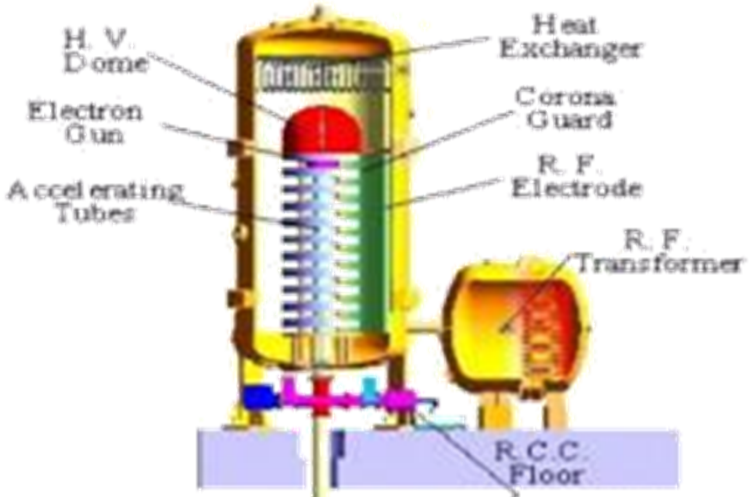
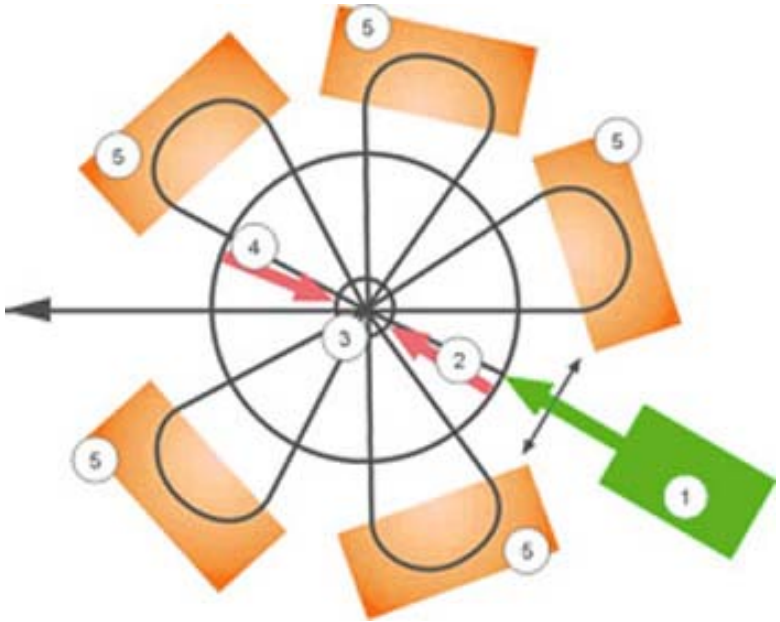
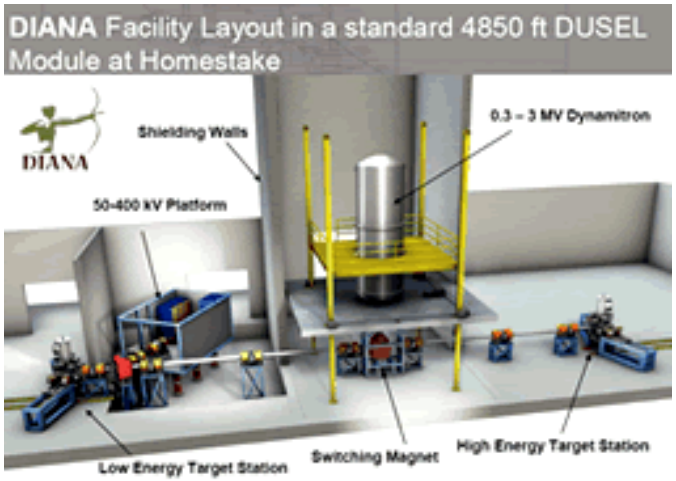
A Dynamitron or Rhodotron for the JUNO Positron Calibration







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(February 19, 2015)

JUNO Positron Accelerator Workshop
Brookhaven National Laboratory

Low-Rate Positron Beams

High-rate positron beams for e^+e^- colliders are produced via interaction of > 100 MeV electrons with high-Z targets.

However, a low-rate source of eV-energy positrons can be obtained by coupling an Na^{22} positron emitter to a thin metal "moderator." (Na^{22} β^+ spectrum has 540-keV endpoint.)
Efficiency ~ 10^{-4}, $\Rightarrow$ 1 mCi yields ~ 4000 e^+/s.

Four MeV-energy positron accelerators have been built using such sources;

Pelletrons:

Stuttgart, 6.5 MeV: http://physics.princeton.edu/~mcdonald/examples/accel/bauer_apa_43_261_87.pdf

LLNL, 3 MeV: http://physics.princeton.edu/~mcdonald/examples/accel/selim_nim_b171_182_00.pdf

Rio de Janeiro, 1.7 MeV: http://physics.princeton.edu/~mcdonald/examples/accel/alcantra_aipcp_1525_460_13.pdf

Dynamitron:

BNL, 3 MeV: http://physics.princeton.edu/~mcdonald/examples/accel/huomo_bnl-41953_88.pdf

If desire 5-10 MeV positrons, a Rhodotron may be the most cost-effective accelerator.

Dynamitrons and Rhodotrons are manufactured by IBA Industrial (office near BNL)
The Dynamitron was invented by Marshall Cleland.

Huomo *et al.*, BNL-41953 (1988)

A 0.5 to 3.0 MeV MONOENERGETIC POSITRON BEAM

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Table 1. Beam characteristics of the 3 MeV positron beam at BNL

Source total activity encapsulated	≈70 mCi
Moderator efficiency (fast positron in, moderated positron out)	5×10^{-4}
Total transport efficiency	≈90%
Positron flux at target	3×10^{5} e^+/s
High energy contamination	<10 e^+/s
Beam size (diameter)	≈1.1 mm FWHM @2.2 MeV
Beam divergence	<0.1°
Beam energy	<1 keV FWHM @2.2 MeV
Accuracy of beam energy measurement	±100 eV
Usable energy range from	0.5 MeV to 3.0 MeV

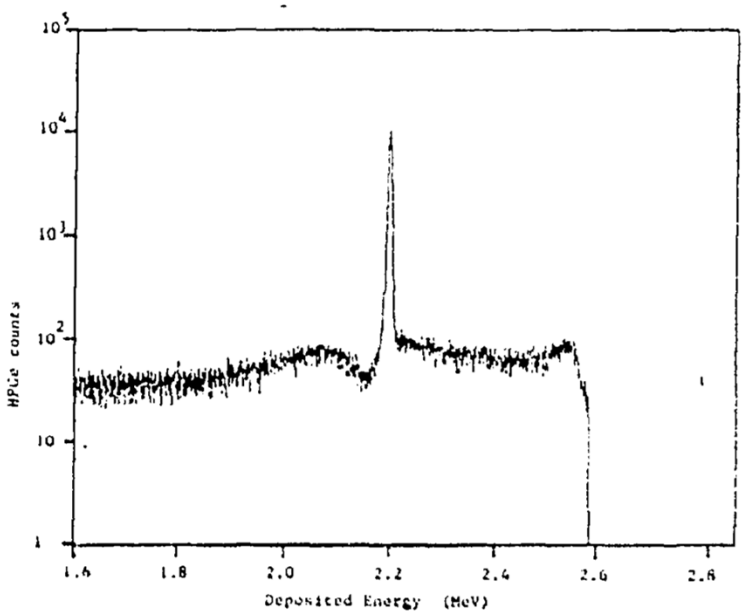


Figure 3. The measured HPGe spectrum of a 2.2 MeV positron beam striking the detector. Resolution of the detector is 3.5 keV FWHM and the width of the spectrum measured by the HPGe detector is 4 keV FWHM. ADC discriminator cutoff is at 2.6 MeV.

If this source still exists, it would produce ~ 300 e^+/s today, given the 2.7-year half life of Na^{22}.

The BNL Dynamitron is still in Bldg 901, but not operational. Visit this afternoon.

Option: Refurbish it, with contemporary electronics. *Could it then go to > 3 MeV?*

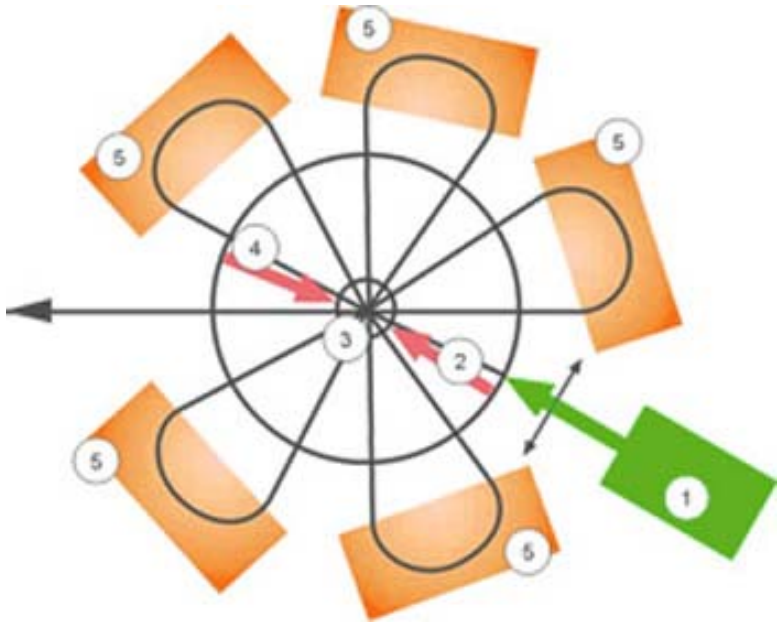
If must consider an all-new accelerator, a Rhodotron is also an option.

Rhodotron

The Rhodotron was invented by Pottier in the late '80's.
http://physics.princeton.edu/~mcdonald/examples/accel/pottier_nim_b40-41_943_89.pdf

Like a cyclotron, particles are accelerated by multiple passes through a single RF cavity.

The RF cavity of a Rhodotron is cylindrical, and the particles move across diameters: external magnets bend the beam 180° for successive passes. Practical limit is ~ 16 passes, ~ 10 MeV.



Readily adapted to use of a positron gun based on a Na^{22} source.

Can only extract beams at ~ ½ MeV intervals. Each such beam would need a separate initial beam transport to bring the positrons to a common final beamline.

Additional References

Dynamitrons:

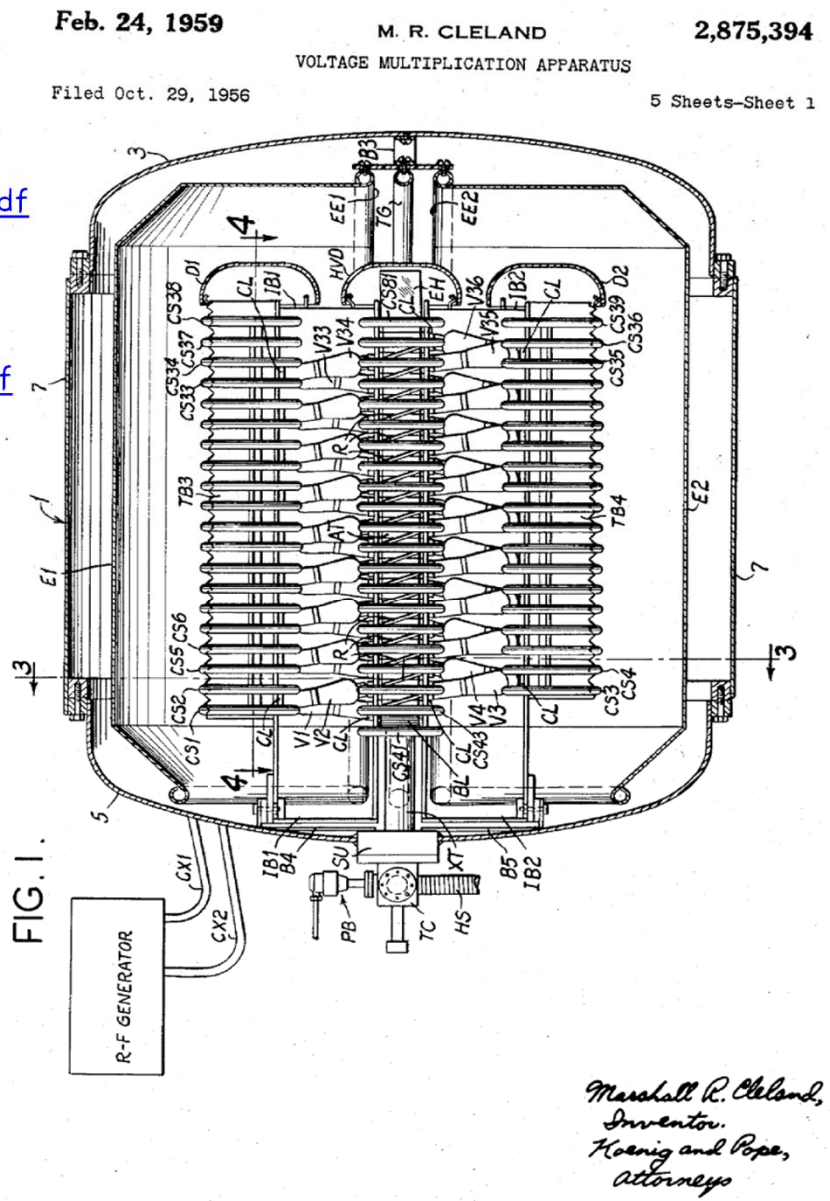
http://physics.princeton.edu/~mcdonald/examples/patents/cleland_us2875394_59.pdf
http://puhep1.princeton.edu/~mcdonald/examples/accel/cleland_ieeetns_12_227_65.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/cleland_tis-79-6.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/asoka-kumar_nim_a337_3_93.pdf

Rhodotrons:

http://puhep1.princeton.edu/~mcdonald/examples/accel/pottier_nim_b40-41_943_89.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/bassaler_nim_b68_92_92.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/jongen_nim_b79_865_93.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/bol_rhodotron.ppt
http://physics.princeton.edu/~mcdonald/examples/accel/abs_rpc_71_285_04.pdf
http://physics.princeton.edu/~mcdonald/examples/accel/jongen_THP076G.PDF

Electron accelerator reviews:

http://physics.princeton.edu/~mcdonald/examples/accel/cleland_industrial_05.pdf
http://puhep1.princeton.edu/~mcdonald/examples/accel/cleland_accelerators.ppt



Marshall Cleland and the BNL 3 MeV Dynamitron

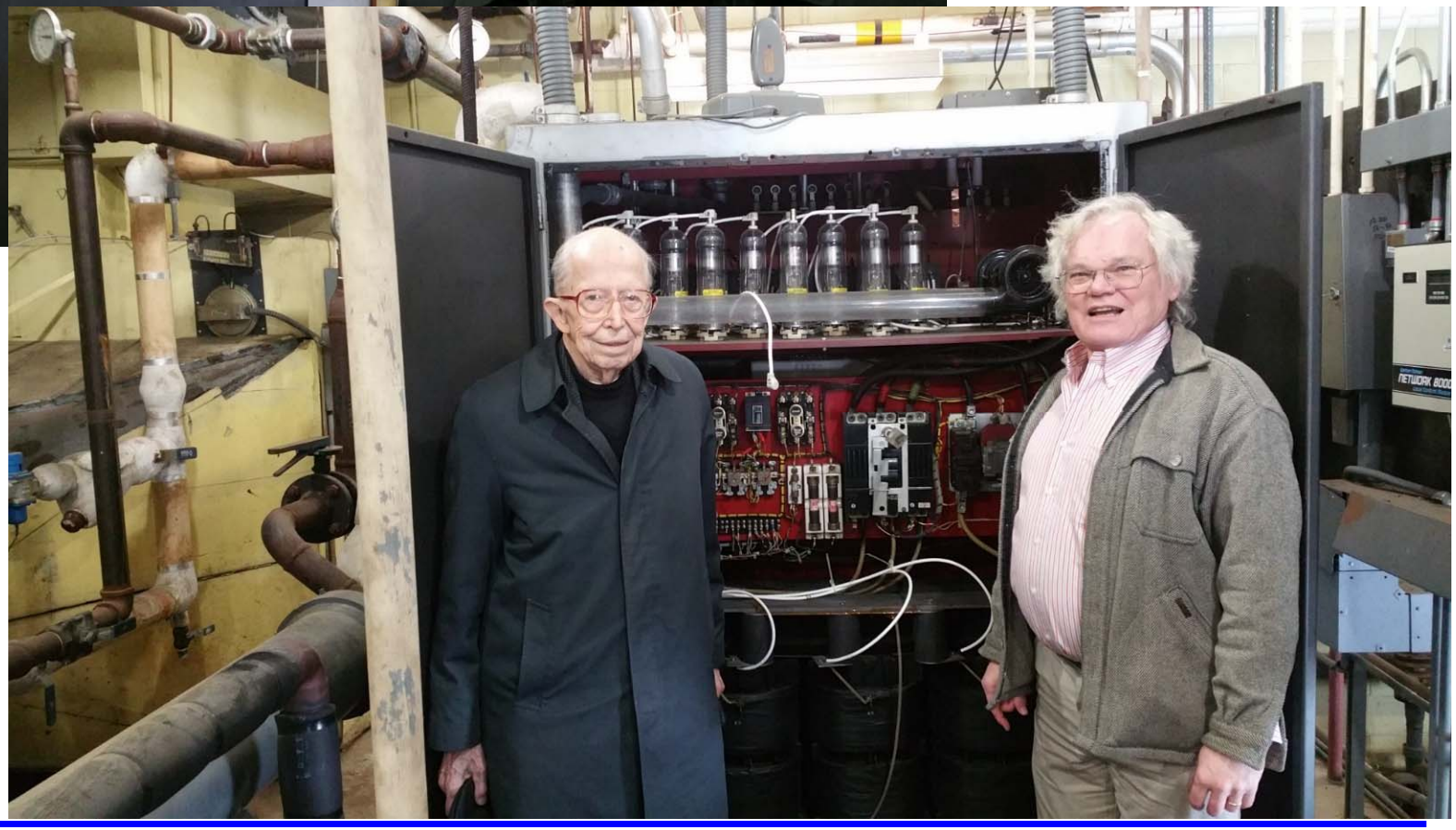
The BNL Dynamitron is in the loft above Bldg 901. Installed ~ 1967.

It is still there, mounted vertically, but has not been used in ~ 20 years.

A crane can lift and rotate the Dynamitron onto a horizontal trunion such that the pressure vessel can be opened for service.

This may have last been done ~ 1988 when the (then) 70 mCi positron source was installed (which effort required considerable radiation safety precautions).

Marshall Cleland and the BNL 3 MeV Dynamitron



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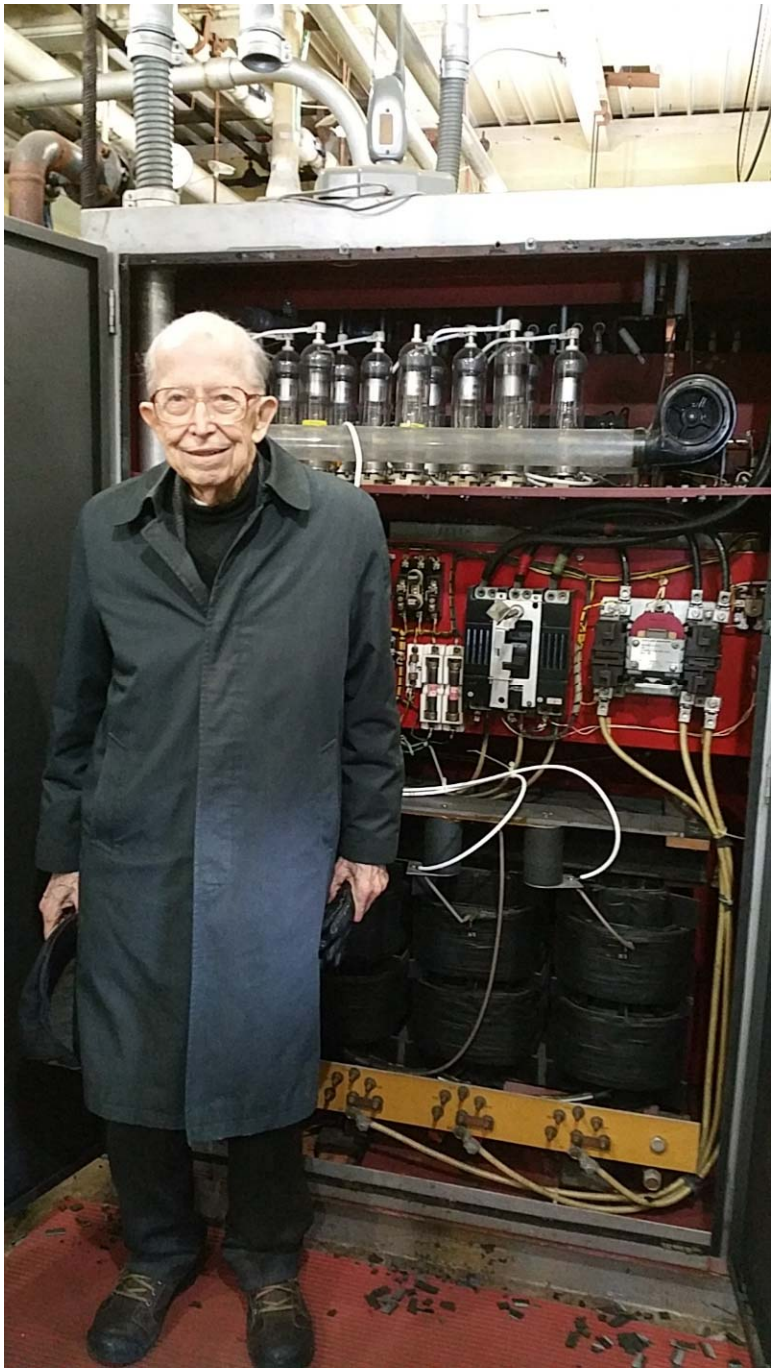

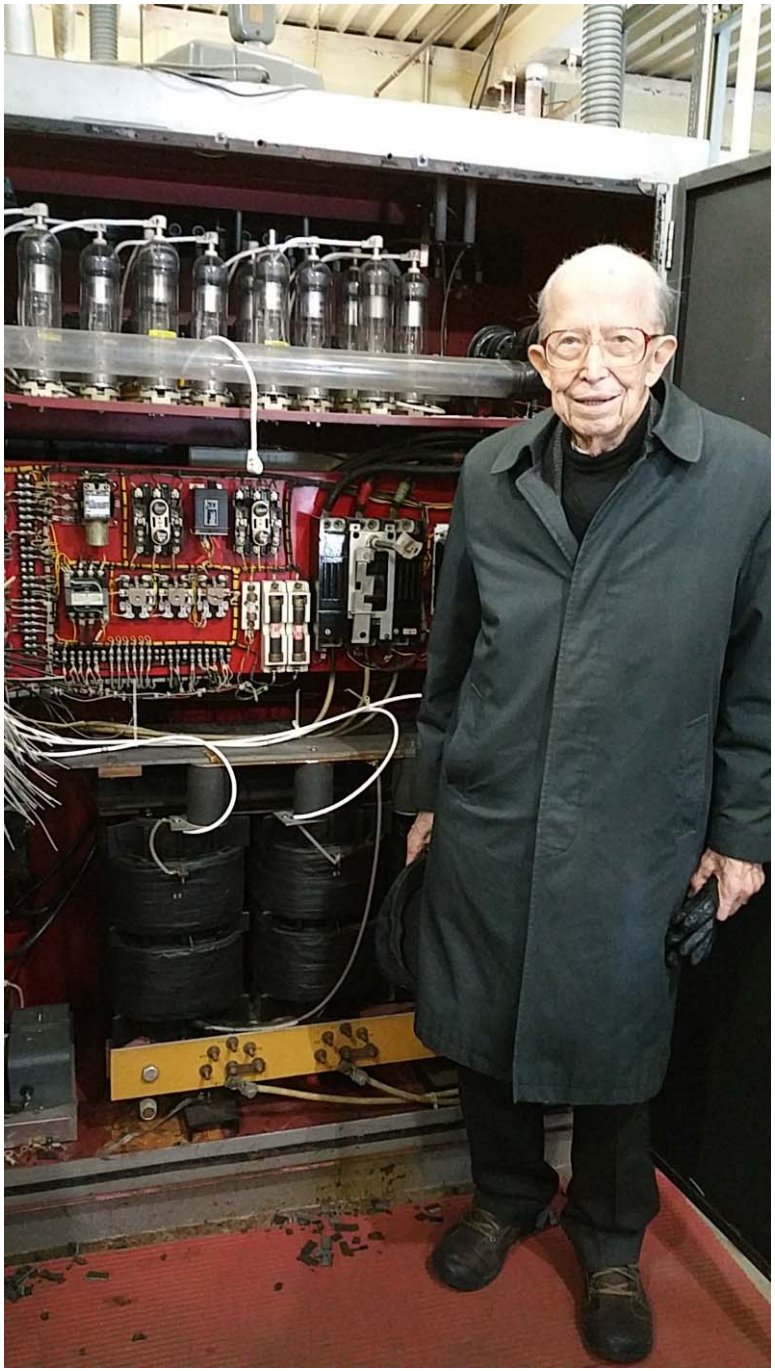

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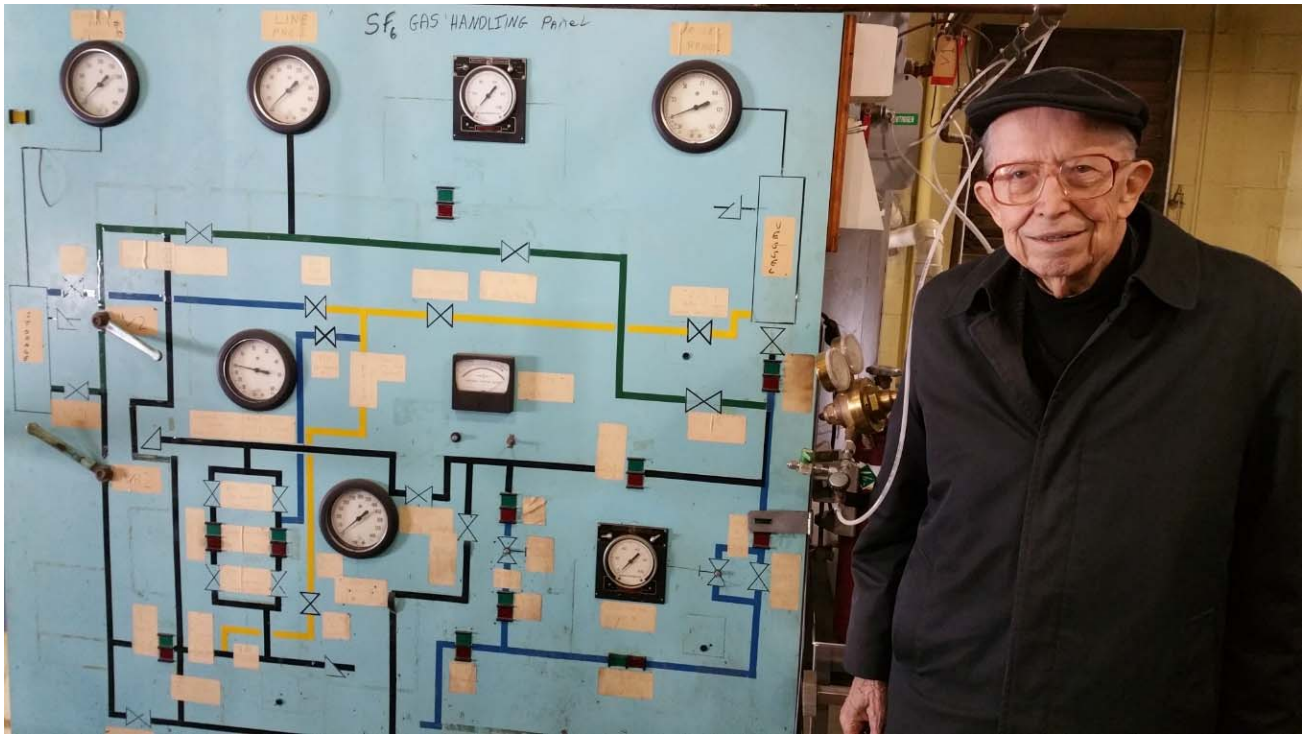

Marshall Cleland and the BNL 3 MeV Dynamitron