

Production of C-14 and stable ion beams at the Argonne Tandem Linac Accelerator System with the ECR3 ion source

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ABSTRACT

The Argonne Tandem Linac Accelerator System (ATLAS) at Argonne National Laboratory (ANL) paused production of carbon-14 ion beams with the removal of the Tandem Van de Graaff in 2013. Installation of ECR3, an Electron Cyclotron Resonance Ion Source, returned that production capability to ATLAS, with the first C-14 beam delivered in December 2020. Information is presented on C-14 beam current, gas consumption and N-14 filtering techniques using stripping foils at different sections of ATLAS. ECR3 also fulfilled the operational goal of adding flexibility to ATLAS stable beam production capabilities. Beneficial impacts to ATLAS operation, beam development and experimental programs are discussed.

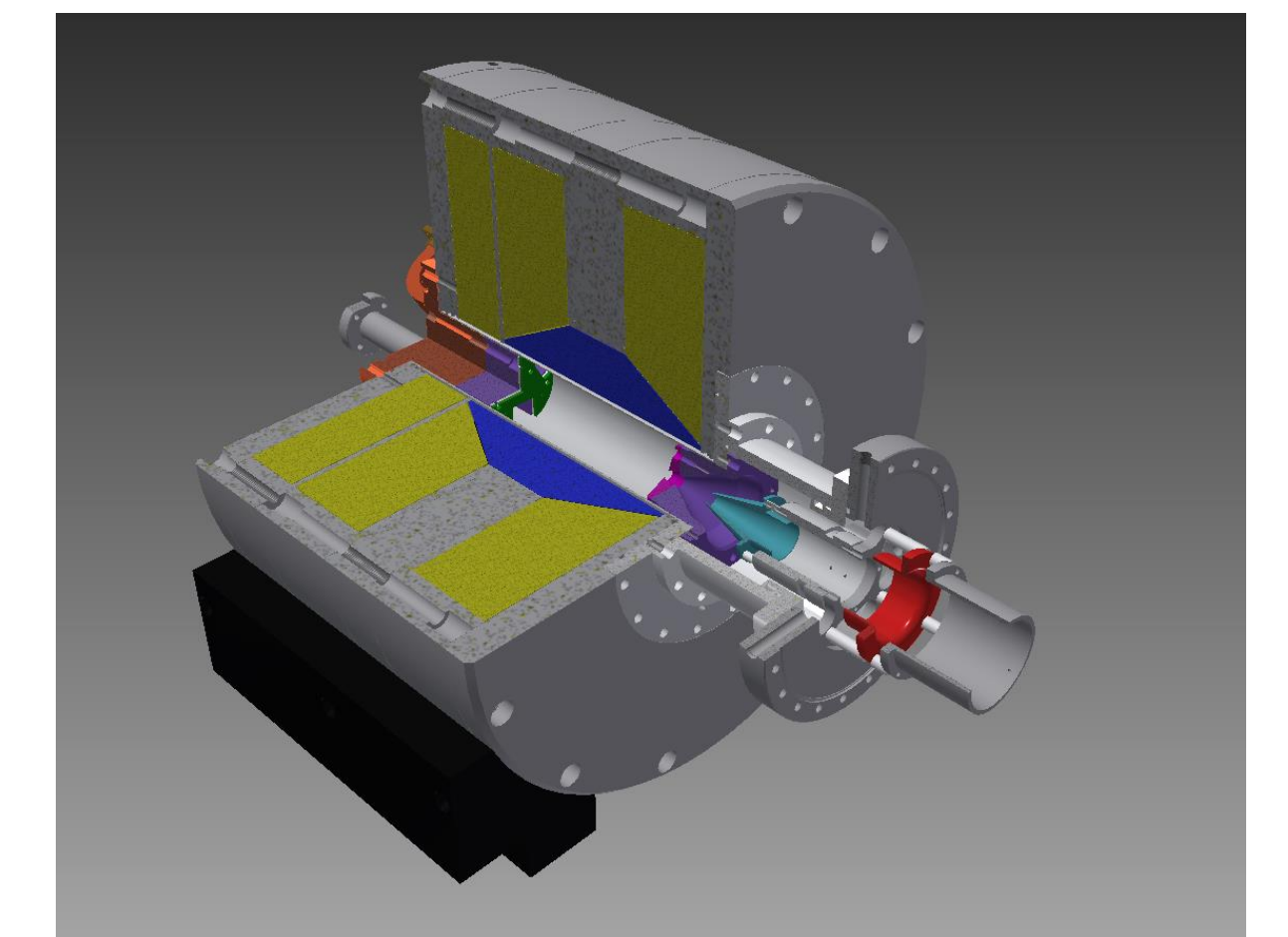
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ECR3 ION SOURCE

BIE100* all permanent magnet based ECR specifications

- P.C. dimensions Φ 6.4 cm / L 17.5 cm
- RF (TWTA) 300W / 11-13 GHz
- Platform potential \leq 200 kV
- Source potential \leq 15 kV
- B_{rad} 1.0 T
- B_{inj} 1.27 T
- B_{min} 0.42 T
- B_{ext} 0.65 T



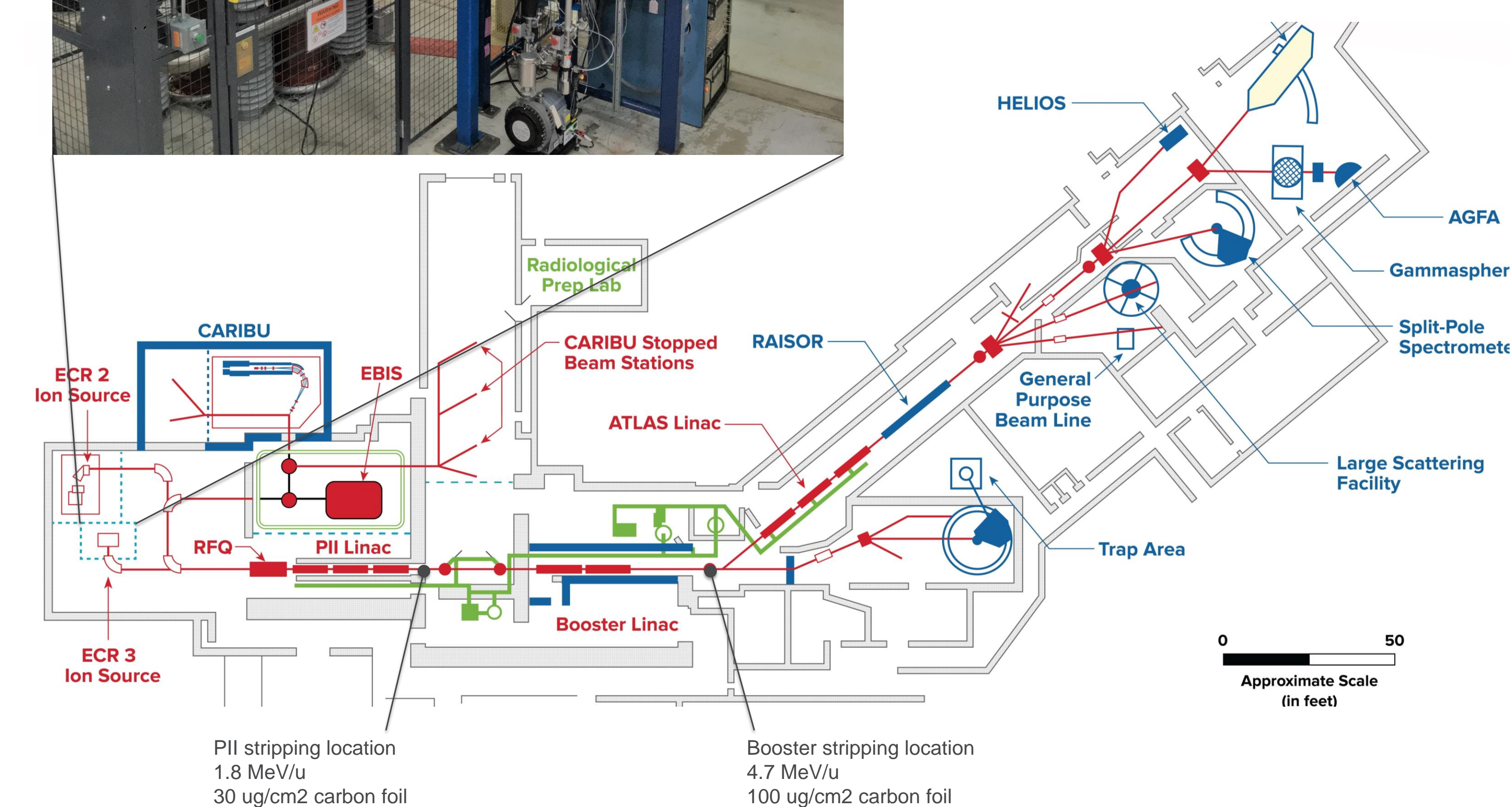
* D. Z. Xie, RSI Vol. 73, No. 2 [DOI: 10.1063/1.1429320]

ECR3 AT ATLAS

- The small footprint of ECR3 allowed it to be built in existing space in the high bay housing ECR2.



- ECR3 delivers stable beams and C-14.
- The additional source allows for development and maintenance time for both sources.



C-14 PRODUCTION

- Experiment Energy Requirements
 - Up to 210 MeV (15 MeV/u)
 - Stripping necessary
 - Start with 3+ (best ionization efficiency / LEBT transmission)

Stripping location	Charge state	Stripping energy (MeV)	Energy Atlas exit (MeV)		
			A	B	C
unstripped	3+	-	90	145	165
Booster	6+	65.7	110	220	242
PII	5+	25	133	220	246
PII	6+	25	147	254	281

- A: Current resonator configuration
- B: Current configuration plus upcoming energy upgrade
- C: All resonators active plus energy upgrade

- Measured nitrogen stripping fractions with pure N beam from ECR2

Stripping location	Nitrogen stripping fraction η (%)			
	4+	5+	6+	7+
PII	1.8	25	53.5	19.6
Booster	0	0.2	8.8	91

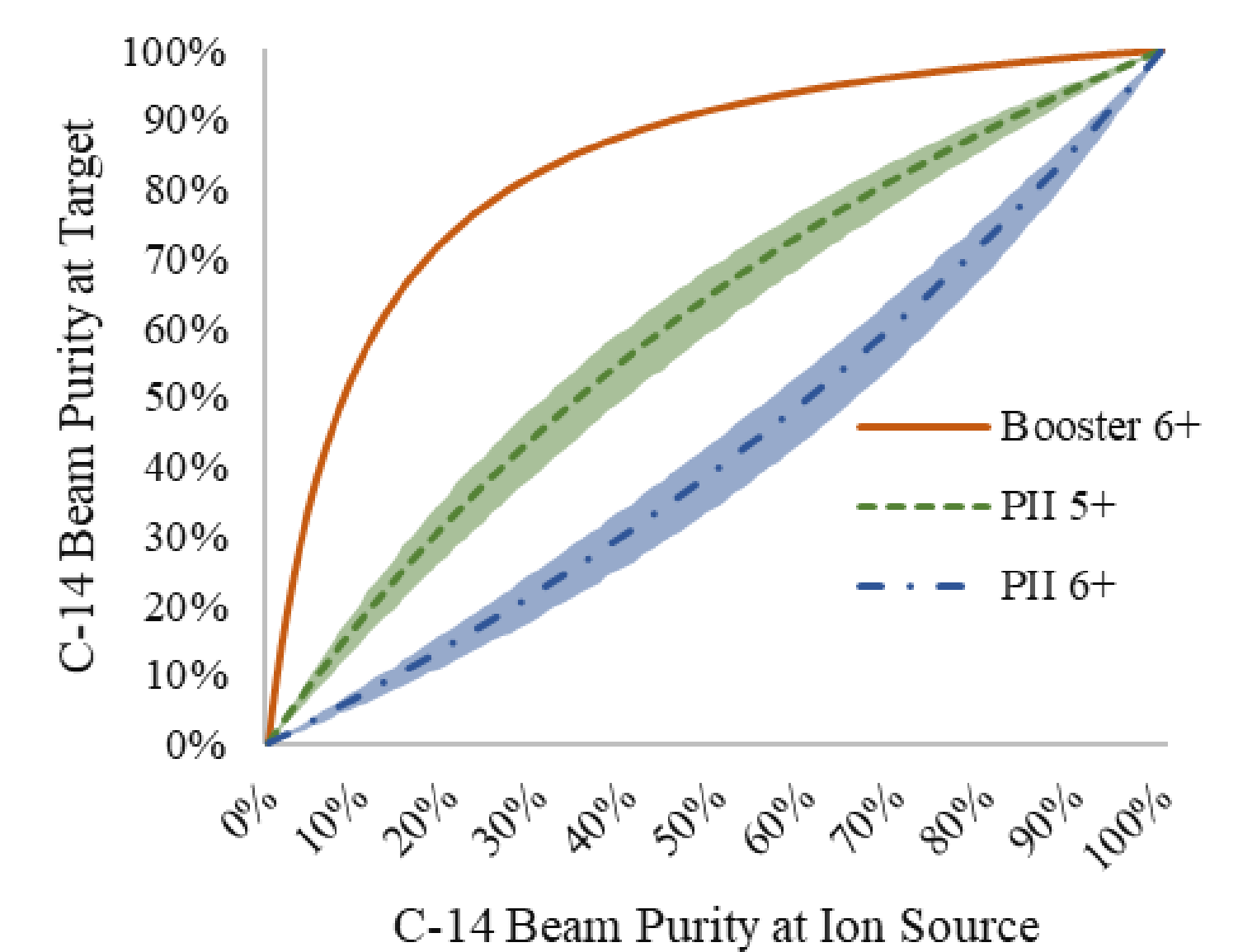
- Determined carbon stripping fractions from C/N mixed beam and/or semi-empirical code

Stripping location	Carbon stripping fraction η (%)			
	4+	5+	6+	Error
PII	17	47	35	+/- 20%
Booster	0	4.5	95.5	+/- 1%

- Error determined from PII nitrogen measurement vs. calculation

BEAM PURITY

- Experiment Purity Requirements
 - Need to filter out nitrogen
 - Purity: % of mixed C-14/N-14 beam that is carbon
 - Typically >80% requested

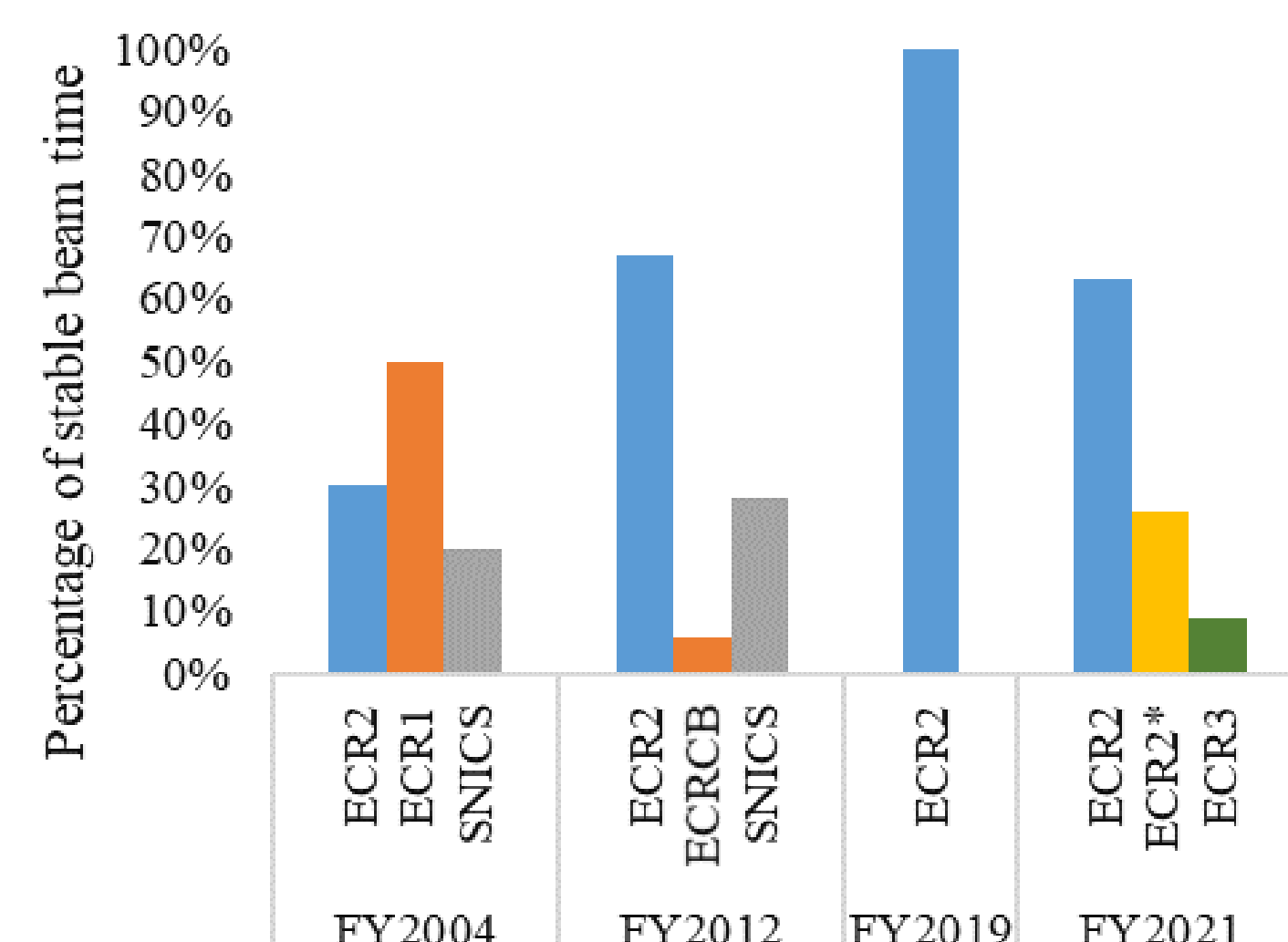


$$P_{tgt} = \frac{P_{src} \eta_C}{P_{src} \eta_C + \eta_N (1 - P_{src})}$$

- Charge Stripping location effects purity
 - Stripping to 6+ at Booster provides the highest C-14 beam purity
 - Energy requirements can require PII stripping despite the low beam purity at the experiment

STABLE BEAM PRODUCTION FROM ECR3

- By 2019 all stable beams came from ECR2
- ECR3 Resumes flexibility of operation to ATLAS
- Multiple source development and maintenance tasks completed at ECR2 during ECR3 stable (and C-14) operation
 - 71 days 10/2019 thru 9/2021



- *29% of FY21 stable beam hours capable from ECR3

CARBON-14 EXPERIMENTS AT ATLAS

- Nuclear physics experiments in order of operation at ATLAS

Experiment number	Hours	Beam parameters at target			Stripping		Carbon-14			
		Intensity (pA)	Energy (MeV)	Purity requested	Location	Charge	Consumption rate (mg/hr)	Transmission	Target purity	RF Power
1728	88	1	140	>50%	PII	6+	0.025	8.5-12%	38 - 45% ^a	20W
1739a	137	100	122	> 80%	Booster	6+	0.075	36-45%	>80% ^b	6W
1732	165	16	100	> 80%	Booster	6+	0 ^d	23-31%	91% - 87% ^c	7W
1739b	216	95	122	> 80%	Booster	6+	0 ^d	36-40%	87% - 85% ^c	14W
1955	160	100	133	> 80%	PII	5+	0.16	6-14%	>80% ^b	5W

a. reported by experimenters (2 independent methods), increased over time

b. not directly measured, results indicate higher than this

c. measured by operations at stripping location, dropped over time

d. no active gas feed indicates wall recycling

ATLAS ION SOURCE OPERATION TIMELINE

