Novel germanium detectors for the MAJORANA experiment

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Outline

Searching for $0\nu\beta\beta$ in 4 easy steps

- Identify a candidate isotope: (e.g. ^{48}Ca, ^{76}Ge, ^{130}Te, ^{136}Xe). Obtain lots of it.
- Make a detector (Source = Detector, or Source + Detector)
- Identify and reduce backgrounds (low-background materials, go underground, analysis cuts, etc.)
- Wait

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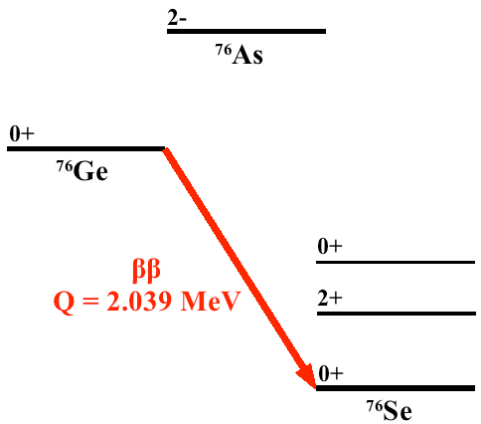
Advantages of germanium

- Source = Detector
- High resolution (e.g. $\sim$0.16% at 2039 keV)
- Background rejection (e.g. Pulse-shape analysis, segmentation)
- High-purity: reduce intrinsic contaminations
- Enriching ^{76}Ge content: established technique
- Easily arrayed
- Q-value: 2039 keV



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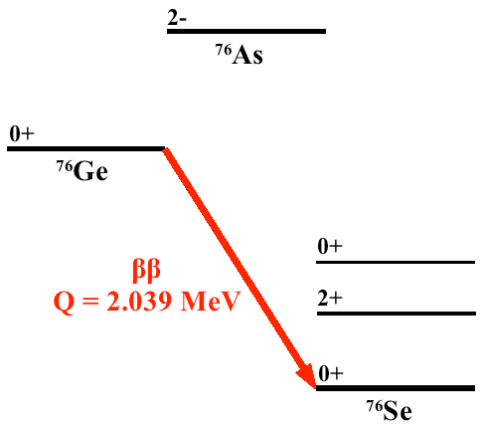
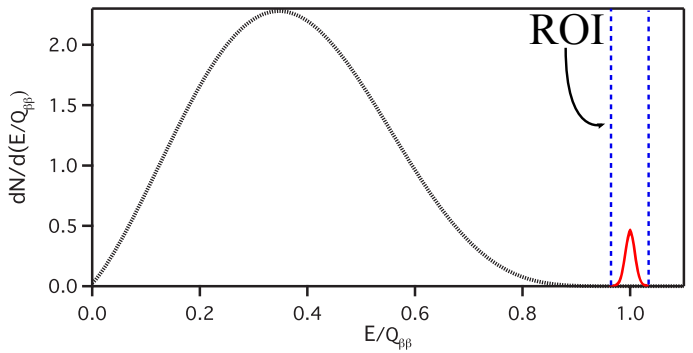
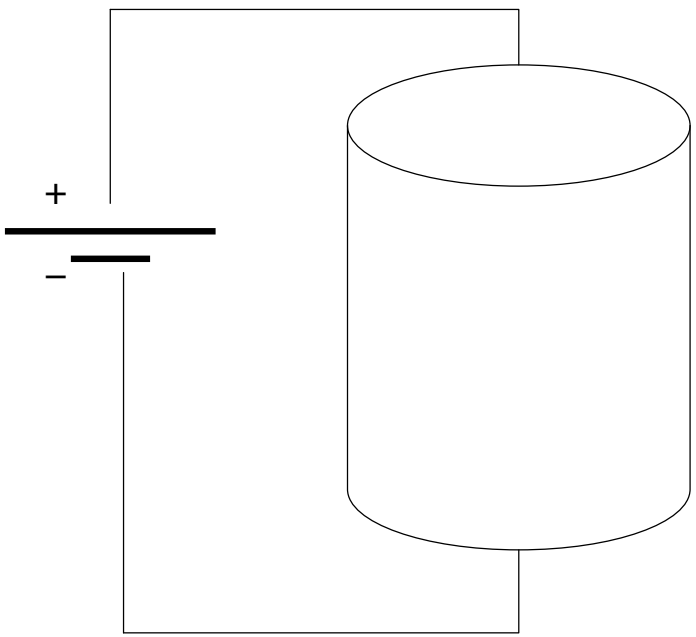


Backgrounds of the MAJORANA experiment



Background Source		Rates for Important Isotopes cnts/ROI/t-y			Total Est. Background cnts/ROI/t-y
		^{68}**Ge**	^{60}**Co**		
Germanium	Gross:	13.49	1.35		
	Net:	0.09	0.05		0.14
		^{208}**Tl**	^{214}**Bi**	^{60}**Co**	
All Materials	Gross:	1.31	1.12	2.17	
	Net:	0.6	0.37	0.04	1.01
Surface Alphas	Alphas originating from all surfaces				0.56
External Sources					0.35
$2\nu\beta\beta$					$<$0.01
			TOTAL SUM		2.07

Solid State Detectors: A crash course



A few basic ideas:

- Apply a reverse bias to a semiconductor diode:
  - Sweep out free charge
  - Create a 'depletion' region
- Depletion region = active detector volume
- Deposit energy into depletion region:
  - Free electron-hole pairs ($N \sim E_{dep}$)
  - Charge carriers swept to their respective electrodes

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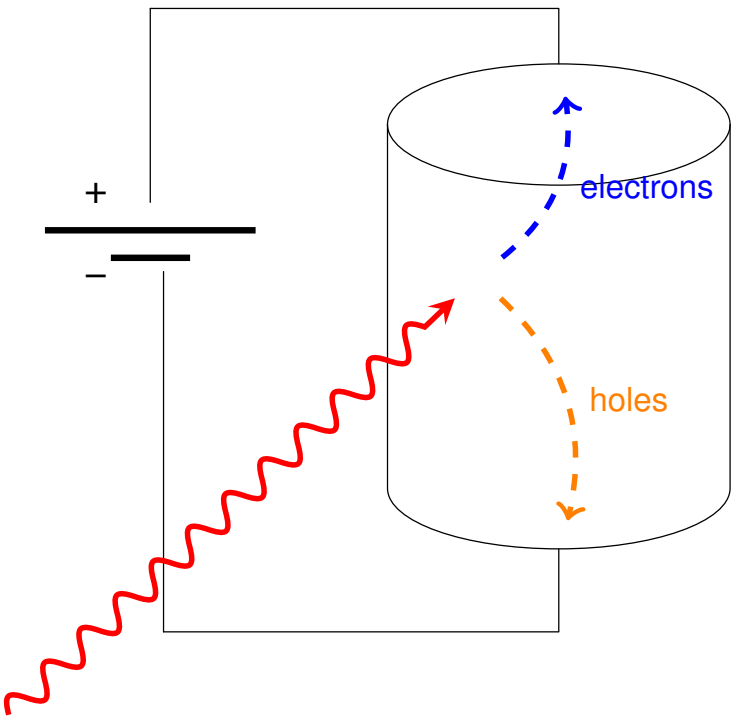
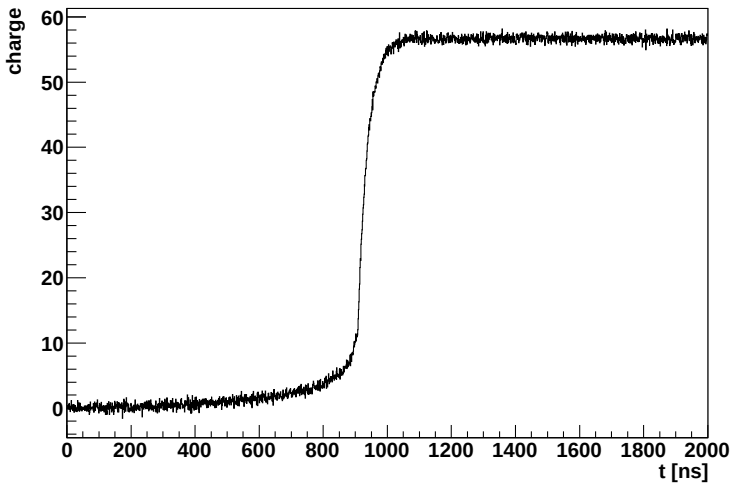


e.g. Single-site event



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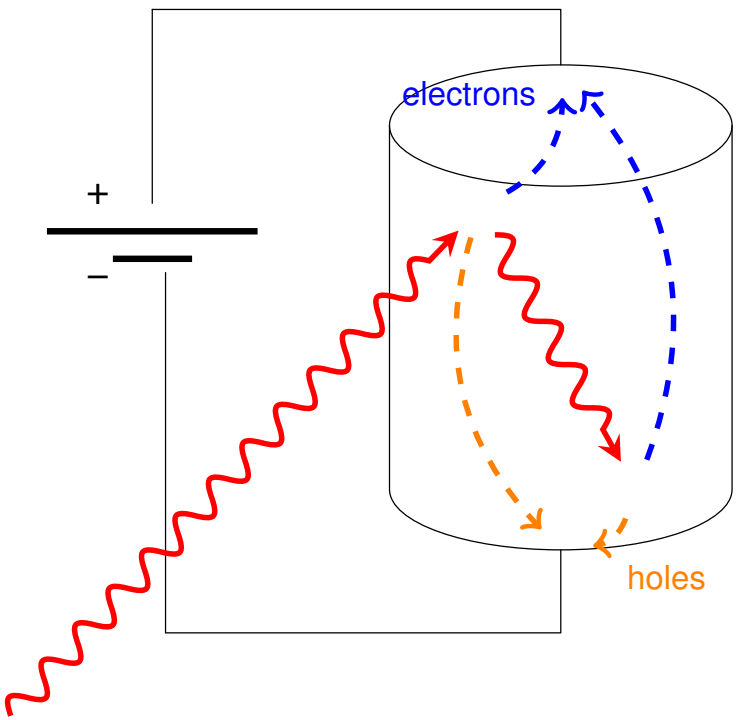

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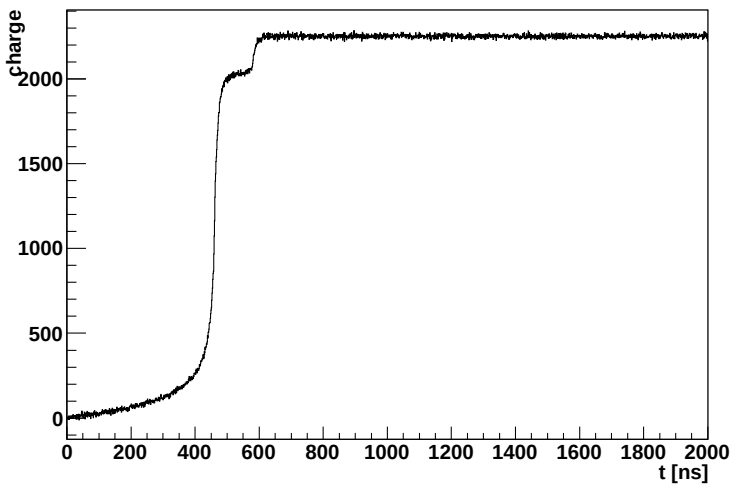
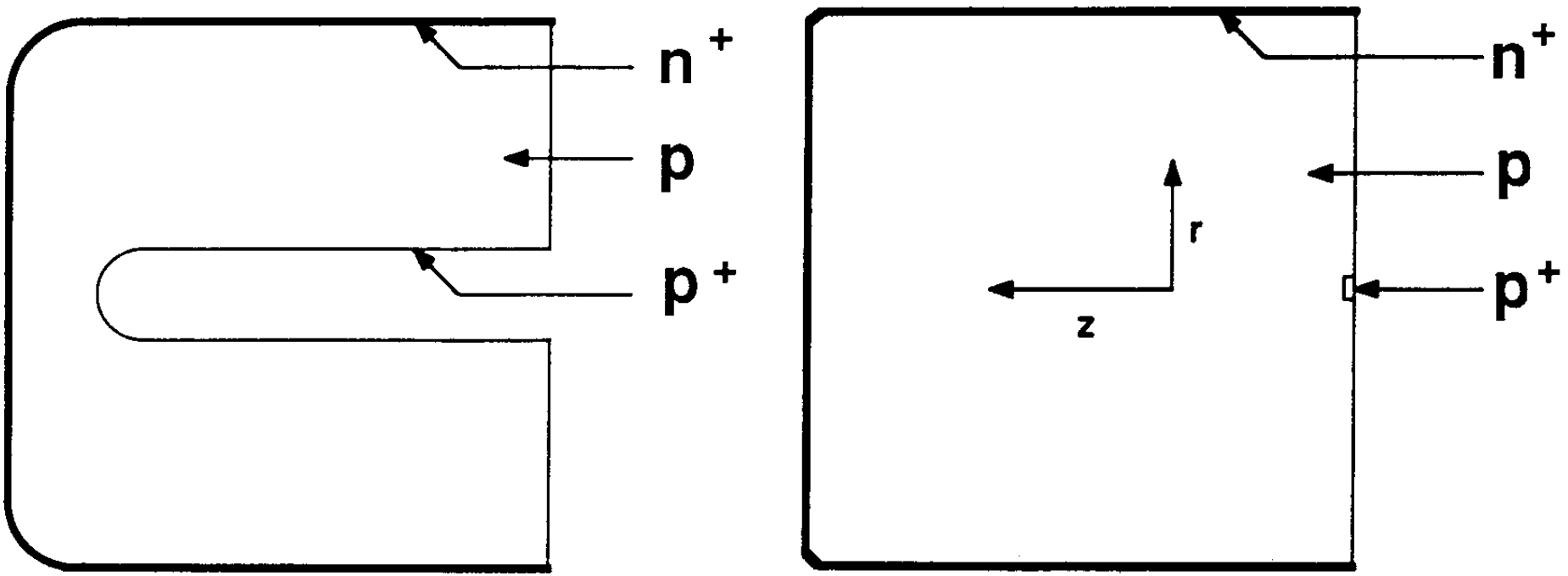


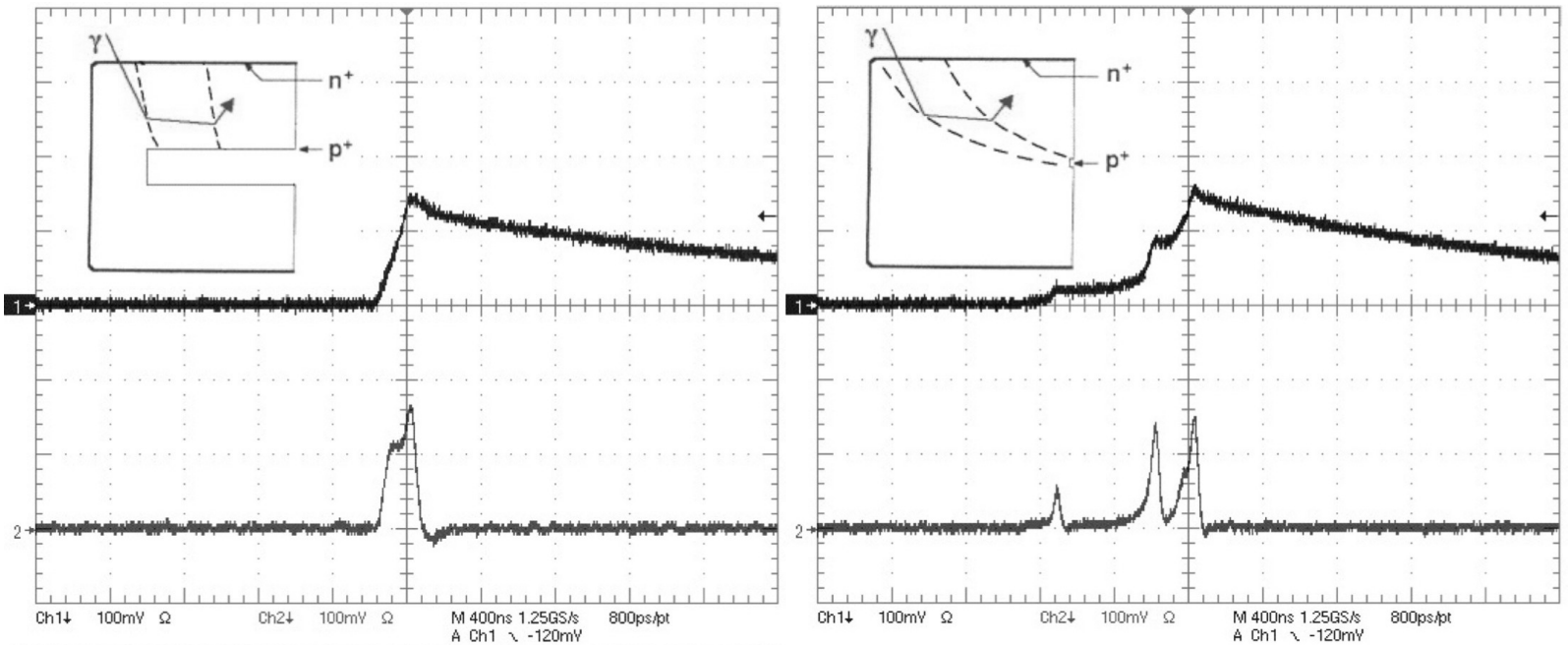
P-type Point Contact (P-PC) Introduction

Low capacitance and therefore low noise (Low energy threshold $\sim$100 eV)



Luke, et al., IEEE Transactions on Nuclear Science, 36 (1989), 926

P-PC Introduction: Charge collection times



Barbeau, et al. JCAP09 (2007) 009

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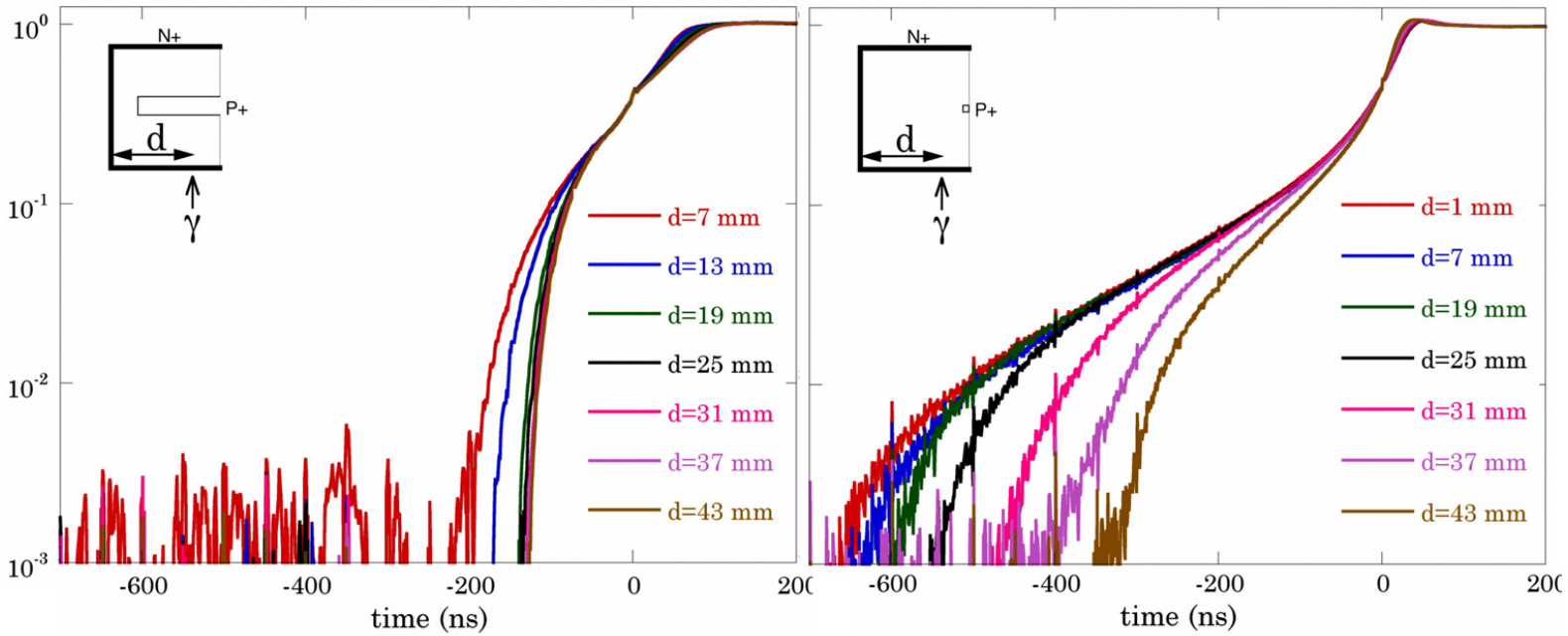

Barbeau, et al. JCAP09 (2007) 009

Background reduction: Low Energy Threshold

^{68}Ge (cosmogenic, $\sim 1 - 10$ atoms/kg/day at the earth's surface, enriched ^{76}Ge)

$$^{68}\mathrm{Ge} \xrightarrow{\epsilon,\ T_{1/2}=271\ \mathrm{d}} {}^{68}\mathrm{Ga} \xrightarrow{\epsilon,\ T_{1/2}=68\ \mathrm{m},\ Q=2921\ \mathrm{keV}} {}^{68}\mathrm{Zn}$$

Goal: Tag ^{68}Ge when it initially decays, veto for a few ^{68}Ga half-lives.

^{68}Ge decays	Percent	Energy (keV)
K-capture	86.4%	10.3
L-capture	11.5%	1.3
M-capture	2.0%	$\sim$0.1

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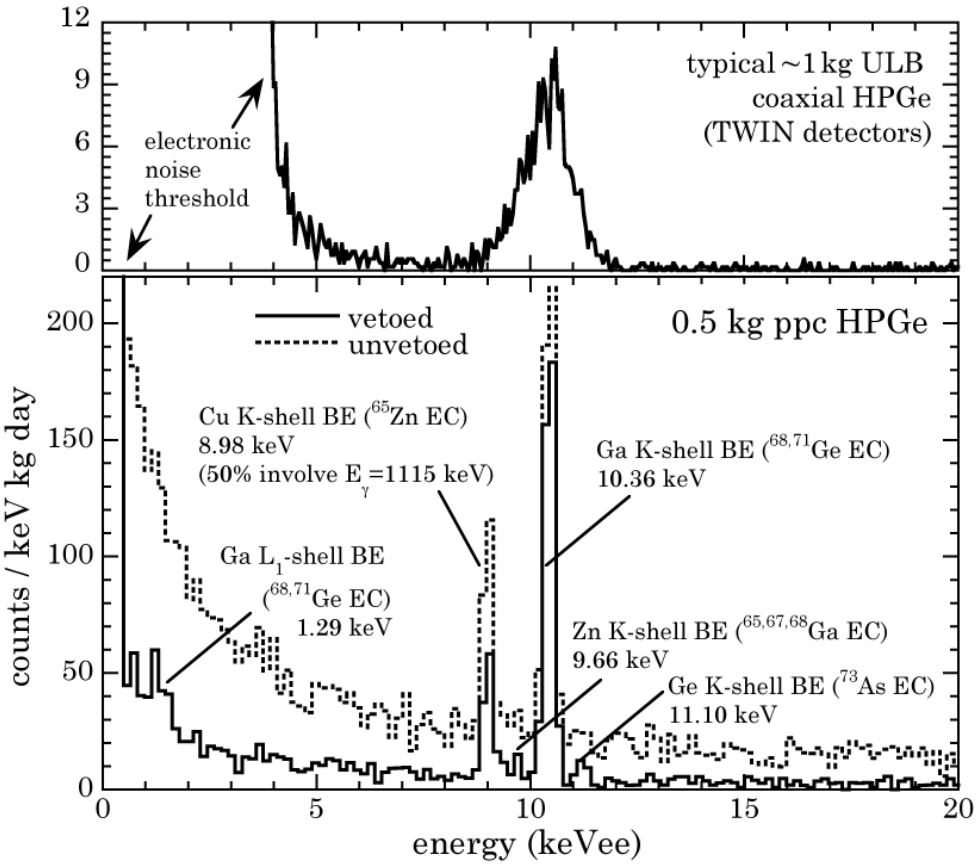
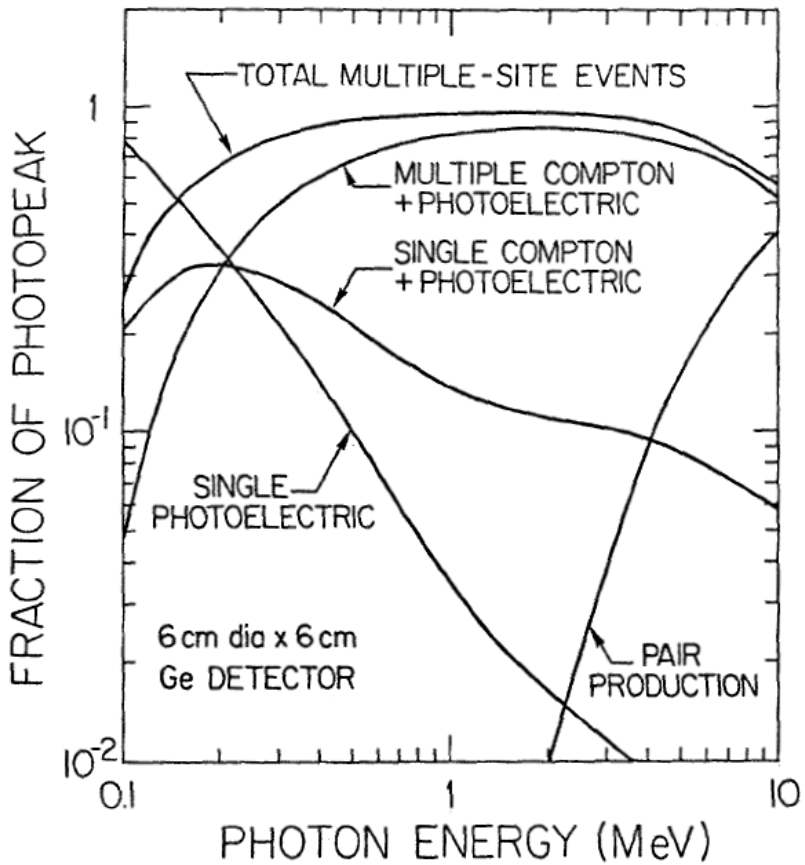


Plot from J. Collar

Background reduction: Multi-site rejection

- Dominant energy loss by γs in Ge at $\sim$MeVs: Compton scattering, multi-site events
- Time expansion of pulse by P-PC improves multi-site tagging



6 cm $\times$ 6 cm coax Ge detector, simulated photons on face of detector
IEEE Trans. Nucl. Sci. **31** (1984) 367

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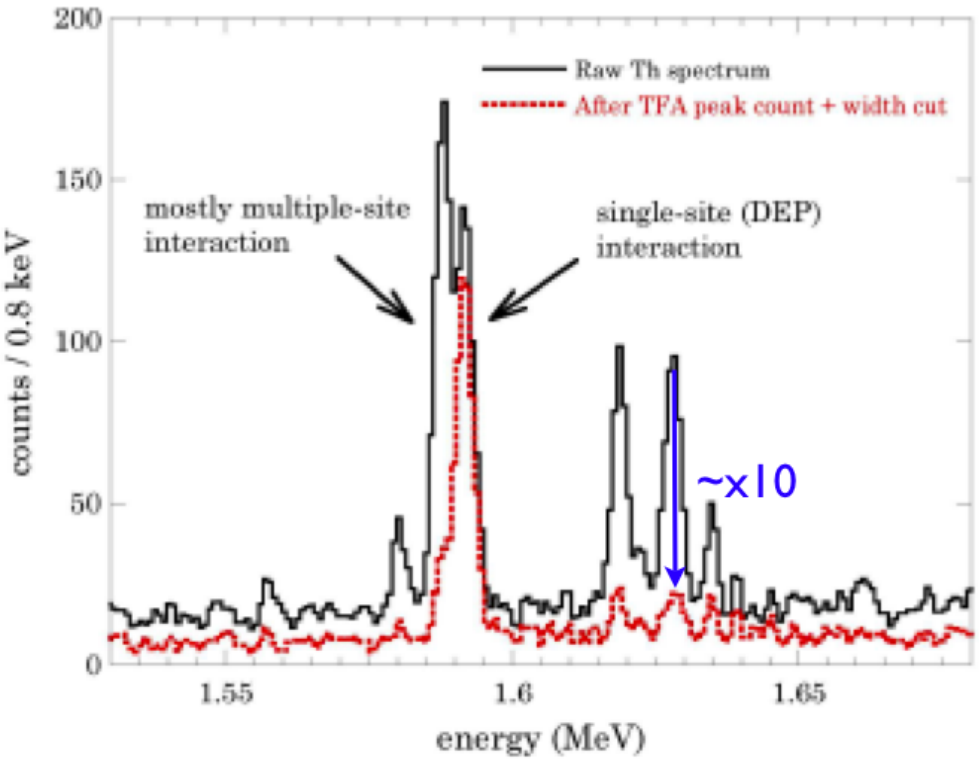
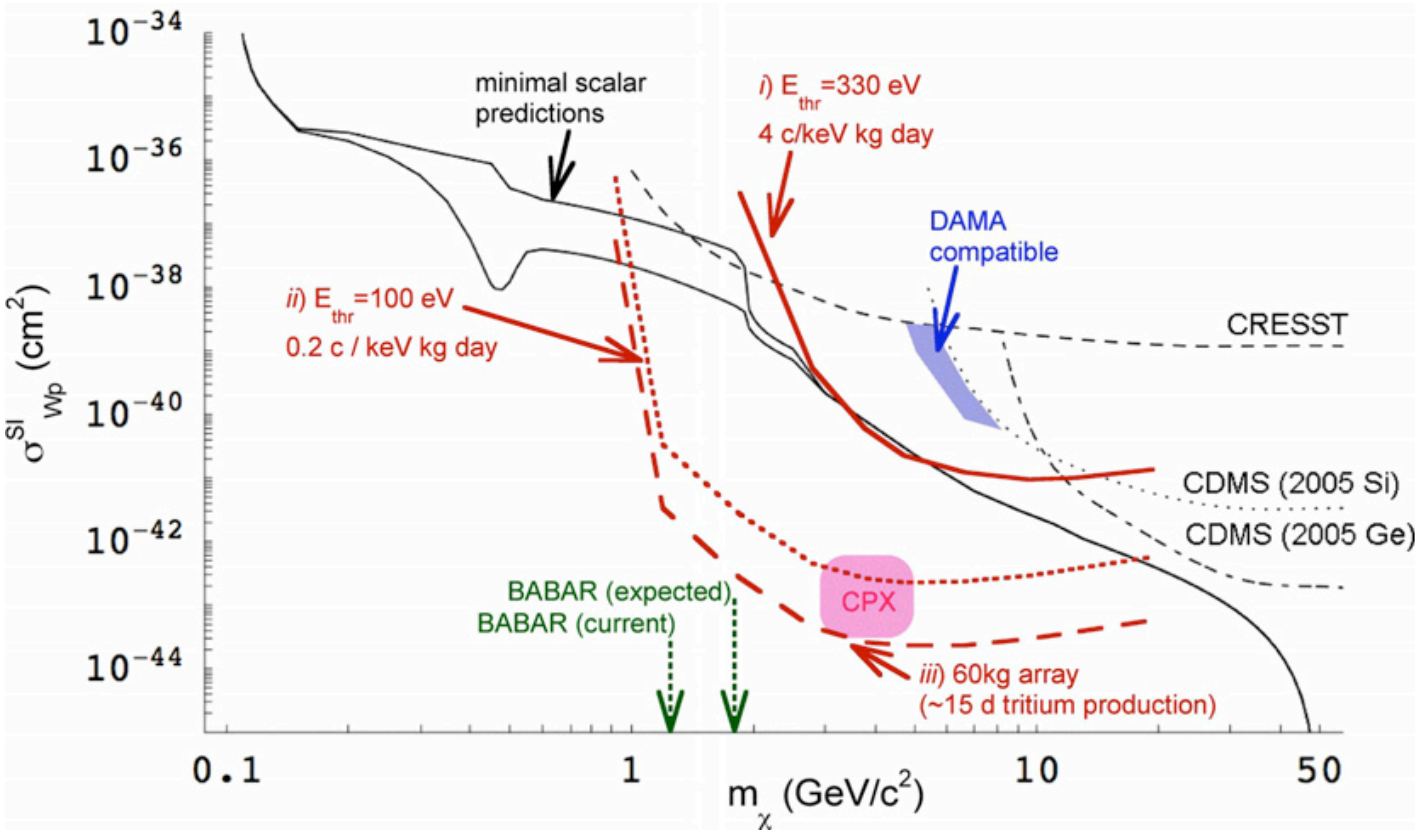


MAJORANA experiment's sensitivity to Dark Matter?



Outline

Status for the P-PC

- P-PC detectors have characteristics (low threshold, longer charge collection) to improve a search for $0\nu\beta\beta$
- 4 detectors currently available or under construction within the collaboration
- MAJORANA plans to deploy an array of unenriched P-PC detectors for R&D beginning the end of this year