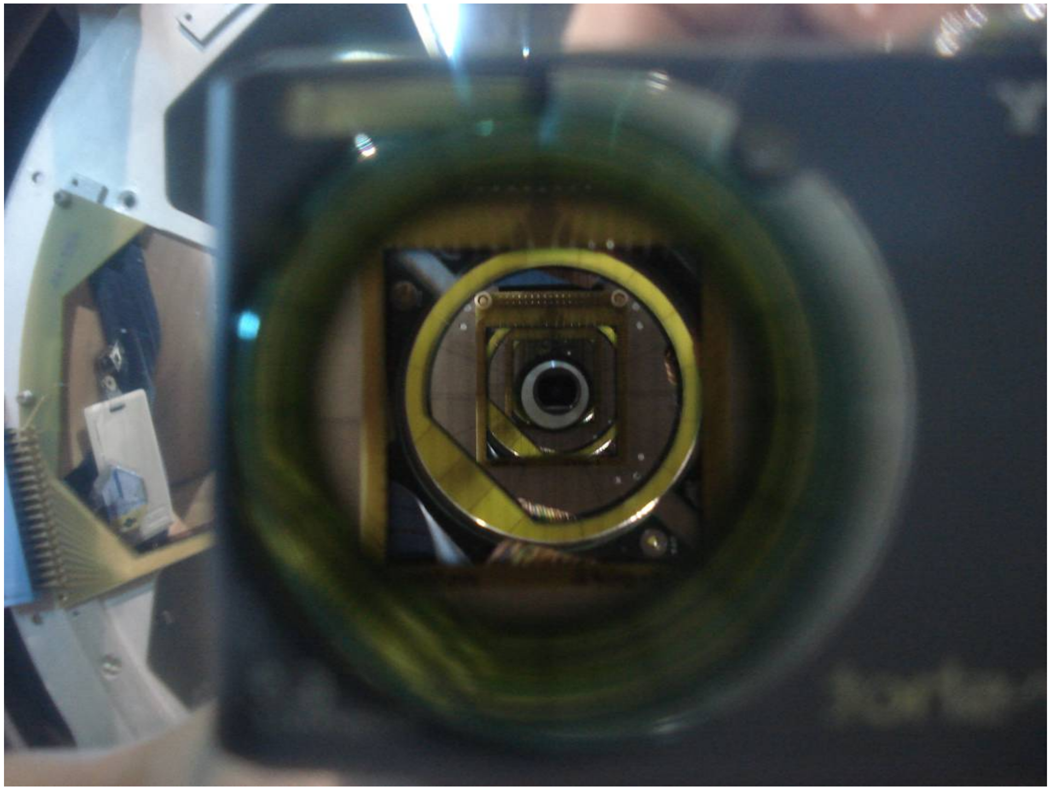
S1103 - (α,p) reactions in type I X-ray bursts: time-reversed approach at ISAC II



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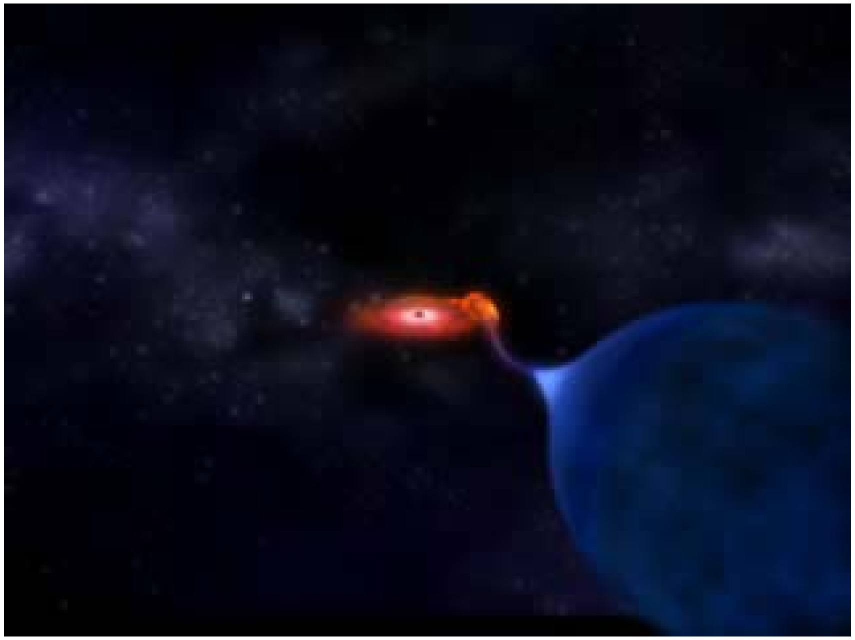
X-Ray Bursts

semi-detached binary system: Neutron star + less evolved star



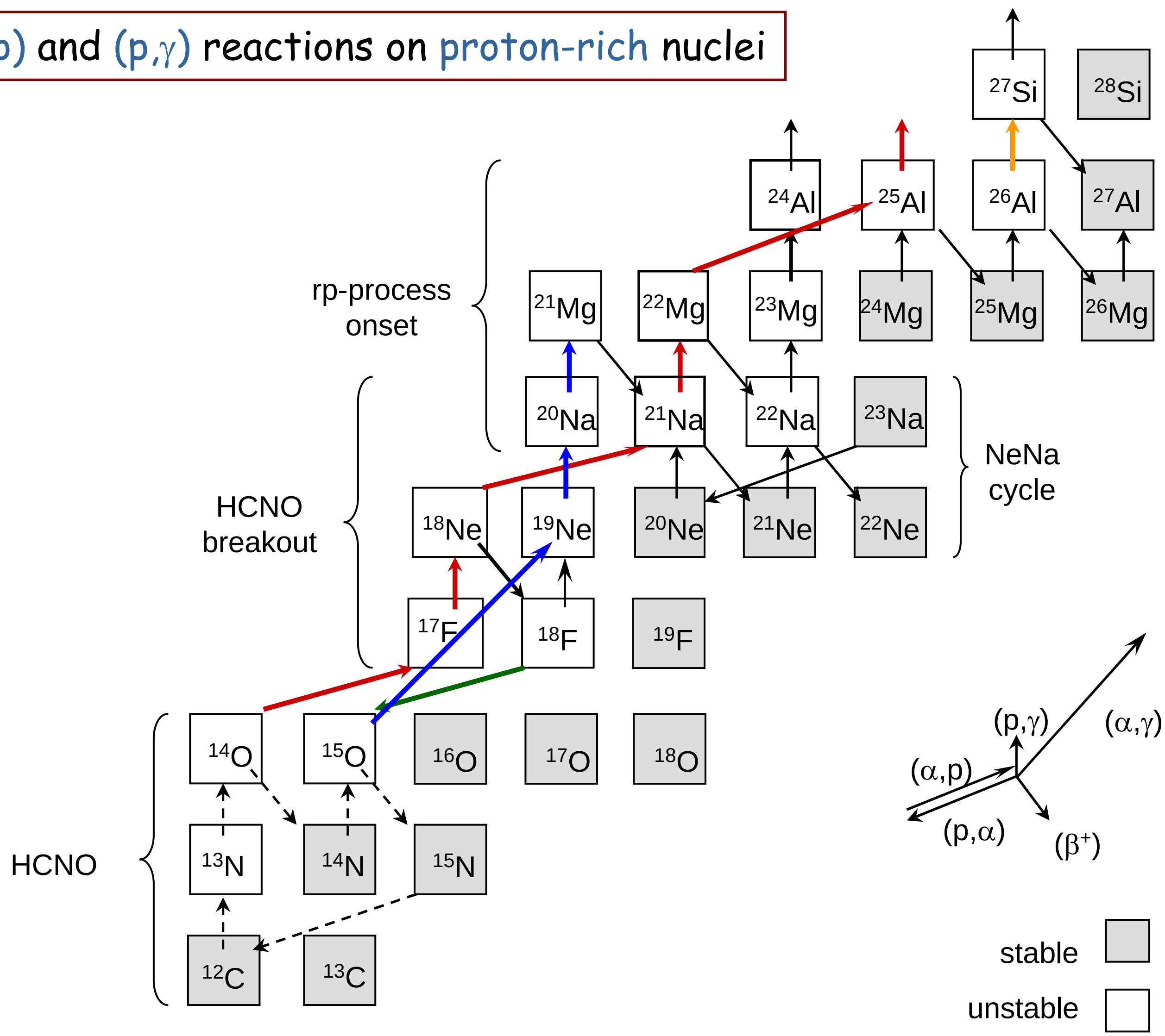
- thermonuclear runaway on surface of accreting neutron star
- explosive ignition of H and/or He
- emission of strong X-rays
- if matter transfer continues process may repeat

explosive hydrogen burning

T ~ 10^9 K
ρ ~ 10^6 g cm^{-3}

nucleosynthesis up to *A* ~ 80-100 mass region

(α,p) and (p,γ) reactions on proton-rich nuclei



(exact path depends on given stellar conditions)

proposal

study key (α,p) reactions relevant to type I X-ray bursts

$^{18}Ne(\alpha,p)^{21}Na$ — breakout from HCNO cycle

direct and indirect investigations exist, but uncertainties remain

$^{22}Mg(\alpha,p)^{25}Al$
$^{26}Si(\alpha,p)^{29}P$
$^{30}S(\alpha,p)^{33}Cl$
$^{34}Ar(\alpha,p)^{37}K$

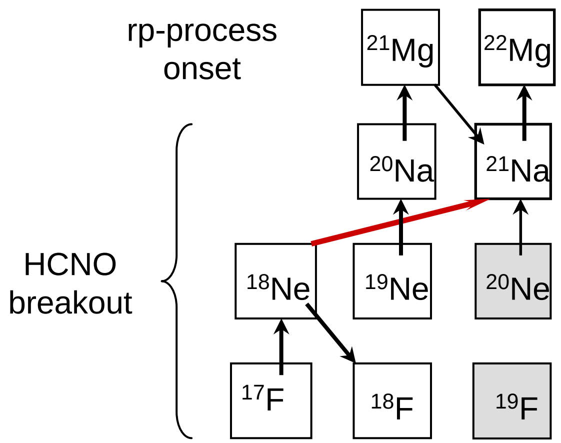
} possible waiting points in type I X-ray bursts

no experimental data available

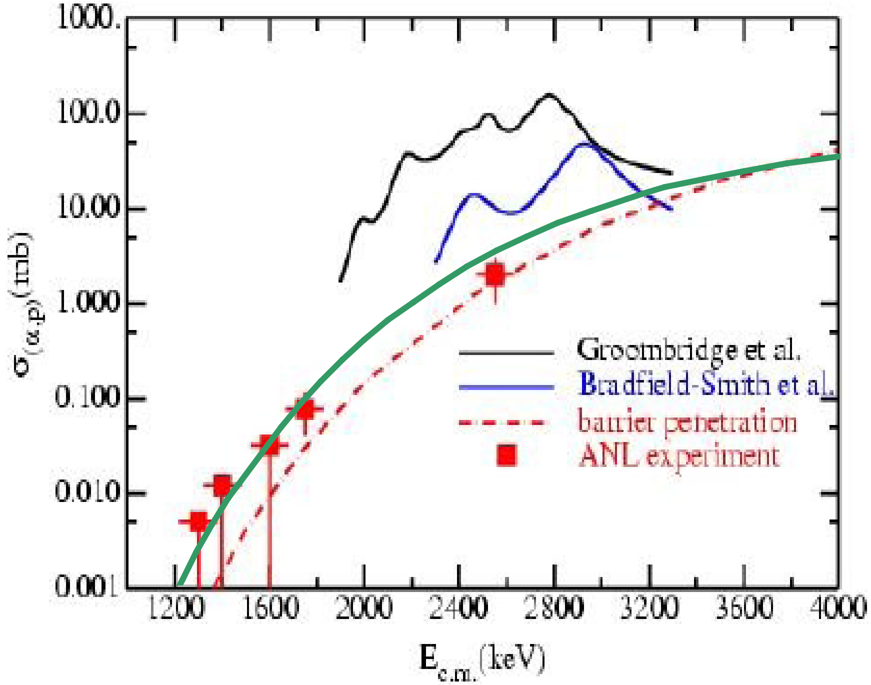
- direct studies hampered both by low RIB intensities and low target densities
- propose to study time-reversed (p,α) processes at relevant astrophysical energies

$^{18}Ne(\alpha,p)^{21}Na$

one of two main breakout routes
from HCNO cycle into rp-process



Argonne National Laboratory
Internal report 2005



<u>current status:</u>

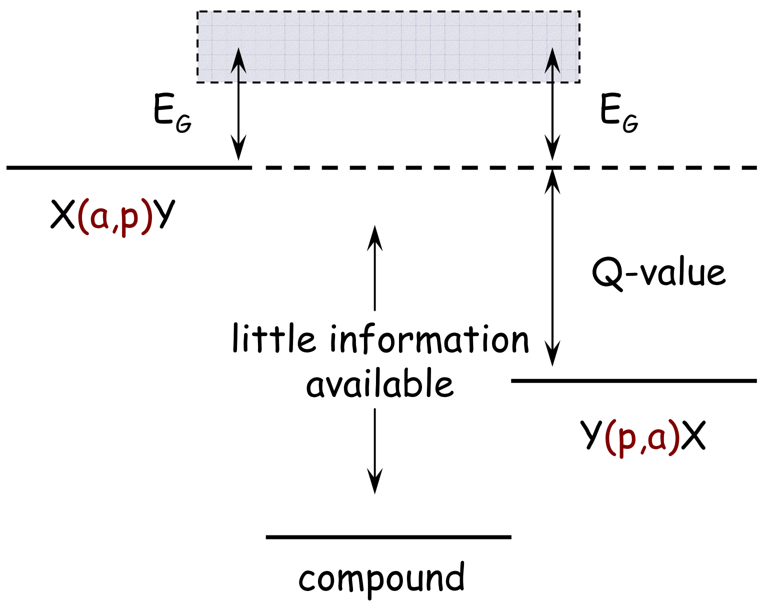
- two direct measurements
- one time-reversed measurement
- theoretical calculation (Hauser-Feshbach)
- large discrepancies

the methodology

time-reversed approach: $X(\alpha,p)Y \Leftrightarrow Y(p,\alpha)X$

detailed-balance theorem

$$\frac{\sigma_{\alpha X}}{\sigma_{pY}} = \frac{m_p m_Y}{m_\alpha m_X} \frac{E_{pY}}{E_{\alpha X}} \frac{(2J_p+1)(2J_Y+1)}{(2J_\alpha+1)(2J_X+1)}$$



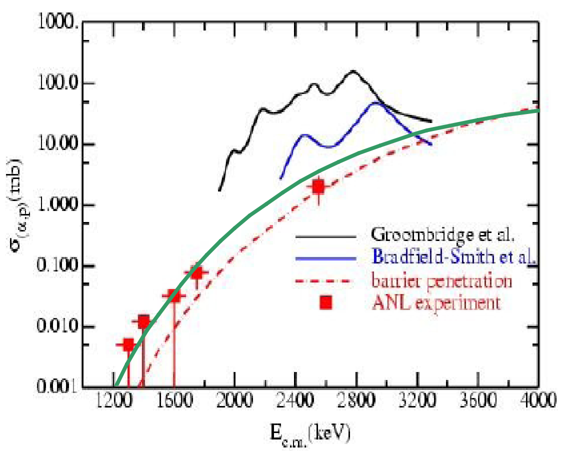
direct approach: spin-less particles ⇒ only natural parity states can be populated

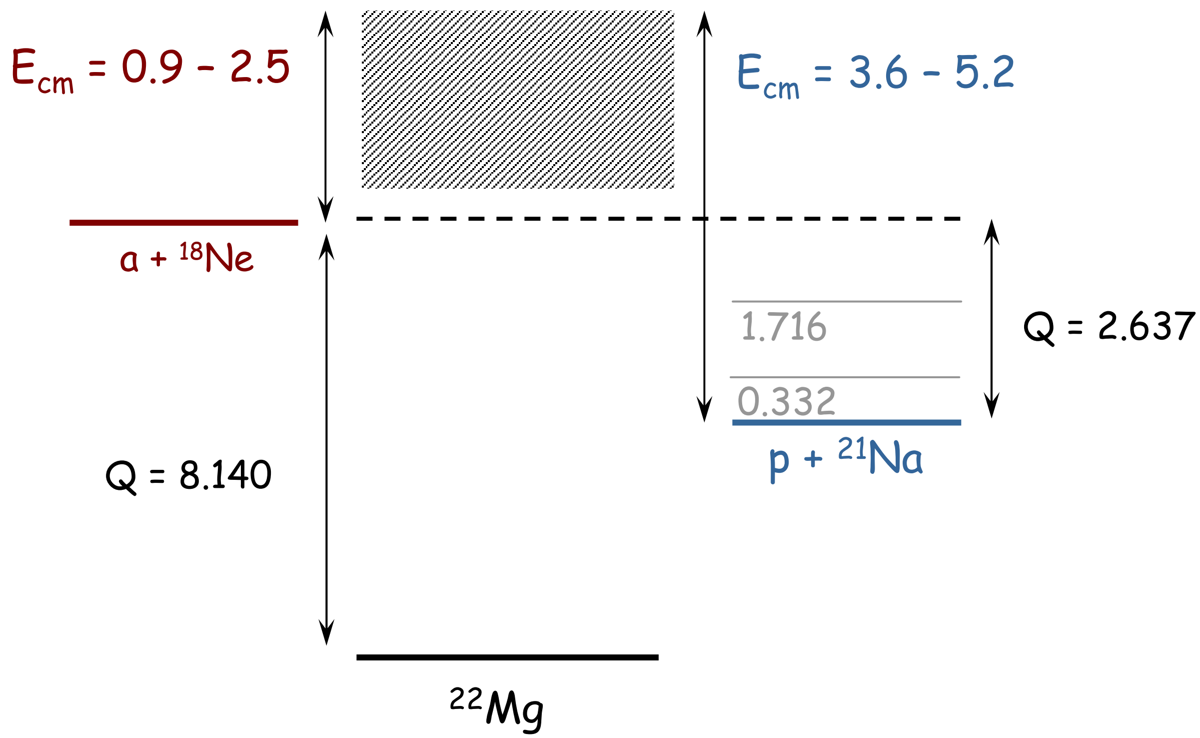
indirect approach: no selectivity

However! kinematic selection on transitions between ground states
⇒ ensure only natural parity states have been populated

the case for $^{18}Ne(\alpha,p)^{21}Na$

(all energies in MeV)





Aims:
1) investigate energy range $E_{cm} \sim 0.9 - 2.5$ MeV by time-reverse approach ($E_{cm} \sim 3.6 - 5.2$ MeV)

2) investigate resonant states in ^{22}Mg ($E_r \sim 8.5 - 10.1$ MeV)

Experimental setup @ ISAC II

^{21}Na 5^{+} beam

I ~ 5x10^{6} pps

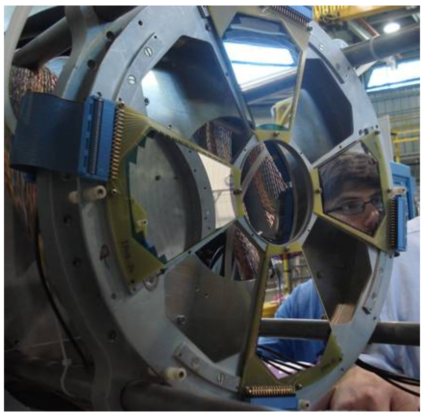
E ~ 5.5 – 3.8 MeV/u

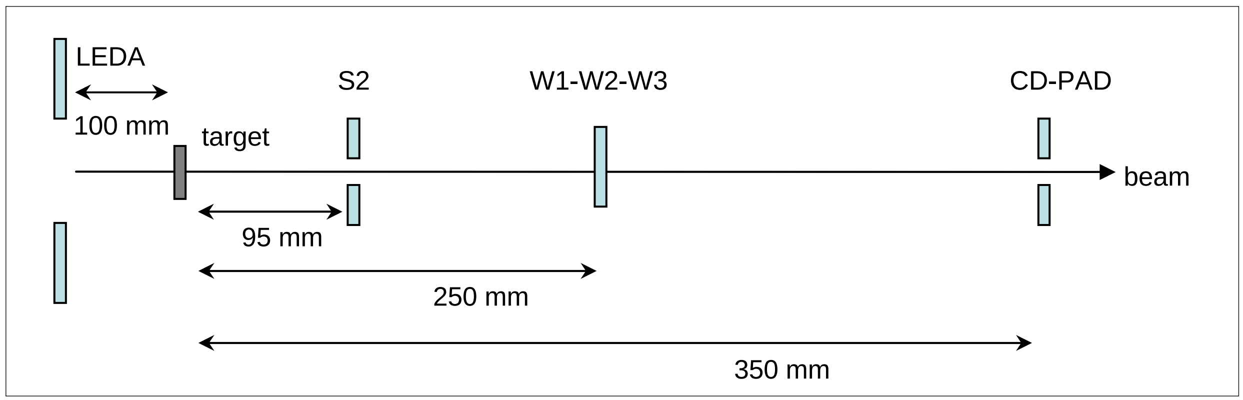
CH2 target

aim 2 ... meas ... elastic proton scattering (thic ... surement)

W: protons (alphas)

LEDA: RBS on Au spot

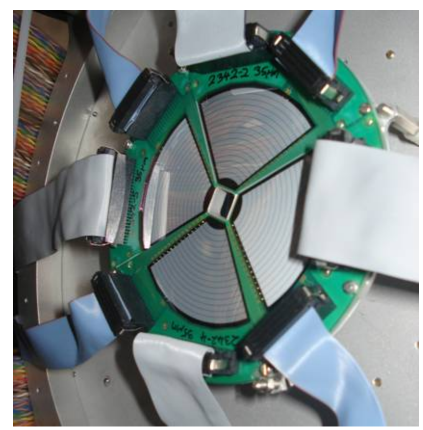


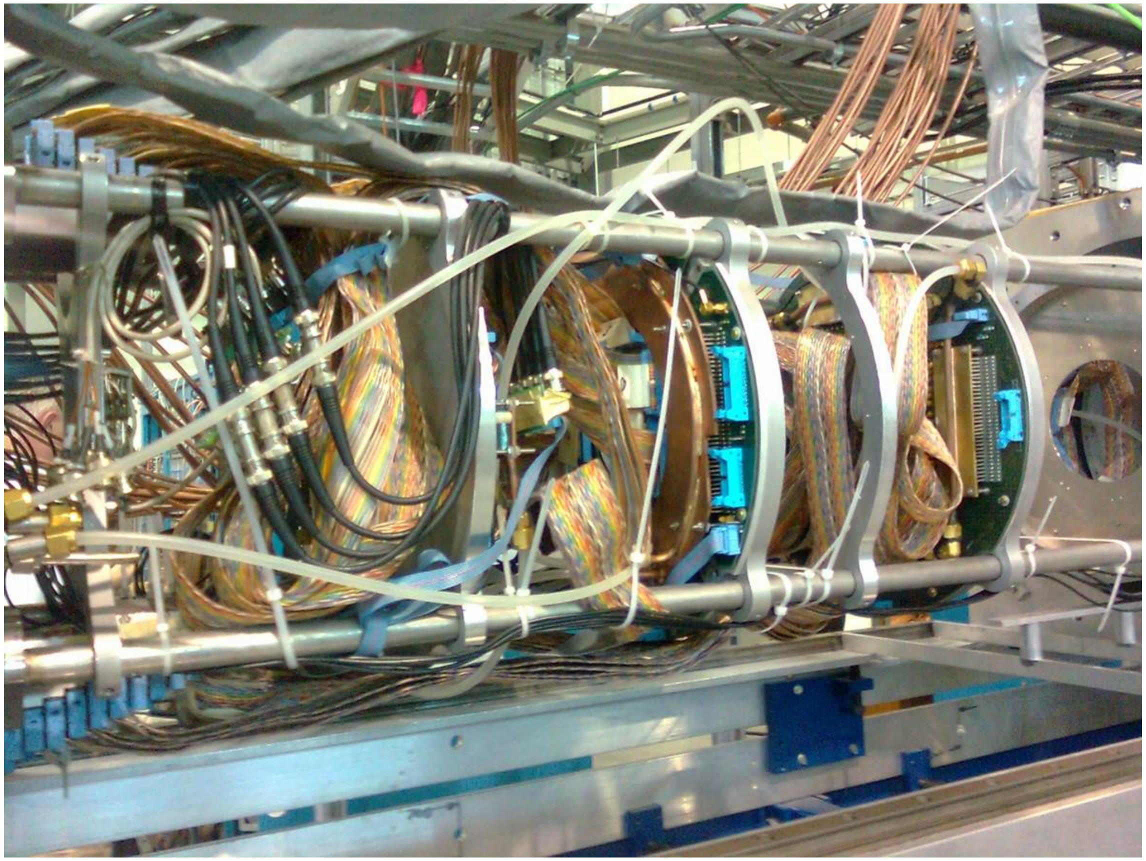


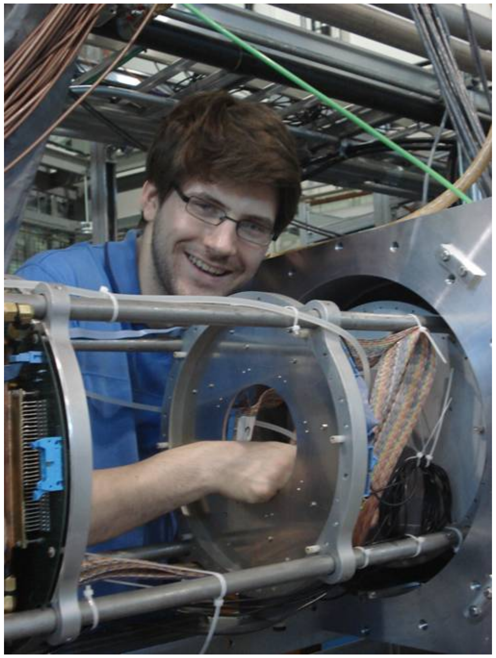
aim 1): measure ... eld for ^{18}Ne+alpha particle ... by ΔE-E technique (thin ta ... nents)

S2 detector:
alpha particles

CD-PAD:
heavy ions
^{18}Ne, ^{21}Na







Gavin Lotay Philip Salter Tom Davinson

work in progress…

the collaboration

S1103 Collaboration

University of Edinburgh

University of York

TRIUMF

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