Accelerator Laboratory
Advanced Research Center for Beam Science
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# Superconducting Accelerator Neutron Source — ScANS —

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# Compact Neutron Sources

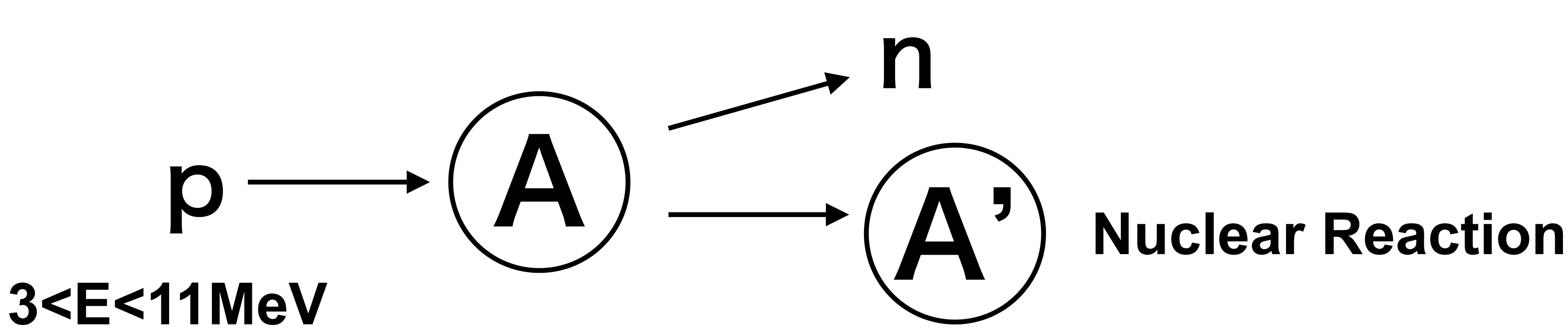
Needs to extract **n** from nuclei by electrons or protons:

1) MeV γ from electrons interact with nuclei at giant resonance.


**Note: No precise energy control needed!**

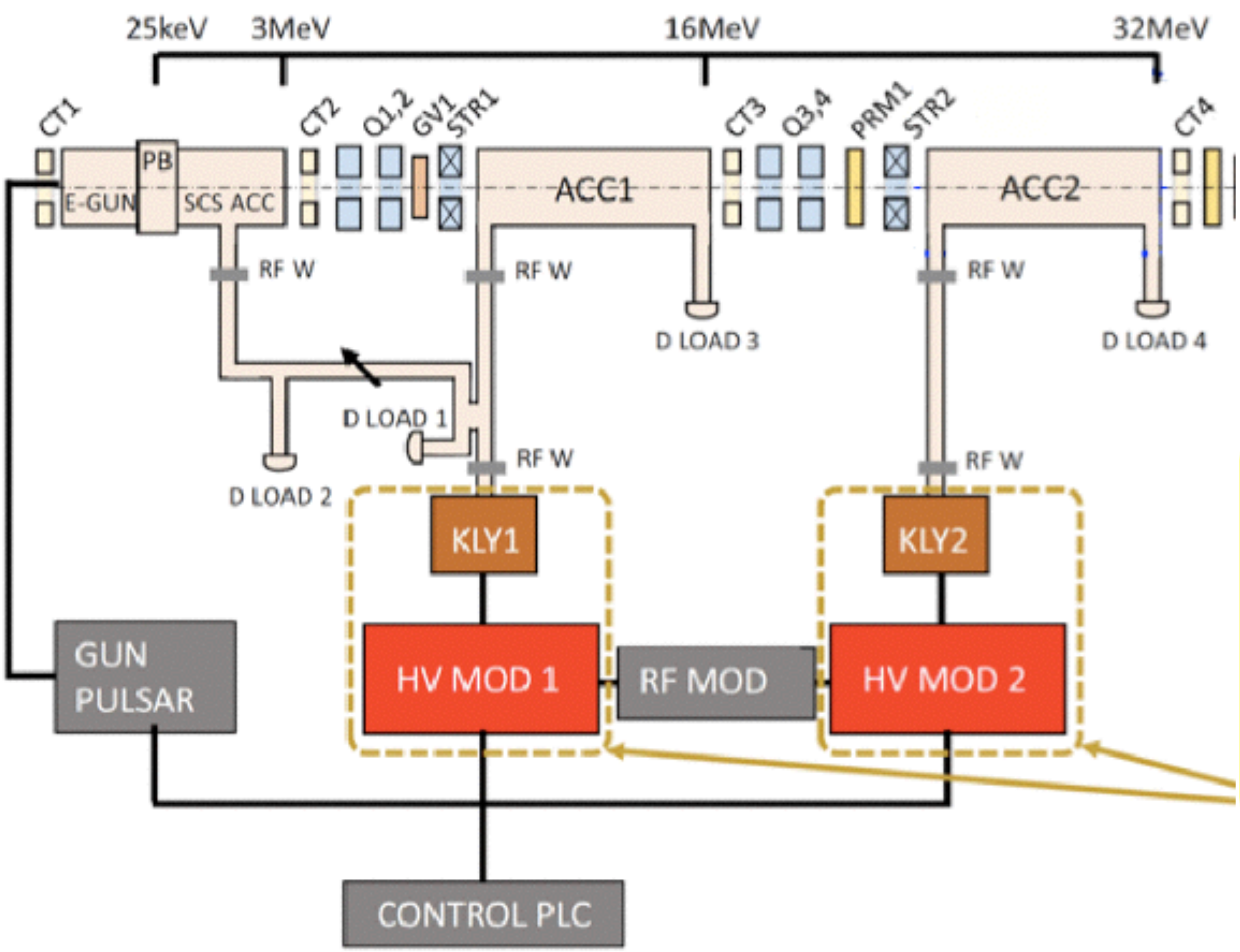
2) Photodisintegration of Beryllium 9

$^{9}Be + \gamma \rightarrow n + {}^{8}Be$ (Sn = 1.665 MeV)



# Typical Compact Neutron Sources

We pick up e-Linac. Specification is following:
30 MeV x 250 mA pk = 7.5MW, 0.1 ~ 4μs, 1~100 pps
x 100 μA ave.= 3 kW. ← **Average is much less!**



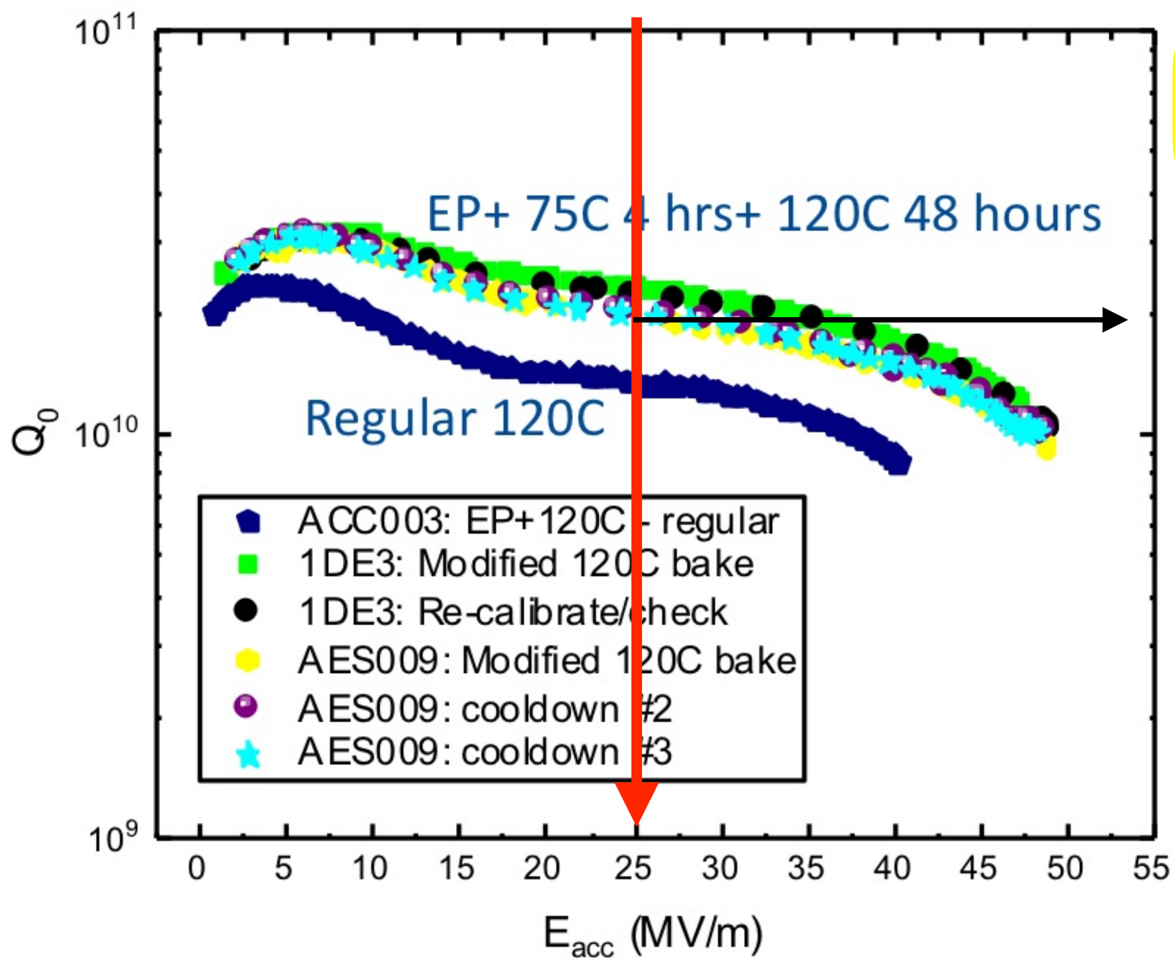

Can generate
cold ~ fast neutrons
~$10^{12}$ n/s.

This system uses
**7.5MW** klystron x 2.

RF power source
costs half of linac.

# Sc Cavity

Repeated on second cavity TE1AES009 (fine grain, AES, WC)




A. Grassellino et al, https://arxiv.org/abs/1806.09824

Fermilab

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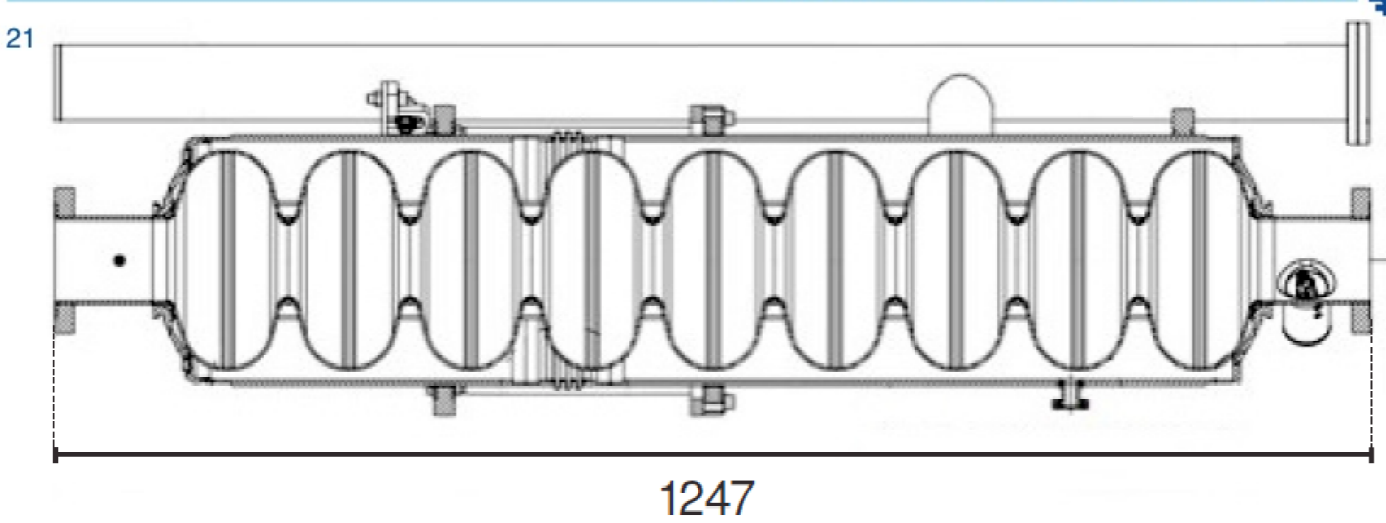


$$Q \equiv \omega W/P, P = \omega W/Q$$

$$Q_0 = 2 \times 10^{10}$$ @25MV/m

$$\omega \sim 10^{10}$$ (L-band)

Wall Loss

$$P \sim W/2 \rightarrow$$ **30 [W]**

($W$= **60 [J]** @ 25MV/m calc. from Superfish)

The beam takes
30 MeV x 250 mApk
=**7.5 MW peak** …

**Beam loading**

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# Work around?

The beam takes **7.5 MWpk**, but one **4μs** bunch takes only **30 [J]**.

Let's compare the bunch energy and the stored energy:

We need two 25 MV/m x1m cavities to get 35 MeV acceleration.

60 [J]@25 MV

+

60 [J]@25 MV

## = 120 [J] @ 50MV **stored energy**

$E_0 \propto \sqrt{W}$ $W'/W_0$=(120-30)/120 = 0.75, $E'/E_0$ = 0.87

- 13 % *E* gradient drops for the longest bunch.
- 30 [J] can be restored in 10 ms (100Hz) with **3 kW** Amp.

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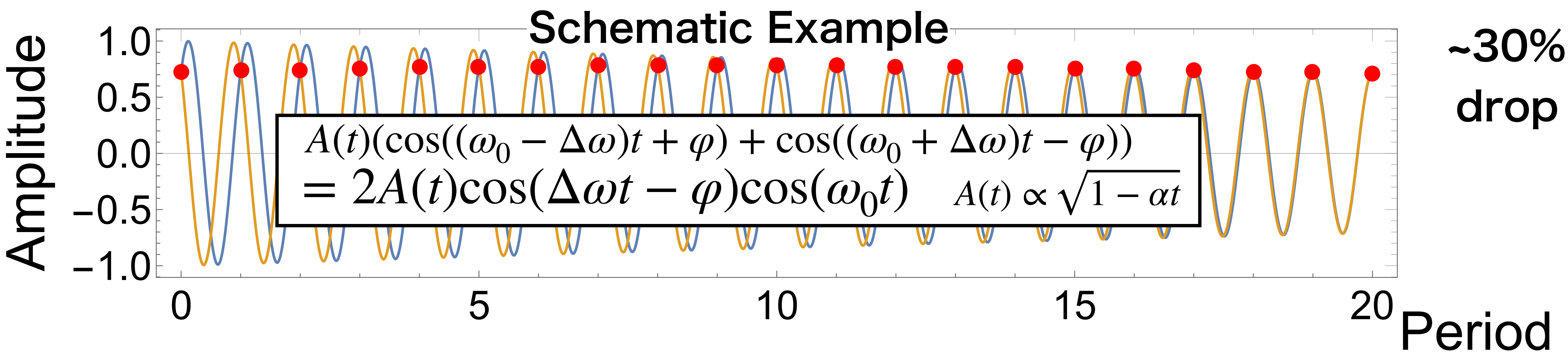
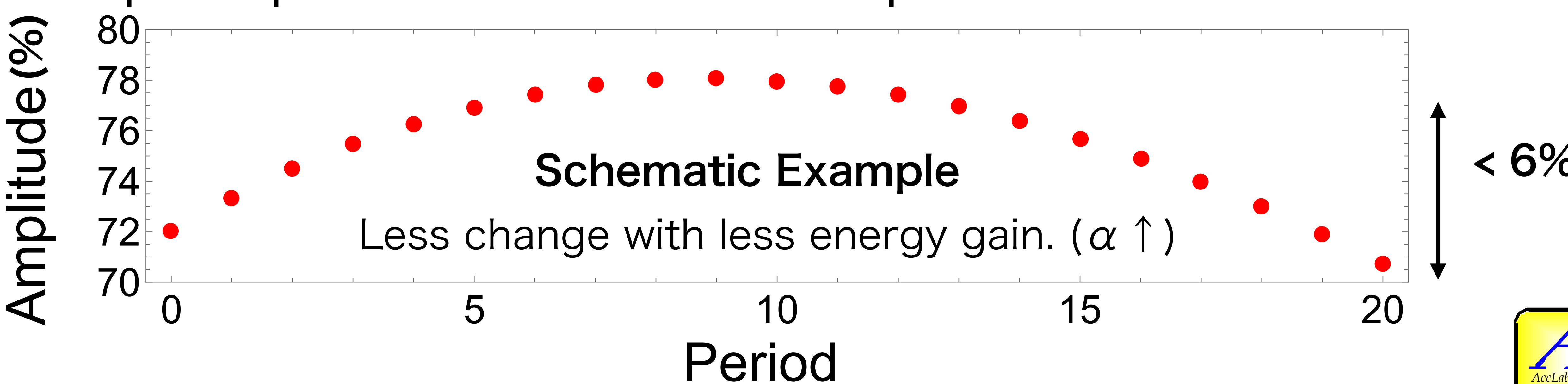
# Two cavity phasing

The two 25 MV/m x1m cavities can be adjusted to achieve 30 MeV acceleration by phasing with slightly different frequencies.

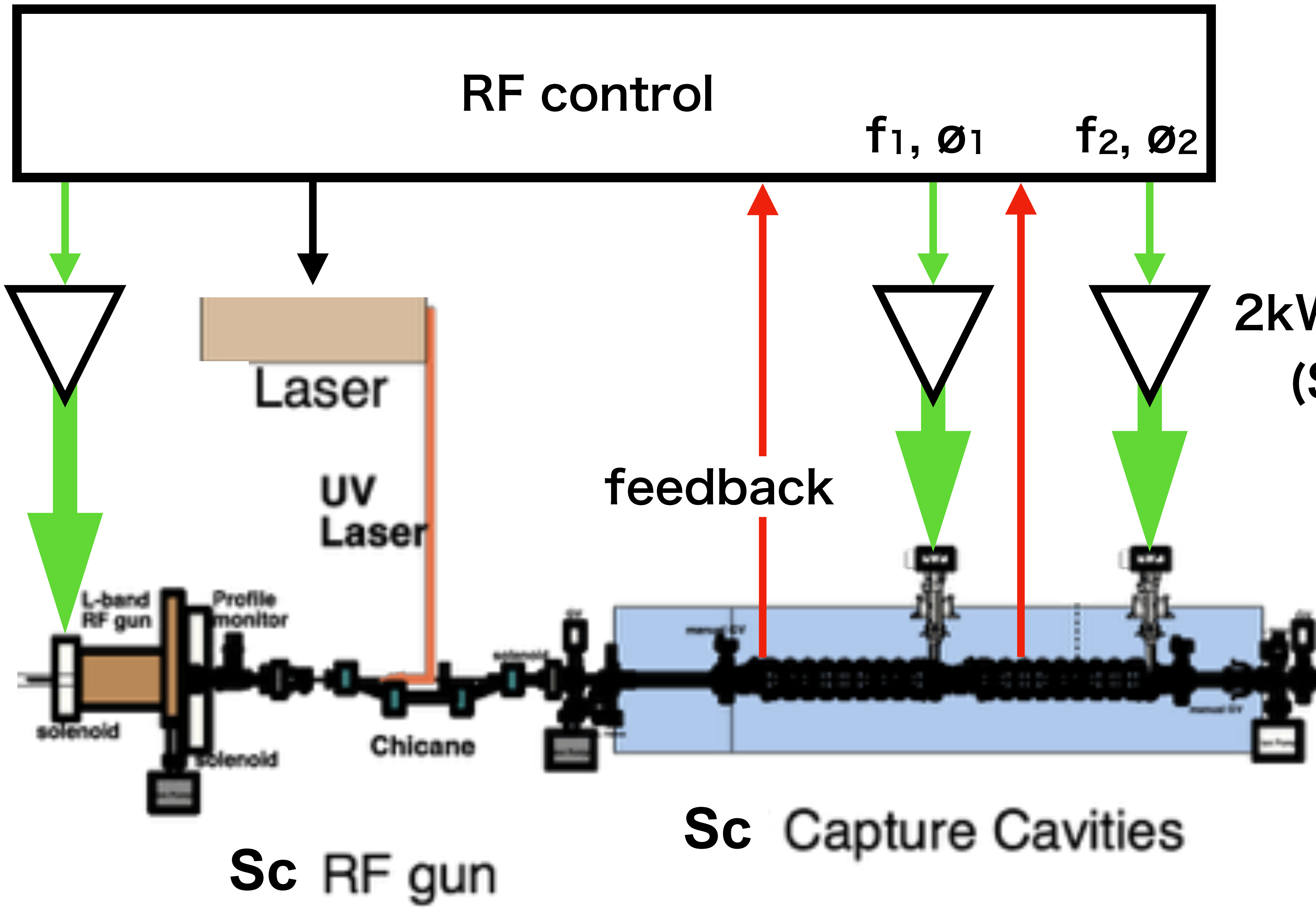



Droop compensated 1/5 in this example. Much less for smaller case.



# Possible configuration

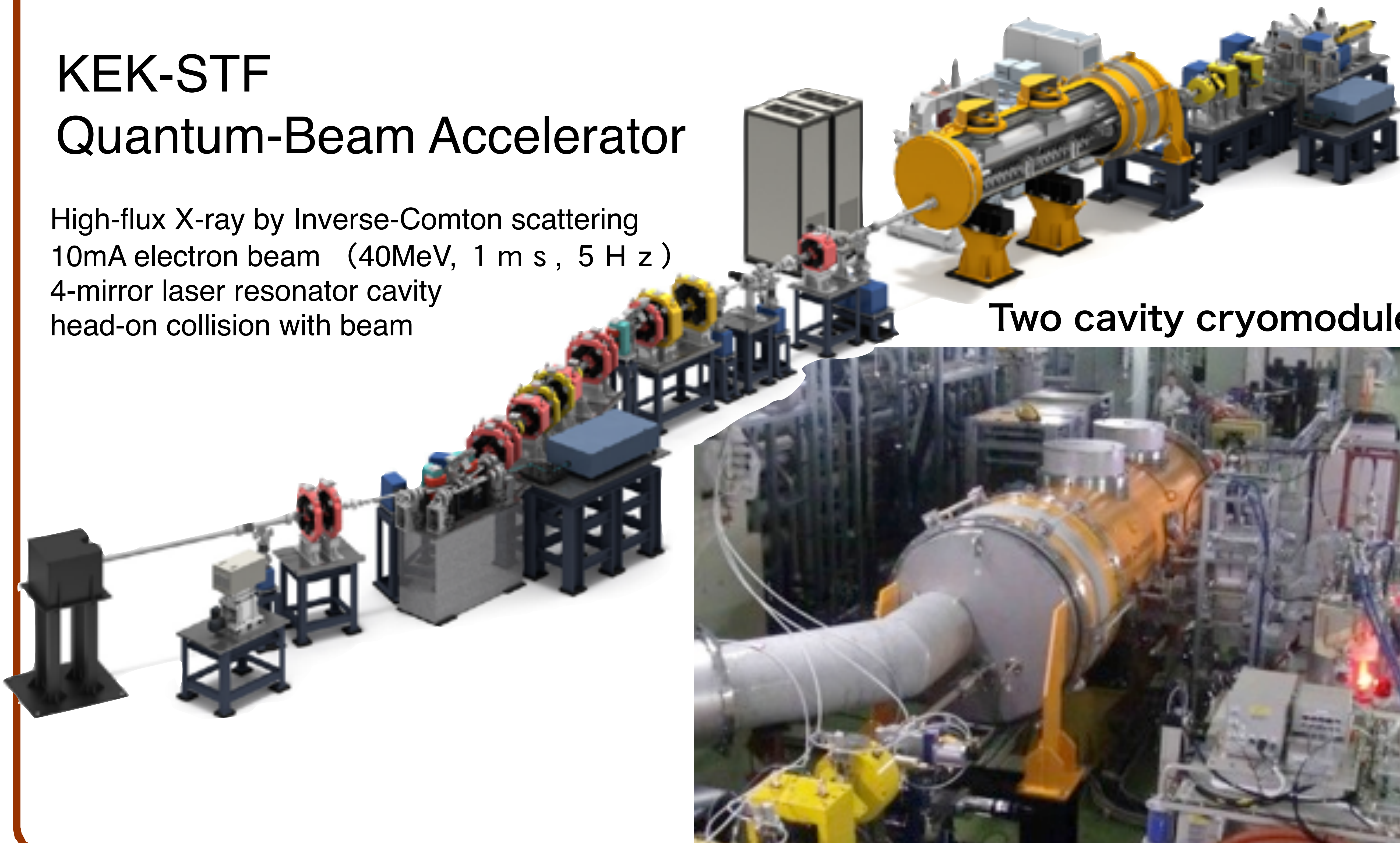
STF@KEK is an examples for the installation.



# STF@KEK

## KEK-STF
## Quantum-Beam Accelerator

High-flux X-ray by Inverse-Comton scattering
10mA electron beam （40MeV, １ｍｓ，５Ｈｚ）
4-mirror laser resonator cavity
head-on collision with beam



**Two cavity cryomodule**

# Summary

- Two Sc cavities accelerate e-beam >30MeV.
- Peak power of 30 MeVx250μA=7.5MW.
- Average power (4μs 100Hz) is 3kW CW.
- No precise energy control needed for this.
- Sc cavity can store RF energy to smooth pulse power.
- 5kW CW RF amp. may be enough incl. HOM power.
- The gradient droop can be compensated by phasing.
- Cryogenic wall loss <30 W (<<5kW RF power).
- Need to know the cryogenic cost for 30W @2K.
- Lower freq. cavity can be operated @4K (Hi-Q helps).

$$R_{BCS}(T, E_{acc}) = A(E_{acc}) \frac{\omega^2}{T} exp\left\{-\frac{\Delta(E_{acc})}{kTc} \cdot \frac{T_c}{T}\right\}$$

- Needs a few MeV injector (Sc RF gun).

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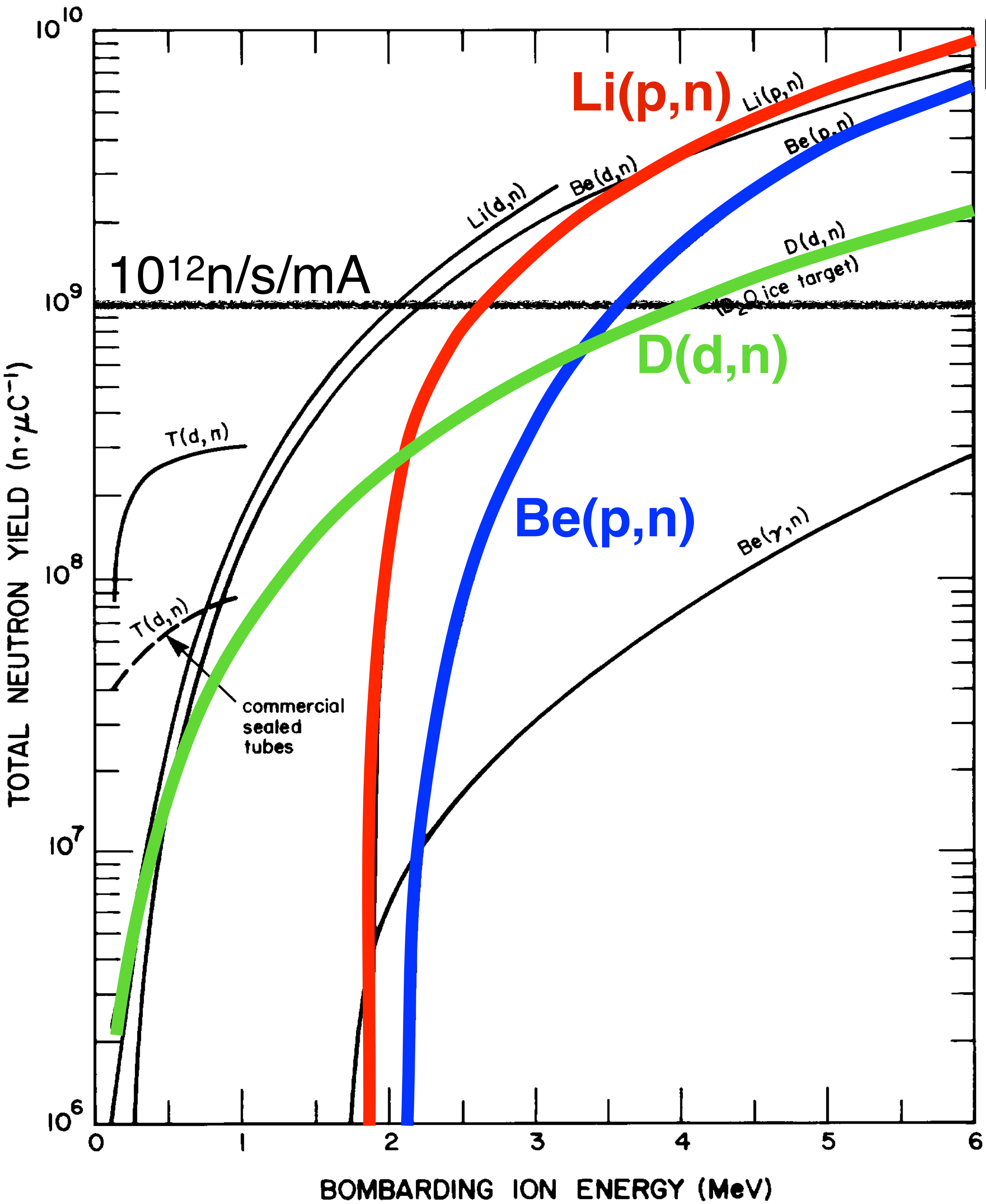
# Neutron yield




M.R. Hawkesworth,
*Neutron Radiography: Equipment and Methods*,
Atomic Energy Review **15**, No. 2, 169-220, 1977.
R.W.Hamm, Proc. SPIE 4142 (2000) 39-47

$n \cdot \mu C^{-1} = n/(\mu A \cdot s)$

$\sim 10^{11}$ n/s $\overrightarrow{@}$ 0.1mA$_{ave}$

3.5MeV x 0.1mA=350W

$D + T \rightarrow {}^{4}He + n$ (14MeV)

$D + D \rightarrow T + p$

$\rightarrow {}^{3}He + n$ (2.5MeV)

$p + {}^{7}Li \rightarrow {}^{7}Be + n$

[237keV total]

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# Neutron production reactions

- Nuclear reaction
  - $^{9}Be + \alpha \rightarrow n + {}^{12}C$
  - $^{7}Li + p \rightarrow n + {}^{7}Be$
  - $^{9}Be + \gamma \rightarrow n + {}^{8}Be$
- Fusion
  - $D + T \rightarrow n + {}^{4}He$   $E_n = 14.1$ MeV
  - $D + D \rightarrow n + {}^{3}He$   $E_n = 2.5$ MeV
- Fission
  - $^{235}U + n \rightarrow$ Fission Products + 2.4 n
- Spallation (J-PARC)
  - Hg + p(~GeV) $\rightarrow$ Fission Products + ~20 n