Particle Physics SS 2016

Stephanie Hansmann-Menzemer

Lectures: Tuesday 14:15-16:00h (INF 227 HS1) and Thursday 14:15-16:00h (INF 227 HS2)

Web-page: http://uebungen.physik.uni-heidelberg.de/vorlesung/2016/pp

Prerequisits: PEP5

Tutorials	Thursday	16:15 - 18:00h	S. Neubert
	Friday	11:15 – 13:00h	S. Esen
	Friday	14:15 – 16:00h	M. Lisovyi

First tutorial this week (21./22.4.) - repetition class of PEP5

First exercise sheet will be on the web today (19.4.), handed in a week later in the lecture
Or in the secretary INF 226 3.104. It will be discussed in the tutorials in the same week (28./29.4.)

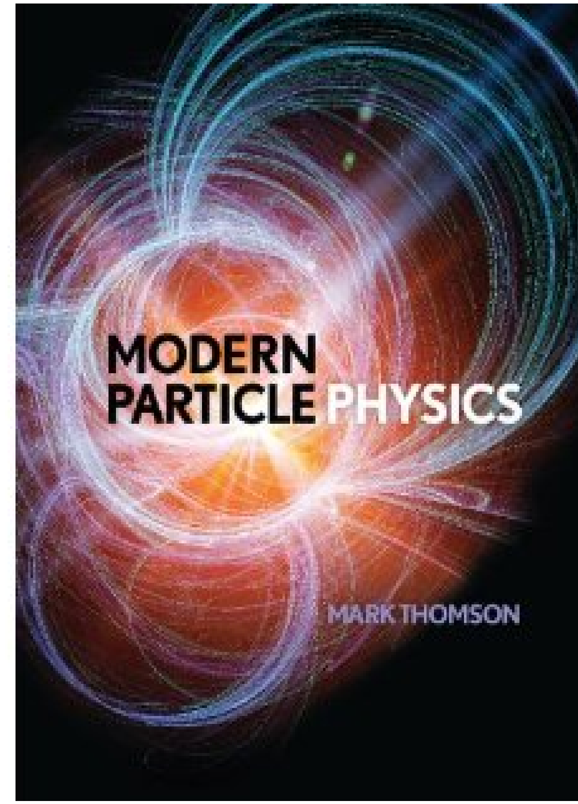
Groups of max. 4 students from the same exercise group can hand in sheet together.

12 Exercise sheets in total, 60% of the points are mandatory for exam.

Tentative Date of exam: Tuesday 26.07.2016 13:00-16:00h, INF 227 HS1

(note collision with Advanced Quantum Theory)

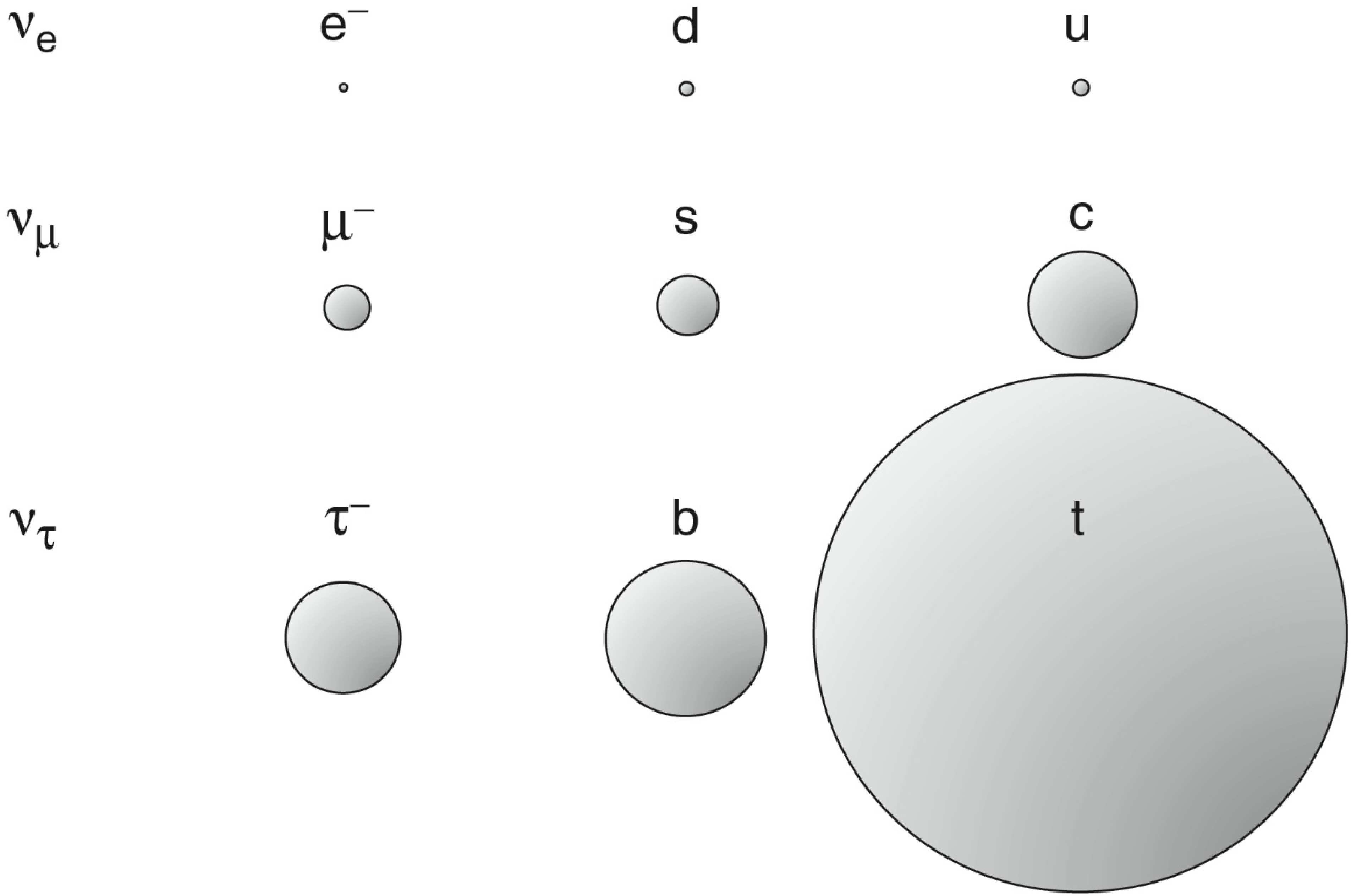
Particle Physics SS 2016



Titel: Modeln particle physics
Autor: Mark Thomson
Verlag: Cambridge University Press
ISBN: 978-1-107-03436-6
1-107-03426-4

STANDARD MODEL OF ELEMENTARY PARTICLES

		mass	charge	spin	
QUARKS	UP	2,3 MeV/c^2	⅔	½	u
QUARKS	CHARM	1,275 GeV/c^2	⅔	½	c
QUARKS	TOP	173,07 GeV/c^2	⅔	½	t
QUARKS	DOWN	4,8 MeV/c^2	-⅓	½	d
QUARKS	STRANGE	95 MeV/c^2	-⅓	½	s
QUARKS	BOTTOM	4,18 GeV/c^2	-⅓	½	b
LEPTONS	ELECTRON	0,511 MeV/c^2	-1	½	e
LEPTONS	MUON	105,7 MeV/c^2	-1	½	μ
LEPTONS	TAU	1,777 GeV/c^2	-1	½	τ
LEPTONS	ELECTRON NEUTRINO	<2,2 eV/c^2	0	½	ν_e
LEPTONS	MUON NEUTRINO	<0,17 MeV/c^2	0	½	ν_μ
LEPTONS	TAU NEUTRINO	<15,5 MeV/c^2	0	½	ν_τ
GAUGE BOSONS	GLUON	0	0	1	g
GAUGE BOSONS	PHOTON	0	0	1	γ
GAUGE BOSONS	Z BOSON	91,2 GeV/c^2	0	1	Z
GAUGE BOSONS	W BOSON	80,4 GeV/c^2	±1	1	W
	HIGGS BOSON	126 GeV/c^2	0	0	H



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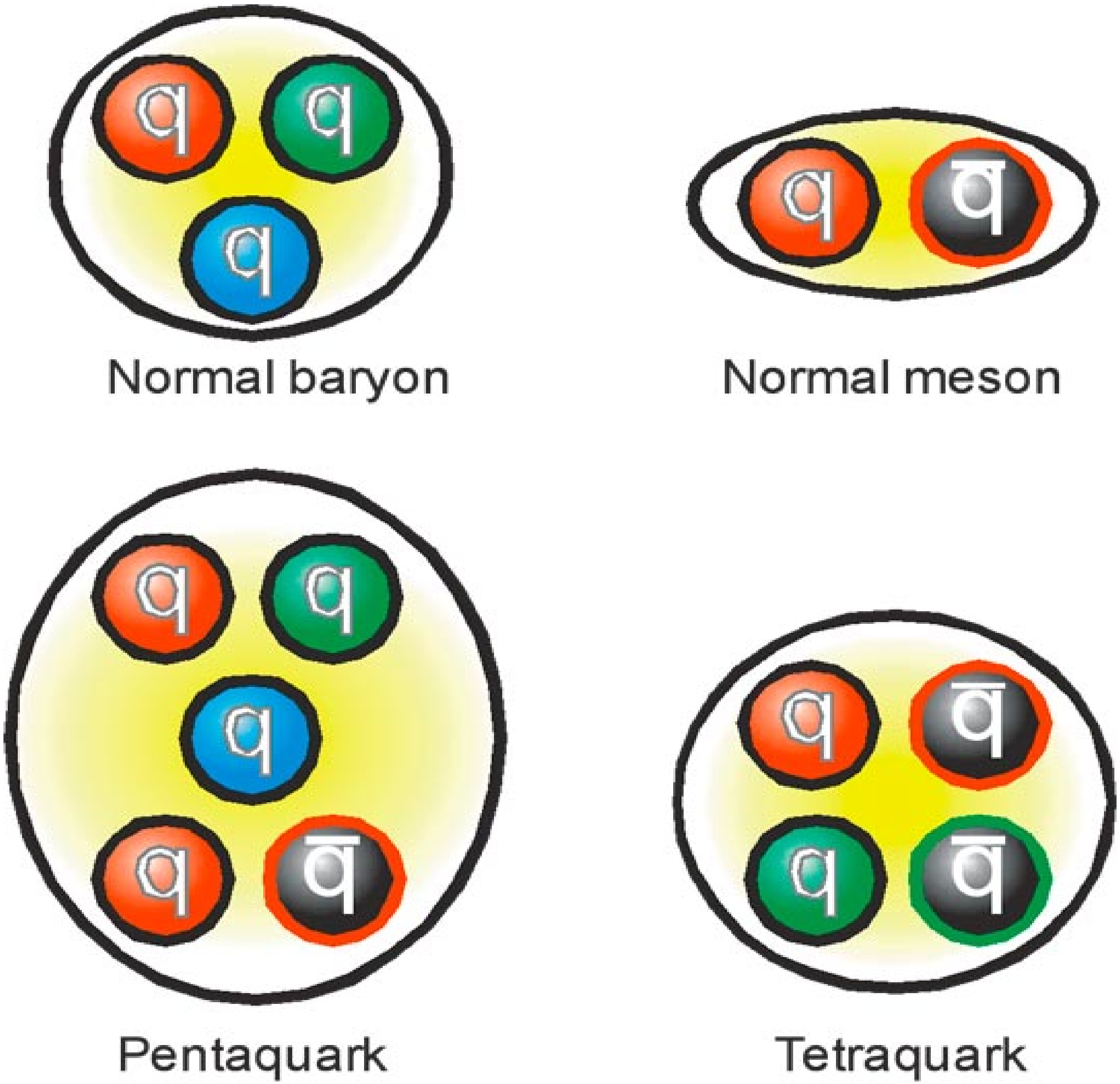
Bound states have to be colour neutral

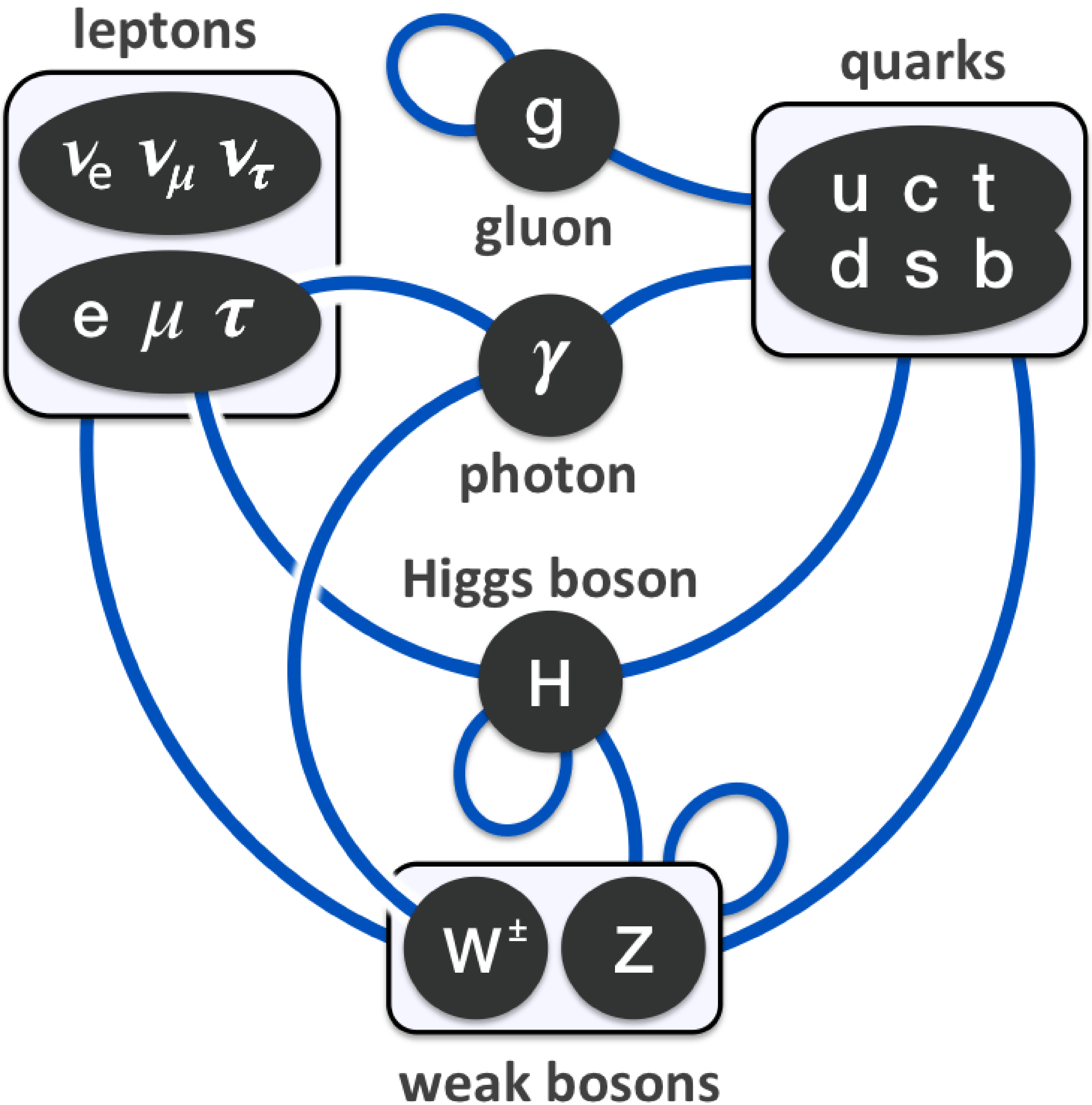
e.g. n, p, Λ

e.g. π, K, B

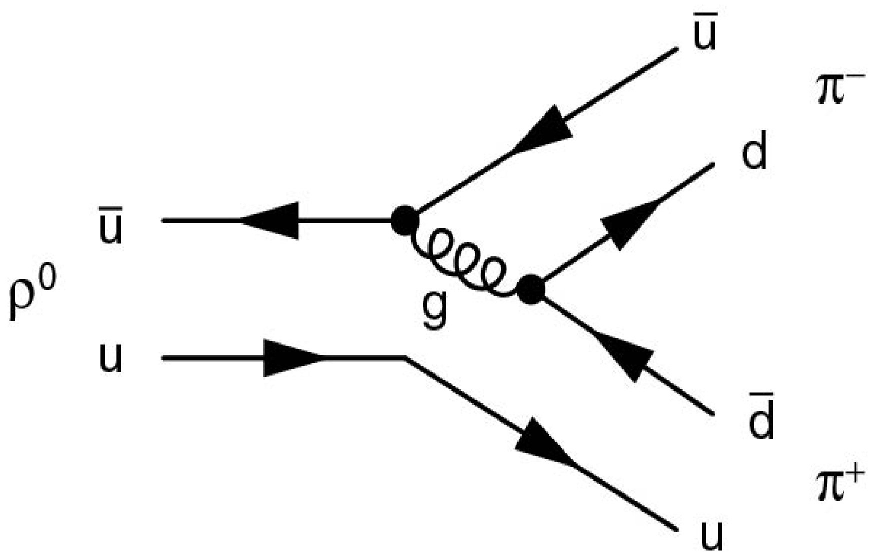


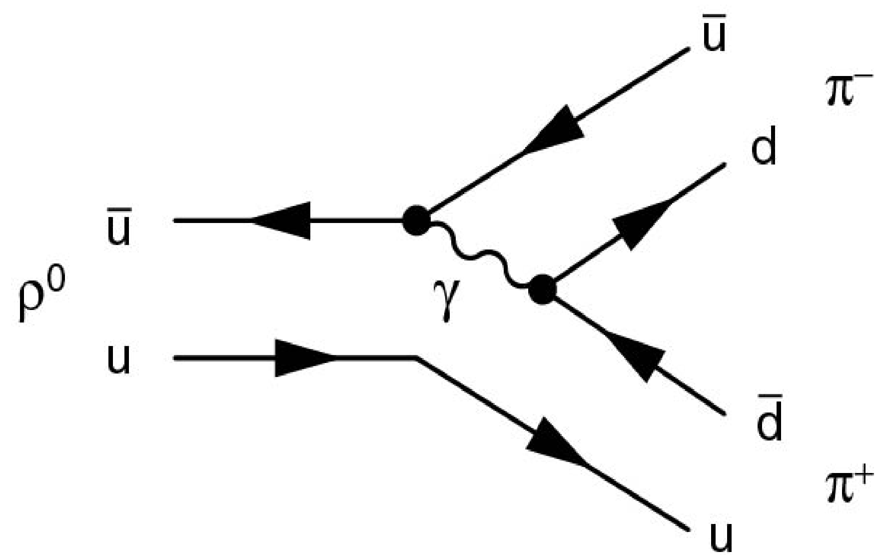
discovered 2015
at LHCb

discovered 2014
at LHCb


leptons
ν_e ν_μ ν_τ
e μ τ
g
gluon
quarks
u c t
d s b
γ
photon
Higgs boson
H
$W^\pm$
Z
weak bosons

High Probability





Low Probability

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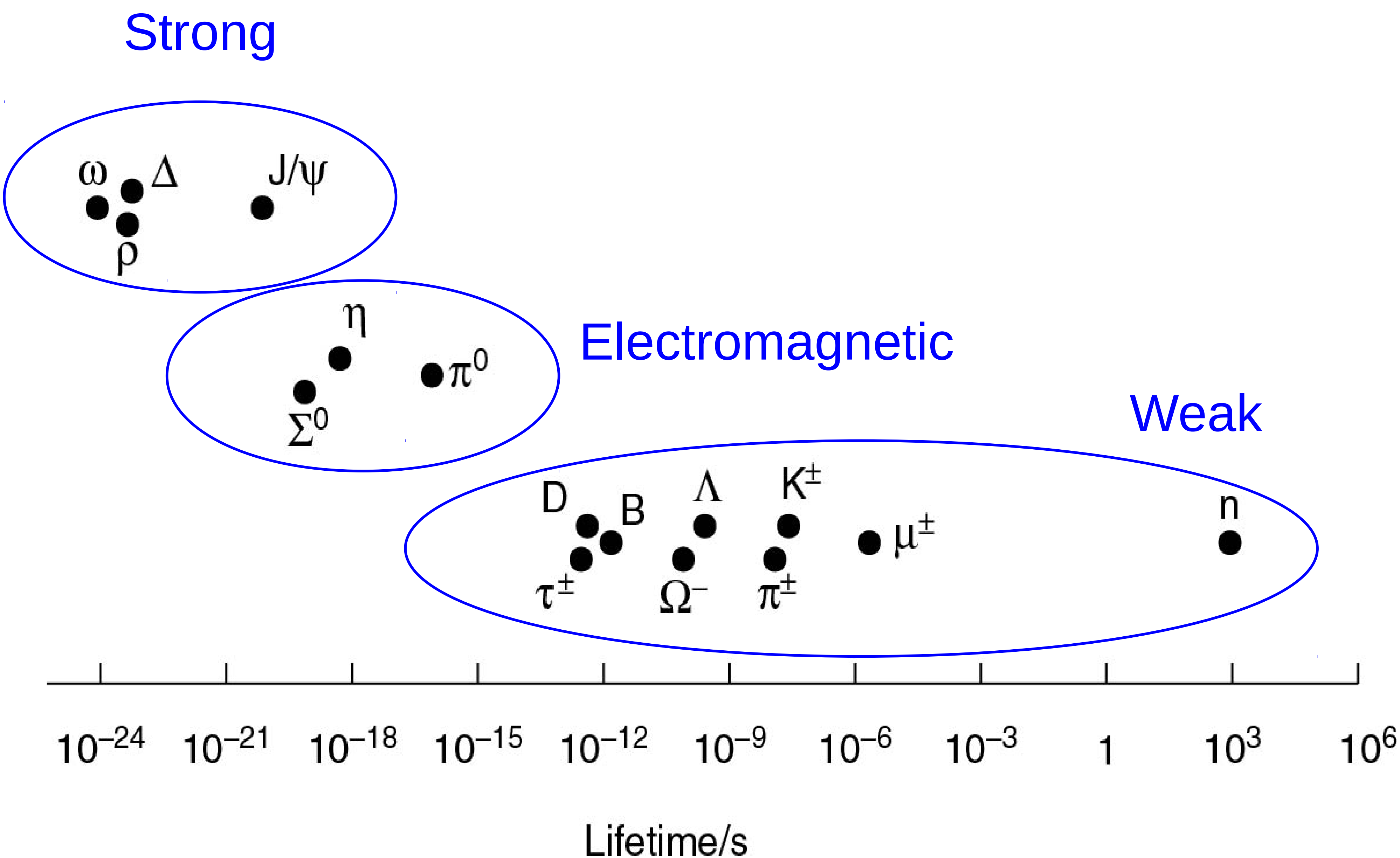

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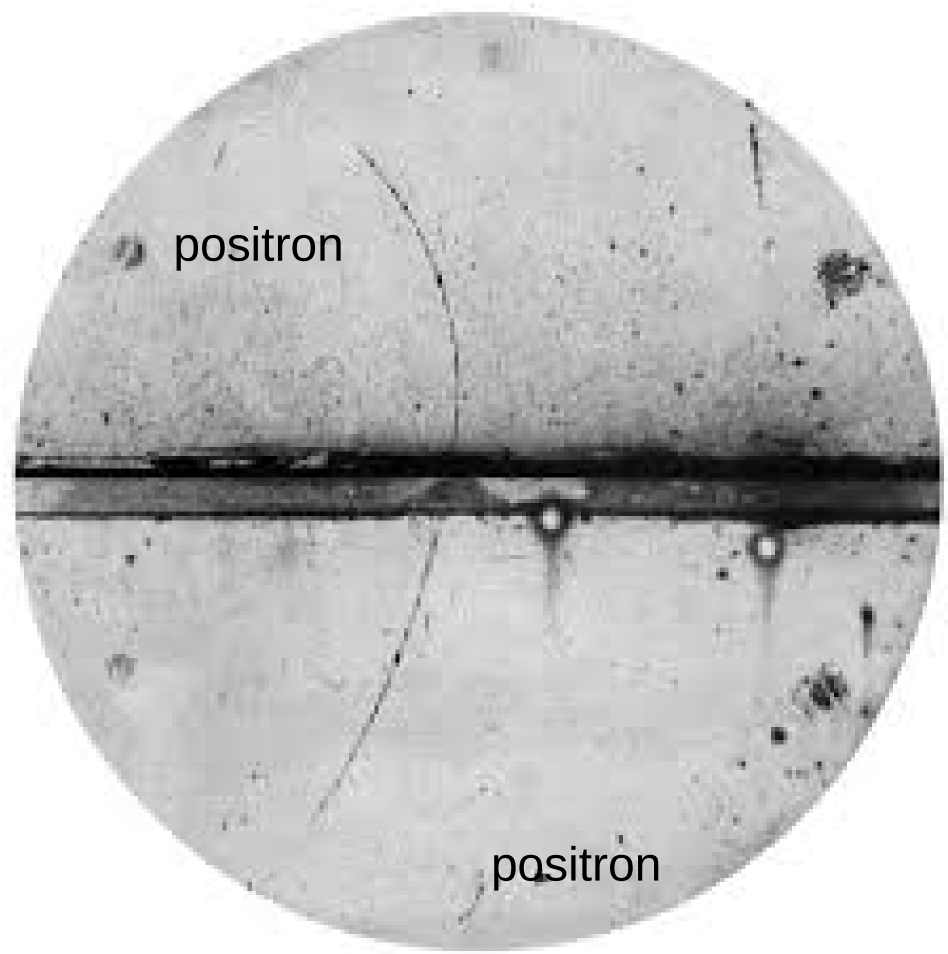
A brief history of particle detectors

Cloud chamber
in magentic field

Discovery of antimatter

[Anderson 1932; Nobel prize 1936]

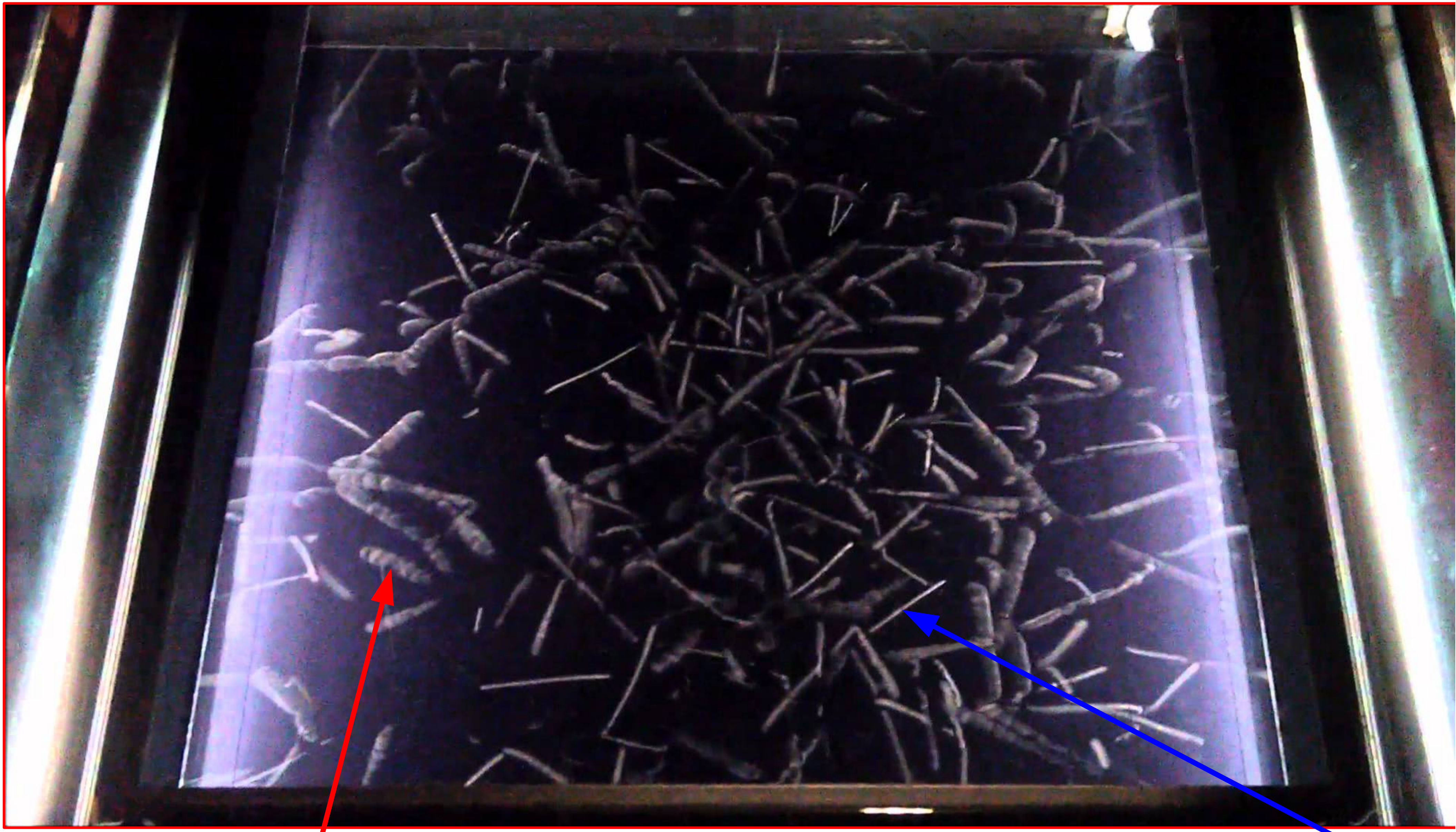
6 mm lead



63 MeV positron passing through
Lead plate emerging as 23 MeV positron

The length of this latter pass is at least ten times
Greater than the possible length of a proton path of this curvature

Have a look at cloud chamber at PI foyer



Thick lines: alpha particles (natural radon contanimation, e.g. in the concrete), thin lines: electrons

(this picture was taken with an alpha source next to the chamber …)

A brief history of particle detectors

Discovery of pion
Nuclear emulsion technique

[Powell 1947; Nobel prize 1950]

$$\pi \rightarrow \mu + \nu$$
$$\mu \rightarrow e + \nu + \nu$$

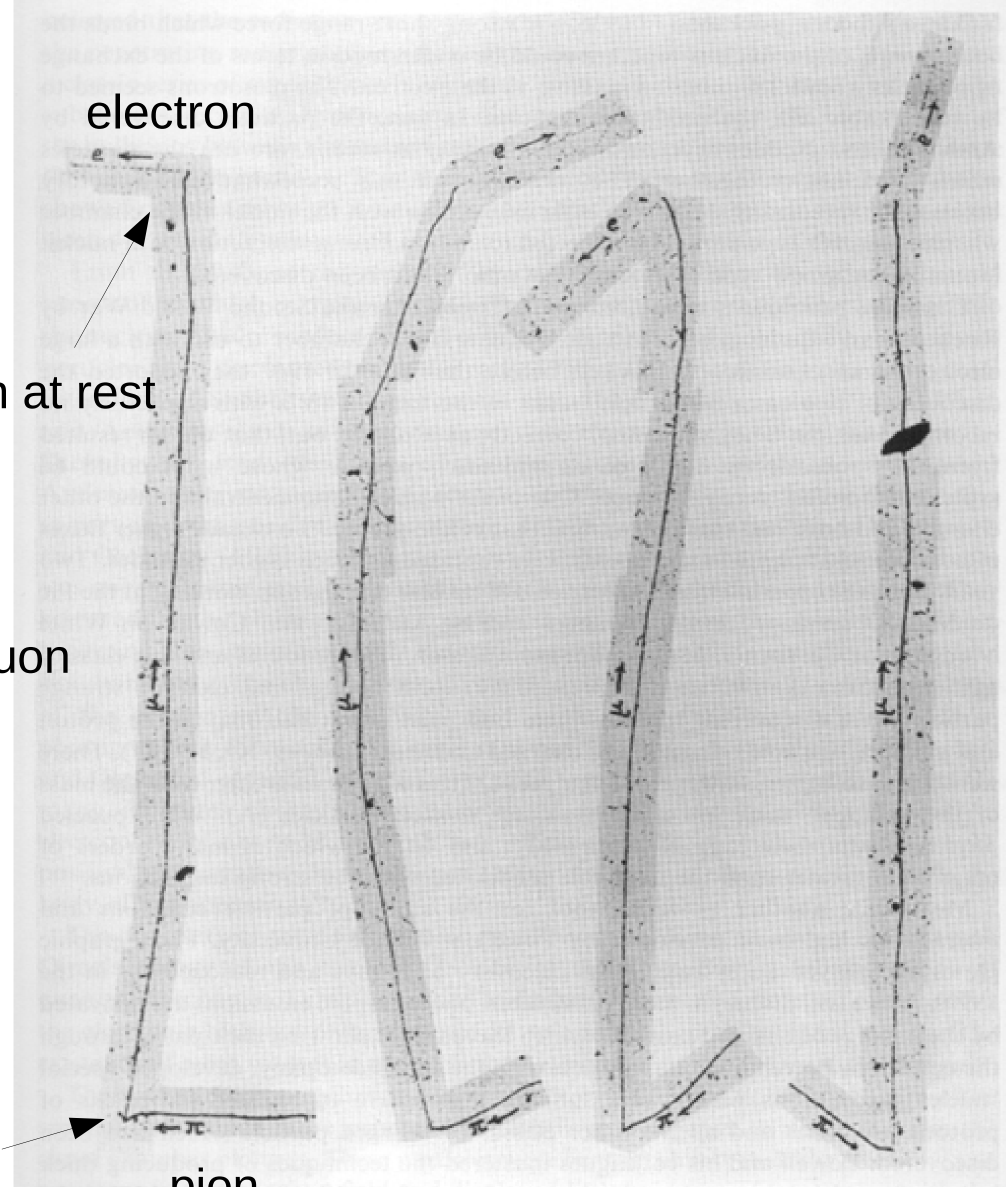


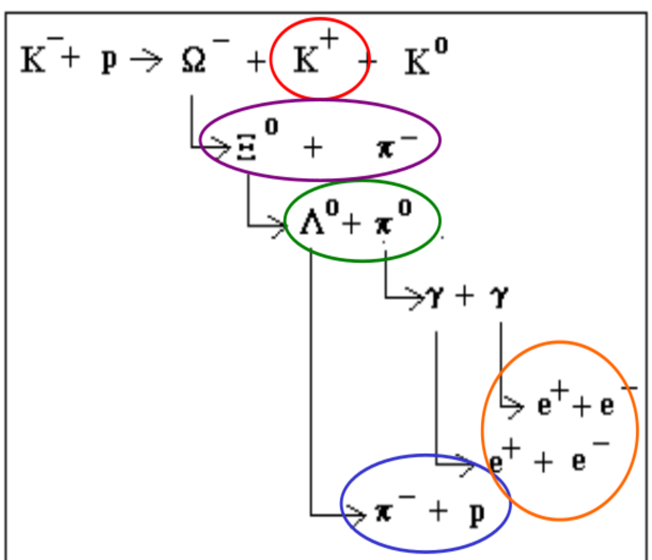
Figure 1.6. Four examples of the decay of a pion into a muon, followed by the subsequent decay of the muon into an electron. These processes were discovered by Powell and his collaborators using nuclear emulsions. (From C. F. Powell, P. H. Fowler and D. H. Perkins (1959). *The study of elementary particles by the photographic method*, page 245, Plate 8-5, Oxford: Pergamon Press.)

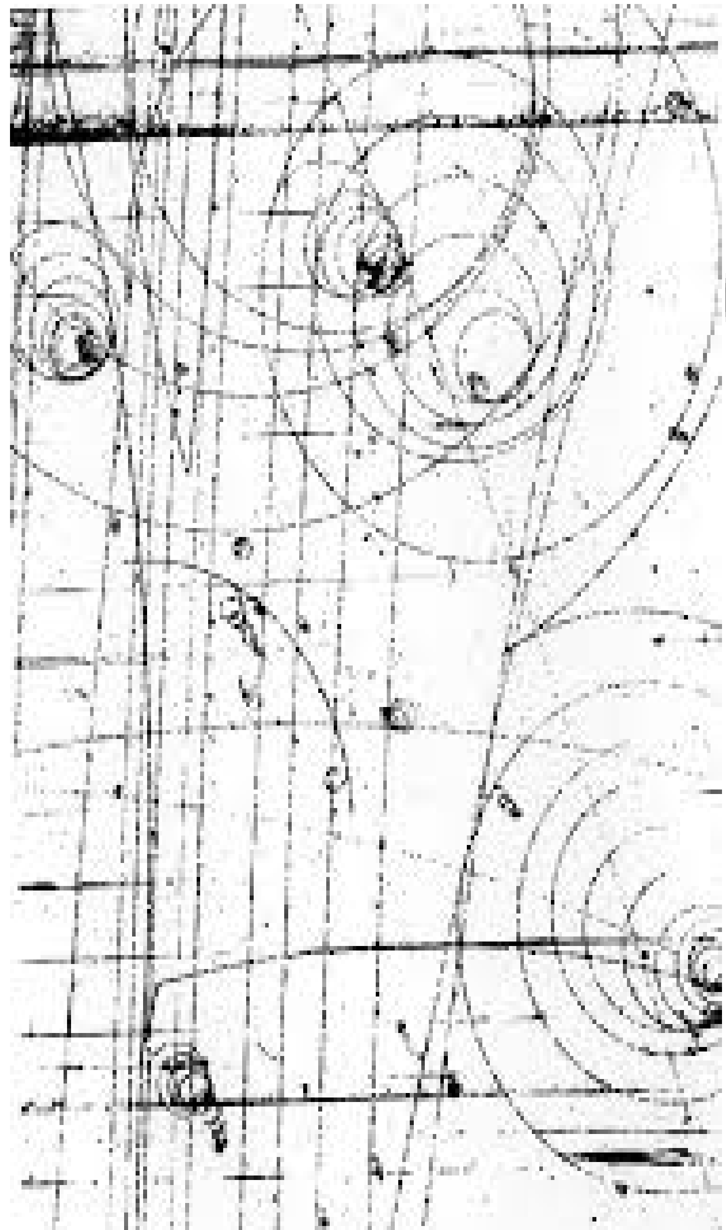
A brief history of particle detectors

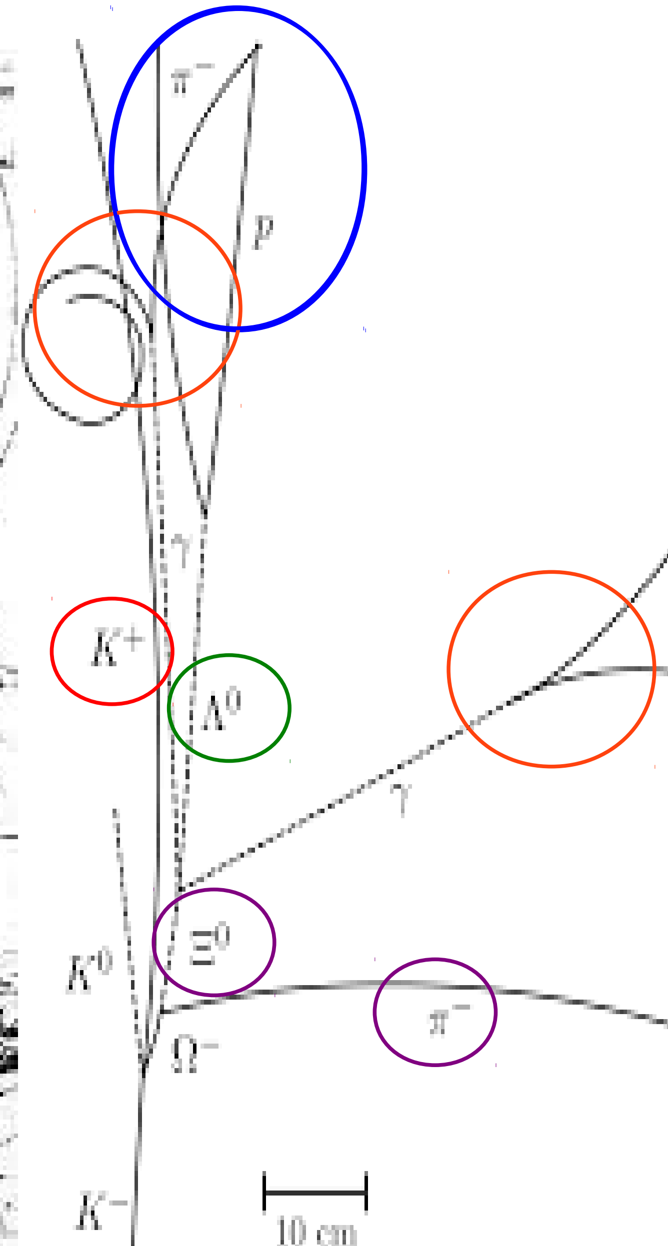
First observed Ω^- (1964)

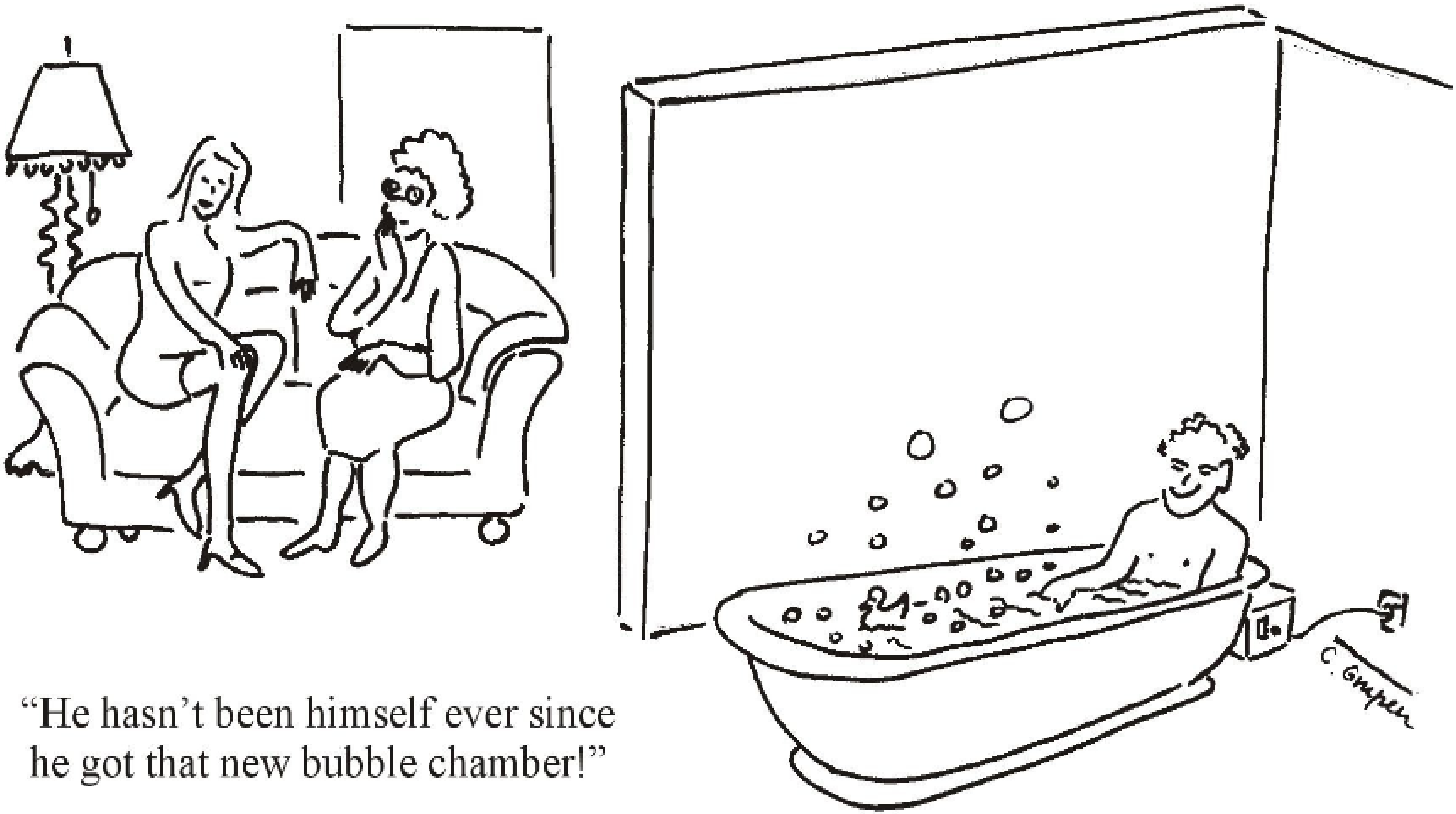
[BNL Bubble Chamber]

Nobelprize for development of bubble chamber 1960 [Donald A. Glaser]









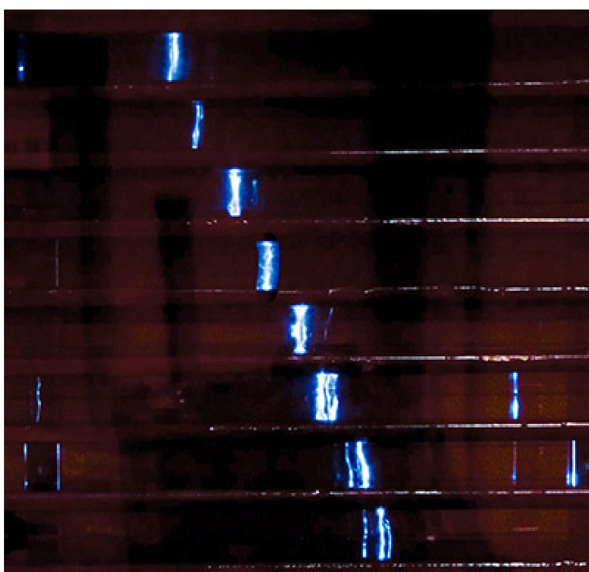
"He hasn't been himself ever since
he got that new bubble chamber!"

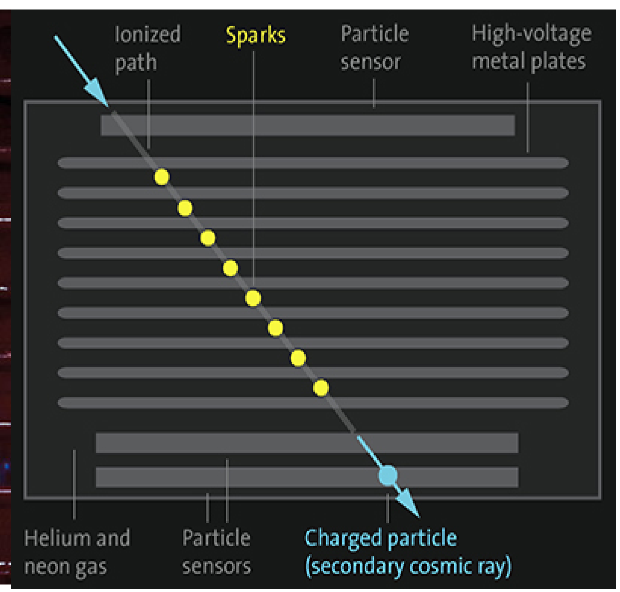
A brief history of particle detectors

Discovery of the muon neutrino (1962)

Leon M. Lederman
Melvin Schwartz
Jack Steinberger

[spark chamber, nobel prize 1988]





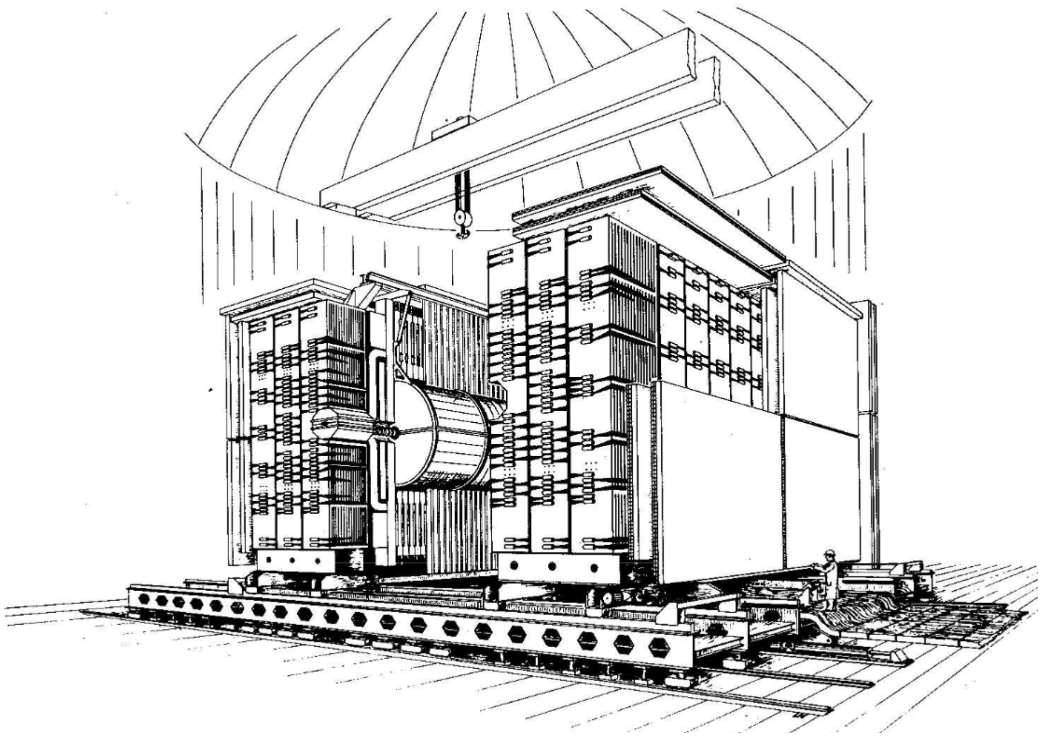
M. Schwartz in front of the spark chamber used to discover the muon neutrino

A brief history of particle detectors

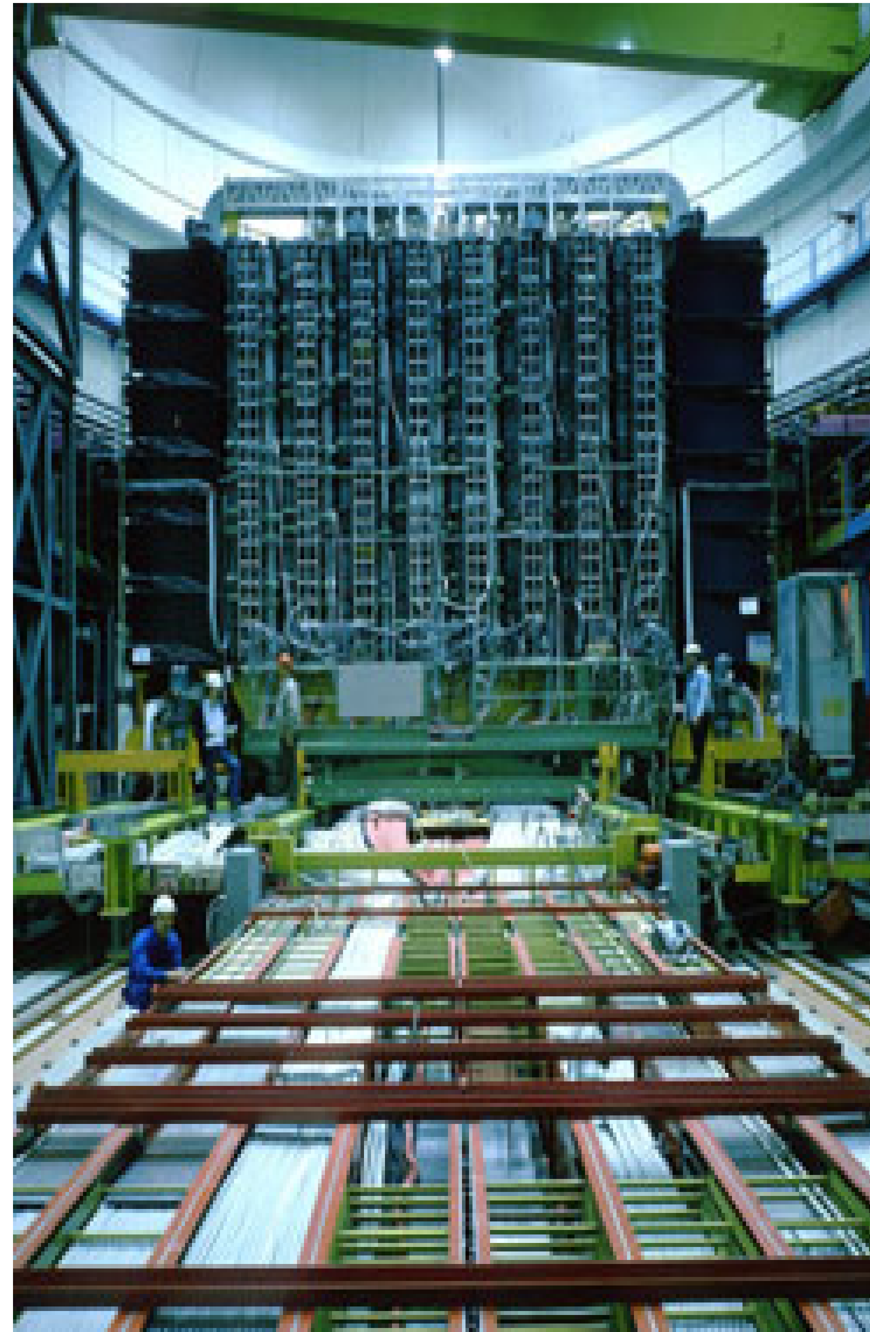
Discovery of the W/Z boson (1983)

Carlo Rubbia
Simon Van der Meer

[Nobel prize 1984]



UA1 detector



A brief history of particle detectors

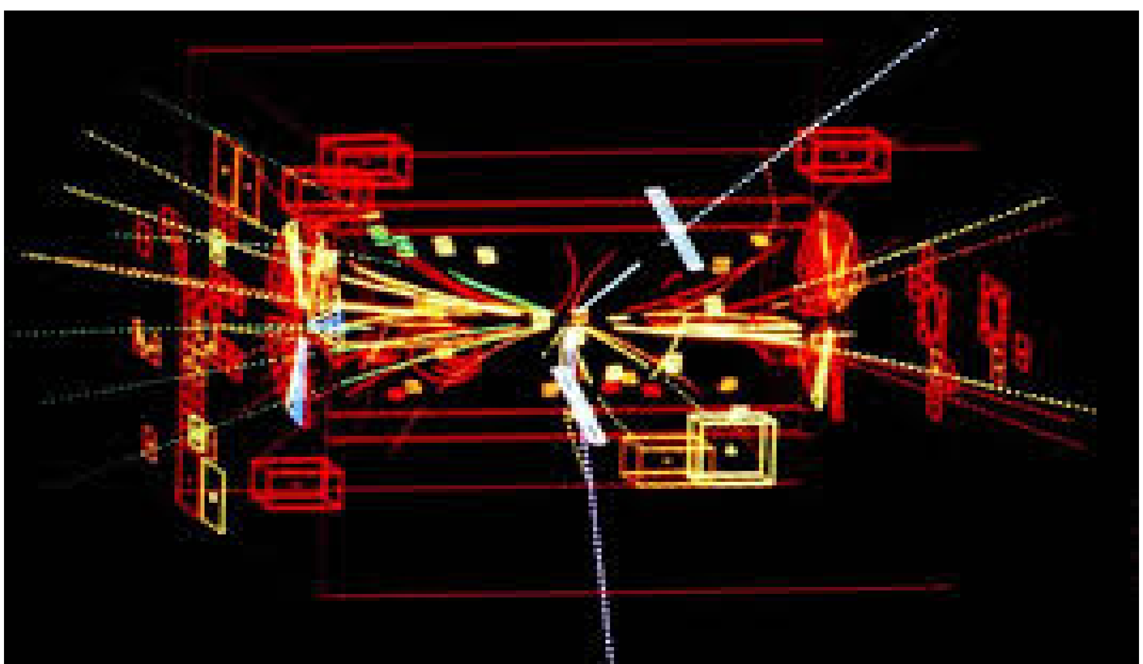
Discovery of the W/Z boson (1983)

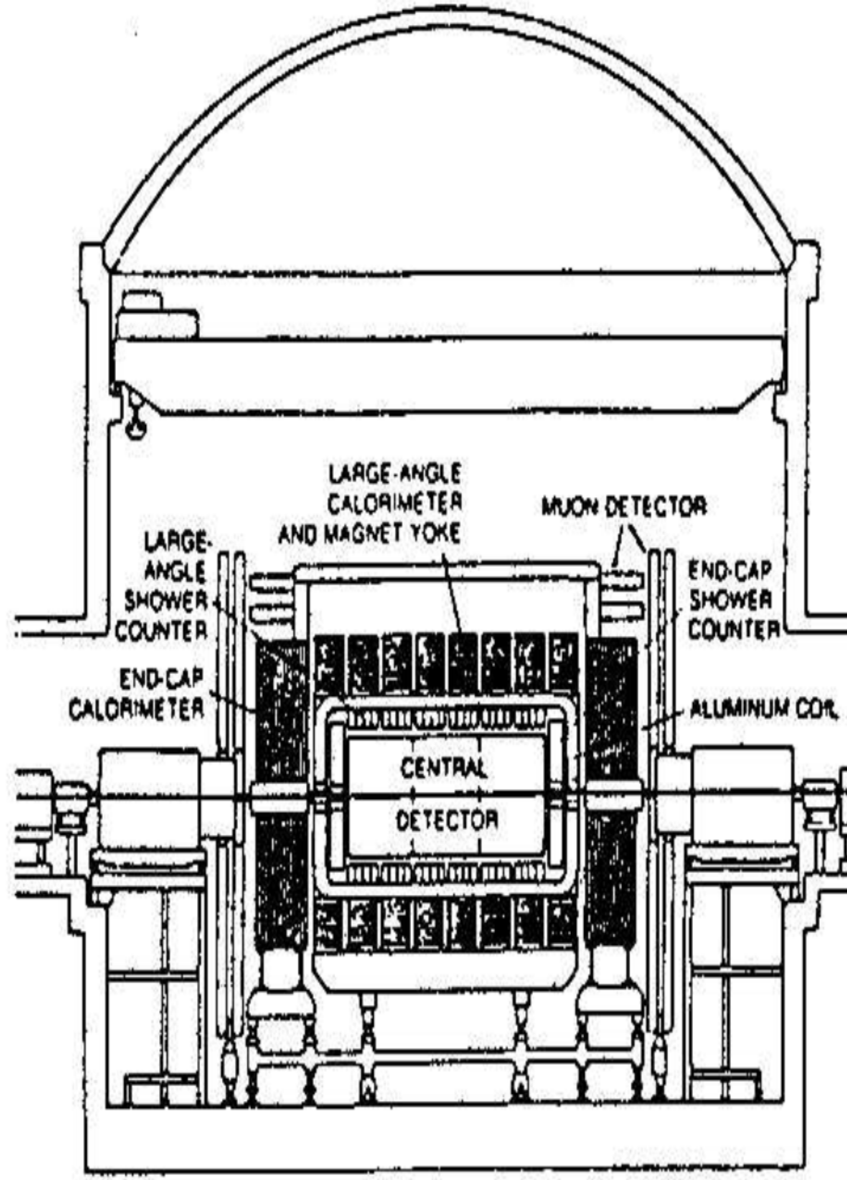
Carlo Rubbia
Simon Van der Meer

[Nobel prize 1984]

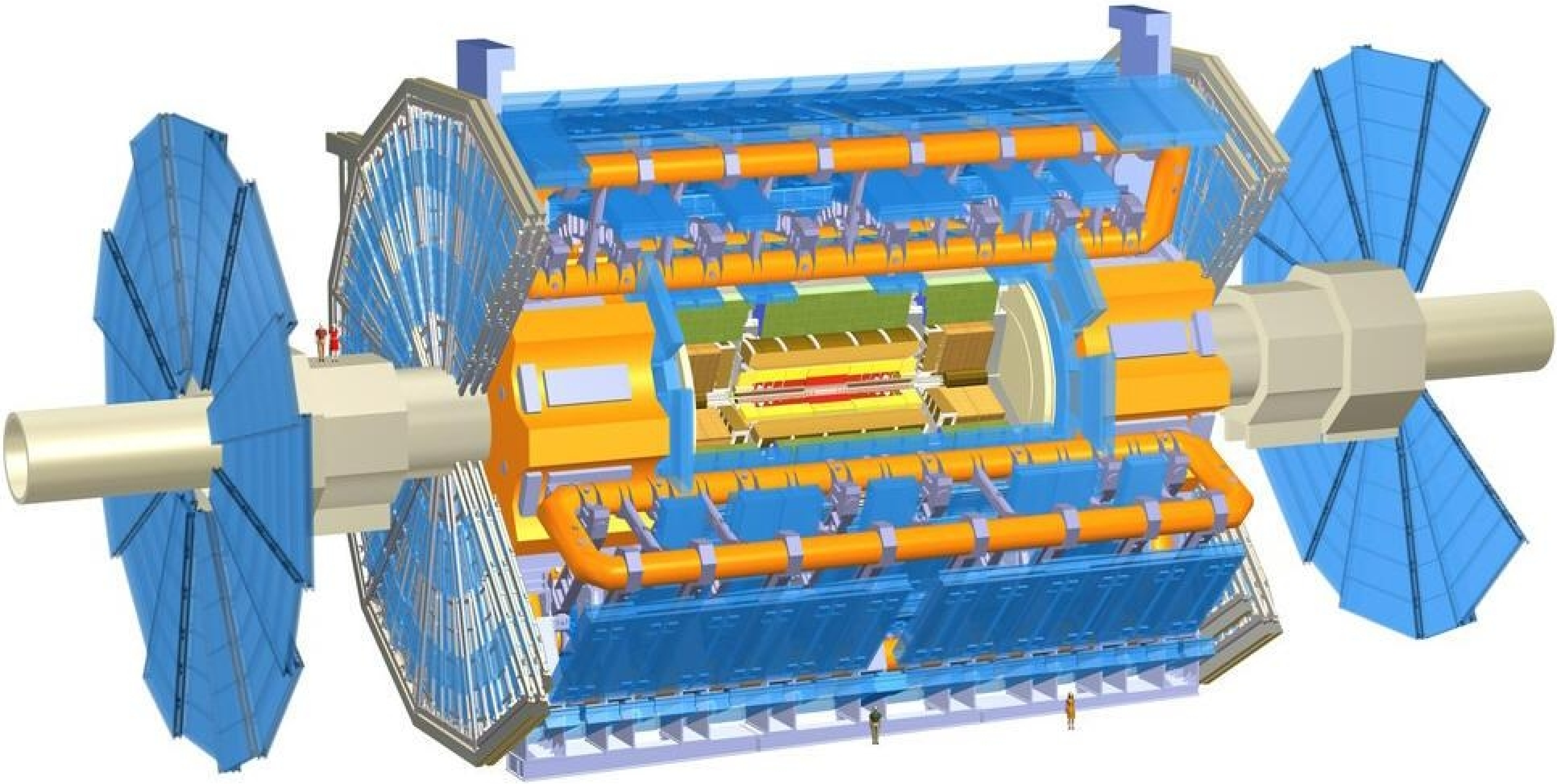
First Z^0 in UA1 experiment

$Z \rightarrow e^+ + e^-$

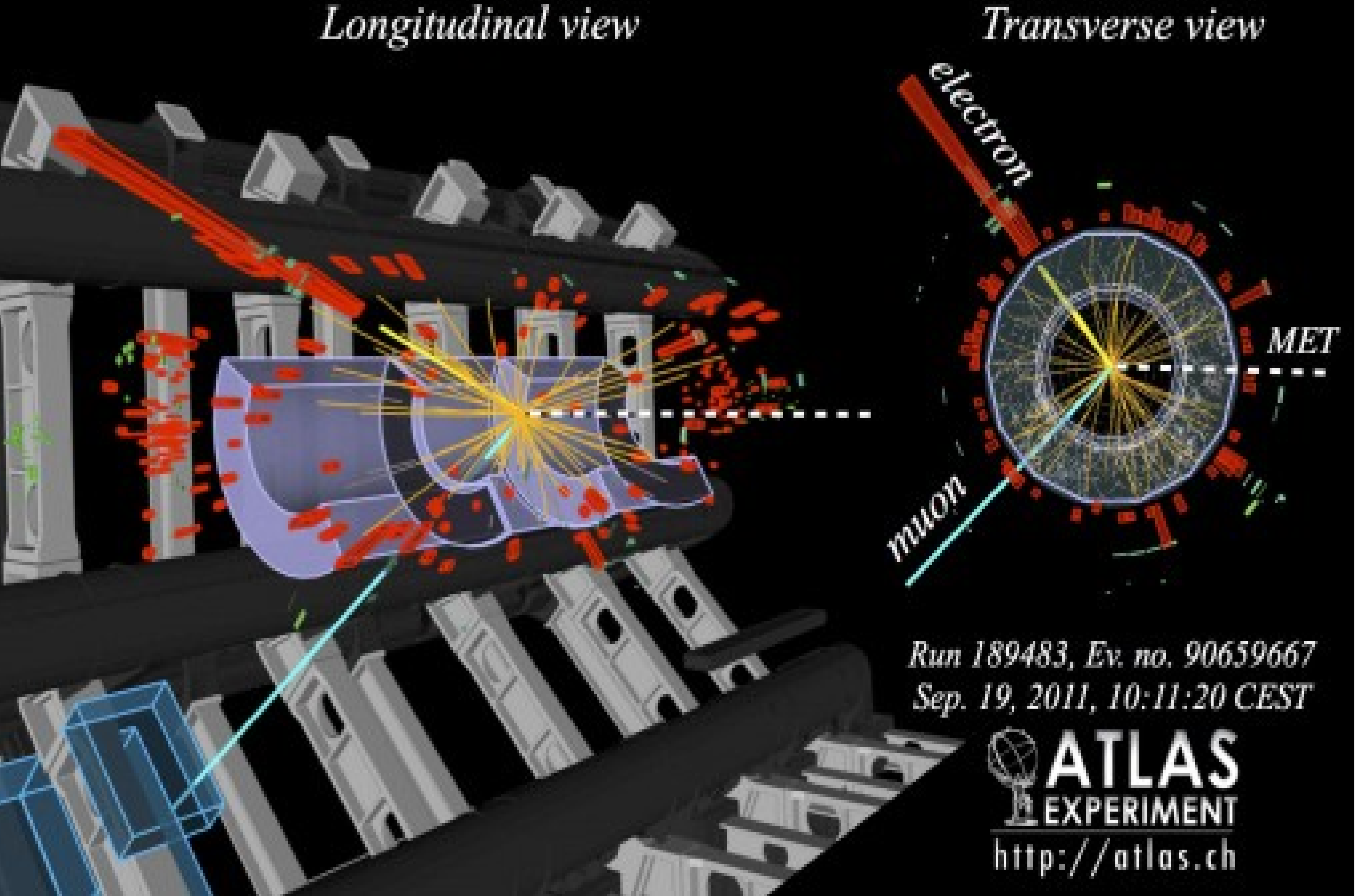


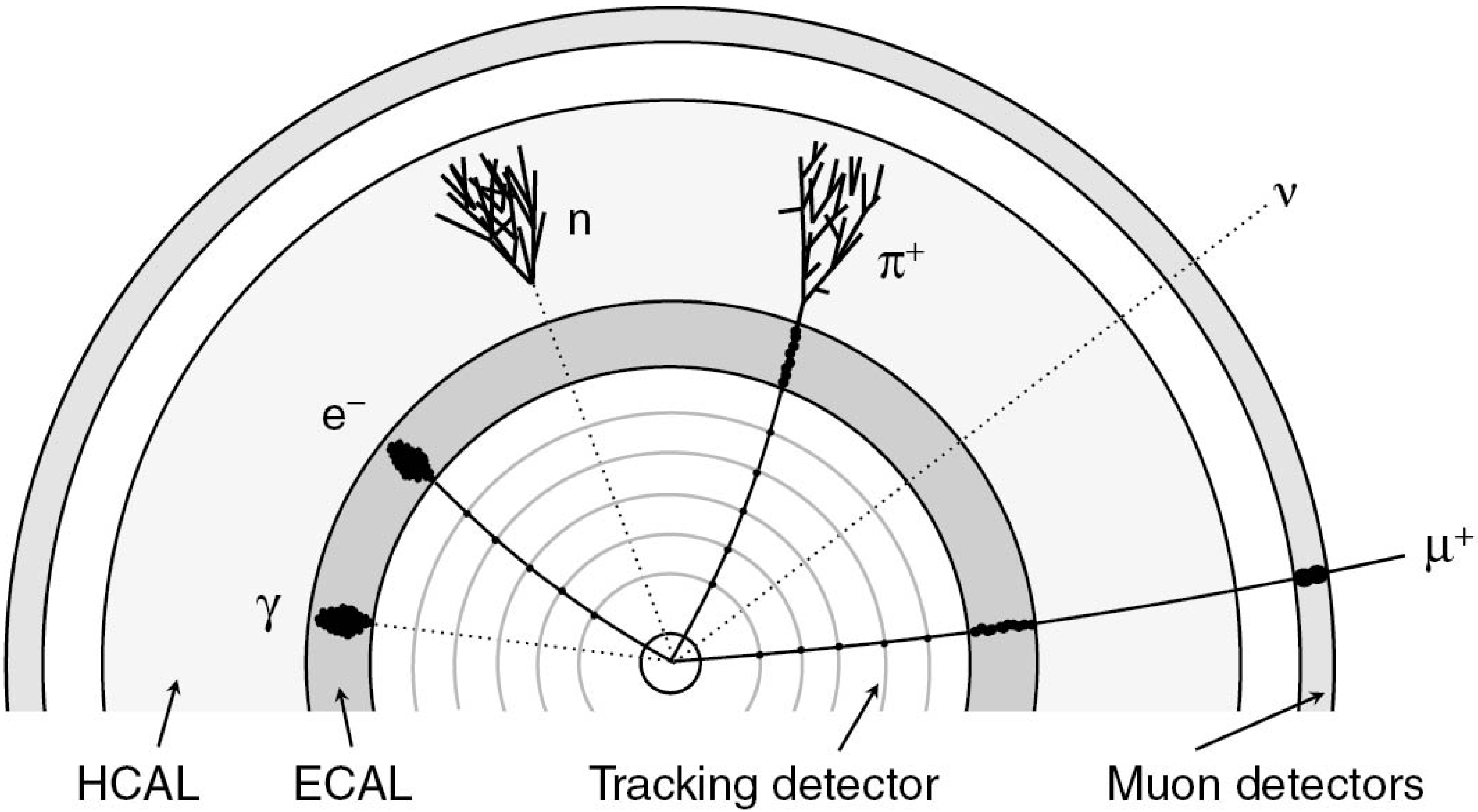


The ATLAS experiment



(a) $H \rightarrow WW^* \rightarrow e\nu\mu\nu$ candidate and no jets





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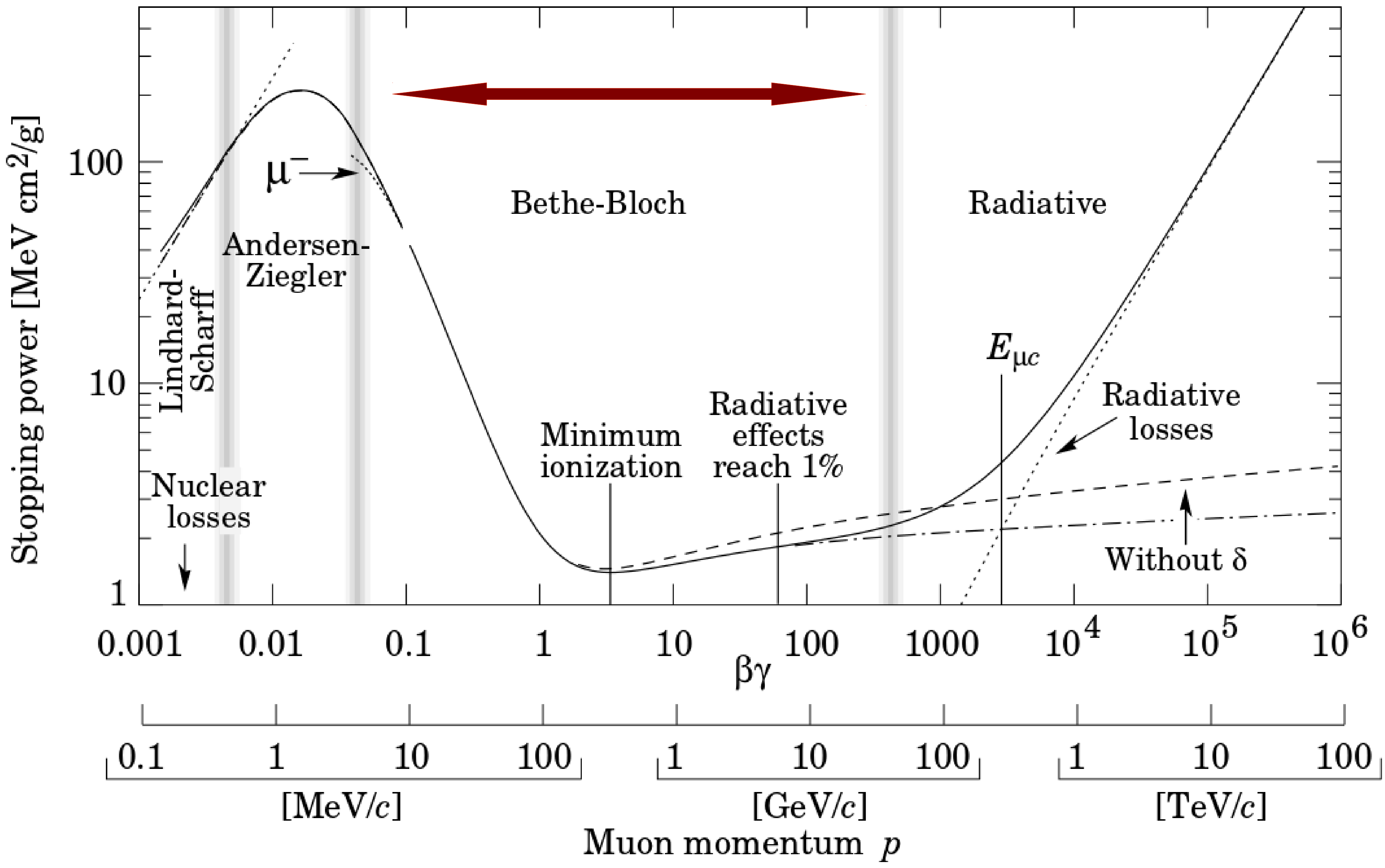
Muon Energy Loss



Energy Loss of Heavy Charged Particles

a) Ionisation and excitation in scattering process

MEAN energy loss given by Bethe Bloch formula

$$-\frac{dE}{dx} = K\,\rho\,\frac{Z}{A}\,\frac{z^2}{\beta^2}\left[\frac{1}{2}\,ln\left(\frac{2\,me\,c^2\beta^2\gamma^2}{I}\right)^2 - \beta^2 - \frac{\delta}{2}\right]$$

$\gamma = E/m$

$\beta = p/E$

N_A Avogadro's number

z charge of incident particle

Z atomic number of absorber

A atomic mass of absorber [g/mol]

$K/A = 4\pi\, N_A\, r_e^2\, m_e\, c^2/A = 0.307075$ MeV g^{-1} cm^2 for A = 1 g/mol

r_e classical electron radius $e^2/4\pi\varepsilon_0\, m_e\, c^2$

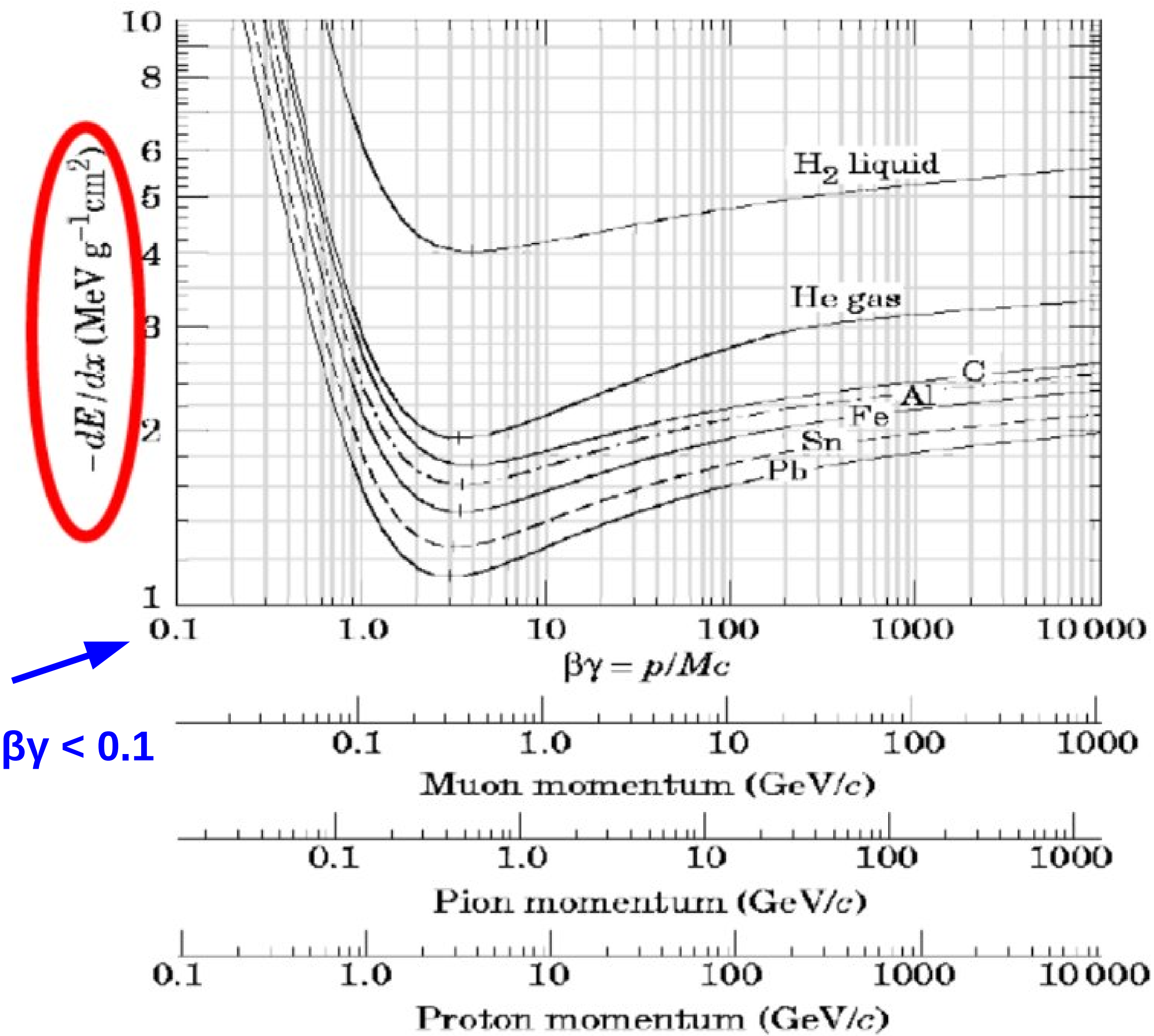
I mean excitation energy [eV] (for $Z > 20$: $I = 10\,Z$ eV)

ρ density

δ density correction to ionization energy loss

Bethe Bloch is an empirical formula/approximation valid of ± 5% up to several 100 GeV. Not valid at very low momenta.

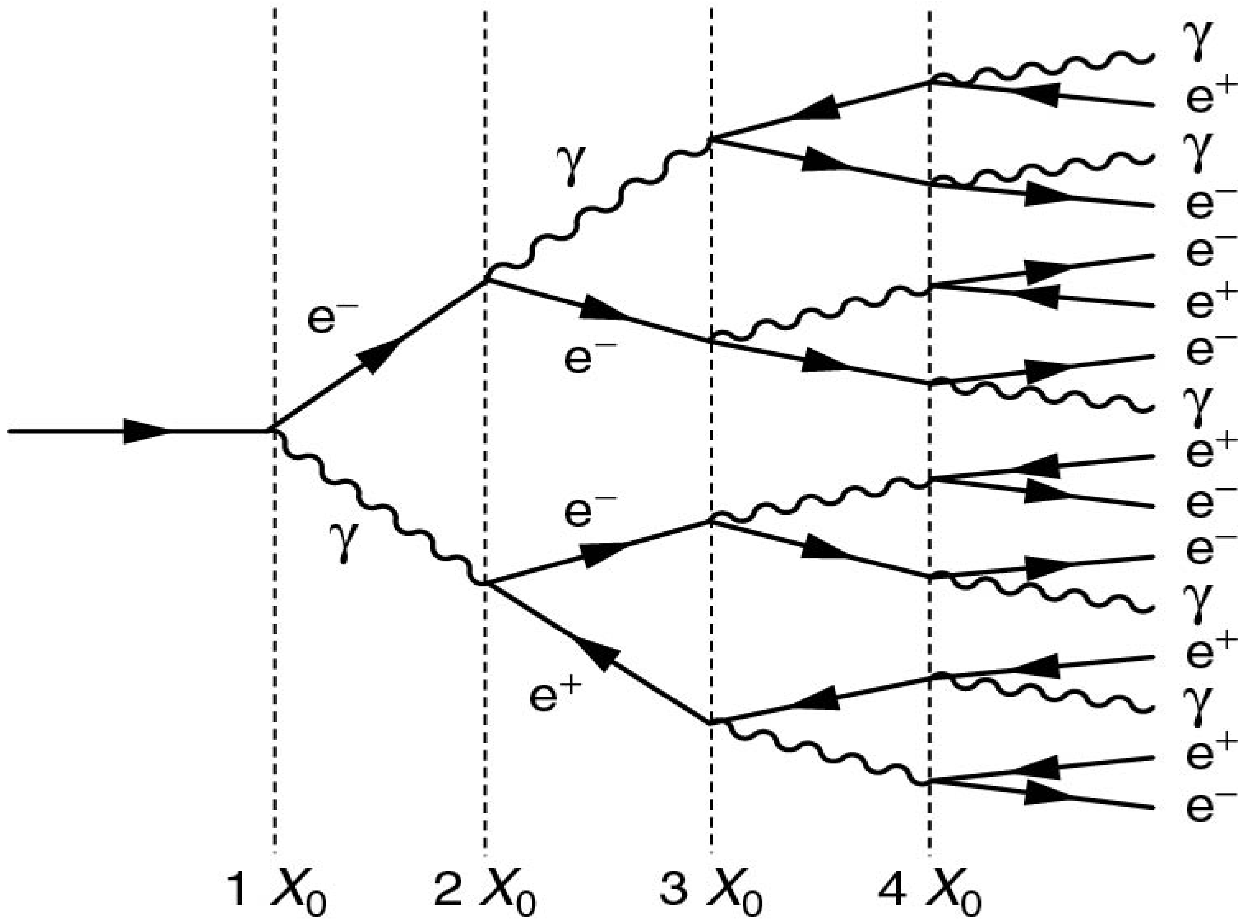
Bethe Bloch II



Bethe-Bloch
not valid below βγ < 0.1

Less material dependent: $-\frac{dE}{dx}\frac{1}{\rho}$

Electromagnetic Shower



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Hadronic Shower

N