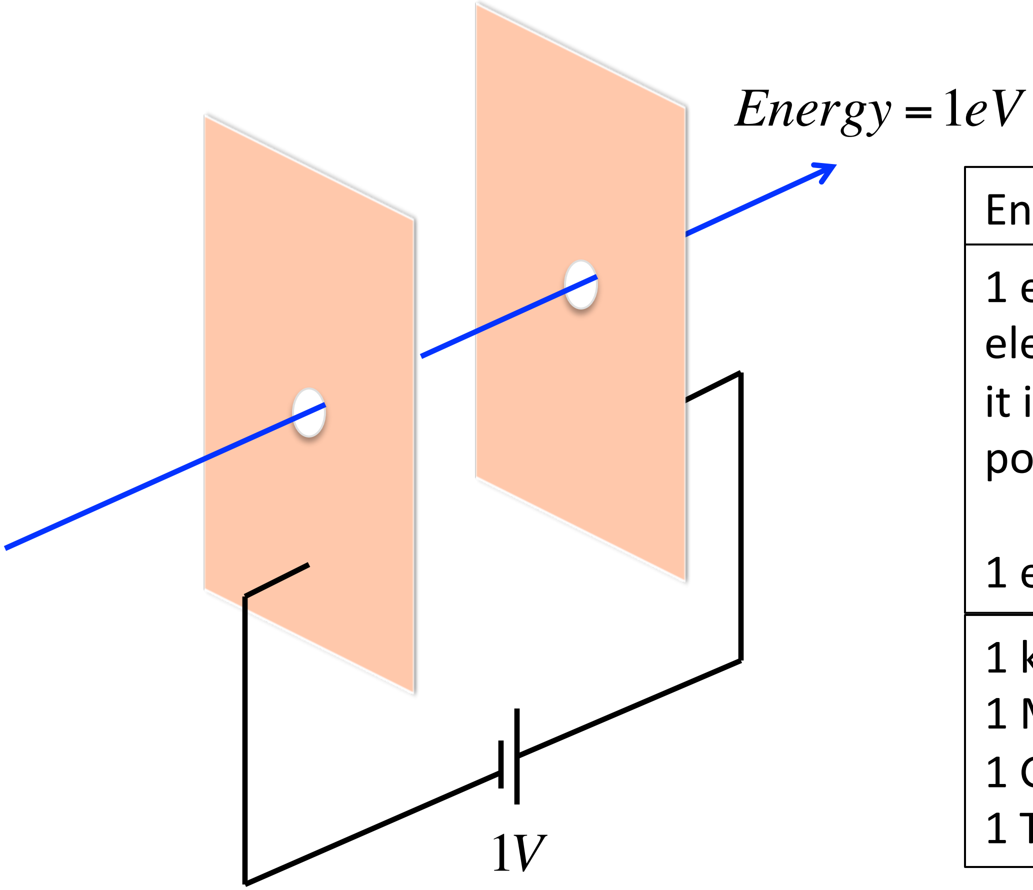
Overview of Particle Accelerators

The CERN Accelerator School

- Units
- Basic types of accelerator
- High energy machines
- Other applications
- Medical applications

Energy units



Energy gain

1 eV is the energy that an elementary charge gains when it is accelerated through a potential difference of 1 Volt

1 eV = 1.6 10^{-19} J

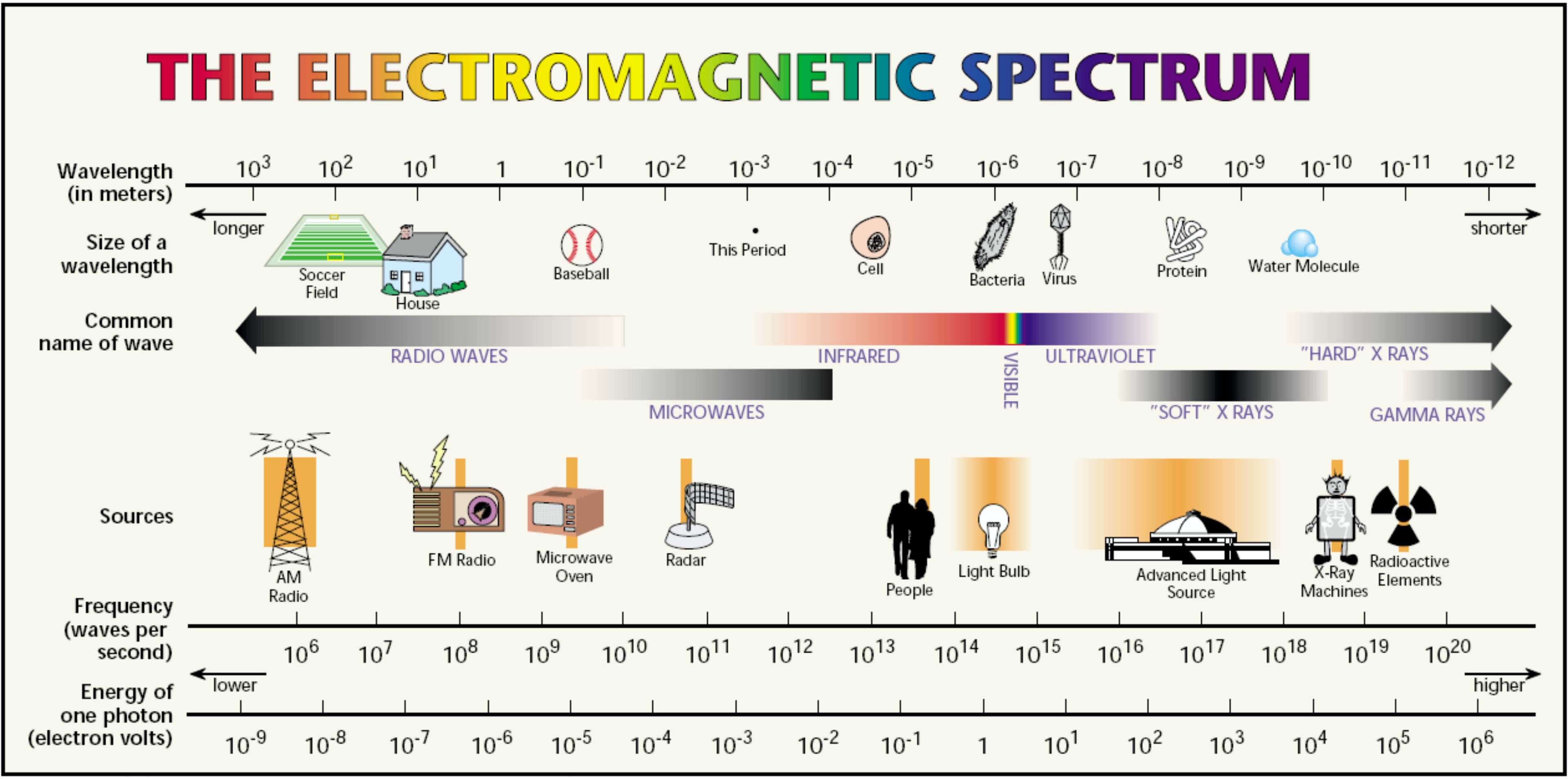
1 keV = 1 000 eV
1 MeV = 1 000 000 eV
1 GeV = 10^{9} eV
1 TeV = 10^{12} eV

Energy, frequency and wavelength

$$E = h\nu = \frac{hc}{\lambda}$$

Increasing the energy will increase the frequency

Increasing the energy will decrease the wavelength



1 eV **1 keV** **1 MeV**

Energy and wavelength (accelerators)

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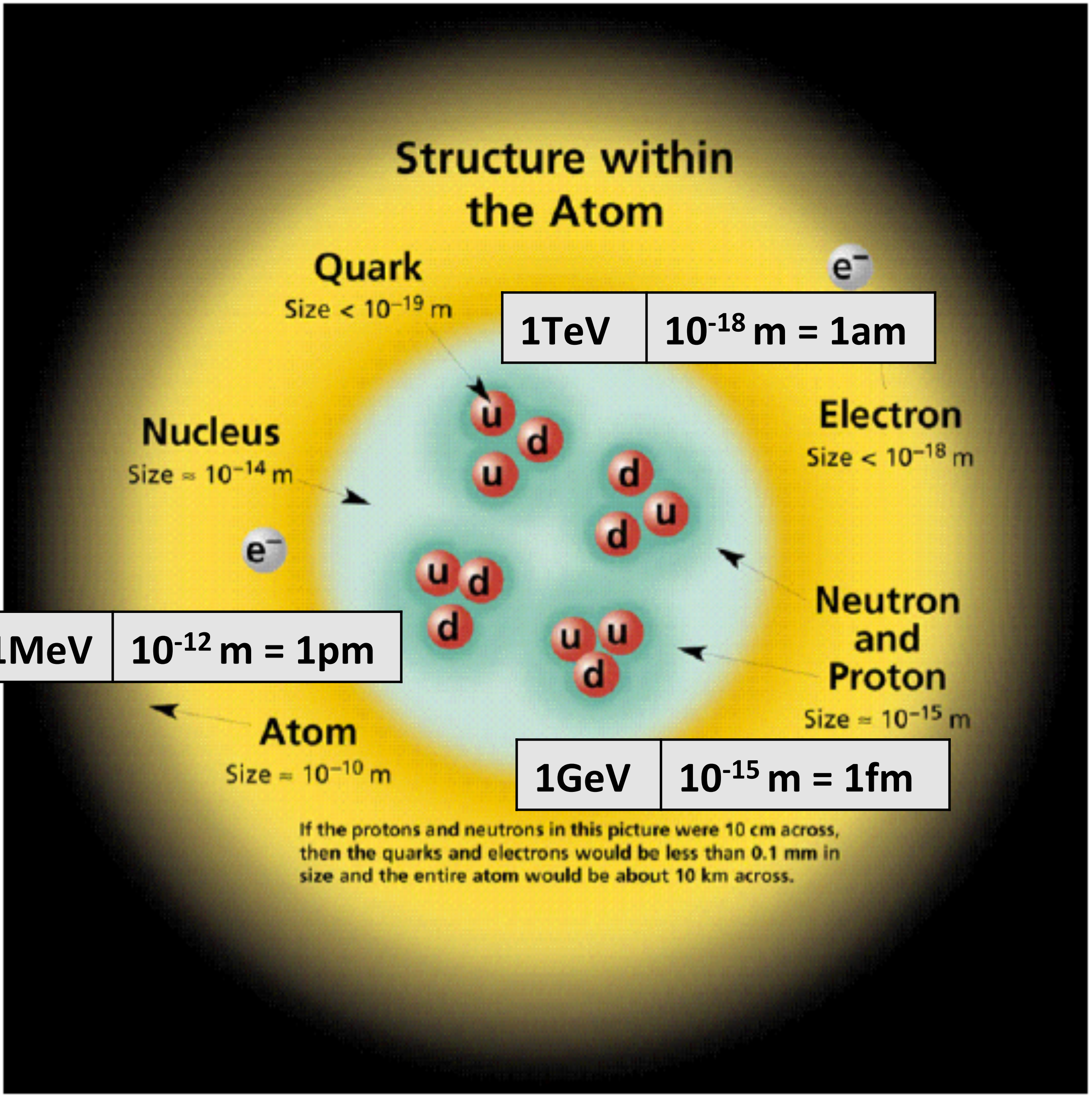

1TeV 10^{-18} m = 1am

1MeV 10^{-12} m = 1pm

1GeV 10^{-15} m = 1fm

Energy and mass and momentum

Einstein's formula: $E = mc^2$, which for a mass at rest is: $E_0 = m_0 c^2$

The ratio between the total energy and the rest energy $\gamma = \frac{E}{E_0}$

The ratio between the velocity and the velocity of light $\beta = \frac{v}{c}$

These two relativistic parameters are related

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \qquad \beta = \sqrt{1-\frac{1}{\gamma^2}}$$

We can write: $\beta = \frac{mvc}{mc^2}$

Momentum is: $p = mv$

$$\left.\begin{array}{l} \beta = \frac{mvc}{mc^2} \\ p = mv \end{array}\right\} \beta = \frac{pc}{E} \quad or \quad p = \frac{E\beta}{c}$$

Units of mass and momentum

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$$E = mc^2$$

Through this can express mass in units of eV/c^2

$$m(eV/c^2) = m(kg)c^2/1.6.10^{-19}$$

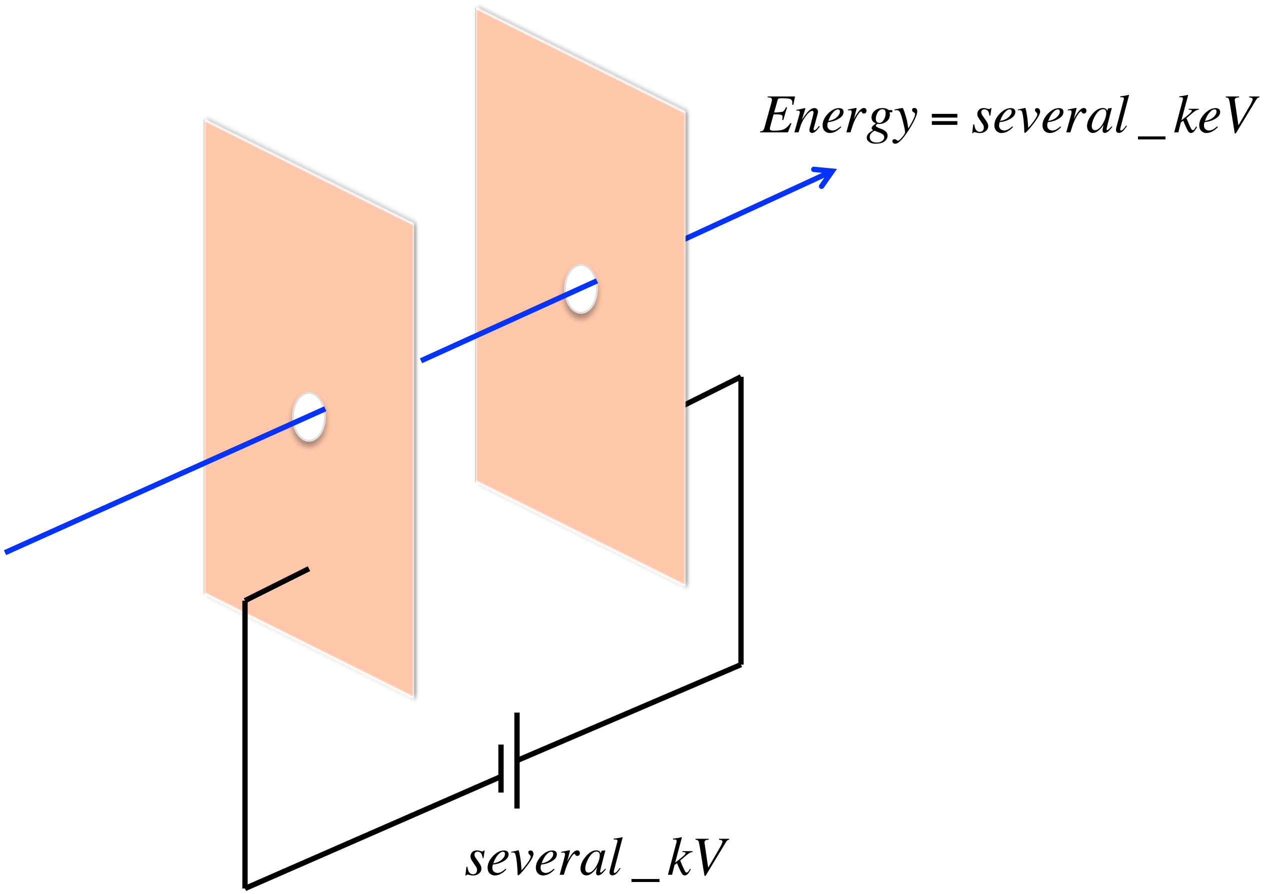
Proton rest mass	1.6726E-27 kg
	938.27 MeV/c^2
Electron rest mass	9.1095E-31 kg
	0.511 MeV/c^2

$$p = \frac{E\beta}{c}$$

Through this can express momentum in units of eV/c

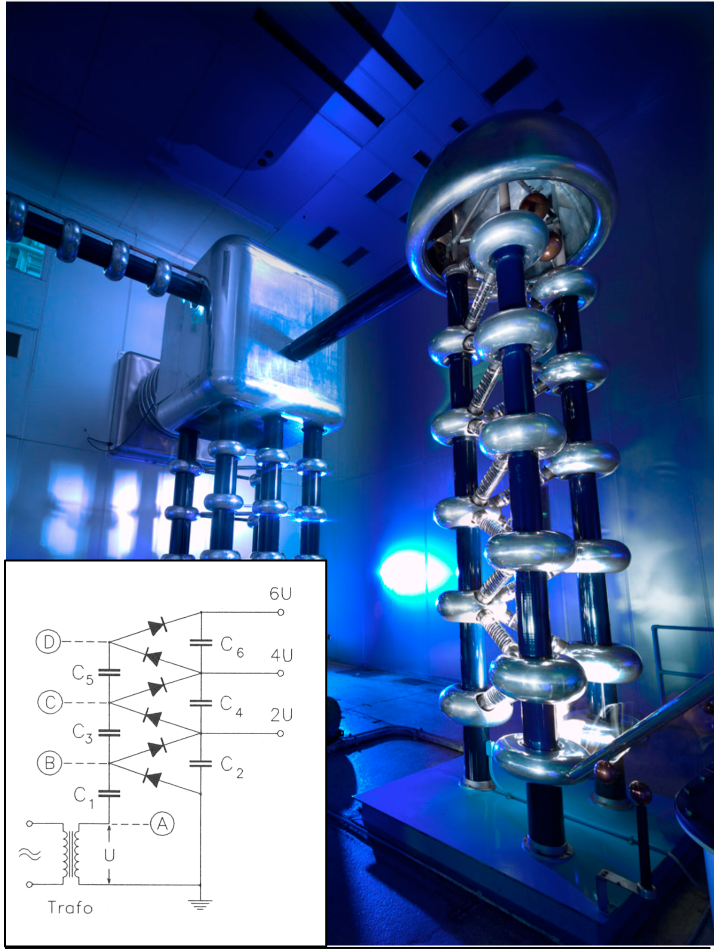
NB In both cases the units are often simply given as eV

Simplest electrostatic device



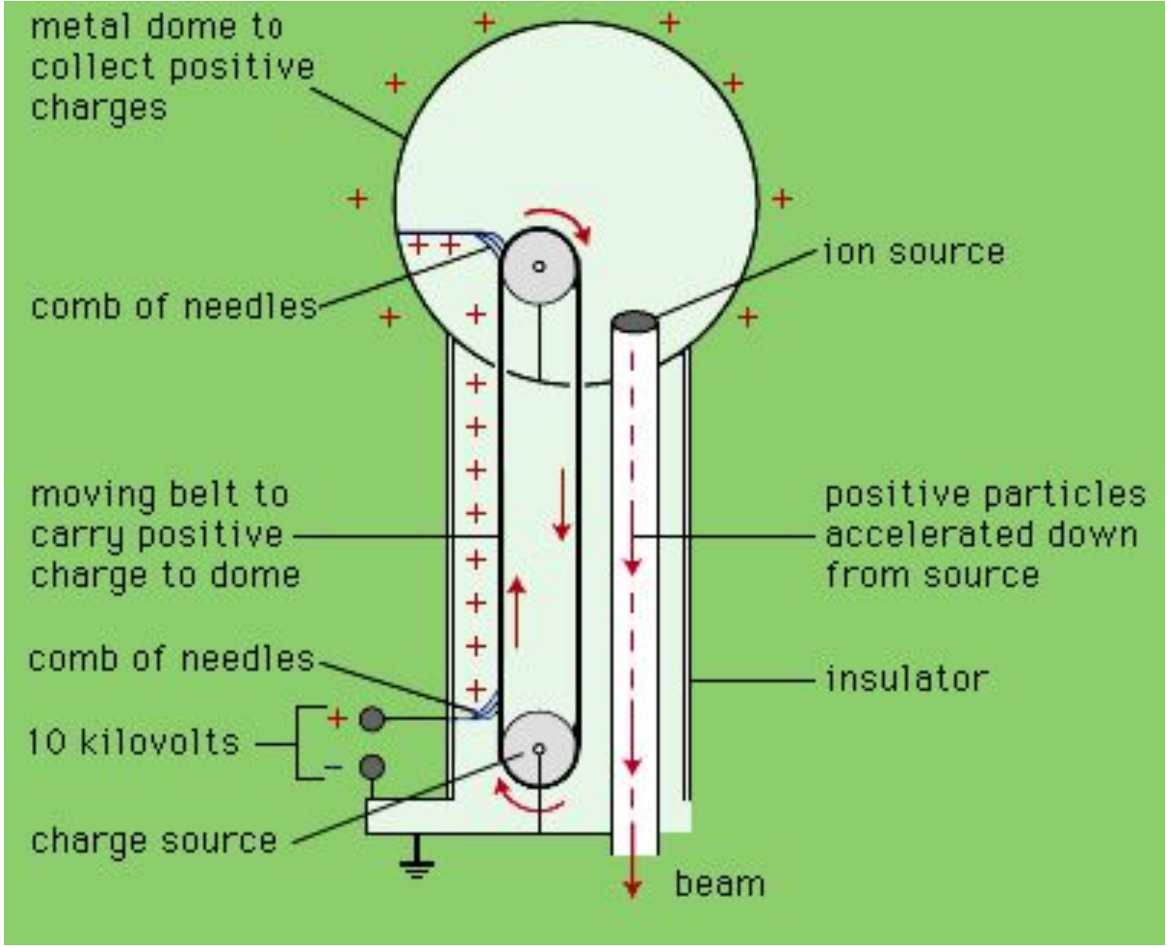
Pushing this simple idea – high voltages

Cockcroft-Walton, 1930s



Staircase of Diode Rectifiers

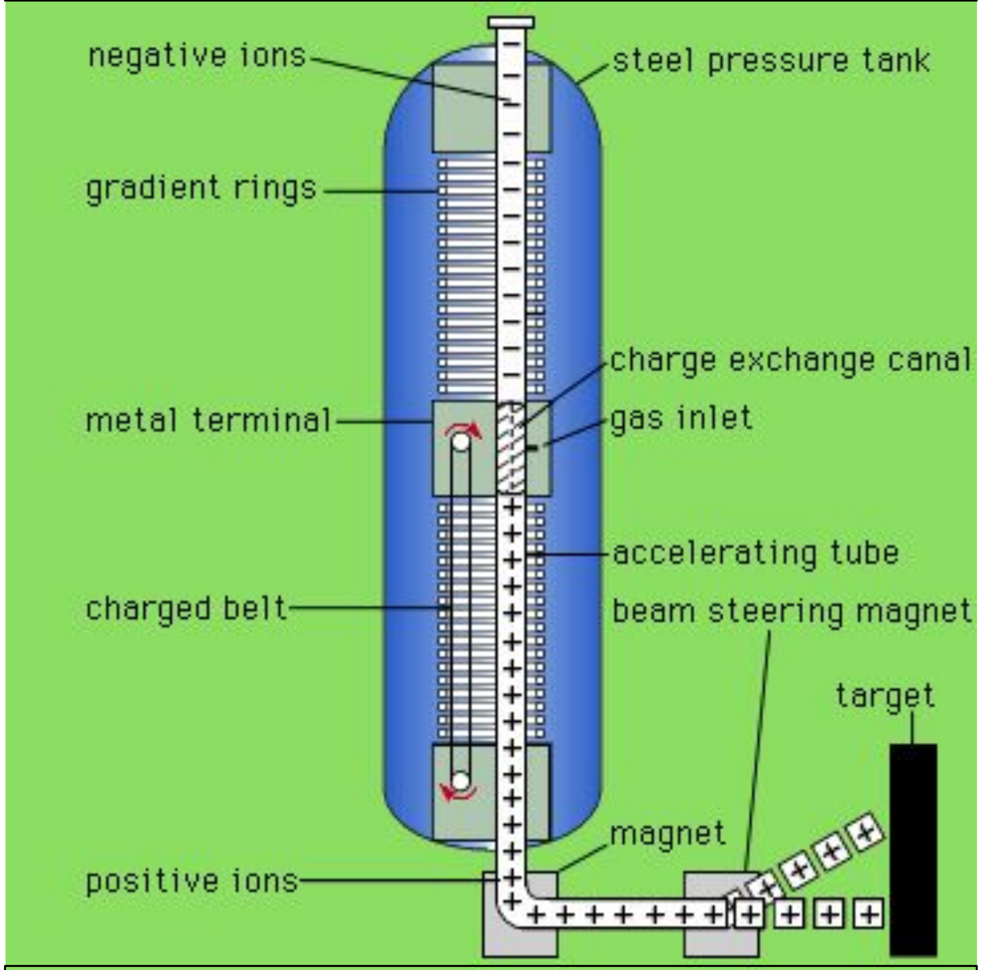
Van der Graaff, 1930s



Moving belt to carry charge to High Voltage Terminal

Tandem Van de Graaff

A clever idea to use the voltage twice

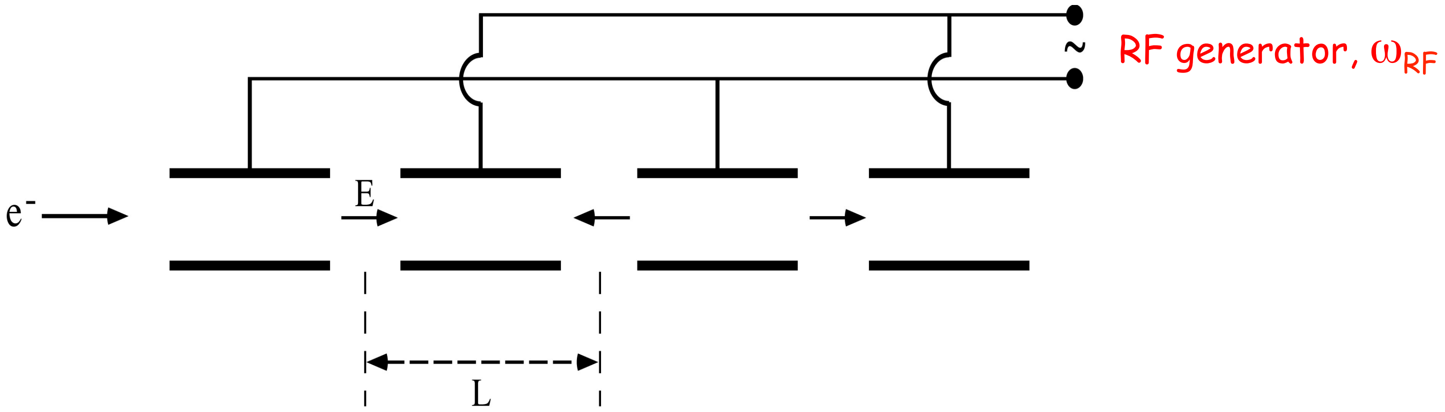


- ions to + HV, stripped, + ions away from HV

These early electrostatic accelerators continue to provide a useful source of low energy particles but ultimately are limited to voltages of around 10 MV by problems of voltage breakdown.

Solution number 1

- Repetitive acceleration in a straight line

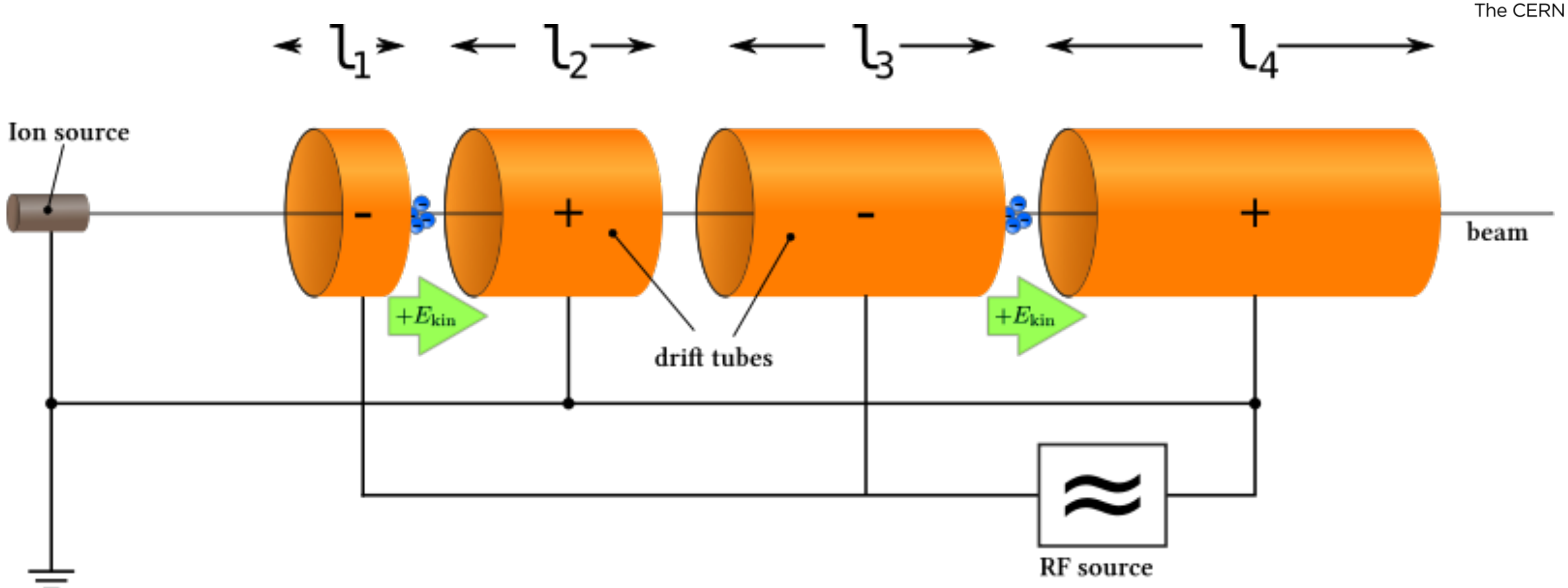


In practice there are cylindrical electrodes (drift tubes) separated by gaps and powered by an oscillator, providing an alternating electric field

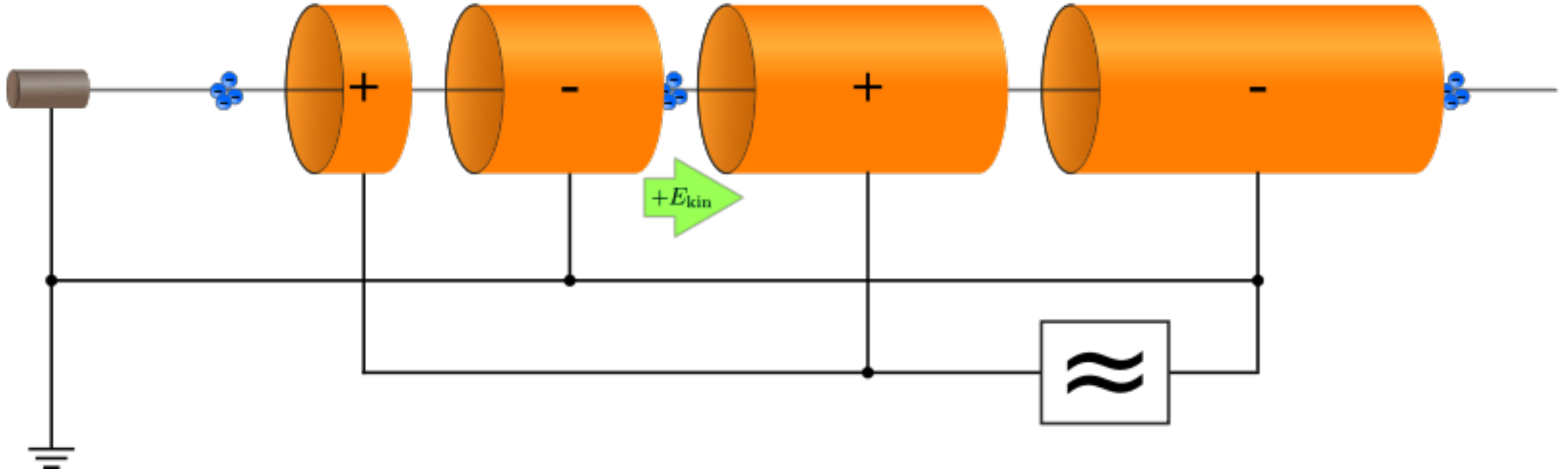
Condition for synchronicity; $L \sim \beta\lambda$ where $\beta = v/c$

As β increases we need to either increase L or decrease λ (higher frequency)

Alvarez linac (drift tube linac, 1940s)

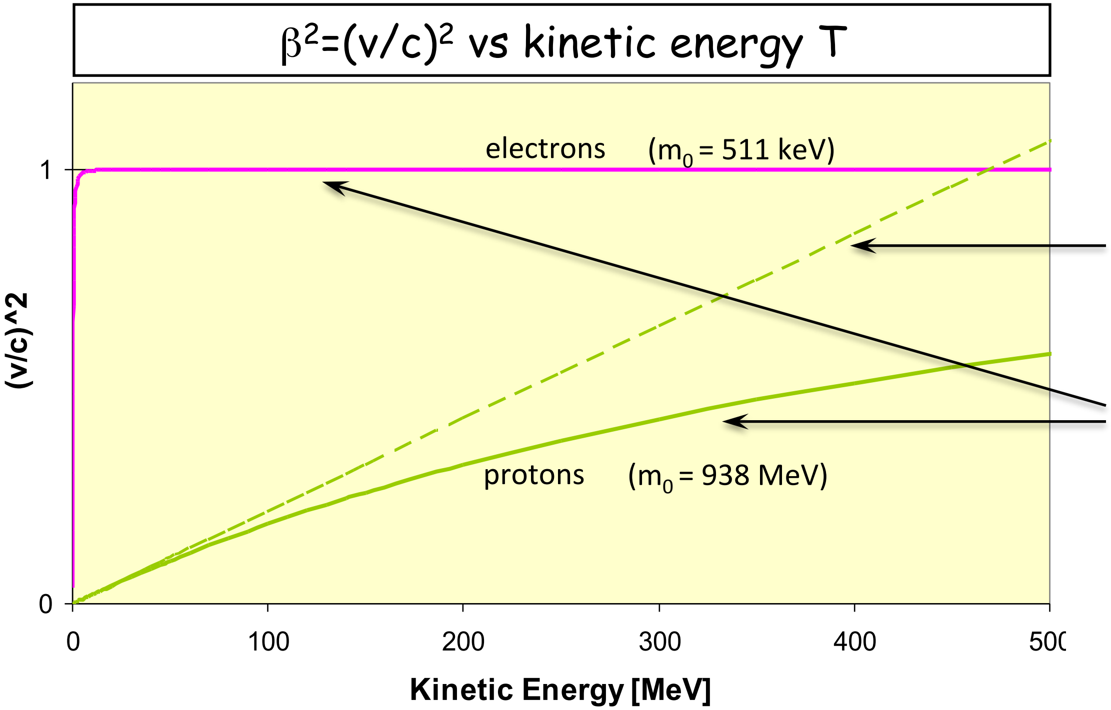


Fixed frequency, increasing length of drift tubes



Relativistic effects

- The velocity and the energy of the particles are increasing
- Things are very different for electrons and protons
- Once (ultra) relativistic, linacs become much simpler



Classic (Newton) relation:

$$T = m_0 \frac{v^2}{2}, \quad \frac{v^2}{c^2} = \frac{2T}{m_0 c^2}$$

Relativistic (Einstein) relation:

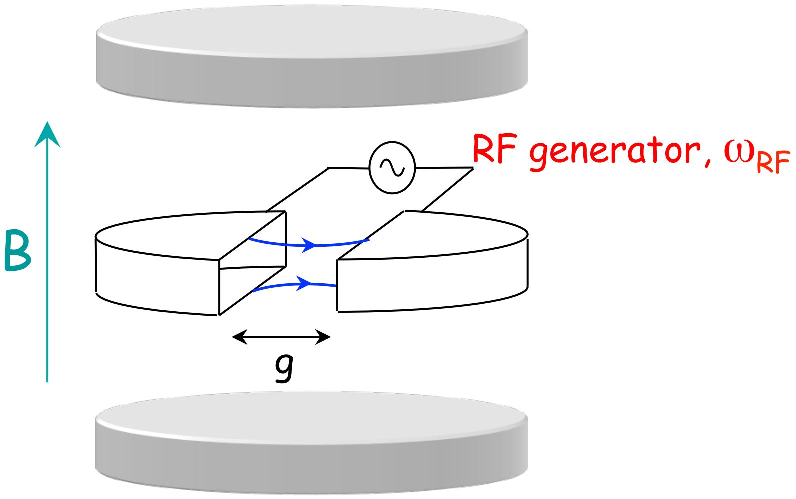
$$\frac{v^2}{c^2} = 1 - \frac{1}{\sqrt{1 + T/m_0 c^2}}$$

Solution number 2

- Repeatedly traverse an accelerating structure
- Implies a circular machine which means a Bending field

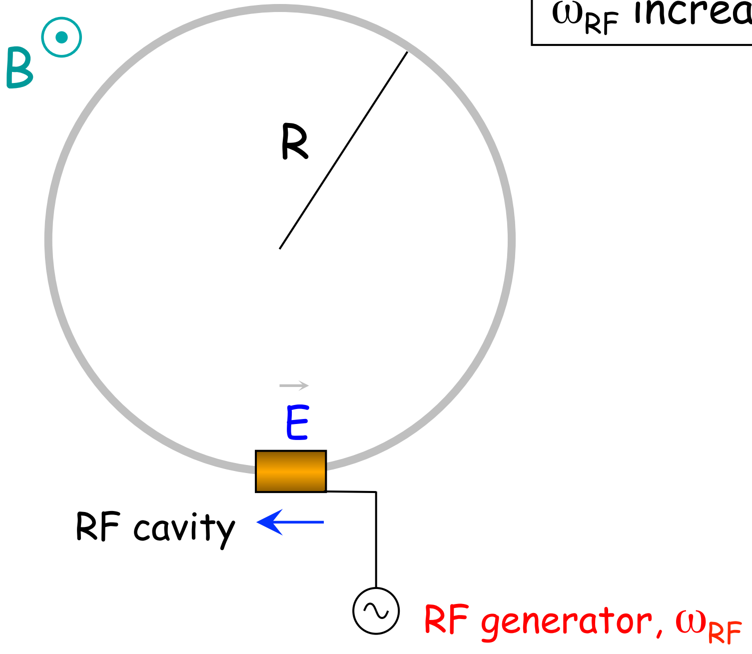
B = constant
ω_{RF} = constant
Spiral orbit

Cyclotron

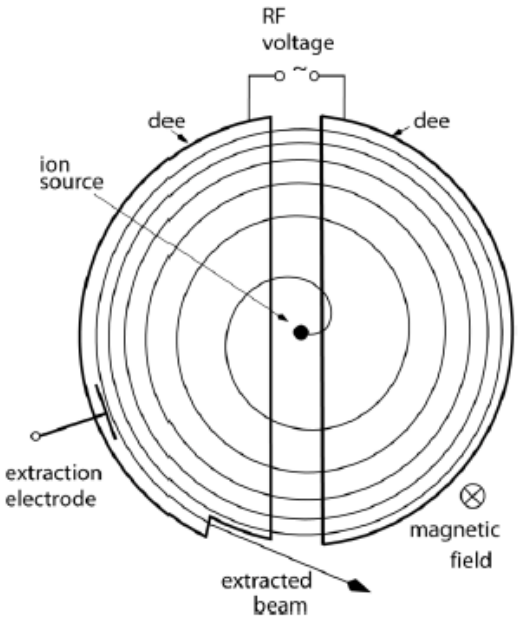


Synchrotron

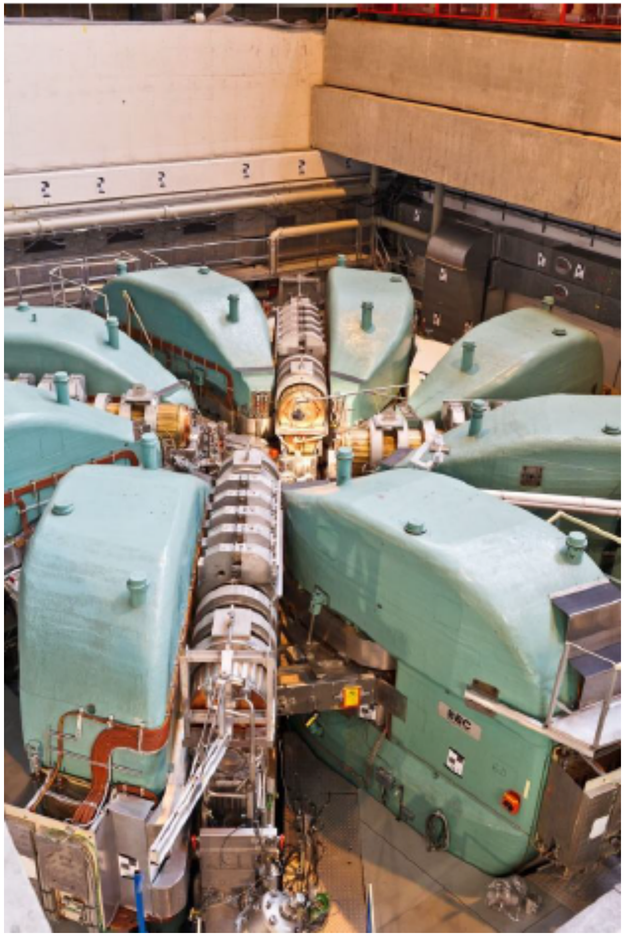
Constant orbit
B increases
ω_{RF} increases



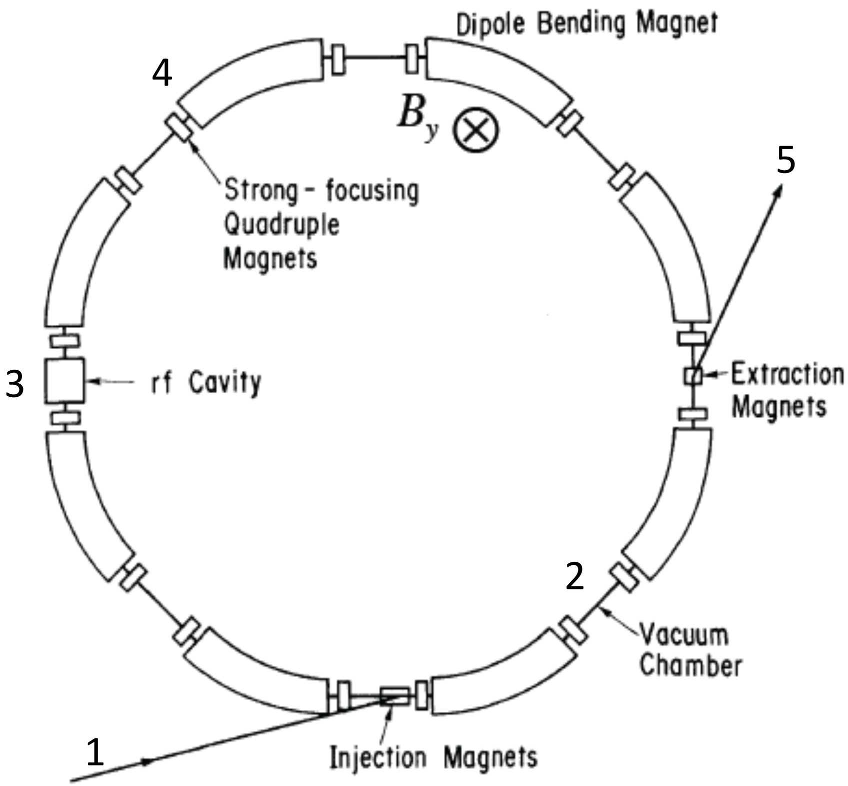
Cyclotrons, 1930s



- Compact and simple
- Efficient
- Energy limited to ~ 1 GeV
- Injection / extraction critical



Synchrotrons, 1940s/1950s



In the simplest case

Need an RF oscillator
Need a bending field *only on the orbit*
Need a vacuum system
Need an injection system
Need an extraction system

- Separated function
- Flexibility
- Scalability

Lorentz force

- Implicit in relativistic formulation of Maxwell’s equations
- Describes the force on a charged particle moving in an em field

$$\vec{f} = q(\vec{E} + \vec{v} \wedge \vec{B})$$

$\vec{E} = 0$ $\vec{B} = 0$

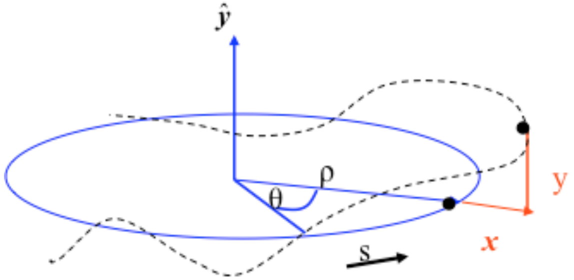
$$\vec{f} = q\,\vec{v} \wedge \vec{B}$$

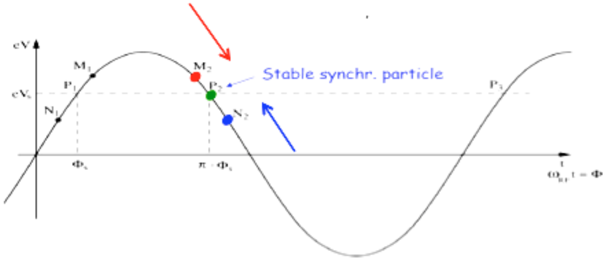
$$\vec{f} = q\,\vec{E}$$

Transverse Beam Dynamics

Monday

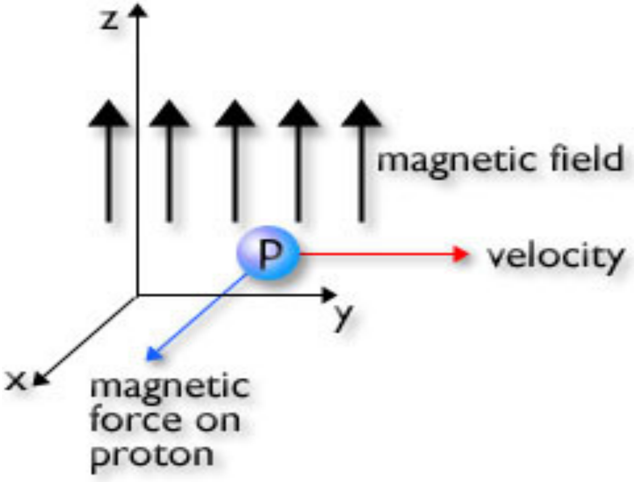
Longitudinal Beam Dynamics

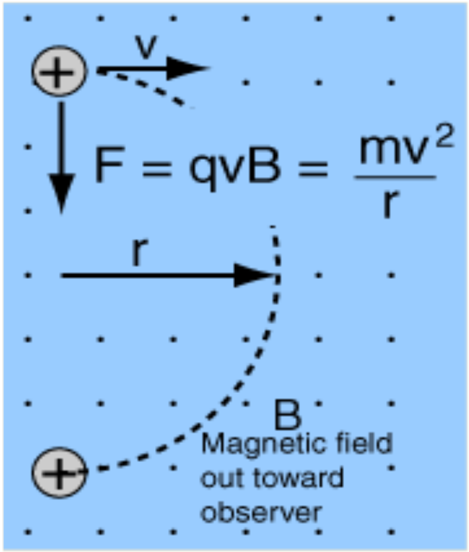




High energy machines

- Synchrotrons are flexible and scalable
- So we use a synchrotron to get to very high energies
- We can learn a lot from just the Bending magnets





$$B\rho = p / e = m_0 v \gamma / e$$

Magnetic rigidity

$$B\rho = p / e = m_0 v\gamma / e$$

$$B\rho[Tm] = 3.335641 \; E[GeV]$$

Known	Reason	Example	Free to choose
B	Normal conducting magnets	SPS	E, ρ
E	Want to run on the Z^0 mass	LEP	B, ρ
ρ	Tunnel already there	LHC	E, B

LEP

Known	Reason	Example	Free to choose
B	Normal conducting magnets	SPS	E, ρ
E	Want to run on the Z^0 mass	LEP	B, ρ
ρ	Tunnel already there	LHC	E, B

$$B\rho[Tm] = 3.335641\ E[GeV] \qquad eU_0 = A\gamma^4 / \rho$$

- We need to use e^+ and e^- (for precision measurements)
  - Synchrotron radiation will be an issue
    - Build a big tunnel
    - Use cheap conventional magnets
      - Bending radius in the dipoles 3096 m
      - Bending field needed for 45GeV 0.048 T
  - LEP2 went up to 100 GeV
      - U_0 3 GeV
    - Big expensive SCRF system

LHC

Known	Reason	Example	Free to choose
B	Normal conducting magnets	SPS	E, ρ
E	Want to run on the Z^0 mass	LEP	B, ρ
ρ	Tunnel already there	LHC	E, B

$$B\rho[Tm] = 3.335641\ E[GeV]$$

$$eU_0 = A\gamma^4 / \rho$$

- We want to take protons to highest possible energy
  - Getting the magnetic field is the issue
    - Need superconducting magnets

– Bending radius in the dipoles	2803 m
– Bending field needed for 7 TeV	8.33 T

  - Synchrotron radiation not (much of) an issue

– U_0	0.00001 GeV

    - Small RF system

Collider

- Why do we collide beams in an accelerator?

- Consider two beams, same particle mass m
  - Beam 1 energy and momentum E_1 p_1
  - Beam 2 energy and momentum E_2 p_2
  - What counts is the energy in centre of mass E_{CM}

- In general, available energy is $E_{CM} = \sqrt{(E_1 + E_2)^2 - (p_1 + p_2)^2}$

- With an accelerator reach of 7 TeV (LHC)

  - Fixed target case, $p_2 = 0$ $E_{CM} = \sqrt{2E_1 m + m^2} \approx 115 GeV$

  - Collider case, $p_1 = -p_2$ $E_{CM} = E_1 + E_2 = 14 TeV$

LHC

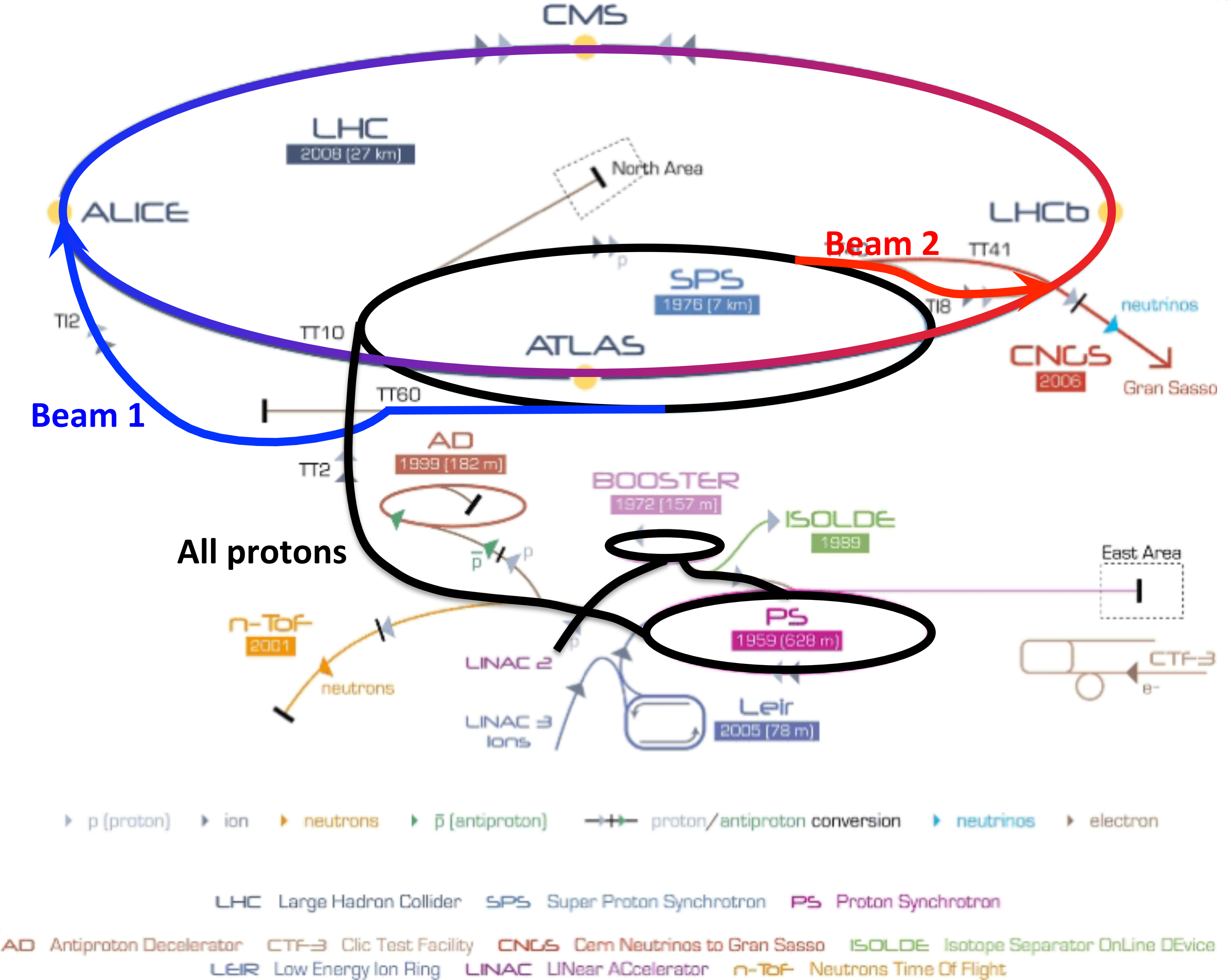
- We started with a 27km tunnel
- We know that we need 8.33T dipole magnets for 7TeV
  - NB for LHC, 2πρ = 17.6km, which is about 66% of 27km

- We know if we collide we make the most of this energy

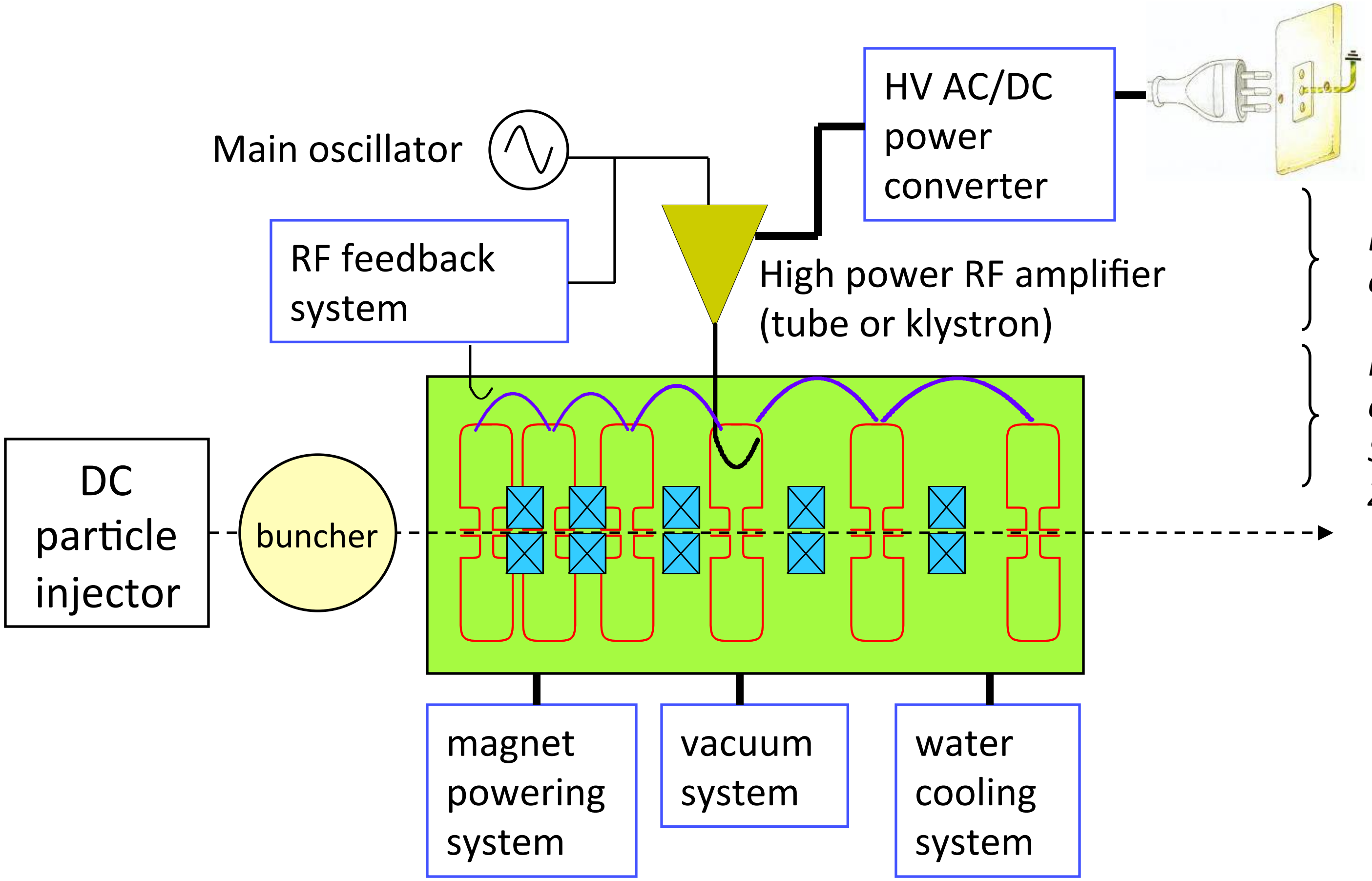
- What else do we need to know ?
  - Magnets designed for 7TeV do not work at very low field
    - We cannot just build a small linac to provide protons to LHC
    - We need an injection scheme to provide protons > 400 GeV
  - We need high intensities in LHC
    - Injection scheme has to provide this

$$L = \frac{N^2 k_b f}{4\pi\sigma_x\sigma_y} F = \frac{N^2 k_b f \gamma}{4\pi\varepsilon_n \beta^*} F$$

Accelerators are often linked together



Linac2 schematic (3 distinct systems)

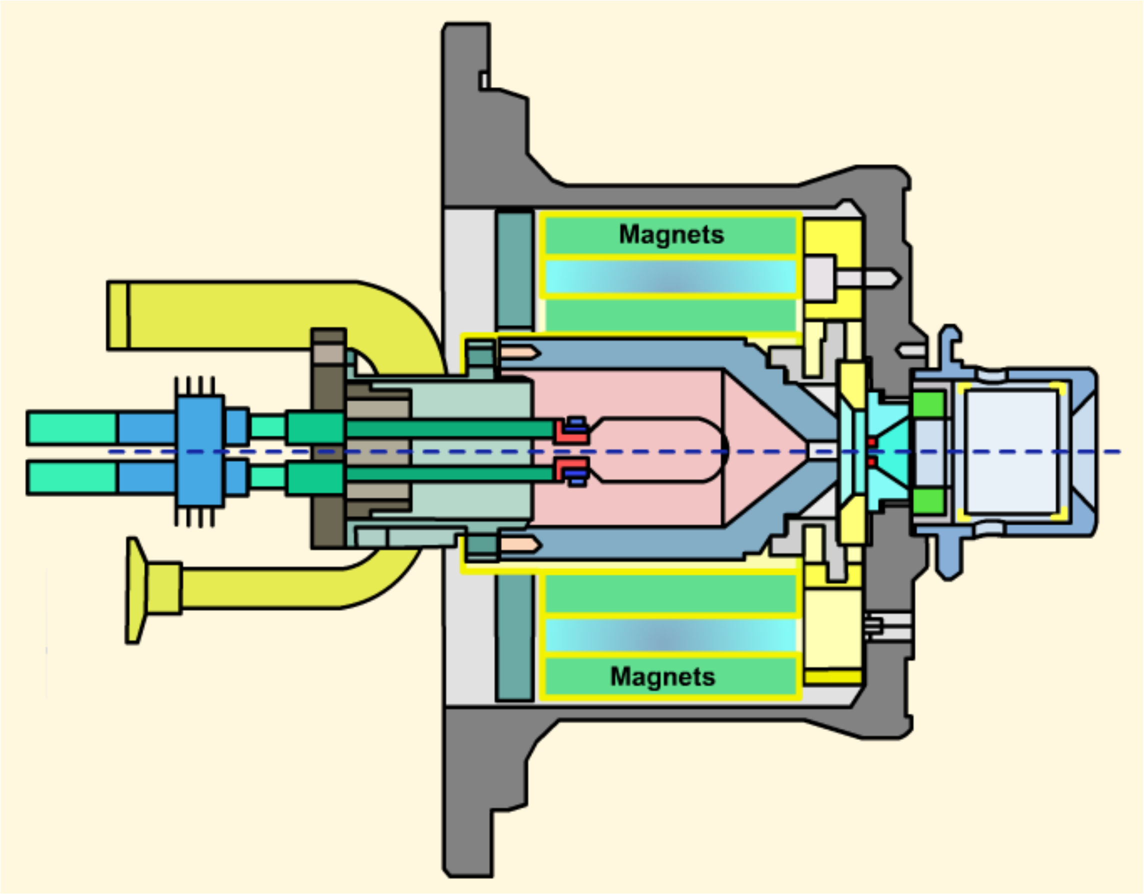


AC to DC conversion efficiency ~90%

DC to RF conversion efficiency ~50%

RF to beam voltage conversion efficiency = SHUNT IMPEDANCE ZT^2 ~ 20 - 60 MΩ/m

Source for linac 2 (0 to 90 keV)



Proton Current	**200 mA**
Proton Energy	90 keV
Emittance	~0.4 mm.mrad
Pulse for LHC	20us @ 1 Hz
# protons / pulse	$2.5\text{x}10^{13}$
# LHC bunches	~24 *

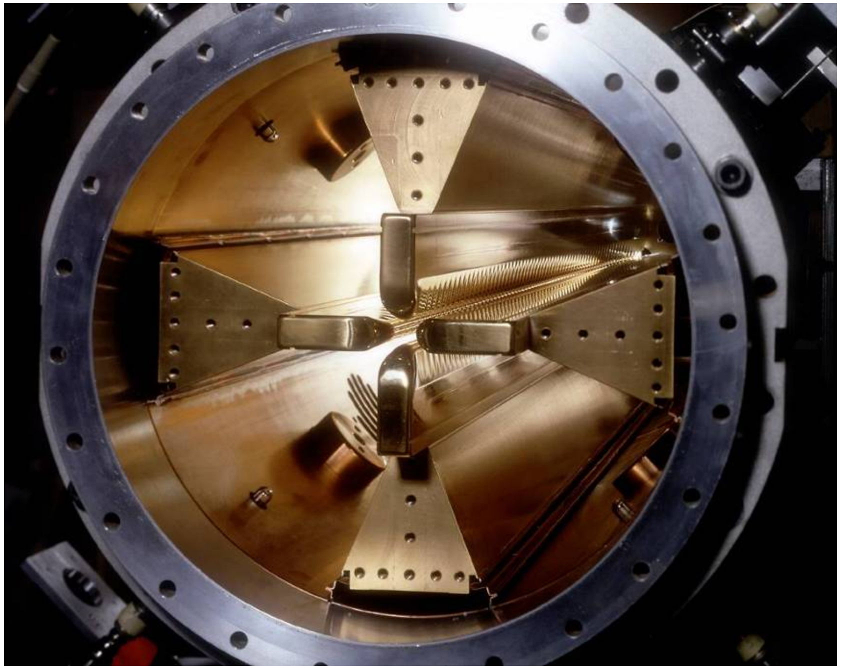
* Creation of LHC bunches is a complicated process, this is an example for 50ns LHC bunches

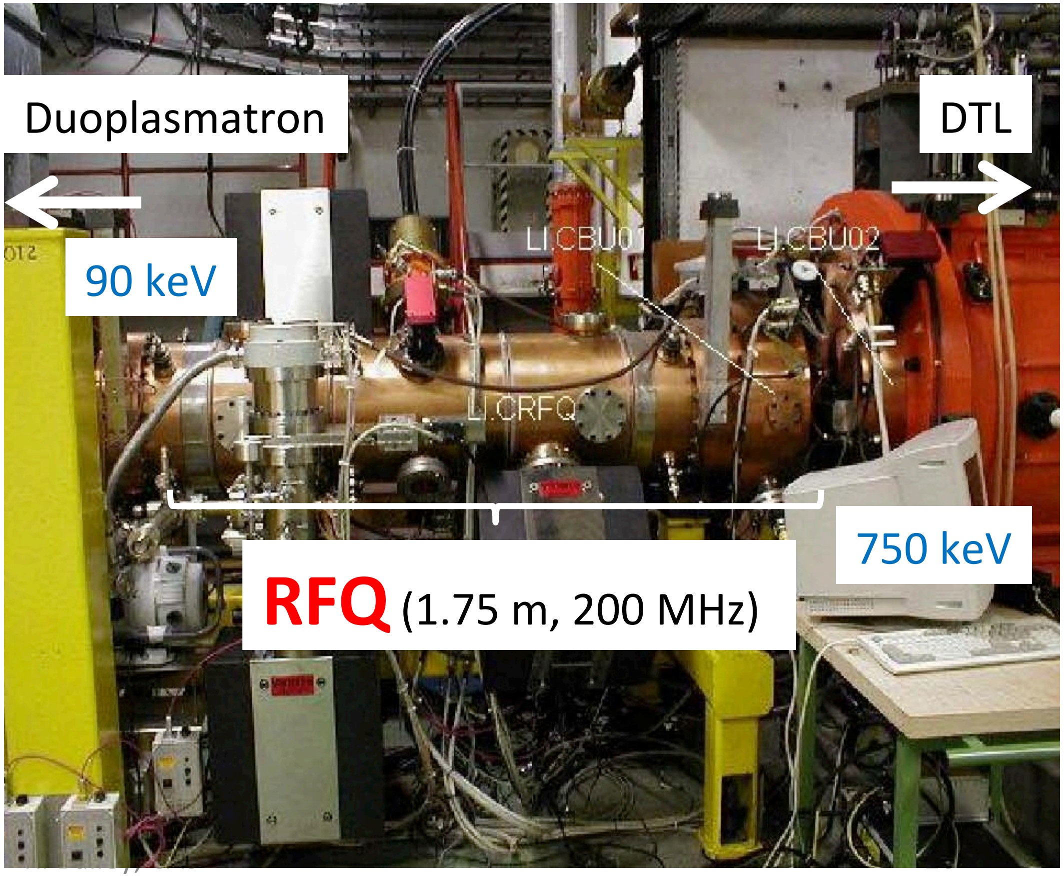
RFQ (90 to 750 keV) replaced C-W device

Originally 750 kV Cockcroft-Walton

The Radio Frequency Quadrupole is a linear accelerator that focuses, bunches and accelerates with high efficiency

The Linac2 RFQ takes protons from the source at 90 KeV and delivers them bunched to the DTL at 750 keV





Duoplasmatron

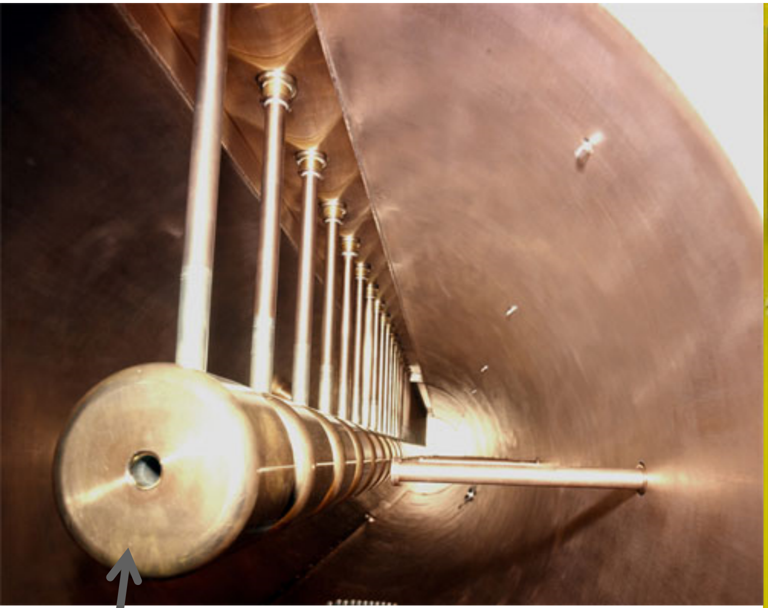
DTL

90 keV

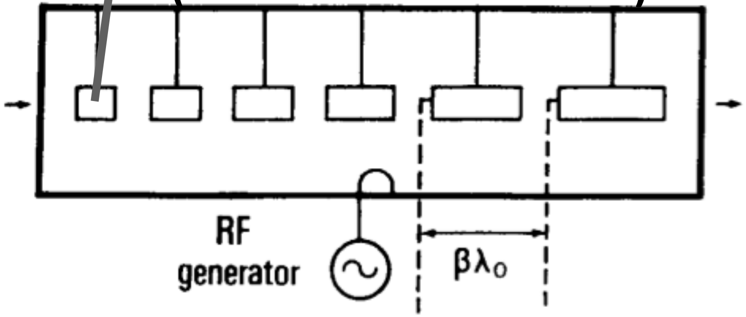
750 keV

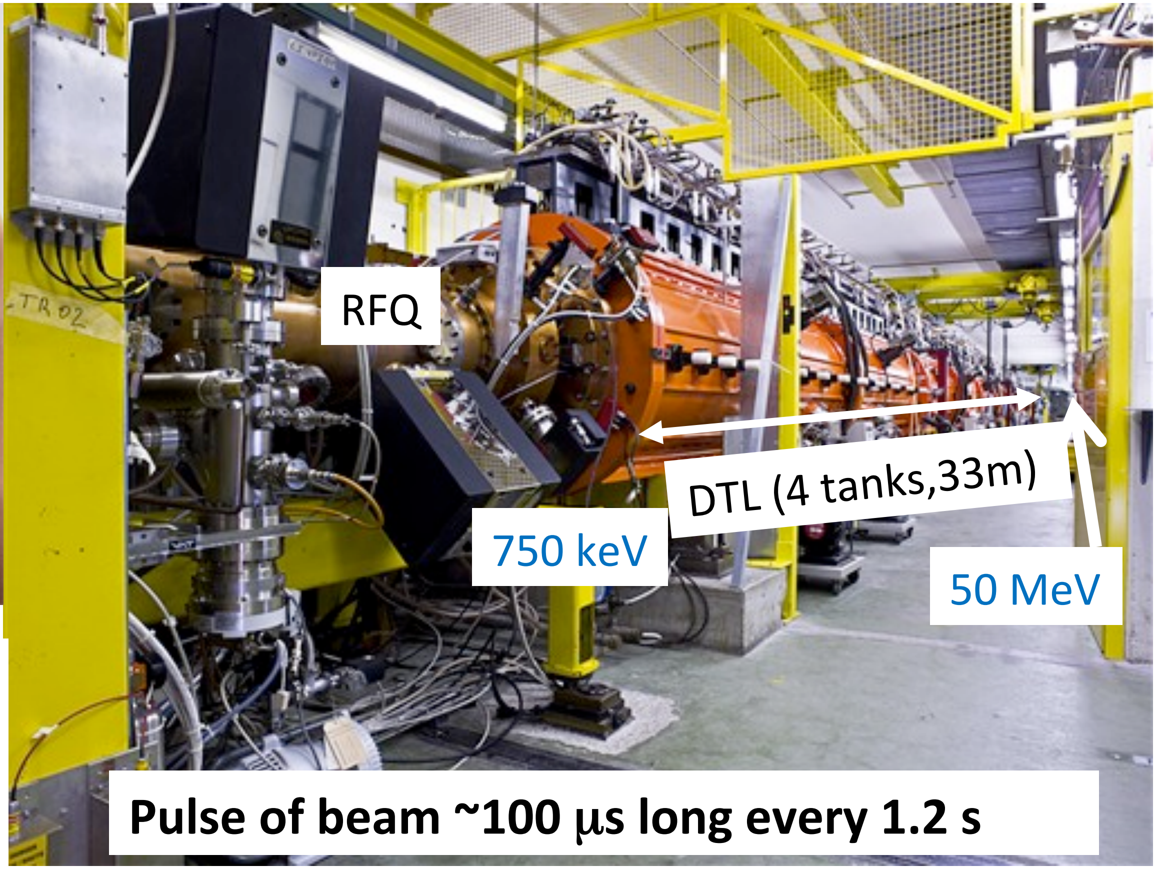
RFQ (1.75 m, 200 MHz)

Linac 2 DTL (750 keV to 50 MeV)



DTL (Alvarez structure 1945)





Pulse of beam ~100 μs long every 1.2 s

Drift tubes and spacing become larger as the energy increases
Focusing quads inside drift tubes

The Synchrotrons

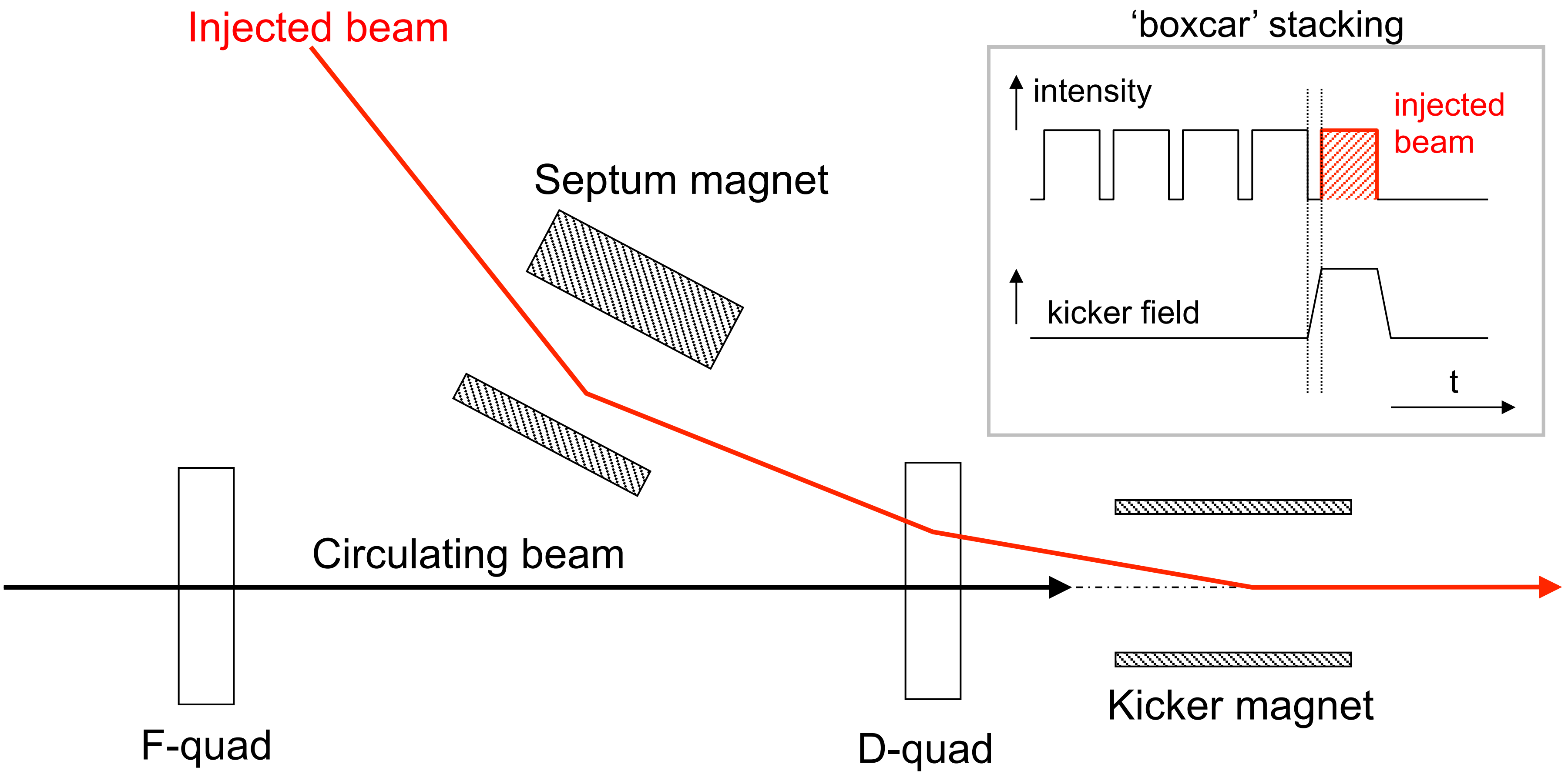
Machine	Injection energy	Extraction energy
Booster	50 MeV	1.6 GeV
PS	1.6 GeV	26 GeV
SPS	26 GeV	450 GeV
LHC	450 GeV	7 TeV

All these machine are conceptually similar (barring a few historical developments)

In practice, LHC is rather different to the others due to

Size (1720 power converters, steady state 63 MW, Peak power 86 MW)
Segmentation of the machine into 8 (Tracking between sectors)
Superconducting (High current Low voltage)
Collider (in a 10h run protons travel 10^{10}km = 72AU ~ diameter of solar system)

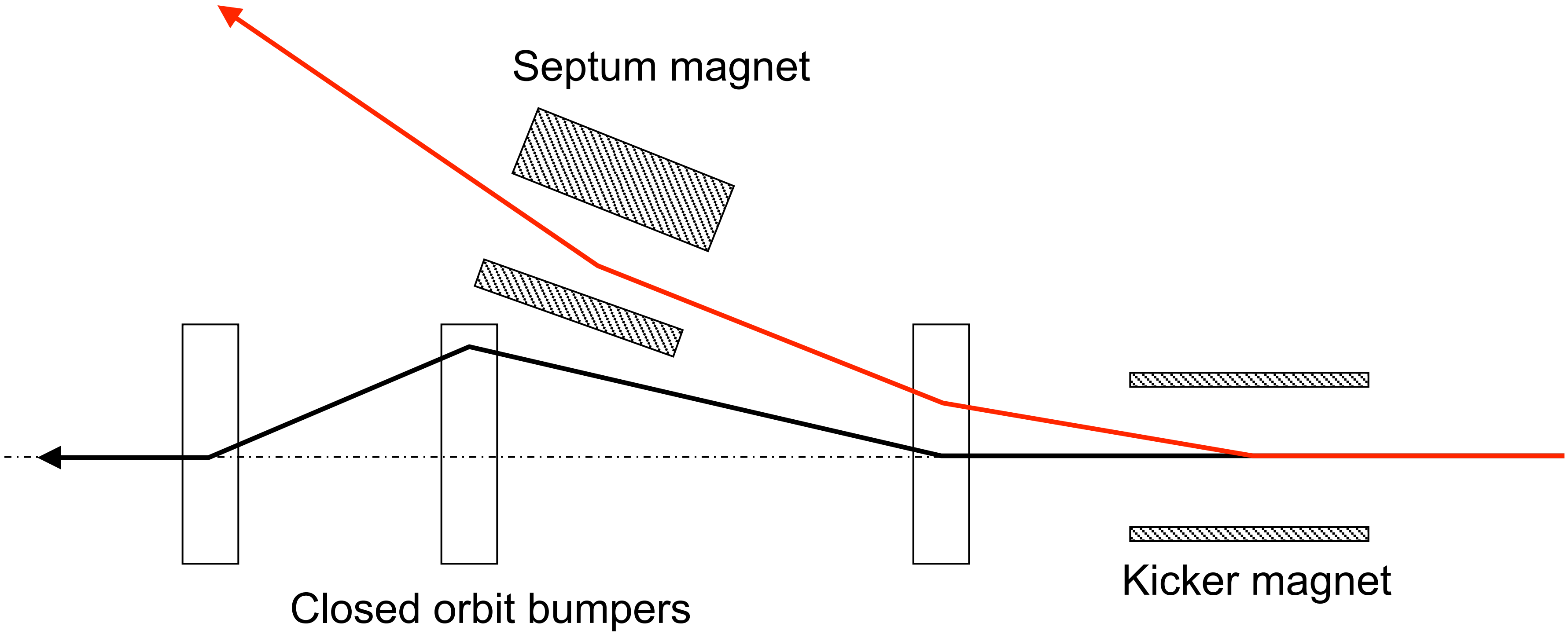
Single-turn injection – same plane



- Septum deflects the beam onto the closed orbit at the centre of the kicker
- Kicker compensates for the remaining angle
- Septum and kicker either side of D quad to minimise kicker strength

Fast single turn extraction

Whole beam kicked into septum gap and extracted.



- Kicker deflects the entire beam into the septum in a single turn
- Septum deflects the beam entire into the transfer line
- Most efficient (lowest deflection angles required) for $\pi/2$ phase advance between kicker and septum

Basic questions in accelerator design

The CERN Accelerator School

- What is the machine for?

- What energy do we need?
- What intensity do we need?
- What beam size do we need?

High Energy

High Power

High Brightness

Frontier Machines

- What availability do we need?

High Reliability

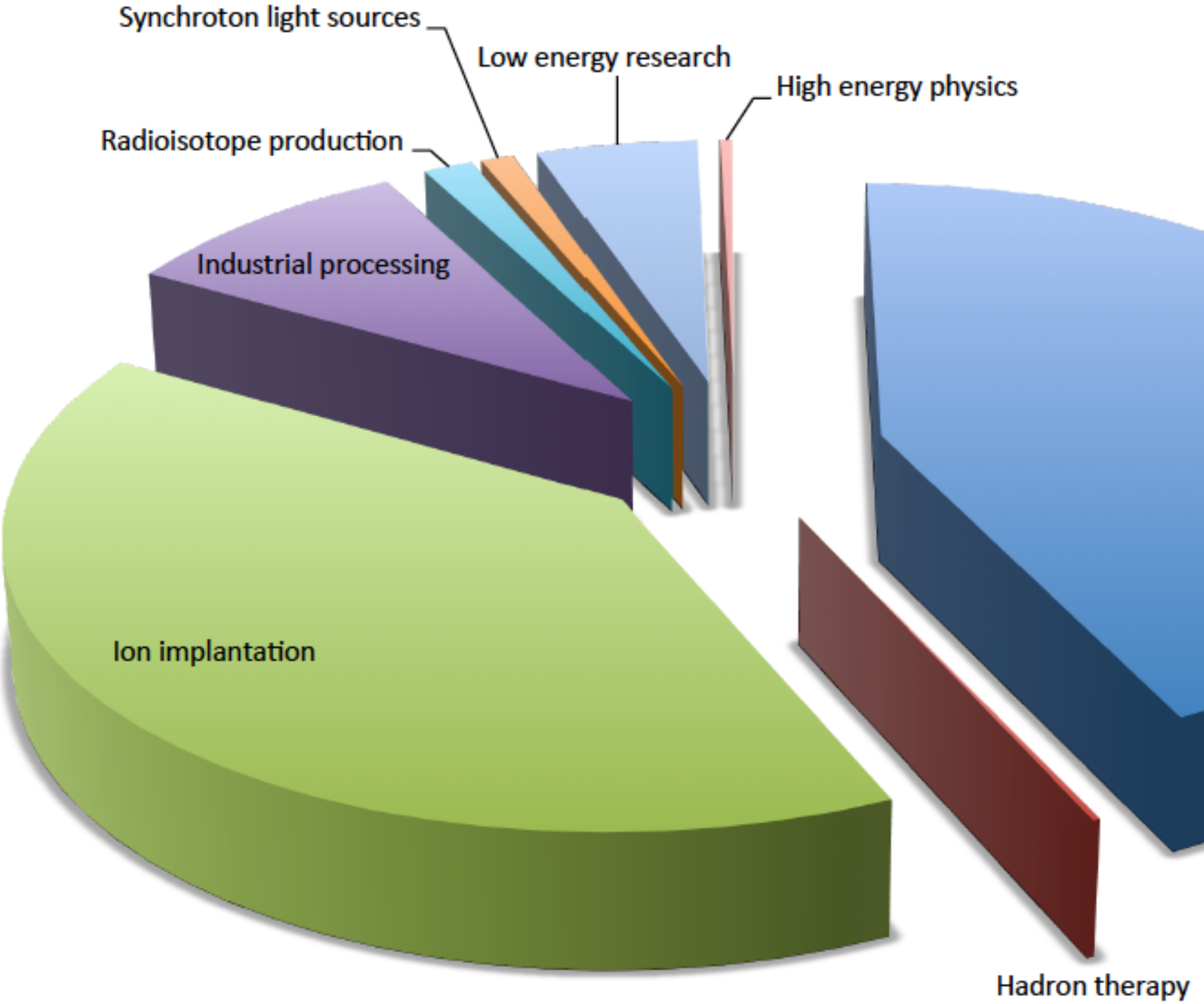
- What particles should we use?
- What type of accelerator is best suited?
- What technology should we use?

Particle accelerators at our disposal

- Linear accelerators (Friday)
  - Good for electrons (which can be used to produce X rays)
- Cyclotrons (Saturday)
  - Compact and (relatively) simple
- Synchrotrons (Monday)
  - Scalable and versatile

- Not forgetting (Thursday)
  - Fixed Field Alternating Gradient accelerators
  - Plasma Wake Accelerators
  - Dielectric Laser Accelerators

Some 30 000 accelerators world-wide



e-, e+
p, pbar, ions
μ-, μ+, ν

Industrial applications snapshot

- Synchrotron light for
  - Biology, chemistry, material science, heritage and more
- Neutrons for
  - Semiconductor system testing
  - Material science (stress measurements)
  - Unblocking oil pipes
- Industrial processes
  - Ion implantation
  - Electron beam processing
  - Food irradiation
- Security and energy applications
  - Cargo scanning
  - Material testing for fusion
  - Accelerator Driven Systems

See Susie Sheehy
Applications of Accelerators
CAS Introductory School
Prague, 2014

Medical applications snapshot

- Radioisotopes
- Cancer therapy
  - X rays
  - Radiotherapy
  - Hadron therapy
- Equipment sterilisation

Radioisotopes (next week)

- A stable element has a given number of p and n
- Many have stable isotopes (different number of n)
- When number of p or n are artificially changed
  - Radioactive isotope, or radioisotope
  - Neutron rich (excess neutrons provided by a reactor)
  - Proton rich (excess protons provided by an accelerator)
- When used in medicine, radiopharmaceuticals)
- Become stable by emission of α, γ or positron
  - Diagnostics (90%)
  - Treatment (10%)

Diagnostic snapshot (more next week)

- Short lived radioisotope = tracer
- Certain chemicals are absorbed by specific organs
- Chemical + tracer allows for selective absorption
- Administered by injection, inhalation, oral
- Most widely used is Tachnetium-99
  - From decay of molybdenum-99 produced in a reactor
  - Single photons detected by a camera from many angles
- Positron emitting radionuclide produced in a cyclotron
  - Fluorine-18 most commonly used
  - Positron annihilates with an electron, emitting 2 photons
  - PET camera allows simultaneous detection of the phtotons
  - Combined with CT for PETCT for much better results

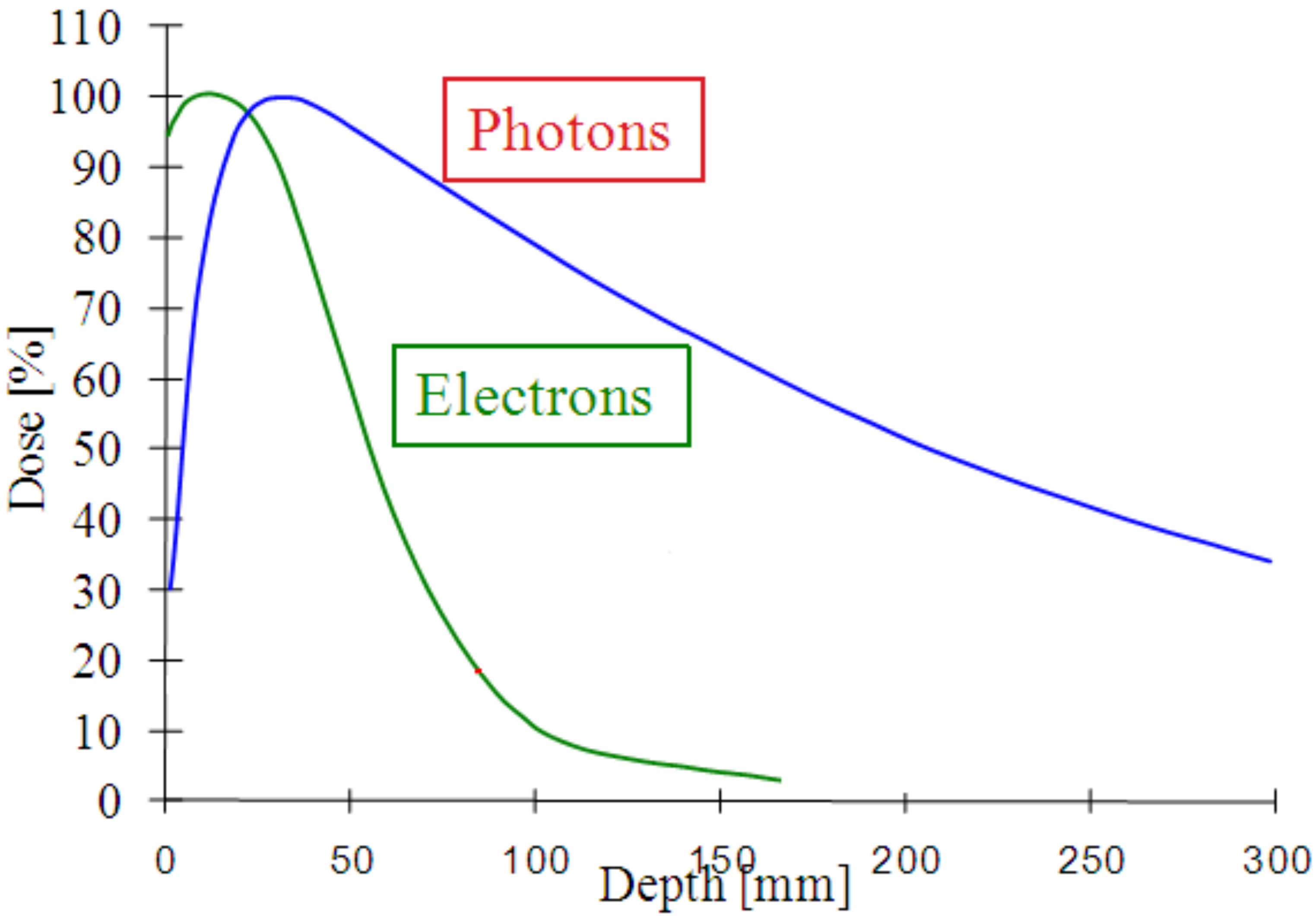
Treatment snapshot (more next week)

- Radioisotope absorbed by specific organs as before
- Local radioactivity to destroy malfunctioning cells
- Either for therapeutic or palliative use
  - Iodine-131 used to treat thyroid disorders
  - Samarium-153 for palliative treatment of bone cancer

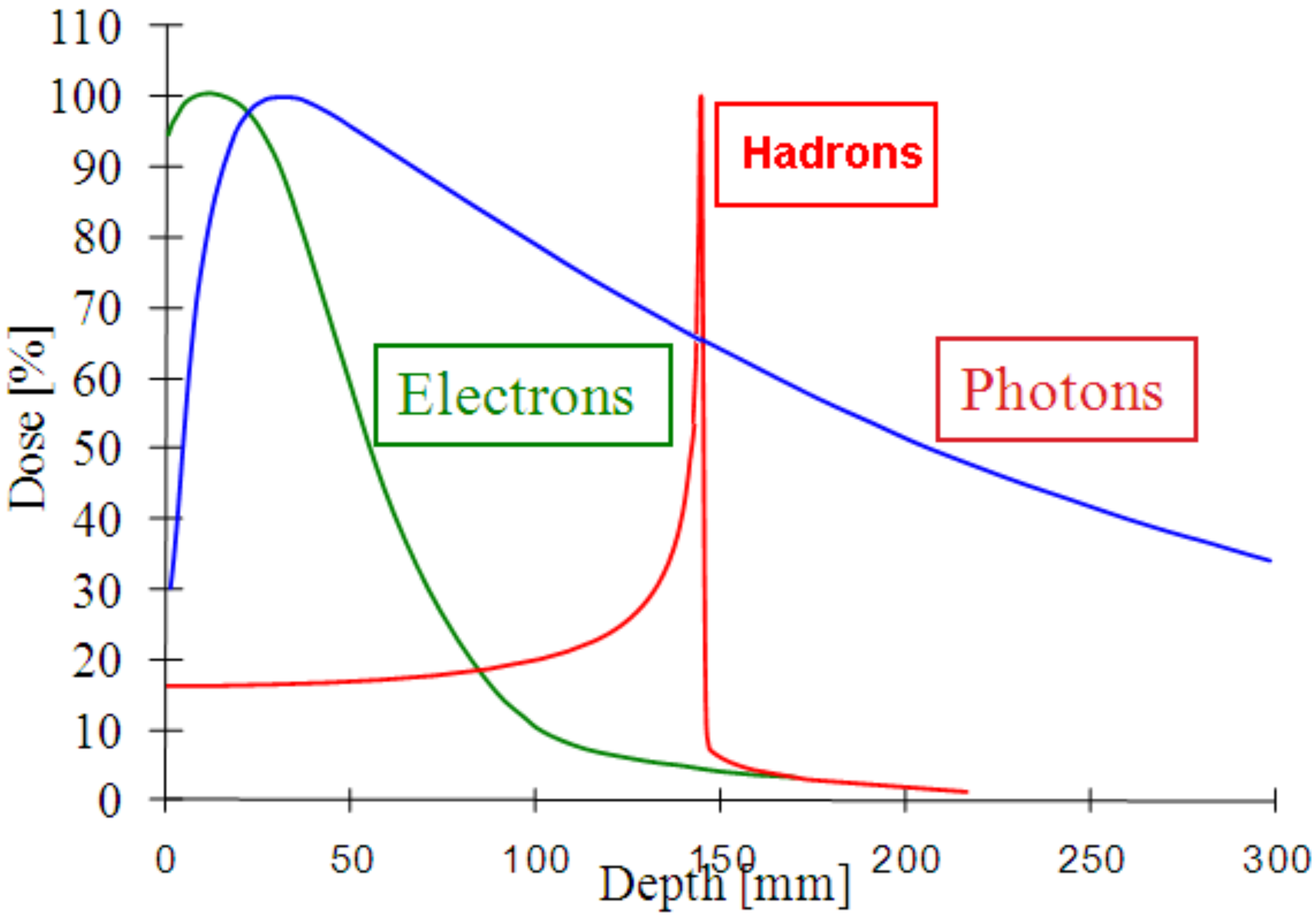
Therapy

- Radiotherapy
  - – Uses electrons and photons to kill cancer cells
  - – Particles lose energy at beam entrance then exponentially
    - ➢ Dose deposition causes damage also to healthy tissue
- Hadrontherapy
  - – Uses protons and ions
  - – Particles at "high" energy deposit little at entrance and transit
  - – Then deposit large amount in a very narrow peak (Bragg peak)
    - ➢ Very localised dose deposition
  - – Depth and magnitude of Bragg peak depends on
    - Mass
    - Charge
    - Particle energy

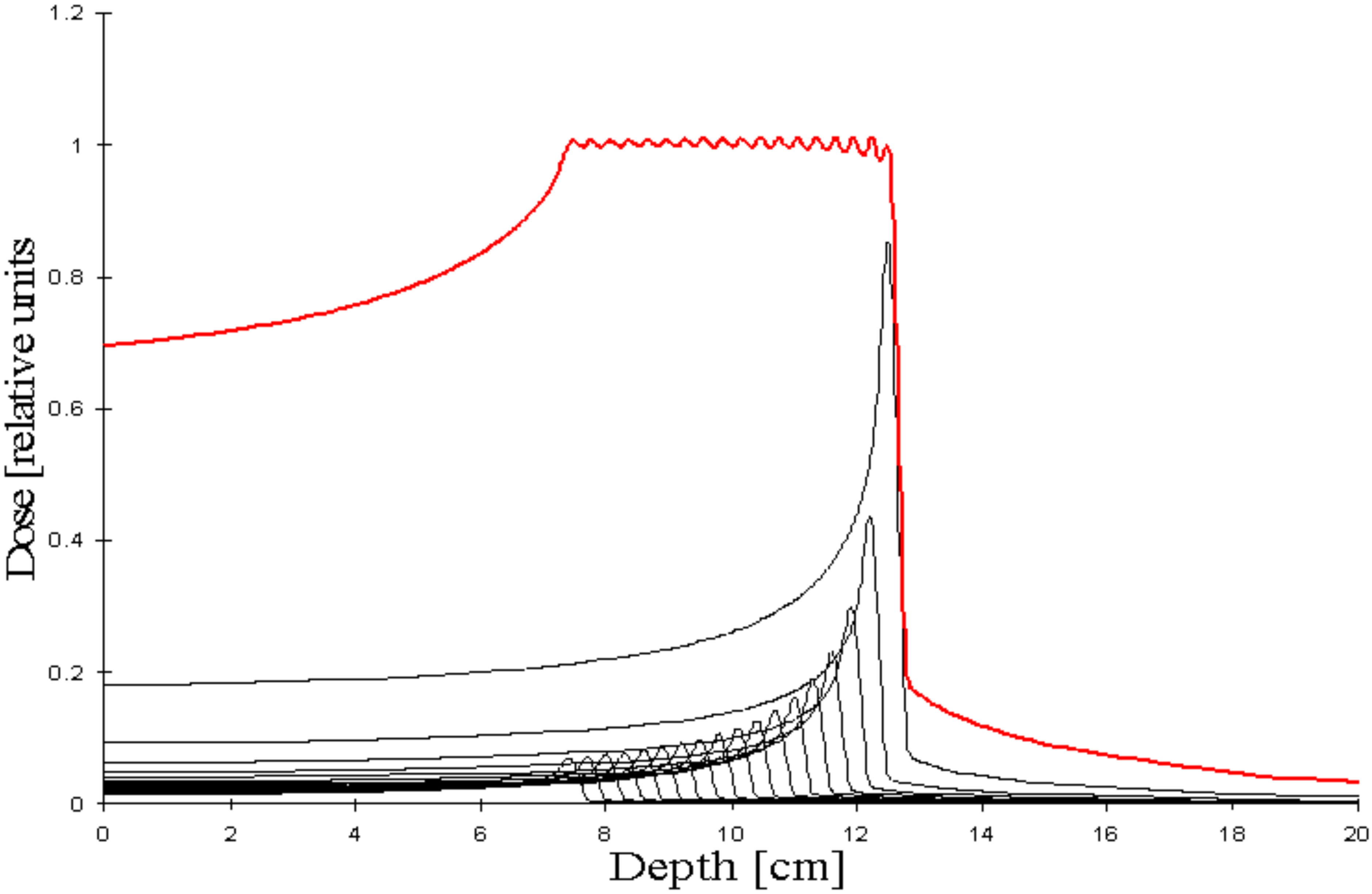
Radiotherapy



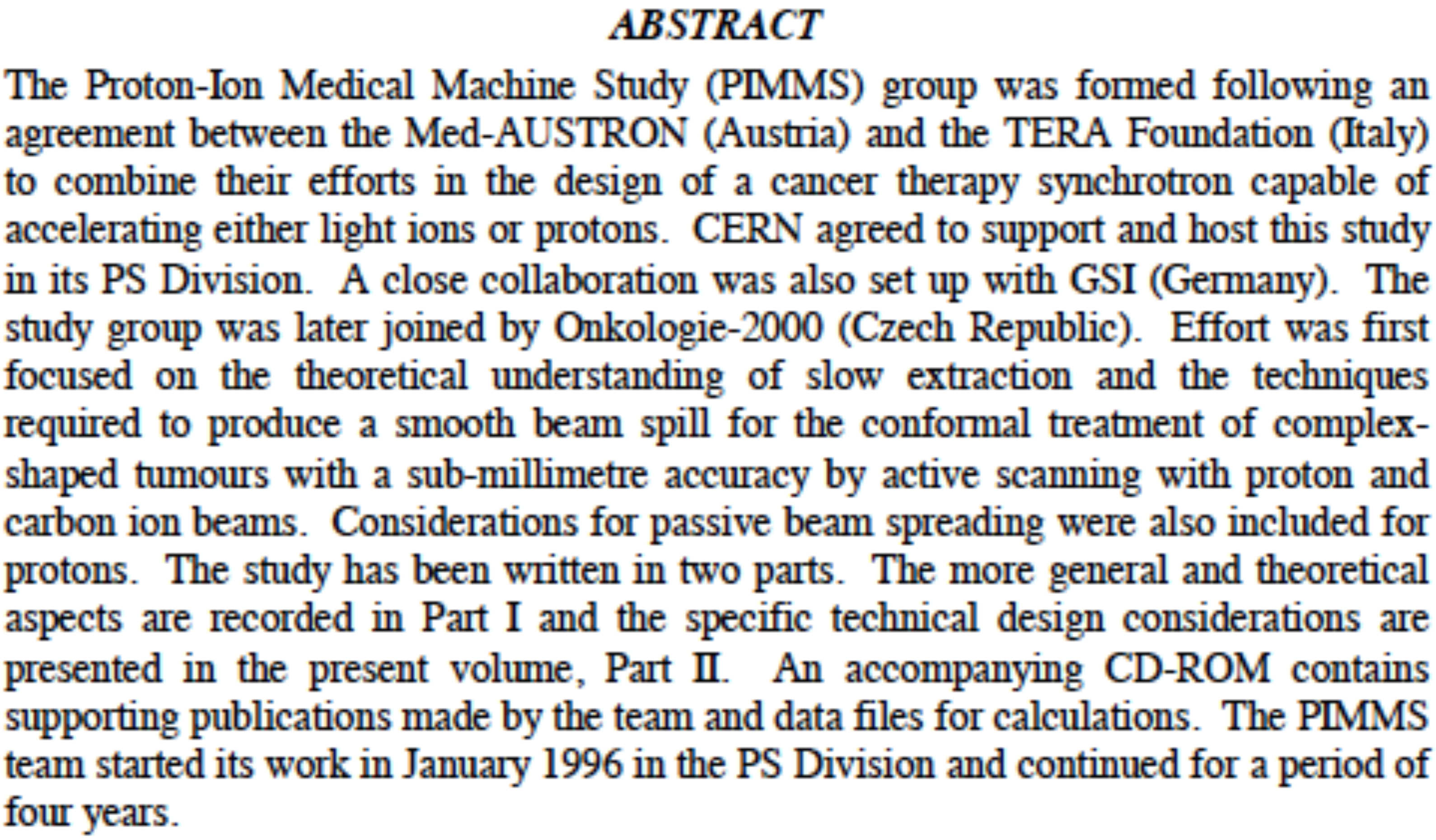
Radiotherapy vs Hadronthertapy



Hadrontherapy – Spread out Bragg peak



Proton Ion Medical Machine Study



ABSTRACT

The Proton-Ion Medical Machine Study (PIMMS) group was formed following an agreement between the Med-AUSTRON (Austria) and the TERA Foundation (Italy) to combine their efforts in the design of a cancer therapy synchrotron capable of accelerating either light ions or protons. CERN agreed to support and host this study in its PS Division. A close collaboration was also set up with GSI (Germany). The study group was later joined by Onkologie-2000 (Czech Republic). Effort was first focused on the theoretical understanding of slow extraction and the techniques required to produce a smooth beam spill for the conformal treatment of complex-shaped tumours with a sub-millimetre accuracy by active scanning with proton and carbon ion beams. Considerations for passive beam spreading were also included for protons. The study has been written in two parts. The more general and theoretical aspects are recorded in Part I and the specific technical design considerations are presented in the present volume, Part II. An accompanying CD-ROM contains supporting publications made by the team and data files for calculations. The PIMMS team started its work in January 1996 in the PS Division and continued for a period of four years.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CERN – PS DIVISION

CERN/PS 99-010 (DI)

PROTON-ION MEDICAL MACHINE STUDY (PIMMS)
PART I

Accelerator Complex Study Group*
supported by the Med-AUSTRON, Onkologie-2000 and the TERA Foundation
and hosted by CERN

Abstract

The Proton-Ion Medical Machine Study (PIMMS) group was formed following an agreement between the Med-AUSTRON (Austria) and the TERA Foundation (Italy) to combine their efforts in the design of a cancer therapy synchrotron. CERN agreed to host this study in its PS Division and a close collaboration was set up with GSI (Germany). The study group was later joined by Onkologie-2000 (Czech Republic). Effort was first focused on the theoretical understanding of slow extraction and the techniques required to produce a smooth beam spill for the conformal treatment of complex-shaped tumours with a sub-millimetre accuracy by active scanning with proton and carbon ion beams. Considerations for passive scanning were also included. The more general and theoretical aspects of the study are recorded in Part I and the more specific technical design considerations are presented in a second volume Part II. The PIMMS team started their work in January 1996 in the PS Division and continued for a period of three years.

*) Full-time members: L. Badano[1)], M. Benedikt[2)], P.J. Bryant[2)] (Study Leader), M. Crescenti[1)], P. Holy[3)], A. Maier[2)+4)], M. Pullia[1)], S. Rossi[1)],
Part-time member: P. Knaus[1)+2)]

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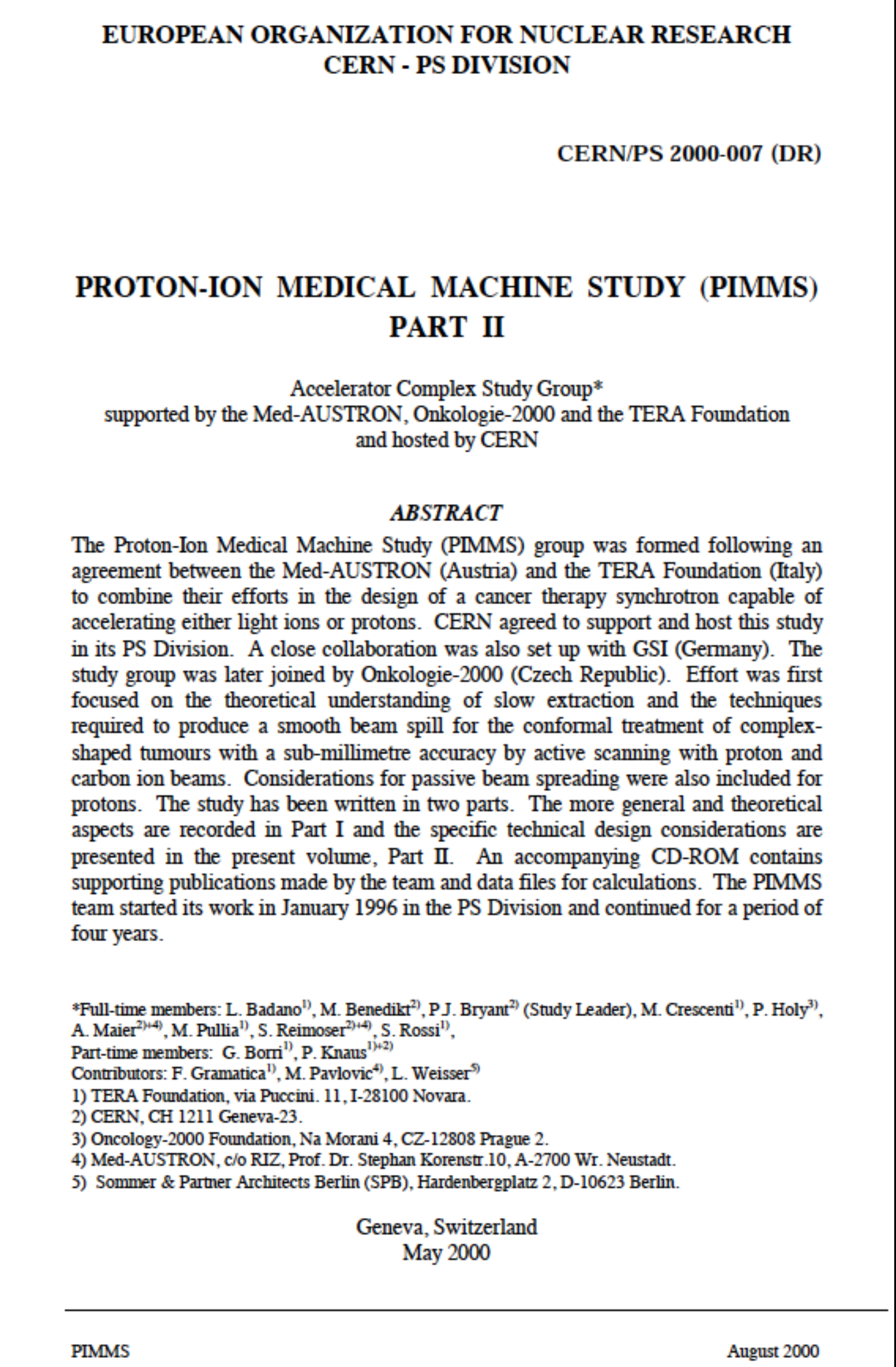
2) CERN, CH 1211 Geneva-23.
3) Oncology-2000 Foundation, Na Morani 4, CZ-12808 Prague 2.
4) Med-AUSTRON, c/o RIZ, Prof. Dr. Stephan Korenstr.10, A-2700 Wr. Neustadt.

Geneva, Switzerland
2 March 1999

PIMMS January 1999



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
CERN - PS DIVISION

CERN/PS 2000-007 (DR)

PROTON-ION MEDICAL MACHINE STUDY (PIMMS)
PART II

Accelerator Complex Study Group*
supported by the Med-AUSTRON, Onkologie-2000 and the TERA Foundation
and hosted by CERN

ABSTRACT

The Proton-Ion Medical Machine Study (PIMMS) group was formed following an agreement between the Med-AUSTRON (Austria) and the TERA Foundation (Italy) to combine their efforts in the design of a cancer therapy synchrotron capable of accelerating either light ions or protons. CERN agreed to support and host this study in its PS Division. A close collaboration was also set up with GSI (Germany). The study group was later joined by Onkologie-2000 (Czech Republic). Effort was first focused on the theoretical understanding of slow extraction and the techniques required to produce a smooth beam spill for the conformal treatment of complex-shaped tumours with a sub-millimetre accuracy by active scanning with proton and carbon ion beams. Considerations for passive beam spreading were also included for protons. The study has been written in two parts. The more general and theoretical aspects are recorded in Part I and the specific technical design considerations are presented in the present volume, Part II. An accompanying CD-ROM contains supporting publications made by the team and data files for calculations. The PIMMS team started its work in January 1996 in the PS Division and continued for a period of four years.

*Full-time members: L. Badano[1)], M. Benedikt[2)], P.J. Bryant[2)] (Study Leader), M. Crescenti[1)], P. Holy[3)], A. Maier[2)+4)], M. Pullia[1)], S. Reimoser[2)+4)], S. Rossi[1)],
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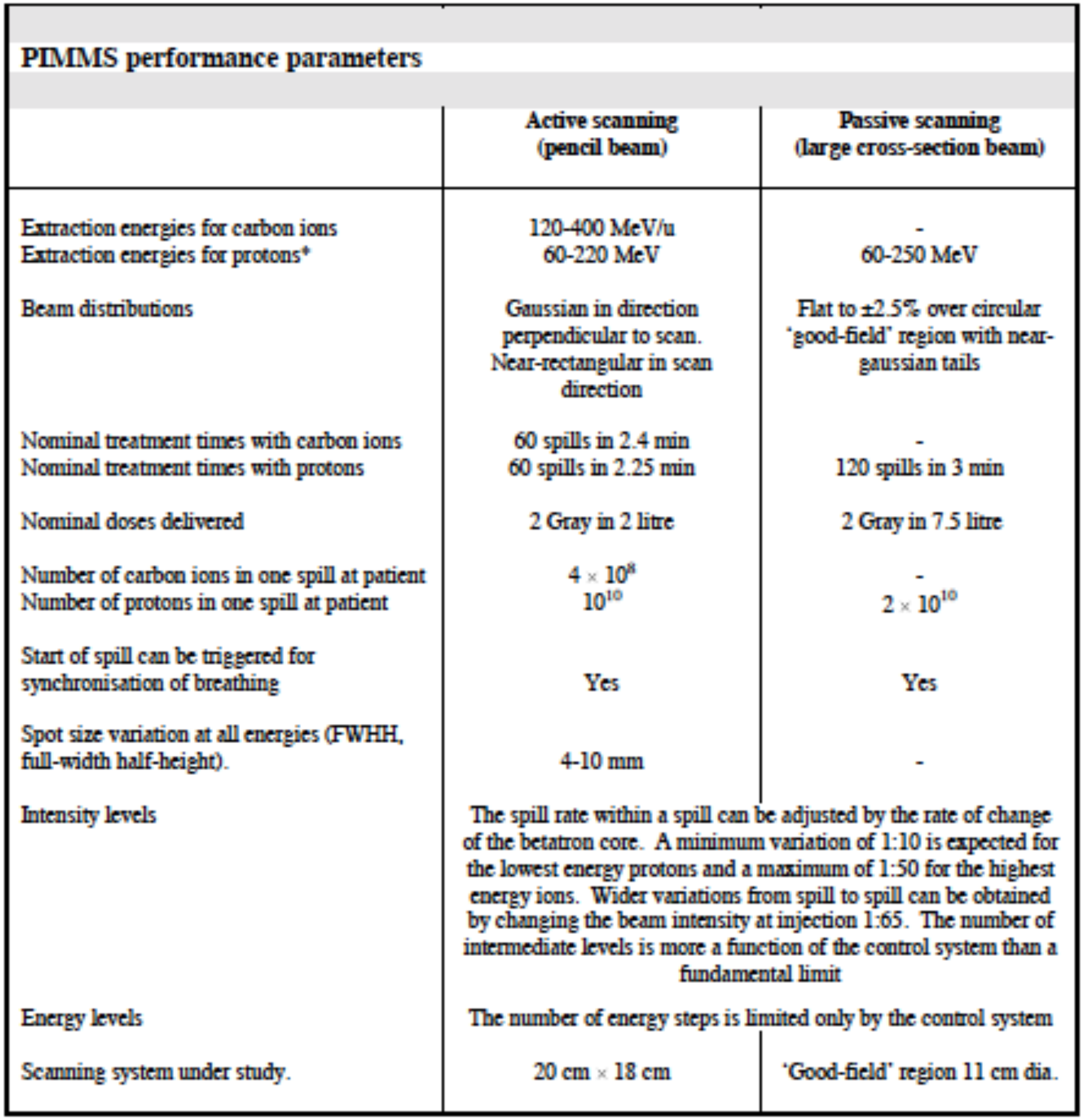
5) Sommer & Partner Architects Berlin (SPB), Hardenbergplatz 2, D-10623 Berlin.

Geneva, Switzerland
May 2000

PIMMS August 2000

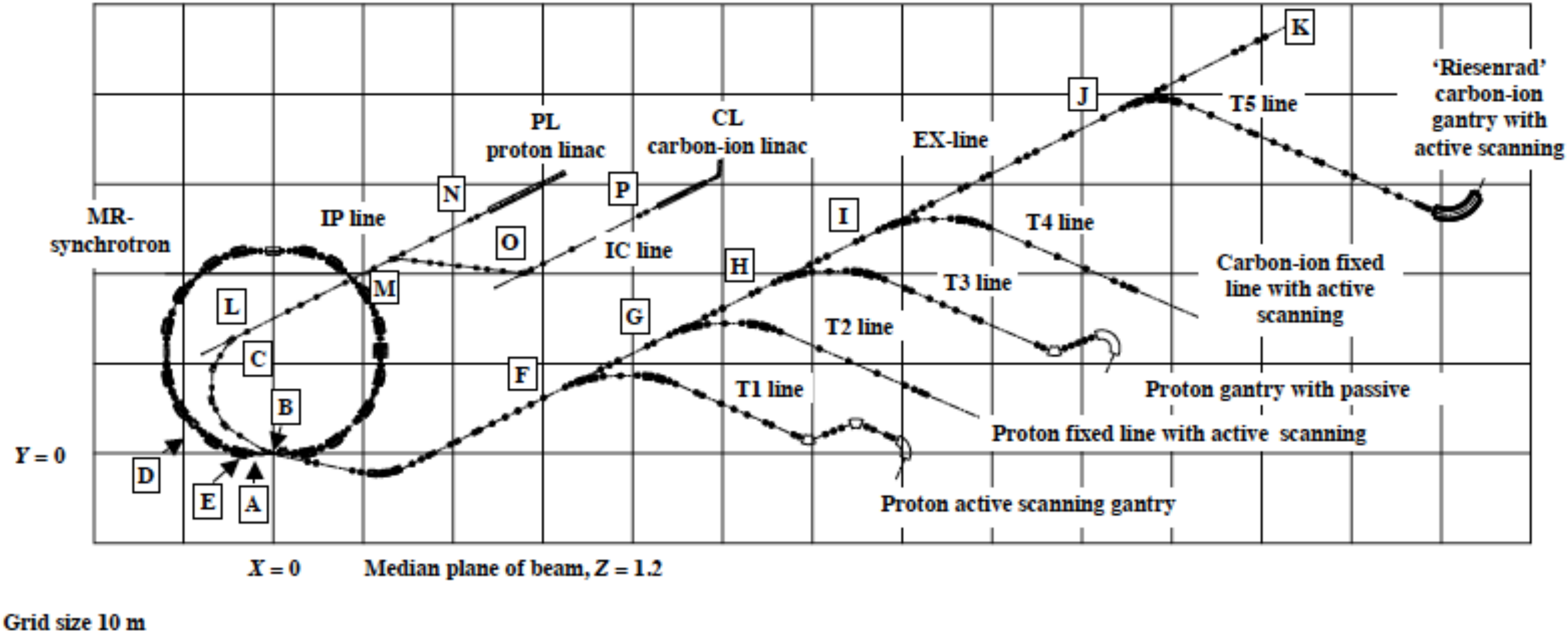
PIMMS performance parameters



PIMMS performance parameters

	Active scanning (pencil beam)	**Passive scanning (large cross-section beam)**
Extraction energies for carbon ions	120-400 MeV/u	-
Extraction energies for protons*	60-220 MeV	60-250 MeV
Beam distributions	Gaussian in direction perpendicular to scan. Near-rectangular in scan direction	Flat to ±2.5% over circular 'good-field' region with near-gaussian tails
Nominal treatment times with carbon ions	60 spills in 2.4 min	-
Nominal treatment times with protons	60 spills in 2.25 min	120 spills in 3 min
Nominal doses delivered	2 Gray in 2 litre	2 Gray in 7.5 litre
Number of carbon ions in one spill at patient	4 × 10^{8}	-
Number of protons in one spill at patient	10^{10}	2 × 10^{10}
Start of spill can be triggered for synchronisation of breathing	Yes	Yes
Spot size variation at all energies (FWHH, full-width half-height).	4-10 mm	-
Intensity levels	The spill rate within a spill can be adjusted by the rate of change of the betatron core. A minimum variation of 1:10 is expected for the lowest energy protons and a maximum of 1:50 for the highest energy ions. Wider variations from spill to spill can be obtained by changing the beam intensity at injection 1:65. The number of intermediate levels is more a function of the control system than a fundamental limit	
Energy levels	The number of energy steps is limited only by the control system	
Scanning system under study.	20 cm × 18 cm	'Good-field' region 11 cm dia.

PIMMS accelerator complex schematic



Medical Applications

1895 – discovery of X-rays by Wilhelm Roentgen

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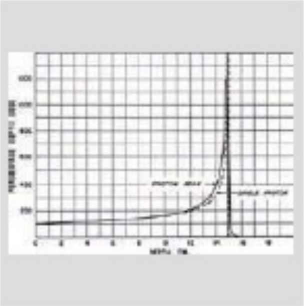
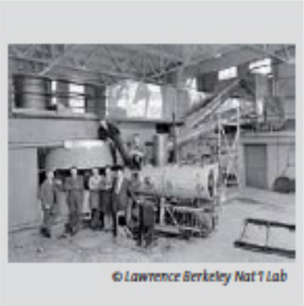
1932 – first cyclotron developed by Ernest Lawrence



1946 – proton therapy proposed by Wilson, exploiting the properties of the Bragg peak



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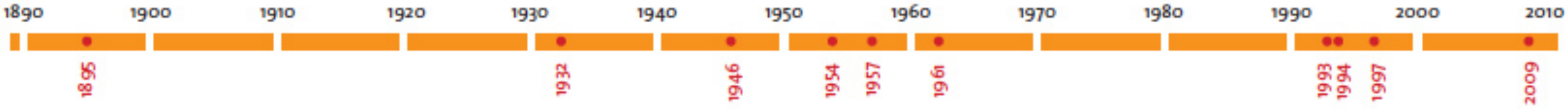
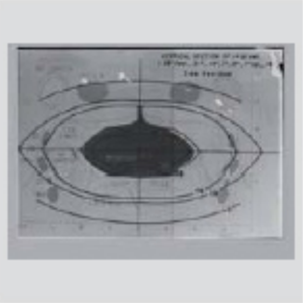
1954 – Berkeley treats the first patient and begins extensive studies with various ions

1957 – first patient treated with protons in Europe at Uppsala





1961 – collaboration between Harvard Cyclotron Laboratory and Massachusetts General Hospital

1993 – patients treated at the first hospital-based facility at Loma Linda

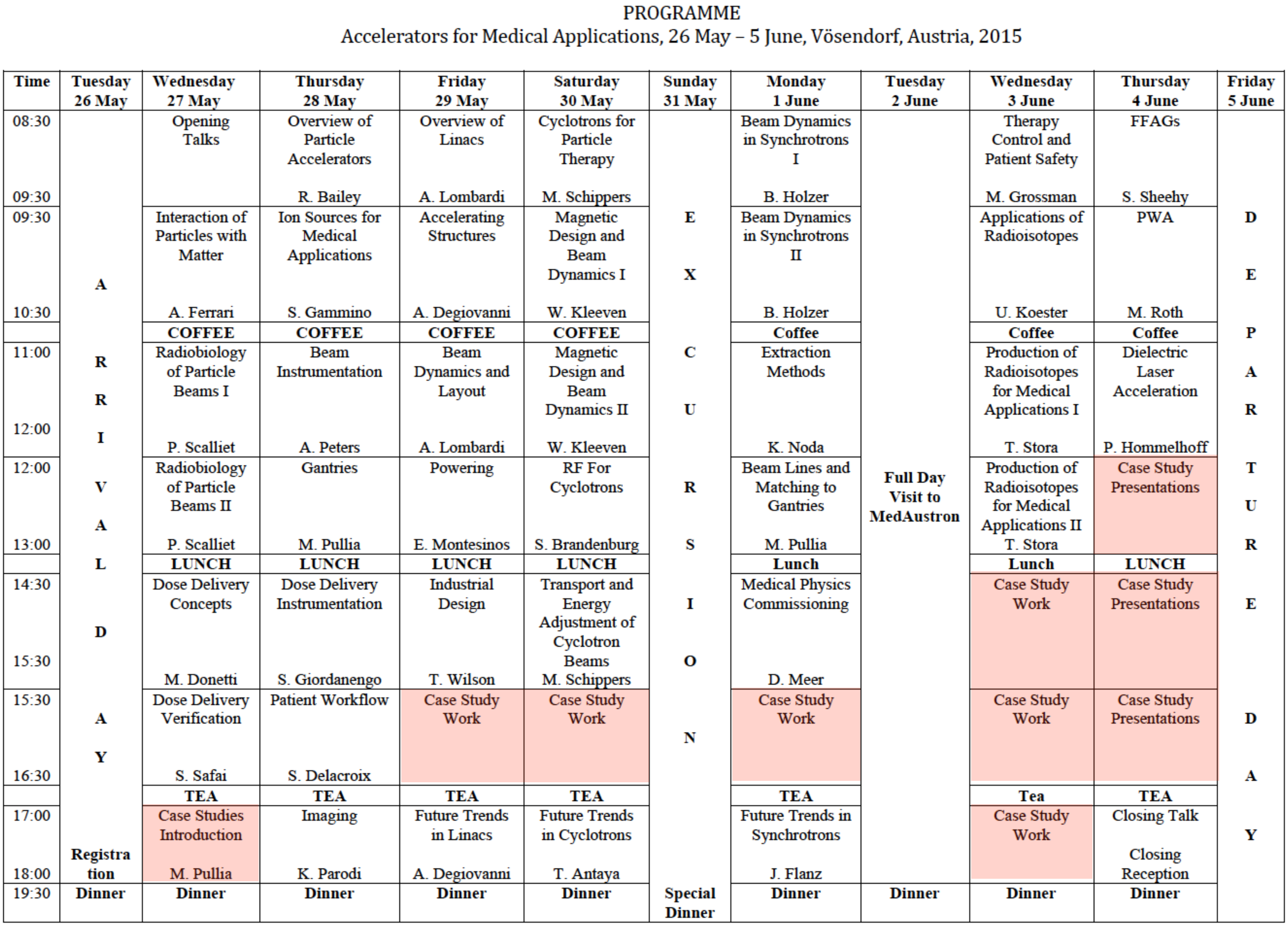
NIRS

1994 – first facility dedicated to carbon ions operational at HIMAC, Japan

1997 – First patient treated with carbon ions at GSI

HIT

2009 – first European proton-carbon ion facility starts treatment in Heidelberg



PROGRAMME
Accelerators for Medical Applications, 26 May – 5 June, Vösendorf, Austria, 2015

Time	Tuesday 26 May	Wednesday 27 May	Thursday 28 May	Friday 29 May	Saturday 30 May	Sunday 31 May	Monday 1 June	Tuesday 2 June	Wednesday 3 June	Thursday 4 June	Friday 5 June
08:30 09:30		Opening Talks	Overview of Particle Accelerators R. Bailey	Overview of Linacs A. Lombardi	Cyclotrons for Particle Therapy M. Schippers		Beam Dynamics in Synchrotrons I B. Holzer	**Full Day Visit to MedAustron**	Therapy Control and Patient Safety M. Grossman	FFAGs S. Sheehy	
09:30 10:30	**ARRIVAL DAY**	Interaction of Particles with Matter A. Ferrari	Ion Sources for Medical Applications S. Gammino	Accelerating Structures A. Degiovanni	Magnetic Design and Beam Dynamics I W. Kleeven	**EXCURSION**	Beam Dynamics in Synchrotrons II B. Holzer		Applications of Radioisotopes U. Koester	PWA M. Roth	**DEPARTURE DAY**
		COFFEE	**COFFEE**	**COFFEE**	**COFFEE**		**Coffee**		**Coffee**	**Coffee**	
11:00 12:00		Radiobiology of Particle Beams I P. Scalliet	Beam Instrumentation A. Peters	Beam Dynamics and Layout A. Lombardi	Magnetic Design and Beam Dynamics II W. Kleeven		Extraction Methods K. Noda		Production of Radioisotopes for Medical Applications I T. Stora	Dielectric Laser Acceleration P. Hommelhoff	
12:00 13:00		Radiobiology of Particle Beams II P. Scalliet	Gantries M. Pullia	Powering E. Montesinos	RF For Cyclotrons S. Brandenburg		Beam Lines and Matching to Gantries M. Pullia		Production of Radioisotopes for Medical Applications II T. Stora	Case Study Presentations	
		LUNCH	**LUNCH**	**LUNCH**	**LUNCH**		**Lunch**		**Lunch**	**LUNCH**	
14:30 15:30		Dose Delivery Concepts M. Donetti	Dose Delivery Instrumentation S. Giordanengo	Industrial Design T. Wilson	Transport and Energy Adjustment of Cyclotron Beams M. Schippers		Medical Physics Commissioning D. Meer		Case Study Work	Case Study Presentations	
15:30 16:30		Dose Delivery Verification S. Safai	Patient Workflow S. Delacroix	Case Study Work	Case Study Work		Case Study Work		Case Study Work	Case Study Presentations	
		TEA	**TEA**	**TEA**	**TEA**		**TEA**		**Tea**	**TEA**	
17:00 18:00	**Registration**	Case Studies Introduction M. Pullia	Imaging K. Parodi	Future Trends in Linacs A. Degiovanni	Future Trends in Cyclotrons T. Antaya		Future Trends in Synchrotrons J. Flanz		Case Study Work	Closing Talk Closing Reception	
19:30	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	**Special Dinner**	**Dinner**	**Dinner**	**Dinner**	**Dinner**	