

R&D efforts for the next generation of very large scale Liquid Argon detectors for Neutrinos and Dark Matter

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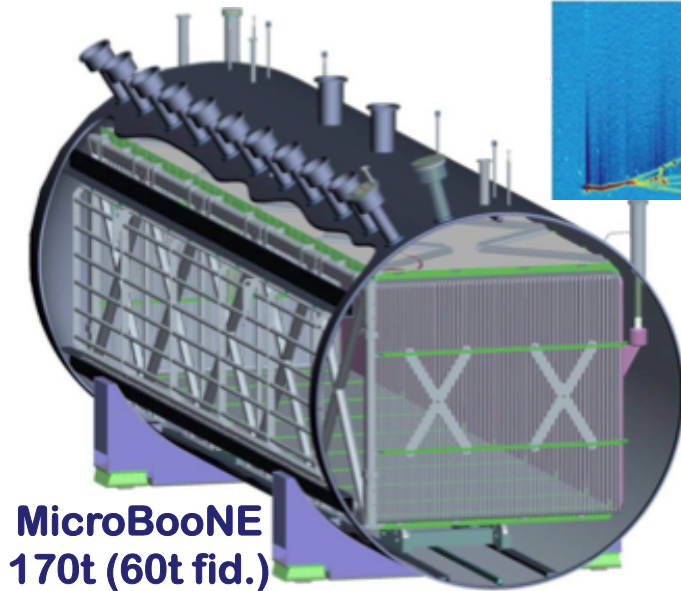
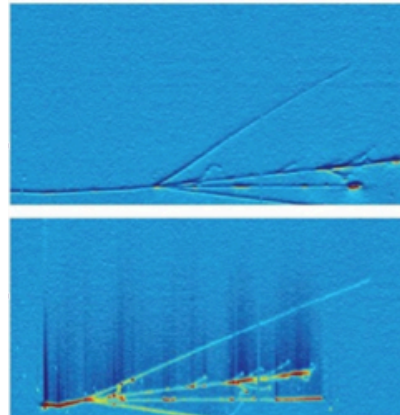
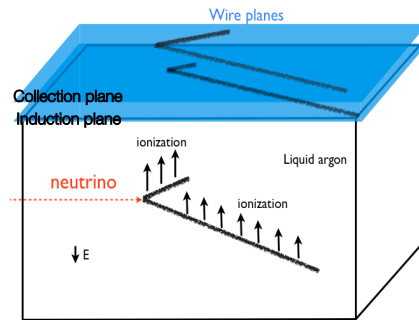


April 10th 2013

Liquid Argon detectors

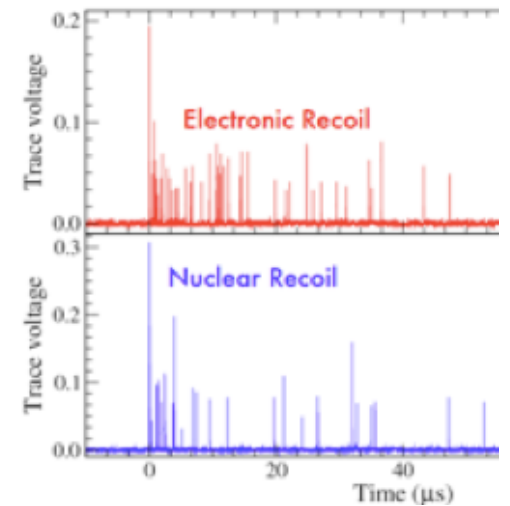
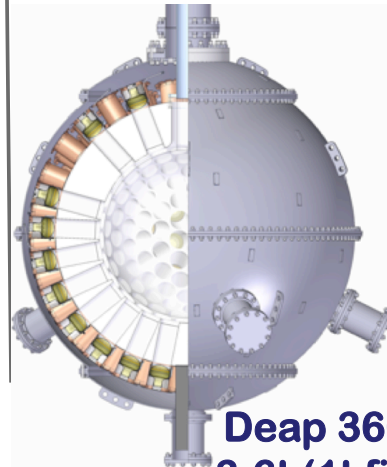
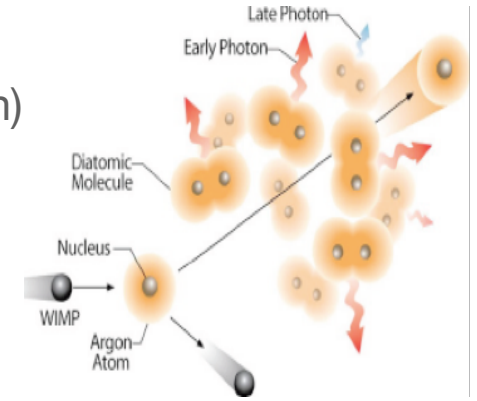
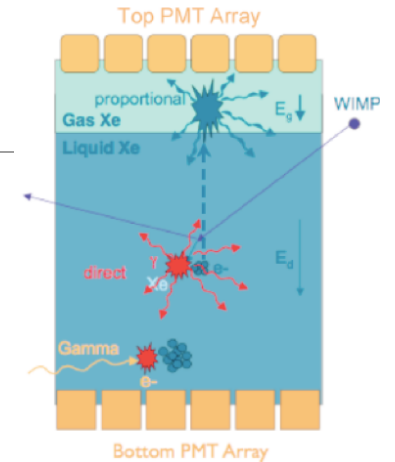
Neutrino Physics

- LAr TPC
- Ionization (3D-imaging)
- Scintillation (trigger)



Dark Matter Detections

- Single/dual phase
- Scintillation (pulse shape discrimination)
- Low background

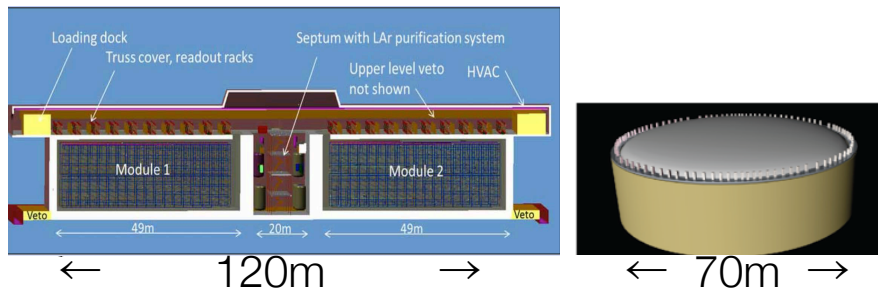


Next Generation of LAr detectors

Neutrino Physics

- 50-100 kt
- LBNE / LBNO

R. Wilson's talk



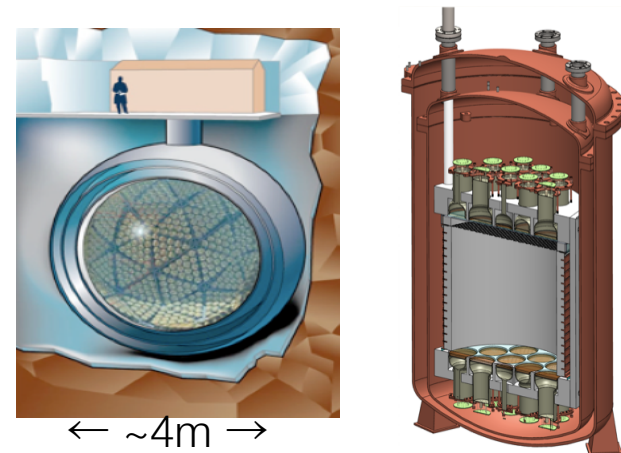
Goals:

- Identify Mass Hierarchy
- Search for CP violation
- Precision measurements of oscillation parameters
- Search for proton decay
- Study supernova neutrinos
- Study atmospheric neutrinos

Dark Matter Detection

- 10-100t
- DEAP/CLEAN, DarkSide-5000

D. Chamkaur's talk



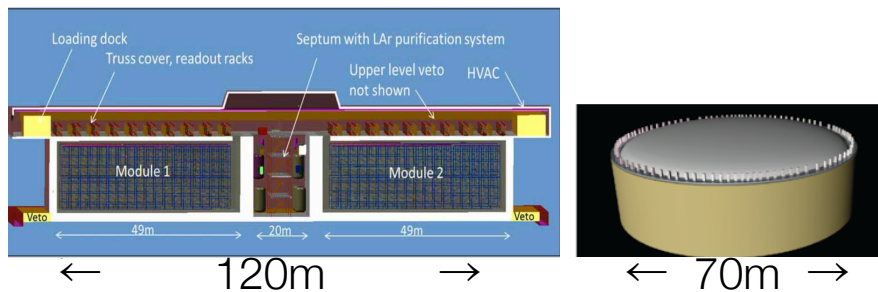
Goals:

- DM search/study ($> O(1000)$) events
- Study pp solar neutrinos
- Study supernova neutrinos
- Search for rare events

Next Generation of LAr detectors

Neutrino Physics

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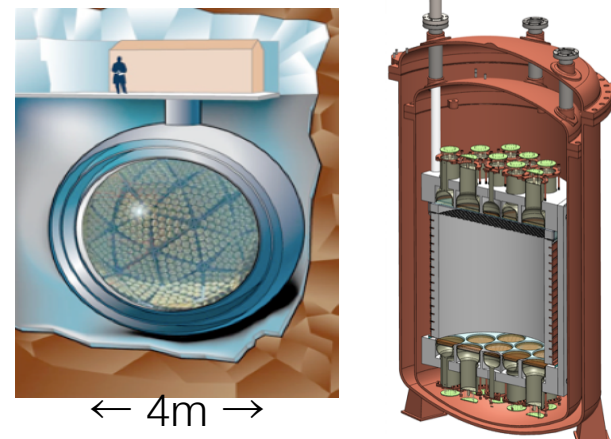


Challenges:

- Purity in large volumes
 - ✓ Long drift distances
 - ✓ No evacuation
- Low noise electronics at low cost (650k channels!)
- Costs
 - ✓ Less expensive than Water Cherenkov detectors
 - ✓ Smaller Caverns

Dark Matter Detection

- 10-100t
- DEAP/CLEAN, DarkSide-5000



Challenges:

- Background/Trigger systems
- Optical effects
 - ✓ Rayleigh Scattering
 - ✓ Temp./Press. effects on scintillation

R&D effort (Neutrinos)

ArgoNeuT (US/Italy)

LArSoft (US/Italy/UK)

Liquid Argon Purity Demonstrator (LAPD) (US)

Long Bo: long drift distance test and cold electronics (US)

35 ton membrane cryostat prototype (US)

Light collection R&D (US)

MicroBooNE (US/Italy/UK)

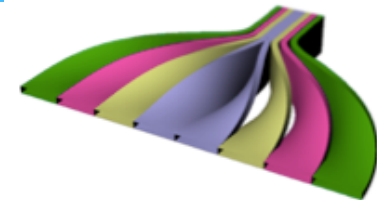
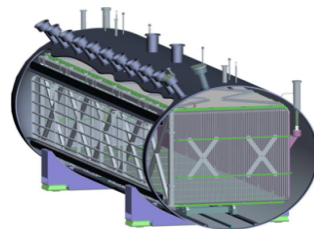
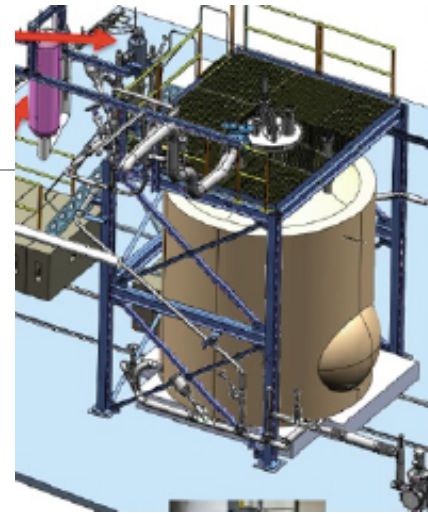
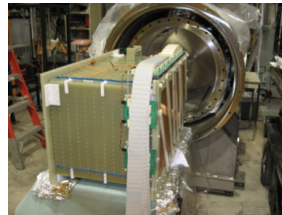
LAr1 (US)

Liquid Argon In a Test Beam (LArIAT) (US/Italy/UK)

ArgonTube (Switz./UK)

Japan Efforts

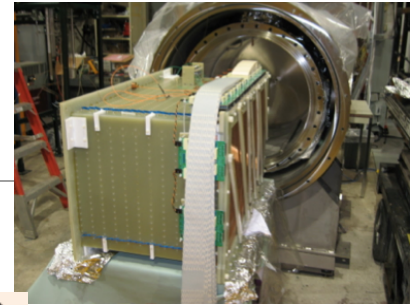
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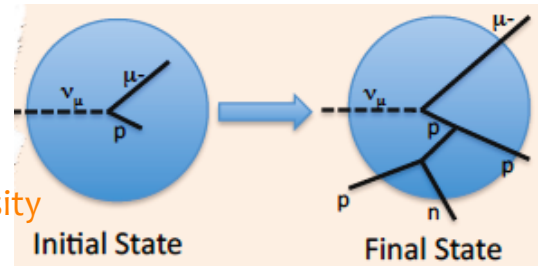
Non-exhaustive list! Sorry for the ones I missed

R&D effort (Neutrinos)

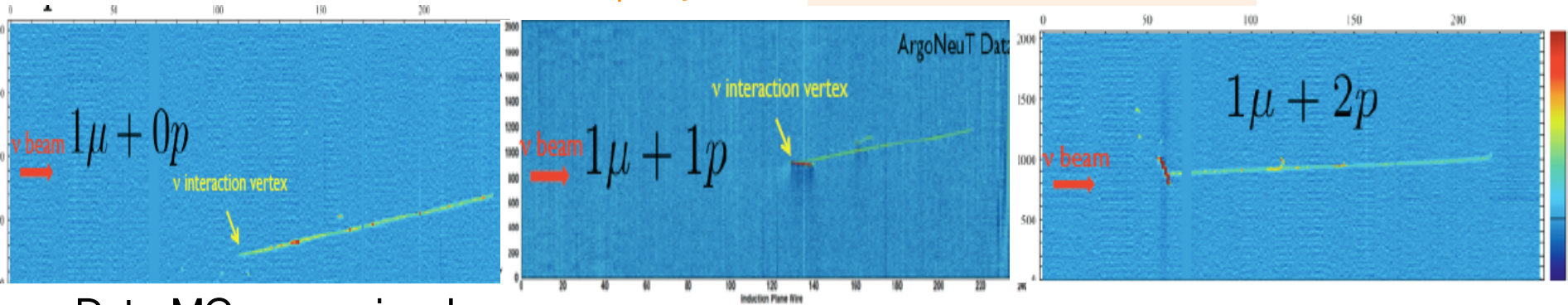
ArgoNeuT: 175l LAr TPC in NuMI beam (2010-2011)



- Physics results!
C. Anderson et al., Phys. Rev. Lett. 108 (2012)
- Hints for Final State Interactions!
- K. Partyka (for the ArgoNeuT Coll.), NuINT 2013
- O. Pallamara (for the ArgoNeuT Coll.), SLAC Intensity Frontier Neutrino Workshop 2013

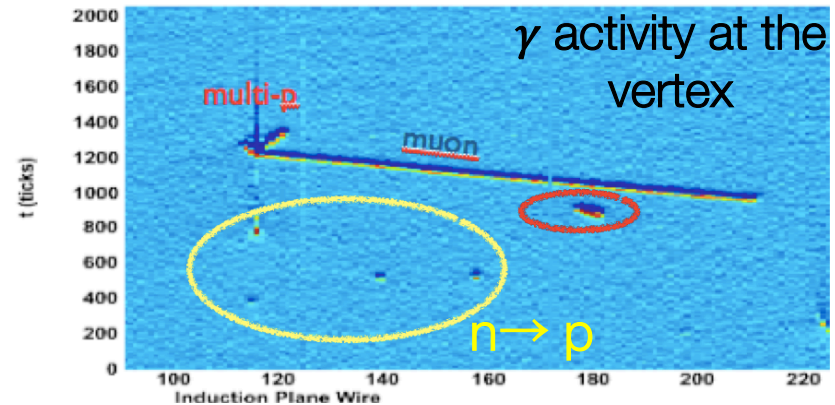
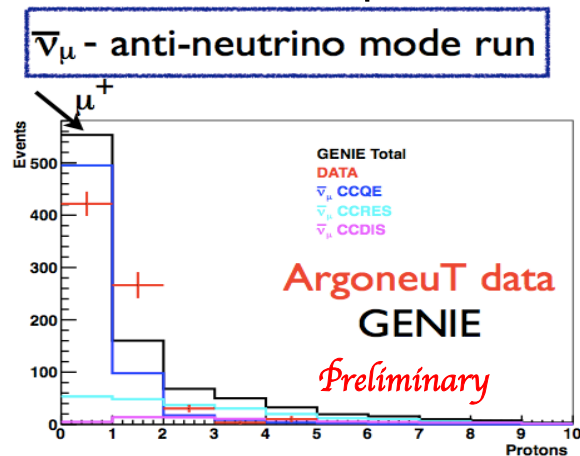


Intra-nuclear re-scattering



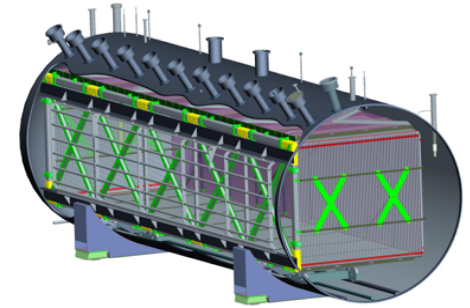
Data-MC comparison!

⇒ Topological analysis



R&D effort (Neutrinos)

MicroBooNE: 170t TPC in construction at FNAL
(start 2014)



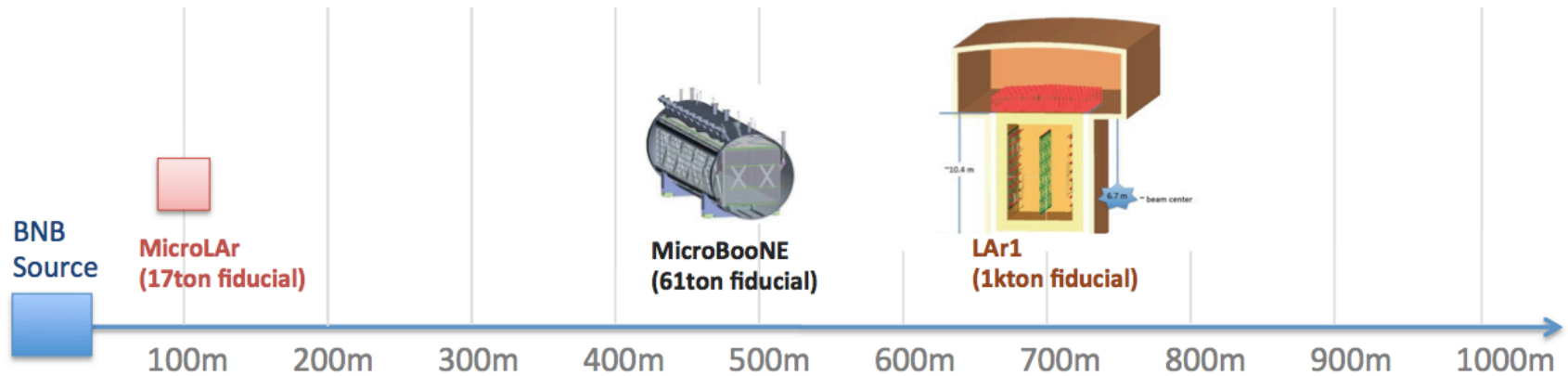
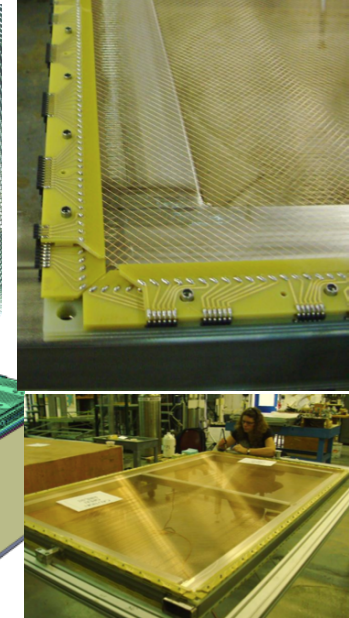
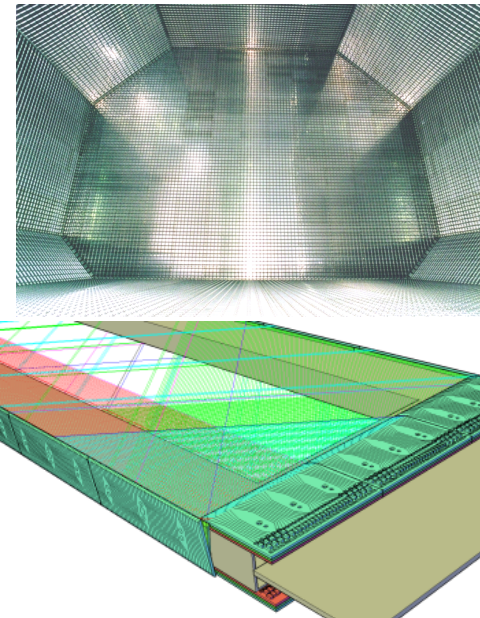
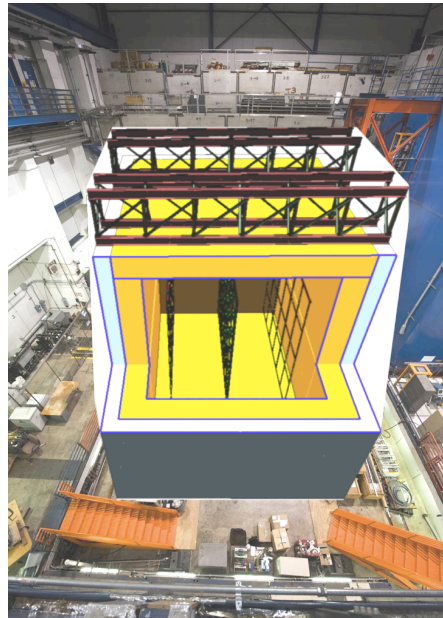
- Physics and R&D goals:
 - ✓ Demonstrate the electron/photon separation
 - ✓ Develop cold electronics
 - ✓ Test purity in large detector
 - ✓ Test ability to run on/near the surface for proton decay studies in LAr TPC
 - ✓ Develop analysis tools
 - ✓ Develop cost scaling model for larger detector



R&D effort (Neutrinos)

LAr1 proposal

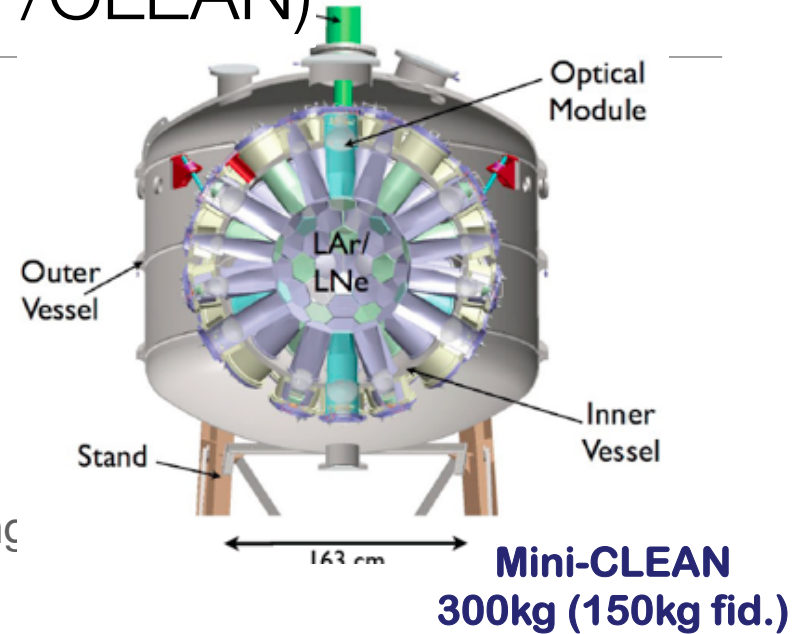
- 1kt LAr detector
- R&D goals for very large scale
- **Definitive** answer to short-baseline anomalies ($>5\sigma$)



R&D effort (Dark Matter DEAP/CLEAN)

DEAP 3600 and MiniCLEAN

- Main Goals:
 - ✓ Demonstrate the technology (world-leading limits on dark matter searches)
 - ✓ Demonstrate Pulse Shape Discrimination using scintillation timing at 1E9 level



	MiniCLEAN (G1)	DEAP-3600 (G2)
Target Capability	LAr / LNe	LAr
Target Radius	500 kg / 150 kg	3600 kg / 1000 kg
Target / Fiducial Volume	45 cm/30 cm	85 cm/55 cm
Cryogen Containment	Code-Stamped SS Pressure Vessels	Monolithic Acrylic Sphere
Light Collection	92 Optical Modules PMTs Submerged "Cold"	266 "Warm" PMTs Outside of Cryogen
Neutron Shielding	10 cm Acrylic + 20 cm Cryogen	50 cm Acrylic
Surface Background Mitigation	Modular Cassettes Assembled under Vacuum	In Situ Resurfacing of Inner Acrylic Surface
Process Systems	Pulse Tube Refrigerators With Heat Exchangers	LN-Cooled Thermal Siphon
Magnetic Compensation	Active	Passive+Active
G3 Scientific Program	Dark Matter <i>pp</i> -Solar Neutrinos Supernovae Neutrinos	Dark Matter



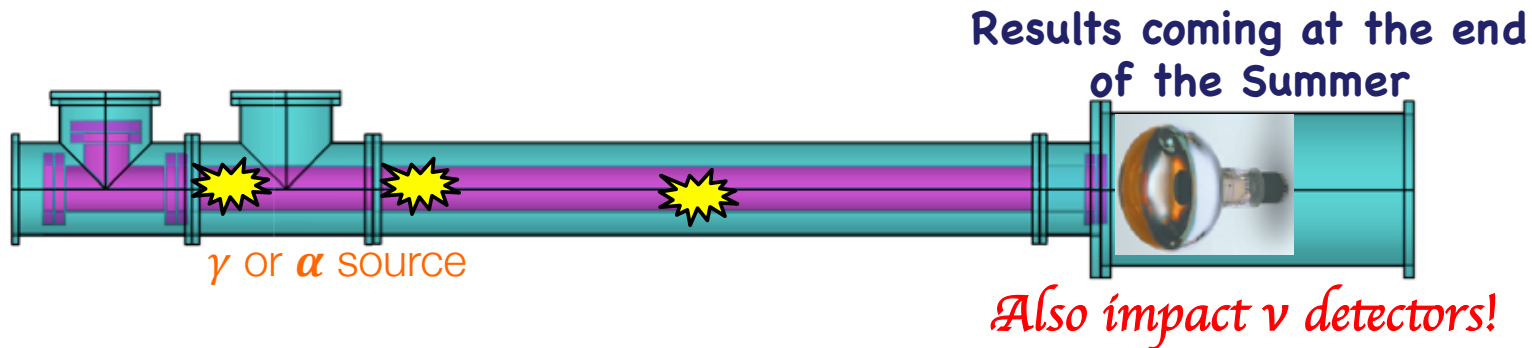
UK R&D effort (Dark Matter DEAP/CLEAN)

Optical properties measurements:

- Rayleigh Scattering length (RHUL)

- ✓ Rayleigh scattering length in LAr not well known (60-90 cm) (Seidel et al., NIM A 489 (1992))

- ⇒ impact: 20% change in leakage into fiducial volume



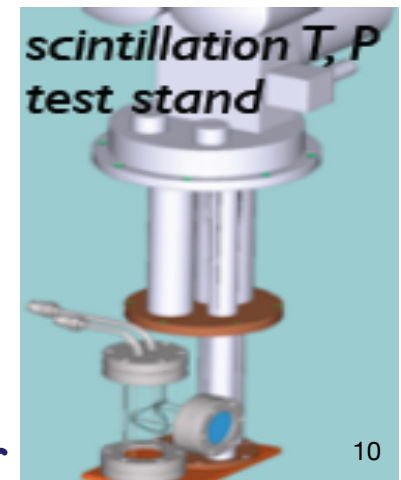
- Temperature and Pressure effects on scintillation light (RHUL)

- ✓ Anecdotal evidence of anomalous temp. Dependence

- (Ishida et al., NIM A 37 (1993))

- ✓ Measured unexpected scintillation temp. dependence

- (Lippincott et al., Phys. Rev. C86 015807 (2012))



Results coming this Summer

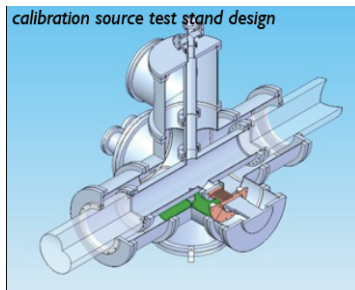
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Optical properties measurements:

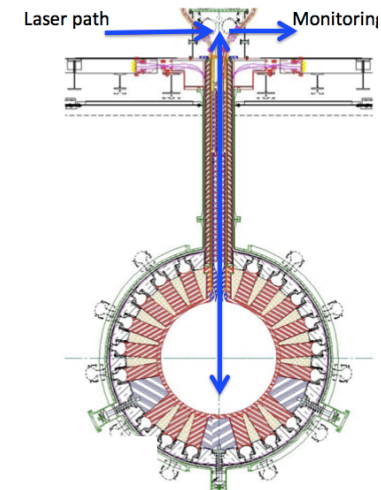
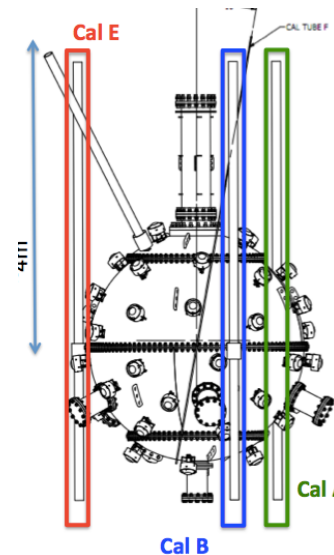
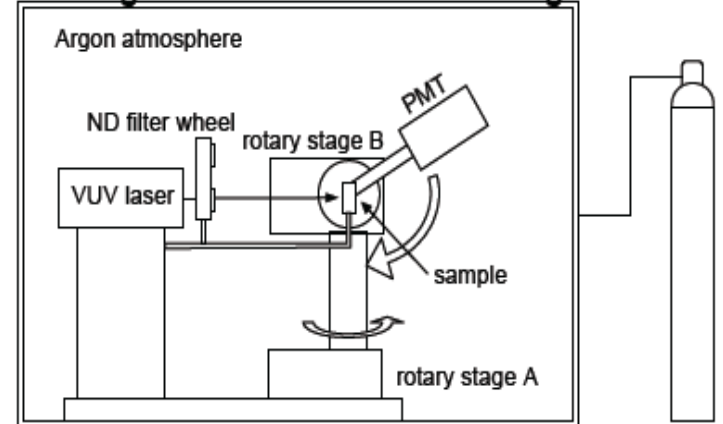
- TPB angular emission measurements (Sussex)

Calibration system R&D:

- Calibration system development:
 - ✓ Optical calibration (Sussex)
 - ✓ Gamma calibration (RAL)
 - ✓ Neutron calibration (RHUL)
- Calibration test stand (RAL)



TPB angular emission test stand design



J. Walding's talk

Conclusion

- LAr detector development is being strongly encouraged by funding agencies
- R&D is still required to demonstrate scalability of LAr detectors for both neutrino physics and dark matter searches
- A lot of effort is currently dedicated to push the understanding of LAr detectors → Integration!
- Very exciting results will come out of these R&D projects!