Measurement of 2b2v Half-Life of Zr96

and

Lightguide Studies for SuperNEMO Calorimeter

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Outline

1 Measurement of Zr96 Half-Life

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- External Backgrounds
- Internal Backgrounds
- Event Selection Cuts
- 2b2v Measurement
- Future Plans

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- Motivation
- Test Setup
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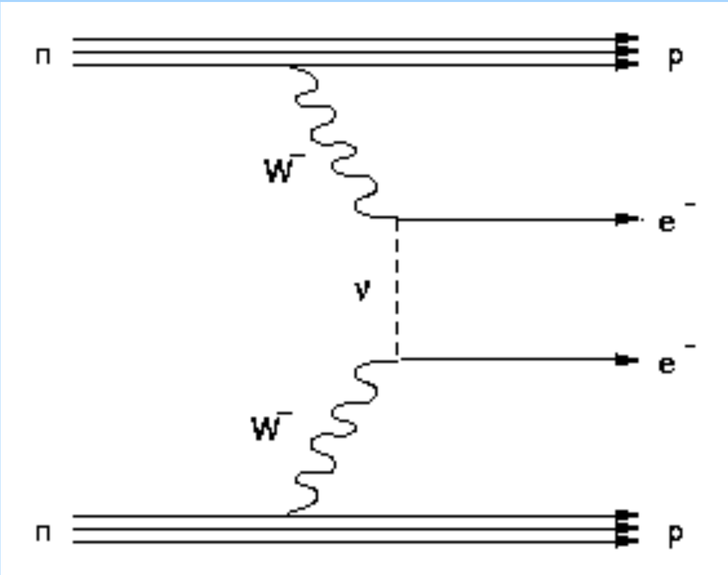
- Polished Lightguide
- Future Plans

2b0v - Motivation

Neutrinos oscillate and have mass
- Dirac or Majorana Neutrino?
- Absolute mass scale?

2b0v decay answers both questions
- Observation of 2b0v is direct evidence that neutrinos are Majorana
- Effective Majorana mass is inversely proportional to 2b0v half-life



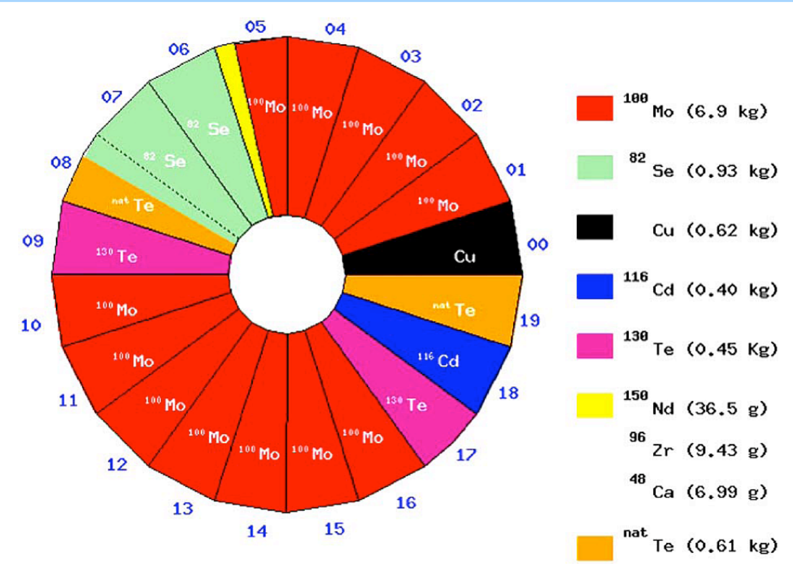
$$n \rightarrow p + e^-_L + \nu_e{}^M{}_R$$

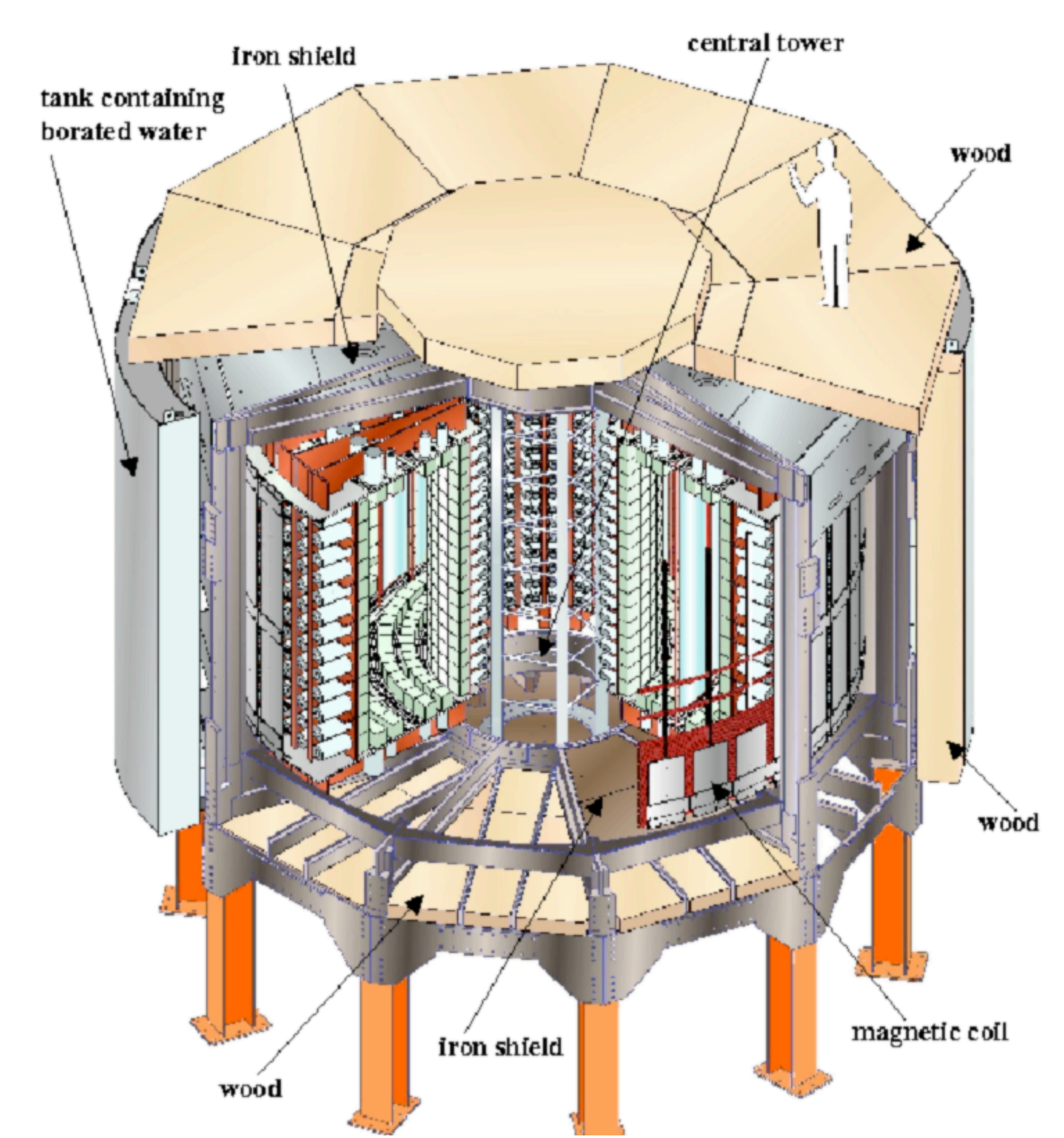
$$\nu_e{}^M{}_L + n \rightarrow p + e^-_L$$

$$[T_{1/2}{}^{0\nu}]^{-1} = G^{0\nu} \; |M_{0\nu}|^2 <m_{\beta\beta}>^2$$

NEMO-3 Detector

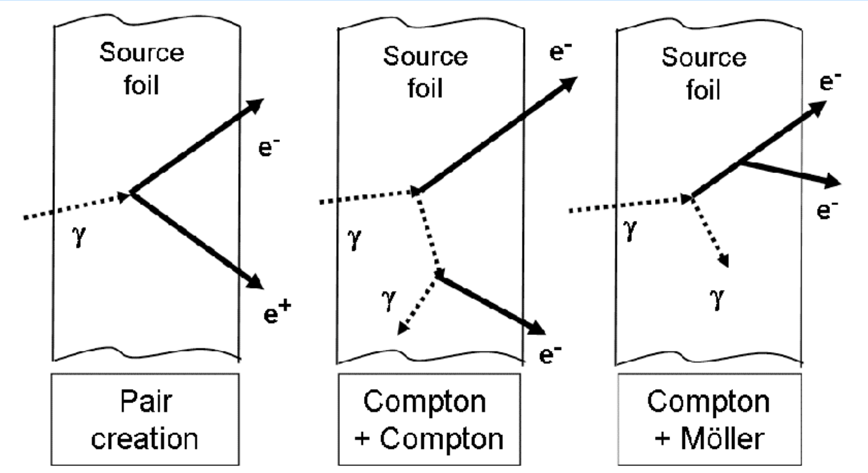
- Tracker + Calorimeter
- 10 kg of source
- Magnetic Field
- passive shielding
- 4800 MWE
- 0.3 eV sensitivity





External Backgrounds

Success of NEMO-3 depends on how well we understand our backgrounds



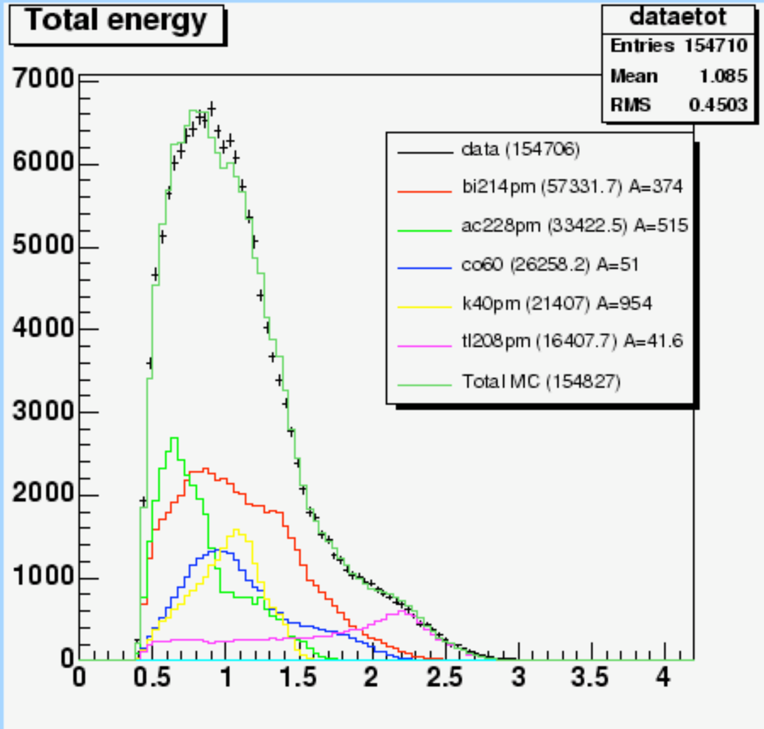
External backgrounds are characterized as radioactive impurities NOT within the source foils

- support structure
- PMTs
- drift cell wires
- radon

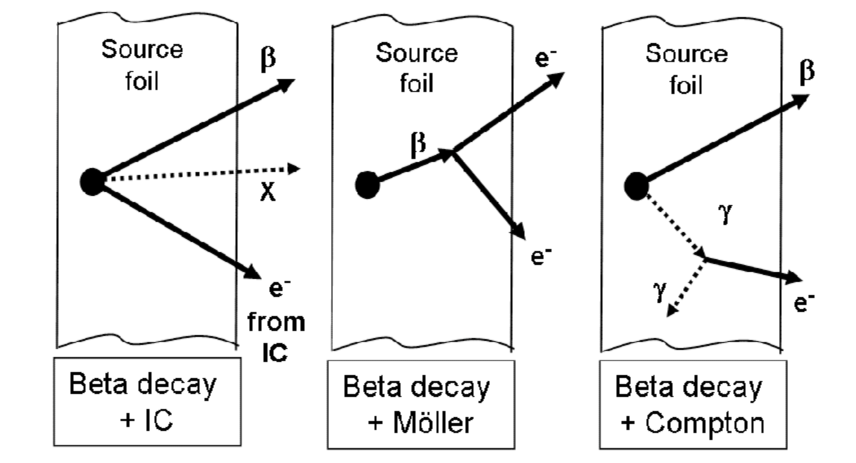
Measure the external background using the Cu sector

Look in the eγ channel for more statistics

Background	Phase-1 Bq	Phase-2 Bq
air_bi214	580.0	0.0
iron_co60	50.7	50.7
pm_ac228	515.0	515.0
pm_bi212	515.0	515.0
pm_bi214	374.0	374.0
pm_k40	954.0	954.0
pm_tl208	41.6	41.6
sf_bi214	0.0200	0.0085
sw_bi214	0.6000	0.1400
sw_tl208	0.0028	0.0028
sf_bi210	2.2000	2.2000
sw_bi210	8.8100	8.8100
sf_pb214	0.0200	0.0085



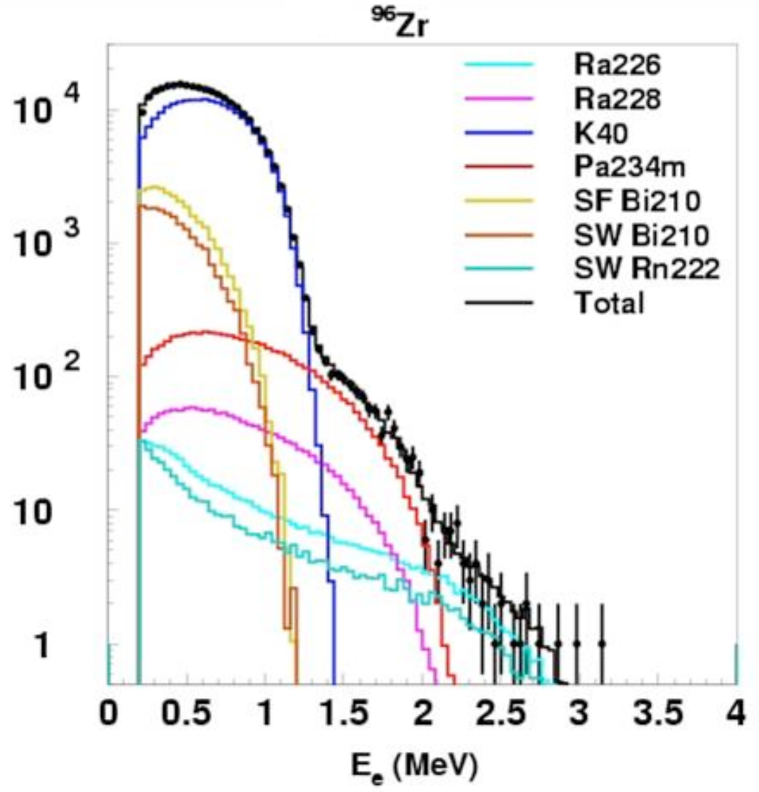
Internal Backgrounds



Internal backgrounds are characterized as radio-impurities within the source foil

Keep the external background activities fixed and measure the internal backgrounds using different channels

1 electron channel

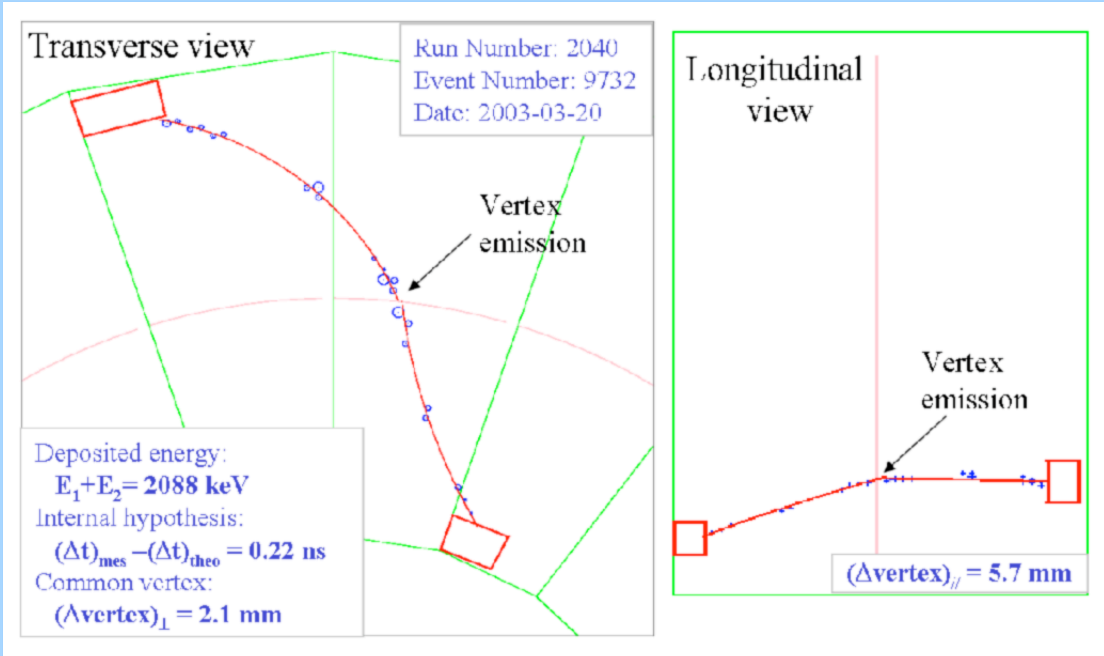


Background	Bq
foils_ac228	1.63E-4
foils_bi212	1.63E-4
foils_bi214	1.35E-4
foils_pb214	1.35E-4
foils_k40	1.90E-2
foils_pa234m	6.55E-4
foils_tl208	5.88E-5

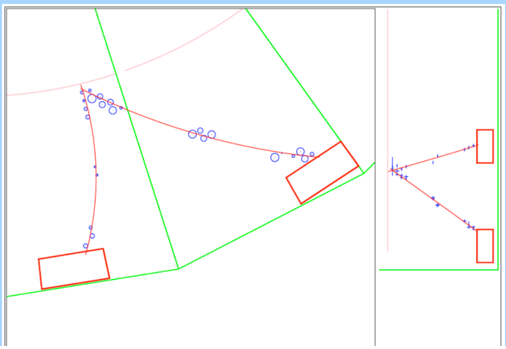
Bi214 → e + alpha
Pb214=Bi214
Tl208 → egg, eggg
Ac228=Bi212~Tl208
Bi210,K40,Pa234m → e, eg

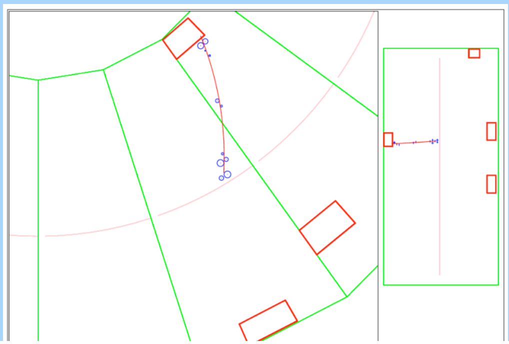
Selection Cuts

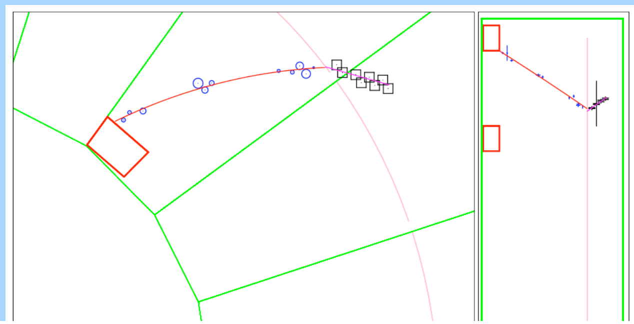
- 2 tracks with negative curvature
- each track has associated scint hit with E > 200keV
- scint hits are isolated
- track hits face of scintillator
- no other energy deposit in calorimeter
- reconstructed vertex
- distance between track origins, XY<2cm and Z<4cm
- event vertex in Zr96 sector
- has GG hit in one of the 2 closest layers
- sum of track lengths > 60cm
- TOF prob internal >4% and TOF prob external < 1%
- less then 3, non associated, fast GG hits with distance to event vertex < 15cm (checks track reconstruction quality)
- if both tracks in one part of detector, no fast GG hits in other part with distance to event vertex < 15cm (checks that the event didn't start on the opposite side of foil)
- 700 microSec time delay to cut out alpha events from Po214



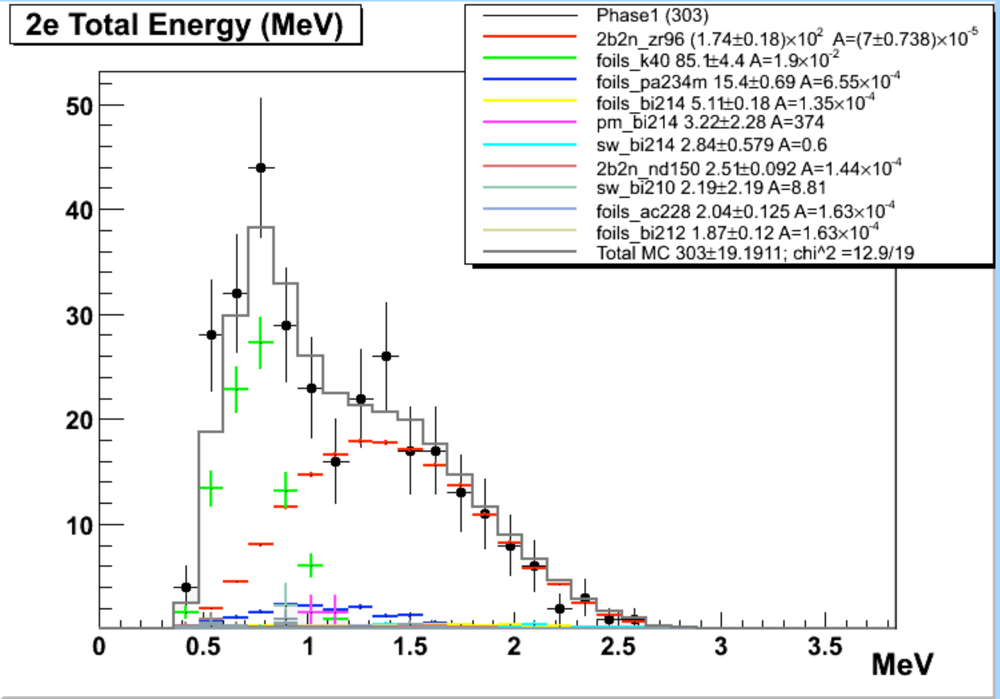
- 2 electron tracks
- 2 scint hits where tracks end
- event vertex is in the foil
- check reconstruction quality







2b2n Measurement



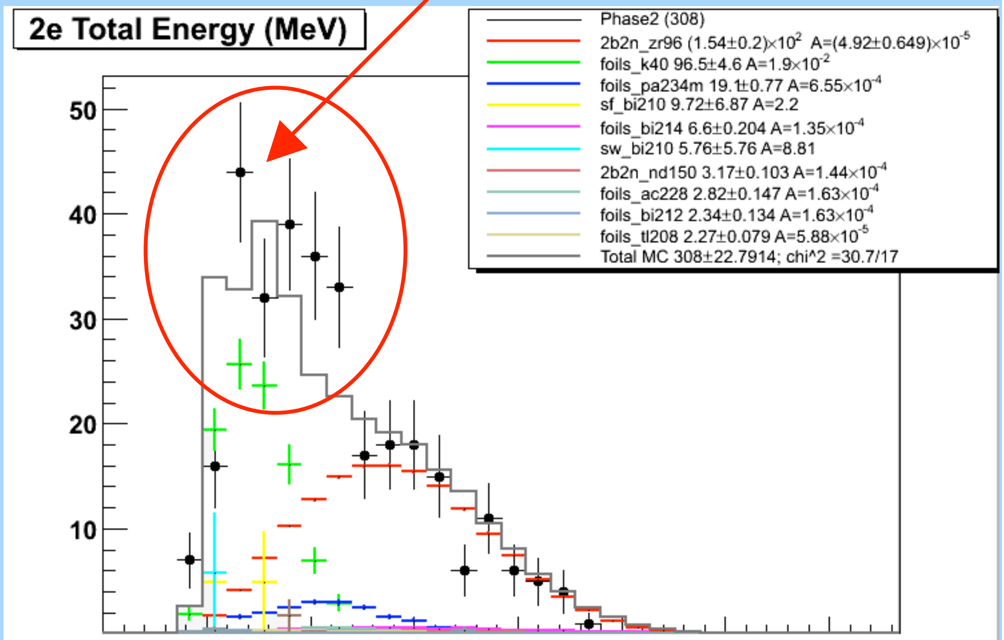
Phase-1

Runtime = 404 days

Data = 303.0 +/- 17.4
Bgr = 129.3 +/- 5.7
Signal = 173.7 +/- 18.3

Half-life = **1.85 +/- 0.12 e19 years**
ε = 7.1%

investigate



Phase-2

Runtime = 534 days

Data = 308.0 +/- 17.5
Bgr = 153.8 +/- 10.3
Signal = 154.3 +/- 20.3

Half-life = **2.63 +/- 0.35 e19 years**

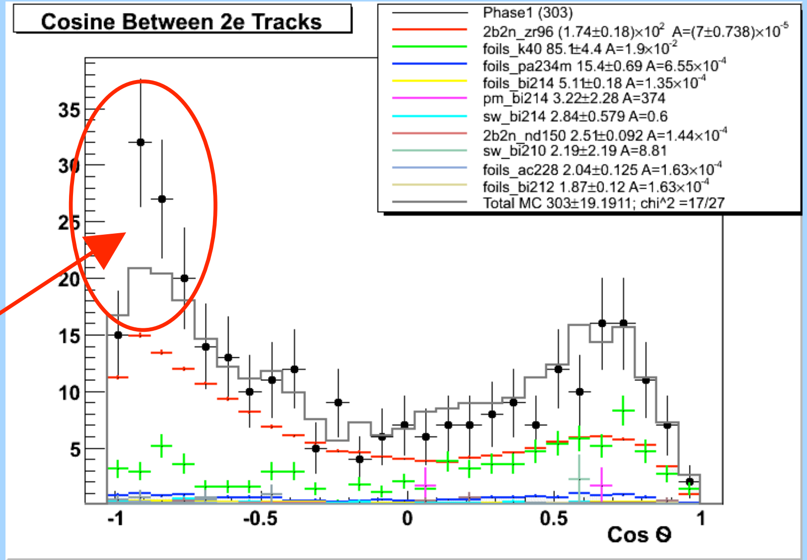
Compare Angular Distribution and Min Energy Electron

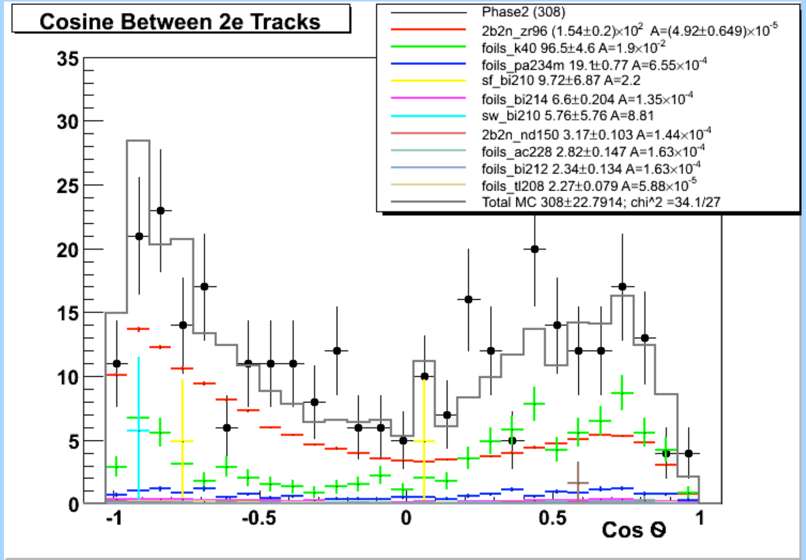
Phase-1

Phase-2

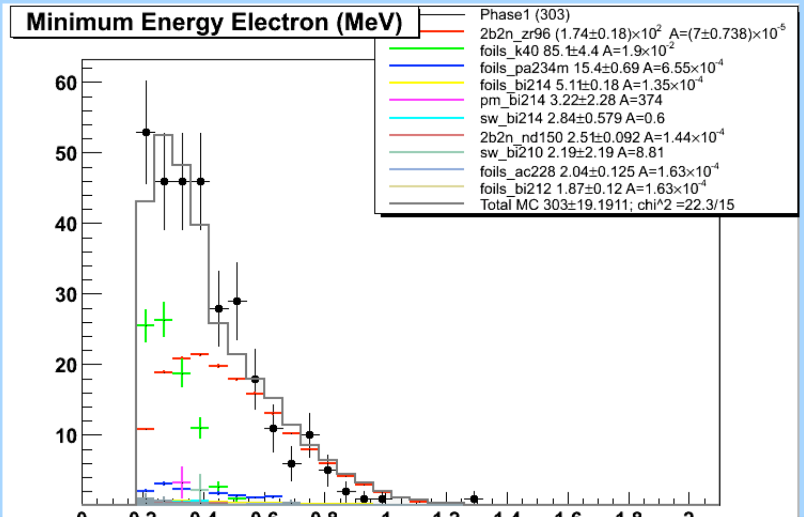
Angular distribution reveals crossing electrons and Moller scattering from backgrounds

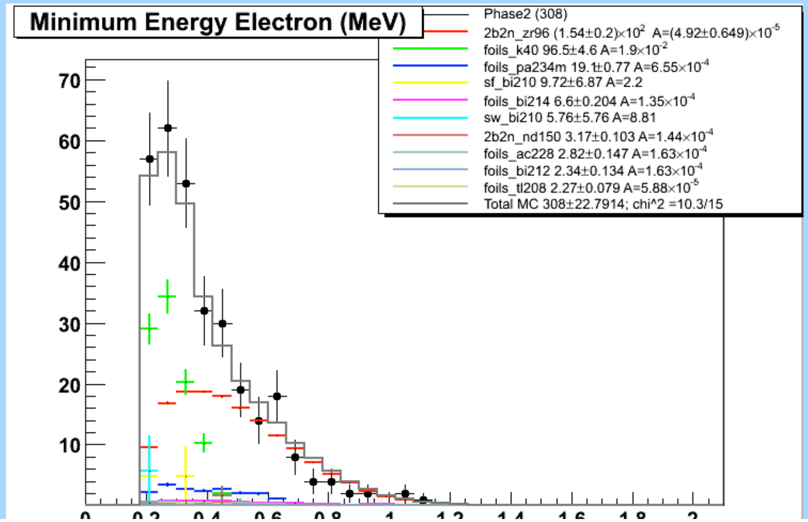
investigate





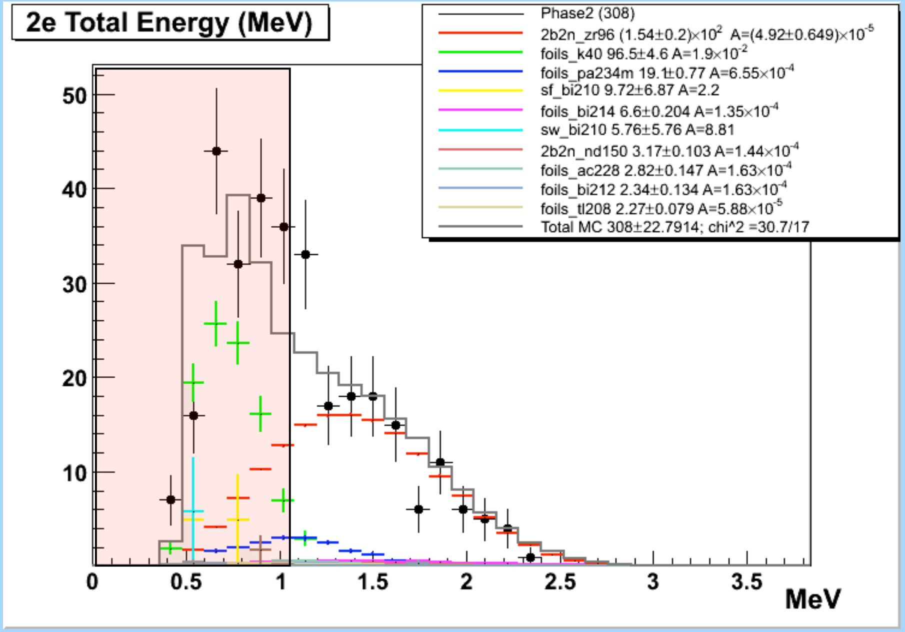
Minimum energy electron reveals conversion electrons from backgrounds





Dependence on Energy Cut

Fit the data above the energy threshold



Half-life measurement should not depend on energy cut

Energy Cut (MeV)	Phase-1 Half-Life 10e19 Yrs	error x10e19	Phase-2 Half-Life 10e19 Yrs	error x10e19	significance sigma
0.4	1.85	0.20	2.63	0.35	1.93
0.8	2.02	0.21	2.53	0.27	1.49
0.9	2.06	0.21	2.44	0.23	1.22
1.0	2.06	0.20	2.58	0.25	1.62
1.1	2.05	0.20	2.71	0.28	1.92
1.2	1.94	0.19	3.13	0.36	2.92
1.5	2.17	0.29	3.20	0.46	1.89

Consistency check to show how well we understand our backgrounds

Phase-2 has strong dependence on energy cut

- < 2σ difference so this is statistical fluctuation
- missing low energy background, Pb211 and Tl207
- no measurement of the U235 chain with HPGe

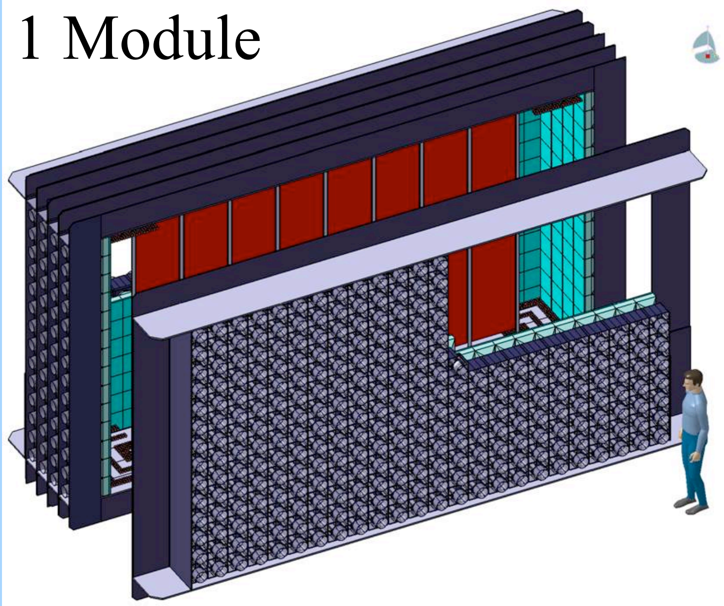
Future Plans:

- determine independent internal background model
- study the systematic errors of the analysis
- do analysis of the 2b0n channel
- finalize a 2b2n half-life result
- find limit for 2b0n half-life
- submit a report of my analysis to NEMO-3 collaboration to be published in joint paper.

Lightguide Studies for SuperNEMO Calorimeter

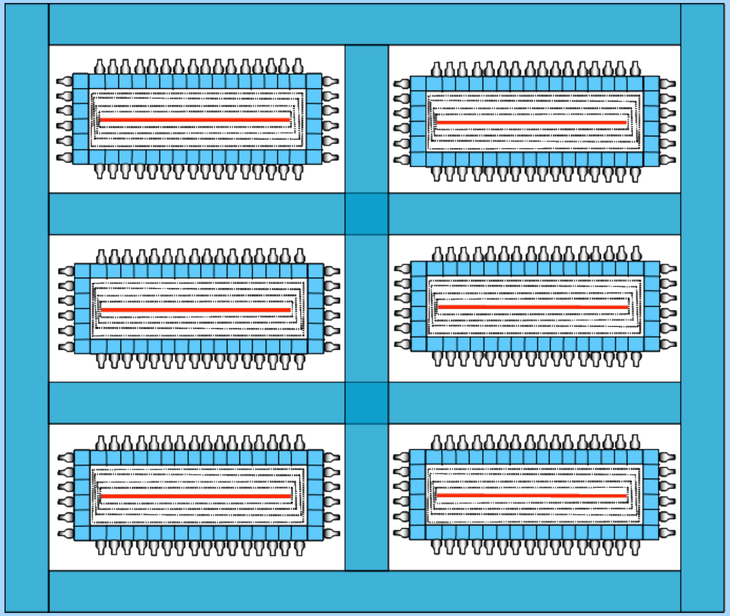
SuperNEMO

- continuation of NEMO-3
- 100 kg of source
- tracker + calorimeter
- modular (20 modules)
- better performance than NEMO-3
- 50-80 meV sensitivity
- energy resolution < 7% at 1 MeV where NEMO-3 has ~14%



Lightguide Studies - Motivation

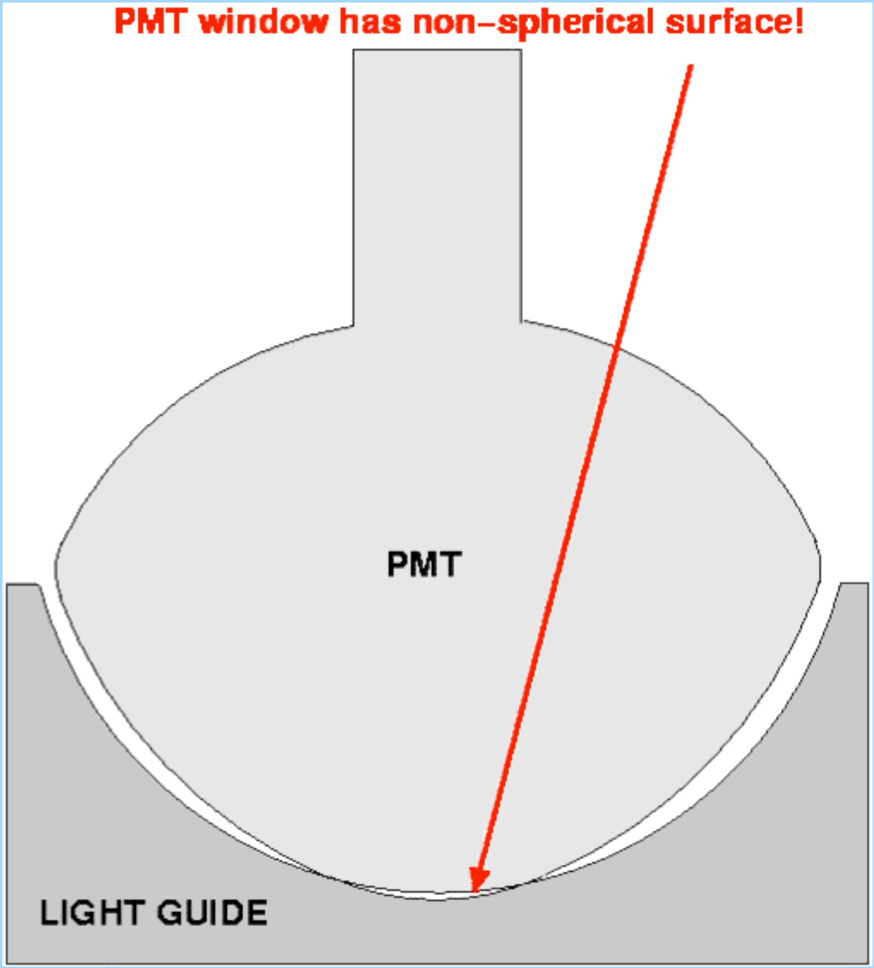
- With small 5x5 cm scint. we get nice resolution
- 7-7.5% at 1 MeV even ~6.8% for high QE PMT
- Baseline SuperNEMO design calls for 20x20cm scintillator blocks
- The biggest PMT with flat window is 5”
- It is likely we will need a concave light guide to couple to the hemispherical PMT window



Top View of 6 modules

Lightguide Problems

- PMTs not ideally hemispherical
- Not repeatable
- Standard optical gel (BC-630) not ideal due to its high viscosity
- Preliminary results from DETECT2000 simulations show configuration with light guide should not worsen resolution as long as the **optical contact is good!**



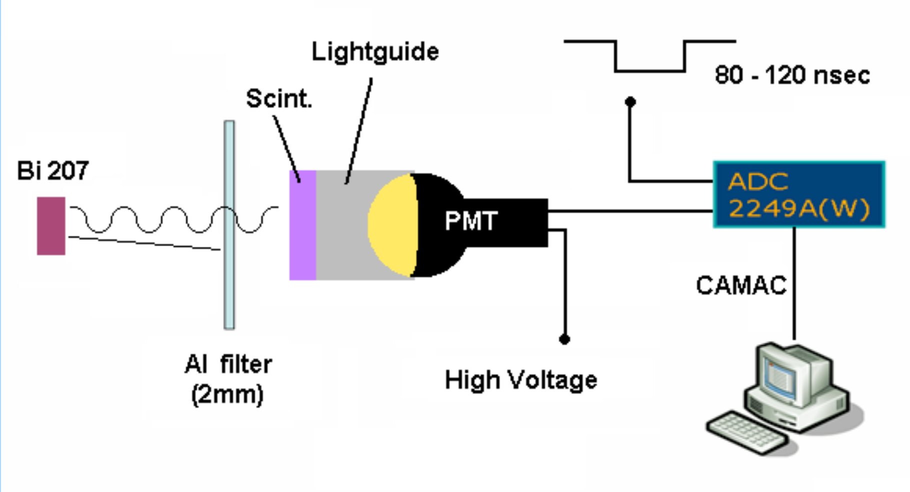
Suggested solution:

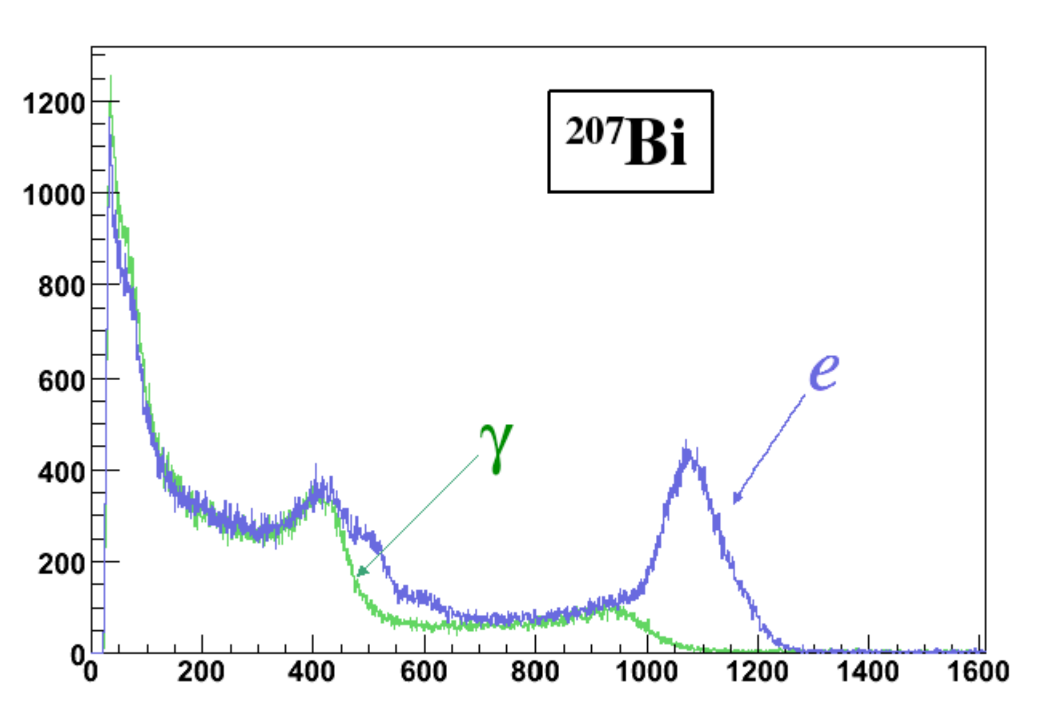
Fluid: Cargille Laboratories fused silica matching fluid type 06350

Viscosity ~ water and an index of refraction = 1.48

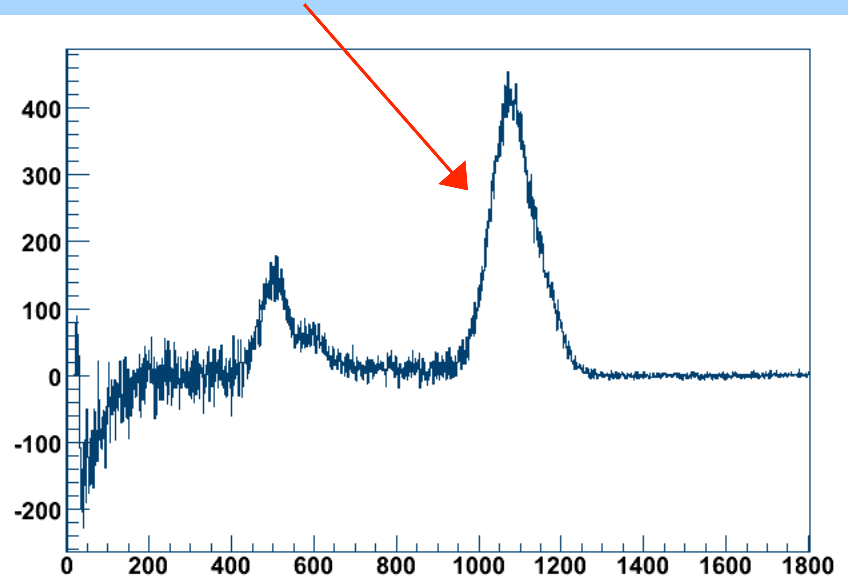
Test Setup

- use conversion electron from Bi207 source
- do a run with the full Bi207 spectrum
- do a run filtering out conversion electrons
- subtract the filtered run from the full spectrum

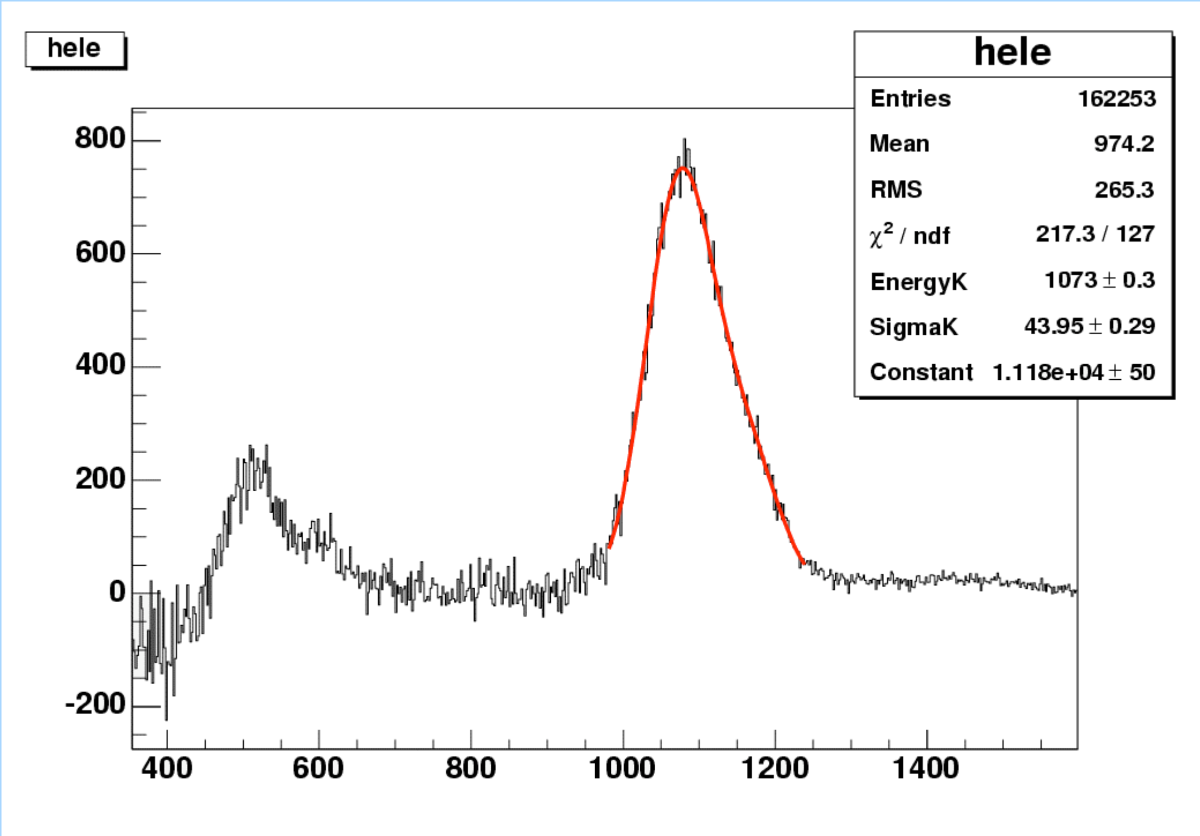




Fit the K, L, M conversion electron peak with 3 Gaussians

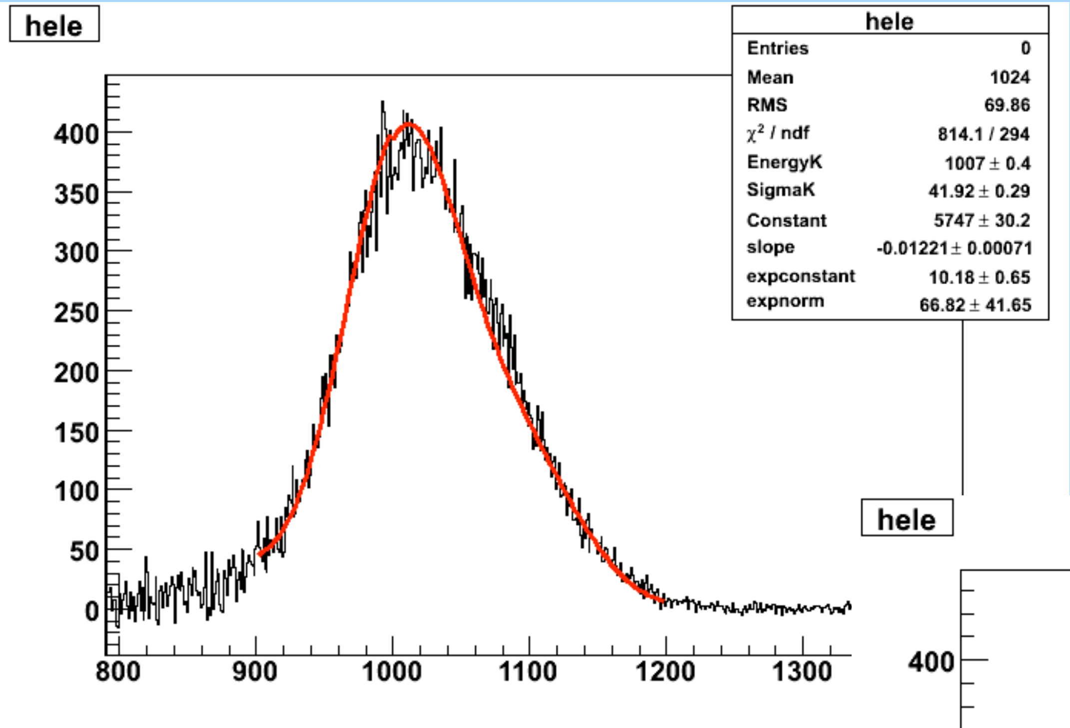


BC-630 Optical Gel Results

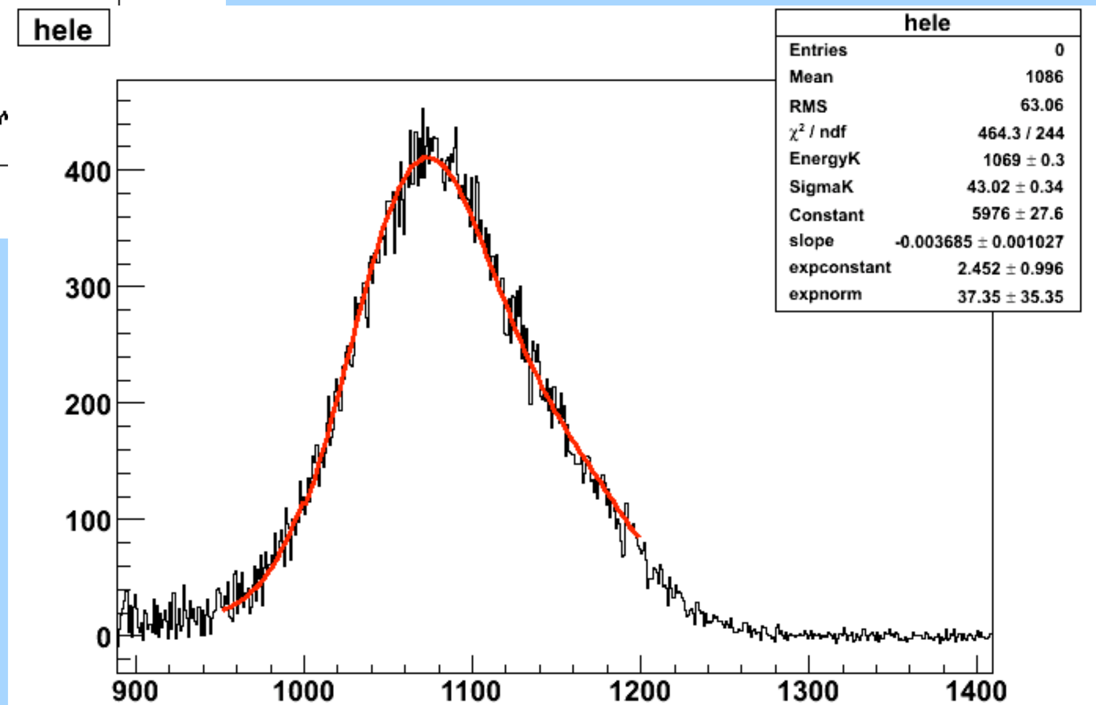


9.7% dE/E at FWHM at 976 keV

Optical Fluid 06350 Results



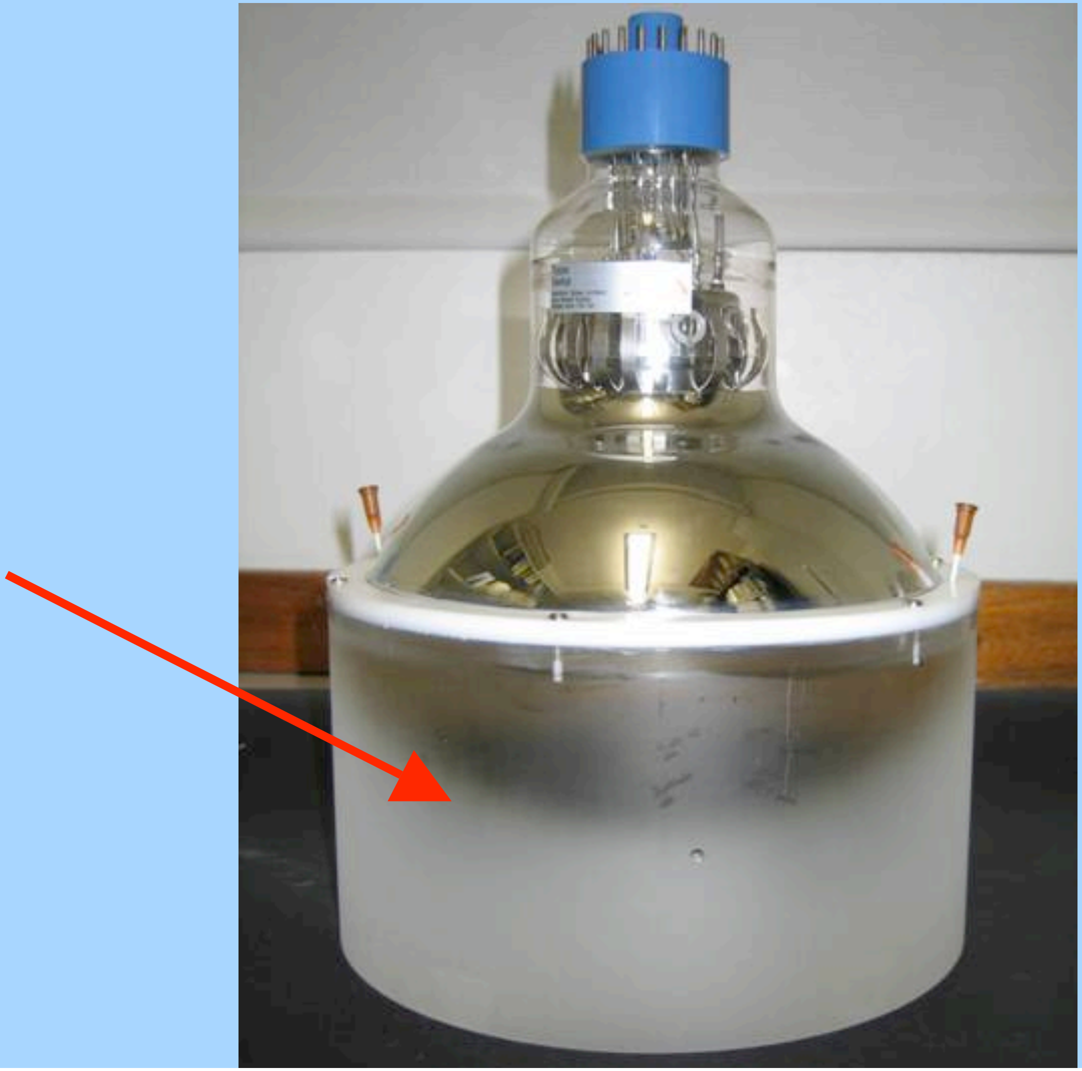
Mylar dE/E = 9.8% at 976 keV



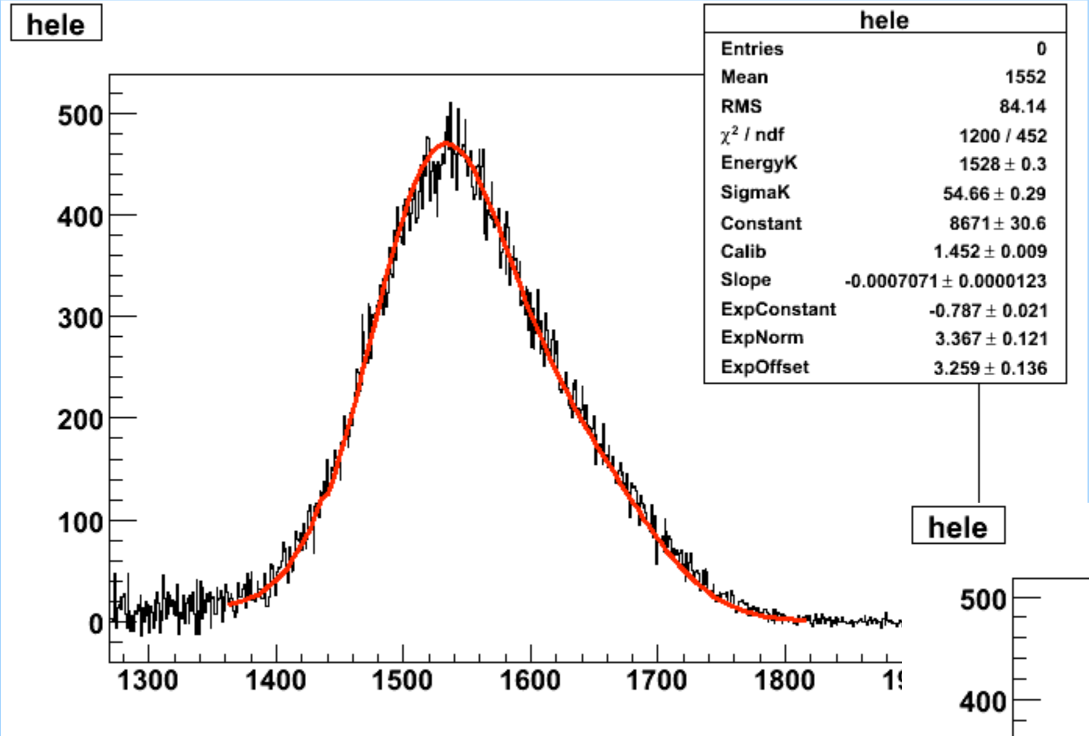
Teflon = 9.5%

Polish the surface of the lightguide to reduce diffusive reflections.
And see how strongly the resolution depends on this factor.

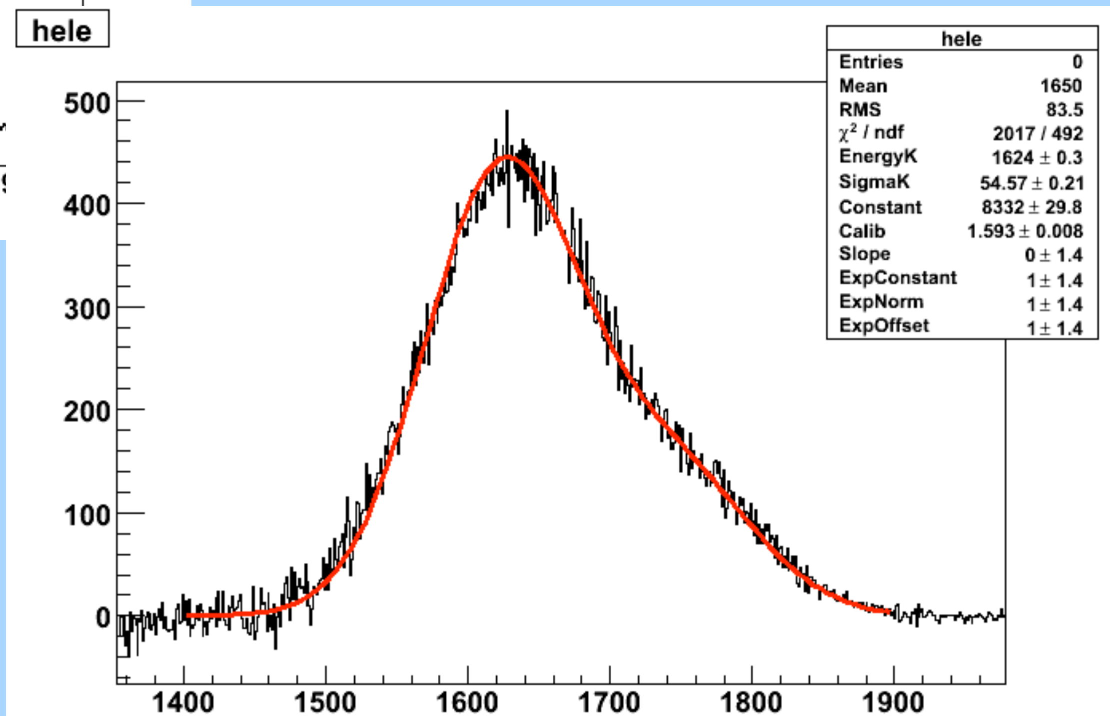
- Brian Anderson polished by hand for days and days….



Polished Lightguide with 06350



Mylar = 8.4%



Teflon = 8.0%

Looking better…

Future Plans:

- use LED and LASER to test transmittance of light guide as function of wavelength
- test new high QE PMs (~35-40%) from ETL and Hamamatsu
- do light simulations for PMT / lightguide coupling
- testing PMs and scintillator for SuperNEMO prototype
- "physics rich" SuperNEMO simulations