Future Power Generation by LENR with Thin-Film Electrodes

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Outline

- Some personal experiences in Cold Fusion
- Thin film electrode concept and the SEL theory
- Evidence for cluster formation based on thin-film electrolysis
  - Rx products occur in numerous localized areas over electrode surface
  - CR-39 detectors show localized chg. Particle emission areas
  - Film shows local areas of x-ray emission
- Other evidence – superconducting state in highly loaded dislocation loops using multiple loading for formation of loops
- Estimates for cluster reaction rates
- "Roadmap" for future power unit based on thin films and clusters.

Personal reflections

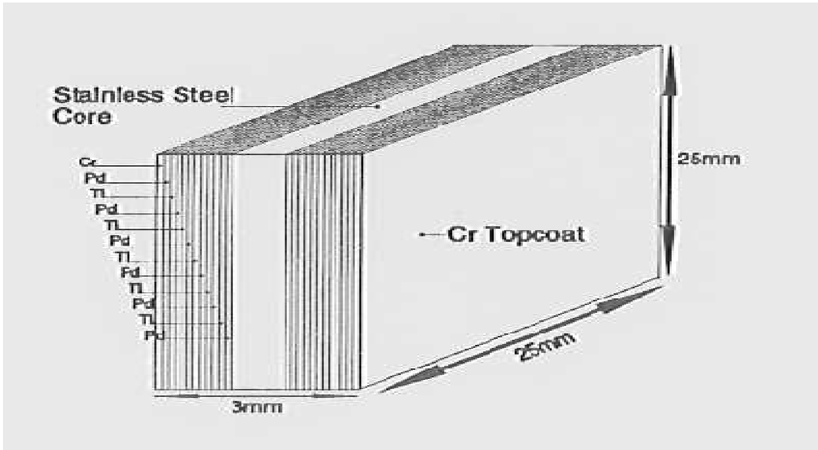
- Why I believe nuclear reactions occur in highly loaded solids at low temperatures

- *Thin film electrode* concept and the SEL theory
  - Thin-films provide interfaces where the reactions occur
  - Thin films offer high power density since the non-reactive volume is greatly reduced
  - Thin films can be made in a controlled fashion (lead to reproducibility)
  - Thin films load very quickly – hours vs weeks

B A C K G R O U N D

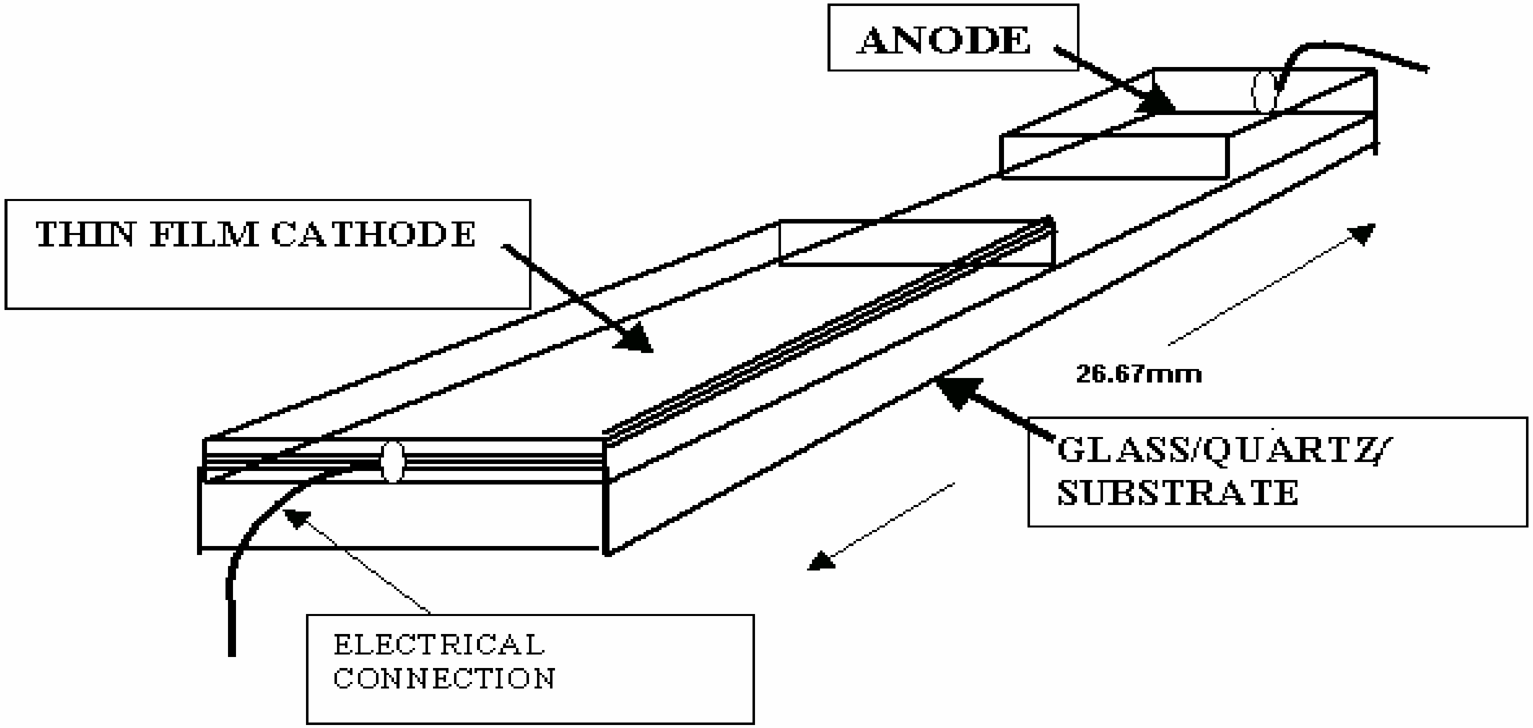
SEL Theory Lead to Multilayer Thin-film electrodes; theory is now modified to include clusters at interfaces

Fusion of two nuclei, shielded by the swimming electron layer



Early Multilayer thin-film electrode design with alternating layers of Pd & Ti with a topcoat of Cr

Thin-film Electrode designed for both interface loading and flow.



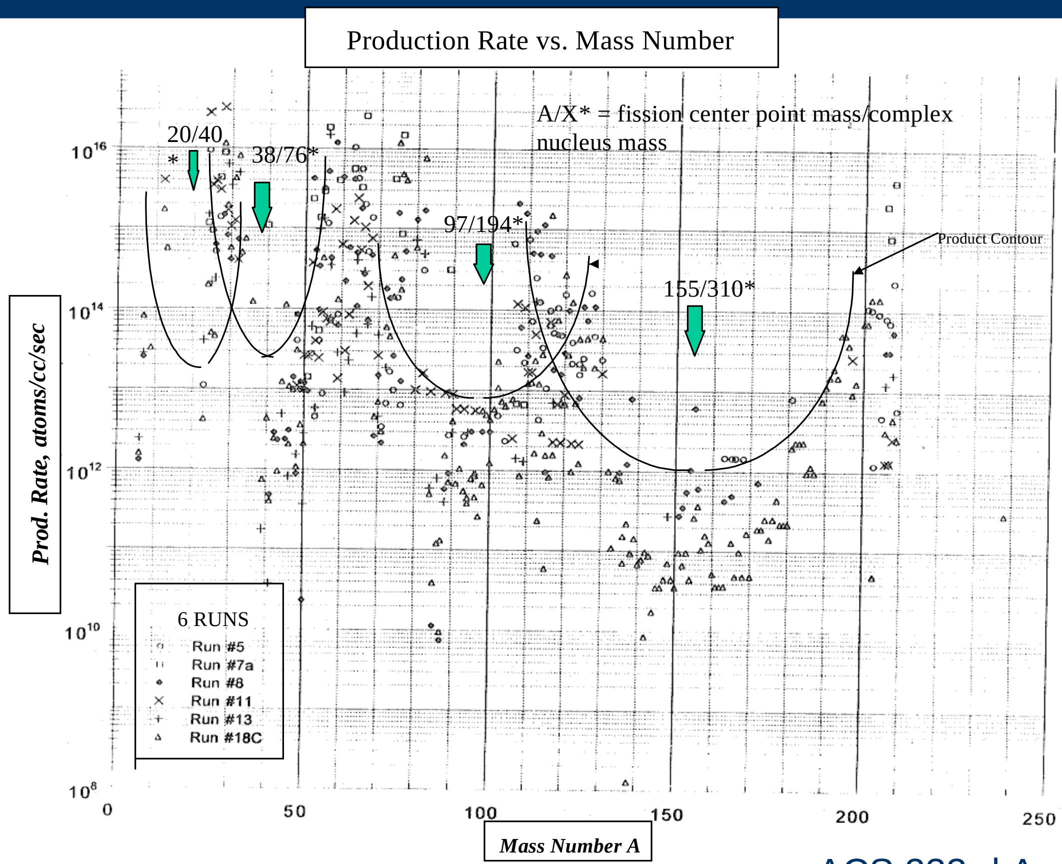
Discovery of 4-peak nuclear reaction products using thin films

- Can be explained in terms of cluster reactions

Transmutation products from thin-film electrolysis suggest localized reaction zones distributed across electrode

Production rate (atoms/cc-sec) vs.A **shows zones of high yield (~ 10^{16} atoms/cc-sec) separated by low yield zones (<10^{12}), ~ fission of heavy neutron rich complexes.**

Sims broad surface scan shows numerous localized reaction areas.



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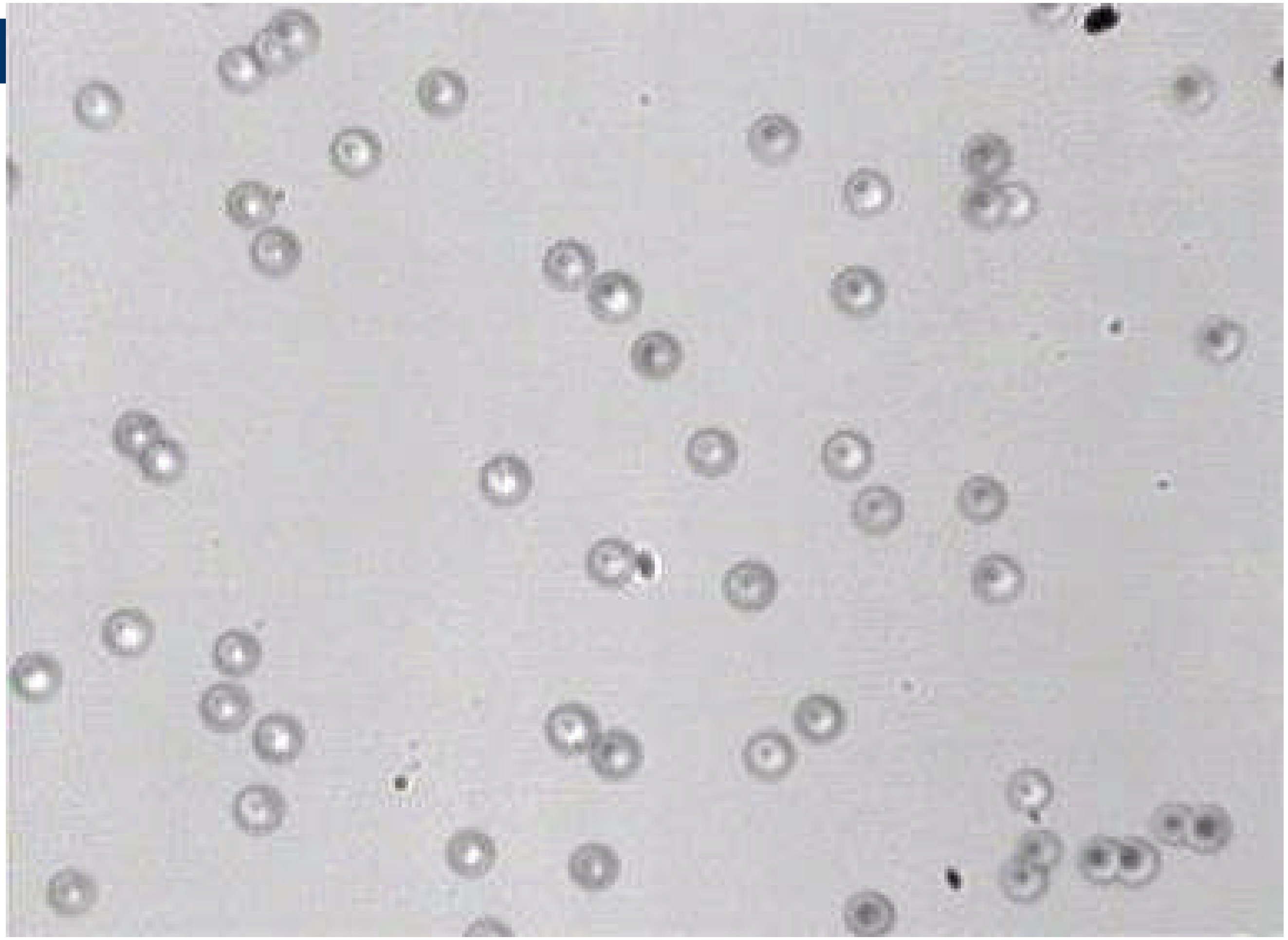
Other evidence for cluster reactions

- Detection pattern of
  - MeV charged particles
  - Soft X-rays

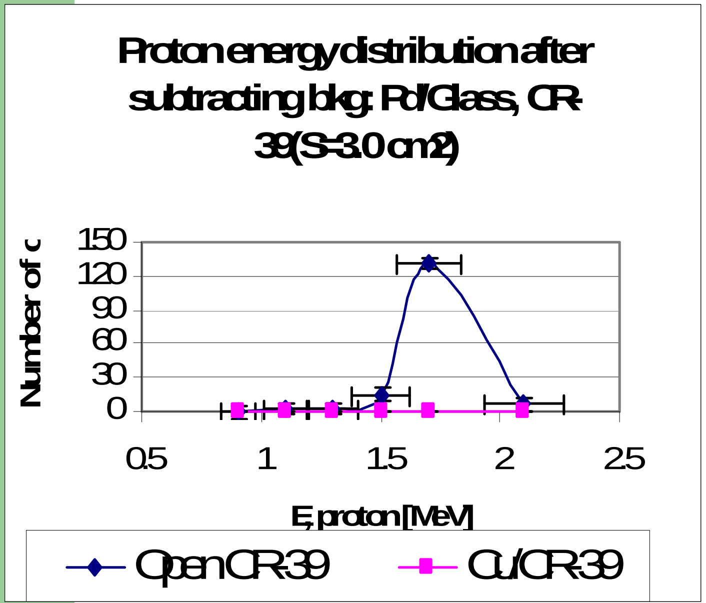
CR-39 track Detectors Indicate ~1.5-MeV protons & ~14-MeV alpha particle emission

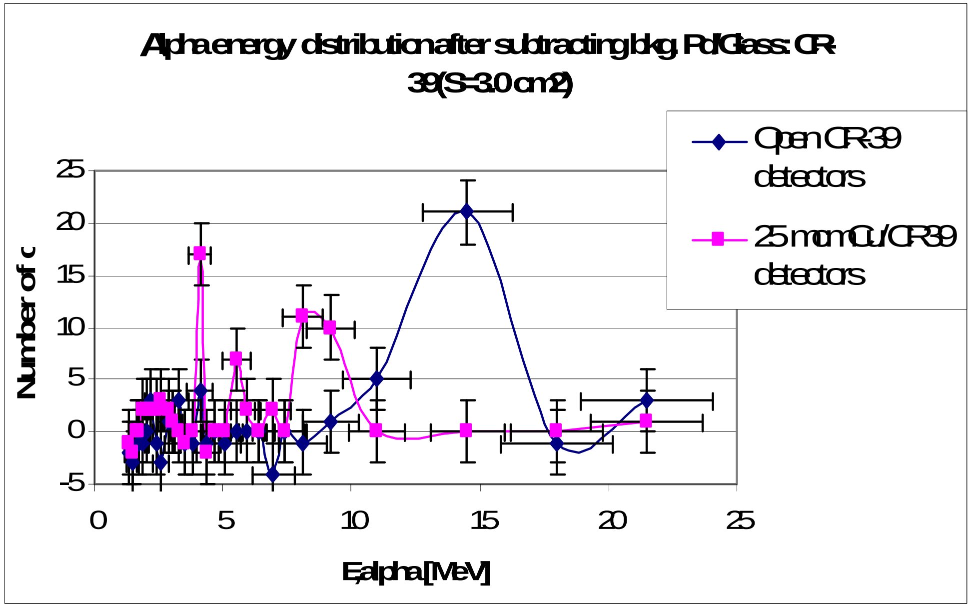
- CR-39 detectors “Landauer” rad-track chips; S=2.0x1.0 cm^2 attached to Pd/Ni thin film cathode(Foreground); to substrate side or/and immersed in electrolyte in the cell (Background). Low initial Bg before electrolysis: N(Bg) < 40 track/cm^2.
- In special experiments used CR-39 covered with 25 μm Cu-film to identify type of emitted particle

Tracks from 12.0 MeV α-particles; image area S= 0.2x0.2 mm, (X 700)



CR-39 tracks show ~ 1.7 MeV protons and ~15 MeV alphas.
Tracks were localized, suggesting cluster emission sites

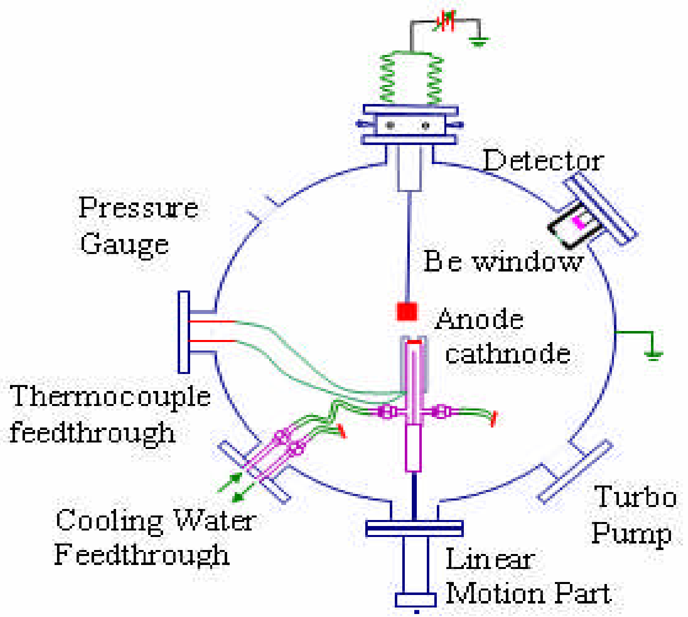




X-ray evidence

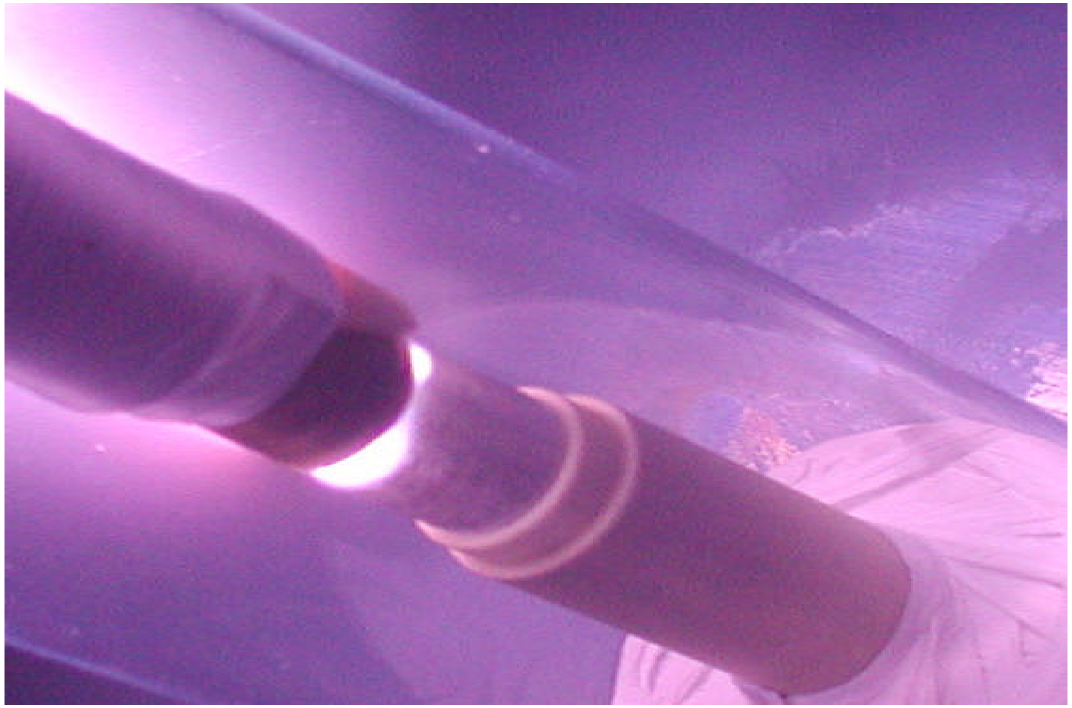
- Soft X-rays (~ 1 keV) found from plasma discharge loaded foils
- Damage pattern on plastic target suggests beamlets = cluster source

Experimental GD Setup at UIUC

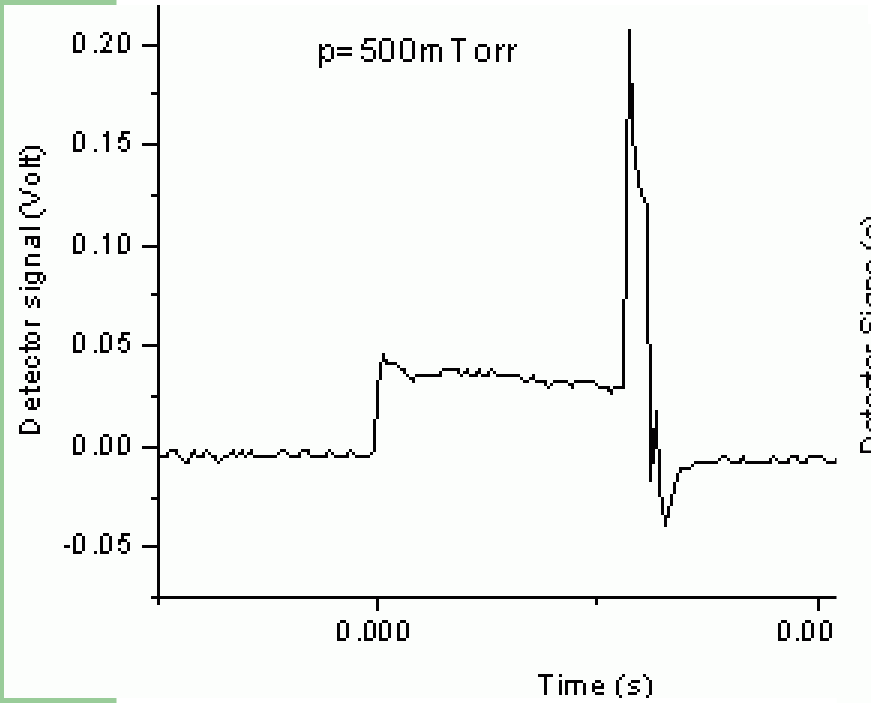


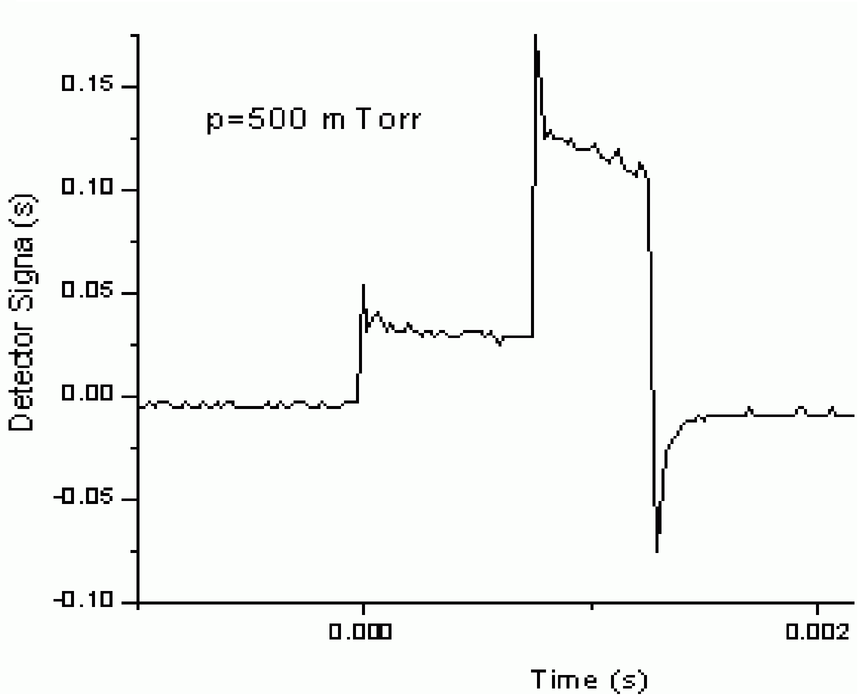
- A positive voltage is applied at the anode. Cathode and vessel are grounded.
- A plasma is produced between this and the water-cooled cathode.
- Cathode on movable mount to vary electrode spacing.
- The GD plasma is covered by glass cylinder.
- The photodiode uses a a thin Beryllium filter to block light and set threshold x-ray energy.

Discharge used to pulse load Pd with D for x-ray studies



Typical result -- filtered AXUV detector indicates peak p=500 mTorr V=250V I=2A for a Pd cathode. The delay time of ~ msec before onset of x-raysis associate with D diffusion time. X-rays are > 600 eV with 250 V discharge! Blank experiment - a cu foil in front of the Be causes the trailing spike (x-rays) to disappear as expected,





Close-up of a damaged plastic window in Karabut exps– holes appear to be from beamlets corresponding to localized emission sites

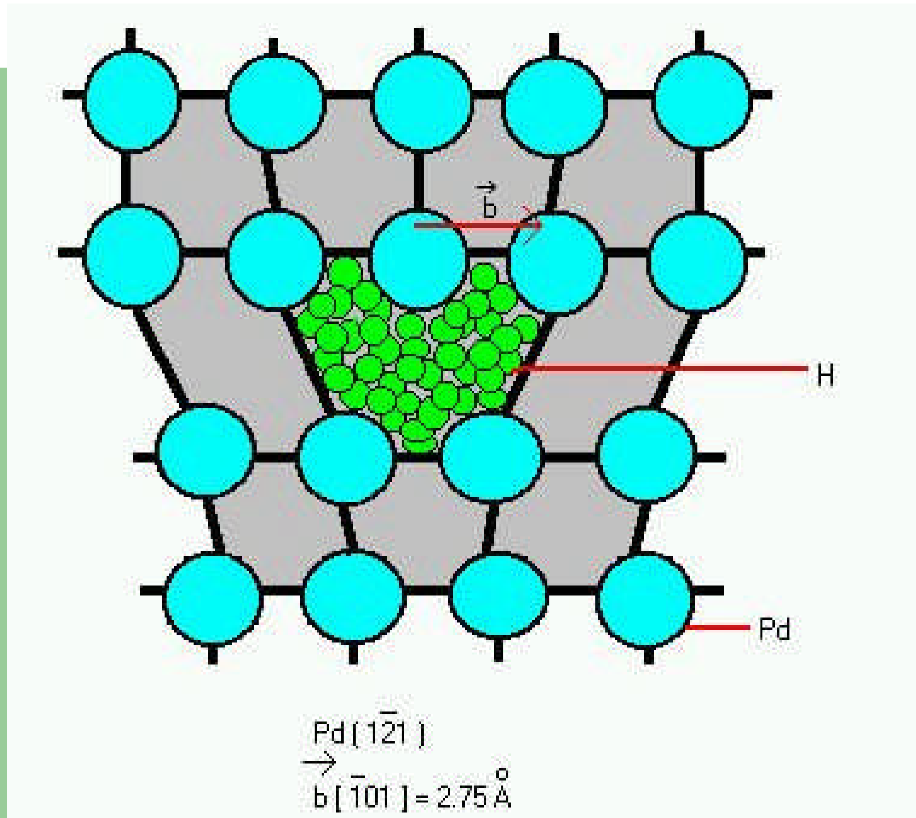
Other effects

- Evidence of clustering in dislocation loops created by multiple loading-deloading.
  - Superconducting regions detected confirming extremely high density in dislocation loops

Summary- dislocation loop loading

- after H-cycling and annealing at T=573 K, Pd:H_x and Pd/PdO:Hx samples contain condensed hydrogen phase inside dislocation cores: x=H/Pd = (3.8-5.5) x 10^{-4} with respect to the sample. Inside dislocation nanotube x=H/Pd ~ 5-10.
- Accordingly to SQUID measurements the H2-cycled PdHx demonstrates a weak type II superconductivity, involving condensed hydrogen phase in dislocation cores [PdH_x-Pd] below 30 K.
- Both magnetic and transport measurements in Pd/PdO:Hx suggest superconducting transition below 70 K. Reproducible Meissner-effect was obtained at H≤ 1.0 Oe in AC field (f = 1 kHz).

Schematic of edge dislocation core in Pd with D-cluster

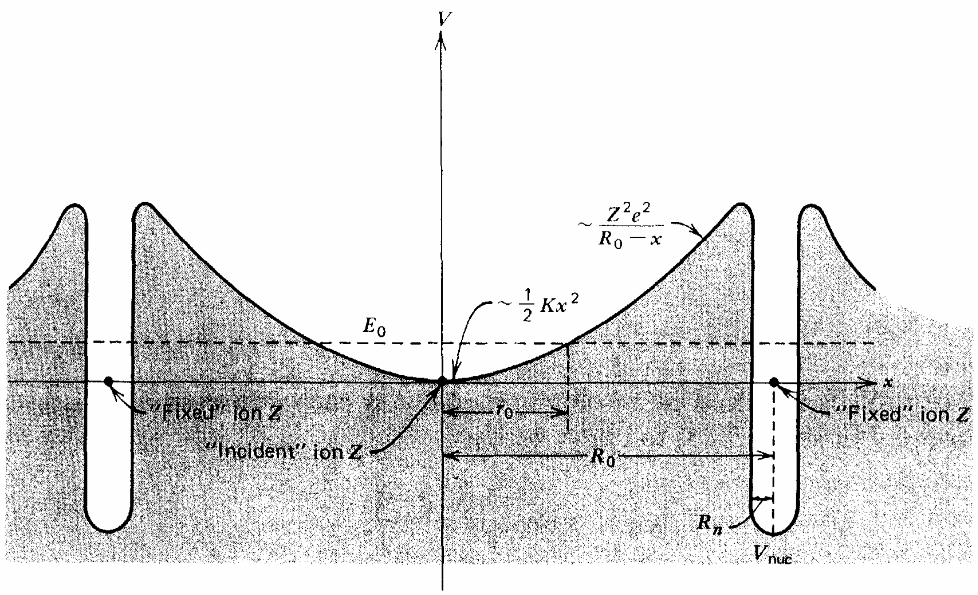


Theoretical basis for cluster fusion in dislocation loops follows pycnonuclear theory used in astrophysic.

Pycnonuclear Reactions

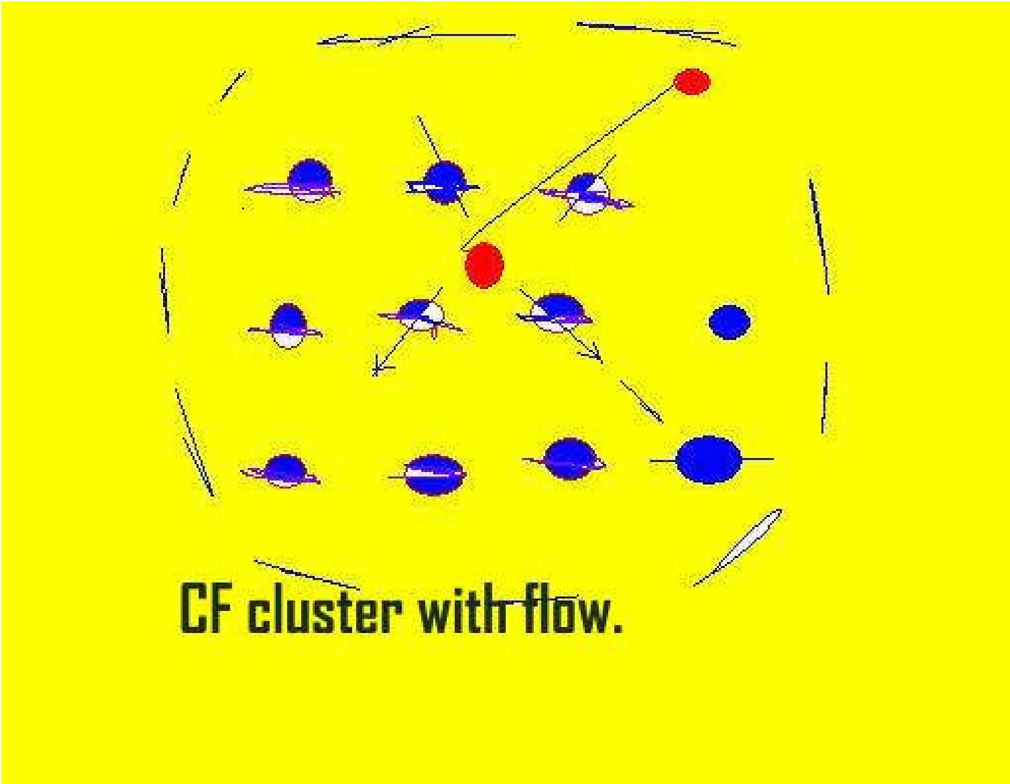
Nuclear reactions can take place even at zero temperature in condensed matter. Such reactions proceed because ions fluctuating about their lattice sites with zero-point energy $E_0 \sim \hbar\omega_0$ can penetrate the Coulomb barrier of a neighboring ion.

Zero temperature reactions are enhanced by flow = eff T



The potential governing the motion of one "incident" nucleus relative to an adjacent "fixed" nucleus in a one-dimensional ion lattice. The ions (nuclei) are separated by a distance R_0. Zero-point fluctuations (energy E_0) in the harmonic potential well near the "incident" ion lattice site can lead to Coulomb barrier penetration and nuclear reactions.

Cluster Reactions Require Diffusion Driven Flow Initiation



Reaction rate calculation w/o flow

Now turn to reactions in a crystal lattice. The reaction rate per ion pair is

$$W = (\text{inc. flux}) \times T \times 4\pi R_n^2 P_n$$
$$= v|\psi_{\text{inc}}|^2 \frac{TS(E)}{E},$$

where we have to calculate $|\psi_{\text{inc}}|^2$ and T using the lattice potential for $r > R_n$. The measured nuclear factor $S(E)$ remains the same as before.

$$P_0 = \left(\frac{\rho}{A}\right) A^2 Z^4 S \gamma \lambda^{7/4} \exp(-\varepsilon \lambda^{-1/2})\ \text{s}^{-1}\ \text{cm}^{-3},$$

with

$$\gamma = 3.90 \times 10^{46}, \qquad \varepsilon = 2.638,$$

Some results– Rx strongly depends on dislocation loading and on flow rate

- Case I: Cr-39 tracks during unloading (flow)

  At ~ 1 rx/cm^3-sec =

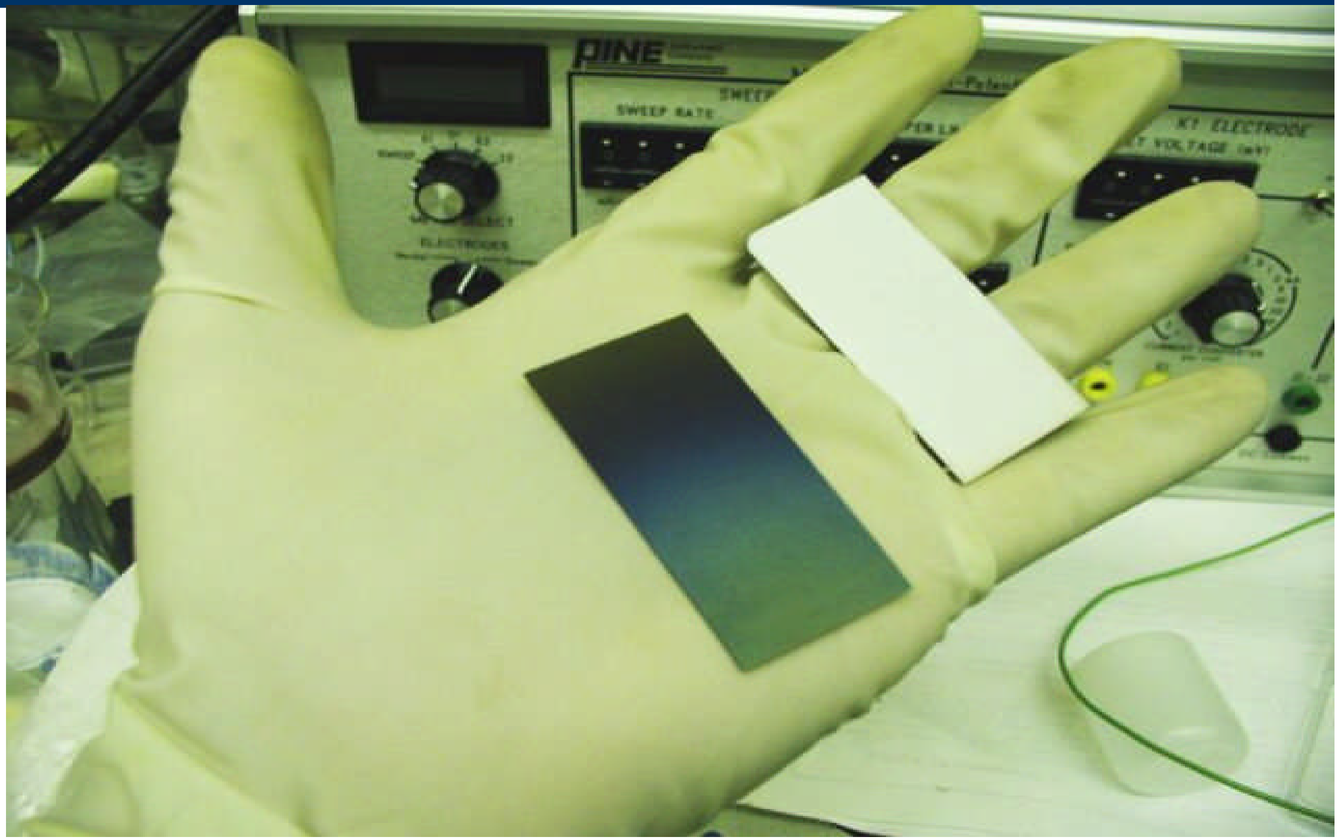
  - without flow: ~ 8 D/Pd
  - with deloading flow: ~ 2 D/Pd

- Case II –Transmutations in FT electrolysis = very high rates, ~ 10^{14} rx/cc-s
  - Potential driven flow (5x above), ~ 12 D/Pd

Based on cluster concept = a “road map” to a future power unit

- Use thin-film electrodes as building block
- Maximize the “dislocation tube” density and trapped loading with interface design
- For heat producing LENR unit, design a Dawson type “wet wood burner” BOP

“Building Block” Thin-Film Electrode using Alumina Substrate.



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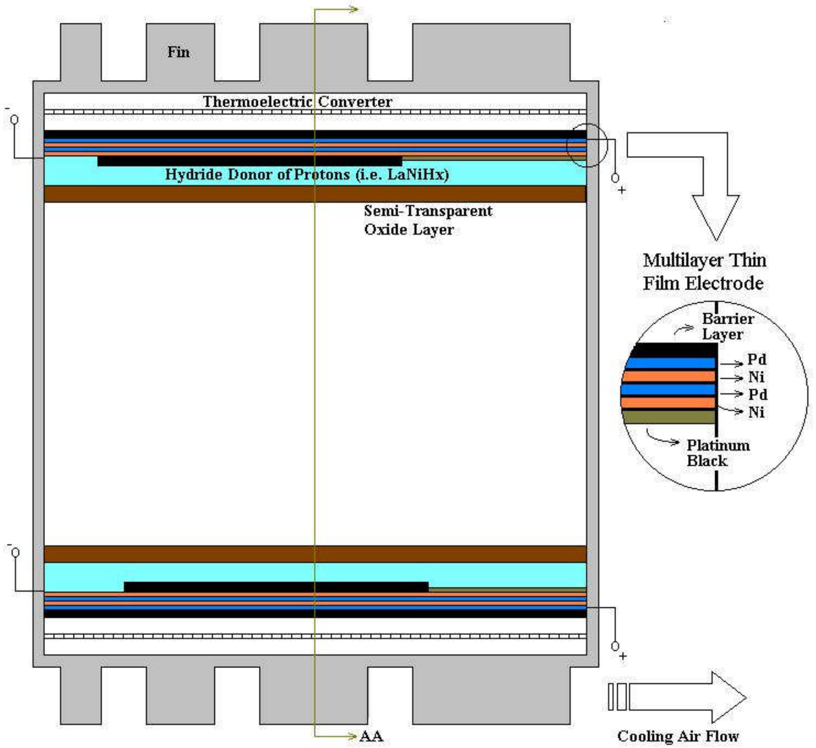
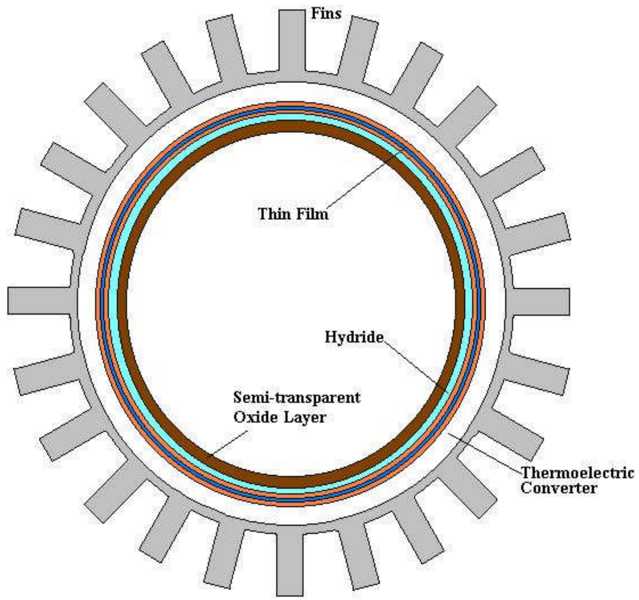
A Hydride Gas-Loaded Thin Film Electode Cell





Conclusion = Development plan for power unit studies

- Key 1 – **Create local area for NRS**
  - Use treatment at thin film interfaces
  - Use plastic substrate for elasticity
- Key 2 – **Continue & extend diagnostics**
    - *Simultaneous measurements including-*
  - Precision calorimetery
  - Periodic product sampling – NAA and SIMS
  - X-ray and charge particle monitoring
  - He4 and T detection
  - Soft x-ray detection

Thank you for your attention

- For further discussion:
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Note – if time comment on added slides

Added comments about theory

- From APS meeting Denver, March 2007.

Maruhn-Greiner Fisson Theory and Low Energy Nuclear Reactions with Magic Numbers

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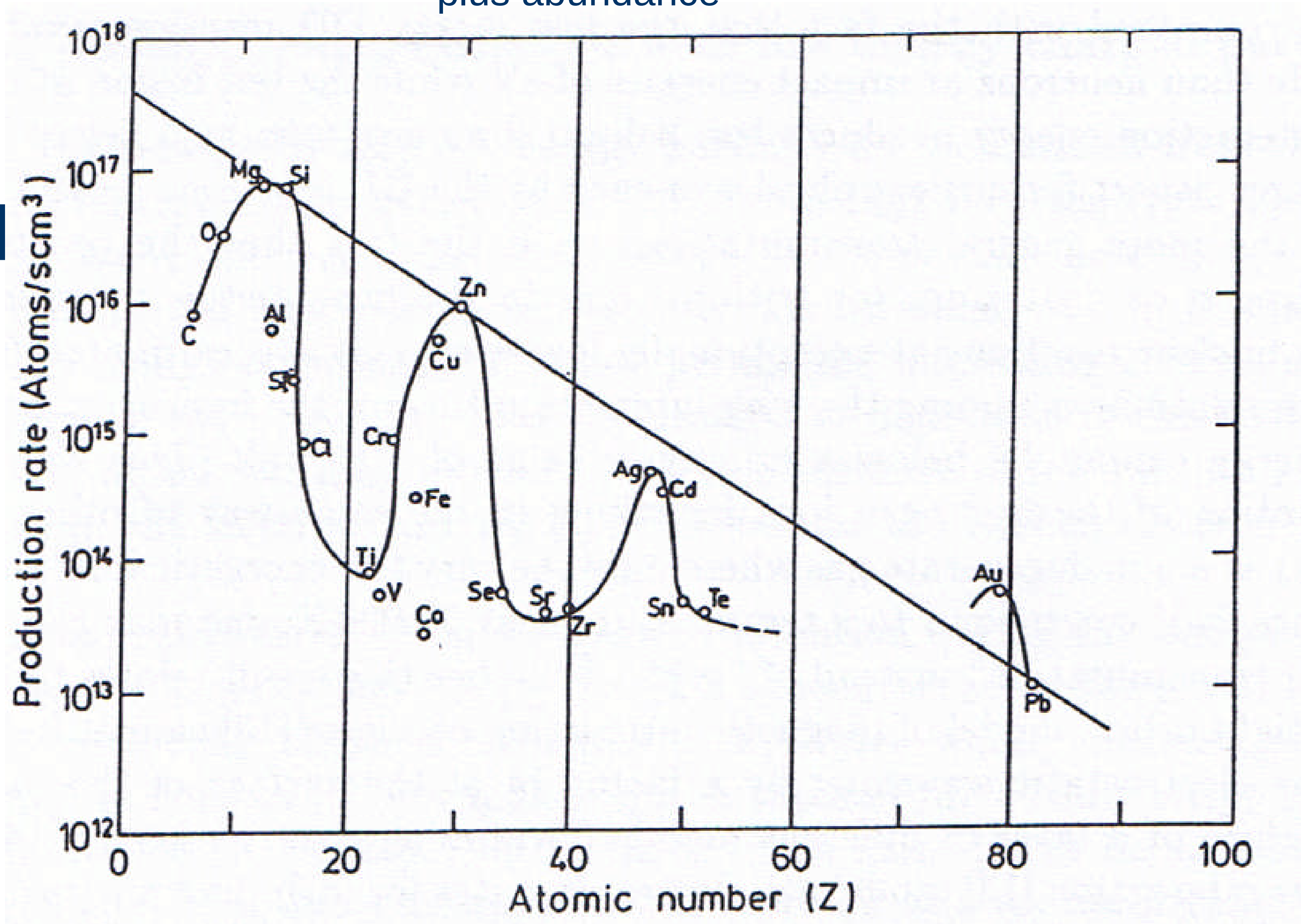
Results agree and extend magic number sequence plus abundance



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Working hypothesis for generation of element X with A = 306 (2 times 153)

From new <u>magic numbers</u> this would well fit for a double magic number nucleus with Z = 126 and a number A-Z = 180. Distinguished property of Z = 126, see Greiner (1997) Nuovo Cimento 110A, 1237 (1997)

[K. Rutz, M. Bender, et al. Phys. Rev. C56, 238 (1997)]

Suggestion: Relatively stable Element $^{306}X_{126}$

Unexcited may be <u>long lived alpha emitter</u>
With spontaneous fission
Alpha decay into relatively stable $^{266}Sg_{106}$

M. Schädel et al. Nature 388, 55 (1997)

Maybe that these long lived alpha emitter <u>nuclei are still</u> in the samples of G.H. Miley or X.Z. Li where they may be recognized by <u>shortest wave length K-shell x-ray line</u>

FACTS FOR LENR:

Analogy to Astrophysics (SAD)

With new basis for magic numbers (quarks)

Local maximum of element distribution

Similar to Maruhn-Greiner for uranium fission

<u>This should justifiy a rigorous repetition of experiments</u>

<u>Theory</u>: anomaly at hot fusion ,

model of Picometer-Megasecond nuclear reactions,

deuteron clusters?

compound nuclear reaction via semistable $^{306}X_{126}$

End

Thank You

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