

The background of the slide is a deep blue space filled with numerous stars and several spiral galaxies. In the lower-left foreground, a magnifying glass is positioned over a circular area that contains a stylized representation of a particle detector or a cluster of particles, with red and purple spheres and green lines. The title text is centered in the upper half of the image.

Astroparticle Physics I: Experiments for direct WIMP detection

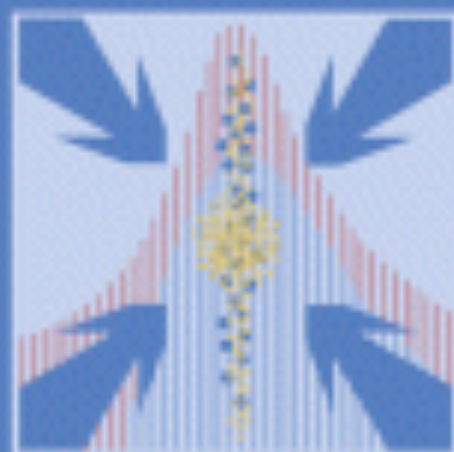




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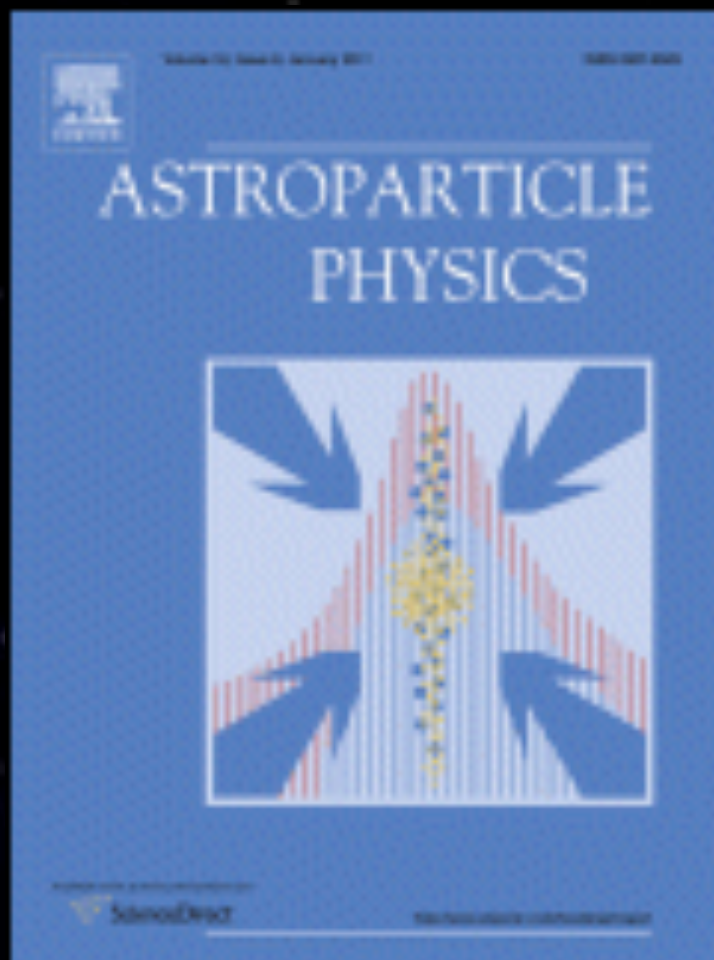
ASTROPARTICLE PHYSICS



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- Part I (Nicolas) :
Experiments for direct
detection of WIMPs
- Part II (Jana):
Cosmic Rays
Observations
- Part III (Cherry):
• Astroparticle physics
and pulsars



Weakly Interacting Massive Particles (WIMPs)

- Interaction through weak force
- Mass: $1 \text{ KeV} \leq M \leq 300 \text{ TeV}$ ($\sim 100 \text{ GeV}$)
($M_{H_2} = 1 \text{ GeV}$, $M_U \sim 240 \text{ GeV}$)
- Velocity (Galactic WIMPs): $\sim 300 \text{ km s}^{-1}$

Weakly Interacting Massive Particles (WIMPs)

- Principle: WIMP/detector particle elastic collision

Energy transfer to medium

- Important: cross-sections, expected event rates
- Tests with neutron collisions

Cryogenic Dark Matter Search (CDMS)

- Direct Detection: WIMP interaction with fermions in detector
-

- Cross-section (elastic scattering with fermions, today)
 10^{-38} cm^2

- Event Rate $\sim 0.1 \text{ kg}^{-1} \text{ day}^{-1}$

- \Rightarrow Needs :

Large detector mass,

Extremely low rate of background noise (low T)

Cryogenic Dark Matter Search (CDMS)

The CDMS experiments:

Detector: Cryogenic Ge/Si crystals

Cryogen: $^3\text{He}/^4\text{He}$ Dilution Refrigerator (5-10 mK)

Physical Quantity Measured : Energy deposited in crystal by interaction

Means of Measurement: Change in conductivity of



Matter Search (IS)

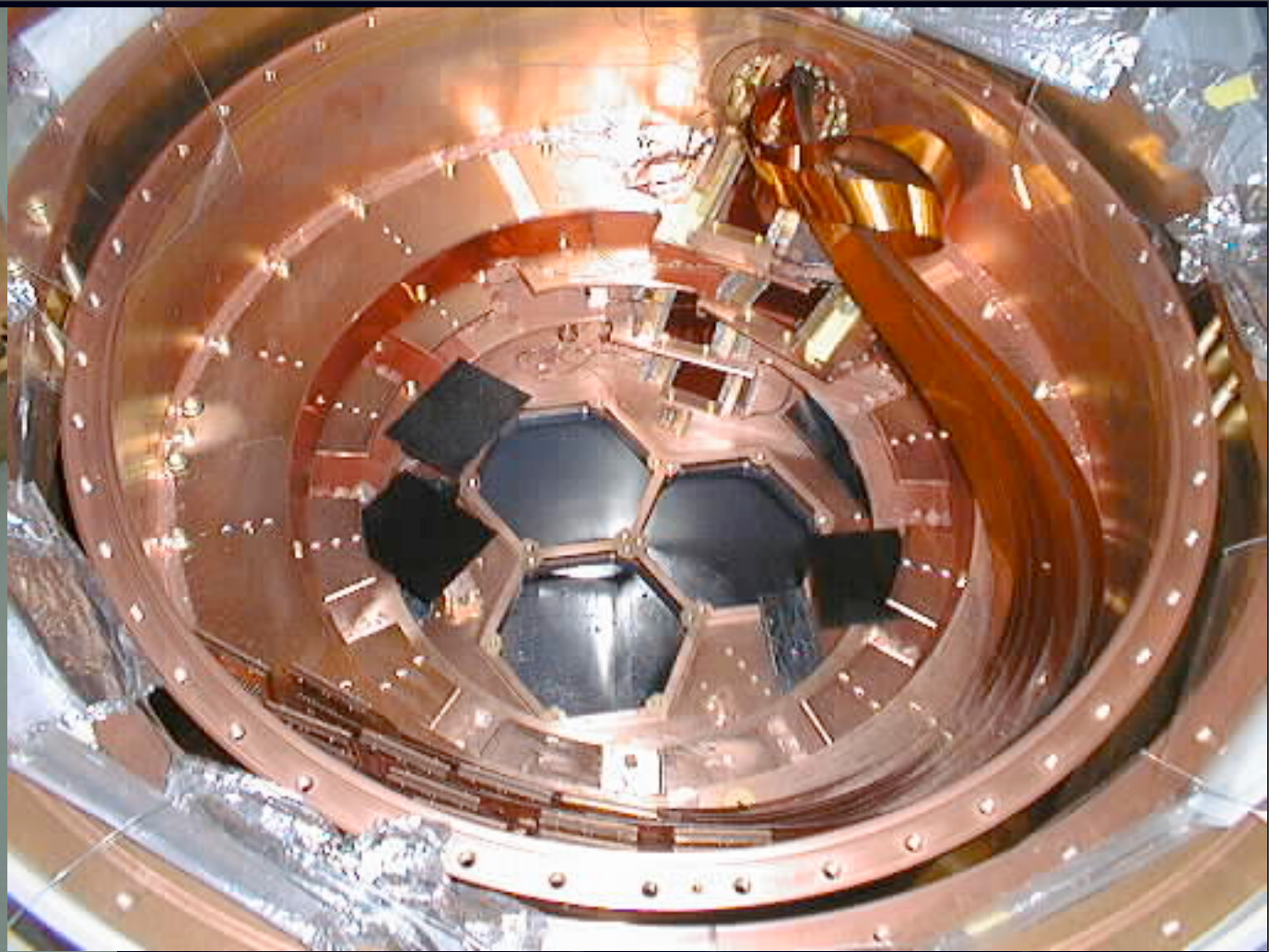
periments:

tals

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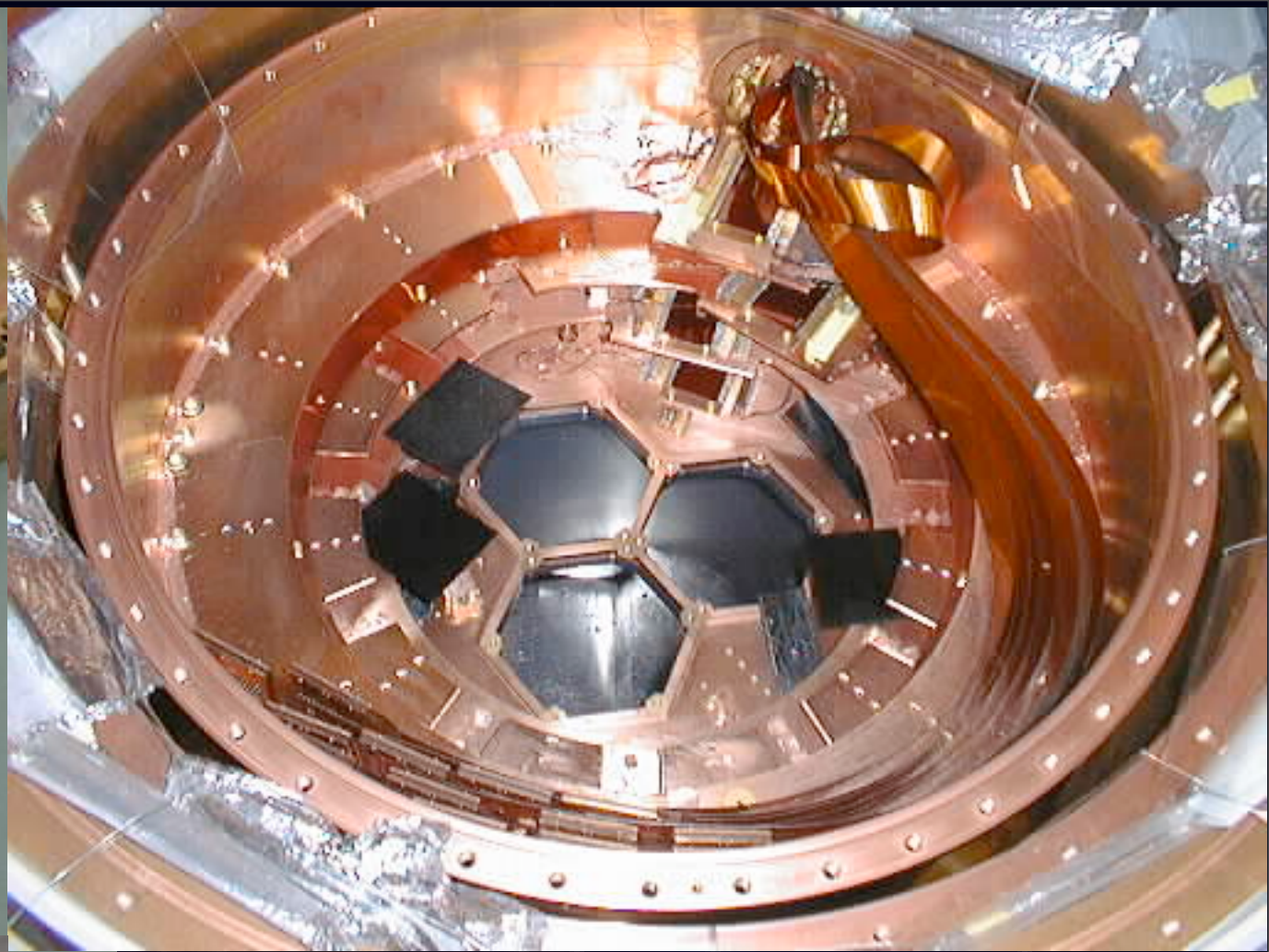
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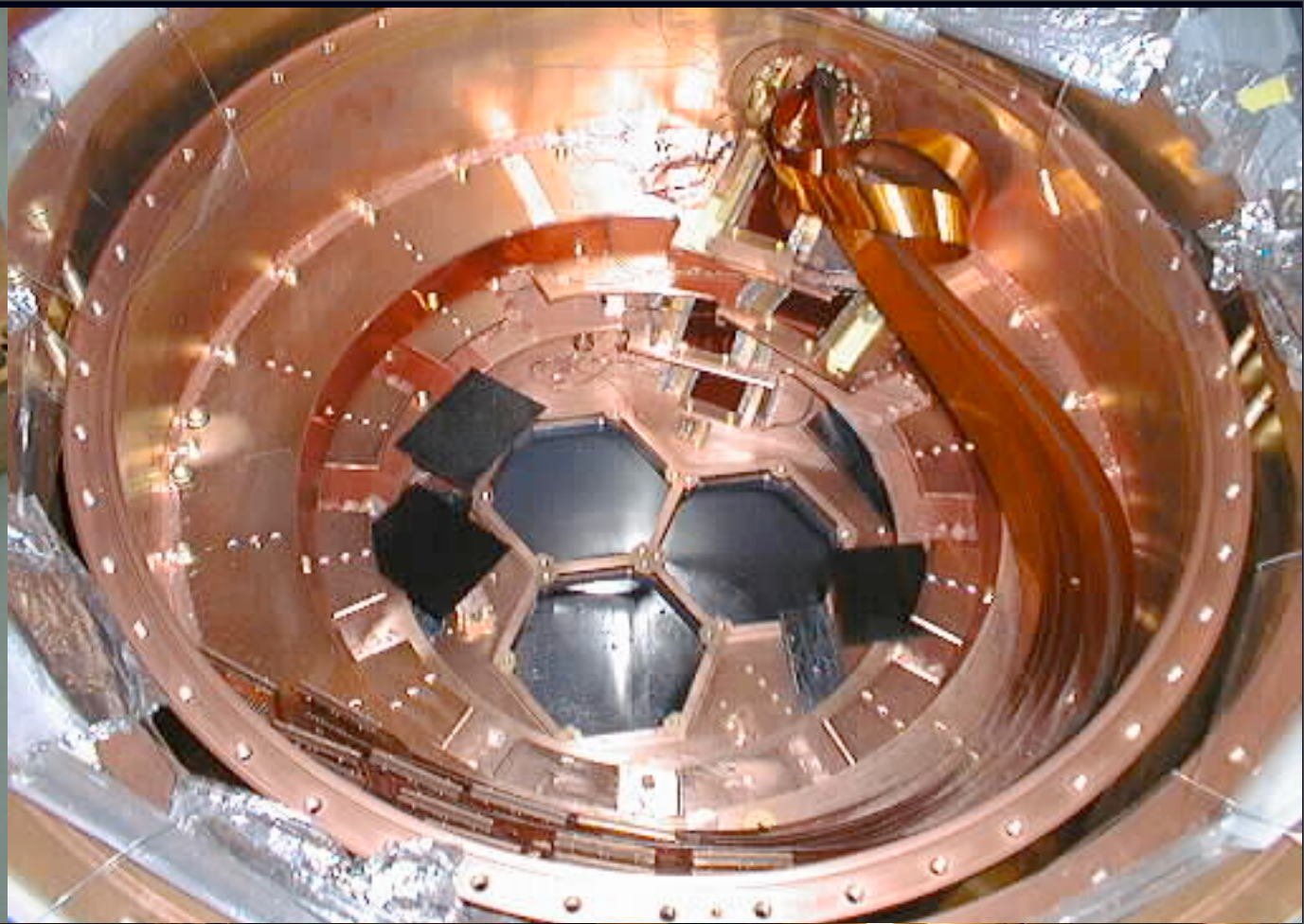
Means of Measurement: Change in conductivity of



Refrigerator (5-10 mK)

: Energy deposited in

change in conductivity of



Cryogenic Dark Matter Search (CDMS)



Cryogenic Dark Matter Search (CDMS)

(1) WIMP collides with detector nucleus



Cryogenic Dark Matter Search (CDMS)

- (1) WIMP collides with detector nucleus
- (2) Vibration: Phonons propagation through crystal



Cryogenic Dark Matter Search (CDMS)

- (1) WIMP collides with detector nucleus
- (2) Vibration: Phonons propagation through crystal
- (3) Some phonos reach the detector surface



Cryogenic Dark Matter Search (CDMS)

- (1) WIMP collides with detector nucleus
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- (3) Some phonos reach the detector surface
- (4) Phonos absorbed by Al collector fins



Cryogenic Dark Matter Search (CDMS)

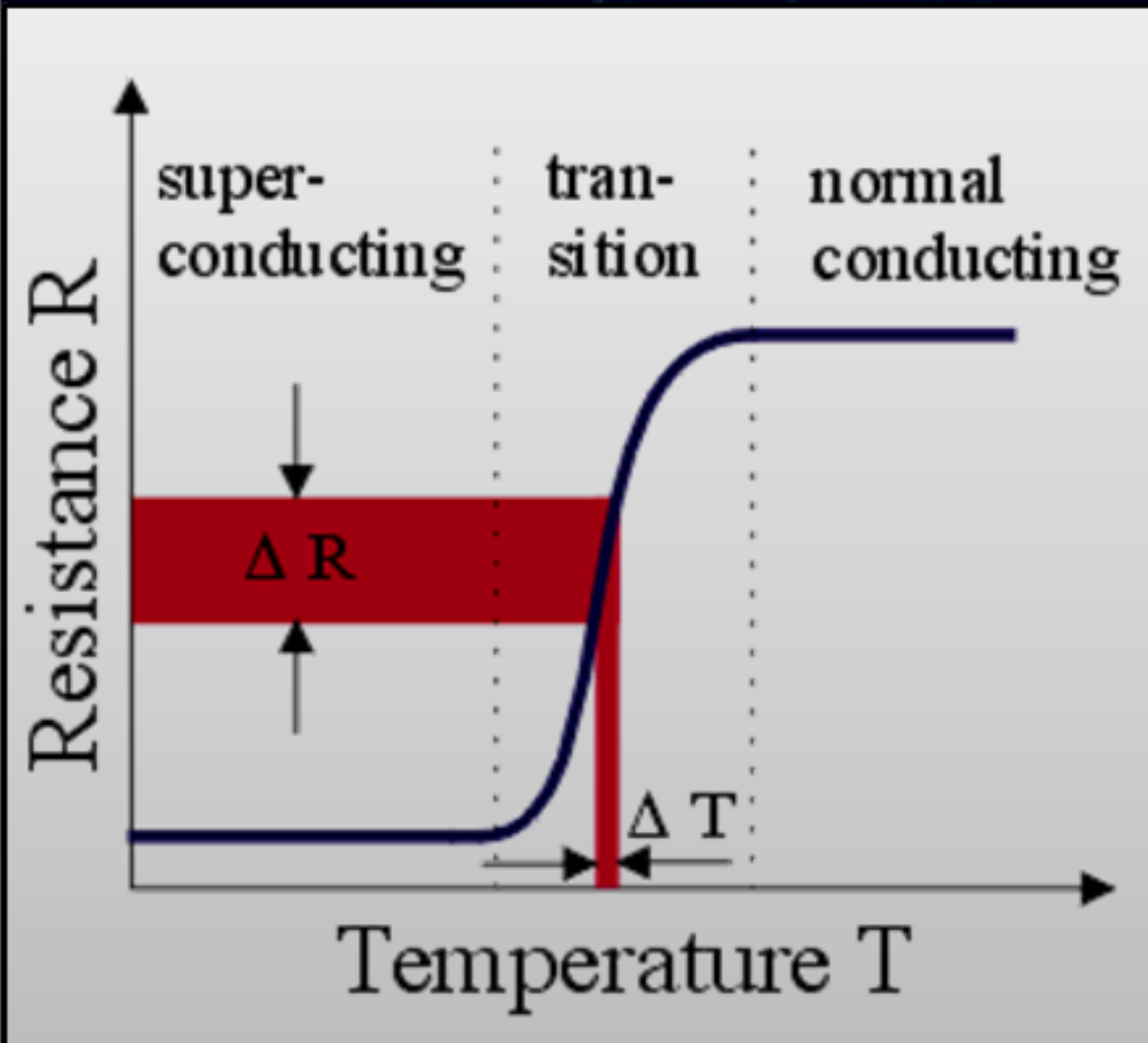
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- (5) Phonon energy \rightarrow to quasi-particles= e^- in super-conducting Cooper pair/ pair breaks



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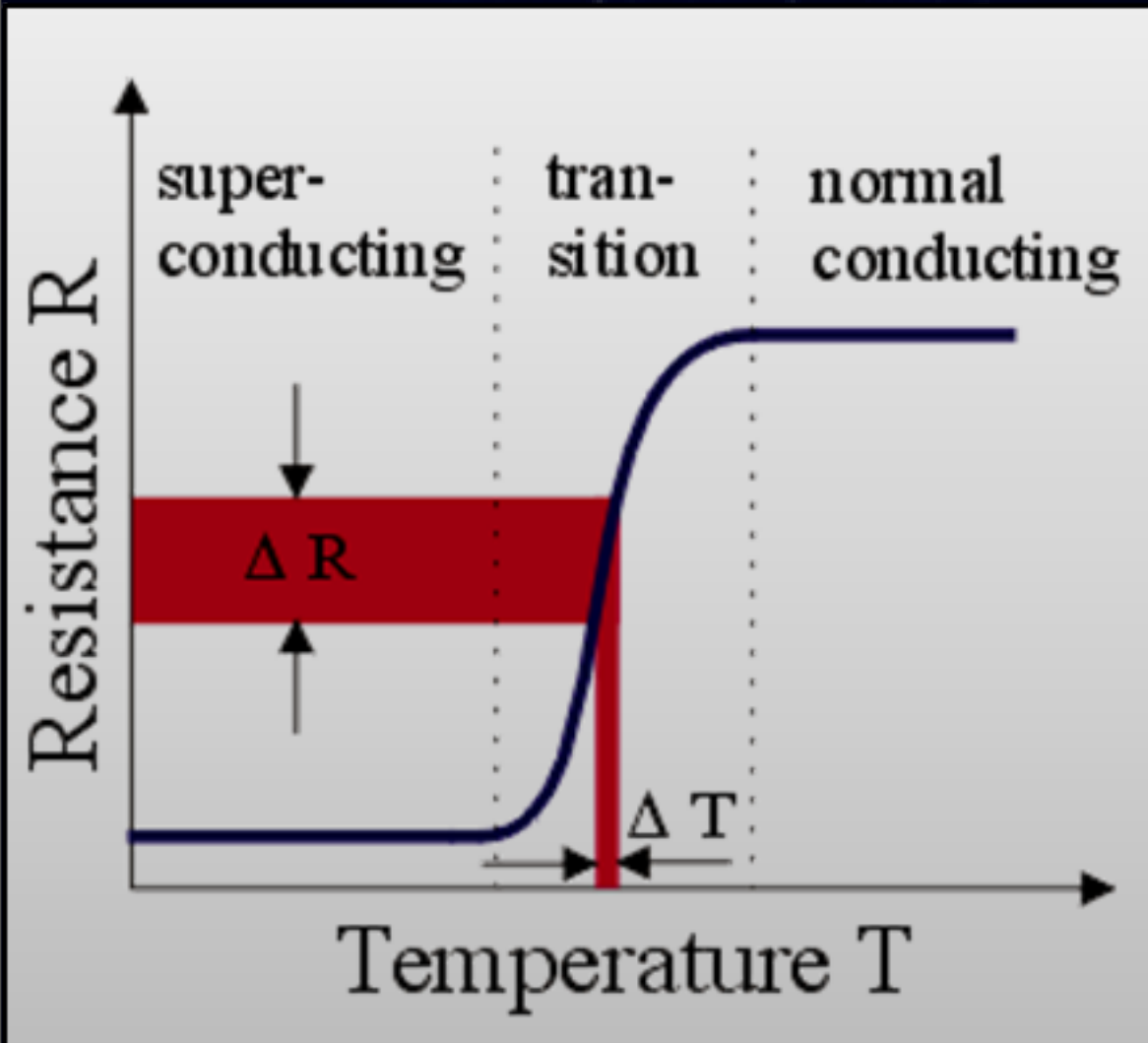
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- (6) e^- migrate to W strip

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Cryogenic Dark Matter Search (CDMS)



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- (5) Phonon energy \rightarrow to quasi-particles= e^- in super-conducting Cooper pair/ pair breaks
- (6) e^- migrate to W strip
- (7) Excess current pushes W from superconductor state back to conductor \Rightarrow dramatic change in the W electrical resistance

Directional Recoil Identification from Tracks (DRIFT)

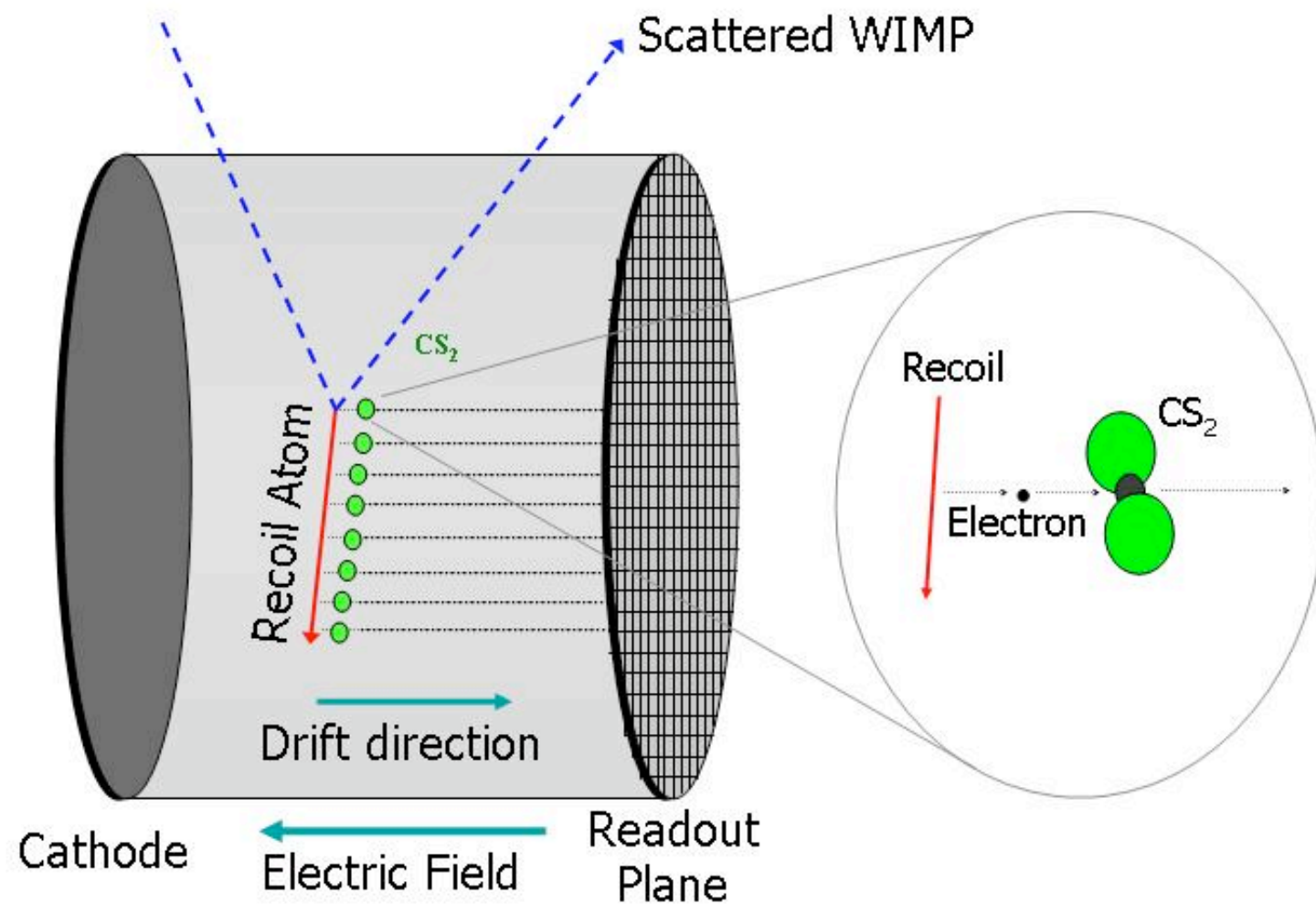
- Direct Detection: WIMP interaction with low pressure gas molecules in detector (e.g. CF_4 / CS_2 mixture)
-

Needs :

Large detector mass,

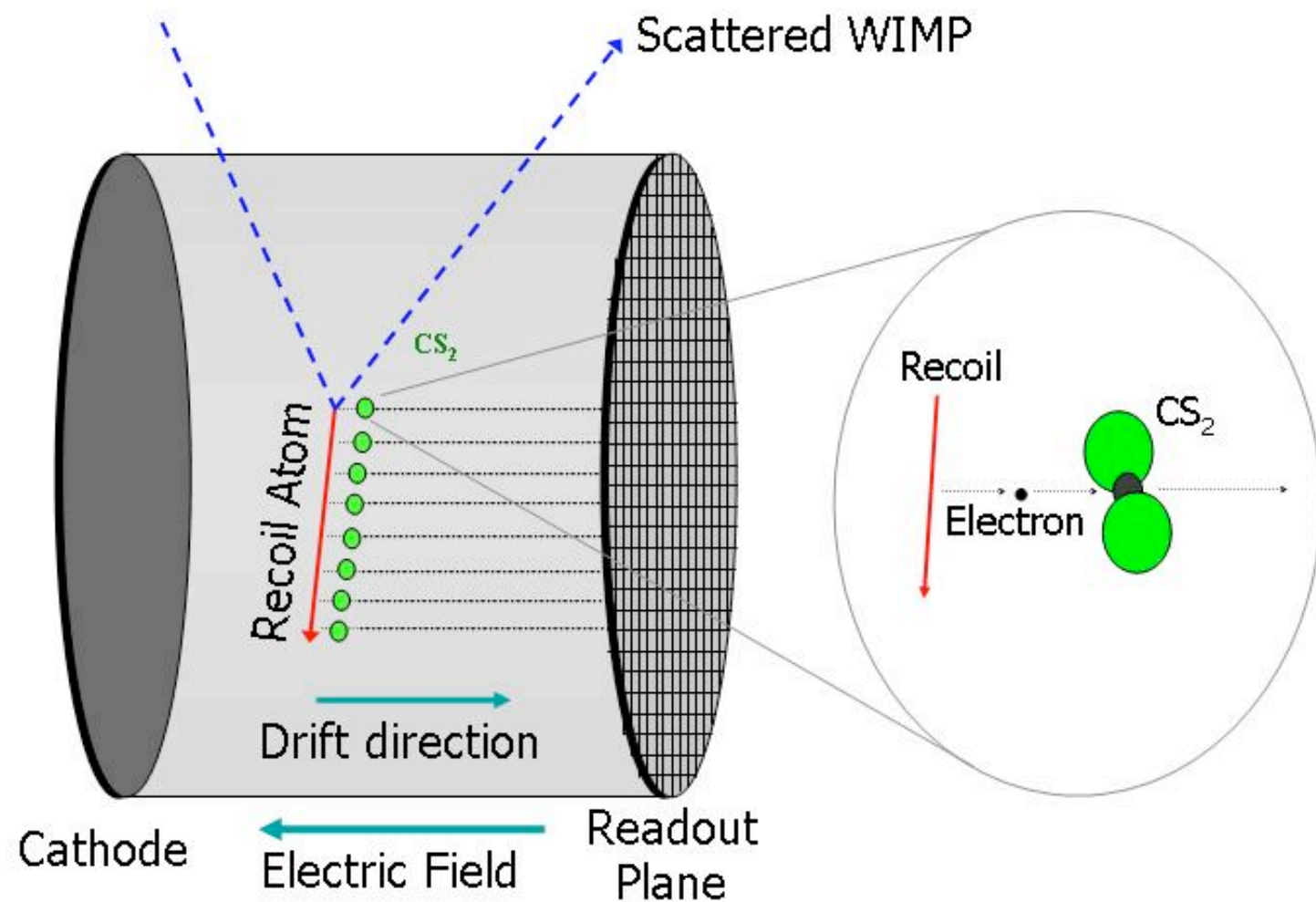
Extremely low rate of background noise (low T)

Directional Recoil Identification from Tracks (DRIFT)

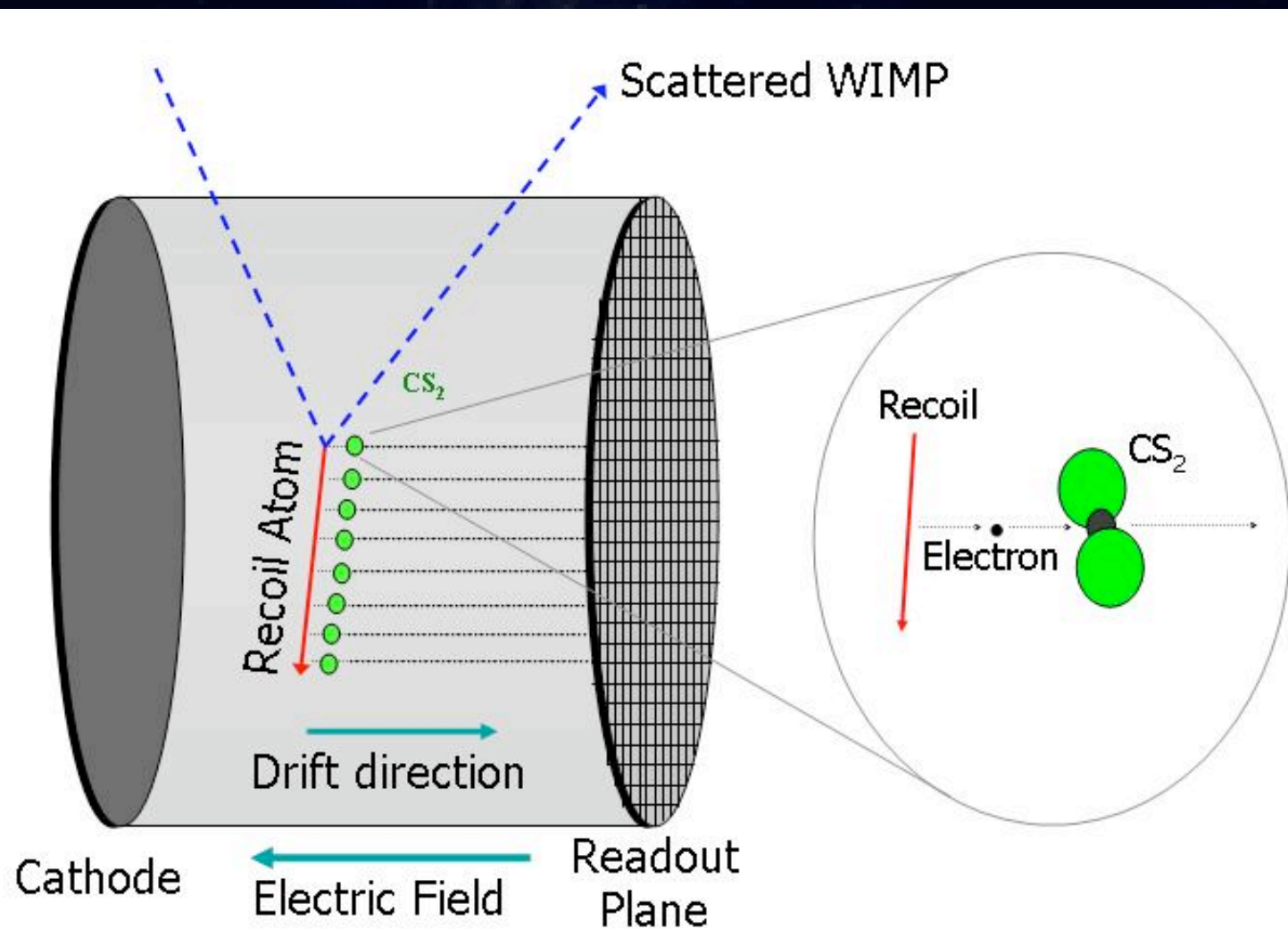


Directional Recoil Identification from Tracks (DRIFT)

(1) WIMP collides with target gas nucleus \rightarrow nucleus recoil

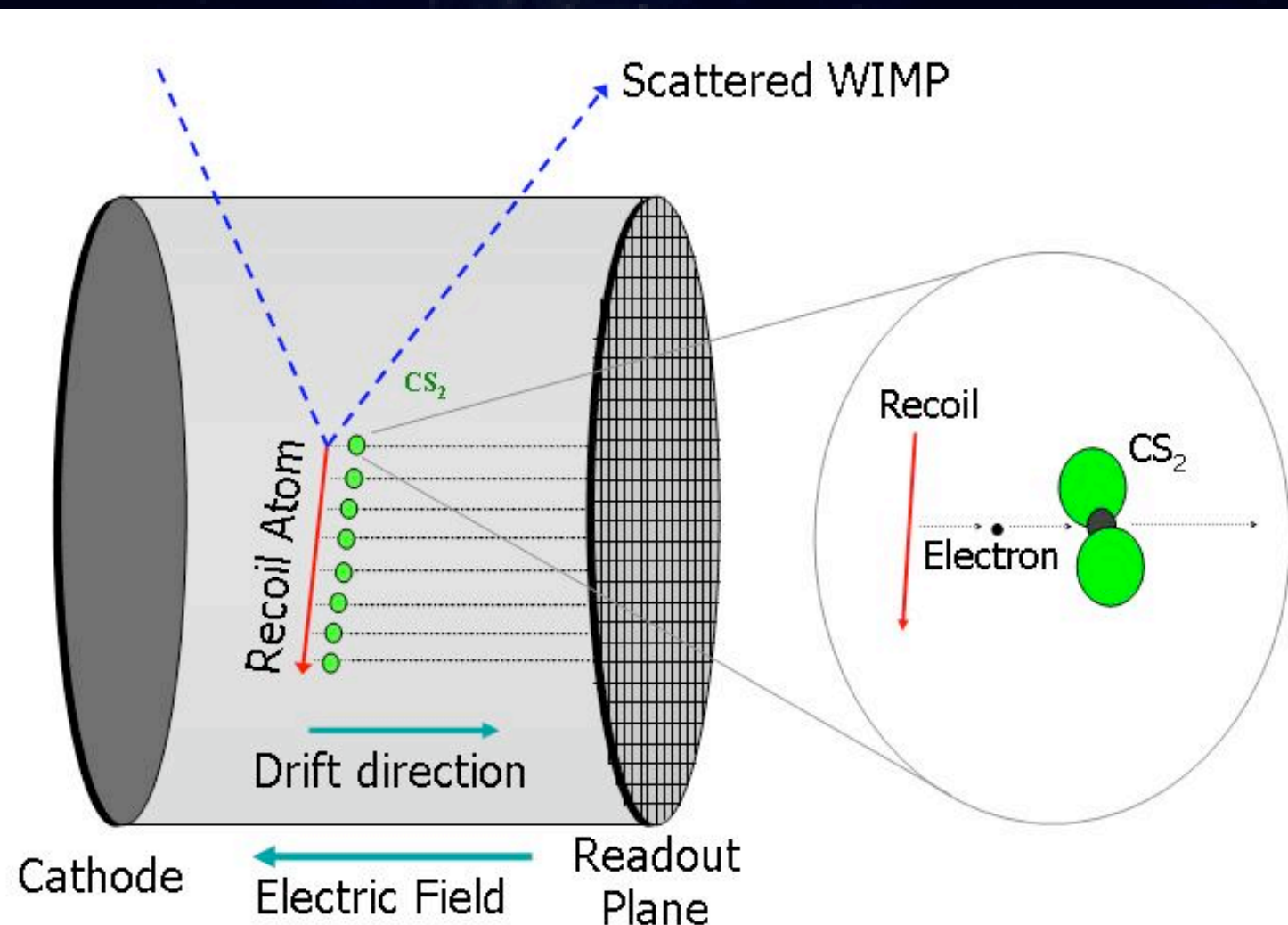


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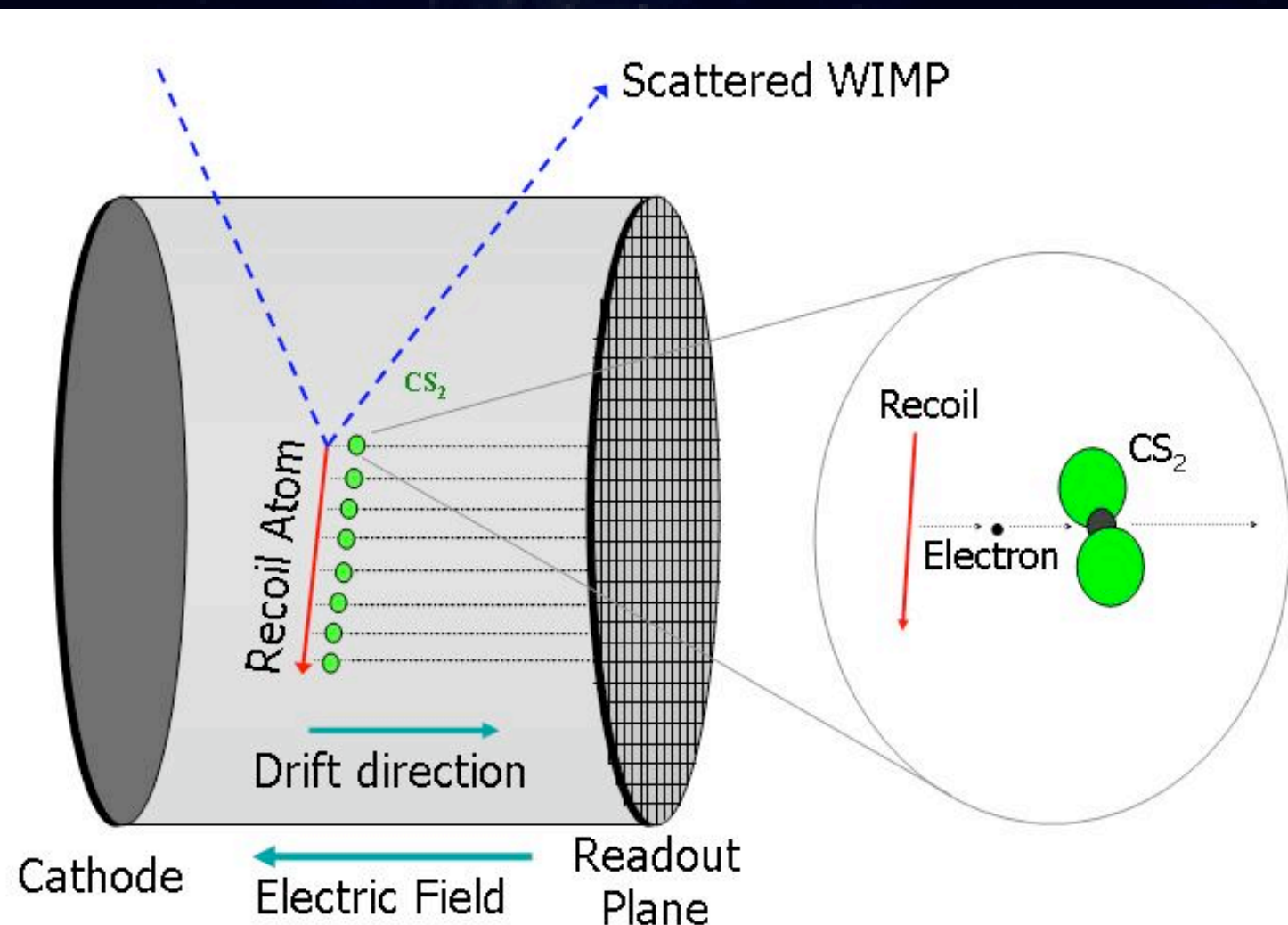
- (1) WIMP collides with target gas nucleus → nucleus recoil
- (2) Recoil nucleus/molecule ionises gas (CF₄)

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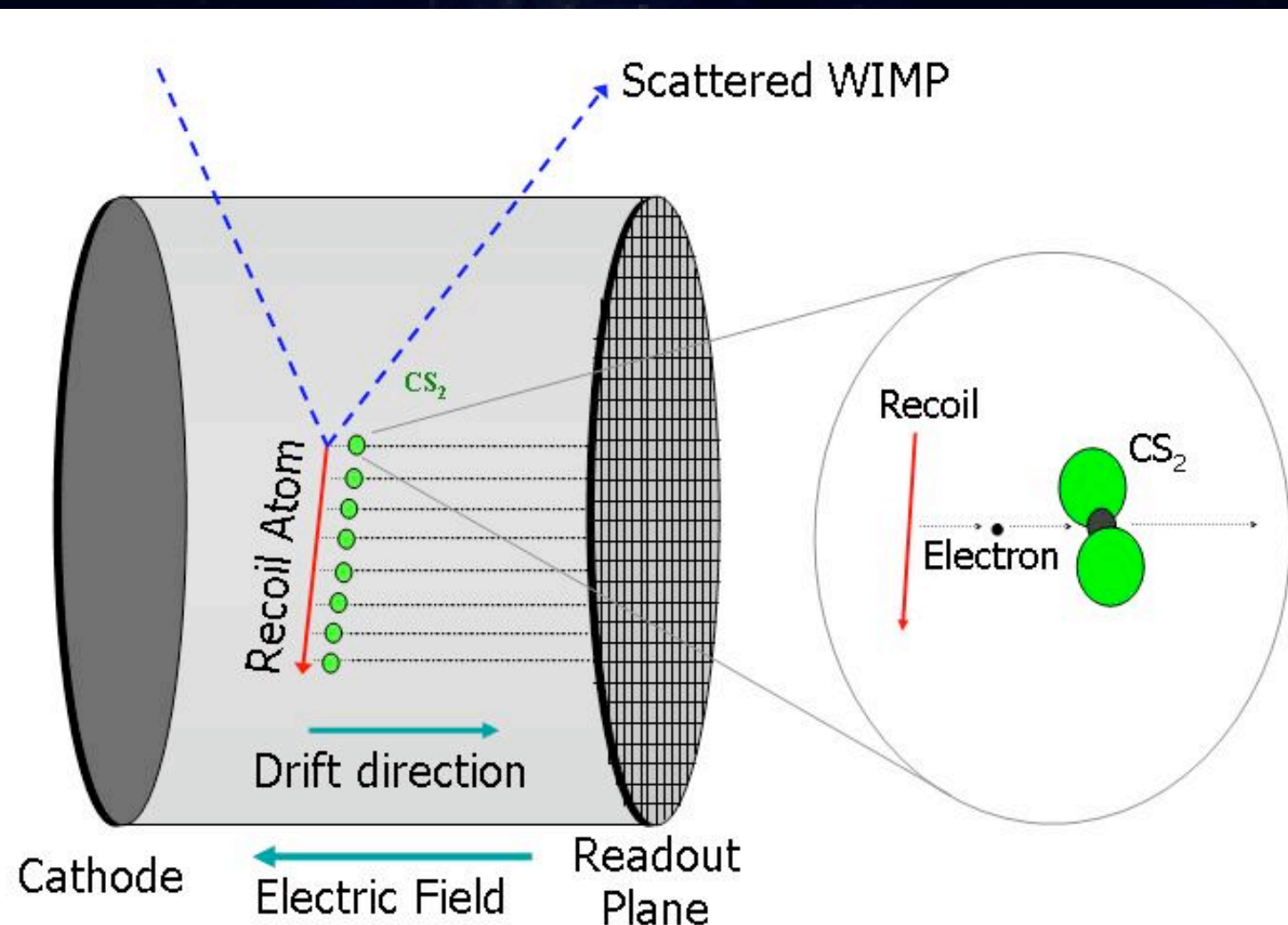
- (1) WIMP collides with target gas nucleus \rightarrow nucleus recoil
- (2) Recoil nucleus/molecule ionises gas (CF_4)
- (3) \Rightarrow Path of free e^- in the gas

Directional Recoil Identification from Tracks (DRIFT)



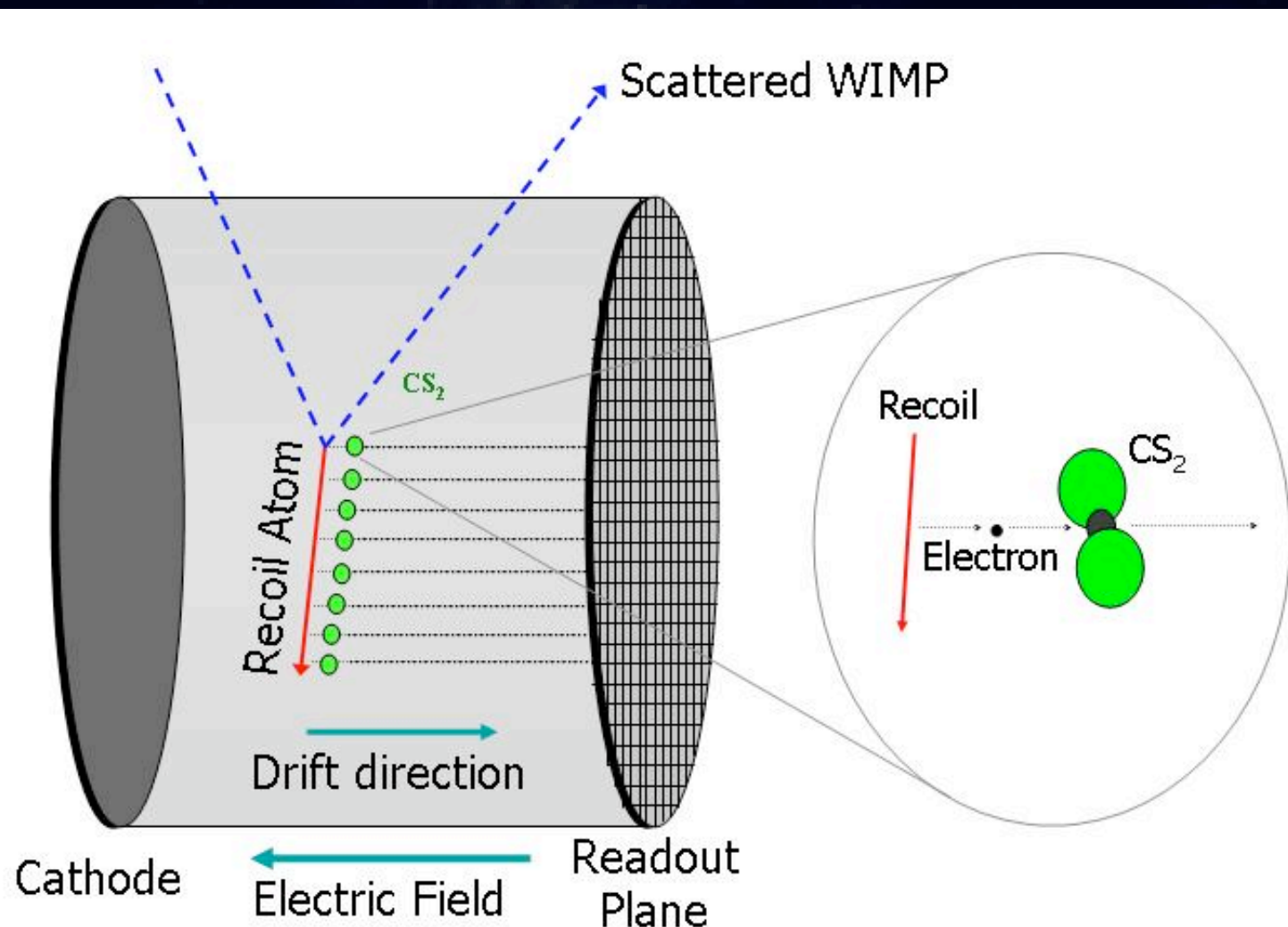
- (1) WIMP collides with target gas nucleus → nucleus recoil
- (2) Recoil nucleus/molecule ionises gas (CS₂)
- (3) ⇒ Path of free e⁻ in the gas
- (4) Free e⁻ are attached by electronegative CS₂ molecules ⇒ CS₂⁻ ions track

Directional Recoil Identification from Tracks (DRIFT)



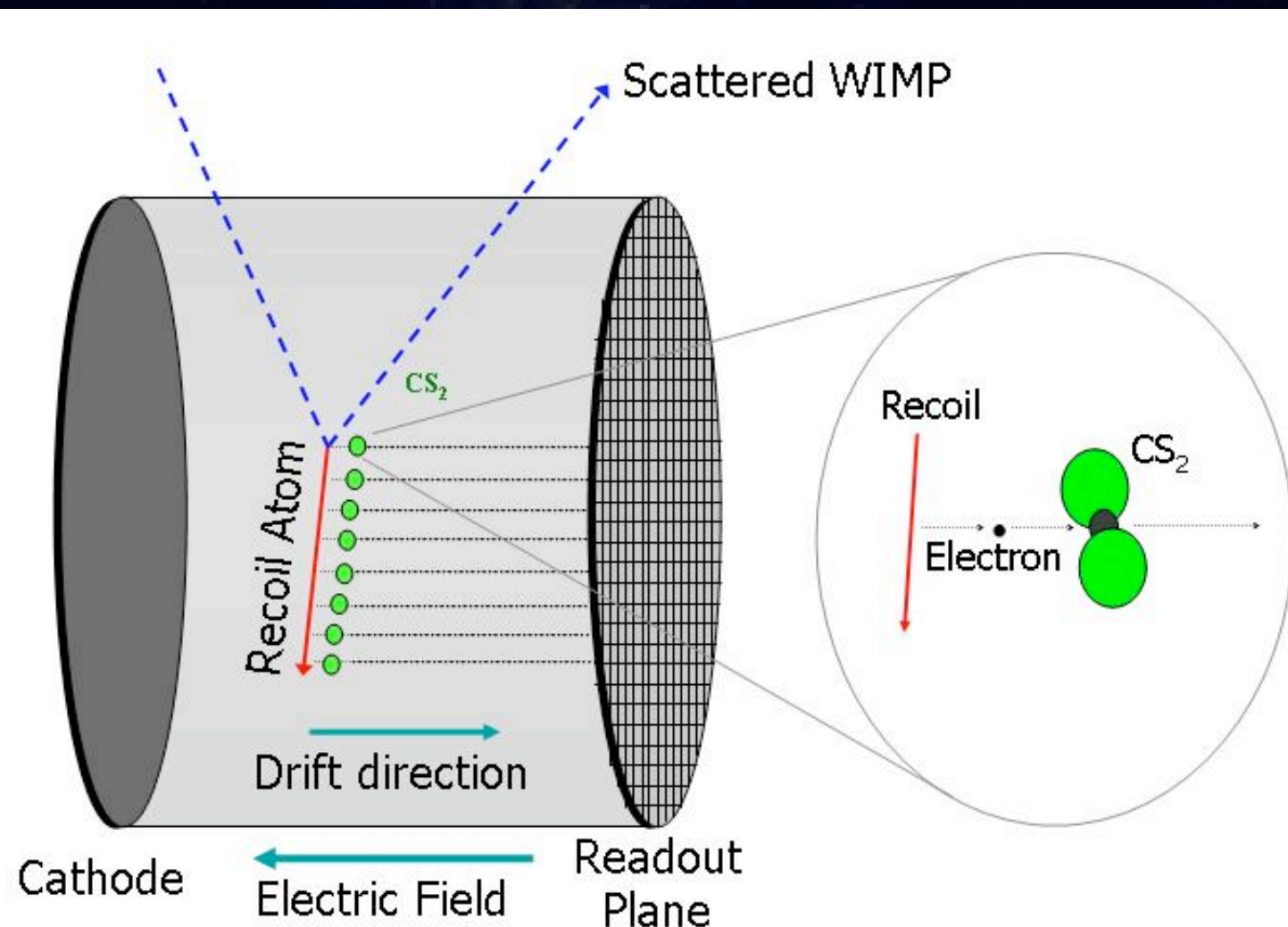
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- (6) Large mass of ion (vs e⁻ mass) ⇒ the original track structure maintained

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- (5) Applied E field makes CS₂⁻ ions drift to the readout plane
- (6) Large mass of ion (vs e⁻ mass) ⇒ the original track structure maintained
- (7) High directional sensitivity

WIMP Argon Programme (WARP)

Dark matter detection through scintillation:

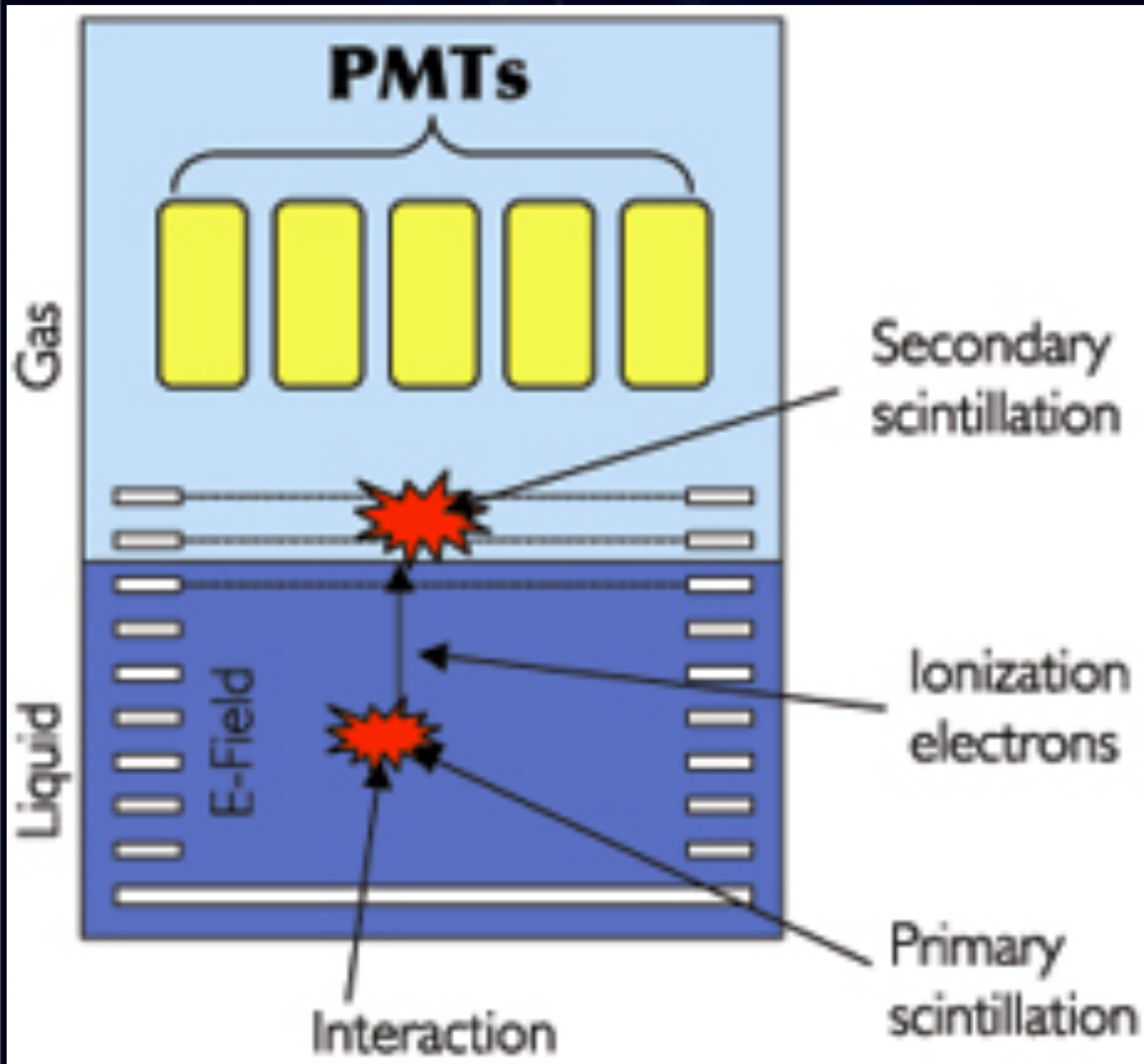
Detector: cryogenic noble liquid (Ar, Xe)
Allows ionisation & scintillation detection

Cryogen: external liquid Argon bath (~ 87 K)

Physical Quantity Measured : energy deposited in
medium by recoil

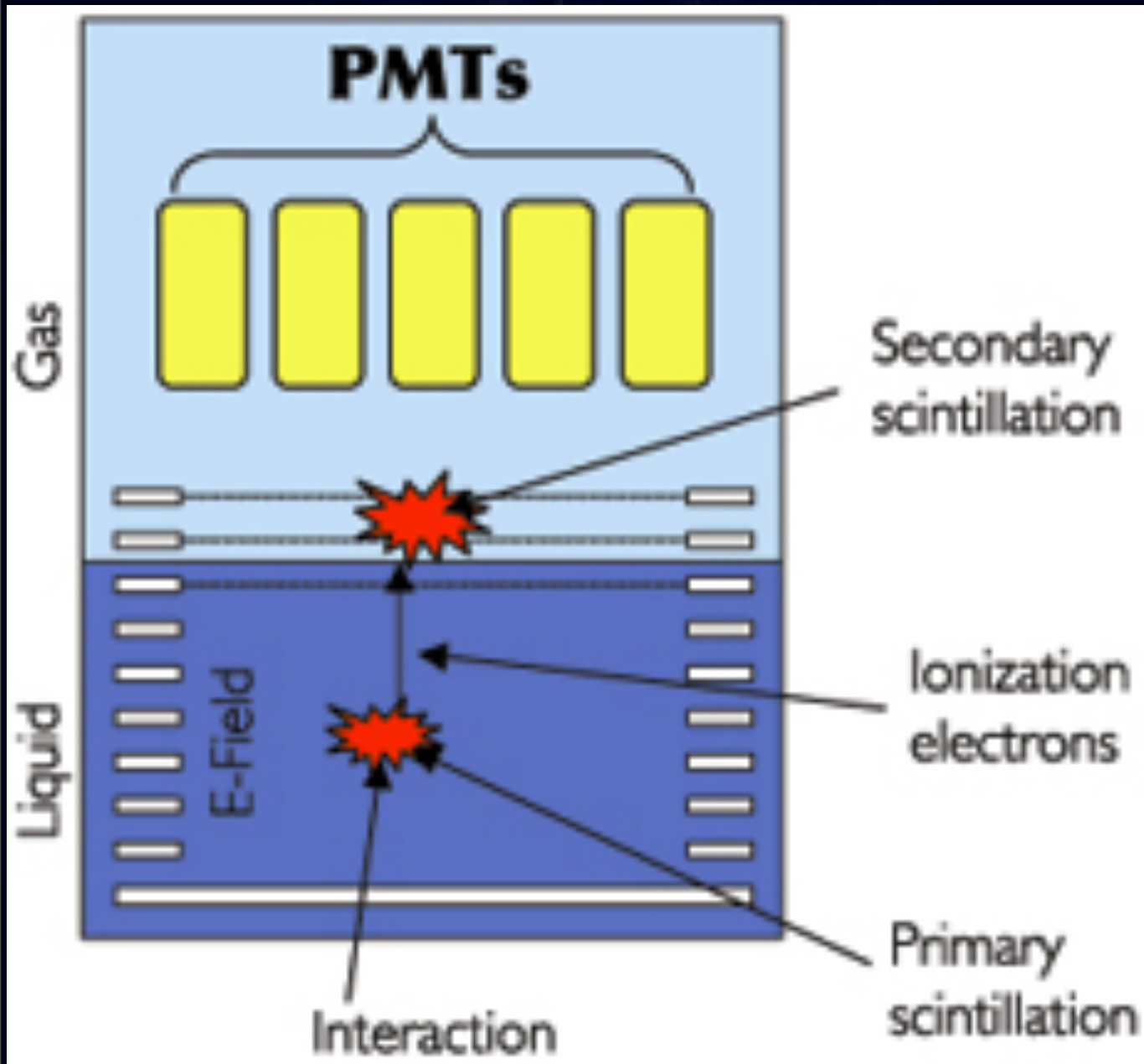
Means of Measurement: Scintillation light

WIMP Argon Programme (WARP)



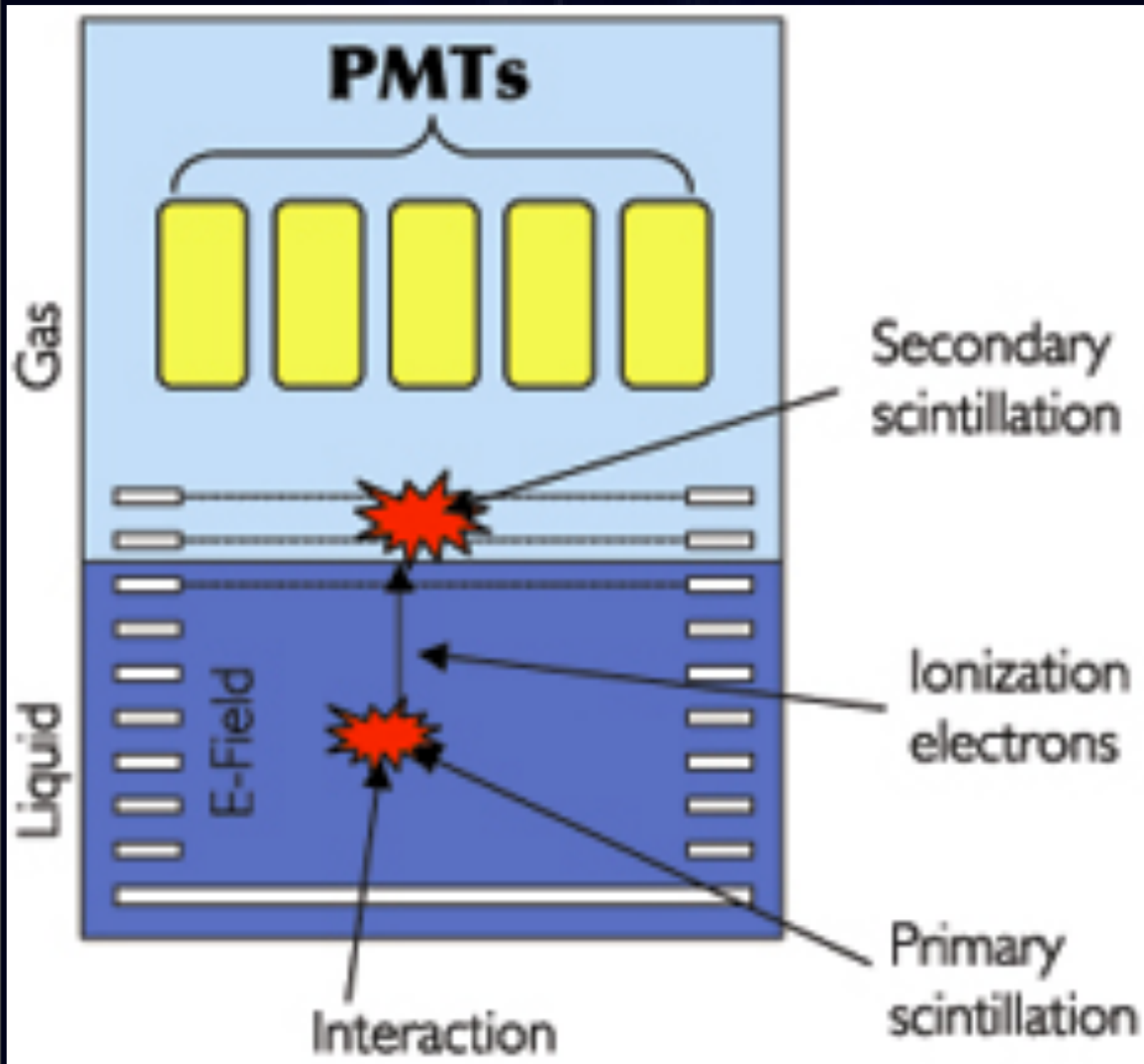
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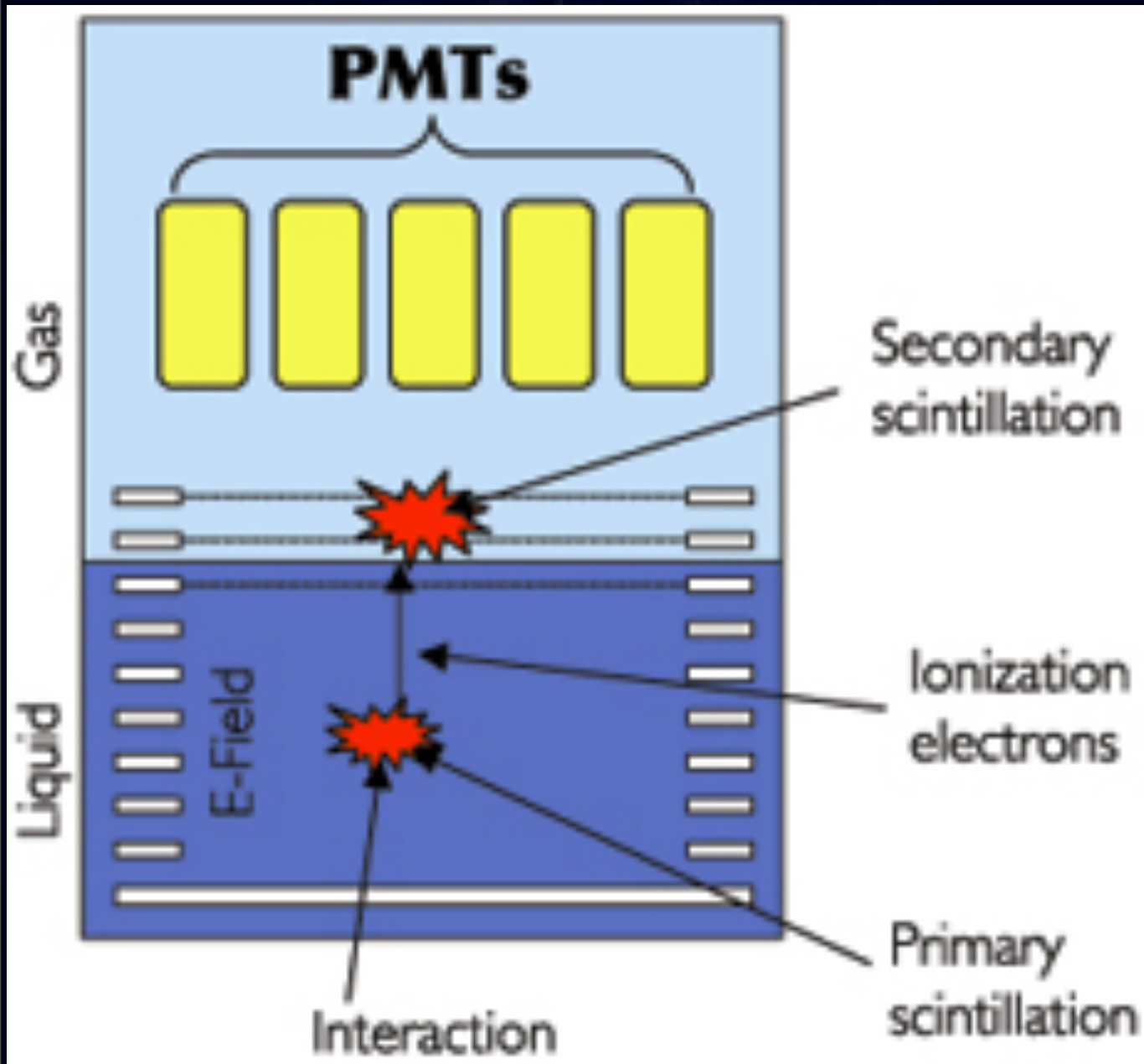
WIMP Argon Programme (WARP)

- (1) WIMP collides with target gas nucleus \rightarrow nucleus recoil
- (2) Recoil nucleus/ excitation-ionisation of atoms



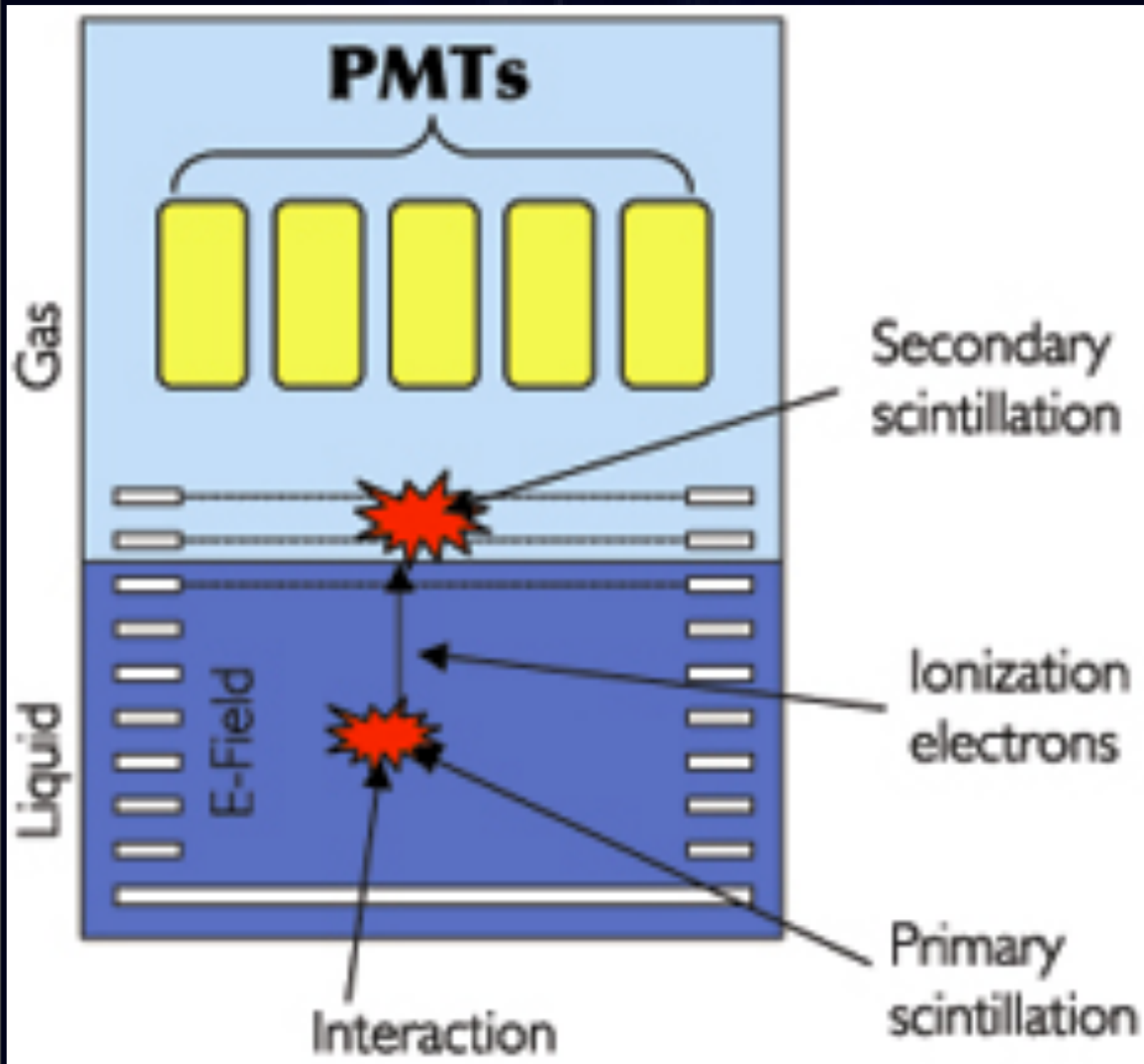
WIMP Argon Programme (WARP)

- (1) WIMP collides with target gas nucleus \rightarrow nucleus recoil
- (2) Recoil nucleus/ excitation-ionisation of atoms
- (3) De-excitations ,re-combinations \Rightarrow primary scintillation signal



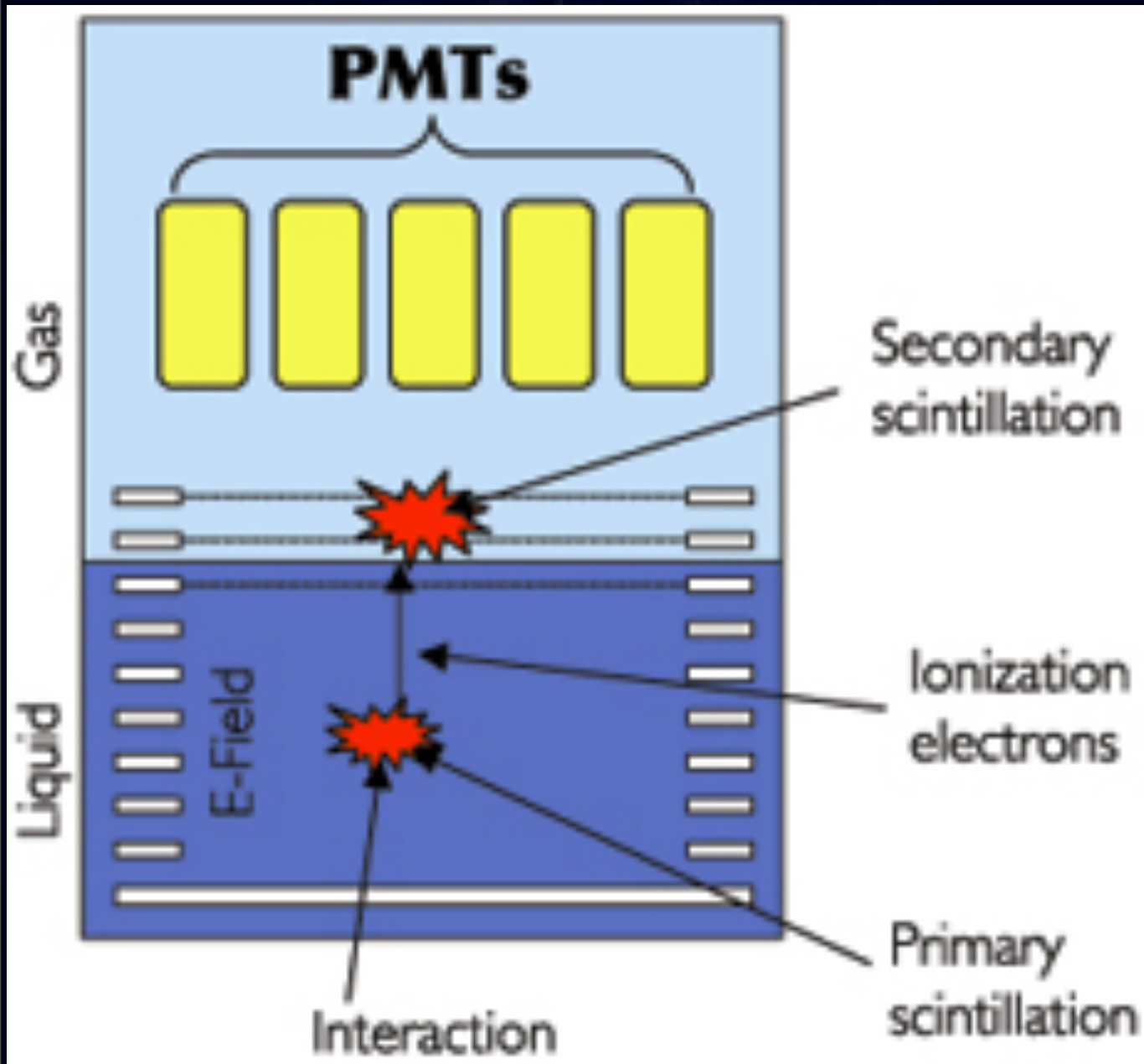
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- (4) Applied E field \Rightarrow free e^- go to gas

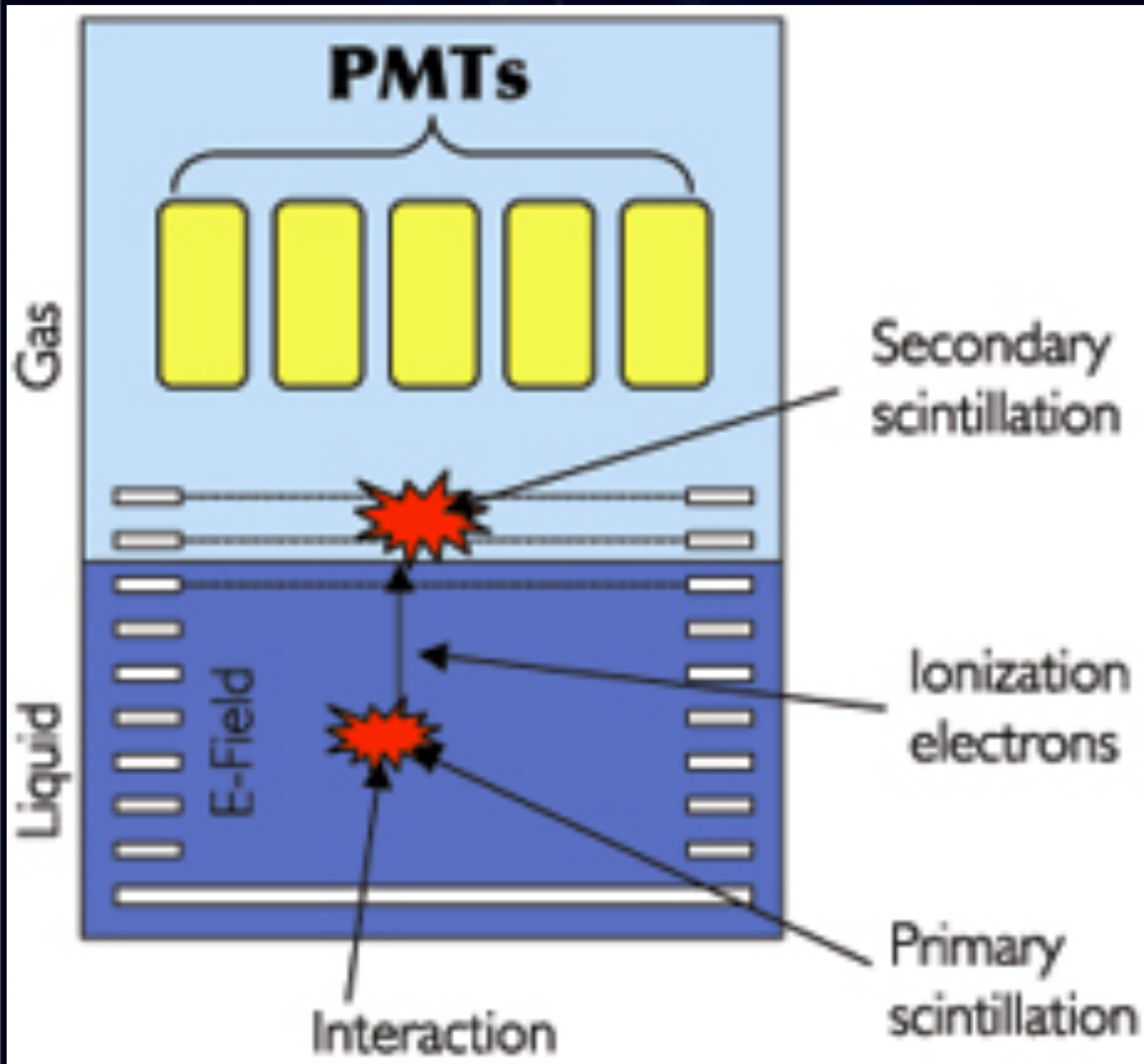


WIMP Argon Programme (WARP)

- (1) WIMP collides with target gas nucleus \rightarrow nucleus recoil
- (2) Recoil nucleus/ excitation-ionisation of atoms
- (3) De-excitations ,re-combinations \Rightarrow primary scintillation signal
- (4) Applied E field \Rightarrow free e^- go to gas
- (5) e^- accelerated, collide with gas atoms \Rightarrow secondary scintillation signal



WIMP Argon Programme (WARP)



- (1) WIMP collides with target gas nucleus \rightarrow nucleus recoil
- (2) Recoil nucleus/ excitation-ionisation of atoms
- (3) De-excitations ,re-combinations \Rightarrow primary scintillation signal
- (4) Applied E field \Rightarrow free e^- go to gas
- (5) e^- accelerated, collide with gas atoms \Rightarrow secondary scintillation signal
- (6) primary/secondary are dependent on the nature of the kind of impinging particle.

Results so far

?



Also, Axions are searched...



CAST (CERN)

ADMX
(Washington)



The background is a deep blue space scene. It features several galaxies: a prominent spiral galaxy on the right, a smaller one at the top, and a bar-shaped galaxy on the left. Numerous stars of varying brightness are scattered across the field. In the lower-left foreground, a magnifying glass is positioned, its lens focusing on a detailed molecular model. This model consists of several red spheres (likely representing oxygen or hydrogen) connected by thin grey lines, showing a complex three-dimensional structure. The word "Thanks!" is centered in the upper half of the image in a white, serif font.

Thanks!