Berömda Experiment

1933	Upptäckten av positronen	→	boken 1.2
1968	Upptäckten av kvarkar	→	boken 7.4
1973	Upptäckten av neutral ström	→	boken 8.0
1974	Upptäckten av J/ψ	→	boken 3.4
1979	Upptäckten av gluonen	→	boken 7.2
1983	Upptäckten av Z^0 och $W^{\pm}$	→	boken 8.1

Upptäckten av positronen (1933)

Laboratorium = California Institute of Technology

Accelerator = Universum ($E_{beam} = 1 - 10^{11}$ GeV)

Experiment = Kosmiskt dimkammarexperiment

Processer = Tex $p + O \longrightarrow \pi^+ + X$

$\hookrightarrow \mu^+ + \nu_\mu$

$\hookrightarrow e^+ + \nu_e + \bar{\nu}_\mu$

Nobelpristagare = Anderson

Kosmisk strålning

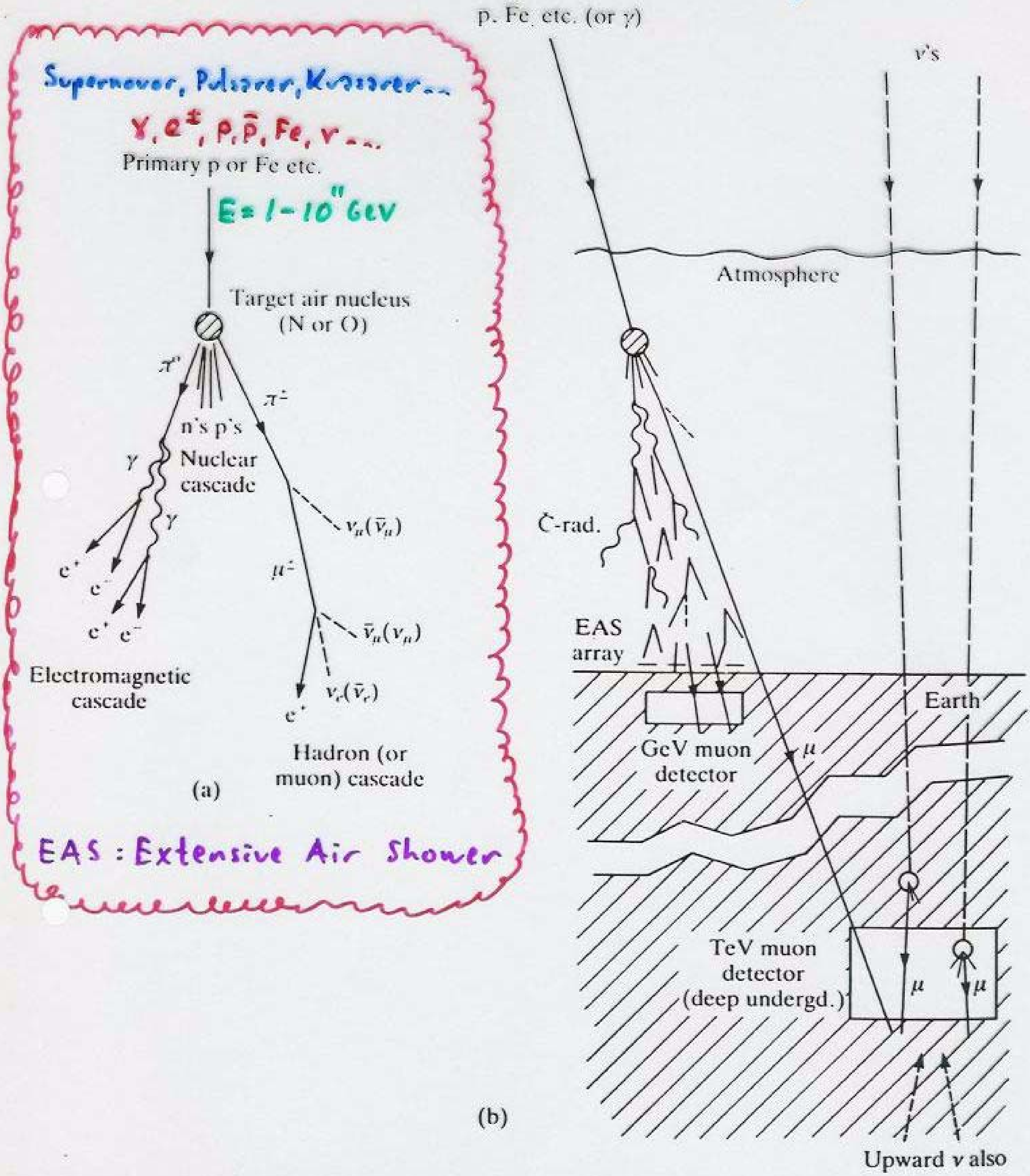
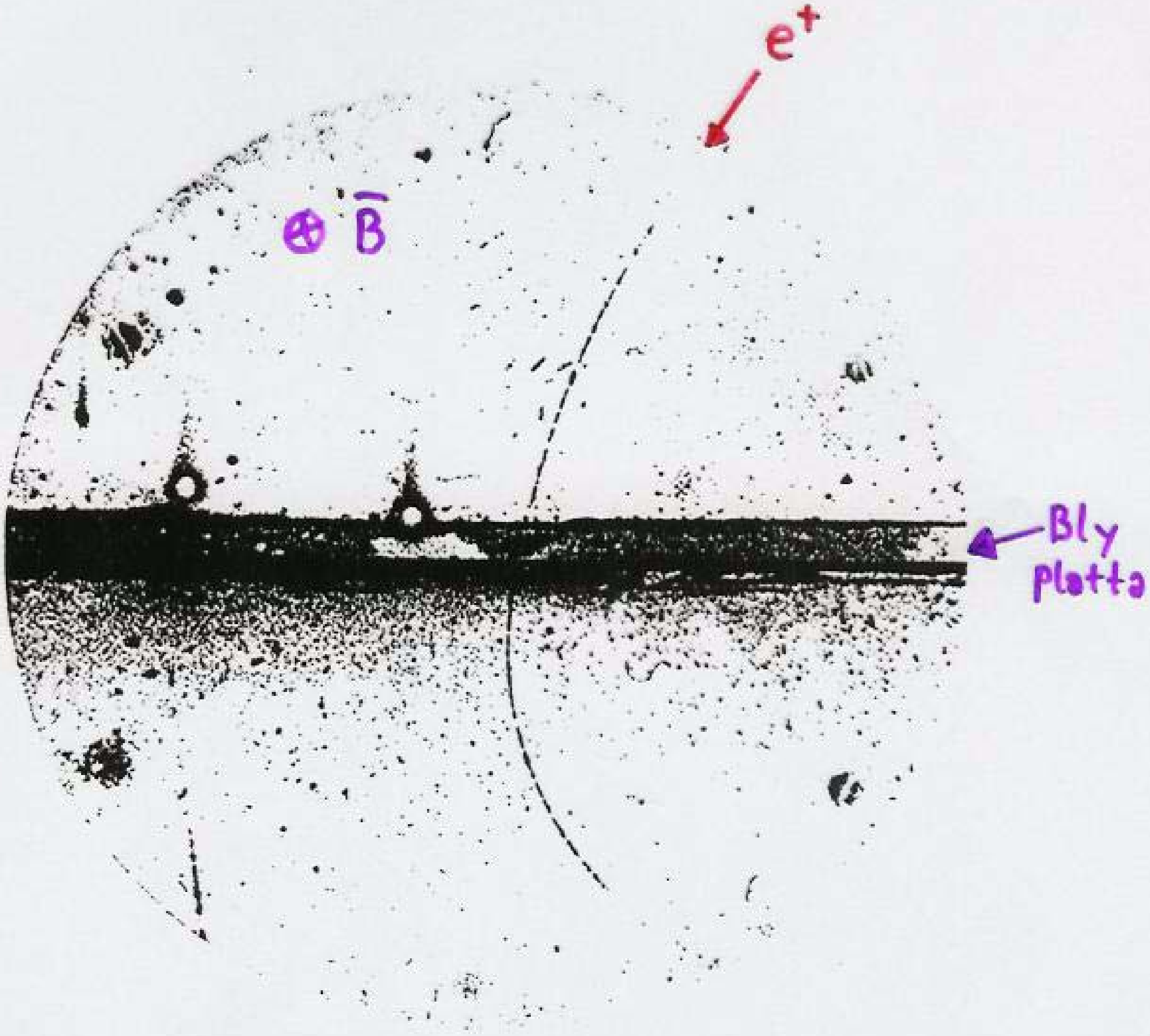


Fig. 18.3 (a) The development of an air shower caused by a primary proton or heavy nucleus hitting an air nucleus, and producing a nuclear cascade of neutrons and protons, as well as pions which subsequently decay and produce electromagnetic cascades (via $\pi^0 \rightarrow \gamma\gamma$) or so-called "hadron" cascades through $\pi^{\pm} \rightarrow \mu^{\pm}\nu$. (b) A summary of the techniques used to observe cosmic ray particles. The Čerenkov radiation that accompanies the cascade can be detected on Earth by Čerenkov telescopes even when the cosmic-ray shower does not penetrate to the ground.

Dimkammarbild av en positron



Upptäckten av "neutral current" (1973)

Laboratorium = CERN

Accelerator = PS

Experiment = Gargamelle (νN fixed target)

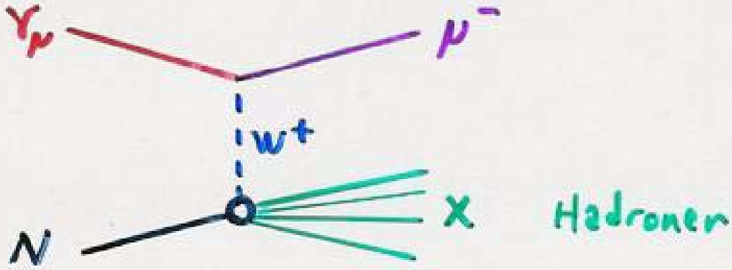
Processer =

$$\left.\begin{array}{l} \nu_\mu + N \rightarrow \nu_\mu + X \\ \bar{\nu}_\mu + N \rightarrow \bar{\nu}_\mu + X \end{array}\right\} \text{Neutral current}$$

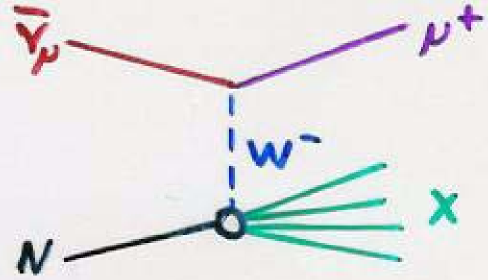
$$\left.\begin{array}{l} \nu_\mu + N \rightarrow \mu^- + X \\ \bar{\nu}_\mu + N \rightarrow \mu^+ + X \end{array}\right\} \text{Charged current}$$

Charged current:

$\nu_\mu + N \rightarrow \mu^- + X$

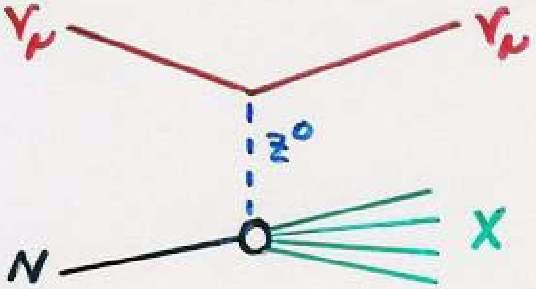


$\bar{\nu}_\mu + N \rightarrow \mu^+ + X$

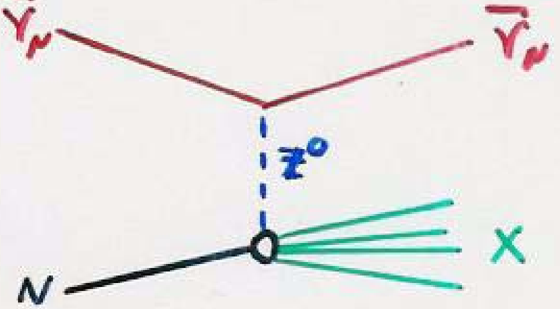


Neutral current:

$\nu_\mu + N \rightarrow \nu_\mu + X$

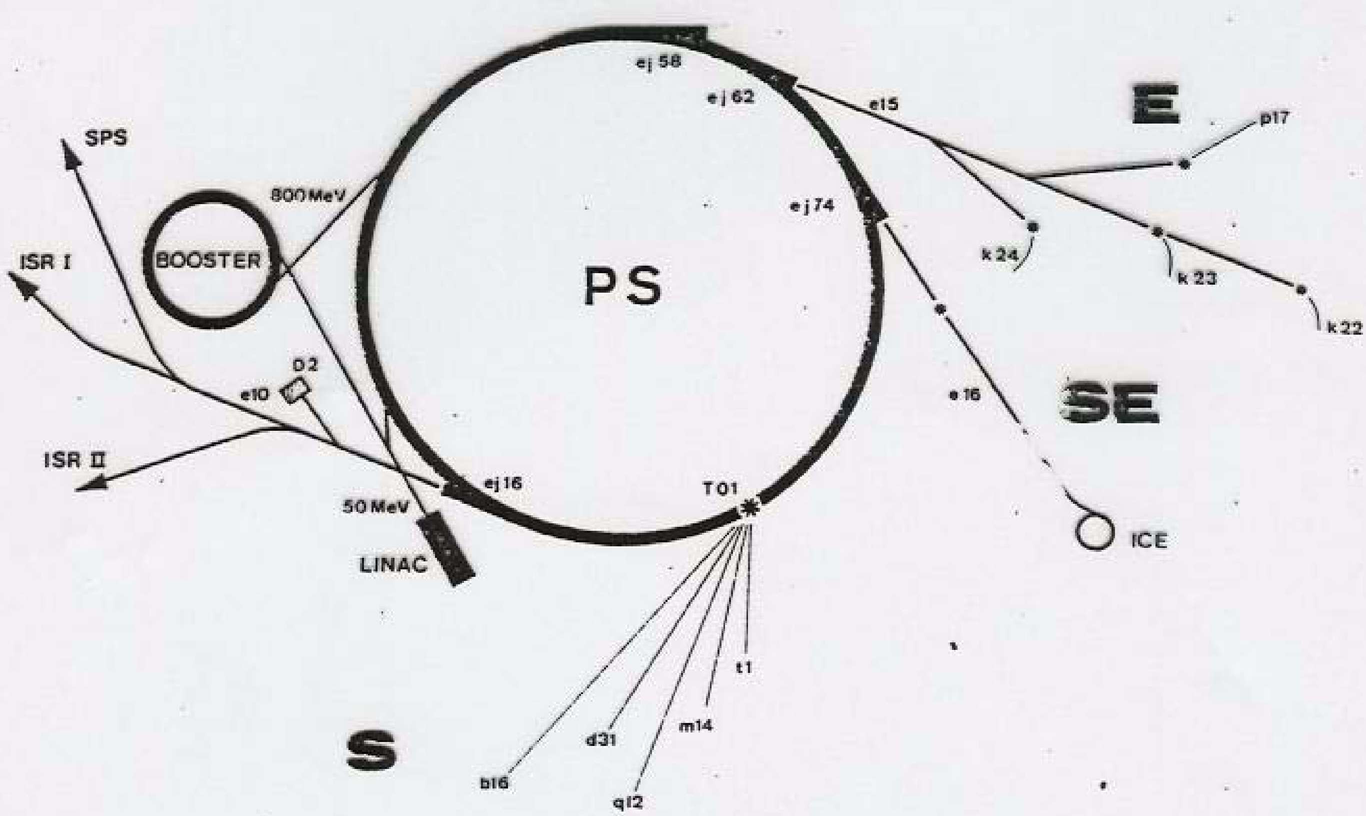


$\bar{\nu}_\mu + N \rightarrow \bar{\nu}_\mu + X$



OBS: En neutrino kan ej växelverka elektromagnetiskt dvs genom fotonutbyte.

PS - Acceleratorn



D2: *external dump, buried in the earth outside the ring wall; mainly used for adjustment of the extraction systems providing beam for the SPS and ISR and for PS machine development.*

SOUTH HALL (S)

Target 01: five beams are derived from this target:

- t_1: *for tests; ~ 1 GeV/c;*
- m_{14}: *partially separated; mainly $\bar{p}$ up to 0.9 GeV/c;*
- q_{12}: *test beam $\leq$ 4.4 GeV/c;*
- d_{31}: $\pi^+ \leq 10$ *GeV/c;*
- b_{16}: *neutrals at 0° production angle; protons for tests.*

EAST HALL (E)

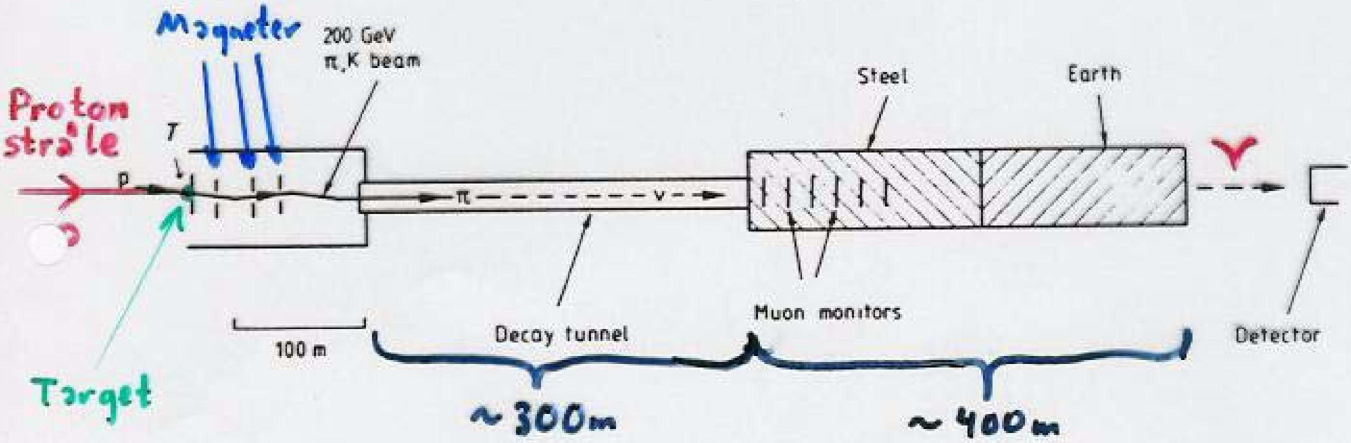
Slow extraction from straight-section 62; the primary beam, e_{15}, is divided into three branches, and from targets in these four secondary beams are derived:

- p_{17}: *π beam with high momentum resolution; 6-15 GeV/c;*
- k_{22}: *separated $K^{\pm}$ ~ 1 GeV/c;*
- k_{23}: *separated $\bar{p}$ ~ 1 GeV/c;*
- k_{24}: *separated K^- $\leq$ 1.5 GeV/c.*

SOUTH-EAST AREA (SE)

e_{16}: *(i) protons between 50 MeV and 2.1 GeV/c for ICE, or (ii) protons of up to 18 GeV/c on a target to supply antiprotons to the ICE ring.*

Tillverkning av en neutrinostråle



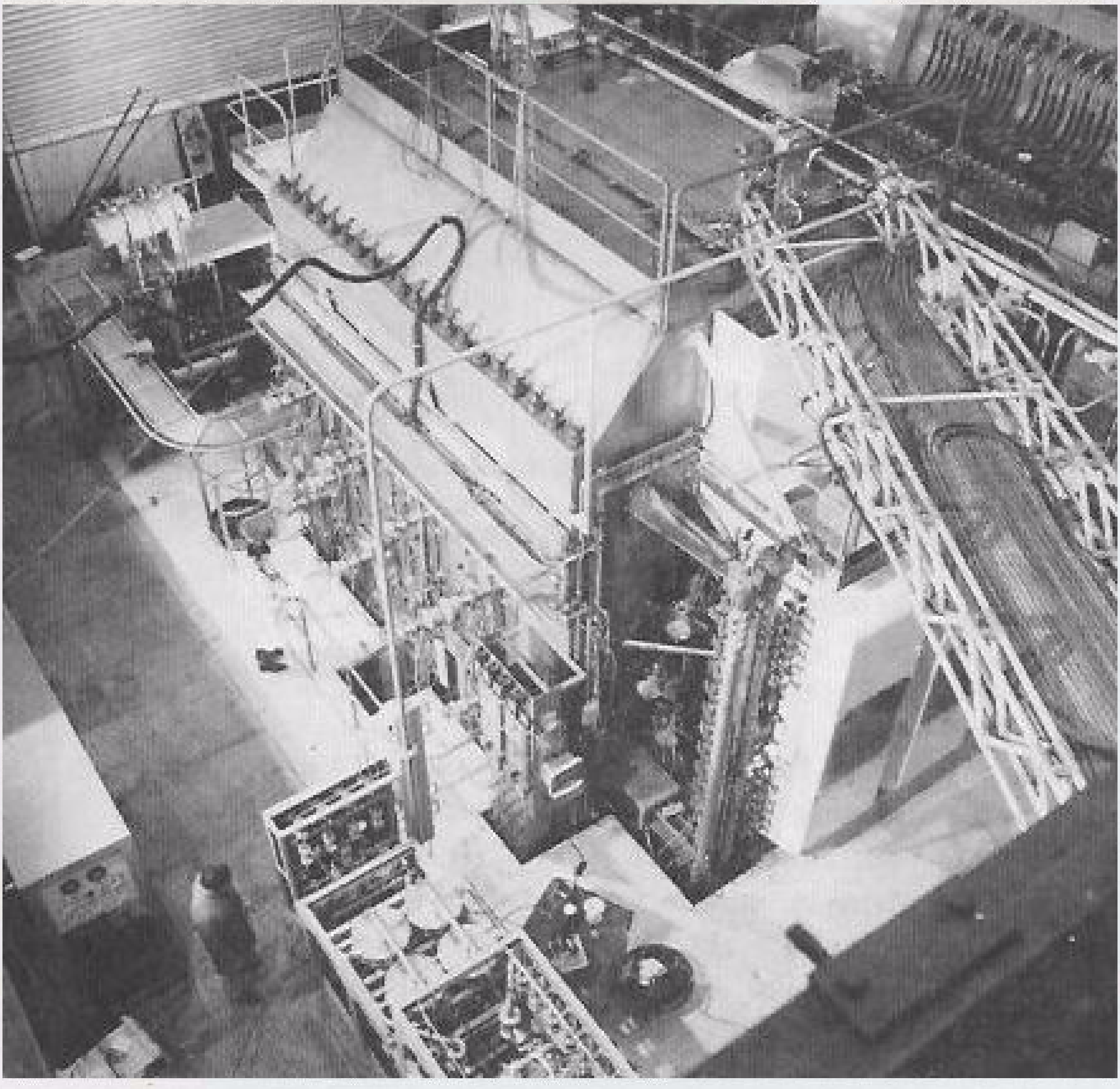
$$\pi^+ \rightarrow \mu^+ + \nu_\mu$$
$$\quad \hookrightarrow e^+ + \nu_e + \bar{\nu}_\mu$$

$$\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$$
$$\quad \hookrightarrow e^- + \bar{\nu}_e + \nu_\mu$$

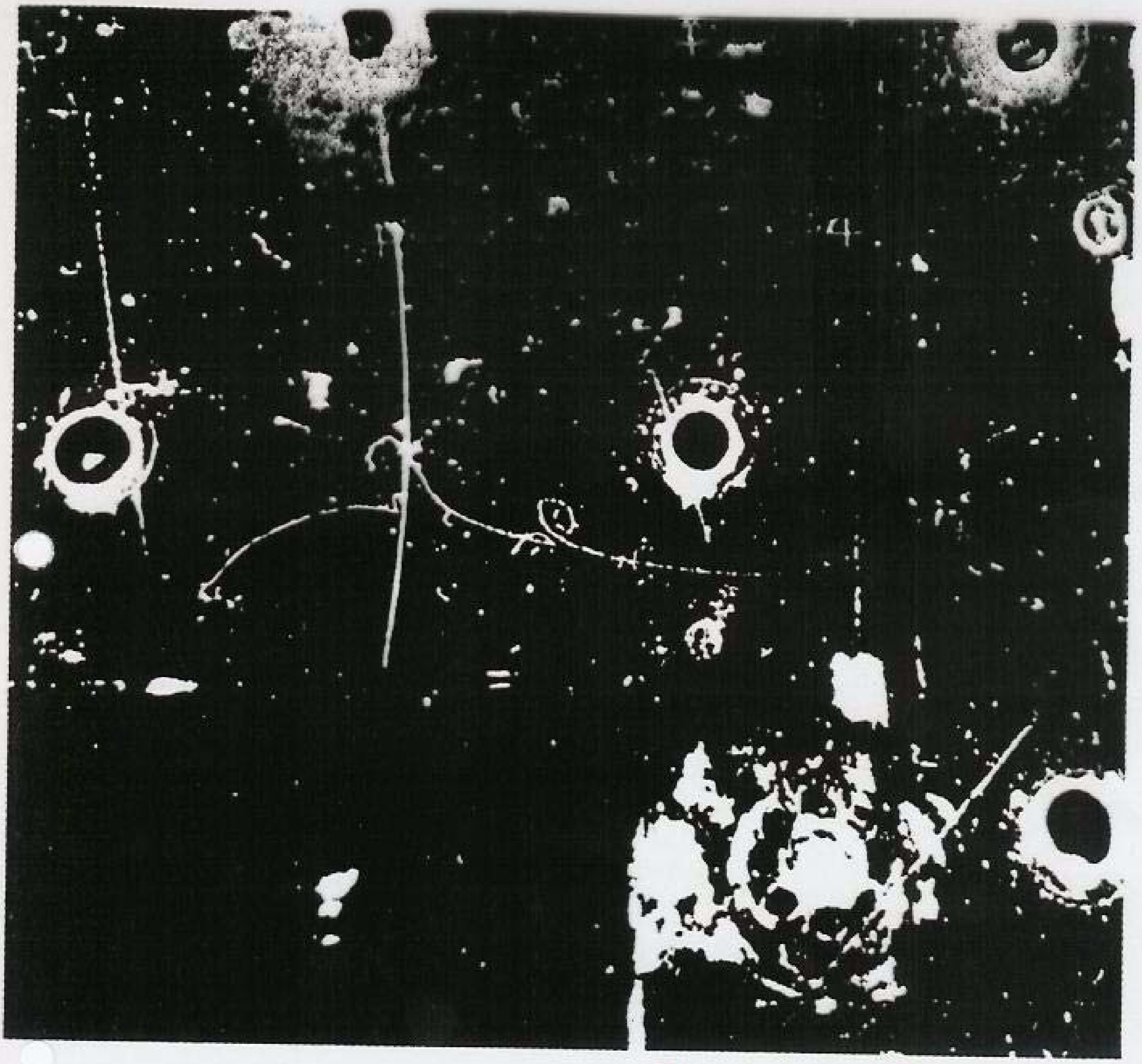
$$\left(K^\pm \rightarrow \mu^\pm + \nu_\mu \right)$$

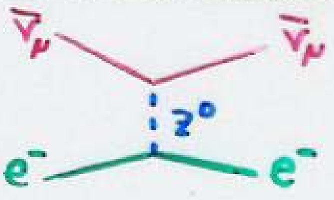
GARGAMELLE

6.4 Bubbelkammaren GARGAMELLE vid CERN (utsidan). Kammaren är fylld med en speciell vätska. Så fort en stråle med neutriner far igenom kammaren reducerar man plötsligt trycket i kammaren. De laddade partiklarna bildar spår i kammaren bestående av blåsor, vilka fotograferas. Kammaren är omgiven av en magnet, som skapar ett starkt magnetfält i kammarens inre. Av riktning och styrka på de laddade partiklarnas avböjning i magnetfältet kan man dra slutsatser om deras energi och laddning.



Bubbelkammarbild av en "neutral ström" händelse





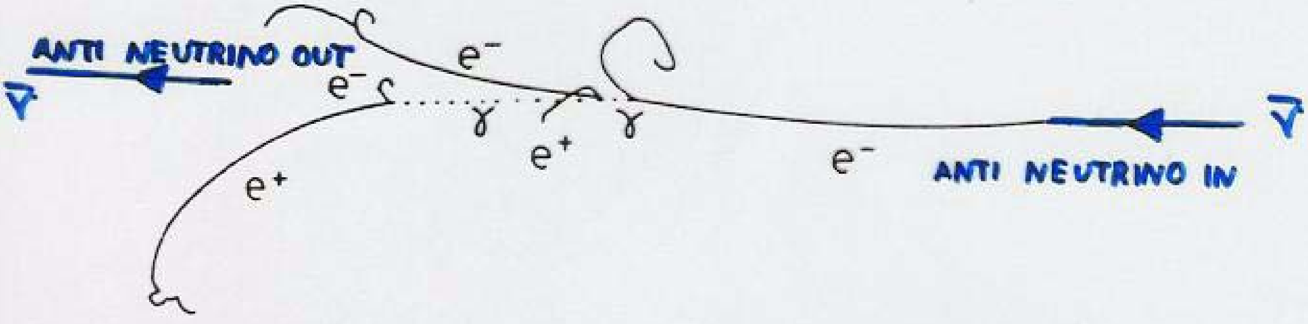
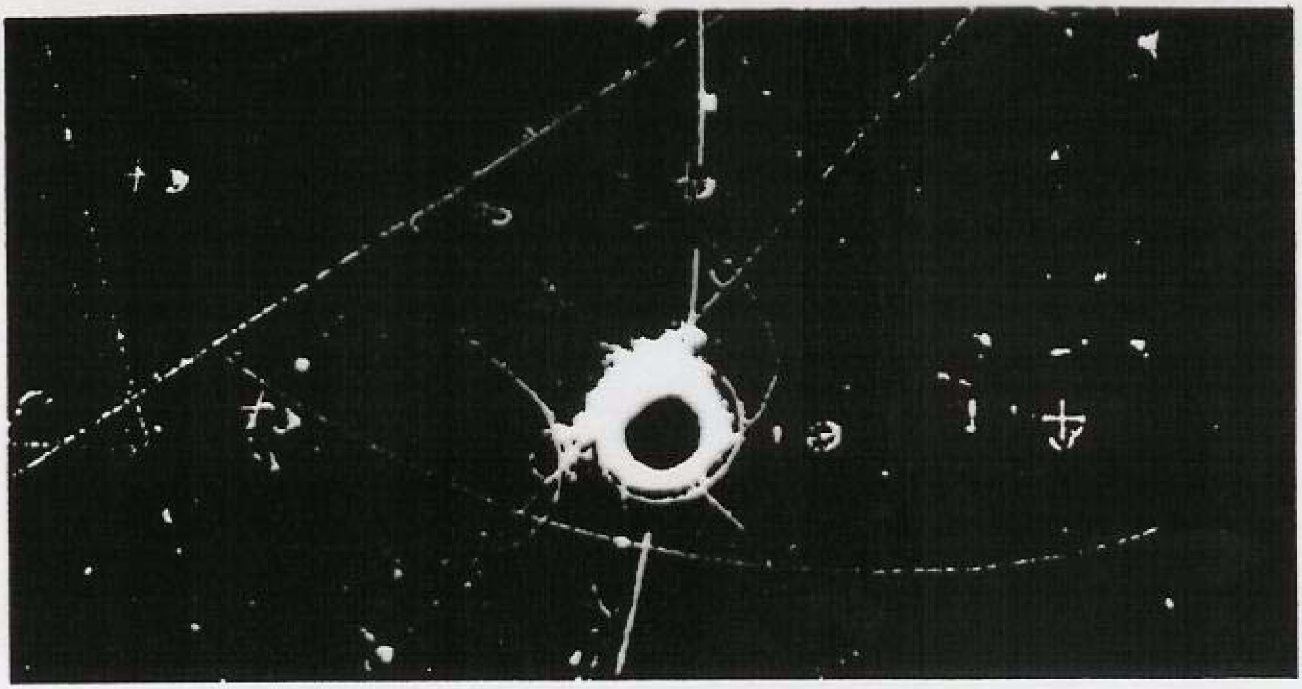
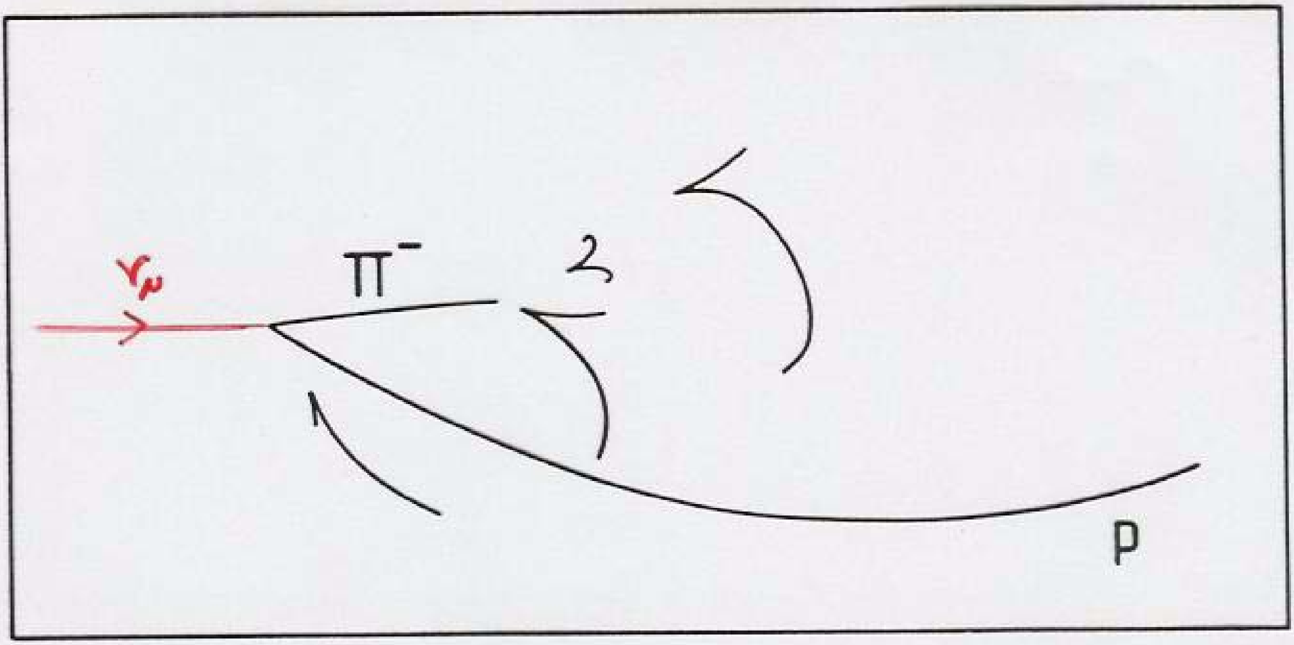
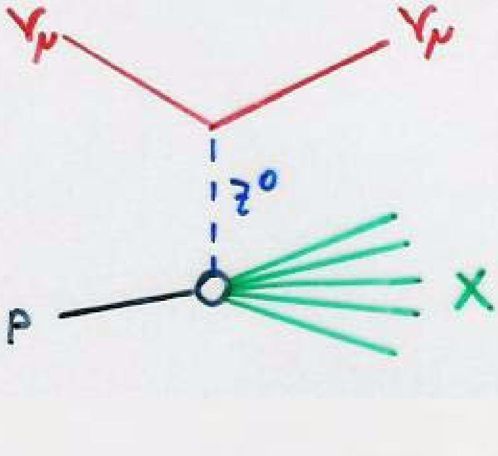


Fig. 8.4 Photograph of the first weak neutral-current event $\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$ recorded in the Gargamelle Bubble Chamber (Hasert, 1973a). (Photograph courtesy CERN.) The annotated line diagram shows the identities of particles seen and unseen (γ and $\bar{\nu}$).





ν_μ
π^-
p



ν_μ
ν_μ
Z^0
p
X

Upptäckten av $Z^0, W^\pm$ (1983)

Laboratorium = CERN

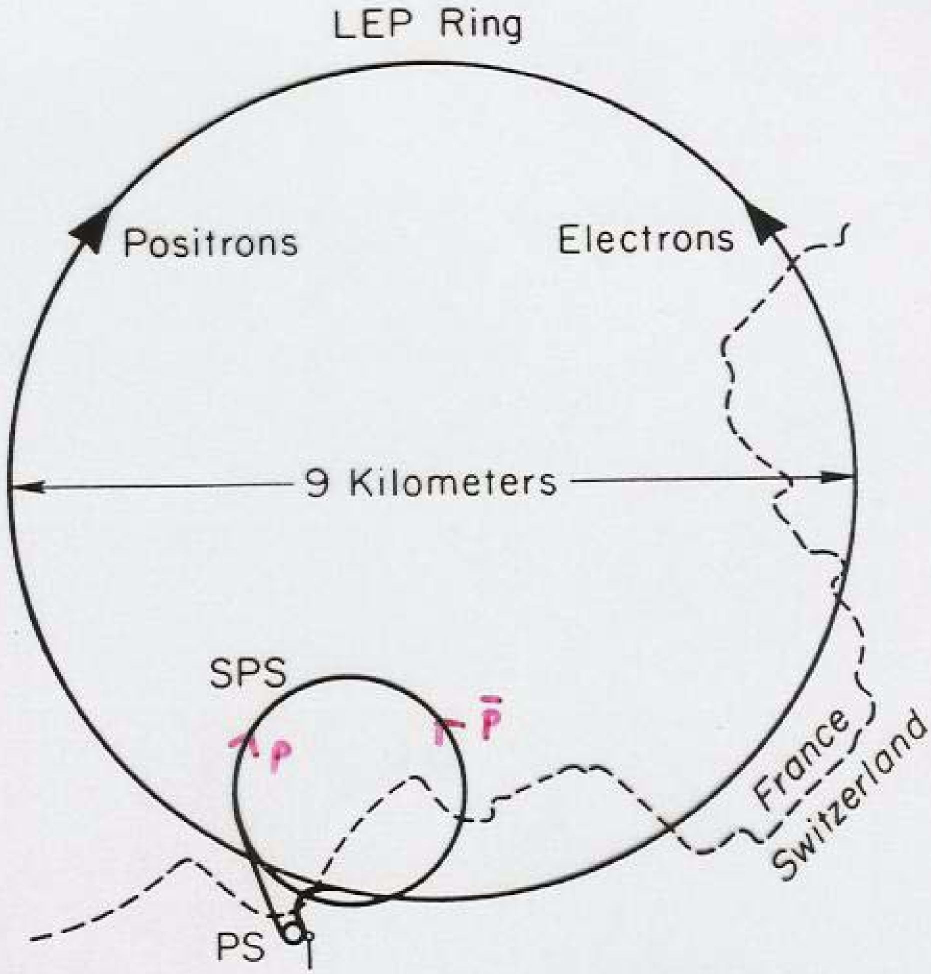
Accelerator = $Sp\bar{p}S$ ($\sqrt{s} = 540-900$ GeV)

Experiment = UA1 + UA2 ($p\bar{p}$ kollisions experiment)

Processer =

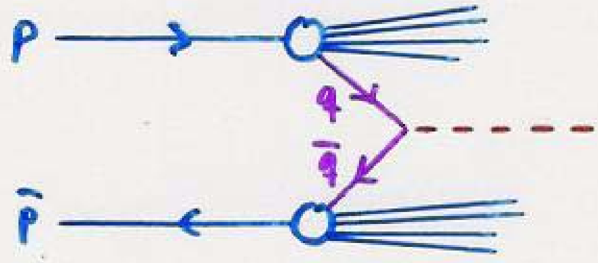
$$\begin{cases} \bar{p}+p \rightarrow W^+ + X^- \rightarrow l^+ + \nu_l + X^- \\ \bar{p}+p \rightarrow W^- + X^+ \rightarrow l^- + \bar{\nu}_l + X^+ \\ \bar{p}+p \rightarrow Z^0 + X^0 \rightarrow l^+ + l^- \end{cases} \quad \begin{pmatrix} \text{där} \\ l^+ = e^+, \mu^+ \\ l^- = e^-, \mu^- \end{pmatrix}$$

Nobelpristagare = Rubbia + Van der Meer



- **Tvärsnitt:** ca 1 Z^0 produceras per 10^8 $p\bar{p}$ kollisioner
  ca 1 $W^\pm$ produceras per 10^7 $p\bar{p}$ kollisioner

- **Produktion:**



Z^0 ($q\bar{q} = u\bar{u},\ d\bar{d}$)
$W^\pm$ ($q\bar{q} = u\bar{d},\ d\bar{u}$)

- **Sönderfall:**

$W^- \to$
- $e^- + \bar{\nu}_e$
- $\mu^- + \bar{\nu}_\mu$
- $\tau^- + \bar{\nu}_\tau$
- $q + \bar{q}$

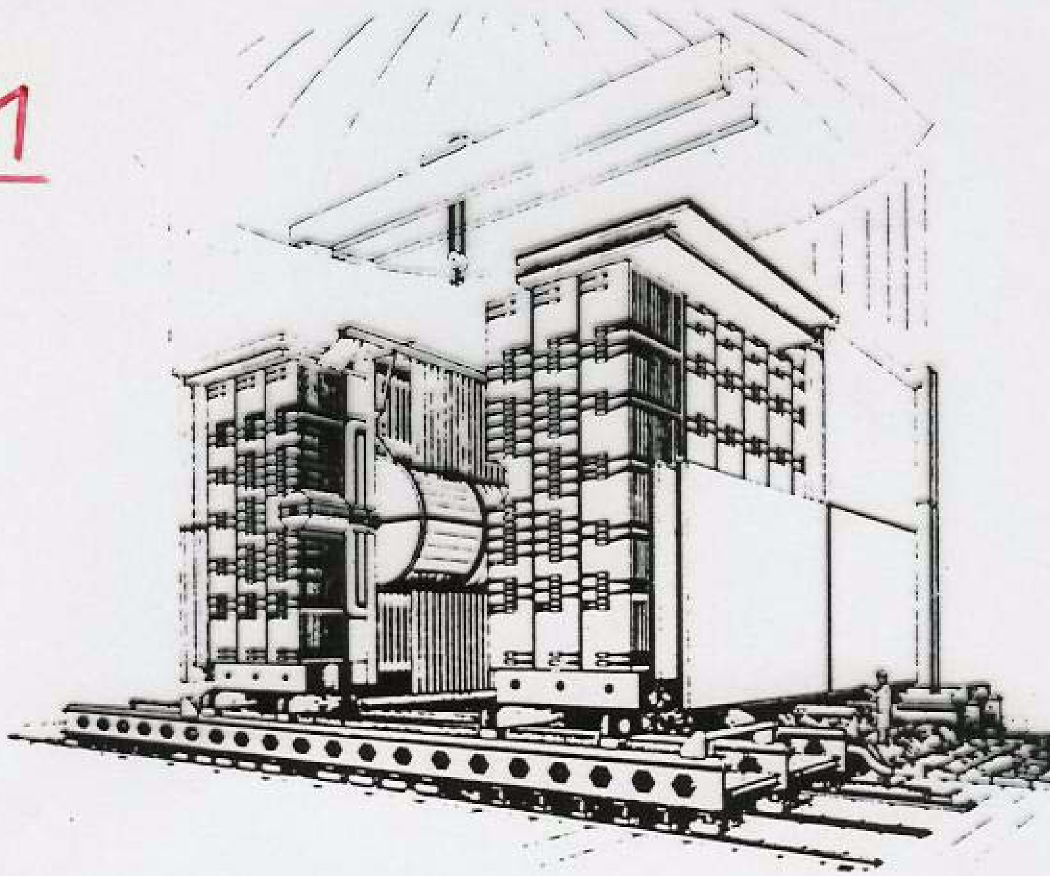
$W^+ \to$
- $e^+ + \nu_e$ ca 10%
- $\mu^+ + \nu_\mu$ ca 10%
- $\tau^+ + \nu_\tau$ ca 10%
- $q + \bar{q}$

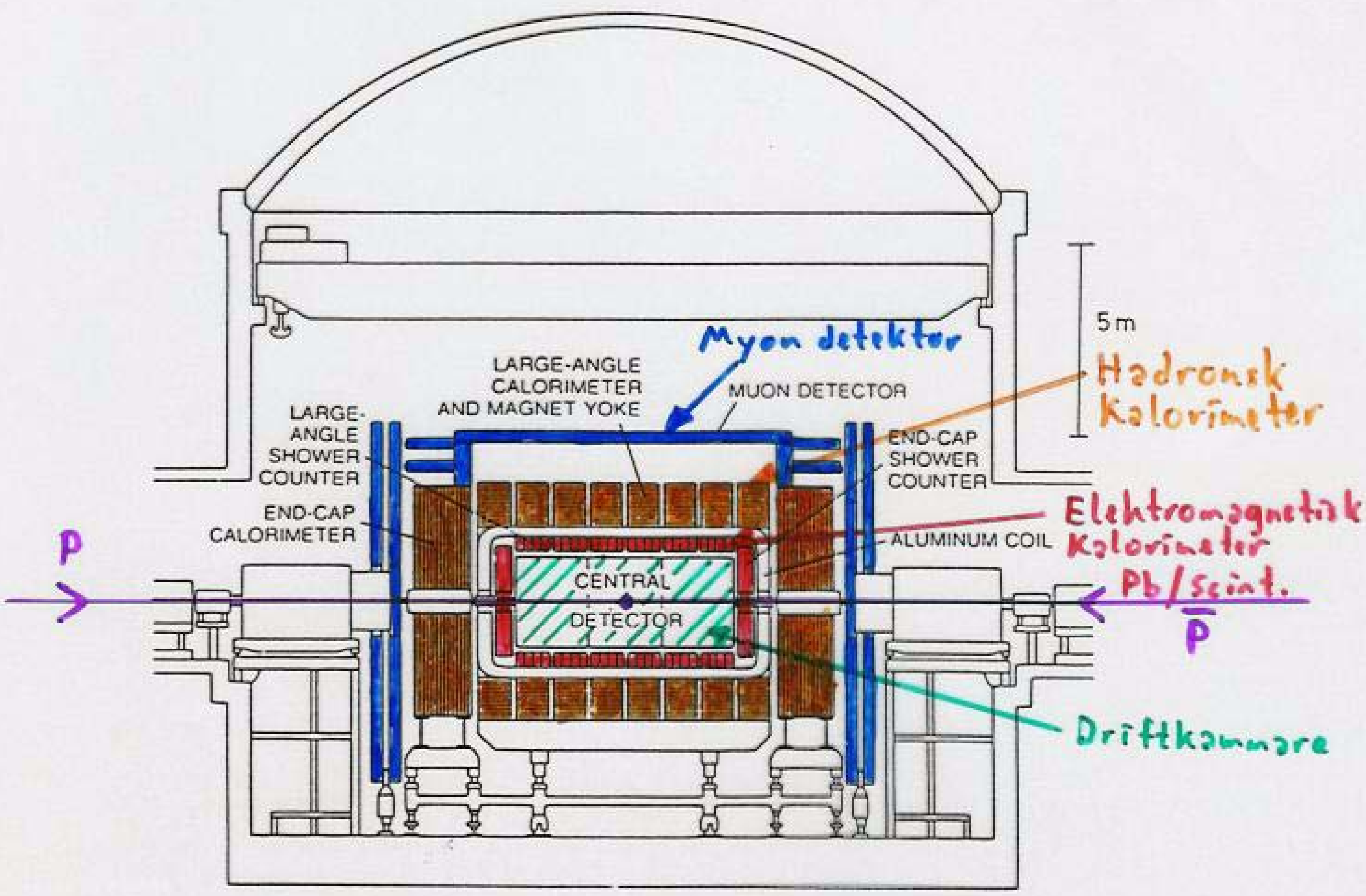
$Z^0 \to$
- $e^+ + e^-$ ca 3%
- $\mu^+ + \mu^-$ ca 3%
- $\tau^+ + \tau^-$ ca 3%
- $q + \bar{q}$ ca 70%
- $\nu + \bar{\nu}$ ca 20%

- **Massa:**

$m_W = 81$ GeV
$m_Z = 92$ GeV

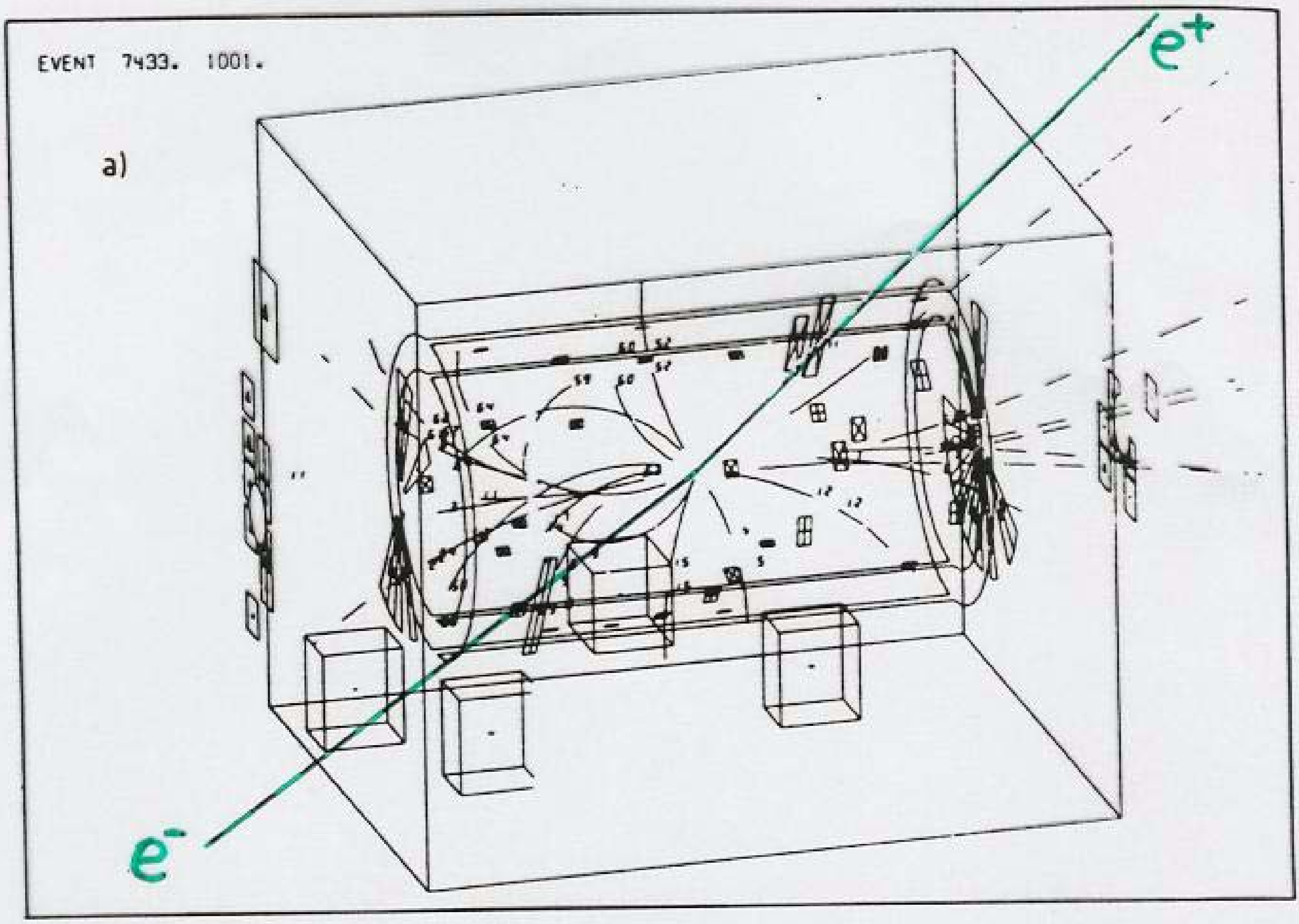
UA1




Myon detektor
LARGE-ANGLE CALORIMETER AND MAGNET YOKE
MUON DETECTOR
Hadronsk Kalorimeter
LARGE-ANGLE SHOWER COUNTER
END-CAP SHOWER COUNTER
END-CAP CALORIMETER
Elektromagnetisk Kalorimeter Pb/Scint.
ALUMINUM COIL
p
CENTRAL DETECTOR
$\bar{p}$
Driftkammare
5 m

UA1

$$p + \bar{p} \longrightarrow Z^0 + X^0$$
$$\hookrightarrow e^+ + e^-$$

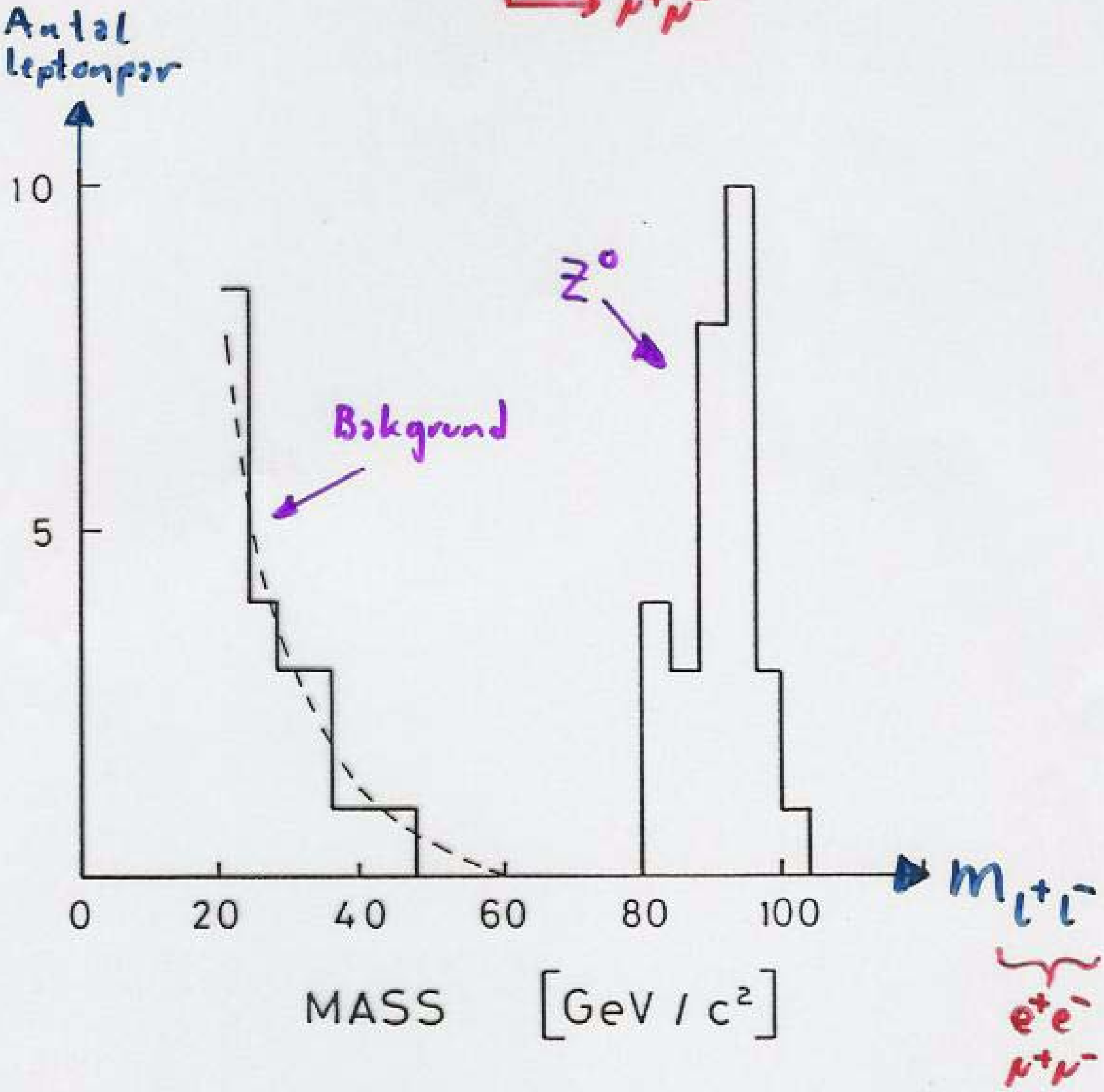


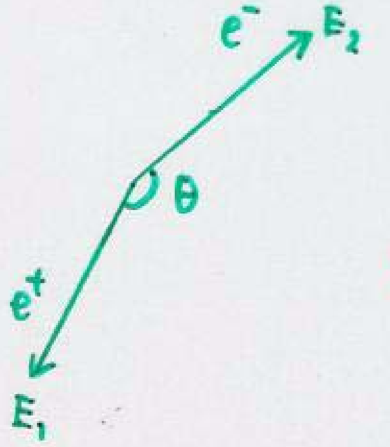
UA1

$$p\bar{p} \rightarrow Z^0 + X^0$$

$Z^0 \rightarrow e^+e^-$

$Z^0 \rightarrow \mu^+\mu^-$

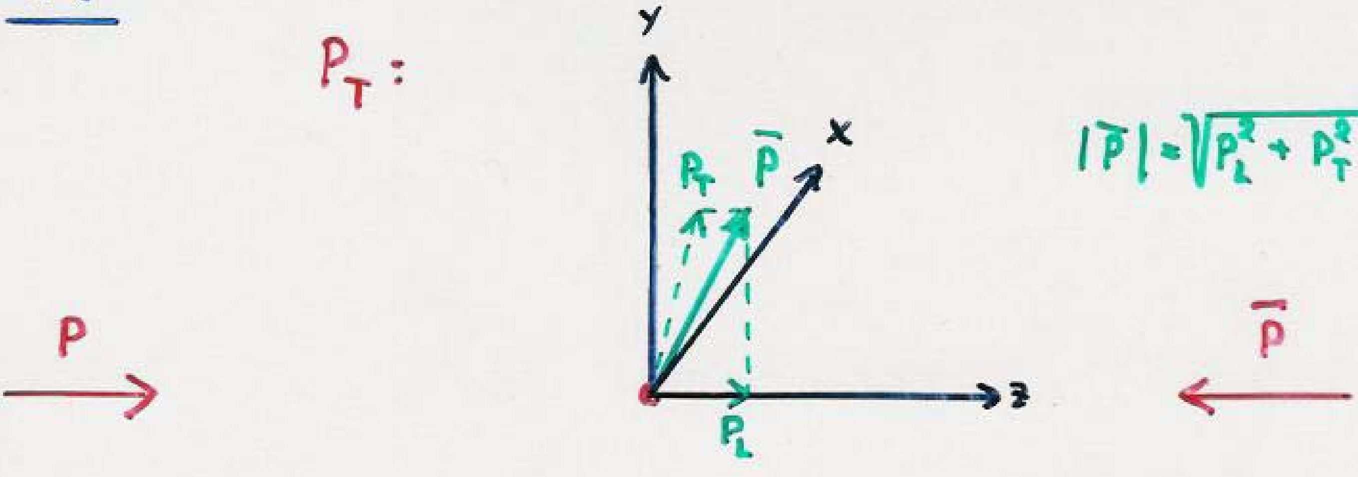




$$m^2_{e^+e^-} = (\vec{P_1} + \vec{P_2})^2 \approx 2E_1E_2(1-\cos\theta)$$

W

P_T:



P_T : Transversell rörelsemängd
P_L : Longitudinell rörelsemängd

$\left(\sum_i P_{T_i} = 0 \quad \text{där } i \text{ är alla partiklar} \right)$

Massan för ett par av masslösa partiklar med öppningsvinkeln θ ges av

$$m = \sqrt{2 P_1 P_2 (1 - \cos\theta)}$$

Den transversella massan för ett par av partiklar ges av

$$m_T = \sqrt{2 P_{T1} \cdot P_{T2} (1 - \cos\theta)}$$