# Synergies of FCC-ee with ILC and EIC

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@BrookhavenLab

# Outline

Timeline Highlights in Accelerator Developments for Future Higgs Factories

Recent Directives towards FCC-ee, the ILC and the EIC

Selected Synergistic Developments in Accelerator Science and Technology

Summary

# Timeline Highlights in Accelerator Developments for Future Higgs Factories

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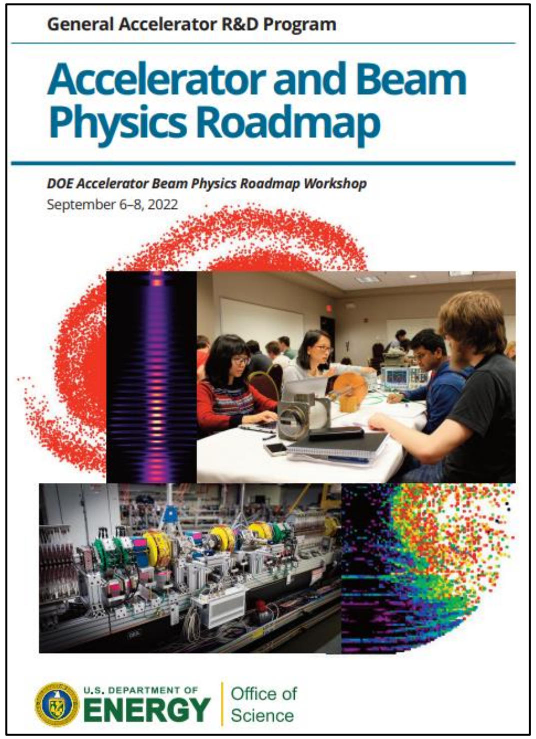
## Timeline Highlight – 2022 Acc. and Beam Physics Roadmap

lead author: S. Nagaitsev

- addressed four grand challenges: beam intensity, quality, control and prediction
- described **roadmap for Accelerator and Beam Physics** for the GARD program
- reference for Snowmass




## Timeline Highlight – 2022 Snowmass: Accelerator Frontier

conveners: S. Gourlay, T. Raubenheimer, V. Shiltsev

- 7 Topical Groups and multiple sub-groups
- preceded by **US FCCee planning panel** meetings with reference document

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## Timeline Highlight – 2023 (published): On the Feasibility of Future Colliders: Snowmass Implementation Task Force

lead author: T. Roser

**comprehensive summary** (see backup slide) of both time and cost scales of

- accelerator-related R&D
- associated test facilities
- facility operations

with uniformly applied metrics to compare project cost, schedule/timeline, technical risk, operating costs, environmental impact, R&D status and plans

**evaluated in four categories of colliders: Higgs factory colliders**, lepton colliders with up to 3 TeV COM energy, colliders with 10 TeV or higher parton COM energy, lepton-hadron colliders

| Proposal Name (c.m.e. in TeV) | Collider Design Status | Lowest TRL Category | Technical Validation Requirement | Cost Reduction Scope | Performance Achievability | Overall Risk Tier |
|---|---|---|---|---|---|---|
| FCCee-0.24 | II | | | | | 1 |
| CEPC-0.24 | II | | | | | 1 |
| ILC-0.25 | I | | | | | 1 |

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# Recent Directives towards FCC-ee, the ILC and the EIC

# 2023 P5 Report

From Executive Summary: The panel endorses an **off-shore Higgs factory**, located in either Europe or Japan, to advance studies of the Higgs boson …

- Recommendation #2 – Plan and start the following major initiatives … **an off-shore Higgs factory,** realized in collaboration with international partners…**The US should actively engage in feasibility and design studies**.

- Recommendation #6 - **Convene a targeted panel** with broad membership across particle physics **later this decade that makes decisions on the US accelerator-based program** at a time when major decisions concerning and off-shore Higgs factory are expected, and/or significant adjustments within the accelerator-based R&D portfolio are likely to be needed... The panel would consider the following:
  - The level and nature of US contribution in a specific Higgs factory including an evaluation of the associated schedule, budget, and risks once crucial information becomes available.
  - Mid- and large-scale test and demonstrator facilities in the accelerator and collider R&D portfolios.
  - …

- OHEP responses to P5 recommendations presented at the HEPAP meeting (9-10 May 2024)

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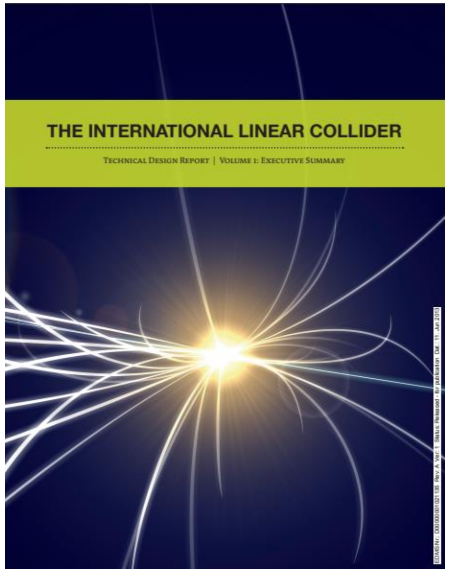
Joint Statement of Intent between [US and CERN] signed at the US White House indicating intent to collaborate on FCC-ee construction and physics exploitation if CERN member states determine FCC-ee likely as CERN's next facility subject to appropriate domestic approvals (26 Apr 2024).

# ILC Developments




The ILC TDR (Technical Design Report) was published in 2013.

In 2020, the International Committee for Future Accelerators (ICFA) appointed an **ILC International Development Team (IDT)**[1]**.**

The IDT outlined the remaining technical preparations necessary before ILC construction[2]; e.g. work planned to be executed during the ILC Preparatory Phase through an ILC Pre-laboratory (ILC Pre-lab), an international laboratory organized to perform the work. Launching the ILC Pre-lab requires a level of international agreement that does not yet exist.

KEK and the IDT are initiating **the ILC Technology Network (ITN)**[3] – a global collaboration of laboratories who wish to contribute to ITN's purpose; i.e. execution of high priority tasks identified by the IDT from the work packages described in the ILC Pre-Lab Proposal with framework defined in 2023.

[1] https://linearcollider.org/ [2] https://zenodo.org/records/4884718 [3] https://linearcollider.org/wp-content/uploads/2023/09/IDT-EB-2023-00

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**DOE-HEP has indicated that DOE, or the DOE national labs, do not intend to formally join the ITN at this time, but support for related technologies, including workforce development efforts, are planned to be coordinated under the U.S.-Japan Cooperation Program.**

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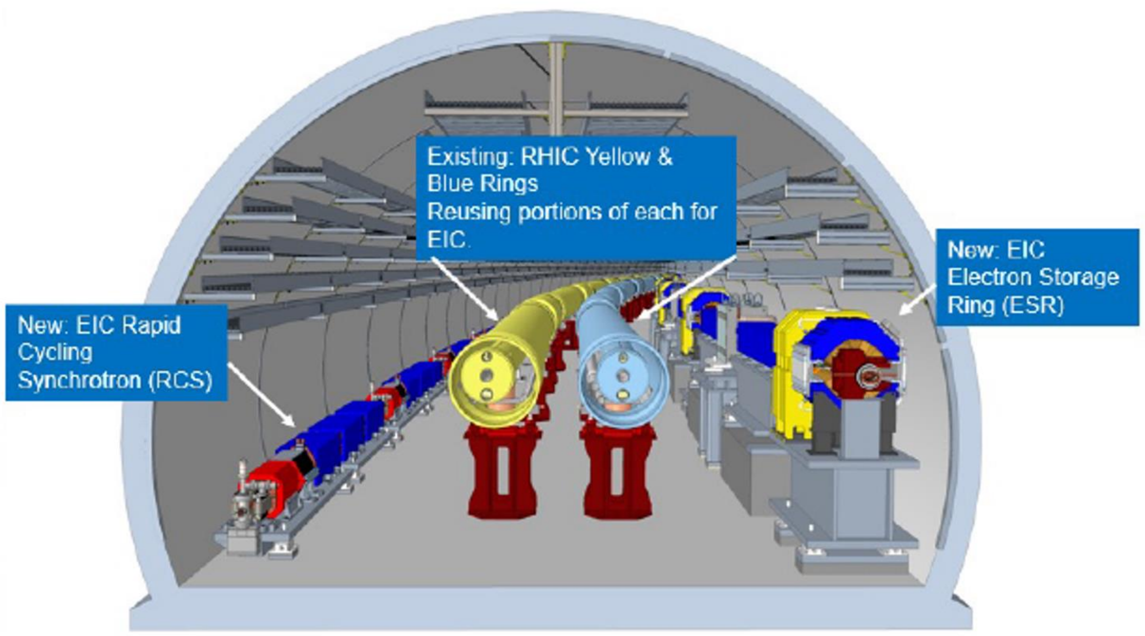
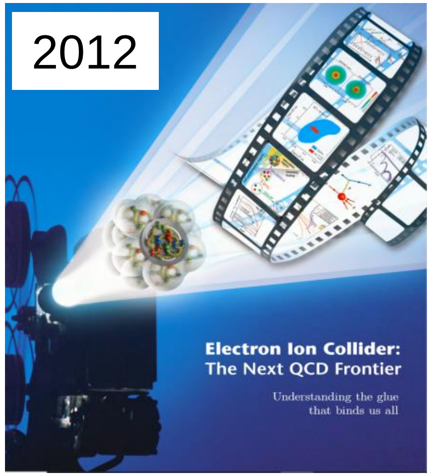
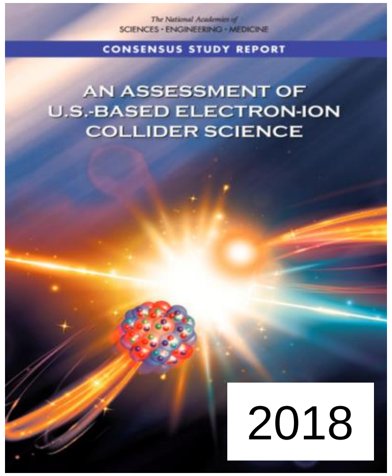
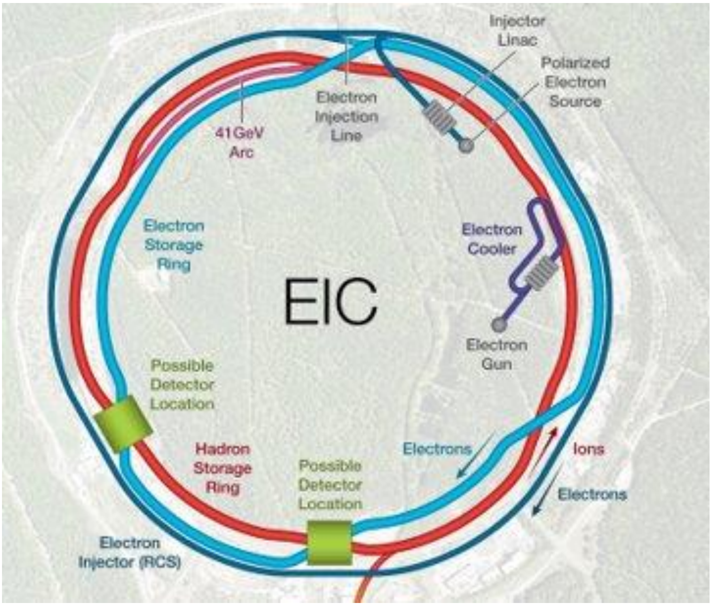
# Electron-Ion Collider (EIC) Project

- Q3FY2021 CD-1
- Q2FY2024 CD-3A
- Target Critical Decision (CD) milestones
  - Q1FY2025 CD-3B
  - Q3FY2025 CD-2/3
  - Q1FY2033 CD-4 (early)
  - Q1FY2035 CD-4



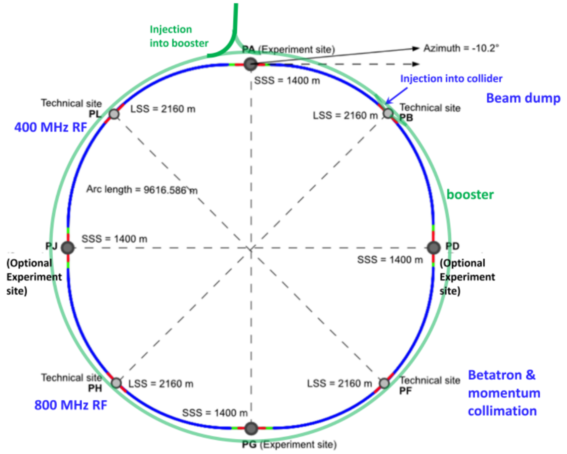
# Selected Synergistic Developments in Accelerator Science and Technology

A few examples illustrating relevant US expertise and core capabilities.

# FCC-ee / EIC / ILC – Layouts and Common Design Features

## FCC-ee

- double ring $e^+e^-$ collider
- asymmetric IR layout and optics to limit SR towards the detector
- 4 interaction points, 30 mrad crossing angle, crab-waist collisions

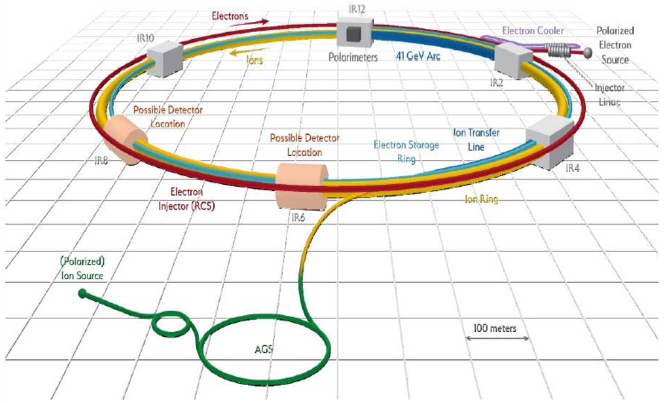



**Injector complex (baseline) -** e- and e+ sources, e- (6 GeV), e- (1.5 GeV) and common (20 GeV) linac; e+ damping ring (1.5 GeV), full-energy booster synchrotron (20 GeV to collision energy)

**Injector complex (post MTR, revised)** - e+ and e- (2.86 GeV) and common linac (20 GeV), damping ring

## EIC

- double ring $e^-$ - ion collider
- highly polarized e and p (& light ion) beams
- 1 interaction point with provisions for a second, 25 mrad crossing angle with crab cavities




**Injector complex**

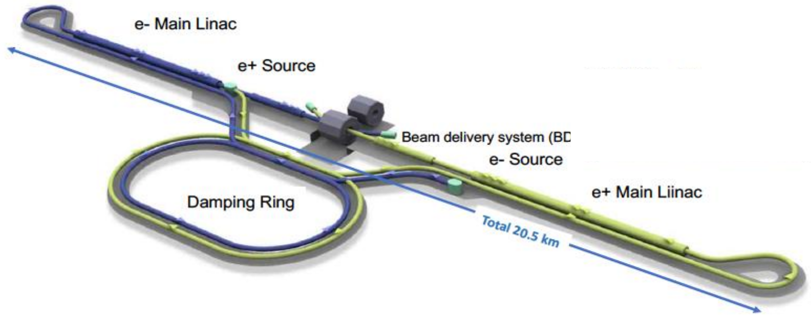
- ion (existing) injector and new electron source and 2856 MHz linac
- rapid-cycling, spin-transparent synchrotron (0.4 to 18 GeV)
- alternative: 1.3 GHz NC linac (200 MeV)+3 GeV booster or 1.3 GHz SC linac (200 MeV)

## ILC

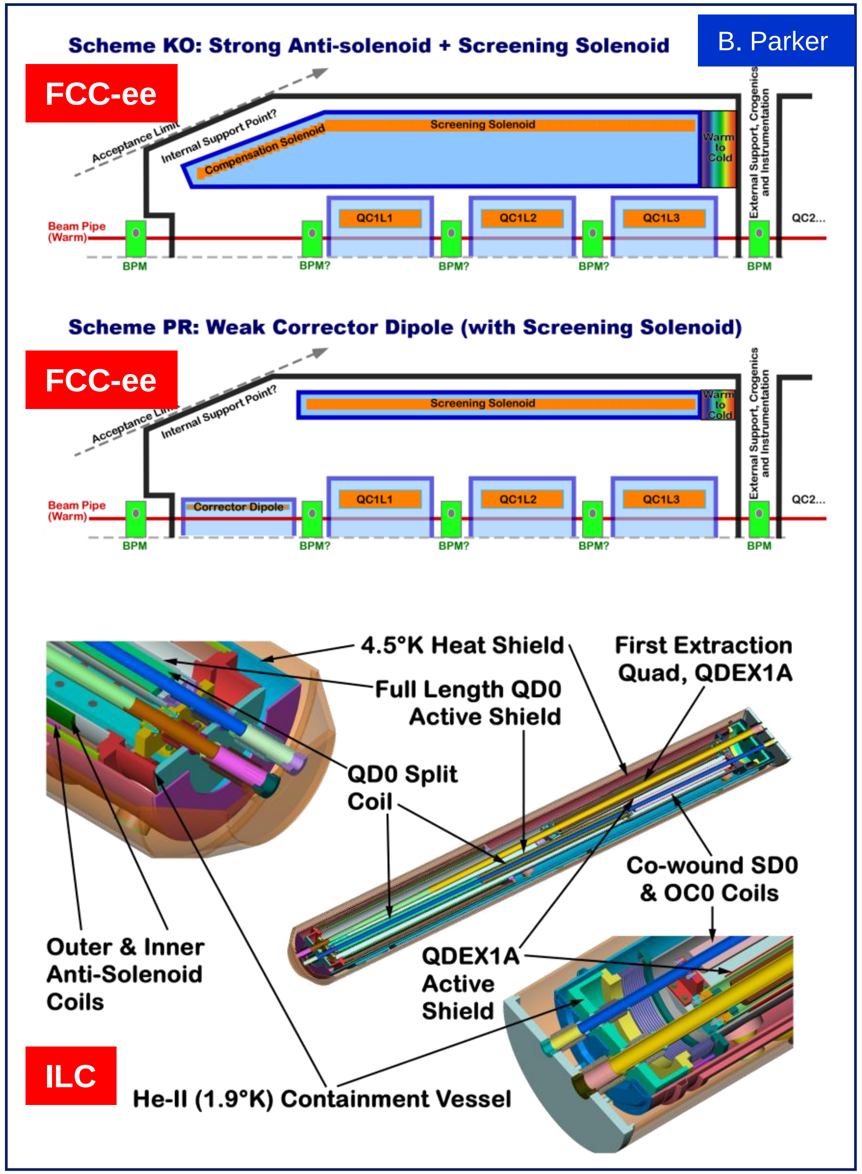
- double linac $e^+e^-$ collider, separate e+ and e- linacs (250 GeV)
- beam delivery systems with demagnification optics
- 1 interaction point, 14 mrad crossing angle, crab cavities for head-on collisions

**Injector complex**

- e- and e+ sources (polarized), e+ (5 GeV) booster linac
- damping rings (5 GeV)



# FCC-ee / ILC / EIC Synergies: Machine Detector Interface (MDI)




## Physics requirements

- detector stay clear (L* and forward angle)
- interplay with accelerator performance optimization

## Mechanical engineering requirements

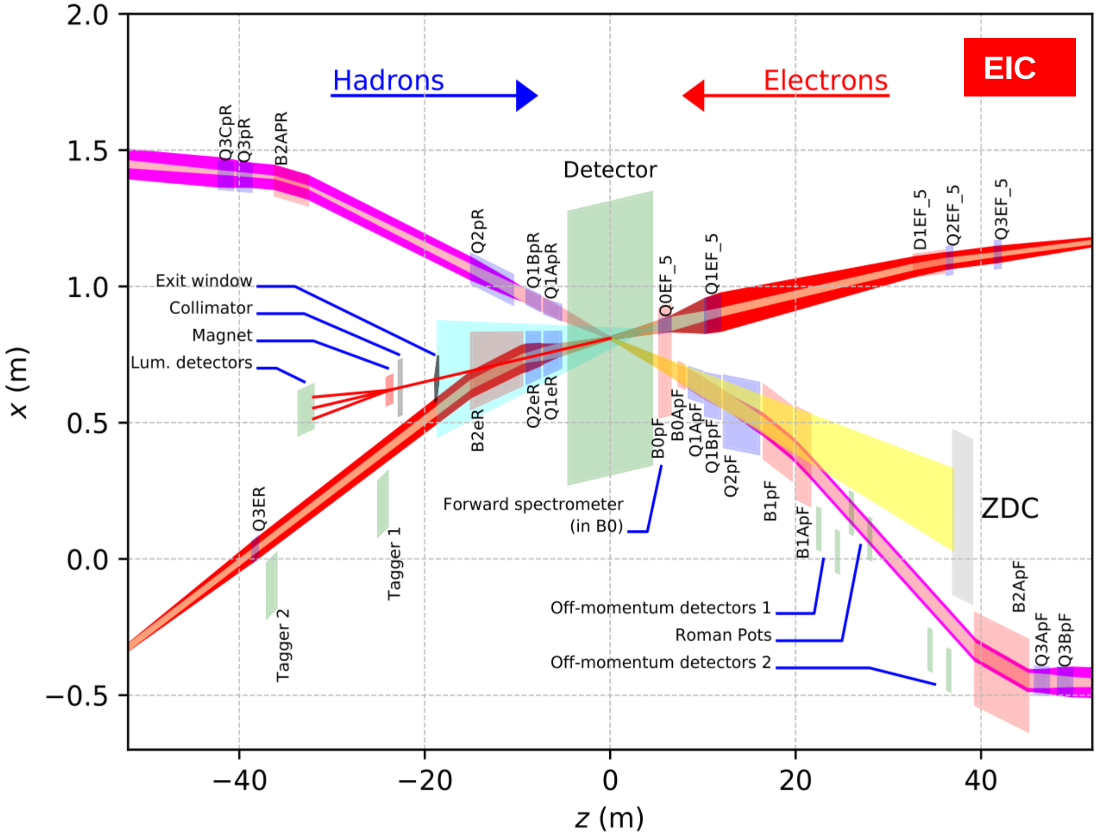
- beam pipe design (warm/cold transitions)
- cryostat support (from detector or external)
- detector installation and access requirements
- utility interfaces (cryogenics, leads etc.)

## Overlapping requirements

- vibration mitigation (including interactions with beam-based trajectory feedback systems)
- instrumentation (luminosity and beam position monitors)
- radiation shielding (beamstrahlung and radiative Bhabhas)
- space constraints

Collective experience in past and future colliders is critical in advancing MDI optimization.

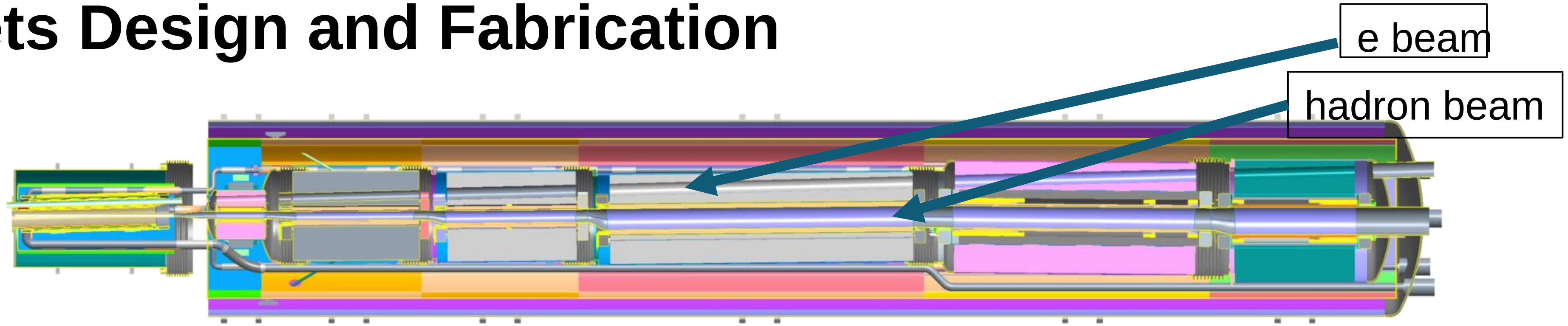
# EIC: Interaction Region Design



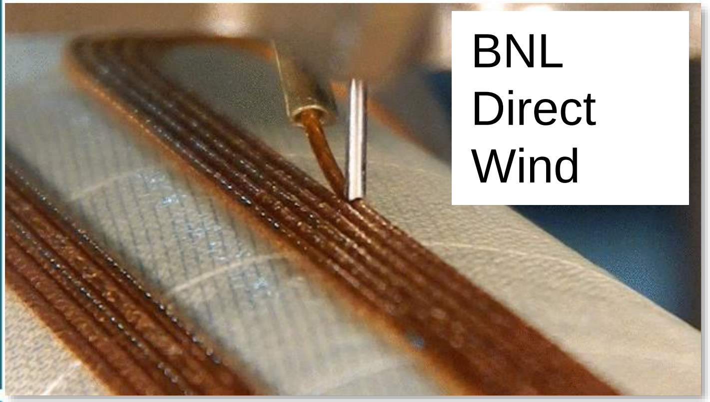

## FCC-EIC Synergies

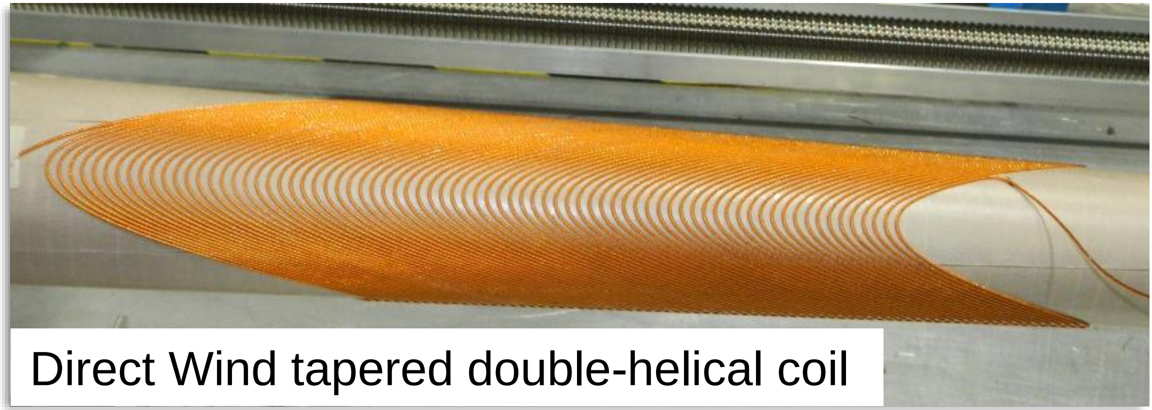
- modeling and simulations for dynamic aperture, chromatic aberrations, beam-beam effects, beamstrahlung, optics correction
- magnet designs and fabrication methods – coil configuration, field quality, coil forces, structural analyses
- quench protection, adjustable collimators
- luminosity monitors, control and measurements of beam losses and backgrounds, machine fault handling

# IR Magnets Design and Fabrication




- Direct Wind magnet technology (adapts to compact spaces, CCT-like local field adjustment)
- Collared magnet technology (warm e-beampipe, field crosstalk low)
- Complex magnet systems (integrate: 4.5K, 1.9K and warm systems, BPMs, current leads, low vibration supports)
- Development, prototyping, manufacturing, quench protection, testing





Direct Wind tapered double-helical coil

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# Superconducting Cavities
# Bulk Nb SRF Development

Presentation by K. McGee
(this afternoon, 11 June 2024)

- High-Q/High-gradient advancements to reduce overall cost of construction (length of ILC) or cooling (both ILC and FCC)
  - Moving away from complex N-doping process and exploring simpler and less costly low-($\sim 120℃$) and mid-($\sim 300℃$) temperature baking benefit FCC and ILC

1.3 GHz 9-cell baking treatment

- Modest R&D needed to bring sub-GHz bulk cavity performance to FCC 800 MHz spec (FCC-ee)
  - FCC-ee requirement of $Q_0 = 3 \times 10^{10}$ at 25 MV/m requires R&D to realize a consistent ~20% improvement over current sub-GHz cavity performance

- R&D in low-temperature baking and two-step baking shows potential to significantly increase 1.3 GHz cavity gradient, but more development needed to reach 50 MV/m+

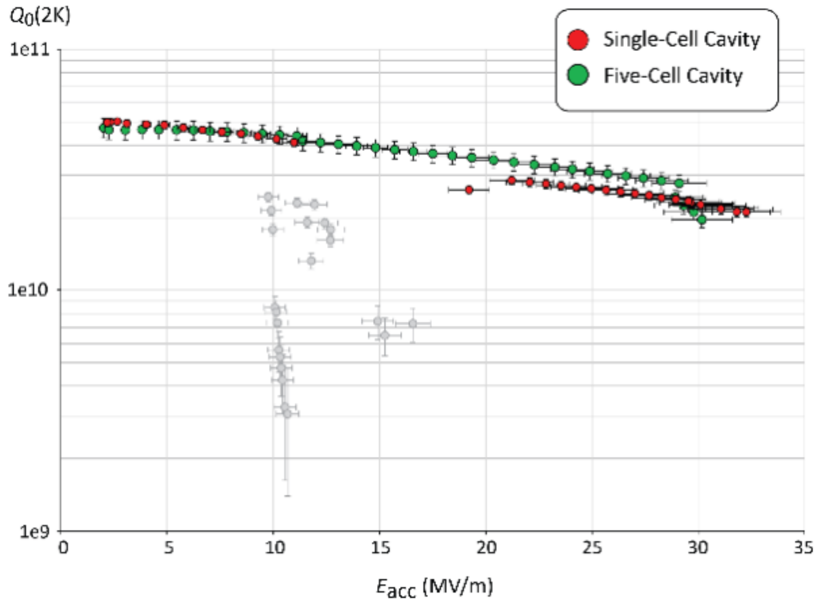


Figure 4: Combined VTA results for the five-cell and single-cell cavity as measured at 2 Kelvin.

Courtesy Kellen McGee

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# Superconducting RF Cavities Nb3Sn Development

Presentation by K. McGee (this afternoon, 11 June 2024)

Current status of Nb3Sn at FNAL

- > 20 MV/m demonstrated in 1-cell
- 15 MV/m demonstrated in multicell

FCC gradient demonstrated in Nb3Sn sub-GHz cavities

- R&D needed to realize this performance in multicell cavities and the cryomodule context

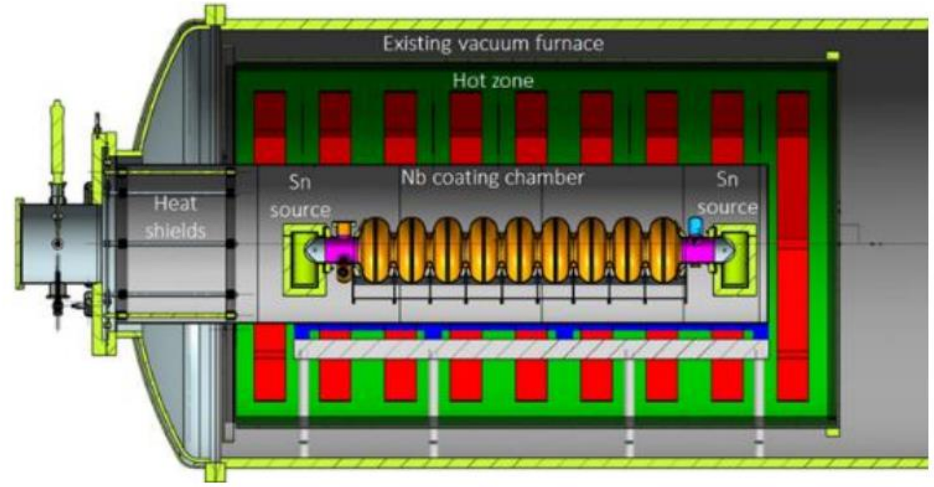



**Figure 3:** Horizontal furnace for $Nb_3Sn$ multicell cavity coating at Fermilab.

*Significant* further R&D is needed to reach high gradients in 1.3 GHz Nb3Sn cavities for potential use in ILC

- Nb3Sn cavity processing and handling techniques also require R&D to enable consistent quality in ~16,000 cavities for ILC.

Courtesy Kellen McGee

# EIC Design Overview

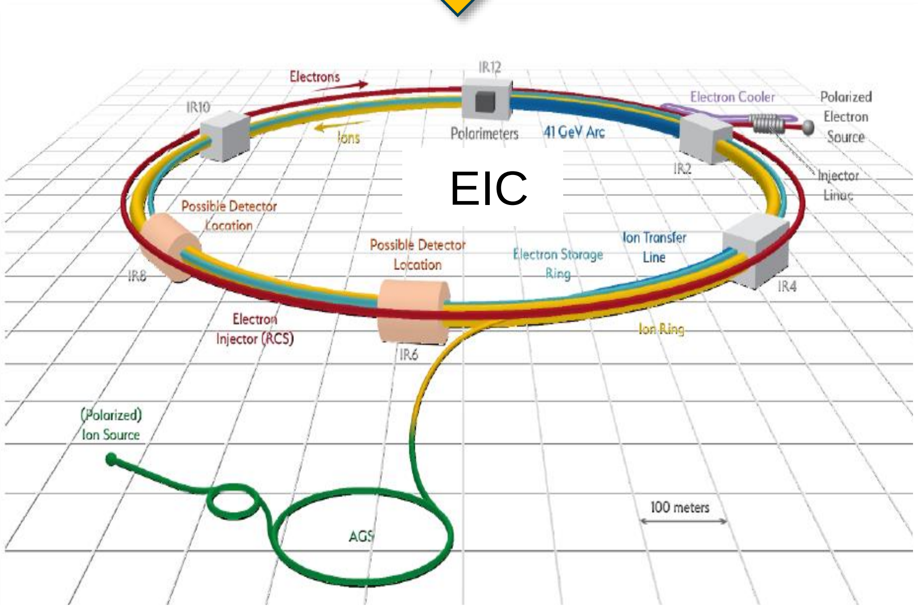
Design based on **existing RHIC Complex**
RHIC is well maintained, operating at its peak
RHIC accelerator chain will provide EIC Hadrons
EIC constructed in Collaboration with **JLab**

**Hadron storage Ring (RHIC Rings) 40-275 GeV**
- Superconducting magnets (existing)
- 1160 bunches, 1A beam current (3x RHIC)
- bright vertical beam emittance 1.5 nm
- strong cooling (coherent electron cooling)

**Electron storage ring 2.5–18 GeV**
- large beam current, 2.5 A ➔ 9 MW S.R. power
- S.C. RF cavities
- Need to inject polarized bunches

**Electron rapid cycling synchrotron 0.4 (or 3.0) to 18GeV**
- 1-2 Hz
- Spin transparent due to high periodicity

**High luminosity interaction region(s)**
- $L = 10^{34} cm^{-2} s^{-1}$
- Superconducting magnets
- 25 mrad Crossing angle with crab cavities
- Spin Rotators (longitudinal spin)
- Forward hadron instrumentation

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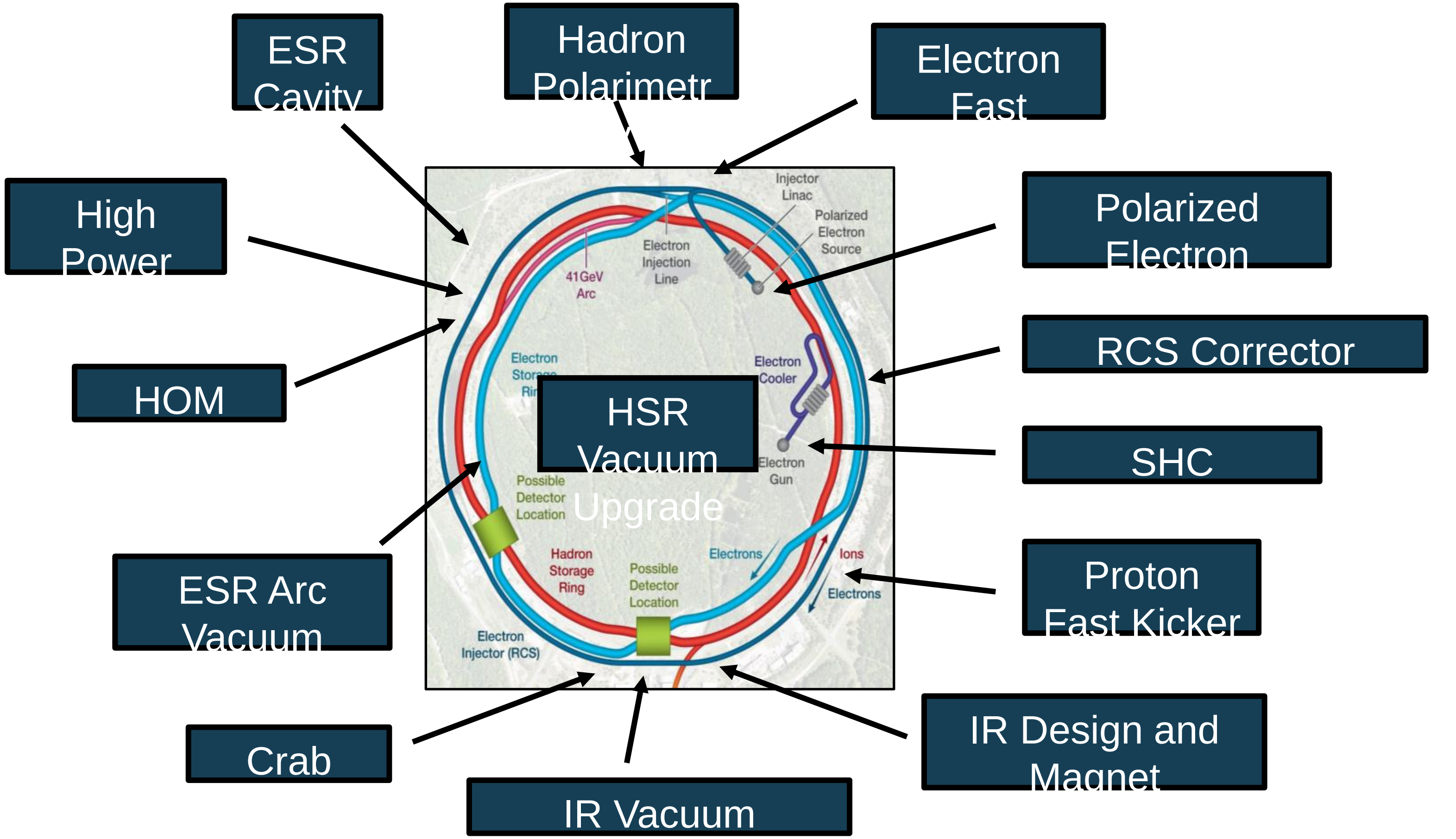
# Synergies with the Electron Ion Collider (EIC)




The EIC Project **R&D** efforts support **innovative and critical conceptual designs** by providing an initial design process with calculations, simulations, and layouts… Thus, project **R&D** is very **focused on the needs of the project** to advance to manufacturing the state-of-the-art system components required for the EIC.

Courtesy Qiong Wu

- FCC-EIC Joint & MDI Workshop (Oct 2022) https://indico.cern.ch/event/1186798/
- EIC Workshop – Promoting Collaboration on the EIC (Oct 2020) https://indico.cern.ch/event/949203/
- First annual US FCC workshop (May 2023) https://www.bnl.gov/usfccworkshop/
- Second annual US FCC workshop (Mar 2024) https://indico.mit.edu/event/876/

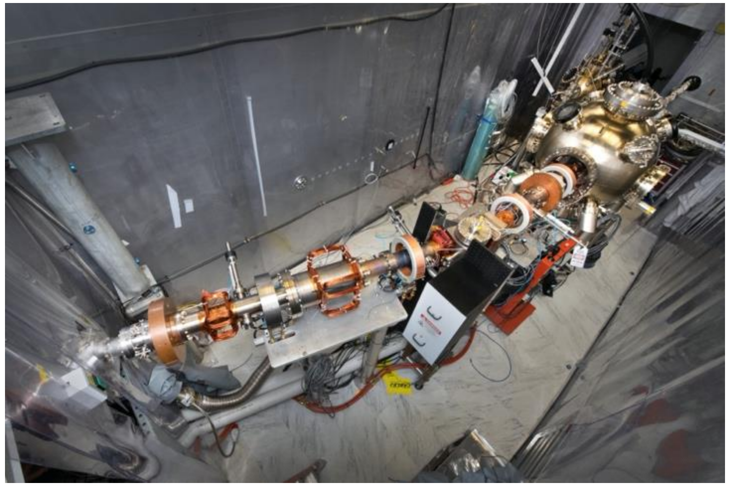
# Ongoing EIC project R&D

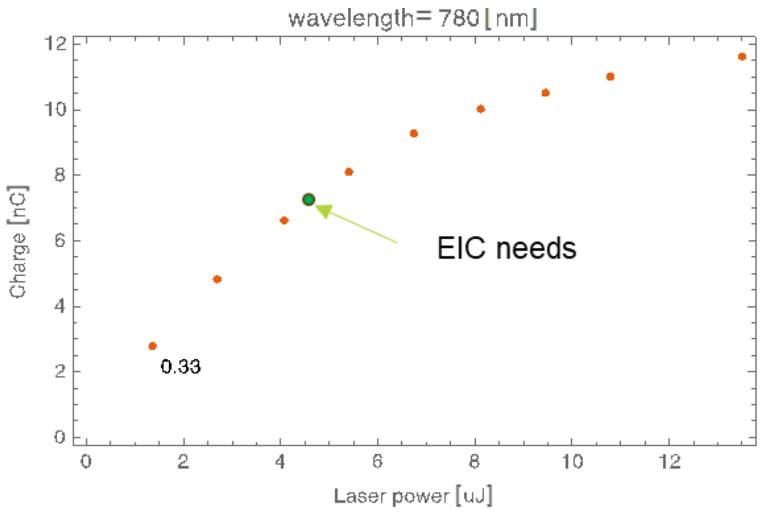


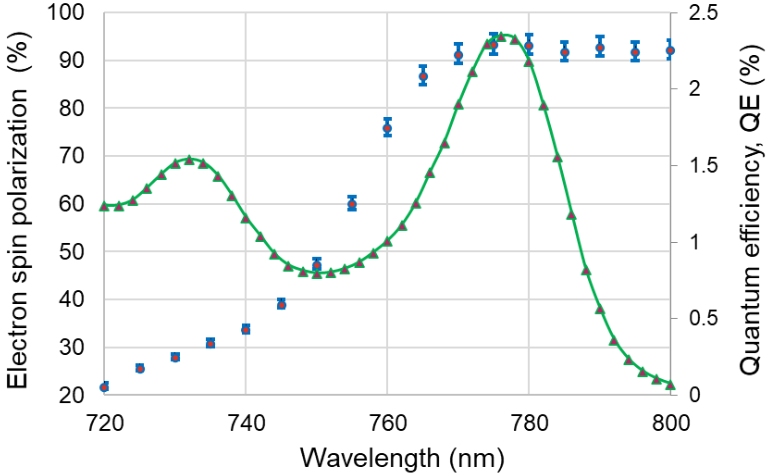
## Polarized electron source

Demonstrate a DC electron gun with a polarized photocathode delivering 4 bunches per second with 7 nC per bunch; The gun can be operating at 56 nA or above continuously for approximately one week

| | EIC | Achieved in stable operation |
|---|---|---|
| Bunch charge [nC] | 7 | 7.5 |
| Peak current [A] | 3.8 | 4.8 (No SCL) |
| Frequency [Hz] (Bunch train #) | 1(8) | 1 (3000) |
| Voltage [kV] | 300 | 320 |
| Average Current | 56 nA | 22.5 uA |
| Polarization [%] | > 85% | 90% |






- Jlab/BNL/ODU developed MOCVD DBR-SL-GaAs wafer shows **91% polarization and 2% QE**. The polarized source supply risk for the EIC project has been retired.
- Successfully passed the surface charge limit and achieved a high-intensity polarized electron beam in June this year.

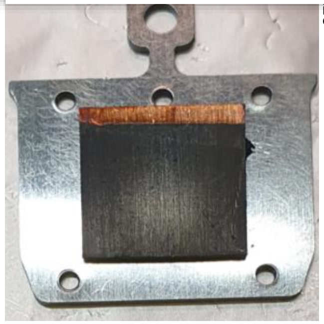
# Ongoing EIC project R&D

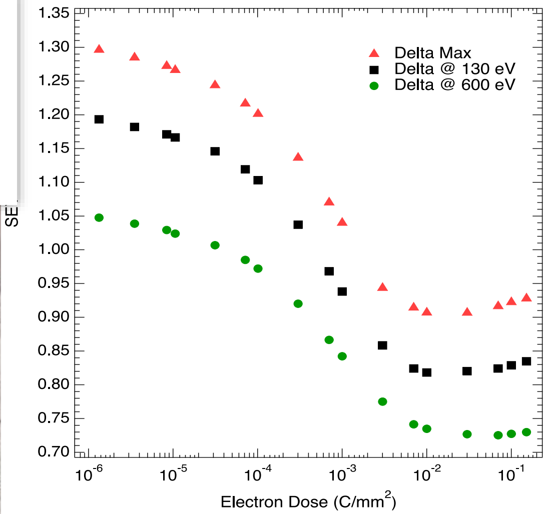
S. Verdú-Andrés

## Hadron Ring Vacuum System

- **a-C coating development**
- systems for **RRR and SEY measurements**
- Full length screens
- Future work on particulate generation, mockups of critical components, in-tunnel installation tooling development

BNL a-C film sample. SEY evolution with dose



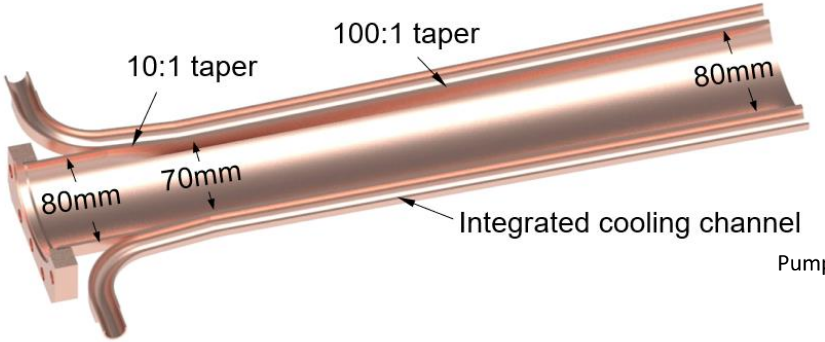


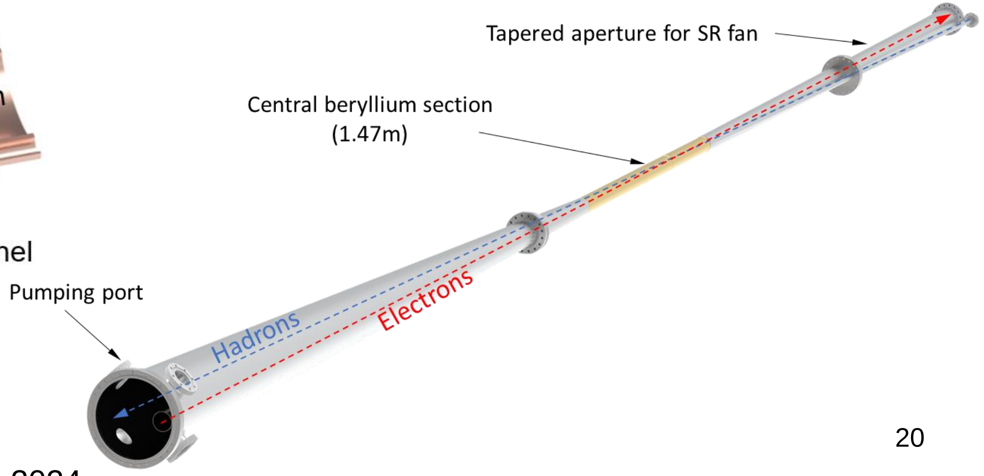

a-C coating system

## Electron Storage Ring and IR Vacuum Systems

C. Hetzel

ESR vacuum chambers for dipole and multipole;
Challenging elements of detector interface vacuum system;
RF shielded bellows for both vacuum systems

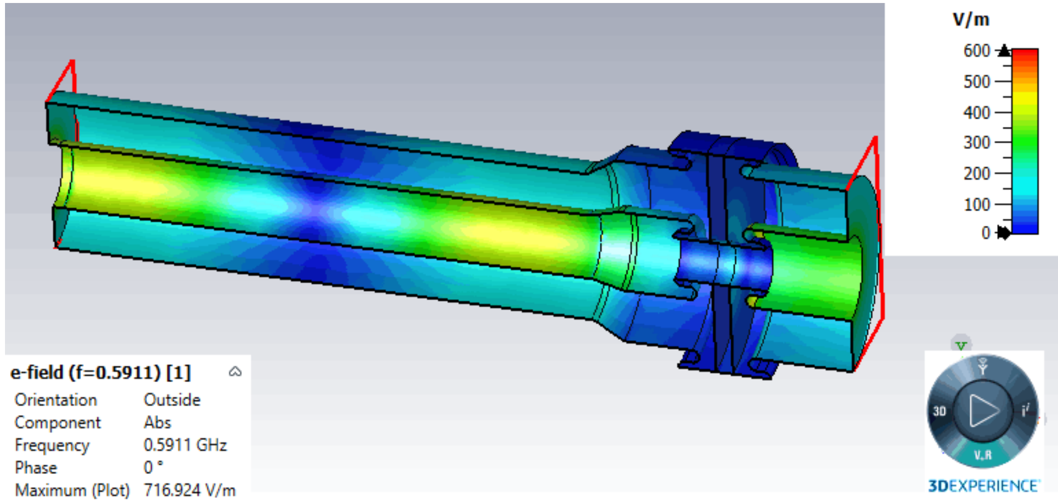



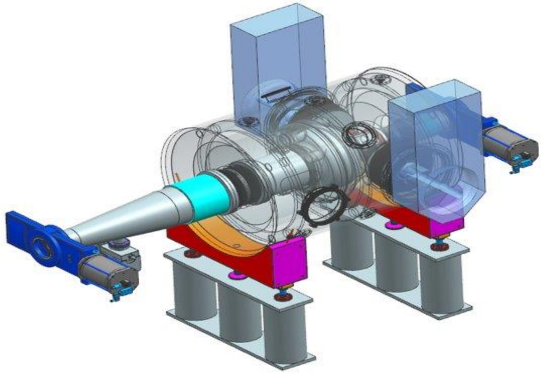



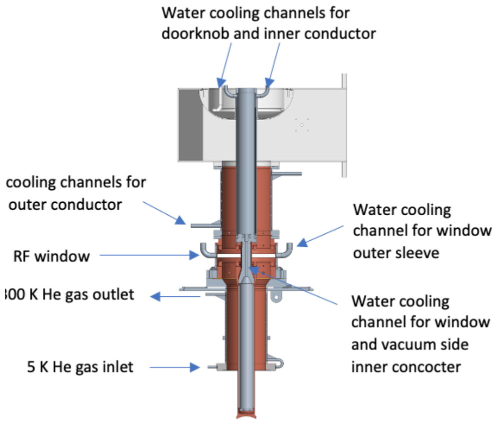
# EIC: RF Technologies – high power SRF

## Highest CW Power Fundamental Power Coupler

Transmit 500 kW RF power at ~600 MHz

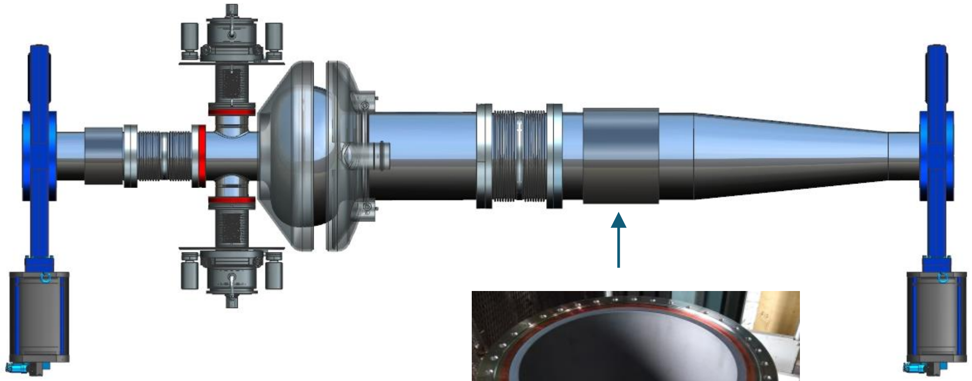


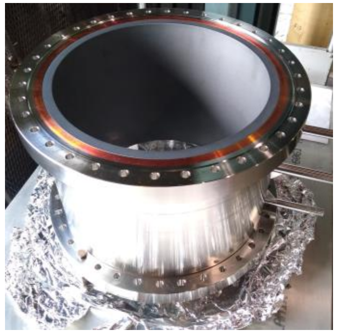






## Higher-Order-Mode Absorber

Absorb > 40 kW with large diameter and high thermal conductance





Synergies

- electromagnetic analyses (wakefields)
- thermal analyses
- detailed mechanical engineering designs
- material evaluations and pressure fitting methods
- RF Test Facilities: high-power test stand

# US Contributions proposed by US-FCCee Planning Panel

**US-FCCee Planning Panel**

**Panel Coordinators:**
Tor Raubenheimer (SLAC/Stanford) and Vladimir Shiltsev (FNAL)

**Machine Design:**
Yunhai Cai (SLAC), John Byrd (ANL), Michiko Minty (BNL), Sergei Nagaitsev (JLab)

**Magnet Systems:**
Kathleen Amm (BNL), Steve Gourlay (FNAL), Soren Prestemon (LBNL)

**RF Systems:**
Sergey Belomestnykh (FNAL), Mark Kemp (SLAC), Matthias Liepe (Cornell)

## Focus on

- projects needs (including cost and schedule reduction, power efficiency)
- US expertise and capabilities while still benefiting the US programs

## Three main areas of potential contributions with several topics in each area identified

Area 1 – RF Systems
Area 2 – Magnets and Machine Detector Interface
Area 3 – Modeling, Design, Collimation, Polarization, Instrumentation

## Phases and deliverables defined

- technology R&D
- preliminary design and component prototyping
- system design and system prototyping
- preproduction models and fabrication

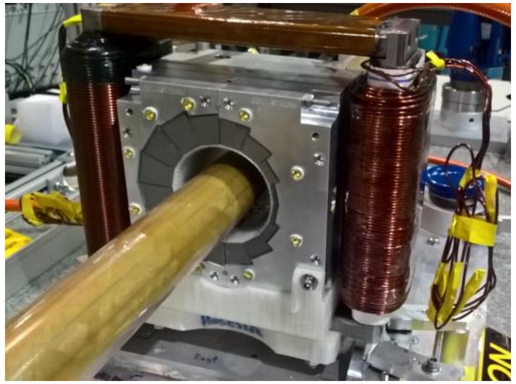
| | ANL | BNL | FNAL | LANL | LBNL | JLab | SLAC | Universities |
|---|---|---|---|---|---|---|---|---|
| SRF cavities/CMs | | | ■ | | | ■ | ■ | Cornell, ODU ... |
| RF sources/modul. | ■ | | | | | | ■ | IIT, Stanford |
| Copper RF linac | ■ | | | ■ | | | ■ | NIU, IIT |
| IR magnets | | ■ | ■ | | ■ | | | FSU, MIT, TAMU |
| Booster/MR magnets | ■ | ■ | ■ | | ■ | | | |
| Beam Optics | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Cornell, ... |
| Collimation | | ■ | ■ | | | | ■ | |
| Polarization | | ■ | ■ | | | ■ | | Cornell, UNM, ... |
| Instrumentation | ■ | ■ | ■ | | ■ | ■ | ■ | many |
| Infrastructure | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |

Comprehensive review pre-P5 performed.

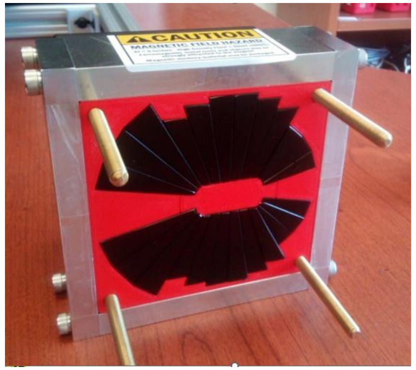
# Permanent Magnets

- new applications with permanent magnets
  - combined function magnets
  - open mid-plane

CBETA (SC energy recovery LINAC)



CEBAF 20 GeV upgrade




Modified Halbach Magnets for Emerging Accelerator Applications, IPAC 2021, S.J. Brooks
Permanent Magnets for the CEBAF 24 GeV Upgrade, IPAC 2022, S.J. Brooks

# Summary

# Summary

The US Accelerator Physics community is strongly engaged in strategic planning for future colliders

- 2015 Strategic Plan for Accelerator R&D in the US
- 2021 EIC project initiation (CD-1)
- 2022 Accelerator and Beam Physics Roadmap
- 2023 Snowmass Implementation Task Force on Feasibility of Future Colliders

Specific to an off-shore Higgs Factory

- 2013 major contributions to the ILC TDR
- 2022 US FCC-ee planning panel
- 2023 strong engagement in the ILC Pre-Lab
- 2024 Joint Statement of Intent between the US and CERN (Apr)
- 2024 U.S. Higgs Factory Coordination Consortium (May)

FCCee, the ILC and the EIC share design and engineering aspects with multiple opportunities for synergistic R&D. Many other synergies not covered here: sustainability (e.g. energy-efficient cryogenic systems and RF power sources), site-specific civil engineering design as well as to future upgrades.

Continuity in engagement drives progress and ensures continuity of expertise

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The US Accelerator Physics community offers much expertise and has great interest in both R&D and in in-kind contributions for an off-shore Higgs Factory. Down-selection of contributions will be challenging and is expected to be addressed in the context of the the US Higgs Factory Coordination Consortium.

# Acknowledgements

Thank you to all whose collective contributions were represented here.

Special thanks, with contributions towards both FCCee and ILC initiatives, especially to Sergey Belomestnykh, Kellen McGee, Brett Parker and Alex Zaltsman.  Thanks to Qiong Wu and Ferdinand Willeke for contributions on the EIC.

Am thankful for continuous and extended communications with John Byrd, Sergei Nagaitsev, Tor Raubenheimer, Vladimir Shiltsev, and Frank Zimmermann and would like to recognize Derun Li for strong support and guidance.

# Additional Material

# FCC-ee main machine parameters

FUTURE CIRCULAR COLLIDER

| Parameter | Z | WW | H (ZH) | ttbar |
|---|---|---|---|---|
| beam energy [GeV] | 45.6 | 80 | 120 | 182.5 |
| beam current [mA] | 1270 | 137 | 26.7 | 4.9 |
| number bunches/beam | 11200 | 1780 | 440 | 60 |
| bunch intensity [$10^{11}$] | 2.14 | 1.45 | 1.15 | 1.55 |
| SR energy loss / turn [GeV] | 0.0394 | 0.374 | 1.89 | 10.4 |
| total RF voltage 400/800 MHz [GV] | 0.120/0 | 1.0/0 | 2.1/0 | 2.1/9.4 |
| long. damping time [turns] | 1158 | 215 | 64 | 18 |
| horizontal beta* [m] | 0.11 | 0.2 | 0.24 | 1.0 |
| vertical beta* [mm] | 0.7 | 1.0 | 1.0 | 1.6 |
| horizontal geometric emittance [nm] | 0.71 | 2.17 | 0.71 | 1.59 |
| vertical geom. emittance [pm] | 1.9 | 2.2 | 1.4 | 1.6 |
| horizontal rms IP spot size [μm] | 9 | 21 | 13 | 40 |
| vertical rms IP spot size [nm] | 36 | 47 | 40 | 51 |
| beam-beam parameter $\xi_x$ / $\xi_y$ | 0.002/0.0973 | 0.013/0.128 | 0.010/0.088 | 0.073/0.134 |
| rms bunch length with SR / BS [mm] | 5.6 / 15.5 | 3.5 / 5.4 | 3.4 / 4.7 | 1.8 / 2.2 |
| luminosity per IP [$10^{34}$ $cm^{-2}s^{-1}$] | 140 | 20 | ≥5.0 | 1.25 |
| total integrated luminosity / IP / year [$ab^{-1}/yr$] | 17 | 2.4 | 0.6 | 0.15 |
| beam lifetime rad Bhabha + BS [min] | 15 | 12 | 12 | 11 |
| | 4 years<br>5 x $10^{12}$ Z<br>LEP x $10^5$ | 2 years<br>> $10^8$ WW<br>LEP x $10^4$ | 3 years<br>2 x $10^6$ H | 5 years<br>2 x $10^6$ tt pairs |

Design and parameters dominated by the choice to allow for 50 MW synchrotron radiation per beam.

- x 10-50 improvements on all EW observables
- up to x 10 improvement on Higgs coupling (model-indep.) measurements over HL-LHC
- x10 Belle II statistics for b, c, τ
- indirect discovery potential up to ~ 70 TeV
- direct discovery potential for feebly-interacting particles over 5-100 GeV mass range

Up to 4 interaction points → robustness, statistics, possibility of specialised detectors to maximise physics output

F. Gianotti

# Parameters for Highest e-p Luminosity at $E_{cm}$ =105 GeV

- Collision parameters of unequal species chosen for each beam chosen as they would collide with own species
- Hadron beam parameters differ from present RHIC by smaller vertical emittance [“flat beam”] 10x bunches, 3 times more average beam current
- Two hours IBS growth time requires hadron cooling
- Electron beam parameters resemble a B-Factory high beam current, large beam-beam tune shift

| Species | | Protons | Electrons |
|---|---|---|---|
| Beam Energy | [GeV] | 275 | 10 |
| Bunch Intensity | [$10^{10}$] | 6.9 | 17.2 |
| number of bunches | | 1160 | |
| Beam Current | [A] | 1 | 2.5 |
| Beam emittance h/v | [nm] | 9.6 / 1.5 | 20 / 1.2 |
| β* h/v | [cm] | 90 / 4 | 43 / 5 |
| beam-beam ΔQ | [$10^{-2}$] | 1.4 / 0.7 | 7.3 / 10 |
| $\sigma_s$ [cm] | [cm] | 6 | 2 |
| Δp/p | [$10^{-4}$] | 6.8 | 5.8 |
| $\tau_{IBS}$ long./trans. | [h] | 3.4 / 2.0 | n/a |
| Luminosity | [$10^{34}cm^{-2}s^{-1}$] | 1.0 | |

# On the Feasibility of Future Colliders: Snowmass Implementation Task Force (here)

*T. Roser (BNL), R. Brinkmann (DESY), S. Cousineau (ORNL), D. Denisov (BNL), S. Gessner (SLAC), S. Gourlay (LBNL/FNAL), P. Lebrun (ESI Archamps), M. Narain (Brown Univ.), K. Oide (KEK), T. Raubenheimer (SLAC), J. Seeman (SLAC), V. Shiltsev (FNAL), J. Strait (LBNL, FNAL), M. Turner (LBNL), L. Wang (Univ. Chicago)*

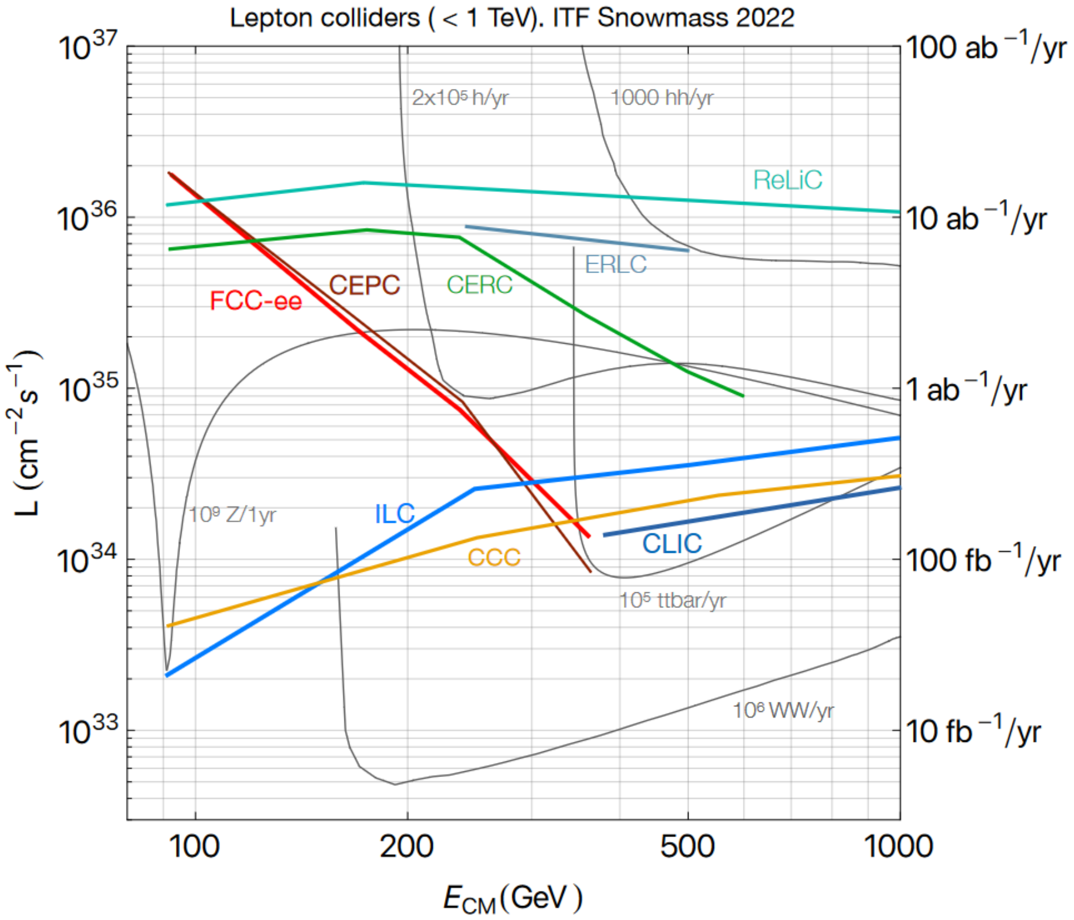



**Figure 1.** Peak luminosity per IP vs CM energy for the Higgs factory proposals as provided by the proponents. The right axis shows integrated luminosity for one Snowmass year ($10^7$ s). Also shown are lines corresponding to yearly production rates of important processes.

| Proposal Name (c.m.e. in TeV) | Collider Design Status | Lowest TRL Category | Technical Validation Requirement | Cost Reduction Scope | Performance Achievability | Overall Risk Tier |
|---|---|---|---|---|---|---|
| FCCee-0.24 | II | | | | | 1 |
| CEPC-0.24 | II | | | | | 1 |
| ILC-0.25 | I | | | | | 1 |
| CCC-0.25 | III | | | | | 2 |
| CLIC-0.38 | II | | | | | 1 |
| CERC-0.24 | III | | | | | 2 |
| ReLiC-0.24 | V | | | | | 2 |
| ERLC-0.24 | V | | | | | 2 |
| XCC-0.125 | IV | | | | | 2 |
| MC-0.13 | III | | | | | 3 |
| ILC-3 | IV | | | | | 2 |
| CCC-3 | IV | | | | | 2 |
| CLIC-3 | II | | | | | 1 |
| ReLiC-3 | IV | | | | | 3 |
| MC-3 | III | | | | | 3 |
| LWFA-LC 1-3 | IV | | | | | 4 |
| PWFA-LC 1-3 | IV | | | | | 4 |
| SWFA-LC 1-3 | IV | | | | | 4 |
| MC 10-14 | IV | | | | | 3 |
| LWFA-LC-15 | V | | | | | 4 |
| PWFA-LC-15 | V | | | | | 4 |
| SWFA-LC-15 | V | | | | | 4 |
| FCChh-100 | II | | | | | 3 |
| SPPC-125 | III | | | | | 3 |
| Coll.Sea-500 | V | | | | | 4 |

**Table 9.** Table summarizing the TRL categories, technology validation requirements, cost reduction impact and the judgement of performance achievability on technical components and subsystems for the evaluated collider proposals. Colors and categories are described above in Sec.3 and go from lighter/lower/easier to darker/higher/more challenging. The first column "Design Status" indicates current status of the design concepts: I - TDR complete, II - CDR complete, III - substantial documentation; IV - limited documentation and parameter table; V - parameter table. The last column indicates the overall risk tier category, ranging from Tier 1 (lower overall technical risk) to Tier 4 (multiple technologies that require further R&D).

# US Contributions proposed by US-FCCee Planning Panel

**Focus on**

- projects needs (including cost and schedule reduction, power efficiency)
- US expertise and capabilities while still benefiting the US programs

**US-FCCee Planning Panel**

**Panel Coordinators:**
Tor Raubenheimer (SLAC/Stanford) and Vladimir Shiltsev (FNAL)

**Machine Design:**
Yunhai Cai (SLAC), John Byrd (ANL), Michiko Minty (BNL), Sergei Nagaitsev (JLab)

**Magnet Systems:**
Kathleen Amm (BNL), Steve Gourlay (FNAL), Soren Prestemon (LBNL)

**RF Systems:**
Sergey Belomestnykh (FNAL), Mark Kemp (SLAC), Matthias Liepe (Cornell)

## Three main areas of potential contributions with several topics in each area identified

Area 1 – RF Systems
Area 2 – Magnets and Machine Detector Interface
Area 3 – Modeling, Design, Collimation, Polarization, Instrumentation

## Phases and deliverables defined

- technology R&D
- preliminary design and component prototyping
- system design and system prototyping
- preproduction models and fabrication

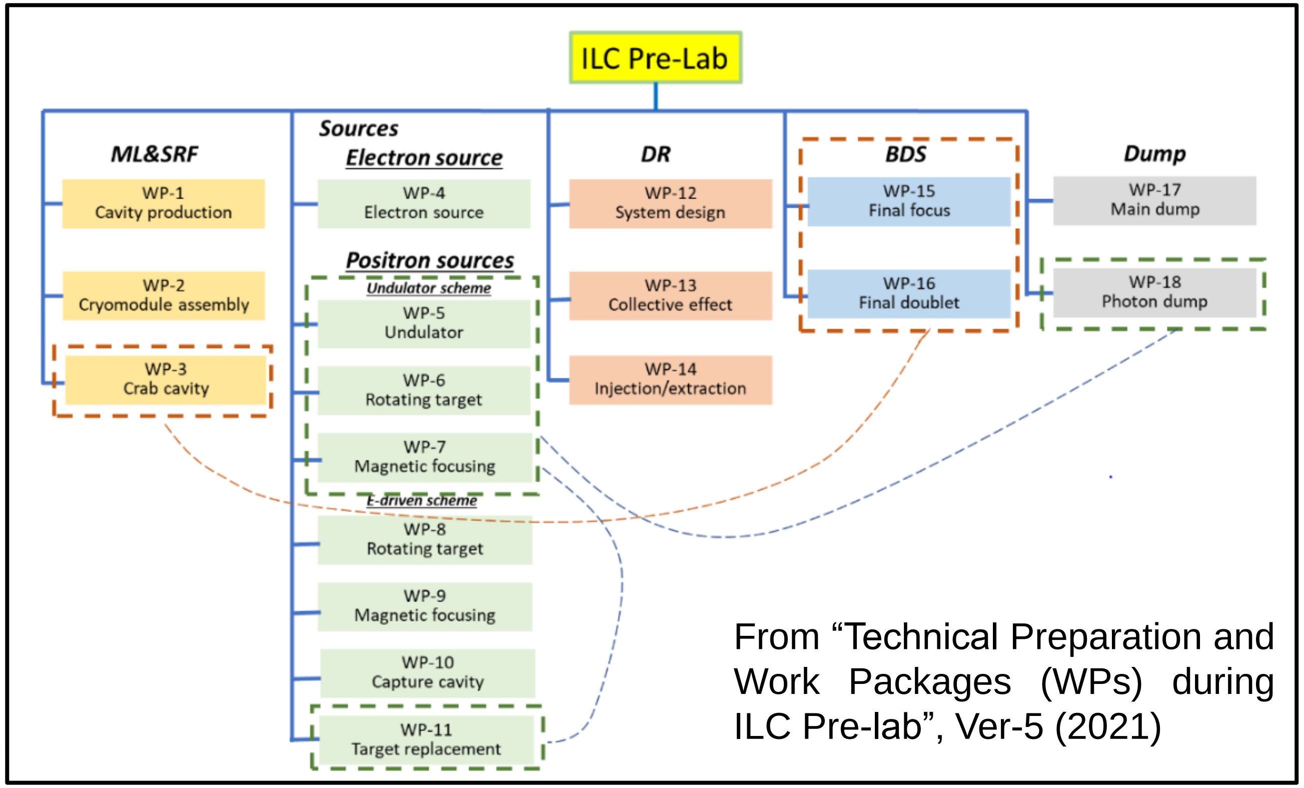
| | ANL | BNL | FNAL | LANL | LBNL | JLab | SLAC | Universities |
|---|---|---|---|---|---|---|---|---|
| SRF cavities/CMs | | | ■ | | | ■ | ■ | Cornell, ODU ... |
| RF sources/modul. | ■ | | | | | | ■ | IIT, Stanford |
| Copper RF linac | ■ | | | ■ | | | ■ | NIU, IIT |
| IR magnets | | ■ | ■ | | ■ | | | FSU, MIT, TAMU |
| Booster/MR magnets | ■ | ■ | ■ | | ■ | | | |
| Beam Optics | ■ | ■ | ■ | ■ | ■ | ■ | ■ | Cornell, ... |
| Collimation | | ■ | ■ | | | | ■ | |
| Polarization | | ■ | ■ | | | ■ | | Cornell, UNM, ... |
| Instrumentation | ■ | ■ | ■ | | ■ | ■ | ■ | many |
| Infrastructure | ■ | ■ | ■ | ■ | ■ | ■ | ■ | |

Comprehensive review pre-P5 performed.

# US Accelerator Expertise Relevant to the ILC

- Major role, including leadership, of the worldwide Global Design Effort that led to the ILC Technical Design Report

- Contributions to the IDT-WG2 and to IDT-WG2's identification of accelerator-related activities for the ILC Pre-lab with IDT-WG2 US Member Affiliations – BNL(1), Cornell (1), FNAL (3), JLAB (2), ORNL (1), SLAC (3) + contributions from ANL, LBNL, and Old Dominion University




From "Technical Preparation and Work Packages (WPs) during ILC Pre-lab", Ver-5 (2021)

Similar to US expertise for the FCCee:

- extensive (multi-laboratory) experience in
  - beam optics and collective effects, beam delivery design and instrumentation
  - damping ring system and subsystem design (SRF, vacuum chambers, magnets, instrumentation, etc.)
- and core capabilities in
  - SRF (Cornell, FNAL, JLAB, SLAC)
  - final focus magnets (BNL, FNAL, LBNL)
  - polarized e-sources (BNL, Cornell, JLAB, SLAC)
- and in
  - undulators for polarized e+ sources
  - crab cavities
  - fast kickers