GridPix – better charge readout for dark matter search experiments?

MC-PAD Project P5: Time Projection Chamber with Micro Pattern Gaseous Detector readout

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Nikhef, Amsterdam
Detector R&D

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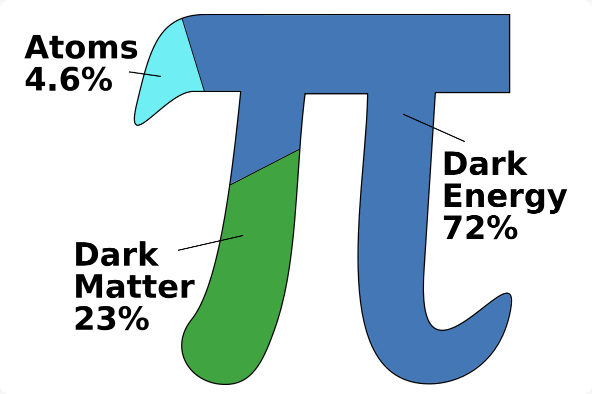
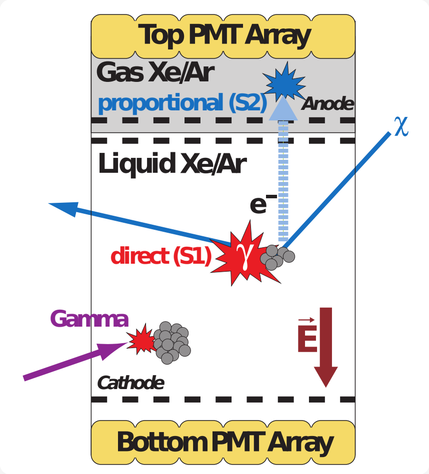
Dark matter



hypothetical candidate: weakly interacting massive particle (WIMP)

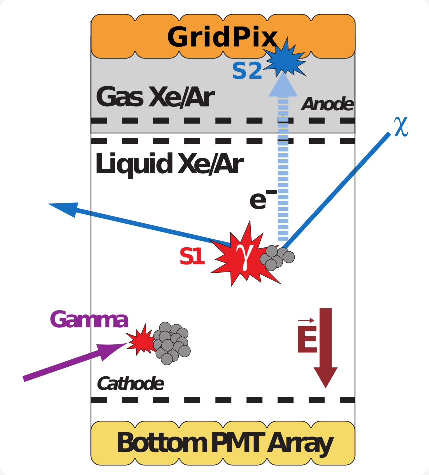
WIMP detection with noble gases



dual-phase noble gas TPC

$$\left.\frac{S2}{S1}\right|_{\text{nuclear recoil}} \neq \left.\frac{S2}{S1}\right|_{\text{electronic recoil}}$$

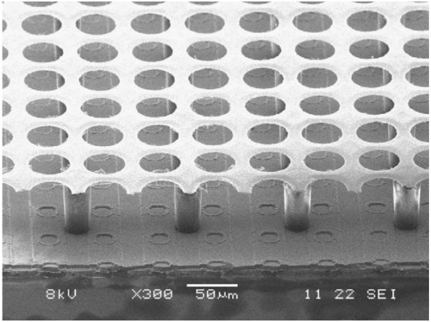
Alternative: direct charge readout



DARWIN

- candidate technology within DARWIN R&D (Dark matter WIMP search with noble liquids) arXiv:1012.4767
- less S1 signal vs. high electron efficiency (better S2 resolution)
- sensitivity increase for low energy events

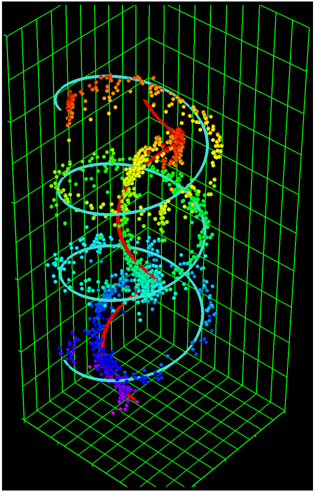
The GridPix detector



- Micromegas-like mesh, 1 µm Al
- insulating spacer, 50 µm photoresist
- spark protection layer, 8 µm silicon-rich SiN
- Timepix readout chip

GridPix features

- 65k pixels on 14 mm × 14 mm
- single electron detection efficiency $> 98\,\%$
- $x - y$ resolution $< 20\,\mu\text{m}$
- Timepix chip ⇒ µTPC
- threshold 1100 electrons (at room temperature)



GridPix in dual-phase noble gas

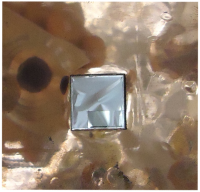
Main challenges

- low temperature: $T_{\ell\mathrm{Ar}} = -186\,°\mathrm{C}$, $T_{\ell\mathrm{Xe}} = -108\,°\mathrm{C}$
  - thermal stress on material
  - high gas pressure
  - lower electronic noise of Timepix
- pure gas
  - material with low/no outgassing
  - no quencher allowed? $\Rightarrow$ higher discharge probability $\Rightarrow$ lower achievable gain

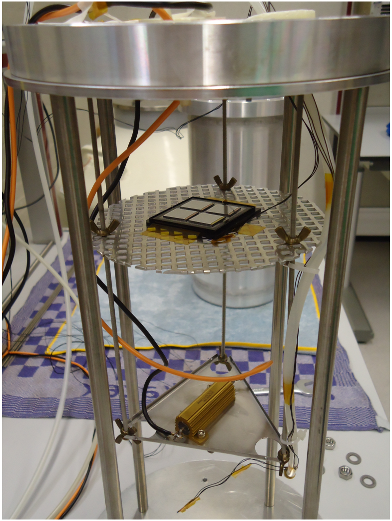
Operational test in an Ar cryostat

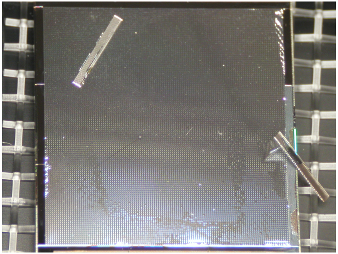
- ArDM test cryostat at CERN (Rubbia group)
- operation in high purity Ar at room temperature and close to $T_{\ell\mathrm{Ar}} = -186\,^\circ\mathrm{C}$
- lessons learned:
  - stably operating GridPix in quencher-free argon at room temperature
  - GridPix amplification stage works down to $-186\,^\circ\mathrm{C}$

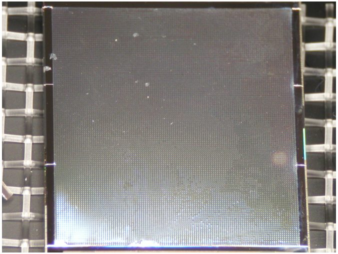
  $\Rightarrow$ no show-stopper: concept works
- but improvements needed:
  - improvements on material robustness
  - noise of Timepix at low temperatures
  - gain in pure xenon (at room temperature and at $-110\,^\circ\mathrm{C}$)



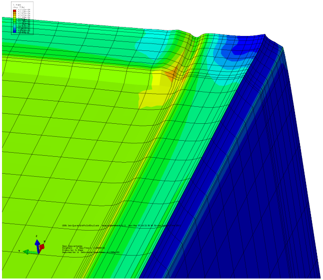
Robustness of GridPix at $-130\,^{\circ}C$

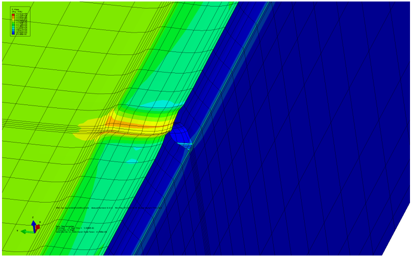




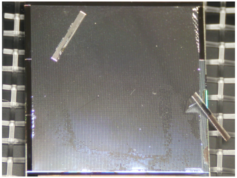


Simulating stress

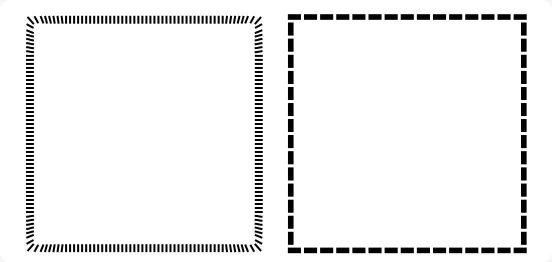


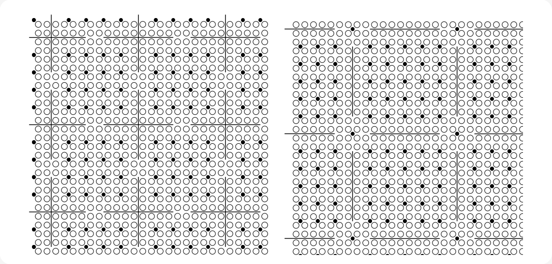


⇒ reduce/avoid stress by changing structure of grid support



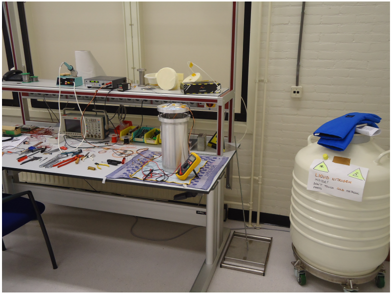
New photoresist structures

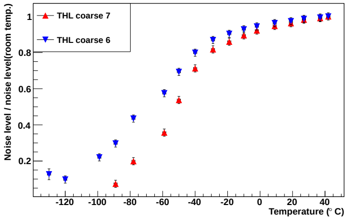




- reduce lateral stress on edges (“*dykes*”)
- reduce radial stress of Al grid
- test structures to be produced at IZM, Berlin
- 2–3 dummy wafers (8”) à 100 chips

Electronic noise of the Timepix chip



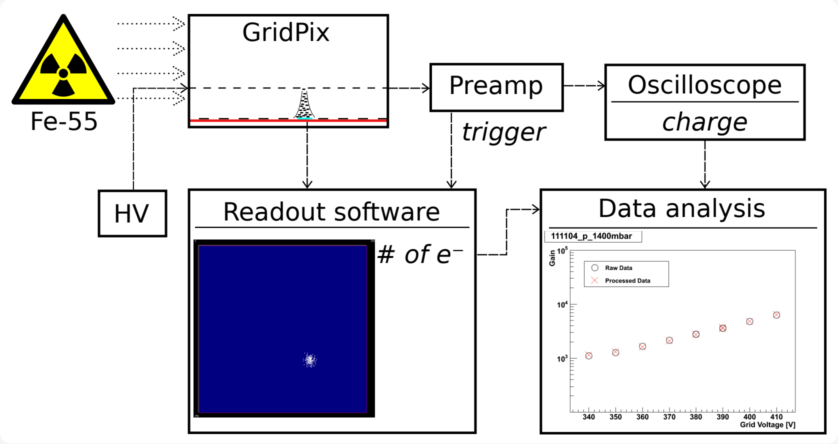


- scans of threshold DAC

⇒ noise level

- normalised to values at chip's "room temperature" $\simeq 40\,^\circ\mathrm{C}$
- cooled down to $-130\,^\circ\mathrm{C}$

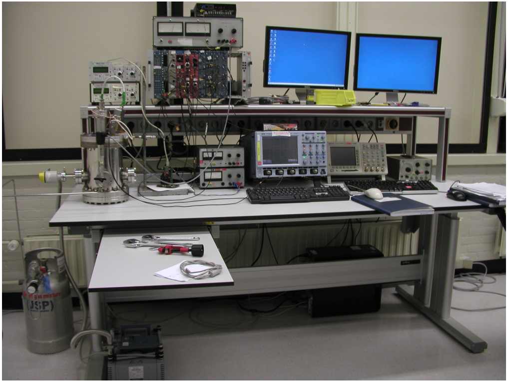
Gas gain measurement setup

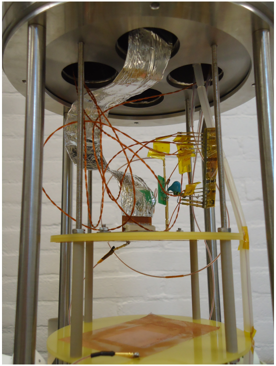


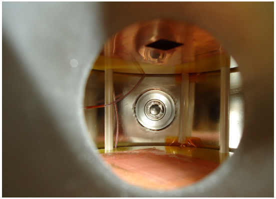
- reduced noise on the preamp < 12 mV
- increased data collection rate: 35 frames/s

Setup in real life

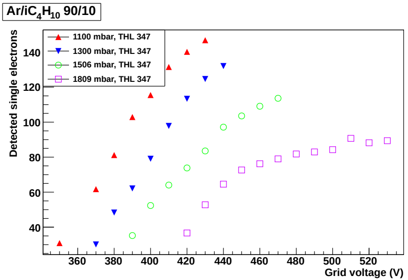
- gain measurements at room temperature
  - reference gas Ar/iC_4H_{10} 90/10
  - without quencher: Ar 4.7

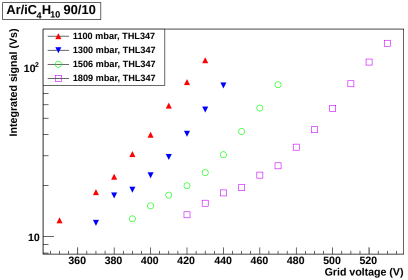




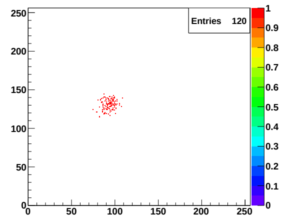


Reference gas Ar/iC_4H_{10} 90/10

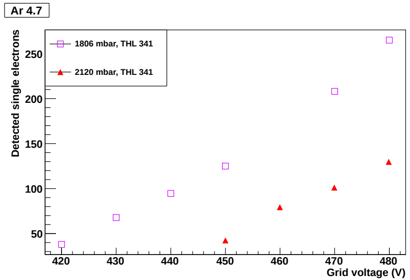


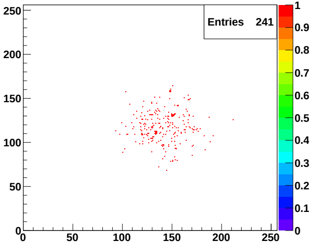


- detected electrons = hit pixels
- integrated signal from preamp on grid
- calibration is work in progress
- example event: $p = 1506\,\text{mbar}$, $V_{\text{grid}} = 470\,\text{V}$



Getting clean: 99.997 % purity Ar





- no quencher gas

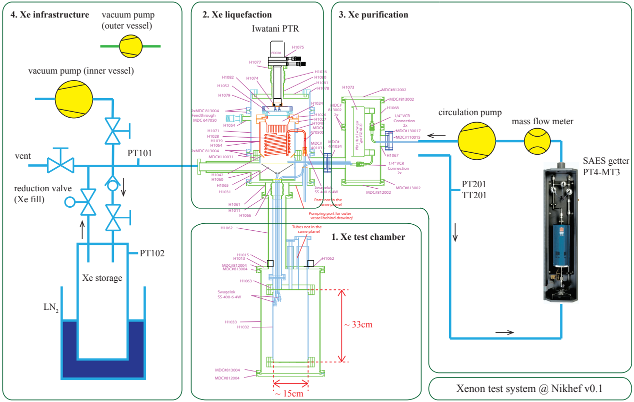
$\Rightarrow$ less electron attachment during drift

$\Rightarrow$ more hit pixels

- example event: $p = 1806\,\text{mbar}$, $V_{\text{grid}} = 470\,\text{V}$

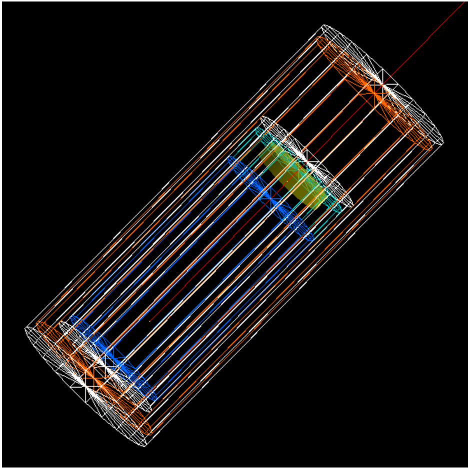
Look out! The outlook

- gain measurements at room temperature
  - pure(r) argon (Ar 6.0)
  - pure xenon
- for dual-phase Xe: XAMS – a xenon facility in Amsterdam



XAMS – detector simulation

- simulate detector response in GEANT4
- aid decision for parts of the TPC
- implement and test NEST toolkit

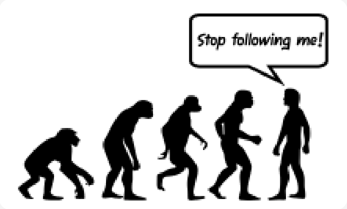


To be continued...

- Achievements
  - studied improvements of GridPix amplification structure
  - measured noise of Timepix chip at low temperatures
  - collected vast amount of data with reference gases
  - took data at higher gas density
- Projects
  - build and test thermally robust GridPix prototypes
  - measure gain in xenon
    - at room temperature: Xe 5.0 and Xe/CH_4 98/2
    - in dual-phase with XAMS
  - implement GEANT4 framework for the XAMS TPC

My personal evolution

May 2010: start of contract as MC-PAD ESR and PhD at Nikhef (promoter: Els Koffeman, supervisor: Jan Visser/Niels van Bakel)



- Sept 2010 (JSI): my first MC-PAD event (Ljubljana), *"There is also a future outside academia!"*
- March 2011 (CERN): my favourite MC-PAD training event, *training for detector people on cutting edge detector technology*
- Nov 2011 (PSI): my most valuable training for the "real" world, *how to sell yourself (in a good way)*
- spring 2012: my first supervision of a B.Sc. project

The MC-PAD network

Looking back at it...

- very good interaction with different people in the "same" field

⇒ excellent network

- a lot of opportunities thanks to generous funding
  - training events = meet and discuss
  - travels = conferences/workshops
- unfortunately few hands-on trainings (missed first two events)

...and beyond

- finish my PhD (until "May 2014"), incl. writing thesis
- start looking for a post-doc position/fellowship (gaseous detectors and/or direct dark matter search)
- defend my thesis
- ...

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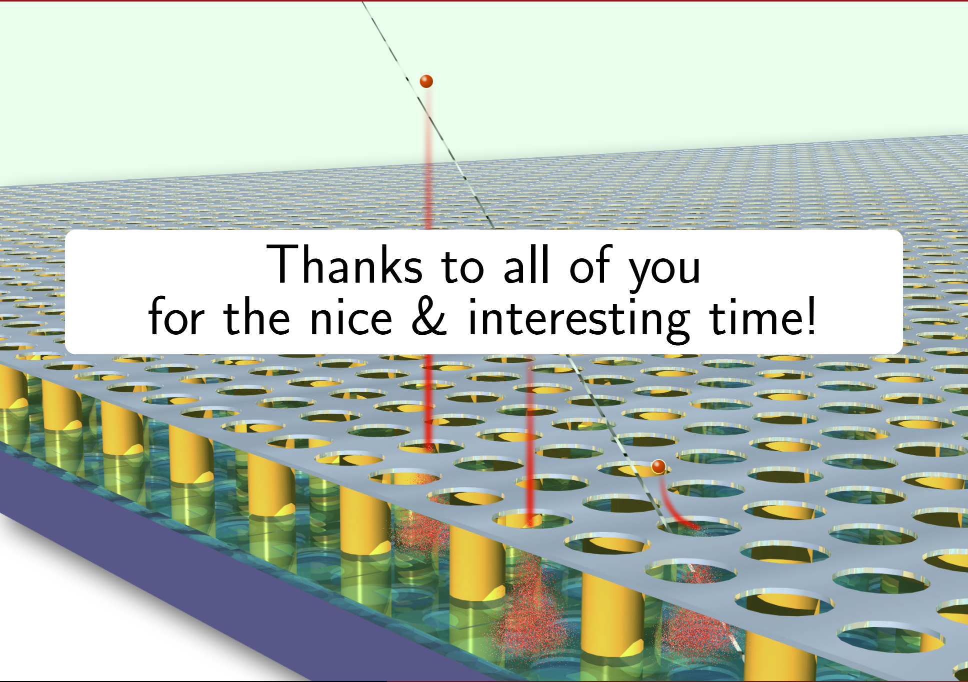
- ...
- live happily ever after



Thanks to all of you for the nice & interesting time!