

FUSION CROSS SECTIONS

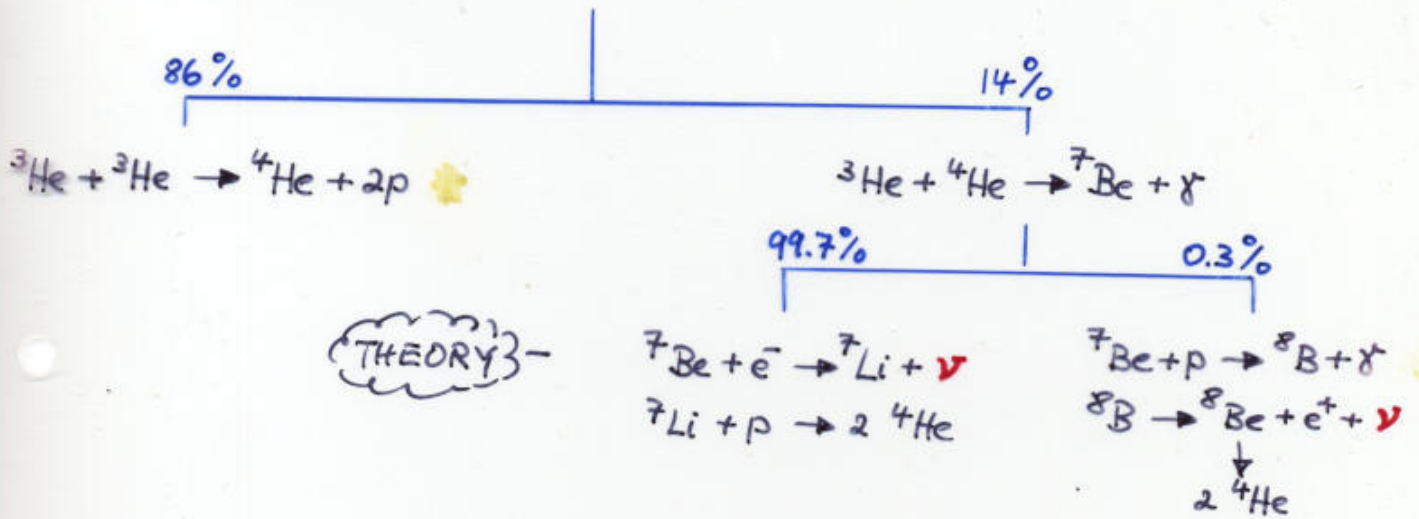
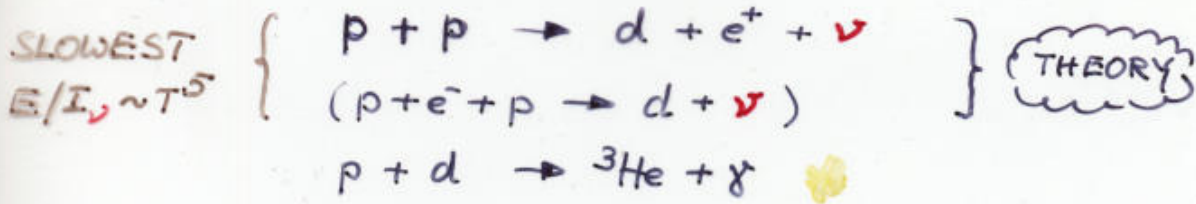
AND

SOLAR NEUTRINOS

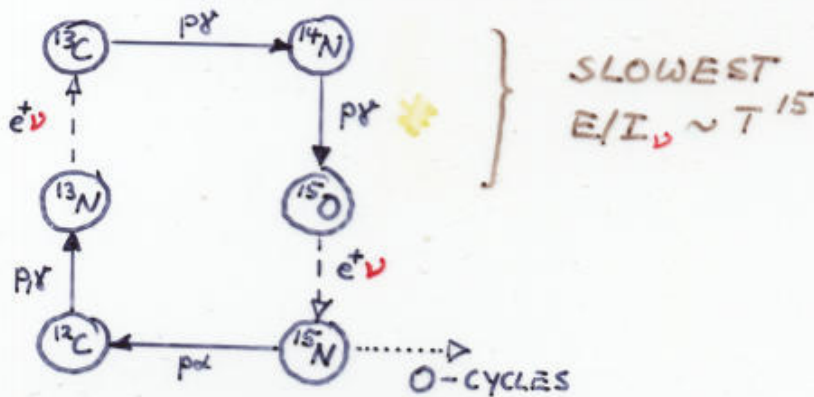
C. ROLFS

RUHR-UNIVERSITÄT BOCHUM

P-P CHAIN



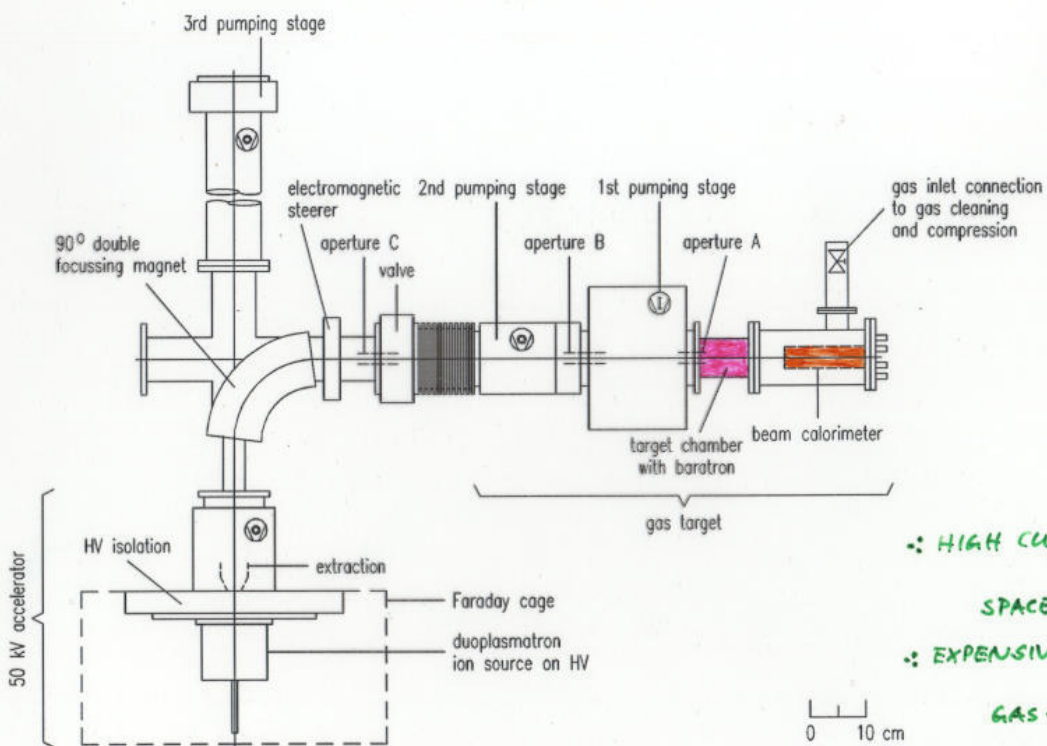
CNO - CYCLES



- HERE:
- EXPERIMENTS
 - ELECTRON SCREENING

FIRST UNDERGROUND ACCELERATOR FACILITY (50 kV)

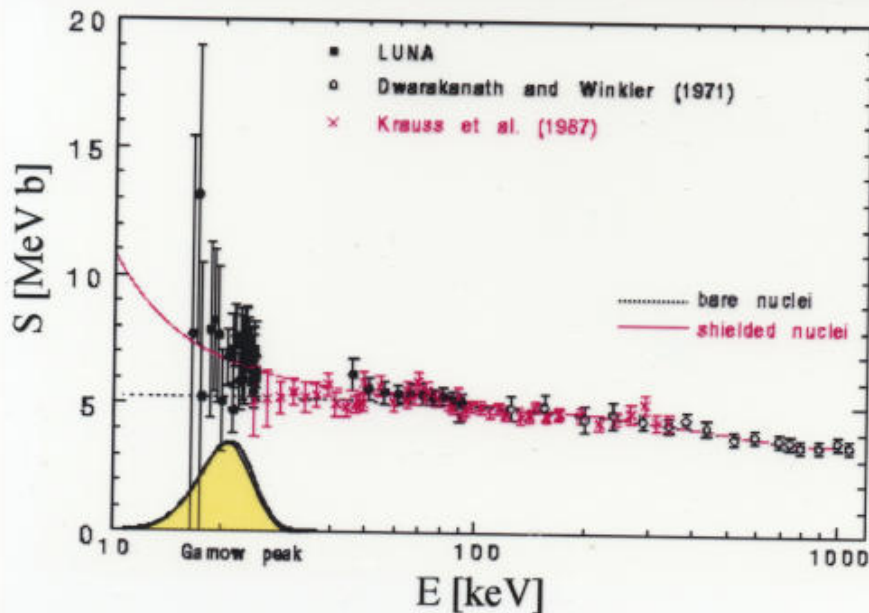
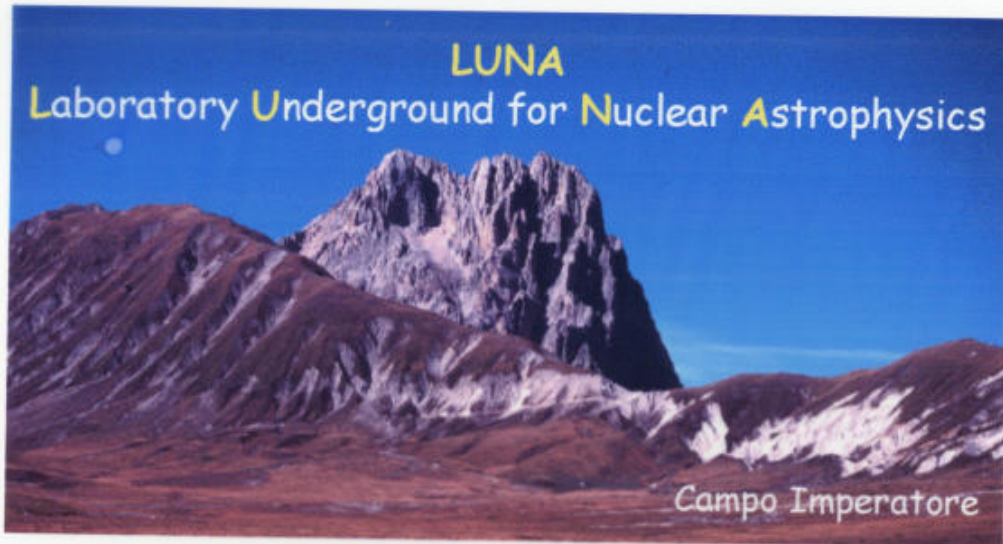
... BUILT MAINLY BY STUDENTS !



- ∴ HIGH CURRENTS / LOW ENERGIES
↓
SPACE CHARGE PROBLEMS
- ∴ EXPENSIVE ^3He GAS
↓
GAS-RECIRCULATION
- ∴ LONG RUNNING TIMES
↓
STABLE EQUIPMENT
AUTOM. CONTROLS
- ∴ DEUTERIUM POISON
↓
SPECIAL CLEANING,

THE CASE: ${}^3\text{He}({}^3\text{He}, 2p){}^4\text{He}$

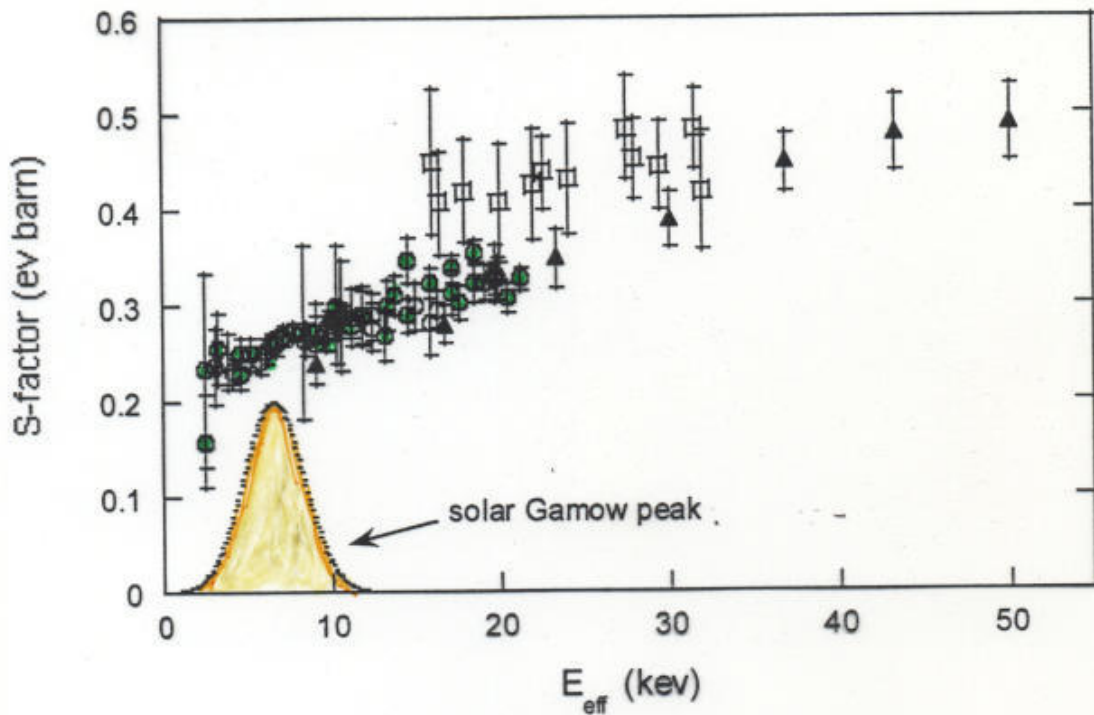
... A RESONANCE AT SOLAR ENERGIES?



- **FIRST MEASUREMENT WITHIN GAMOW PEAK**
⇒ NO EXTRAPOLATION ANYMORE
- NO HYPOTHETICAL RESONANCE FOUND
- LOWEST ENERGY: $\sigma = 20$ FEMTO-BARN
(1 EVENT PER MONTH)

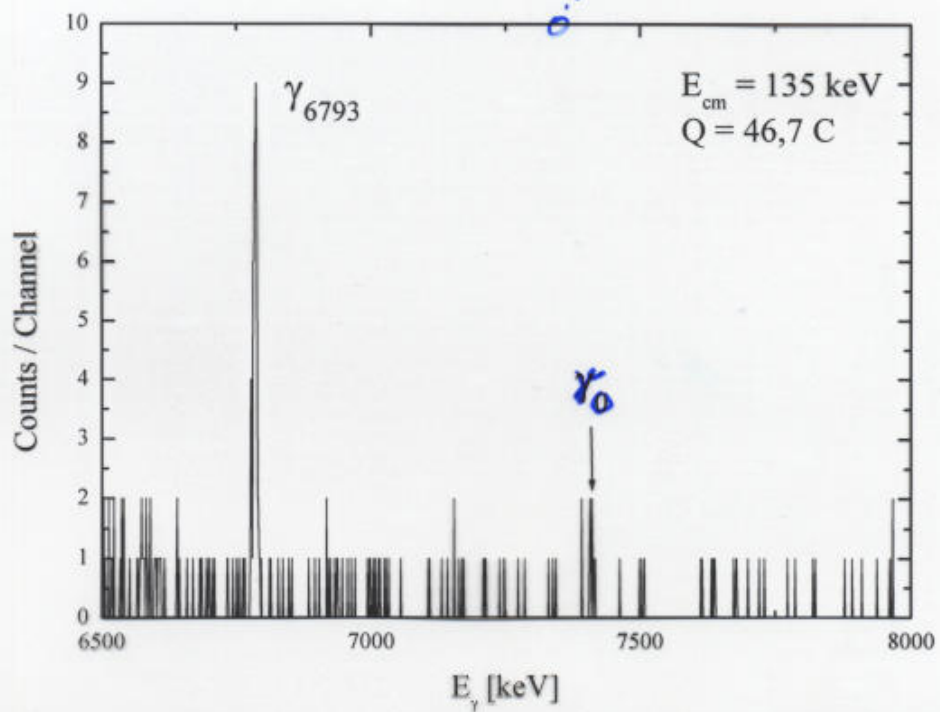
- **ELECTRON SCREENING:** $U_e = 340 \pm 50$ eV
 $U_{ad} = 240$ eV } ?

THE CASE: $d(p,\gamma)^3\text{He}$



- LUNA: GAS-TARGET
4 π BGO CRYSTAL
- FIRST MEASUREMENT WITHIN GAMOW PEAK
OF A CAPTURE REACTION
- PREVIOUS EXTRAPOLATION \approx o.k.

LUNA (2002): NO EVIDENCE !

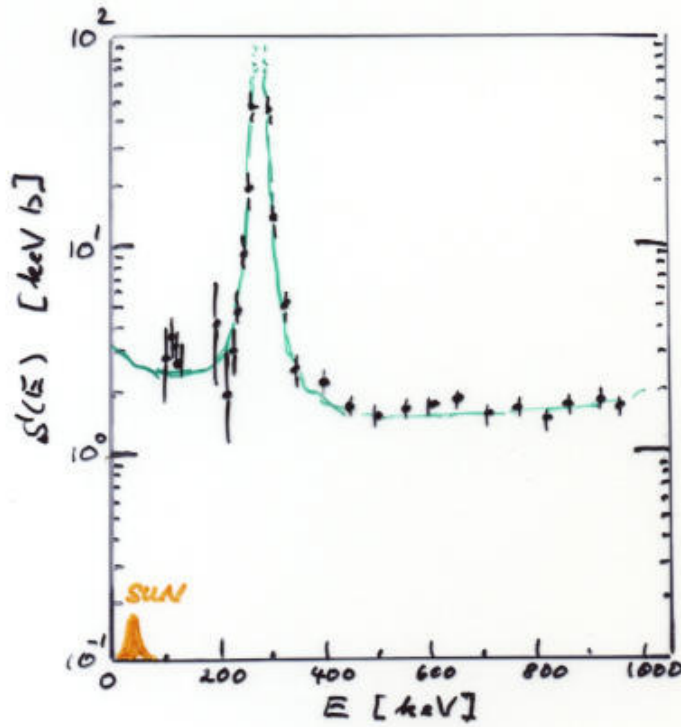


• γ_0
|
|

• •
TRIANGLE (2001): NEW RESONANCE
AT 127 keV

THE CASE: $^{14}\text{N}(p,\gamma)^{15}\text{O}$

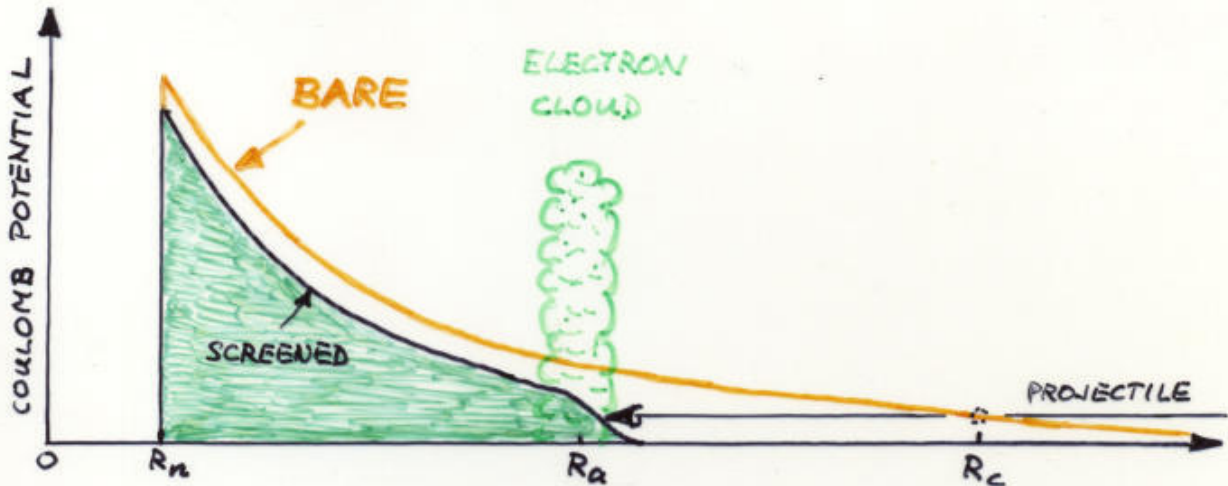
CALTECH/BOCHUM (... 1987)



ELECTRON SCREENING

$$\sigma(E) = S(E) \frac{1}{E} \underbrace{\exp(-2\pi\eta)}_{\text{BARE NUCLIDES}}$$

LABORATORY:

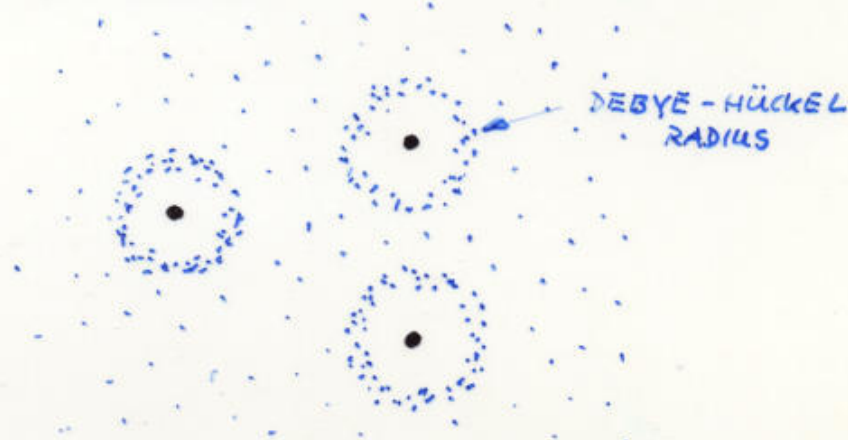


$$\sigma_{\text{LAB}}(E) = f_{\text{LAB}}(E) \sigma_{\text{BARE}}(E)$$

$$f_{\text{LAB}}(E) = \exp\left(\pi\eta \frac{U_e}{E}\right) \geq 1$$

U_e = ELECTRON-POTENTIAL-ENERGY
= FIT-PARAMETER

STELLAR PLASMA:

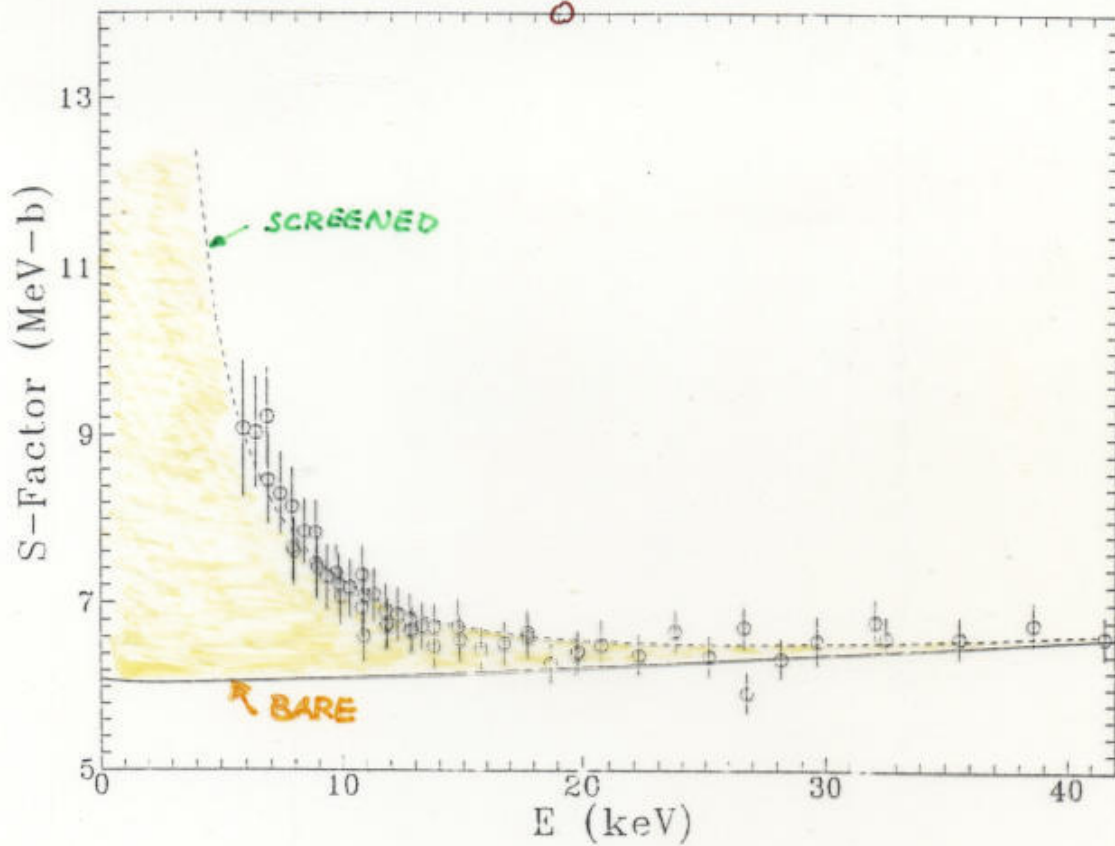


$$\sigma_{\text{PLASMA}}(E) = f_{\text{PLASMA}}(E) \sigma_{\text{BARE}}(E)$$

ENERGY PRODUCTION
NEUTRINO FLUXES

ENGSTLER et al.: ${}^3\text{He}(d,p){}^4\text{He}$
(1988)

- FIRST OBSERVATION OF ELECTRON SCREENING

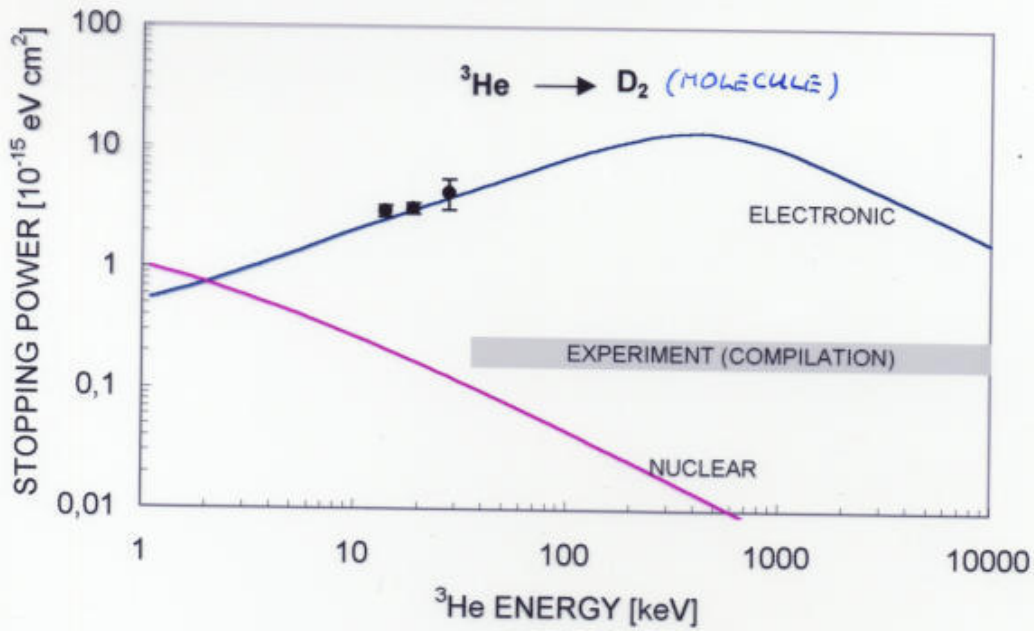


- BUT; $U_e = 192 \pm 8 \text{ eV}$
 $U_{ad} = 102 \text{ eV}$ } $U_e \gg U_{ad} ?$
... ALSO IN OTHER CASES

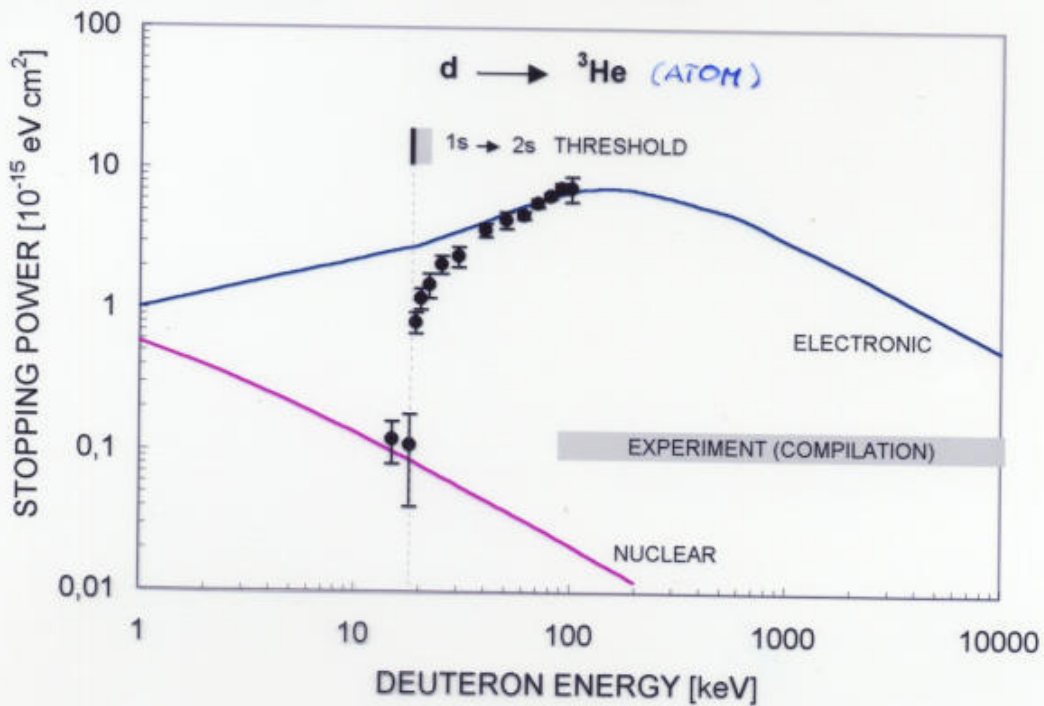
IS IT

- ENERGY-LOSS EXTRAPOLATION ?
- ATOMIC PHYSICS ?
- NUCLEAR PHYSICS ?

LUNA:



BOCHUM/LUNA: $^3\text{He}(d, p)^4\text{He}$

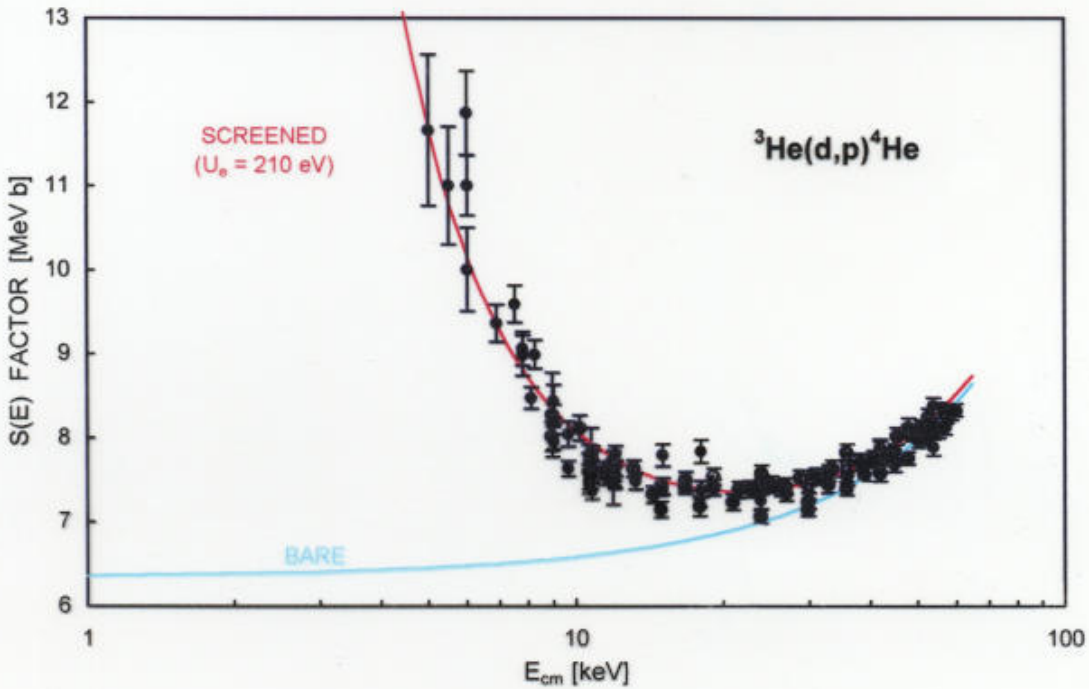
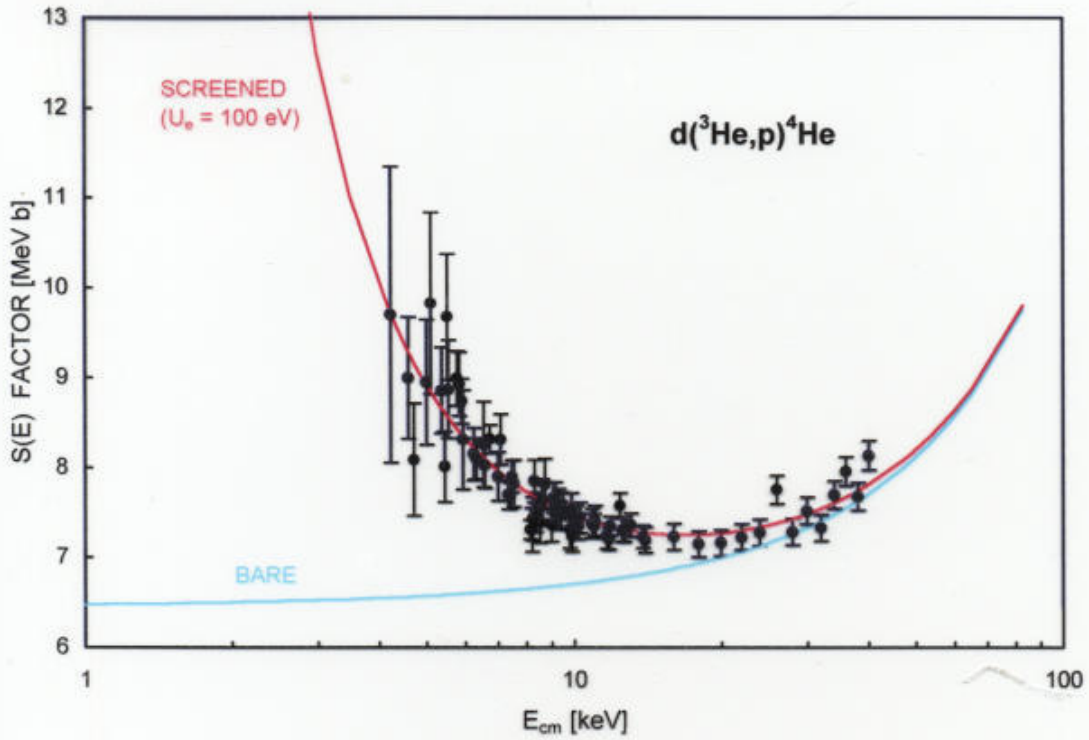


SURPRISE: THRESHOLD EFFECT!

$E(\text{He}, 1s \rightarrow 2s) = 19\text{eV} \Rightarrow E_d = 18.2\text{keV}$

\cong SUPERCONDUCTIVITY

LUNA/BOCHUM: RESULTS



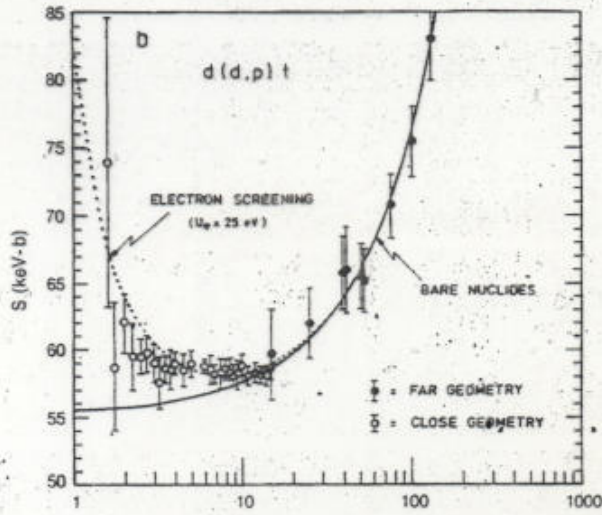
IS IT

.... ATOMIC PHYSICS ?

NUCLEAR PHYSICS ?

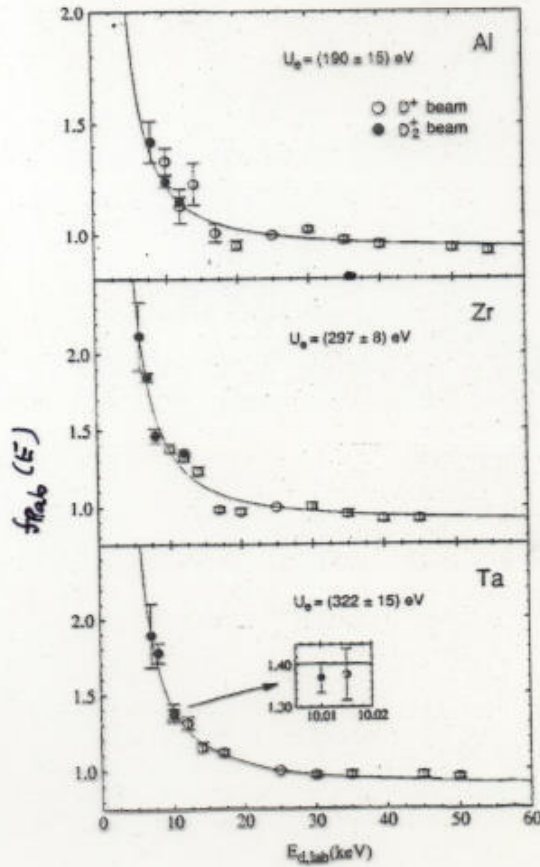
D + D FUSION REACTIONS

DEUTERIUM GAS TARGET (BOCHUM)



$U_e = 25$ eV

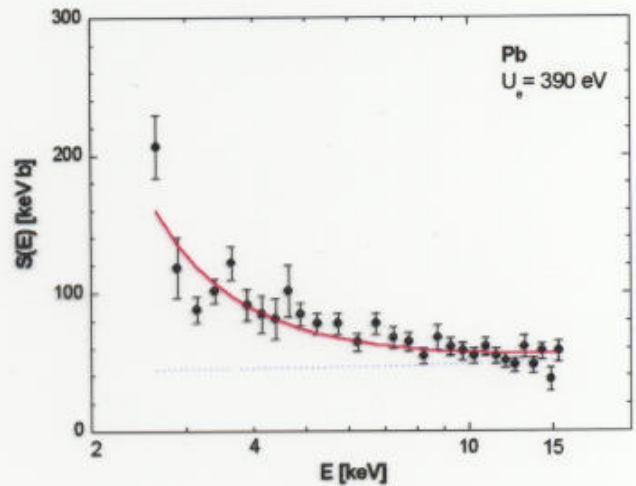
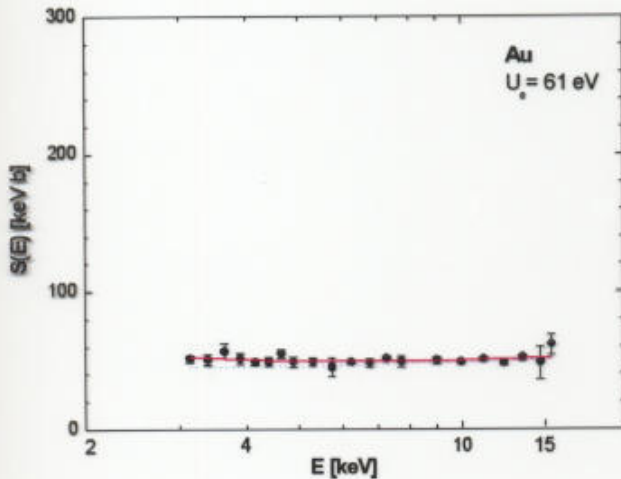
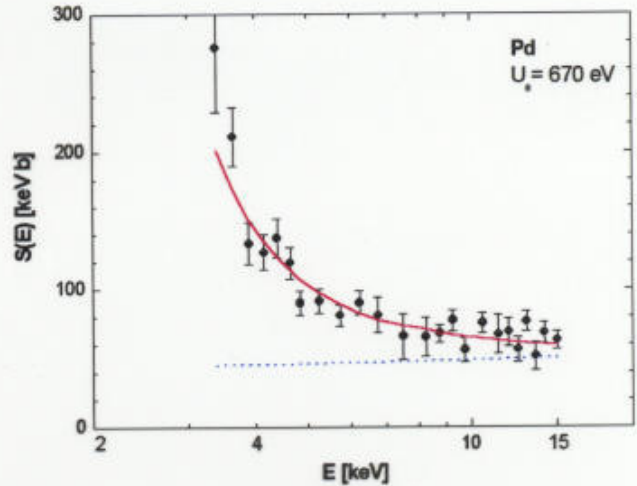
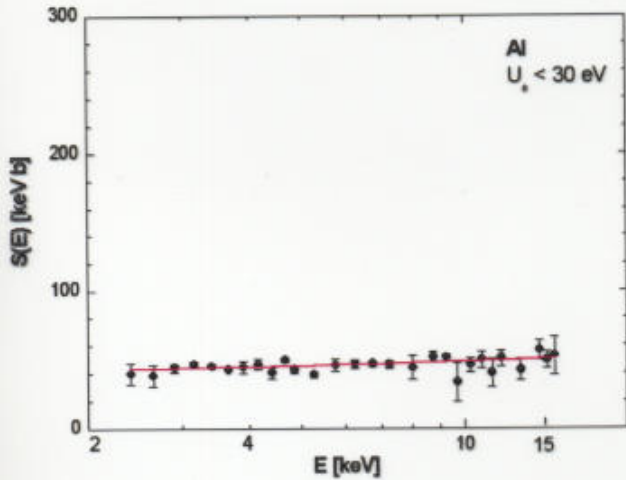
DEUTERATED METALS (BERLIN)



$U_e = 322$ eV

UFF!

DEUTERATED MATERIALS (BOCHUM)



STUDY: 23 METALS AND 3 INSULATORS

HIGH $U_e = 13$

LOW $U_e = 13$

SYSTEMATICS ?

YES: PERIODIC TABLE

PERIODIC TABLE

1																	18
1	2											13	14	15	16	17	2
H	He											B	C	N	O	F	Ne
3	4											5	6	7	8	9	10
Li	Be											Al	Si	P	S	Cl	Ar
11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Na	Mg	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
55	56	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs	Ba	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

Large Effect
 Small Effect

Lanthanides
 Actinides

WHAT IS CORRELATION ?

WHAT IS ACCELERATION ?

⋮

CONNECTION WITH STARS ?