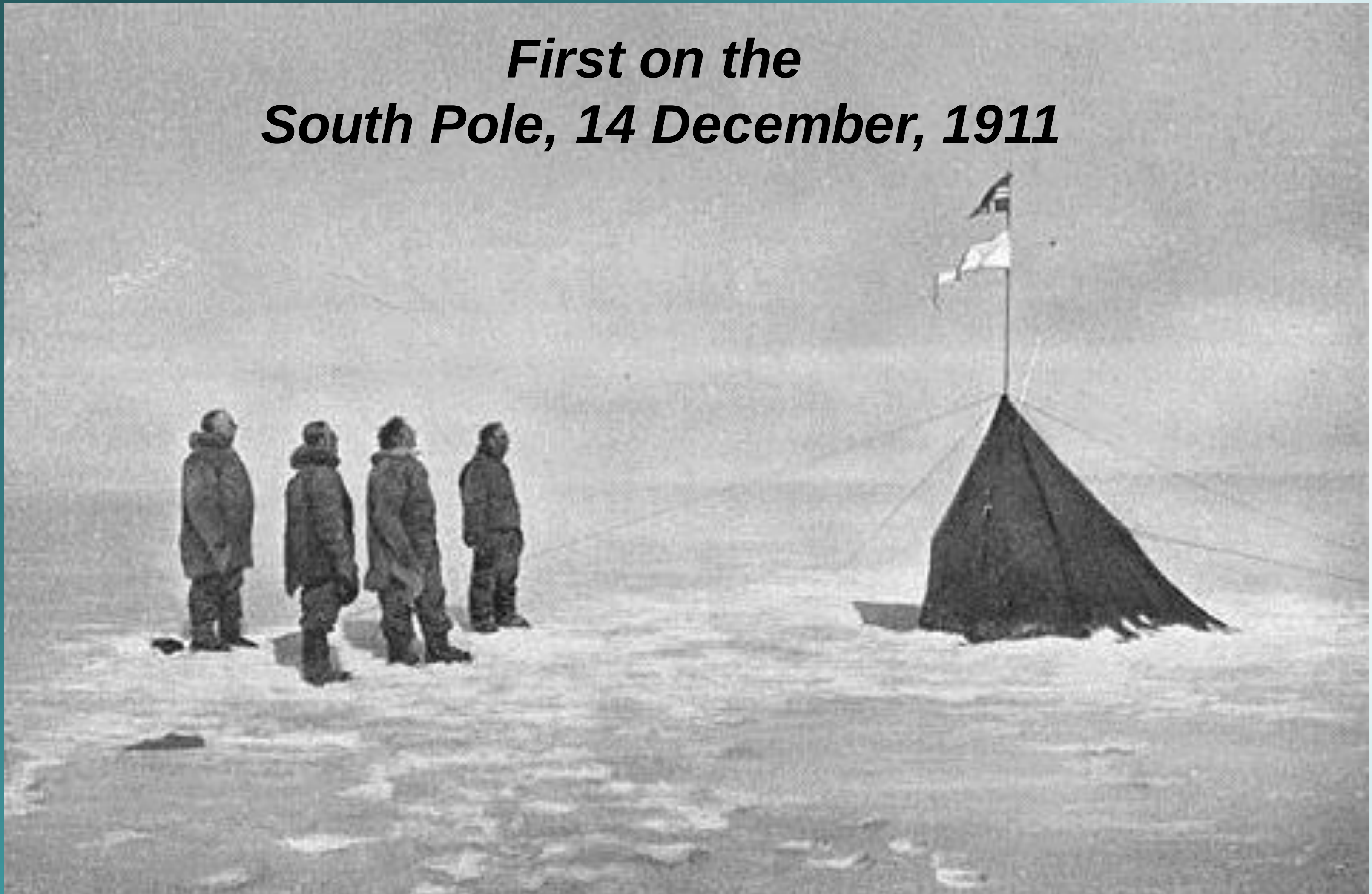
First on the South Pole, 14 December, 1911



The potential use of small transportable neutron generators for studies of industrial mass flow

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Institute for Energy Technology (IFE) and
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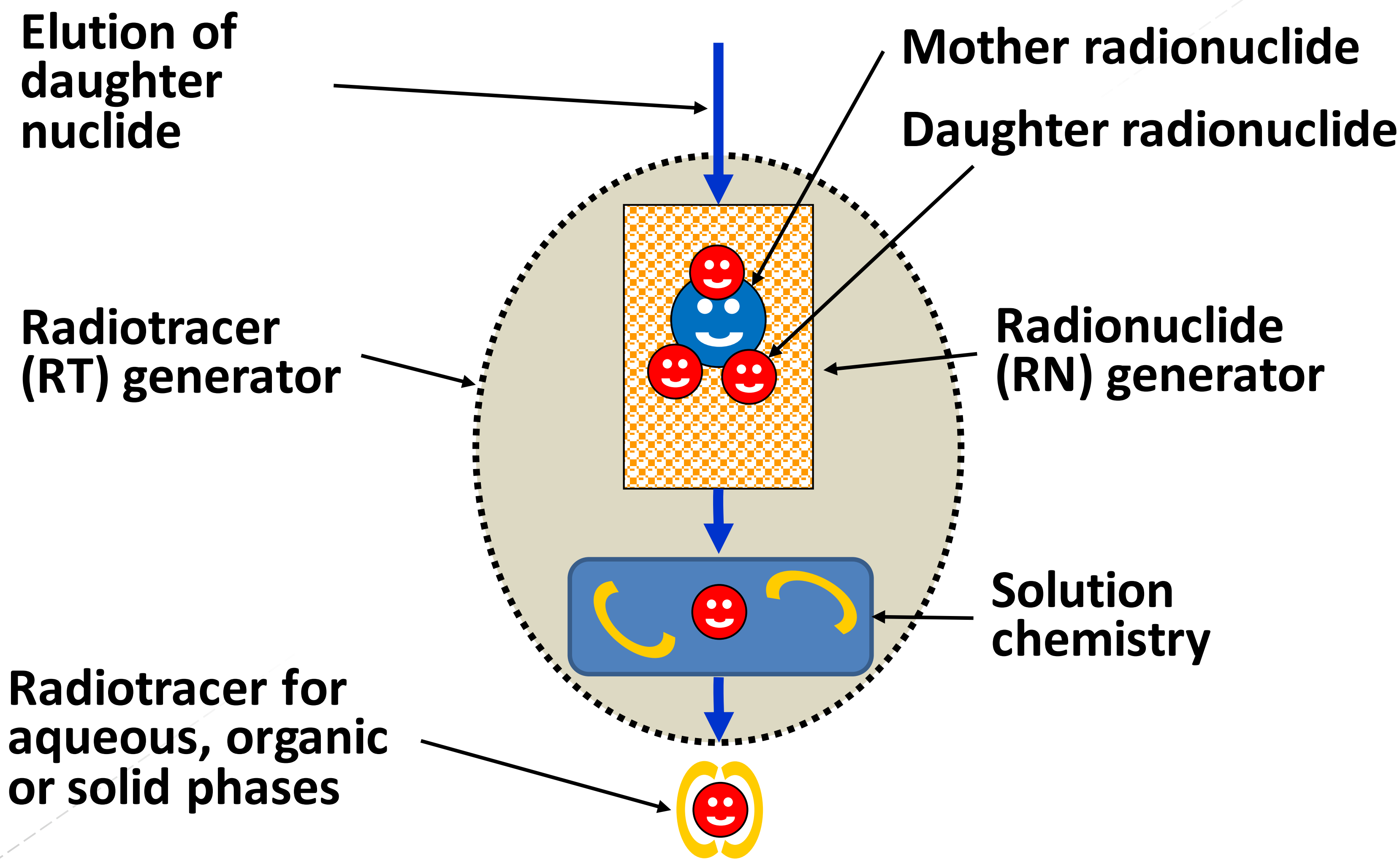
On demands….

- **Short-lived radioactively labeled tracers for liquid and solid phases at remote locations**

- **How to generate short-lived radionuclides?**
  - *Nuclear reactors - cannot be moved!*
  - *Particle accelerators – cannot be moved!*
  - *Isotopic/isotropic neutron sources – can be moved but not turned off!*

- **Are there other solutions?**

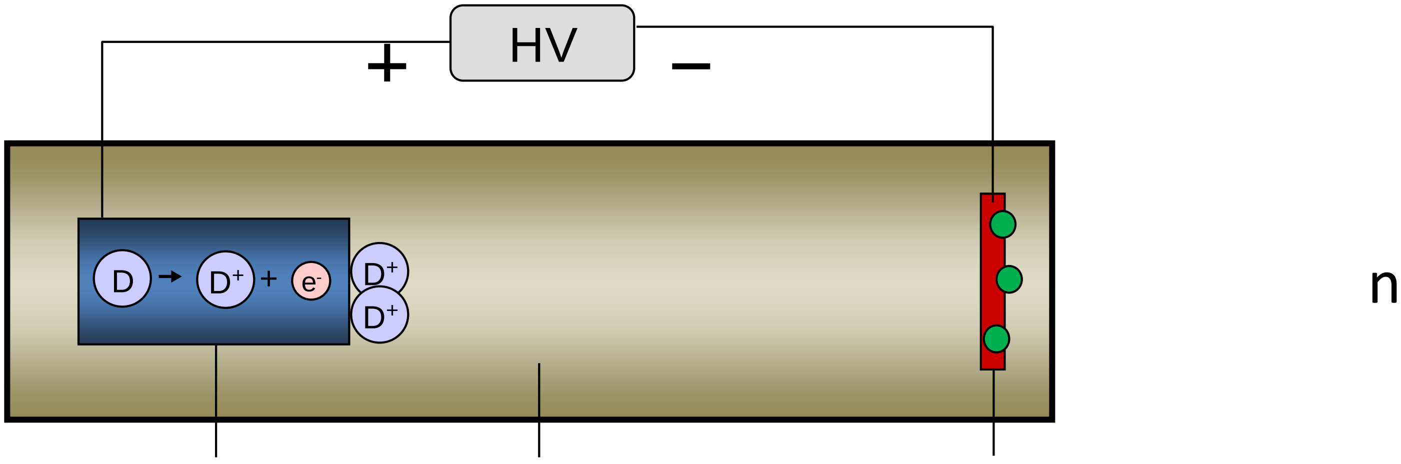
Radiotracer generator principle



Principle of a neutron generator

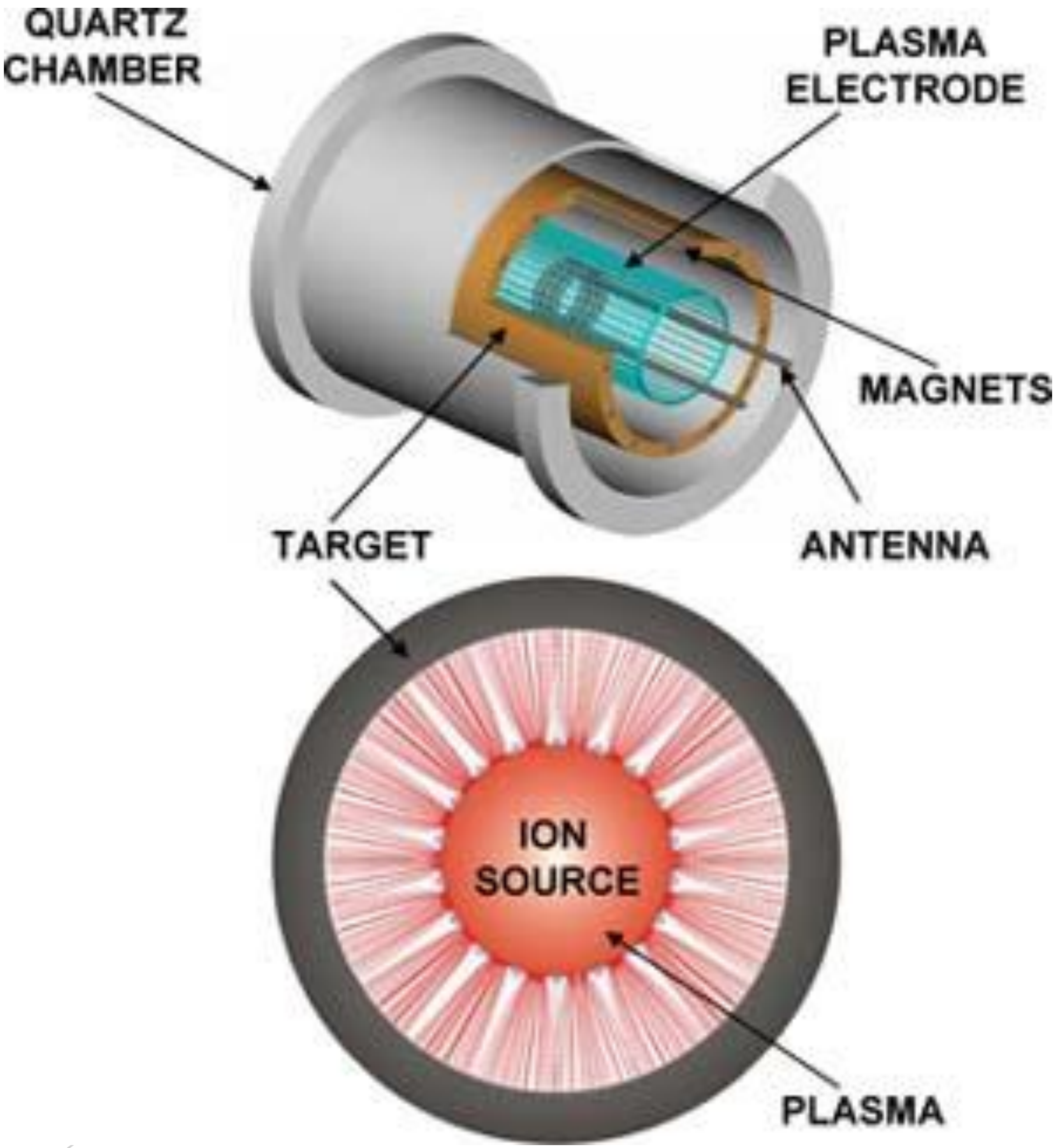
Sealed-tube neutron generator:

The principle of a neutron generator is illustrated below:



Deuterium accelerated against tritium or deuterium gives the reactions:

D + T → ^{4}He + n (14.1 MeV)
D + D → ^{3}He + n (2.5 MeV)



Sealed tube neutron generator

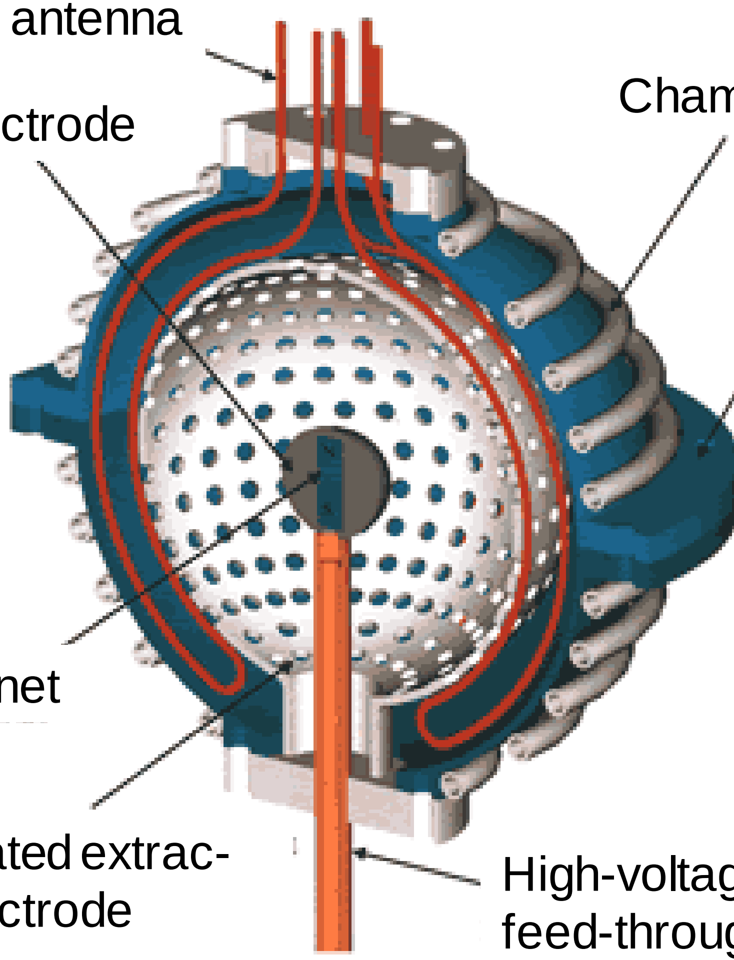
Berkeley design

Compact Spherical Neutron Generator,

IB-1675, Berkeley design

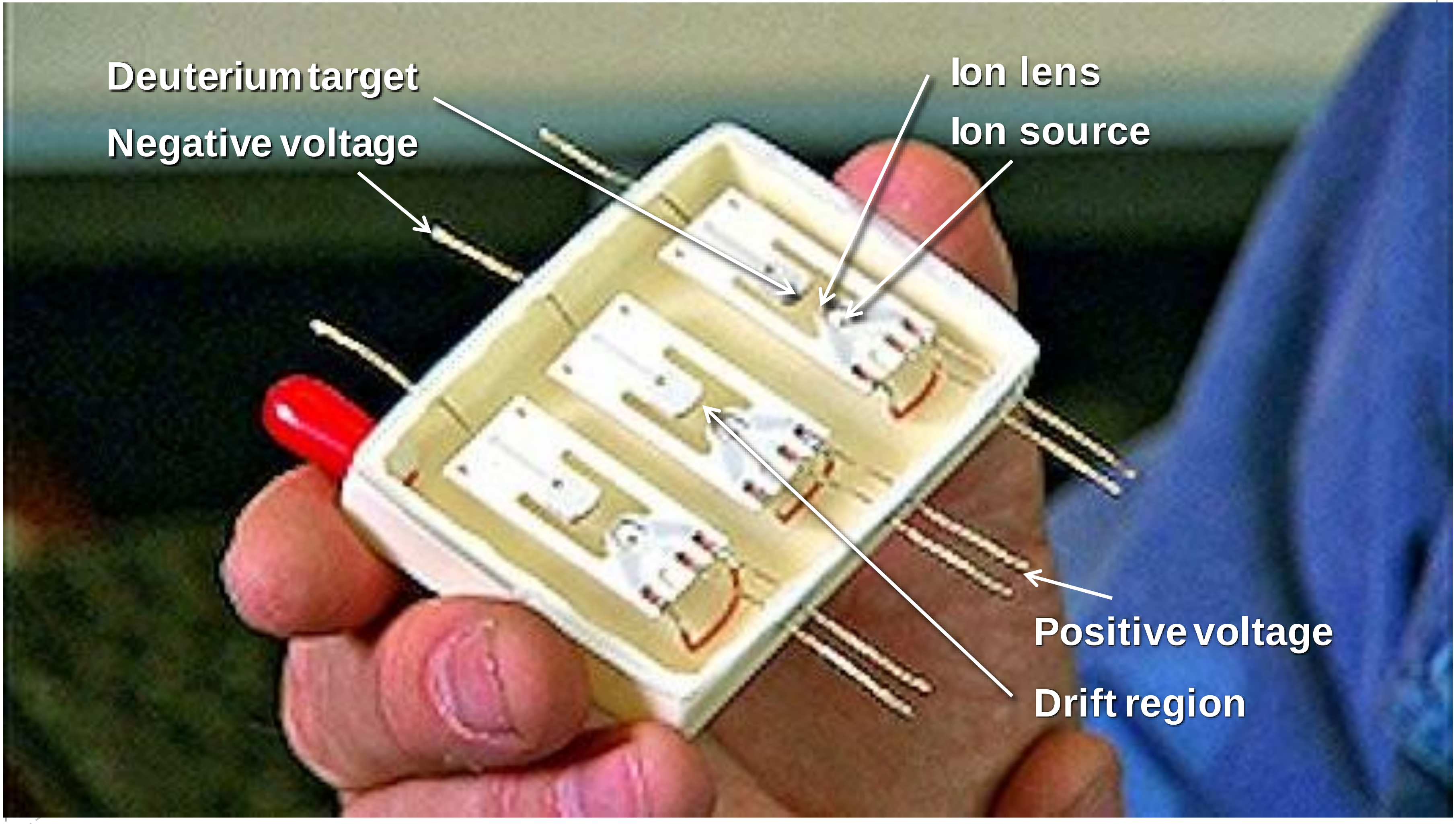
Advantages:

- High brightness
- Works like a point source
- High Flux
- High neutron field
- Safe D-D reactions



World's smallest neutron generator-

The Sandia Laboratories' Neutristor



Neutron generators (D-D and D-T)

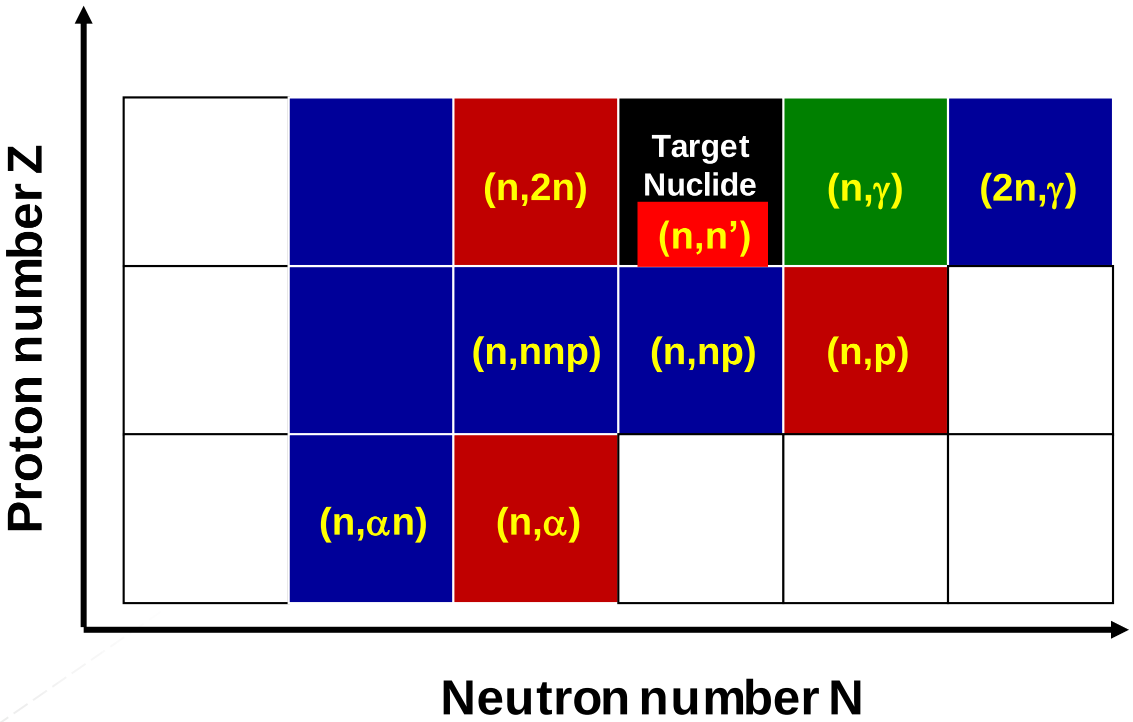
- Neutron Energy : 14 MeV (DT) or 2.5MeV (DD)
- Neutron yield : up to 10^{10} n/s/4πsr (DT) or 10^{8} n/s/4πsr (DD)
- Typical tube lifetime at $2{\cdot}10^{9}$ n/s/4πsr (DT) : 4000 hour

SODERN sealed tube

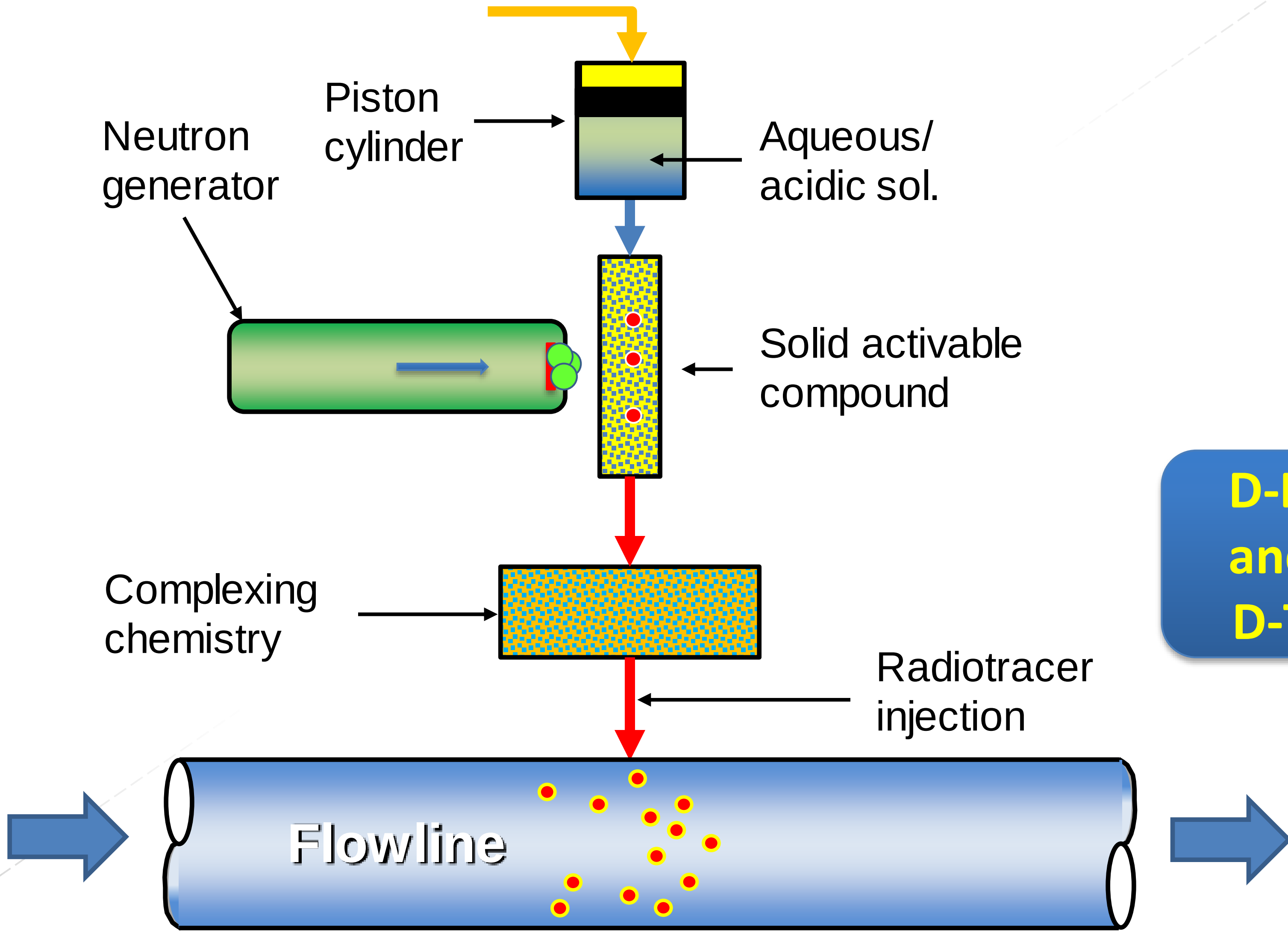
- Neutron Energy: 14 MeV (2.5 MeV for D-D)
- Neutron yield: up to $2{\cdot}10^{8}$ n/s (2.10^{6} n/s for D-D)
- Typical tube lifetime: 4000 working hours (for 10^{8} n/s)

SODERN Sealed tube

Various reactions with «fast» particles

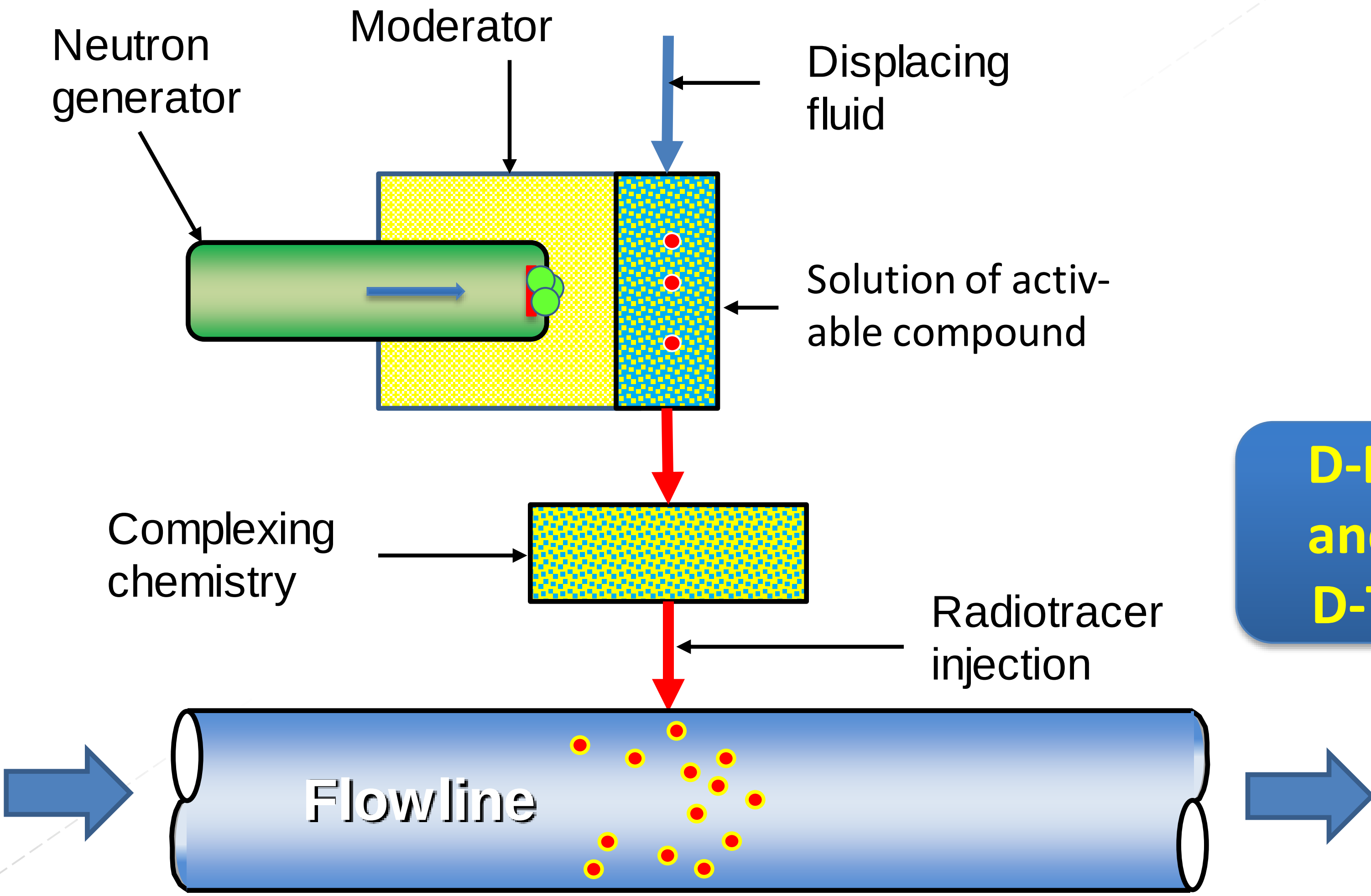


Off-line fast neutron activation – on-line mount.



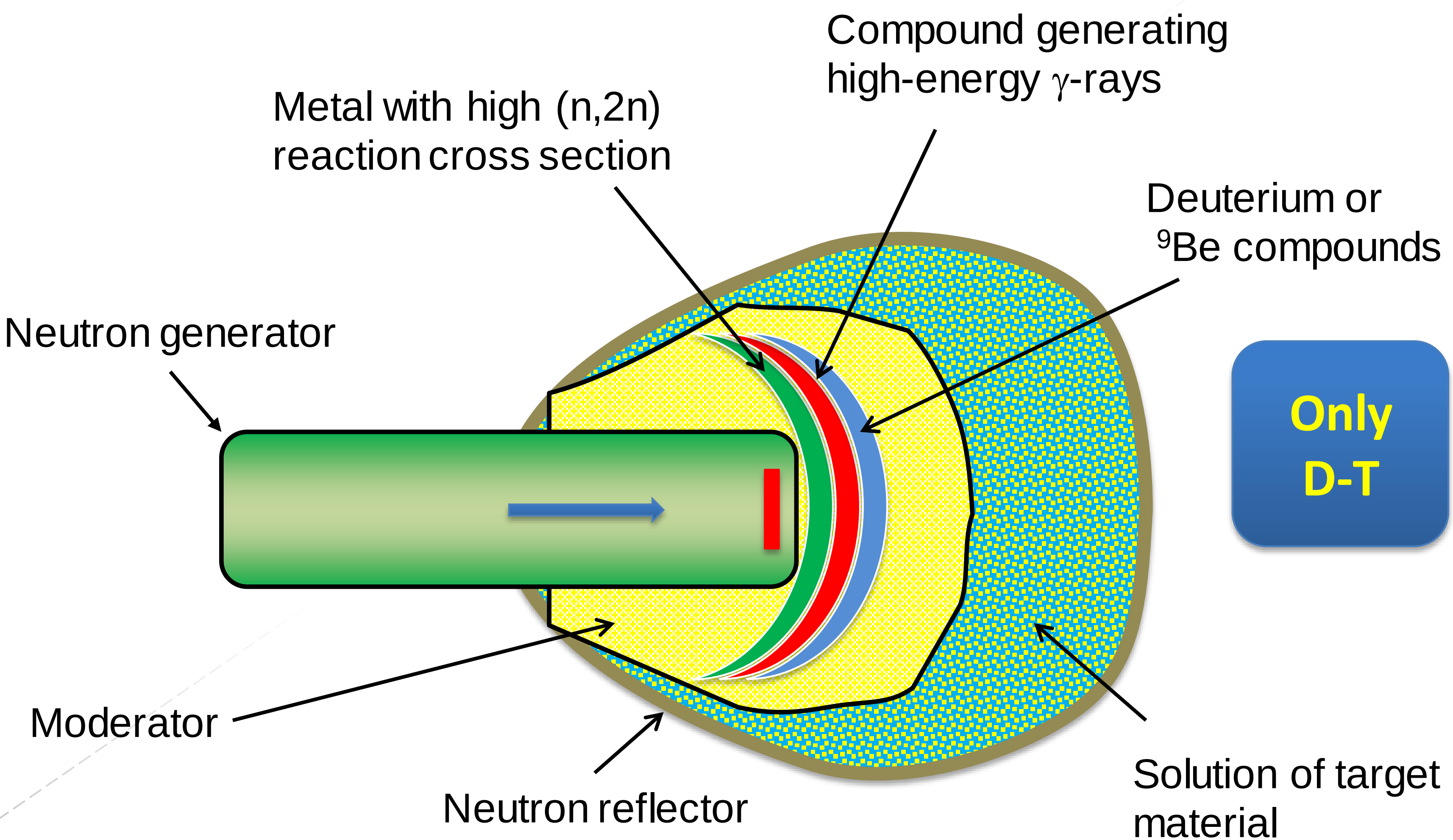
D-D and D-T

Off-line thermal NA on-line mount.



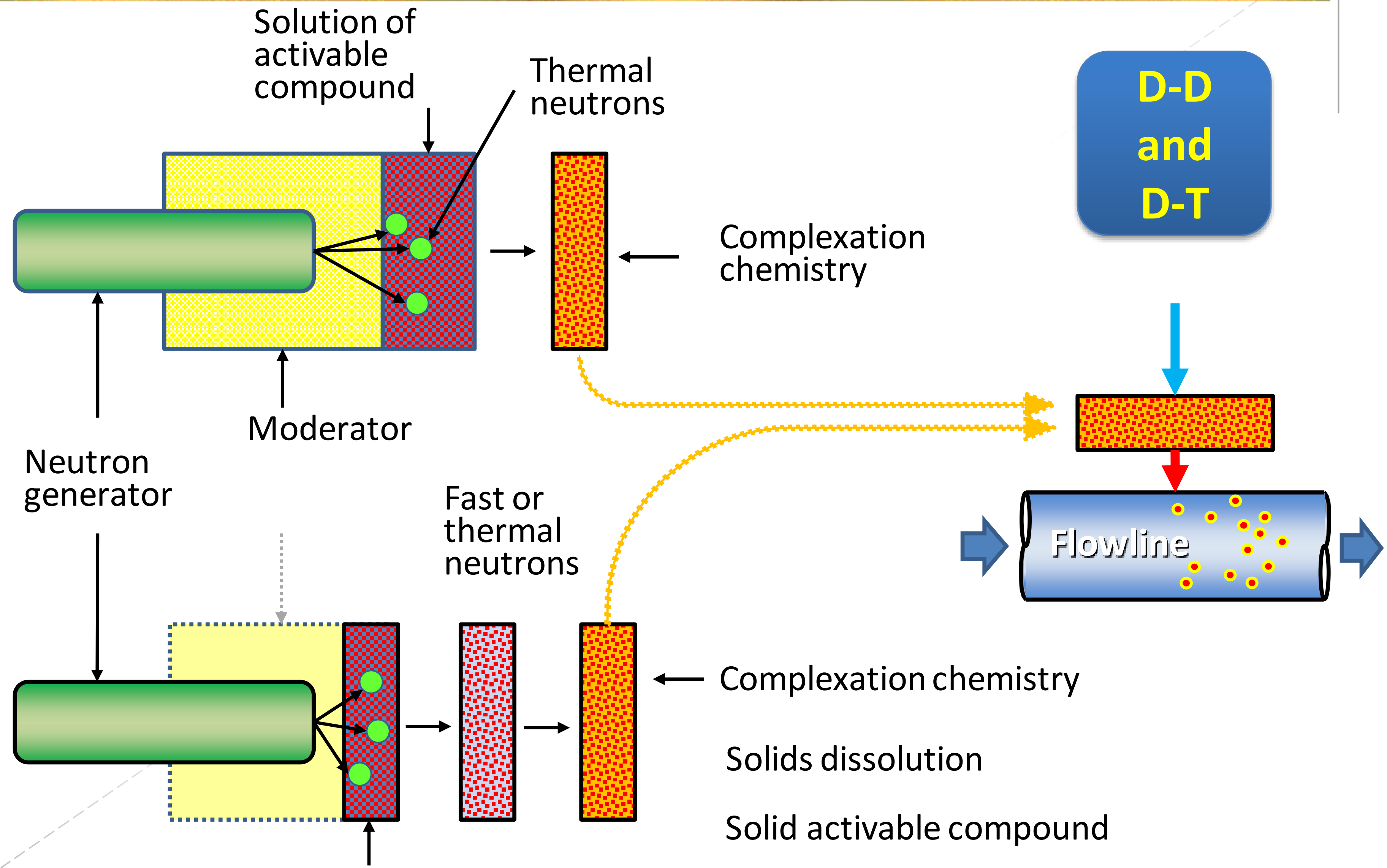
D-D and D-T

Neutron flux multiplication by moderator optimization ?

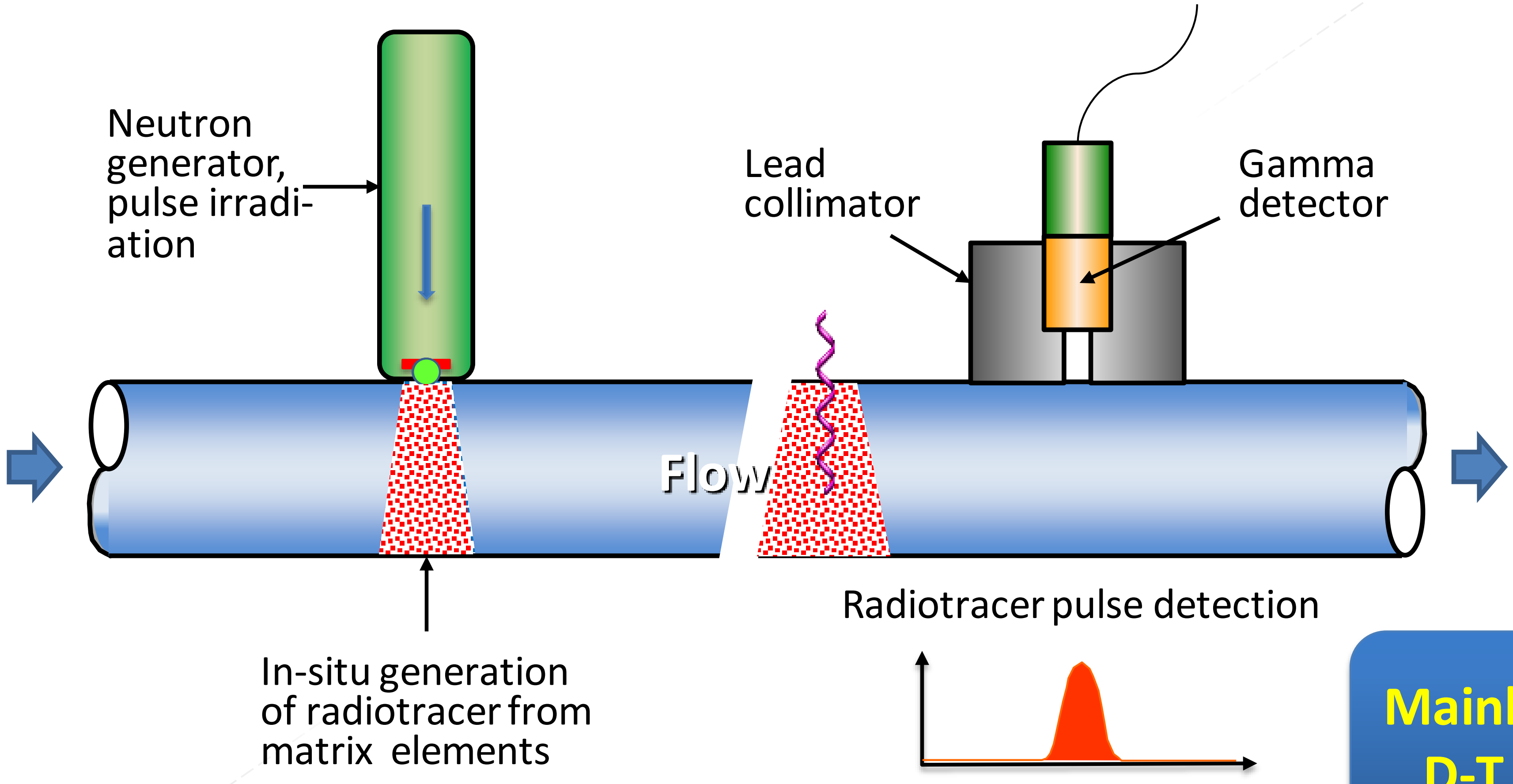


Only D-T

Off-line fast or thermal NA – off-line mount.



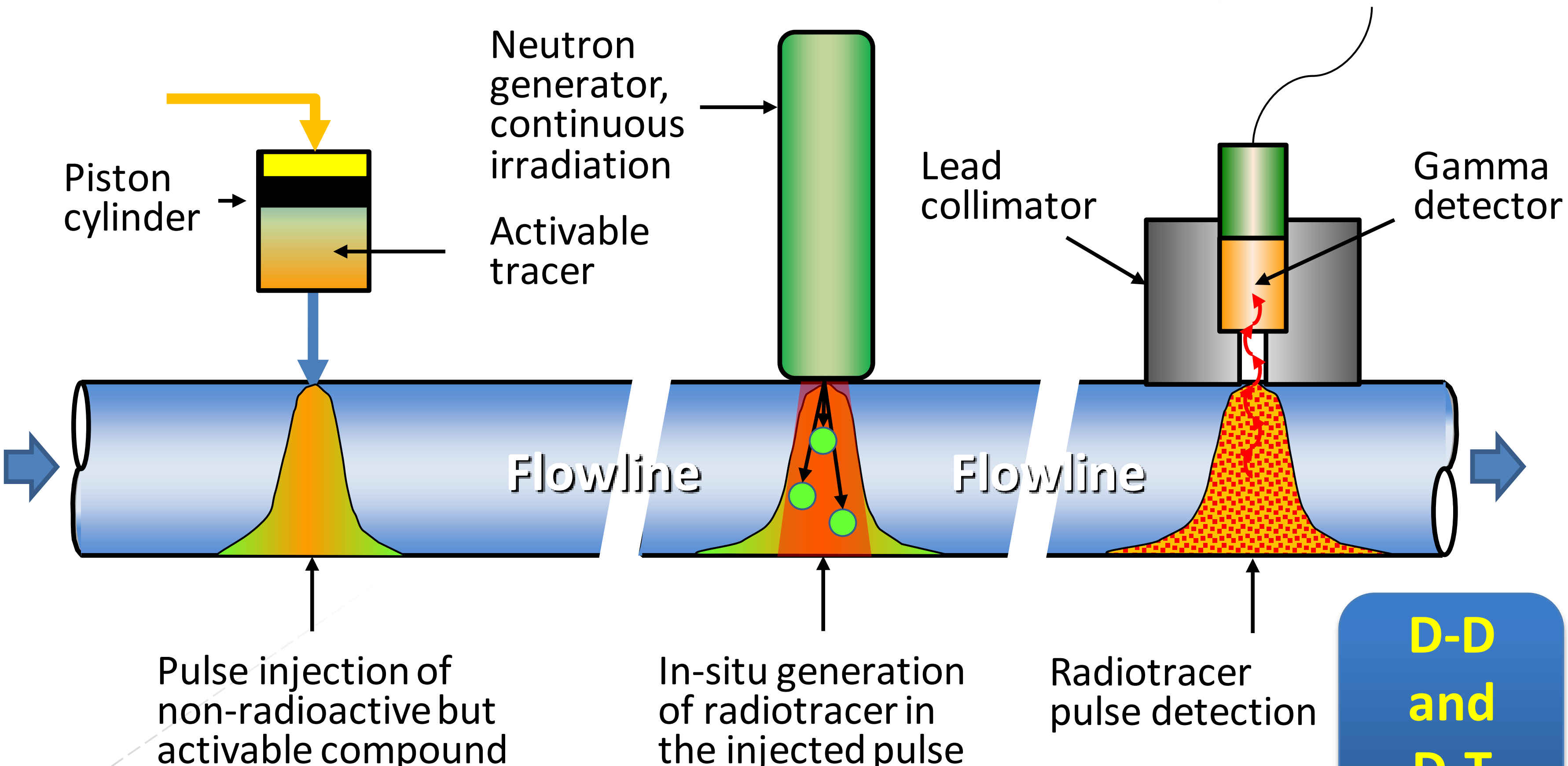
In-flow fast «pulse» NA – on-line mount.



Mainly D-T

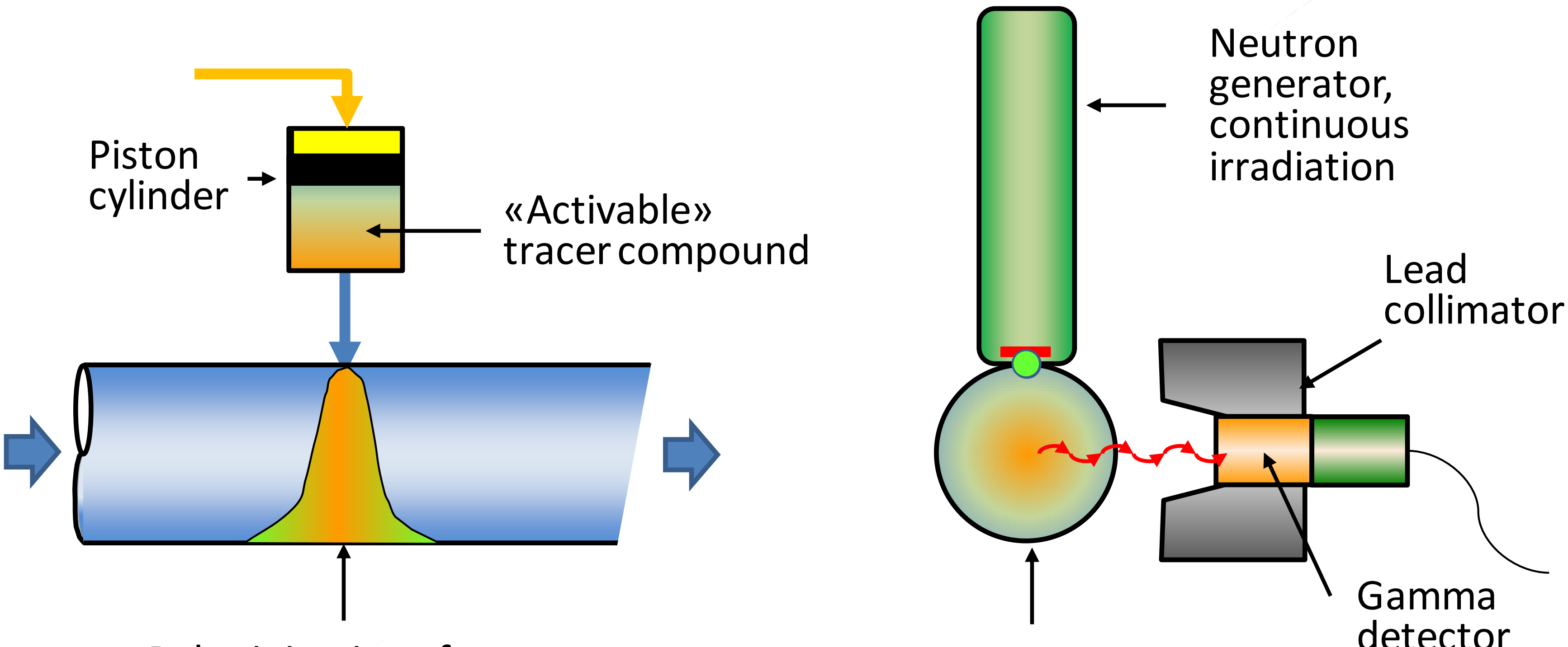
Example - irradiation of water: $^{16}O + n_{14MeV} \rightarrow$ ^{16}N (7.13 s)

In-line tracer generation by activation of injected non-radioactive compound



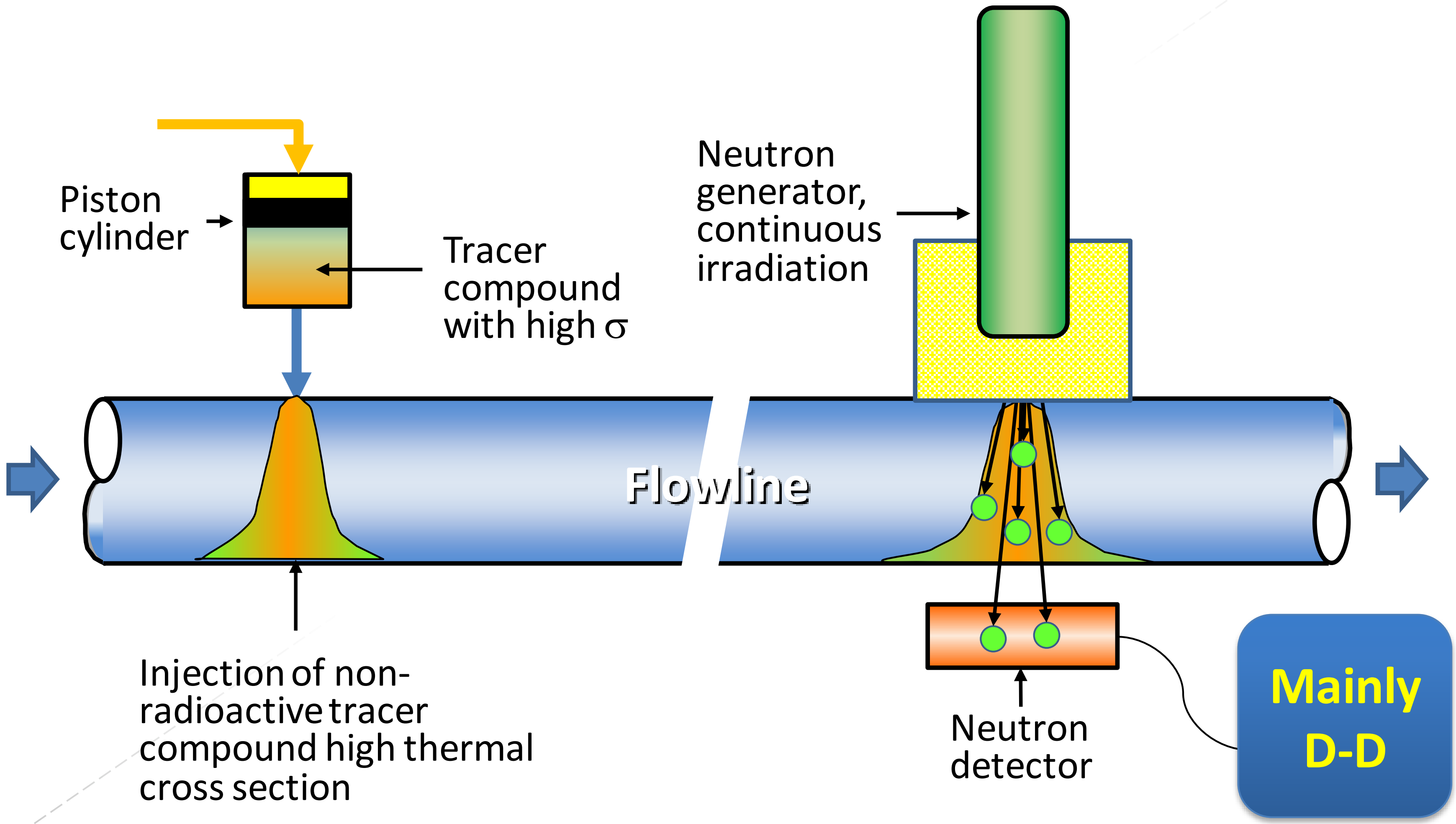
D-D and D-T

On-line PGNA of injected non-radioactive «tracer» compound

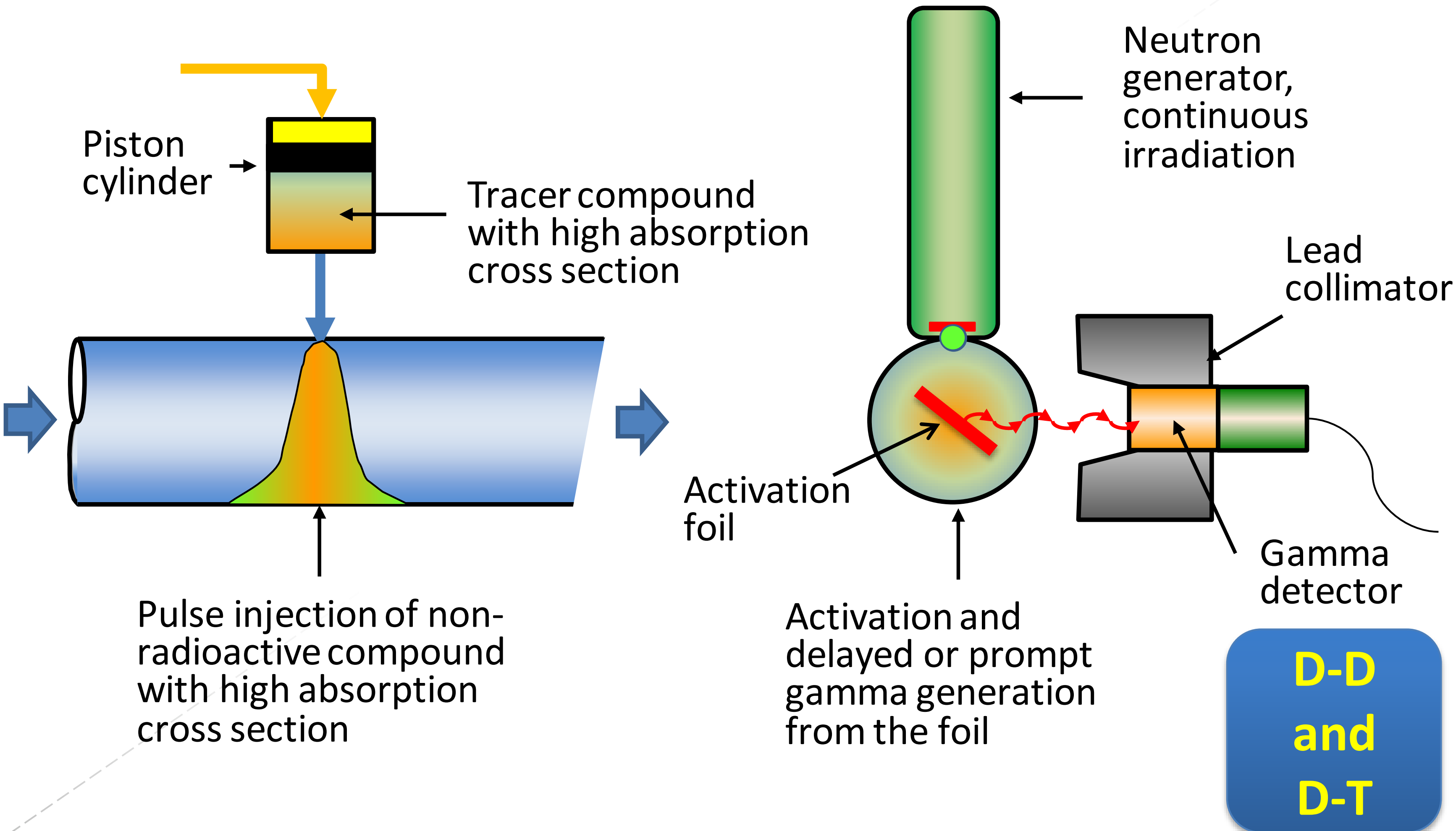


D-D and D-T

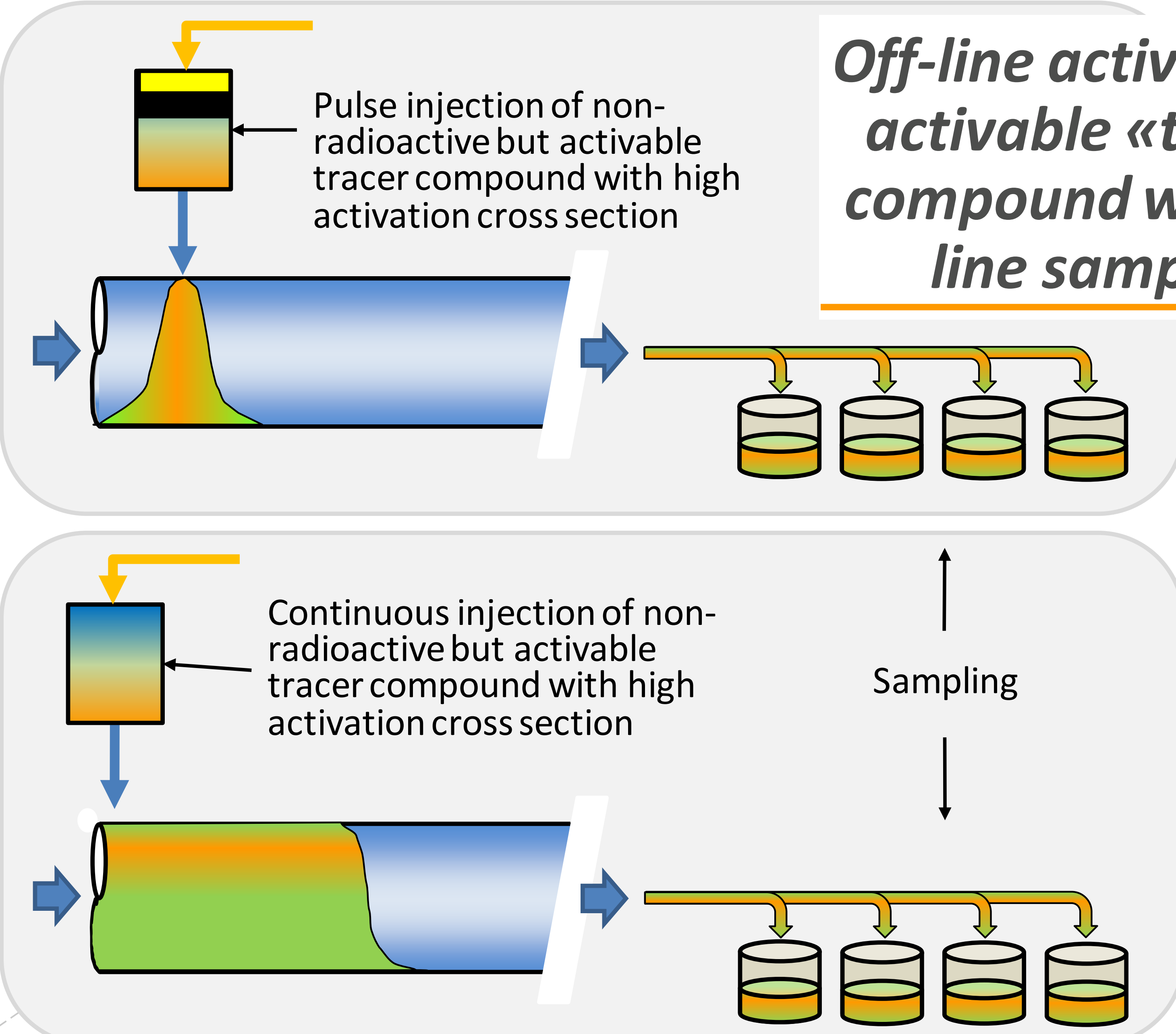
On line detection of injected non-radioactive «tracer» compound by neutron transmission



On-line detection of injected non-radioactive «tracer» compound by activation foil method



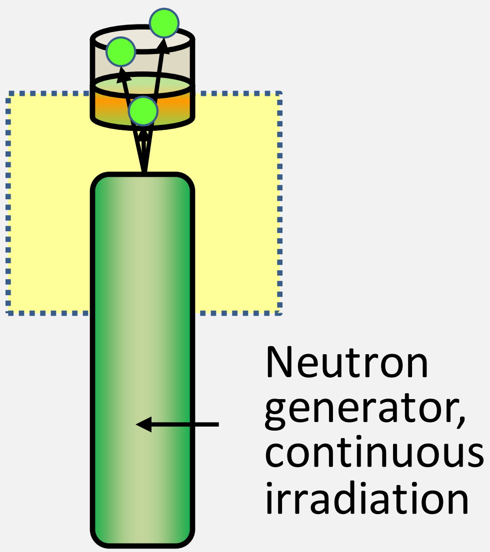
Off-line activation of activable «tracer» compound with off-line sampling



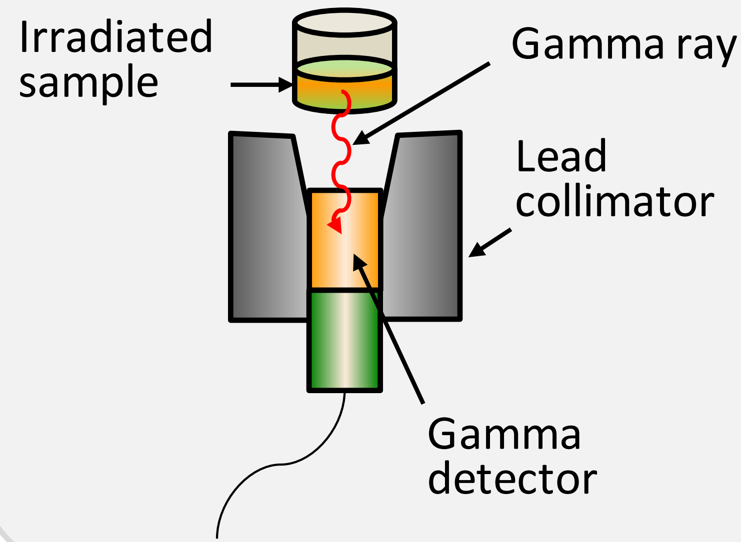
D-D and D-T

Off-line activation of collected activable «tracer» compound

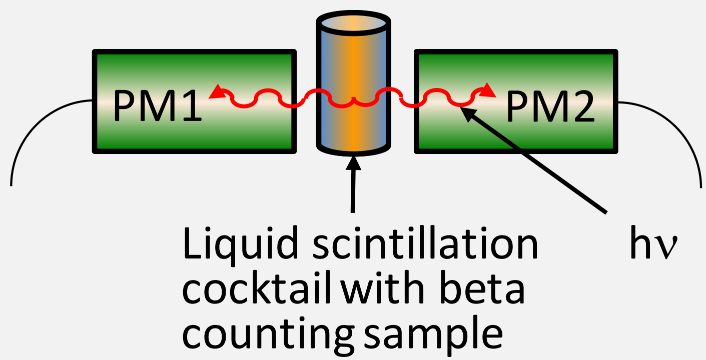
Off-line, on site neutron irradiation (NAA)



Gamma spectroscopy



Liquid scintillation counting (β)



Summing up

- Availability of small transportable neutron generators makes possible, in principle, RTD experiments to be carried out on «remote» locations
- A number of methods are possible, as outlined in the previous picture frames.
- None of these sketched methods have, as of yet, been properly examined and developed.
- A major obstacle for further method development and general dissemination is probably the up-front investment cost.
- Major laboratories, supported by IAEA, should possibly lead the way and propose the most affordable and flexible combination of instrumentation and basic method(s). CRP?