Preinjector Upgrade Plan

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Outlines

- Introduction
- Preinjector
- Proton upgrade
- Light Ion Linac
- Summary

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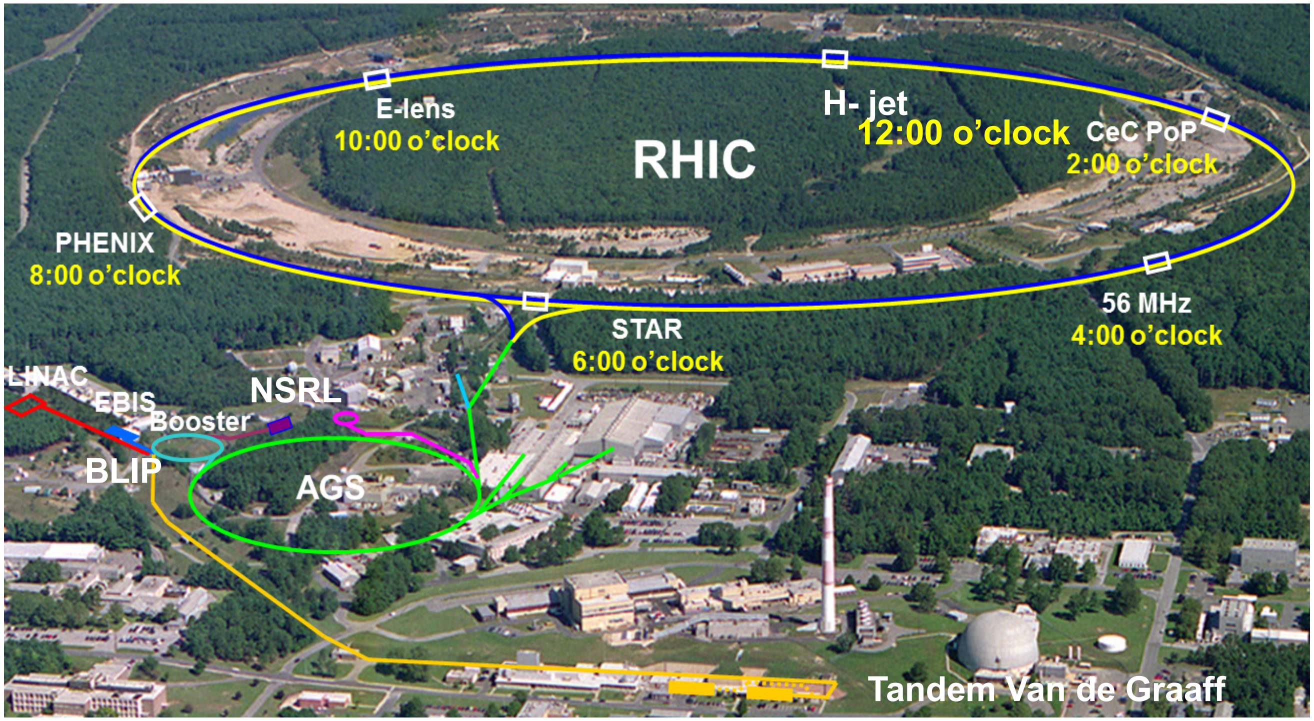
Overview of the BNL Hadron Complex



Hadron-based user and research facilities:
Linac Isotope Production (BLIP) / Medical Isotope Research and Production Program (MIRP)
NASA Space Radiation Laboratory (NSRL)
Tandem van de Graaff accelerators
Relativistic Heavy Ion Collider (RHIC)

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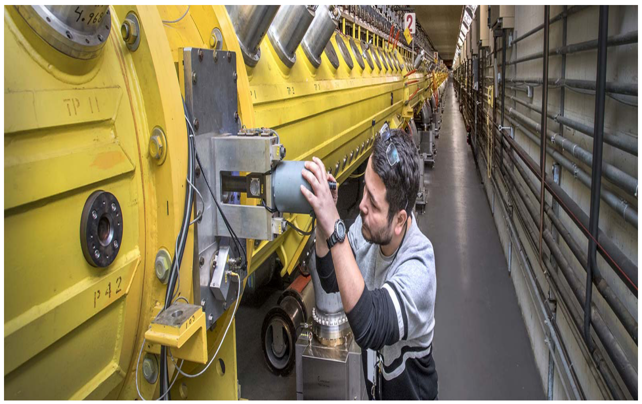
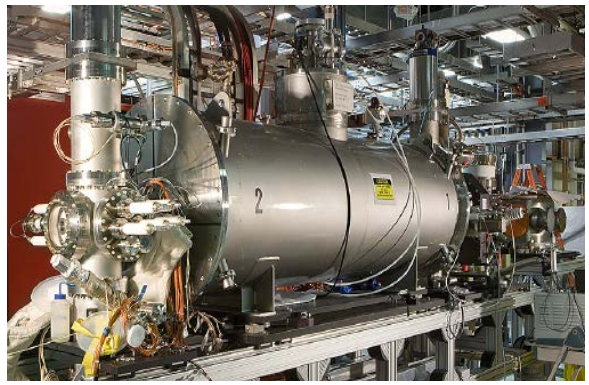
Hadron Preinjector at BNL

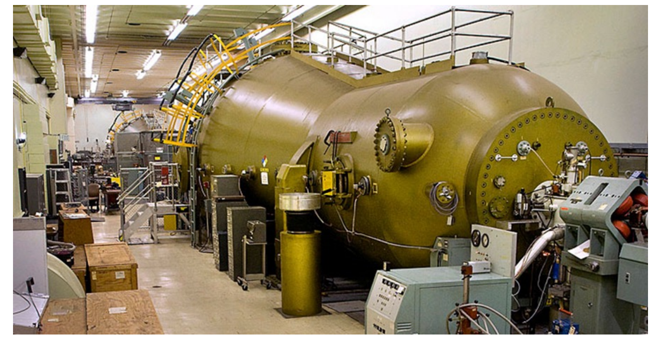
Linac (1970)



EBIS injector (2010)



Tandem (1970)



	Linac (1970)	EBIS injector (2010)	Tandem (1970)
Ion:	H-, H-^	H-U	H-U
E:	10 -200 MeV	2 MeV/u	14 MV(1+q)
I_{ave} :	200uA,	~150 nA	~10 uA
RR:	10 Hz	5 Hz	dc/pulsed
User:	BLIP, NSRL, RHIC	NSRL, RHIC	SEU, NSRL RHIC,

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Can serve all the users simultaneously

Motivation

- Increase proton energies to 600 MeV or higher
  - Allow for more spallation target irradiations
  - Higher energy allow more fast neutrons for radiation damage studies.

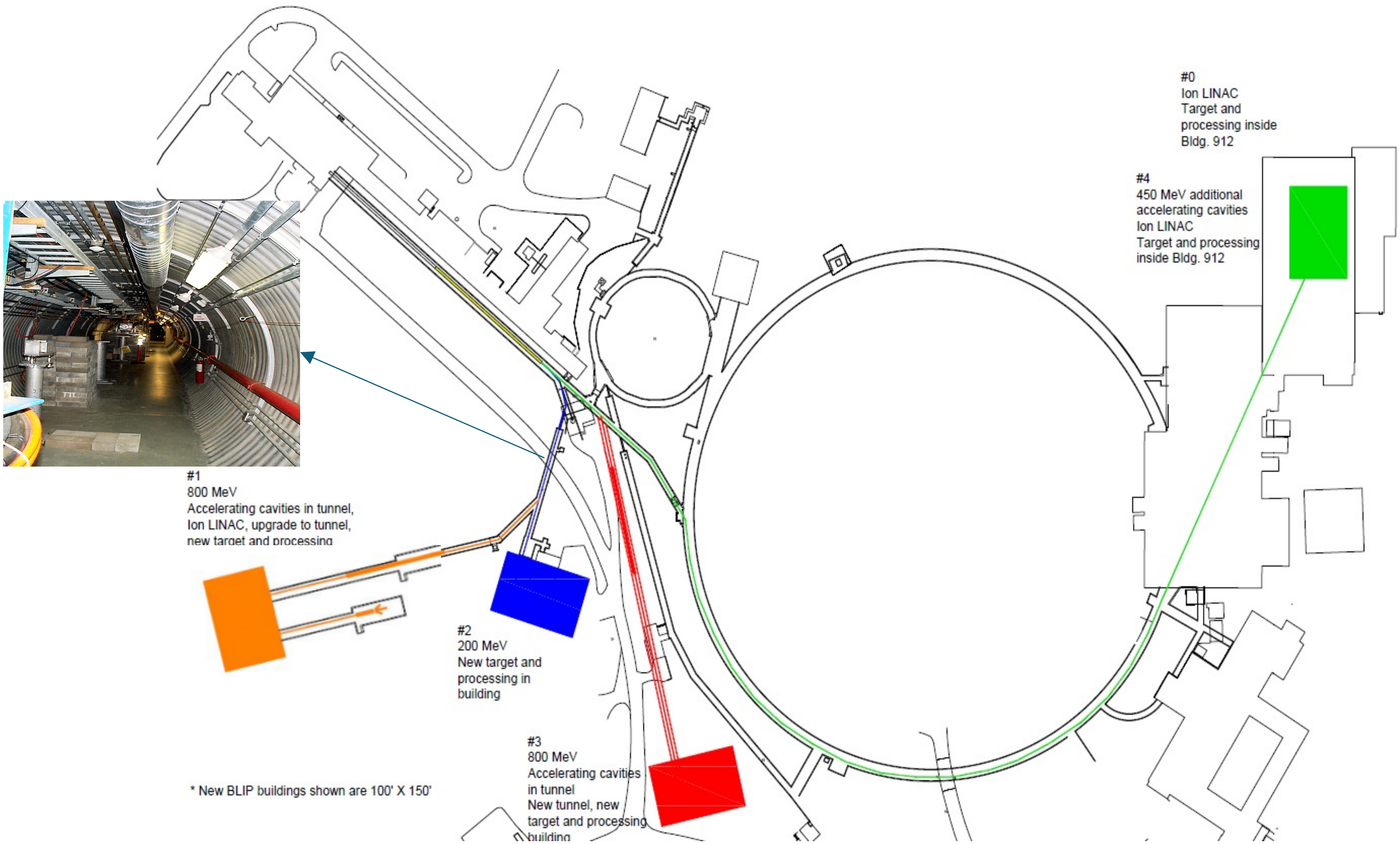
- Light Ion linac energies up to 60 MeV/u
  - To reach the energies and current of light ions which are not available elsewhere for a variety of applications
  - Nuclear reaction cross section measurements

Requirements

Proton:	
Energy	600 MeV
Av. Beam Current	200 μA
Beam Power	120 kW
Ion:	
m/q	<2.3
Energy	60 MeV/u
Av. Beam Current	200 μA
Beam Power	84 kW

Protons

Options for Proton and Ions



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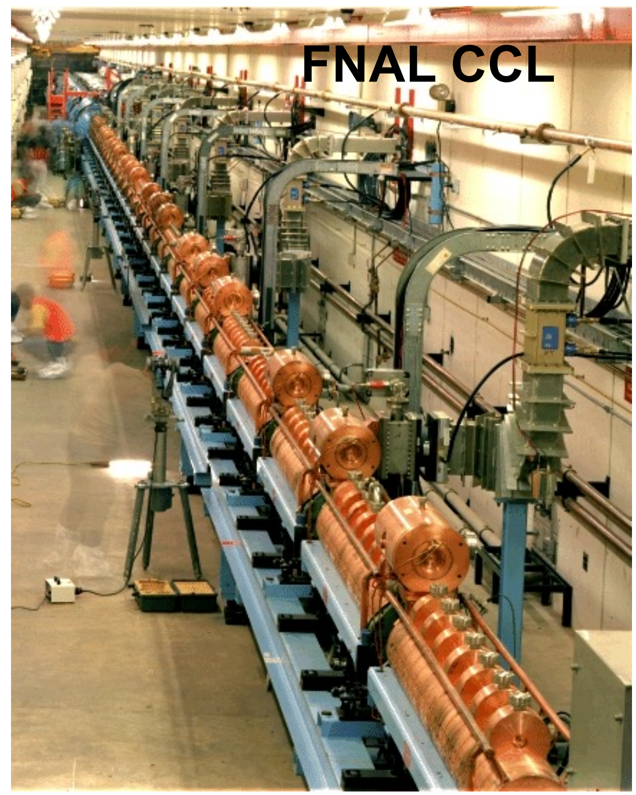
Options for Protons (Cont.)

- Green field 600 MeV SC cw/pulse Linac: Too costly
- Addon 400 MeV SC linac: Will not fit in the existing tunnels (currently idle), need new tunnel
- Replace 5 or 4 tanks of DTL: Interrupt many programs
- A 400 MeV CCL in existing tunnel to add on 200 MeV Linac leaving room for expansion



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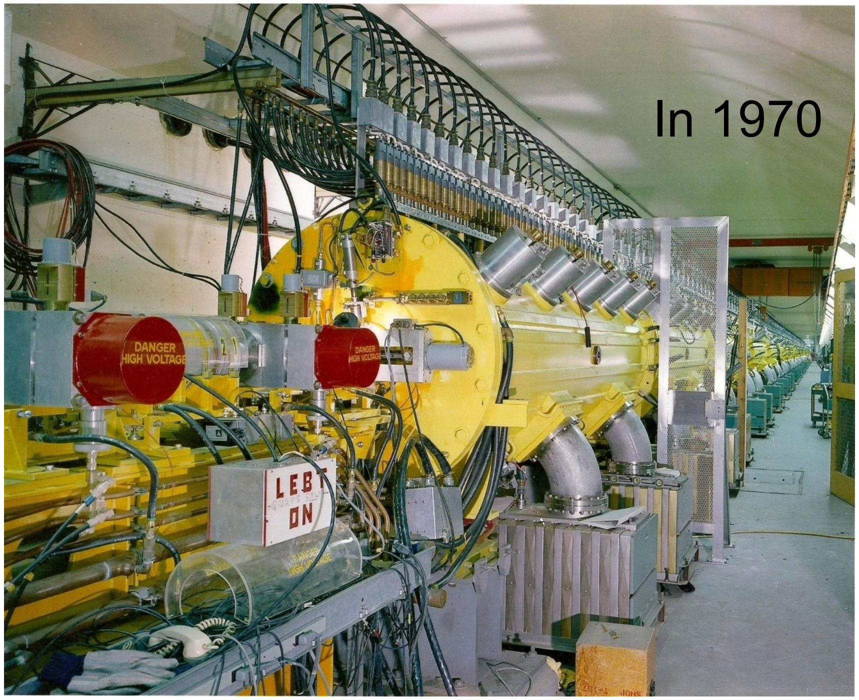
BNL 200 MeV LINAC Beam Parameters

Ion	H^-
Frequency	201.25 MHz
Injection Energy	0.750 MeV
Final Energy*	10-200 MeV
Peak Current	60 mA/ ~ 1.5 mA P^ (~85%)
Pulse Length	575 μs
Repetition Rate	6.67-10 Hz
Number of Tank	9
Length	144.8 m
Total Peak RF Power	22 MW

*Energy can be changed pulse to pulse

Build in 1970



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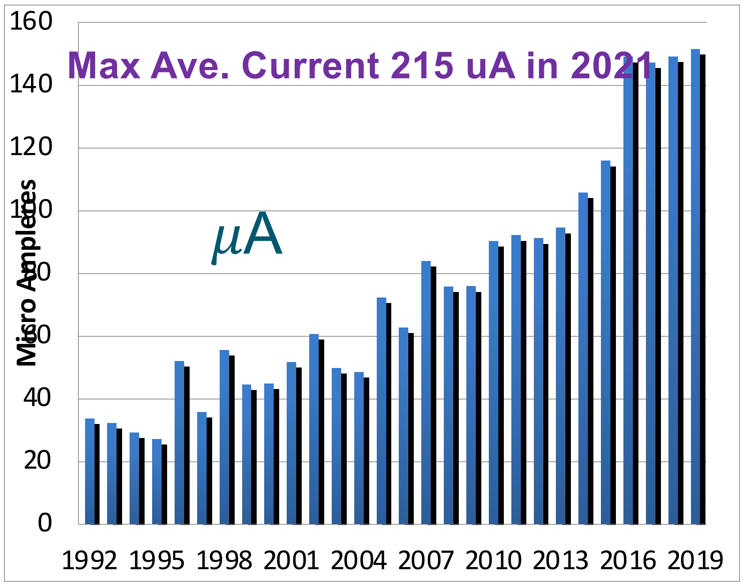
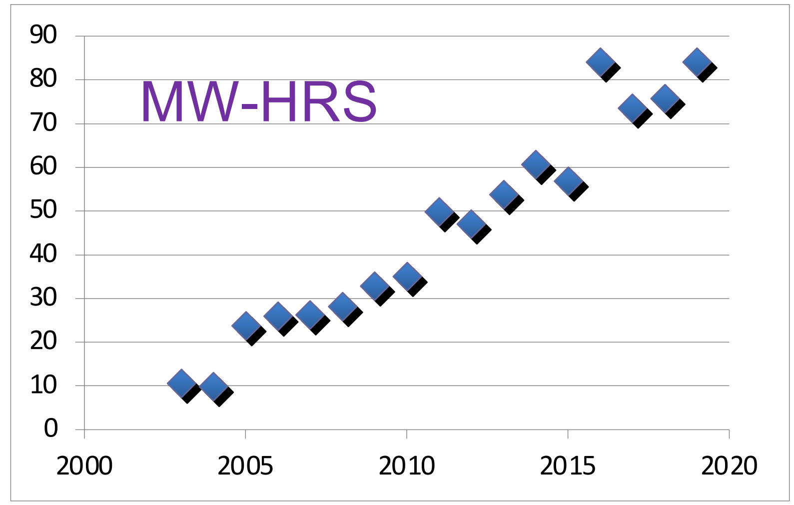
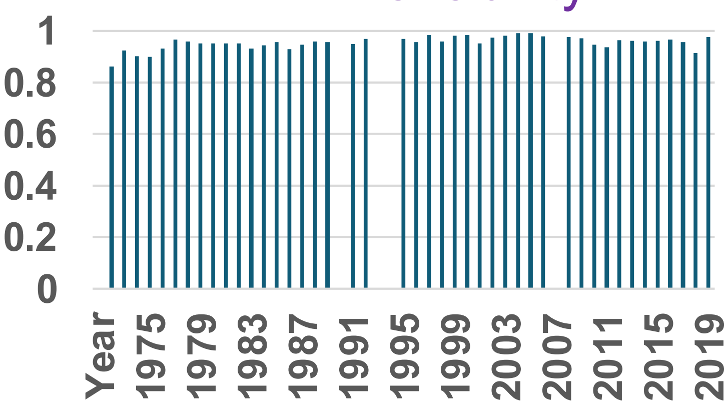
Yearly Ave. Current and Beam Power, Availability and Residual Radiation

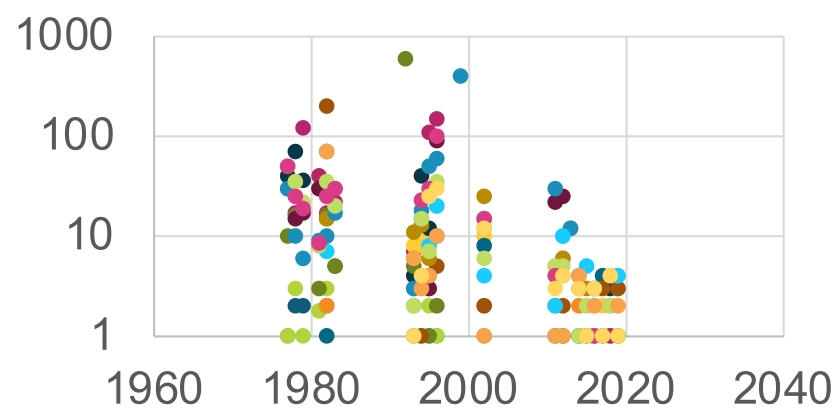




Availability



Residual Radiation (mrem)



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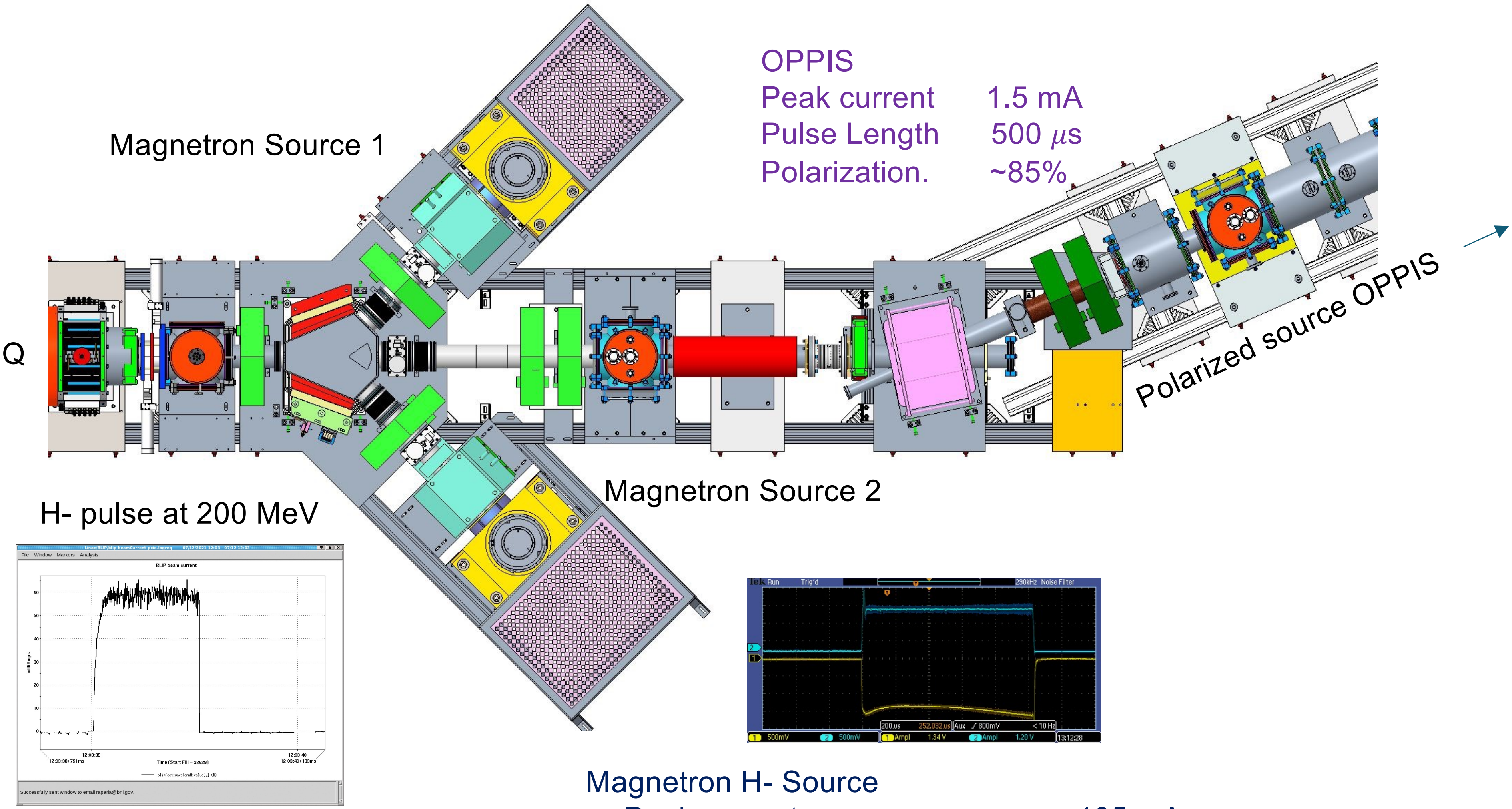
Two High Intensity Sources

OPPIS
Peak current 1.5 mA
Pulse Length 500 μs
Polarization. ~85%



H- pulse at 200 MeV

Magnetron H- Source

- Peak current 135 mA
- Pulse Length 1.1 ms
- Extraction 35 kV

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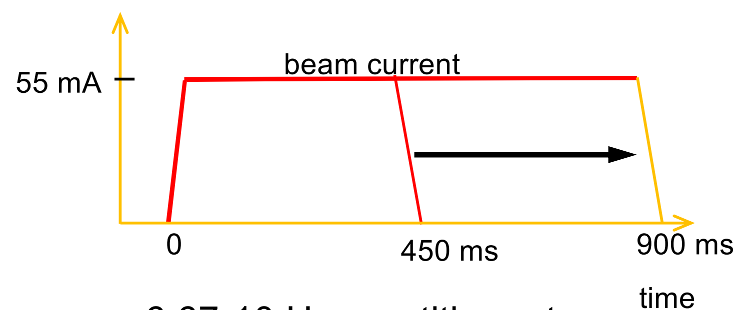
Linac Intensity Upgrade Phase II

Upgrade all hardware and controls to allow operation with
2x pulse length (increase from 450 to 900 μs); peak current and repetition rate unchanged

Project goal: increase average current to I_{avg} = 250 μA
(with potential for larger increase)

Upgrades to

1. RF system
2. Controls
3. Instrumentation
4. Pulsed quadrupoles PS
   Two prototypes' PS tested
5. Tanks #5 and #7 were
   tested with 1.1 ms RF



6.67-10 Hz repetition rate

Shovel Ready

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Proposed CCL

- 200 MeV: β=0.5662, γ=1.213, $\beta\gamma$=0.687
- 600 MeV: β=0.7944, γ=1.6395, $\beta\gamma$=1.2992
- E_{max} = 0.8 Kilpatrick (${E_{max}}$= 1.4 Kilpatrick*)
- 8 CCL Module (12 MW each)
- 4-8 section per module (3-7 Bridge couplers ; 3/2 $\beta\lambda$)
- 16 cells per section
- Total number of cell 48*16=768
- Two 16 cell buncher (200kW each)
- Total Length with Transition 120 meters
- 90 meter of tunnel length for future upgrade

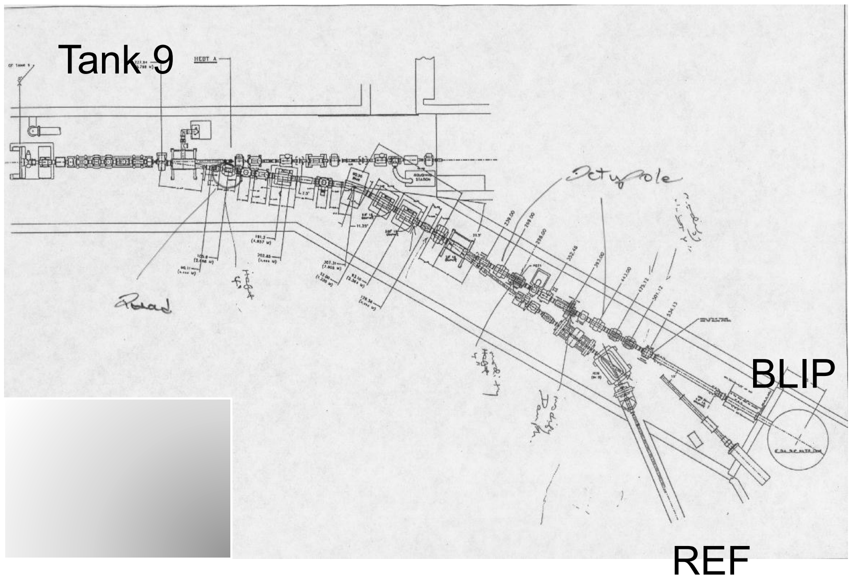
* Fermilab CCL, Nose not water cooled

CCL Comparison

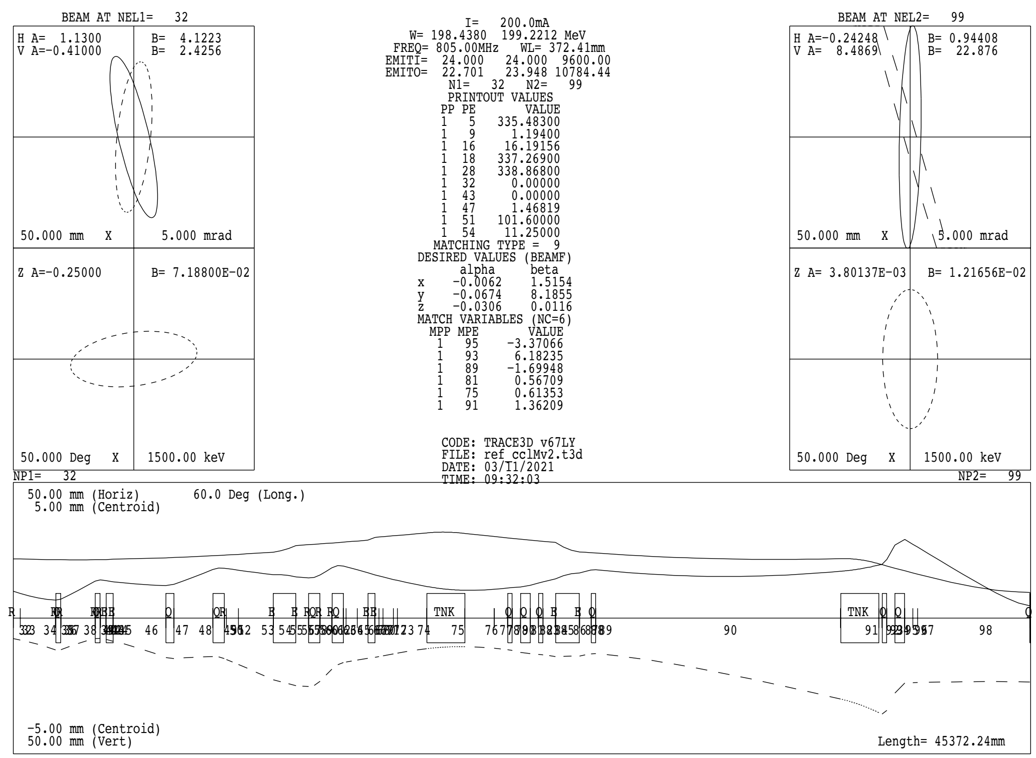
	BNL	LAMPF	FERMI	SNS	BNLII
Structure	DTL	CCL	CCL	CCL	CCL
Freq.	201.25	805	805	805	805
E in (MeV)	0.75	100	116	86.8	200.4
E out (MeV)	200.4	800	400	185.6	608
E_0T (MV/m)	1.4-1.0	1.4-1.3	6.8-6.1	2.1-2.0	4.4*
Length (m)	145	731	64	55.1	~121
Pulse Len (μs)	500	1000	60	1000	1000
Spark Rate			<0.1%		
ΔE (RS) (MeV/m)	1.37	0.96	4.4	1.8	3.4

* 0.8 Kilpatrick

Tank 9 to RFF, TRACE3D

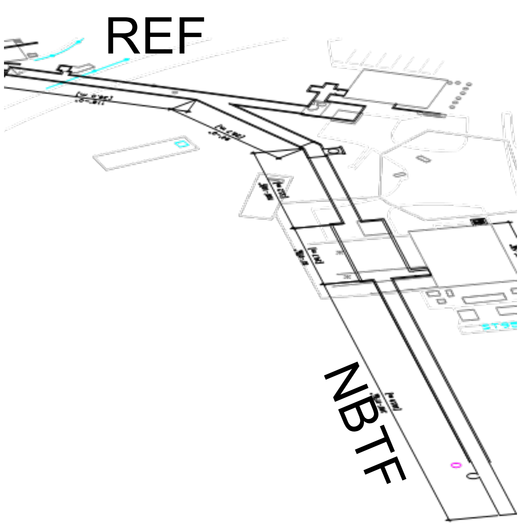


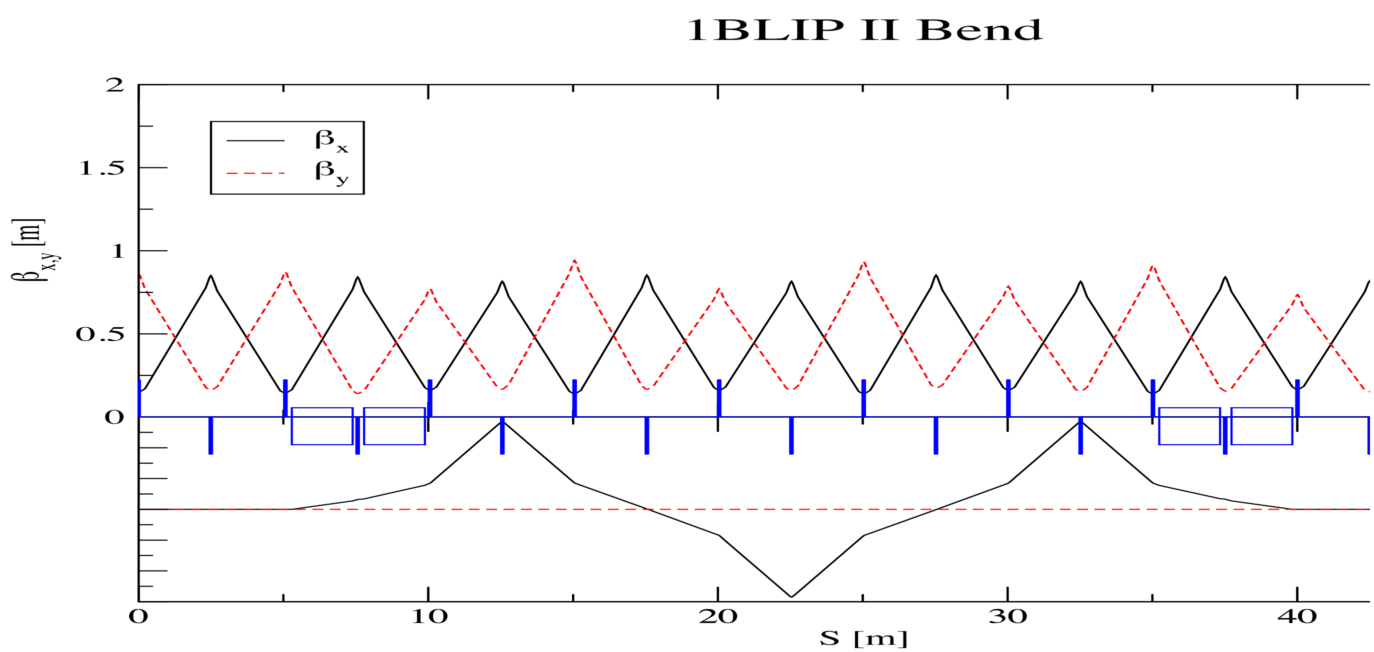
TRACE3D SIMULATIONS



REF To BNTF Tunnel

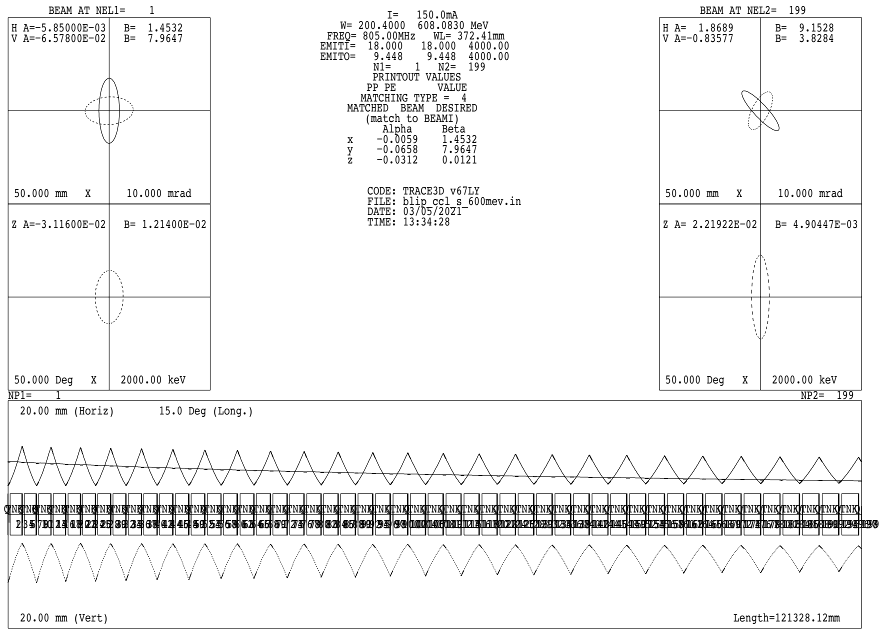
- Length between wo 30-degress bend 29 m
- Six 90-degrees FODO cells, canceling dispersion
- Maximum beam size 15 mm. aperture 30 mm
- In dipole Lorenz stripping looses < 1e-10
- 10 accelerating section in two module



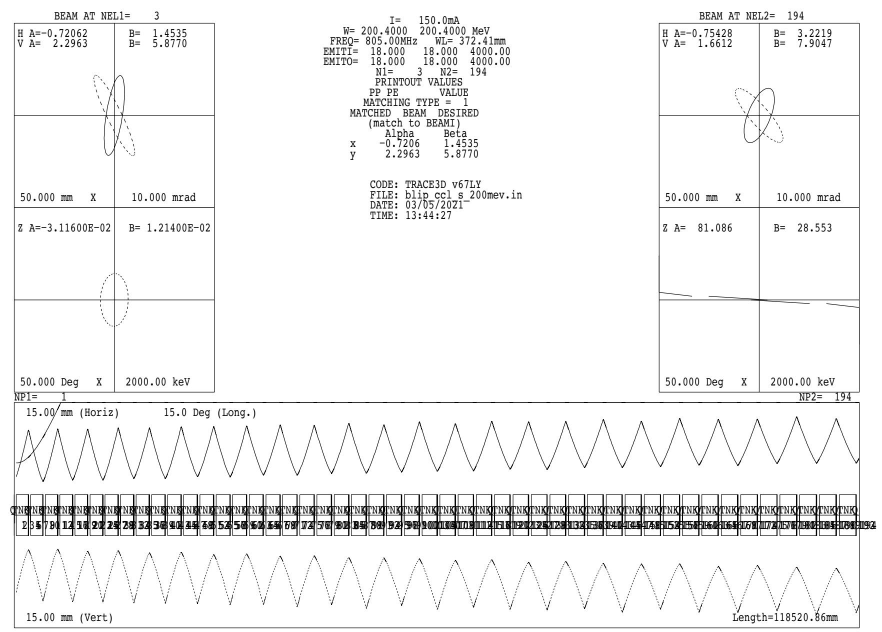


TRACE3D simulation 200 to 600 MeV

Accelerated to 600 MeV



200 MeV beam drifting through CCL



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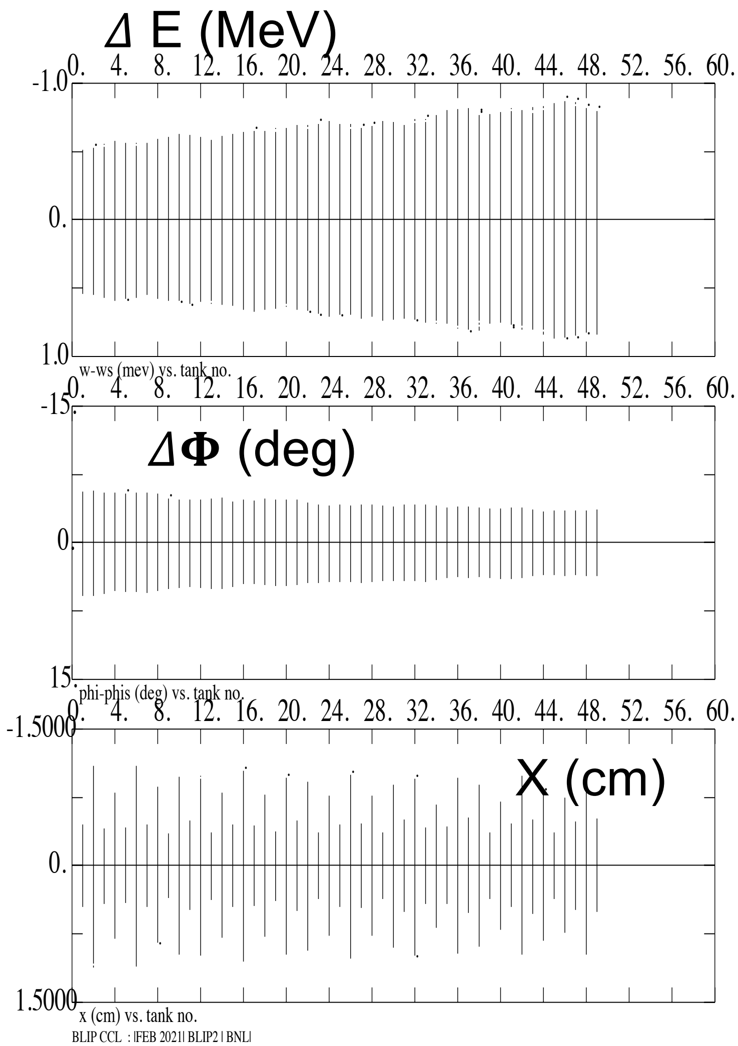
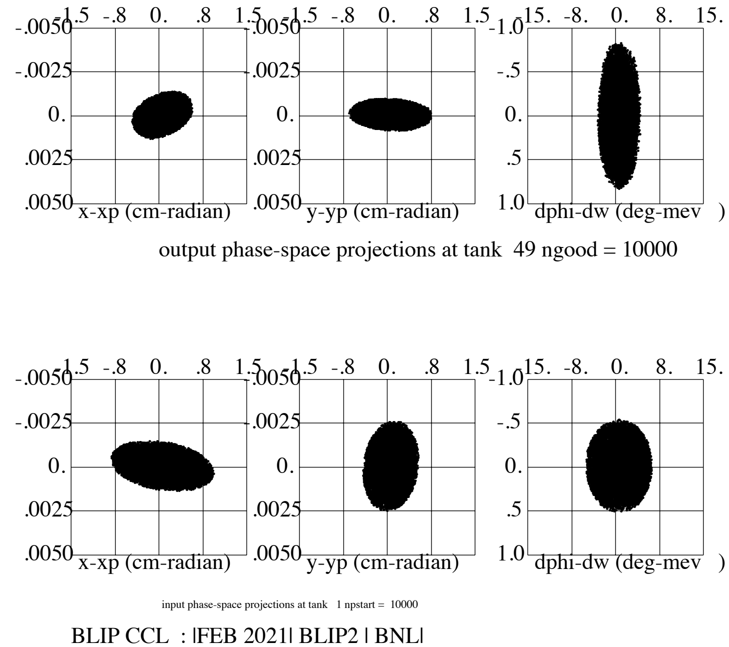
CCLDYN simulations , 10k particle, no losses , less than 10% emittance growth





Light Ion Linac

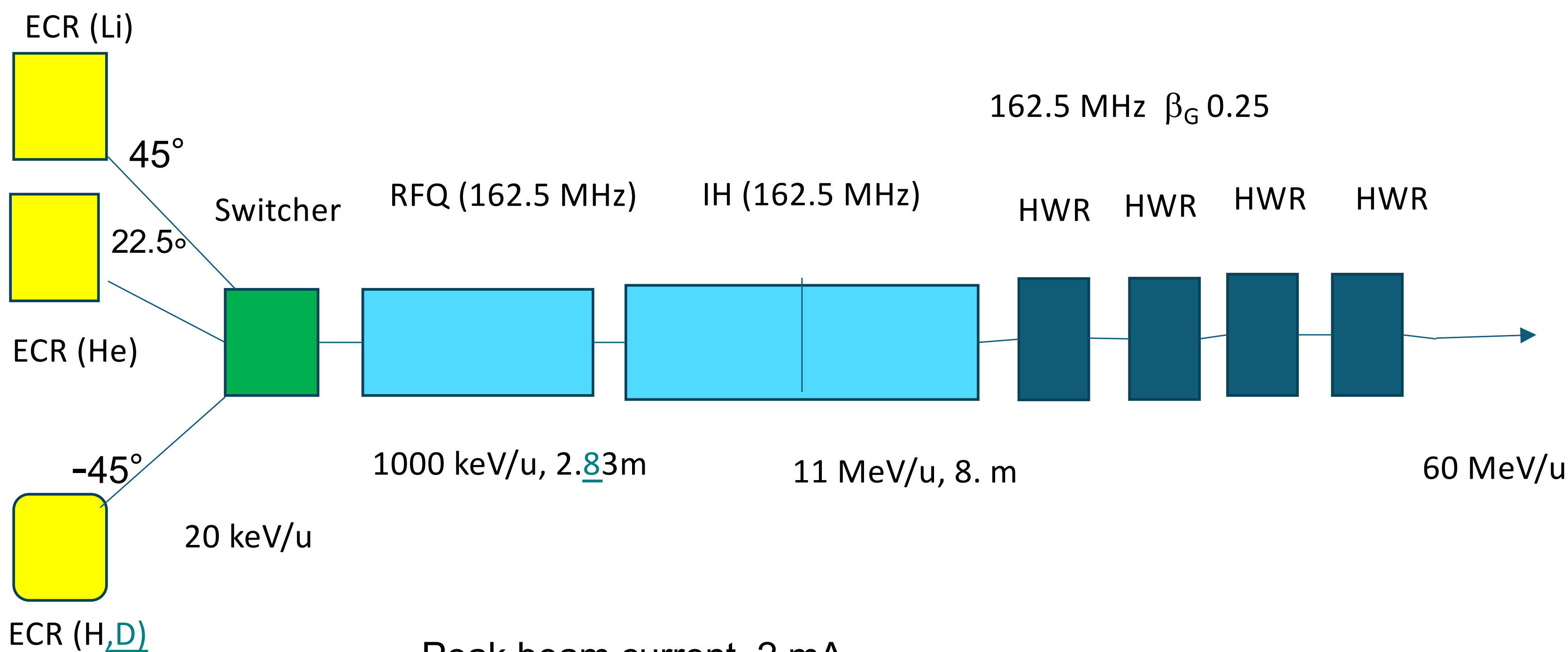
Light Ion Linac

Options

- Room temperature , Superconducting , or combinations
  - Wide range of experience with RT RFQ and IH up to several MeV/u
  - Higher energy, superconducting linac
  - Transition energy RT to SC (depends on peak current, Space charge)
- Pulse or CW
  - Limited experience with RT CW operation
- Higher current ion source for light ions (Laser, EBIS, ECR)

What is riskier, high peak current IS (Li) or CW RFQ (RT) ?

Proposed Design for Light Ion Linac



Peak beam current 2 mA
Beam pulse length 1 ms
Repetition rate 100 Hz

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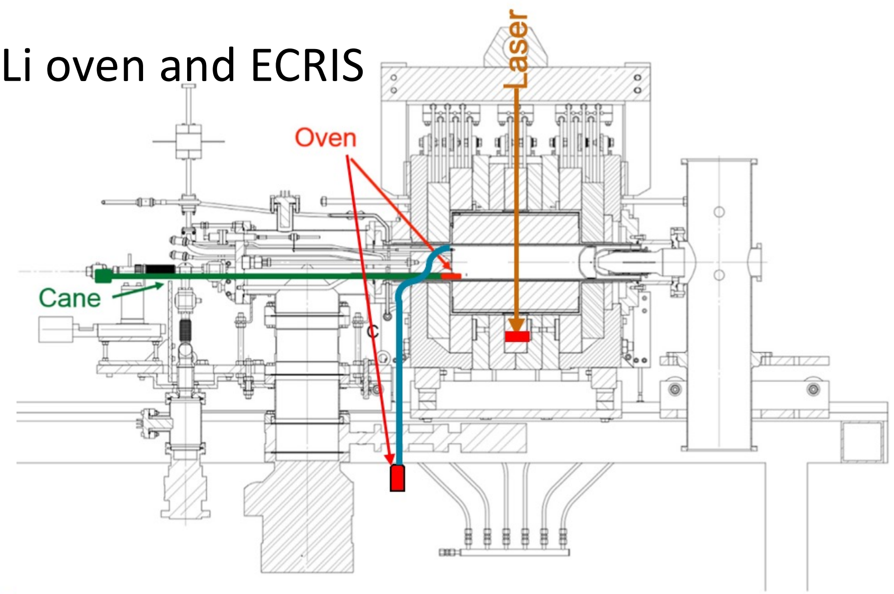
Ion Sources and LEBT (20 keV/u)

ECR sources could be used for the light ions

IONS	source	Frequency	current	Emittance
H, D	ECR	2.5 GHz	2 mA	<1 pi mm mr
He, Li	ECR	14-18 GHz	2 mA	<1 pi mm mr

Li oven and ECRIS



LEBT

-Magnetic switchyard to inject the beam from either source into the RFQ.

-To provide mass to charge separation big angles (-45º, +22.5º, and +45º) to RFQ

- Adjustable water-cooled slits all three lines expected total power several hundred Watts

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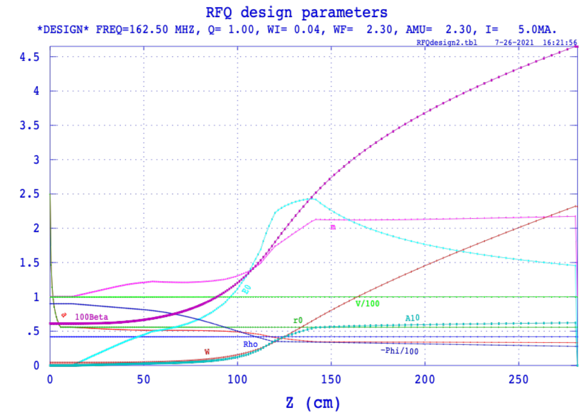
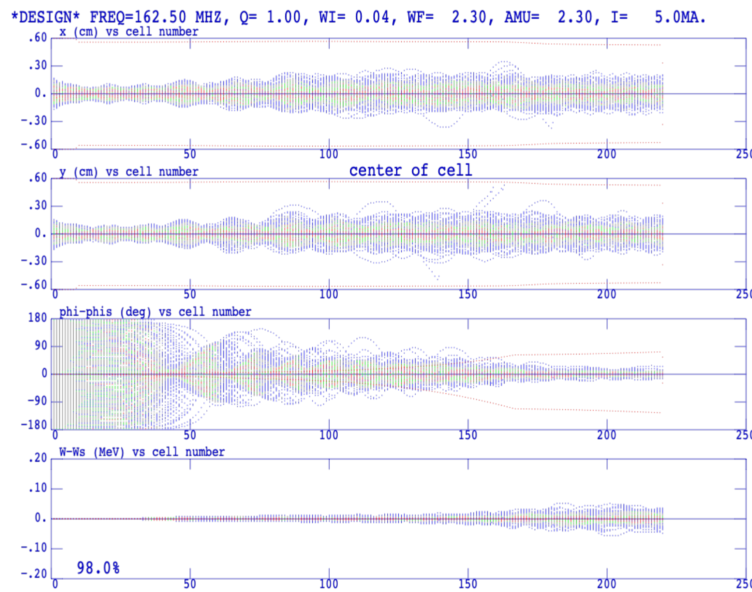
RFQ: 1 MeV/u

Parameters		
ions	<2.3	M/Q
Frequency	162.5	MHz
Ein	20	keV/u
Eout	1000	keV/u
Length	2.82	m
Ave. Radius	5.6	mm
Vane Voltage	90	kV
power	~ 180	kW
Transmission	98	%
current	5	mA
emittance	0.7	Π mm mr

RFQ parameters



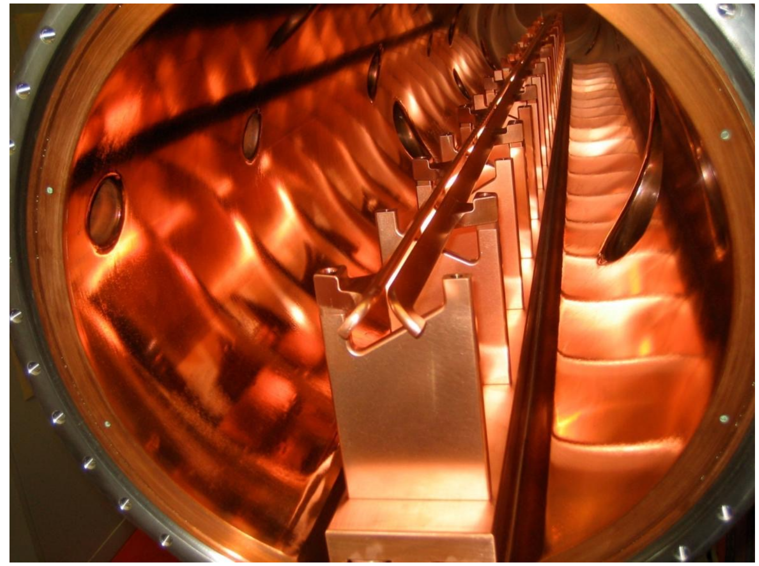
PARMTEQM simulation for Li^{+++}



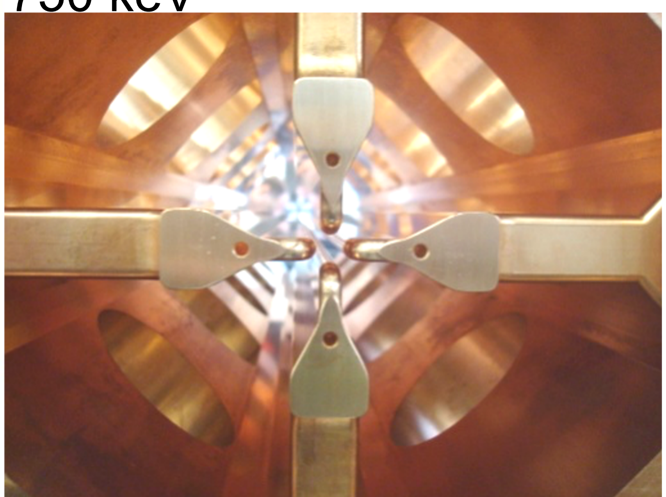
RFQs

BNL Polarized RFQ 200 MHz
750 keV

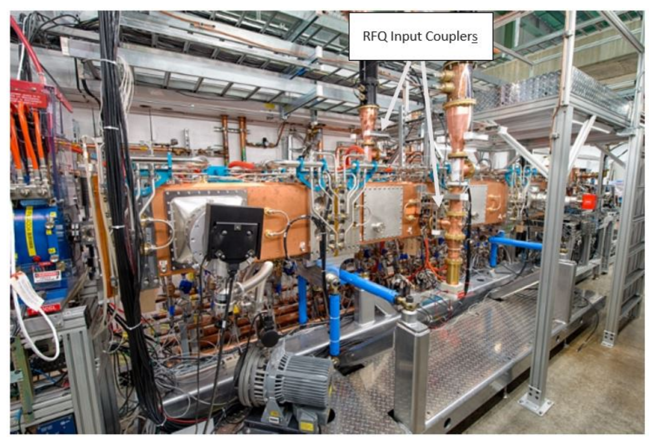
BNL EBIS RFQ 100 MHz, 300 keV/u, M/Q ~ 6



BNL high intensity RFQ 200 MHz
750 keV

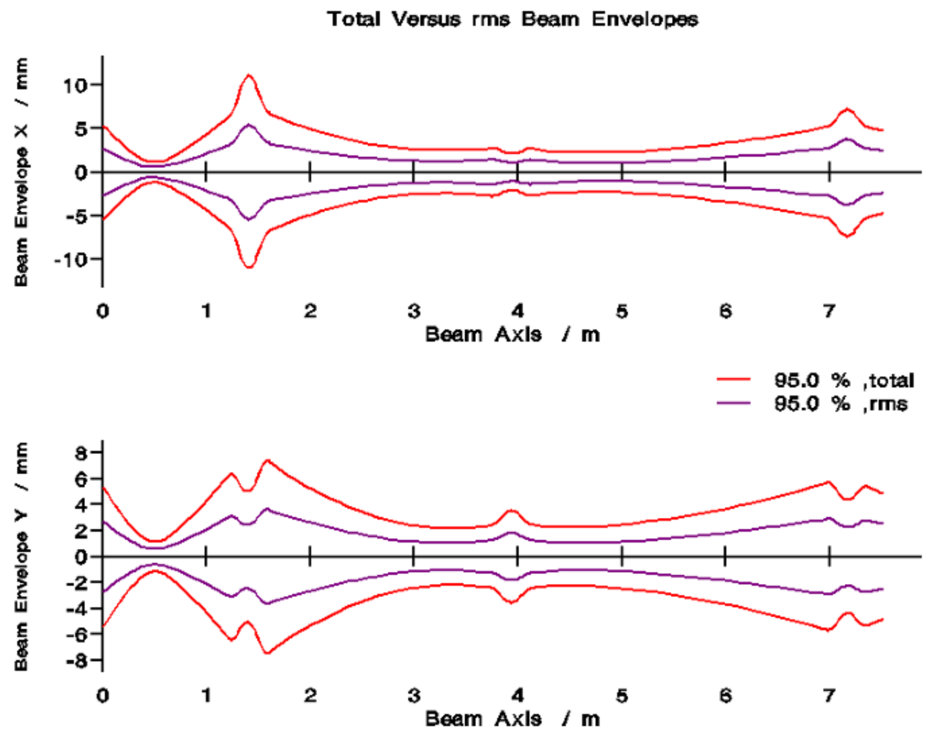


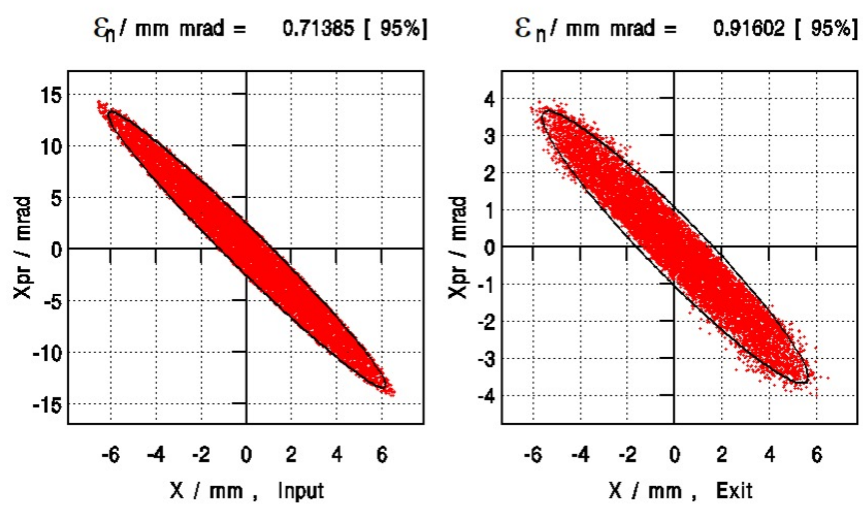
PIP IT RFQ 162.5 MHz, 2.1 MeV



IH Linac: 11 MeV/u

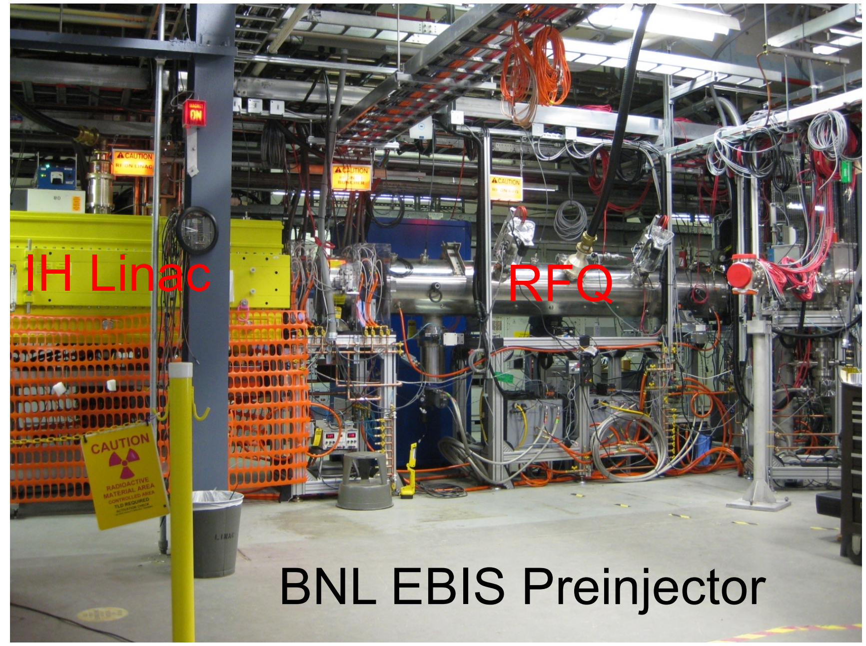
Paramweter	Values	Units
Ions	<2.3	M/Q
Ein	1	MeV/u
Eout	10.8	MeV/u
Section	2	
# of Gap	63	
Length	7.8	m
Power	~1.5	MW
Transmission	100	%
Emittance	0.9	Π mm mr





IH Linac at BNL

BNL EBIS IH Linac



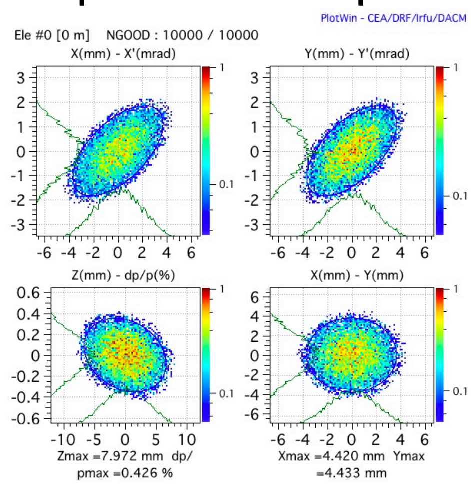
Ion	D-U
Q/M	.16-0.5
Energy	2 MeV/u
Current	1.5 emA
Pulse Length Rep. Rate	10 μs 5 Hz
Emittance	0.7 π mm rad (nor, 90%)
Energy Spread	1.8 keV/amu

SC Sections

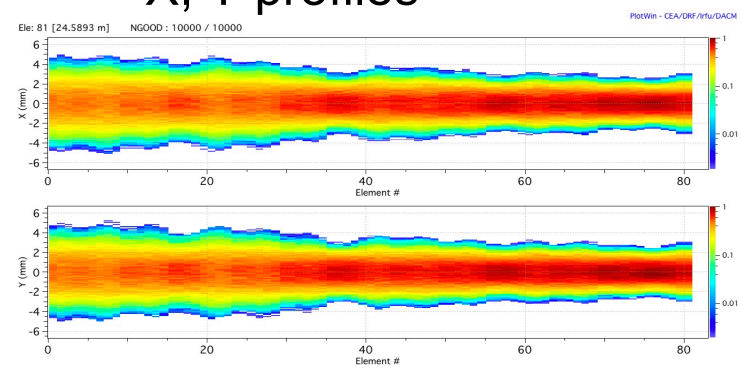
TraceWin Simulation

Parameters	Value
E in	10.8 MeV/u
E Out	60 MeV/u
Cryomodule	4
Cavity /(CM)	6
Solenoid/(CM)	3
Cavity type	HWR
β_G	0.25
Eacc	10.5MV/m
Length	25 m

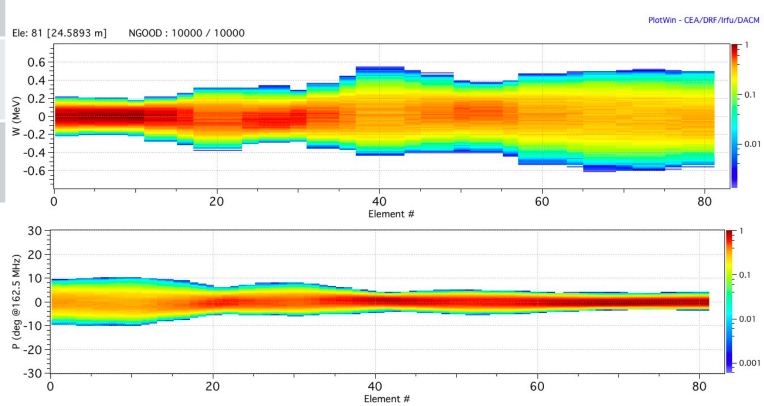
Input Phase Spaces



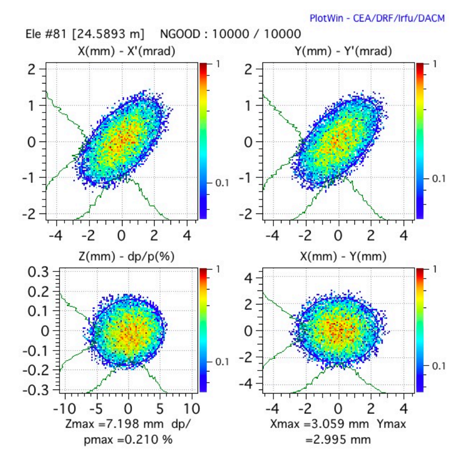
X, Y profiles



ΔE and Φ Profiles



Output Phase Spaces



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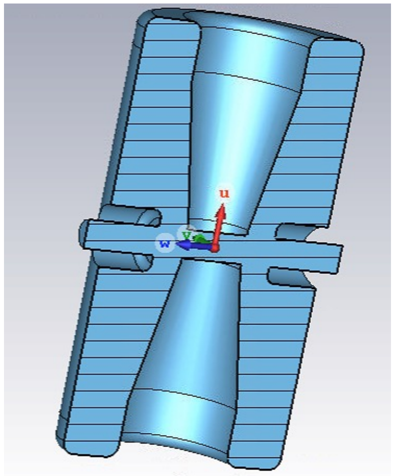
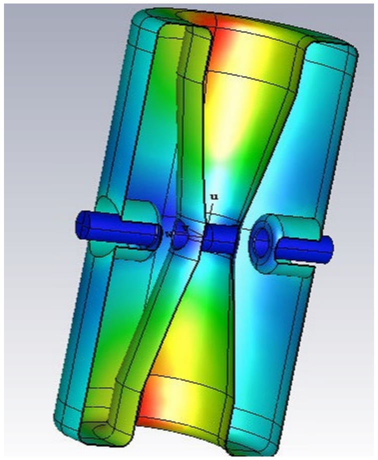
HWR Cavity

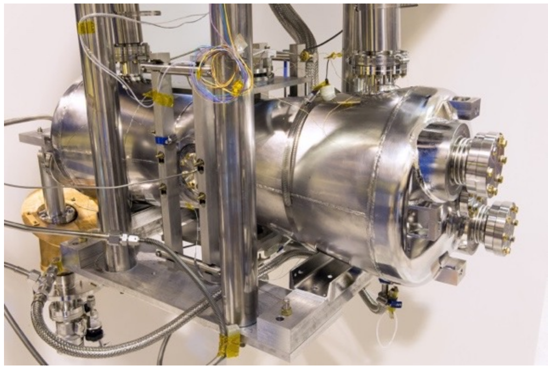
Parameter	HWR	UNITS
Frequency	162.5	MHz
b_G	0.25	
Length bl	0.46155	m
E_{acc}	14.8	MV/m
Phase	-20	deg
E_{Peak}	68	MV/m
B_{Peak}	72.5	mT
E_{peak}/E_{acc}	4.9	
B_{peak}/E_{acc}	6.9	
R/Q	256	Ohm
		Ohm
# of cavities	24	

HWR Design

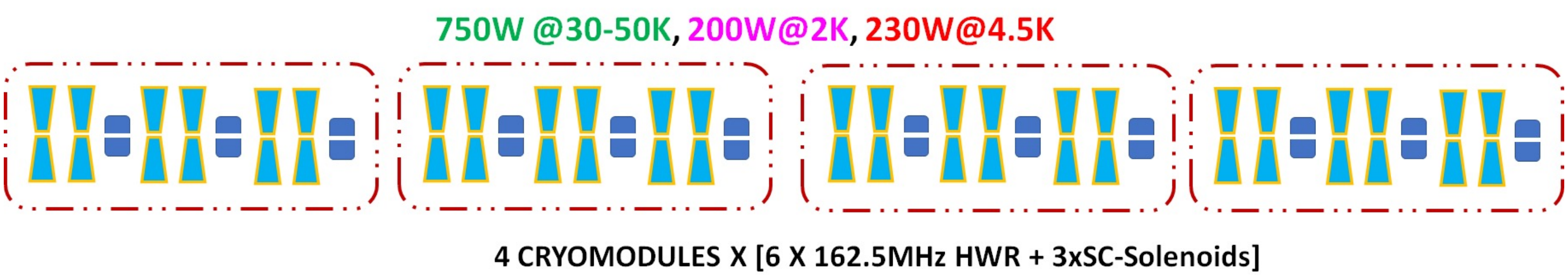




PIP II 162.5 MHz HWR



Cryomodule



Cryogenic Load Requirements

	2K	4.5K	30-50K	LN2 Shield
	W	W	W	W
SRF modules	200	230	750	
Cryo-Distribution		50	50	1000
Total	200	280	800	1000

Summary

- Protons
- Protons 200 to 600 MeV, max beam power 120 kW
- Will use existing linac as injector,
- Based on Fermilab CCL design at lower Kilpatrick
- Use existing tunnel, new RF gallery
- A 90 m tunnel available for future upgrades
- Since linac can change user 100 ms , will satisfy existing user (RHIC, NSTL, BLIP)
- Light ions
- Light ions 60 MeV/u (m/q ~ 2.3), max beam power 84 kW
- Use existing technologies
- New tunnel and RF gallery