Dark Matter Group

Patrick Decowski
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Dark Matter Group

Joran Angevaare
PhD
Start Jan'19

Peter Gaemers
PhD
Start Apr'18

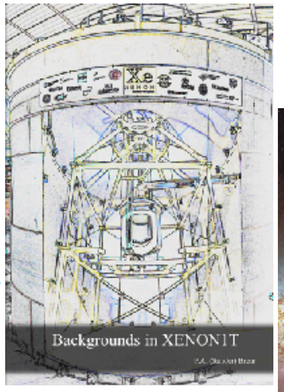
Stefan Brünner
Postdoc
Start Aug'19

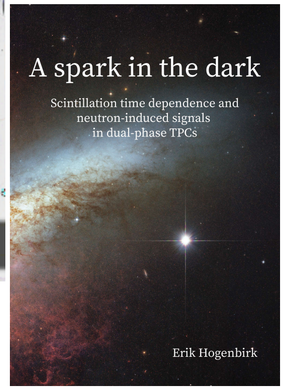
Alvaro Loya Villalpando
PhD
Start Nov'19

MSc students:
- **Olivier Kesber**
- **Gijs Leguijt**
- **Frederick van der Meulen**
- **Davey Oogjes**
- **Leonora Verveld**
- **Lucas de Vries**

BSc students:
- **Maricke Flierman**
- **Isis Hobus**

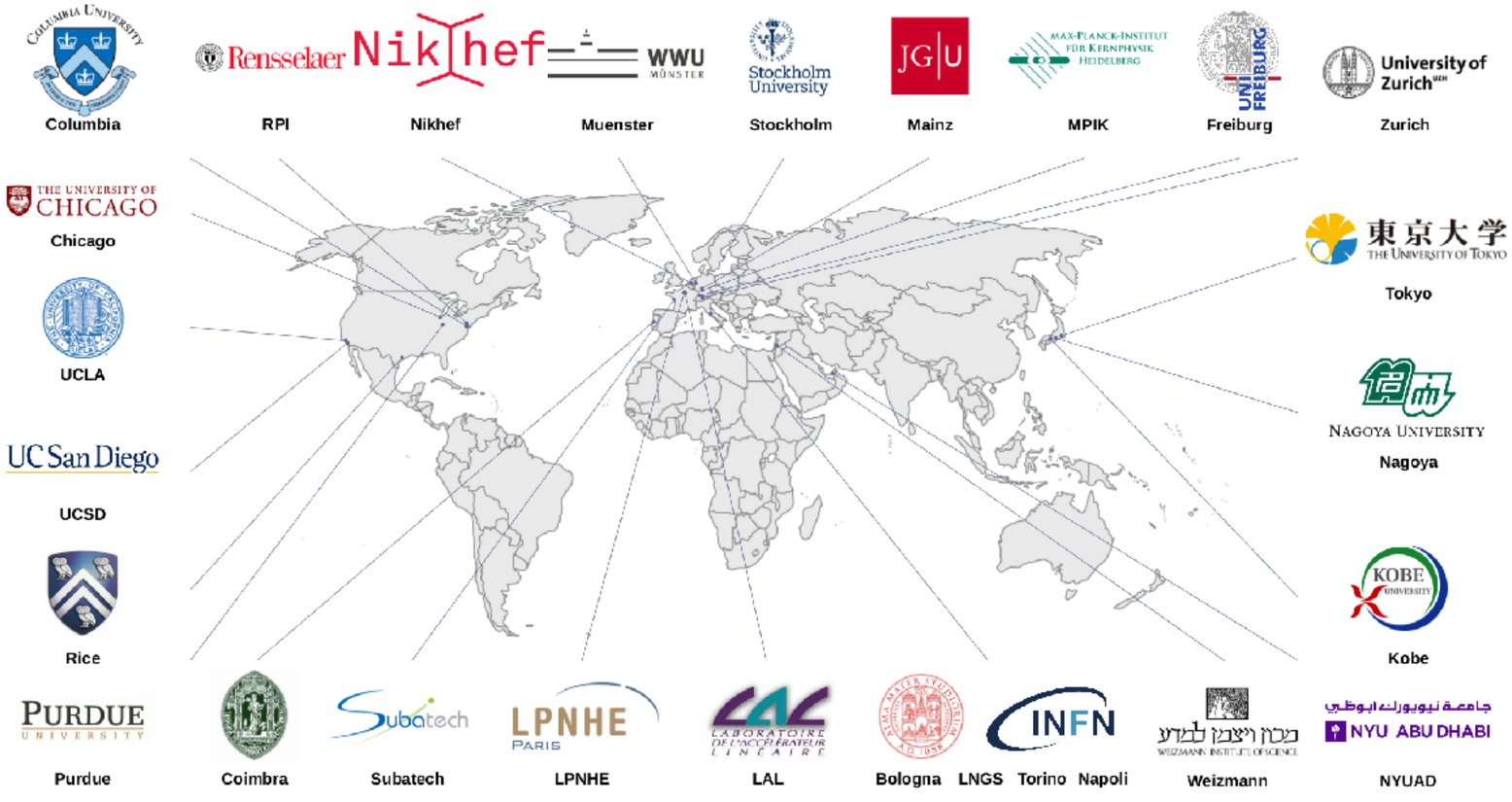
Most of them at LNGS today!





27 institutes,
150 scientists

XENON
Dark Matter Project




Xe
XENON
Matter Project
XENON1
enlightening the

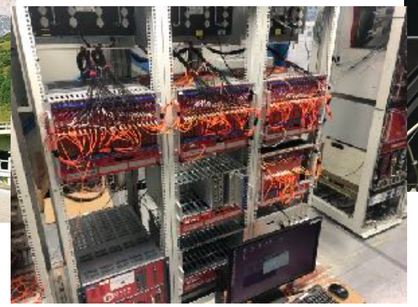
Building XENONnT

XENON1T open again

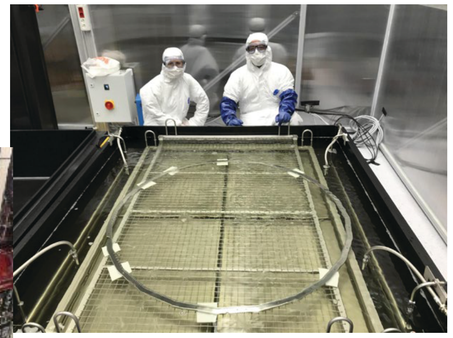
Gran Sasso tunnel on Autostrada A24 may close next month

Following claims of being unsafe, Strada dei Parchi has announced it will shut down the tunnel that stretches underneath the Gran Sasso massif on May 19 until further notice

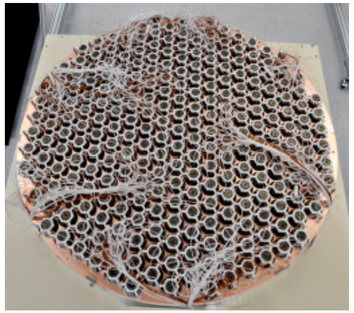
New DAQ



Clean, clean and … clean



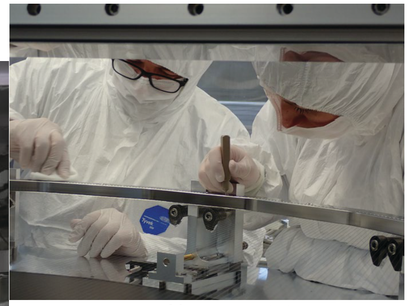
Top PMT Array Ready



Neutron Veto ready

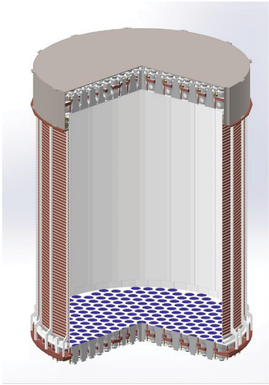
Take it all apart

New electrodes

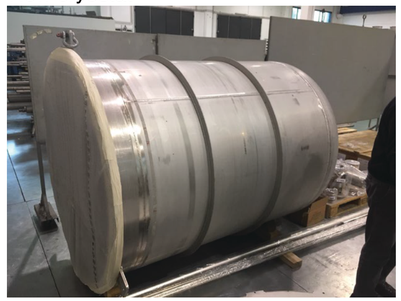


TPC puzzel: >1000 parts

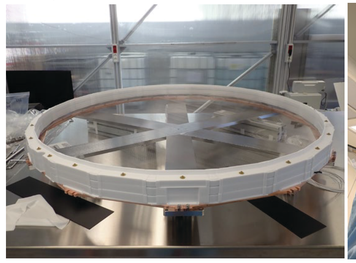
XENONnT TPC ready



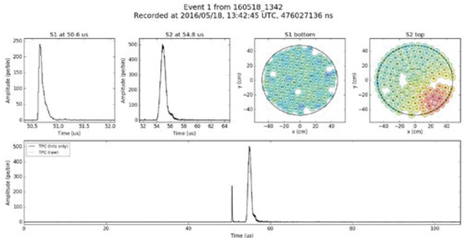
New cryostat



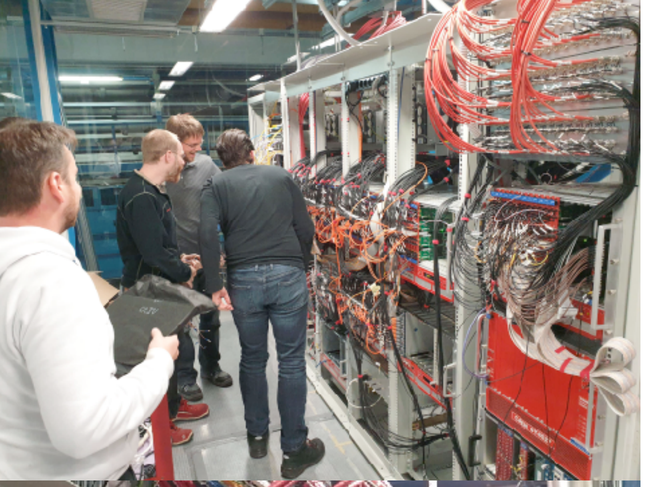
Test, Test and … Test

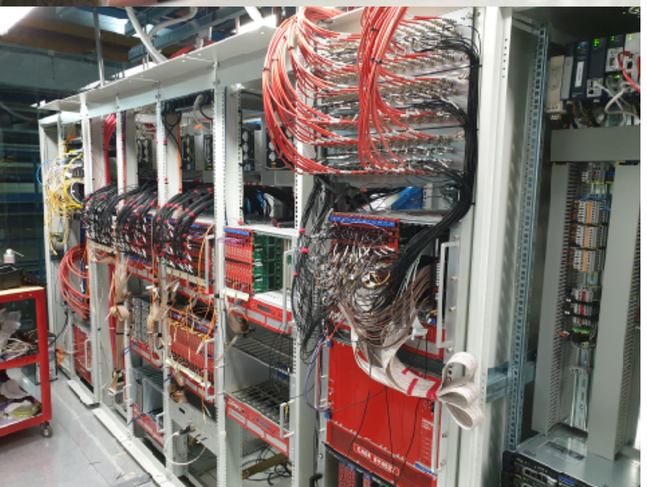


Commissioning…



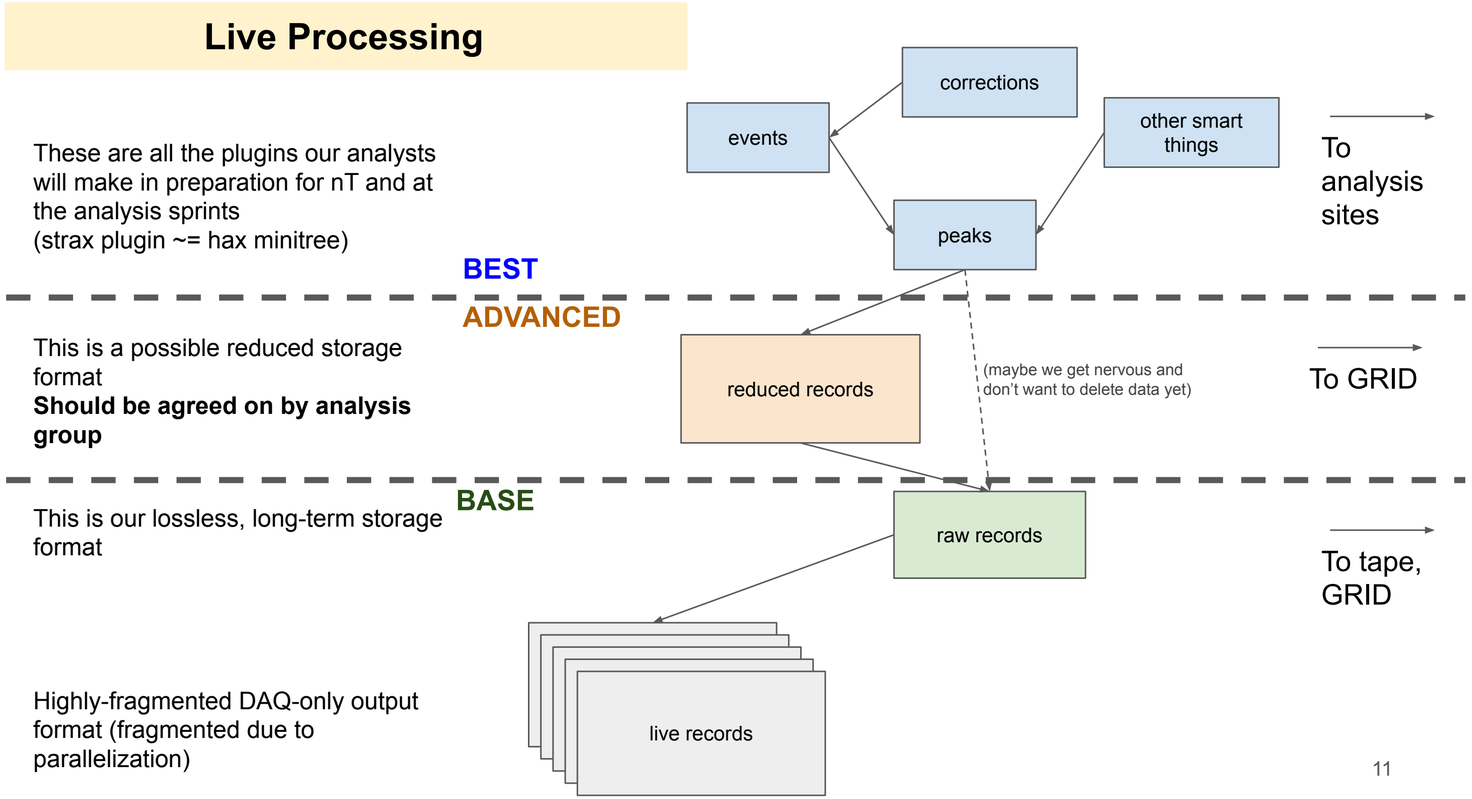
2018 2019 2019 2020





Upgraded DAQ System

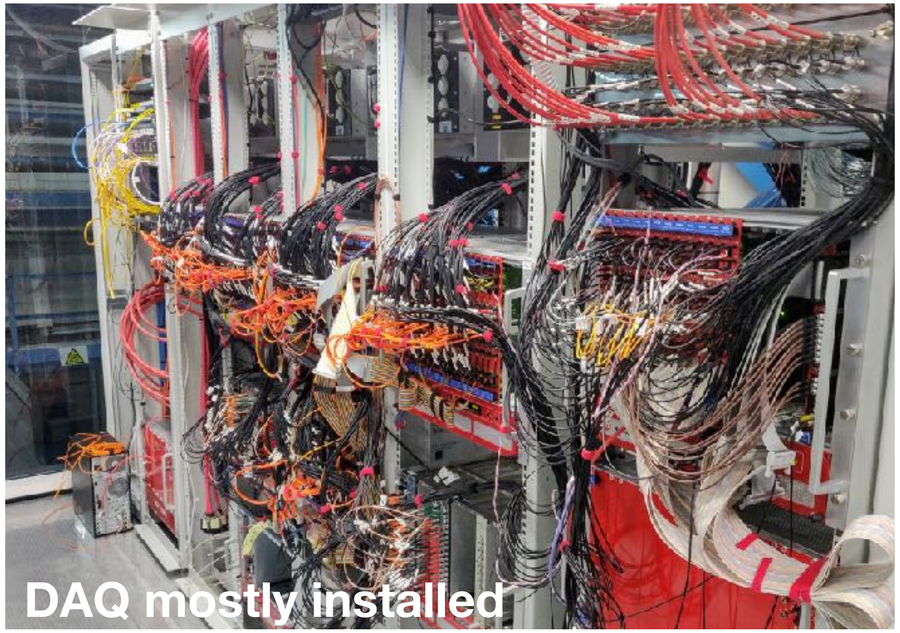
- "Triggerless" DAQ - all signals readout continuously
  - Lower thresholds & new event signatures
- Two different gain readouts
  - "Dark Matter": ~10 keV
  - "0ν2β": 2.5 MeV

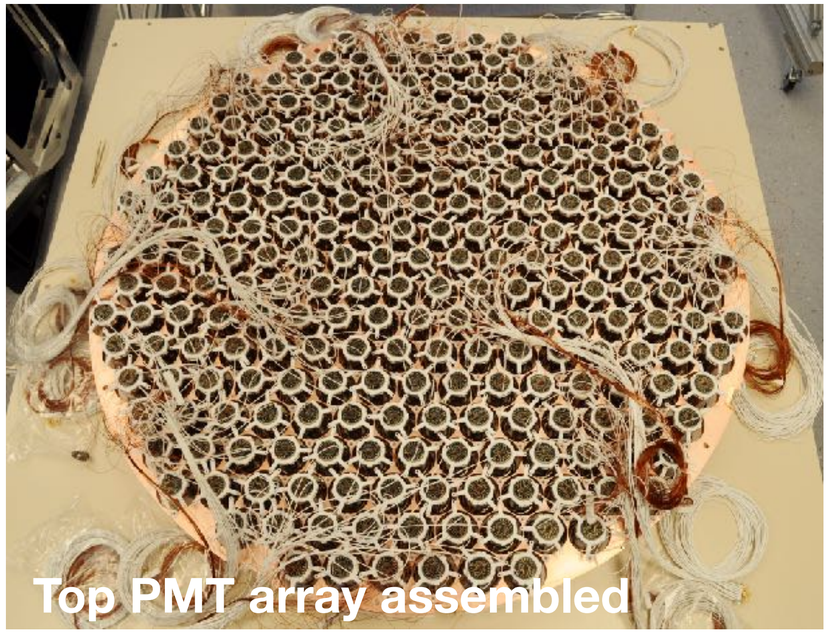


XENONnT Installation Ongoing

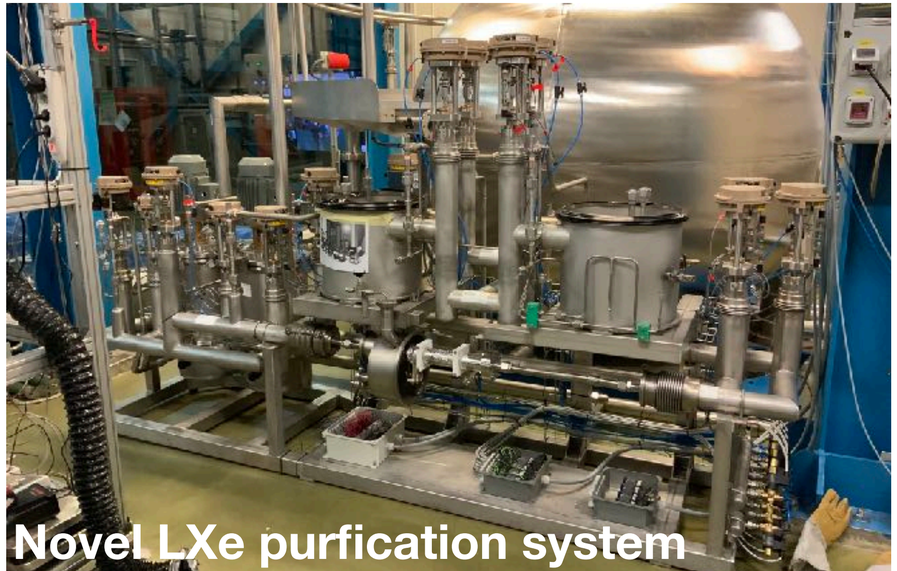
On schedule for a start in early 2020!


Test of Grids in LXe


DAQ mostly installed


Top PMT array assembled


Cryostat Modified


Novel LXe purfication system

XENON1T Analysis: Publications in 2019

- **Light Dark Matter Search with Ionization Signals in XENON1T,**
  Accepted by Phys. Rev. Lett., arXiv:1907.11485

- **Search for Light Dark Matter Interactions Enhanced by the Migdal Effect or Bremsstrahlung in XENON1T**,
  Phys. Rev. Lett 123, 241803 (2019), arXiv:1907.12771

- **XENON1T Dark Matter Data Analysis: Signal Reconstruction, Calibration and Event Selection**,
  Phys. Rev. D 100, 052014 (2019), arXiv:1906.04717

- **XENON1T Dark Matter Data Analysis: Signal & Background Models, and Statistical Inference**,
  Phys. Rev. D 99, 112009 (2019), arXiv:1902.11297

- **The XENON1T data acquisition system**, JINST 14 (2019) no.07, P07016, arXiv:1906.00819

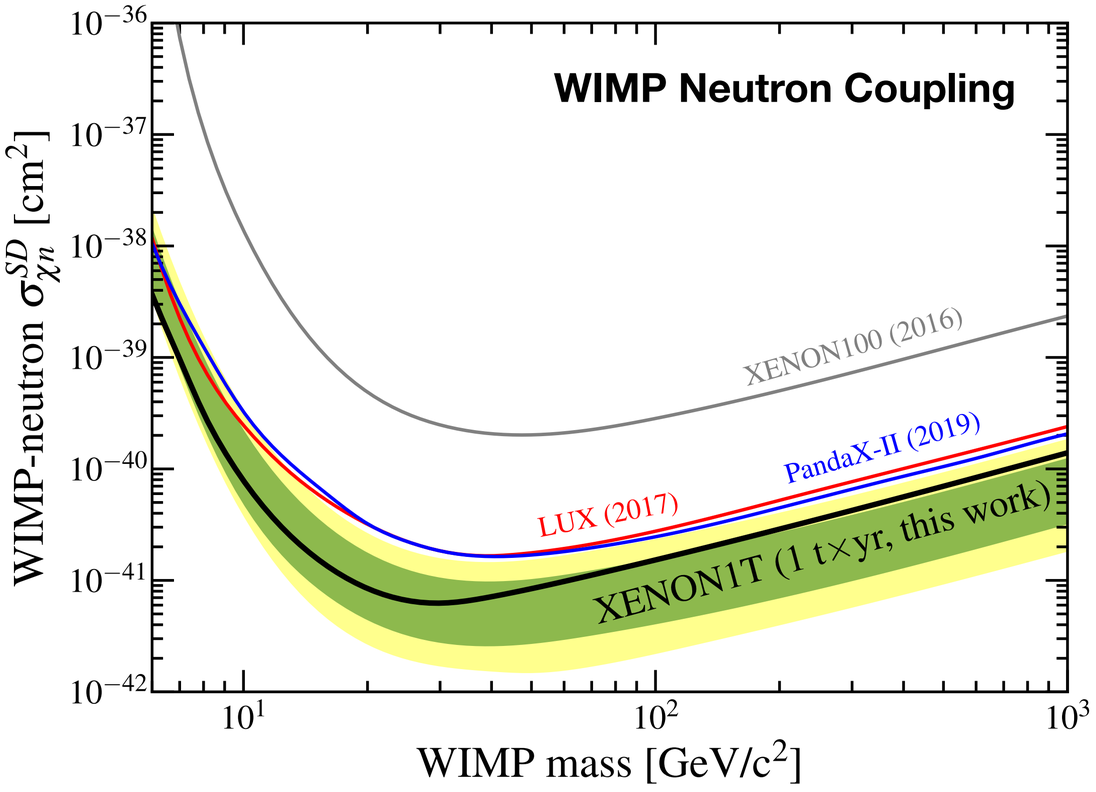
- **First detection of two neutrino double electron capture in ^{124}Xe - the longest half-life ever observed directly**,
  Nature 568, 532–535 (2019), arXiv:1904.11002

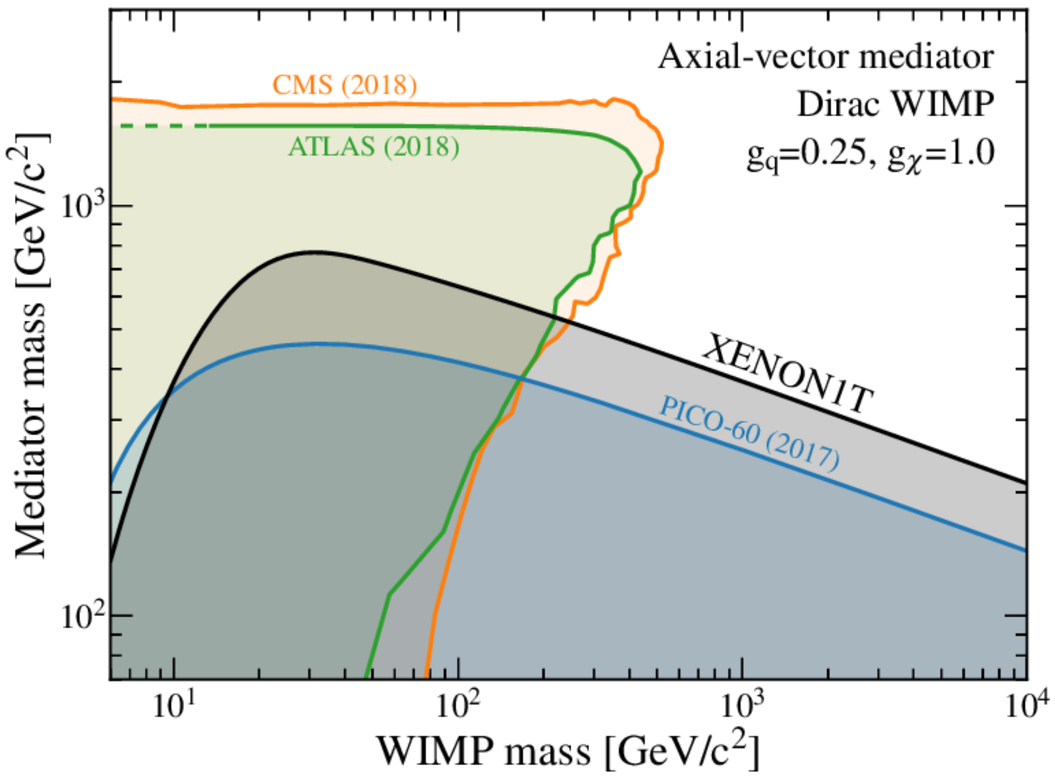
- **Constraining the Spin-Dependent WIMP-Nucleon Cross Sections with XENON1T**,
  Phys. Rev. Lett. 122, 141301 (2019), arXiv:1902.03234

Spin Dependent Results

Sander Breur

Reanalysis of the 1 ton-year data set with spin-dependent couplings - coupling to Xe nuclei with spin: ^{129}Xe and ^{131}Xe





Constraining the Spin-Dependent WIMP-Nucleon Cross Sections with XENON1T,Phys. Rev. Lett. 122, 141301 (2019), arXiv:1902.03234

Double Electron Capture

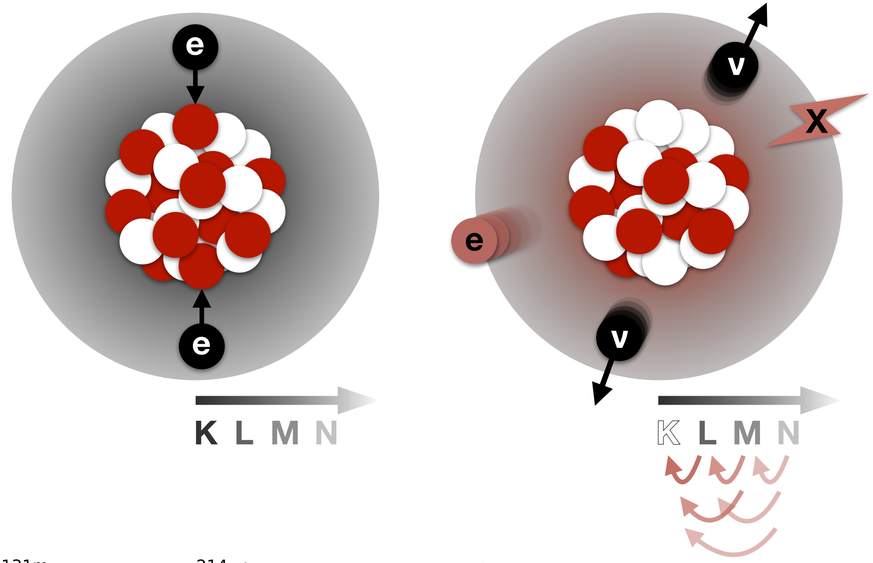
Slowest process ever: 2νDEC

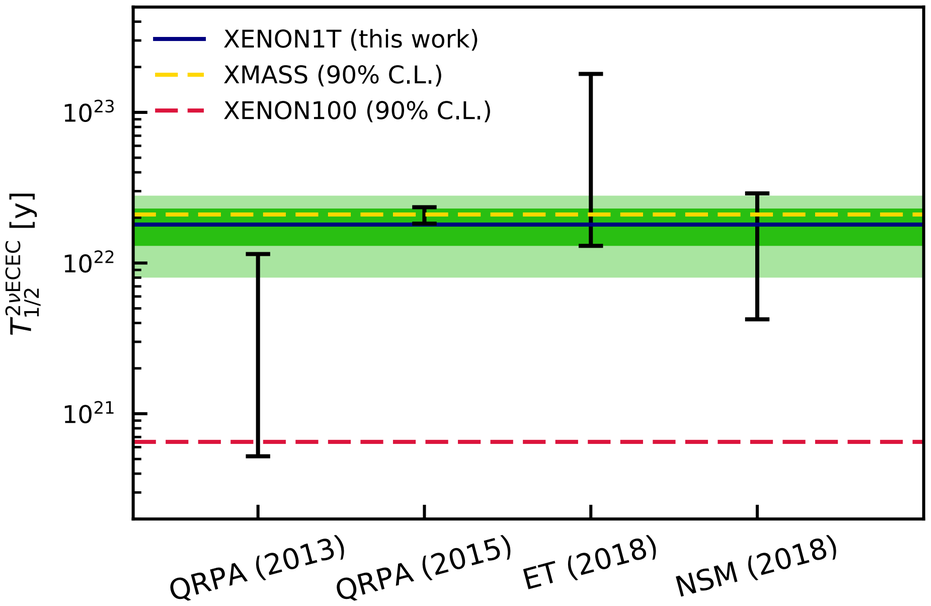
- Second order process like double β-decay, but longer lived
  - ^{124}Xe is a candidate isotope
  - 0.095% Nat. abundance:
  - Peak at 64.3 keV from K-shell captures

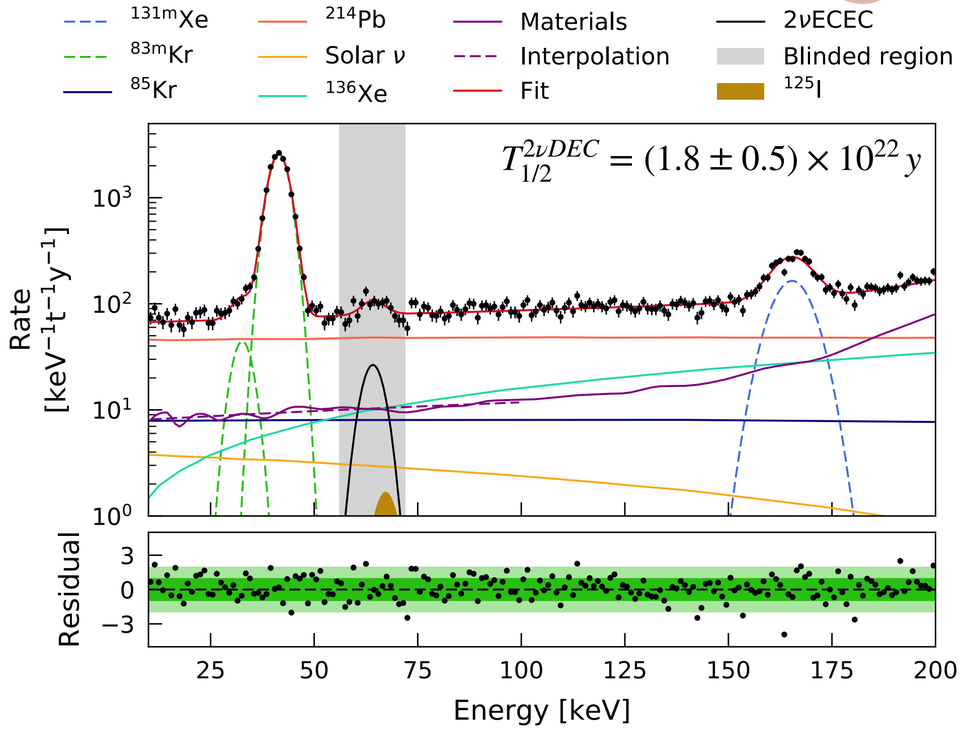
$$T_{1/2}^{2\nu 2EC} \propto G_{2\nu} |M_{2\nu}|^2$$

Phase Space Factor

Nuclear Matrix Element



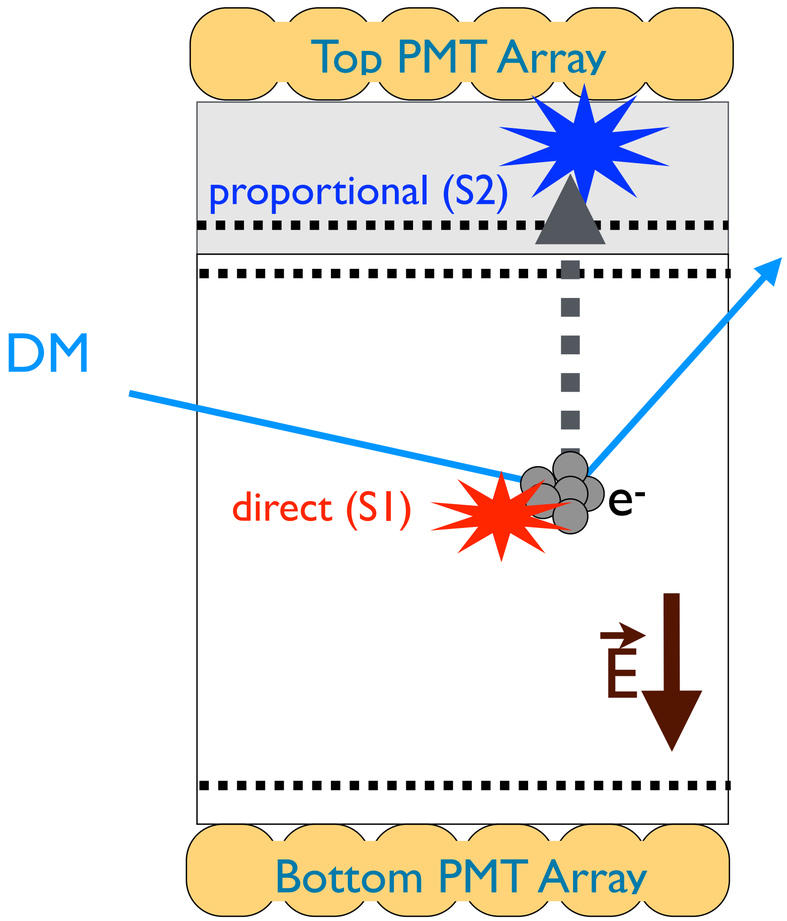




First detection of two neutrino double electron capture in 124Xe - the longest half-life ever observed directly, Nature 568, 532–535 (2019), arXiv:1904.11002

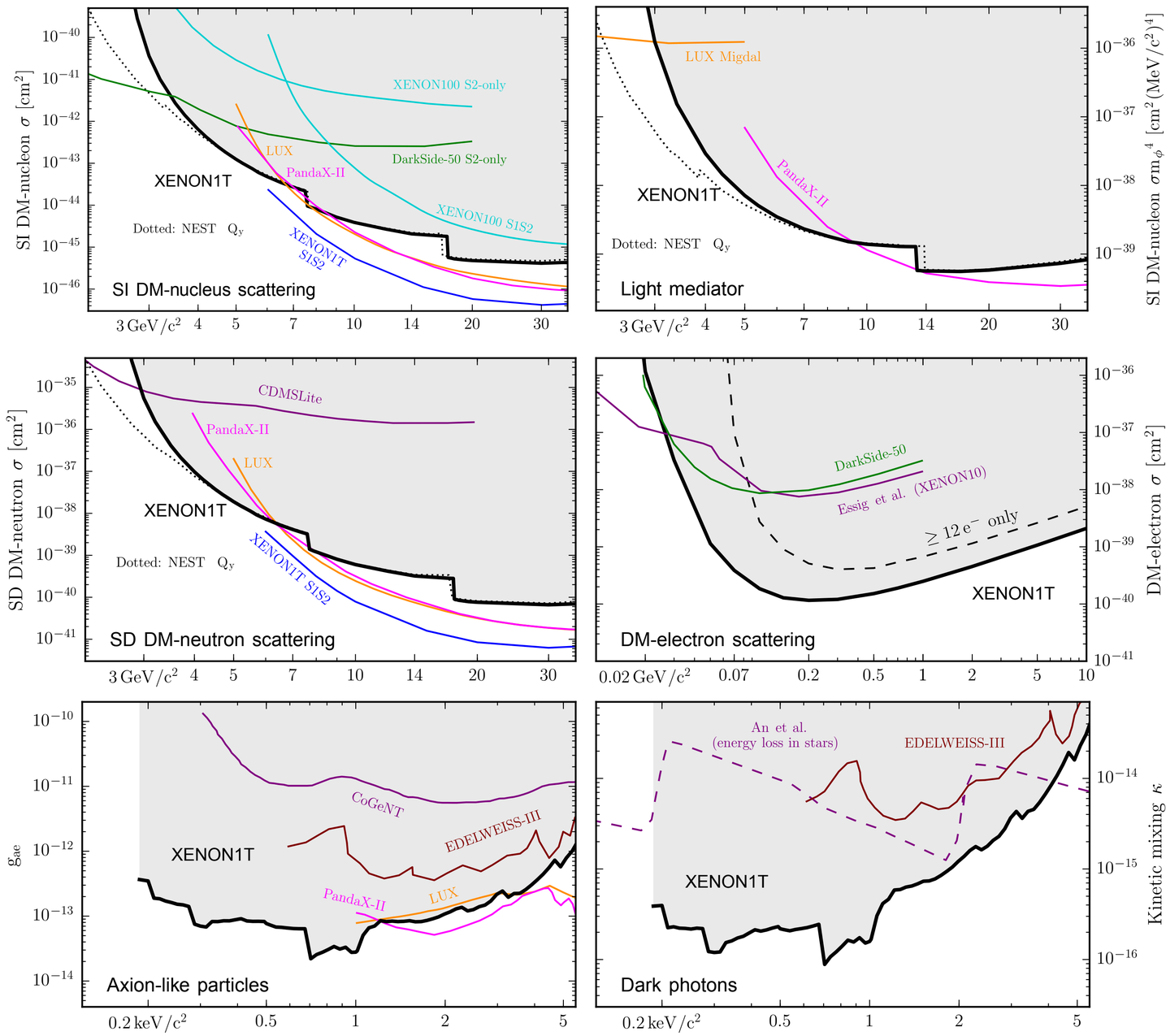
Ionization Channel (S2)-only: Light Dark Matter

Jelle Aalbers



Do the analysis without the S1 signal - lower thresholds!

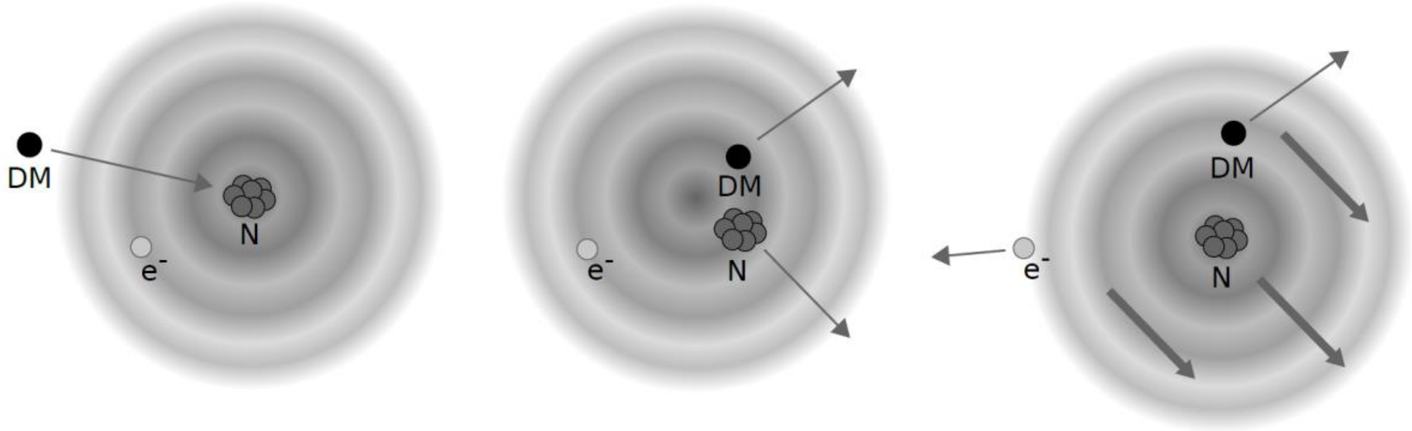
Drive to be sensitive to sub-GeV mass DM



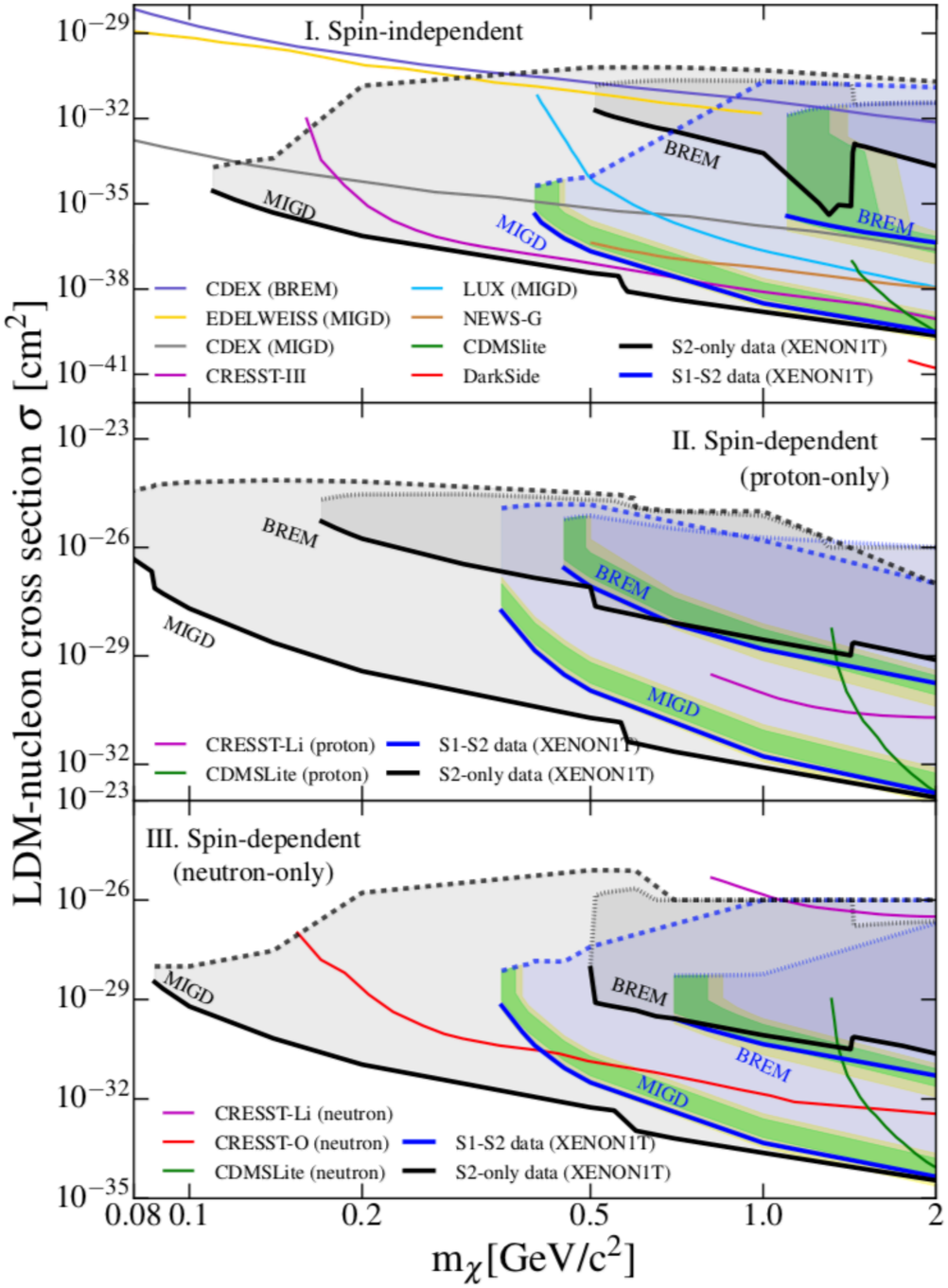
Light Dark Matter Search with Ionization Signals in XENON1T, Accepted by Phys. Rev. Lett., arXiv:1907.11485

Searching for Sub-GeV WIMPs

“Migdal”-effect



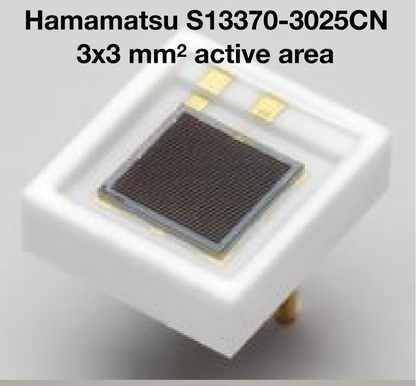
Look for ER signal from ionization and bremsstrahlung

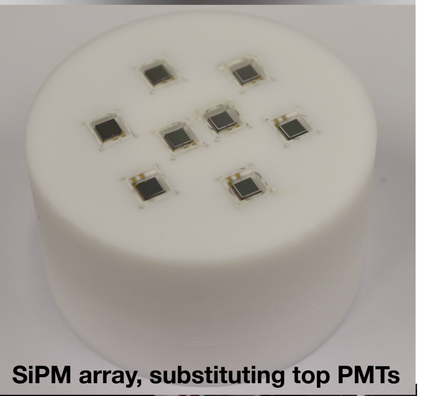


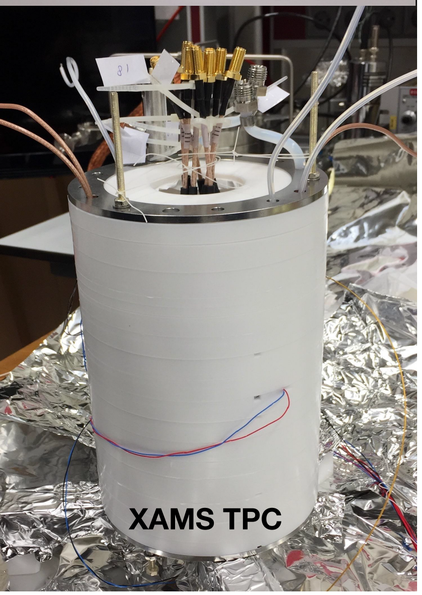
Search for Light Dark Matter Interactions Enhanced by the Migdal Effect or Bremsstrahlung in XENON1T, Phys. Rev. Lett 123, 241803 (2019), arXiv:1907.12771

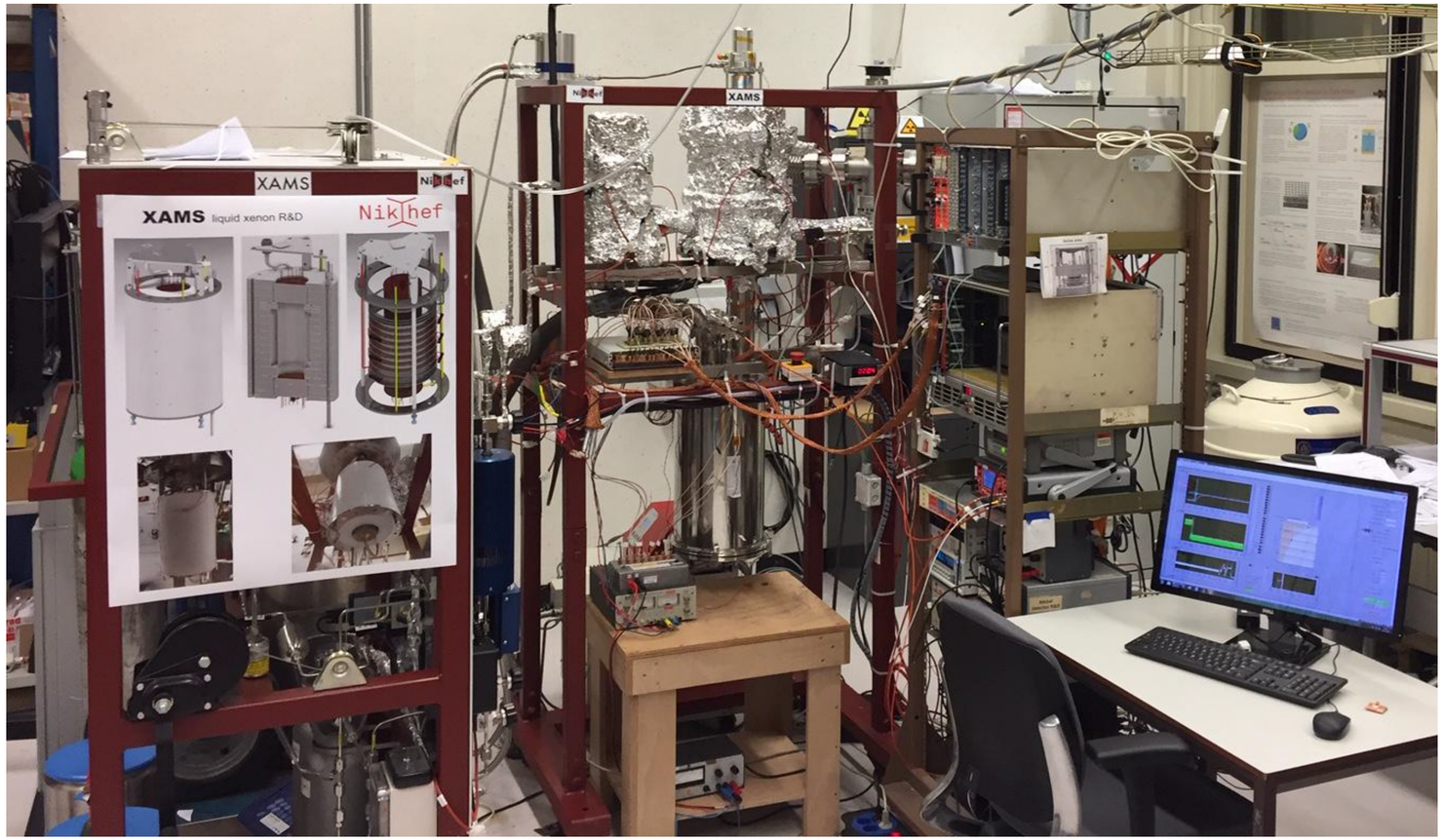
XAMS: Local LXe R&D

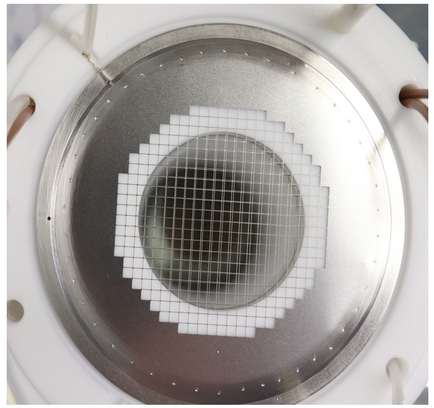
Alvaro Loya Villalpando [MSc]

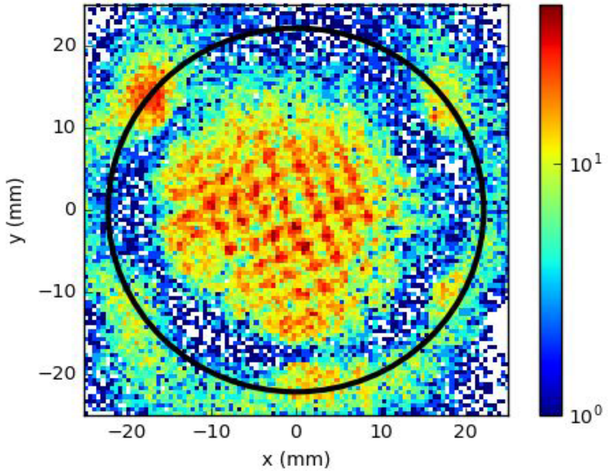










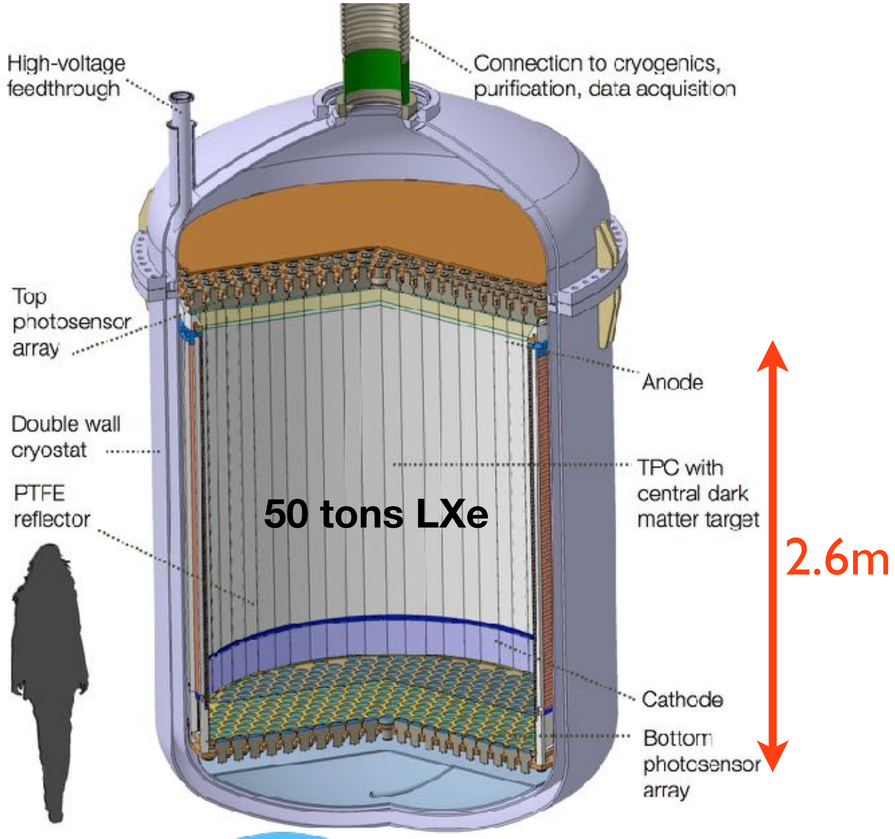


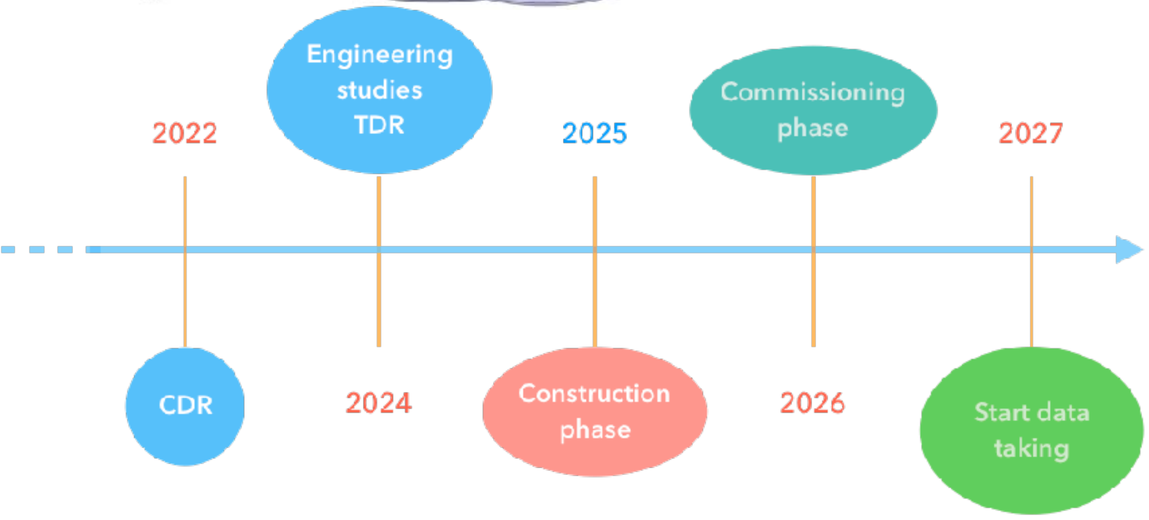
R&D for DARWIN:

- Using SiPMs for position reconstruction, substituting PMTs in top array
  - First results look promising
- Better single- vs multi-site discrimination: important for DM and 0ν2β searches

Field dependence of electronic recoil signals in a dual-phase liquid xenon time projection chamber,
E. Hogenbirk, M.P. Decowski, K. McEwan, A.P. Colijn, JINST 13 (2018) P10031, arXiv:1807.07121

DARWIN: Low-BG, low-threshold APP detector



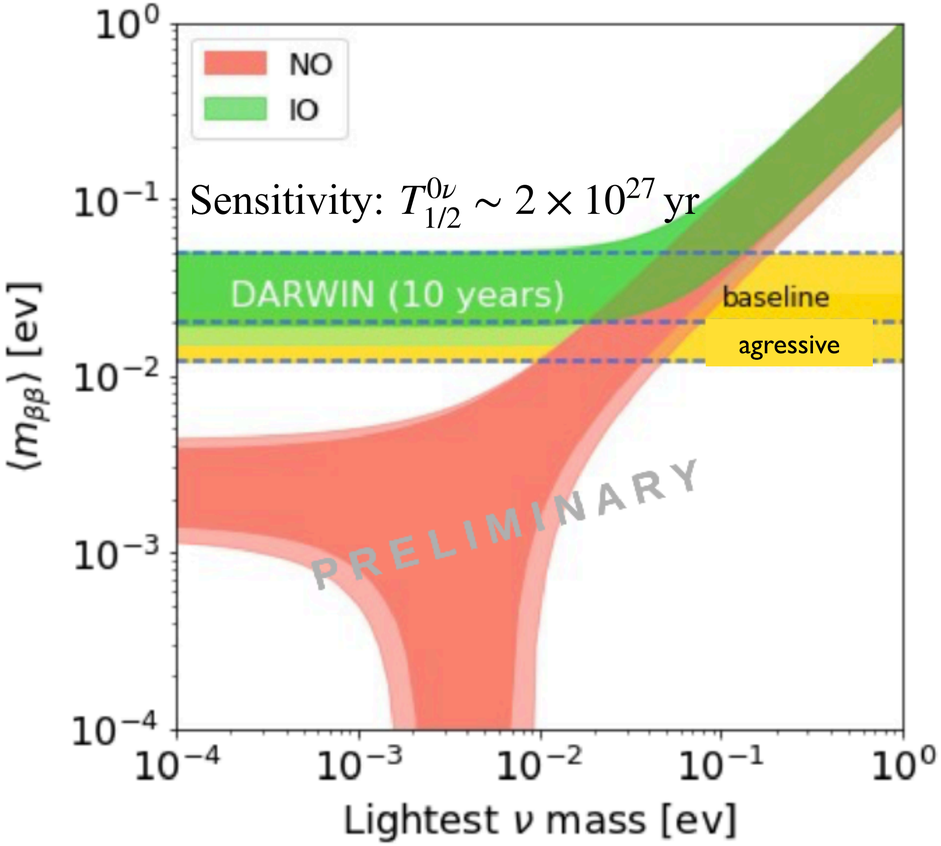


- **WIMP searches**
  - Spin-independent
  - Spin-dependent and inelastic interactions
- **Solar axions and galactic axion-like particles (ALPs)**
  - Alternative dark matter candidates
  - Coupling to electrons via axio-electric effect
- **Supernova neutrinos**
  - Sensitivity to all neutrino flavors (via CNNS)
  - Complementarity to large-scale neutrino detectors
- **Coherent neutrino-nucleus scattering (CNNS)**
  - Predicted by SM, *only very recently observed!*
- **Low-energy solar neutrinos: pp, ^{7}Be**
  - Test/improve solar model, test neutrino models
- **Neutrinoless double beta decay**
  - Lepton number violating process, effective Majorana mass
  - No enrichment in ^{136}Xe required

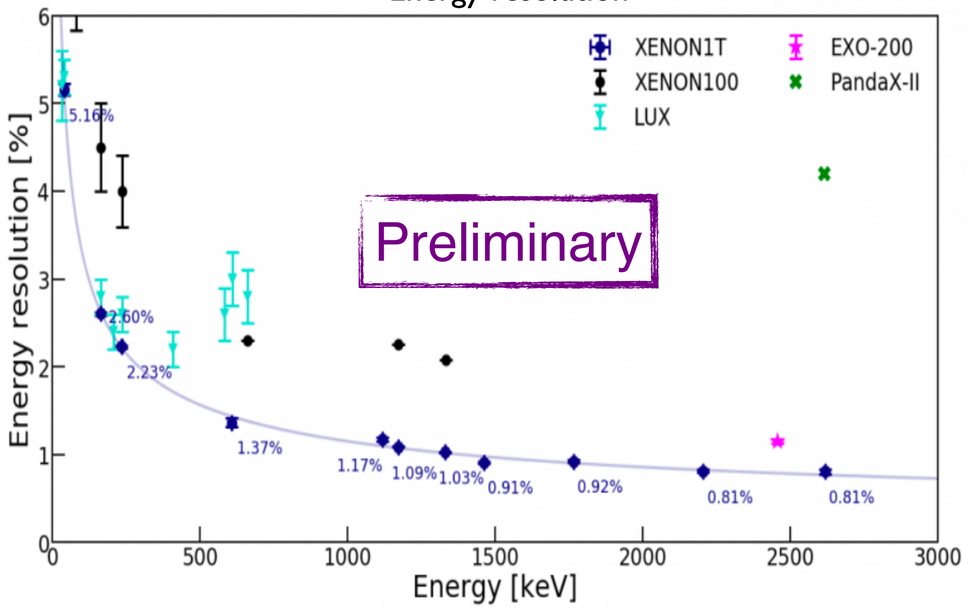
As detector size increases physics channels open up

DARWIN 0ν2β Study

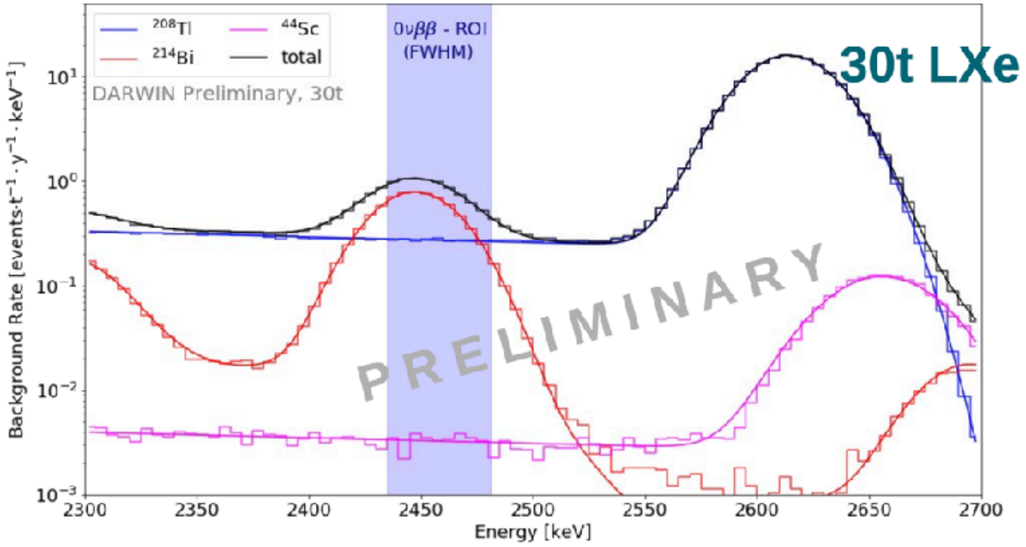
- Excellent DM detector
- 40t LXe target contains 3.5t of ^{136}Xe
  - Excellent energy resolution
  - Fiducialization using "cheap" natural LXe



Energy resolution



External Backgrounds



DARWIN: The low-background, low-threshold Astroparticle Physics Observatory

Blogs!

- Blogs at http://www.nikhef.nl/blog
  - Auke-Pieter Colijn on his work on XENON
  - Bouke Jung on his 6 month KamLAND internship in Japan

1 april 2019

Weekblog Gran Sasso: Nieuwe collega's

Nikhef werkt mee aan de bouw van de nieuwe XENONnT-detector voor donkere materie op Gran Sasso in Italië. Technisch coördinator Auke-Pieter Colijn is vrijwel wekelijks ondergronds in Italië...

Lees meer →

18 maart 2019

Weekblog Gran Sasso: Glansheid

Nikhef werkt mee aan de bouw van de nieuwe XENONnT-detector voor donkere materie op Gran Sasso in Italië. Technisch coördinator Auke-Pieter Colijn is vrijwel wekelijks ondergronds in Italië...

Lees meer →

13 maart 2019

Beyond the blinding background: the future of low-background particle physics (part 1)

(This blog post was originally posted on Bouke's personal blog. Bouke is a master student in the Nikhef Dark Matter group and is in Japan for an internship..

Lees meer →

11 maart 2019

Weekblog Gran Sasso: Uitgelachen en toegejuicht

Nikhef werkt mee aan de bouw van de nieuwe XENONnT-detector voor donkere materie op Gran Sasso in Italië. Technisch coördinator Auke-Pieter Colijn is vrijwel wekelijks ondergronds in Italië...

Lees meer →

1 maart 2019

WEEKBLOG Gran Sasso: XENON-cowboy

Nikhef werkt mee aan de bouw van de nieuwe XENONnT-detector voor donkere materie op Gran Sasso in Italië. Technisch coördinator Auke-Pieter Colijn is vrijwel wekelijks ondergronds in Italië en houdt een blog bij over de...

Lees meer →

25 februari 2019

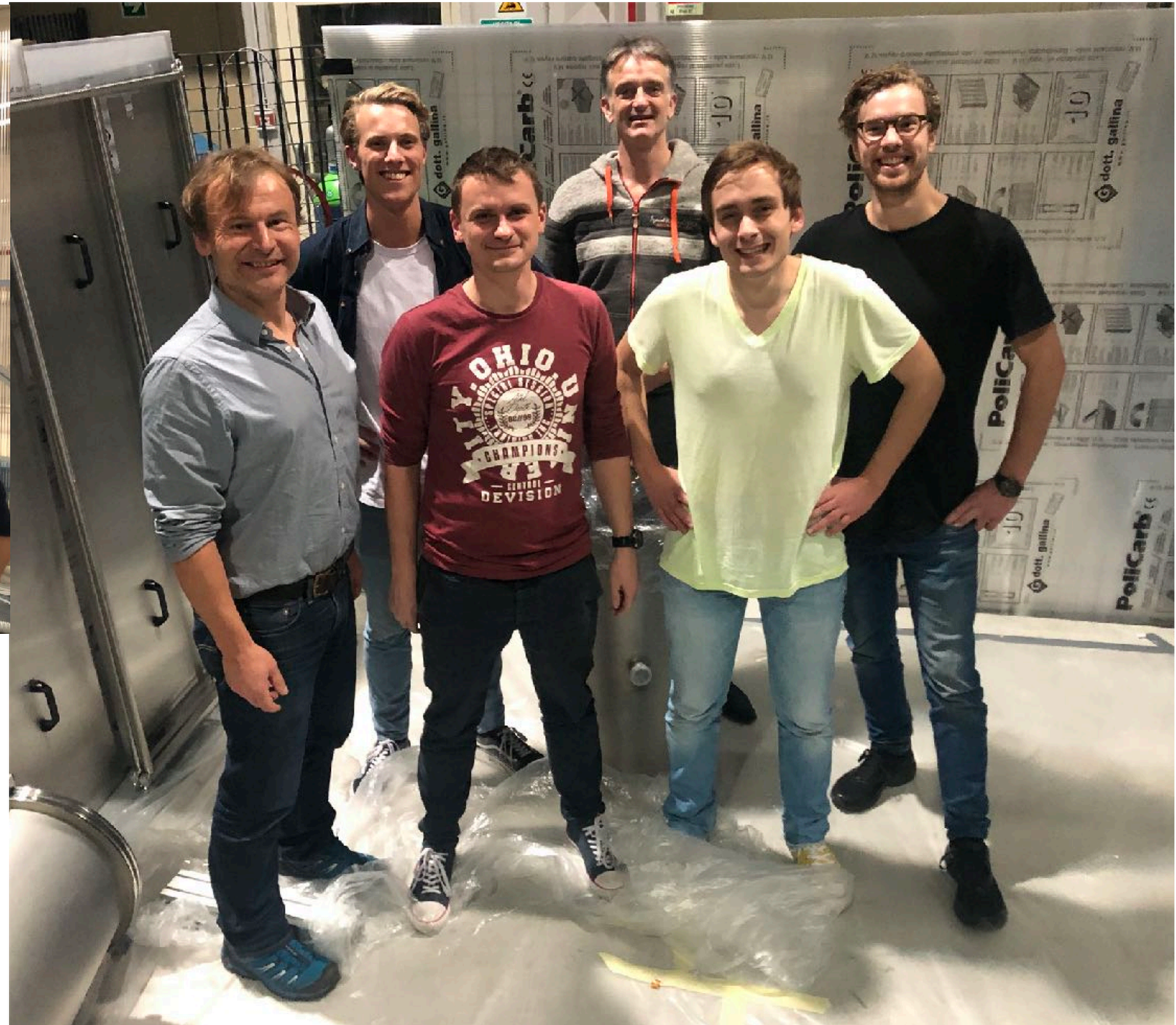
WEEKBLOG Gran Sasso: Opmeten van XENON1T

Nikhef werkt mee aan de bouw van de nieuwe XENONnT-detector voor donkere materie op Gran Sasso in Italië. Technisch coördinator Auke-Pieter Colijn is vrijwel wekelijks ondergronds in Italië...

Lees meer →

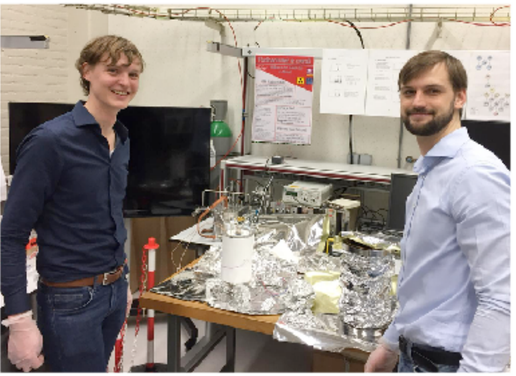

Our BSc student Maricke spent
the summer at LNGS
BE FREE

MSc Students Working at LNGS



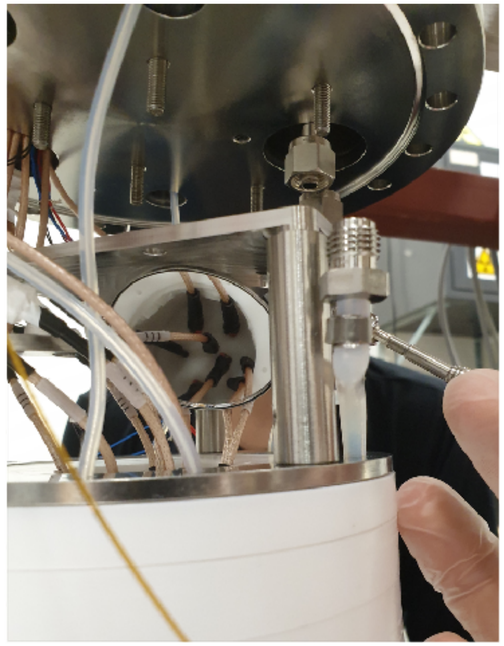
Last week:
Cleaning, cleaning, cleaning…

Joran



Dear Diary:

My AHA moment came when we finally realized that we could connect the SiPMs [in XAMS] with a mirror.



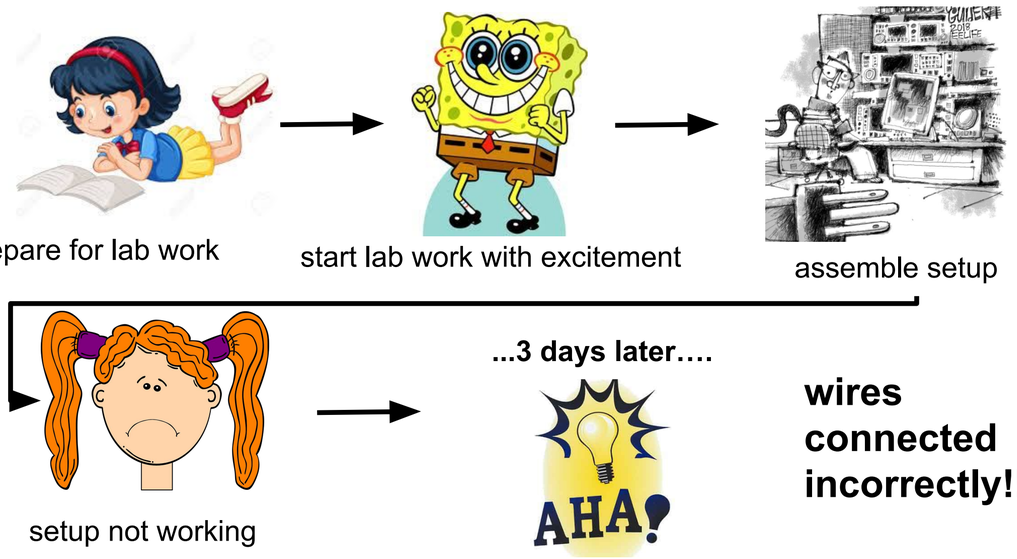
The real "Aha" moment was when realizing that we will be connecting a 4000000 gr / 434 gr = 10 000x larger detector this year - without a mirror!

Alvaro

Dear Diary:

My AHA moment came when we put together XAMS with the cathode and anode reversed and forgot to swap the connections on the power supply - HAHA !

Lab Work: An Example



Frederick

Dear Diary:

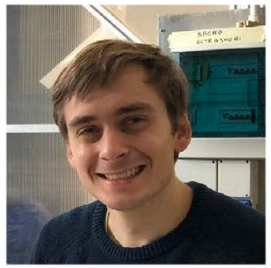
"My AHA moment happend during a security bootcamp I went to this year. I learned during this bootcamp how to build backdoors into router firmware, how to read data from chips, how to set up a Bluetooth proxy connection to take over Bluetooth devices, how to use an old TV antenna and be able to sniff radio data over the air etc. However, my aha was that I realized how day to day products that we assume are 'secured', are not safe at all. That all you need is the right tools and you can take over car radios, phones, headsets and even medical devices such as pacemakers!"

Lucas

Dear Diary:

My AHA moment was at the start of the last academic year, when I mastered the index-notation of Christoffel symbols / Rieman Tensors... that took a while!

Gijs



Dear Diary:

My Aha moment came last week at LNGS, when I realized that the cleanroom can have gaps - initially I thought: why clean everything when the cleanroom is open to the outside. But the pressure difference will of course not let any outside air in!

Auke-Pieter

Dear Diary:

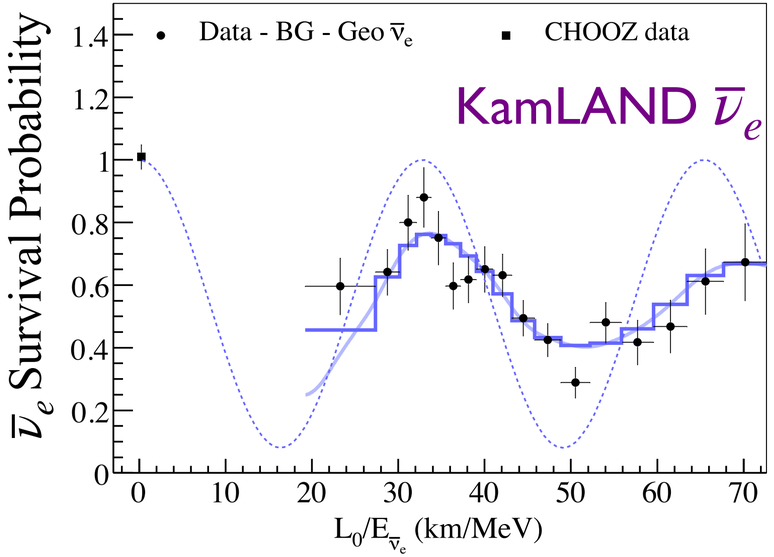
I didn't have many scientific AHA moments in the past year, but:

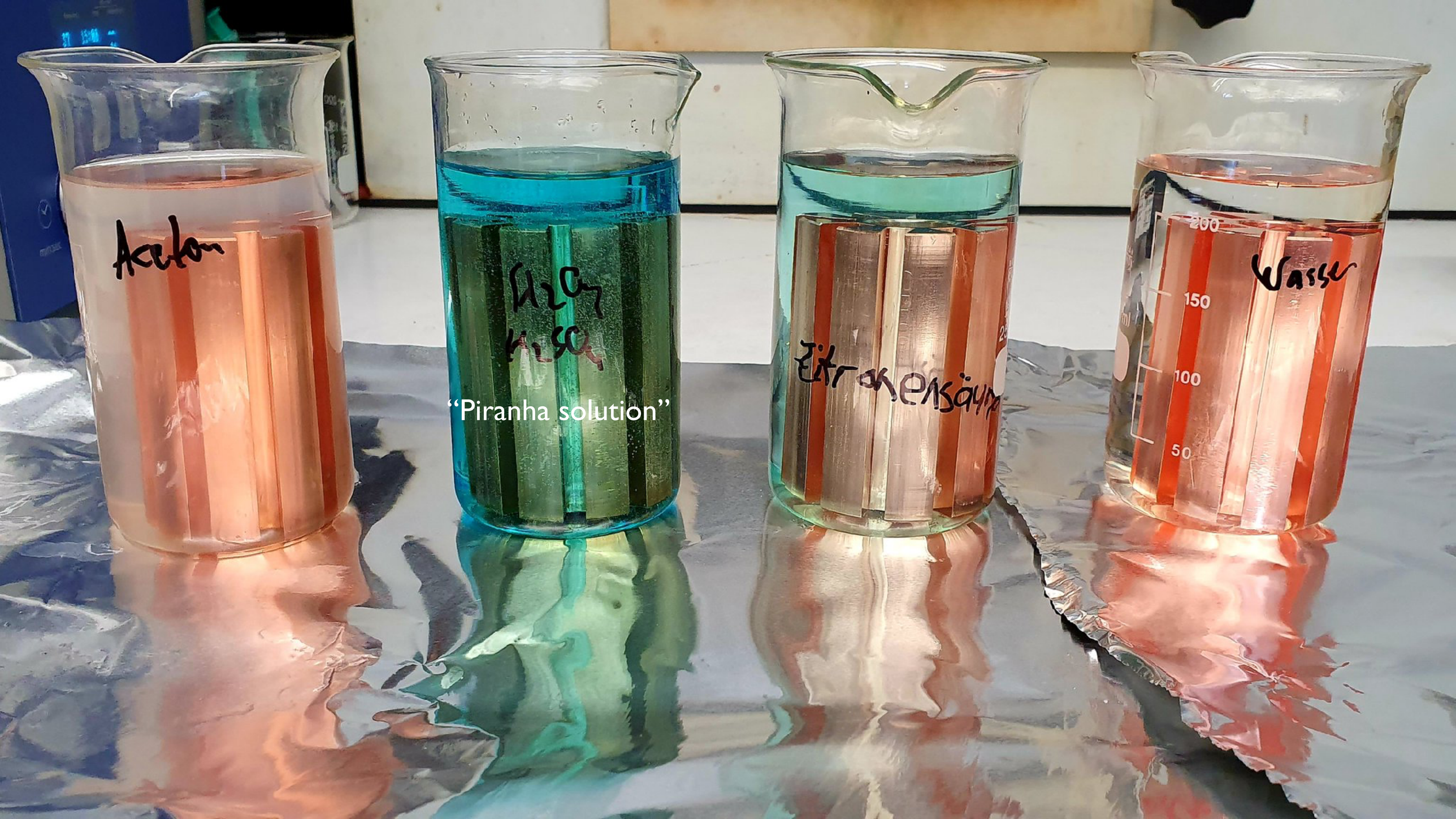
- I realized in September that I would not be finished as the XENONnT Technical Coordinator in January
- During our PTOLEMY meeting in December, I realized that tritium migrates through stainless steel tubes - more of an "Oh-Oh" than "AHA"

Patrick

Dear Diary:

I experienced the AHA moment twice: last week, when I was preparing the Neutrino Topical Lectures and (more importantly) in 2004 when I was making the KamLAND "L/E plot" demonstrating that $\bar{\nu}_e$ disappear and reappear!





"Piranha solution"