CYGNUS2007

(Cosmology with Nuclear Recoils)

a cooperation on directional R&D

Objective

To discuss the coordination in R&D, design, prototype experiments and theory necessary to define and then construct an eventual definitive large-scale DIRECTIONAL dark matter experiment.

Towards a Large International TPC Experiment
at reasonable international budgets

CYGNUS 2007

First Workshop on Directional Detection of Dark Matter

22-24 July 2007

Boulby Underground Laboratory, UK

ILIAS-N3 - advanced detectors meeting

Roadmaps

DMSAG (US) roadmap

Recommendation 5: Superheated Liquids and Directional Sensitivity

In addition to the above main lines of development,
a) The sub-panel recommends the development of superheated liquid detectors. The program proposed by COUPP appears to be well balanced and has recently been approved by the Fermilab PAC.
b) On the basis of the performance and background levels presented by the DRIFT collaboration, the sub-panel recommends the development of a single prototype detector module with the principal goal of demonstrating track reconstruction and directionality determination.

Priority 2:

The development of superheated liquid detectors and detectors capable of determining WIMP direction. Although these ideas have great promise, they still have significant R&D questions remaining to be answered.

Roadmaps

ASPERA (EU) roadmap

.....clear demonstration of directionality and, if possible, of track sense determination would prepare the final stage demonstration of galactic origin of WIMP signal if observed in « first detection » experiments....

Design studies for cryogenic (CRESST + EDELWEISS EURECA) and liquid noble targets (ArDM, WARP) + (XENON, ELIXIR) experiments 2008-2011

Dedicated R&D on directionality

Recommend significant participation (Lisbon group, others…) in COUPP

Unification of similar technique/same target experiments recommended ?

Overall, 20-30 M€ first stage program over next 3-4 years

In ≈ 2011, decision on 2 (if possible 3) ton-scale experiments with total budget ≈ 100 M€

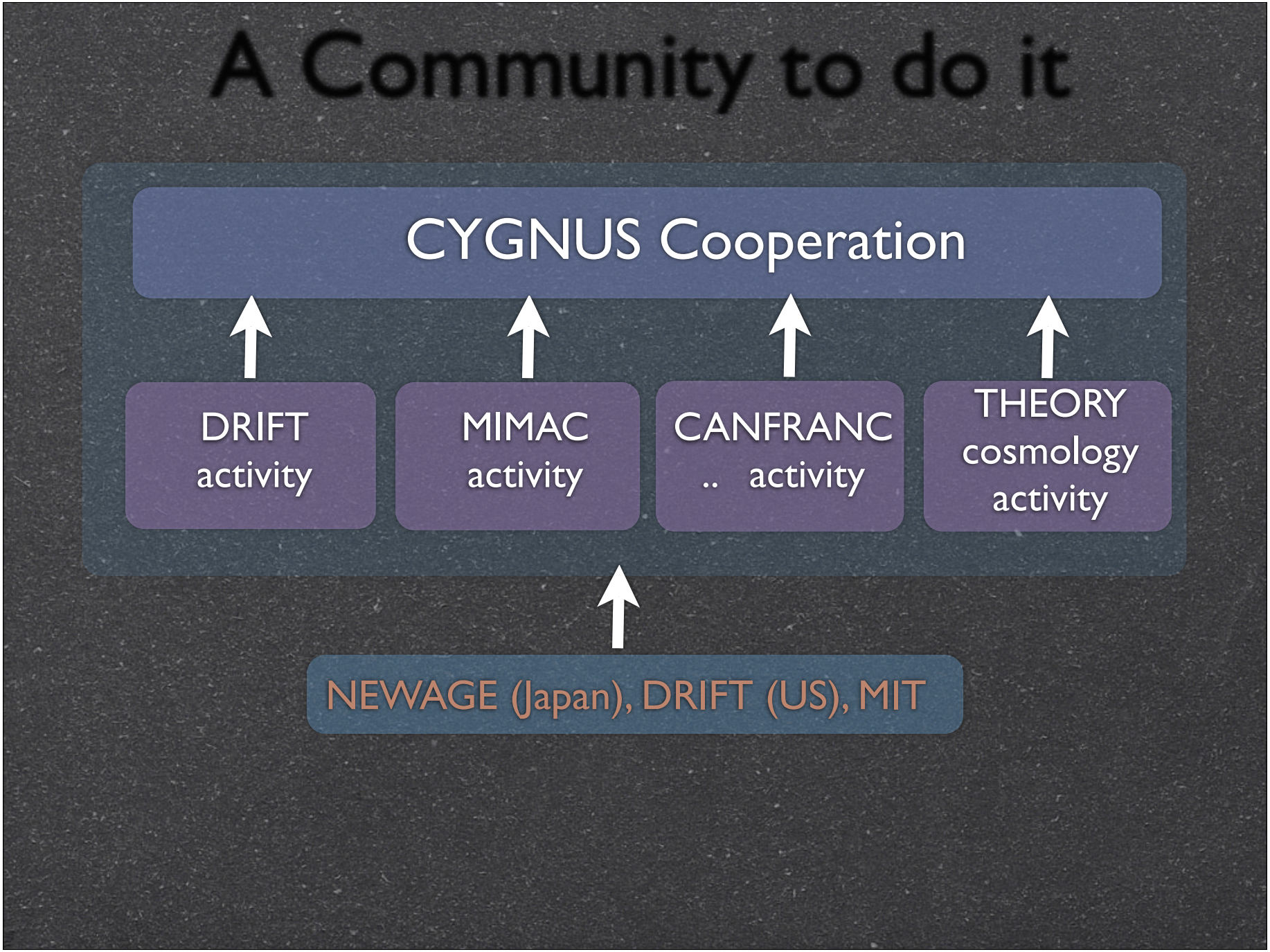
Question

Is a directional signal NEEDED to identify WIMPs in the galaxy?

i.e. that non-directional technologies will in fact not be able to determine that a signal is WIMPs

discuss

A Community to do it



A Community to do it - this LOI

Organisation	Country	Short description of role
University of Edinburgh	UK	DRIFT - background simulations, operations
UC, London	UK	TPC - detectors, vessels, gas, large scale designs
University of Nottingham	UK	Directional cosmology theory
University of Sheffield	UK	DRIFT - design, daq, construction, analysis, operation
TU - Darmstadt	Germany	DRIFT - kk-axion search, electronics, analysis
NCSR, Demokritos	Greece	TPC micro-readout, electronics and analysis
University of Ioannina	Greece	Theory and simulations
University of Patras	Greece	kk- axion search
Saclay	France	MIMAC - Development of micromegas, TPC design
CNRS/IN2P3/LPSC	France	MIMAC - Electronics, readout, spin-dependent target
Institute Laue Langevin	France	MIMAC -Gas treatment and control, scintillation readout.
University of Granada	Spain	Spin dependent interaction (SUSY models)
University of Zaragoza Niels Bohr Institute	Spain Denmark	TPC - detector design, background, gas tests Directional cosmology theory (TBC)
MIT	*US*	*DRIFT - electronics, daq, simulations*
University of Boston	*US*	*DRIFT - electronics*
University of New Mexico	*US*	*DRIFT - GEM readout, analysis, operations*
Occidental College, LA	*US*	*DRIFT - construction, analysis, scintillation readout*
[Kyoto University	*Japan*	*NEWAGE - cooperation]*

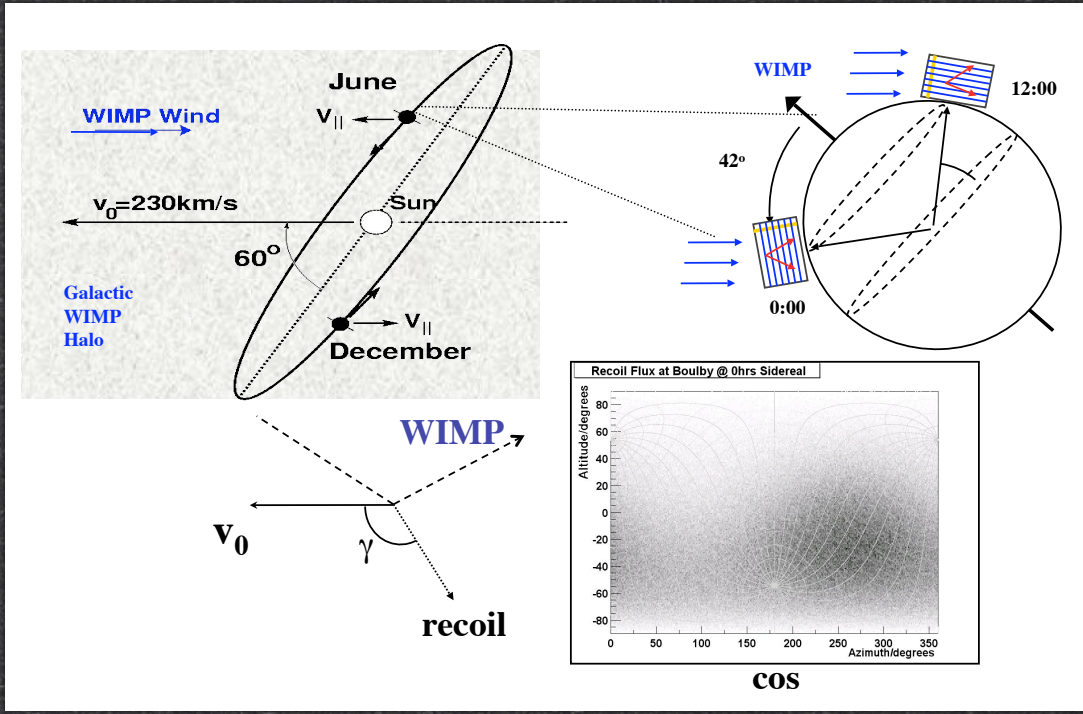
Agencies: UK (STFC), Germany (DFG), France (CNRS,CEA, Programme National d'Astroparticules, ANR), Spain and Greece (national and local, EU), US (NSF)

14 institutes also signed for the ILIAS-NEXT TPC LOI

Motivation

The **best signal** identification

- Determine Galactic origin of WIMPs
- Reject neutron background
- even reject neutrino background!



News 2007: recoils from solar neutrino coherent scattering are a limiting background for 1 tonne at low threshold

J. Monroe and P. Fisher
http://arxiv.org/pdf/0706.3019

Target	T>0 keV	T>2 keV	T>5 keV	T>10 keV
^{12}C	240.4	195.7	106.3	36.8
^{19}F	382.1	207.0	90.3	13.7
^{40}Ar	801.3	233.7	21.8	<1.0
^{76}Ge	1522.0	115.6	<1.0	<1.0
^{132}Xe	2642.9	15.5	<1.0	<1.0

What you get

- Event by event detections with DIRECTION
- Full particle identification (gamma, beta, alpha, radon progeny) i.e. zero background
- identification of nuclear recoils from neutrons, solar neutrino coherent scattering, radon progenies
- Correlation of WIMP induced recoils with galactic motion - halo studies
- A daily (sidereal) modulation signal impossible to mimic with terrestrial background
- Multiple target nuclei - spin dependent and spin independent

Can you get sufficient 3D direction sensitivity at low threshold and low background in a multi-tonne design at reasonable cost?

12 R&D Challenges

(1) Demonstration of 3D reconstruction at low threshold
(2) Demonstration of low background underground
(3) Demonstration of head-tail discrimination
(4) Understanding of quench factors and calibrations
(5) Selection of electronics and readout technology
(6) Optimisation of gas mixtures and pressures
(7) Demonstration of SD sensitivity with high pressure
(8) Demonstration of detector mechanical engineering
(9) Optimisation of veto shielding design
(10) Determination of underground infrastructure and safety
(11) Determination of relevant SUSY and cosmology
(12) Demonstration of capability for axion sensitivity

12 R&D Challenges

- Can we agree priorities?
  - to improve efficiency, work together better
- A possible joint "white paper" - a lobby paper

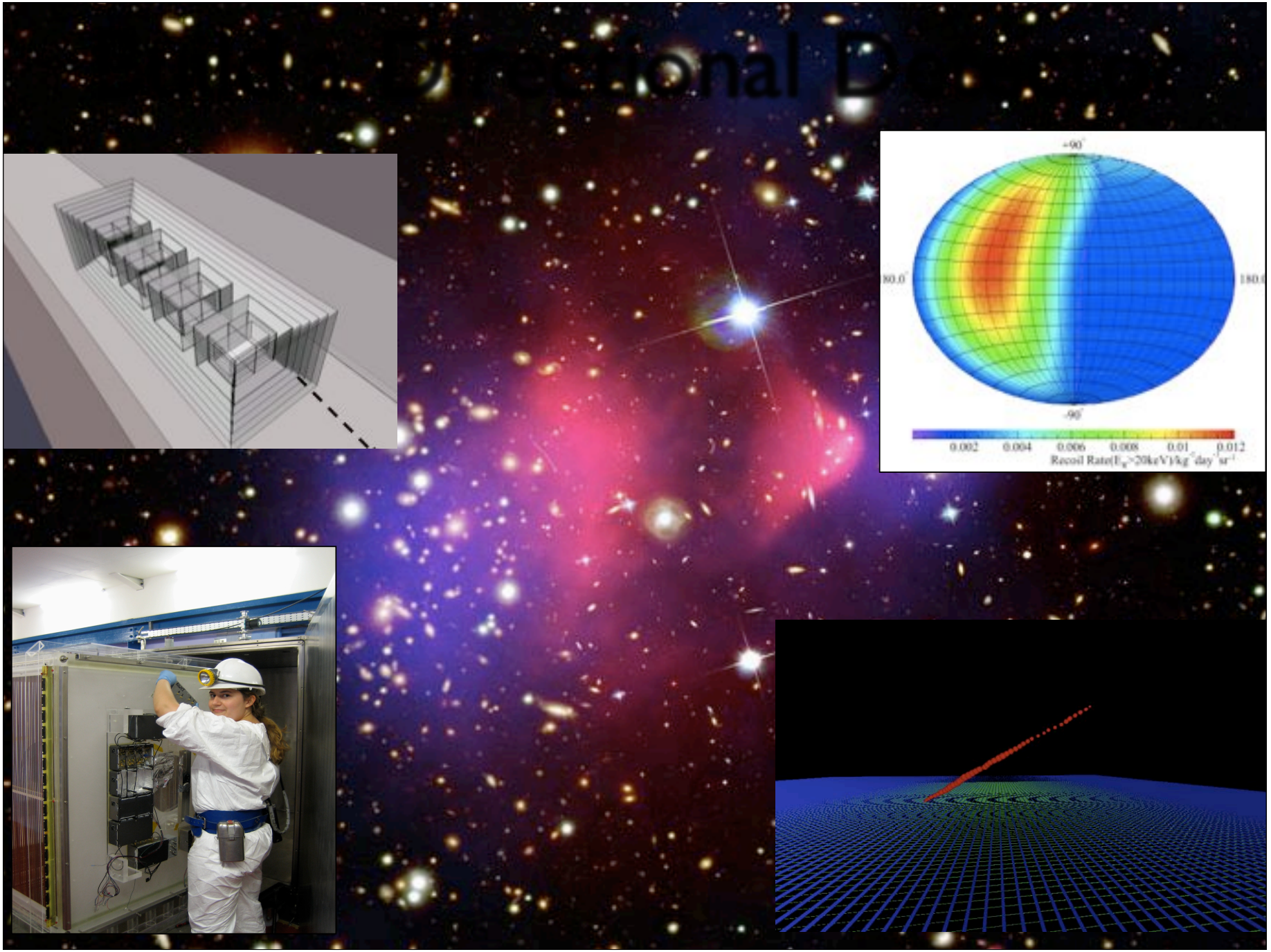
  This was done for proton decay recently...
- A first conceptual design

Housekeeping

- Talk times are nominal - leave time for discussion
- Sunday lunch: here, please select from menu
  Sunday dinner: White Horse and Griffin Inn, Whitby
  7.30 pm sign sheet for numbers
  Monday lunch: Ellerby Inn - see menu
  Tuesday lunch: Ellerby Inn - see menu
  Underground visit - Monday evening - sign up

wireless internet available

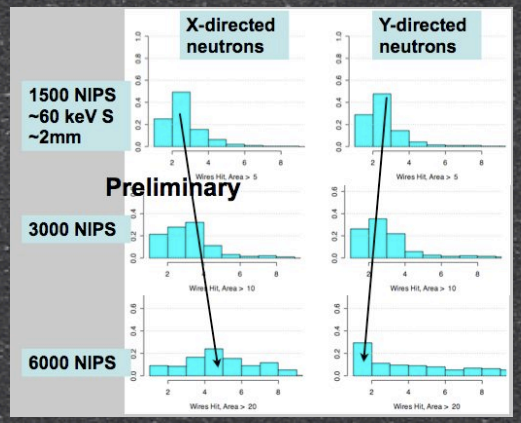
`wwwcache.rl.ac.uk 8080`


-90°
180.0°
0.002
0.004
0.006
0.008
0.01
0.012
Recoil Rate(E_R>20keV)/kg/day/sr

Progress so far - what is missing?

(1) 1m³ basic technologies work safely underground

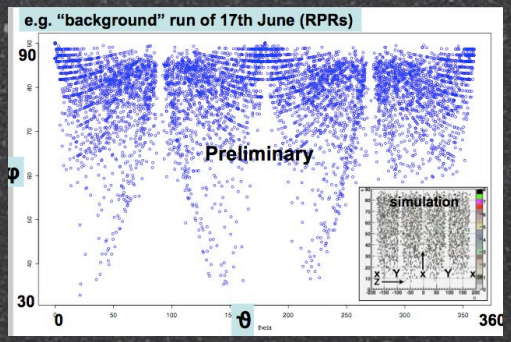
(a) 1-2D directionality



(b) 3D track reconstruction

(d) Background: ~10 cts/day/m³

(c) ϑ,ϕ direction sky map



Data papers out

Burgos et al. arXiv:0707.1488 – first DII data

Burgos et al. arxiv:0707.1758 – DII alpha analysis

issues now:

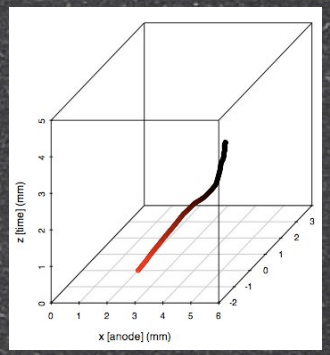
- show low threshold 3D sky maps
- remove radon progeny events

→ DRIFT IIc,d

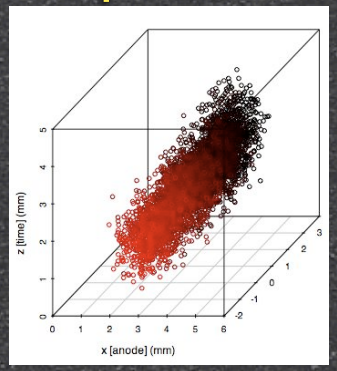
Progress so far - what is missing?

(2) end-end detector and gas simulations good

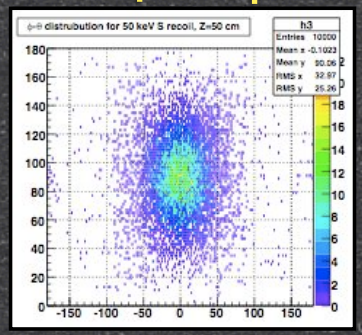
input S track



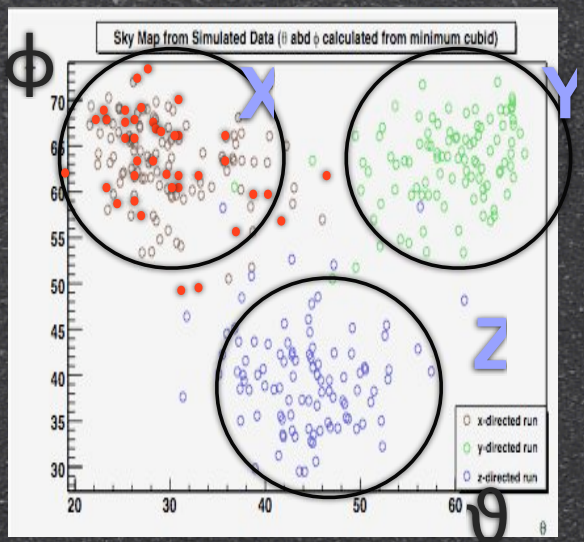
transport/diffsion



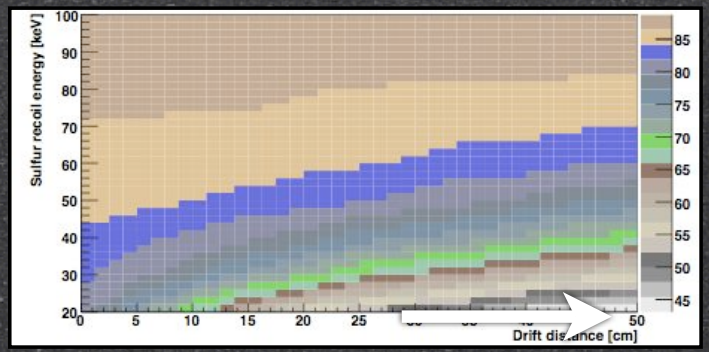
ϑ,ϕ maps



Simulated x,y,z directed runs in full DII model



angular resolution response matrix for DRIFT II



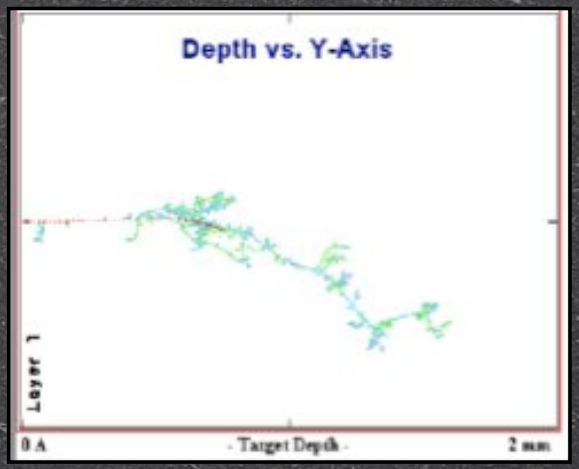
dedicated R&D and analysis

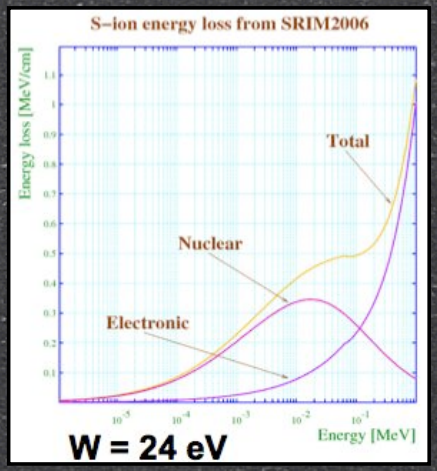
issues now:

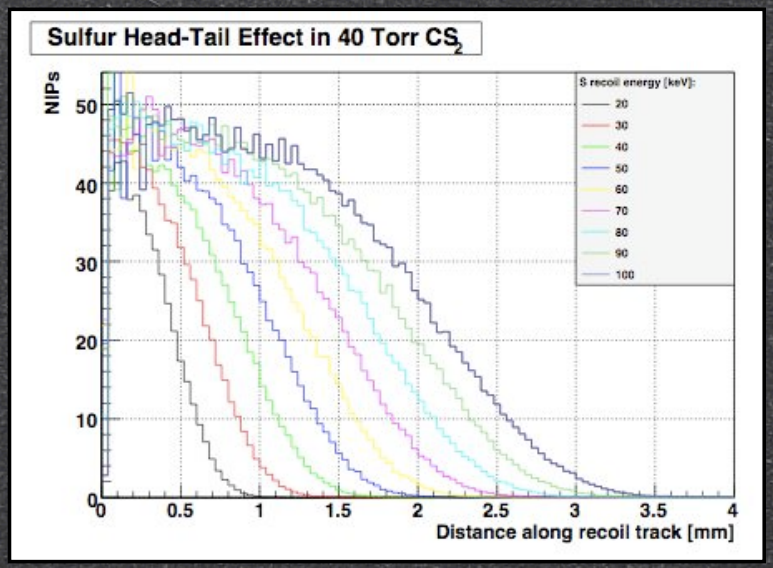
- demonstrate angular response matrix at low energy
- simulate tonne-scale

Progress so far - what is missing?

(3) head-tail discrimination looks feasible!







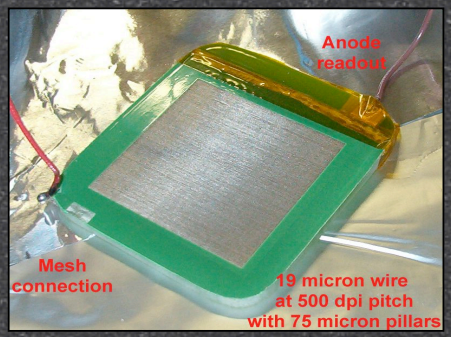
issues now:

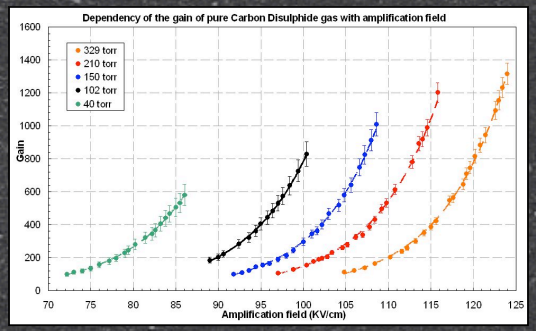
- show head-tail experimentally
- simulate tonne-scale

→ dedicated R&D and analysis

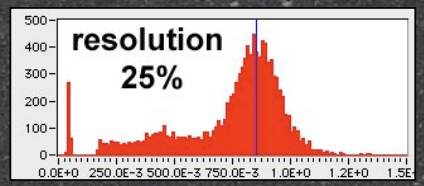
Progress so far - what is missing?

(4) readout technology for scale-up





e.g. low cost bulk m^2 micromegas (and GEM) works with CS_2



readout papers out Lightfoot et al. Astrop. Phys. 27 (2007) 490

it gets cheaper....

now 1 m^3 with full shielding ~ €80K

	DI	DIIa	DIIb
Cost	$234k	$139k	$100k
Design	1 year	2 months	1 month
Construction	36 person-months	26 person-months	14 person-months
Installation	6 months	1 month	5 days!

→ Engineering and readout R&D

Progress so far - what is missing?

(5) requirements for a site

At 40 Torr a 1 tonne target would occupy about 1/30th LNGS

At 160 Torr (an achievable pressure increase) a 1 tonne target would for instance be ~25% smaller than MINOS

issues now:

- where?
- what design?

ILIAS-NEXT, LAGUNA, new u/g labs

Underground space is, in principle, not a major cost factor

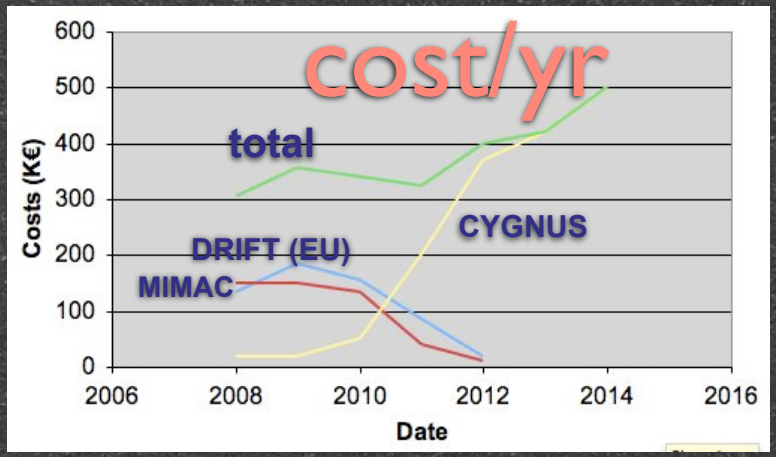
Next steps are clear

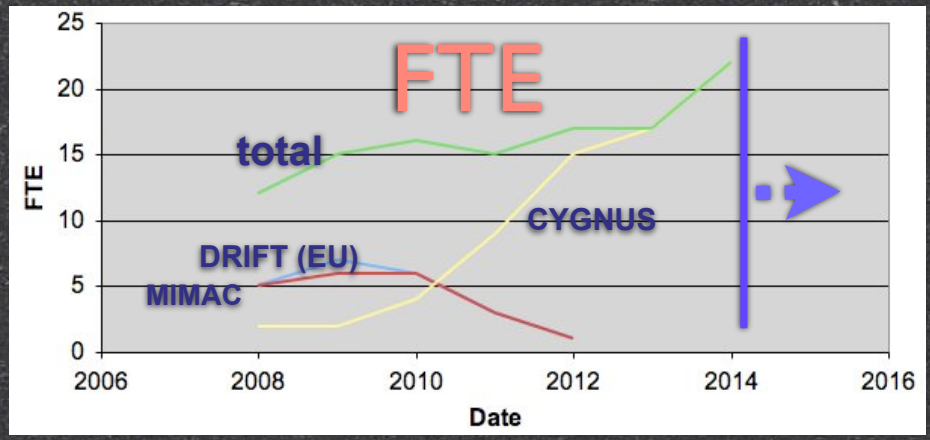
A coordinated directional R&D effort

Major Milestone Activity: Please colour code the relevant years for CDR, TDR and Decision for Construction

	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Conceptual design study (CDR)											
Technical design study (TDR)											
Critical review & Decision for construction											

- 12 major R&D topics
  (priority 3D, low background, low threshold scale-up concepts)
- 4 year initial timescale to Design Review, prototype





- NB: R&D resources are indicative; >2014 not assessed yet

Indicative DRIFT schedule