ERL Demonstrator for LHeC:

Critical issues

-Choice of multi-turn ERL configuration

➔ the only operating multi-turn ERL is in Novosibirsk using normal conducting RF (5mA beam current ➔ 20mA)

➔ all other multi-turn ERL proposals are only studies

-Post CDR increase in the electron beam current: 6.6mA ➔ 25mA

➔ 25mA with 3 re-circulations and ERL

➔ 150mA inside SC RF cavities!

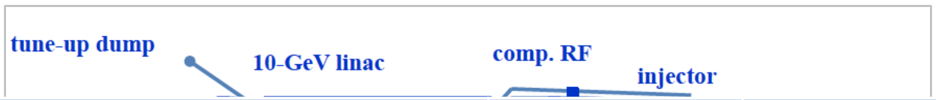
➔ all operating ERL facilities feature substantially smaller currents (ALICE: 6.5mA, JLab 8mA)

➔ potentially complex transient effects during operation

CDR Choices: ERL as LHeC Baseline

Super Conducting Recirculating Linac with Energy Recovery

Choose ⅓ of LHC circumference ➔ Two 1 km long 10 GeV SC linacs with 2 accelerating and



10^{34} cm^{-2} s^{-1} Luminosity reach	PROTONS	ELECTRONS		PROTONS	ELECTRONS
Beam Energy [GeV]	7000	60		7000	60
Luminosity [10^{33}cm^{-2}s^{-1}]	16	16		1	1
Normalized emittance $\gamma\varepsilon_{x,y}$ [μm]	2.5	20		3.75	50
Beta Funtion $\beta^*_{x,y}$ [m]	0.05	0.10		0.1	0.12
rms Beam size $\sigma^*_{x,y}$ [μm]	4	4		7	7
rms Beam divergence σ□$^*_{x,y}$ [μrad]	80	40		70	58
Beam Current @ IP[mA]	1112	25		430 (860)	6.6
Bunch Spacing [ns]	25	25		25 (50)	25 (50)
Bunch Population	$2.2*10^{11}$	$4*10^9$		$1.7*10^{11}$	$(1*10^9)$ $2*10^9$
Bunch charge [nC]	35	0.64		27	(0.16) 0.32

ERL Demonstrator for LHeC:

- Proposal to build a TF to validate LHeC design choices

-Need to test and validate beam current limit in SC RF

-Need to test beam stability limit and design HOM coupler

-Need to study operational issues:

→ Machine setup and boot-strapping (no closed orbit but requires correct path length)

→ Transient effects (current ramp up & beam abort)

→ Machine protection issues and implications

→ Identify and develop required beam diagnostics (dynamic range and required bandwidth)

→ develop operational experience and application tools

ERL Demonstrator for LHeC:

Auxiliary applications:

-A test setup presents a unique infrastructure on its own

- ➔ Could eventually serve as injector for the LHeC
- ➔ Launched early on discussions with other potential clients

-Interesting auxiliary application for CERN investment:

- ➔ SC magnet and cable development: quench tests with beam
- ➔ Generic SC RF development: Cavity tests with beam
  - ➔ relevant for any SC RF development (CC in SPS)
- ➔ Test facility for Beam Diagnostics (after closure of CTF3)
- ➔ Detector component tests?
- ➔ Physics applications (electron and photon beam via Compton)

ERL Demonstrator for LHeC:

- Baseline parameter choices:

-3 re-circulations

-Beam current of at least 10mA

-Use of LHeC proto-type SC RF Cryomodule

-Beam energy of approximately 1 GeV (chosen for physics)

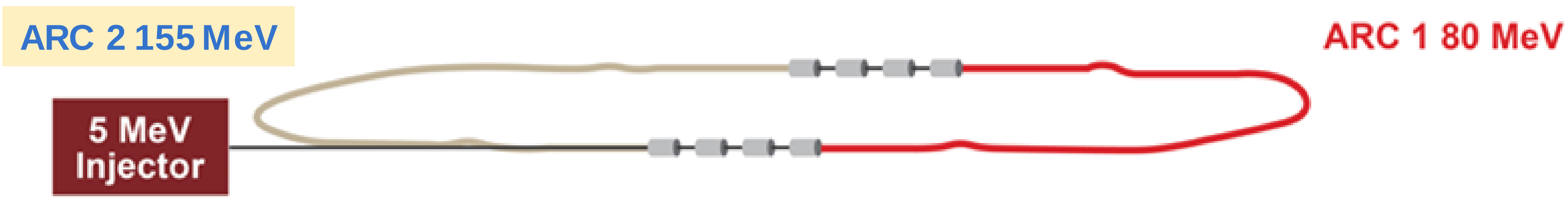
-Sufficient space and infrastructure for SC magnet tests

With a photo-injector the facility could test a range of RF frequencies [E. Jensen]

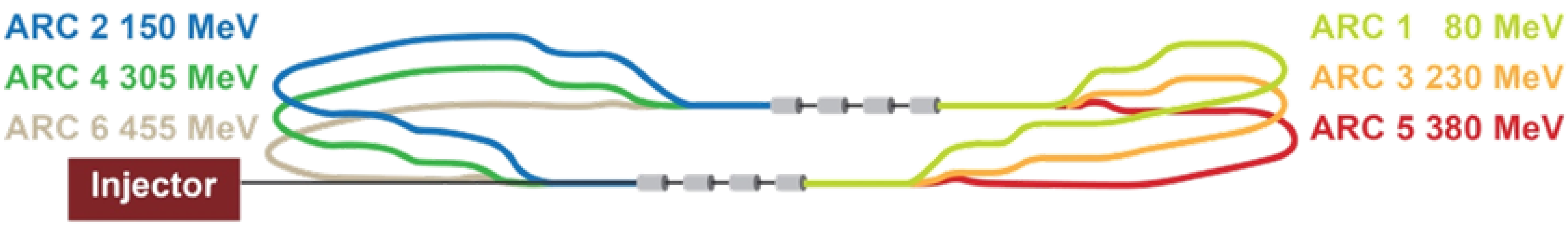
-Staged implementation to build up expertize in steps and to tailor facility to different applications and tests

Staged Installation

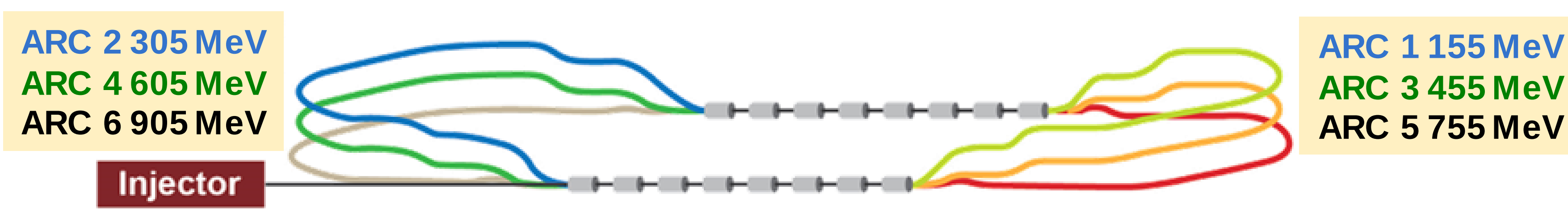
Stage 1 – 2 CMs, test installation – injector, cavities, beam dump.



Stage 2 – 2 CMs, set up for energy recovery, 2…3 passes



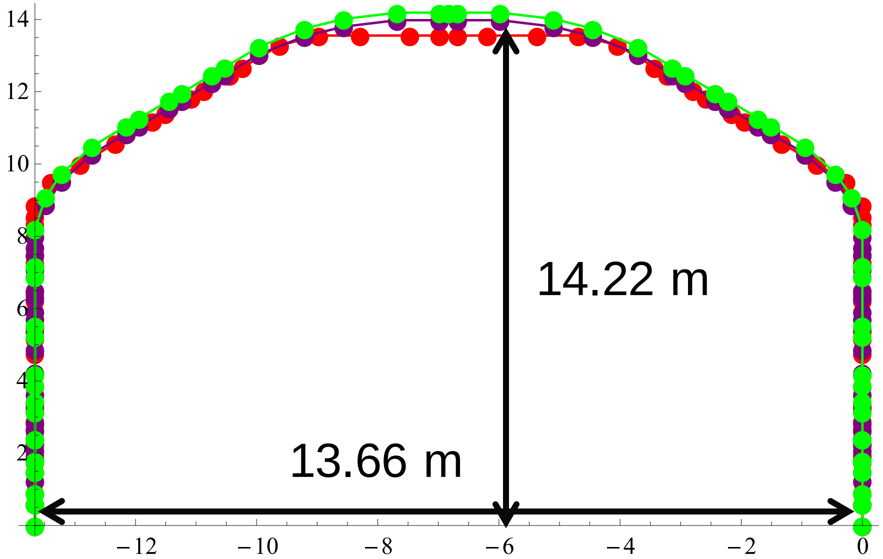
Stage 3 – 4 CMs, set up arcs for higher energies – reach up to 905 MeV

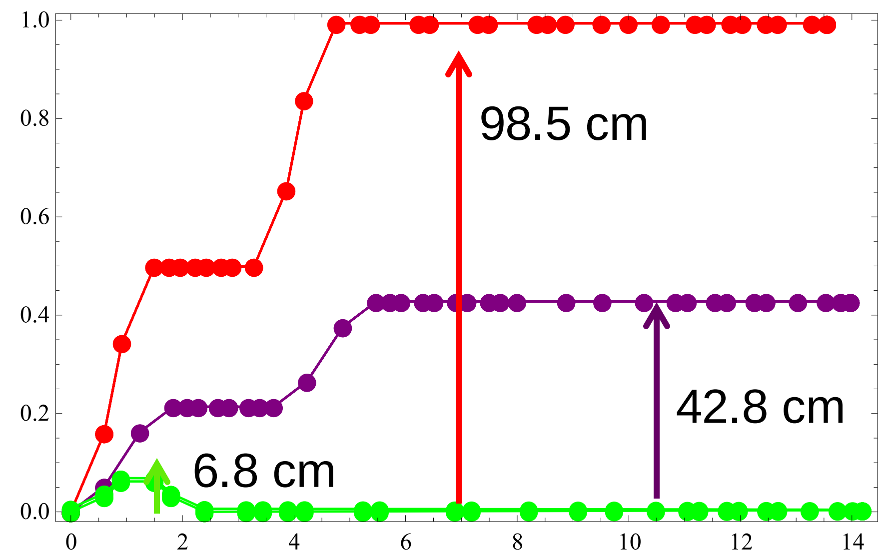


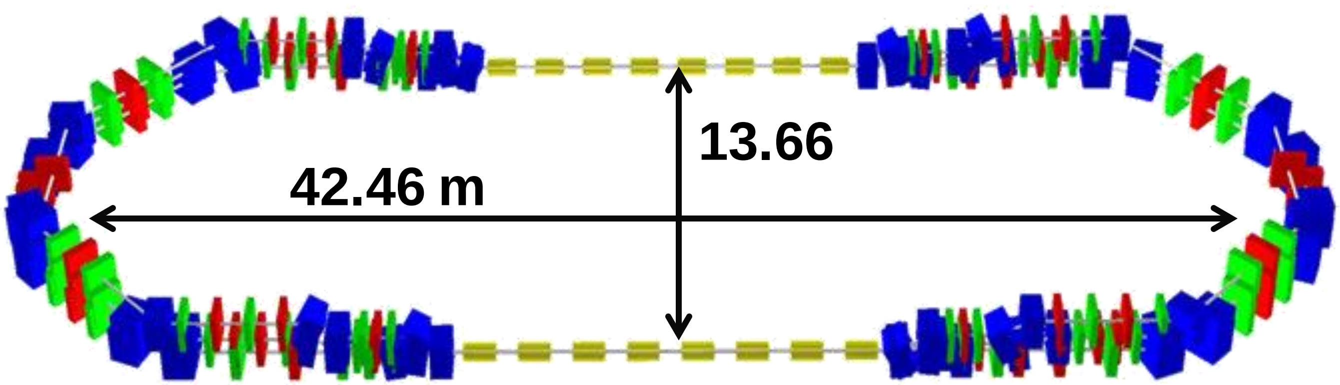
PERLE Parameters: CDR by end 2015:

Parameter	Value	
injection energy		
RF frequency		
acc. voltage per cavity		
# cells per cavity	5	
, total cavity length		
# cavities per cryomodule	4	
RF power per cryomodule		
# cryomodules	2-4	
max. acceleration per module pass		
bunch repetition		
injected beam current		
nominal bunch charge		
number of passes	1	3
top energy		
duty factor	CW	

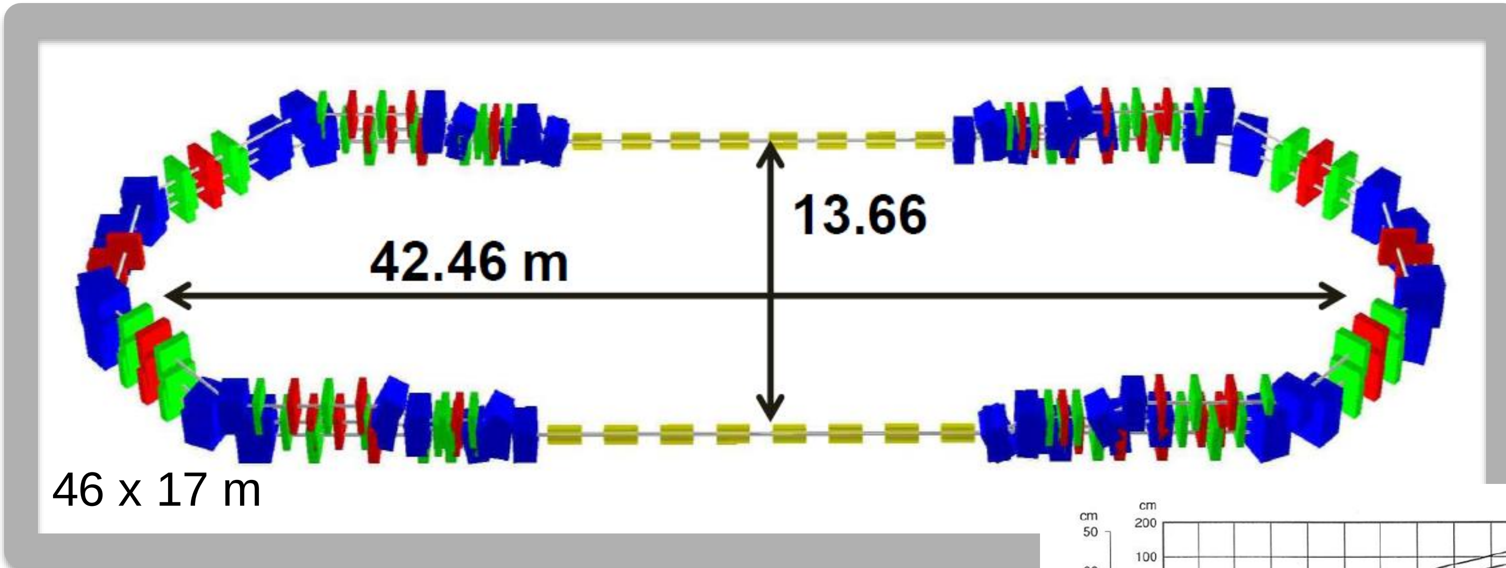
PERLE Footprint:



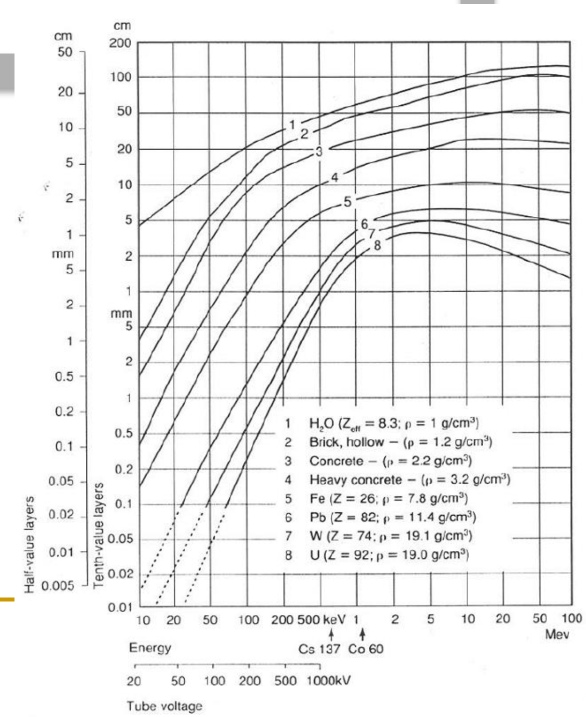




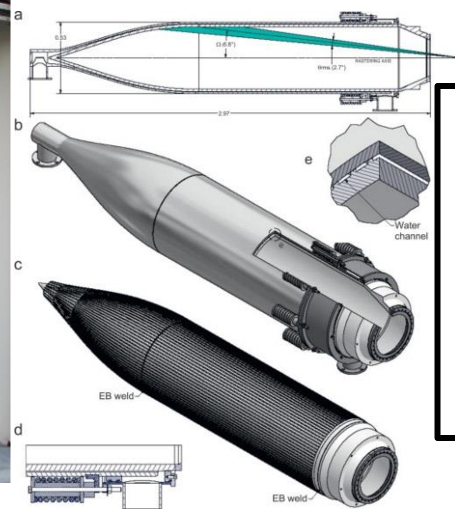
Passage and shielding: overall footprint



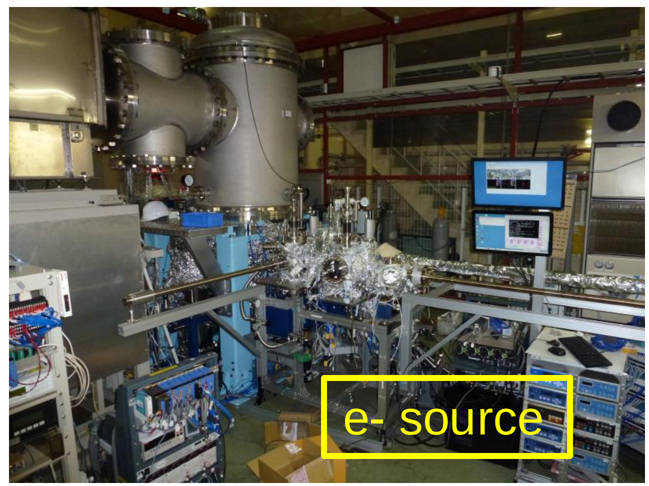
- Shielding and passage ~4m on each direction
- Assuming 50cm concrete shielding
- Can be reinforced with heavier materials if space is a concern or for special areas
- Minimum passage for interventions1.20 m



Other systems:



Electron dump



Power converters

ERL Demonstrator for LHeC:

- Questions during last IAC:

-Why do we to need to build a test facility @ CERN?

→ Develop operational experience and application tools @ CERN

→ We are proposing a major new facility at CERN (LHeC)

→ Approval will require a clear demonstration of key technology

→ Critical timeline for realizing LHeC during LHC lifetime

-Risk for an external test facility:

→ No control of timeline → delays!

→ Might miss technology challenges and options for system designs

→ Do not develop operational expertize for a new type of machine @ CERN

ERL Demonstrator for LHeC:

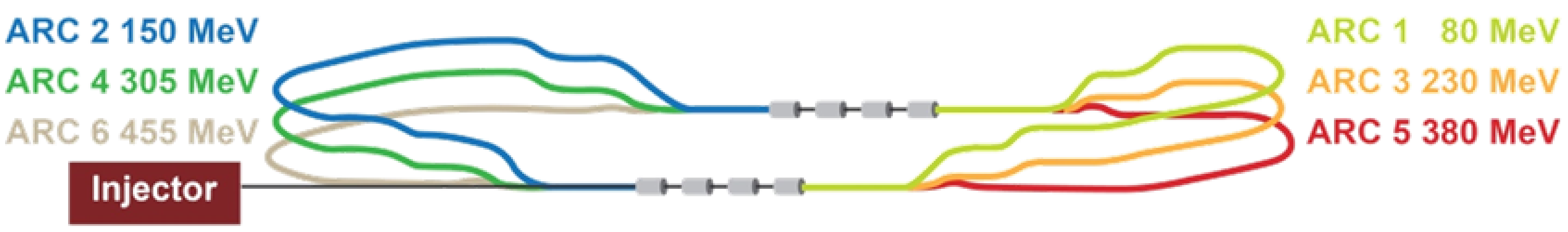
IAC outcome:

-Develop a Conceptual Design Report for a minimal test facility @ CERN

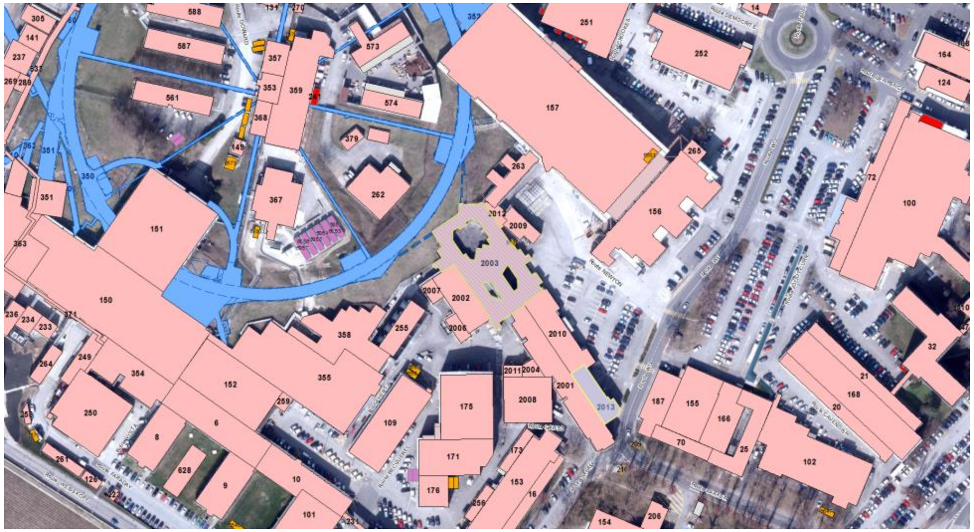
➔ Footprint, and required infrastructure

➔ Reduced version of PERLE Stage 2

Stage 2 – 2 CMs, set up for energy recovery, 2…3 passes



Building 2003 CTF3 combiner rings

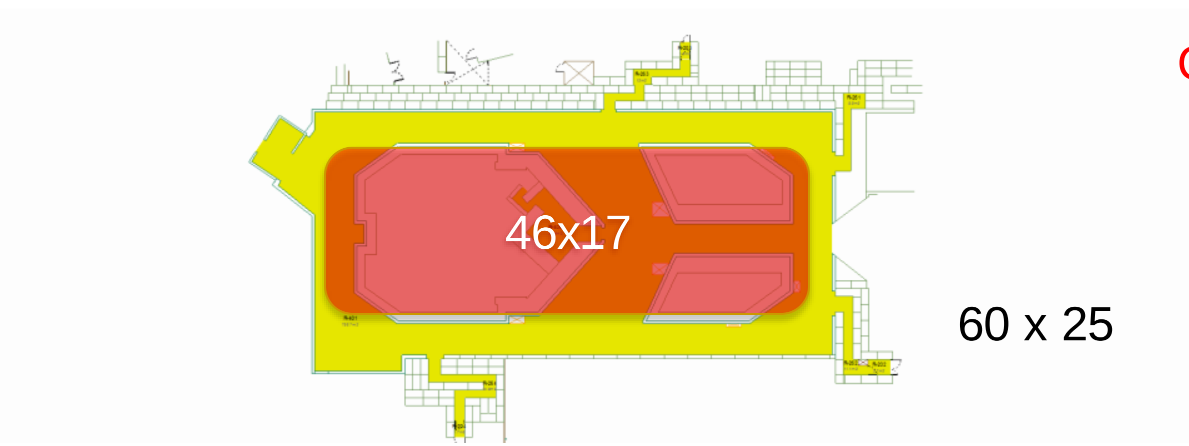


Currently CTF3 to end operation in 2016

It is a beam facility: shielding, access, galleries, etc

Complicated topology. Expensive to clean out

Cryogenics?



Reserve Transparencies

Total space needs

46x17m ~ 800m^2

- double the area of the accelerator itself to allocated all
- services. 1500 m^2
- some services like RF power generation or power supplies may be placed on a different level than the accelerator itself,
- We do not consider here the use of the interior part of the ring as the scape route would be compromised.
- It may however be used to house a low energy dump which itself needs to be shielded and who will be on restricted access.

This is a significant size comparable to CFT3, AD or ISOLDE

Around point 18:

No space available in any of the buildings on the site but lots of empty space around it.

Why not build a new facility building in the north storage area?

Cryogenics water power and other services already available. May be upgraded

Accessibility for quench tests

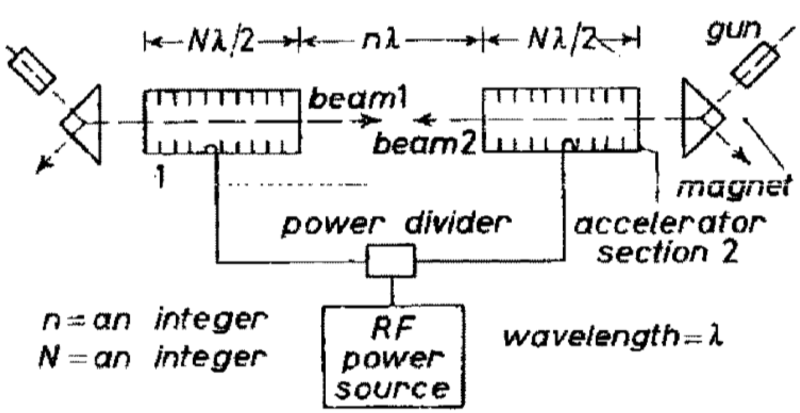
Completely new construction

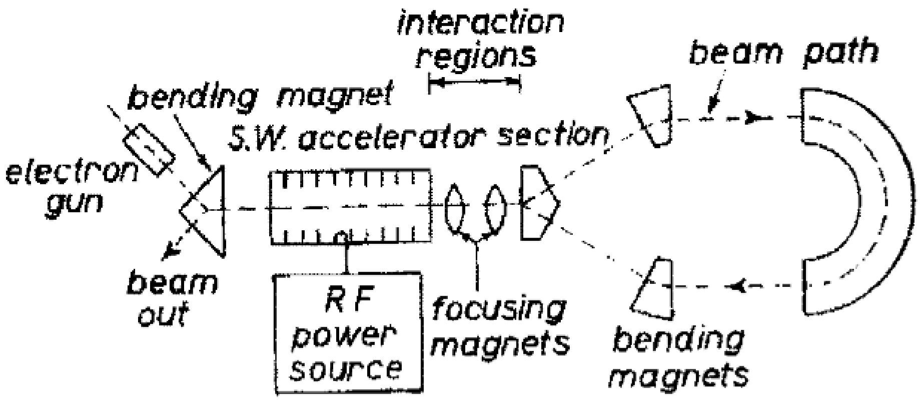
Motivation: Accelerator Technology Development

LHeC

- **Energy Recovery Linac concept:** First proposal 50 years ago

  M. Tigner: "A Possible Apparatus for Electron Clashing-Beam Experiments", Il Nuovo Cimento Series 10, Vol. 37, issue 3, pp 1228-1231,1 Giugno 1965

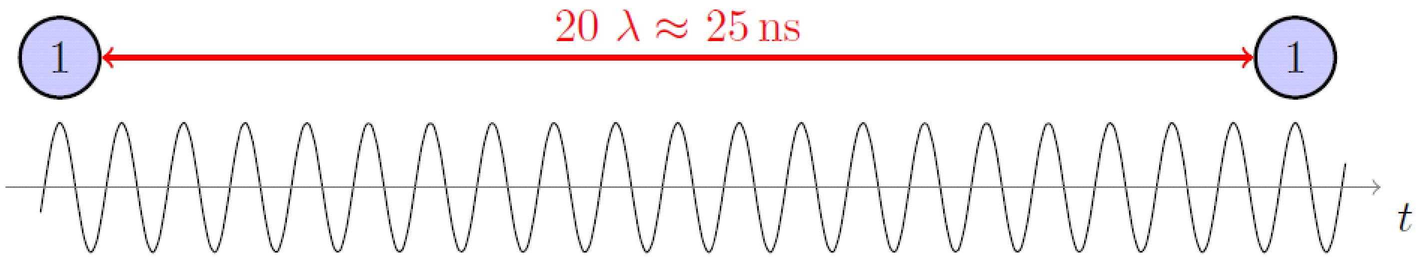




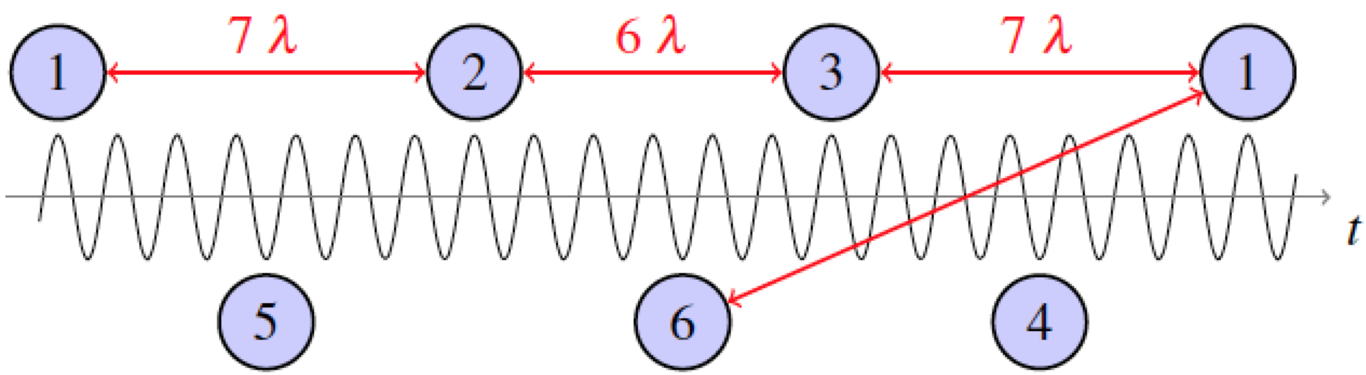
- **First Tests:** Done at SCA @ Stanford in 1986

  Interesting concept for FELs and Compton photon light sources, and high current electron cooler concepts and colliders

Recombination Pattern:

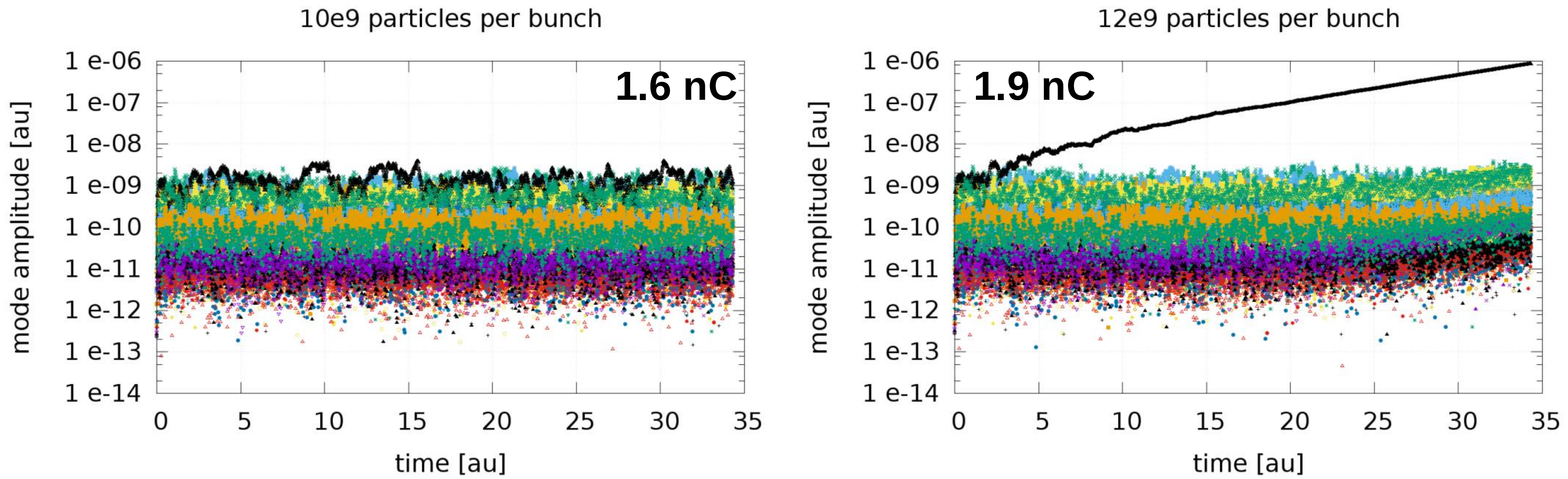


Arc's lengths tuned to avoid bunches in the same bucket
Lattice adjusted to achieve a nearly constant bunch spacing



Long Range Wakefields Threshold Current:

Multi-bunch tracking simulations with PLACET2 and optimal recombination pattern
26 dipole modes of the SPL cavity scaled to 802 MHz
100 particles per bunch – BBU triggered by statistical fluctuations of the centroid



Offending mode builds up in the vertical plane (coupling between a specific mode frequency, time of flight and the vertical betatron tune).

Threshold current >5 times higher than the nominal (2e9 particles per bunch)