Karlsruhe Institute of Technology

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# Search for hidden-photon dark-matter with FUNK

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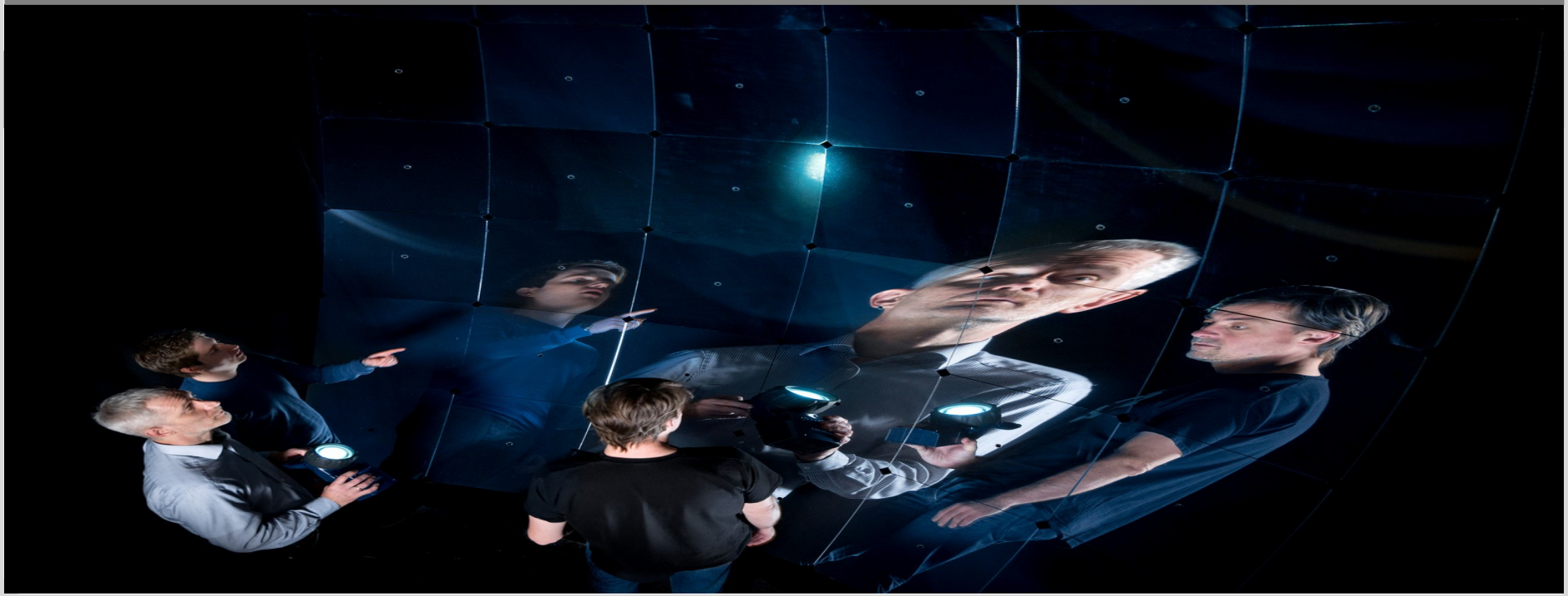
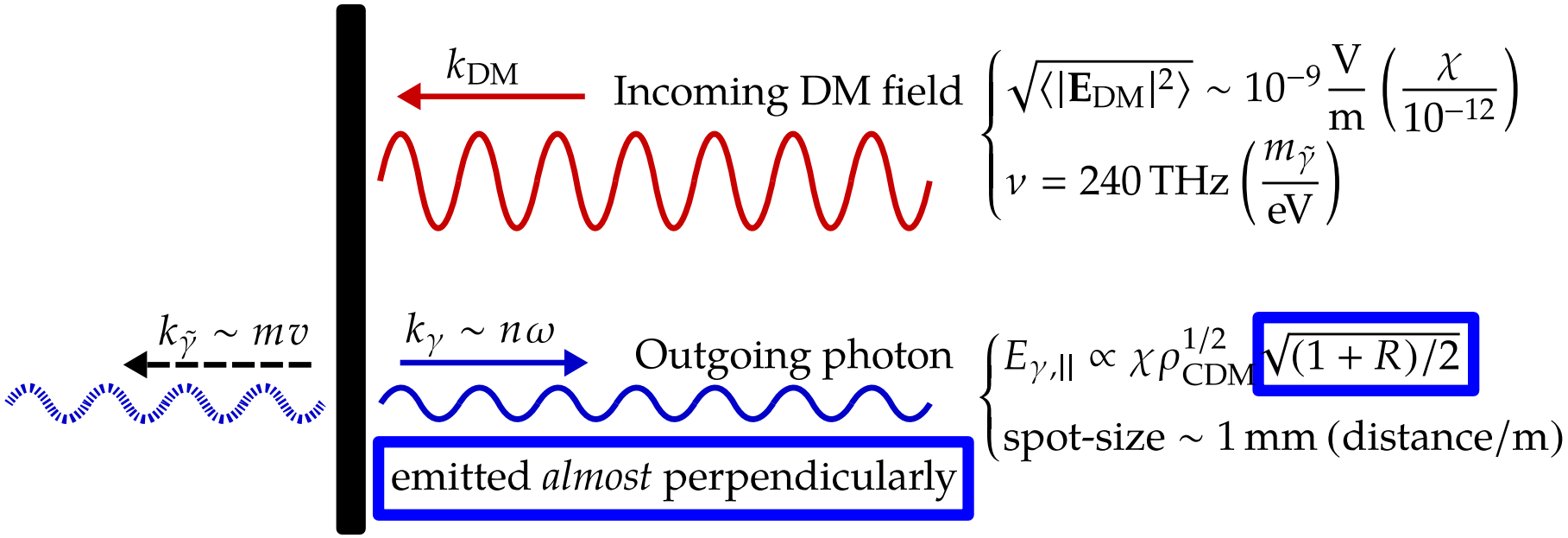
INSTITUTE FOR NUCLEAR PHYSICS (IKP)



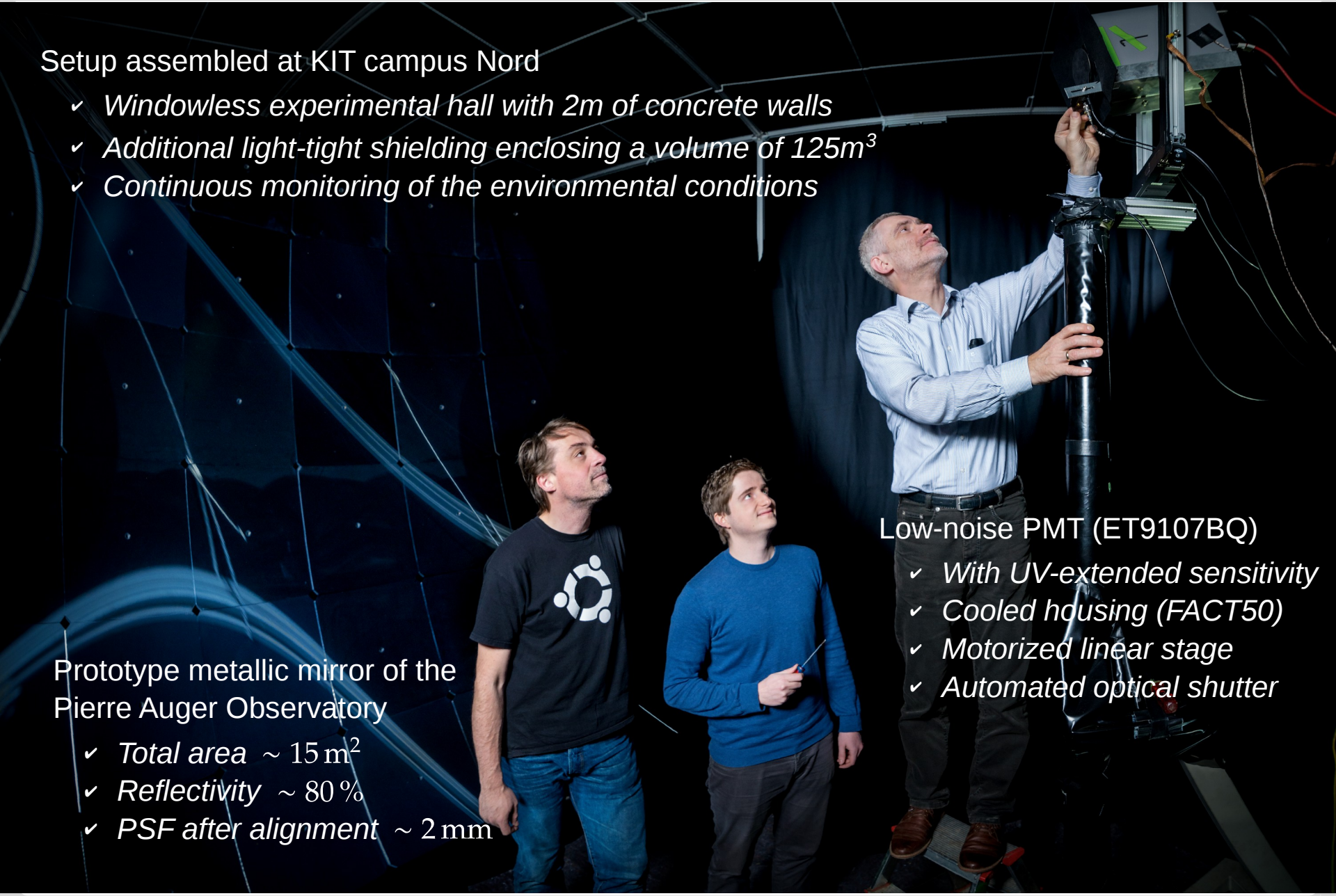
# Detection technique

- Maxwellian-like transition at a dielectric interface




- Expected HP-signal power $\langle P \rangle \sim 10^{-19}\,\mathrm{W} \left(\frac{\chi}{10^{-12}}\right)^2 \left(\frac{A_{\mathrm{eff}}}{1\,\mathrm{m}^2}\right)$
- Build a **good**, **spherical** and **big** reflector
- Then put a photo-detector at its **radius point**

# FUNK: Finding U(1) of Novel Kind



Setup assembled at KIT campus Nord

- ✔ *Windowless experimental hall with 2m of concrete walls*
- ✔ *Additional light-tight shielding enclosing a volume of 125m$^3$*
- ✔ *Continuous monitoring of the environmental conditions*

Low-noise PMT (ET9107BQ)

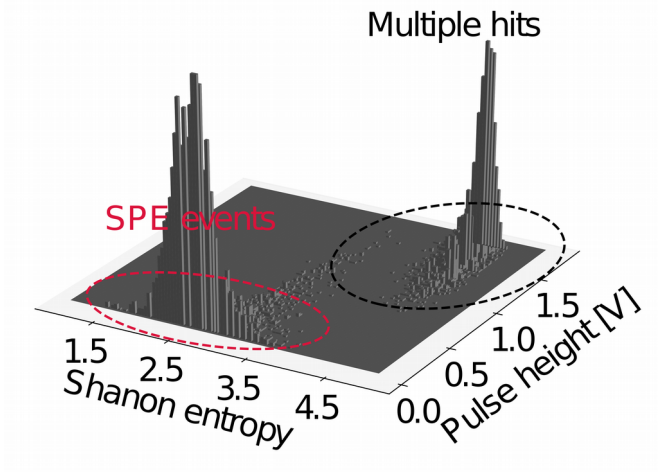
- ✔ *With UV-extended sensitivity*
- ✔ *Cooled housing (FACT50)*
- ✔ *Motorized linear stage*
- ✔ *Automated optical shutter*

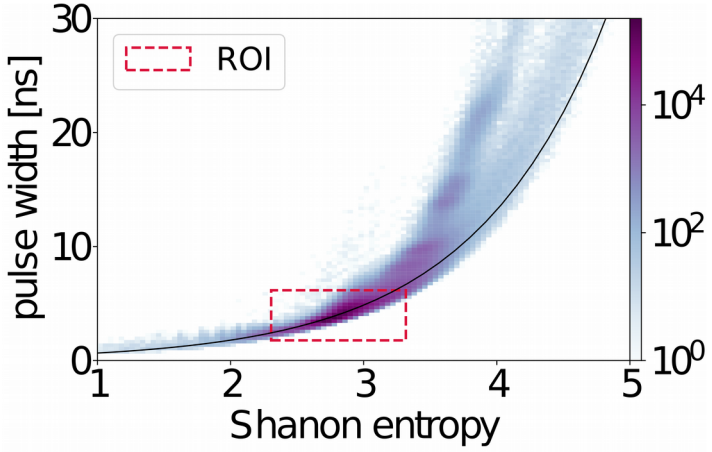
Prototype metallic mirror of the Pierre Auger Observatory

- ✔ *Total area* $\sim 15\,\mathrm{m}^2$
- ✔ *Reflectivity* $\sim 80\,\%$
- ✔ *PSF after alignment* $\sim 2\,\mathrm{mm}$

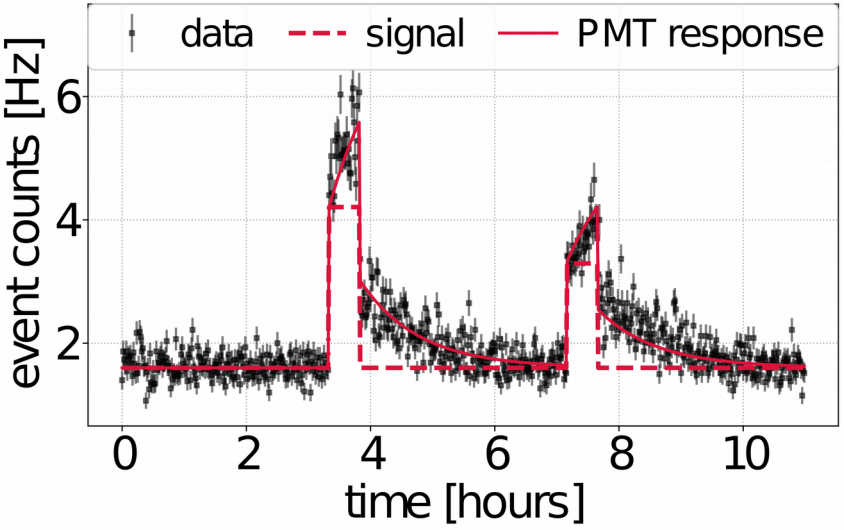
# Counting single photons... properly!

- Single photon discrimination with nanosecond time-resolution



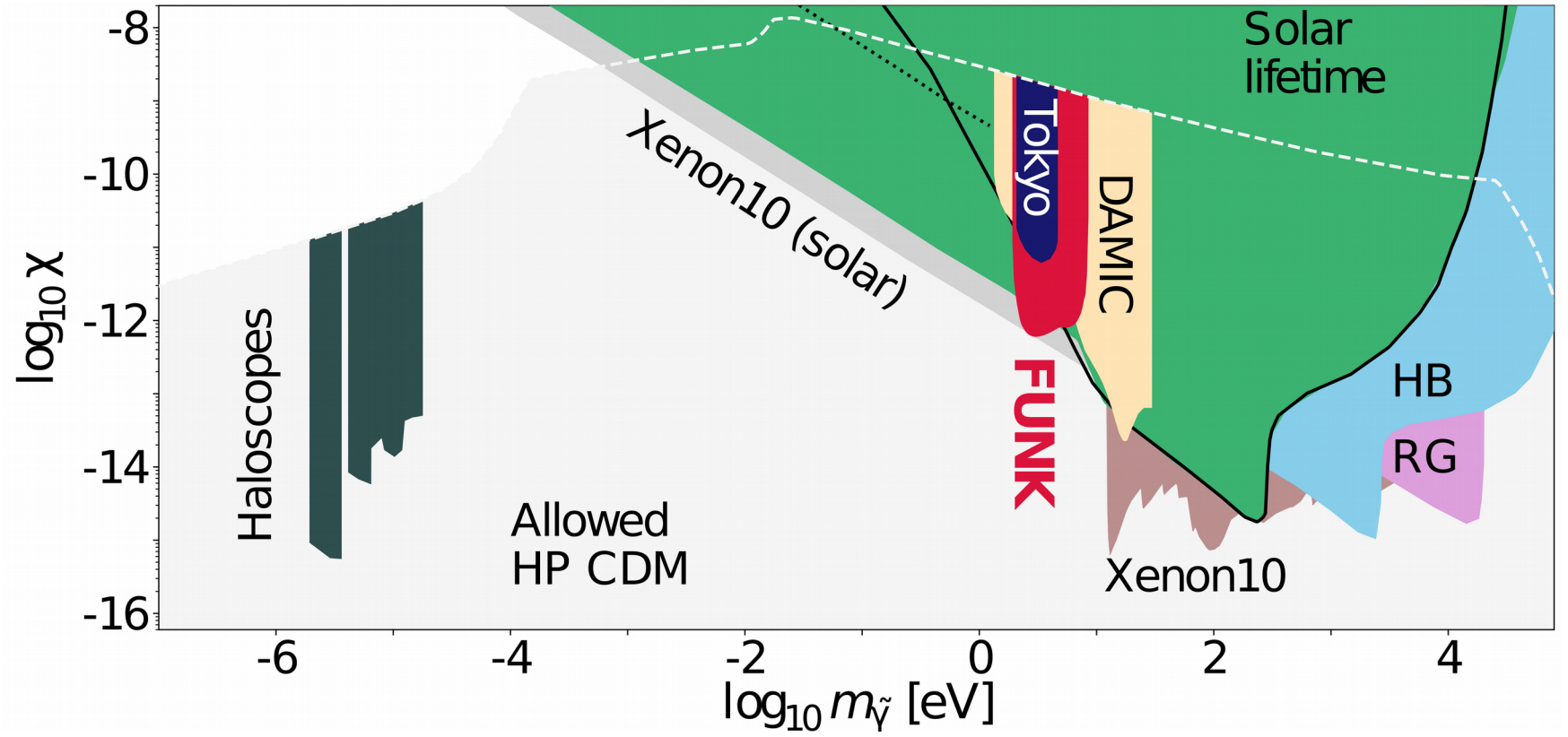

- PMT memory effect



# Preliminary results – No hidden photons (yet)

- *True* events are fully reconstructed to account for the detector features
- HP-signal determined from difference of event-rate *inside* and *outside* the region of interest

$$\mathrm{S/Hz} = -0.0161 \pm 0.0122$$



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# Search for hidden-photon dark-matter with FUNK


## A. Andrianavalomahefa for the FUNK experiment*

***Institute for Nuclear Physics, Karlsruhe Institute of Technology, Germany***


- Hidden photon (HP) as vector portal into hidden sectors

$$-\mathcal{L}_{\text{eff}} \supset \frac{1}{4}\left(F_{\mu\nu}F^{\mu\nu} + X_{\mu\nu}X^{\mu\nu}\right) - J_\mu A^\mu - \frac{m_{\tilde{\gamma}}}{2}X_\mu X^\mu + \frac{\chi}{2}F_{\mu\nu}X^{\mu\nu}$$

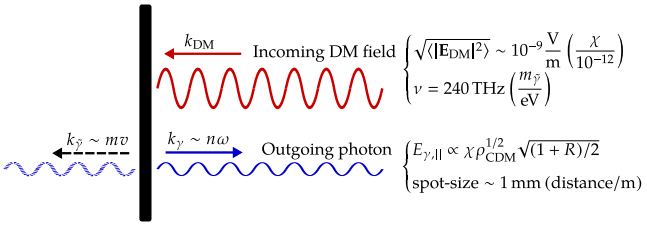
- Survival of HP condensate as cold dark-matter (CDM) if non-thermally produced in the early universe

## FUNK: Finding U(1) of Novel Kind

- Mixing between hidden and visible electric-fields

$$\begin{pmatrix}\mathbf{E}\\ \hat{\mathbf{E}}\end{pmatrix}_{\text{DM}} = \mathbf{E}_{\text{DM}}\begin{pmatrix}-1\\ 1/\chi_{\text{eff}}\end{pmatrix} e^{i(m_{\tilde{\gamma}}t\ -\mathbf{k}_{\text{DM}}\cdot\mathbf{x})}$$

- Maxwellian-like transition at a dielectric interface



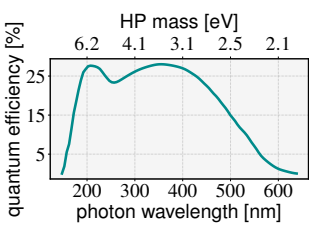

- Expected HP-signal power focused by an effective area $A_{\text{eff}}$

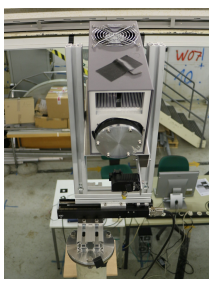
$$\langle P\rangle \sim 10^{-19}\,\text{W}\left(\frac{\chi}{10^{-12}}\right)^2\left(\frac{\rho_{\text{CDM}}}{3\,\text{GeV/cm}^3}\right)\left(\frac{A_{\text{eff}}}{1\,\text{m}^2}\right)$$

- Build a large spherical reflector

  - Prototype metallic mirror of the Pierre Auger fluorescence telescopes: $6\times6$ mirror matrix, total area $A \approx 15\,\text{m}^2$, reflectivity $R \approx 80\,\%$
  - Fine alignment: point spread function ~ 2 mm spot radius

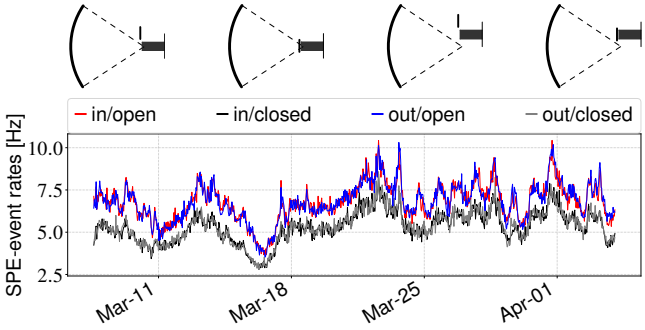
- Broadband scan: low-noise PMT (ET9107BQ), FACT50 cooled housing, motorized linear stage, automated optical shutter



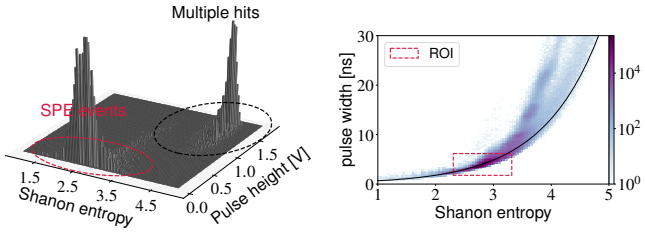



## Preliminary Results

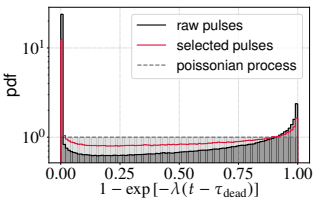
- Dataset (27.5 days run): cycle through four measurement configurations, 60 s at each, total live-time $145.3\times4$ hours



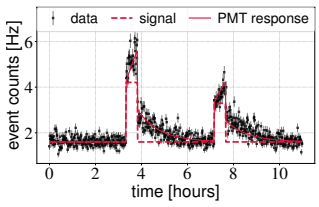

- Single-photon discrimination with nanosecond time-resolution




- Correlated events



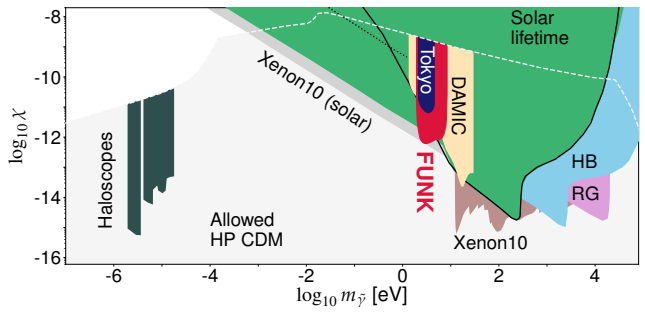

- PMT memory effect




- *True* events are fully reconstructed with a model-based approach in order to account for the characteristics of the detector
- HP signal determined from the event-rate difference *"in" – "out"*

$$(r_{\text{in/open}} - r_{\text{out/open}})/\text{Hz} = -0.0161 \pm 0.0122$$
$$(r_{\text{in/closed}} - r_{\text{out/closed}})/\text{Hz} = -0.0278 \pm 0.0112$$

- No hidden photons (yet)! Exclusion limit at 90 %CL





[1] D. Veberič *et al.*, PoS (ICRC2017) 880


* http://www.ikp.kit.edu/funk