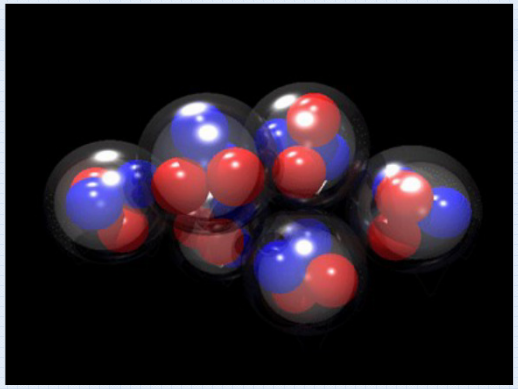
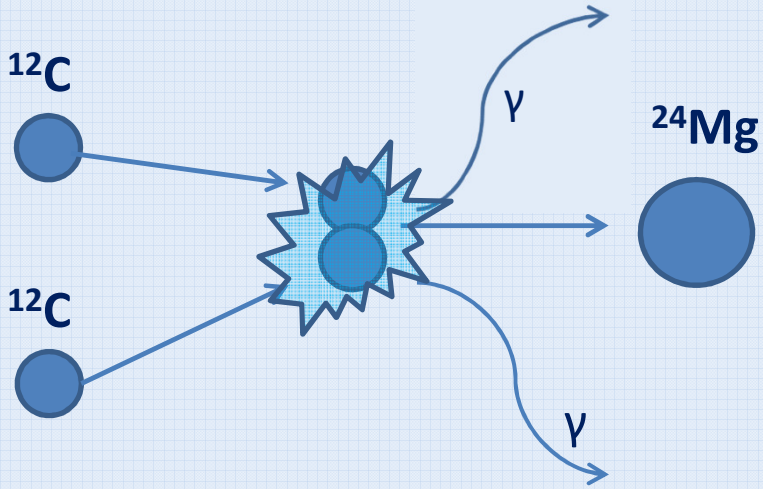


Search for ^{24}Mg resonances inside the Gamow window for ^{12}C+^{12}C fusion



Neven Soić, Ruđer Bošković Institute, Zagreb, Croatia

Collaborators

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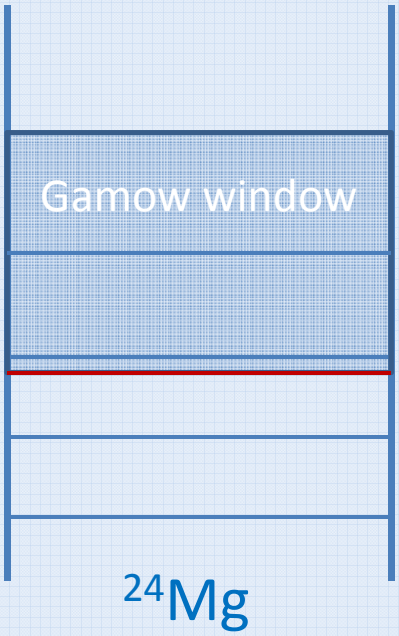
- 3 experiments performed, 1 proposal approved at INFN - LNL
- Objective: search for $^{12}C+^{12}C$ resonances at ^{24}Mg excitations 15 -20 MeV and their full characterization: excitation energy, width, spin, parity, partial decay widths
- Low energy data for $^{12}C+^{12}C$ fusion reaction: quiescent burning of massive starts, super-AGB stars, super-bursts and supernovae type Ia

Important new result is even observation of the 0^+ state at these excitations which decay into $\alpha+^{20}Ne$ and/or $^{1}H+^{23}Na$

20 MeV

$E_{thr}(n+^{23}Ne) = 16.532$ MeV
$E_{thr}(\alpha+\alpha+^{16}O) = 14.044$ MeV
$E_{thr}(^{12}C+^{12}C) = 13.931$ MeV
$E_{thr}(^{1}H+^{23}Na) = 11.692$ MeV
$E_{thr}(\alpha+^{20}Ne) = 9.313$ MeV



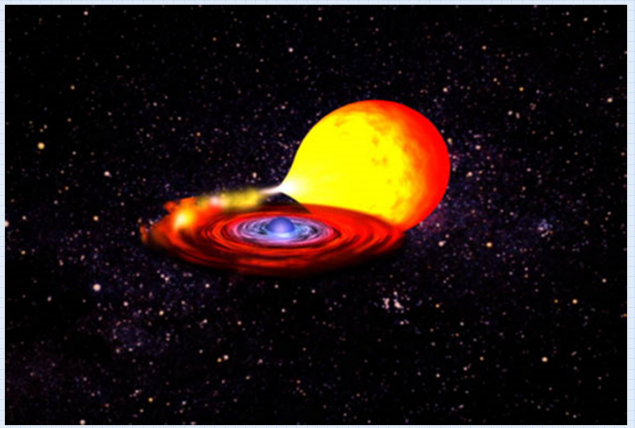
Explosive phenomena in binary systems

SNIa: initiates thermonuclear runaway on white dwarf

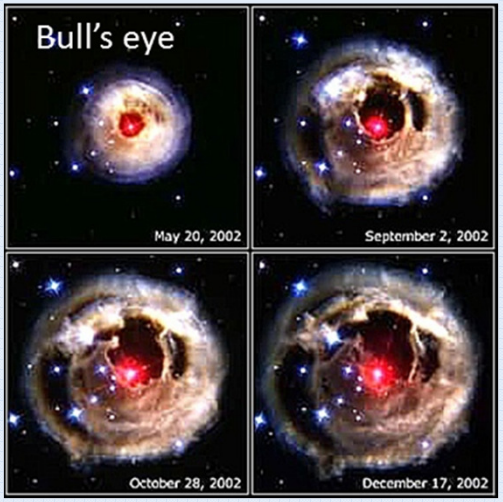
temperature 0.5 - 1.2x10^9 K → E_{cm}=1.5-3.3 MeV

Super-bursts: trigger of ^{12}C ignition

up to 2.5x10^9 K - 5.7 MeV



Stellar outbursts



Massive stars:^{12}C+^{12}C fusion is differentiating between the evolutionary paths leading to either white dwarf or heavy elements burning stages

The most relevant quantity: total reaction fusion rate

$^{12}C + {}^{12}C \rightarrow {}^{24}Mg + \gamma$

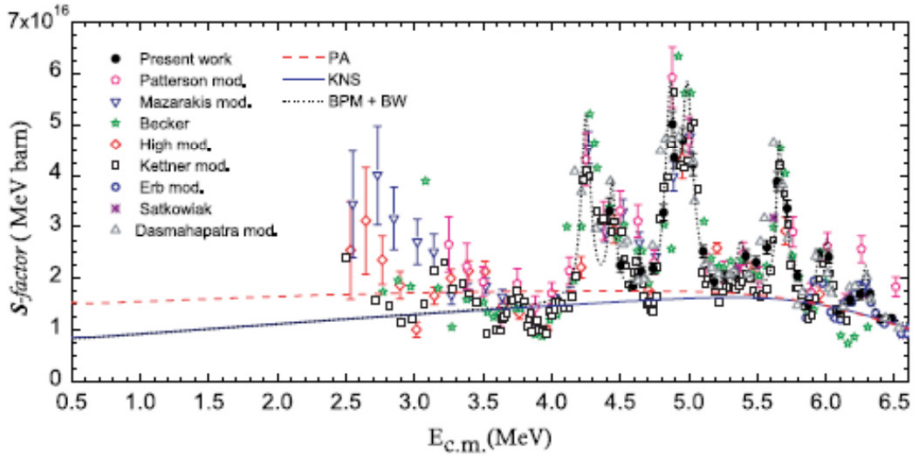
$^{12}C + {}^{12}C \rightarrow {}^{20}Ne + \alpha$

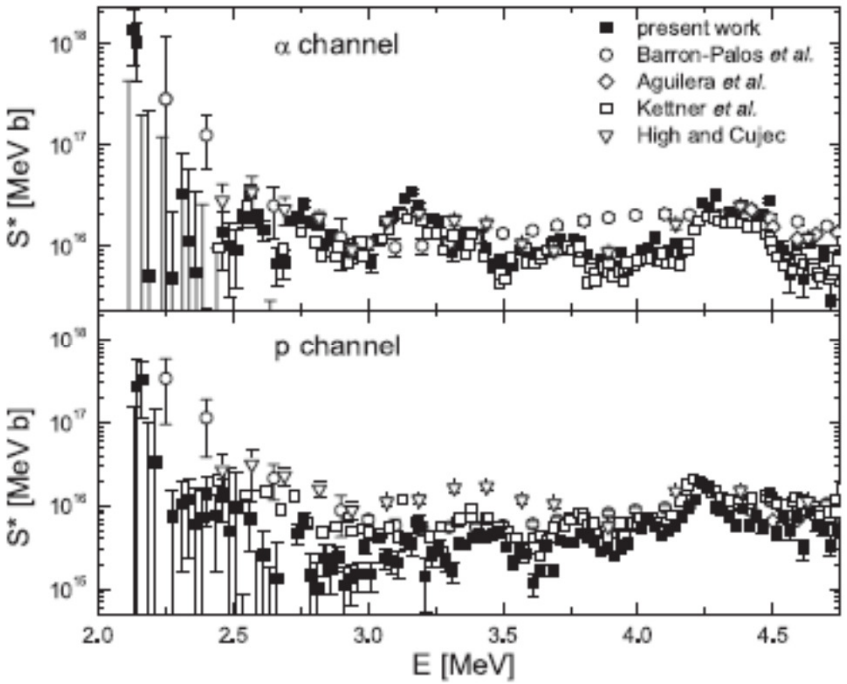
$^{12}C + {}^{12}C \rightarrow {}^{23}Na + p$

$^{12}C + {}^{12}C \rightarrow {}^{23}Mg + n$

Existing data show large discrepancies
Low energy resonance ?

E. F. Aguilera et al, Phys. Rev. C 73 (2006) 064601
T. Spillane et al, Phys. Rev. Lett. 98 (2007) 122501





Experiment at INFN – LNS

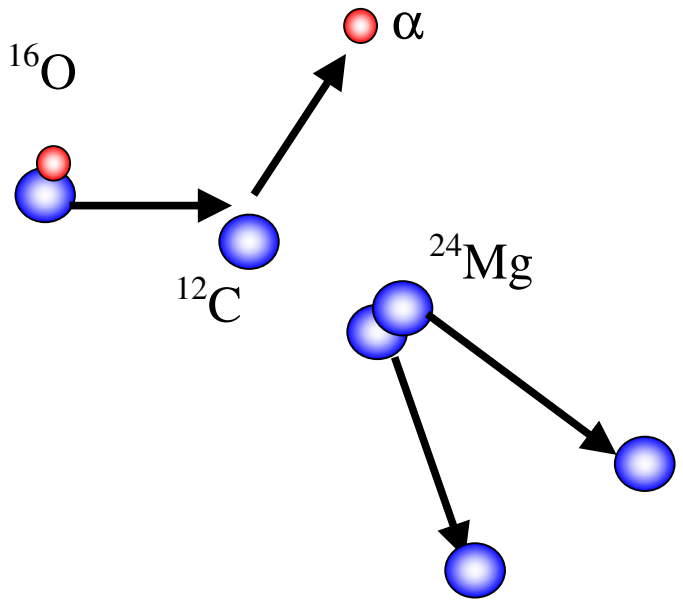
Coincident detection of 2 reaction products

$^{12}C + {}^{16}O \rightarrow {}^{4}He + {}^{12}C + {}^{12}C$ Q=-7.16 MeV $E_{thr}(^{24}Mg)$=13.93 MeV

$\rightarrow {}^{4}He + {}^{16}O + {}^{8}Be$ Q=-7.37 MeV $E_{thr}(^{24}Mg)$= 14.14 MeV

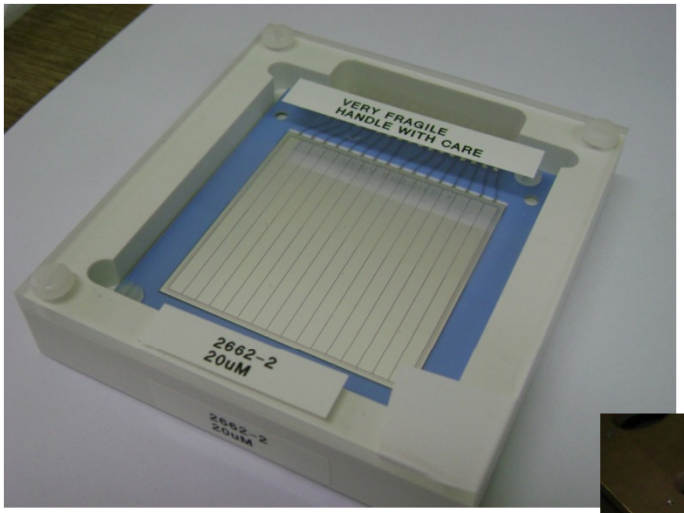
$\rightarrow {}^{4}He + {}^{20}Ne + {}^{4}He$ Q=-2.54 MeV $E_{thr}(^{24}Mg)$= 9.31 MeV

$\rightarrow {}^{4}He + {}^{23}Na + {}^{1}H$ Q=-4.92 MeV $E_{thr}(^{24}Mg)$= 11.69 MeV

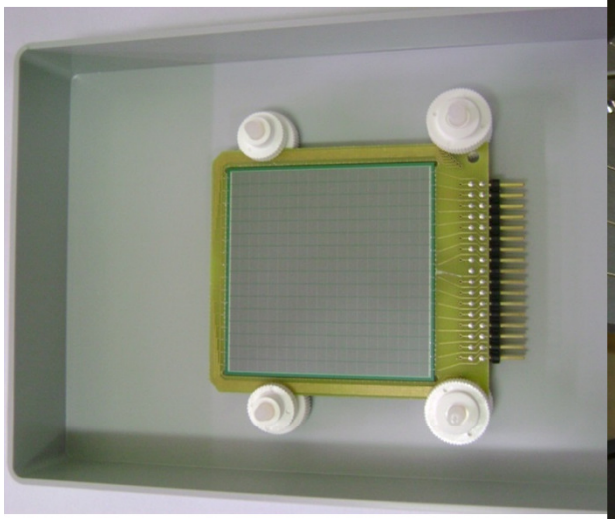


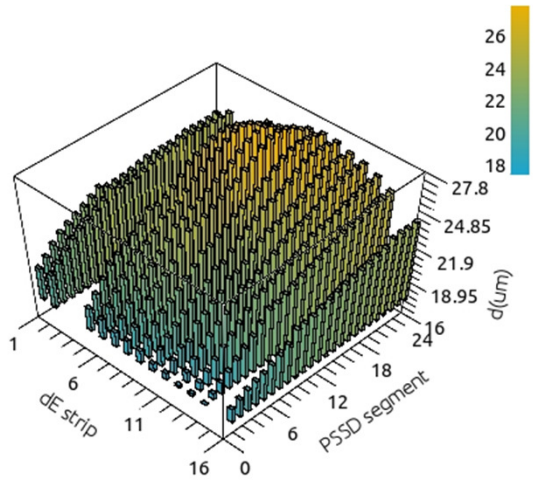
^{16}O beam energy 90 MeV

11 days of beam-time



Detector telescopes: 50 x 50 mm^2
20 µm SSSD + 1000/500 µm PSD & DSSD
Particle identification from p to ^{12}C

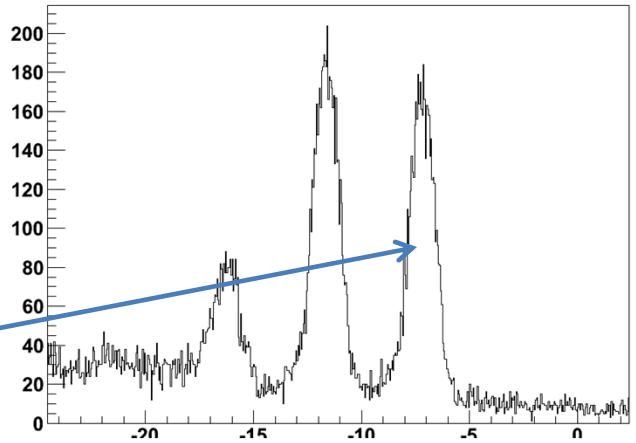




Work in progress:

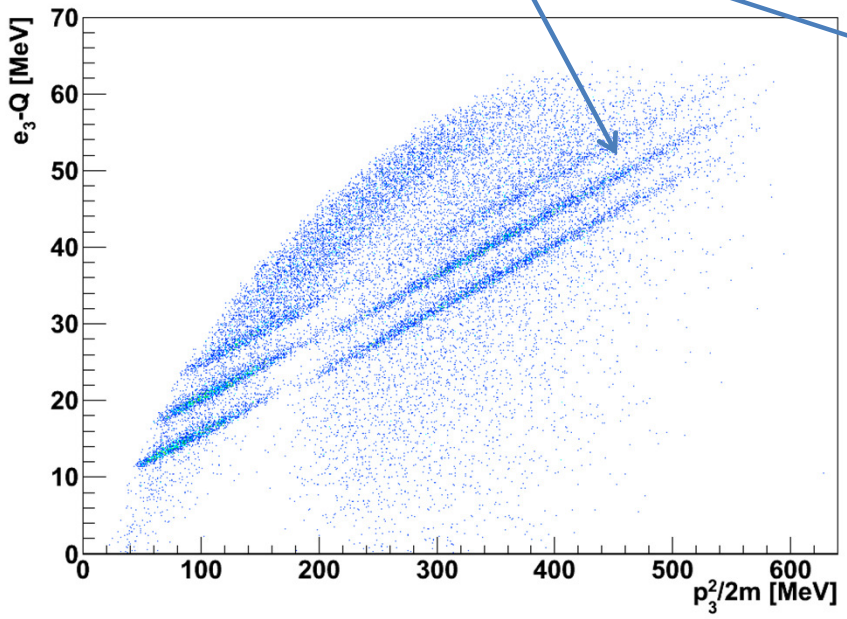
Calibration, re-calibration, calibration checks

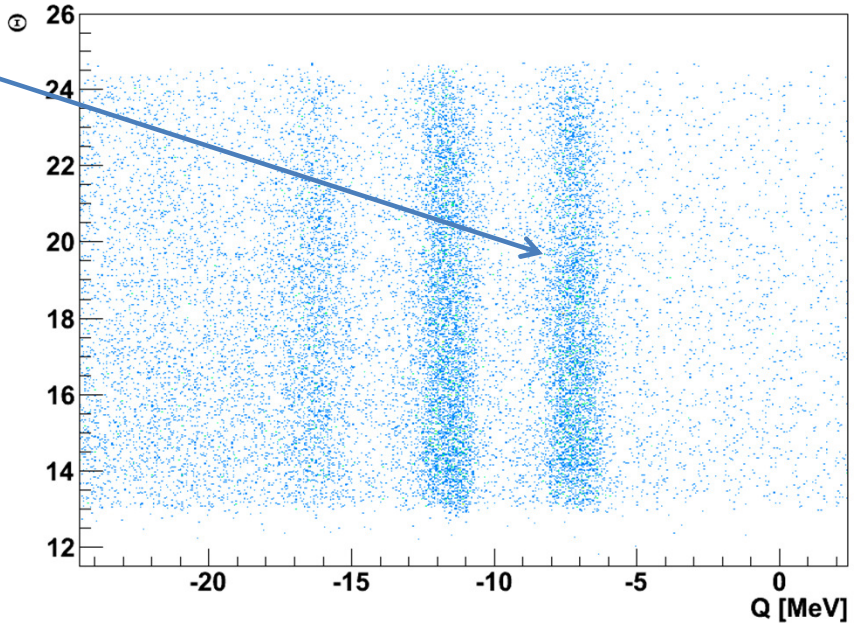
Thickness profile of the SSSD: 17 – 27 µm

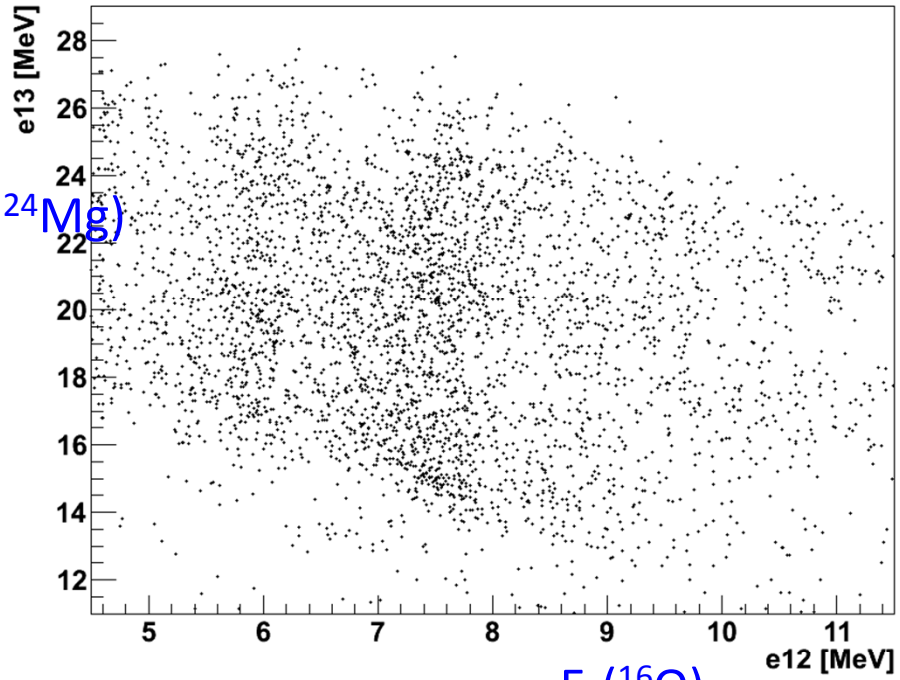


reaction identification

$^{12}C(^{16}O\ ,^{4}He+^{12}C\ )^{12}C$





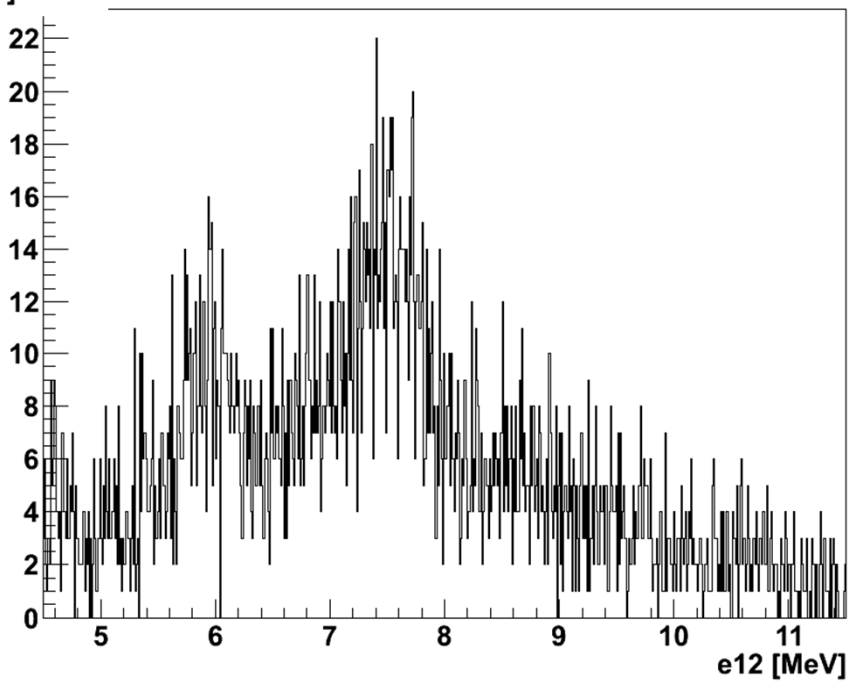


$E_x(^{24}Mg)$

$E_x(^{16}O)$

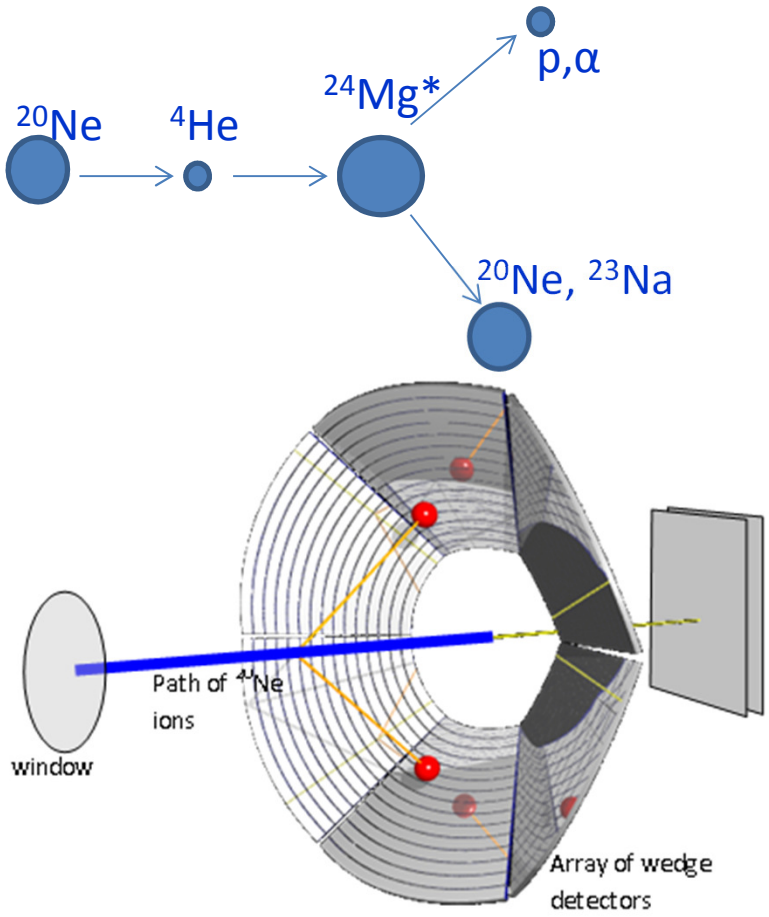
The first excitation energy spectra
very preliminary results

^{16}O excitation spectrum



Experiment at GANIL

- Resonant scattering technique: heavy beam particle into thick gas target - $^{20}Ne + {}^{4}He \rightarrow {}^{24}Mg^* \rightarrow \alpha + {}^{20}Ne, \alpha + {}^{20}Ne^*$



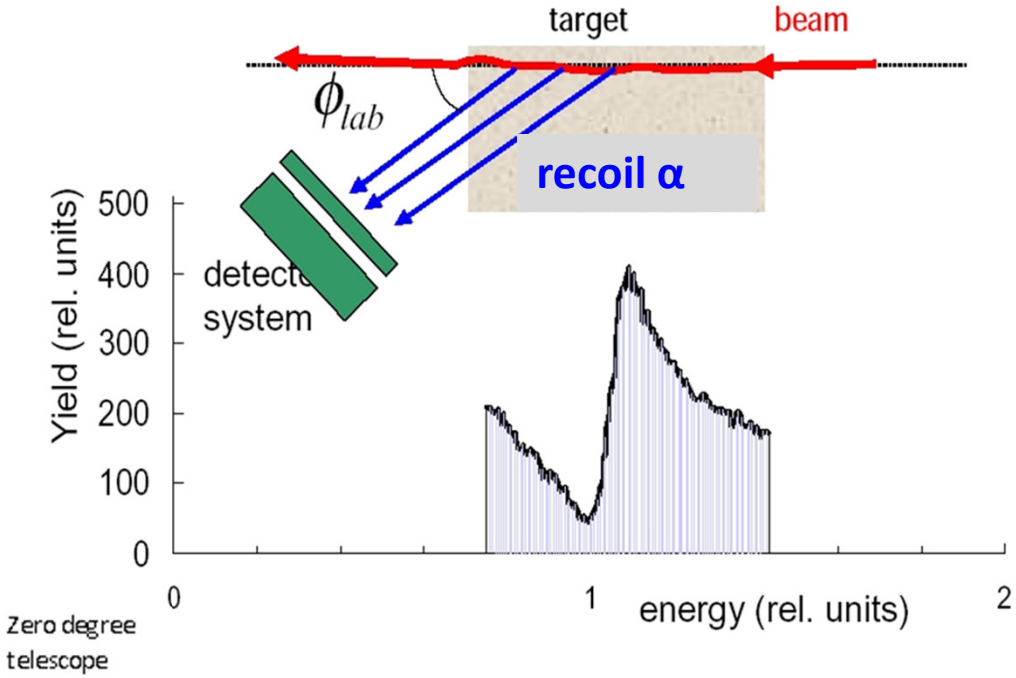
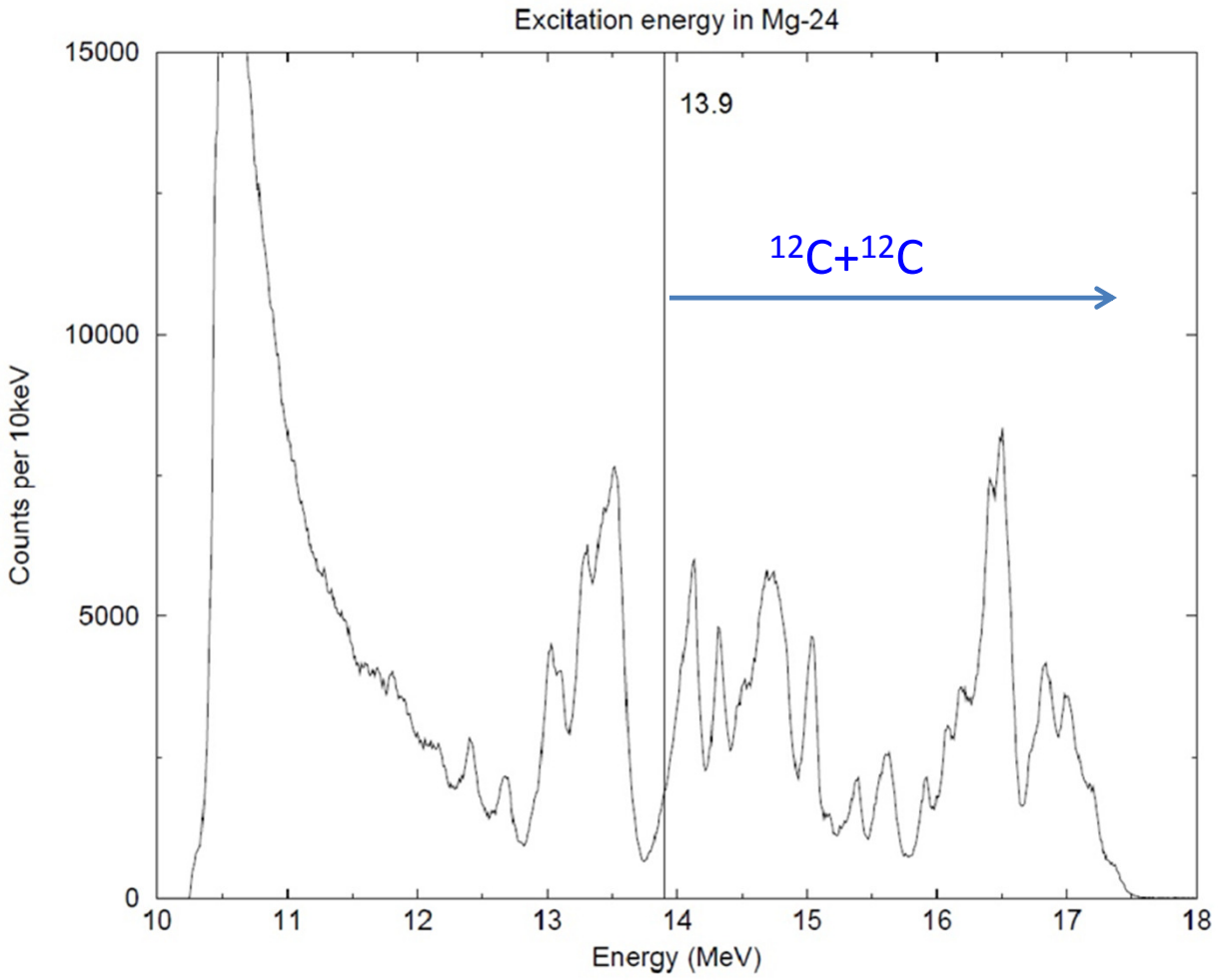


Fig. 3. The proposed experimental arrangement to be placed within the gas volume.

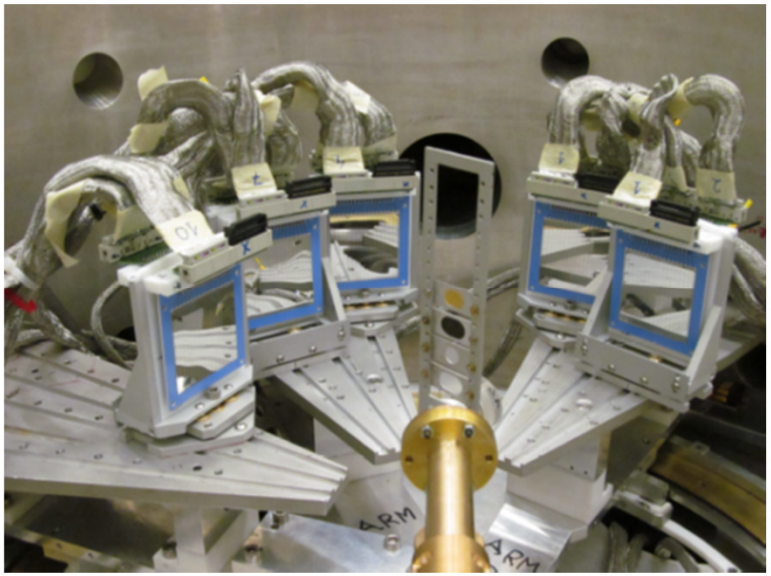


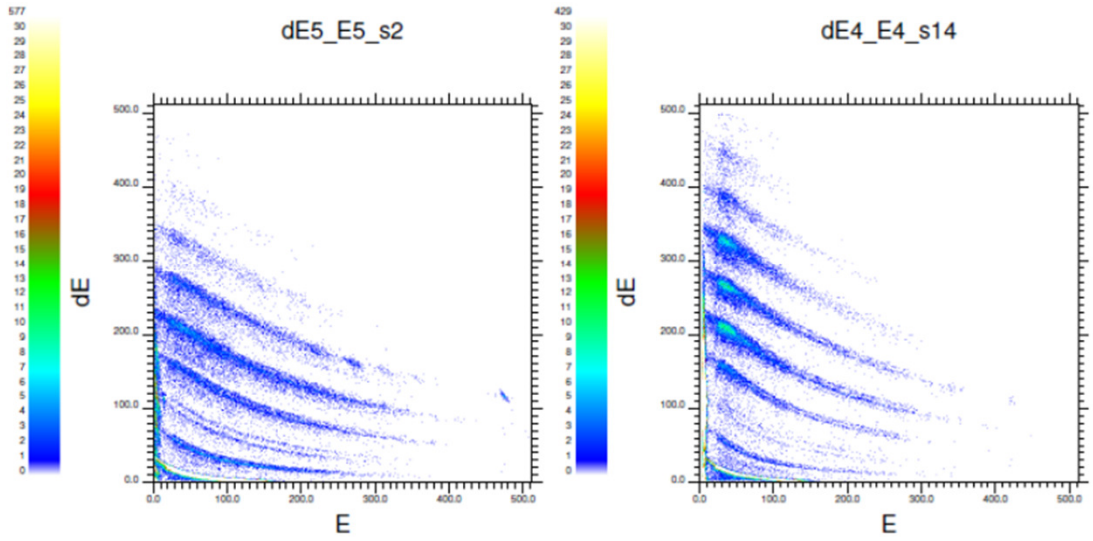
1-day beam-time
Setup was not fully optimized for this measurement as it was test/calibration run

- Very complex structure, many overlapping resonances
- Angular distributions & R-matrix fits don't provide spin infrmation
- There is some 0^+ strenght in peaks below 15 and above 16 MeV

Proposal & experiment at INFN-LNL

- improved measurement of the resonant scattering experiment
  $^{20}Ne + {}^{4}He \rightarrow {}^{24}Mg^{*} \rightarrow \alpha + {}^{20}Ne, \alpha + {}^{20}Ne^{*}, p + {}^{23}Na$
- we built new beam-line & scattering chamber
- schedulled for May 2013 but PIAVE did not work
- new run in 2014 or look for another facility with ^{20}Ne beam
- we run $^{12}C + {}^{14}N \rightarrow {}^{2}H + {}^{12}C + {}^{12}C$, $^{4}He + {}^{20}Ne + {}^{4}He$, $^{4}He + {}^{23}Na + p$



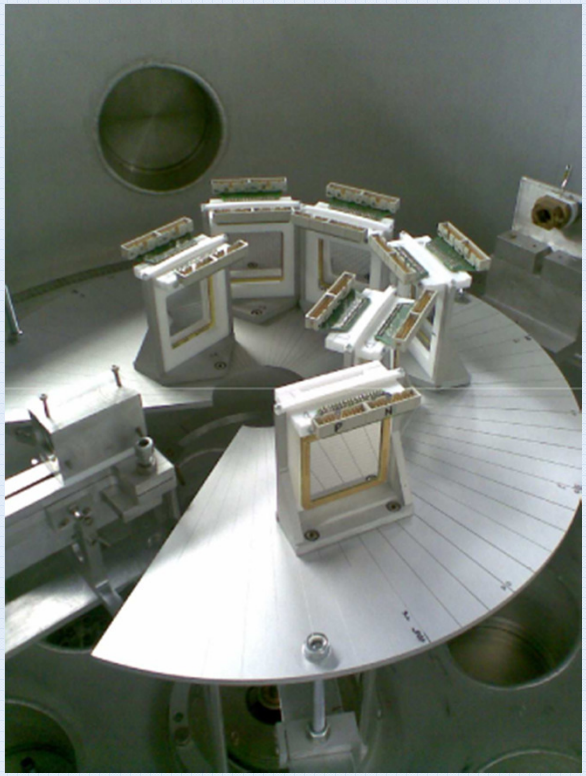


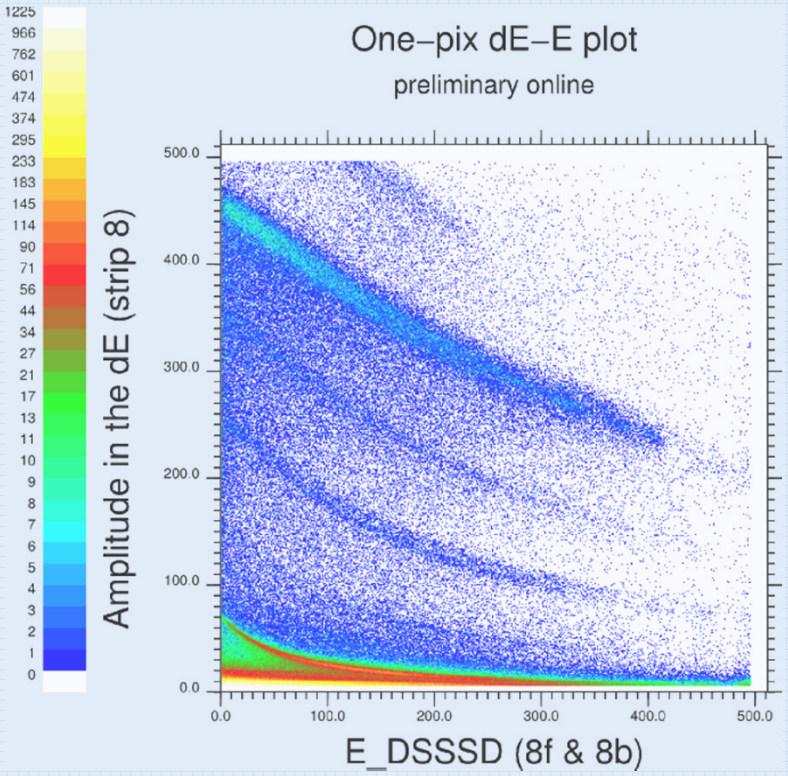
Study of ^{18}Ne resonances relevant for the ^{14}O(α,p)^{17}F reaction: experiment performed

HCNO breakout: X-ray bursts, cc supernovae, novae

IPN Orsay Nov 2012: study of the isobar analogue nucleus ^{18}O

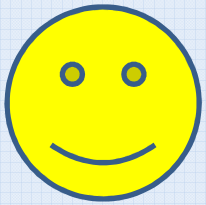
$^{13}C + {}^{9}Be \rightarrow \alpha + {}^{18}O^* \rightarrow \alpha + \alpha + {}^{14}C$





Work in progress

Conclusion & Prospects
personal view



EuroGENESIS project was important step ahead for Zagreb group

New research programme after succesfull applications for large investment in research instrumentation - 2 FP7 REGPOT projects, EuroGENESIS, some national funding – in total 500 000 €

1 new PhD student positions – in total 4 PhD in 5 years

It provides funding for 4 experiments – we have data to analyse

Many thanks to all who brought EuroGENESIS into life !

THANK YOU JORDI !

It would be great to have EuroGENESIS successor !