EXECUTIVE SUMMARY
Accelerator Advisory Committee Meeting
November 16-18, 2009, Fermilab

Swapan Chattopadhyay (Cockcroft Institute), Chair

Roland Garoby (CERN)
Katsunobu Oide (KEK)
Hassan Padamsee (Cornell)
Tor Raubenheimer (SLAC)
Stuart Henderson (SNS)
Ilan Ben-zvi (BNL)
Guenther Geschonke (CERN)
Kathy Harkay (ANL)
Hans Weise (DESY)

Absent: Kwang-Je Kim (ANL) and Jamie Rosenzweig (UCLA)

Charge to the Committee

- **Review and comment on activities related to the ongoing high intensity proton development programs**
  - **Project X ICD-2 and R&D Plans**
  - Roland Garoby* (Chair), Katsunobu Oide, Hassan Padamsee,
  - Tor Raubenheimer, Stuart Henderson (S. Chattopadhyay)
  - **High Intensity Neutrino Source Program (HINS)**
  - Stuart Henderson *(Chair), Ilan Ben-zvi, Guenther Geshonke,
  - Kathy Harkay, Hans Weise (S. Chattopadhyay)
  - The committee added a third:
  - **SRF Integration**
  - Ilan Ben-zvi *(Chair), Hans Weise, Hassan Padamsee, Stuart
  - Henderson, Roland Garoby (S. Chattopadhyay)

PREAMBLE

- **The committee heard a set of competent and professional talks, were impressed with the facilities tour and wishes to thank Fermilab staff for their dedication and excellent engagement;**

- **The overview talks on the physics by Tschirhart, ICD-2 by Nagaisev and HINS by Webber were most appreciated, showing responsible and competent engagement and thoughtful stewardship of these activities towards FNAL's evolving future program in a moving scenario;**

- **The committee did not have the opportunity to have read the ICD-2 document prior to the review, which is now made available to us;**

- **The committee recognizes the very early and fresh nature of the exciting new development of ICD-2 for Project-X and wishes to be cautious in its deliberations with regards to associated technical risks in this newly thought-out scenario;**

- **The committee notes that HINS goals and missions have not changed over the years while definition and vision for the next high current proton facility or Project-X has been shifting from ICD-1 to ICD-2 to……and recognizes the exercise of caution in managing expectations of alignment lab-wide.**

Charge to the Committee
ICD-2

- **Project X ICD-2 and R&D Plan**
- **The Committee is asked to review and offer comment/recommendations relative the ICD-2 and the accompanying Project X RD&D plan. In particular we request specific comments/recommendations in the following areas:**
  - **Does ICD-2 describe a configuration that is likely to meet the proposed mission objectives (reference to Tschirhart's report)? Does it meet broader and more flexible physics demands on beams?**
  - **What are the primary technical risks associated with ICD-2? In particular, are there areas in which ICD-2 is regarded as either more or less technically risky than ICD-1? Are these risks recognized and addressed effectively in the RD&D plan?**
  - **Is the RD&D plan appropriately integrated with the ILC, SRF, HINS, and Muon programs?**
- **More generally, we would be happy to receive comments and suggestions from the AAC on how the initial configurations and associated RD&D program could be strengthened.**

Charge 1

- Does ICD-2 describe a configuration that
- is likely to meet the proposed mission
- objectives (reference to Tschirhart's
- report)?

- Does it meet broader and more flexible
- physics demands on beams?

Review Findings/Observations/Comments

- The committee heard an excellent presentation on the physics motivation for rare decay physics reach of the ICD-2 PX CW option, a strategic contribution to the intensity frontier. We can broadly look forward to increase in sensitivities of about two orders of magnitude better than the present limit. These studies will elucidate flavor physics, CP violation in the neutrino sector, and physics beyond the Standard Model.

- The minimum beam power necessary is 200 kW and the minimum beam energy is 2.6 GeV. Higher beam energies are preferred for several experiments but beam powers up to 2 MW provide some options for trade-offs between energy and beam power (a Table was presented). Preferred beam energies of 2.6 to 3 GeV were discussed. The variety of bunch structures required can only be fulfilled by a CW linac, rather than slow extraction, due to limits of beam losses at the septum.

- The committee finds that the ICD-2 configuration with beam energy 2.6 – 3 GeV and 2 MW beam power will meet the mission of the Rare Decay experiments.

Review
Findings/Observations/Comments(cont'd)

- To meet the objectives for LBNE, two options are considered for acceleration between 2.x and 8 GeV: an RCS of 1/6th the size of the Main Injector or a pulsed superconducting linac. The higher the energy of the ICD-2 linac the less attractive is the RCS option as compared to the pulsed linac follow-on. Increase of ICD-2 energy from 2 GeV (initial design) to 3 GeV will have a major impact on cost and choice of optimum gradient. For 2.6 GeV the strategy of adding five more cryomodule could be adopted.
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- The long range physics goals include high intensity proton drivers for the Neutrino Factory and the Muon Collider. The minimum beam power requirement is 4 MW with energy in the range of 5 – 15 GeV. The challenging pulse structure needed favors the pulsed linac approach.

- Therefore ICD-1 is the favored approach for extrapolation to the NF and MC. The ICD-2 configuration also favors a follow-on higher energy "pulsed" linac over the RCS approach. However there is no clear path to 4 MW beam power without replacing the CW front –end, which would be only a small fraction of such a major facility.

RECOMMENDATIONS

- **The entire physics case has been an exciting proposal without much details worked to date: details of physics needs, the necessary detector configuration for kilowatts at GeV level and finer demands on the beam, etc. We recommend FNAL leadership to mobilize the US and global Rare Decay community to further sharpen the definition of the experimental program in rare decays and develop a more detailed and robust beam specifications to address the physics goals.**

Charge 2

- What are the primary technical risks
- associated with ICD-2?

- In particular, are there areas in which
- ICD-2 is regarded as either more or less
- technically risky than ICD-1?

- Are these risks recognized and addressed
- effectively in the R&D plan?

Review Findings, Observations and Comments

- **What we heard was a collection of very first albeit exciting thoughts on an expanded physics program enabled by an alternate ICD-2 design;**

- **The added new elements are the CW Front-end, Chopper requirements, associated beam power, activation loss and issues of multi-turn injection into RCS;**

- **It is premature to judge the technical risks this early without detailed evaluation;**

- **The added risks are recognized but not integrated into a coherent R&D plan which is yet to be developed.**

RECOMMENDATIONS

- **Need to develop a detailed and thorough R&D plan for 2010 to 2012, for readiness of CD-2 by 2013.**

- **The R&D plan should recognize that the generic SRF development at FNAL must include pulsed and CW SRF developments simultaneously for institutional goals that transcend ILC developments.**

- **NOTE:**

- **FNAL has received funds for generic SRF skills base**
- **enhancement independent of ILC.**

Charge 3

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- Is the RD&D plan appropriately integrated
- with the ILC, SRF, HINS, and Muon programs?

Review Findings, Observations and Comments

- **A coherent RD&D plan, integrating ICD-2 within the ILC, HINS, SRF and Muon programs does not exist yet but the committee recognizes that this must be under active development at present.**

RECOMMENDATIONS

- **Establish both pulsed and CW SRF as R&D items at FNAL;**
- **The SRF test facility must allow electromagnetic testing of rf structures designed for not only electron beams but also for 2MW high current proton beams ;**
- **Organizational improvements (see comments later under HINS).**

Project-X ICD-2 Detailed Technical Comments

- **See separate report by Roland Garoby.**

Charge to the Committee
HINS

- **High Intensity Neutrino Source (HINS) Development**
- **The committee is asked to review and offer comments and recommendations relative to the current status of the HINS program and the strategy for achieving alignment of the HINS and Project X programs. More specifically we would like the Committee to comment on:**
  - **Are the technical goals of the HINS program well aligned with the needs of Project X? What are the primary technical risks within Project X that can and should be addressed within the HINS program?**
  - **Does the execution strategy of HINS mesh with the requirements of Project X? What modifications to the HINS program would be effective in aligning with either ICD-1 or ICD-2?**
  - **Are there other approaches, beyond those being explored in the HINS program, that should be investigated as the front end of the Project X facility?**
  -

Charge 1

- Are the technical goals of the HINS program
- well aligned with the needs of Project X?

- What are the primary technical risks within
- Project X that can and should be addressed
- within the HINS program?

Review Findings, Observations and Comments

- **The committee finds that there is room for better alignment of the technical goals of HINS with Project-X, recognizing the fact that Project-X has been shifting from ICD-1 to ICD-2, with drastic changes such as pulsed to CW front-end etc. making the task of alignment difficult. The technical goals of HINS were better aligned with ICD-1 prior to this change-over;**

- **The committee recognizes the need for thoughtful management of expectations from the laboratory leadership on alignment of its programs, given changing scenarios;**

- **The primary technical risks within Project-X that can and should be addressed by the HINS program are in the areas of Chopper development and appropriate and necessary beam instrumentation for Project-X.**

RECOMMENDATIONS

- **The chopper and beam instrumentation should be developed for CW applications for Project-X ICD-2 version but can be checked with pulsed beam to a large dgree.**

Charge 2

- Does the execution strategy of HINS mesh
- with the requirements of Project X?

- What modifications to the HINS program
- would be effective in aligning with either
- ICD-1 or ICD-2?

Review Findings, Observations and Comments

- The HINS leadership and team have demonstrated significant effort in developing a strategy that meshes with the shifting requirements of Project-X – a difficult and challenging call;

- The committee notes that HINS goals and missions have not changed over the years while definition and vision for the next high current proton facility or Project-X has been shifting from ICD-1 to ICD-2 to……

- The result is still far from satisfactory: HINS and Project-X integration need the direct attention and thoughtful support of laboratory leadership now, both to preserve the HINS expertise and resources and to streamline laboratory overall resources to advance Project-X.

RECOMMENDATIONS

- FNAL leadership should consider HINS as part of the Project-X program organizationally and not an independent program;

- HINS should be completed as far as is needed to be an effective R&D test facility only for the Project-X. Certain elements will need to be re-examined as to their essential nature to Project-X or otherwise e.g. superconducting solenoids, extra cavities and cryostats, RF converters and vector controllers for multiple cavities etc;

- In view of the fact that it will be difficult to consider HINS as morphing into the real front-end of the ICD-2 and that FNAL is developing into a high current proton laboratory, FNAL leadership should consider transforming the HINS program into a proton test facility of much reduced scope, with limited operation for R&D but a definite and affordable albeit identifiable budget and external partners and stakeholders from other laboratories to join in advancing high current proton R&D and applications.

Charge 3

- Are there other approaches, beyond those
- being explored in the HINS program, that
- should be investigated as the front end of
- the Project-X facility?

Review Findings, Observations, Comments and Recommendations

- There are a few European and Asian programs that have similar front-ends: ESS, SPL, RAL Front-End Test Stand, Chinese Neutron Source etc.;

- The committee recommends that FNAL look into these already existing designs and benefit from them.

HINS Detailed Technical Comments

- **See separate report by Stuart Henderson**

Charge to the Committee
Committee's discretion

- **As usual the committee is invited to issue comments or suggestions on any aspect of the programs discussed beyond those specifically included in this charge.**

- **→ The committee has chosen to look into the**
- **aspect of integration of SRF activities across**
- **the laboratory and comment on it.**

- **→ See separate report by Ilan Ben-zvi.**

HINS Program

Stuart Henderson (Chair)
Ilan Ben-zvi
Guenther Geshonke
Kathy Harkay
Hans Weise
And the entire AAC

Integration with Project-X

- The original goals of HINS remain reasonably well-aligned with the ICD-1 linac, but ICD-2 deviates from those same HINS goals in significant ways. In particular, the motivation for a substantial beam demonstration program, focusing on emittance and halo growth is partially obviated in the CW approach.
- There is therefore a range of capabilities that one would want to see demonstrated in HINS, depending on which approach is followed for Project X. For a CW approach, HINS offers a test-bed for development, even at reduced beam energy. For a high-intensity pulsed approach, it remains necessary to evaluate beam dynamics issues like emittance and halo growth.
- In any case, HINS offers a platform that will enable development and testing of components that are critical to Project X. In particular, the chopper system that is required in ICD-2 is beyond the present state-of-the-art. A platform that allows the possibility of dedicated beam experiments is critical, and is **justification enough for continuing the HINS program to an energy beyond 2.5 MeV for the evaluation of chopped beam quality and extinction following RF capture.**

Integration with Project-X

- Likewise, HINS offers a platform that will enable development and testing of beam instrumentation that will be essential for Project X which is difficult to obtain elsewhere.
- In fact, HINS would offer H-/proton test beam capability to the larger community, a valuable resource which is currently lacking in the U.S. There is the potential to engage the community in the formation of a very unique experimental program.
- The beam dynamics issues that HINS was originally designed to answer still remain relevant to the world-wide community, regardless of the direction that PX takes. However, the committee recognizes that there are finite resources and that those resources have to be deployed to the greatest benefit of the laboratory. **Therefore, we recommend an alignment of the HINS effort toward the specific goals of Project X,** as described below.

Integration with Project-X

- The superconducting spoke resonator program, currently part of HINS, obviously has to continue in either variant of Project-X. There is an opportunity now to better align the ongoing development of the 325 MHz acceleration technology with the specific needs of Project X. **The time is right for the SSR development work to be directed toward the specific Project X goals, which in the case of ICD-2 means CW, 2K operation.**
- Regarding potential beam demonstration through spoke cavities: **provided that the decision is taken to prototype an SSR1 cryomodule, then the committee recommends a beam test through an SSR cryomodule to serve either technical approach for Project X.**
- Likewise, the HINS chopper development provides a solid platform upon which to build the PX chopper. The time is right to align the chopper development program with the specific goals for Project X.
- Further, the beam instrumentation development envisioned for PX can be fully integrated into the HINS effort.

Recommendations

1. The committee recommends that HINS be fully integrated into, and serve the Project-X RD&D Program.
2. Ensure that the ultimate configuration of HINS, including the beam energy and the diagnostics suite, is sufficient to demonstrate the chopped beam quality that meets specifications for ICD-2.
3. Direct the SSR development program towards the specific Project X goals.
4. Provided that the decision is taken to prototype an SSR1 cryomodule, then the committee recommends a beam test to serve either technical approach for Project X.

Technical Issues - General

- The committee was pleased to see recent progress on resolving the RFQ detuning and conditioning issue, the test of a prototype H- ion source, source/LEBT emittance measurements, the very successful test of the second SSR1 cavity and successful test of a number of RT-CH cavities with LLRF control.

Technical Issues – Solenoid Focusing

- The fringe field at the location of the cavity has been reduced to 10 Micro Tesla using bucking coils and shielding. This is an outstanding result considering the space limitations and strong field of the solenoid. However, if the cavity quenches at this field level, the Q value would be degraded by a factor of two or possibly more. This might eventually require a temperature cycling of the cavity.

Recommendations

1. Evaluate the impact of a potential factor of 2 degradation in Q, and consider a mitigation strategy for the fringe field, for example a cold magnetic shield around the cavity

Technical Issues – Spoke Resonators

- Regarding the use of SSR1 cavities for the Project X cw linac: the cavity and coupler should be fine up to 1 mA cw. Cryogenically, the cavity has to be operated at 2 K. The actual HINS infrastructure does not allow for this.
- The work on the two SSR1 prototypes is showing progress. The results are promising and one can expect good results from the first test with the jacketed cavity.
- **The SSR work should be continued in the context of the needs of Project X.**

Technical Issues – Chopper Systems

- The HINS chopper is at the edge of the state-of-the-art.
- For Project X the requirements are even more challenging. Such a chopper system does not exist anywhere today. The chopper is a very important component of Project X, and needs a substantial development effort. **For ICD-2 it represents one of the major risks of the entire technical approach.**
- SNS found that beam tests were necessary to understand the extinction ratio and the efficiency and quality of chopping. **The Committee strongly supports the use of HINS for these vital tests, and emphasizes the importance of ensuring that HINS is configured in such a way that fully supports the chopper development and beam quality demonstration program.** Adequate beam diagnostics have to be available, in particular to qualify beam tails and the extinction.
- It should be emphasized that the handling of such high chopped beam powers at 2.5 MeV is itself a real challenge for the absorber design. There are strong arguments for **pursuing two-stage chopping by incorporating a chopper system before the RFQ.**

Recommendations

1. Align the chopper development effort to address Project X needs, making full

Technical Issues - Beam Instrumentation

- The preliminary suite of proposed diagnostics is an excellent start. HINS provides a very valuable platform for Project X instrumentation development and testing. **A vigorous program making the best use of HINS capabilities is encouraged.**
- The characterization of the chopper system is a critical issue for Project X ICD-2. Characterization of chopped beam quality and extinction will require the development of longitudinal diagnostics. The need to quantify beam halo for the high power Project X linac requires development of techniques with sufficient sensitivity and dynamic range. **It is encouraging to see the instrumentation team considering these issues already at this stage.**
- The committee applauds the collaborative approach taken for instrumentation and encourages its continuation.

Recommendations

1. Fully utilize the HINS capabilities for development and testing of instrumentation for Project-X

ICD-2 and RD & D Plan

R. Garoby, S. Henderson, K. Oide,
H. Padamsee, T. Raubenheimer

OUTLINE

1. ICD-2 objectives
2. ICD-2 design

FNAL AAC

Findings (1/2)

1. ICD-2 Objectives

- The Committee heard an excellent presentation on the physics motivation for the rare decay experimental program at Project-X, a strategic contribution to the intensity frontier. The potential is an increase in sensitivities of about two orders of magnitude wrt the present limits.
- IC-2 makes use of a CW superconducting linac accelerating up to 2.x GeV to meet the associated requirements:

	Proton Energy (kinetic)	**Beam Power**	**Beam Timing**
Rare Muon decays	2-3 GeV	>500 kW	1 kHz – 160 MHz
(g-2) measurement	8 GeV	20-50 kW	30- 100 Hz.
Rare Kaon decays	2.6 – 4 GeV	>500 kW	20 – 160 MHz (<50 psec pings)
Precision K^0 studies	2.6 – 3 GeV	>100 μA (internal target)	20 – 160 MHz (<50 psec pings)
Neutron and exotic nuclei EDMs	1.5-2.5 GeV	>500 kW	> 100 Hz

Findings (2/2)

1. ICD-2 Objectives

- To inject into the Main Injector and meet the objectives of Long Baseline Neutrino Experiments (LBNE), two options are considered in IC-2 for acceleration between 2.x and 8 GeV: an RCS of 1/6th the size of the Main Injector or a pulsed superconducting linac.
- The long range physics goals include high intensity proton drivers for a Neutrino Factory or a Muon Collider. They have to deliver a beam of 4 MW in the energy range 5 – 15 GeV with a challenging pulse structure which favors the pulsed linac approach. Therefore IC-1 is the favored option for extrapolation to the NF and MC. In the case of IC-2, the upgrade to the requirements of the Proton Driver for a Neutrino Facility or a Muon Collider remains possible, although more complicated than for IC-1, if a pulsed linac is used for acceleration between 2.x and 8 GeV.

Comments/assessments

1. ICD-2 Objectives

- *The 2.x GeV – 2 MW CW linac proposed in ICD-2 can meet the requirements of the rare decay experiments.*

- *Both the RCS and the pulsed linac can fulfill the LBNE objectives.*

- *An RCS would make difficult the upgrade of Project-X for becoming the Proton Driver of a Neutrino Factory and progressing towards a Muon Collider. It should however be noted that these projects are still far in the future with uncertain designs.*

Findings (1/3)

2. ICD-2 Design

- The configuration initially proposed for Project-X (“IC-1”) correctly addressed the needs of Long Baseline Neutrino Experiments using the Main Injector (2 MW at 60-120 GeV), but it could not supply the high power (MW) and quasi-continuous, beam required at a few GeV by world-class rare decay experiments. The new configuration (“IC-2”) is proposed to satisfy this need.
- IC-2 makes use of two cascaded accelerators to bring the beam to the kinetic energy of 8 GeV for injection into the Main Injector:
  - a CW superconducting linac up to 2.x GeV to serve a variety of experiments on rare decays (The precise energy remains be defined with users. Today’s preferred value is 2.6 GeV.).
  - an RCS of 1/6th the size of the Main Injector or a pulsed superconducting linac to accelerate between 2.x and 8 GeV.

Findings (2/3)

- The present design of the CW linac in IC-2 is derived from IC-1. It uses the same types of accelerating structures, at the same frequencies with the same transition energies.
  - The main differences are:
    - The ion source is DC
    - Field is always present in the accelerating structures
    - RF amplifiers operate in CW
    - Instantaneous beam current is low (1 mA).
  - As a result:
    - a reduced accelerating gradient is used to reduce heat loss to cryogenics, which makes the linac longer,
    - the beam is bunched at 162.5 MHz by the RFQ to ease chopping in the 2.5 MeV MEBT.

Findings (3/3)

2. ICD-2 Design

- The basic concepts for the design of a 10 Hz RCS accelerating from 2.x to 8 GeV to fill the Main Injector in 6 pulses have been worked out. Main specificities:
  - Long injection time (4.3 ms) resulting from the small linac current of 1 mA,
  - Ultimate limit in beam power at 8 GeV: ~ 1 MW (time structure unlikely to meet NF/MC demand)
- The design of a pulsed linac accelerating from 2.x to 8 GeV would be derived from IC-1. Multiple solutions are envisaged for its operating mode. The upgrade to a multi-MW beam power is conceivable, after replacement of the RF in both linacs. Concepts have been proposed for getting the beam time structure necessary for a NF/MC(?).

Comments/Recommendations (1/3)

2. ICD-2 Design

- ***The precise needs of the experiments have to be defined before designing the CW linac.*** *The present design of the 2.x GeV CW linac in IC-2 can only be considered as preliminary.*

- ***A proper design shall be based on the users needs and result from an optimization of all linac parameters*** *(types and number of cavities, RF frequencies, transition energies, gradient and temperature in the cavities, segmentation of cryogenics and vacuum, type and location of beam instrumentation, interest of H+ etc.).*

- ***Existing hardware should be taken into account when deciding between sc and rt technology for the RF separator.***

Comments/Recommendations (2/3)

2. ICD-2 Design

- ***The RCS is feasible but challenging.*** *For example, electron cloud effects deserve investigation and study of cures/mitigation, as well as instabilities due to the impedance of RF cavities.*

- ***An operating mode remains to be selected in the case of the pulsed linac.*** *Immediately after will a detailed design be possible, taking into account the specificities which make it differ from the IC-1 proposal.*

- ***Because of the preliminary nature of the present designs, IC-2 cost estimates necessarily suffer from a significant uncertainty.***

Comments/Recommendations (3/3)

2. ICD-2 Design

- *The preliminary nature of the IC-2 design makes it difficult to fully evaluate the risk of this new approach.*
- ***For the time-being, the Committee does not see any topics other than the low energy chopper and the accumulation in the MI or RCS that appear to pose significant risk.***
- ***No IC-2 specific RD&D plan was submitted to the Committee. Such a plan has to be prepared by the design team, once a detailed design will be made.***
- ***Within IC-2, the decision between RCS and pulsed linac will only be possible when convincing solutions will be described addressing the technical difficulties.***

SRF Integration

Ilan Ben-Zvi, Roland Garoby,
Stuart Henderson, Hassan Padamsee, Hans Weise

Findings

- The committee was impressed with the advances in setting up general infrastructure
- We were presented with convincing evidence for the need to broaden the Project-X mission to CW operation
- Various changes are required by the proposed change to CW
- We were presented with excellent results in SRF 1.3 GHz, 3.9 GHz, 325 MHz.

Observations

- A good degree of integration is found in the SRF efforts.
- The strong infrastructure supports all programs, such as ILC, Project-X and HINS.
- The possibility of a SRF CW mated to a pulsed linac with no RCS is very attractive.

Recommendations

- The EP processing facility at Argonne has been successfully qualified for 35 MV/m for single cells, but the facility still needs to be fully qualified to reach 35 MV/m gradients for 9-cell cavities needed for ILC and helping a pulsed linac. We recommend that this effort be intensified as available resources will allow.

Recommendations

- The first 1.3 GHz, 9-cell cryomodule was successfully assembled. The testing of this module has been delayed. The committee recommends a re-organization of priorities to complete this urgent test. There is no guarantee that this module will show excellent results given that there is a learning curve.

Recommendations

- We recommend developing an overall RD&D plan describing the path from IC-1 to IC-2:
  - Choice of optimum gradient, optimum operating temperature should be done with the best recent results concerning the BCS and residual surface resistances.
  - Need to study impact of HOM on beam optics, power generation at cryogenic temperatures.
  - Study of an SRF RFQ which might be a natural approach for a CW Project X injector.

Recommendations

- Study the use of a lower frequency (650 MHz) elliptical cavities as the intermediate beta which could offer many advantages including:
  - Better effective gradient
  - Lower cryogenic load
  - Reduced HOM load
  - Larger bore to reduce halo interception