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Initial Conceptual Document 2 (ICD-2)
For a High Intensity Proton Source
@ Fermilab
"Project X"

Ralph J. Pasquinelli

Accelerator Division

Fermilab

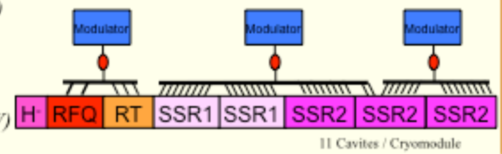
Project X
1000 kW 8GeV Linac

31 Klystrons (2 types)
453 SC Cavities
57 Cryomodules

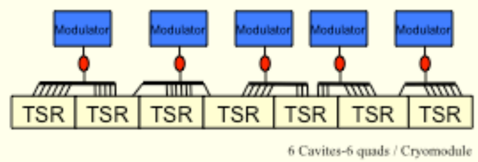
Front End Linac

325 MHz 0-10 MeV
1 Klystron (JPARC 2.5 MW)
RFQ + 18 RT Cavities

325 MHz 10-120 MeV
2 Klystrons (JPARC 2.5 MW)
51 Single Spoke Resonators
5 Cryomodules



325 MHz 0.12-0.42 GeV
5 Klystrons (JPARC 2.5 MW)
42 Triple Spoke Resonators
7 Cryomodules



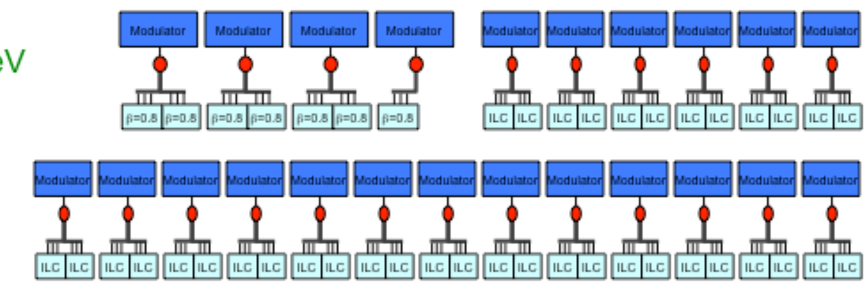
2.5 MW JPARC Klystron

Multi-Cavity Fanout
Phase and Amplitude Control

1300 MHz LINAC

1300 MHz 0.42-1.3 GeV
4 Klystrons (ILC 10 MW MBK)
56 Squeezed Cavities (β=0.81)
7 Cryomodules

1300 MHz 1.3-8.0 GeV
19 Klystrons (ILC 10 MW MBK)
304 ILC-identical Cavities
38 ILC-like Cryomodules



ILC … not any time soon…

William Brinkman, who took over the $4.9 billion science office (DOE) in late June (2009), also had some harsh words for advocates of the International Linear Collider, a 30-kilometer-long straight-shot particle smasher that would study in detail the new particles and phenomena physicists hope to glimpse at the LHC. "With all the contingencies, you're talking about $20 billion. In my opinion, that price pushes it way out into the future, and onto the backburner."

DOE Policy for Projects Exceeding $750M

ICD-1 cost estimate exceeds this value by a factor of 2.

DOE requires an alternative design (ACD) be submitted and reviewed.

ICD-1 physics program concentrates mostly on neutrino program, the ACD could augment the experimental program.

An ACD was devised and reviewed in Aspen summer 2009. It gained significant support over ICD-1 and it was suggested it not be presented as an alternative but renamed ICD-2.

Physics Experimental Program

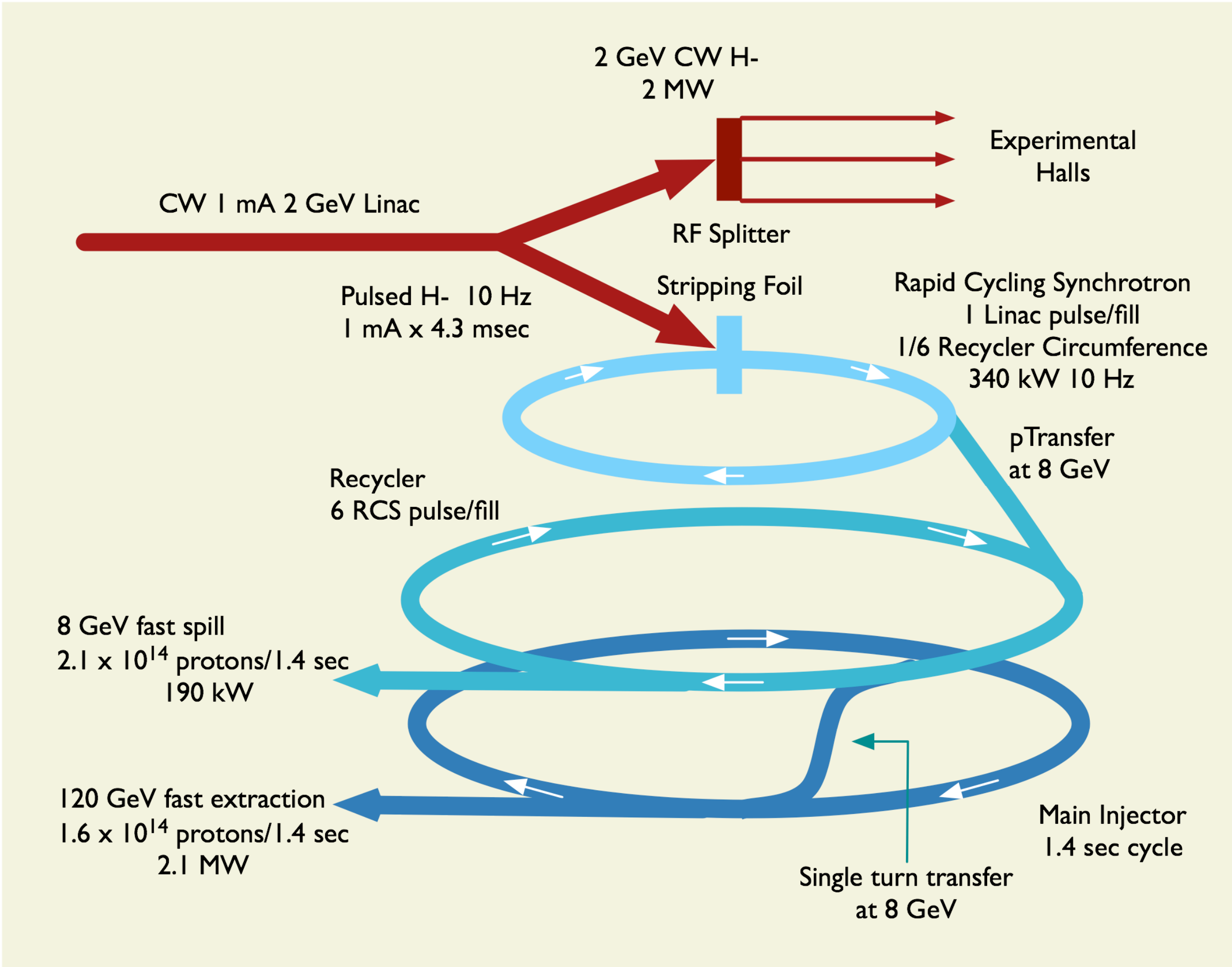
ICD-1:

neutrino program to 2 Mwatt at 120 GeV
Mu2e 150 Kwatt at 8 GeV
Upgradeable to higher power for Muon experiments
Slow spill not easily implemented

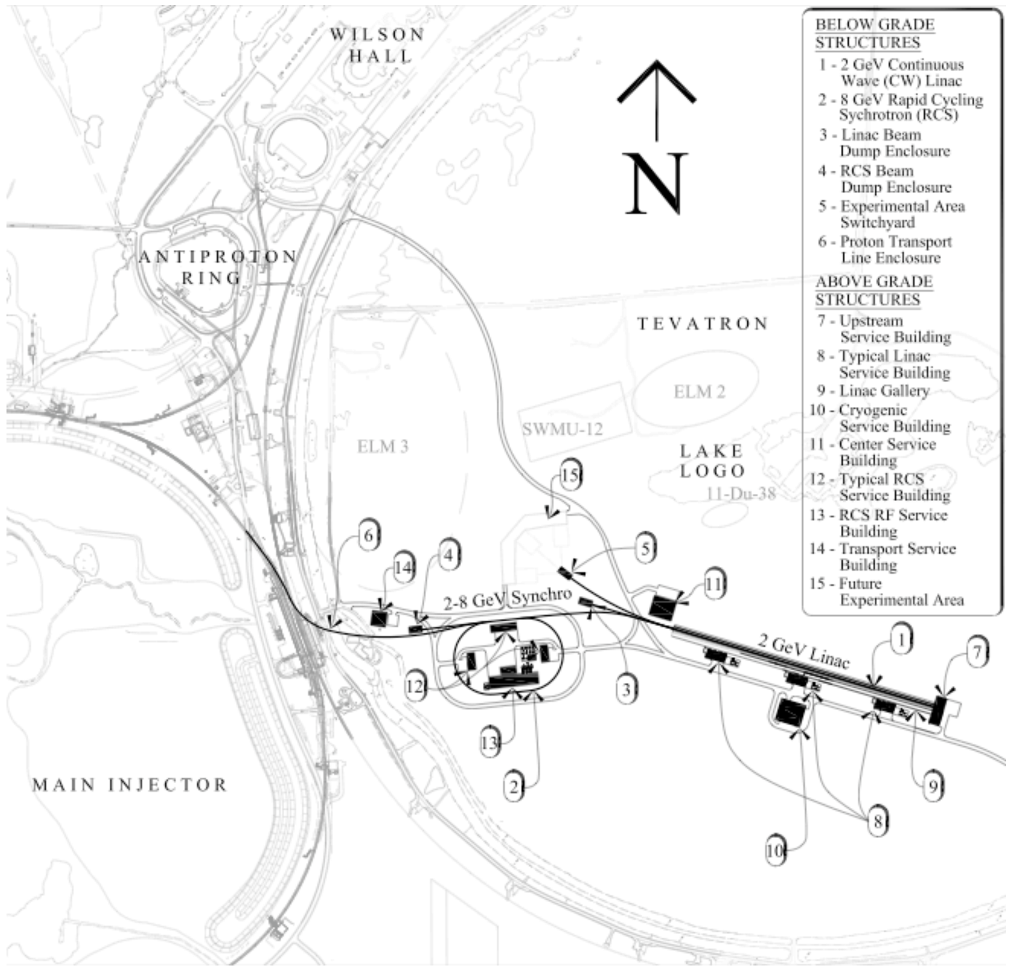
ICD-2:

neutrino program to 2 Mwatt at 120 GeV
Mu2e up to to 1 Mwatt at 2 GeV
Rare Kaon experiments 0.5 Mwatt at 2 GeV
Other experiments to 0.5 Mwatt at 2 GeV
190 Kwatt available at 8 GeV
Upgradeable to higher power for Muon Experiments
Desirable slow/continuous spill capabilities

Fermilab Schematic Layout of ICD-2

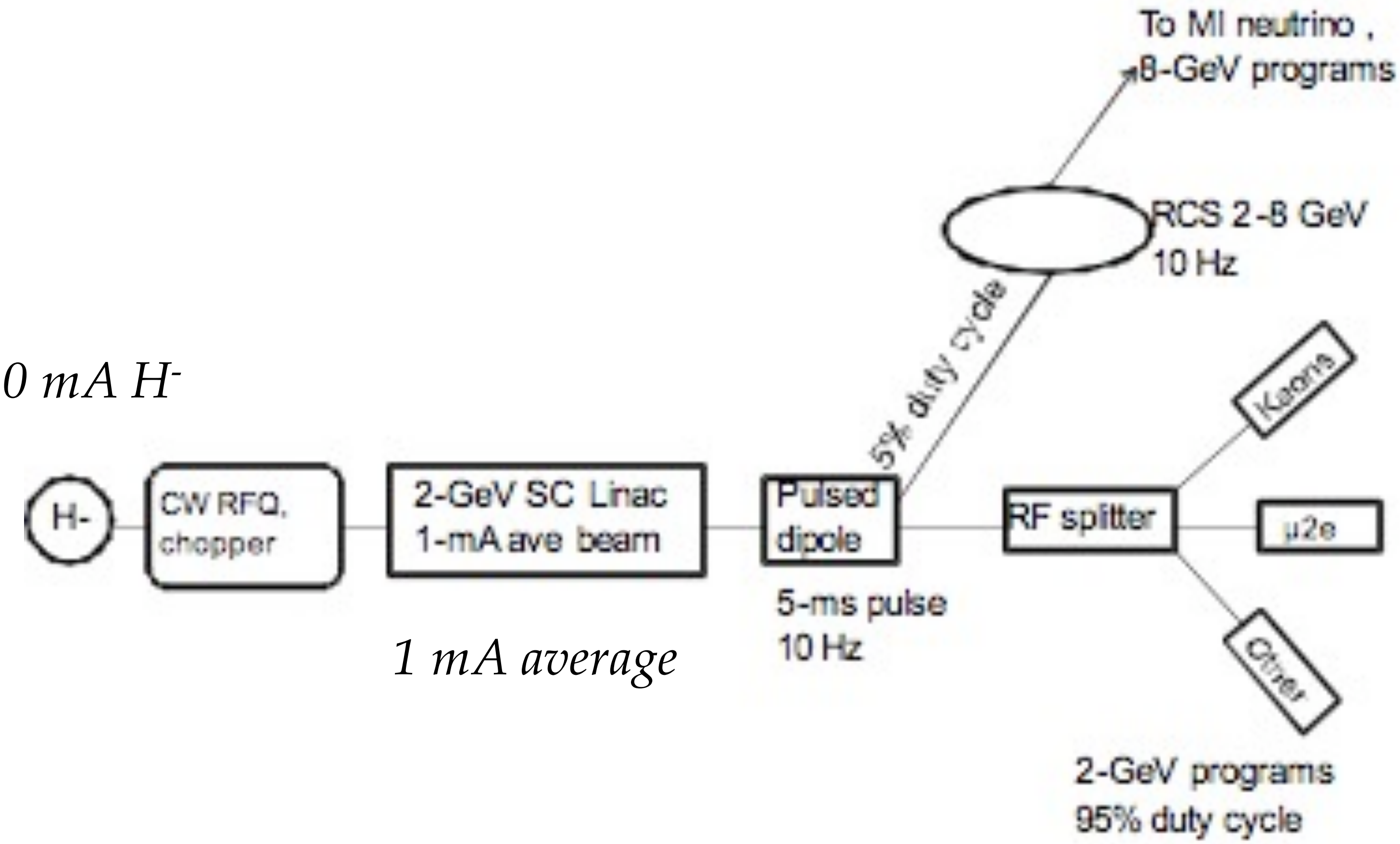


ICD-2 Site Plan



Fermilab ICD-2 Accelerator Complex

10 mA H$^-$



1 mA average

Performance Goals for Project X Accelerator Facility

Req. No.	Description	Req.	Unit
1.0	**General**		
1.1	MI Beam Power	2	MW
1.2	Linac Beam Power	2	MW
1.3	RCS Beam Power	0.34	MW
1.4	Available (outside of MI) 8 GeV Beam Power	60	kW
1.5	MI Availability	80	%
1.6	8 GeV Availability	85	%
1.7	2 GeV Availability	90	%

Fermilab RFQ Parameters

	CRITS	KOMAC	LEDA	IUCF	Proj-X 162	Proj-X 325	
Frequency	267	350	350	213	162.5	325	MHz
Injection Energy	50	50	75	20	35	30	keV
Output Energy	1270	3000	6700	700	2500	2500	keV
Current	86	23	110	1	10	10	mA
Length	147	324	800	118	385	287	cm
Length/Lambda	1.3	3.8	9.3	0.8	2.1	3.1	
Vane-Vane Voltage	78	100	102	35	90.8	64.2	kV
Peak E-field	28.8	33.1	33.6	13.8	20.7	27.6	MV/m
E-field/Kilpatrick	1.75	1.8	1.83	0.91	1.52	1.55	
Cavity Power	159	350*/417	1200	8.4*/12	155*	149*	kW
Power/Length	107	108	150	7.1	40	52	kW/m
Avg Wall Power Density	4.6	13	11.4	0.7	2.1	5.2	W/cm²
Max Wall Power Density	116.7		65				W/cm²
r_0 (transverse vane tip radius)				0.31	0.61	0.31	cm
minimum longitudinal radius				0.52	1.2	0.69	cm
Output rms Momentum Spread					0.15	0.15	percent
Output Longitudinal Emittance		0.246	0.174	0.024	0.056	0.046	MeV-Degree
Output Transverse Emittance		0.023	0.022	0.010	0.031	0.028	cm-mrad
Transmission			90	85	94	90	percent

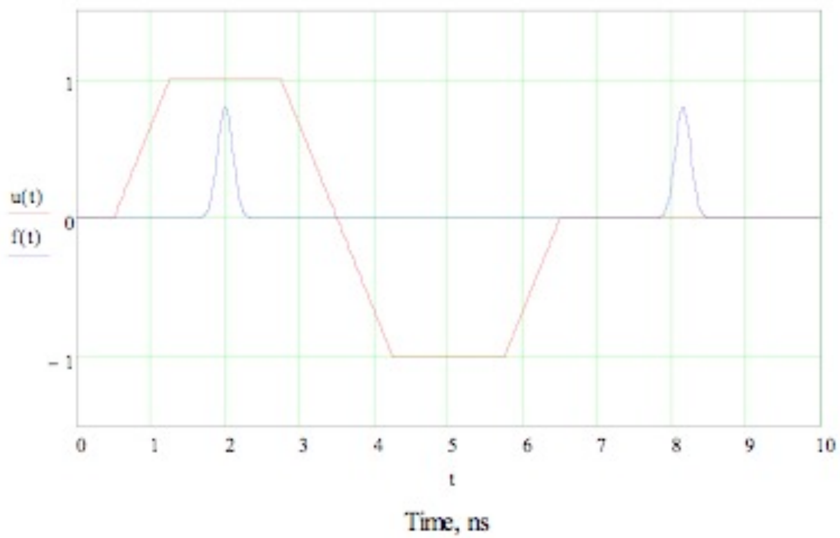
*=Calculated
Thanks: Dale Schrage for CRITS, LEDA

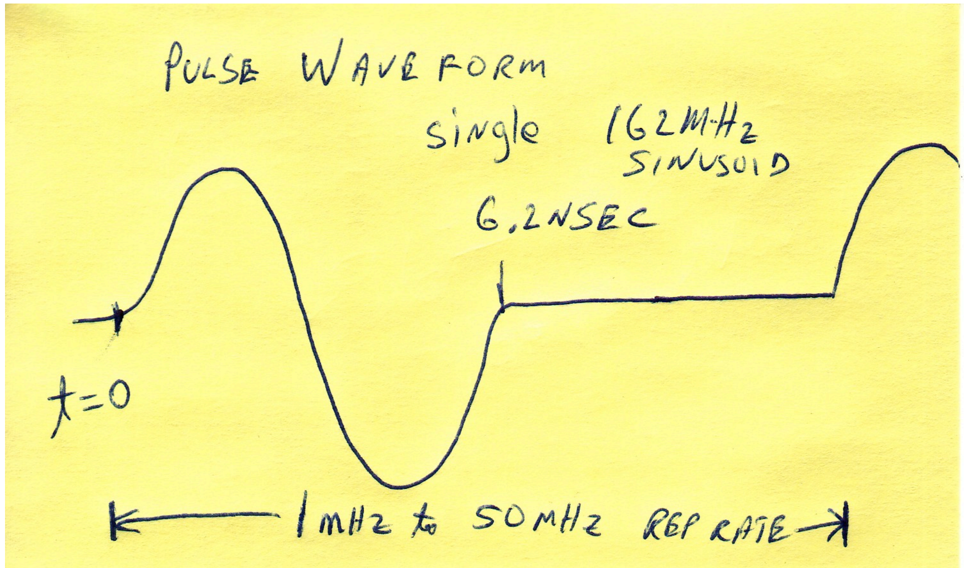
162.5 MHz RFQ Parameters

Section	ε_{rms} norm, mm-mrad	Energy, MeV	β_{out}	Type of cavities	Power/cavity, kW (I_{av}=1 mA)
RFQ	0.25	2.5	0.073	CW, Room Temperature	350-450

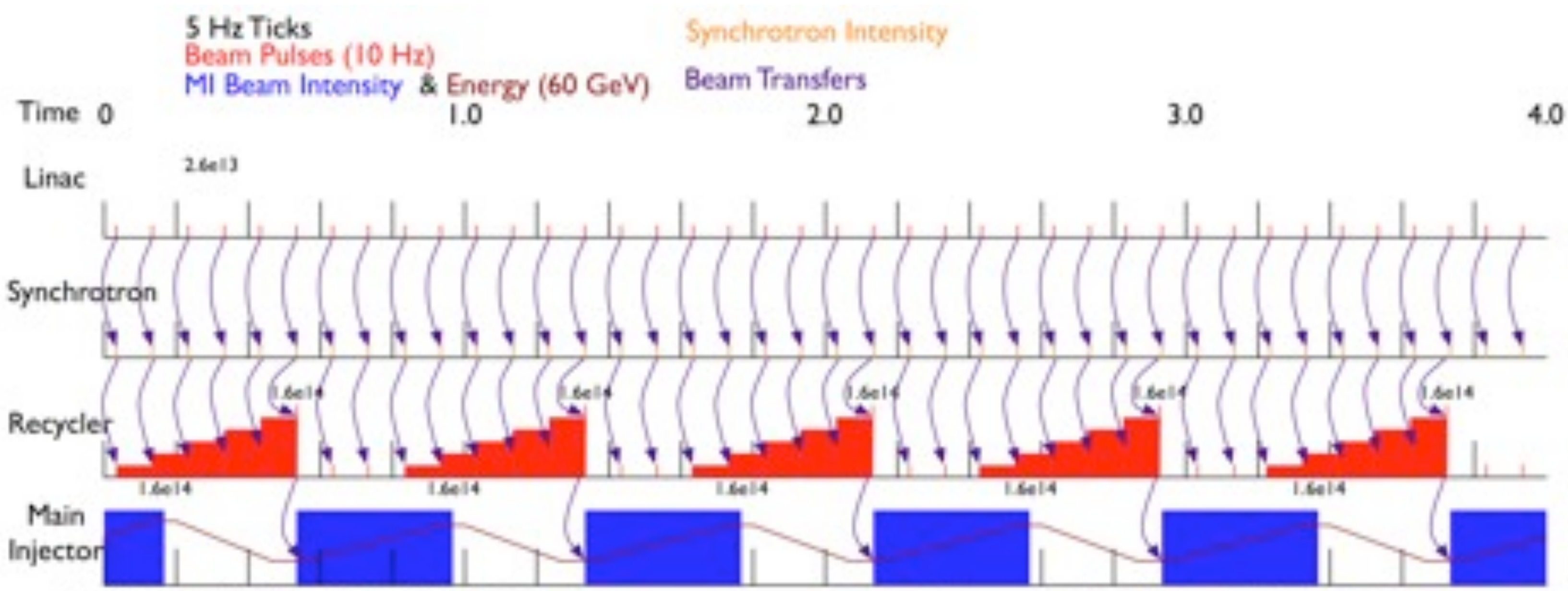
Fast Chopper Waveform

Fast rise/fall time allows for arbitrary bunch trains from 162.5 MHz Source





Fermilab *Beam Duty Cycle to Main Injector*

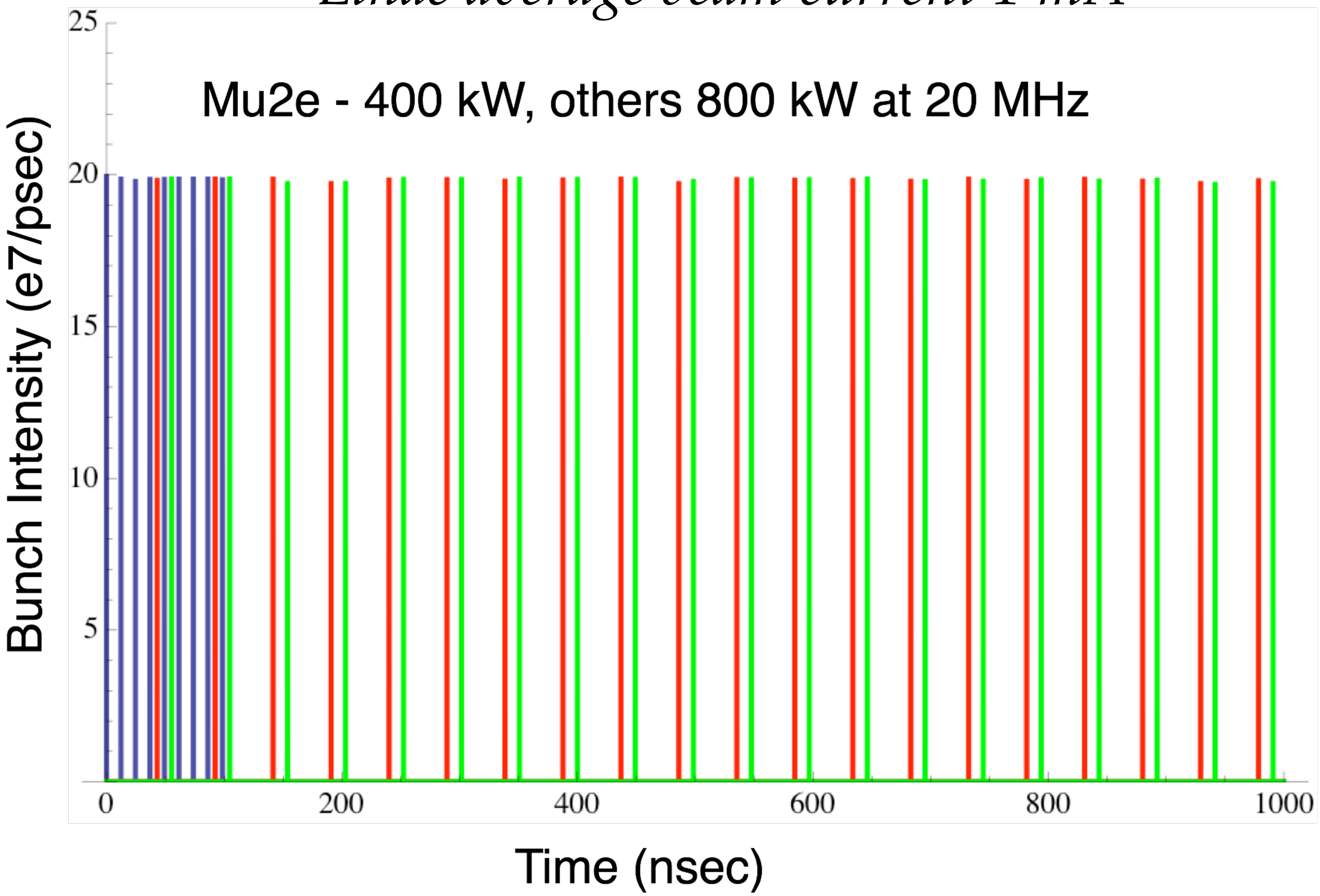


Beam Chopping for RCS

An example of the bunch chopping pattern for the RCS injection. The bunch repetition rate is 162.5 MHz (red), while the RCS RF cavity voltage frequency is 50.33 MHz (blue). Bunches outside of the ±7.3-ns long gate (black) are to be removed by the chopper.

Pulse Structure for 1 usec in Linac

Linac average beam current 1 mA



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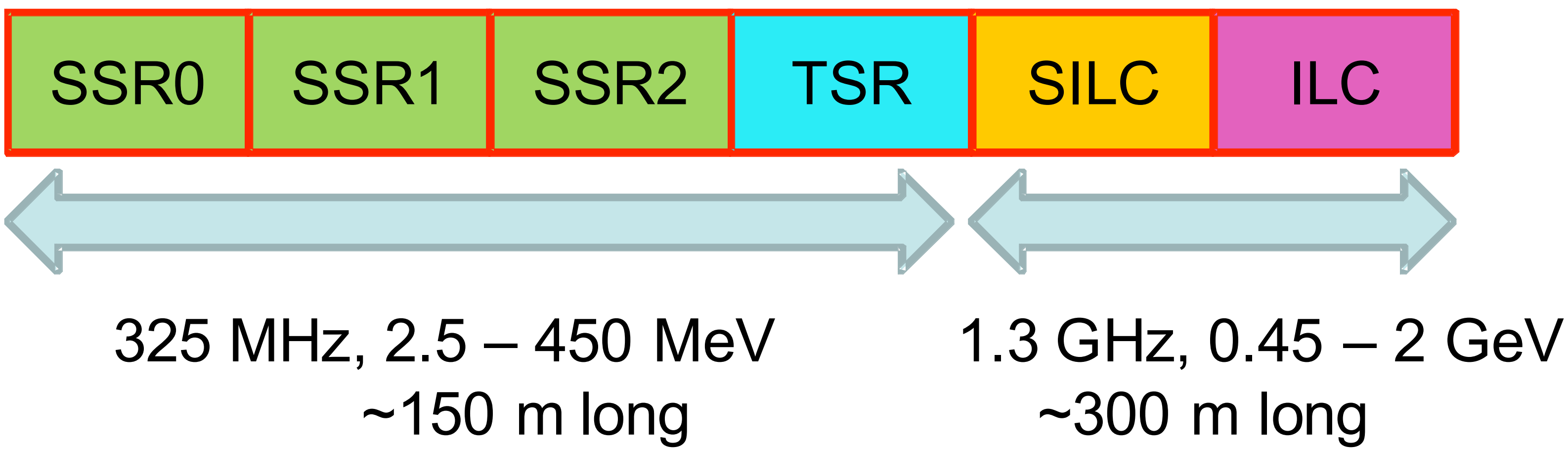
Schematic of CW Linac 2.5 MeV to 2 GeV

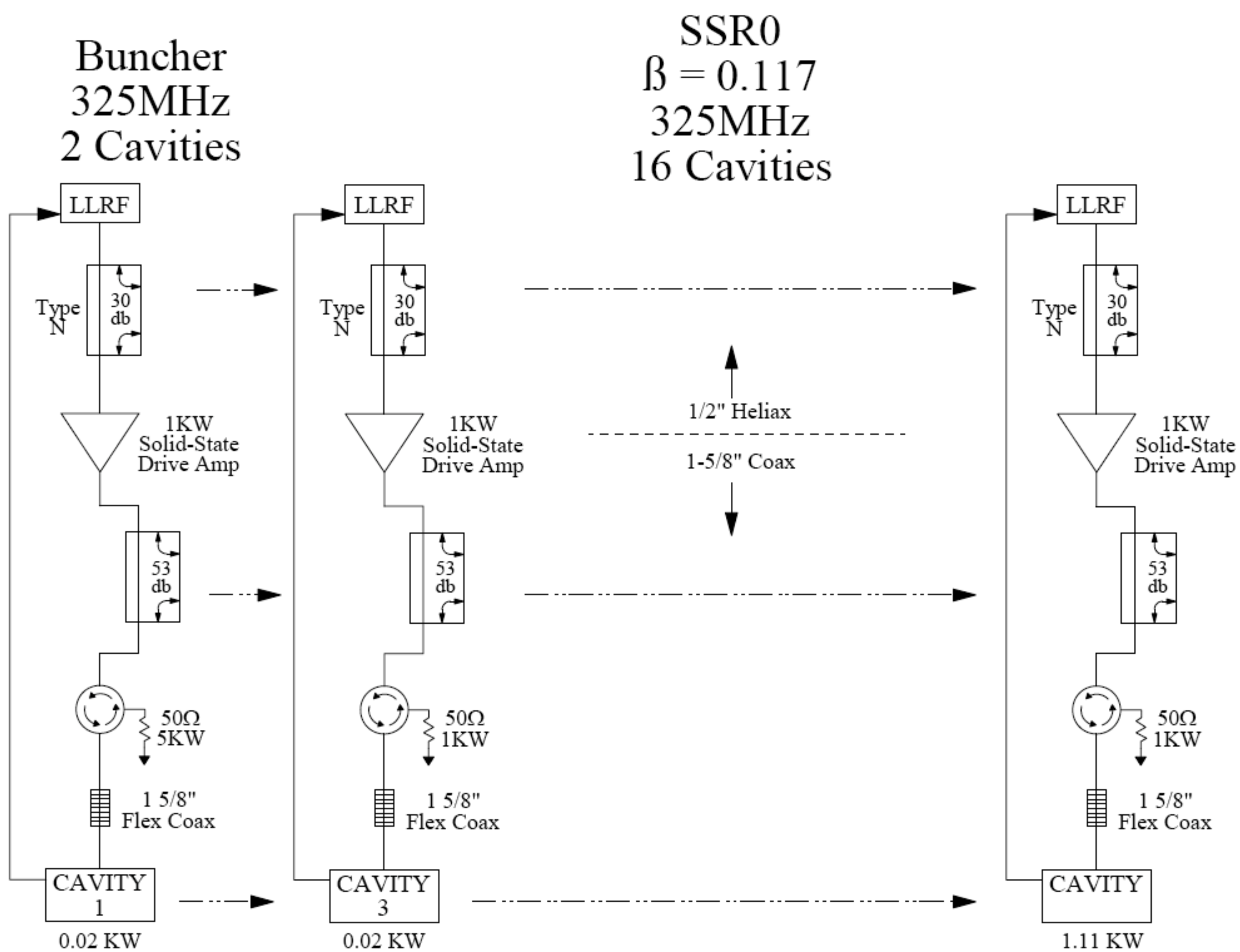


Break Points 325 MHz Linac
β_G is Cavity Geometrical Phase Velocity
Total of 117 Cavities in 17 Cryomodules

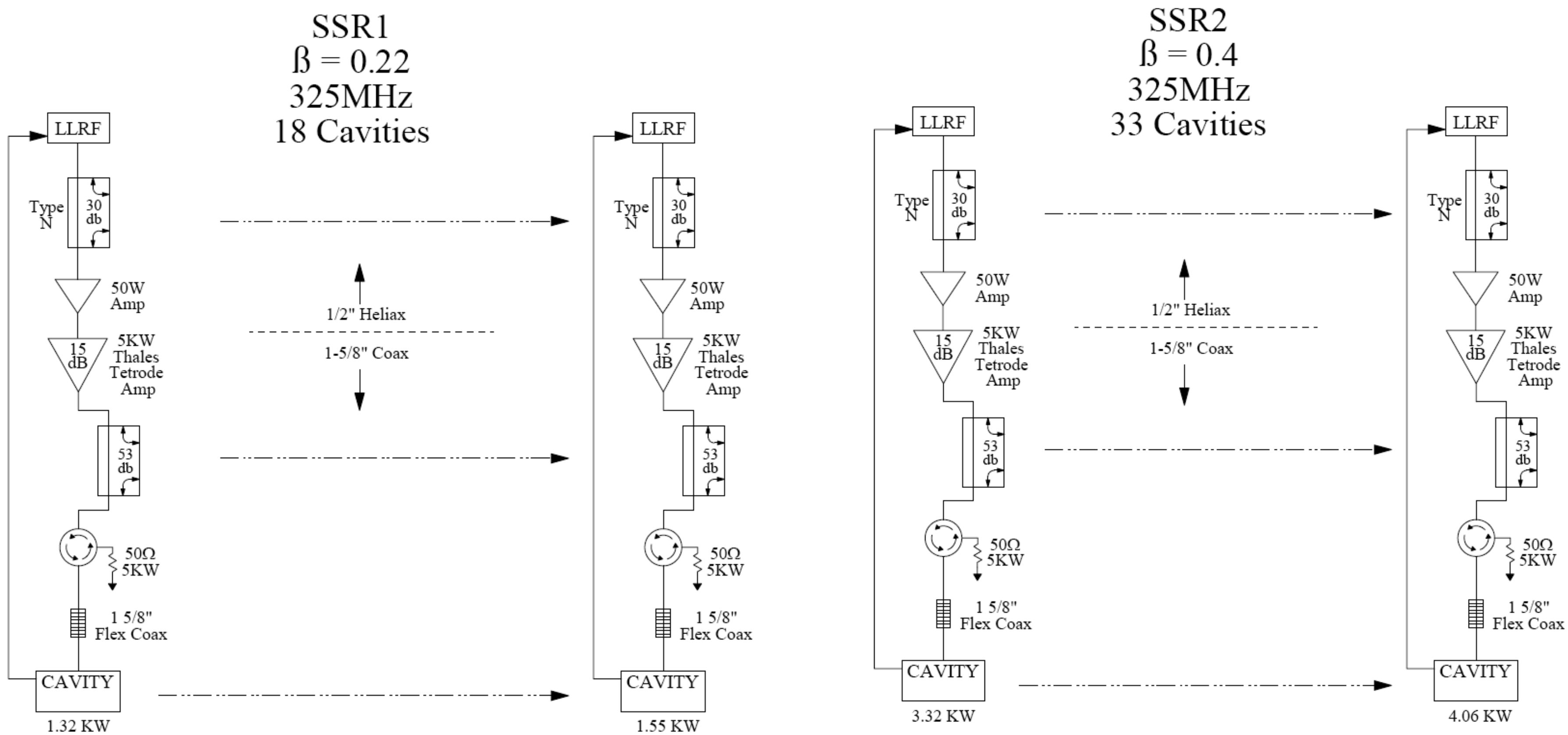
Section	Energy range MeV	β	Number of cavities/ lenses/CM	Type of cavities and focusing element	Power/cavity , kW (I_{av}=1 mA)
Bunching SSR0 (β_G=0.11)	2.5	0.073	2/3/2	Single spoke cavity, Solenoid	0.5
SSR0 (β_G=0.11)	2.5-10	0.073-0.146	16/16/2	Single spoke cavity, Solenoid	0.5
SSR1 (β_G=0.22)	10-32	0.146-0.261	18/18/2	Single spoke cavity, Solenoid	1.3
SSR2 (β_G=0.4)	32-117	0.261-0.5	33/17/3	Single spoke cavity, Solenoid	4.1
TSR (β_G=0.6)	117-466	0.5-0.744	48/48/8	Triple spoke cavity, quads	8.5

cavity type	F [MHz]	$U_{acc,\,max}$ [MeV]	E_{max}, [MV/m]	B_{max} [mT]	R/Q Ω	G Ω	$Q_{0,2K}$ $\times 10^9$	$Q_{0,4K}$ $\times 10^9$	$P_{max,2K}$ [W]	$P_{max,4K}$ [W]
SSR0	325	0.78	53	59.5	120	57	9.5	0.7	0.77	10.4
SSR1	325	1.53	34.4	50.8	242	84	14.0	1.0	0.94	13.2
SSR2	325	3.16	33	54	322	112	18.0	1.3	2.07	28.6
TSR	325	8.5	31.4	67	554	117	19.0	1.4	7.9	106.9

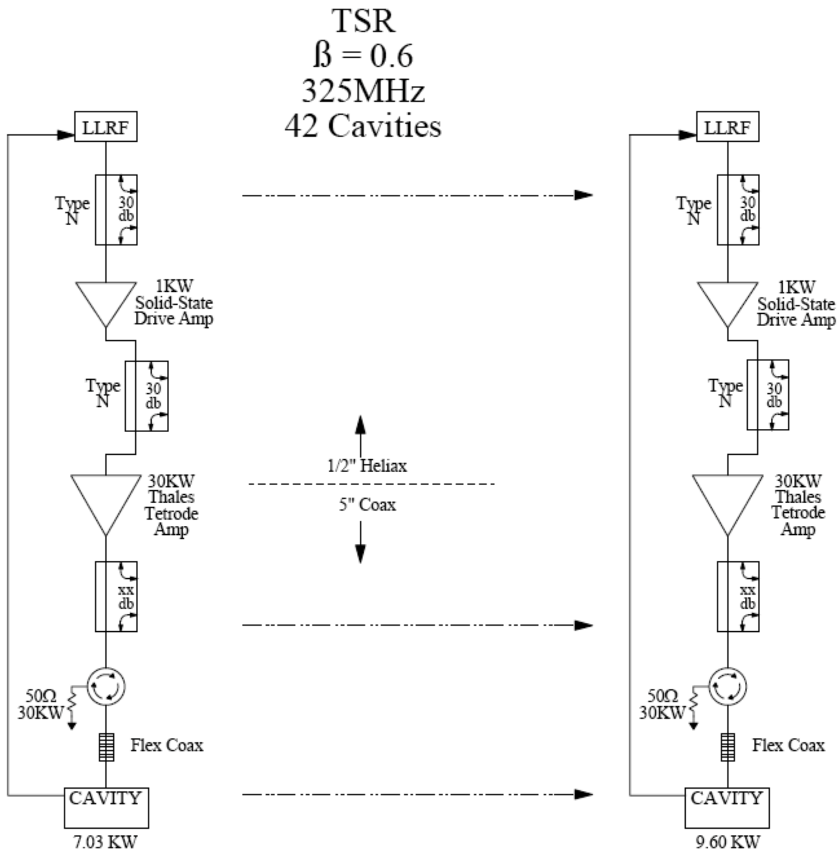
Fermilab Solid-State RF Drive 325 MHz



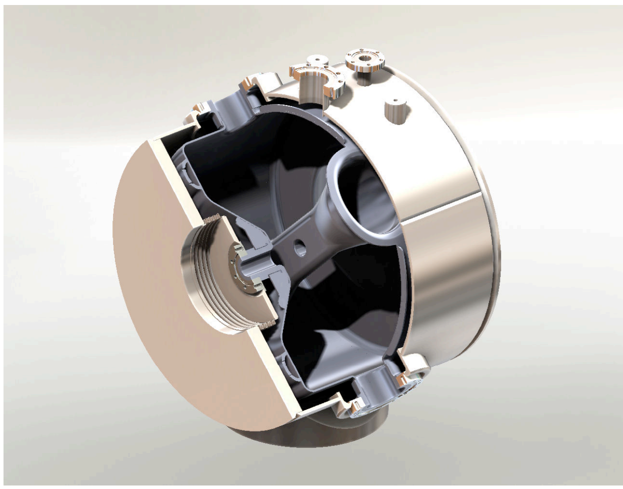
Tetrode RF Drive 325 MHz



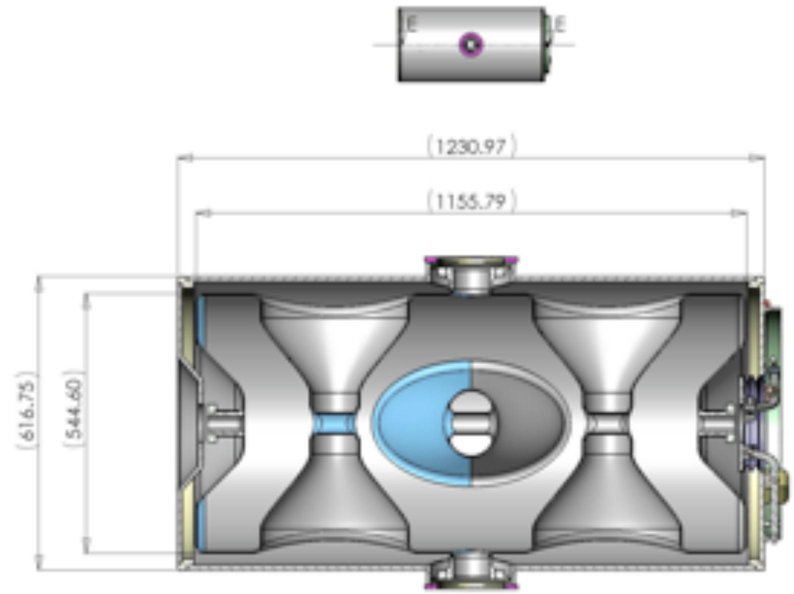
IOT RF Drive 325 MHz



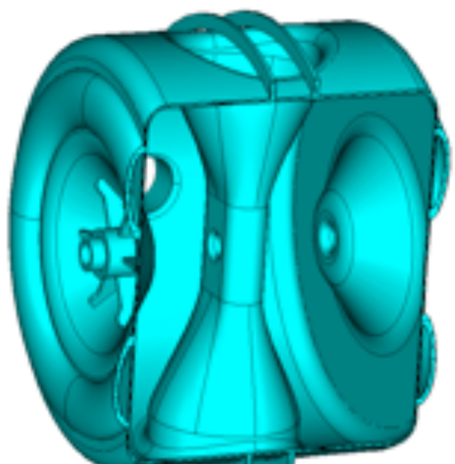
Fermilab Spoke Cavities



SSR1

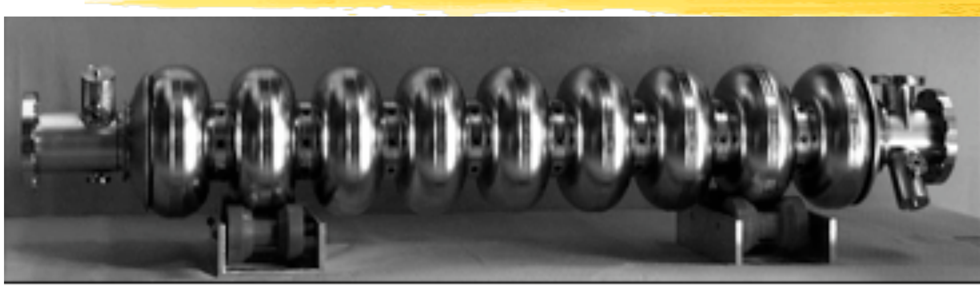


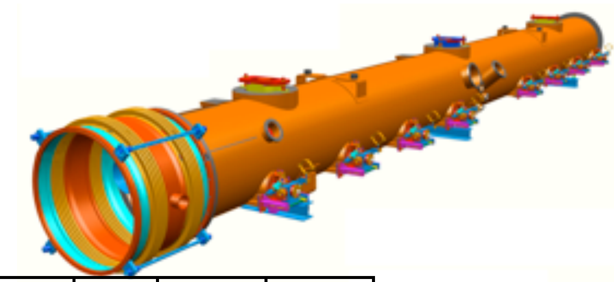
TTR



SSR2

1.3 GHz SRF Cavities
134 cavities in 20 cryomodules

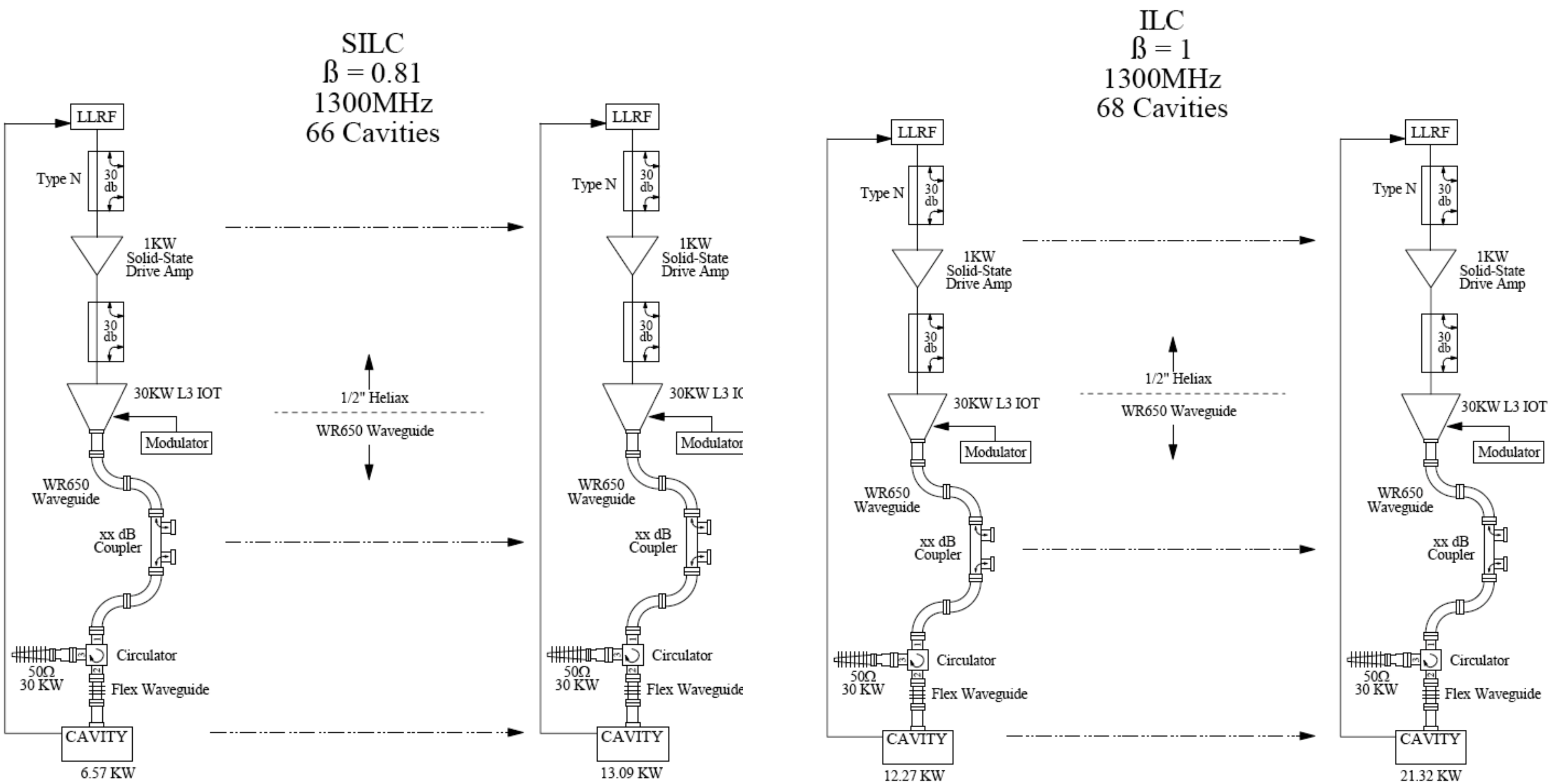




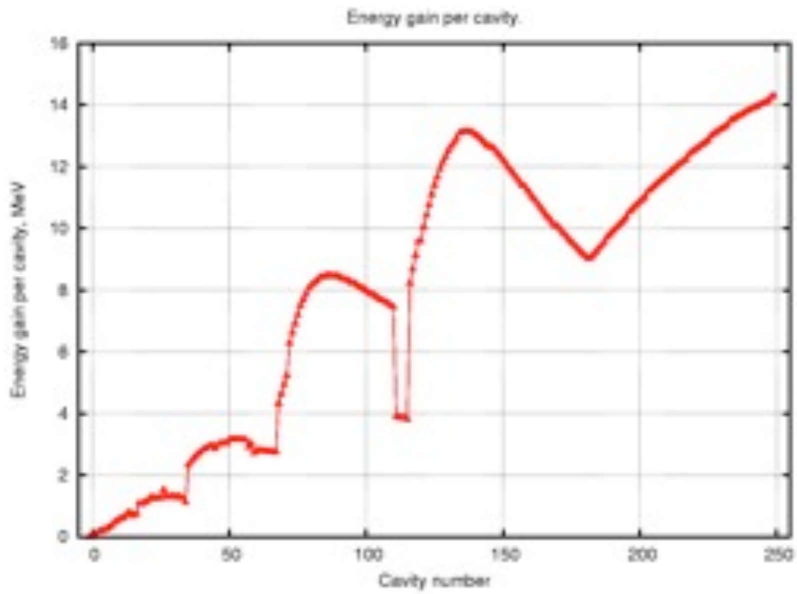
cavity type	f [MHz]	E_{acc} [MV/m]	L_{eff}, mm	E_{max} [MV/m]	B_{max} [mT]	R/Q Ω	G Ω	$Q_{0,2K}$ $\times 10^9$	$Q_{0,4K}$ $\times 10^9$	P_{2K} [W]	P_{4K} [W]
11-cell, β=0.81	1300	14.4	1028	35	72	750	228	12.7	n/a	22.4	n/a
9-cell, ILC	1300	16.9	1038	34	72	1036	270	15.0	n/a	19.0	n/a

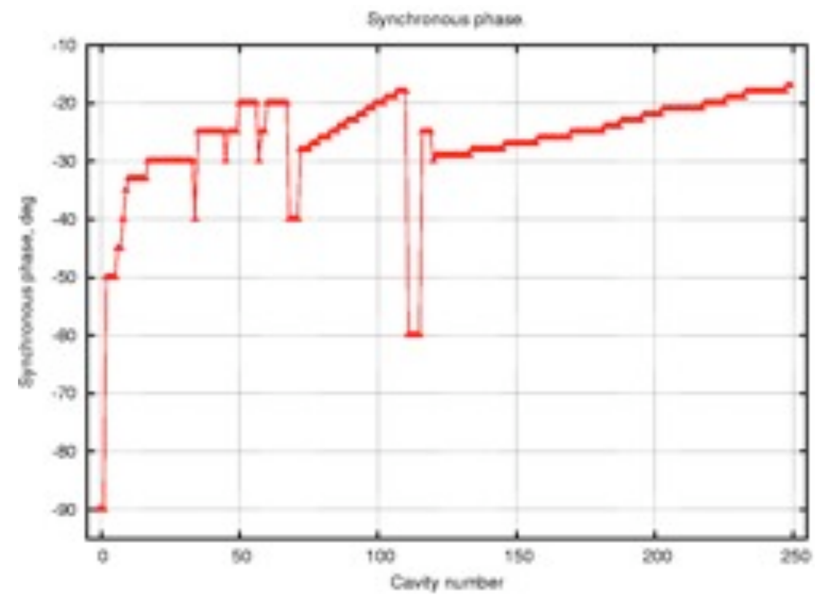
Section	Energy range MeV	β	Number of cavities/ quads/CMs	Type	Max Power/cavity (on crest), kW (I_{av}=1 mA)
S-ILC(β_G=0.81)	466-1200	0.744-0.9	66 / 42/ 11	Squeezed elliptical	13
ILC (β_G=1)	1200-2000	0.9-0.95	68 / 13 / 9	9-cell ILC	15

IOT RF Drive 1.3 GHz



Energy Gain and Phase of Cavities



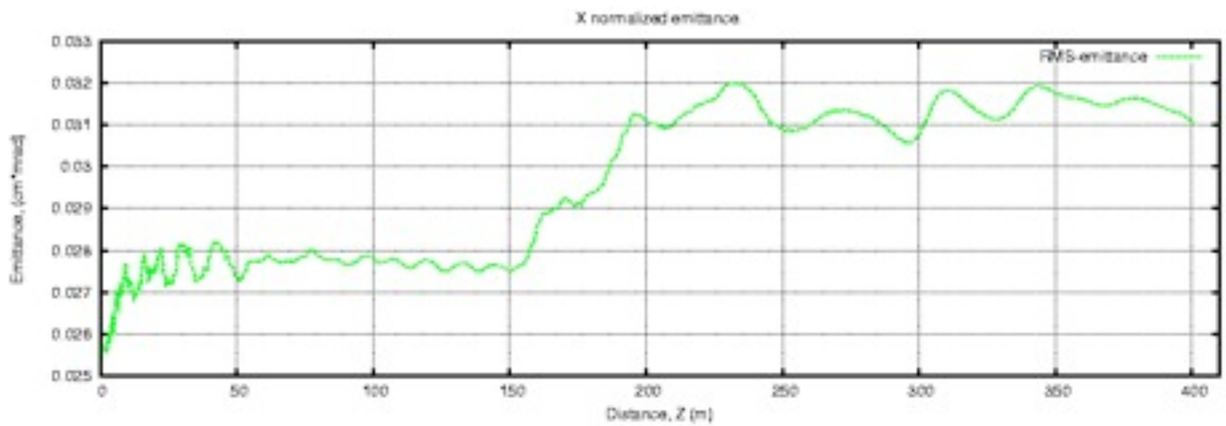


325 MHz *1.3 GHz*

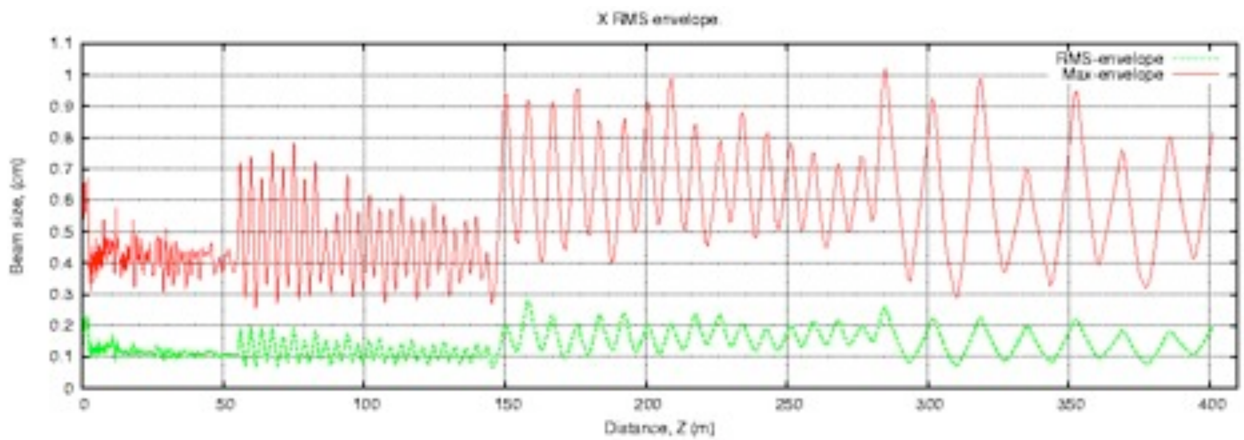
325 MHz *1.3 GHz*

Fermilab Horizontal Emittance Simulations

*Emittance cm*mrad*

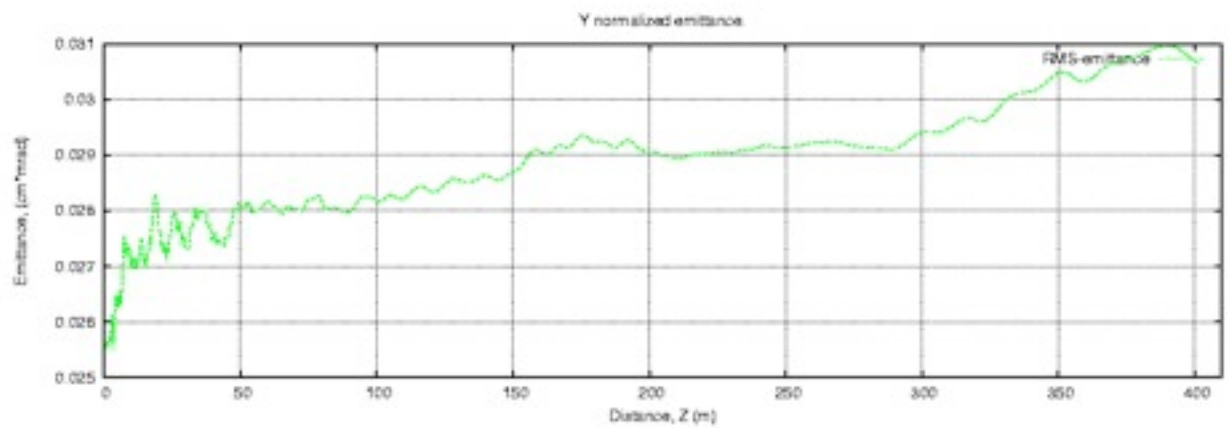


Beam Size cm

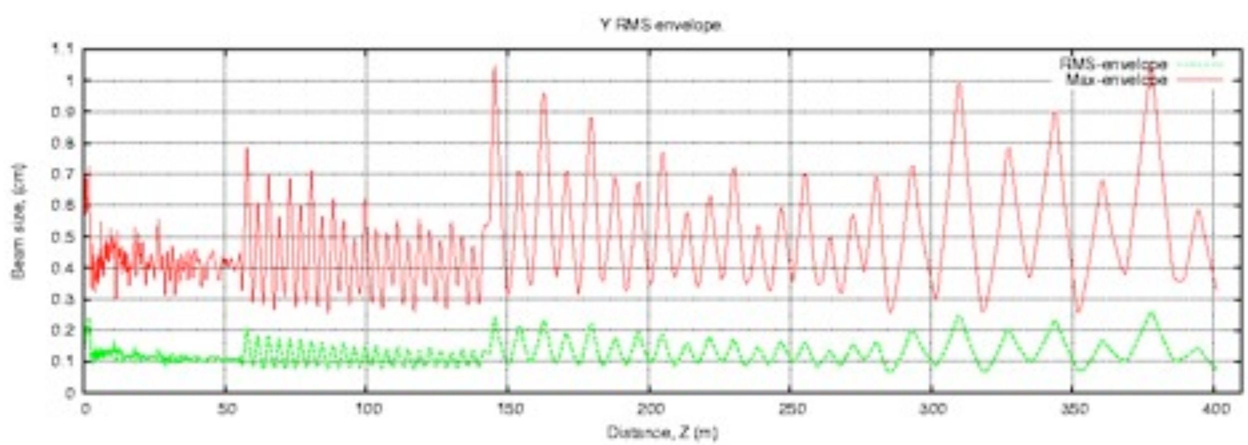


Fermilab Vertical Emittance Simulations

Emittance
*cm*mrad*

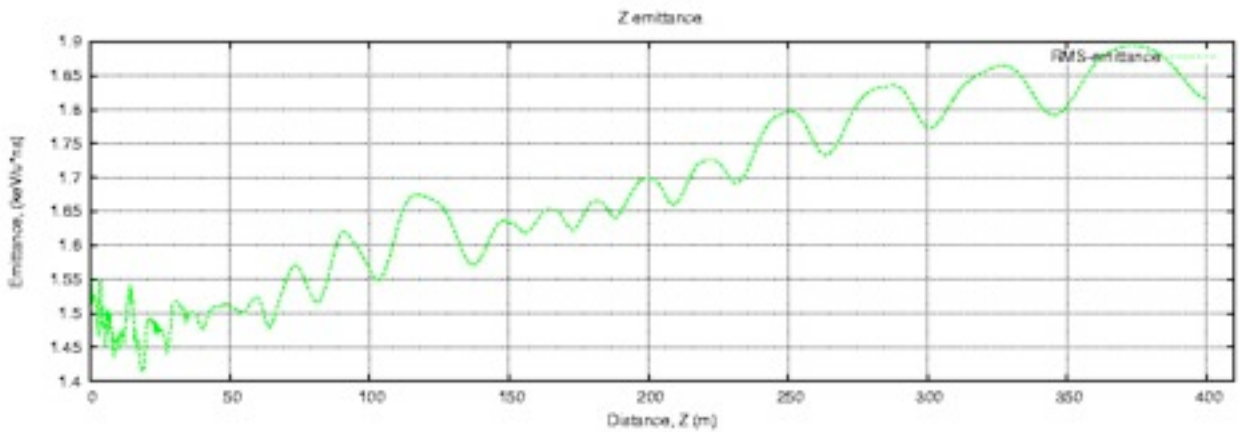


Beam
Size
cm

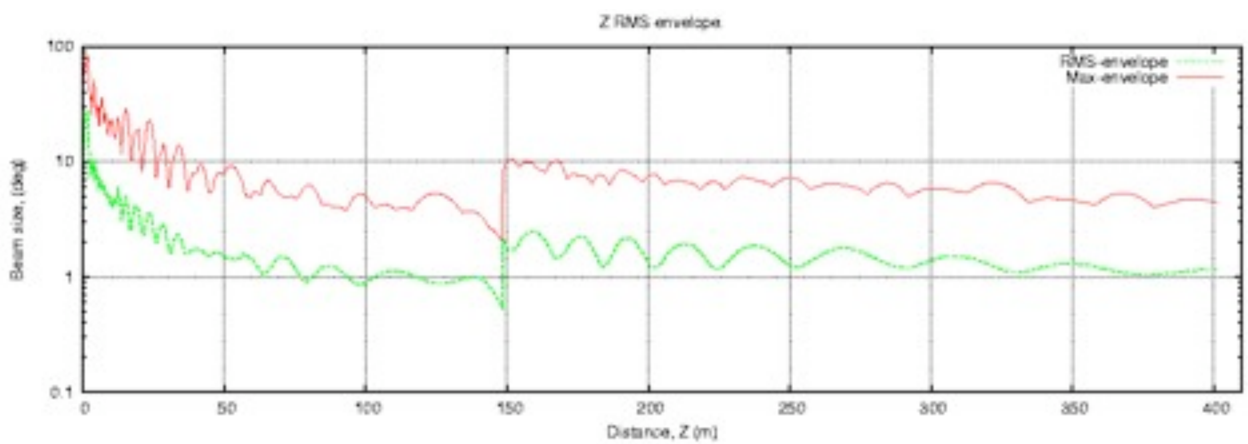


Longitudinal Emittance Simulations

*Emittance keV/u*ns*

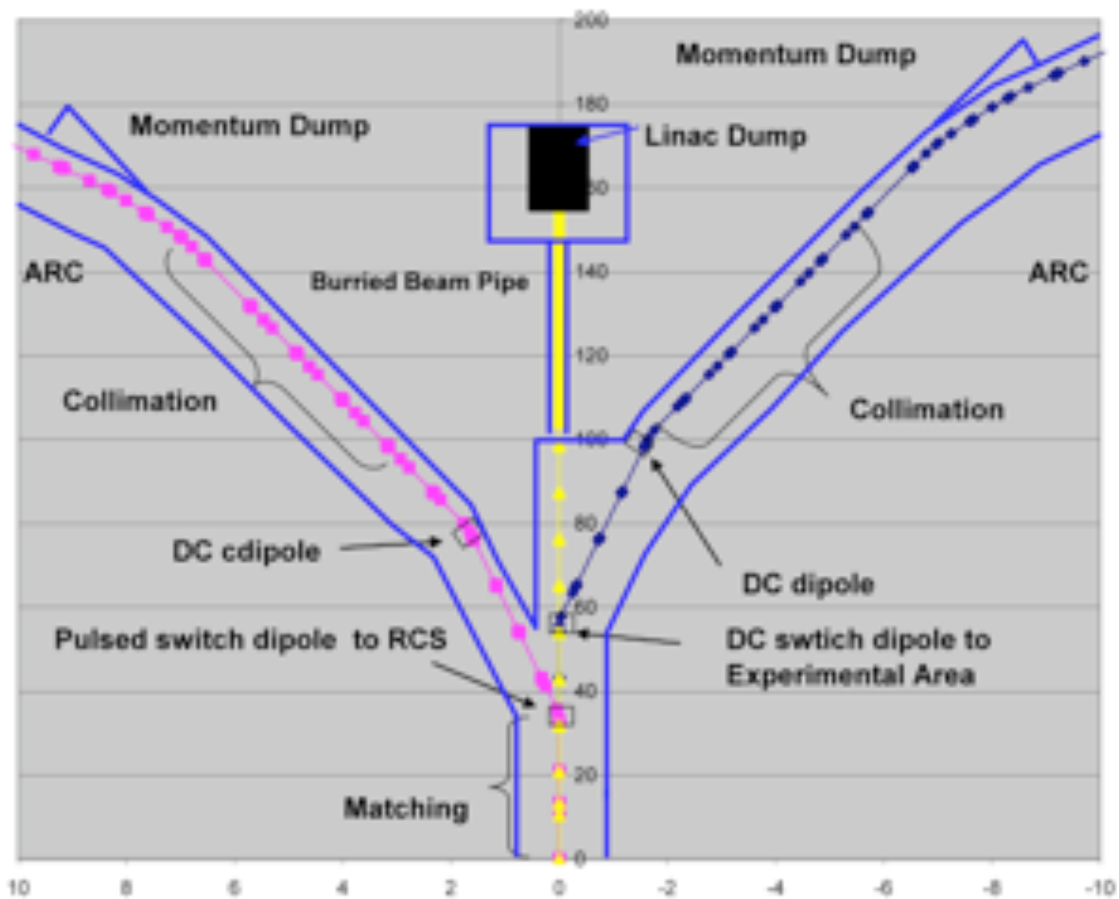


Beam Size deg



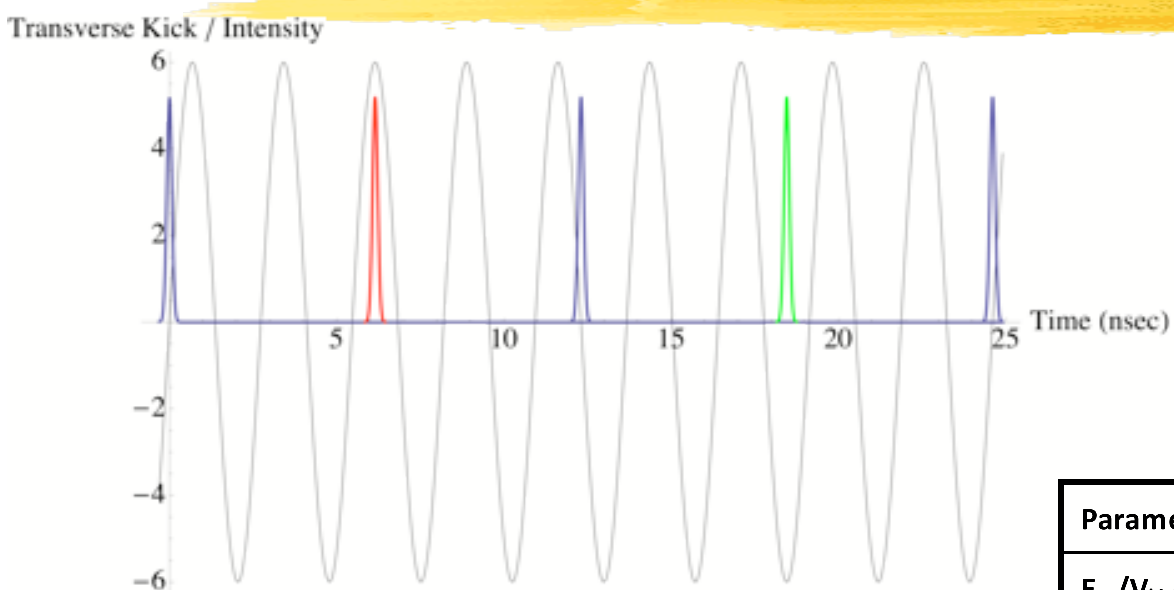
Fermilab *Switchyard*

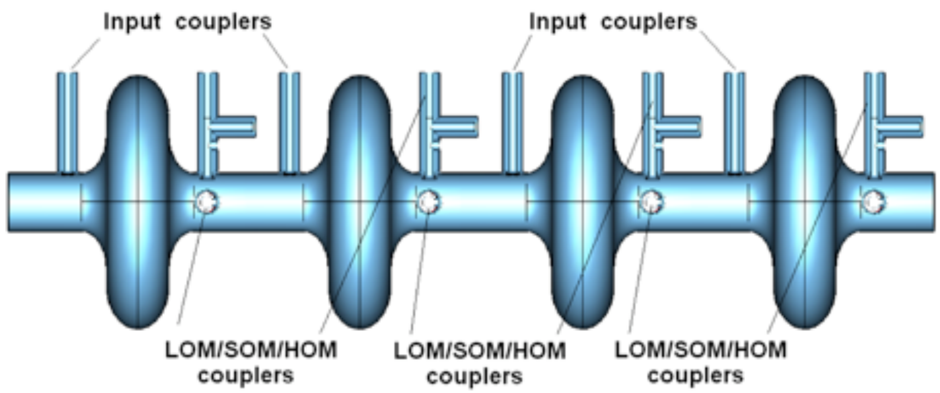
To RCS



To 2 GeV Experiments

Fermilab 2 GeV RF Separator 365.625 MHz





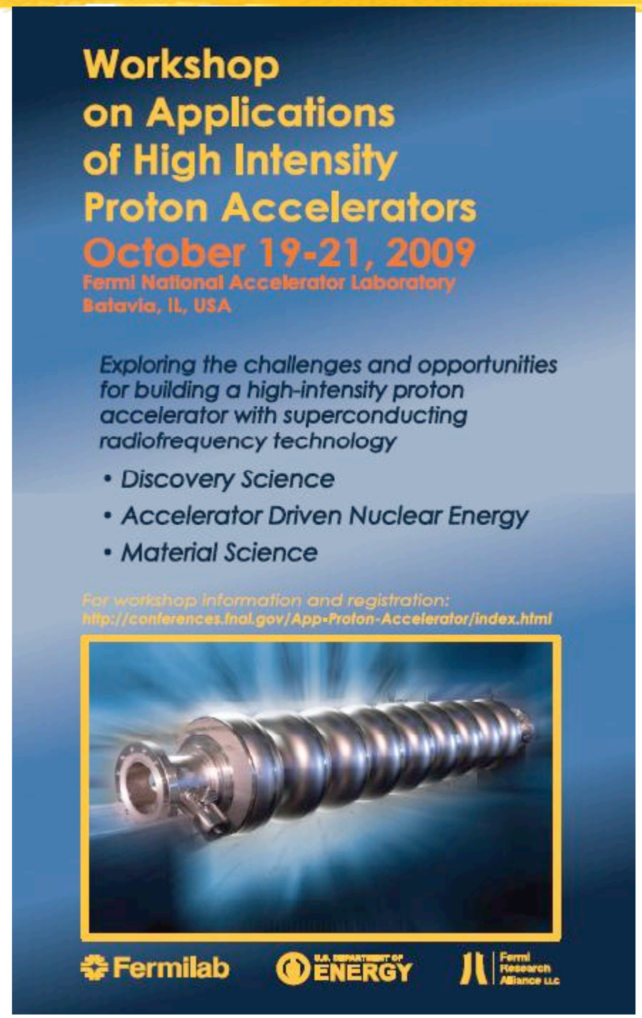
Parameters	
E_{sp}/V_{kick}, (MV/m)/MeV	7.8
B_{sp}/V_{kick}, mT/MeV	19.2**
	27
Longitudinal size (mm)	440
Vertical size (mm)	865
Horizontal size (mm)	962

Fermilab At What Cost?

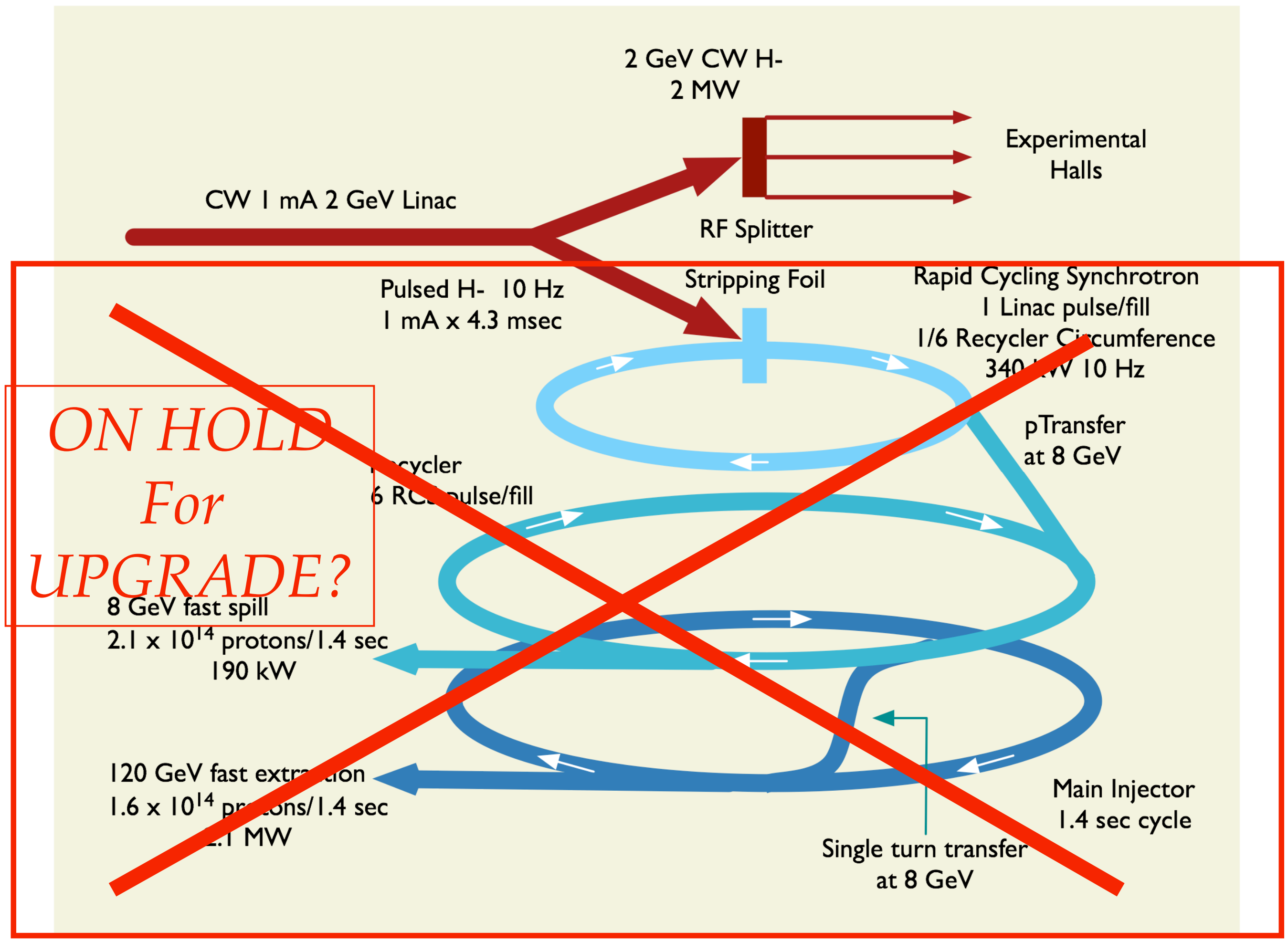
Fermilab *High Intensity Proton Accelerators*

Accelerators for America's Future, October 26-28, 2009

More than 400 people met in Washington, DC to discuss how future accelerators could provide better ways to slice silicon into chips, treat cancer, stop terrorist attacks, tap new sources of energy, reduce the world's growing burden of nuclear waste or turn air pollutants into fertilizer.



Fermilab DOE Would Like Project Cost < $$10^9$



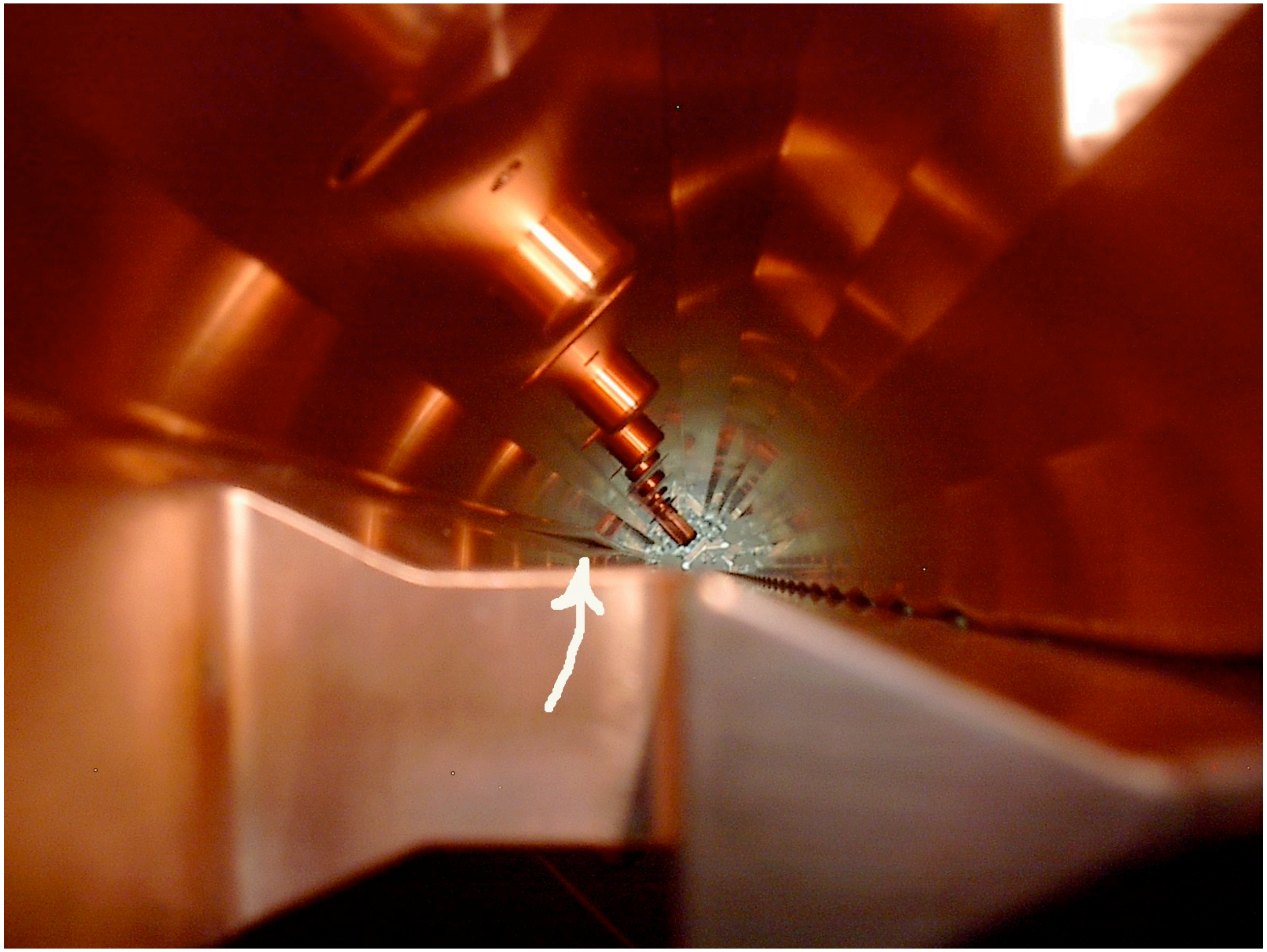

THE
WAITING
GAME

Fermilab

Update on HINS

Fermilab

HINS RFQ Popped Seal



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Update on HINS

What's happened since last meeting:

Spring of 2009, RFQ fails due to broken internal seal
Summer of 2009 RFQ returned to manufacturer for repair
Fall of 2009 RFQ returned to Fermilab and reconditioned

Plans for the remainder of the year and 2010:

After conditioning RFQ accelerate H^+ to 2.5 MeV
Finish construction of shielding cave
Hook up and commission six copper cavities with vector modulators
Commission beam to 3 MeV with vector modulators in feedback
Operate HINS as a proton instrumentation test bed
Depending on Project X what will be the next phase?