Operating the GridPix detector in dark matter search experiments

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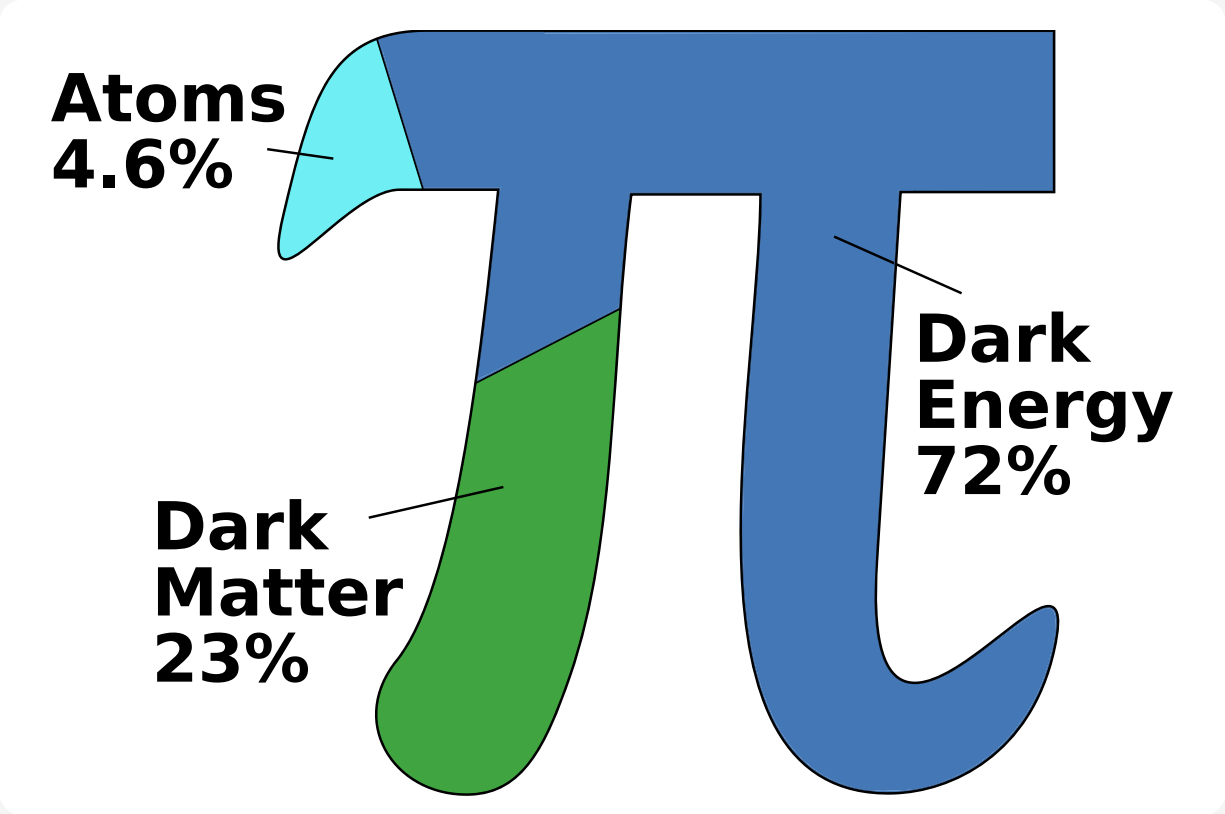
Detector R&D

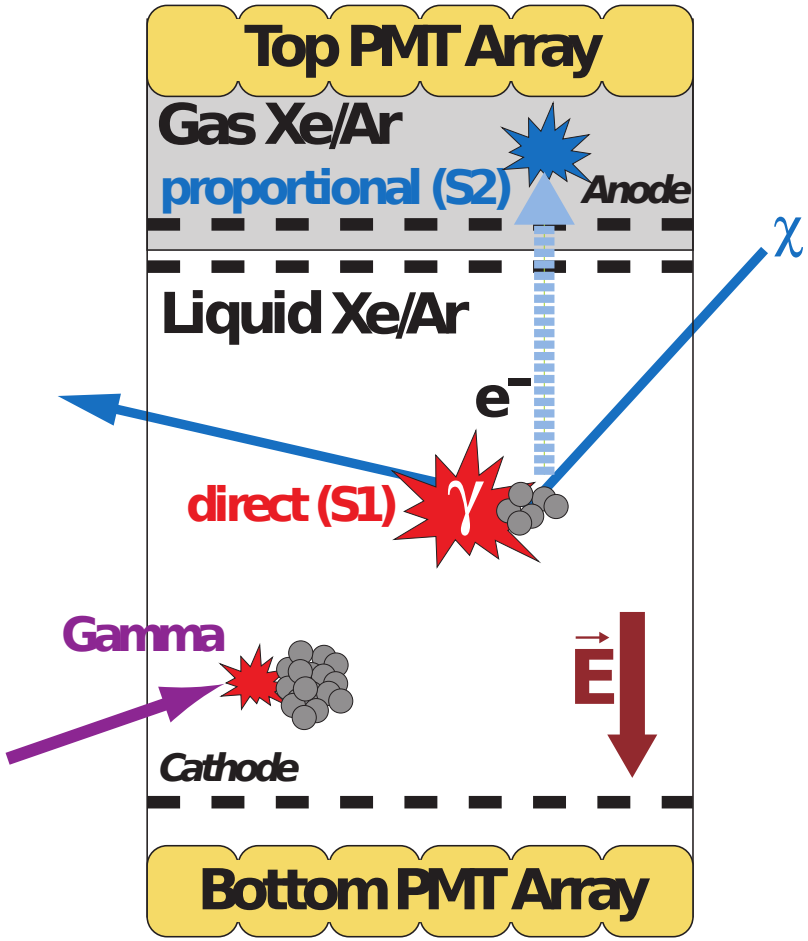
May 25, 2012

Dark matter



hypothetical candidate: weakly interacting massive particle (WIMP)

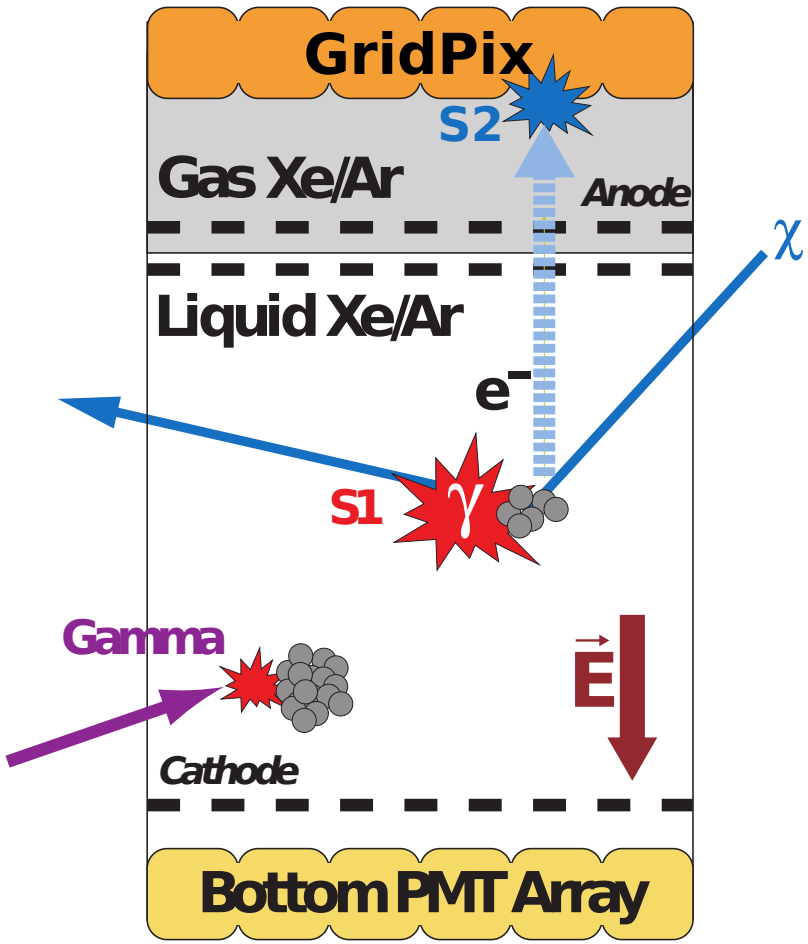
WIMP detection with noble gases



dual-phase noble gas TPC

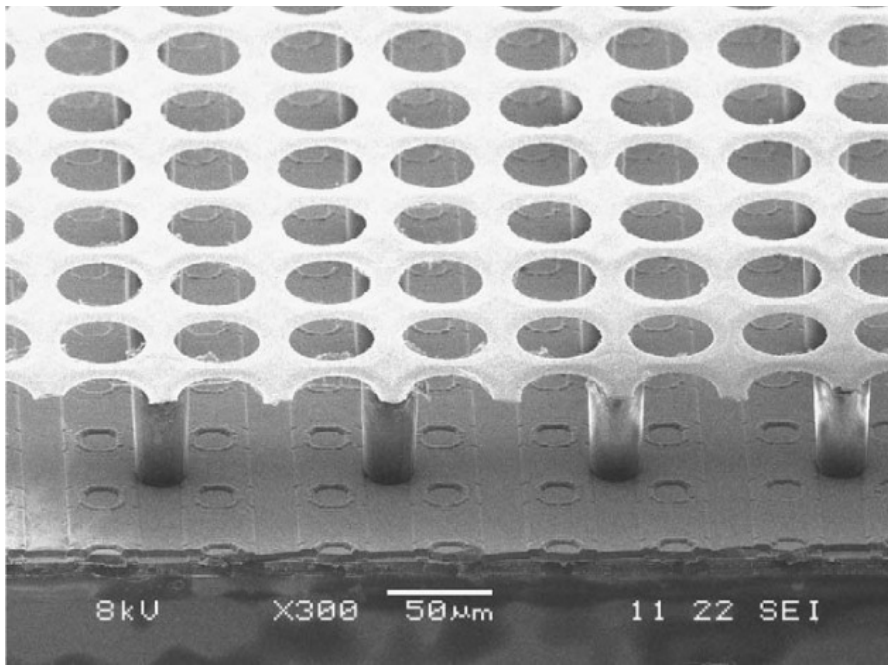
$$\left.\frac{S2}{S1}\right|_{\text{nuclear recoil}} \neq \left.\frac{S2}{S1}\right|_{\text{electronic recoil}}$$

Alternative: direct charge readout



- 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)

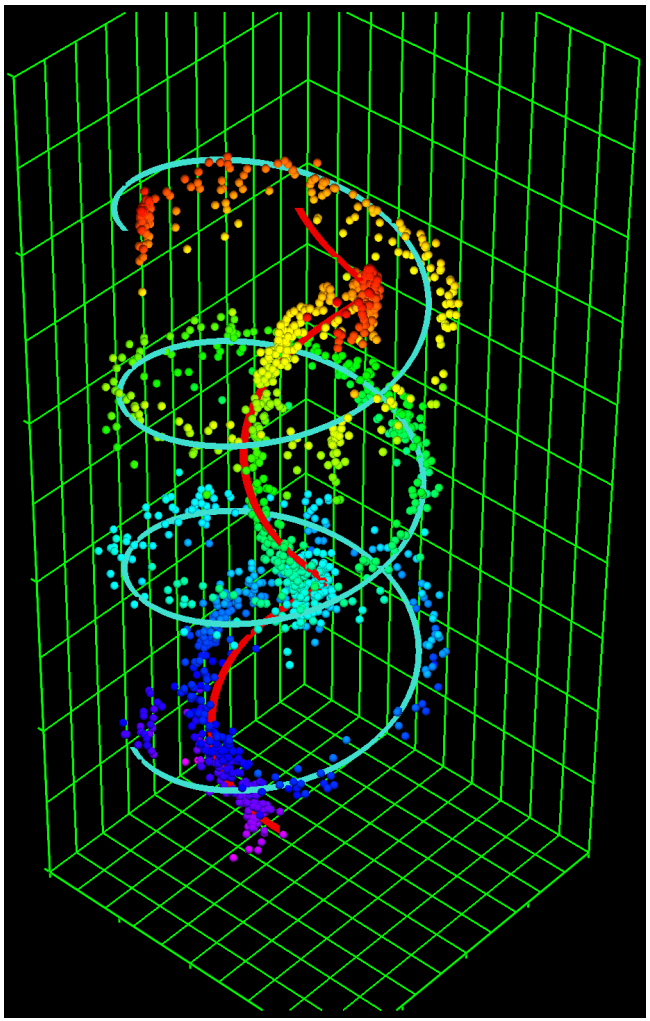
The GridPix detector



- 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 $\times$ 14 mm
- single electron detection efficiency $> 98\,\%$
- $x - y$ resolution $< 20\,\mu$m
- Timepix chip $\Rightarrow$ μTPC
- threshold 1100 electrons (at room temperature)



GridPix in dual-phase noble gas

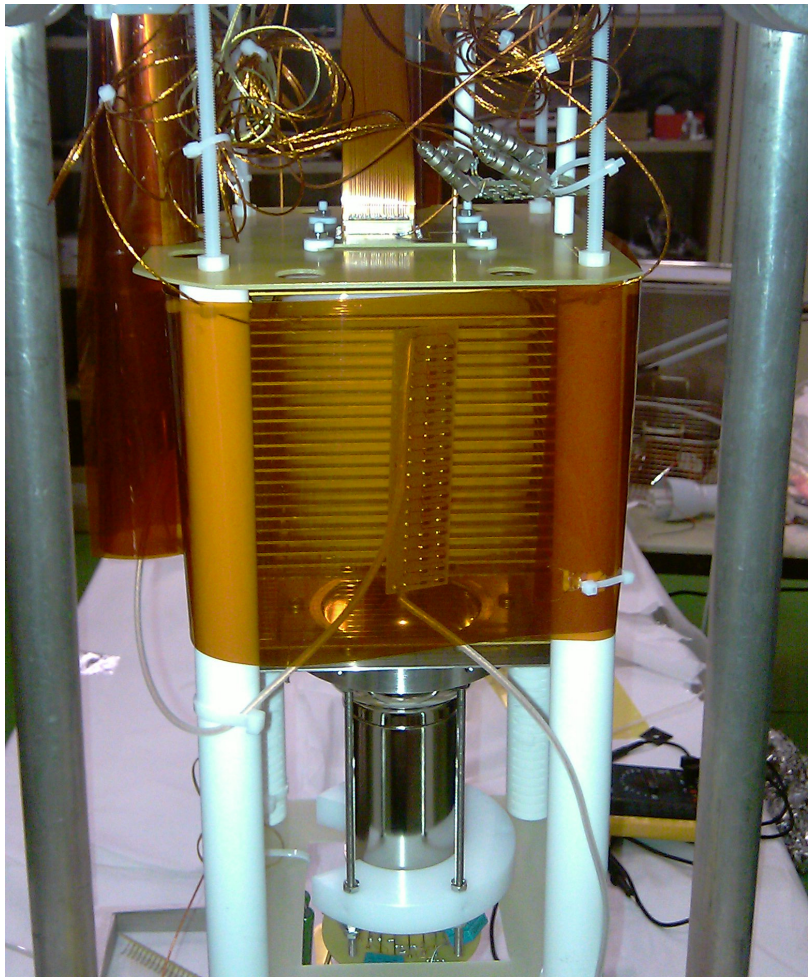
Main challenges

- cryogenic
  - thermomechanical stress
  - high gas density

$T_{\ell Xe}$	$T_{\ell Ar}$	$T_{\ell N_2}$
165 K	87 K	77 K
−108 °C	−186 °C	−196 °C

- pure noble gas
  - no quencher
  - materials must not outgas

The ArDM test cryostat

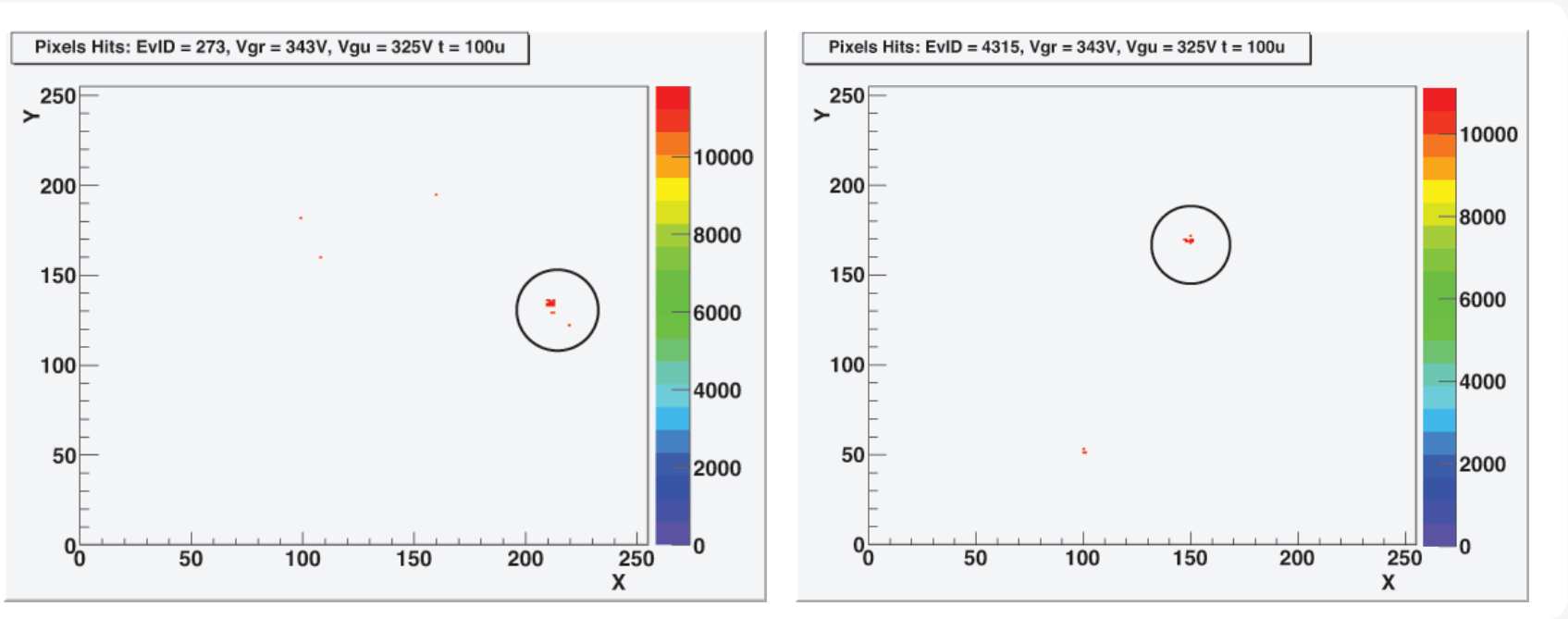


Measure in pure Ar (1 ppm impurity level)

1. at room temperature
2. cooldown to $T_{\ell \mathrm{Ar}}$ (gas phase)
3. add liquid (dual-phase)

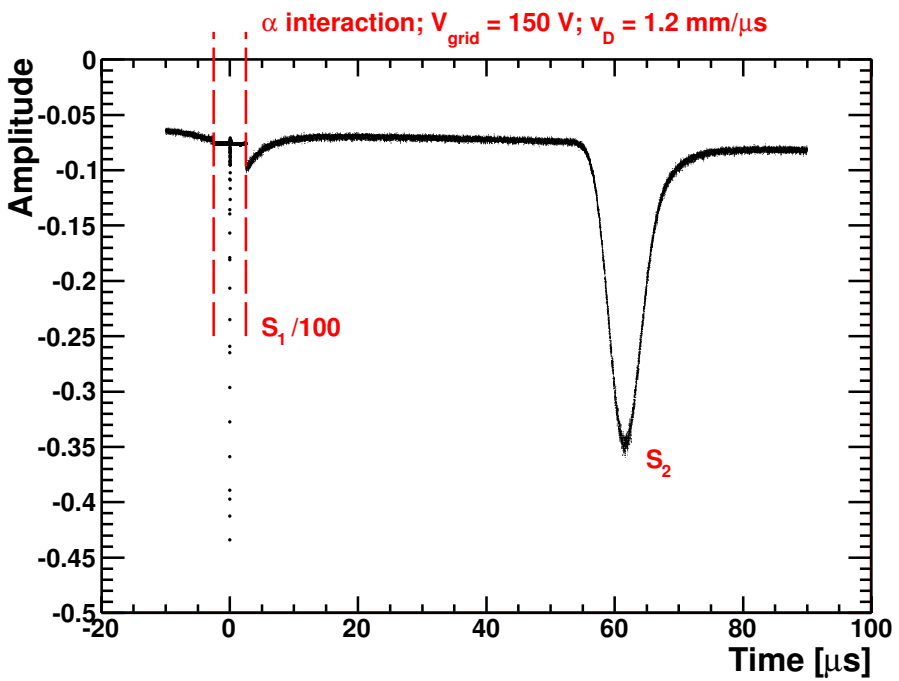
Ar gas at room temperature

- recorded events of ^{55}Fe photons (5.9 keV) in quencher-free Ar at room temperature (triggered by PMT)

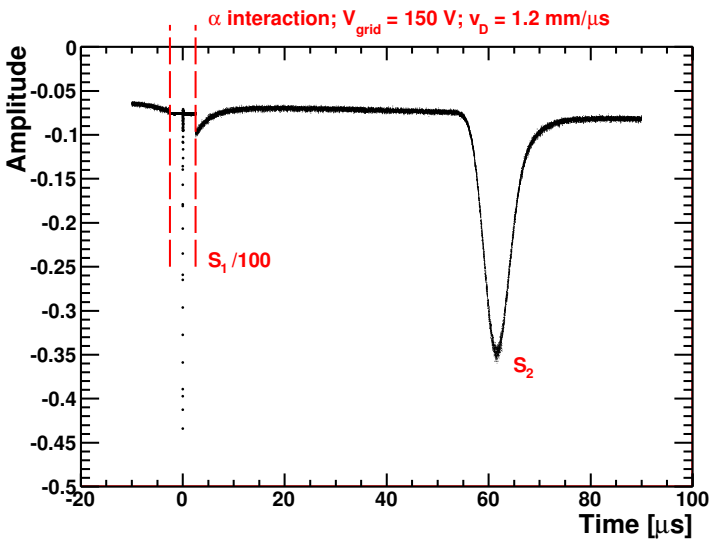


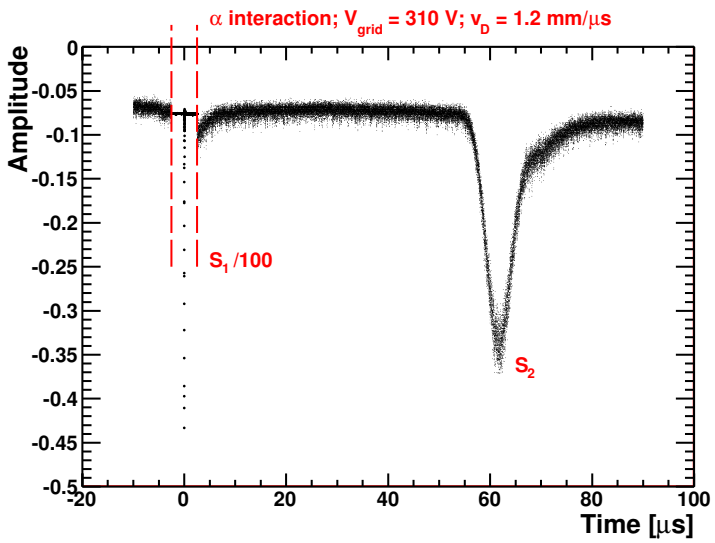
Ar gas at 87 K

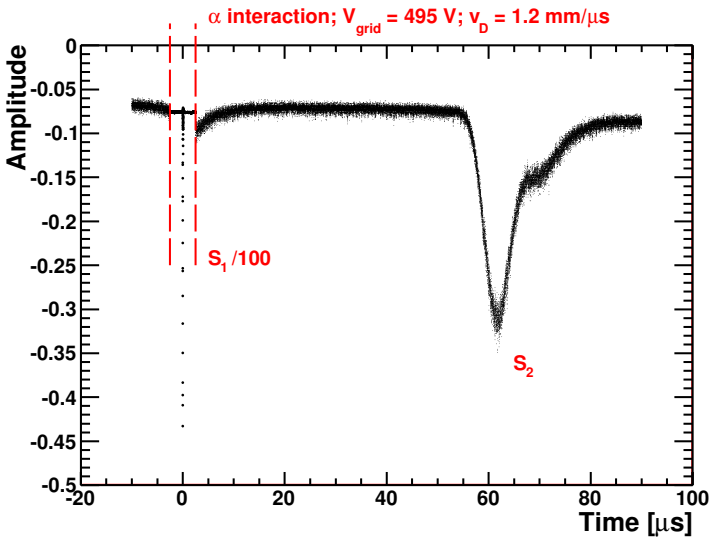
- low gain/no signal in pure Ar at $T_{\ell\mathrm{Ar}}$
- amplification works at $T_{\ell\mathrm{Ar}}$
- PMT spectrum of ^{241}Am α source (59.6 keV):

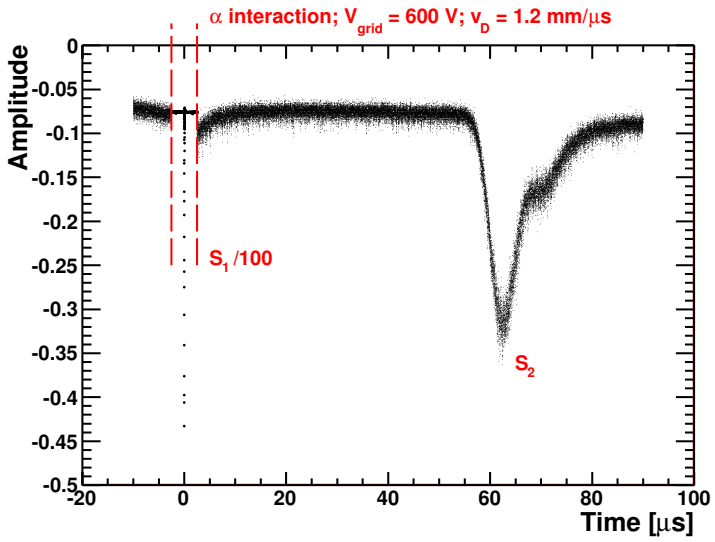


Ar gas at 87 K

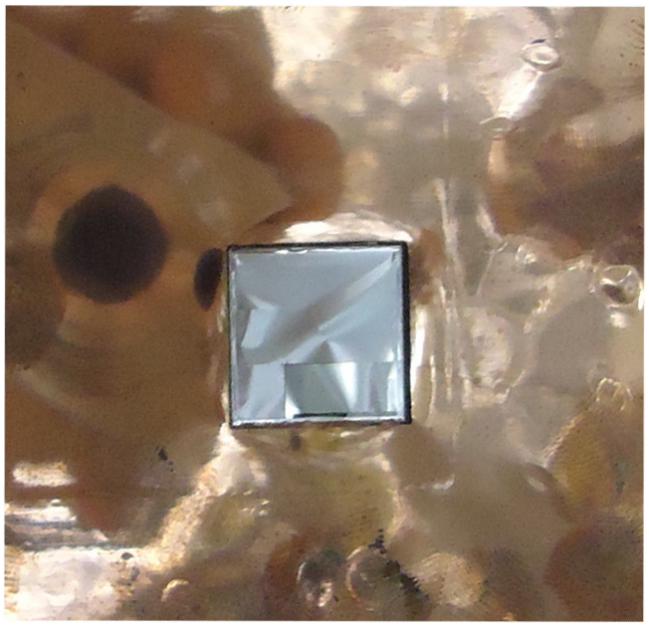

α interaction; V_grid = 150 V; v_D = 1.2 mm/μs
Amplitude
Time [μs]
S1 /100
S2

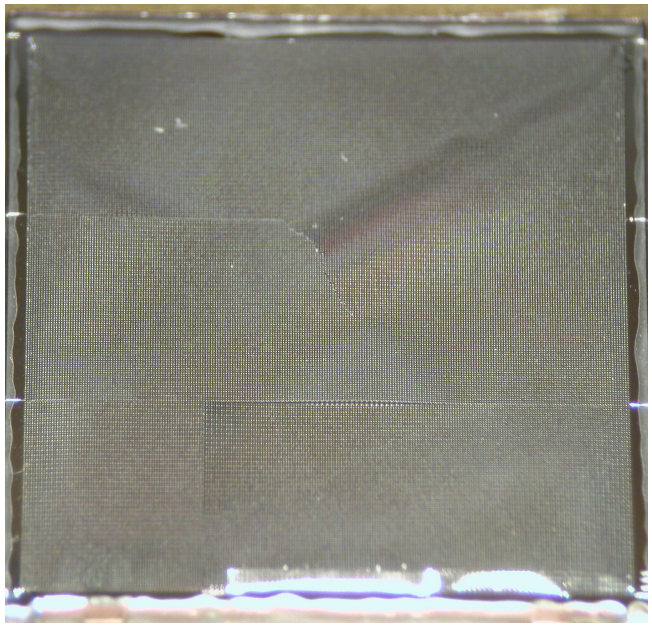

α interaction; V_grid = 310 V; v_D = 1.2 mm/μs
Amplitude
Time [μs]
S1 /100
S2


α interaction; V_grid = 495 V; v_D = 1.2 mm/μs
Amplitude
Time [μs]
S1 /100
S2


α interaction; V_grid = 600 V; v_D = 1.2 mm/μs
Amplitude
Time [μs]
S1 /100
S2

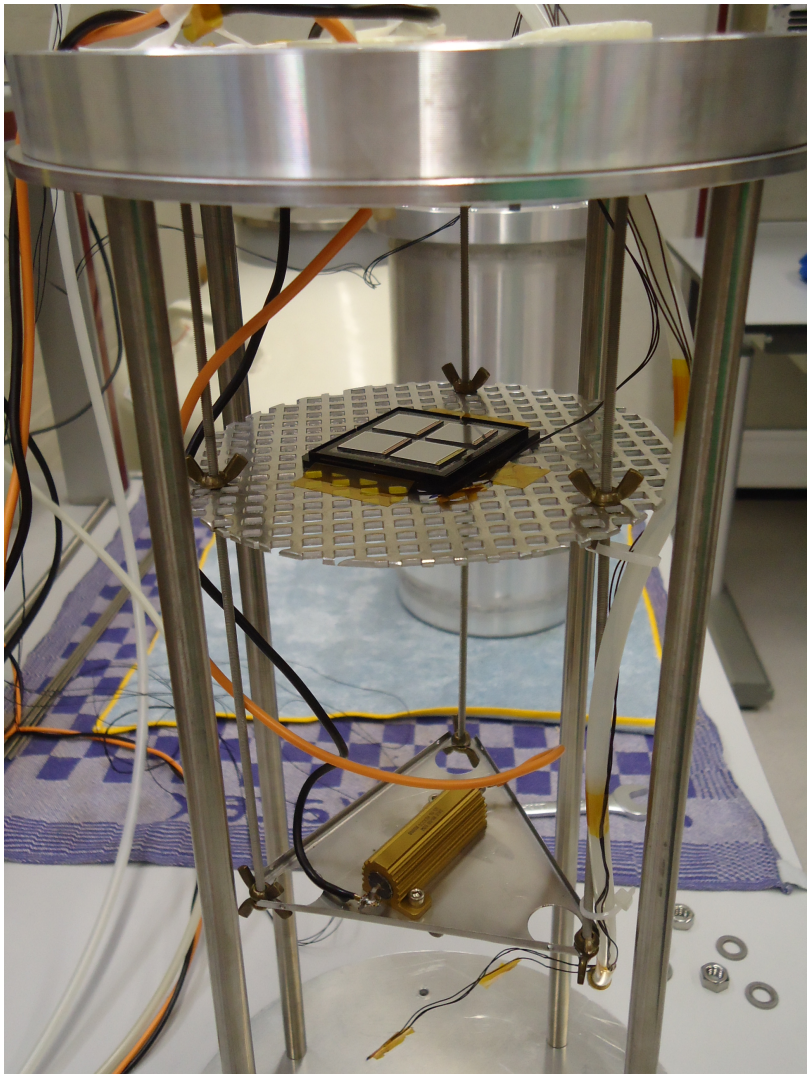
No measurements in dual-phase Ar

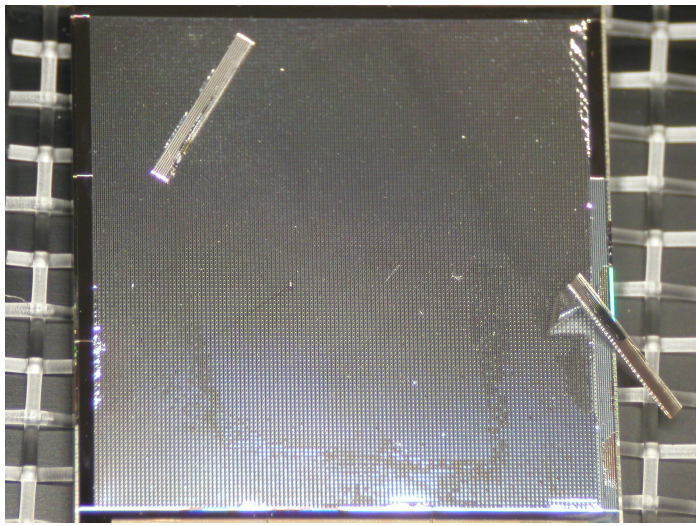


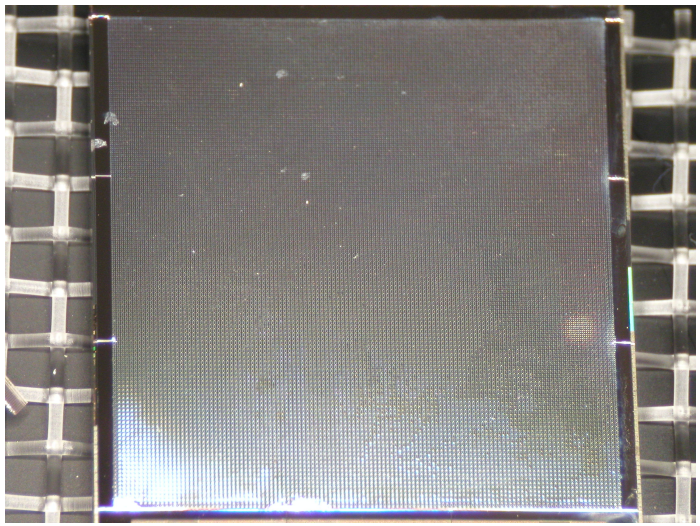


- boiling liquid the cause?

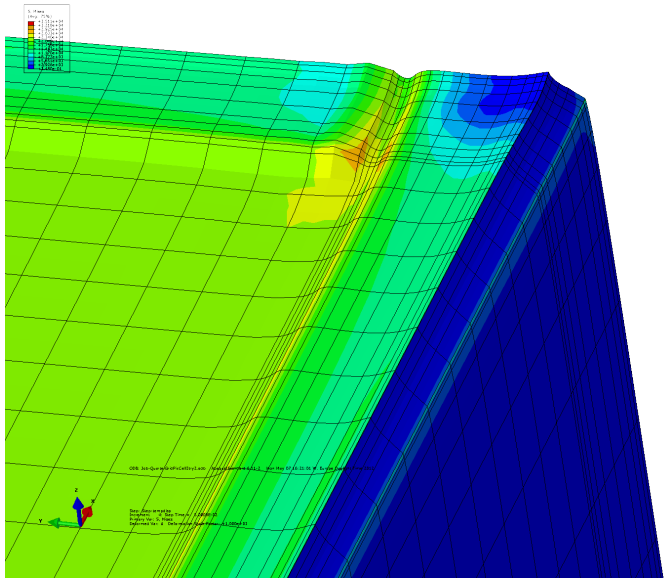
Robustness of GridPix at $T_{\ell Xe} = 165\,K$

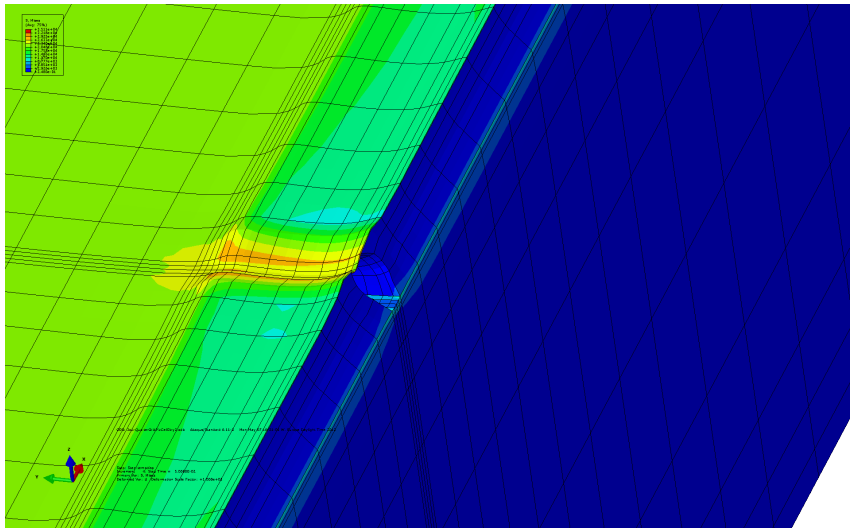




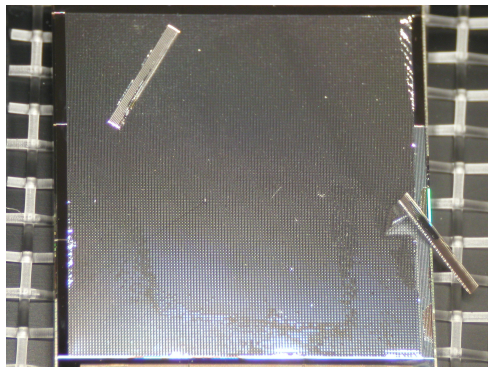


Simulating stress

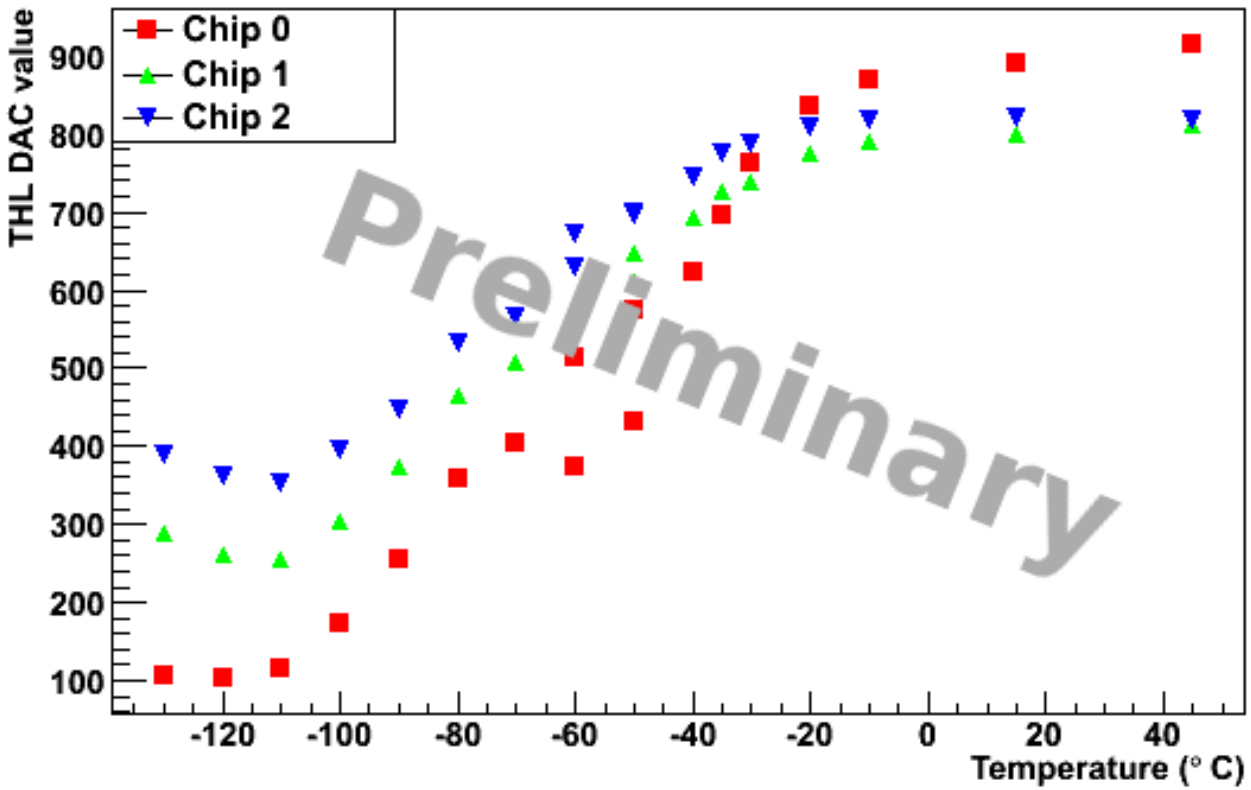




⇒ reduce stress by changing structure of grid support



Timepix noise at low temperatures



Conclusion

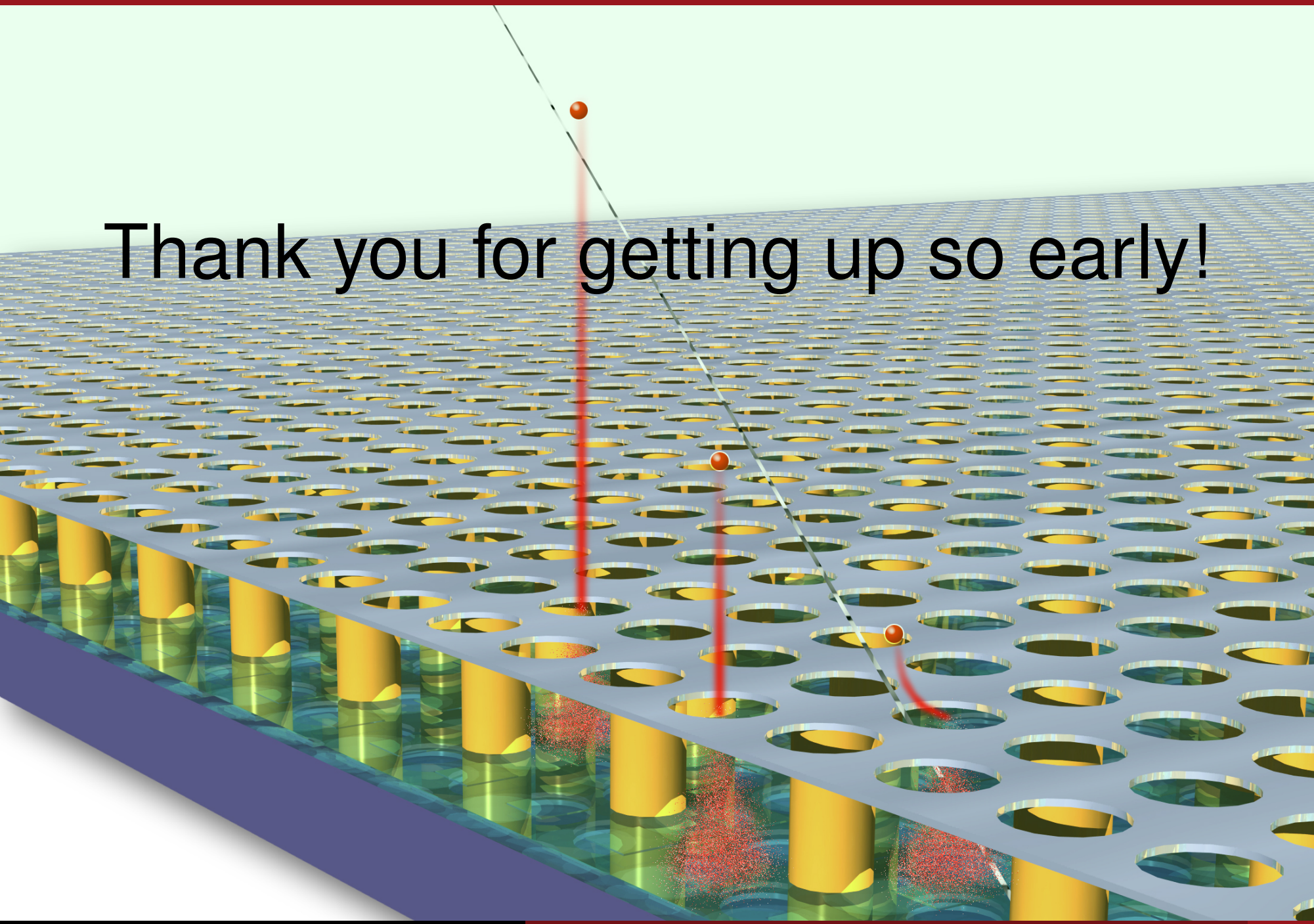
- We learned a lot
  - stably operating GridPix in quencher-free argon at room temperature
  - GridPix amplification stage works down to 87 K

  $\Rightarrow$ no show-stopper: concept works, but has to be improved
- We will learn about
  - noise of Timepix at low temperatures
  - improvements on material robustness
  - gain in pure xenon (at room temperature and at 165 K)

Acknowledgements

NIKHEF

- Bas vd Heijden, Vincent v Beveren, Joop Rövekamp, Berend Munneke, Peter Thobe, Herman v Boer Rookhuizen, Richard Rosing
- Fred Hartjes, Josef Uher
- Filippo Resnati, Devis Lussi (A. Rubbia's ArDM group)
- and . . .


Thank you for getting up so early!