SLACmass Accelerators Summary

Brendan O'Shea

Outline

- SLACmass Accelerators was run using an open mic format
- Sought out initial speakers the during these meetings took requests for future speakers

Talk outline:

- General HEP + Accelerators @ SLAC
- Impression of HEP science goals for SLAC
- What challenges are addressed by accelerator research
- Summary of a subset of technologies

Topic	*Speaker*
C3 Cryo Cooled Copper	*Emilio Nanni*
Accelerator Discussion - Final Focus	*Glen White*
Superconducting Technology - ILC	*Marc Ross*
A Novel Magnetron Phase Locking Method	*Lili Ma*
Plasma Lenses	*Spencer Gessner*
Advanced RF Sources Research at SLAC	*Brandon Weatherford*
Dark Matter Searches at Accelerators	*Tim Nelson*
High Intensity Attosecond Electron and Photon Beams - Crossover Interest from HEP to BES	*Claudio Emma*

This talk is a summary of what Brendan took away from Accelerators + HEP @ SLAC

Accelerators and HEP

- SLAC research has traditionally been ‘energy frontier’
- Existing infrastructure has been a key driver of accelerator projects in the last 20 years - efficient and reduces costs
  - ex: LHC built in LEP tunnel
  - ex: LCLS and LCLS-II in the SLAC tunnel/RF structures
- Accelerator technologies divided across labs
  - SLAC has a tradition of RF structure and power source development
  - RF research closely linked to linear collider history
- RF accelerators are a mature technology
- Improvements usually require several changes
  - ex: RF technology pushing evolution in power source and accelerator

By design, accelerator research at SLAC is aligned with prior SLAC programs

Impression of HEP Science Goals and Accelerators for SLAC

e^+e^- Colliders

- Case for Higgs Factory (International Linear Collider) is well understood and anxiously awaited (<=1 TeV)
- 1-3 TeV range doesn't seem as universally interesting as previously indicated
  - Need to make this case (white paper)
  - e^+e^- technologies stop here on the way to higher energies
- Long range goals appear to be 10-30 TeV

Accelerator but not e^+e^- Colliders

- Dark Matter searches - (4 to 10) GeV scale (LDMX)
- Strong field QED (SFQED) - 10 GeV scale - non-perturbative QED @ FACET-II

Snowmass and P5 understandably focuses on bigger projects

Meetings HEP Goals using Accelerators

Accelerators face two challenges:

- They are getting really big (expensive) - increase gradient
- They use a lot of power (expensive) - increase efficiency

Accelerator research is currently focused on bending the cost curve

- Higher gradients / higher efficiency
  - RF is currently a well understood technology (SLAC strength)
  - SRF is a generation younger than NCRF
  - Advanced acceleration (plasma) younger still than SRF (but also a SLAC strength)
- Technologies required for higher gradients
  - Beam transport technology should prepare for extremely high quality beams, including final focus
  - Extreme beams - study collective effects
  - RF infrastructure, modulators and klystrons

Demonstrations are needed to certify complex, evolving accelerator technologies

SLAC Accelerators and Accelerator Research

- SLAC is well positioned for the near (<2030) and long term (>2040)
- SLAC should fill the 'missing middle', 2030-2040
- Match 'demonstration' facilities with intermediate physics results

Current SLAC Research	*Timescale for working demo [years]*	*Frontier*
Normal Conducting RF	*2.5*	*Energy*
Superconducting RF (through LCLS)	*5*	*Energy*
Advanced accelerators (plasmas, lasers, non-metallic materials	*10*	*Energy*

Missing middle options (with LOIs)

- $\gamma\gamma$-collider - 65 GeV + x-ray line - study Higgs
- Strong field QED with 30 GeV beams - nonperturbative QED
- Plasma driven light source / ILC 'afterburner'
- C^3 or its predecessor

Medium scale projects should be ambitious; enable longer term, larger experiments

Normal Conducting RF

A major cost driver of future accelerators

- Tackling challenges requires start to end innovation and integration

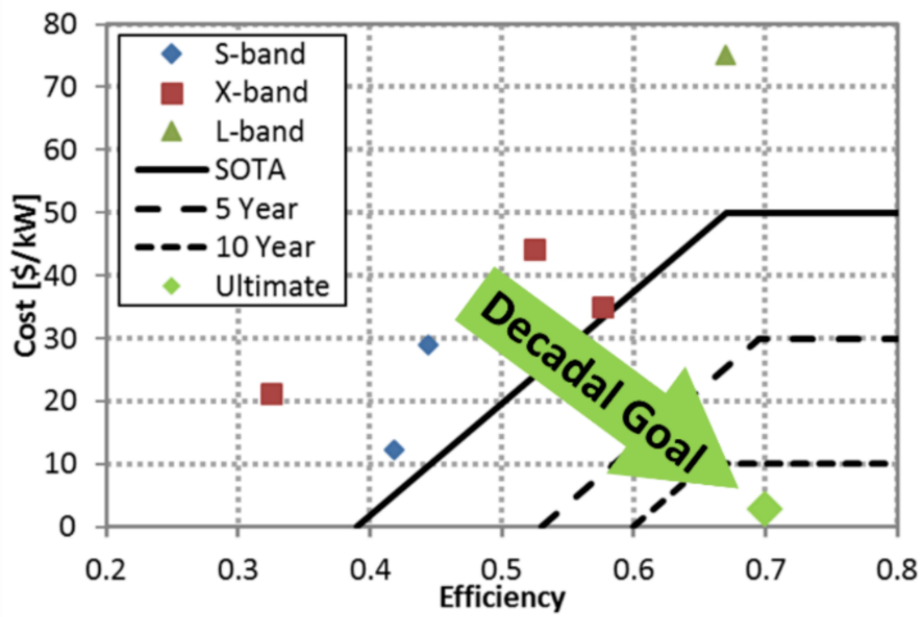
Current efforts at SLAC RF Power Sources

- Goal: 70% efficiency (currently 40%)
  - New RF sources: radial beams, trajectory modulation, multiple beams, magnetrons
- $2/kW (currently ~$10/kW)
  - Pivot to off-the-shelf components
  - Developing energy recovery systems

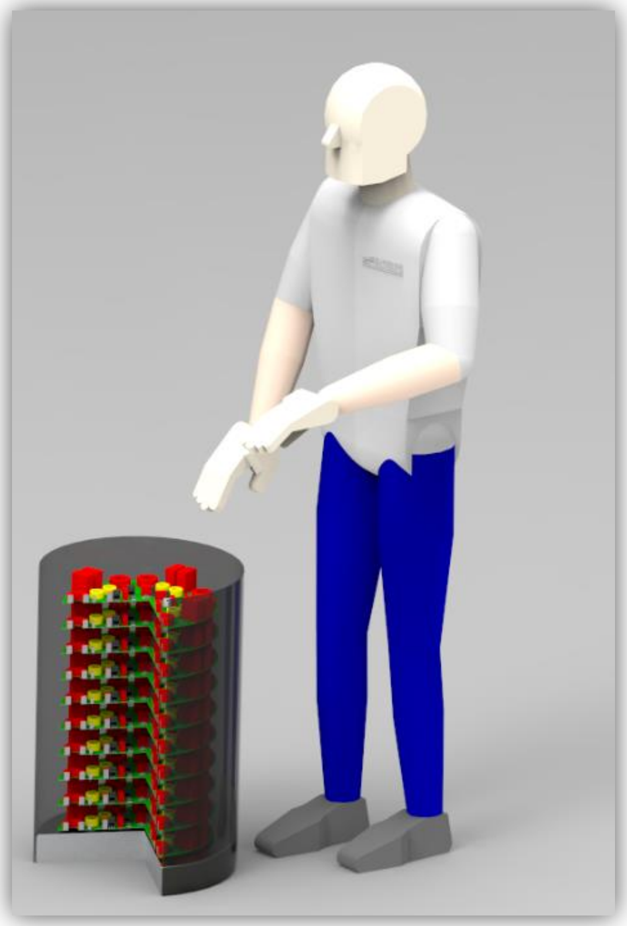
Current efforts at SLAC: RF Accelerating Structures

- Increase gradient by cooling the structures (45K)
- Optimize cavity shapes
- Distribute coupling (LCLS/FACET use on-axis coupling)
- To do: meter scale prototype

*Radiofrequency Accelerator R&D Strategy Report



*Radiofrequency Accelerator R&D Strategy Report



B. Weatherford - "Advanced RF Sources Research at SLAC"

Lili Ma - "A Novel Magnetron Phase Locking Method"

Superconducting RF

Technology that ILC is based on

- ILC ~31 km long
- Estimated to require 270 MW of power

Work spread across Fermilab, JLab and SLAC

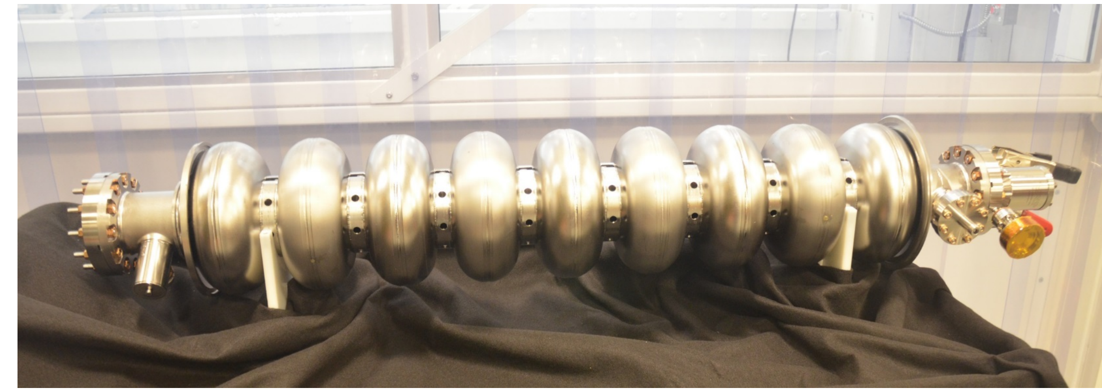
- SLAC responsible for linac integration and commissioning

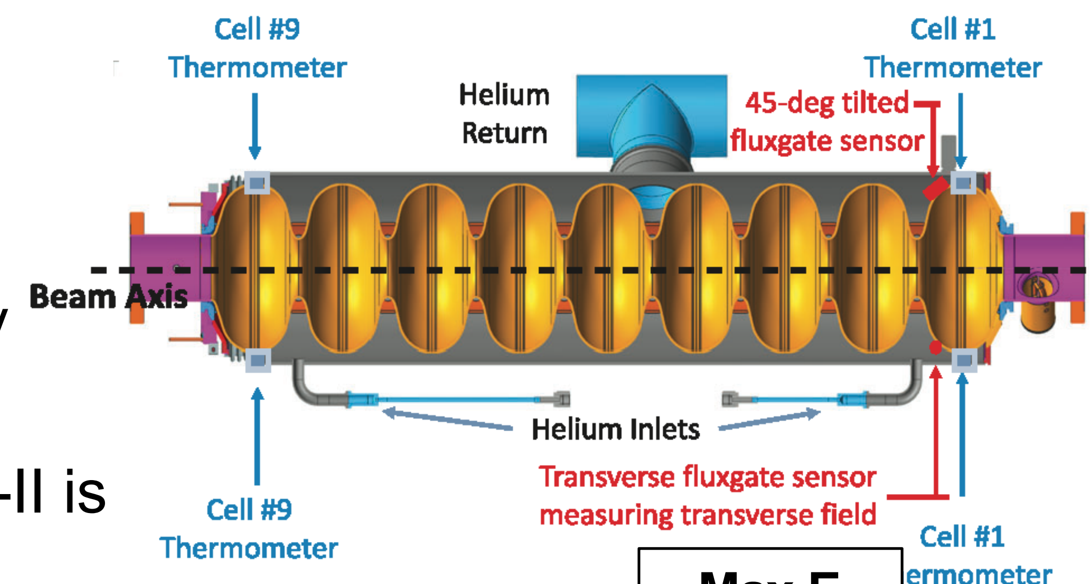
Results since P5

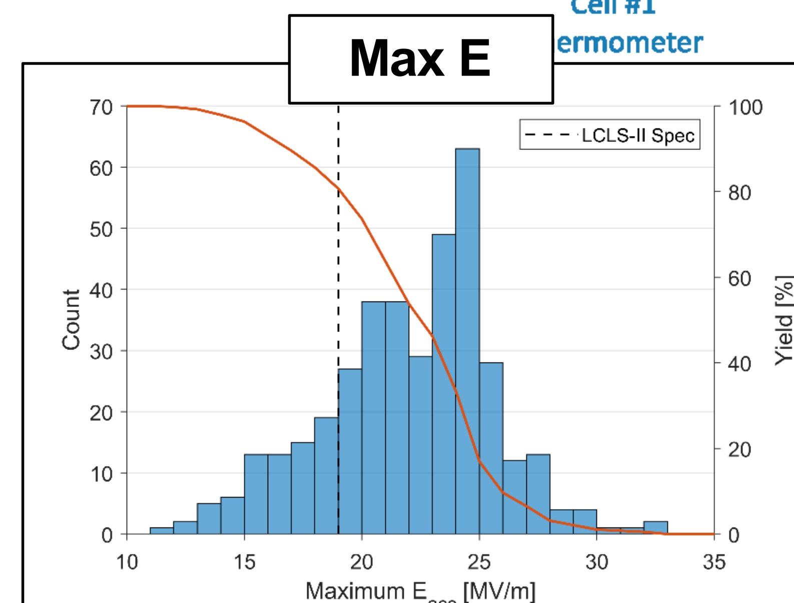
- Parameters demonstrated allow for 6X luminosity upgrade of ILC beyond TDR
- R&D performed for LCLS-II (ILC is pulsed, LCLS-II is CW)

Current Research

- Working on chemistry to further improve power requirements
- Cavity shaping to increase gradient (250 GeV -> 500 GeV)
- New materials to reduce cooling requirements







M. Ross - "Superconducting Technology - ILC"

Plasma based advanced accelerators

Headline: Gradients are 1000x larger than current accelerators

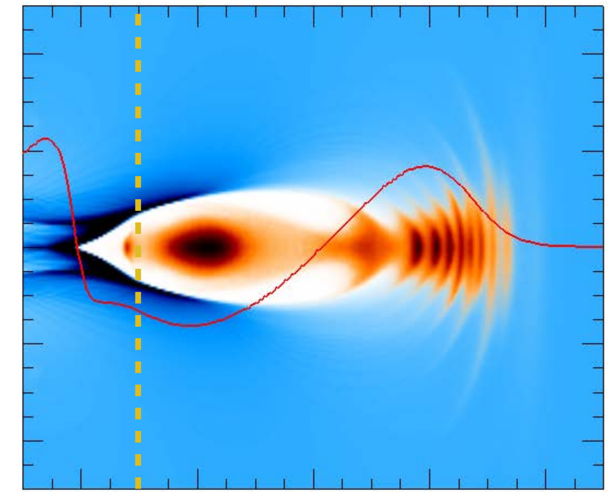
- but plasmas are mercurial - tolerances are challenging - positrons are an open priority

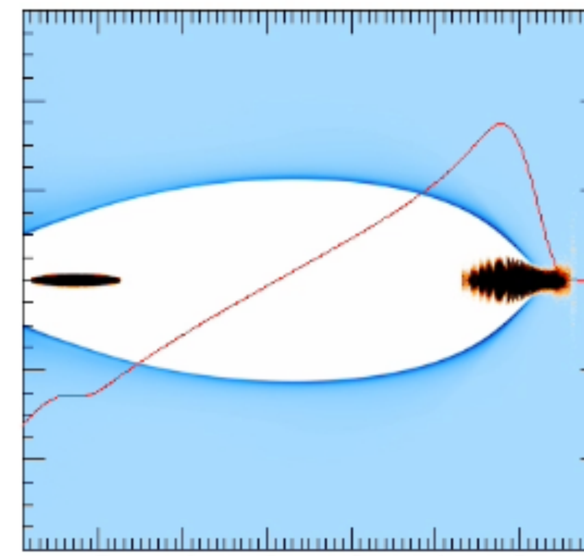
SLAC leads the way on beam drive plasmas (PWFA): FACET-II to study 'accelerator stage'

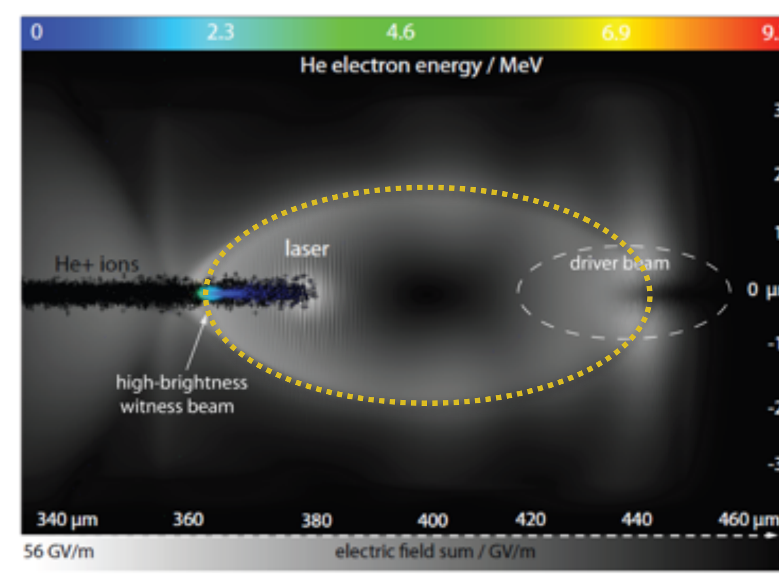
- Efficiently accelerate a beam from 10 GeV to 20 GeV in ~ 1 m, while preserving state-of-the-art emittance
- Generation of beams of 10x better quality
  - 10x increase in luminosity
  - Light sources could use to generate 100 as pulses
- Plasmas require collider quality beams - can study advanced focusing

Long term technology with medium term applications:

- ILC 'afterburner'
- 10+ keV x-rays
- e^-e^- collider
- Plasma focusing technologies







C. Emma - High Intensity Attosecond Electron and Photon Beams - Crossover Interest from HEP to BES

S. Gessner - Plasma Lenses

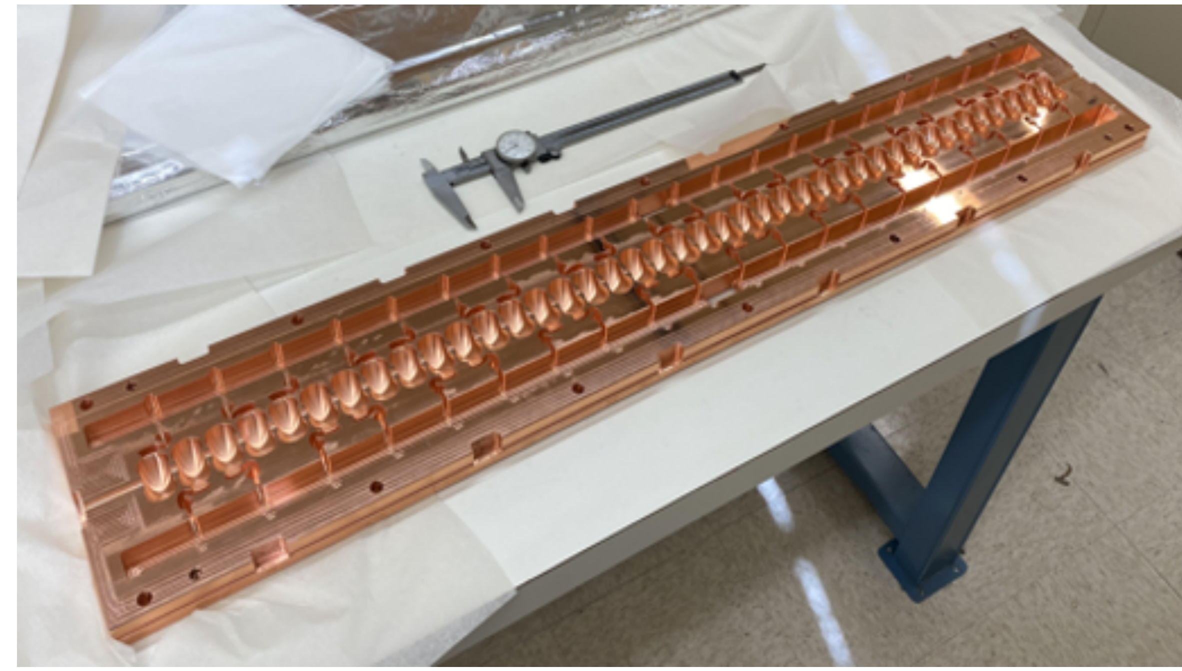
C³ - Cool Copper Collider

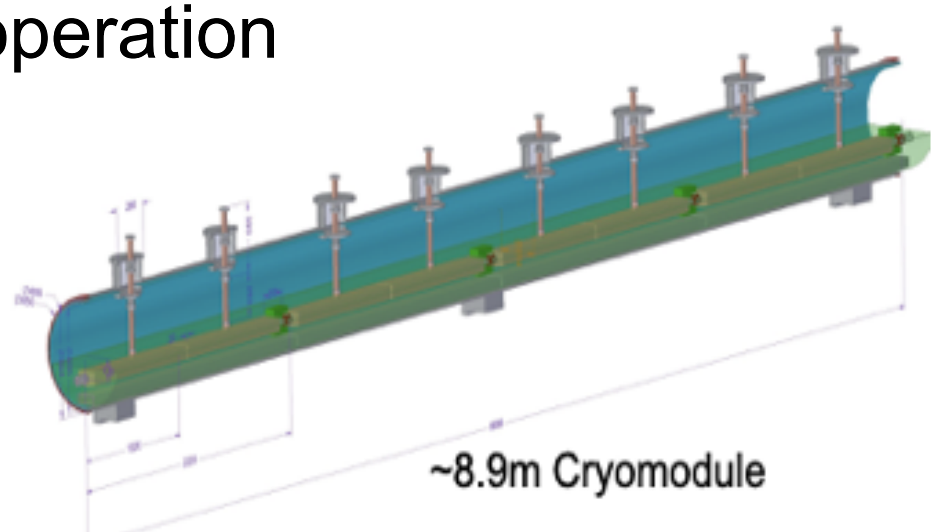
More Details See: Bane et al., *ArXiv* 1807.10195 (2018)
C³ Colloquium: https://sites.slac.stanford.edu/colloquium/node/159
C3 LOI Link

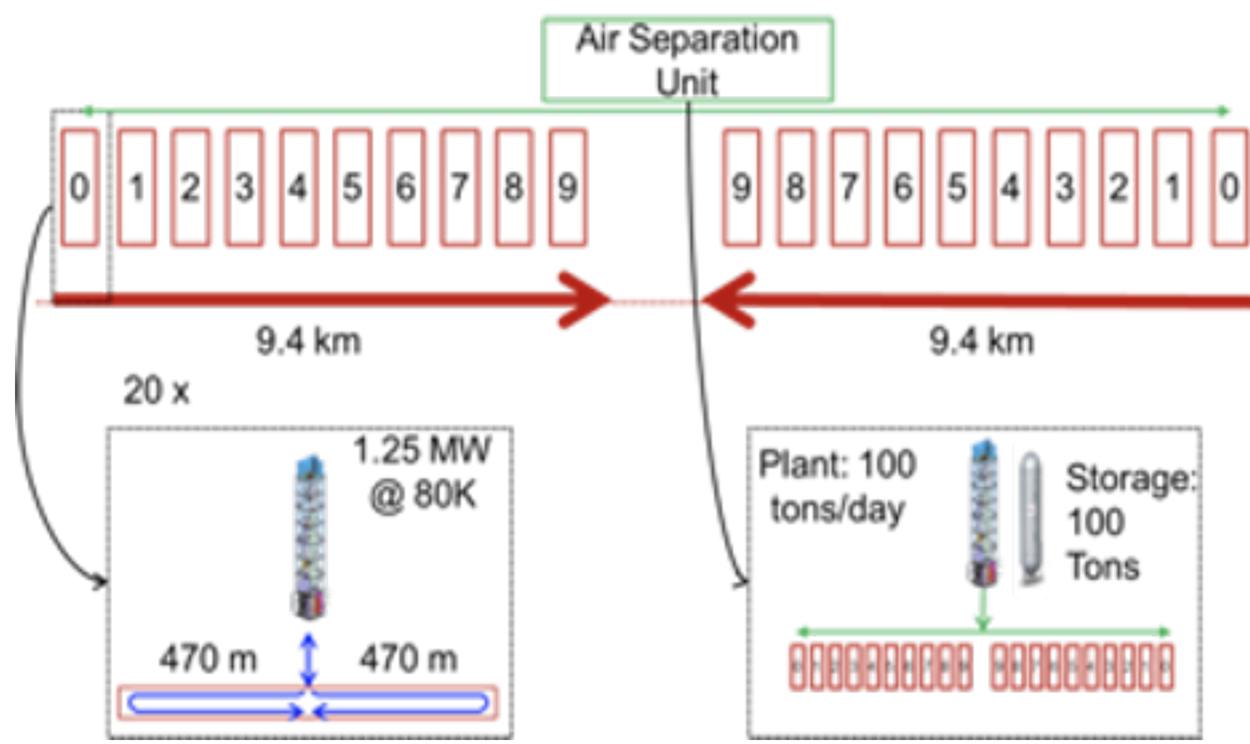
SLAC

- SLAC technology for normal conducting accelerator at cryogenic temperature
- Aim to achieve high gradient (110 MeV/m real footprint) on short time scale
- Potential for hight brightness polarized sources to eliminate damping rings
- Scalable technology optimizing for multi-TeV operation

First C3 structure at SLAC







Timeline:
2 years - meter scale, wakefield damping, cryogenics
4 years - modular GeV units
Target operation in parallel w/ HL-LHC

E. Nanni - C3 Cryo-Cooled Copper

Dark Matter + Strong Field QED

SLAC

- Both desire $\mathcal{O}$(50 GeV) electron beams
- HEP experiments that don't require new tunnels
- Can use existing accelerator technology but might be a good stop for technologies under development
- Callout of small accelerator-based experiments would be nice

- Dark Matter (LDMX)
  - Uses beam from LCLS-II in End Station A
  - LDMX phases with LCLS through 2030
  - Other experiments stop taking data in 2024
  - Not yet a project

- Strong Field QED - 'strong-field vacuum breakdown'
  - One option uses 'modest' laser - 100 to 1000 TW
  - Another option is beam-beam
- Study electron-positron plasmas in extreme conditions
- Future colliders use beams in this regime

T. Nelson - "Dark Matter Searches at Accelerators"

Conclusions

- SLAC accelerator research is aligned to HEP goals
  - Near term we use our expertise to develop LCLS capabilities, soon LCLS-II (HE)
  - SLAC aligned to DoE RF Roadmap
  - FACET-II aligned DoE Advanced Accelerator Roadmap
    - FACET-II works to define FACET-III
- Midterm: What comes after LCLS-II HE?
- Developing accelerator technology requires meeting several challenges at once
- Stepping stones can be used to mitigate risk and increase probability of funding
  - Stones must be aligned to HEP
  - Decision process seems to be HEP -> infrastructure -> accelerator technology -> HEP
- Several options exist to bring accelerators for HEP physics back to SLAC
- ~50 LoI submitted across 7 Accelerator Frontiers
  - Challenge to the community is generate well coordinated white papers
- Snowmass 2021 Community Planning Meeting is next week!
  - Register Here