FRIBs

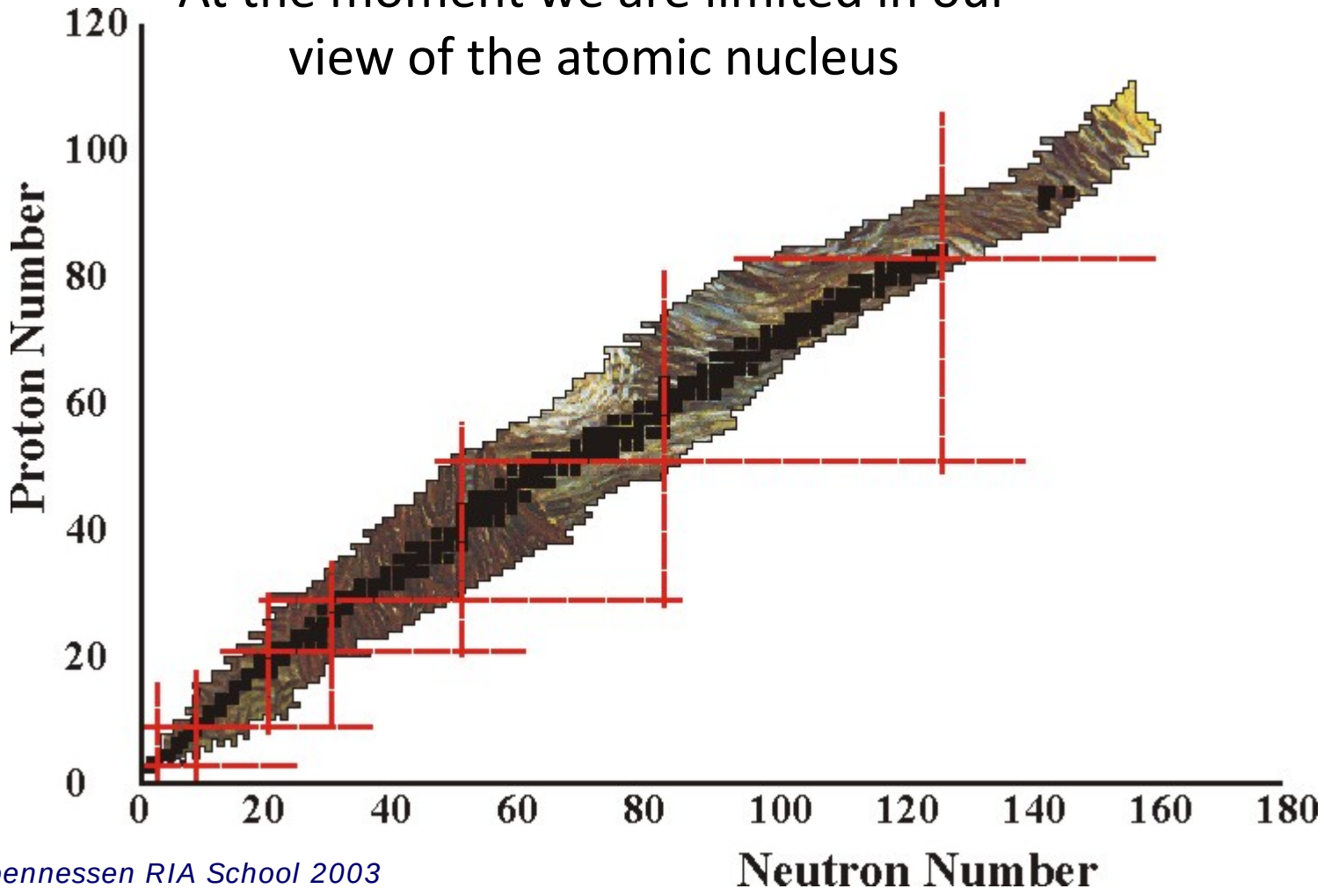
past, present, and future of radioactive ion beams (RIBs) produced In-Flight @ LNS

... remembering Giovanni Raciti

- Why RIBs are important?
- How to reach the Driplines
- FRIBs: from an exciting idea to a real facility
- The Upgrade

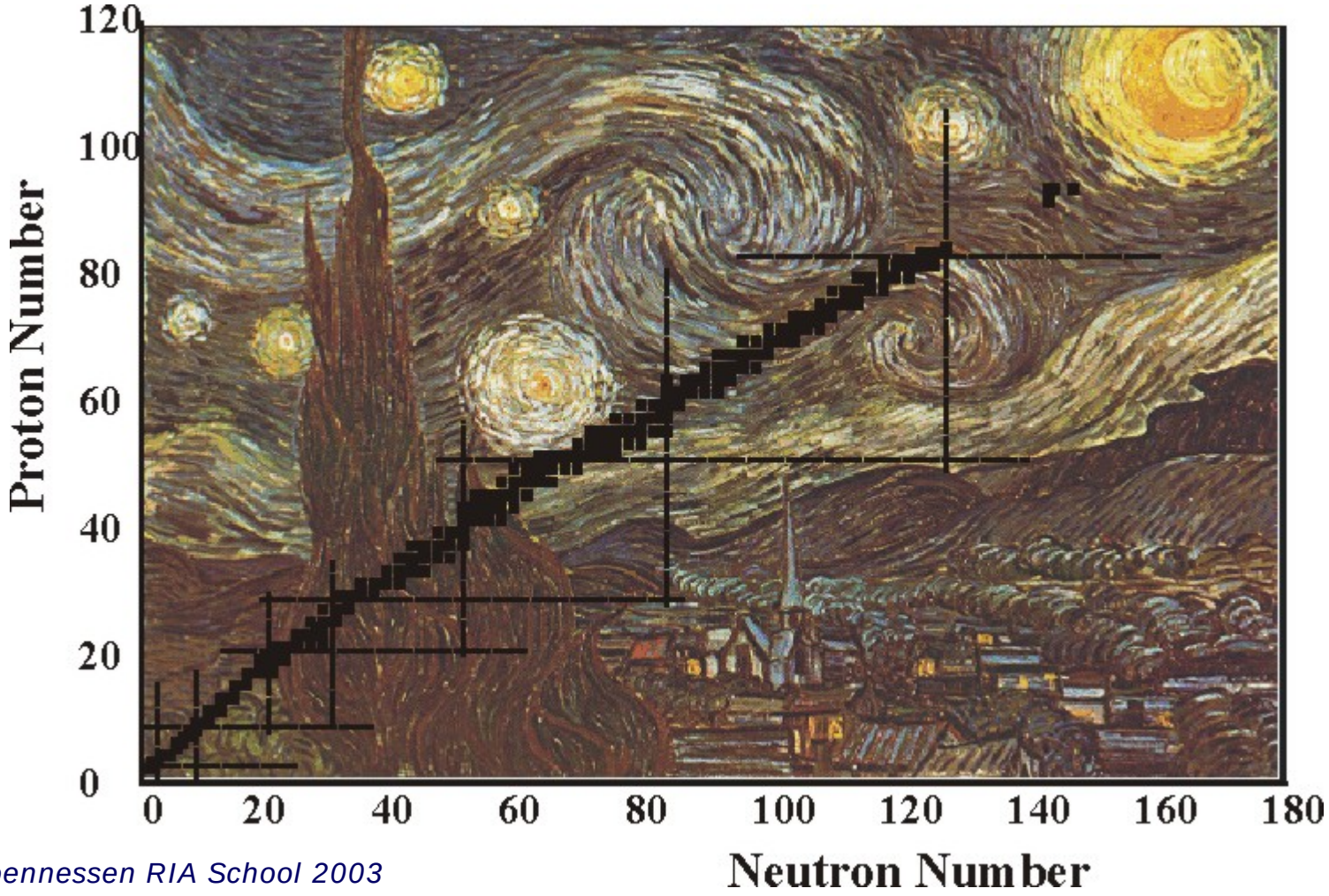
Looking Through the keyhole of nature

At the moment we are limited in our view of the atomic nucleus



M. Thoennessen RIA School 2003

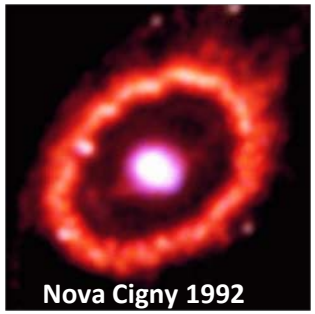
Looking Through the keyhole of nature



M. Thoennessen RIA School 2003

Physics with Radioactive Ion Beams

- ~ The nature of Nuclear Matter and strong interaction
- ~ Limits of nuclear existence
- ~ Astrofisical question: The origin of elements → *Nucleosynthesis, rp-process*
- ~ Fundamental interaction and symmetry: *test of Standard Model*



Alpha decay

Proton-neutron pairing

Super-allowed Beta-decay

N=Z

82

126

r-process

50

82

Burning cycles

rp-process

NeNa

CNO

2

50

protons

neutrons

Halo nuclei

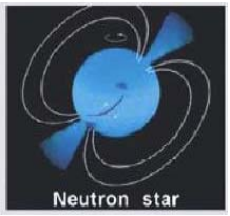
^{11}Li

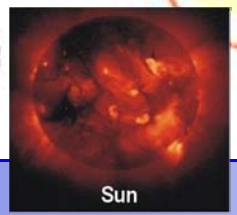
^{6}He

^{78}Ni

Doubly magic nuclei

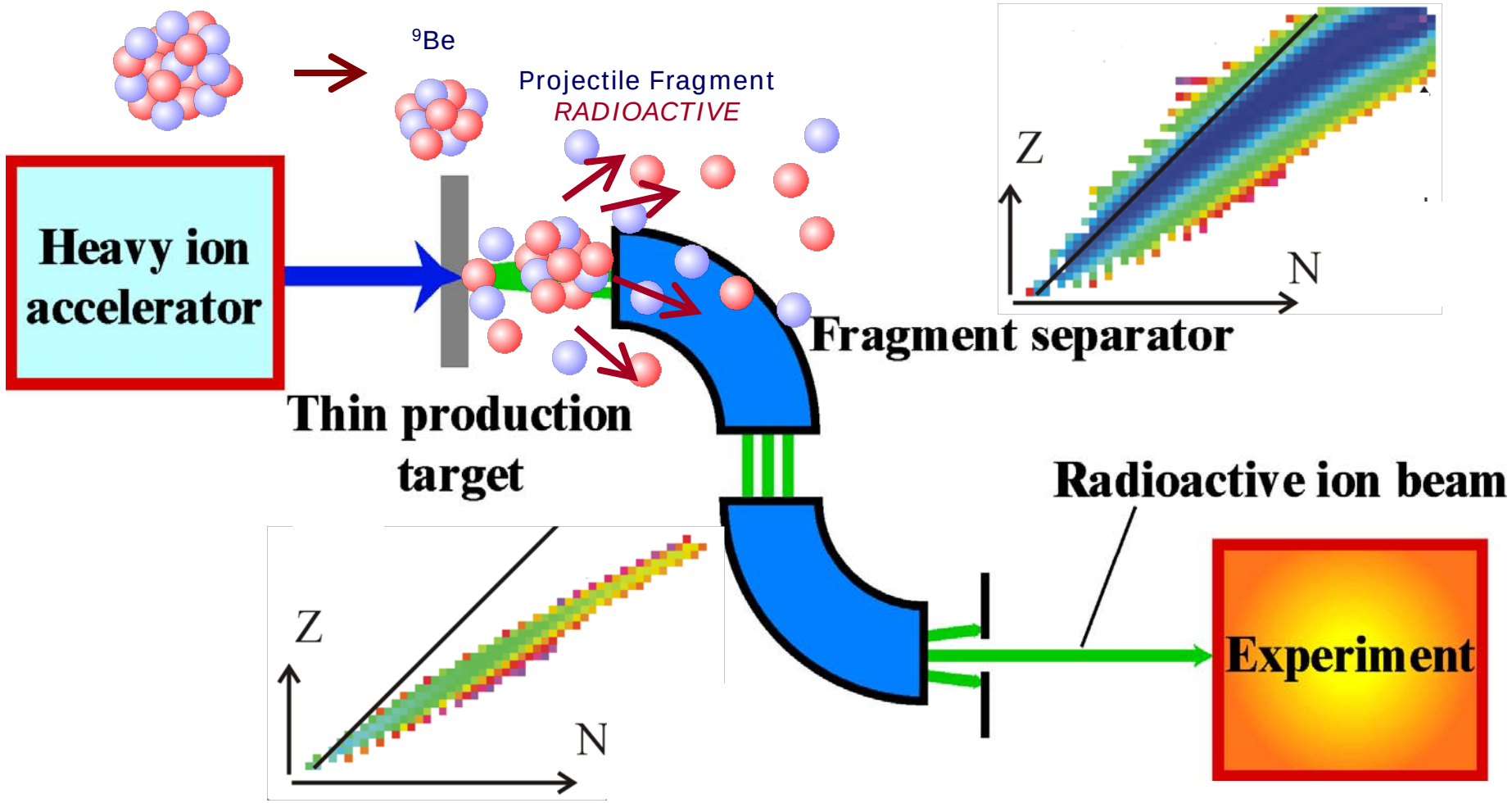
K isomers





How to reach the Driplines

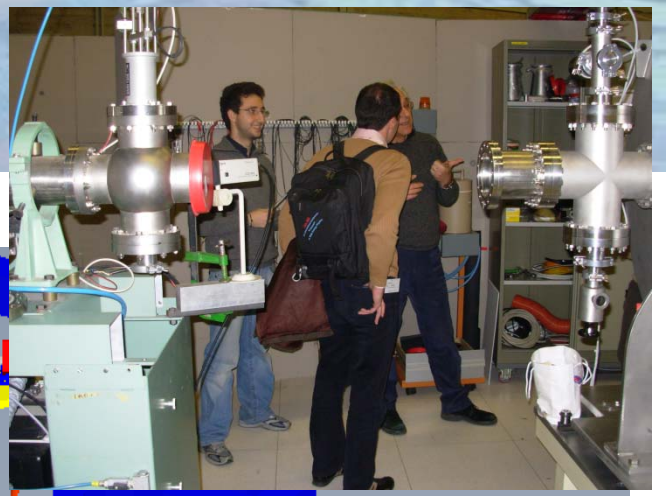
Projectile Fragmentation : In-Flight method



G. Raciti et al.
NIM B 266 (2008) 4632

The FRIBs Idea

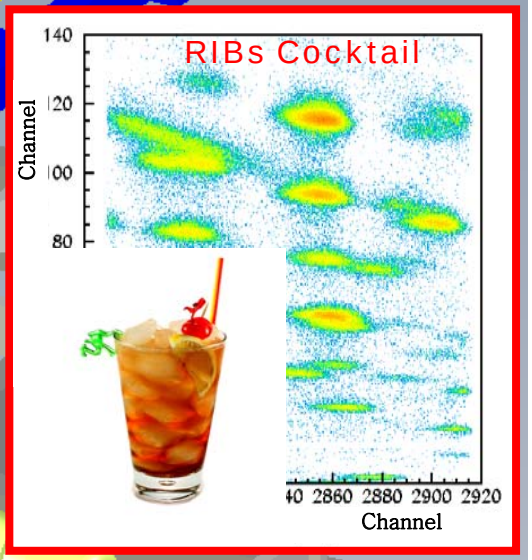
"Part of the CS extraction line can be used as a Fragment Separator"



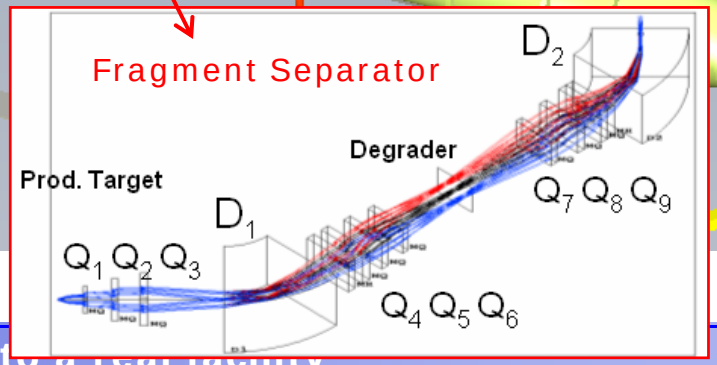
Superconducting Cyclotron

INFN LNS

Some Primary Stable Beams
12C @ 60 AMeV
20Ne @ 45 AMeV
40Ar @ 40 AMeV
.....



Production Target
9Be 500 um
.....



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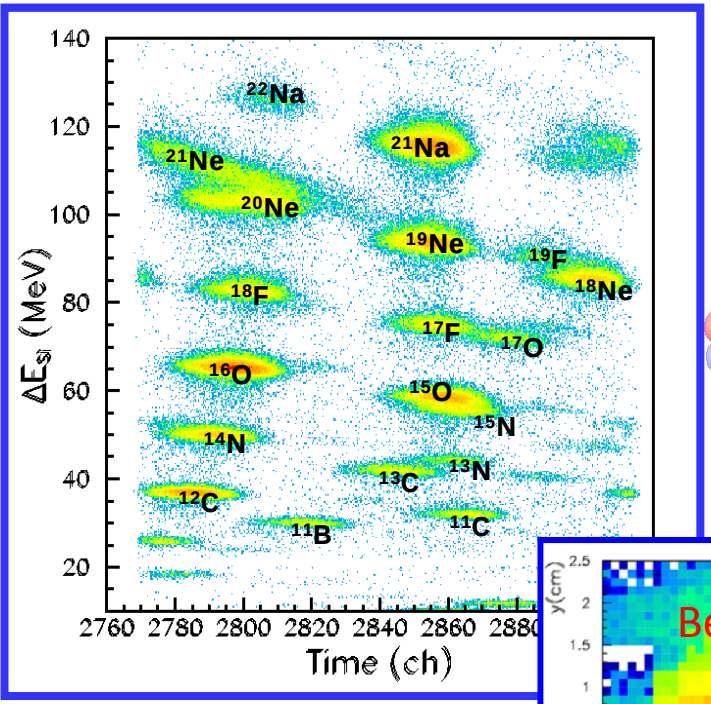
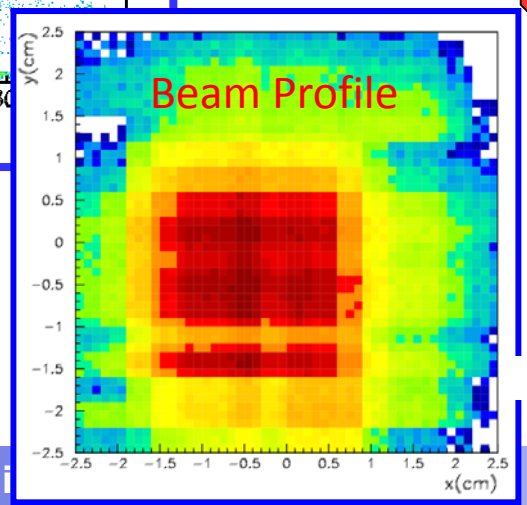
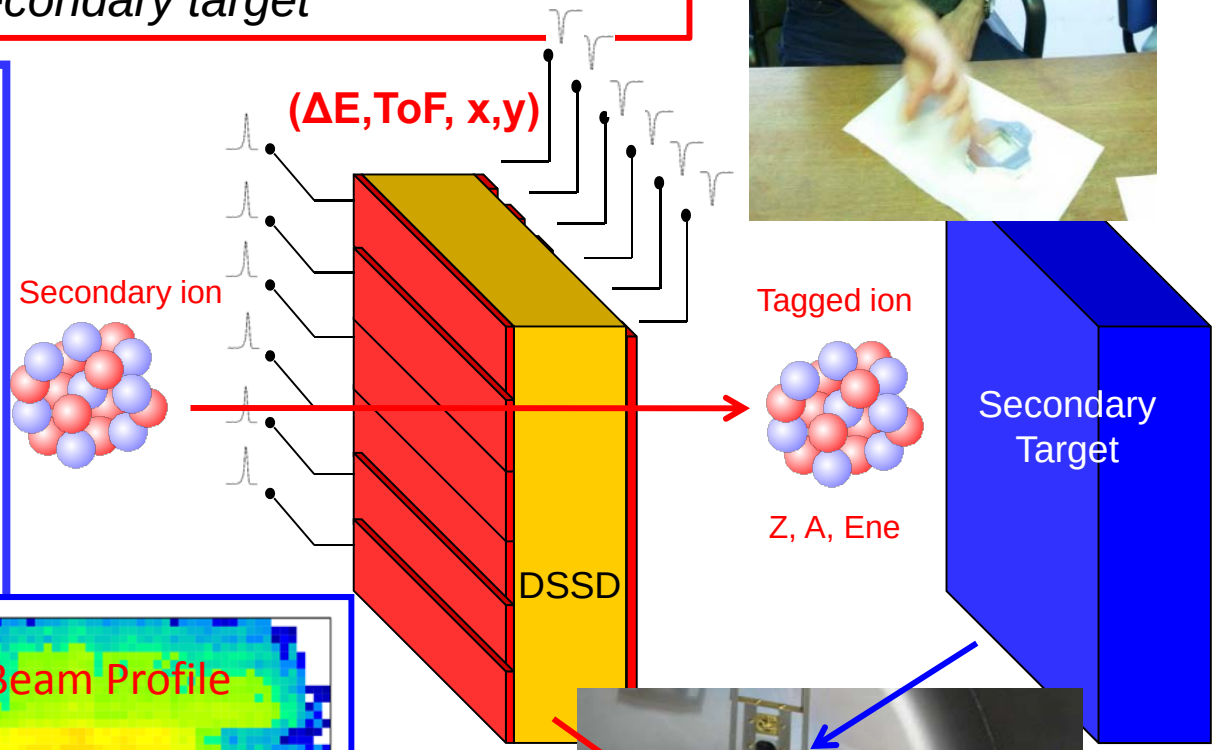
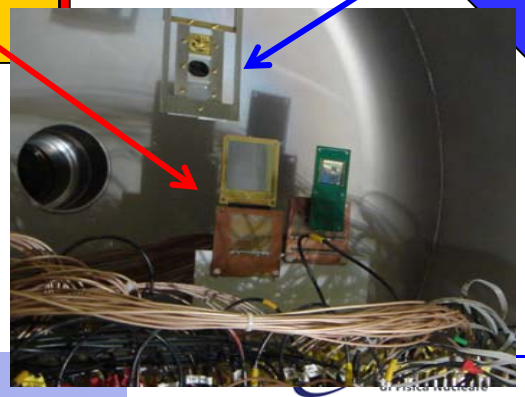
The Tagging Idea

" Identify, event-by-event, in charge, mass and energy each ion of the RIBs cocktail selected by the fragment separator, before it interacts with the secondary target "



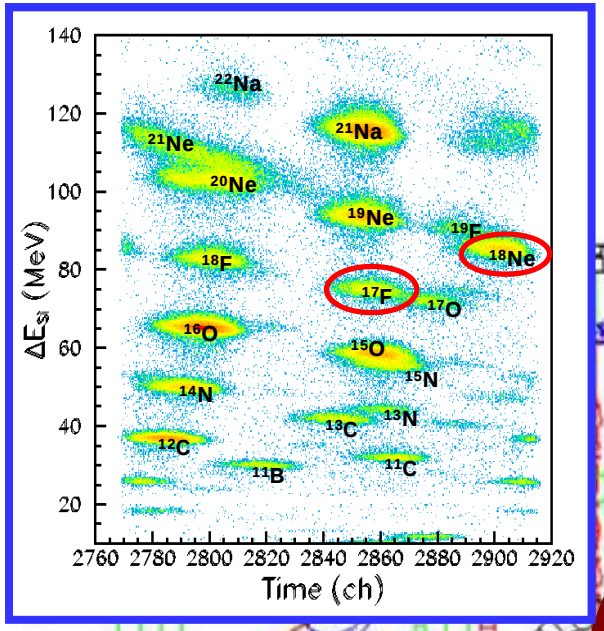






The Tagging Idea

" The tagging technique allows to perform simultaneous (same primary beam, target and reaction target) experiments "



^{20}Ne @ 40 AMeV + ^{9}Be
Primary current: 600 nA

^{17}F Coulomb breakup (FLUBBER experiment)

P. Capel , C. Sfienti et al. Proc. of XLVIII International Winter Meeting on Nuclear Physics, Bormio

^{18}Ne Two-proton decay (DIPROTON experiment)

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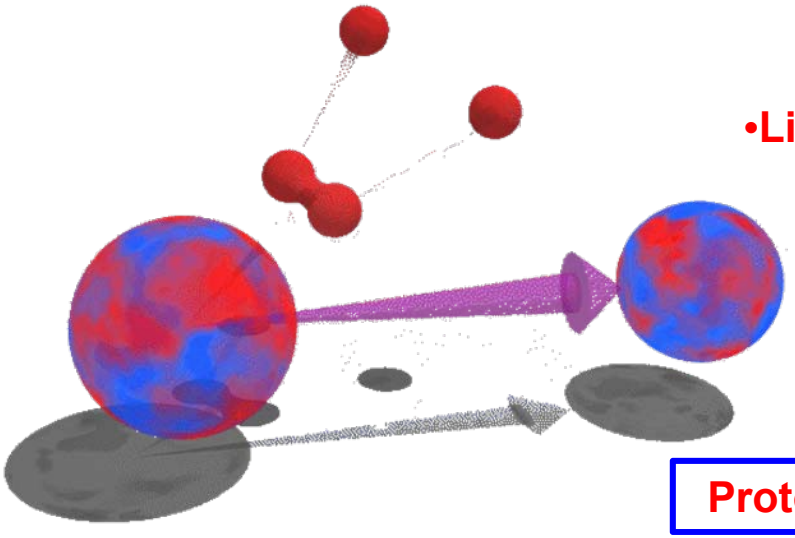
Making ideas become reality

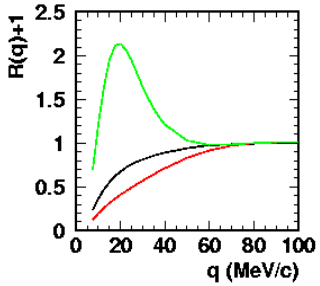
Two-proton decay

nucleus ➔ two protons + (nucleus – 2)

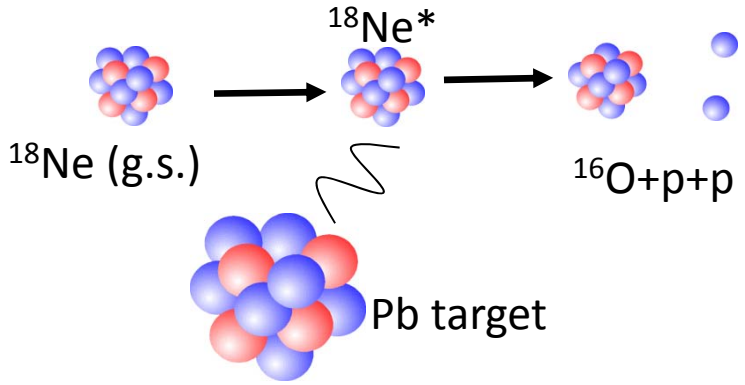


Intensity Interferometry

- **Astronomy**
- **Particle Physics**
- **Liquid -Gas Phase Transition**



Proton-Proton correlation function



" la fisica su quattru cosi e u baddu"

UNIVERSITÀ Catania

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RICERCA ALL'INFN

Scoperto nei Laboratori del Sud un nuovo tipo di radioattività

Un nuovo tipo di radioattività, mai osservata prima, è stata individuata con chiarezza in un esperimento condotto dal gruppo del prof. Giovanni Raciti dell'Università di Catania, presso i Laboratori Nazionali del Sud dell'Istituto Nazionale di Fisica Nucleare (Infn). Lo studio, pubblicato dalla rivista Physical Review Letters nel suo numero di maggio, ha mostrato l'esistenza di un isotopo dell'elio, l'elio-2, costituito da soli due protoni. Si tratta di un nucleo molto instabile, con una vita media inferiore ad un miliardesimo di secondo, che decade disintegrandosi in due protoni. Non è quindi, almeno per ora, utilizzabile a fini pratici ma sicuramente, come spiega il professor Raciti al bollettino dell'American Institute of Physics, «ci aiuterà a comprendere la struttura di nuclei instabili con un numero di protoni che eccede quello dei neutroni e come, per contro, i nuclei pesanti si formano all'interno delle stelle».

Prestigioso traguardo per il gruppo del prof. Raciti, che ha «isolato» un isotopo dell'elio

L'esperimento è basato su un ingegnoso procedimento. Prima di tutto si fa scontrare un fascio di ioni di neon-20 contro un "foglio" di berillio. Durante questa collisione ad alcuni dei nuclei incidenti vengono "sottratti" due neutroni, cosicché si trasformano in nuclei di neon-18. A questo punto gli stessi nuclei incontrano uno strato di piombo. Questo secondo scontro ha l'effetto di eccitare i nuclei di Neon-18 in uno stato energetico estremamente instabile. Per raggiungere un'energia minore e quindi più stabile, ciascun nucleo di Neon-18 decade emettendo un frammento più piccolo ed una o più particelle. Questa trasformazione si produce in diversi modi. Tra questi i fisici italiani hanno dimostrato esservi un processo, estremamente raro e mai dimostrato prima, in cui i nuclei di Neon-18 producono un nucleo di Ossigeno-16 ed uno di He-2 che rapidamente si disintegra in due protoni.

In precedenza altri studi avevano osservato l'emissione di due protoni rilasciati in processi fisici di questo tipo, ma non erano mai riusciti a dimostrare che questi provenissero dal decadimento di un nucleo di He-2.

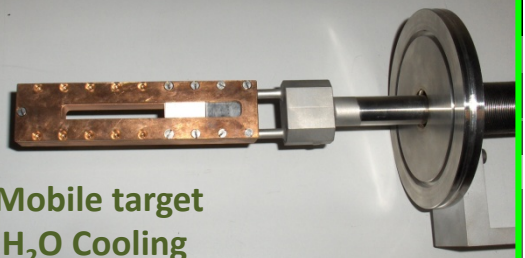
Questi studi d'avanguardia, anticipa l'Istituto nazionale di Fisica Nucleare, continueranno nei prossimi mesi presso i Laboratori Nazionali del Sud alla ricerca di nuovi nuclei leggeri instabili con le stesse caratteristiche.

First Experimental Evidence of 2He Decay from ^{18}Ne Excited States
G. Raciti et al., PRL 100, 192503 (2008)

The Upgrade

" New quadrupoles in the fragment separator will increase the total acceptance by a factor 10 and rates of the order of 10^5 – 10^6 ions/sec can be achieved " Varenna, 2003

New production target



- ✓Mobile target
- ✓ H_2O Cooling
- ✓Power up to 300 Watt

New FRS setup

New diagnostic detectors

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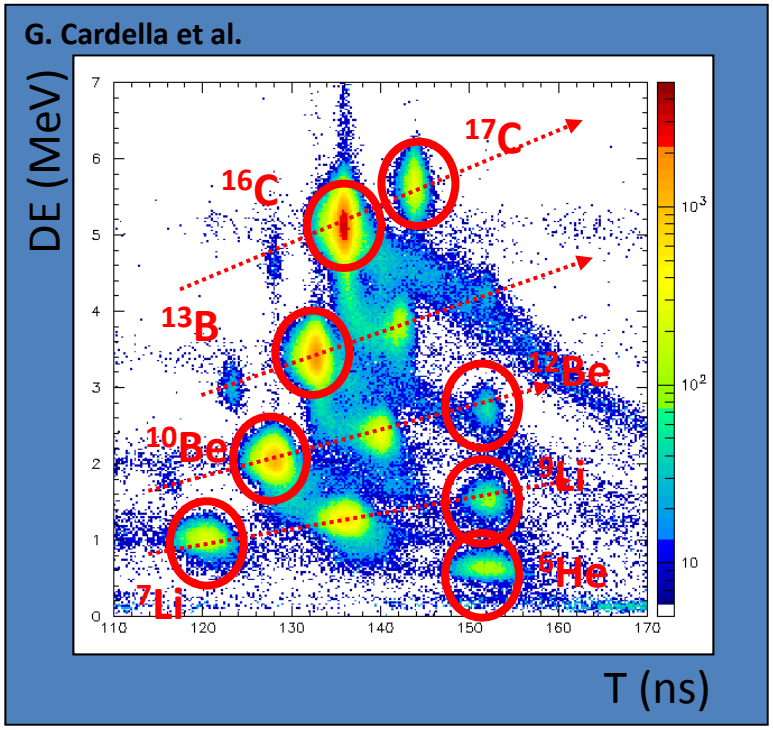
New RIBs

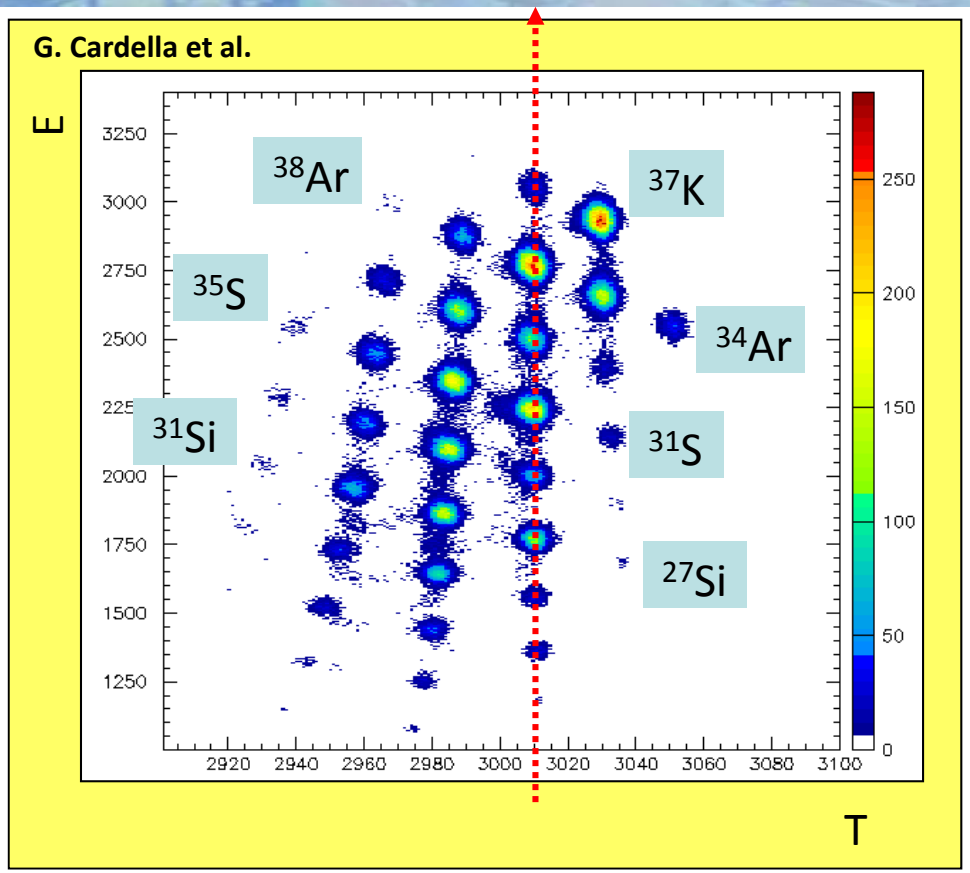
Rates measured in front of the CHIMERA detector (March 2011)



^{18}O @ 55 AMeV + 9Be 1.5 mm
88W, 5.5x10^{11} p/s Bρ=2.71 Tm

	Khz
^{16}C	40
^{17}C	4
^{13}B	23
^{11}Be	6
^{10}Be	21
^{8}Li	11

@ 40-50 AMeV



^{36}Ar @ 42 MeV/A + 9Be 0.5 mm 25W 1x10^{11} p/s

	Khz		
^{37}K	14	^{34}Cl	6.5
^{36}Ar	12	^{31}S	0.8
^{35}Ar	8.5	^{32}S	10
^{34}Ar	1.8	^{28}Si	5
^{33}Cl	1.5	^{29}Si	6.5

@ 20-25 MeV/A

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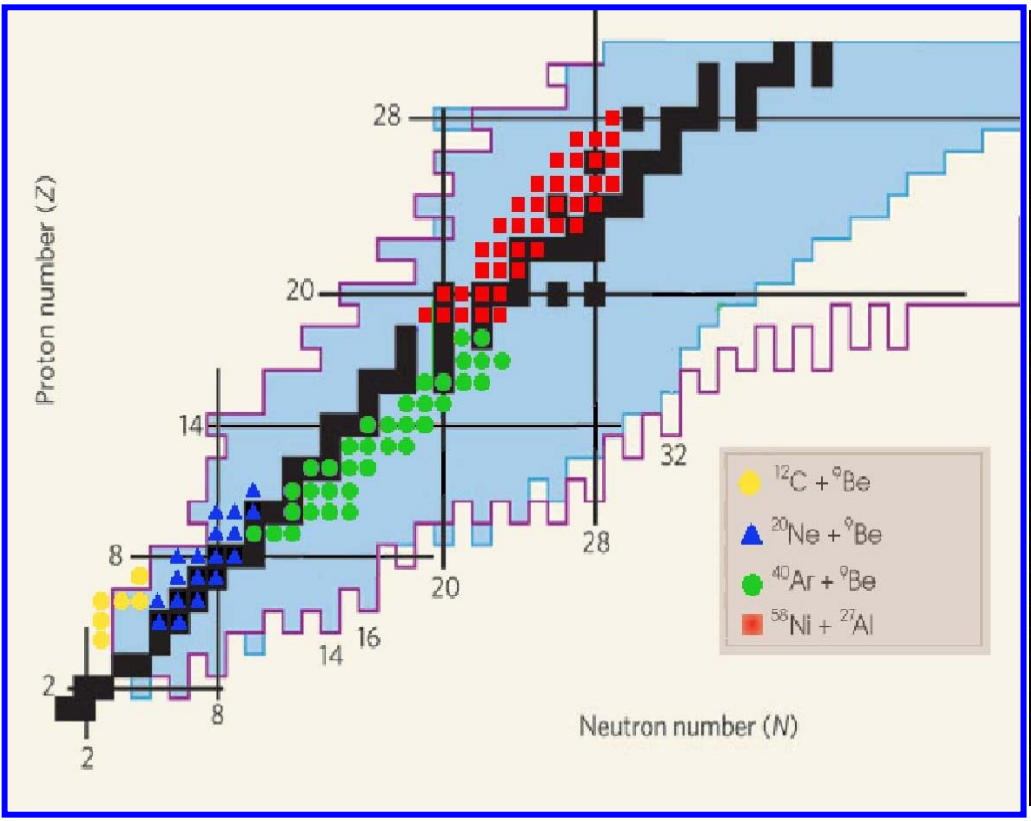
Yields Summary

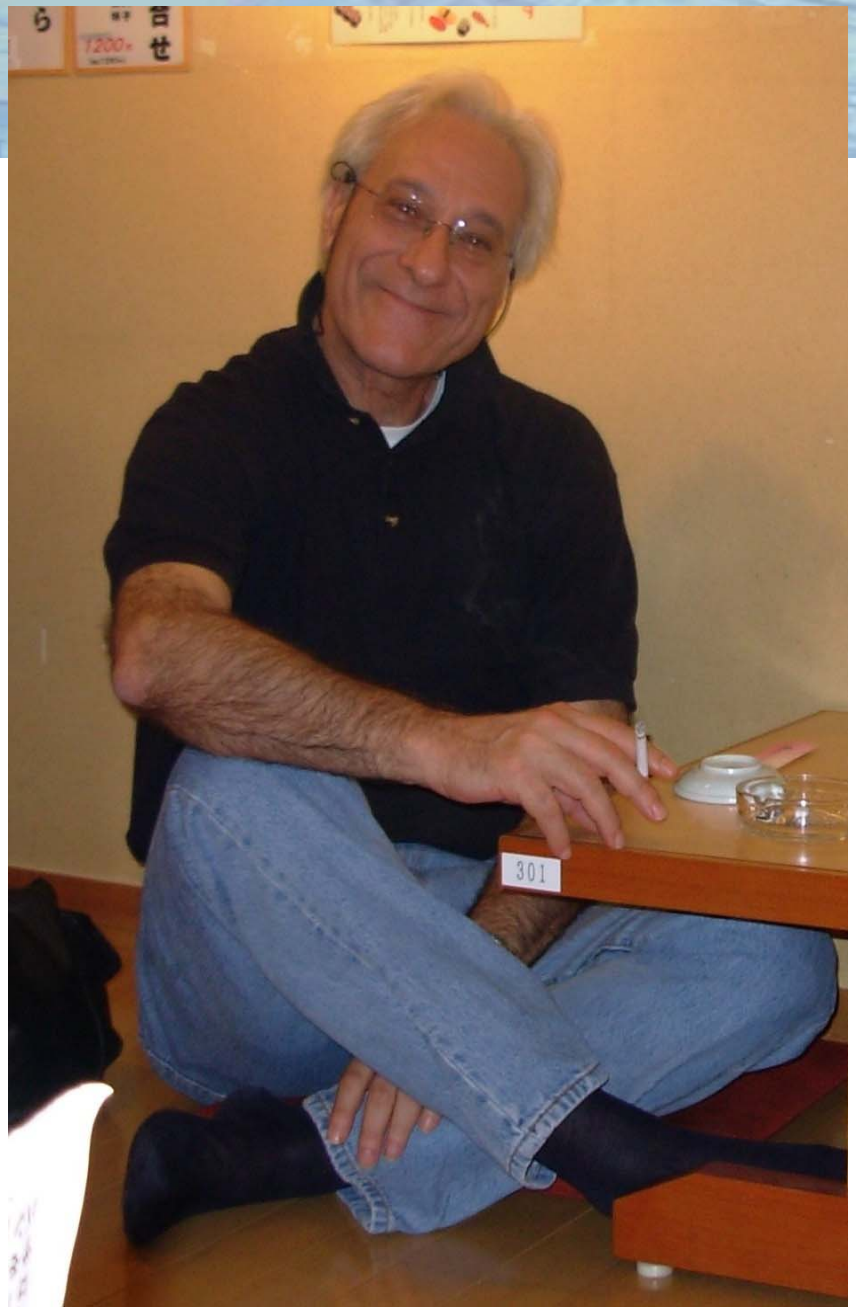


preliminary results data analysis going					
beam	primary beam	setting	intensity with old FRIBS (kHz/100W)	intensity (kHz/100W) March 2011	foreseen yield (kHz/100W) END 2011
16C	18O 55MeV/A	11Be	9	59	>120
17C	18O 55MeV/A	11Be		6	>12
13B	18O 55MeV/A	11Be	4.5	37	>80
11Be	18O 55MeV/A	11Be	2	11	>20
10Be	18O 55MeV/A	11Be		31	>60
8Li	18O 55MeV/A	11Be	3	9	>20
14B	18O 55MeV/A	12Be		1.2	>3
12Be	18O 55MeV/A	12Be		2	>5
9Li	18O 55MeV/A	12Be		2.7	>6
6He	18O 55MeV/A	12Be		4.7	>12
11be	13C 55 MeV	11Be	10		>50
12B	13C 55 MeV	11Be	20		>100
37K	36Ar 42 MeV	34Ar		50	>100
35Ar	36Ar 42 MeV	34Ar		35	>70
36Ar	36Ar 42 MeV	34Ar		50	>100
37Ar	36Ar 42 MeV	34Ar		12	>25
33Cl	36Ar 42 MeV	34Ar		6	>10
34Cl	36Ar 42 MeV	34Ar		25	>50
35Cl	36Ar 42 MeV	34Ar		26	>50
18Ne	20Ne 35 MeV	18Ne	9		>50
17F	20Ne 35 MeV	18Ne	3		>20
21Na	20Ne 35 MeV	18Ne	20		>100

G. Cardella et al. www.lns.infn.it – IFEB@LNS

Thank you

“ Our death is not an end if we can live on in our children and the younger generation. For they are us, our bodies are only wilted leaves on the tree of life “
A. Einstein



G. Raciti 1.01.49 -19.08.2009