AAPPS Bulletin August 2006 11

Articles

Nucleosynthesis in Classical Nova Explosions: Modeling and Nuclear Uncertainties

Jordi José and Alain Coc

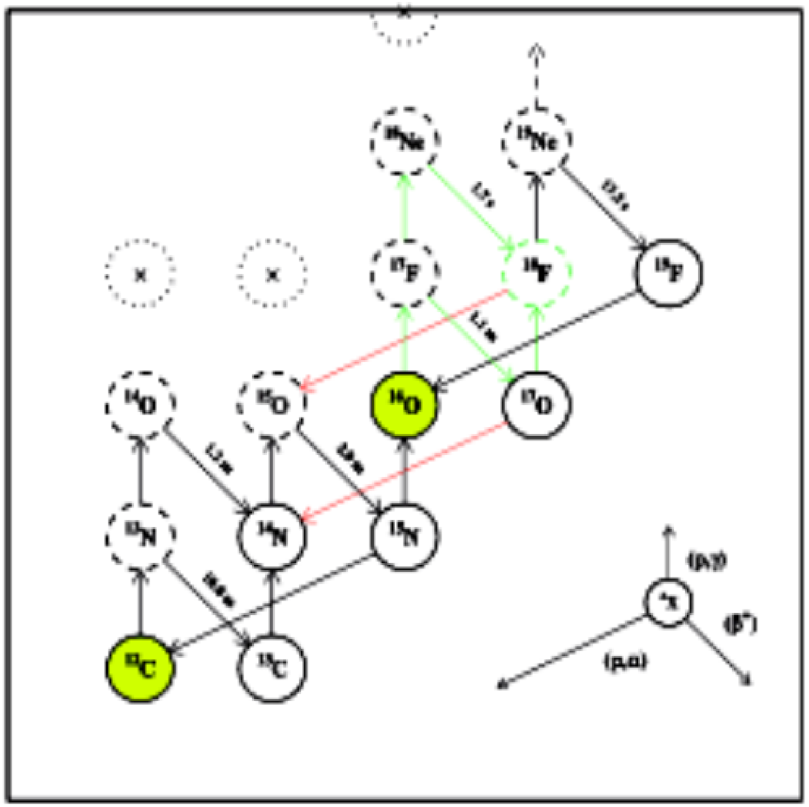


Fig. 4: Main CNO-cycle reactions during nova outbursts.

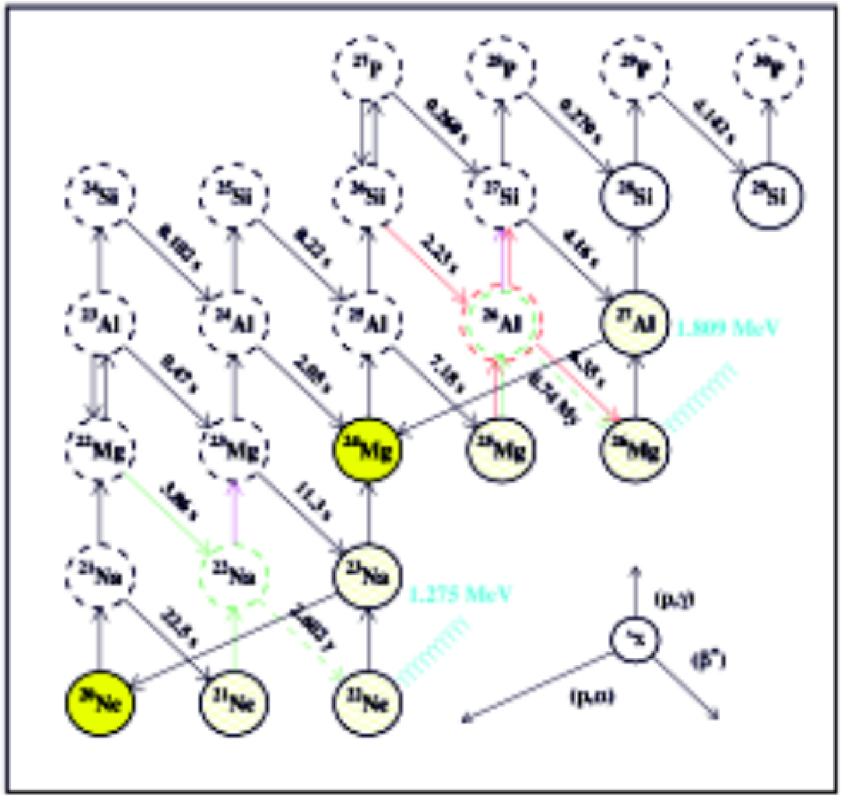
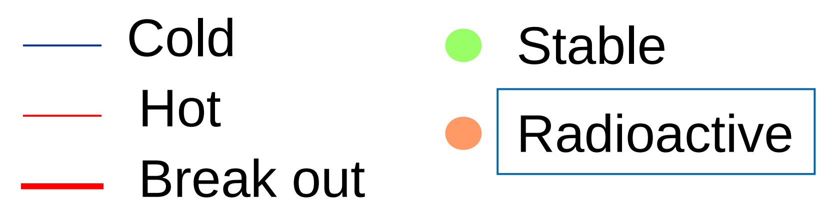
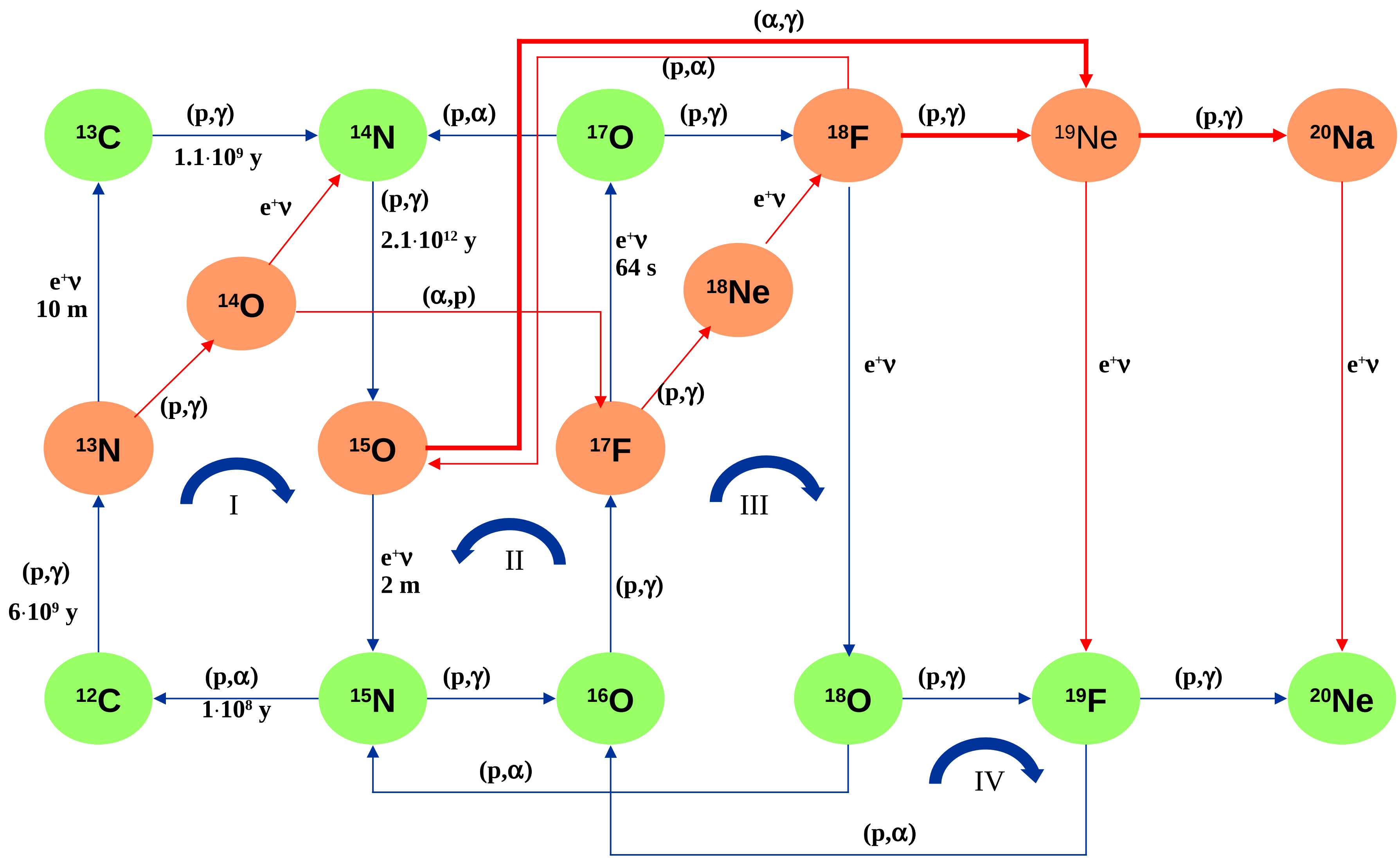


Fig. 5: Main nuclear activity in the Ne-P region during nova

Hot CNO (T_9~0.1)



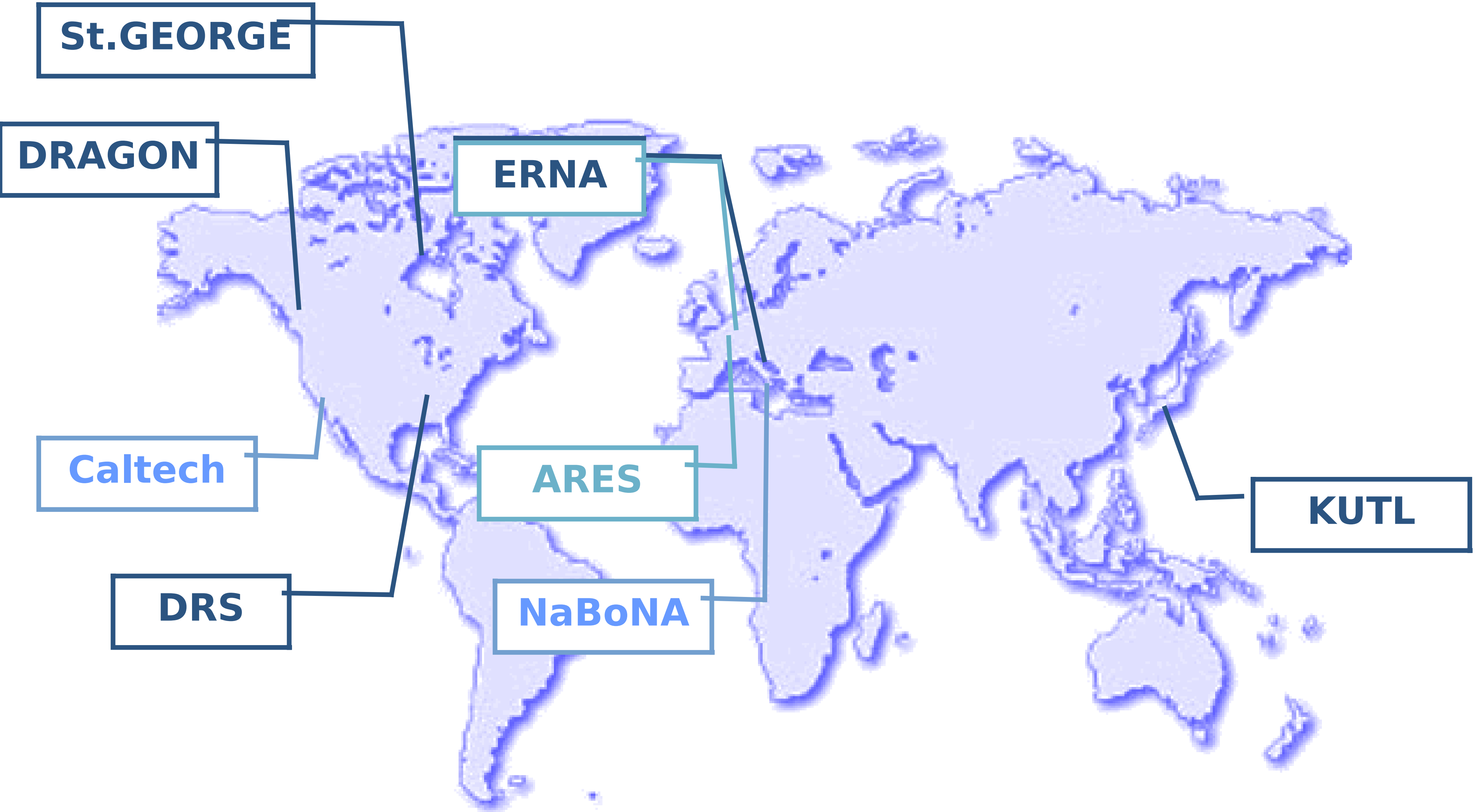
Cold
Hot
Break out
Stable
Radioactive



(α,γ)
(p,α)
13C
(p,γ)
1.1·10⁹ y
14N
(p,α)
17O
(p,γ)
18F
(p,γ)
19Ne
(p,γ)
20Na
e+ν
(p,γ)
2.1·10¹² y
e+ν
64 s
e+ν
e+ν
10 m
14O
(α,p)
18Ne
e+ν
e+ν
e+ν
(p,γ)
(p,γ)
13N
15O
17F
I
III
e+ν
2 m
II
(p,γ)
(p,γ)
6·10⁹ y
12C
(p,α)
1·10⁸ y
15N
(p,γ)
16O
18O
(p,γ)
19F
(p,γ)
20Ne
(p,α)
IV
(p,α)

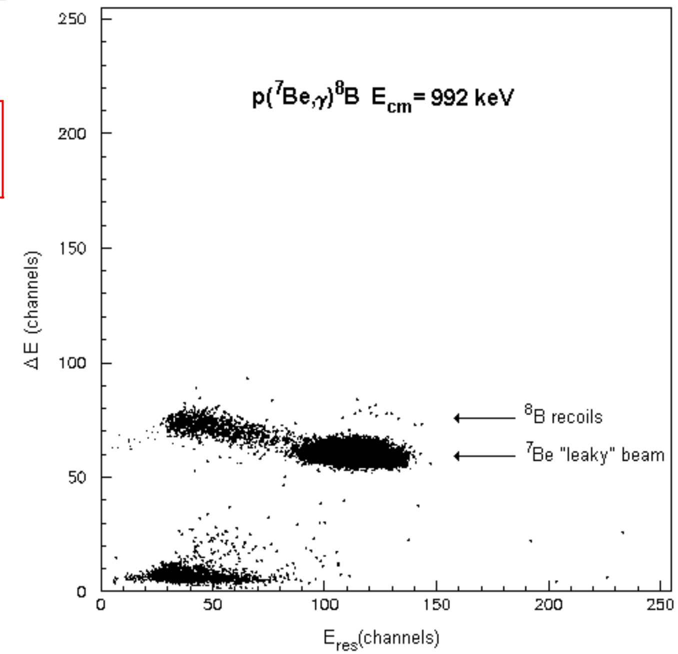
Element	A	Z	N	T1/2 s	RIBs at 40 KeV 1+ a 200µA	Re-accelerated RIBs C.B.eff=3- 4 % Linac tr.=50% a 200µA	RIBs at 40 KeV 1+ a 5 µA	Re-accelerated RIBs C.B.eff=3- 4 % Linac tr.=50% a 5 µA	q+ 2014 Estimated Data Experimental Data ** (see attached Notes)	A/Q 2014 * (see attached Notes) ** " *** " **** "	Energy Max Mev/A ±10 % *Based on Comunian Formula	Surface Ion Source SIS	Laser Ion Source LIS	Plasma I Source FEBIAI	
												Legend 1 Feasible 3 Upgrade to do 5 Major Upgrades			
Be*	7	4	3	4.60E+06				2.E+07 **	1	7,0	9		2		
Be*	10	4	6					3.E+07 **	2	5,0	13		2		
F *	17	9	8	6.48E+01				2.E+07 **	4	4,3	15		4		
F *	18	9	9	6.58E+03				2.E+06 **	4	4,5	14		4		
Na*	21	11	10	2.25E+01					6	3,5	18	5			
Na*	22	11	11	2.60E+00					6	3,7	17	5			
Mg*	22	12	10	3.86E+00					6	3,7	17		5		
Mg*	23	12	11	1.13E+01					6	3,8	16		5		
Al*	24	13	11	2.05E+00					6	4,0	16	1	1		
Al*	25	13	12	7.18E+00				1E+04 **	6	4,2	15	1	1		
Al*	26	13	13	6.35E+00				1E+04 **	6	4,3	15	1	1		
Si*	26	14	12	2.21E+00				1E+03 **	7	3,7	17				
Si*	27	14	13	4.16E+00				1E+03 **	7	3,9	16				
P*	29	15	14	4.10E+00					7	4,1	15				
Cl*	34	17	17	1.53E+00				5E+03 **	8	4,3	15				

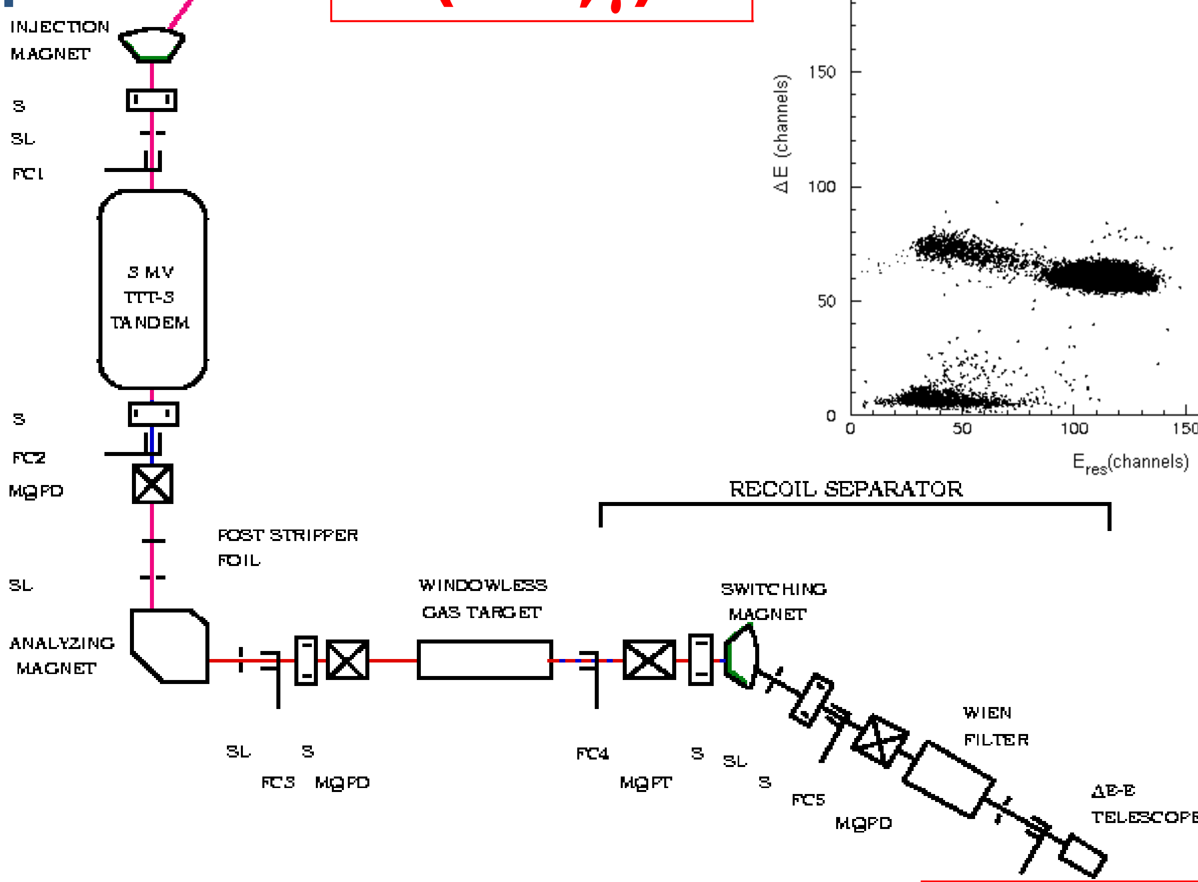
RMS for Nuclear Astrophysics



NaBoNA
Naples

$^{1}H(^{7}Be,\gamma)^{8}B$



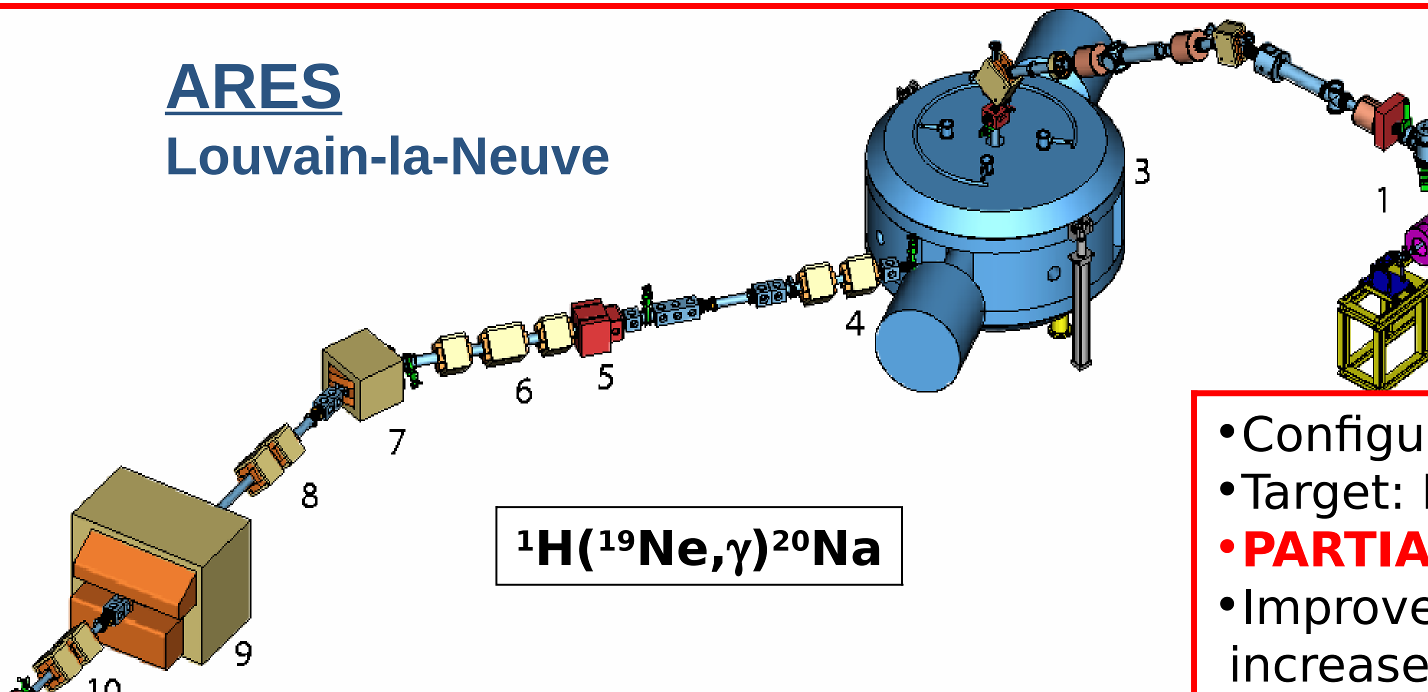


D

KUTL

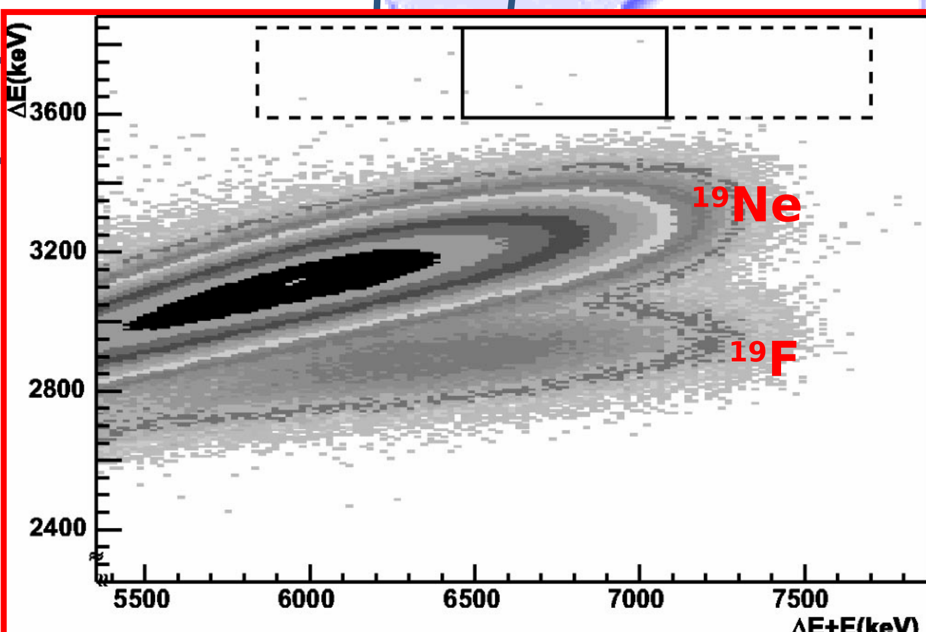
- Configuration: M-W
- differentially pumped gas target
- Acceptances
- Fully stripped recoils

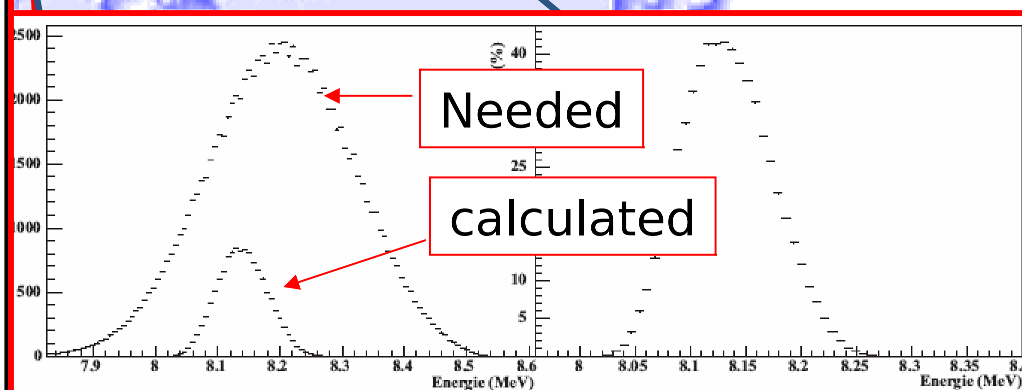
ARES
Louvain-la-Neuve



$^{1}H(^{19}Ne,\gamma)^{20}Na$

- Configuration: M-W
- Target: H containing foil
- **PARTIAL ACCEPTANCES**
- Improvements planned to increase suppression (add. Magnet)





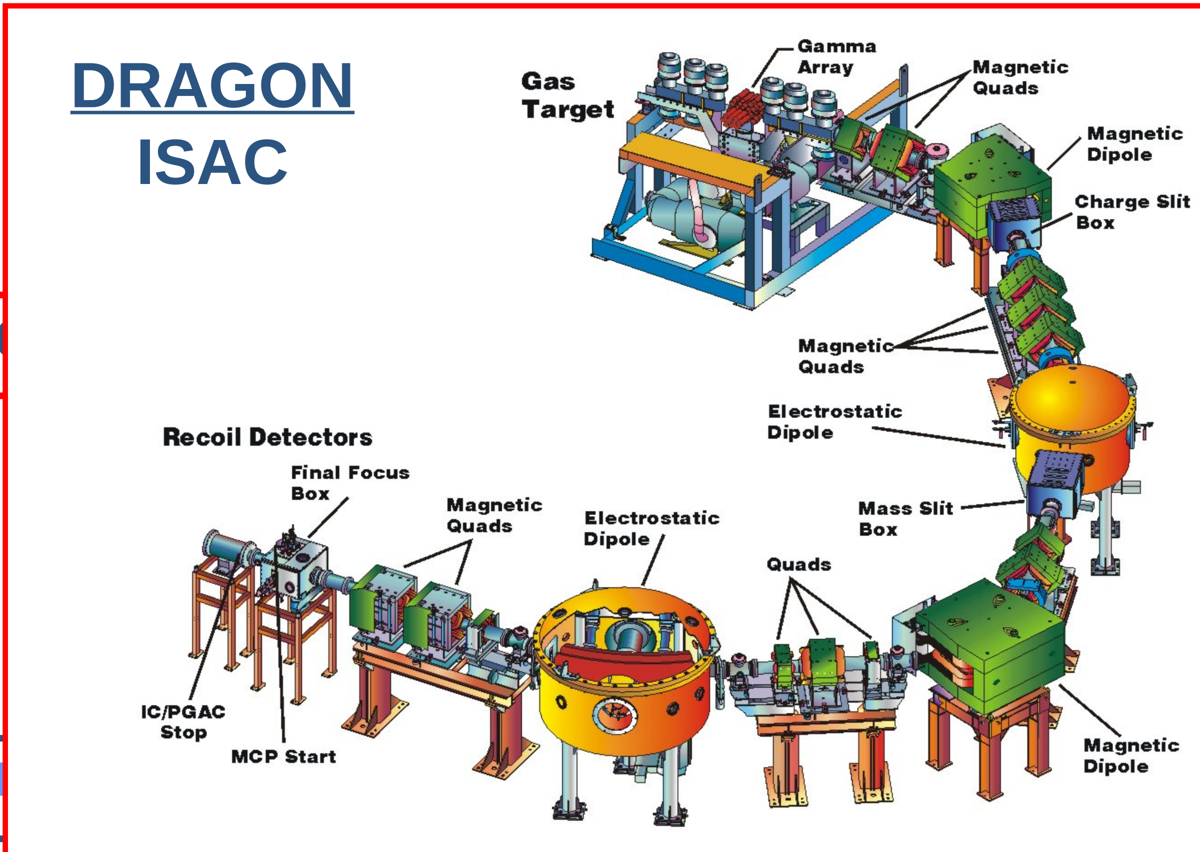
Calculated acceptance
vs reaction kinematics

Courtesy of M. Couder, Notre Dame

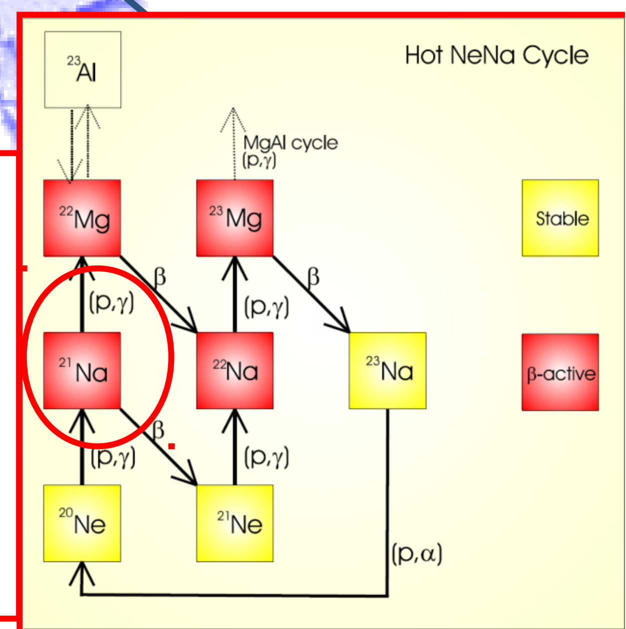
DRAG

Calt

DRS

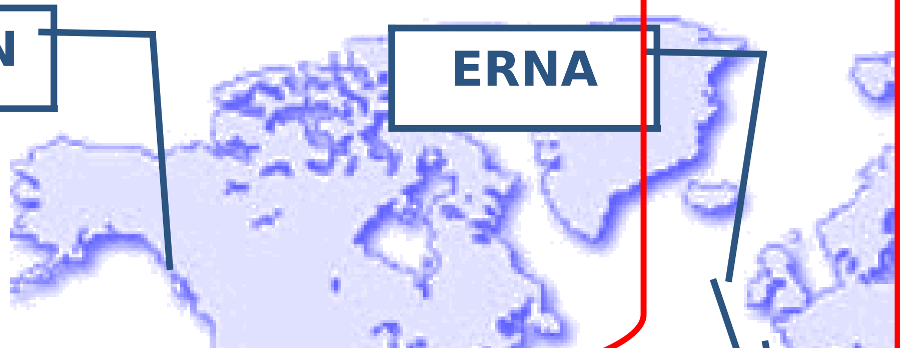


- Configuration: M-E-M-E
- radioactive ion beams
- differentially pumped gas target
- Acceptances 18mrad (?)
- Assumption of **FULL acceptances**

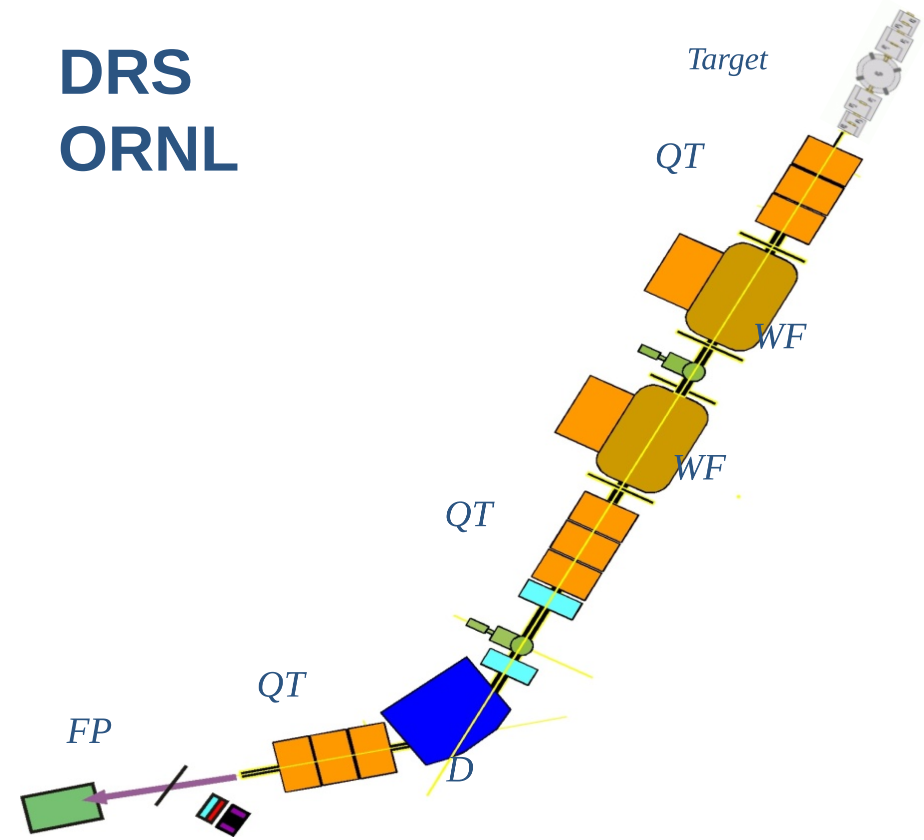


DRAGON

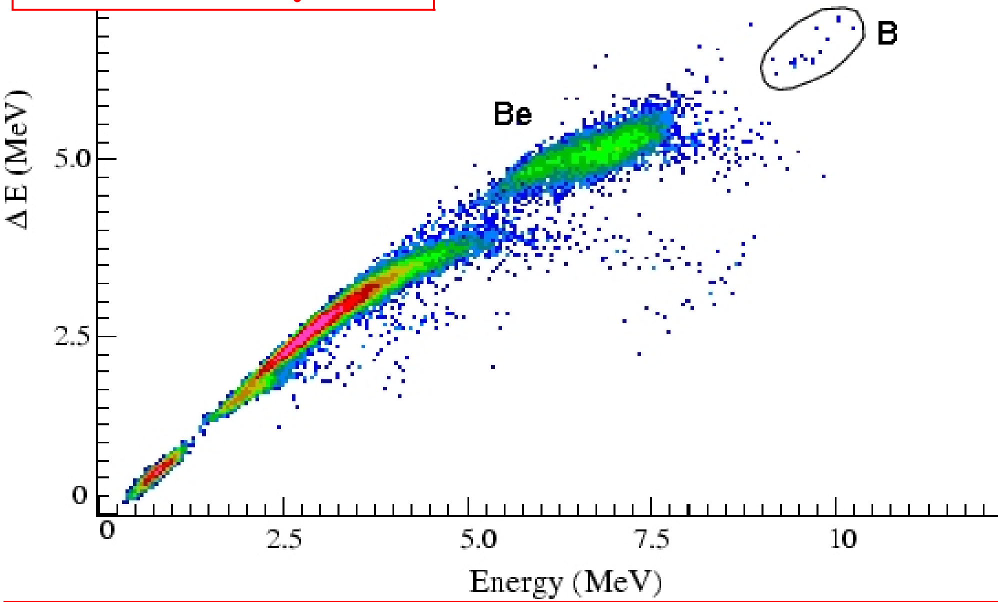
ERNA



DRS ORNL



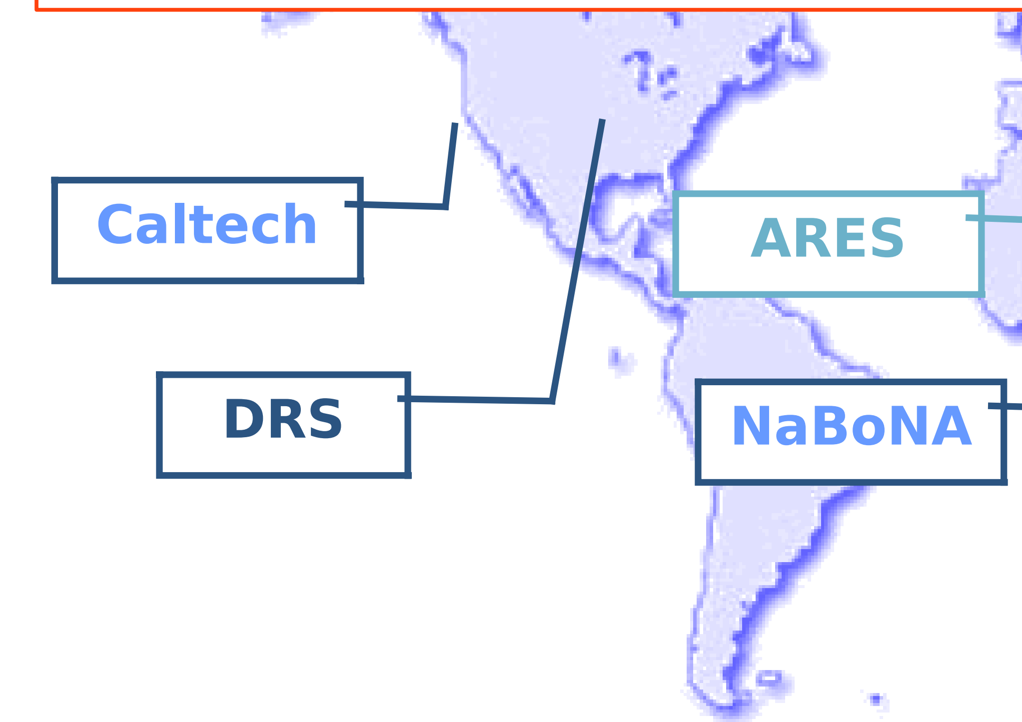
$^{1}H(^{7}Be,\gamma)^{8}B$



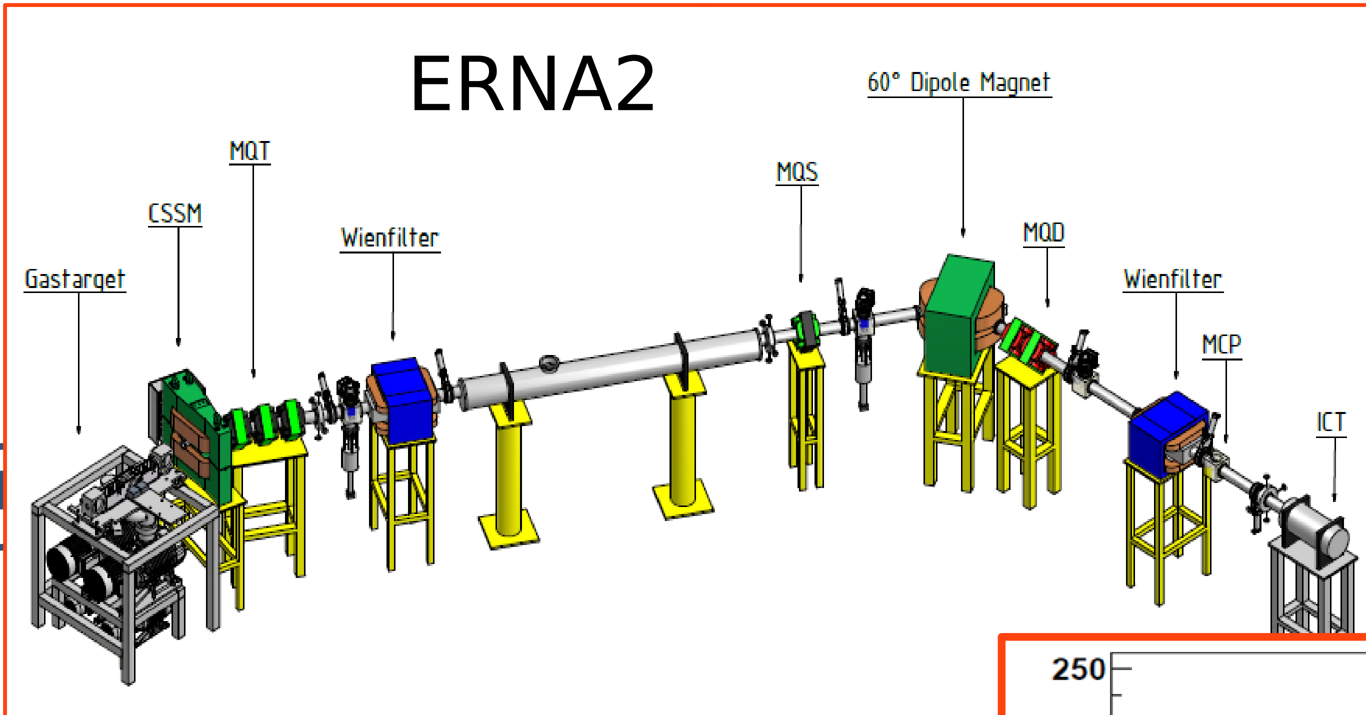
- Configuration: W-W-M
- Acceptances angle +-45 mrad
  energy +-5%

- H-Gastarget
  (differentially pumped, windowless)

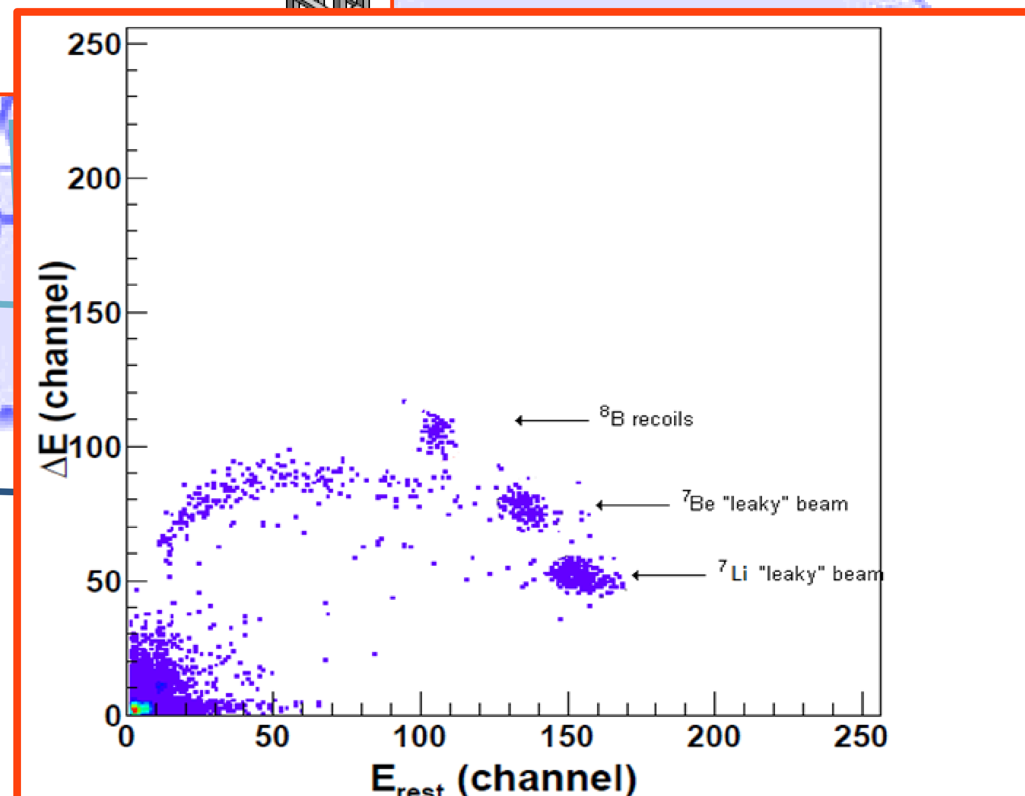
hysics



Caltech
DRS
ARES
NaBoNA

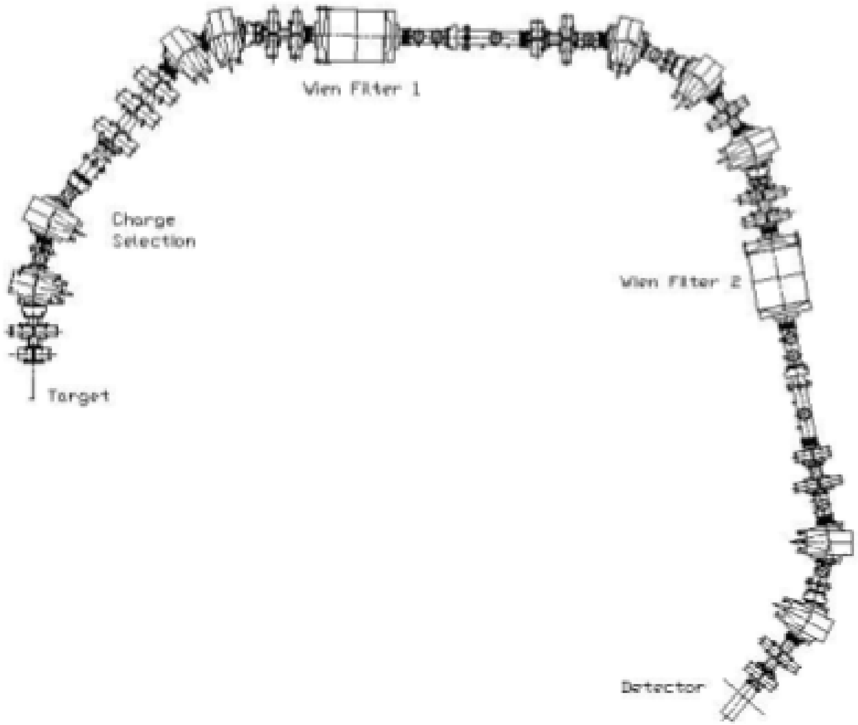


ERNA2
Gastarget
CSSM
MQT
Wienfilter
MQS
60° Dipole Magnet
MQD
Wienfilter
MCP
ICT



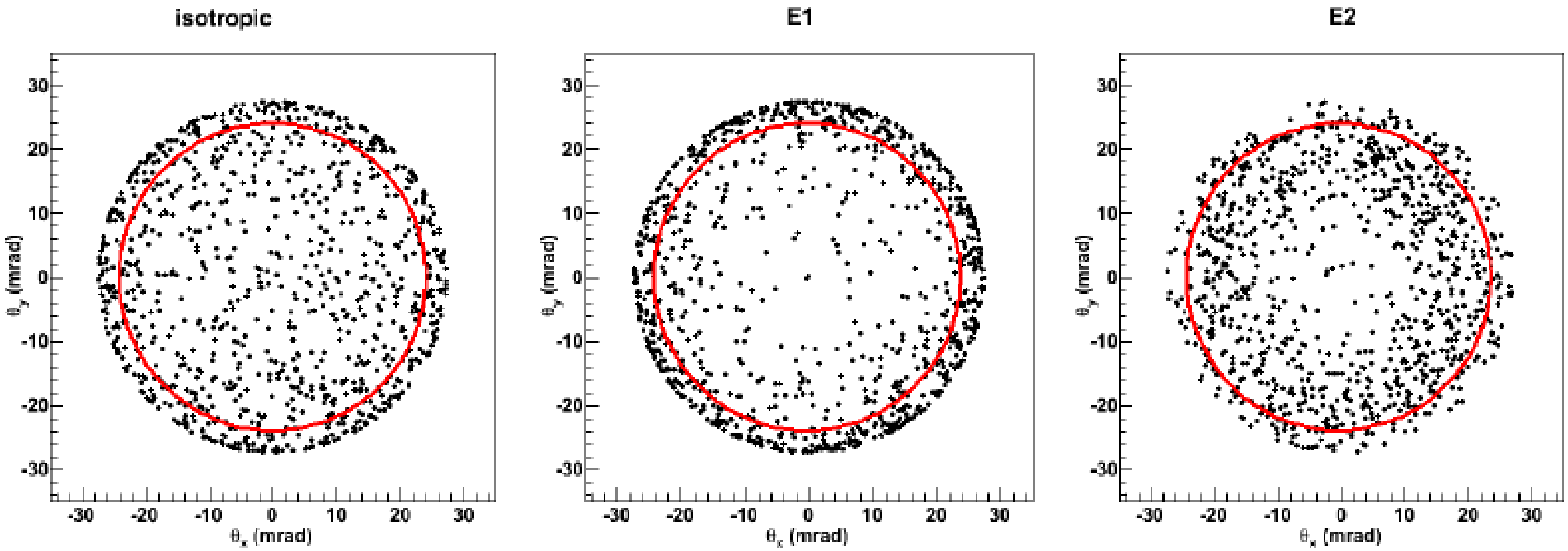
ΔE (channel)
E_rest (channel)
8B recoils
7Be "leaky" beam
7Li "leaky" beam
0
50
100
150
200
250

Next to come: SECAR at FRIB



But don't forget acceptance. An example: $^{12}C(\alpha,\gamma)^{16}O$ at E_{cm}=1 MeV

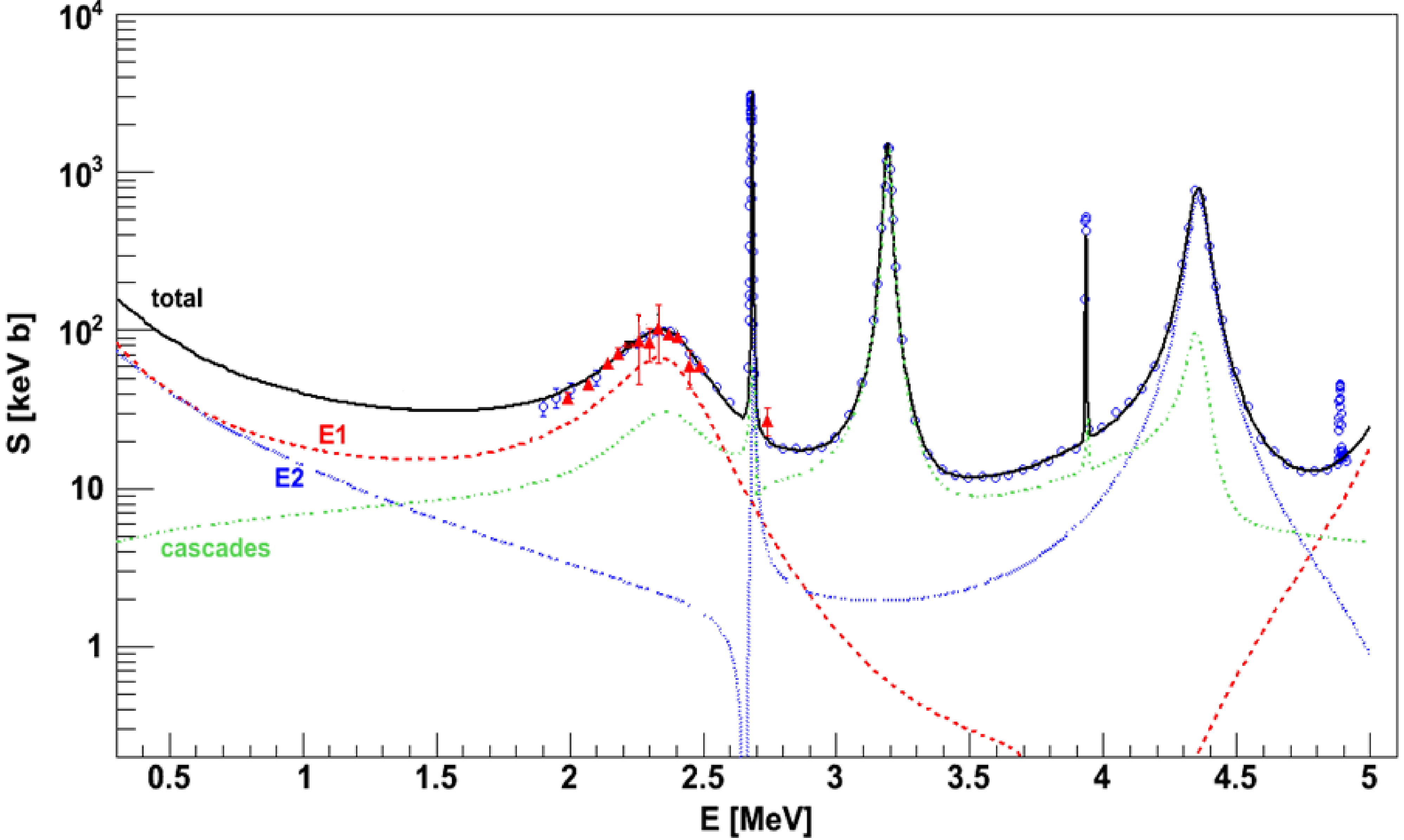
Required acceptance:27 mrad
Actual acceptance: 24 mrad



Recoils 47% 66% 23%
Loss (beam and target effects not included)

L. G. and D. Schuermann *ENA VI* – POS 2011

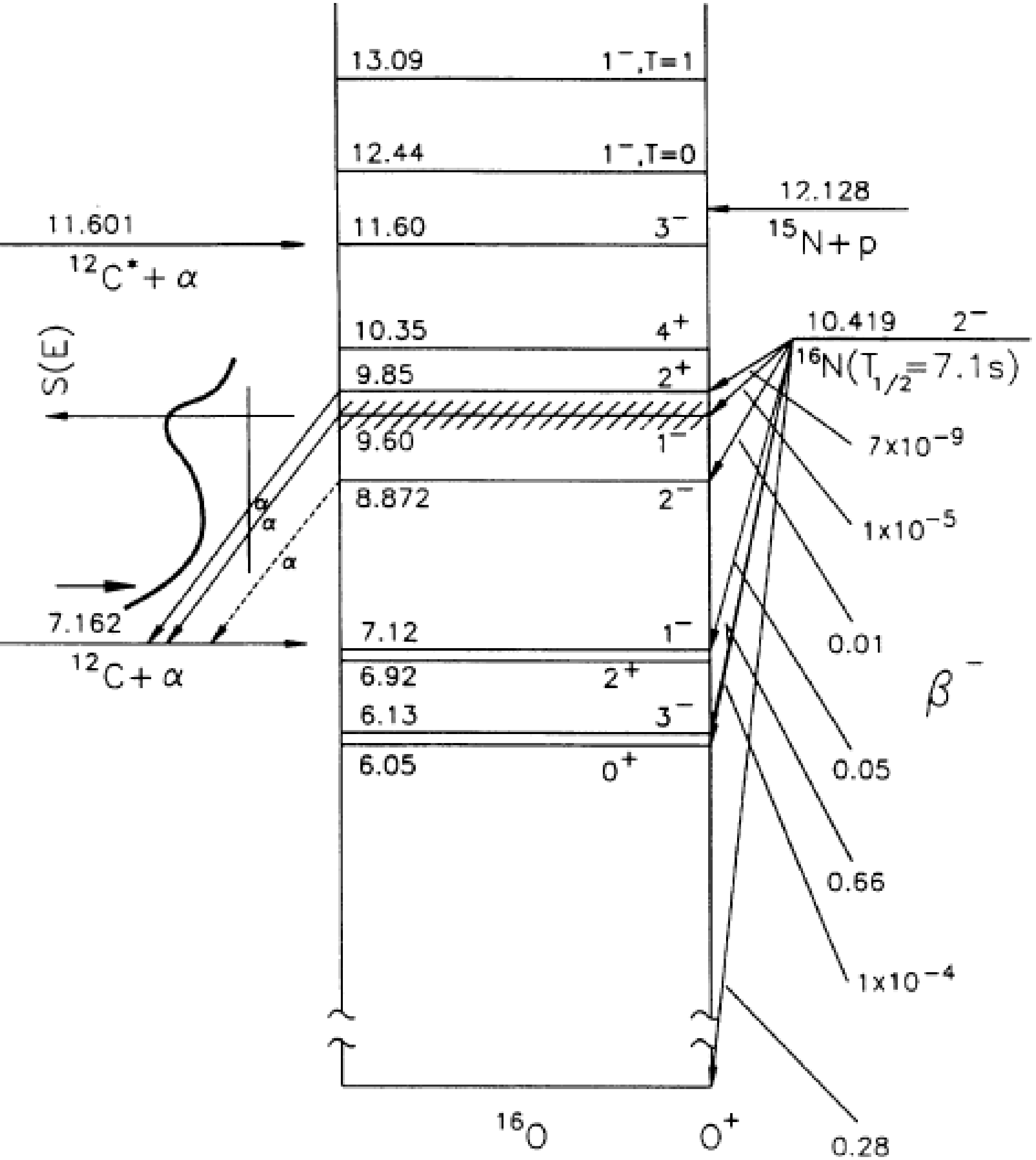
Total cross section

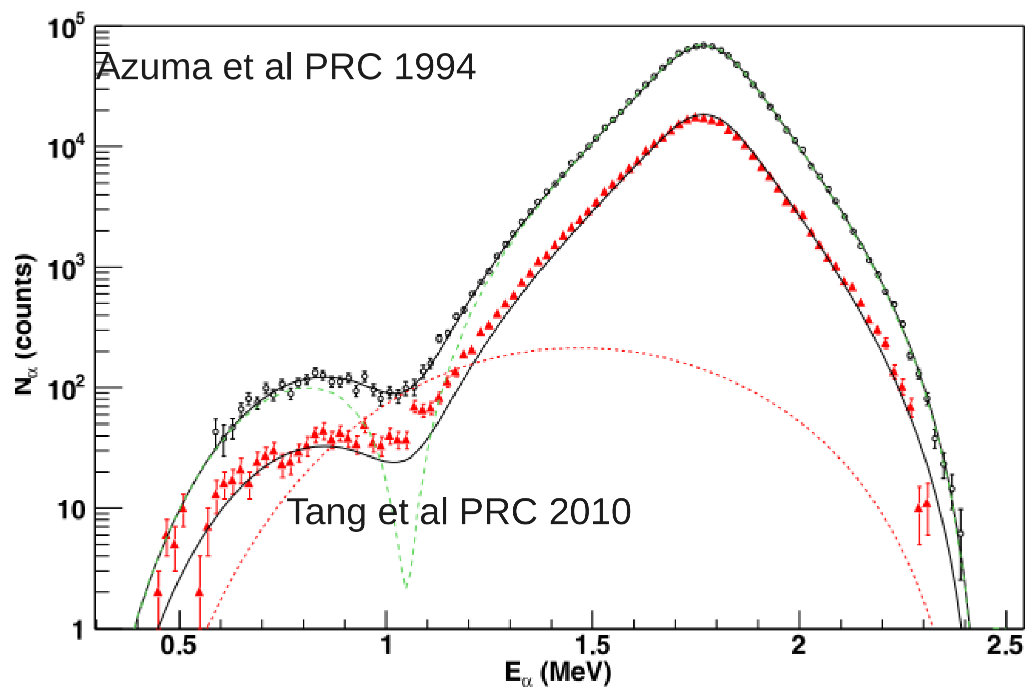


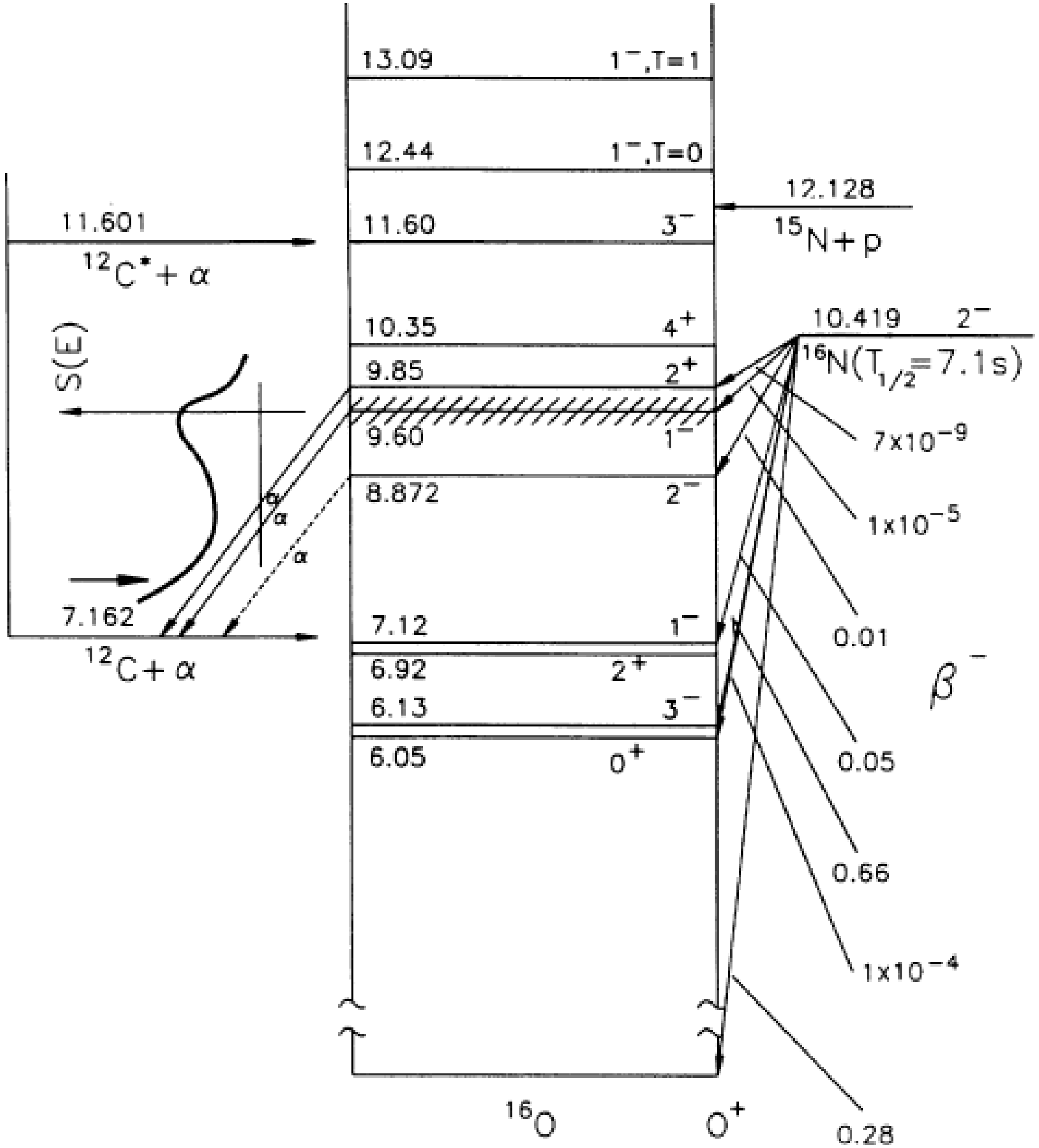
-data selection
-normalization
-Monte Carlo

$S(300)=161\pm19_{stat}{}^{+8}_{-2\ sys}$

Schuermann, Gialanella, Kunz, Strieder PLB 2011


13.09
1⁻,T=1
12.44
1⁻,T=0
12.128
$^{15}N+p$
11.601
$^{12}C^*+\alpha$
11.60
3⁻
10.35
4⁺
10.419
2⁻
$^{16}N(T_{1/2}=7.1s)$
S(E)
9.85
2⁺
9.60
1⁻
7×10^{-9}
1×10^{-5}
8.872
2⁻
α
α
α
7.162
7.12
1⁻
$^{12}C+\alpha$
0.01
6.92
2⁺
6.13
3⁻
β^-
6.05
0⁺
0.05
0.66
1×10^{-4}
^{16}O
0⁺
0.28


Azuma et al PRC 1994
Tang et al PRC 2010
N_α (counts)
E_α (MeV)
10^5
10^4
10^3
10^2
10
1
0.5
1
1.5
2
2.5



Final state		Branch (%)
^{16}O* (MeV)	J^π	
0	0^+	26 ± 2 [c]
6.05	0^+	$(1.2 \pm 0.4) \times 10^{-2}$ [d]
6.13	3^-	68 ± 2 [c]
7.12	1^-	4.9 ± 0.4 [c]
8.87	2^-	1.0 ± 0.2 [c]
9.63	1^-	$(1.20 \pm 0.05) \times 10^{-3}$ [e]
9.85	2^+	$(6.5 \pm 2.0) \times 10^{-7}$ [f]

Relative BR	S300 (keV·b)
4000 fixed	80
3650 fitted	85
3800 fitted + norm	86
3800 fitted + norm + select	90
1550 free	154

Outlook

-

Possibly one might develop the low energy section of SPES for proton
and alpha captures on light isotopes using a RMS, but beam quality neeeds to be very good.

What about N16?