Direct Dark Matter Detection

CDMS, ZEPLIN, DRIFT
(Edelweiss)

ICHEP 31

Amsterdam

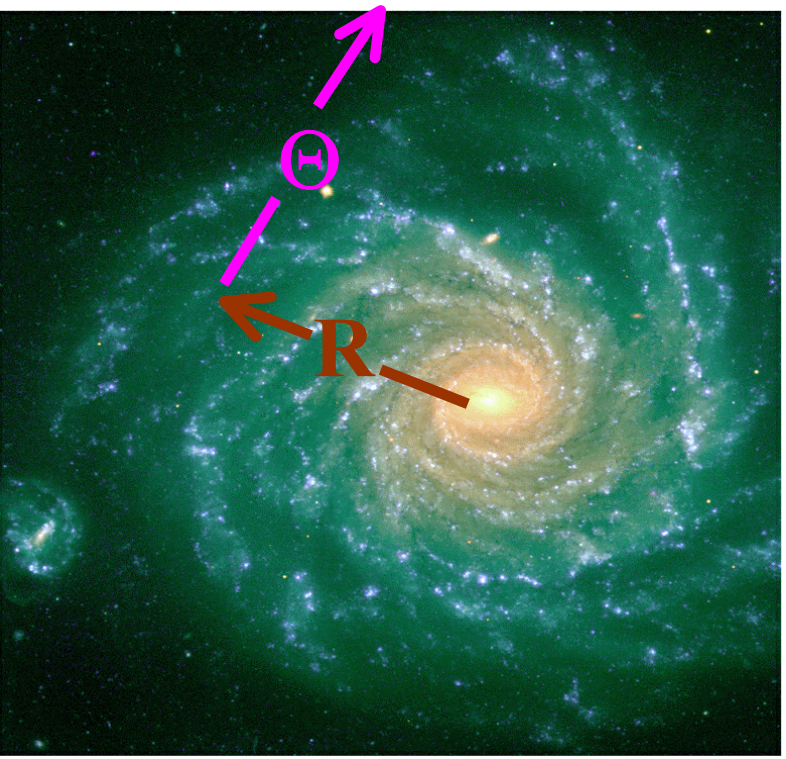
July 26, 2002

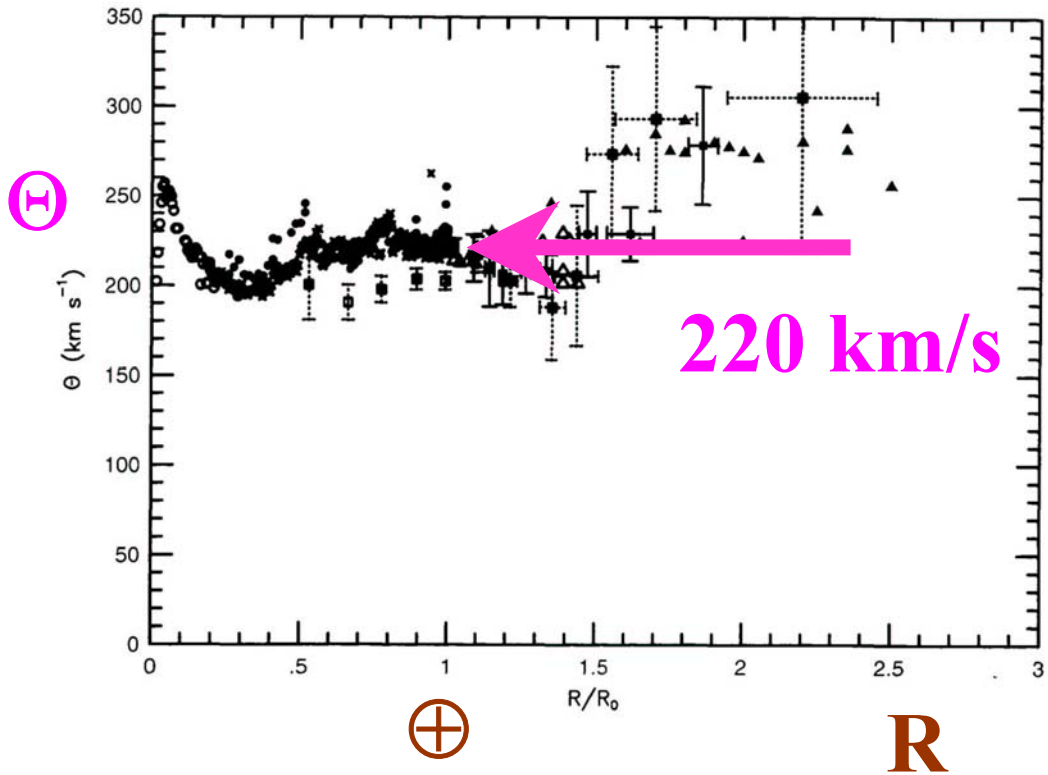
Harry Nelson

Santa Barbara

Physics Motivation

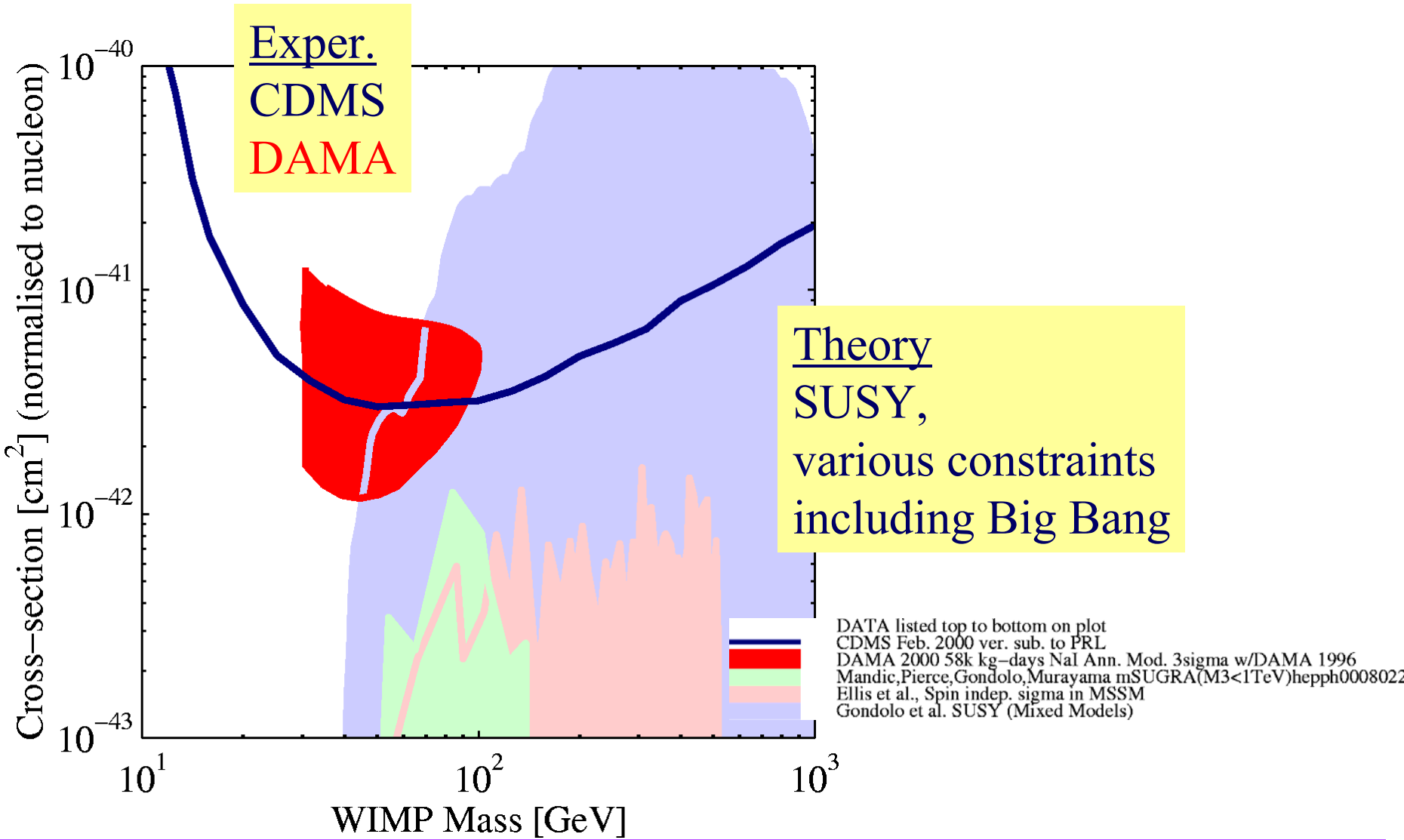
- Several Arguments for Dark Matter
- Milky Way's Rotation Curve





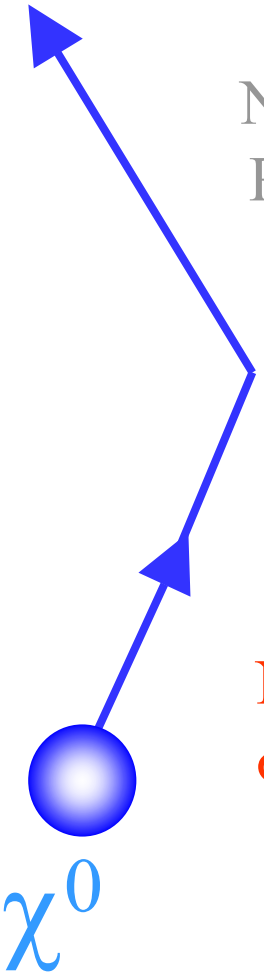
- Massive Particle Popular
- Weak Interactions (WIMP):
  - » Dark/Luminous Balance
  - » SUSY Broken at Weak Scale… χ^0 (neutralino)

WIMP/nucleon $\sigma \approx 10^{-42}$ cm



Direct Detection

Signal



Nucleus Recoils

E_r

$v/c \approx 10^{-3}$

Dense Energy Deposition
v/c small; Bragg

Neutrons same, but
$\sigma \approx 10^{20}$ higher - shield

χ^0

Background

Electron Recoils

E_r

$v/c \approx 0.3$

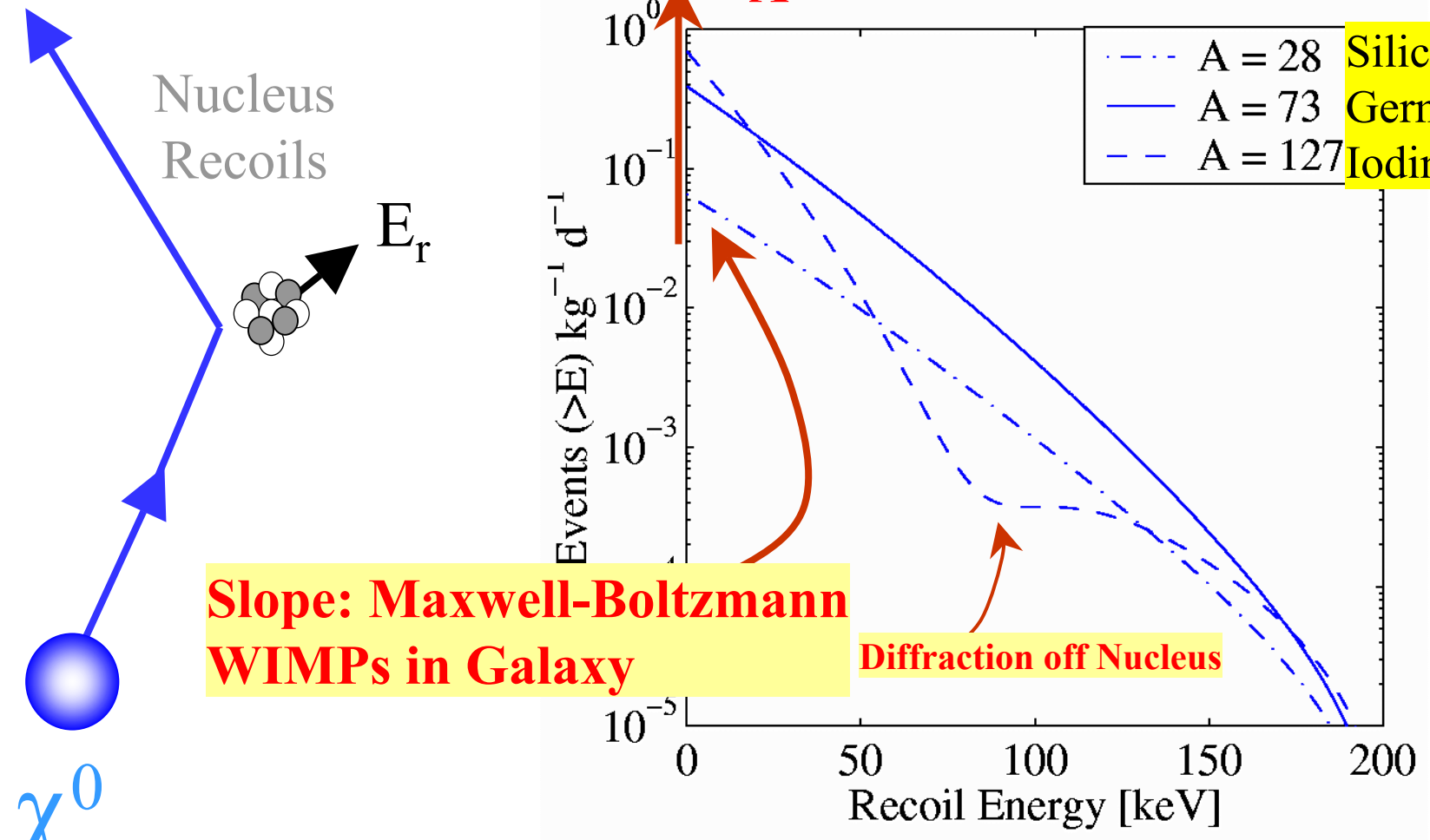
Sparse Energy Deposition

γ

Density/Sparsity Basis of Discrimination

Rate, Energy Spectrum

M_{WIMP}=100 GeV
$\sigma = 10^{-42}$ cm^2/nucleon



The Experiments

CDMS - Ge/Si, measure ionization (Q) and heat/phonons (P)
Recoil/γ discrimination: Q/P
2 Detector Types, 2 sites! Updated Result

Edelweiss!

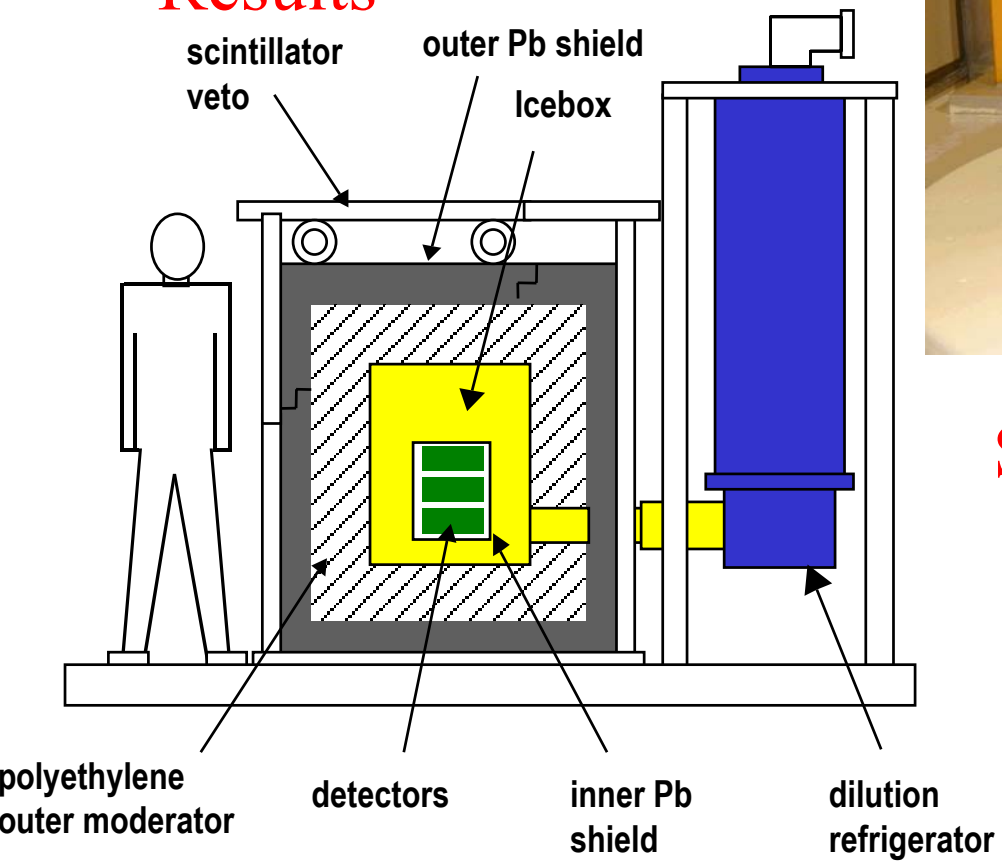
ZEPLIN 1 - Liq Xe, measure scintillation
Recoil/γ discrimination: Pulse Shape in Time
2 more ZEPLIN's - add ionization New Result

DRIFT - CS_2, measure ionization (Q)
Recoil/γ discrimination: Spatial Distribution of Q
Directionality

CDMS Sites

Stanford Site:

- 16 mwe
- Substantial neutron flux
- Results



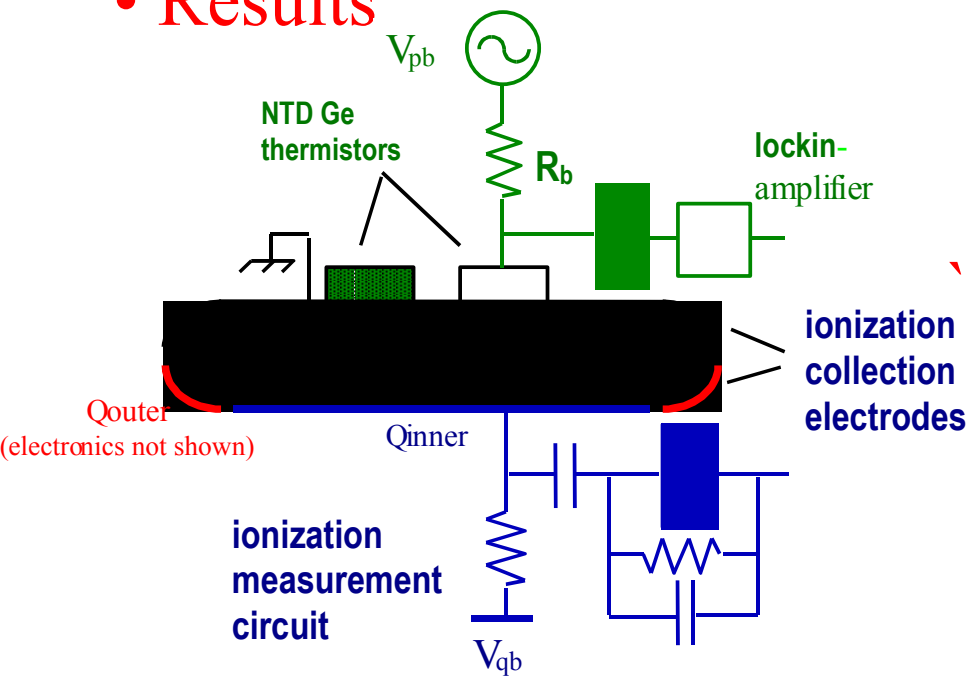
Soudan Site:

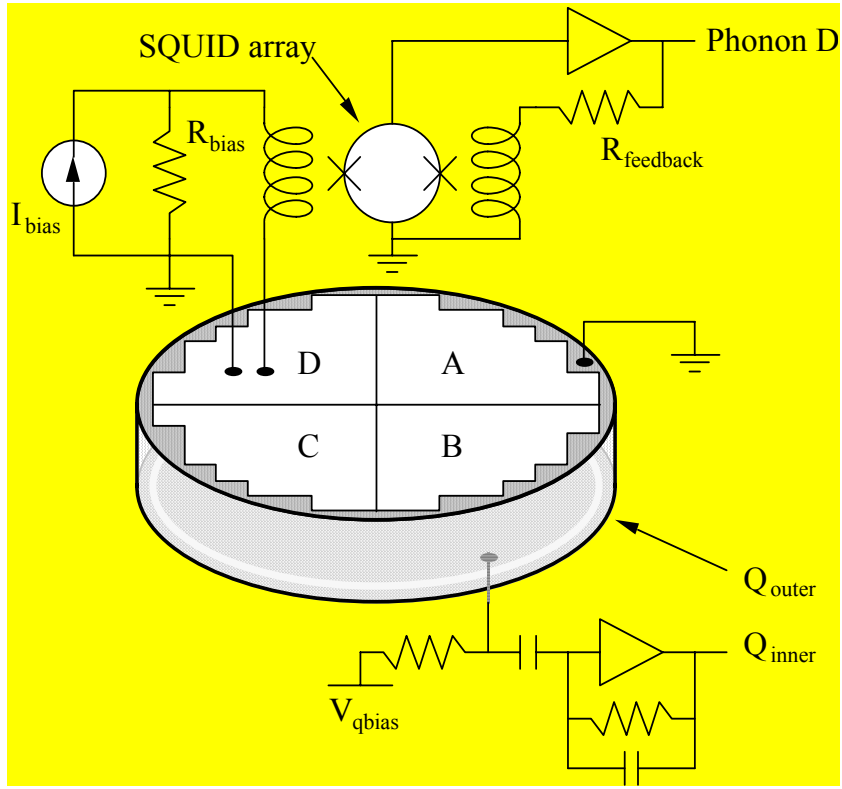
- 2000 mwe
- Neutron flux down 1/300
- Commissioning fridge
- Operation this winter

CDMS Detectors

`BLIPs'

- 1/6 kg disks
- One Side Ioniz. (Q)
- Thermistor - Phonons (P)
  - slow
- Results



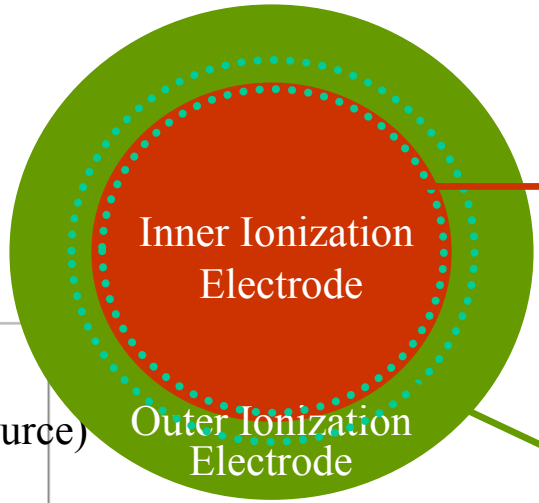


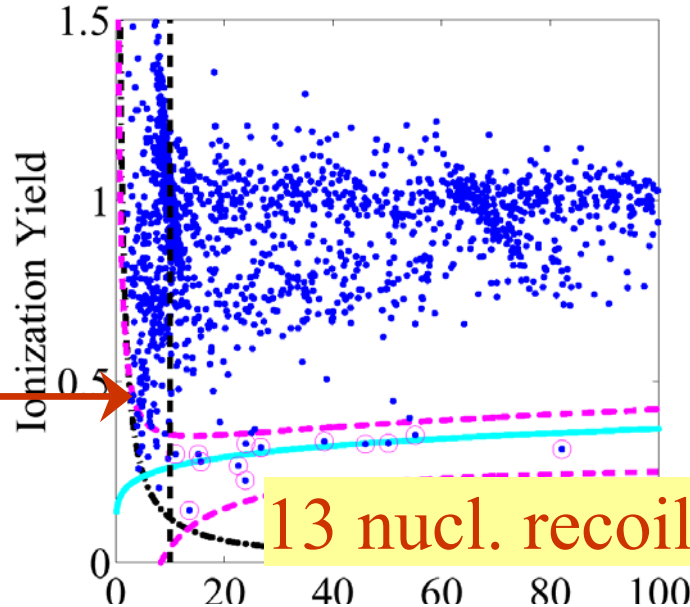
`ZIPs'

- P - ahtermal photons
- `TES' - Trans. Edge Sens
- Fast Signal: x, y, z
- Performance at Stanford

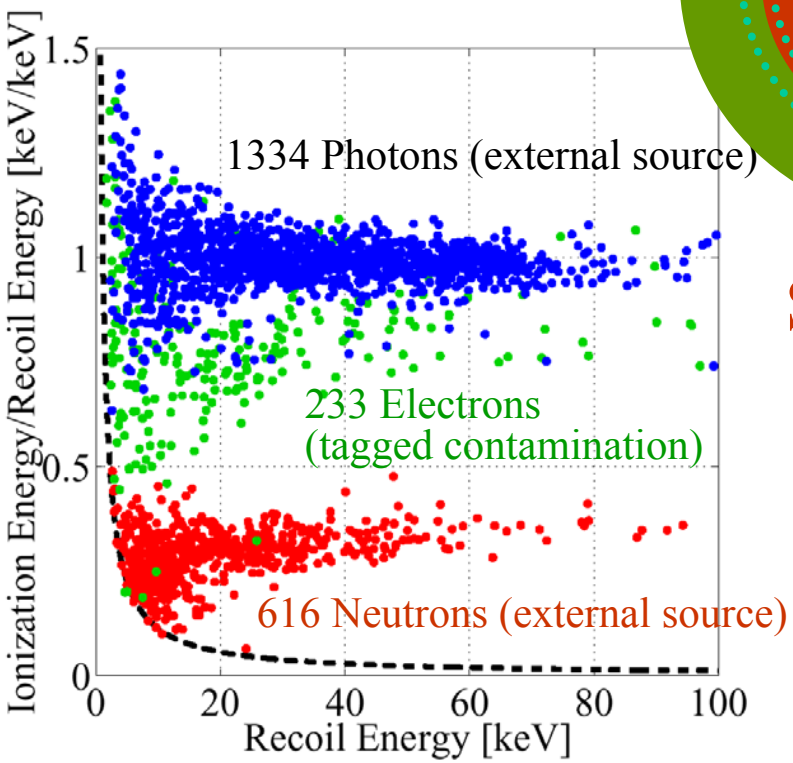
CDMS Data (BLIP)

Inner: 12 kg-d

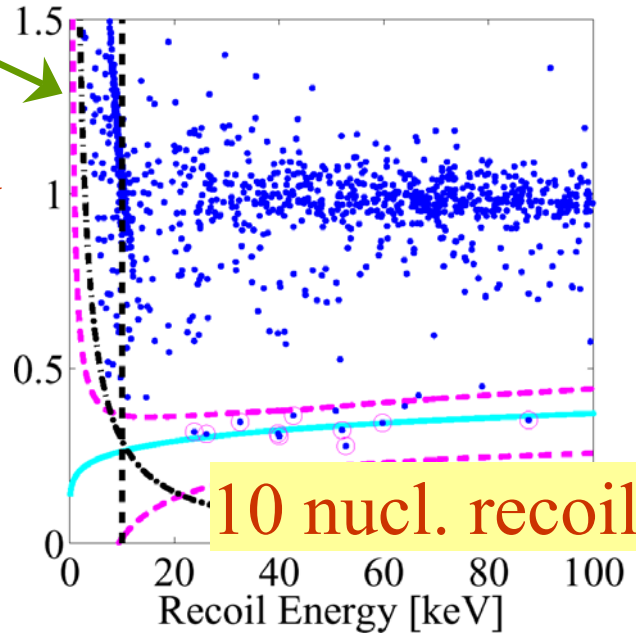




Calibration



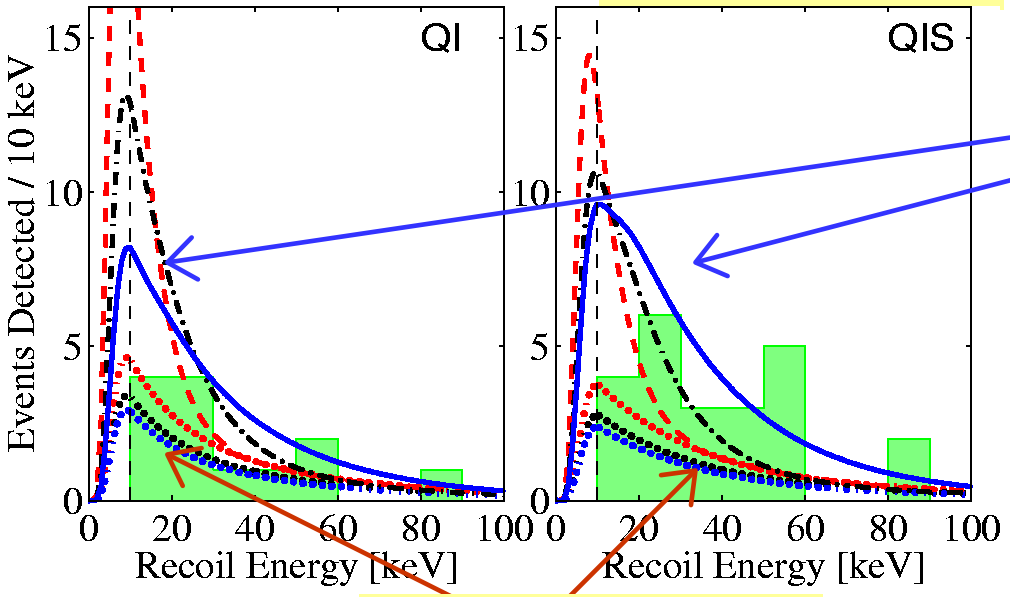
Shared: 4.4 kg-d



Shallow: Neutrons

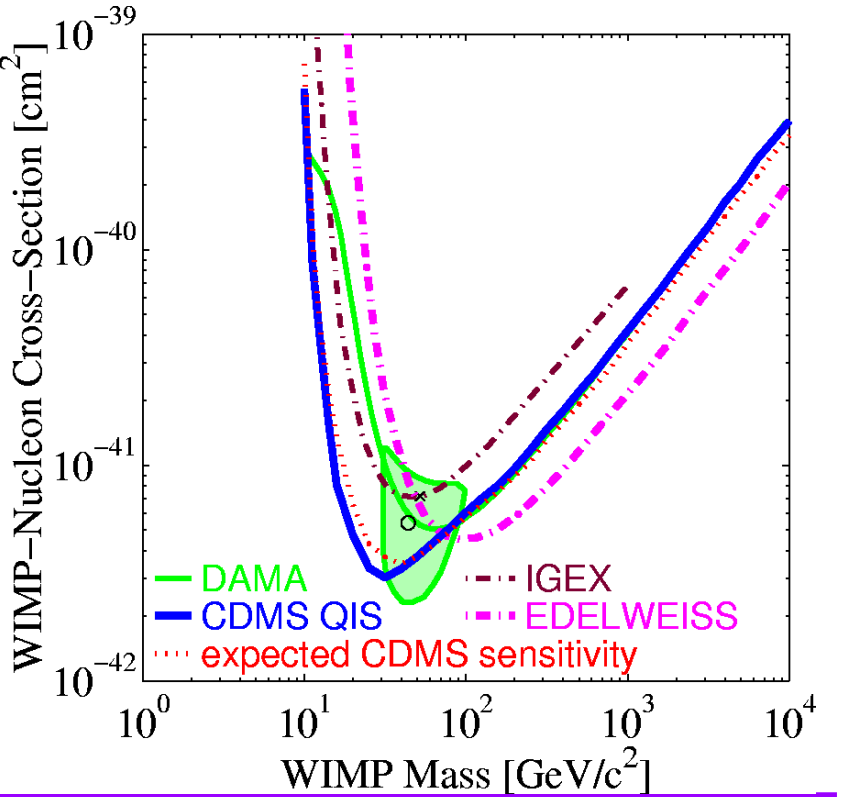
Updated Limits

Shared Electrode



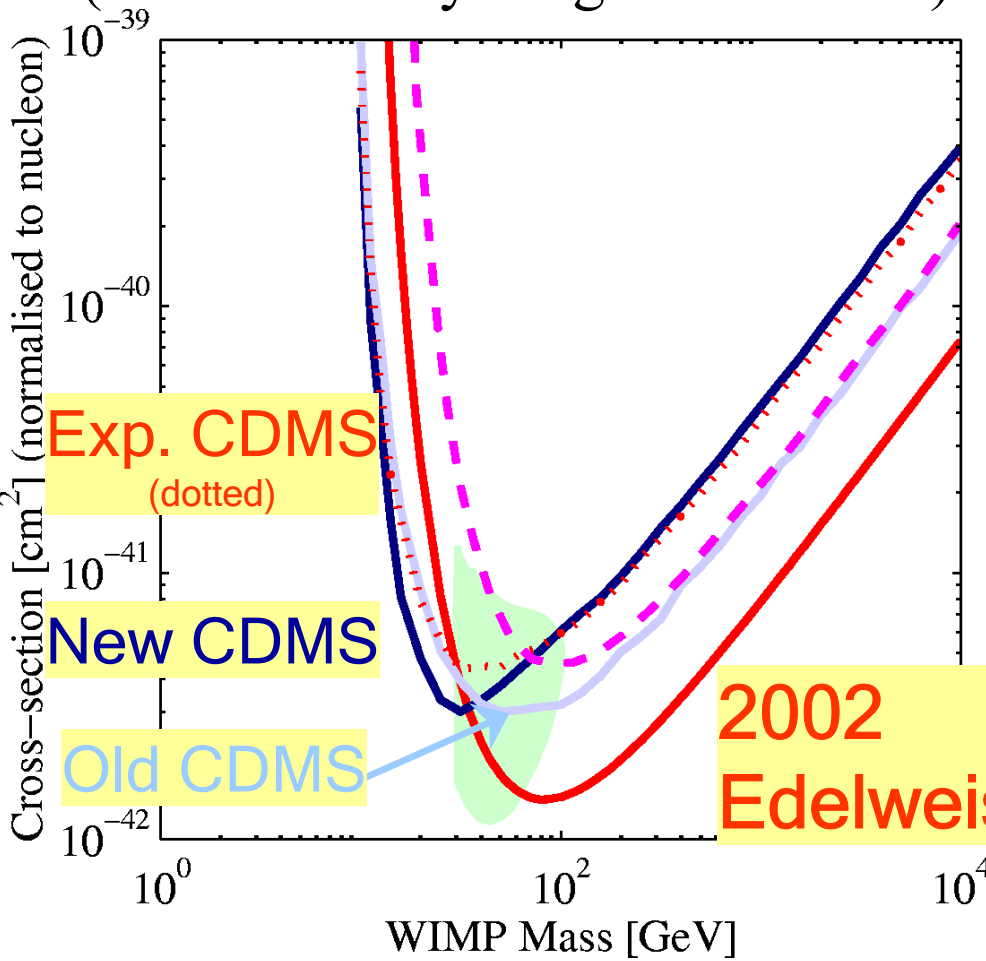
With WIMPs
Various Masses

Neutron Bkgd

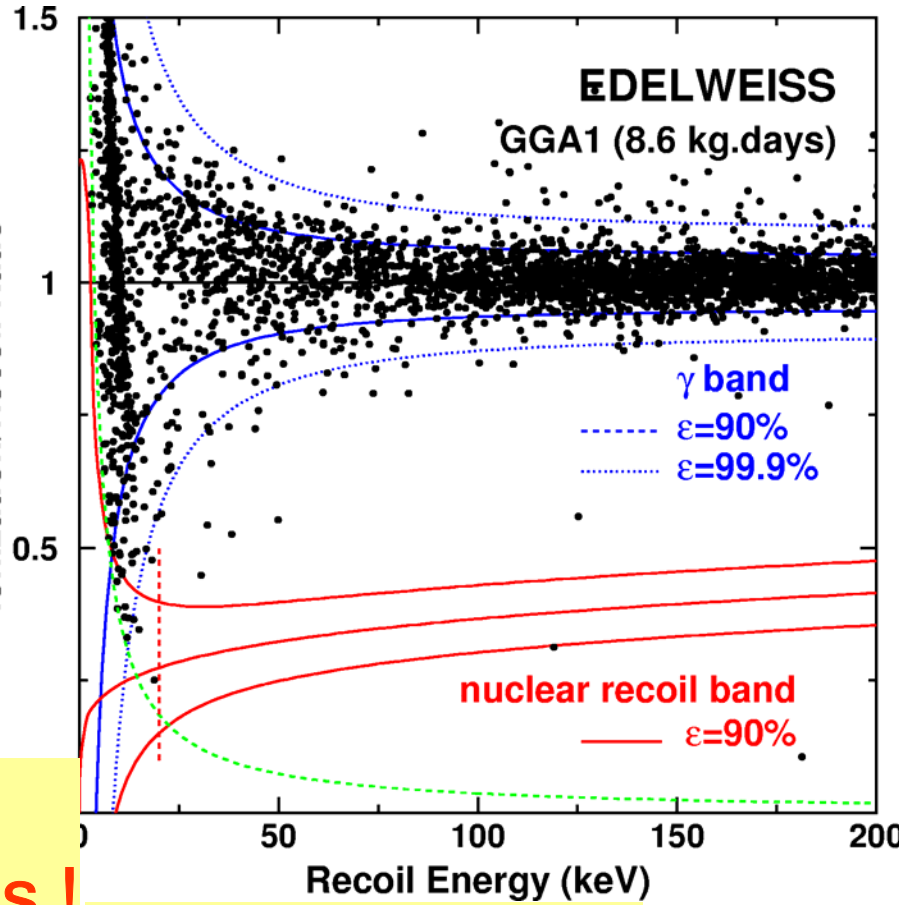


Explanation, Edelweiss

CDMS: shift toward expected
(old had `lucky' bkgd fluctuation)



Detectors: similar to CDMS



0.2% CL for consis-
tency with DAMA

15.8 kg-d / 16 mwe depth

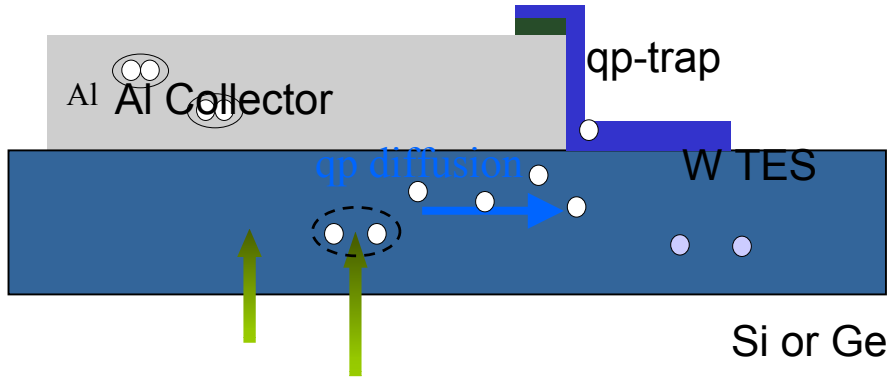
11.7 kg-d / 4800 mwe

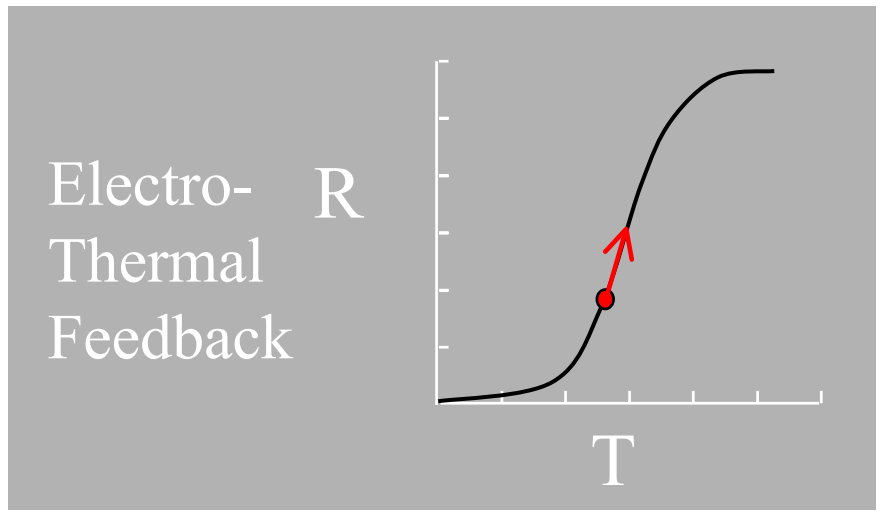
CDMS Status

- At Shallow Site (16 mwe):
  - ⇒ Neutron Shielding Added (reduce 1/2)
  - ⇒ Detector Technology Completely Changed
    - → `ZIP'… detect athermal phonons
    - → Pulse faster - microseconds
    - → Pulse Risetime - rejection of external electrons
  - ⇒ 27 kg-d accumulated, more being gathered
    - ⇒ Data Terrific
    - ⇒ Results Later This Year
- Move to Soudan (2100 mwe) ASAP

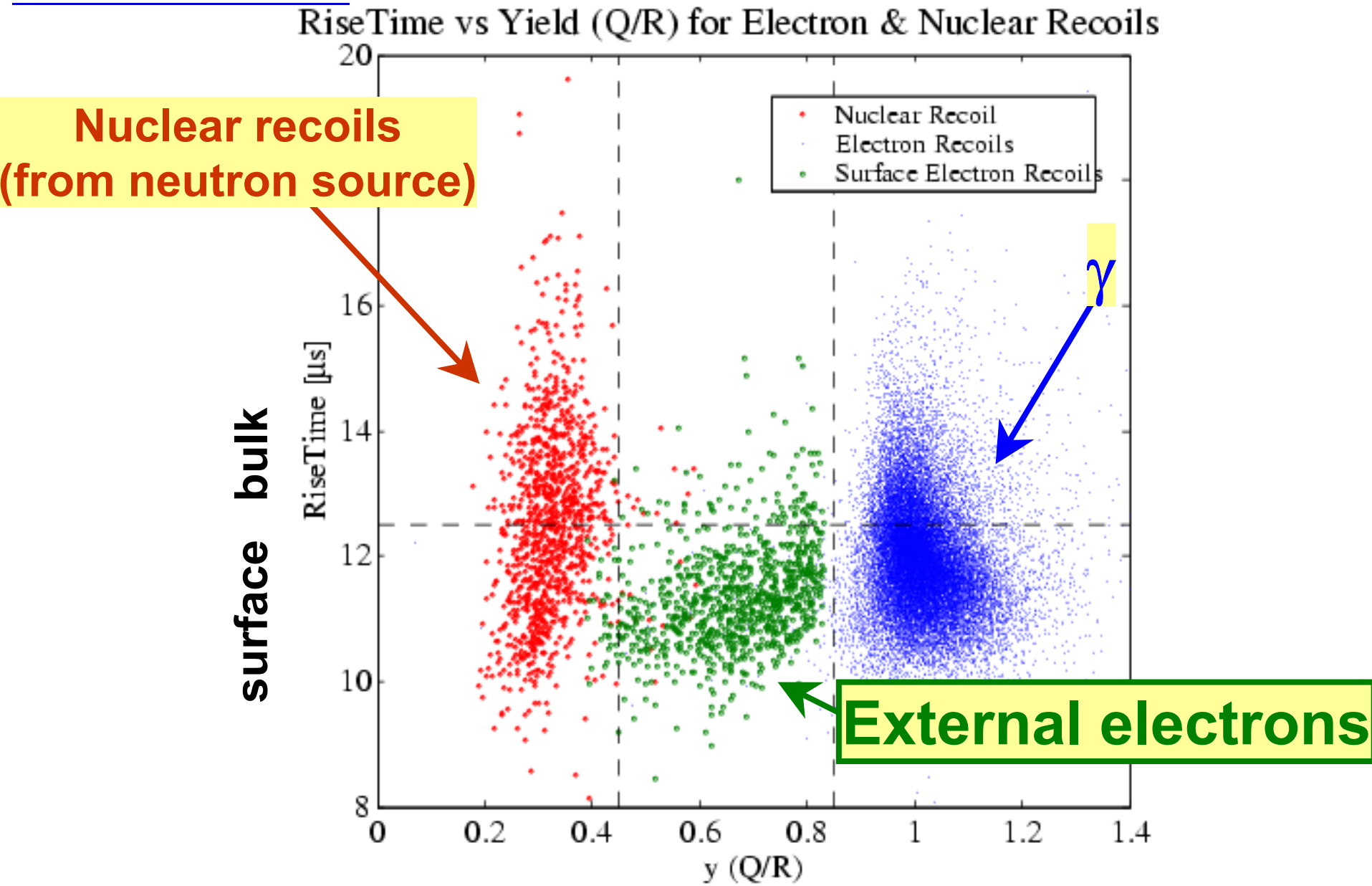
ZIP Detection Mechanism

- Recoil - THz phonons
- Phonons go to surface SC Al-fins, break Cooper pairs, giving quasiparticles.
- and create quasiparticles
- Quasiparticles diffuse in ~ μs to W transition-edge sensors (TES)
- where they release their
- energy to the W electrons
- Release energy, T is raised, R is raised
- Current change is measured with SQUIDs



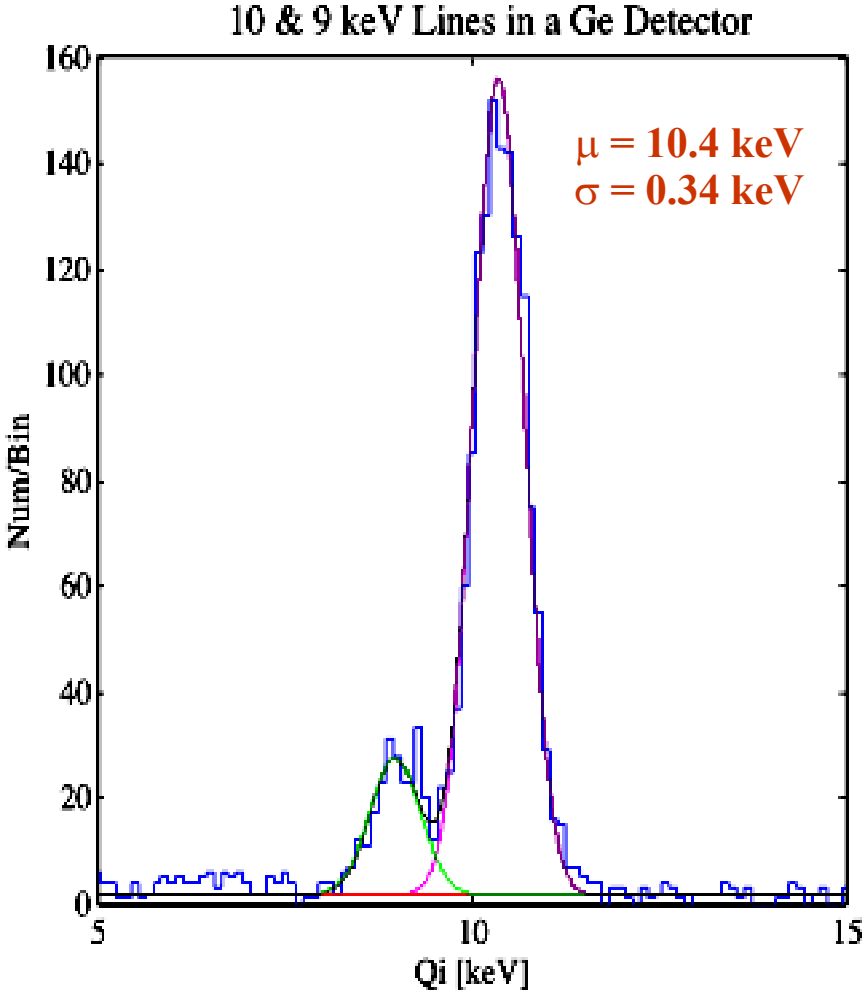


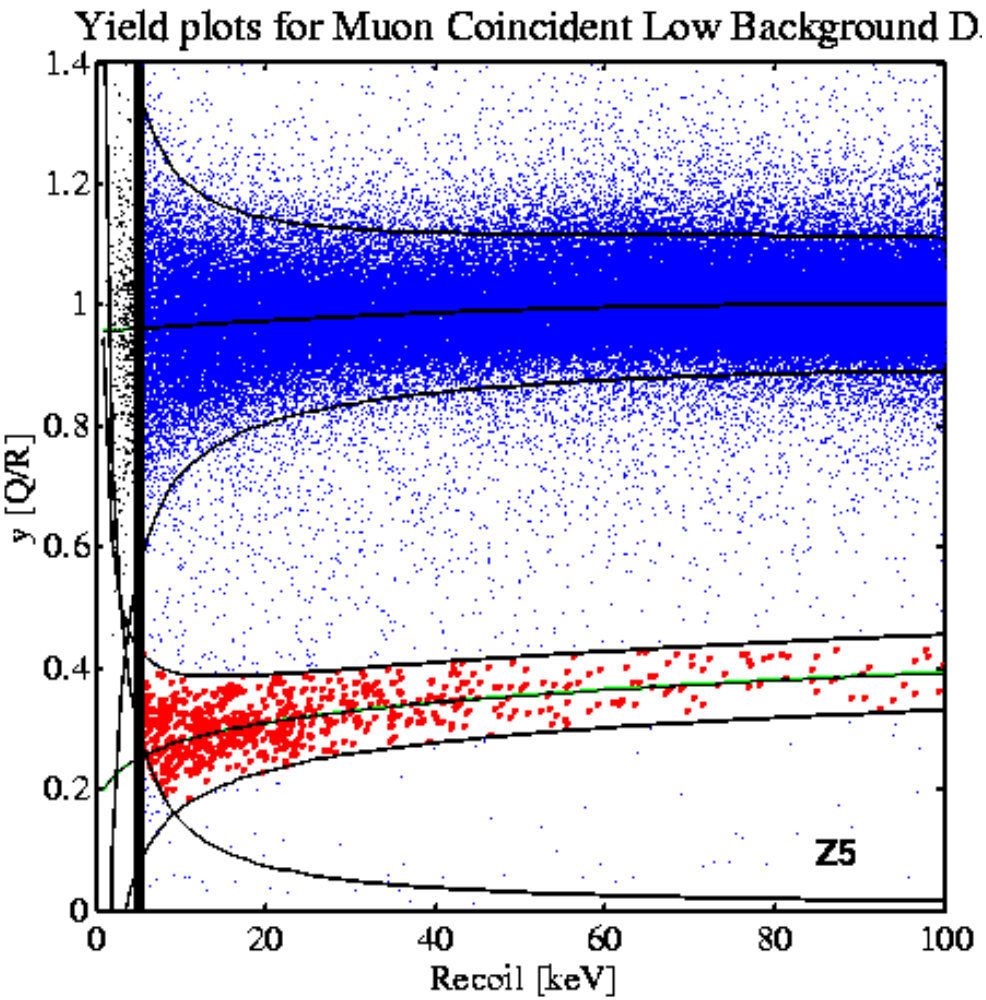
Risetime Discrimination



Recent ZIP Data

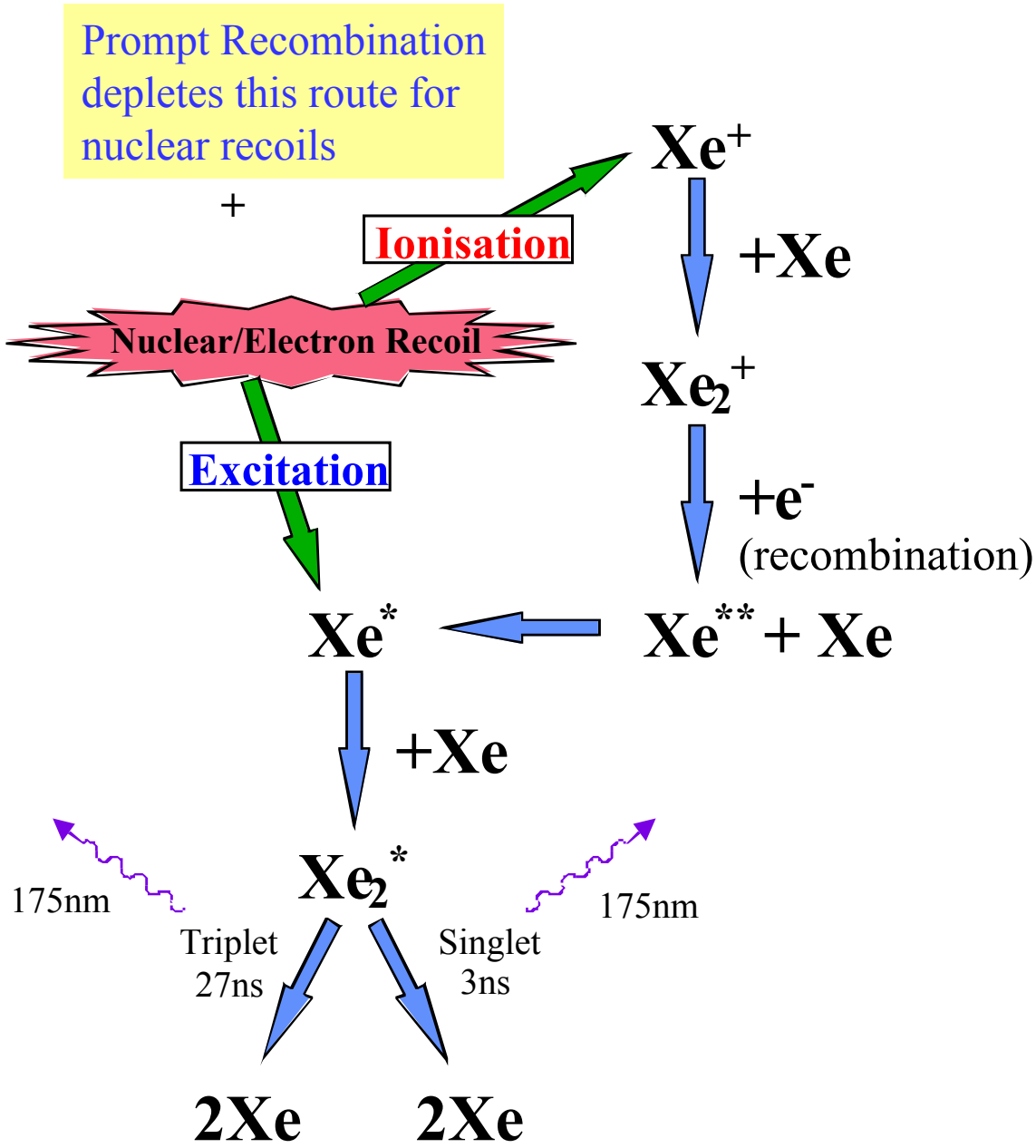
With Activity in Veto





ZEPLIN

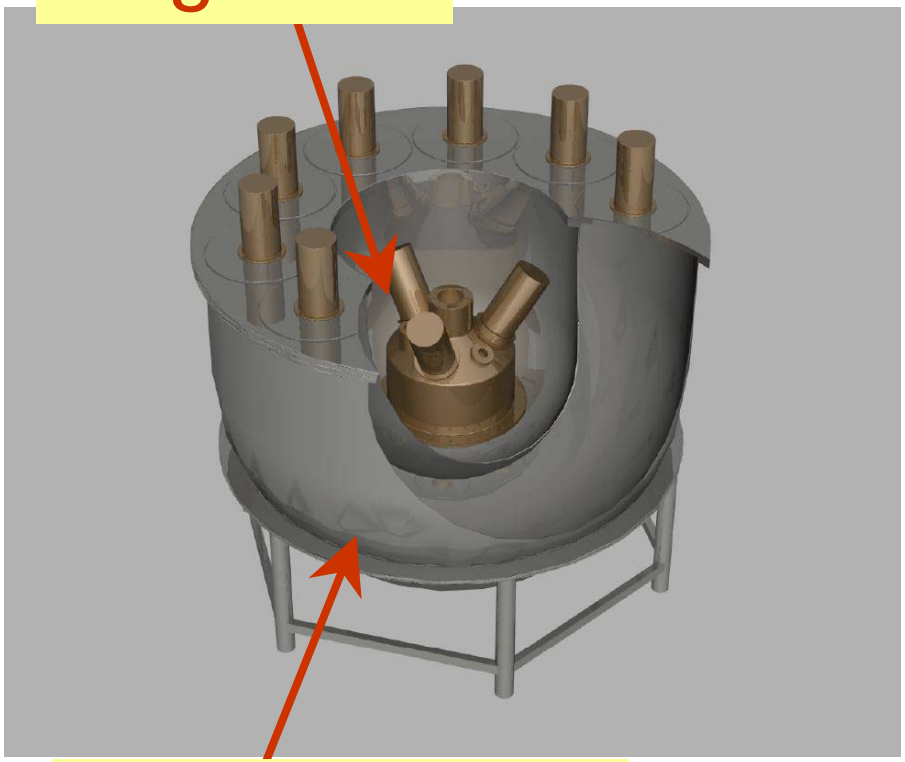
- Liquid Xenon
  - ⇒ Scale-up to 1000 kg
  - ⇒ Scintillates without additives
  - ⇒ Pulse Shape - recoil/γ discrimination
  - ⇒ Zeplin 1
- Sensitivity Enhancement
  - ⇒ Ionization (Z2/3)
  - ⇒ non - PMT



ZEPLIN-1

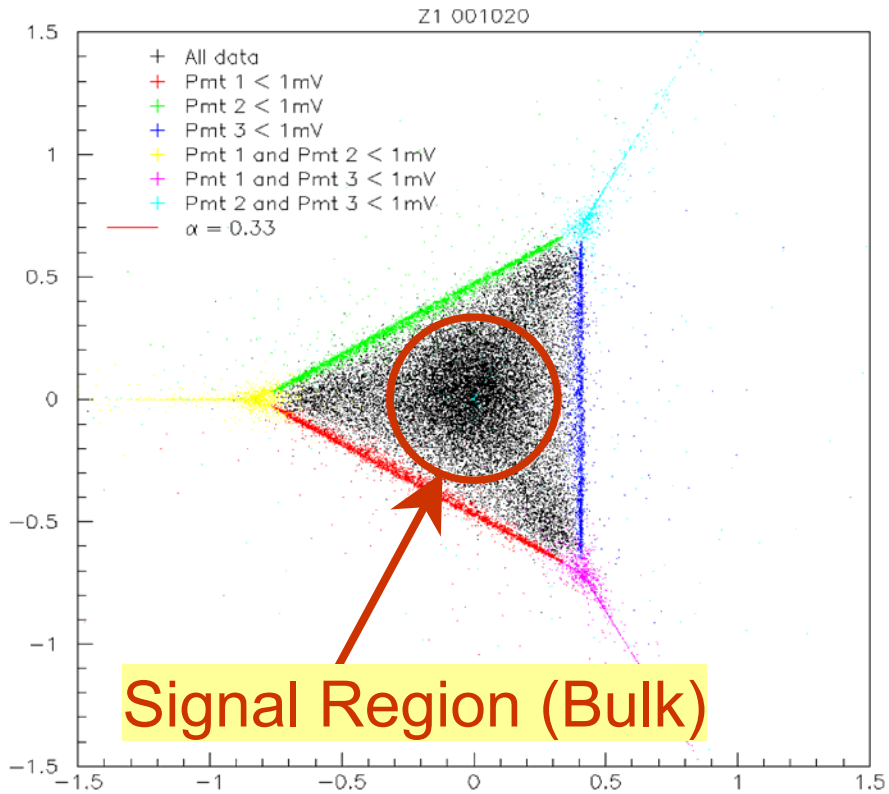
Boulby in UK - 3600 mwe depth

3 tubes
4 kg L Xe



Active Shield

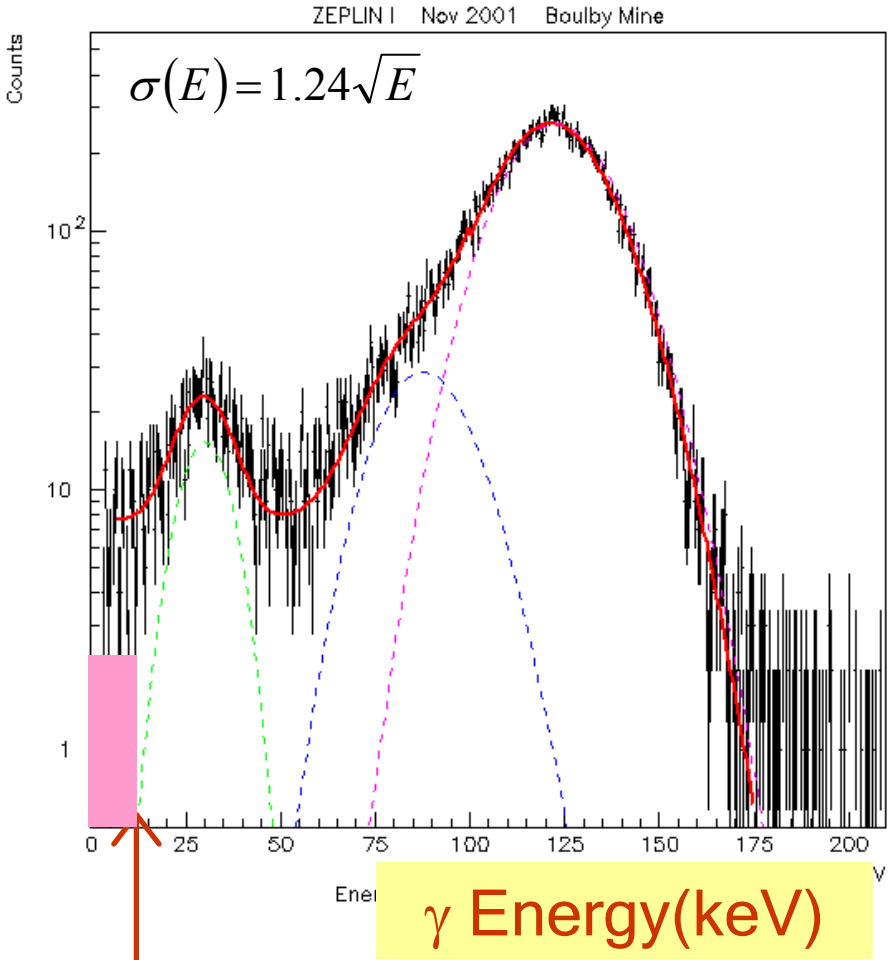
Data



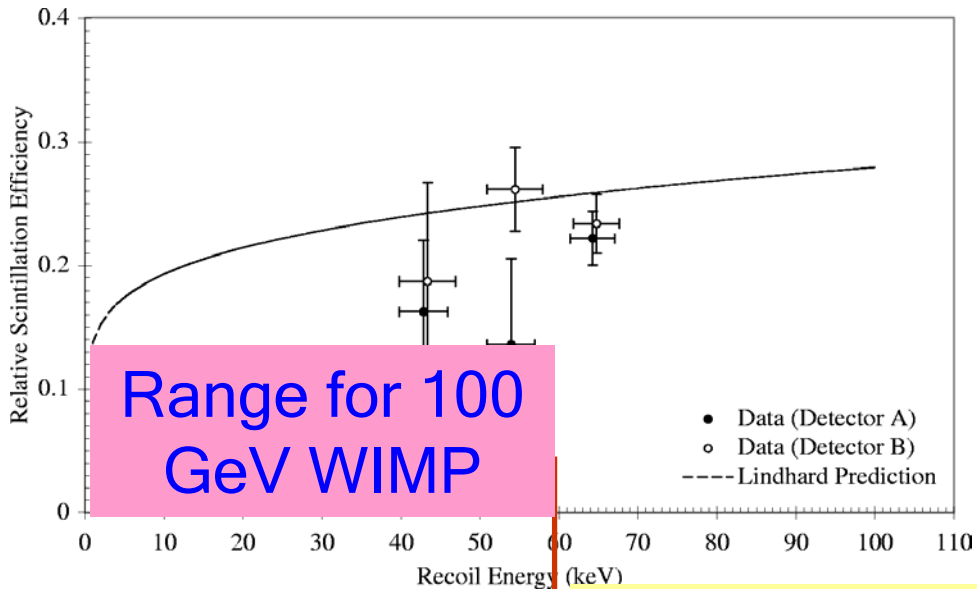
Signal Region (Bulk)

Calibration

≈ 1/5 of energy from nuclear recoil appears as scintillation



γ Energy(keV)

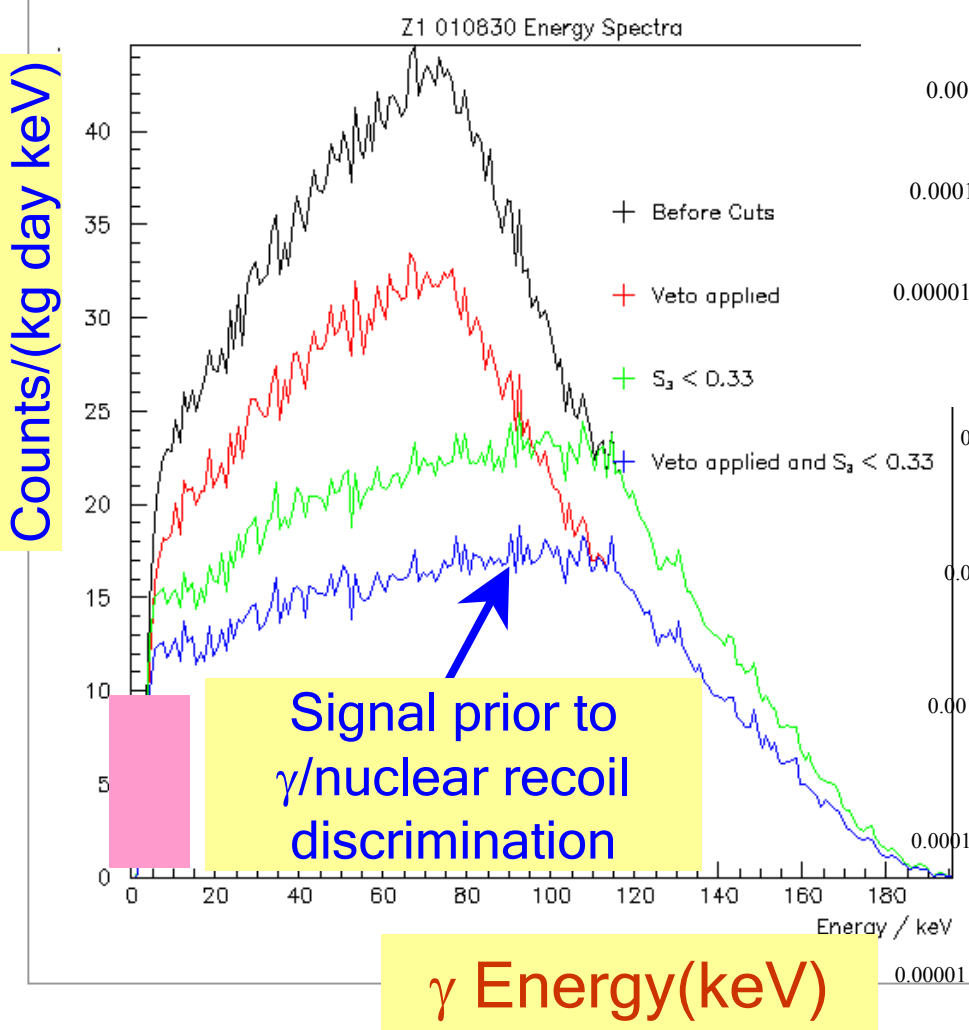


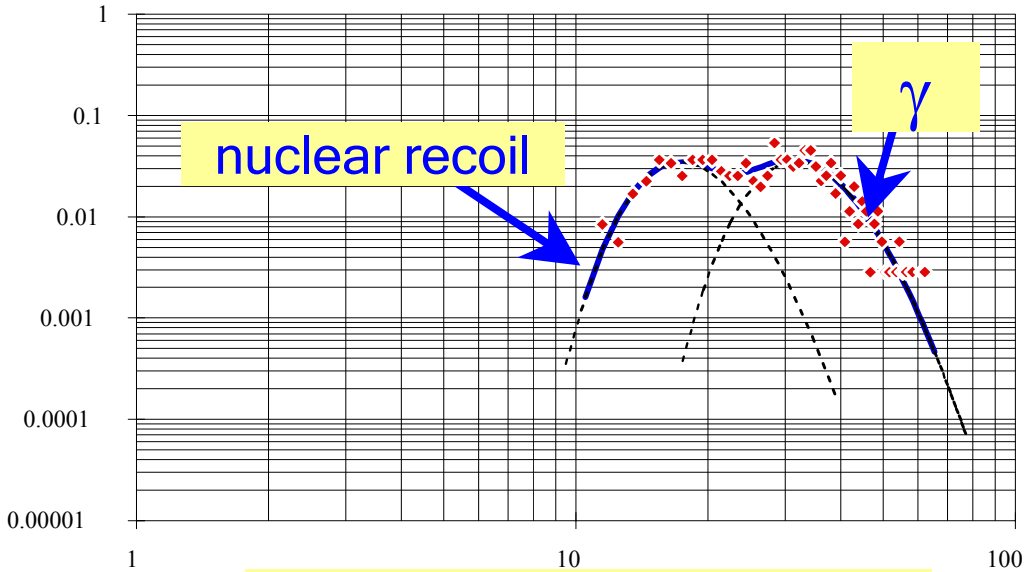
Range for 100 GeV WIMP

Recoil Energy (keV)

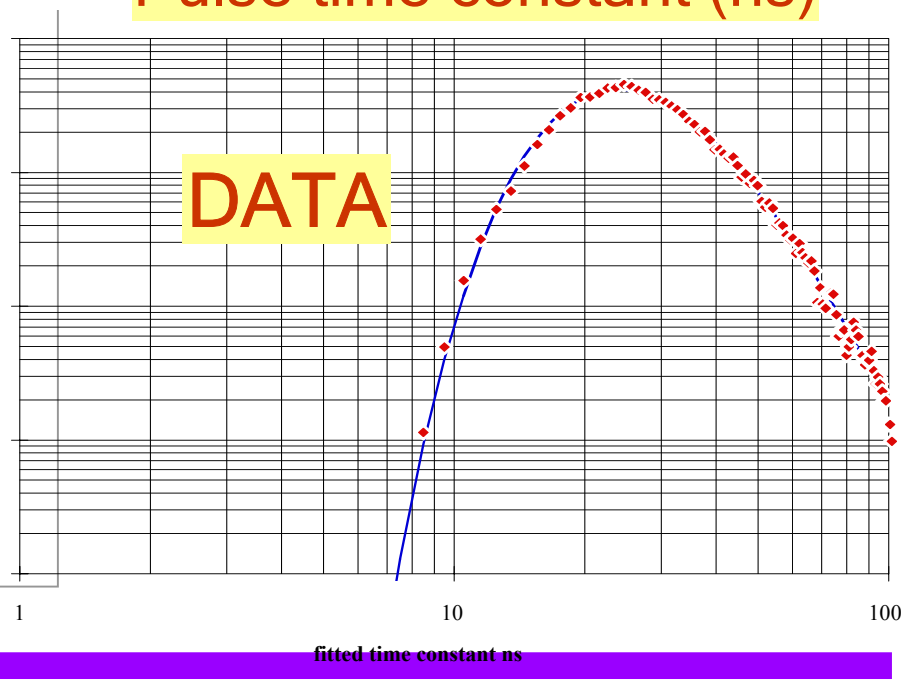
WIMP Data

90 kg-days

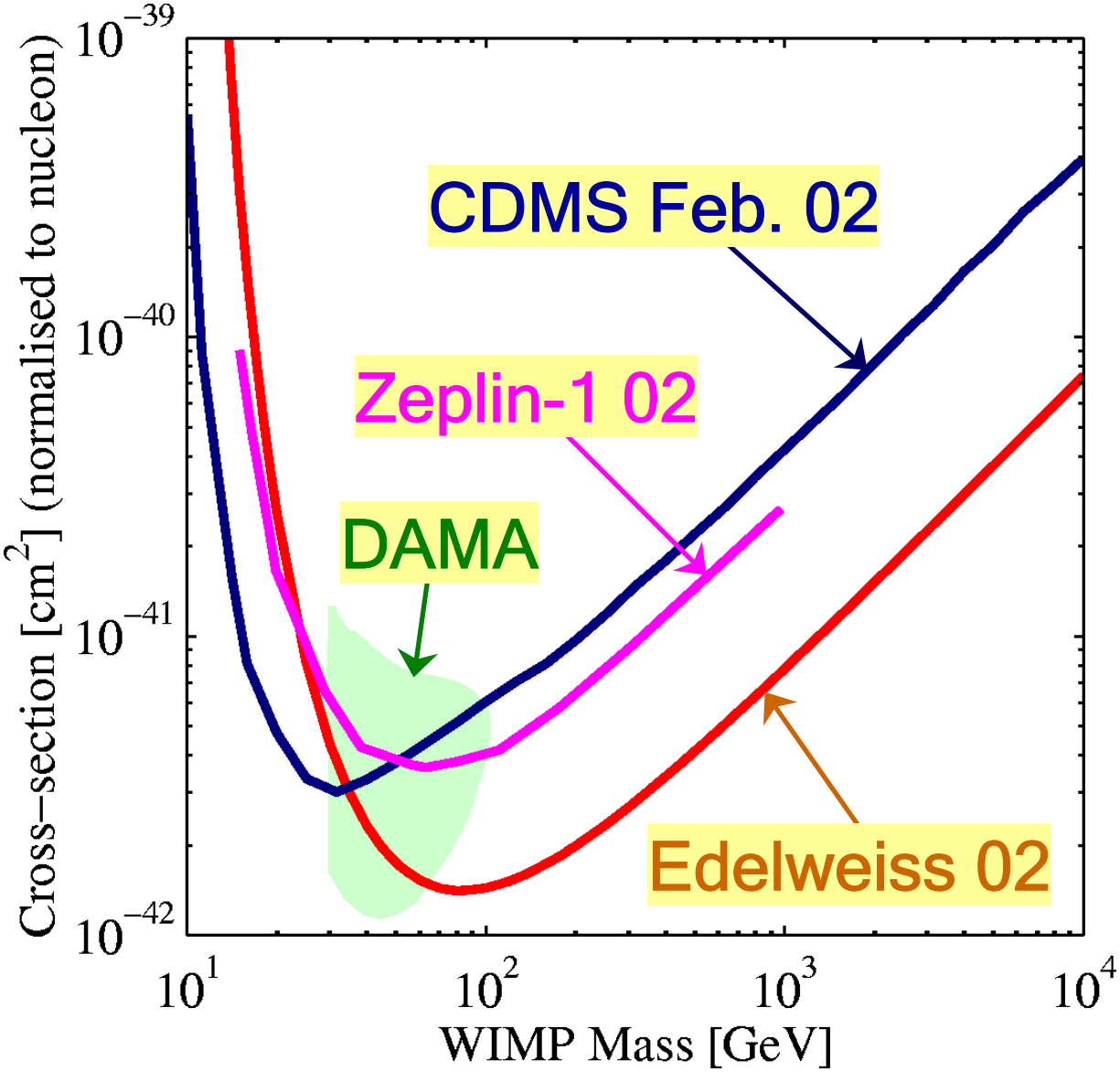




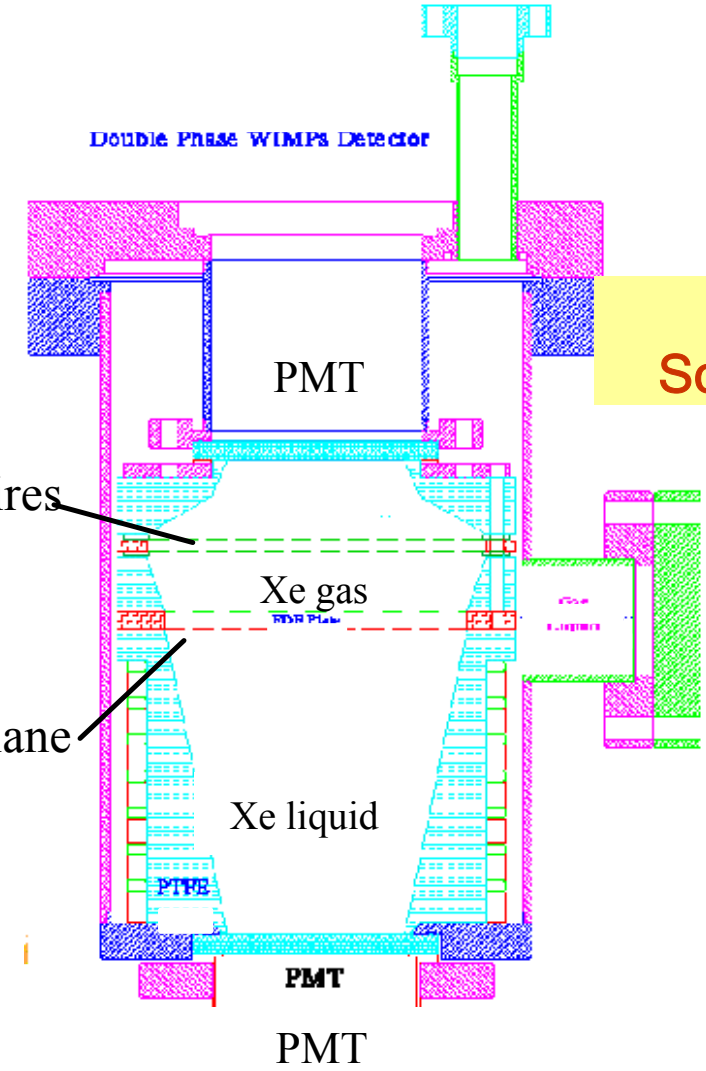
Pulse time constant (ns)

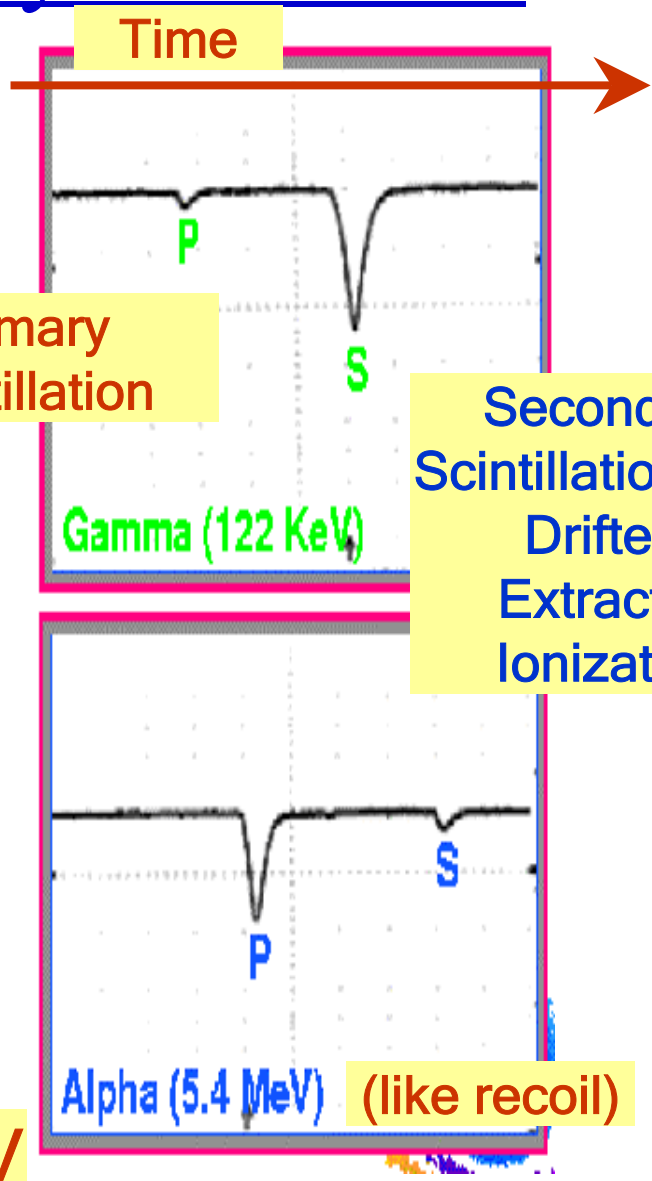


Summer 2002 Status



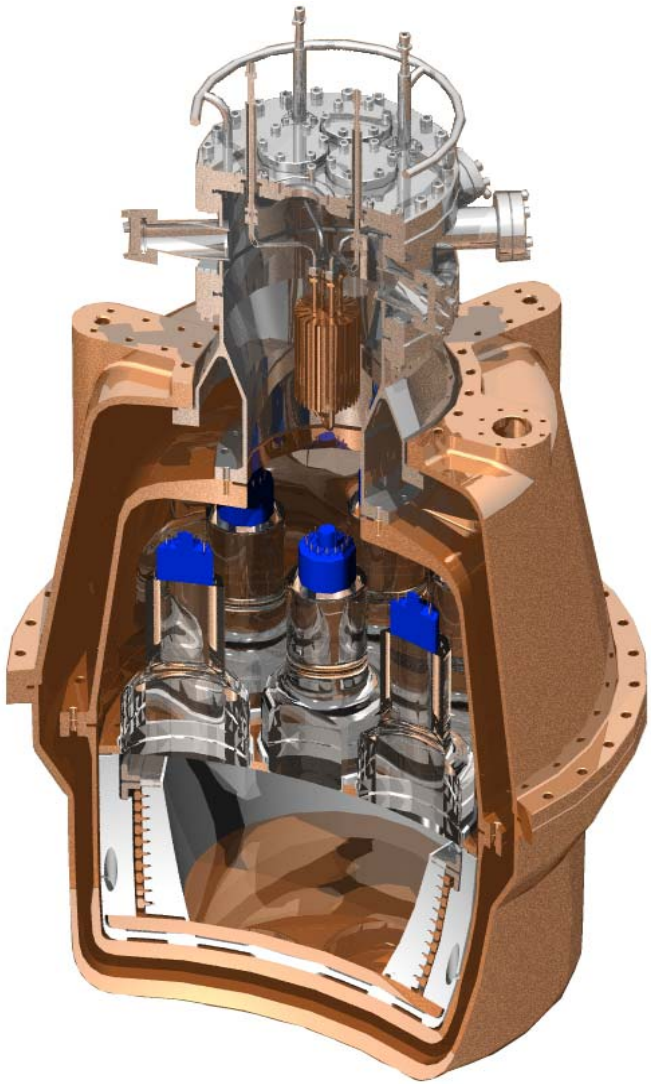
Zeplin II, III: drift, amplify ionization



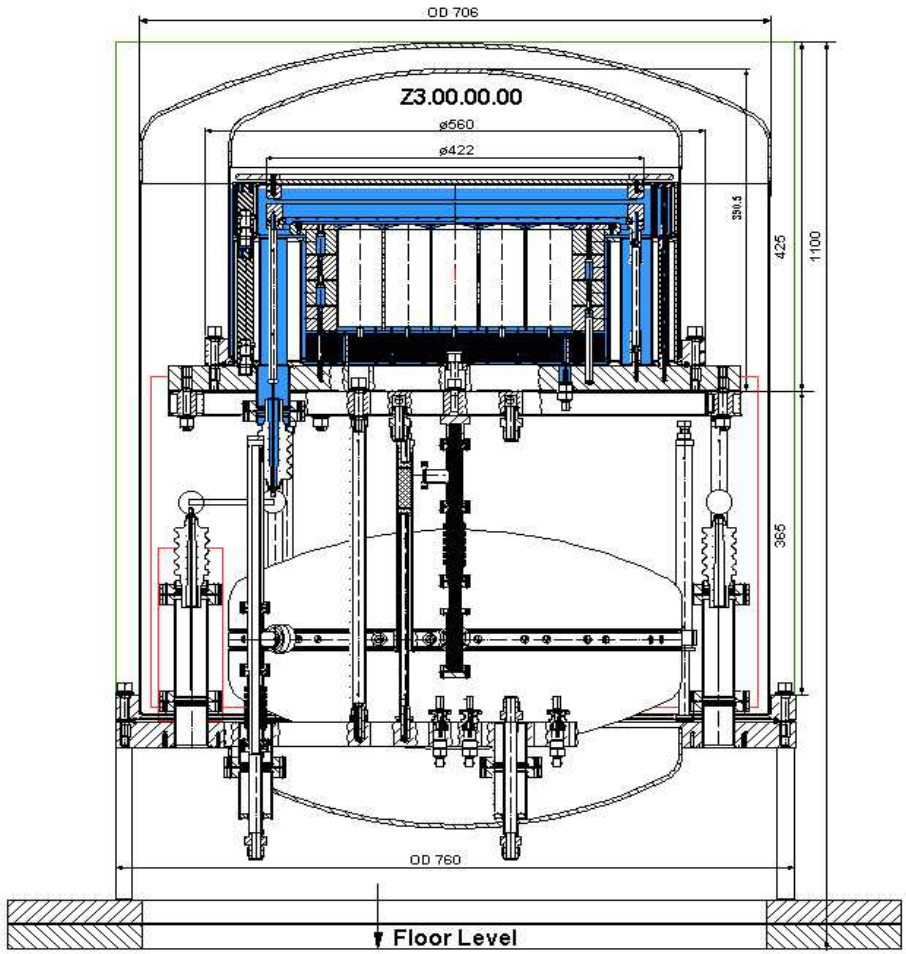


... nuclear recoil threshold of 5 keV

Zeplin II (30 kg)



Zeplin III (6 kg)



Long Term Goal is 1000 kg....

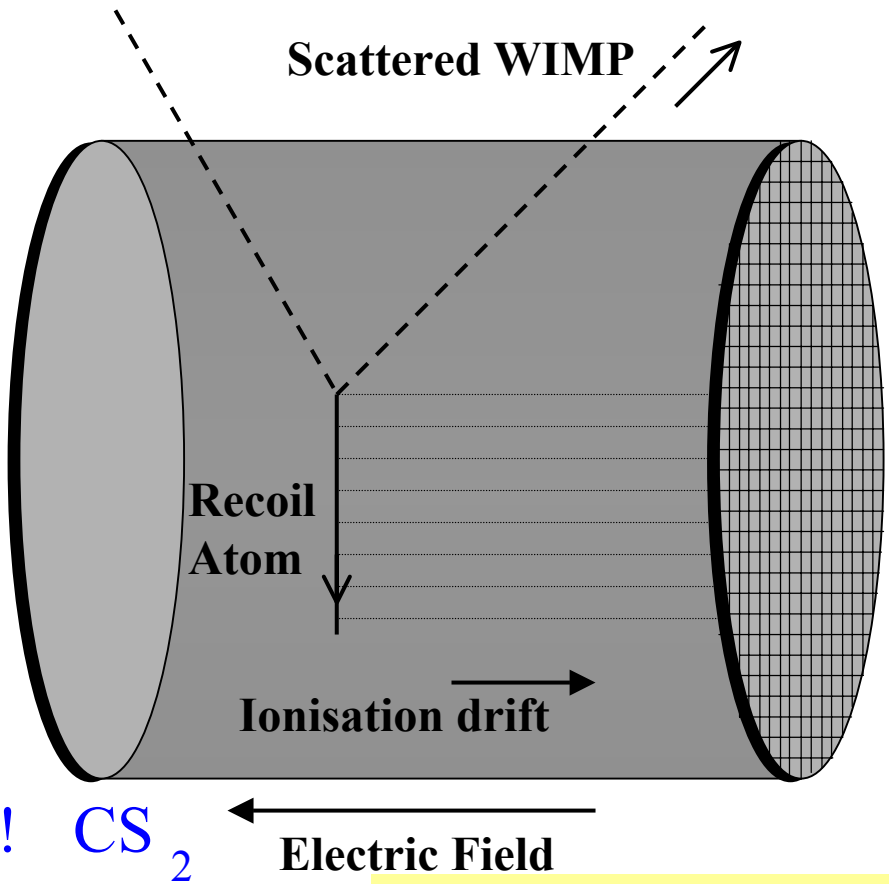
DRIFT

Boulby in UK - 3600 mwe depth

TPC

1 m^3 40 Torr CS_2 (0.17 kg)

Mass Comparable to CDMS/Edelweiss Detector



$e + CS_2 \rightarrow CS_2$

Drift the CS_2

Suppresses Diffusion (no B field)
Preserve Spatial Info

Discrimination by Imaging

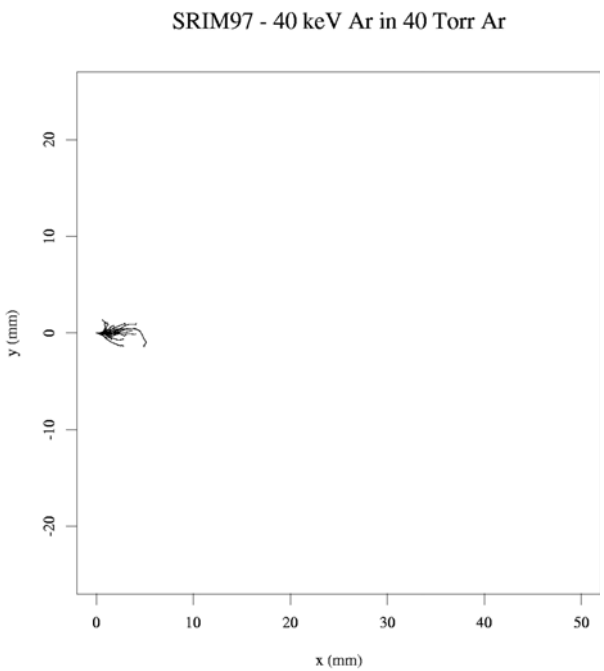
Nuclear Recoils

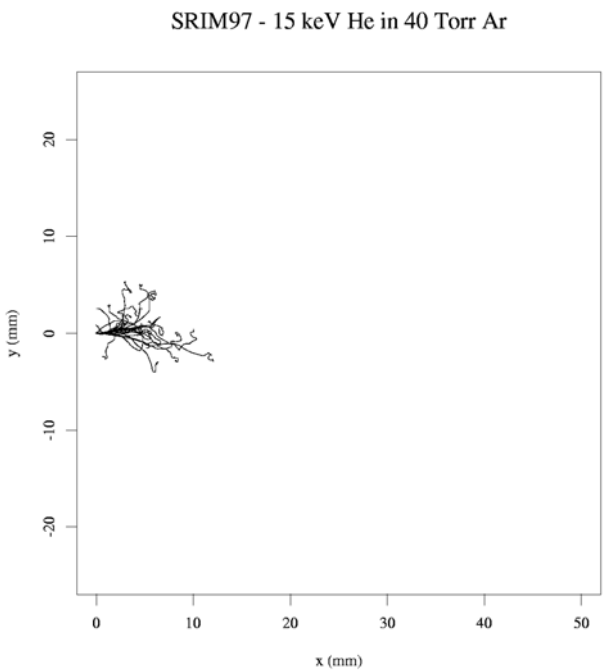
γ

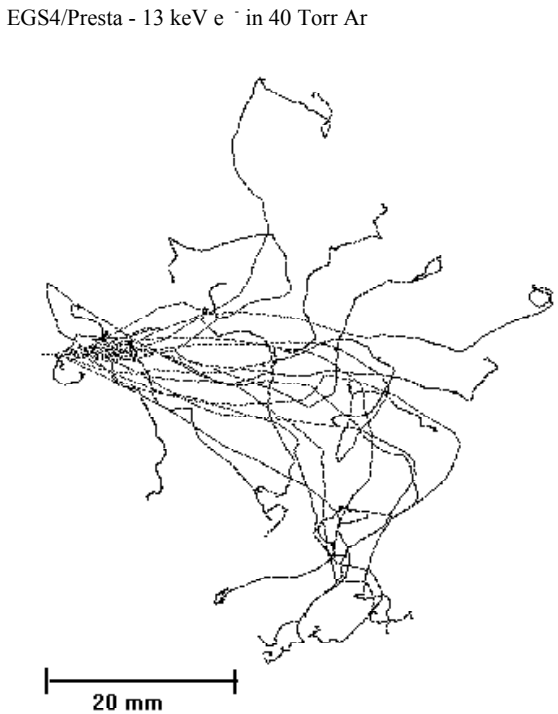
40 keV Ar recoils
500 electron-ion pairs

15 keV α s
500 electron-ion pairs

13 keV e^-
500 electron-ion pairs

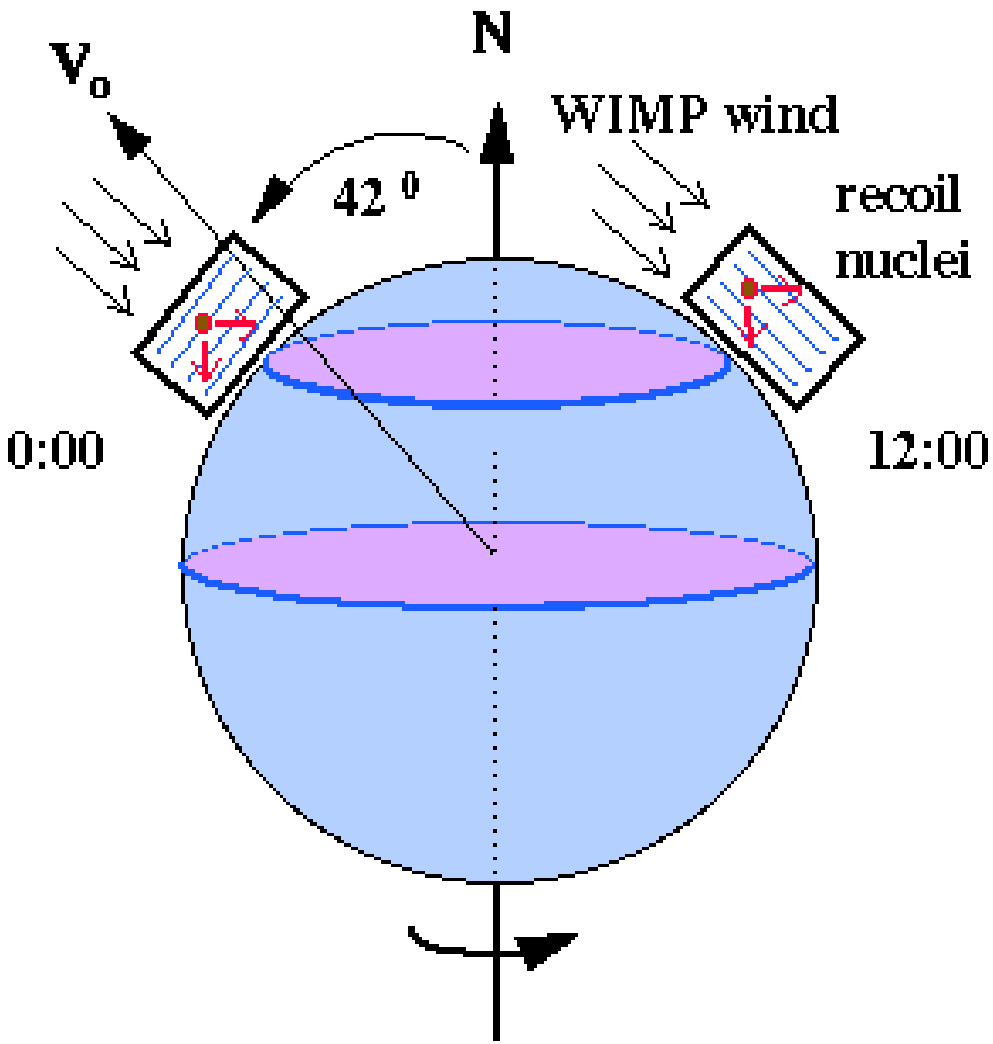






… Maybe even the direction of the recoil can be reconstructed

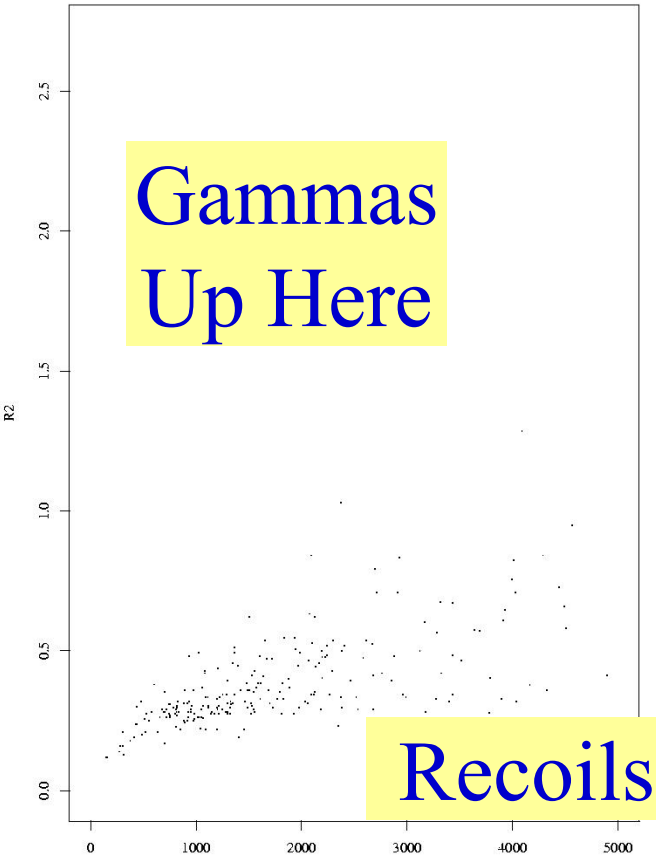
Diurnal Variation (if WIMP `wind')



TPC operating now

Calibration

Spatial Size



Gammas Up Here

Recoils

Ionization

Competitive sensitivity after a few months of running

Summary

- Lots of recent progress
  - ⇒ Edelweiss
  - ⇒ Zeplin-1
  - ⇒ CDMS in a few months
  - ⇒ DRIFT on line
- Everyone has expansion plans to keep gain orders of magnitude both in near and long term future
- 2010… let's hope we have an LSP WIMP and are doing astrophysics with it and studying it in LHC decays!

Acknowledgements

- CDMS collaboration, particularly Tarek Saab, Richard Schnee, Rick Gaitskell, Chris Savage, Ron Ferril
- Zeplin - Nigel Smith, Neil Spooner
- DRIFT - Dan Snowden-Ifft, Jeff Martoff