Internal e^- e^+ pair creations in the D-D reactions for cold fusion experiments

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Outline

- **An overview**
  - Observations of fusion products produced by the DD reactions in cold fusion experiments
  - Example : Cold fusion experiments and ^{4}He productions
- **New thrust to measure the internal pair (e^+ e^-) creations**
  - Recent Theoretical Development
  - Experimental facility requirement
- **Experimental set up**
- **Results and Discussions**
- **Outlook**

D-D fusion in metallic or gaseous environment

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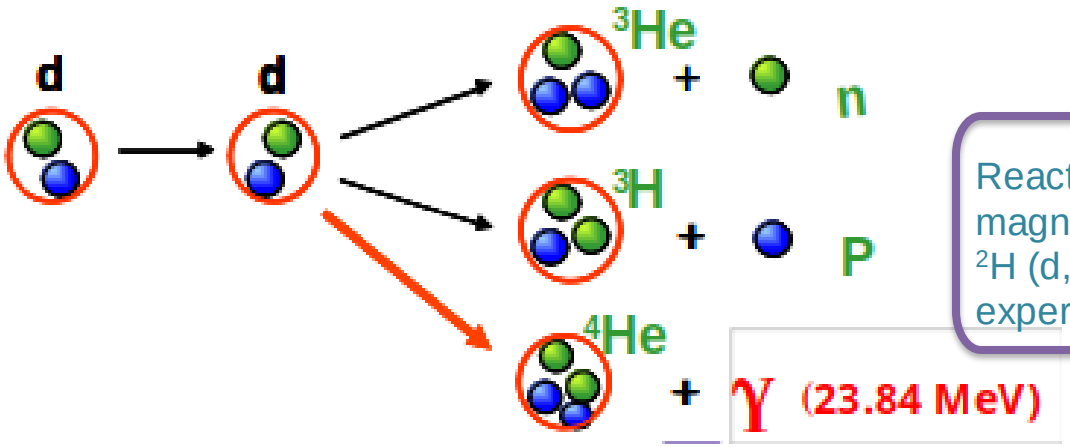
D-D reactions at very low energies



Reaction channel ^{2}H (d, γ) ^{4}He, is 7 orders of magnitude weaker compared to the ^{2}H (d, p) ^{3}H, ^{2}H (d, n) ^{3} He reactions measured in accelerator experiments.

D-D Fusion Products;

Charge particles : Helium-3(^{3}He), Helium-4 (^{4}He), Tritons (^{3}H), Protons (P);

Neutral particles : Neutrons (n), Gammas

At room temperature, ^{4}He production without gamma emission seems the most dominant reactions channel !!

Pics courtesy: *Nature* **570**, 45–51 (2019).

D-D fusion products measuremnts at very low energies

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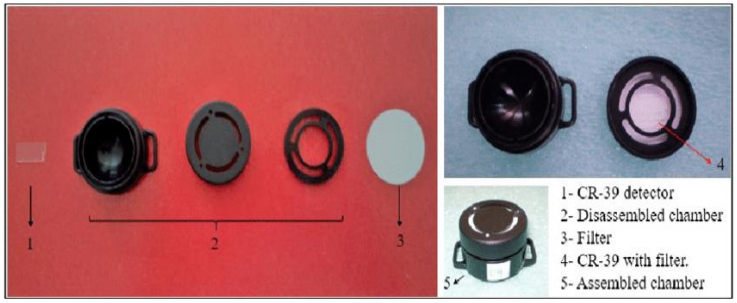
Charge particles detections

Gas Discharge/Electrolysis/Diffusion[1]



Detector CR-39:

- A polymer with a density of ~1.3 g/cm 3 .
- When a charged particle crosses the detector surface it causes radiation damage along trajectory.
- This zone of structure damage may be increased by etching in a chemical reagent

Low energy Accelerator Facility

Pics courtesy: ORTEC, MIRION tech.

Detectors: PIPS, SiLi, SiGe etc.

Tracking method

D-D fusion products measuremnts at very low energies

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Neutral particles and Gammas Detections

Neutrons

Scintillators Detectors and Neutron Counters

Gammas and X rays

Detectors: NaI, HPGe etc.

Pics courtesy: ORTEC, MIRION, KROMEK

Charges Particles Tracking

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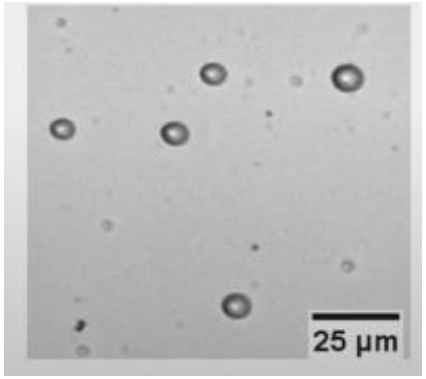
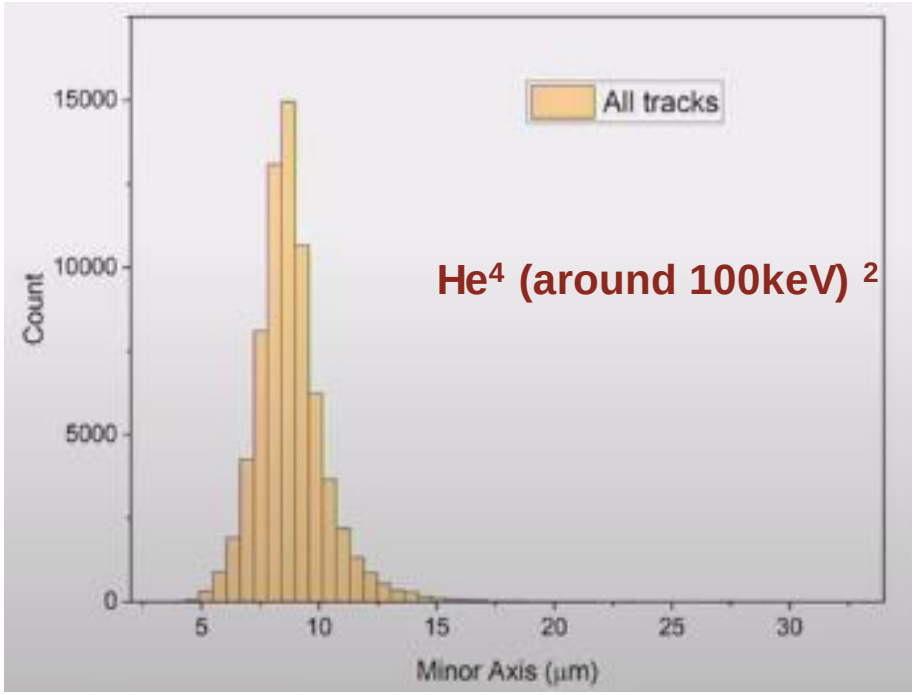
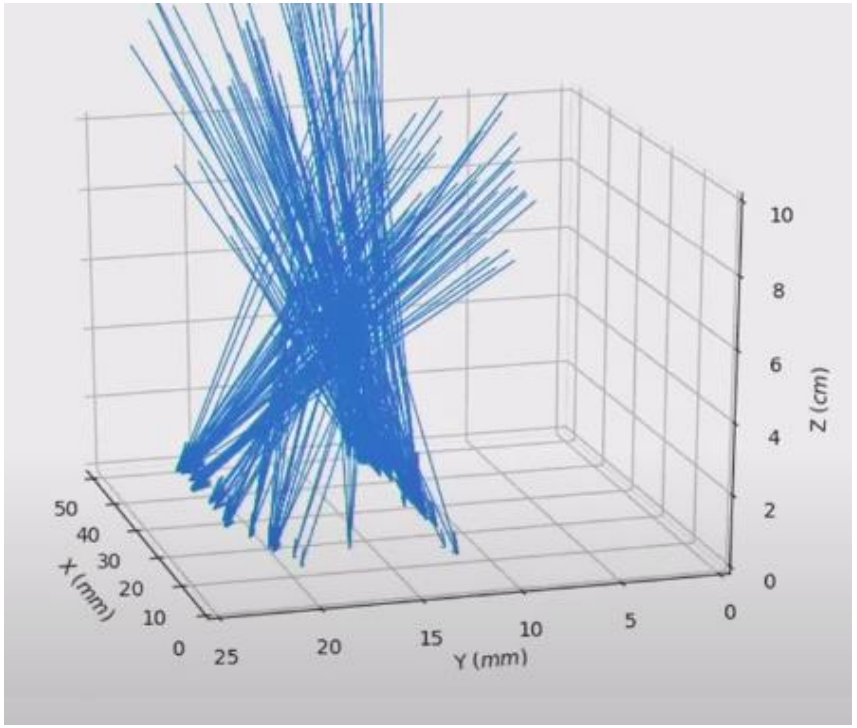
DC Glow Discharge with Pd Electrodes set up [1]



SEM
Detector : CR39



He^4 (around 100keV) [2]



Extrapolation to look the origin [1]

Detection of Alpha Particles using CR-39 During a Deuterium with **550 V** applied voltage
No He3, H-3 channel
He 4 without Gamma

Reference: 1) Erik Zeim University of Illinois at Urbana-Champaign, USA thesis and talk http://dx.doi.org/10.13182/T123-33056, **https://www.youtube.com/watch?v=8FD-eJ8tDdg**

Neutrons Observations

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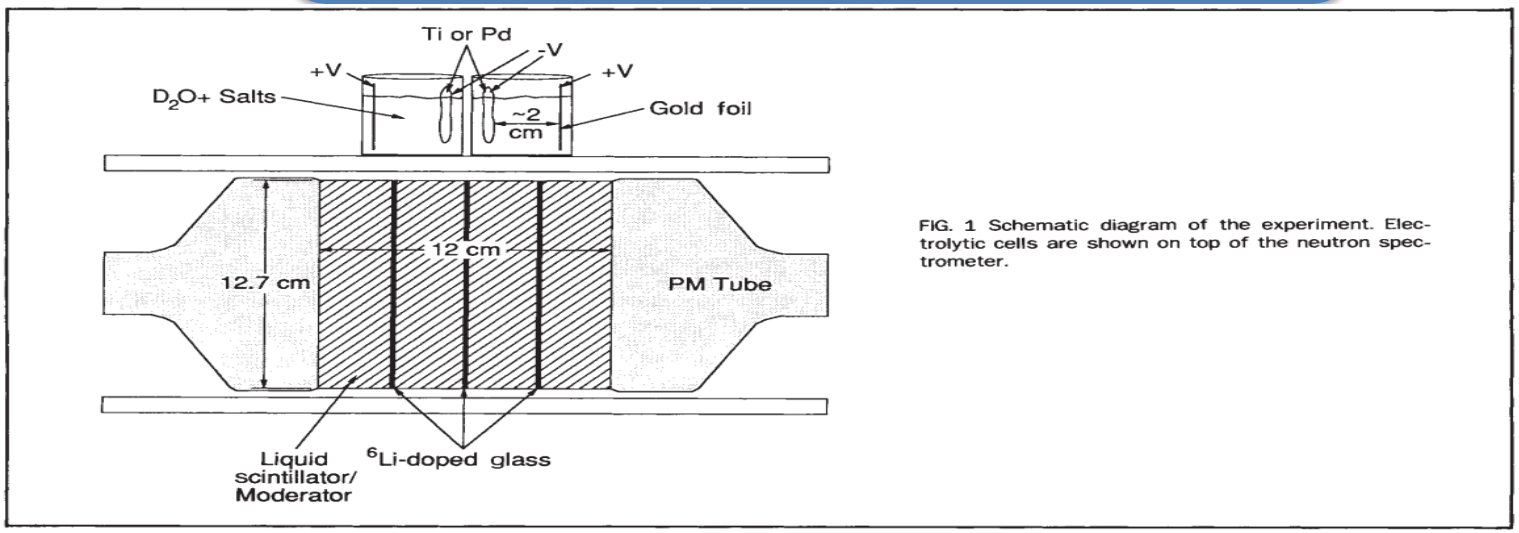

FIG. 1 Schematic diagram of the experiment. Electrolytic cells are shown on top of the neutron spectrometer.

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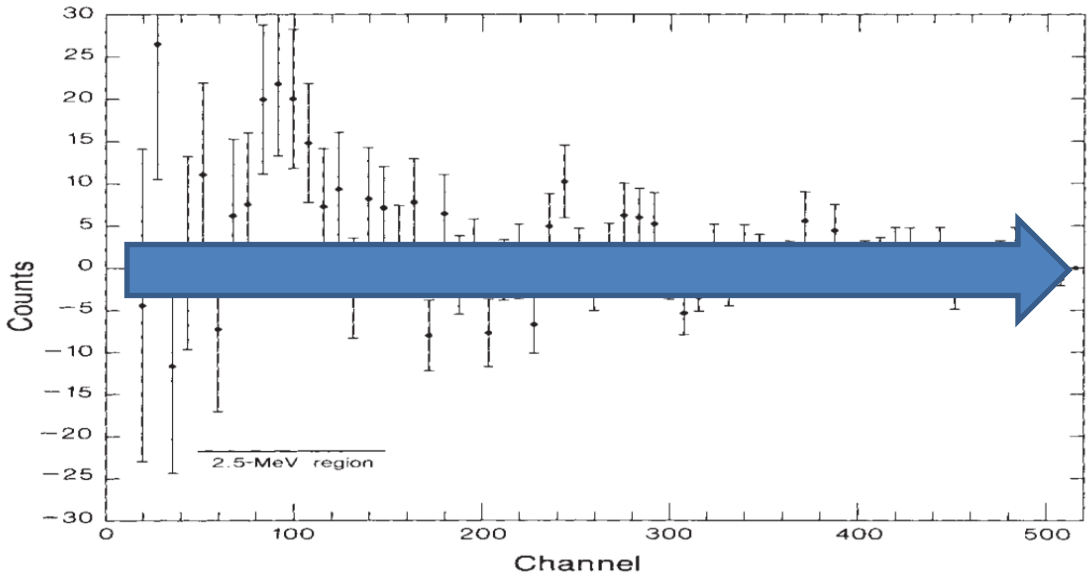

Very poor statistics, No TOF

Gammas Observation

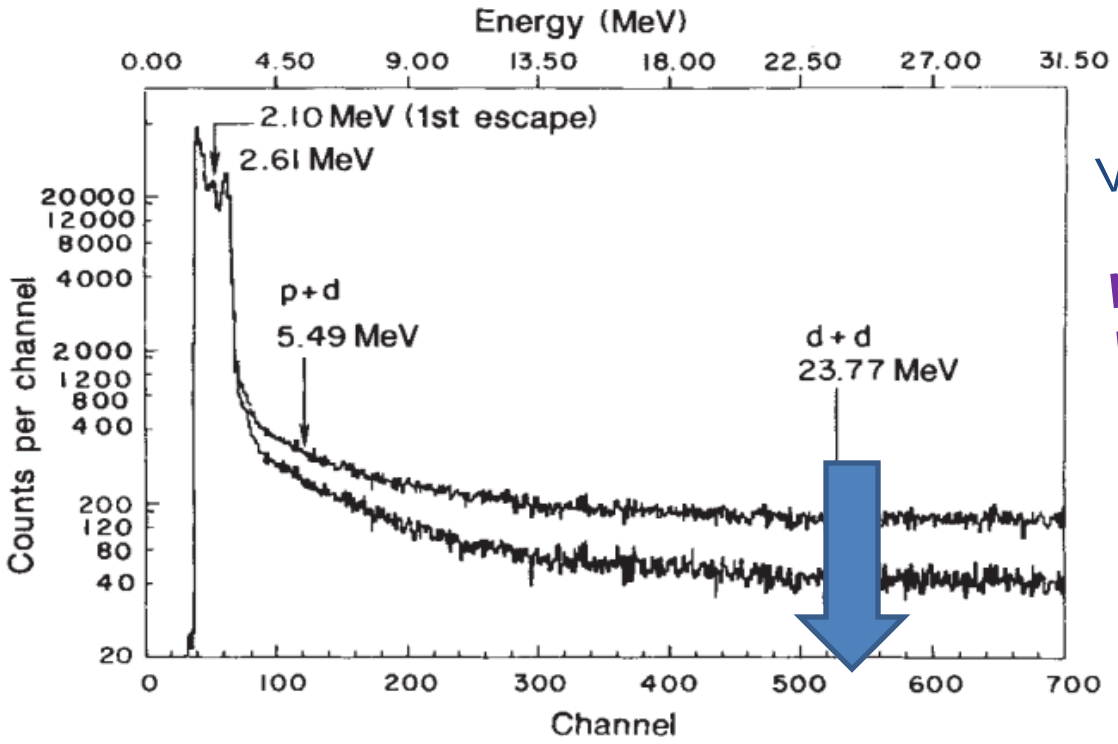

FIG. 3 Typical spectra from NaI(Tl) γ-ray detector 2 (run 6). The locations of the expected γ-rays from reactions listed in text are indicated. The raw γ-ray counts before and after vetoing on cosmic rays correspond to the upper and lower curves respectively.

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Very nice expt set up

BUT !!!

No Gamma,

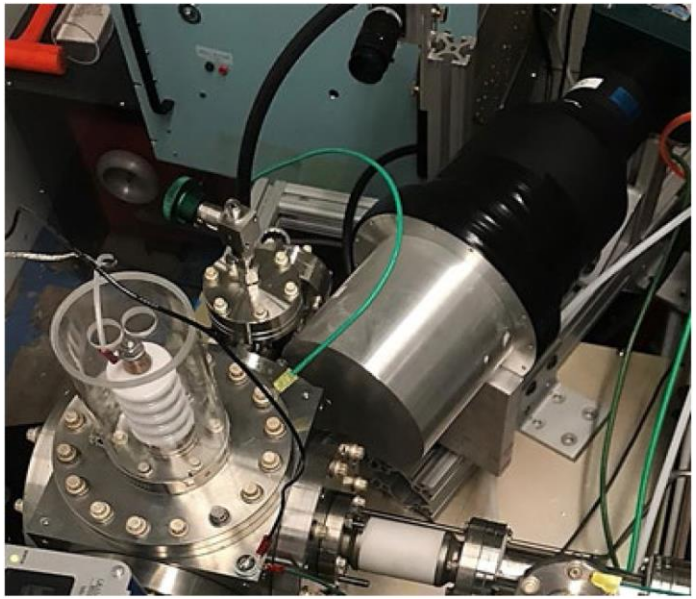
No Neutron,

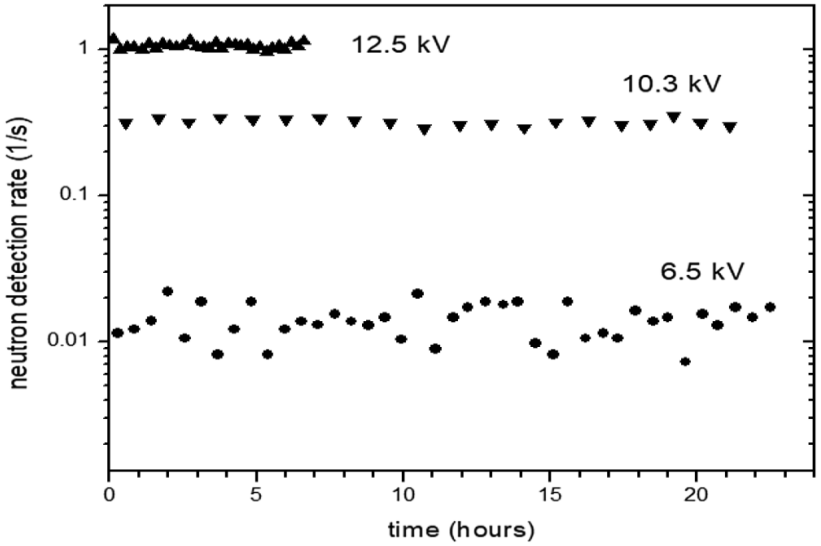
Intrestingly No Heat excess as well

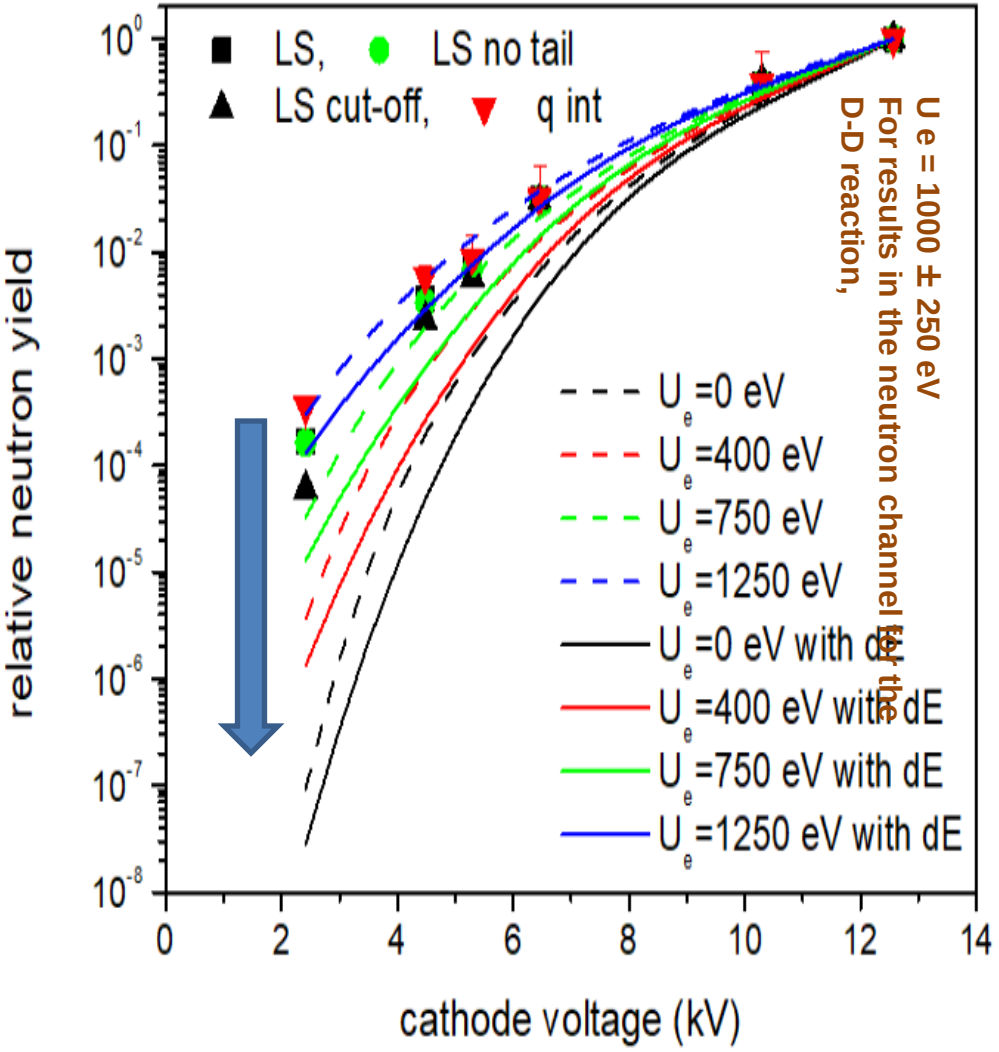
However declined the Jone`s work !!

Where Heat excess, Neutrons were observed !!

Recent neutron measurements[1]







Reference 1: *Nature* **570**, 45–51 (2019), Journal of Applied Physics **126**, 203302 (2019)

Summary of observations

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Challenges : Correlation, Consistency and Limitation

First the correlation of dominant reaction channel and Heat excess successfully should be proven !!!

However not very well established !!!

Next what ! Precisely nuclear branching ration and corresponding theoretical modelling at room temperature

Repeat the process until Direct and consistent correlation established.

Required!!! Initial Instrumental Development and Validation

Example : Heat excess and He-4 production : Observation [1]

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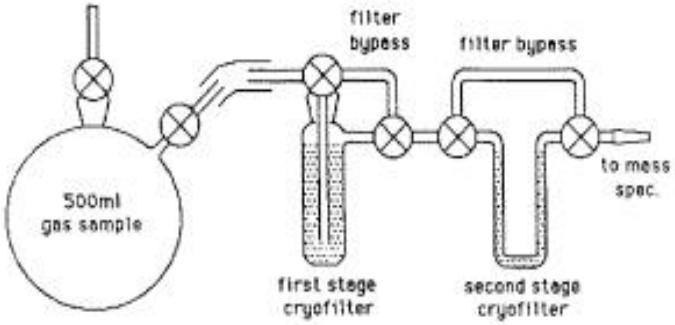

^{4}He productions

D_2O + LiOD electrolysis. The presence of helium in the effluent gas compared to the generation of excess power and heat

Sample	P_{ex} /W	$\Delta H_{out}/\Delta H_{in}$	Results [a]
(1) 12/14/90 A	0.52 [b]	1.20/1 [b]	^{4}He observed as large peak, long dwell; no ^{3}He [b]
(2) 05/05/75 B	0.46	1.27/1	^{4}He observed as large peak, long dwell [c]
(3) 11/25/90 B	0.36		^{4}He observed as large peak, long dwell; no ^{3}He
(4) 11/14/79 B	0.17		^{4}He observed at detection limit; no ^{3}He
(5) 04/29/65 A	0.24	1.10/1	^{4}He observed medium peak, some dwell; no ^{3}He
(6) 11/27/90 A	0.22	1.09/1	^{4}He observed as large peak, long dwell [c]
(7) 03/26/69 A	0.14	1.08/1	^{4}He observed at detection limit; no ^{3}He
(8) 01/18/37 A	0.07	1.03/1	No ^{4}He or ^{3}He observed
(9) 12/17/90 B	0.29 [d]	1.11/1 [d]	No ^{4}He or ^{3}He observed [d]

[a] Mass spectrometer, always at highest sensitivity.
[b] Current was 660 mA, all other experiments used 528 mA.
[c] No measurement of ^{3}He was made.
[d] The D_2O solution level of the cell was found to be excessively low resulting in an erroneous calorimetric result.

^{4}He production in D_2O + LiOD electrolysis experiment !

[1] Ref: B. F. Bush, Helium production during the electrolysis of D2O in cold fusion-experiments, J. Electroanal. Chem., 1991, 304, 271–278.

^{4}He production : Observation[1,2]

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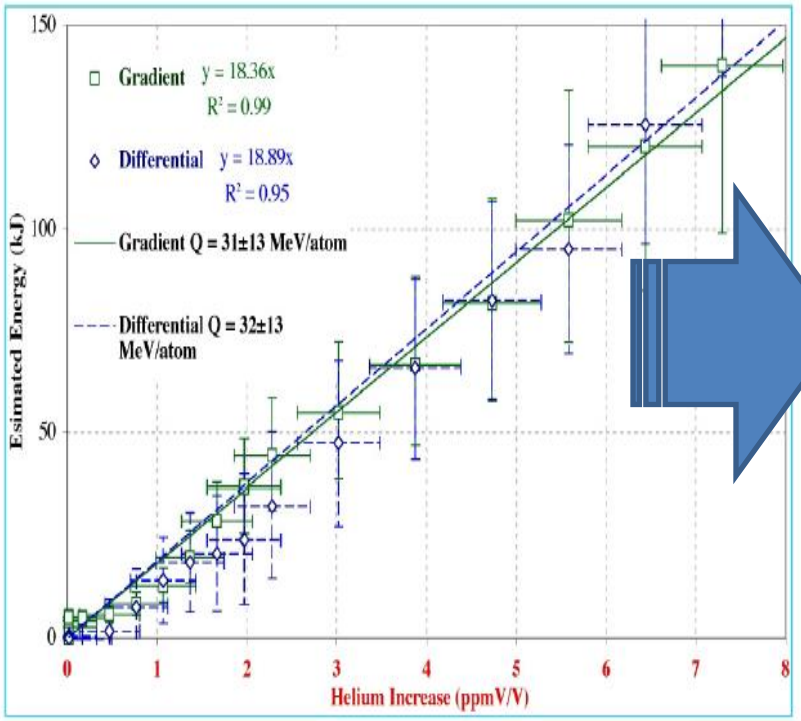
Excess Power vs. ^{4}He Concentration

Recent measurement[2]
Detection of Alpha Particles using CR-39 During a Deuterium DC Glow Discharge with Pd Electrodes
(Erik presented at ICCF24)



Yes, ^{4}He production correlated in Cold fusion expt; **firstly !!!**

We need a nuclear theoretical model for better understanding of ^{4}He production at room temperature !!!!

However no, well accepted theoretical model was developed so far !!!!

[1]Michael McKubre et al, SRI California, 2004

Recent Theoretical Development

"He ^{4} formation and its decay"

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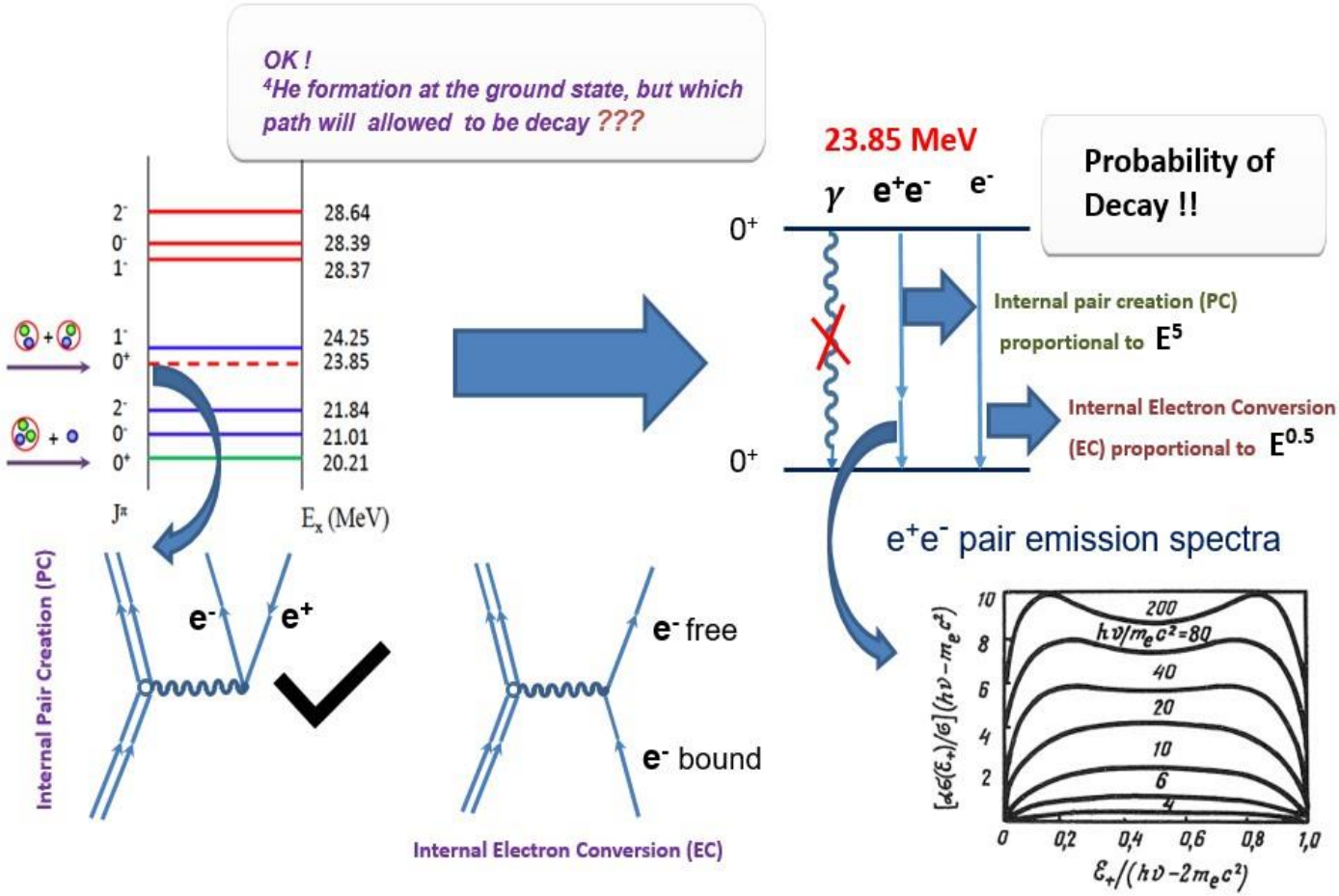

PHYSICAL REVIEW C 106, L011601 (2022)

Letter

Deuteron-deuteron nuclear reactions at extremely low energies

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(Received 15 January 2022; revised 2 May 2022; accepted 24 May 2022; published 12 July 2022)

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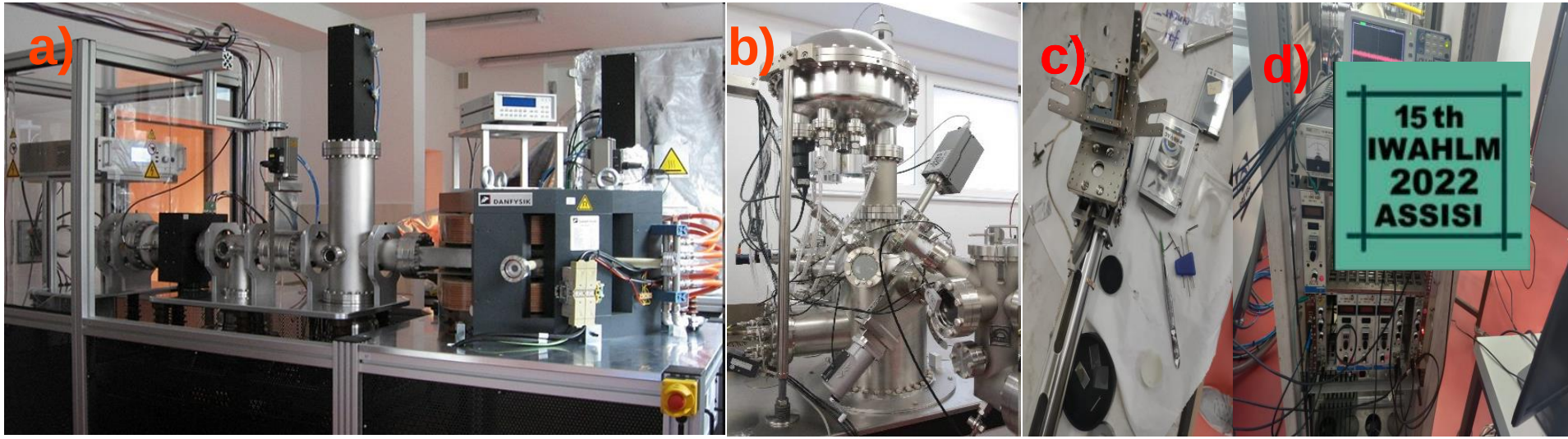
Experimental facility

"Internal pair $e^+ e^-$ measurements from DD threshholds resonance @ eLBRUS Lab"



a) Accelerator with Ultra High Vacuum, b) Target Chamber c) Detector holder with Al foils d) Electronics set up

a)Prototype ECR ion source, low emittance , high current, light ions – a few mA

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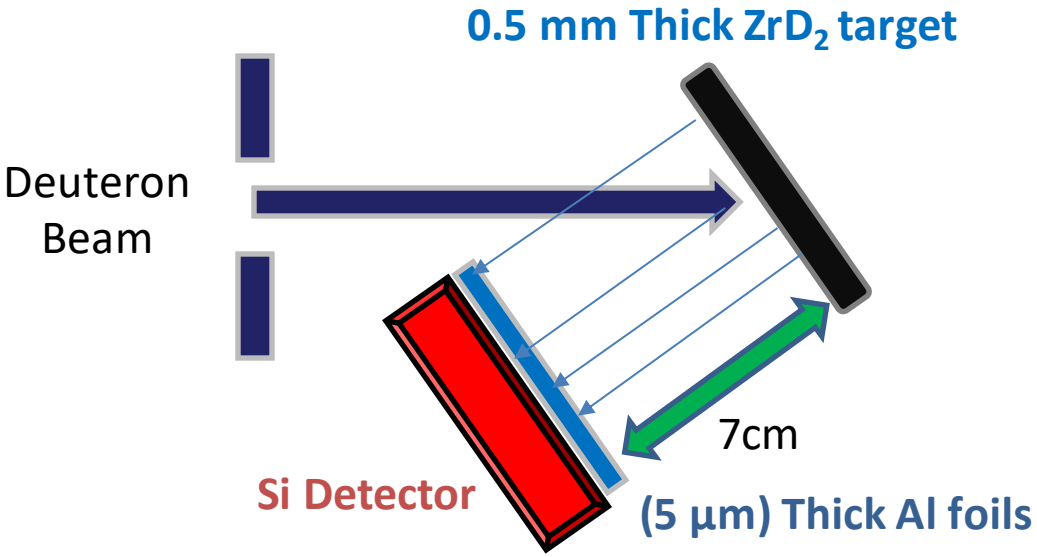
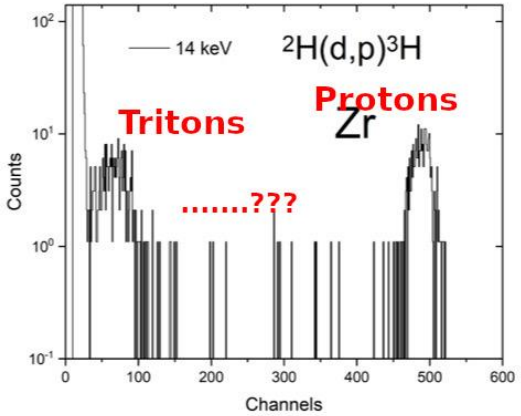
[a,b]Ref : M. Kaczmarski, et al., Acta Phys. Pol. B 45, 509 (2014).

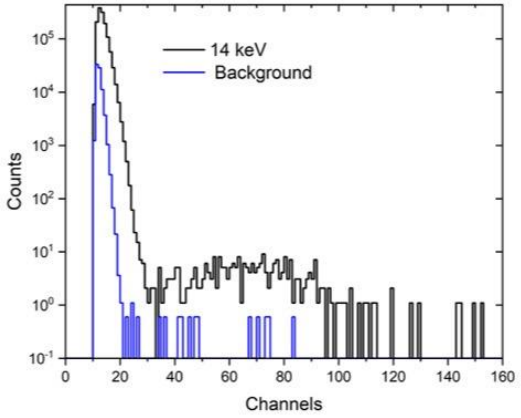
Experimental set up

First observation

"Internal pair $e^+ e^-$ measurements from DD threshholds resonance"







D2-beam Energy : 6-16 keV
EG ORTEC silicon detector : 1000 µm thickness and Surface area 100 mm ^{2} ,
Target temperature varies from around 20 – 50 0C as per current intensity 20-40 microamp and time duration of irrediation under UHV

Thick ZrD 2 target that was tilted at 45° to the beam, resulting in the beam spot size of 7x12 mm.

Experimental Evidence

"Internal pair e + e- measurements from DD threshholds resonance @ eLBRUS Lab"

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A series of experiments ;
- **with different metallic targets**
- **With different detector and foil thickness**

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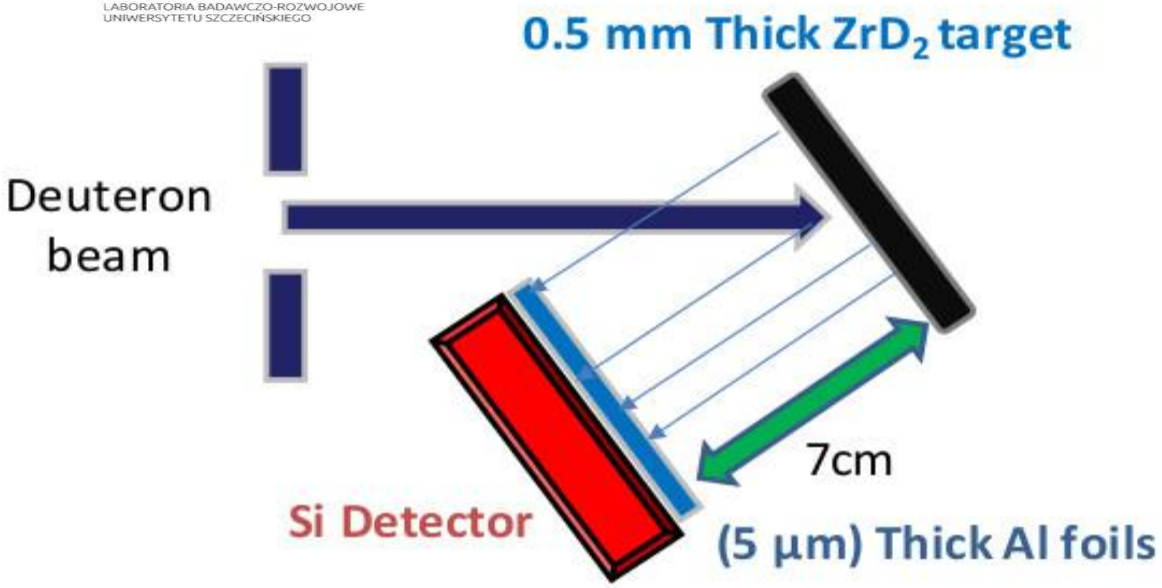
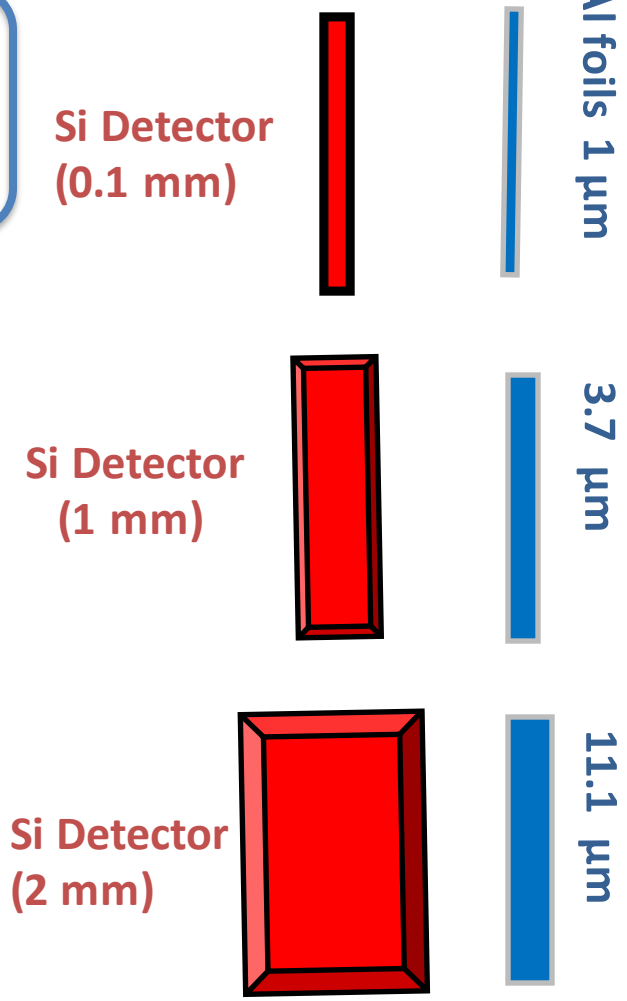
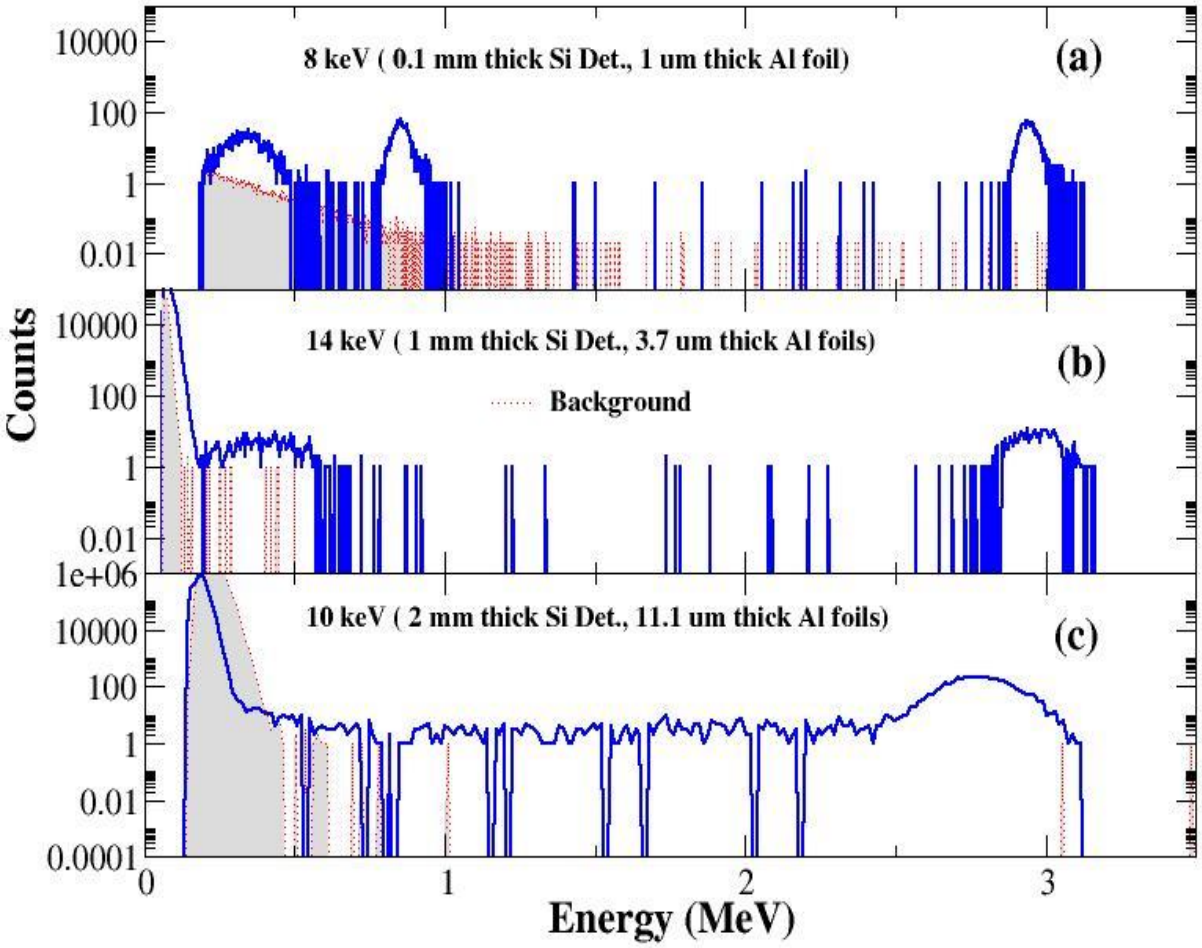
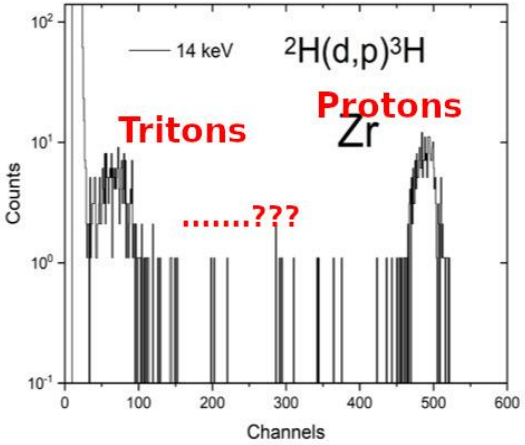


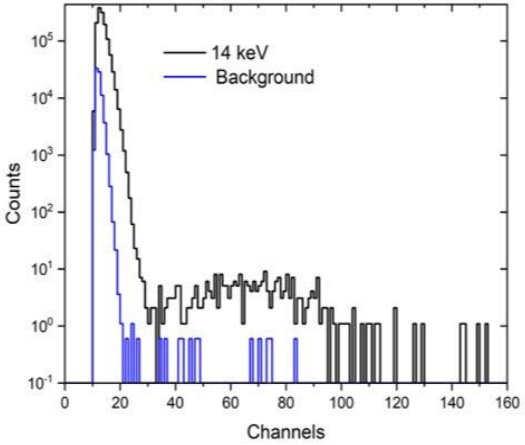


D2-beam Energy : 5-20 keV
EG ORTEC silicon detector : 0.1, 1, 2 mm thickness

Results
Charged Particles Spectra







Experimental set up of Si detector calibration

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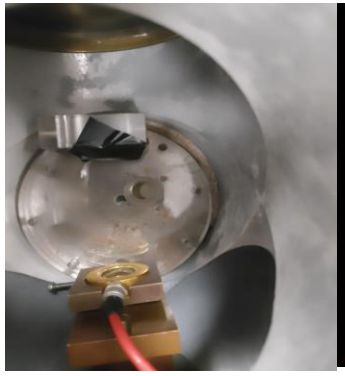
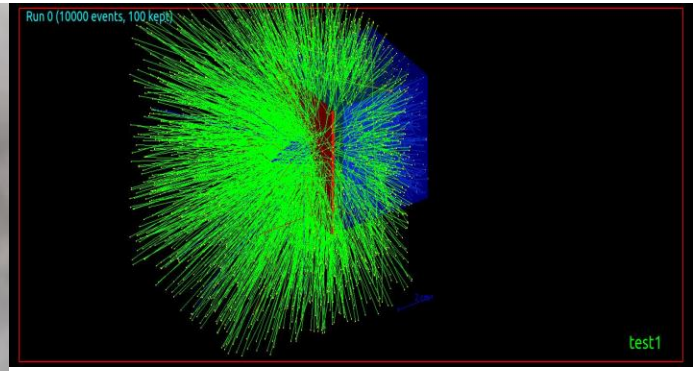
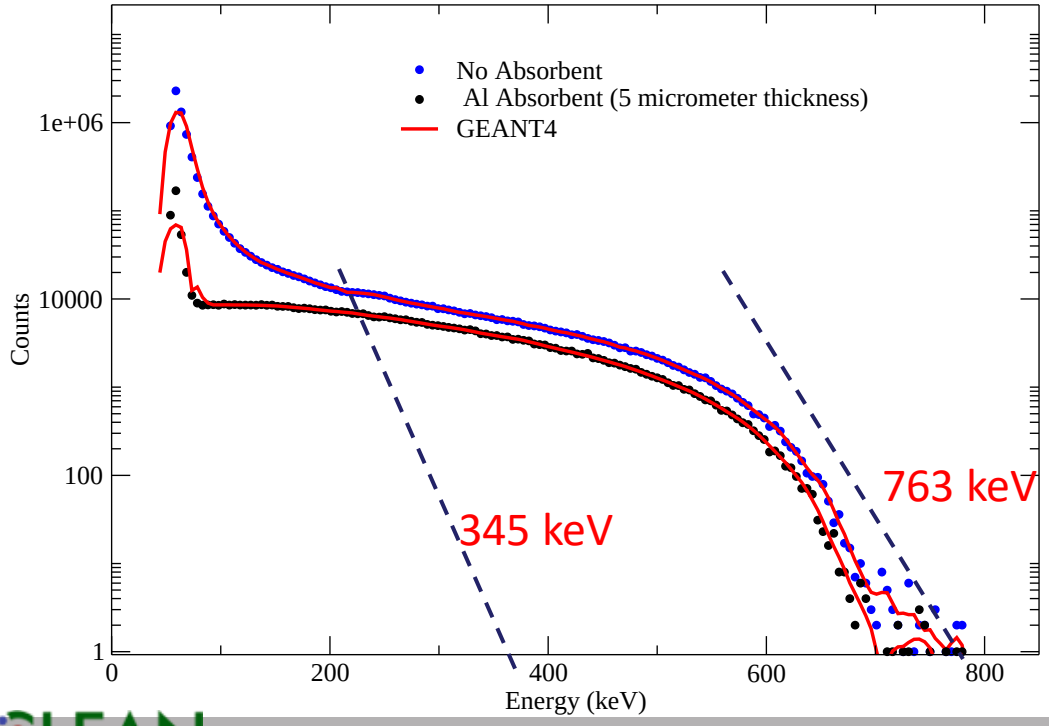
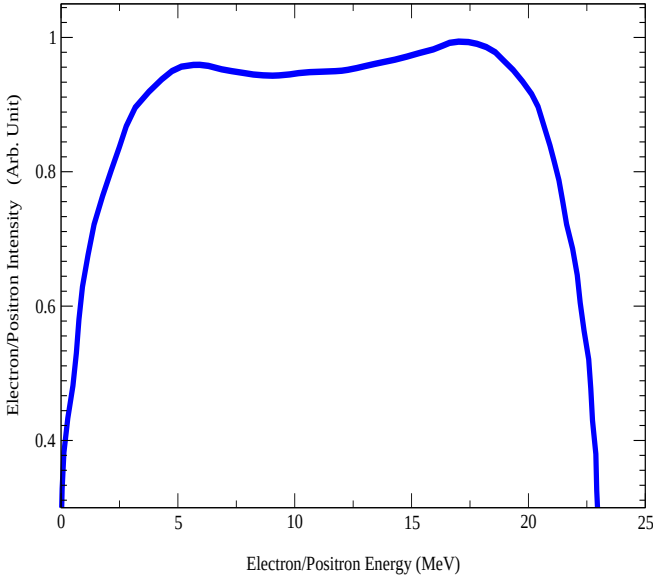




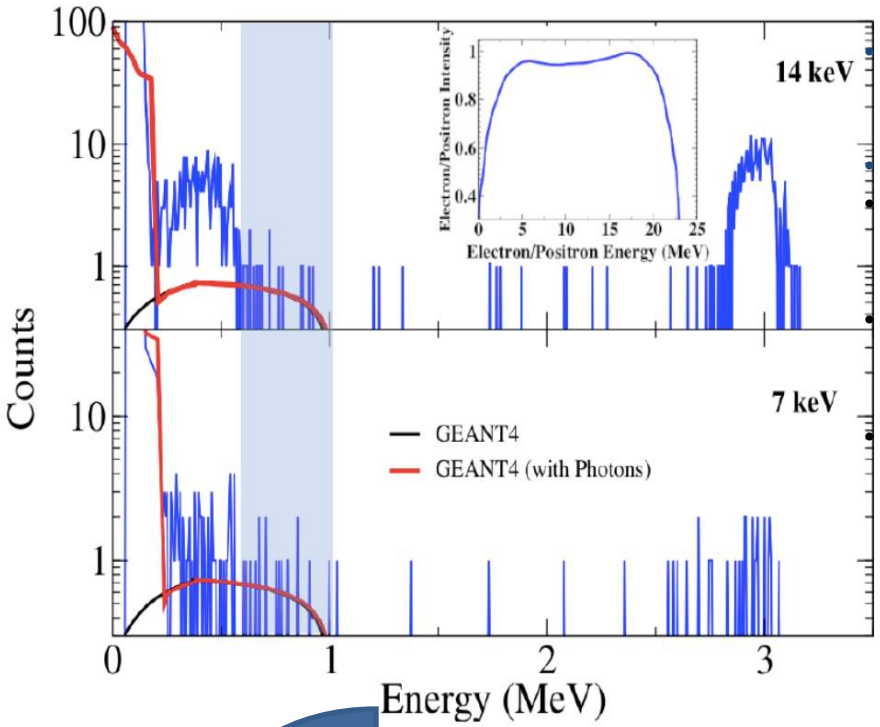
Geant 4 simulations





Electron-positron energy spectrum

Results
Charged Particles Spectra[1]



Upper panel: The two distinct peaks are protons, and tritons along with electrons/positrons from the DD reaction at the deuteron energy 14 keV.
Bottom panel: the spectrum obtained for 7 keV.
Solid lines correspond to the Geant 4 simulated, **Electronic part only (black line)** and **electrons together with low energy photons (red -line)**.
The insert in the upper part presents the energy spectrum of emitted electrons/positrons from the threshold resonance according to the Geant 4 simulation.
The shaded box corresponds to the electron/positron counting integration area.

Followed similar method e-p ratio calculation for other energies E_d = 6 – 16 keV

e- Observed part of the spectrum: 0.6 – 1.0 MeV, 42%

[4] K. Czerski, R. Dubey, M. Kaczmarski, A. Kowalska, N. Targosz-Sleczka, M. Valat submitted for publication to Phys. Rev. Letters

Discussion and Conclusions
Electron-Proton Branching Ratio

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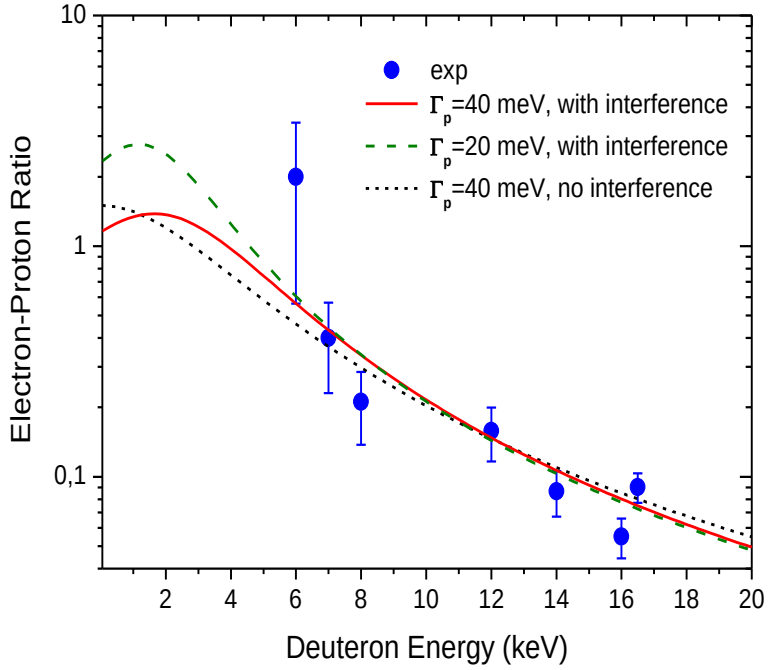

Experimental electron-proton branching ratio estimated for the electron energy loss 0.6-1.0 MeV and compared with the theoretical calculations

	$\Gamma_p = 40\ meV$		$\Gamma_p = 20\ meV$
	coherent	incoherent	coherent
$\Gamma_{pair}\ (meV)$	55±7	71±12	55±7
Γ_{pair}/Γ_p	1.4±0.2	1.8±0.3	2.8±0.4

First time the electron emission in the DD reactions at very low energies

This new 0^+ resonance was previously suggested to explain the experimentally determined enhancement factor of the $^2H(d,p)^3H$ reaction for both metallic Zr and gaseous targets

Arguments for the existence of the 0^+ threshold resonance in the DD reactions and might have large consequences for the nuclear astrophysics and the nuclear fusion applied studies..

For further details, please follow **Prof Konrad Czerski's talk**

Summary

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If correlation of dominant Reaction channel and Heat excess successfully will be proven for e.g, in case of He^4 production

Theoretical modelling for consistency and correlation

Next what !

Repeat the process until consistency and correlation well established.

Instrumental Development and Validation (For all kind of set up for e.g diffifusion/plasma/elctrolysis etc)

"Can e+e- decay from DD threshold resonance will be the new way to look cold fusion long standing consistency puzzle ???"

1)Annihilation radiation
2) Bremsstrahlung (23.84 MeV of e+e-)!!
Outside the Cold fusion measurement set up !!

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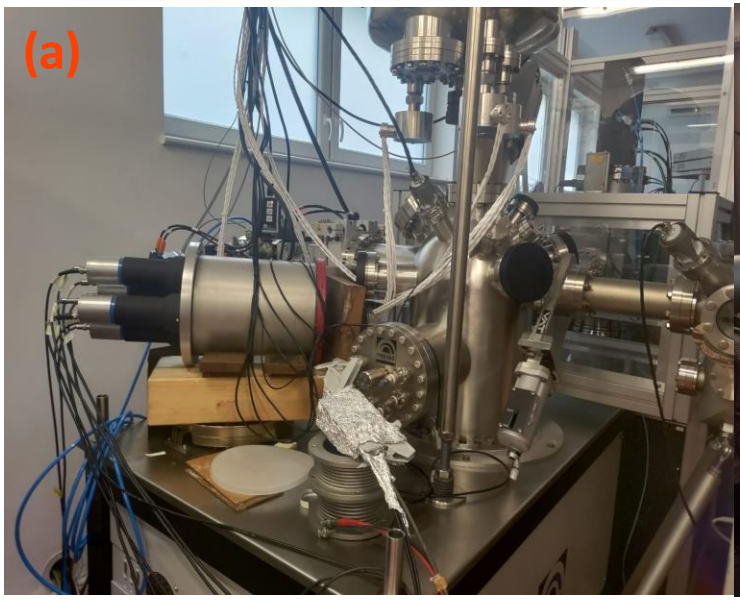
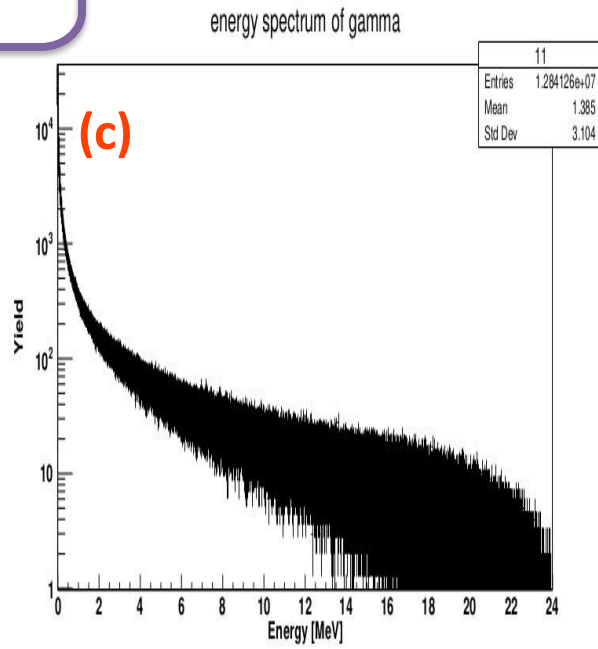
Outlook

Can e^+e^- decay from DD threshold resonance be the new way to look cold fusion long standing consistency puzzle ???

An expt. attempt is going on to measure the Bremsstrahlung using (a) Big 4 NaI detectors, (b) Ge detector (c) Geant 4 Simulation for 23.84 MeV electron passes through NaI crystal





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