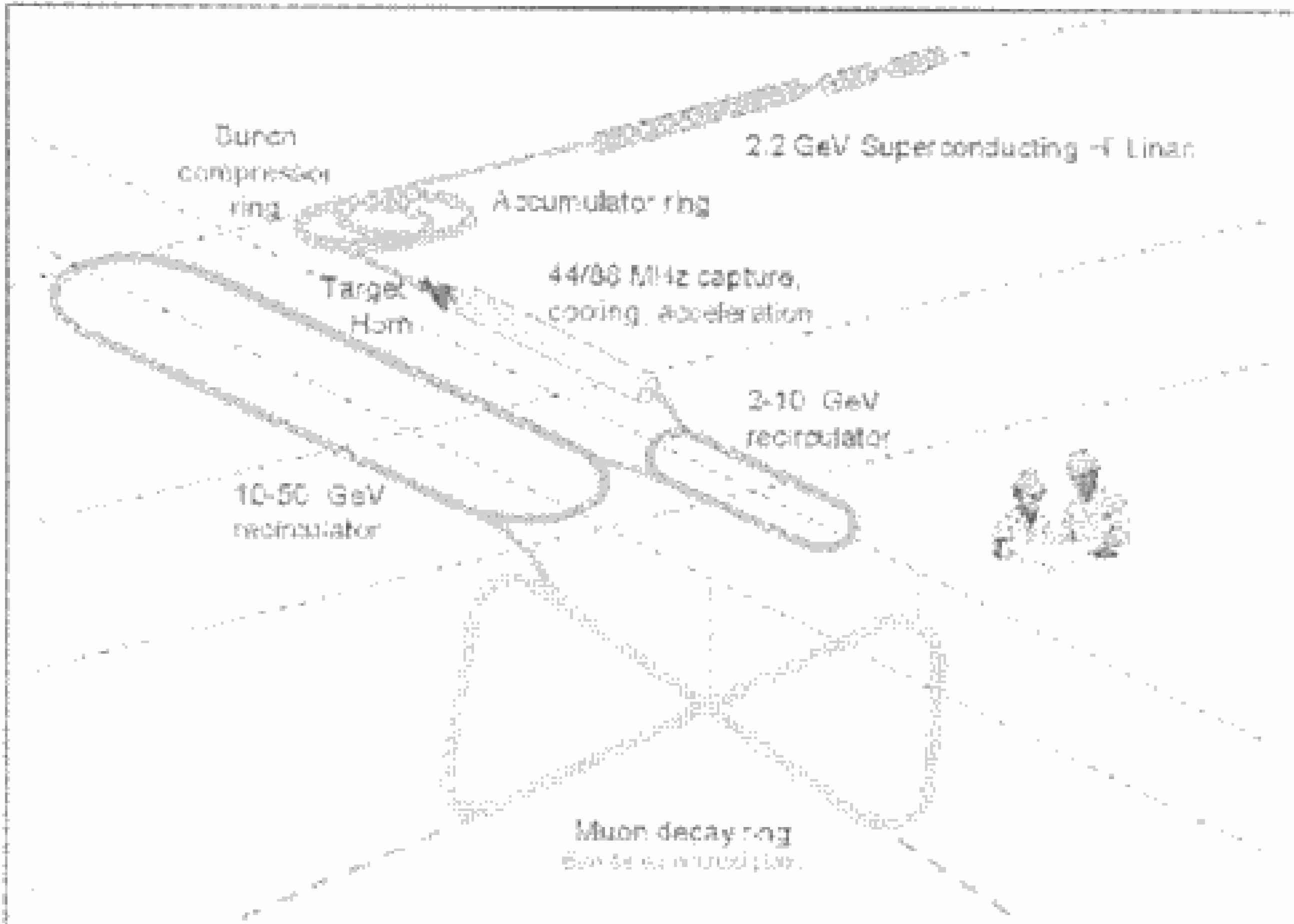
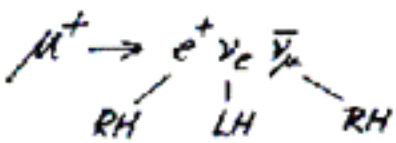
Neutrino Factory: experimental aspects

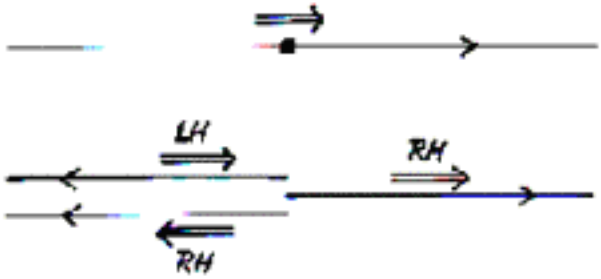
F. Dydak / CERN

Workshop on Neutrino Telescopes
Venice, 6 - 9 March, 2001



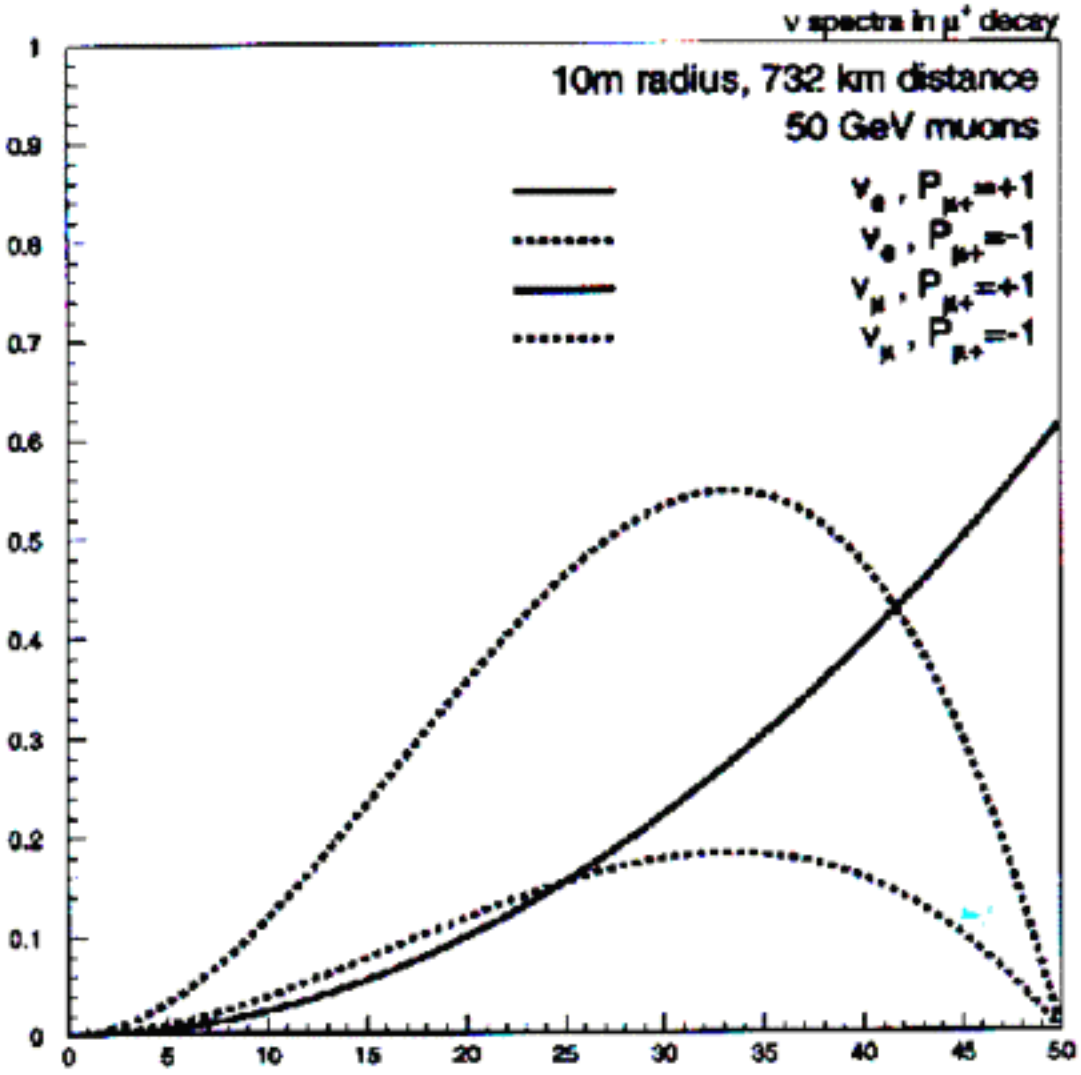
Neutrino Factory schematic (isometric view)





$P_\mu = +1$

$\Rightarrow$ det.



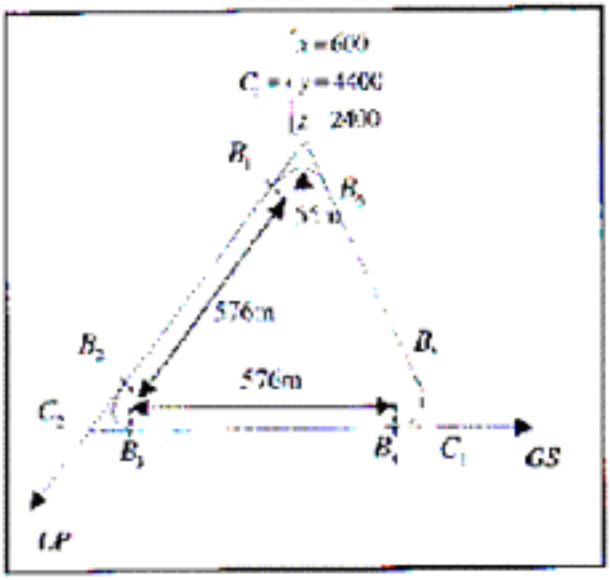
The outstanding and unparalleled feature of the neutrino factory is its

- **high-intensity**
- **background-free**
- **well-determined**

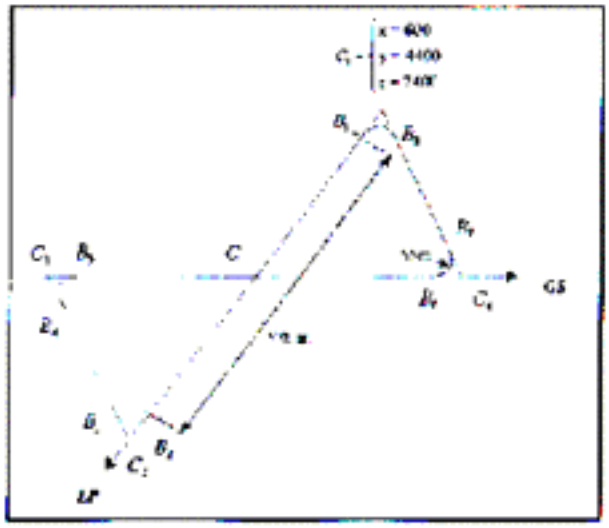
electron-neutrino beam

Machine parameters: the (European) experimentalist's desiderata

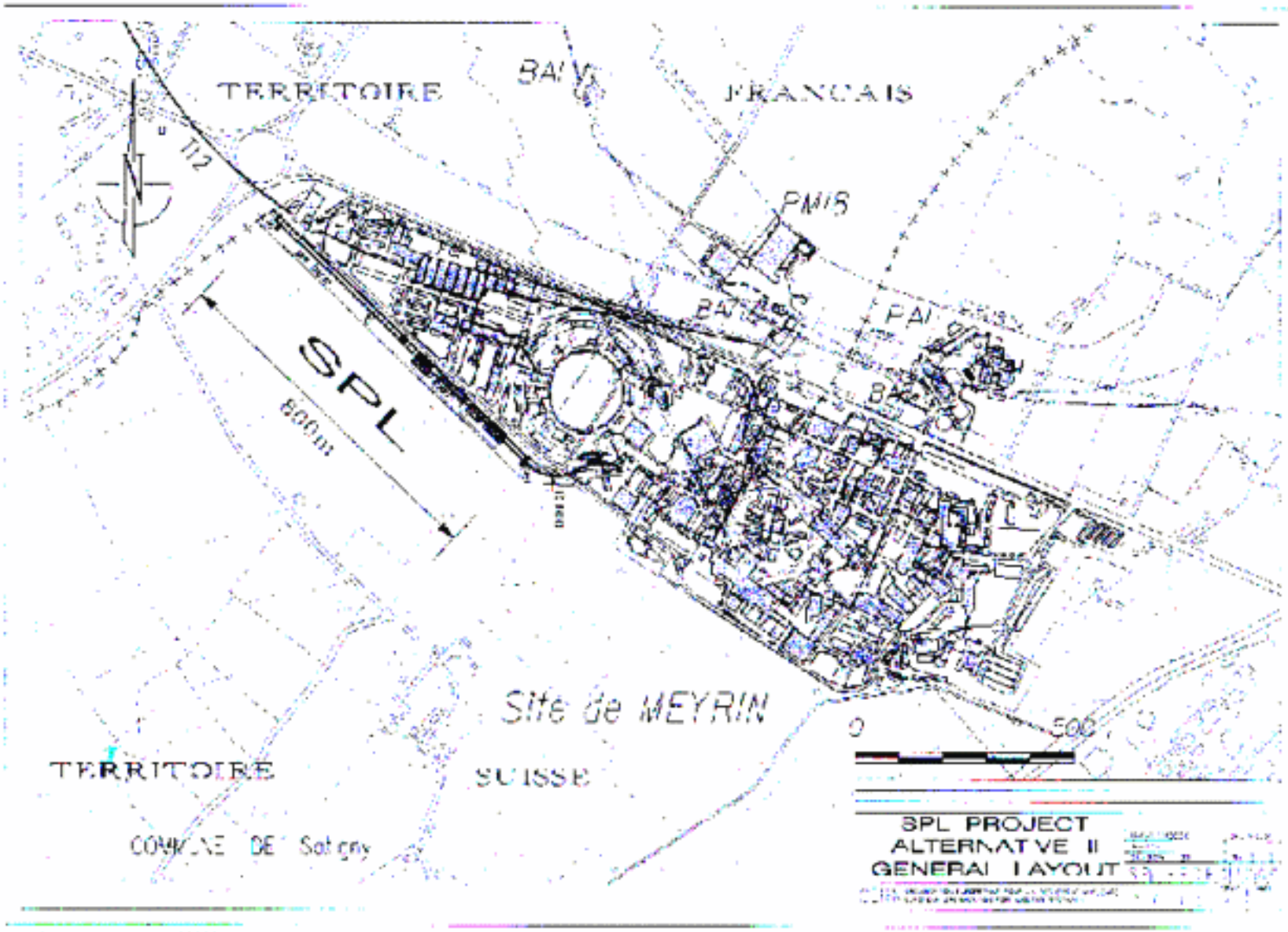
- *Energy of circulating muons*
  The higher the better; default: 50 GeV/c.
- *Charge sign of circulating muons*
  Both signs needed; as far as possible the same intensity; no concurrence of both signs.
- *Injected muons per year*
  Baseline 10^{21}; upgradable to 10^{22} or more.
- *Fraction of 'useful' decays*
  25% or larger.
- *Beam divergence in long straight sections*
  Less than $0.1/(\beta\gamma) = 0.2$ mrad at 50 GeV/c, known to better than 10%.
- *Geometric configuration of the storage ring*
  'Triangle' or 'bow-tie'.

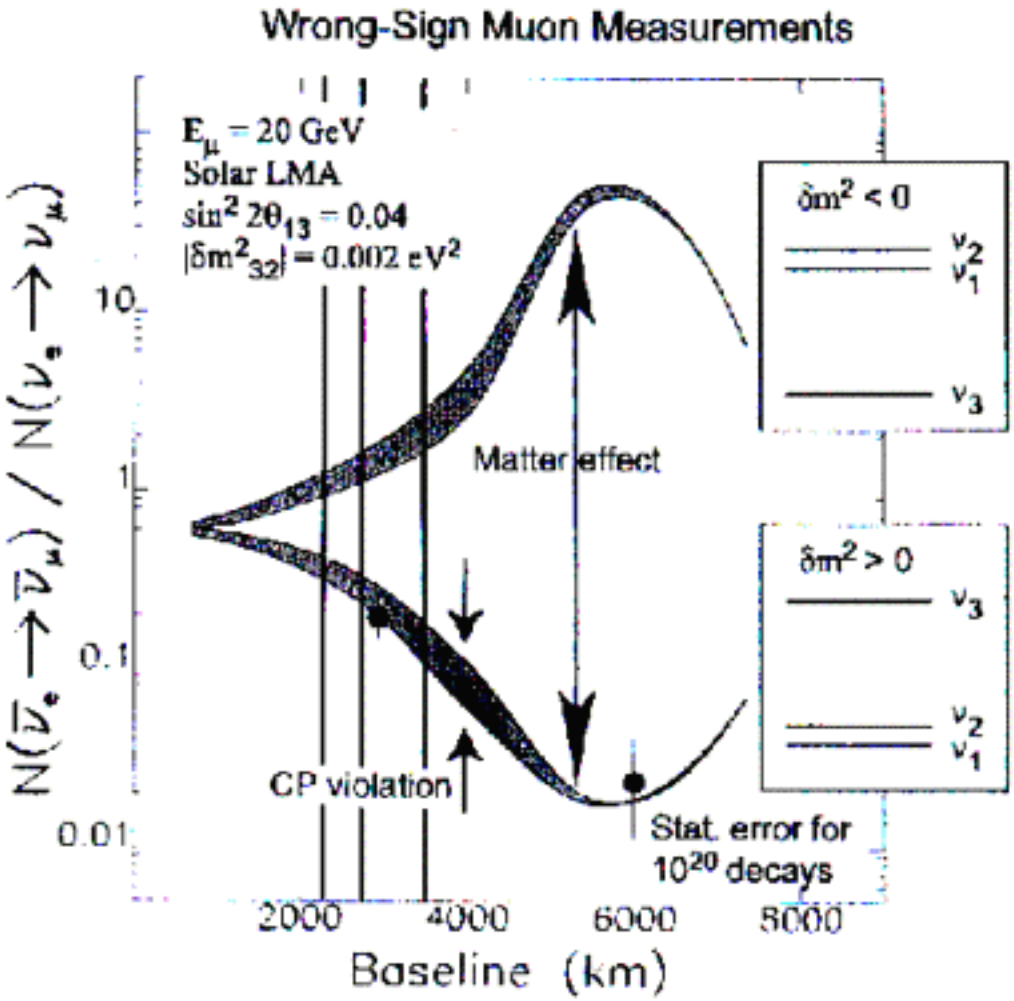


'Triangle' CERN - Gran Sasso - Canary islands



'Bowtie' CERN - Gran Sasso - Canary islands


TERRITOIRE
FRANCAIS
PMIS
SPL
800m
Site de MEYRIN
TERRITOIRE
SUISSE
0
500
SPL PROJECT
ALTERNATIVE II
GENERAL LAYOUT


Wrong-Sign Muon Measurements
E_μ = 20 GeV
Solar LMA
$\sin^2 2\theta_{13} = 0.04$
$|\delta m^2_{32}| = 0.002$ eV^2
$\delta m^2 < 0$
ν_2
ν_1
ν_3
Matter effect
$\delta m^2 > 0$
ν_3
ν_2
ν_1
CP violation
Stat. error for
10^{20} decays
10
1
0.1
0.01
2000
4000
6000
8000
Baseline (km)
$N(\bar{\nu}_e \rightarrow \bar{\nu}_\mu) / N(\nu_e \rightarrow \nu_\mu)$

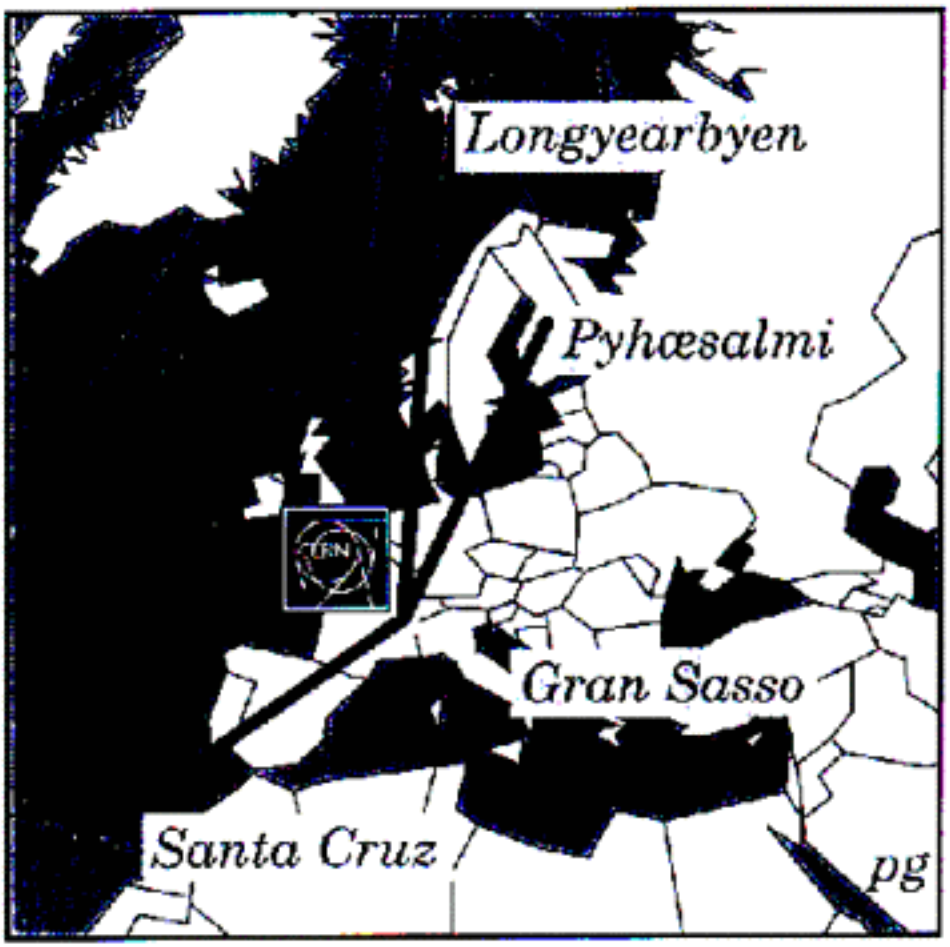
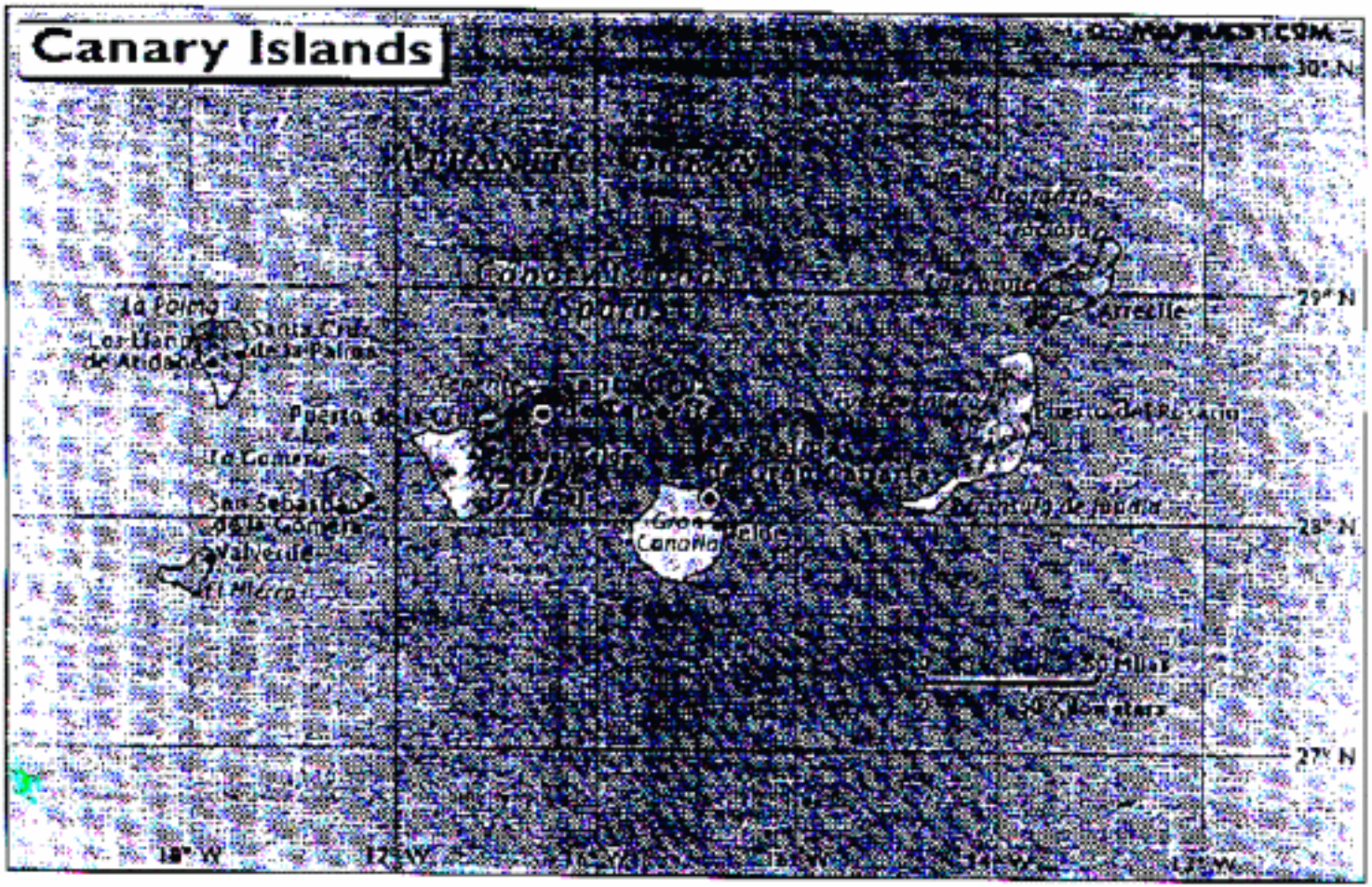


Figure 1: European long-baseline candidates

Detector sites

Criteria

- Distance / angle from CERN
- Underground depth
- Infrastructure
  - airport
  - transport of heavy equipment
- Support
  - local
  - national


Canary Islands
30° N
29° N
28° N
27° N
18° W
17° W
16° W
15° W
14° W
13° W
La Palma
Santa Cruz de La Palma
La Gomera
San Sebastián de La Gomera
Valverde
El Hierro
Las Palmas de Gran Canaria
Gran Canaria
Arrecife
Puerto del Rosario
Fuerteventura
Lanzarote

Santa Cruz de Tenerife

Underground tunnel

Location:

On Tenerife (the largest island of the Canary islands).

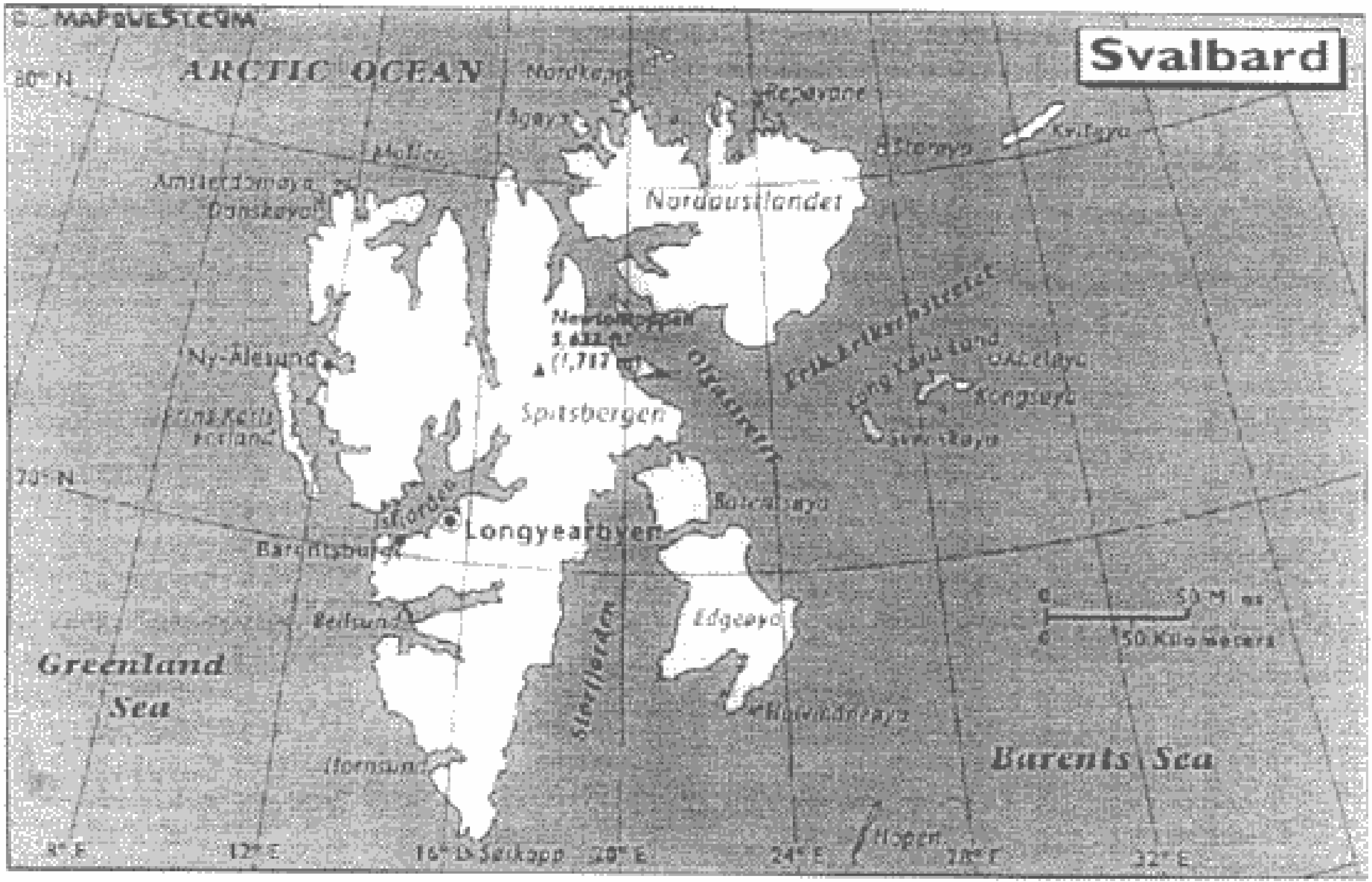
Excellent plane connections.

Strong local scientific activities (astronomy, astrophysics).

Some characteristics:

Underground hall to be constructed, either from one of the very many water tunnels, or from a road tunnel which is being planned.
O(800) m rock overburden.


N
Santa Cruz
de Tenerife
Galería
Pozo
Las Cañadas
del Teide
0
10 Km


Svalbard
© MAPQUEST.COM
ARCTIC OCEAN
Nordaustlandet
Spitsbergen
Longyearbyen
Ny-Ålesund
Barentsburg
Edgeøya
Greenland Sea
Barents Sea
Hopen
Kongsøya
Kvitøya
80° N
76° N
12° E
20° E
24° E
32° E
50 Miles
50 Kilometers

Longyearbyen

Active coal mines

Location:

On Spitsbergen (the largest island of the Svalbard archipelago).

Longyearbyen is the administrative centre of the Norvegian authority. 1400 inhabitants. Seat of Svalbard University Courses.

Regular plane connection to Tromsø, Norway (7 - 9 times per week, 90 min flying time).

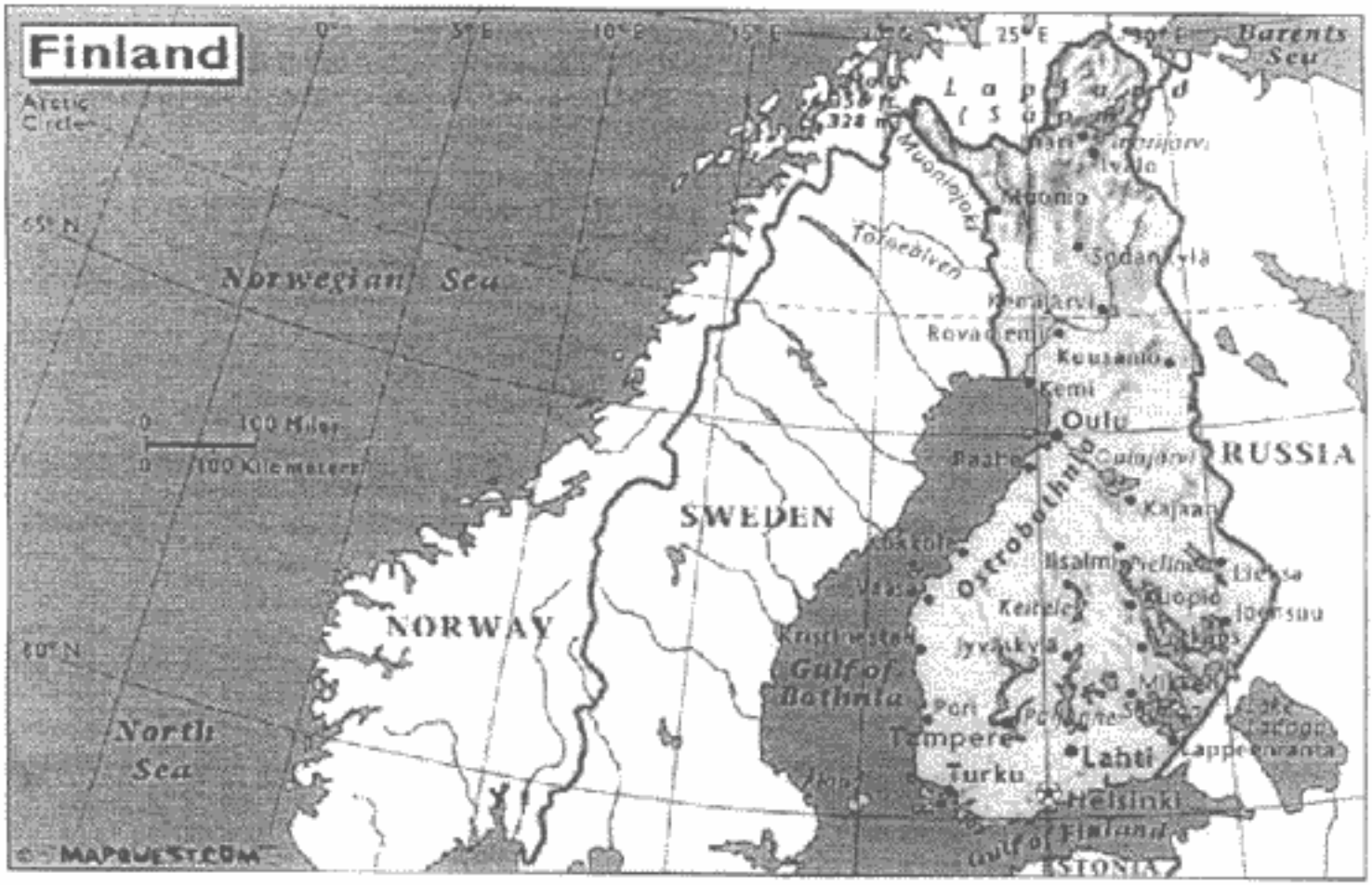
No roads between settlements. 45 km of roads in and around Longyearbyen.

Temperature -14 to +6 degrees. 4 months of midnight sun, 4 months arctic night.

Some characteristics:

Several candidate mines.

O(300) m rock overburden, maybe up to 500 m.


Finland
Arctic Circle
65° N
60° N
Norwegian Sea
North Sea
Barents Sea
Lapland
Muonio
Muonionjoki
Torneälven
Sodankylä
Rovaniemi
Kuusamo
Kemi
Oulu
Raahe
Oulujärvi
RUSSIA
Kajaani
SWEDEN
NORWAY
Ostrobothnia
Kokkola
Vaasa
Kristinestad
Gulf of Bothnia
Jyväskylä
Pori
Tampere
Turku
Lahti
Helsinki
Gulf of Finland
ESTONIA
Lappeenranta
Joensuu
Kuopio
Mikkeli
0 100 Miles
0 100 Kilometers
© MAPQUEST.COM

Pyhäsalmi

Active zinc and copper mine

Location:

160 km south of Oulu, Finland
(Oulu has an international airport, good connections to Stockholm and Helsinki).

Highway connections to Oulu and Helsinki.

Pyhäjärvi (7000 inhabitants) at 5 km distance.

Some characteristics:

Depth 1440 m (4050 m water equivalent).

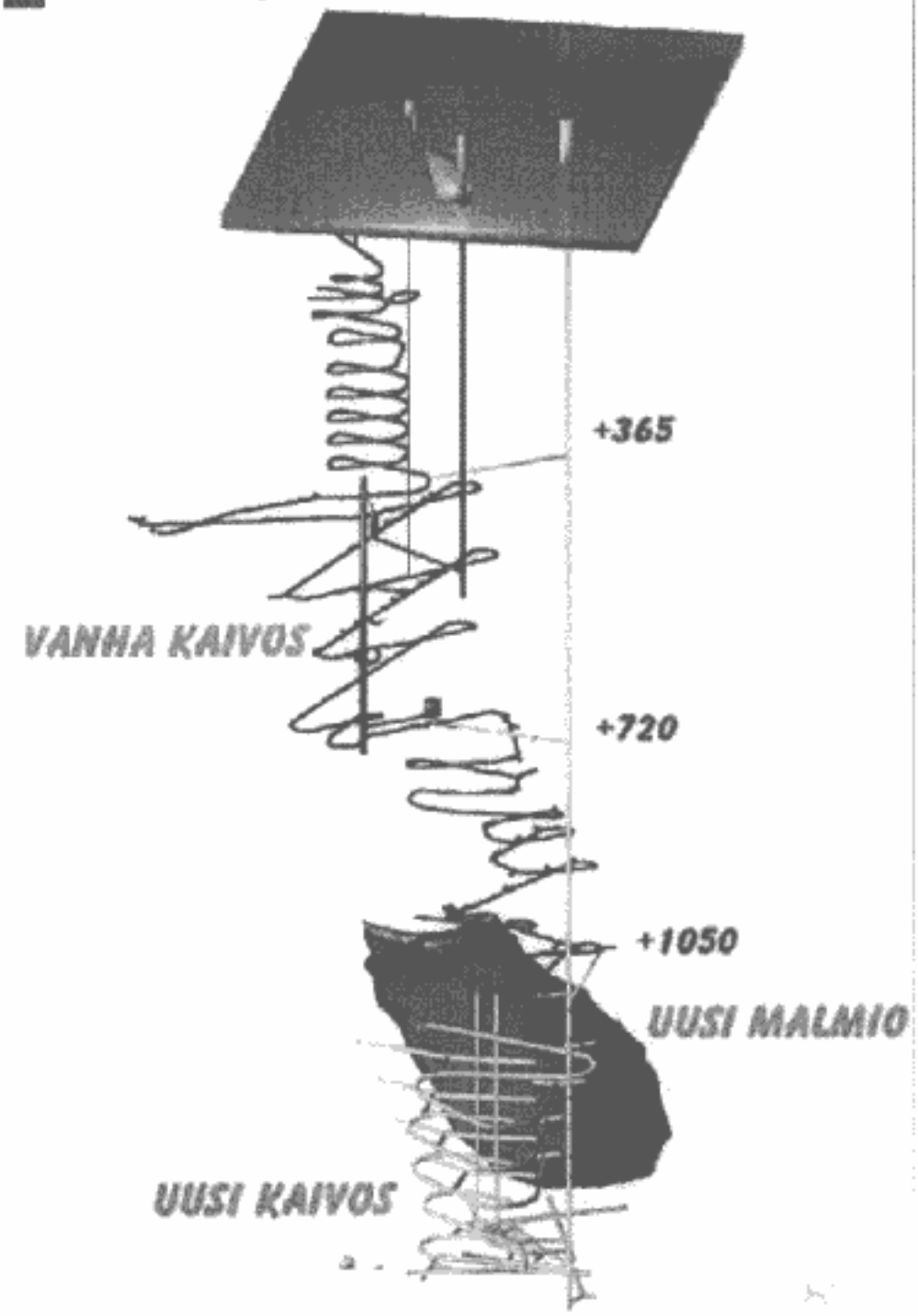
Accessible by truck (container size 2.6 m x 2.8 m x 8 m).

A new lift down to 1440 m under construction.

Large caverns can be built after 2001, at a cost of 60 - 80 Euro/m^3 (= 10 MioEuro for a large-size cavern).

outokumpu

AXONOMETRINEN KUVA



Outokumpu Mining oy | Pyhäsalmi mine | Base Metals

Candidate medium- and long-baseline detector sites at the CERN Neutrino Factory					
	Latitude	Longitude	Depth (km)	Distance (km)	Angle (deg.)
CERN	46N 15' 22.93"	06E 03' 01.10"	0.4506		
Gran Sasso	42N 27' 11.31"	13E 34' 31.24"	1.014	733	-3.25
Santa Cruz de Tenerife	28N 27' 00.00"	16W 14' 00.00"	0.1	2753	-12.47
Longyearbyen	78N 00' 00.00"	16E 00' 00.00"	-0.1	3518	-16.01
Pyhäsalmi	63N 39' 34.74"	26E 02' 29.94"	-1.345	2268	-10.38
Modane	45N 08' 32.00"	06E 41' 21.00"	1.2	133	-0.28

F. Dydak / 04.03.2001

European (ECFA-sponsored) programme towards a neutrino factory

- Neutrino oscillation working group
- Other physics studies (high-intensity stopped muons, deep inelastic neutrino scattering, radioactive beams, ...)
- Machine physics working group
- Ongoing R & D programme:

  HARP (study of pion production for the neutrino factory and for the atmospheric neutrino flux)

  MUSCAT (muon scattering in hydrogen at large angles)

  Liquid Hg targets

  RF cavities in high radiation fields

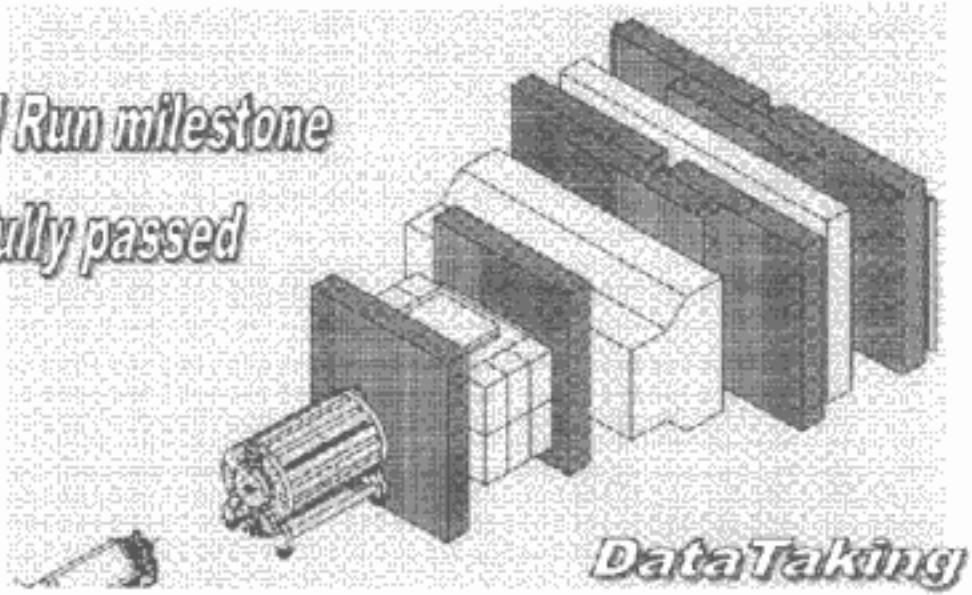
  Muon cooling initiative

HARP Experiment

Measurements for Proton Drivers at Neutrino Factory

Precision measurements for the Atmospheric Neutrino Flux

Technical Run milestone successfully passed (2000)



DataTaking : 2001

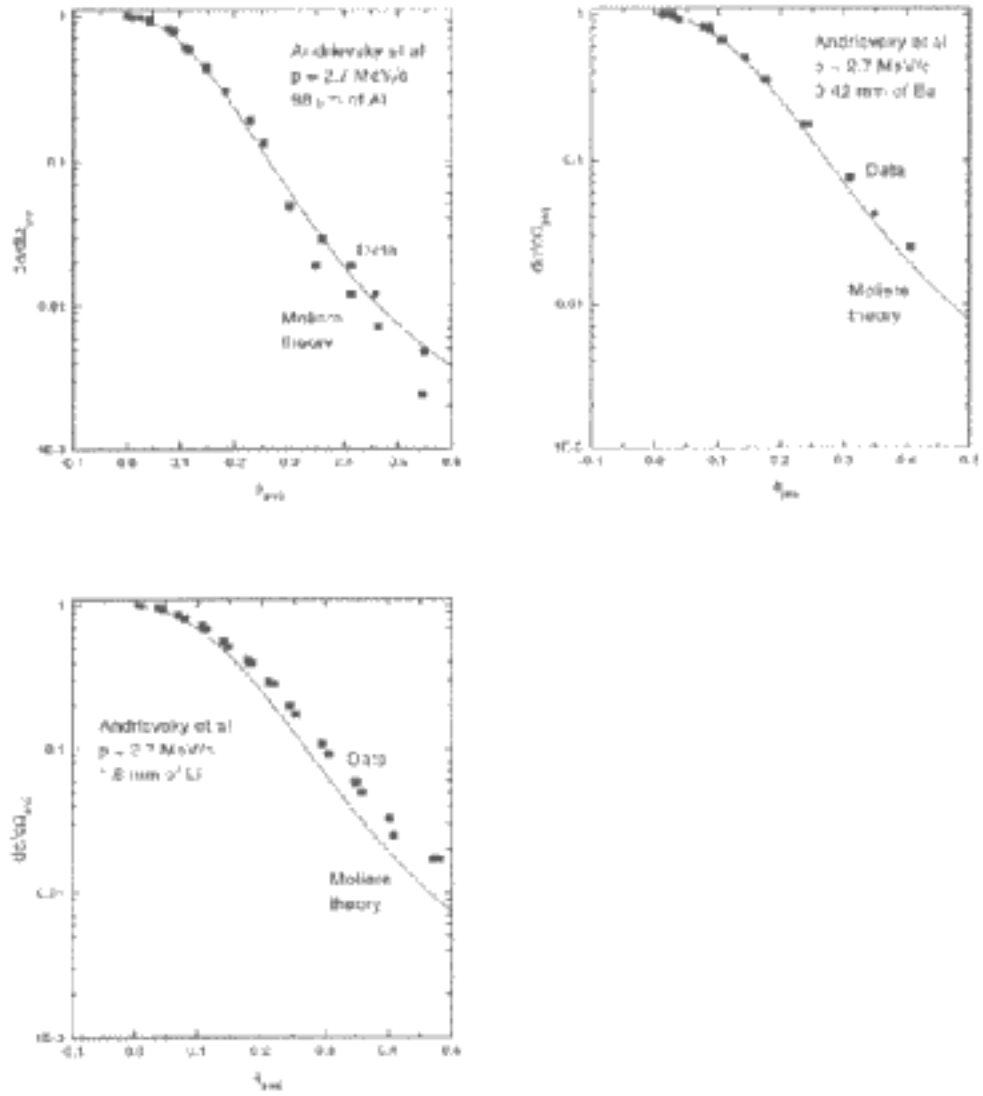


Figure 3: A comparison between Moliere theory and the electron scattering data of Andrievsky et al on aluminium, beryllium and lithium. The scattering angle is plotted in radians.

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Physics at a Neutrino Factory

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EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

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THE NEUTRINO FACTORY: BEAM AND EXPERIMENTS

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Abstract

The discovery of neutrino oscillations marks a major milestone in the history of neutrino physics, and opens a new window to the still mysterious origin of masses and flavour-mixing. Many current and forthcoming experiments will answer open questions; however, a major step forward, up to and possibly including CP violation in the neutrino-mixing matrix, requires the neutrino beams from a neutrino factory. The neutrino factory is a new concept for producing neutrino beams of unprecedented quality in terms of intensity, flavour composition, and precision of the beam parameters. Most importantly, the neutrino factory is the only known way to generate a high-intensity beam of electron neutrinos of high energy. The neutrino beam from a neutrino factory, in particular the electron-neutrino beam, enables the exploration of otherwise inaccessible domains in neutrino oscillation physics by exploiting baselines of planetary dimensions. Suitable detectors pose formidable challenges but seem within reach with only moderate extrapolations from existing technologies. Although the main physics attraction of the neutrino factory is in the area of neutrino oscillations, an interesting spectrum of further opportunities ranging from high-precision, high-rate neutrino scattering to physics with high-intensity stopped muons comes with it.