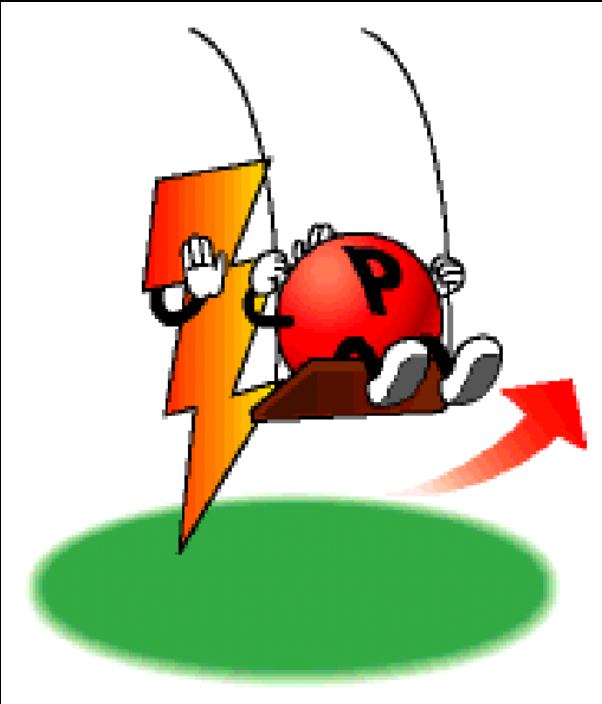


Approximate de Broglie ($\lambda = h/p$) table for orientation

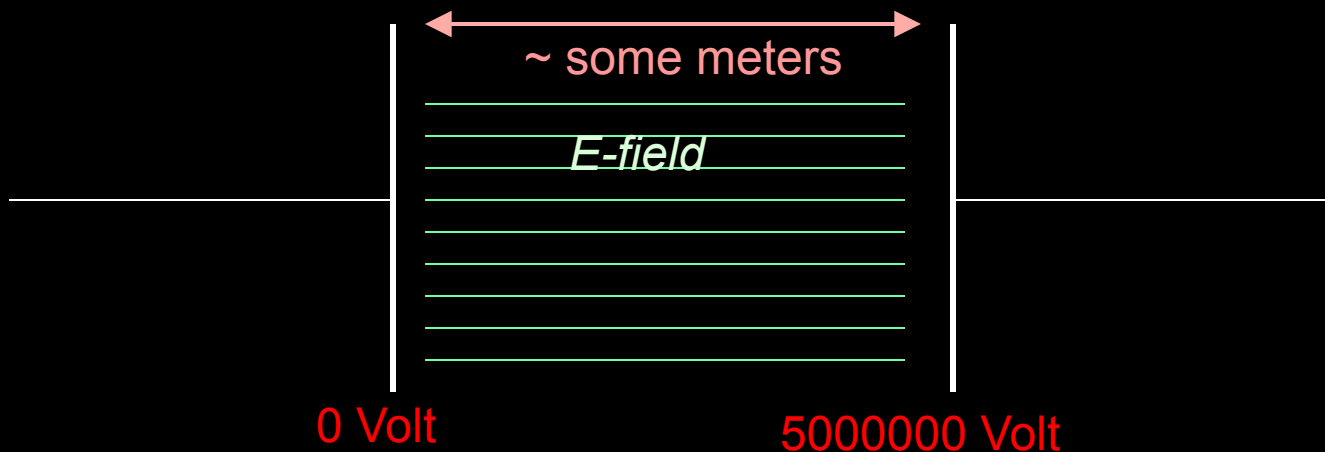
Wave-length	$p=E_k$ if photon	E_k if electron	E_k if p/n
10^{-9} m (10^{-10} m)	1.2keV/c (12keV/c)	1.4eV (140eV)	Thermal
10^{-12} m	1.2MeV/c	0.79MeV	0.76keV
10^{-15} m	1.2GeV/c	1.2GeV	0.59GeV
10^{-18} m	1.2TeV/c	1.2TeV	1.2TeV

Acceleration in E-field

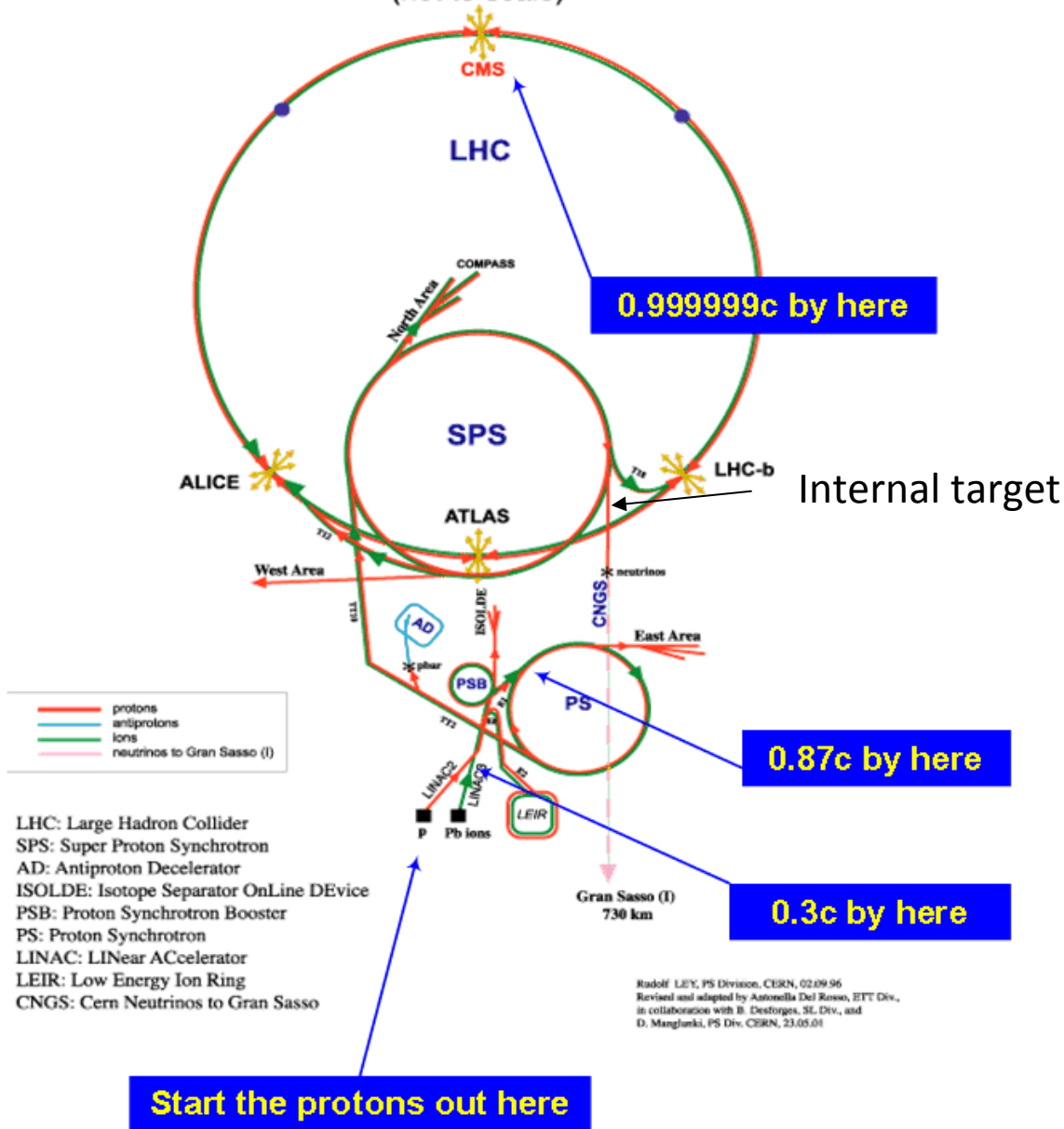


A charged particle with charge $+e$ gains an energy of 1eV (electronVolt) when passing a voltage gap of 1Volt

1eV is $1.6 \cdot 10^{-19}$ Joule

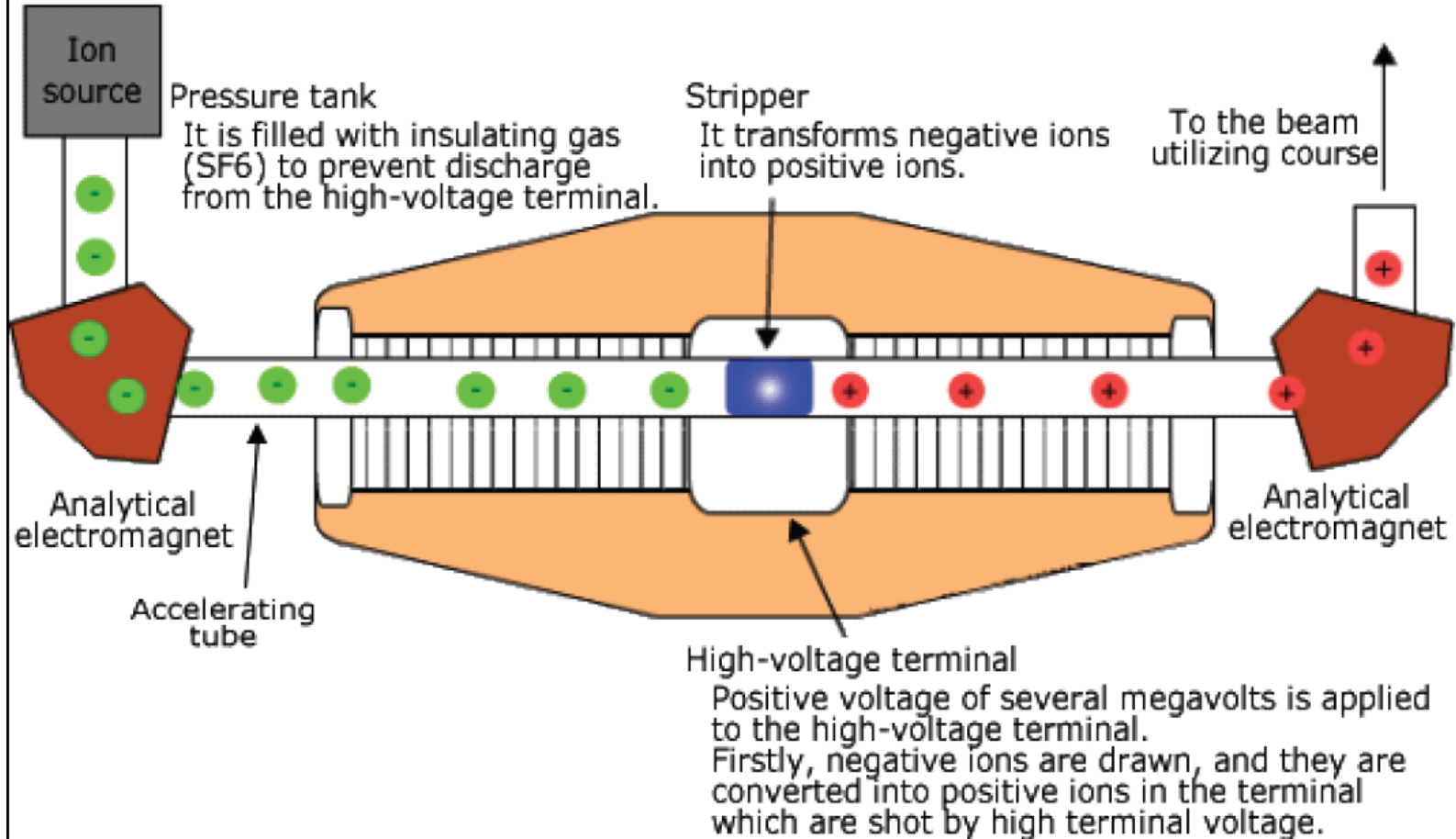


CERN Accelerators (not to scale)

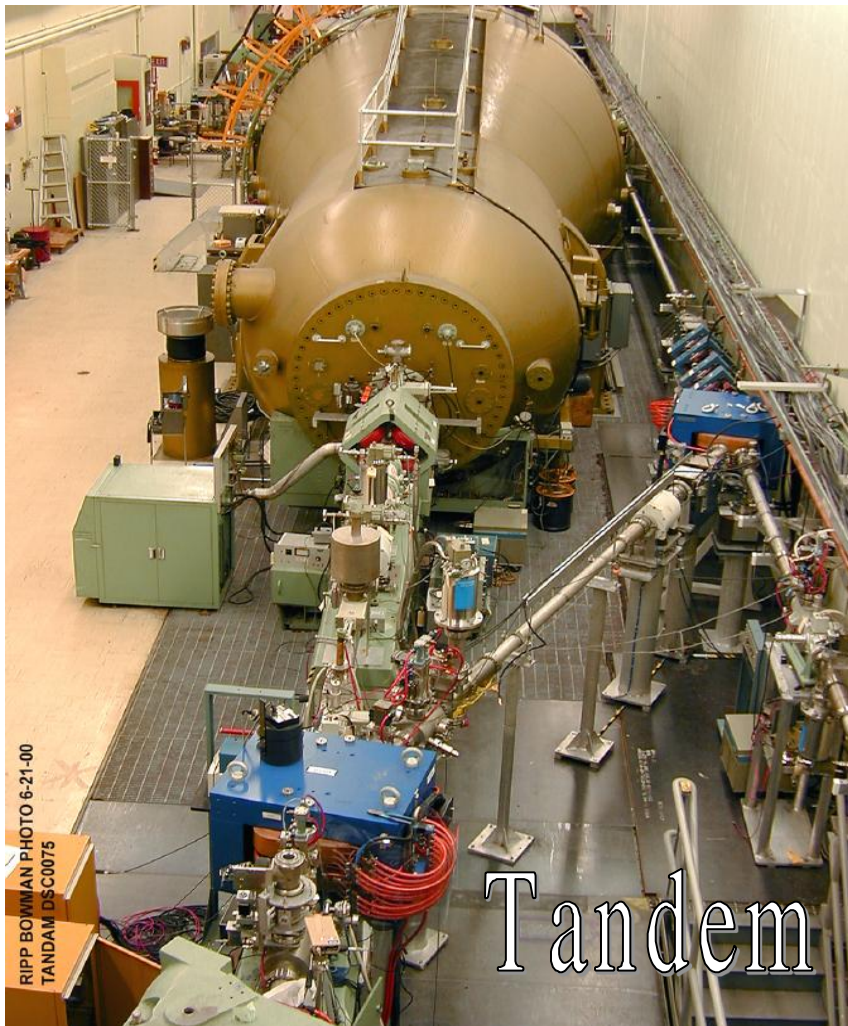


Tandem van de Graaf

Equipment to produce negative ions
It outputs negative ions at energy of
around 100 to 200 keV.



RHIC Injectors: Pictures (A.Drees)

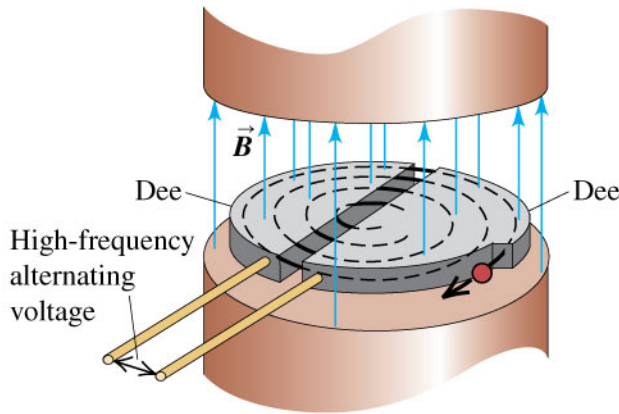


↑
LINAC, since late 60s, accelerates (polarized) protons up to 200 MeV

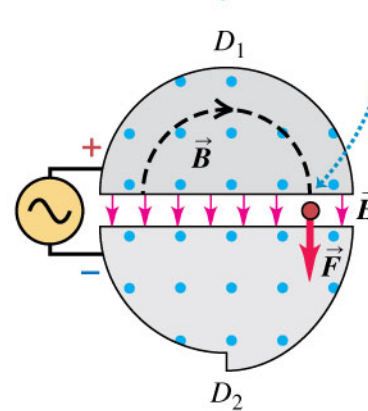
←
Tandem Van De Graaff, since 1970, accelerates 40 species, from hydrogen to uranium

Cyklotron

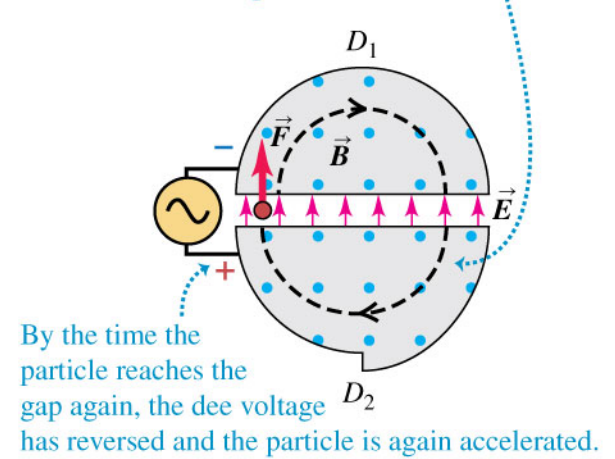
(a) Schematic diagram of a cyclotron



(b) As the positive particle reaches the gap, it is accelerated by the electric-field force ...



(c) ... and the next semicircular orbit has a larger radius.



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$$qvB = mv^2/R$$

Up to 1GeV protons

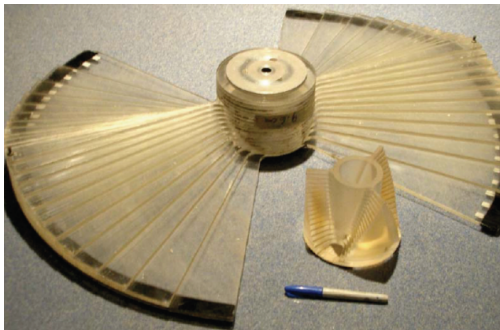
$$qB = mv/R$$

$v/R = qB/m$ v/R , angular velocity is constant, constant time between passage of acc field

IBA & Varian cyclotrons



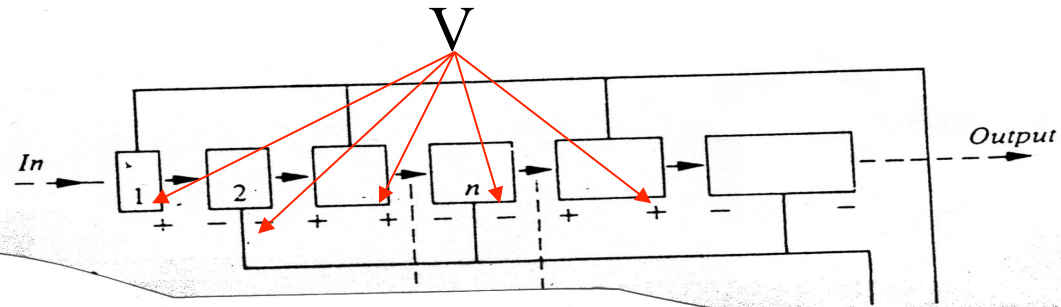
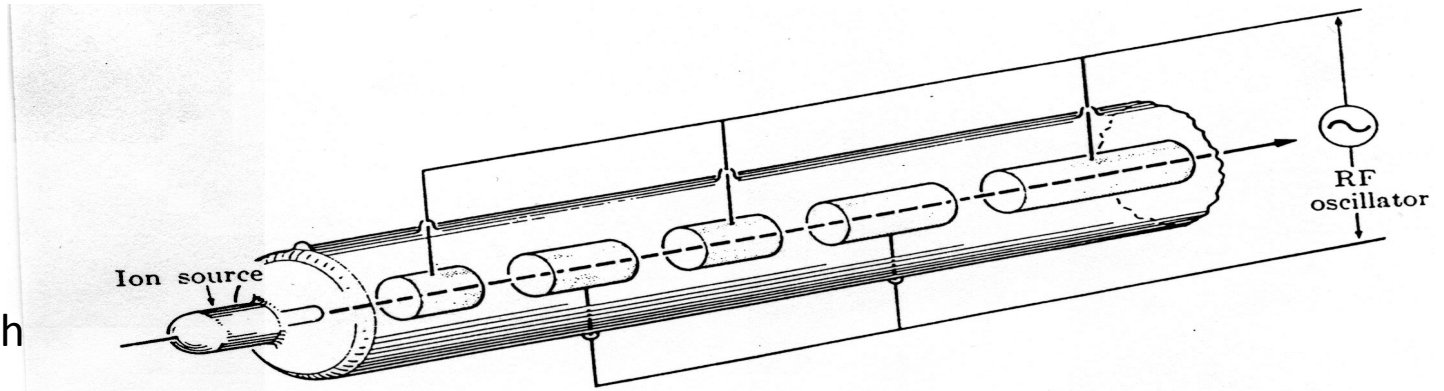
energy extraction



Isotope production at hospitals

LINAC principle

Often injector
But also very high
energy
(ILC)



Can use fixed frequency if L is made longer to
match increase in velocity

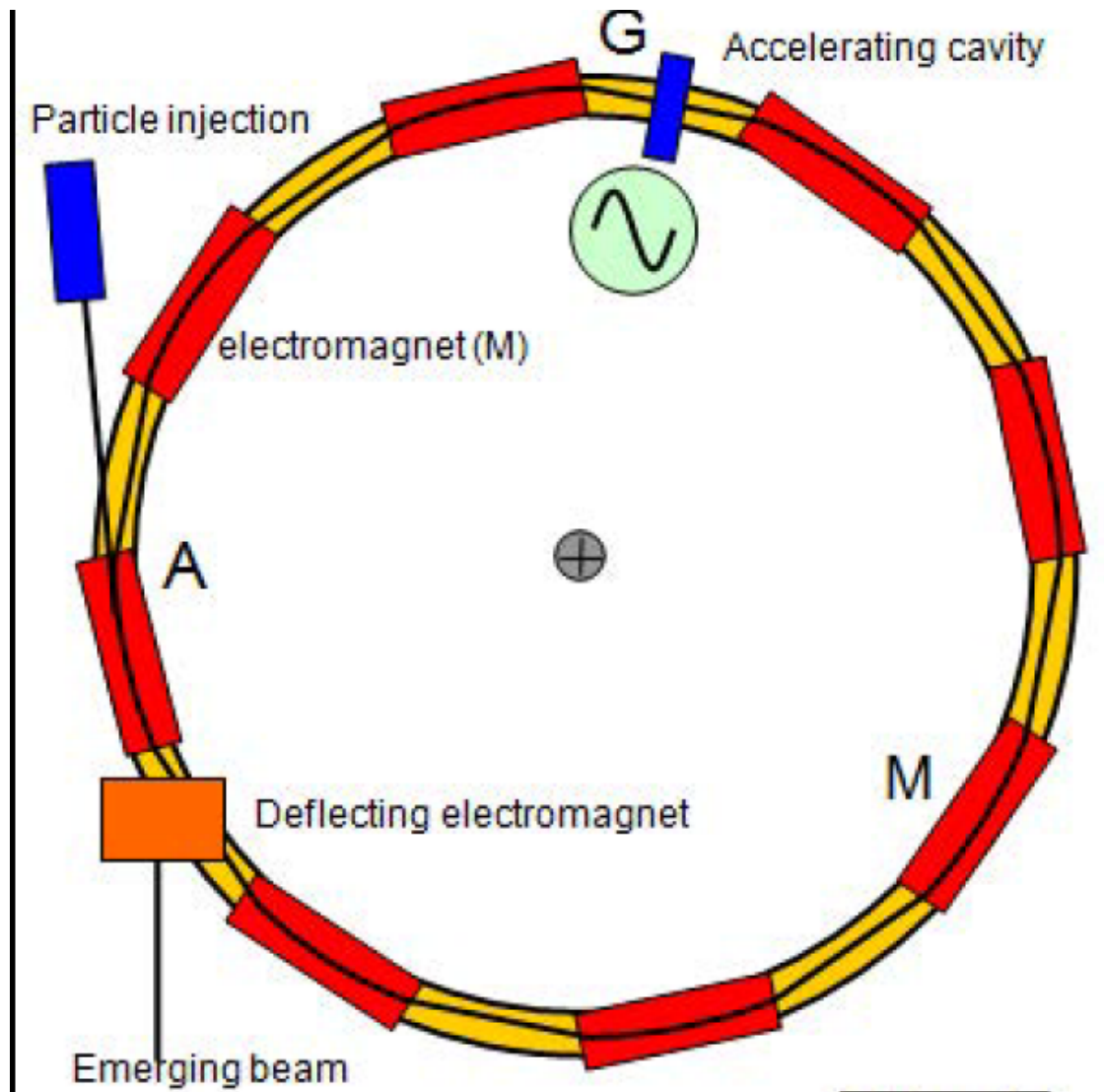
L_n corresponds to half wavelength



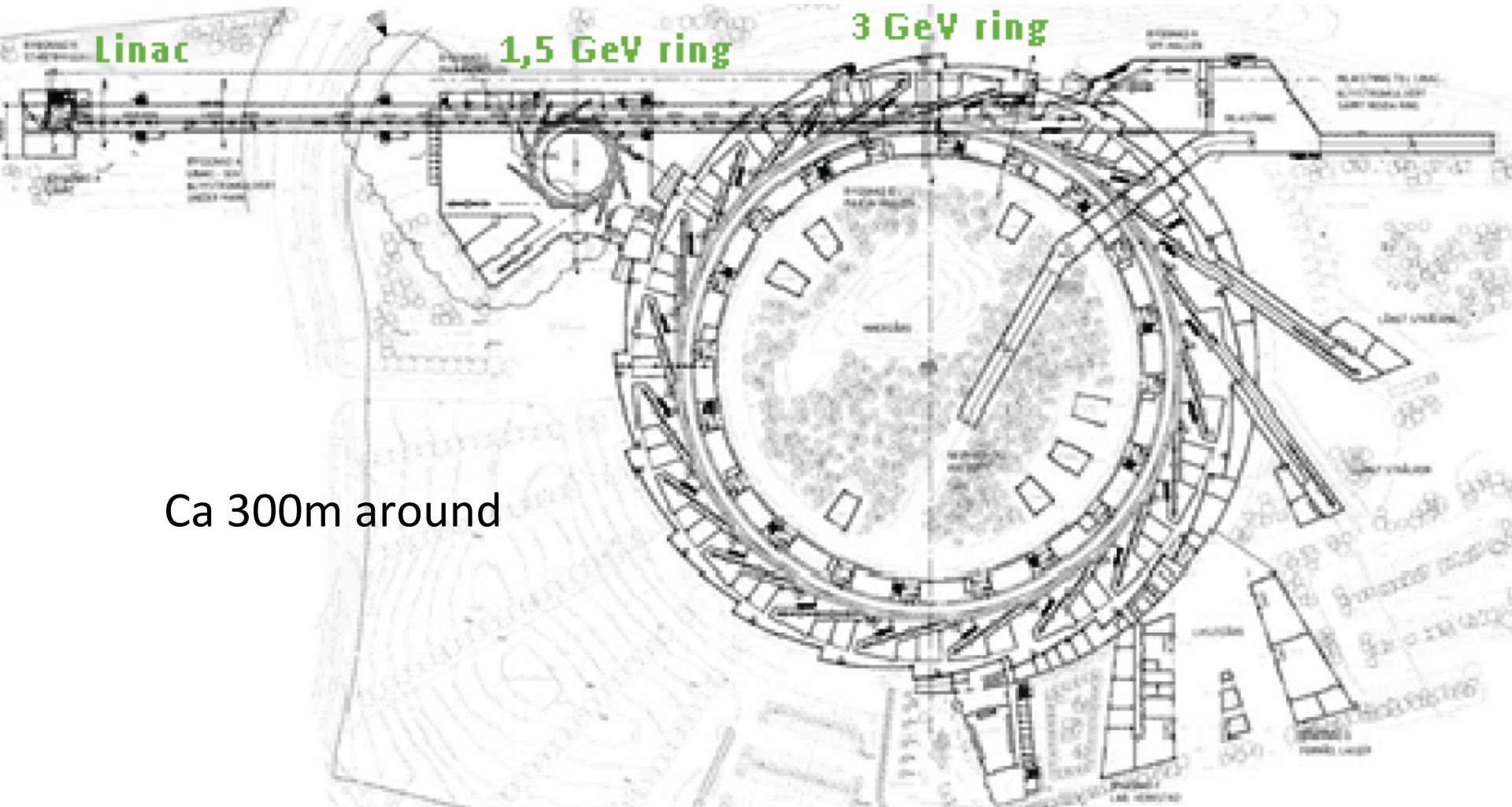
ESS will be a LINAC with ca 2.5GeV protons

Synchrotron. B and E field increase synchronized with momentum increase

LHC largest
7 TeV
27km circumfer.



MAX IV. Synchrotron för synchrotronlight.
Emitted when electrons bend in B-field.



Ca 300m around

CERN Accelerators (not to scale)

