Project X Cryomodule Status

Jim Kerby
(w/ thanks to the Project X team)

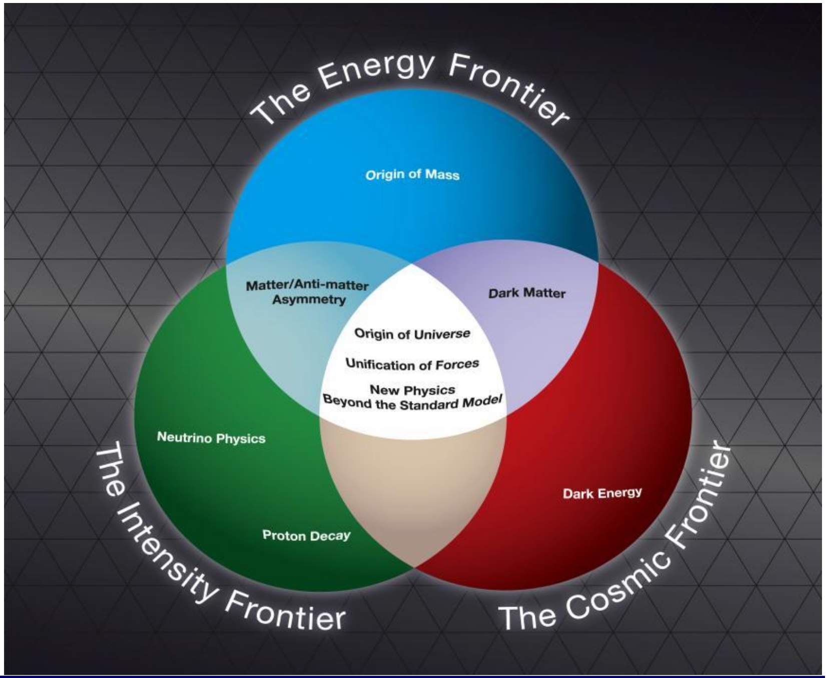
SPL Meeting

CERN
19 October 2010

Fermilab Long Range Plan

Fermilab is the sole remaining U.S. laboratory providing facilities in support of accelerator-based Elementary Particle Physics

⇒ ***The Fermilab strategy is to mount a world-leading program at the <u>intensity frontier</u>, while using this program as a bridge to an <u>energy frontier</u> facility beyond LHC in the longer term.***

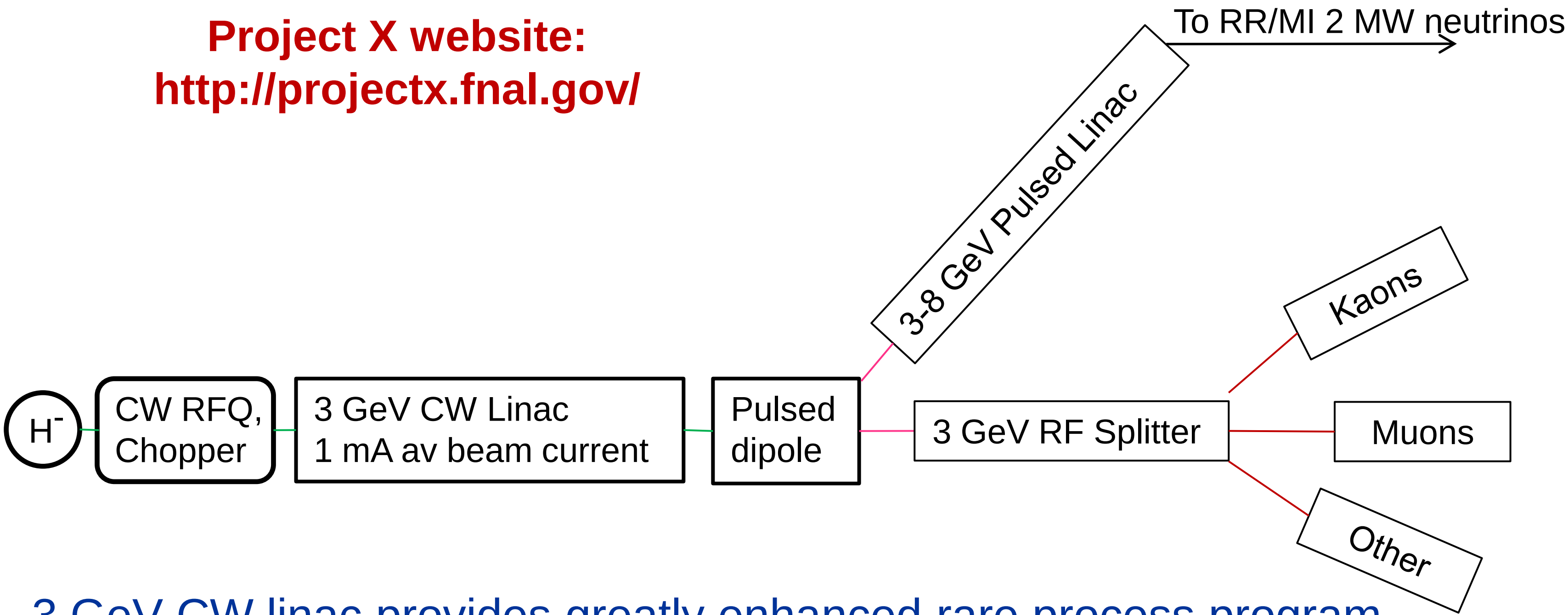


Evolution of the Fermilab Accelerator Complex

- A multi-MW Proton Source, Project X, is the linchpin of Fermilab's strategy for future development of the accelerator complex.
- Project X provides long term flexibility for achieving leadership on the intensity and energy frontiers
  - Intensity Frontier:
    NuMI→ NOνA→ LBNE/mu2e→ Project X → Rare Processes → NuFact
    - Continuously evolving world leading program in neutrino and rare processes physics; opportunities for applications outside EPP
  - Energy Frontier:
    Tevatron → ILC or Muon Collider
    - Technology alignment
    - Fermilab as host site for ILC or Muon Collider

Reference Design

Project X website:
http://projectx.fnal.gov/



- 3 GeV CW linac provides greatly enhanced rare process program
  - ~3 MW; flexible provision for beam requirements supporting multiple users
- Preferred option for 3-8 GeV acceleration: 1.3 GHz pulsed linac
- Reference Design Report in final edit

Project X Performance Goals

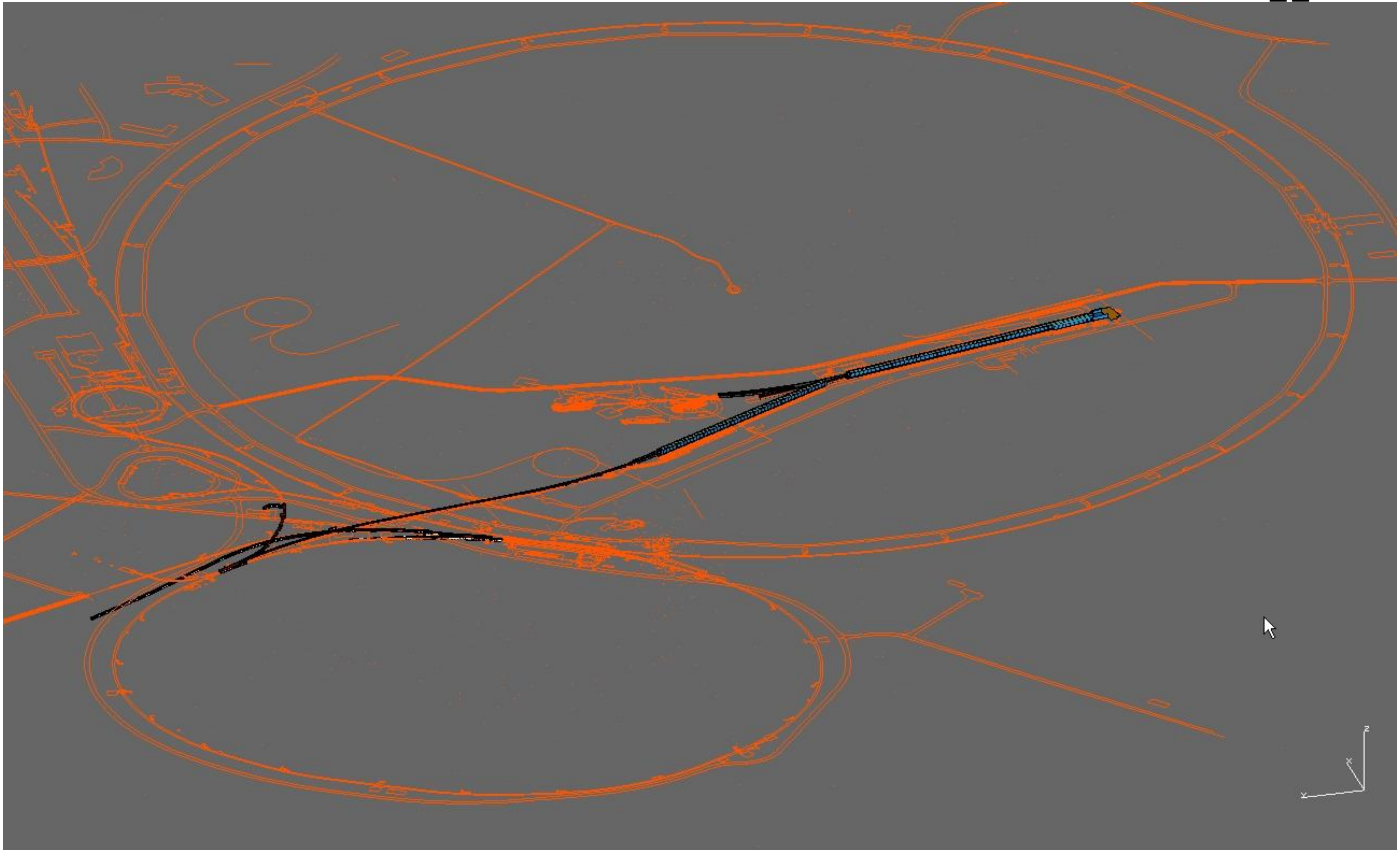
Linac

Requirement	Description	Value
L1	Delivered Beam Energy, maximum	3 GeV (kinetic)
L2	Delivered Beam Power at 3 GeV	3 MW
L3	Average Beam Current (averaged over >1 μsec)	1 mA
L4	Maximum Beam Current (sustained for <1 μsec)	10 mA
L5	The 3 GeV linac must be capable of delivering correctly formatted beam to a pulsed linac, for acceleration to 8 GeV	
L6	Charge delivered to pulsed linac	26 mA-msec in < 0.75 sec
L7	Maximum Bunch Intensity	1.9×10^{8}
L8	Minimum Bunch Spacing	3.1 nsec (1/325 MHz)
L9	Bunch Length	<50 psec (full-width half max)
L10	Bunch Pattern	Programmable
L11	RF Duty Factor	100% (CW)
L12	RF Frequency	325 MHz and harmonics thereof
L13	3 GeV Beam Split	Three-way

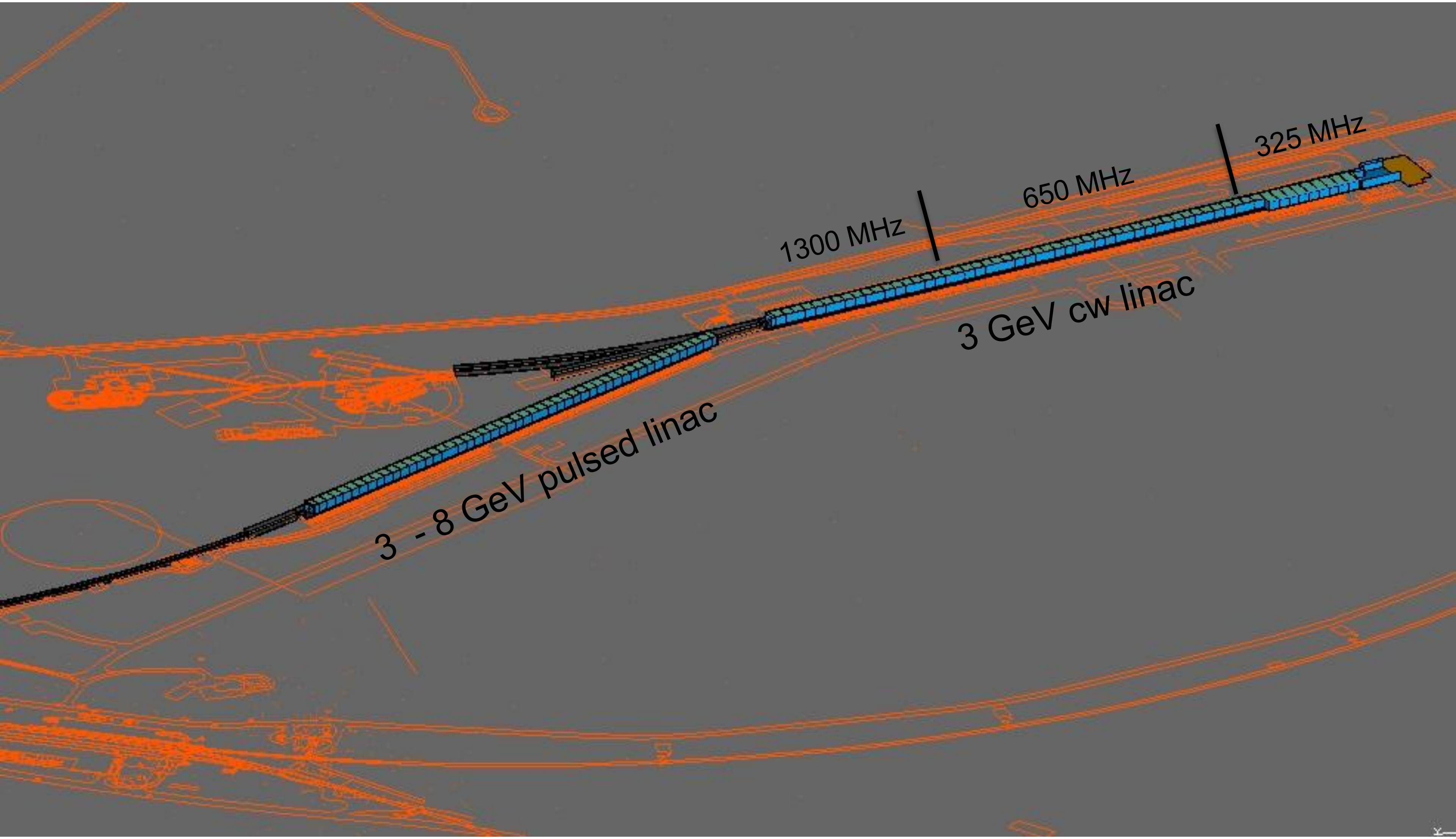
3-8 GeV Pulsed Linac

Requirement	Description	Value
P1	Maximum beam Energy	8 GeV
P2	The 3-8 GeV pulsed linac must be capable of delivering correctly formatted beam for injection into the Recycler Ring (or Main Injector).	
P3	Charge to fill Main Injector/cycle	26 mA-msec in <0.75 sec
P4	Maximum beam power delivered to 8 GeV	300 kW

Layout



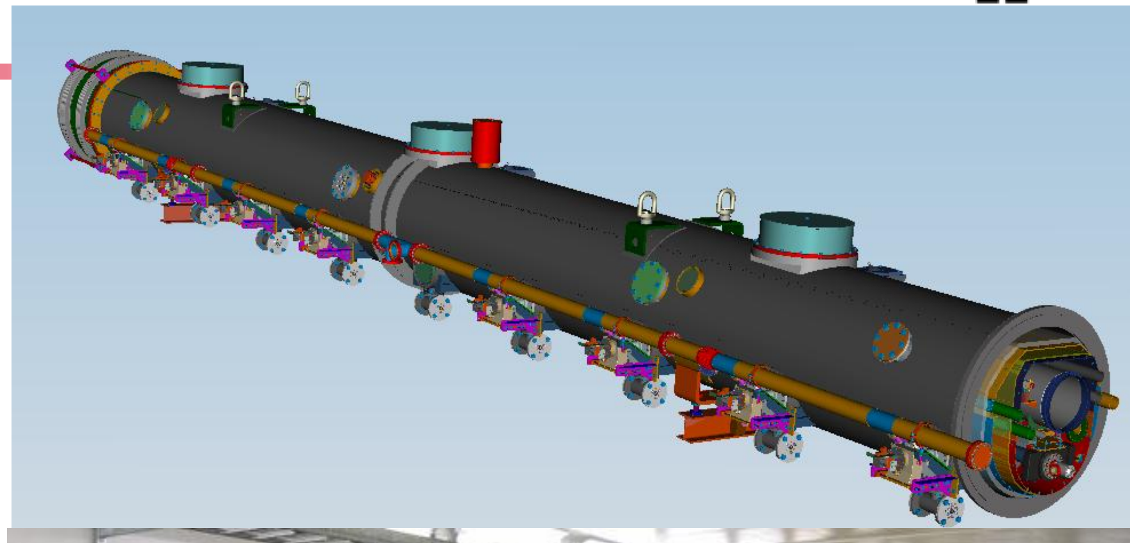
Layout



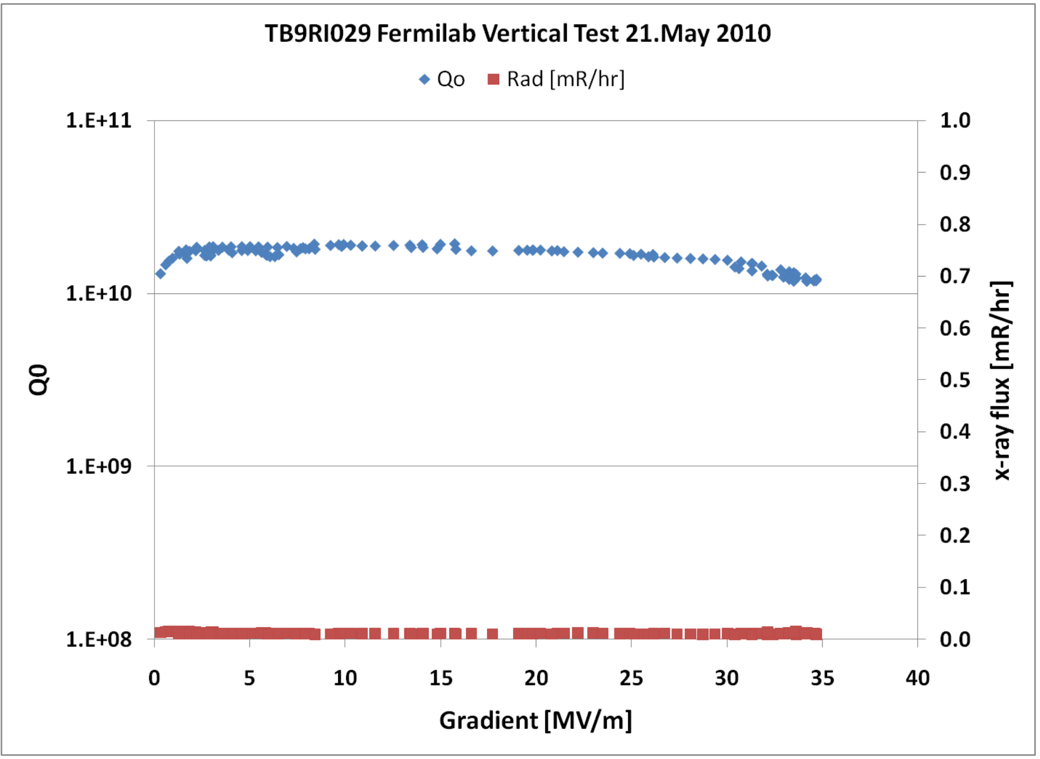
Project X

3-8 GeV Pulsed Linac

- ~4% duty factor, 200 1300MHz cavities operating at 25 MV/m
- 25 ILC-type (Type IV) Cryomodules
- Existing design, CM1 cooldown next week, CM2-6 following (in addition to XFEL pre-production / production expereince)
- Technical R&D into injection into Main Injector at lower energies



Recent VTS Results

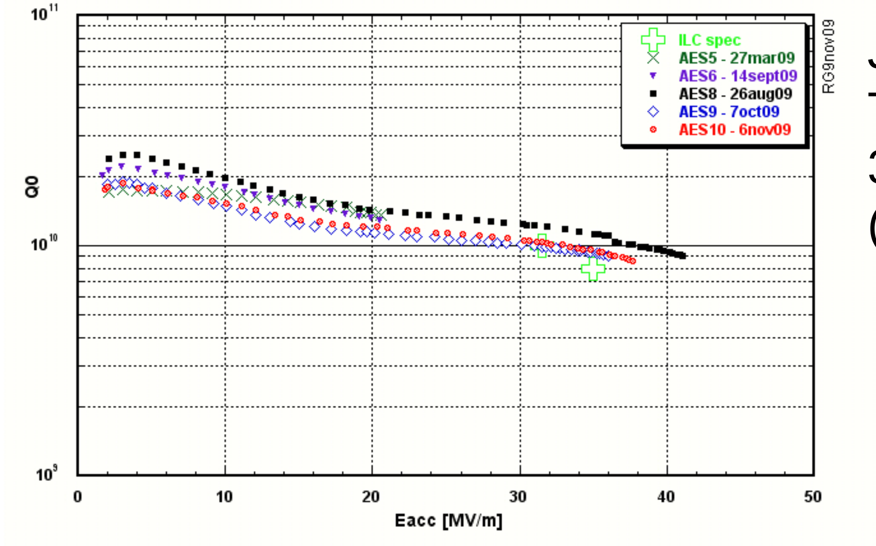


FNAL vertical test result 21.May 2010: 34.6 MV/m maximum gradient with Q0=1.2E10 (quench)
No field emission measured above background

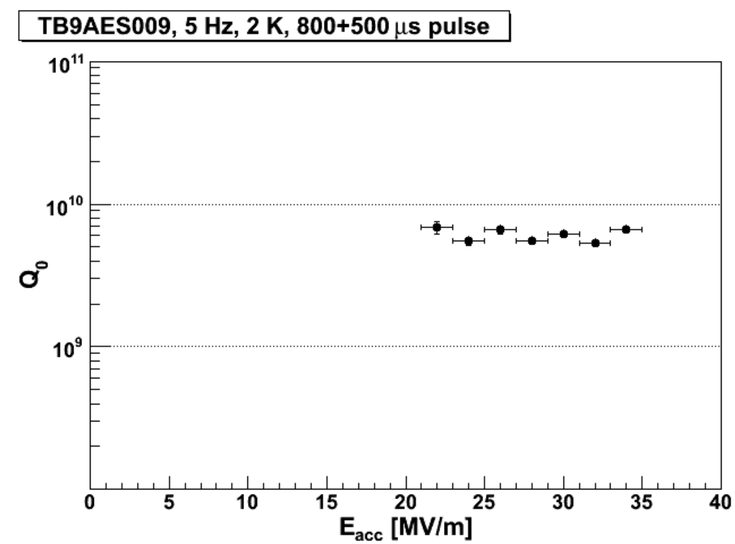
TB9RI029 is first FNAL/ANL-processed production-style cavity to reach ~35 MV/m
Bulk-EP was at RI

[AES003 after a long history was also light-EP'd recently at FNAL/ANL and reached 32.2 MV/m (some FE); TB9RI024, also with FNAL/ANL light-EP, reached 33.9 MV/m; some FE]

Recent HTS Results

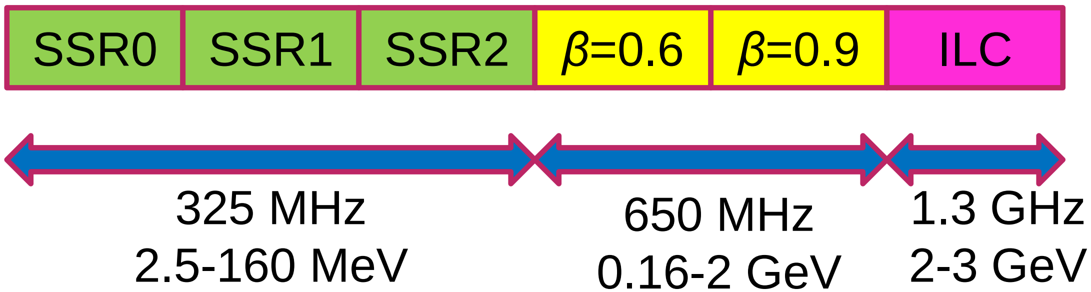


JLab vertical test data 7.Oct 2009: TB9AES009 maximum gradient 36.0 MV/m with Q0=9.1E9 (quench)



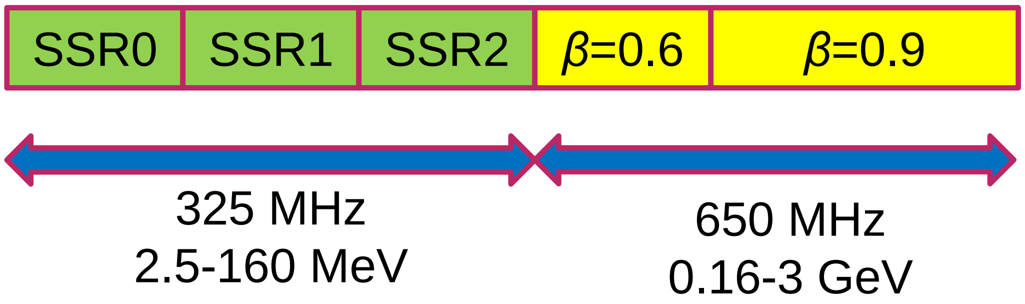
FNAL HTS data April/May 2010: TB9AES009 maximum gradient 35 MV/m with Q0=6.6E9 (quench)

3GeV cw Linac
Technology Map



Section	Freq	Energy (MeV)	Cav/Mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	26 /26/1	SSR, solenoid
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	44 /24/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-520	42 /21/7	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	520-2000	96 /12 /12	5-cell elliptical, doublet
ILC 1.3 (β_G=1.0)	1300	2000-3000	64 /8 /8	9-cell elliptical, quad

3GeV cw Linac
Technology Map

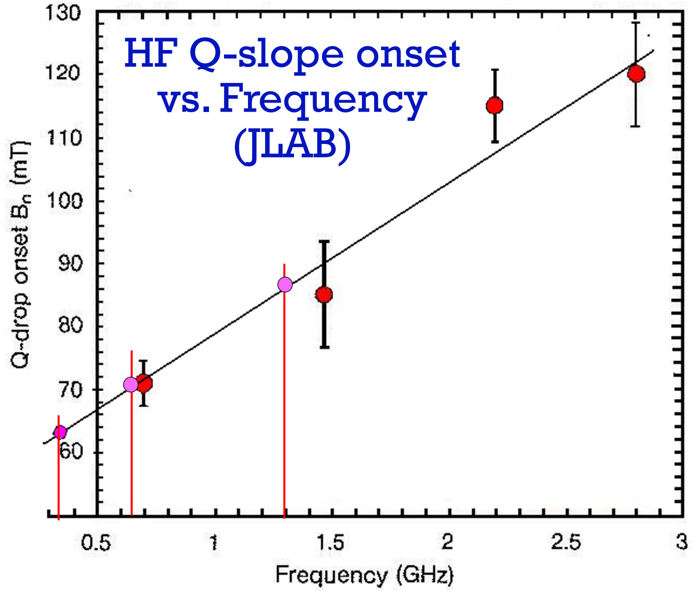


Section	Freq	Energy (MeV)	Cav/mag/CM	Type
SSR0 (β_G=0.11)	325	2.5-10	26 /26/1?	SSR, solenoid
SSR1 (β_G=0.22)	325	10-32	18 /18/ 2	SSR, solenoid
SSR2 (β_G=0.4)	325	32-160	44 /24/4	SSR, solenoid
LB 650 (β_G=0.61)	650	160-487	36 /24/4?	5-cell elliptical, doublet
HB 650 (β_G=0.9)	650	487-3000	160 /38 /20	5-cell elliptical, doublet

Project X

Choice of Cavity Parameters

- Identify maximum achievable surface (magnetic field) on basis of observed Q-slope "knee"
- Select cavity shape to maximize gradient (subject to physical constraints)
- Establish Q goal based on realistic extrapolation from current performance
  - Goal: <25 W/cavity
- Optimize within (G, Q, T) space



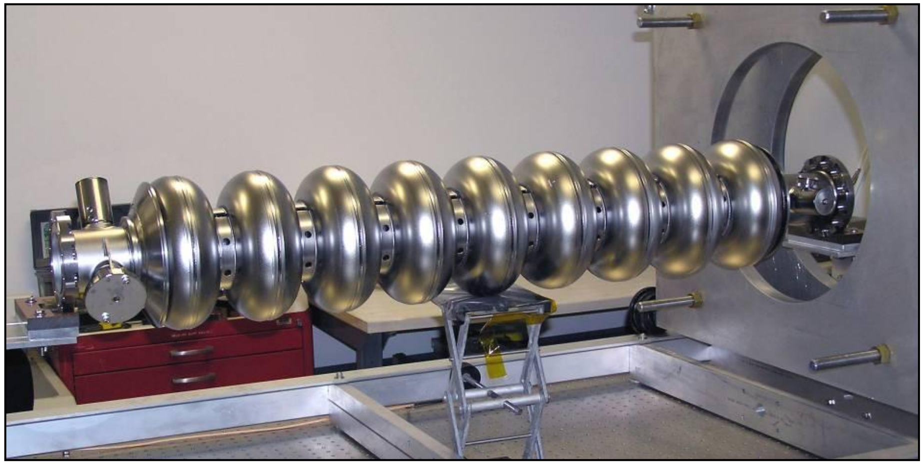
<u>(Initial) Performance Goals</u>

Freq (MHz)	B_{pk}(mT)	G (MV/m)	Q	@T (K)
325	60	15	1.4E10	2
650	72	16	1.7E10	2
1300	72	15	1.5E10	2

SRF Technology Development

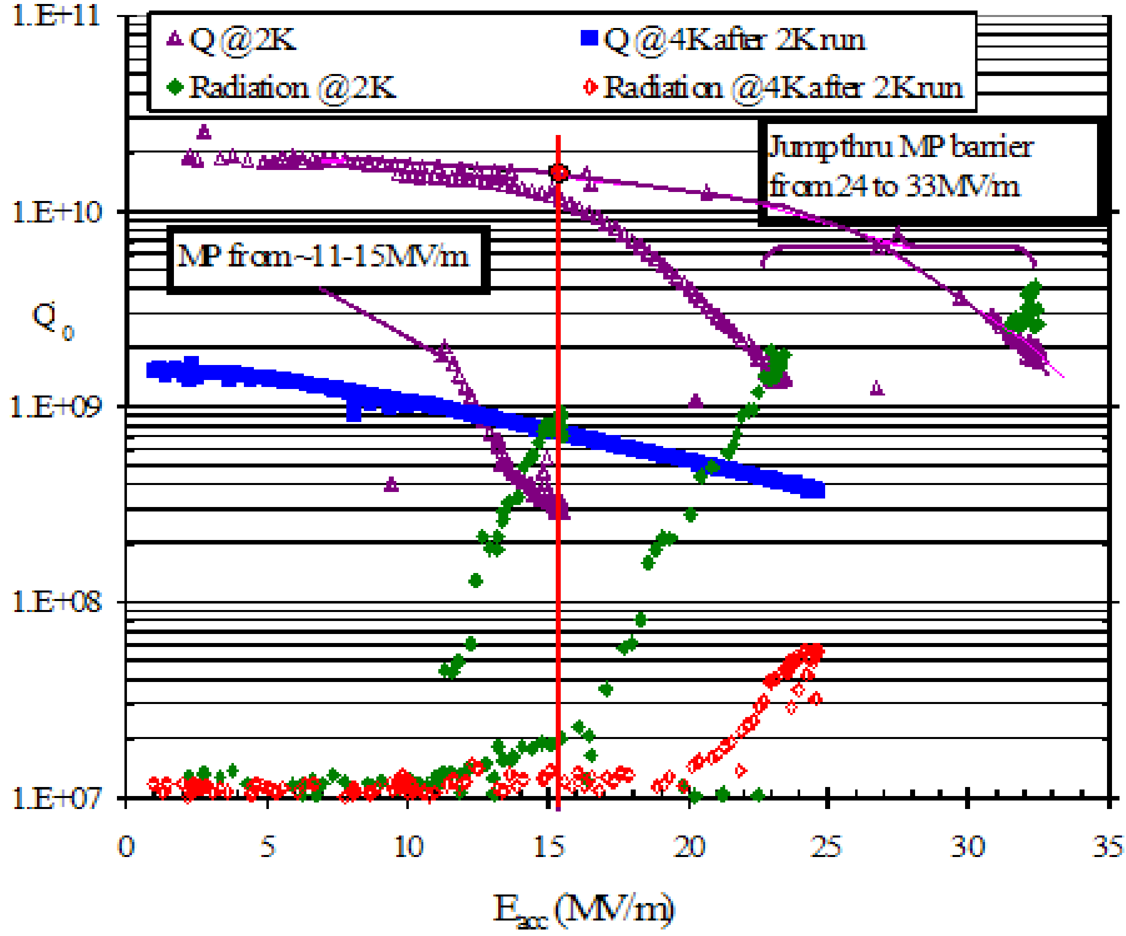
Single Spoke Resonators
(325 MHz)
Roark, Zanon, IUAC…

Elliptical Cavities
(650 and 1300 MHz)
AES, RI, Jlab, Cornell, Niowave-Roark, RRCAT, Pavac….



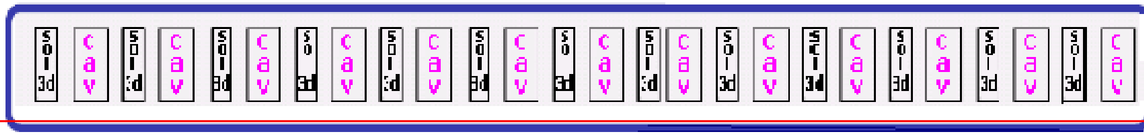
SSR1 Test Results

- Roark and Zanon SSR have been tested successfully
- Two in process at IUAC
- 10 more ordered from Roark
- SSR0, SSR2 designs following
- Ultimately a prototype SSR1 Cryostat will be assembled



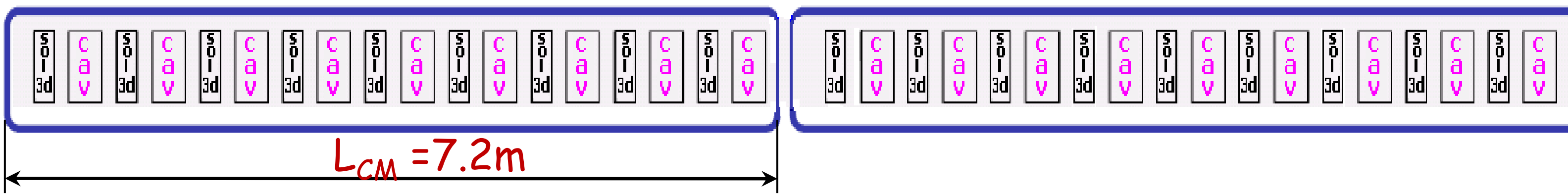
325 Cryomodule

- 1 CM of SSR0, 18 – 26 cavities

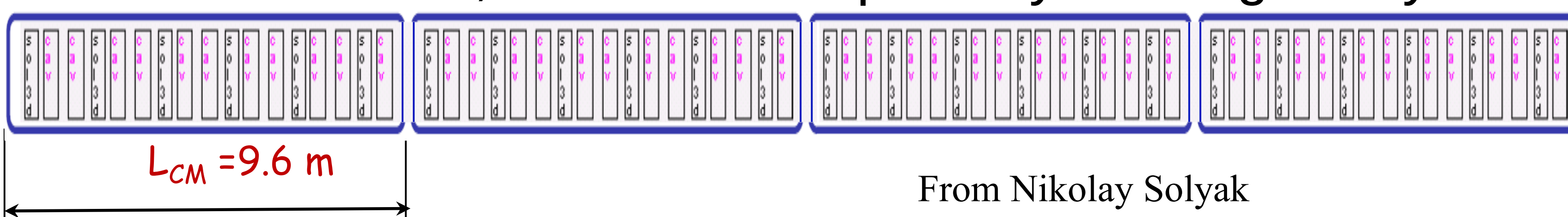


Vent pipes every 6 - 8 cavities, 40+ mm thermal contraction, assembly

- 2 CM of SSR1, Minimize of the inter-cryostate drift space

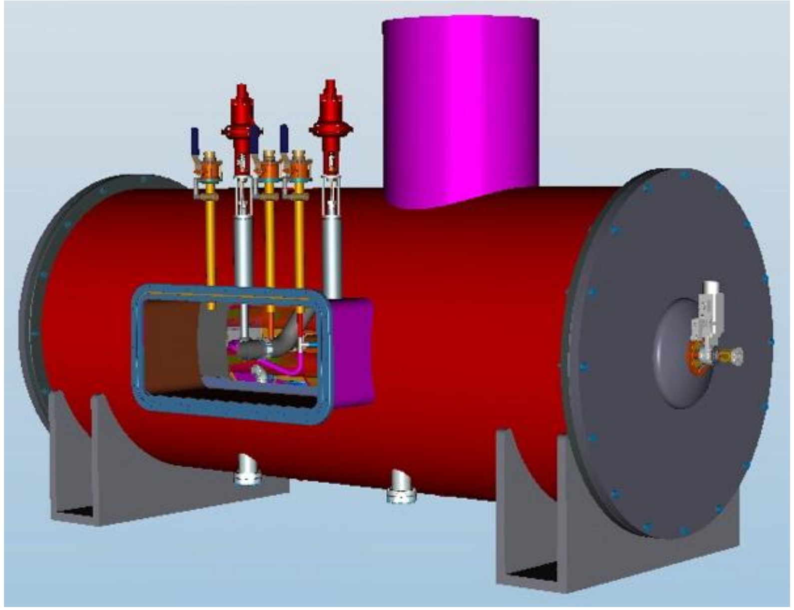


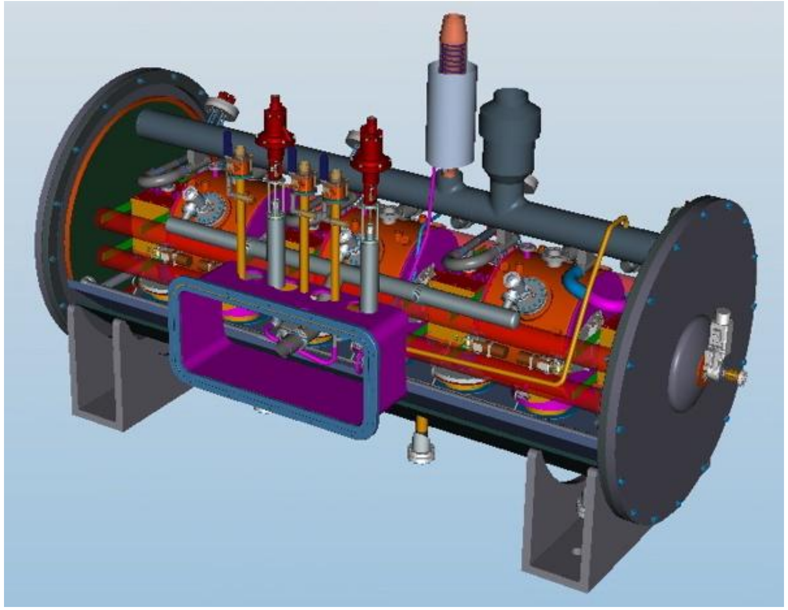
- 4 CM of SSR2, Provide drift space by missing cavity



From Nikolay Solyak
Project-X, CW Linac (ICD-2+)
Lattice Design, 16 Mar 2010

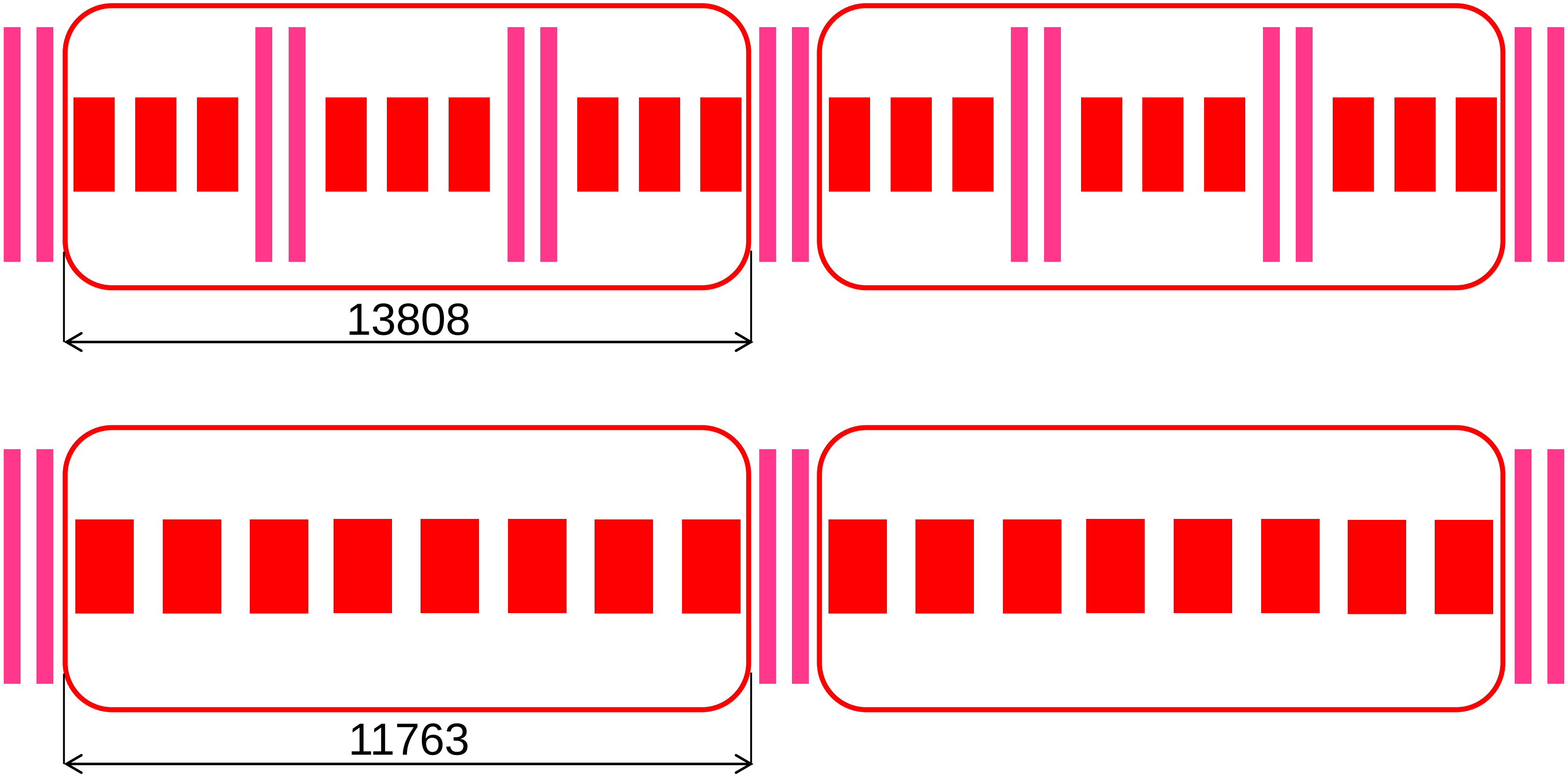
Project X 325 Prototype Cryomodule





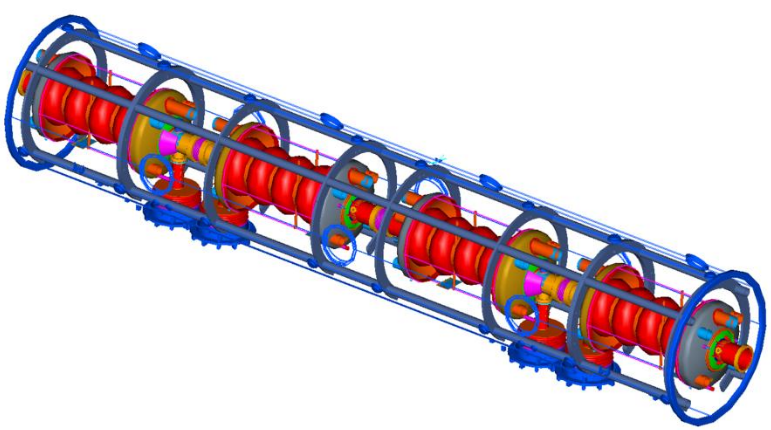
- Prototype design being developed to test 3 SSR1 and 4 solenoid magnets

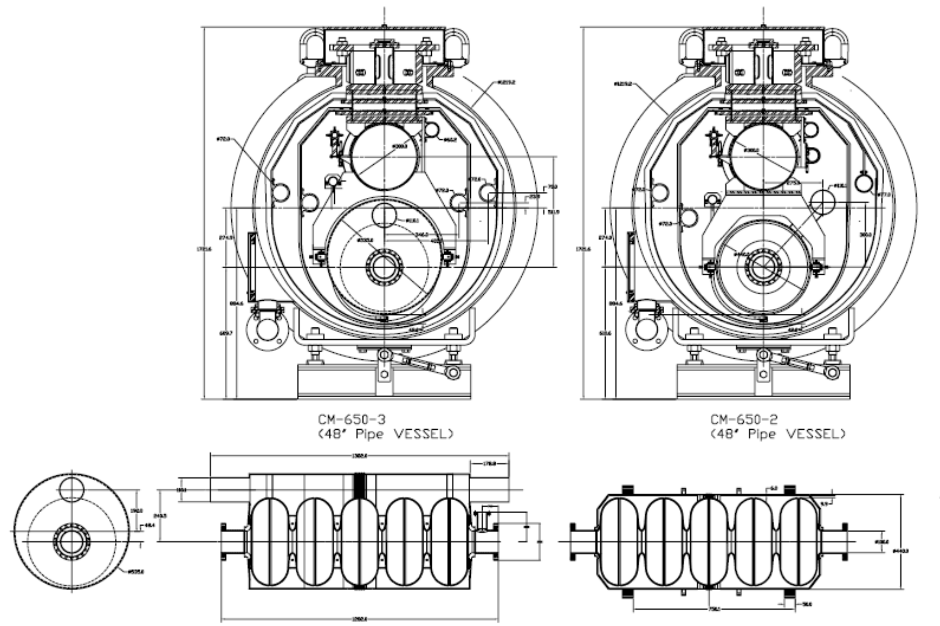
650 Low and High Beta Optics



650 MHz Cryomodules

- Individually segmented, each with ~250W to 2K
- Design options range from “Spaceframe” to “TESLA” derivatives
- Discussion on the effect of vapor and liquid volumes fractions and flow rates on pressure regulation

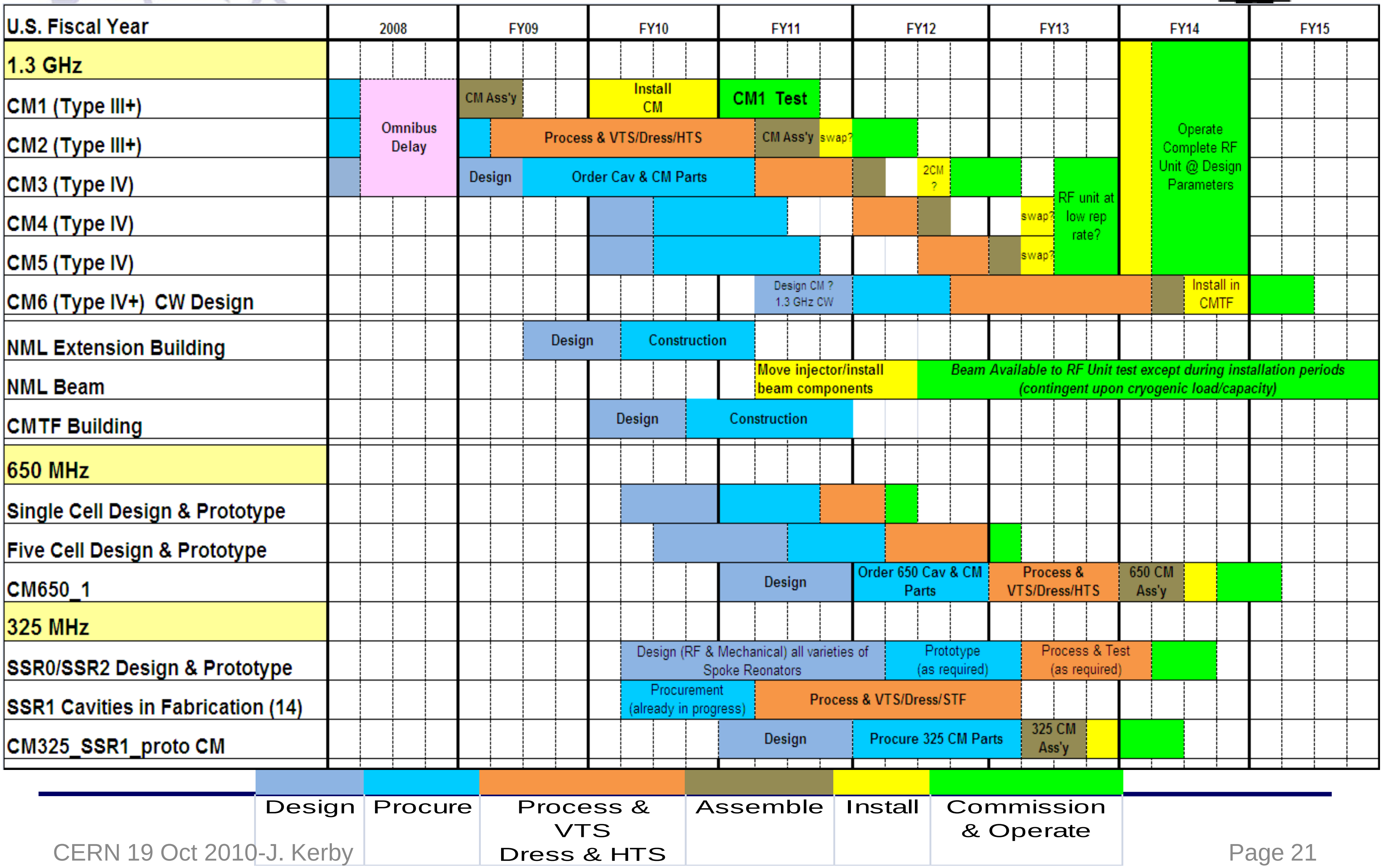




650 MHz Status

- The optics design of the 2-3 GeV portion of the Project X CW Linac is under review.
- The dynamic heat load per cavity, and per cryomodule, has individually segmented cryomodules under serious consideration for the CW linac
- Initial alignment tolerances are 0.5mm rms, with a 1mm limit. The use of multiple correction elements and BPMs is motivating the numbers
- 650 Beta = 0.9 optics are more settled than Beta = 0.61 optics on a ‘cryomodule’ basis
- Warm and cold magnet options are under consideration.
- Inclusion of heat exchangers and cryogenic bayonets in the interconnect or directly from the vacuum vessel in discussion

SRF Plan


U.S. Fiscal Year
2008
FY09
FY10
FY11
FY12
FY13
FY14
FY15
1.3 GHz
CM1 (Type III+)
CM2 (Type III+)
CM3 (Type IV)
CM4 (Type IV)
CM5 (Type IV)
CM6 (Type IV+) CW Design
NML Extension Building
NML Beam
CMTF Building
650 MHz
Single Cell Design & Prototype
Five Cell Design & Prototype
CM650_1
325 MHz
SSR0/SSR2 Design & Prototype
SSR1 Cavities in Fabrication (14)
CM325_SSR1_proto CM
Omnibus Delay
CM Ass'y
Install CM
CM1 Test
Process & VTS/Dress/HTS
CM Ass'y
swap?
Design
Order Cav & CM Parts
2CM ?
swap?
swap?
RF unit at low rep rate?
Operate Complete RF Unit @ Design Parameters
Design CM ? 1.3 GHz CW
Install in CMTF
Design
Construction
Move injector/install beam components
Beam Available to RF Unit test except during installation periods (contingent upon cryogenic load/capacity)
Design
Construction
Design
Order 650 Cav & CM Parts
Process & VTS/Dress/HTS
650 CM Ass'y
Design (RF & Mechanical) all varieties of Spoke Reonators
Prototype (as required)
Process & Test (as required)
Procurement (already in progress)
Process & VTS/Dress/STF
Design
Procure 325 CM Parts
325 CM Ass'y
Design
Procure
Process & VTS Dress & HTS
Assemble
Install
Commission & Operate

Summary

- Project X is central to Fermilab's strategy for development of the accelerator complex over the coming decade
  - World leading programs in neutrinos and rare processes
  - Aligned with ILC and Muon Accelerators technology development;
  - Potential applications beyond elementary particle physics
- The machine design is converging, though iterations of the optics are underway (and expected) at this conceptual stage
- At a minimum with respect to SPL cryogenics, alignment, and component thermal performance all appear to be areas of useful cross-calibration if not collaboration
  - Fermilab Director and CERN DG signed a letter of intent on future cooperation last friday