Particle Physics II (KT2), Practical Course

“Pion Decay”

PHY213

Department of Physics, University of Zürich

Organization

The KT2 praktikum will take place at the high-intensity proton accelerator facility at the Paul Scherrer Institute (PSI) in Villigen

We have reserved beam time in weeks 28 and 29 (from July 10 to July 23)

Assistants:

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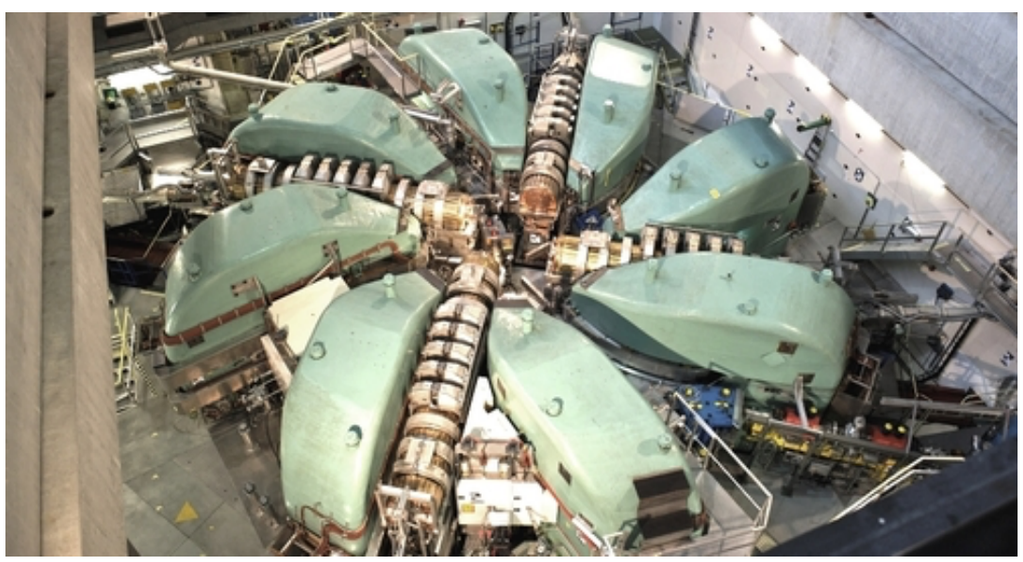
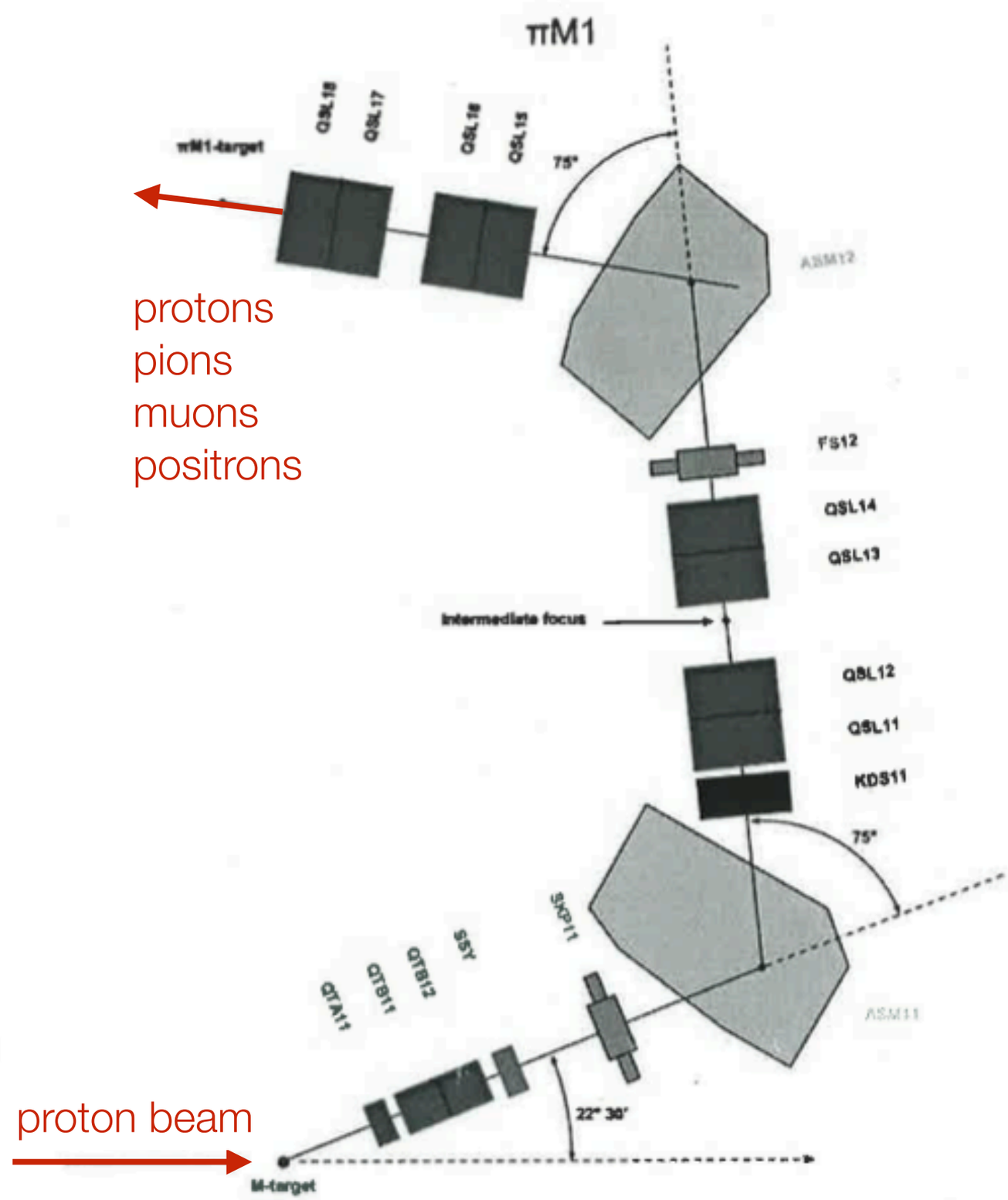
Proton Accelerator, Pion Production

HIPA:

proton accelerator, includes
– 870 keV Cockroft-Walton pre-injector
– 72 MeV cyclotron injector
– 590 MeV ring cyclotron





Experimental Area at PSI

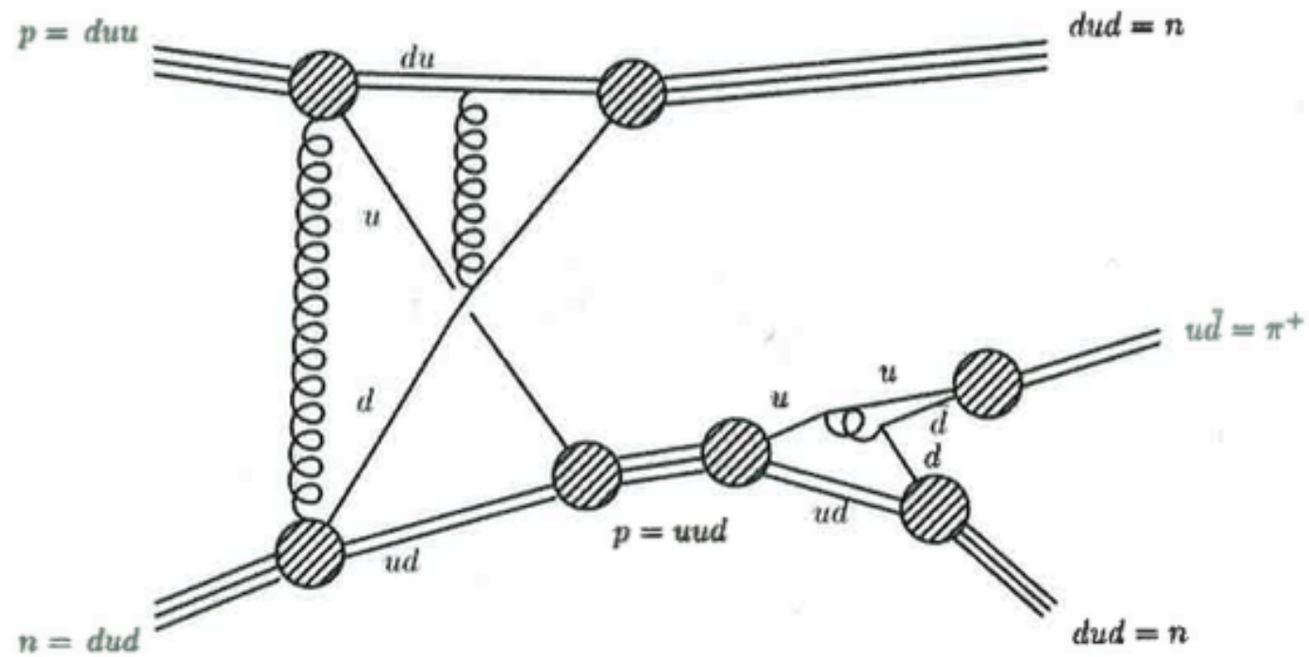
Experimental area PiM1

Control room

Pion Production

- The protons are accelerated onto the carbon target, where they interact with nucleons and produce pions

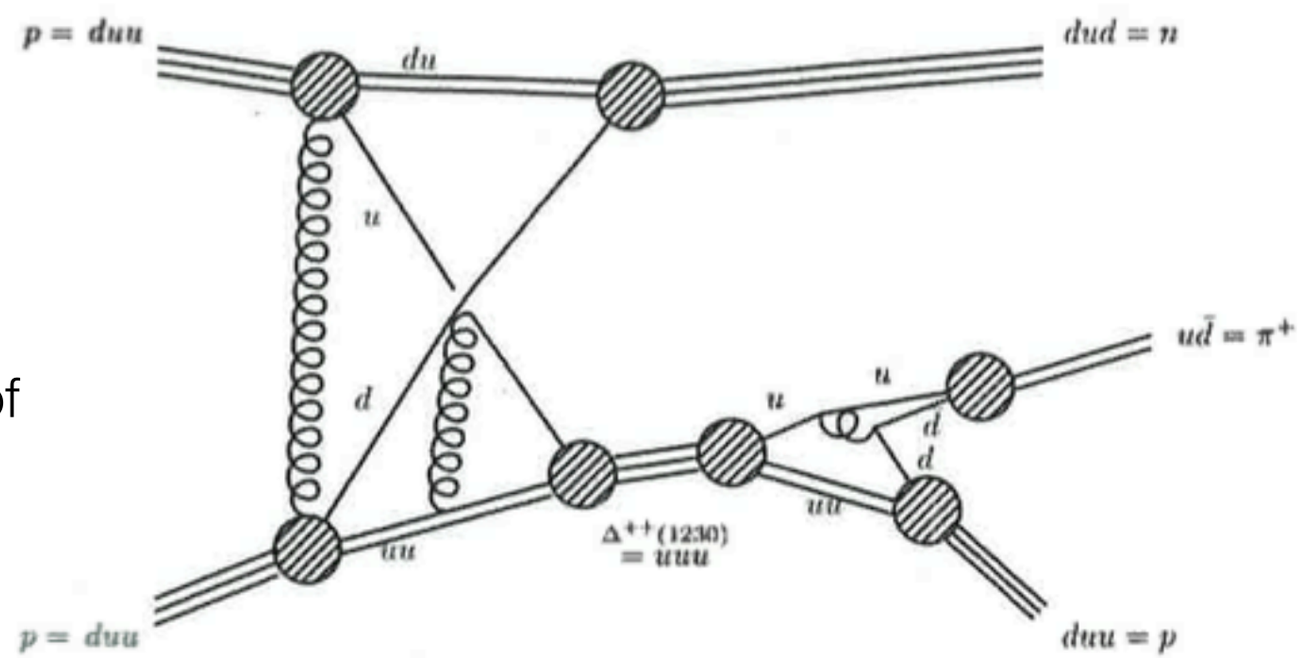
π^+-Einzelproduktion	$p\,p \to n\,p\,\pi^+$
	$p\,p \to d\,\pi^+$
	$p\,n \to n\,n\,\pi^+$
π^+-Doppelproduktion	$p\,p \to d\,\pi^+\,\pi^0$
	$p\,n \to n\,p\,\pi^+\,\pi^-$



π^+-Produktion über $pn \to nn\pi^+$ Reaktion

- Negatively charged particles are electrostatically separated

- The particle beam in PiM1 area consists of
  π^+, μ^+, e^+
  with a typical momentum range
  from 150 to 450 meV/c^2



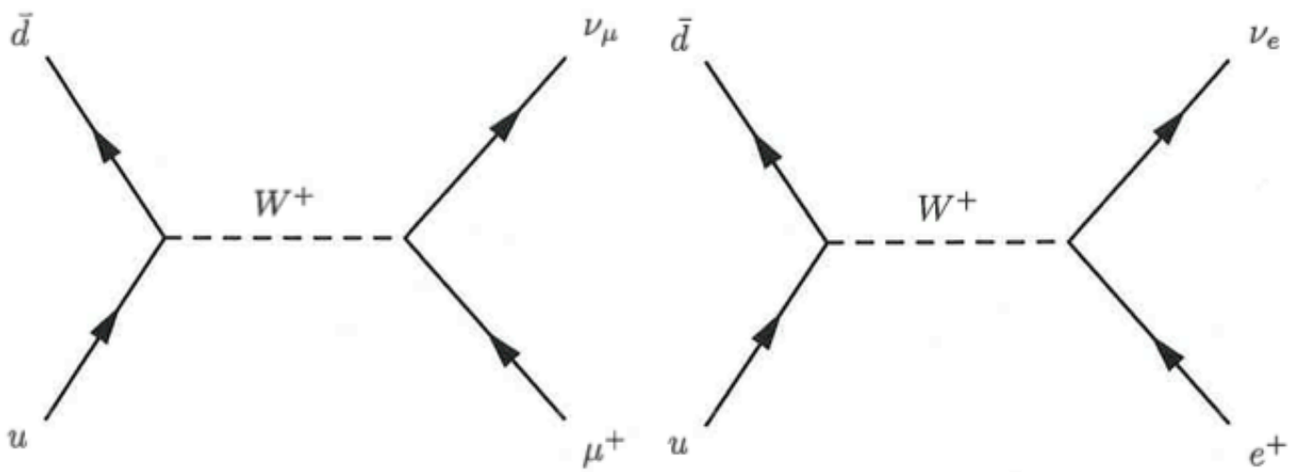
π^+-Produktion durch $pp \to np\pi^+$ mit Δ^{++} als Zwischenprodukt

Pion Decay

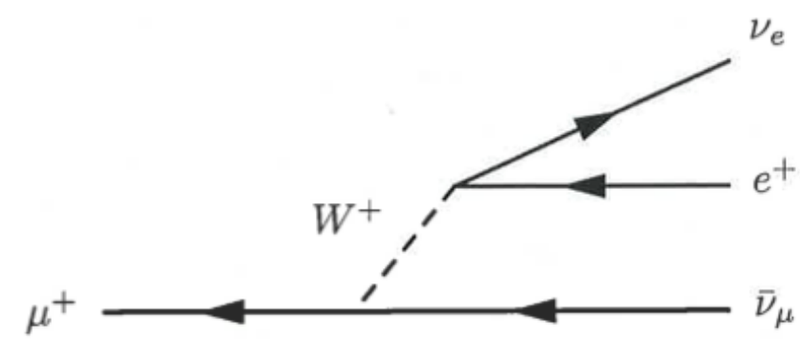
The subject of study are the following decays:

- pion into muon and muon neutrino
- pion into positron and electron neutrino
- muon into positron and electron neutrino

$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\downarrow$$
$$e^+ + \nu_e + \bar{\nu}_\mu$$



π^+-Zerfall Unterdrückter π^+-Zerfall



Kanal	Mode	Anteil $\Gamma_i/\Gamma[\%]$
1	$\mu^+ \nu_\mu$	99.98770 ± 0.00004
1.1	davon $\mu^+ \nu_\mu \gamma$	$(2.00 \pm 0.25) \times 10^{-4}$
2	$e^+ \nu_e$	$(1.230 \pm 0.004) \times 10^{-4}$
2.1	davon $e^+ \nu_e \gamma$	$(7.39 \pm 0.05) \times 10^{-7}$

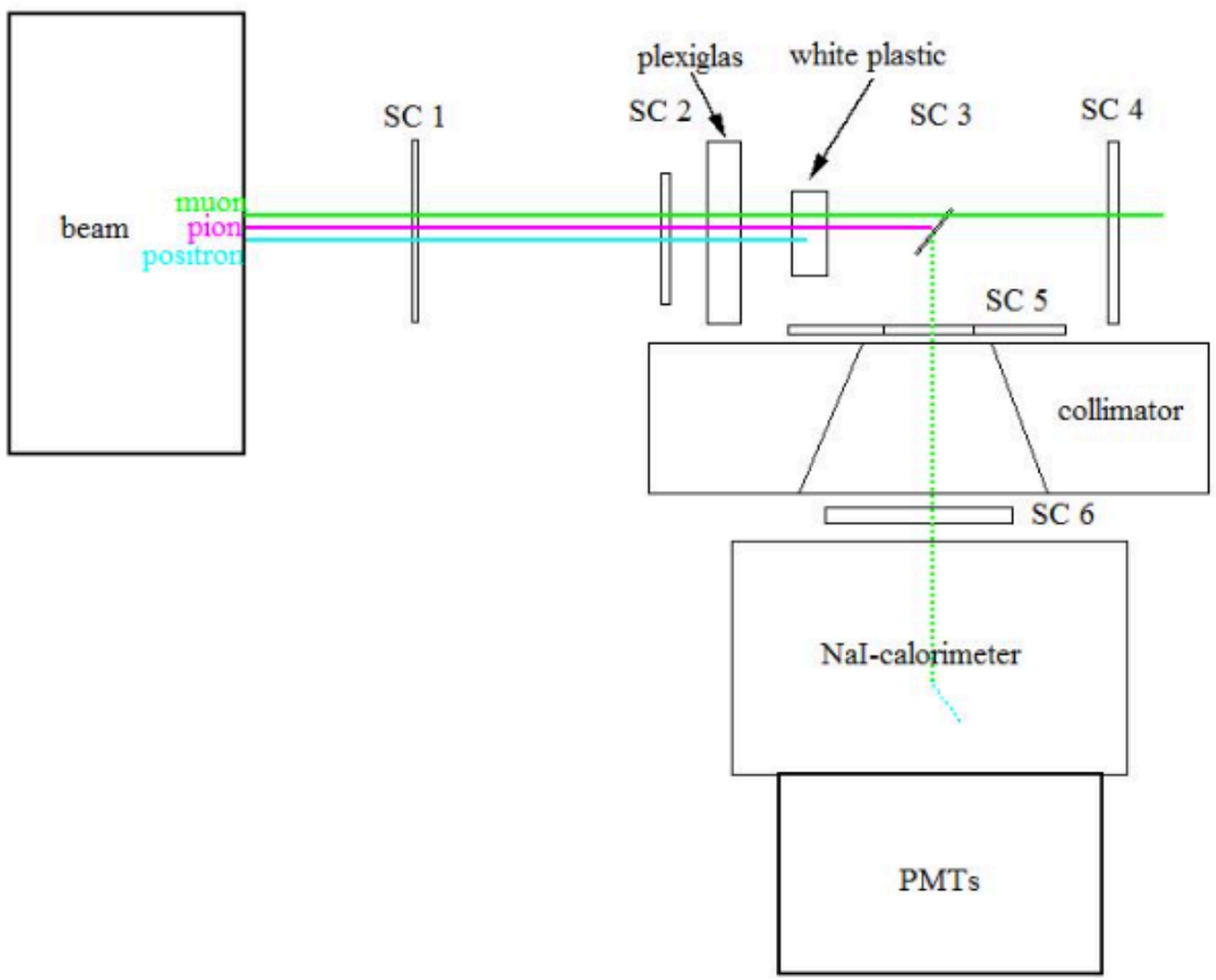
Kanal	Mode	Anteil $\Gamma_i/\Gamma[\%]$
1	$e^+ \nu_e \bar{\nu}_\mu$	≈ 100
2	$e^+ \nu_e \bar{\nu}_\mu \gamma$	(1.4 ± 0.4)

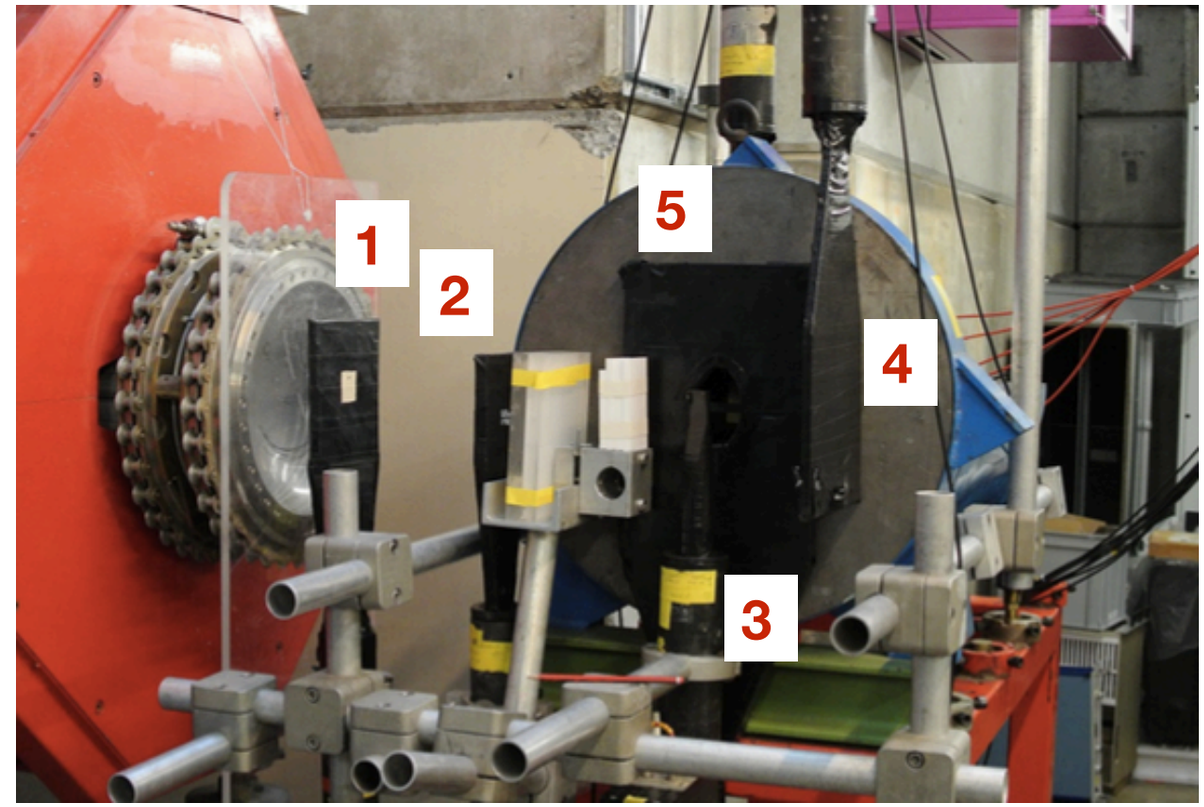
Measurements

- The particles incoming with the beam (protons, positrons, pions, muons) are:

(a) passing through the plastic scintillators 1 and 2

(b) slowed down in the moderator





(c) pions are stopped in scintillator 3 (and decay there), vetoed with scintillator 4

(d) background is vetoed with scintillator 5

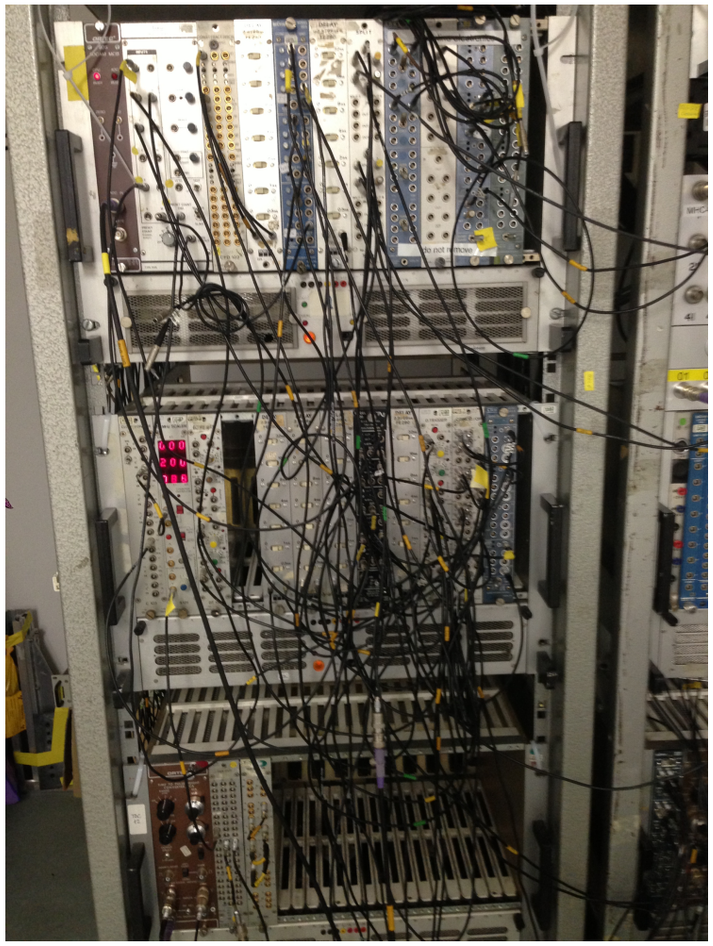
(e) decay products are tagged with scintillator 6 and measured with NaI calorimeter

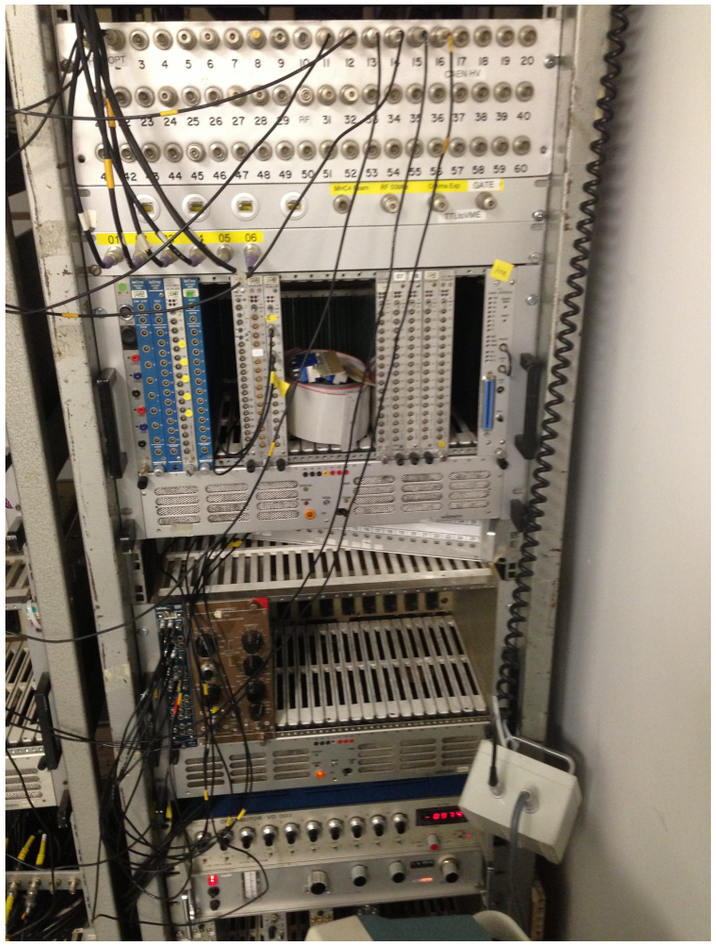
Electronics

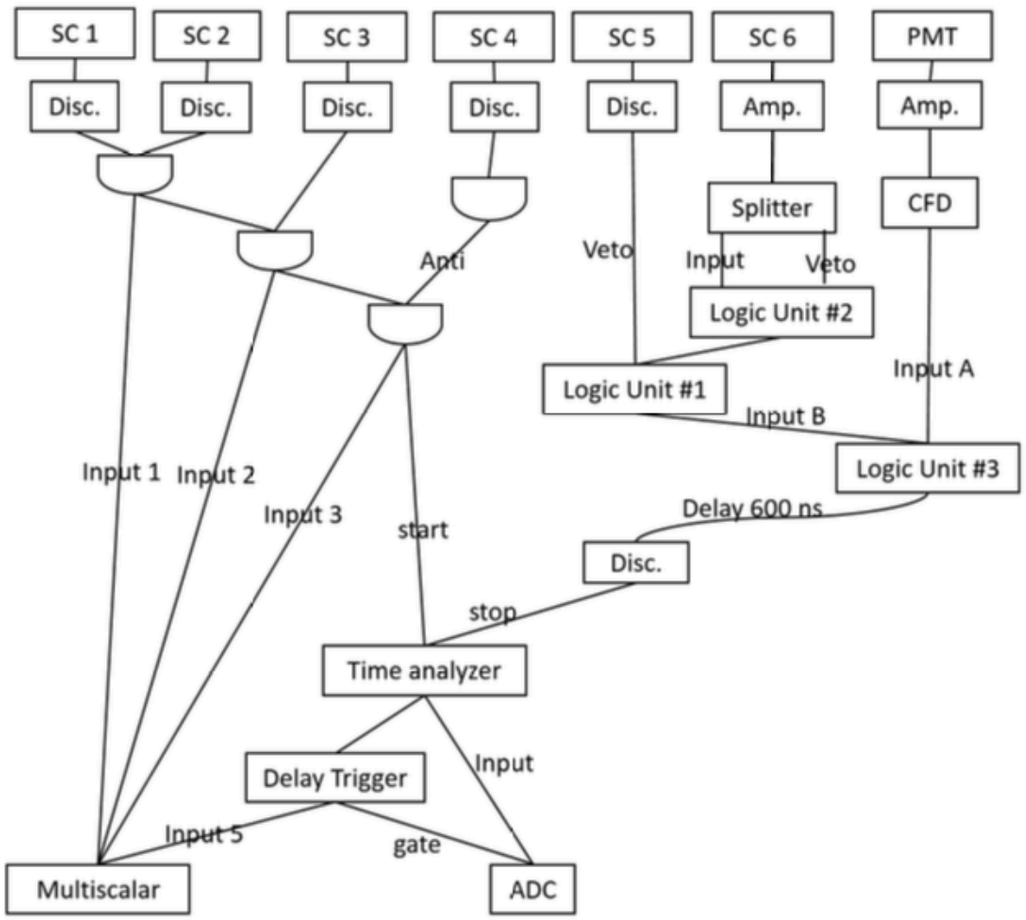
The signals will be processed online with hardware modules:

– amplifiers
– coincidence logic modules
– scalers, pre-scalers
– clock
– time-to-amplitude converter
– multi-channel analyser/ADC

→ We have used most of them in the KT1 course







Measurements

We will record time and energy spectra and perform the measurements of:

- pion and muon lifetimes

  τ_π = 26 ns
  τ_μ = 2.2 μs

- pion and muon rest mass

  m_π = 134.98 MeV
  m_μ = 105.66 MeV

- ratio between decay probabilities in channels
  $\pi^+ \rightarrow \mu^+ + \nu$ and $\pi^+ \rightarrow e^+ + \nu$

  (= 1.23×10^{-4})