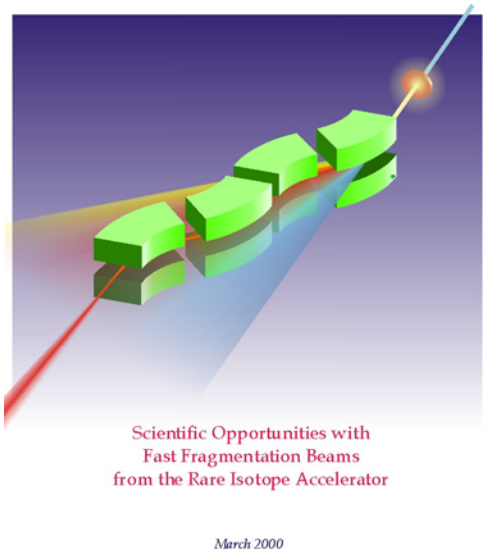
Fast Beams at RIA, what will it take?

D.J. Morrissey,
NSCL & Dept. of Chemistry,
Michigan State Univ.



Appendix C in March/2000 report
from the NSCL …
M.R. Thoennessen, et al.
http://www.nscl.msu.edu/research/ria/whitepaper.pdf

Studies of nuclear structure and reactions with Fast Exotic Beams

Limits of Stability	Identification (1/day)
Properties of nuclei at the extremes & Delineation of a comprehensive model Origin of the Elements	Mass through ToF (100/day) Interaction cross sections (100/day) Knockout Rxns (0.01/s = 1000/day) Coulomb Excitation (0.1/s)
Bulk nuclear matter & EOS	Reaction Dynamics, EoS (1000/s)

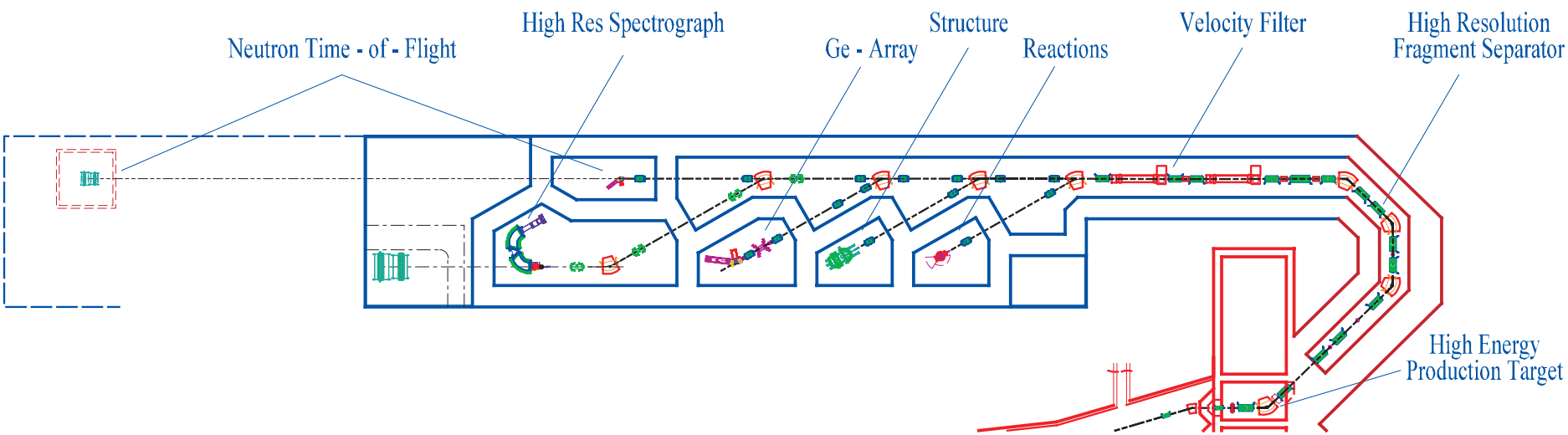
High luminosity $N_0\Phi$ of fast beams allows studies with the most exotic nuclei

RIA on the MSU campus

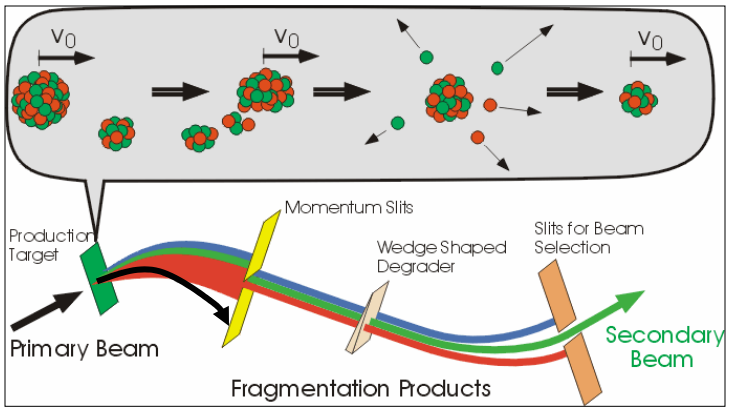
Parallel experimental program

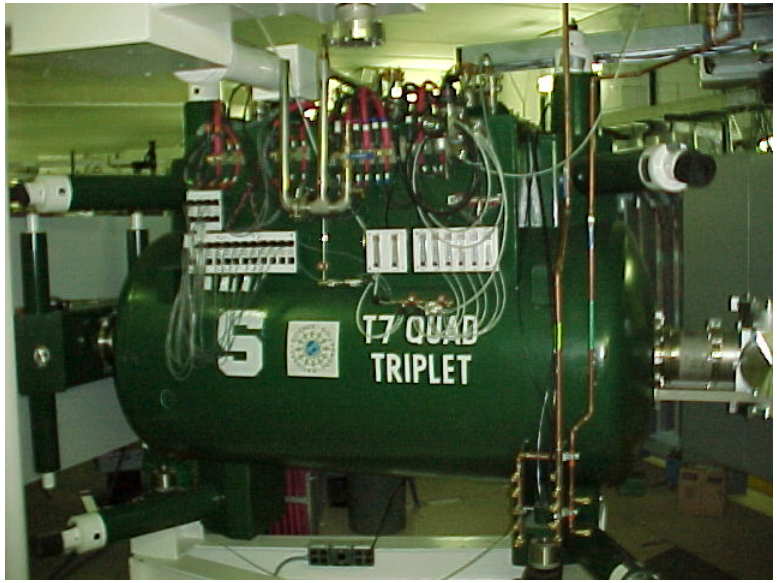
High Resolution Fragment Separator

and High Energy Experimental Hall



High Resolution Fragment Separator

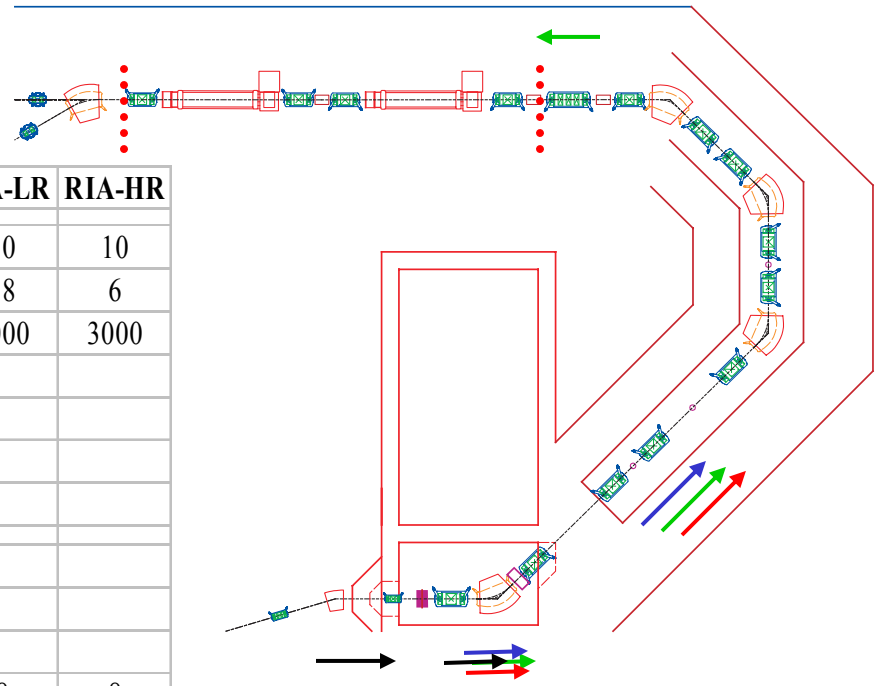




A900 Quadrupole Package

	$\Delta p/p$	$d\Omega$	$B\rho$	
A1200	±1.5	0.8	5.4	(1991-99)
A1900	±2.5	8	6	(2001-)
RIA(HR)	±3%	10 msr	~8 Tm	

Fragment Separator in Perspective



Parameter	A1200	RIPS	A1900	RIA-LR	RIA-HR
Solid Angle (msr)	0.8	5	8	10	10
Momentum Acceptance (%)	3	6	5.5	18	6
Resolving Power *	2400	1500	2915	1000	3000
Intermediate Image ^					
Magnification Mx	0.7	-1.6	2.04		
Magnification My	3	-5.7	0.75		
Dispersion (cm/%)	1.67	2.4	5.95		
Length (m)	22	21	35		
Maximum Quadrupole Gradient (kG/cm)	3.5	1.41	2.2		
Dipole Full Vertical Gap (cm)	5	14	9		
Rigidity (T.m)	5.4	5.76	6	8	8
RELATIVE ACCEPTANCE	**1.0**	**12.5**	**18.3**	**75.0**	**25.0**
figure of merit	0.5	3.6	10.2	14.3	14.3

A1200 Symmetric medium acceptance optics, NIM B56/57 (1993)1106.

RIPS Proc.1st Intl. Conf. Radioactive Nuclear Beams (1989) p. 563.

* --Resolving Power = Dispersion/X0 Mx, where X0 is the beam spot size at the target (assumed to be 1 mm) and Mx is the magnification.

^ At the wedge position.

High power target, liquid Li

Front end & beam stop

Separator (supercon) :

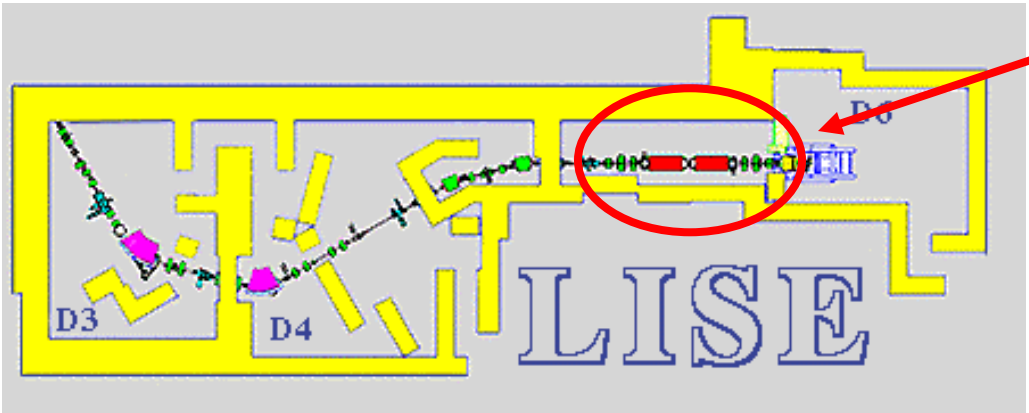
3D, 41Q's & multipoles

Chambers, power supplies, etc.

Velocity Filter

Separation of contaminants, particularly p-rich nuclei

Estimate that ~20 meters is necessary



GANIL Bρ = 3.2 Tm
(5m, 0.1m gap, 400kV)

MSU RPMS (~3m)

Example: Production of ^{17}Ne in A1200 / RPMS:

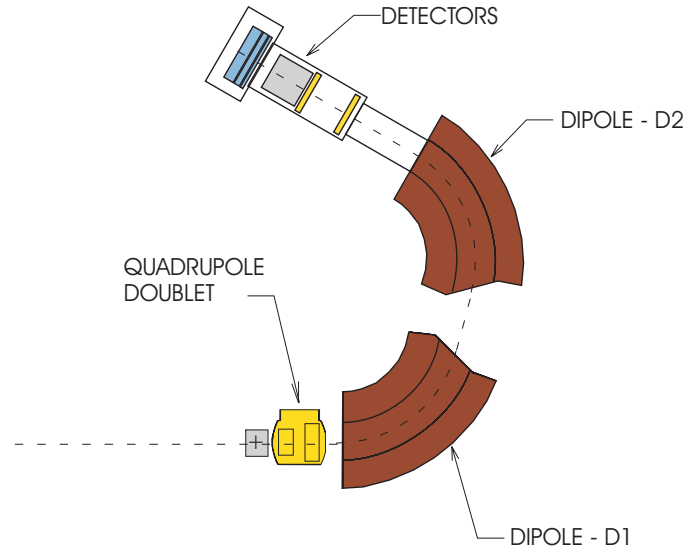
Primary Beam:	100 MeV/u ^{20}Ne
After Separator:	^{17}Ne : ~5%
Others:	^{15}O, ^{14}N
After Wien filter:	95% ^{17}Ne

High Resolution Spectrograph

Examples:

SMART (RIKEN) – swing beam

$p/\Delta p$=12000, $d\Omega$=10 msr, $B\rho$=3.6Tm

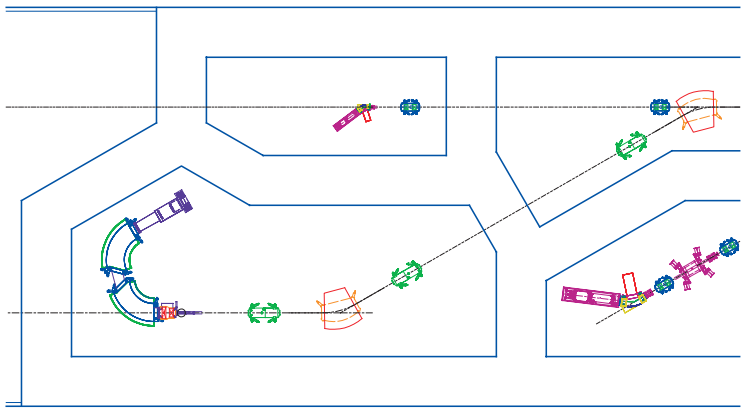


SPEG (GANIL) – horz. spectrometer

$p/\Delta p$=10000, $d\Omega$=4.9 msr, $B\rho$=2.9Tm

S800 (NSCL) – vert. Spectrometer

$E/\Delta E$ = 10000, $d\Omega$=20 msr $B\rho$=4 Tm



Want:

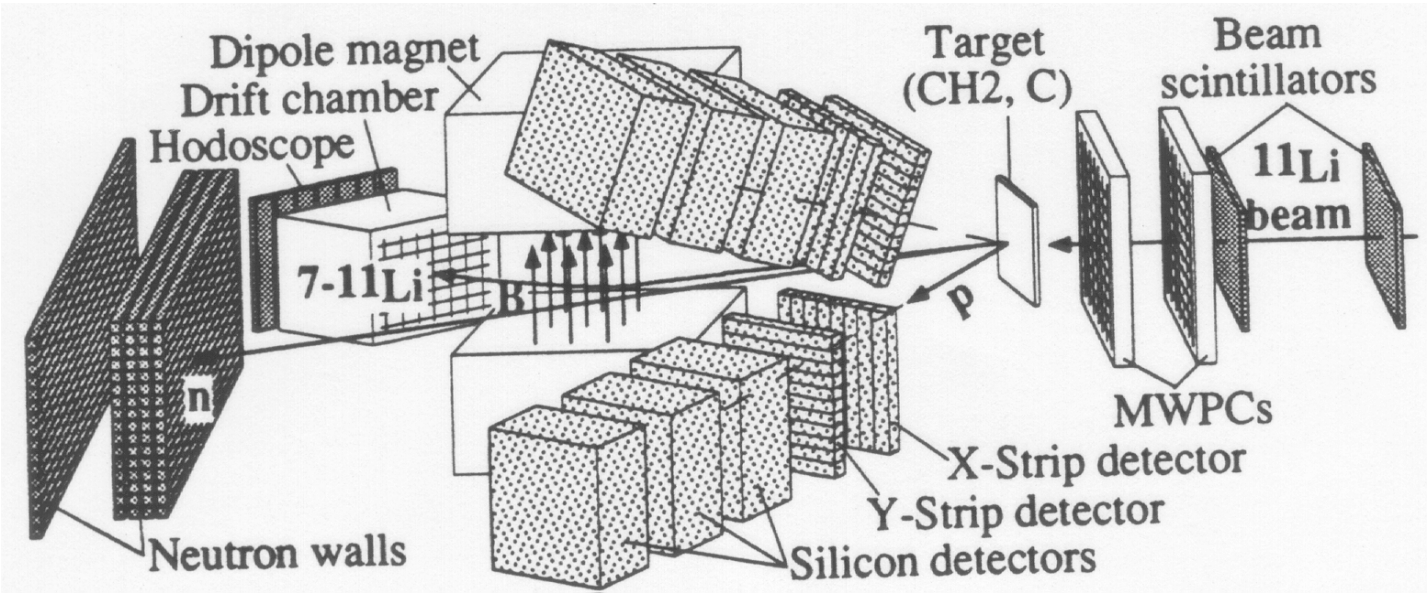
$E/\Delta E$ = 10000, $d\Omega$=20 msr, $B\rho$=8 Tm

Complete system scaled from S800, 14.3 M$

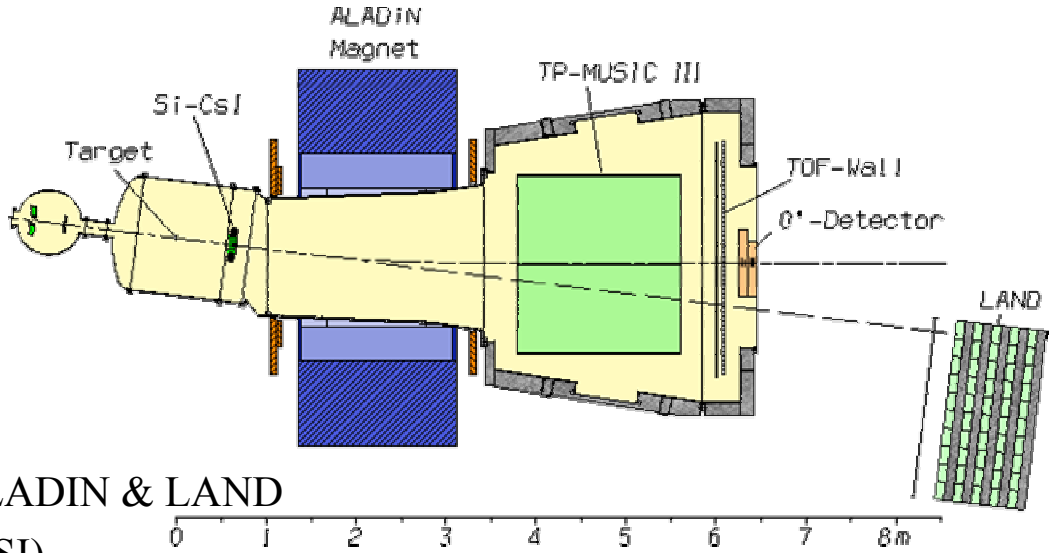
Example Coincidence Study

Studies of resonances beyond the drip-lines
using a combination of equipment & RIBs at ~10^3/s

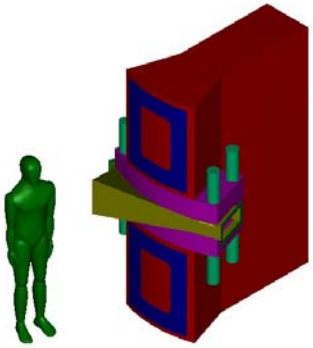
Example: ^{11}Li Korsheninnikov et al. RIKEN

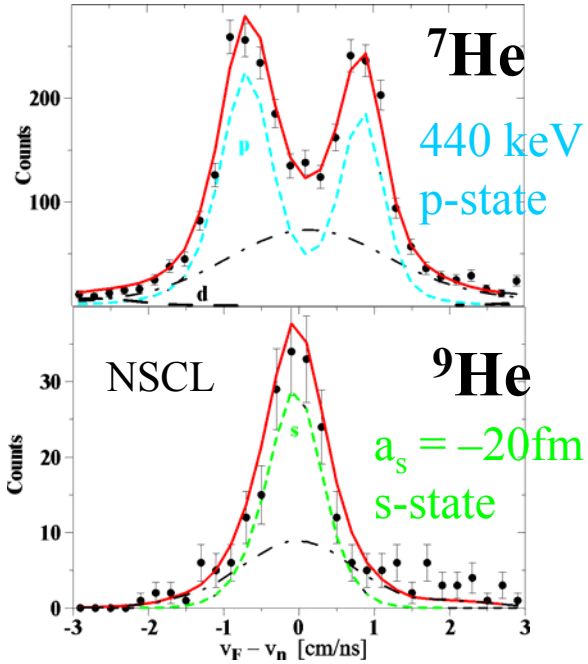


Sweeper Magnet & Neutron Walls



ALADIN & LAND
(GSI)



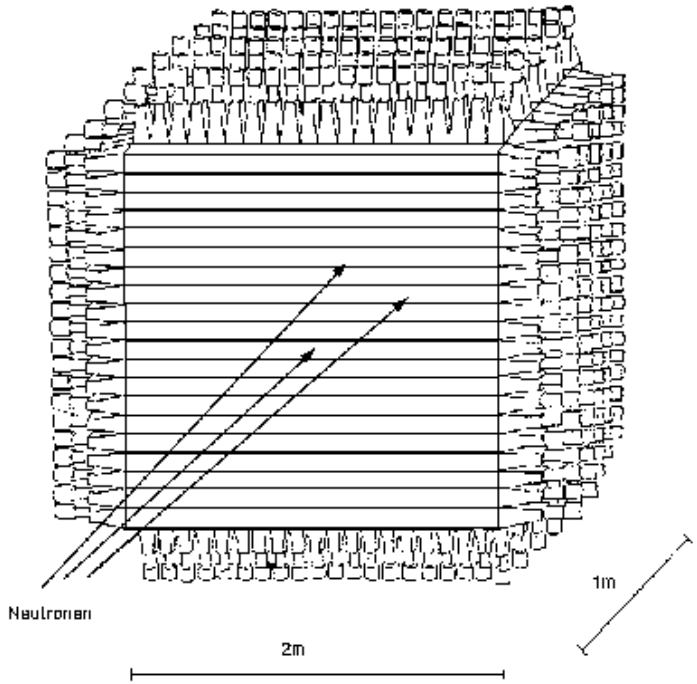


Coincident neutron and proton measurements near 0° for structure studies at/beyond the drip lines

8 Tm, large gap dipole

Costs scaled from 4 Tm device at MSU: 5M$

Neutron Walls



LAND-GSI

NSCL-neutron Wall

Neutron unbound final states

Graded scintillator/radiator .. ~ 4 m^2 x 1m

ToF .. E_n ~ 50 – 400 MeV .. Flight path ~50 m

Costs scaled from existing arrays: 2 M$

Charged Particle Array

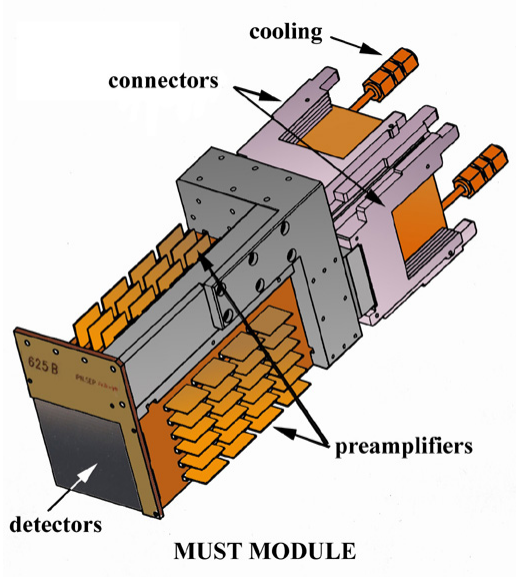
RIB reactions have Inverse kinematics

p(A,A)p ; p(A,A')p' reactions (~90°)

d(A,A+1)p ;p(A,A-1)d reactions (~0°, ~180°)

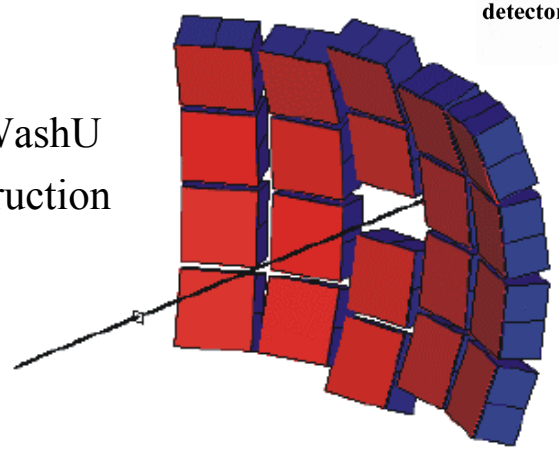
Modular, high angular resolution

Estimated costs: 3 M$



IPN-Orsay

NSCL-IU-WashU
under construction



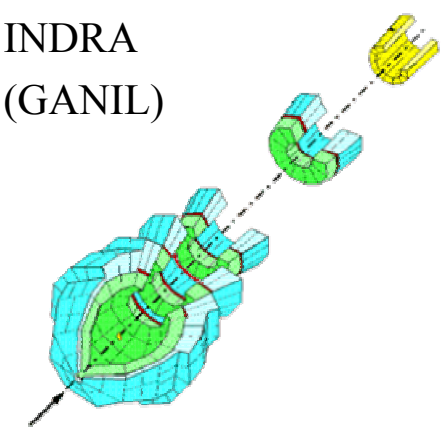
Reaction Dynamics

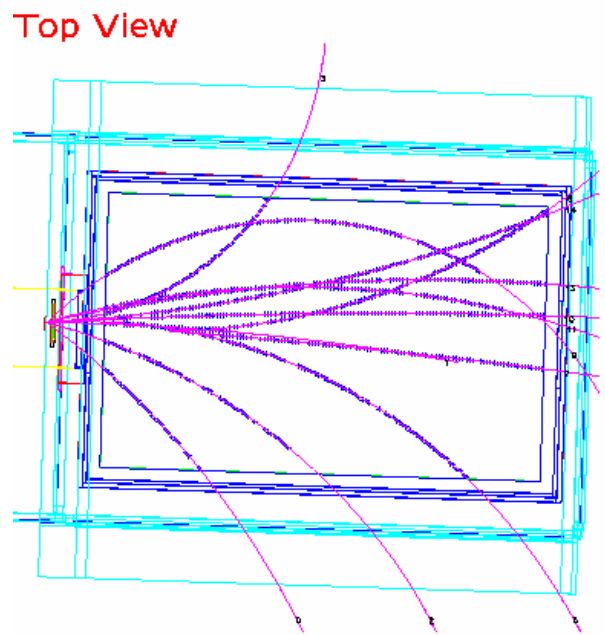
High-energy, $^{A}Z + {}^{A}Z'$ reactions, isotopic particle identification

Isospin in the Eq.of S, Nuclear compressibility & phase transitions

Best option: Time Projection Chamber @ 4 M$

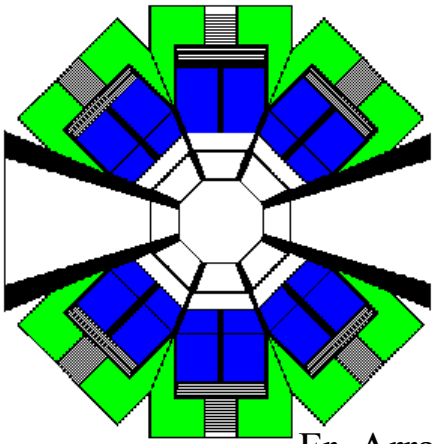
INDRA
(GANIL)





EOS-TPC
18 GeV/c p+Au

γ-ray Detector Array (shared equip.)

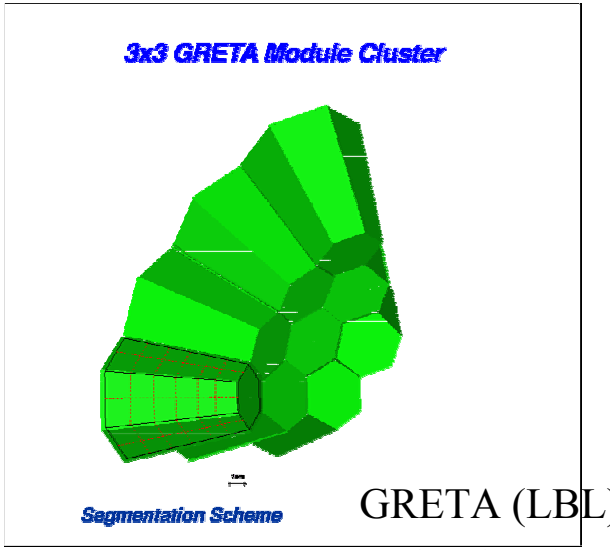


EXOGAM
Fr. Array of Clovers
probably not sufficient

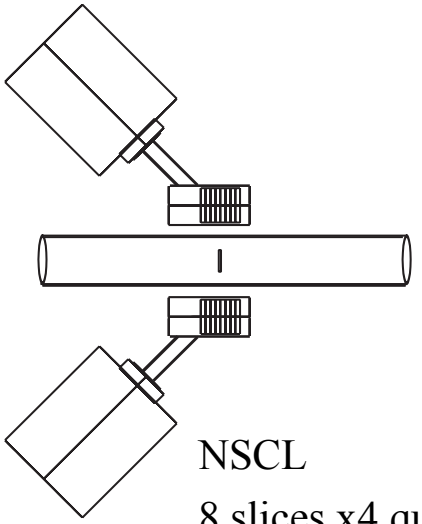
Particle-γ coincidence array for knock-out and coul-ex rxns.

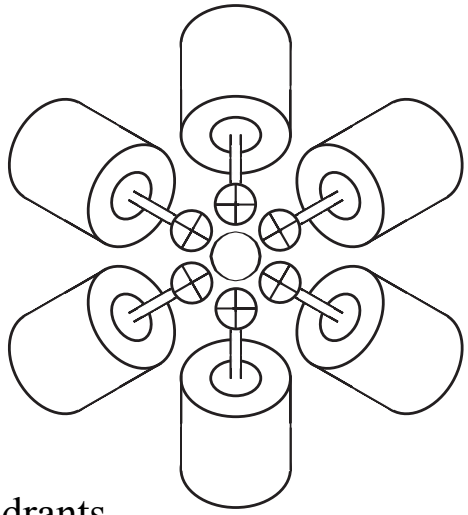
Coincident γ-rays at $\beta \sim 0.2 - 0.6$

Doppler shift correction and broadening minimization requires a few millimeter position resolution



GRETA (LBL)
under development





NSCL
8 slices x4 quadrants

Fast Beam Production		Cost (M$)
Production Region Transport	Rad-hard magnets	4.8
High Res. Fragment Separator	3 dipoles, 41 quads&multipoles, etc.	19.2
Velocity Filter system	Beam purification (p-rich beams)	2.3
Beam Transport	Magnets, chambers, vacuum	3.8
	Production Subtotal	30.1
	With Contingency	40.6

Experimental Equipment	Use	Cost (M$)
High Resolution Spectrograph	Heart of experimental program	14.3
Large Area Neutron Detector	Neutron measurements at zero degrees	2
Modular Charged Part. array	Inverse kinematics studies	3
Sweeper Magnet	Properties of nuclei beyond the drip lines	5
Time Projection Chamber	Equation of State, Rxn. Dynamics	4
Implantation Station	Half lives, decay studies	1
	Equipment Subtotal (no contingency)	29.3
Pos'n Sensitive γ-array	Coulomb excitation, Knock-out rxns.	10/2
Large scale γ-array	Decay studies, etc.	24.8/2
	One-half of shared equipment costs	17.4
	Production Subtotal (with contingency)	40.6
	Total for High Energy Area	87.3