GDT Symposium 2015

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

Infamous Last Words

Let me start with R & D and then discuss why and what for.

I.Abt, MPI für Physik

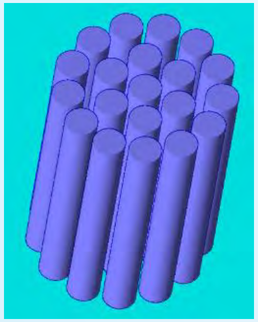
Germanium Detector Technology

Two lines of development:

- **specialty detectors to understand germanium and detector response**

interesting and attractive →

- **“mass” production detectors**

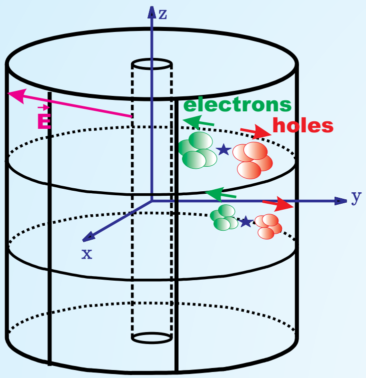


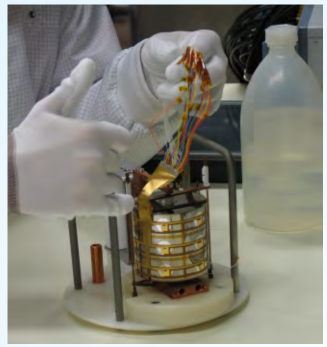
boring and cumbersome

kiss —
keep it simple stoopid...

Germanium Detector Technology

coax





threshold: ~5keV

NDBD okay   DM not

useful to study

all kinds of effects

→ always fully metalize

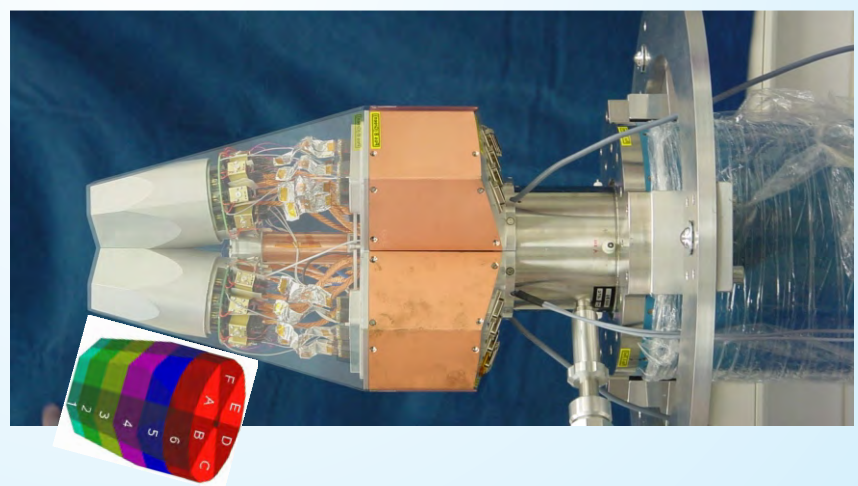
gamma tracking

probably the best

studied detectors?

almost mass

produced



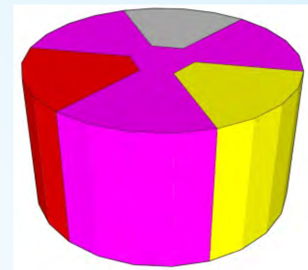
Germanium Detector Technology

“point” contact

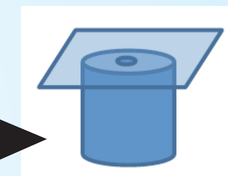
segmented BeGe

study this detector type

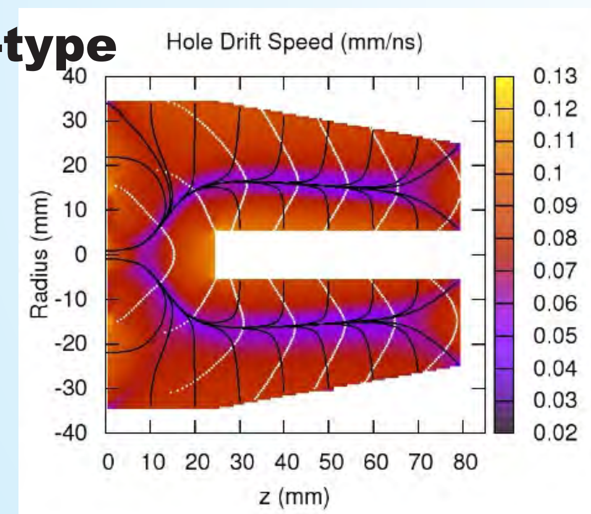
— are individual characters



n-type



n-type



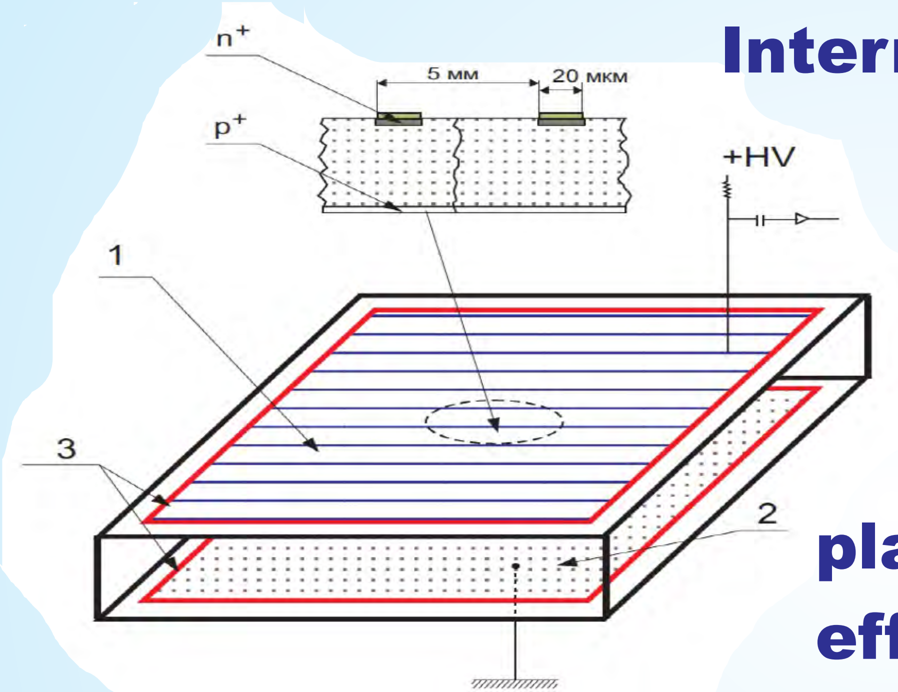
inverted detector

study basically all germanium properties

tracking

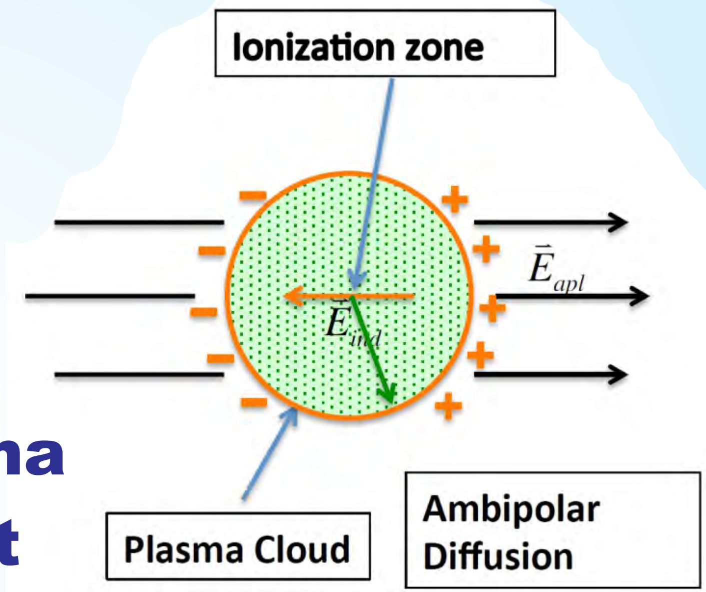
→ **going p-type**

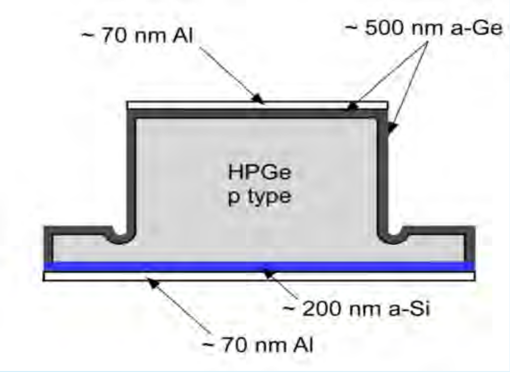
Germanium Detector Technology

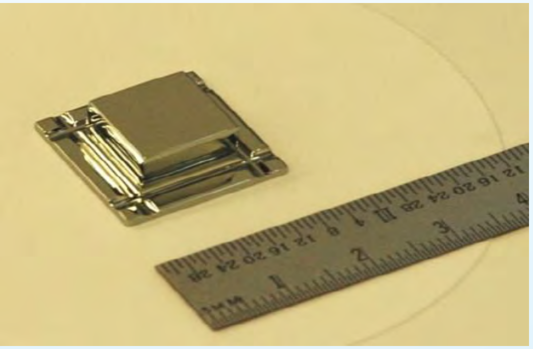


Internal amplification

plasma effect



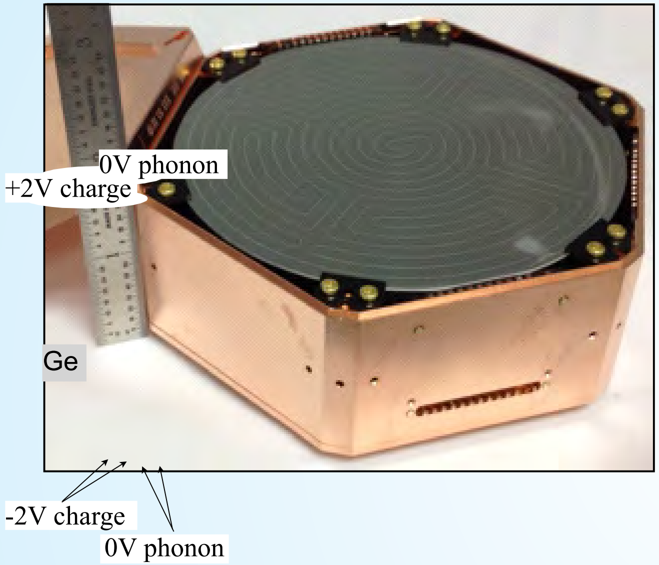


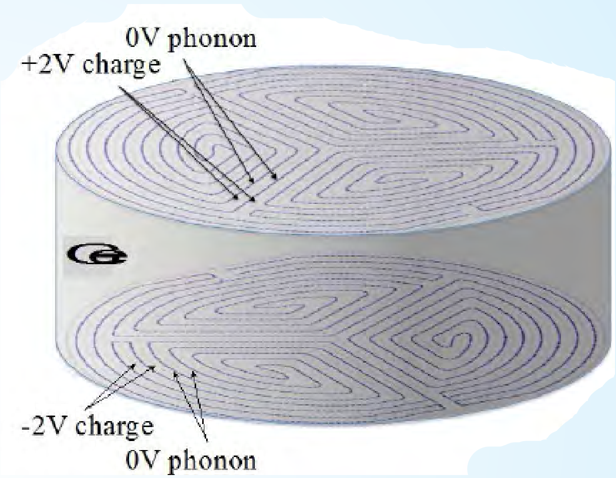


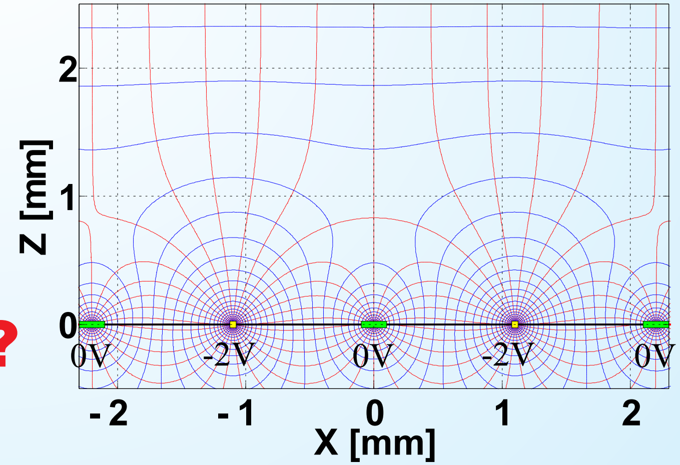
Work has started

Germanium Detector Technology

"really" cold



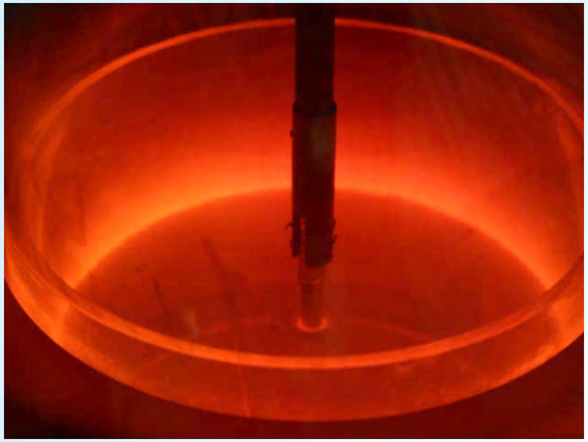




Can we share

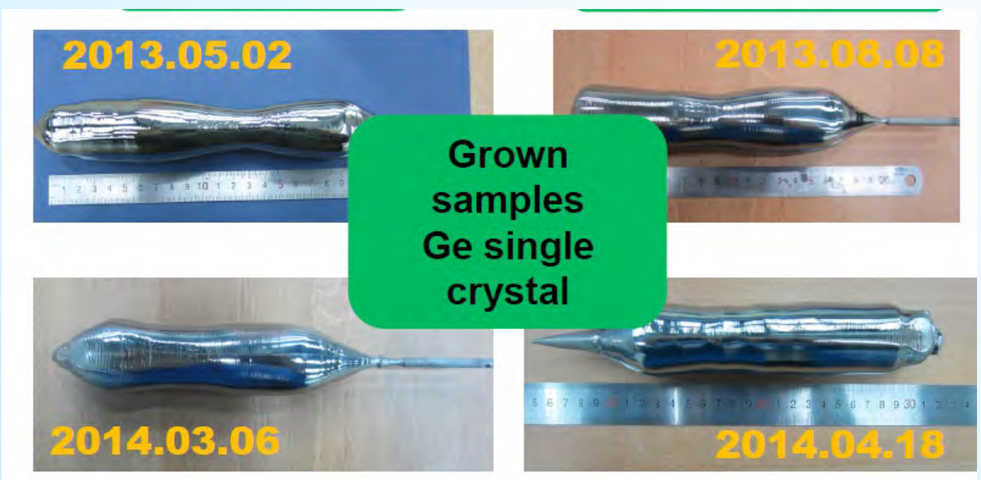
- **tools [software]**
- **handling procedures ?**

Germanium Crystals



connection with com-mercial detector makers?

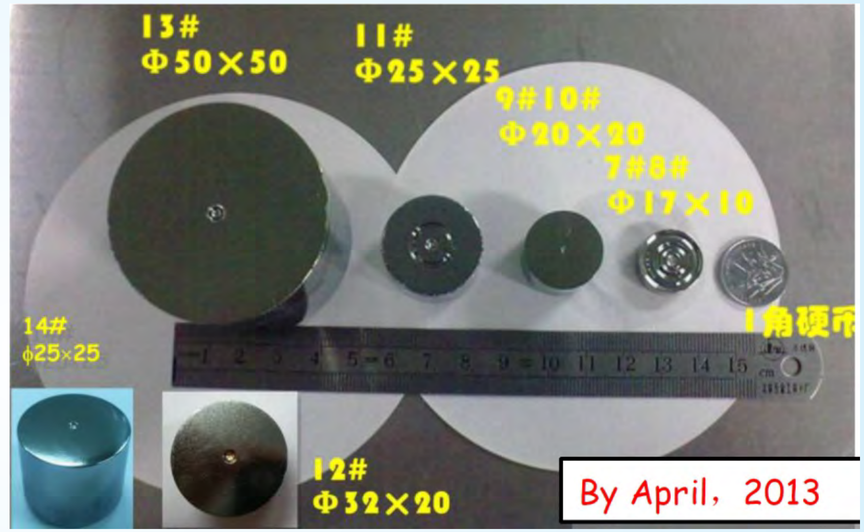
buying is not the only option



This is not easy at all.

Detector Manufacturing

beyond buying from manufacturers with impressive products



First BeGe produced at Tsinghua

1.9keV for Co lines

Mass production for CDEX 10 → 200

Test Facilities

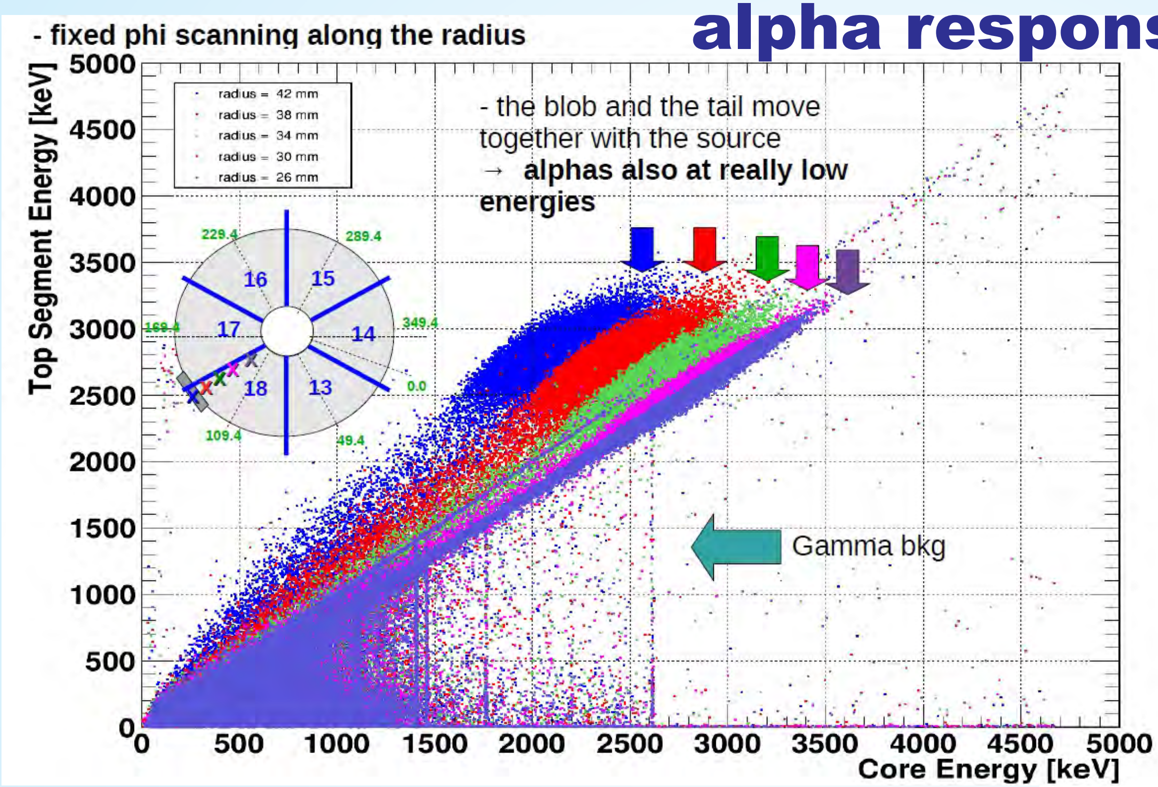
Every body has some.

Should have more exchange of experience.

Can facilities be used by more than one group?

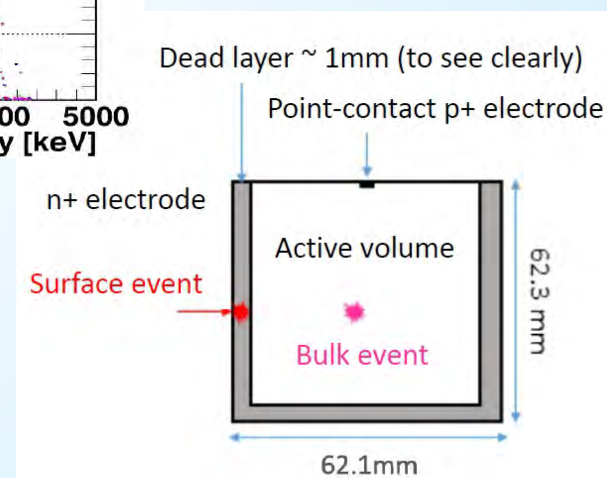
Test Results

alpha response



probe dead layer under the end-plate of a true coax

~10µm plus
~10µm transition

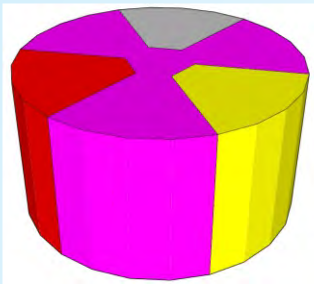


probe dead layer of p-type point contact

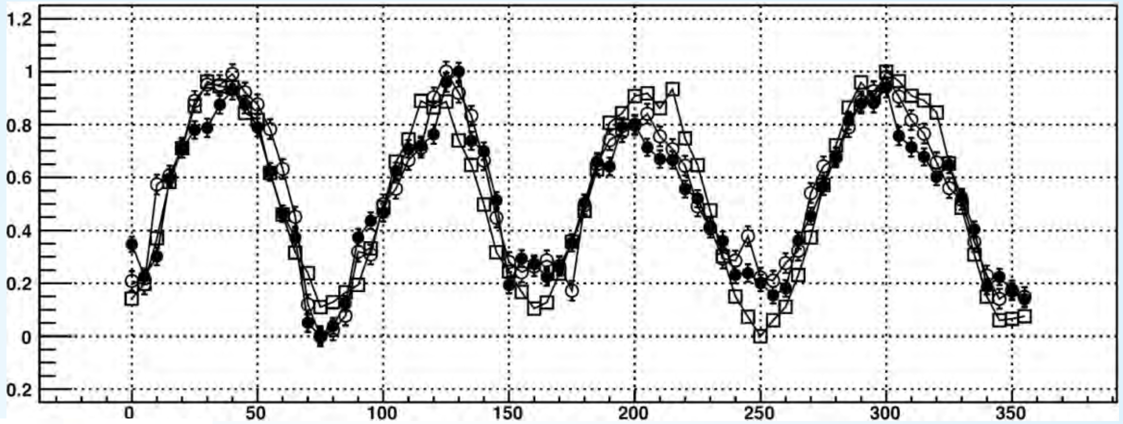
~.9 ± .1mm

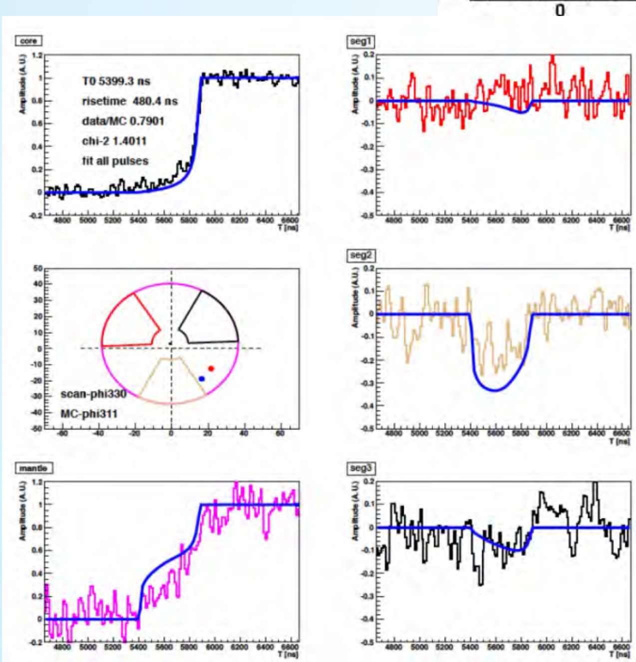
Test Results

segmented



BeGe

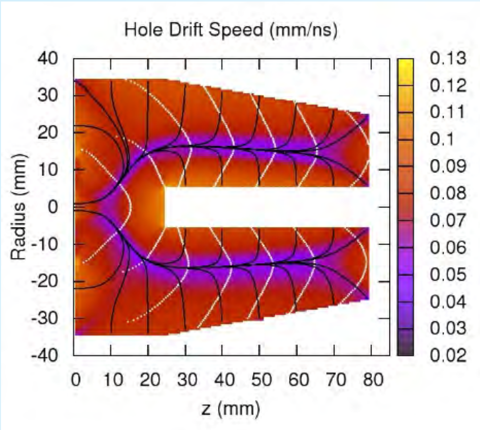




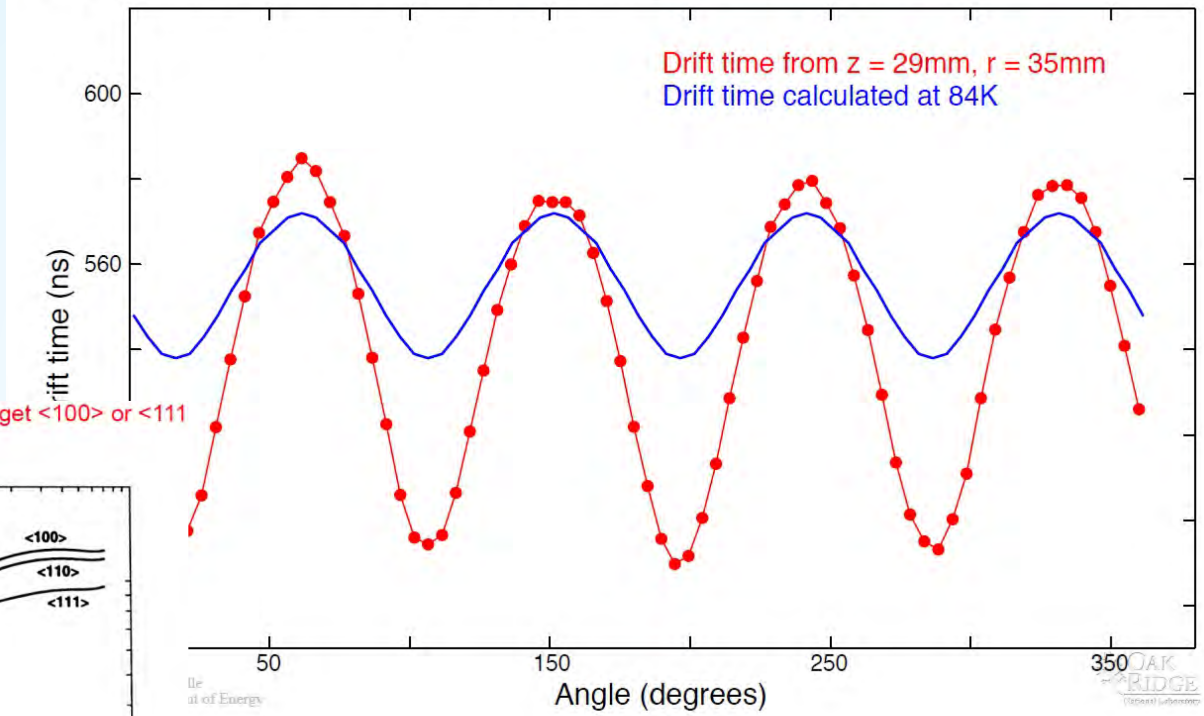
Reconstruct phi of individual events to some degrees.

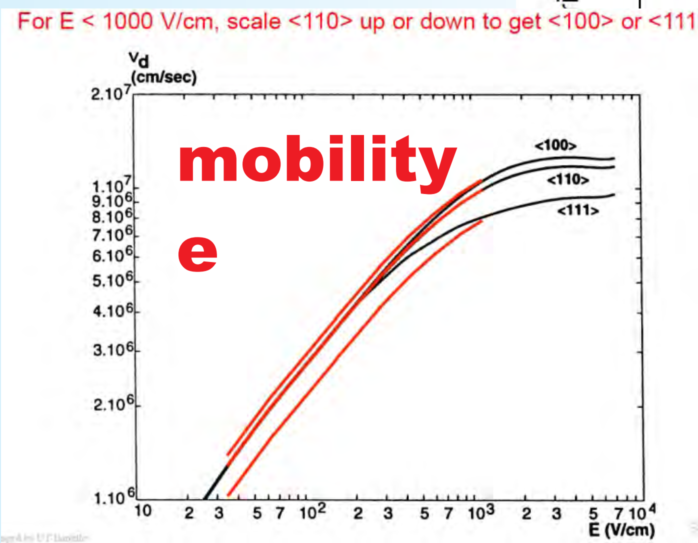
simulated pulses do not quite match, under-estimate unisotropies.

Test Results



- Collimated Am source scanned around the circumference of the detector
- Calculated drift times give far too small a variation with angle





simulated pulses massively underestimate unisotropies.

Mobility in Germanium

There are two models around.

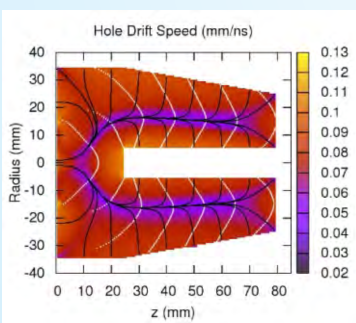
They are based on very old measurements

which do not go below 1kV cm

two models for tensor algebra

assumptions, assumptions

We should really measure this.



money and manpower

e? → holes ???

Electronics

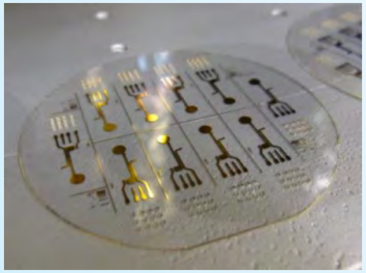
Inside the "can", the manufacturer rules.

Impressive preformance,

Not easy to integrate in a large scale experiment.

ASICs

These beasts are a bit difficult



Everything has to be very clean, even gold.

Materials

Component	Material	Purity (g / g) ^{232}Th	Purity (g / g) ^{238}U	Counts / ROI / t / y ^{232}Th	Counts / ROI / t / y ^{238}U	Ref.
Substrate	Fused silica	101×10^{-12}	284×10^{-12}	0.0259	0.0616	MJ ICP-MS
Resistor	a-Ge	5×10^{-9}	5×10^{-9}	0.0001	0.0001	MJ ICP-MS
Traces	Au	$47(1)\times10^{-9}$	$2.0(0.3)\times10^{-9}$	0.0421	0.0015	MJ ICP-MS
Traces	Ti	$< 400\times10^{-12}$	$< 100\times10^{-12}$	~ 0	~ 0	MJ ICP-MS
FET	FET die	$< 2\times10^{-9}$	$< 141\times10^{-12}$	< 0.0107	< 0.0006	MJ ICP-MS
Bonding wire	Al	$91(2)\times10^{-9}$	$9.0(0.4)\times10^{-12}$	0.0004	~ 0	MJ ICP-MS
Epoxy	Silver epoxy	$< 70\times10^{-9}$	$< 10\times10^{-9}$	< 0.0685	< 0.0082	MJ gamma
Total				<0.1476	<0.0720	

accounting nightmare

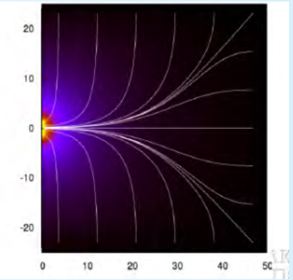
PEN

a bottle of Ln/LAr

Simulation/Analysis

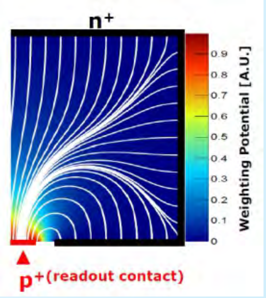
MaGe → **open source ???**

“ Time for a fresh start !”



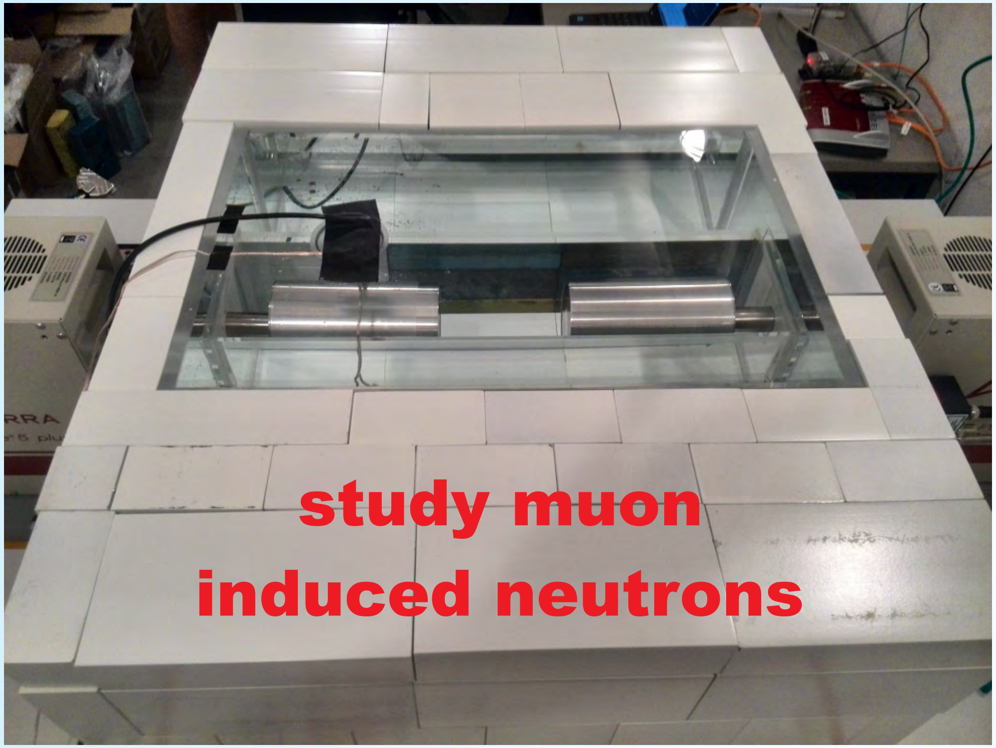
Siggen **open source**

MuSiG → **open source**

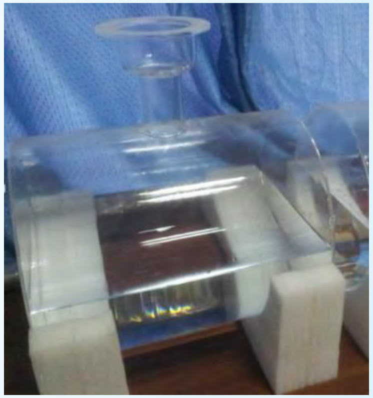


Data brics **open source**

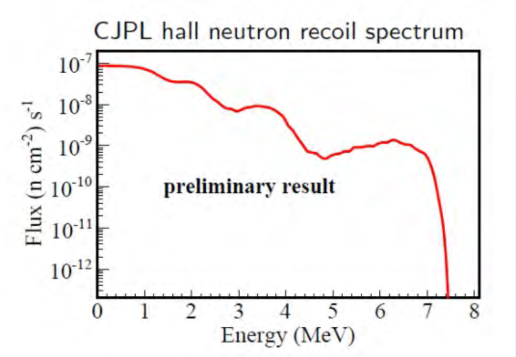
Neutrons

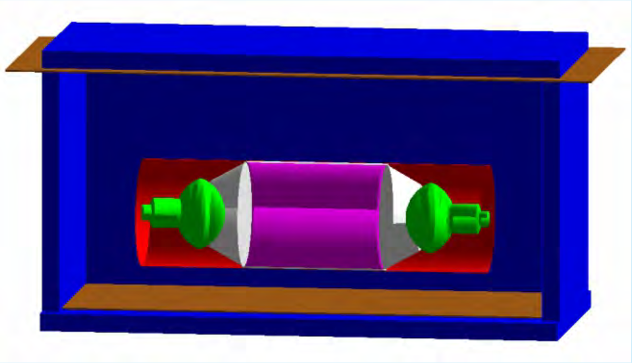


Minidex plus fast neutron detector



Neutron spectrum in CJPL measured



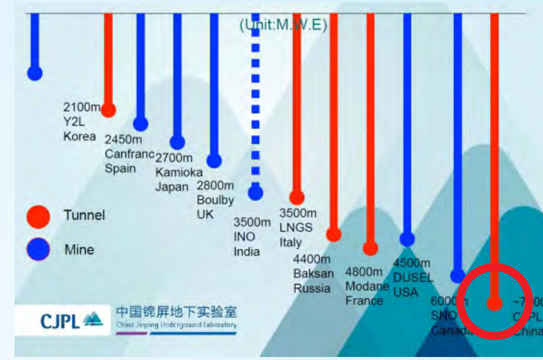


Infrastructure

CJPL 2

substantial enlargements

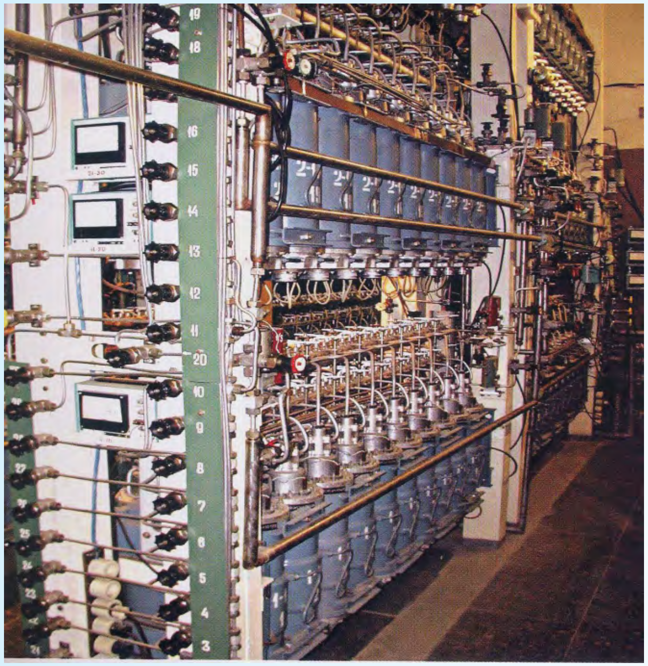
	CJPL-I	CJPL－II
Rock Work	4000 m^3	131000m^3
Electric Power	70 kVA	1000 kVA
Fresh Air	2400 m^3/h	45000 m^3/h



lots of work

to be com-pleted end of 2016

Enrichment



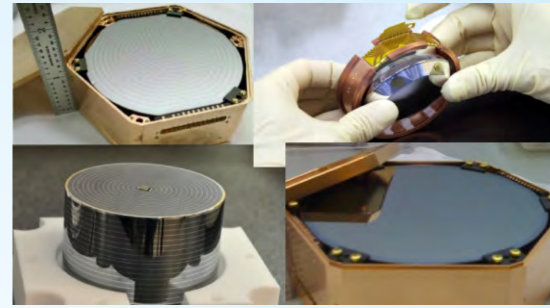
Centrifuges in
Russia, Germany, China
$$$$$$$

(Mass separation in "spectrometer" in France)

Tsinghua is starting an effort to enrich ^{76}Ge to ~85%

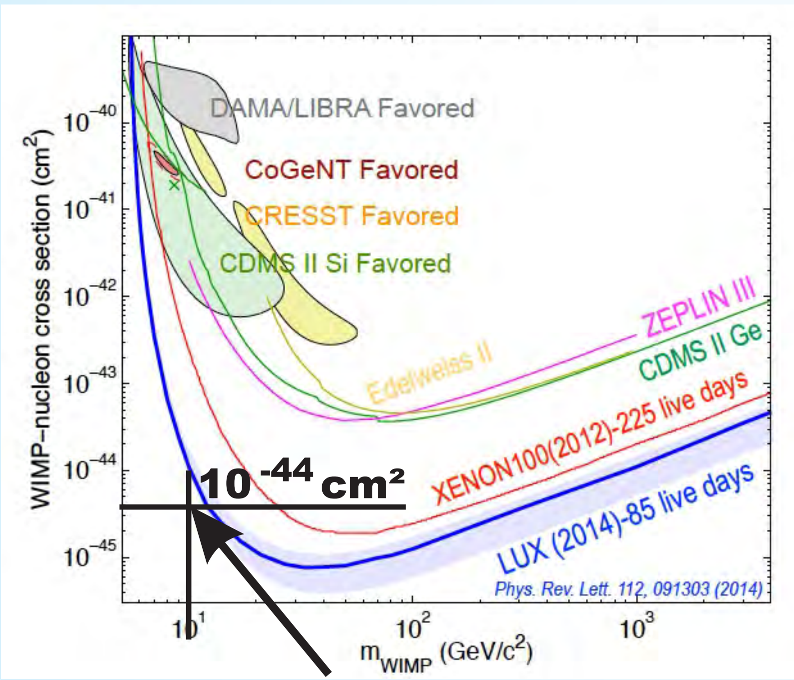
Supply and control system of cascade

Physics Case



Dark Matter

Germanium detectors target low mass wimps.



10GeV

There is competition from Xenon.

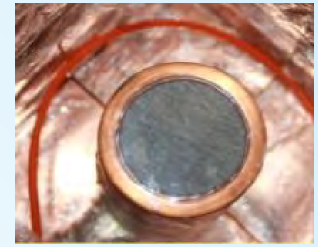
There are always loop-holes, but how much do you want to bet on a black xenon-avoiding crystal-lover ?

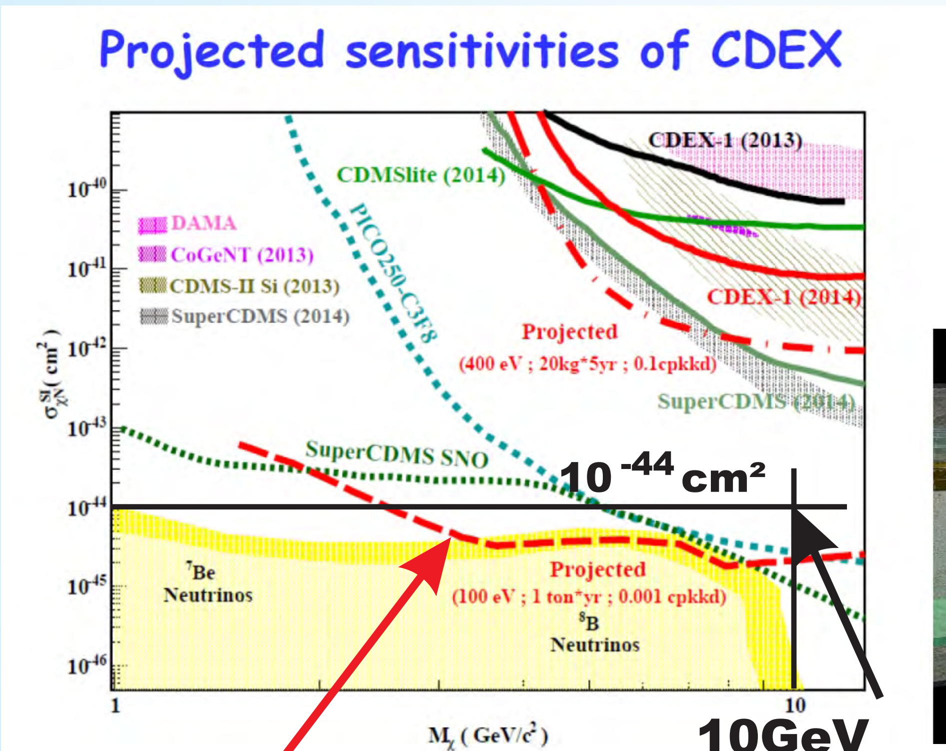
go for lighter WIMPS and lower threshold

Physics Case

Dark Matter

Germanium detectors target low mass wimps.

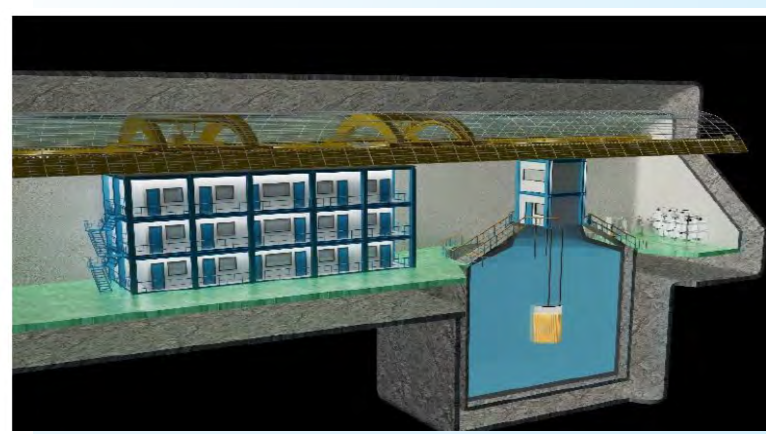




100eV 1ty 0.001c/kg/keV/y

Future large scale efforts:

CDEX 200 at CJPL

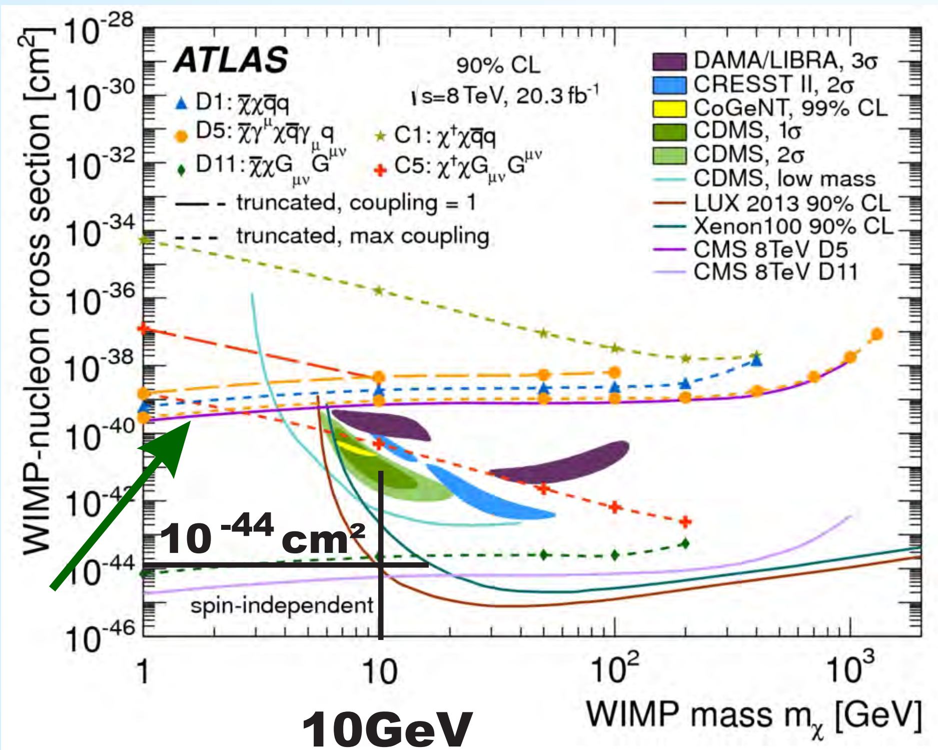


but how? → R&D

Physics Case

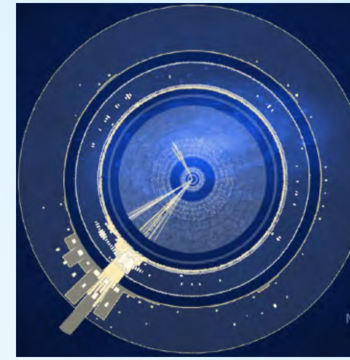
Dark Matter

Germanium detectors target low mass wimps.



There are always loop-holes, but how much do you want to bet on a little green crystal-eater ?

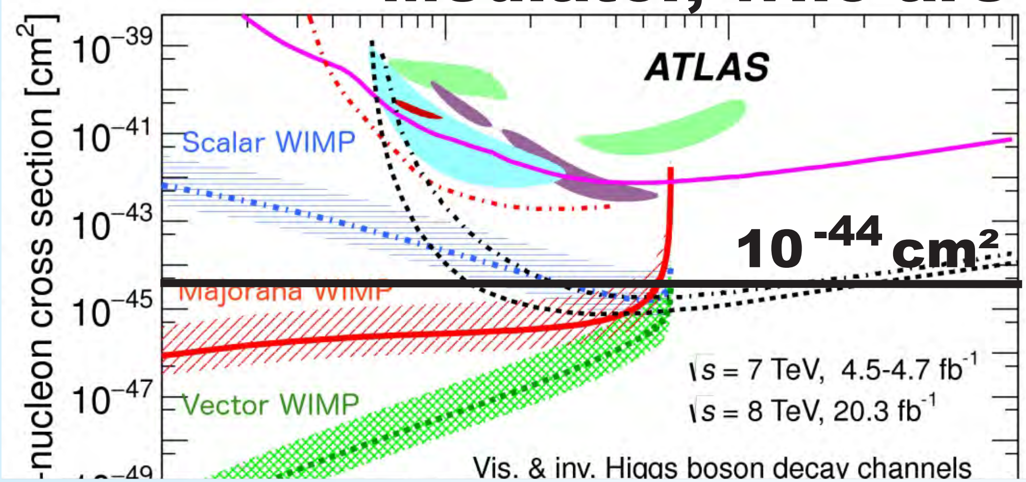
Physics Case



Dark Matter

Germanium detectors target low mass “wimps”.

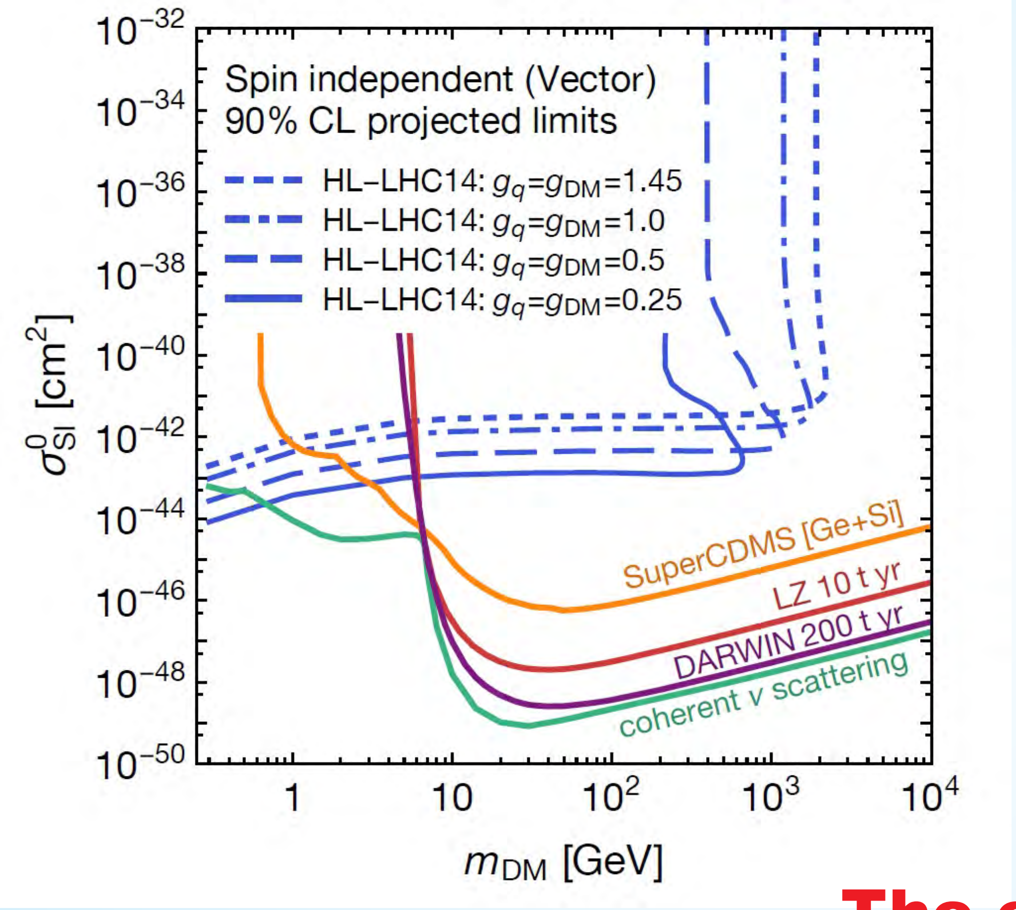
Mediator, who are you?



The Higgs at least exists. If DM only couples to the Higgs, this is covered by LHC.

Models affect LHC limits, but the “direct searches” also make assumptions.

Physics Case



1409.4075v3 [ref 28]

Simplified model currently used by DM community:

vector boson

DM is spin1/2 fermion

pure s wave

point like nucleon

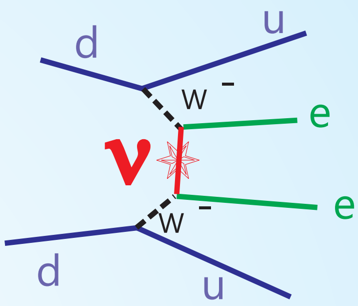
LHC does best at low masses.

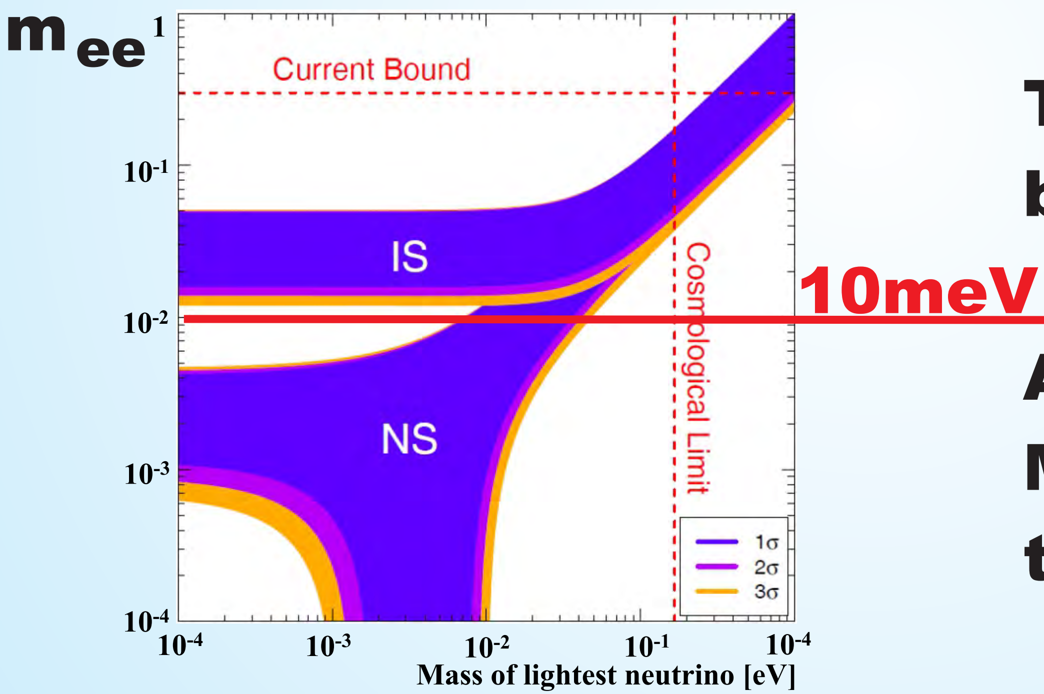
The end of the single exclusion plot!

Physics Case

Neutrinoless Double Beta Deacy

The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.



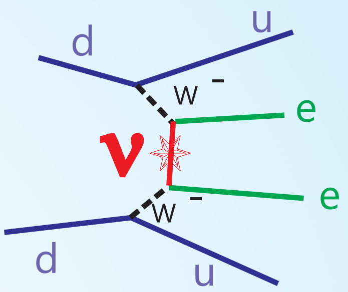


This diagram is being questioned.

Assumes a "simple" Majorana neutrino is the only player.

Physics Case

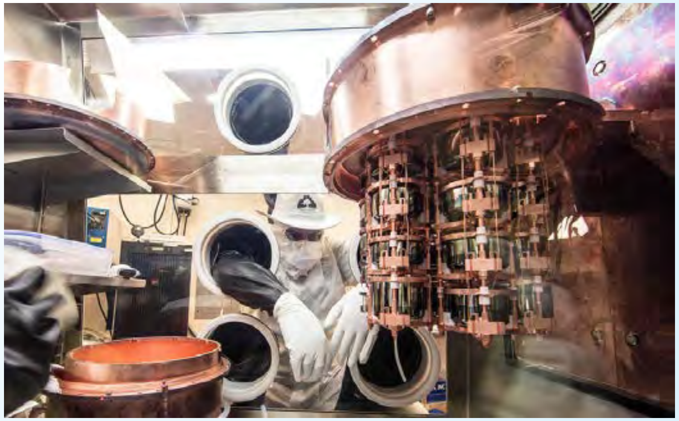
Neutrinoless Double Beta Deacy



The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.

GERDA

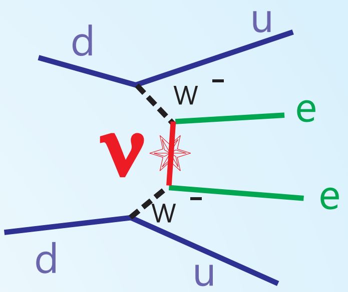
MAJORANA



Both: too little mass ⟶ background techniques

Physics Case

Neutrinoless Double Beta Deacy

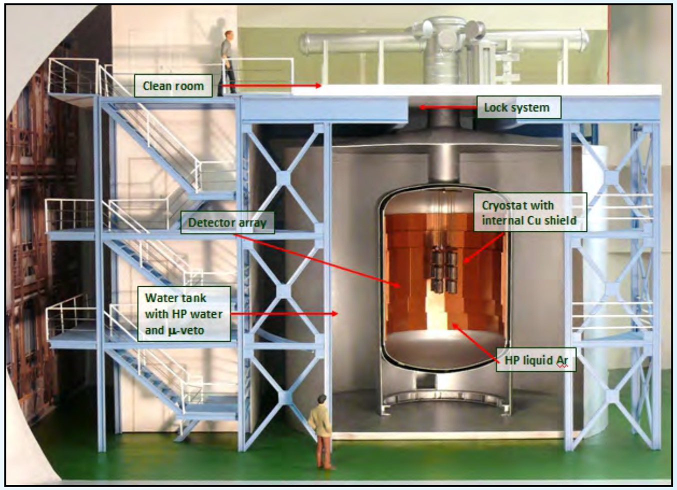


The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.

MAJORANA

Cu
Pb

GERDA

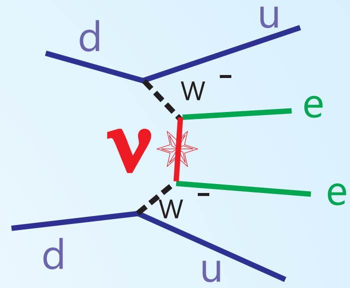


Lar
LN

Background techniques → And the winner is.....

Physics Case

Neutrinoless Double Beta Deacy



The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.

Right now a normal hierarchy is favored.

We can looks as far as possible.

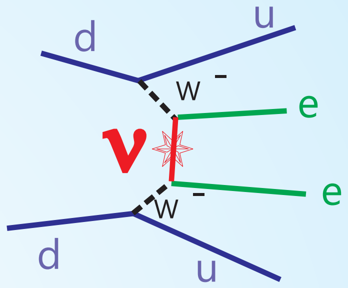
What is possible will depend on background.

Mediator who are you?

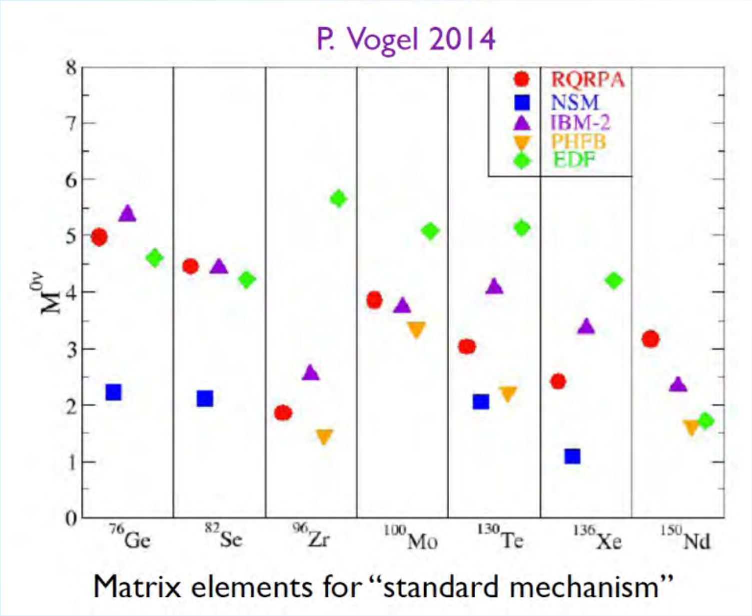
If KATRIN would see something,
we could probably exclude a Majorana nature.

Physics Case

Neutrinoless Double Beta Deacy



The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.

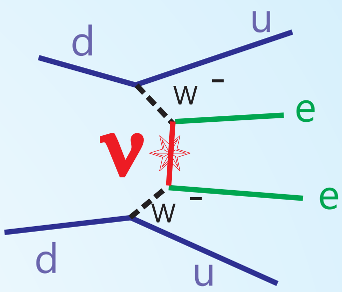


Is Germanium the technology of choice ?

For neutrinoless double beta decay, there is no clear winner.

Physics Case

Neutrinoless Double Beta Deacy



The goal of 10 meV was set to exclude the Majorana nature in case of inverted hierarchy.

Is 100t feasible?

Half life (years)	~Signal (cnts/tonne-year)
10^{25}	500
5×10^{26}	10
5×10^{27}	1
5×10^{28}	0.1
$>10^{29}$	0.05

Mass is needed.

↓

Background

0.1/roi/t/y ⇔ $<10^{-4}$/keV/kg/y

enrichment

underground fabrication

Physics Case

Axions???

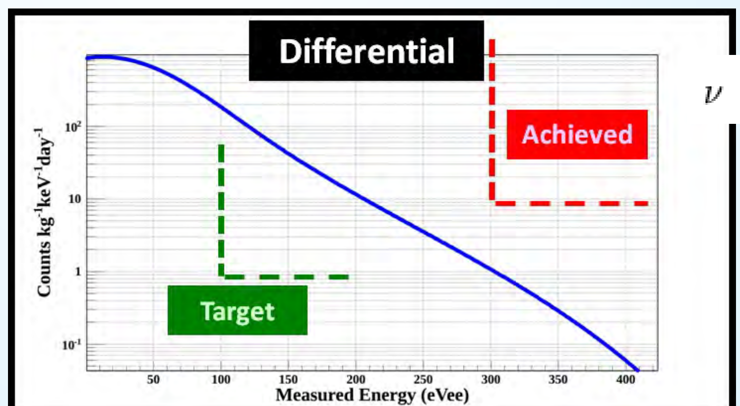
Neutrino Observatoy

The first goal would be to measure solar neutrinos.

Is Germanium a suitable technology?

Is 100t feasible?

In the R&D phase, we can look at reactors.



$$\nu + \mathrm{N} \rightarrow \nu + \mathrm{N}$$

low thresholds

Future

Some ongoing cooperation projects will be brought to a good end.

During this week, we discussed several efforts to get new projects started – with broad participation.

Needs work!

An EoI for CJPL was presented. Please let me know, if you would like to sign up.

The R & D for a large scale experiment is challenging. We have to find ways to better organize ourselves and to better cooperate.

We all lack man-power.

Impressions

Impressions

Impressions

Impressions

Impressions

Impressions

Impressions

Impressions

Impressions

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