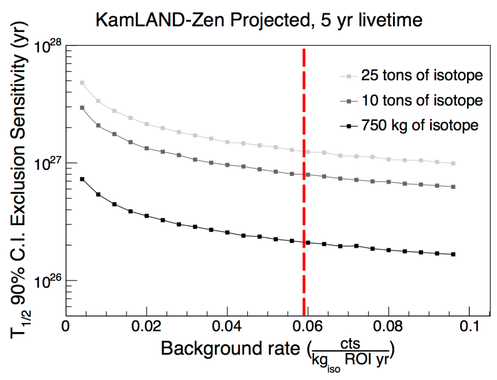
Perovskite Quantum Dots in Liquid Scintillator

Diana Gooding, for the NuDot Collaboration

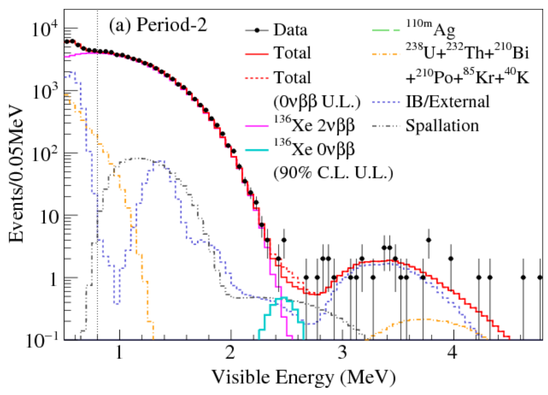
Diana Gooding[1,2], Julieta Gruszko[2], Brian Naranjo[3], Chris Grant[1], Lindley Winslow[2]
[1]Boston University, [2]Massachusetts Institute of Technology, [3]UCLA

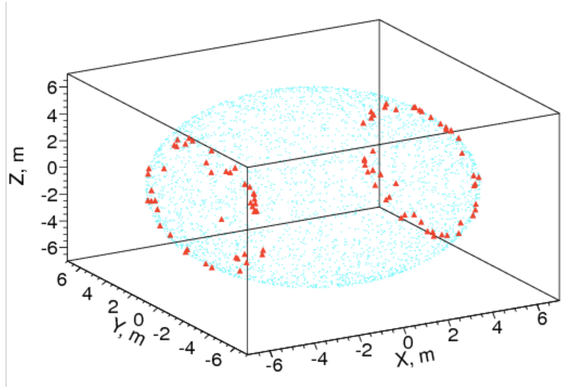
Toward the Normal Hierarchy in 0νββ Searches



Isotope	Endpoint (MeV)	Abundance (%)	
^{48}Ca	4.271	0.187	
^{150}Nd	3.367	5.6	
^{96}Zr	3.350	2.8	Possible future quantum dots
^{100}Mo	3.034	9.6	
^{82}Se	2.995	9.2	Common quantum dot materials
^{116}Cd	2.802	7.5	
^{130}Te	2.533	34.5	
^{136}Xe	2.479	8.9	
^{76}Ge	2.039	7.8	

- Increasing detector sensitivity requires increased isotope loading.
- Candidate isotopes are common quantum dot materials.



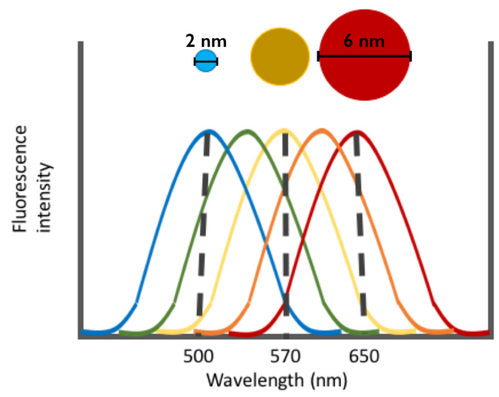


- **Question:** Can we maintain energy resolution while increasing background rejection?
- **Goal**: Use quantum dots to load isotope, improve Cherenkov detection, and reject backgrounds by event topology.

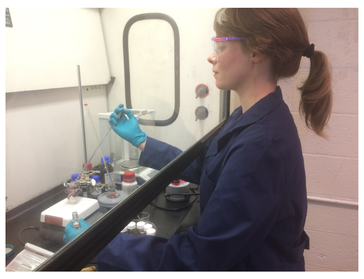
KamLAND-Zen Collaboration (Asakura, K. et al.) AIP Conf.Proc. 1666 (2015) 170003 arXiv:1409.0077 [physics.ins-det]

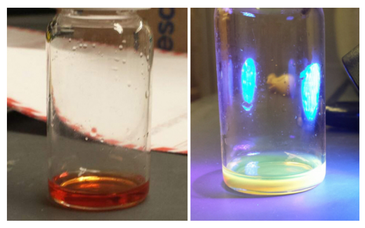
Elagin, Andrey et al. Nucl.Instrum.Meth. A849 (2017) 102-111 arXiv:1609.09865 [physics.ins-det]

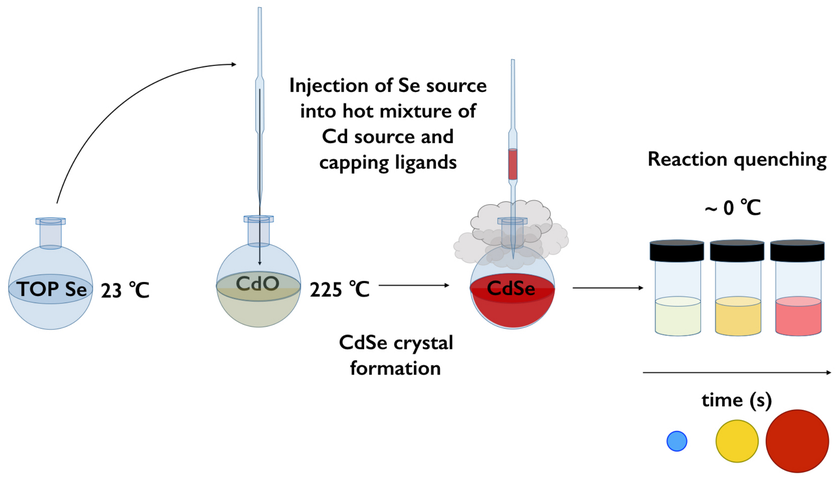
Canonical Quantum Dot Synthesis



- Quantum dots are semiconducting crystals with size on the order of nanometers.
- Quantum confinement causes the band gap to increase with decreasing crystal size.

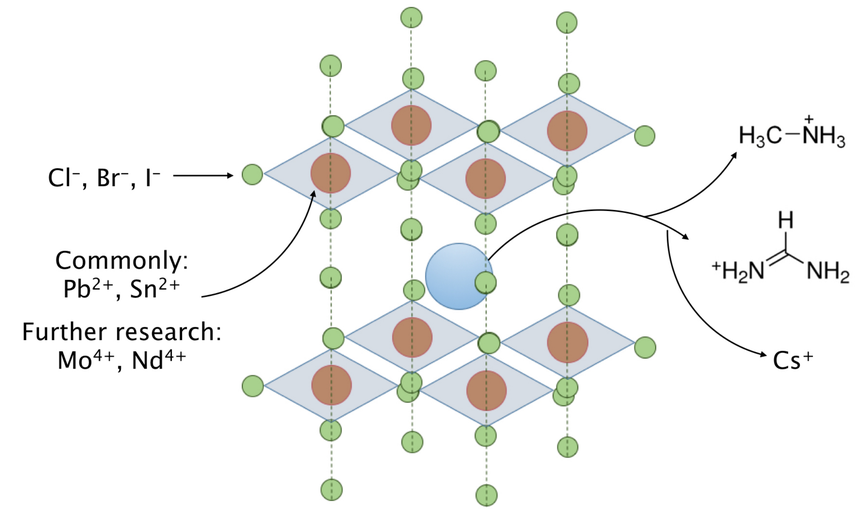




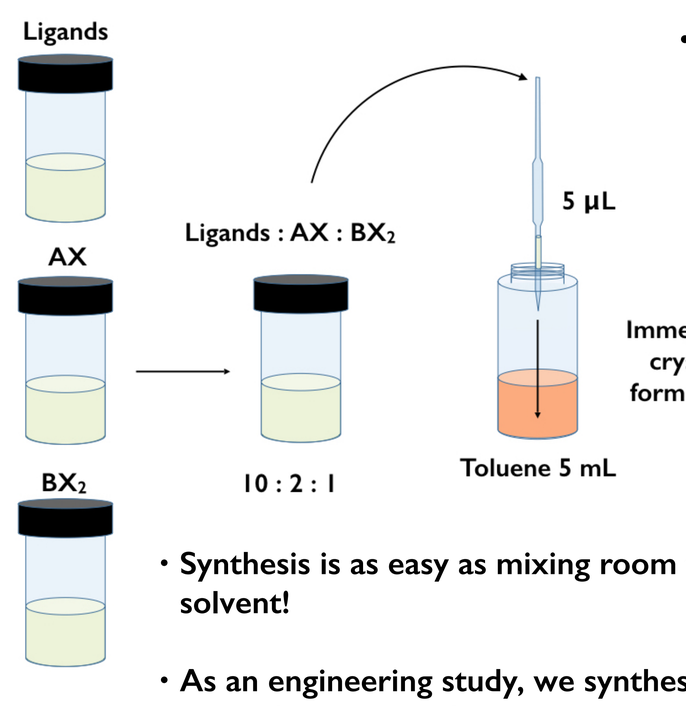


- Hot injection synthesis causes size to depend on kinetics of the reaction —often difficult to control precisely.

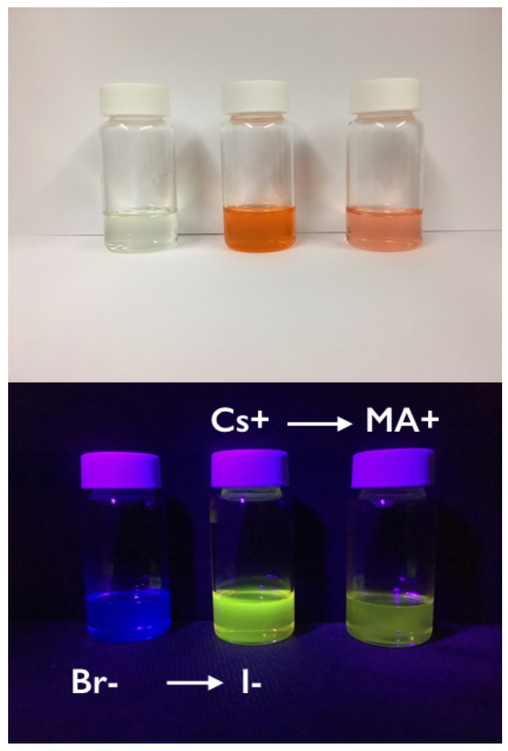
Perovskite Quantum Dots



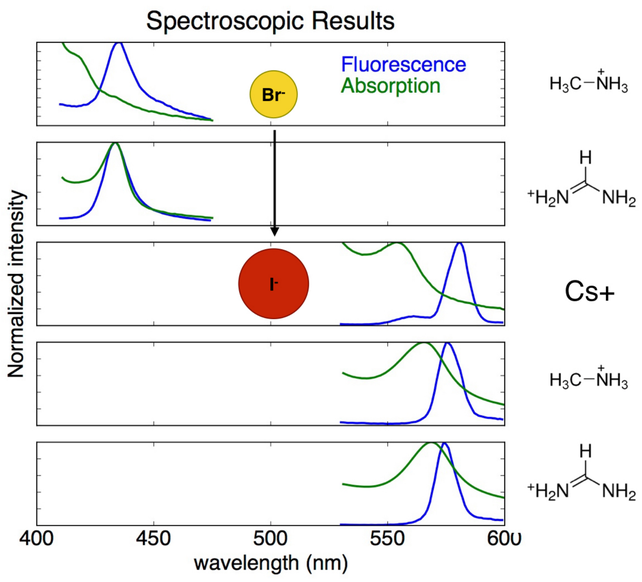
- Crystal structure is of the form ABX_3, for A (blue) a monovalent cation, B (red) a divalent cation, and X (green) a halide anion.
- Tune the size of the crystal by switching the halide anions.
- Candidate isotopes may be used for the B-site cations.



- Synthesis is as easy as mixing room temperature solvent!
- As an engineering study, we synthesized lead perovskites, since they are well-studied.
- **Right:** Perovskite quantum dots synthesized by the NuDot group



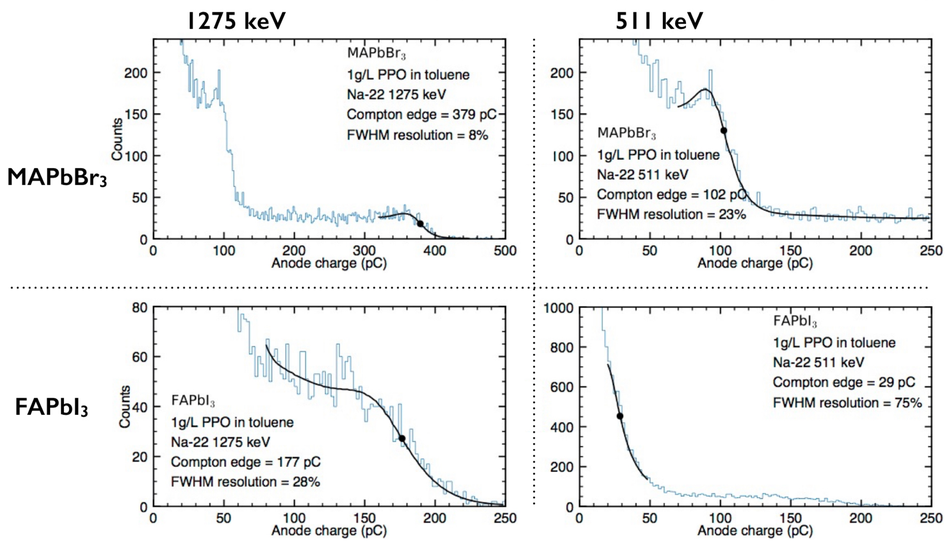
Optical Properties and Light Yield



- Top: Fluorescence and absorption curves for smallest (top) through largest (bottom) crystal.
- Right: Sample Compton fits for highest light-yield crystal (top) and lowest (bottom).

Absorption and Fluorescence Peaks		
Material	Fluorescence (nm)	Absorption (nm)
$MAPbBr_3$	435	415
$FAPbBr_3$	433	433
$CsPbI_3$	582	554
$MAPbI_3$	576	566
$FAPbI_3$	573	569

Light Yield at ^{22}Na Compton Shoulders (relative to 1g/L PPO in Toluene)		
Material	1275 keV	511 keV
$MAPbBr_3$	0.86	0.74
$FAPbBr_3$	0.85	0.74
$CsPbI_3$	0.42	0.27
$MAPbI_3$	0.43	0.23
$FAPbI_3$	0.40	0.21



Outlook and Goals

- The bromide perovskites resolve the 1275 and 511-keV Compton shoulders of Na-22 better than the iodide perovskites.
- The quantum efficiency of our PMTs drops quickly above 500nm. This explains most of the reduction in light yield.
- We will continue this study with Sn2+. It is a 0νββ candidate, and actively studied as a less toxic alternative to Pb.
- Can we move on to more exotic materials and neutrino less double beta decay candidates like ^{150}Nd, ^{100}Mo, and ^{48}Ca?