LENS: Prototyping Program

The mini-LENS and μLENS prototype detectors

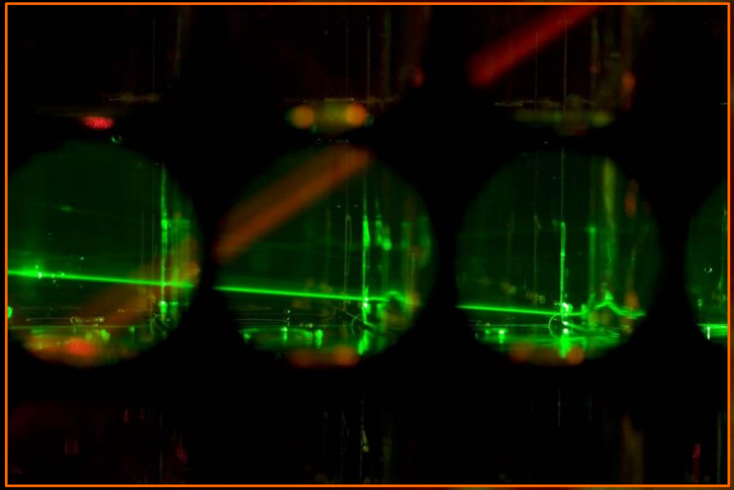
@ The Kimballton Underground Research Facility (KURF)

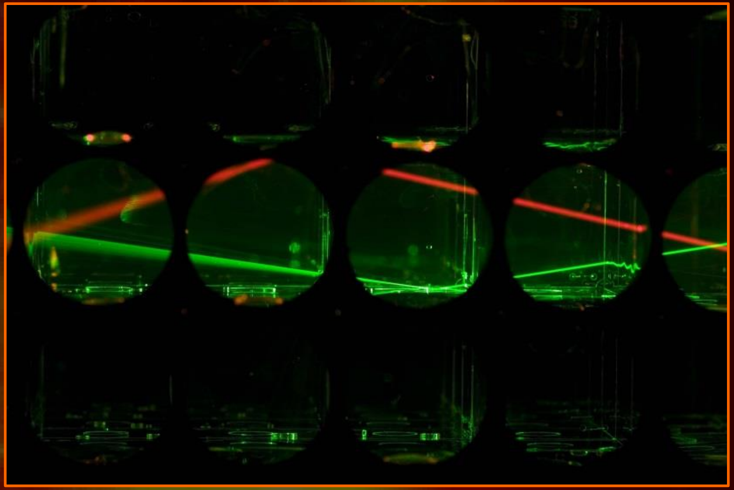
Presented by

S. Derek Rountree

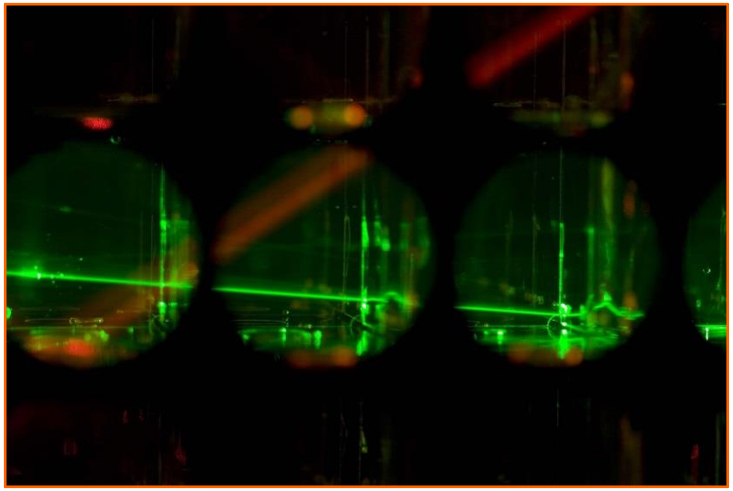
On behalf of the

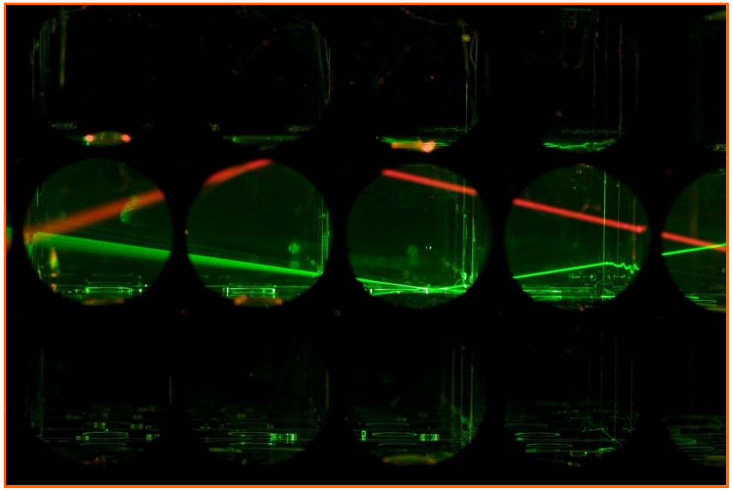
LENS Collaboration





- LENS
  - Science
  - Background reduction
- μLENS
  - Construction
  - Early results
- miniLENS – upcoming program





LENS: Science Scope and Development Stages

- LENS will measure flux of neutrinos from reactions originating on CNO nuclei
- Photospheric solar abundance analyses: 30-50% lower metalicities than previous

$\rightarrow$ Problem with helioseismology

$\rightarrow$ Reduces predicted CNO neutrino fluxes

- Measurements of CNO flux critical – but ***very*** difficulty via elastic scattering
- Cross-check of surface and core abundances would test homogeneous zero-age assumption of SSM

  [W. Haxton, A. Serenelli, ApJ **687** (2008)]

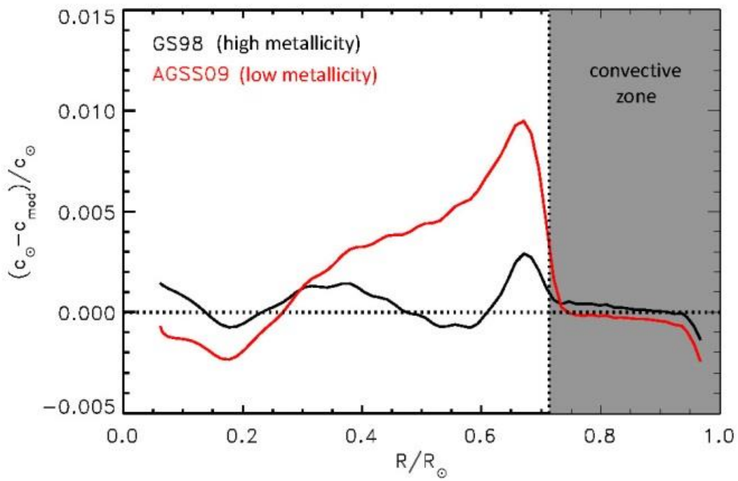


Figure 3: Relative comparison of sound speed from SSM to helioseismological observations (from ref. 15)

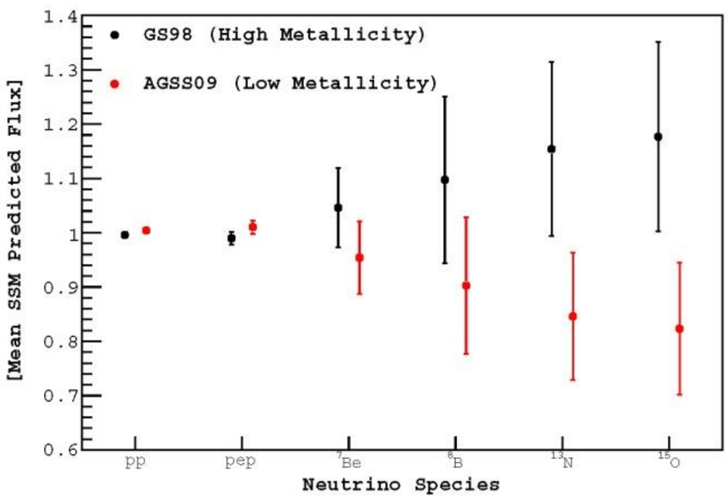
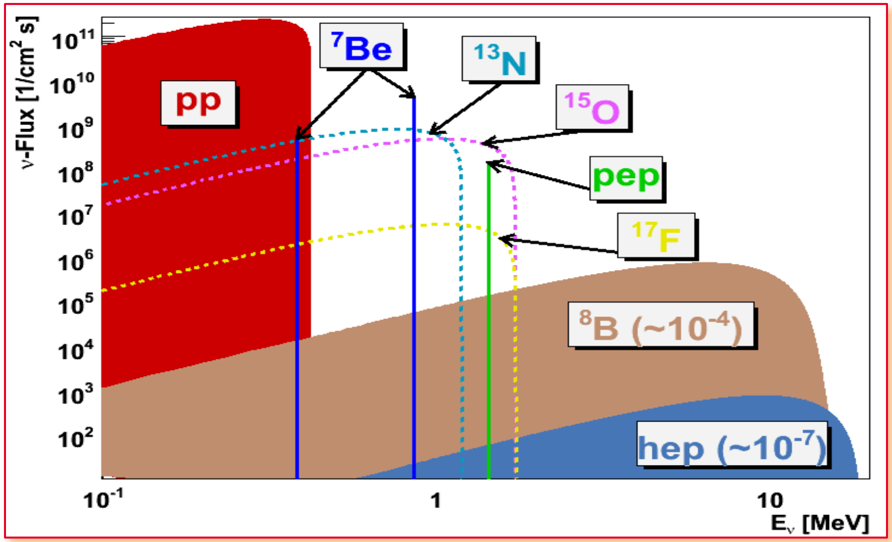
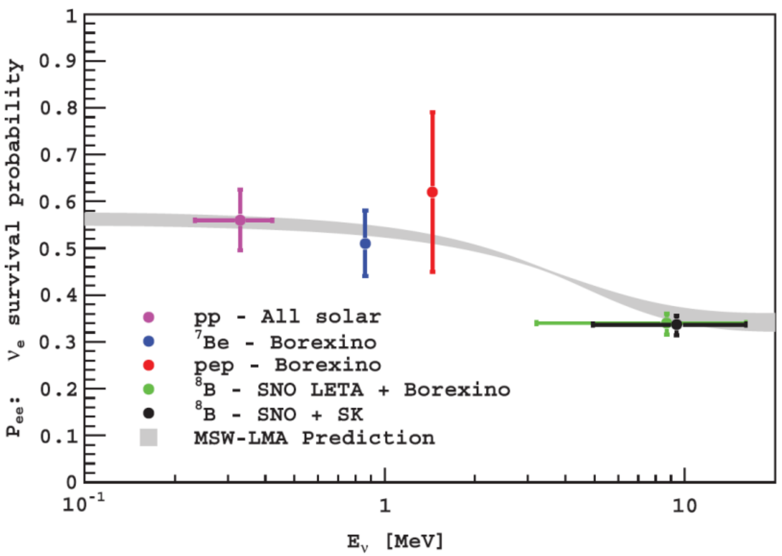


Figure 4: Comparison of predicted solar neutrino fluxes under two abundance assumptions (from ref. [17]).

Solar Luminosity

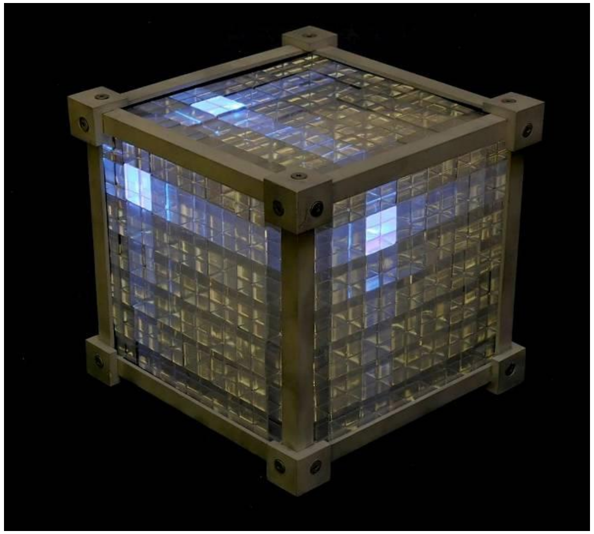




$$L_\nu = (1.00 \pm 0.14)\ L_{hf}$$

LENS Goal:

$$L_\nu = (1.?? \pm 0.03)\ L_{hf}$$



LENS Collaboration

VT - *R. Bruce Vogelaar, Mark Pitt, Camillo Mariani, S. Derek Rountree, Laszlo Papp, Zachary Yokley, Tristan Wright, Joey Heimburger, Lillie Robinson*

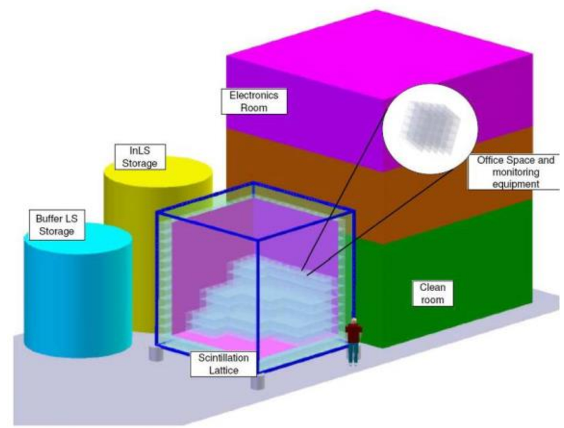
LSU - *Jeff Blackmon, Charles Rasco, Liudmyla Afanasieva, Kevin Macon*

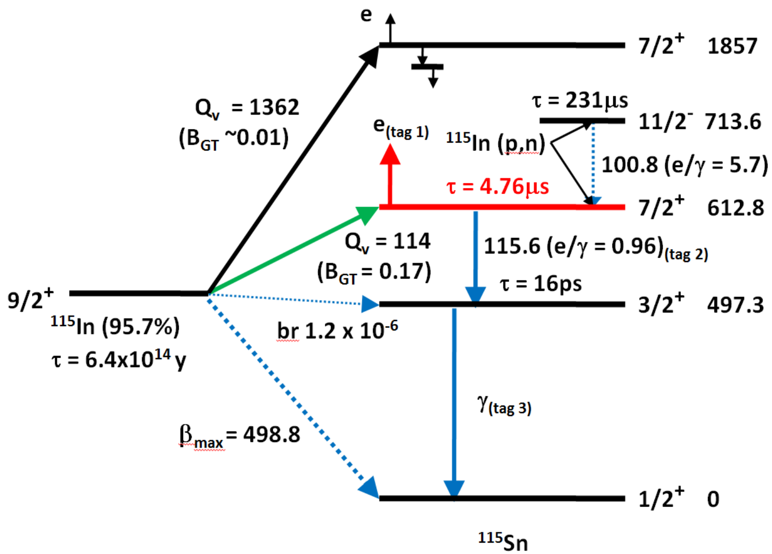
BNL - *Minfang Yeh, Lianming Hu*

NCCU - *Diane Markoff,* Israel Esan, Iman Fetiha, John Martin

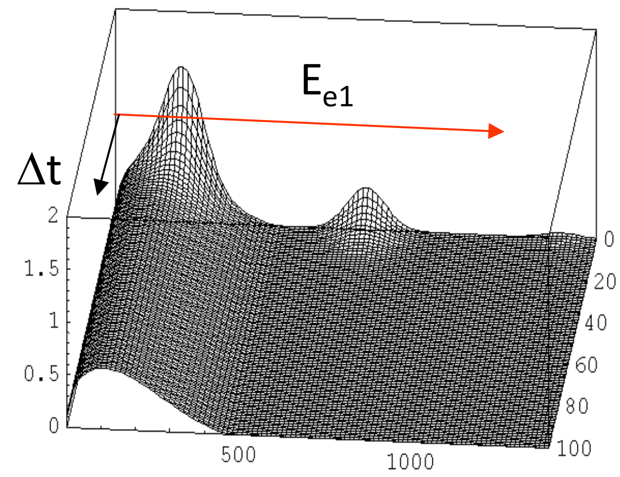
UNC - *Art Champagne*

HBNI, India – *Vivek Datar*

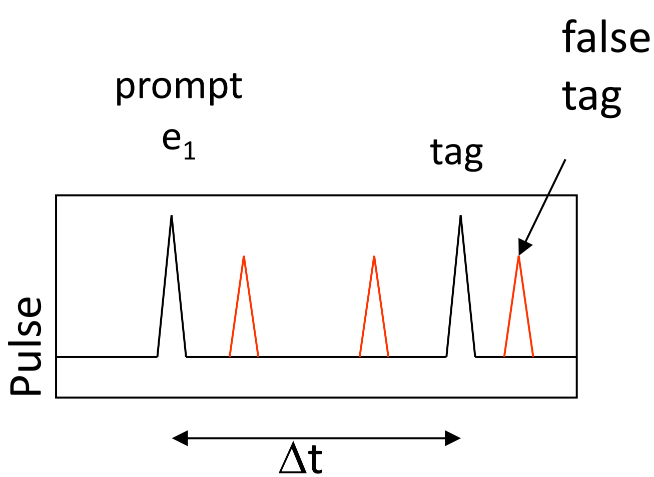




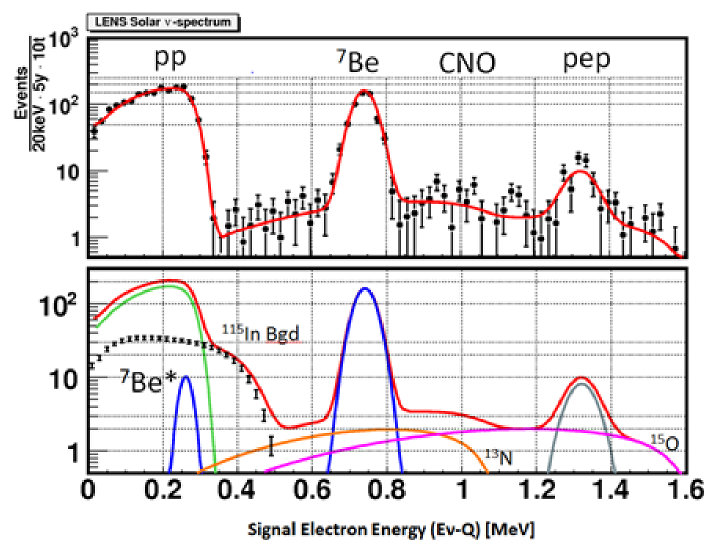
e
7/2+ 1857
Q_ν = 1362
(B_{GT} ~0.01)
τ = 231μs
11/2- 713.6
e(tag 1)
115In (p,n)
100.8 (e/γ = 5.7)
τ = 4.76μs
7/2+ 612.8
Q_ν = 114
(B_{GT} = 0.17)
115.6 (e/γ = 0.96)(tag 2)
τ = 16ps
9/2+
3/2+ 497.3
115In (95.7%)
τ = 6.4x10^14 y
br 1.2 x 10^-6
γ(tag 3)
β_{max} = 498.8
1/2+ 0
115Sn



E_{e1}
Δt

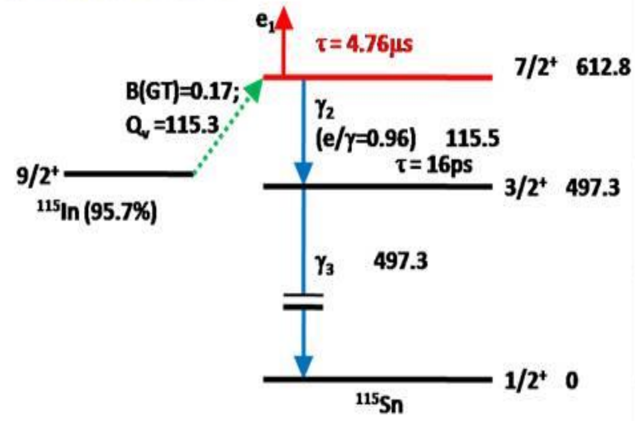


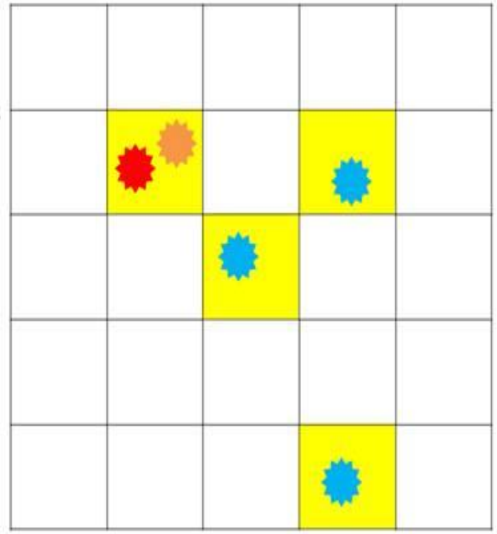
false tag
prompt e_1
tag
Pulse
Δt



LENS Solar ν-spectrum
Events / 20keV · 5y · 10t
pp
7Be
CNO
pep
115In Bgd
7Be*
13N
15O
Signal Electron Energy (Eν-Q) [MeV]

ν-SIGNAL EVENT

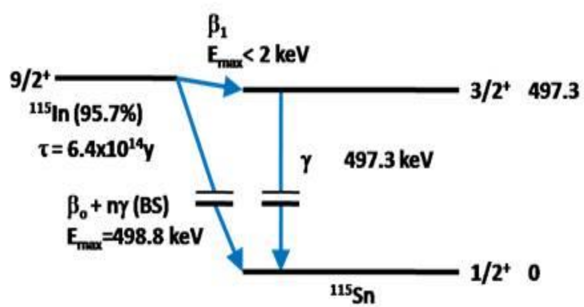


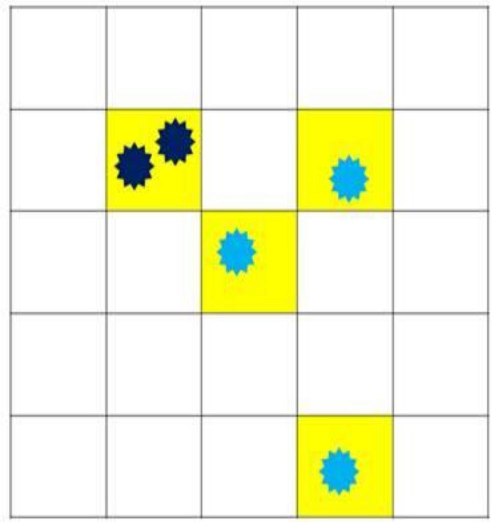


ν signal signature:

Prompt electron (●)
followed by
γ_1 (●) in the same cell
and
Compton scattered γ_2 (●)

INDIUM BACKGROUND EVENT





False ν – Background:

A1: 1 In beta (with Bremsstrehlung)

A2: 1 In beta (to 497 plus gamma)

B: 2 In betas (with Brem.)

C: 3 In betas

NOTE: all the 'tag' cells must fire within a 10 ns window (Δt_w)

Internal 'false tags' due to ^{115}In dominate

External 'false tags' eliminated by shielding

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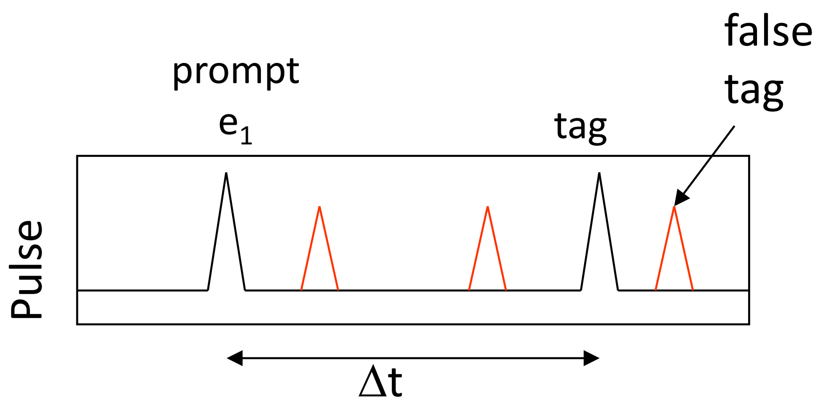
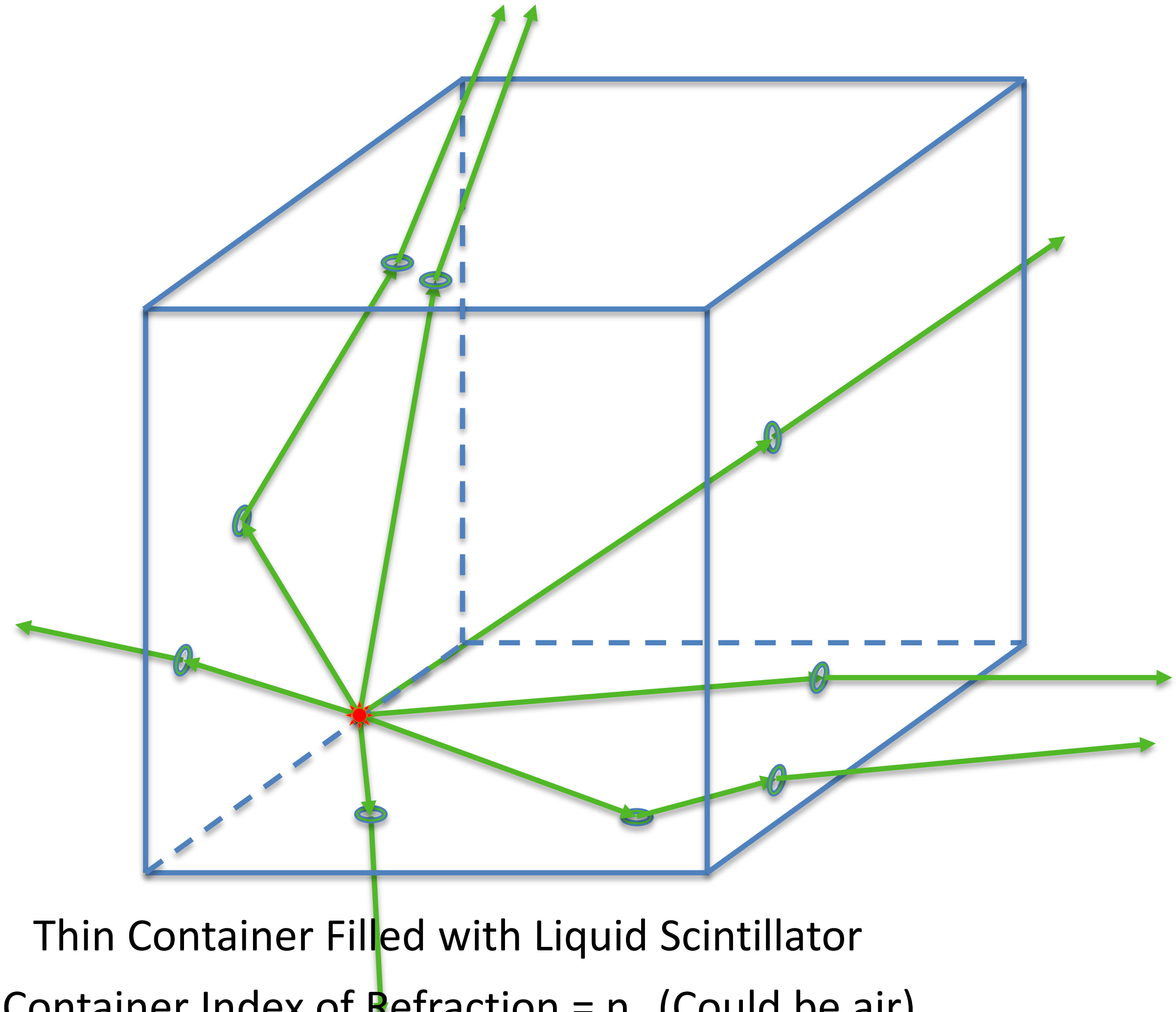
Demonstration via mini-LENS



need to check rate of ‘false’ tags from In ***or any other unknown source***

- shield mini-LENS detector to allow Δt_w to be opened from 10ns to much larger
- which increases ***all*** false tags involving random ‘coincidence’, making them observable at required LENS levels even in mini-LENS

What is a Scintillation Lattice?



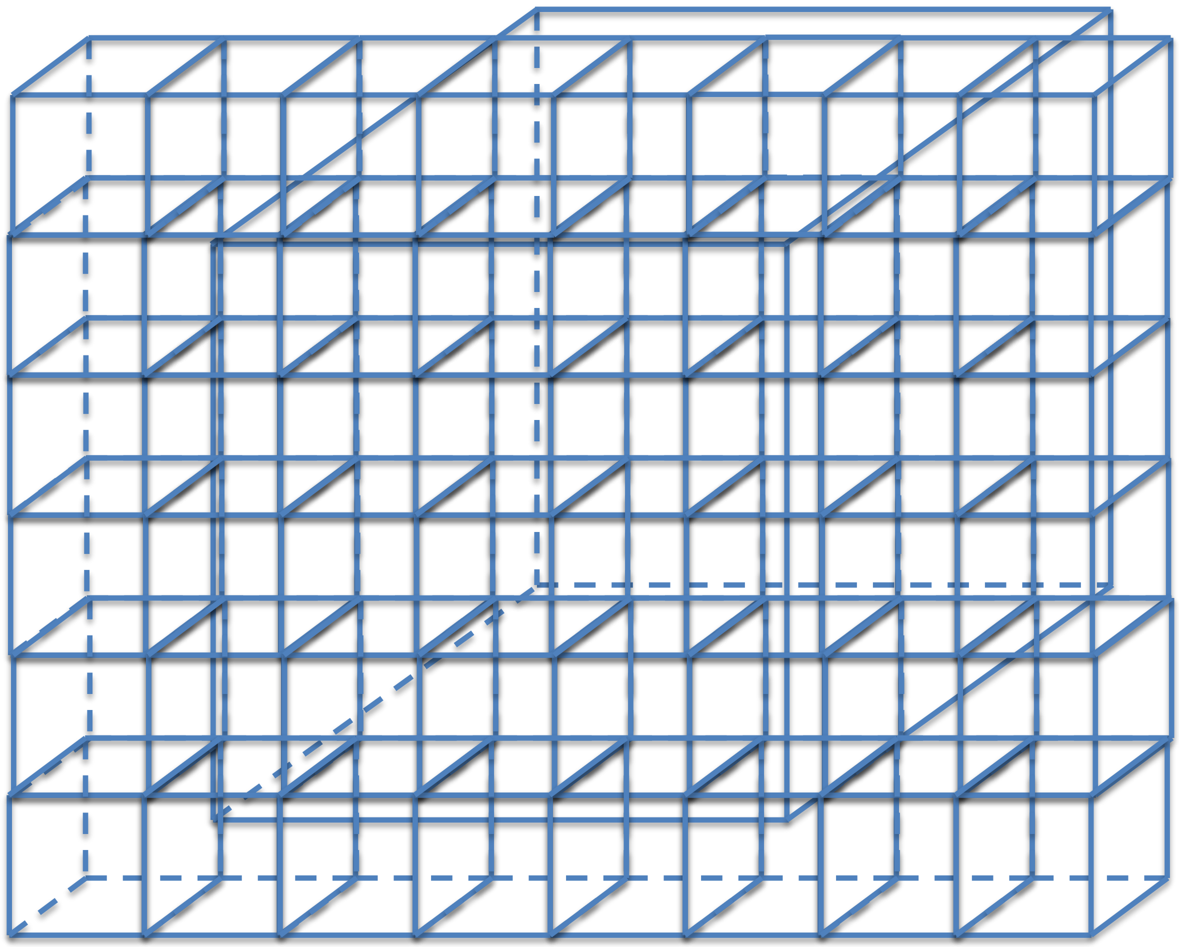
Thin Container Filled with Liquid Scintillator

Container Index of Refraction = n_1 (Could be air)

Liquid Scintillator Index of Refraction = $n_2 > n_1$

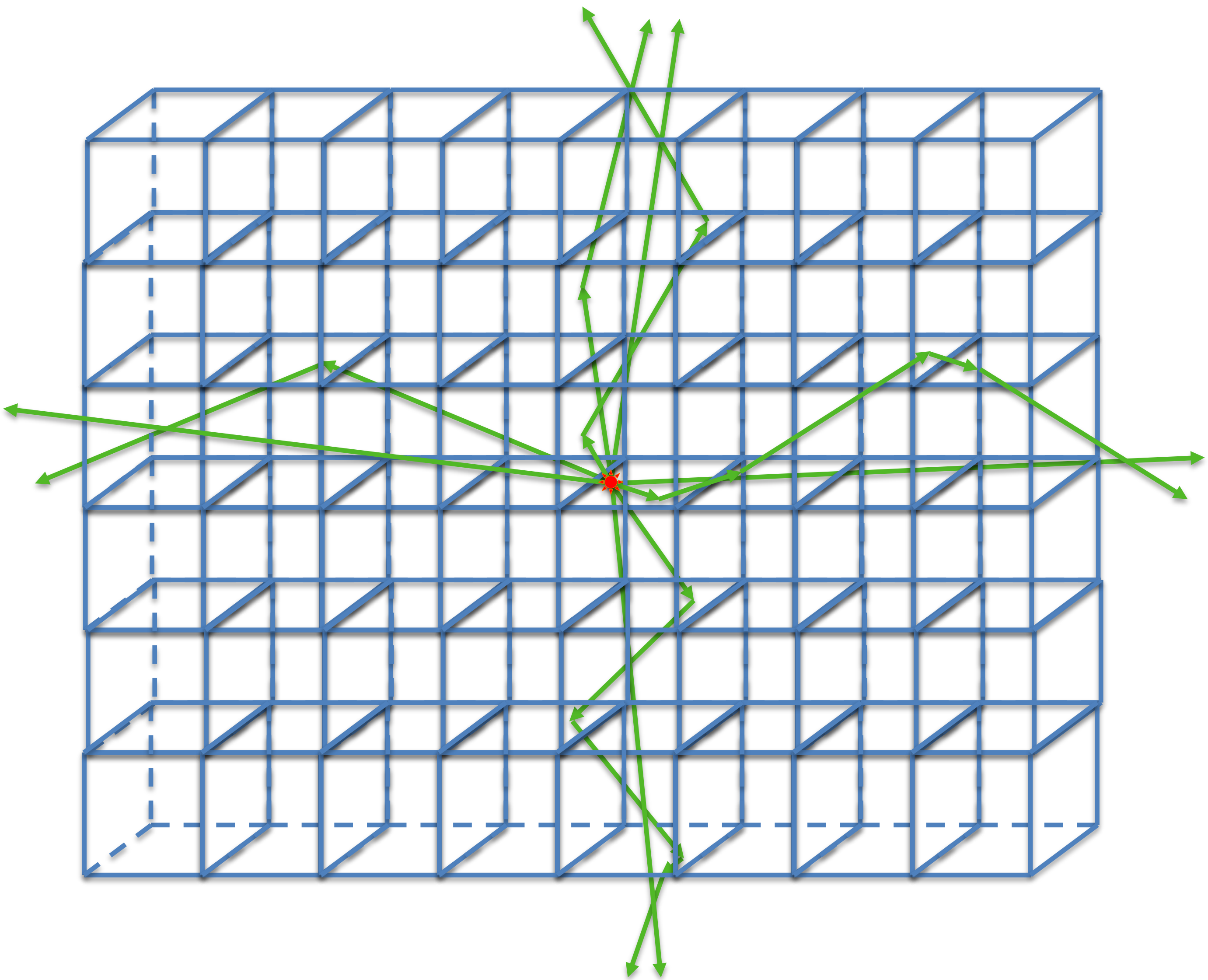
What is a Scintillation Lattice?

We call this a Scintillation Lattice



(Though this animation just shows a Scintillation Plane)

What Is LENS?

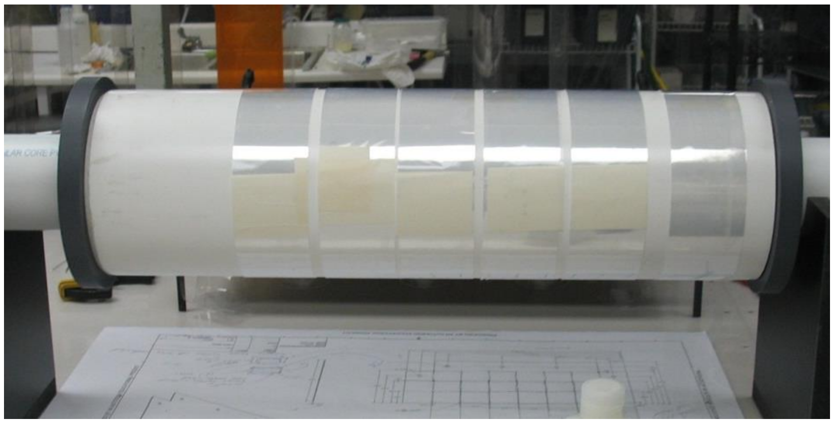


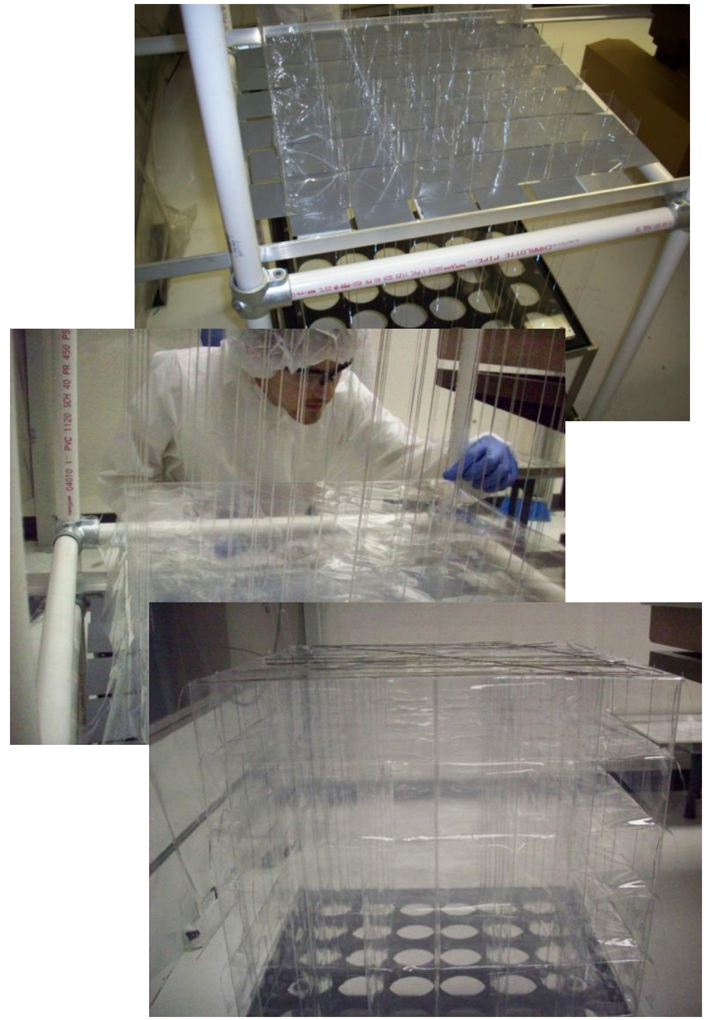
μLENS Objectives

6x6x6 Cell scintillation lattice (SL)

- Develop technologies and infrastructure at KURF towards the construction of mini-LENS (9x9x9 Cell SL)
- Provide a test platform for mini-LENS development
- Mechanical systems development:
  - Scintillation Lattice (SL) construction techniques
  - Detector purge and fill systems
  - Test filling SL detector with liquid scintillator
  - Test draining SL detector
- Test light transportaion in the as built SL and benchmark Monte Carlos
- Test electronics and trigger schemes

μLENS Construction





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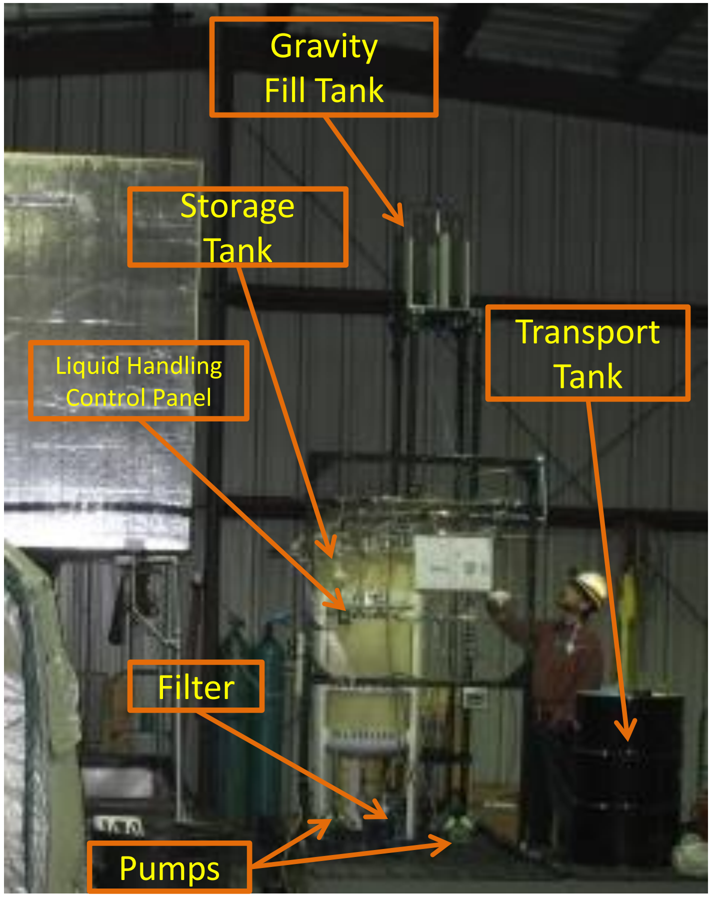
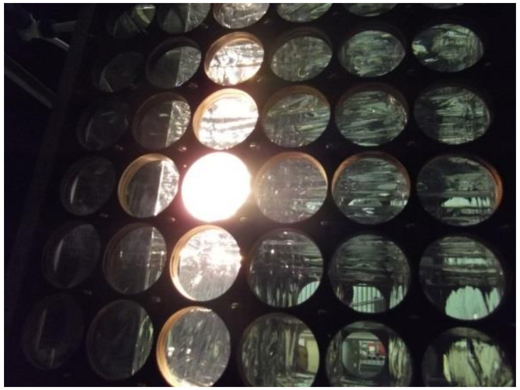
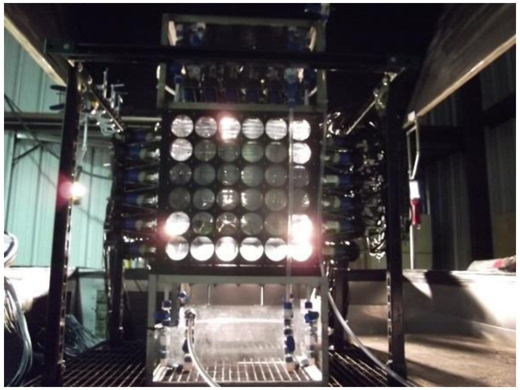
μLENS Infrastructure at KURF

μLENS Liquid Handeling

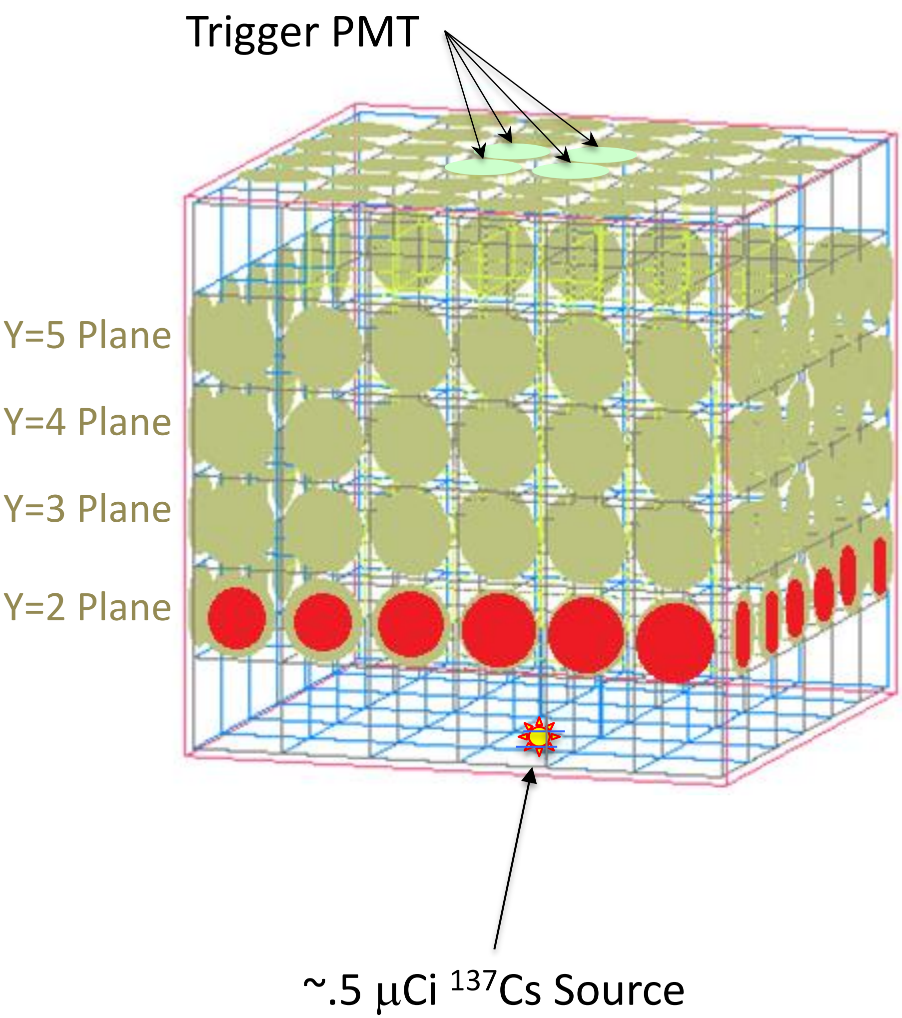


μLENS Mounting PMTs





What Was Measured?



~.5 μCi ^{137}Cs Source Located Near Center Bottom of μLENS for ~ 1 hour

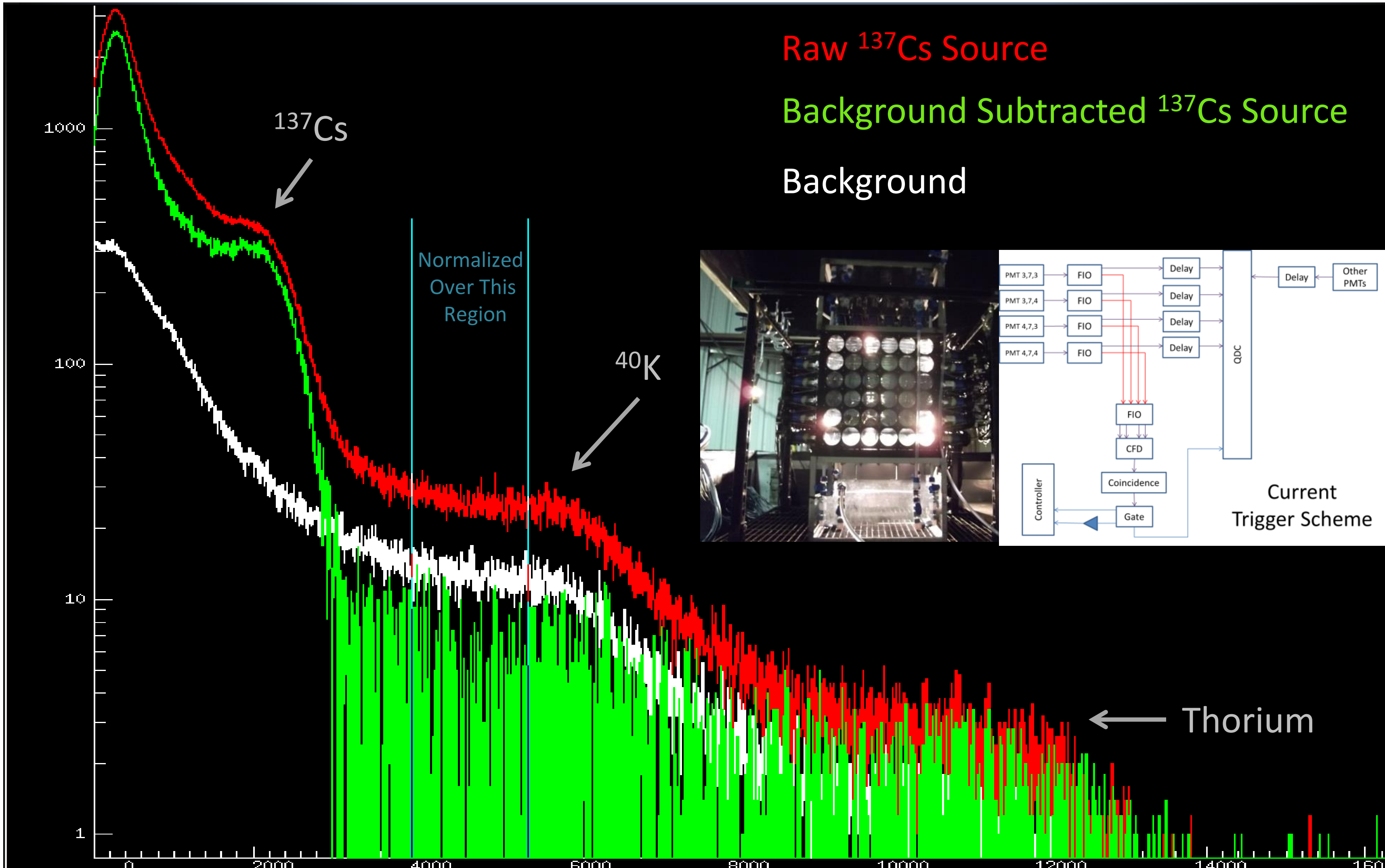
Background Run for ~ 1/2 hour

Longer Background Run for ~ 1 week

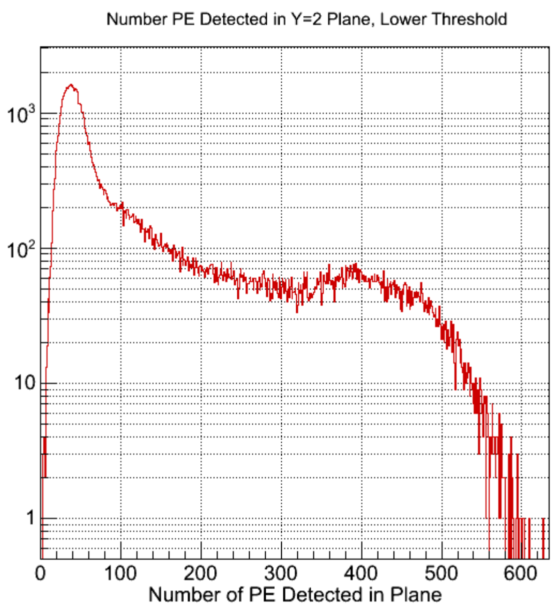
All Runs Triggered on Center Four Top PMT

PMT All Approximately Normalized by Previous Measurements

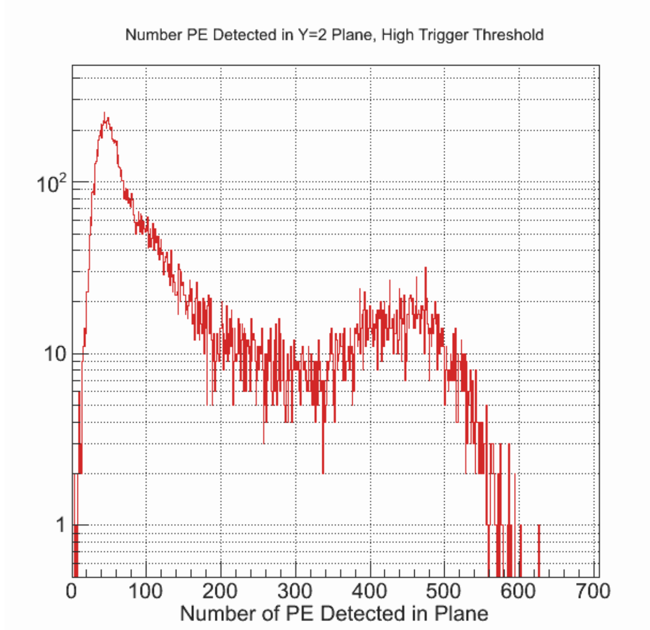
μLENS ^{137}Cs Data



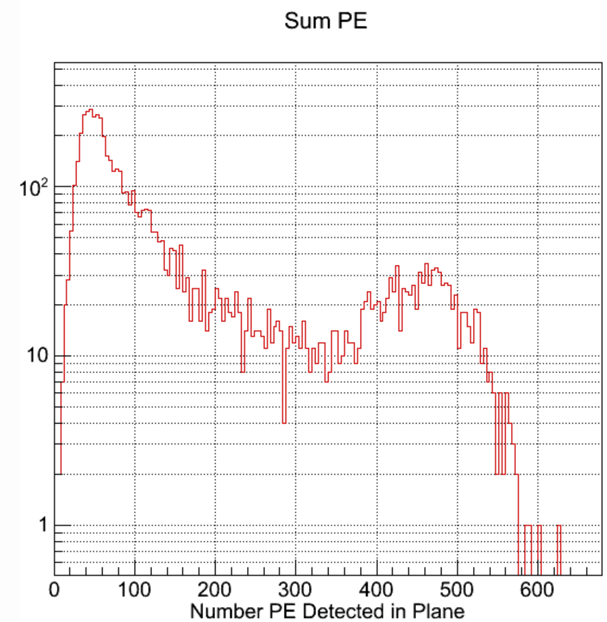
Simulation of ^{137}Cs Source at Bottom of μLENS



Low Trigger Threshold



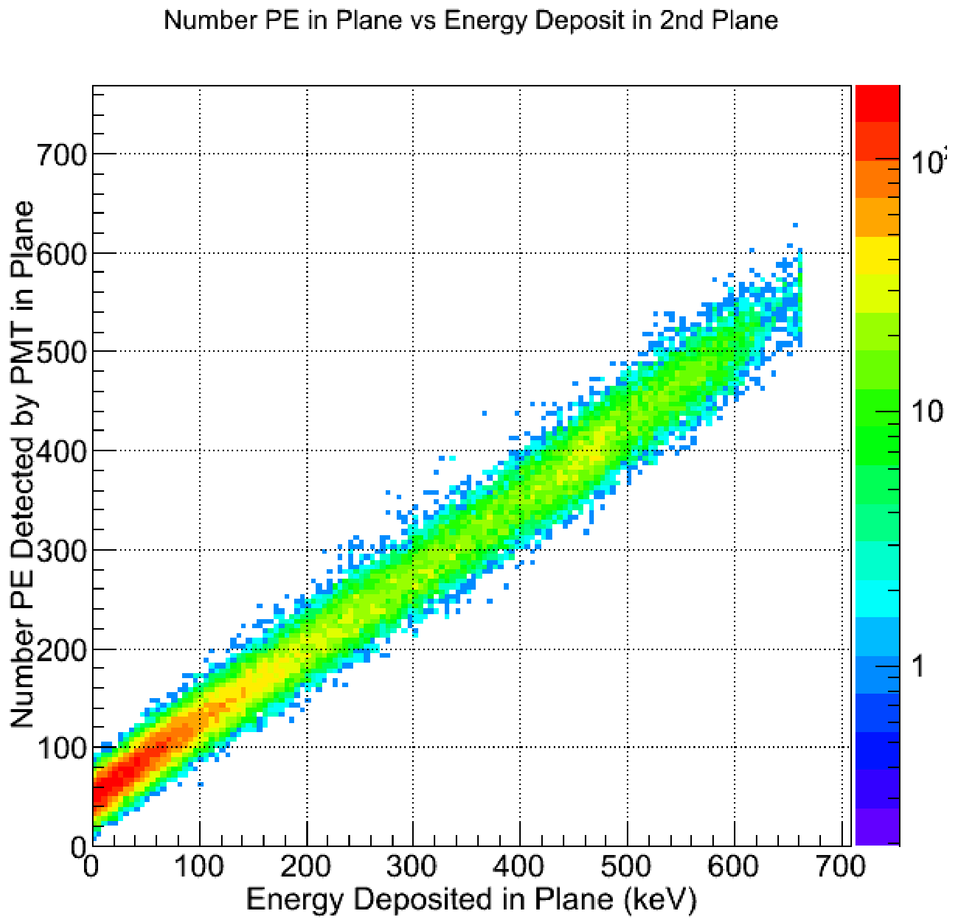
Medium Trigger Threshold



High Trigger Threshold

Relative height of low energy bump to high energy bump depends on the trigger level.

Simulation of ^{137}Cs Source at Bottom of μLENS



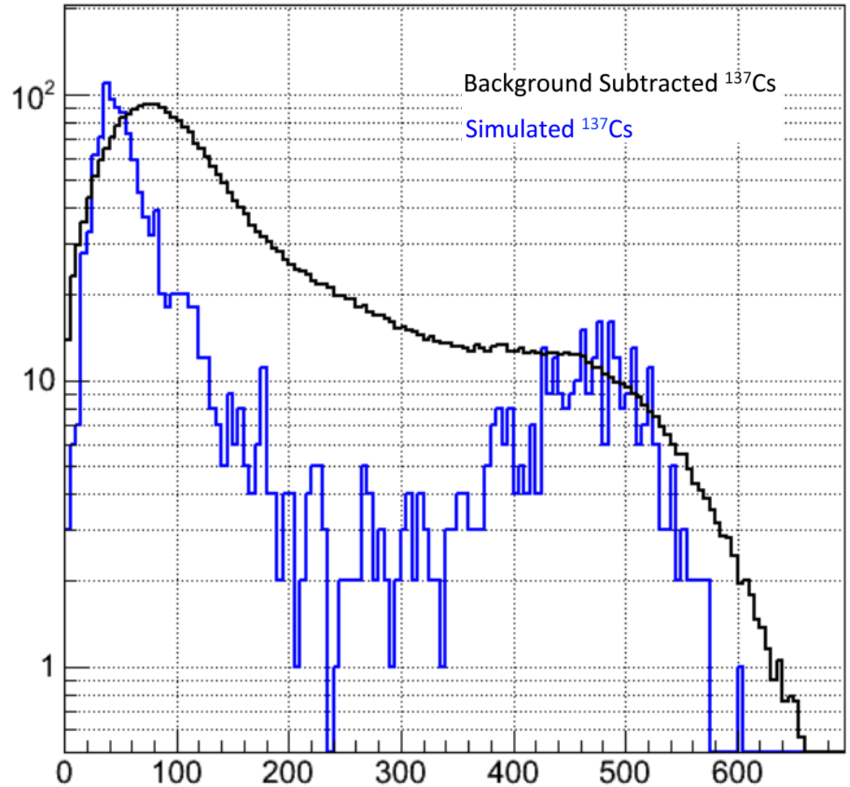
Low Trigger Threshold

Low Energy Peak is a Low Energy Deposit in the Plane. Most Likely Several Mostly Forward Compton Interactions (The Most Probable to Happen) in a Single Cell as the γ Crosses the Plane.

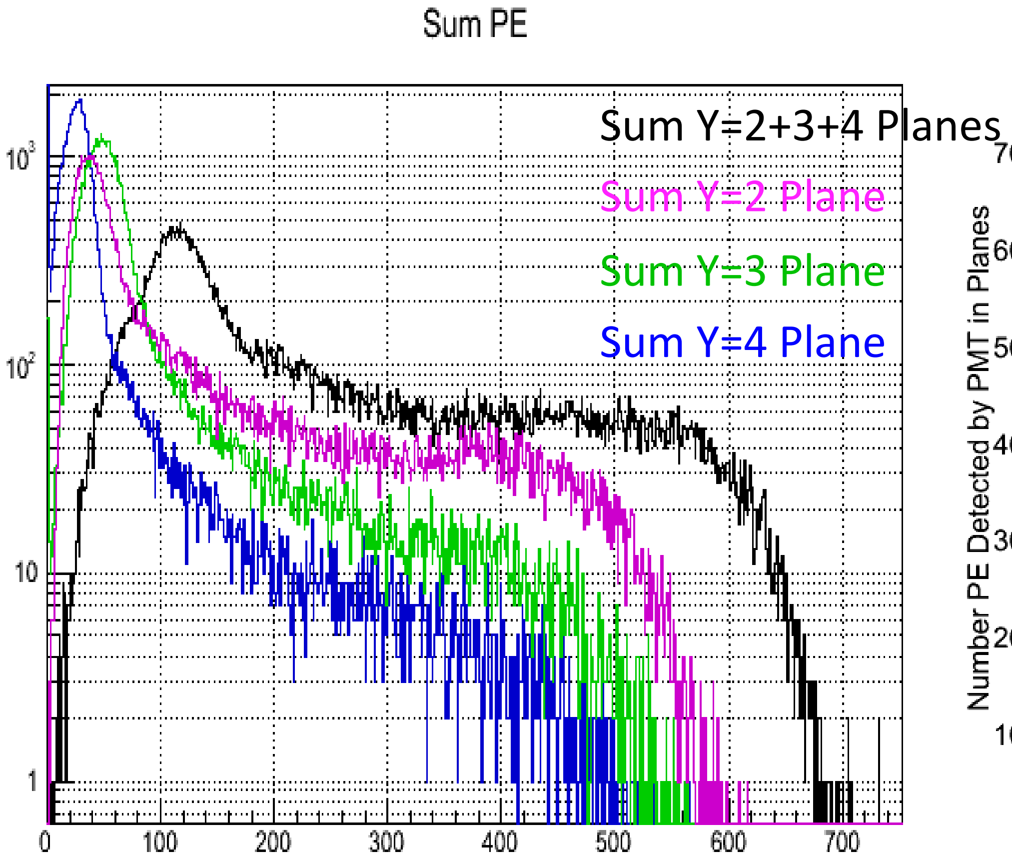
High Energy Peak is a Mixture of the Full Energy Deposit, Full Energy Minus Loss in the Outer Acrylic Shell, and the Compton Edge Deposit in the Plane.

μLENS

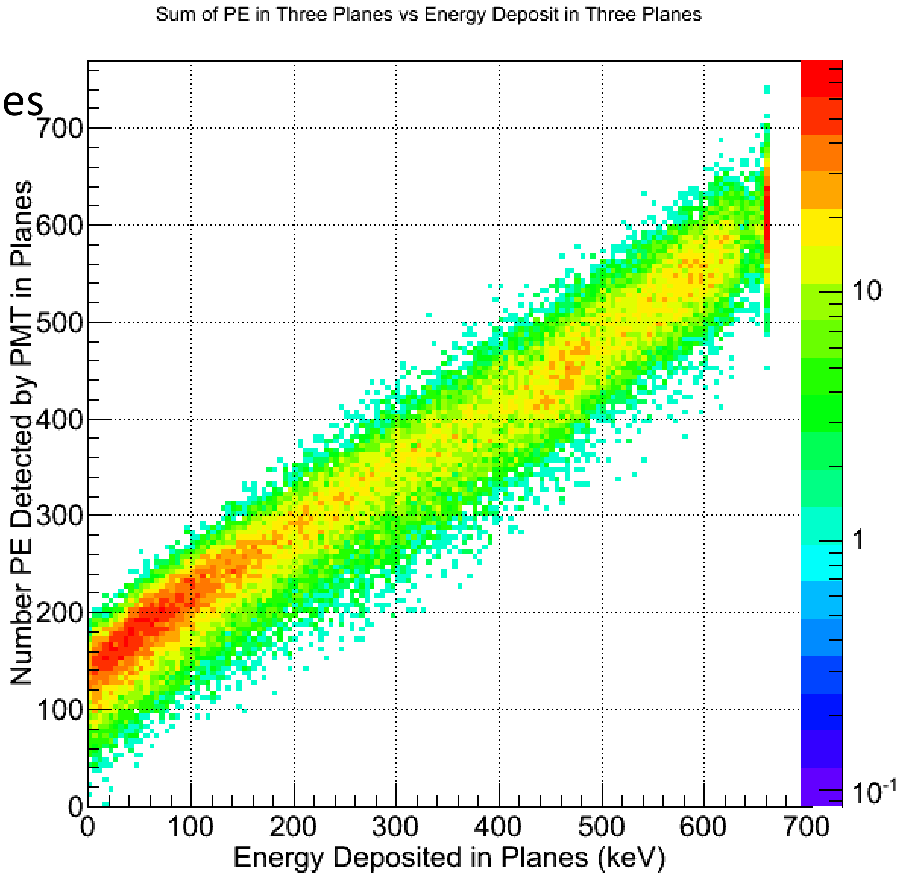
Simulated Number of PE / Proportionally Scaled Channel Number



Prediction for 3 Plane μLENS with Low Trigger



Measurement with Low Trigger Threshold



And What it Translates to Measuring

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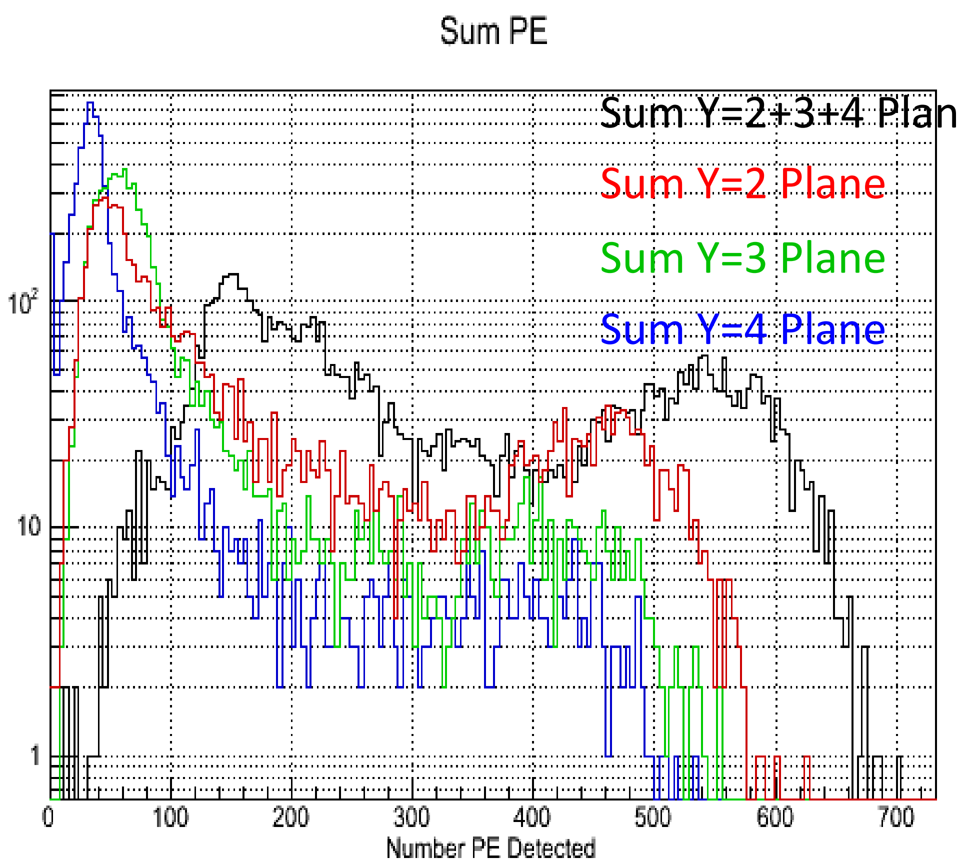
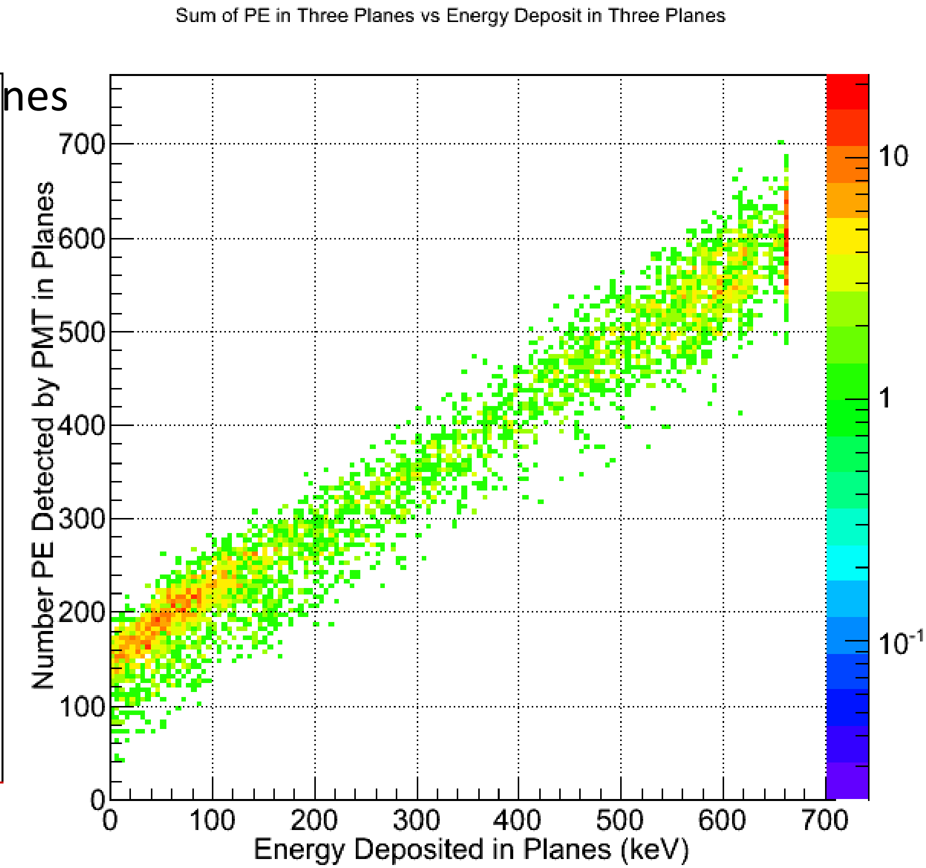
Prediction for 3 Plane μLENS with High Trigger



Measurement with High Trigger Threshold

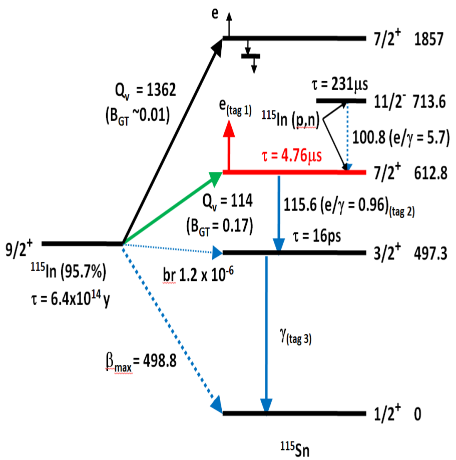


And What it Translates to Measuring

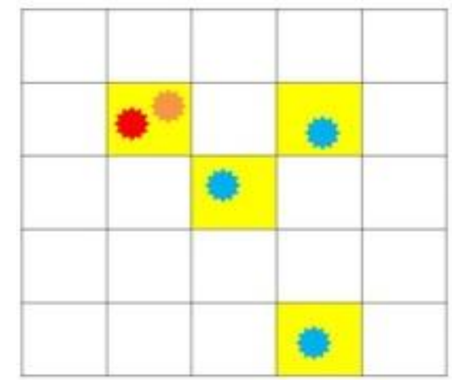
mini-LENS Program Objectives

- Demonstrate background reduction at levels required for LENS
- ^{115}In liquid scintillator production and handling
- Develop electronics and trigger scheme for LENS
- Develop scalable SL production methods
- Explore options for higher light collection efficiency

Signal and Background Rates in mini-LENS

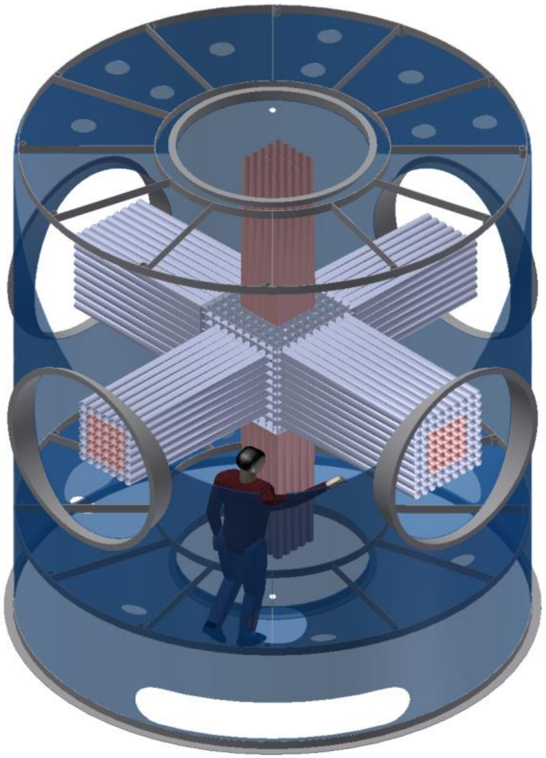


Background Description		Relative Importance
One ^{115}In decay in the delayed tag	A_1 = β + Bremsstrahlung γ (E_{point} = 499keV)	x1
	A_2 = Sn $3/2^+$ --> Sn $1/2^+$ (E_{tot} = 498kev)	x 1
Two ^{115}In decay in the delayed tag	B = β + β with at least one Bremsstrahlung γ	x τ
Three ^{115}In decay in the delayed tag	C = 3 β-decays	x τ^2
Four ^{115}In decay in the delayed tag	D = 4 β-decays	x τ^3



Rates per month in 5x5x5 cells of mini-LENS	pp Signal	Equiv. Singles	In induced Bgd tot	Bgd A1	Bgd A2	Bgd B	Bgd C
RAW	0.031	265	3.9E+09				
Valid tag (Energy, Branching, Shower) in Space/Time delayed coinc. with prompt event in vertex	0.027	233	5.8E+05	1.8E+05	5.9E+03	4.0E+05	93.0
+ ≥3 Hits in tag shower	0.024	210	1.3E+05	1.2E+05	5.8E+03	3.0E+03	92.6
+Tag Energy = 613 keV	0.022	188	970.5	1.0	11.0	942.9	17.0
+Shower Radius	0.022	186	572.1	1.0	10.8	559.4	1.5
+Hit Separation	0.020	170	28.2	1.0	10.0	17.2	0.008

mini-LENS Detector Shielding



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