FUSION- EVAPORATION AND DIRECT REACTIONS IN THE INTERACTION OF ^{20}Ne + ^{12}C

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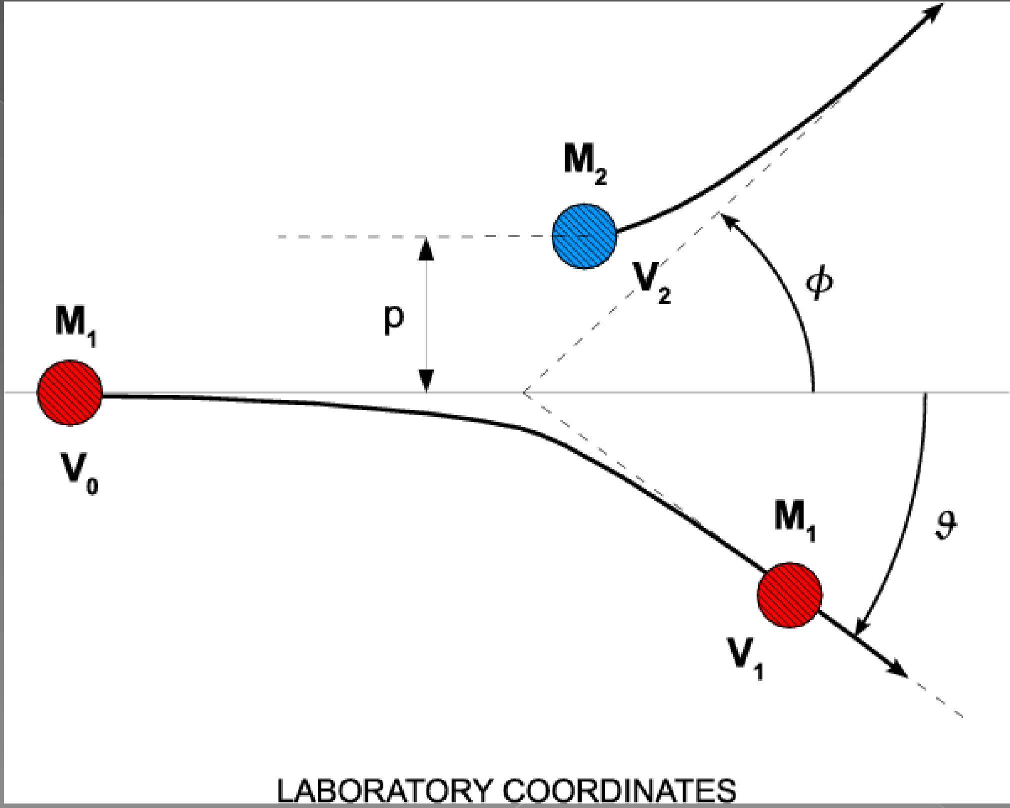
MOTIVATION

- Understand what happens when a 54,6MeV ^{20}Neon hits a ^{12}Carbon nucleus.
  - Fusion
  - Elastic Scattering
  - Direct Reactions

WHAT IS ELASTİC SCATTERİNG ?

- There is no kinetic energy losses: $E_0 = E_1 + E_2$

- In scattering theory and in particular in nuclear physics and particle physics, **elastic scattering** is one of the specific forms of scattering. In this process, the kinetic energy of the incident particles is conserved in the center-of-mass frame, only their direction of propagation is modified.



WHAT IS FUSION?

$$^{20}Ne + ^{12}C \longrightarrow ^{32}S \rightarrow \{Na,\ Mg,\ Al,\ Si,\ P\}$$

Na
Mg
Al
Si
P

In nuclear physics, **nuclear fusion** is a nuclear reaction in which two or more atomic nuclei collide at very high speed and join to form a new type of atomic nucleus. During this process, matter is not conserved because some of the mass of the fusing nuclei is converted to photons which are released through a cycle that even our sun uses. Fusion is the process that powers active stars.

"Q" VALUES

- In nuclear physics and chemistry, the Q value for a reaction is the amount of energy released by that reaction:

$$Q = E\,(\text{Reactants}) - E\,(\text{Products})$$

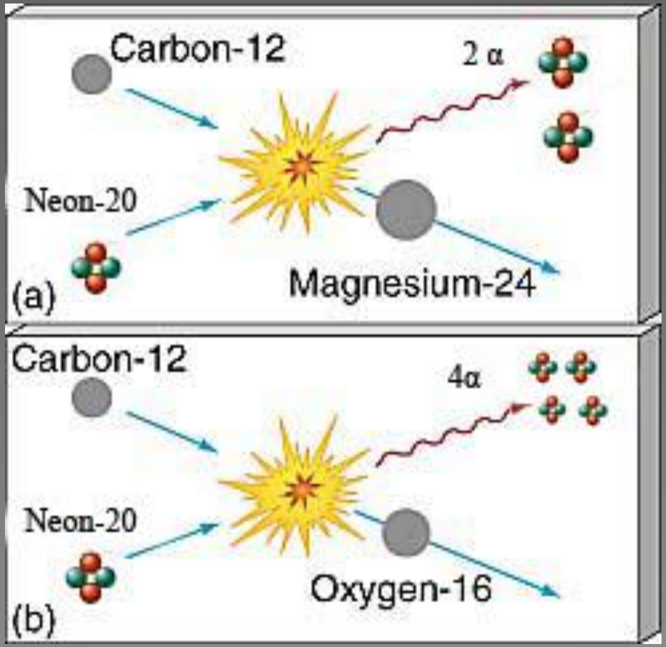
$$Q = \text{Initial mass} - \text{Final mass}$$

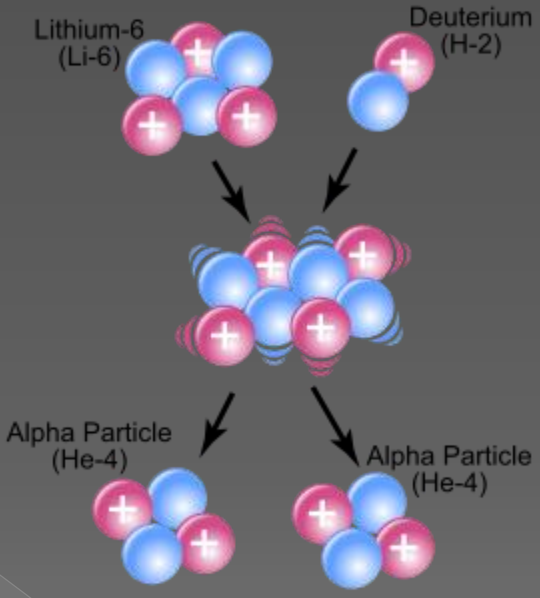
- A reaction with a positive Q value is exothermic (has a net release of energy), while a reaction with a negative Q value is endothermic (requires a net energy input)

WHAT IS A DIRECT REACTİON ?

Transfer of particles between beam and target

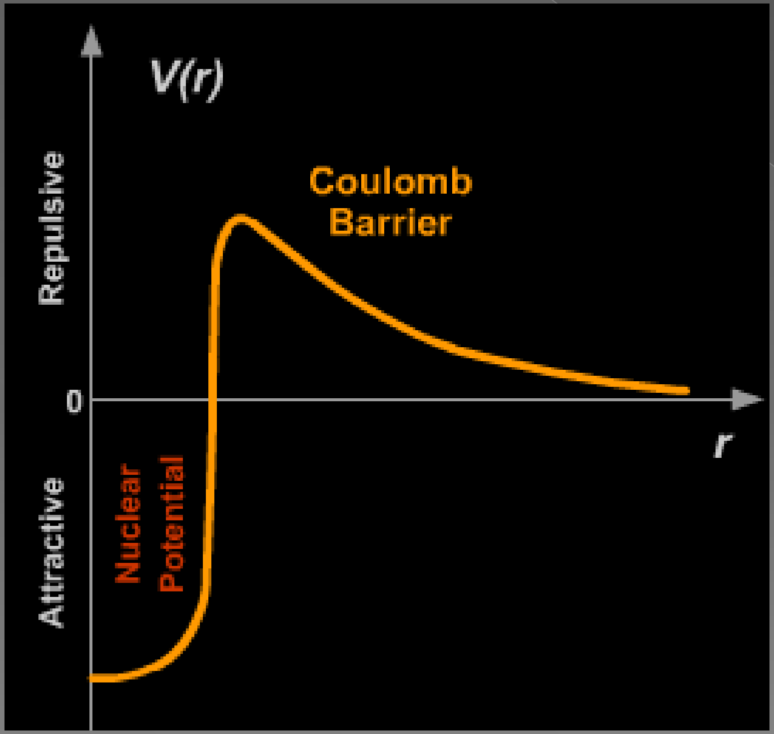
- $^{20}Ne + ^{12}C \rightarrow ^{16}O + ^{16}O$
- $^{20}Ne + ^{12}C \rightarrow ^{12}C + ^{20}Ne$
- $^{20}Ne + ^{12}C \rightarrow ^{8}Be + ^{24}Mg$





Lithium-6 – Deuterium Reaction

- The **Coulomb barrier**, named after Coulomb's law, which is named after physicist Charles-Augustin de Coulomb (1736-1806), is the energy barrier due to electrostatic interaction that two nuclei need to overcome so they can get close enough to undergo a nuclear reaction.



- This energy barrier is given by the electrostatic potential energy:

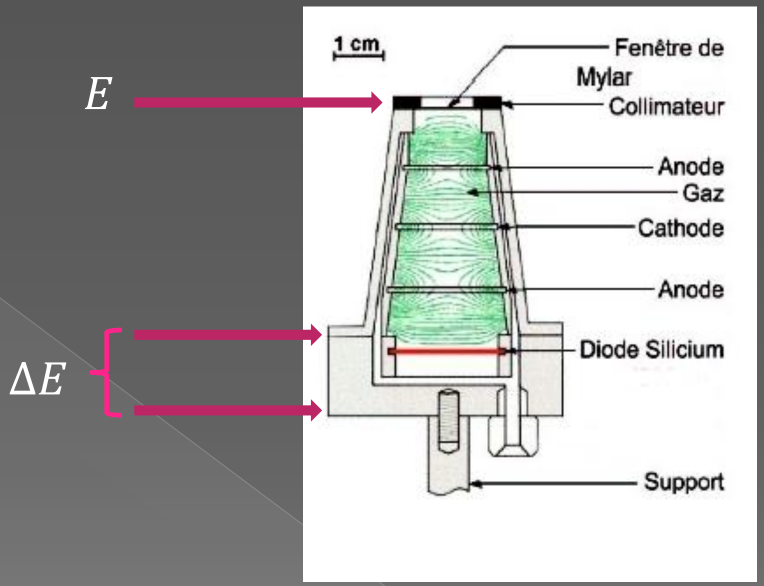
$$U_{coul} = k\frac{q_1 q_2}{r} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r}$$

k is the Coulomb's constant =8.9876×109 N m² C−2;
ε0 is the permittivity of free space
q1, q2 are the charges of the interacting particles;
r is the interaction radius.

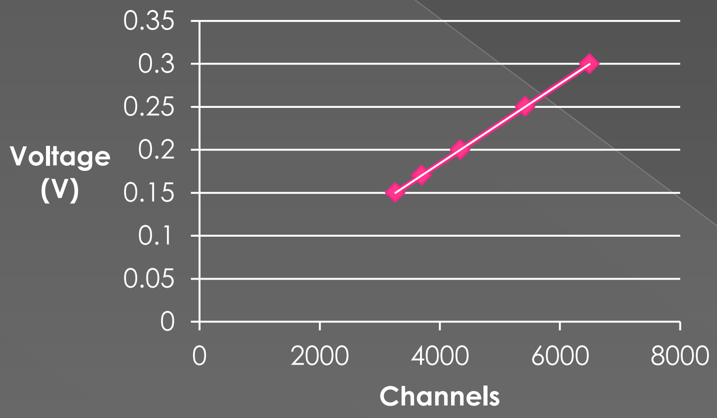
TELESCOPES

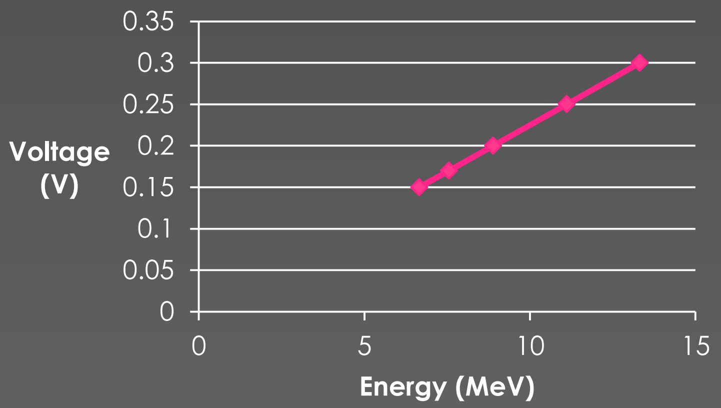
- Schematic view

- $\Delta E \propto \frac{M\,Z^2}{E}$



CALIBRATION





We used ^{241}Am as a source of alpha particles at 5,486 MeV. Some 166 keV was lost due to the window of the detector which is made of mylar putting the energy of our alphas at 5,32 MeV, which we used for the calibration.

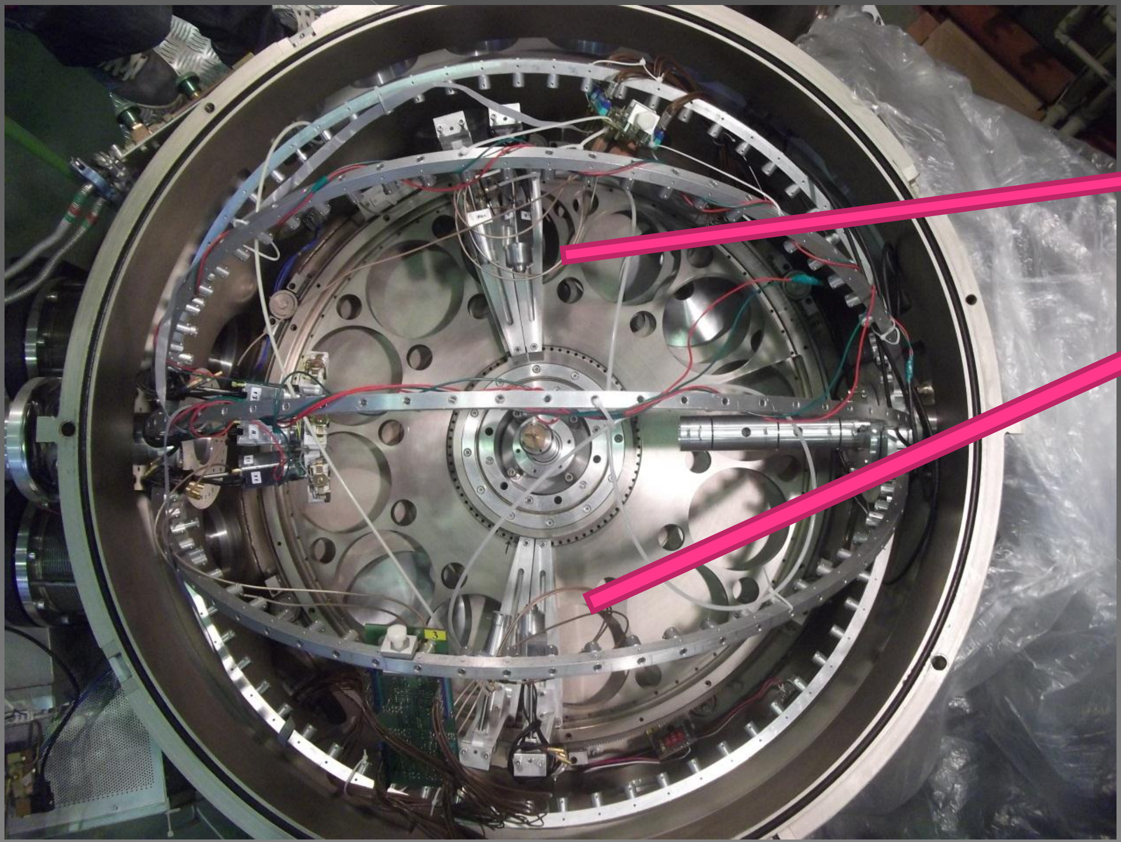
EXPERIMENTAL SETUP

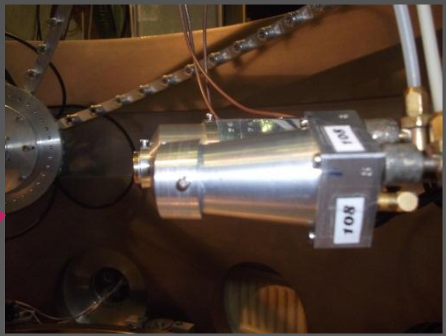
Control Pannel for gas

Vacuum Controls

Telescope's gas (Iso-Butane)

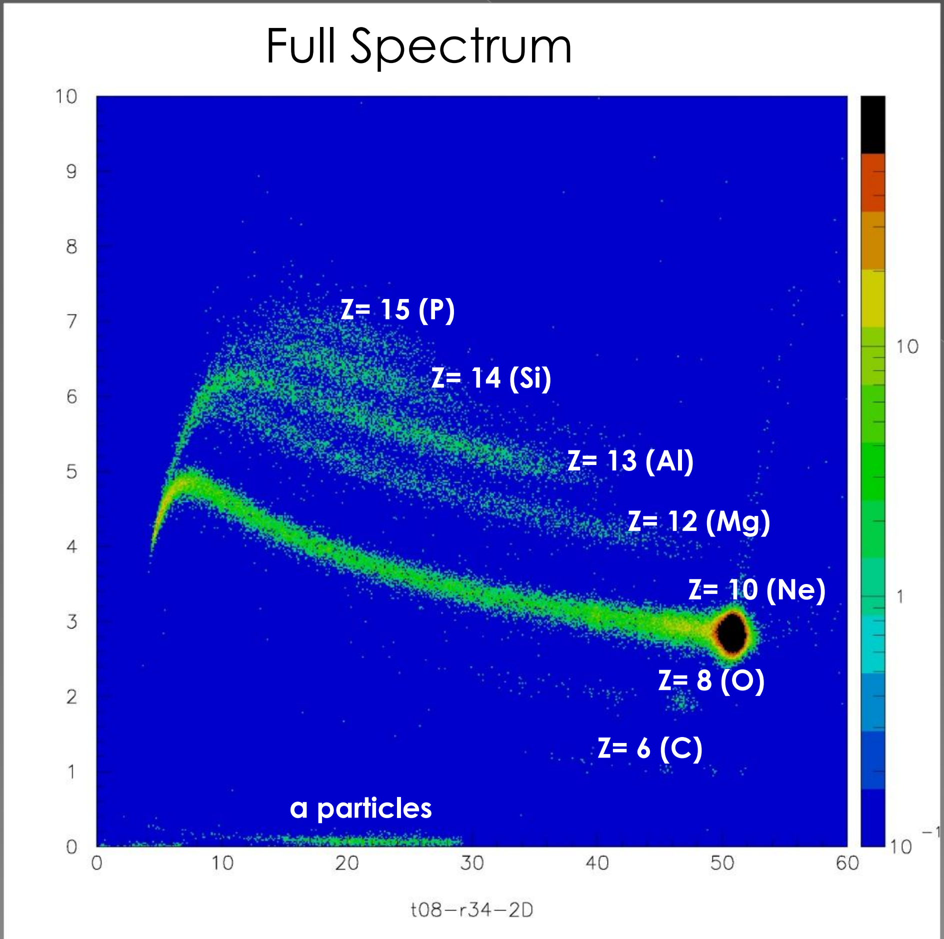
EXPERIMENTAL SETUP

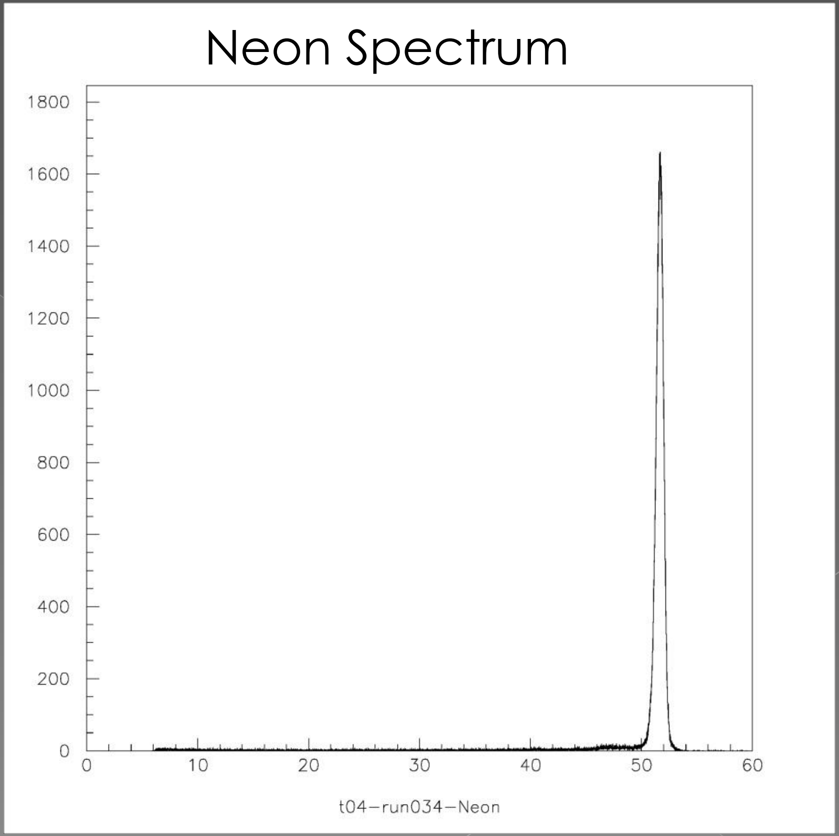




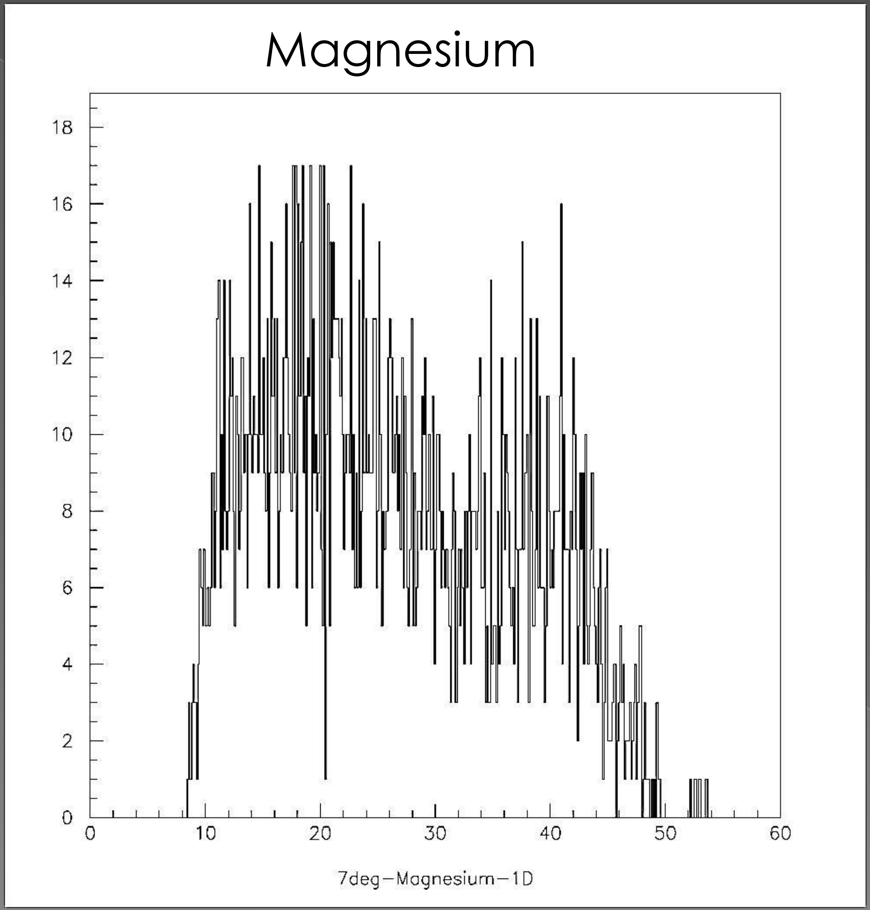
Gas-Si Telescopes

ANALYSIS

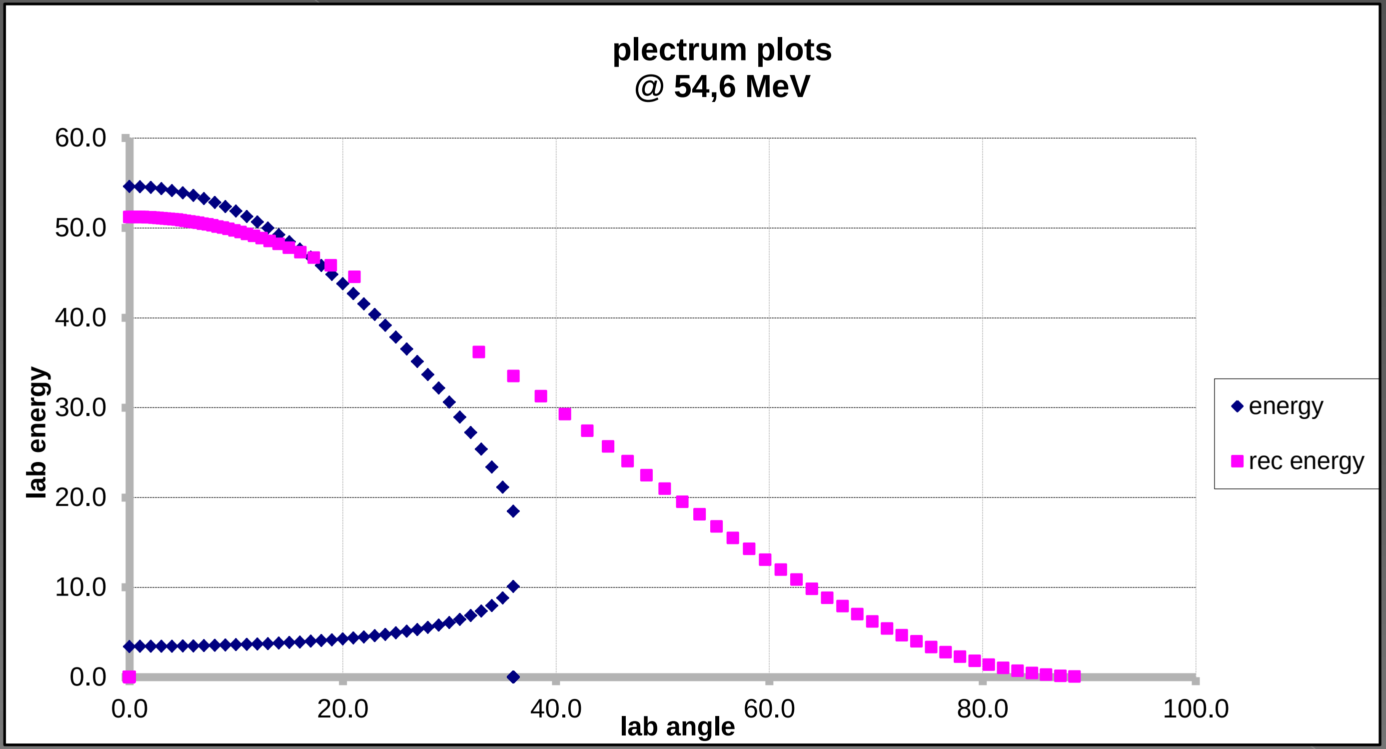

Full Spectrum
Z= 15 (P)
Z= 14 (Si)
Z= 13 (Al)
Z= 12 (Mg)
Z= 10 (Ne)
Z= 8 (O)
Z= 6 (C)
a particles
t08−r34−2D


Neon Spectrum
t04−run034−Neon

ANALYSIS STEPS



THEORETICAL KINEMATICS SIMULATIONS



Elastic Scattering model of ^{20}Neon from ^{12}Carbon (Catkin simulation)

COMPARING RESULTS

PACE4 simulation results

------ **Output results for compound nucleus decay** -----

1.Yields of residual nuclei

Z	N	A		events	percent	x-section(mb)
16	15	31	S	80	0.8%	6.7
15	16	31	P	239	2.39%	20
16	14	30	S	2	0.02%	0.167
15	15	30	P	2485	24.9%	208
14	16	30	Si	726	7.26%	60.8
15	14	29	P	5	0.05%	0.419
14	15	29	Si	894	8.94%	74.8
13	16	29	Al	2	0.02%	0.167
14	14	28	Si	511	5.11%	42.8
14	13	27	Si	203	2.03%	17
13	14	27	Al	4635	46.4%	388
12	12	24	Mg	216	2.16%	18.1
11	12	23	Na	2	0.02%	0.167
TOTAL				10000	100%	837

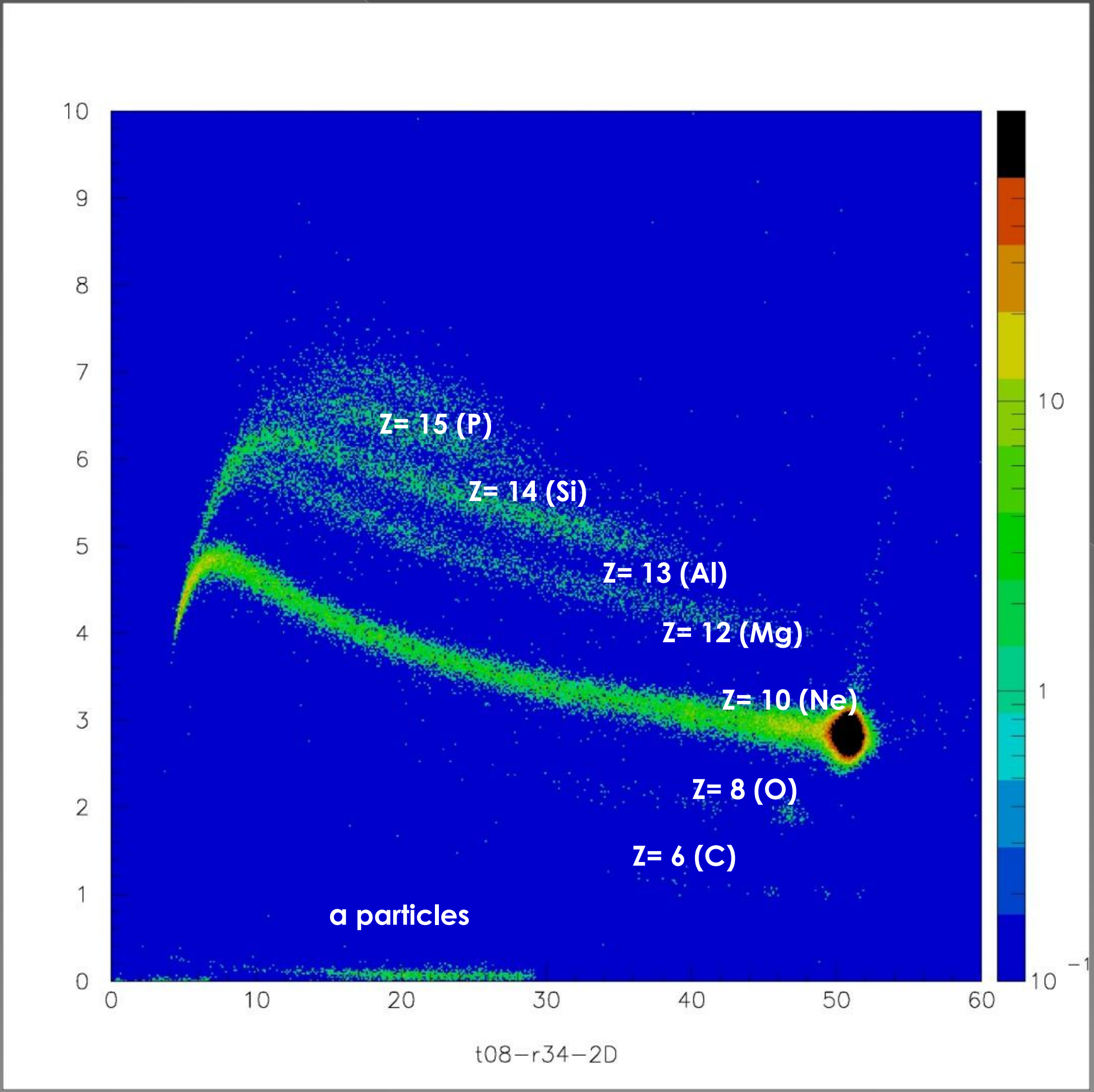
Experimental results

Experimental Results for 7°

Particles	Counts	%
**Alphas	1127	
**Carbon	42	
**Oxygen	183	
Magnisium	2748	24,670%
Aluminum	5164	46,360%
Silicon	2555	22,937%
Phosphorus	672	6,033%
Total Counts	11139	100,000%

** Products obtained from direct reactions

Why is there no sodium?



Beam at ~20 MeV energy at CM

The Q-value of reactions involving Na are higher than 20 MeV

CONCLUSIONS

- We have observed fusion evaporation from ^{32}S to P, Si, Al, Mg
- Direct reactions – O, C, Mg
- Fusion evaporation dominates the spectrum.
- Good match with catkin (kinematics) and PACE4 (fusion products) expected values.
- Phosphorus levels below expectations due to setup limitations.
- Lack of Sodium due to the high Q-value of the reaction needed to produce it.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uwagę ☺
Thanks for
your attention
Vespa