Workshop on Diffraction Limited Storage Rings
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SLAC National Accelerator Laboratory, Menlo Park, CA

ALS-II Vacuum system and NEG coating

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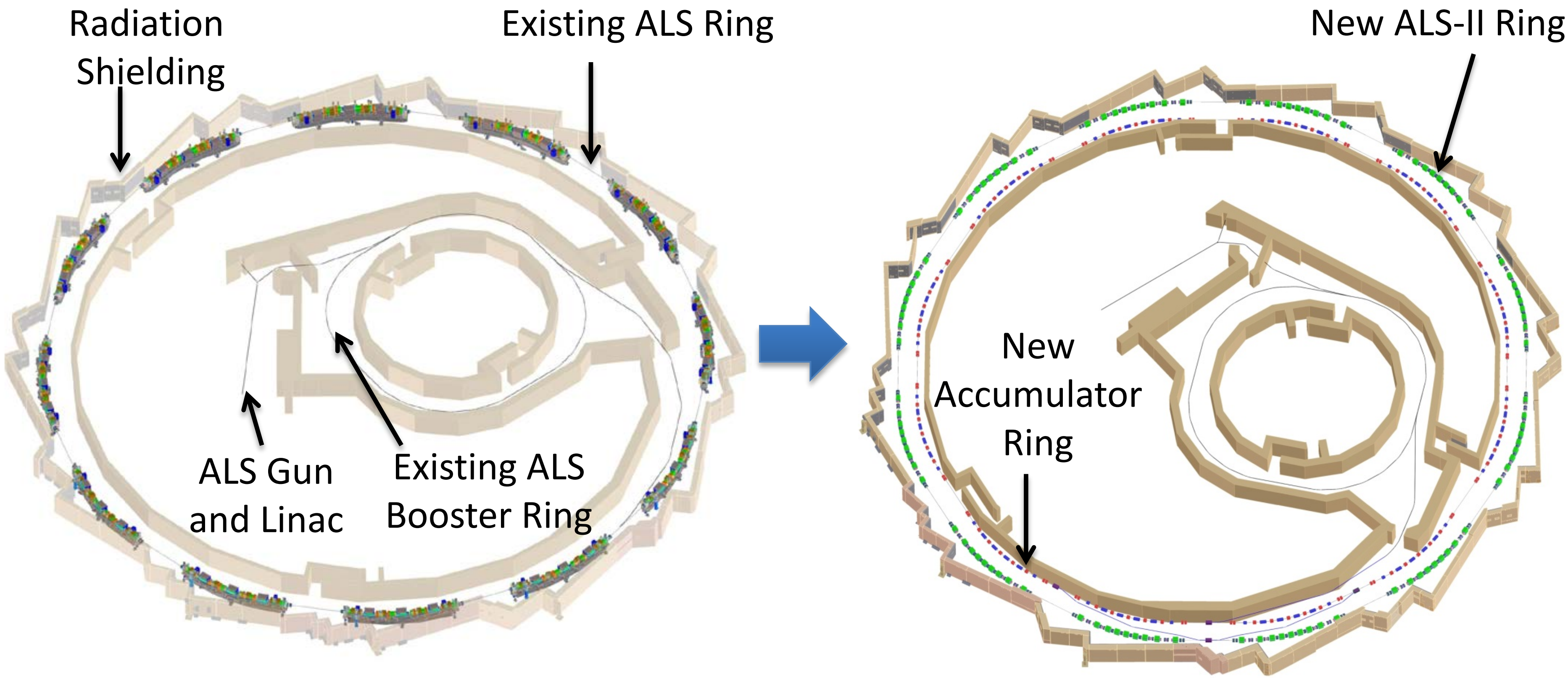
From ALS to ALS-II



- New high performance storage ring based on multi-bend achromat (9 bends per arc) in same building and tunnel
- Same circumference (197 m), straight section length, location and symmetry

Why Distributed Ti-Zr-V NEG Technology?

- Research and development underway since early 1990's: first at CERN, later also at other places, incl. commercial developments, incl. SAES
- Proven technology for achieving UHV in chambers with small cross sections: Matured technology used at ESRF and SOLEIL; more work is underway at BESSY and NSLS-II, and at other light sources.
- a section of ~ 2 m length has ~300 l/s pumping speed at pressures $< 10^{-9}$ Torr
- this pumping rate compares favorably with existing antechamber structures; allowing small gap designs.
- Typical activation range 180°C for 24 h, or 200°C for 1 h, which is compatible with designs and procedures for synchrotrons

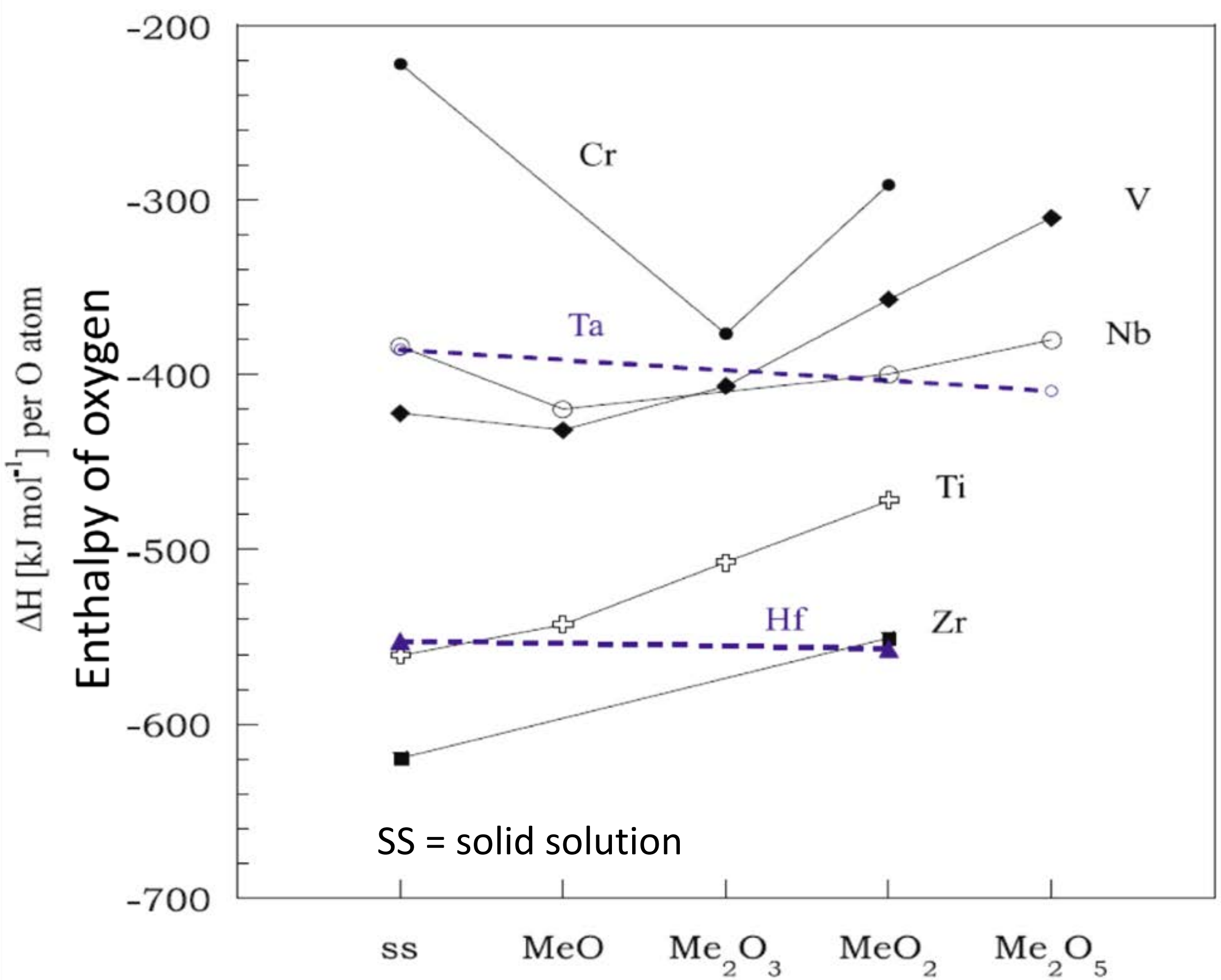
Reminder: NEG – how does it work?

thermodynamic considerations

- oxygen from the surface diffuses into bulk because this lowers the free energy of the system: Free energy of oxygen in SS must be smaller than free energy of oxide
- solubility increases in the presence of grain boundaries

kinetic considerations

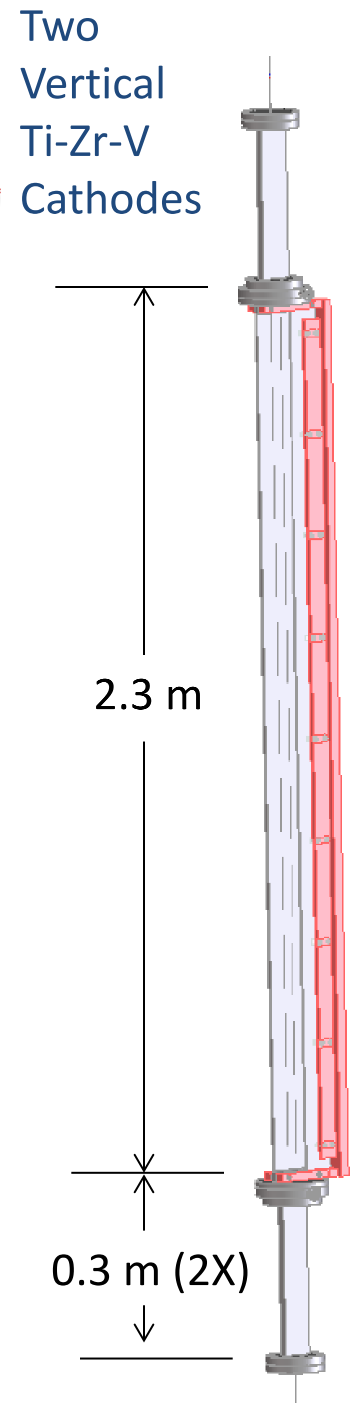
- oxygen diffusivity increases with temperature
- solubility increases with temperature
- concentration gradient needs to be sufficiently high for diffusion to occur



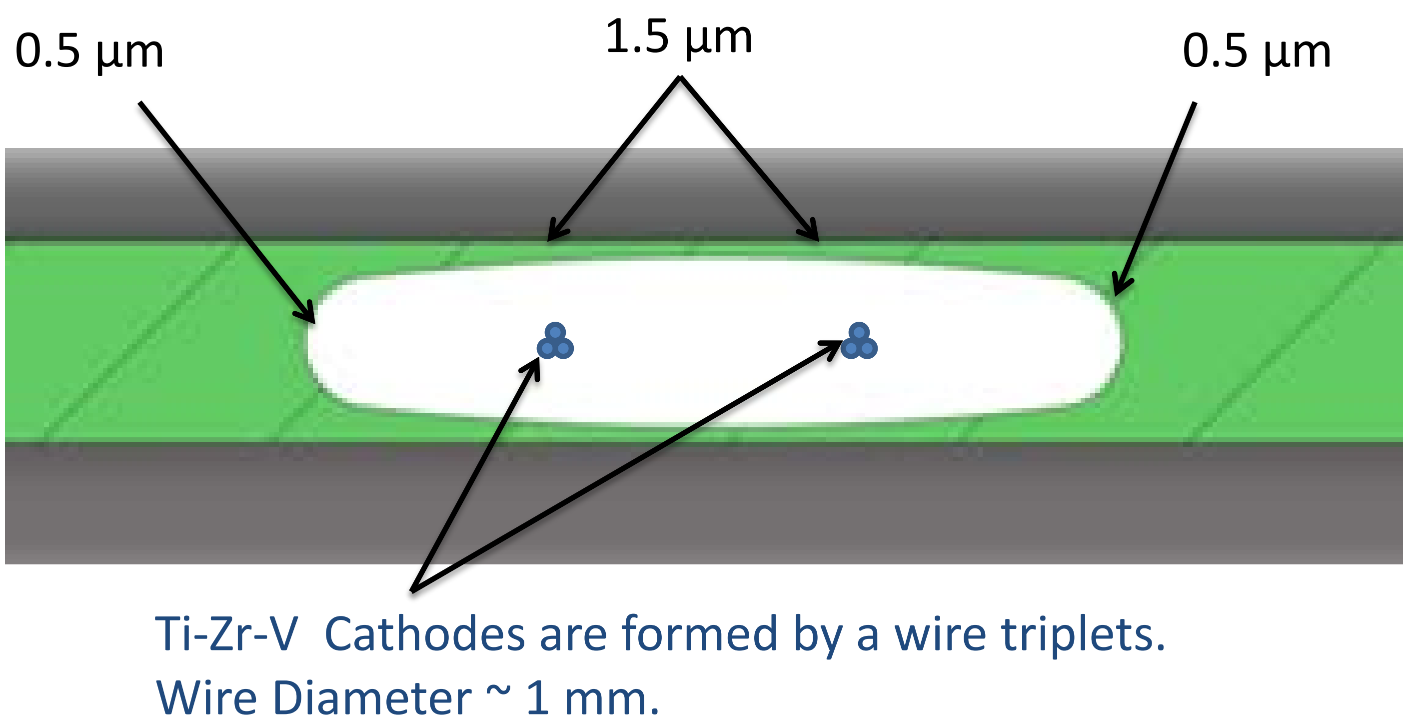
"activation" of the Ti-Zr-V (Hf) coatings at about 180°C

A. Prodromides, Thesis, Lausanne, Switzerland, 2002.

NEG Coating Process (SAES)

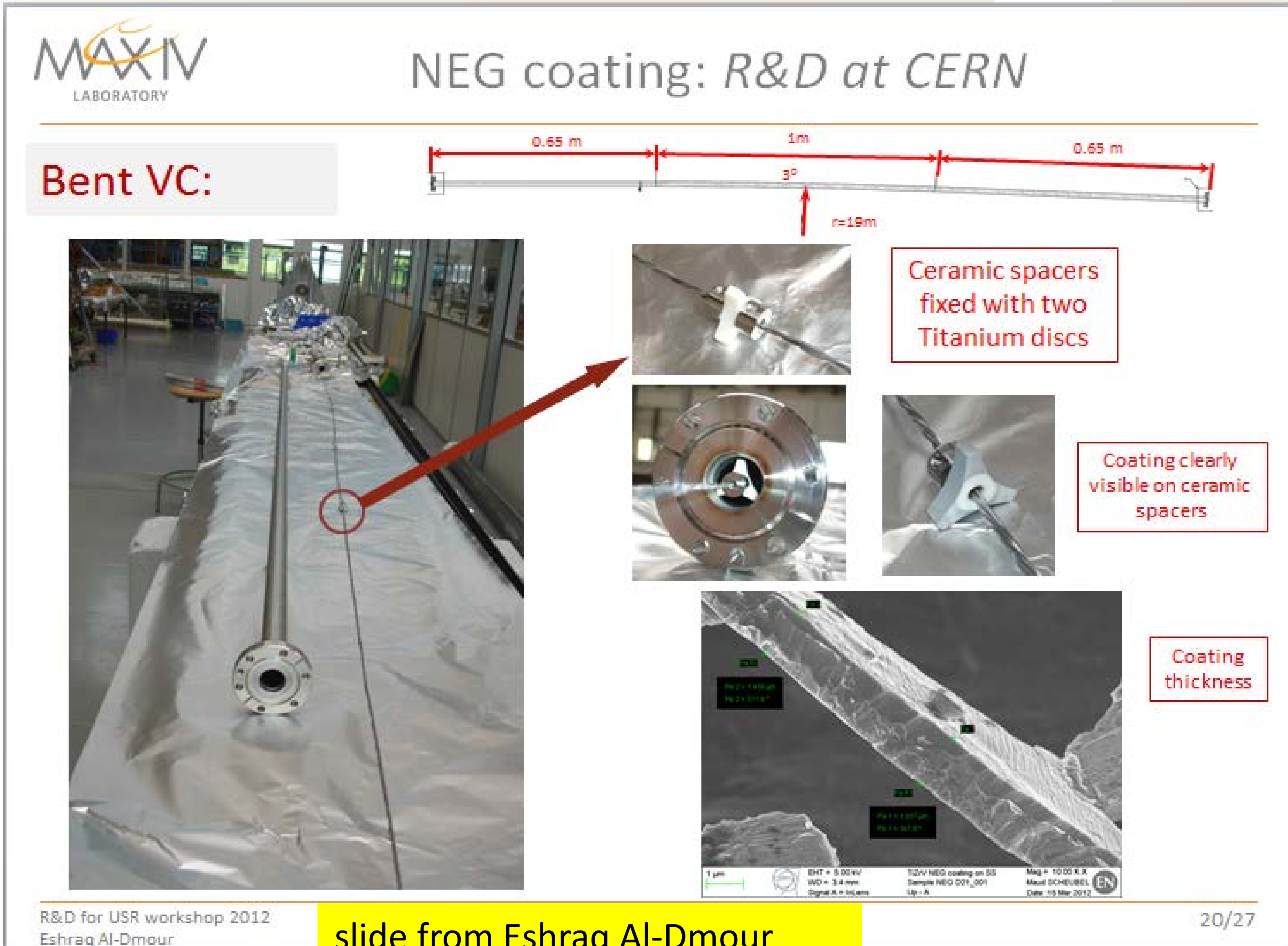


- Magnetron sputtering process inside vertical chamber
- Room temperature process
- Coating thickness = 1 µm (±0.5 µm)



NEG coating inside long straight vs. curved chambers

SLAC



slide from Eshraq Al-Dmour

Challenges

The challenges are:

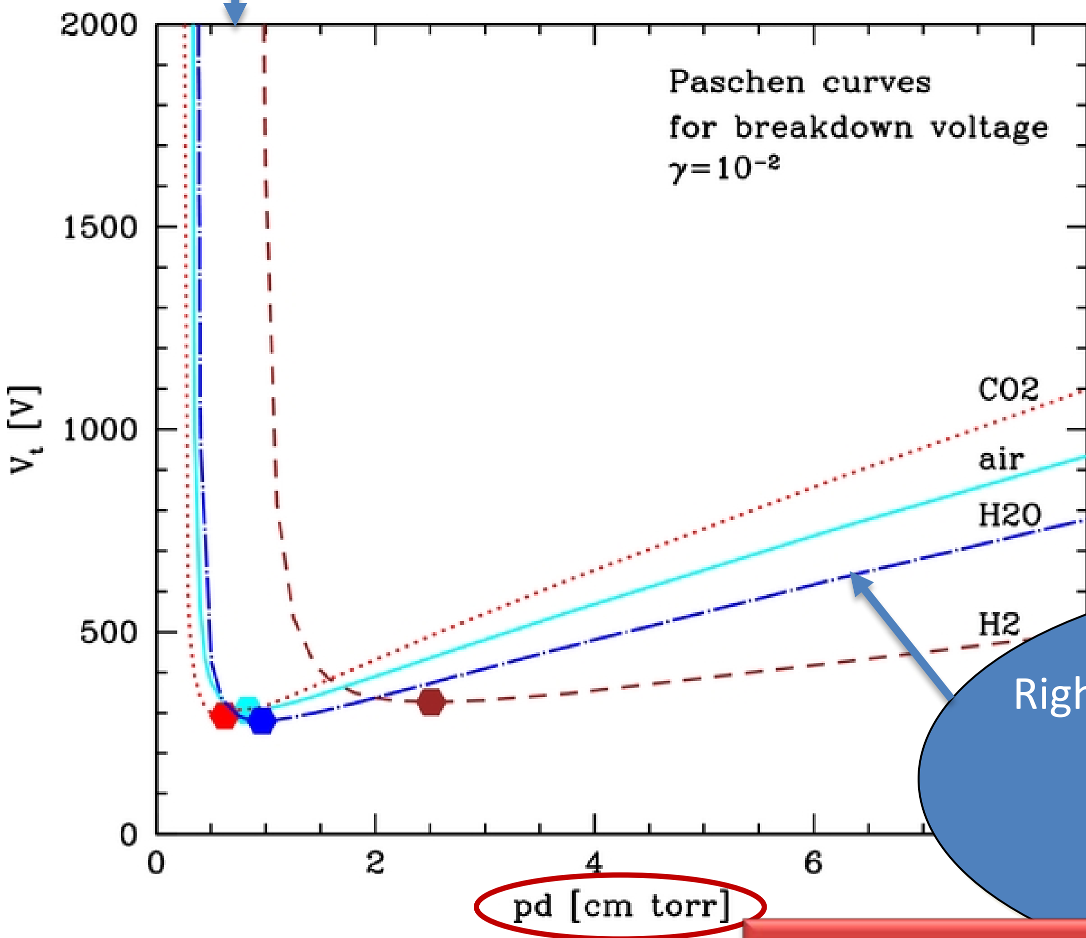
- to make NEG coatings in very small (< 10 mm) aperture, high length/diameter ratio (200-500) vacuum chambers.
- to integrate ports for many beamlines into the small aperture vacuum system, implying many aperture changes and changes of the width/height ratio where the photon beamlines leave the main chamber

Options regarding the coating include:

- scaling of the established process
- inventing new processes

Paschen Curves

Left side of the curve's minimum:
Few ionizing collisions:
mean free path > *d*



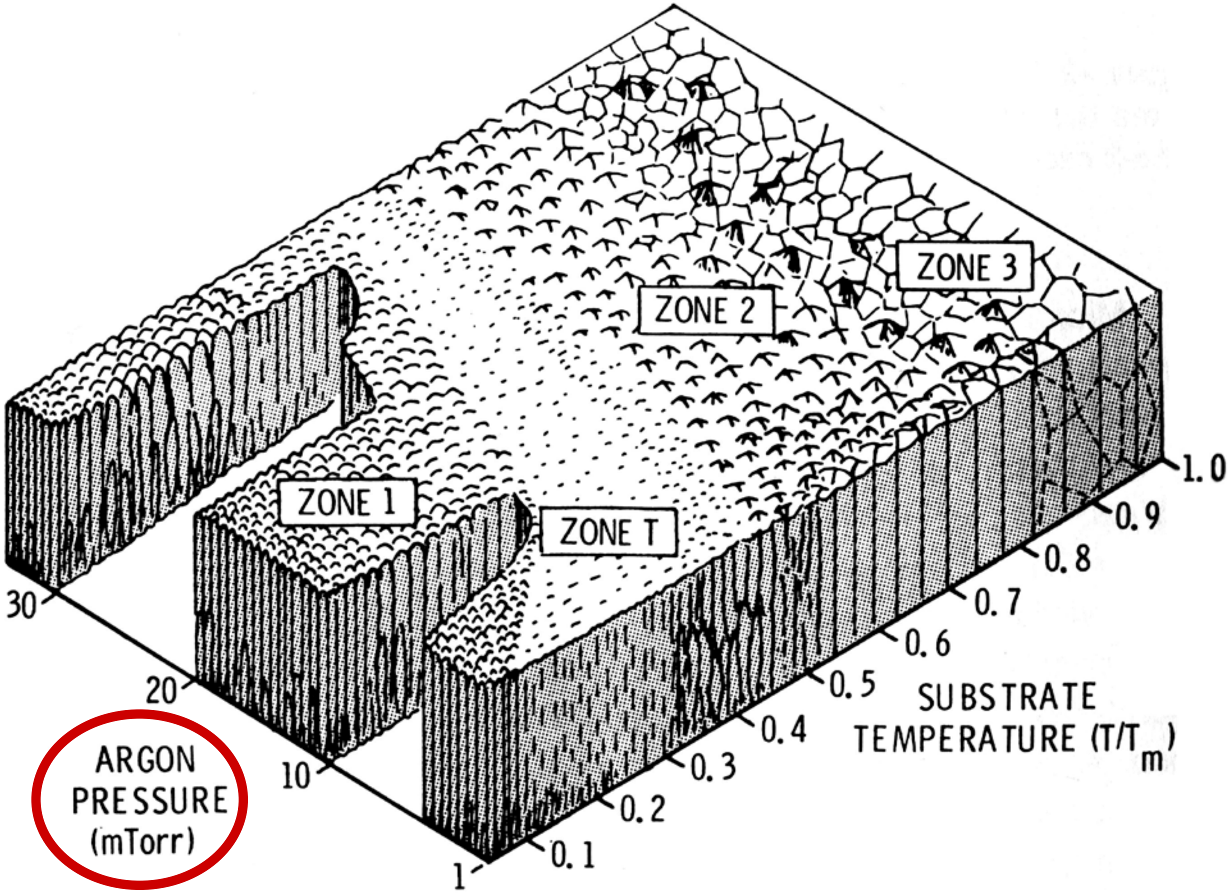
Right side of the curve's minimum:
Many collisions prevent
electron energy gain:
mean free path << d

pd contains the scaling with pressure!

Louis Karl Heinrich
Friedrich Paschen
(1865 - 1947)

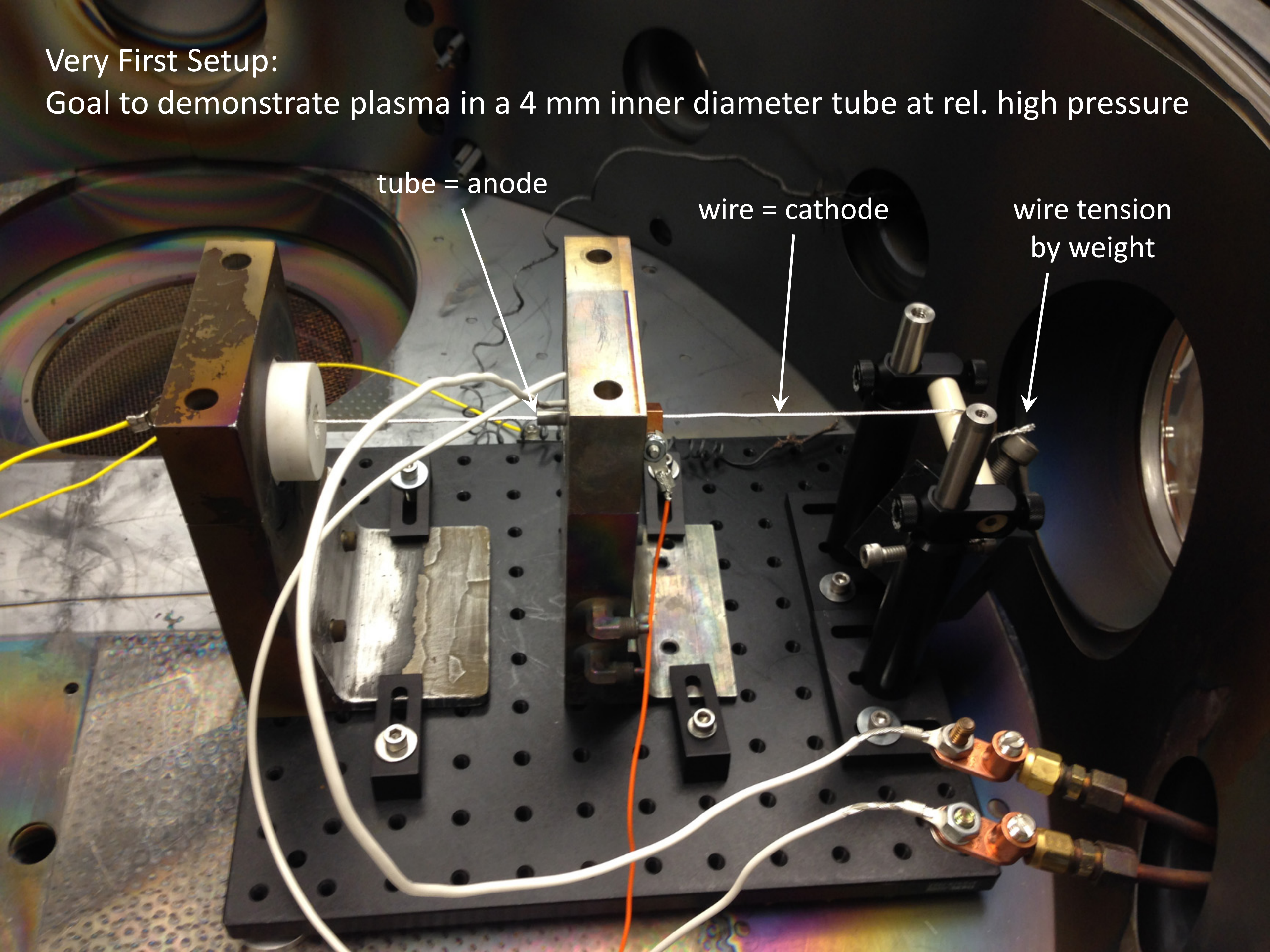
original work: F. Paschen, Ann. Phys. Chem., Ser. 3, **3**7, 69 (1889);
figure from: Helling, M. Jardine, C. Stark, D. Diver, Astrophys. J. **767** (2013) 136.

Thorton's Structure Zone Diagram of Film Microstructure for Sputtering



Contains the effects of energetic particle bombardment, and more precisely, it should be pd

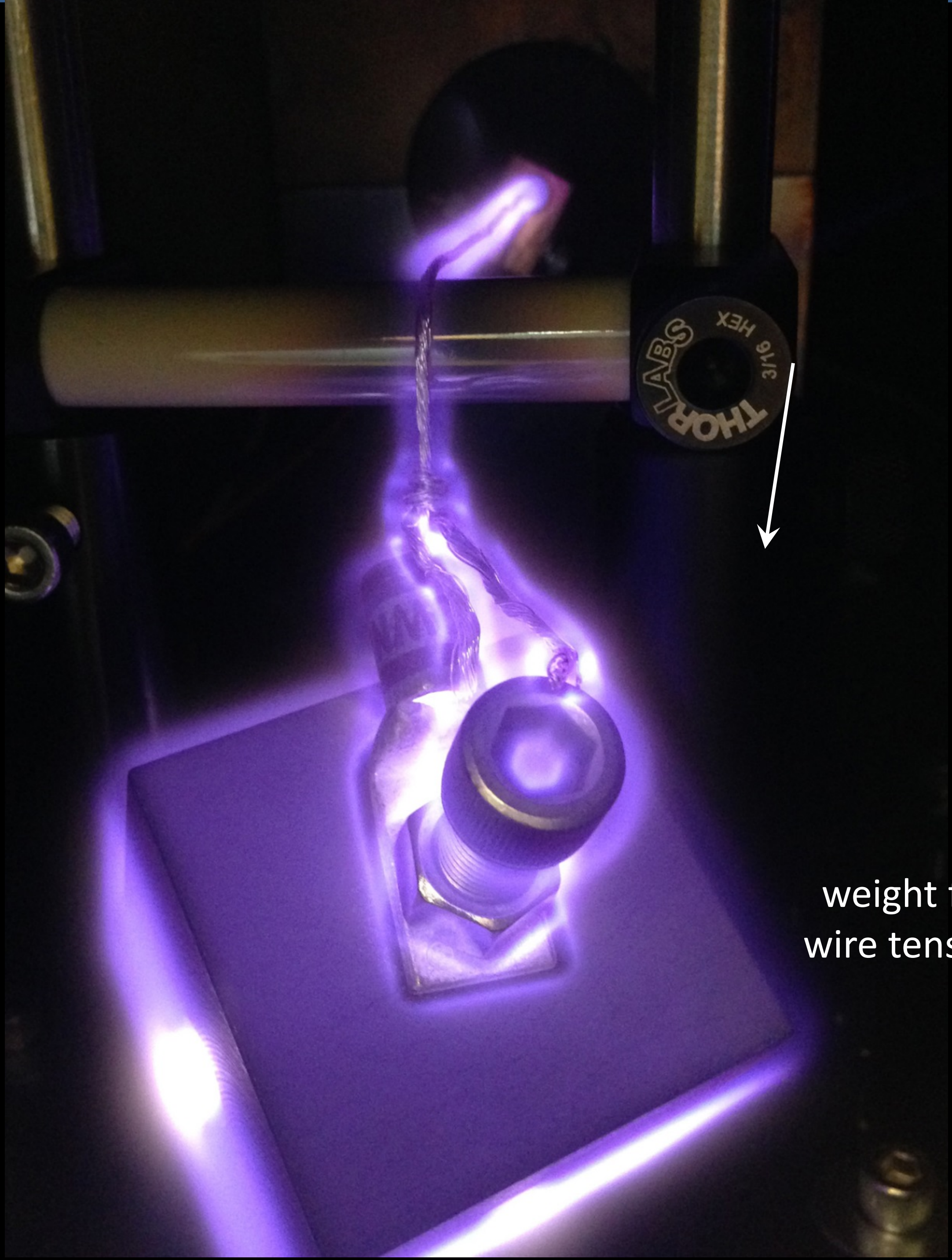
J. A. Thornton, *J. Vac. Sci. Technol.* **11** (1974) 666


Very First Setup:
Goal to demonstrate plasma in a 4 mm inner diameter tube at rel. high pressure
tube = anode
wire = cathode
wire tension
by weight

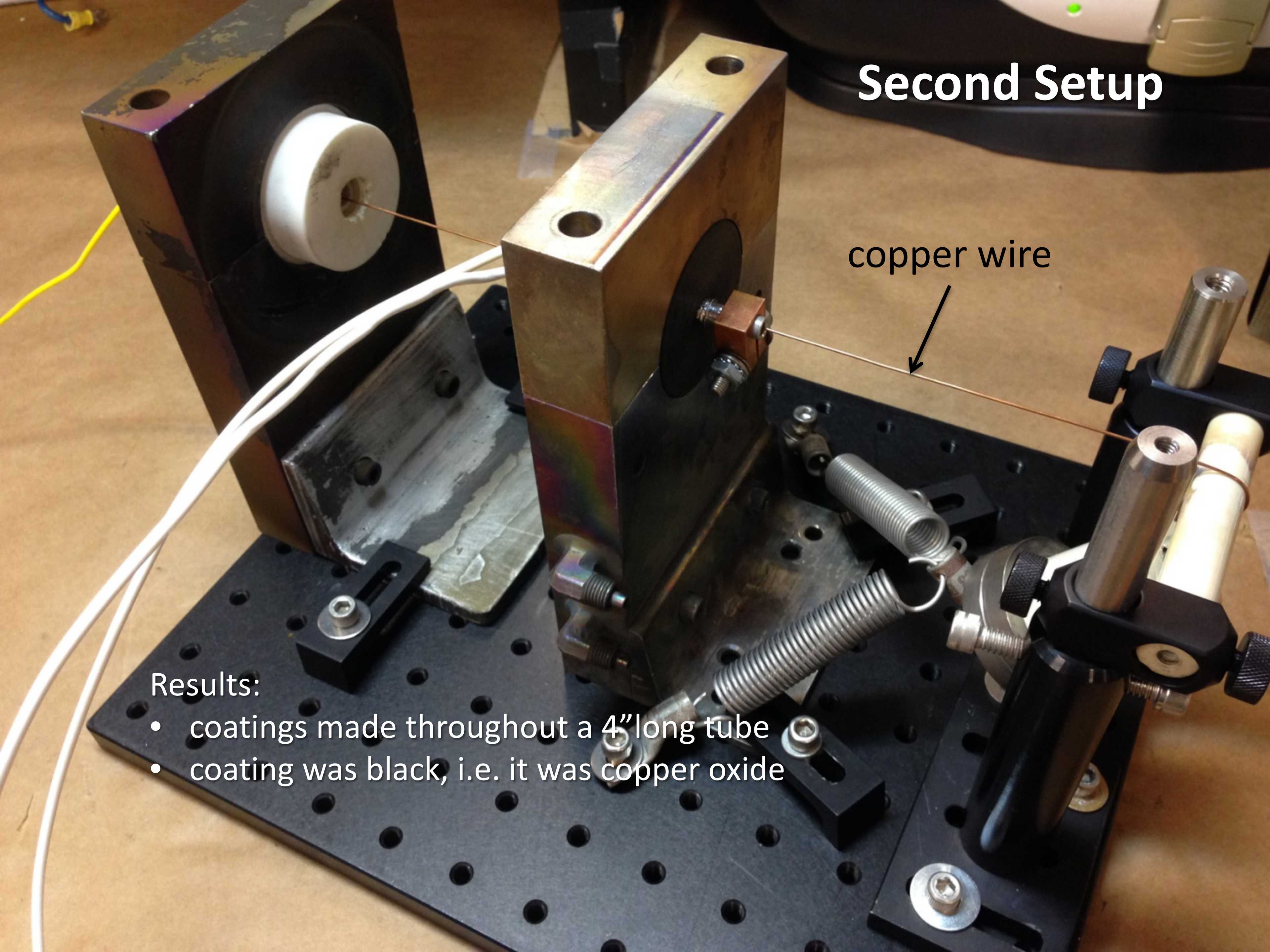
Glow Discharge at 4 Torr

↓

negative glow
plasma has a
scale ~ mm



weight for
wire tension


Second Setup
copper wire
Results:
• coatings made throughout a 4"long tube
• coating was black, i.e. it was copper oxide

Summary of Preliminary Results & Outlook

- ALS-II vacuum system has the same length as original synchrotron (~ 200 m) but significantly smaller chambers: preliminary design calls for straight sections that have inner diameter down to 4 mm, and varying cross sections and aspect ratios at beamlines
- 10^{-10} Torr range is required → NEG (Ti-V-Zr) coating is needed
- NEG with low activation temperature is highly desirable (e.g. 180°C)
- Challenges
  - to scale the deposition technology to very small apertures
  - to deal with varying cross sections and aspect ratios
- Approach:
  - either scale the proven central-wire-cathode-based sputtering method, or
  - invent alternate options: none of the ideas have been tested yet
- Preliminary, crude experiments showed that plasma can be made in relatively short, 4 mm inner diameter tubes, and coating can be produced, yet much remains to be solved.