Boron-10 and Lithium-6 Loaded Scintillator for Neutron Detection

Xiongxin Dai

China Institute for Radiation Protection, Taiyuan, China

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中国辐射防护研究院
CNNC CHINA INSTITUTE FOR RADIATION PROTECTION

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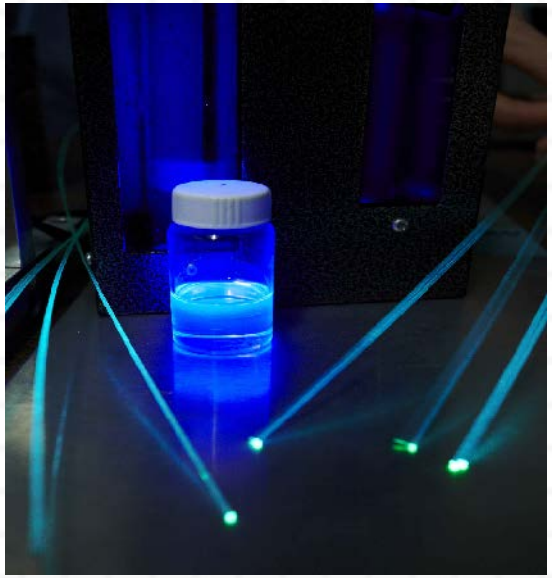
- Summary



Motivation

- Neutron detection has broad applications in many fields for various purposes.
  - Radiation safety
  - Homeland security
  - Neutron imaging

- He-3 based detectors have been extensively used for neutron detection because of their good neutron-to-gamma discrimination capability.

- Due to global shortage of He-3, an alternative neutron detecting material for He-3 replacement needs to be developed.

Neutron capture isotope

- **^{10}B** (3838b, natural abundance 19.9%)

$$^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{7}\mathrm{Li}^{*}\,(0.84\,\mathrm{MeV}) + \alpha\,(1.47\,\mathrm{MeV}) \qquad (93.7\%)$$

$$\hookrightarrow {}^{7}\mathrm{Li} + \gamma\,(0.48\,\mathrm{MeV})$$

$$^{10}\mathrm{B} + \mathrm{n} \rightarrow {}^{7}\mathrm{Li}\,(1.02\,\mathrm{MeV}) + \alpha\,(1.78\,\mathrm{MeV}) \qquad (6.3\%)$$

- **^{6}Li** (940b, natural abundance 7.5%)

$$^{6}\mathrm{Li} + \mathrm{n} \rightarrow \mathrm{t}\,(2.05\,\mathrm{MeV}) + \alpha\,(2.73\,\mathrm{MeV})$$

- The light yield of the 2-MeV triton (on ^{6}Li) is nearly 10x higher than that of the 1.5-MeV alpha (on ^{10}B).

- The neutron capture signature from ^{6}Li is well separated from the noise and most background sources.

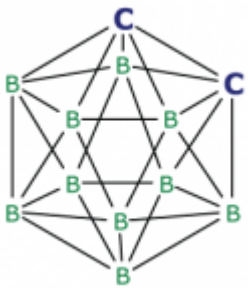
Requirements for scintillator

- High light yield
- High loading capacity for neutron capture materials
- Good optical transparency
- Good discrimination of neutron signal from noise and gamma-beta background radiation
- Long-term chemical and optical stability
- Safe: high flash point and low toxicity
- Low cost
- High refractive index & low afterglow for neutron imaging

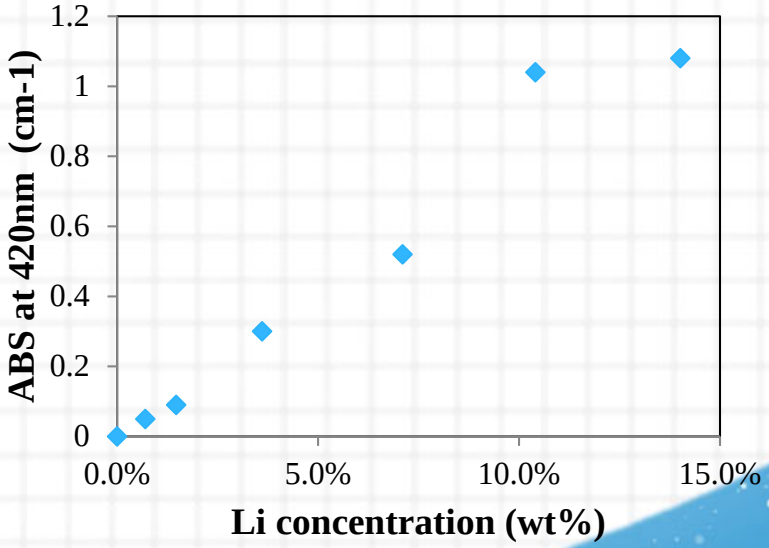
Preparation of LS

- **Boron loaded liquid scintillator**
  - Solvent: LAB, DIN, etc
  - Fluors: PPO + bis-MSB
  - B: o-carborane ($C_2H_{12}B_{10}$), 5% boron (w/w)
  - Patented: # CA 2767658 A1 (2013), US 20150014588 A1 (2015)

o-carborane



- **Lithium loaded gel scintillator**
  - Solvent: LAB, DIN, etc
  - Fluors: PPO + bis-MSB
  - Li: LiCl, ~1.5% Li (w/w)
  - Tissue equivalent
  - Ongoing tests



B-loaded LS: Pulse shape discrimination

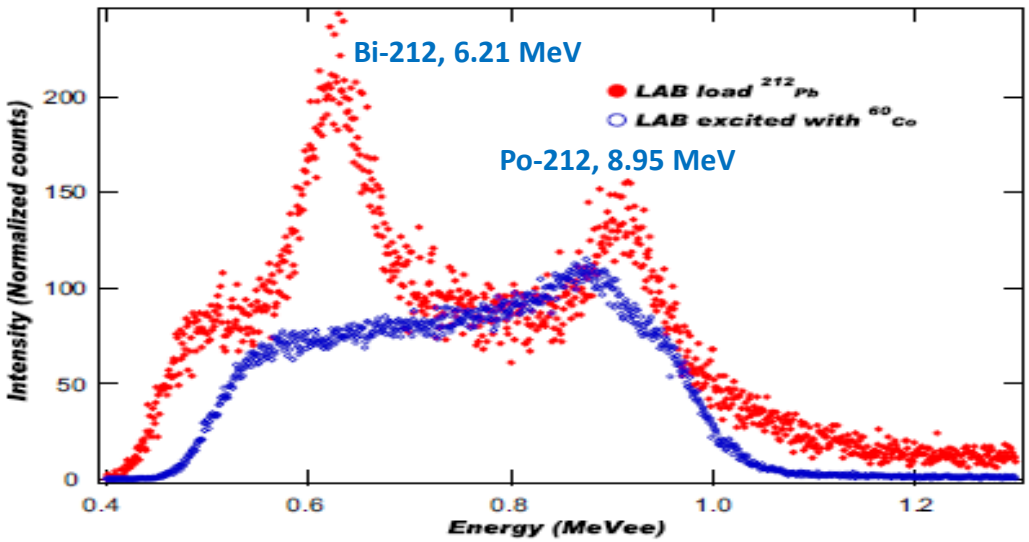
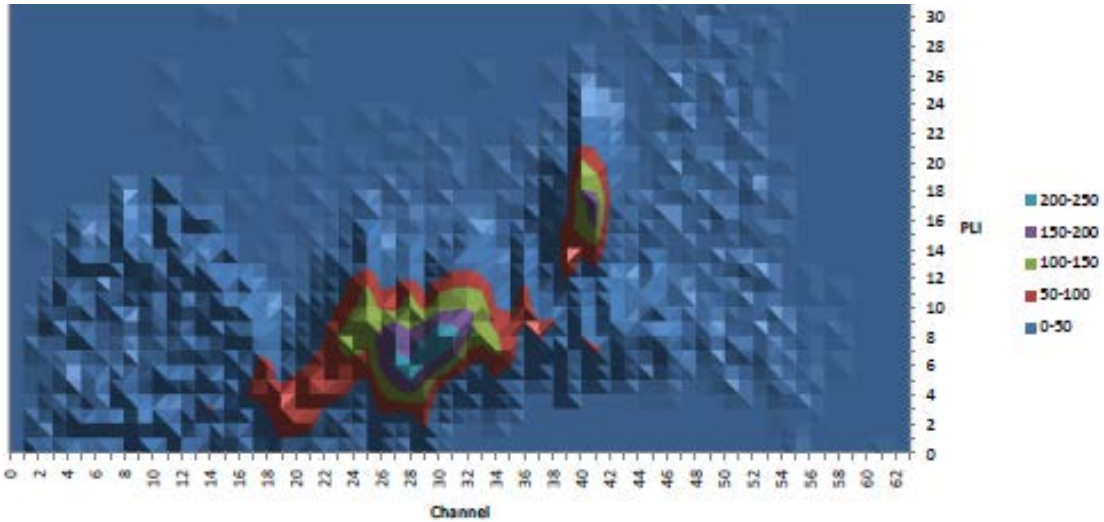
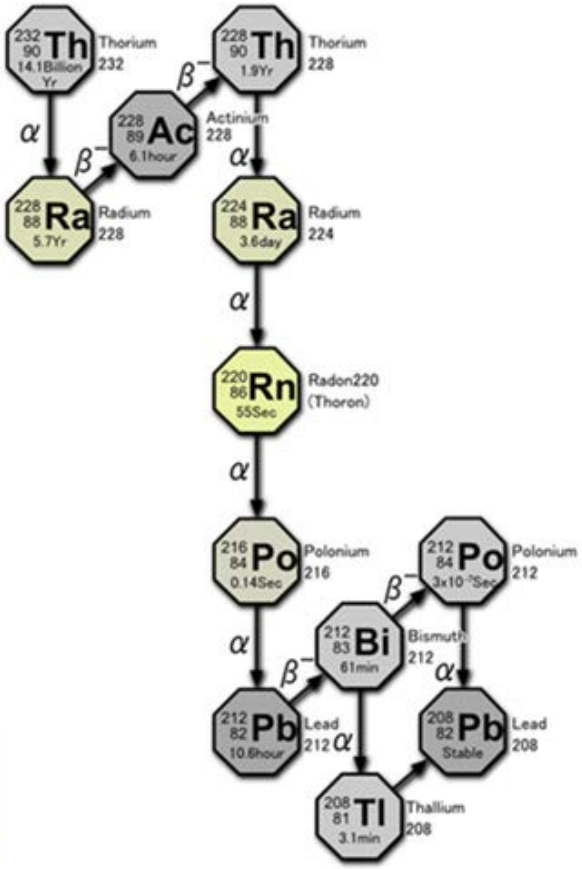


Fig. 2. ^{212}Pb Energy spectrum detected by LAB based scintillator.





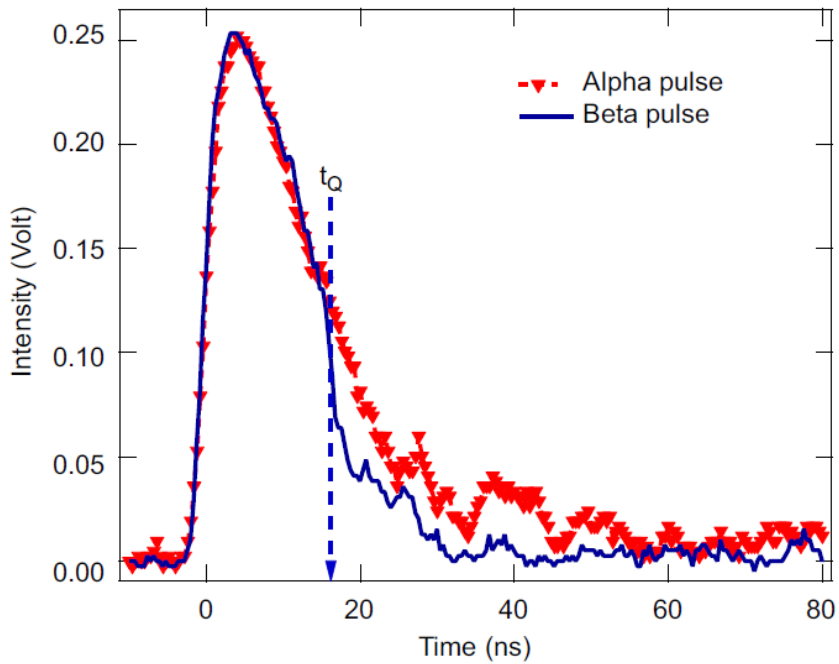
Beta/alpha discrimination of B-loaded LS spiked with Pb-212

B-loaded LS: Pulse shape discrimination

$$FOM = \frac{(Alpha - Beta)_{separation}}{Bandwidth(R_{alpha}) + Bandwidth(R_{beta})}$$

$$R = \frac{S_{tail}(t_Q \rightarrow t_{end})}{S_{total}(t = 0\ \text{ns} \rightarrow t_{end})}$$

FOM = 1.75



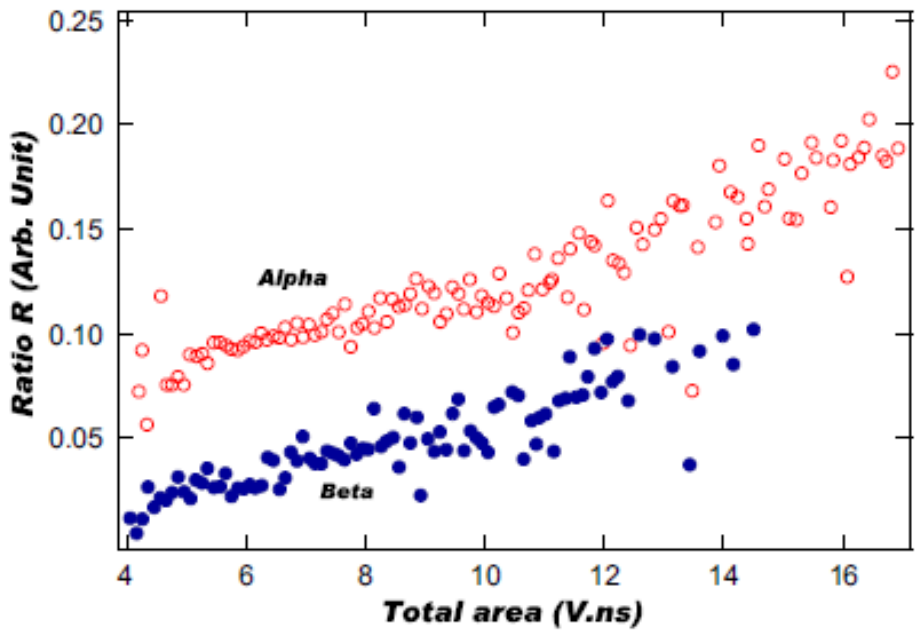
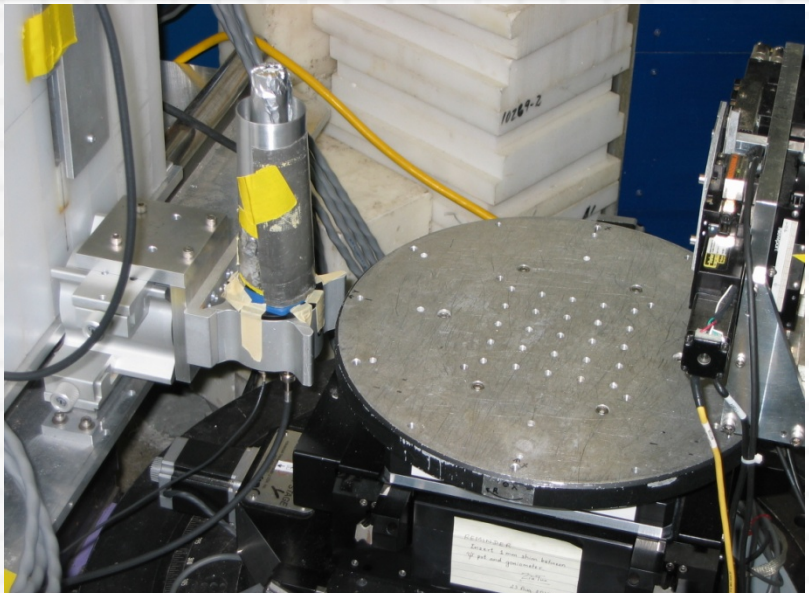
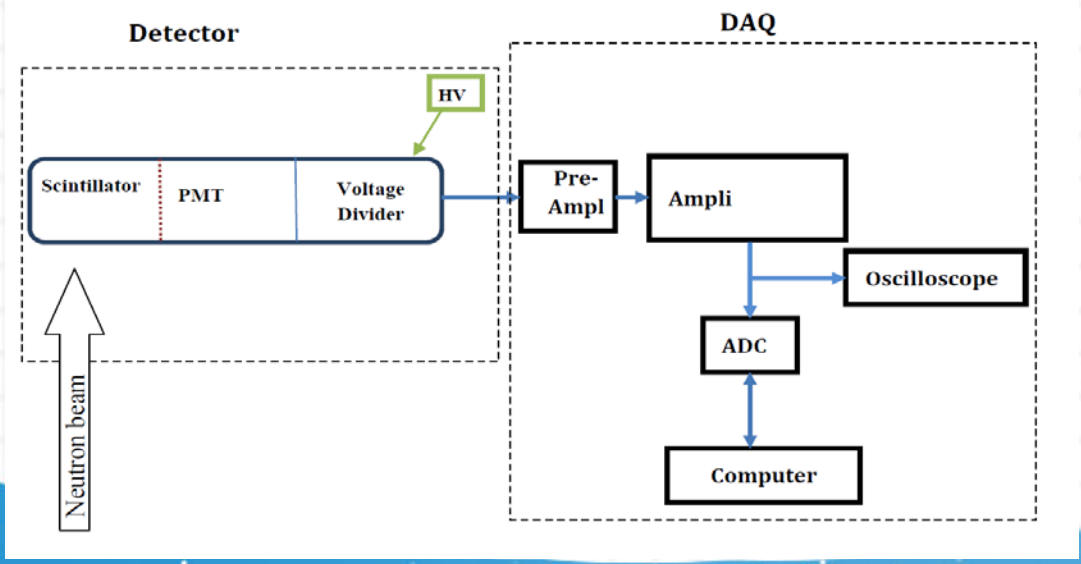


Fig. 5. Average of ratio R for alpha and beta pulses.

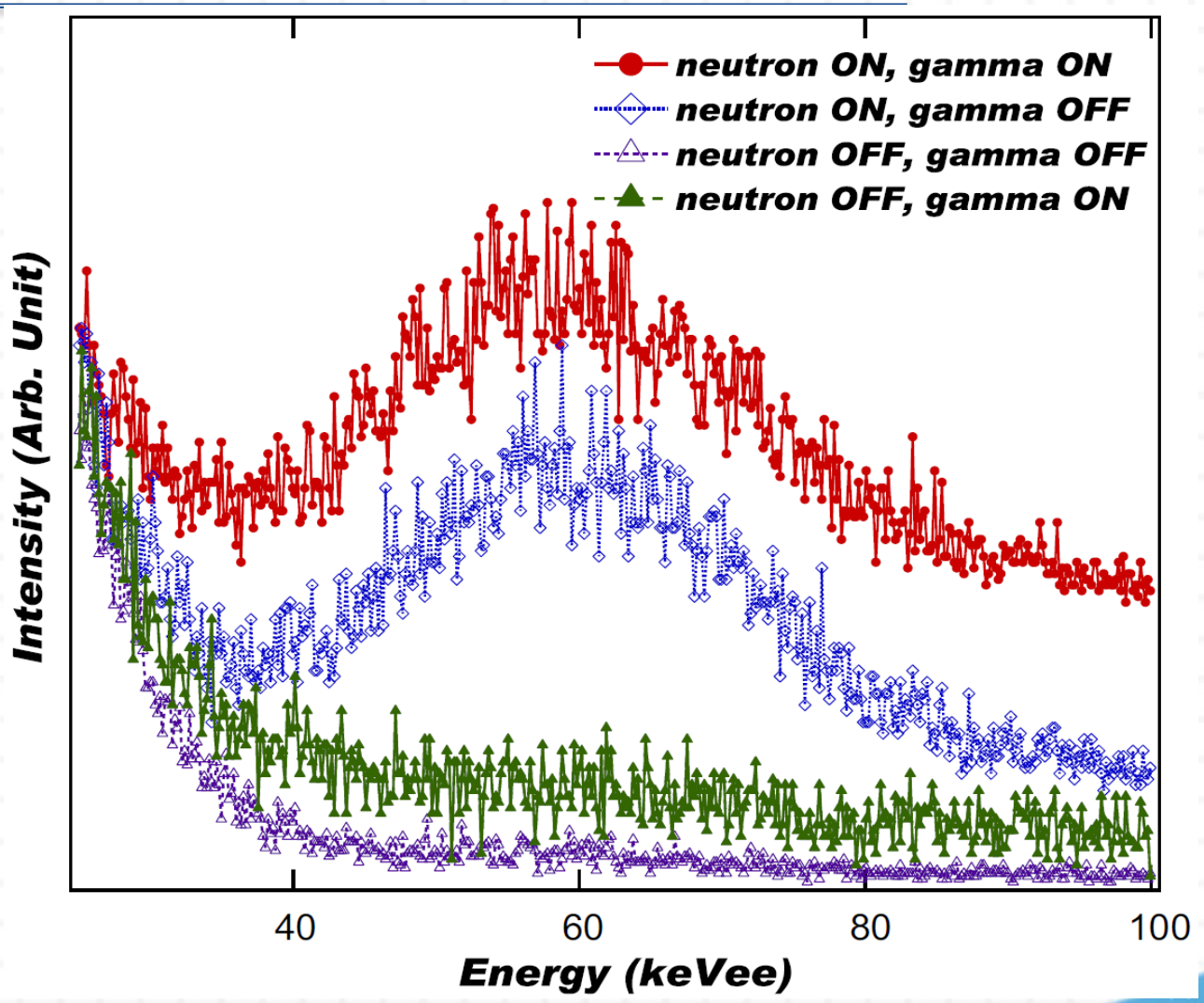
B-loaded LS: Tests with neutron beam





- **Tests at the National Research Universal (NRU)**
- **Neutron wavelength of 2.37 ˚A (E=14.56 meV)**

B-loaded LS: Tests with neutron beam



Summary

- Methods for preparation of boron-loaded liquid scintillator and lithium-doped gel scintillator were developed for neutron detection.
- The boron-loaded LS has been characterized, and the results confirmed that it is suitable for neutron detection in a gamma ray environment using PSD technique.
- Tests on the Li-doped gel scintillator is on-going.
- Promising candidates for replacement of He-3 for neutron detection.

Acknowledgements

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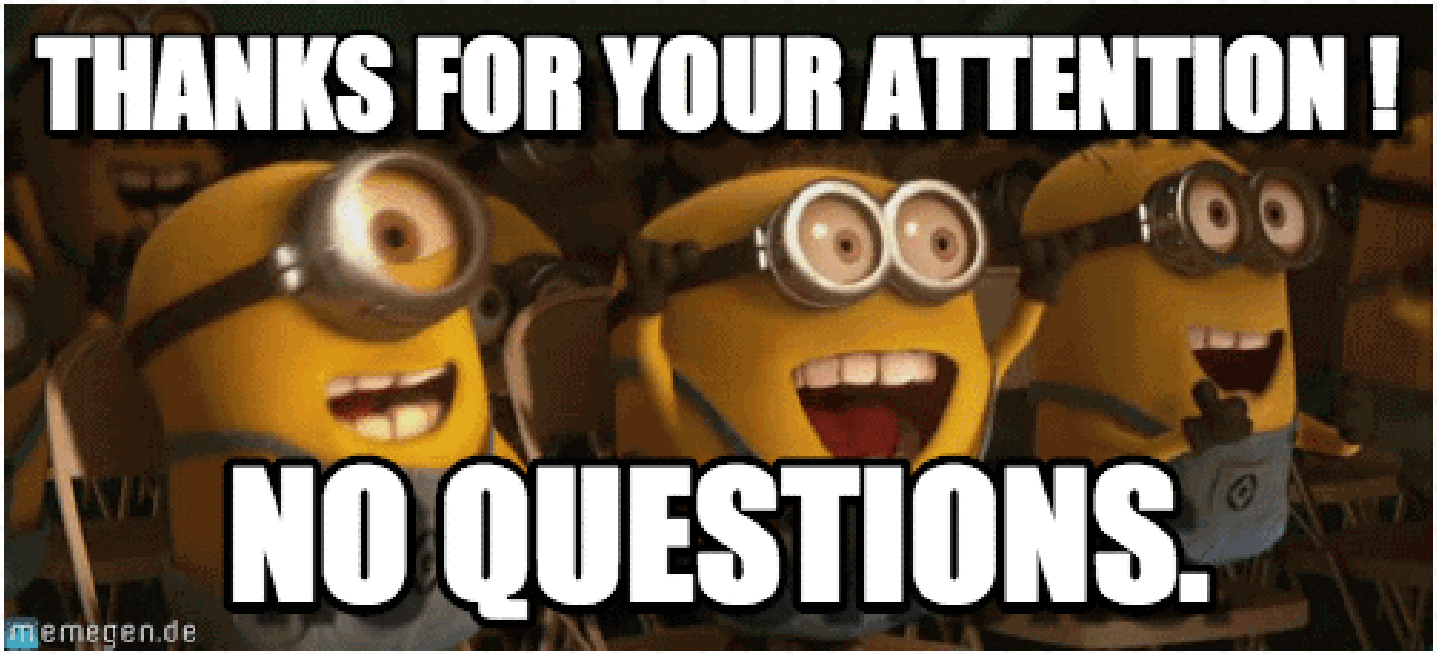
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NO QUESTIONS.
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