### Future Stable-beam Accelerators for Nuclear Physics

Leigh Harwood Jefferson Lab

#### SRF2003 September 12, 2003 Lubeck, Germany



**Thomas Jefferson National Accelerator Facility** 

Operated by the Southeastern Universities Research Association for the U.S. Department Of Energy



### Outline







### **J-PARC**

### Japanese Proton Accelerator Research Complex

#### Collaboration between JAERI and KEK Complex of accelerators for MANY goals

- Nuclear and particle physics
  - 50 GeV primary beam
  - Secondary beams
    - Kaon, pion, hyperon, neutrino, muon, and anti-proton
- Materials and life sciences
  - Pulsed neutron source (3 GeV, pulsed)
- Accelerator transmutation of radioactive waste
  - Includes an srf linac section





### JPARC (cont'd)



### **J-PARC Schedule**

#### ��∕CEPAF/JAERI

Center for Proton Acc. Faciliti



#### Phase I is underway Phase II is not yet approved

### **Brookhaven National Lab**

## RHIC-II

#### **Upgrade in the luminosity of RHIC**

### eRHIC

#### **Electron-ion collider**





### **RHIC-II**

**RHIC-II** is a luminosity upgrade to RHIC (Relativistic Heavy Ion Collider)

#### The route is to use electron-cooling.

- Copper Novosibirsk
- SRF BNL/JLab collabroation

#### Anticipated increased average luminosity

- 9x for Au-Au (100 GeV/u):  $0.8 \times 10^{27} \Rightarrow 7 \times 10^{27}$
- 3x for  $\vec{p}$   $\vec{p}$  (250 GeV/u): 2.4 x10<sup>32</sup>  $\Rightarrow$  8x10<sup>32</sup>





### **RHIC Luminosity with and without e-cooling**





### **RHIC Electron Cooler R&D**



dampers and high beam break-up threshold BNL-JLab collaboration

# Energy Recovery Linac – large bore (19 cm diameter)



#### **Energy Recovery Linac – HOM Damping**







#### **Energy Recovery Linac – HOM damping**

TDBBU results: 4 cavities; ferrite damping; 1 A



### **Electron-lon Colliders**

Over the past two decades we have learned a great amount about the hadronic structure

#### Some crucial questions remain open:

- What is the structure of the proton and neutron in terms of their quark and gluon constituents?
- How do quarks and gluons evolve into hadrons?
- What is the quark-gluon origin of nuclear binding?

A high-luminosity electron—ion collider has been proposed as a powerful new microscope to probe the structure of matter.



**Thomas Jefferson National Accelerator Facility** 



### **EIC** parameters

#### Center-of-mass energy between 20-45 GeV with energy asymmetry of ~10

- 3 GeV electrons on 30 GeV/nucleon ions
- 5 GeV electrons on 100 GeV/nucleon ions

#### Ion species of interest:

Whole periodic table (theorist dependent)

#### **CW** Luminosity:

>10<sup>33</sup> cm<sup>-2</sup> sec<sup>-1</sup> per nucleon (HERA achieved ~5x10<sup>32</sup>)

#### Polarized beams (electrons and light ions)

- Longitudinal polarization ≥ 50%
- Transverse polarization of ions extremely desirable
- Spin-flip of both beams extremely desirable

**Review article on EIC's: ICFA Beam Dynamics Newletter #30;** April, 2003; (Wei and Merminga, ed.)



**Thomas Jefferson National Accelerator Facility** 





### eRHIC: ring-ring option (baseline)







### eRHIC: linac-ring option



### **Jefferson Lab**

### 12 GeV

#### **Upgrade the present accelerator from 6 GeV to 12 GeV**

### 25 GeV

#### **Upgrade the 12 GeV accelerator to 25 GeV**

### eLIC

#### Use the 5 GV of linac as the basis for an EIC





### 12 GeV

Advances in understanding of hardonic matter using JLab's 6 GeV electron accelerator.

- Detailed mapping of the charge structure of the neutron
- Detailed mapping of electro-magnetic structure of the proton
- Dirth of strange quarks in the proton
- Discovery of the penta-quark.

New windows would be opened by increasing to 12 GeV

- Exotic mesons (hybrids of gluonic flux tubes and quarks)
- Route to possible explanation of quark confinement
- Symmetry tests of the Standard Model
- Short-range behavior of QCD









### 12 GeV cryomodule

#### **Specifications**

- 7-cell cavities
- Average accelerating field: 19.2 MV/m
- Q<sub>0</sub>: >8x10<sup>9</sup>

#### Status:

- 1st cryomodule with 7-cell cavities operating in CEBAF
- 2nd will soon be installed in JLab FEL
- "100 MV" cryomodule
  - Being constructed
  - Exploring cavity shape options for overall system optimization





### **Cavity Designs for 12 GeV**

	00	HG	LL
Ø <sub>equator</sub> [mm]	187	180	174
Ø <sub>iris</sub> [mm]	70	61	53
k <sub>cc</sub> [%]	3.3	1.7	1.5
E <sub>peak</sub> /E <sub>acc</sub>	2.6	1.9	2.2
B <sub>peak</sub> /E <sub>acc</sub> [mT/(MV/m)]	4.6	4.3	3.7
R/Q [Ω]	96	112	129
G [Ω]	274	265	280
R/Q·G [Ω·Ω]	26k	30k	36k

Poster: Kneisel, et al







### electron-Light-Ion Collider (eLIC) at JLab

#### Could do a linac-ring

- Same luminosity as eRHIC
- Same leap needed in injector performance

#### Alternative: hybrid between ring-ring and linac-ring

- Store the electron beam for ~100 turns in a circulator ring (CR)
- Potential advantages:
  - •Electron beam disruption less of a problem than for ring-ring
  - •Reduces average current in linac by 100x (pulsed beam in linac)
    - •Reduces requirement on electron source by 100x
    - •BBU/HOM problems easier by  $100x \Rightarrow$  cavities are easier
- Don't know how far circulator ring concept can really be pushed ⇒ needs accelerator physics R&D



**Thomas Jefferson National Accelerator Facility** 



### eLIC with a Circulator Ring





### **R&D Needs for EIC's**

	Ring-ring	Linac-ring	CR-ring	Active R&D
Luminosity	10 <sup>55</sup>	1055	10°° 10° 10°°	NaD
e-cooling "¼A" cw gun "½A" cavities	. Yes	Yes	Yes	BNL, Cornell, Jlab
Radiative polarization	Yes	_	_	BNL
e-gun current (~1mA now)		130 mA	5 16 25 mA mA mA	JLab
High-energy, high-current energy recovery	_	Yes	Yes	JLab
Circ. ring accel. physics.			Yes	Jlab





### SRF R&D

#### **Electron cooling**

- 705 and 1497 MHz
- Cutting-edge SRF performance is not critical
- HOM damping: ~<sup>1</sup>/<sub>2</sub>A

#### Linacs

- 705 and 1497 MHz
- "Floor gradient" (MV per meter of tunnel) is important
- Heat load reduction
  - Increase Q<sub>0</sub>
  - Optimize shape
- HOM damping
  - Linac-ring: >130 mA
  - CR-ring: 25 mA



**Thomas Jefferson National Accelerator Facility** 



### Summary

## New fixed-target and collider facilities are being built or designed in Japan and the US.

### SRF is integral to all the US facilities.

### **Plenty of R&D opportunities**

