Introduction to ORNL group

Michael Febbraro
Staff, Physics Division

Marcel Demarteau
ORNL Physics Division Director

Oak Ridge National Laboratory

ORNL Physics Division – Q-PIX**

- Marcel Demarteau
- Michael Febbraro
  - Photon detection R&D

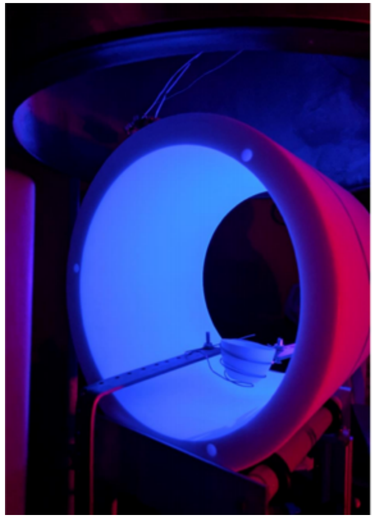
**Not currently supported on Q-PIX

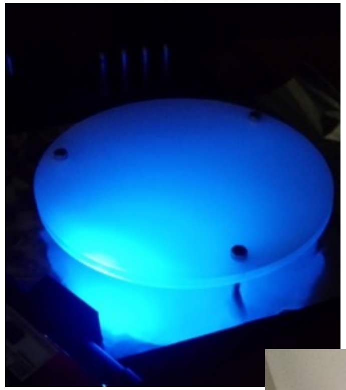
HEP neutrino experiments at ORNL

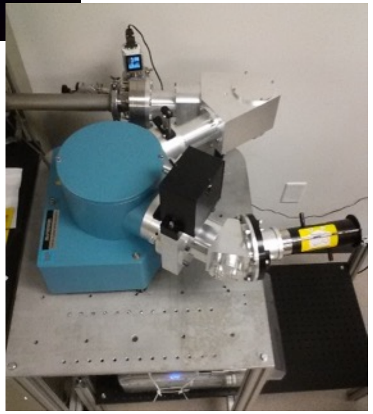
- COHERENT
  - Coherent neutrino-nucleus scattering
- PROSPECT
  - Precision reactor neutrino experiment

Physics Division - Capabilities

- Two world-class neutrino sources
  - SNS & HFIR
- Class 10000 reduced-background cleanroom
  - Located within a shielded vault (2 meter concrete overburden)
- Renovated scintillator laboratory
  - 1000 sqft dedicated to synthesis, fabrication, and characterization of scintillators, wavelength shifters, and detectors
  - VUV monochromator
- Cryogenic test stands – LAr / Xenon-doping
- Multicharged Ion Research Facility
  - High intensity ion source which supports detector R&D
- High performance computing



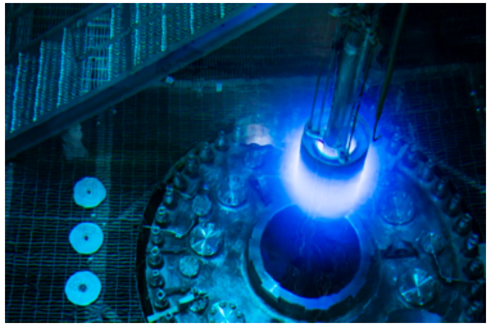




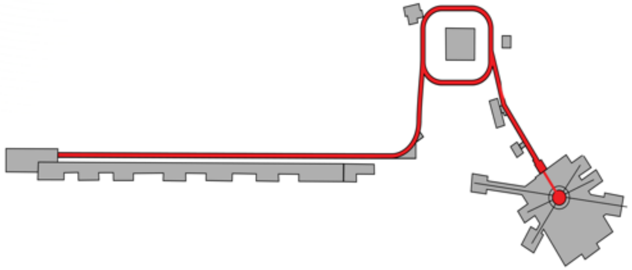
Neutrino sources at ORNL

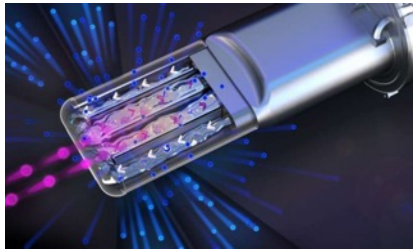
- Superconducting H^- LINAC: 1 GeV @ 1.4MW @ 60 Hz
- Storage Ring: 1200 pulses, 1us Period, 350ns FWHM
- Liquid Mercury Target: circulates 20 tons with He gas injection to mitigate cavitation
- Operation ~5000 hours per year: 25 Terajoules/year

- 85 MW steady-state reactor
- Compacted core design
- 2.6 x 10^{15} n/cm2/s
- Operation: 3900 hours per year



Spallation Neutron Source at ORNL





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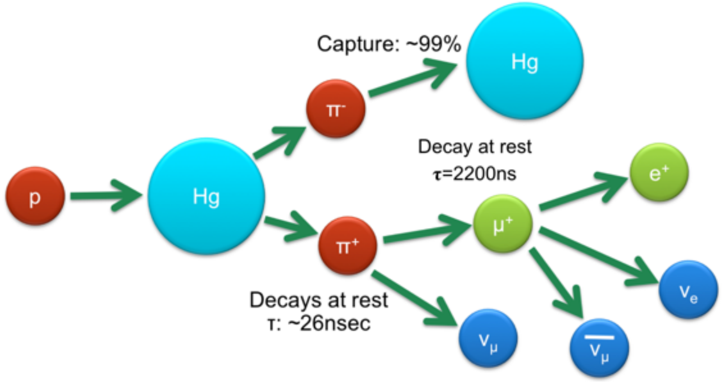
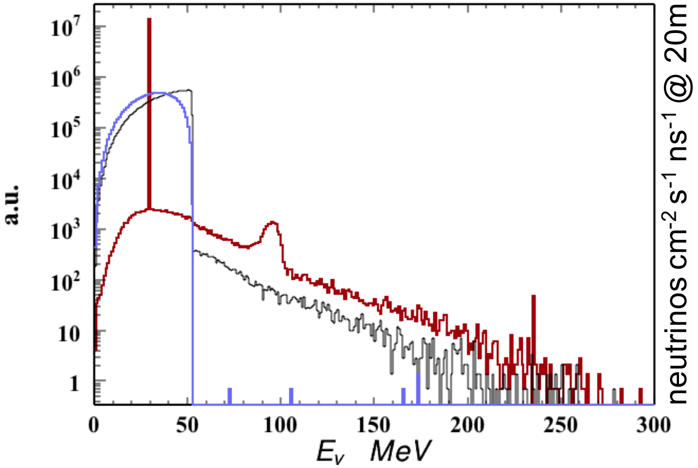
Neutrinos via Pion Decay-at-Rest

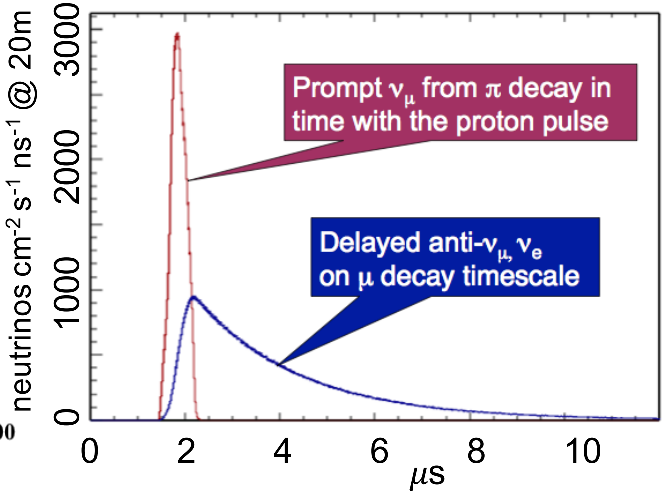


2.81×10^{14} ν/cm^2/flavor/SNSYear @ 20m

Neutrino Energy



Neutrino Timing

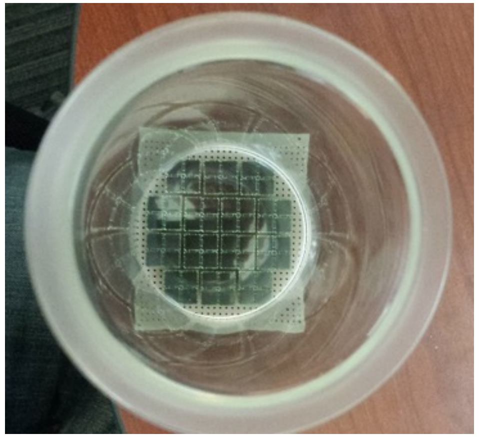


- SNS timing preserves DAR flavor structure
- Mono-energetic ν_μ separated from ν_e, ν_μ

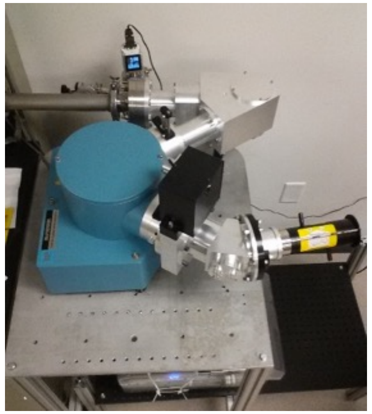
Credit: Slide from Jason Newby

Cryogenic materials research

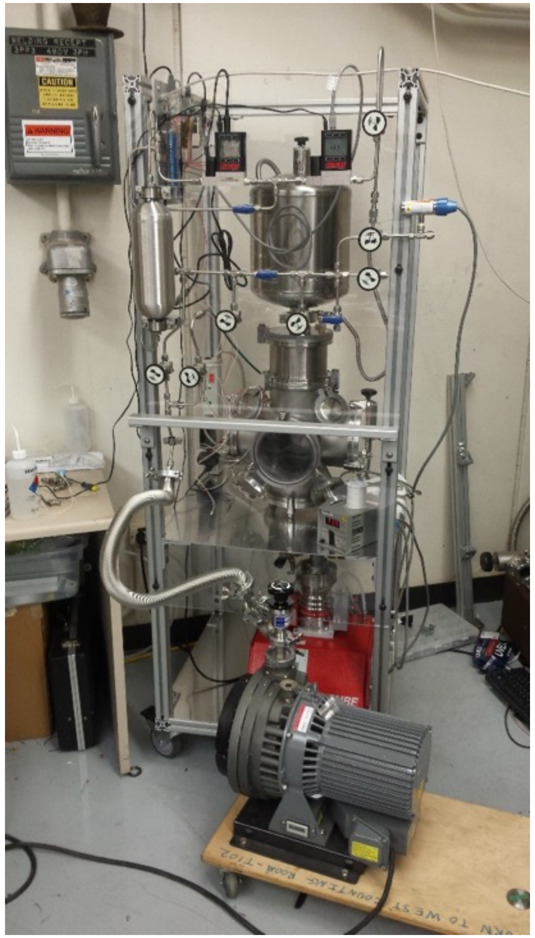
- Cryogenics material testing apparatus
  - PT-90 pulsed tube cryocooler
  - Gas purification and handling system
  - Insulting vacuum chamber and modular interior LAr vessel
  - Temperature control provided by liquid nitrogen dewar and resistive heating system
  - Optical readout with SiPMs and/or PMT
- Vacuum ultraviolet (VUV) spectrometer
  - Determination of absorption and emission spectra of materials at LAr emission wavelength (128 nm)
- Work with glass vessels
  - Using ORNL glass blowers



View of the 76 mm diameter SiPM array on the LAr vessel



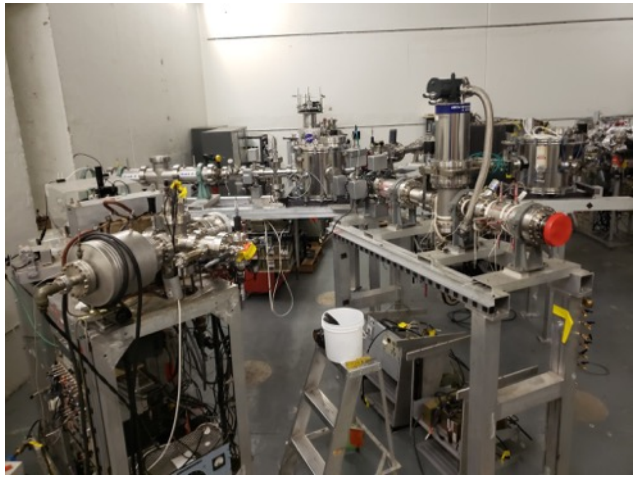
McPherson VUV spectrophotometer

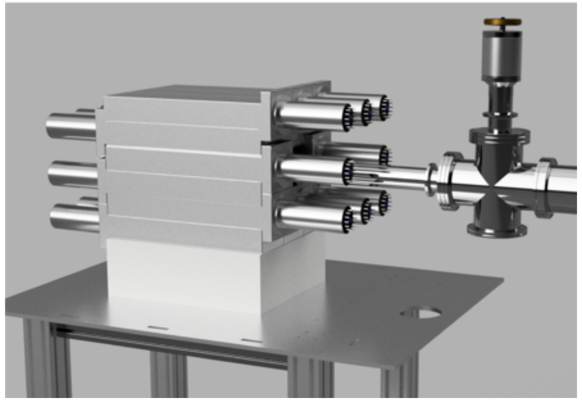


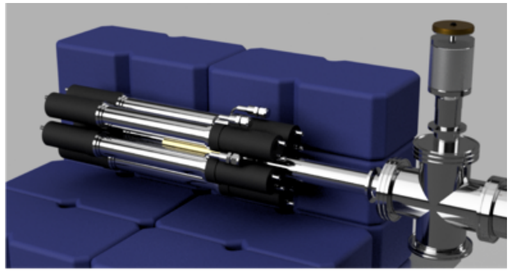
Cryogenic materials testing apparatus

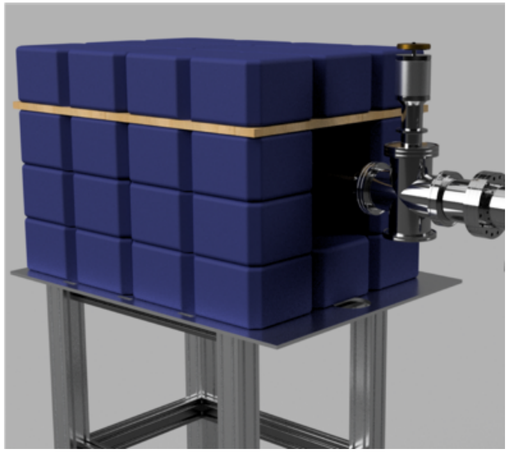
Multicharged ion research facility

- Two ECR ion sources
  - 250 kV HV platform
  - Wide range of ions from H to W
  - Complex molecular ion beams
  - Beam currents up to ~mA (100s μA typical)
- Negative, positive, and neutral particle beams
- Multiple experimental end stations
  - General purpose
  - Surface interactions
  - Ion implantation
  - Merged beams







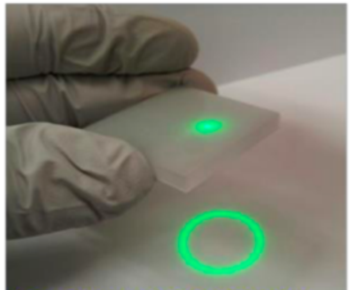


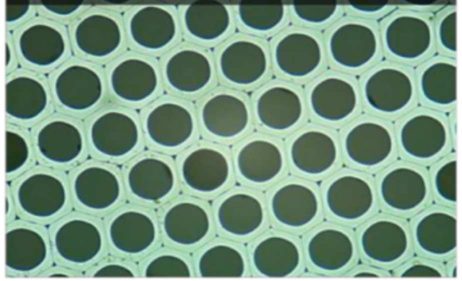
Currently undergoing upgrades

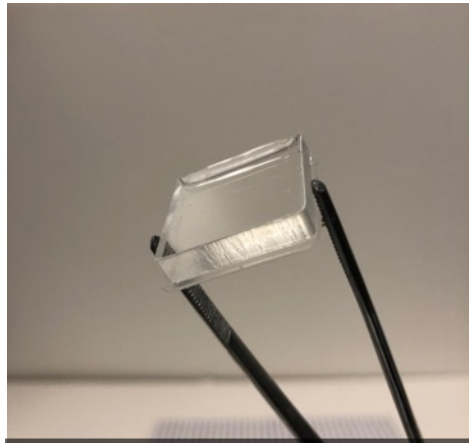
Scintillator Laboratory at ORNL

- Physics division's chemistry support laboratory
  - 1000 sqft dedicated laboratory space for R&D of scintillators, detectors, and accelerator targets
  - Evaporator, electroplating, injection molding
  - Experience with isotopically enriched scintillators and detectors
  - Organic synthesis, cleanroom capabilities, cryogenics test stand
  - Material characterization - GCMS, VUV-NIR spectroscopy, high intensity ion source


Deuterated liquid scintillator

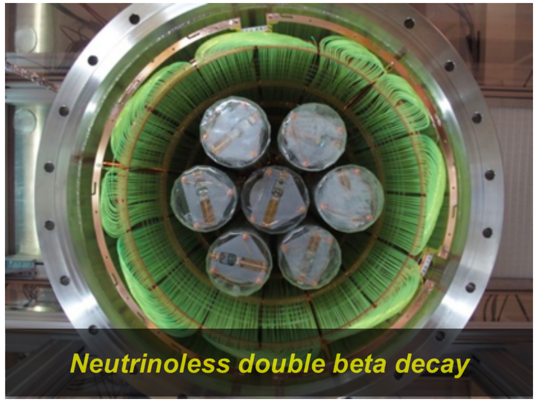

Laser-illuminated capillary plate

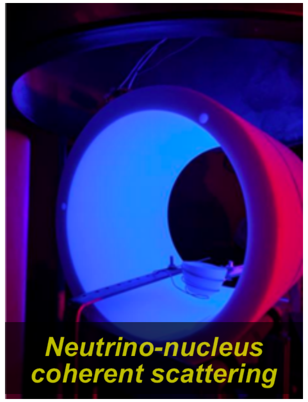

End-on microscope image of capillaries

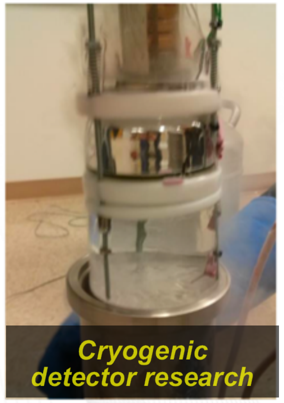

PSD – formulation
Deuterated polystyrene scintillator

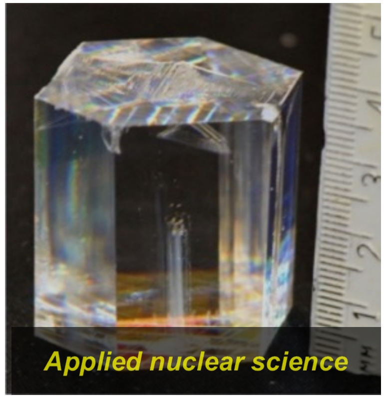

Polyethylene naphthalate (PEN)

Overview of scintillator R&D at ORNL



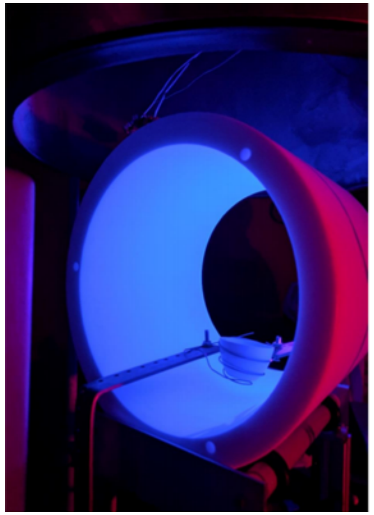
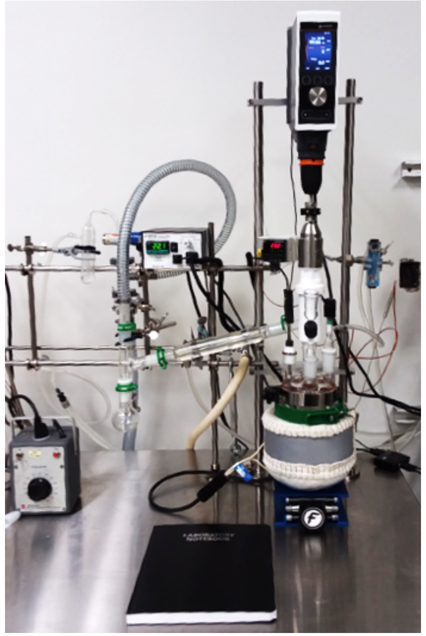






- Broad science focus on HEP, NP, and applied nuclear science missions throughout DOE
    - Neutrino physics (COHERENT)
    - Neutrinoless double beta decay (LEGEND)
    - Physics of stellar burning and explosive nucleosynthesis (FRIB)
    - Applied nuclear science

Scintillator & WLS R&D

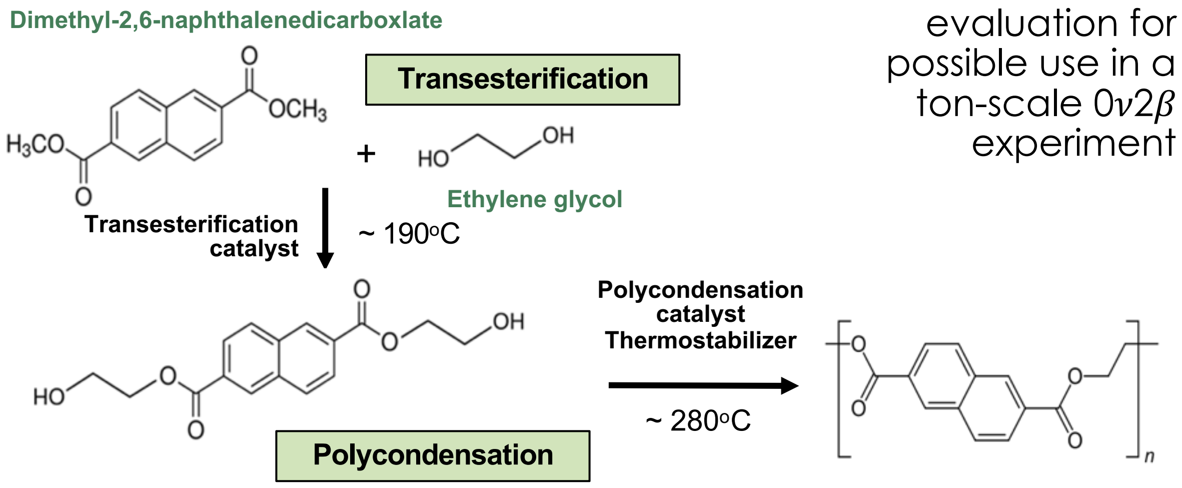




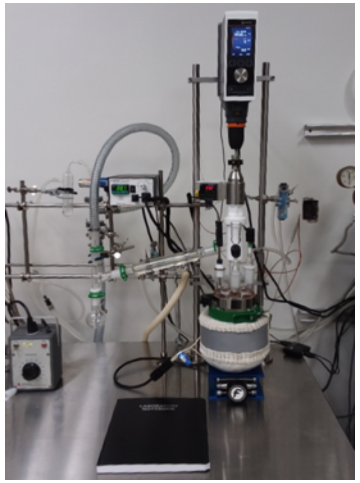
- Liquid, plastic, single-crystal scintillators
- Organic synthesis
- Fabrication techniques
  - Polymerization –
    - Temperature controlled baths
    - UV Cure
    - Centrifuge
  - Evaporation
  - Injection molding
- Organic purification



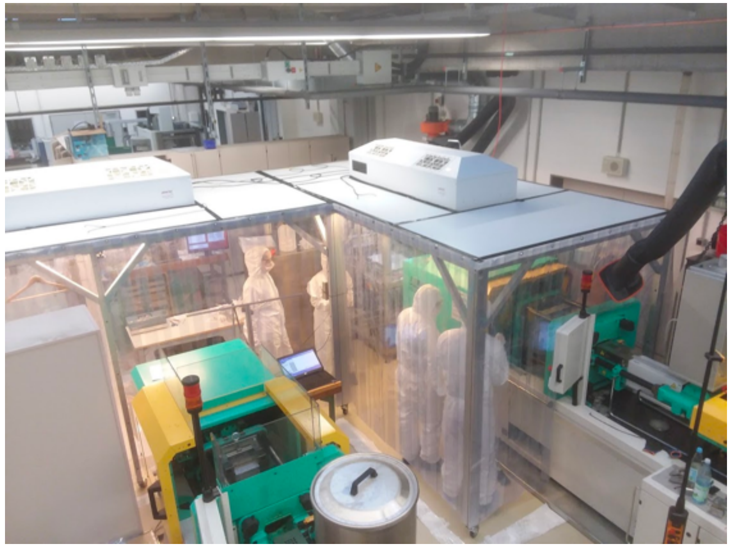
Structural low-background scintillators

- Designed to replace inactive structural components with scintillating materials
  - Improve active veto capability
  - VUV-VIS wavelength shifting in LAr
  - Poly(ethylene naphthalate) (PEN) is a potential candidate material
    - Scintillates around 440 nm
    - Yield strength higher than copper at cryogenic temperatures
- ORNL efforts focused on synthesis of low-background PEN derivatives with enhanced properties
  - Reduced radio impurities
  - Optical transparency
  - Improved processability
  - Improved scintillation yield





Experimental setup for polyester synthesis at ORNL

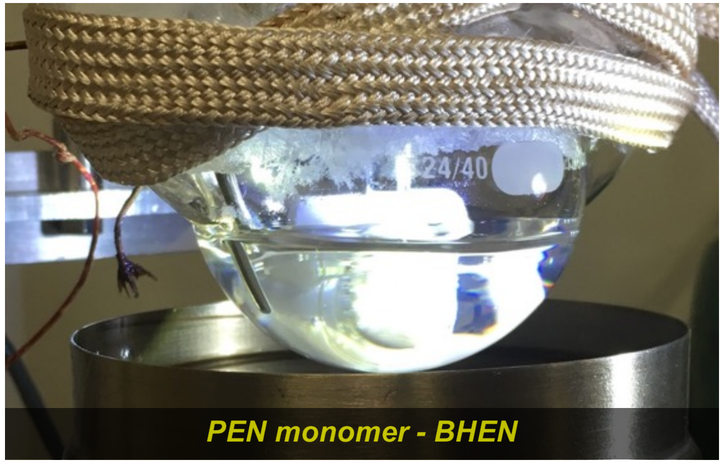


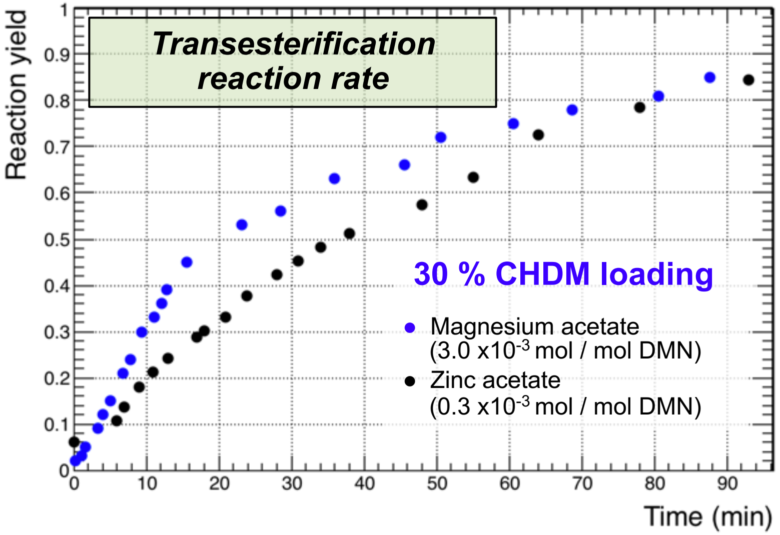
Radio-clean production run at TU Dortmund

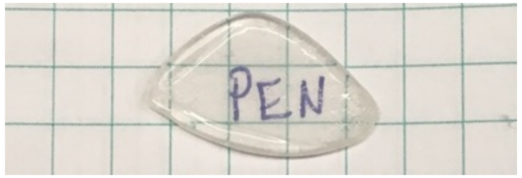
PEN tile under evaluation for possible use in a ton-scale $0\nu2\beta$ experiment

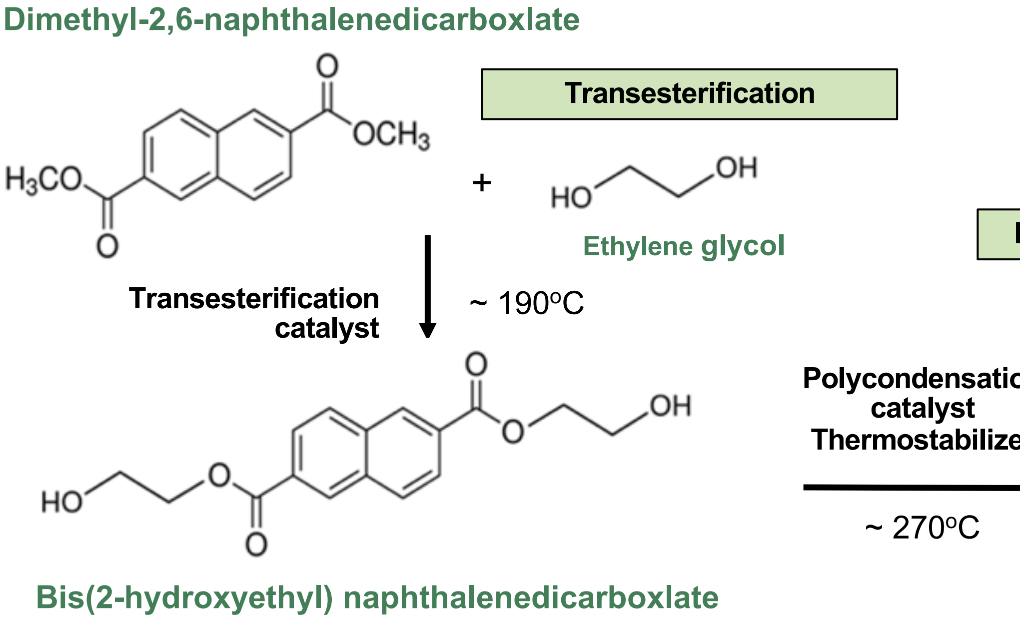
PEN synthesis at ORNL

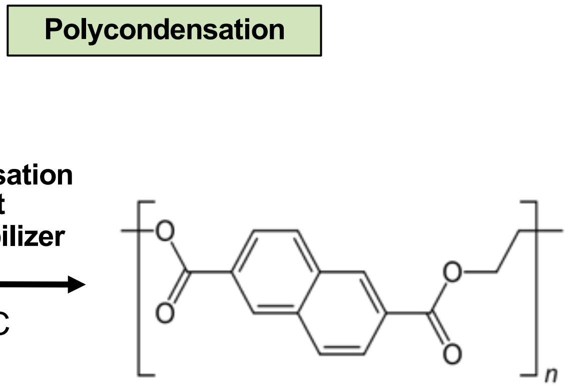
- *Can we make low-background scintillator grade PEN?*
- Synthesis efforts focused on low-background PEN derivatives
  - Higher light yield, reduction in radio impurities, improved optical properties
- Two-step synthesis method: *Transesterification → Polycondensation*

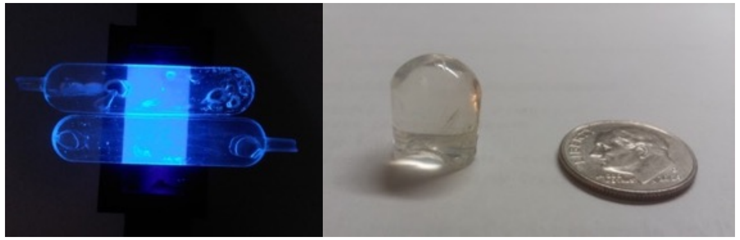






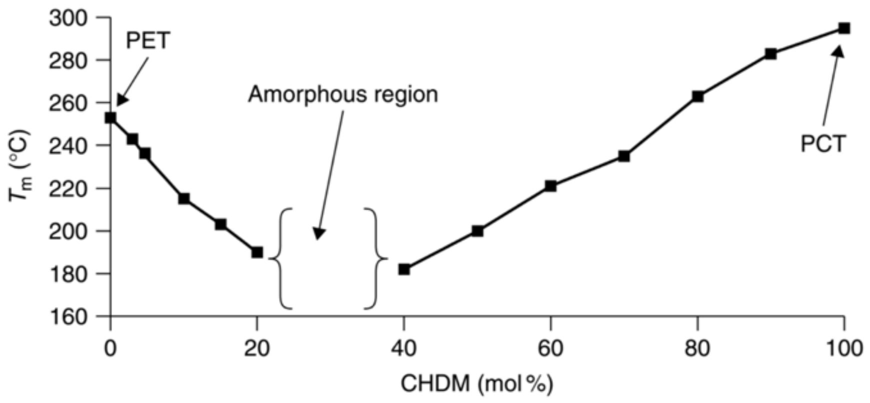




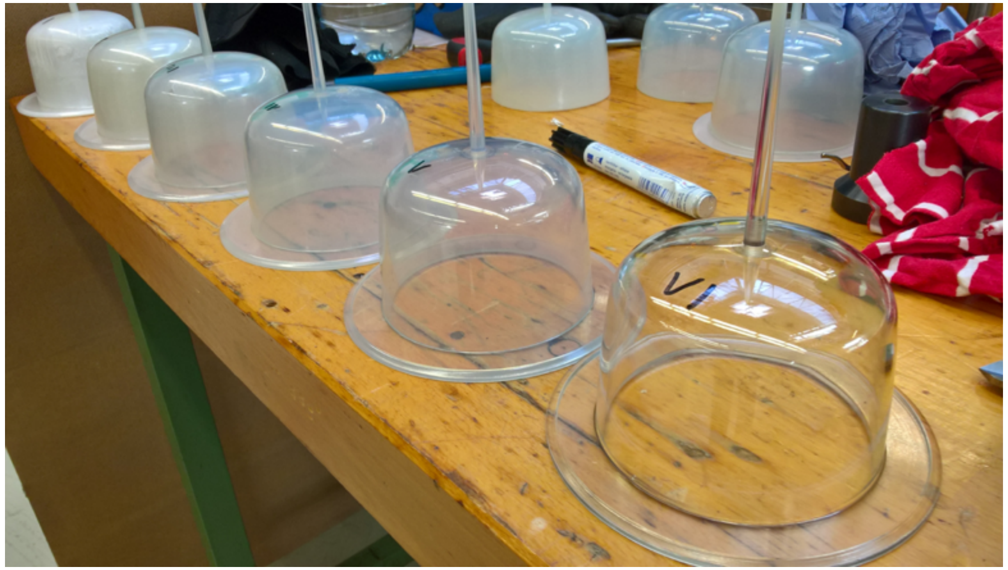


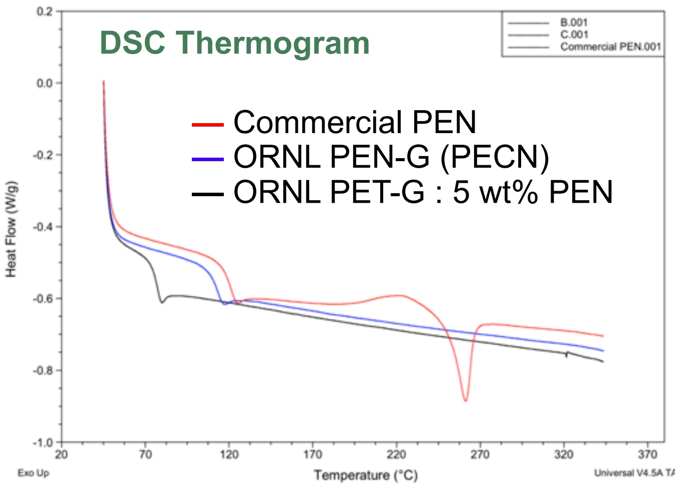
Transparency of PEN

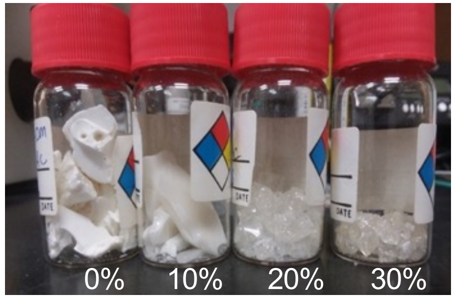
- Crystallization leads to scattering of light on boundaries
  - Polymer becomes opaque
  - Can be controlled using rapid cooling but not always possible for complex or large geometries
- Introduction of a copolymer can reduce crystallization
  - Demonstrated with PET
  - PETG or "glycol modified – PET"
  - Common copolymer is cyclohexanedimethanol or CHDM



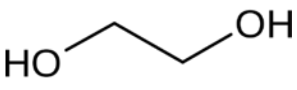
Modern Polyesters: Chemistry and Technology of Polyesters and Copolyesters. Edited by J. Scheirs and T. E. Long
 ISBN: 0-471-49856-4



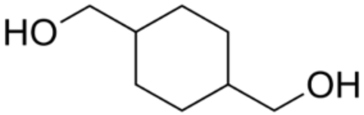




ORNL synthesized PEN - CHDM loading (mol %)



Ethylene glycol



1,4-Cyclohexane dimethanol (CHDM)

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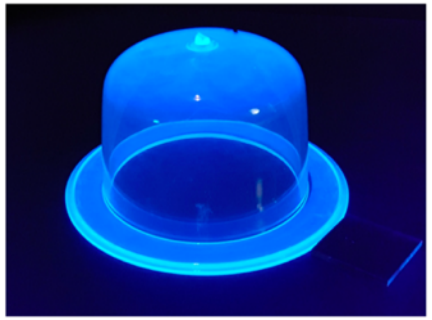
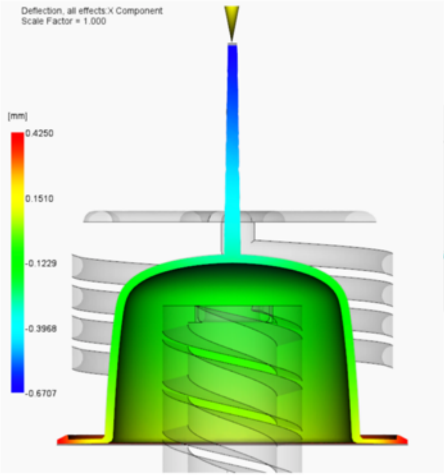
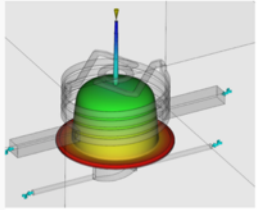
R&D on injection molding and bonding







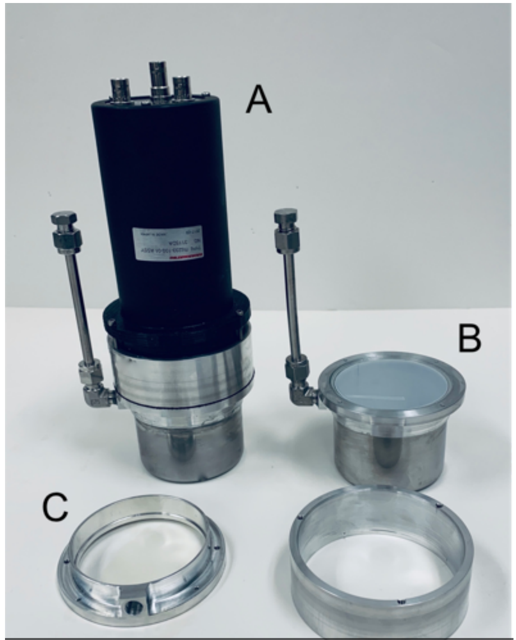
- Low-background production run
- Progress on producing arbitrary shapes
  - Plates / disks
  - Fibers
  - Capsules / containers
- Evaluation of radio-clean joining techniques
  - Ultrasonic welding
  - Low-background glues and adhesives

Oak Ridge National Laboratory

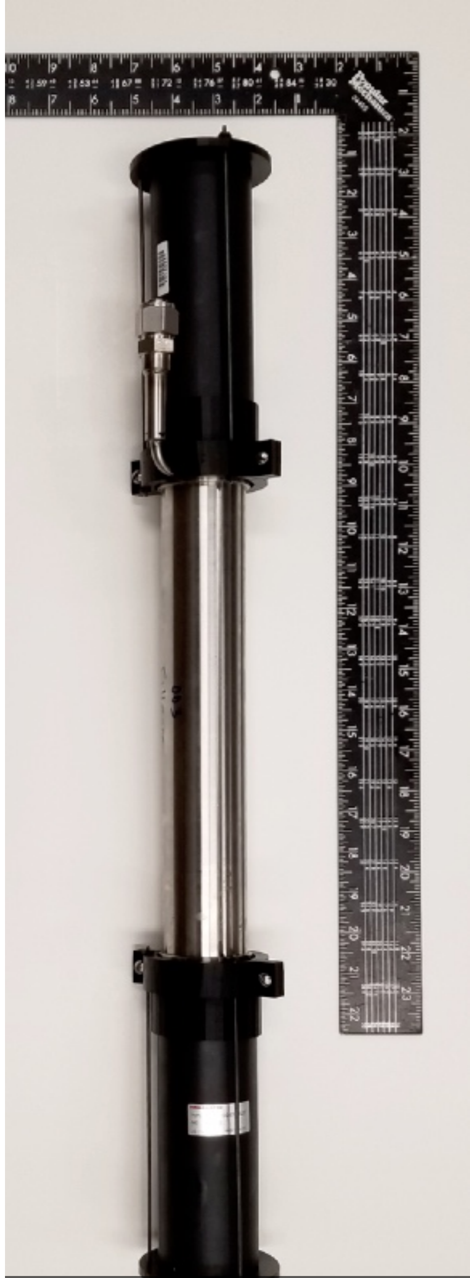
Questions?

Neutron detectors

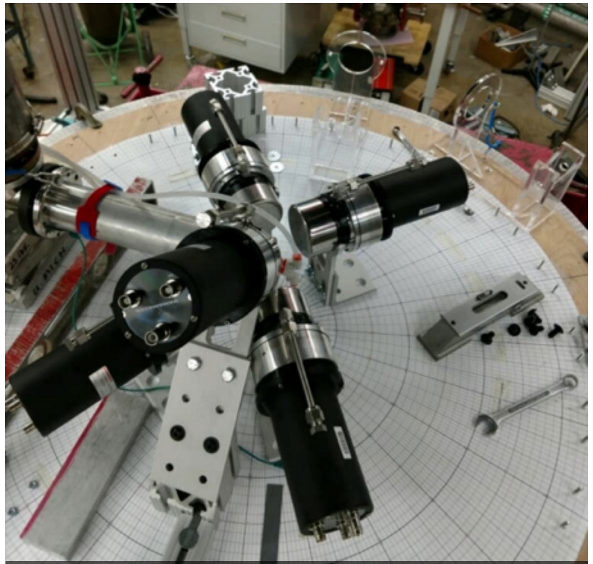
- Experience with neutron detectors
- Oak Ridge Deuterated Spectroscopic Array (ODeSA)
- Scintillator Array of Bars for Reaction Experiments (SABRE)
- In-house scintillators



ODeSA – deuterated scintillator for neutron spectroscopy



SABRE array – position sensitive neutron ToF



ODeSA – in action