Early History of Jefferson Laboratory

W&M Colloquium -- April 20, 2007

Franz Gross

JLab and W&M

- ★ What is Jefferson Laboratory?
- ★ Early history phrased in terms of key questions:
  - How did the national community define the scientific need and the accelerator requirements? (i.e. why spend $500M of public money?)
  - How did the Southeast emerge from underdog to frontrunner?
  - Why was the initial choice of 2 GeV changed to 4 GeV? The great energy debate.
  - What were the consequences of the open competition between SURA, Argonne, and MIT?
  - Why did the CEBAF team change the design from pulse stretcher ring to superconducting linac?
- ★ Warning: I will use some of the same "cartoons" to illustrate the physics I used in the 1980's.
- ★ Conclude with some lessons learned

What is Jefferson Laboratory?

- ⋆ Its full name is "Thomas Jefferson National Accelerator Facility " with the official nickname Jefferson Lab. It was originally called the Continuous Electron Beam Accelerator Facility (CEBAF).
- ⋆ It consists of
  - *A 6 GeV continuous electron beam* accelerator (CEBAF) for Nuclear and Particle physics research, to be upgraded to 12 GeV in the near future
  - A high intensity tunable Free Electron Laser (FEL) for condensed-matter research
  - Educational and research programs for K-12 and advanced studies

⇒ 2 SLIDES

Jefferson Lab Site Plan

Existing in 1980

VARC

(Virginia Associated Research Center)

&

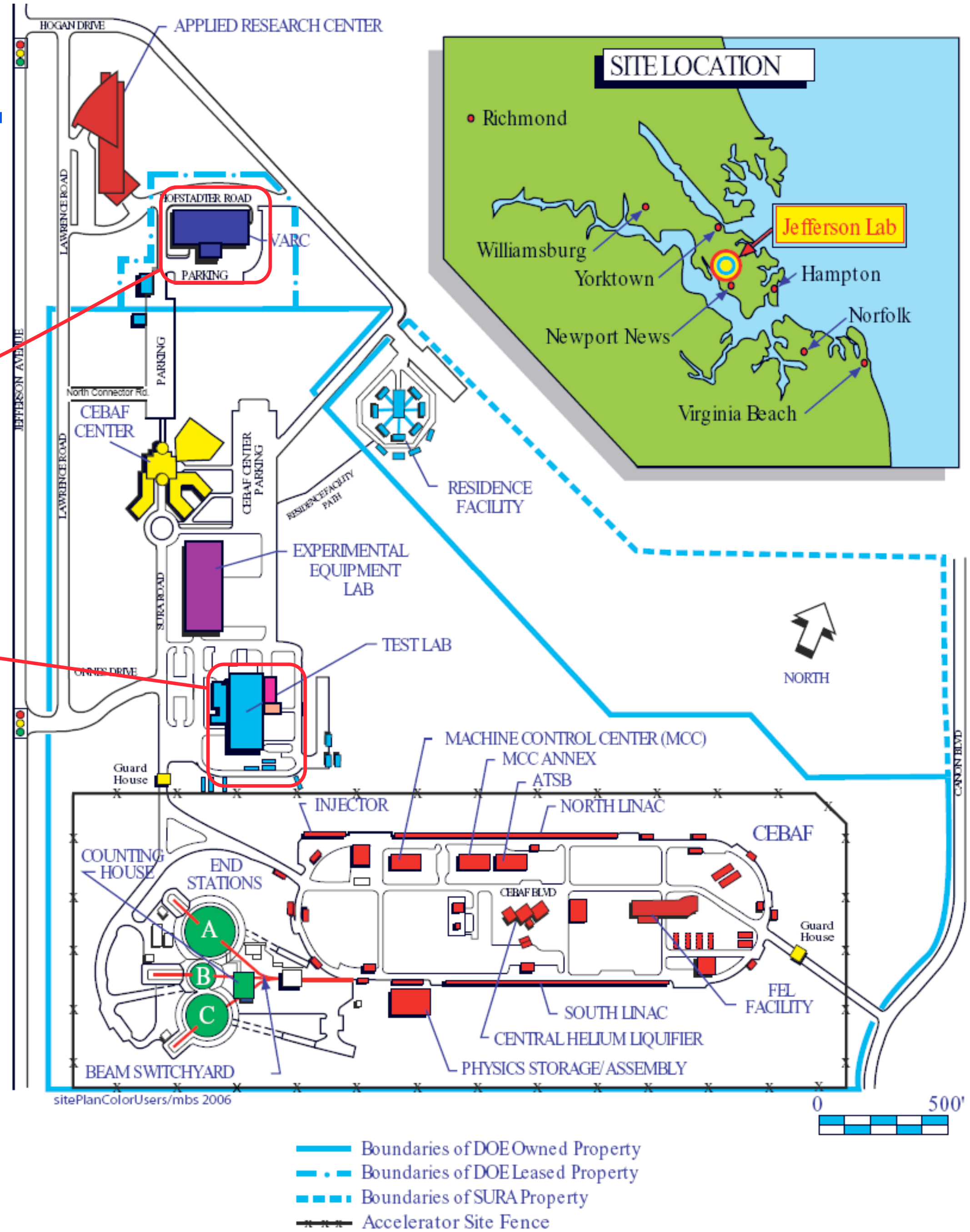
SREL

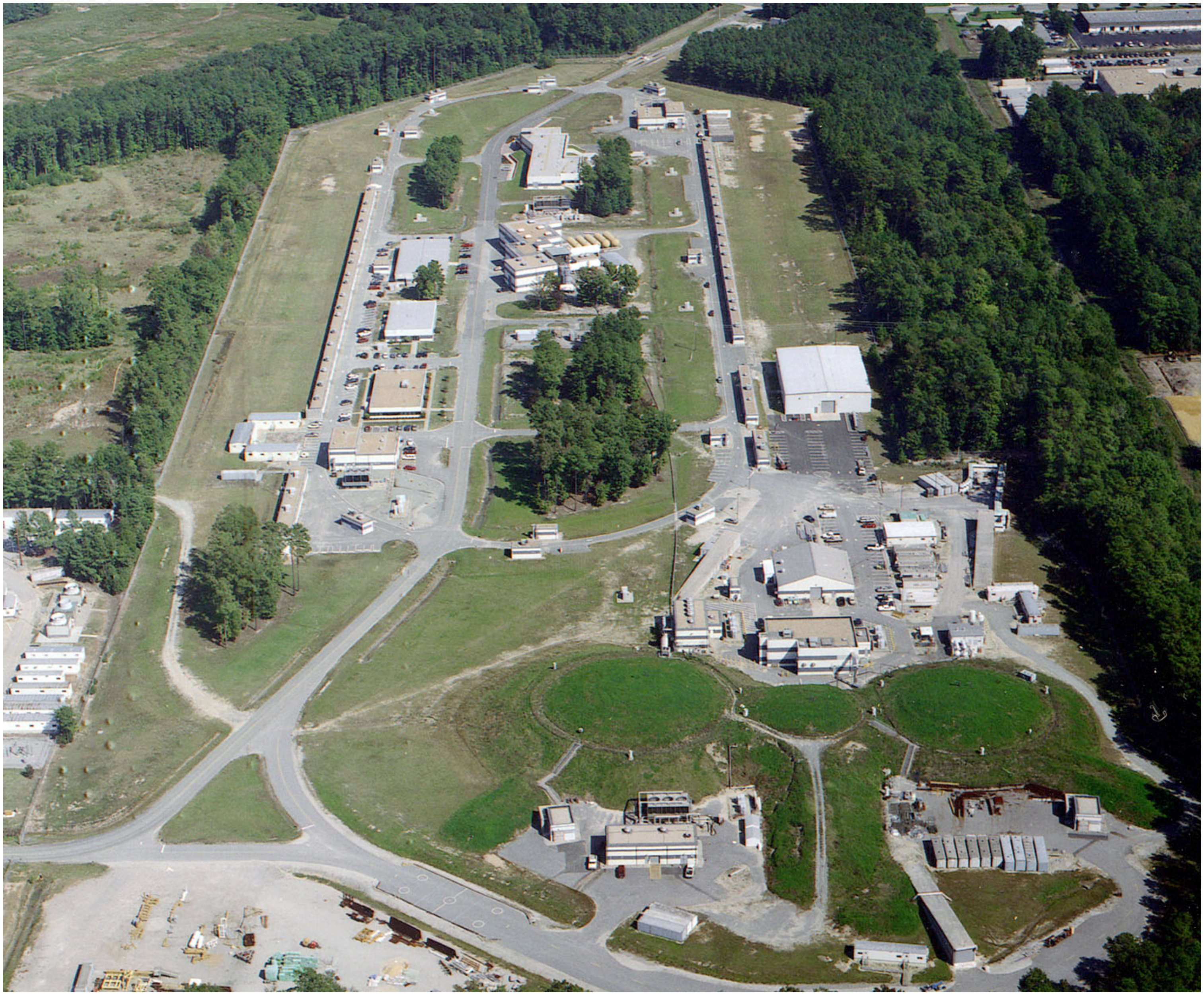
(Space Radiation Effects Loboratory)

Aerial View

(next page)

Open House tomorrow 9 - 2 !!





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  - A 6 GeV *continuous electron beam* accelerator (CEBAF) for Nuclear and Particle physics research, to be upgraded to 12 GeV in the near future
  - A high intensity tunable Free Electron Laser (FEL) for condensed-matter research
  - Educational and research programs for K-12 and advanced studies
- ★ It was conceived of as early as 1976, with proposals for specific designs received in 1982, selection of the Newport News site in 1984, and beginning of the scientific program in 1995.
- ★ Its capability is not matched anywhere else in the world, yet it is, in many ways, identified with the Southeast (and W&M!).
- ★ The early history of Jefferson Lab is an interesting case study of the scientific, technical, and political effort required to start a major new scientific laboratory in the US.

The beginning: before 1980

Early identification of scientific need

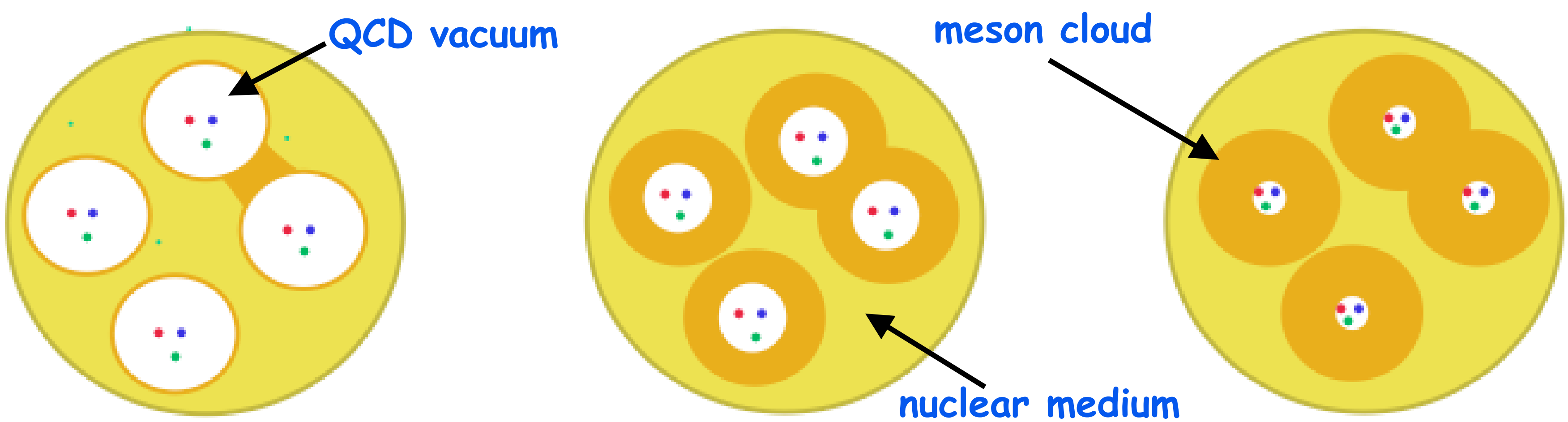
- ★ The discovery of quarks had created a crises in Nuclear Physics in the late 1970's $\Rightarrow$ 2 SLIDES

Status of Nuclear Physics in 1980 -- Where are the quarks?

- ★ Quarks were first introduced in 1961.
- ★ At first no one thought they were real; just a way of describing the symmetries of the strong interactions ("eightfold way")
- ★ They were "observed" in a series of deep inelastic scattering experiments carried out at SLAC from 1967 to 1973. Friedman, Kendall and Taylor got the 1990 Nobel prize for this work.
- ★ In 1973, Gross, Politzer, and Wilczek showed that QCD was asymptotically free, which explained why quarks could not be isolated and firmly established their existence. (Nobel prize 2004)
- ★ Burning questions in the late 1970's:
  - what role do quarks play in the structure of nuclei?
  - how is the nuclear force explained in terms of quarks and QCD?

Status of Nuclear Physics in 1980 (cartoon from colloquia)

★ Three possible views of the nucleus and the role of quarks
R_C = effective quark confinement radius (white circles)
R_N = radius of the nucleon (dark orange circles)



$R_C \sim R_N$	$R_C \sim \frac{1}{2} R_N$	$R_C \ll R_N$
no meson cloud	**meson skin**	**tiny (or no) quark core**

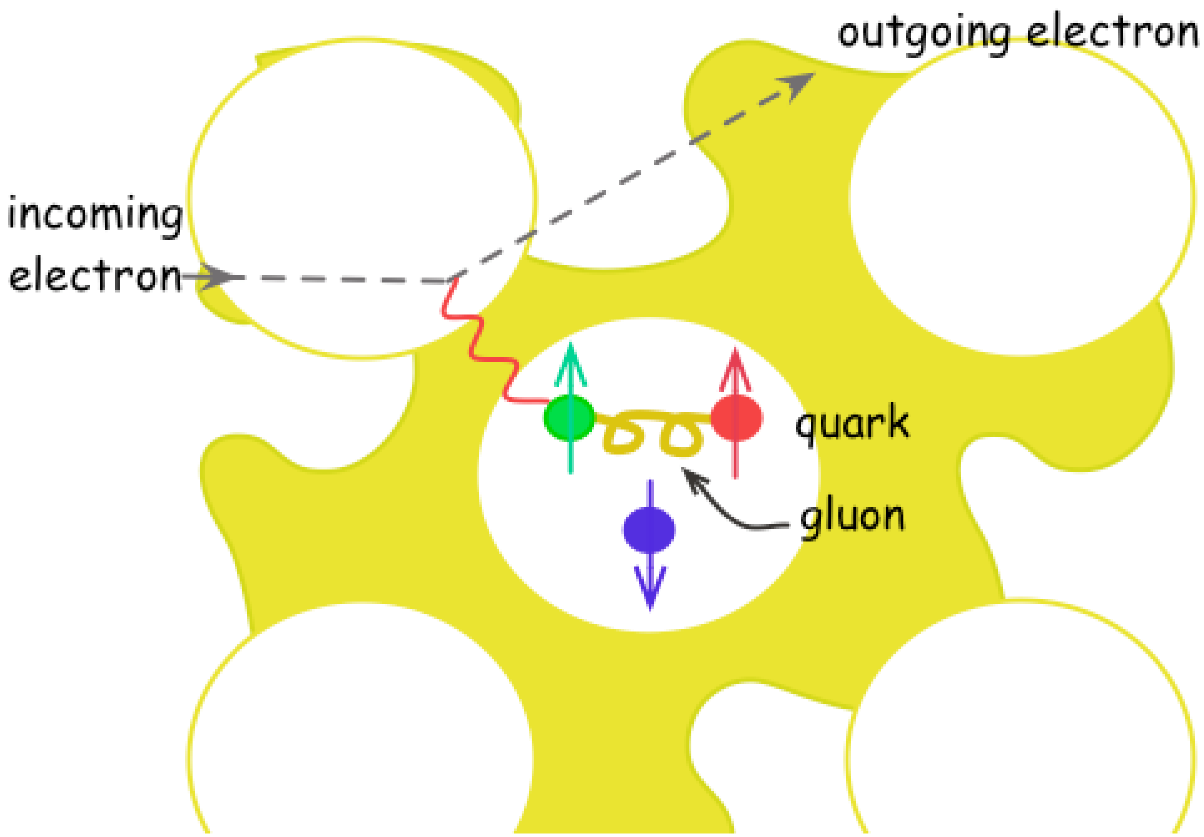
★ Which of these is closest to the truth?

Early identification of scientific need

- ★ The discovery of quarks had created a crises in Nuclear Physics in the late 1970's $\Rightarrow$ 2 SLIDES
- ★ The electron was a precise probe that could penetrate matter; like (as Jim McCarthy used to say) a "sharp knife" $\Rightarrow$ SLIDE

The electron is a precise, well understood probe (CEBAF cartoon)

- Electrons interact with QUARKS only
- Electrons have no structure of their own
- Electrons can penetrate deep inside the nucleus and see its internal structure



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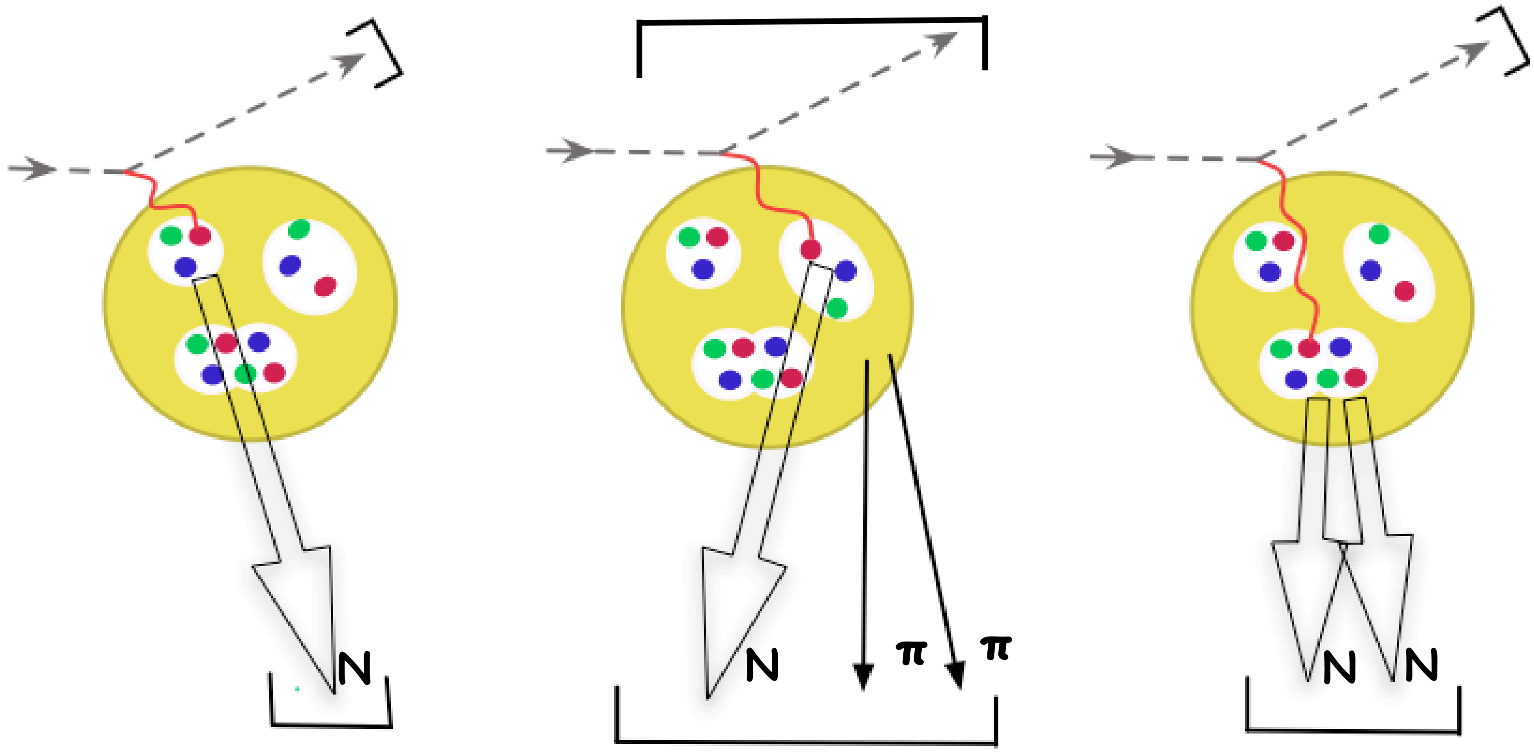
- ★ The physics program required a CW electron accelerator $\Rightarrow$ 2 SLIDES

Coincidence will "fingerprint" rare events (CEBAF cartoon)

Three types of experiments:

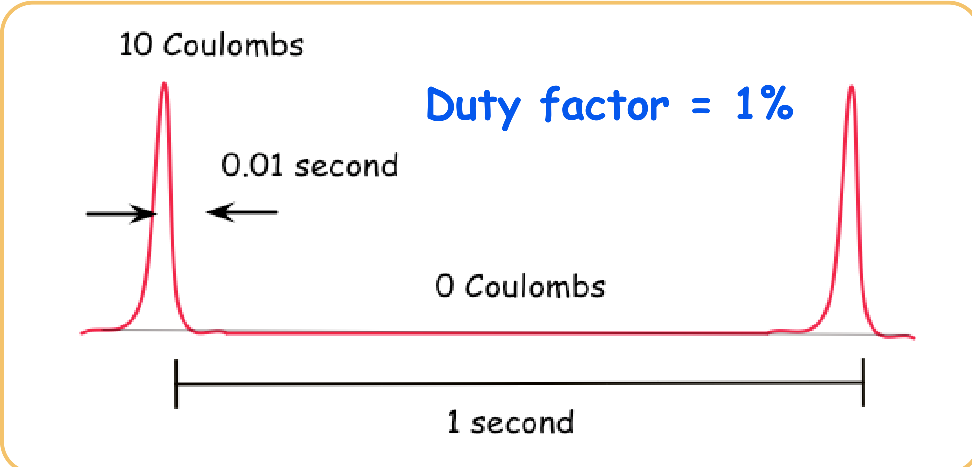
nucleon knockout	multiparticle production	2 nucleon knockout
$^4He(e,e'N)X$	$^4He(e,e'N\pi\pi)X$	$^4He(e,e'NN)X$



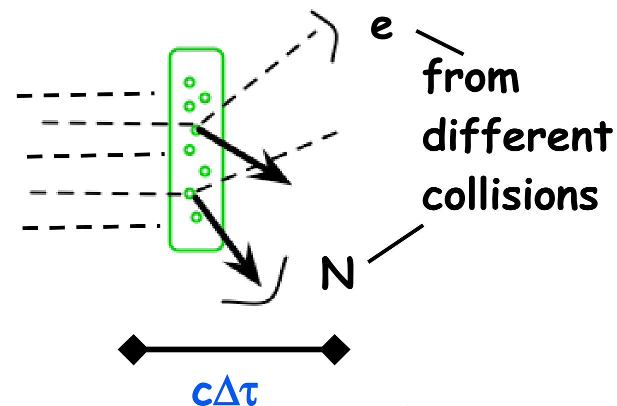
HRS - Hall A	CLAS - Hall B	MRS - Hall C
Are nucleons modified by the medium?	Are there excited nucleons in the medium?	Are there 6-quark bags in the medium?

A continuous beam is needed for coincidence experiments

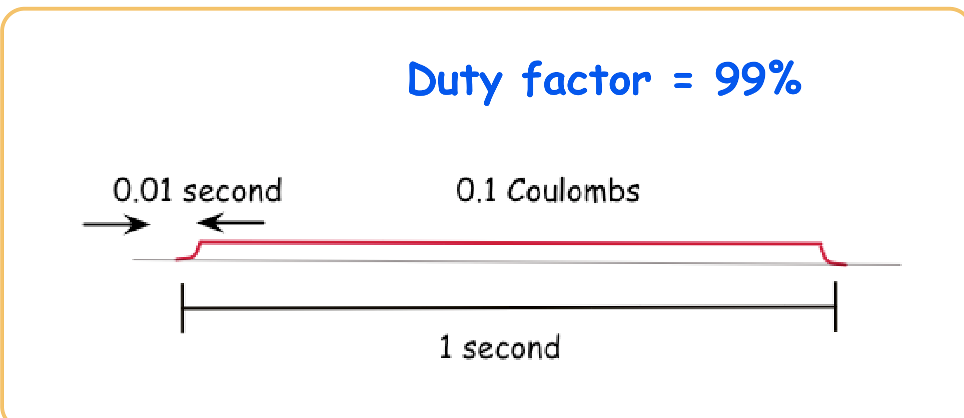
★ Pulsed beams used prior to 1980 (100 mA)



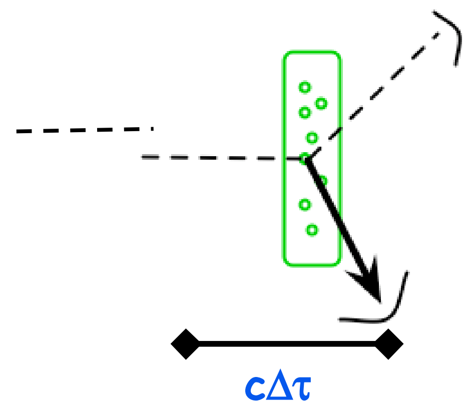
too many electrons in the target over the time interval $\Delta\tau$
lots of random coincidences



★ Advantages of a continuous beam with the same average current



few electrons in the target --
few random coincidences



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- ★ This was articulated by several panels:
  - 1976: Friedlander panel (included Dirk Walecka)

    "An early start on a feasibility and design study for a high-current cw electron accelerator in the energy region >1 GeV is recommended. If technical feasibility is established, the panel recommends that early construction of such a national facility be considered."
  - 1977: Livingston panel (included Bob Welsh)
  - Jan., 1979: UVA Accelerator Conference
  - 1979: NSAC's first Long Range Plan: recommended construction of a "continuous beam, high energy electron accelerator which would be a national facility." Herman Feshbach, MIT, was chair of NSAC.

NAS Panel 1976

Friedlander Panel on the Future of Nuclear Science

1976

Dirk Walecka Art George Bertsch Bob Stockstad Gery Garvey
Harry Gove Herman Feshbach Gerhart Louis Rosen John Schiffer

Members of the Livingston Panel

- ★ R. S. Livingston
- ★ G. E. Brown
- ★ P. A. Carruthers
- ★ F. W. K. Firk
- ★ G. T. Garvey
- ★ I. Halpern
- ★ L. S. Kisslinger
- ★ E. A. Knapp
- ★ J. E. Leiss
- ★ J. S. McCarthy
- ★ R. E. Welsh

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Accelerator properties

- ★ Probe: electrons
  - electron is a point with well understood interactions; will not be confused with the target
- ★ High energy (greater than 2 GeV)
  - to produce short wave lengths for resolving the structure *inside* the neutron and the proton (*where the quarks are*).
- ★ High duty factor (continuous beam or cw)
  - to separate different multi-particle final states from one another
  - find rare events
- ★ High intensity (~100 mA)
  - to overcome the small electron cross section and get enough events for an accurate statistical analysis
- ★ Multiple end stations
  - to allow several experiments at once, because each take a long time to set up and to run

Startup: 1980

Response to the 1979 NSAC LRP -- 1980

National

- MIT saw the new facility as a natural upgrade to the existing Bates accelerator.
- Bates users group took the lead and called a meeting at MIT on January 3-4, 1980. I went!
- The plan was to write a general justification and then prepare many "mini-proposals" for specific experiments to be done at the new accelerator.
- Draft of the "Blue Book" was largely completed in 1980, but it was not published by RPI until the summer of 1981.

Southeast

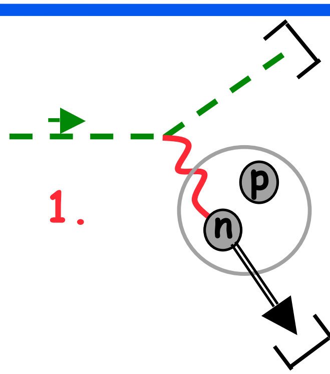
- Jim McCarthy (UVA), with the help of several young physicists (including Richard York, Blaine Norum and Roy Whitney), wanted to design and build the next accelerator. Hans von Baeyer (W&M's director of VARC) Bob Siegel (former director of SREL) and I (theory) wanted the site at VARC. McCarthy agreed to let the location be open to later decision. We were IN!
- May 16 meeting at W&M to organize a University consortium (SURA) to submit the proposal. About 40 physicists from many universities attended. SURA was initially incorporated by W&M, UVA, & VSU. Other universities joined later.
- Other key players were Harry Holmgren (SURA president, UMd), Tom Clegg (SURA treasurer, UNC), Dana Hamel (Commonwealth of Virginia liaison), and Cary Stronach (VSU rep).
- First NEAL proposal at the end of 1980. No other groups were ready. We were too early, but it helped establish our credibility.

The role of Southeastern physicists

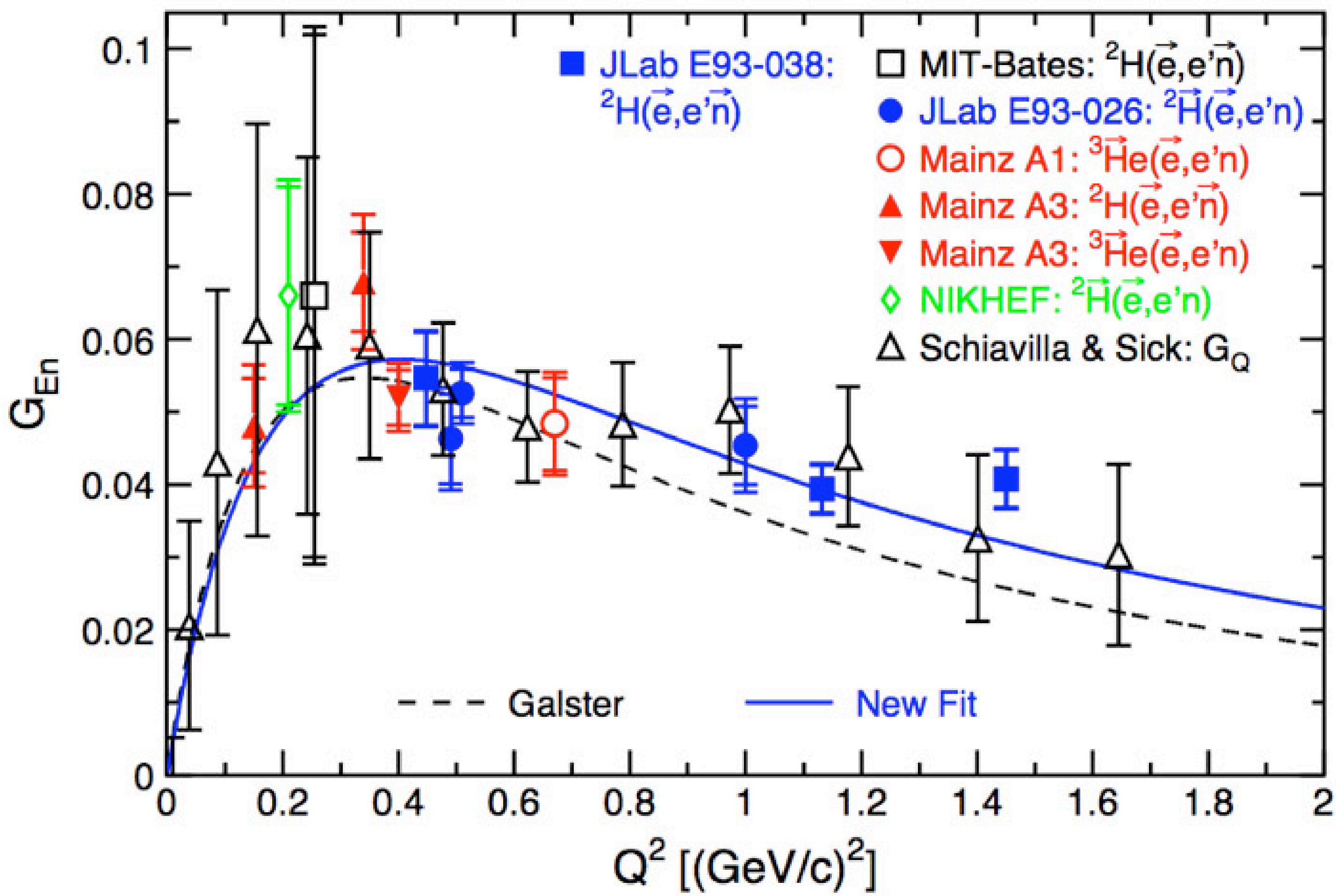
- "Blue Book" contributions of SURA physicists
  - 2 of the 6 authors of the summary section
  - 15 of 57 general contributors
  - 12 of 26 mini-proposals
- SURA physicists met at 6 meetings and one workshop to discuss and prepare the mini-proposals for the two NEAL proposals
- 1982 proposal:
  - 40 physicists from SURA contributed
  - 26 mini-proposals:
    - 9 new ones not included in the "Blue Book"
    - 6 written by physicists outside of the Southeast
- We needed to show the world that SURA physicists were leaders in this field.

5 key mini-proposals to motivate the accelerator

1. Charge distribution of the neutron (very small!):
   - coincidence measurement
   - polarized beam
2. Charge distribution of the deuteron (masked by other contributions)
   - coincidence measurement
   - polarized beam
3. Single nucleon emission (distribution and motion of nucleons)
   - coincidence measurement
4. Excited states of the nucleon and search for "missing" states
   - coincidence measurement
   - multiple particle detection
5. Study of strangeness in nuclei
   - coincidence measurement
   - high resolution



Charge distribution of the proton -- as expected



Charge distribution of the proton -- A SURPRISE

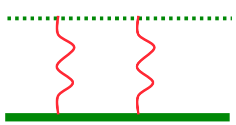
Two measurement techniques
- Polarization transfer
- Rosenbluth separation

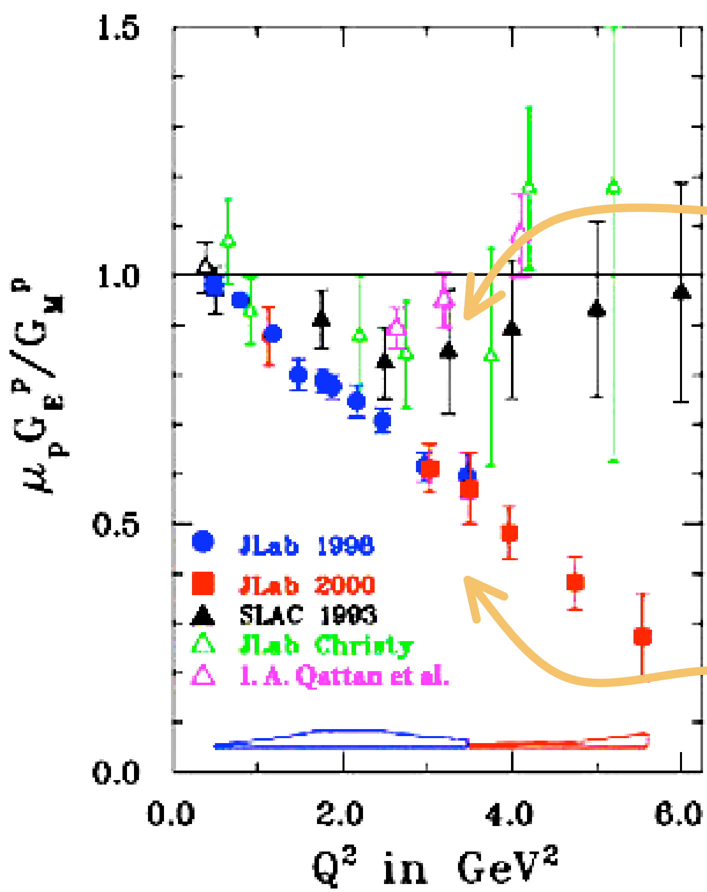
give different results

Explained by two photon exchange effects

<u>Work by W&M people:</u>

Charles Perdrisat (expt)
Carl Carlson (theory)
M. Vanderhaeghen (theory)





Rosenbluth separation
2 γ effects
LARGE

polarization transfer
2 γ effects
SMALL

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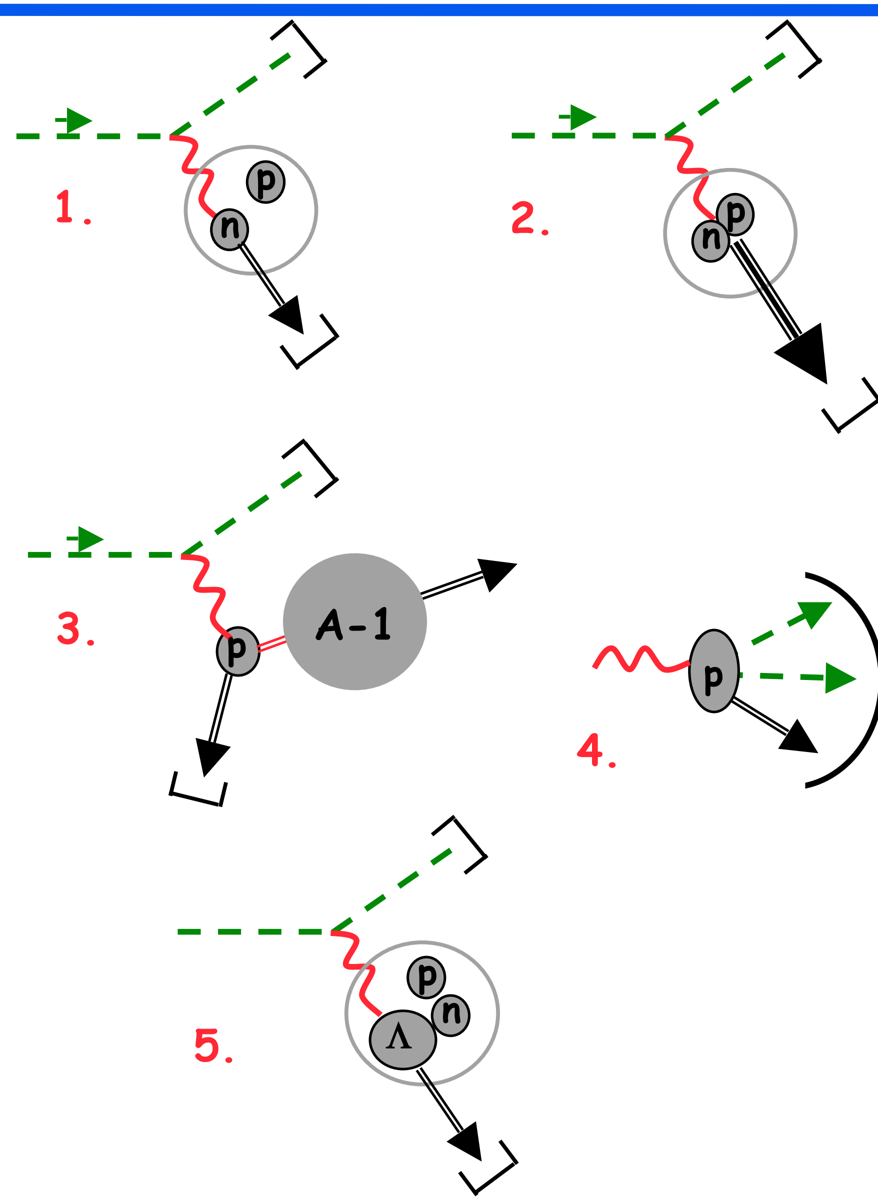
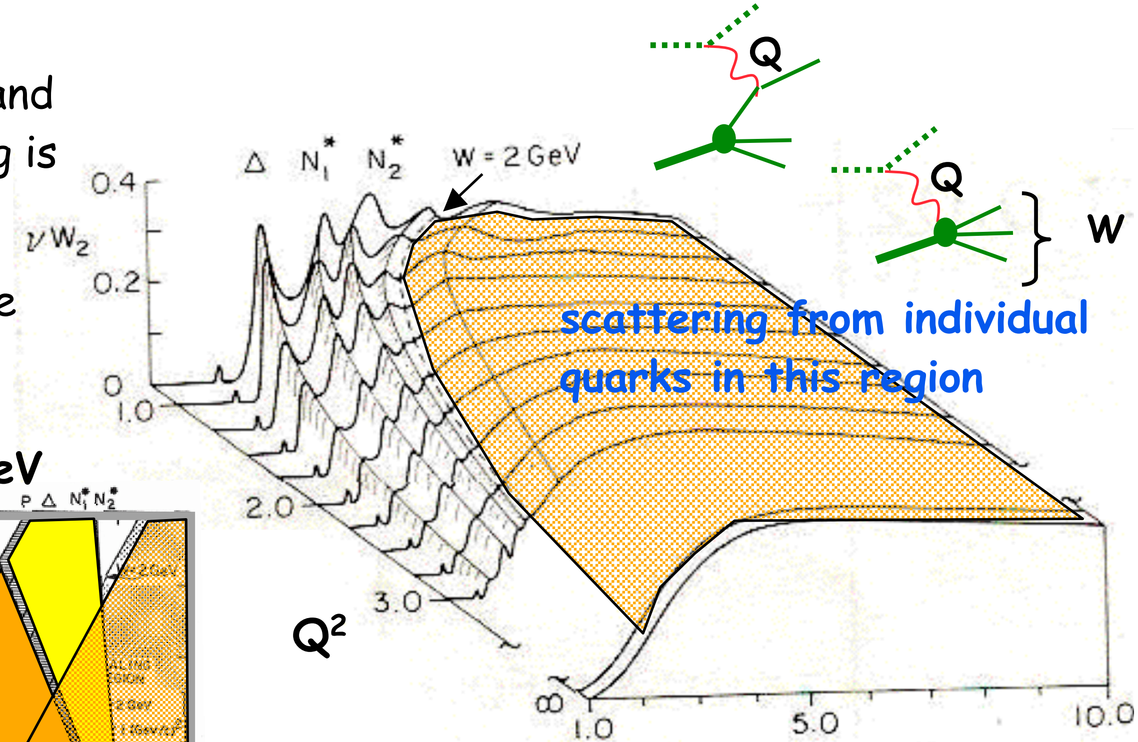
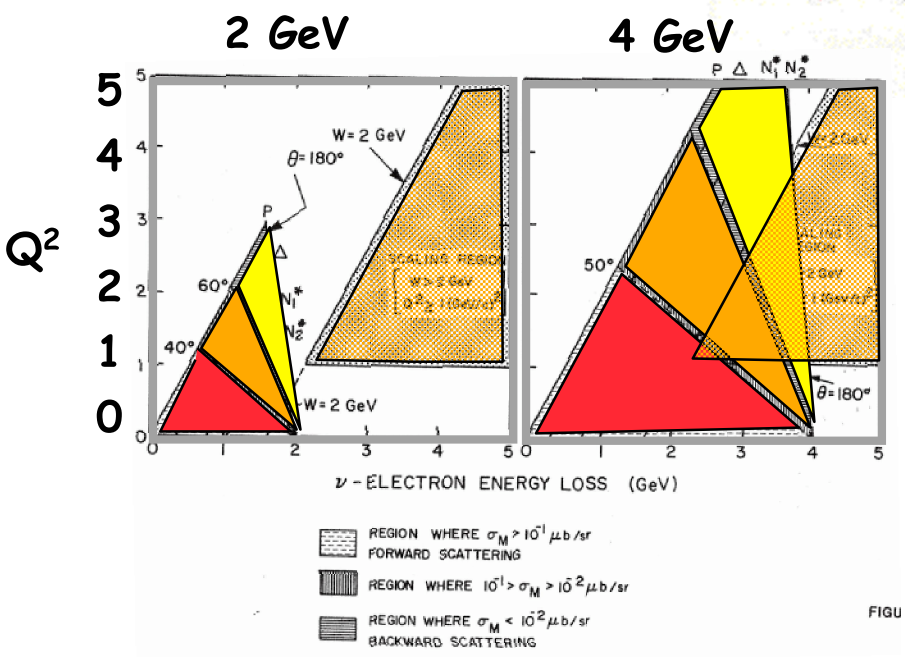


Defining the options: 1982

The decision to go for 4 GeV (Barnes committee)

- ★ The deep inelastic terrain and the region where scattering is from individual quarks.
- ★ This region is not accessible with a 2 GeV accelerator





W>2
Q^2>1

$$\omega' = 1 + \frac{W^2}{Q^2}$$

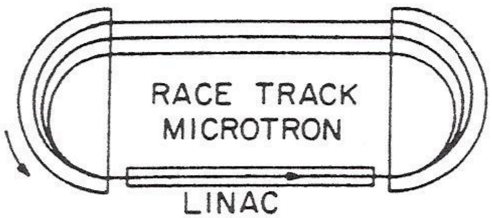
- low counting rates
- medium counting rates
- high counting rates

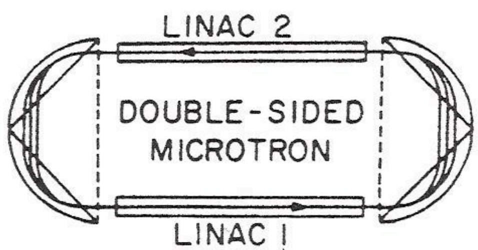
The five proposals submitted by the end of Dec. 1982

- ★ SURA's second NEAL proposal: 4 GeV; Linac recirculator and pulse stretcher ring
- ★ Argonne National Laboratory: 4 GeV; Hexatron microtron fed by racetrack microtron $\Rightarrow$ SLIDE
- ★ Massachusetts Institute of Technology: 2 GeV (with 4 GeV possible for the future); Linac recirculator and pulse stretcher ring
- ★ National Bureau of Standards: 1 GeV; 2-Stage cascade racetrack microtron
- ★ University of Illinois: 0.75 GeV; 3-Stage cascade racetrack microtron

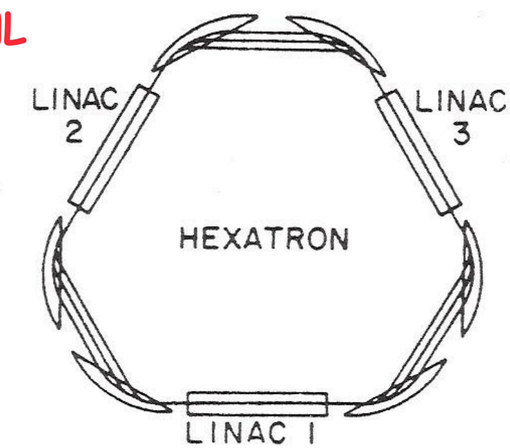
Competing accelerator designs

NBS: 2
UI: 3

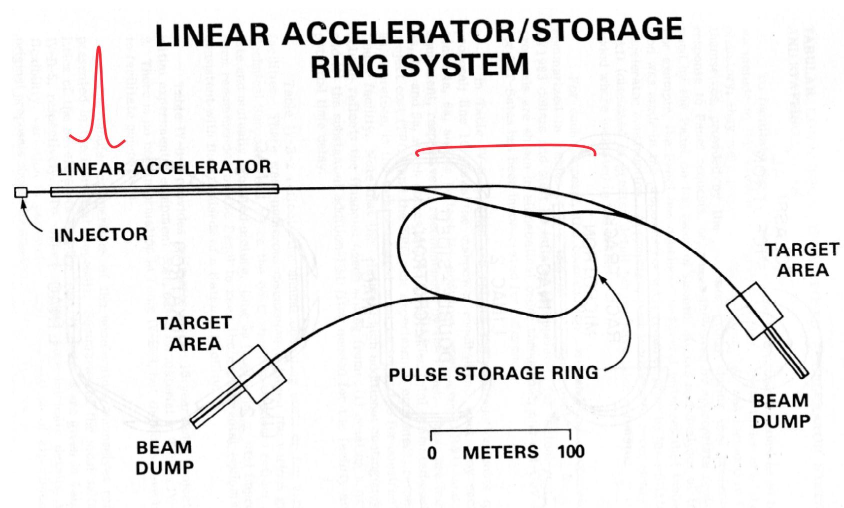




ANL



SURA
MIT had a similar design



Decision and controversy: 1983 -- 1984

The Bromley panel

- ★ An panel, chaired by D. Allan Bromley of Yale, was appointed by NSAC on Jan. 12, 1983. It was to review the proposals and make a recommendation to NSAC.
- ★ We found, to our dismay, that the panel was empowered to reconsider the 4 GeV energy recommendation of the Barnes Committee. The Bromley panel did not include the experts that had been on the Barnes subcommittee. We thought this was a bad sign; it had been a hard fight to get the 4 GeV recommendation, and MIT was known to favor 2 GeV.
- ★ The Bromley panel gave each group an opportunity to submit written questions about the other proposals, which were answered in writing.
- ★ An open meeting was scheduled for Feb. 17-18 in Washington. This was it!
- ★ The panel made its recommendation to NSAC, which was accepted and forwarded to DOE and NSF on April 29.
- ★ The panel had a technical subcommittee chaired by Hermann Grunder!

The Washington "shoot-out" -- Feb. 17 - 19, 1983

- ★ Argonne and MIT were well known, established groups.
- ★ SURA was comparatively unknown and a clear "underdog."
- ★ Illinois and NBS were there primarily to be sure their desire to upgrade existing facilities was considered, but they were not in competition for the National Lab.
- ★ We had to defend both our design, and argue again for 4 GeV.
- ★ The schedule:
  - 1st day: SURA, Illinois, and NBS
  - 2nd day: Argonne and MIT

  Was it an unfavorable placement? (I thought so, but events proved me wrong.)
  - Bromley repeatedly asked "why 4 GeV?" Each time I answered, and no one else disagreed. Gerry Garvey (scientific spokesman for Argonne) agreed with me (Argonne also wanted 4 GeV). Bromley eventually asked me to "be quiet."
  - I kept expecting arguments from MIT for 2 GeV - where were they? But MIT did not show until the 2nd day. Fatal mistake; the momentum for 4 GeV had built, they had not answered Bromley's questions, and it was too late.

The selection of the SURA NEAL proposal - 1

- ★ MIT lost because they had no serious proposal for 4 GeV. The competition reduced to SURA vs. Argonne.
- ★ Argonne lost because their design was very risky. One of the world's experts in microtrons (H. Herminghaus) was unsure it would work.
- ★ April 22, 1983:

  The Bromley panel agreed with the Barnes Subcommittee that the highest priority go to an electron accelerator with at least 4 GeV maximum energy.

  The Panel recommended "that the SURA proposal be accepted and funded." (By a 9 to 3 vote we learned later.)

The selection of the SURA NEAL proposal - 2

- ★ SURA was selected because

  (i) It promised to create at least 35 new faculty positions in nuclear physics to support CEBAF (by 1996, 127 CEBAF related positions had been created).

  (ii) The SURA design could readily be extended to 6 GeV, while the Argonne design could not. ⟹

  (iii) The SURA design was more conservative (if downgraded to half the current) while there were significant concerns "potential beam loss" of the ANL design. ["Hard vs. soft failure modes.]

- ★ SURA was urged to
  - Hire an experienced management and construction team
  - Create a National Advisory Board (NAB) to "engage in all major decisions"
  - Create a Program Advisory Committee (PAC) and announce a formal solicitation of experimental proposals
  - Look into utilizating SLAC, and
  - Consider possibility of relocating NEAL "near one or more major university campuses and one or more major airports"

Aftermath

- ★ You would have thought we would begin right away, but Argonne protested DOE's decision.
  - Funding and selection of a Director was delayed.
- ★ DOE changed the name from NEAL to CEBAF.
- ★ The 1993 second NSAC LRP did not give CEBAF the highest priority; it emphasized the need for RHIC.
- ★ We were in trouble, as summarized in articles in Physics Today (September, 1984) and Science (Aug. 17 1984).
  - Senators Hatfield and Johnson: "is there a scientific need for such a machine? Is it the most cost-effective facility for nuclear science? Is its justification to satisfy a political or geographical constituency, because do many states and universities are involved and the Southeast is without a major accelerator?"
  - Senator Warner from Virginia defended it. Some called it the "Warnertron." Was this another Isabelle?
  - A PRL paper by Isgur and Llewellyn-Smith, casting doubt on the ability of perturbative QCD to explain CEBAF physics, was circulation through Congress!
- ★ DOE asked for another review

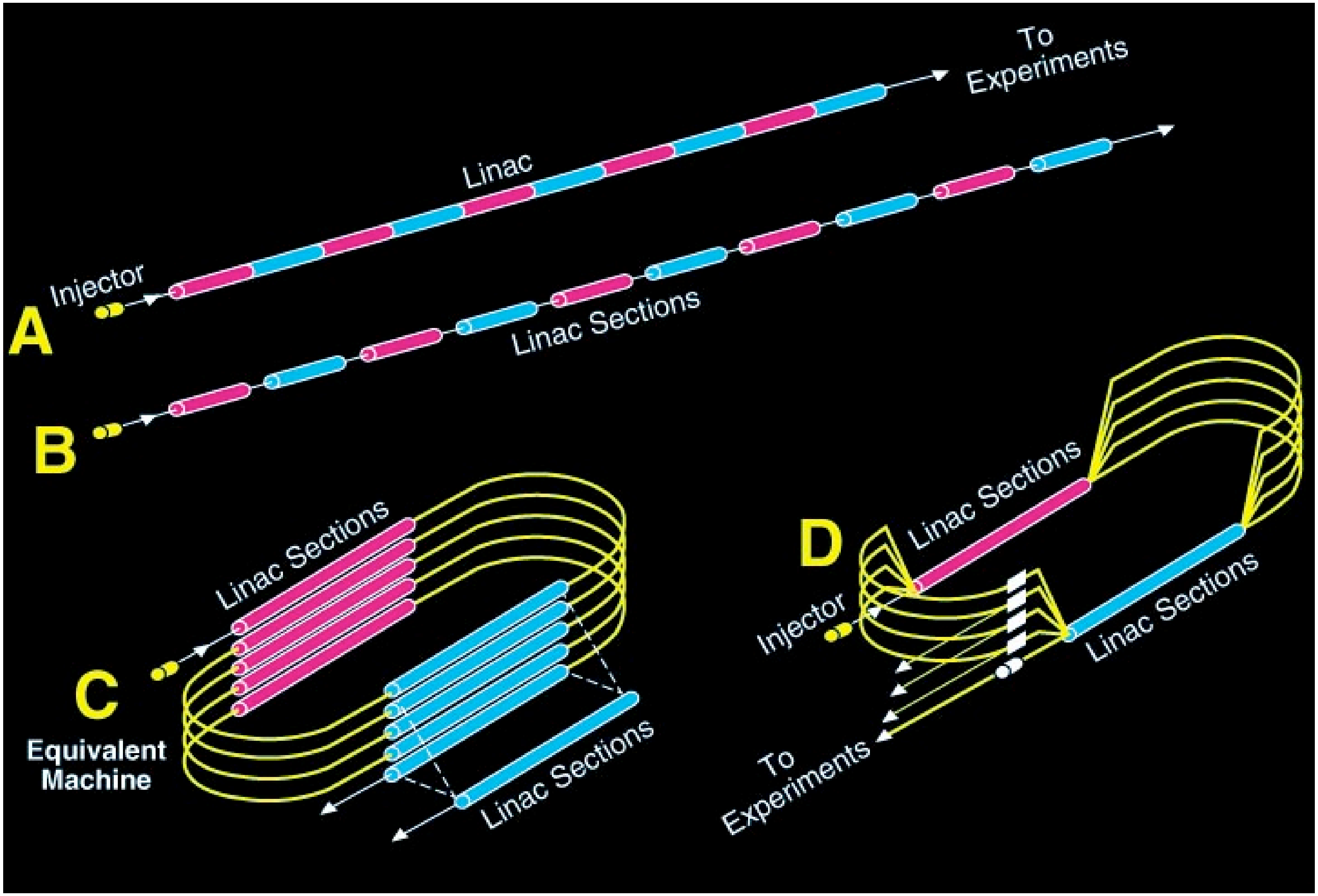
  Sept. 1984: Vogt Subcommittee report "reaffirms a 4 GeV CW electron accelerator as the first major construction project for nuclear physics"

Taking off: 1985 -- 1986

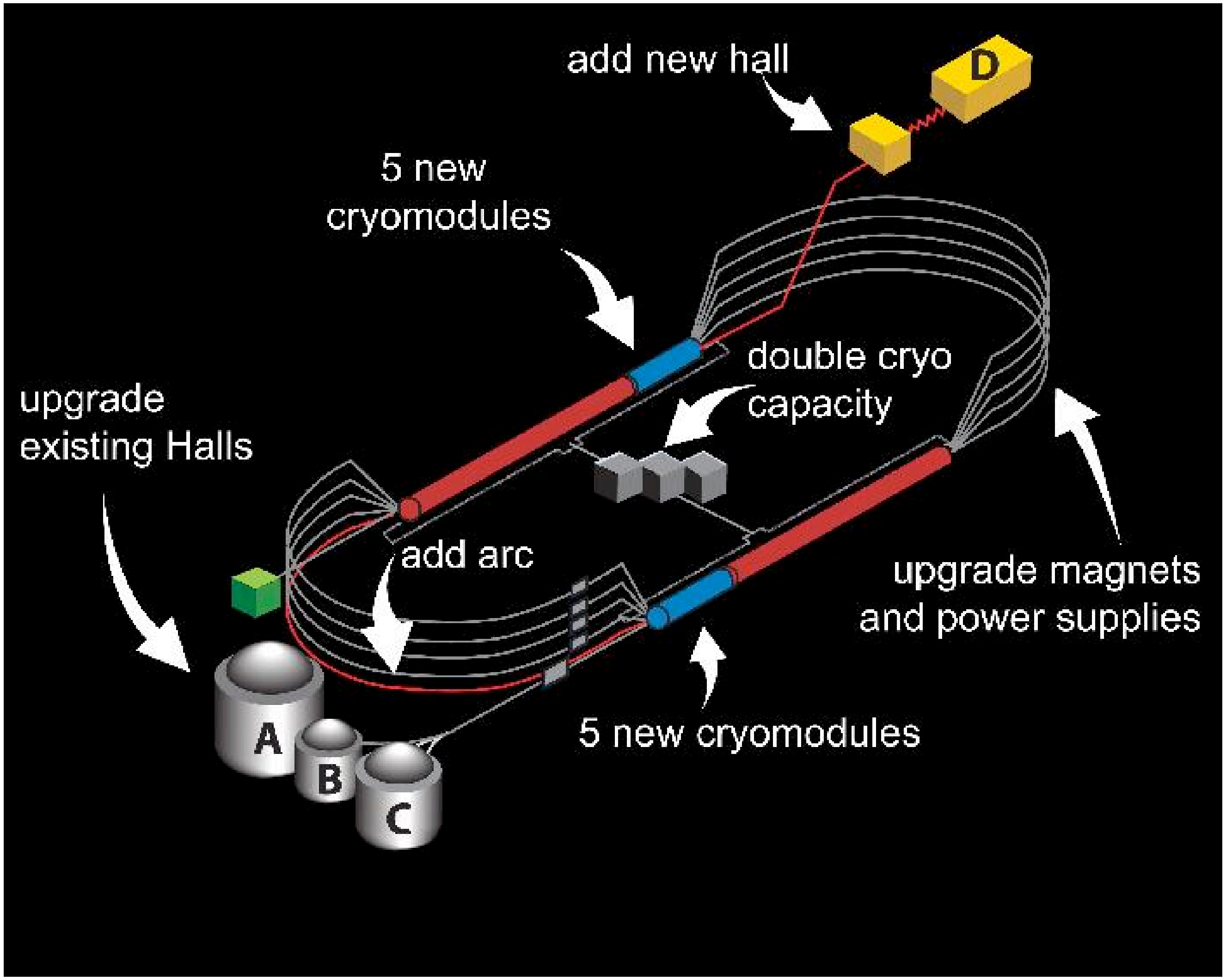
Taking off with a new team and a new design

- ★ Establishment of a credible National team:
  - Hermann Grunder arrives in May, 1985; his Berkeley team a month later
  - J. Dirk Walecka becomes Scientific Director on May, 1986
- ★ Superconducting technology was developing fast. Hermann Grunder ordered one last look at this technology
- ★ The staff decided to go for the superconducting linac design ⇒ SLIDES
- ★ Advantages:
  - lower cost (in the end it may have been a wash)
  - better beam quality
  - "easy" energy upgrade (got 6 GeV from the original design)
  - each of the 3 end stations could be given a beam with a different energy and a different current
- ★ The state-of-the-art technology made CEBAF a more successful laboratory and was a major achievement.

Recirculated Linac Concept



Accelerator schematic with 12 GeV upgrade options



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Historical review -- 1976 to 1986

The beginning	1976	Friedlander panel
	1977	Livingston panel
	Dec 1979	First NSAC Long Range Plan
Startup	1980	Formation of SURA and submission of the First NEAL proposal
Defining the options	Fall 1982	Barnes NSAC Subcommittee recommends 4GeV
	Dec 1982	DOE receives 5 proposals; 2 for lower energy accelerators
Decision and controversy	April 1983	NSAC endorses the SURA proposal
	July 1983	DOE names NEAL the Continuous Electron Beam Accelerator Facility
	Dec 1983	Second NSAC Long Range Plan
	Sept 1984	Vogt Subcommittee report
	Dec 1984	Reaffirmation of the NSAC Long Range Plan
Taking off	May 1985	Arrival of Hermann Grunder and the Berkeley team
	Dec. 1985	CEBAF staff prepares plans for a SRF accelerator
	May 1986	J. Dirk Walecka joins CEBAF as Scientific Director
	Oct 1986	Appropriation of Construction Funds
	July 25, 1994	First beam on target!

Major Milestones -- 1980 to 1996

- 1980 - Formation of the Southeastern Universities Research Association (SURA) and submission of its first NEAL proposal
- 1982 - Five (including second NEAL) proposals submitted to DOE
- 1983 - SURA proposal selected by DOE
  NEAL named the Continuous Electron Beam Accelerator Facility
- 1984 - Newport News site selected and federal funding for R&D
- 1985 - Arrival of Hermann Grunder and the Berkeley team
  Superconducting design developed
- 1986 - J. Dirk Walecka joins CEBAF as Scientific Director
- 1987 - CEBAF construction start
- 1990 - Nathan Isgur becomes Theory Group Leader
- 1994 - first beam on target
- 1995 - Physics program begins in Hall C
- 1996 - CEBAF dedicated by SURA;
  laboratory named Thomas Jefferson National Accelerator Facility

Major themes:

1. Development of the scientific justification and need for such an accelerator, and determination of its general specifications.
2. Preparation of specific proposals for meeting these scientific needs. Three were in serious contention:
   - SURA's NEAL proposal for a 4 GeV pulse-stretcher ring (later changed to the present SRF linac design).
   - Argonne's proposal for a 4 GeV Hexatron microtron
   - MIT's proposal for a 2 GeV pulse stretcher ring

   Argonne and MIT were well known, established groups. SURA was comparatively unknown and a clear "underdog."
3. Review of these proposals, involving public debate before DOE review committees, and selection of a winning proposal (SURA's).
4. The aftermath: failure of some in the scientific community to initially accept DOE's decision. POLITICS!!

Lessons learned

★ Selection of an "underdog" in science is possible provided:

- the science is on your side (4 GeV)
- your work VERY hard at every step
- your are as good as the competition (McCarthy design team was good)
- the competition is open (DOE's decision)
- you have political power (SURA, Senator Warner)

★ Getting $500 M for any project will not be solely a scientific decision; it may lead to a serious political fight

★ In the end, science plays by different rules, but is subject to the same political forces affecting all government decisions.

END