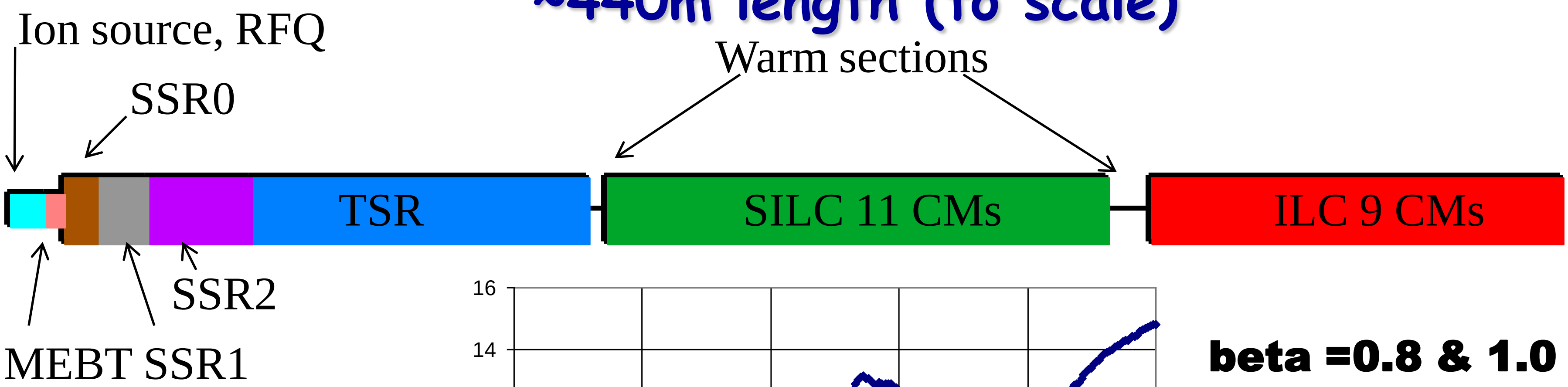
Project-X vs a 10 MW ADS linac

Bob Kephart
Fermilab

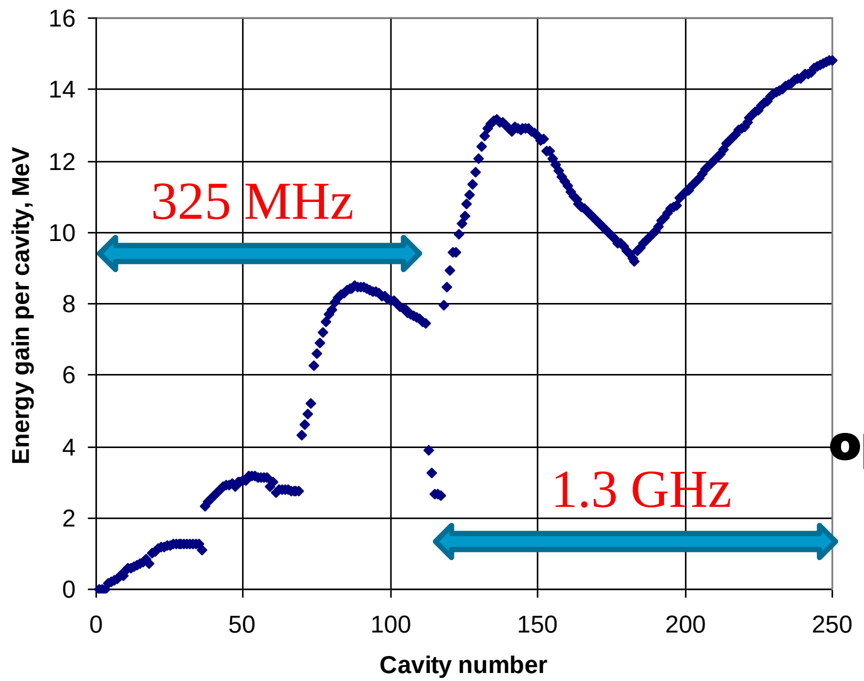
ICD-2
2-GeV CW linac schematic

~440m length (to scale)



4 families of spoke resonators (similar to ICD-1)

325 MHz to 460 GeV



beta =0.8 & 1.0 elliptical cavities 1.3 GHz to 2 GeV

but

operate@15-17 MV/m in CW mode
$Q_0 > 1.5 \times 10^{10}$

Requirements for ADS linacs

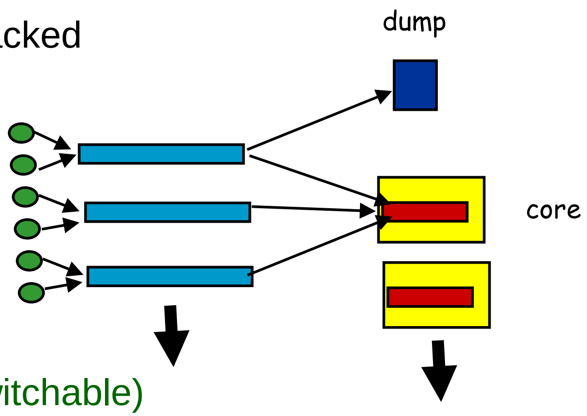
- A 10 MW proton source to create neutrons for ADS might be similar to the 2 GeV 2 MW CW linac under consideration for Project X
- Project X could in principle be modified to deliver 10 MW
  - However, the optimal energy for ADS is probably lower than 2 GeV
  - Required power for an ADS accelerator is probably above 10 MW
- Nevertheless there is much that could be learned about an ADS linac with Project X
  - but…
  - we should realize that there are quite a few possible differences in the <u>basic</u> specifications of an ADS linac vs an upgraded Project X linac
  - should focus discussion on the areas where there is commonality

Differences Px vs ADS linac

- Commericial: Power Production is a business
  - Basic purpose of the linac is different
  - ADS Linac is part of a facility intended to make money vs acquire knowledge
- Optimization:
  - Research accelerators usually emphasize optimization of performance vs capital cost, availability, operating costs, efficiency, project risk, etc. (even though many of these also are important for a research accelerator)
  - Availability requirements for commercial power production are much higher vs a research accelerator like Project X. (but perhaps are more similar to ILC ?)
  - A commercial power plant will be built around this linac ➔ requires a very conservative design with low risk (must satisfy investors vs your colleagues or the DOE reviewers)
  - A company building an ADS linac would probably do a better job of optimizing capital costs vs operating cost with a long term view
    - easier for industry since they will borrow money to do this right vs research environment in which we want the project approved
    - ie DOE environment favors solutions with lower initial construction costs
- Maintenance and Operation: ADS linac must be operable and maintainable for long periods without large on-site laboratory accelerator staff

Differences, Development

- Reliability: (some requests seem extreme! < 5 trips/yr > 1 sec)
  - Cryogenics and RF power are likely weak points but can be attacked
  - Use high availability approach to control electronics
  - Avoid single point failures… e.g. beam pipe vacuum
  - A lot could be learned about reliability from Project X



- Redundancy:
  - ➢ Linacs with multiple sources (PX could develop this)
  - ➢ Multiple linacs in separate enclosures. (1needed/core , switchable)
  - ➢ Hot spare linac with power switched from dump to ADS core ?
  - ➢ Multiple independent cryo systems so one or more linacs could be off for maintenance
  - ➢ Px might then ~simulate <u>one</u> of these machines
- Operating Efficiency:
  - Need efficient wall plug to beam power efficiency (SRF)
  - Electrical power use for cryogenics will be important ➔ use high Q cavities, low operating gradients (BCS losses go as G**2/Q), efficient cryogenic cycles
  - Likely an optimal ADS machine would be lower frequency (cryo efficiency and rad losses)
  - Optimization of cavity gradient vs linac capital cost may be different for a high efficiency ADS linac vs a research linac

Changes for a 10 MW Project X

- RF Power Source:
  - Project X upgrades to 10 MW at 1-2 GeV → ~5-10 mA beam current → 90-180 KW per 9-cell elliptical cavity (@ 18MV/M)
  - Need ~100-200 KW CW RF power source per cavity → Could be klystron or IOT
    - High power IOT's are potentially attractive due to increased efficiency, but lower gain vs klystron and harder to make them work at 1.3 GHz vs lower frequencies
    - 200 KW IOTs do not exist at 1.3 GHz. Project X development of high power IOTS would be valuable contribution to ADS)
    - Magnetrons might be very attractive if one could control phase and amplitude (SBIR)
- Cavity couplers
  - A 10 MW Project X would need a higher power main RF power couplers
    - Present XFEL couplers can take ~ 5 KW
    - Upgradable to higher power for Project X cooling "warm end" of coupler. Cornell modifications indicate 50 KW is achievable, OK for Project X baseline (20 KW) but …
    - 100-200 KW average power per coupler probably require a significant redesign of XFEL coupler
  - One limitation will be the size of the "cold end" of the XFEL coaxial coupler.
    - Constrained by the 40 mm port size in the ILC/Project X nine-cell elliptical cavities
    - Could consider increasing port size to e.g. 60 mm (but requires R&D)
    - Might consider dual couplers like ERL's ? (have to decide this up front)

Changes for a 10 MW Project X

- Front end changes:
  - Assume an ADS machine would accelerate Protons vs H-
  - Need to develop a reliable, redundant >10 ma CW proton source, higher current RFQ, switching mechanism, etc
- Controls, LLRF, Fast Fault Recovery
  - A real challenge given ADS availability requirements
  - ADS requirement ➔ keep beam on… machine protection ➔ turn beam off!
- 10 MW capable dumps and/or targets !
- Maintenance:
  - Linac activation at SNS is already an issue at 1 MW ➔control of losses in an upgraded Project X will be very important
  - If serious about 10 MW for Project X➔ should include provisions for remote handling and maintenance of cryomodules, and other linac components etc. <u>well beyond anything currently considered for Project X</u>
  - Losses, and activation: Probably favor larger cavity apertures and lower frequencies than current Project X plan of 1.3 GHz (e.g. 650 MHz or lower) Could try this for beta = 0.8 but this would be a <u>big change</u>.

Summary

- The design choices for a commercial ADS linac will likely be much different that for a research accelerator like Project X
- Nevertheless, Project X can provide a lot of useful operational information to guide the design of a linac for ADS power production. However, much of this information does not require Px be upgraded to 10 MW.
- Provisions to upgrade Project X to 10 MW at some point would require inclusion of some expensive “hooks” early in the program
- A 2 GeV 10 MW linac would be expensive and would require a serious potential user of this power…
  - ADS or waste transmutation research facility
  - Neutron source?
  - HEP ?
  - Something else ?