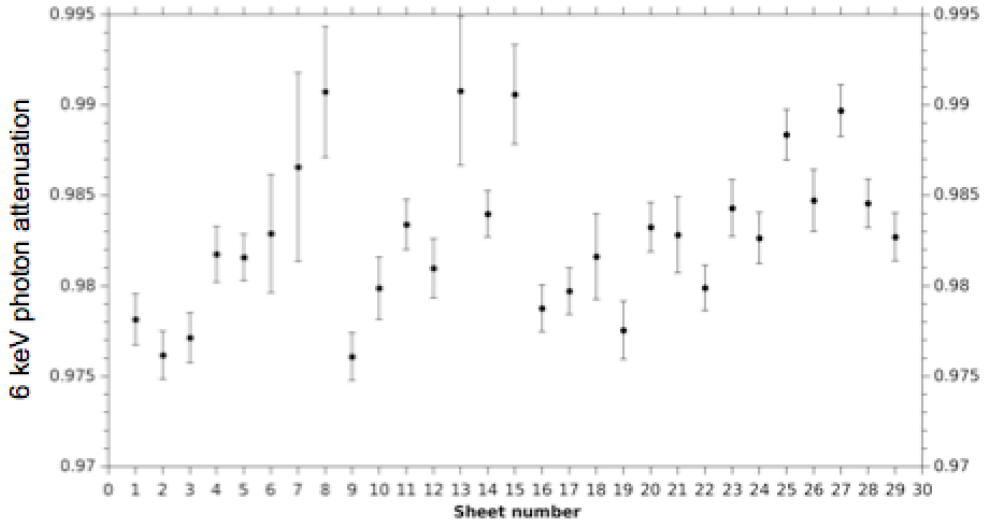
Graphene expected

Graphene radiator (final production).

Very different absorption within samples!

3 batches :
1st - Test batch 5 folis
2nd - Production batch 100 folis
3rd - Production batch 300 foils

Very different absorption within samples!

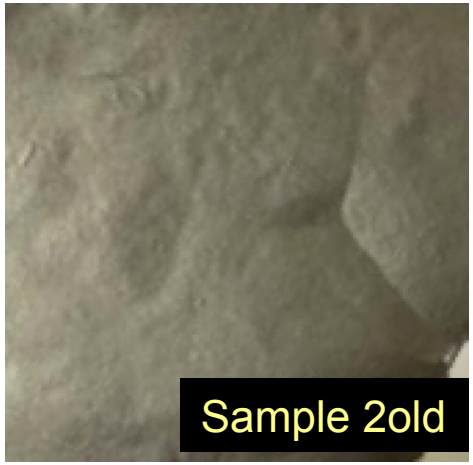


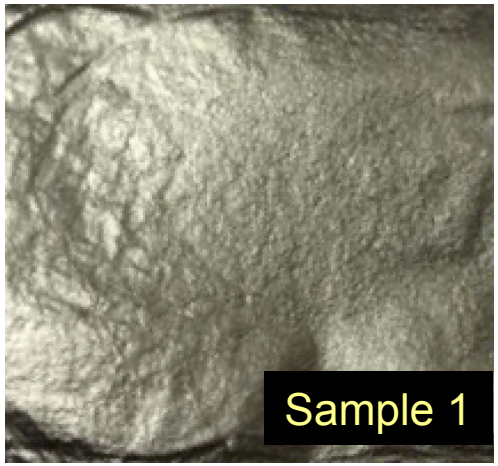
Big difference of X-ratv attenuation between foils.

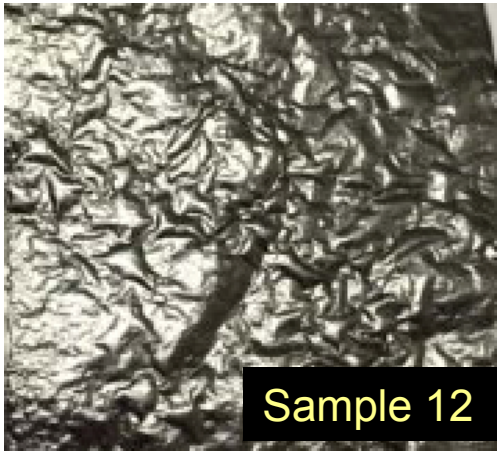
Total spread corresponds to a a factor of 3 difference in the absorption length!

Real foil parameters are very different.

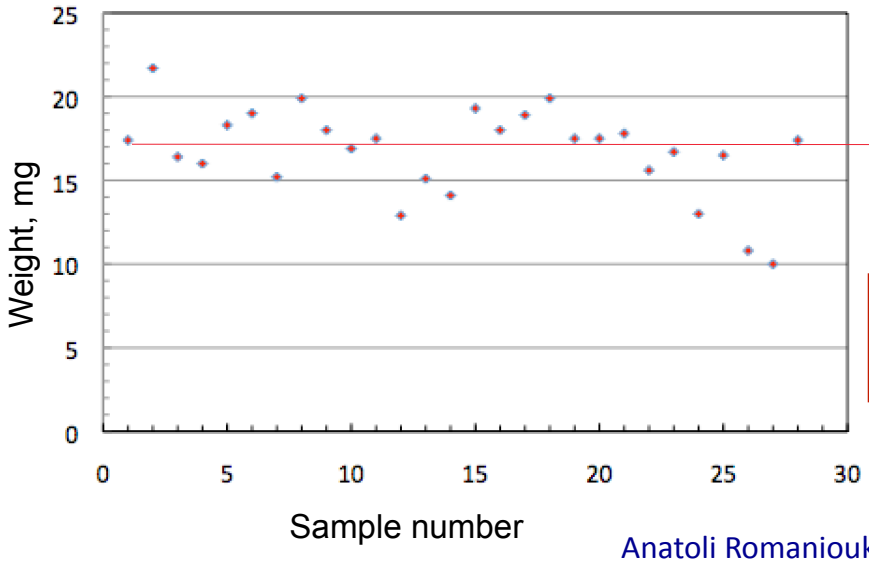
A few foil samples were studied.







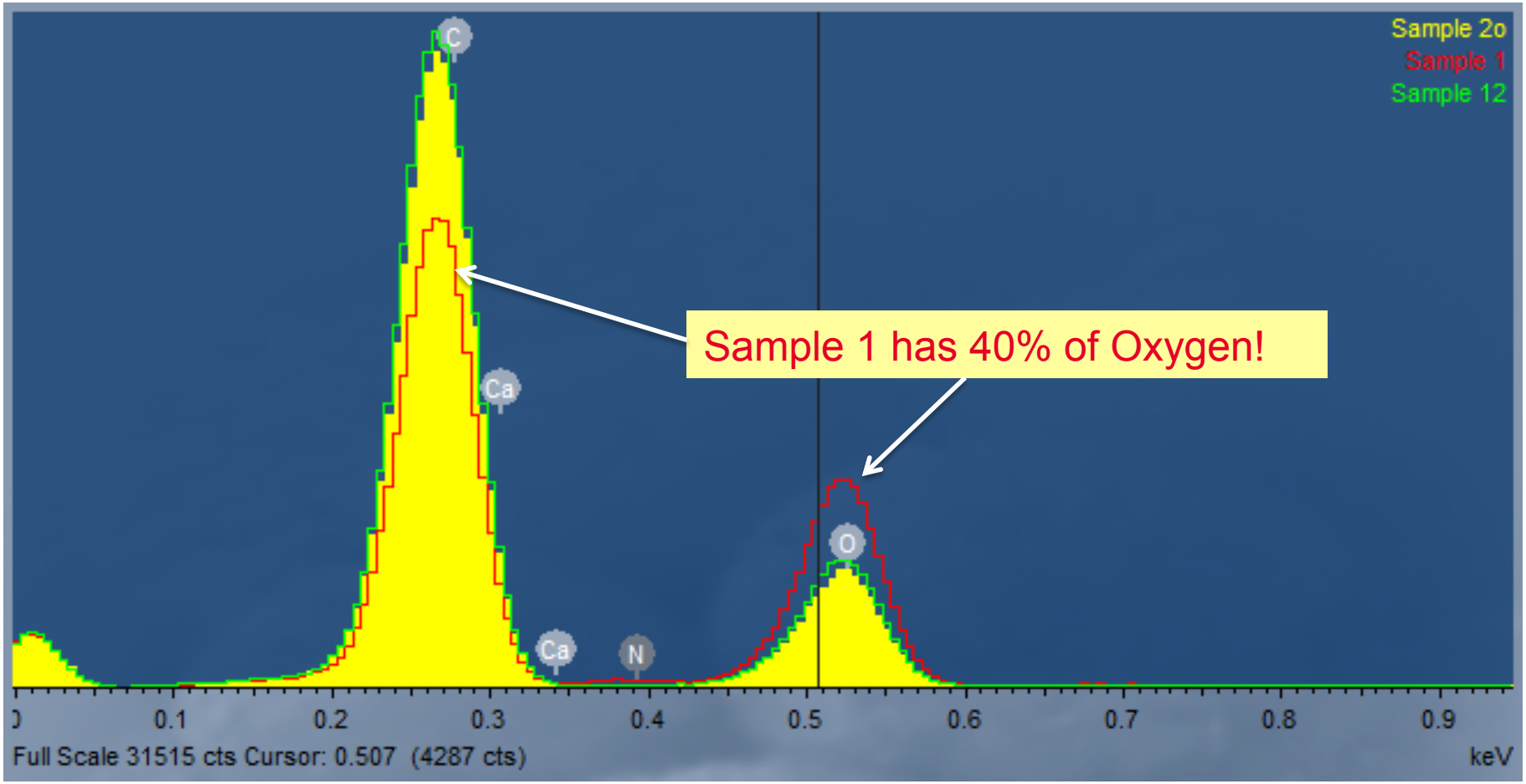
Foils have different structure!



Average 1.050 mg/cm2

Expected from test batch ~0.76 mg/cm2

Oxygen content



*Oxygen contamination of 20% gives factor of - $(8/6)^{3.5}$*0.2+0.8 = 1.3*
in X-ray absorption coefficient . 40% give factor of 1.7

Samples are very and spread is very large.
Agreed with Manchester to learn how to reduce O_2 concentration by 1 order of magnitude.

What did we learn about graphene paper?

Statements and questions:

- *Spectrum in one foil is softer than in PP foil radiator*
- *For 5 layers of radiator detector PP is better.*
- *Removing of O2 will increase a number of photons but will not change the spectrum.*
- *Effect of large ω would lead to an increase of harder part of the spectrum, however no change of the spectrum shape is observed*
- *Most likely a potential gain in TR after O2 removal can be explained by radiator properties including conductivity.*
- *What fraction of G-paper has graphene properties?*
- *Do we need more tests to look for graphene effects*
- *We desperately need good MC simulations*

What next:

- *MC simulation including O2 effect*
- *Remove O2 from samples?*
  Simulate the effect of a surface conductivity.
- *Are the results we have now conclusive enough?*

Discussion by the end of the session.