

Direct Underground Searches For Cold Dark Matter

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London

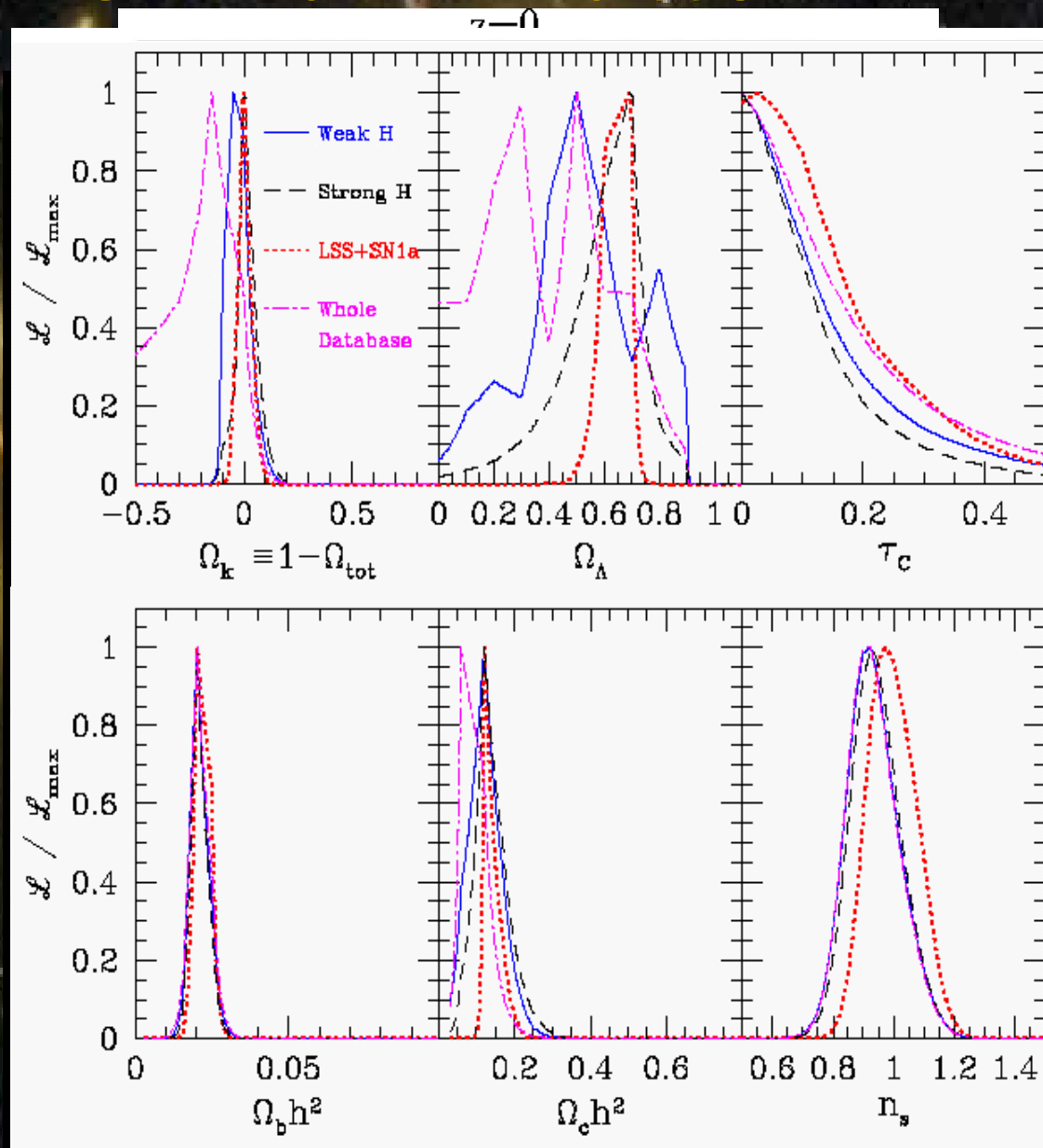
- Evidence for cold dark matter
- Galactic candidates
- Neutralino detection requirements
- Underground experiments



Evidence for Dark Matter

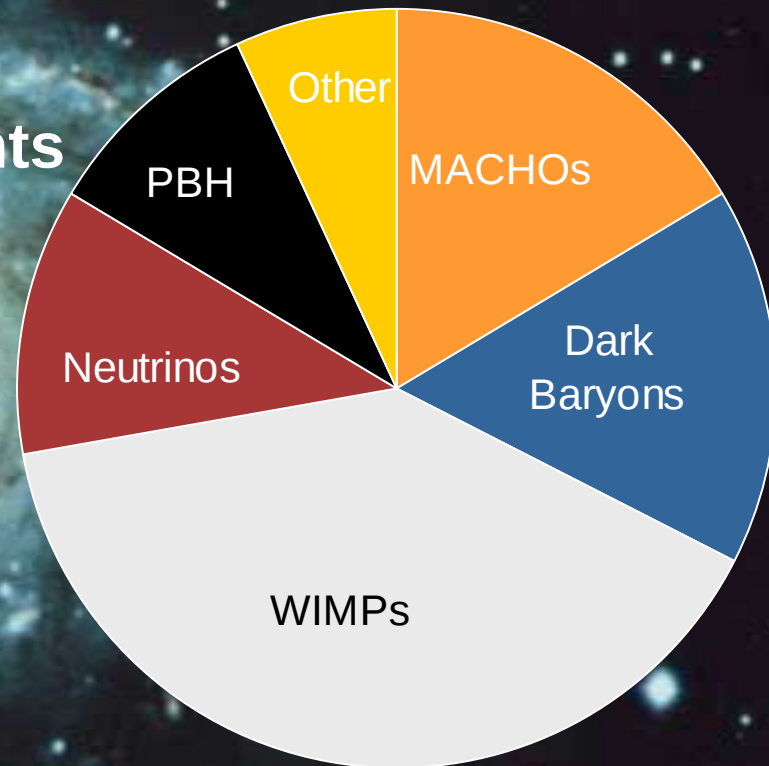
Probing Gravitational Potentials

- Local stellar dynamics
- Galaxy rotation curves
- Cluster dynamics
- X-Ray haloes
- Gravitational lensing
- Cluster streaming
- Universe geometry
- Structure formation
- Cosmological models



Galactic DM Candidates

- N-body simulations
- Dark baryons - primordial nucleosynthesis constraints
- MACHOs - microlensing constraints
- Neutrinos - mass?
- Primordial Black Holes
- WIMPS - SUSY Neutralino?
- Other - many speculative ideas, including axions



Experimental Neutralino Targets

- Expected Scattering Rates

$$R = \int_0^\infty V n_w(v) n_t \sigma(v) v dv$$

- Expected Energy Deposit

$$\left. \frac{dR}{dE} \right|_{obs} \propto \frac{R_o}{f(E) E_o r} e^{-E/f(E) E_o r} F^2(E)$$

- Local cold dark matter density
- Galaxy model
- Modulation effects
- Quenching factors
- Form factors
- Cross-sections



$n_w(v)$ - local neutralino velocity distribution

- local dark matter density
~ 0.3-0.4 GeV/cm³
- ~spherical 1/r² density distribution
- Truncated Maxwellian velocity distribution
- neutralino mass?
- Earth's spin
- Earth's orbital motion
- Solar system orbital motion

Standard Model

- Non-spherical halo
- Halo rotation
- Galactic in-fall - cusps?
- Bound solar system Earth-crossing component
- clumpy halo
- cluster in-fall
- sub-dominant density

Options



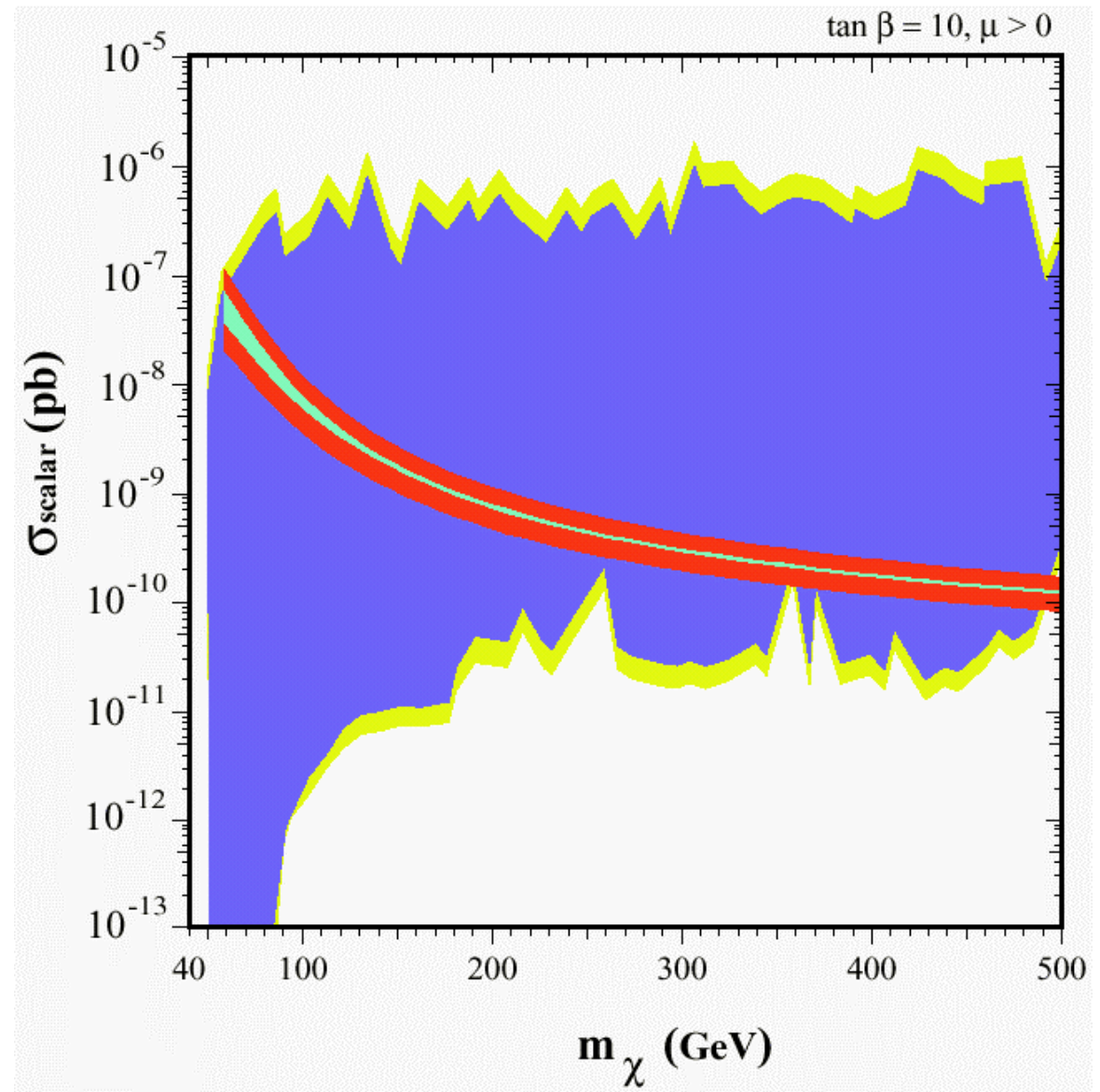
Neutralino cross-sections

- Neutralino model?
- Spin-independent
- Spin-dependent
- Form-factors?
- Spin factors?

10^{-9} pb gives
 ~ 1
event/day/ton

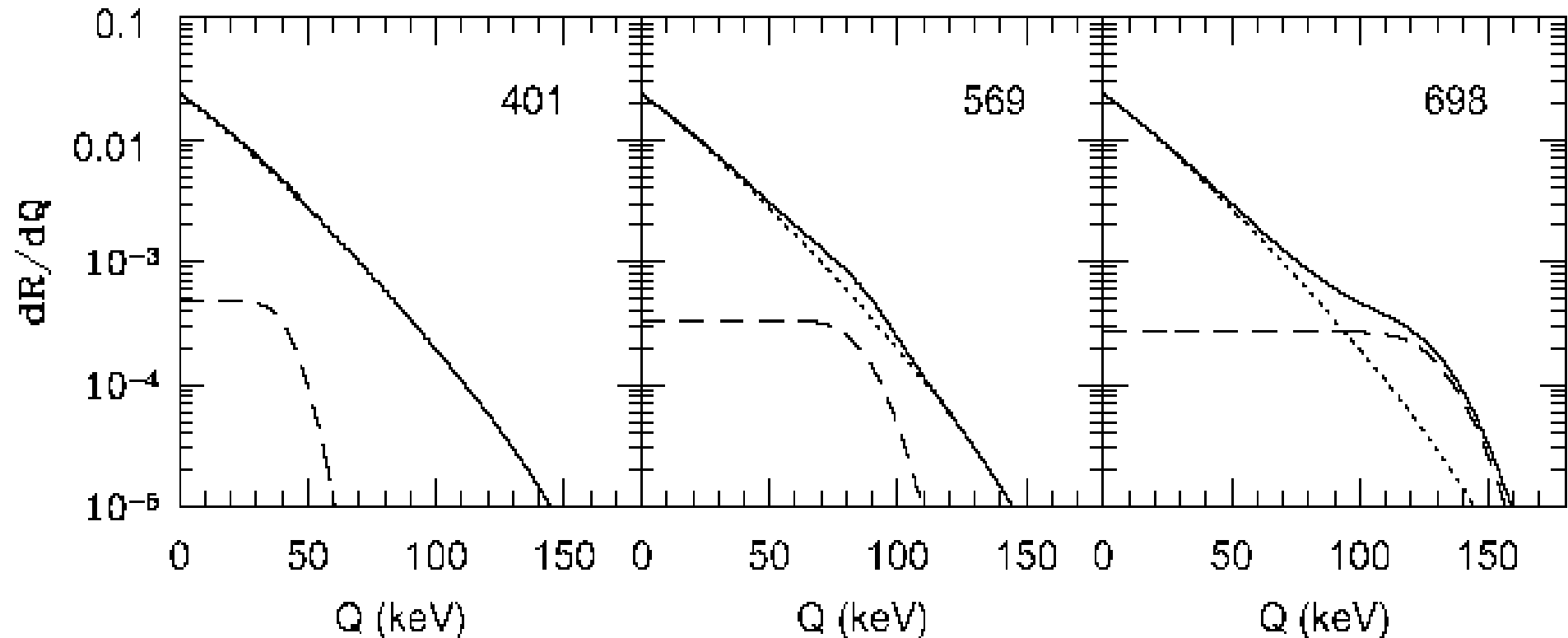


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Ellis et al. 2001 - hep-ph/0106148

Neutralino recoil spectrum



Stiff, Widrow & Frieman - astro-ph/0106048

Quenching factor

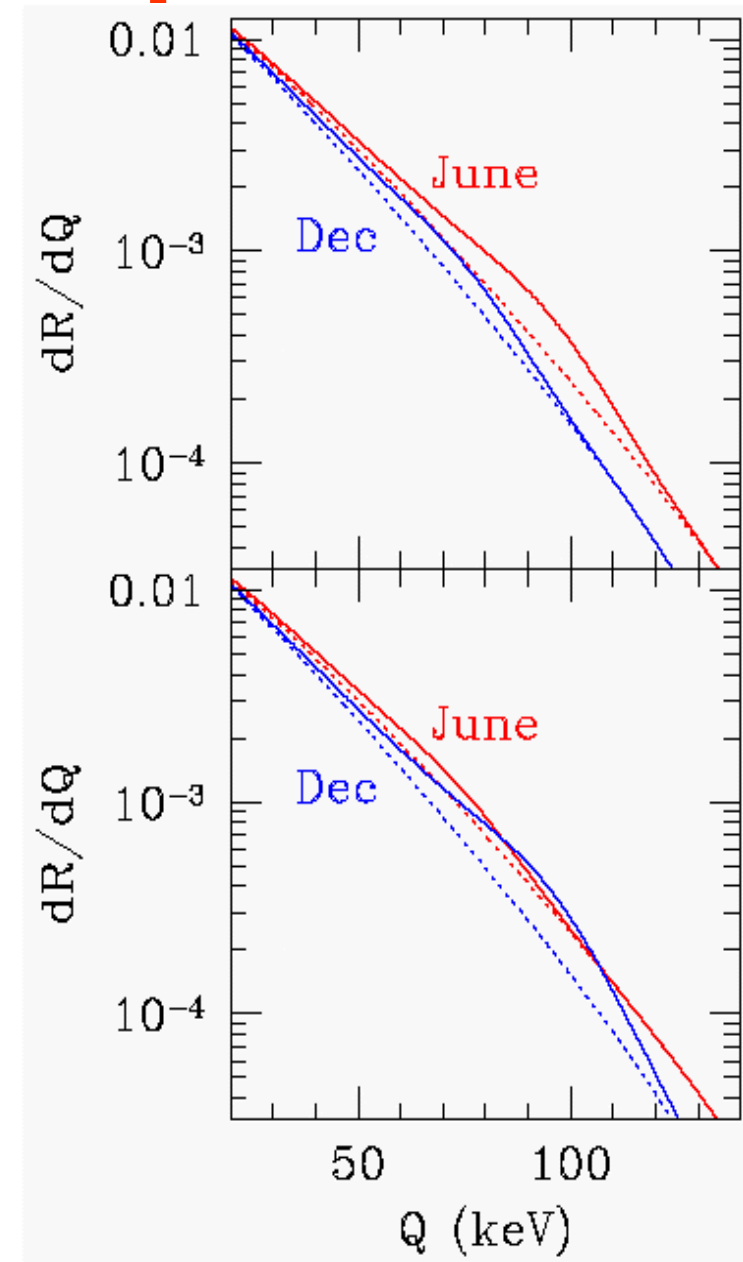
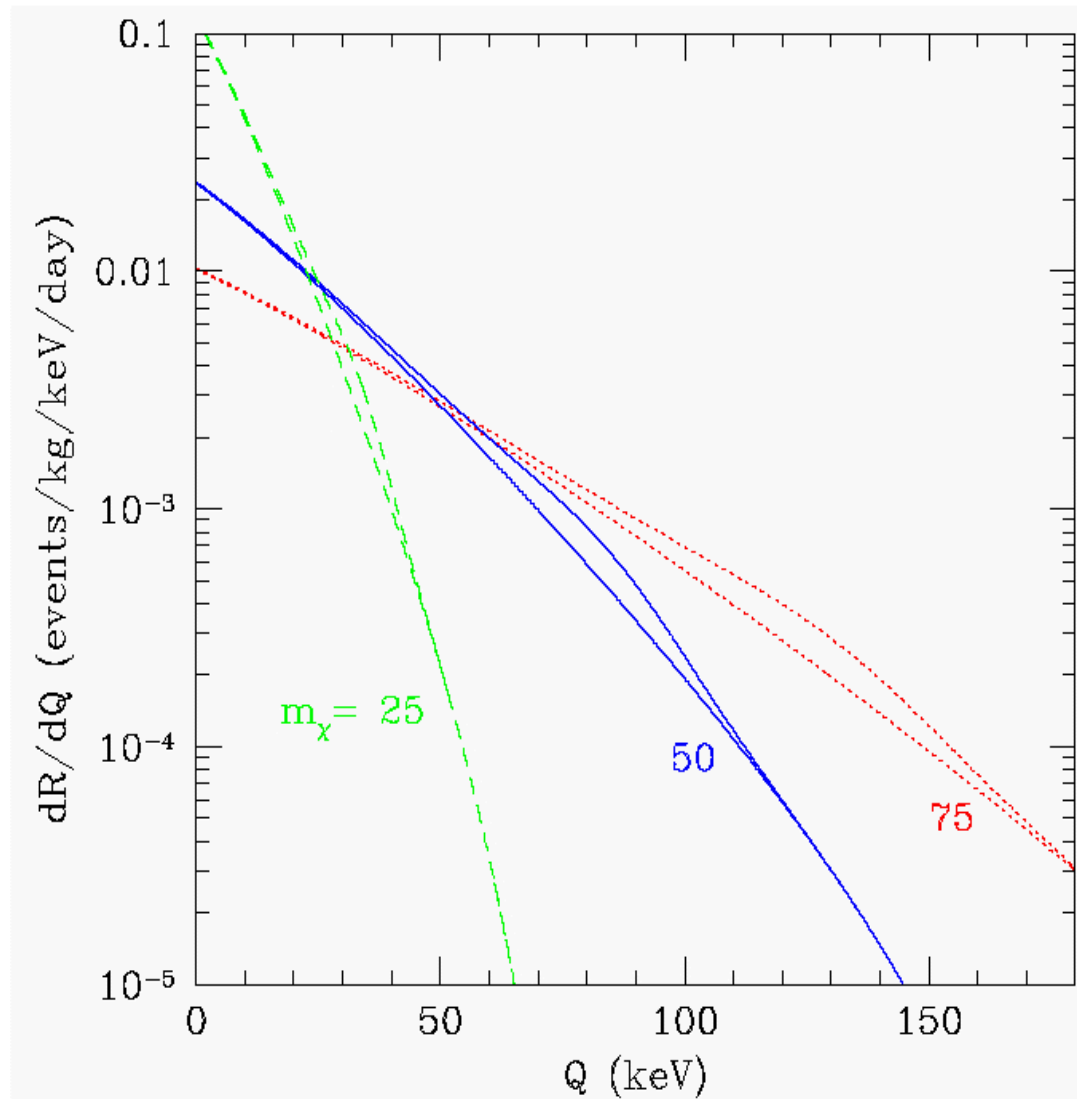
Form factors

Requires low threshold $\sim 1\text{keV}$



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Neutralino recoil spectrum



Stiff, Widrow & Frieman - astro-ph/0106048

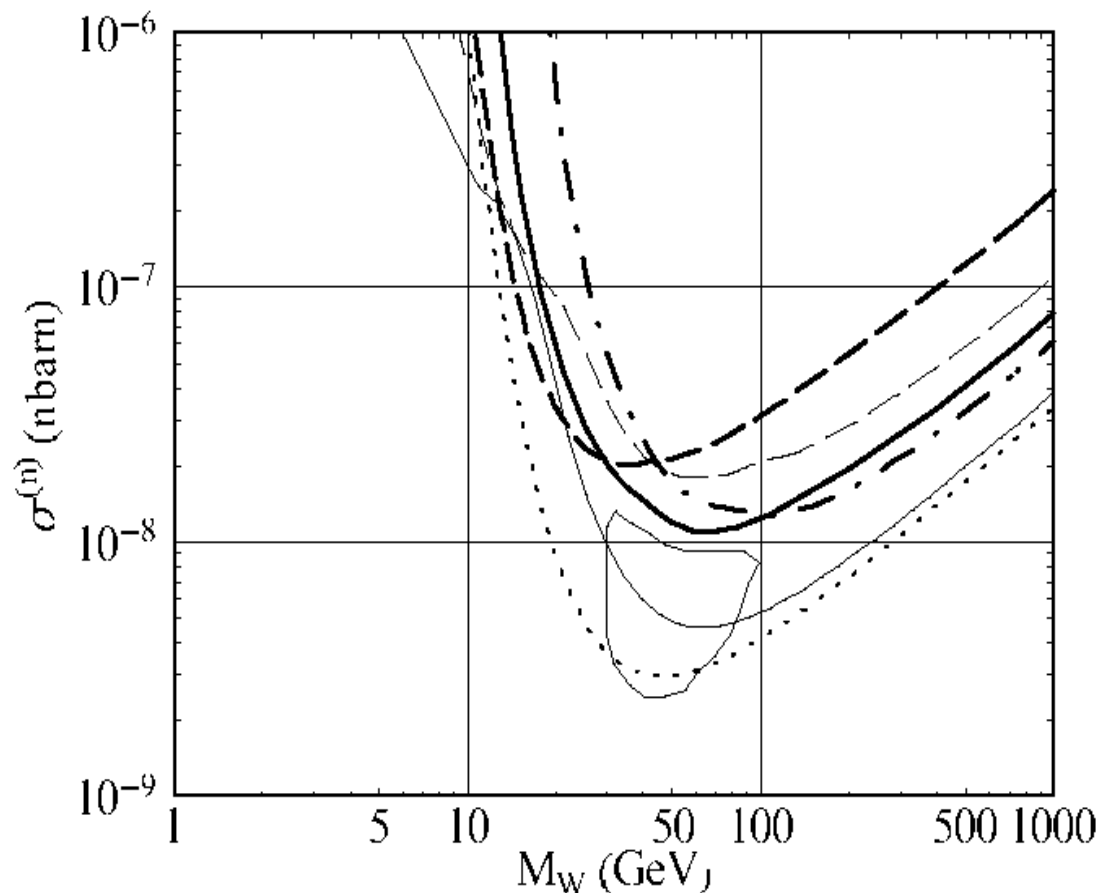
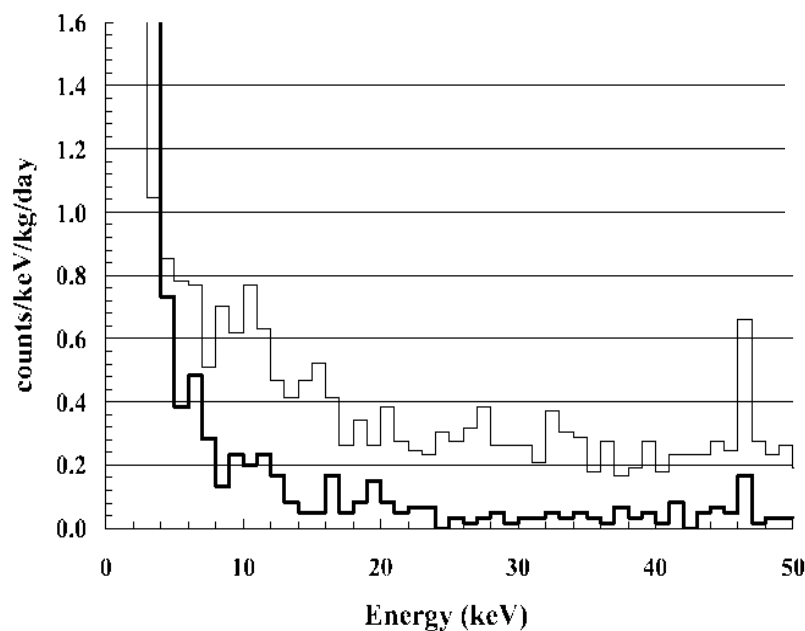
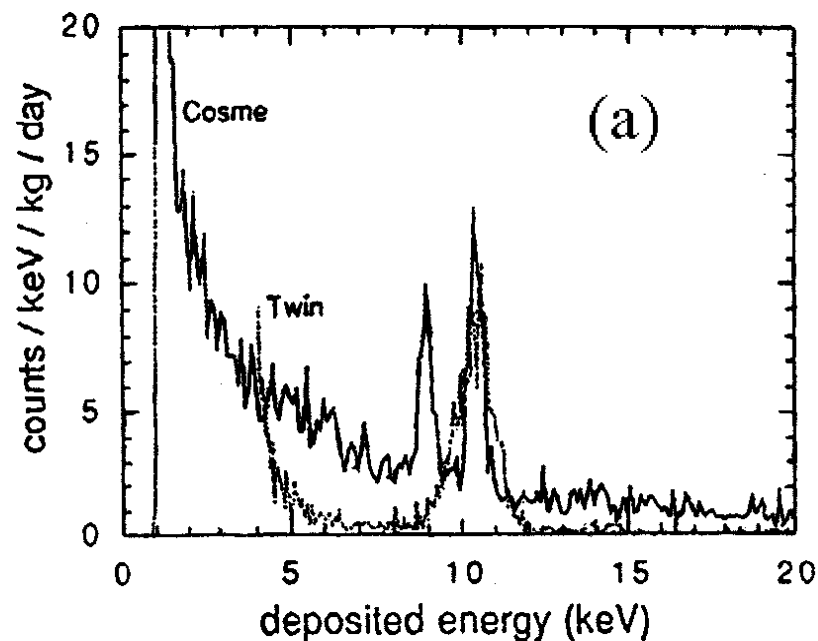
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Neutralino signatures

- Characteristic (but featureless) recoil spectrum which depends on target nuclear mass.
- Annual modulation expected in the event rate.
- Annual modulation expected in the spectrum.
- Directional modulation on daily basis.
- Directional modulation on yearly basis.
- Site independent signal.
- Characteristic event ‘properties’ - depends on detector.
 - (i) Anti-coincidence veto - ionisation/scintillation
 - (ii) Pulse-shape analysis - scintillation
 - (iii) Pulse height ratios - scintillation/ionisation
phonons/ionisation or photons
 - (iv) Range



Germanium Detectors



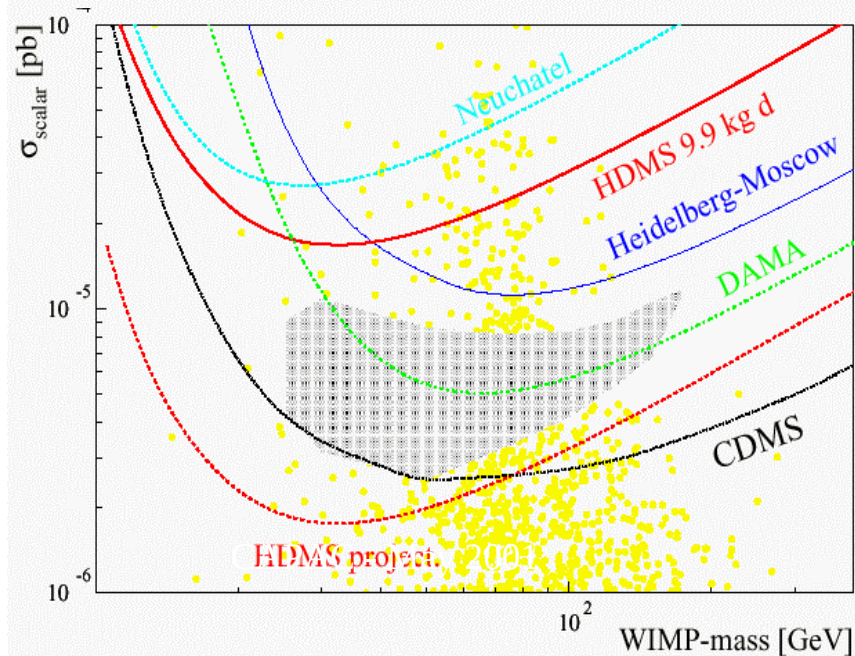
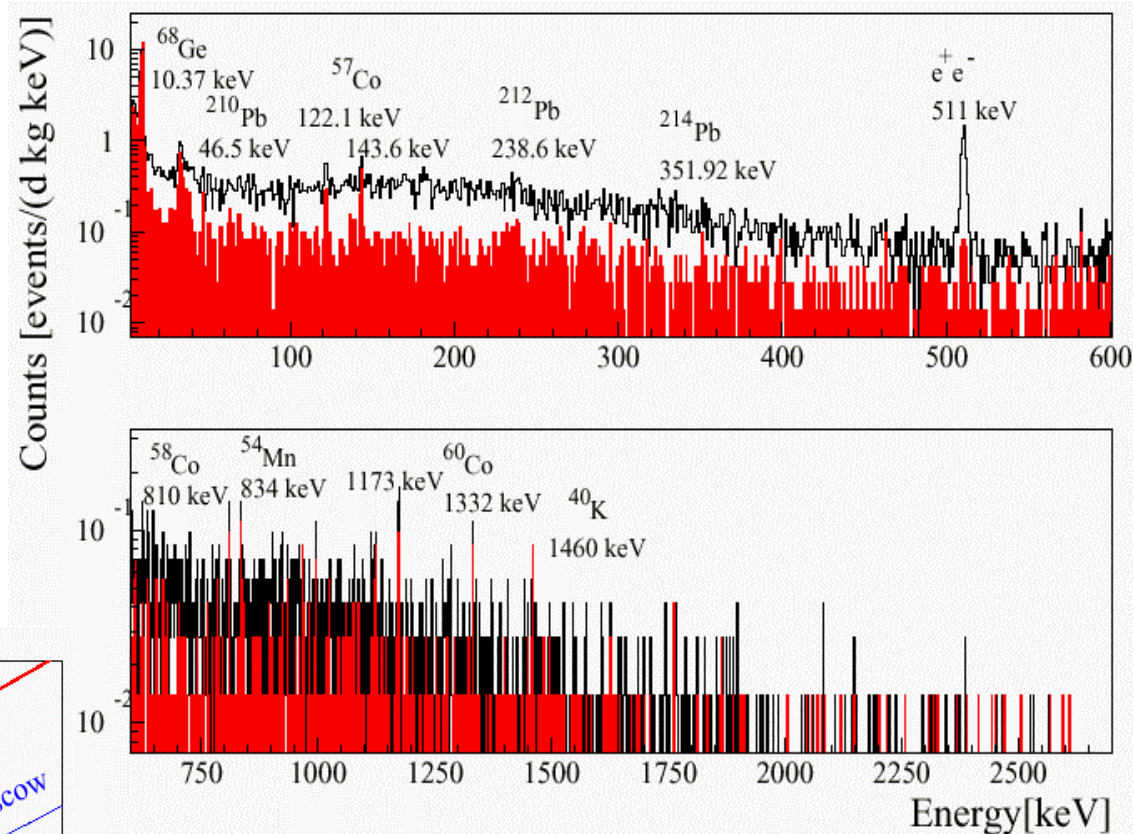
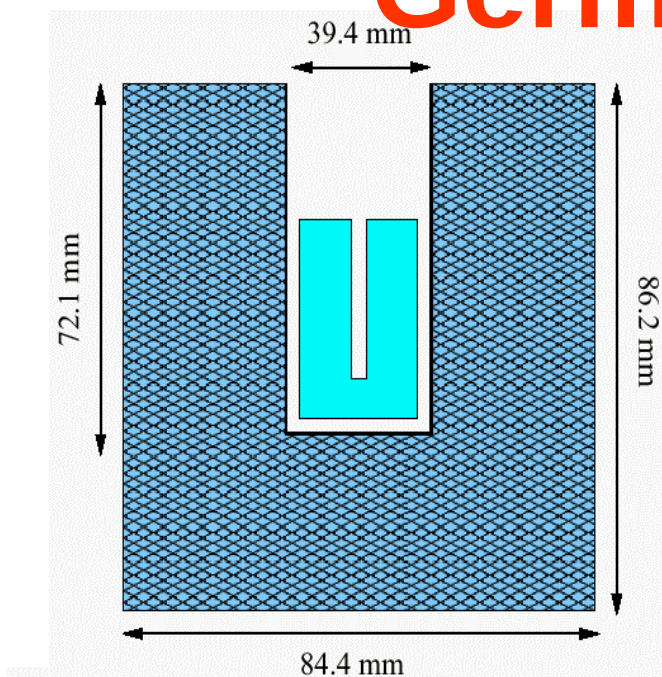
2kg ^{76}Ge - 60kg.day

Irastorza et al. 2000 - hep-ph/0011318

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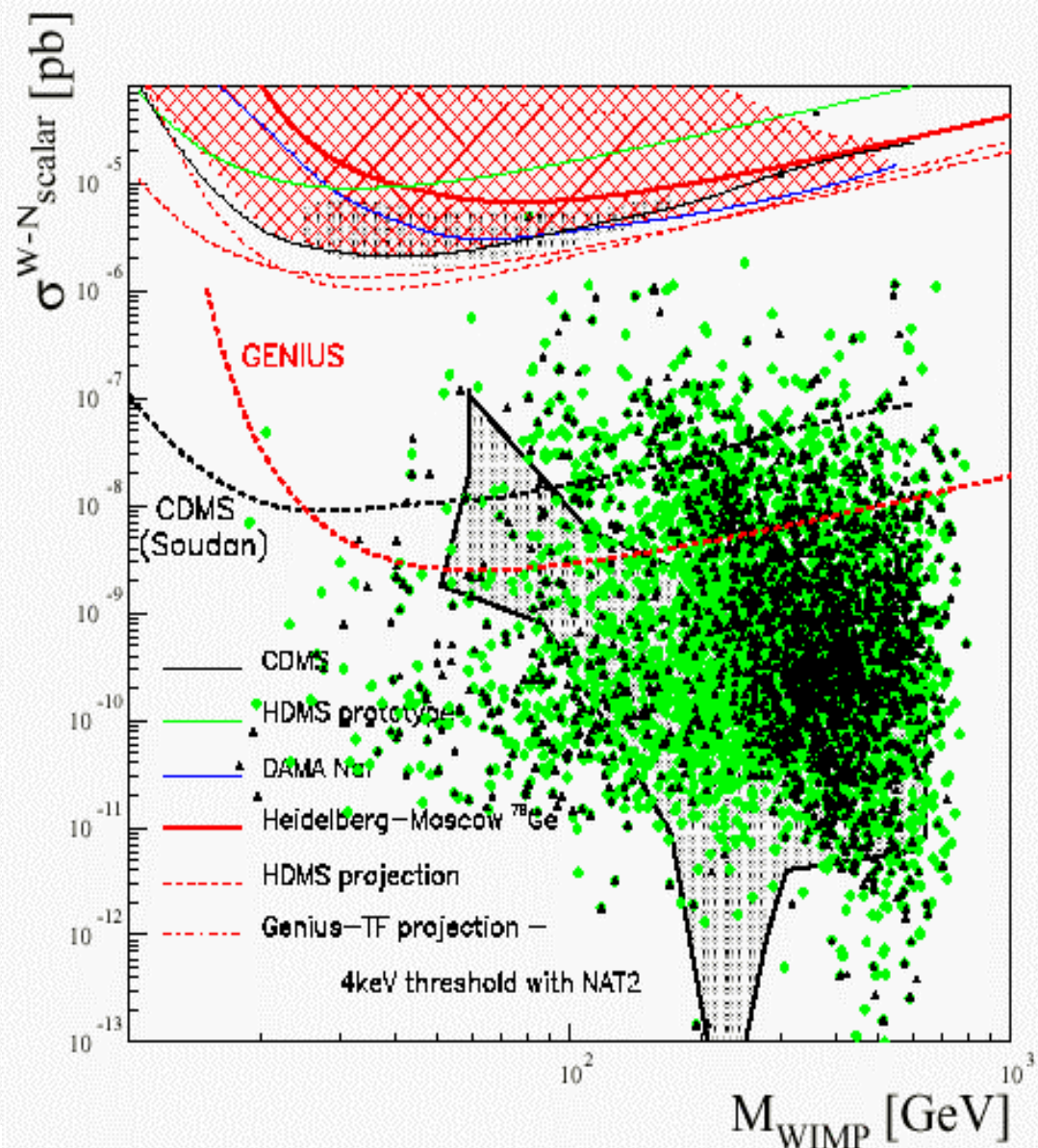
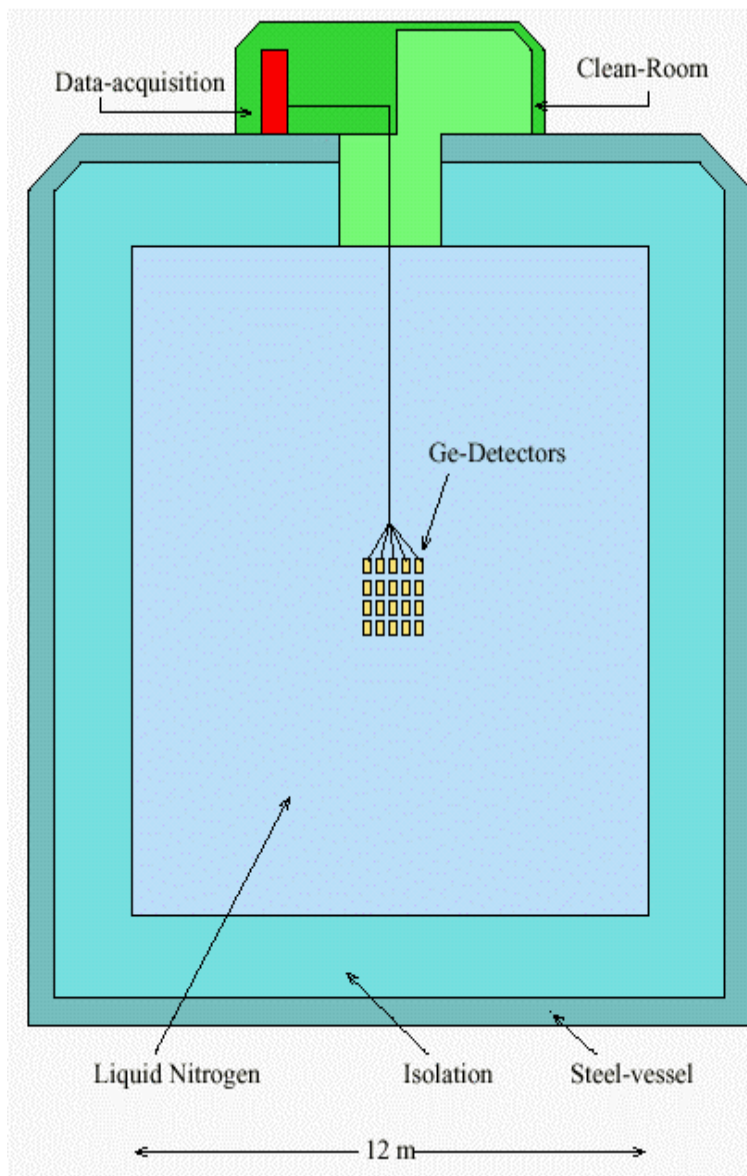
Germanium Detectors



Klapdor-Kleingrothaus et al. 2001 - hep-ph/0103077



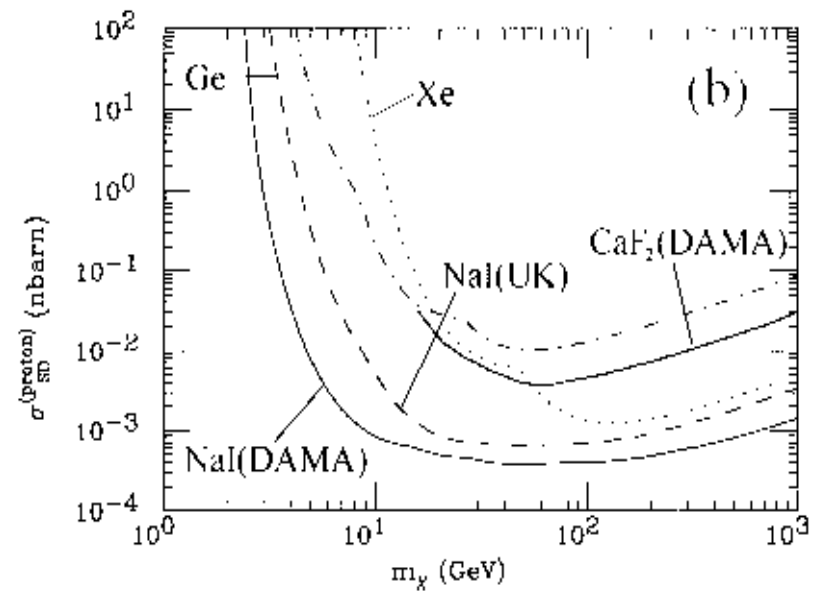
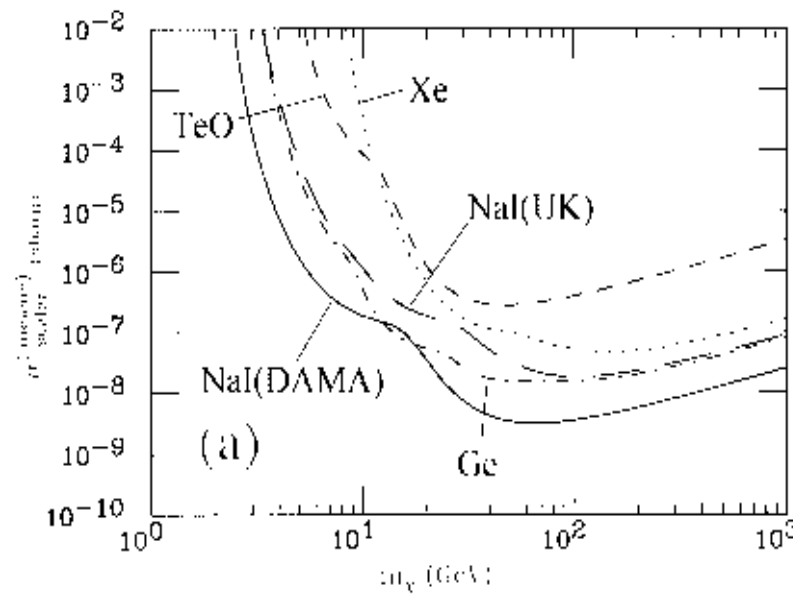
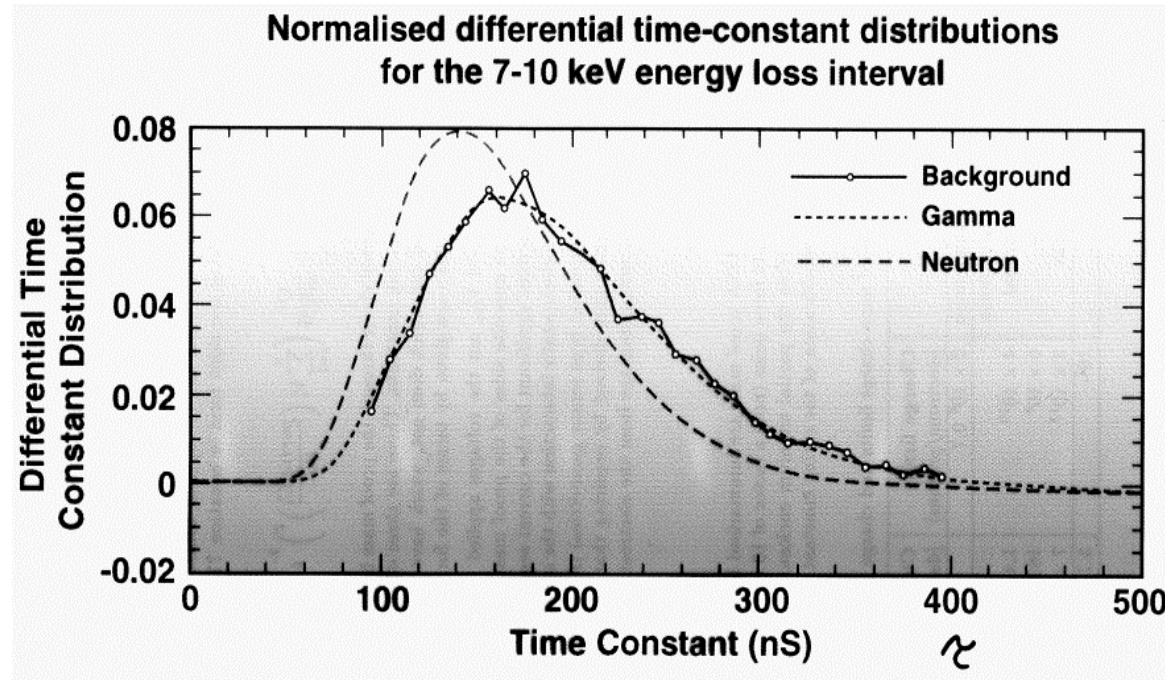
Germanium Detectors



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Klapdor-Kleingrothaus 2001 - hep-ph/0104028

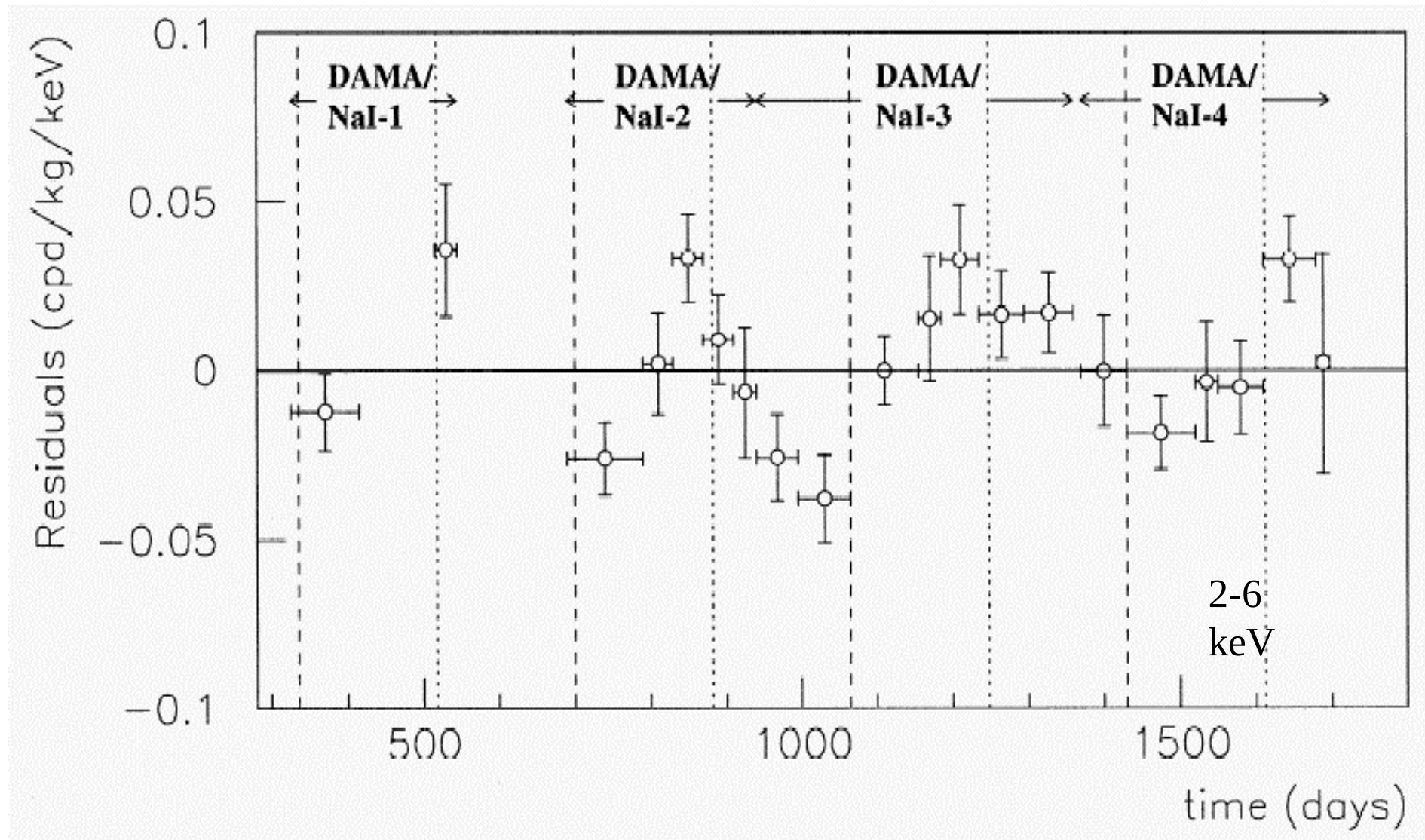
Scintillation Detectors - NaI



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Scintillation Detectors - NaI

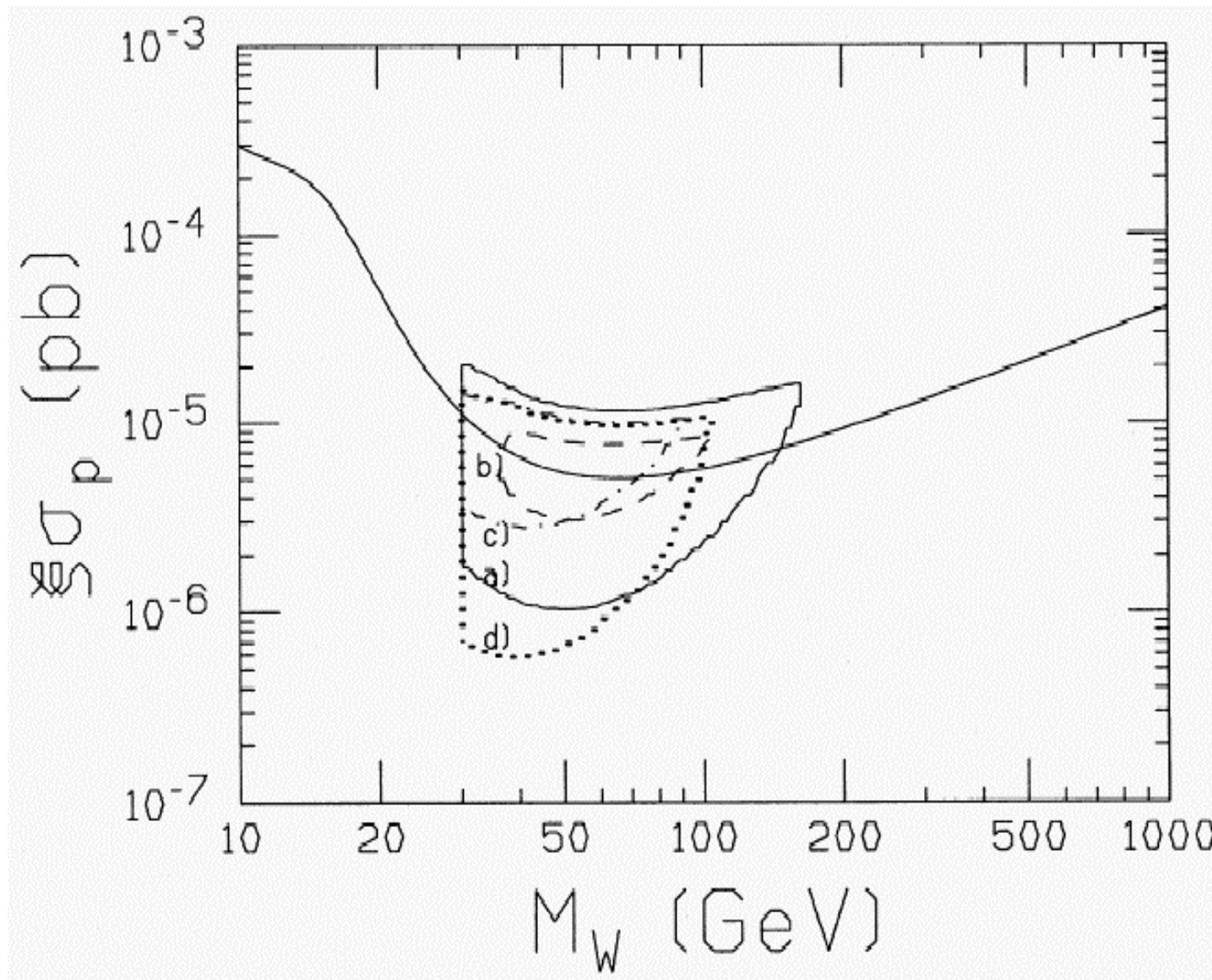


Bernabei et al. 2000 - Phys.Letts. B480 -- 100kg NaI with 57986 kg.days



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Scintillation Detectors - NaI

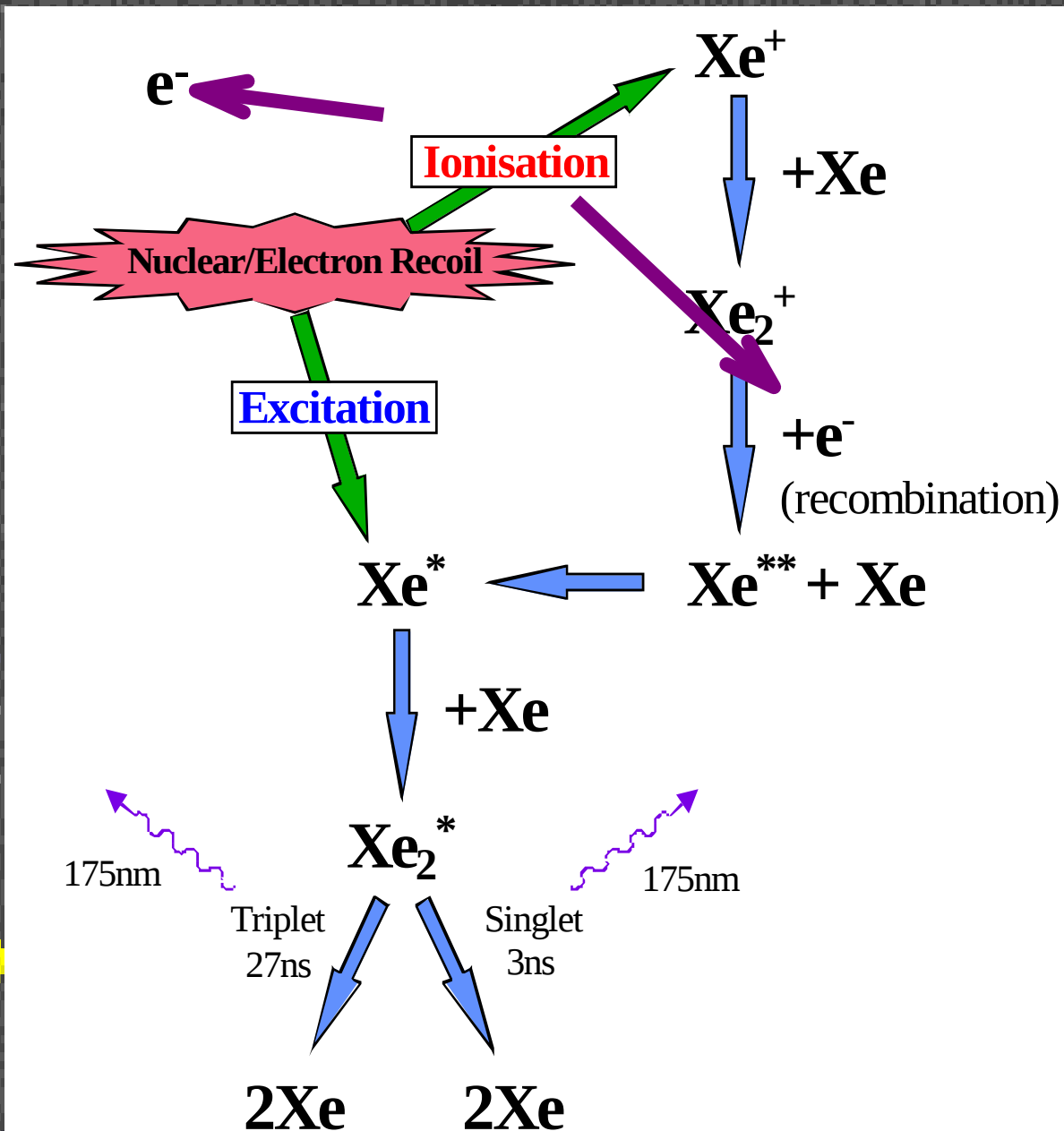


Bernabei et al. 2000 - Phys.Letts. B480



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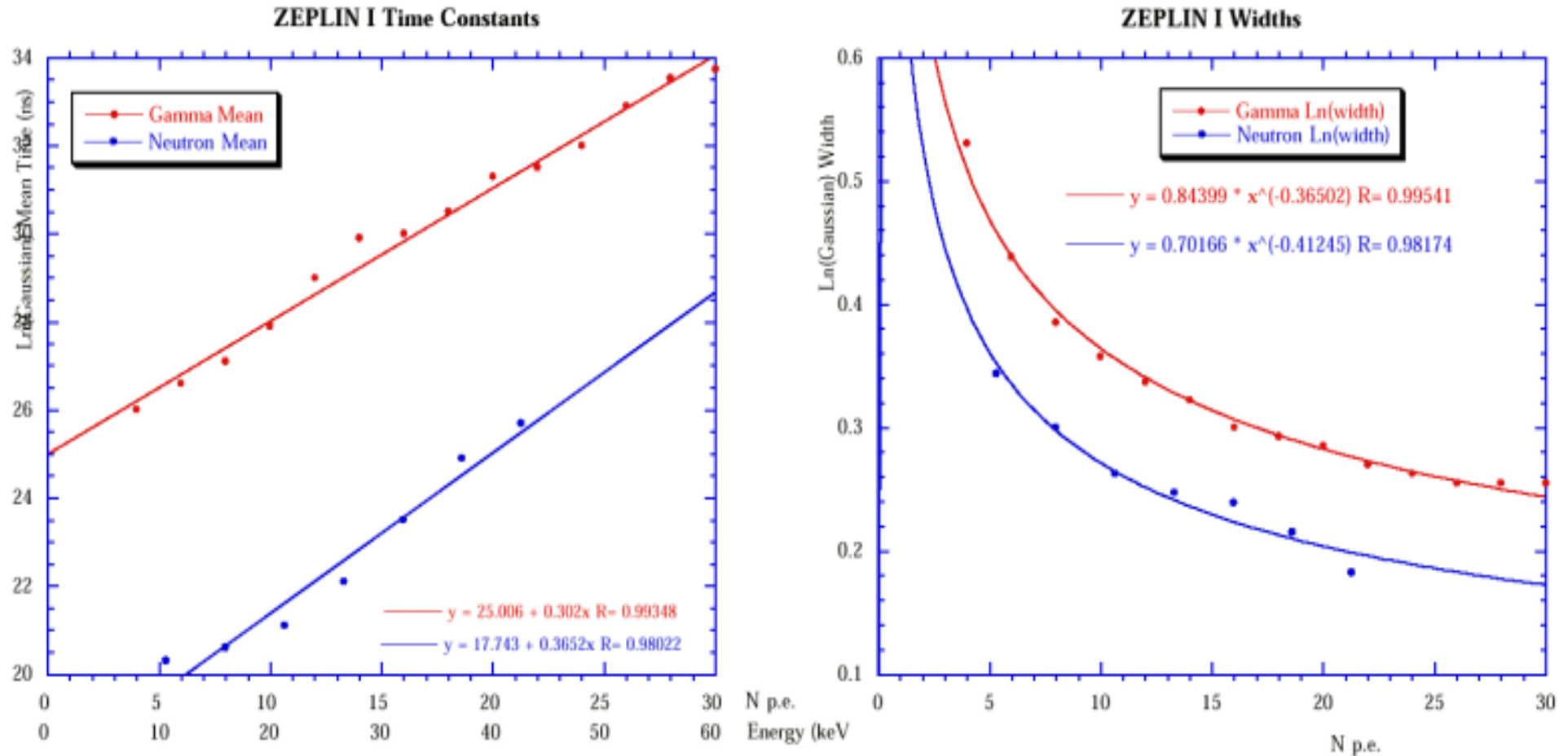
Scintillation Detectors - Xe



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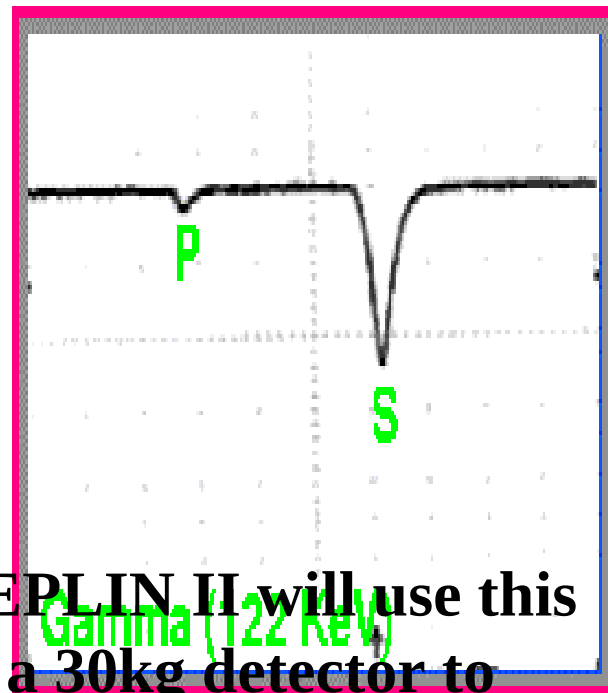
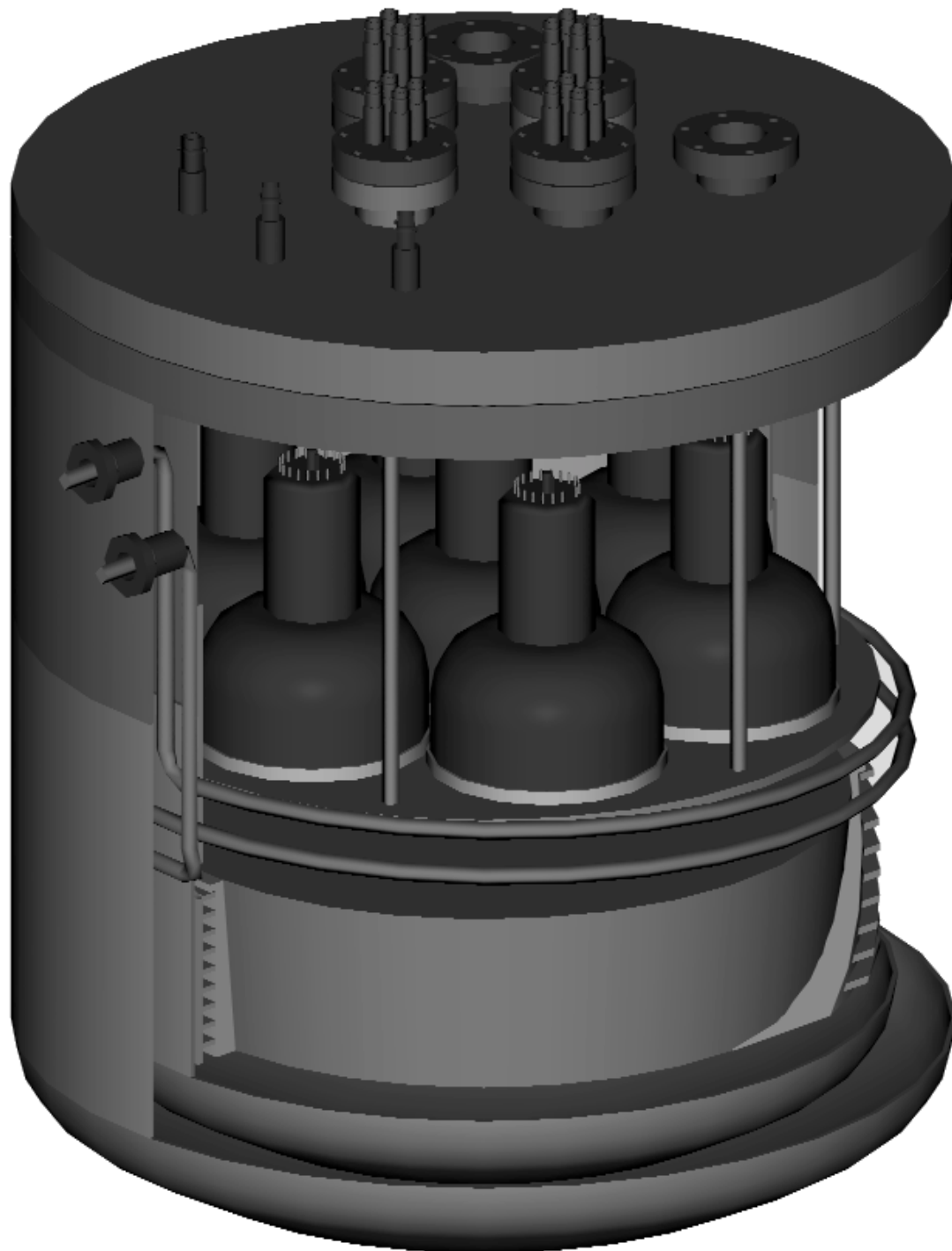
Time Constant Discrimination



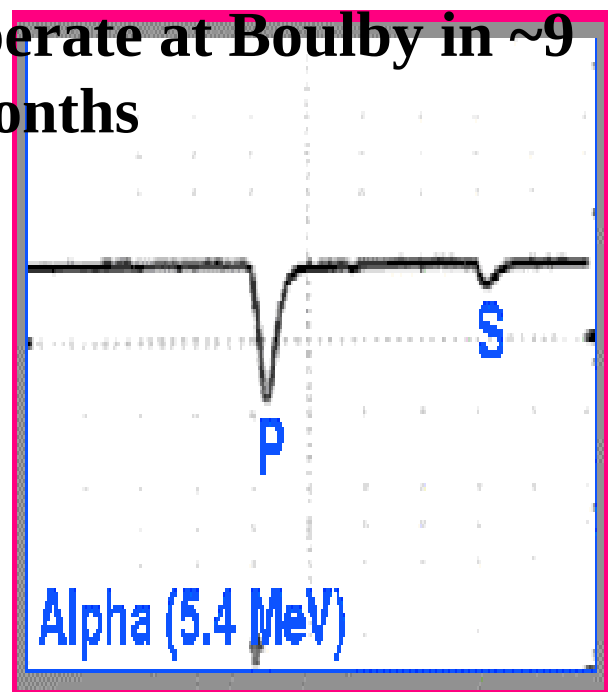
A 6kg detector - ZEPLIN I - is operating at Boulby

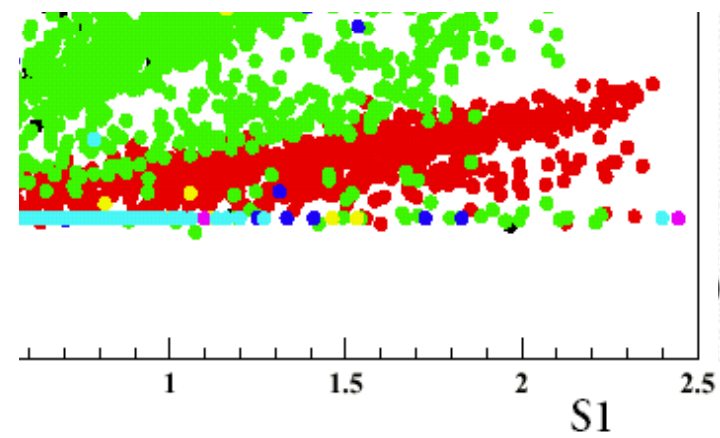
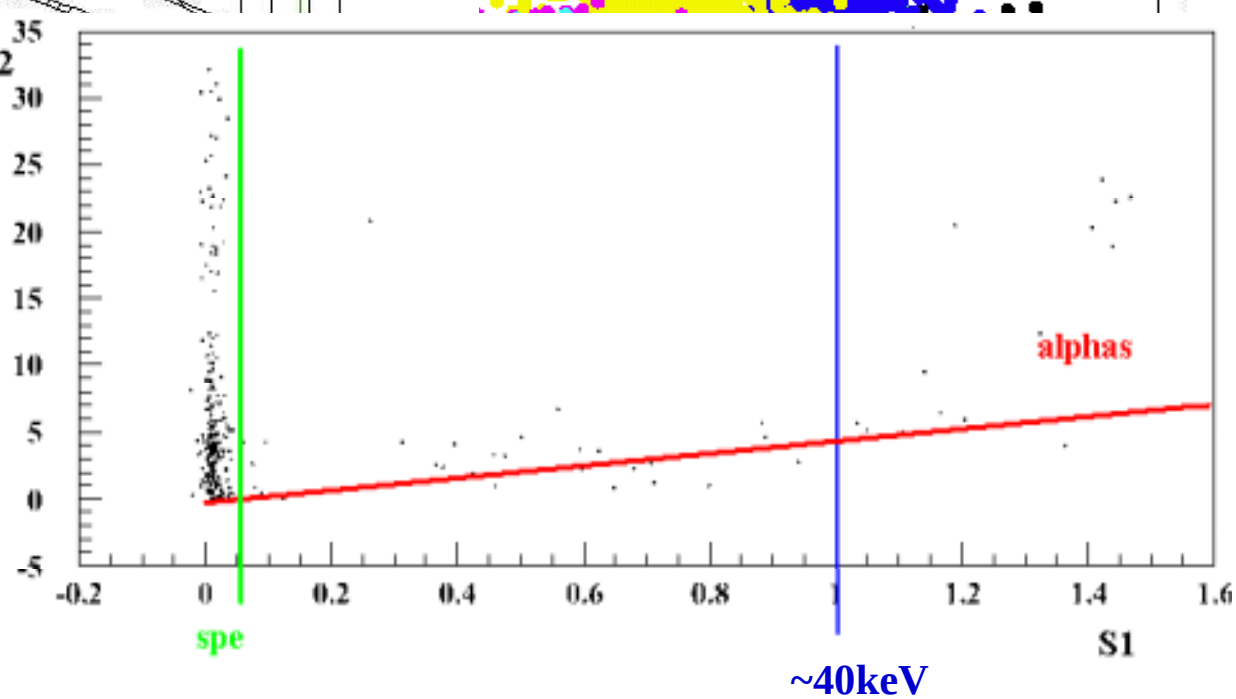
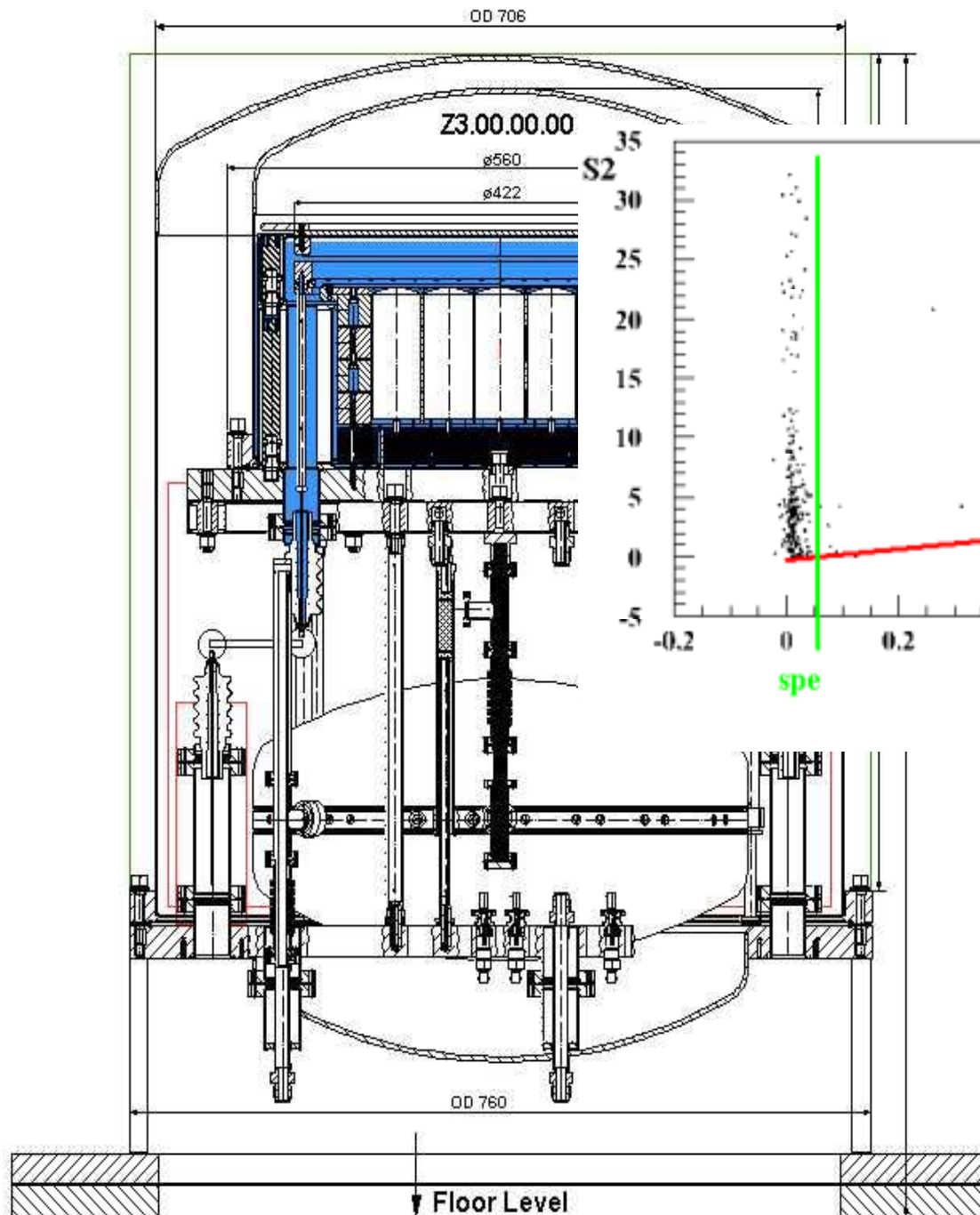


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**ZEPLIN II will use this
in a 30kg detector to
operate at Boulby in ~9
months**



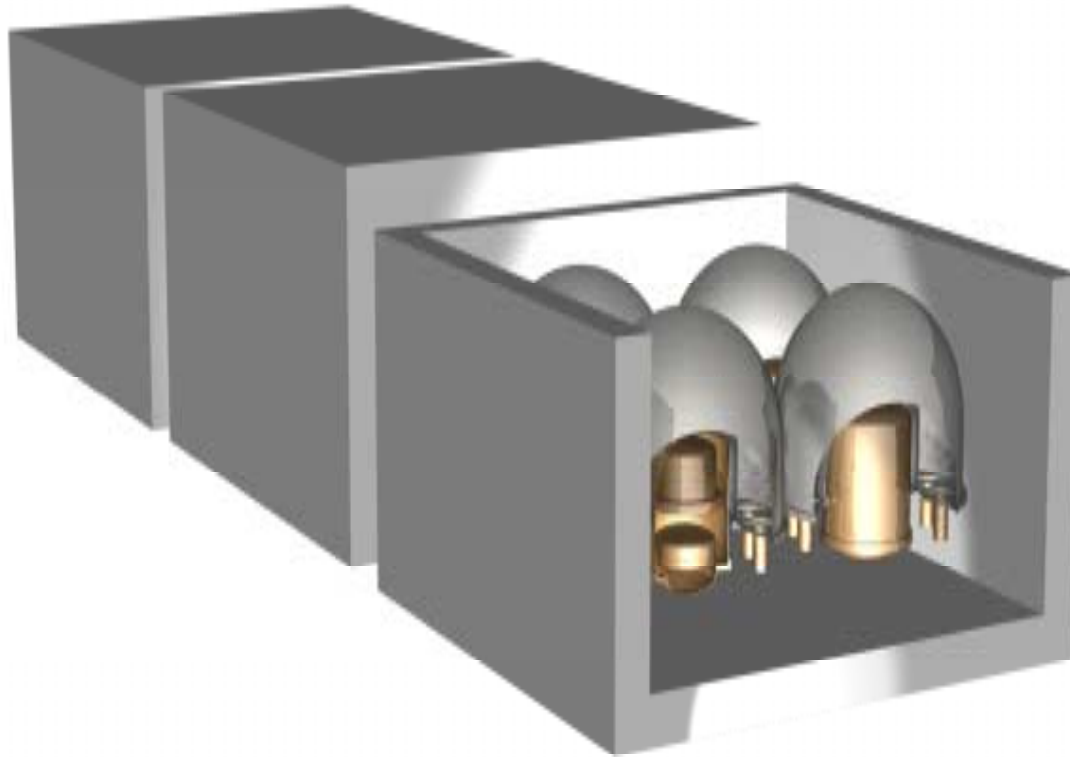


Sumner et al. 2001

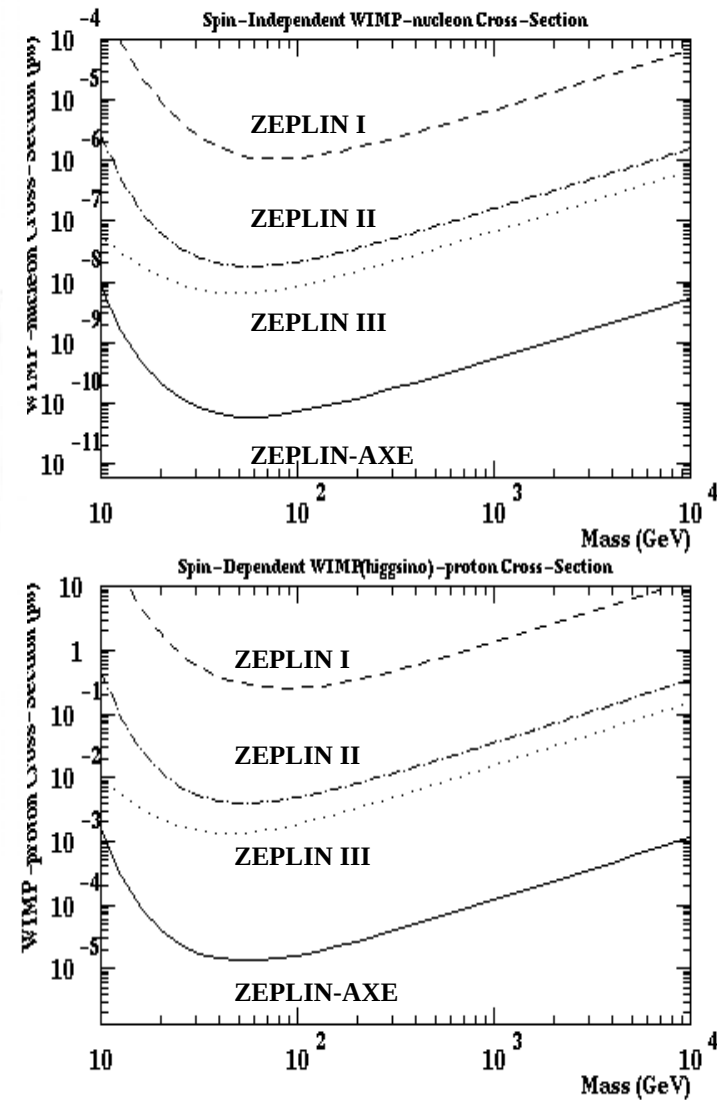
DESY - Sept 2001



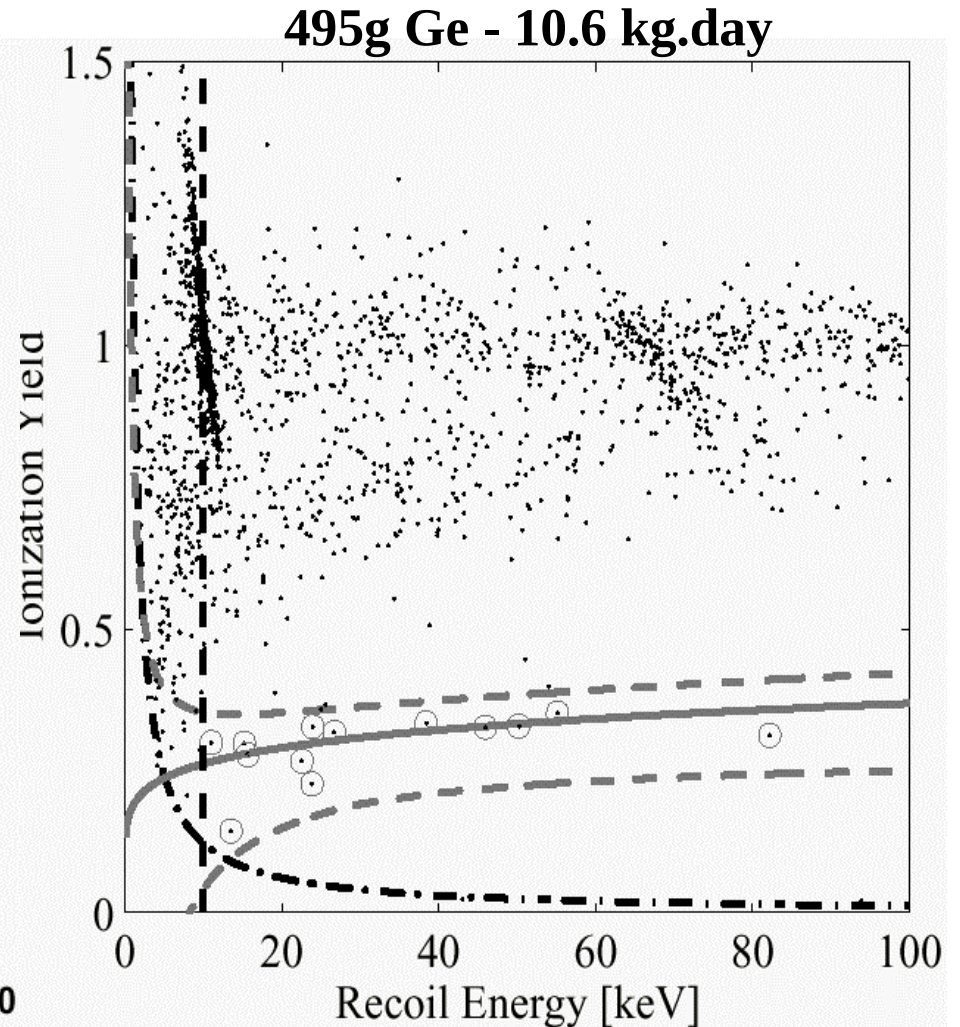
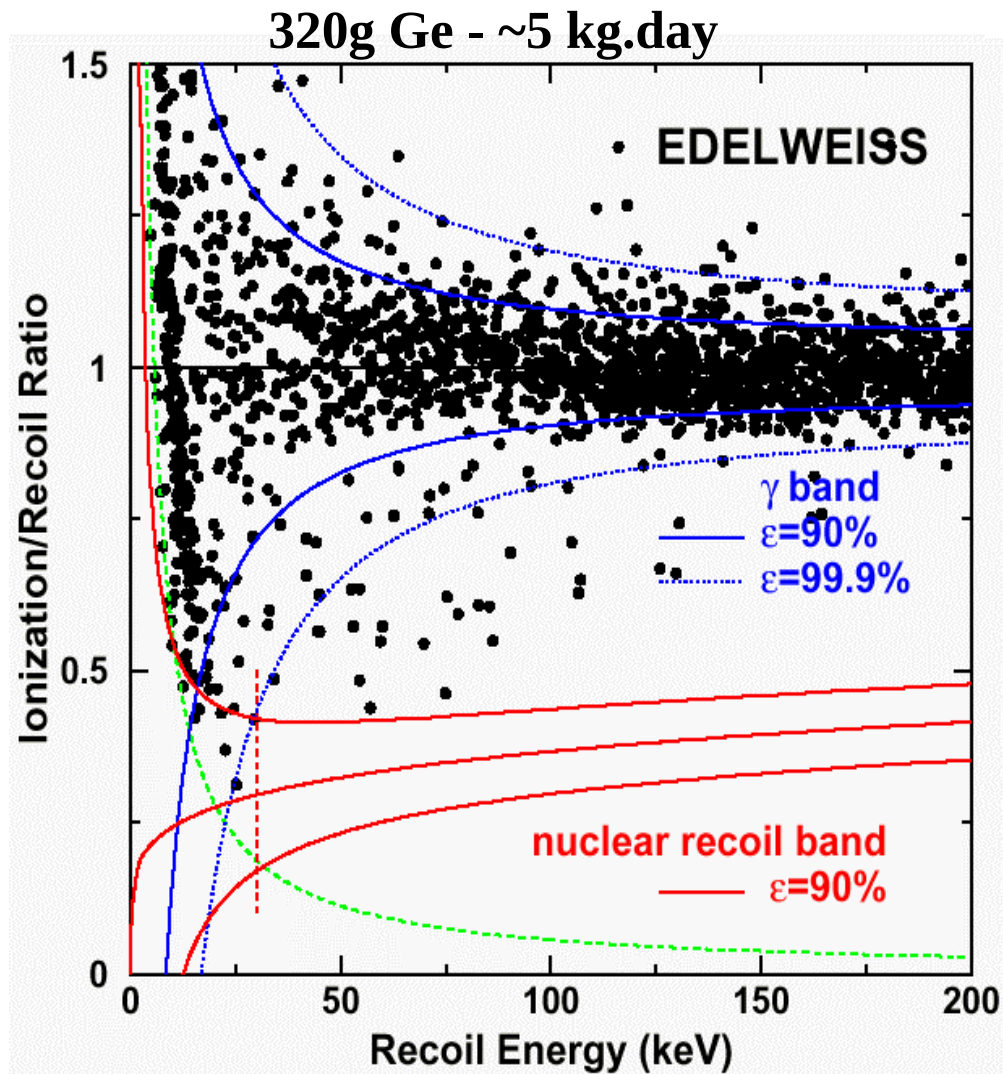
UKDMC ZEPLIN PROGRAM



**ZEPLINs II&III will lead way to
scale up to 1 ton using modular
approach - 4 years?**



CRYOGENIC DETECTORS

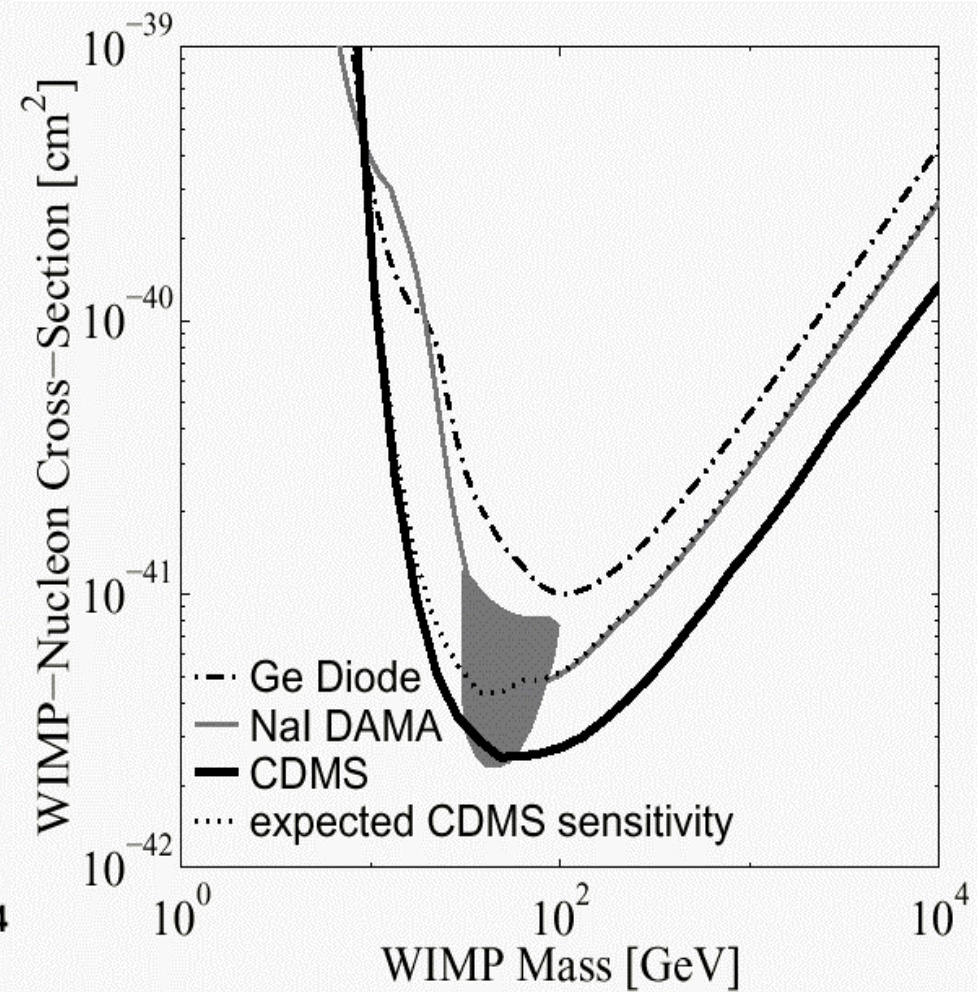
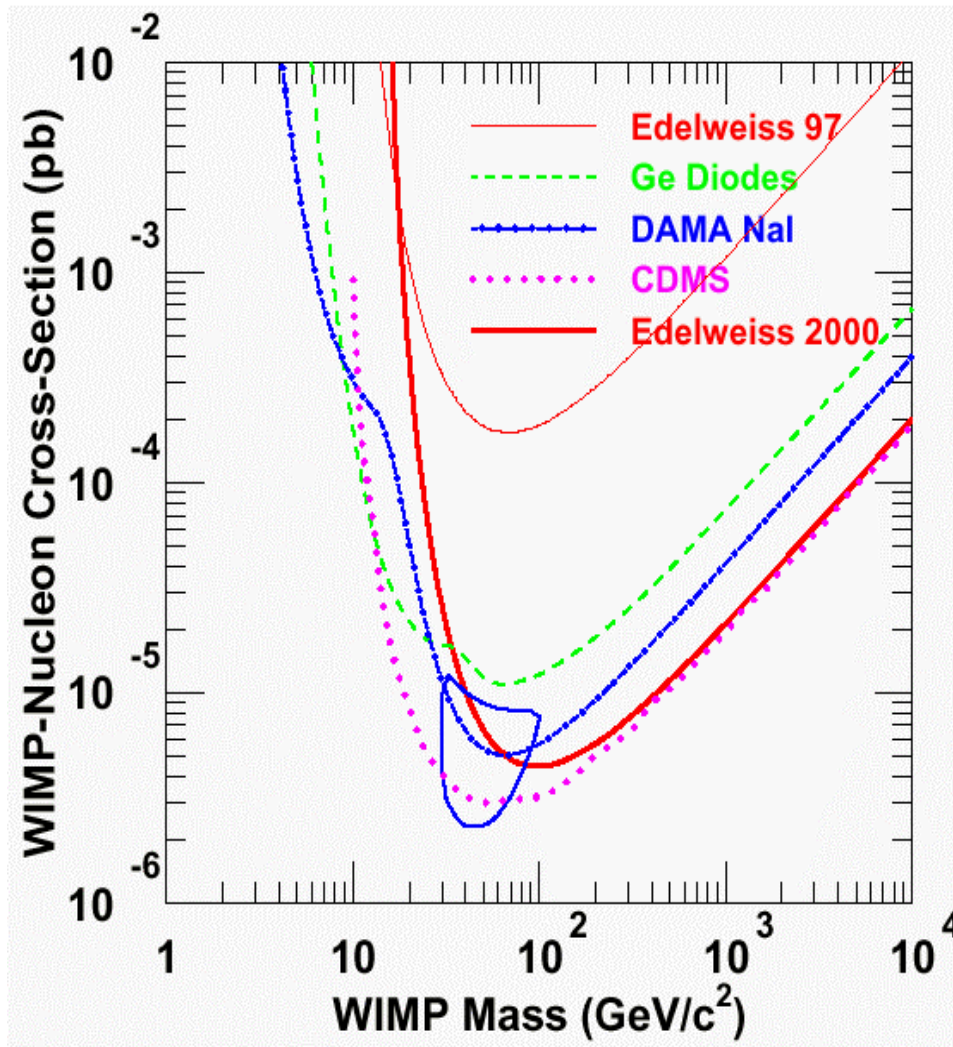


DESY - Sept 2001

Benoit et al. 2001 - astro-ph/0106094

Abusaidi et al. 2000 - astro-ph/0002471

CRYOGENIC DETECTORS

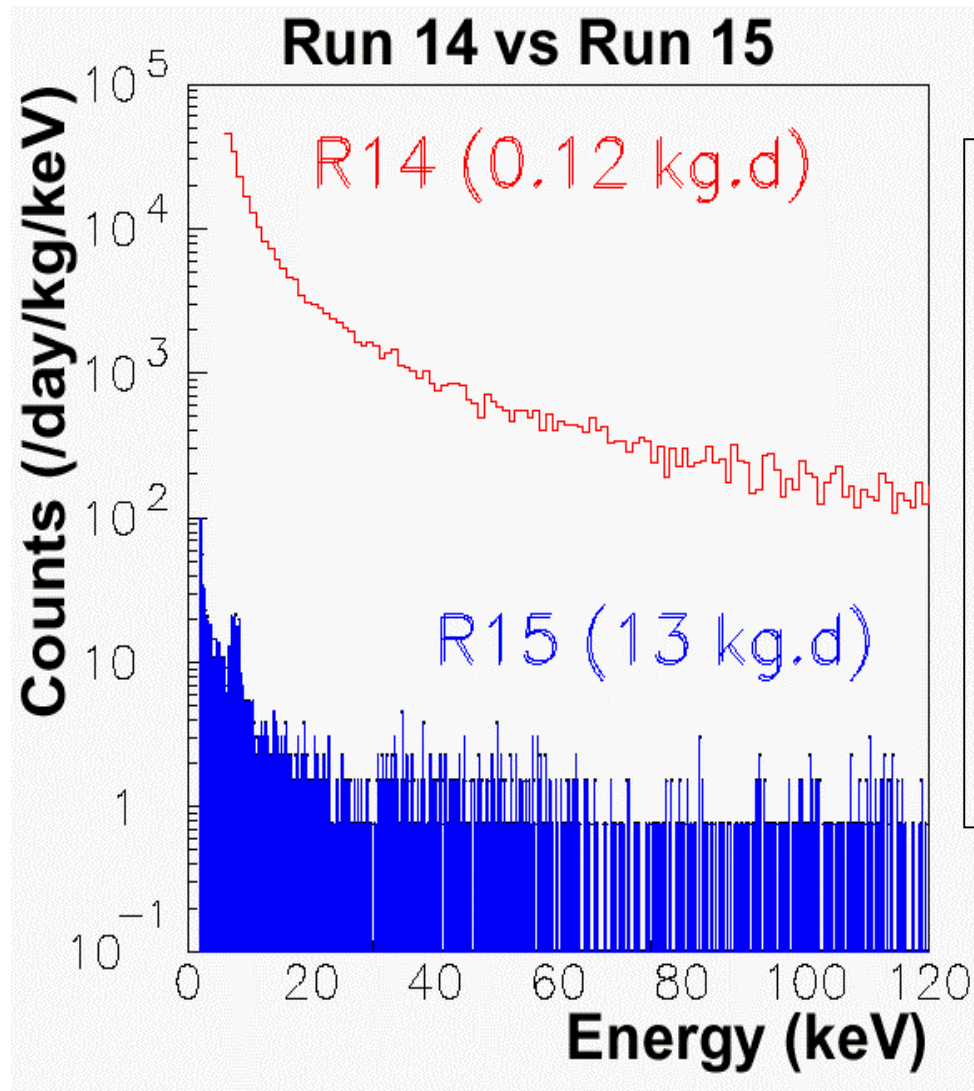


DESY - Sept 2001

Benoit et al. 2001 - astro-ph/0106094

Abusaidi et al. 2000 - astro-ph/0002471

CRYOGENIC DETECTORS



- First low-noise run using superconducting transition bolometer on 262g sapphire
- Developing discrimination using light and phonons from 300g CaWO_4 crystal
- Planning 10kg CaWO_4

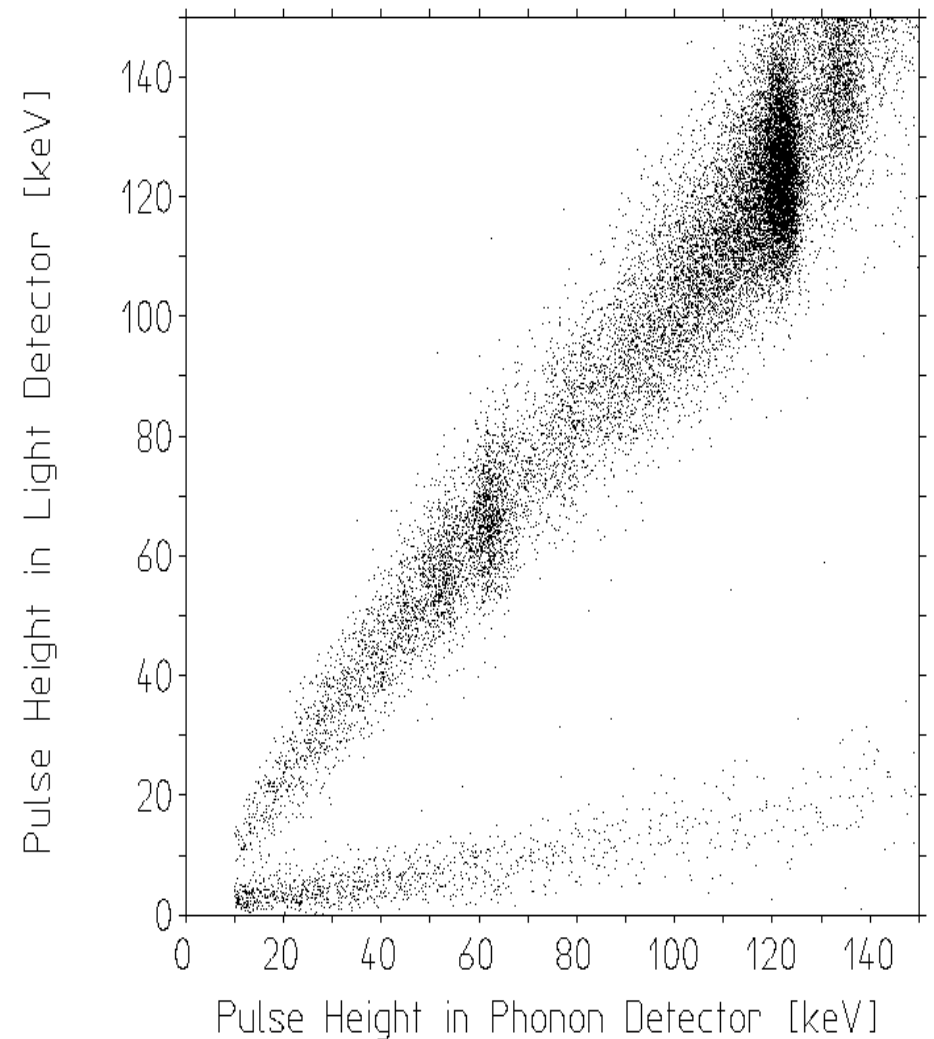
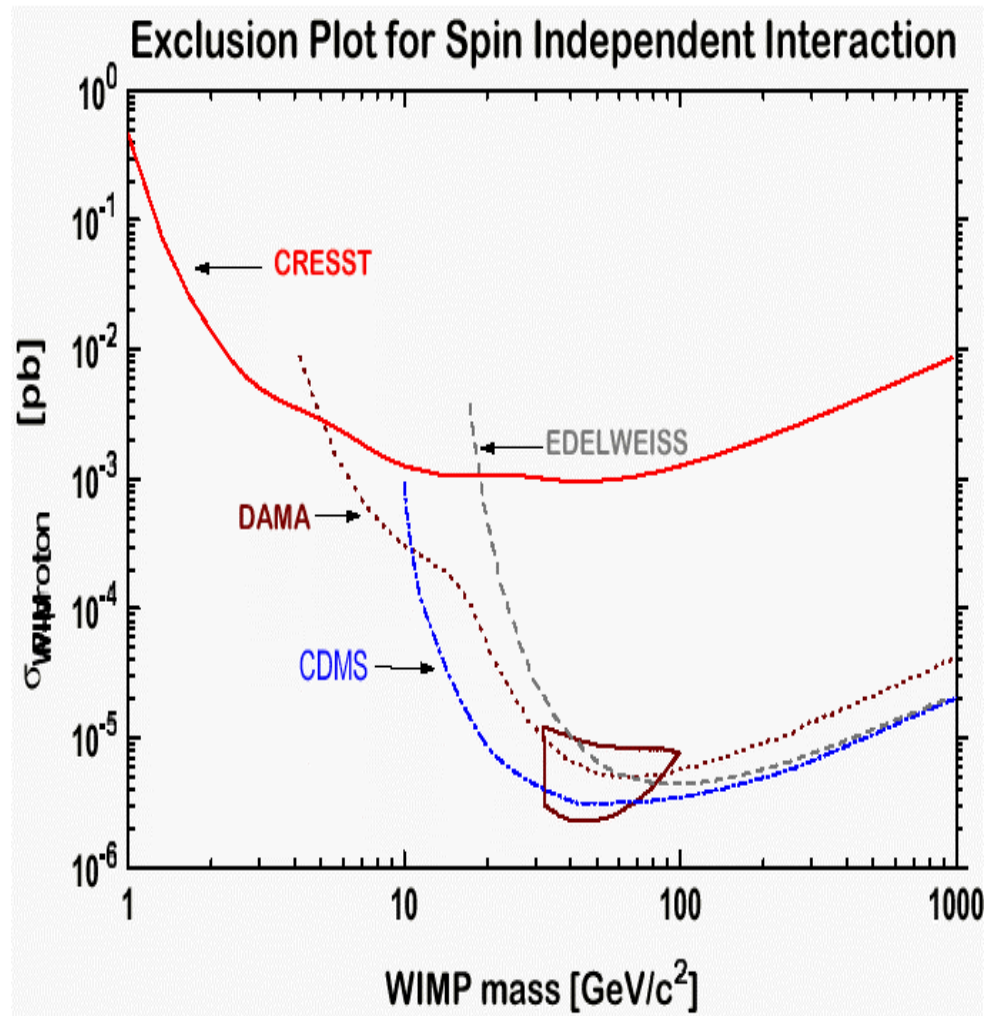
CRESST

Di Stefano et al. 2000 - hep-ex/0011064



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CRYOGENIC DETECTORS



DESY - Sept 2001

CRESST

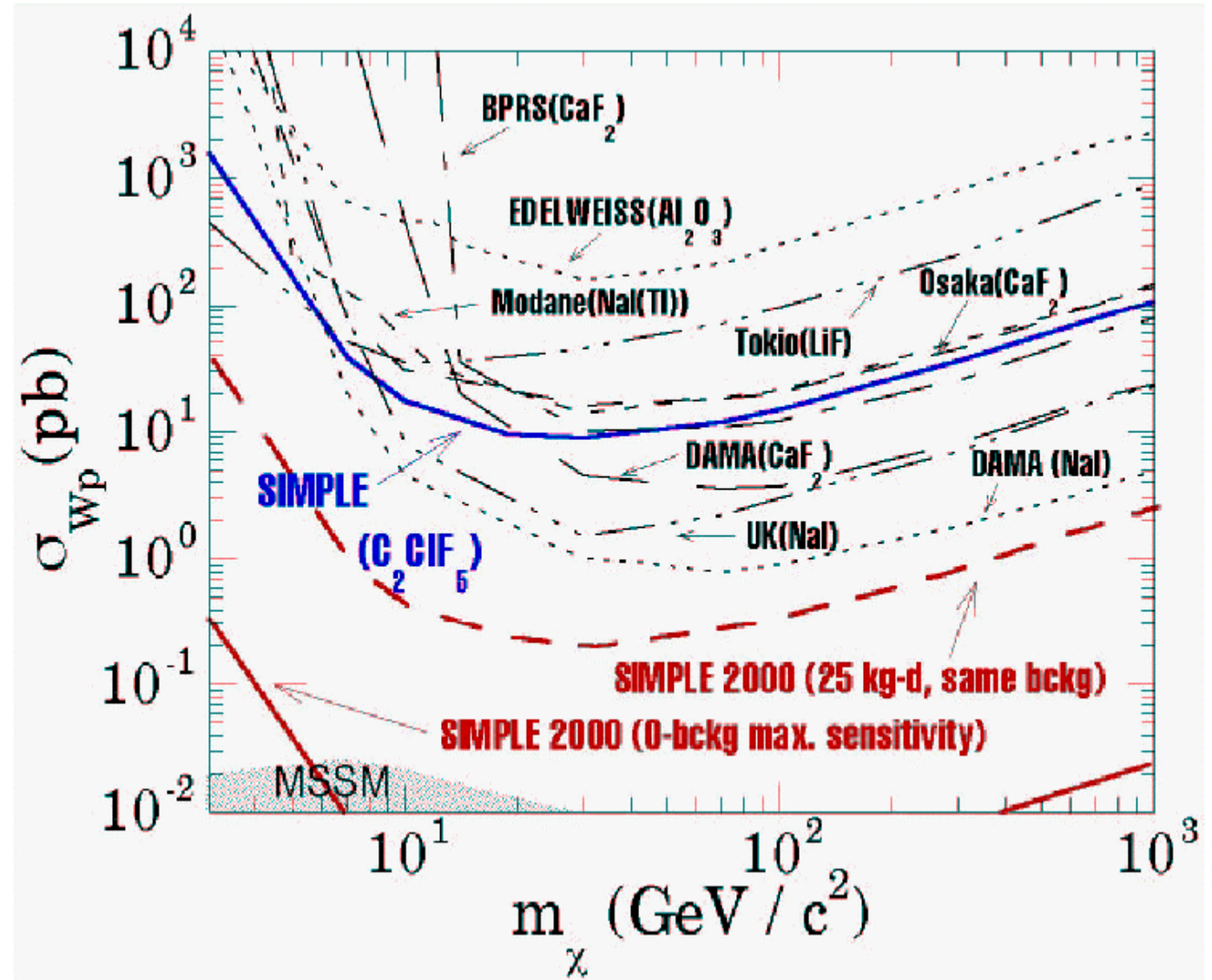
Altmann et al. 2000 - astro-ph/0106314

SUPERHEATED DROPLETS

Target is flourine
in C_2ClF_5

spin-dependent

- 0.19 kg.day so far
- acoustic detection
- plans to scale-up
- plans for higher z nuclei

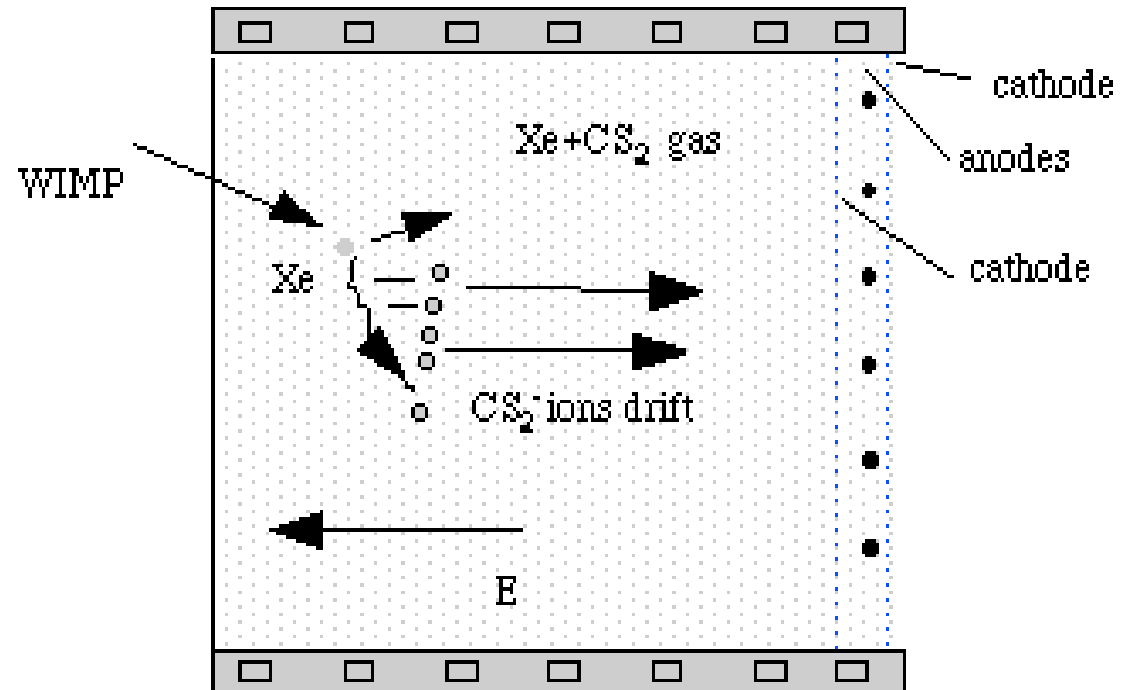
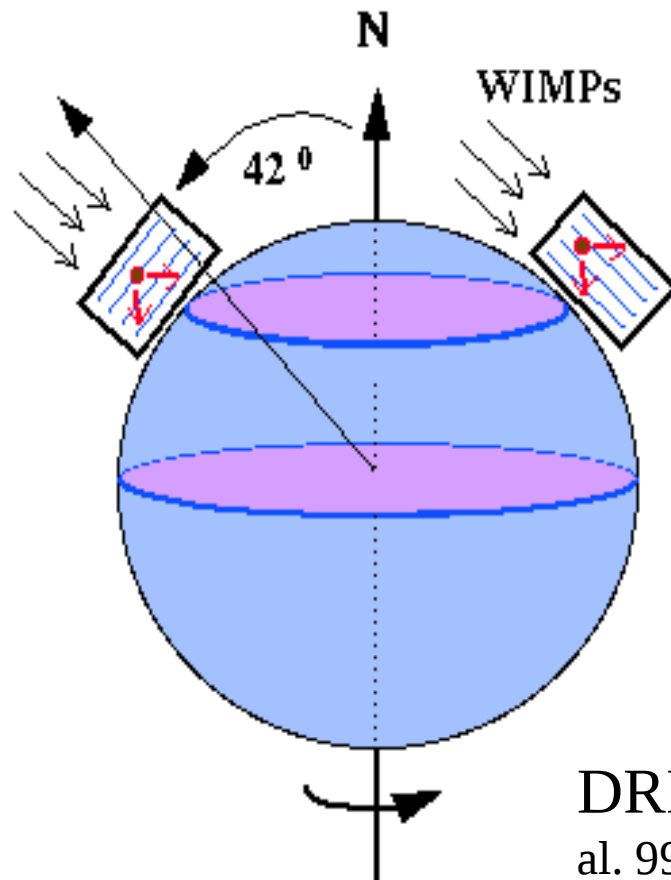


DESY - Sept 2001



Collar et al. 2001 - astro-ph/0101176, Zacek et al. 2001 for PICASSO results

DIRECTIONAL DETECTORS

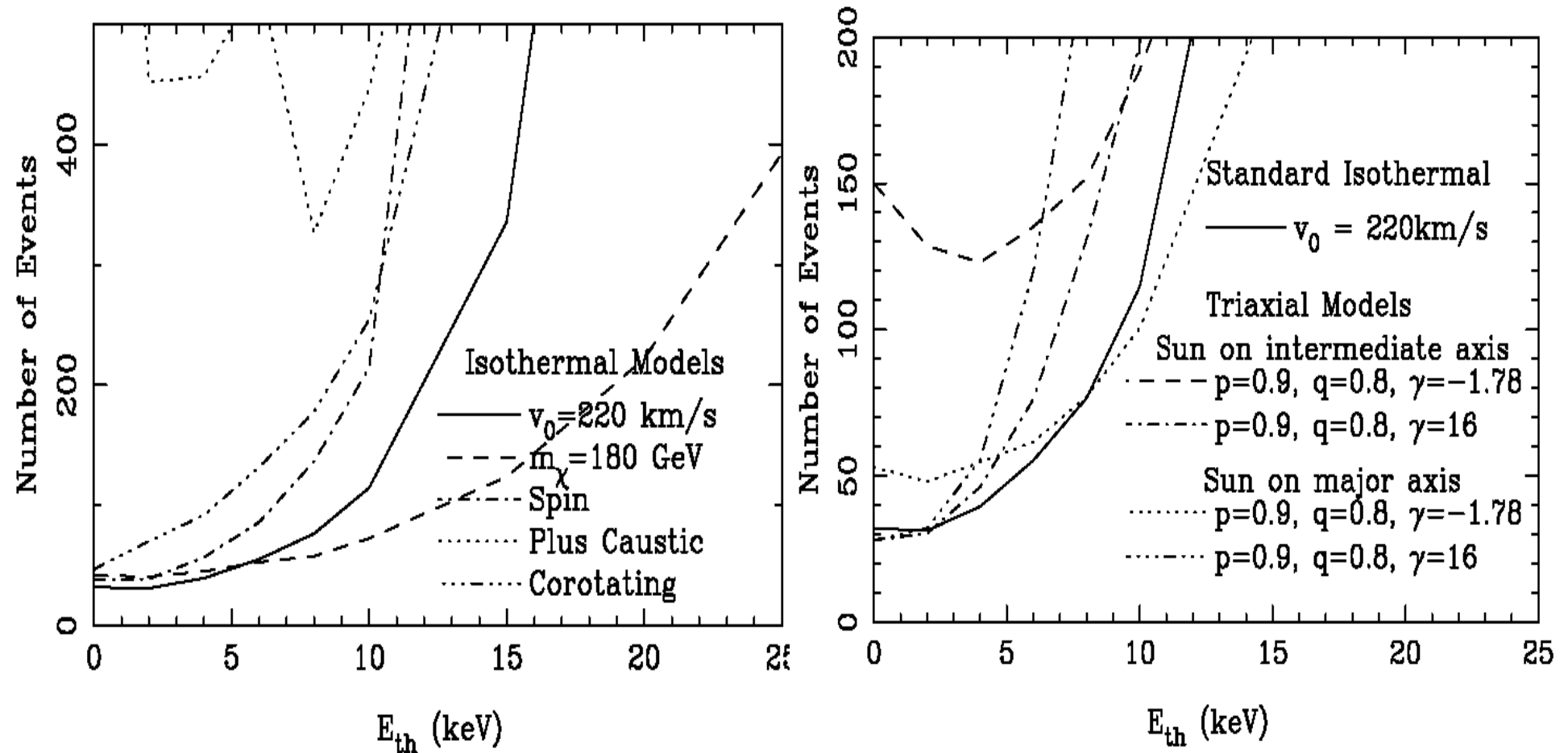


DRIFT - Martoff et al. 96, Snowden-Ifft et al. 99, Lehner et al. 99

1m³ prototype has been installed at Boulby



DIRECTIONAL DETECTORS



Copi & Krauss 2000 - astro-ph/0009467



SUMMARY

Spin-independent wimp-nucleon sensitivities in pb

Done

Running

‘Modifications’

Building

Dreaming

1×10^{-3}

2×10^{-5}

2×10^{-5}

10^{-5}

4×10^{-6}

3×10^{-6}

3×10^{-6}

2.5×10^{-6}

2.5×10^{-6}

2.5×10^{-6}

2×10^{-6}

10^{-6}

10^{-6}

$> 2 \times 10^{-7}$

4×10^{-8}

3×10^{-8}

2.5×10^{-8}

1.5×10^{-8}

10^{-8}

2×10^{-9}

10^{-10}

CRESST Sapphire

HDMS Ge

UKDMC NaI

CANFRANC Ge

EDELWEISS Ge

CANFRANC Ge

DRIFT CS₂

CDMS Ge(+Si)

DAMA NaI

CRESST I+

HDMS Ge

EDELWEISS Ge

ZEPLIN I Xe

COURICINO TeO₂

COURE TeO₂

ZEPLIN II Xe

CRESST II

CDMS II Ge

ZEPLIN III Xe

GENIUS Ge

ZEPLIN MAX Xe



SUMMARY

**Spin-dependent
wimp-nucleon
sensitivities in pb**

Done

Running

‘Modifications’

Building

Dreaming

15

15

10

10

4

2

1

0.3

0.2

5×10^{-3}

?

2×10^{-3}

?

10^{-5}

Osaka CaF_2

Tokyo LiF

SIMPLE F

CRESST Sapphire

DAMA CaF_2

UKDMC NaI

DAMA NaI

ZEPLIN I Xe

SIMPLE F

ZEPLIN II Xe

CDMS II Ge

ZEPLIN III Xe

GENIUS Ge

ZEPLIN MAX Xe

