STUDY OF THE TRANSFER AND FRAGMENTATION REACTIONS NEAR FERMI ENERGY

BY

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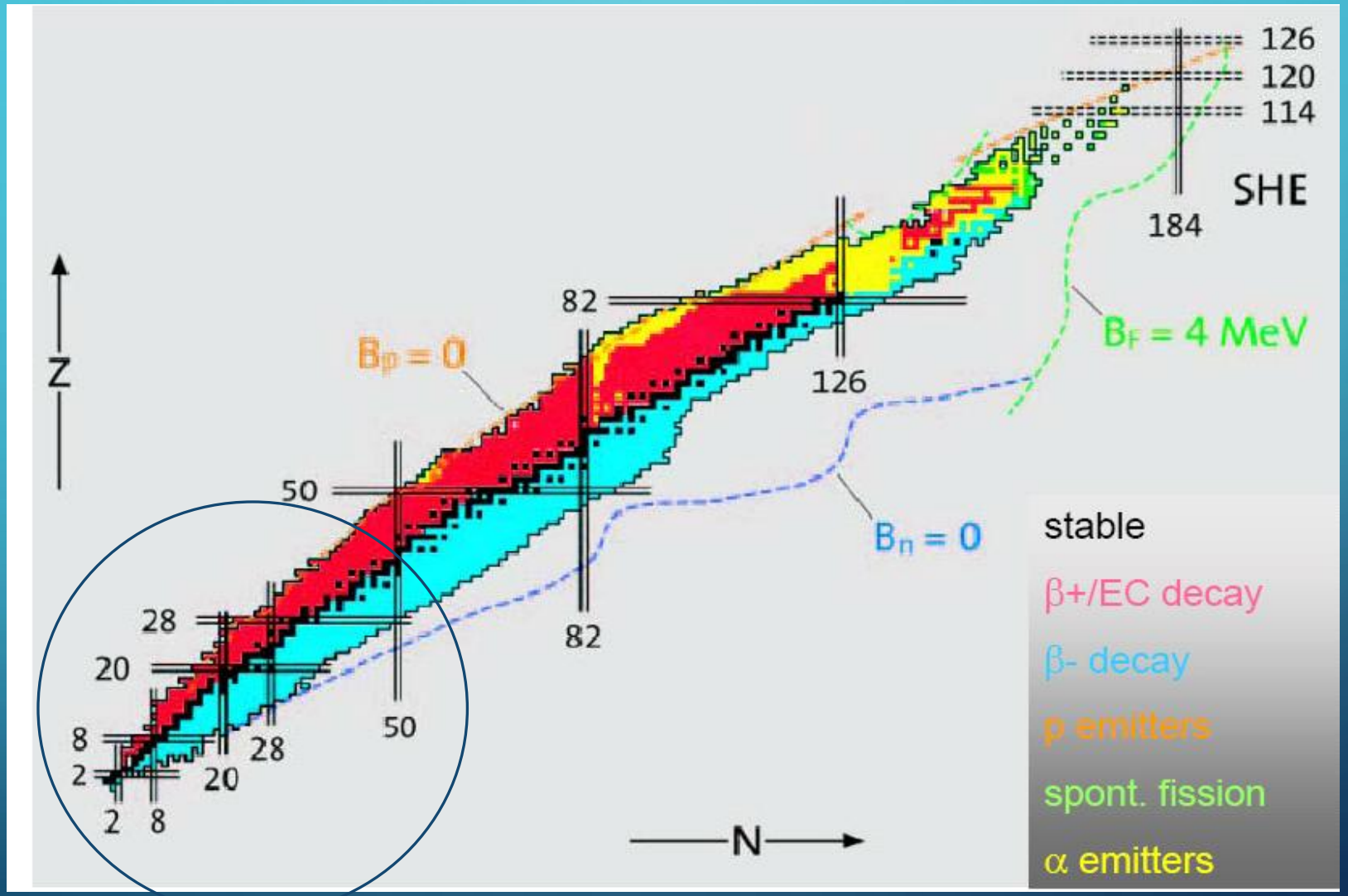
OUTLINE

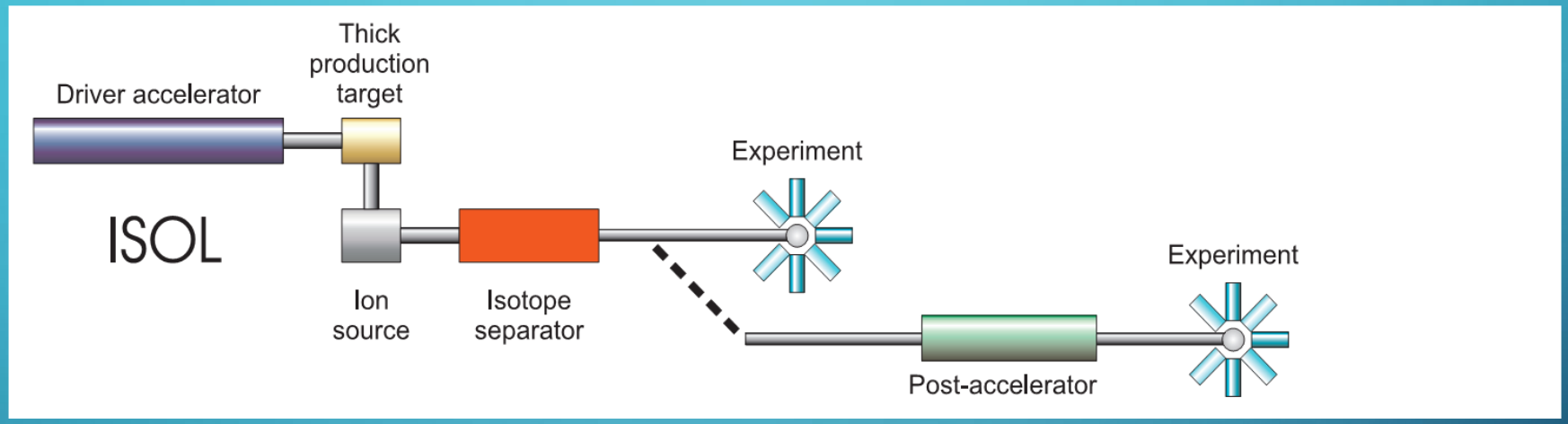
- Properties of nuclei
- Radioactive Ion Beams (RIBs) - production Methods
- Separator COMBAS
- Fragmentation reaction & Fermi energy
- Identification of elements (Lise++)
- Results

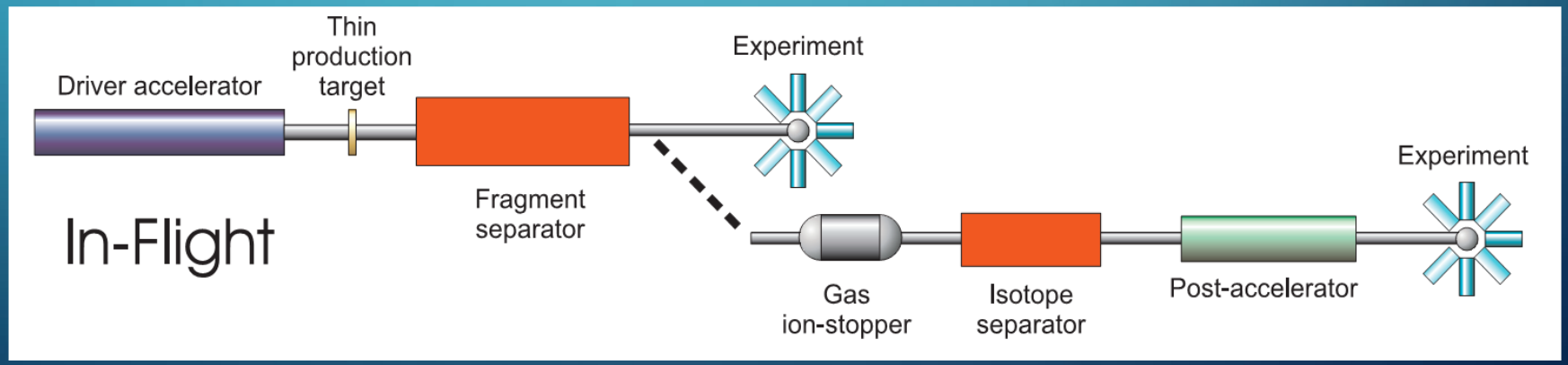


From: Exotic Nuclei, J. Enders, TU Darmstadt, Summer 2003

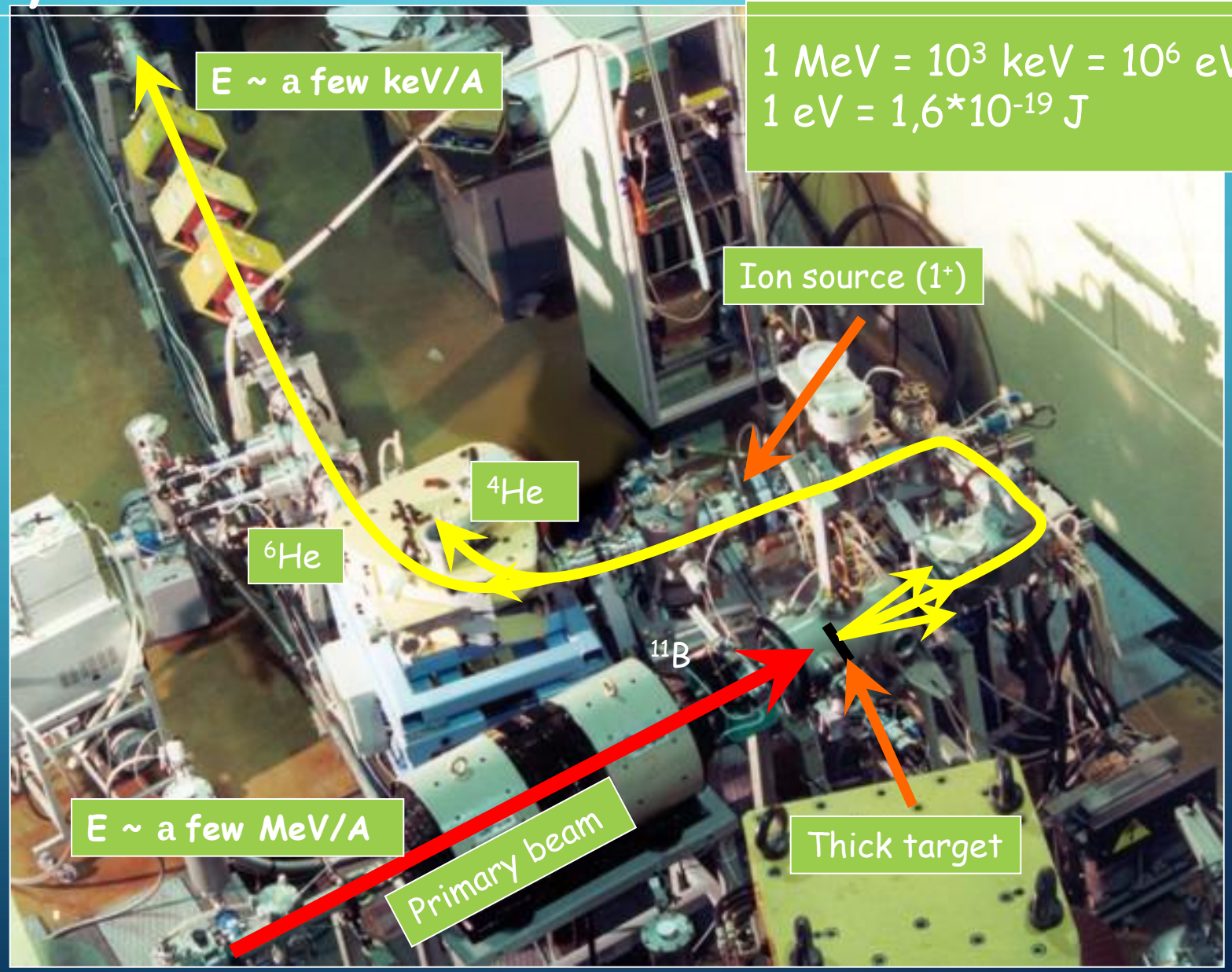
Two main methods:

- Isotope Separation On-Line
- In Flight





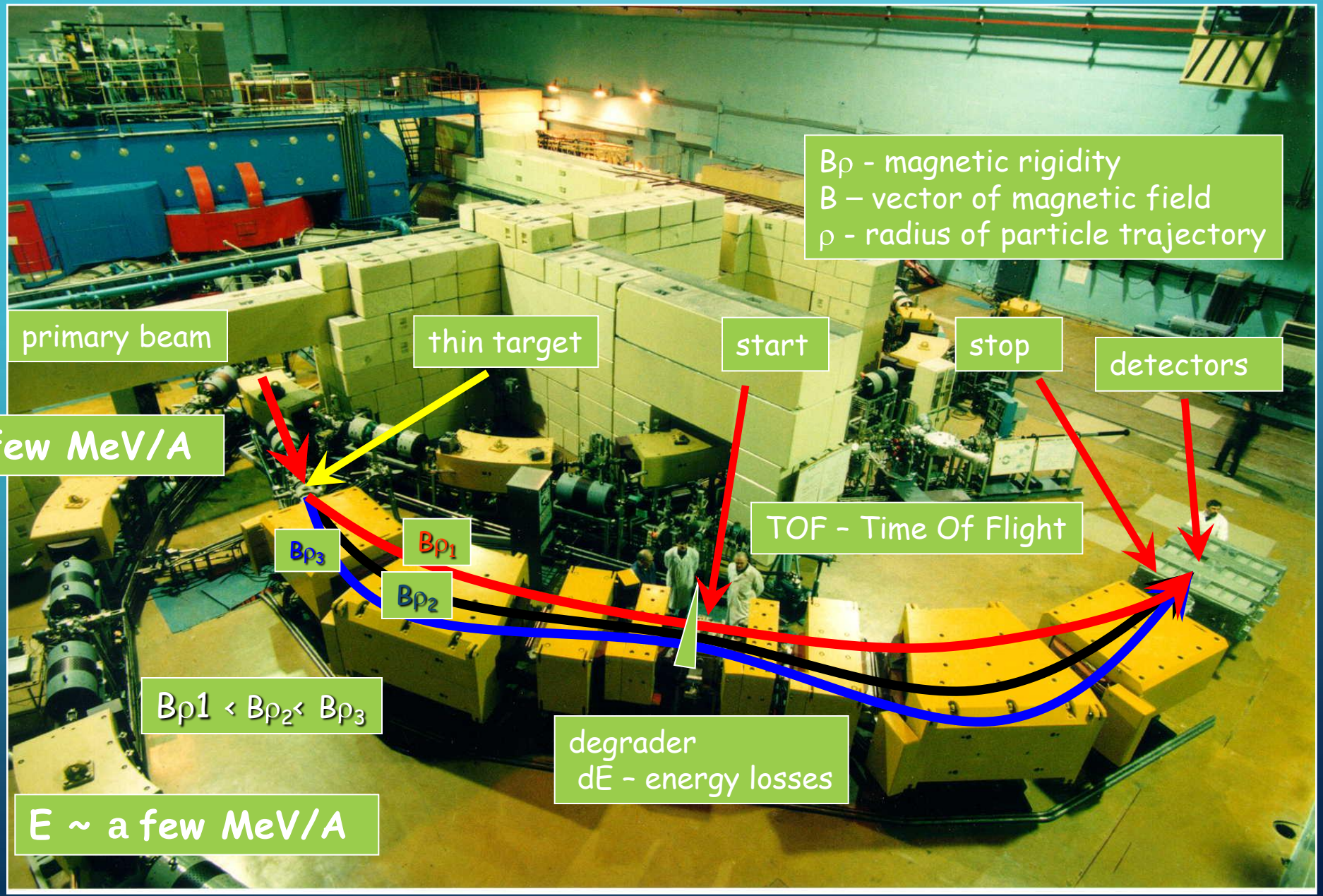
Isotope Separation On-Line example



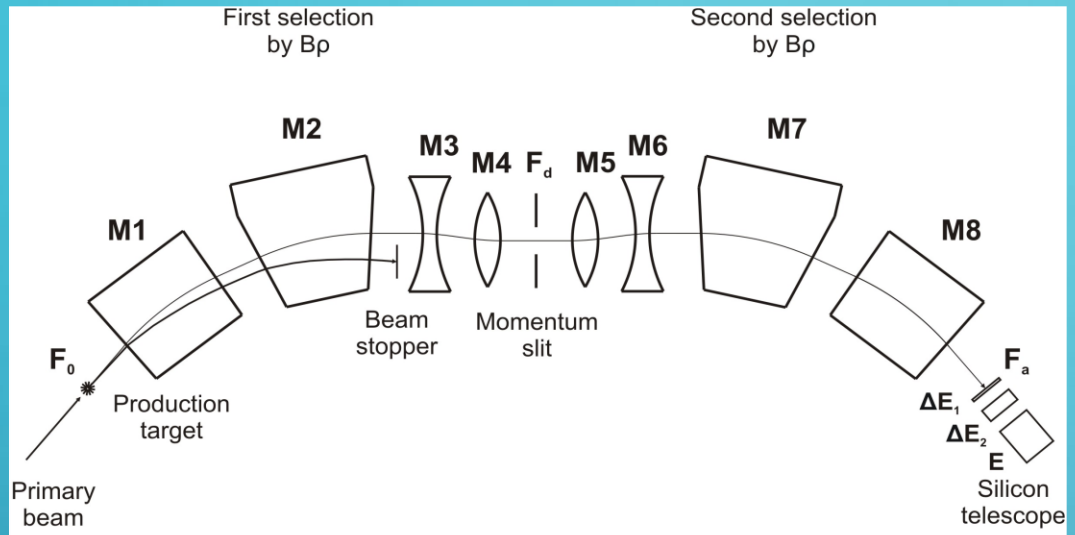
1 MeV = 10^3 keV = 10^6 eV
1 eV = $1{,}6 * 10^{-19}$ J

In-Flight example

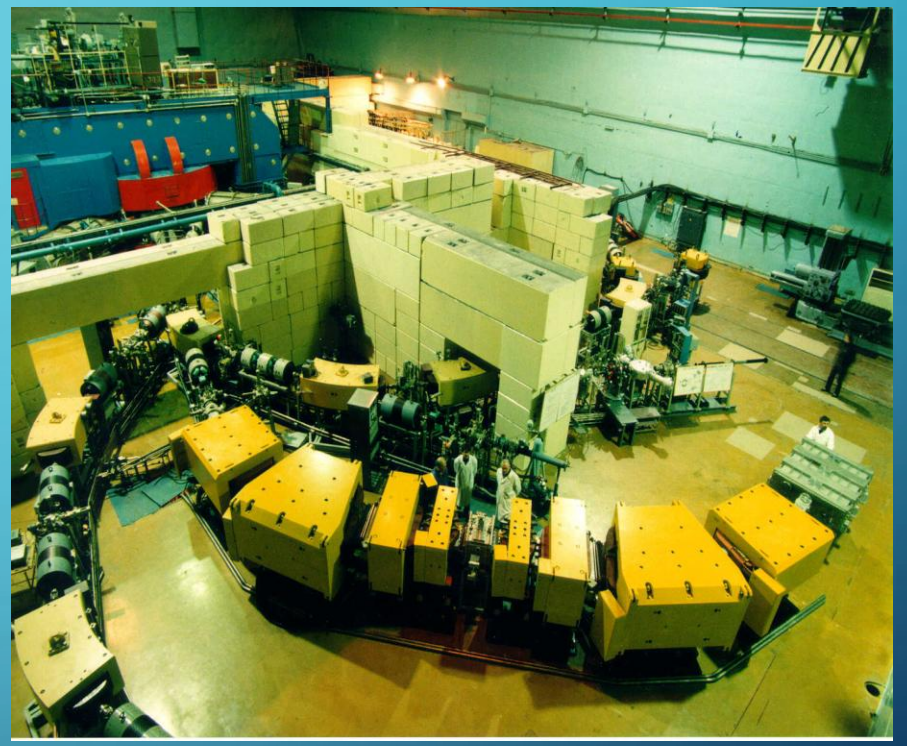
COMBAS



THE MAIN SCHEME OF COMBAS



CONFIGURATION	ΔΩ (msr)	Δp/p (%)	Bρ (T·m)	$R_{p/\Delta p}$	L (m)
$M_1M_2M_3M_4F_dM_5M_6M_7M_8F_a$	6.4	±10	4.5	4360	14.5



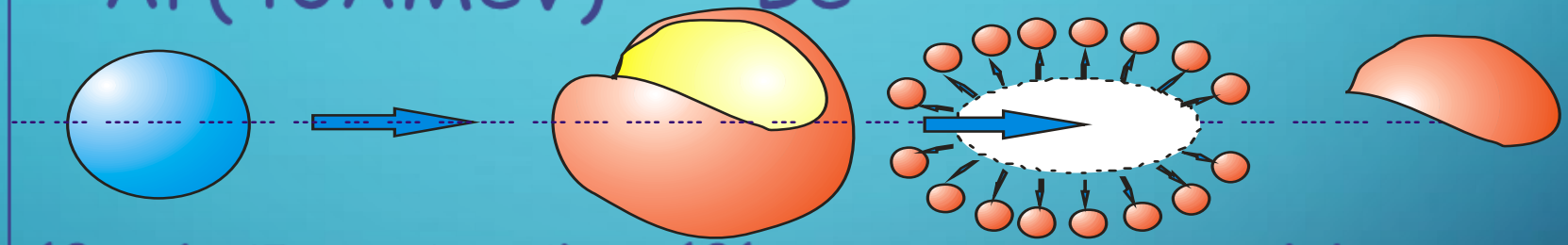
fragmentation&multifragmentation

^{18}O(35 AMeV) + ^{9}Be - inverse kinematics

^{22}Ne(40 AMeV) + ^{9}Be

^{11}B(33 AMeV) + ^{9}Be

^{40}Ar(40AMeV) + ^{9}Be



^{18}O(35 AMeV) + ^{181}Ta - normal kinematics

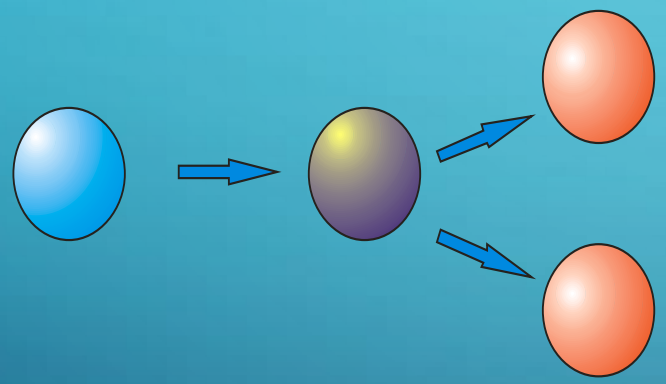
^{11}B(33 AMeV) + ^{27}Al

^{11}B(33 AMeV) + ^{197}Au

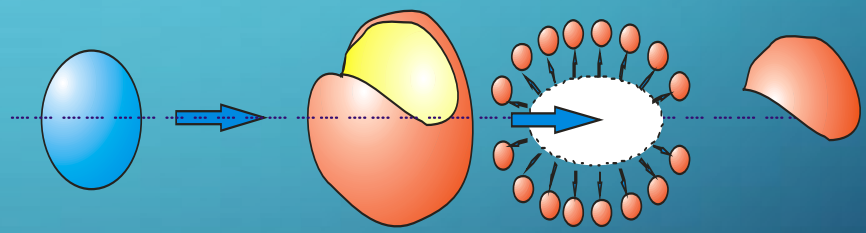
Intermediate energy region 20-200 MeV/A

low energy | transition region | high energy

5-20 MeV/A



30-1000 MeV/A

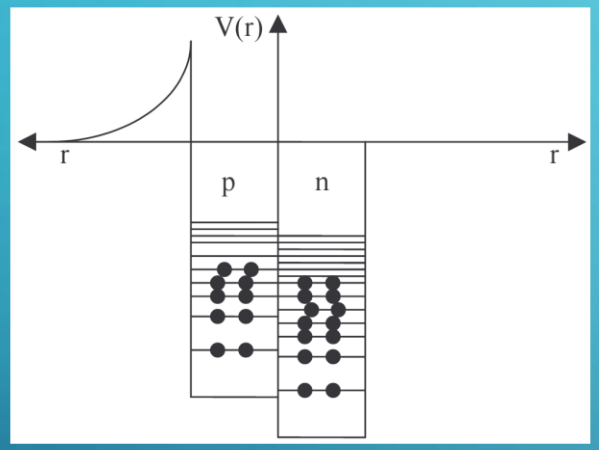


binary reactions (transfer, direct reactions)

fragmentation and multiframentation processes

Intermediate energy region 20-200 AMeV

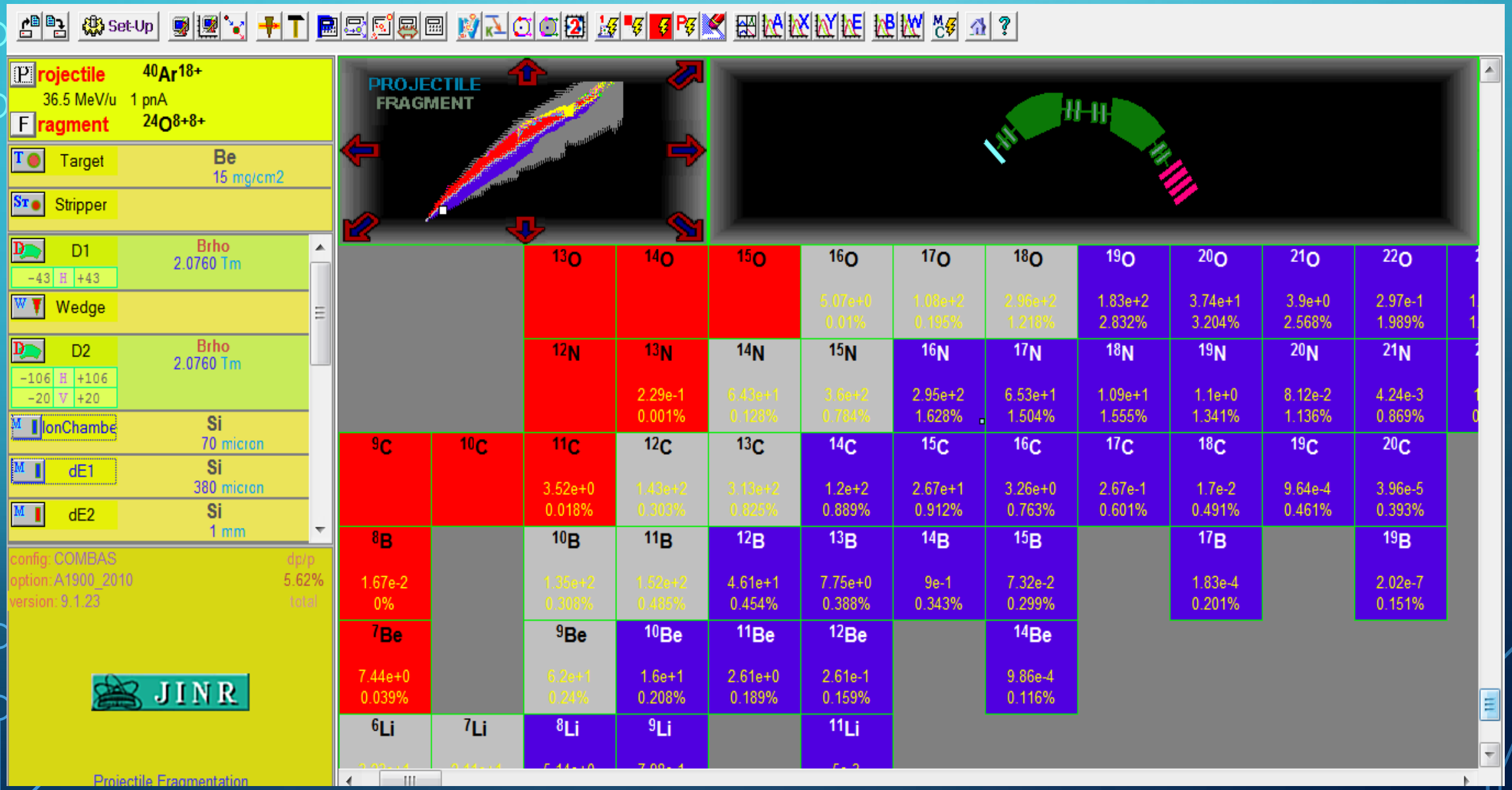
Fermi gas model

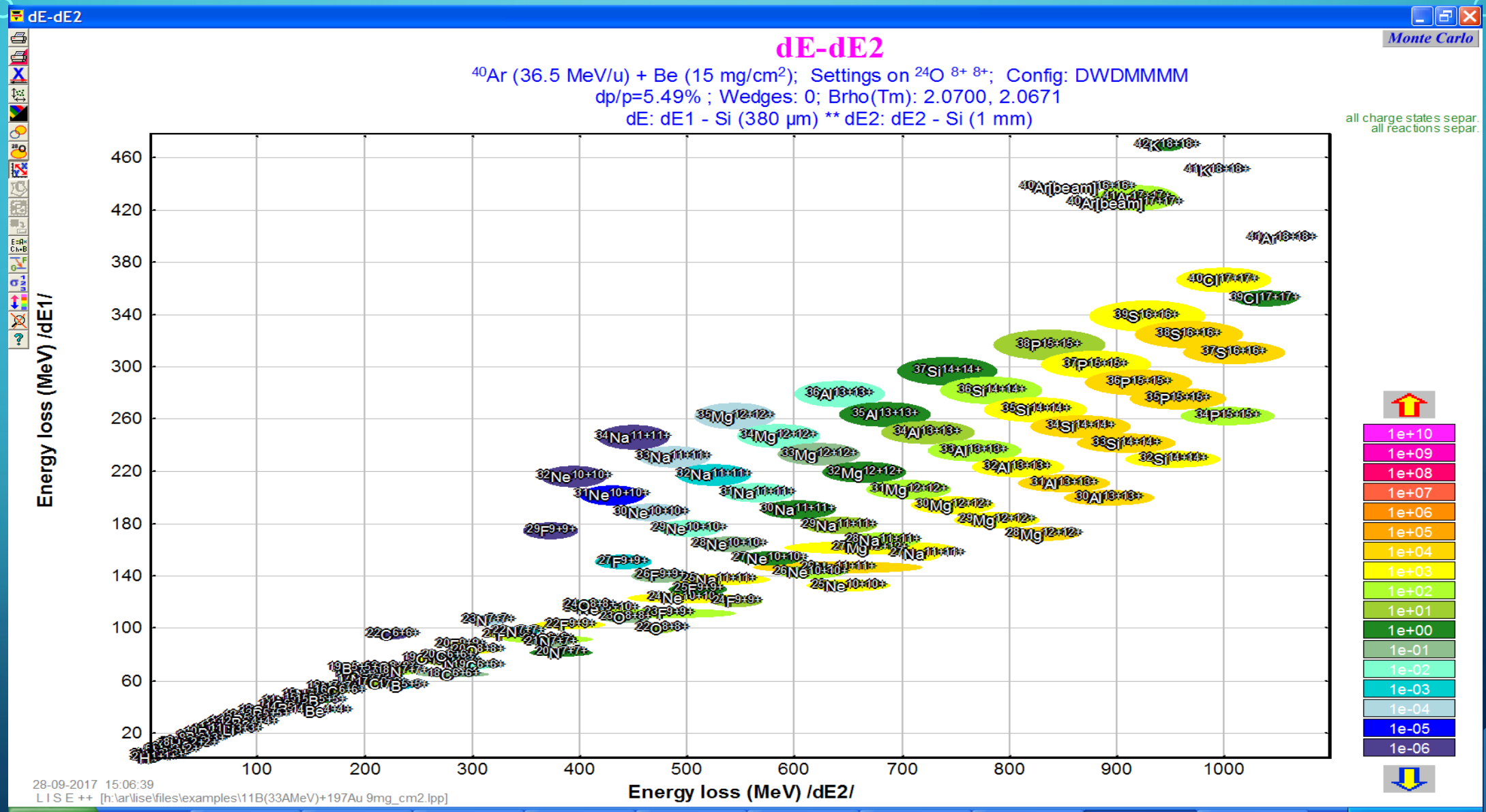


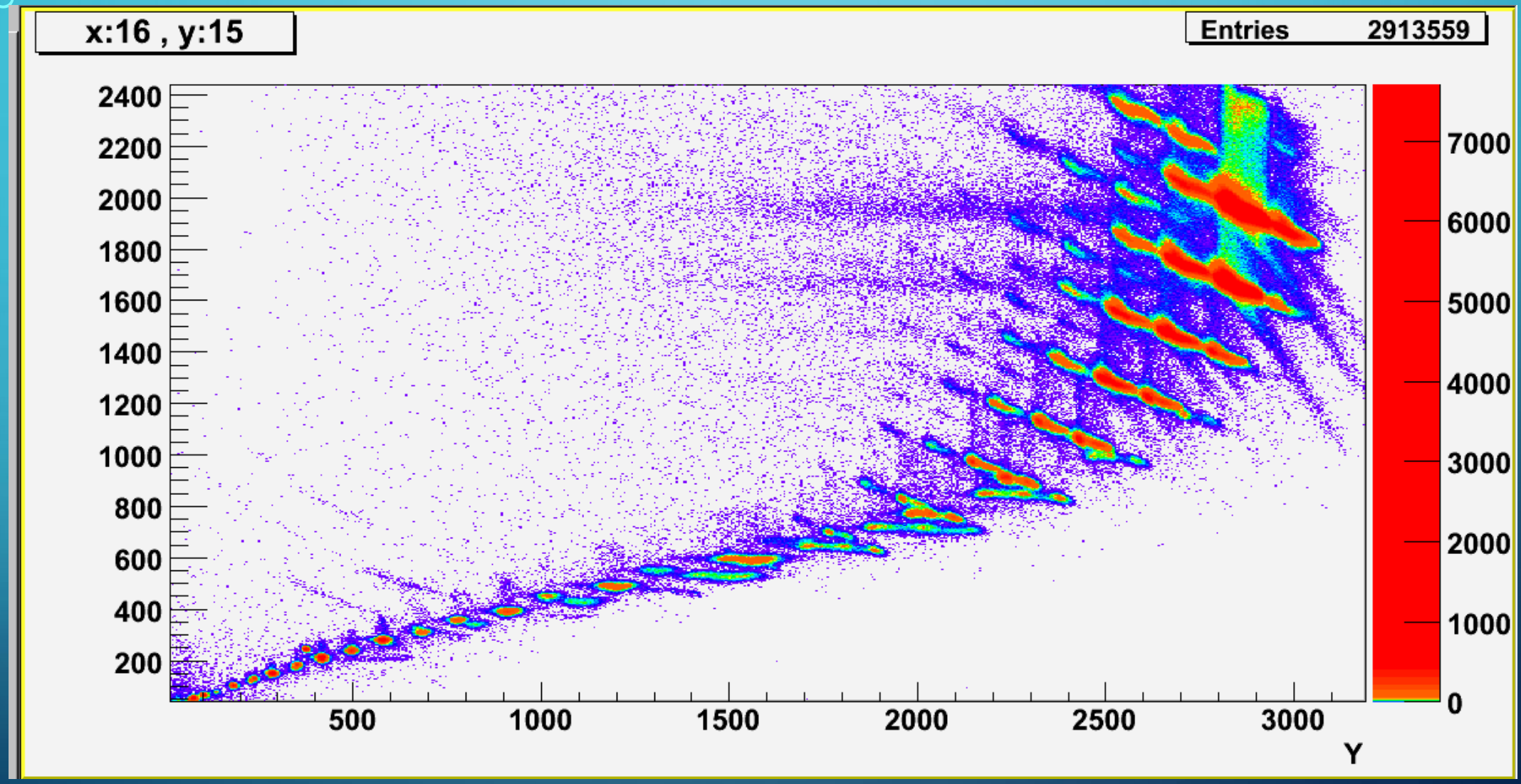
The higest energy level – Fermi energy level
Fermi Energy ~ 37 MeV

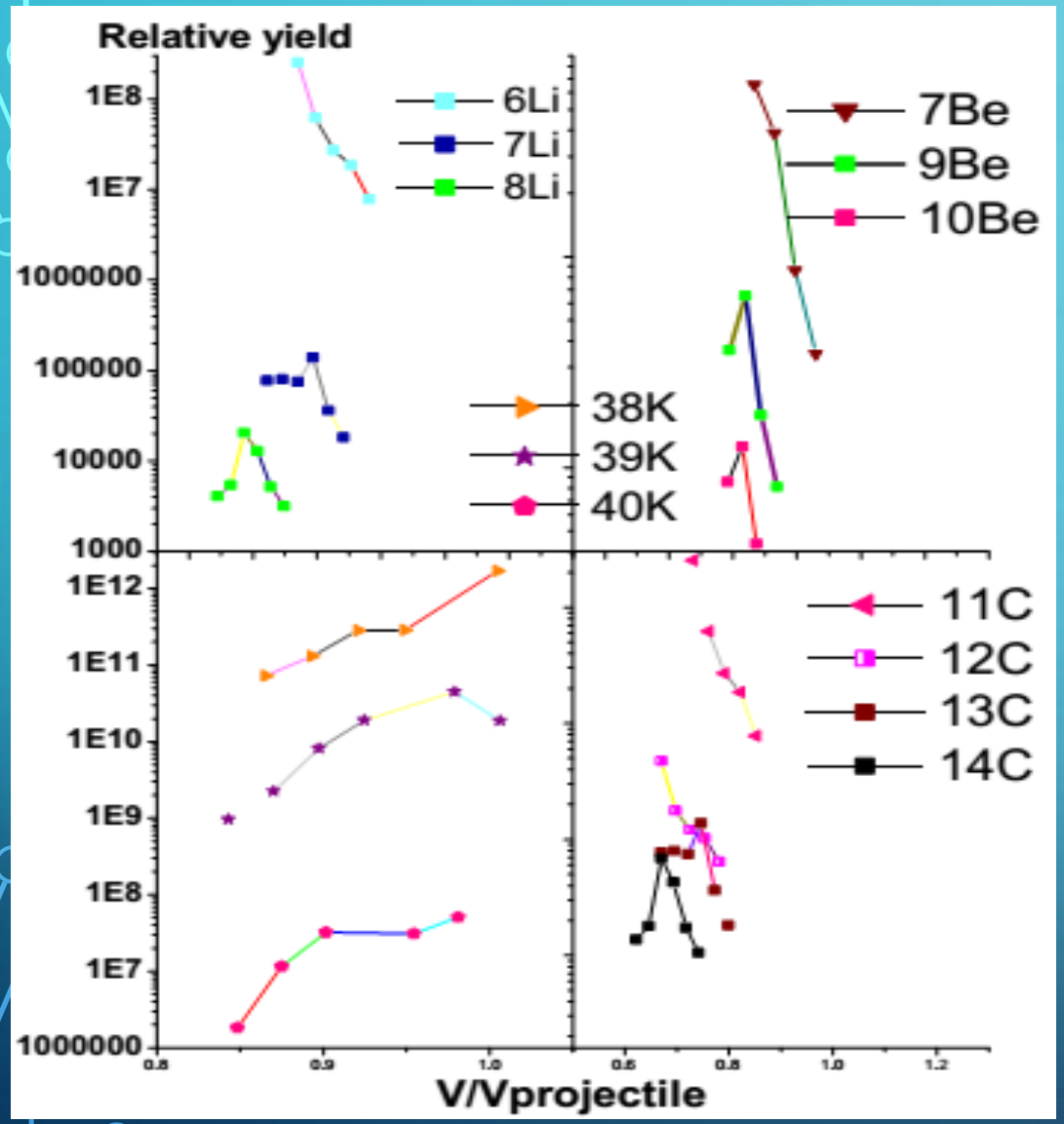
In the Fermi energy region 20-50 MeV/A velocity of the beam is comparable to the velocities of internal motion of nucleons inside the target (nucleons at the surface of target nucleus)

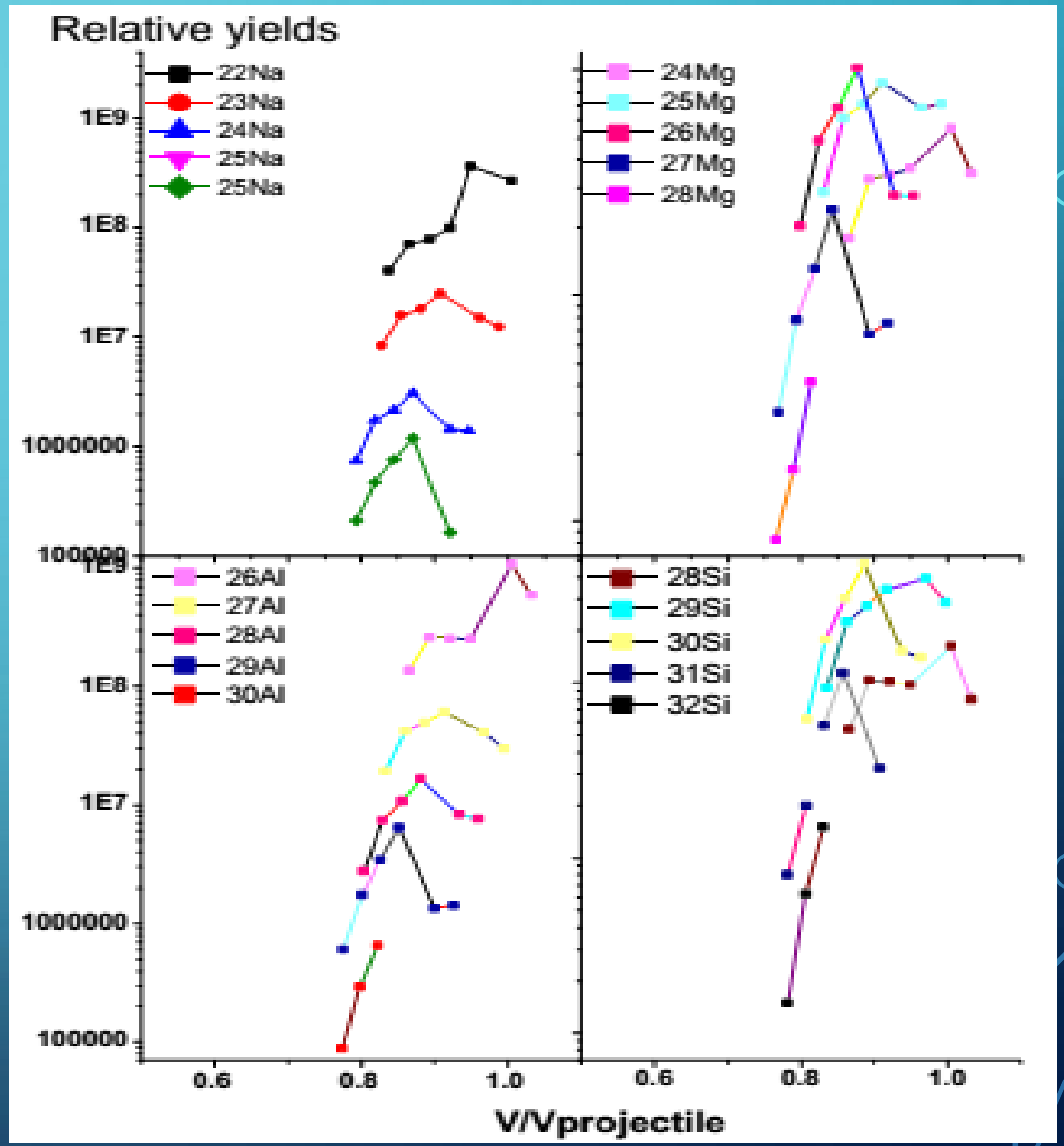
RESULTS

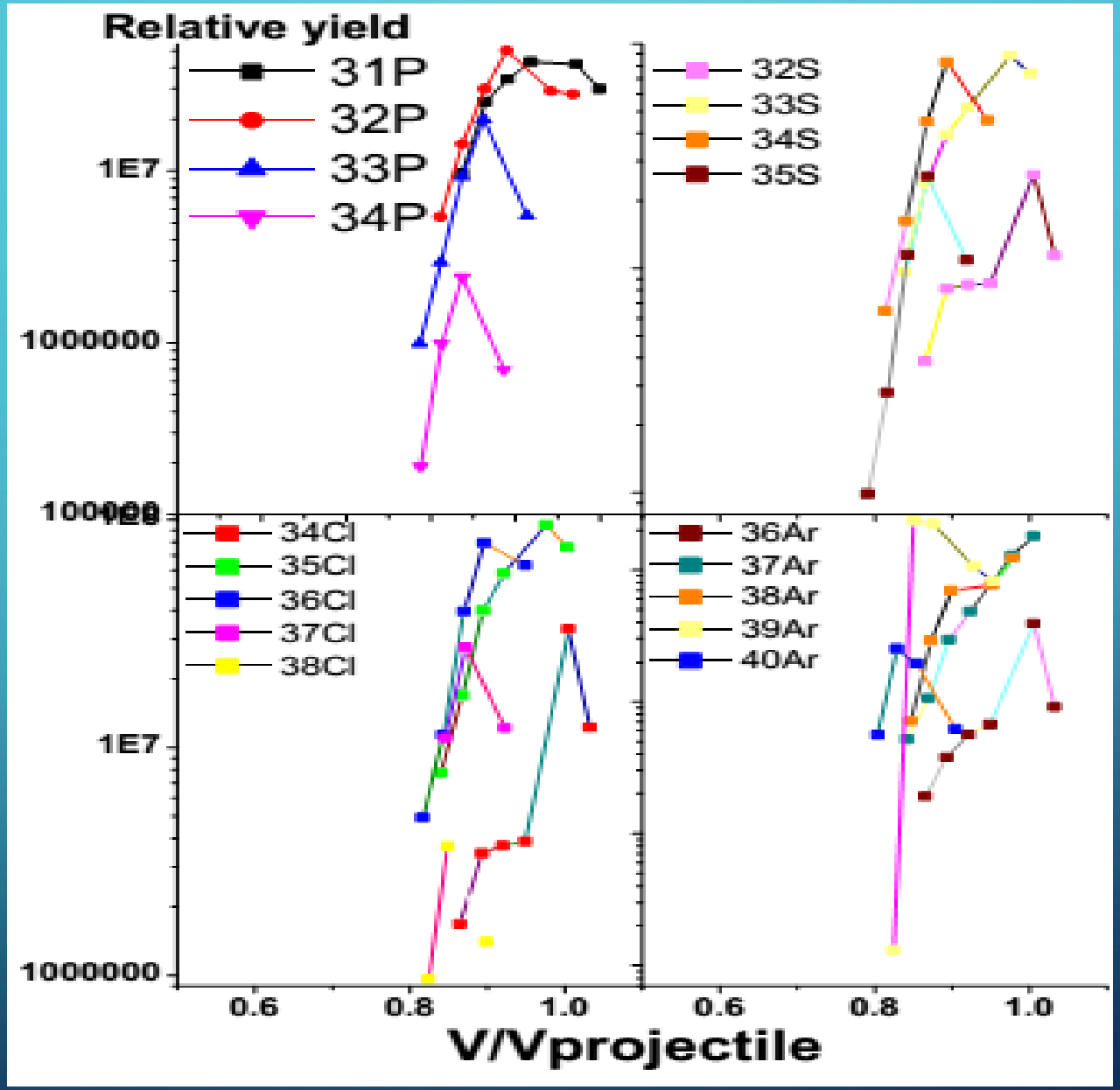

Set-Up
Projectile 40Ar18+
36.5 MeV/u 1 pnA
Fragment 24O8+8+
Target Be 15 mg/cm2
Stripper
D1 Brho 2.0760 Tm
-43 H +43
Wedge
D2 Brho 2.0760 Tm
-106 H +106
-20 V +20
IonChambe Si 70 micron
dE1 Si 380 micron
dE2 Si 1 mm
config: COMBAS
option: A1900_2010
version: 9.1.23
dp/p 5.62% total
JINR
Projectile Fragmentation
PROJECTILE FRAGMENT
13O 14O 15O 16O 17O 18O 19O 20O 21O 22O
5.07e+0 0.01%
1.08e+2 0.195%
2.96e+2 1.218%
1.83e+2 2.832%
3.74e+1 3.204%
3.9e+0 2.568%
2.97e-1 1.989%
12N 13N 14N 15N 16N 17N 18N 19N 20N 21N
2.29e-1 0.001%
6.43e+1 0.128%
3.6e+2 0.784%
2.95e+2 1.628%
6.53e+1 1.504%
1.09e+1 1.555%
1.1e+0 1.341%
8.12e-2 1.136%
4.24e-3 0.869%
9C 10C 11C 12C 13C 14C 15C 16C 17C 18C 19C 20C
3.52e+0 0.018%
1.43e+2 0.303%
3.13e+2 0.825%
1.2e+2 0.889%
2.67e+1 0.912%
3.26e+0 0.763%
2.67e-1 0.601%
1.7e-2 0.491%
9.64e-4 0.461%
3.96e-5 0.393%
8B 10B 11B 12B 13B 14B 15B 17B 19B
1.67e-2 0%
1.35e+2 0.308%
1.52e+2 0.485%
4.61e+1 0.454%
7.75e+0 0.388%
9e-1 0.343%
7.32e-2 0.299%
1.83e-4 0.201%
2.02e-7 0.151%
7Be 9Be 10Be 11Be 12Be 14Be
7.44e+0 0.039%
6.2e+1 0.24%
1.6e+1 0.208%
2.61e+0 0.189%
2.61e-1 0.159%
9.86e-4 0.116%
6Li 7Li 8Li 9Li 11Li


dE-dE2
dE-dE2
Monte Carlo
40Ar (36.5 MeV/u) + Be (15 mg/cm2); Settings on 24O 8+ 8+; Config: DWDMMMM
dp/p=5.49% ; Wedges: 0; Brho(Tm): 2.0700, 2.0671
dE: dE1 - Si (380 µm) ** dE2: dE2 - Si (1 mm)
all charge states separ.
all reactions separ.
Energy loss (MeV) /dE1/
Energy loss (MeV) /dE2/
1e+10
1e+09
1e+08
1e+07
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
28-09-2017 15:06:39
L I S E ++ [h:\ar\lise\files\examples\11B(33AMeV)+197Au 9mg_cm2.lpp]


x:16 , y:15
Entries 2913559
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
500
1000
1500
2000
2500
3000
Y
7000
6000
5000
4000
3000
2000
1000
0


Relative yield
6Li
7Li
8Li
7Be
9Be
10Be
38K
39K
40K
11C
12C
13C
14C
V/Vprojectile


Relative yields
22Na
23Na
24Na
25Na
25Na
24Mg
25Mg
26Mg
27Mg
28Mg
26Al
27Al
28Al
29Al
30Al
28Si
29Si
30Si
31Si
32Si
V/Vprojectile


Relative yield
31P
32P
33P
34P
32S
33S
34S
35S
34Cl
35Cl
36Cl
37Cl
38Cl
36Ar
37Ar
38Ar
39Ar
40Ar
1E7
1000000
0.6
0.8
1.0
V/Vprojectile

CONCLUSION

- The production of 3<Z<20 isotopes that is induced in the inverse-kinematics reaction $^{40}Ar + ^{9}Be$ in the Fermi energy domain (40A MeV) has been studied in forward-angle measurements by using the COMBAS double achromatic kinematical separator
- Forward-angle inclusive velocity distributions relative to the yields (Li to Ca)
- The use of Lise ++ software was successfully used

ACKNOWLEDGMENT

UNISA university of south africa

NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

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JINR University Centre

THANK YOU