FRIB Estimated Rates

v 2.10

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FRIB

This document describes the assumptions used to generate version 2.10 of the estimated FRIB fast, stopped, and reaccelerated beam rates.

Primary beams: PAC2

Element	Z	A	E(PAC2)	P(PAC2)
			MeV/u	kW
O	8	16	288	10
O	8	18	253	10
Ne	10	22	258	10
Ar	18	36	288	10
Ca	20	48	238	10
Ni*	28	58	263	10
Ni*	28	64	241	10
Zn*	30	70	238	10
Kr	36	78	256	10
Se	34	82	230	10
Kr	36	86	231	10
Mo	42	92	248	10
Xe	54	124	227	10
Pt*	78	198	186	5
Pb*	82	208	185	5
U	92	238	180	5

* new beam offered for PAC2

Transmission and yield calculations

Transmission efficiency calculations were performed with LISE^{++} v. 16.6.20 using the “Distribution” analytical method [1]. Calculation settings are given in Table 2. An approximation of the optimum production target thickness was chosen to speed the calculations.

Table 2. *Fragment separators characteristics, physical models, and assumptions been used LISE^{++} in transmission calculations:*

Objects/characteristic	Parameter	Value / Model
Target	Material	C
	Thickness	**40**% of range of projectile in target
Angular acceptance after target	Horizontal (full)	80 mrad
	Vertical (full)	80 mrad
	Solid angle	5 msr
Momentum acceptance	dp/p (full)	10 %
Momentum distribution:	Convolution model	[1] – Es (s0=160, coef=1,shift-1)
Charge states :	Yes (target,wedge)	[3] – Global
Energy loss model :		[1] – Atima 1.4
Primary reactions in target:		NP=32; EPAX 3.1 [2]
Secondary reactions in target:	Yes	NP=64; EPAX 3.1 [2]

The optimal charge state combination through the various stages of separation was chosen, and then spectrometer has been tuned for maximum production of each isotope. The production cross sections for projectile fragmentation have been calculated using the EPAX 3.1 parameterization [2] for each beam from the list.

Fission

Production cross sections following projectile fission of ^{238}U have been calculated with the use of the LISE^{++} 3EER model [3]. BigRIPS tabulated user cross sections were used to assist in fission yield estimations. The characteristics of excitation energy regions used in calculations are given in Table 3.

Table 3.

Region	A Z	CS, mb	E*, MeV
Low	^{236}U	576	34
Middle	^{230}Ac	492	144
High	^{220}At	557	394

For each excitation energy region, yield calculations were done and used to optimize the fragment separator. Depending on which region provided the highest yield for a given fragment, the resulting maximum yield was used for the fission fragment rate displayed.

NOTE: The FRIB "ultimate" yields are 40 x the PAC2 yields to account for 400 kW vs 10 kW beam power. The actual ultimate yields will also have additional beams added and will benefit from knowledge of better beam-target and energy optimization.

Stopped Beams

Beam intensities in the stopping beam areas have been estimated for each isotope taking into account actual performances observed using the Advanced Cryogenic Gas Stopper (ACGS). The estimates included a beam stopping efficiency in the gas stopper using an optimal fast beam momentum compression settings and an extraction efficiency experimentally obtained during various ACGS runs. The stopping and extraction efficiencies vary as a function of the atomic number. The stopping efficiency spans from a maximum of 95% for heavy ions down to 10% for low atomic numbers. The maximum extraction efficiency adopted is 25% for atomic numbers greater than 10, down to 1% for atomic numbers down to four. Half-life of isotopes were taken into account assuming an average extraction time of 75 ms for the gas stopper. Atomic numbers lower than four were excluded from estimates.

Reaccelerated beams

Beam intensities in the reaccelerated beam areas have been estimated using the stopped beam intensities multiplied by the following efficiencies:

- Beam-cooler-buncher
- Electron Beam Ion trap
- Radio Frequency Quadrupole accelerator
- LINAC and the beamlines

The efficiencies are based on experience. The efficiency for bunching and breeding varies with the atomic number and spans from 30% to 8%. The average breeding time also varies depending on the atomic number from 30 ms to 300 ms for high atomic numbers.

The LINAC plus RFQ and beamline transport efficiencies were assumed to be 80% based on experience.

References:

[1] O.B.Tarasov and D. Bazin, NIM B 266 (2008) 4657-466.

[2] K. Sümmerer, Phys. Rev. C 86 (2012) 014601.

[3] O.B. Tarasov, Tech.Rep. MSUCL1300, NSCL, Michigan State University 2005.