PHYS 575A/B/C

Autumn 2015

Radiation and Radiation Detectors

Course home page:

http://depts.washington.edu/physcert/radcert/575website/

9: Case studies: Non-Cherenkov neutrino detectors; neutron detectors; accelerators

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Course calendar (revised)

week	date	day	topic	text
1	10/1/15	Thurs	Introduction, review of basics, radioactivity, units for radiation and dosimetry	Ch. 1, notes
2	10/6/15	Tues	Radioactive sources; decay processes;	Ch. 1, notes
3	10/13/15	Tues	Photomultiplier tubes and scintillation counters; Counting statistics	Chs. 3, 8, 9 (I-V)
3	10/15/15	Thurs	**LAB: Room B248** Scopes, fast pulses; PMTs and scintillation counters; standard electronics modules	Chs. 4, 9, 16, 17
4	10/20/15	Tues	Overview of charged particle detectors	Ch. 4
4	10/22/15	Thurs	**LAB: Room B248** Coincidence techniques; nanosec time measurement, energy from pulse area	Chs. 17, 18
5	10/27/15	Tues	Interaction of charged particles and photons with matter; counting statistics; gas detectors; Proposal for term paper must be emailed to JW by today	Chs. 2, 3; Chs. 5, 6, 7
6	11/3/15	Tues	ionization chambers; solid-state detectors	Chs. 11, 12, 13
7	11/10/15	Tues	Statistics for data analysis; Case studies: classic visual detectors (cloud and bubble chambers, nuclear emulsion, spark chambers)	Ch. 19, notes
8	11/17/15	Tues	Case studies: Cosmic ray detectors (Auger, Fermi gamma ray observatory); Cherenkov detectors: atmospheric Cherenkov, triggering Cherenkov	Ch. 19, notes
9	11/24/15	Tues	Case studies: neutrino detectors (IceCube, Daya Bay, Majorana), Detecting neutrons; high energy accelerators;	Ch. 19, notes Ch. 14, 15, 18
Tonight → 10	12/1/15	Tues	Finish case studies; begin student presentations	Notes
11	12/8/15	Tues	Student presentations	-
11	12/10/15	Thurs	Student presentations **Term papers due by 6:30pm**	

Announcements

- Presentation dates: tonight!, Tues Dec 8, and Thurs Dec 10
  - You MUST send me your presentation (pdf or ppt) no later than 5:30 pm on the day of your talk
    - I will upload all slides for each session so online attendance is possible
    - Listening to other students' reports is an important part of this course!
  - Final paper due Thurs 12/10 before class: email pdf or .doc to JW

PHYS 575 Au-15: Report Presentations			
Please send me your presentation ppt/pdf (or URL) at least 1 hour before class on your date			
Day	Time	Name	Topic
12/1/2015	7:00 PM	Per Provencher	Low Background Laboratories
	7:20 PM	Rick McGann	Neutron Generation and Effects on Materials and Electronics
	7:40 PM	Chris Provencher	Electric Discharge Experiments
	8:00 PM	Charles Ko	Radiometric Dating
	8:20 PM	Ricky Blake	Fusion reactors
12/8/2015	6:40 PM	Diana Thompson	NORM
	7:00 PM	Shawn Apodaca	Fast Neutron Time of Flight and Spectroscopy
	7:20 PM	Erin Board	Cosmic Radiation and Shielding
	7:40 PM	Louie Cueva	Thermal Neutron Detection
	8:00 PM	Xavier Garcia	Silicon PMTs
	8:20 PM	Padmaja Vrudhula	Dosimetry
12/10/2015	6:40 PM	Nathan Hicks	Methods of Radionuclide Production for Medical Isotope Usability: Meeting the Demand
	7:00 PM	Farrah Tan	QCD
	7:20 PM	Nicolas Michel-Hart	microXRF
	7:40 PM	Michael Esuabana	proton-Boron11 fusion
	8:00 PM	Kaifu Lam	Synchrotrons
	8:20 PM	Johnathan Slack	X-rays/Gamma rays of comets and asteroids

Tonight: Case studies in Particle/nucleus accelerators

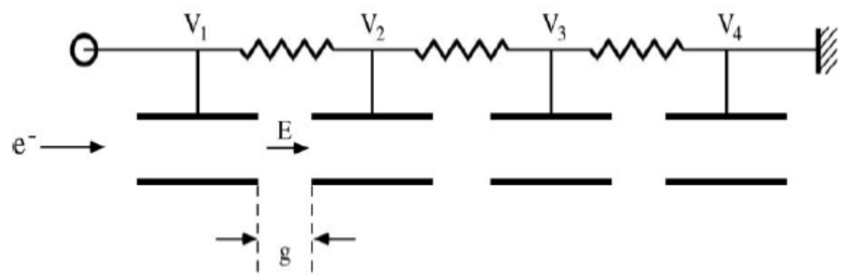
- How to accelerate particles or nuclei
  - Linear DC or RF accelerators
  - RF cavities
  - Beam optics
- Cyclotrons, synchro-cyclotrons, betatrons
- Early history: Cockcroft-Walton, van de Graaf, Lawrence
- Colliders
- Collider detectors

Illustrations borrowed from:
K. Wille, The Physics of Particle Accelerators, 2000
And presentations by
Erik Adli, University of Oslo/CERN, 2009;
A. Chao, USPAS 2007

How to accelerate particles (or nuclei)

Linear accelerators

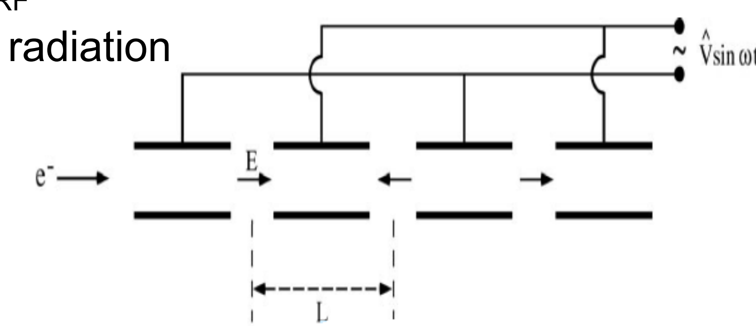
- DC electric fields: chain of electrodes with voltage drops
  - Particle is accelerated between electrodes
  - Energy kick: $\Delta E = q\Delta V$ per stage
  - Limitation: hard to provide insulation for voltages > 10 MV



- Oscillating (RF) fields
  - Particle must see the field only when the field is in the accelerating direction
    - Previous electrode repels, next electrode attracts, at each gap
  - Requires synchronization: $\Delta T = \frac{1}{2} T_{RF}$
  - Limitations: large power loss due to radiation

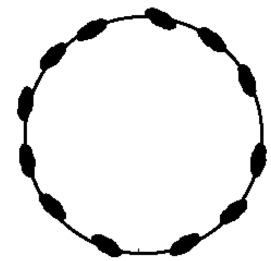
$$L = (1/2)vT$$

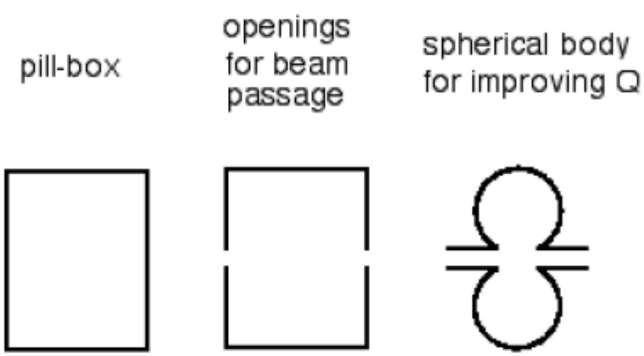
Need to ramp up RF frequency, or increase spacing of electrodes, as particle speeds up



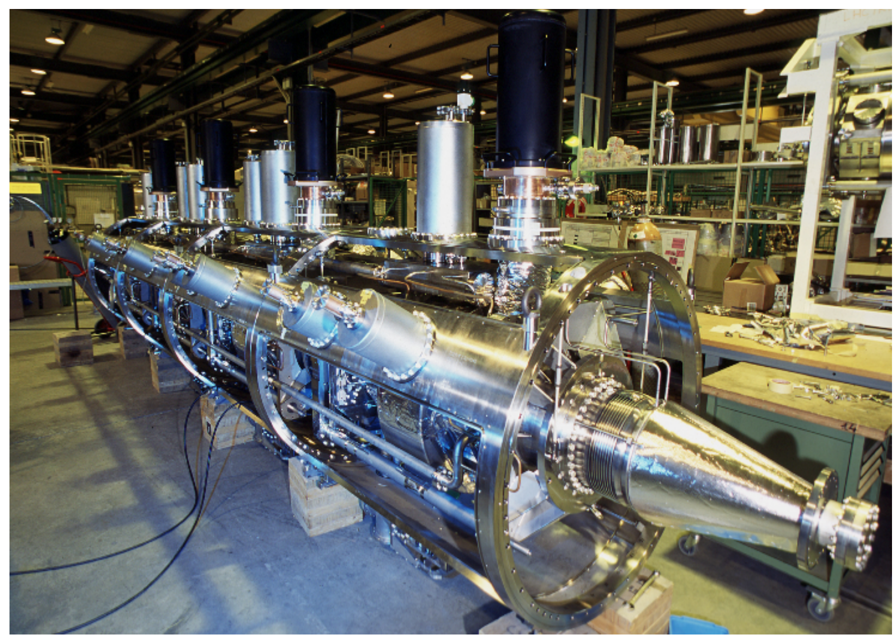
Using RF cavities for acceleration

- Electromagnetic power is stored in a resonant volume, instead of being radiated between electrodes
- RF power feed into cavity (typically from Klystrons, industrial radio broadcasting technology)
- RF cavities require **bunched beams:** particles grouped in bunches separated in space by spacing between RF cavities
- Cavity evolution:

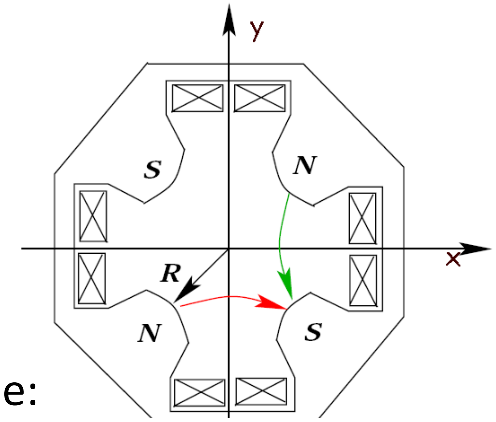




LHC cavity module

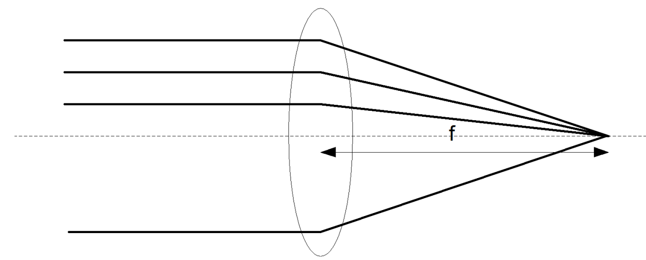


Charged particle beam optics

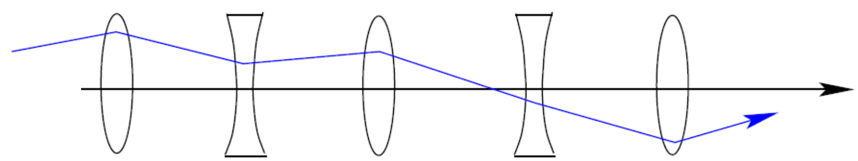


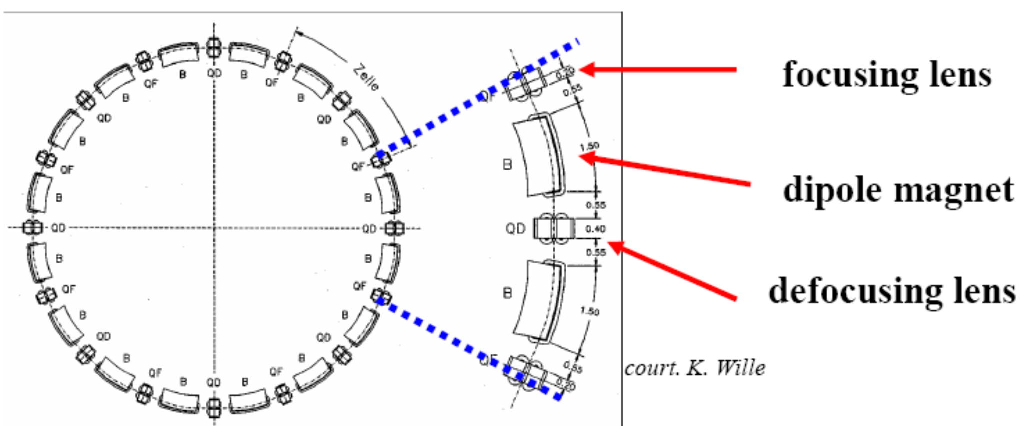
- Quadrupole magnets have linear B field in x and y:
  - $B_x = -gy$
  - $B_y = -gx$
- B forces focus in one plane and *defocus* in the orthogonal plane:
  - $F_x = -q\ v\ gx$ (focusing)
  - $F_y = q\ v\ gy$ (defocusing)
  - Focal length of a quadrupole: $1/f = kL$

    $k \sim$ field strength, L = length of the quadrupole



- Alternate focusing/defocusing in x or y planes by rotating quadrupoles 90°
  - Result: Net focusing effect in both planes
  - "Alternating Gradient" focusing





Synchrotron: circular accelerator using dipoles, quads and RF cavities

Repeated sequence of components

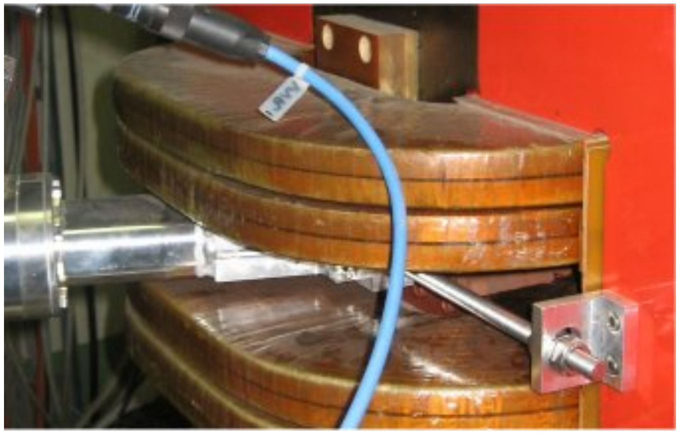
= Accelerator's "lattice"

(Must fit circumference used!)

Examples of lattice components

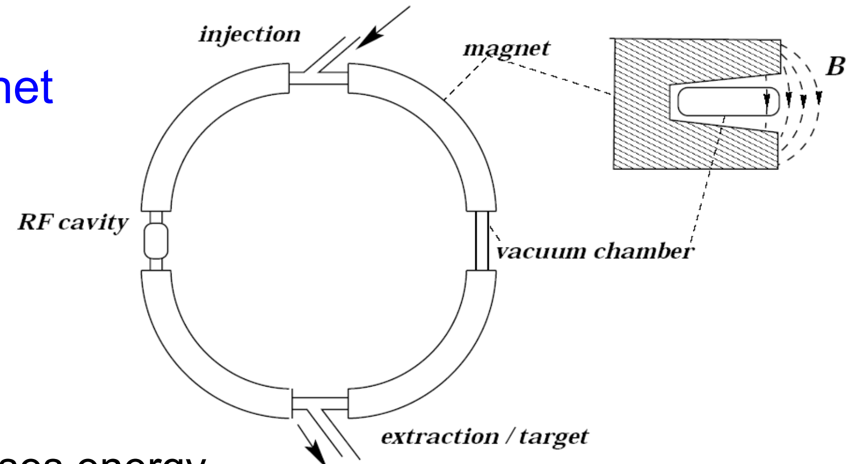
- Dipoles

quadrupole

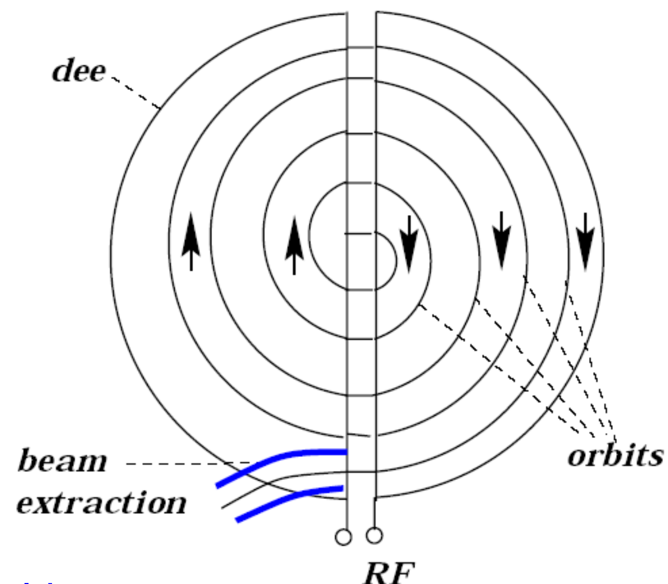


Cyclotrons, synchro-cyclotrons, betatrons

Circular vacuum chamber inside magnet



- Cyclotron:
  - constant B field
  - constant RF field in the gap increases energy
  - radius increases proportionally to energy
  - limit: relativistic energy, RF phase out of synch
  - Requires large-area vacuum chamber for beam
  - Simpler than the synchrotron,
    sometimes still used as medical accelerators



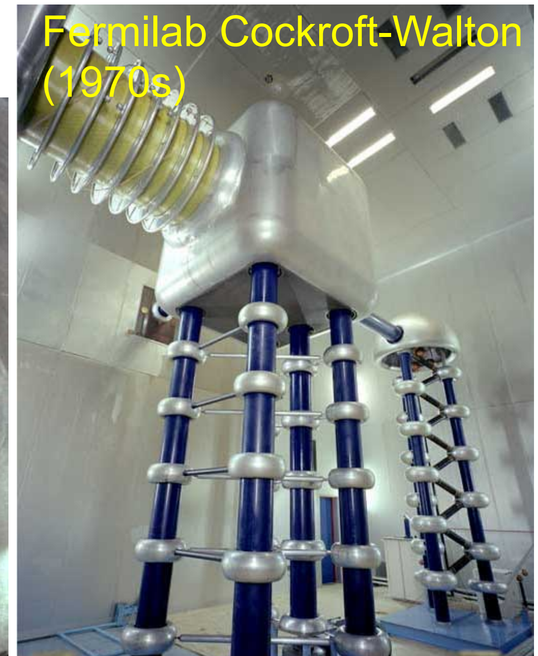
- Synchro-cyclotron
  - Cyclotron with varying RF phase
- Betatron (electron accelerator)
  - Acceleration induced by time-varying magnetic field

Early history: Cockcroft-Walton, van de Graaf, Lawrence (1930s)

- van de Graaf = motorized friction-belt static electricity generator

THE GENERATOR IN THE HANGAR AT ROUND HILL

Cockcroft-Walton = charge up capacitors in parallel; spark gap breakdown puts them in series → high voltage

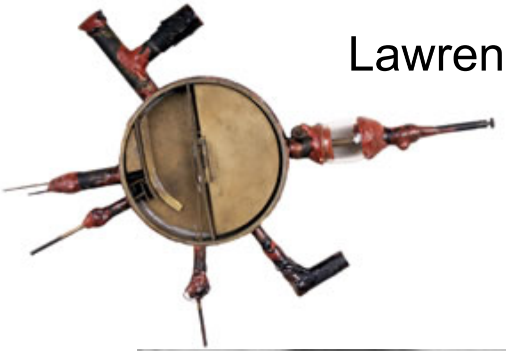


Tandem accelerator for nuclei: central high V electrode attracts negative ions; they are stripped to become positive ions; then it repels them through same ΔV

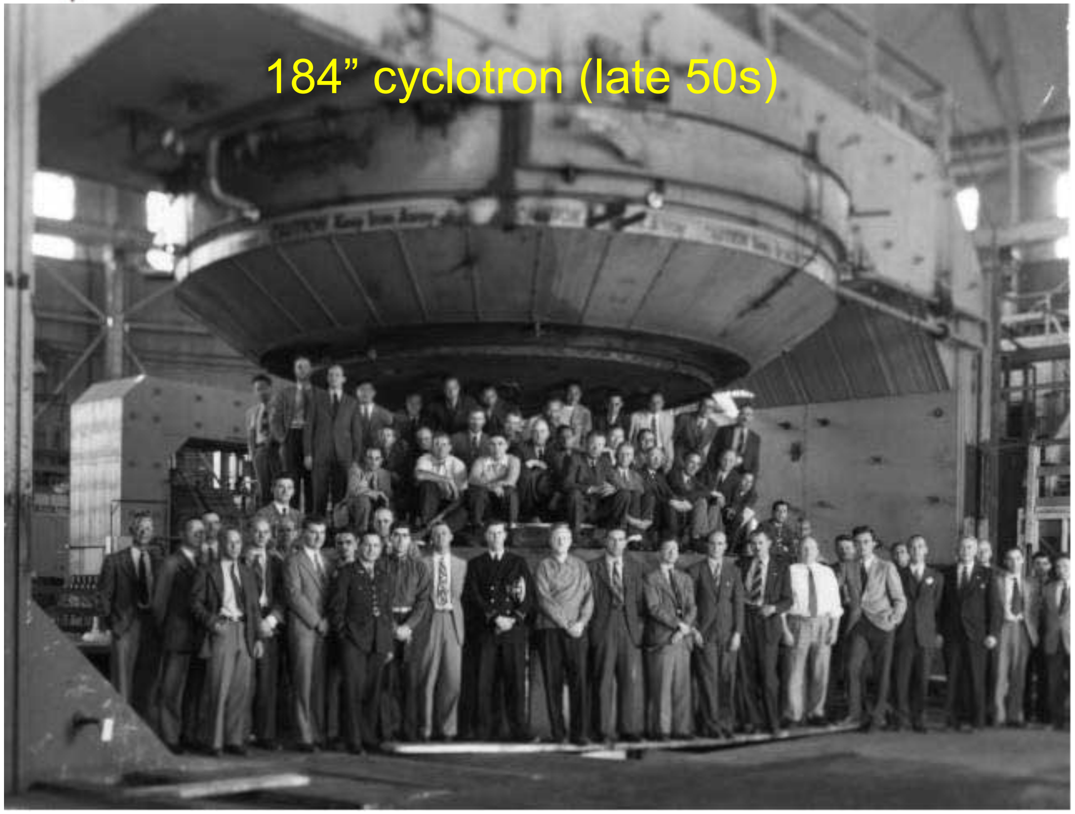
UW’s tandem 300 kV Van de Graaf accelerator

Work with this next term in Prof. Garcia’s phys 576 course

E.O.Lawrence (UC/Berkeley, 1930—50s)



Lawrence's original 5" cyclotron



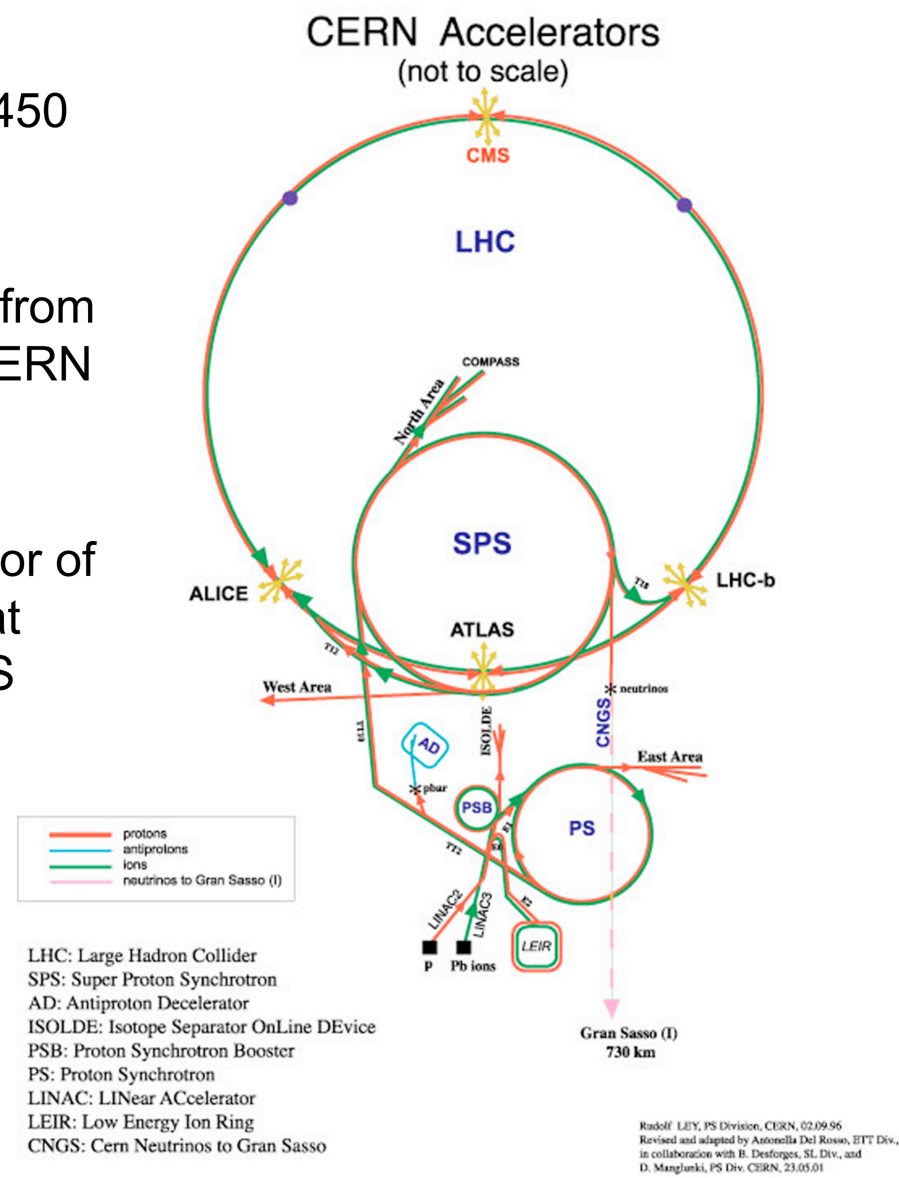
LHC pre-accelerator system

- LHC ring accelerates protons from 450 GeV up to 7000 GeV

- 450 GeV protons injected into LHC from the SPS (Super PS, 1980s: main CERN accelerator before LHC))

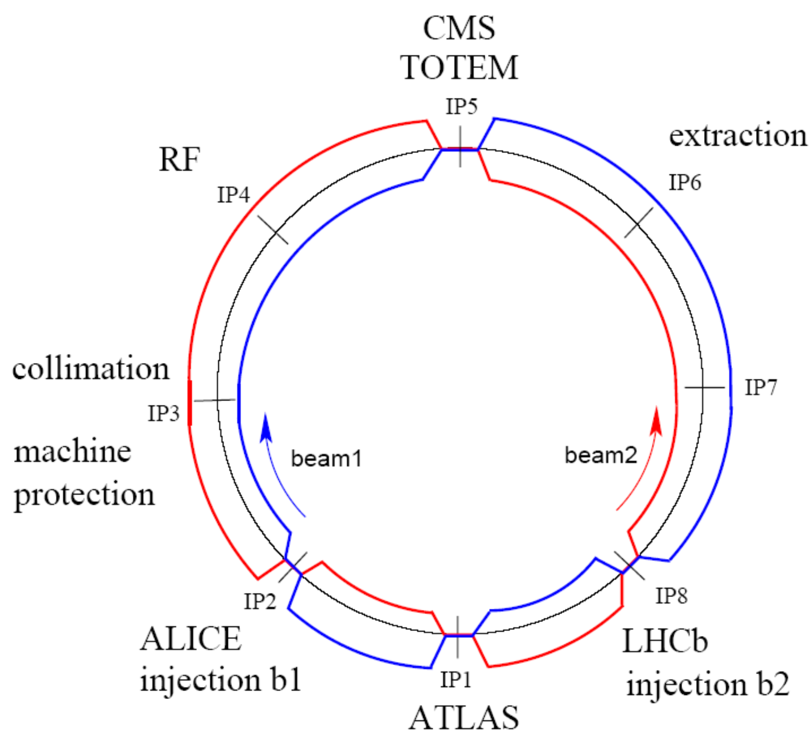
- PS (Proton Synchrotron, predecessor of SPS, 1959; original main machine at CERN, 28 GeV) injects into the SPS

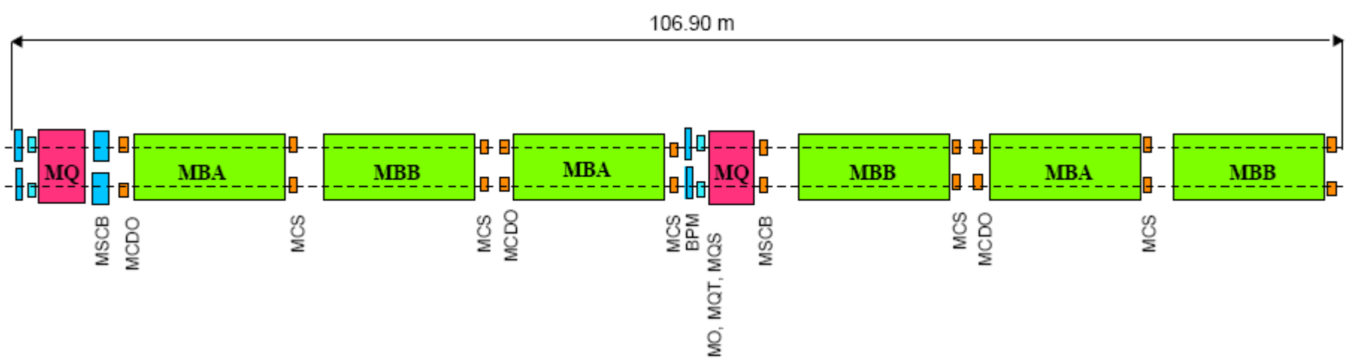
- LINAC injects into the PS

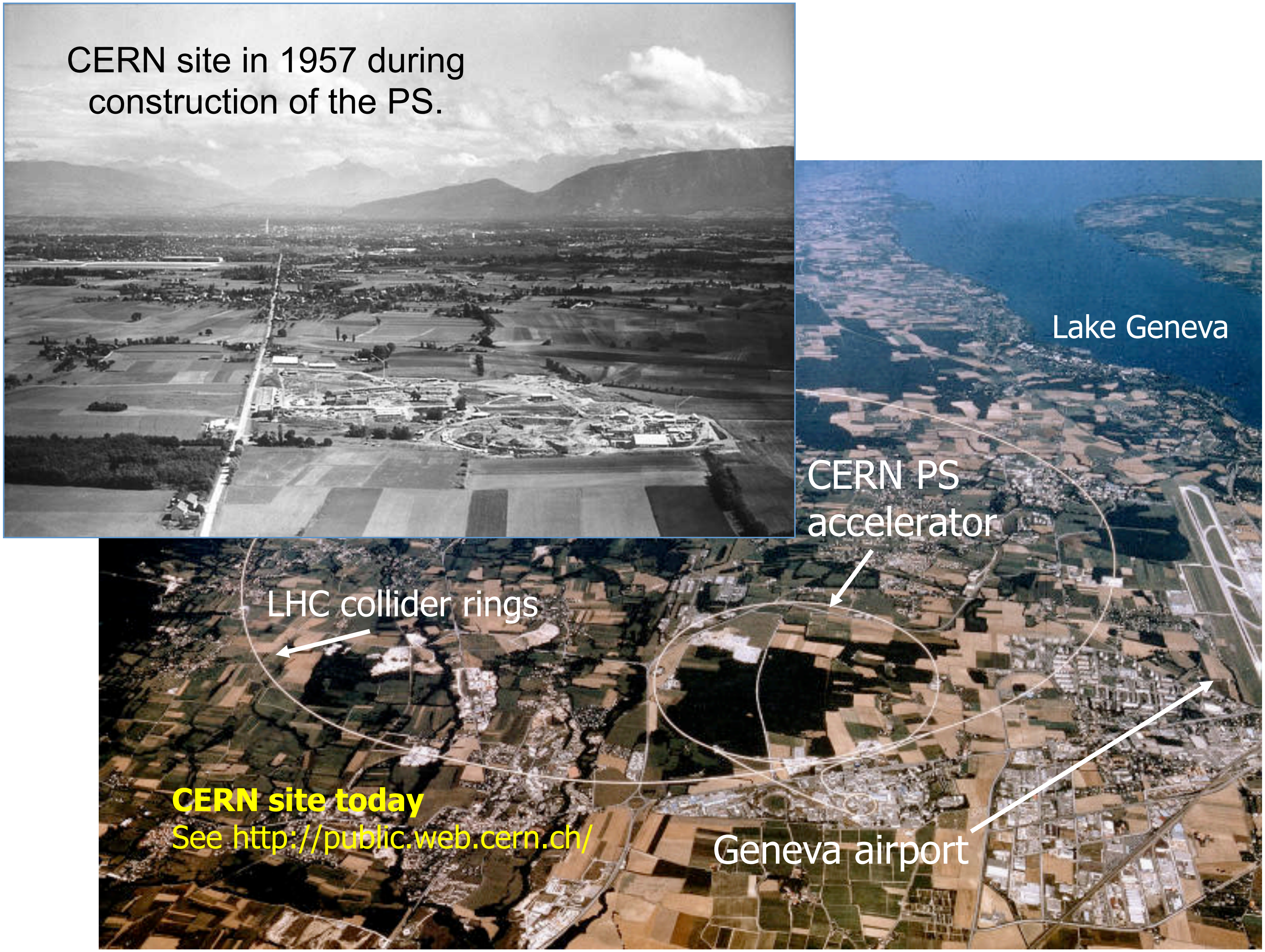


LHC layout

- circumference = 26.6 km
- 8 interaction points, 4 of which contain detectors where the beams intersect
- 8 straight sections, containing the IPs, around 530 m long
- 8 arcs with a regular lattice structure, containing 23 arc cells
- Each arc cell has a F0D0 lattice (Focus, bend (=0), Defocus, bend), 106.9 m long



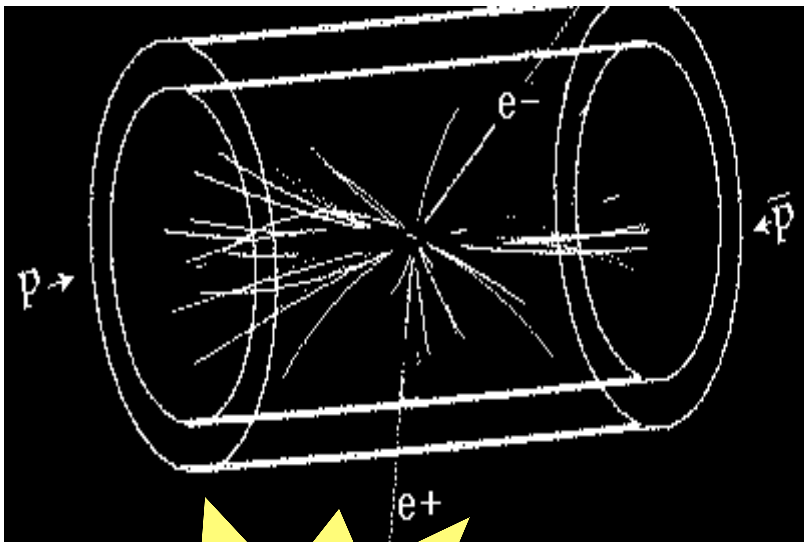



CERN site in 1957 during
construction of the PS.
Lake Geneva
CERN PS
accelerator
LHC collider rings
CERN site today
See http://public.web.cern.ch/
Geneva airport

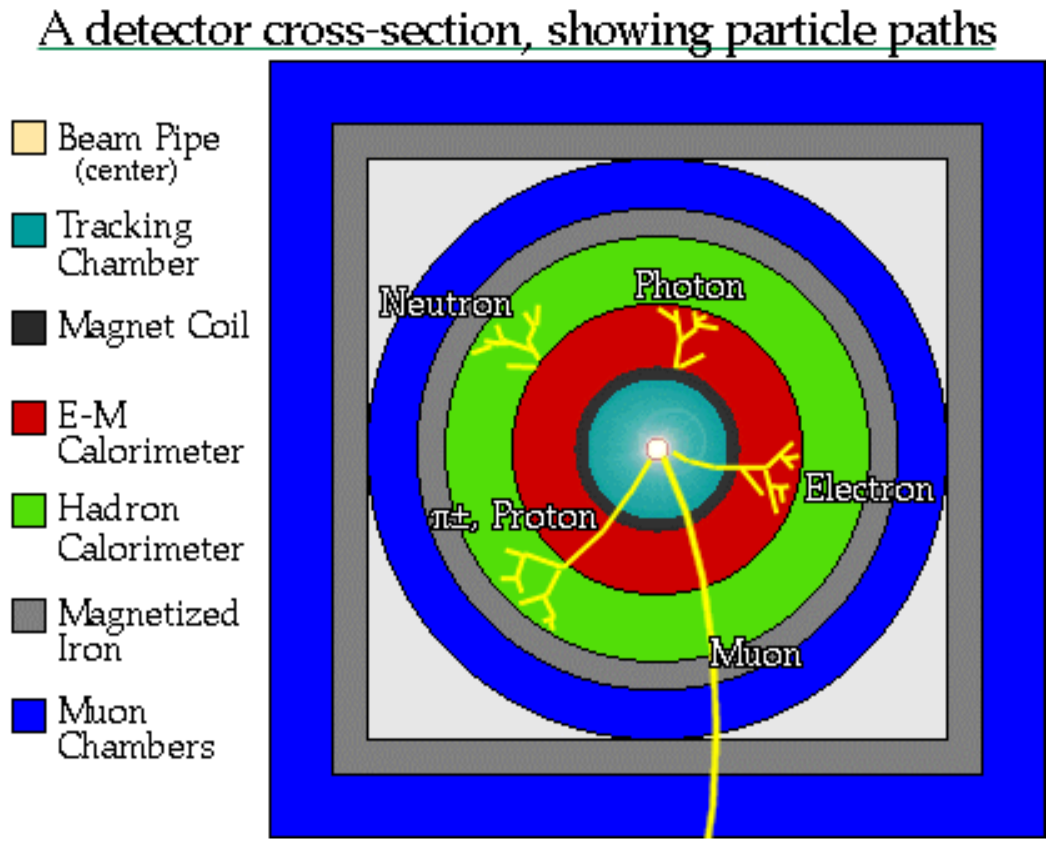
Collider Detectors

The outgoing composite particles interact with the matter of the detector, leave tracks, and deposit their energies.

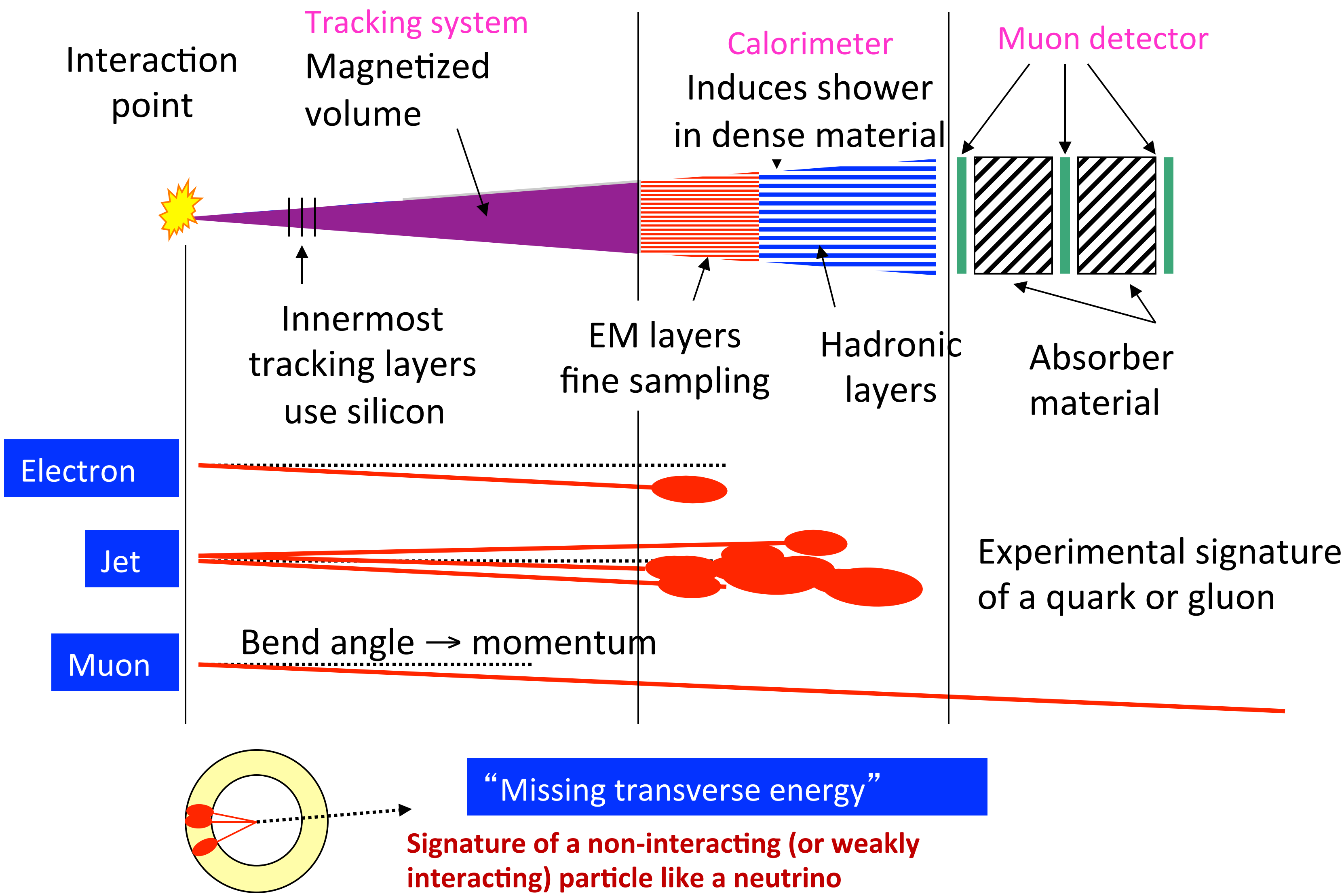
From the tracks and the energy deposits, we can reconstruct what happened during the collision.



Energy & Momentum conservation

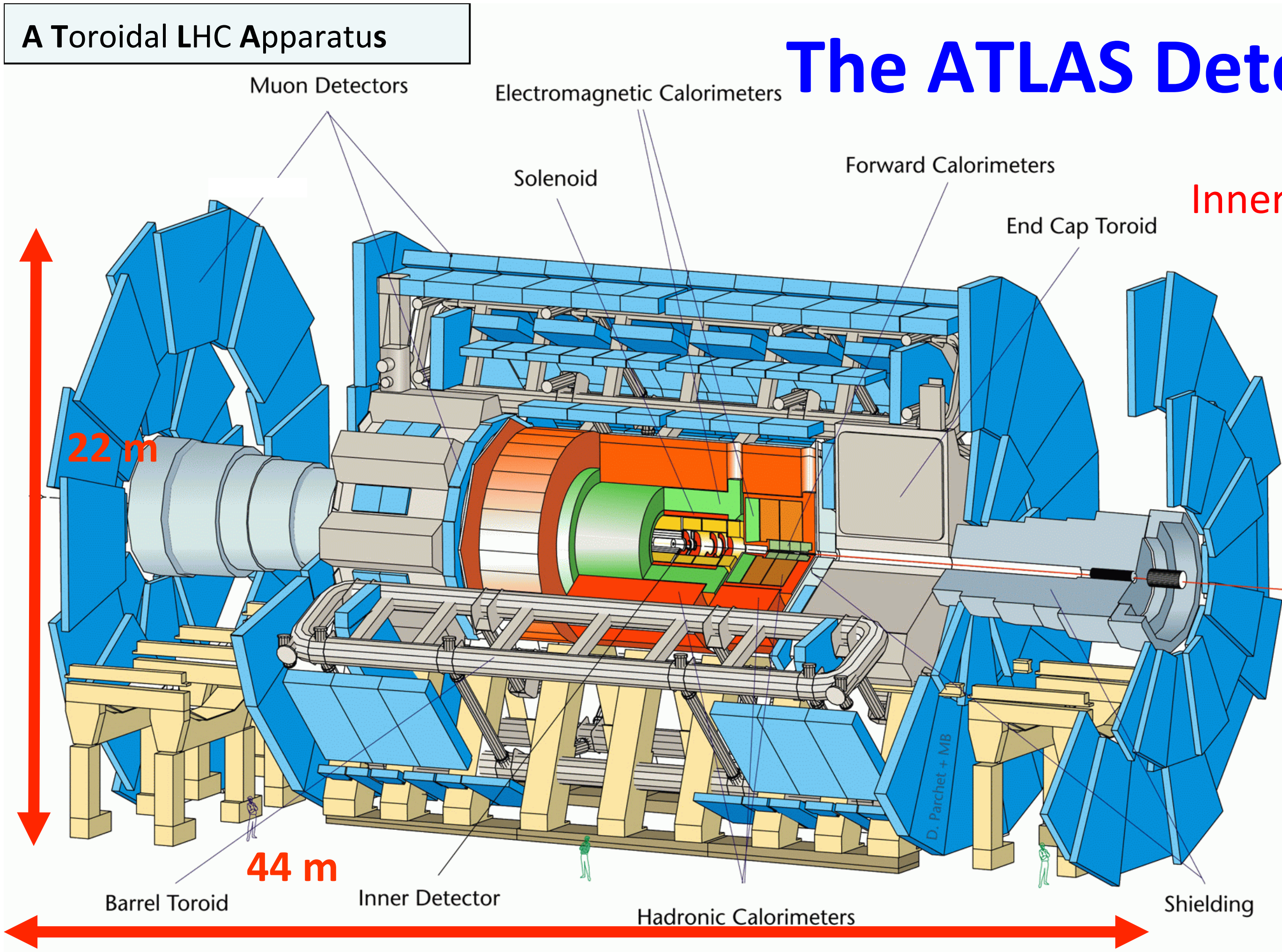


A typical contemporary HEP detector



Signature of a non-interacting (or weakly interacting) particle like a neutrino (based on energy/momentum conservation)

The ATLAS Detector



Inner Detector (ID)

- Si pixel and strip detector
- Transition Radiation Tracker: e/π separation
- Solenoid magnet of 2T

Calorimeter

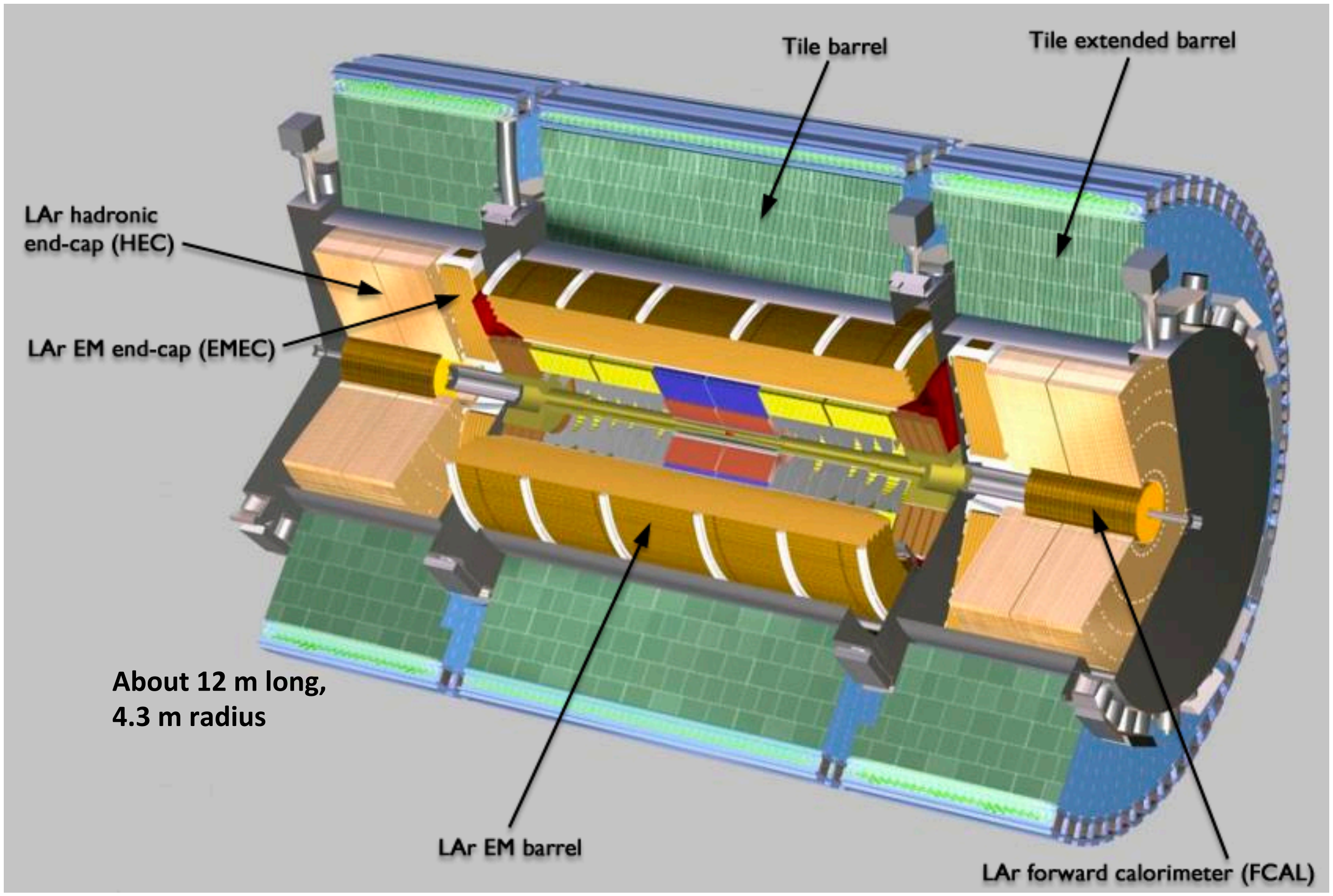
- High granularity LAr EM calorimeter: $|\eta| < 3.2$
- Hadron calorimeter: $|\eta| < 4.9$ (scintilator-tile in barrel and LAr in end-caps and forward)

Muon spectrometer

- Air-core toroid system average ~ 0.5 T
- MDTs & CSCs; RPCs & TGCs

ATLAS Calorimeter

– The Calorimeter of the ATLAS experiment at the CERN LHC
  - The Tile barrel Calorimeter uses plastic scintillator



Time for presentations !

- Tonight's victims:

12/1/2015	7:00 PM	Per Provencher	Low Background Laboratories
	7:20 PM	Rick McGann	Neutron Generation and Effects on Materials and Electronics
	7:40 PM	Chris Provencher	Electric Discharge Experiments
	8:00 PM	Charles Ko	Radiometric Dating
	8:20 PM	XXXX ~~Ricky Blake~~	XXXX ~~Fusion reactors~~

Due to dropped talk, you can have 25 min total (20 + 5) each

7:00 pm Per
7:25 Rick
7:50 Chris
8:15 Charles