Technologies

Accelerators for ADSRs

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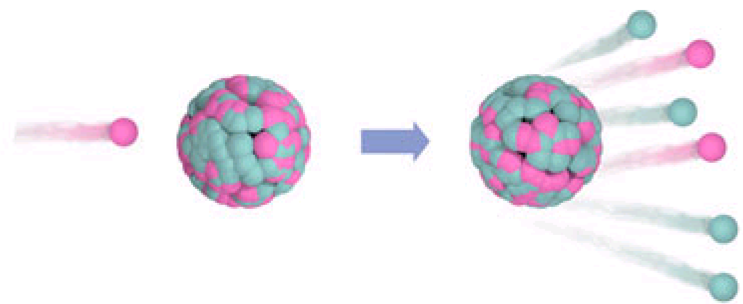
An account of the requirements for the accelerator component of an ADSR,looking at energy, current and reliability, and at the possible solutions provided by different types of accelerator

The accelerator



Neutrons produced by spallation – high energy beam on heavy metal target

Proton beam – little point in using any other nucleus. May be advantage in using H^- or H_2^+ rather than H^+

Requirements	Solutions
Energy	Linac
Current	Cyclotron
Reliability	Synchrotron
	FFAG / nsFFAG

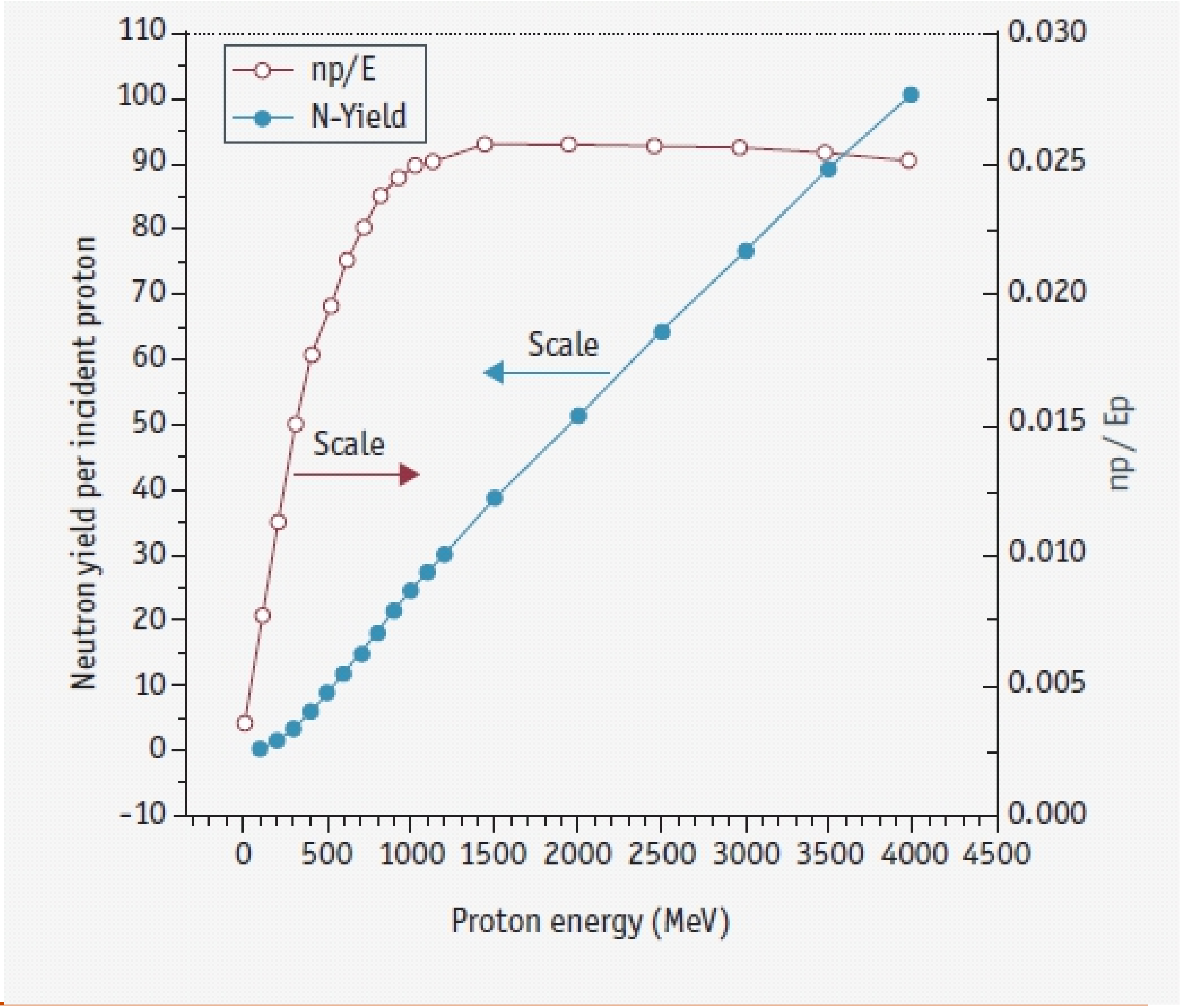
Energy

Neutron yield increases rapidly up to ~1 GeV and only linearly thereafter, so this is probably optimum energy.

(or 2 GeV for H_2^+)

Gives ~20 spallation neutrons / proton

Easy



Current

Current ~ 10 mA (5 mA for H_2^+) ~ 10 MW

(Depends on reactor size and on how close to critical you can run.)

This is uncomfortable. Typical currents microamps.

Storage rings have run at high currents (amps) but that does not compare directly

Problems with space charge and losses (goal is <1W/m)

Moderately difficult

Reliability

High reliability: ~ 3 trips/year is quoted, though there is no hard number

For financial and engineering reasons
•No accelerator – no reactor – no power
•Repeated heating/cooling leads to expansion/contraction and thermal stresses. Affects reactor core, target and window (if there is one)

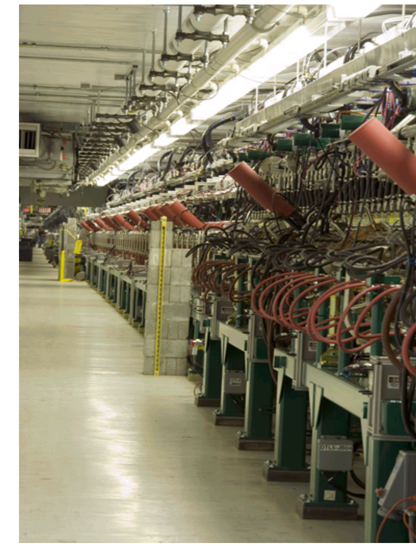
Accelerators generally trip several times/day

Reliability can be achieved through
•Redundancy (ultimate is multiple accelerators)
•Under-rating
•Graceful failure
•Scheduled preventive maintenance
Coupled with deep and holistic understanding of system

Extremely hard

Designs(1) - Linac

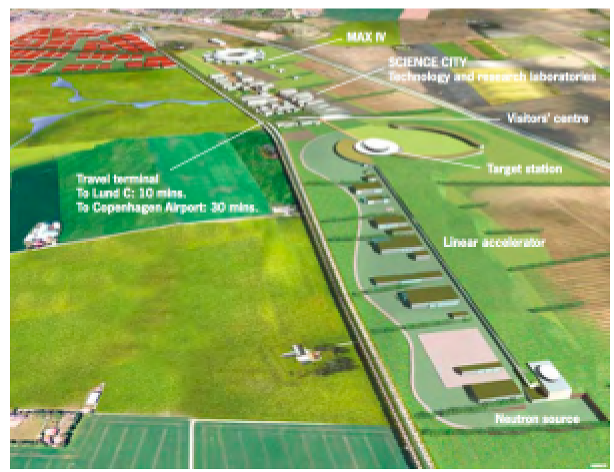
Probably the most buildable – but expensive (capital and running costs)



Examples

SNS: 1 GeV 1.4 MW

ESS: 1 GeV 5 MW

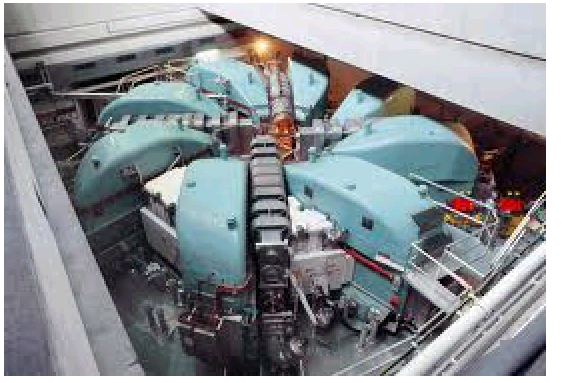


~ 1 km of magnets and RF cavities

Potential for good reliability

Designs(2) - Cyclotron

Continuous pulse train so high current achievable – but essentially limited to nonrelativistic energies



Examples:
PSI : 650 MeV 2 mA

Texas A & M stacked cyclotron
5 PSI equivalents with shared magnet

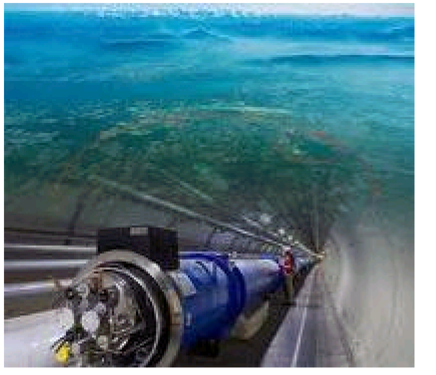
Compact – though Magnets are solid (large and expensive)

RF is long wavelength and so low frequency

RF is single point of failure

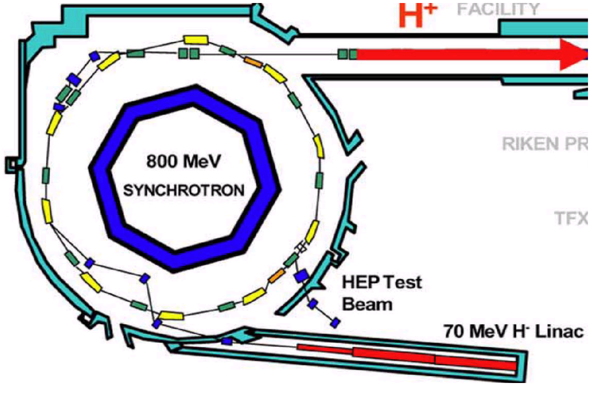
Designs(3) - Synchrotron

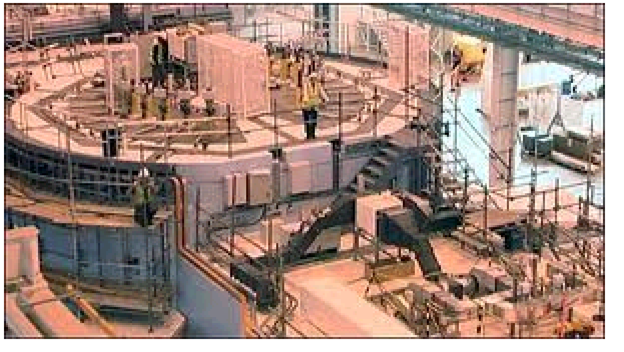
Particle bunches accelerated in separate trains. Can achieve the energy, but limited in current (rep. Rate ~Hz). (Rapid Cycling Synchrotron can operate at ~100 Hz.)



Magnets smaller than cyclotron, but AC rather than DC, hence less intrinsically reliable

Examples: LHC and ISIS (800MeV, ~0.1 mA)





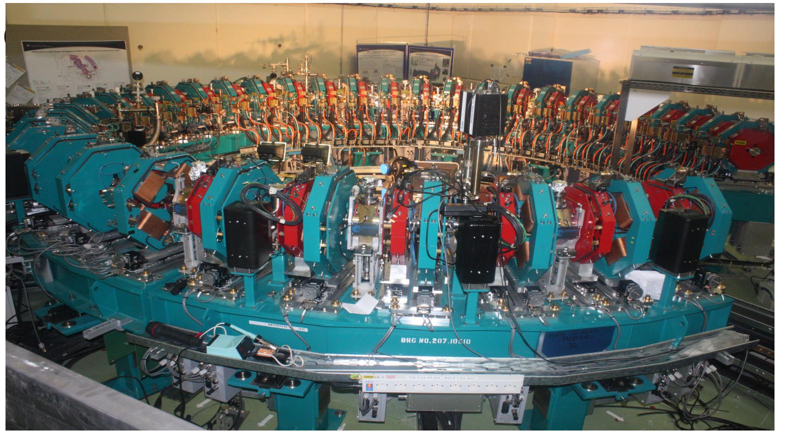
Designs(4) -FFAG and nsFFAG

(non scaling) Fixed Field Alternating Gradient machines

Magnetic field fixed in time, changes across beam pipe (gradient) to accommodate more energetic particle bunches.

Different (alternating) gradients focus bunches.

If gradients scale with fields, optics (focussing/bending) is constant through the acceleration cycle. If not, not.



Examples:
- Kyoto KURRI (150 MeV, 0.1 nA)
- EMMA

Better reliability than Cyclotron/Synchrotron

Summary

Building an accelerator with enough energy and power (at a reasonable cost) is challenging but possible.

All 4 types of accelerator have their supporters

Achieving the required reliability will require a lot more work