CYGNO simulations update

G. D'Imperio for the simulation group

CYGNO meeting 25/03/21

AmBe source

- AmBe source is made of $^{241}AmO_2$ and ^{9}Be
- ^{241}Am decay:
  - Radioactive ^{241}Am has a half-life of 432.2 years and decays via α emission (five different energies averaging 5 MeV) to ^{237}Np.
  - The dominant energy of the resulting background gamma-rays from the decay of the intermediate excited states in ^{237}Np is 59.5 keV.
  - Fast neutrons are produced when the decay α particles interact with ^{9}Be.

- (α ,n) reaction with ^{9}Be

  $\alpha + {}^{9}Be \rightarrow {}^{12}C + n$ (~42%),

  $\alpha + {}^{9}Be \rightarrow {}^{12}C^{*} + n$ (~58%),

  ${}^{12}C^{*} \rightarrow {}^{12}C + \gamma$ (4.38 MeV)

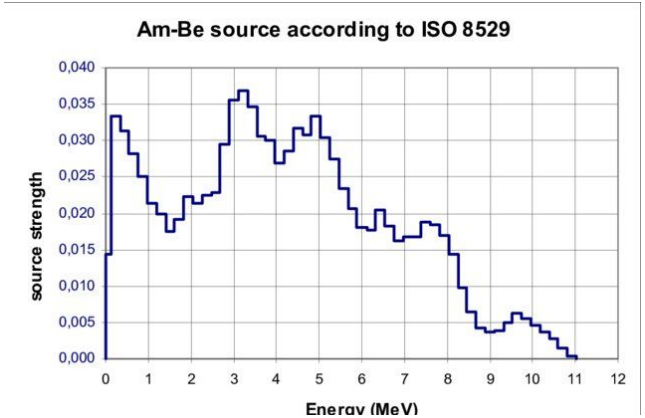
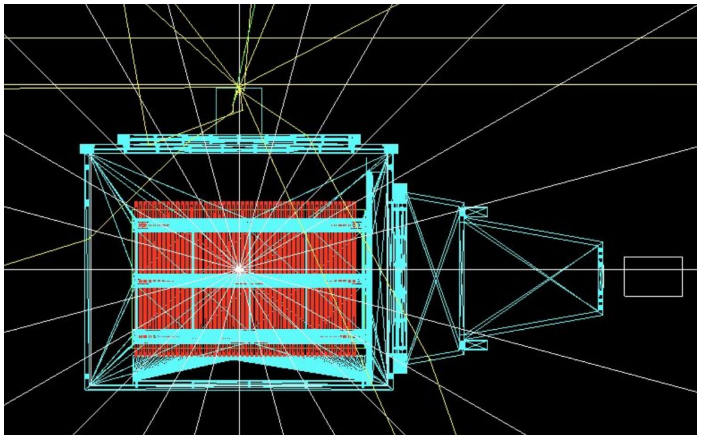


Fig. from https://rifj.ifj.edu.pl/handle/item/217

Ref: https://www.sciencedirect.com/science/article/abs/pii/S0969804307001200

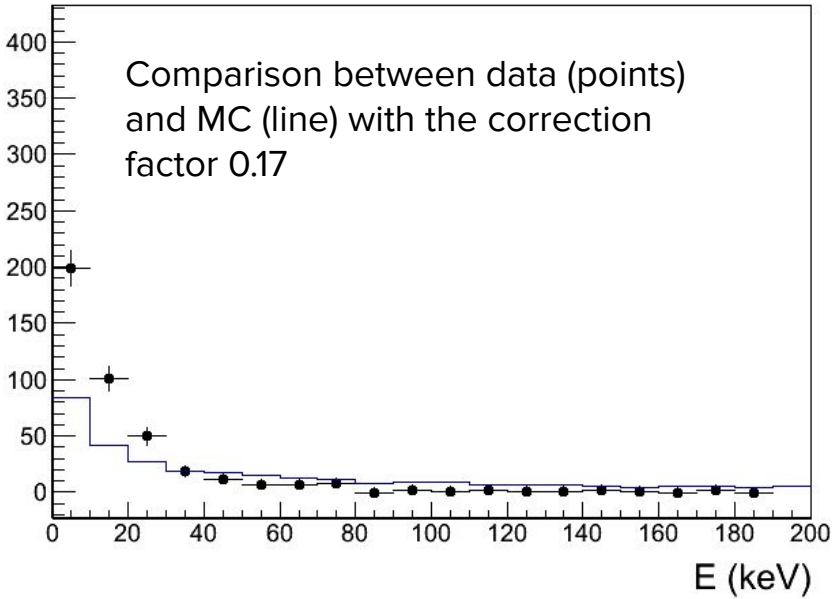
AmBe simulation in LIME

- LIME simulation code https://github.com/CYGNUS-RD/CYGNO-MC/tree/lime
- Added macros in the `macro` directory to simulate separately:
  - neutrons with spectrum from figure in previous slide
  - 4.438 MeV gammas
  - ^{241}Am decay (mostly gammas at 59.5 keV)
- Position of the source above the LIME box + 10x10x10 cm^3 Pb shield



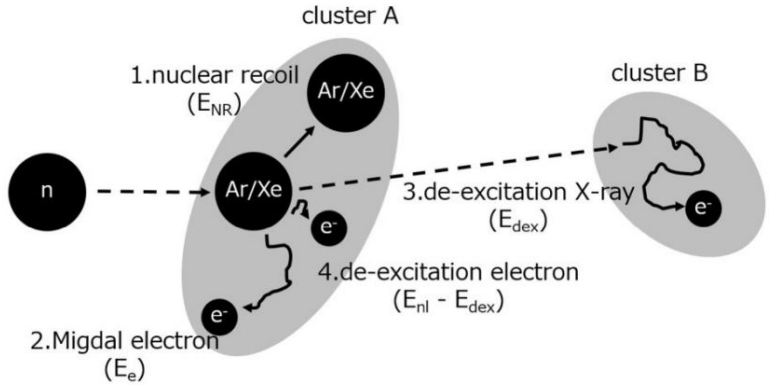
Basic comparison with AmBe data

- **2555** entries for **MC** with **LIME**
  ➜ ~**50 sec** equivalent data taking
- **407** for experimental data in **LEMON**
  ➜ ~**60 sec** live-time
- ratio between the total entries = **0.16**
  ➜ matches with factor obtained considering the volumes LEMON (7), LIME (50) and equivalent time ratio = **0.17**
- distribution in data shows no events at high energy and more events at low energy
  ➜ not surprising: QF not included in MC, maybe saturation not fully corrected, filters in the reco for high density pixels, ...



Feasibility of Migdal study with LIME (LEMON)

How the Migdal effect can be measured



target gas	Ar 1 atm $(30\,\mathrm{cm})^3$	Xe 8 atm $(30\,\mathrm{cm})^3$
number of nuclei	7.26×10^{23}	5.81×10^{24}
cross section for 565 keV neutron	0.65 barn	6.0 barn
Migdal branching	7.2×10^{-5}	4.6×10^{-6}
fluorescence yield (K shell)	0.14	0.89
scaling factor $(q_e^{max}/511\,\mathrm{eV})^2$	2.92	0.280
event rate	603 events/day	975 events/day

1000 n/s/cm^2

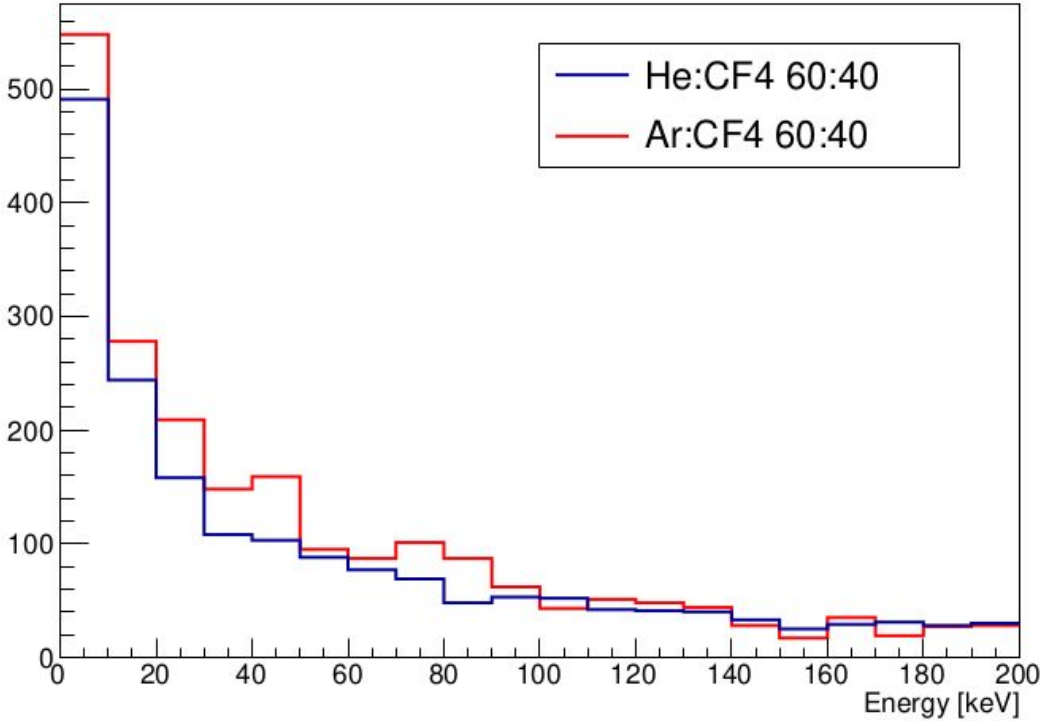
Table 1 Typical values of parameters for estimating the Migdal effect. The branching ratios for $(n, l) = 1s$ and $q_e = 511\,\mathrm{eV}$ are shown.

https://arxiv.org/pdf/2009.05939.pdf

Signal: use the (1s, K shell) x-ray de-excitation line @ 3 keV as an event tag. The signature is a NR with an ER separated by O(cm)

- Source activity: 2.2 10^5 neutrons/sec
  - LIME: 50 NR/sec
  - LEMON: 7 NR/sec
- To study Migdal effect we need at least O(100) interesting events
  ➡ considering the BR of Migdal and probability of X-ray emission, we need **~10^7 NR**
  - LIME: 200000 sec livetime (~3 days)
  - LEMON: 1400000 sec livetime (~17 days)
- Dead time could be a factor 2-3
  ➡ few weeks of data taking

First comparison with Ar:CF4 mixture



- 10^7 generated neutrons
- 2555 NR in He:CF4 mixture
- 2585 NR in Ar:CF4 mixture
- The spectrum for Ar:CF4 has more recoils at low energy