

Introduction to Accelerator Physics

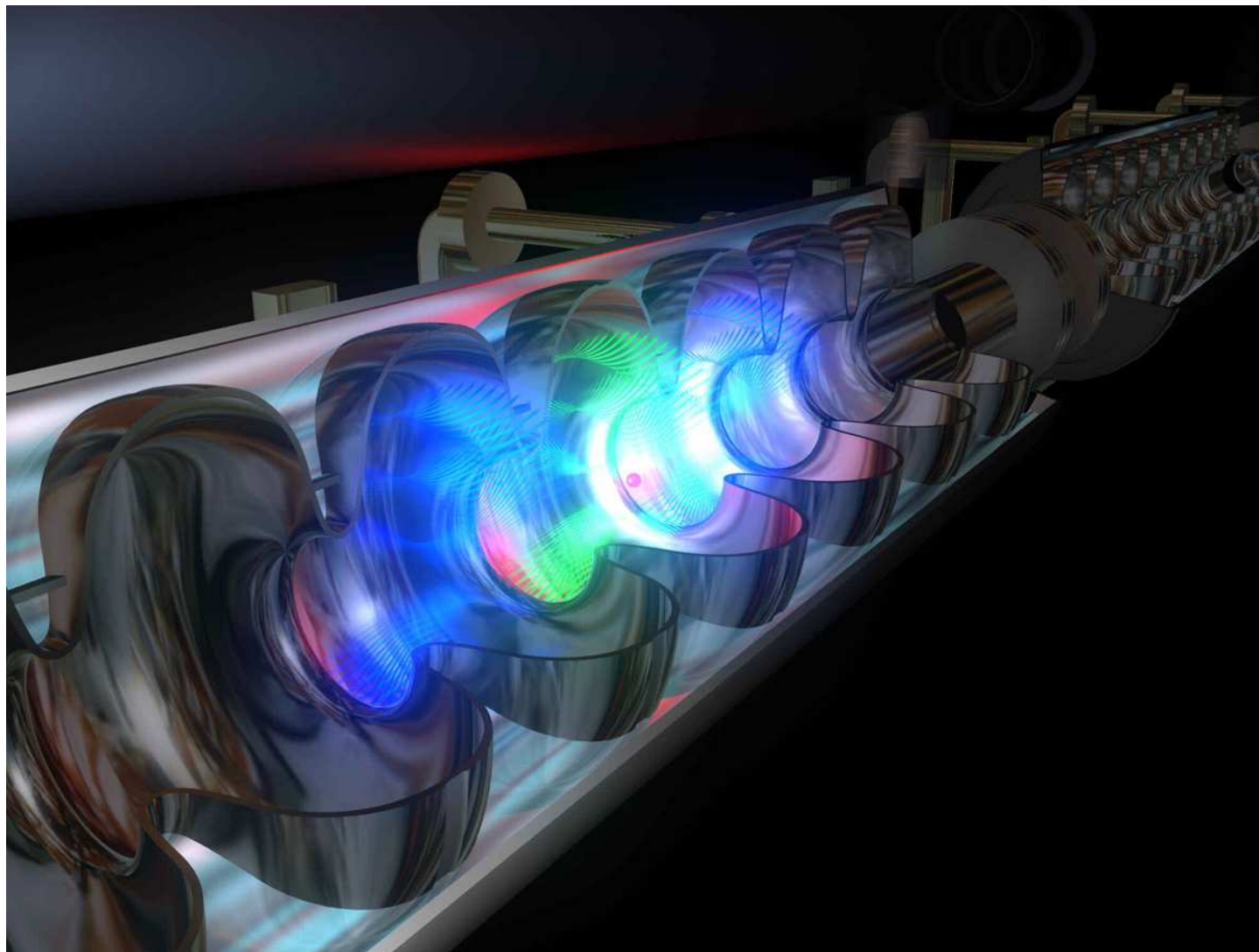
Part 1

Pedro Castro / Accelerator Physics Group (MPY)
Introduction to Accelerator Physics
DESY, 28th July 2014

	lab	run	length	particle(s)	energy	dipole field
DORIS	DESY	1980-2012	0.3 km	e- or e+	4.45 GeV	1.22 T
PETRA	DESY	2009- ?	2.3 km	e- or e+	6 GeV	0.10 T/0.87 T
HERA	DESY	1992-2007	6.3 km	e- or e+ p	27.5 GeV 920 GeV	0.274 T 5 T
LEP	CERN	1989-2000	27 km	e-/e+	2x105 GeV	0.135 T
LHC	CERN	2010- ?	27 km	p	2x7000 GeV	8.3 T
FLASH	DESY	2004- ?	0.3 km	e-	1.2 GeV	
XFEL	DESY	2015- ?	3 km	e-	17.5 GeV	
ILC	?	?	30 km	e-/e+	2x250 GeV	



How electromagnetic fields accelerate particles



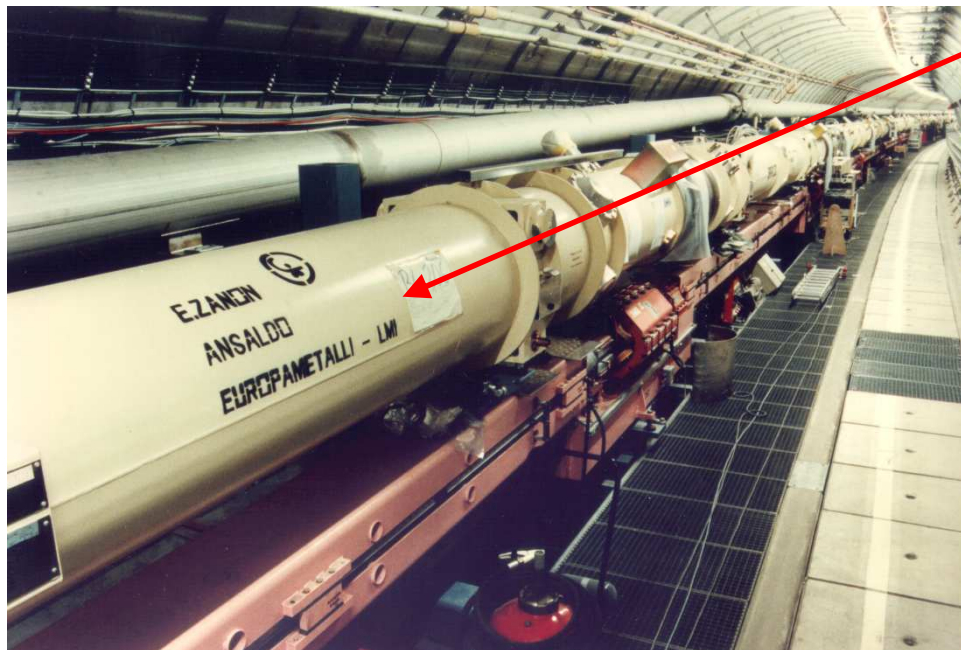
Why we need superconducting magnets



LHC: Large Hadron Collider
at CERN

p: 7 TeV

superconducting magnets



HERA: Hadron-Electron Ring Accelerator
at DESY

p: 920 GeV

e: 27.5 GeV



Differences between proton and electron accelerators

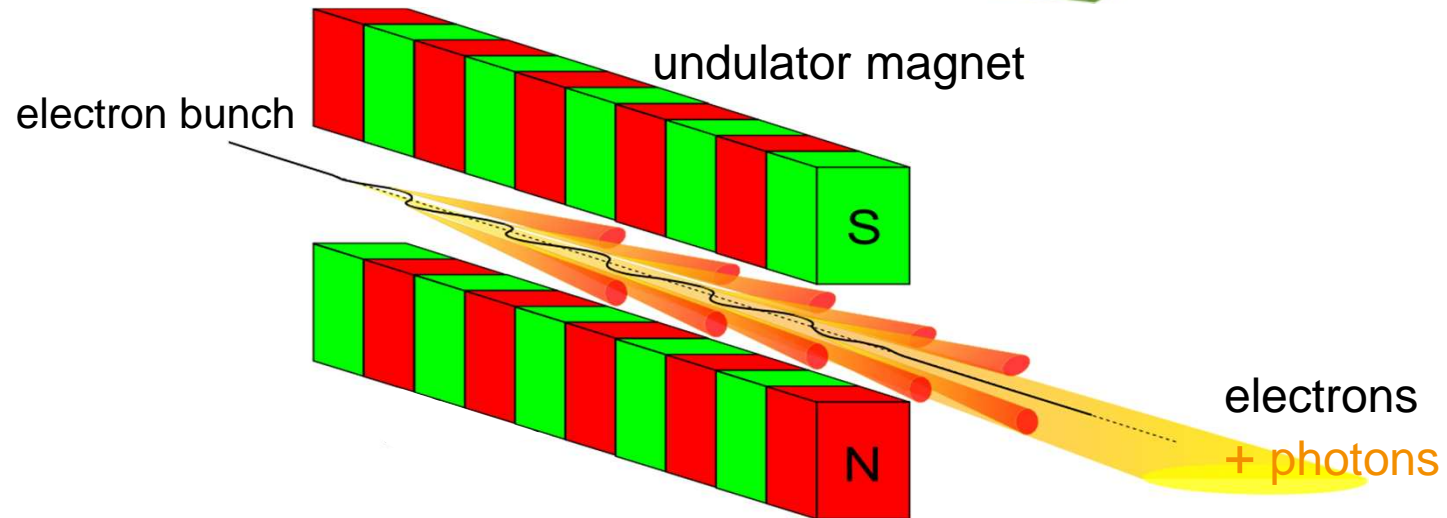
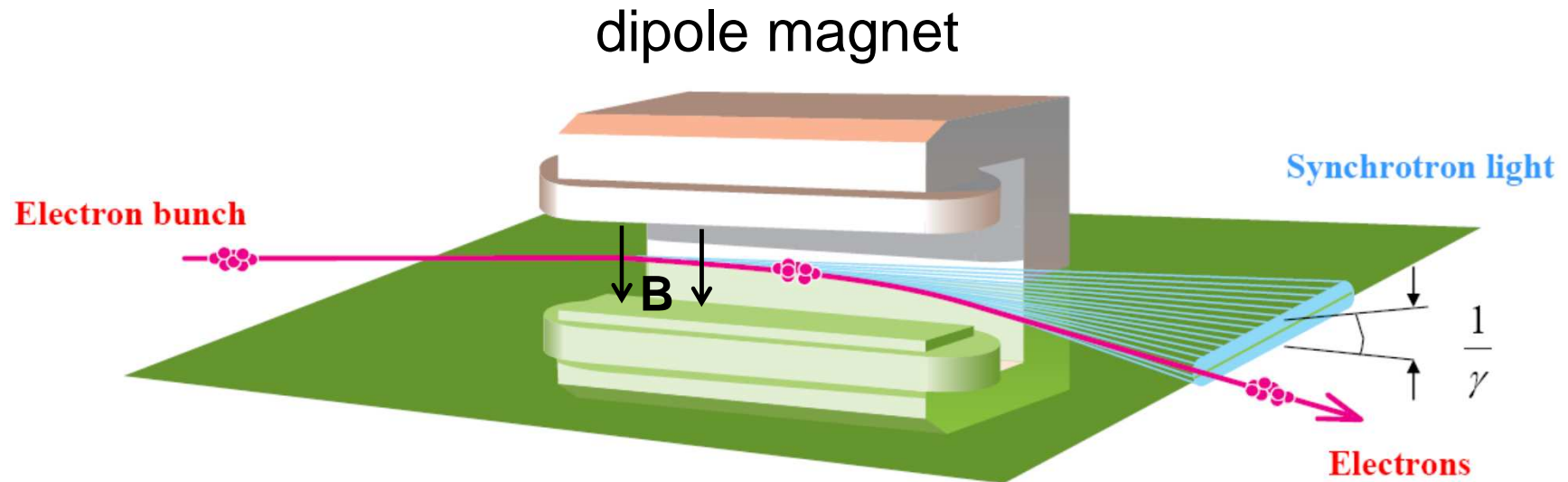
HERA (Hadron Electron Ring Accelerator) tunnel:



proton
accelerator
920 GeV

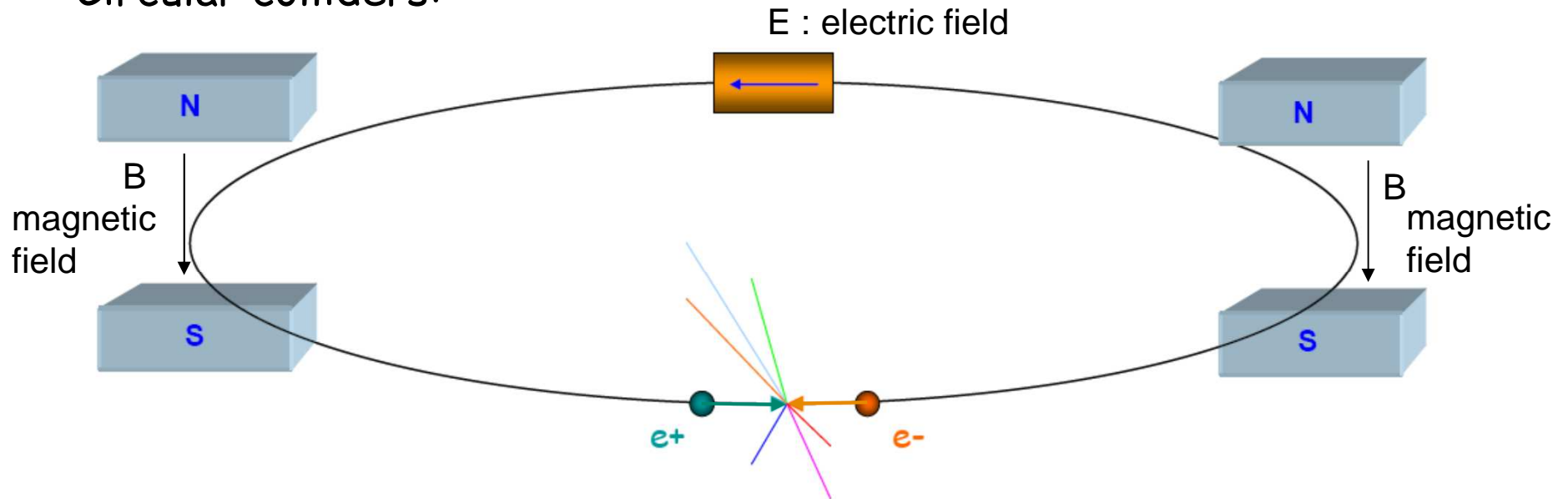
electron accelerator
27.5 GeV

Synchrotron radiation

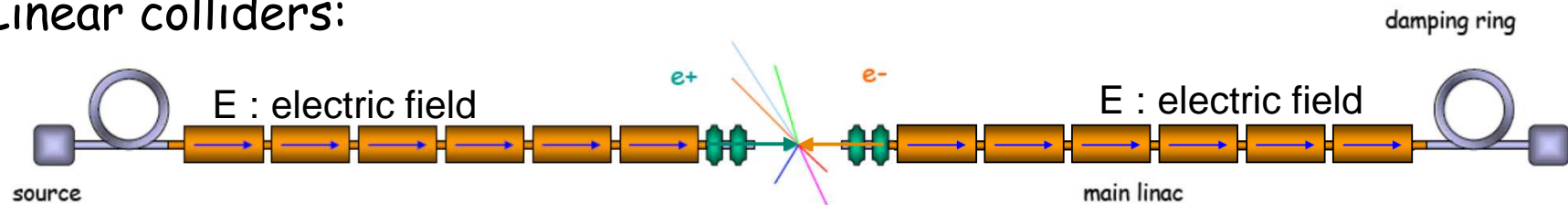


Which collider is better?

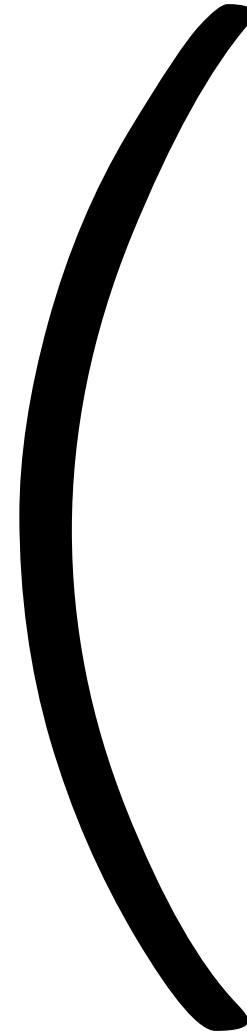
Circular colliders:



Linear colliders:



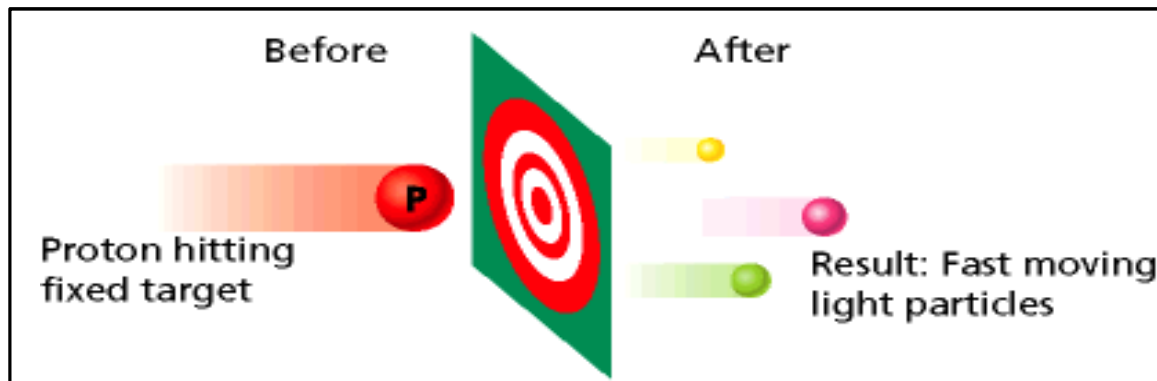
Applications of accelerators



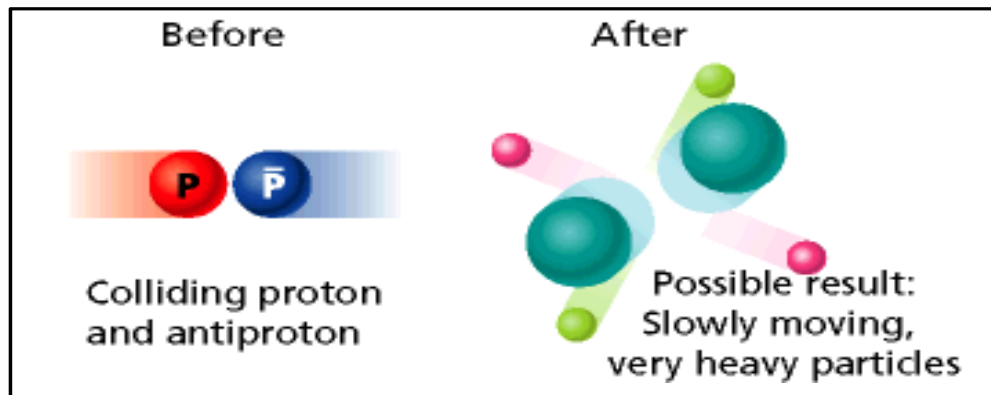
Applications of Accelerators (1)

Particle colliders for High Energy Physics (HEP) experiments

Fixed target experiments



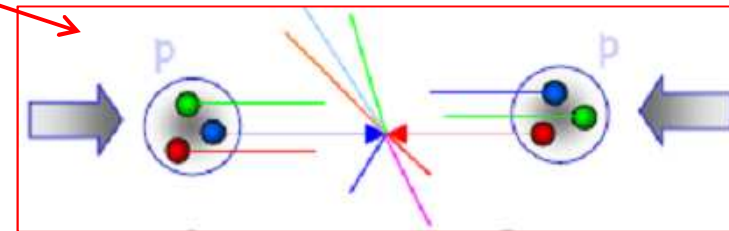
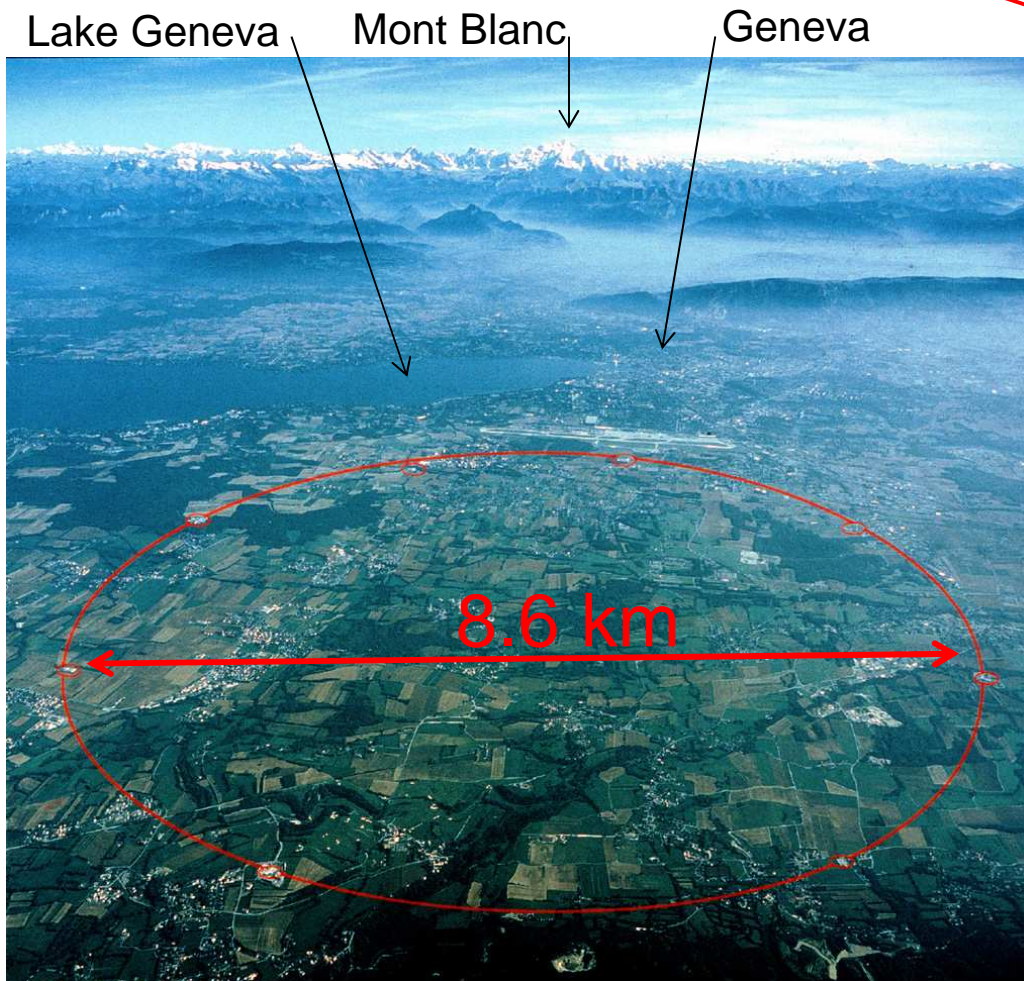
Two beams collider experiments



Applications of Accelerators (1)

Particle colliders for High Energy Physics experiments

Example: the Large Hadron Collider (LHC) at CERN

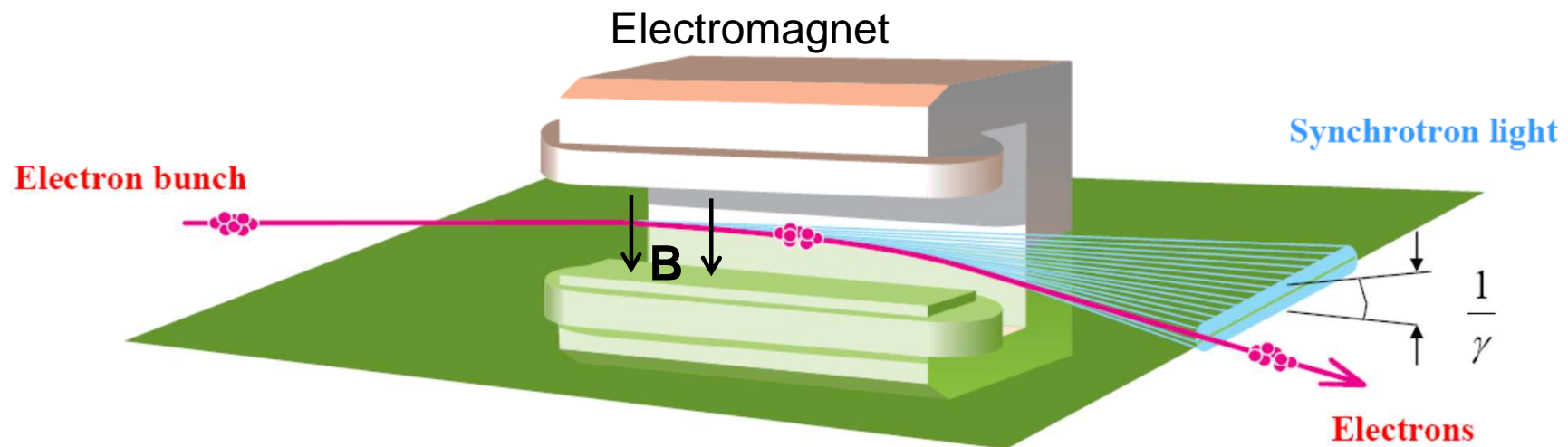


/MPY | Accelerat

superconducting magnets
(inside a cryostat)

Applications of Accelerators (2)

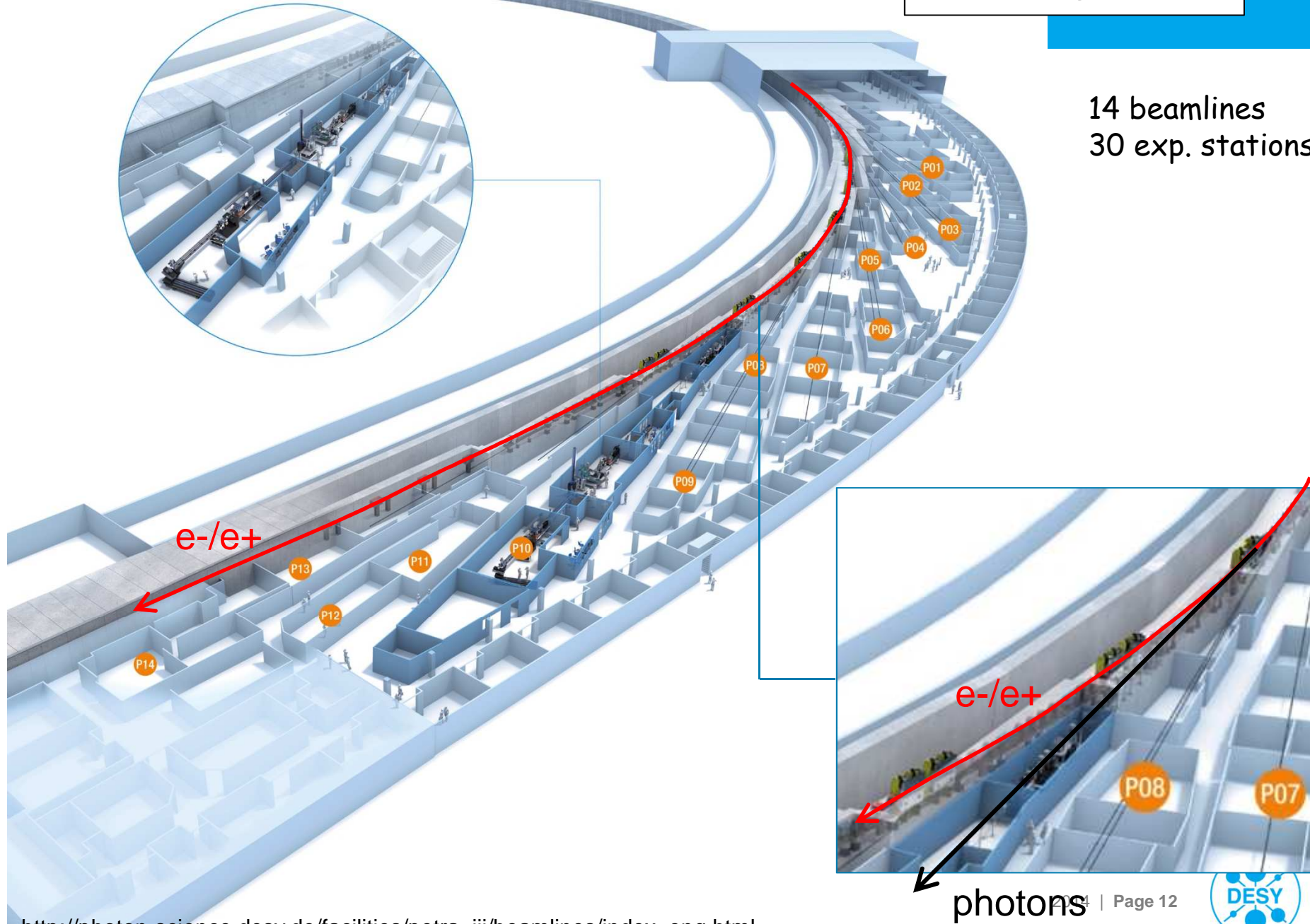
Light sources for biology, physics, chemistry... experiments



- structural analysis of crystalline materials
- X-ray crystallography (of proteins)
- X-ray microscopy
- X-ray absorption (or emission) spectroscopy
- ...

Max von Laue hall

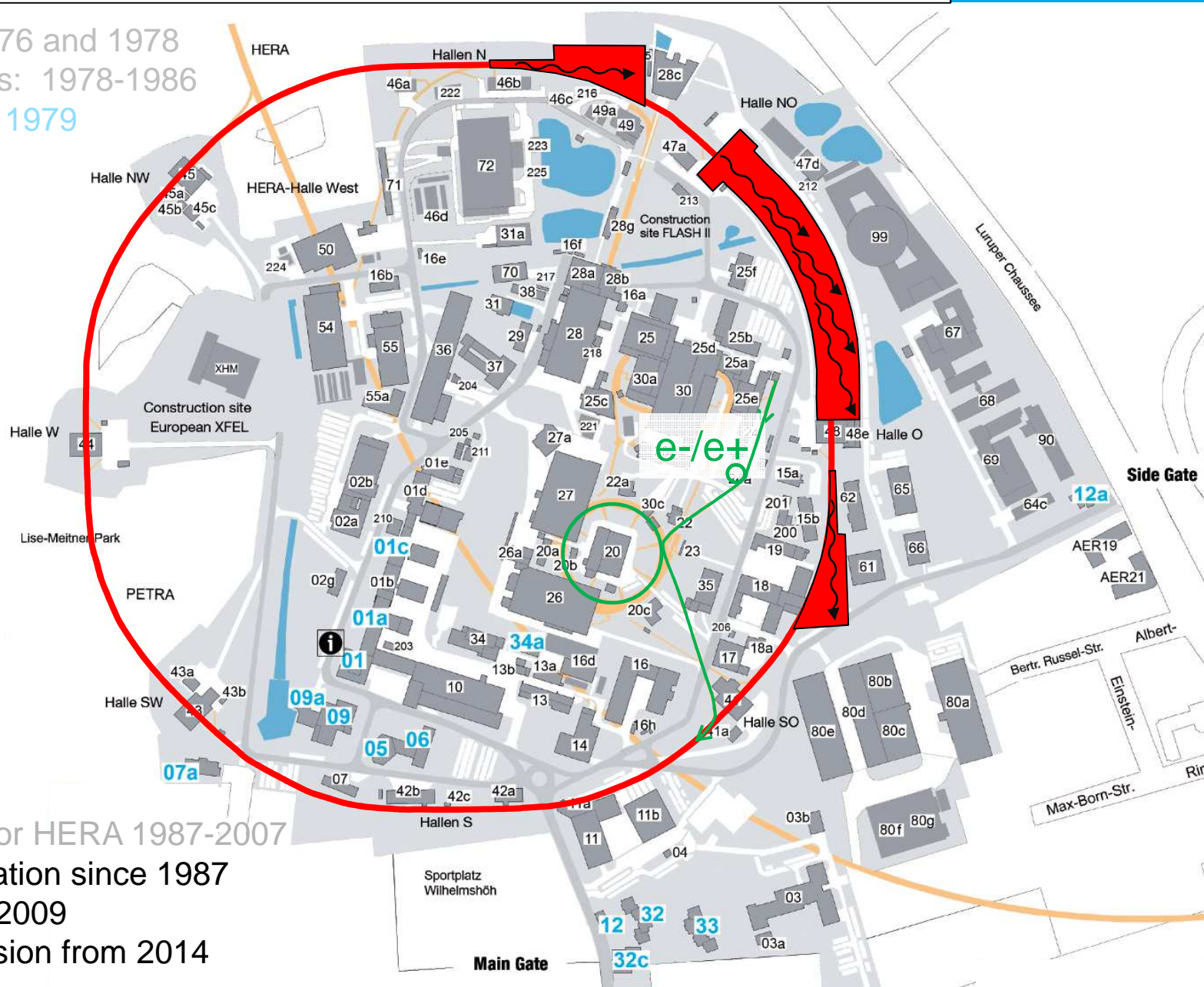
14 beamlines
30 exp. stations



Example: Positron-Elektron-Tandem-Ring-Anlage (PETRA) 'positron-electron tandem ring accelerator' at DESY

built between 1976 and 1978
HEP experiments: 1978-1986
gluon discovery: 1979

2.3 km long



pre-accelerator for HERA 1987-2007
synchrotron radiation since 1987
PETRA III since 2009
PETRA III Extension from 2014

Applications of Accelerators (3)

Medical applications

For radioisotope production

proton beam + stable isotope $\xrightarrow{\text{transmutation}}$ radioactive isotope

For radiotherapy and radiosurgery:

- x-rays and gamma-rays
- ions (from protons to atoms with atomic number up to 18, Argon)
- neutrons



Applications of Accelerators (3)

Medical applications

For radioisotope production

For example:

cyclotron

18 MeV proton accelerator

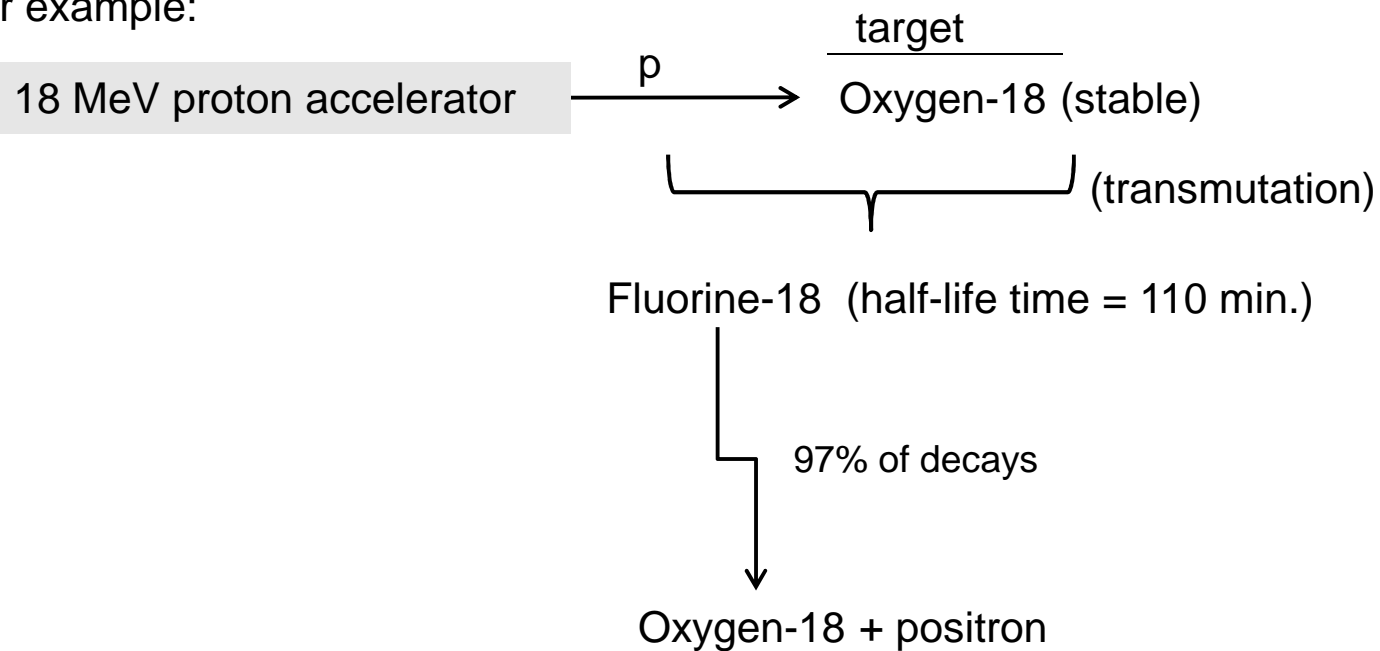


Applications of Accelerators (3)

Medical applications

For radioisotope production

For example:



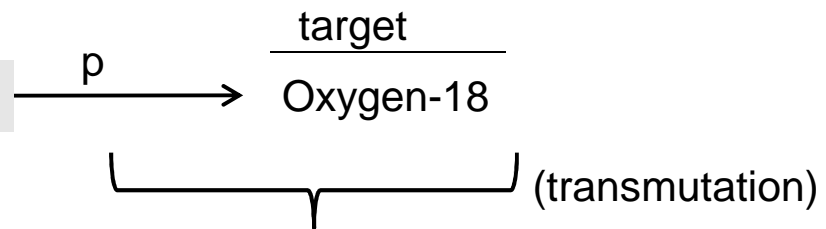
Applications of Accelerators (3)

Medical applications

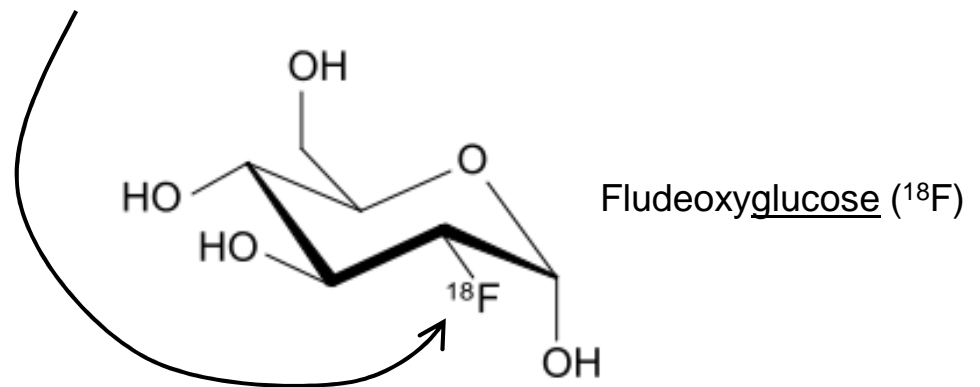
For radioisotope production

For example:

18 MeV proton accelerator



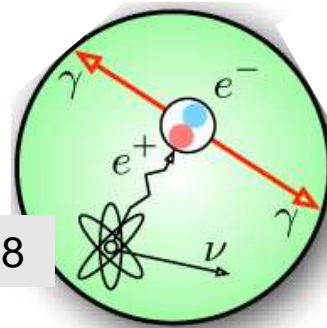
Fluorine-18 (half-life time = 110 min.)



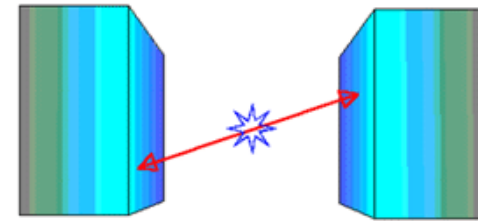
Applications of Accelerators (3)



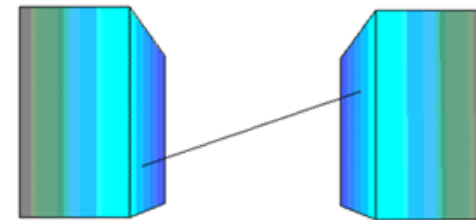
Fluorine-18



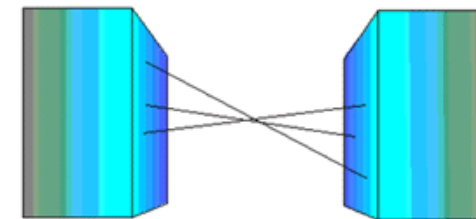
Annihilation



Detection



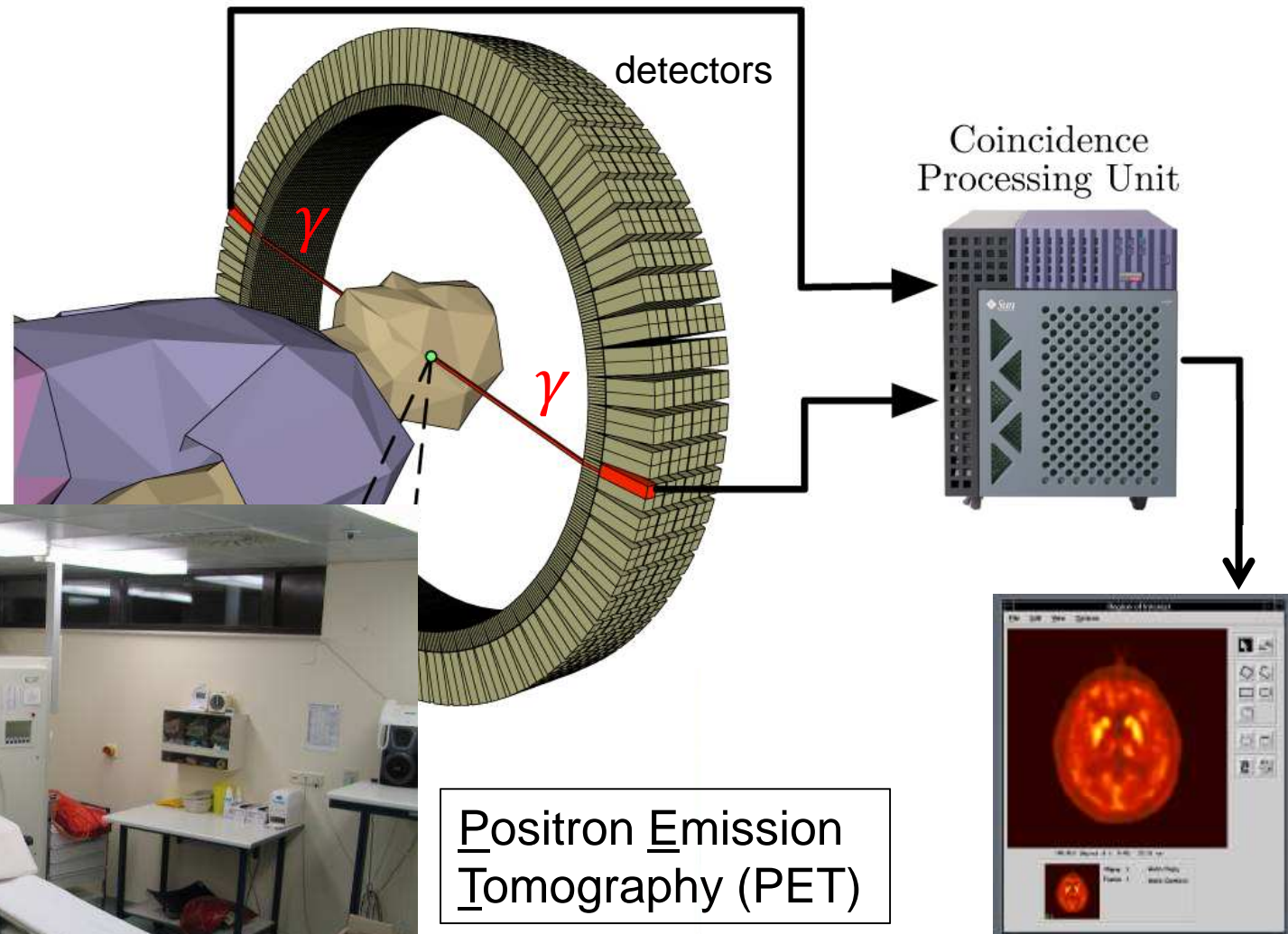
Reconstruction



Particle Location



Applications of Accelerators (3)



Positron Emission
Tomography (PET)

Applications of Accelerators (4)

For industrial applications:

Application	
Ion implantation	~ 9500
Electron cutting and welding	~ 4500
Electron beam and x-ray irradiators	~ 2000
Ion beam analysis (including AMS)	~ 200
Radioisotope production (including PET)	~ 900
Nondestructive testing (including security)	~ 650
Neutron generators (including sealed tubes)	~ 1000

approx. numbers from 2007 (worldwide)

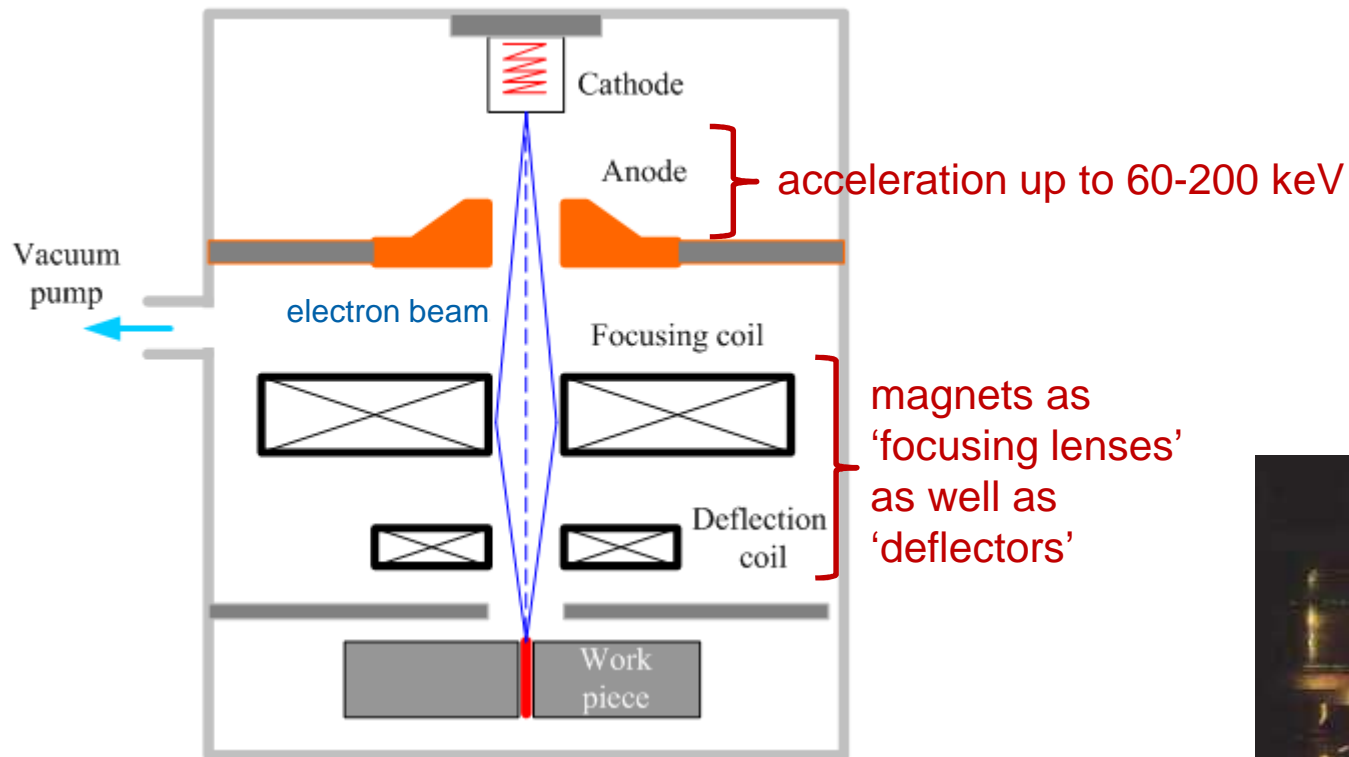
with energies up to 15 MeV



Applications of Accelerators (4)

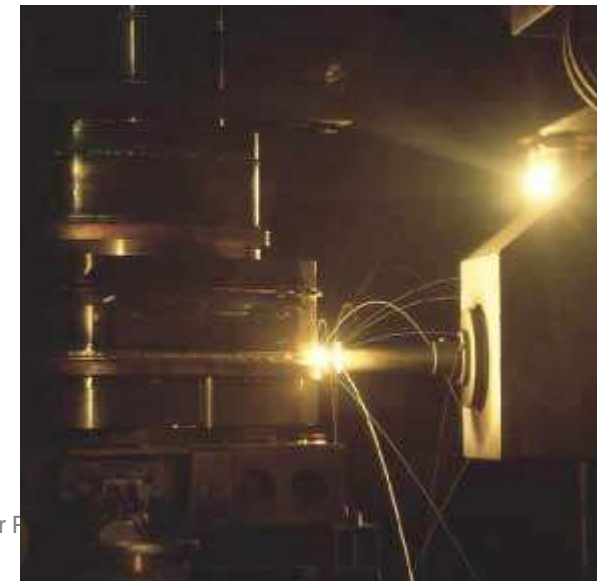
For industrial applications:

an example: electron beam welding



up to 15 cm

'deep welding effect'



Worldwide ...

- > About 120 accelerators for research in “nuclear and particle physics”
- > About 70 electron storage rings and electron linear accelerators used as light sources (so-called 'synchrotron radiation sources')

-
- > More than 7,000 accelerators for medicine
radiotherapy (>7,500), radioisotope production (200)
 - > More than 18,000 industrial accelerators
ion implantation (>9,000) , electron cutting and welding (>4,000) ...



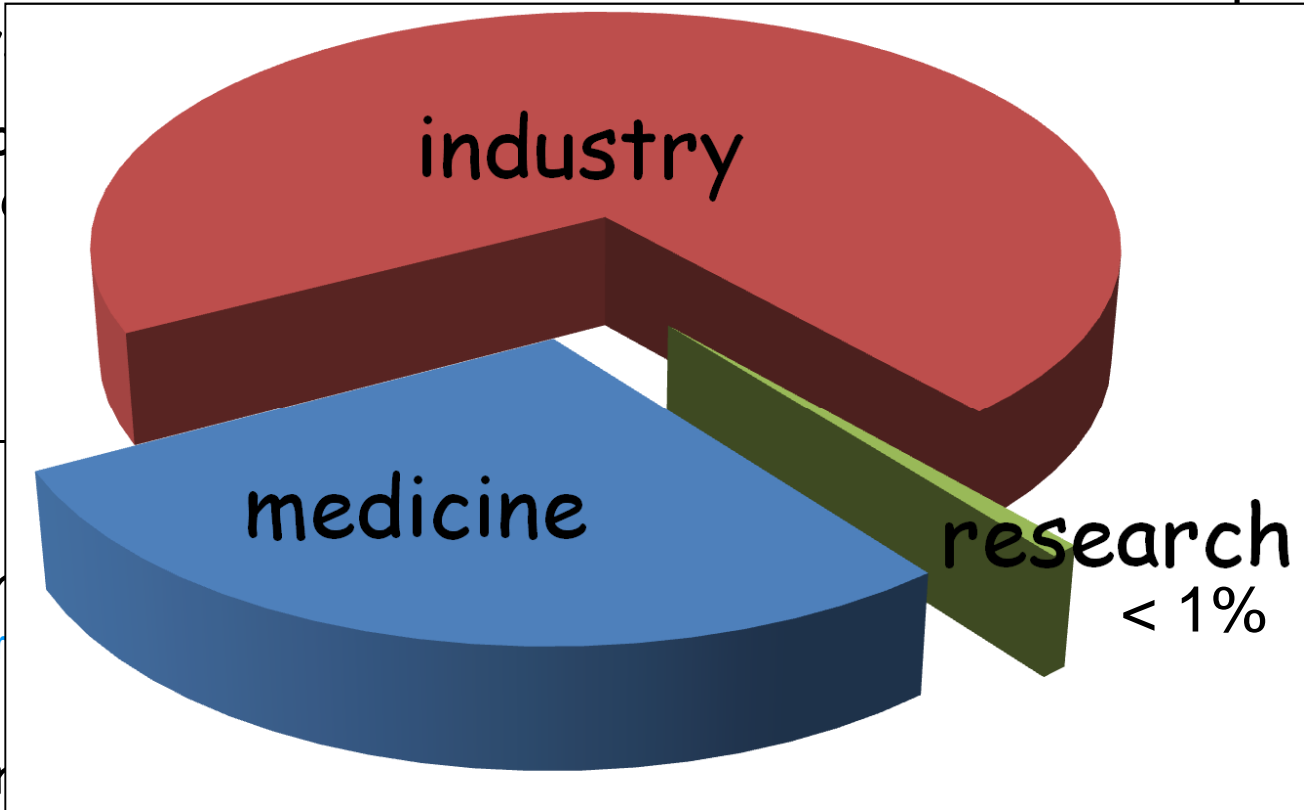
Worldwide ...

> About 120 accelerators for research in "nuclear and particle physics"

> About 1000 accelerators used in other fields

> More than 1000 accelerators used in medicine

> More than 1000 accelerators used in industry



accelerators sources')

ion implantation (>9,000) , electron cutting and welding (>4,000) ...

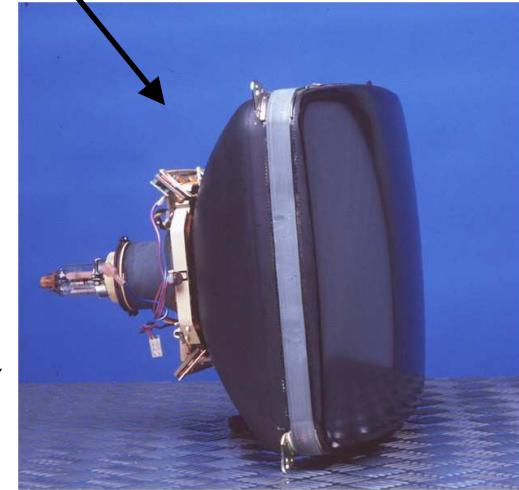


Applications of Accelerators (5)

Many millions of television sets, oscilloscopes using CRTs (Cathode Ray Tube)



TV

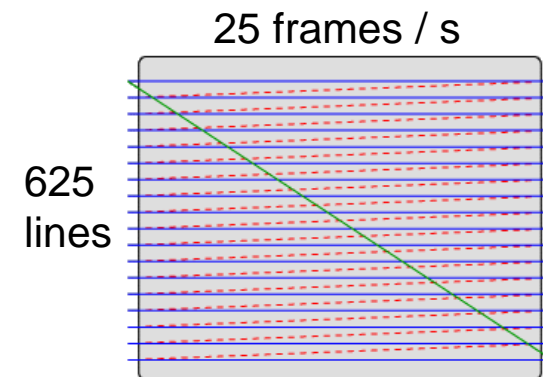
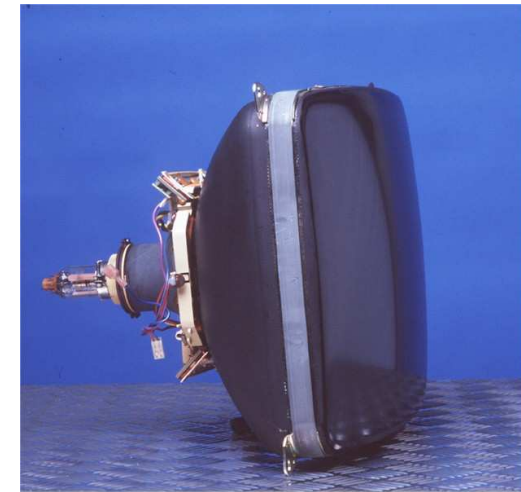
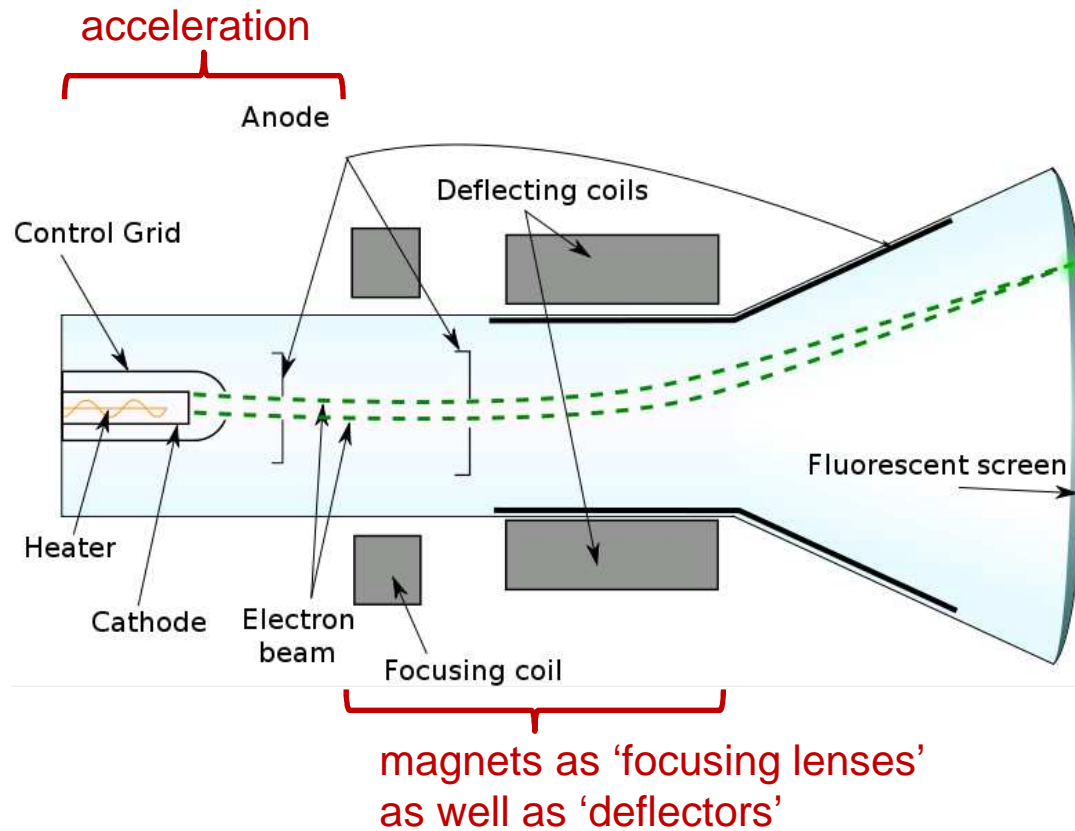


oscilloscope



Applications of Accelerators (5)

Many millions of television sets, oscilloscopes using CRTs (Cathode Ray Tube)



Applications of Accelerators (6)

X-ray tubes

