Possible Evolution of RIB Production Methods and the Associated Instrumentation: a Personal View

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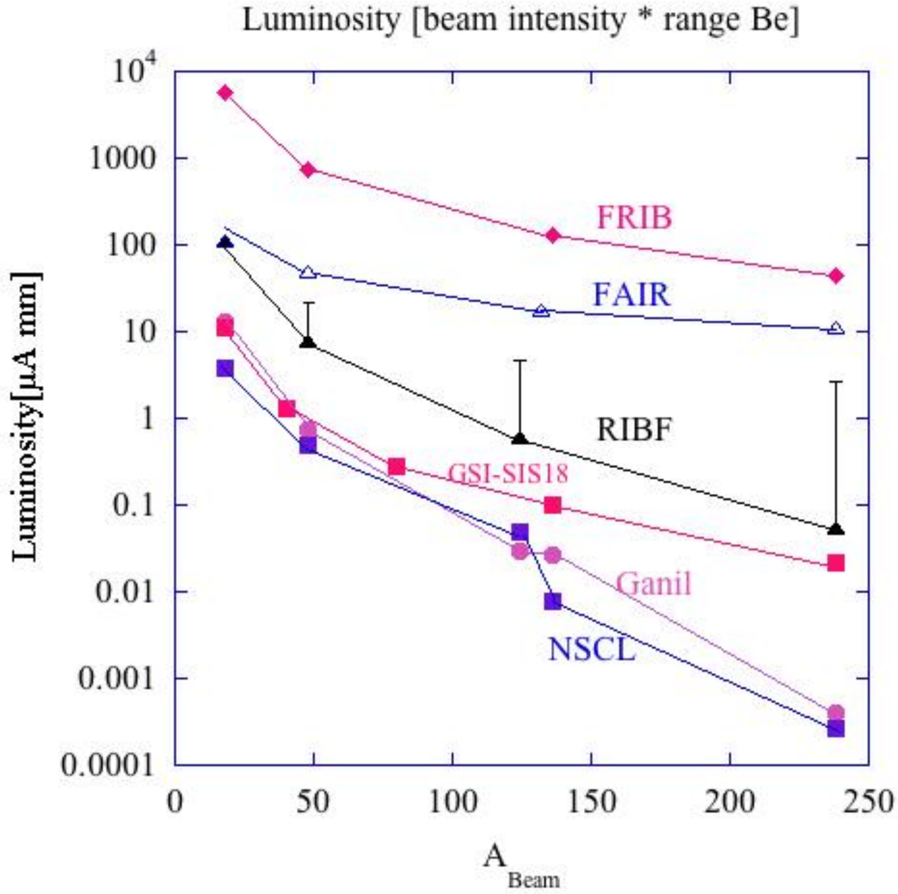
EMIS XVI Matsue December 2012

- Some remarks on present situation: Production of RIB by Fragmentation and Isol
- Use of secondary beams: efficiency, resolution and precision
- Example of future evolutions and improvements: multi-use(r)

Luminosity of Production by Fragmentation



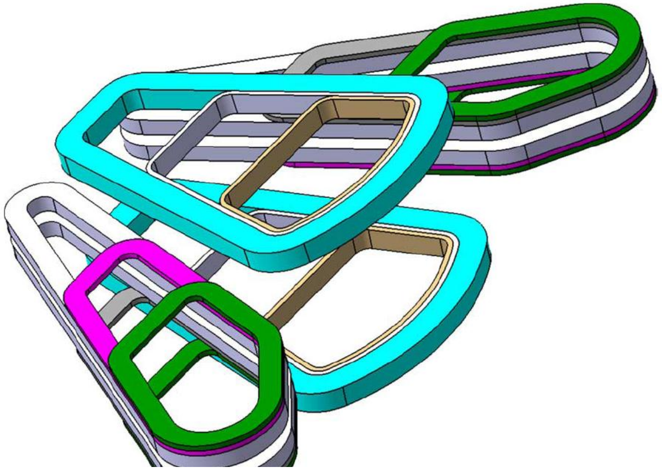
Intensity of Fission/Spallation Sources for Isol

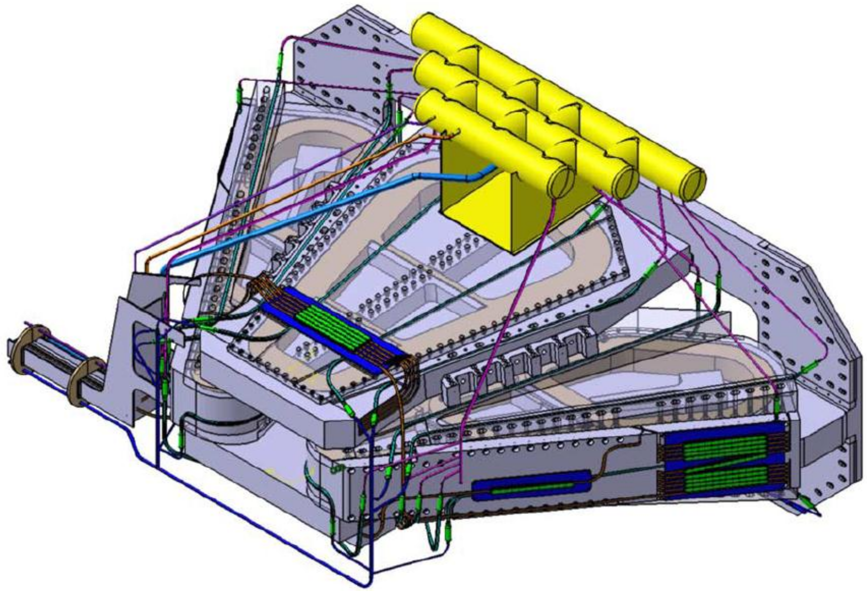
Facility	Location	Target		Driver beam			Fiss. rate
			g/cm2	Type	MeV	uA	per s
TRIGA-SPEC	Uni Mainz, D	249Cf	3E-4	(n,f)	3E-8	"0.03"	2E+08
CARIBU	Argonne, US	252Cf	nr	sf	nr	nr	1E+09
ALTO	Orsay, F	238U	40	(g,f)	50	10	8E+10
TRIAC	Tokai, JP	238U	1	(p,f)	36	3	1E+11
IGISOL	Jyväskylä, FIN	238U	0.12	(p,f)	30	10	1E+11
HRIBF	Oak Ridge, US	238U	2.1	(p,f)	42	10	4E+11
ISOLDE	CERN, CH	238U	50	(p,f)	1400	2	2E+12
CARR-ISOL	Beijing, CN	235U	3E-2	(n,f)	3E-8	32	7E+12
SPES	Legnaro, I	238U	2.5	(p,f)	40	200	1E+13
ISAC2	Vancouver, CAN	238U	(40)	(g,f)	50	10000	5E+13
SPIRAL2	Caen, F	238U	(40)	d>(n,f)	40	5000	<1E14

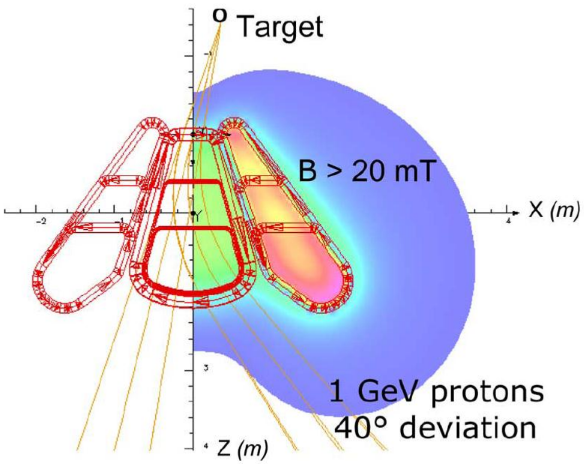
Efficient Use of RIB-Intensities

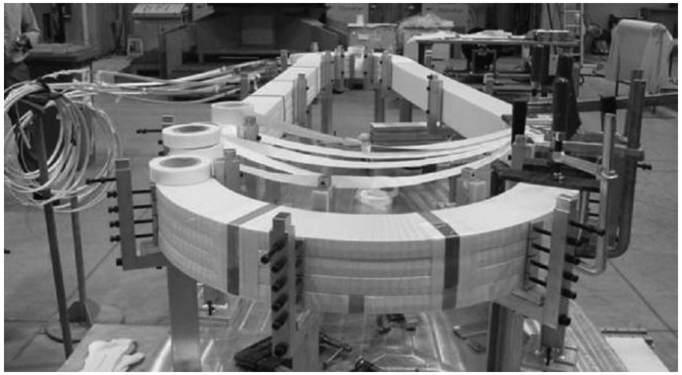
- High Transmission: large acceptance spectrometers
  Important improvements by powerful simulations/ high order corrections and new optical element technology
  (see sessions I,II, IV-2)
- Capture and Cooling of beams : better transmission, higher resolution
  (session IV-1)
- High resolution detectors and necessary beam rate
- High Efficiency Detectors: 4π detectors, active targets, high efficiency detectors (part of session II)

High Solid Angle Spectrometers with Active Shielding: example R3B-Glad



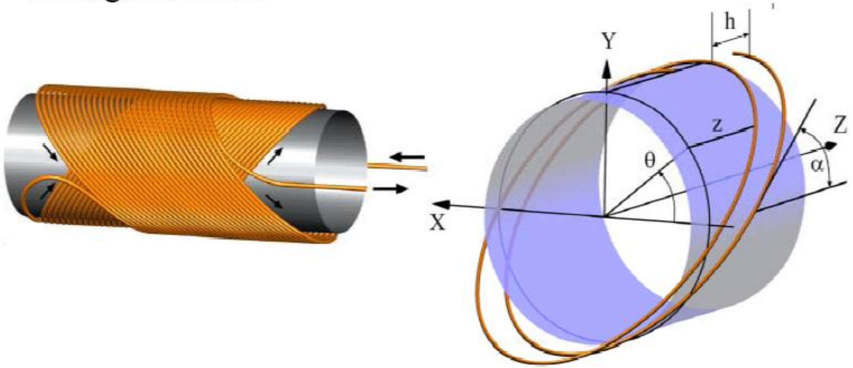






B.Gatineau et al.,IEEE TRANSACTIONS ON APPLIED SUPERCONDUCTIVITY, VOL. 18, NO. 2, JUNE 2008

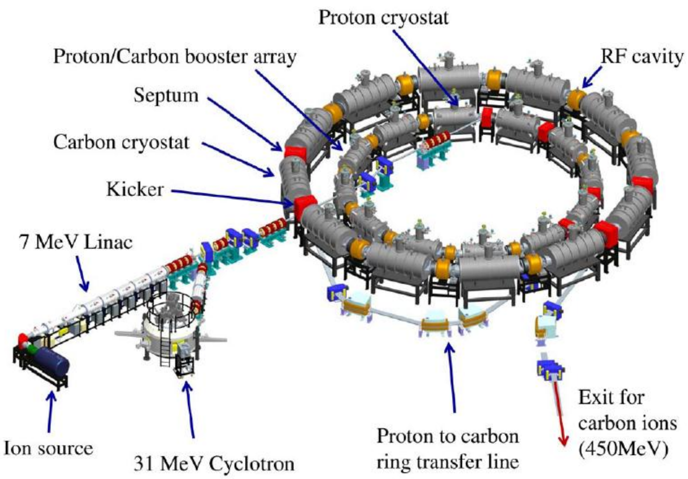
New Magnet Structures: Double Helix Coils



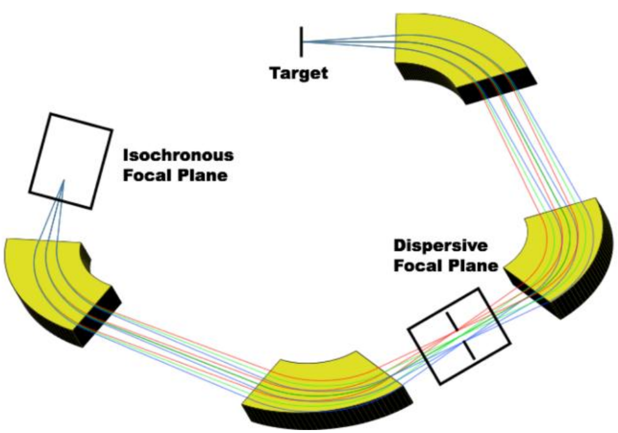
MOPAS055 Proceedings of PAC07, Albuquerque, New Mexico, USA

COMBINED FUNCTION MAGNETS USING DOUBLE-HELIX COILS *

C. Goodzeit, R. Meinke, M. Ball, Advanced Magnet Lab, Inc., Melbourne, FL 32901, U.S.A.



The Advantages and Challenges of Helical Coils
for Small Accelerators—A Case Study



Isla Project: see Poster

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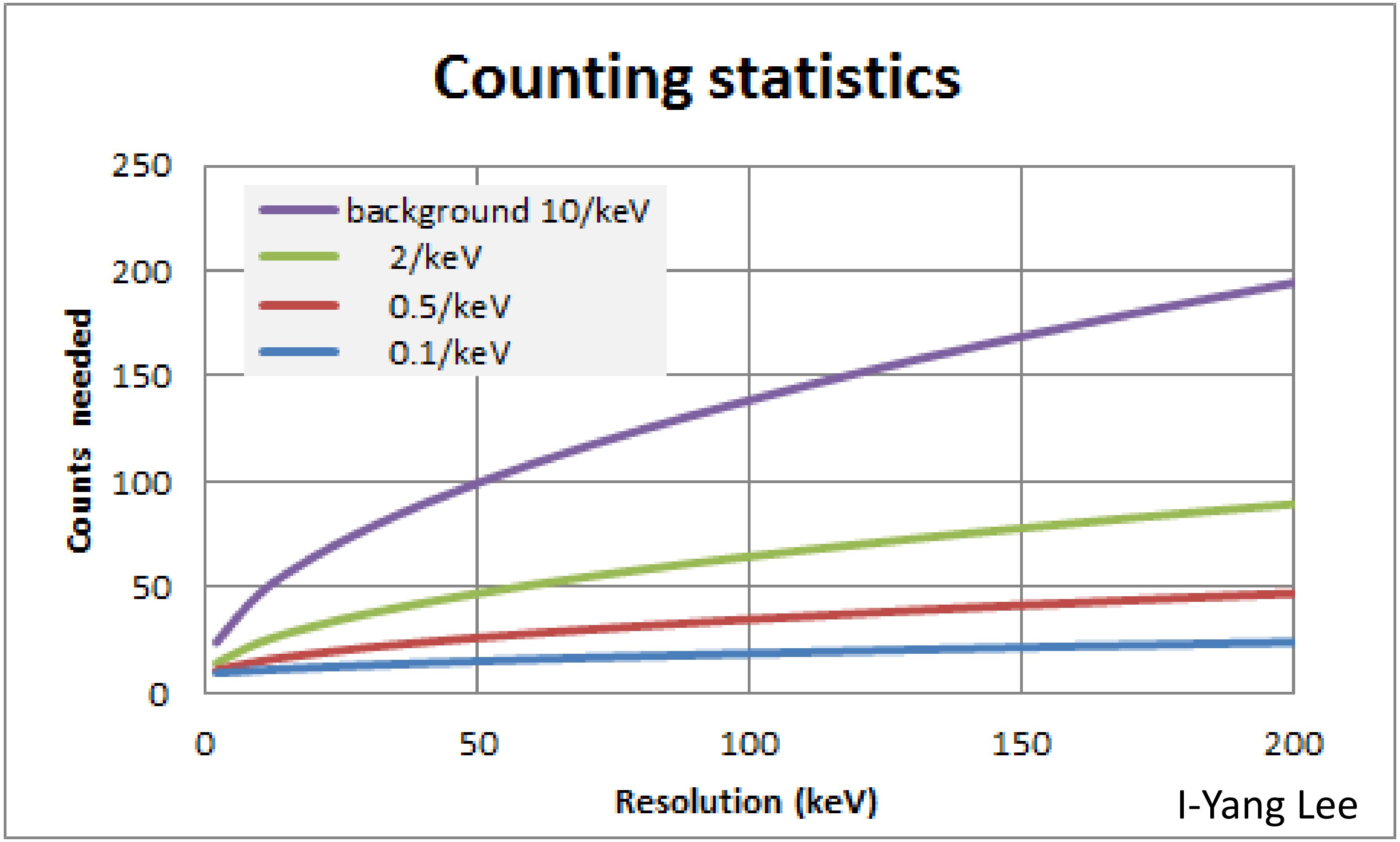
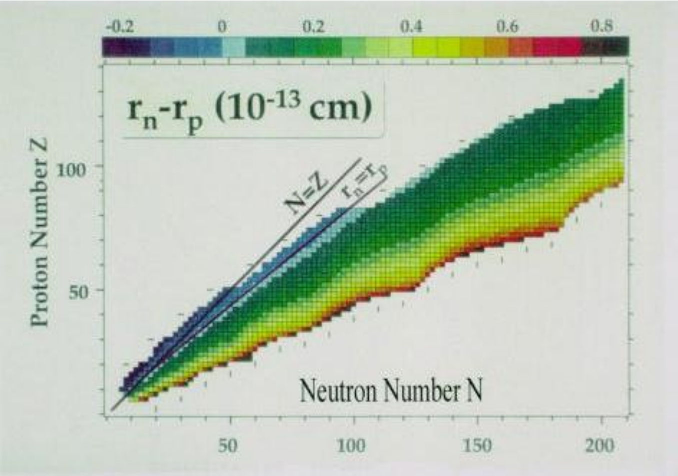
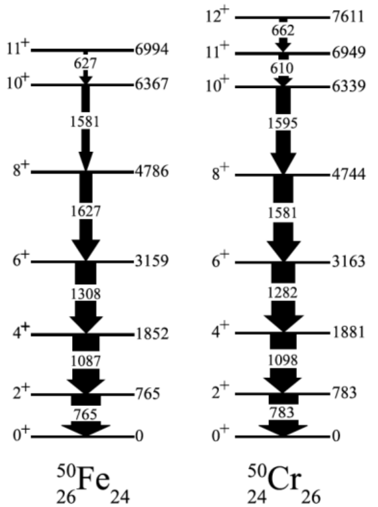
Efficient Use of RIB: statistics versus resolution

example: gamma evidence (3σ) for the existence of a transition in a spectrum with background

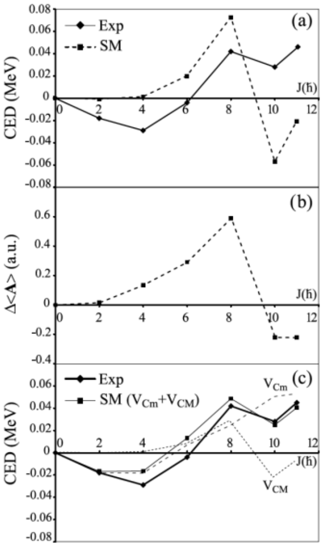


Example: Isospin symmetry violation in rotational bands as magnifying glass for nuclear structure phenomena near the proton dripline





Yrast states in the $T = 1$ ^{50}Fe and ^{50}Cr mirror nuclei



S.M.Lenzi et al.,PRL 87(2001)122501

1MeV gamma Center of Gravity Energy with precision of 1keV

NaI 5% =	50keV	2500 cts needed
LaBr 2% =	20keV	400 cts
Ge	2keV	4 cts

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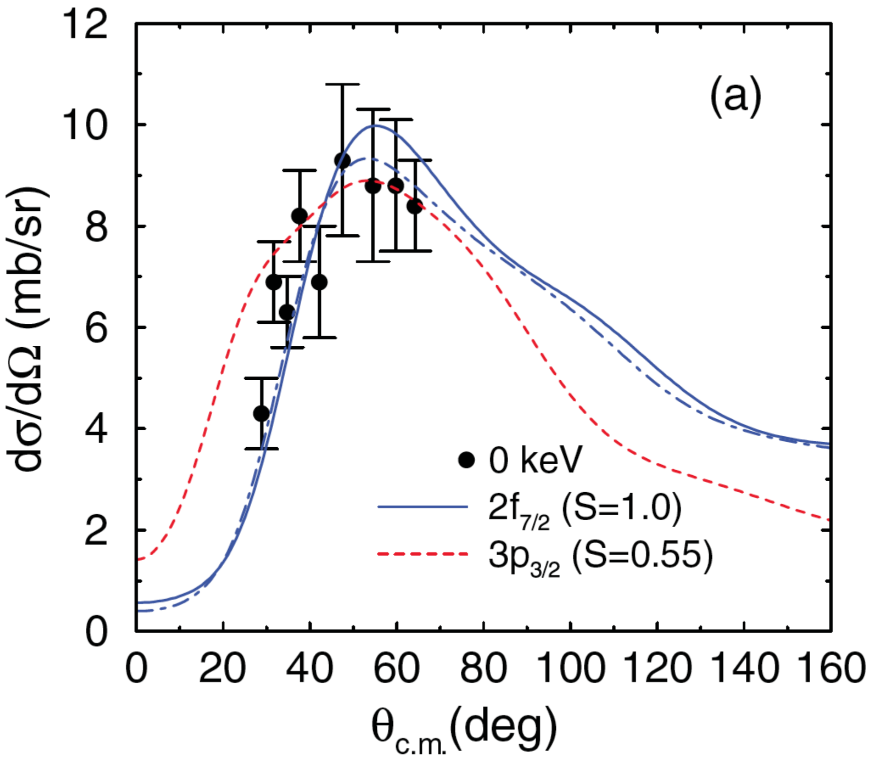
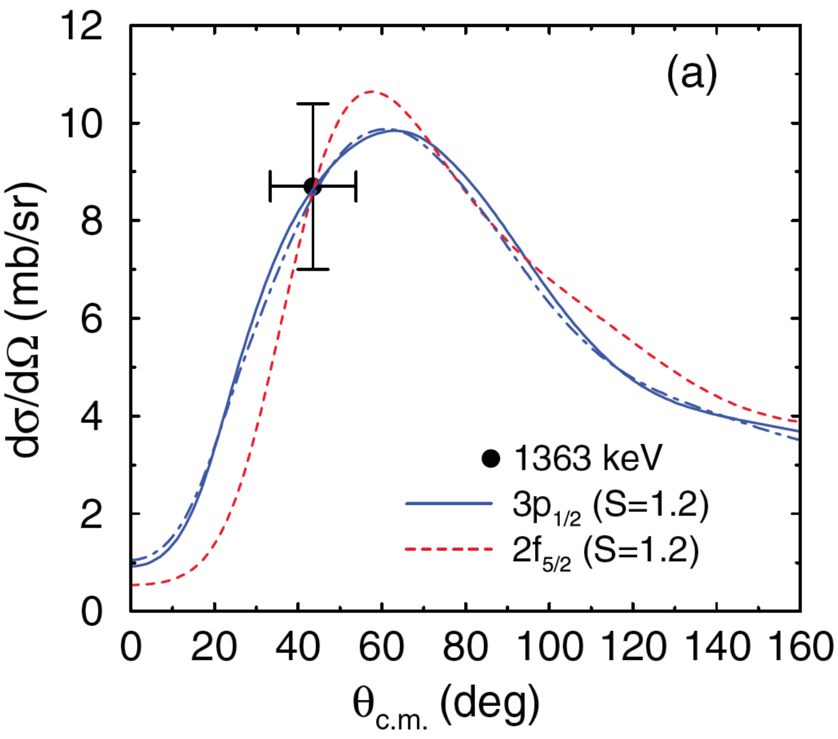
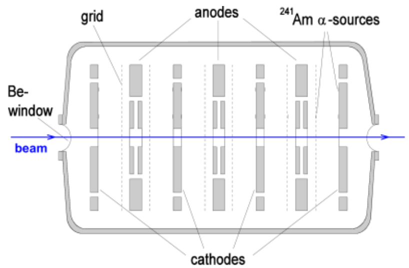
Statistics: example angular distributions $^{132}Sn(d,p)$

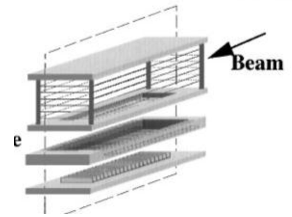




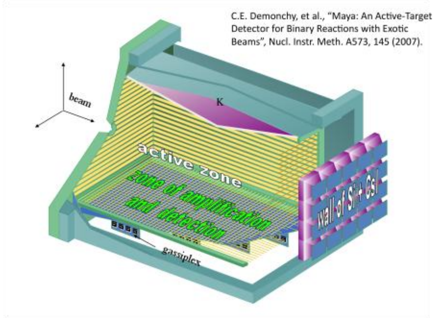
PHYSICAL REVIEW C **84**, 034601 (2011)



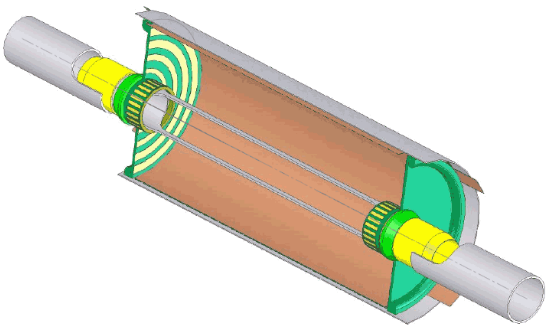
IKAR-GSI



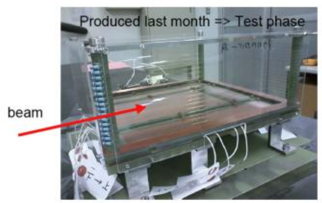
Mizoi et al
MSTPC



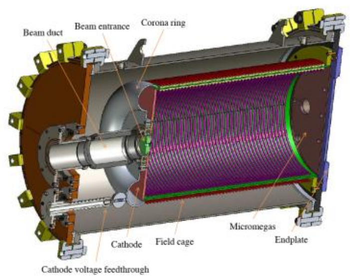
Maya@Ganil



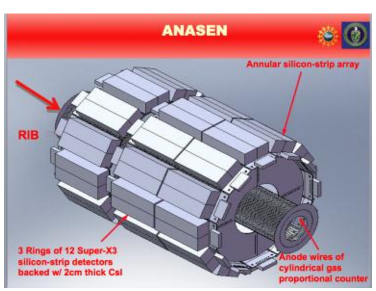
TACTIC: York-TRIUMF Collaboration



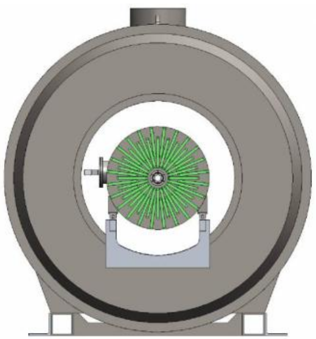
CNS-Riken



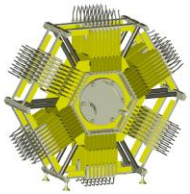
Prototype AT-TPC at MSU



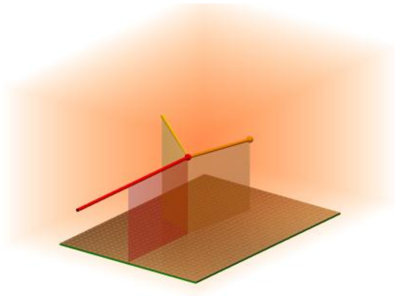
Anasen



AT-TPC at MSU



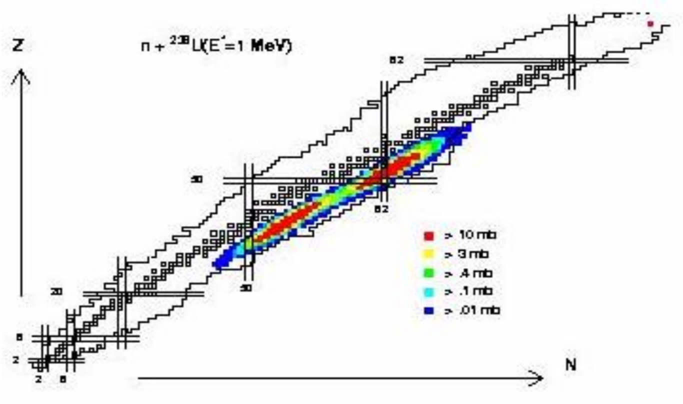
Fission TPC LLNL



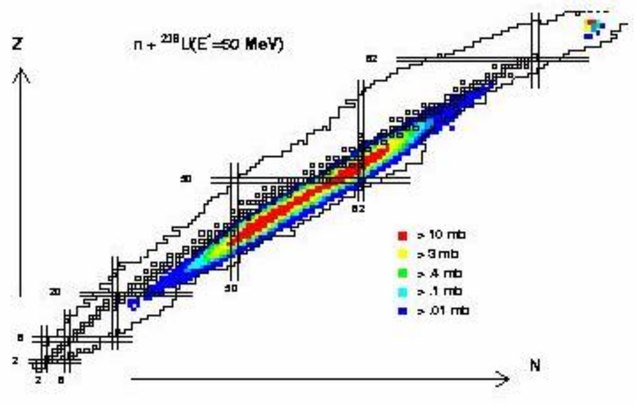
Actar-Ganil-Saclay-CENBG

Production Yields of with U beam

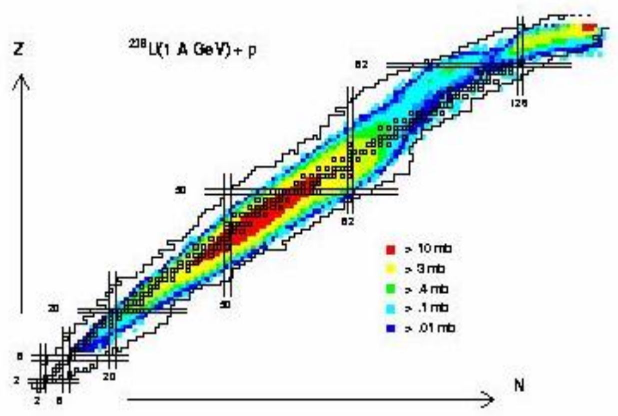
Reactor/Bremsstrahlung + ISOL



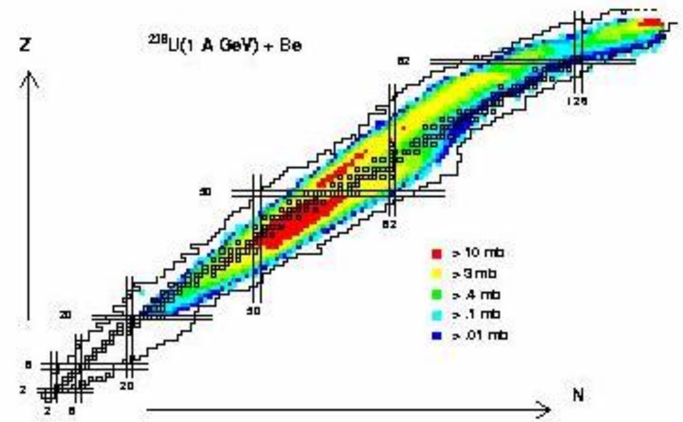
Converter(d→n) + ISOL



Proton induced spallation + ISOL



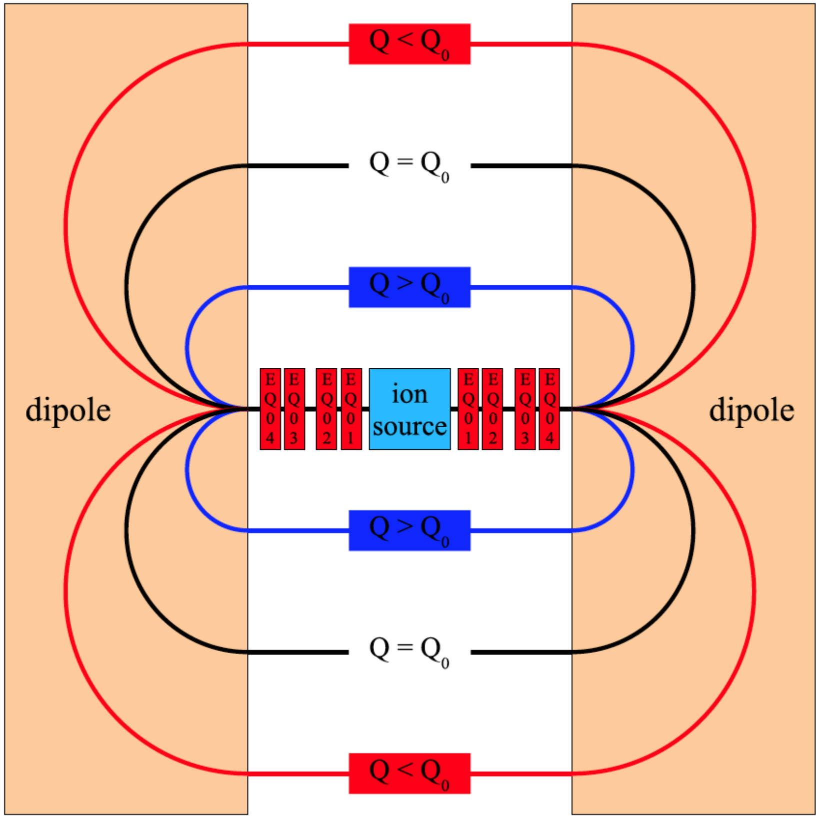
In-flight fragmentation



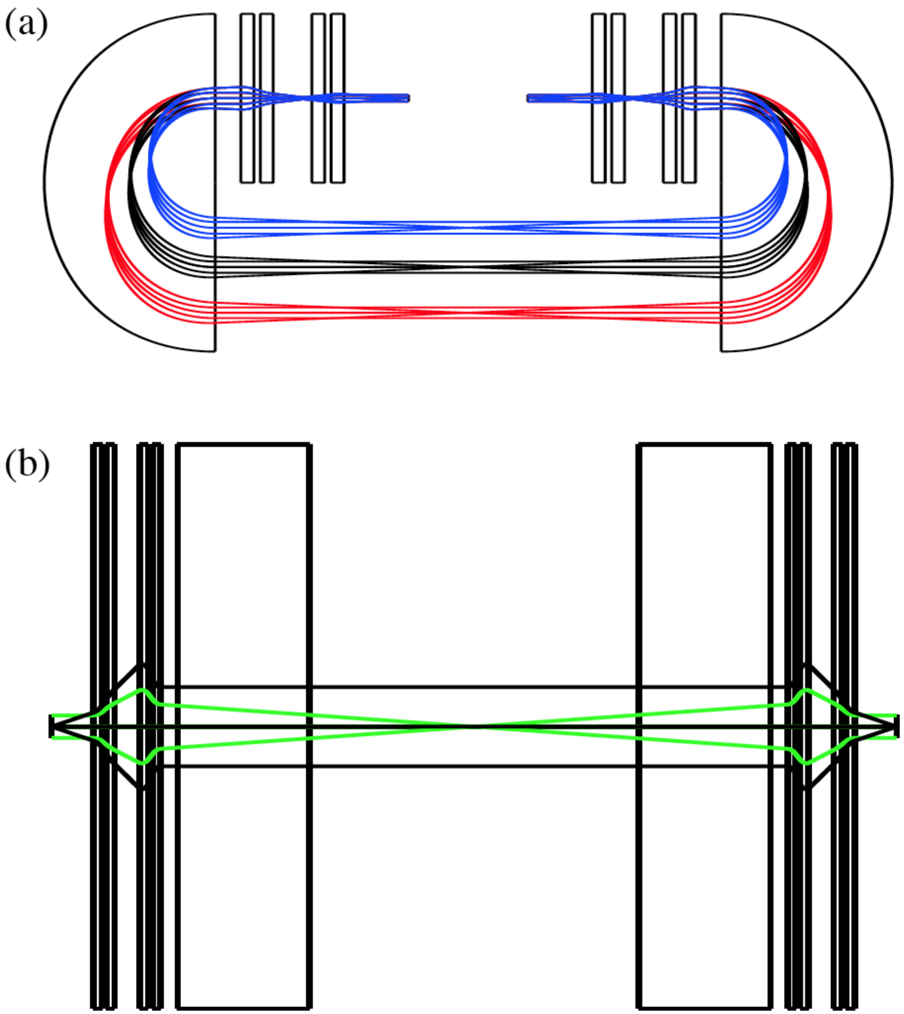
J. Benlliure

Efficient Use of RIB: recycle, do not throw away

Recirculation of charge states



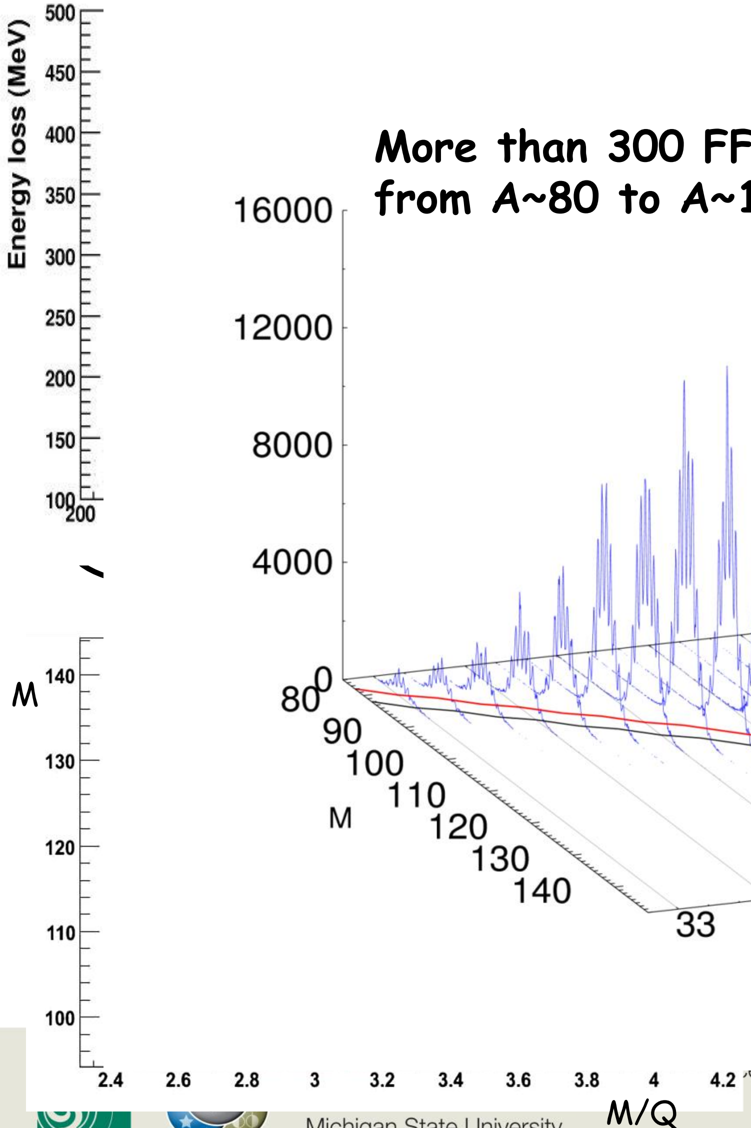
R.Cee, WM, ACC Villari, Proceedings of EPAC 2004, p.1267

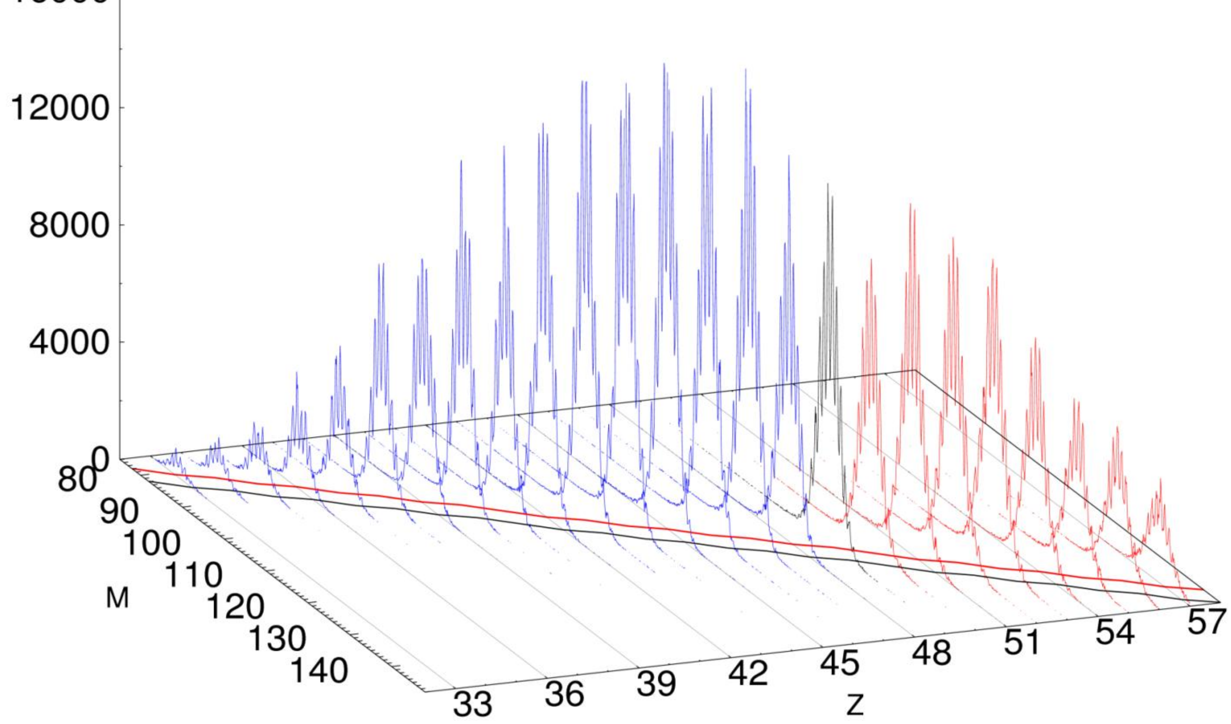


Efficient Use of RIB: do not throw away !

$^{238}U+^{12}C$ 6.1 MeV/n

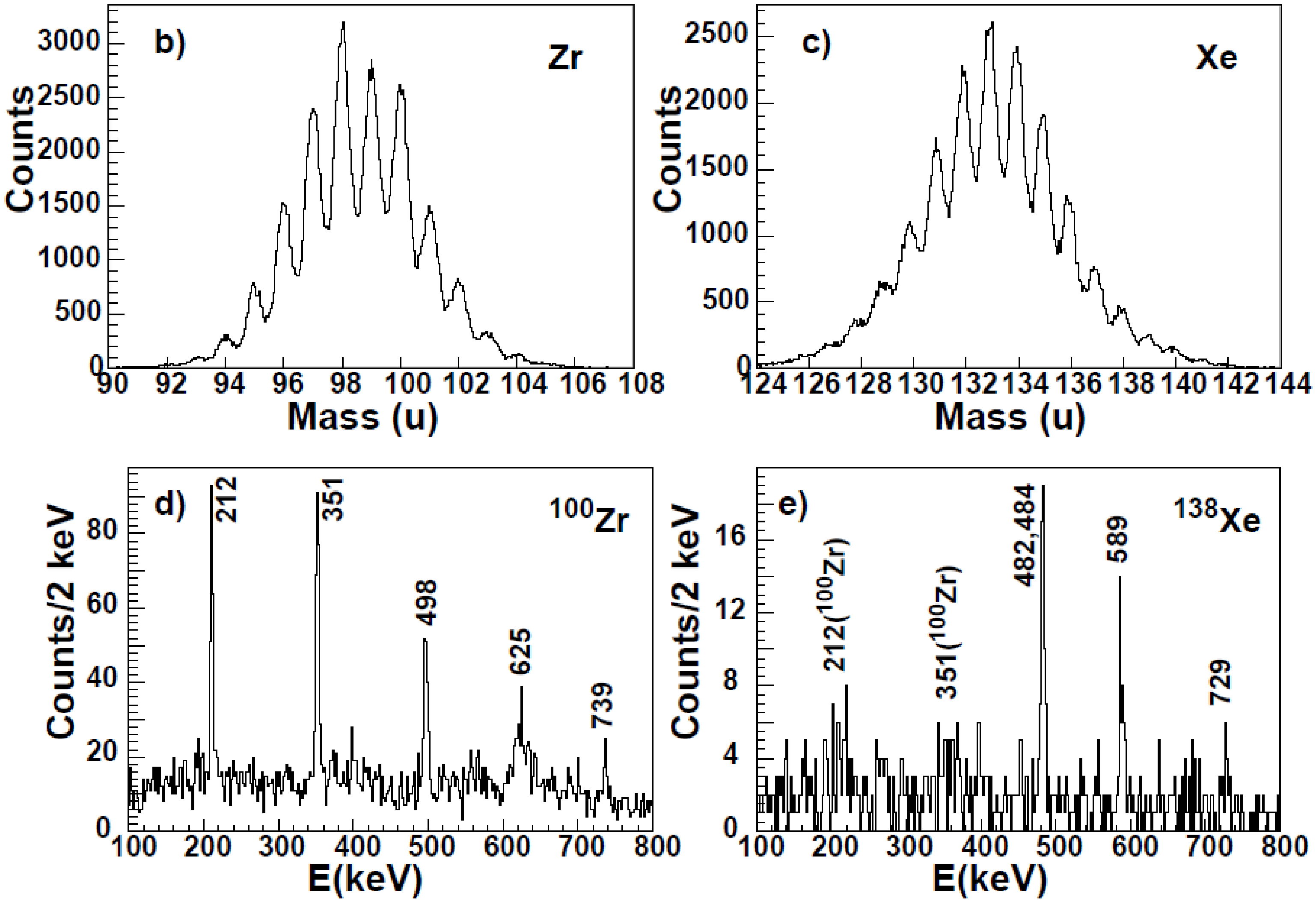
More than 300 FF isotopically identified from A~80 to A~150



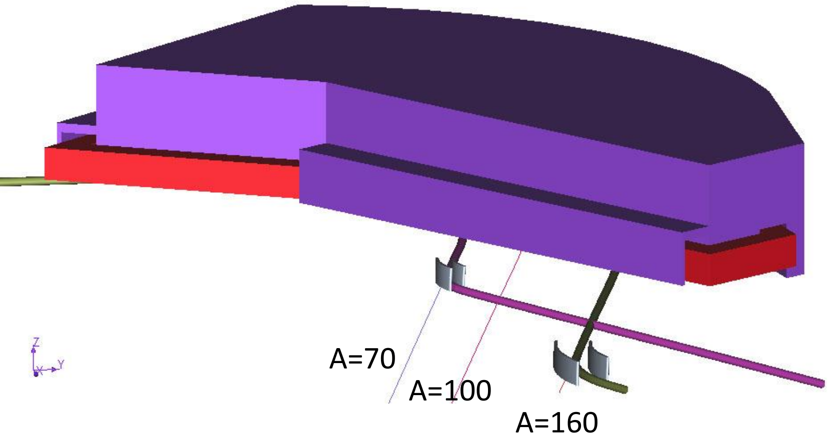


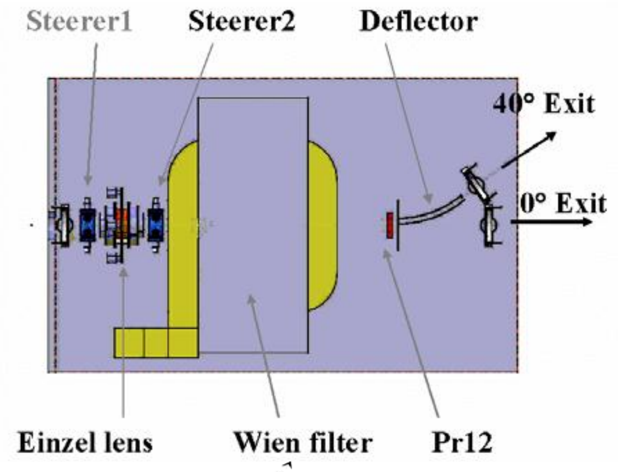
A.Shrivastava et al.,PHYSICAL REVIEW C **80**, 051305(R) (2009)
A.Navin private comm.

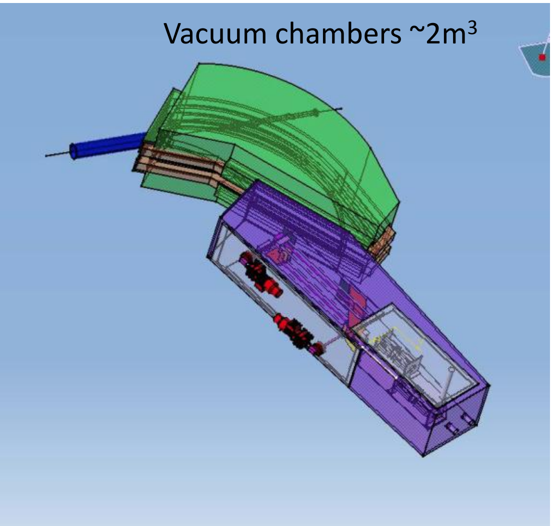
Efficient Use of RIB: do not throw away !

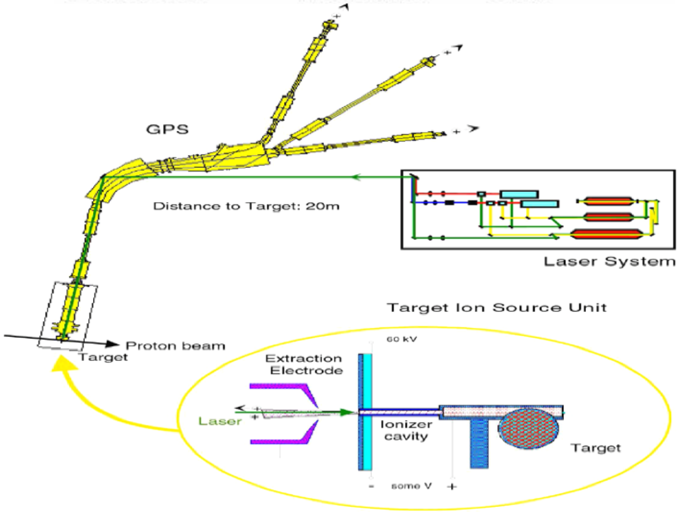


Multi-User Spectrometers for Low Energy Isol Beams
Brama-like, Wien, GPS,…





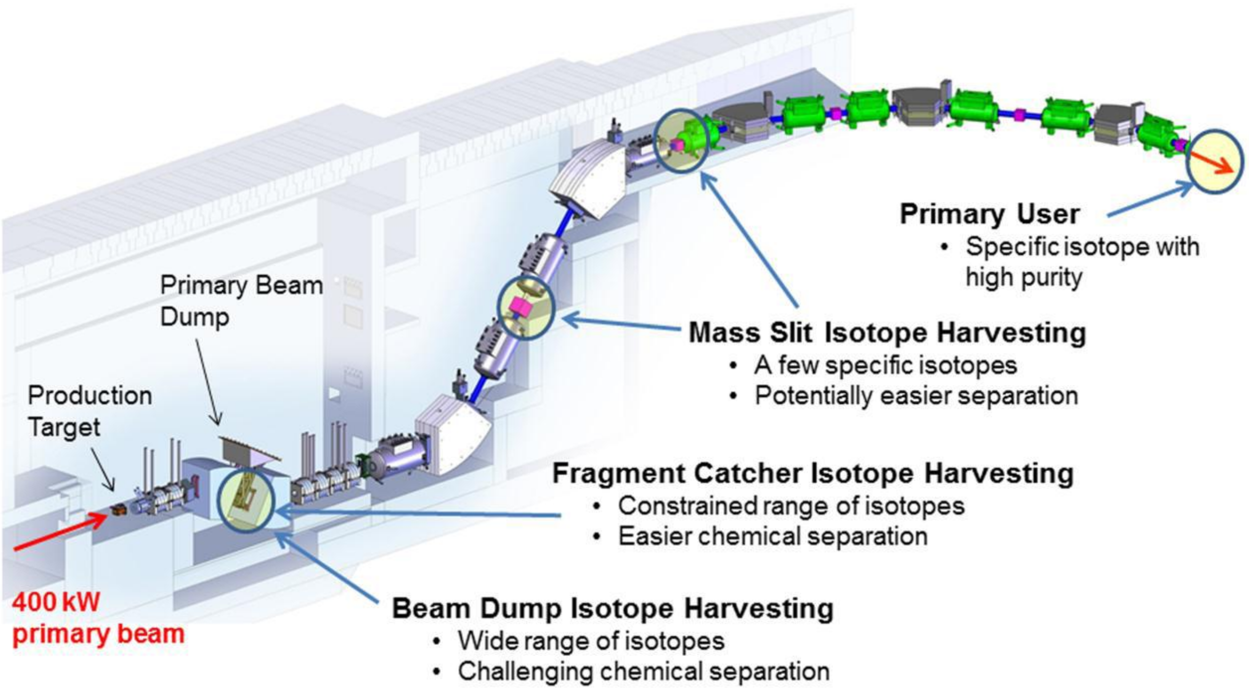


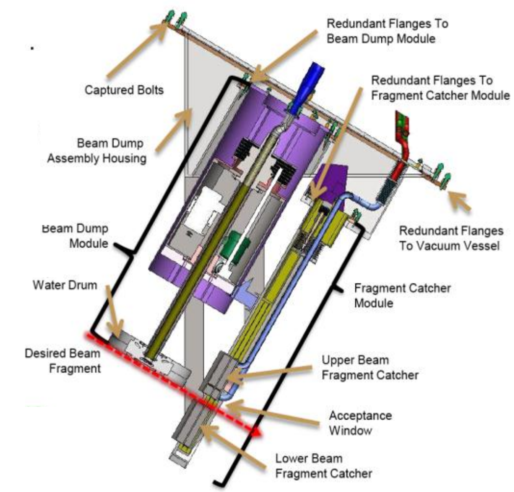


U.S. Department of Energy Office of Science
National Science Foundation
Michigan State University

Use of High Energy Fragmentation Beams: Harvesting

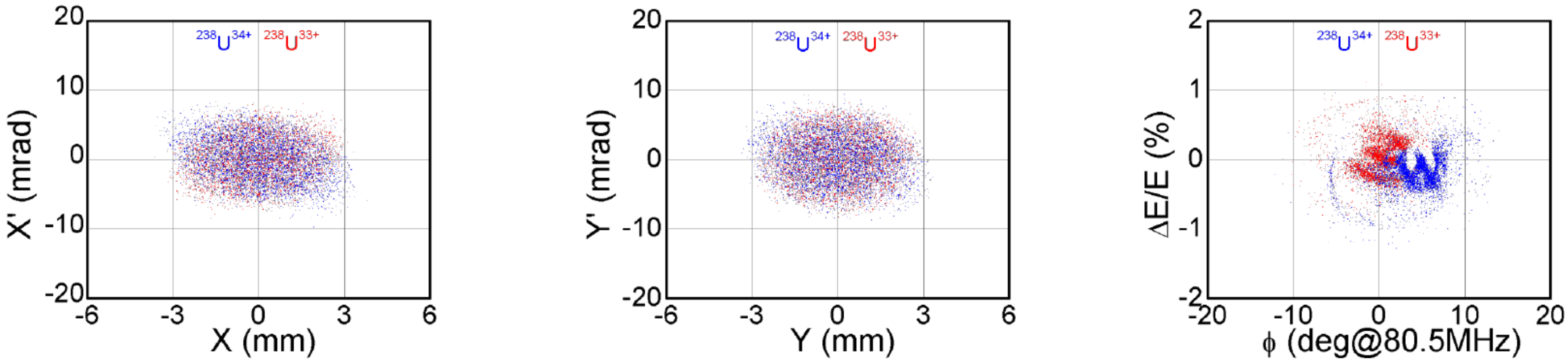
FRIB: Isotope Harvest



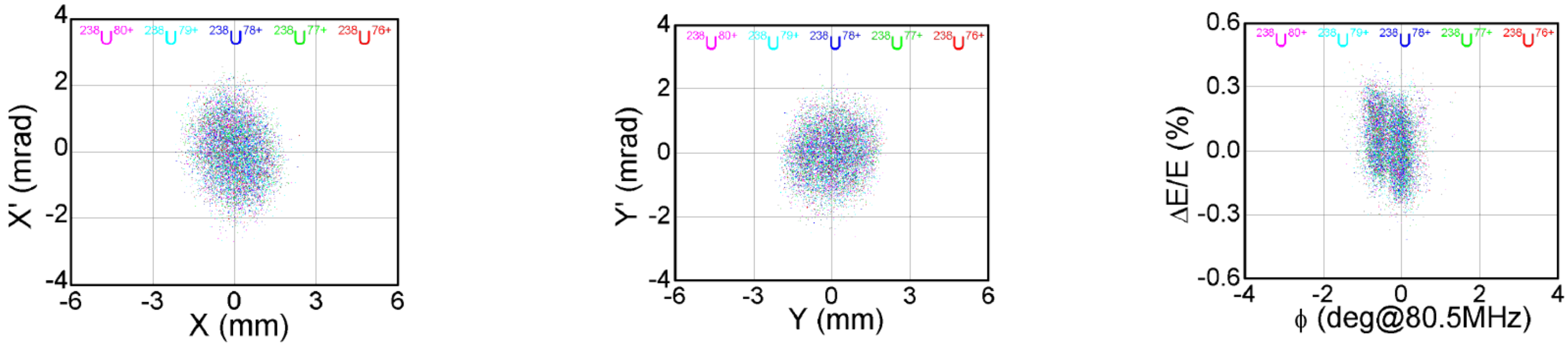


Multi-Beam Acceleration

Phase space plots of a two-charge-state uranium beam at the entrance of Linac Segment-1



Phase space plots of a multi-charge-state uranium beam right after beam stripper



http://hb2010.web.psi.ch/proceedings/talks/tuo1b05_talk.pdf

Multi-A/Q Acceleration

Example: acceptance +-2.5%

In the Sn region, this would allow for the simultaneous acceleration of for example ^{129}Sn to ^{135}Sn

In a linear accelerator scheme, the velocity is the same, and hence $B\rho = Mv/Q$

After acceleration a septum magnet to separate ~1% different magnetic rigidities is needed

Questions:

•septum magnet technology

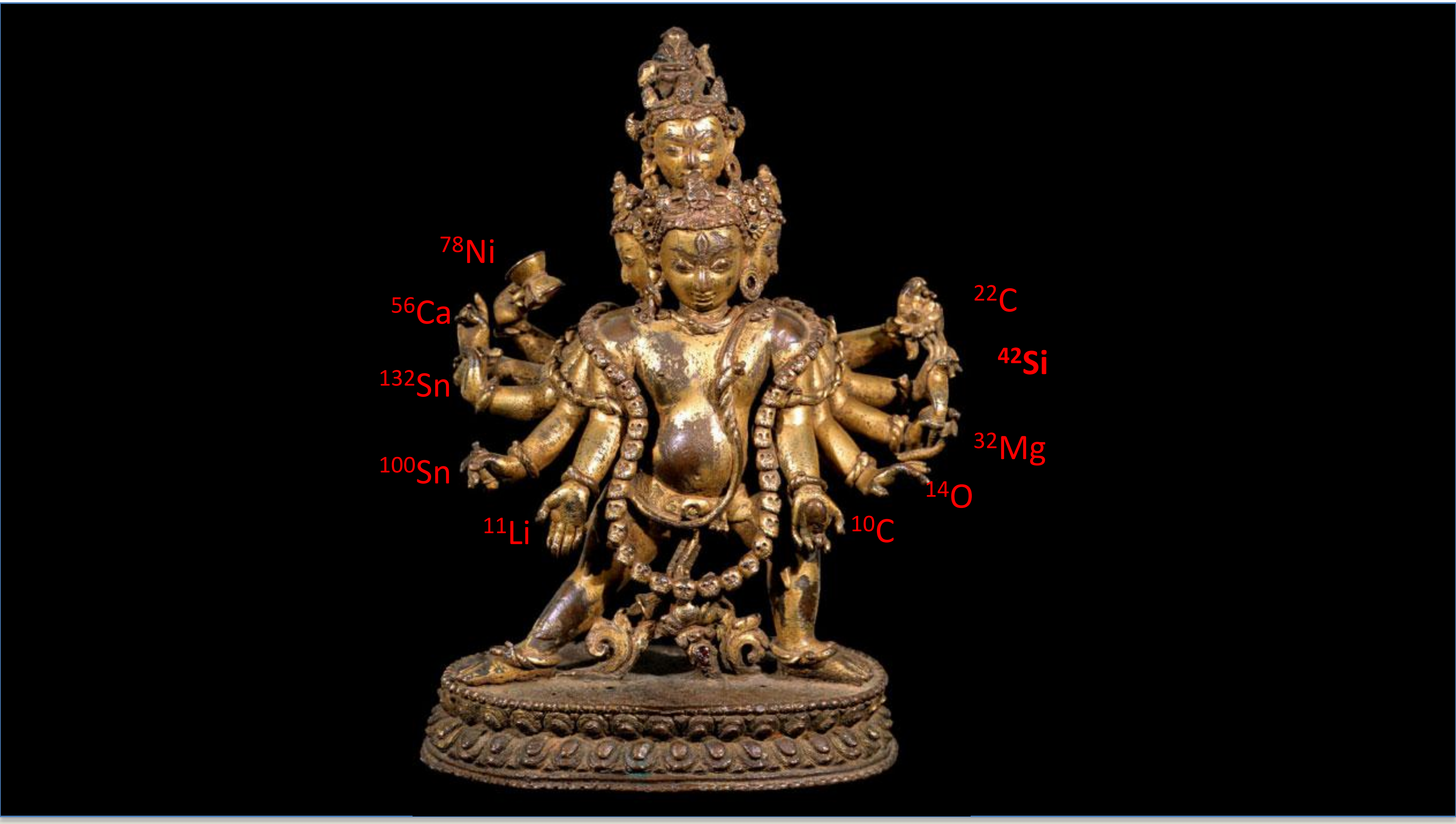
•can acceleration accept even larger (+-10%?) range of A/Q

Efficient Use of RIB: Multi-User Concepts

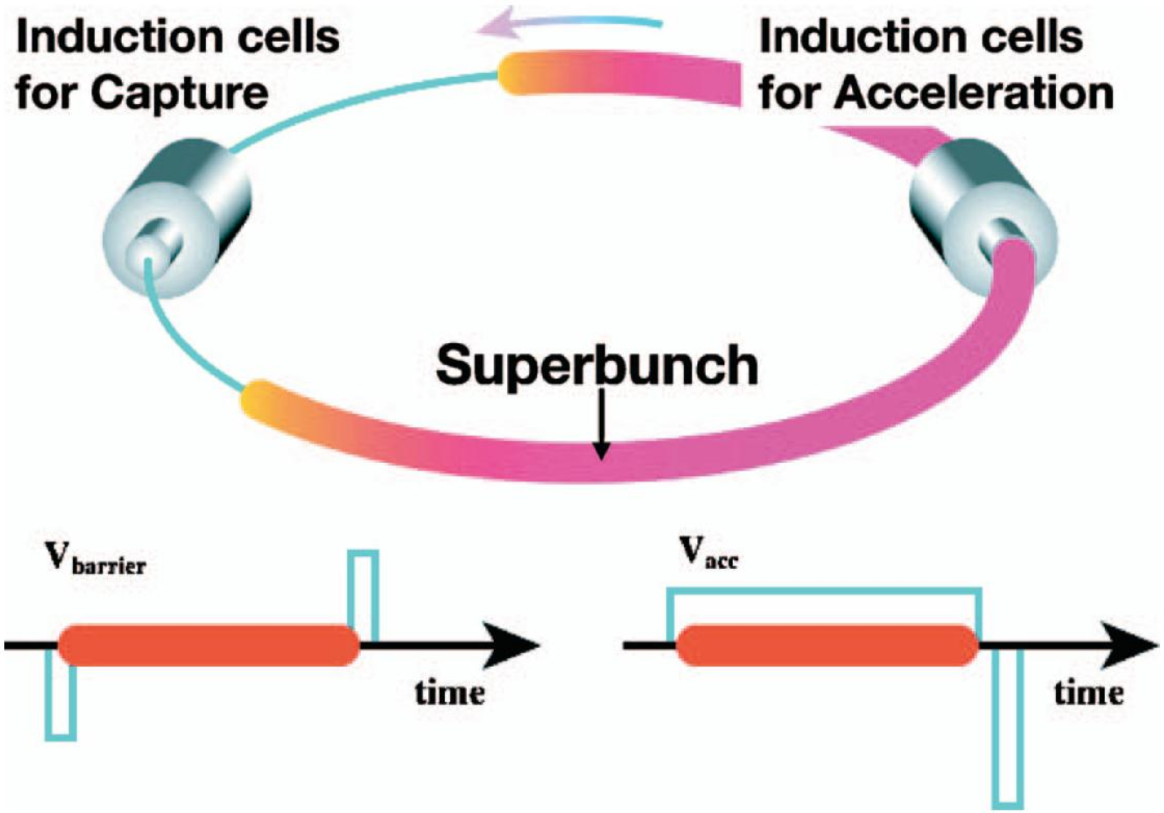
Most (all?) accelerators have made efforts to have some multi-use(r) possibility. We can distingish different categories:

- Simultaneous Sharing of primary beam intensity; example: Triumf, partial stripping of H^-
- Eurisol sharing of primary beam on multitarget-multipostaccelerator
  (2 secondary beams)
- Use of otherwise lost ions:
  - -Primary beam time structure sharing: Cern-Isolde, GSI: SIS and Unilac (~1s)
  - -Stripping: Ganil (SME)
- Sharing of Secondary Composite Beams
  example Cern-Isolde by General Purpose Separator GPS
- FRIB: isotope harvesting in beam dump

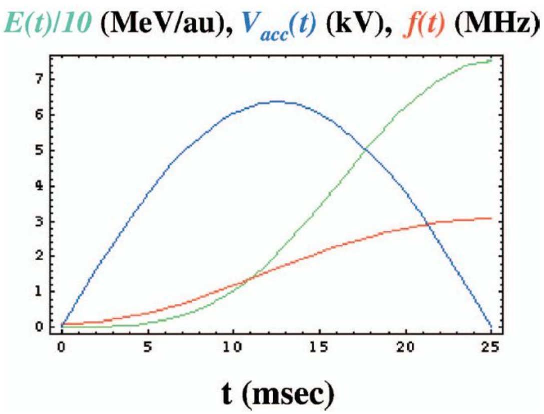
Efficient Use of RIB: multi-user concepts



All Ion Synchrotron: AIS

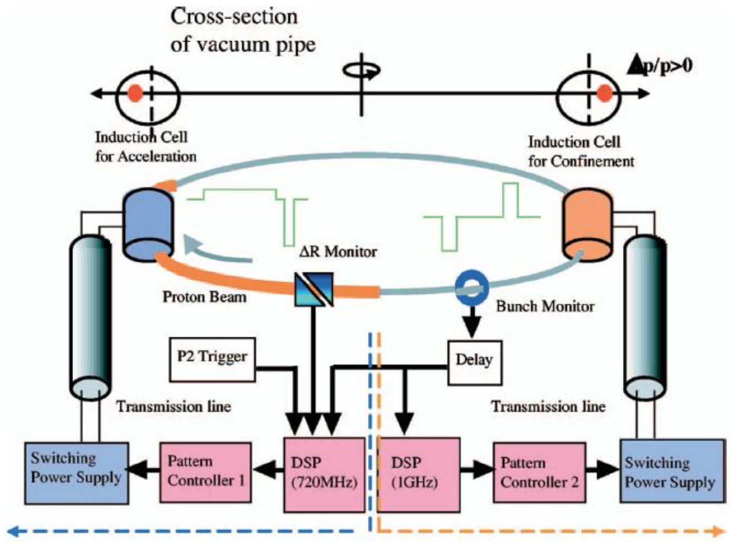


All Ion Synchrotron



Circumference (m)	C_0	37
Curvature (m)	ρ	3.3
Minimum field (T) for Ar^{+18}	B_{min}	0.029
Maximum field (T) for $^{+18}$	B_{max}	0.8583
Acceleration voltage (kV) from (3)	V_{acc}	6.36
Operation cycle (Hz)	f	20

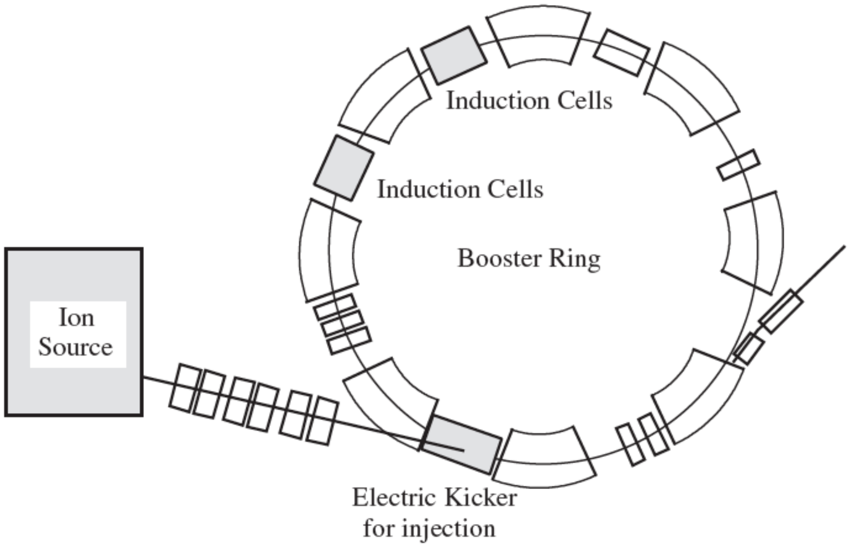
Ken Takayama et al.,
PRL 98, 054801 (2007)

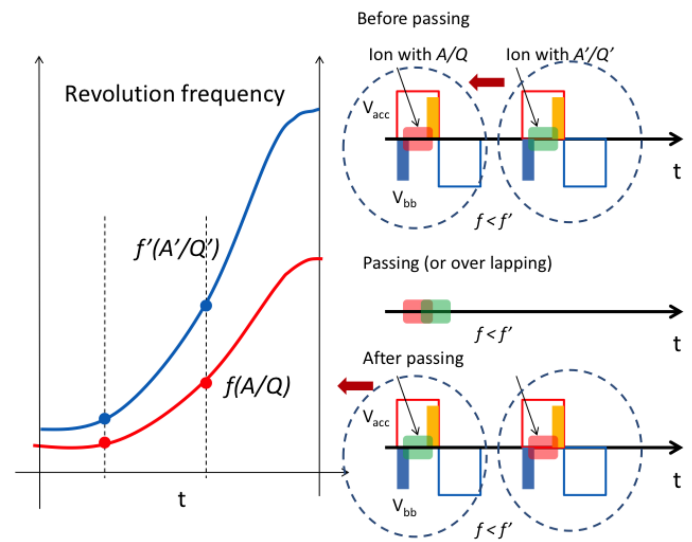


2 operation schemes:

- Fast cycle with sequential injection from several charge breeders and ejection to different beamlines
- Simultaneous acceleration of different A/Q

AIS Reaccelerated Multi Beams





Ken Takayama, private comm.

- Isol Ion source: must be pulsed (charge breader)
- All ions must have the same magnetic rigidity (RF kicker, multiple ion sources,…)
- Acceleration and confinement must take into account the different revolution frequencies (off if conflict)
- Ejection could be synchronized selectively with the different ions (different ejectors for different lines?)

Conclusion

- Enormous progress in primary beam intensities for RIB production done and going on
- Large solid angle angle and good (high) resolution spectrometers have been and are developed with powerful optical calculation/computation tools
- New technology for the construction of large bore optical elements with control of high orders becoming available (multi-poles, helix, active shielding devices,…)
- High resolution, high efficiency detectors
- Place for considerable progress in multi-use, multi-user concepts in present and future installations: need of progress in septum, kicker and breeder-accelerator technology

Thank you and Good EmisXVI !!!

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National Science Foundation
Michigan State University

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