1 cm Thick Silicon(Ge)Detectors at Liquid Helium Temperature

From Surface to Volume (Neutrino Physics)

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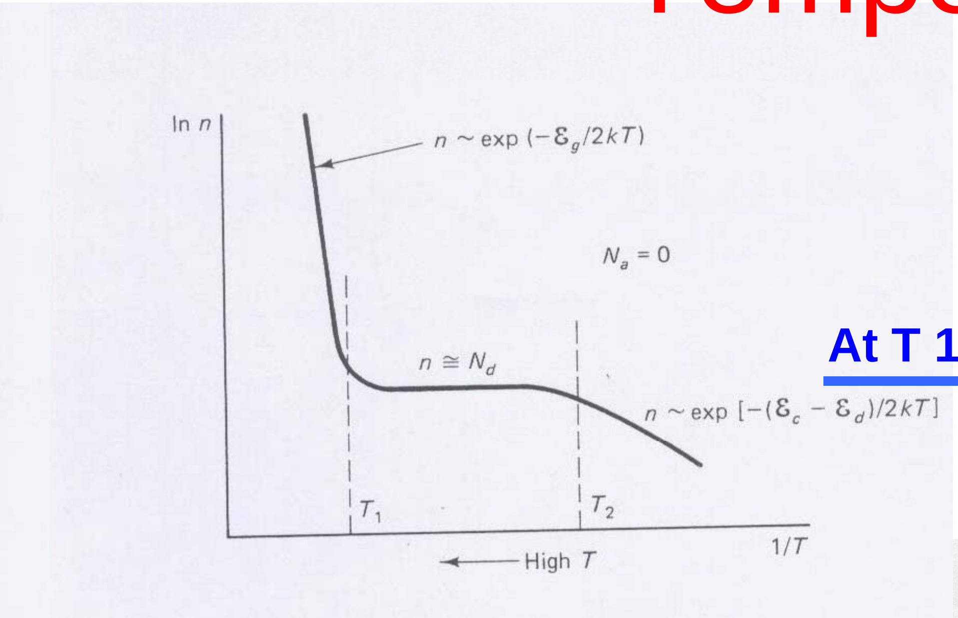
1. **Large Drifting Distances: Requirements**
   - Freeze out Effect
   - Charge Trapping vs Si Purity
   - Mobility and Mean free path
2. **Silicon Processing Stages**
3. **Experimental Set-Up**
4. **Results:**
   - I-V ; C-V Characteristics
   - Charge Collection Efficiency vs V bias
   - Collection Efficiency vs Si Purity
5. **Conclusions**

Freeze-out Effect at Low Temperature

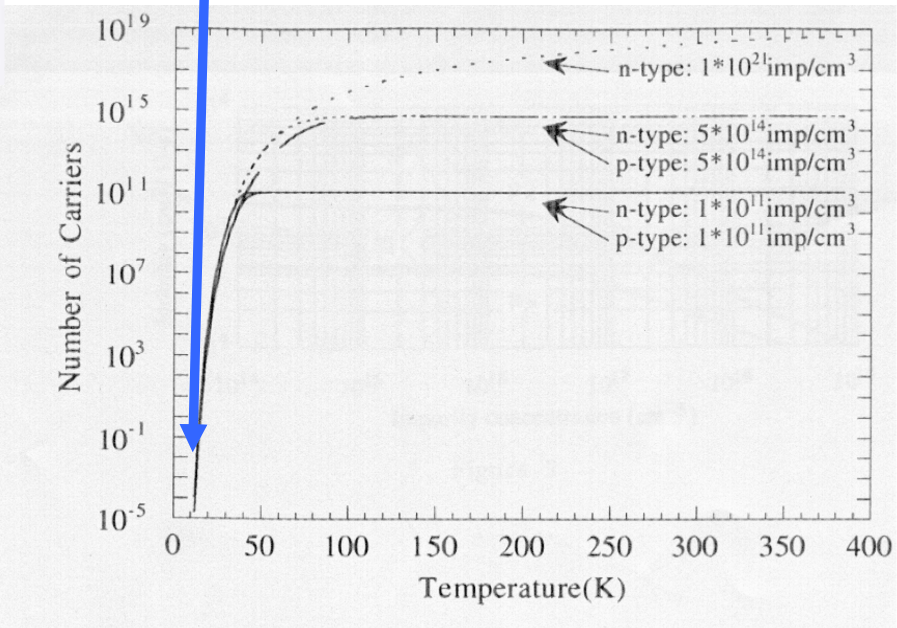


Ec-Ed = 10 meV , Ea – Ev = 30 meV

E $_{KT@4\ Kelvin}$ = 0,3 meV

At T 10 kelvin Silicon is Intrinsically depleted

Cap. Detector = Geometrical Cap.



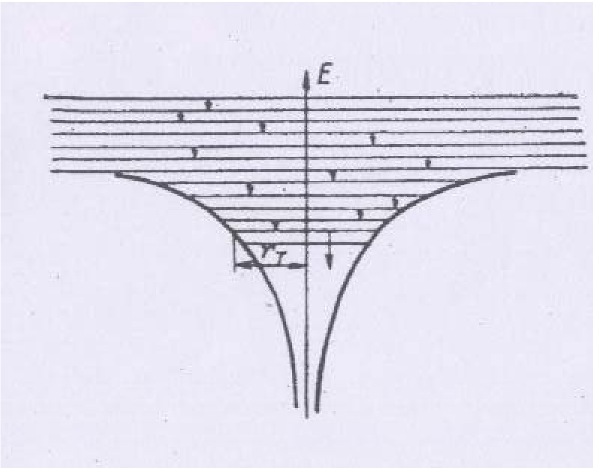
BENEFITS:

No leakage current

Low Bias Voltage

But not enough

Charge Collection + Trapping at Low Temperature



Cascade Capture Model Developed by Pitaevskii

Review Paper from Abakumov Sov.Phy.Sem.1978

2 Type of competiting processes:

a) Scattering Cross Section from Coulomb center

b) S.C.S from “forming dipoles”

For High Purity Material (less 10^14 imp/cm3) process b is dominating

b) Type Cross Section is proportional to (Nd,a)3/4

To Decrease Dipoles SCS We Need High Purity Silicon

Silicon Detector study at low Temperature for Dark Matter

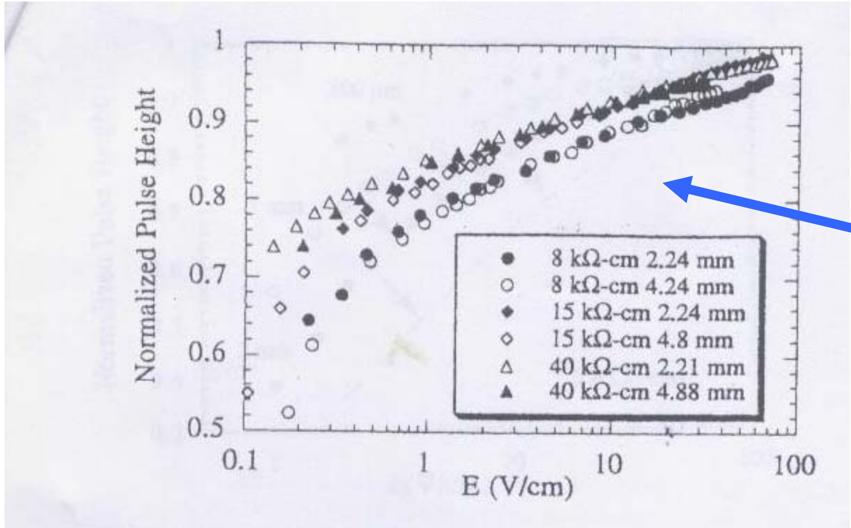
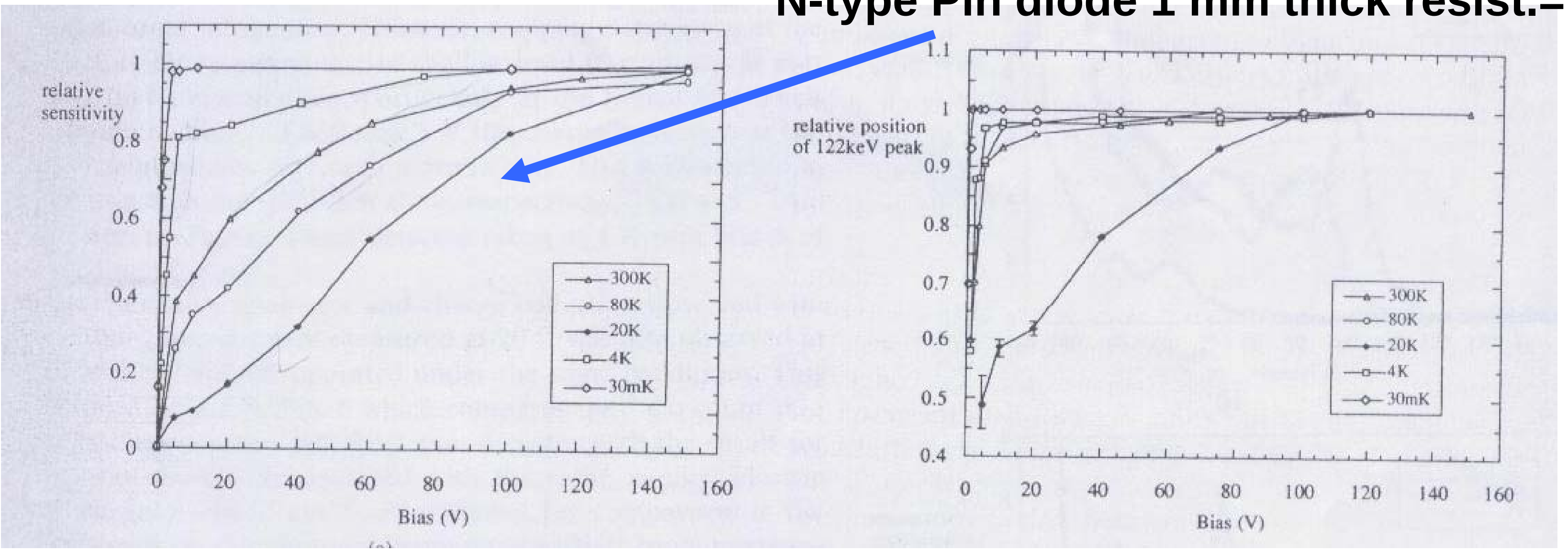


FIG. 3. Normalized pulse height vs electric field for high-purity samples.

Schotky type junctions @ 30 mKelvin

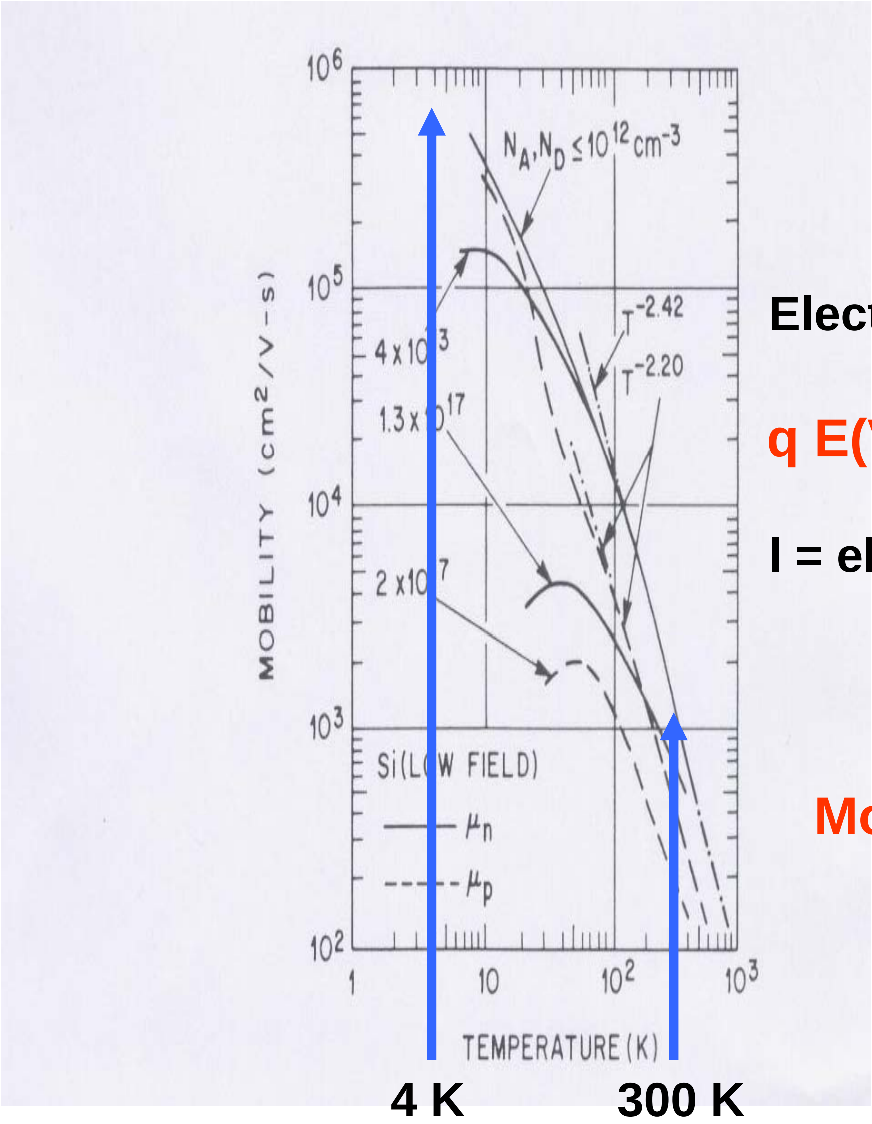
Cabrera et J.Appl.Phys.79-1996-8179

N-type Pin diode 1 mm thick resist.=10KOhmcm



Spooner et al IEEE Trans.Nucl.Scien.40-1993-105

Mobility and Mean Free Path



At LHe Temp.mobility increases almost 3 O.M. respect to R.T.

Electron mean free path increases at Low Temp.

q E(V/cm) l = E ion (eV)

l = electron mean free path

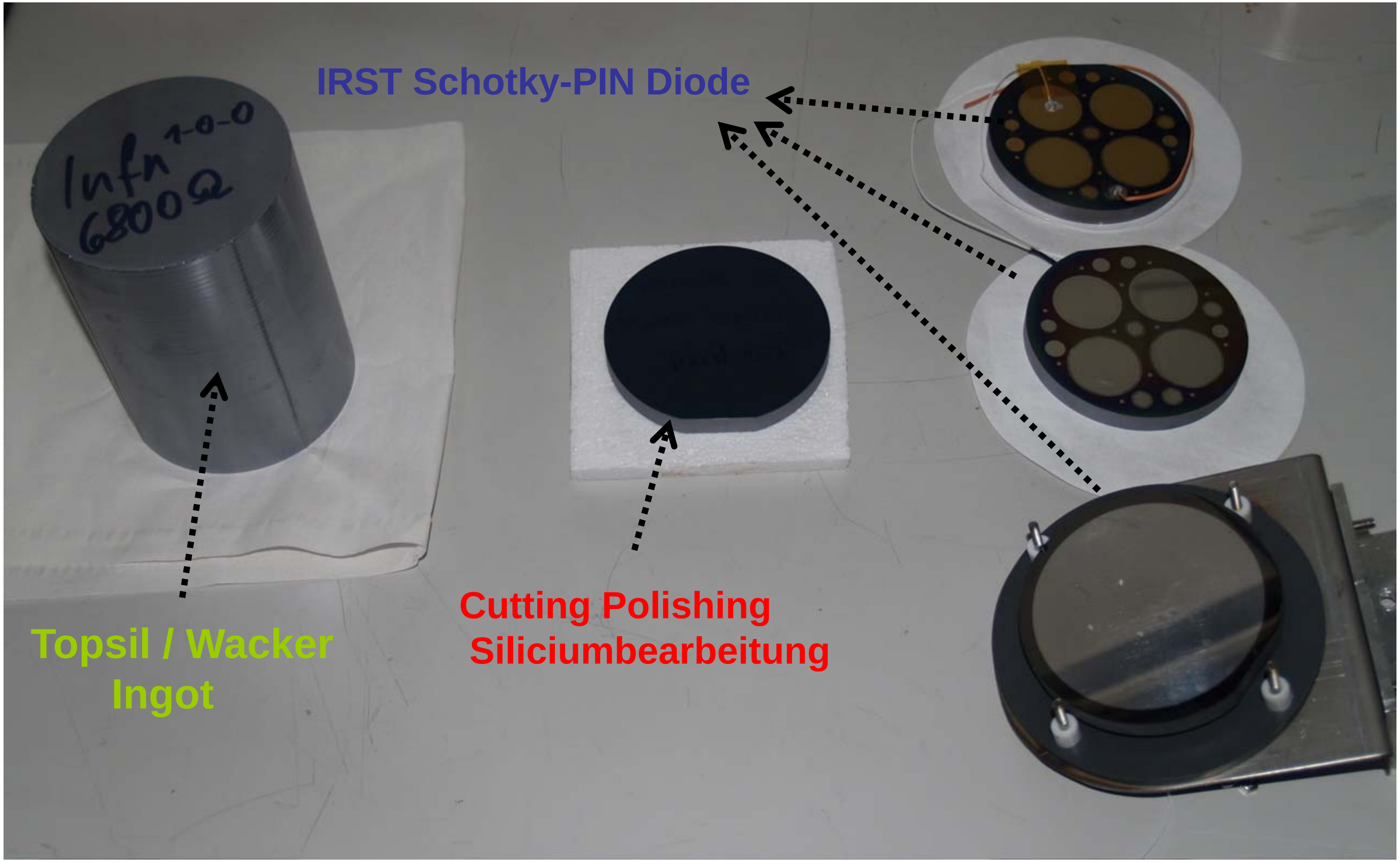
l = vsat. * Tau

Tau = mobility * mass / e

Mobility increases more than a factor 100

E avalanche from 10^5 to 10^3 V/cm

Silicon Processing Stages

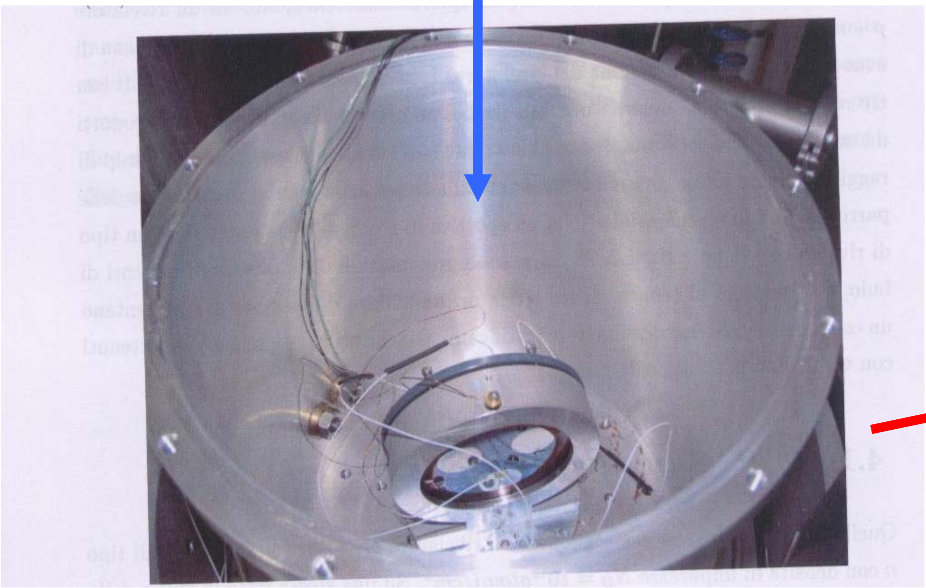


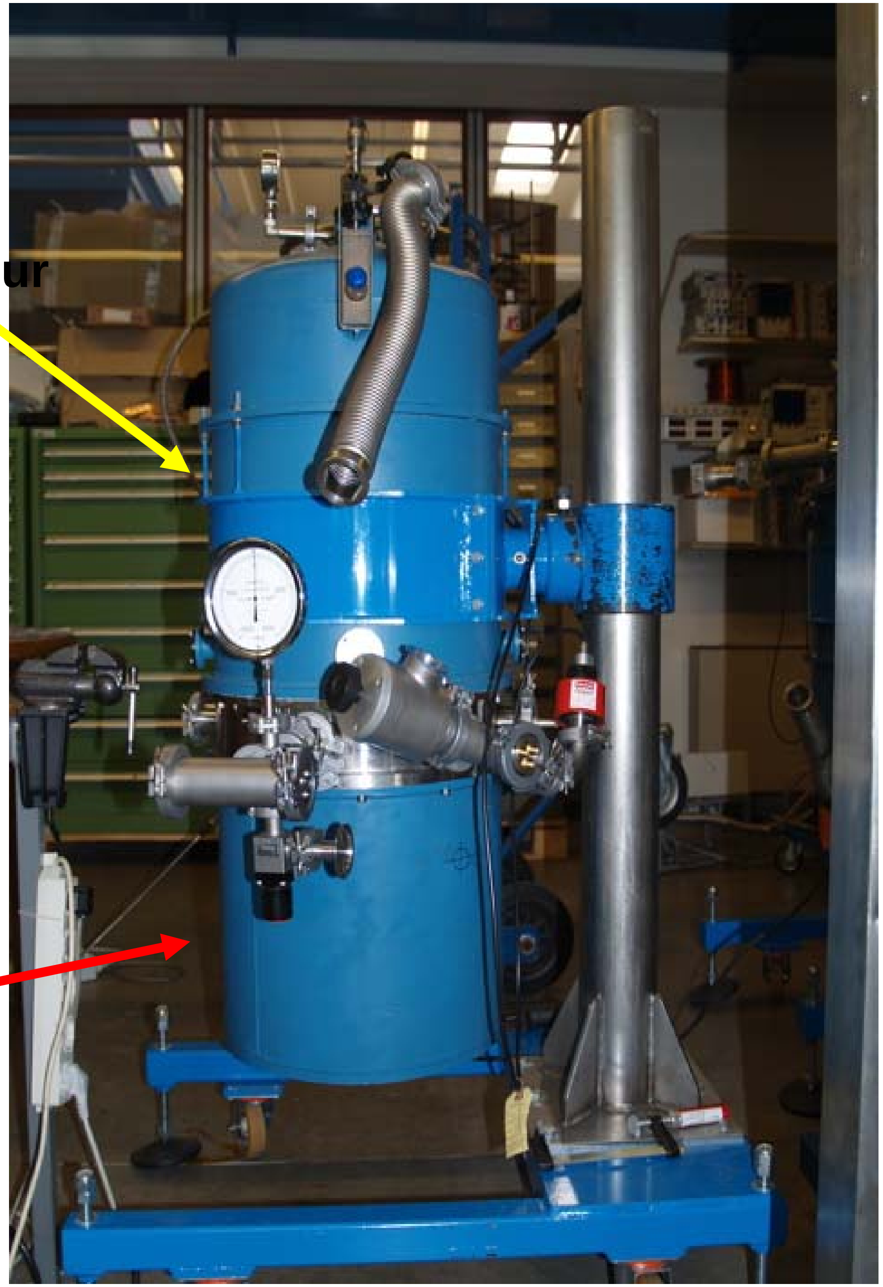
Experimental Set-Up

20 Lt LHe Dewar with LN2 Shielding

Liq. Helium Evaporation Rate:1,3 Liq.Liter/hour

Silicon detector chamber
Filled up with 2 mbar He Gas
To attain good thermalization

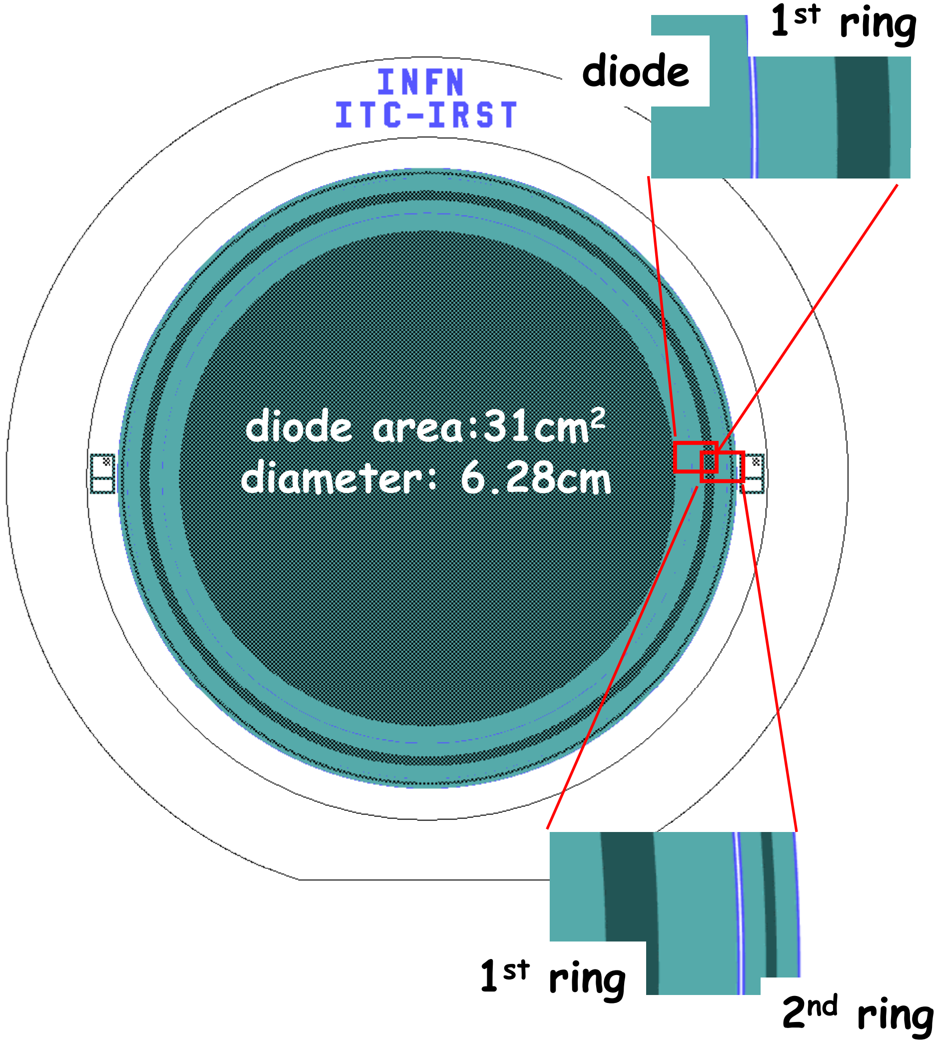


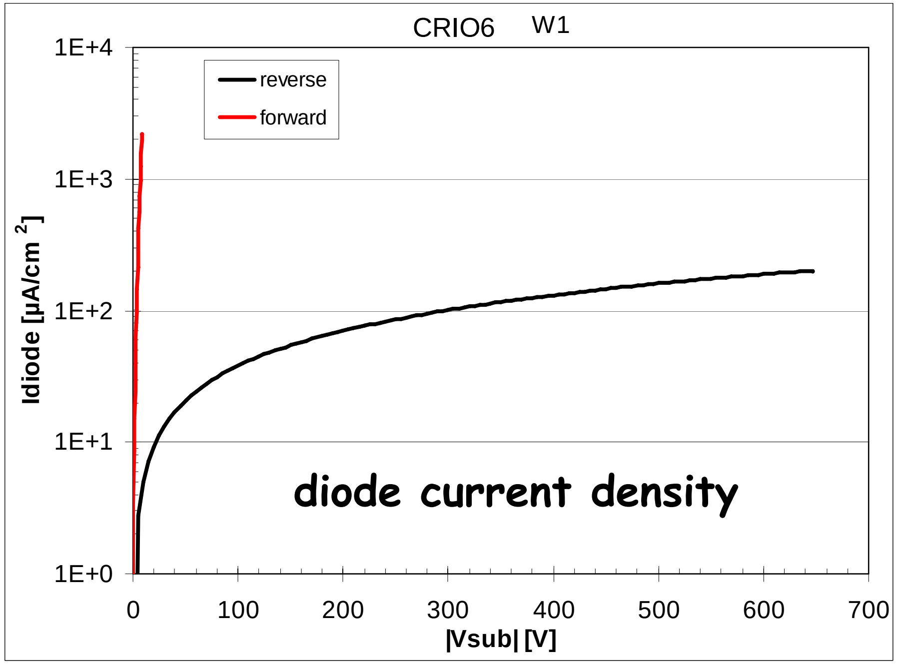


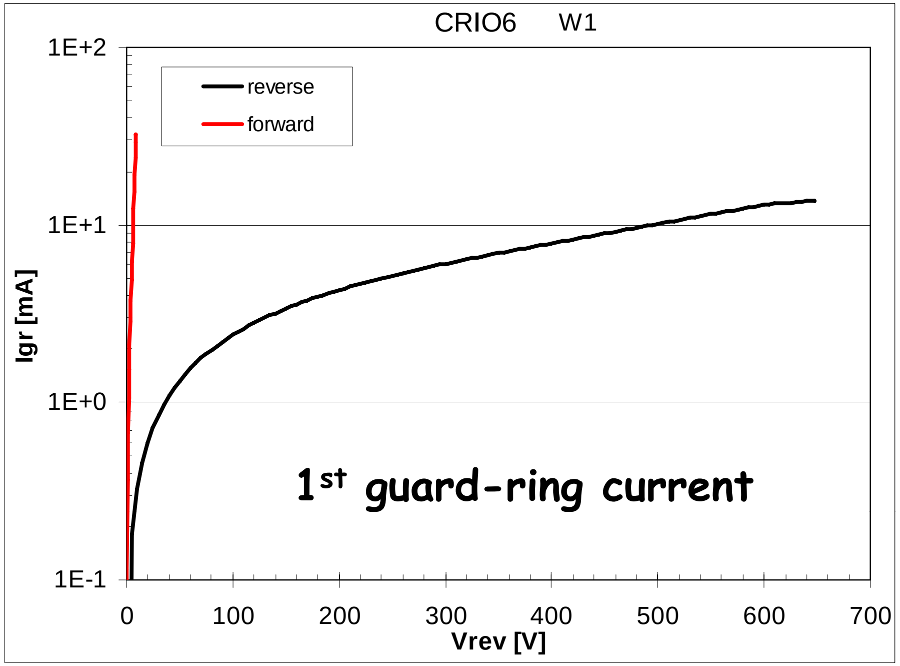
P-Type Silicon PiN diode

Preliminar meas on test diodes
and single PAD diodes

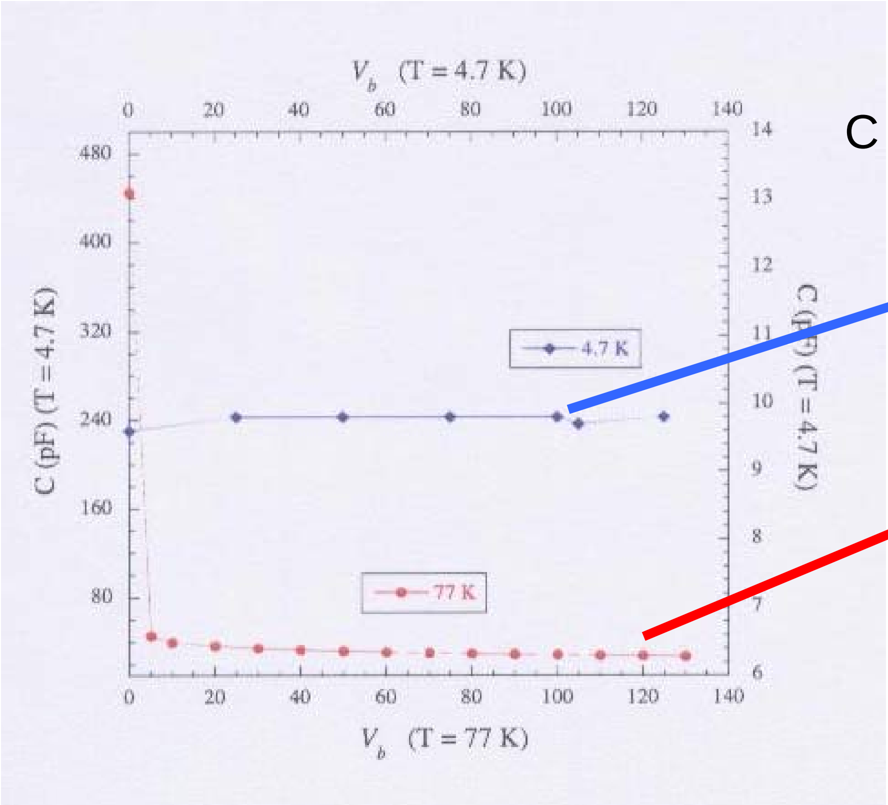
Topsil material 40 KOhm*cm RT







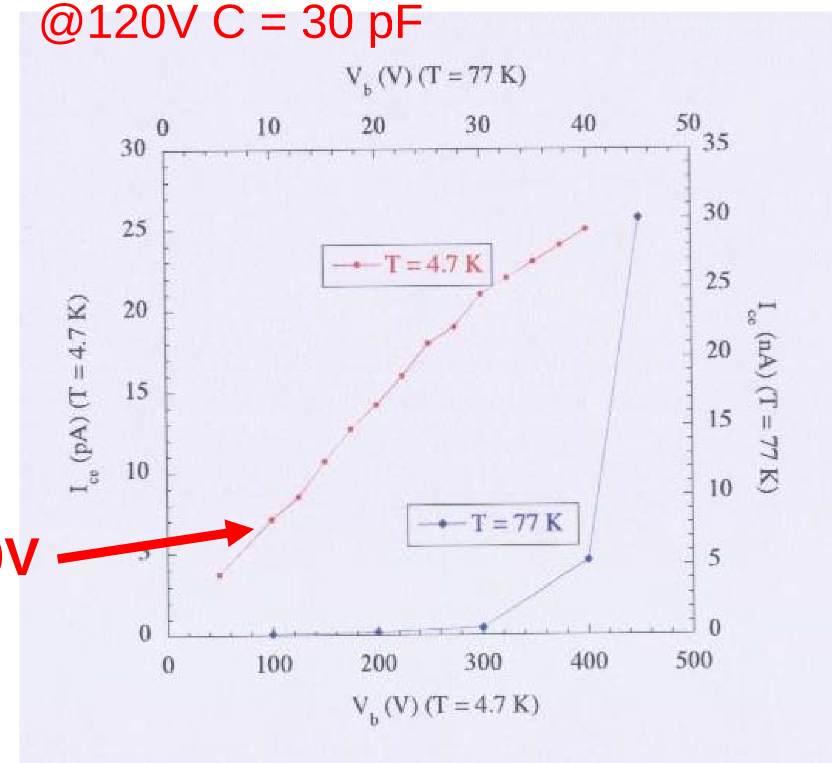
Capacitance + Leakage Current



C and I vs Vbias measurements for 3 cm diam.

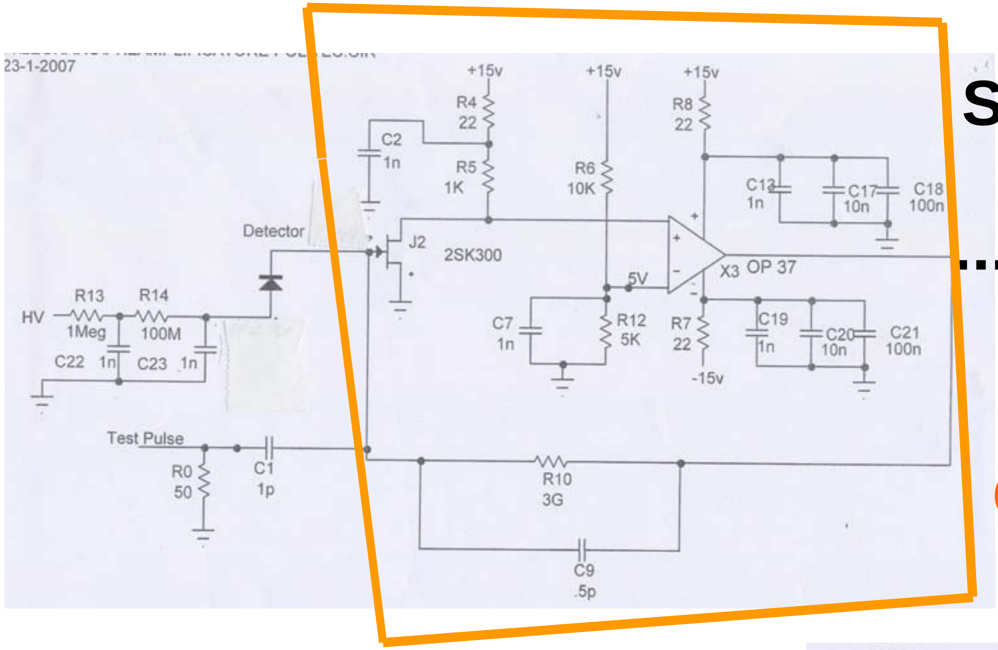
Capacity is costant vs Vbias at 4 Kelvin
C =9,5 pF =Geom. Cap.

At 77 K C doesn't saturate
@120V C = 30 pF



Detector Leakage Current 1 pA/cm2 at 100V

Cold Electronic Chain



Si Detector at 4,7 Kelvin

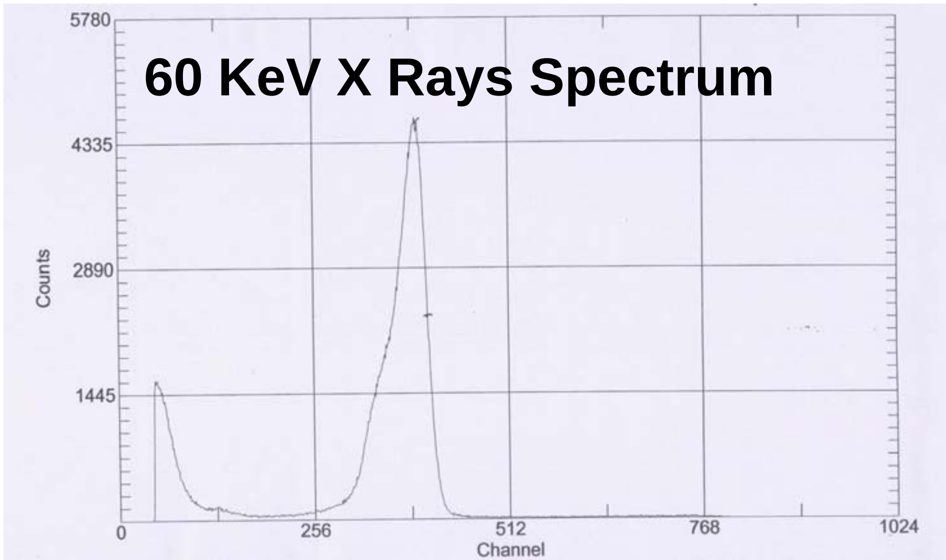
To Silena Shaping Amplifier
+
EGG MCA

Charge Amplifier at 120 K

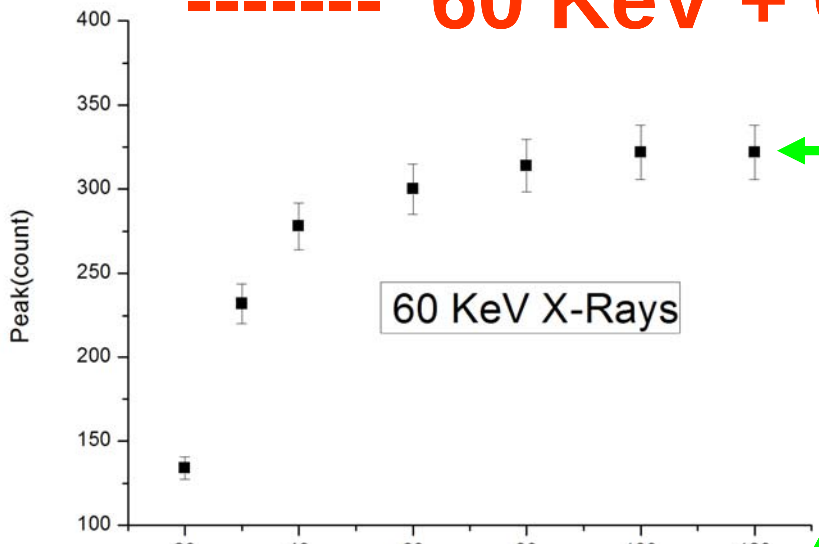
Electronic Noise = 1,9 KeV

FWHM (Right side) 60 Kev =4,2 KeV

60 KeV X Rays Spectrum

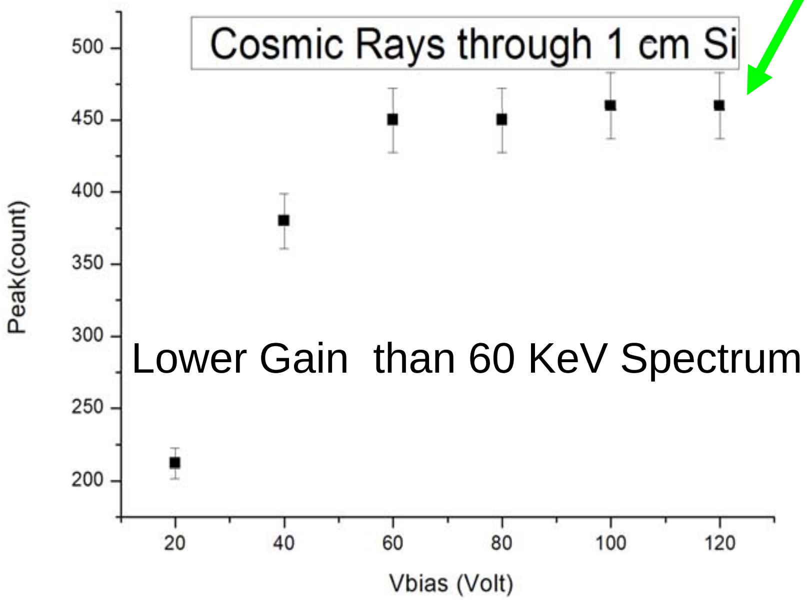


Peak Positions vs Vbias
------- 60 KeV + Cosmic Rays --------



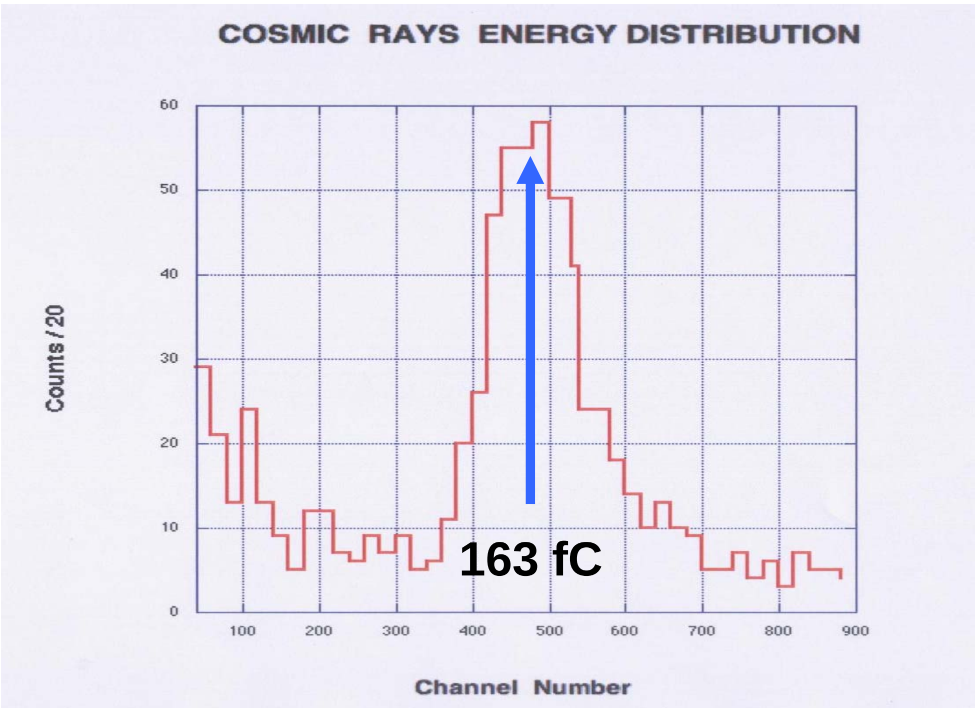
100 % Charge Collection Efficiency

PIN diode P-type 40 KOhm*cm



Lower Gain than 60 KeV Spectrum

Plateau value at 90 - 100 V/cm



Collection efficiency vs Purity

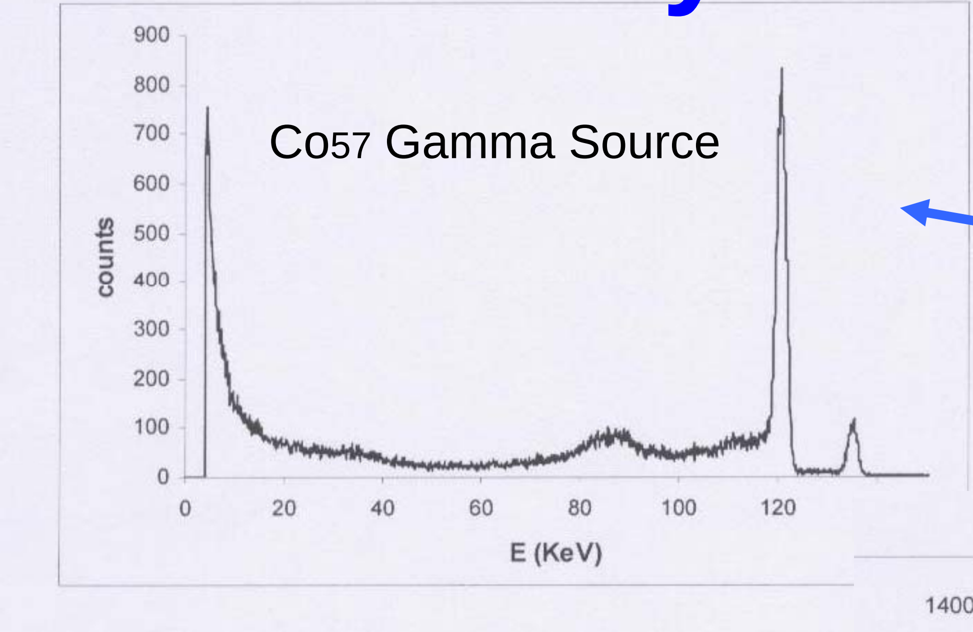
E (V/cm) @ 100% charge coll.eff. **VS** **Resistivity (KOhm*cm @ RT)**

a) 1000	6,8	n - type	Wacker
b) 125	12	n – type	Wacker
c) 90	40	p – type	Top-Sil

a) Braggio et al NIMA 568 (2006) 412
b) Braggio et al NIMA accepted for pub.
c) Braggio et this work

Charge Collection Efficiency Depends Critically from Purity Sample

Home Made Germanium Schotky Barrier Detector

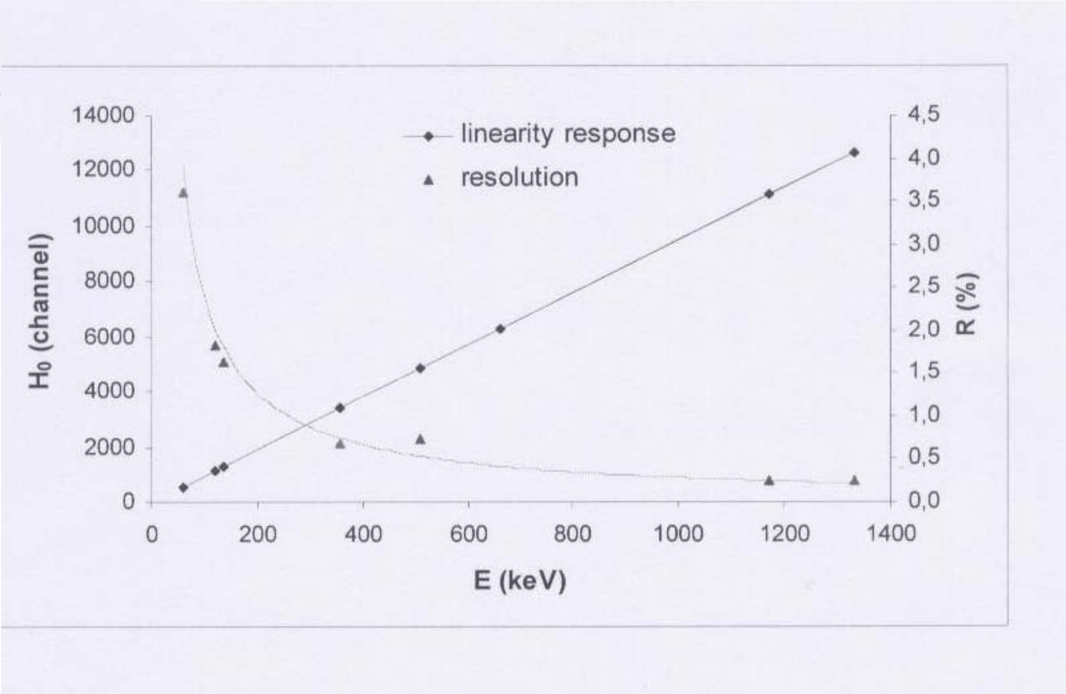


Cleaning procedure and electrode evaporation made in our lab.

1 Cm thick 3 cm Diam.

Vbias = 25 Volt

Germanium purity 2 OfM Better than Silicon



Germanium detector cost 50 times Lower than same planar device

↓

Energy Resolution comparable With a standard Germanium

Conclusions
Perspectives at 4K

1) Freeze-out effect observed clearly through Capacity at LHe Temperature

2) Leakage Current less than 1 pA/cm^2

3) Low E Field 100% Charge Collection Efficiency depends on Samples Purity

4) Detectors Processing easy to arrange also with X-Y Strips

5) High Purity Samples can be processed to have 5 cm Thick Detectors TPC

6) Large electron mean free path decreases the Avalanche Electric Field

7) 4 Kelvin Cryocooler available nowadays No Liquid Helium handling