COMITATO UTENTI LNS - 2013

Nuclear Astrophysics at LNS: status and perspectives

ASFIN

Silvio Cherubini

For ASFIN Collaboration

6-Dec-2013

CELEBRATING 20 YEARS

- **1990-1991 C.S. starts thinking of NA**
- **1992 NA group founded at LNS**
- **1993 ASFIN Funded by INFN**

20 years of NA @ LNS

Personal piece of pride: I was there!

ASFIN ACTIVITIES

- **RESEARCH (of course)**
- **TEACHING**

  (European Network of Nuclear Astrophysics Schools – ENNAS)

- **DISSEMINATION**

  (Scientific WeekS LNS and DFA – personal initiatives)

TEACHING 2013

- **Organized Santa Tecla School 2013**
  (two weeks)

- **Partecipation in Russbach school 2013**
  (5 lecturers)

- **Invited lectures at PhD schools**

RESEARCH

Geographics & Technicalities:

- **LNS Activities**
- **Non LNS Activities**
- **THM**
- **Non-THM**

REMARK: also for non-LNS, non-THM activities ALL of Data Analysis always carried out by ASFIN member at LNS.

Publications: « we will do whatever it takes and, I can tell you, it will be enough» (@ M. Draghi)

LNS ACTIVITIES

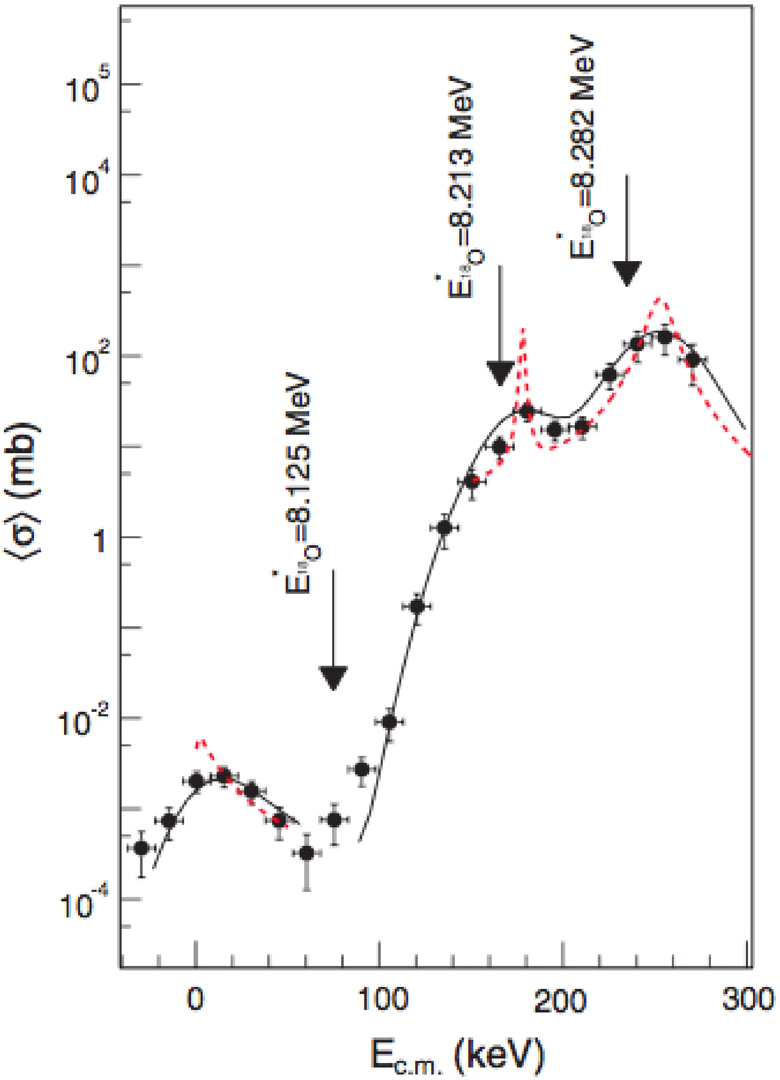
- **Reduced operations due to accelerators temporary problems at LNS (…but Premiale «Astrofisica», already mentioned, C.S.)**

- **Nonetheless: 2 long runs (~ 1 month) performed at TANDEM accelerator (June-July)**

Non-LNS ACTIVITIES

- Laboratori Nazionali Legnaro
- Rez (ANC)
- TAMU
- CNS-RIKEN (THM and non-THM)
- Kazhakstan INP
- …

Neutron induced reactions



Suppression of the centrifugal barrier effects in the off-energy-shell neutron +17O interaction

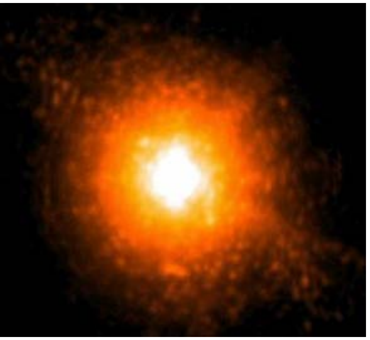
M. GULINO et al.,

PHYSICAL REVIEW C 87, 012801(R) (2013)

published 4 January 2013

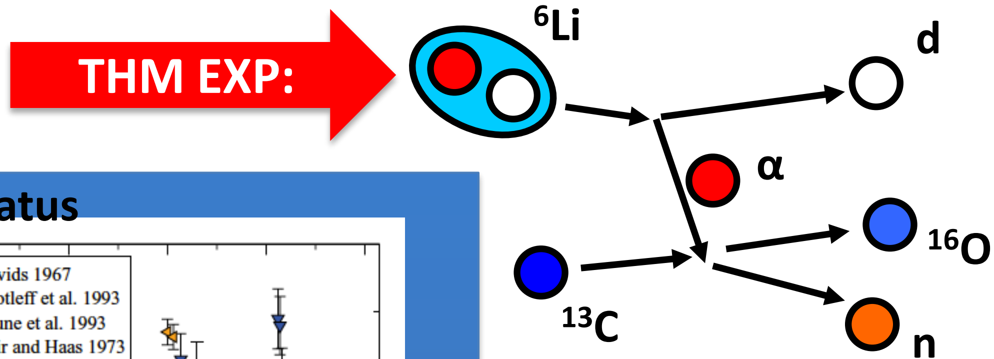
Indirect measurements of the -3 keV resonance in the $^{13}C(\alpha, n)^{16}O$ reaction: the THM approach

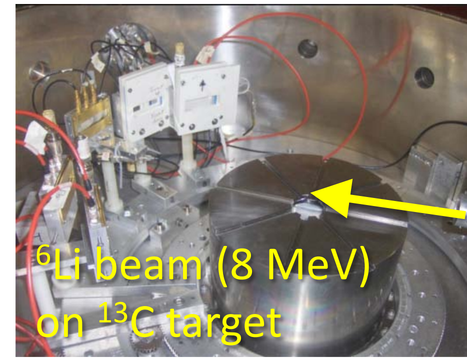
(M. La Cognata)



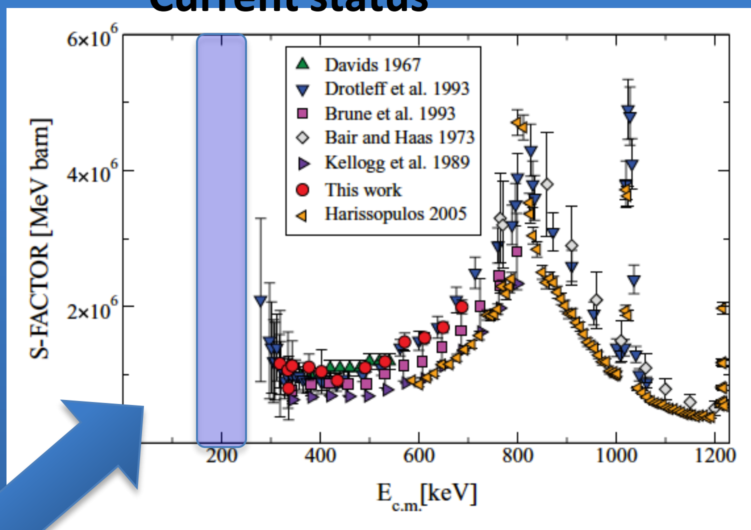
The $^{13}C(\alpha,n)^{16}O$ reaction is the main neutron source for the s-process (slow neutron capture), responsible of the synthesis of most heavy nuclei.

Its cross section must be known between 150 and 230 keV



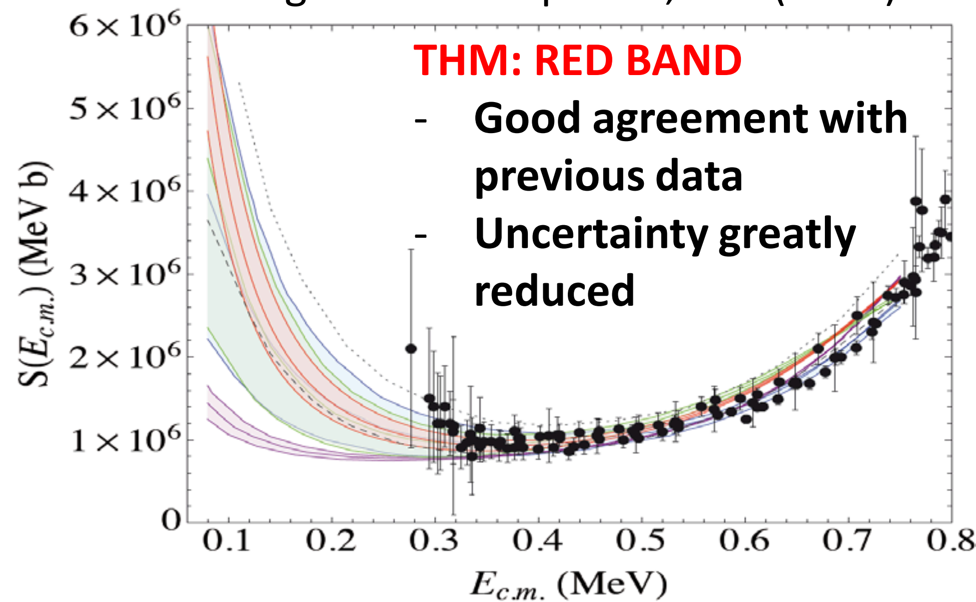


Current status



- No data at astrophysical energies
- Extrapolation subject to big uncertainties owing to the poor data presently available

M. La Cognata et al. ApJ 777, 143 (2013)

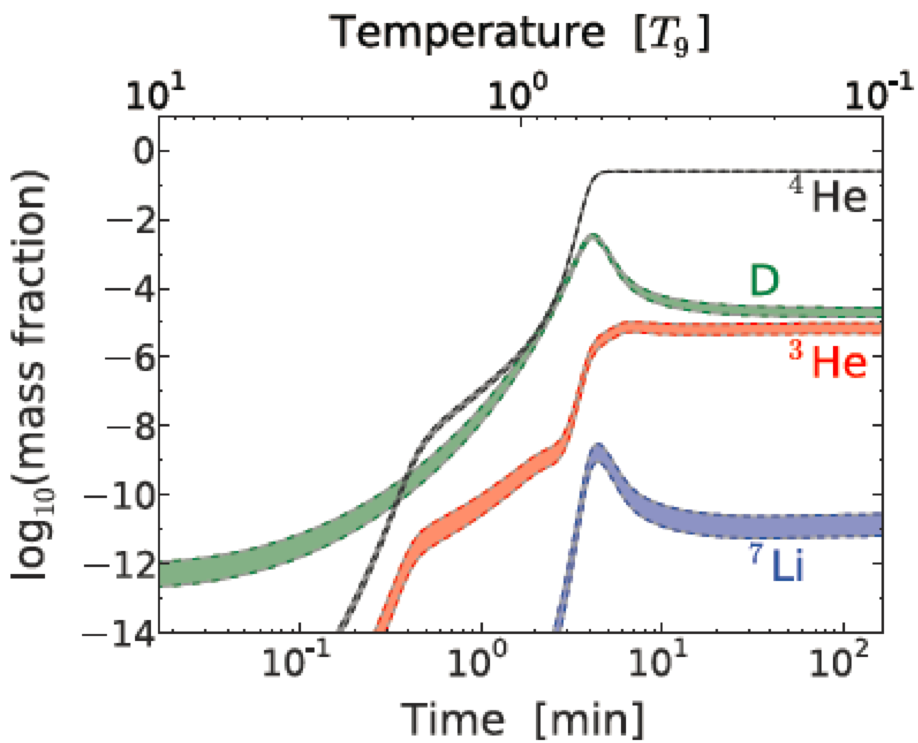


THM: RED BAND

- Good agreement with previous data
- Uncertainty greatly reduced

Applications to primordial Nucleosynthesis SKM code

RGP, C.Bertulani, Spartà et al. 2013



The ^{7}Li(p,α)^{4}He reaction THM rate Was adopted as a physical input for the BBN model (Kawano 1988), in collaboration with Carlos Bertulani togheter with d(d,p)t & d(d,n)^{3}He reaction rates The results are in agreement with Observations (except ^{7}Li) and with results obtained using direct nuclear Inputs.

Figure 7: Calculated BBN abundance of ^{3,4}He, D and ^{7}Li as a function of time and temperature. Black line represents ^{4}He mass fraction, green the deuterium abundance, red the ^{3}He abundance and blue the ^{7}Li abundance. The band error represents the uncertainty in the THM measurements and their influence on the abundances.

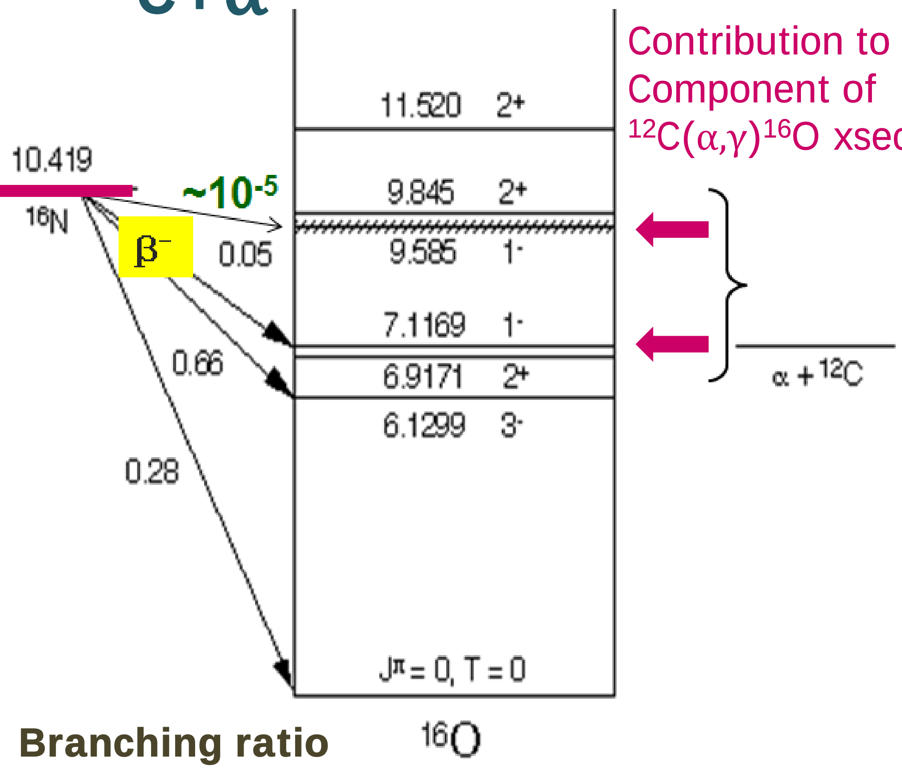
Yields	Direct data	TH d(d,p)t	TH d(d,n)^{3}He	TH ^{3}He(d,p)α	TH ^{7}Li(p,α)^{4}He	TH all	Observation
Y_p	0.2486	$0.2485^{+0.001}_{-0.001}$	$0.2485^{+0.000}_{-0.000}$	$0.2486^{+0.000}_{-0.000}$	$0.2486^{+0.000}_{-0.000}$	$0.2485^{+0.001}_{-0.002}$	$0.2565 \pm 0.006^{(a)}$
D/H ($\times 10^{-5}$)	2.645	$2.621^{+0.079}_{-0.048}$	$2.718^{+0.077}_{-0.036}$	$2.645^{+0.002}_{-0.007}$	$2.645^{+0.000}_{-0.000}$	$2.692^{+0.177}_{-0.070}$	$2.82 \pm 0.26^{(b)}$
^{3}He/H ($\times 10^{-6}$)	9.748	$9.778^{+0.216}_{-0.078}$	$9.722^{+0.052}_{-0.092}$	$9.599^{+0.050}_{-0.003}$	$9.748^{+0.000}_{-0.000}$	$9.441^{+0.511}_{-0.466}$	$\geq 11. \pm 2.^{(c)}$
^{7}Li/H ($\times 10^{-10}$)	4.460	$4.460^{+0.001}_{-0.001}$	$4.470^{+0.010}_{-0.006}$	$4.441^{+0.190}_{-0.088}$	$4.701^{+0.119}_{-0.082}$	$4.683^{+0.335}_{-0.292}$	$1.58 \pm 0.31^{(d)}$

Measurement of ^{16}N β-delayed α decay

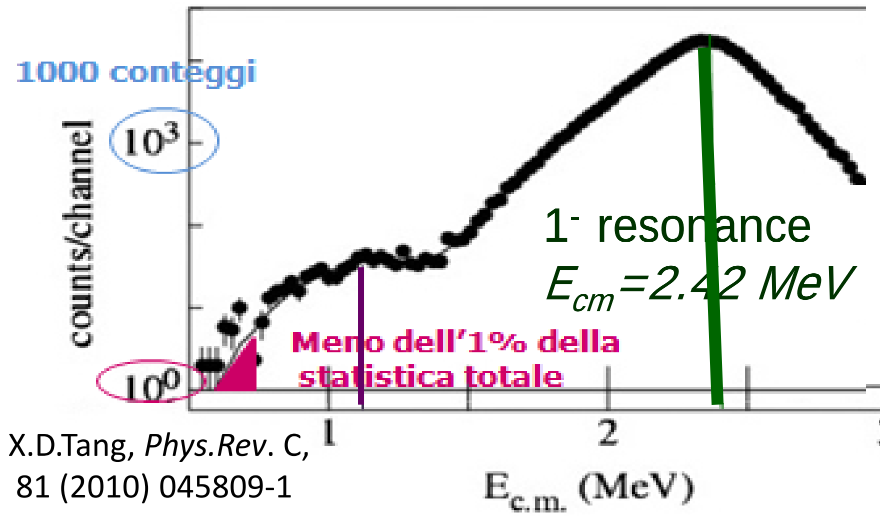
Two-step decay

$^{16}N \xrightarrow{\beta} {}^{16}O \longrightarrow {}^{12}C + \alpha$

Contribution to E_1 Component of $^{12}C(\alpha,\gamma)^{16}O$ xsec



Branching ratio E_{cm}=2.42 MeV: (1.20± 0.05)x10^{-5}



X.D.Tang, *Phys.Rev*. C, 81 (2010) 045809-1

Destructive interference peak between 1$^-$ states
E_{cm}=1.1 MeV ⬇

Peak height $\propto S_{E1}(300\ \mathrm{keV})$

⬇

E_1 component of xsec of $^{12}C(\alpha,\gamma)^{16}O$ reaction dominated by subthreshold resonance E_{cm}= - 45keV

TPC EXPERIMENT (S.C.)

In a study of the ^{16}N β−delayed α decay, three aspects are important:

(1)a particles with energies down to 0.6 MeV have to be detected in coincidence with ^{12}C ions of even lower energies (0.1 MeV). Any significant energy loss of the outgoing particles in the catcher foil will deform the shape of the spectrum.

(2) If a particle, emitted from the foil, is stopped in the support frame, only a part of the energy is deposited in the gas. Such events must be clearly separated from the true coincidence events producing the interference peak.

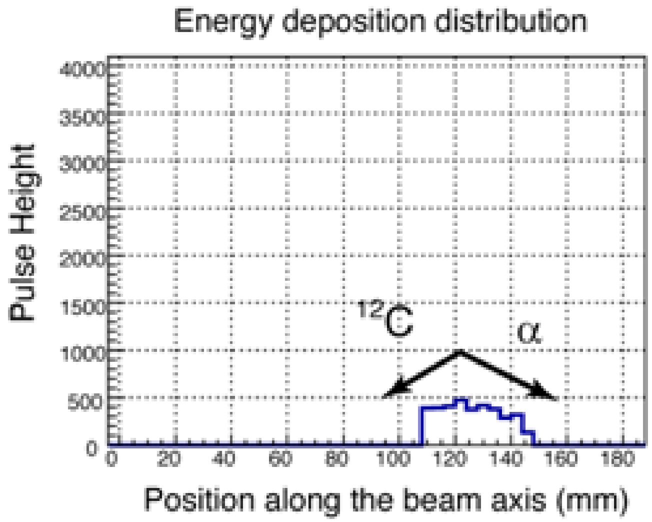
(3) The detection efficiency must be constant over the energy range from 0.2 MeV to 2 MeV."

1), 2) No foil, no frame: NO PROBLEMS

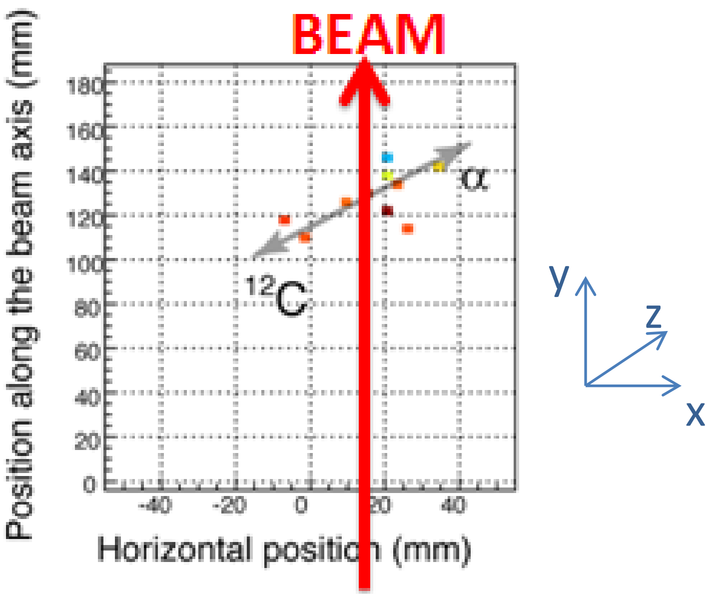
3) Monitor the energy response of the detector event by event

X. D. Tang *et al.* *Phys Rev Lett 99 052502 (2007)*

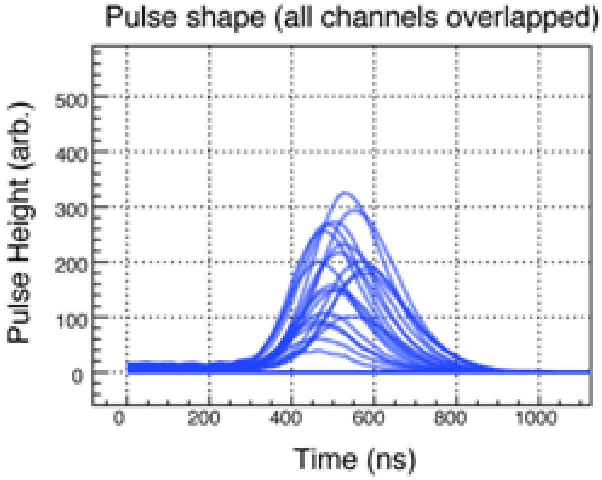
1st candidate event of decay



Energy loss in the TPC along beam direction



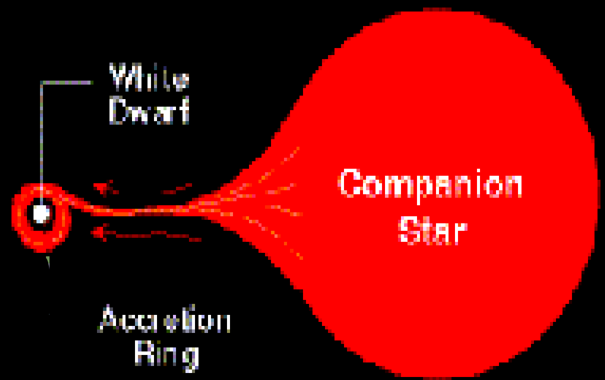
Projection on plane xy



ADC CAEN V1740

ASFIN+ M. Lattuada, A. Di Pietro, P. Figuera,
D. Torresi
M. Mazzocco

A NOVA MICKEY MOUSE PICTURE AND $^{18}F(p,\alpha)^{15}O$



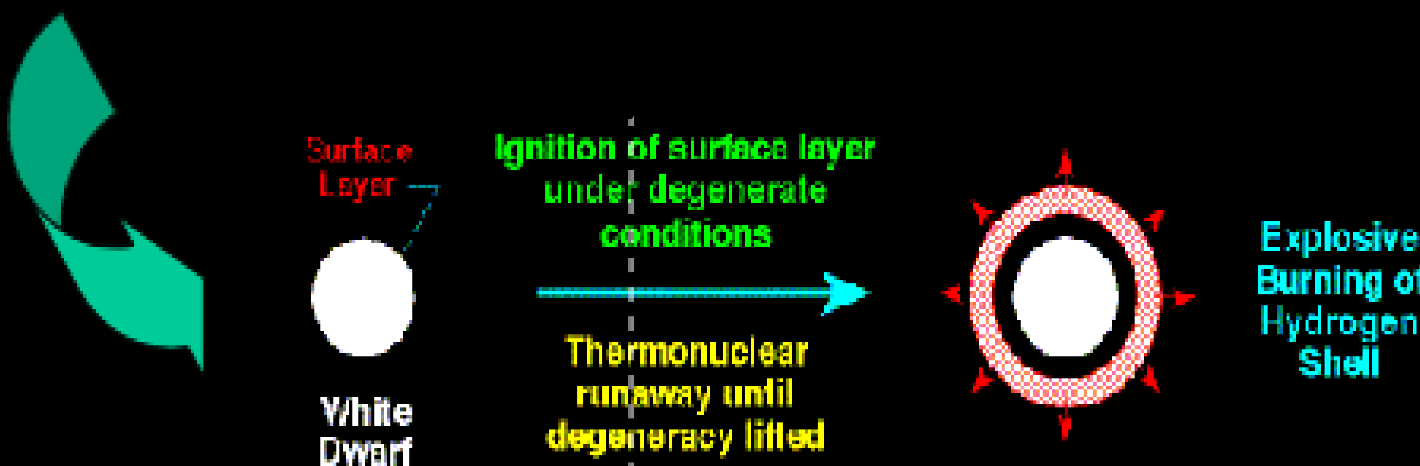
Thin hydrogen surface layer accumulated on white dwarf through accretion ring

Observed γ- rays come from e^+e^-

e^+ come from ^{18}F decay mostly

At novae temperatures (100 - 500 keV) ^{18}F can be mainly destroyed by

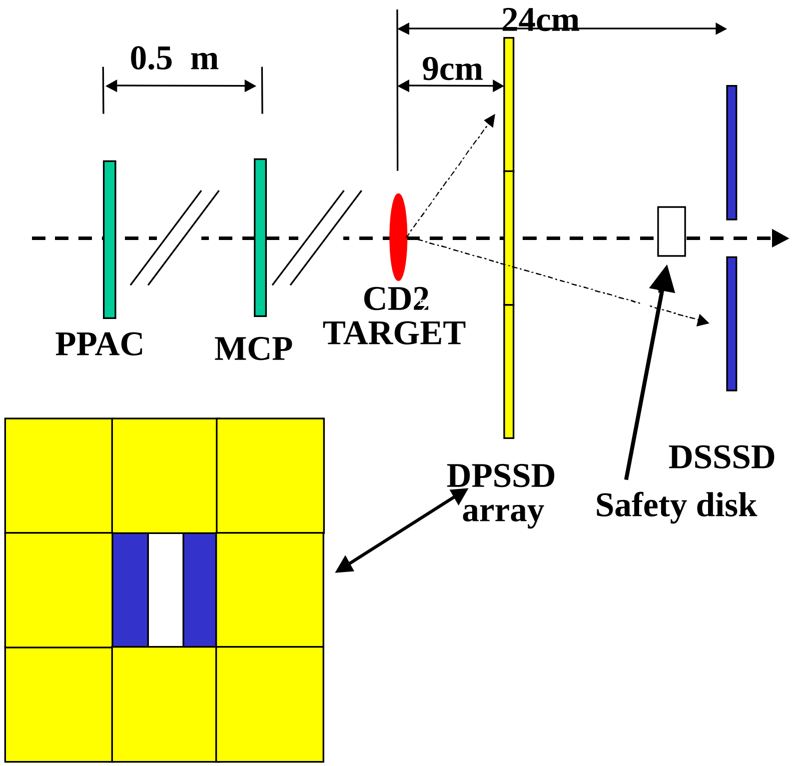
$^{18}F(p,\alpha)^{15}O$

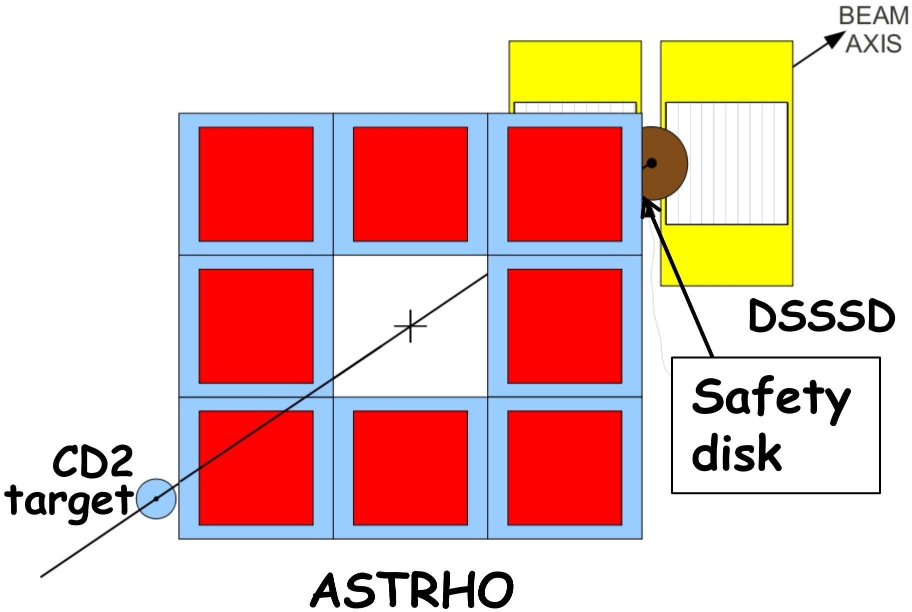


For the star energetics this are peanuts!

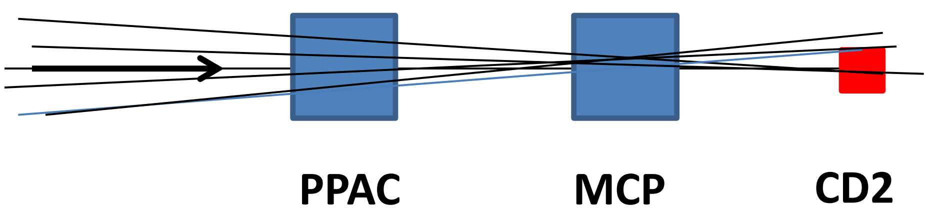
EXPERIMENTAL SETUP

(other than CRIB.....)

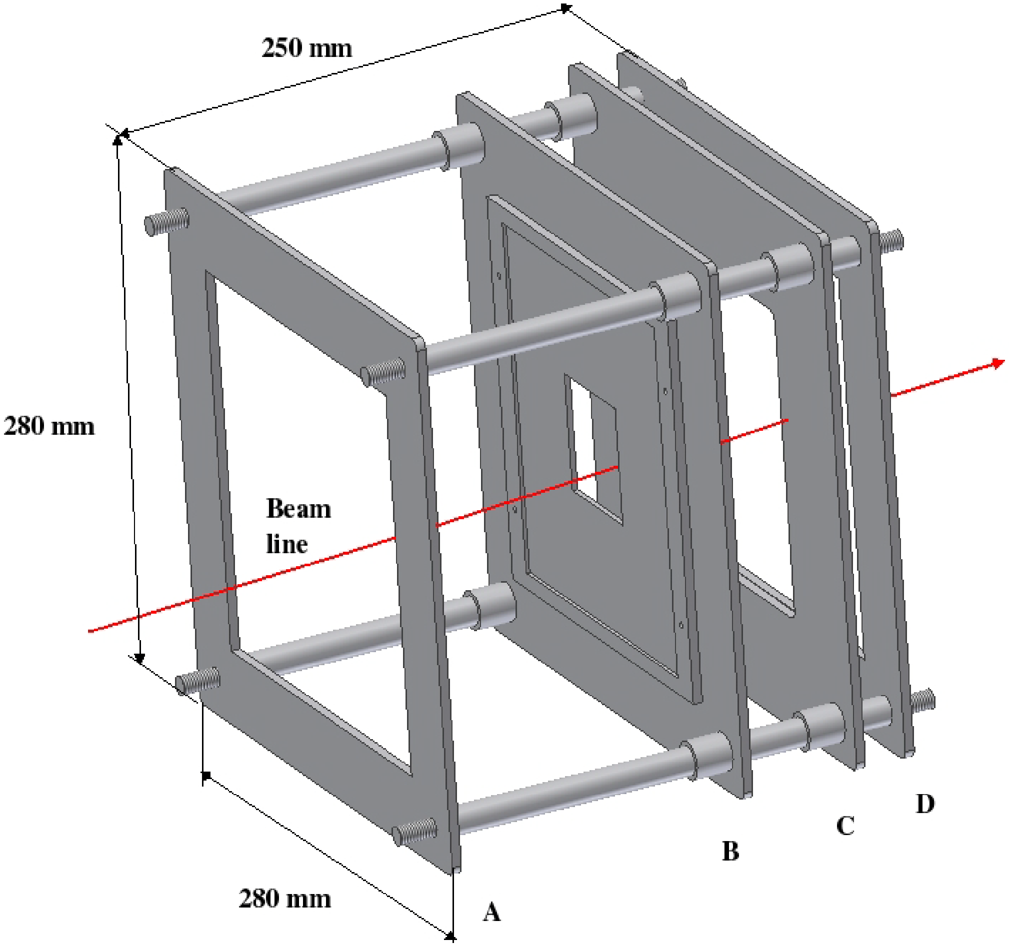


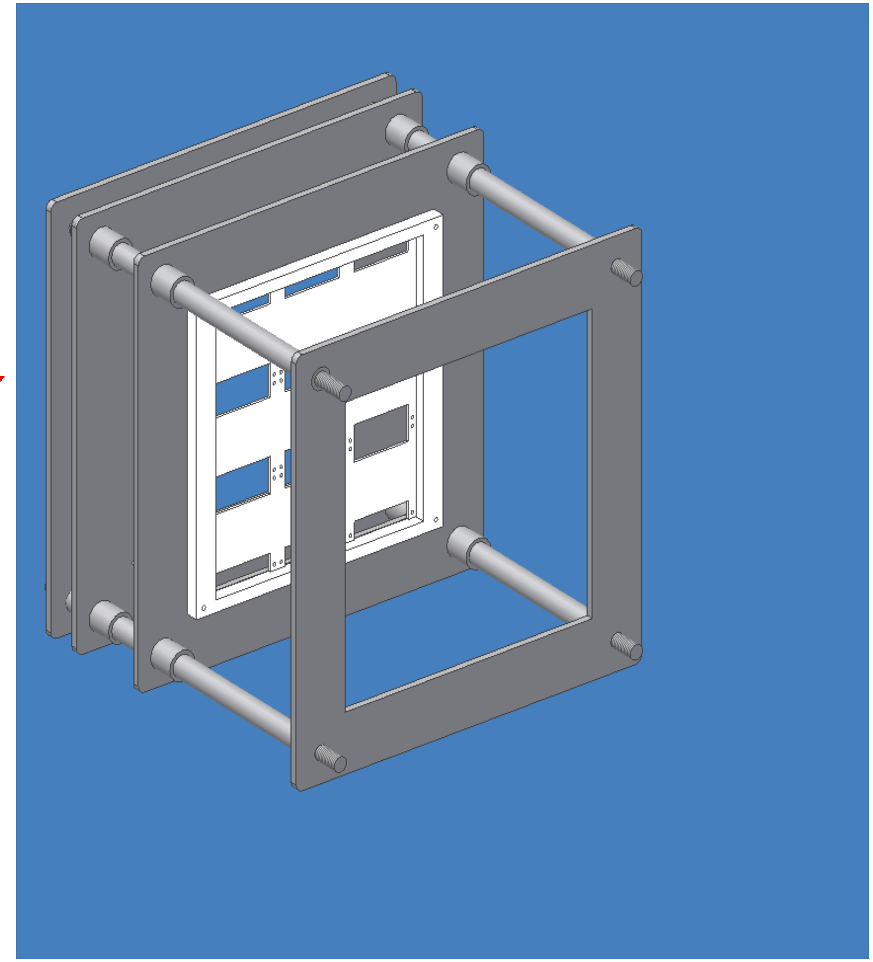


ASTRHO:
Array of Silicons for TRojan HOrse

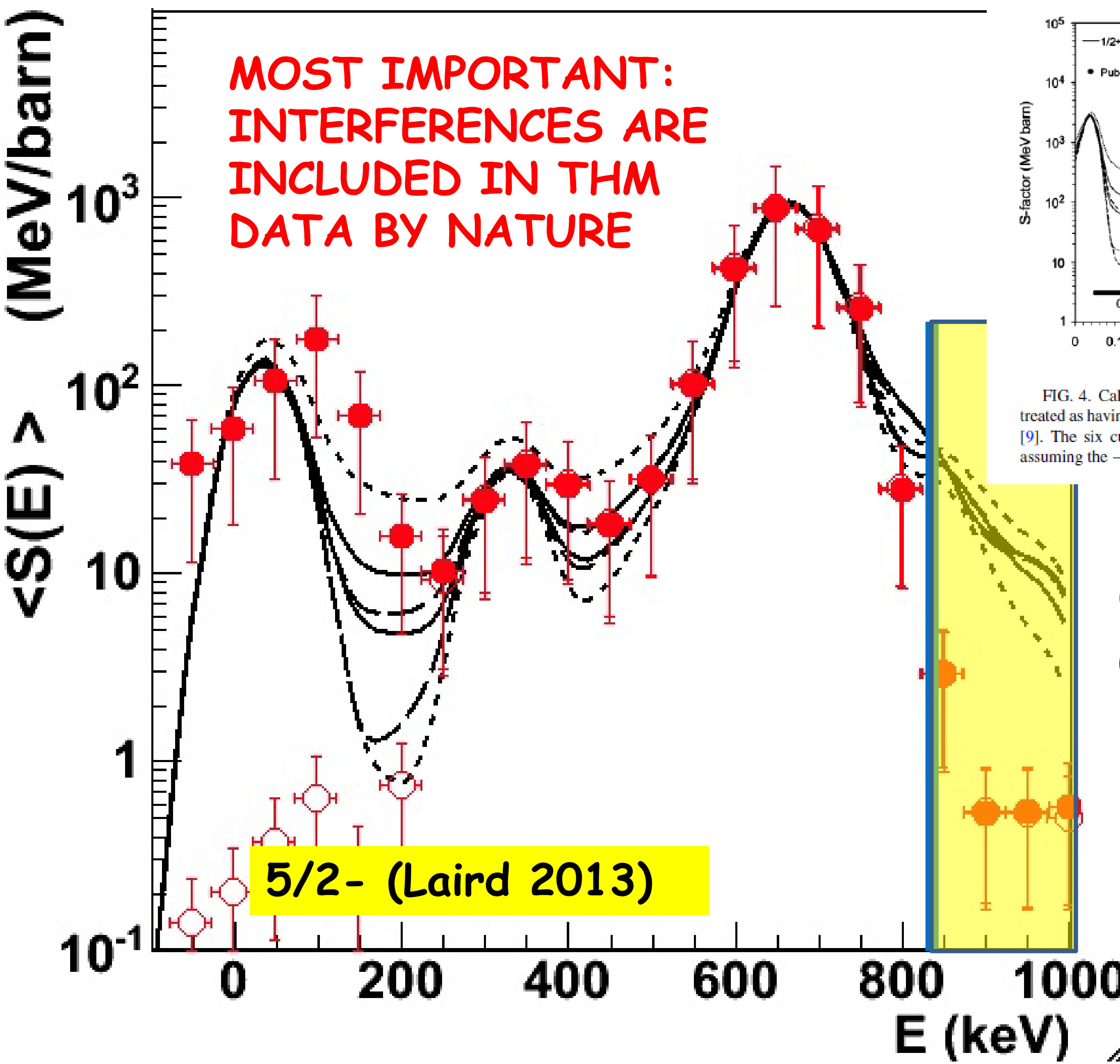


Beam track reconstruction





ASTRHO and the DSSSD were hosted in a mechanical system that allowed for easy movement of the detector holder plates



C. E. BEER *et al.*

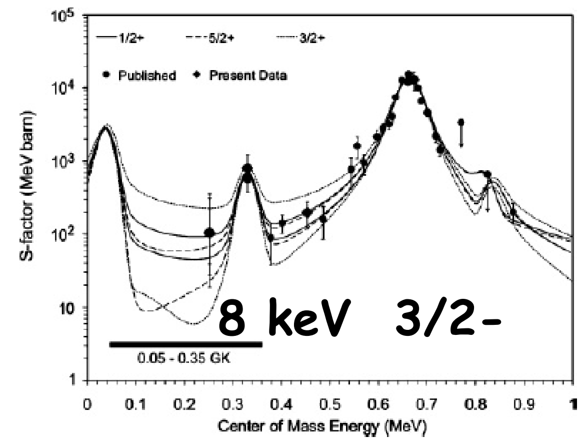


FIG. 4. Calculated $^{18}F(p,\alpha)^{15}O$ S factors with the 8 keV state treated as having a spin-parity of $3/2^-$ using the Adekola parameters [9]. The six curves correspond to the upper and lower S factors, assuming the −121 keV resonance to be $1/2^+$, $5/2^+$, or $3/2^+$.

THM data

C.E. Beer, Phys. Rev. C 83, 042801(R) (2011)
Smeared to THM resolution

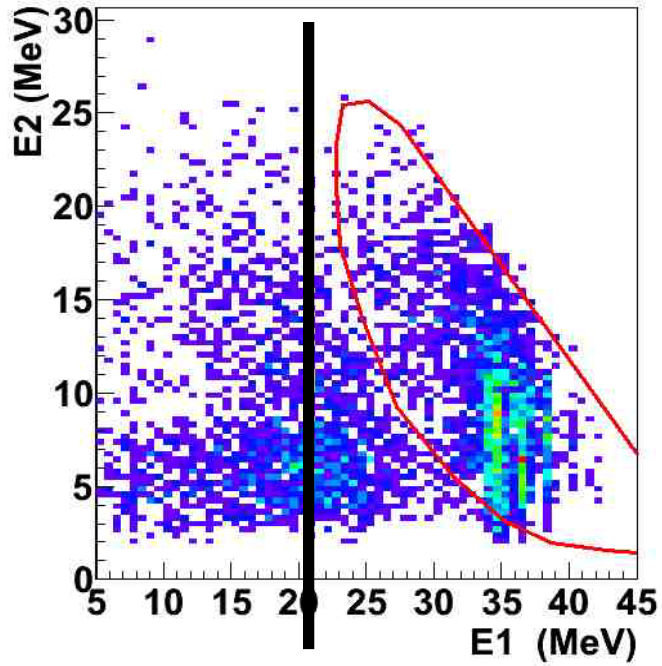
Q-VALUE SPECTRUM

$^{18}F+d \rightarrow ^{15}N+a+p$ @ q=4.194

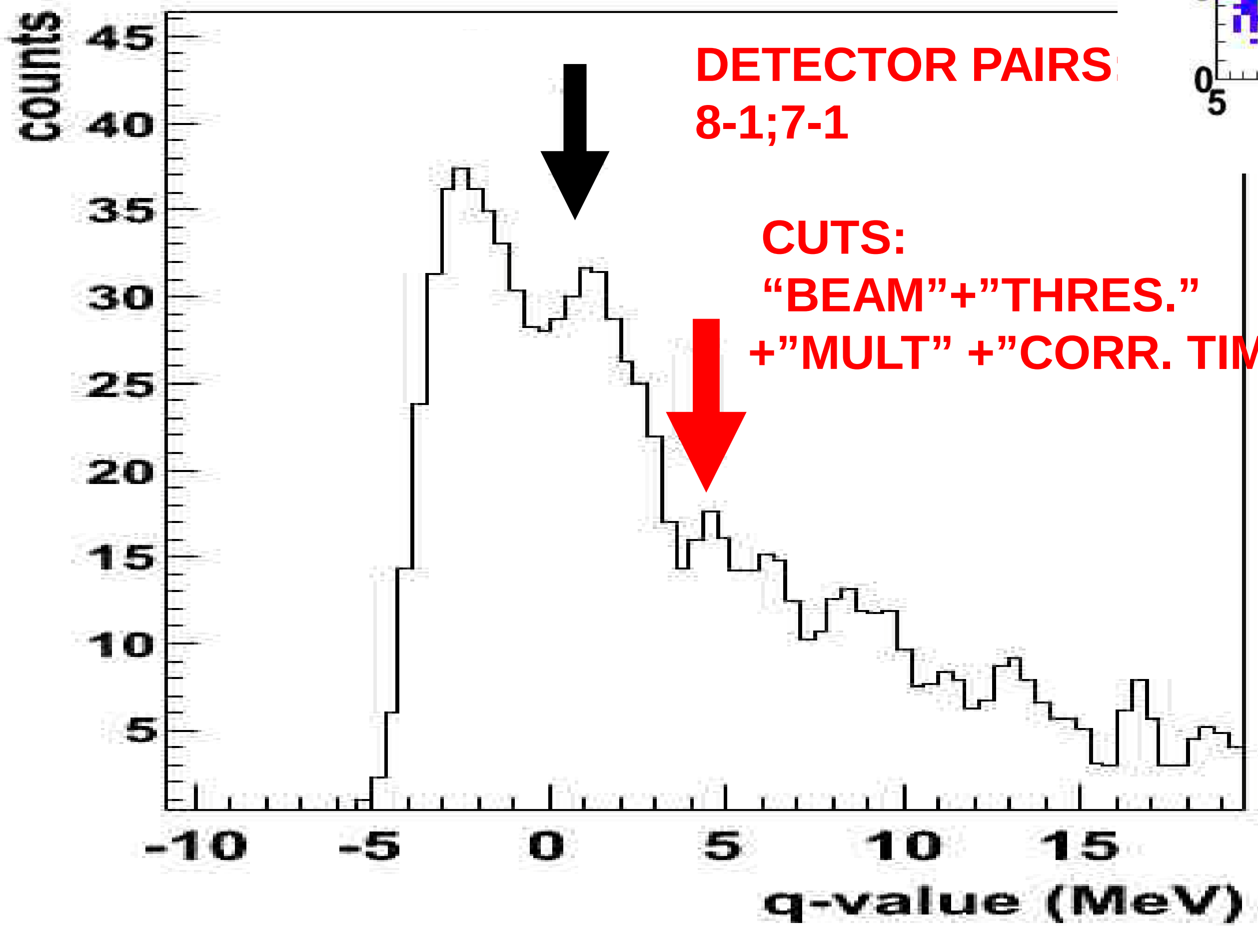
$^{18}F+d \rightarrow ^{15}O+a+n$ @ q=0.658

$^{18}F+d \rightarrow ^{18}O+p+p$ @ q=0.213

$^{18}F+d \rightarrow ^{18}F+p+n$ @ q=-2.225



DETECTOR PAIRS: 8-1;7-1



CUTS:
"BEAM"+"THRES."
+"MULT" +"CORR. TIME"

PERSPECTIVES

- **COME PRIMA/ PIÙ DI PRIMA/ T H M**
- **N-A interaction**
- **Super ASTRHO (premiale)**

CREW

S. Romano, S.C., R. G. Pizzone, (R. Naz./Loc.)

L. Lamia, A. Tumino, M. Gulino, S. Hayakawa,

M. La Cognata, L. Sergi, G. Rapisarda,

N. Puglia, S. Palmerini, L. Guardo, R. Spartà, I. Indelicato

+

C. SPITALERI