First Results from a CEvNS Search with the CENNS-10 Liquid Argon Detector

2018 APS DNP Meeting

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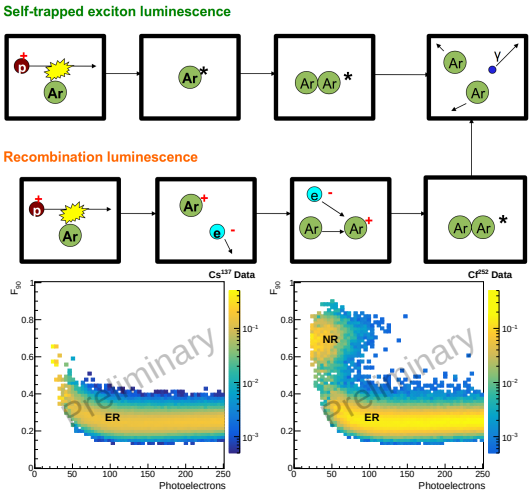
Why LAr

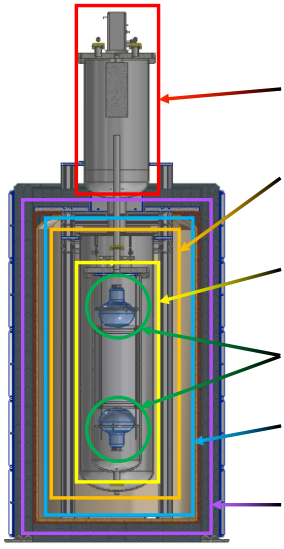
- Complementary to heavier Cs and I
  - Map out low N σ_{CEvNS}
  - Lower σ but more energetic recoils
- Large scintillation yield
  - 40 γ/keVee
- Quenching factor well measured
- Pulse Shape Discrimination!
  - Argon scintillates with 2 time constants
    1. Singlet light: ~6 ns
    2. Triplet light: ~1.6 µs
  - Electronic Recoils mostly triplet light
  - Nuclear Recoils mostly singlet light

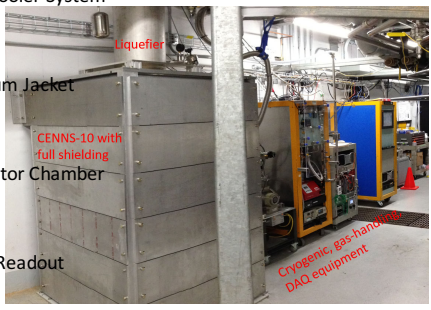


[0]Scint. Diagram courtesy of B. Jones *Introduction to Scintillation Light in Liquid Argon*

Specs

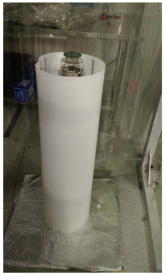
- Single phase liquid argon detector
- 2x Hamamatsu R5912-20 PMTs
- Caen 1720 digitizer
  - 12 bit, 250 MS/s
- PT90 cold head
- Saes MonoTorr gas purifier
- Running at SNS 2016-present
  - "Engineering Run": This talk
  - "Production Run": Light collection upgrade, add'l shielding
    - Analysis in progress, stay tuned

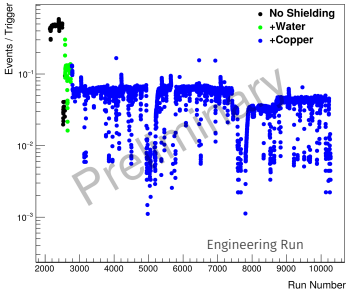


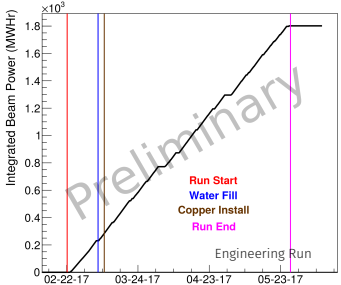


Run Summary

- 29 kg fiducial volume
- Tetraphenyl butadiene (TPB) coated acrylic cylinder backed by teflon
- TPB coated acrylic disks in front of PMTs
- Water, Cu shielding
- 1.5 GWh (3.5×10^{22} pot) full shielded config.
- Light collection upgrade Summer 2017
  $\rightarrow$ Production Run





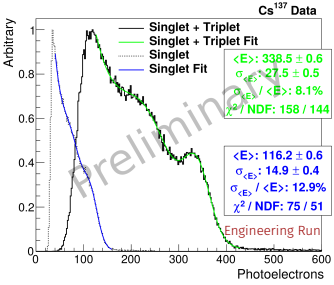


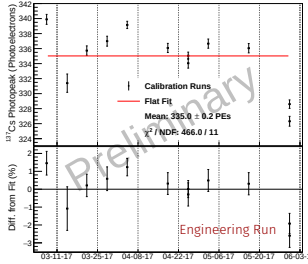
Detector Characterization

- Weekly calibration runs
  - LED for SPE calibration
  - ^{137}Cs for light yield calibration
- Monthly ^{252}Cf source for nuclear/electronic recoil discrimination
- Light yield 0.5 PEs/keVee
  - Much improved for Production Running!

Cuts

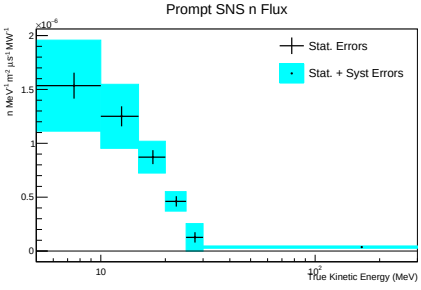
- General waveform quality cuts: no saturation, valid baseline...
  - $>$ 99 % waveforms pass
- Event specific cuts: pileup, pre-trace...
  - $>$ 98 % events pass
- Beam related events: PSD

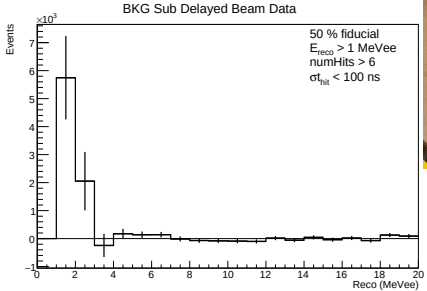


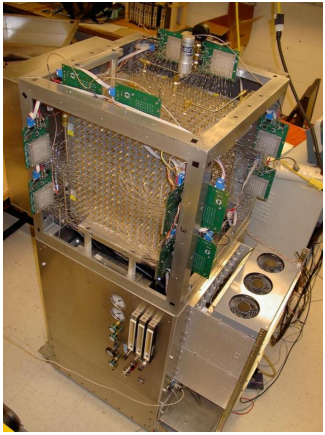


Neutrons

- BRNs cause nuclear recoils in time with the beam
  - Mimic CEvNS signal!
- SciBath neutron measurement in LAr location Fall 2015
- Prompt fast neutron flux ((5-30) MeV): $(2.1 \pm 0.4) \times 10^{-5}\,\mathrm{n/m^2/\mu s/MW}$
  - Limit $>$ 30 MeV flux
- Delayed fast neutron flux consistent with 0
  - Evidence for thermal neutron captures

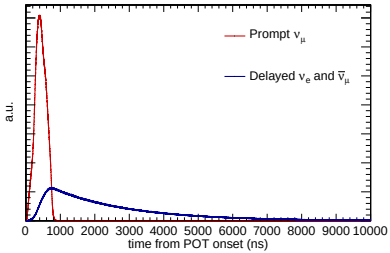


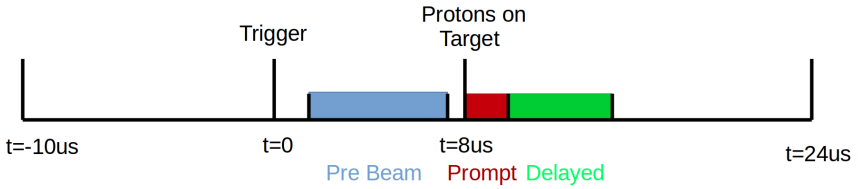




Beam Trigger Configuration

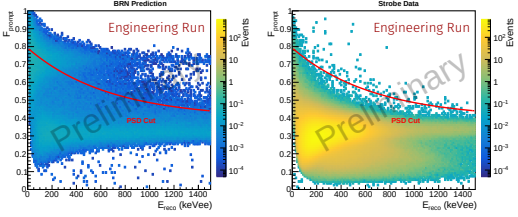
- Beam triggers divided into 3 regions:
  1. ‘Pre-beam’: characterize beam unrelated bkgs (BUBs)
  2. ‘Prompt’: 1 μs centered on beam: BUBs + Beam Related Neutrons + CEvNS
  3. ‘Delayed’: 3 μs window post-beam: BUBs + CEvNS
- Add’l strobe trigger
  - Strobe triggers further characterize beam unrelated bkgs (BUBs)

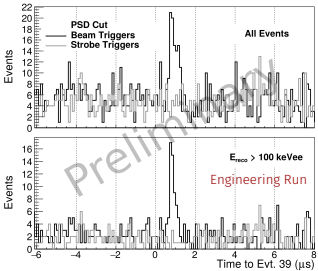


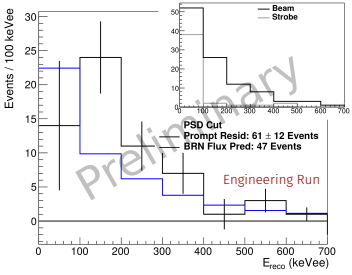


No Shielding Neutron Run

- Minimal shielding run to further characterize ‘Neutrino Alley’ neutron flux
- 2 weeks of data
- Excess of (61 ± 12) events with PSD cut
- Delayed flux consistent with zero
  - (-18 ± 23) events



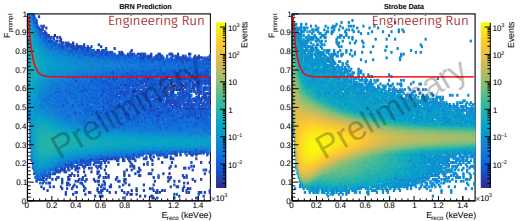




Full Shielding Predictions

- Addition of 20.3 cm H_2O and 1.27 cm Cu
- 2 analyses:
  1. Counting exp't: cut in PSD/energy/time and count events
     - Both prompt ($0.4 < t_{POT} < 1.4$ µs) and delayed ($1.4 < t_{POT} < 4.4$ µs)
  2. Likelihood fit in energy/psd/time space

Counting Exp't PSD Cut

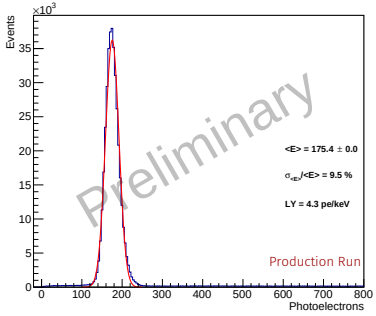


Engineering Run Prediction

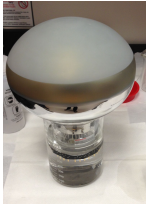
	BUB	BRN	CEvNS
Total (< 700 keVee)	5.8×10^5 µs^{-1}	800	6.8
Prompt Count. Exp't < 700 keVee	87	133	0.3
Prompt Count. Exp't < 30 keVee	3.4	8.9	0.2
Del. Count. Exp't < 700 keVee	261	< 1	0.7
Del. Count. Exp't < 30 keVee	10.2	< 1	0.5

Production Run

- Light collection upgrade Summer 2017
  - TPB coated teflon walls, PMTs
  - 22 kg fiducial volume
  - ~4.5 PEs/keVee!
- Add'l lead shielding
- 6.2 GWh expected
- Initial low energy Kr^{83m} results promising!

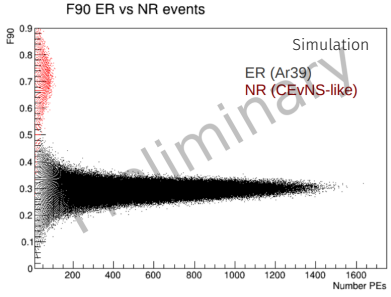


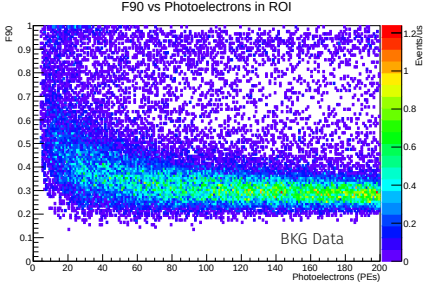
Kr^{83m} Holder



Expected Sensitivity

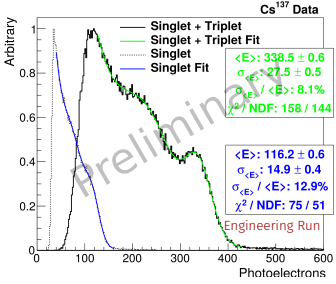
- Threshold ~20 keVnr
- Major beam unrelated background ^{39}Ar
  - ~1 Bqkg^{-1}
- Initial MC estimates indicate ^{39}Ar/CEvNS separation adequate
  - Expect ~100 CEvNS events Production Run
  - BRN predictions (all prompt) in progress
  - Tuning MC to better match calibration data

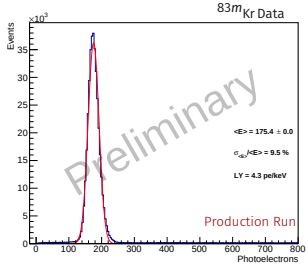




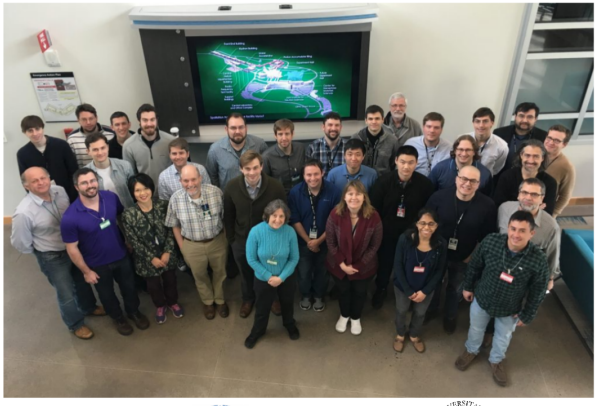
Summary

- Engineering Run results soon
  - Beam related neuton rates constrained with no shielding
  - ‘Full shielding’ results any day
  - Neutron flux informs production run background predictions
  - CEvNS limit from likelihood analysis
- CENNS-10 taking data
  - Production Run analysis underway!
  - Stay tuned!





COHERENT



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UNIVERSITY of WASHINGTON

OAK RIDGE National Laboratory

CNEC Consortium for Nonproliferation Enabling Capabilities

KCP

NNSA National Nuclear Security Administration

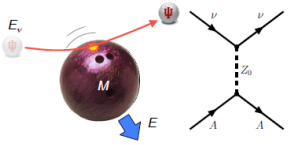
NSF

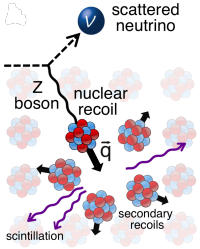
U.S. DEPARTMENT OF ENERGY

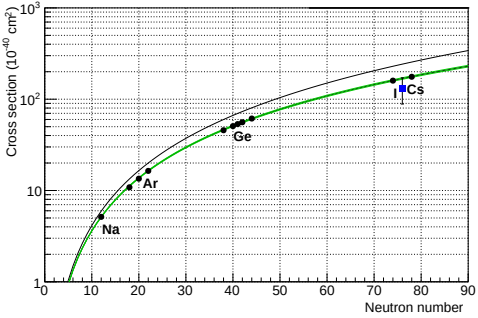
Backups

Coherent Elastic Neutrino Nucleus Scattering

- Neutrino collides with large nucleus which recoils coherently
  - $E_\nu \lesssim \frac{hc}{R_N} \approx 50\,\text{MeV}$
- Small recoil energy
  - $E_r^{max} \lesssim \frac{2E_\nu^2}{M_N} \simeq 50\,\text{keV}$
  - Difficult to detect
- Deploy a suite of detectors to measure N^2 cross section dependence
  - CsI[1], Ar, NaI, Ge

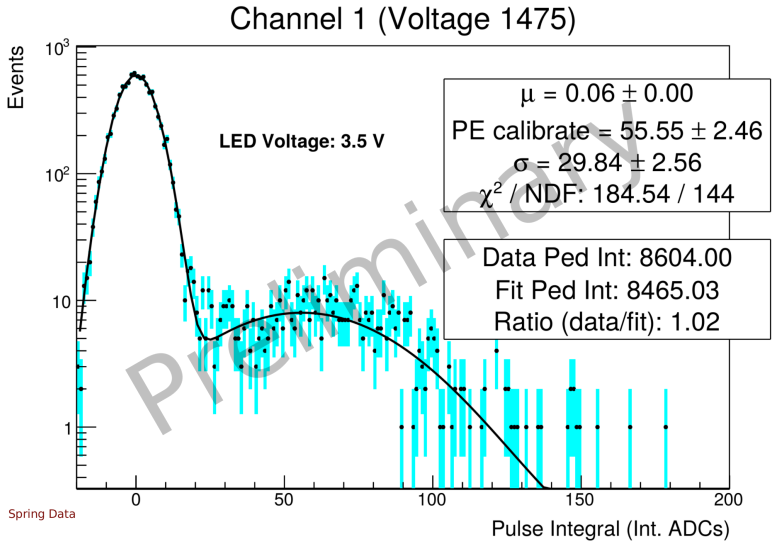






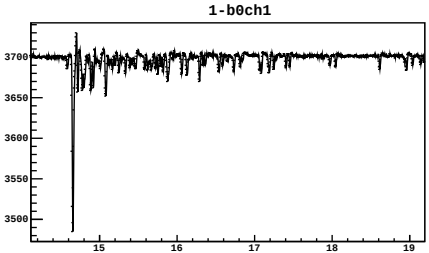
[1] DOI:10.1126/science.aao0990

SPE Spectrum

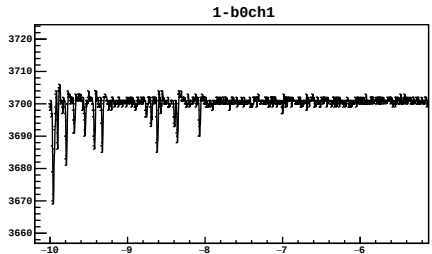


Event Quality Cuts

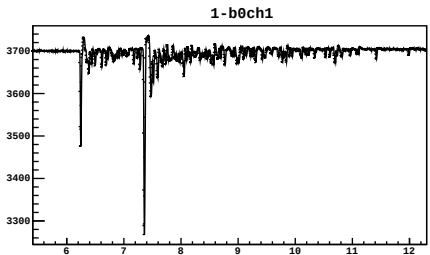
Bad Local Baseline



Bad Fit Result (usually too close to beginning for valid baseline)

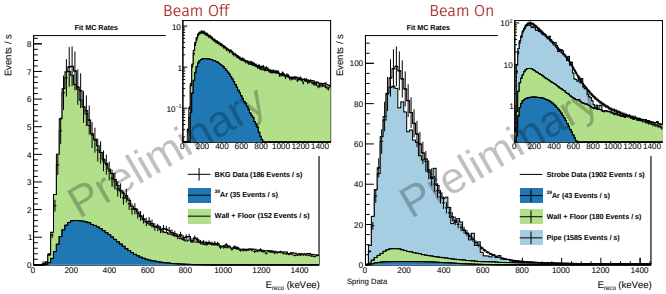


Bad Peak (typically pileup)

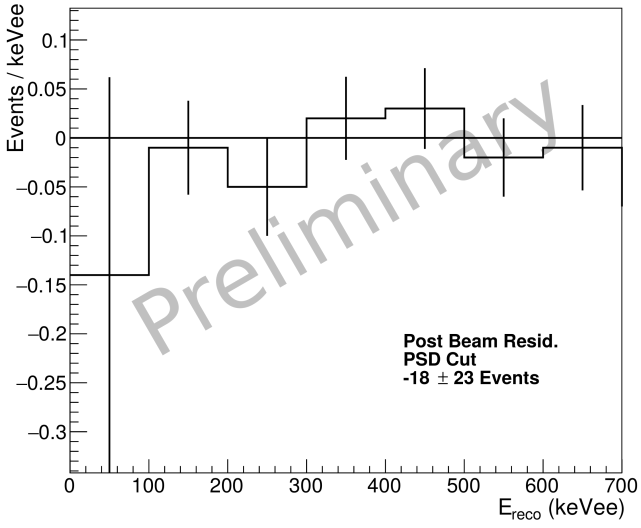


Steady State Backgrounds

- ^{39}Ar, 511 γs, wall + floor gammas dominate
- Bkg calibration runs give ^{39}Ar, wall + floor rates
- 511 γs from beam on strobe triggers
  - From beam exhaust pipe
- ~1.9 kHz steady state bkg rate

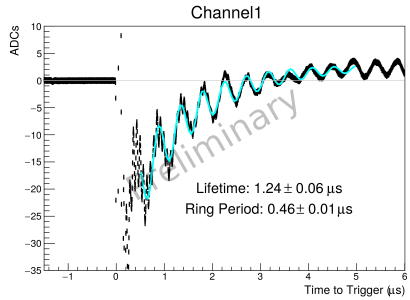


No Shielding Delayed Residual

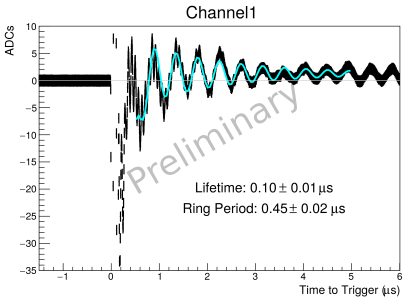


Triplet Lifetime

Pre-Doping



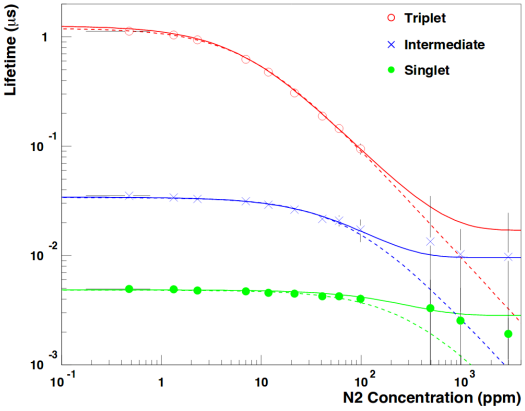
Post-Doping

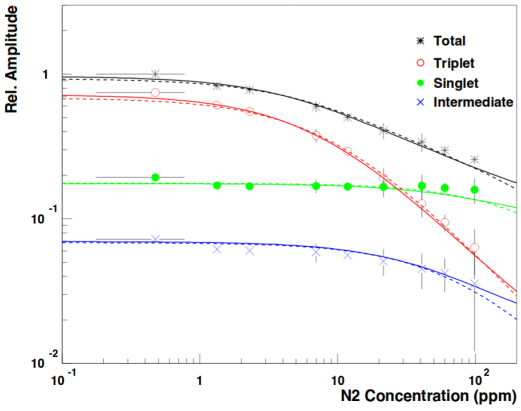


- As data quality check introduce N_2 after spring run
  - ~25 ppm
- Triplet lifetime changed from ~1.2 μs to 0.2 μs
  - Roughly 1 ppm and 20 ppm respectively[2]

[2] arXiv:0804.1217 [nucl-ex]

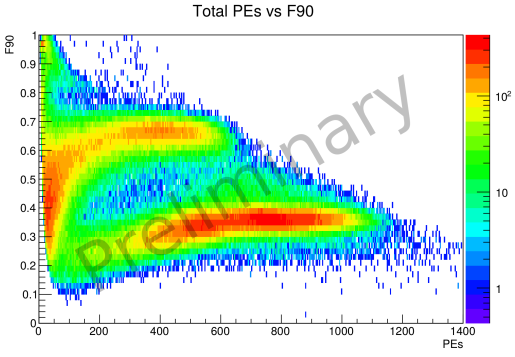
N2 Contamination



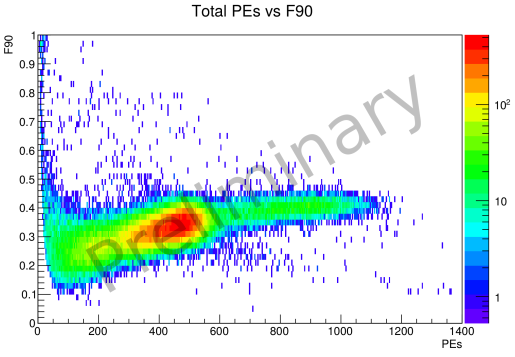


[2] arXiv:0804.1217 [nucl-ex]

Production Run PSD



AmBe



^{57}Co