Recirculating Energy Recovery Linac: An Upgrade Concept for the Advanced Photon Source

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Outline

- Why an ERL
- What could an ERL look like at APS
- R&D - prepare to design and build an ERL

An ERL could provide excellent beam performance for the APS Users

- Same number of photons/sec as today's APS
- 4 orders of magnitude more brilliance, and ~100fs-long pulse
- Could be constructed and integrated with minimal disruption to the APS and its vast existing experimental infrastructure
- Challenging and fun

ERL@APS: poster - 2003 SRF Workshop

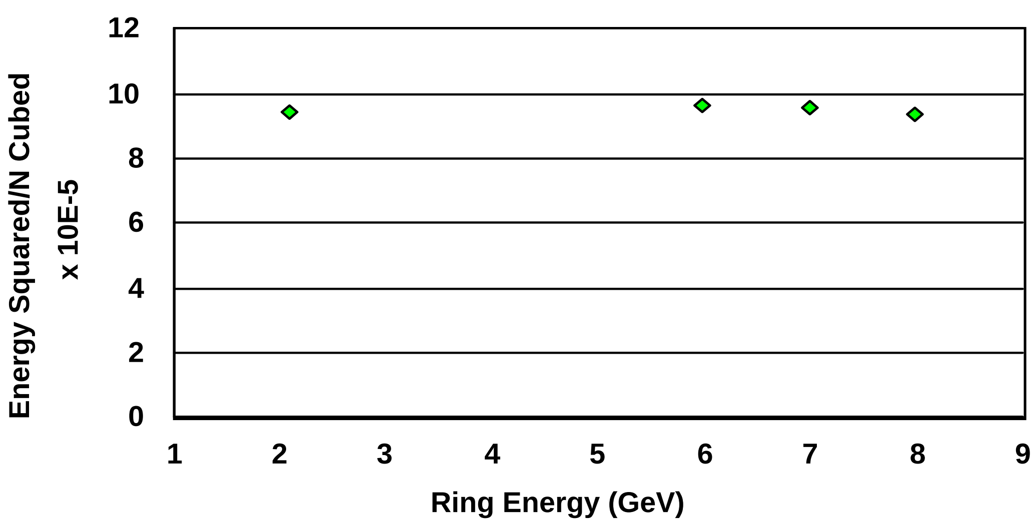
Y. Cho and M. White,

"Conceptual Design of a Multi-turn Energy-Recovery Linac for the Advanced Photon Source Ring"

- Upgrading the APS is in DOE's 20-year plan – an ERL driver is now under serious consideration. Work so far is limited to conceptual.

New look @ERLs: Make Light using a Linac

- Source Brilliance ~ 1/(electron beam emittance)^2 >> ***Make emittance small***
- Ring Emittance ~ E^2/N^3 N = No. of Dipoles in the Ring
- Ring Design - optimize E vs. N to get desired Emittance



PLS (2 GeV) N = 36

ESRF (6 GeV) N = 64

APS (7 GeV) N = 80

SPring-8 (8 GeV) N = 88

All machines have ~ ε (designed for ~7nm)

Linac Emittance

- Linac Beam Emittance ~ 1/E
  - **Emittance can be made very small by increasing Beam Energy**
- 7 GeV linac beam can have emittance as small as ~ 1Å [$\beta\gamma$E ~7e-11m]
  - ***(compare to APS 3 nm)***

If the emittance is reduced by 10^2 then:

- Brilliance of the linac-based light source could be four (4) orders of magnitude greater – Brilliance ~ $1/(\varepsilon^2)$
- The linac bunch length can be shortened by bunch compression – use existing FEL and LC technology
- **Thus, the photon beam pulse length could be ~100 fs rather than 20~30 ps from the storage ring.**

Drawback – high linac beam power

- The goal is to maintain the same average beam power to our users as they presently get in "top-up" mode… thus, need a CW linac

- APS (7 GeV, 100 mA) is equivalent to 700 MW
  - **Prohibitive AC power requirements**
  - **Immense beam dump issues [SNS @ 1.4 MW]**

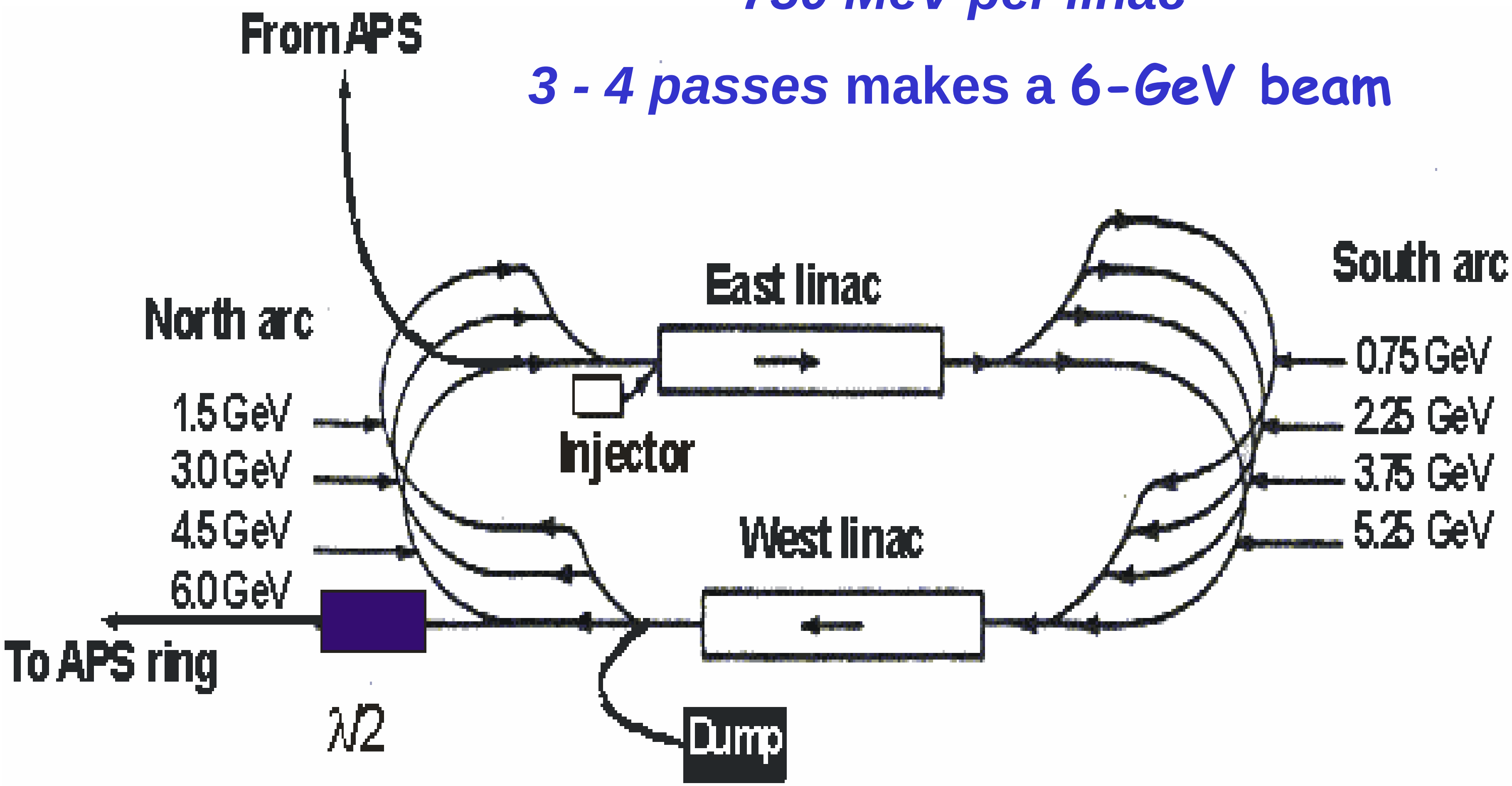
Why recirculate?

- With today's SRF technology, a 6-GeV CW linac would require a huge cryoplant.
- If the beam energy is recovered and reused, such a linac-based light source is feasible.
- Recirculation can greatly improve the efficiency.

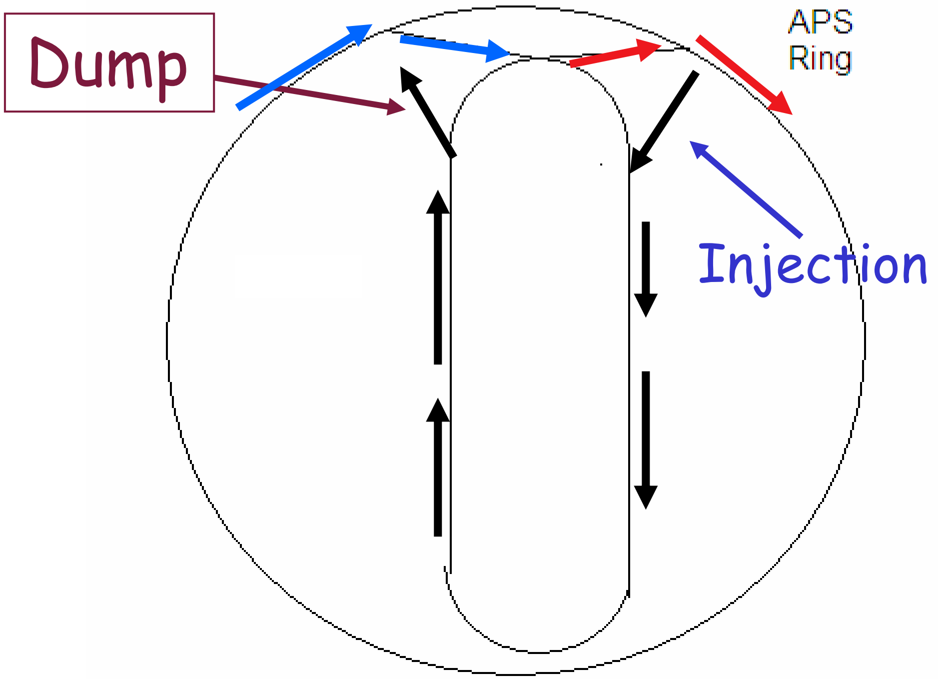
Use a CEBAF-like Recirculating SRF Linac

750 MeV per linac

3 - 4 passes makes a 6-GeV beam



Single pass thru APS - then recover rf power and dump beam at low-energy



- dE/dx = 10 MV/m
- 2x75 m linacs
- 4 turns = 6 GeV

Re-circulating linac in he APS Infield.

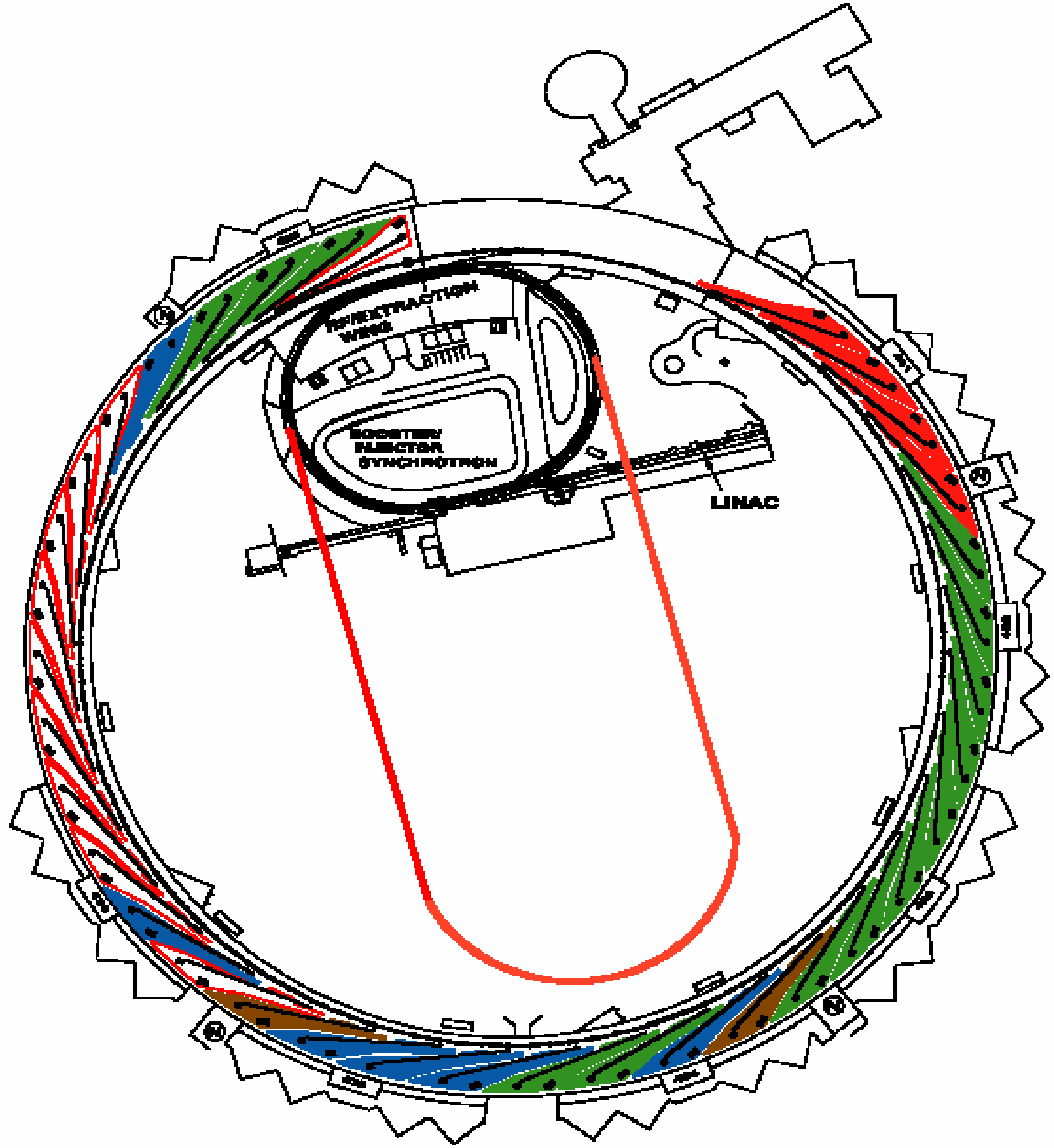
Geometry meets the .nergy recovery ondition (Folded fig8).

Shorter Linac (less tored energy) >> Easier" to control

- RF energy goes directly to beam.

Two 750-MeV, 100mA-CW Recirculating Energy Recovery Linacs in the APS Infield

Same APS Ring: ERL can be constructed and operated with minimal impact to the vast existing user infrastructure.



ERL could be implemented without destroying the existing injection chain if desirable.

- The synchrotron damping time is order of 2.5ms or 1000 turns.
- The betatron damping time is order of 5ms or 2000 turns.
- Minimal degradation in one turn
- But, need to understand CSR… BBU… etc…

Need to know what the users will want by that time

- Single high-current bunch: can run without recirculation
- From just a few bunches in the ring up to CW – at some point recirculation is necessary… depends on various factors…
- how close together must the bunches be for it to work? Long time constants, should be ok?

R&D – in preparation for ERL design/build

- Collaboration saves time and money
- Gun R&D
- ERL design, beam simulations
- Rf and rf control simulations
- Need sophisticated mechanical design and simulations – microphonics, resonances…
- Beam experiments – what can we do now or in the near future?

R&D – SRF Cavities, CMs, and Control

- Need hi-Q SRF cavity optimized for this purpose – BNL, Cornell, Bessy, JLAB…
- Dampers, tuners, couplers…
- Need high-efficiency cryomodules with low static losses while maintaining swap-out capability for good availability.
- Rf power source, phase/amplitude stability… need state of the art SRF LLRF control, how much overhead – see SNS, LBNL, JLAB…
- Assume >95% availability – design for that.

- Need R&D on recirculation of high currents
- Handling energy-recovered beam
- Need to optimize operating frequency and temperature – 700MHz, 1.3GHz ? 2K or less?
- A long road, lots of excitement, good collaborations will get us all there!

Conclusion

- An ERL driver for the APS offers the potential for excellent performance [low emittance, short pulse, high brilliance] for the users, and exciting challenges for us.
- The Re-circulating ERL Concept can be used to Upgrade all 2nd and 3rd Generation Light Sources