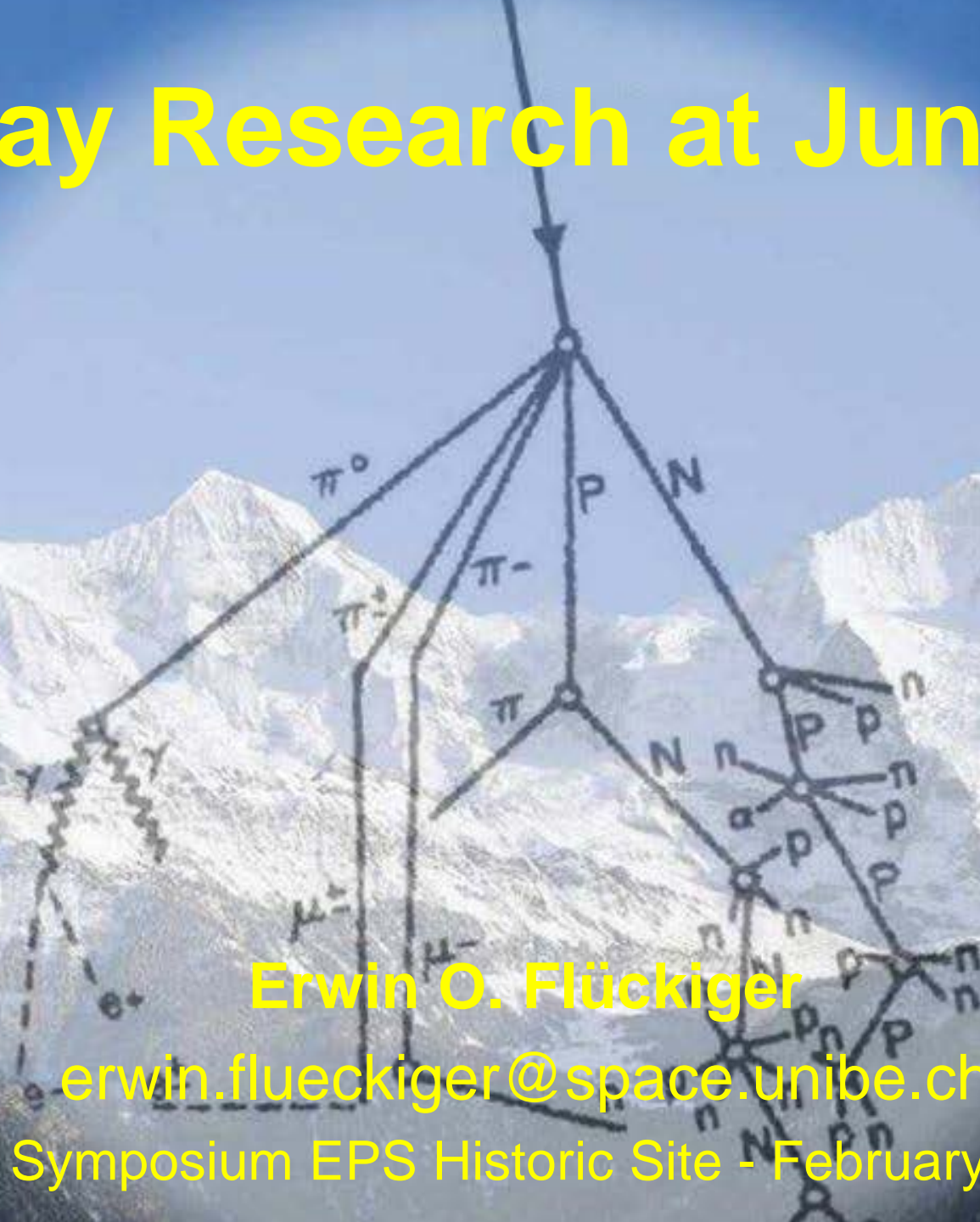


Cosmic Ray Research at Jungfraujoch



Erwin O. Flückiger

erwin.flueckiger@space.unibe.ch

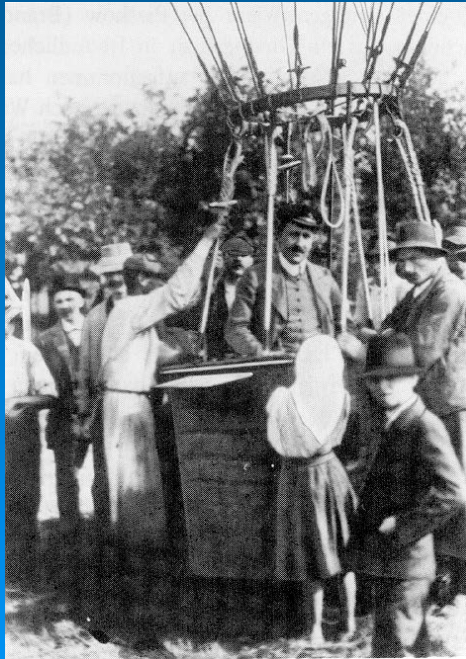
HFSJG Symposium EPS Historic Site - February 7, 2019

The Magic Epoch - 1912

Discovery of Cosmic Rays



Theodor Wulf
1868-1946



Viktor F. Hess
1883-1946

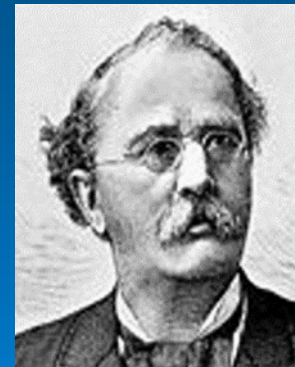


Albert Gockel
1860-1927

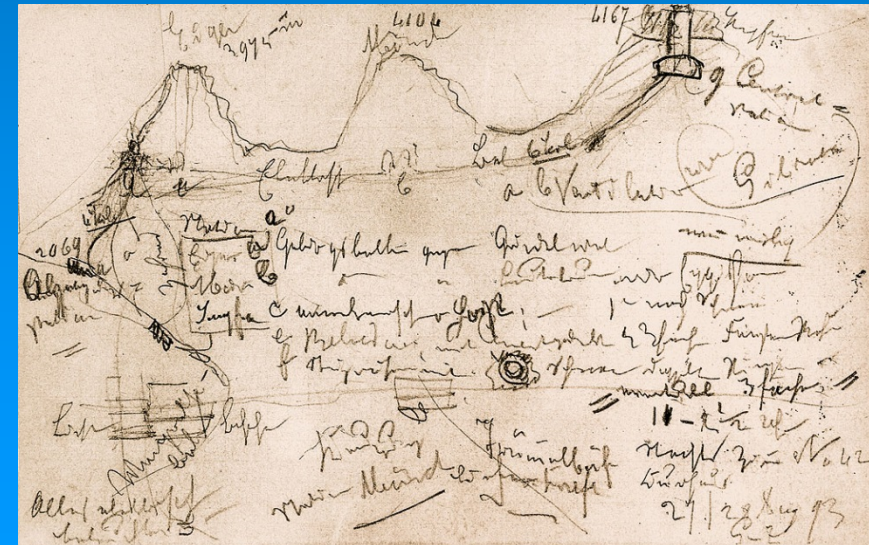


Domenico Pacini
1878-1934

Opening of the Jungfrau Railway



Adolf Guyer-Zeller
1839-1899



The CR Pioneers at Jungfrauoch I

1920 Nobel Laureate **Walther Nernst**
and his assistant **Werner Kolhörster**
were probably the first to perceive and exploit the
potential of Jungfrauoch (altitude and easy access) for
cosmic ray studies

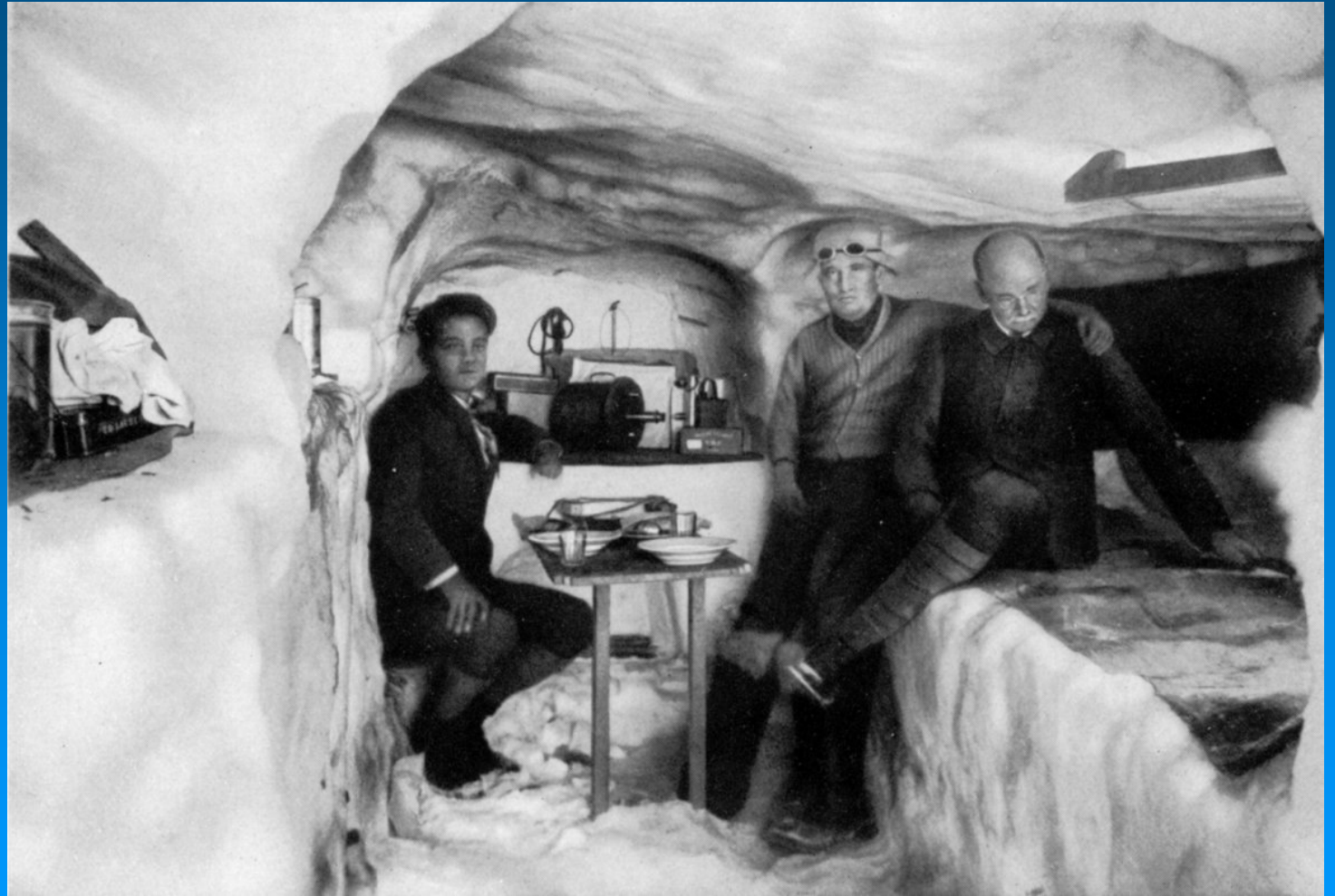
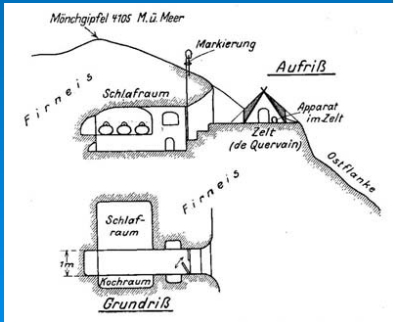
1923 exploratory expedition
Werner Kolhörster & Gubert von Salis
(a grandson of Guyer-Zeller)

1925/26 follow-up expeditions
Werner Kolhörster & Gubert von Salis

→ Publication: Die tägliche Periode der Höhenstrahlung, 1927

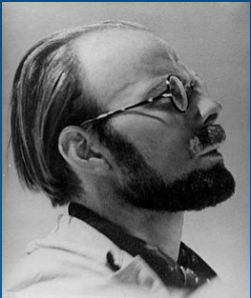


The CR Pioneers at Jungfrauoch II



W. Kolhörster et G. von Salis during the expedition at the Mönch in 1926

... further famous names 1934-1936



Pierre Auger
1899-1993

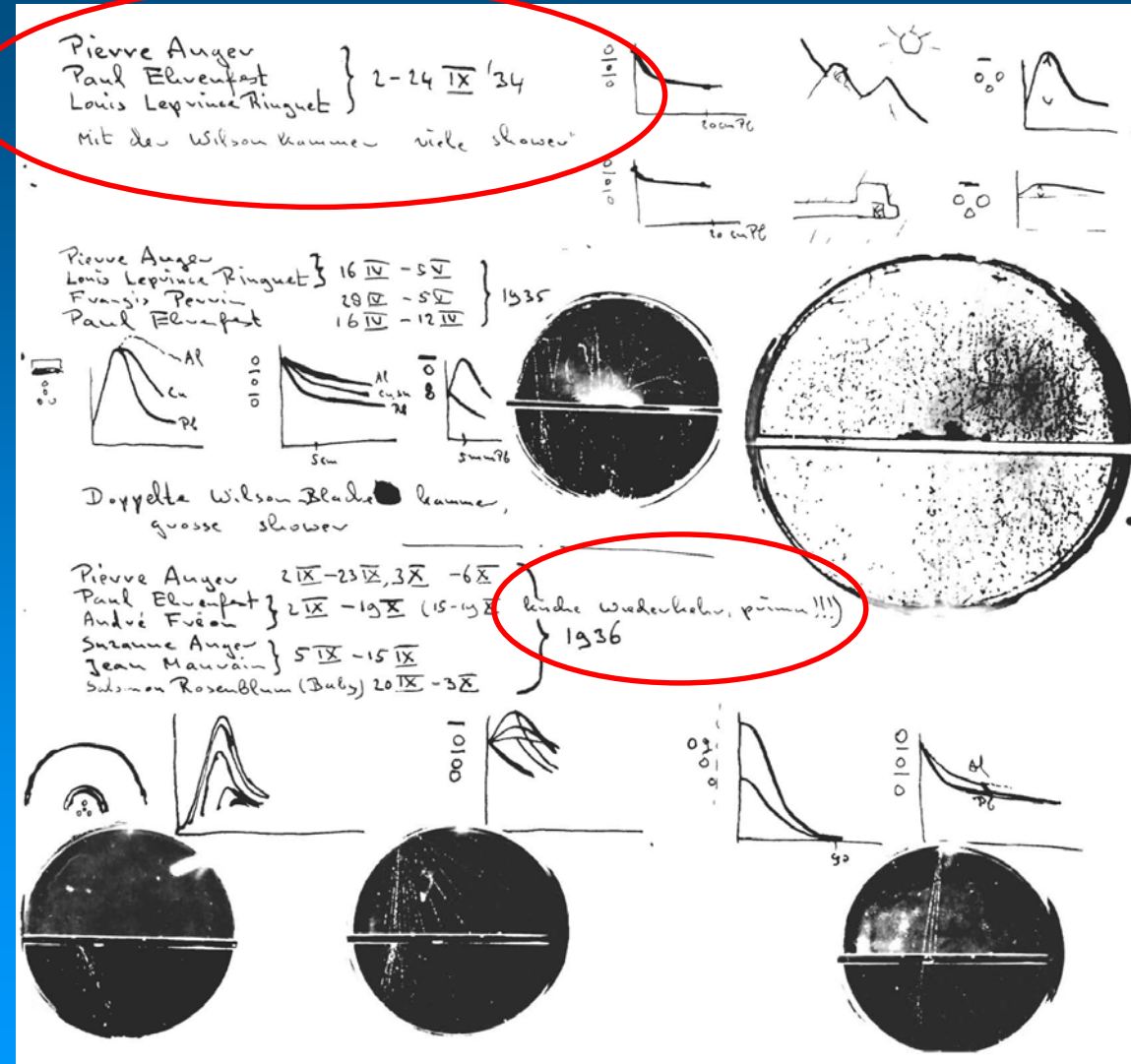


Paul Ehrenfest
1880-1933



Louis Leprince-Ringuet
1901-2000

EPS Historic Sites
CNRS Refuge des
Cosmiques
Aiguille du Midi



Record in the guest book of the High Altitude Research Station Jungfrauoch, 1934-36

...the Spirit of the Time...

“ In 1938 the theoretician Walter Heitler (then in Bristol) mentioned to Powell that in 1937 two Viennese physicists, Marietta Blau and Herta Wambacher, had exposed photographic emulsions for five months at 2,300 m in the Austrian Alps and had seen the tracks of low energy protons as well as 'stars' or nuclear disintegrations, probably caused by cosmic rays. **Heitler commented that the method was so simple that 'even a theoretician might be able also to do it'.** This intrigued Powell and Heitler travelled to Switzerland with a batch of Ilford half-tone emulsions, 70 microns thick, and exposed them on the Jungfrauoch at 3,500 m. In a letter to 'Nature' in August 1939, they were able to confirm the observations of Blau and Wambacher.”



CERN Courier, June 1997

Heitler W., C.F. Powell, and G.E.F. Fertel, Heavy Cosmic Ray Particles at Jungfrauoch and Sea-Level, *Nature*, **144**, 283–284, 1939



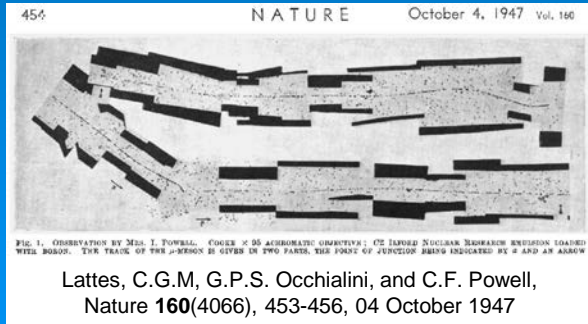
Abstract

The heavy ionizing particles in the cosmic rays are so rare that it seems unlikely that much information can be obtained from experiments with cloud chambers. The only method at present available which can yield quantitative results is the method of direct photography, which has been used recently by several investigators mainly for investigating the nuclear disintegrations which the cosmic rays produce.

The Bristol and Manchester Groups I

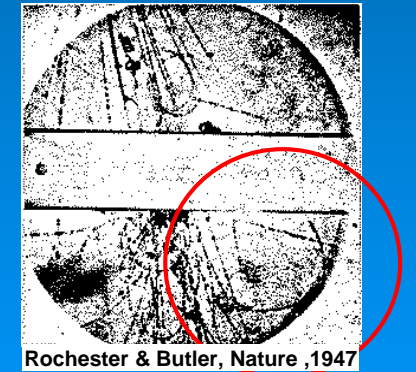
Bristol group under the direction of 1950 Nobel Laureate **Cecil Powell**

Discovery of the π -meson in cosmic radiation using the photographic emulsion technique



Manchester group under the direction of 1948 Nobel Laureate **Patrick Blackett**

Discovery of the V-particles in a Wilson cloud chamber



→ Extensive world-wide experimental research activity at high altitude, e.g. at Zugspitze (Germany), Pic du Midi and Aiguille du Midi (France), Testa Grigia and Marmolada (Italy), Echo Lake and Mount Evans (USA), Chacaltaya (Bolivia), Ootacamund (India), and **Jungfrau**

The Bristol and Manchester Groups II

Bristol group

1947: Start of extensive work with **nuclear emulsions** related to the π -meson

***1949: Discovery of the first heavy meson in photographic emulsions from Jungfraujoch
→ « τ -meson» → later reidentified as «kaon»***

Manchester group

1947: P.M.S. Blackett proposes Jungfraujoch experiment:

“Magnet Cloud Chamber”

Design guided by J.G. Wilson

Magnet: 14 tons, 5000 Gauss, power consumption 25kW

Cloud chamber: ~50cm

1950: Installation of the equipment

1951-1955: Operation of the experiment

>120'000 photographs, all scanned for V-events at Jungfraujoch

~50 events/day $E > 25\text{GeV}$, ~7 events/day $E > 100\text{GeV}$

→ significant contributions to the identification of the V-particles (e.g. charged K-mesons, Σ - and Ξ -hyperons)

1955: apparatus handed over to **CERN**

→ 1953/1954/1955: 800/1085/985 cosmic ray person working days at Jungfraujoch (total: 1700/2400/2400)

LES SAVANTS DU JUNGFRAUJOCH

CINÉ JOURNAL SUISSE

1951

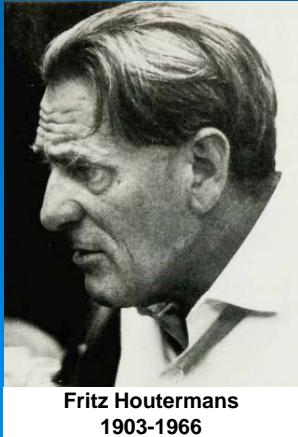


1957/58

The International Geophysical Year IGY

Start of the Neutron Monitor Era

Commissioning of the first Neutron Monitor by the Physikalisches Institut
of the University of Bern



- ... worldwide collaboration
- ... the Earth's magnetic field is used as a giant spectrometer
- ... standardized detectors (IGY, NM64)
- ... homogenized measuring procedures (World Data Centers)

Neutron Monitors at Jungfraujoch



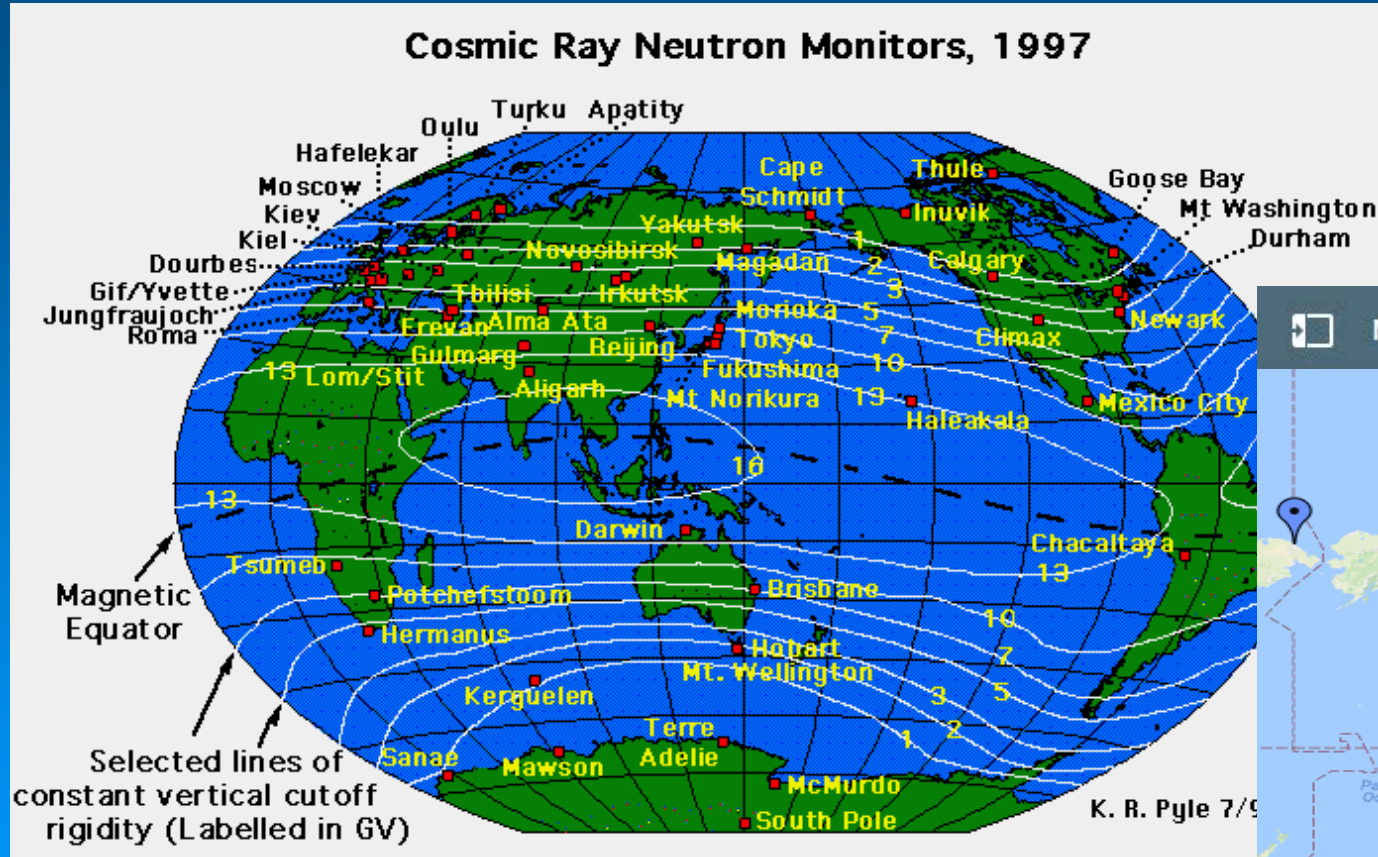
18-IGY



3-NM-64

Worldwide Network of Neutron Monitors (NM)

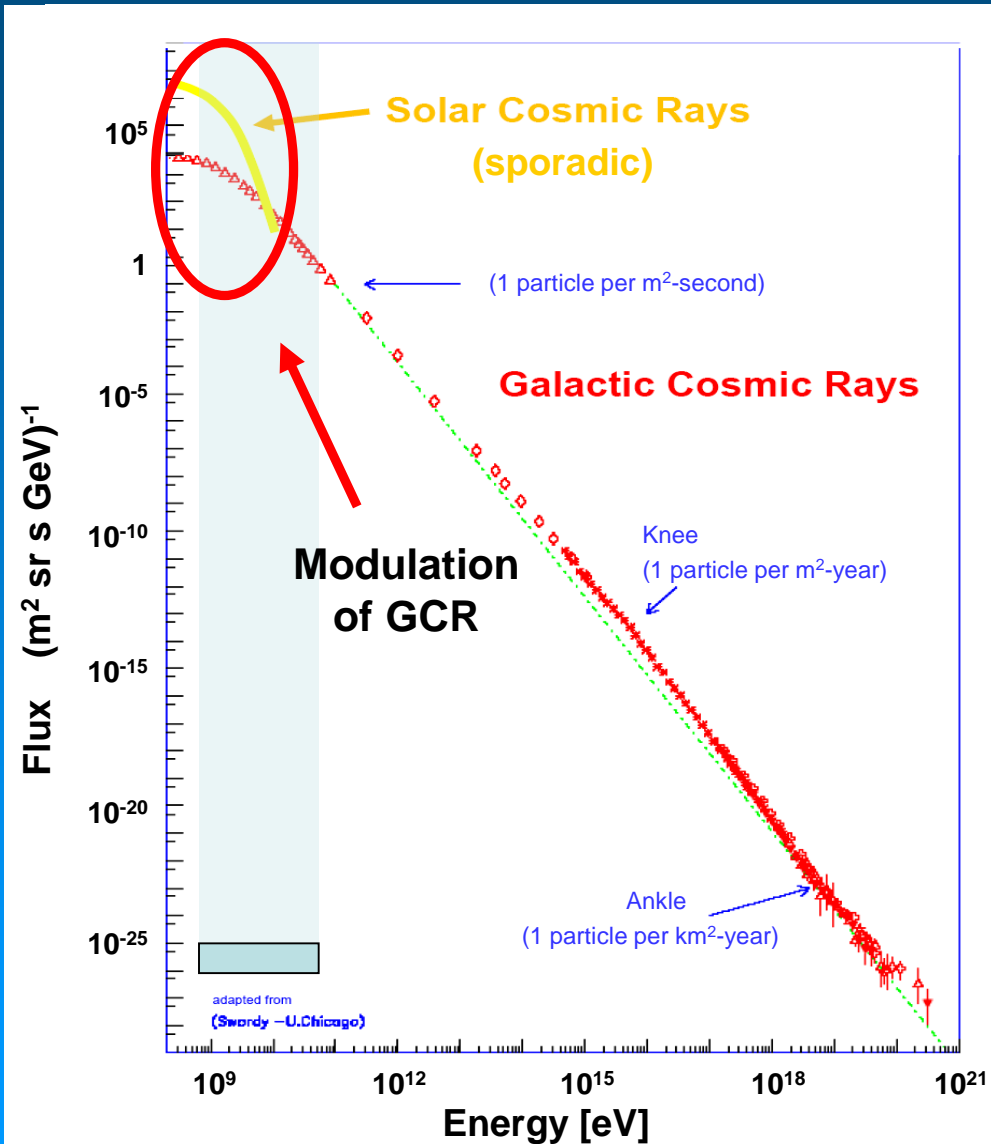
→ NMDB (real time)




Today →
Real Time Neutron Monitor
Network NMDB
www.nmdb.eu



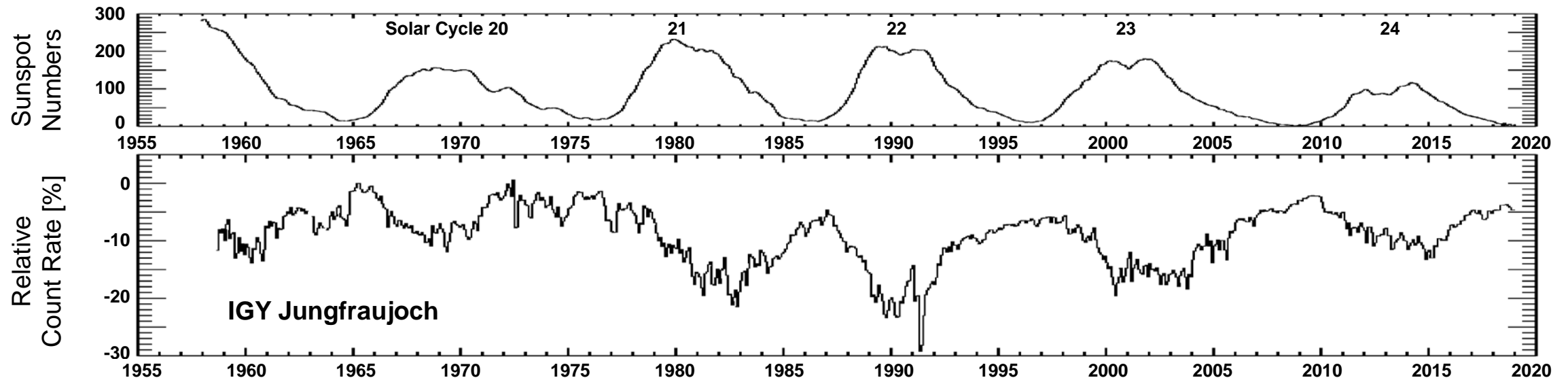
Neutron Monitors and the Cosmic Ray Primary Spectrum



Neutron Monitors (NMs)

- cover only ~ 1.5 of the more than 12 orders of magnitude in the energy spectrum 
- but cover energy region that
 - includes solar modulation of GCR,
 - contains sporadic solar cosmic rays, and
 - has most important effects on Earth
- are the prime instruments for CR research in the low GeV region
- have longest series of CR measurements in history (since 1956)

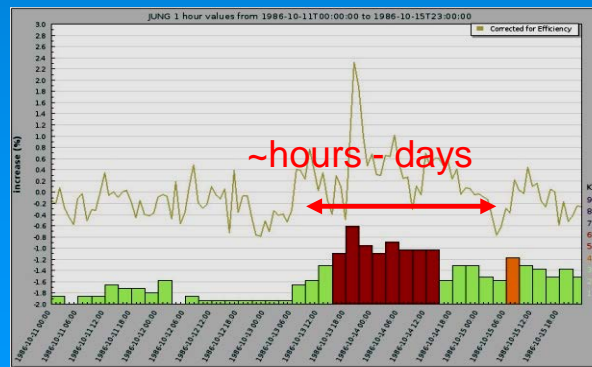
Earth's Cosmic Ray Environment



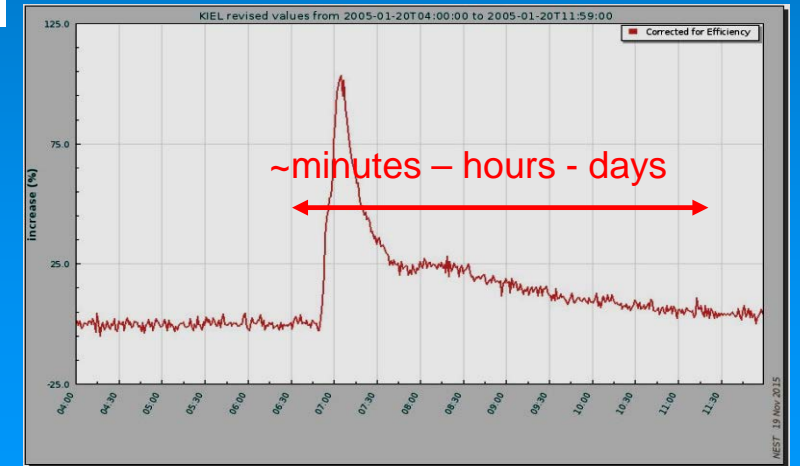
Solar Modulation of GCR ~15%



Forbush Decreases
up to ~ 20%



Geomagnetic Effects
a few %



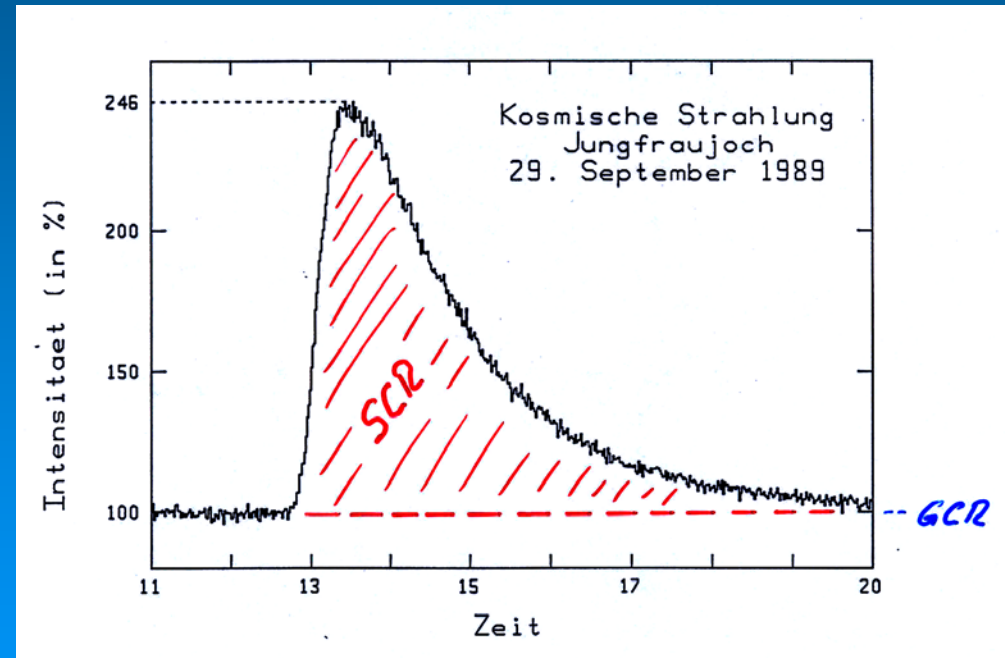
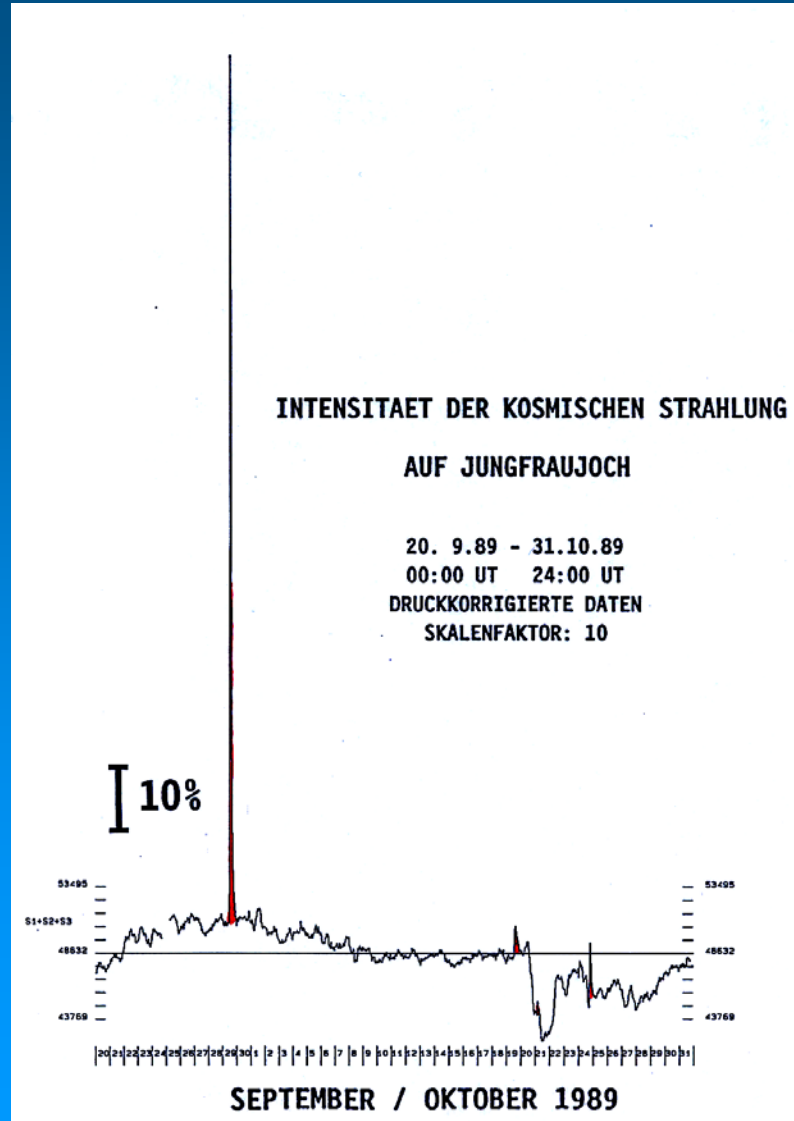
Solar Particle Events / GLEs
up to several 100%

Research Topics of the University of Bern Cosmic Ray Group

H. Debrunner, E.O. Flückiger, R. Bütikofer, et al.

- Analysis of **transient events**
(Forbush decreases, energetic solar particle events, geomagnetic effects)
- Investigation of the **transport of cosmic ray particles in near-Earth space and in the magnetosphere** (cutoff rigidities, asymptotic viewing directions)
- Investigation of **detector characteristics**
- Analysis of **space weather effects** (assessment of radiation dosage at flight altitude, in particular during energetic solar particle events)

Solar Particle Event - 29 September 1989 GLE (GLE = Ground Level Enhancement/Event)



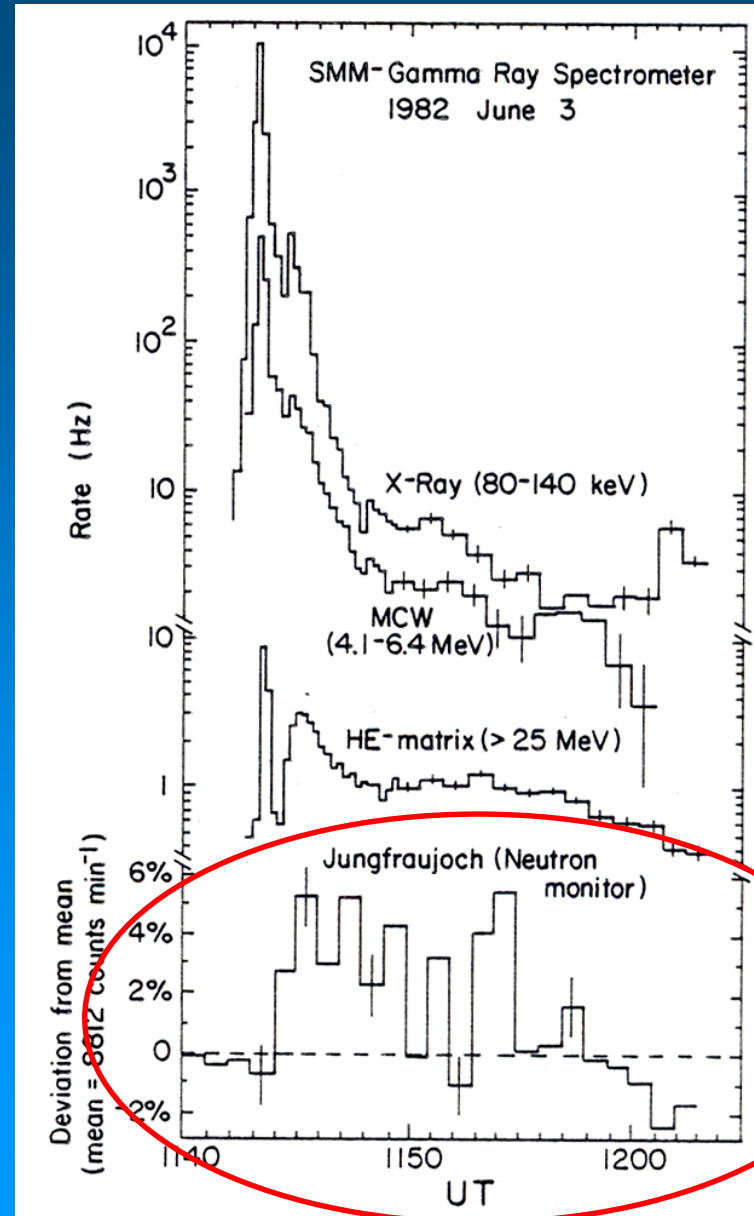
Neutron Monitor Jungfraujoch

First Proof of Solar Neutron Impact at Earth

3 June 1982

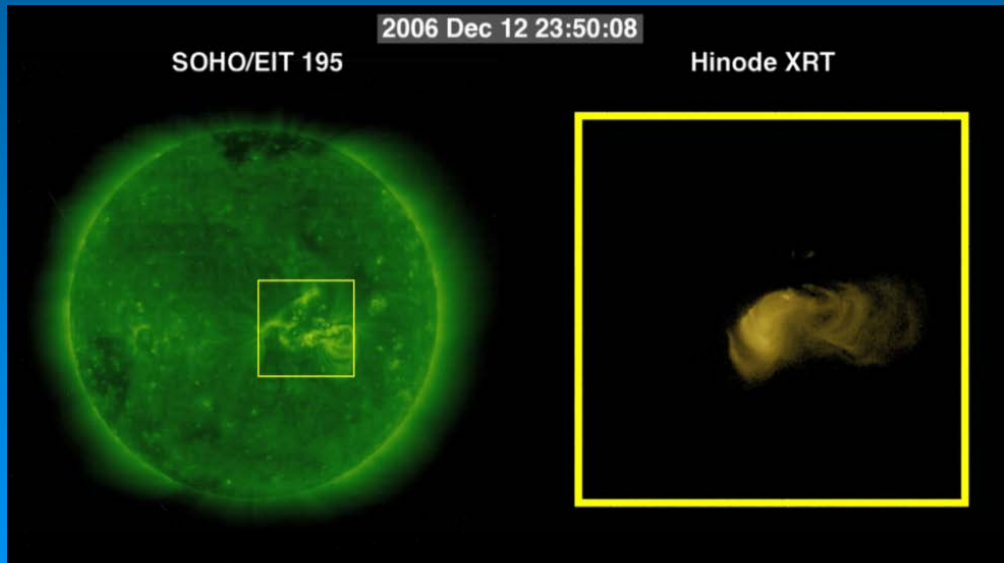
Signal
observed by
neutron
monitors at
Jungfraujoch,
Lomnický štít,
and Rome

Chupp et al., Ap.J., 1987

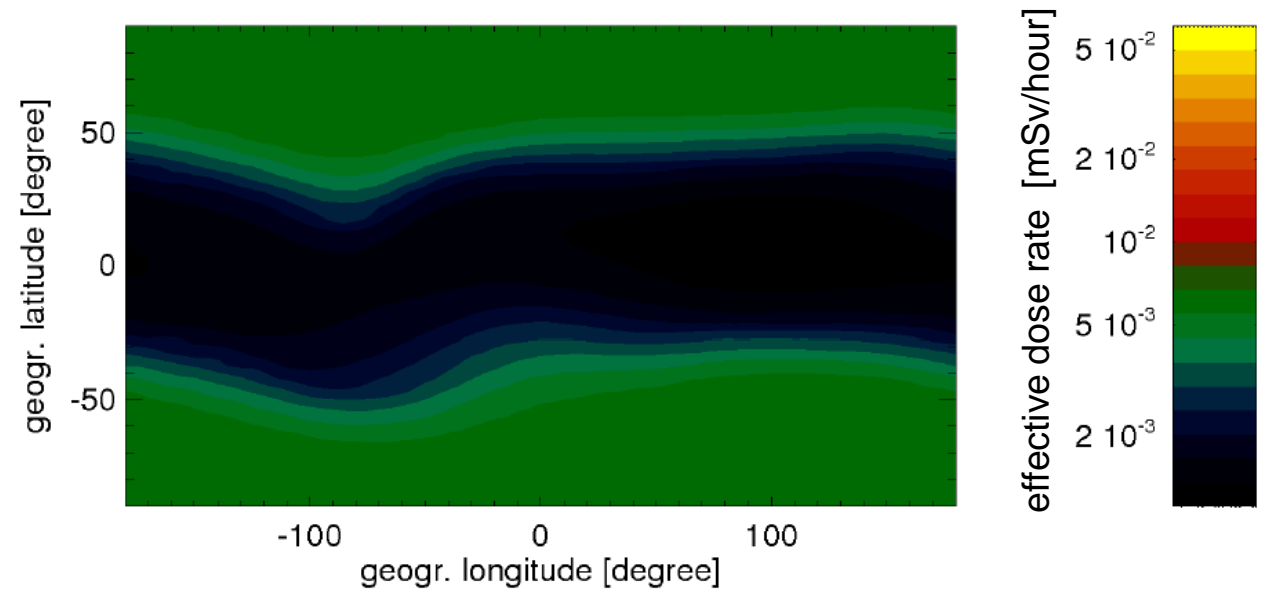
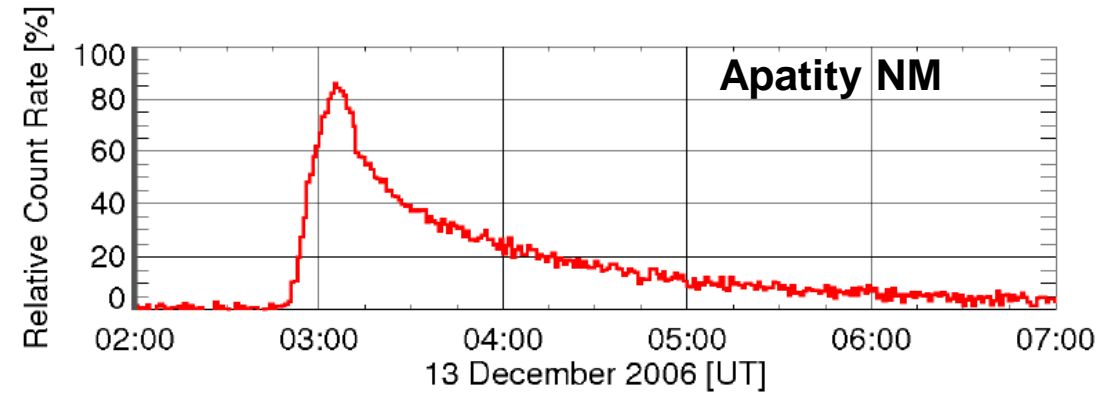


The 13 December 2006 Solar Particle Event

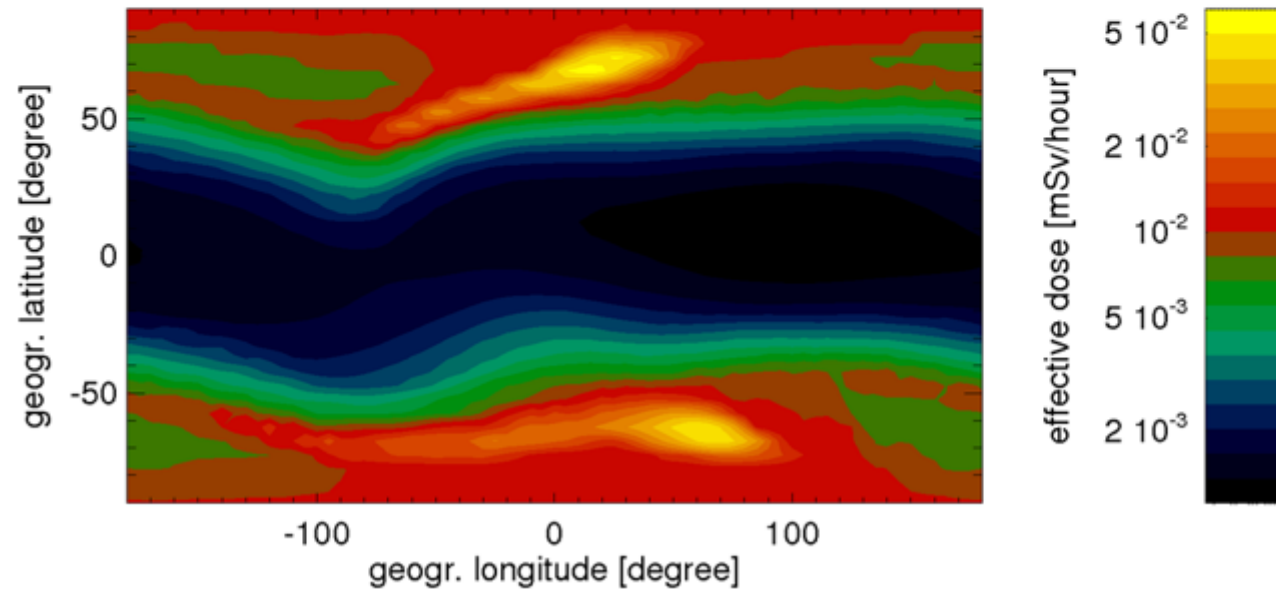
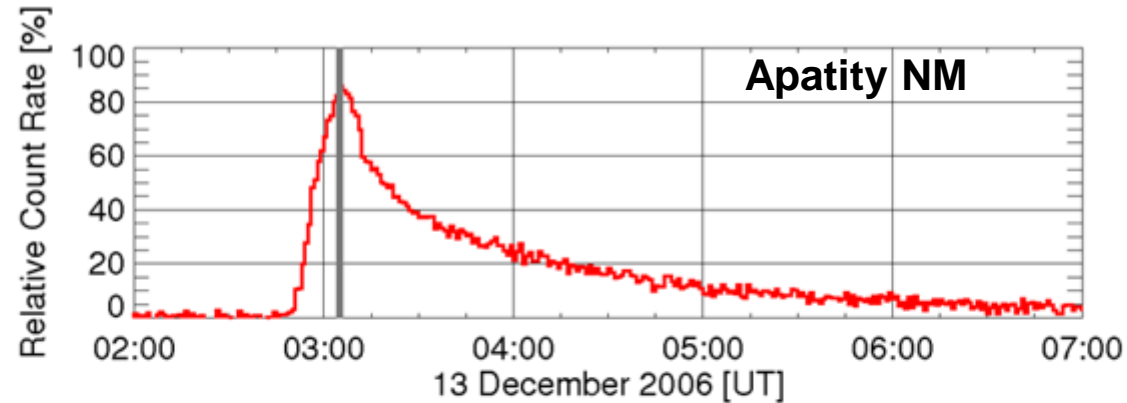
Radiation Exposure at Aircraft Altitude



NASA/Goddard Space Flight Center Scientific Visualization Studio



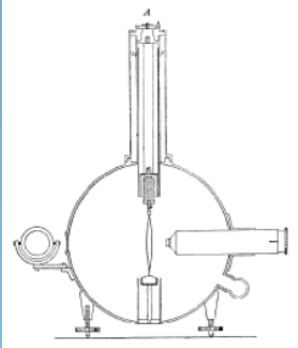
The 13 December 2006 Solar Particle Event Radiation Exposure at Aircraft Altitude



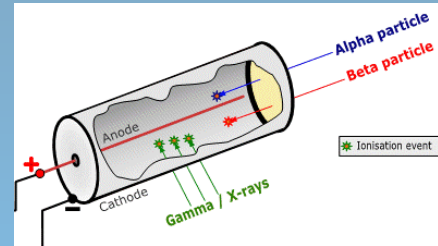
History of Cosmic Ray Research at Jungfraujoch

=>

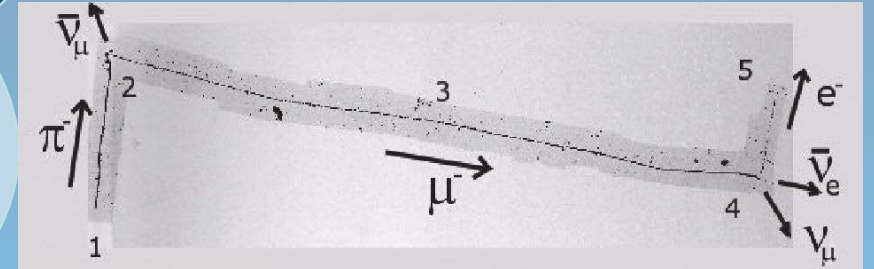
reflects History of Particle Detectors



Electroscope
as used by Father
Theodore Wulf ~1907



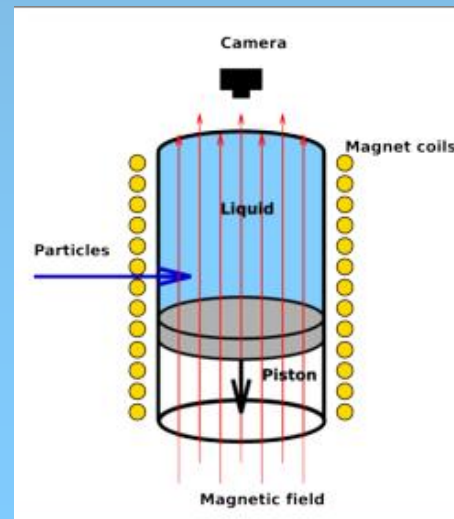
Ionisation Chamber



Photographic Emulsion
developed by Ilford & Kodak



Cloud Chamber
invented by C. T. R. Wilson ~1896



Magnet Cloud Chamber



Neutron Monitors
invented by J. Simpson ~1948

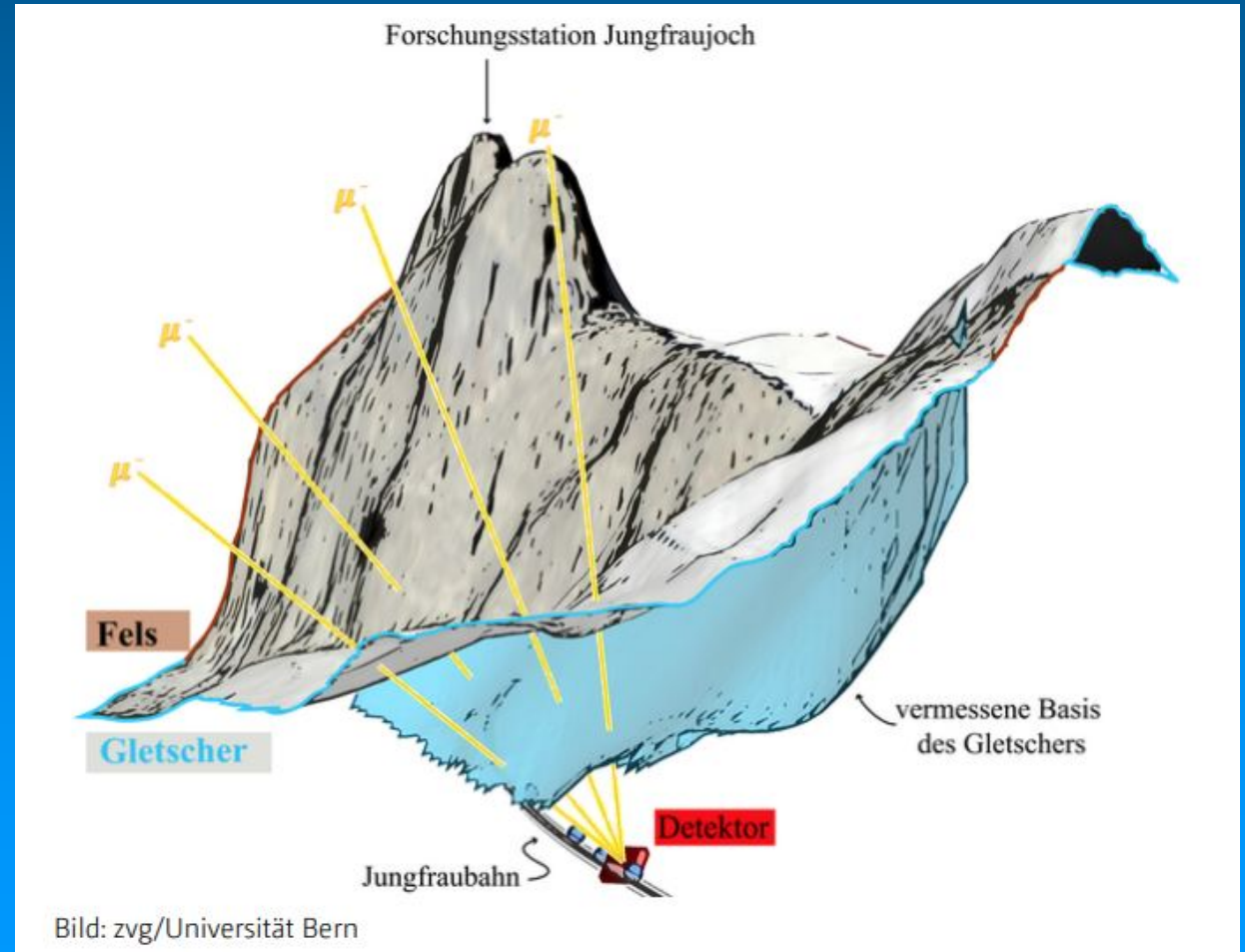
First Measurement of Ice-Bedrock Interface of Alpine Glaciers by Cosmic Muon Radiography

Nishiyama et al., Geophys. Res. Lett., **44**, 6244–6251, 2017

Renaissance of the Emulsion Technique



Automatic Emulsion Scanning Laboratory
at the University of Bern / LHEP



Summary

- Due to the characteristics of the site (high altitude, easy access, supporting infrastructure, internationality) cosmic rays have been a key research topic at Jungfraujoch since their discovery in 1912
- Through work done at Jungfraujoch by many research teams pioneering contributions to the advancement of high energy particle physics, galactic and solar cosmic ray physics, and to the understanding of solar terrestrial phenomena have been achieved
- Therefore the cosmic ray community is delighted and highly appreciates the honorable distinction of the Jungfraujoch as a «Historic Site» awarded by the European Physical Society EPS

