BOOK40R

Notes:

Blank pages: inside cover sheets, 2-4, 6, 7, 24, 29, 30, 32, 34, 37-158, 5 sheets (part of book and unnumbered), inside back cover sheets

- page 8 has 4 small pieces of paper glued
- page 9 has graph sheet (big) glued to it
- page 23 has 2 small pieces of paper glued

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Record Ruled (27 Lines)

Made in 150, and 300 Pages
Hydrogen (Proton) Recoil Proportional Counter for Neutron Spectra Measurements

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E. F. Bennett, Fast Neutron Spectroscopy by Proton Recoil Proportional Counter, N.S.F. MS No. 58-65 (R)

FAST NEUTRON PROPORTIONAL COUNTER
fabricted for L.V. Kubinski by R.E. Zedler
10 Oct.

At \( V = 3500 \), \( A = \approx 90 \), \( \frac{1}{4} \) 1 MeV recoil proton.

From Herem's plot, pulse count \( 3.3 \times 10^4 \times 90 = 3 \times 10^6 \) electrons. Therefore, Herem's pulse height distribution may be used.

Bennett states that one gets into space charge effects for an acceleration per pulse of \( \approx 10^5 \) and he tries to limit this to \( 10^5 \).

However, his emitter has 1 mil anode wire.

Zeller's has 2 mil...""

At \( V = 2500 \), \( A = \approx 3.5 \times 3.3 \times 10^4 = 1.2 \times 10^5 \)

Need P.S. range greater than \( A J E = \approx 2.5 \) keV.

Diffusion Velocities for CH₄ \((e/p = 0.1)\) \( v \approx 10 \text{ cm/\mu sec} \)

Electric Field \( \frac{V}{d} \) < 1.5 V/cm.
Summary of Preliminary Experiments with electronics in 20 by 9213.

1. With RT = 5 nsec, TMC not triggered properly.
2. With RT = 0.3 nsec, not certain all charge is collected.
3. Noise levels on system high -- ~200 riggs on gain settings of 16 of same magnitude as pulses.
4. Reproducibility questionable.
5. With 10 pV bias source, record proton pulses observed @ 2500 V, (Gain 3 V) A-1 gain 10.
   Most pulses stored before. An apparent shift of pulses greater than expected through all 256 channels -- may be swee.
6. Pulse output from DD-2 amp and 5000 volt supply changed to DD-2 amp and 5000 volt supply.

Noise observed when TMC print copy mechanism.

2. Noise adds pulses when TMC started only if DD-2 is connected.
3. Gamma source pulse from SrCo$^{137}$ are smaller than the largest proton pulses.
4. With $V = 4000$, no counts in all high channels.
   In 10', counts 3 kg count $\approx 0$. Perhaps is
   more noise rather thanoron pulses.
5. Count Dist. does not resemble Herbst's
   data - some pretty different!
7. PuBe source energy is too high.
   Calc. peaks @ 15, 4, and 7 MeV. with
   neutrons up to 10-11 MeV.

Oct 25, 46
1. Wrapped counter sensitive volume with 4 mCi U$^{235}$
   foil surrounded with 2 1/2 ID x 5 3/4 OD plastic (plastic)
   placed Pu Be source outside 2 mm of 2 plaskas.

2. Repeated counts with Pu Be source
   with 2" lead, broadside and end
   and w.o. lead.

3. No real diff in pH, no T noted.
Range from Protons in $\text{H}_2 = 7.3$ cm at 160 mev.

1 MeV in CH$_4$ = 1.1 cm

1.4 MeV Protons in CH$_4$ = 2.0 cm

1.8 MeV Protons in CH$_4$ = 3.1 cm

Carbon recoils expand 40% more energy than pair formed with proton recoil:

$\frac{C}{\text{H}} = \frac{2.6}{4.3}$

$\frac{H}{\text{rec}} \times \frac{4.3}{2.6} \times 4 = 1.05 \times 4 = 6.67$

Thus, Carbon recoils = 13.1% of a sizeable low energy component.

Range at 800 cm $\text{H}_2$ = 10.1 cm

(10 + 100)

Vol I, F. N. H. Phys.,

"from 70 kev up to 3.0 Mev, an amplification not greater than 30 or less than 10 will be required."

a) A > 10 plate hit independent of position in counter.

b) for 70 kev energy, more in any corner.
OCT 26, 64

Thomson: ORNL Health Physics Div.

question Bennett's pulse discrimination technique as on which separate protons from gammas. As a result of a computer program, they found a strong dependence of pulse rise time as a function of track orientation with respect to the wire anode, ranging from tens to hundreds of microseconds, differentiating (150 mV) selects only those with rise times less than 150. (It was not made clear to me why gammas and electrons give pulses with long rise times.) Pules parallel beam short R.T.
Pules I have long R.T. TRACK. It also questioned the neutron spectra unscrambling technique used by Bennett, preferring one he had computerized one of Bureau Hall used at Fermi and Brook Shielding Facilities.

He is going to look into neutron energy spectra measurements with prep. counters, looking in particular at the pulse discrimination method and trying to improve the electronics in general. Please will work with him.

(Many seq. with 14 MeV neutrons in Nevada will have priority!)
27 Oct

For neutron spectrum measurements above 1 MeV, the
proton recoil (in liquid scintillators) method, Verbinski
shall all could be set up immediately essentially
multiplying their data.

For measurements below 1 MeV, we need a complete
new set up in including

1. Proton recoil proportional counters
   a) large to minimize end- and well corrections
   b) avoid methane if possible to avoid H
      correction for carbon recoils, no CH
   c) high pressure hydrogen to shorten
      proton range (also minimizing end
      and well corrections
   d) Anode wire uniformity .001 vs .002

2. High Voltage Supply
   a) Digital type for accurate reproducibility
   b) voltage settings:
   d) $0 - 70.00$ for 0.002 anode
      less for 0.001 anode

3. Amplifiers and Preamp
   a) Low Noise and High Gain
      Noise of DD-2 reduced x100
      Gain of DD-2 probably adequate
   b) L.A. in PHA CV-110 may be used
      with adequate gain in pre-amps.
      To be matched
c) DD-2 Gain 200 Gas Amp 10

Pu-Be Source, high level input
pulse stored as high as 20,000
perhaps 10 MVI. No peaks observed
at 7 MeV or 4 MeV. END and
Wall correction must be severe
for these proton ranges!

To observe 10 keV neutrons overall
gain probably should be 10³ higher in
gas amp if 100 ± 500
could be used and main amplifiers
2 X
gain 10 x higher than (20 DD 2) used.

— higher than (20 DD 2)

3) Low Energy neutron Source

Li-7 - N peaks at 200 keV with neutrons
up to 1 MeV.

N₂ calibration reaction with thermal neutrons
\[ N(n, p) ^4 He \] 615 keV proton
resolution obtained by Bennett as low as 5%
means of counter acceptance in N(n, p) ^4 He)
27 Oct

Telephone Verkinski re fast action proton recoil liquid scintillator N5 213. With pulse shaping, etc.

1. Base location of components very important recommend duplicating their arrangement exactly.

2. Linear signal uses Tennelec Voltage Sems. preamplifier, 2 polarity and DD-2 amplifier (cannot use DD-2 preamplifier, polarity / phase is wrong.

3. Delayed gas using HH 2000 cable to PHA.

4. And signal - preamplifier white base triode cathode follower to a Mod A-8 coincidence etc. etc. (tuning with what other pulse?)

5. Selected 6812A photo tube give better perf. Photo cathode sens. 80 - 120 ma/lum.

See V. McKay, J & C.

Selected Thomson RCA 7265 for pion tests with N5-213, 2 in x 2 in Scintillator
Rabin & Kaganov discussed details of Neutron Spectra near
with V. Verbinski. Confirmed their discussion. Agreed
upon final diagram.

2 Nov 66 If light pulse from Stilbene (RSI, 32, 646)

\[ I(t, E) = \alpha(E) e^{-t/\lambda_2} + \beta(E) e^{-t/\lambda_{1370}} \]

\[ t = \text{ms} \]

total light output = \[ \int \alpha(E) e^{-t/\lambda_2} dt + \int \beta(E) e^{-t/\lambda_{1370}} dt \]

\[ = 6.2 \alpha(E) + 370 \beta(E) \]

For protons a few MeV \( \beta/\lambda \approx 0.02 \)

\[ \text{electrons} \]

Ratio \[ \frac{\text{fast}}{\text{slow}} = \frac{6.2}{370 \times 0.02} = \frac{6.2}{7.4} \text{ for protons} = 0.83 \]

\[ = \frac{6.2}{370 \times 0.011} = \frac{6.2}{4.07} \text{ for electrons} \]

proton \[ \frac{\text{slow}}{\text{fast}} = 0.79 \]

\[ \frac{\text{electron}}{\text{fast}} = 0.66 \]
1st attempt to see the signal on Dynode 12 using an PM tube with some values of voltage divided. The pulse shape is unexplained. Attempts to modify the 15μs part of pulse were unsuccessful. Voltages on voltage divider seemed normal when checked with VOM. Increased 0.0022 Mfd cond - no change.

Added 0.01 " to Dynode 11 - no change

Tripled cable length on input to preamp - no change.

MKR 15/12
TR Rohn wind a PM base, as Verbinski.

Signal observed at preamp input. observed as a function setting of 2k potentiometer. 60 gamma rays. Although the cell was fine. No 102, do not have noise.
amounts of slow component, it must be present to get the cancellation effects observed at preamplifier. A range of + and - pulses were observed with decay times of a few microseconds. Varying the 2K pot changed the ratio of these + and - pulses as well as amplitudes. Using a setting of the 2K pot which minimized the pulse on PSD, neutron-particle spectra with and without were run on the TMC using a coincidence gate from the PSD.

The spectra from Co\textsuperscript{60} on NE-102 does resemble Verbinski's data on 213, however 213 has a sharper cut off. Co\textsuperscript{60} spectra recorded from Dyn. 11 and TMC L.A. seems to have much more noise or low energy pulses! However, the argon machine in counting runs might be some of these low energy pulses.
Pulse from Dynode 11 and pre-amplifier D-2 was fed to 4 Ak 1ME set for 4 pulses. This arrangement was not ideal because the delay line in D-2 put a notch on the pulses. Actual pulse +1 1/2 μs.

A notch from delay line 2.5 μs decay

was not clear. Initial overshoot also not explained. Shape should be

if slow and fast component are equal. On D-2 anode one could see some

rounding due to slow component or other pulse distortion effects not understood.
Pulse shape described on p. 19 not understood.
Dec 12, 1966

Mounted NE-213 #4006 (Vert. Mount Style) on RCA 7265 No. 10141

Observed to be very noisy -- possibility of high dark current or decay of point which were both exposed to light.

- 0.70 mV for one week @ 68°F, 50% RH
- (Base line -- light here, returned back to PM tube 7265)

Also mounted NE-213 #4007 (Horiz. Mount) on RCA 1265 No. 10349. Covered with Al Foil and Black Tape.

---

TEST DATA

- TYPE: 7265
- SERIAL #: 210141
- CATHODE SENS: 160: 1 mA
- CATHODE RED SENS: 54: 1 mA
- ANODE SENS: 1600: nA
- DARK CURRENT: 1050: nA
- 2400: V

TEST CONDITIONS BASED ON TUBE BULLETIN DATED 4-58 AND REV DATED 8-63.
Recorded spectrum from $^{60}$Co and Pu Be source

1. $4006 \ @-1250V$ 2D-2 gain 10 x 10 $^{60}$Co; Hi-level signal
2. $4006 \ @-1250$  "  0.4 x 1.0 Pu-Be from end
3. $4007 \ @-1250$  "  10 x 1.0 $^{60}$Co
4. $4007 \ @-1250$  "  0.4 x 0.5 Pu Be

Using PM base for HV supply

5. $4006 \ @+1950V$ TMC - gain 61 x 1.0 $^{60}$Co low level TMC+ (from Hi-grade)

6. $4006 \ @+1950V$  "  10 x 1.0 Pu Be
7. $4007 \ @+1950V$  "  1.0 Pu Be
8. $4007 \ @+1950V$  "  61 x 1.0 $^{60}$Co
9. $4007 \ @+1950V$  "  10 x 1.0 Pu Be + 2 in Pb
10. $4007 \ @+1950V$  "  32 x 0.75 Pu-Be
11. $4006 \ @+1950V$  "  32 x 0.75 Pu-Be
12. $4007 \ @+1950V$  "  32 x 0.75 Pu-Be with
To complete Temple is developing two new methods for pulse shape discrimination.

1. Essentially the system Drue obtained from Bell.

   Time to zero crossover is different for \( \beta \) and \( p_\perp \) called TAC system.

2. Pulse amplitude

   Ratio measured electronically. Tail amplitude

   Neutron (proton recoil) pulse has \( \approx 20\% \) slow light

   Gamma (electron) pulse has \( \approx 5\% \) slow light

   Dependence is not having a pedestal.

   \[ \text{anti log} \left[ \log (\text{pulse integration}) - \log (\text{tail integration}) \right] \] separation.

   Divide into 2 groups. Log device must have long

   [small has no similar] dynamic range.
Nov 6, 1967

On Nov 5 E.R.A. Durn discussed measuring neutron spectra with T. Love and W. Zobel. They are improving the the Verdone system. They have used the No-219...good down to 200-300 keV and perhaps 100 keV by careful attention to details - Temple believes that one could get down perhaps 30 keV with the LiF sandwich.

again considerable development going on in pure thin LiF "radiators." Energy loss differences between Ne and T recoils limit the resolution. Also suggested was the Ne spectrometer in which the recoil gas content is detected in a scintillating detector. Now the methods are really suitable for reactor spectra.

We also discussed Bennett's (Ann) work with hydrogen filled proportional. Temple was rather all familiar, but from results published he was of the opinion that the method was promising.

Later I called for Able, Court, Leslie, to inquire if they had done anything on ionization recoil counters since last year. He informed that MacKennald and Cifford, Trigg, Wegg, Dey, still...were ordering immediately. For our own, six spherical H2 filled proton recoil counter from the Century Elect. E.g. for this purpose. Hygiene of Horwell lead...
calibrated container filled with 1, 3, and 10 atm H₂ and these calibration data have been (or will be furnished) and the computer unscrambling based on these data will also be sent.

Further connection with Meredith revealed that Thonger of H.P. did some work for them over the last year but he wasn't interested in building a system but wanted to make a research project out of it. Probably related to the problem of pulse rise time with recoil direction, position, etc. when compared to an electron. They are using the Akrasil system because it works! as has worked for Benjamin Hall at Stanford (Glasser & Thonger accomplished little in the past year, dec 14)

Electronic work with Glasser last Dec indicated that the TAC system resolves m-3 pulse well, but the relationships vary with amplifier settings, with voltage on counter, etc and each system must be investigated separately to find the correct settings to get good n-3 discrimination.
Check of parallel plate fission counters.
Rules height distributions measured (1962) show poor resolution of fragments.
Counters re-filled by Zeller, not checked since.

FC-9 $^{235}U$ 2.38 $\mu g$ $\frac{59}{50}$ measured 2.04 Oct 12-14-67
FC-10 $^{235}U$ $\approx \frac{59}{50}$

13 $^{237}U$ m. Rate 1.21 12-9, Est 4.32
14 $^{237}U$ $\approx 1.21$ 12-7, Est 7.29
11 $^{239}U$ 1.04 0.85 9.7% Est 10
12 $^{237}U$ 0.99 9.7% Est 10
7 $^{232}U$ -
8 $^{235}U$ N.G

17 $^{237}Np$ 1.7 mg m. Rate C. Rate 19 Small step to open
18 $^{237}Np$ 2.1 mg 1.010 1.699 27% 

See Rafferty notes for details, since calibration was done with sources from 29" blocks.
1/4" o.d. fission counters 235-3 & 238-2 measured essentially the same fission ratios as the parallel plate counters did.

Have concluded that the uranium foils are not good, mass does not agree! Thickness may vary considerably to give rise to small pulses.
Feb 7, 1968

Upon T. Love's recommendation, NE-213 was unmounted to remove the "plastic" white reflecting coating on the glass vials. He recommended putting crumpled al foil next to glass. He also recommended putting an aperture on the photo tube. Used a 1 3/8" x 1/2" hole in al foil on end of photo tube base. Resesembled and covered with black electrician tape.

Vert. Mount 4006 on 7265 Serial No. 210141
Horiz. 4007 on 7265 " 210349 All Done Coming 20th.
Discussion with Joe Nichols by phone on Aug 21, 69

Subject:
Material Analysis of fuel elements using delayed neutrons at Keevin.

To be able to confirm that an irradiated fuel element contains more $^{233}U$ than that which was loaded into it,

a. Accuracy needed: less than $\pm 1\%$
   probably $\pm 0.1\%$

b. Source strength $\gamma$ from fuel element from $(n,\alpha), (\alpha, n)$ etc., large $\geq 10^8$

Assume irradiation by fast reactor or ORELA

During 150 sec, count time $\sim 90-93\%$ of all delayed neutrons are emitted.

Background: $100 \times 10^5 = 10^{10}$

Delayed neutrons should be $\sim 10^{13}$

Proportion $\beta = 0.2 \quad 1.5 \times 10^{15}$

$\gamma$ fission: $\sim 2 \times 10^{15}$ with seconds $\sim 0.6 \times 10^{15}$

$0.066 \text{ MW sec}$

If burn-up in ORELA, $0.17\%$ absorbed in fuel element

ORELA Burnt $\sim 2 \times 10^{18}$ required.
For an EBR I LW reactor program ORNL EF G9-3-34

Pu power density is 5-8 x 10^5 mrem/kg Pa.

Full element has 7.69 kg fissile in 6 x 10^6 m^2.

Count for 100 sec source strength = 6 x 10^8 background

Total delayed X 100 = 6 x 10^10

Total prompt X 500 = 3 x 10^13

Total fission = 7 x 10^13

Total neutrons in delayed fission X 1000

= 1 x 10^6

Of total fission are 1 x 10^12

Pu/Th enriched to 10^2