The Cockcroft Institute
of Accelerator Science and Technology

Lancaster University

# First Results of the CASCADE Experiment


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# -The Hidden Sector

The hidden sector photon(HSP) refers to the spin 1 gauge boson associated with an additional U(1) field.

Electromagnetic Field — Kinetic Mixing Term

$$\mathcal{L} = -\frac{1}{4}F^{\mu\nu}F_{\mu\nu} - \frac{1}{4}B^{\mu\nu}B_{\mu\nu} - \frac{1}{2}\chi F^{\mu\nu}B_{\mu\nu} + \frac{1}{2}m_{\gamma'}^2 B_\mu B^\mu$$

HSP Field — HSP Mass Term

The HSP couples weakly to SM U(1) through kinetic mixing similar to neutrino flavour oscillations.

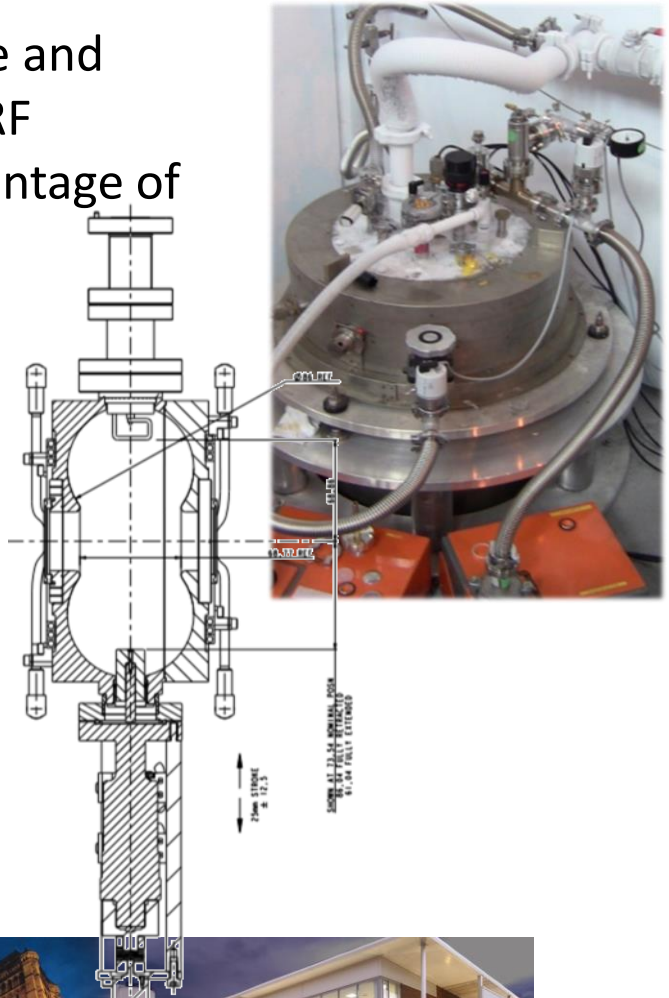
To be observable the HSP needs to have mass.

# -Shining Light Through a Wall

- HSPs can transport energy to regions forbidden to photons.
- This allows the HSP to excite the EM field inside a perfectly shielded box.
- Conversely a box shielded to contain an electric field can lose energy via the HSP field.
- This allows us to experimentally search for the HSP by using a light shining through a wall experiment.
- At microwave frequencies UWA , Yale and CERN have experiments and at optical frequencies ALPs is the leading experiment. (apologies to anyone I've missed)


# -The Opportunity

The Cockcroft Institute of Accelerator Science and Technology routinely tests superconducting RF structures. CASCADE is designed to take advantage of these tests, acting as a detector.



Upcoming Tests*,

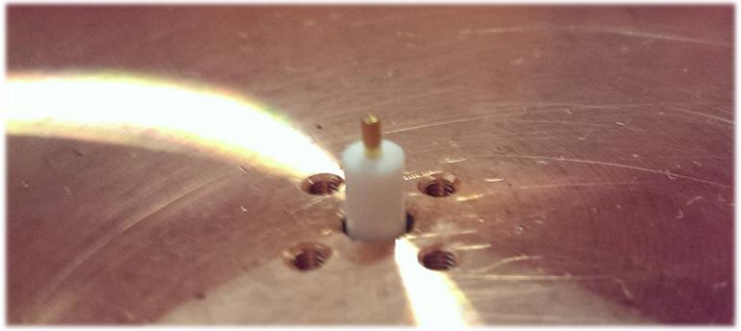
- 1.3 GHz Superconducting 2015/16
- 704 MHz Superconducting 2017/18
- 8 GHz Superconducting 2015
- 3 GHz Normal conducting 2015
- 12 GHz Normal conducting TBC

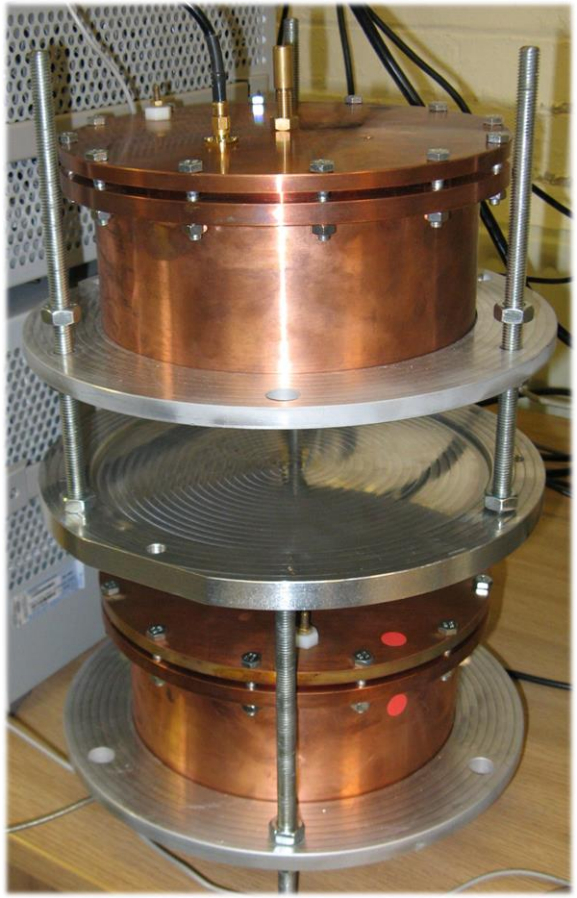
*Dates are provisional

# -Building CASCADE

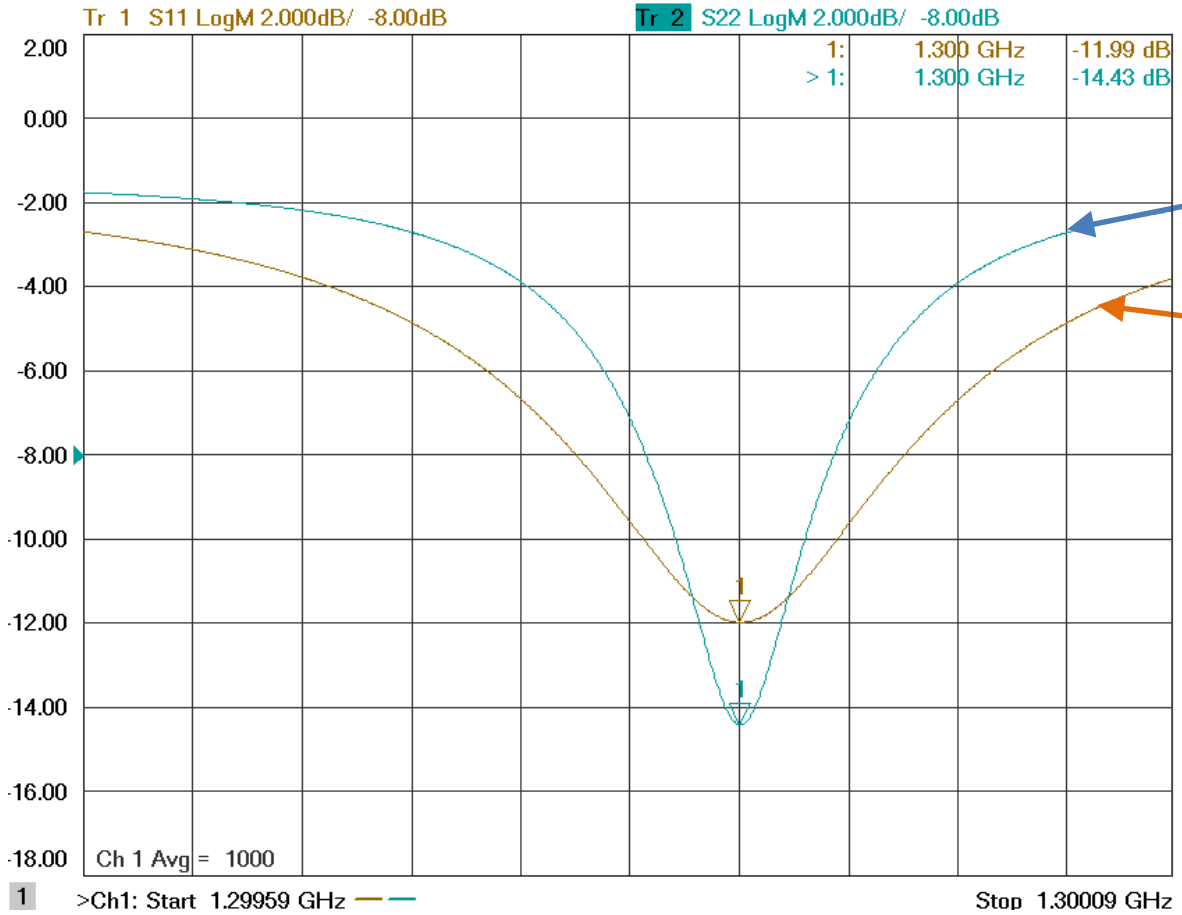
RF cavities were designed specifically for CASCADE:

- Operation in the TM010 mode.
- Resonant at 1.3GHz.
- A tuning screw for easy adjustment.
- Coupled through a simple stud.
- Q ≈ $10^4$ at room temperature, limited by the copper quality.





# -Cavity Optimisation




Trace 2, First optimisation Q=7652

Trace 1, Post cleaning Q=3569

Further optimisation resulted in emitter Q of 10690 and detector Q of 10680

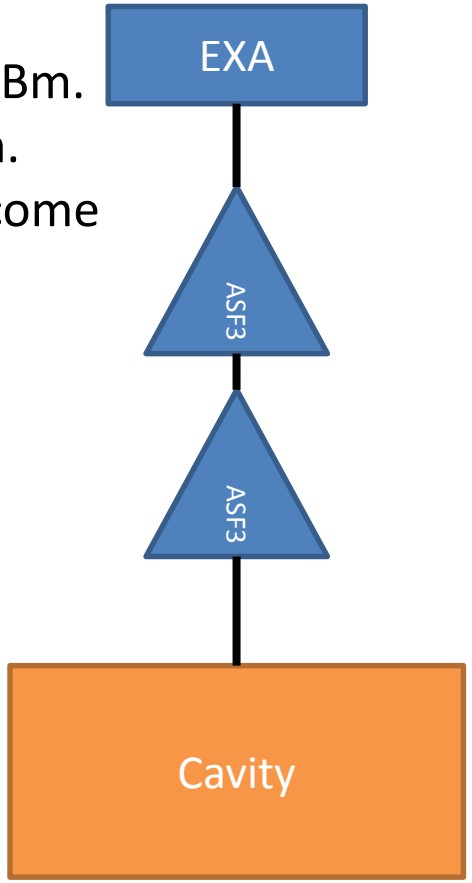
# -CASCADE Amplifers

The expected signal is expected to be below -200dBm.
The internal noise of the signal analyser ~-160dBm.
A large amount of amplification is needed to overcome the difference.

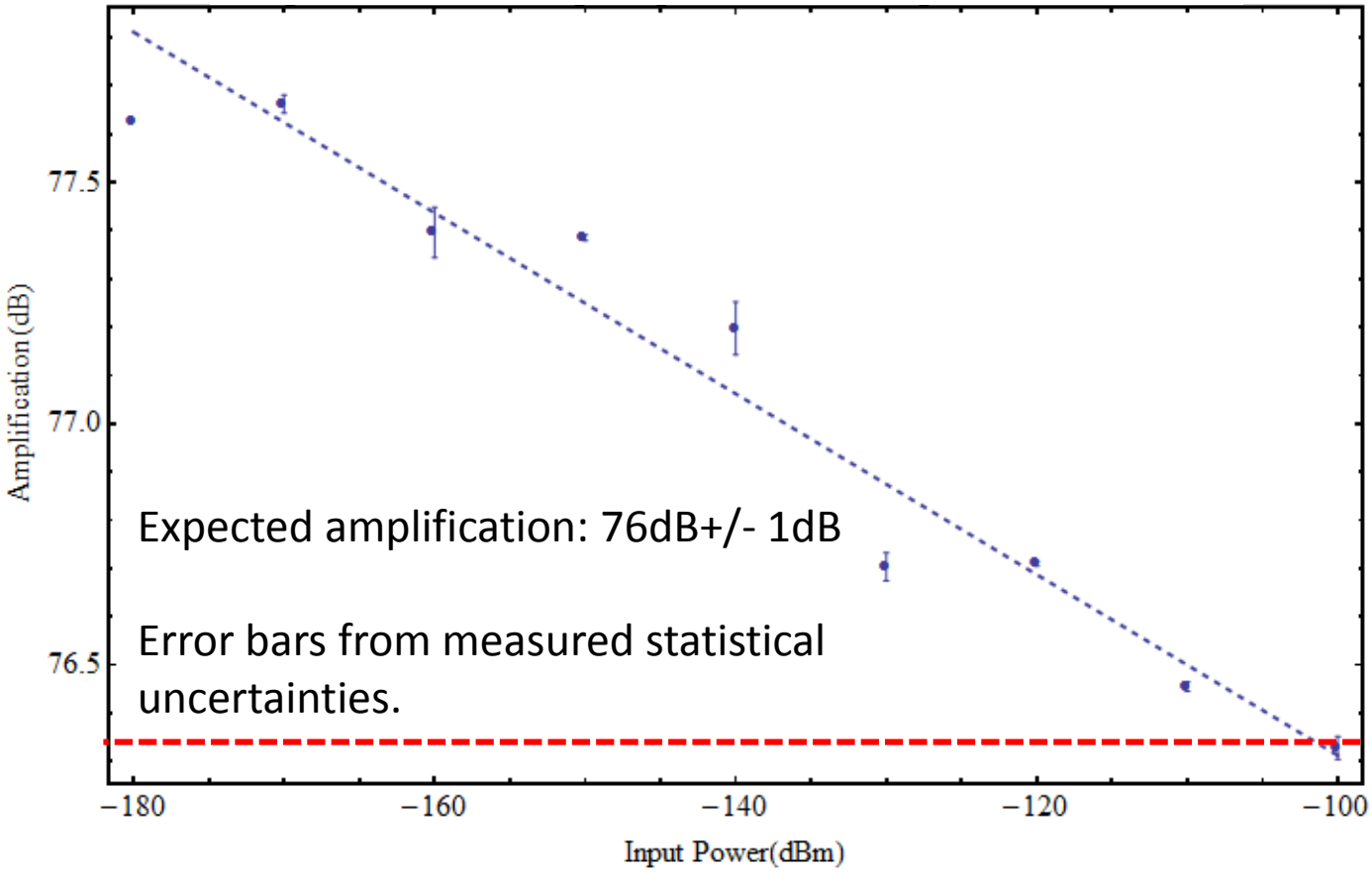
We used 2 Miteq ASF3 CR amplifiers.

Spec sheet values:

- Gain: 38dB.
- Gain Flatness: +/-1dB.
- Noise Figure: 0.6dB Max.

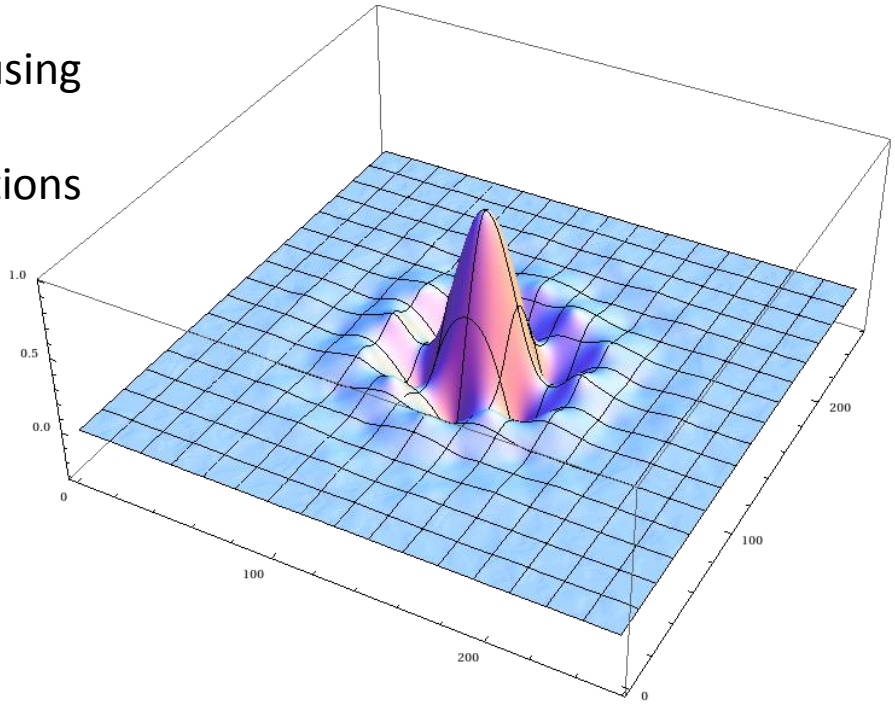


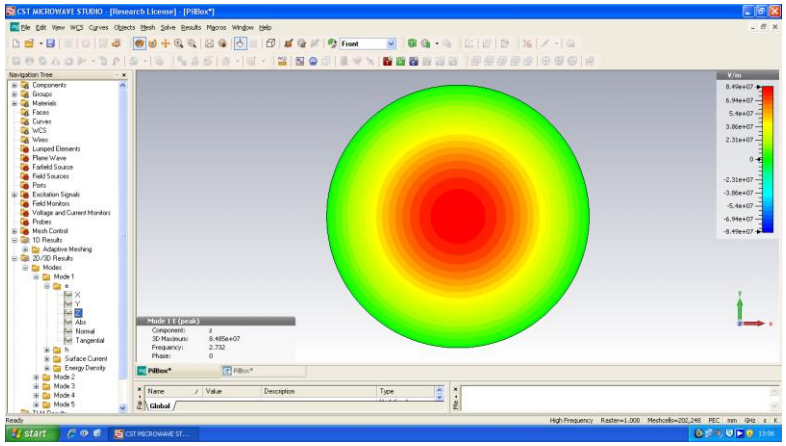

# -CASCADE Amplifiers



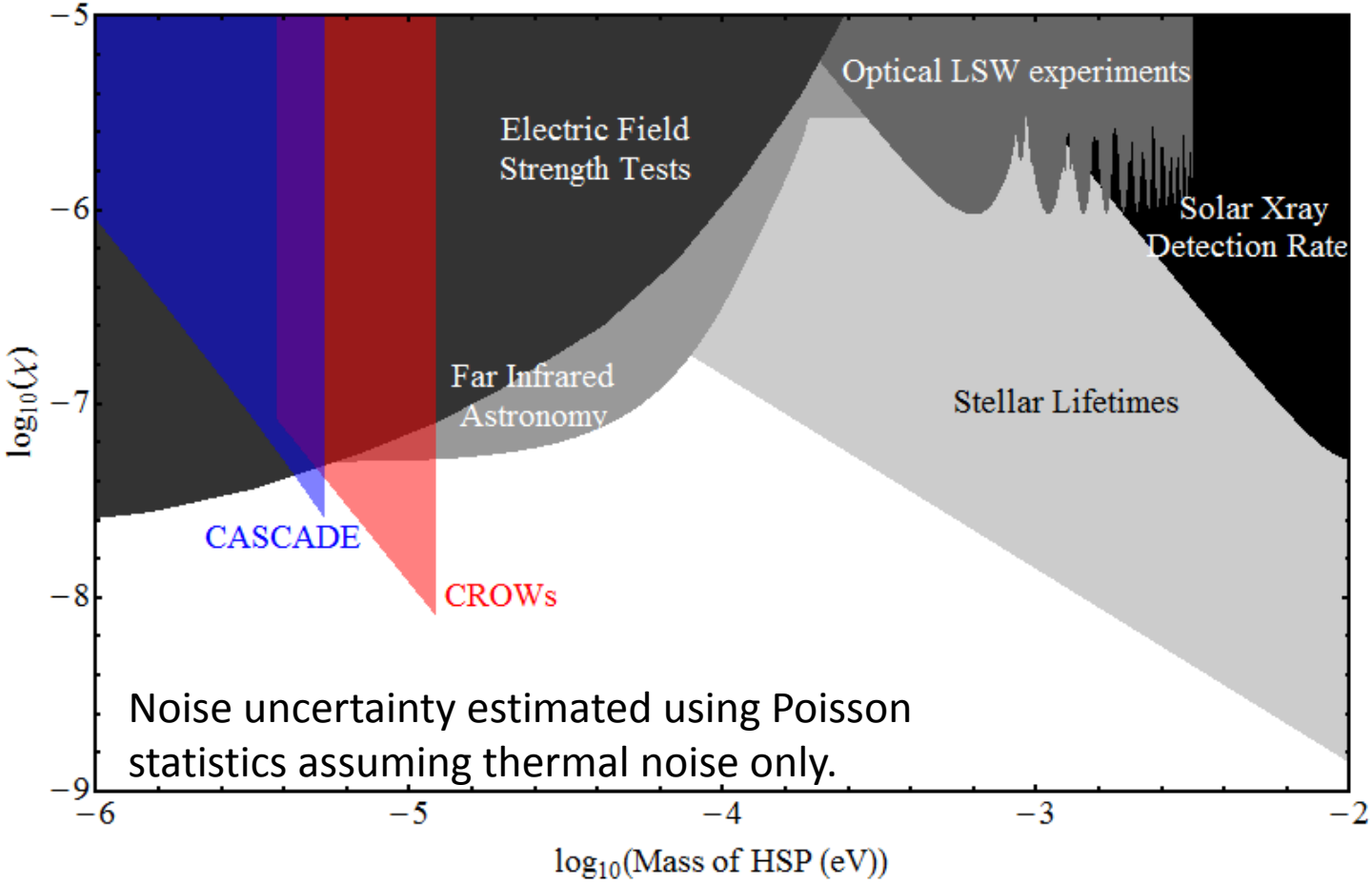

# -Expected Exclusion

- Before data taking was performed an estimated exclusion was calculated.
- Cavity simulations were performed using CST Microwave Studio to estimate expected Q and quantify field distortions caused by the coupler.
- An analytical framework was built in Mathematica.

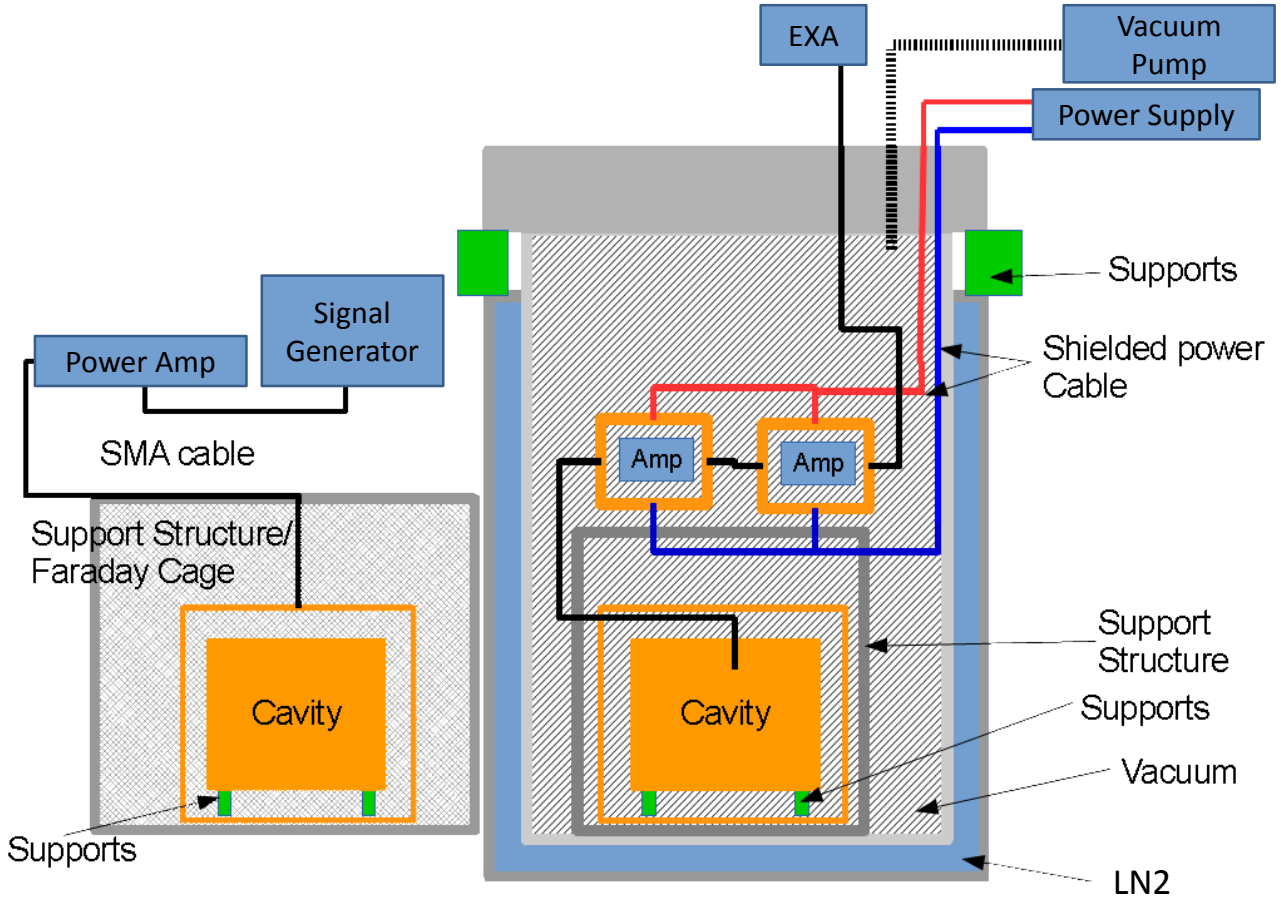


# -Expected Exclusion



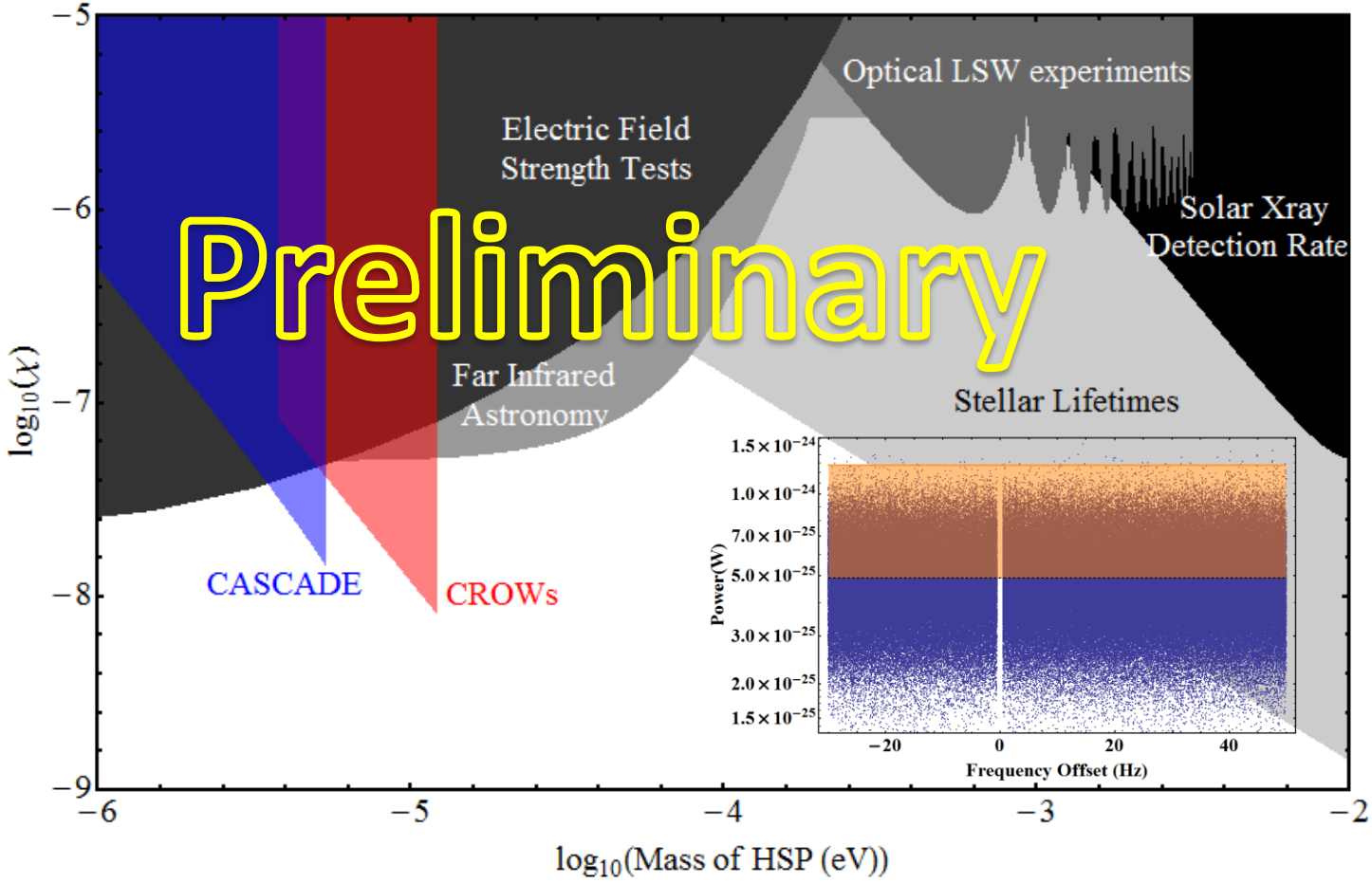

# -CASCADE Schematic




*Not to scale

# -CASCADE Phase 1

# -First Results

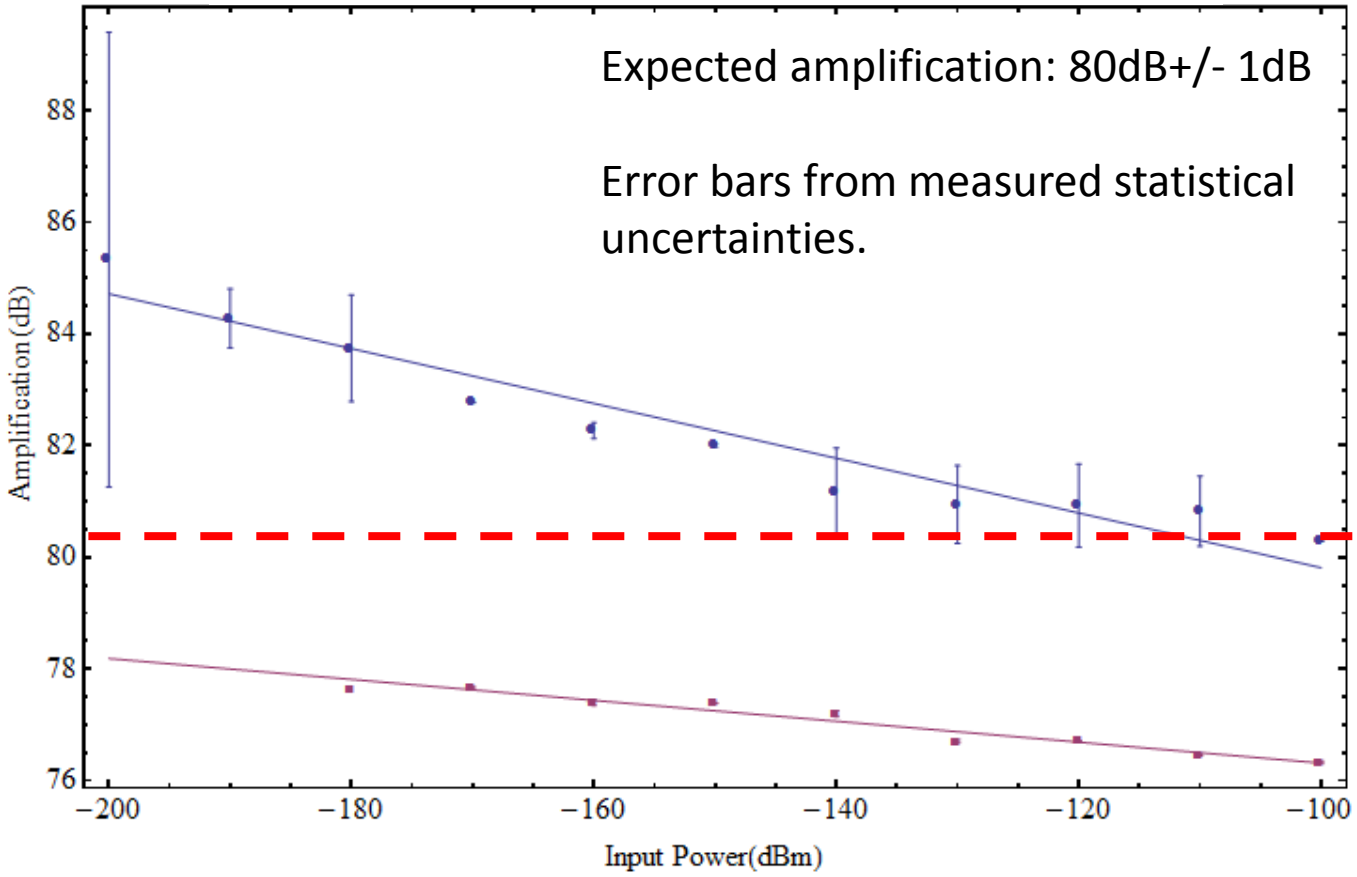



# -Cryo Run

Cooling the experiment is expected to improve performance through:

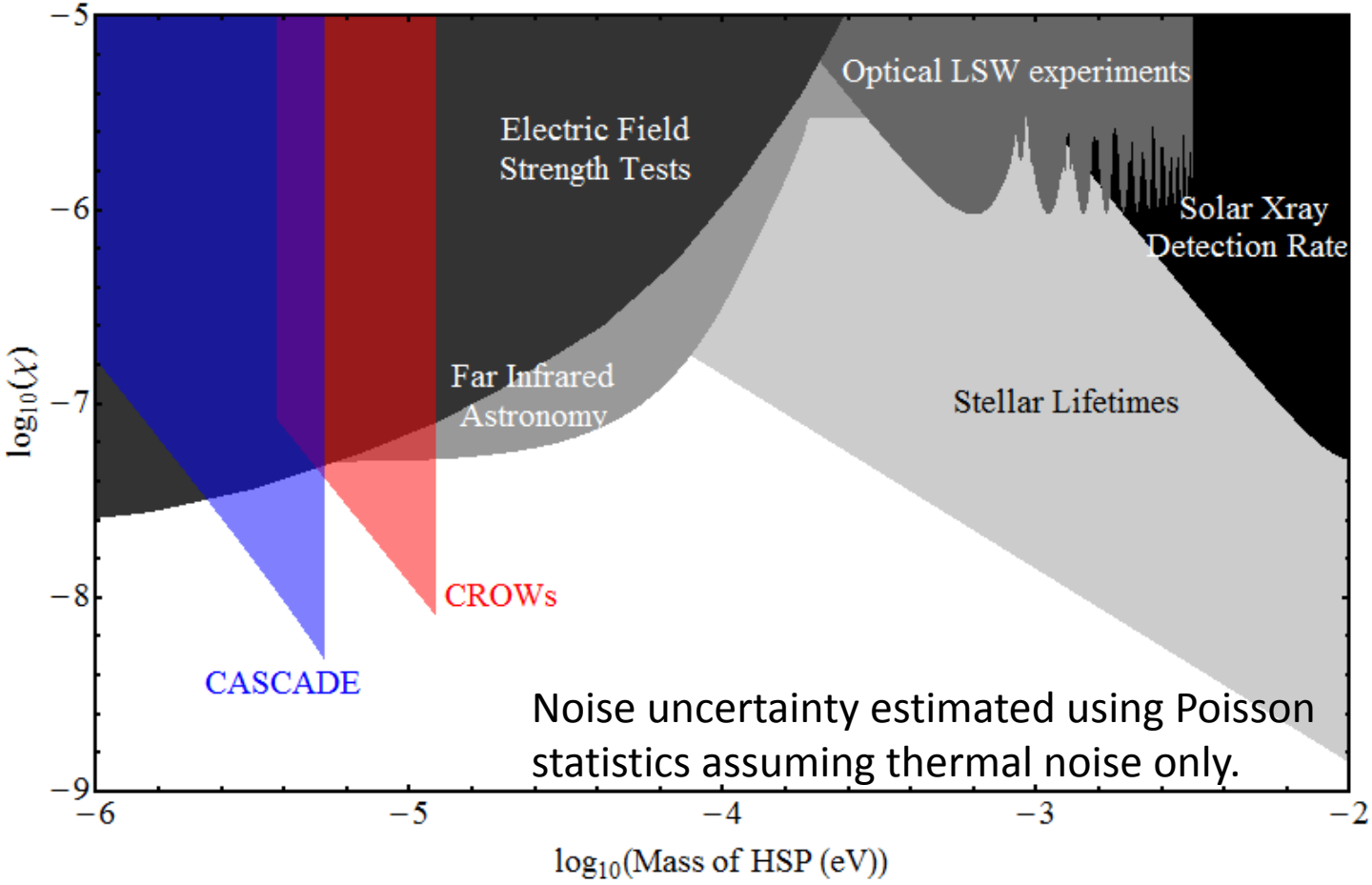
- Increased Q factor of the cavities from 10500 to 13500.
- Increased amplification: +2dB.
- Reduced Noise Figure: -0.4dB .
- Reduced thermal noise.

# -Cryo Amps

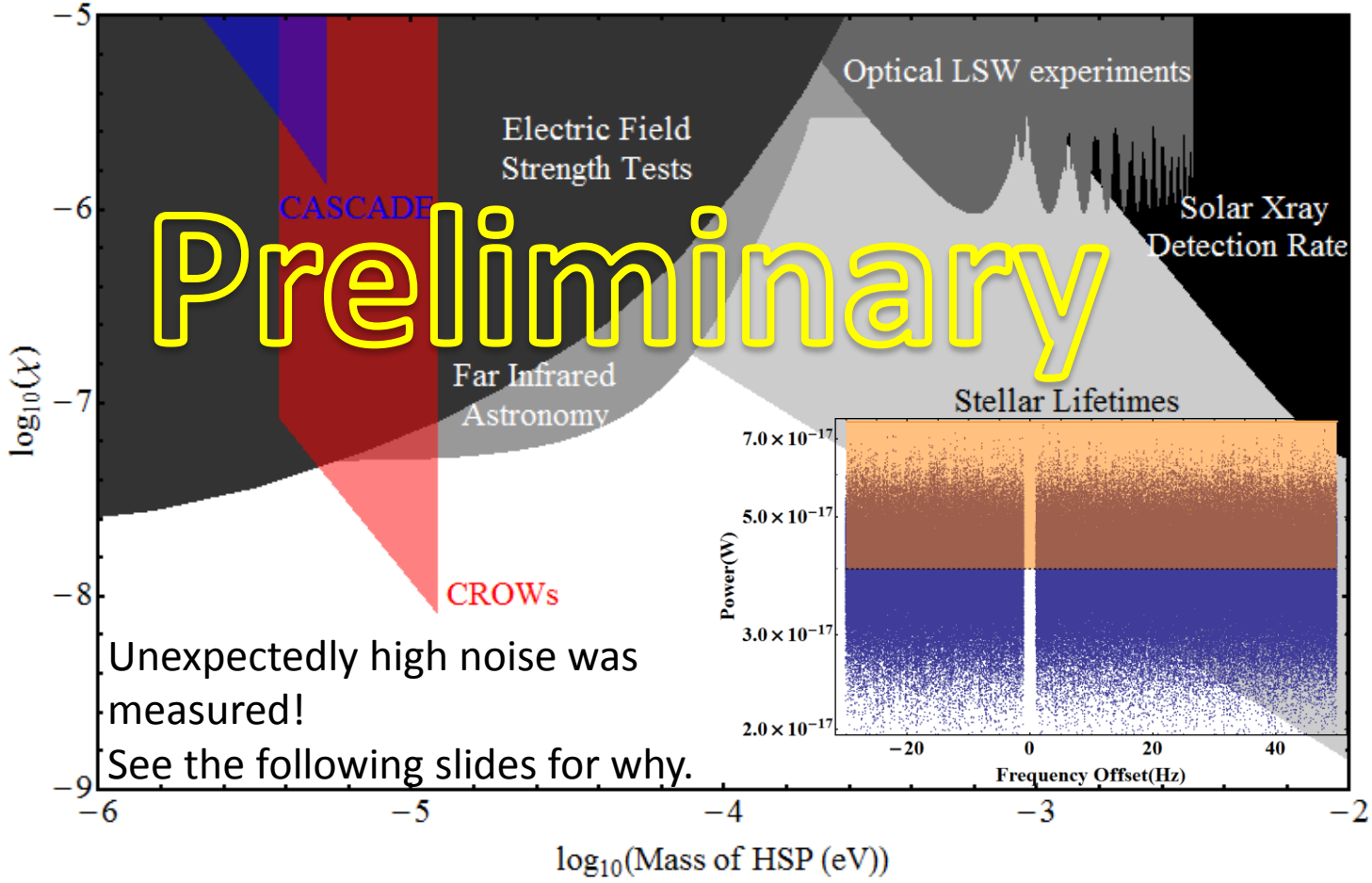



Amplification assumed for exclusion

# -Expected Cryo Exclusion



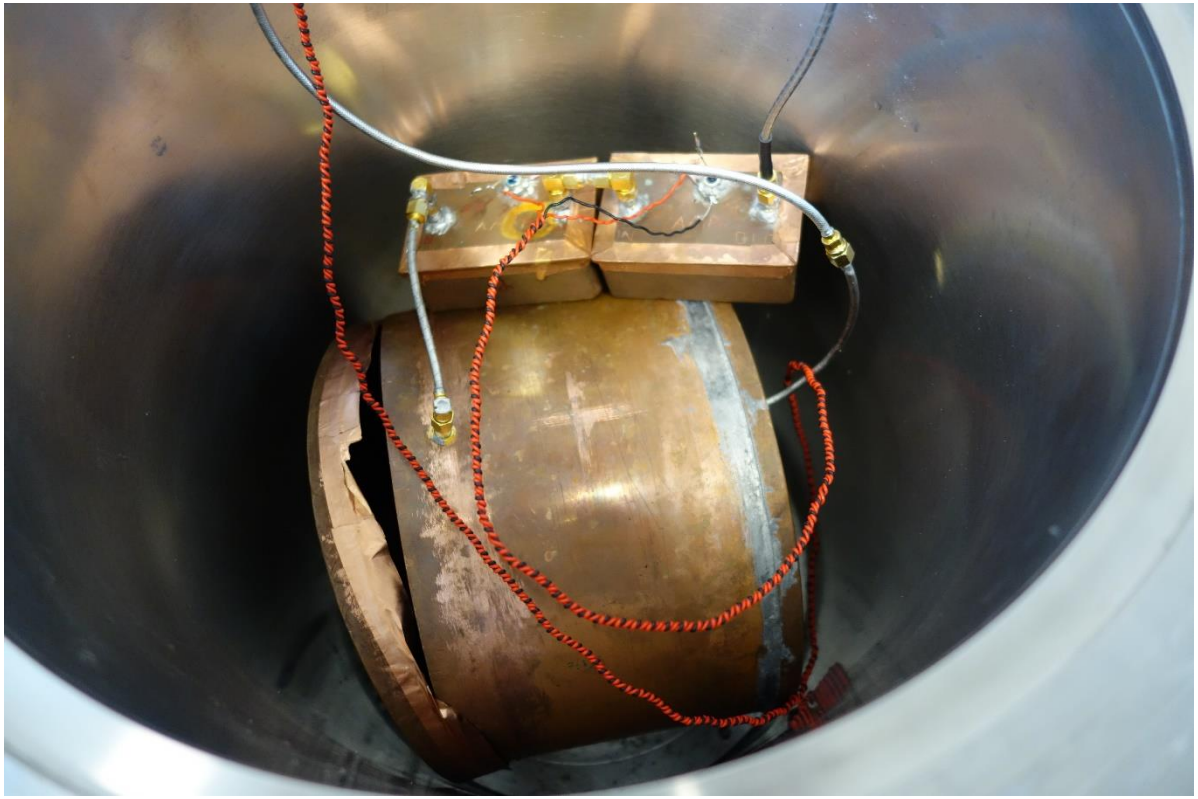

# -Actual Cryo Exclusion




Unexpectedly high noise was measured!

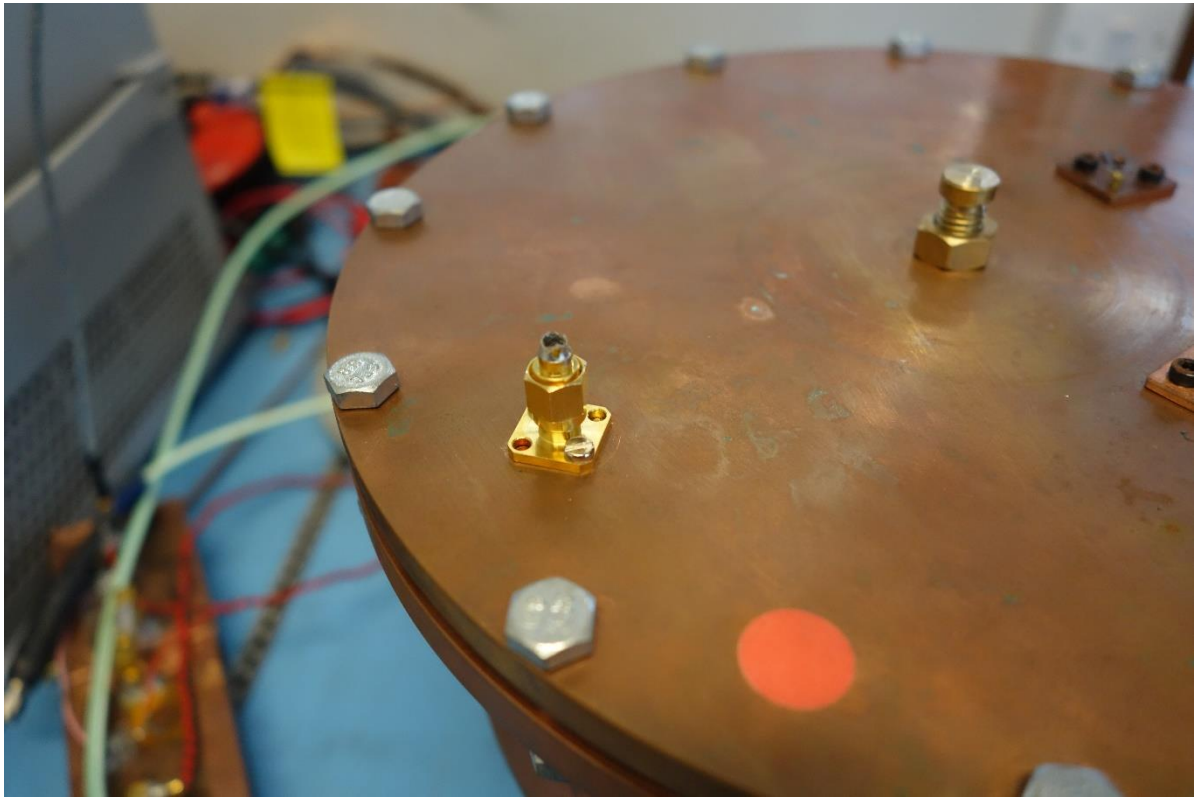
See the following slides for why.

# -The Damage



The shielding box buckled whilst cooling.

# -The Damage



A number of co-axial connections had ruptured during cooling.

# -Coupling Longitudinally

PHYSICAL REVIEW D 90, 075017 (2014)

## Parametrically enhanced hidden photon search

Peter W. Graham,[1] Jeremy Mardon,[1] Surjeet Rajendran,[1,2] and Yue Zhao[1]

[1]*Stanford Institute for Theoretical Physics, Department of Physics, Stanford University, Stanford, California 94305, USA*

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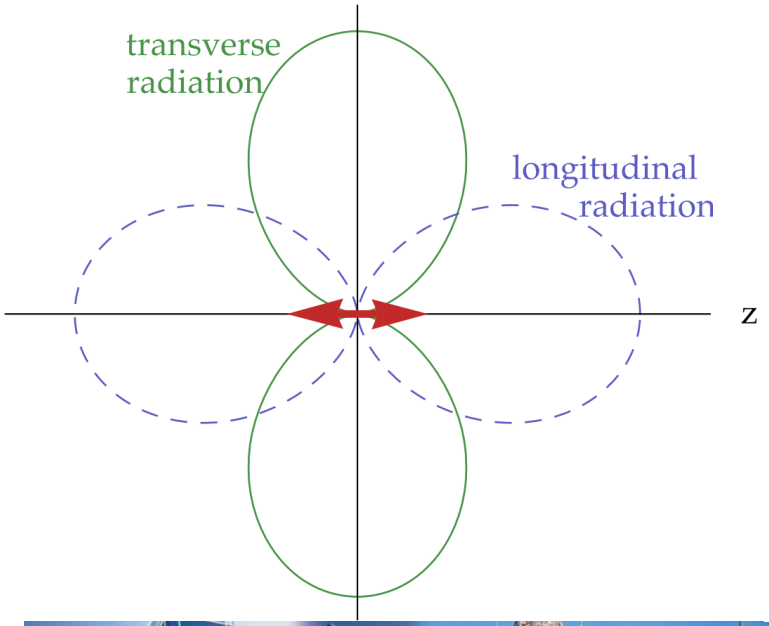
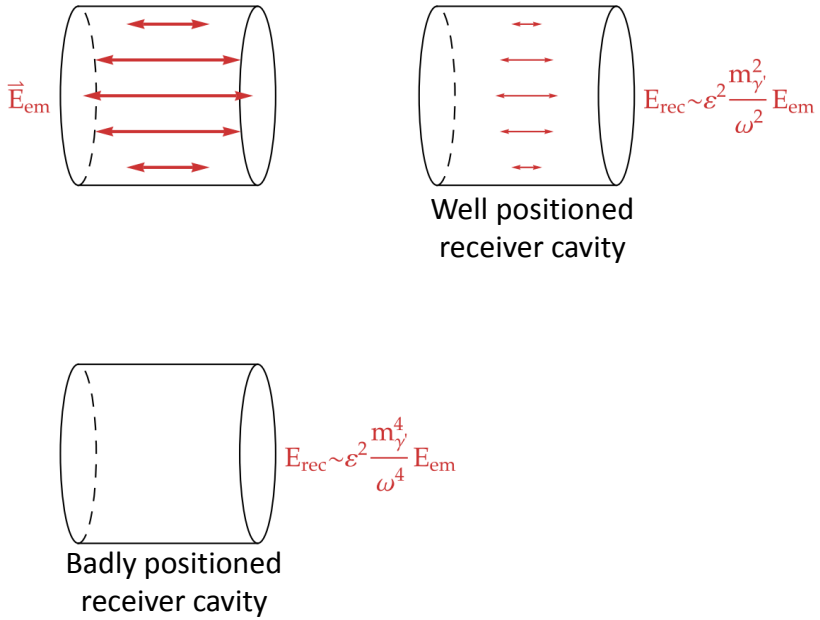
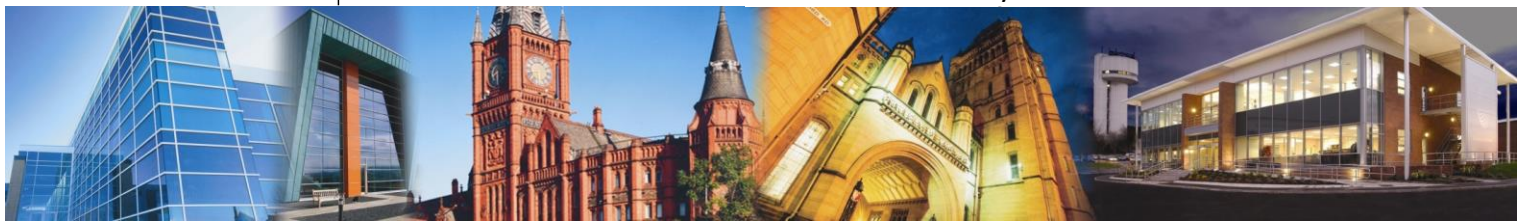
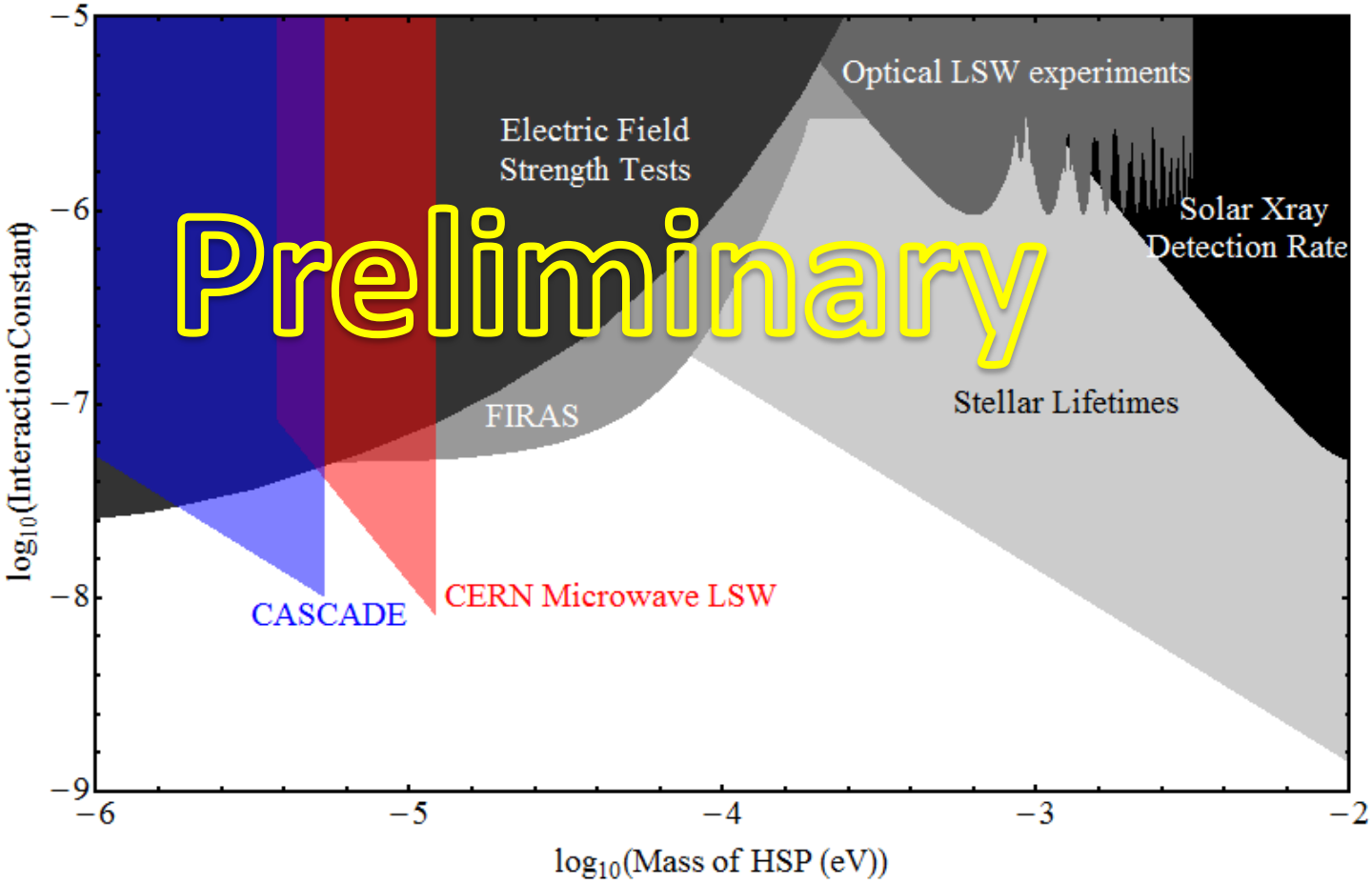


# -Longitudinal Exclusion




# -PHARAOH

The group is not only pursuing conventional RF LSW experiments:

- In 2014 a paper introduced the concept of a photonic structure based LSW.
- The experimental plan being known as PHAROAH.
- Some questions were raised so we have had a masters student work on addressing some of these questions.

**Hidden-sector photon and axion searches using photonic band gap structures**

**Rebecca Seviour[1,2], Ian Bailey[3,4], Nathan Woollett[3,4] and Peter Williams[4,5]**

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[2] Lund University, Lund, Sweden
[3] Physics Department, Lancaster University, Lancaster, UK
[4] Cockcroft Institute, Sci-Tech Daresbury, Warrington, Cheshire, UK
[5] STFC Daresbury Laboratory, Sci-Tech Daresbury, Warrington, Cheshire, UK

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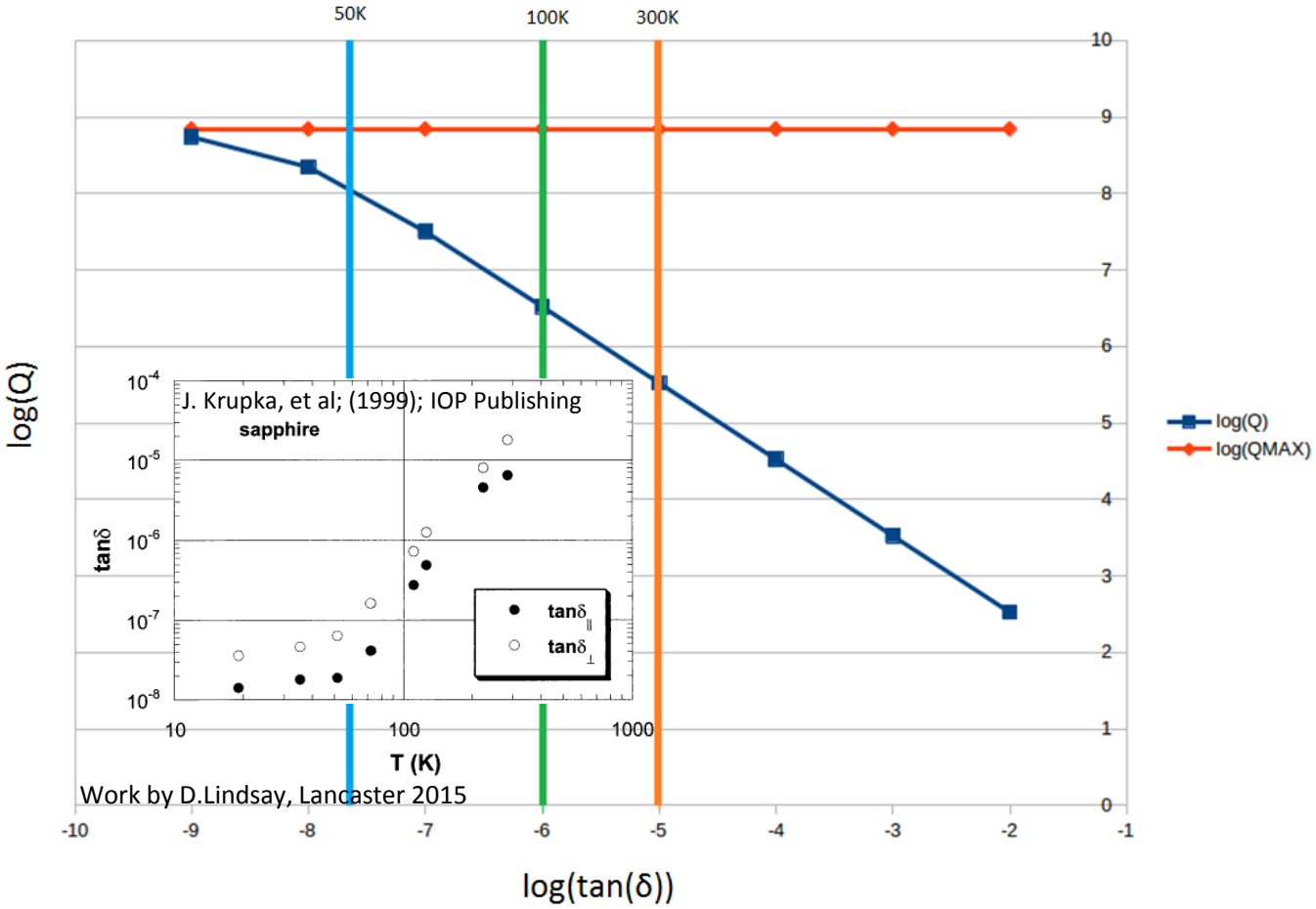
# -Loss Tangent Simulations




# -Whats next

This stage of CASCADE was always meant to be a proof of principal experiment, so where are we going next?

- Complete longitudinal analysis giving us the strongest bounds in the $10^{-5.2}$ to $10^{-5.8}$eV mass range.
- A paper on the results is in preparation and expected to be out late summer 2015.
- Repair the damage from the first cryo-run for future runs.
- Improve the shielding design to minimise leakage.
- Implement electro-optic links.
- Customised read-out chain.
- Follow up paper to PHAROAH expected in 2016.

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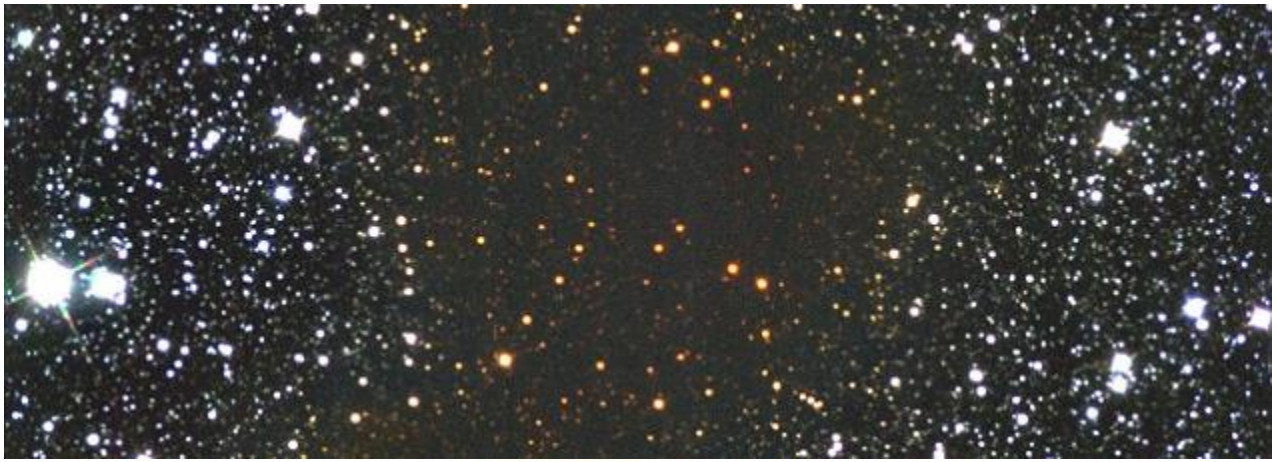
# *Thanks For Listening*

# *Any Questions?*

# -Introduction

The standard model is a successful description of the particle physics we have observed however there are many phenomena that cannot be explained.

- The strong CP problem
- Solar coronal heating
- Transparency of the universe at high energies.



One solution to the above observations is the Hidden Sector Photon(HSP)