columnar recombination and directional nucleus reconstruction

D. Gonzalez Diaz (IGFAE),

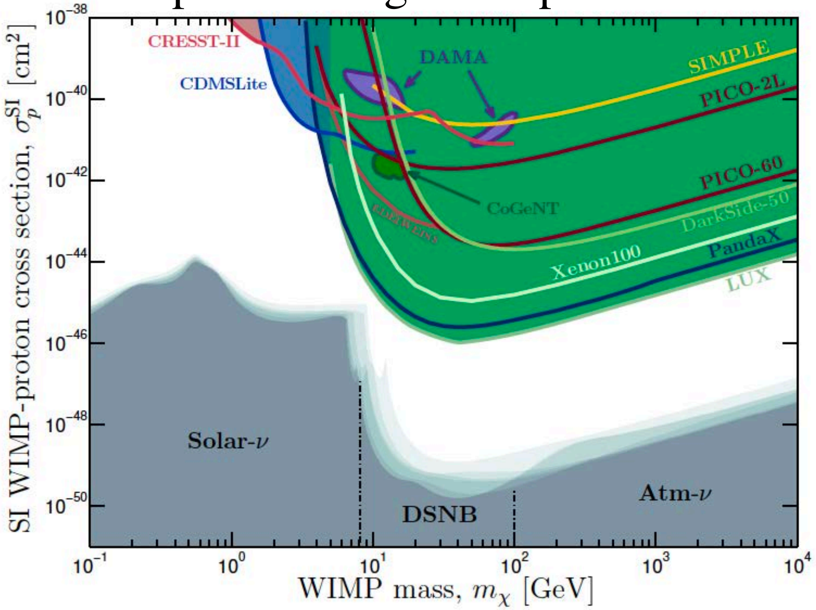
presenting work from **Manuel Fontaíña (graduate student)**, David Gonzalez (technical assistant), Damián Garcia (PhD student) and Marwan Ajoor (master student)

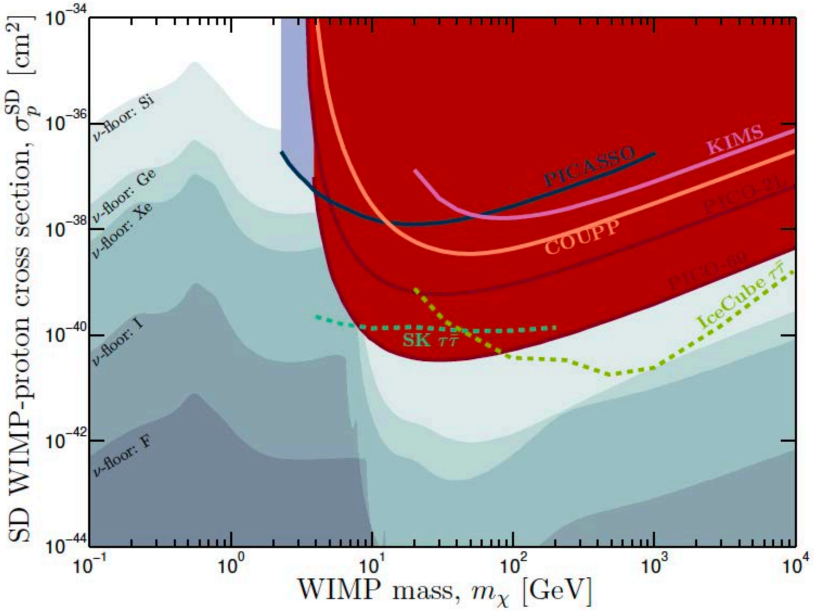
6-Feb-2018

‘top-down approach’ to a directional signal

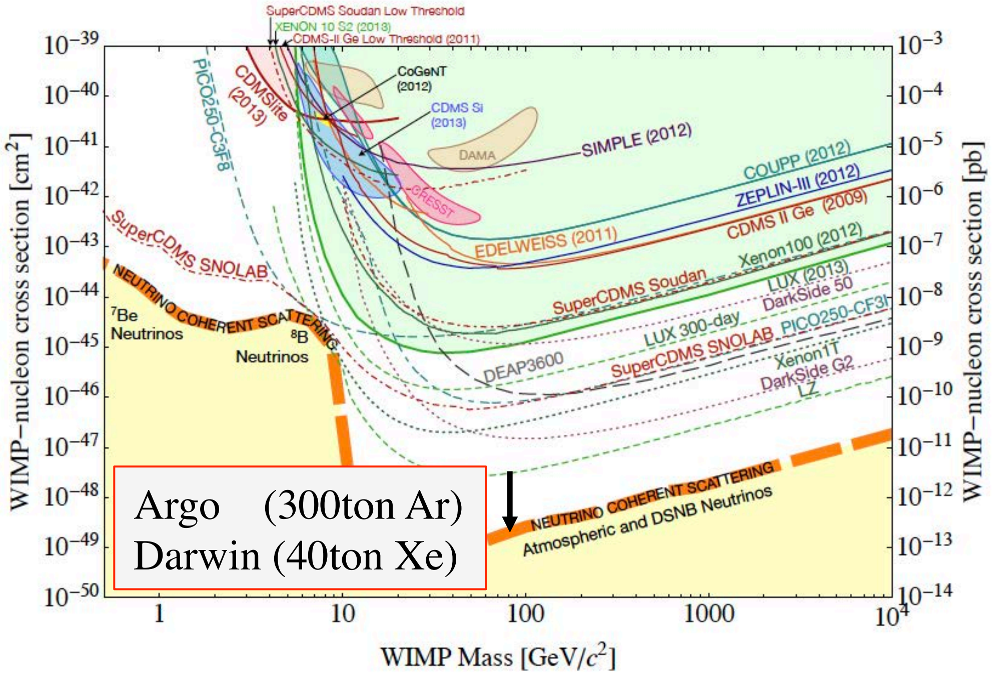
(aka: if all you have is a hammer, everything looks like a nail)

present range of experiments





+ future range of experiments

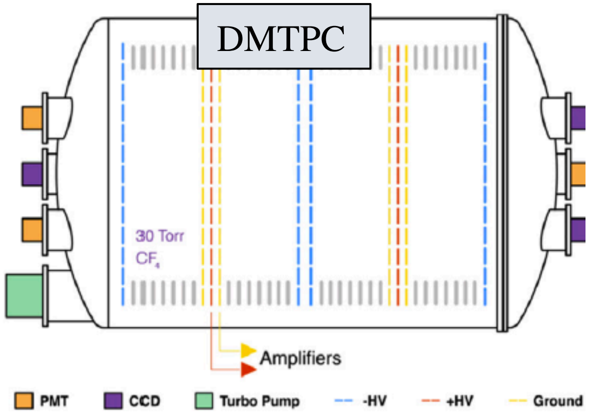


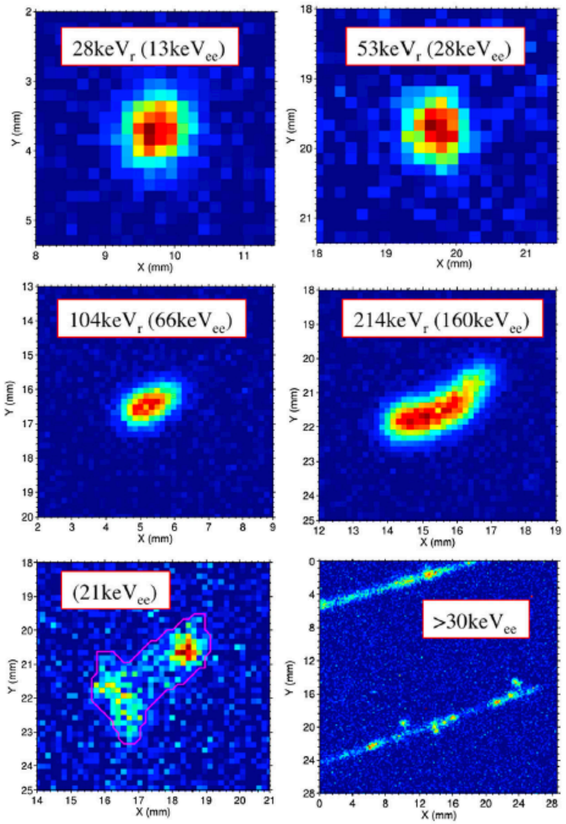
from C. O’Hare

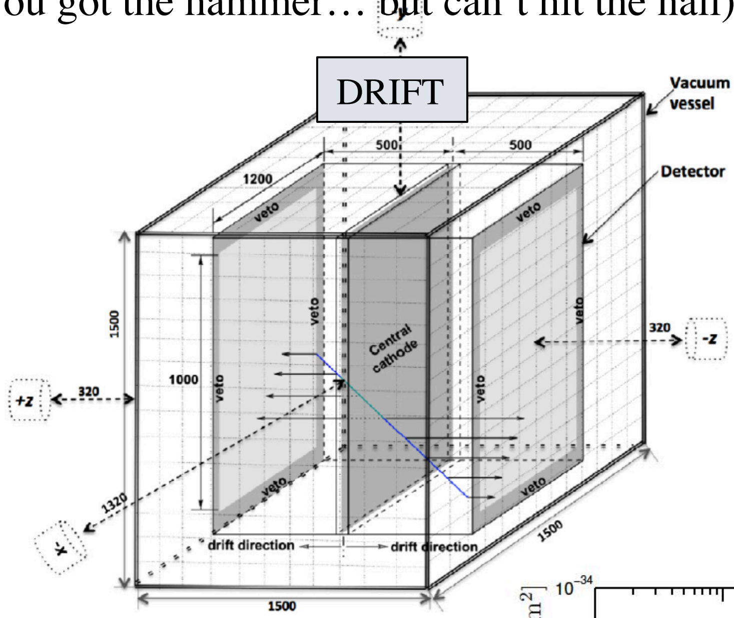
‘bottom-up approach’ to a directional signal

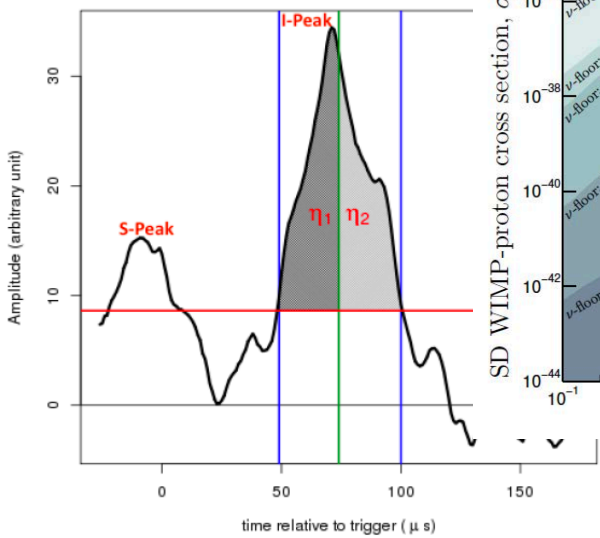
(aka: you got the hammer… but can’t hit the nail)

~1m^3, 50mbar
~200g!



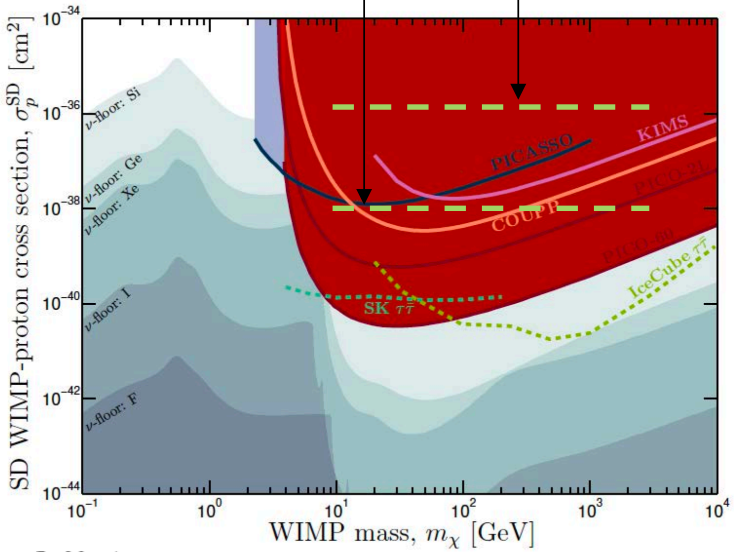




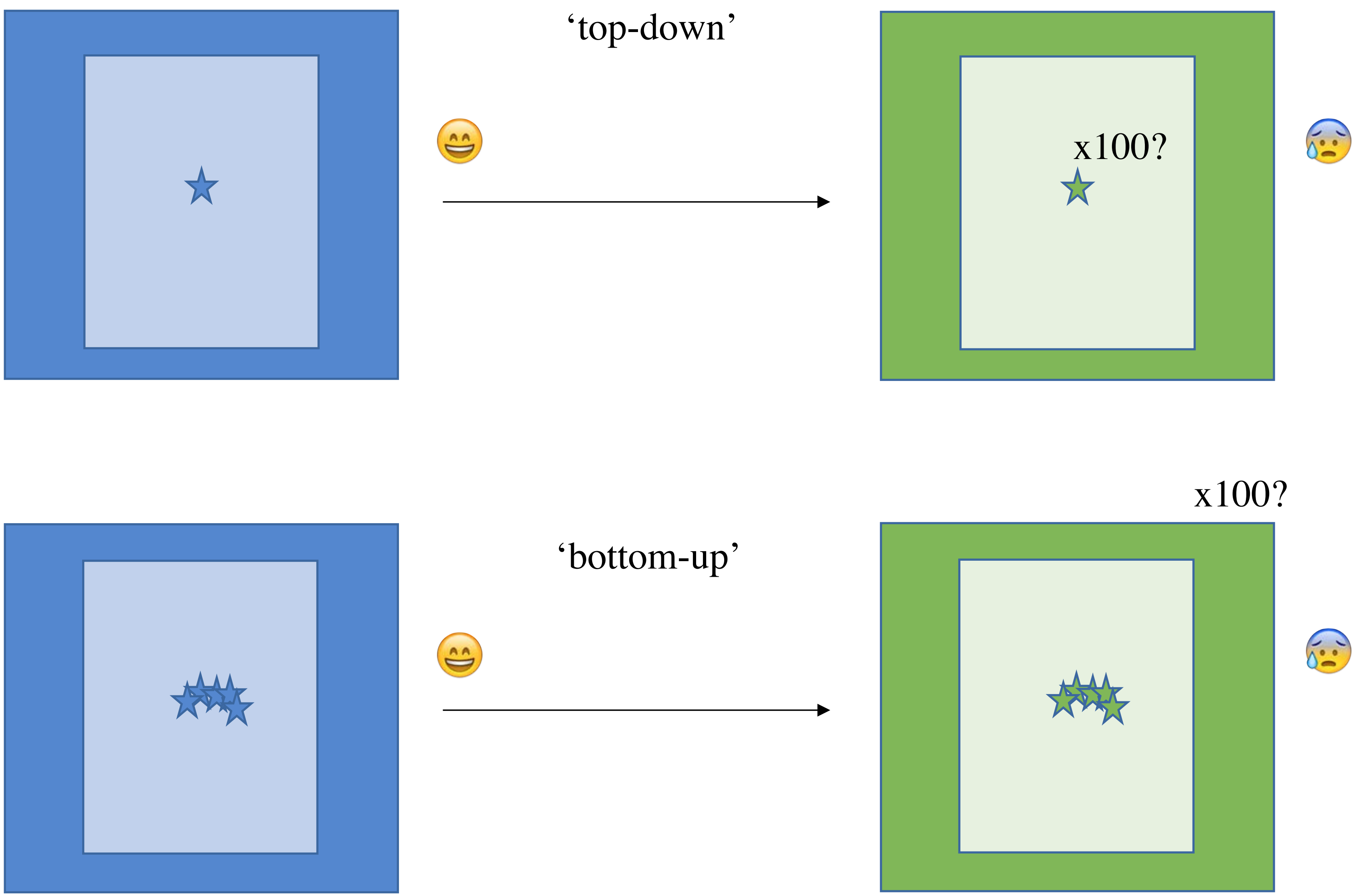


DMTPC projection (5y)

DRIFT (~2months)

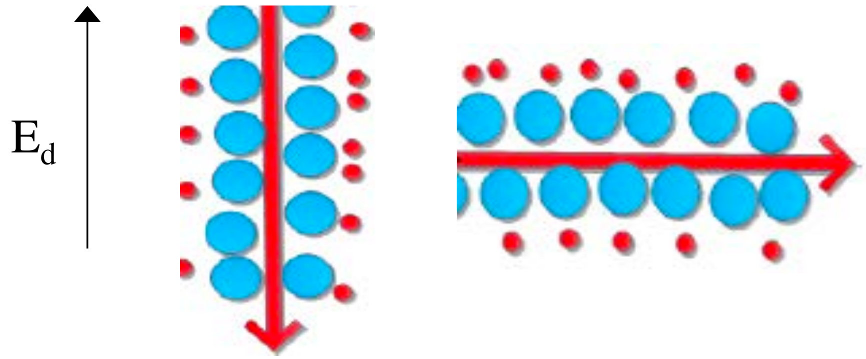


brief summary of the main approaches to the directional problem



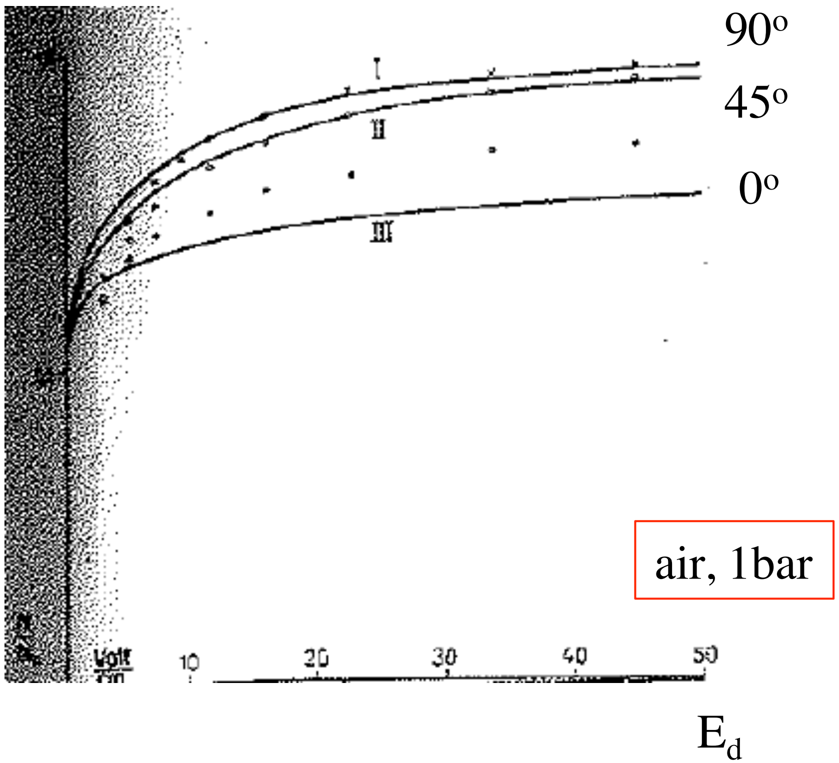
columnar recombination

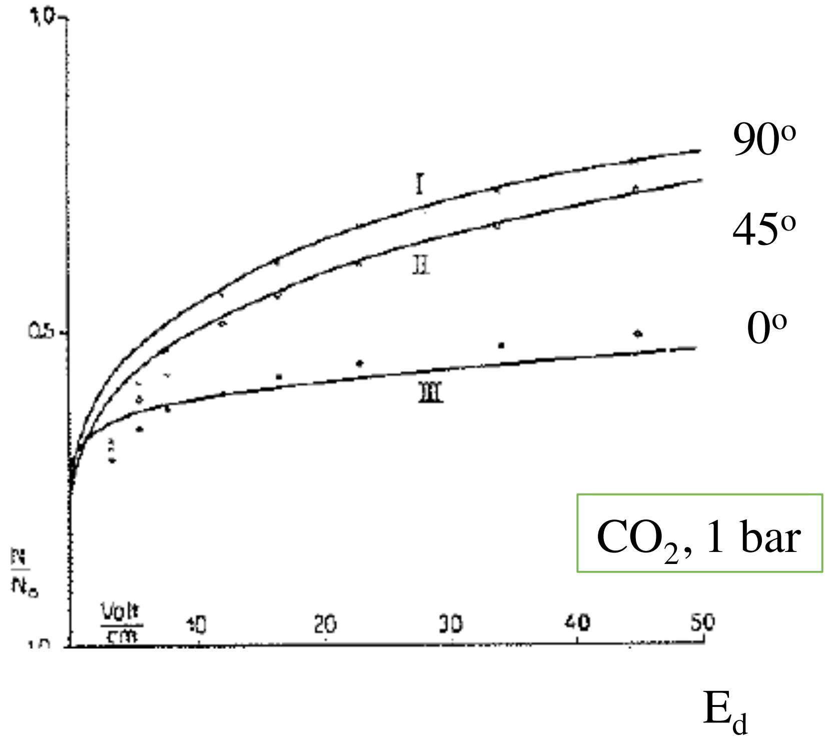
(rescued from oblivion by D. Nygren, Journal of Physics: Conference Series 460 (2013) 012006)



G. Jaffé, Ann. Phys. 42 (**1912**) 303

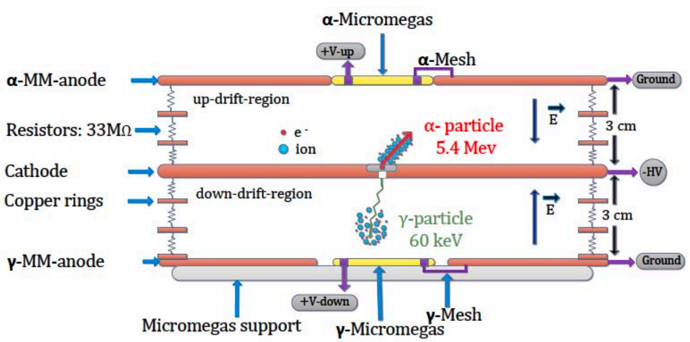
α tracks

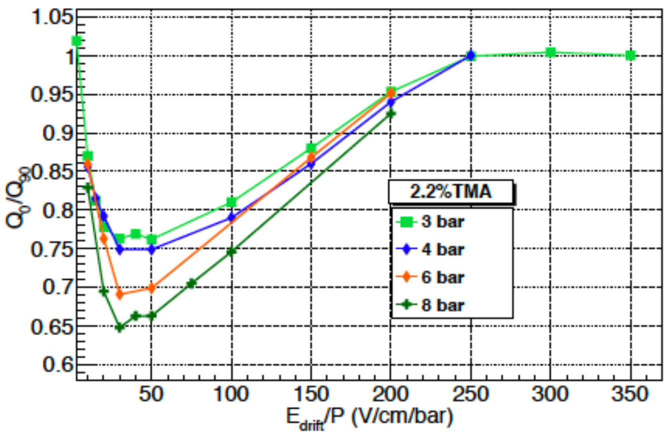




columnar recombination (*some* modern results for **α** tracks in gas)

charge mode for Xe/TMA (*direct method*)

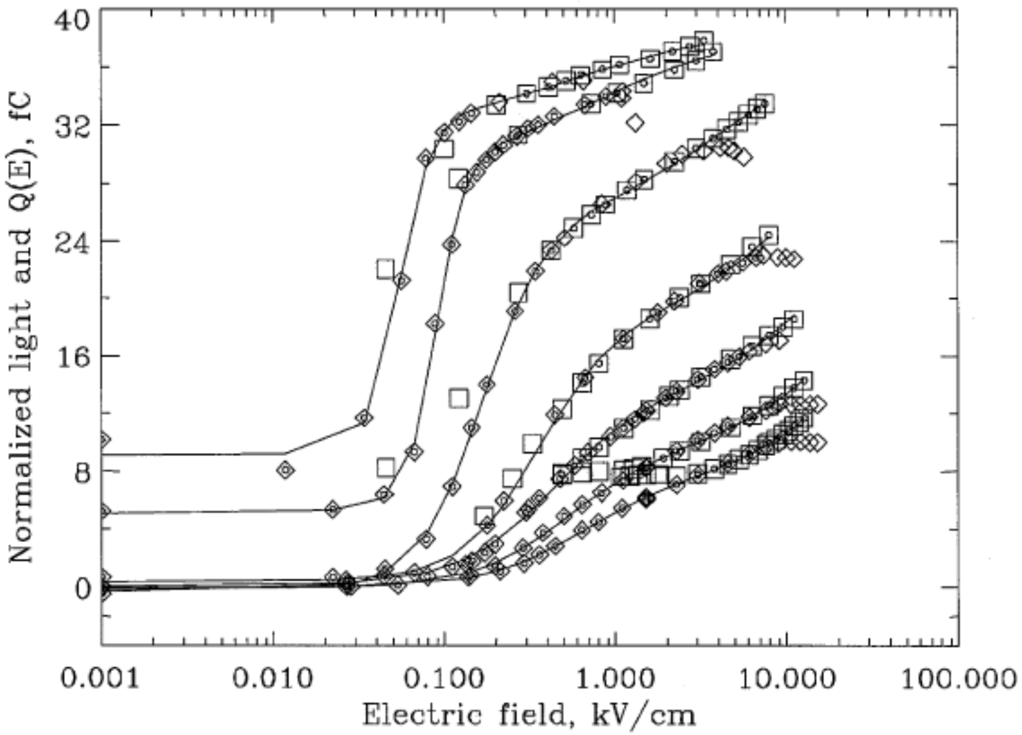




by D. C. Herrera

charge and light mode for xenon (*indirect method*)

Ramsey, Bolotnikov



- **charge** yield (diamonds)
- model-dependent charge-yield, from **light** (squares).

gas purity controlled!

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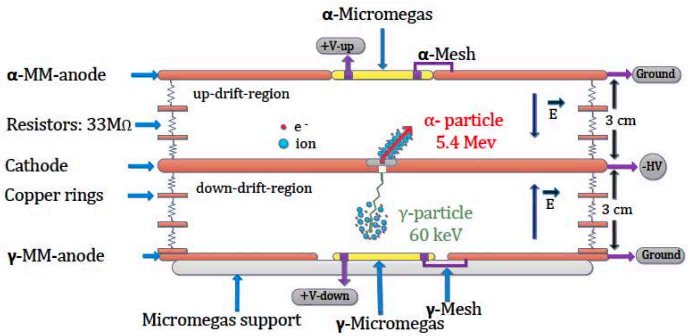

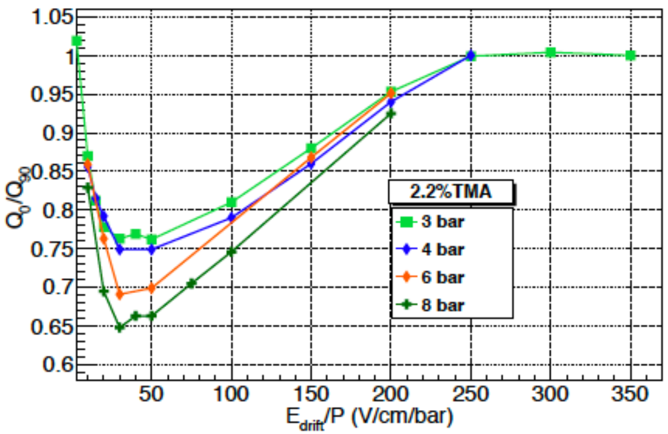

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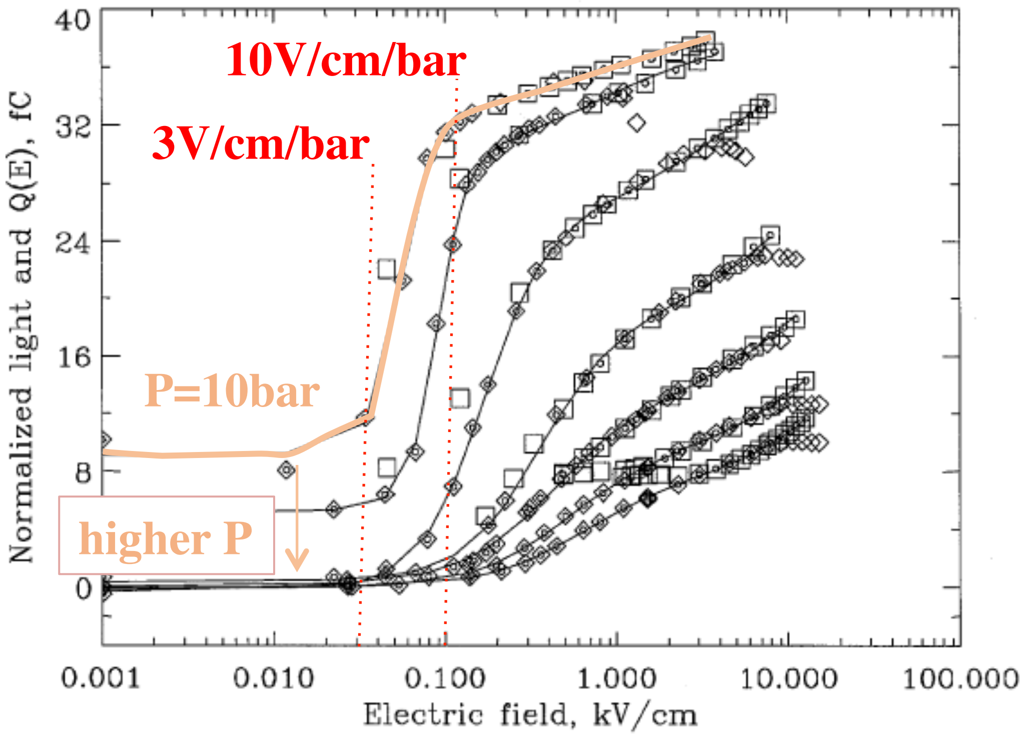

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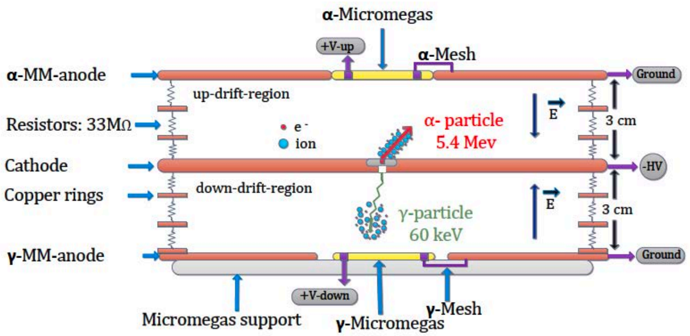

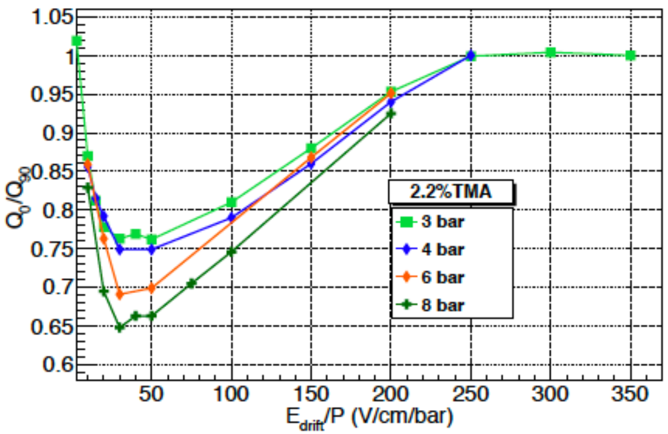

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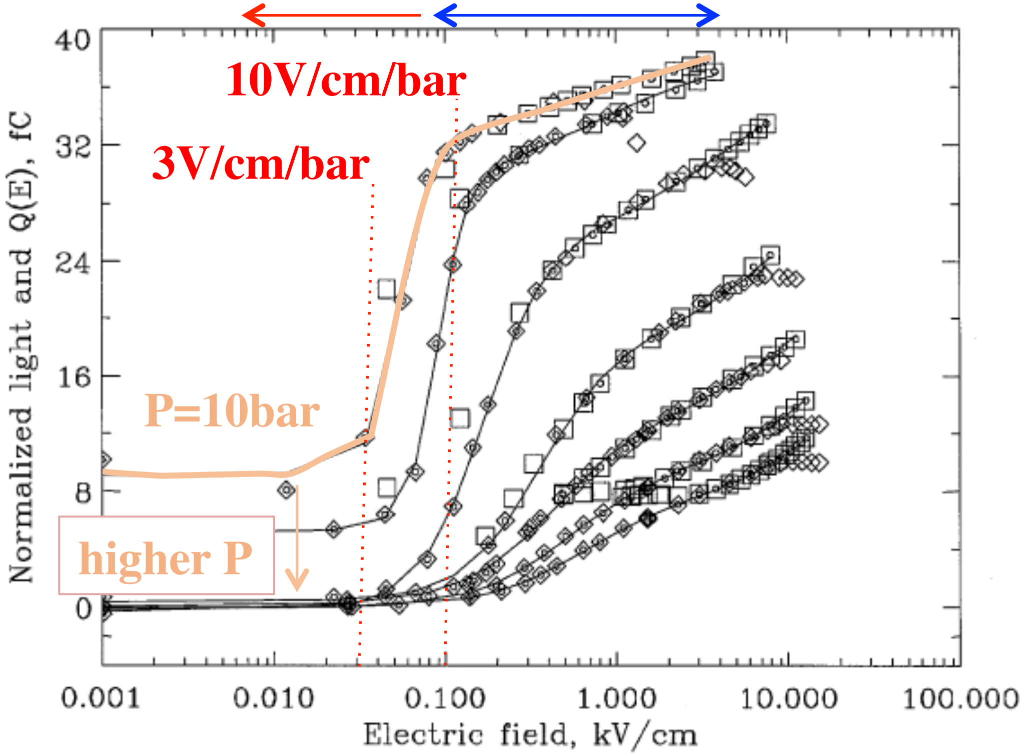
charge and light mode for xenon (*indirect method*)

mainly columnar recombination

small (residual) recovery of initial recombination



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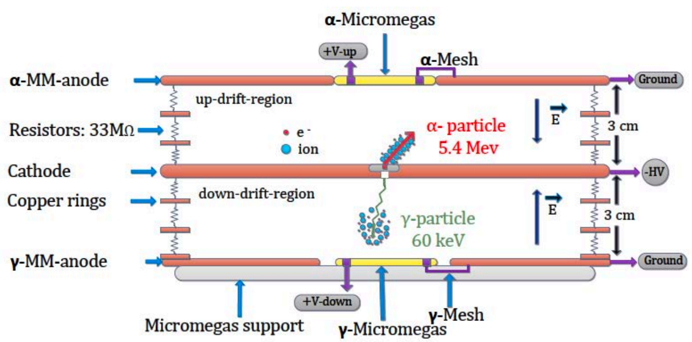

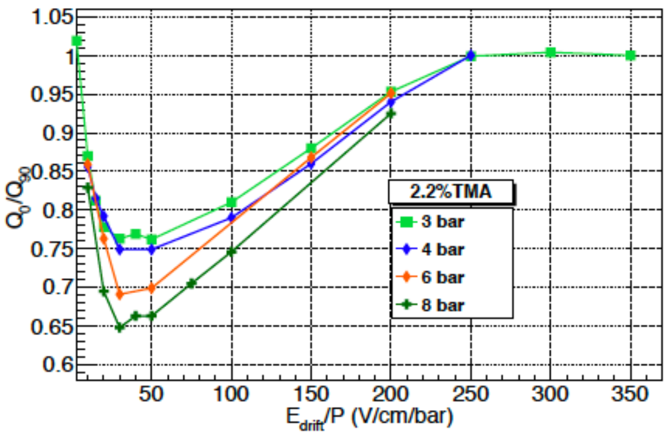

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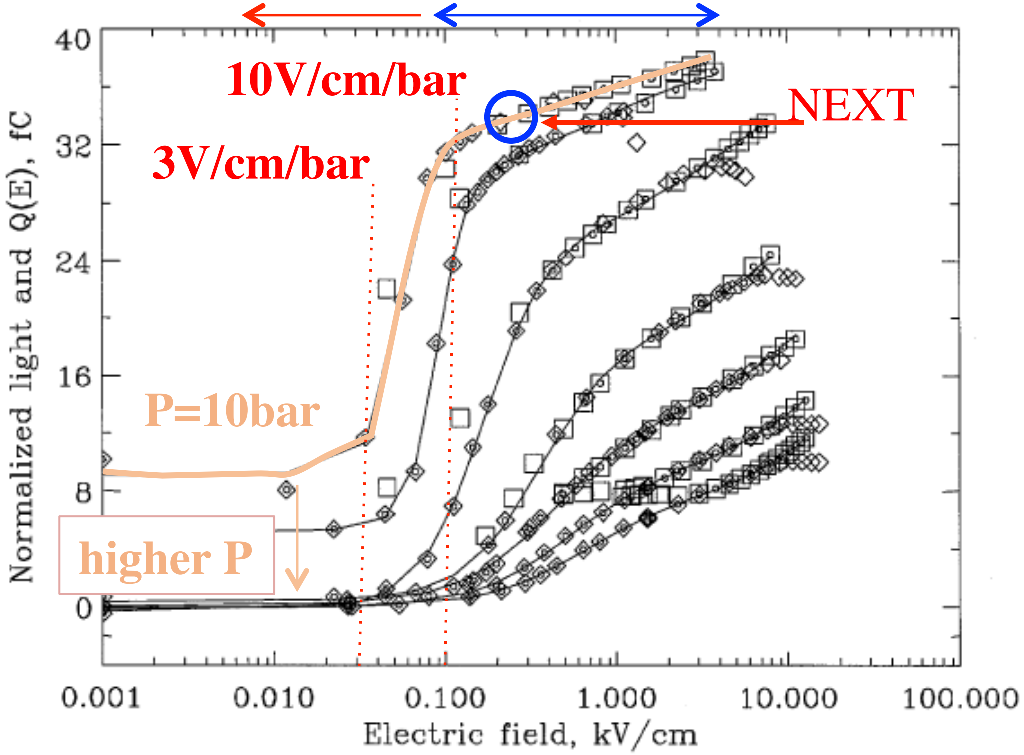

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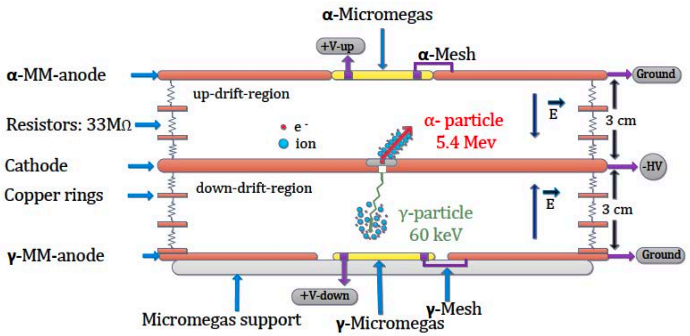

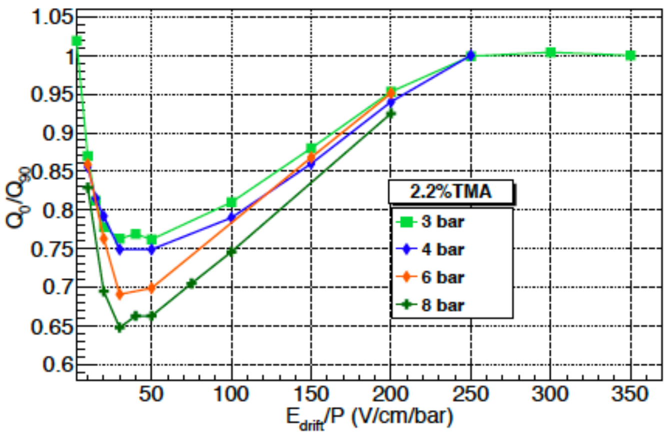

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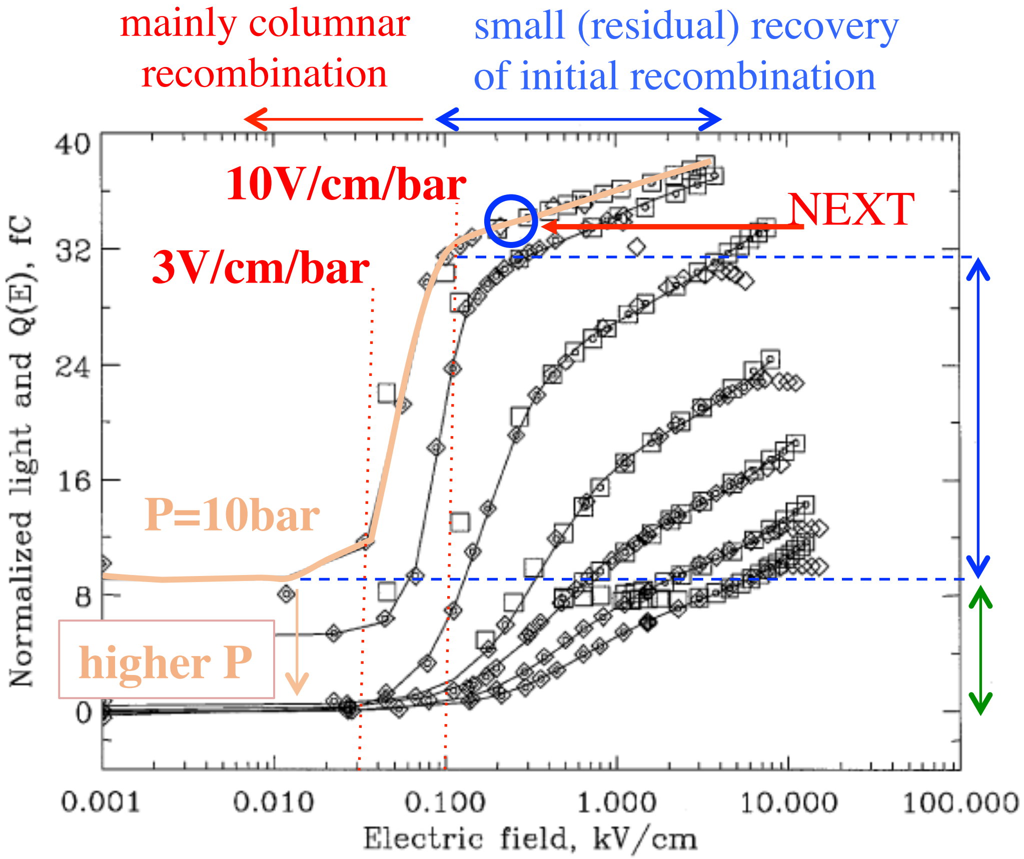


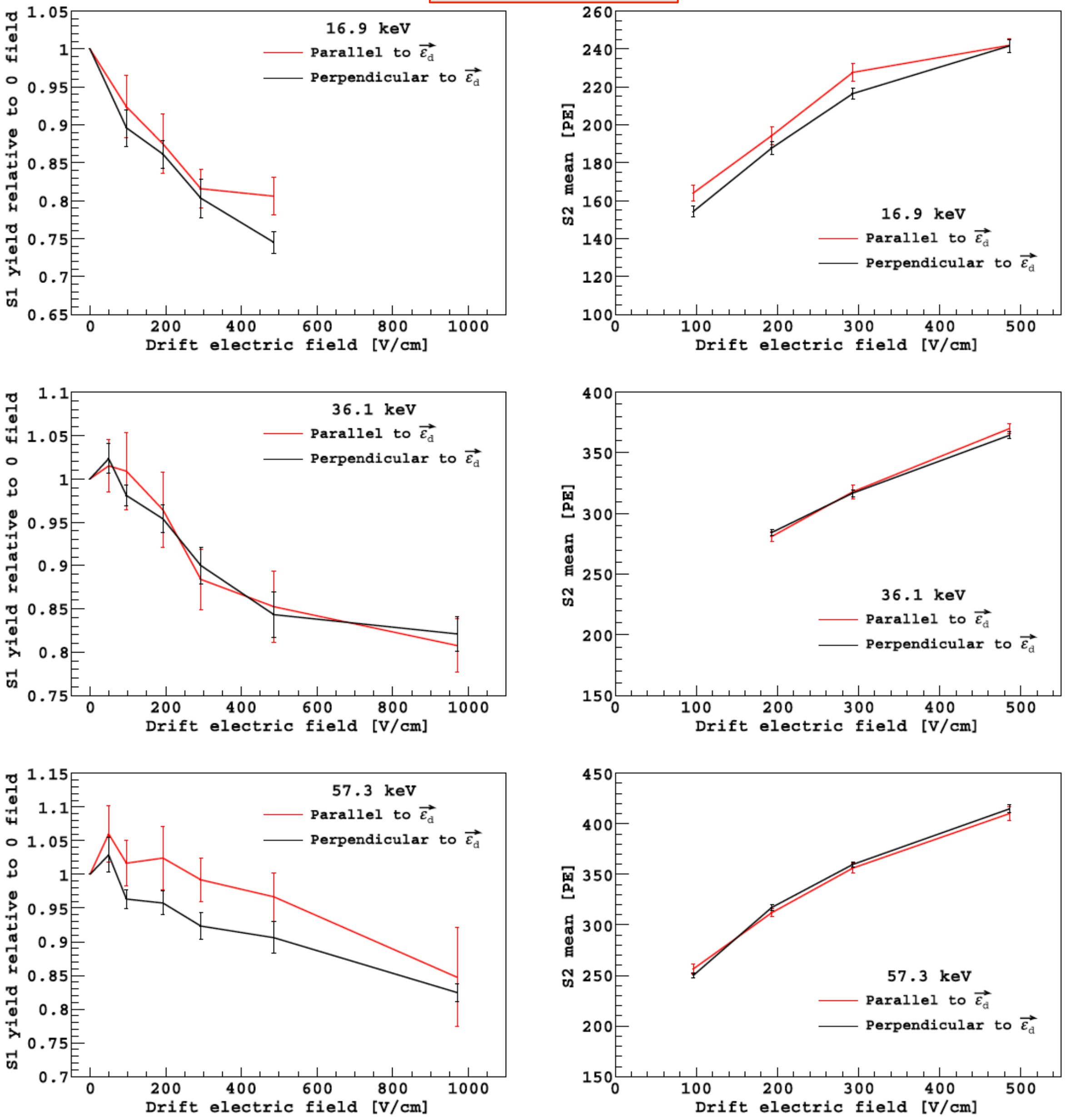
- **charge** yield (diamonds)
- model-dependent charge-yield, from **light** (squares).

charge lost due to initial +columnar reco

charge that escapes reco at 0 field

columnar recombination (*some* modern results for nuclear recoils in liquid)

liquid argon



<u>columnar recombination and important parameters</u>

- Onsager radius: ('size' of the interaction)

Onsager radius: ('size' of the interaction)	$r_o = e^2/4\pi\epsilon\varepsilon_{el} \sim e^2/4\pi\epsilon\,3/2\,KT$	in liquid (**80nm** for LAr, **54nm** for LXe)
	$r_o = e^2/4\pi\epsilon\varepsilon_{el} > e^2/4\pi\epsilon\,3/2\,KT$	~**200 nm** can be assumed in gas if electrons properly cooled (e.g., with additives)
Track size:	~**90nm**/36.1 keV_r	for LAr
	~1/P x **20μm**/30 keV_r	for xenon gas
Diffusion coefficient:	~**240nm**/√90nm	for LAr
	~**30 μm**/√20 μm @1bar	for xenon gas with additives

- Drift velocity: a low value will enhance the effect but may lower electron lifetime.
- Multiple scattering: might be reduced with suitable dopants (difficult in liquid phase)
- Recombination light: present in noble gases and CF_4, at least.
- Charge quenching: smaller the lighter the gas. More ionization -> more directionality.

good 'columnarity' signal!

gas vs liquid phase

phenomenological parameterizations exist for the 'bulk' ionization:

$$(1 - \mathcal{R}) \sim \frac{1}{1 + \frac{k}{E_d} \cdot d\varepsilon/dx}$$

derived for gases

$$(1 - \mathcal{R}) \sim \frac{E_d}{k'} \ln(1 + \frac{k'}{E_d})$$

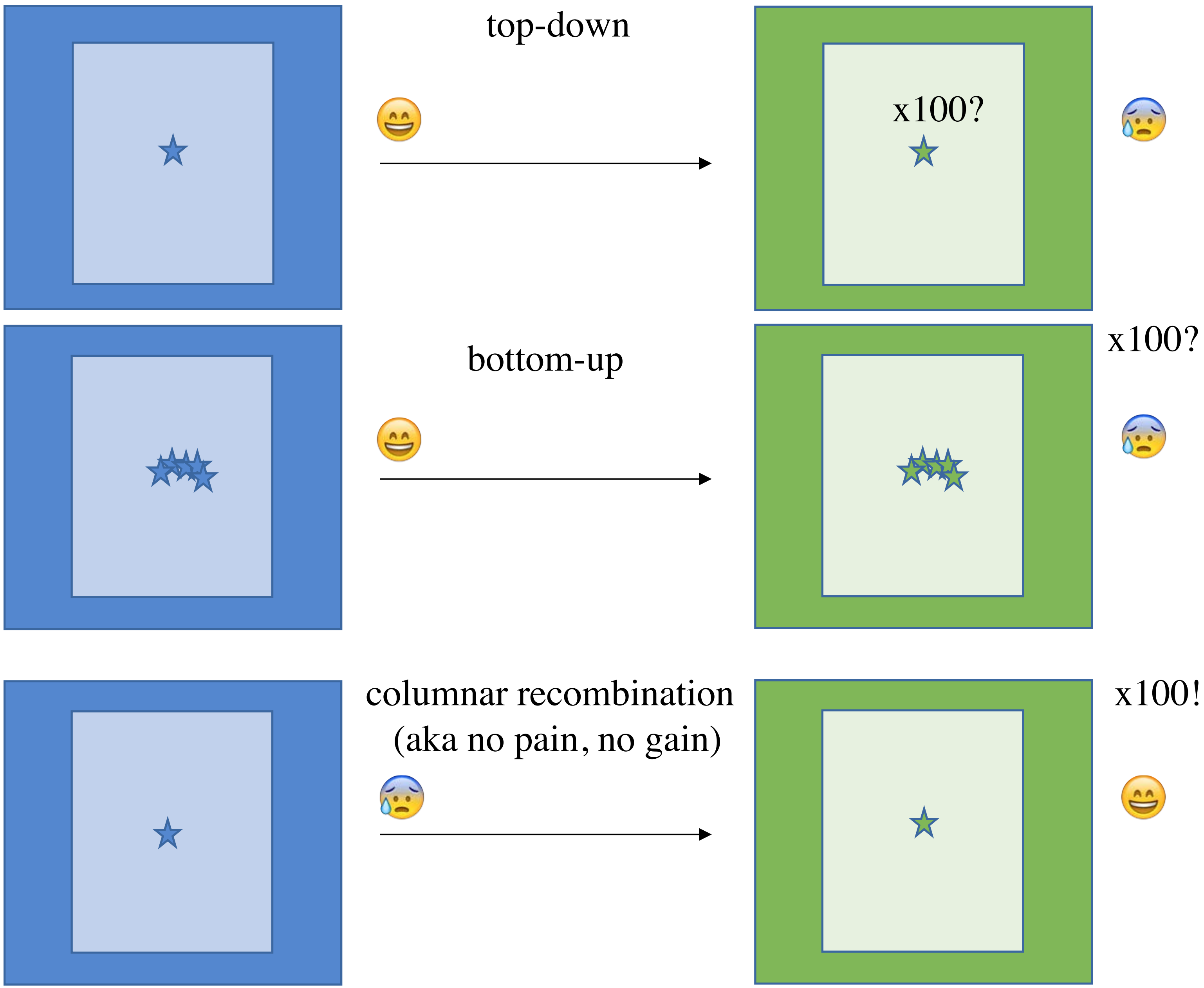
derived for liquids

(e.g: NEST conveniently includes those for pure Ar and Xe)

MC simulations also exist, but only in specific cases.

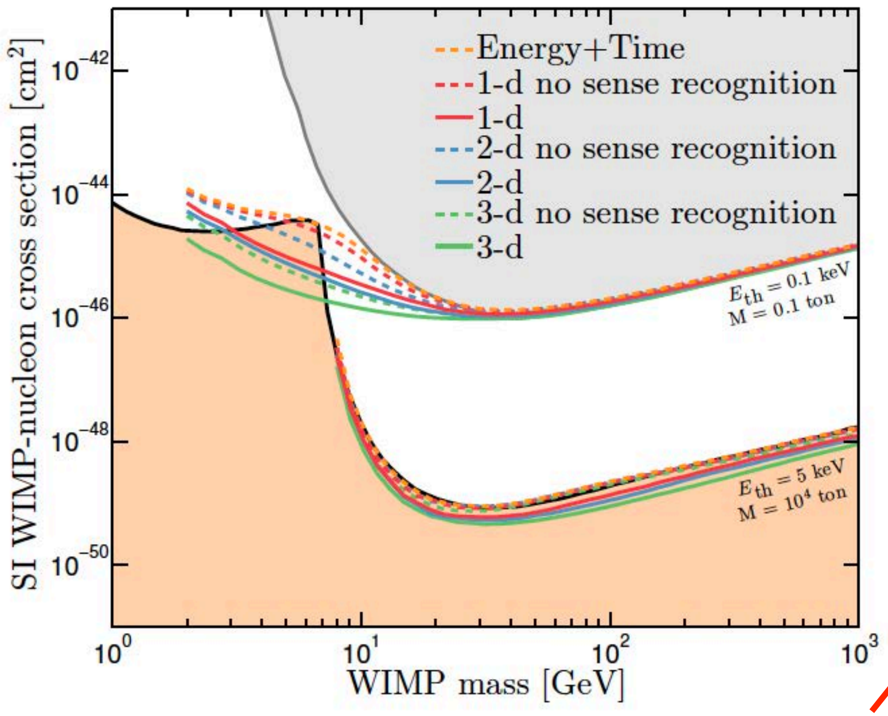
Neither a fundamental theory nor sufficiently systematic measurements available for optimizing the columnar effect!

brief summary of the main approaches to the directional DM problem



why columnar recombination still pretty much alive?

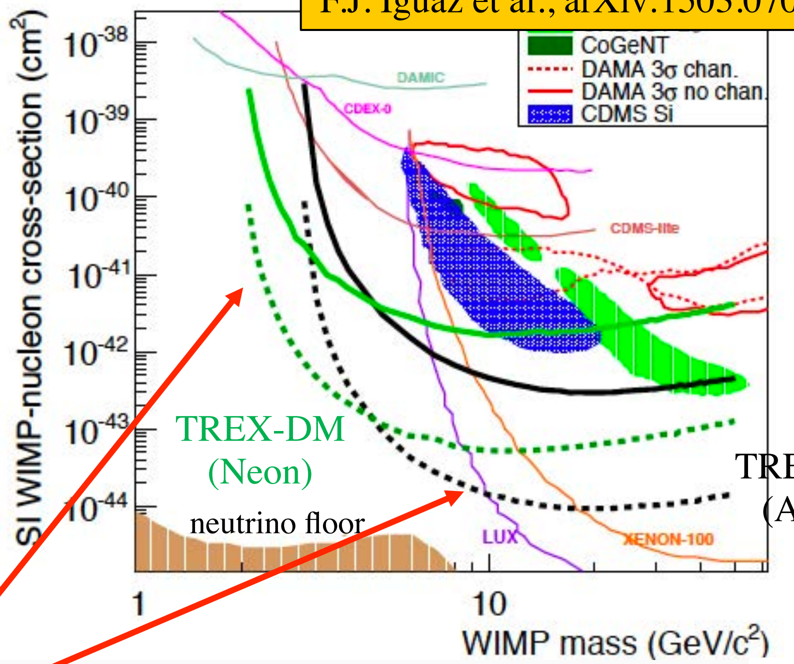
high mass



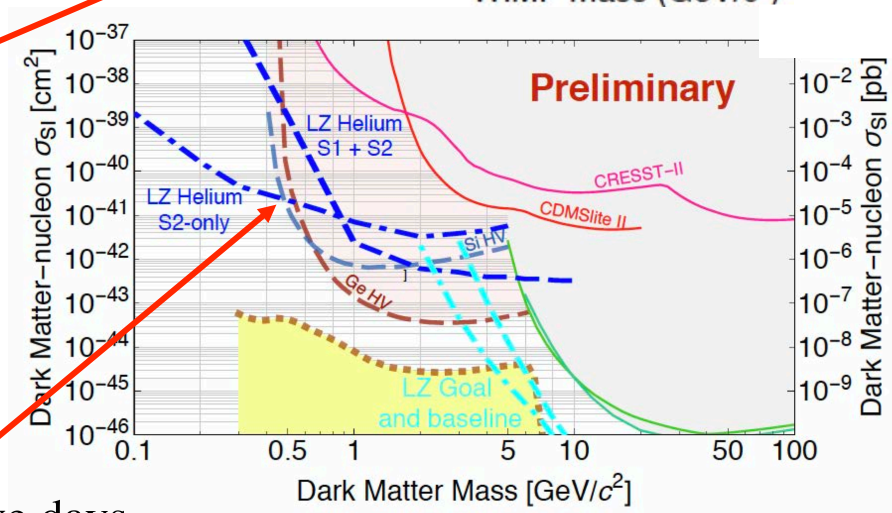
from C. O'Hare

low mass

F.J. Iguaz et al., arXiv:1503.07085v1



10kg y exposure

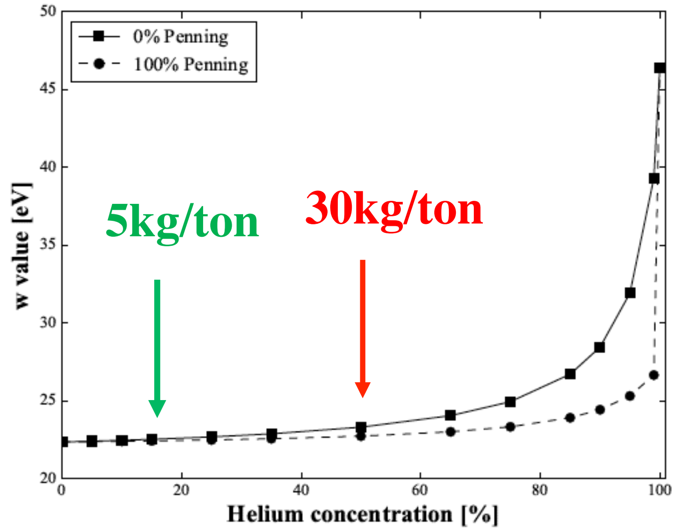


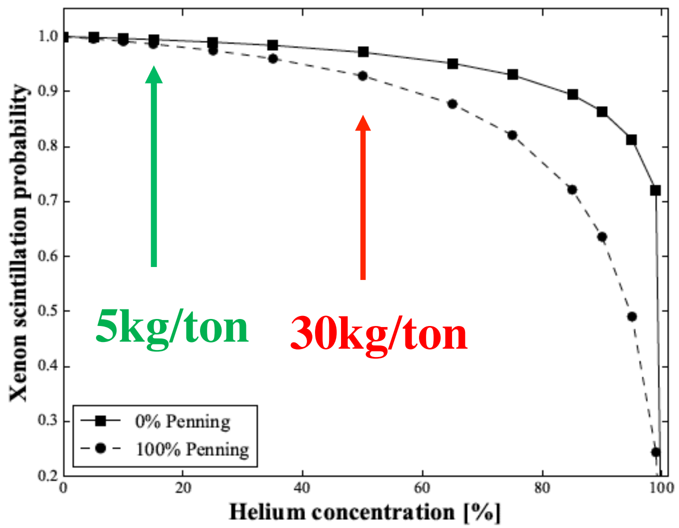
17kg, 20live days

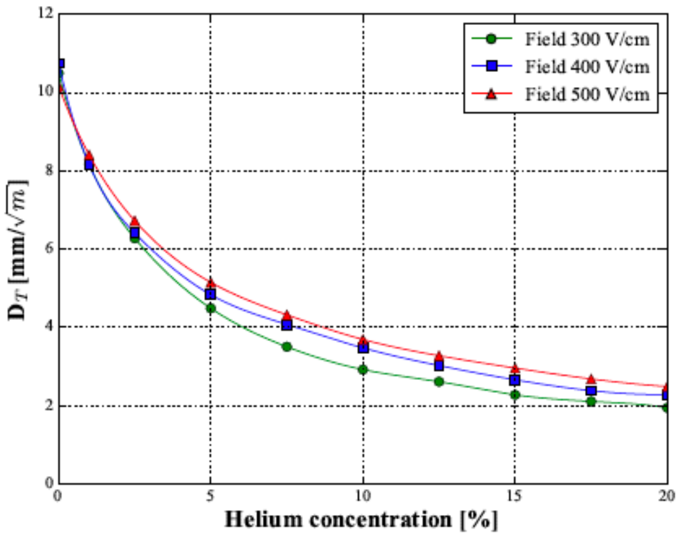
Hugh Lippincott talk (LIDINE 2017)

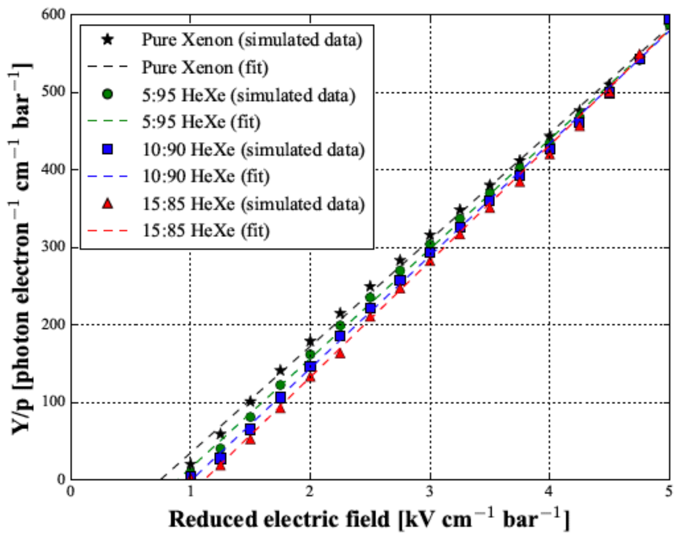
and potentially very important!
background suppression

is it possible to build an optical gas-TPC with Xe/He, Xe/Ne, He/X, Ne/X?







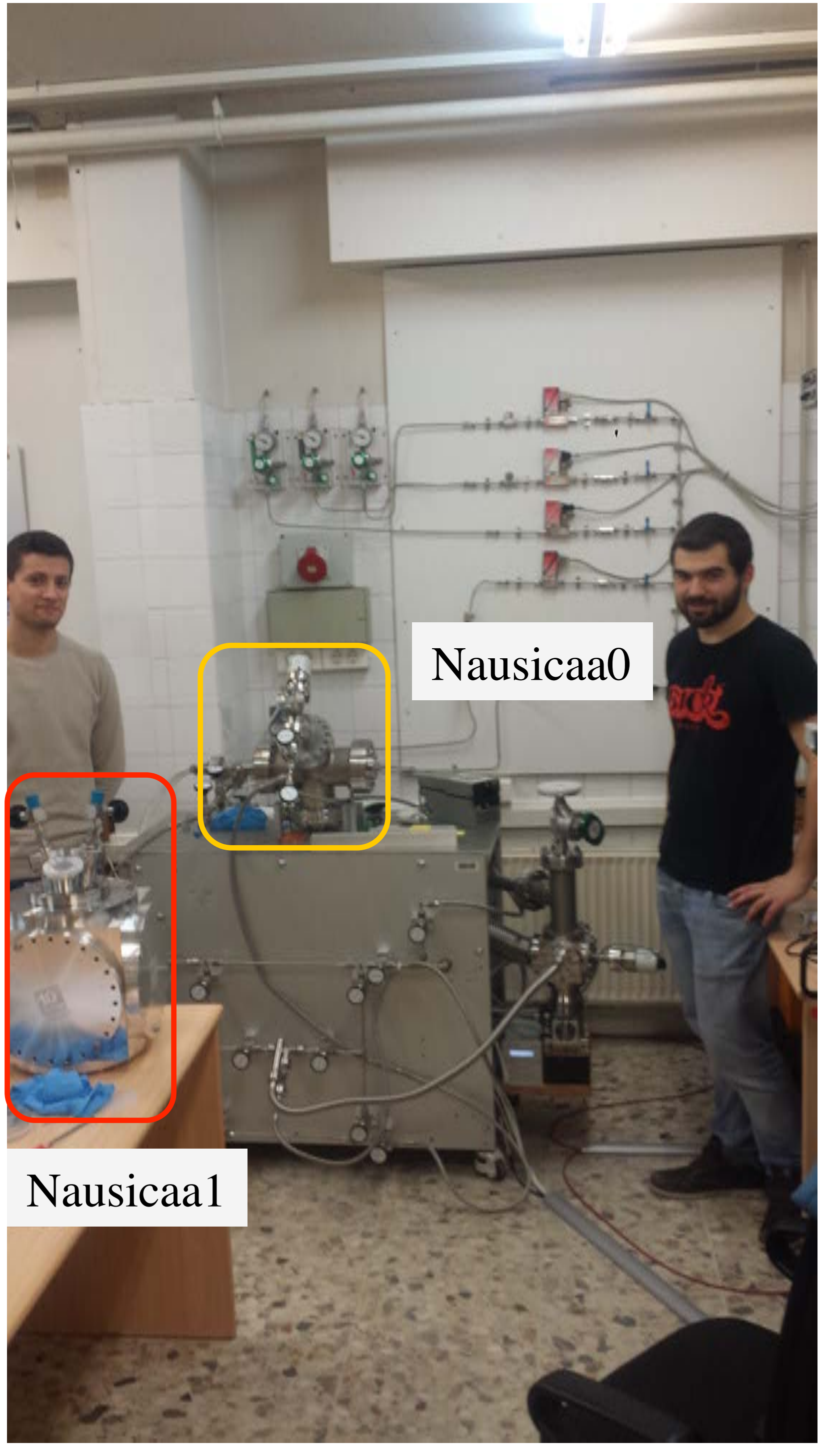


R. Felkai, F. Monrabal, DGD et al., arXiV:1710.05600 tools

basic setup at IGFAE (USC)

- Input stage (standard swagelok M6) based on mass-flow regulators, leak-tested down to 10^{-5} mbar l/s @10bar.
- Recirculation system (all VCR) leak-tested down to $<10^{-4}$ mbar l/s @6bar (commissioning at 10bar ongoing).
- Vacuum level down to 10^{-6} mbar after one night (system fully assembled).
- RGA sensitivity in the range 10-30ppms. (System purity under evaluation).
- Slow control system based on Arduino+NEXT-SC.
- Scope-based wvf acquisition at ~3-10Hz.
- Xe, CF4, Ar/Xe, N_2 bottles procured.
- **Nausicaa0** used for testing novel acrylic thick-GEMs for NEXT.
- **Nausicaa1** vessel foreseen as test-bed for large GEM tile (~20cm x 20cm) testing. Will be misused for the first months as a TPC!.

Loads of help from NEXT crew, impossible to acknowledge…

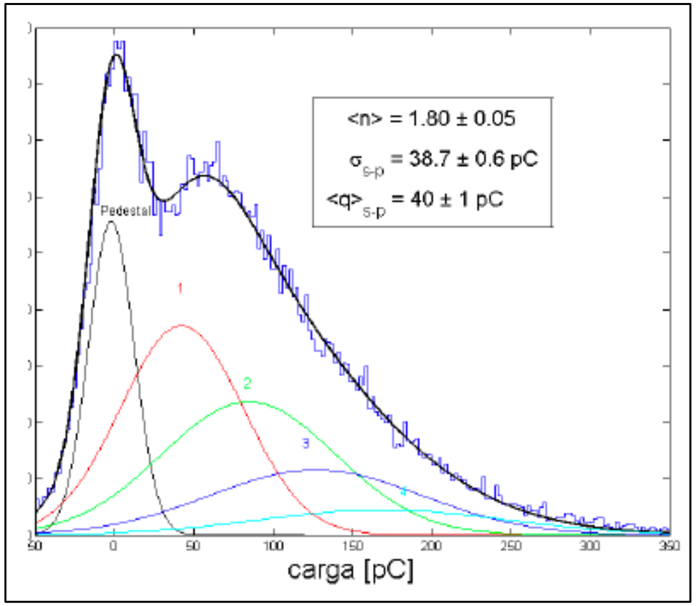


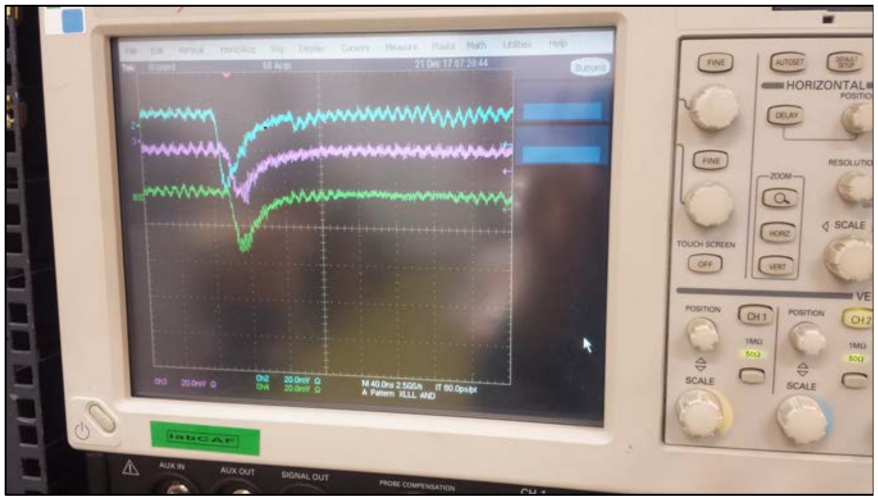
Nausicaa0: generic setup for testing new scintillating structures

PMT teflon-frame test assembly Nausicaa0

acrylic hole-based scintillator
(akin to GEMs, but x100 larger)

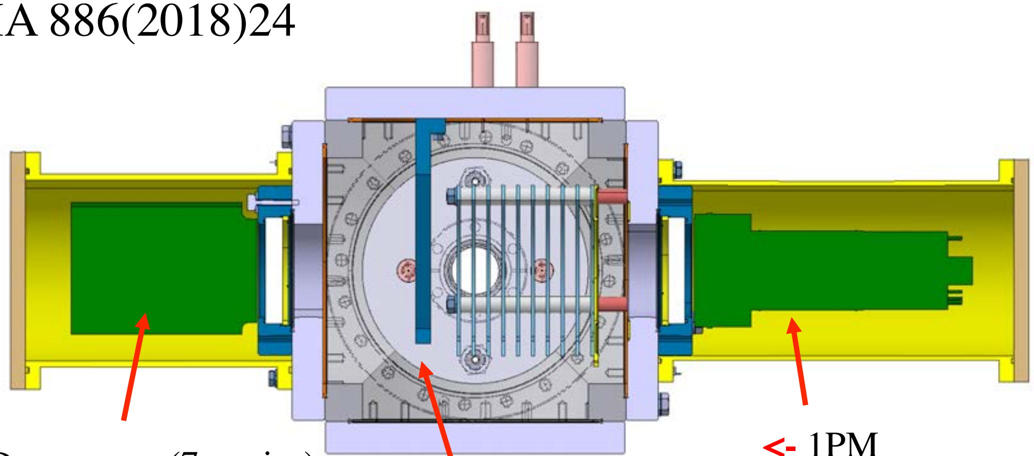
single-photon PM response





- voltage across the tile: 5kV
- drift field: 1kV/cm/bar
- pressure: 3bar
- First light: signal seen in 3PMTs simultaneously!.

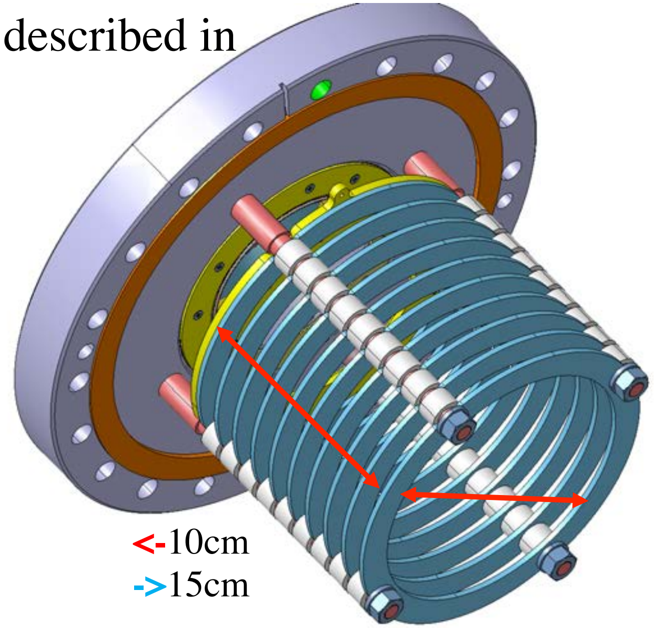
Nausicaa1: TPC based on an enhanced version of the system described in NIMA 886(2018)24



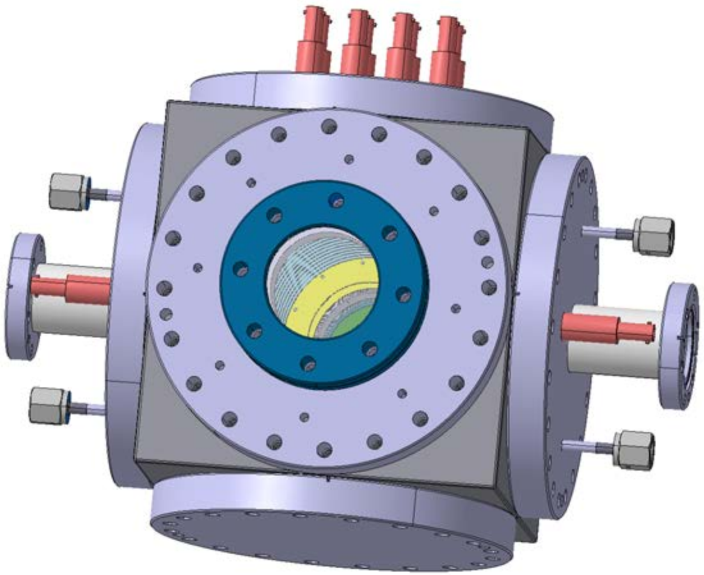
<- CCD camera (7e noise)
-> CMOS camera (1e noise)

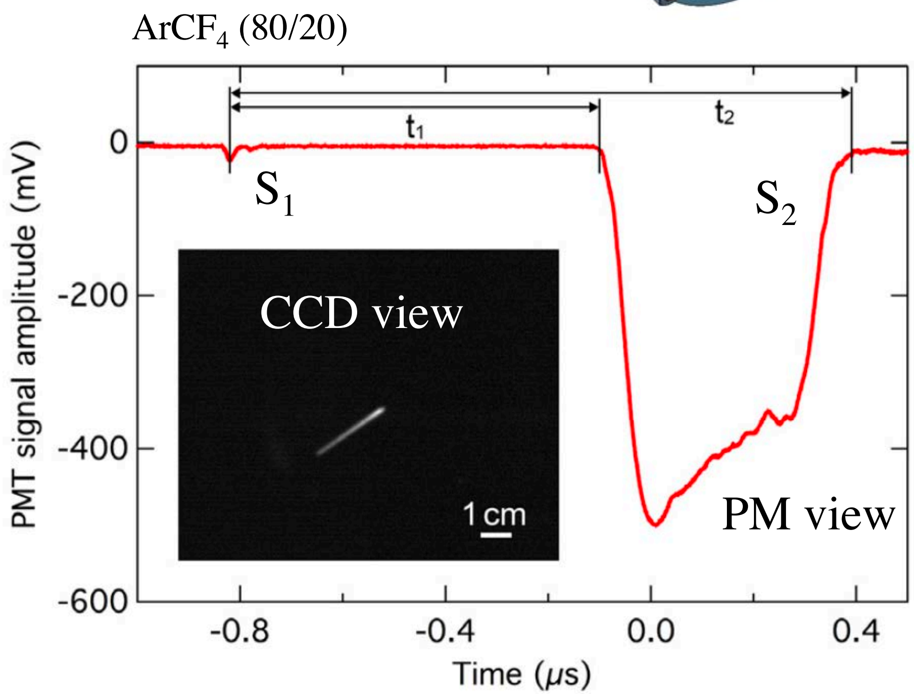
<- 3-GEM
-> acrylic t-GEM

<- 1PM
-> 4PMs



<-10cm
->15cm





F.M. Brunbauer*, G. Galgóczi, DGD et al. NIM A, 886(2018)24–29.

α-tracks from the decay of Rn diffused inside the chamber

status and outlook

- Nausicaa0, for testing new scintillating structures, developed and almost fully operational (working at 6bar).

- Nausicaa1, in TPC configuration:

1) Design finished.
2) Construction of pieces started.
3) Assembly and commissioning foreseen by June 1st.

4) Experimental studies and simulations of columnar recombination in Ar-CF_4 and CF_4 for **α**-particles in the range 0.1-10bar will follow.

5) Complementary, measurements in NEXT and Xe/He mixtures are intended (the latter will require an upgrade).

6) The aim of the project is to determine favorable conditions for columnar recombination to be of any use in the future for either DM or ***ββ***0 experiments.