



Automation of the ReAccelerator Linac Phasing

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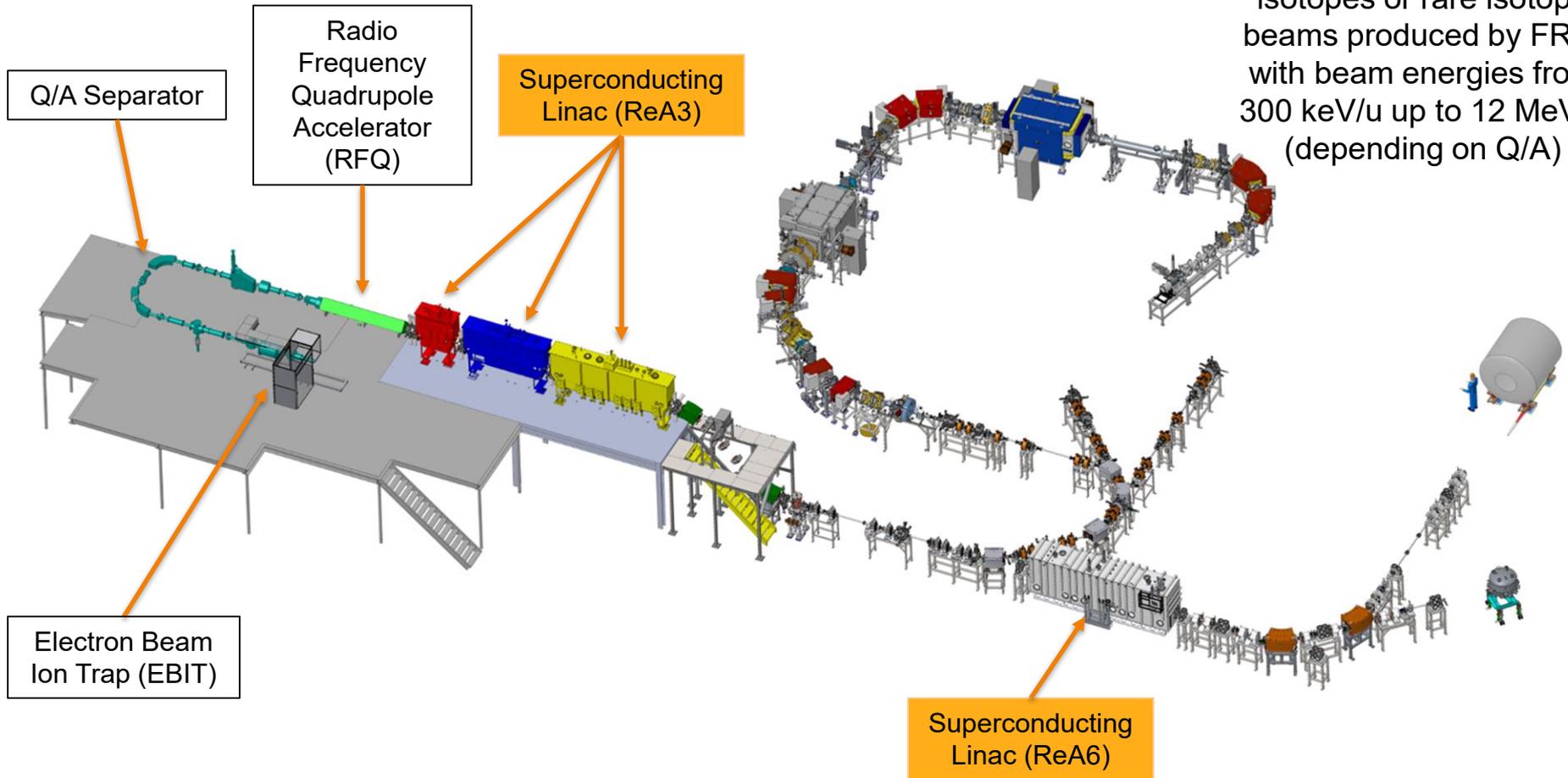


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What is the ReAccelerator?

Accelerates stable isotopes or rare isotope beams produced by FRIB with beam energies from 300 keV/u up to 12 MeV/u (depending on Q/A)



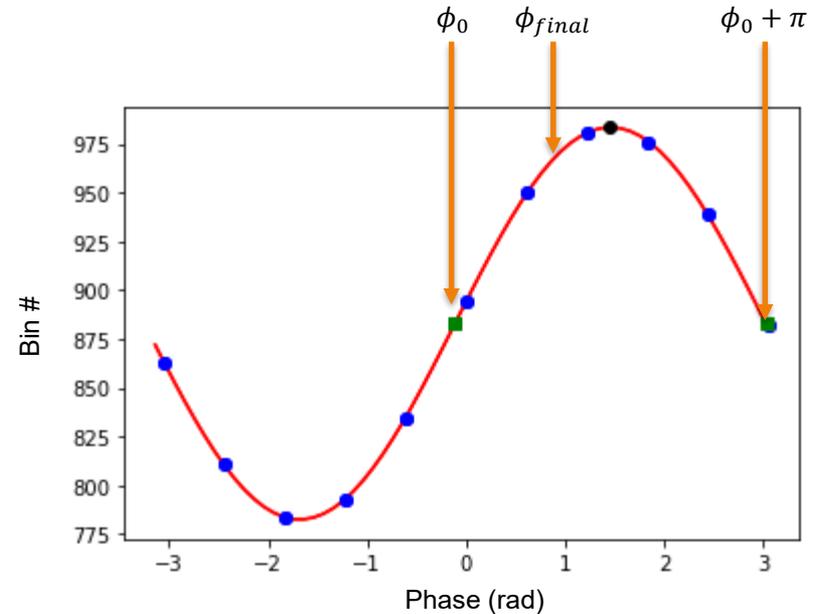
Linac Phasing

- Determining the phase delay of the RF cavities to achieve desired beam acceleration

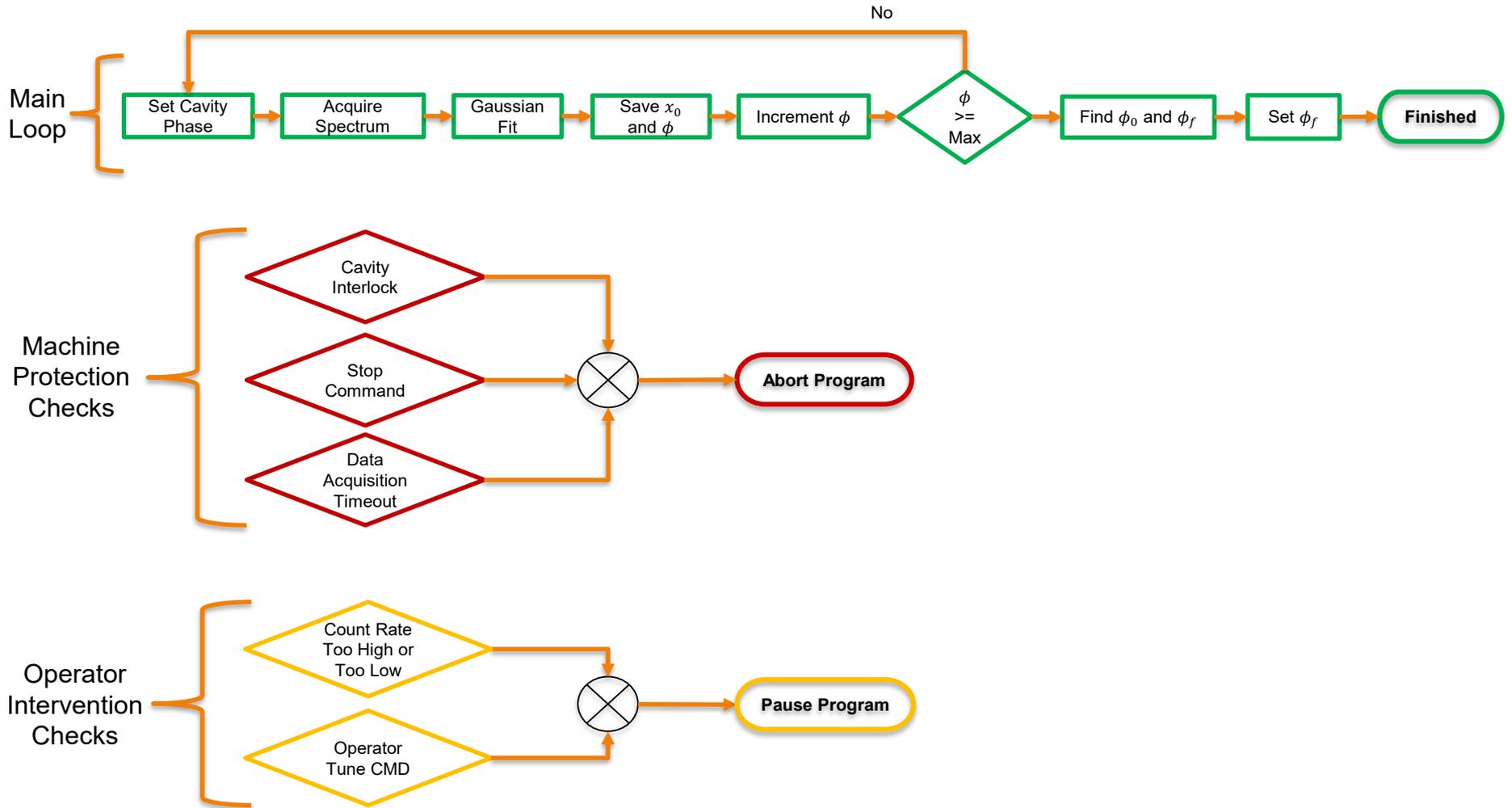
$$E_{Beam} = qV \cos(\phi - \phi_s)$$

- Using a silicon detector
 - Diagnostic boxes after ReA3 and ReA6 cryomodules

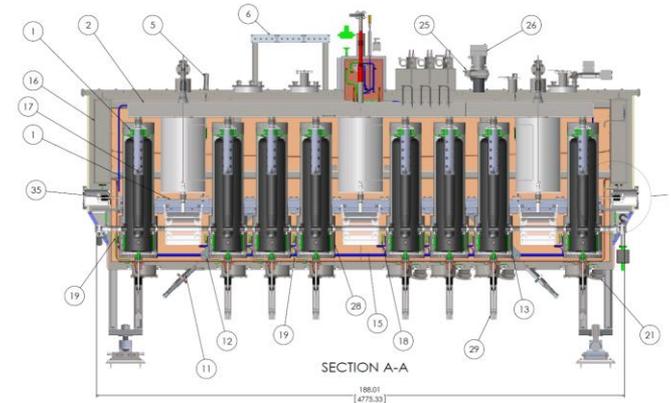
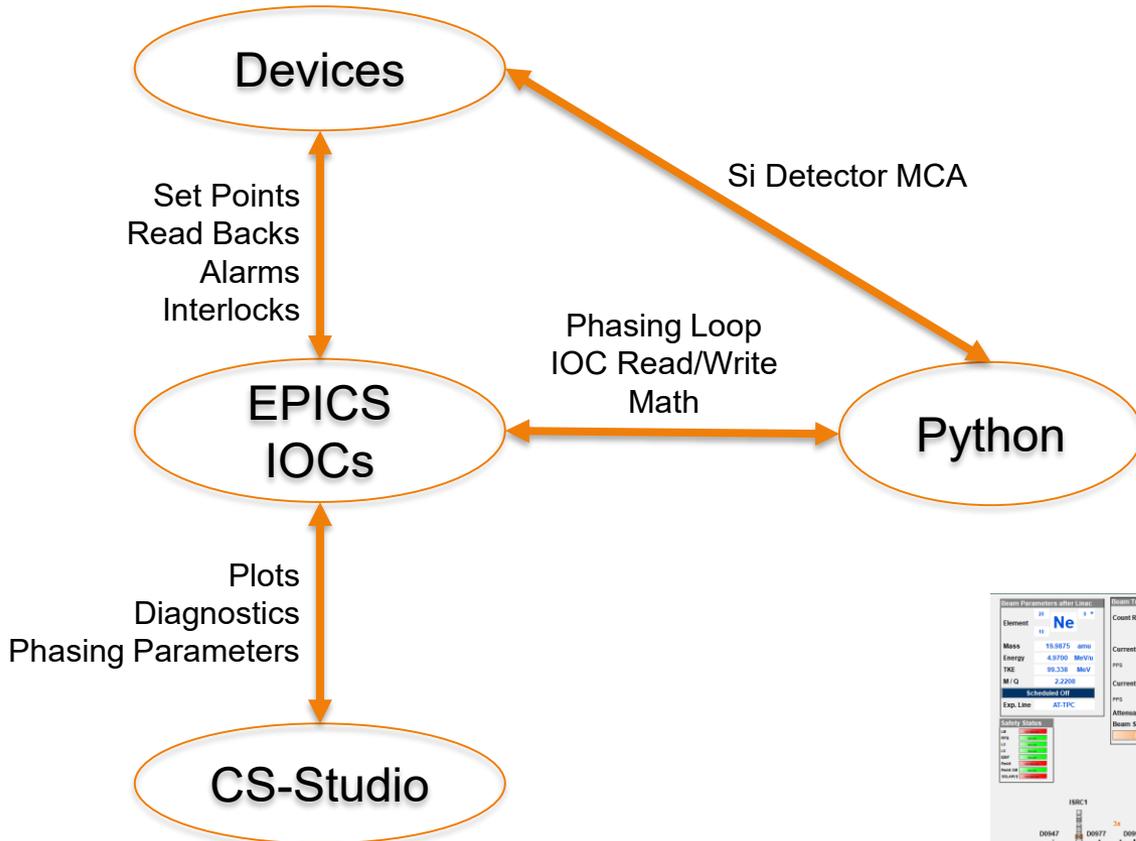
- Historically phased manually



ReA Phasing Automation Logic

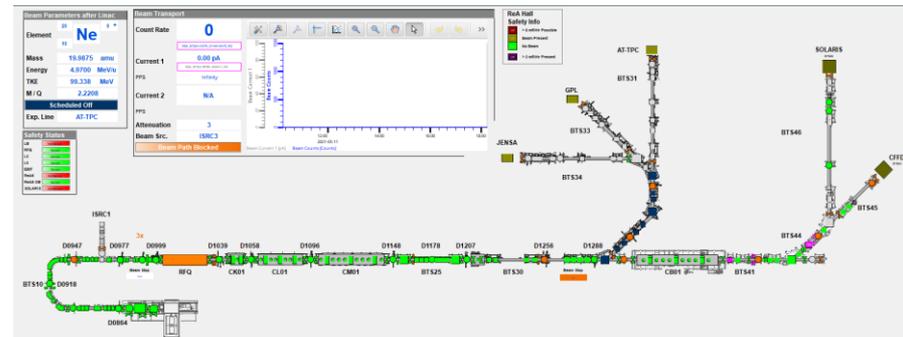


Tools Used & Testing



```

record(ao, "$(PRE)_$(SUB):$(DEV)_$(LOC):AP_PHASE_ZERO") {
    field(VAL, "0")
}
record(ao, "$(PRE)_$(SUB):$(DEV)_$(LOC):AP_SYNC_PHASE") {
    field(VAL, "$(SYNC)")
}
record(stringin, "$(PRE)_$(SUB):$(DEV)_$(LOC):AP_STATUS"){
    field(VAL, "...")
}
  
```



Phasing Interface

FRIB ReAccelerator

ReA3 Linac ReA6 Linac

ReAccelerator Auto-Phasing Application

Autophase Data

Legend: ● Gaussian Fit Centroids ◆ $\sin(\phi) = 0$ Crossing ◆ Final Phase — Sin Fit Curve

Lynx Spectrum

Legend: | ROI Spectrum — Fit • Centroid

ReA6 Linac

CB01 Enabled Reset PLC

	Amplitude	Phase	Final Phase Offset	Zero Crossing	Autophase Status
D1316	5.33	115	75	0.0	...
D1328	5.33	177	75	0.0	...
D1332	5.33	-104.5	75	0.0	...
D1336	5.33	-58	75	0.0	...
D1348	5.33	-172.5	75	0.0	...
D1352	5.33	152	75	0.0	...
D1356	5.33	-139	75	0.0	...
D1368	5.33	133.9	75	58.9	Cavity phased successfully

Time to phase cavity = 146 seconds

Controls

Program Controls

START AUTO-PHASING

START TUNING

Cavity Selected: D1368

Attenuators

REA_JSRC1:ATP_D0958 x10 Out In

LB Source (LB005) x100 Out In

REA_BTS10:ATP_D0915 x10 Out In

After EBIT (L016) x100 Out In

REA_BTS19:ATP_D0974 x100 Out In

Before MHB (L052) x3 Out In

REA_BTS20:ATP_D1038 x100 Out In

After RFQ (L072) x10 Out In

OPI's

Lynx

Diagnostics

RF

Magnets

Safety

Tune Linac

Expert Page

Scan Parameters

Initial Scan Phase: -175

Final Scan Phase: 175

Minimum Counts For Fit: 500

Phase Scan Steps: 6

Phase Scan Step Size: 70,000

Rate Timeout Counter: 0.0

DAQ Timeout Counter: 0.0

Lynx Parameters

Lynx Count Rate: 25.0

Lynx Counts: 4138.0

Lynx IP Address: ReA6 Stub

Faraday Cups (Stub and Upstream)

BTS10 D0947 Out In 46.90 pA

BTS24 D1164 Out In 3.67 pA

Status

Cavity D1368 phased successfully

ILK LTCH

Max Rate Interlock OK OK

Low Rate Interlock OK OK



Summary and Acknowledgements

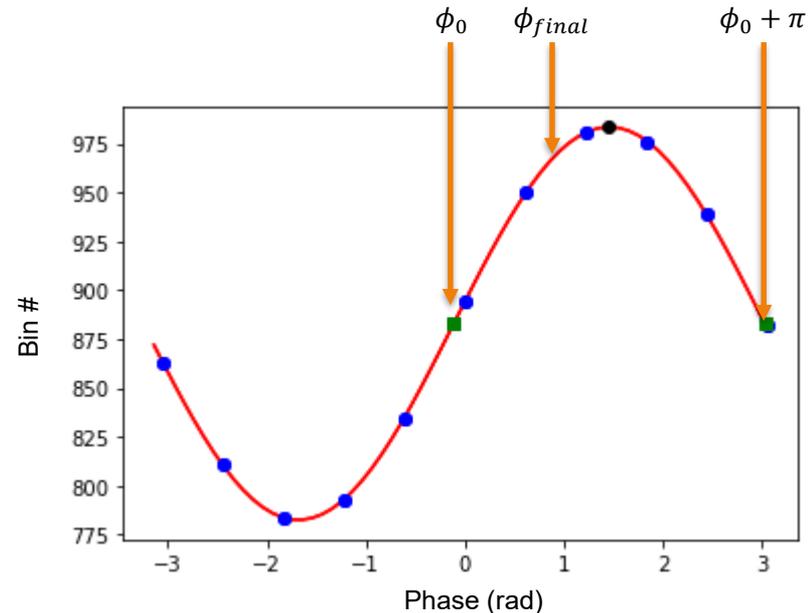
- Automated the ReAccelerator phasing process
 - Sped up process
- Now a standard part of our beam preparation procedure
- Thanks to the generous help and support from:
 - National Science Foundation grant No. PHY-1565546
 - ReAccelerator Division
 - Human Machine Interface Development Group
 - Accelerator Physics Group
 - Accelerator Operations Department



Appendix: Phasing Procedure

■ Phasing procedure:

- Record beam energy with RF cavity off
- Turn cavity on, vary phase, record beam energy
- Find phase where beam energy is the same as with the cavity off
- Verify it's the correct zero crossing
- Add final phase offset



Appendix: Expanded Program Logic

