Feel free to post here questions for the speakers

Future Colliders Workshop

5/17 Accelerator Session

Introduction to CCC Demonstration Plan and Goals – Emilio Nanni

https://indico.fnal.gov/event/54189/contributions/239904/attachments/155205/202057/CCC%20Demo%202022.pdf

● High-gradient (≥155 MeV/m) test with gradient margins of a damped and detuned C3 accelerating structures at S-band and C-band

Is it ok to show this in Stage 1 without beam? Where can we do this as soon as possible? Single structure or a raft?

● Testing of the cryomodule at gradients required for C3-550 (goal is to reach ≥155 MeV/m for margin)

If we do this in Stage 2 what type of beam should it be with? Single bunch or bunch train from DC gun with full beam loading? What do we need to measure - energy/rf stability? Alignment?

● Demonstration of a fully engineered cryomodule with full beam loading in at least one cryomodule

With beam from thermionic gun or photoinjector?

● Demonstration of full C3 LN2 and vapor flow in 3 cryomodules as well as verification of vibrations and alignment stability.

Could this be done with just 1 or 2 cryomodules? Are vibration measurements enough or should we also run with beam?

● What controls/LLRF systems do we need for the demo and to develop for the full complex?

● Experimental verification of the tolerances and specifications for production of the main linac cryomodules, including assembly procedures.

How many cryomodules and rafts do we assemble and test? Industry or lab built/assembled?

● Demonstration of a viable rotation and cooling system for a positron production target When does this need to happen?

● Plan is to use commercial rf sources for the demonstration R&D Some modifications required to modulator and klystron - optimize for our average power.

When does this happen? Starting in stage 1 or after Stage 4?

● What does the injector look like for the demo?

● Liquid nitrogen delivered by truck for the demo and re-liquified for a collider. What studies are needed to optimize cryogen distribution and production?

● What is the right staging and siting for the Demo R&D needed for C3 ?

● What are we missing?

Kevin : what has been already demonstrated for the gradient?

150 MeV/m been demonstrated at X-band with beam, single cavity in C-band has been demonstrated at RadiaBeam, limited by the RF power

https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.24.093201

Question: how does the structure lifetime change as a function of operations.
> It has been studied from the High Gradient program, CLIC has studied this too. Copper structures being operated within the same conditions show stable performance over time, i.e. SLAC linac.

Vladimir:
1) Gradient < x2 → energy goes up by > 2x within the same footprint, how is that possible?
→ spare capacity within the structure, which roughly sums up to 400 m spare linac during 250 operations.
Q : What do we do with the spare cryomodules?
2) final system ?
3) show the minimal cost estimate for C3-250 with the shortest tunnel with smallest radius and assuming Cut and Cover

Michael P.: There is a particular consideration here for C^3. C^3 250 will certainly be cheaper with a shorter BDS, cut and fill installation, minimal linac length for 250 GeV. There are two savings, one in the linac cost, one in the overall length. The linac cost saving is a small part of the budget, since the linac cost is dominated by the RF cost, and the higher RF is not being installed at the 250 GeV stage. The more problematical issue is the length. If the minimal cost optimization leads to a siting such that the linac cannot be extended in energy to do the top quark physics and Higgs self-coupling (both require ~ 500 GeV), this would be a poor choice with respect to the physics.

Structure Design and Damping Zenghai and Shumail:

https://indico.fnal.gov/event/54189/contributions/240822/

John Power: How does HOM power loss compare to fundamental power loss?

HOM power loss is much lower than fundamental power loss. Fundamental power loss is 2500 W per m. A simple estimate from longitudinal wake gives 1 W per m lost to HOM.

Sergey B.: Is damping required in halves or quadrants?

Yes absolutely

Alignment requirement to avoid coupling of fundamental mode to the damping slot coupling?

The current flow from the fundamental mode is parallel to the slot and azimuthally symmetric. Vertical offsets and lateral offsets don't break this symmetry so the coupling is extremely weak. A tilt in the cut with respect to the beam axis would break this symmetry and it could couple. Fortunately the cut is machined with reference to the beam axis so we

have ~10 micron machining accuracy. The gap size is 300 microns at the cavity surface so the tilt over does not pose a problem.

Lateral alignment and longitudinal alignment will be very important in terms of producing distortions in the field profile of the fundamental on the beam axis.

Raft Design and Alignment Valery:

https://indico.fnal.gov/event/54189/contributions/240823/

How does this compare to the alignment procedure for CLIC?

CLIC has similar tolerances, also plans on stretched wire

Structure Testing Update and Plans - Evgenya Simakov

https://indico.fnal.gov/event/54189/contributions/240824/

LANL interested in C-band both for proton linac booster as well as compact x-ray source. Space is at a premium

Vladimir : how close are the parameters to those needed to demonstrate C^3?
>> it can be made as close as possible to fit C^3 needs in terms of charge and repetition rate. Early July it would be known if they're funded at LANL for an injector.

Sami: doping copper improves the breakdown rate. Evgenya: they have done tests already at room temperature & high gradient but not yet at low temperature.

Simulations of doping Cite as: Appl. Phys. Lett. 120, 134101 (2022); https://doi.org/10.1063/5.0084266

How does the performance change 0%-Ag vs 0.8%-Ag vs 2%-Ag - I thought I saw both dopings of Cu-Ag alloys. If increased doping is promising, could the alloy go to 5%-Ag?
Evgenya's answer: theory does say that higher Ag concentration should increase the breakdown limit. We have to test that. We are fabricating a CuAg cavity with 2% of Ag. 5% of Ag may even be better, but more expensive. Eventually though we will reach the solubility limit, which I think is around 5%.

Jannicke: How are cavity temperature (slide 19) and breakdown probability/pulse heating (slide 10) inter-related? Is it possible to study breakdown probability as a function of cavity temperature?
Evgenya's answer: it should be possible for as long as we are capable of keeping the cavity's temperature constant at various values. The tests were done at room temperature, at 80K (liquid nitrogen) and at 40K (liquid neon). It is somewhat tricky to keep the temperature constant with a cryo-cooler.

Polarized Emitters & Cornell Activities - Jared Maxson

https://indico.fnal.gov/event/54189/contributions/240825/

Recent progress on developing new coatings to ease transfer and don't have as much sensitivity for UHV exposure

John Power : polarized cathode generation @ Pitz?
>> It was not looking at polarized. Challenge for polarized

Emilio: Jared - you mentioned thin coatings… I think you showed few hundred nm…. Could we look at 7-10 micron thick coatings? Jared: Very probably. What materials are of interest? Emilio: NiCr or other "bad" conductors at 80K

Emilio: Jare - What do think of cryo-pumping in the rf gun for improving UHV conditions in high gradient gun? Jared: This is a great point. It might have a huge benefit. The only drawback is that if the photocathode is cold, it will also be a pumping surface–interesting surface effects have been seen in SRF guns when the cathode gets cold (QE decrease), which could be from cryopumping. So in that sense, starting with a very pure vacuum even when warm might be important. But, like all vacuum issues, the real proof will be in a measurement–my speculations may be useless. :)

Donato Passarelli

Resolution that can be achieved with the HBCAMS depends on the distance between the camera and the target position. For 2.5 m is sub-μm level precision in the transverse direction. Longitudinally ~40μm accuracy

The camera has a flash that provides the light for the target. The camera is at room temperature. Possibly they can work at Cryo temperature. Targets are staggered along the cryomodule length but remain fixed.

Marty : The dissipation for C^3 (2.5kW/m) with liquid nitrogen (80K) can be accomodated in this cryostat ? To be checked for C^3 cooling requirements.
Christian Boffo: for liquid nitrogen (80K) the cryomodule design should be simplified.

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High Efficiency Klystron Development Igor Syratchev

Klystron code development very far along at CERN for HE rf sources development

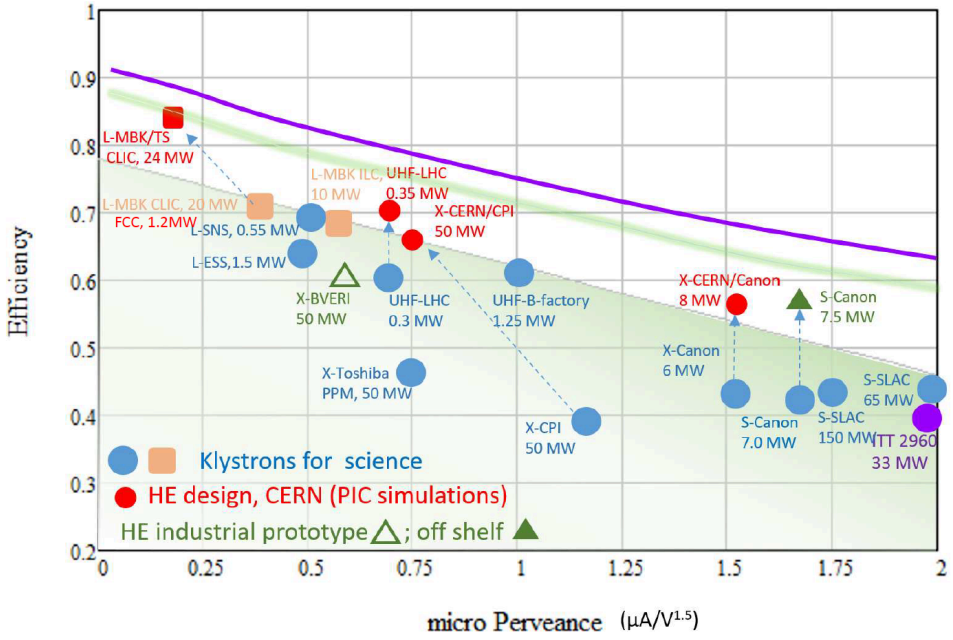
Klystrons shifting to industrial prototype production. Pursuing 10-50 MW class prototypes

(Emilio) If a prototype 50 MW class HE tube is built at X-band what concerns would there be scaling this to C-band? Igor - Easier going down in frequency due to the beam tunnel size.

Vladimir: How much time would it take to make this progress on the klystron efficiency - for magnets R&D reaching 16 T is a 20-years program because it's a very sophisticated technology.

>> depends on money available for the R&D

Efficiency performance of the selected commercial klystrons and the new HE klystrons (May 2022).



Complementarity Between Linear and Circular Colliders - Alain Blondel

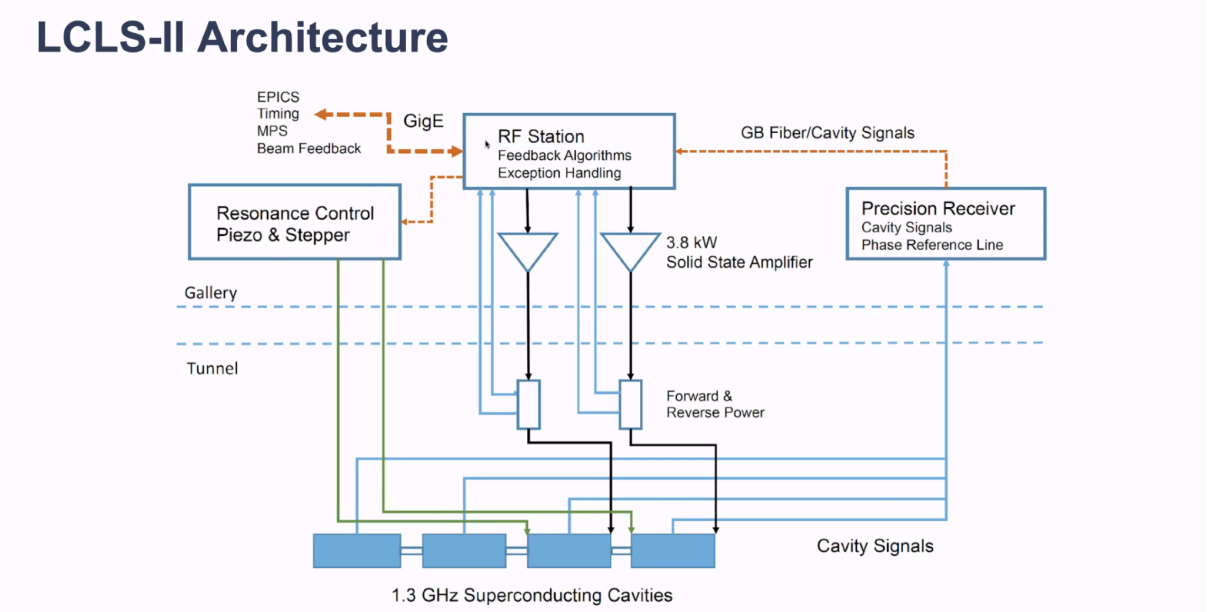
Large-Scale Cryogenics - Air Liquide

Modification of liquid N generation would have N2 gas inlet for cold box moved from 300K to the 80K side. This keeps all the same HW as commercial systems

$30-50M - 1.5 MW Plant $10M for HW rest is the site construction

Operations fairly simple. LN production plants operate with staff 40 hrs per week. Guess of 1 dedicated person to monitor plant operations.

LLRF - Carlos Serrano



Low latency could be very interesting for additional increase in beam performance. What effort level would be required to evaluate what approach would be needed to do low latency feedback on the rf signal? and then what timeline would be needed for demonstrating this with hardware? Is this something that could be added on later as a luminosity upgrade by making the beam better?

CCC structure has a relatively long fill time so low latency limit is probably around 100 ns for the structure. But the bunch train is long so would could be