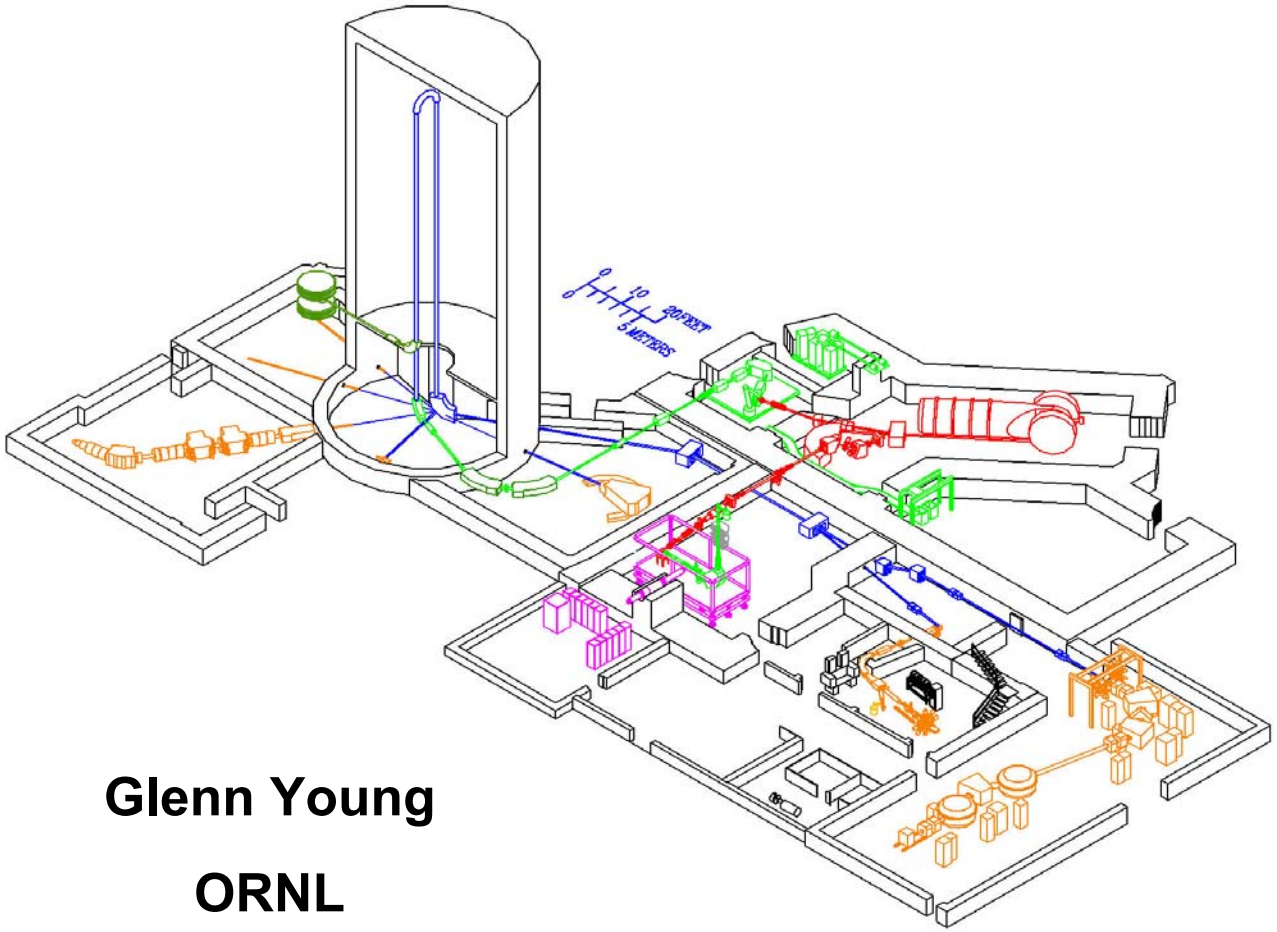
Report to NSAC on HRIBF



Glenn Young

ORNL

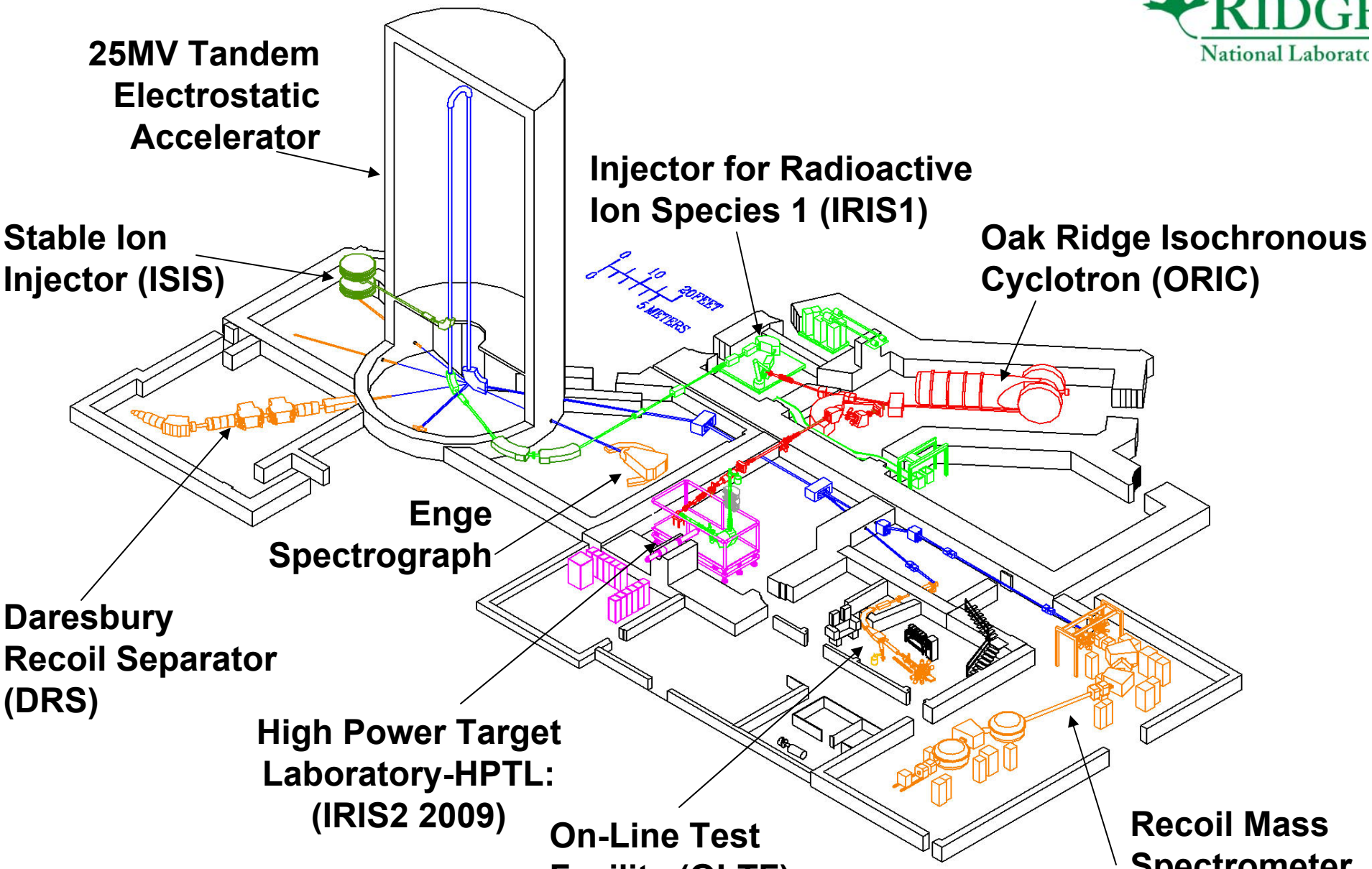
NSAC Meeting

August 21, 2008

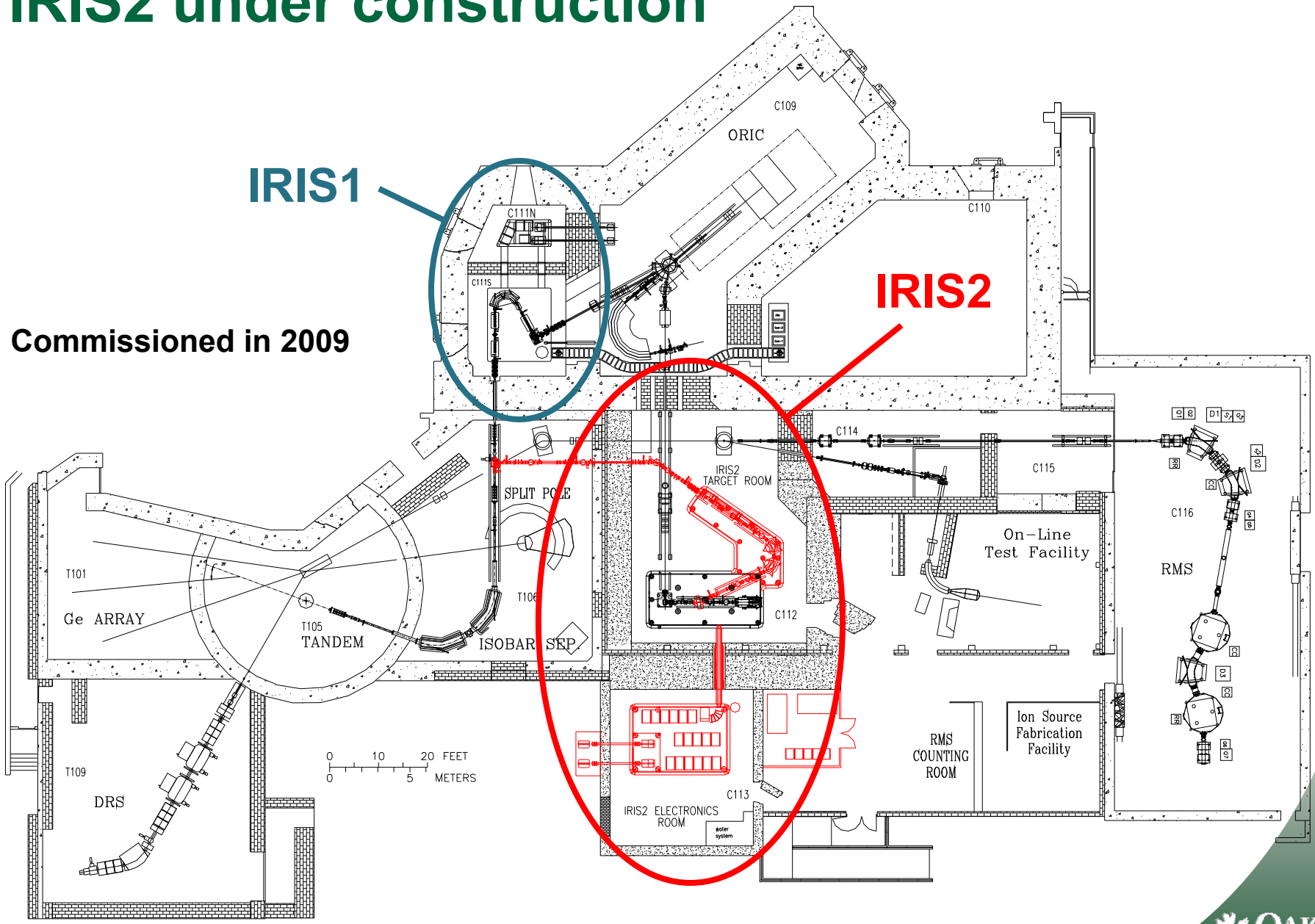
Managed by UT-Battelle
for the Department of Energy

OAK RIDGE National Laboratory

HRIBF

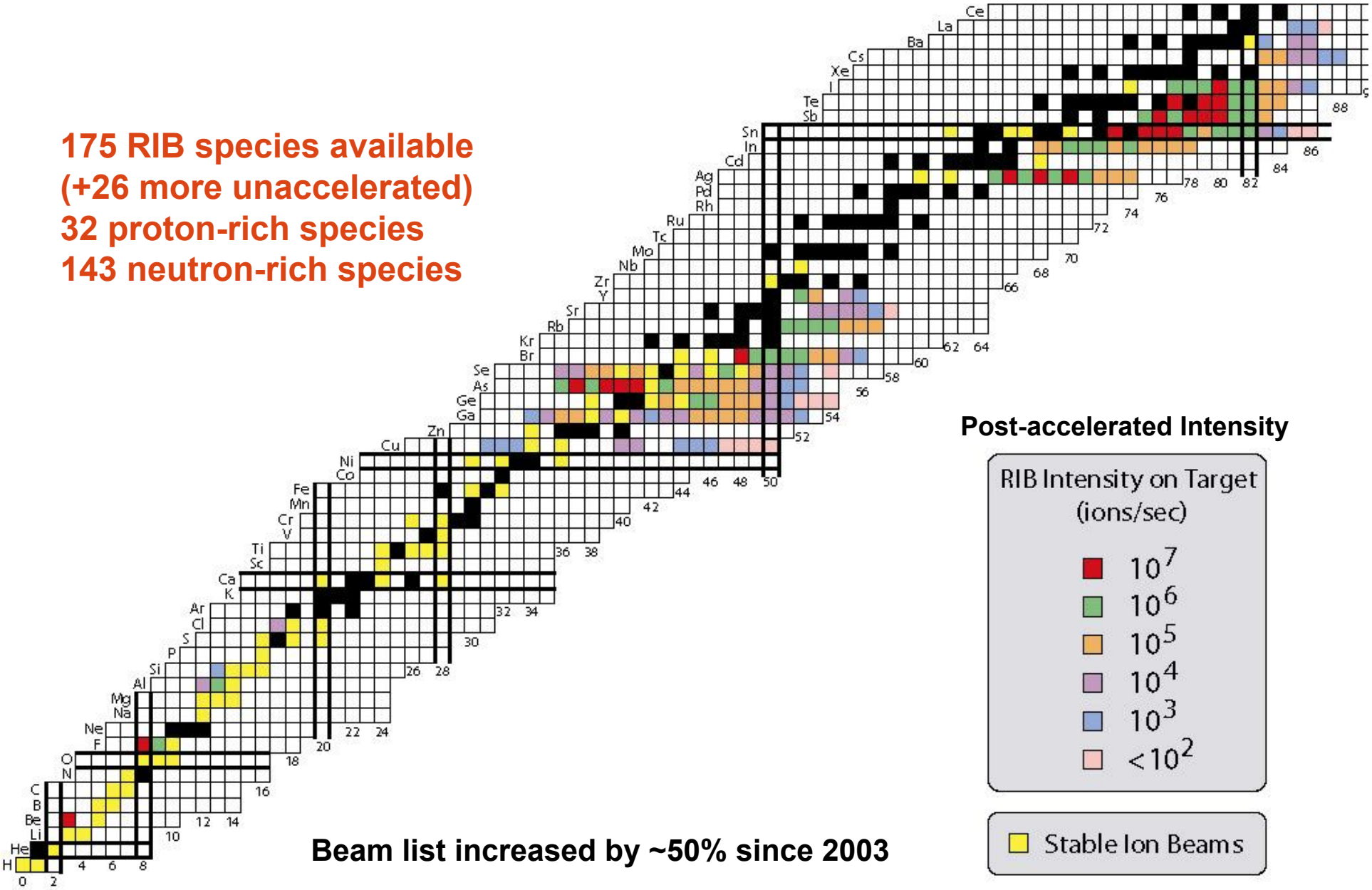

25MV Tandem Electrostatic Accelerator
Stable Ion Injector (ISIS)
Injector for Radioactive Ion Species 1 (IRIS1)
Oak Ridge Isochronous Cyclotron (ORIC)
Enge Spectrograph
Daresbury Recoil Separator (DRS)
High Power Target Laboratory-HPTL: (IRIS2 2009)
On-Line Test Facility (OLTF)
Recoil Mass Spectrometer (RMS)

IRIS2 under construction



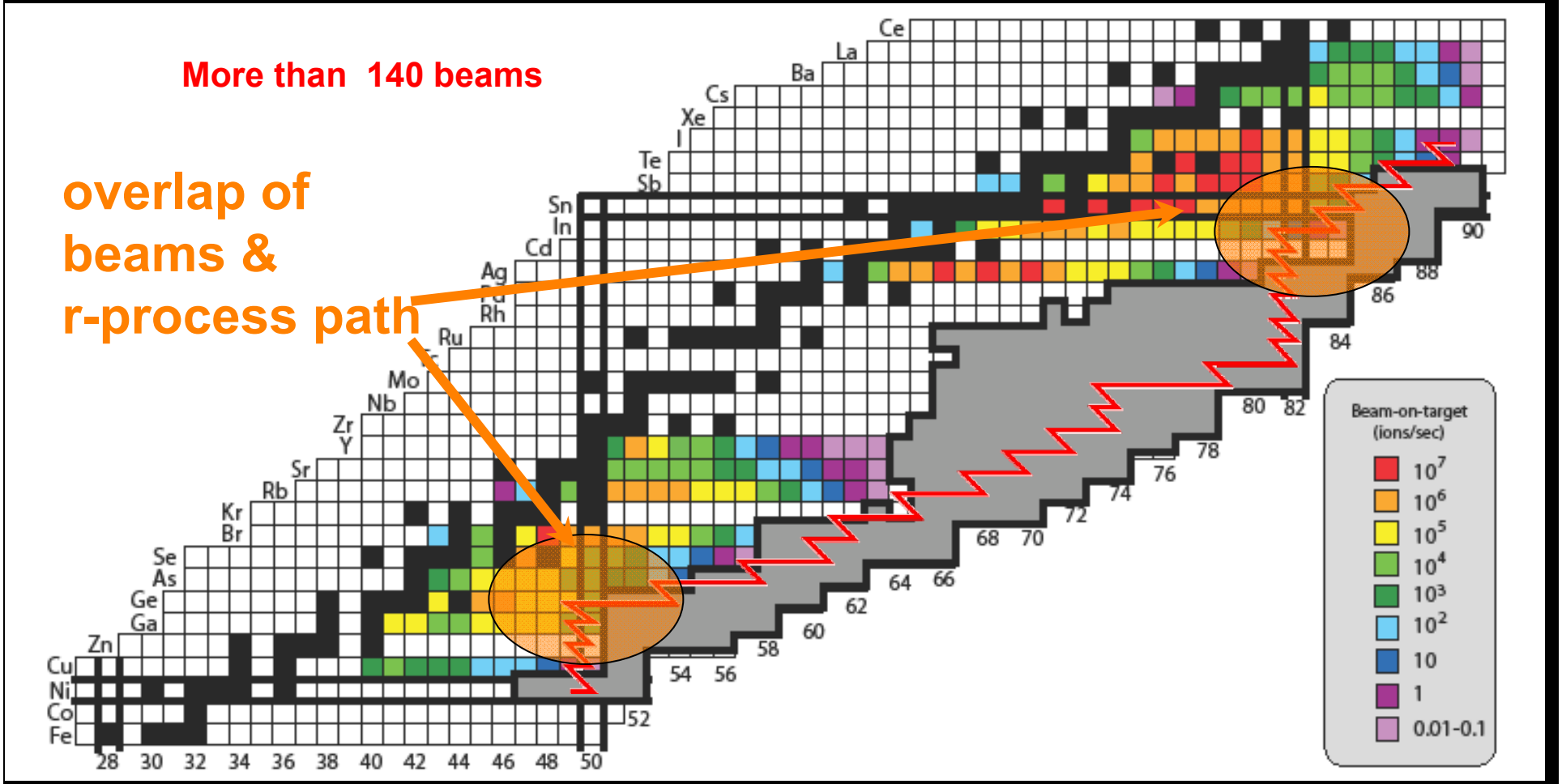
HRIBF Post-accelerated Beams

175 RIB species available
(+26 more unaccelerated)
32 proton-rich species
143 neutron-rich species



Beam list increased by ~50% since 2003

Unique neutron-rich unstable beams for transfer



ORNL has capability - **unique in world** - to produce neutron-rich nuclei in or near the r-process path and measure transfer reactions with them

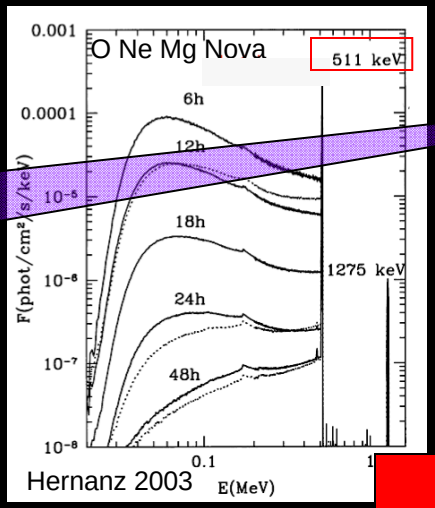
FY2007
Beam hour statistics

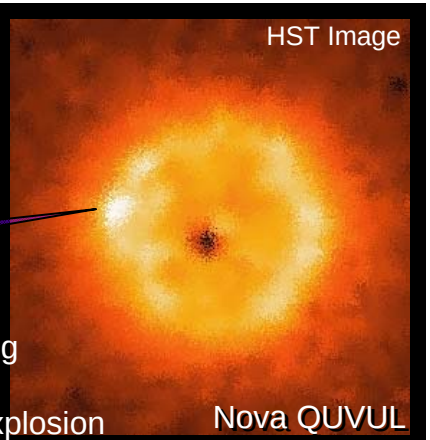
HE ISOL RIBS	1821
LE ISOL RIBS (ORIC - LeRIBSS / HPTL)	131
TOTAL "RIBS" = ORIC DRIVEN ISOL	**1952**
**Most productive FY for RIBs in facility history	
LE ISOL RIBS (Tandem driven - OLTF)	241
In-flight RIBS (stable to RMS for decay)	278
RIB support	837
SIB	255
Development	85
Total SIB + Tandem RIB	**1696**
Total Research	**3648**
Reliability	91%
Total Ops (Research + Beam Studies + Setup)	4986

Recent Highlights

- **Novae and the rp-process: $^{17}F(p,\gamma)$**
- **Alpha decay studies near ^{100}Sn**
- **Beta decay and beta-delayed neutron emission near ^{78}Ni**
- **Pioneering neutron transfer measurements on r-process path**
- **Solar physics: $^{7}Be(p,p)$ and $^{7}Be(p,\gamma)$**
- **Investigations of surrogate reactions**
  - **Rutgers, ORAU Center of Excellence**
- **Central collisions in very n-rich systems**
  - **Shapira et al., Eur. Phys. J. A 25, s01, 241 (2005)**
  - **Liang et al., PRL 91, 15271 (2003); PRC 75, 054607 (2007)**
- **In beam spectroscopy and shell structure: Coulex, static moment measurements, transfer, etc. near N=82, Z=50 and N=50, Z=28.**
  - **Padilla-Rodal et al. Phys. Rev. Lett. 94, 122501 (2005)**
  - **Yu et al., Eur. Phys. J. A 25, s01, 395 (2005)**
  - **Radford et al., Nucl. Phys. A752, 264c (2005)**
  - **Varner et al., Eur. Phys. J. A 25, s01, 391 (2005)**
  - **Baktash et al., to be published**

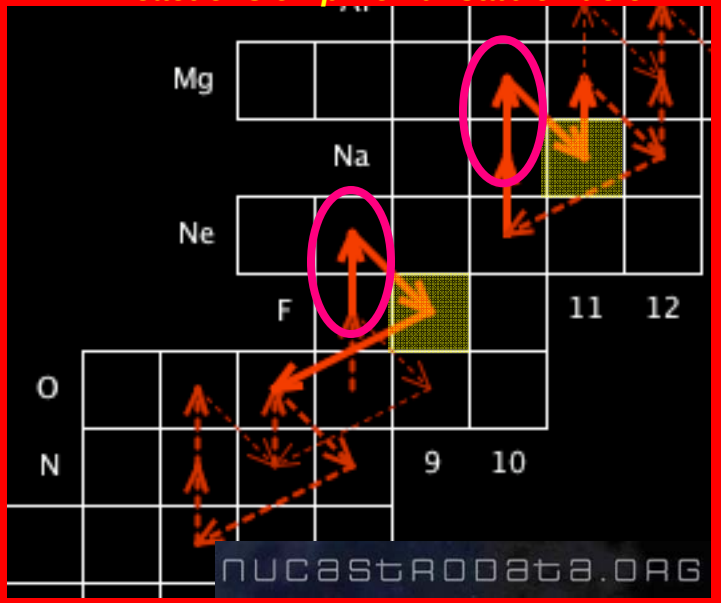
RIB measurements for Novae

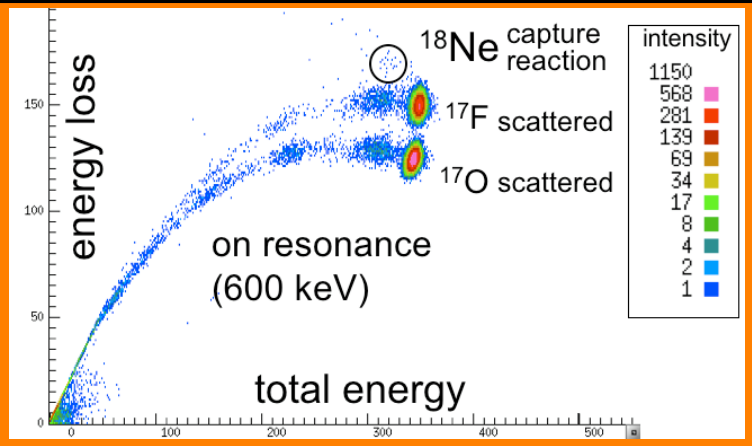




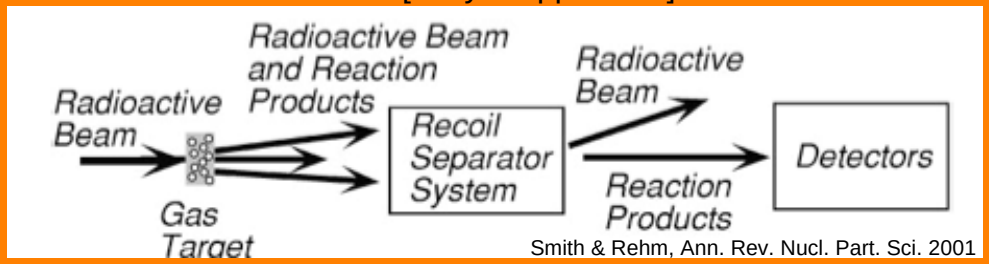
• predicted γ-ray flux from decaying radionuclide ^{18}F synthesized in explosion

flux depends on rates of (p,γ) reactions on p-rich unstable nuclei





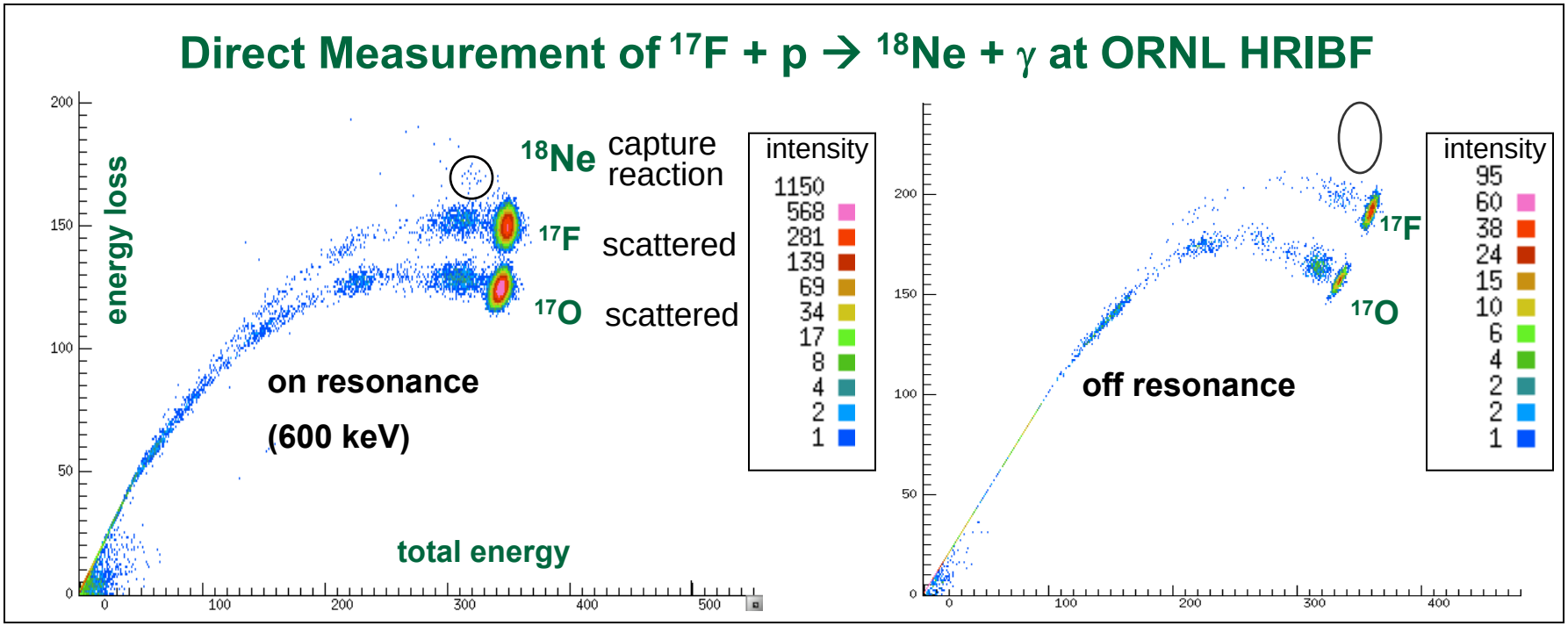
^{17}F(p,γ)^{18}Ne measured at ORNL HRIBF Feb 2008 [Kelly Chipps et al.]



Smith & Rehm, Ann. Rev. Nucl. Part. Sci. 2001

• simulation of Nova Outburst on a 1.15 M O Ne Mg White Dwarf
• ^{17}F(p,γ) & ^{21}Na(p,γ) are dominant production reactions for ^{18}F and ^{22}Na

Direct Measurement of $^{17}F + p \rightarrow {}^{18}Ne + \gamma$ at ORNL HRIBF



- Proton capture on radioactive ^{17}F - never before directly measured - is an important link in the thermonuclear burning that powers nova explosions
- Rate of this capture reaction needed to determine amount of radioactive ^{18}F produced and the ^{17}O / ^{18}O ratio
- Decay of radioactive ^{18}F is searched for by satellite observatories, can constrain constrain nova explosion models
- Previous attempts to indirectly determine this rate using beams of stable nuclei uncertain by orders of magnitude
- Low energy beam of radioactive ^{17}F nuclei produced at ORNL's Holifield Radioactive Ion Beam Facility [HRIBF]
- Intensity of over 15 million particles per second was sufficient to directly measure this weak reaction (a few counts/day)
- Daresbury Recoil Separator used to directly detect the recoiling ^{18}Ne from the capture reaction
- Measurement completed February 2008; data currently under analysis, will be Ph.D. thesis for Kelly Chipps
- First proton capture measurement on a radioactive beam in the U.S.; first U.S. facility [3rd worldwide] with this capability
- New reaction rate will be used in explosion simulations to determine astrophysical impact

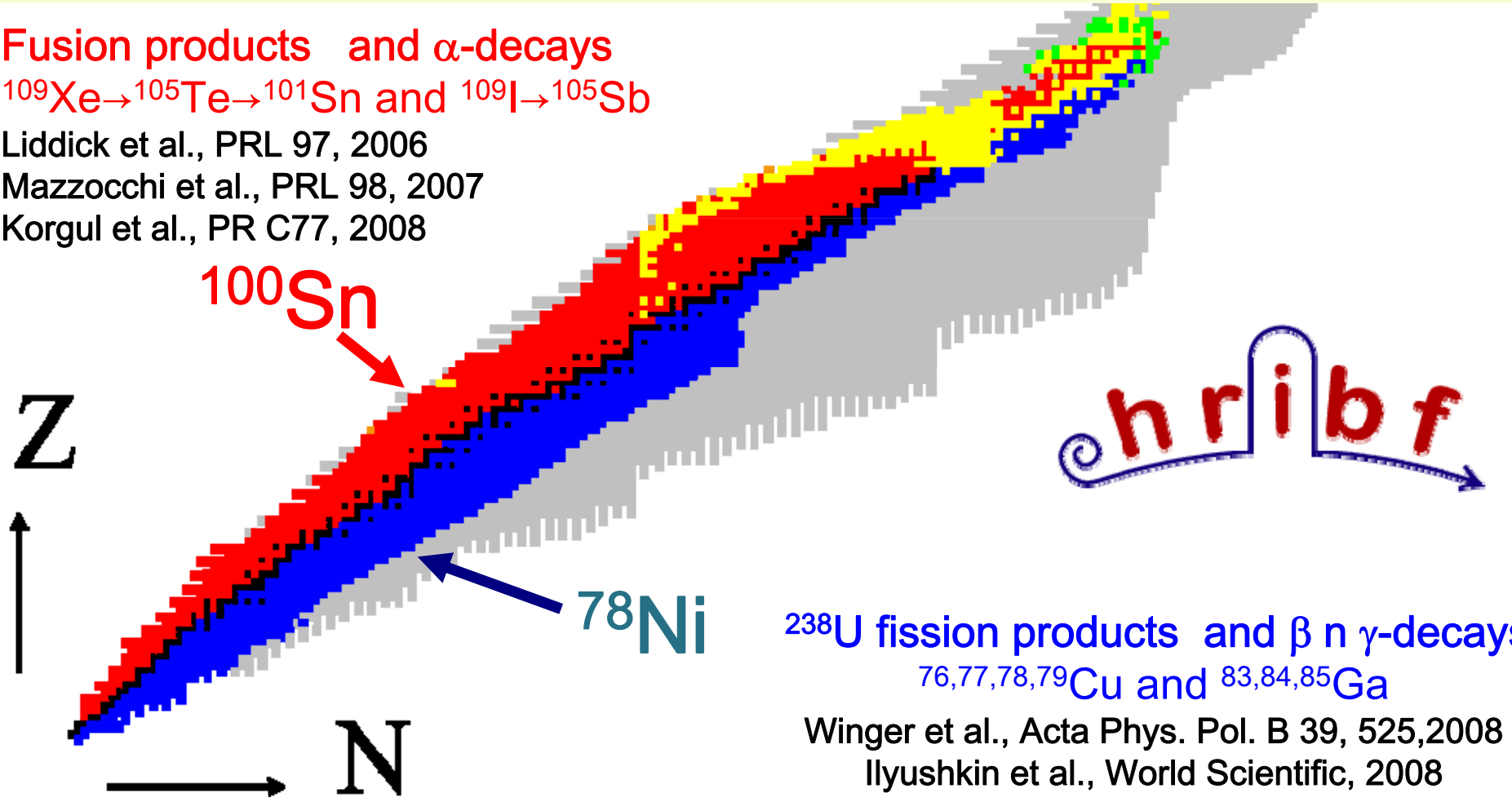
Approaching doubly-magic nuclei ^{78}Ni and ^{100}Sn

Radiation emitted during spontaneous decay of several exotic nuclei near doubly magic ^{78}Ni and ^{100}Sn has been observed for the first time at the HRIBF. These measurements advance the understanding of the evolution of nuclear structure and provide information on the path of rapid stellar processes responsible for the formation of elements in the Universe . The rates of beta and neutron emission from ^{238}U fission products contribute to the understanding of processes relevant for the Advanced Fuel Cycle program.

Fusion products and α-decays

^{109}Xe→^{105}Te→^{101}Sn and ^{109}I→^{105}Sb

Liddick et al., PRL 97, 2006
Mazzocchi et al., PRL 98, 2007
Korgul et al., PR C77, 2008



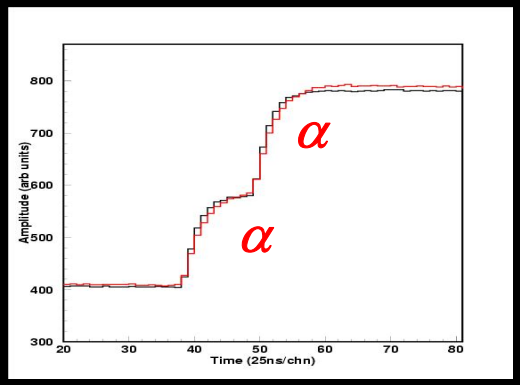
^{238}U fission products and β n γ-decays

^{76,77,78,79}Cu and ^{83,84,85}Ga

Winger et al., Acta Phys. Pol. B 39, 525,2008
Ilyushkin et al., World Scientific, 2008

Superallowed α-decay $^{109}Xe \rightarrow ^{105}Te \rightarrow ^{101}Sn$

Halflife ratio- 20000:1



$(5/2^+)$ **620 ± 70 ns**

$^{105}_{52}Te_{53}$

l=0

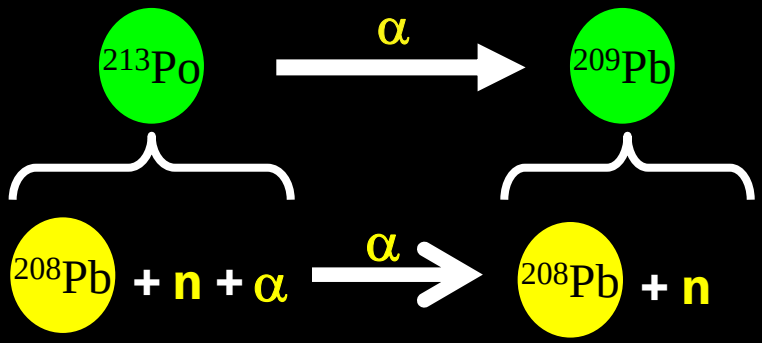
E_α = 4.703 keV

S. Liddick et al., PRL 97,082501(2006)

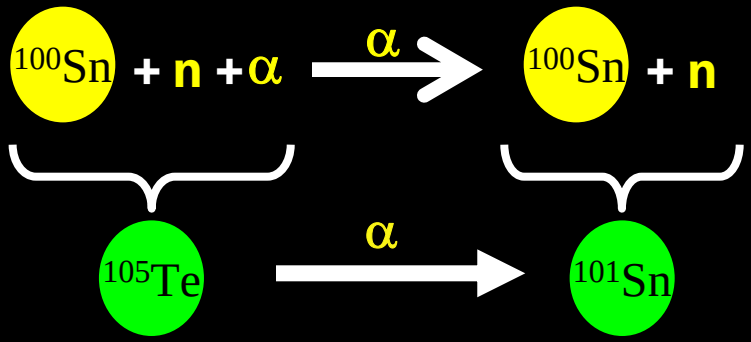
$(5/2^+)$ 1.9 s

$^{101}_{50}Sn_{51}$

Old standard (different shell structure for neutrons and protons)



New standard (the same shell structure for neutrons and protons)



Identification at HRIBF of fastest known alpha decays:

$\delta^2(^{105}Te)/\delta^2(^{213}Po) = 2.4(3)$

The evolution of shell structure in very neutron-rich nuclei beyond the N=50 shell closure

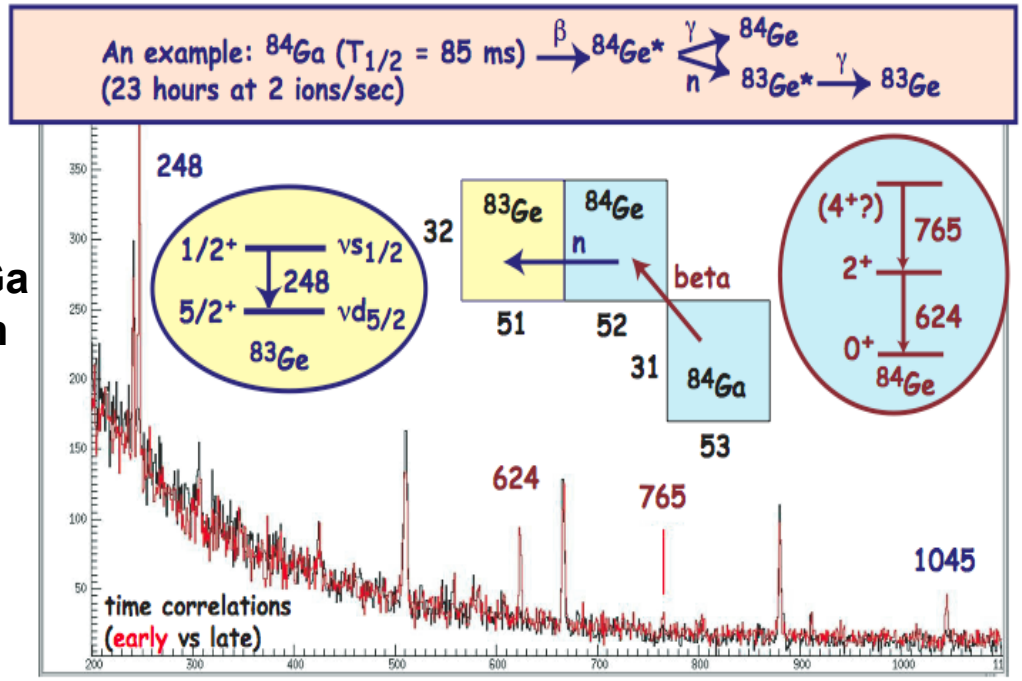
β-decay studies around ^{78}Ni with postaccelerated (3 MeV/u) pure neutron-rich RIBs

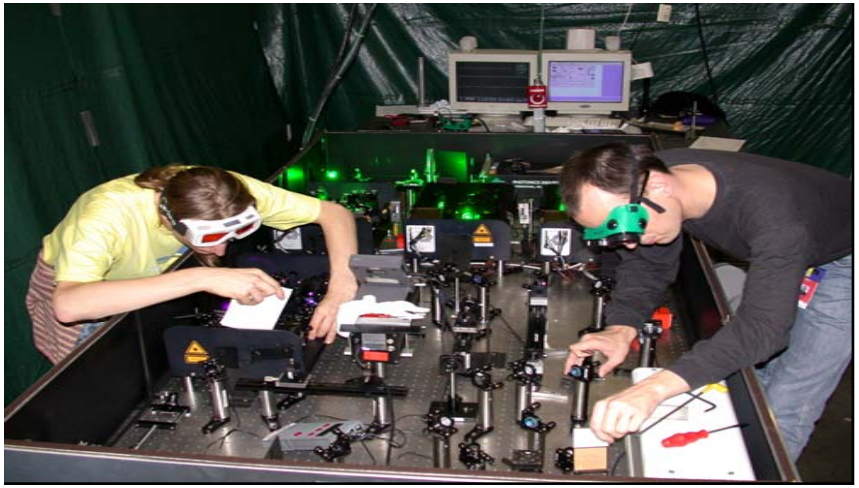
beam	$T_{1/2}$ (s)	main results
^{76}Cu	0.65	βn-branching ratio $I_{βn}$
^{77}Cu	0.46	$I_{βn}$, ν- levels in N=47 ^{77}Zn
^{78}Cu	0.35	$I_{βn}$, $I^{π}$ of $^{78}Cu_{49}$ revised
^{79}Cu	0.19	βnγ decay observed first time
^{83}Ga	0.30	βnγ,βγ, $νs_{1/2}$ in N=51 ^{83}Ge
^{84}Ga	0.08	2^+ in N=52 ^{84}Ge
^{85}Ga	~0.07	rate of 0.1pps…

- $t_{1/2}$ & βn rates for many r process nuclei are accessible
- Energy levels test evolving nuclear structure
- Range out unwanted high-Z contamination with high pressure & tape transport

- Absolute beta-delayed neutron branching ratios for $^{76-79}$Cu and $^{83-84}$Ga
- Identification of new excited states in ^{77}Zn, ^{78}Zn, ^{82}Ge, ^{83}Ge, and ^{84}Ge
- Systematics of single particle levels (e.g. neutron $s_{1/2}$) near doubly magic ^{78}Ni

Winger et al.





Laser Ion Source Development

(will deploy on IRIS-2)

- Ion beams of 12 elements have been produced using the LIS at HRIBF
- 9 of these elements were ionized for the first time with Ti:Sapphire lasers

Element	Sn	Ni	Ge	Cu	Co	Ga	Mn	Fe	Al	Ho	Tb	Dy
Efficiency Measured (%)	22	2.7	3.3	2.4	>20					40		

compared with10% at ISOLDE RILIS

Y. Liu, et al., Nucl. Instr. and Meth. B 243 (2006) 442-452.

compared with >3.8% at ISOLDE RILIS

(Paper in preparation)

highest LIS efficiency ever reported for any element

(Paper in preparation)

Effect of 6-month Continuing Resolution

- Case 1: 6-month CR then full FY09 PB
- Case 2: 6-month CR then half the FY09-FY08 difference
- Case 1
  - Believe we can maintain overall operating hours
    - Research 3600 hr, total operations 4800 hr, 'HE" RIB 1900 hr
  - Accept increased risk in recovering from major breakdown in first half of FY
  - Planned hires under PB are 2 operators to transition from 5-day to 7-day operation, postdoc for ISOL development, and 0.5 FTE RF engineer
    - Under Case 1 these must delay at least 6 months
    - Would likely mean only one operator and postdoc hired FY09
    - Thus transition to 7-day would start in FY10
- Case 2
  - Requires some scale-back in hours
    - Research 3400 hr, total operations 4500 hr, "HE" RIB 1600 hr
    - Hire one operator, might hire postdoc, transition to 7-day delays further into FY10
    - Increased downside risk from major breakdown

Recent Operating Numbers

- **Total operating hours:**
  - **FY2005: 4869**
  - **FY2006: 5215**
  - **FY2007: 4986**
  - **FY2008: 3800 planned (3973 so far)**

- **“HE” RIB hours**
  - **FY2005: 1201**
  - **FY2006: 830**
  - **FY2007: 1952**
  - **FY2008: 1100 planned**