Sep 9th, 2019
TAUP 2019
Toyama, JAPAN

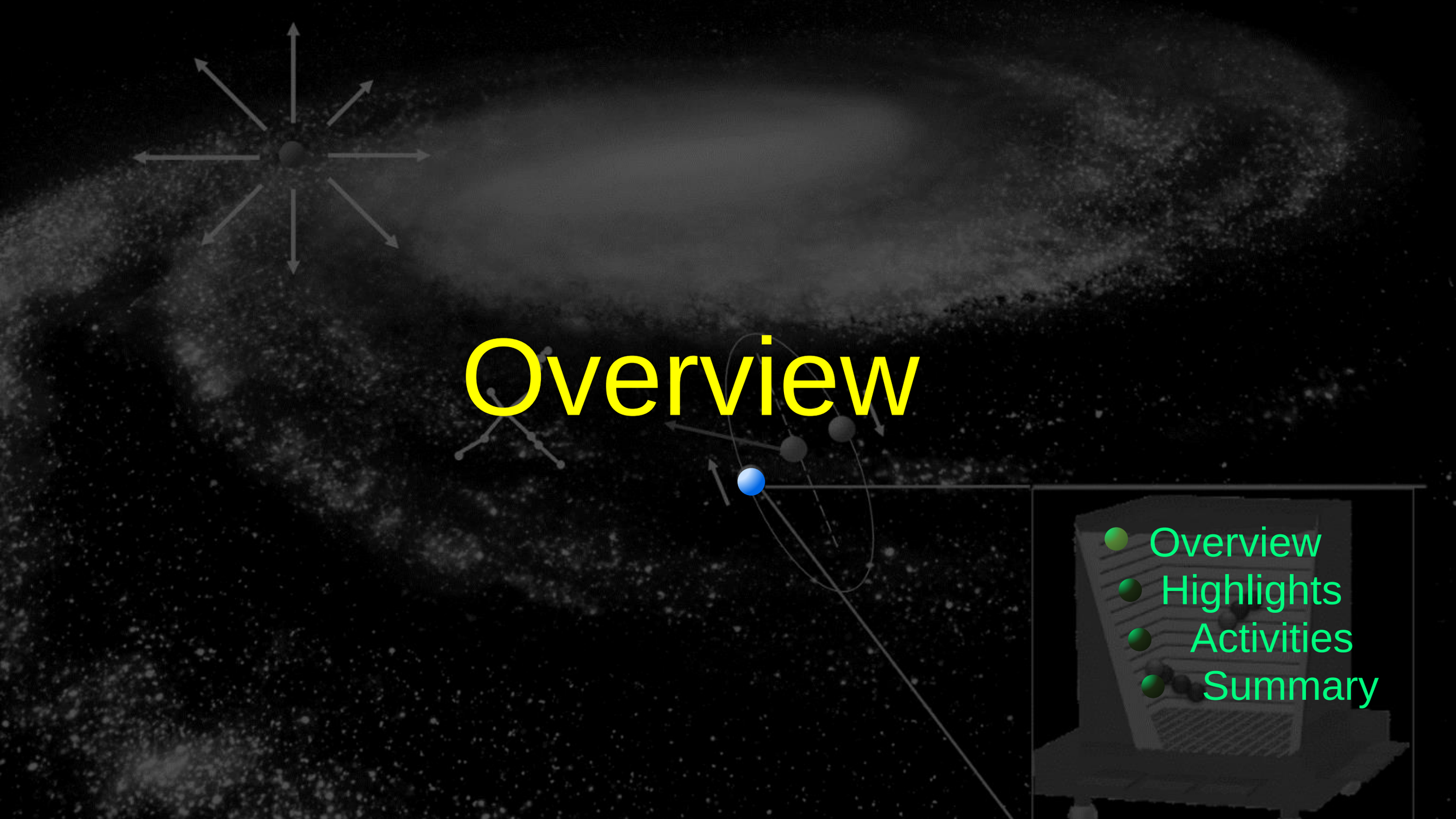
CYGNUS

Kentaro Miuchi
(Kobe University)

- Overview
- Activities
- Highlights
- Summary

科研費
KAKENHI

Overview



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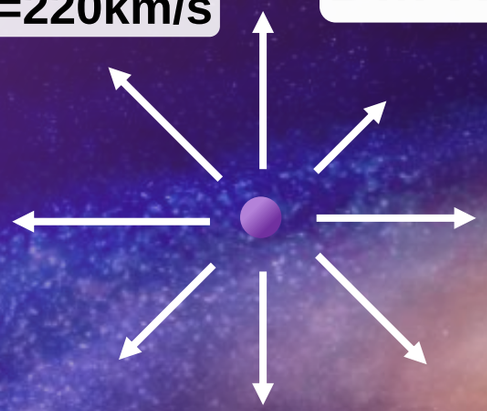
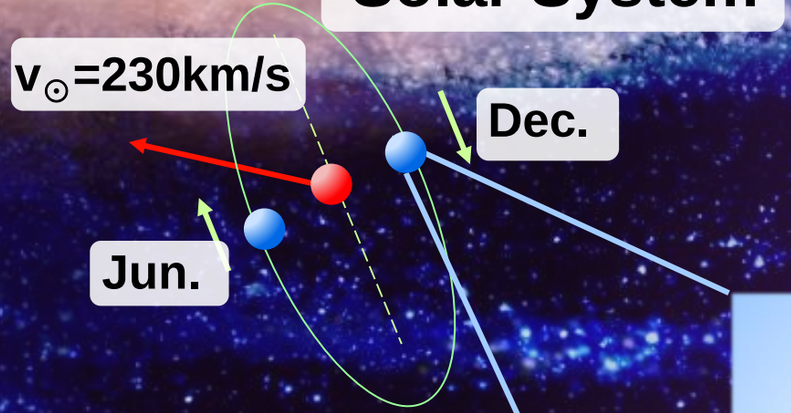
“CYGNUS” concept

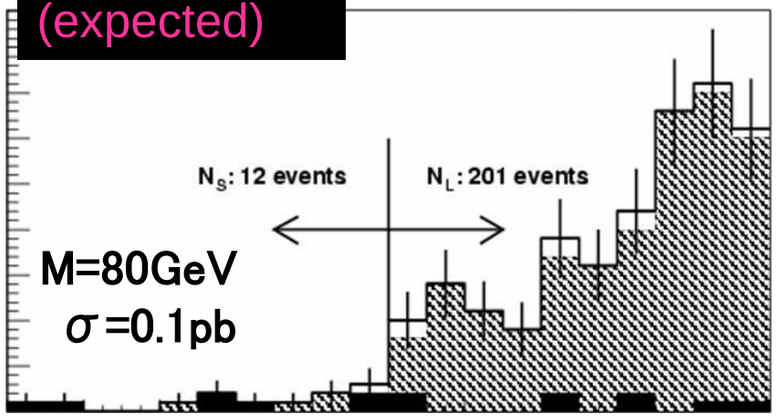
WIMP-wind detection

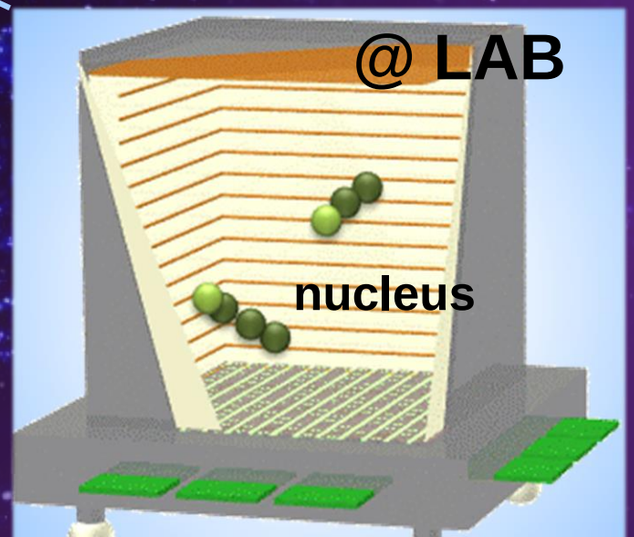


G. C.



directionality (expected)



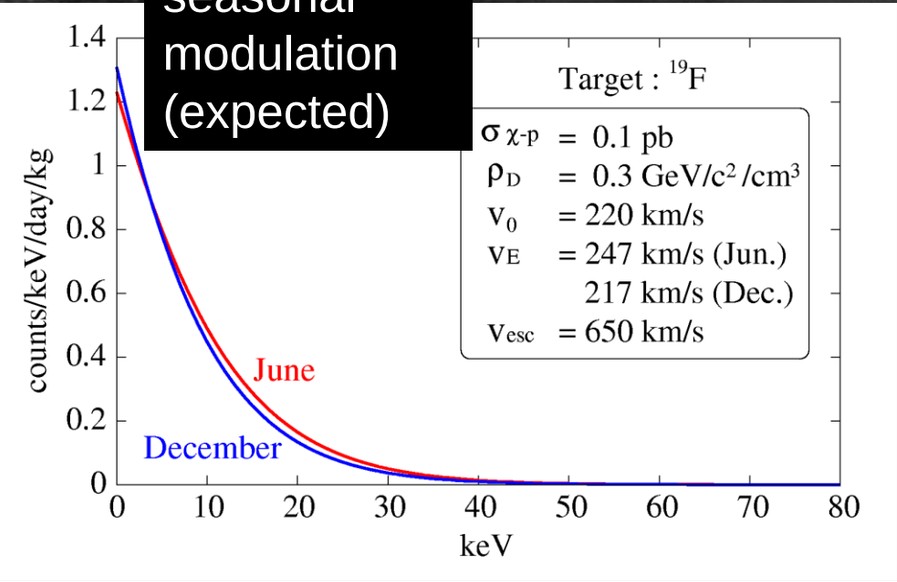


Physics Letters B 578 (2004) 241–246

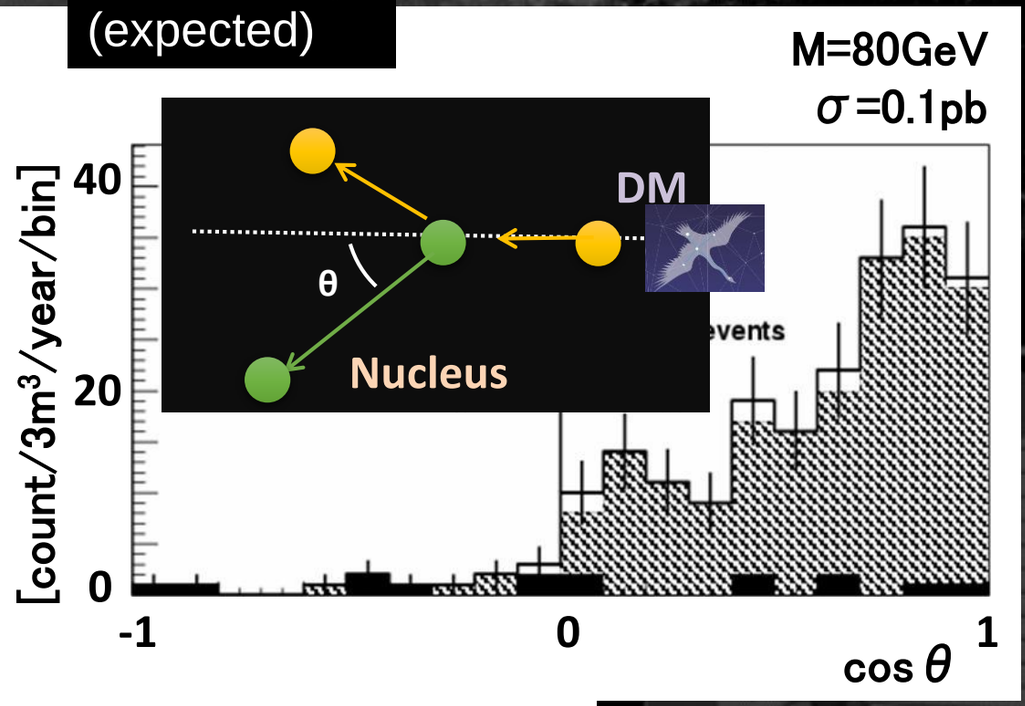
CYGNUS: Directional Detection

- Clear Discovery
  + study the nature of DM after discovery

seasonal modulation (expected)



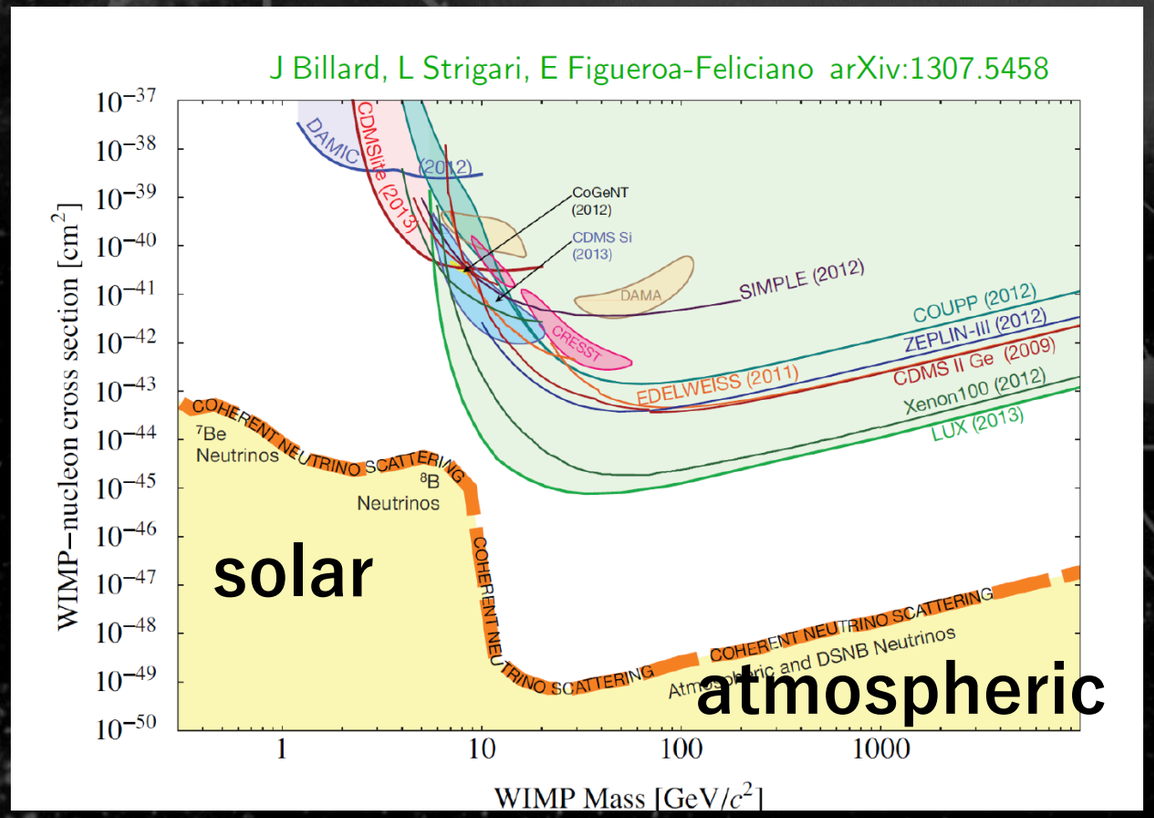
directionality (expected)

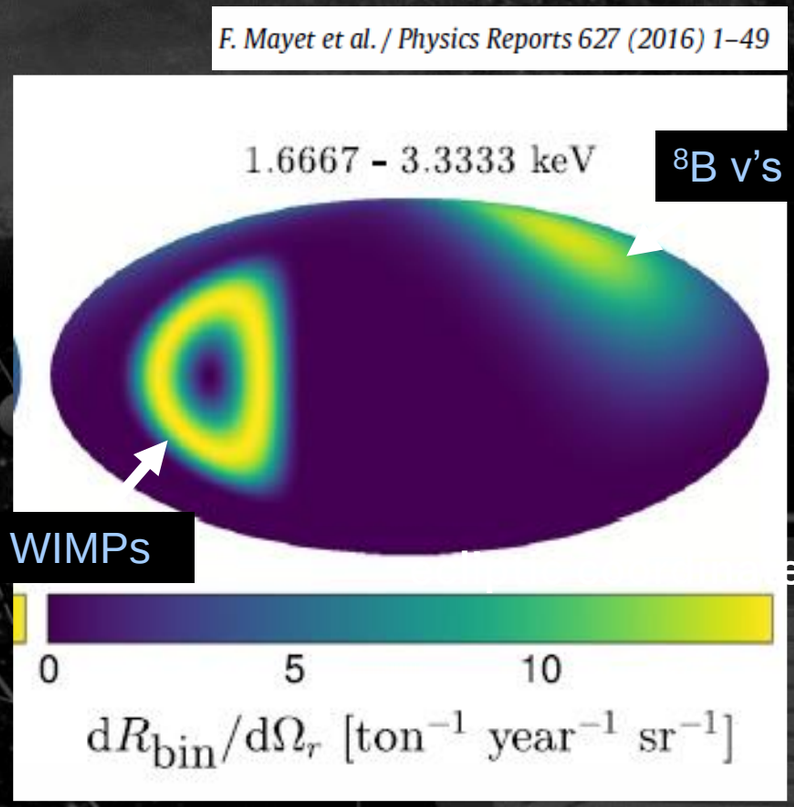


Physics Letters B 578 (2004) 241–246

Toward discovery

- Potential to search beyond the “neutrino floor” where large detectors are reaching.





- distinguishable

CYGNUS: community

- 7 × bi-annual workshops (2007-)
  - CYGNUS 2017 Xichang, Sichuan, China June 13 - 16, 2017
  - CYGNUS 2015 Occidental College, Los Angeles, California, USA June 2 - 4, 2015.
  - CYGNUS 2013 Toyama, Japan June 10 - 12, 2013.
  - CYGNUS 2011 Aussois, France June 7 - 10, 2011.
  - CYGNUS 2009 Massachusetts Institute of Technology, Cambridge, Massachusetts, USA June 11 - 13, 2009.
  - CYGNUS 2007 Boulby Underground Laboratory, Saltburn-by-the-Sea, Cleveland, UK July 22 - 24, 2007.

CYGNUS 2019 @Roma

- 2 × review papers, another is coming

International Journal of Modern Physics A
Vol. 25, No. 1 (2010) 1–51

World Scientific
www.worldscientific.com

THE CASE FOR A
DIRECTIONAL DARK MATTER DETECTOR AND
THE STATUS OF CURRENT EXPERIMENTAL EFFORTS

Readout technologies for directional WIMP Dark Matter detection

Physics Reports 662 (2016) 1–46

J.B.R. Battat [1,*], I.G. Irastorza [2], A. Aleksandrov
E. Baracchini [6], J. Billard [7,8], G. Bosson [7], O. Bourrion [7], J. Bouvier [7],
A. Buonaura [3,9], K. Burdge [10,11], S. Cebrián [2], P. Colas [12], L. Consiglio [13], T. Dafni [2],

CYGNUS: collaboration

- proto-collaboration (2016-)
  - >50 researchers
  - discussion on-going for actual collaboration

The CYGNUS Galactic Directional Recoil Observatory
Proto-Collaboration Agreement

Now that conventional WIMP dark matter searches are approaching the neutrino floor, there has been a resurgence of interest in the possibility of introducing recoil direction sensitivity into the field. Such directional sensitivity would offer the powerful prospect of reaching below this floor, introducing both the possibility of identifying a clear signature for dark matter particles in the galaxy below this level but also of exploiting observation of coherent neutrino scattering from the Sun and other sources with directional sensitivity. There has also been significant progress recently in development of technology able to record the directional information from nuclear recoils at low energy (sub-100 keV) necessary for these goals. This includes progress on improving the sensitivity of low pressure gas time projection chamber technology but also on novel ideas with higher density targets, such as ultra-fine grain emulsions, scintillation materials, columnar recombination with noble gas targets and concepts

steering committee

E. Baracchini (GSSI)
G. Lane (ANU, Canberra)
K. Miuchi (Kobe)
N. Spooner (Sheffield)
S. Vahsen (Hawaii)

Activities

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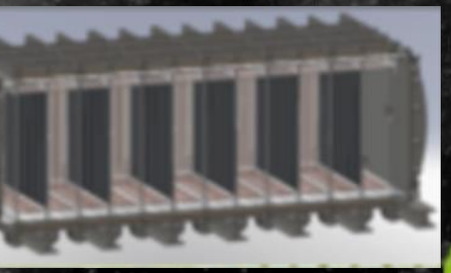
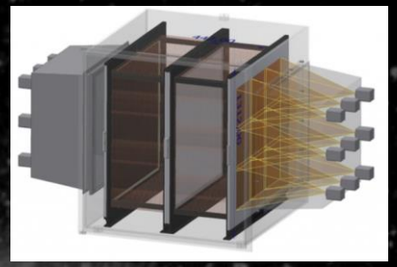
World-wide CYGNUS (ver. TAUP2019)

CYGNUS-10
Boulby, UK
10m^3 He:SF_6
GEM + wire readout



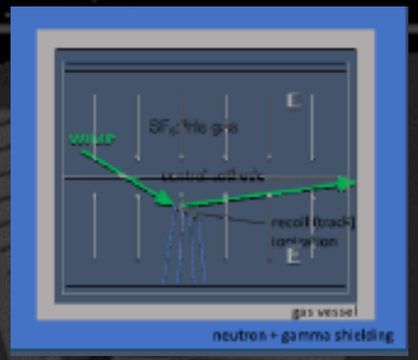
CYGNO-Initium
Gran Sasso, Italy
He CF_4 (SF_6)
sCMOS+PMT readout



CYGNUS-KM
Kamioka, Japan
SF6 / CF4
Strip readout

40cm

CYGNUS-HD10
SURF, USA
He:CF_4:C_4H_{10}
Strip readout



CYGNUS-OZ
Stawell, Australia
R&D leading to 1 m^3
Long-term plan 10 m^3

multi-site observatory

- UK / Boulby
  - pioneered this field (DRIFT)
  - 1m^3 detector running underground (Boulby) for years
  - low BG, large volume

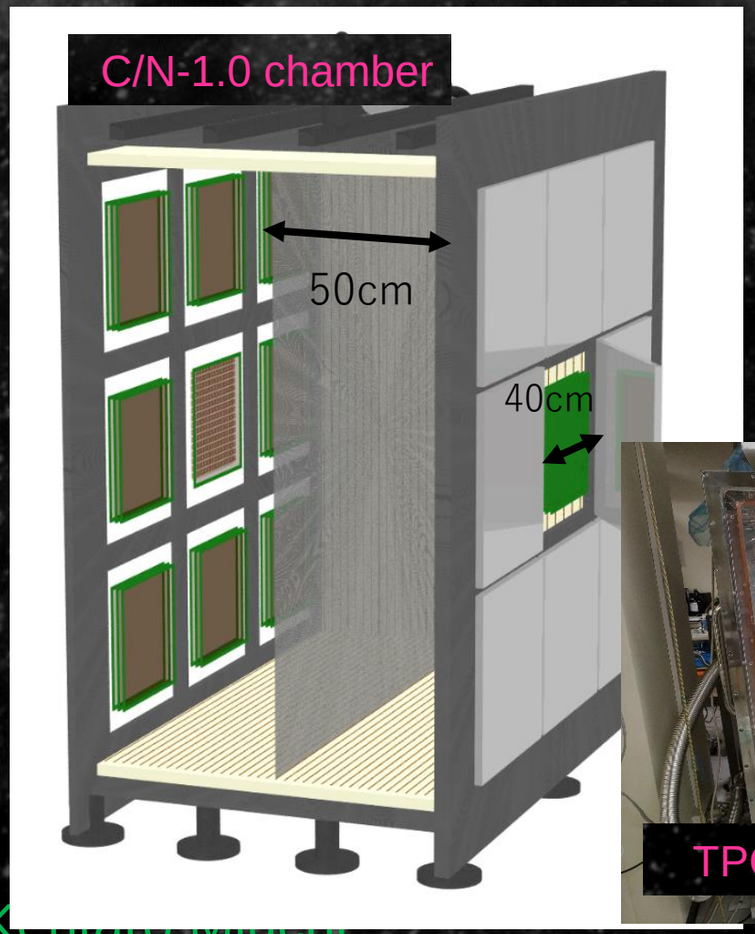
Boulby Underground Lab

- 10m^3 chamber design ongoing
  - low BG vessel design w/ simulation
  - R&D for GEM and wire readout
  - clean space underground at Boulby
  - easy to excavate more

- JAPAN / Kamioka

See T.Ikeda's Talk for NEWAGE

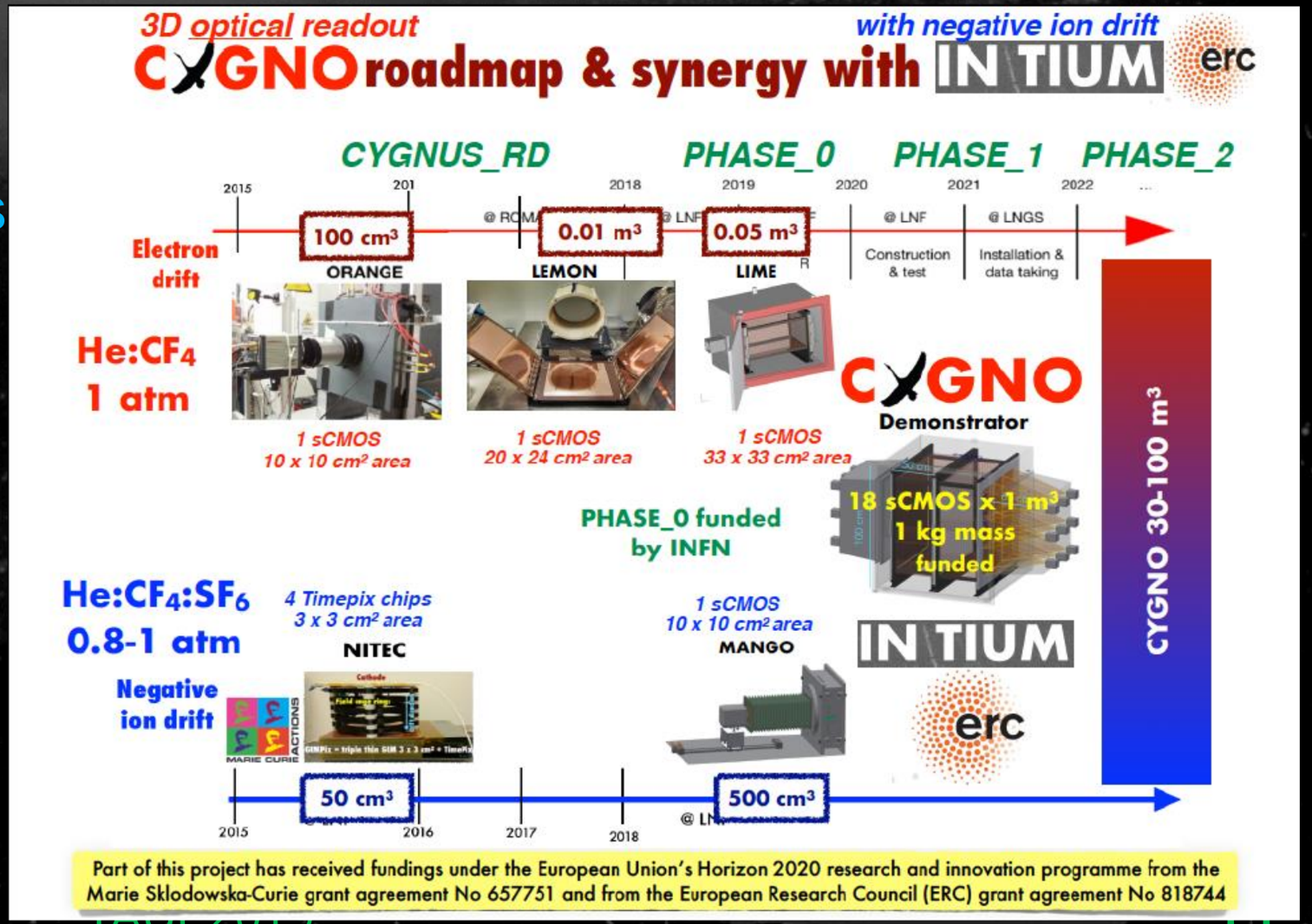
  - pioneered 3d-tracking (direction sensitive) (NEWAGE)
  - C/N-1.0 chamber (18 × 30 × 30 cm^2 detectors)
    - chamber ready
    - TPC cage (w/ resistive sheet), feedthrough being commissioned



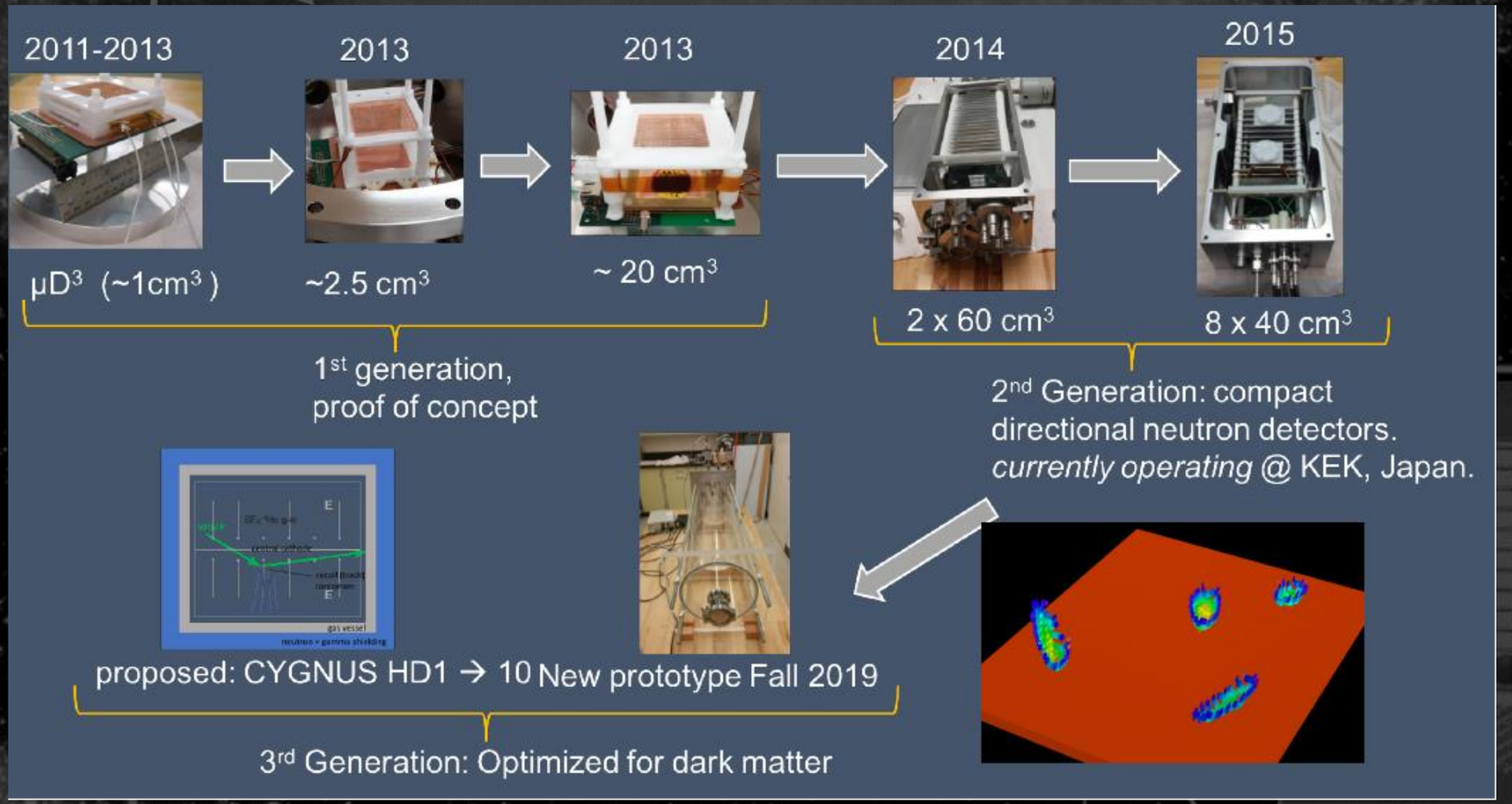
- Negative ion studies
  - 3-D tracking
  - MPGD gas avalanche simulation
- ASICs for negative ion strip readout
  - > 5k channels made
  - chip test started

- Italy / GranSasso (intended)
  - Focusing optical readout
  - Two parallel R&D paths
    - electron drift
    - negative ion drift
  - 1m^3 scale detector funded as demonstrator for 30-50m^3

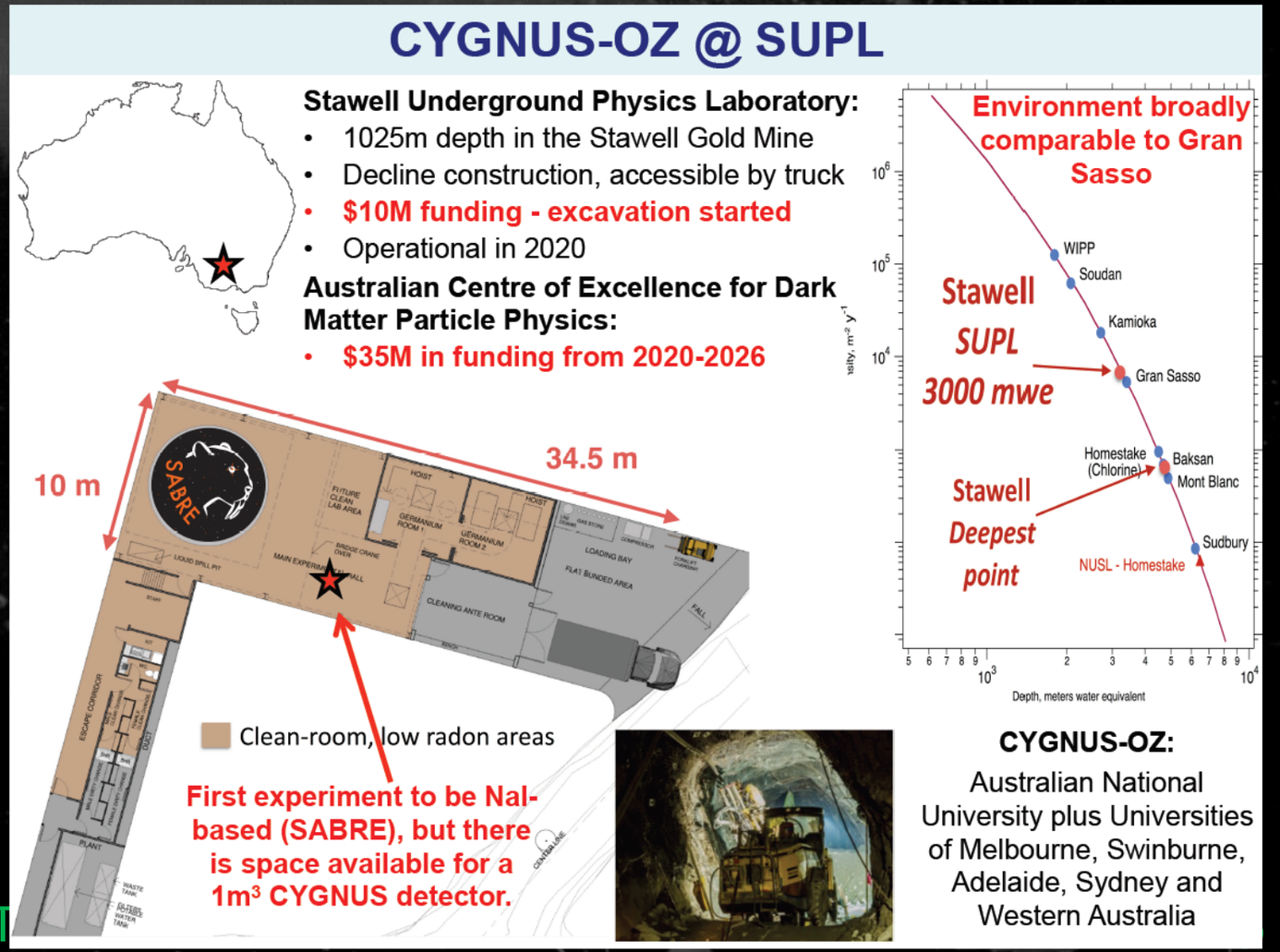
See E.Barracchini's Talk



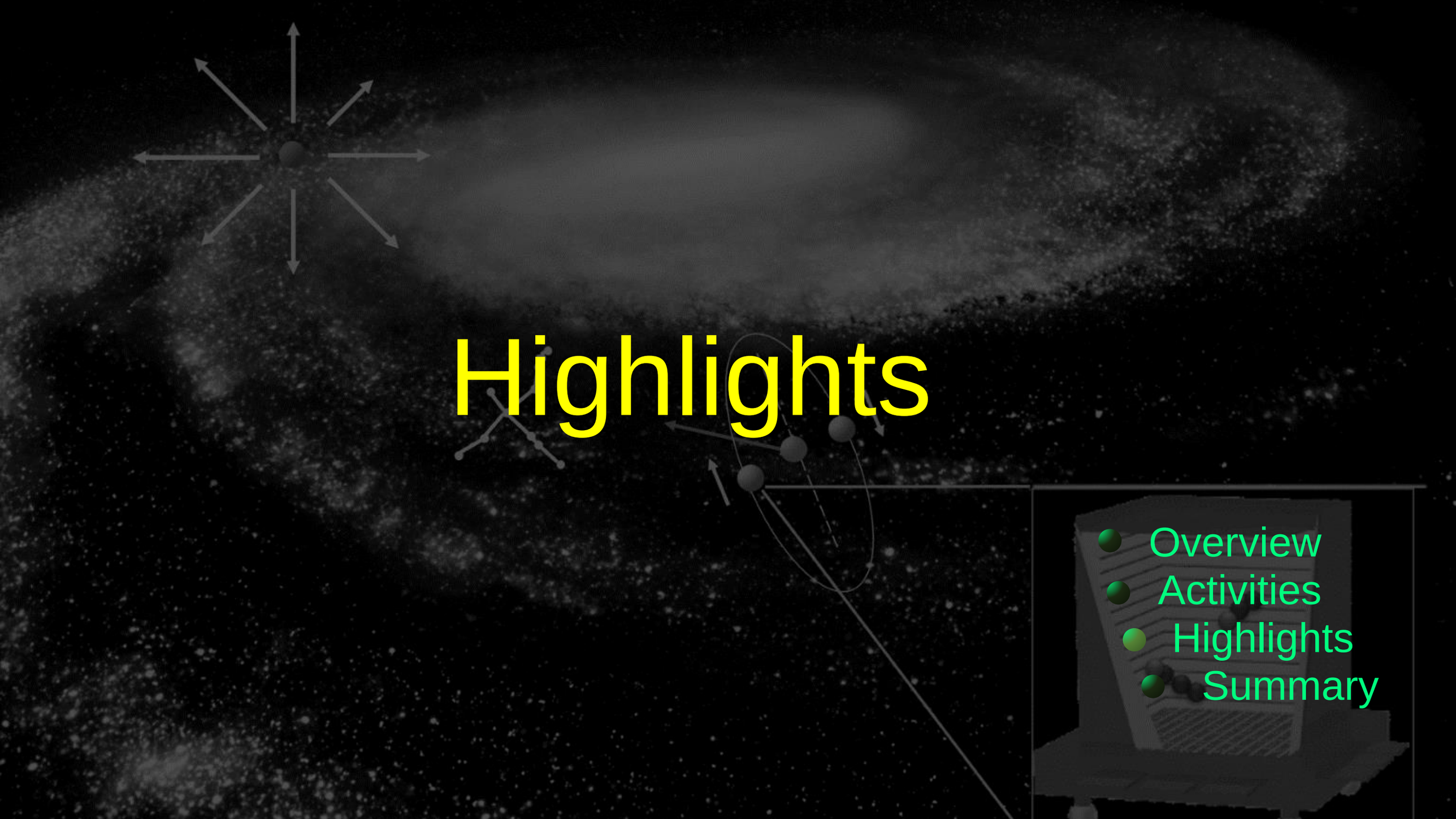
- US / SURF(intended)
  - Focusing on pixel, strip readout (HD)
  - Extensive prototyping completed
  - CYGNUS HD1 1-m^3, demonstrator for 10 m^3, proposed



- Australia / Stawell
  - Excavation of new lab started - operation in 2020
  - Space available in 2020 for 1 m^3 CYGNUS TPC, 10 m^3 in 2025?
  - DM community recently funded - includes R&D for CYGNUS



Highlights



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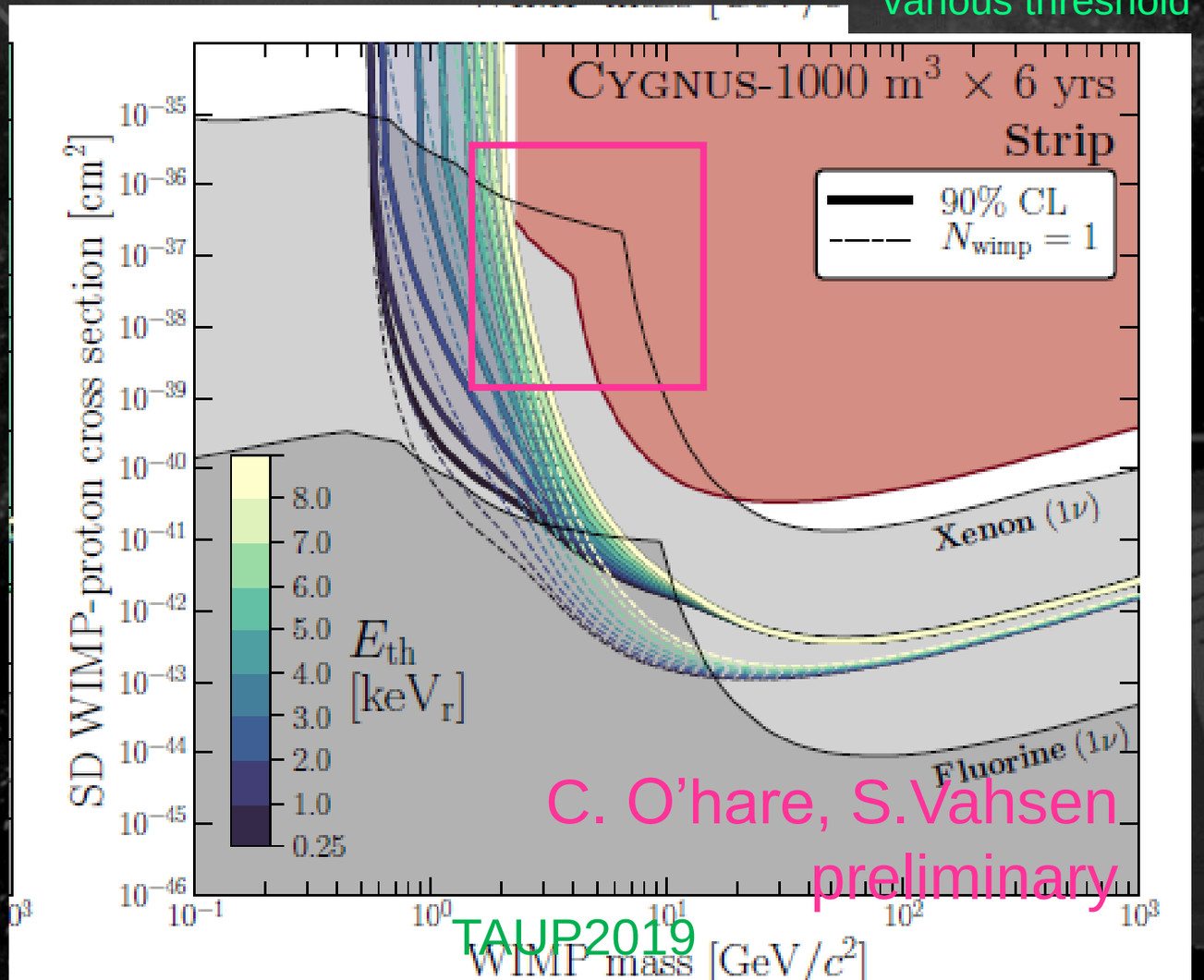
Highlight 1: Feasibility Study

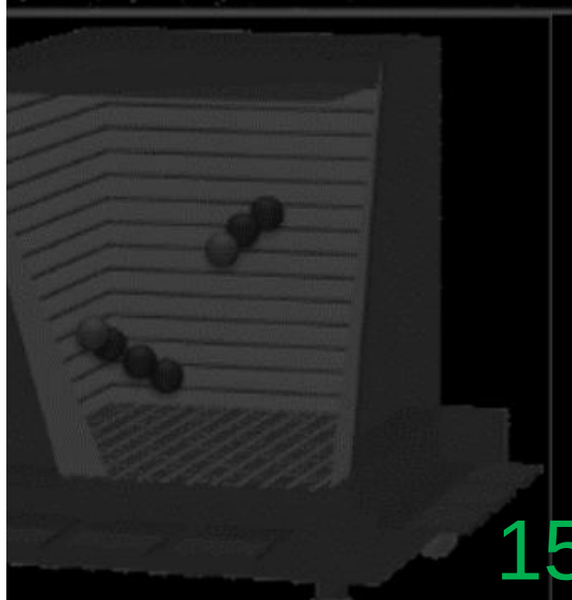
Paper in internal review

- Realistic simulation (strip readout)

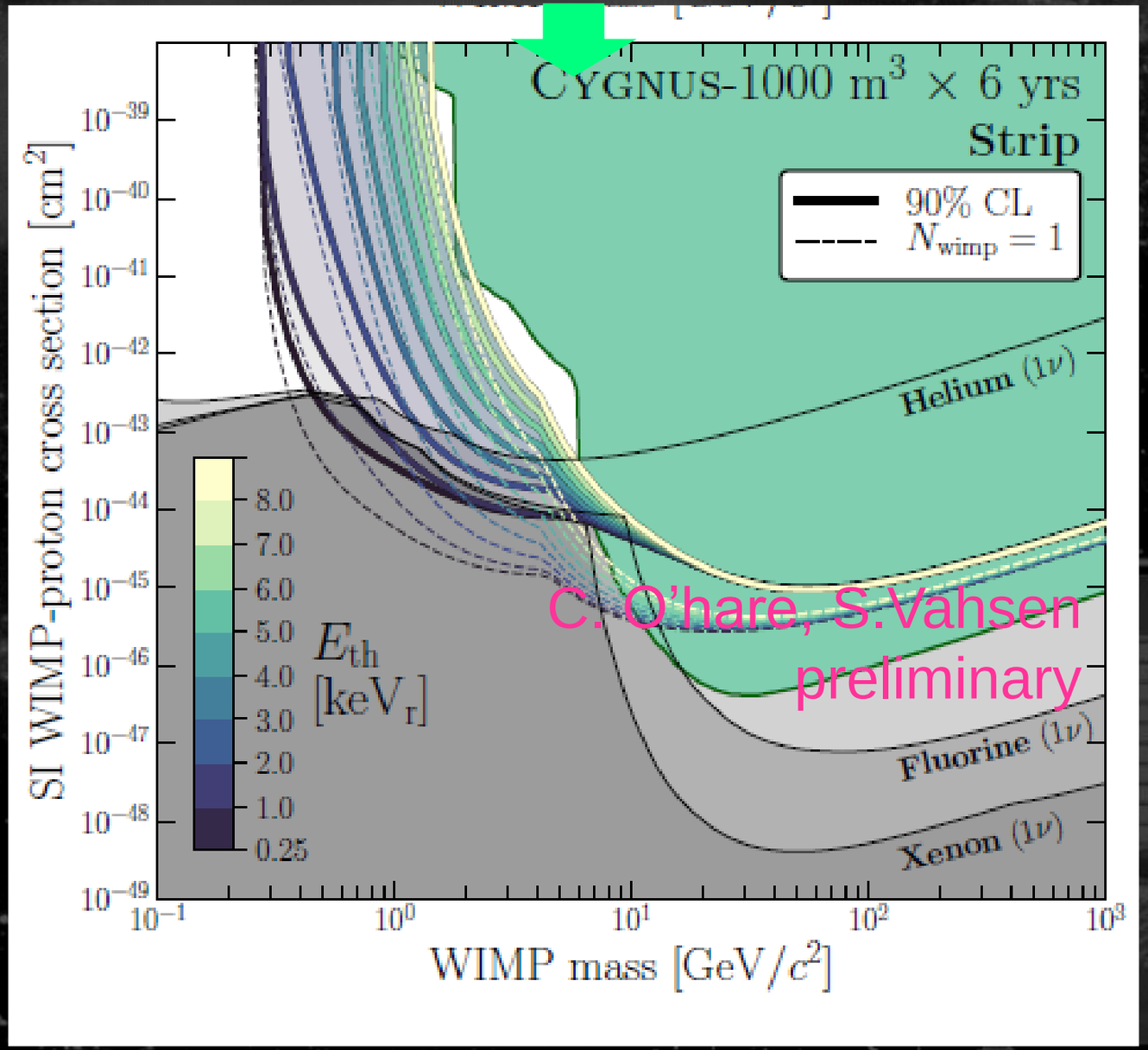
1000m^3 strip readout with various threshold

even 10m^3 detector (3 order magnitude higher than the shown curves) can start exploring Xe neutrino floor



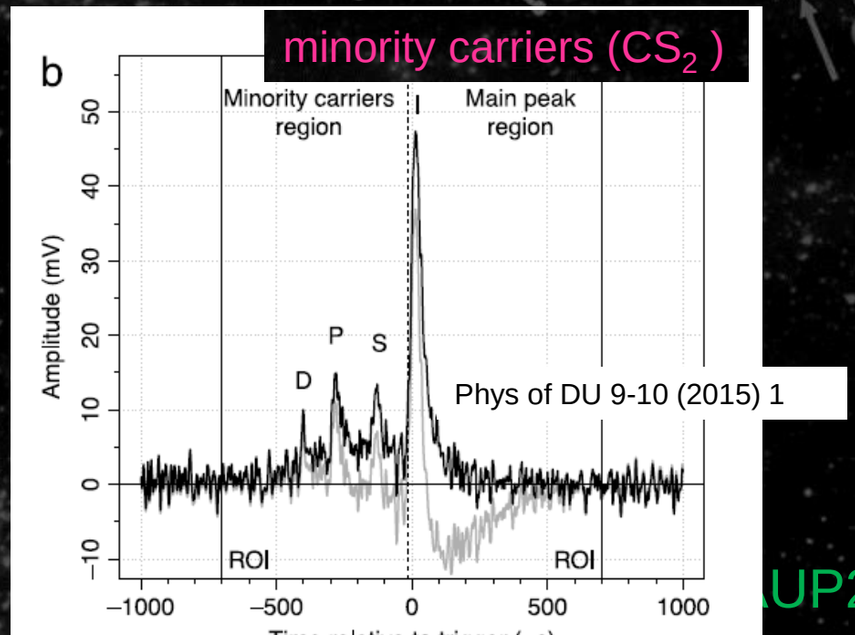


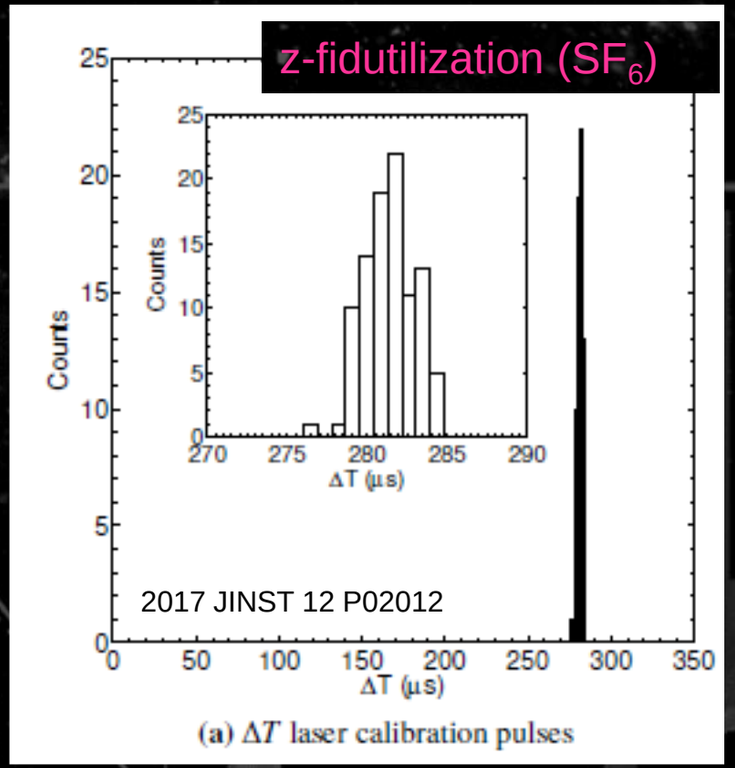
strip readout with
various threshold



Highlight 2: Negative ion TPC Study

- Pioneered by DRIFT group small diffusion
- Minority carrier discovery (CS_2+O_2, Occidental group)
  - use several ion species with different drift velocities
  - ⇒ z fiducialization possible ⇒LOW BG !
- SF_6 discovery (2015, UNM group).
  - z-fiducialization 7.3mm FWHM





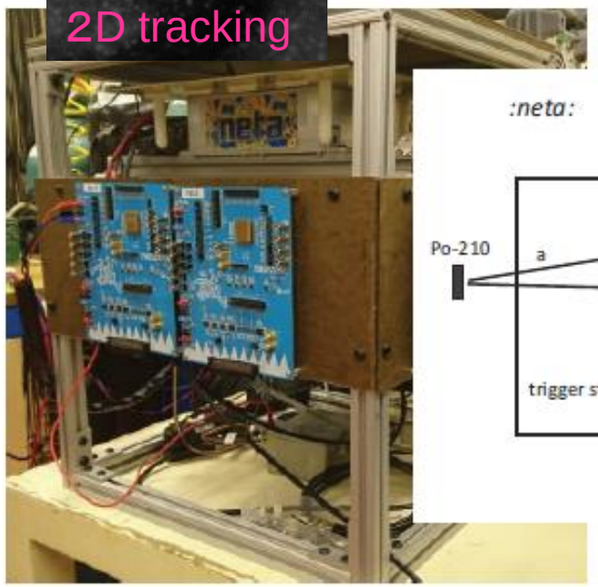
• to be CYGNUS: Trackings

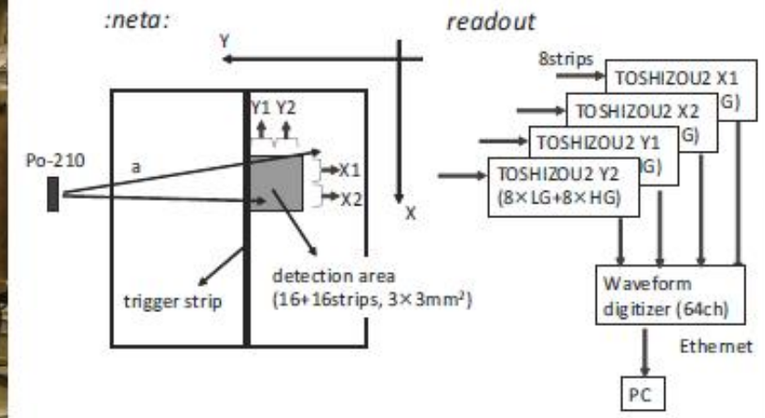
• strip readout + ASICs

for optical redout: See E.Barracchini's Talk

LTARS2016 + Wellesley's micromegas resistive-strip readout

2D tracking





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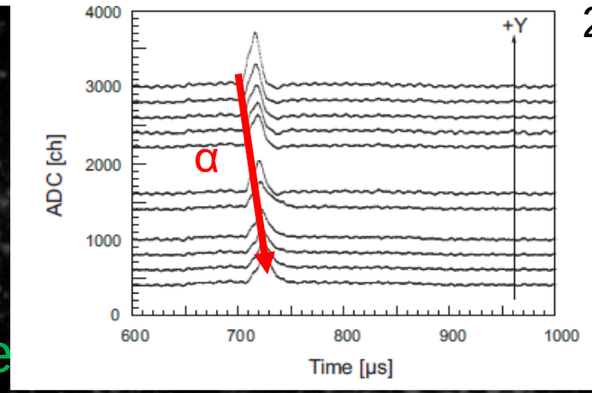
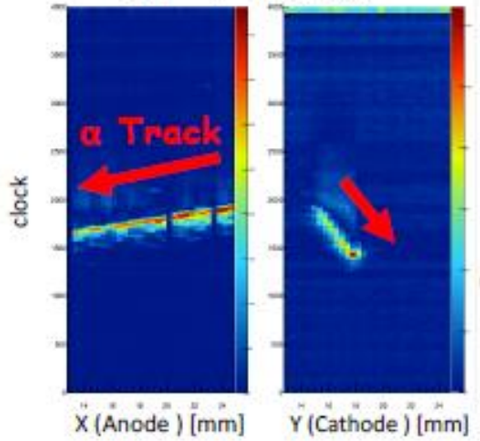
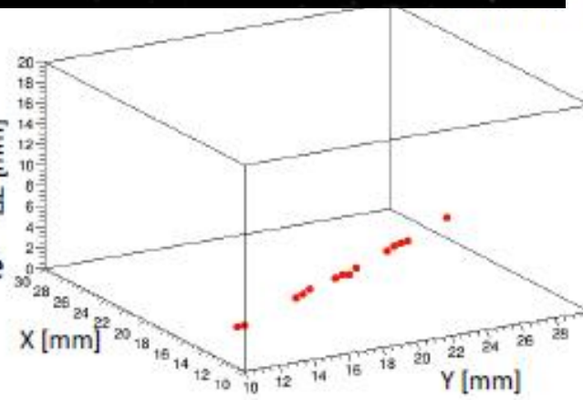


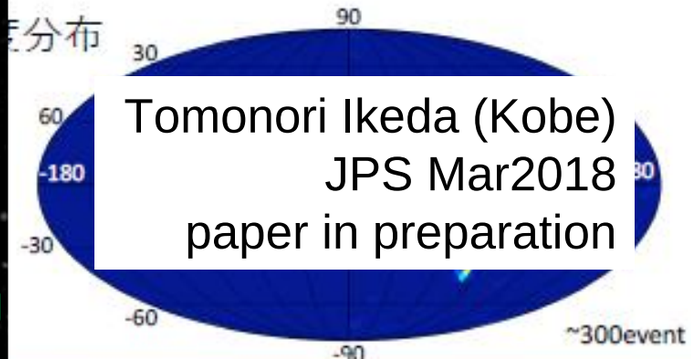
1イベントの波形



coincidence

3D tracking+ fiducialisation





Tomonori Ikeda (Kobe)
JPS Mar2018
paper in preparation

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Ke

TAU

Summary

- CYGNUS: direction sensitive DM direct search
- community, collaboration
- multi-site observatory ($1m^3$ ⇒ larger scale detectors)

- New comers (physics, detectors…) are welcome!