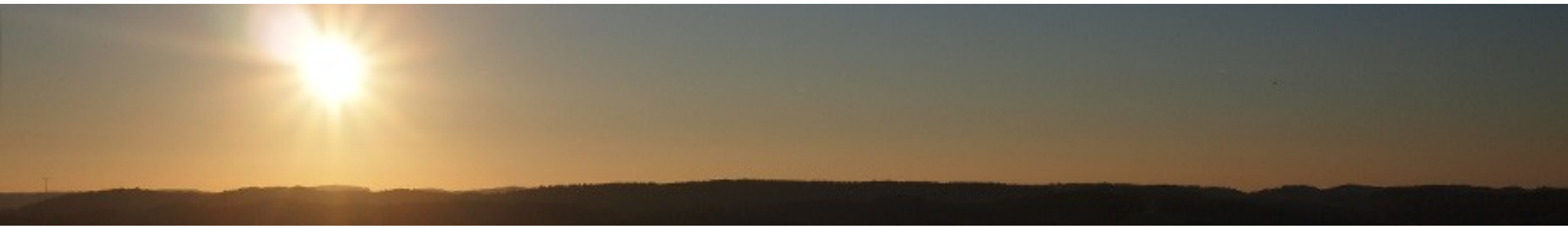
hamburger sternwarte

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

DESY



SHIPS

Solar Hidden Photon Search

Matthias Schwarz

A. Ringwald, G. Wiedemann, J. Redondo, A. Lindner, M. Schneide, P. Arias, E.-A. Knabbe, C. Blohm, C. Martens, C. Niebuhr, E.-O. Saemann

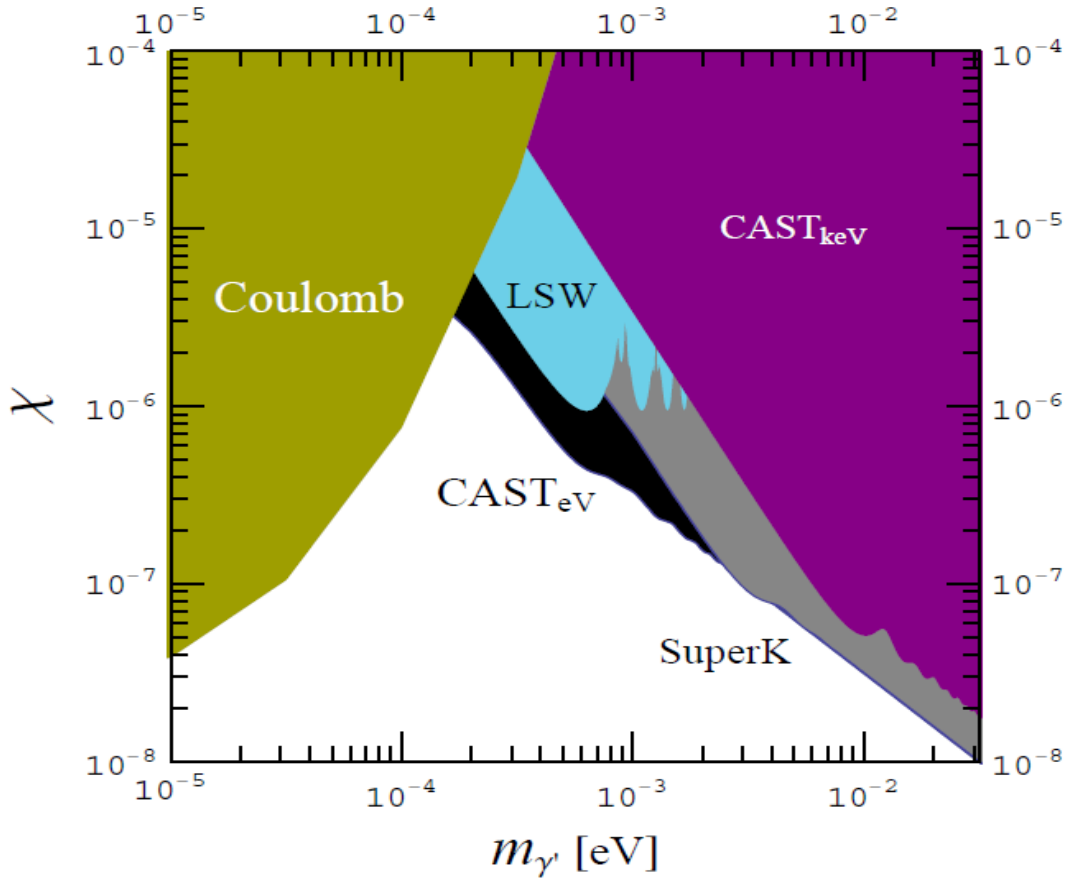
Outline

- Aims of the SHIPS-project
- Theory of hidden photons (HP)
- Detectors and optics
- Experimental setup

Aims of the SHIPS-Project

- Hint of hidden photons
- Estimation of hidden photon mass and coupling parameter χ
- In any event: Further improvement of constraints to hidden sector boson parameters

Hidden photon mass and coupling plane



Theory of hidden photons

Hidden photon (HP)

- Gauge boson of local U(1) hidden symmetry (common symmetry kind in String Theory)
- No direct interaction with other particles (→ hidden)

Hidden photon (HP)

Very massive particles (mediator fermions) with both electric and hidden charge can generate kinetic mixing with the standard photon.

$$L_{mix} = -\frac{1}{4} \cdot \chi \cdot A_{\mu\nu} \cdot B^{\mu\nu}$$

(A = Photon field strength, B = HP field strength, χ = coupling parameter)

Hidden photon (HP)

- Presence of kinetic mixing term signals photon and HP fields are not orthogonal.
- Photon is by definition an interaction eigenstate (couples to electric charge), HP is generally massive.
- Kinetic mixing misaligns the interaction and propagation eigenstates of the photon.

Hidden photon (HP)

- Misalignment of interaction and propagation eigenstates is known to produce flavour oscillations.
- VACUUM oscillation probability:

$$P(\gamma \rightarrow \gamma') = 4\chi^2 \sin^2\left(\frac{m_{\gamma'}^2 \cdot L}{4\omega}\right)$$

with m = HP mass, L = path length, ω = photon energy

Hidden photon (HP)

- Only photon oscillations produce hidden photons
- Oscillations make HPs from the sun detectable with telescopes, so called Helioscopes.

Tracing hidden photons

$$N_{\gamma'} = \int \frac{d\,\Phi_{\gamma'}}{d\,\omega} \cdot A \cdot T \cdot P_{(\gamma' \to \gamma)}\left(\chi, m_{\gamma'}, \omega, L, \Delta n\right) d\,\omega$$

with m = hp mass, L = path length, ω = photon energy,

$\Delta n = n - 1$, n: index of refraction of the medium

Tracing hidden photons

$$N_{\gamma'} = \int \frac{d\Phi_{\gamma'}}{d\omega} \cdot A \cdot T \cdot P_{(\gamma' \to \gamma)}(\chi, m_{\gamma'}, \omega, L, \Delta n)\, d\omega$$

with m = hp mass, L = path length, ω = photon energy,

$\Delta n = n - 1$, n: index of refraction of the medium

Photon - hidden photon oscillations

- The probability of photon - hp oscillations is given by:

$$P(\gamma \rightarrow \gamma') = \frac{\sin^2 2\chi}{\left(cos2\chi + \frac{2\omega^2 \Delta n}{m_{\gamma'}^2}\right)^2 + \sin^2 2\chi} \sin^2 \frac{m_{\gamma'}^2 \cdot L \cdot \sqrt{\left(cos2\chi + \frac{2\omega^2 \Delta n}{m_{\gamma'}^2}\right)^2 + \sin^2 2\chi}}{4\omega}$$

with m = hp mass, L = path length, ω = photon energy,

$\Delta n = n - 1$, n: index of refraction of the medium

- Oscillations are significantly smaller when $\Delta n > 0$
- For visible light a pressure below 10^{-4} mbar ensures that oscillations will not be damped

Photon - hidden photon oscillations

- The probability of photon - hp oscillations is given by:

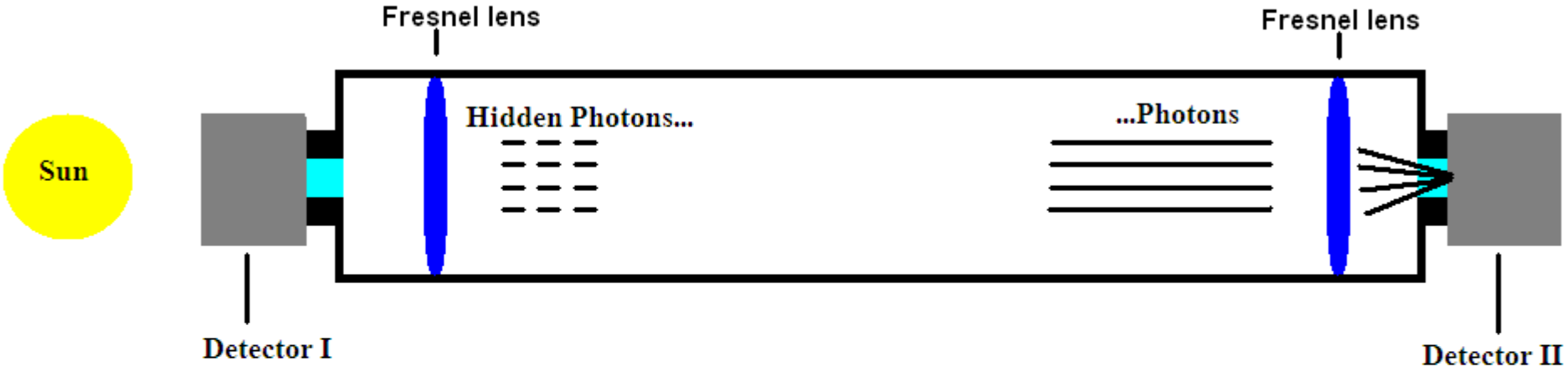
$$P(\gamma \rightarrow \gamma') = \frac{\sin^2 2\chi}{\left(cos2\chi + \frac{2\omega^2 \Delta n}{m_{\gamma'}^2}\right)^2 + \sin^2 2\chi} \sin^2 \frac{m_{\gamma'}^2 \cdot L \cdot \sqrt{\left(cos2\chi + \frac{2\omega^2 \Delta n}{m_{\gamma'}^2}\right)^2 + \sin^2 2\chi}}{4\omega}$$

with m = hp mass, L = path length, ω = photon energy,

$\Delta n = n - 1$, n: index of refraction of the medium

- Oscillations are significantly smaller when $\Delta n > 0$
- For visible light a pressure below 10^{-4} mbar ensures that oscillations will not be damped

Helioscope design



Hps have no tree level interactions with SM particles and can pass matter freely

- *Vacuum:*

  < 10 $^{-4}$ mbar required

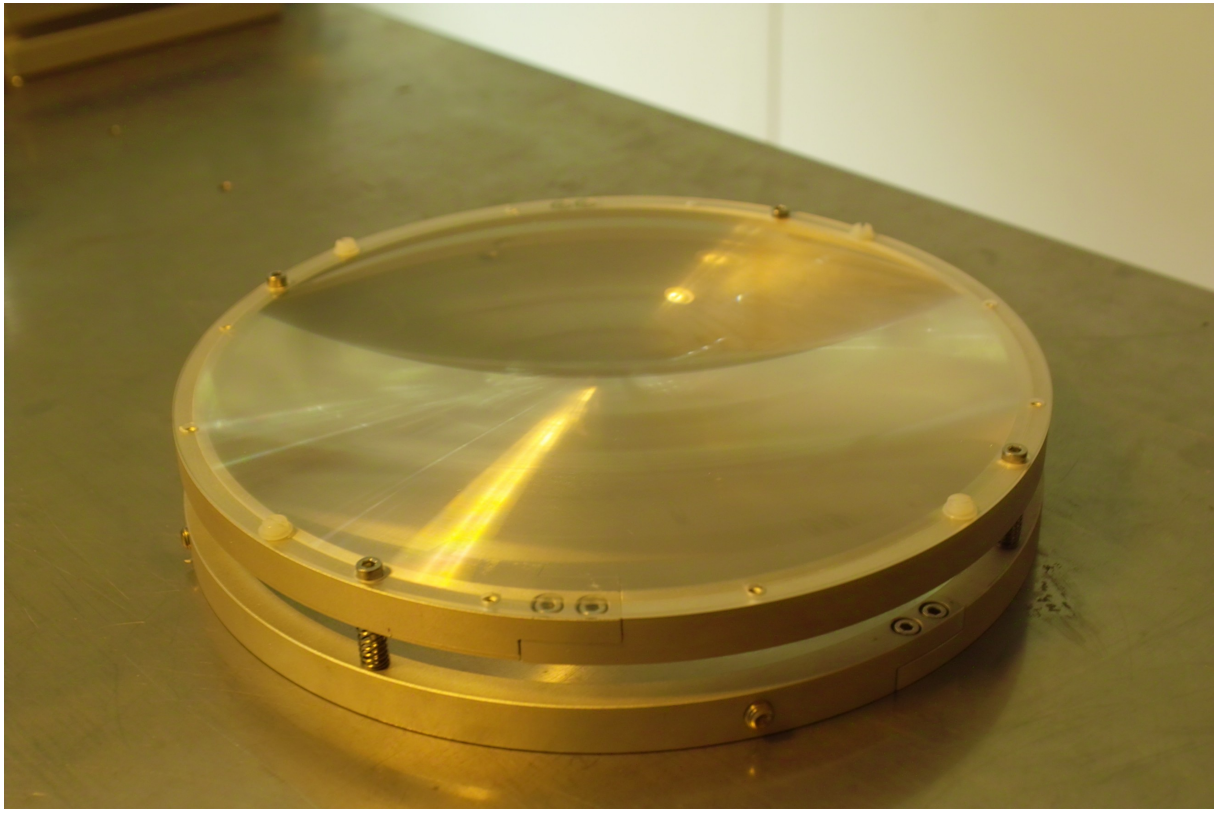
- *Totally shielded from daylight*

Detectors and optics

Optics

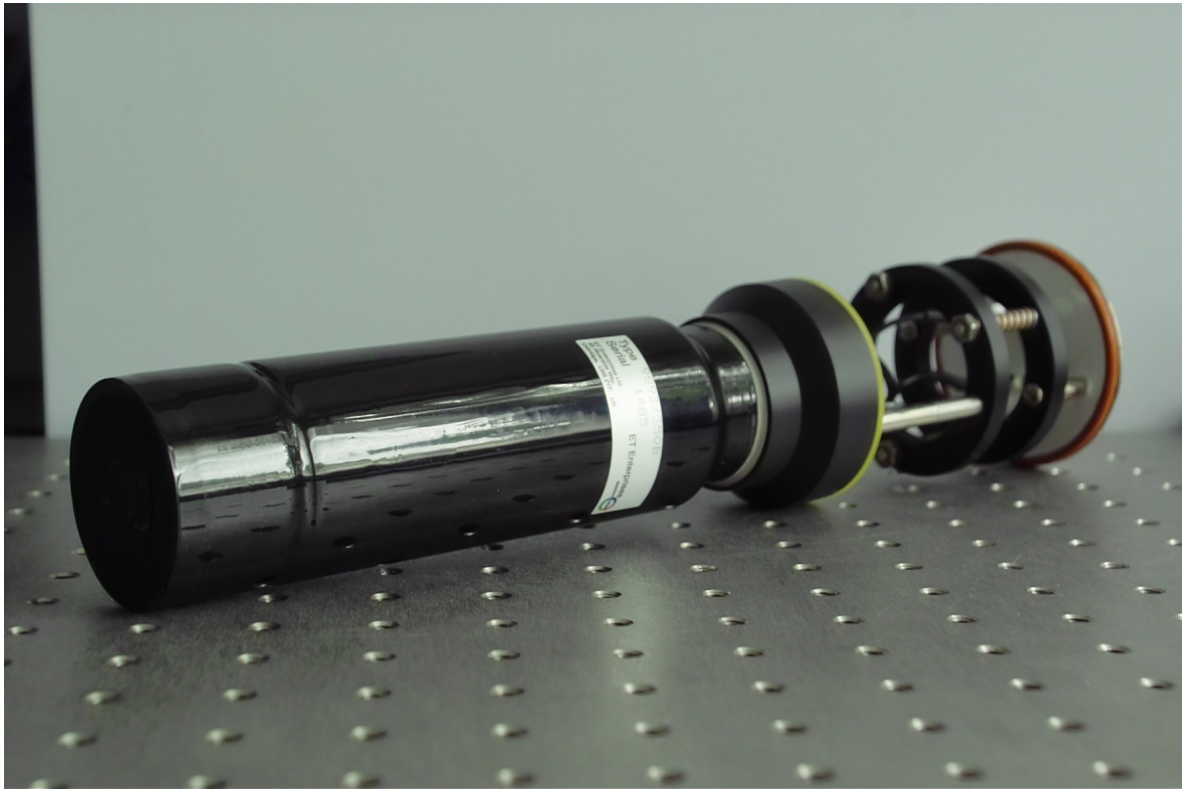
Two detectors (fresnel lens + PMT) on each side of the helioscope allows:

- Simultaneous back-ground measurements
- To point our helioscope at the sun continuously and over long periods



Detectors for SHIPS

Photomultiplier



ET Enterprises 9125SA:

- Very low dark current (2.8 Hz) and dark current noise
- Single photons detectable
- Operated at -20°C

Experimental setup

SHIPS Helioscopes

TSHIPS I:

- 26 cm x 200 cm x 3 mm stainless steel tube
- appr. 75 kg + separate detector compartments

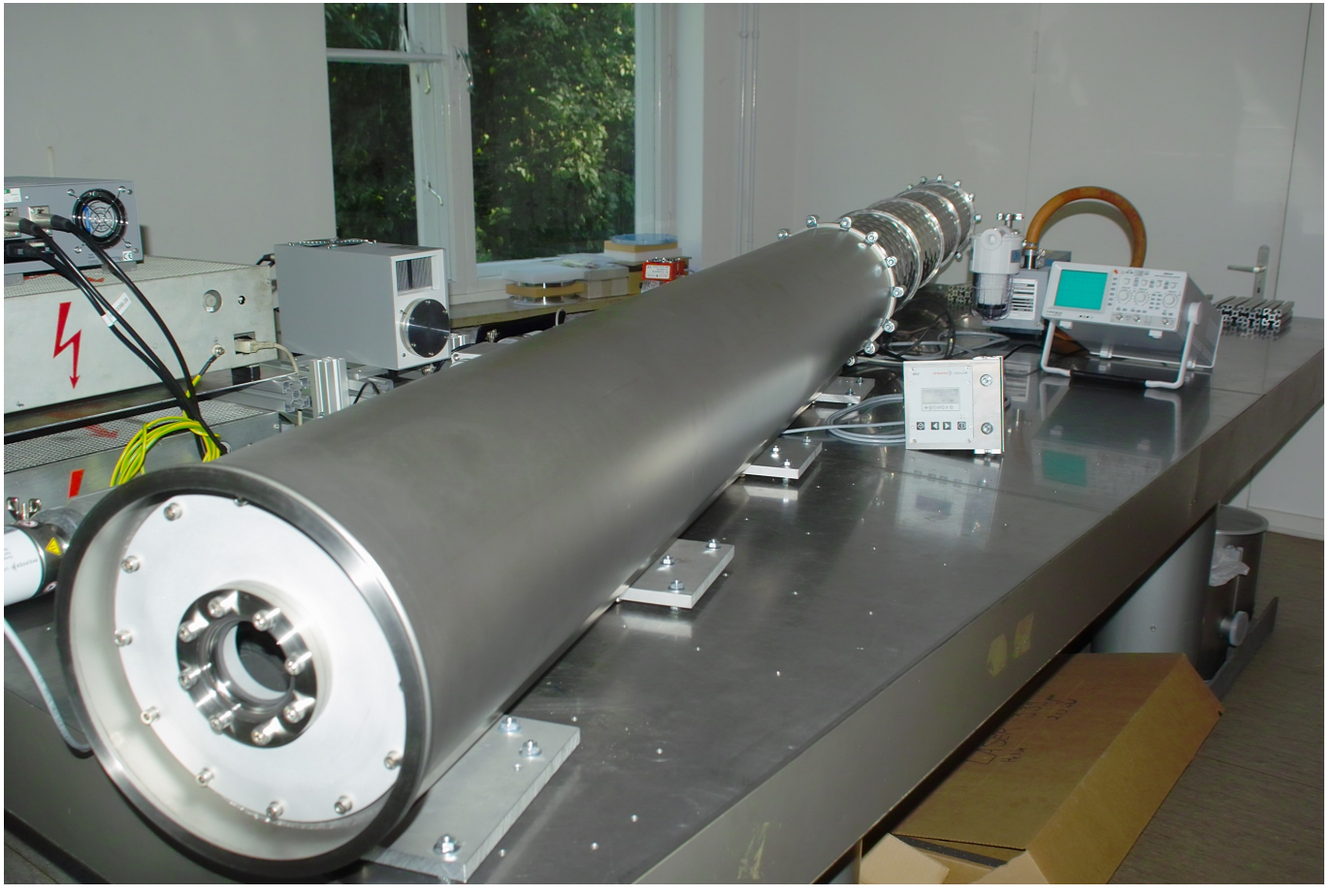
SHIPS Helioscopes

TSHIPS II:

- Vault structure, lightweight, about 14.5 kg
- 2m x 25 cm x 0.8mm same size as TSHIPS I
- Significant reduction of weight (TSHIPS I 75kg)

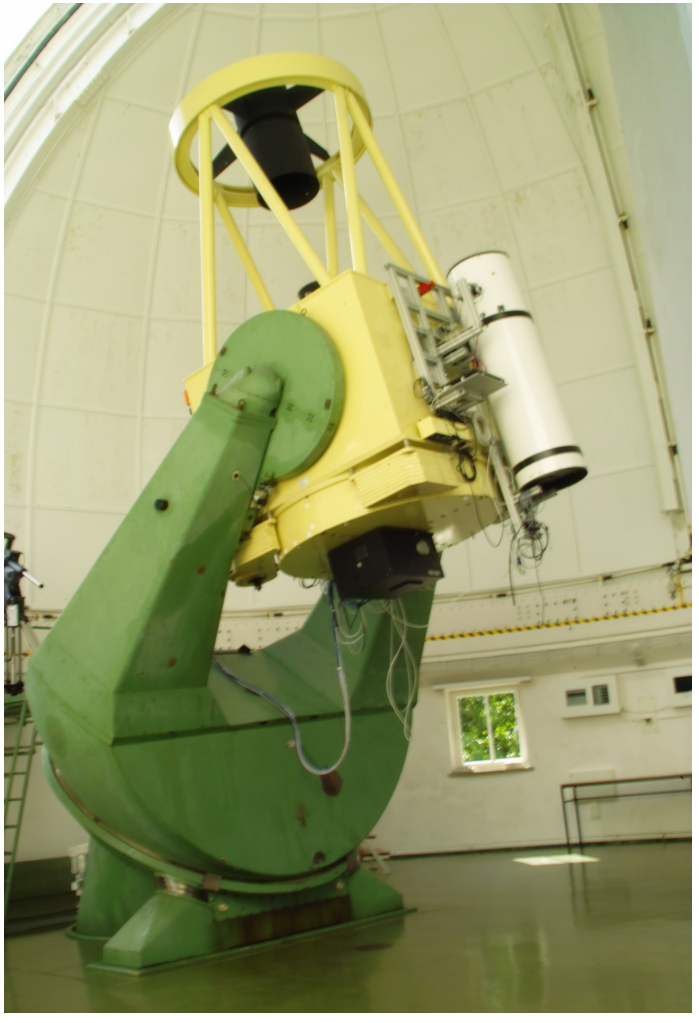
TSHIPS prototype

- The first data will be taken by a 4.3 m long TSHIPS prototype tube (combinated TSHIPS 1 and II plus detector compartment)

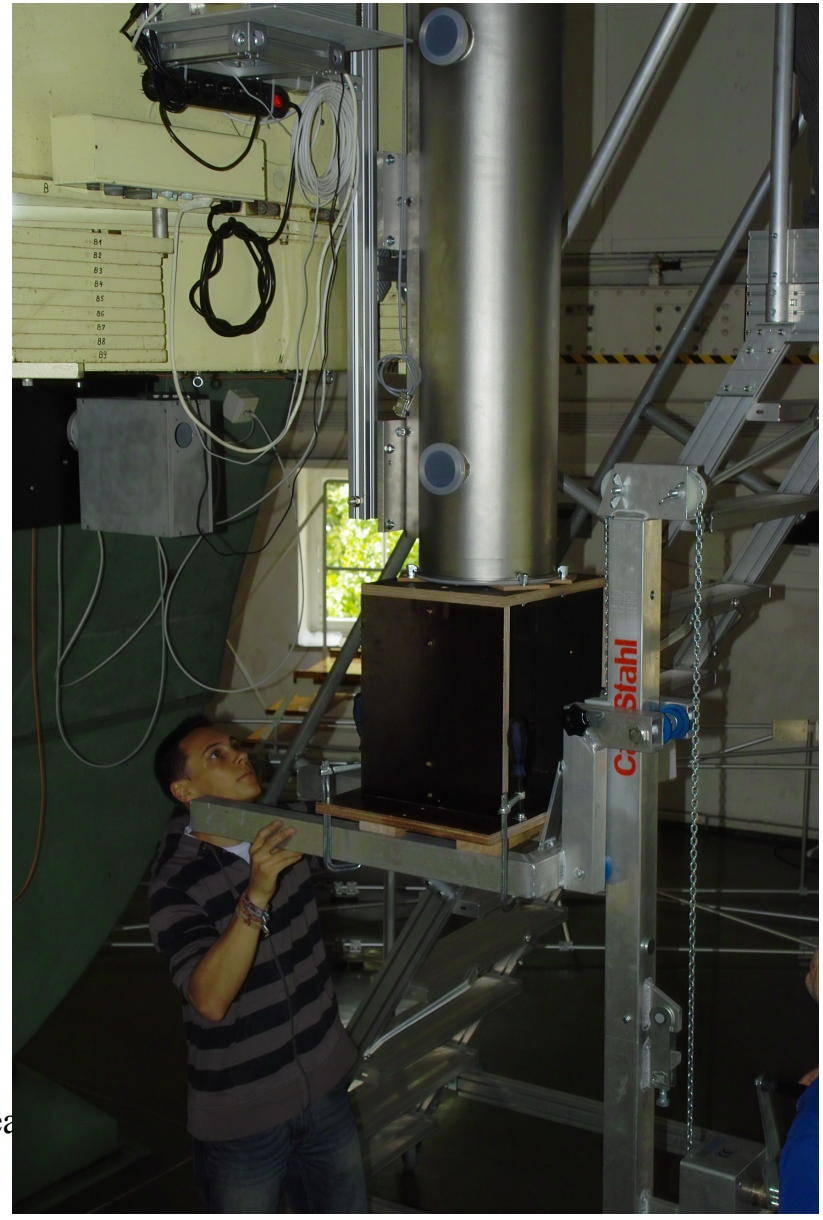


OLT - mount for TSHIPS prototype

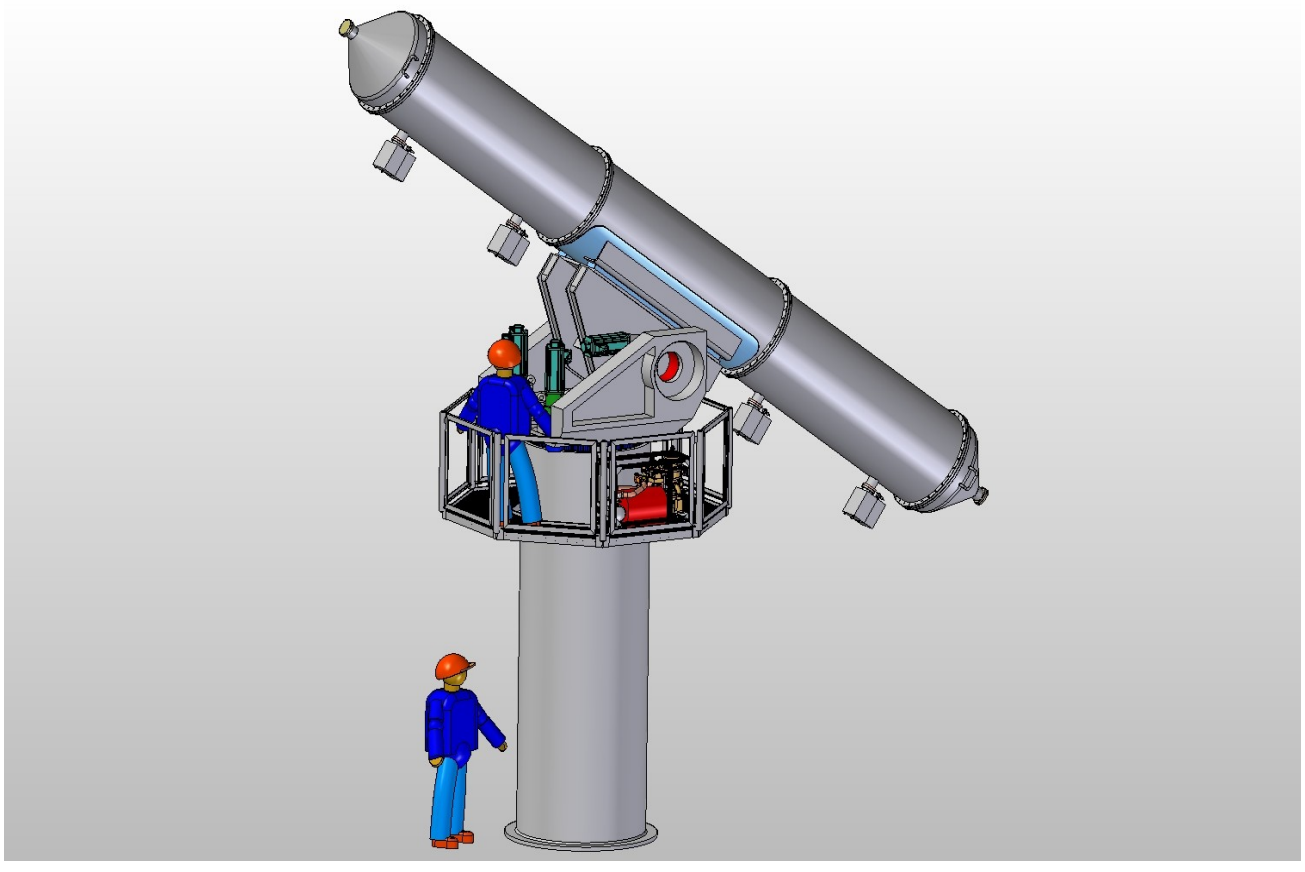
- Oskar-Luehning-Telescope (OLT) located at the Hamburger Sternwarte will be used as mount for TSHIPS in the first phase of the project



TSHIPS prototype mounted onto the OLT



Large SHIPS III setup



- Tube length up to 14 m and 2 m diameter
- Alt-az mount
- To be located inside a hall of the old HERA accelerator ring at DESY

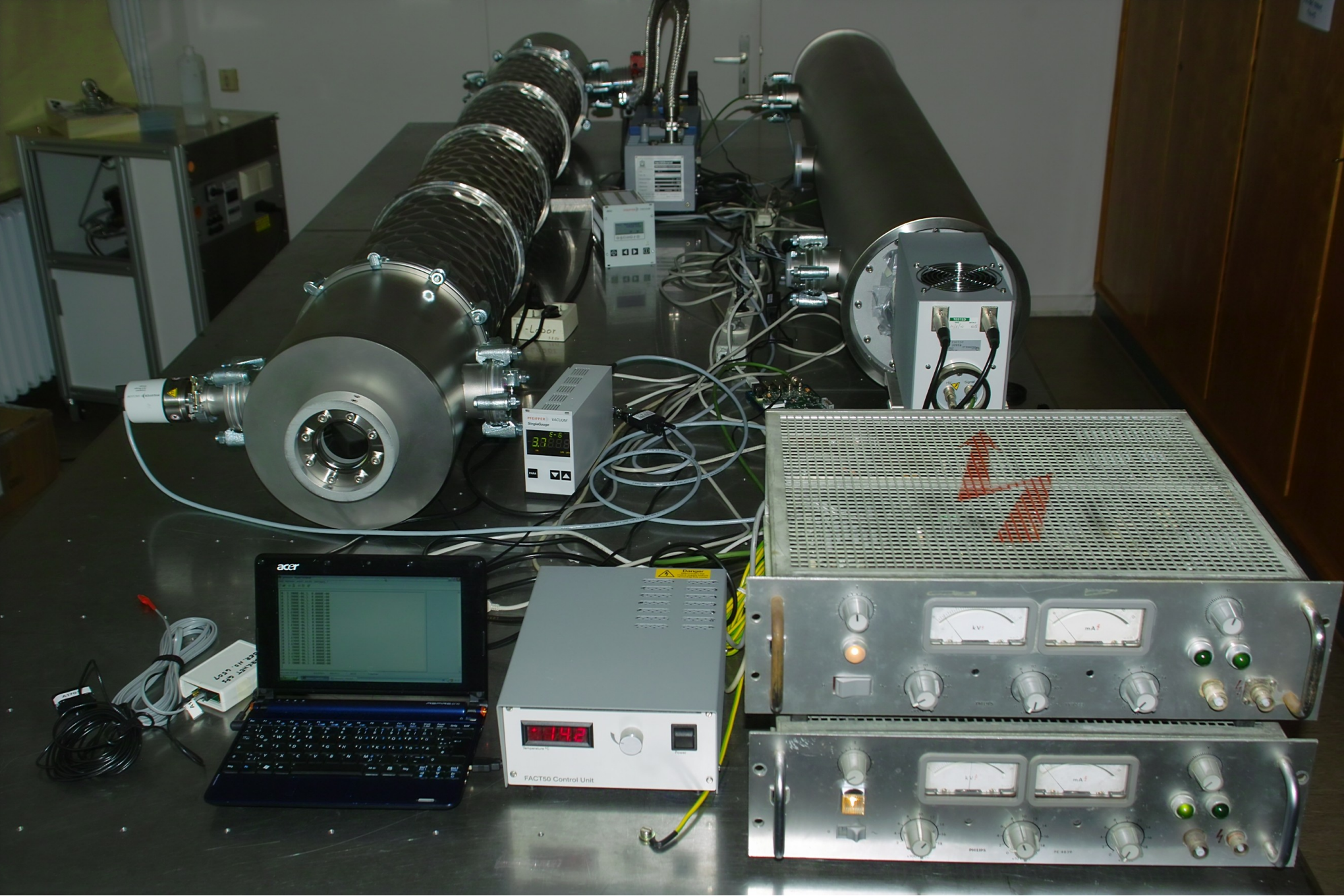

Thank you very much for your attention
... and feel very welcome to visit:
www.ships.uni-hamburg.de
acer
FACT50 Control Unit

Detectors and optics

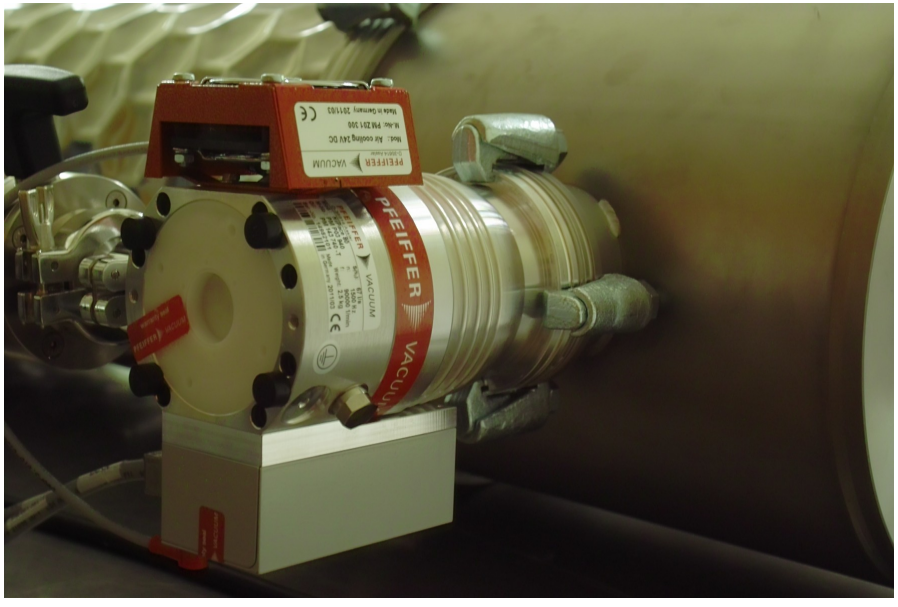
- We estimated the dark current noise Φ_{noise} (single PMT + tube) to be 1.7 counts/sec
- The SHIPS sensitivity (with $3\,\sigma$) is given by:

$$\Phi \simeq 3\sqrt{\left(\frac{\Phi_{noise}}{T}\right)}$$

- Assuming a flux of one hp every 100 seconds on our SHIPS tube, a discovery would be achievable during a long term sun observation of about 1.8 days


acer
FACT50 Control Unit
PHILIPS

Vacuum pumps



- Prevacuum:

  rotary vane pump
  RD 4 with up to 2 * 10^{-3} mbar

- Turbopump HiPace80:

  2.5 * 10^{-7} mbar (TSHIPS I)

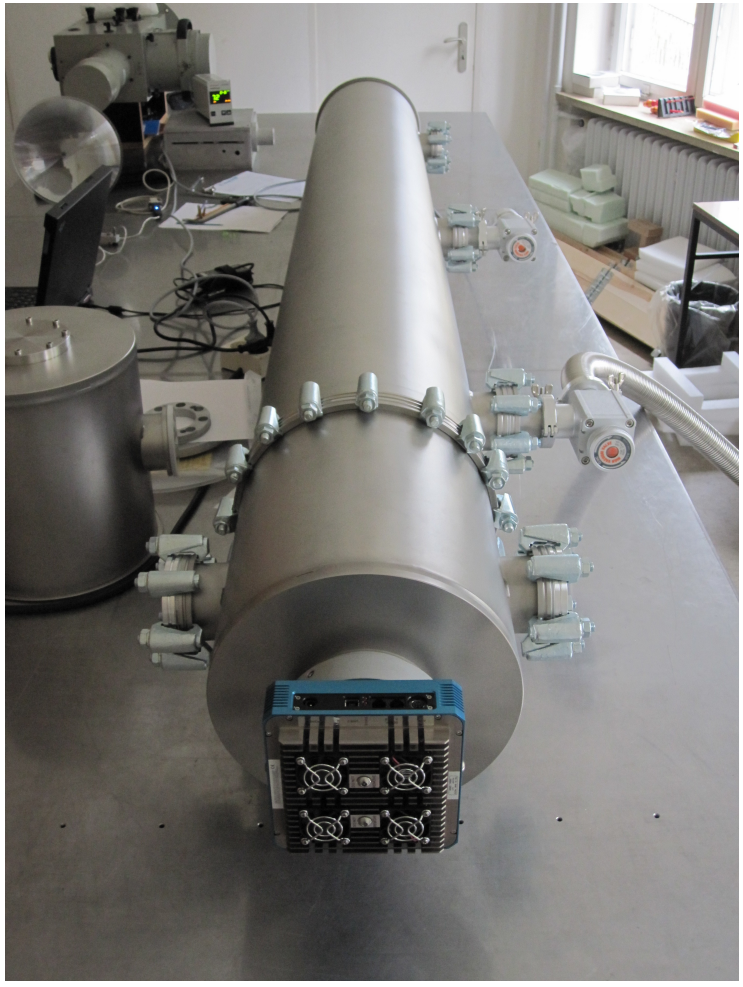
TSHIPS I and II

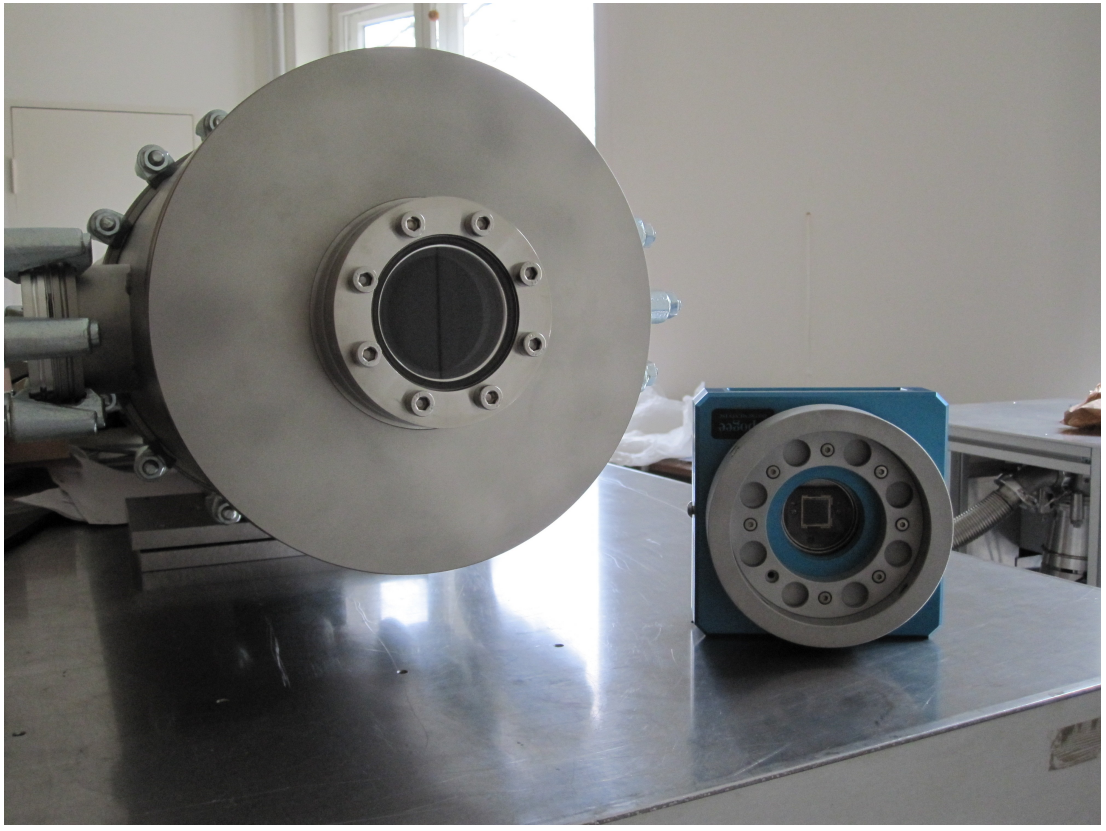
- Both TSHIPS are fully functional helioscopes
- Can be combined to a 4.6 m long vacuum tube
- Both also serve also as test-bench for the much longer and wider TSHIPS III.

SHIPS Signal

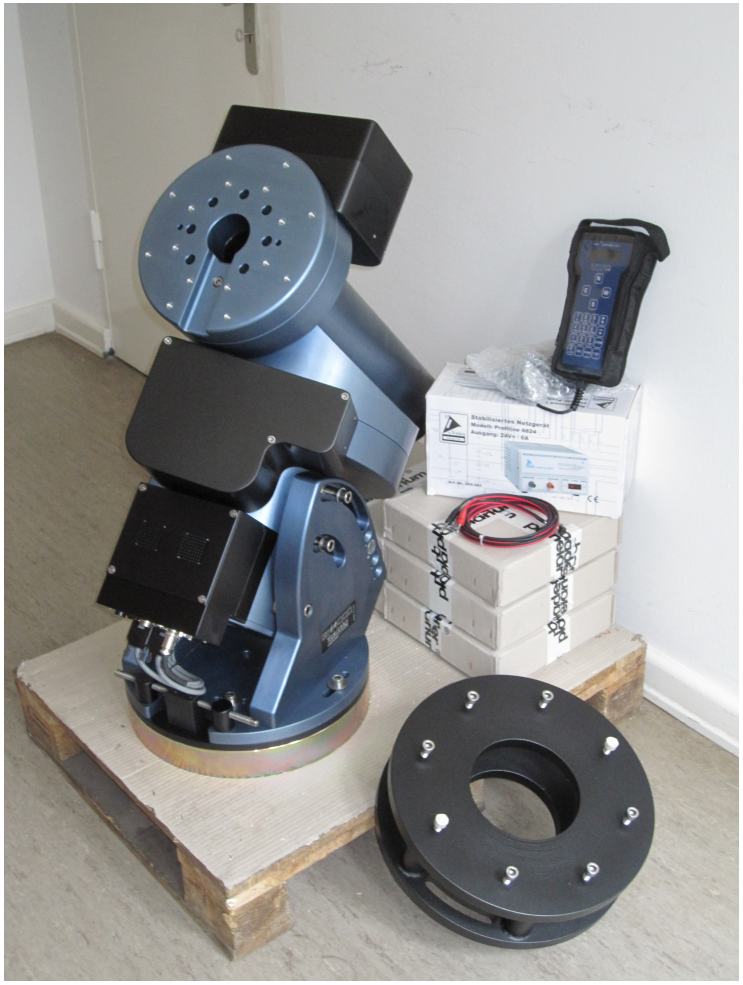
- Best HP source to be exploited is our sun
- Expected signal depends on the volume of the vacuum vessel
- Due to their oscillation from solar photons, Hidden Photons are expected to have the same spectral distribution as these.
- Measurements mainly in optical frequency range

TSHIPS I

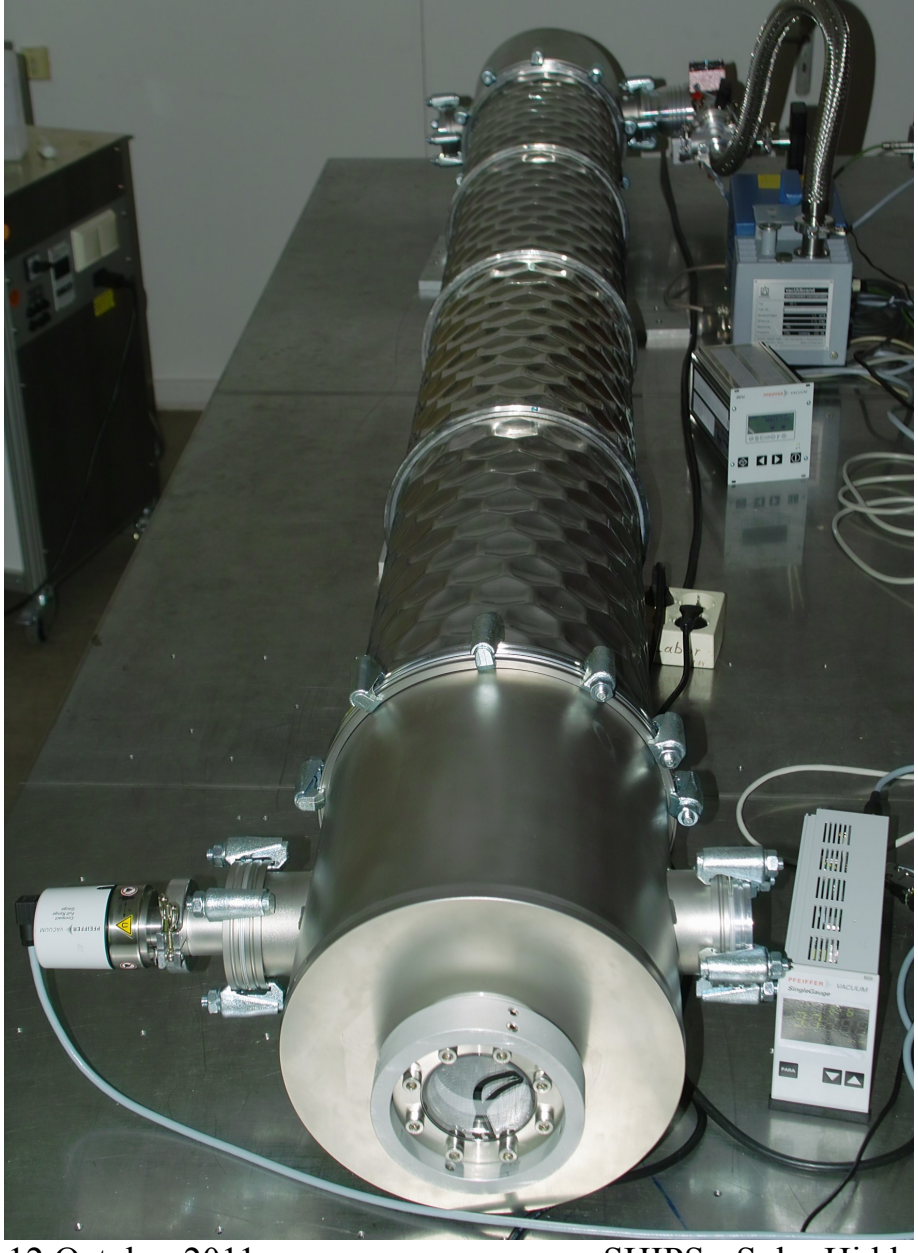




GM4000 – TSHIPS I telescope mount



- Equatorial German mount
- Up to 150 kg instrument weight
- Pointing precision < 2“
- Mean tracking precision < +/- 3“



TSHIPS II

- TSHIPS II with two detector compartments and vacuum pumps attached
- Internal pressure below the required value of 10^{-4} mbar