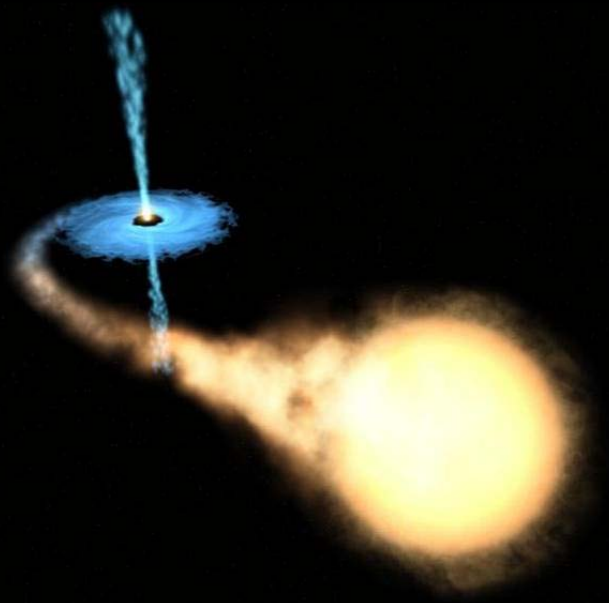
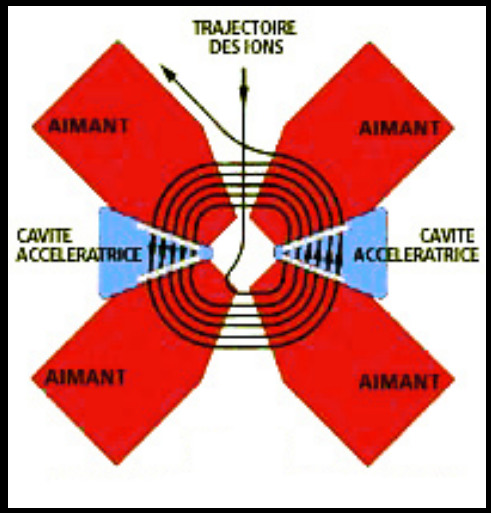
Nuclear Astrophysics @ GANIL





GRAND ACCELERATEUR NATIONAL D'IONS LOURDS

François

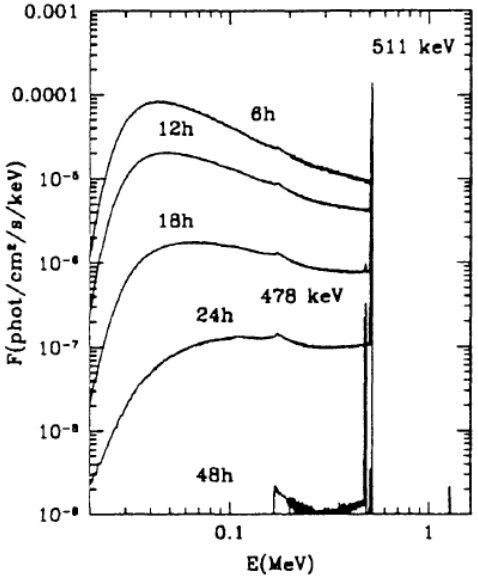
de Oliveira Santos

Novae

J. Gomez-Gomar et al., Mon. Not. R. Astron. Soc. 296, 913 (1998).

M. Hernanz, J. Jose, A. Coc, J. Gomez-Gomar, and J. Isern, Astrophys. J. 526, L97 (1999).

A. Coc, M. Hernanz, J. Jose, and J.-P. Thibaud, Astron. Astrophys. 357, 561 (2000).



^{18}F(p,α)^{15}O

Spectroscopy of ^{19}Ne

^{19}Ne

No	E_x[a] (MeV)	E_r (keV)	J^{π}[b]	Γ_γ[c] (eV)	θ_p^{2}[d]	Γ_p[d] (keV)	Γ_α[e] (keV)
1	6.419	8(6)	$(\frac{3}{2}^+)$	0.77(41)	0.12(2)	2.2(4)E−37	0.27(27)
2	(6.422)	11(30)	$(\frac{11}{2}^+)$	0.35(18)	(0.1)	1.8(18)E−38	20(14)E−3
3	6.437	26(9)	$\frac{1}{2}^-$	[1(1)]	0.01	1.1(11)E−20	220(20) (M)
4	6.449	38(7)	$(\frac{3}{2}^+)$	1.1(6)	0.03(3)	4(4)E−15	1.3(10)
5	(6.504)	93(30)	$(\frac{7}{2}^+)$	0.14(8)	(0.1)	4.6(46)E−10	0.4(4)
6	(6.542)	131(30)	$(\frac{9}{2}^+)$	0.30(16)	(0.1)	2.7(27)E−12	1.3(11)E−2
7	6.698	287(6)	$(\frac{5}{2}^+)$	0.29(15)	0.01	1.2(12)E−5	1.2(10)
8	6.741	330(6)	$\frac{3}{2}^-$	5.0(26)	–	2.22(69)E−3	5.2(37)
9	(6.841)	430(30)	$(\frac{3}{2}^-)$	2.8(15)	(0.01)	9.7(97)E−3	25(18)
10	6.861	450(6)	$\frac{7}{2}^-$	2.3(12)	(0.01)	1.1(11)E−5	1.2(0.9)
11	(6.939)	528(30)	$(\frac{1}{2}^-)$	[1(1)]	(0.01)	3.4(34)E−2	99(69)
12	(7.054)	643(30)	$(\frac{5}{2}^+)$	[1(1)]	(0.1)	4.7(47)E−2	29(25)
13	7.0757	664.7(16)	$\frac{3}{2}^+$	[1(1)]	–	15.2(1)	23.8(12) (M)
14	7.173	762(5)	$(\frac{11}{2}^-)$	0.15(8)	(0.01)	9.8(98)E−8	1.2(10)E−2
15	7.238	827(6)	$\frac{3}{2}^+$	[1(1)]	–	0.35(35)	6.0(52)

Inelastic scattering and p-p correlation

$^{19}Ne + {}^{1}H \longrightarrow p + {}^{19}Ne^{*}$

↳ $^{15}O+\alpha$

↳ $^{18}F + p$

Aligned states

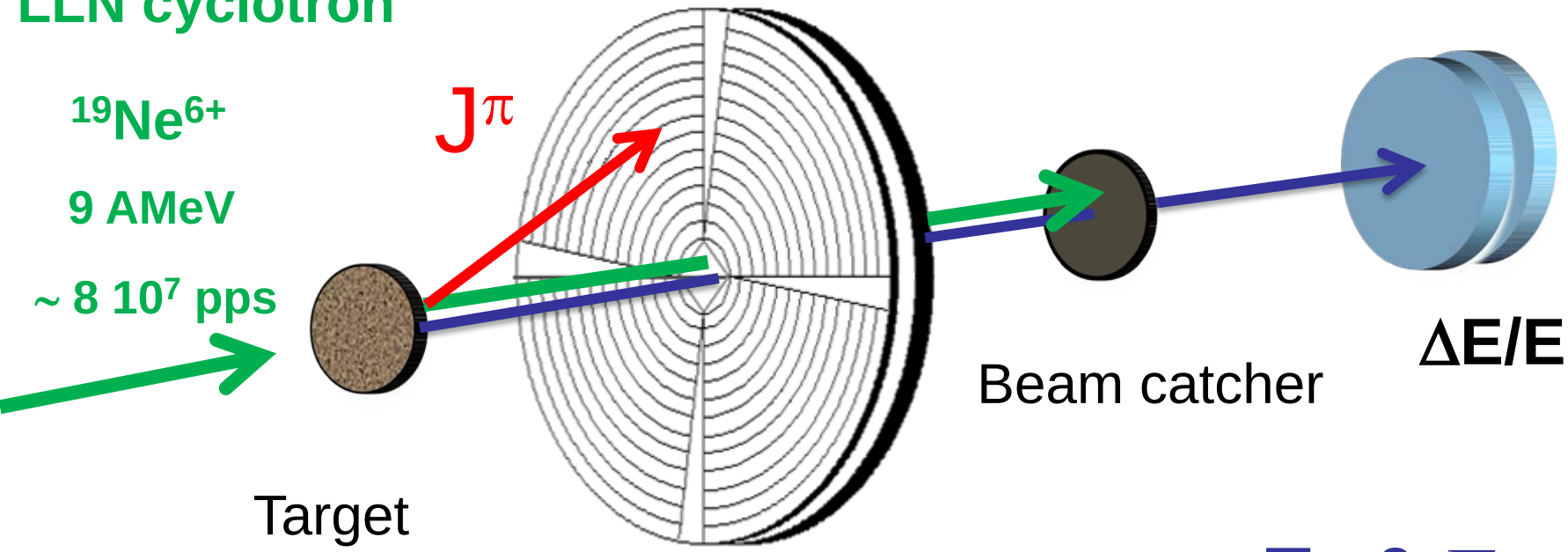
LLN cyclotron

$^{19}Ne^{6+}$

9 AMeV

~ 8 10^{7} pps

J^{π}



Target

CD - PAD

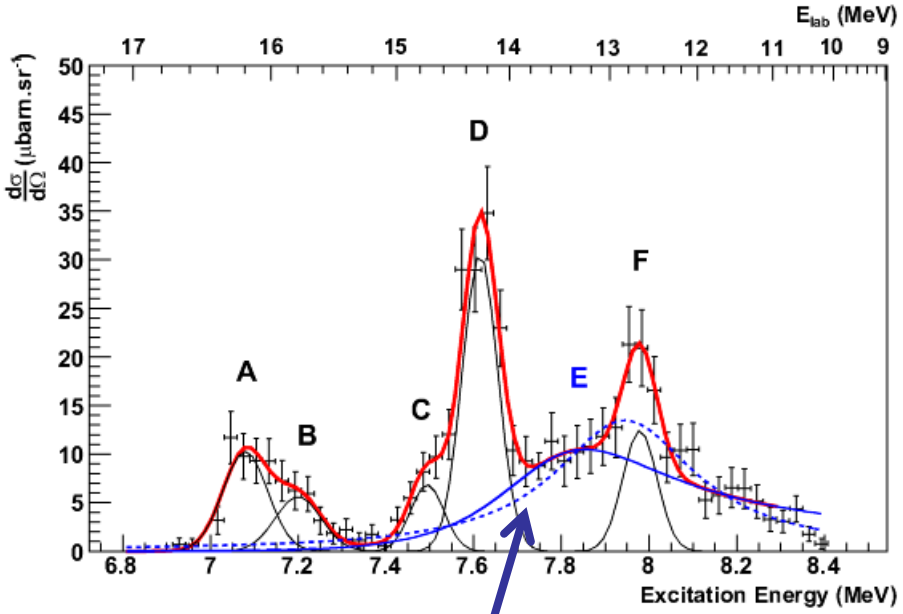
Beam catcher

ΔE/E

E_x & Γ_{Total}

States above proton threshold

$H(^{19}Ne,p')^{19}Ne^*(p)^{18}F$



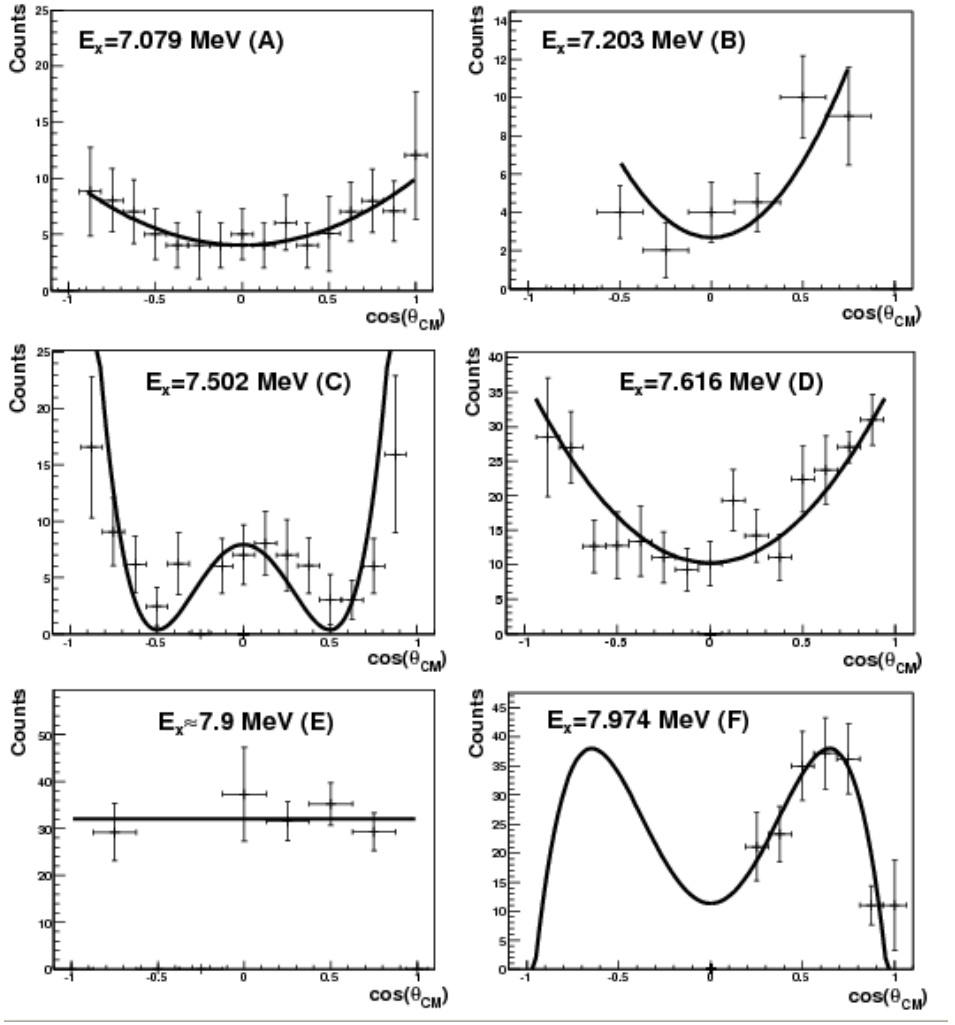
New 1/2+ state

Predicted by

Dufour and Descouvemont

NPA 785, 381 (2007)

Spin Model Independent



Outlook

	This experiment				Previous measurements			
Label	E_r(keV)	E_x(MeV)	Γ (keV)	J^π	E_x(MeV)	Γ (keV)	J^π	ref
A	669(5)	7.079(5)	32(8)	$\frac{3}{2}^{(+)}$	7.075(1.6)	39(2.2)	$\frac{3}{2}^+$	[7]
B	793(31)	7.203(31)	35(12)	$\frac{3}{2}^{(+)}$	7.173(5)	-	-	[5]
					7.238(6)	-	-	[5]
C	1092(30)	7.502(30)	17(7)	$\frac{5}{2}^{(-)}$	7.500(9)	16(16)	-	[5]
					7.531(11)	31(16)	-	[5]
D	1206(5)	7.616(5)	21(10)	$\frac{3}{2}^{(+)}$	7.608(11)	45(16)	$\frac{3}{2}^+$	[17]
					7.644(12)	43(16)		[5]
E	1452(39)	7.863(39)	292(107)	$\frac{1}{2}^{(+)}$	-	-	-	
F	1564(10)	7.974(10)	11(8)	$(\frac{5}{2}^-)$	7.944(15)	-	-	[18]
					8.069(12)	-	-	[18]

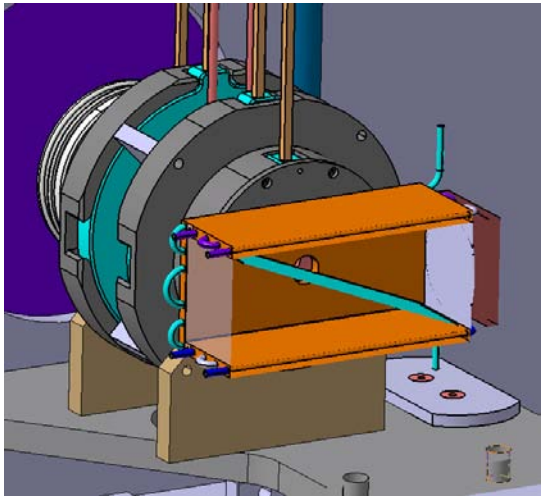
J.C. Dalouzy et al. Physical Review Letters. April 24th 2009

- New (improved using VAMOS spectrometer) experiment accepted at GANIL to study ^{19}Ne states in the Gamow peak

- Other reactions possible in the future, like ^{30}P(p, γ)^{31}S

- Direct measurement possible in the future (SPIRAL2)

^{16}O(^{3}He,p)^{18}F
Expected intensity ~ 10^7 pps



Letter of Intent for SPIRAL 2

The Letter of Intent should be prepared using the following template and sent in electronic form (preferably as a pdf file) to the Chairman of the SPIRAL 2 Scientific Advisory Committee *Muhsin Harakeh* (harakeh@kvi.nl) with a copy to the Scientific Co-ordinator of SPIRAL 2 *Marek Lewitowicz* (Lewitowicz@ganil.fr) before **October 2nd 2006.** Further information on the facility and envisaged physics programme can be found at: http://www.ganil.fr/research/developments/spiral2/

Title: α-capture reactions in inverse kinematics relevant to stellar nucleosynthesis

Spokesperson(s) *(max. 3 names, laboratory, e-mail - please underline among them one corresponding spokesperson):*

S. Harissopulos, NCSR Demokritos, sharisop@inp.demokritos.gr
F. de Oliveira Santos, GANIL, oliveira@ganil.fr

$^{4}He(^{78}Kr,\gamma)^{82}Sr$

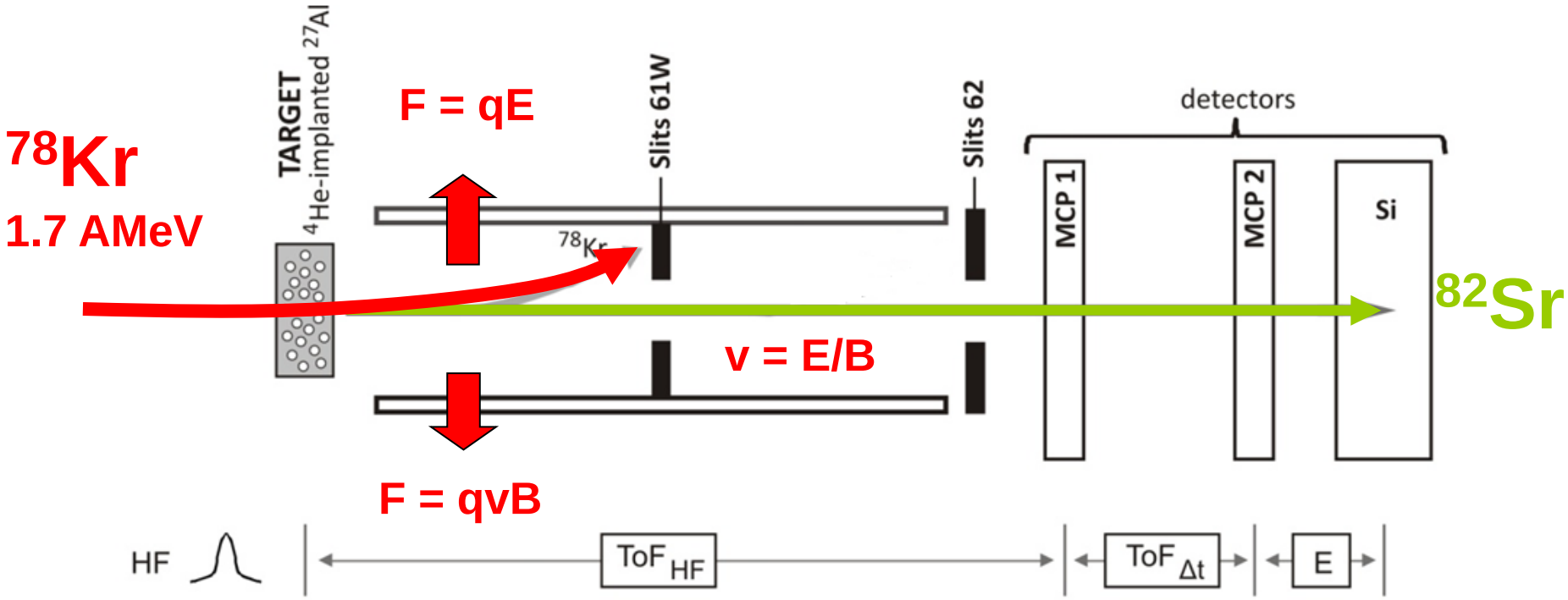
GANIL
PROPOSAL FOR EXPERIMENT

PAC date (fill in):	EXP # (Do not fill in):
May, 2007	**E**

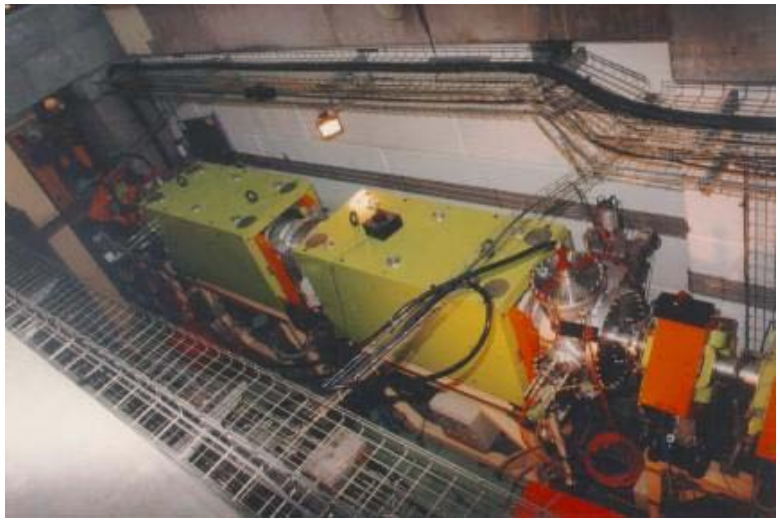
- If Be or Ni production targets are to be used, indicate the maximum beam intensity the target can handle.
- Test runs which may be needed to commission new apparatus are encouraged, but should be presented as separate proposals.

Title*: **Alpha-Capture Reactions in Inverse Kinematics Relevant to P-Process Nucleosynthesis**

Is it a follow up experiment? [Yes/No]: No If yes, experiment number:

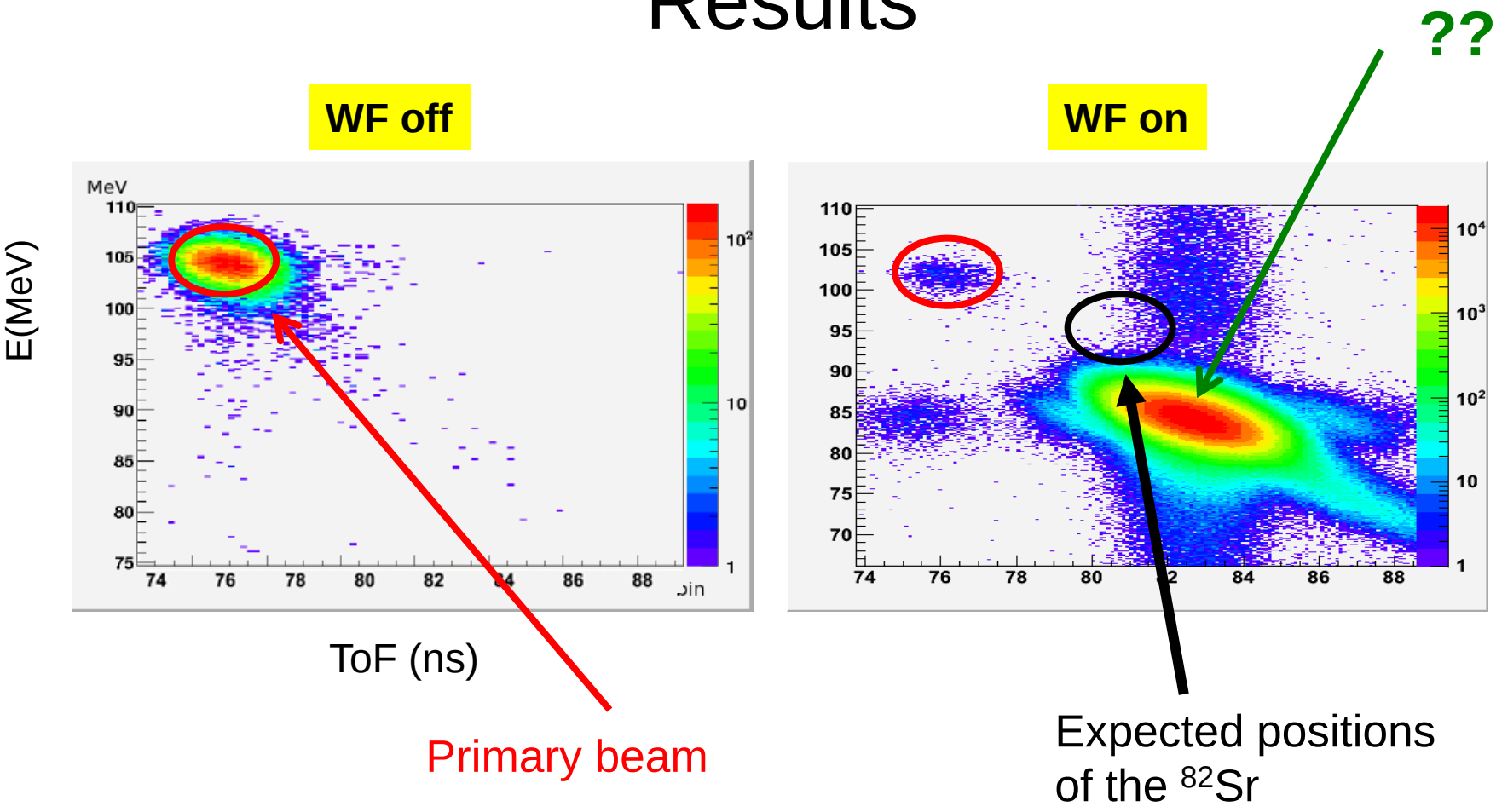


Wien Filter of LISE



- WF collects all charge states of product of interest
- Δv ~ 5% (between the primary beam and the CN)
- The LISE WF has a specific fringe fields – only ion optics code of ray tracing type are relevant

Results



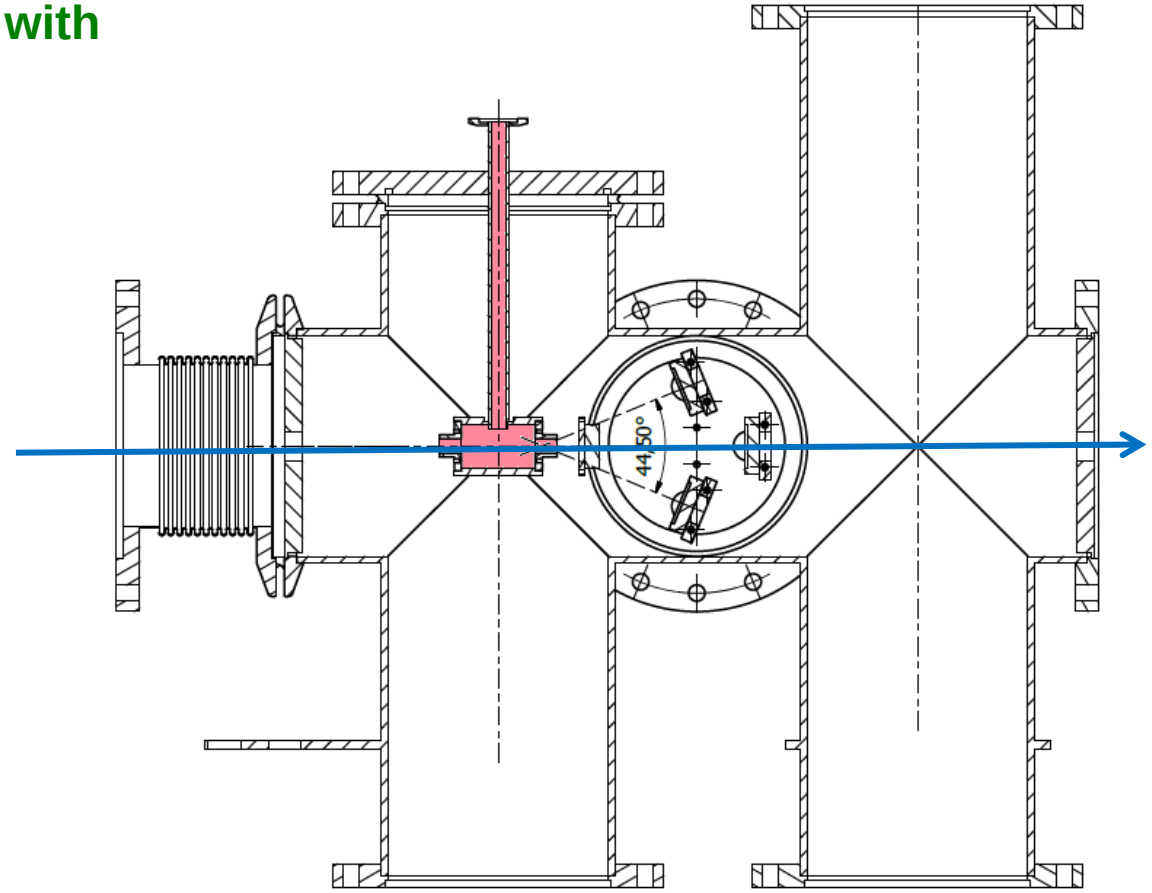
- Primary beam very well rejected, almost with factor 10^{11}
- Too high intensity of scattered beam at energy ~20 MeV lower than the energy of the direct primary beam

Outlook

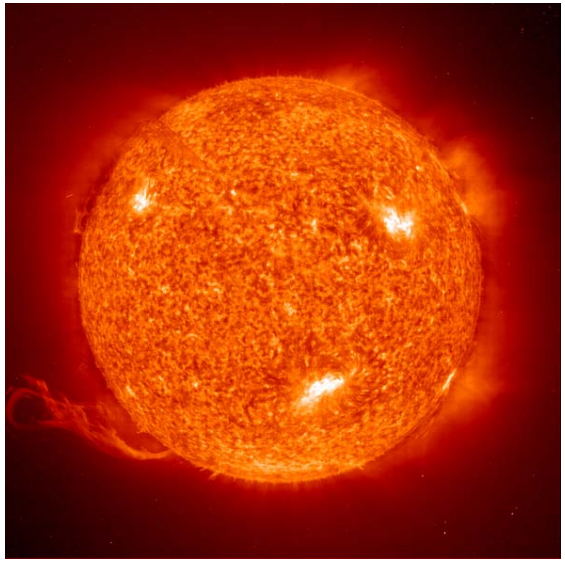
- Very good rejection factor

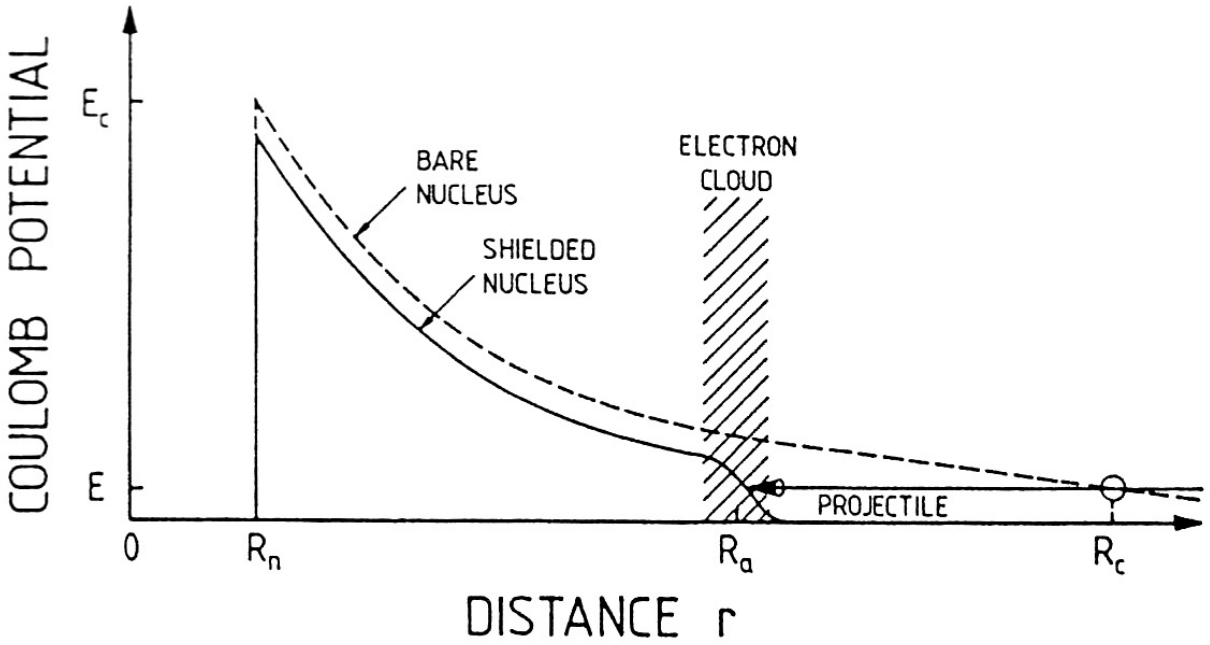
- Target homogeneity is a major issue (dust deposited on solid target)

- New test scheduled in 2012 with windowless gas target



Electron Screening Effect





(Assenbaum et al. Z. Phys. A - Atomic Nuclei 327, 461 468 (1987))

Still not well understood

Beta and EC decay
Influenced by the electron screening in metals

N_0	Nucleus	Host	Measurement	Effect	Reference
1	^{22}Na	Pd	12K and 293K	8.5 %	[Limata 06a]
2	^{22}Na	Al	12K and 293K	No effect	[Ruprecht 08b]
3	^{22}Na	Pd	15K and 293K	3.4 %	[Gang 08]
4	^{7}Be	Pd	Metal at 12K and insulator LiO_2 at 12K	82 %	[Wang 06]
5	^{7}Be	In	Metal at 12K and insulator LiO_2 at 12K	64 %	[Wang 06]
6	^{7}Be	Pd, W, Zr, Ta	Metals at 293K compared to adopted values	No effect	[Limata 06b]
7	^{7}Be	Cu	12.5K and 293K	No effect	[Kumar 08]
8	^{7}Be	C_{60}	5K and 293K	1.5% absolute	[Ohtsuki 07]
9	^{198}Au	Au	12K and 293K	11.8%	[Spillane 07]
10	^{198}Au	Au	10K and 293K	No effect	[Ruprecht 08a]
11	^{198}Au	Au	19K and 293K	No effect	[Goodwin 07]
12	^{198}Au	Al-Au	12.5K and 293K	No effect	[Kumar 08]
13	^{196}Au	Au	10K and 293K	No effect	[Ruprecht 08a]
14	^{64}Cu	Cu	12K and 293K	No effect	[Fallin 08]
15	^{74}As	Ge, Ta	from 250mK to 293K	No effect	[Farkas 09]

A new experiment proposed:

- **Search for superconducting effects**

Nb Tc = 9 K
G. Stoppini, Il Nuovo Cimento 13, 1181 (1991)
Cooper pair = Bose Statistic

- **Minimize systematic error**

^{19}Ne / ^{19}O 5.10^{5} pps 4 AMeV GANIL
Optimized setup (plastics on scalers)
1 hour / 1 hour

- **Measure branching ratios**

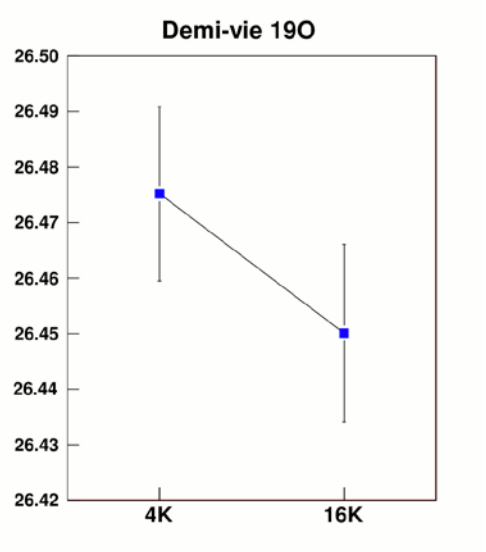
$$ft = f(Q_0', Z)T_{1/2} = \text{const}$$

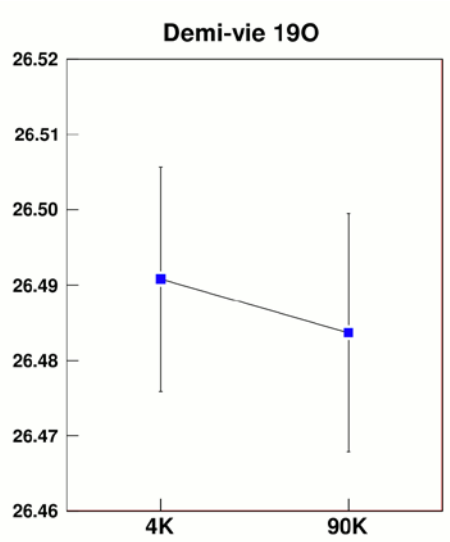
$$\lambda_\beta = \sum_i \lambda^{(i)} \quad \text{or} \quad \frac{1}{T^\beta_{1/2}} = \sum_i \frac{1}{T^{(i)}_{1/2}},$$

$$BR^{(i)} = \frac{\lambda^{(i)}}{\lambda_\beta} \quad \text{or} \quad BR^{(i)} = \frac{T^\beta_{1/2}}{T^{(i)}_{1/2}},$$

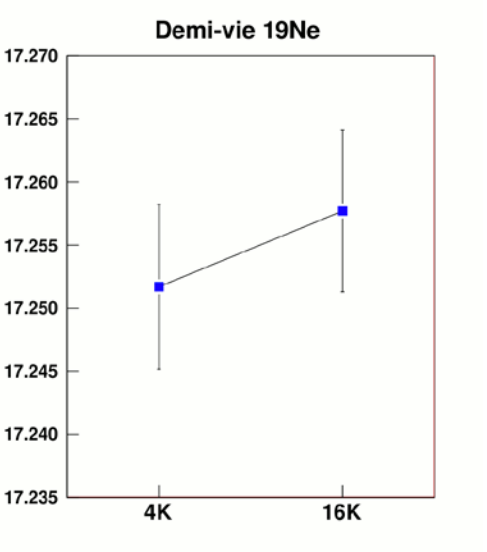
Results

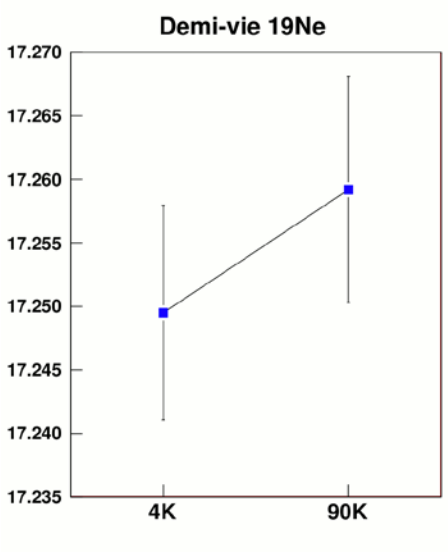
Half-life of ^{19}O – β^- decay





Half-life of ^{19}Ne – β^+ decay

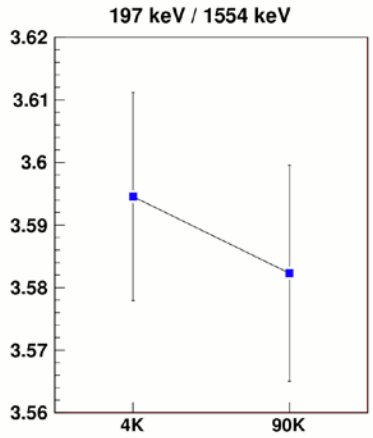


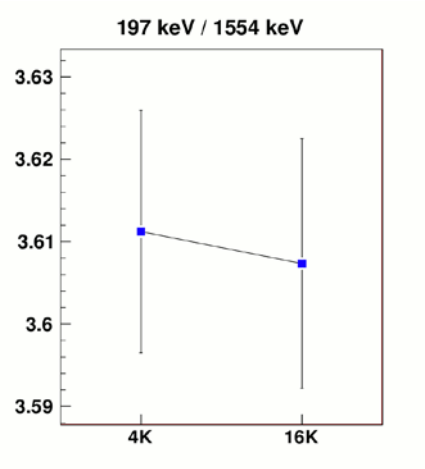


Results

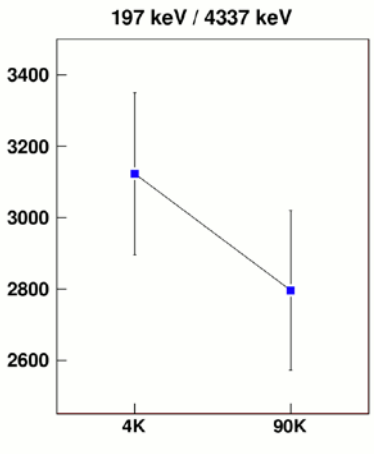
Relative branching-ratios of ^{19}O

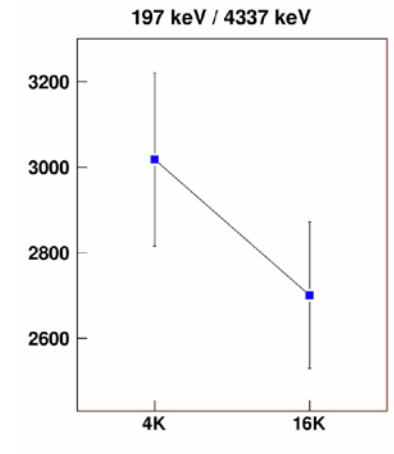
Gamma ray ratio 197keV/1554keV





Gamma ray ratio 197keV/4337keV





Outlook

- Effect observed!

900 eV ^{19}O
400 eV ^{19}Ne

- Smaller than predicted

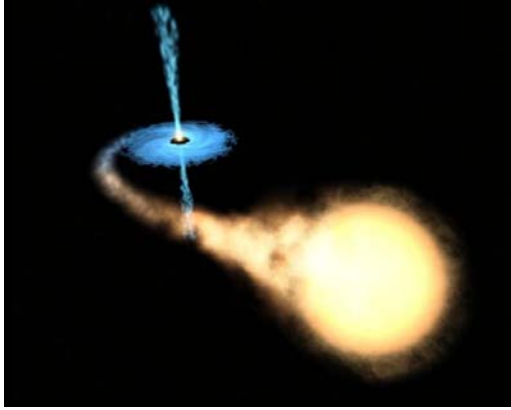
U_{scr}= ~1 or 10 %
of theoretical prediction

- In principle, a factor 10 in precision is possible, if beam intensity higher

Combined half-lives:

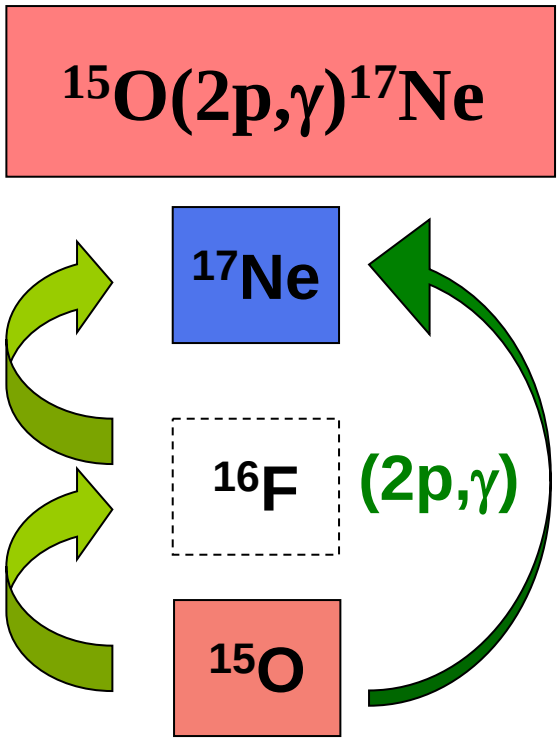
^{19}Ne : 17.254 ± 0.005 s
^{19}O : 26.476 ± 0.010 s

Unbound nuclei



X-ray bursts

J. Gorres *et al.*, Phys. Rev. C51, 392 (1995)
L. Grigorenko et al., Phys. Rev. C72, 015803 (2005)

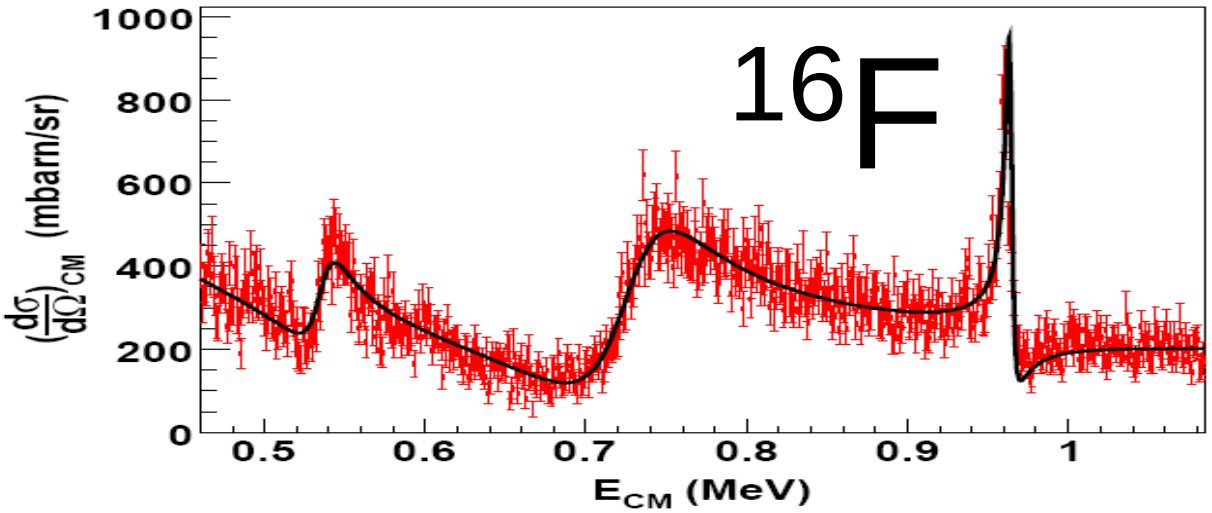


^{15}O

1.2 AMeV 10^6 pps

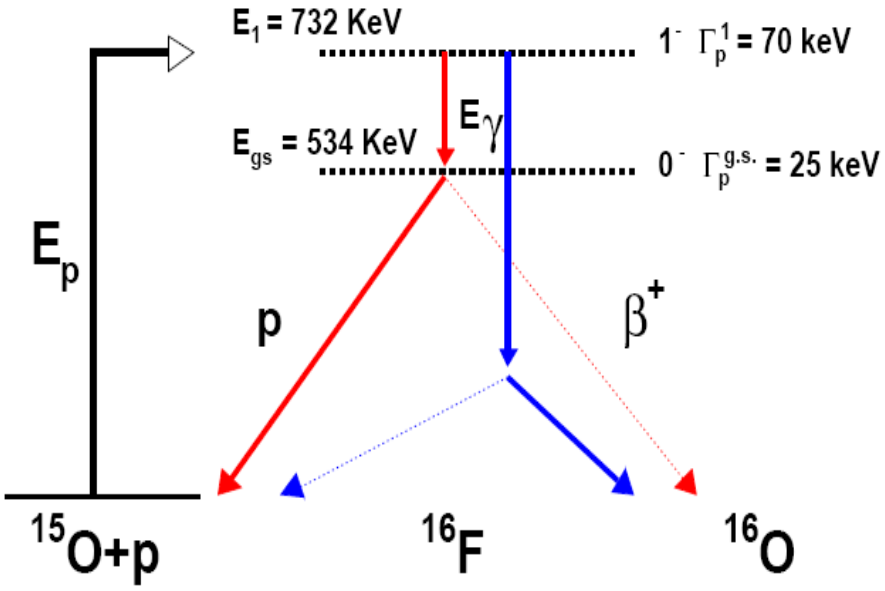
Iulian Stefan Thesis 2007
Tours 2006, Procon 2006
Eprint: nucl-ex/0603020

$H(^{15}O,p)^{15}O$



Longer Lifetime?

$T_{1/2}$ (γ) ~ 10^{-12} s



We used

$$\sigma_{(p,\gamma)(\beta^+)} = \int \sigma_{(p,\gamma)}(E_p, E_\gamma) P_\gamma(E_\gamma) P_{\beta^+}(E_p, E_\gamma) dE_\gamma$$

BW Cross-section to capture a proton with the energy Ep and to emit a gamma with the energy Eγ

Density of the ^{16}F gs

β+ branching ratio

σ ~ 0.1 nb

Thank you

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Alpha-particle capture reactions in inverse kinematics relevant to p-process nucleosynthesis

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