Enhancing the Detector for Advanced Neutron Capture Experiments

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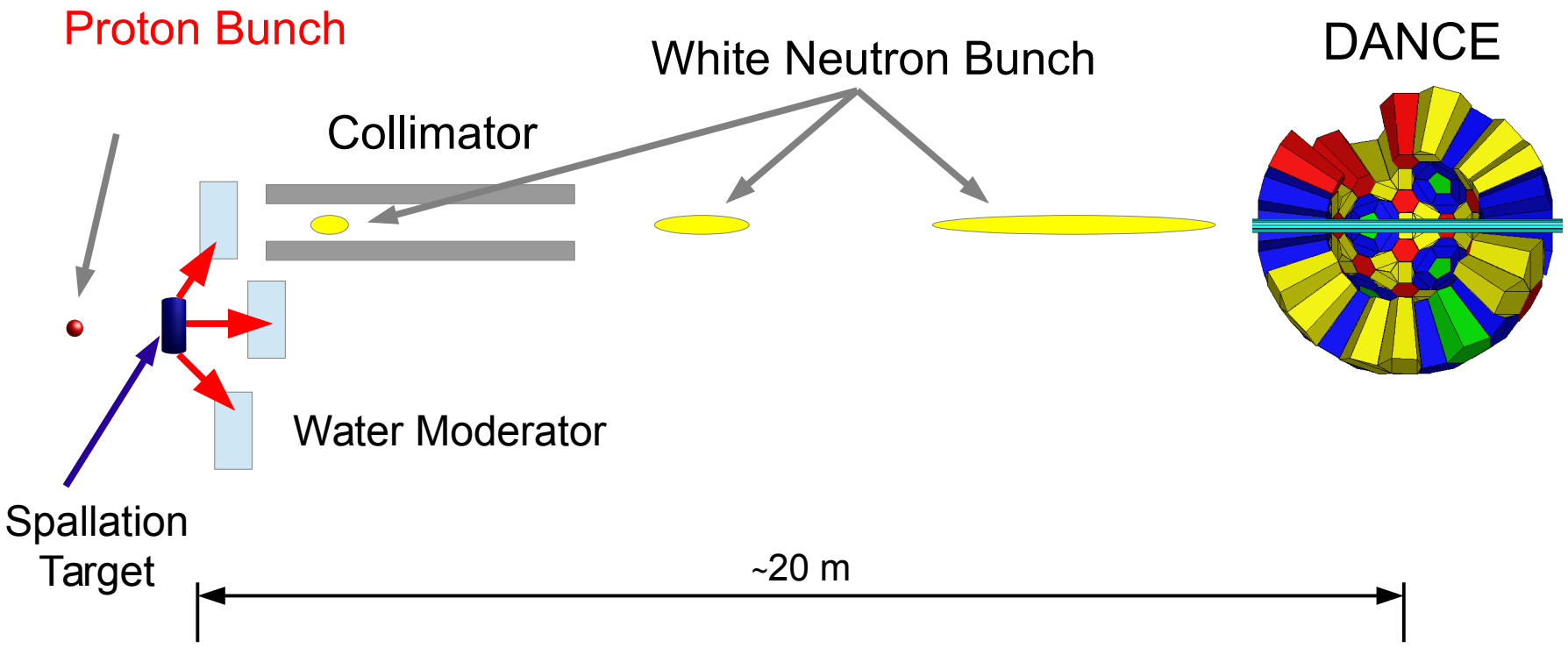
CGS15
25-30 August 2014
Dresden, Germany

Time of Flight with Spallation Neutrons

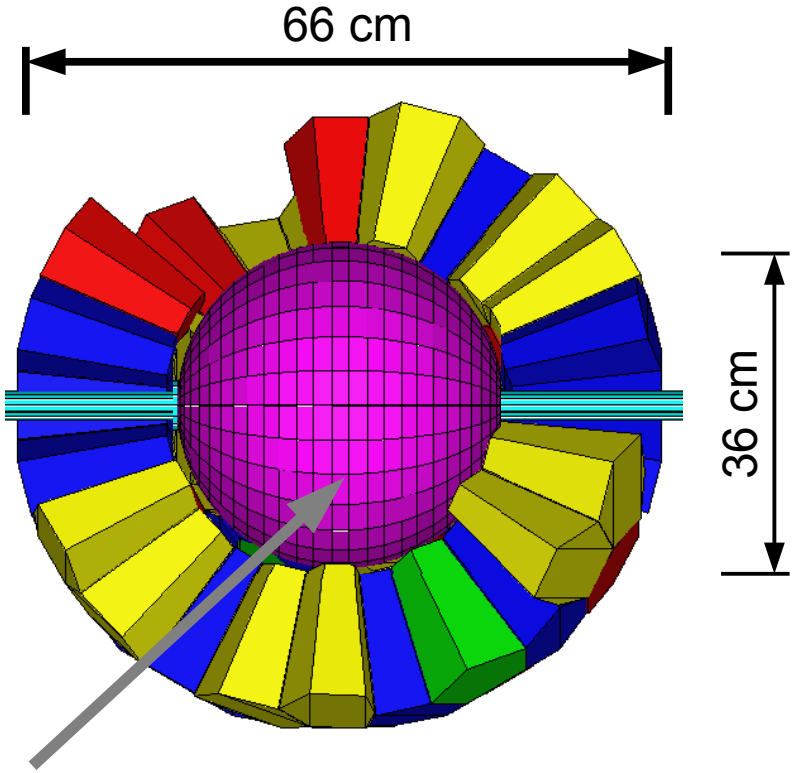


E_p= 800 MeV v_p=20 Hz 10 meV < E_n < 500 keV

$\varphi_n = 3 \cdot 10^5$ n/s/cm^2/decade

The Detector for Advanced Neutron Capture Experiments (DANCE)

- 160 BaF_2 Scintillators
- 2-8-bit, 500MSample/s digitizers/scintillator
- Digitizers are built a on cPCI architecture
- 15 independent cPCI single board computers each control 6 digitizer boads of 4 channels (24 channels/computer)
- 4 Detector shapes, each covering the same solid angle
- $\varepsilon_\gamma \approx 85\ \%$
- $\varepsilon_{casc} \approx 98\ \%$

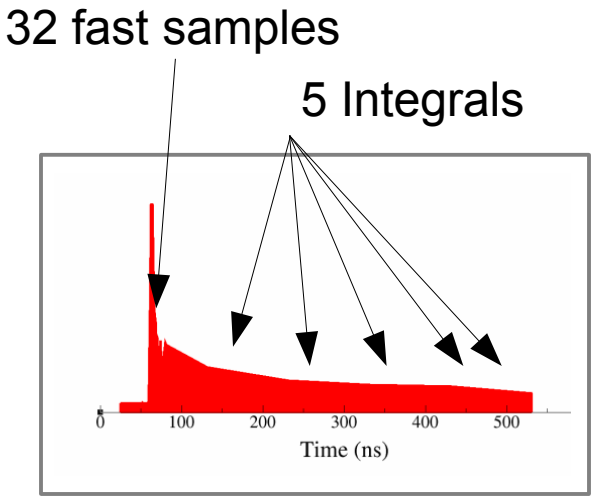


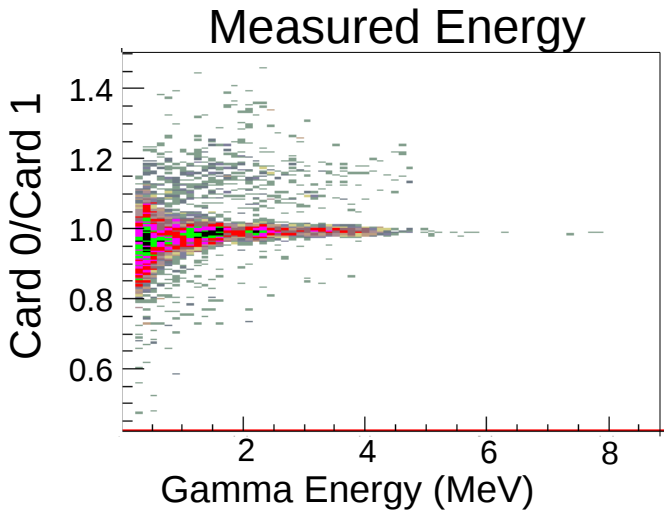
^{6}LiH Shell Surrounds Sample (6 cm)

For details see: Heil *et al,* NIM A 459 (2001) 229-246

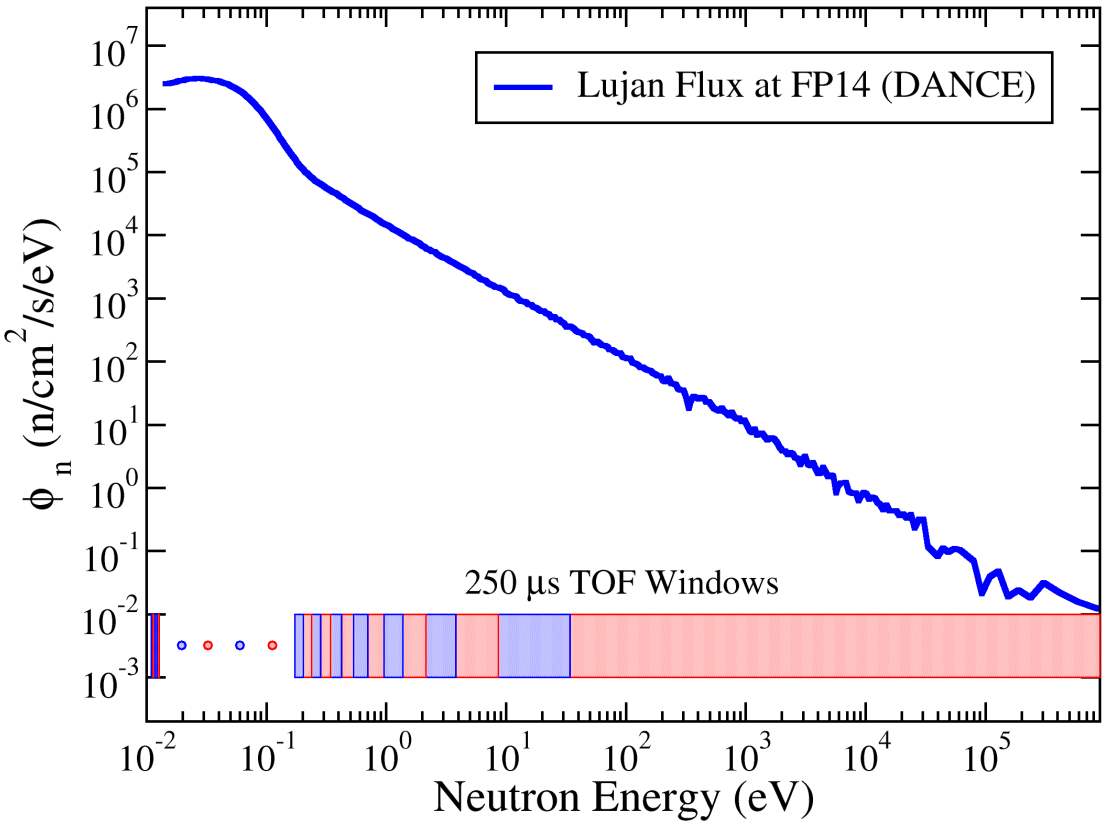
DANCE isn't perfect—yet!

- The algorithms and signal processing are actually quite good, *but*
- Resolution, particularly below 500 keV, is poor
- Limited digitizer memory makes covering the entire energy range of interest time consuming
- Lack of on-board waveform processing imposes high bandwidth requirements
- System handshaking limits the flexibility for auxiliary detectors
  - This is primarily a time-synchronization issue





Neutron Flux at DANCE



- Memory and a lack of onboard signal processing limits acquisition to 250 us
- Thermal neutrons take ~10 ms to arrive—which is 50 time windows to cover the full energy range

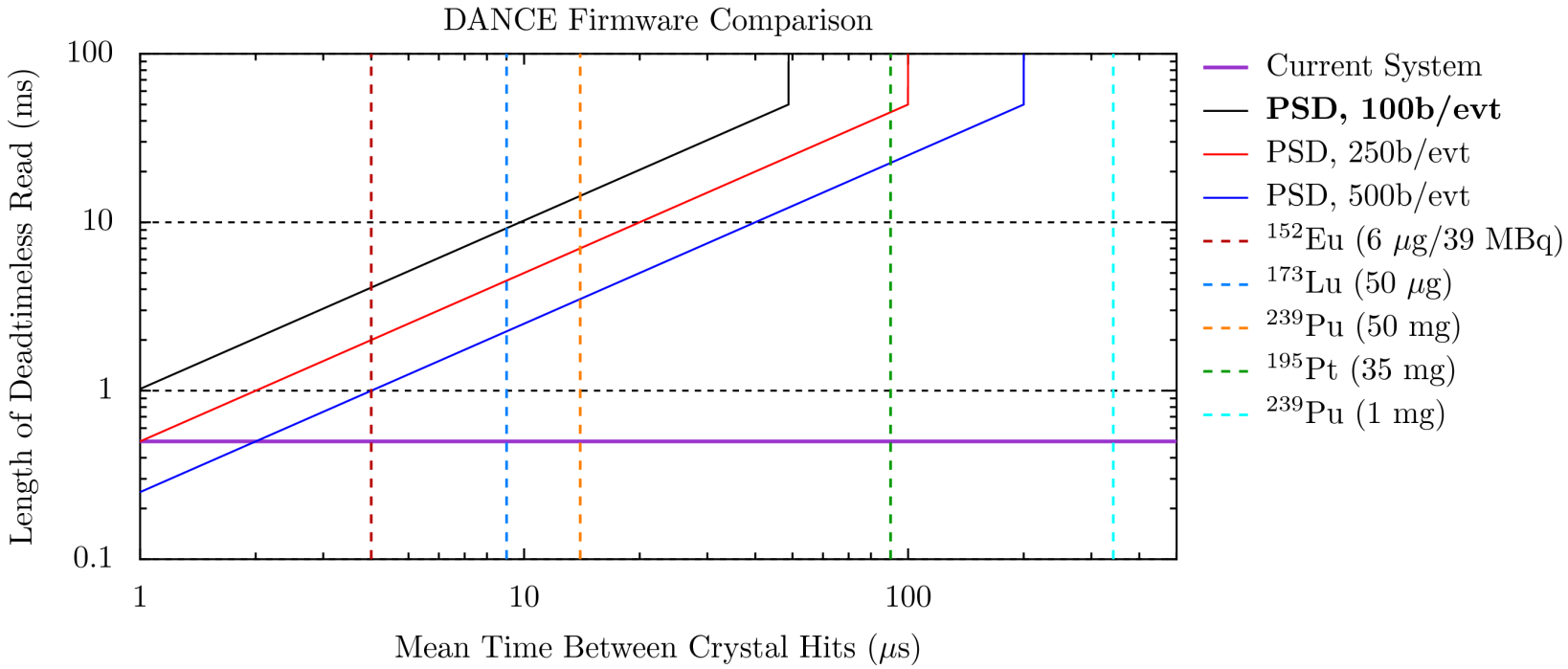
Transition to New Era of Digitizers

- Upgrade is in progress
- Digitizers chosen are CAEN VX1730
  - 16 channel, 14 bit, 500 MS/s digitizers on a VME64X platform
  - 5.12 MSample memory/channel (10+ ms)
  - FPGA firmware for PSD and PHA available
    - Appropriate for BaF_2, liquid scintillator, and solid-state detectors
    - FPGA data compression addresses bus bandwidth issues
  - Allow hardware clock synchronization across all 200 channels
    - Rather than sending a common start to all channels, we will digitize the T0 on a channel with a common clock with the detectors
    - Simplifies addition of auxiliary detectors

Data Acquisition in MIDAS

- The DAQ will be implemented in a MIDAS framework
- Each channel will trigger, analyze, and dump data independently
  - PSD output provides 2 common-start integrals and a 64 bit timestamp as well as an optional waveform portion (programmable width)
  - We are working with CAEN to implement appropriate firmware for pileup handling
- This has already been implemented for a smaller scale system
  - S. Mosby *et al. Nucl. Instr. Meth. A* **757** (2014) 75-81
  - Used 2 synched 8-channel, 12 bit, 250 Msample/s digitizers
  - In a separate test, a prototype x730 board was run DANCE with a HPGe
- All of the known technical barriers have already been addressed

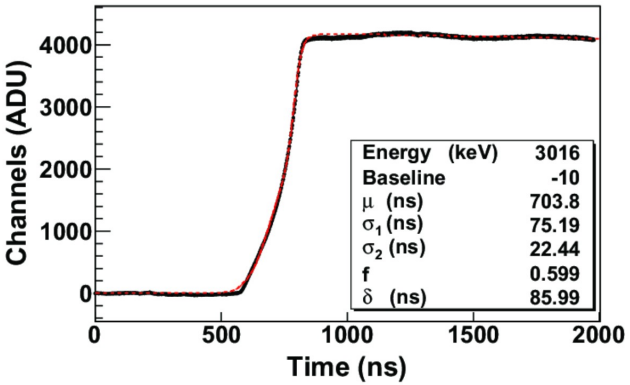
Firmware + High Speed Data Transfer

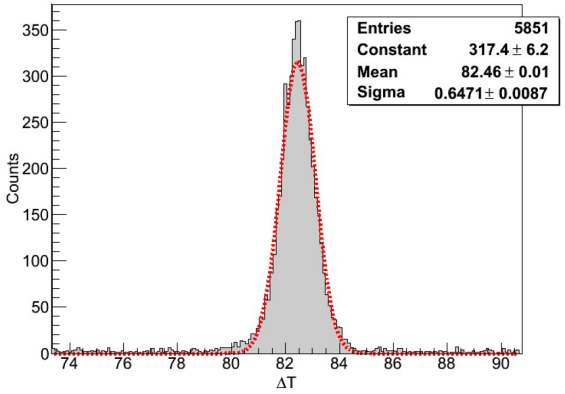


- FPGA firmware decreases data transferred
- Throughput still requires 1 optical link/2 boards/32 channels

Auxillary Detectors

- Tests were performed with HPGe and BaF_2 with 50 mg of ^{239}Pu in DANCE with a prototype digitzer
  - Count rates were quite high, with a very broad range of gamma rays came from prompt fission fragments and beta-delayed gammas
  - PHA firmware was not available and gains were poorly matched to the dynamic range
  - Waveforms were fit in offline analysis to achieve good timing resolution and reasonable energy resolution

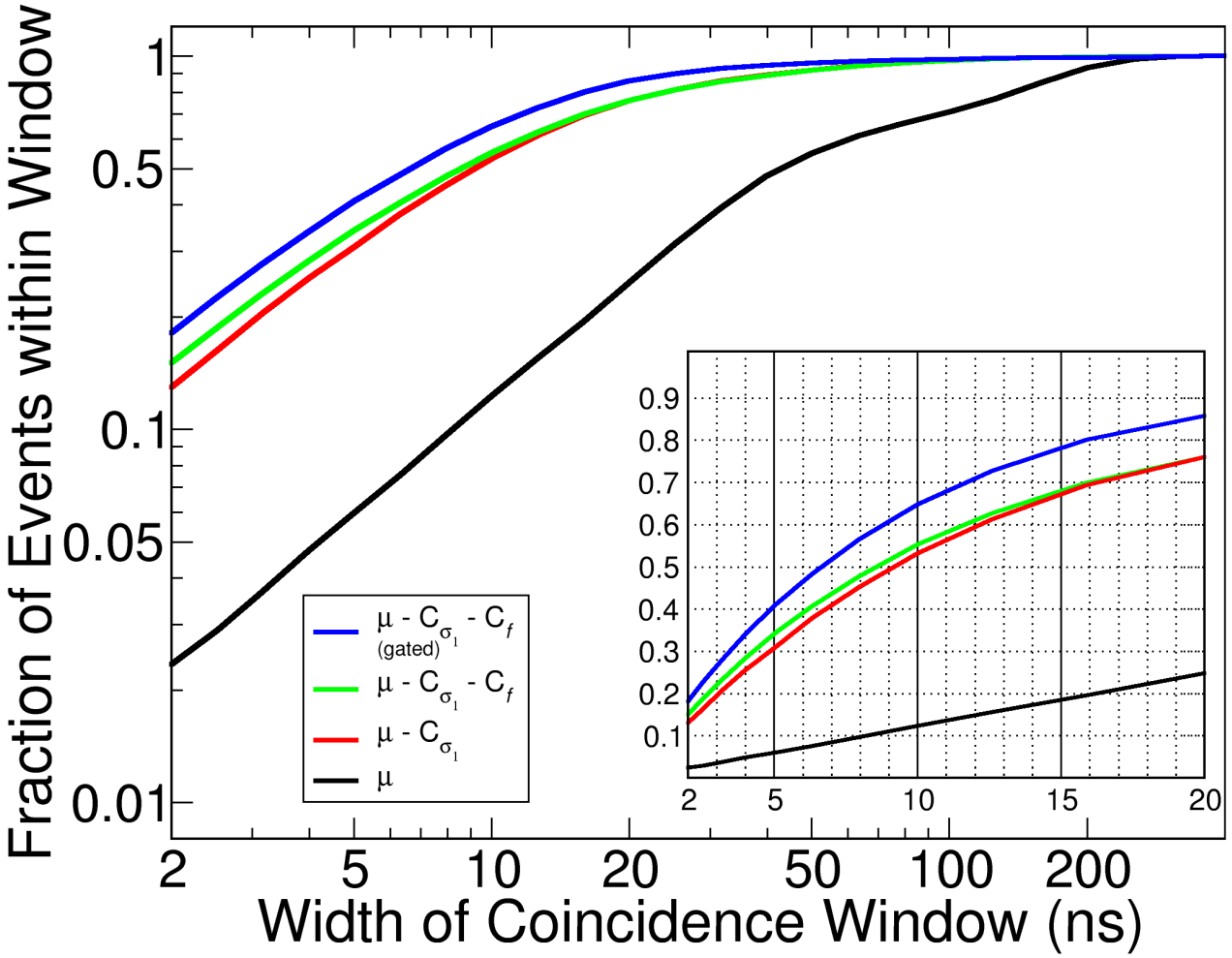




Figures courtesy of K. Macon, Lousiana State Univ.

Initial HPGe timing with DANCE

Waveform analysis and figure
by K. Macon
Louisiana State Univ.



Upgrade Paths for Additional Particle Detection

- Improved matching of dynamic range to detector response for PPAC fission fragment detectors
- Implementation of neutron detectors *inside* DANCE to tag fission on thick samples
- Opens the door for energy-resolved fission fragment detection (Si detectors, eg)
- High resolution gamma spectroscopy in conjunction with DANCE calorimetry opens new scientific opportunities in nuclear structure, cross section measurements, and PSF studies

Drawbacks

- We are dependent on CAEN for FPGA firmware development
  - Before full waveforms were transferred to a CPU for C/C++ based filtering and peak extraction
- The planned event structure will have somewhat less information
  - The slow decay information will be stored in a single integral instead of 5 integrals
  - A peak wavelet will be retained for high-resolution timing and pileup handling
- There's a LOT of work to do...

Implementation Scheme

- The digitzers are to be delivered September 2014
  - 4 are in hand for another project
- The plan is to run the new DAQ in parallel with the current DAQ during the Oct-Jan beam delivery
- This will allow substantial troubleshooting, diagnosis, and experience
- The plan is for the new DAQ to be fully implemented for the Fall 2015 run cycle
- Once the initial implementation is complete, we will investigate more complicated run gating inside of the 50 ms beam window
  - This adds versatility to the pulse structure that can be used

Conclusions

- A major instrumentation upgrade is underway for the DANCE DAQ
- This should significantly improve the resolution and energy coverage of the DANCE array
- It will also expand the versatility of DANCE to detect multiple exit channel particles

Collaborators

LANL:
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