INTERNATIONAL WORKSHOP ON ACCELERATION AND APPLICATIONS OF HEAVY IONS, HIL, Warsaw

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

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Motivation

Detailed study of nuclear reactions at energies around the barrier:

-Better understanding of the competition between direct reactions and fusion-evaporation processes

-Test our knowledge of nuclear potentials and reaction models with stable beams, → improve our theoretical tools needed to investigate exotic nuclei

- FRESCO: Direct reactions
- PACE4: Fusion-evaporation

Interesting system itself: the 12C+ 20Ne and16O+16O systems should lead to same final compound nucleus 32S:

→Are direct reactions and fusion evaporation comparable in both systems?

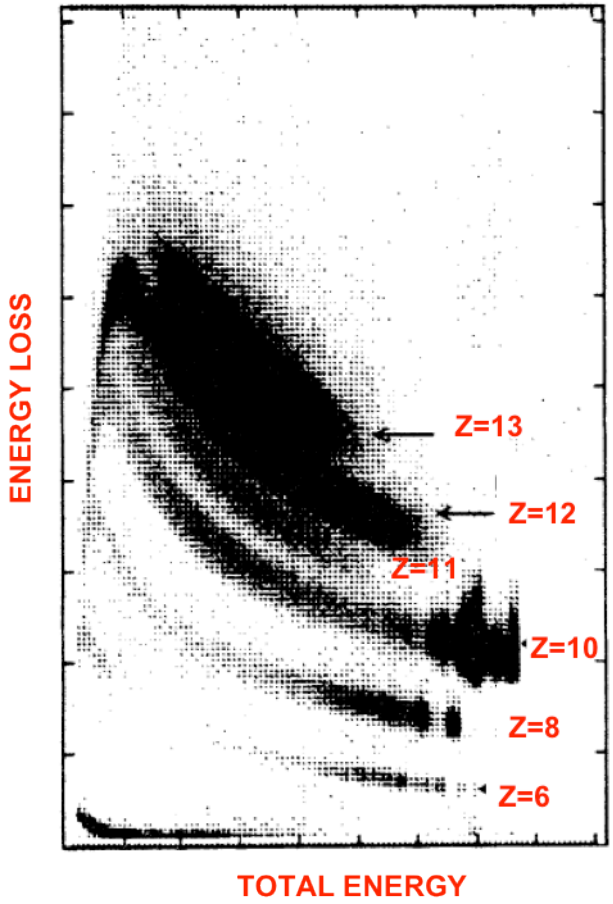
Previous investigations:

R. Vandenbosch, et al, PRL 33, 842 (1974). R. G. Vandenbosch and K. G. Bernhardt, J. Phys. Lett. 37, L161 (1976). H. Doubre, et al., PRC 17, 131(1978). J. Menet, et al, J. Phys. 38, 1051 (1977), F. Osterfeld, et al,Phys. Lett. 68B, 319 (1977). F. Saint Laurent, et al, NPA327, 517 (1979).

ADVANTAGE OF MODERN DETECTOR SETUPS (ICARE) AND HIGH INTENSITY BEAMS PRODUCED AT HEAVY ION LAB AT WARSAW (POLAND)

TYPICAL MASS IDENTIFICATION SPECTRUM

D. Shapira, et al. PRC26 (1982)2470

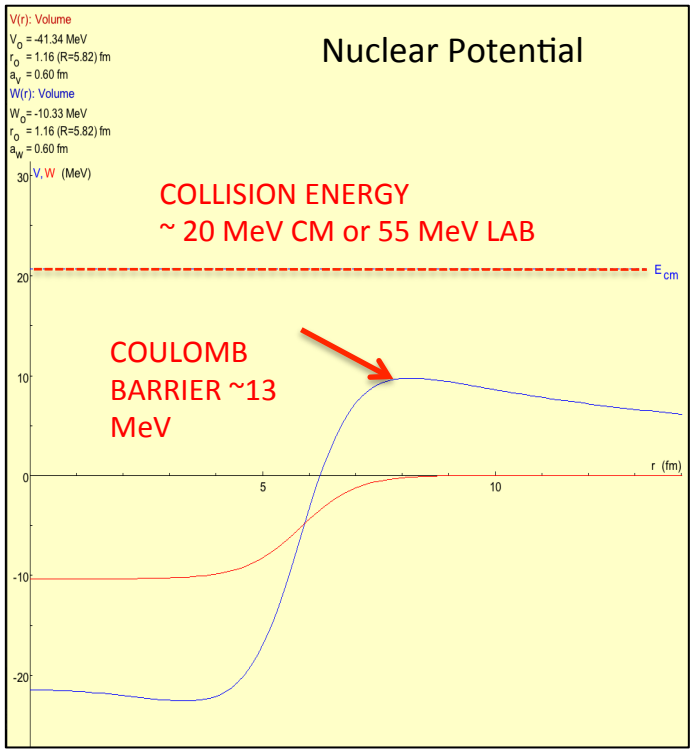


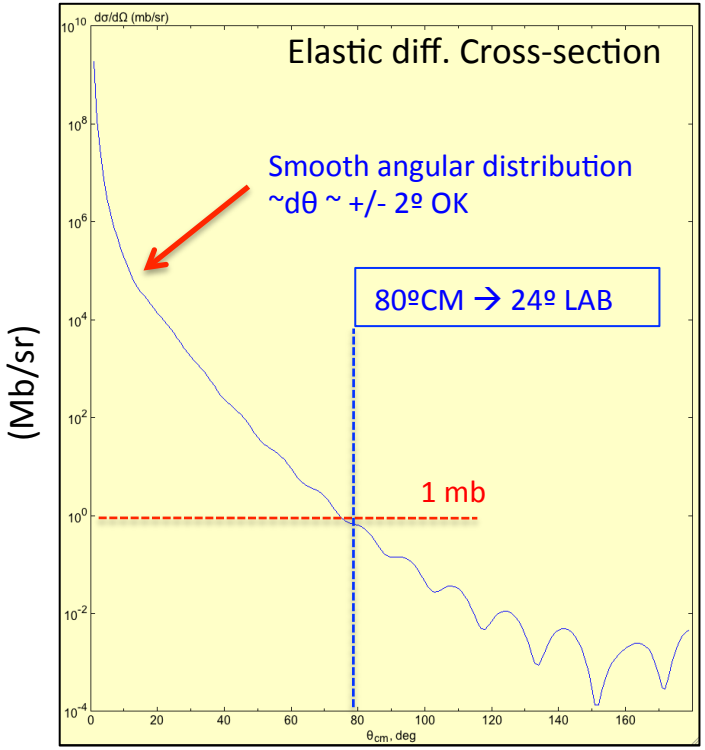
Beam energy:
~ 55 MeV (~ 20 MeV ^{CM}) → rapidly available at HIL Cyclotron with highest intensity (~ 1 nA)
-Just above the Coulomb barrier for $^{12}C+^{20}Ne$ system (13 MeV ^{CM})
- Inverse kinematics: forward focussing of relevant fragments → good setup for a 6 hours measurement

→Preliminary calculations to determine relevant cross sections:

angular range and resolution, Kinematics of fragments, Expected statistics

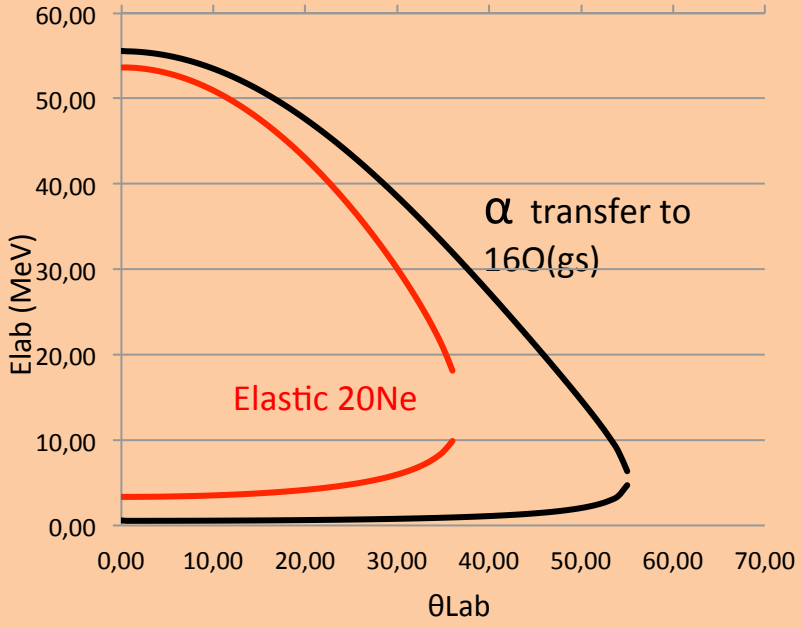
Elastic cross sections → simple OM (http://nrv.jinr.ru/nrv/webnrv/elastic_scattering) with global parameters of R.O. Akyuz and A. Winther (Proc. Enrico Fermi Int. School of Physics, 1979, **"Nuclear structure and heavy-ion reactions"**, ed. R.A. Broglia, C.H. Dasso and R. Ricci (North-Holland, Amsterdam, 1981) p. 491





FULL COUPLED CHANNELS CALCULATION WITH FRESCO → REACTION THEORY GROUP D

Kinematics of direct reactions → Catkin
personal.ph.surrey.ac.uk/~phs1wc/kinematics/

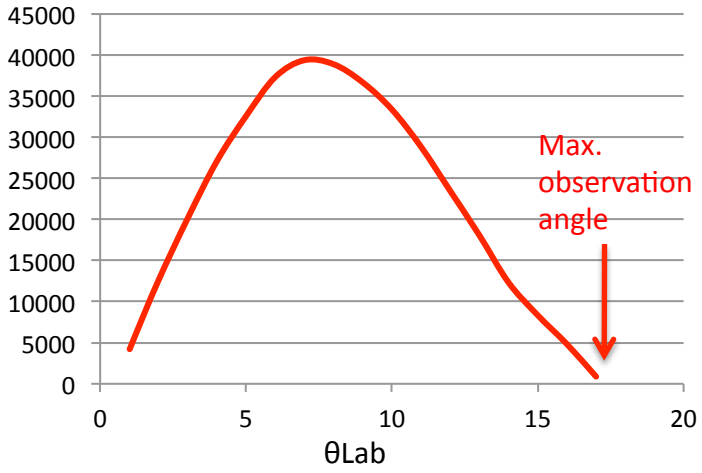


FUSION-EVAPORATION →
Simulation with PACE4

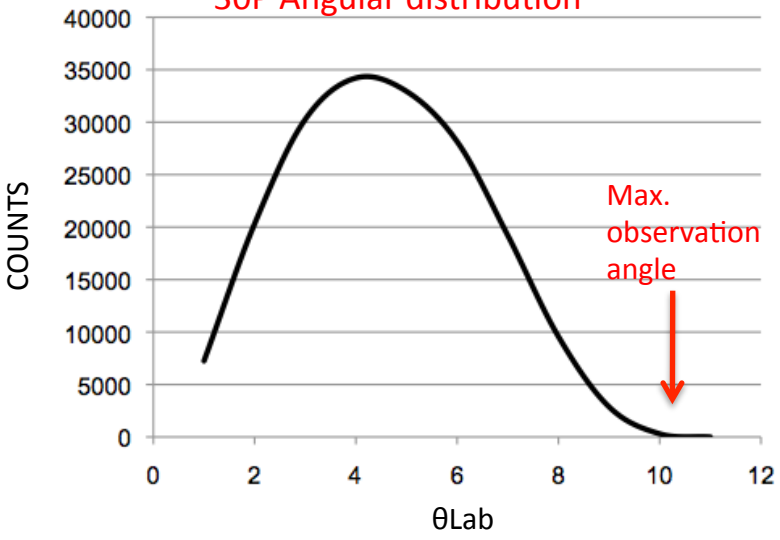
1.Yields of residual nuclei

Z	N	A	events	percent	x-section(mb)
16	16	**32 S**	580	0.0725%	0.679
16	15	**31 S**	6113	0.764%	7.16
15	16	**31 P**	19611	2.45%	23
16	14	**30 S**	144	0.018%	0.169
15	15	**30 P**	185085	23.1%	217
14	16	**30 Si**	55431	6.93%	64.9
15	14	**29 P**	331	0.0414%	0.388
14	15	**29 Si**	53823	6.73%	63
13	16	**29 Al**	27	0.00337%	0.0316
14	14	**28 Si**	70029	8.75%	82
14	13	**27 Si**	16469	2.06%	19.3
13	14	**27 Al**	378791	47.3%	444
12	12	**24 Mg**	13476	1.68%	15.8
11	12	**23 Na**	90	0.0112%	0.105
TOTAL			800000	100%	937

27Al Angular distribution



30P Angular distribution



Experimental Setup

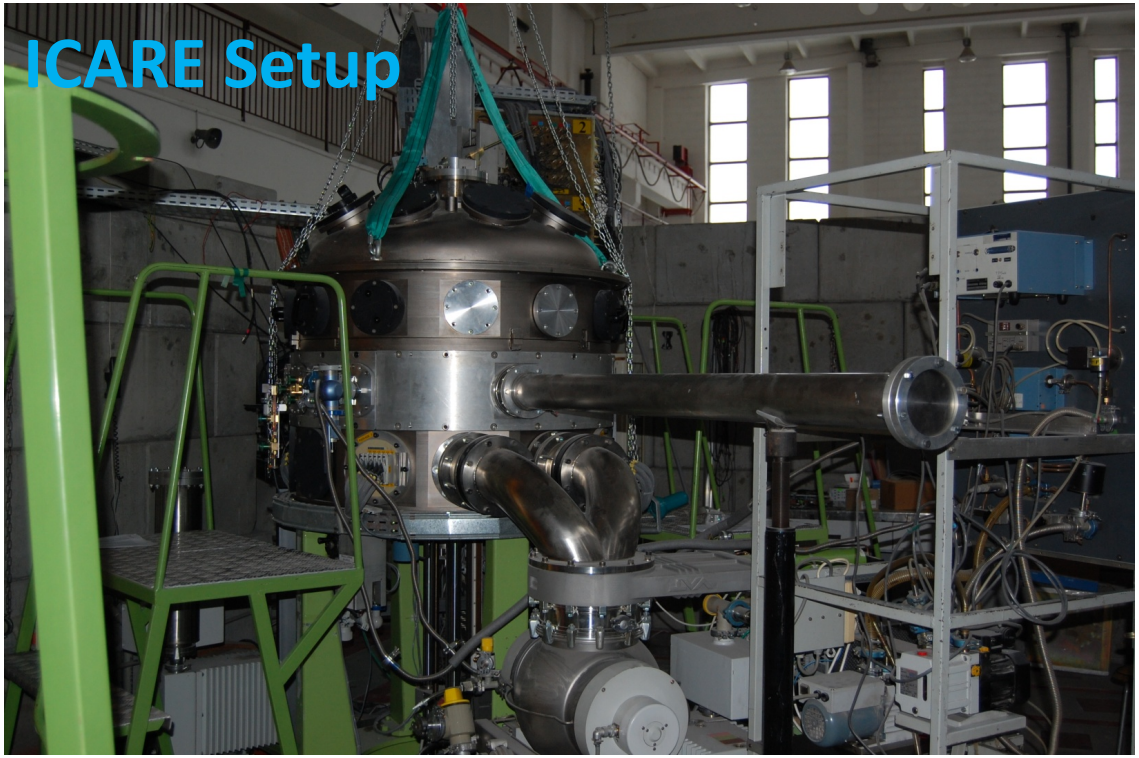


photo credit : I. Strojek

Located at ***Hall D*** ,
Heavy Ion Laboratory

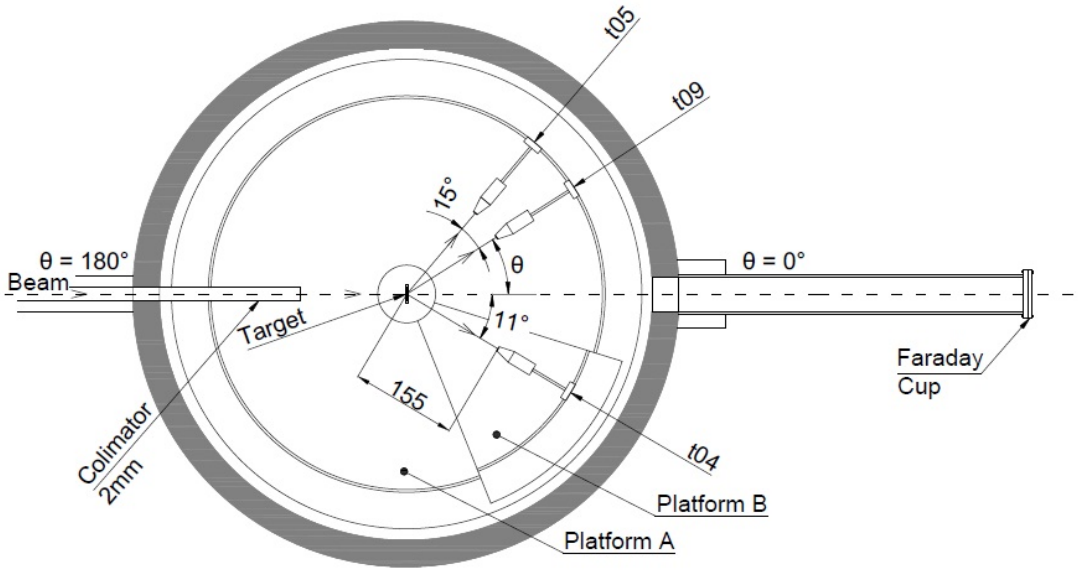
Beam of 53.6 MeV
$^{20}Ne^{+3}$ ions at 4 pnA
from Cyclotron (K=160)

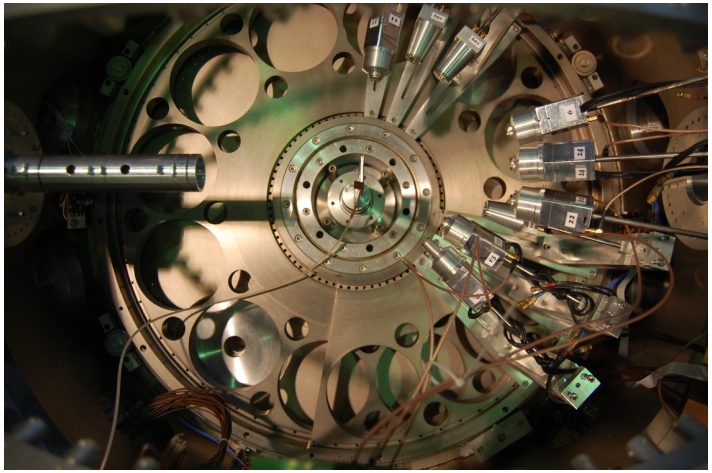
Schematics of the target chamber

Detector **t04** :
@ 11° fixed angular position

Detector **t09** and **t05** :
@ 15° relative angular pos.

Targets:
^{12}C @60 µg/cm^2
(thanks to Anna Stolarz !)





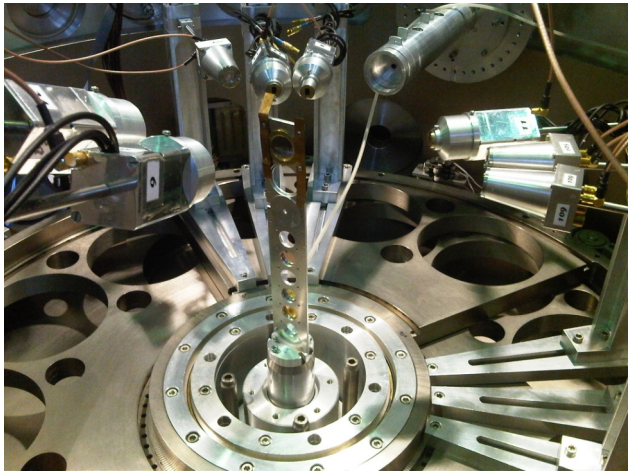
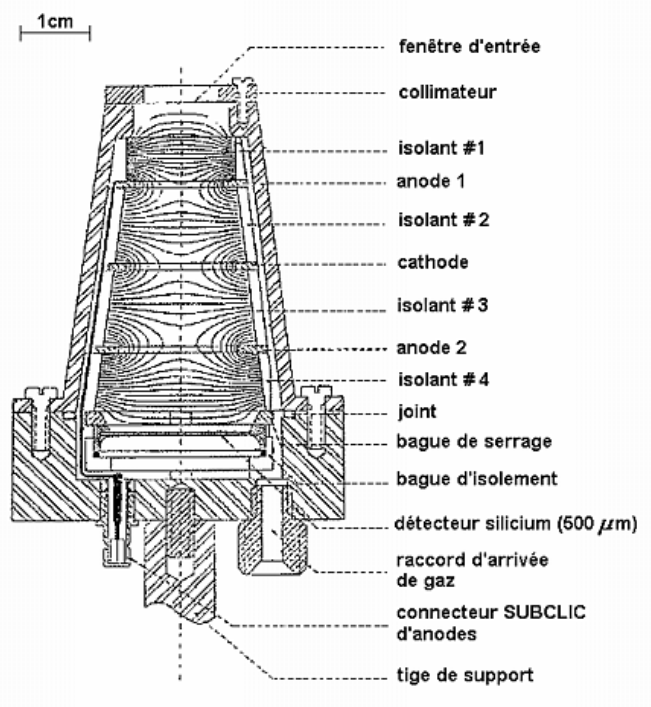


photo credit : I. Strojek

Gas-Si telescope (ΔE-E detector):



Gas: Iso-Butane @ ~14 mbar

Entrance Window:

Mylar foil @ 2.5 µm

Diameter @ 10 mm

Silicon @ 500 µm

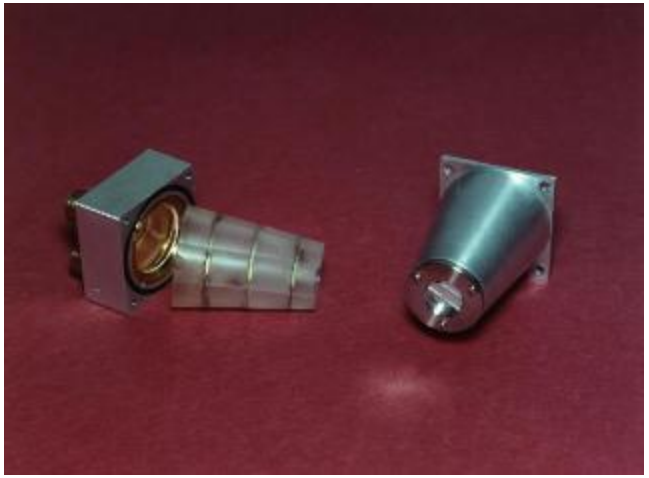
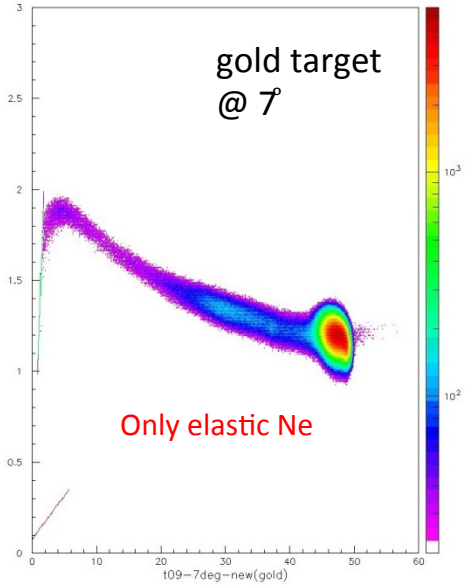


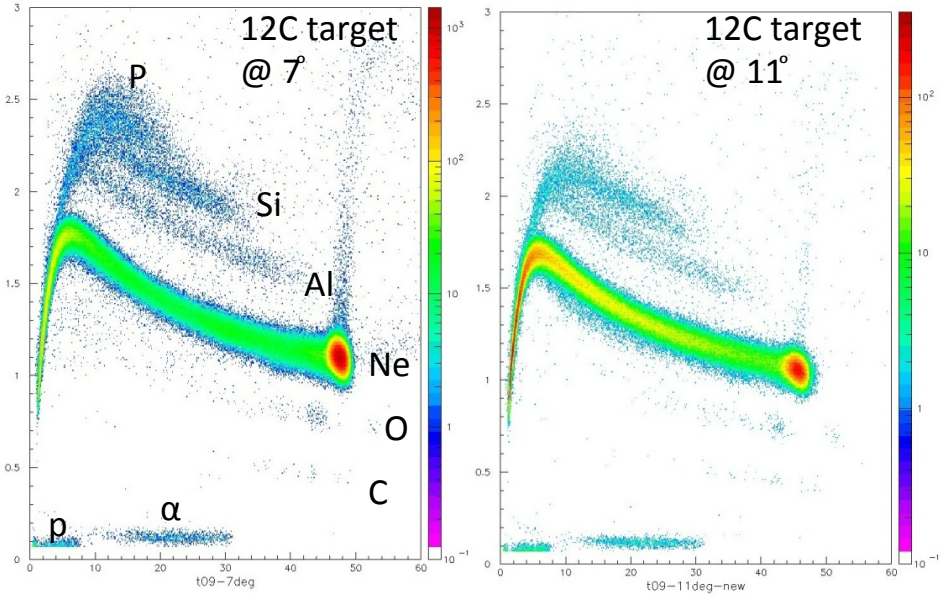
photo credit : I. Strojek

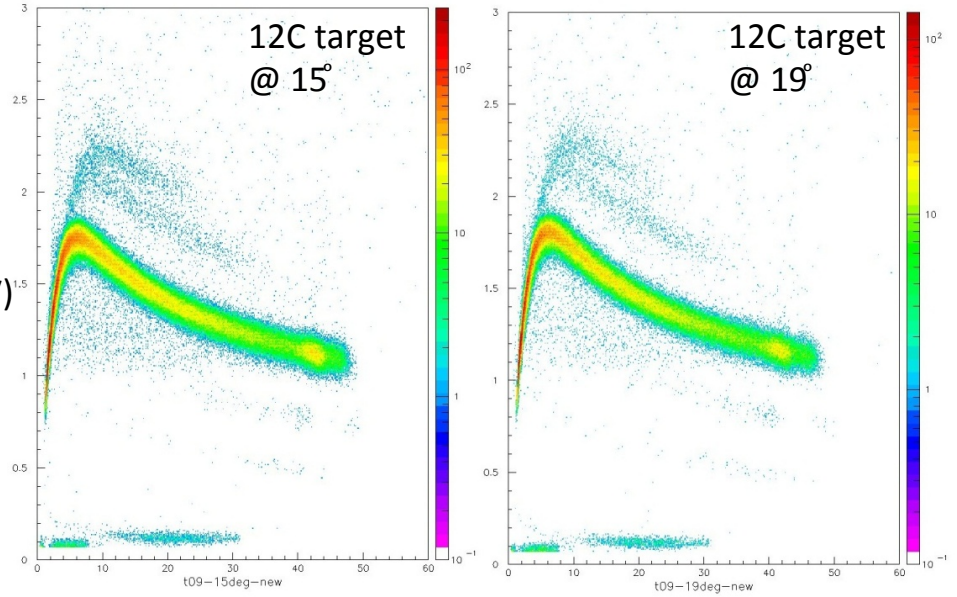
Results:



ΔE (MeV)

E (MeV)





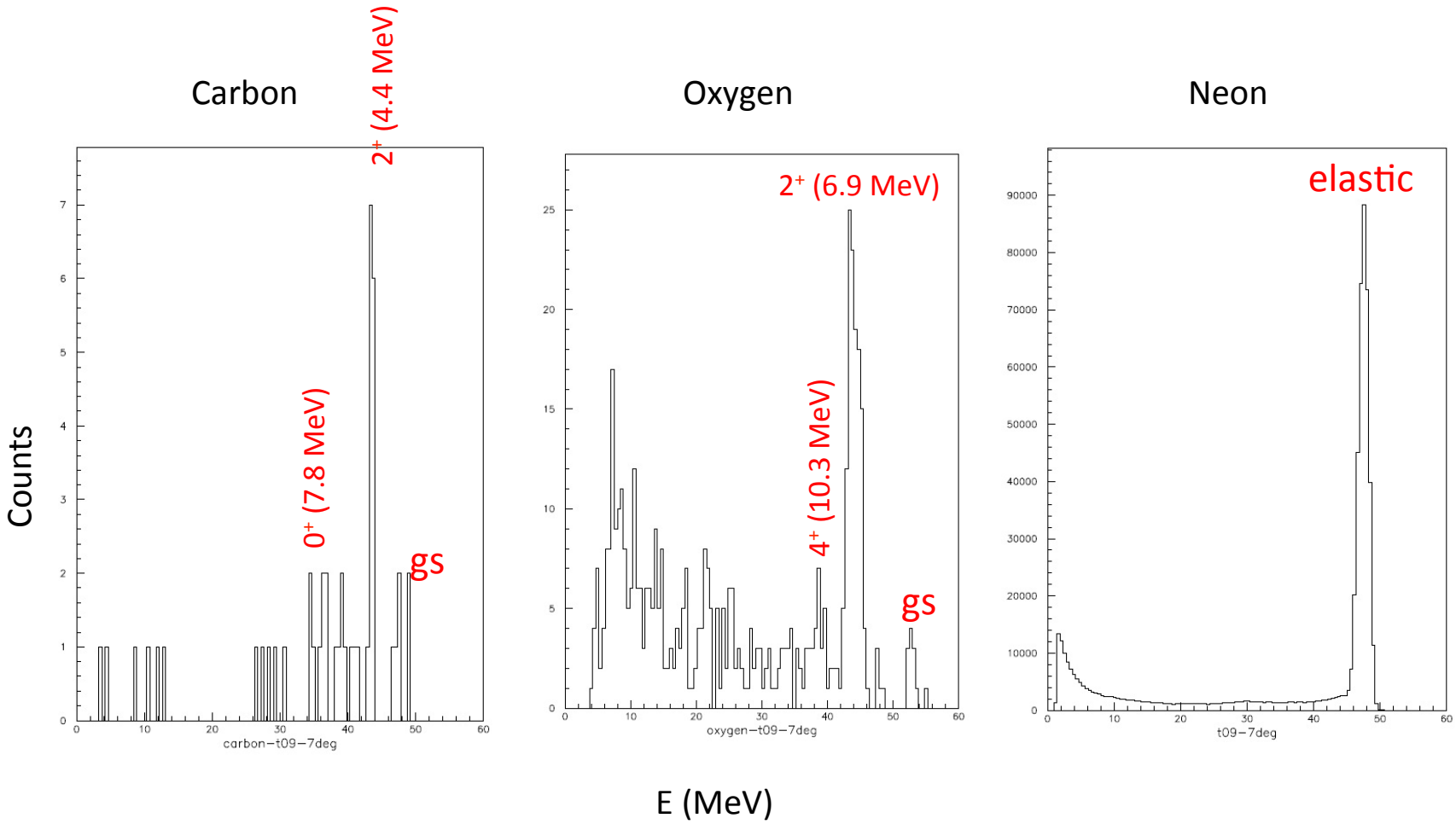
ΔE(MeV)

E (MeV)

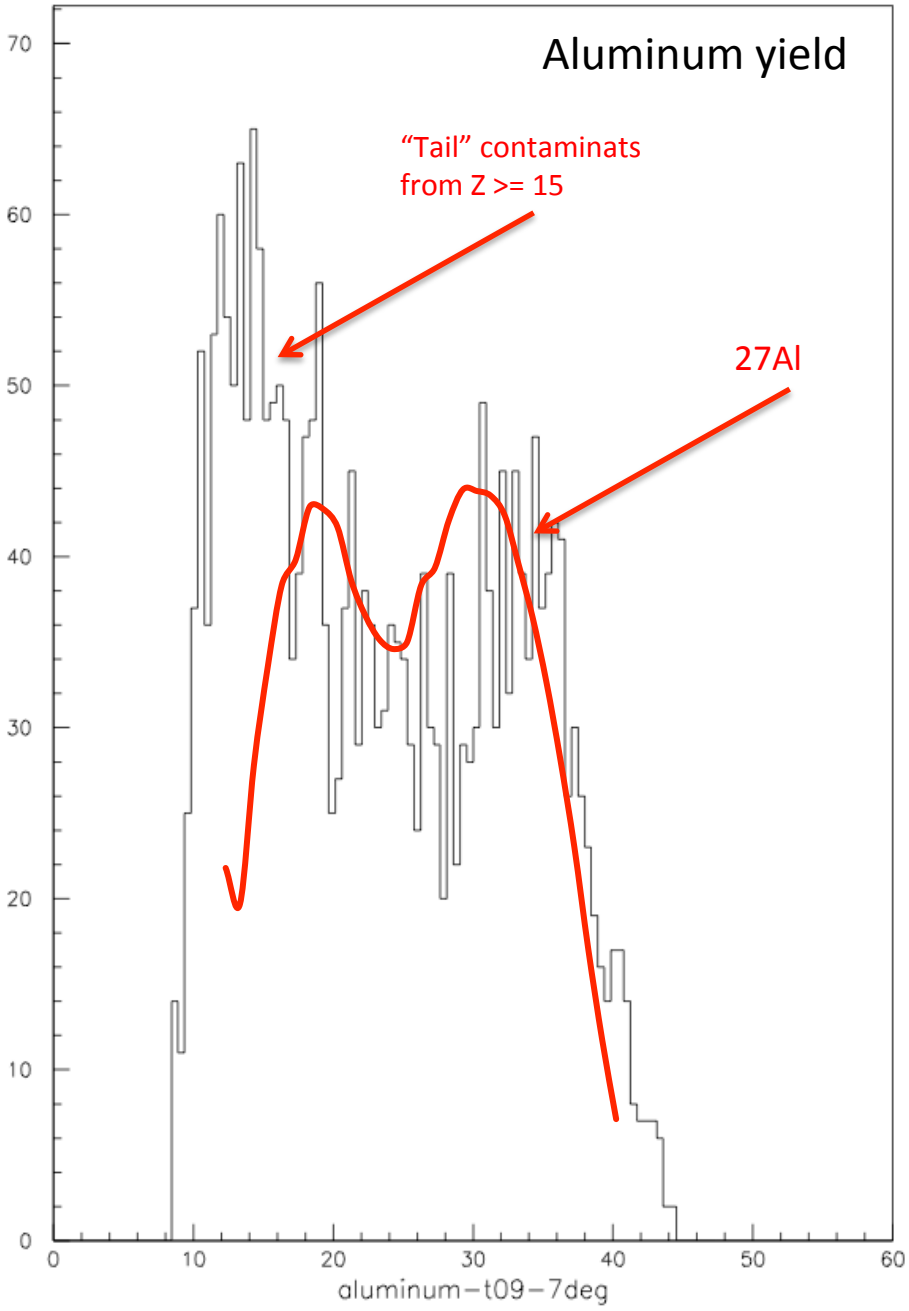
ΔE-E Telescope spectra:

@ gold and 12C target
@ 53.6 MeV

Also some gs and excited states have been identified :



FUSION-EVAPORATION →
Simulation with PACE4



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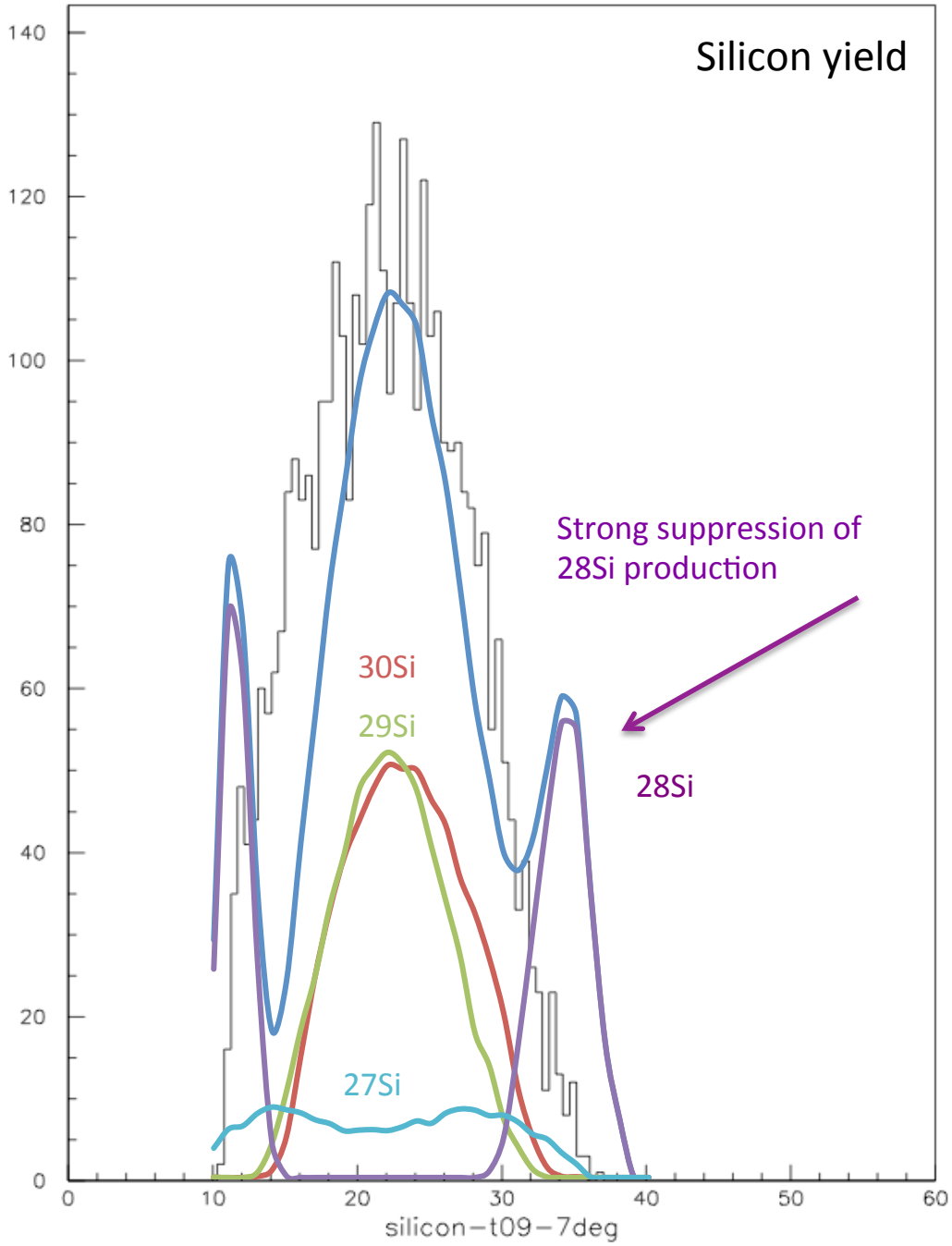

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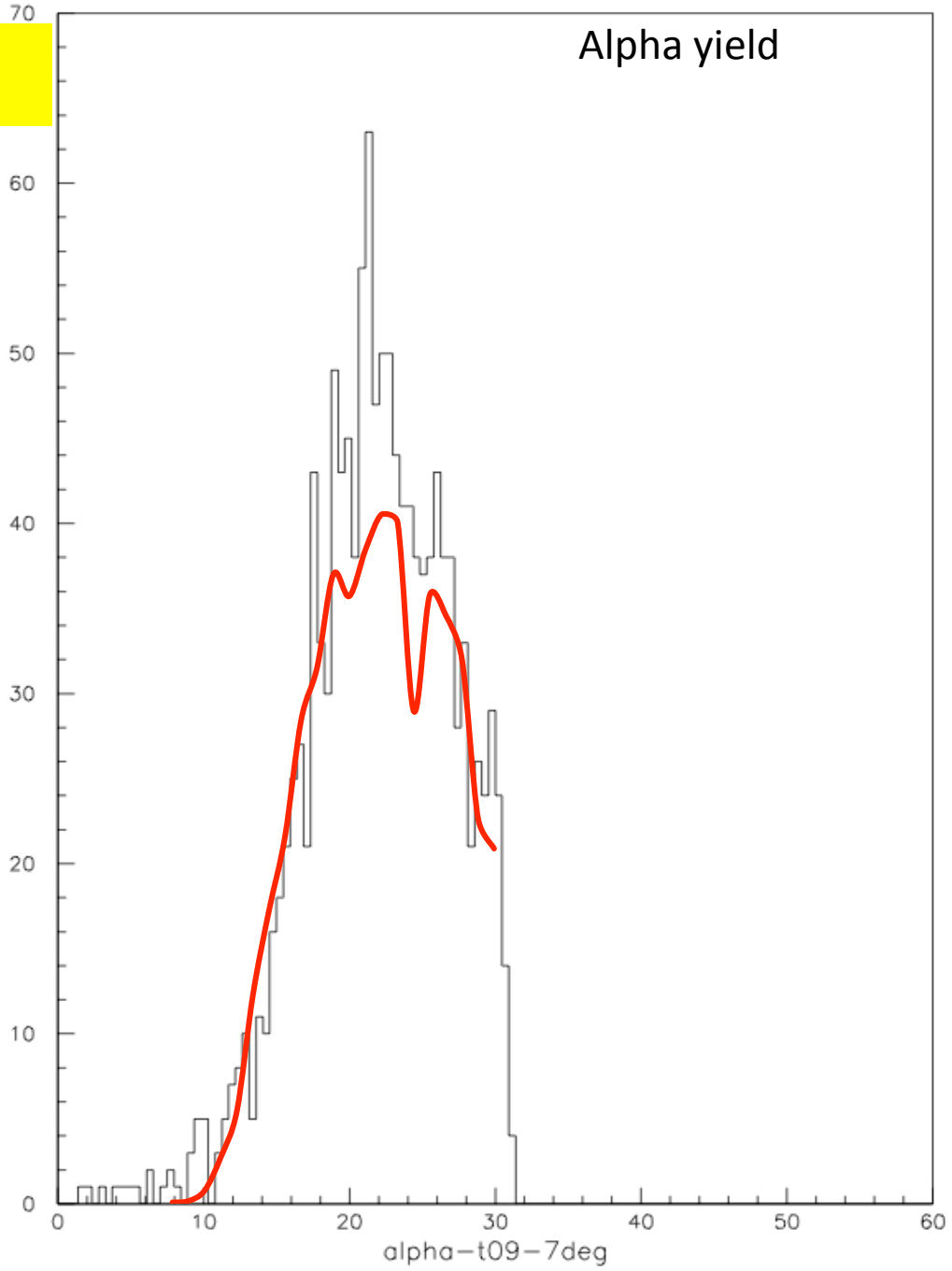
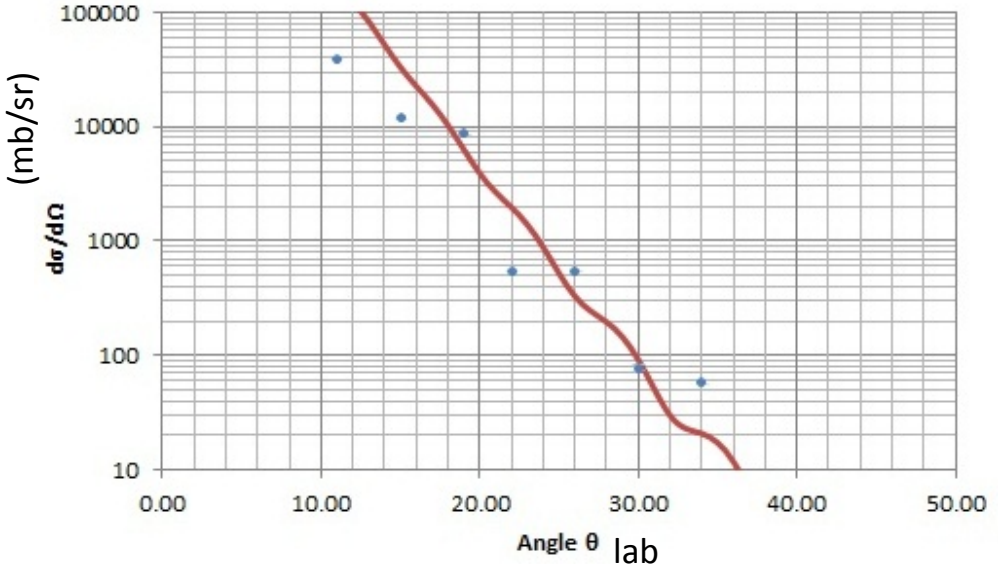
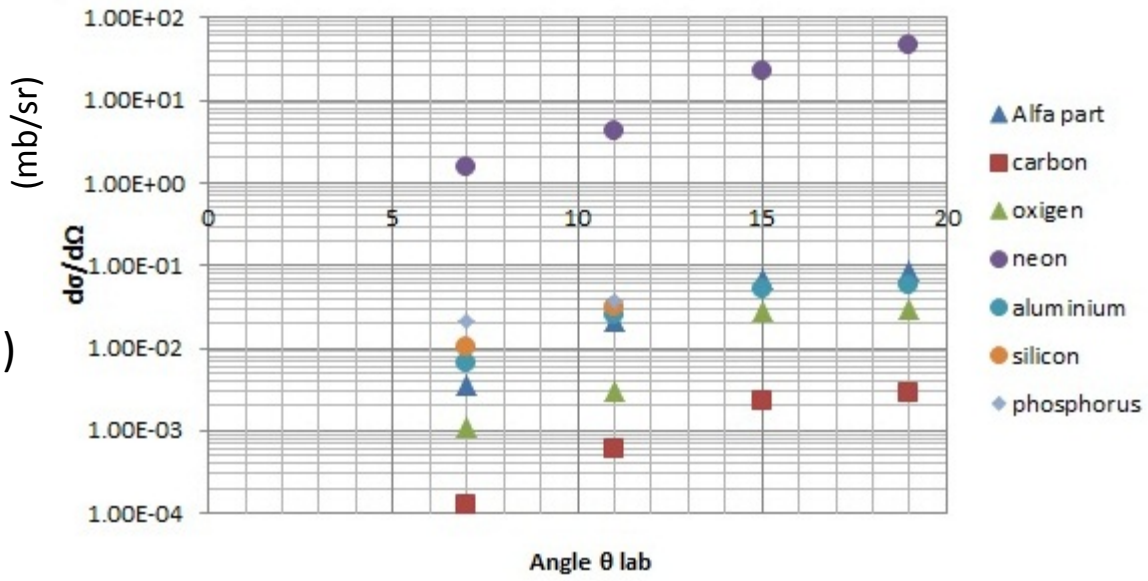


Elastic Diff. cross-sections:
$^{12}C(^{20}Ne, ^{20}Ne)^{12}C$

Comparison with results
obtained by theory Group D



Fusion Evaporation
and direct reaction yields
(normalized to elastic channel)



Summary and Conclusions:

-We have measured angular distributions of direct reactions and fusion-evaporation yields for the system 20Ne+12C at 53.6 MeV, using the ICARE setup at Heavy Ion Laboratory (Warsaw):

-Fusion – Evaporation: alphas, yields of 27Al, silicon isotopes and possibly phosphorus isotopes.

- Direct reactions: Elastic 20Ne, alpha transfer to 16O and 12C reaction channel.

- Preliminary simulations performed with Pace4 can describe the fusion-evaporation data, suggesting strong suppression of 28Si when comparing with experiment.

-Direct reaction analysis based on FRESCO will be presented by the REACTION THEORY GROUP D.

- Data analysis is still in progress

Acknowledgement

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- Prof. Krzysztof Rusek (director of HIL)
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- HIL staff, specially cyclotron operators
- Prof. Stanislaw Kistryn
- Dr Agnieszka Trzcinska (PAW++ woman)
- Group B and Group D at the workshop
- European Commission
- …

Our group

Thank you for your attention