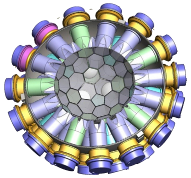
Massachusetts Institute of Technology



Neutron Calibration System for the MiniCLEAN Experiment

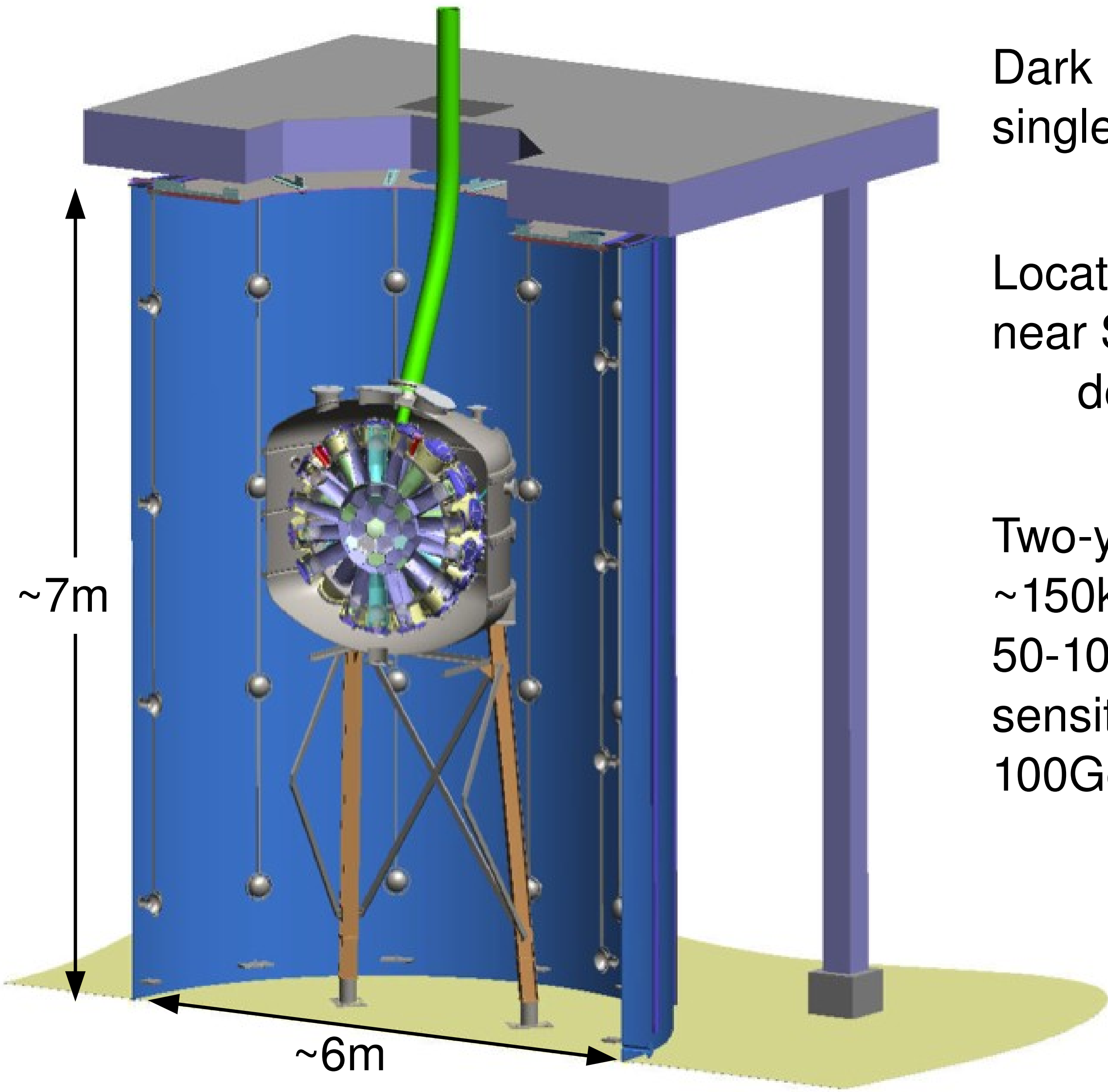
Lu Feng for the MiniCLEAN collaboration

APS April Meeting

May 2, 2011

The MiniCLEAN Experiment

Mini-Cryogenic Low Energy Astrophysics with Noble liquids

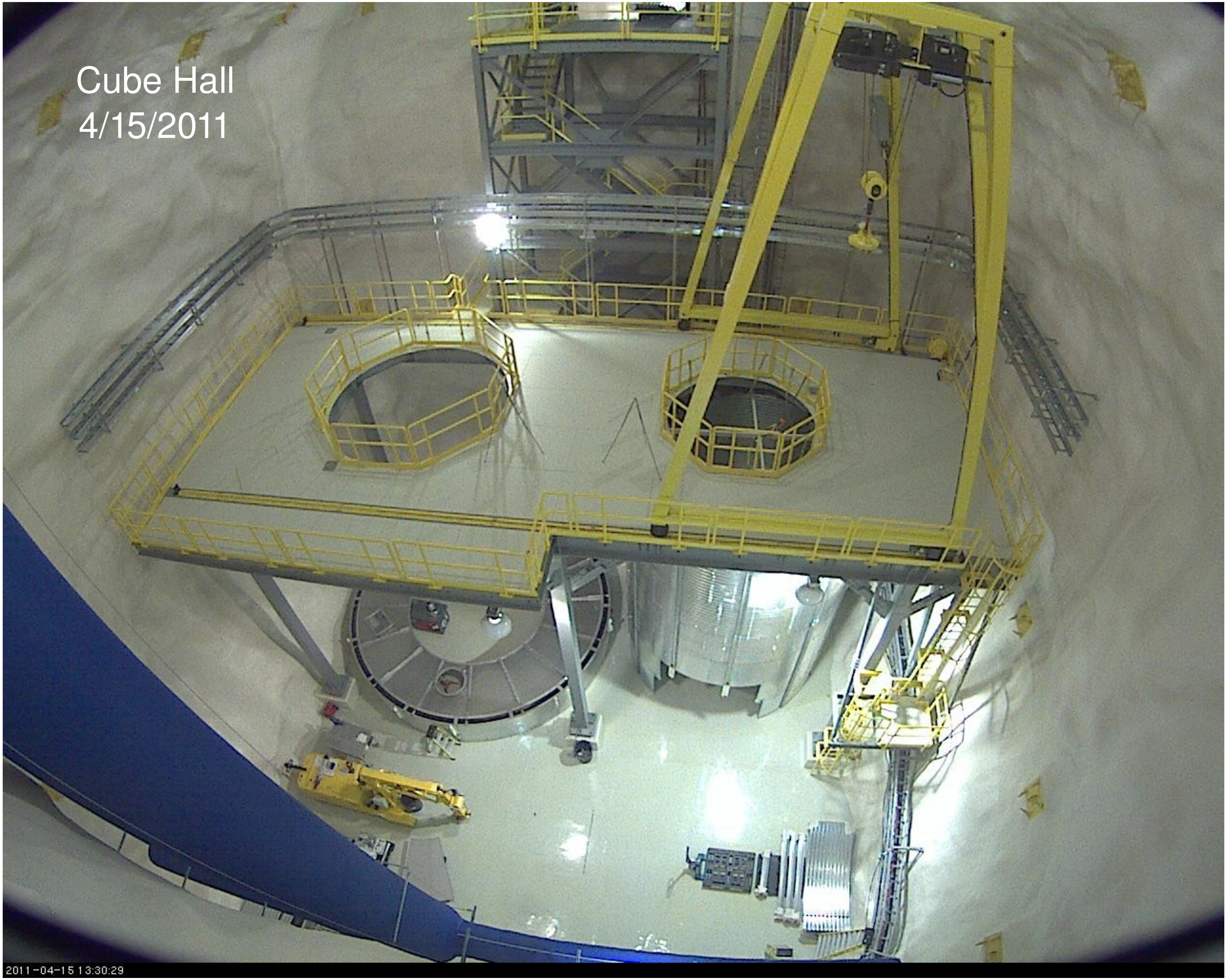


Dark matter direct detection using single-phase liquid argon/neon detector.

Located in Cube Hall at SNOLAB, near Sudbury, Ontario, Canada.
depth ~2073m

Two-year run with liquid argon, with ~150kg fiducial mass, energy range 50-100keVr (12.5-25keVee), and sensitivity $2x10^{-45}cm^2$ at 90% C.L. for 100GeV WIMP mass.

M.G. Boulay and A. Hime, Astroparticle Physics 25, 179 (2006)


Cube Hall
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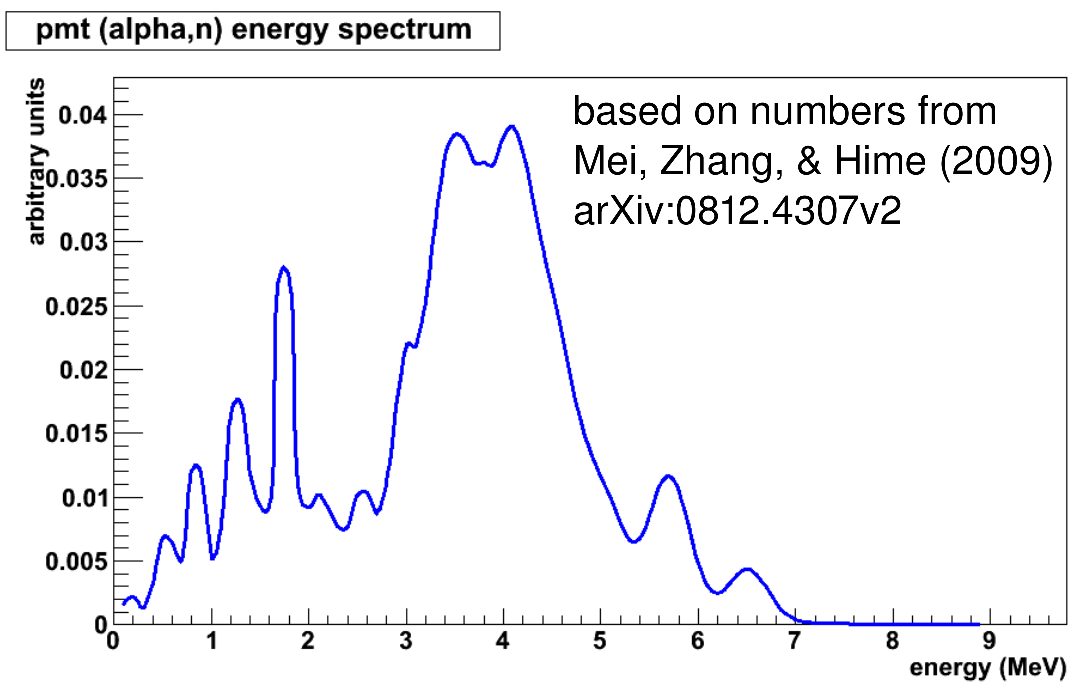
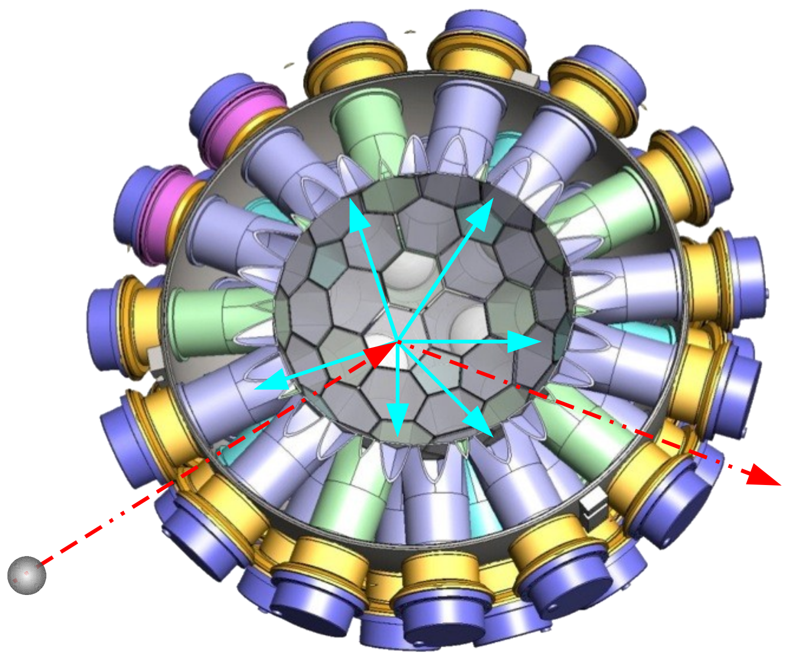
Signal Detection

Detect scintillation light resulting from dark-matter induced nuclear recoils with 92 8-inch Hamamatsu R5912 photomultiplier tubes (PMT).





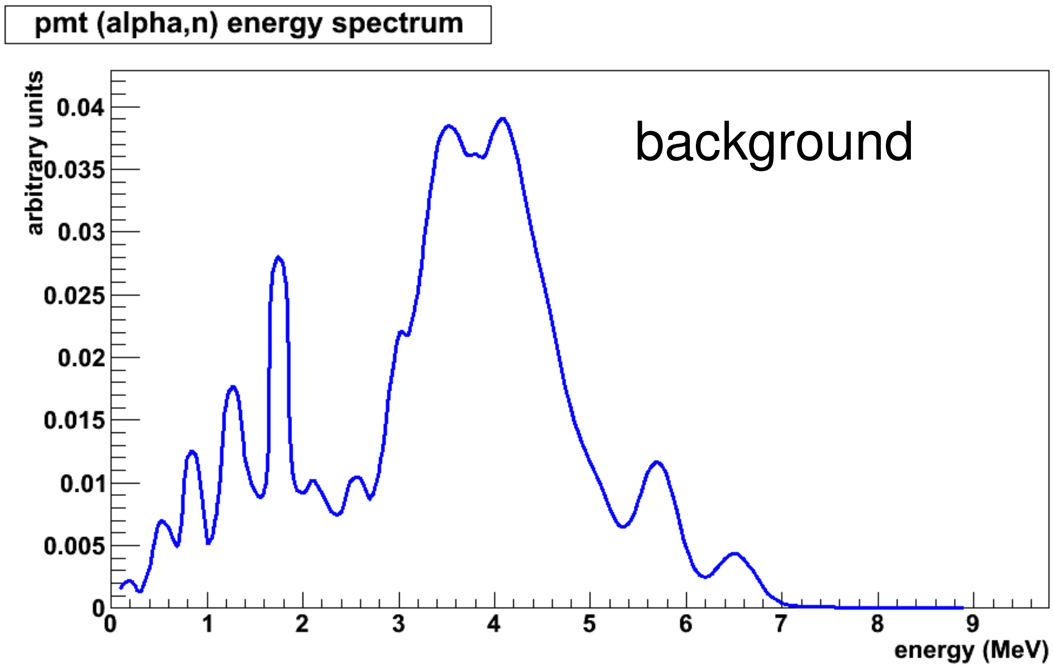
Neutrons produce the same signal:

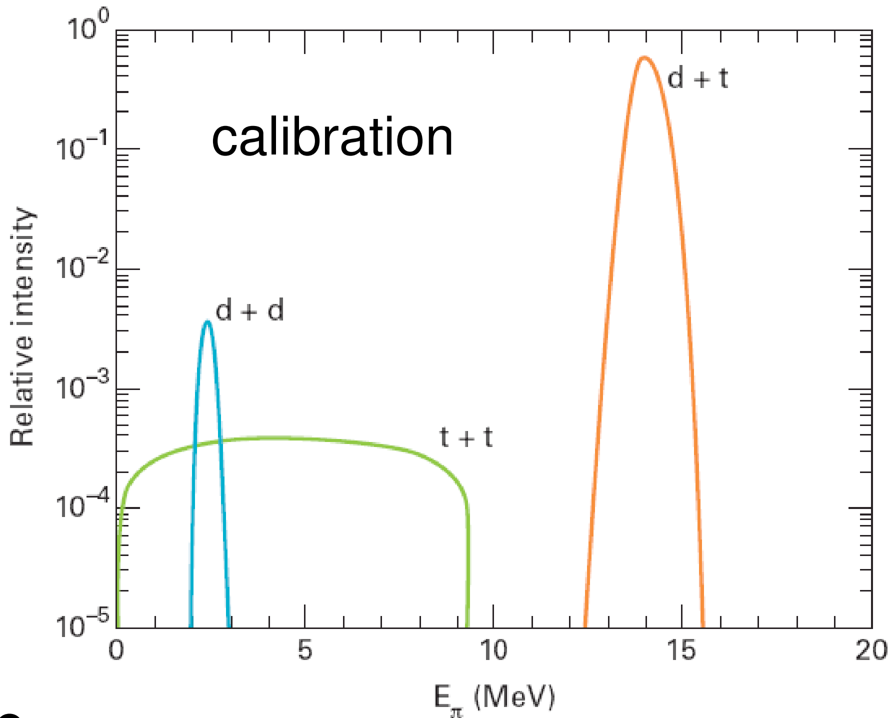
1. Background
   e.g. (alpha, n) PMT neutrons
2. External calibration sources

Calibration Goals

- Characterize detector response to nuclear recoils.
- Benchmark neutron simulation physics to understand background.
- Test techniques to tag neutrons.

Neutron Calibration Sources





1. Deuterium-Deuterium neutron source

- most of the radiation comes from neutrons
- monoenergetic ~2.45MeV
- control: turn (pulsing) on/off, movable source

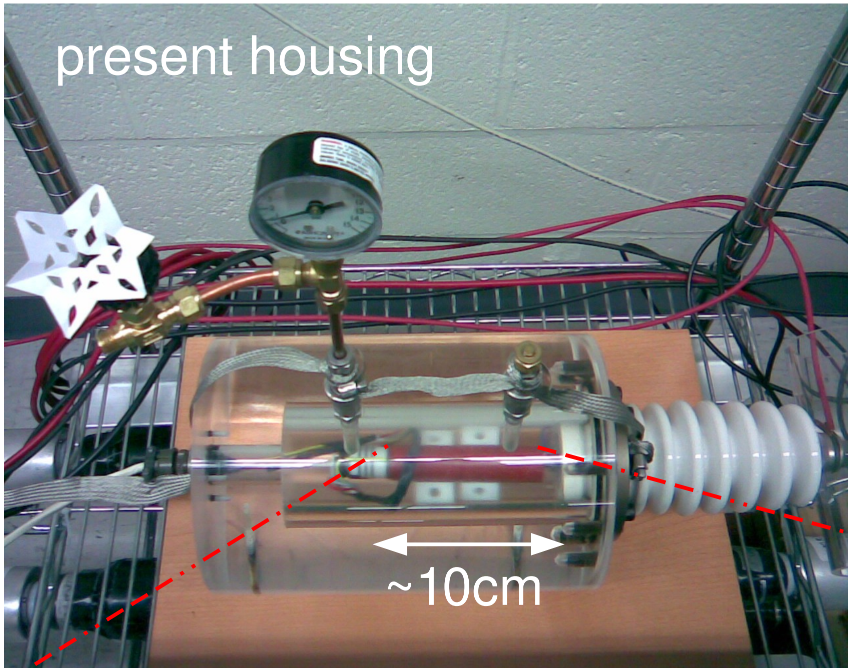
2. Tagged americium-beryllium source

- neutrons with energies up to 12MeV

3. “Hot PMT”: similar to PMT glass but with high uranium/thorium content

Neutron Source: "Minitron"

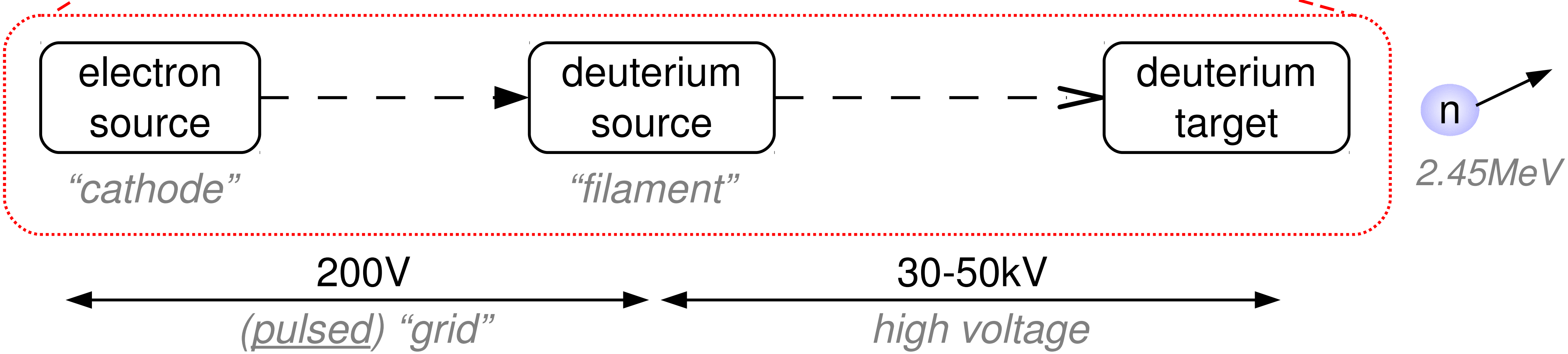
Deuterium-Deuterium neutron source provided by Schlumberger Limited.



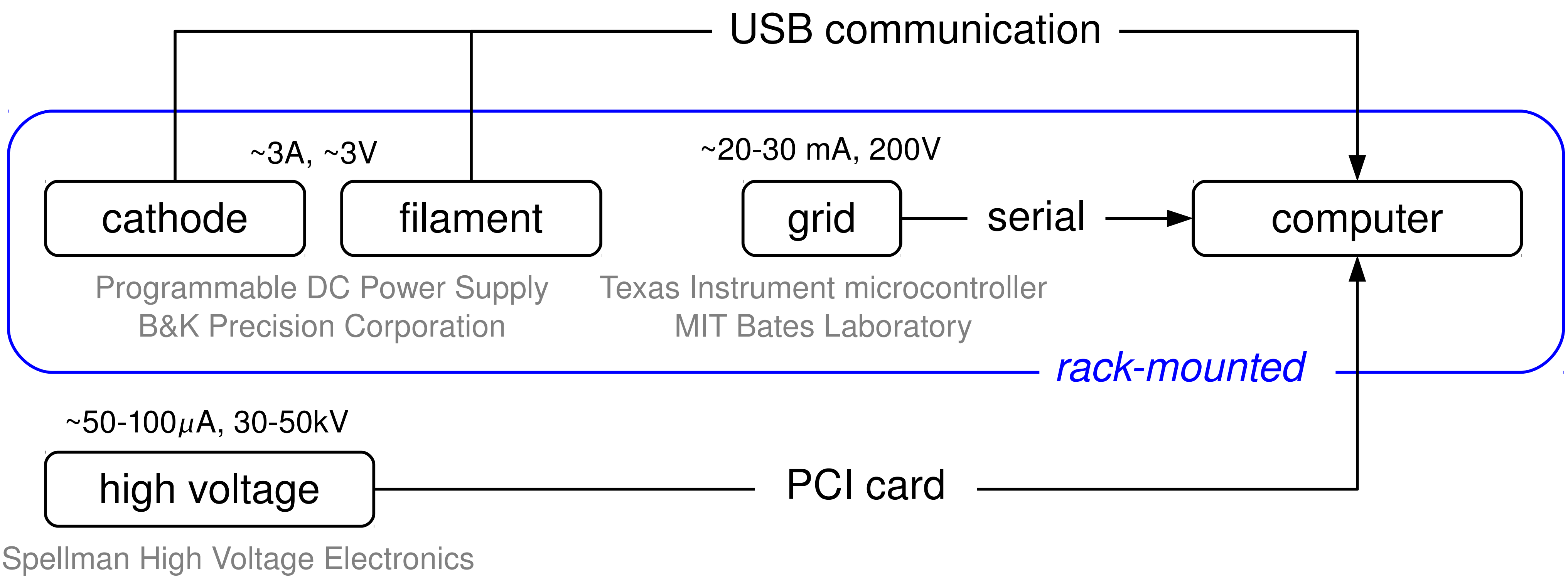
$$D + D \rightarrow {}^{3}He + n + 3.26\ MeV$$

prototype canister

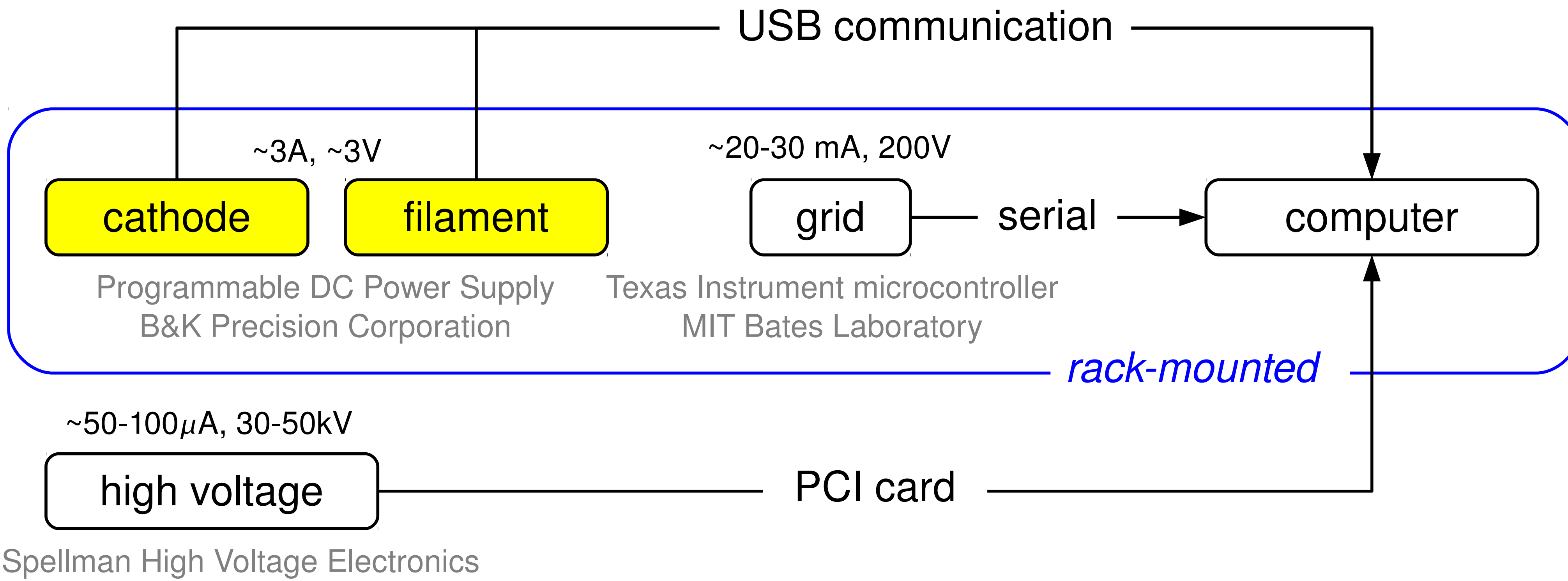
~30cm



Minitron Operation

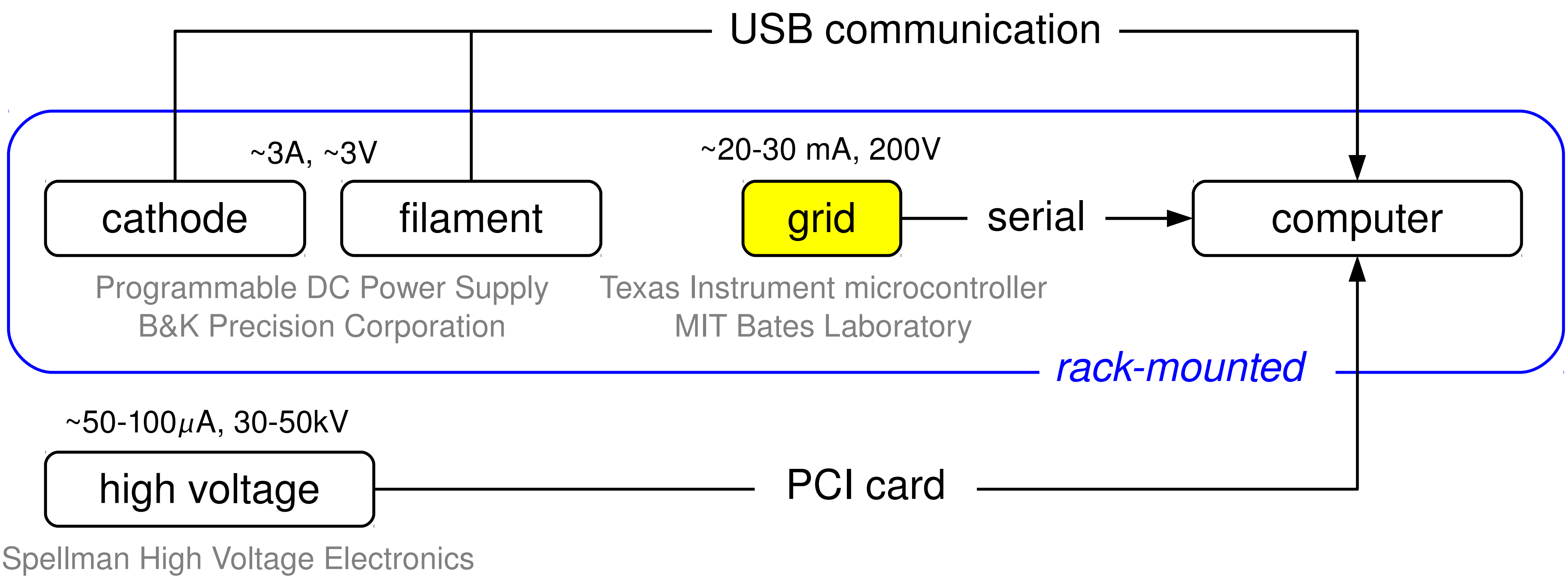


Minitron Operation



>> what affects neutron yield

Minitron Operation

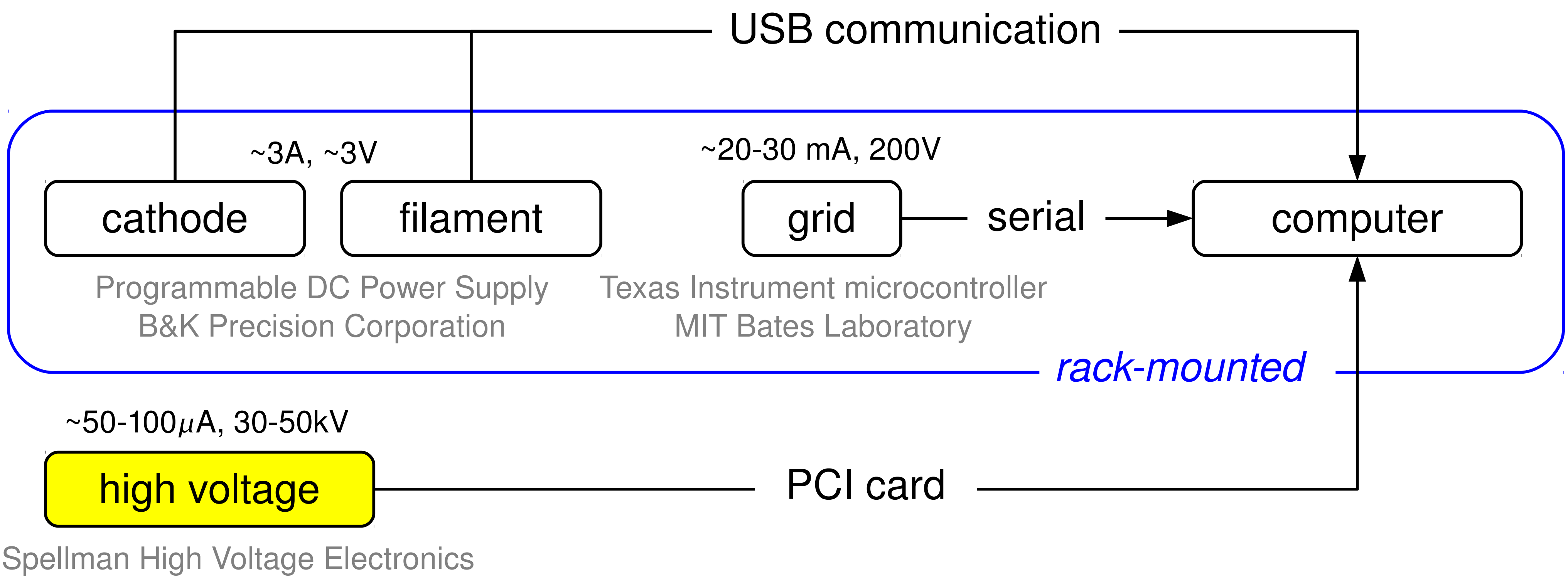


>> what affects neutron yield

>> what controls pulsing

tunable frequency/duty cycle

Minitron Operation



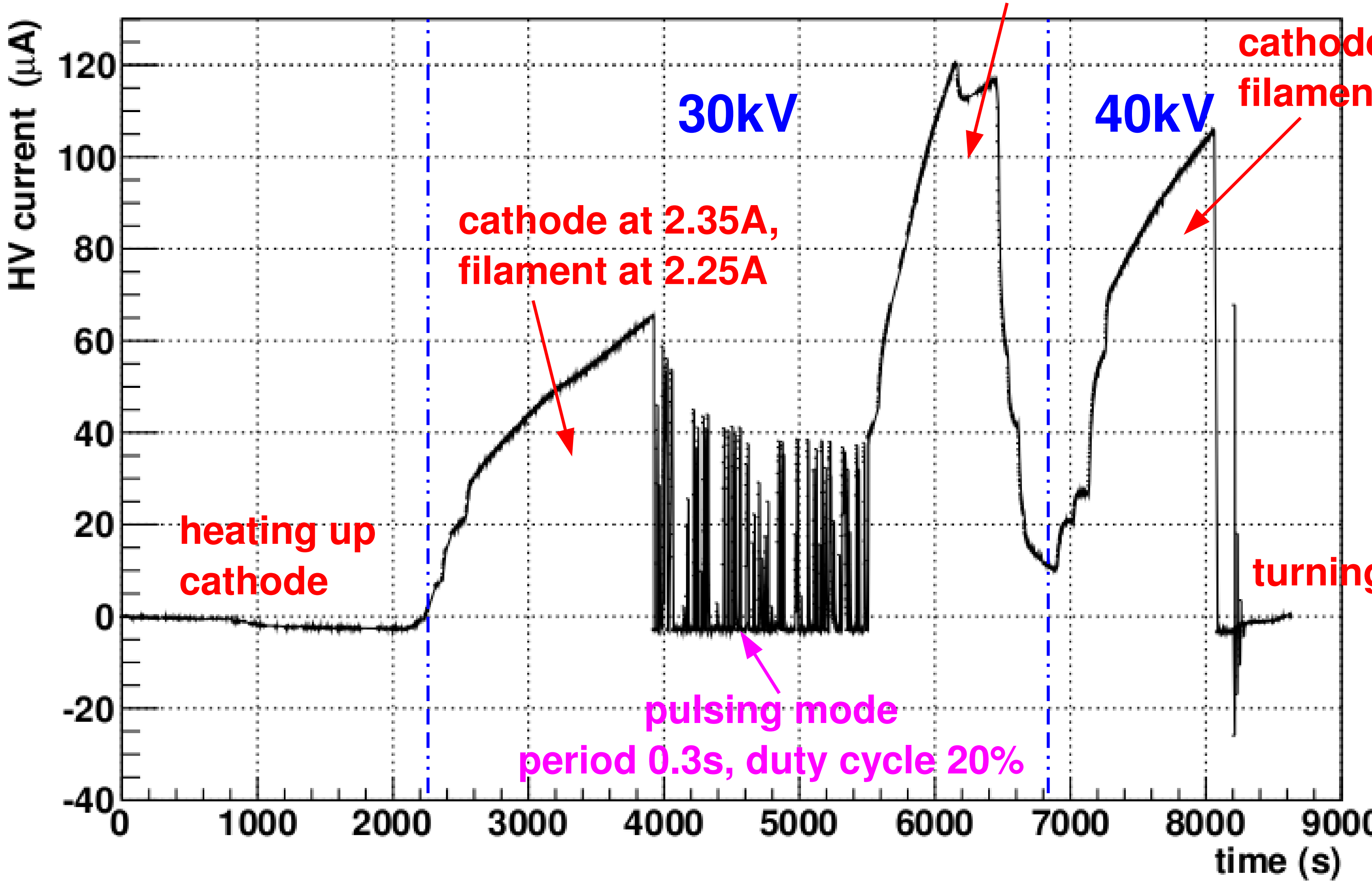
>> what affects neutron yield

>> what controls pulsing

>> what measures neutron yield

~10^5 n/sec at 40kV and 50μA

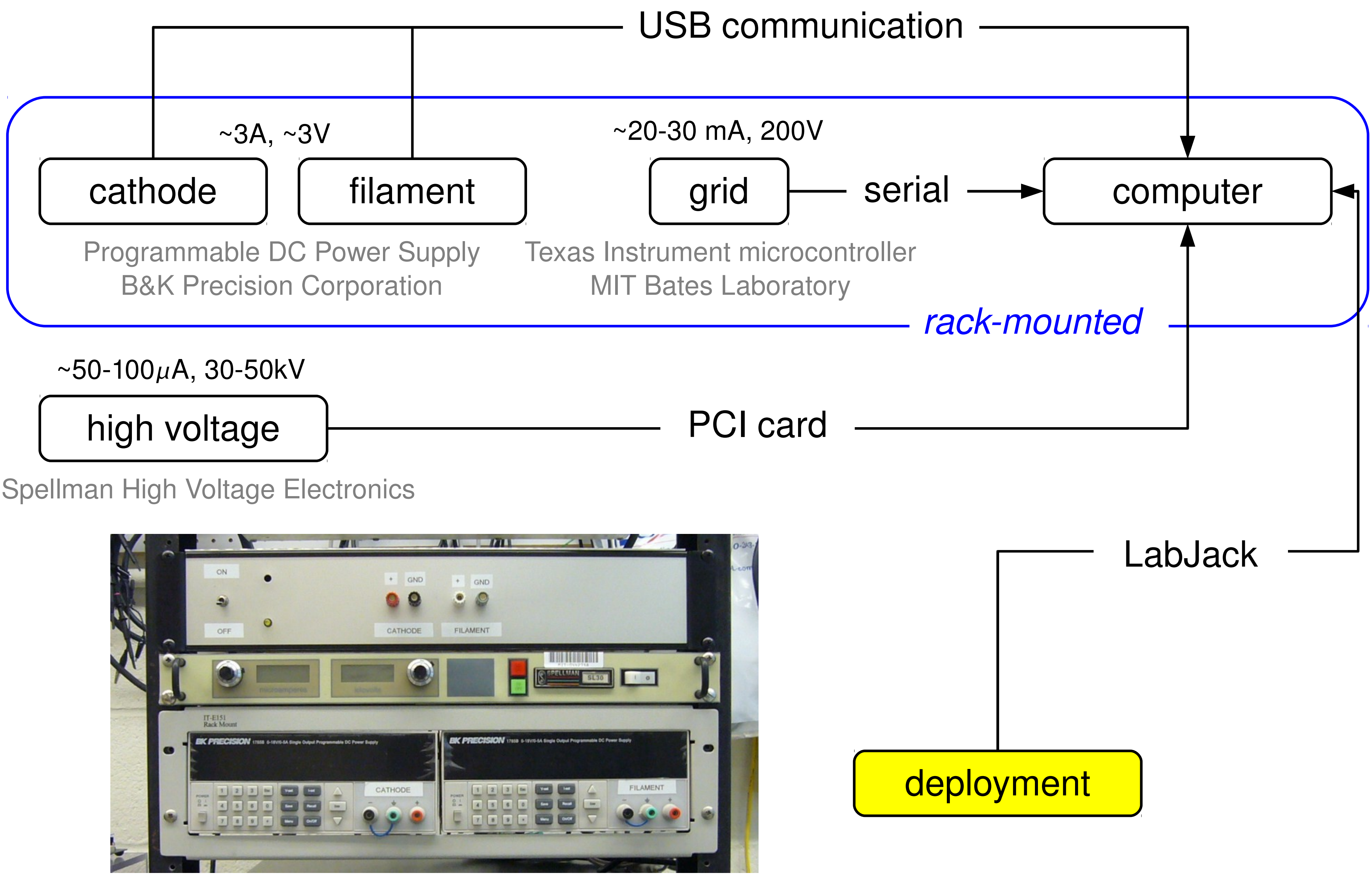
Minitron Measurement



neutron production rate $\propto [\sigma(E) * n_T * n_P]$

→ at 40kV, neutron yield is ~10^3n/μC, resulting in ~10^5n/sec for 50μA

Minitron Operation



Minitron Deployment

high voltage supply holder

canister

prototype

Canister position measured by yo-yo potentiometer.

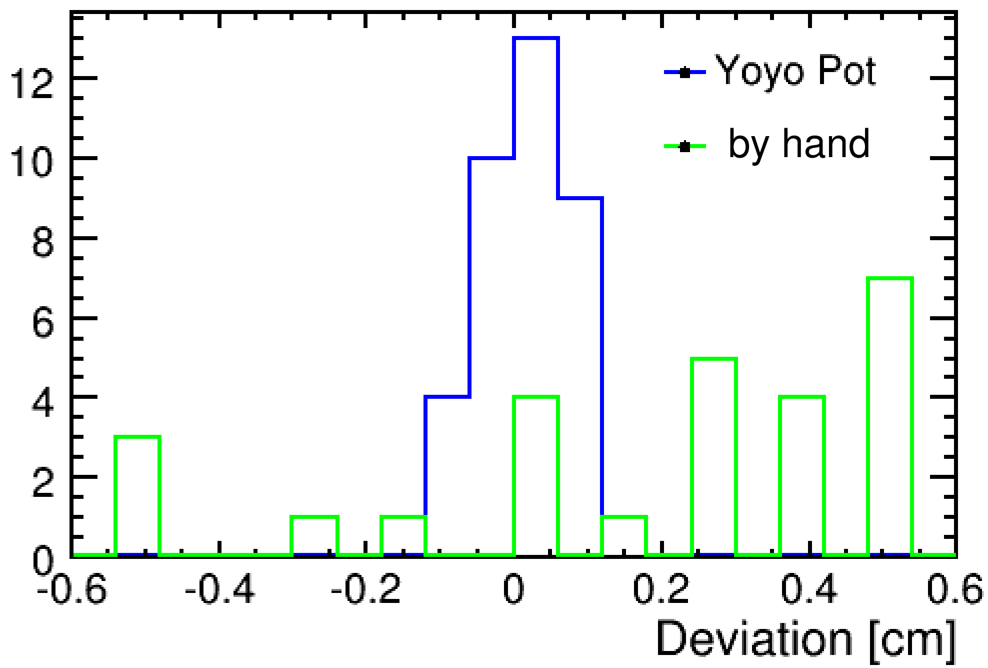
We set the frequency at which the position is measured, and currently we require the winch to stop if the canister is within 1/7cm of its intended location.

Measured velocity of winch:
~1.3 cm/s

“Tall Test”

Mechanical test of the prototype deployment system at roughly the height (~5m) at which it will be positioned relative to the detector.

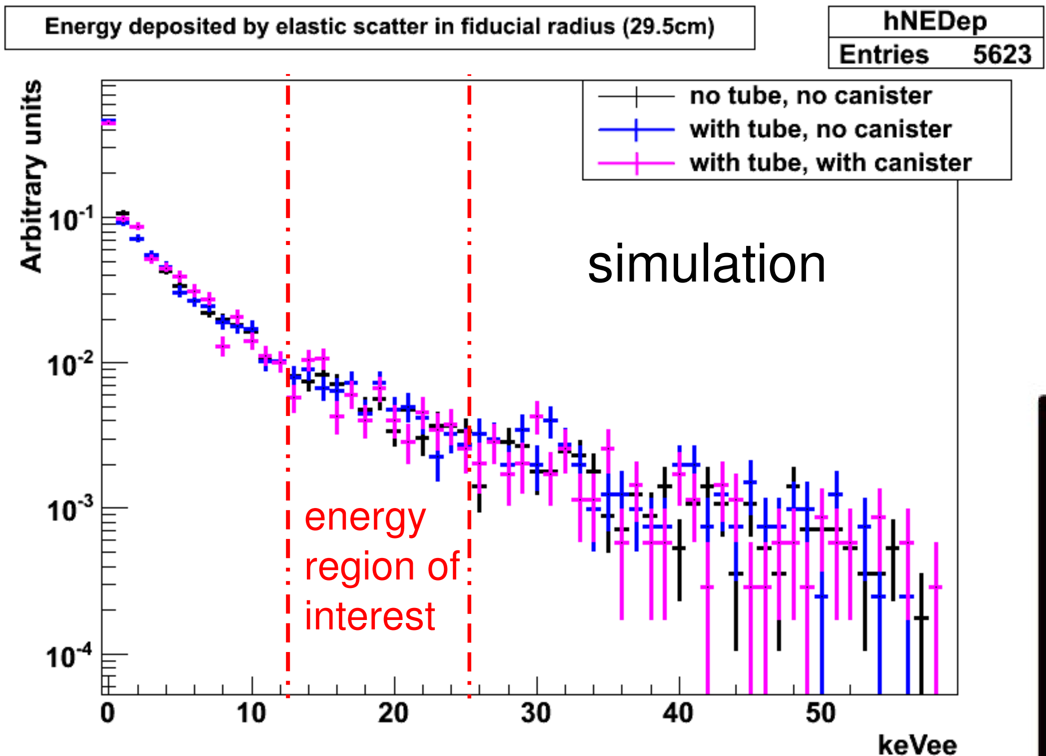
(measured position – intended position)



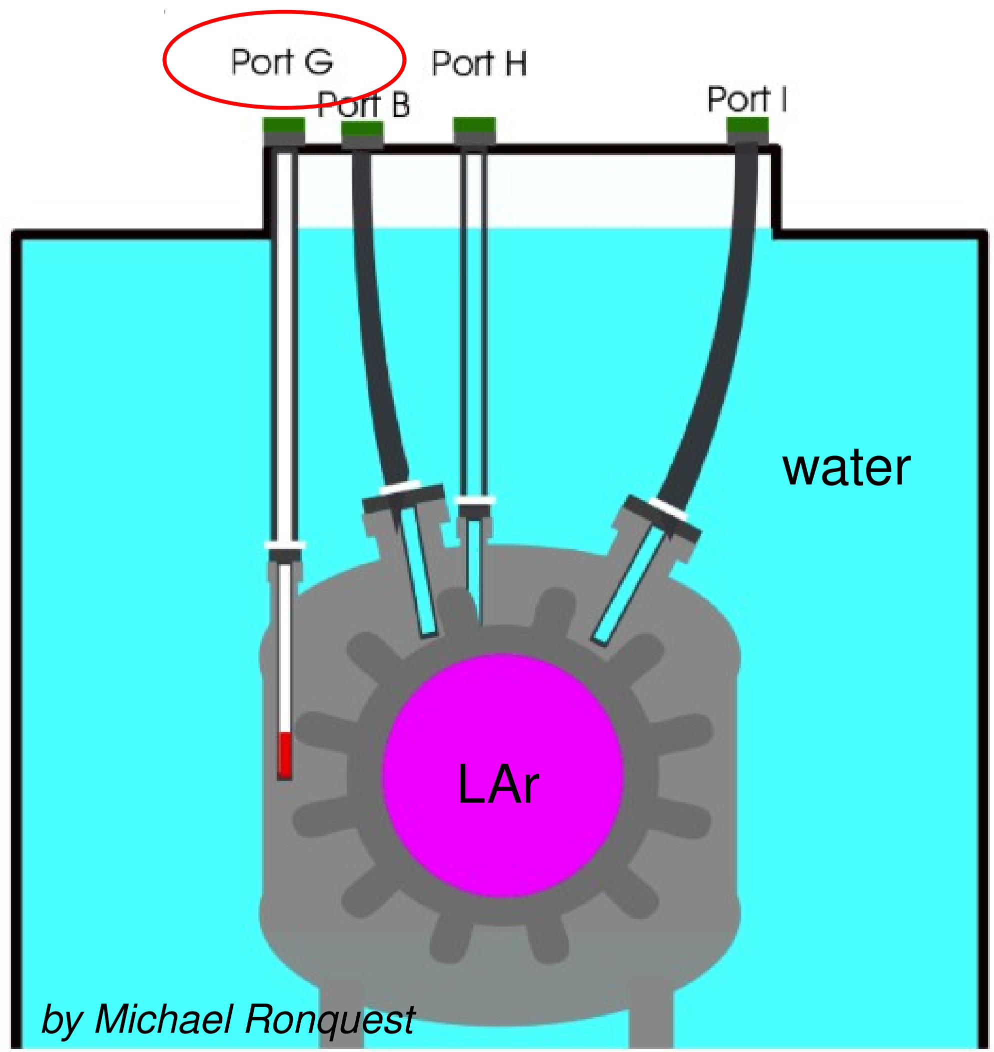
Yo-yo pot: mean = 0.01cm, RMS = 0.05cm

Neutron Calibration System

how everything fits together



Deployment system sits on the deck above the water tank.



Presence of calibration tube and canister do not significantly affect the neutron nuclear recoil spectrum.

Conclusion

Neutrons produce the same signal as dark matter particles.

External neutron sources will help calibrate and benchmark neutron physics.

Minitron: pulsed deuterium-deuterium source

→ pulsing at tunable frequency and duty cycle
→ yield: ~10^5 n/sec
→ variable calibration position
→ material surrounding Minitron does not significantly alter energy spectrum