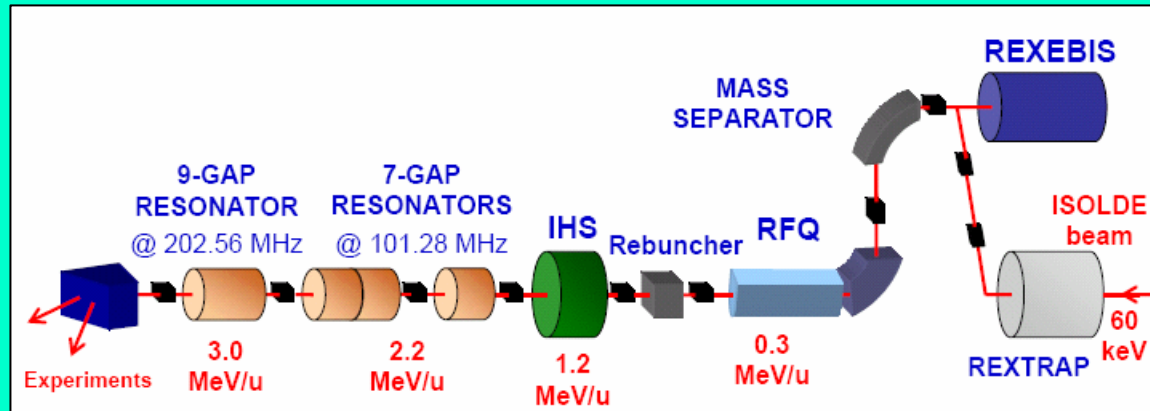


HIE ISOLDE Physics: a personal view

PJ Woods
(University of Edinburgh)



REX post-accelerator



- Originally constructed by several CERN member states
~ 15 MCHF
- Utilises now → 50% ISOLDE running time
- REX has accelerated 43+ different RIBs
- Present RIB yields from ISOLDE allow 10% of all 700 radioisotopes to be used

World ISOL

FACILITY	DRIVER	POWER	USER BEAMS ACCELERATED	ENERGY	PHYSICS REACH
LOUVAIN- LA-NEUVE (BELGIUM) 1989-2008	30 MeV protons	6 kW	${}^6\text{He}$, ${}^7\text{Be}$, ${}^{10,11}\text{C}$, ${}^{13}\text{N}$, ${}^{15}\text{O}$, ${}^{18}\text{F}$, ${}^{18,19}\text{Ne}$, ${}^{35}\text{Ar}$	10 MeV/u cyclotron	Astrophysics, Nuclear structure
HRIBF Oak Ridge (USA) 1997	100 MeV p, d, α (-ve ion source)	1 kW	${}^7\text{Be}$, ${}^{17,18}\text{F}$, ${}^{69}\text{As}$, ${}^{67,83}\text{Ga}$, ${}^{75-79}\text{Cu}$, ${}^{80-87}\text{Ge}$, ${}^{84}\text{Se}$, ${}^{92}\text{Sr}$, ${}^{118,120,122,124}\text{Ag}$, ${}^{129}\text{Sb}$, ${}^{130-134}\text{Sn}$, ${}^{132,134,136}\text{Te}$	2 - 10 MeV/u tandem	Nuclear Structure, Astrophysics
ISAC TRIUMF (CANADA) 2000	500 MeV protons	50 kW	${}^{8,9,11}\text{Li}$, ${}^{11}\text{C}$, ${}^{20,21}\text{Na}$, ${}^{18}\text{Ne}$, ${}^{26}\text{Al}$, ${}^{34}\text{Ar}$	4.5 MeV/u linac	Astrophysics, Condensed matter, Nuclear Structure
SPIRAL GANIL (FRANCE) 2001	100 MeV/u heavy ions	6 kW	${}^{6,8}\text{He}$, ${}^{15,19-21}\text{O}$, ${}^{18}\text{F}$, ${}^{17-19,23-26}\text{Ne}$, ${}^{33-35,44,46}\text{Ar}$, ${}^{74-77}\text{Kr}$	2 - 25 MeV/u cyclotron	Nuclear structure, Astrophysics
REX ISOLDE (CERN) 2001	1.4 GeV protons	3 kW	${}^{8,9}\text{Li}$, ${}^{10-12}\text{Be}$, ${}^{17}\text{F}$, ${}^{24-29}\text{Na}$, ${}^{28-32}\text{Mg}$, ${}^{68}\text{Ni}$, ${}^{67-73}\text{Cu}$, ${}^{74,76,78,80}\text{Zn}$, ${}^{70}\text{Se}$, ${}^{88,92}\text{Kr}$, ${}^{108}\text{In}$, ${}^{106,108,110}\text{Sn}$, ${}^{122,124,126}\text{Cd}$ ${}^{138,140,142,144}\text{Xe}$, ${}^{148}\text{Pm}$, ${}^{153}\text{Sm}$, ${}^{156}\text{Eu}$	0.3 - 3 MeV/u linac	Nuclear structure, Condensed matter, Astrophysics

REX-ISOLDE 2006

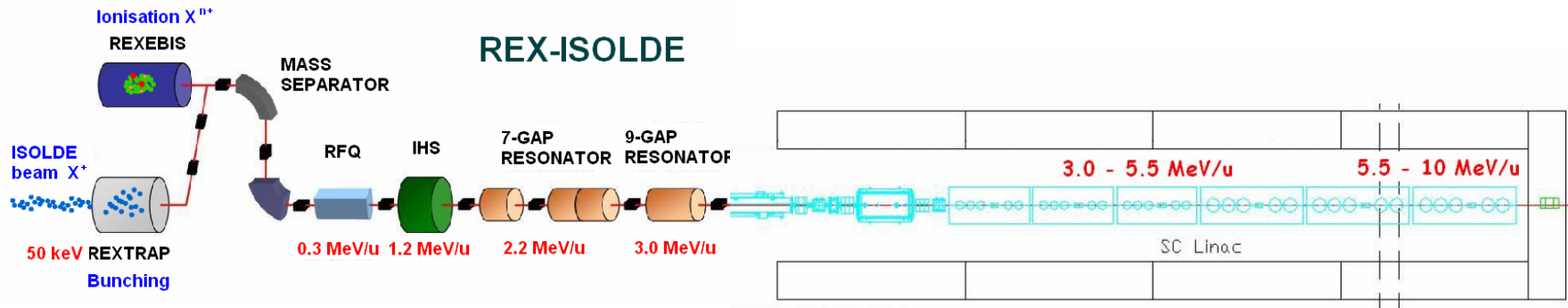


Transfer studies
of light nuclei
e.g. ^{10}Li

MINIBALL
(Coulex,
transfer)

HIE-ISOLDE at CERN

**Increase in REX energy from 3 to 10 MeV/u
(first step in increase to 5.5 MeV/u)**

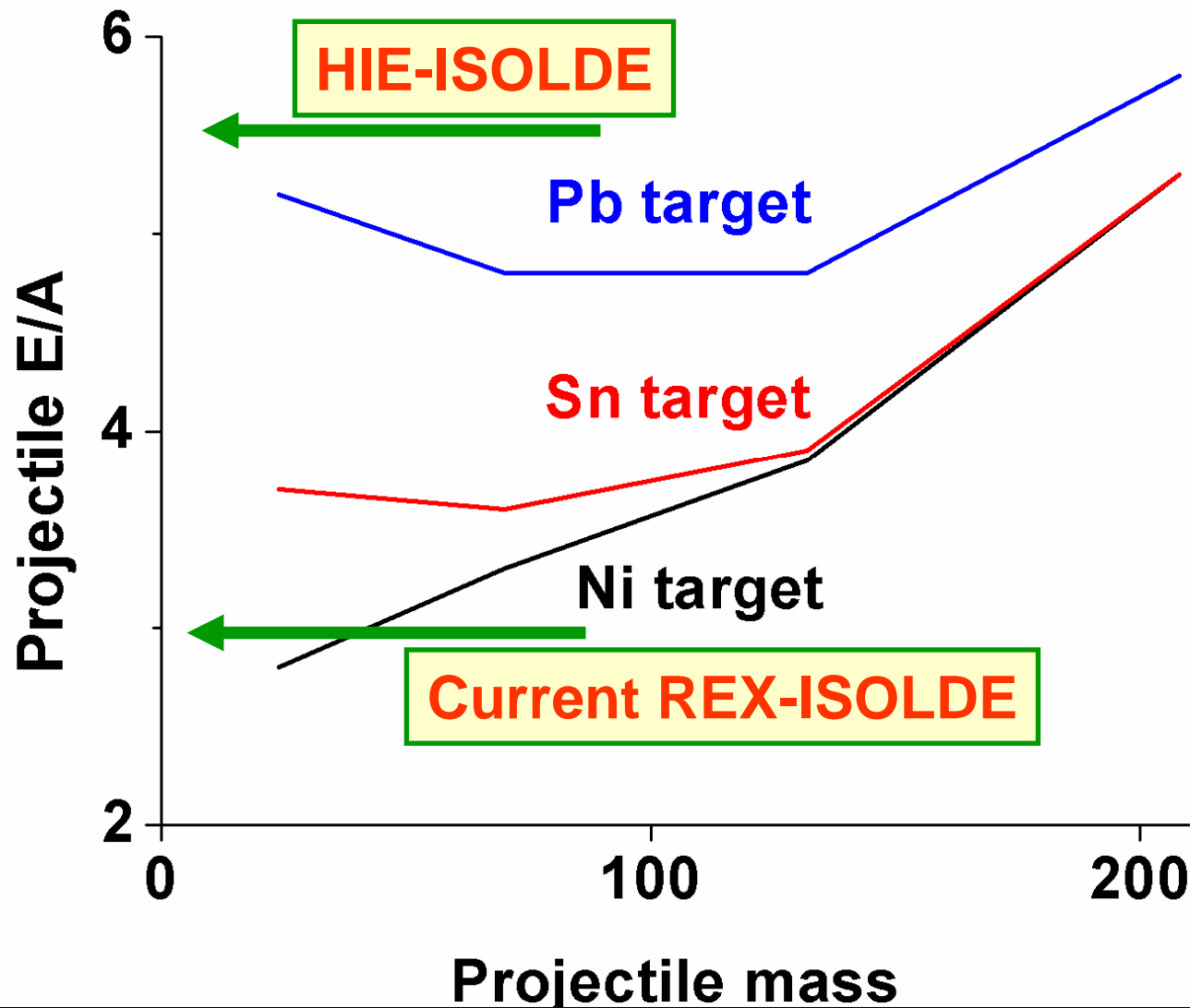


Increase proton intensity $2 \rightarrow 6 \mu\text{A}$ (LINAC4, PSB upgrade) - target and front-end upgrade

**RFQ cooler, REX-TRAP, REX-EBIS
REX-ECR upgrades**

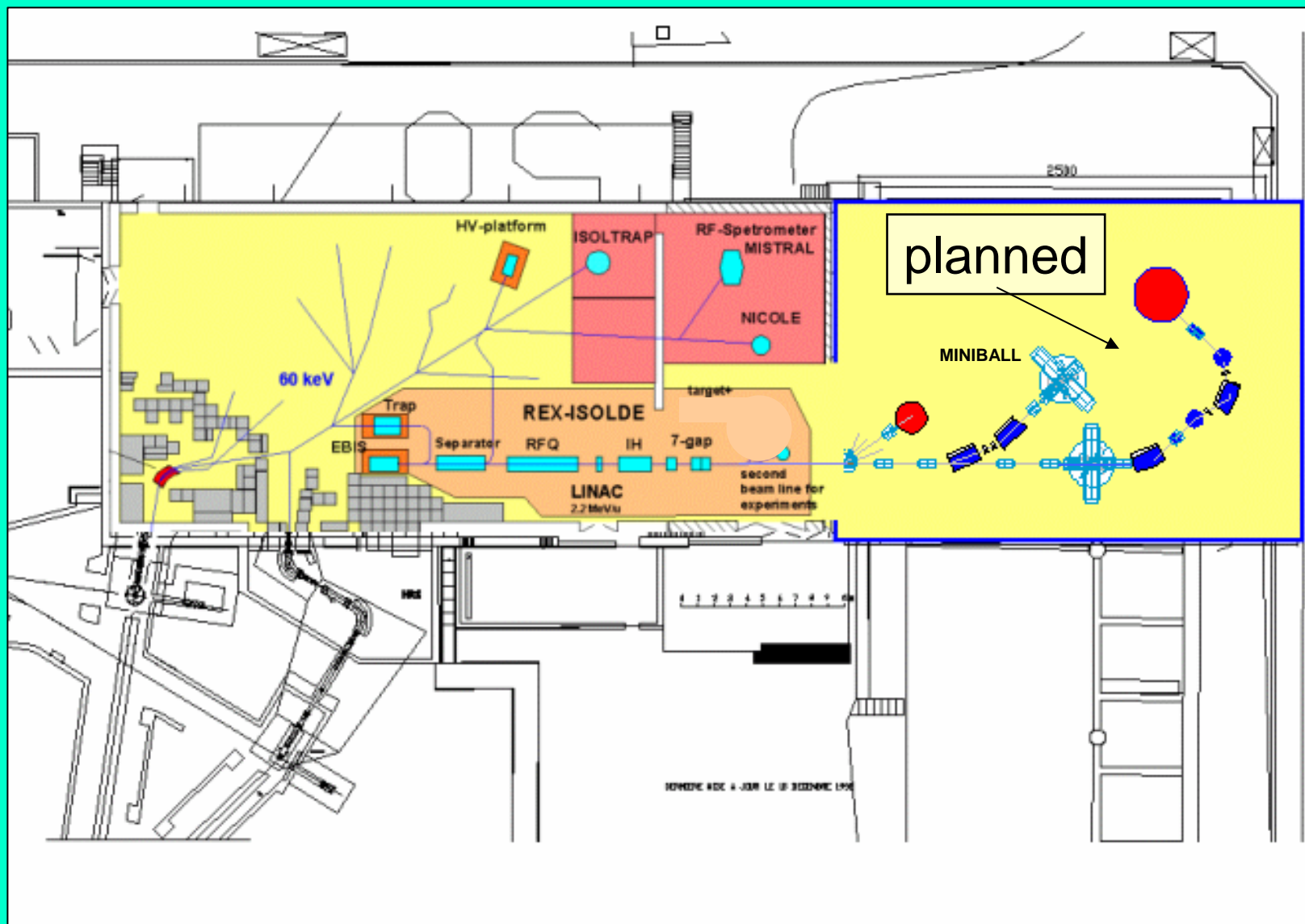
**Super-HRS for isobaric separation
RILIS upgrade & LIST**

Coulomb barrier for RIB



HIE ISOLDE will be a unique new world class facility for studies of exotic nuclei combining:

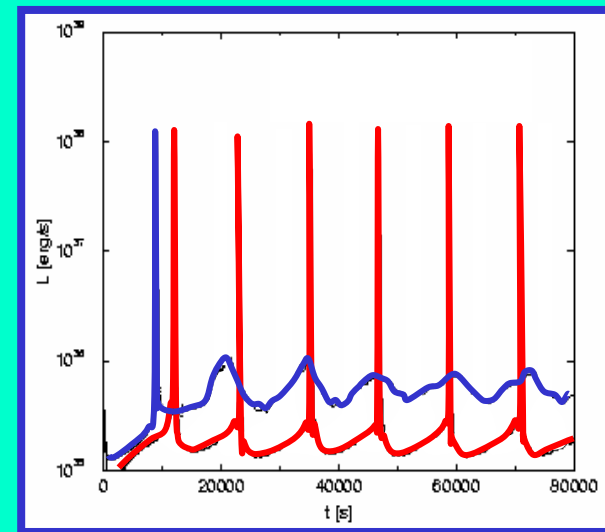
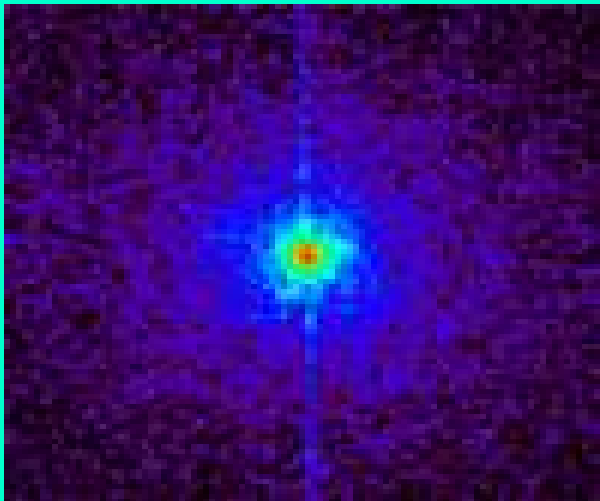
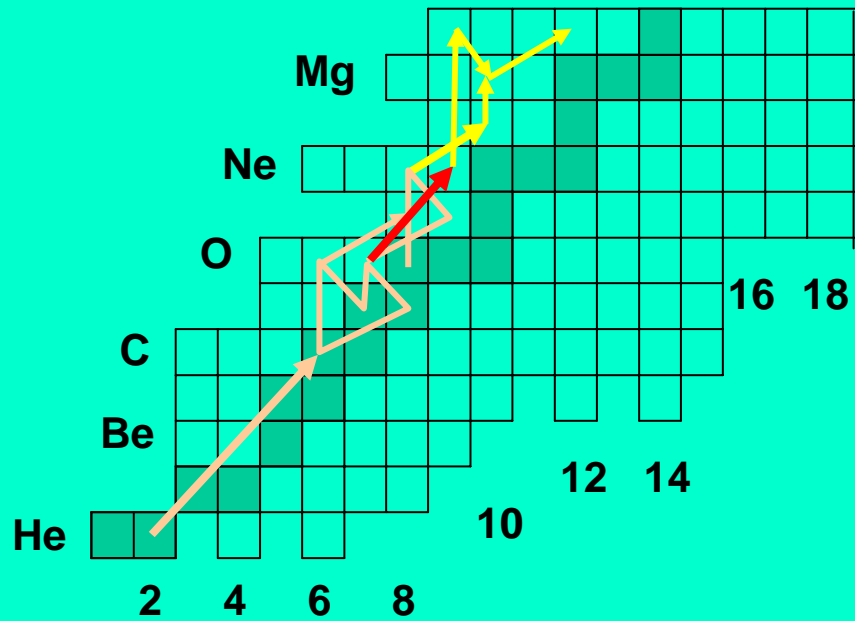
- A unique wide range of high quality beams of exotic nuclei
- RIBs above the Coulomb barrier for heavy nuclei
- A world class suite of experimental equipment, with room for further development



HIE beam energies will:

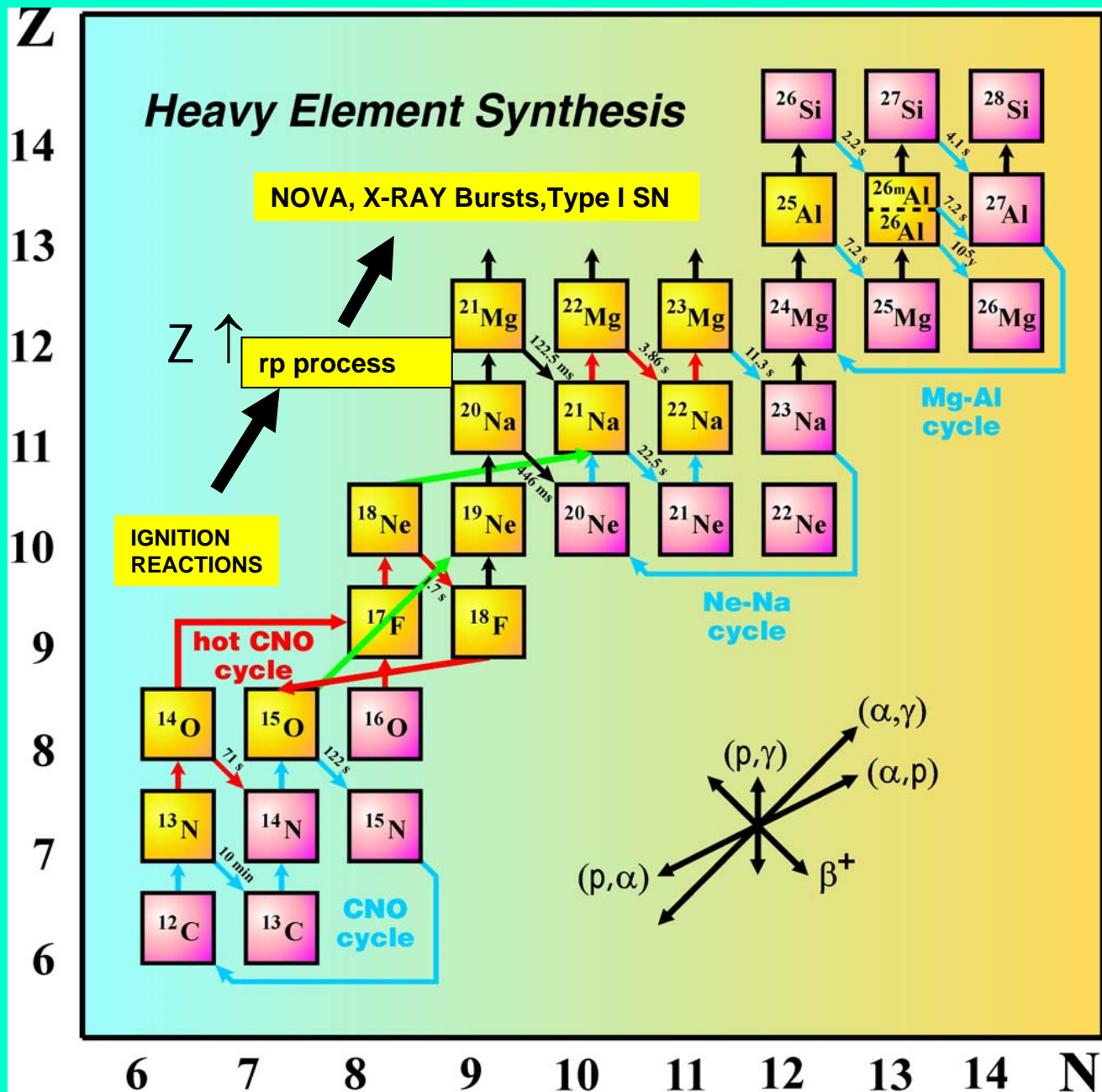
- enter ideal energy regime for transfer reaction studies, see talk of R Raabe
- increase Coulex yields and allow higher excitations
- allow near-barrier fusion, elastic scattering, and break-up reaction studies eg of halo nuclei.
- improved sensitivity in tilted-foil polarization measurements (M Hass)
- allow studies of key resonances of interest for nuclear physics and nuclear astrophysics

Time reverse (α, p) studies for X-ray bursters

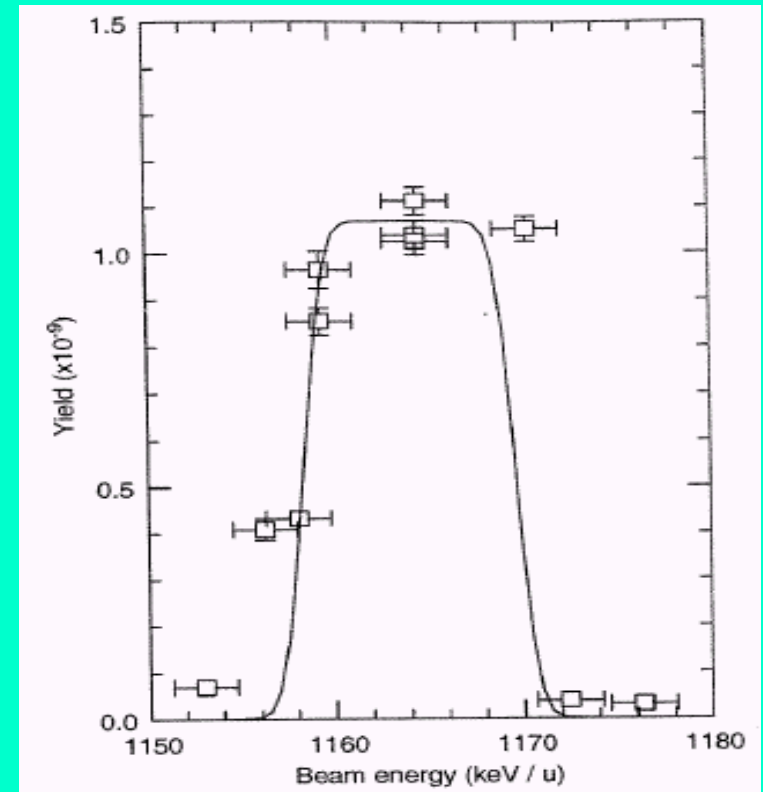
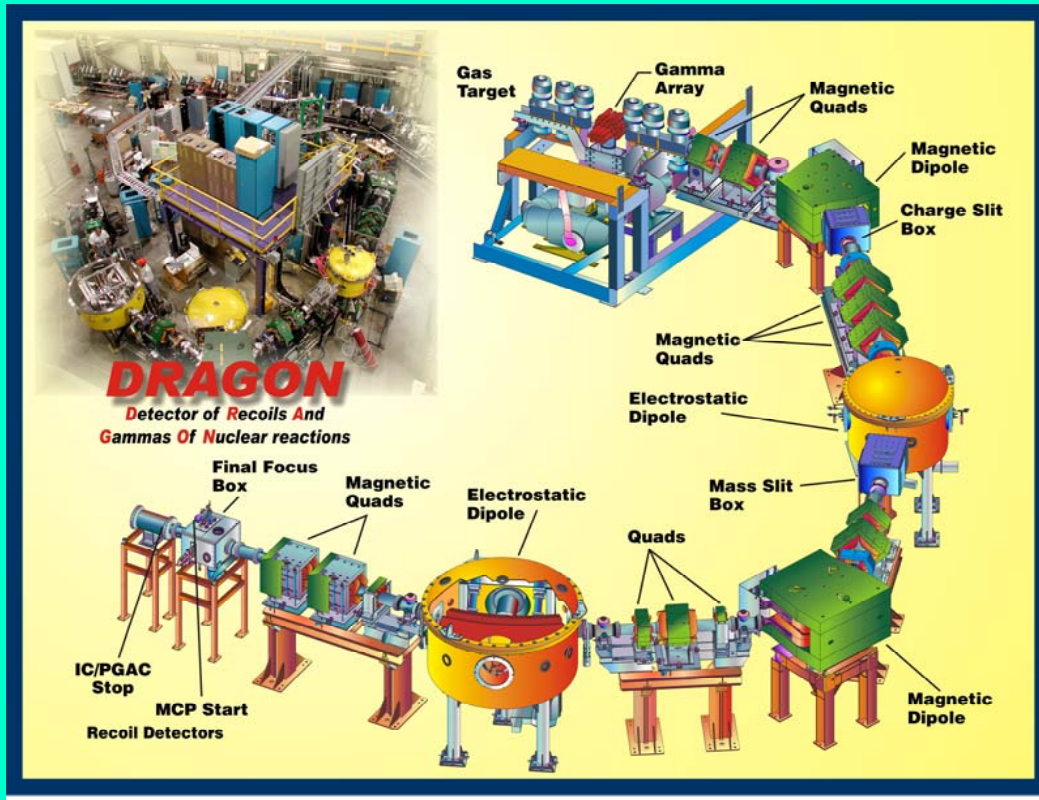


First pioneering study of $^{17}\text{F}(\text{p},\text{p}')^{17}\text{F}$ reaction for $^{14}\text{O}(\alpha,\text{p})^{17}\text{F}$ reaction

- successfully used Miniball + CD set-up to identify decay of key low energy 1^- resonance in ^{18}Ne
- with higher energies, method could be applied to key resonances in other reactions
eg $^{18}\text{Ne}(\alpha,\text{p})^{21}\text{Na}$
- one of two key reactions vital for breakout from the hot CNO cycles into the rp process



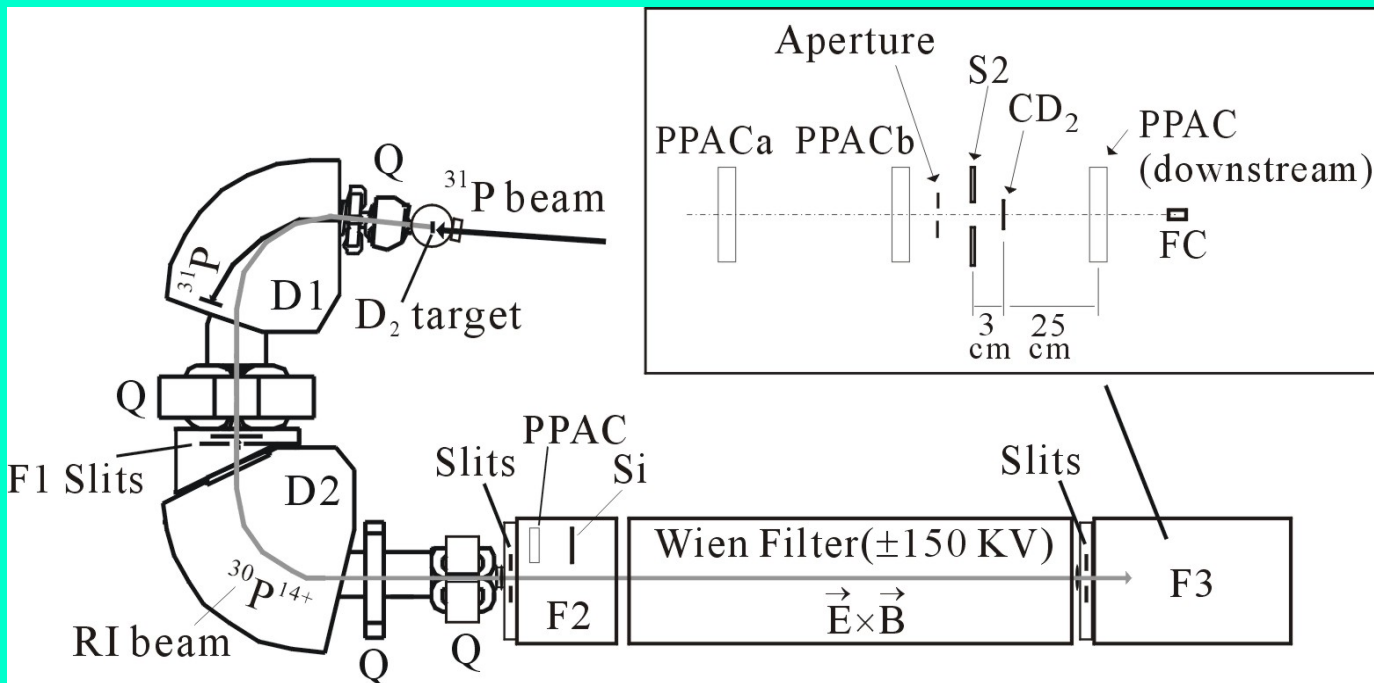
Direct (p, γ) measurements with RIBs



...are usually not possible....and specialist separation device like DRAGON not planned for HIE ISOLDE

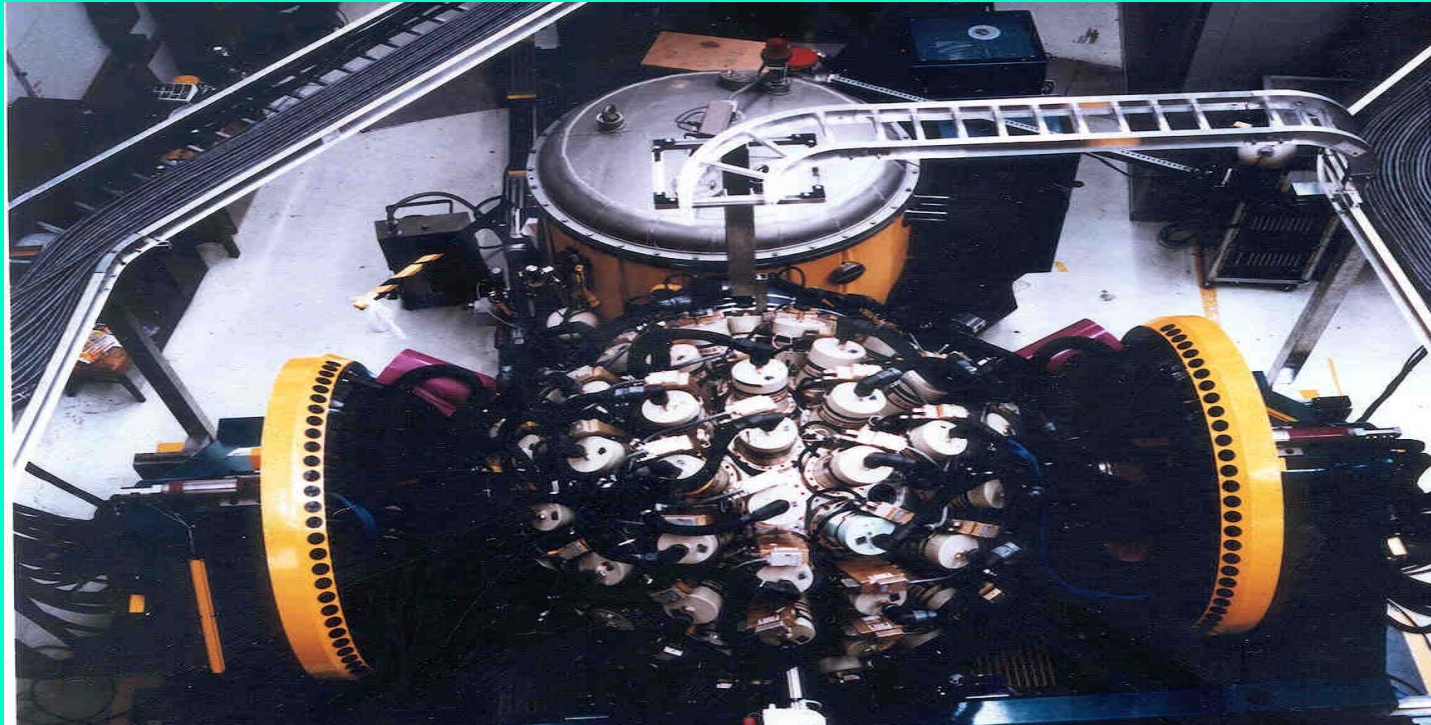
→ Key unknown for resonances fed in (p,γ) reactions is often the proton spectroscopic factor, S_p eg $^{30}\text{P}(p,\gamma)^{31}\text{S}$

- Edinburgh/RIKEN study of $d(^{30}\text{P}, ^{31}\text{P})p$ reaction to study analog states in mirror nuclei $^{31}\text{P}/^{31}\text{S}$



In-flight CRIB beams ~ 3 MeV/u with emittance limiting resolution of individual states in ^{31}P

→ direct alternative to determine S_p is to measure (d,n) reaction - could use Miniball to identify γ -rays from resonances using coincidences with recoil separator!
NB since resonances are above particle threshold, unlikely to be fed by other higher lying γ -decays.

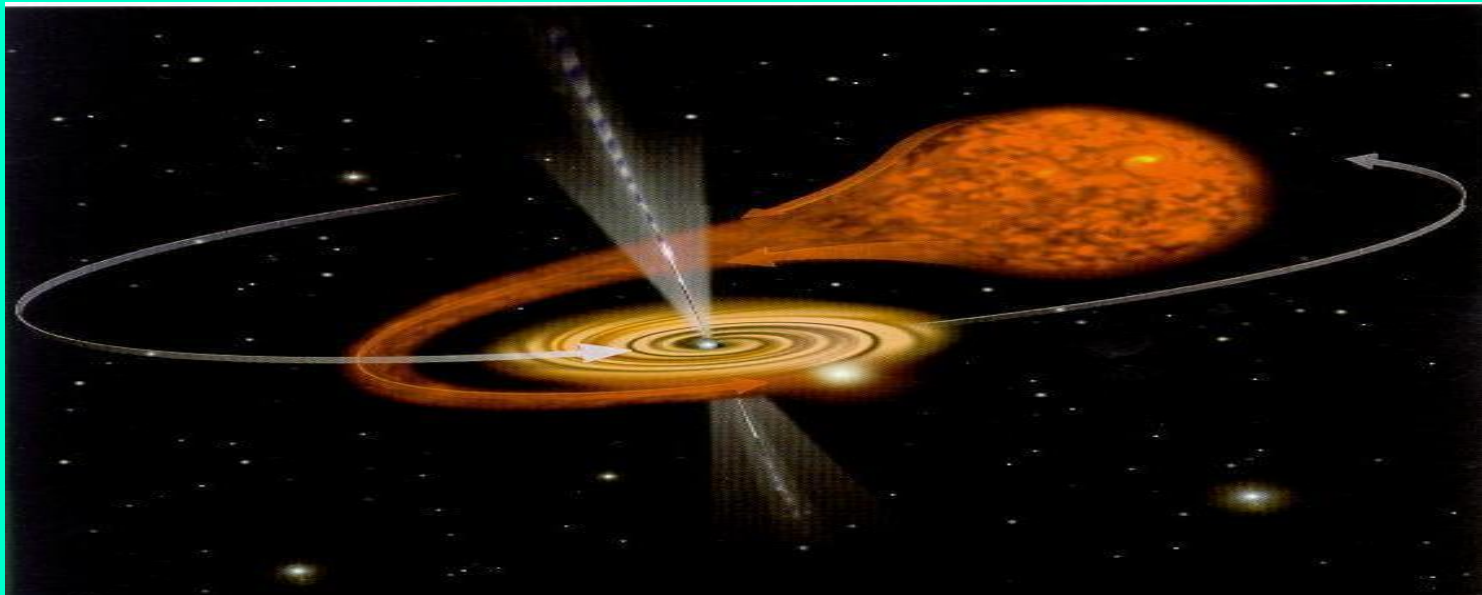


Need separation device combining good A and Z resolution
eg Argonne FMA

→ This could also be a very powerful general technique for nuclei near the proton drip-line, where level densities remain low in the region of the proton threshold energy

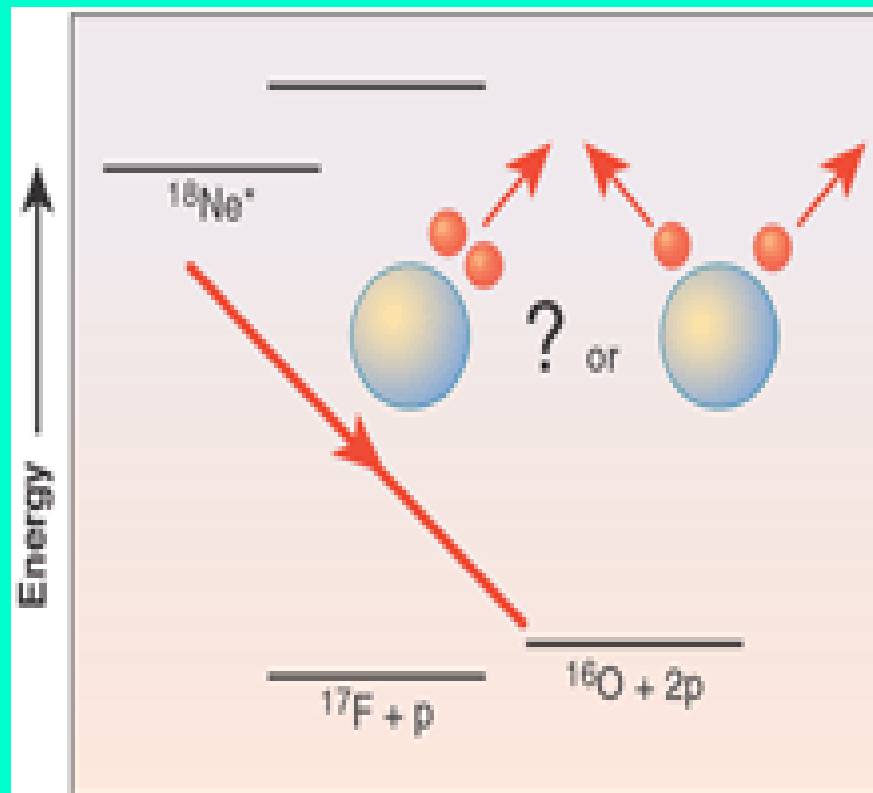
eg $d(^{56}\text{Ni}, ^{57}\text{Cu})n$

→ ^{56}Ni is a critical waiting point nucleus in X-ray/rp process scenarios



High energy resonant reactions on HIE ISOLDE

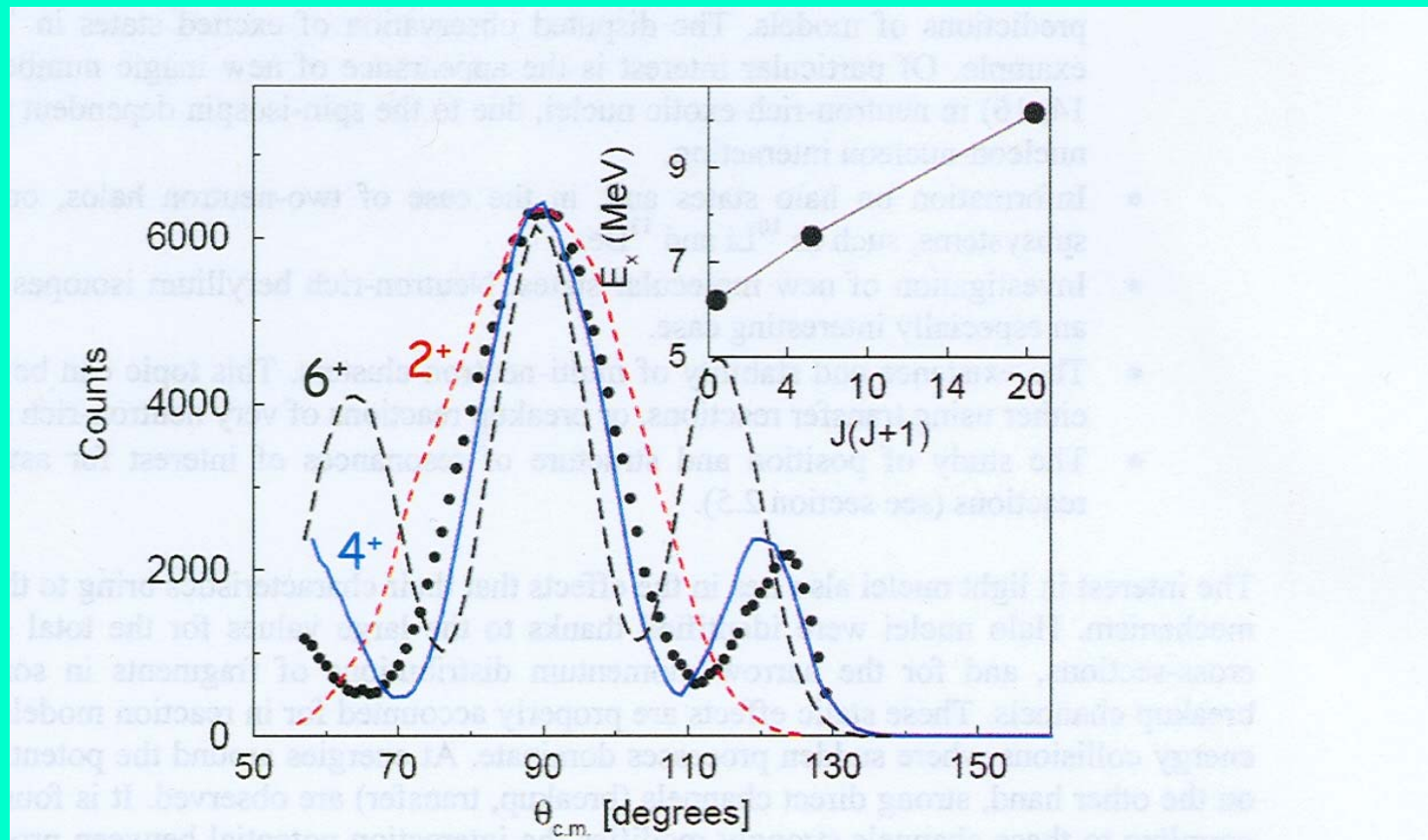
→ could feed excited 2p decaying states for decay mechanism studies, a technique pioneered at LLN and then ORNL for excited states in ^{14}O and ^{18}Ne , respectively



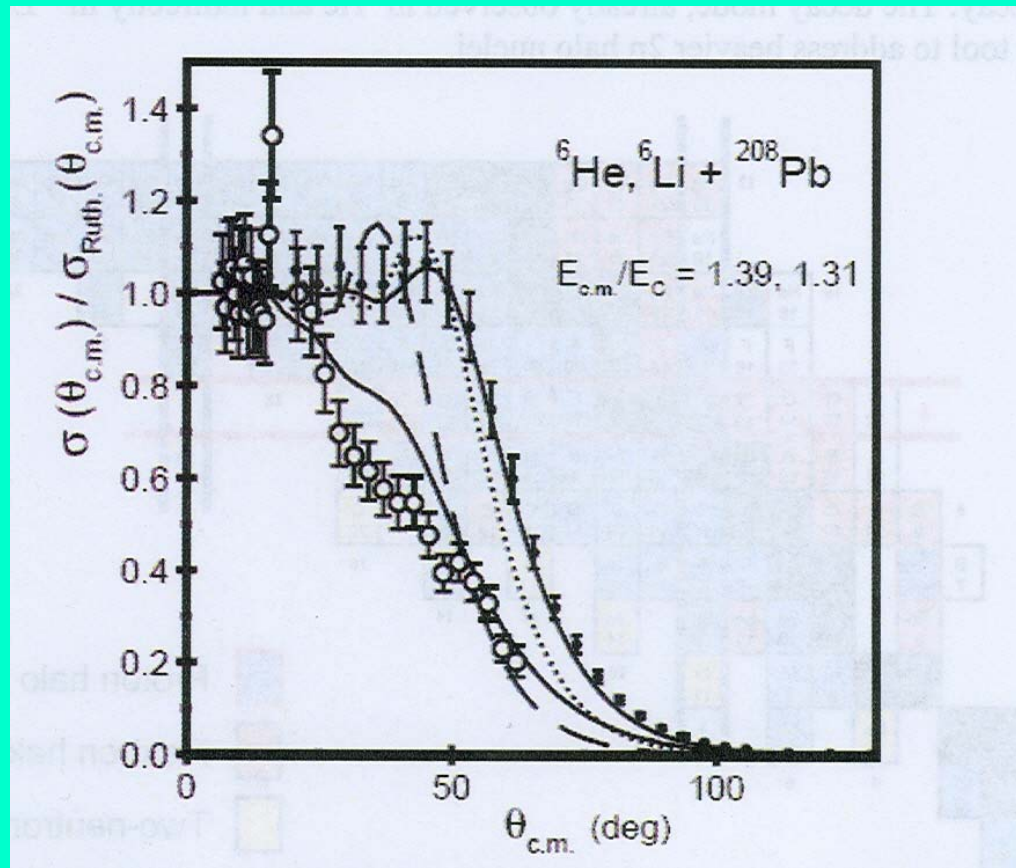
→excite exotic states eg possible cluster structures



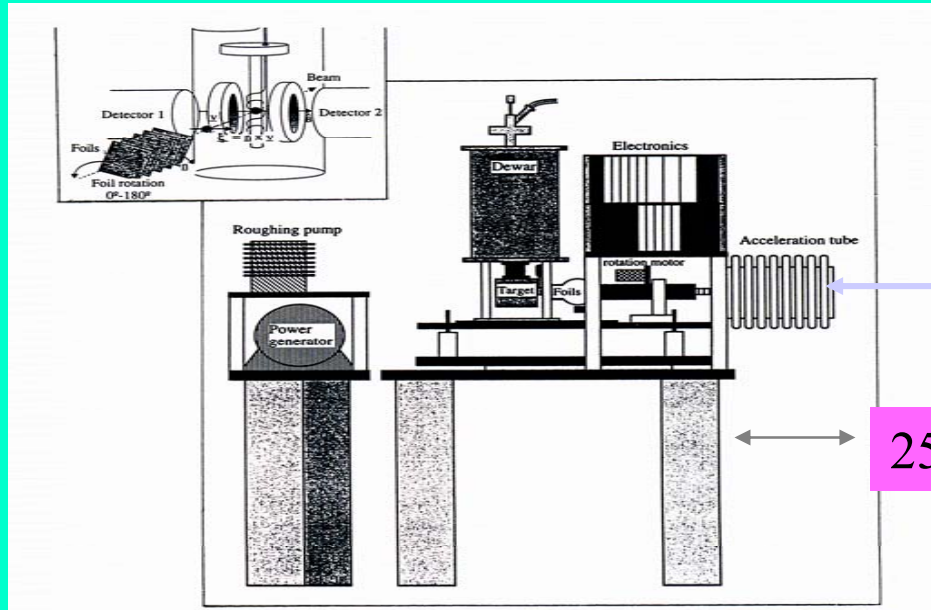
M Freer et al. LLN using LEDA silicon strip detector array



Advanced Si array could be used for near barrier reaction studies eg elastic scattering of halo nuclei



Tilted-foil polarization, β -NMR setup at the HV platform at ISOLDE

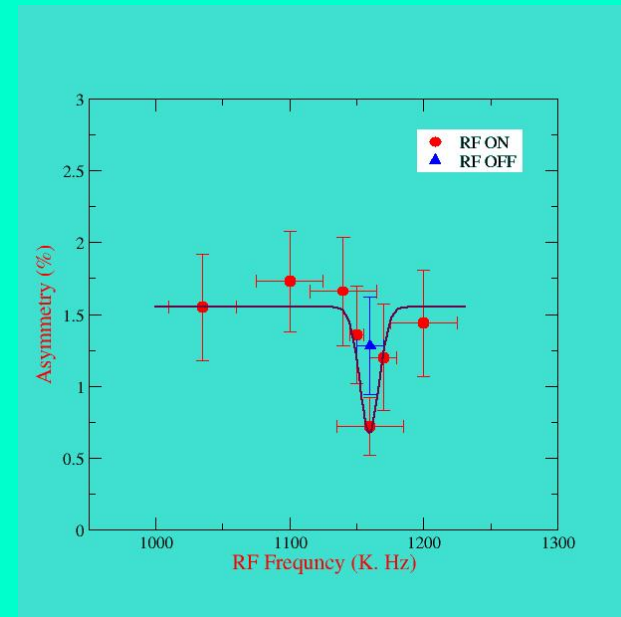


ISOLDE
BEAM

250 kV

Rf resonance curve for ^{17}Ne

$$\mu=0.74(4)$$



Present possibility – move experiment to REX

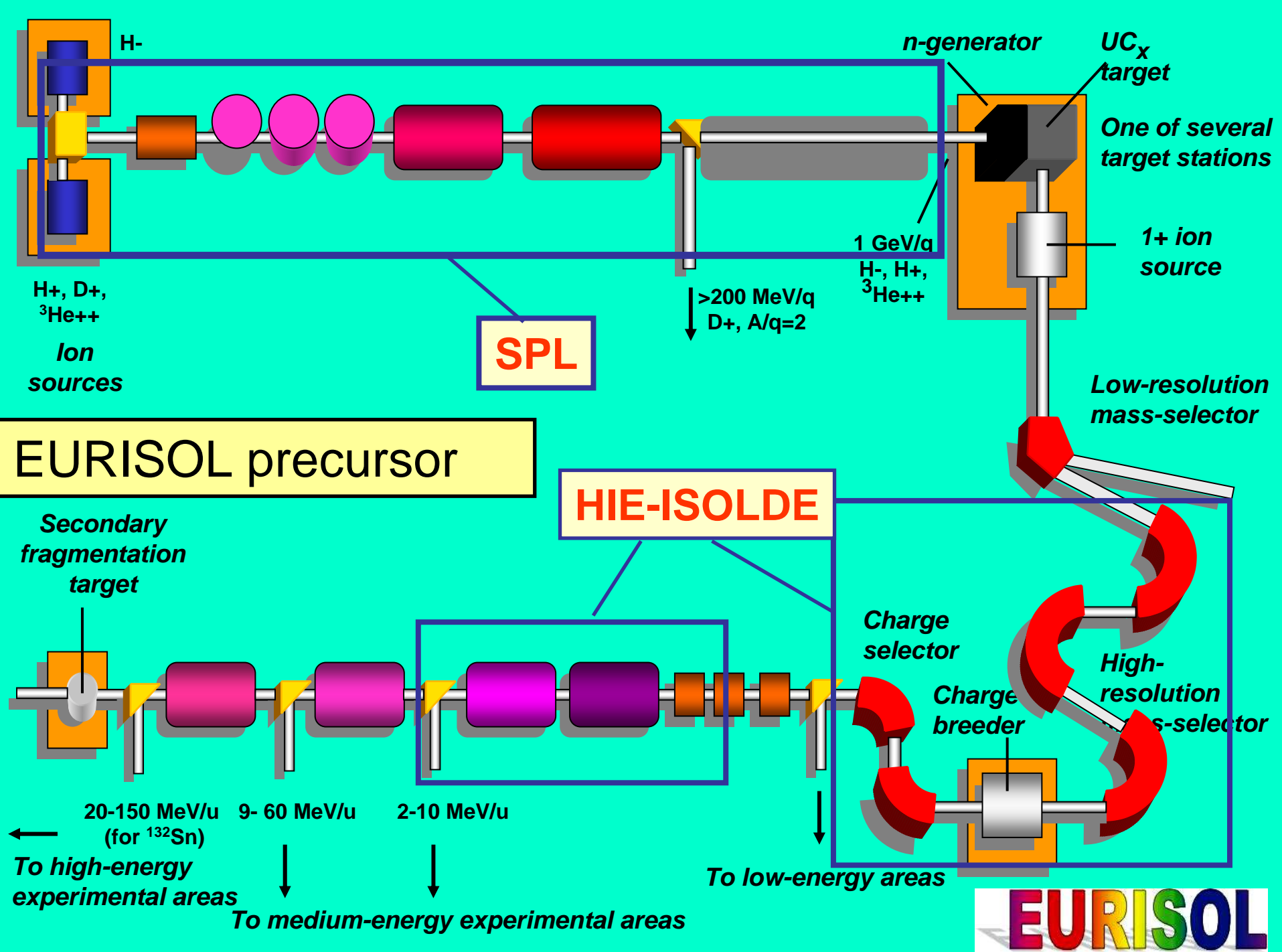
REX@ HIE ISOLDE ADVANTAGES: Higher energy, higher yields:

- Velocity – “no” multiple scattering in foils.
- Variety of charge states, configurations.
- Ease of operation!!
- More “exotic” nuclei accessible

FUTURE:

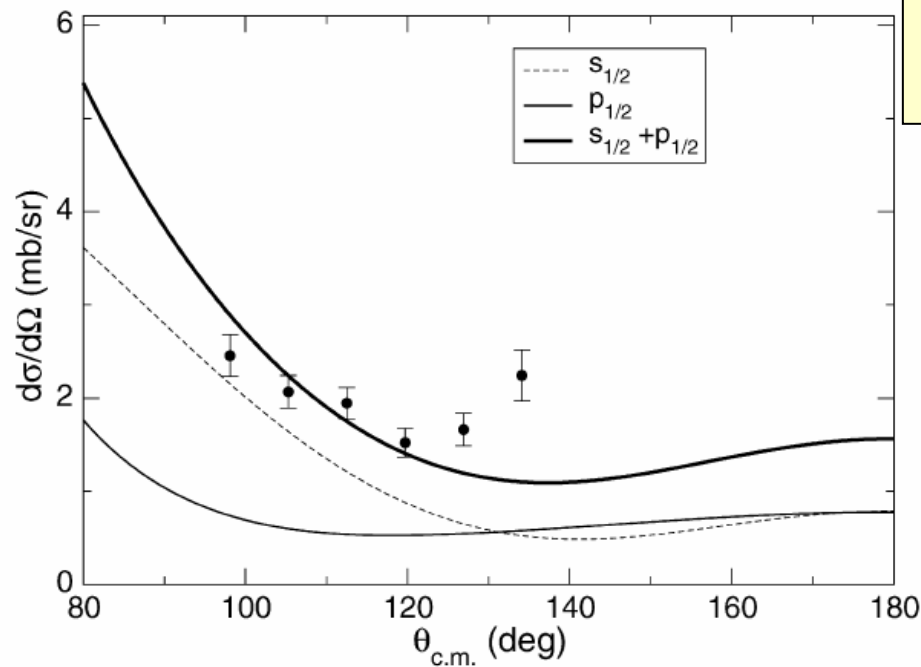
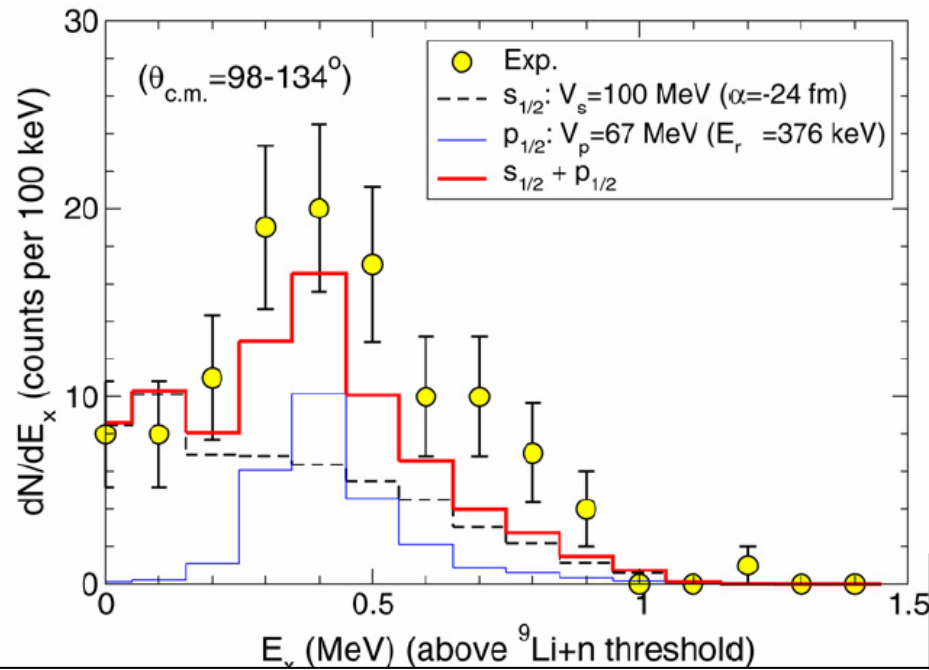
For example:

fp shell, **Z=N+1 nuclei** - ^{55}Ni -- ^{55}Co , ^{59}Zn --



Summary

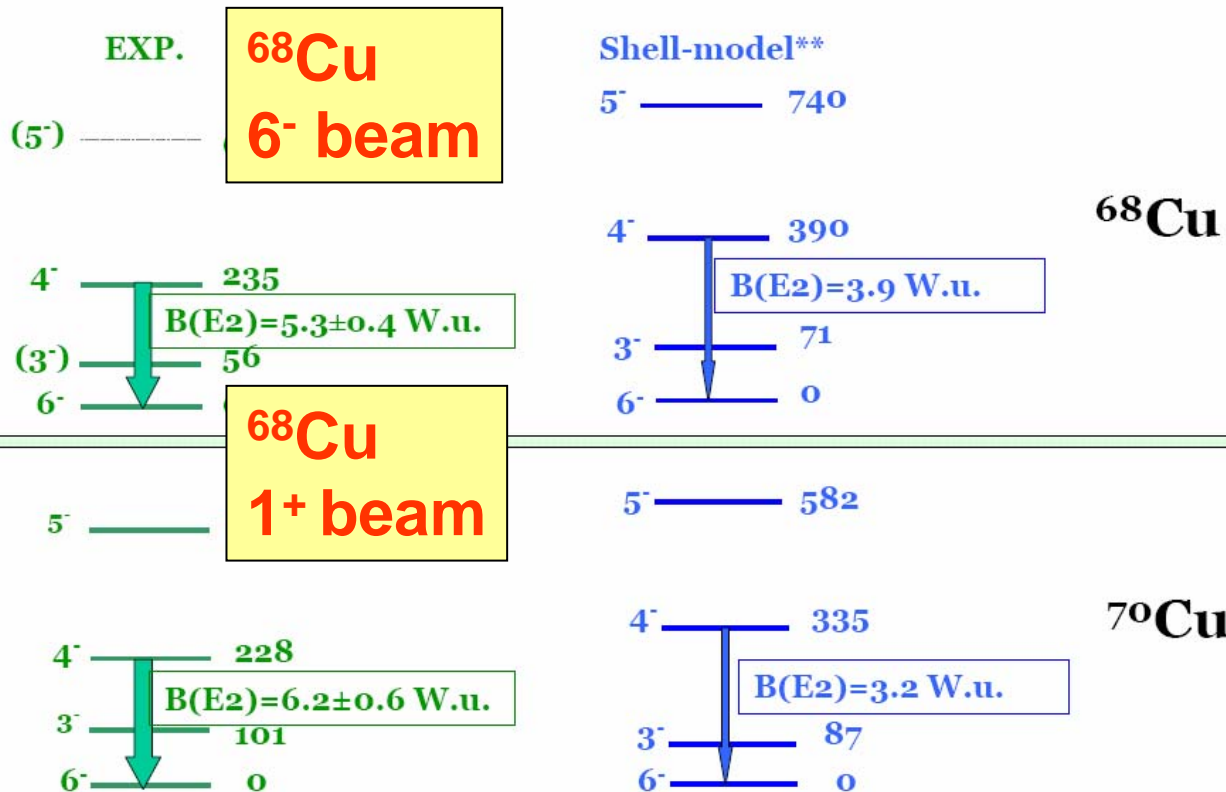
- HIE ISOLDE will be a world class facility
- HIE ISOLDE will produce major advances in the interlinked fields of exotic nuclei and explosive nuclear astrophysics
- It can form the foundation for the ultimate future European ISOL facility, EURISOL



${}^9\text{Li}(d,p){}^{10}\text{Li}$
 Jeppesen et al
 PL B642(2006)449

$^{68,70}\text{Cu}$ Coulex

Coulex of $^{68,70,m,g}\text{Cu}$



**N. Smirnova, Private Communication

I Stefanescu et al, PRL 98 (2007) 122701