Response To Neutrons of a Xenon Based Dark Matter Detector

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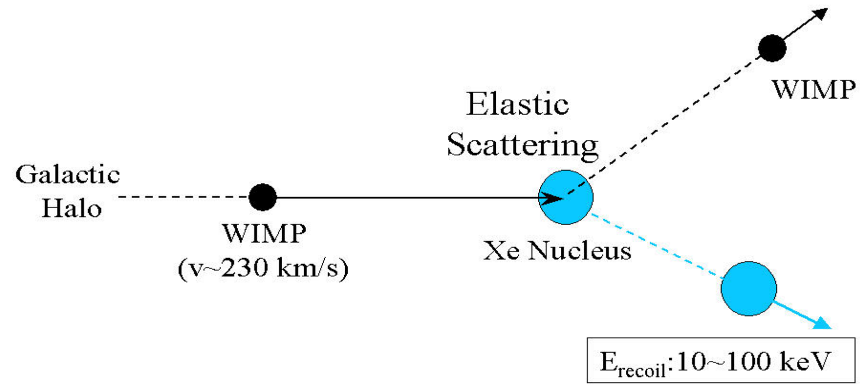
Outline

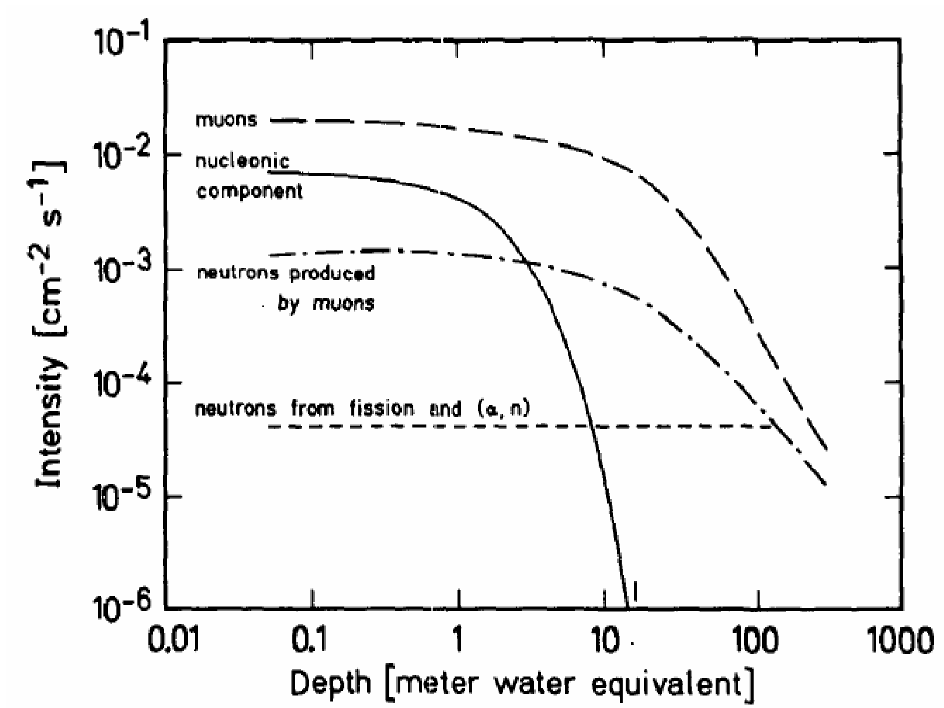
- Searching for dark matter particles called WIMPs
- Why neutrons matter in a WIMP search
- The XENON experiment
- Characterizing the Neutron response to XENON
- XeBaby - A dual phase Xenon detector
  - Experimental set-up
  - Data analysis
  - Features in the data
- Comparison of data and expectations
- Results and conclusions

Why neutrons matter in WIMP searches?

- WIMPs make ~22% of the Universe
- Direct searches look for elastic recoils of WIMPs off nuclei of target atoms.
- Rare WIMP scatters swamped by backgrounds -- Need to reduce/reject
- e-, gamma ->electron recoils->backgrounds

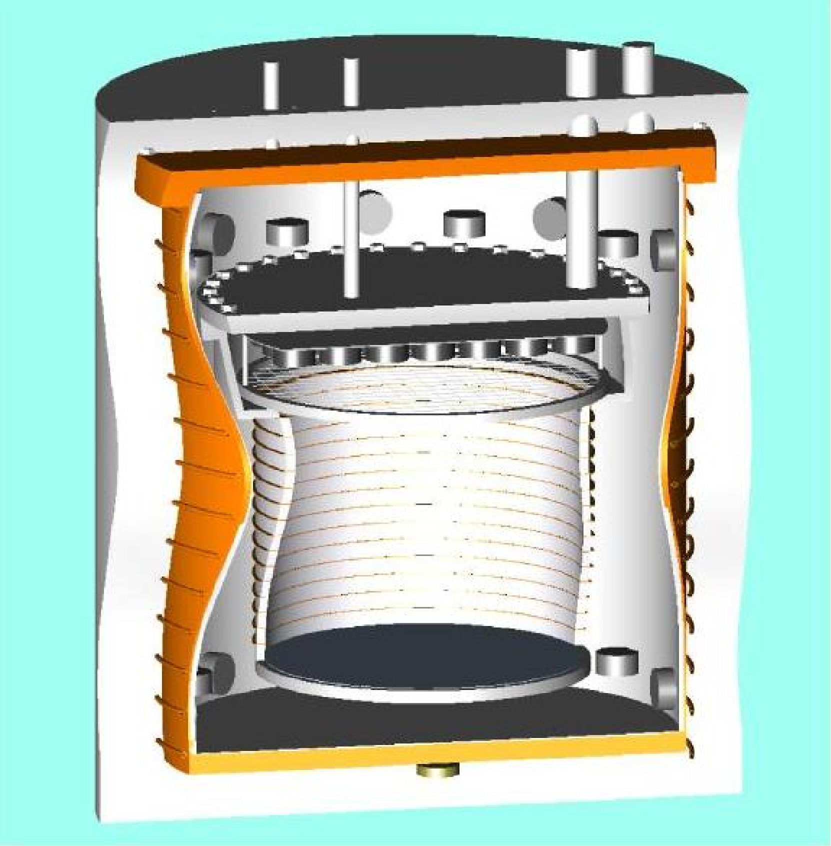
  WIMP, neutron->nuclear recoils->signal?
- Need to discriminate against neutrons





The XENON experiment

- Direct detection WIMP search
- 3D position sensitive dual phase (liquid/gas) time projection chamber with LXe target and LXe scintillator veto.
- Event discrimination by simultaneous detection of ionization / scintillations from recoils.
- Goal of >99.5% discrimination to 16 keVr.
- Plan to deploy 10kg prototype underground in end 2005.
- 100kg prototype to take data by 2008. Expected WIMP sensitivity of 2×10^{-45} cm^2.
- Current best limits(CDMSII) < 1.6×10^{-43}cm^2
- Scale to 1 ton for WIMP sensitivity of 10^{-46}cm^2.



-> talk by E. Aprile, Dark Matter/Energy Session I

The XENON Collaboration

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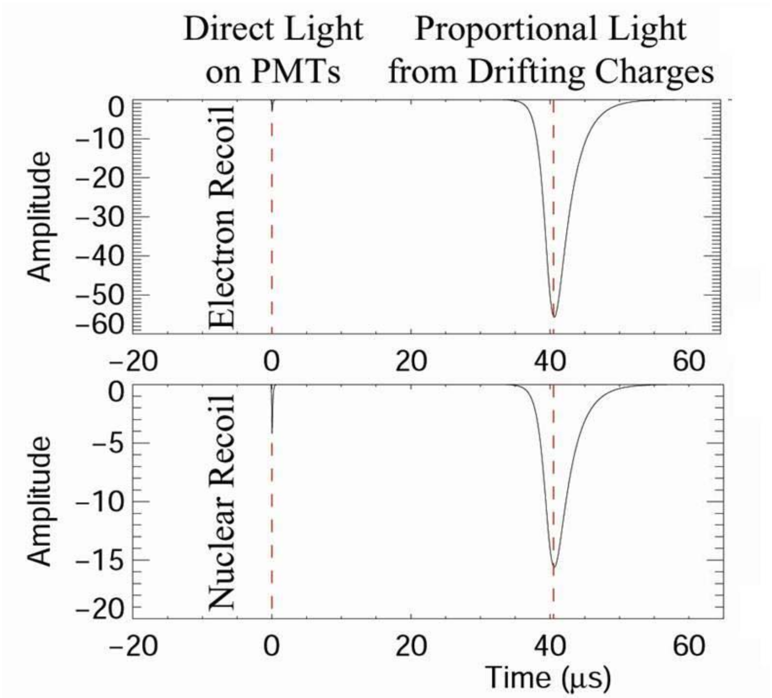
Event-by-event discrimination

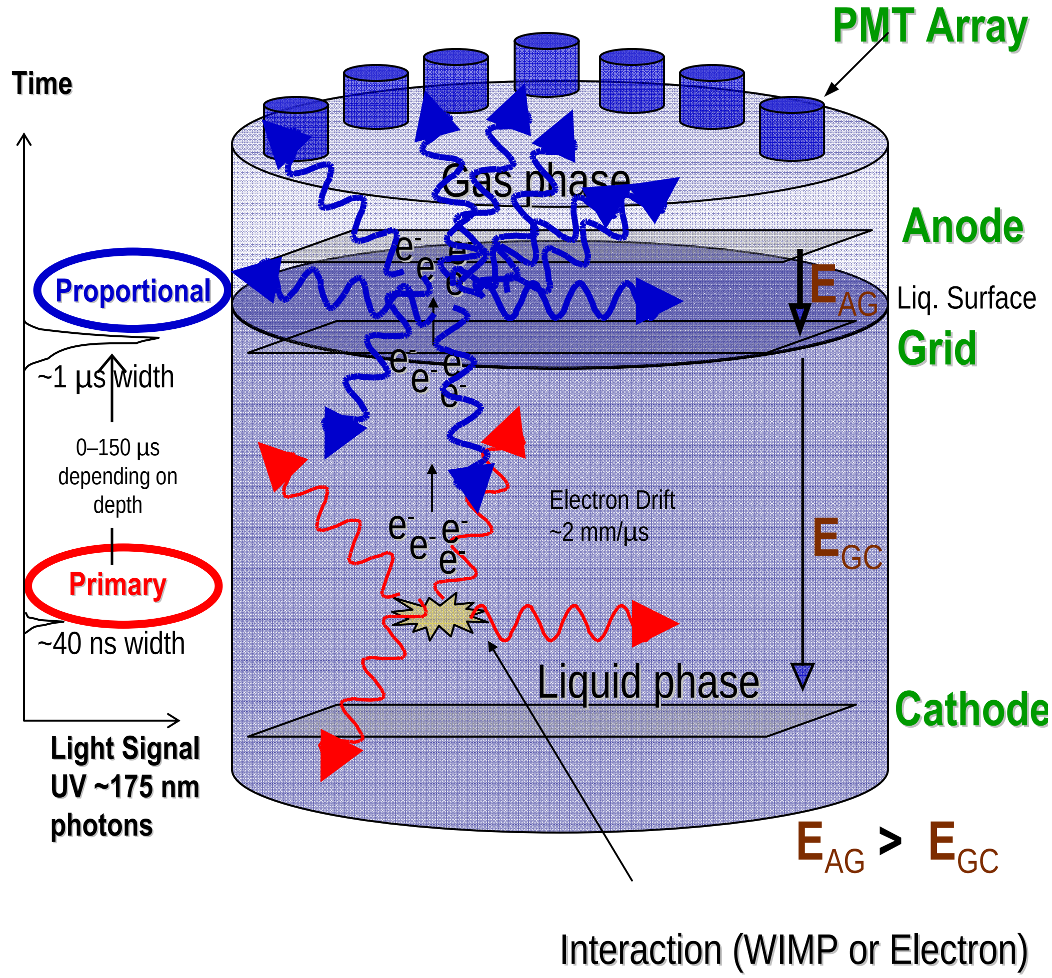
A particle interaction in Liq Xe produces:

- **Scintillation ->primary S1 light ;Ionization (charge signal)**
- **which drift up to the gas/liquid interface and are extracted in gas Xe**
- **to give Secondary light signal S2**

Slow nuclear recoils ->neutrons, WIMPs

Fast electron recoils -> γ, e^-





$(S2/S1)_{nucl.\ recoil} << (S2/S1)_{el.\ recoil}$

- discrimination

A dual phase Xenon detector

- Small dual phase Xe prototype
- Irradiated by 5 Ci AmBe source 45 cm away.
- 10 cm Pb shield to suppress 4.43 MeV γ
- 0.5 cm distance between grid and anode
- 65g fiducial volume between cathode & grid
- 2 two-inch PMTs, one in liquid, one in gas.
- ^{137}Cs and ^{57}Co sources for discrimination and calibration
- Drift field of up to 4 kV/cm used
- Field in gas up to 10 kV/cm
- Study ionization yield of nuclear recoils in LXe

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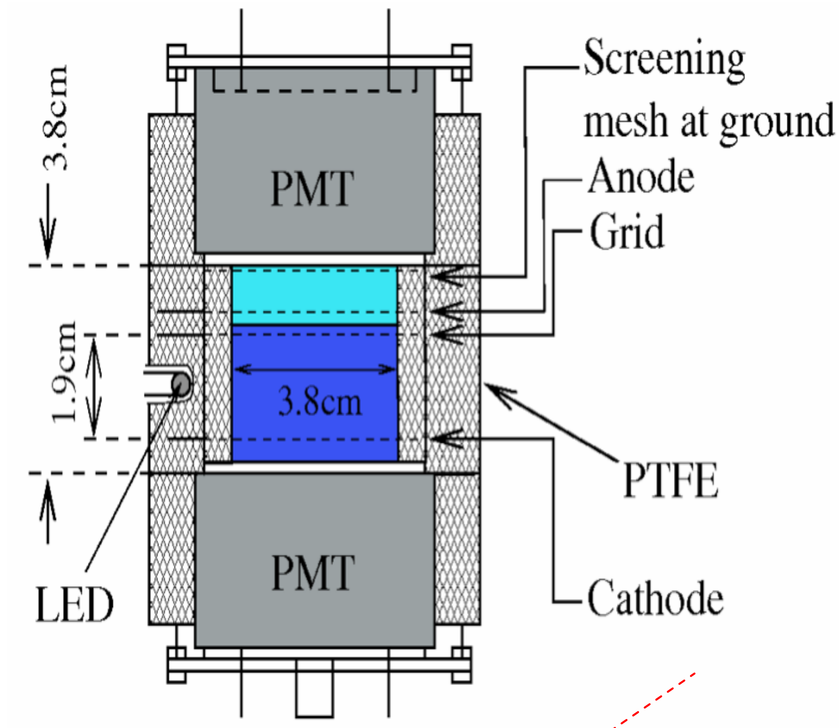
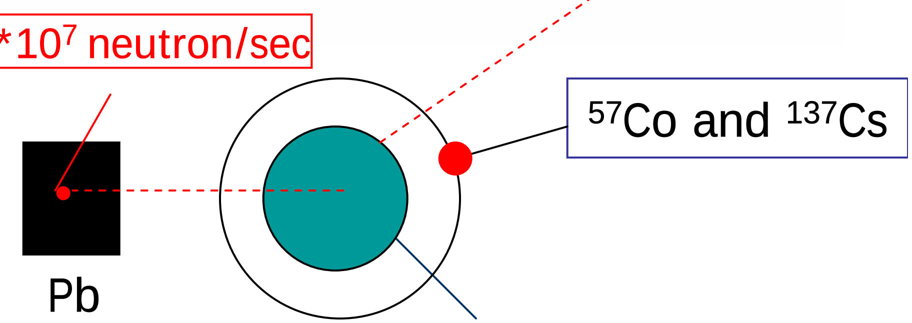
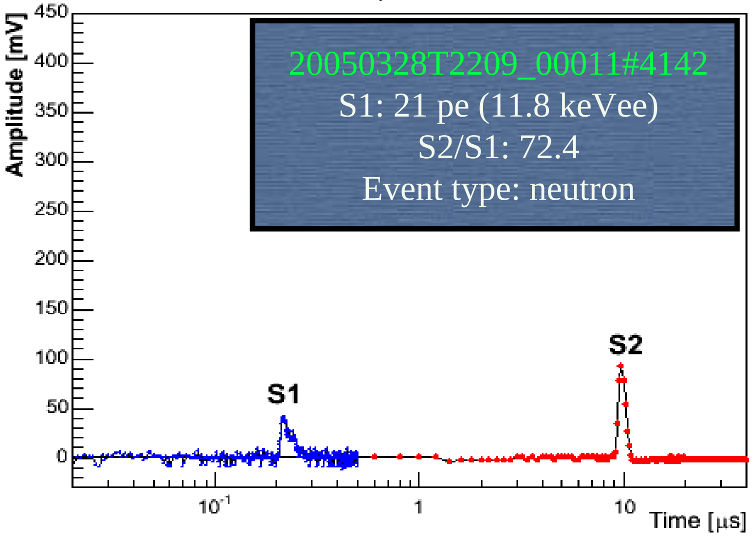


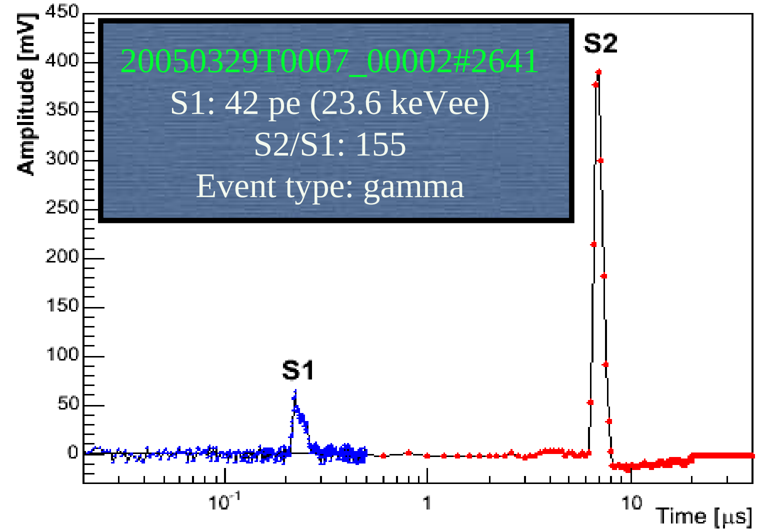


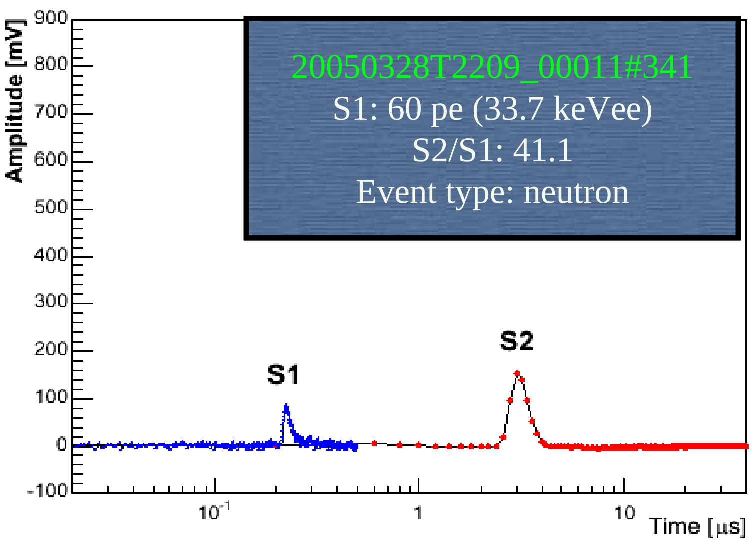
Event Waveforms

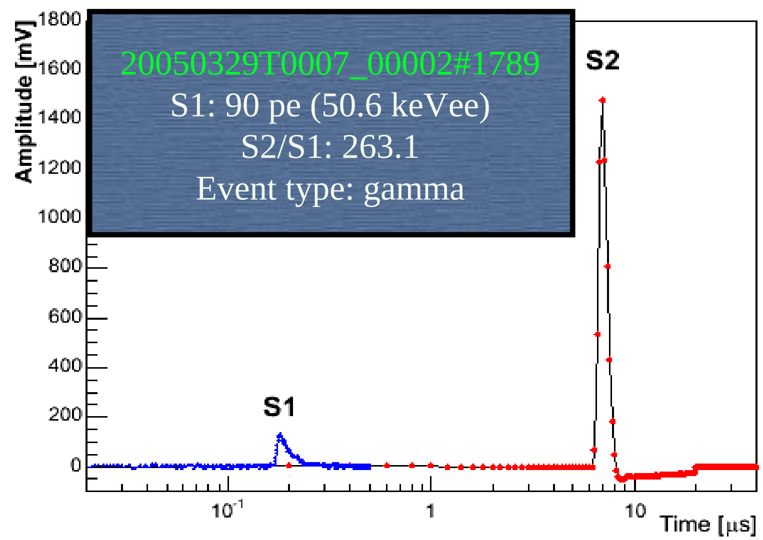
3.8 kV/cm, AmBe



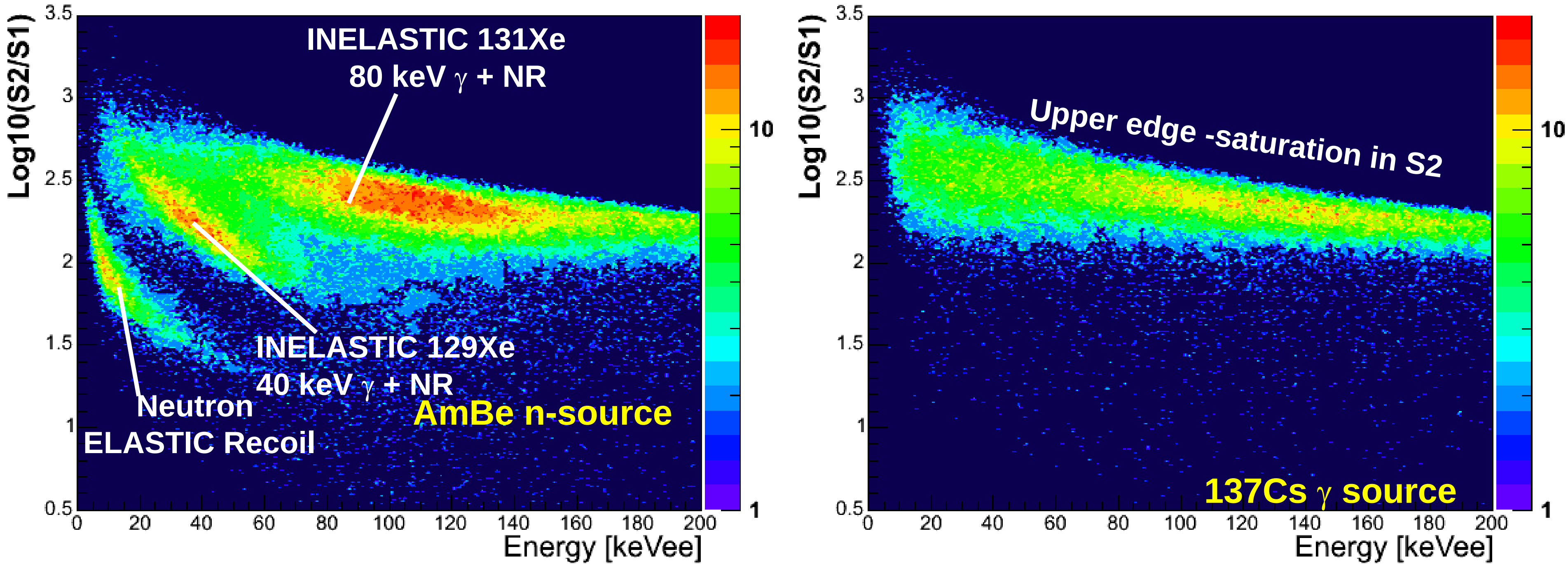
3.8 kV/cm, Cs-137





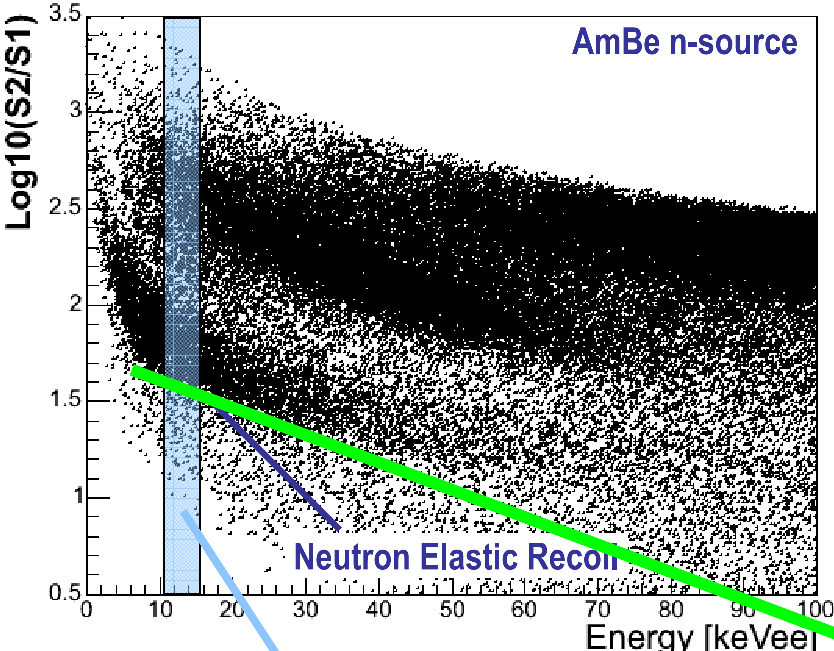


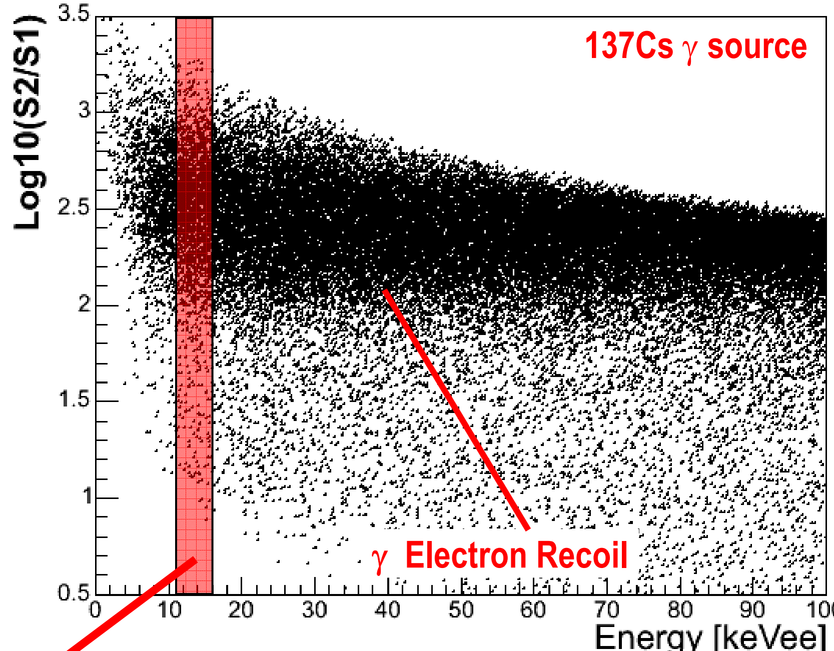
Response to AmBe & ^{137}Cs sources

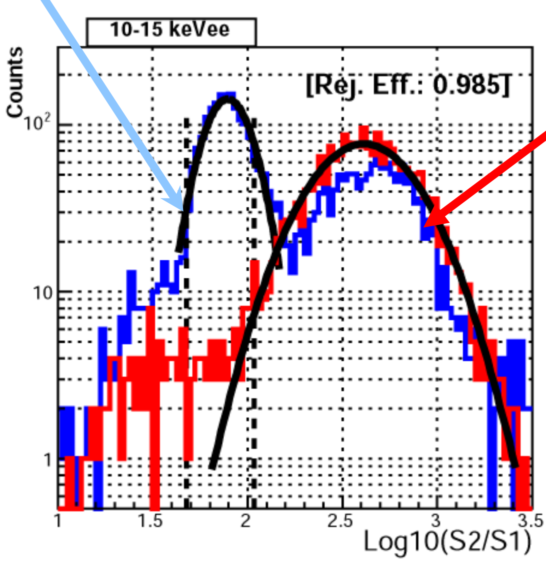


- Calibration of S1 and S2 signals in terms of pe/keVee
- Drift field of 2 kV/cm applied in the liquid
- Clear separation between Nuclear recoil band and electron recoil bands
- Nuclear recoil band down to 5 keVee --> 10 keVrecoil.

Response to AmBe & ^{137}Cs sources



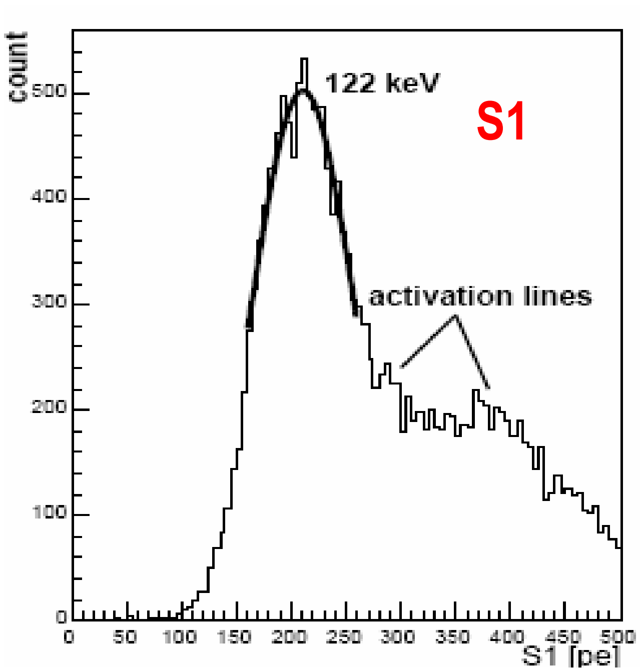


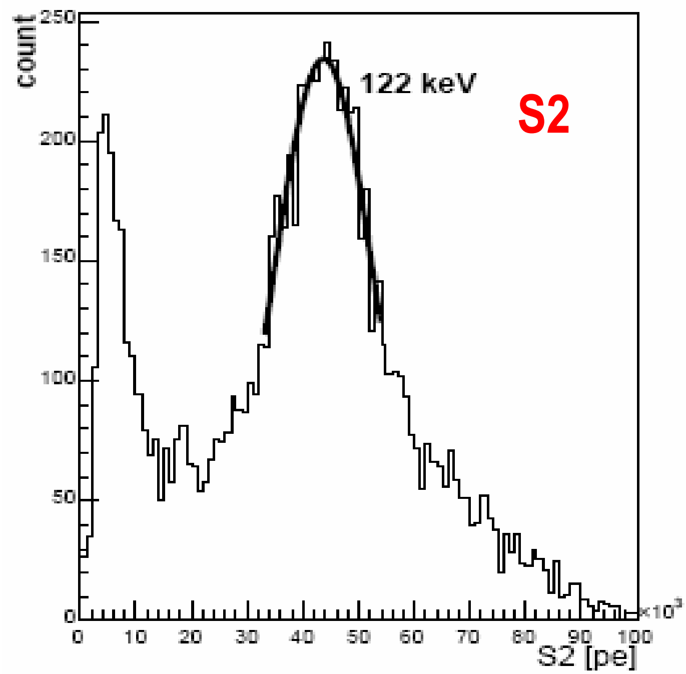


- Elastic recoil band down to 5 keVee --> 10 keVrecoil.

- 80% NR acceptance [-1.65σ, 1 σ]
- γ leakage mainly due to surface events
- further improvement through position cut with a 3D detector

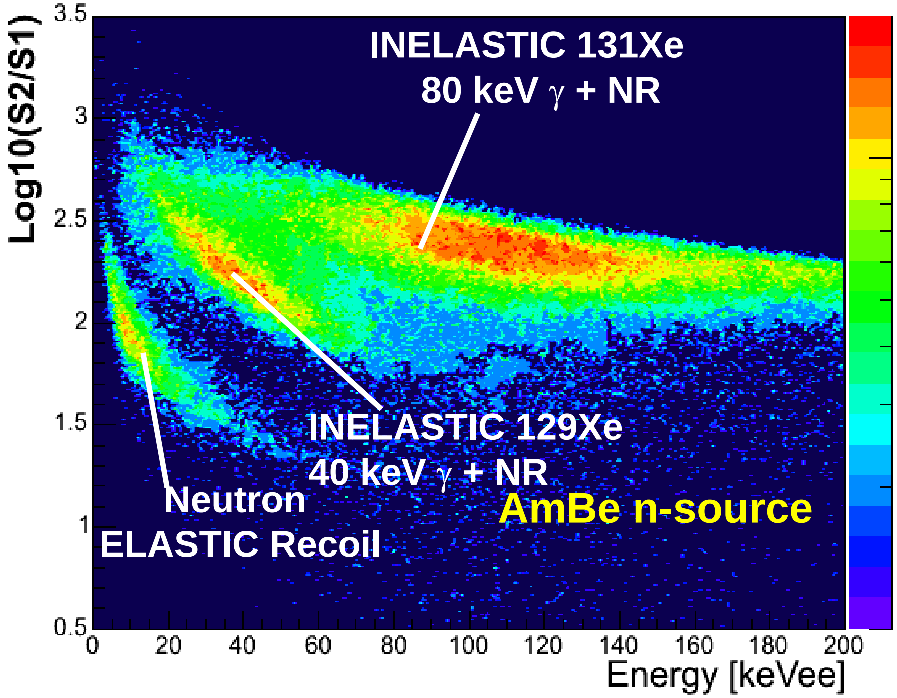
Energy calibration using ^{57}Co source

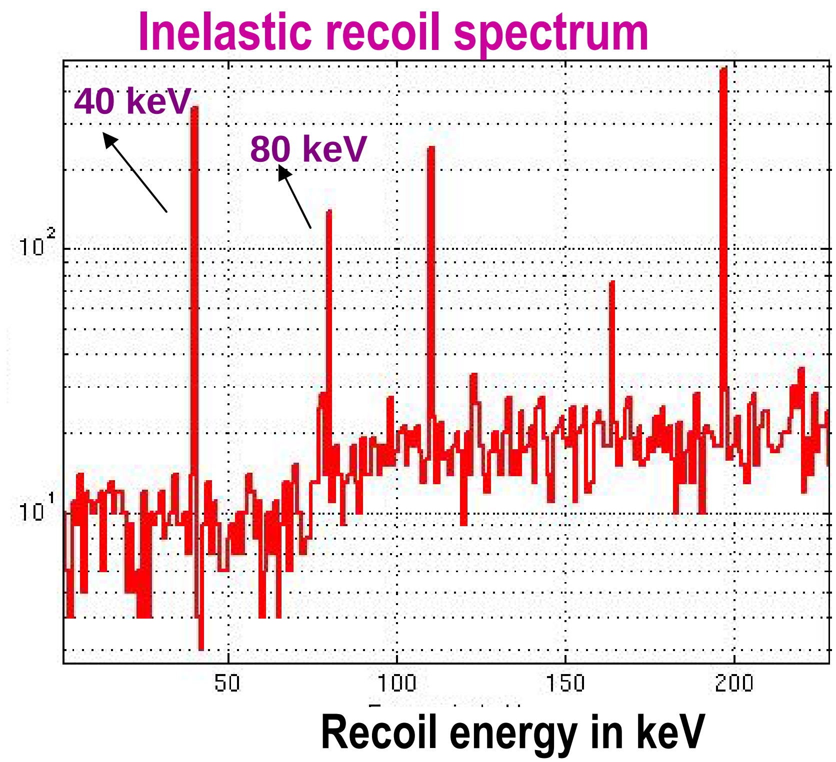




- Energy calibration of S1 and S2 signals using 122 keV line from ^{57}Co source
- S1, S2 in terms of photoelectrons pe/keV ; PMT gain calibrated using LED
- Cut on drift time > 3 μs to ensure choice of events in fiducial volume
- S1, S2 field dependent
- Field strength of 2 kV / cm => S1 : 122 keV corresponds to 210 p.e.

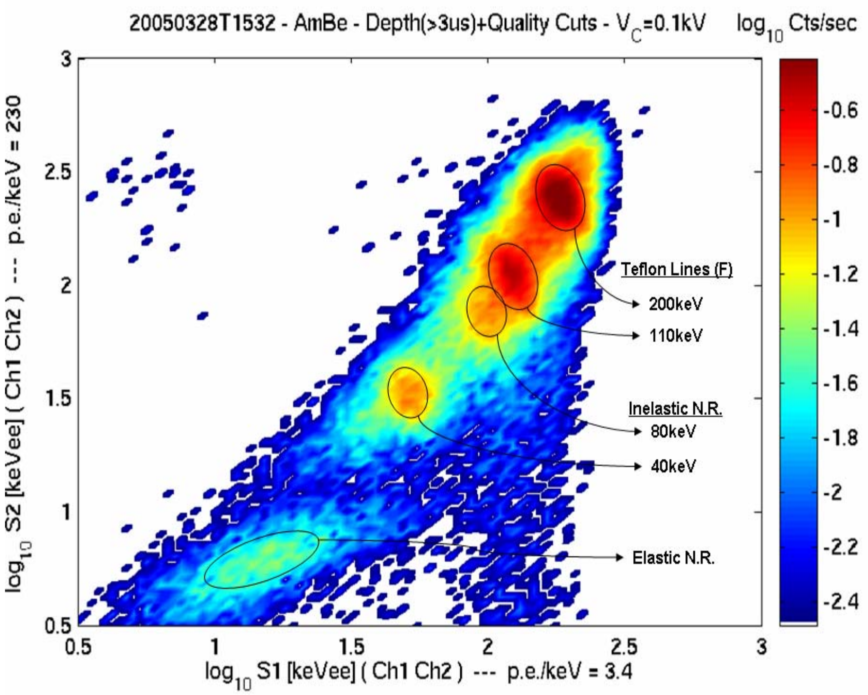
Neutron response to Xenon

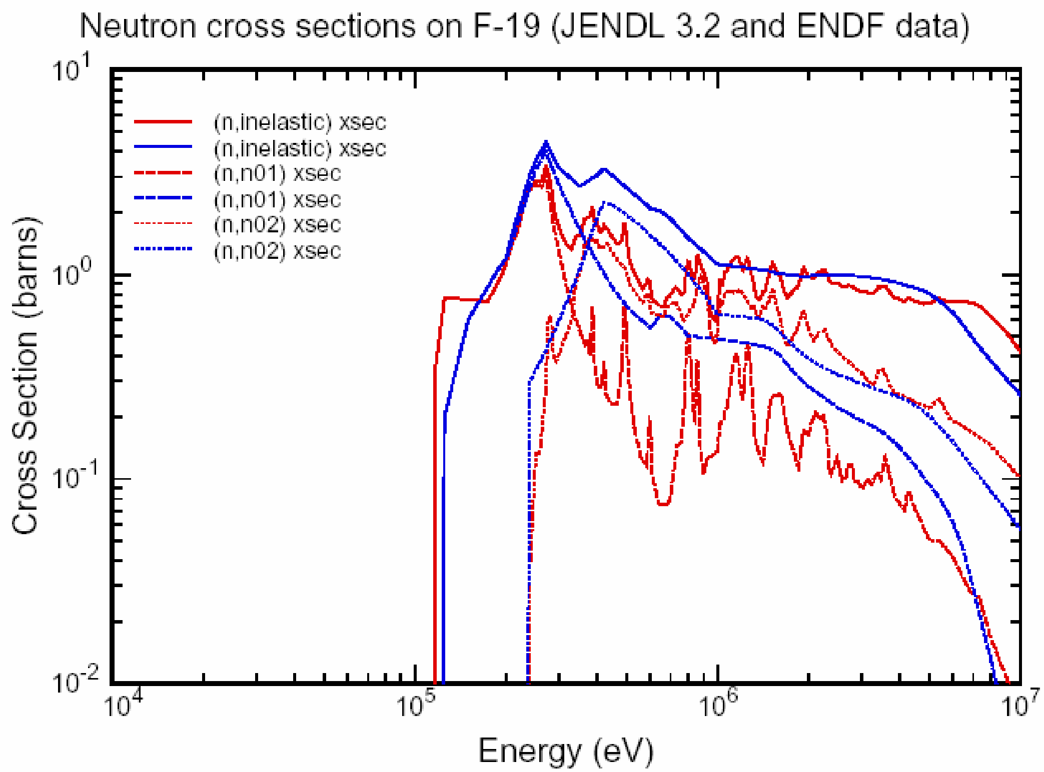




- Natural Xenon: 26% of ^{129}Xe, 21% ^{131}Xe, 27% of ^{130}Xe + 5 other isotopes
- Dominant contribution from ^{129}Xe, ^{131}Xe isotopes
- Features in recoil band
  - 40 keV band from ^{129}Xe$^{m.}$ excited state
  - 80 keV band from ^{131}Xe^{m} excited state
- Examine neutron cross sections on neighboring material ->PTFE (teflon)

Neutron response to Xenon

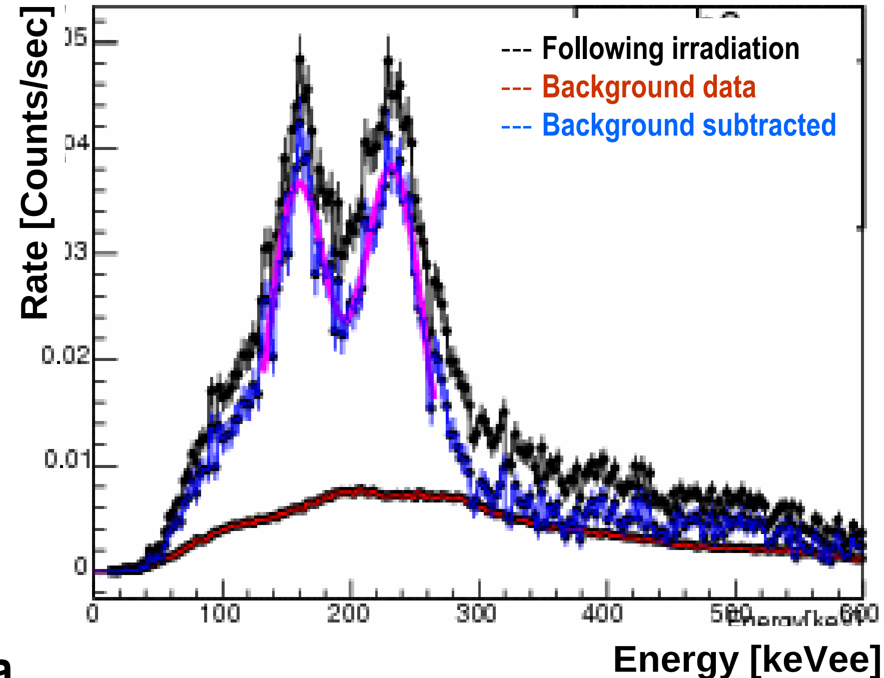




- **Natural Xenon: 26% of ^{129}Xe, 21% ^{131}Xe, 27% of ^{130}Xe + 5 other isotopes**
- **Dominant contribution from ^{129}Xe, ^{131}Xe isotopes**
- **Study inelastic and neutron capture cross sections to explain features in electron recoil band**
- **Examine neutron cross sections on neighboring material ->PTFE (teflon)**

Neutron activation of Xenon

- Study activation of LXe by neutrons
- Select data runs before / after 8 hour irradiation with AmBe source
- As no background run immediately prior to activation, normalize data run to earlier run without irradiation
- Use combined S1 + *a**S2 spectrum, *a* -> inverse of slope of S2/S1
- Subtract background.
- Fit gaussian to background-subtracted data
- Peaks at 164 keV from ^{131}Xe
  236 keV from ^{129}Xe

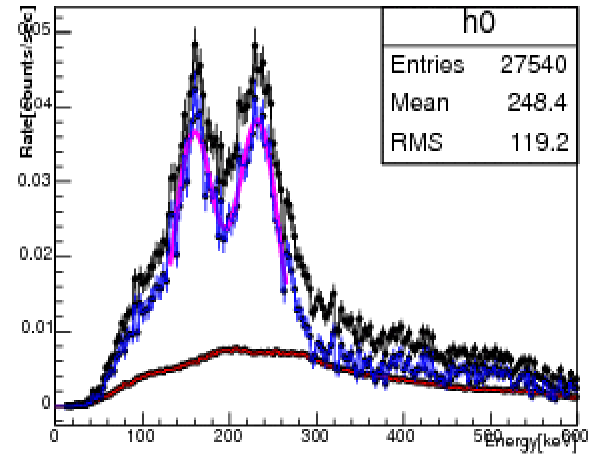


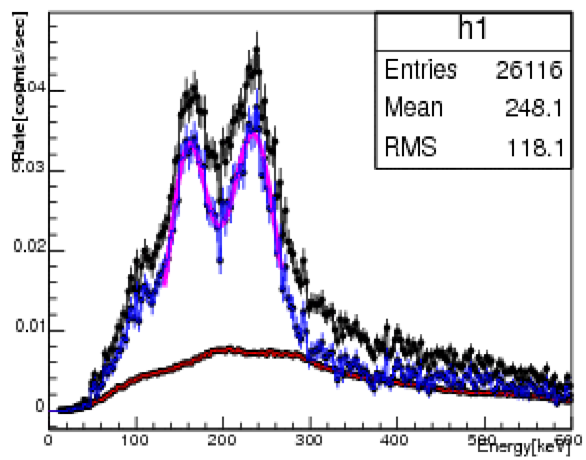
^{A}El	Z	Energy	Half-life
^{131}Xe	54	0.0	Stable
^{131}Xe	54	80.18	0.48 ns
^{131}Xe	54	163.93	11.84 days
^{131}Xe	54	341.14	1.64 ns

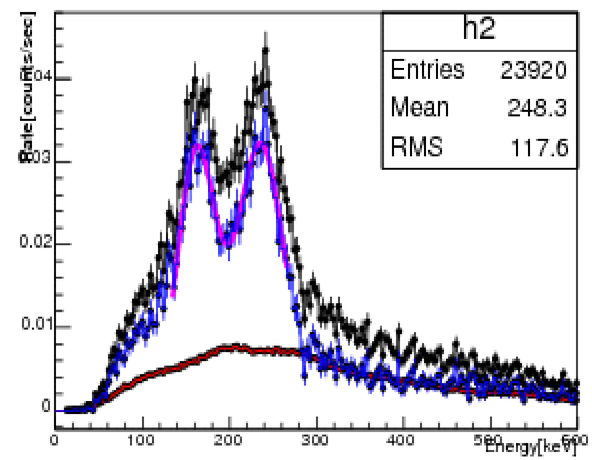
Isotope	Abundance (percent)	Isotopic cross section in barns
128	1.89	5 > 0
129	26.41	45 ± 15
130	4.03	5 > 0
131	21.24	120 ± 15
132	27	5 > 0 (0.02)
134	10.49	5 > 0 (0.02)
136	8.93	5 > 0 (0.15)

Neutron activation of Xenon

- Peaks at 164 keV from ^{131}Xe
  236 keV from ^{129}Xe
- Peaks monitored every hour over a period of time after removal of source







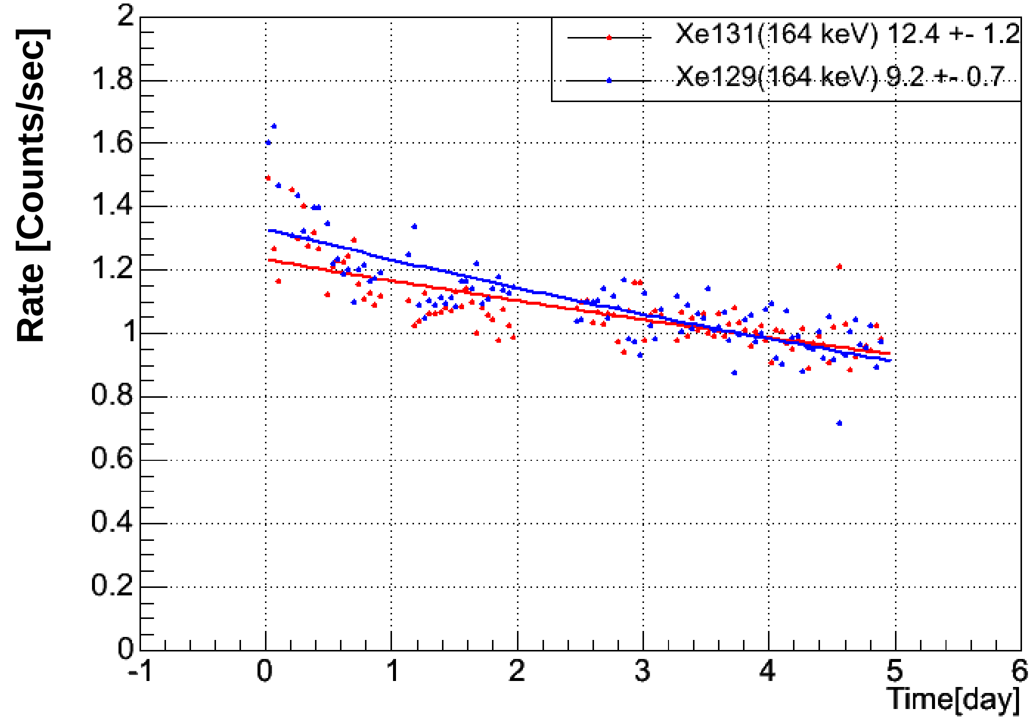
Neutron activation of Xenon

- Activation studied over 5 days following 8 hour irradiation with AmBe
- Two activation lines seen:
  - 240 keV : ^{129}Xe
  - 164 keV : ^{131}Xe
- Half life from fit to data

^{129}Xe : 9.2 ± 0.7 days half-life

^{131}Xe : 12.4 ± 1.2 days half-life

agrees well with databases



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^{A}El	Z	Energy	Half-life
^{129}Xe	54	0.0	Stable
^{129}Xe	54	39.578	0.92 ns
^{129}Xe	54	236.14	8.88 days
^{129}Xe	54	274.28	

Conclusions

- Study neutron response to dual phase Xenon based detector
- Inelastic contributions from ^{129}Xe, ^{131}Xe and ^{19}F (PTFE - surrounding target)
- Thermal contribution studied
- Activation lines can act as internal calibration measure
- Work in progress on relating data and simulations