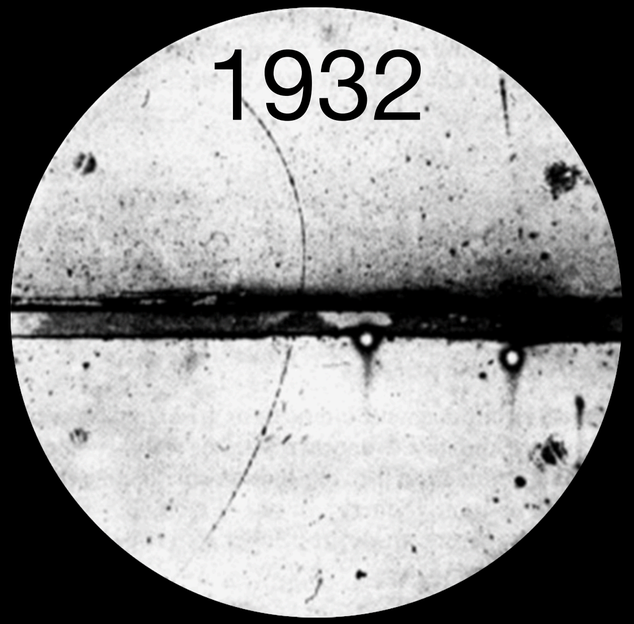
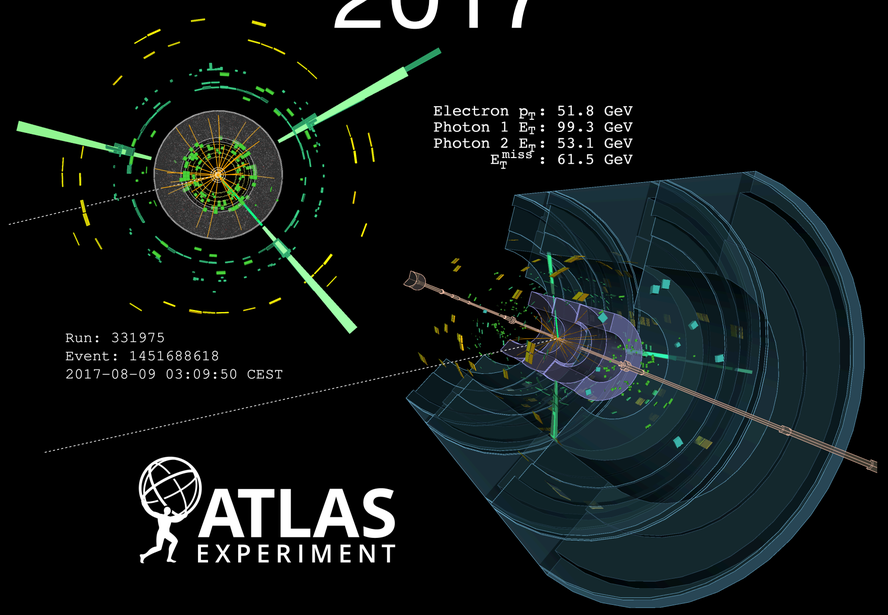
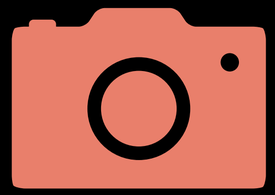
PHYS 7363 - Experimental Particle Detection and Detectors I



2017

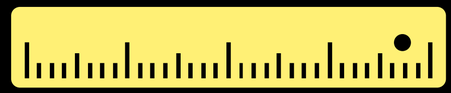


Particle detectors are the workhorses of experimental physics. In this course, we'll dive deep into their physics, exploring the incredible evolution of our experimental techniques over the past nine decades. You'll gain a solid understanding of *particle detection* and *identification*, examine the intricate designs of modern detectors, and learn how machine learning is being harnessed to push the boundaries of detector design. If you're intrigued by how we “see” subatomic particles, this course is for you!



Detect

Identify



Measure

To discuss prerequisites (and any questions on the content of the course), please contact me: saptaparnab@smu.edu

Schedule

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
October	6 ✅ 1.5 hours	7	8 ✅ 1.5 hours	9	10	11	12
	13 ✅ 1.5 hours	14	15 ✅ 1.5 hours	16	17 ✅	18	19
	20	21	22	23 ✅ 1.5 hours	24 ✅ 1.5 hours	25	26
	27: Midterm	28	29 ✅ 1.5 hours	30	31 ✅ 1.5 hours	1	2
November	3	4	5	6	7	8	9
	10	11	12	13	14	15	16
	17	18	19	20	21	22	23
	24	25	26	27	28	29	30
December	1	2	3	4	5	6	7
	8	9	10	11	12	13	14

Scintillators

- Detecting ionizing radiation by observing scintillation light: one of the oldest techniques for radiation detection
- Scintillation: creation of luminescence by absorption of ionizing radiation
- Scintillators for particle detection:
  - Energy deposited in the scintillator should be converted into light with high efficiency
  - Light yield $L_S = \left\langle N_{ph} \right\rangle / E,$ defined as the number of photons of a certain wavelength per deposited energy E should be proportional to energy released (linear response)
  - The scintillation medium should be transparent for the wavelength of the scintillation light
  - The light emission processes should be as fast as possible in order to obtain a fast signal pulse
  - The refractive index of the scintillating material should be close to that of the attached readout unit in order to ensure efficient light transmission
  - Light collection efficiency should be as large as possible
  - Scintillating material should have high Z or low Z and low atomic mass

Scintillators — typical setup

- Part 1
  - *Scintillator:* converts ionizing radiation into light. In order to prevent light from escaping the scintillator medium or entering from outside, the scintillator is made light-tight by a foil which is reflecting on the inside, for example an aluminium foil or diffusely backscattering white paper
- Part 2
  - *Light guide:* The part (i.e. the areal cross section) of the scintillator through which the light must pass towards the photomultiplier. A light guide is most often made of plexiglass

Scintillators — typical setup

- Part 3
  - *Photomultiplier:* The photomultiplier tube (PMT) converts scintillation photons into electrons in its photocathode and provides low-noise amplification
- Part 4:
  - *Amplifier:* The output pulse of the photomultiplier can in most cases be processed without further electronic amplification. Only needed in some cases

Scintillation Mechanism

- The mechanism generating scintillation light depends on the type of the scintillator material and is very different for organic and inorganic scintillators
- Absorbed energy leads to excitations of atomic/molecular states or crystal excitations
- Organic scintillators: scintillation mechanism largely determined by the electronic structure of the carbon atom
  - Typically solid in crystalline form like naphthalene $C_{10}H_8$
  - In polymerized form, they are plastic scintillators

Stokes Shift

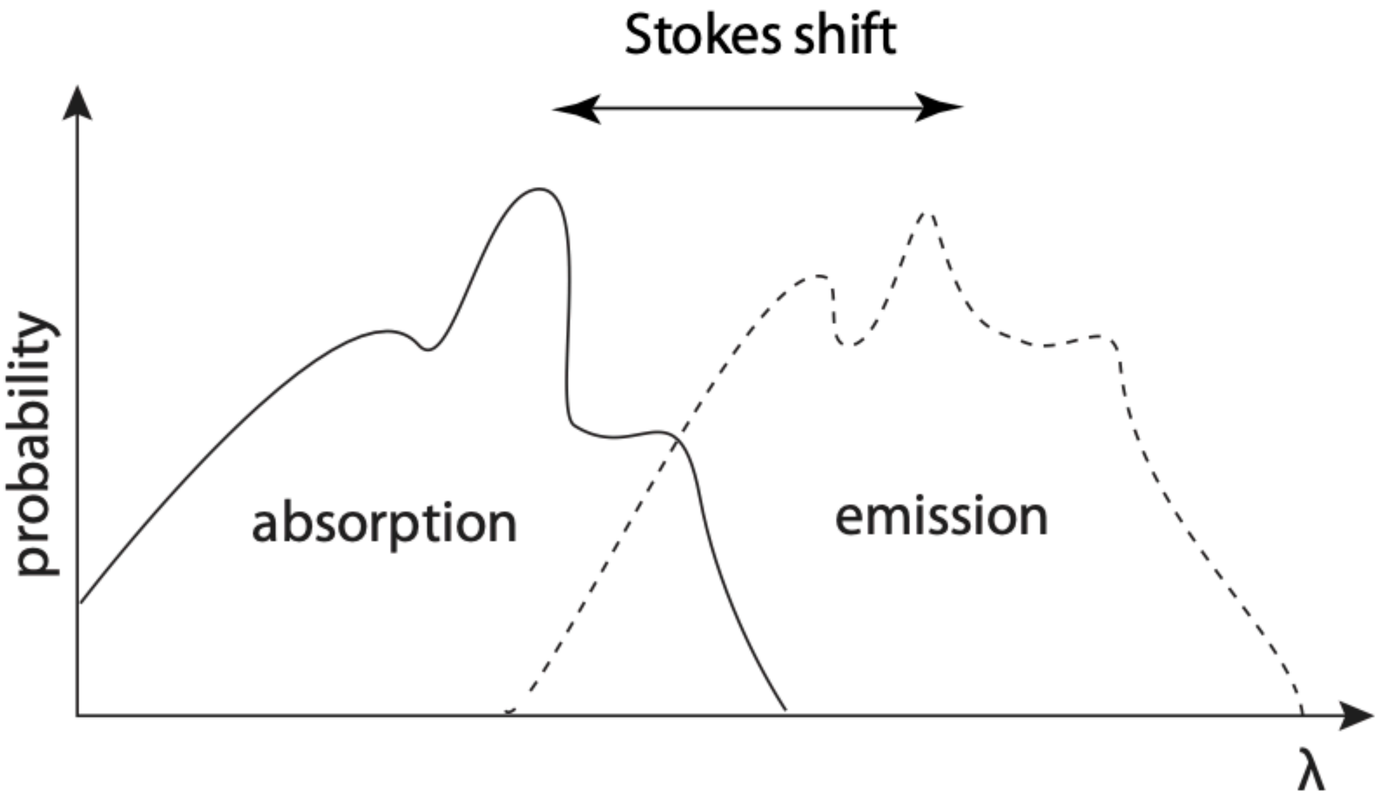


Fig. 13.2 Absorption and emission spectrum of scintillators (schematic).

Plastic Scintillators

- Usage: Plastic scintillators are mostly used to detect charged particles and neutrons
  - Simple handling, cheap fabrication to almost any desirable shape, and by their robustness and reliability
  - Which parts of ATLAS or CMS detectors use plastic scintillators?
  - Interesting presentation: https://cds.cern.ch/record/2835898/files/ATL-TILECAL-SLIDE-2022-532.pdf