Recent results from REX-ISOLDE and future prospects with HIE-ISOLDE

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Shape coexistence in $^{182\text{-}188}$Hg
Octupole collectivity in ^{220}Rn, ^{224}Ra
HIE-ISOLDE
Storage Ring TSR

Accelerated beams at REX-ISOLDE

Structure of light nuclei

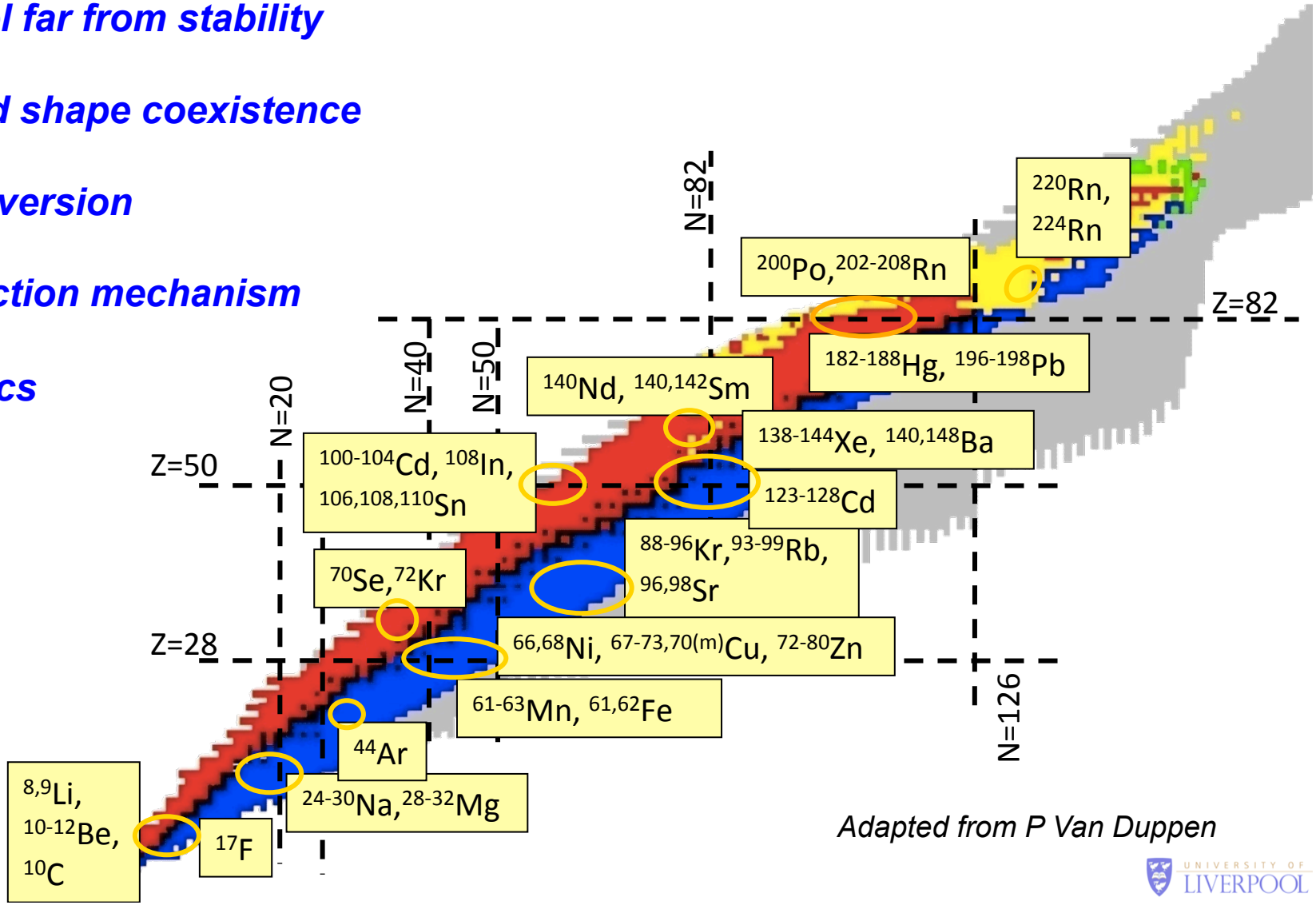
Shell-model far from stability

Shapes and shape coexistence

Island of inversion

Fusion reaction mechanism

Astrophysics



Adapted from P Van Duppen

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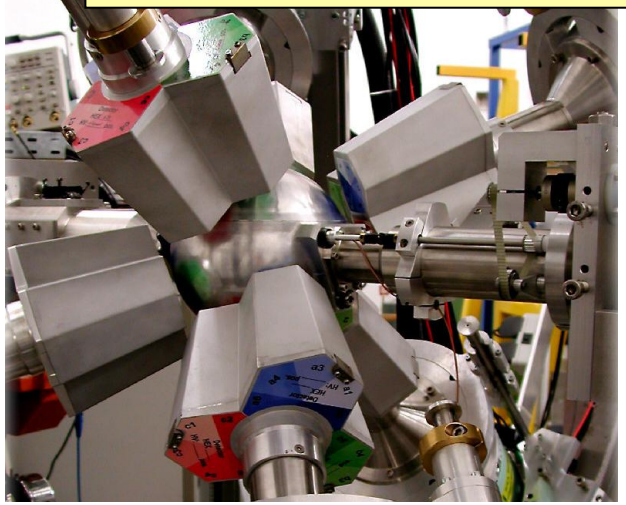
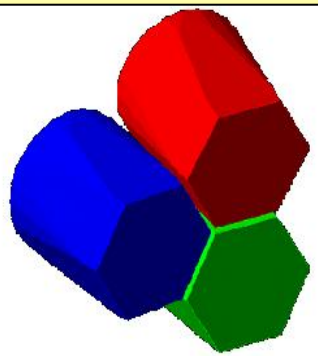
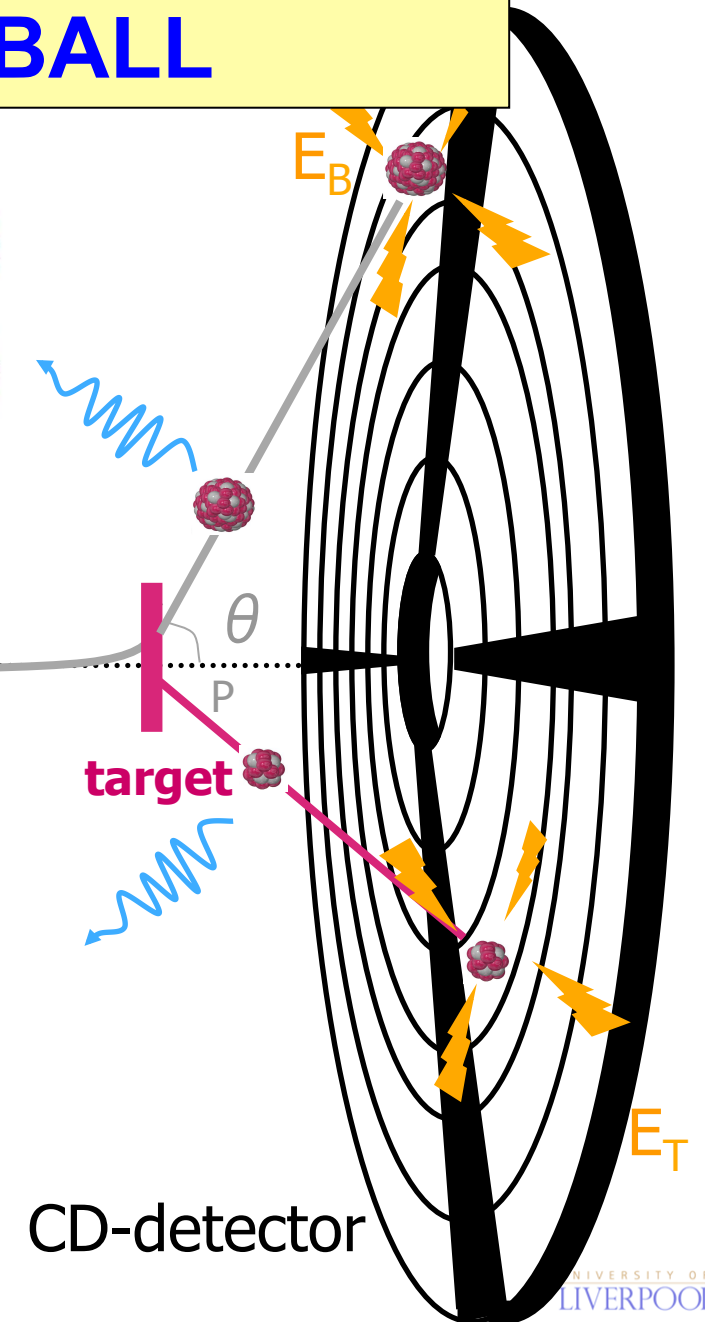
Coulomb excitation of heavy beams at REX-ISOLDE & MINIBALL

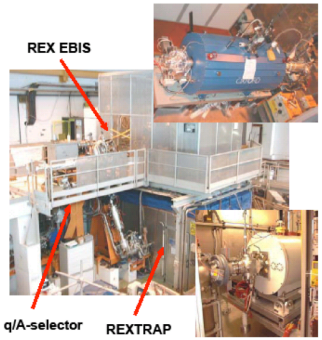


MINIBALL

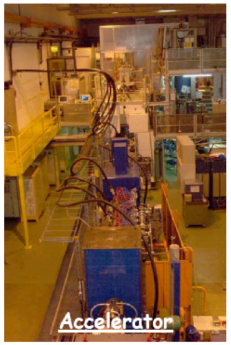




Heavy beam ~3 MeV/u

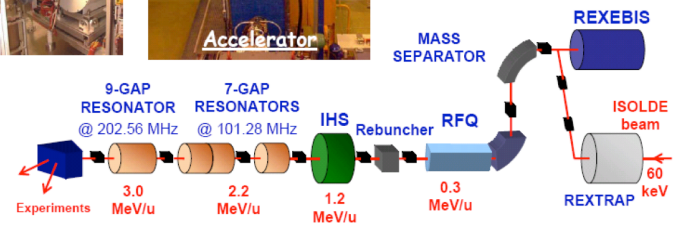


Charge Breeder



Efficiencies
(design values):

Trap Bunching:	90%
Beam Transport:	>85%
EBIS Injection:	>50%
EBIS Qi/ΣQi:	30%
Linac:	90%



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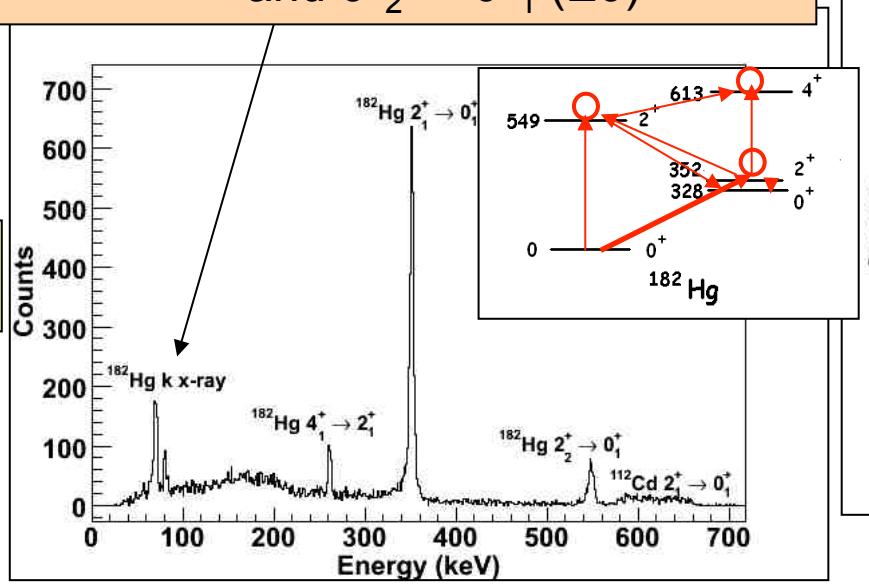
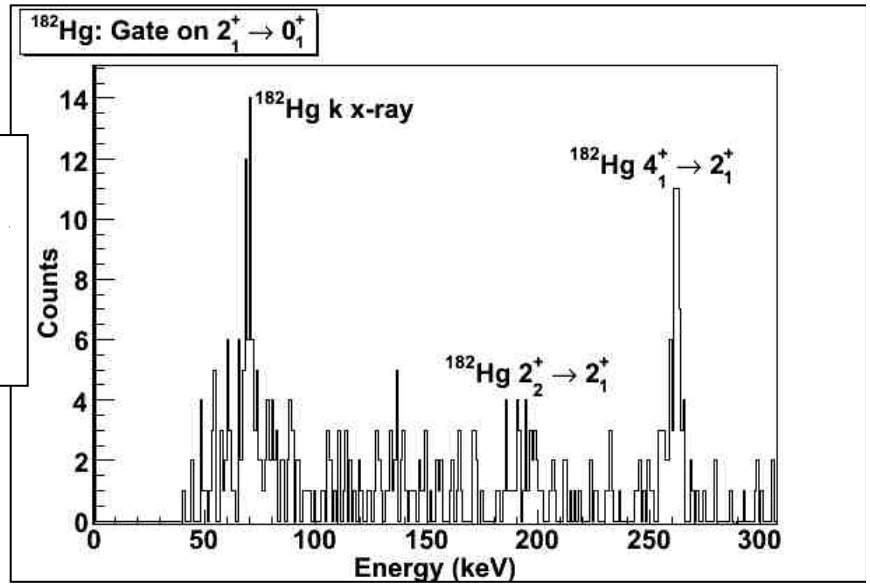
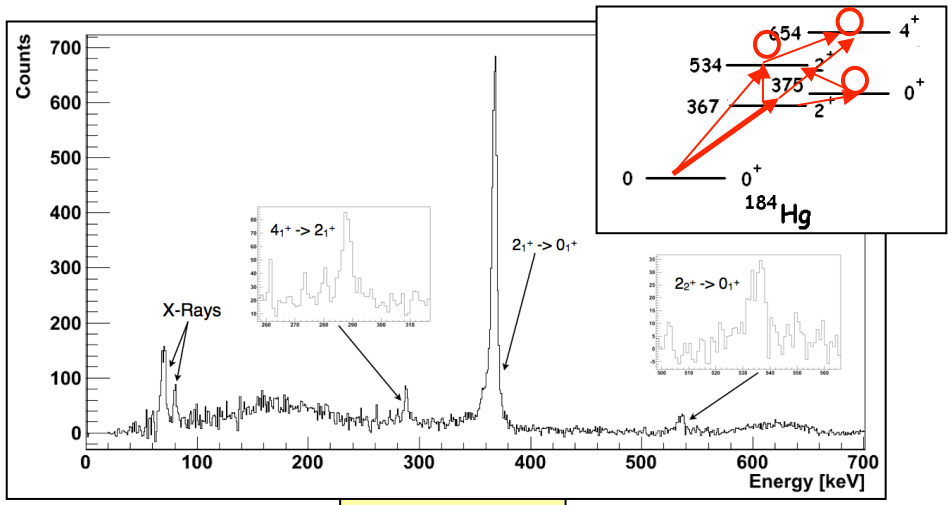
Coulomb Excitation of ^{182,184,186,188}Hg

mostly contributions from $2^+_2 \rightarrow 2^+_1$ (E0/M1/E2) and $0^+_2 \rightarrow 0^+_1$ (E0)

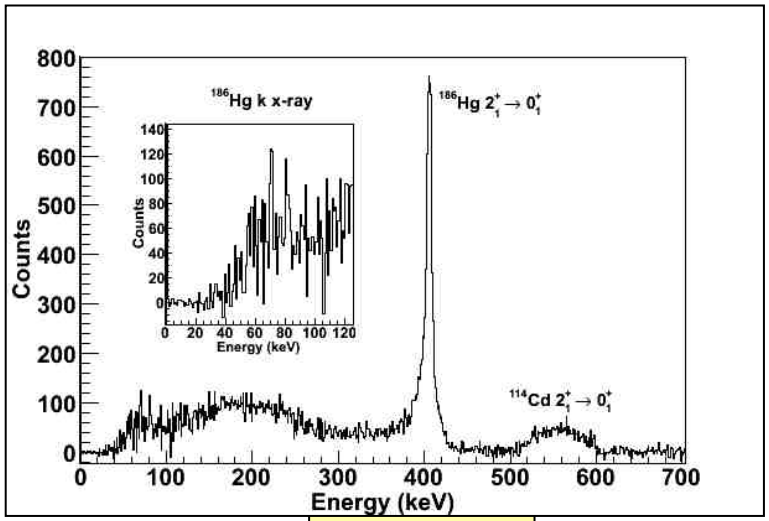
^{182}Hg







^{184}Hg



^{186}Hg

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Experimental Data $^{182-188}$Hg

τ from RDM:

2^+_1, 4^+_1, 6^+_1, 8^+_1 **^{180}Hg**

2^+_1, 4^+_1, 6^+_1, 8^+_1, 10^+_1 **^{182}Hg**

T Grahn, A Petts et al. PRC 80 (2009) 014324

2^+_1, 4^+_1, 6^+_1, 8^+_1 **^{184}Hg**

2^+_1, 4^+_1, 6^+_1, 8^+_1, 10^+_1 **^{186}Hg**

L Gaffney, M Hackstein et al.

Coulex yields, e.g. **^{182}Hg** (also **^{184,186,188}Hg**)

sensitivity to

$\langle 0^+_1||E2||2^+_1\rangle$, $\langle 2^+_1||E2||4^+_1\rangle$, $\langle 0^+_1||E2||2^+_2\rangle$, $\langle 0^+_2||E2||2^+_1\rangle$, $\langle 0^+_2||E2||2^+_2\rangle$, $\langle 2^+_1||E2||2^+_2\rangle$, $\langle 2^+_2||E2||4^+_1\rangle$, $\langle 4^+_1||E2||6^+_1\rangle$,

($\langle 2^+_1||M1||2^+_2\rangle$, $\langle 2^+_1||E0||2^+_2\rangle$ from Γ_e/Γ_γ)

weak sensitivity to

$\langle 2^+_1||E2||2^+_1\rangle$, $\langle 2^+_2||E2||2^+_2\rangle$

N Bree, L Gaffney, A Petts, K Wrzosek-Lipska et al.

Γ_e/Γ_γ from Tl β-decay for $2^+_2 \rightarrow 2^+_1$ **^{180,182,184}Hg**

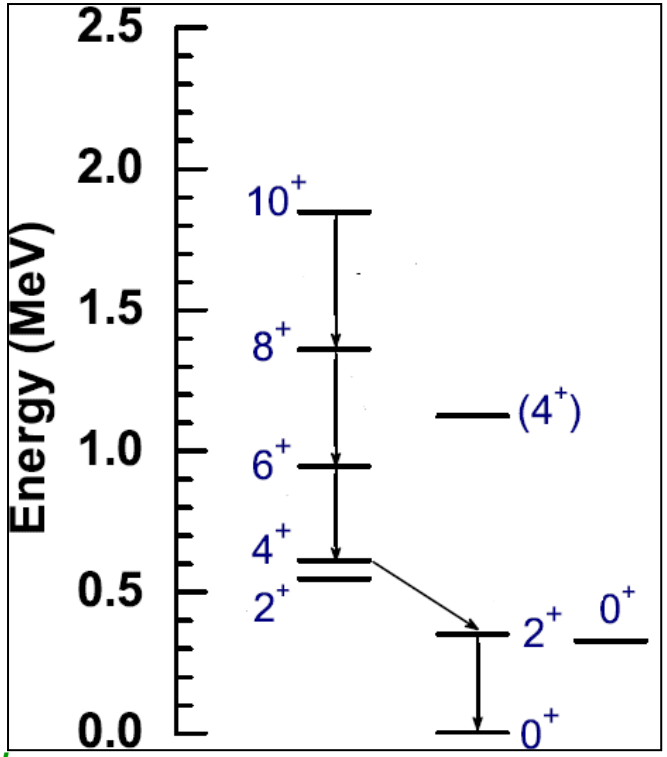
E Rapisarda et al.

Γ_e/Γ_γ from in-beam SAGE for $2^+_2 \rightarrow 2^+_1$ **^{186}Hg**

M Scheck et al. PRC 83 (2011)037303

Population of 0^+_2 from **X-ray analysis**

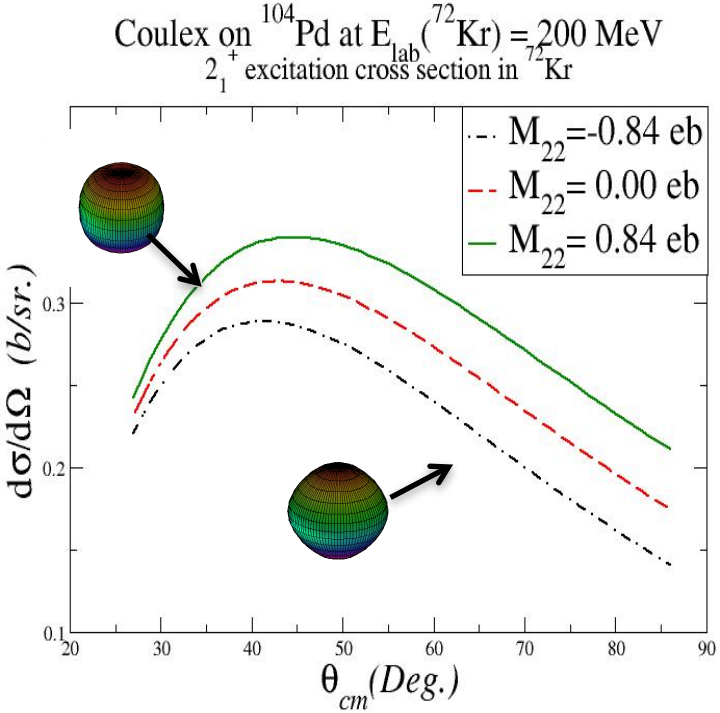
N Bree

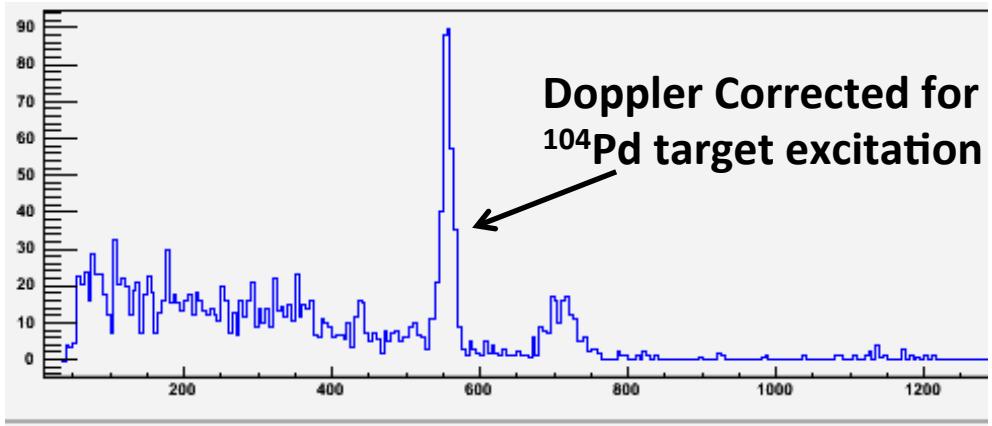


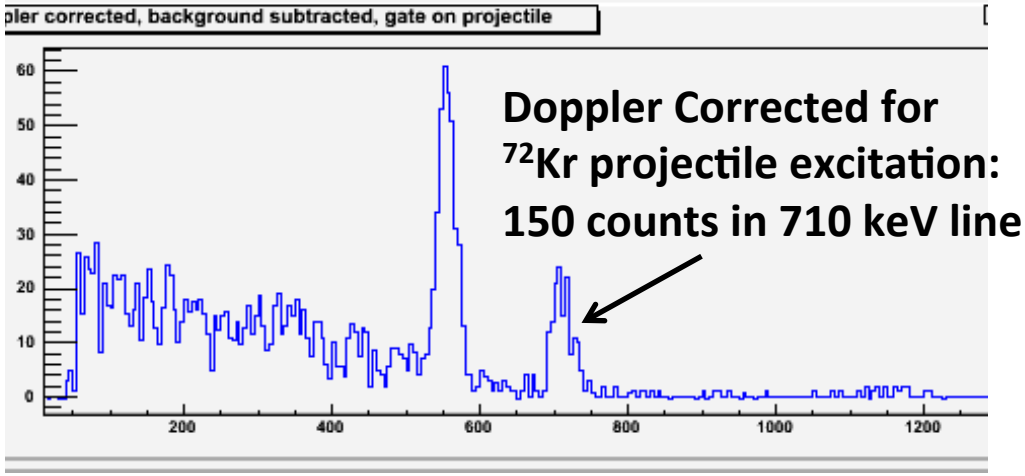
Coulomb excitation of ^{72}Kr

(B.S. Nara Singh, R Wadsworth et al)

Oblate ground state expected







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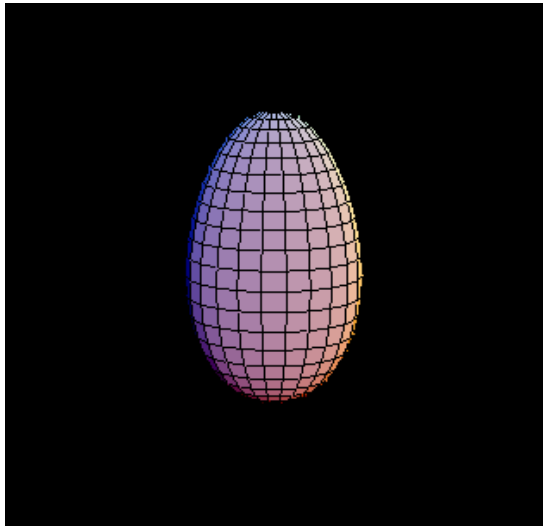
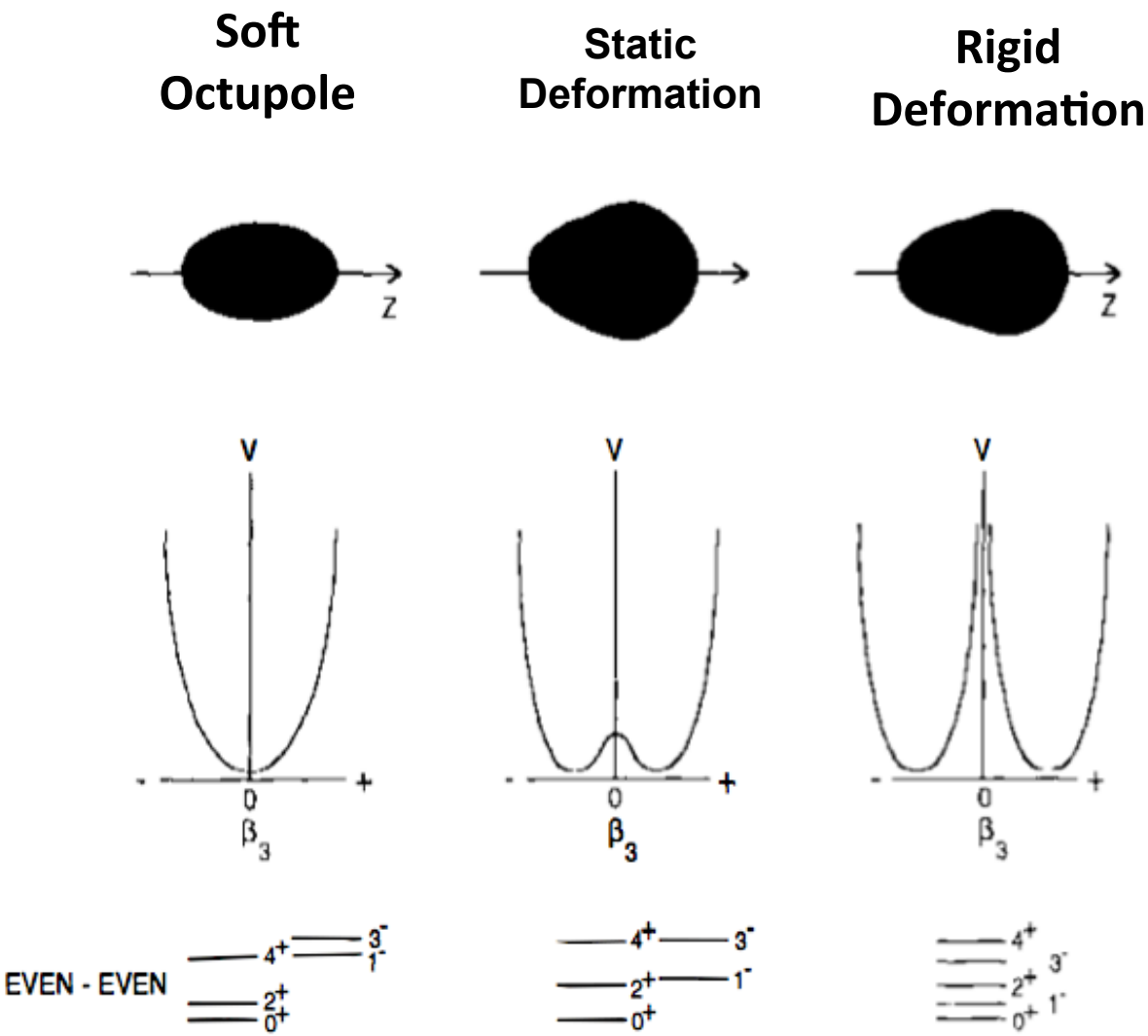
Octupole Collectivity



Octupole (Y_{30}) Vibration



(after I Ahmad 1993)

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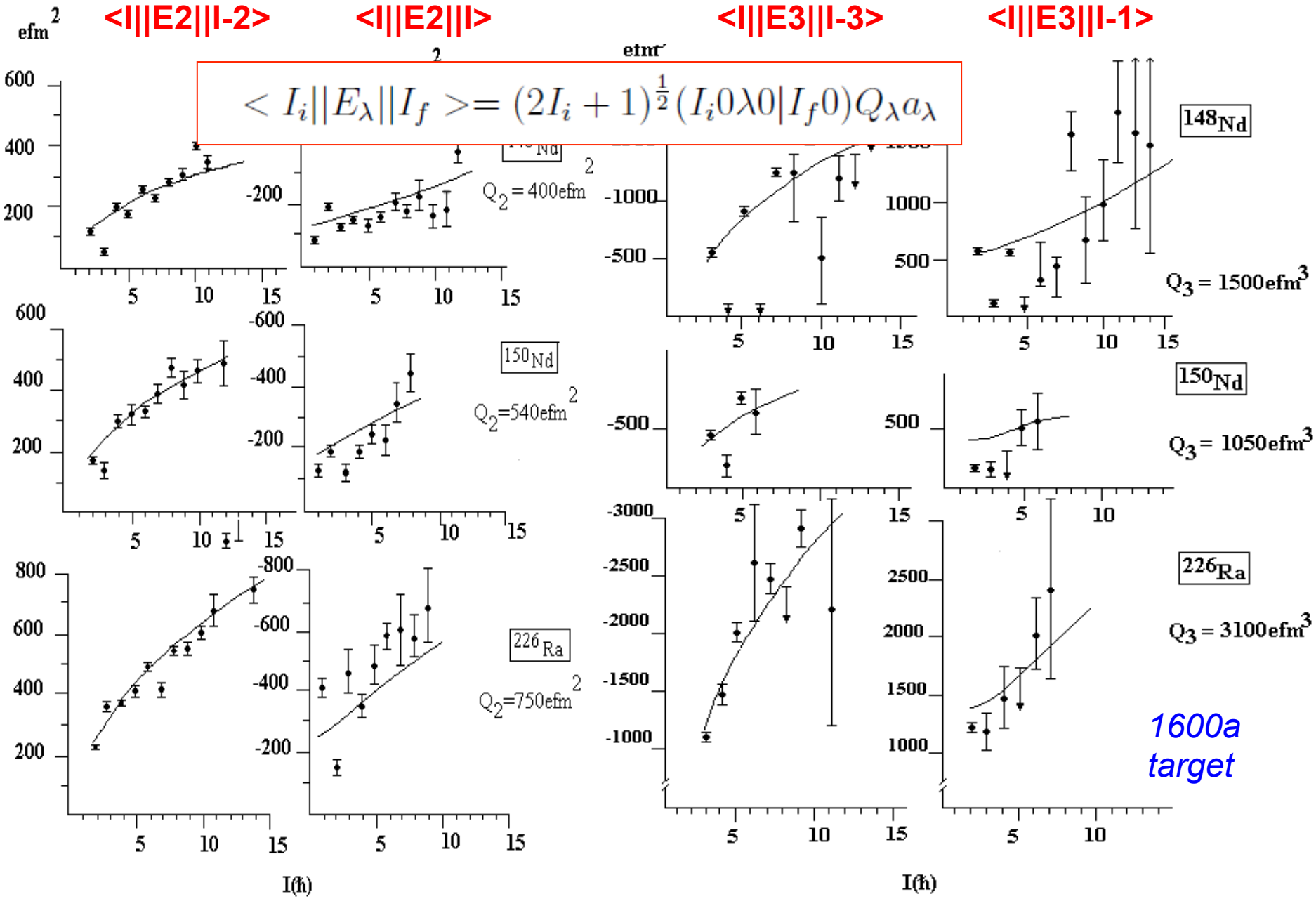
Eλ matrix elements from Coulomb excitation



P Butler *HJ Wollersheim et al., NP A556 (1993) 261* *R Ibbotson et al PRL 71 (1993) 1990*

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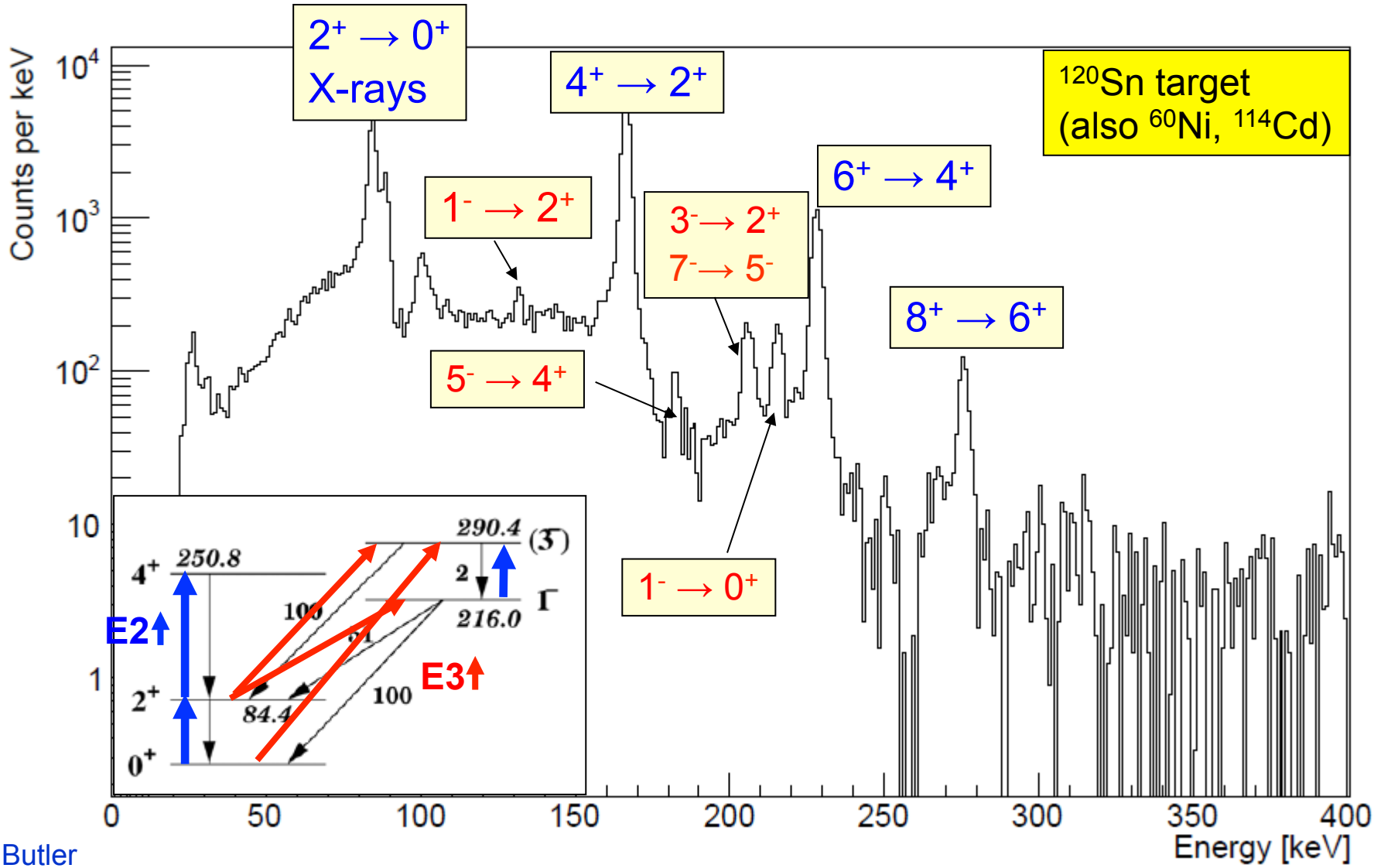
^{224}Ra Coulomb excitation



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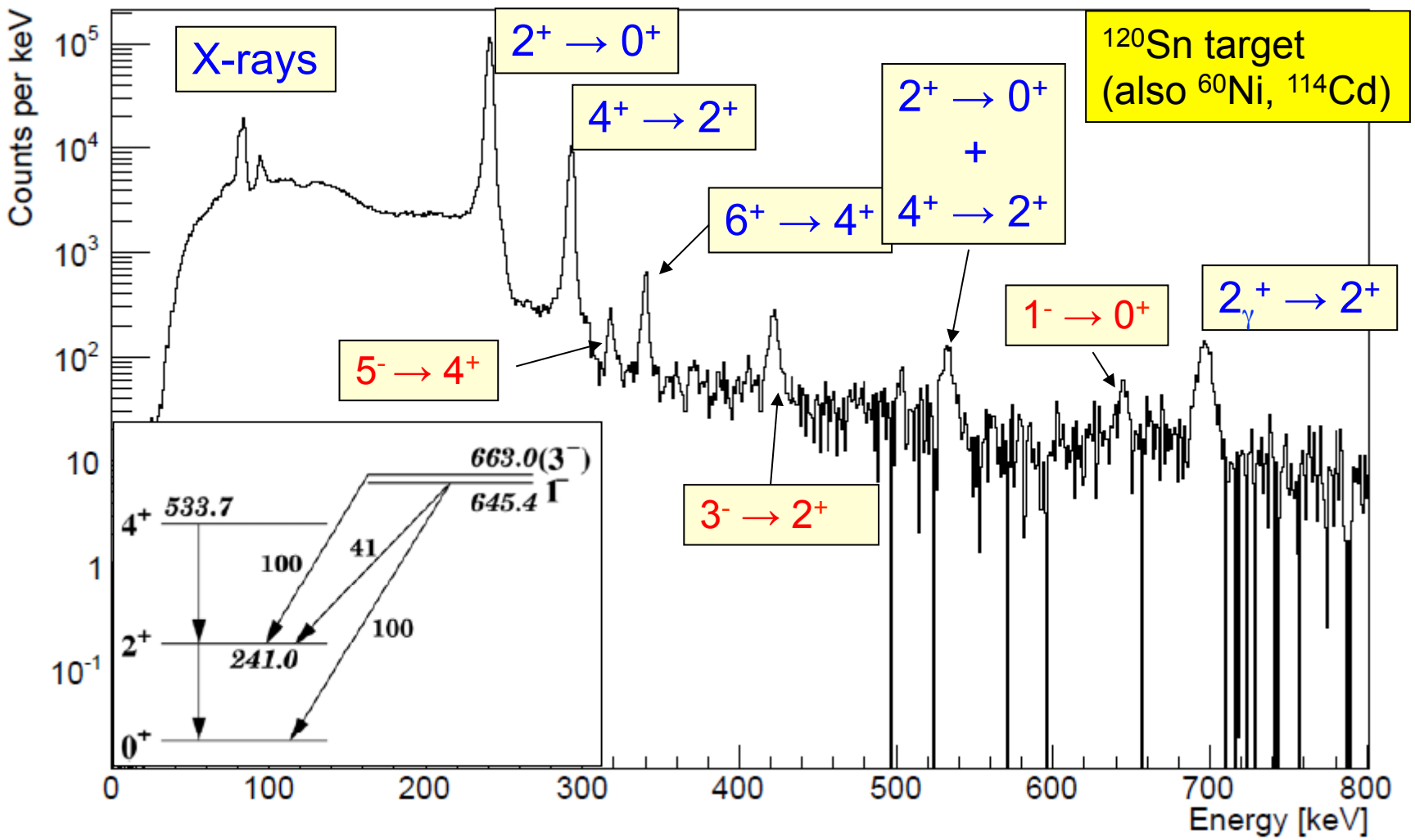
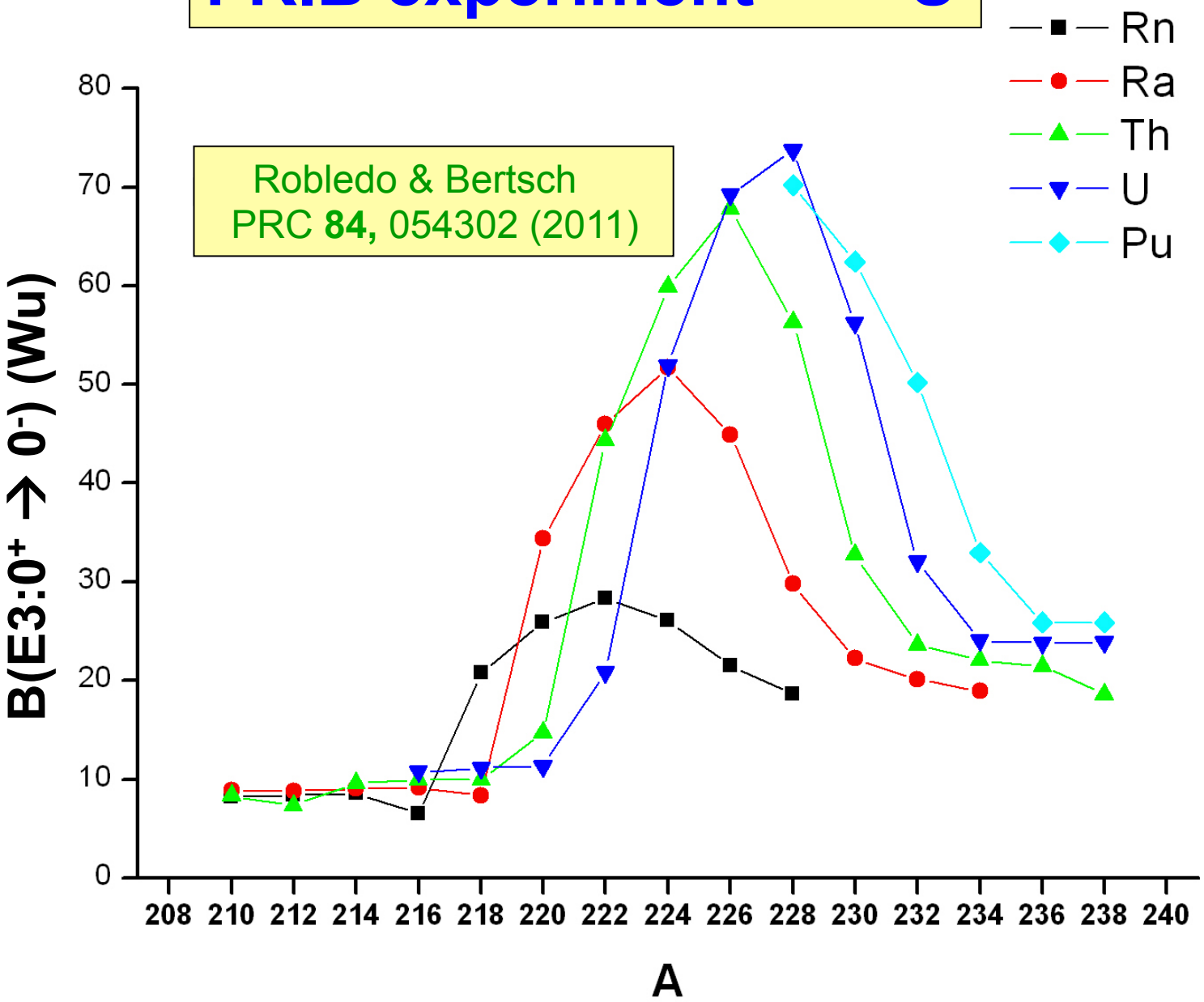
^{220}Rn Coulomb excitation



FRIB experiment – ^{228}U



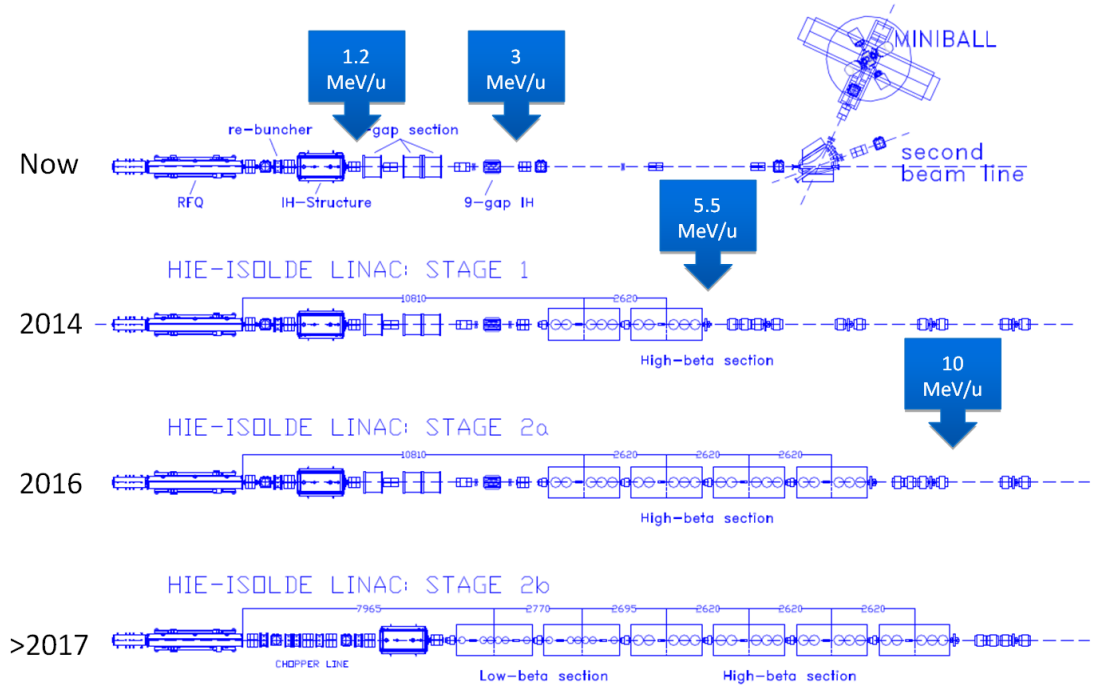
^{226}U is octupole deformed

(PT Greenlees et al J. Phys. G 24 (1998) L63)

HIE-ISOLDE

55M CHF CERN PROJECT

Energy: 3 stage installation



Beam intensity **e.g. ^{144}Ba: 2.10^5/s**

Intensity upgrade **Increase from VADIS: factor of 3-20** ✓

LINAC 4 (160 MeV p injector): factor of 3-5 **2019**

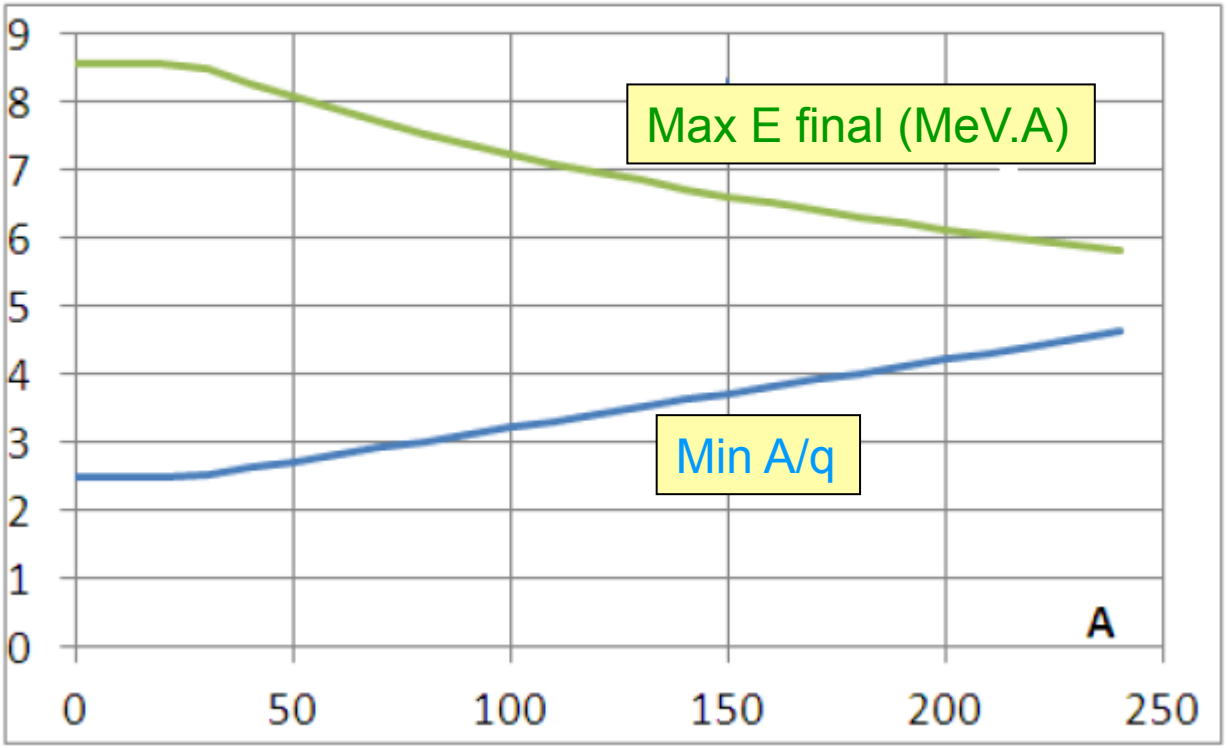
PS Booster 1.4 -> 2 GeV: factor of 3 in some cases **2019**

HIE-ISOLDE construction

HIE-ISOLDE beam energy

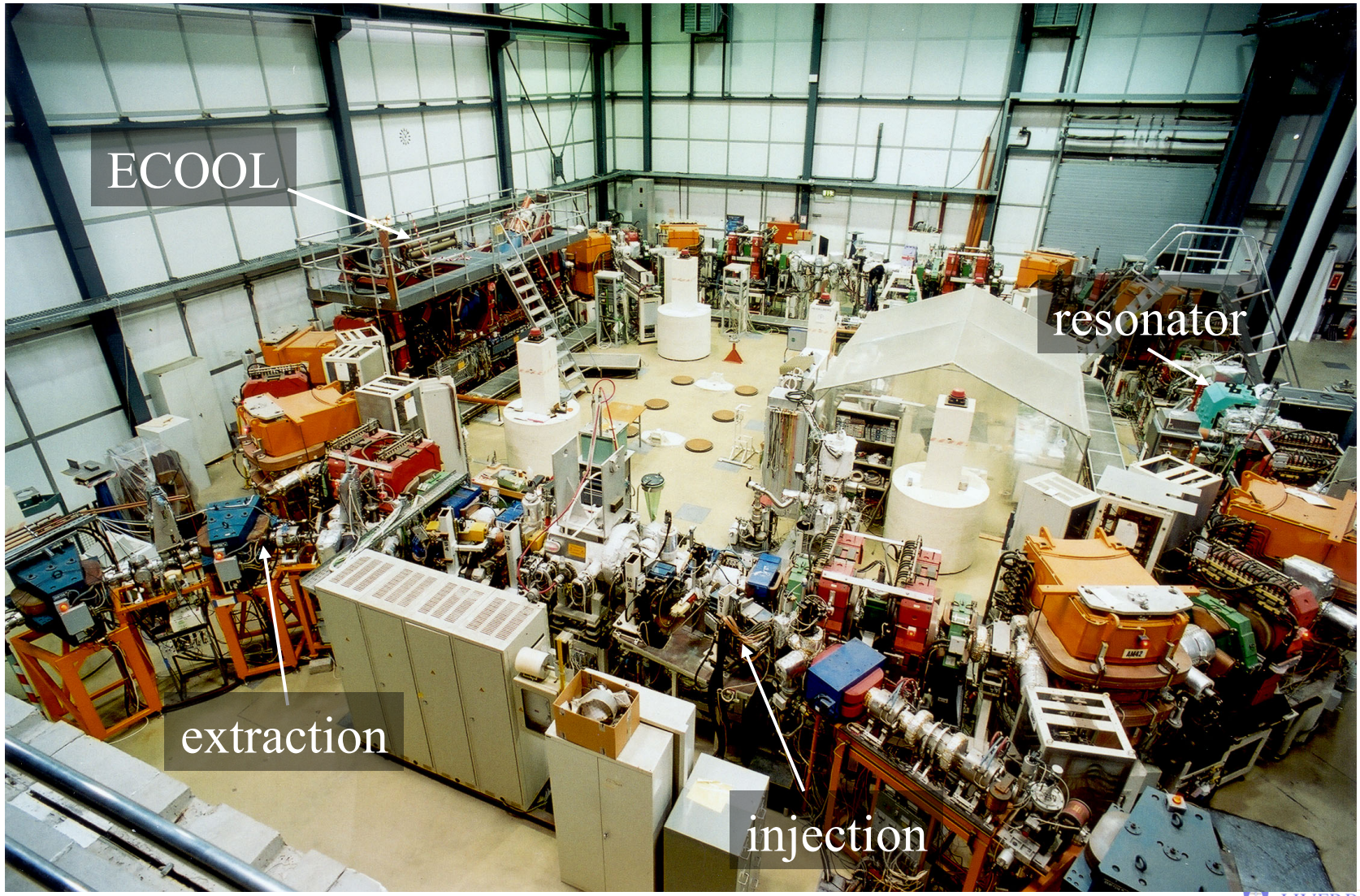
A/q=4.5 and E = 5.5 MeV/u are the nominal parameters of the facility

Higher energy and lower A/q implies
decrease of efficiency and increase of breeding time

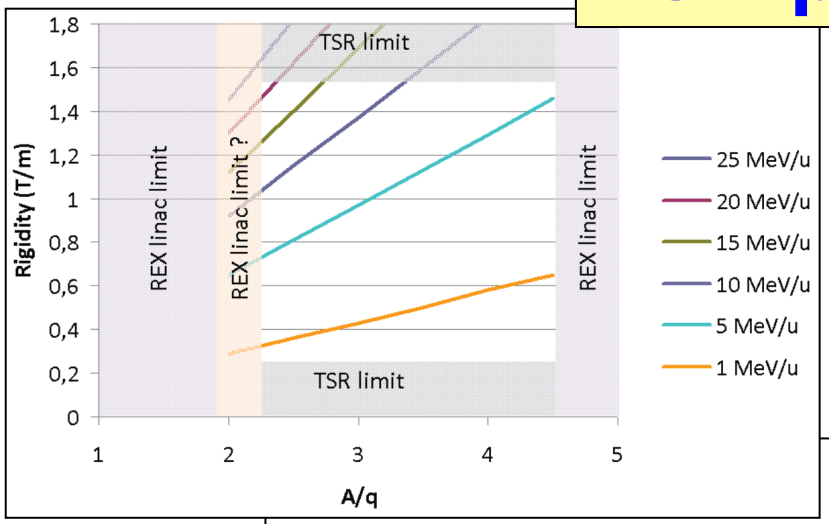


The heavy ion storage ring TSR
MPIK Heidelberg

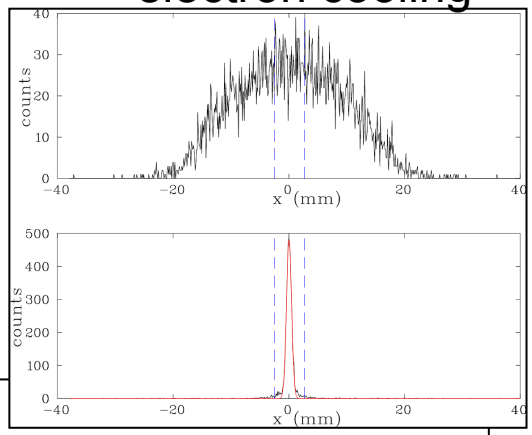
Circumference: 55m

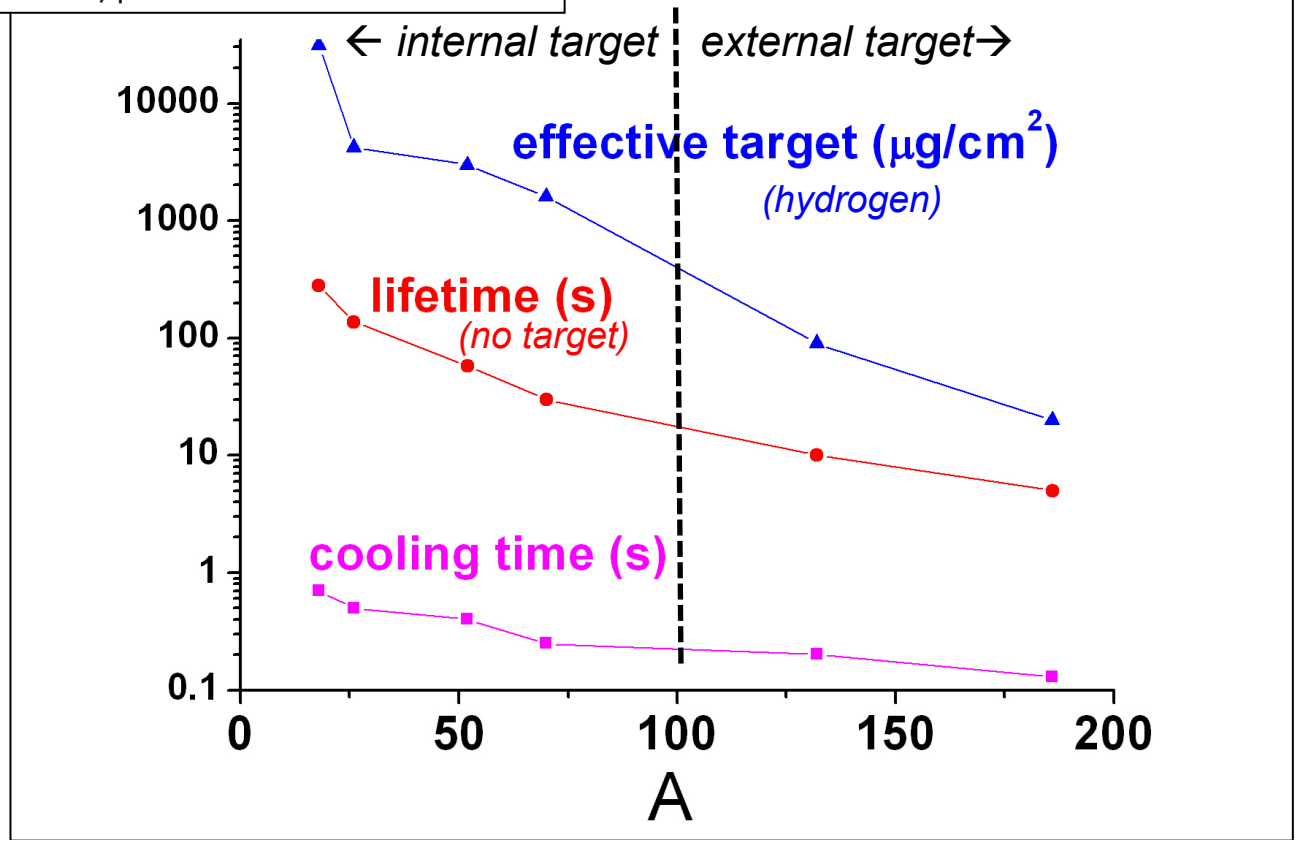


TSR properties



electron cooling





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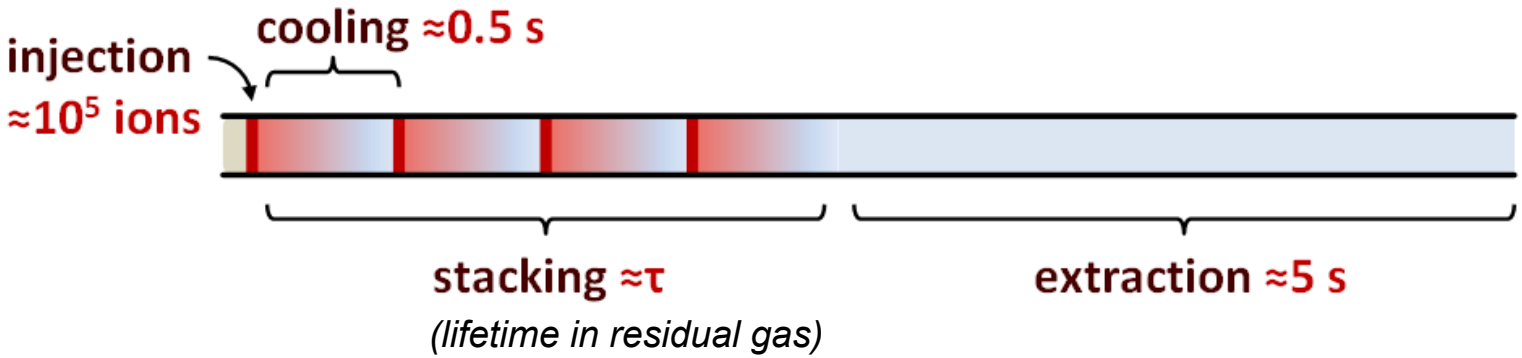
TSR applications

M. Grieser et al. Eur. Phys. J. Special Topics 207, 1–117 (2012)

In-Ring - high luminosity achieved thru multiple beam passes (~1 MHz), important for reaction experiments, and laser measurements of static properties of exotic nuclei.

External – extracted cooled beams for ultra-high resolution studies of heavy nuclei and Coulex studies (better energy spread, beam spot & emittance).

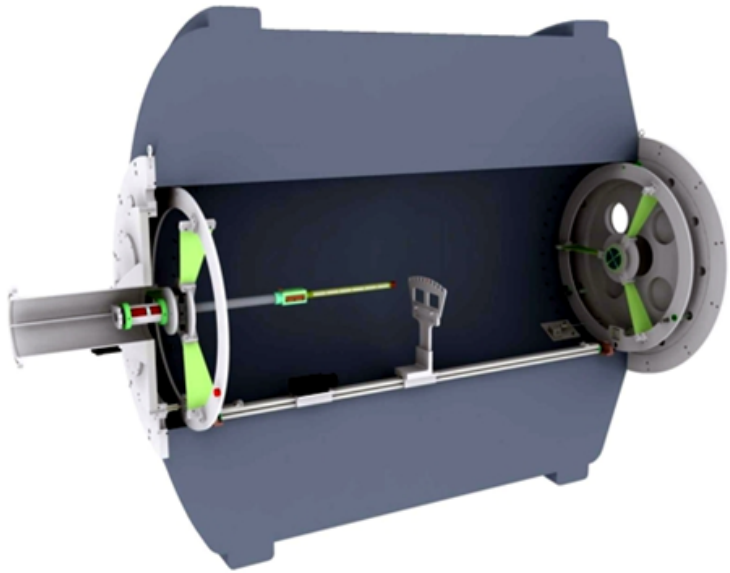


Cooled beams in HELIOS-type spectrometer:

20-30 keV resolution for (d,p)

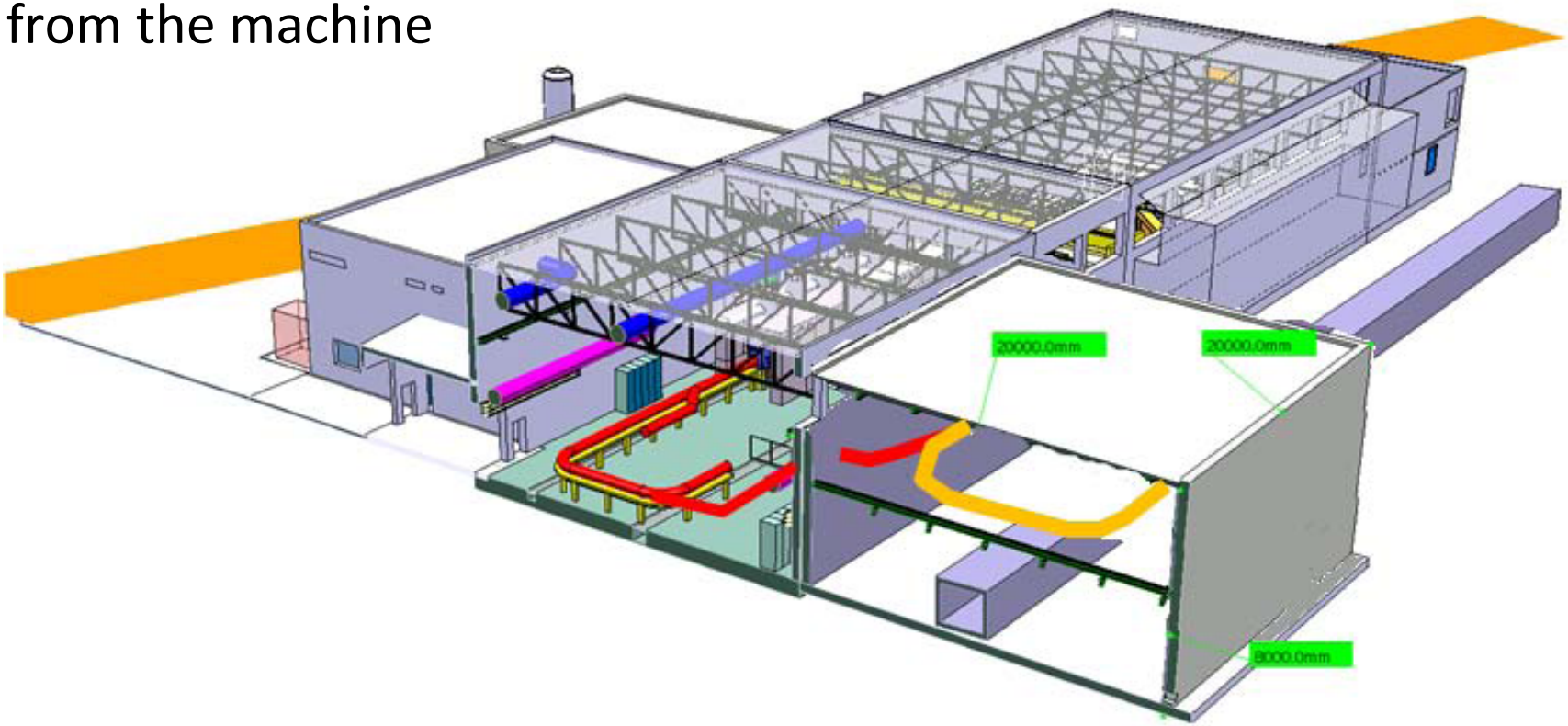
50-70 keV resolution for (C,C')

direct scatter detection possible

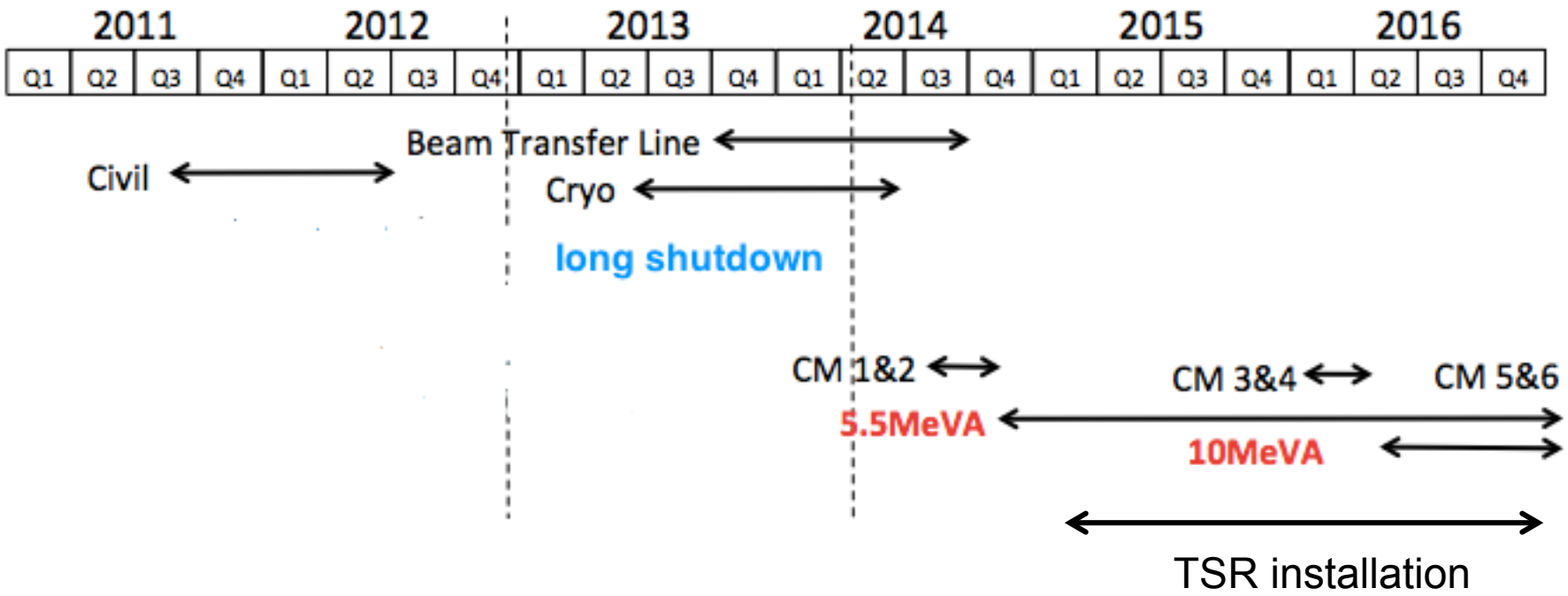


TSR installation

- TSR installation above a cable duct
- Tilted beam line coming up from the machine



HIE-ISOLDE & TSR planning



HIE-ISOLDE proposals considered at INTC Oct 31, **deadline Oct 3**

TSR workshop **Oct 29-30 CERN** (Google "Cern TSR Workshop")

Studies of shape-coexistence in Hg

A. Andreyev[2], B. Bastin[2], P. F. Bertone[6], P.A. Butler[1], A. Blazhev[12], **N. Bree**[2], B. Bruyneel[12], M. Carpenter[6], R. J. Carroll[1], M. Carpenter[6], J. Cederkäll[11], C. J. Chiara[6], E. Clement[3], T.E. Cocolios[2], T. Davinson[7], P. Delahaye[3], A. Dewald[12], J. Diriken[2], J. Eberth[12], A. Ekstrom[11], F. E. E. Filmer[1], L. Fraile[3], C. Fransen[12], T. Grahn[1,9], **L. Gaffney**[1], M. Guttormsen[4], M. Hackstein[12], K. Hadynska[5], R.-D. Herzberg[1], M. Huyse[2], O. Ivanov[2], D.G. Jenkins[8], D. T. Joss[1], R. Julin[9], S. Knapen[2], F. Kondev[6], Th. Kroell[10], R. Krücken[10], A.C. Larsen[4], P. Marley[8], P.J. Napiorkowski[5], P. Nieminen[3], R. D. Page[1], J. Pakarinen[1,3,9], N. Patronis[2], **A. Petts**[1], P.J. Peura[9], E. Piselli[3], P. Reiter[12], S. V. Rigby[1], M. Scheck[1], S. Siem[4], I. Stefanescu[2], J. Van de Walle[3], P. Van Duppen[2], D. Voulot[3], N. Warr[12], H. Watkins[1], F. Wenander[3] **K. Wrzosek-Lipska**[2], S. Zhu[6] and M. Zielinska[5]

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[12]University of **Cologne**, Germany
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[7]University of **Edinburgh**, UK
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[2]University of **Leuven**, Belgium
[1]University of **Liverpool**, UK
[11]University of **Lund**, Sweden
[10]Technical University **Munich**, Germany
[4]University of **Oslo**, Norway
[5]University of **Warsaw**, Poland
[8]University of **York**, UK

Studies of octupole nuclei

M. Albers[2], B. Bastin[12], C. Bauer[6], A. Blazhev[2], P.A. Butler[1], A. Blazhev[2], S. Bönig[6], N. Bree[4], J. Cederkall[13], T. Chupp[10], D. Cline[7], T.E. Cocolios[9], J. Diriken[4], **L.P. Gaffney**[1], T. Grahn[5], A. Hayes[7], A. Herzan[5], M. Huyse[4], D. Jenkins[11], D.T. Joss[1], N. Kesteloot[4], M. Kowalczyk[3], Th. Kröll[6], E. Kwan[8], K. Moschner[2], P. Napiorkowski[3], M. Pfeiffer[2], D. Radeck[2], K. Reynders[4], S. Rigby[1], M. Rudigier[2], S. Sambi[4], M. Scheck[1,2], M. Seidlitz[2], P. Thoele[2], P. Van Duppen[4], M. von Schmid[6], D. Voulot[9], N. Warr[2], **F. Wenander**[9], K. Wrzosek-Lipska[4], C.Y. Wu[8], M. Zielinska[3]

[2]University of **Cologne**, Germany
[6]Technical University **Darmstadt**, Germany
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[10]University of **Michigan**, USA
[7]University of **Rochester**, USA
[3]University of **Warsaw**, Poland
[11]University of **York**, UK

HIE-ISOLDE

Y. Kadi, M. Pasini, F. Wenander et al **(CERN)**

P Butler

TSR

K. Blaum **(MPI Heidelberg)**, Y. Blumenfeld **(CERN)**, P. A. Butler **(Liverpool)**, M. Grieser **(MPI Heidelberg)**, Y. Litvinov **(GSI)**, R. Raabe **(Leuven)**, E. Siesling **(CERN)**, F. Wenander **(CERN)**, P. Woods **(Edinburgh)** et al

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