

Dunsink Observatory

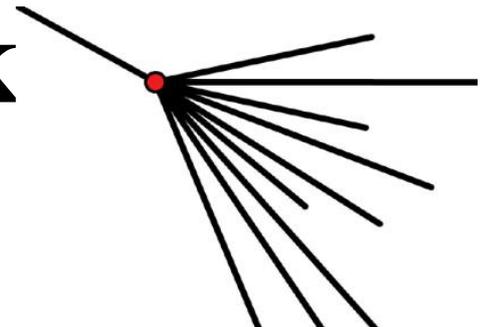
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Building a Giant Observatory to study the Highest Energy Particles in Nature

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- **Cosmic Rays** – nuclei of atoms arriving at top from outer space. Discovered in 1912.
- **Energies** range from about 100 times that of a radioactive source to energies that are 100 times that of Murray's first cosmic ray detector.
- **Primary Particles** are the particles that enter the atmosphere. They are of various types, but most are protons and alpha particles. Some are heavy nuclei of nitrogen, oxygen, iron, etc. Secondaries pass through the atmosphere and are mostly electrons, positrons, muons, and pions.

Big questions: Where do they originate?
 How do they acquire such energies?
 Is there a maximum energy?

... from 2 chest X-rays
 ... strand of DNA might cause a mutation
 ... to reboot phone etc. due to cosmic rays impacting
 ... on memory, particularly on transatlantic flights

Luck: Didn't get a job in Edinburgh

Luck: It was a sunny day when I came to Leeds (1964) for the interview

Bob Reid, open-top car, Haverah Park

- Suppose it had been raining?

Haverah Park: Site of British National Effort to detect **high-energy cosmic rays** (Durham, Leeds, Imperial College, Nottingham)

Some typical energies in electron volts (eV)

Light from laser pointer ~ 3 eV (a photon)

X-rays > 1 keV (10^3)

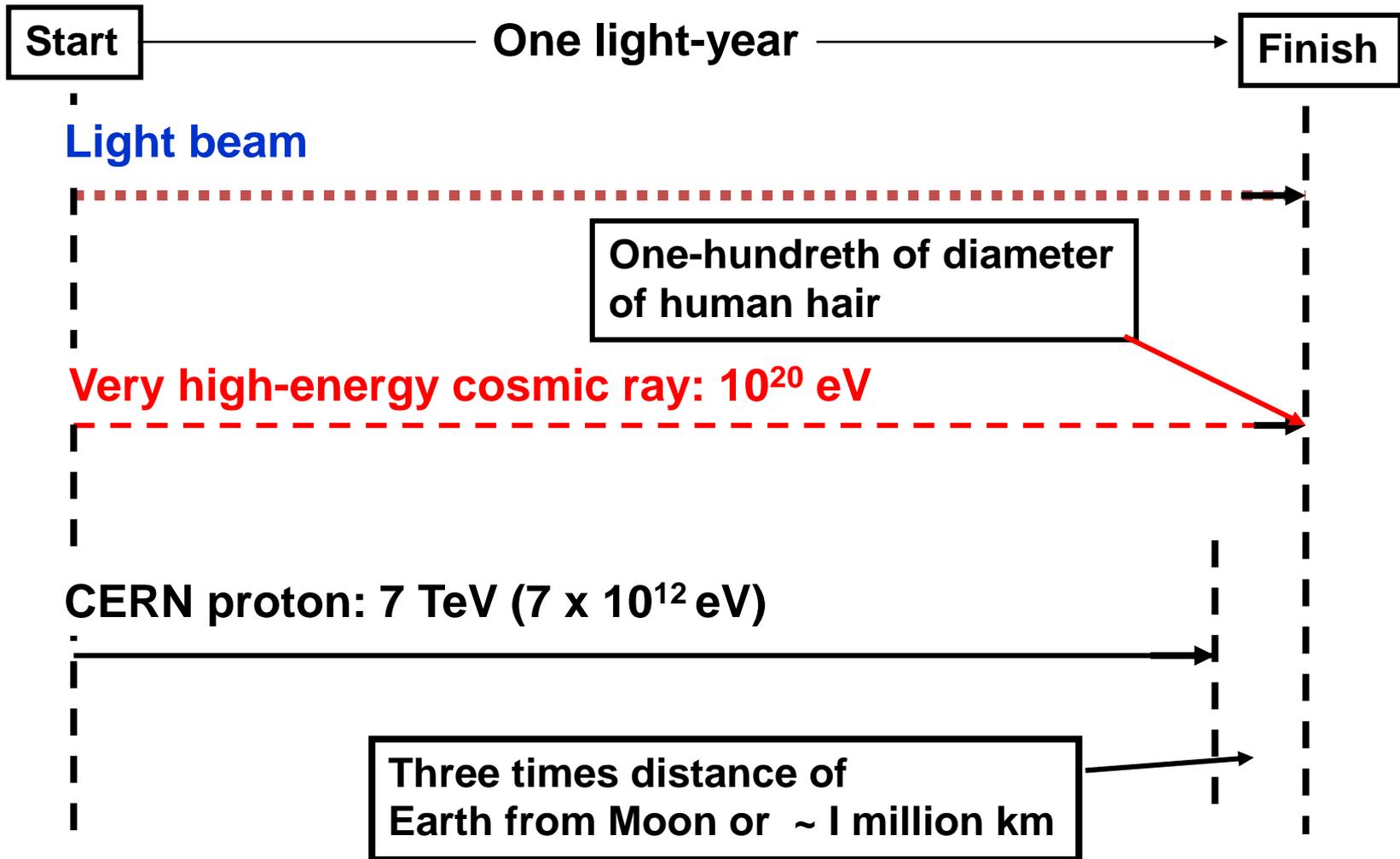
Radioactive Sources 1 – 10 MeV (10^6) (α, β, γ)

Low-Energy Cosmic Ray ~ 1 GeV (10^9)

CERN proton ~ 7 TeV (7×10^{12})

Ultra-High Energy Cosmic-Ray ~ 10^{20} eV

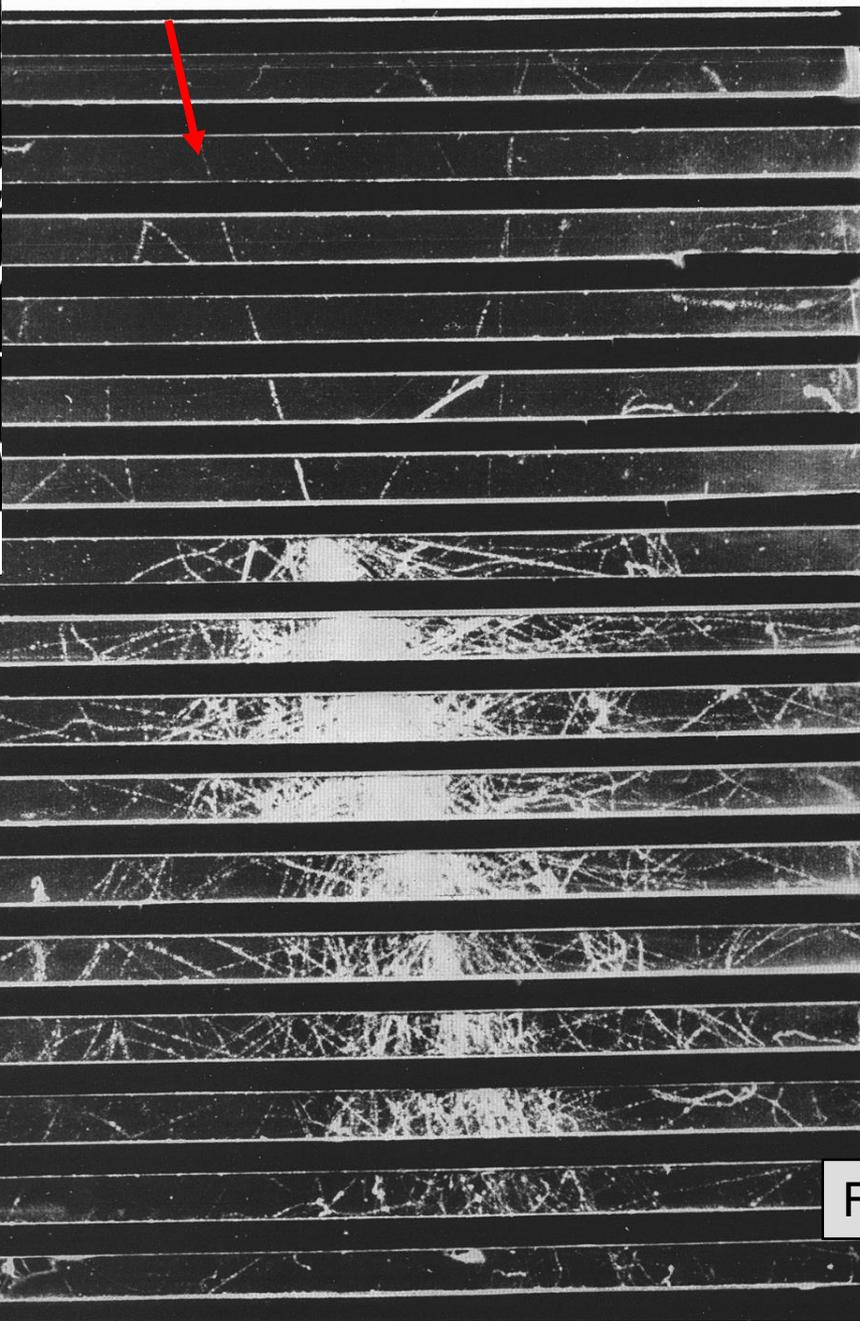
The speed of cosmic rays



Race between a **light beam**, a **high-energy cosmic ray** and a CERN proton lasting 1 light year – or over $\sim 10\,000\,000\,000\,000\,000$ metres (10^{16} m)



P. R. ELLIOTT and J. W. BARNETT
 1949



← 1.3 cm Pb

10 GeV proton

Shower initiated by proton in lead plates of cloud chamber

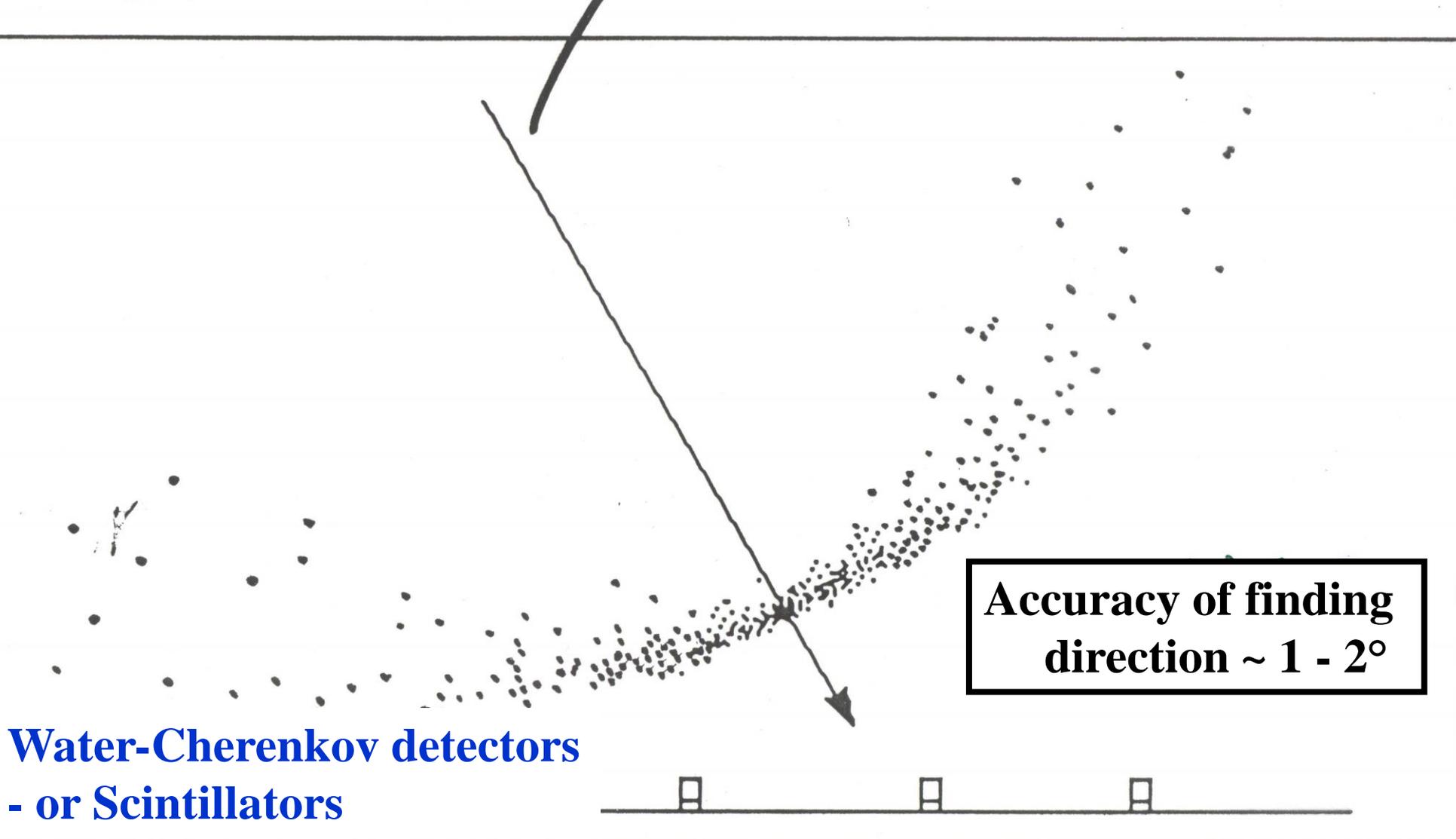
Detectors can find particle number and arrival times

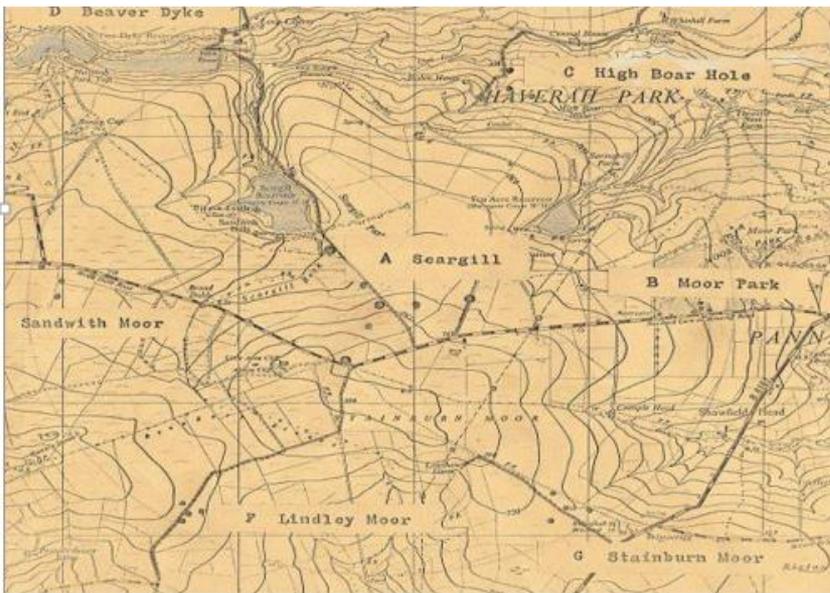
Fretter: Echo Lake, 1949

**Water-Cherenkov detectors
- or Scintillators**

**Accuracy of finding
direction $\sim 1 - 2^\circ$**

'Fast timing' gives the direction





The shower array at Haverah Park. The area enclosed was $\sim 12 \text{ km}^2$

Each point in the diagram represents one or more tanks of water

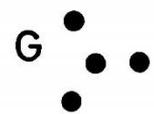
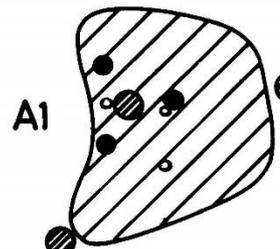
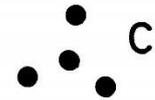
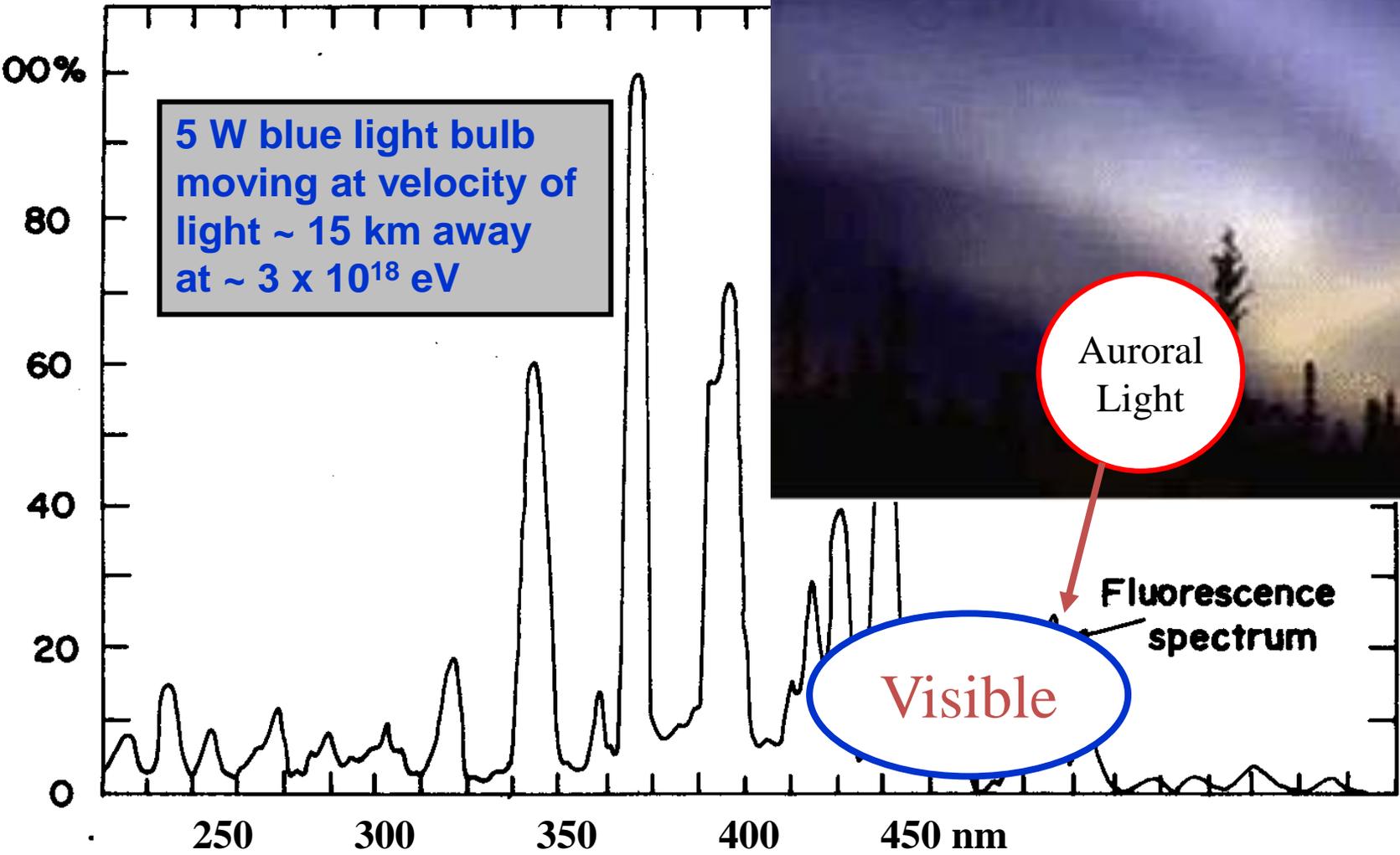
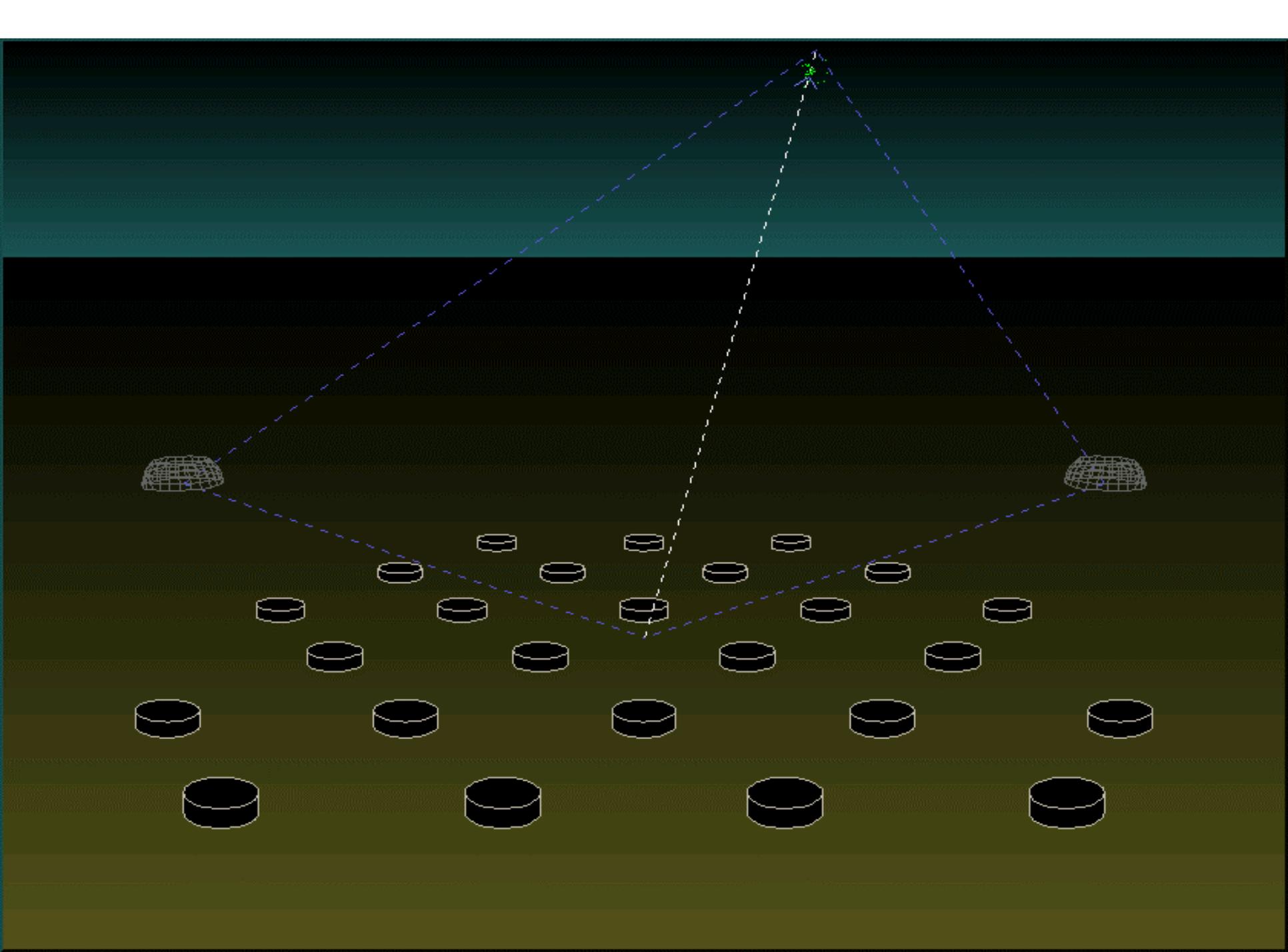


Figure 1

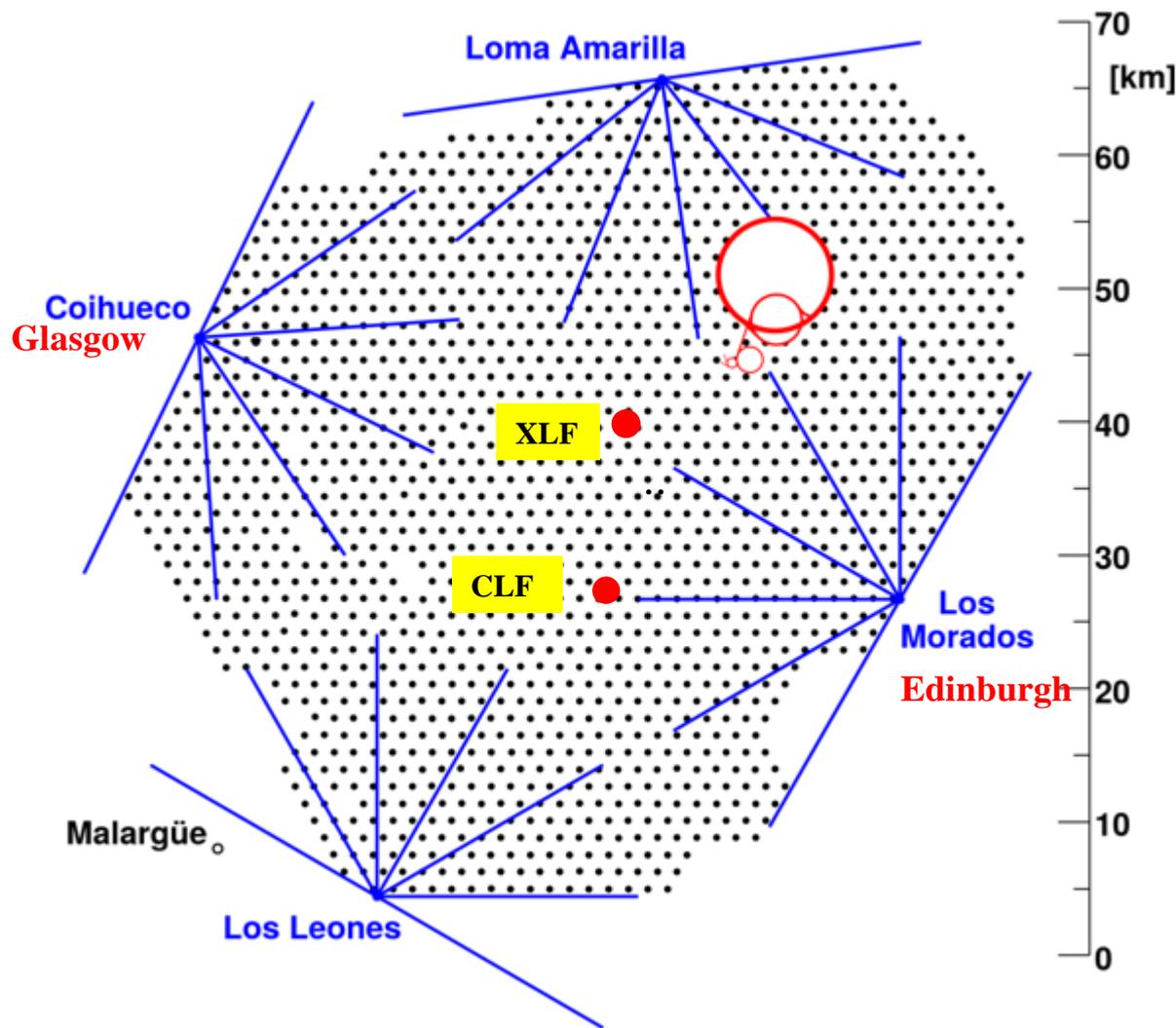
A tank was opened at the 'end of project' party on 31 July 1987. The water shown had been in the tank for 25 years but was quite drinkable! **Used to detect Cherenkov Light**







The Pierre Auger Observatory: Malargüe, Argentina



- 1600 water-Cherenkov detectors: $10 \text{ m}^2 \times 1.2 \text{ m}$
- 3000 km^2
- Fluorescence detectors at 4 locations
- Two laser facilities for monitoring atmosphere and checking reconstruction
- Lidars at each FD site
- Capital cost $\sim \$50\text{M}$
- About the area of County Limerick

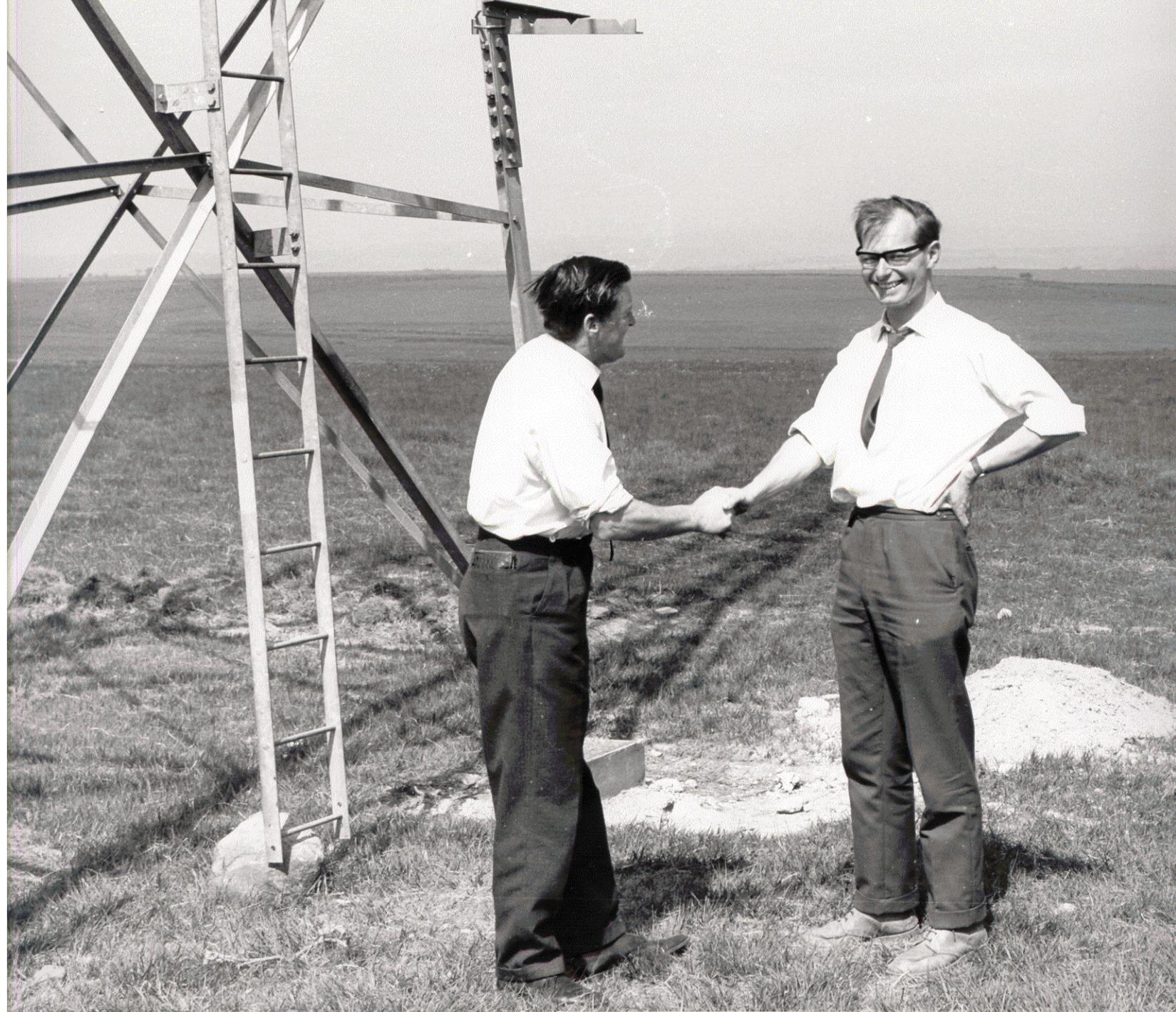
The path to Argentina



Haverah Park Central Building in 1964







Haverah Park project was extremely successful and some important discoveries were made

LUCK: my senior colleagues did not like travelling

The main conclusion, in some ways, was that the device was not big enough!

Rate at highest energies: only ~1 per sqkm per century

Clearly needed to build ~1000 km²

Not too difficult to imagine how to do this - but the technology at the time was the limitation

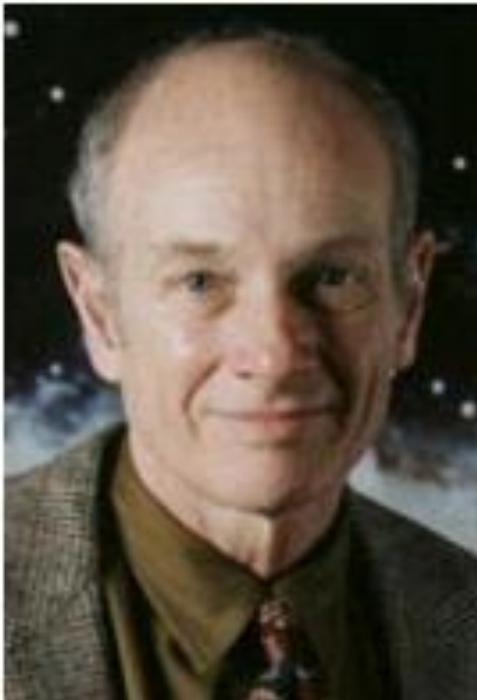
More **LUCK!**

1983: 'Discovery' of cosmic rays from Cygnus X-3 at 10^{15} eV

– Kiel (and then Haverah Park) + TeV work

Focus of work in cosmic rays changed:

Drew many people into the field, including a Nobel Laureate, **Jim Cronin**, who had discovered CP violation in 1964 and been awarded the Nobel Prize in 1980 (particle physics: CERN/FNAL)



Jim decided to build a detector in USA to check these findings

He visited a number of places, including Leeds, to check out his ideas

Our first meeting: November 1986

1990: Retirement meeting in Nottingham

– **LUCK again!**

My conclusion: “We must build 1000 km²”

1991: Dublin: International Cosmic Ray Conference

‘You’re not ambitious enough: we must build 5000 km²’

- Jim Cronin’s view

September – Christmas 1991:

Cronin in Leeds for 4 months: intensive planning

Excellent partnership

aaw: extensive air-showers

jwc: obsessed by project - plus huge range of contacts

I've said many times that Jim could get through doors that I could not even have knocked on:

e.g. UNESCO - \$100,000

Strong mutual interest in malt whisky

Visited Islay – as noted in London Times Obituary!

Getting money to get started

Leeds: Sold aluminium lids from tanks and lots of lead

Jim had a number of benefactors

- **Robert Galvin**, son of the man who founded Motorola – Supported things like travel - and also bought about 1000 GPS engines out of his own pocket
- **Robert Grainger**, made his money in the hardware business: big benefactor of the University of Chicago. Provided money for major building in Argentina

I met both of them both on ‘thank you’ visits

1993 – 1994: Promoted project in US, Latin America and Europe

Big effort targeting the Far East in autumn 1994

Three-week trip to Japan, Hong Kong, China, Vietnam, South Korea and Australia

Typically 3 nights in each place

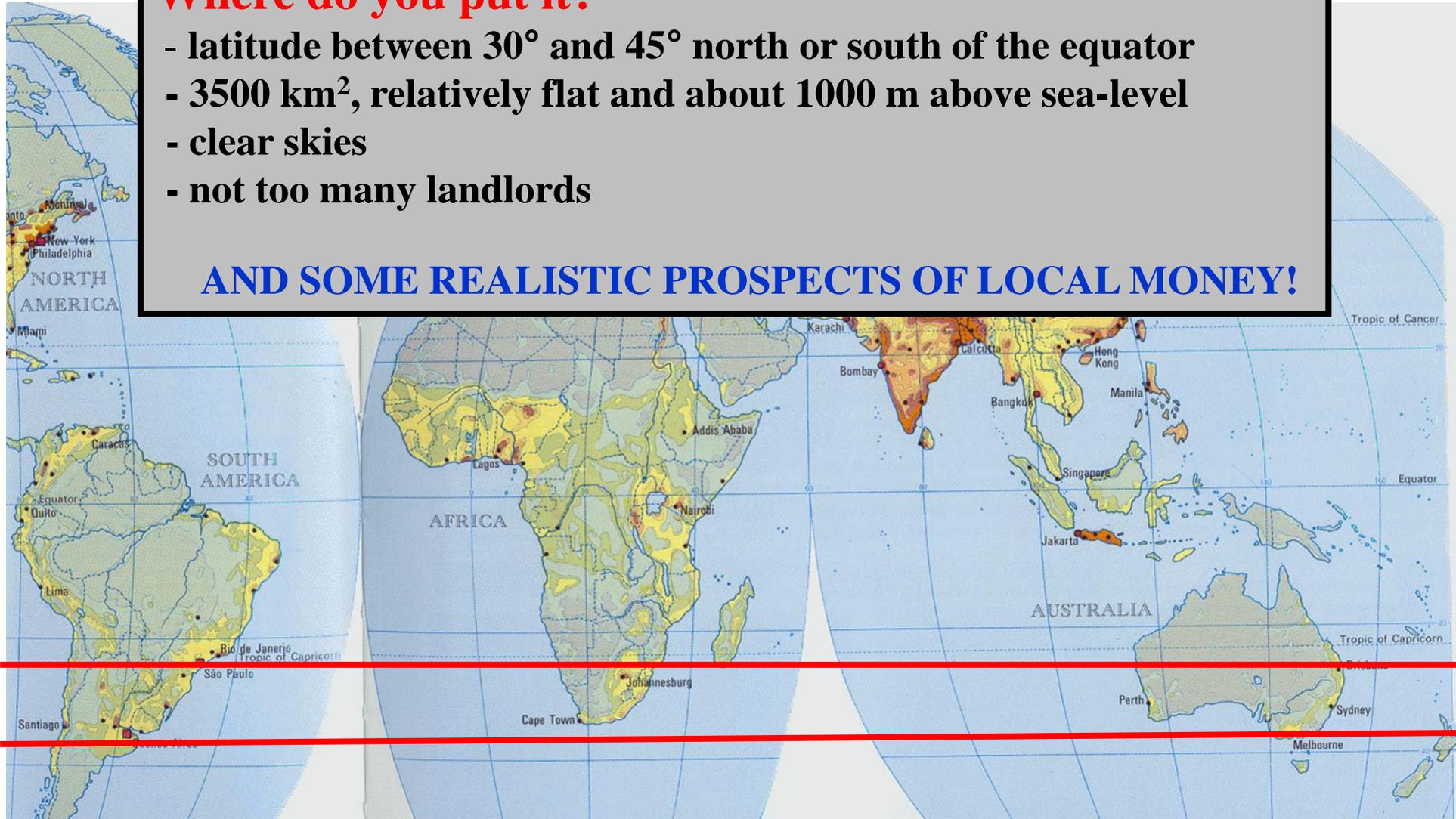
Vietnam was particularly memorable

- **No US - Vietnam diplomatic relations (1994)**
- **Met the Vice-President of the Communist Party, Nguyen Van Hieu (a theoretical physicist) for a couple of hours**
- **Next day saw (on TV) Indira Ghandi being welcomed in the same room**
- **But no photographs – camera stolen in Australia**

Where do you put it?

- latitude between 30° and 45° north or south of the equator
- 3500 km², relatively flat and about 1000 m above sea-level
- clear skies
- not too many landlords

AND SOME REALISTIC PROSPECTS OF LOCAL MONEY!



Site surveys, North and South, made during 1994 and 1995

1995: Design study at FNAL for 6 months

Site studies made simultaneously

My first visit to Argentina (Bariloche) – first of ~30

**Southern Site selection at meeting of Embryonic
Collaboration in UNESCO**

- **Chose Argentina for southern site**

Not South Africa (letter from Mandela) or

Australia

The Pierre Auger Collaboration

Croatia*

Czech Republic

France

Germany

Italy

Netherlands

Poland

Portugal

Rumania

Slovenia

Spain

United Kingdom

Argentina

Australia

Brasil

Bolivia*

Mexico

USA

Vietnam*

**Associate Countries*

~ 400 PhD scientists from

~ 100 Institutions in 17

countries

Choosing Argentina raised interesting political issues

- **Money needed had to be sanctioned at Presidential level**
- **Jim met Menem three times**

**I met him once, with 8 other colleagues, in his offices
in Casa Rosa (like the White House, but pink)**

- **In the 1990s the Argentinian peso was pegged to the US dollar – you could use dollars and pesos interchangeably**
- **Menem promised \$11M pesos which, at that exchange rate, was ~20% of the project**
- **Huge amount of money to spend on fundamental science in Argentina and this led to difficulties with scientists in the country**

1995 – 1999: Raising the profile, several visits to Argentina.

Fight for money in the US

Went to the appropriate Committee three times

Got 50% of what was asked for from US (~20% of capital)

– and told to go South

Jim devastated – but, in Itacaruça, we agreed to go ahead

Once Jim got his money, other countries more or less fell into place

UK gave me £2M - all that I asked for!

Decided to go ahead – though still far short of \$50M needed

Ground-breaking Ceremony 17 March 1999

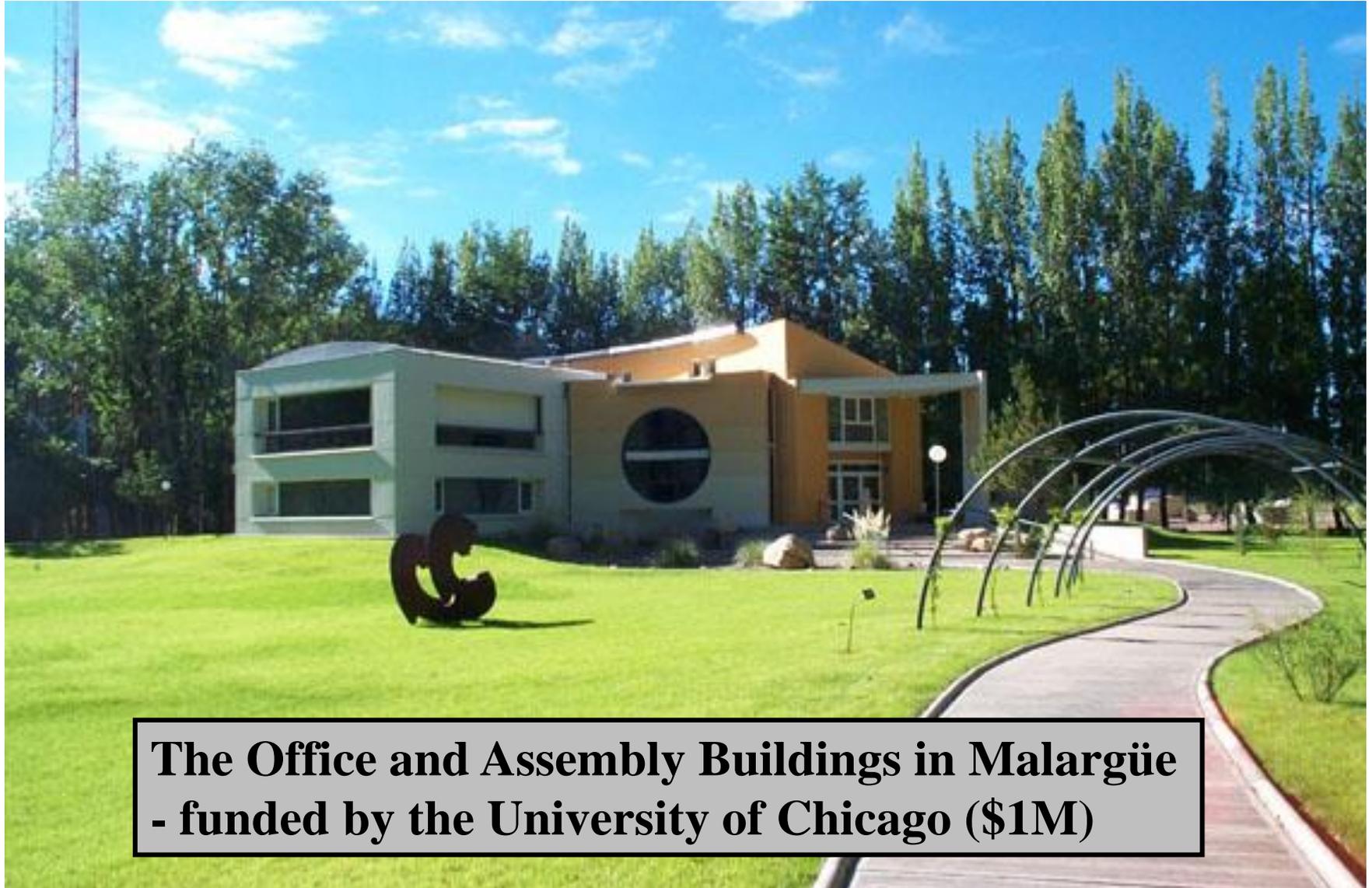


Figure 2: Jim Cronin with Mariette Berl Auger, the daughter of Pierre Auger. She was one of the distinguished guests at the ground breaking ceremony. (Bert is incorrect).

Ground-breaking Day: 17 March 1999

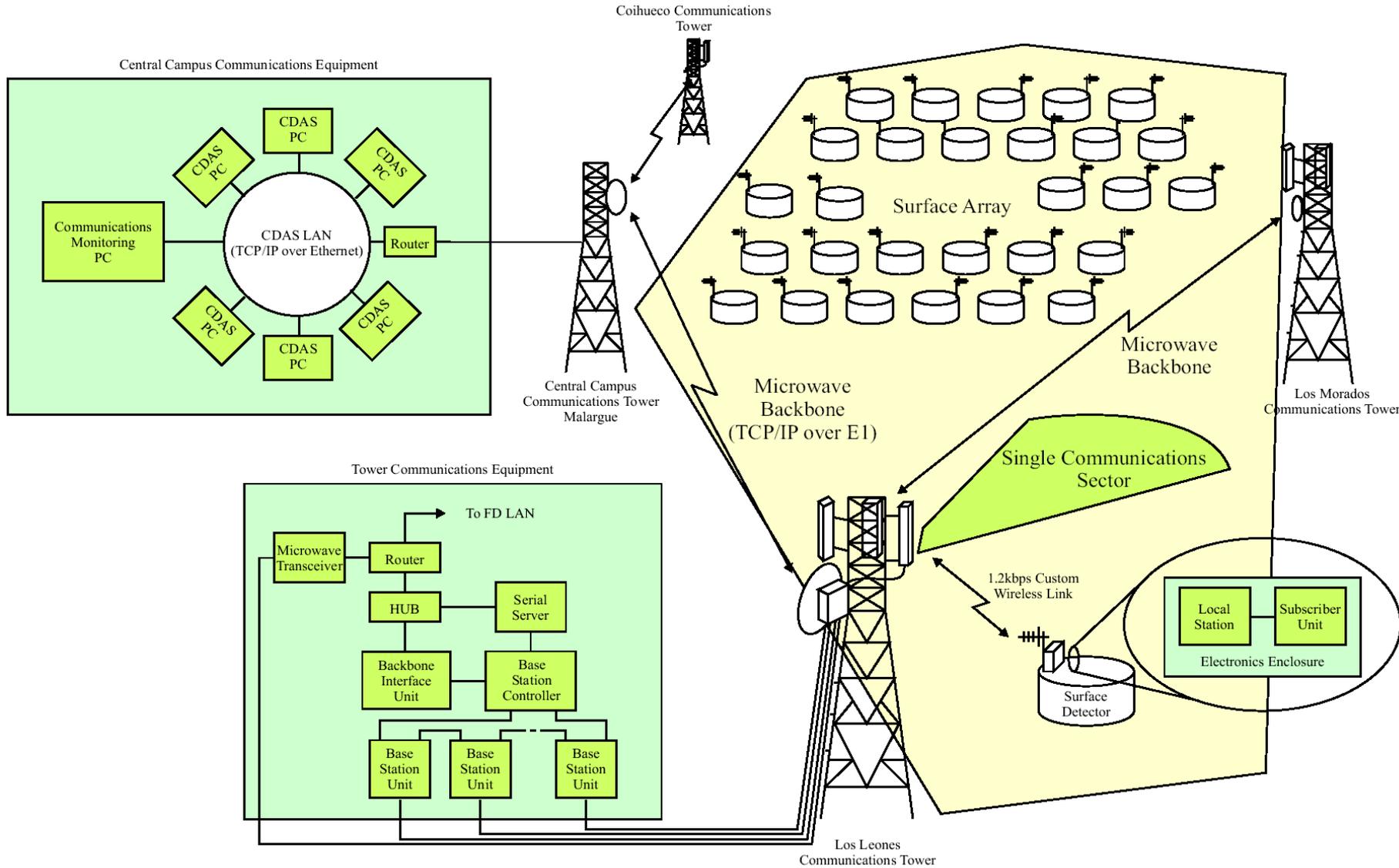


Campus of Auger Observatory in Malargüe



**The Office and Assembly Buildings in Malargüe
- funded by the University of Chicago (\$1M)**

Telecommunication system



**Paul Clark: Electrical Engineer
- now Director of Comms Design**



- **Prototype array was constructed in early 2001**
- **Demonstrated that all sub-systems worked**
- **Passed an International Review Committee - given the go ahead**
- **Communications system came in for great praise**
Only totally novel part of the whole Observatory

So – all systems go

NO!

In 2002 the peso collapsed: 4 pesos needed to buy \$1

We still got 11 M pesos as Menem had promised!

Back to the funding agencies to meet shortfall

All paid up and the UK money (~£250k) was used to buy the fourth tower

Now \$1 buys something like 27 pesos - and even more on the black market

President De La Rúa followed Menem but had less interest in us

However Jim had recently been awarded National Medal of Science

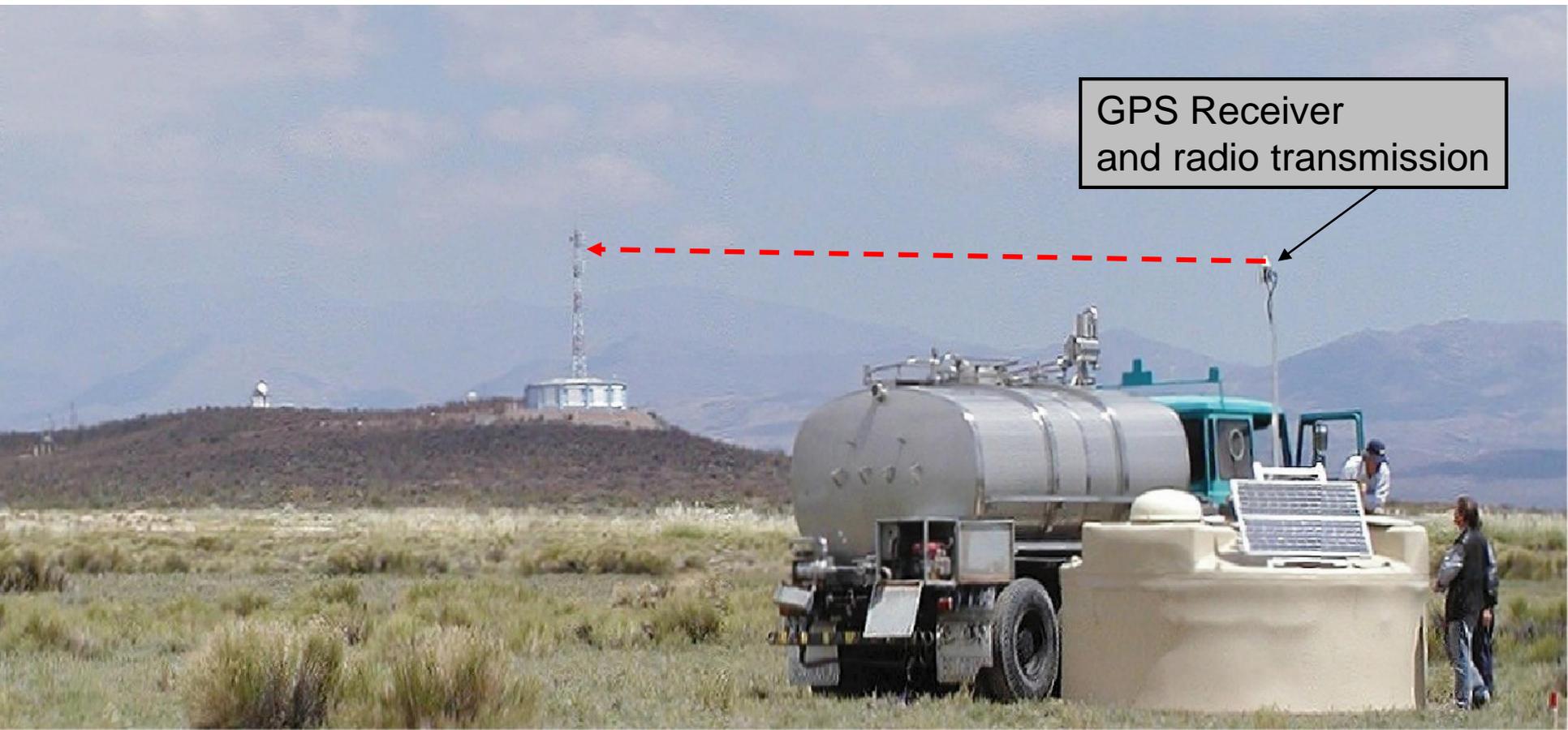
Used this to get Auger Observatory on agenda for a joint meeting of the two presidents in Washington

Lots of lobbying in Argentina: Embassy receptions



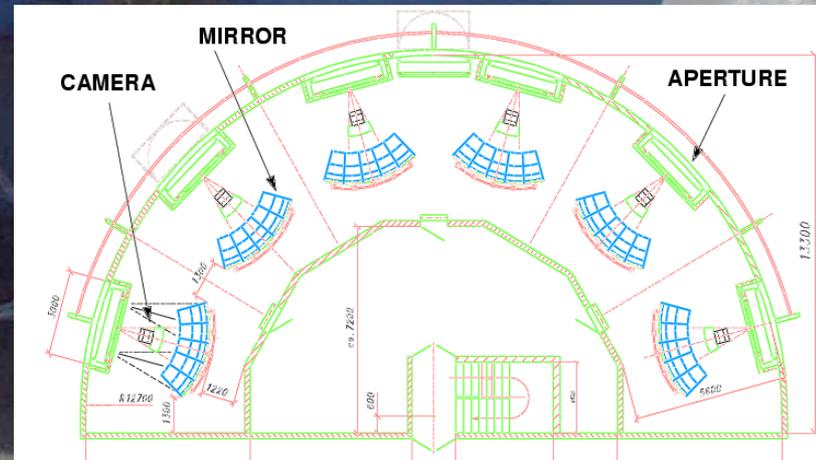


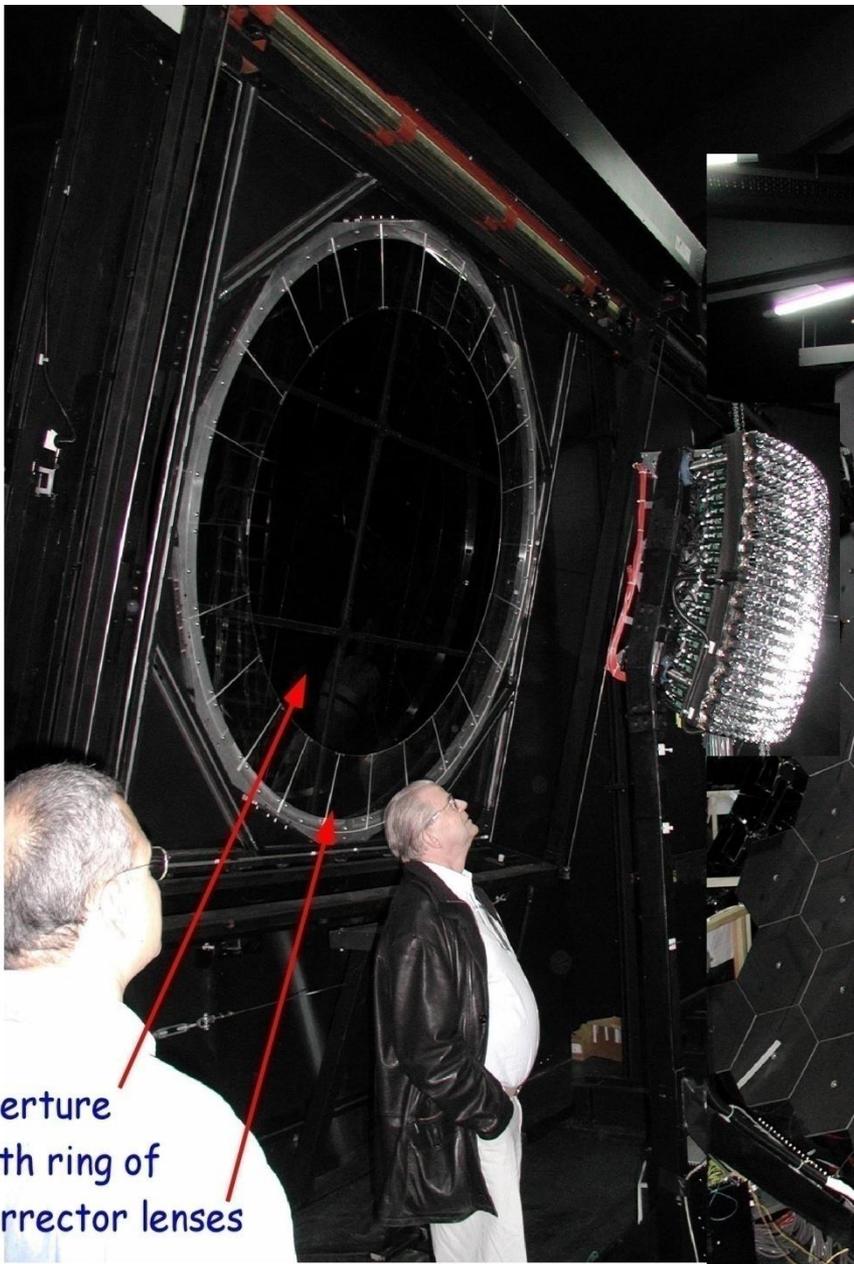
29. 6. 1999



GPS Receiver
and radio transmission

Six Telescopes viewing $30^\circ \times 30^\circ$ each





aperture
with ring of
corrector lenses

two types of mirrors (for testing)
glass aluminum



Fluorescence detector at Los Leones

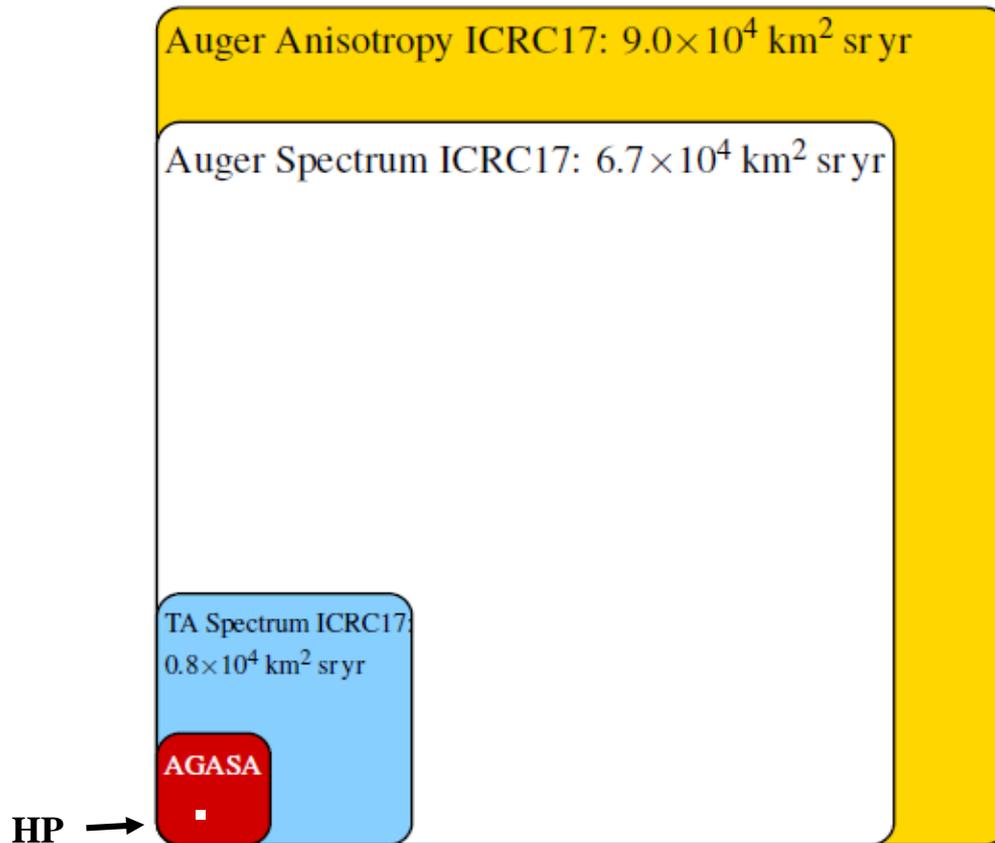
BOZ FOR CHINA
Fluorescence detector
Fluorescence detector
Fluorescence detector



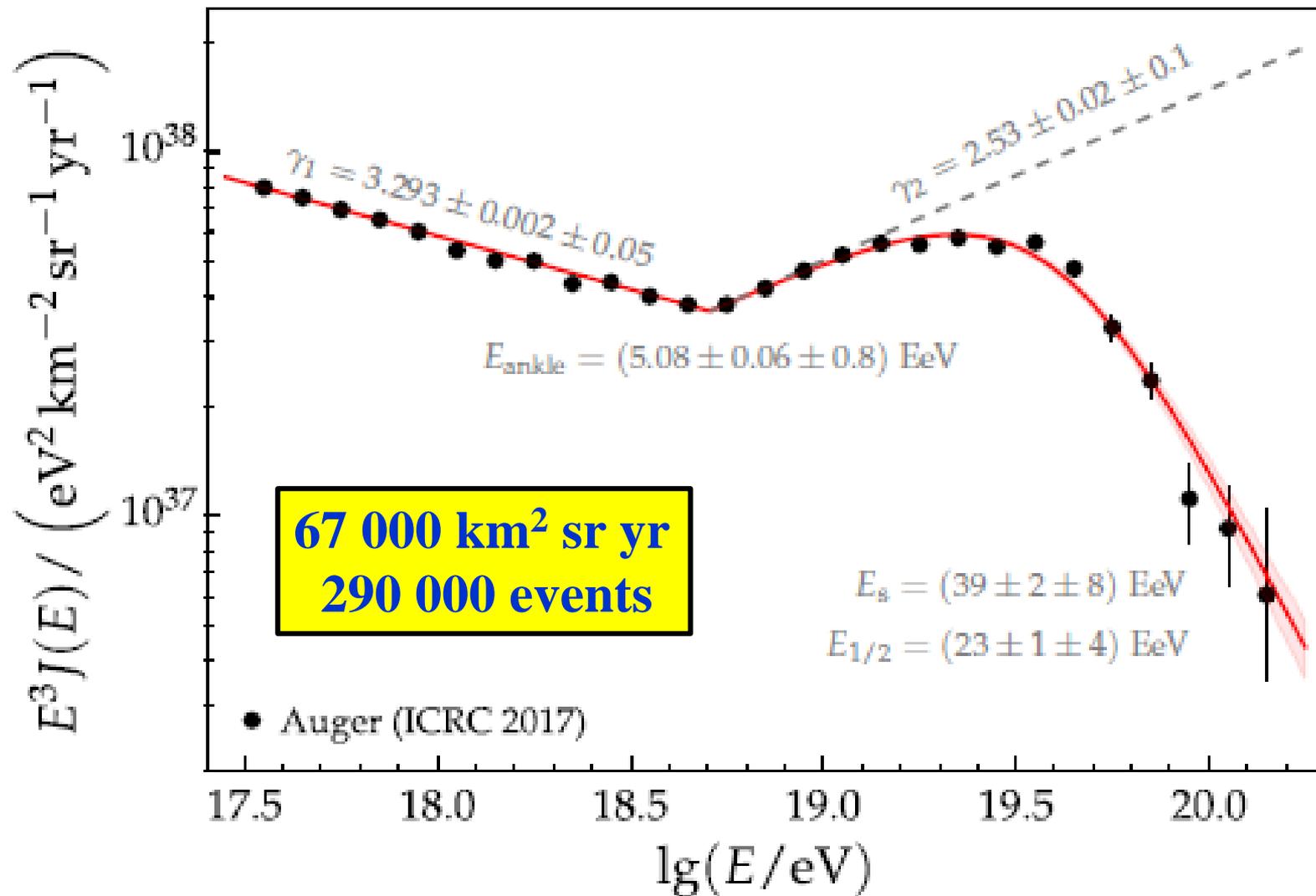
Last tank deployed: 13 June 2008

2004: Data taking started with about 200 water-Cherenkov detectors and two fluorescence telescopes - 13 years after first discussions

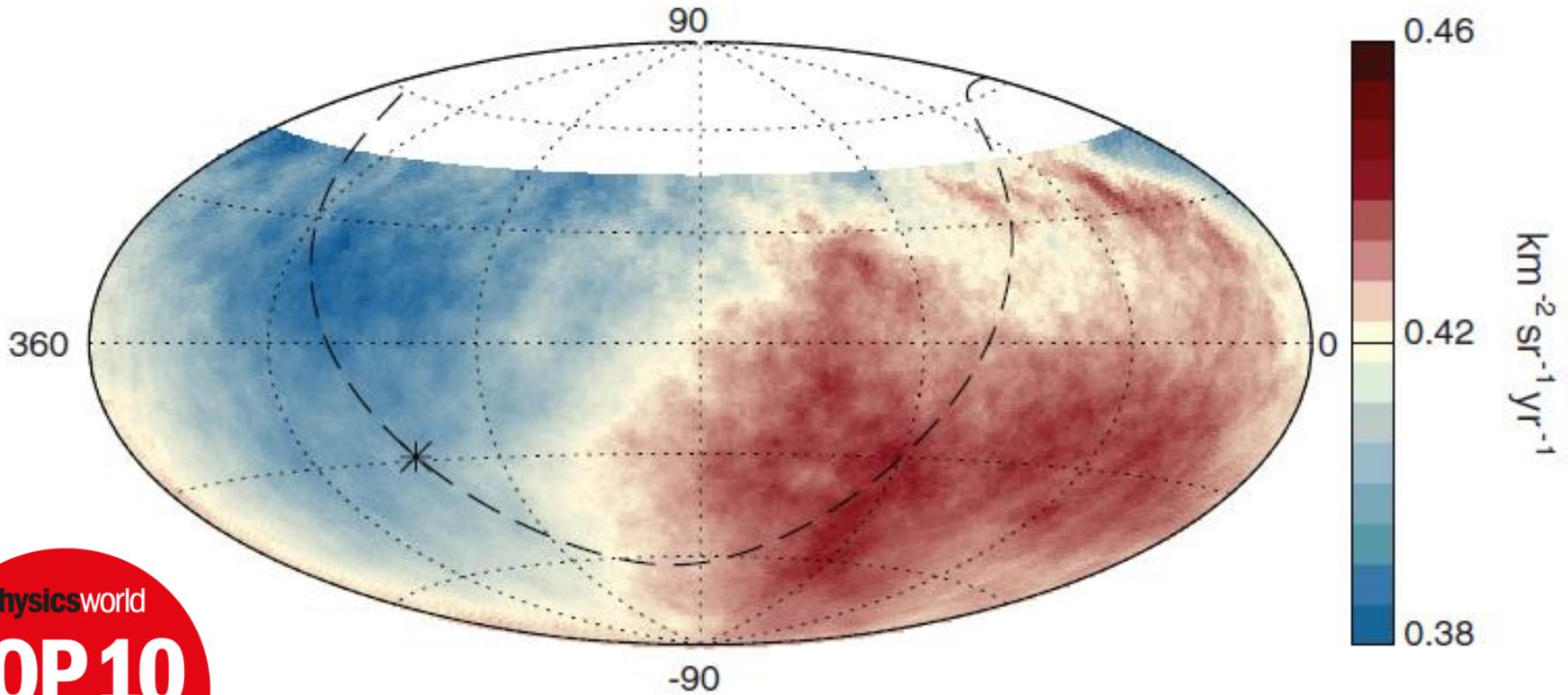
Soon surpassed the exposure at Haverah Park accrued in 20 years – now over 67,000 km² sr years



After Michael Unger 2017



**Cosmic rays with energies above 1.3
Joules come from outside of our Galaxy
– from Galaxies far, far away!**



Exciting new result: published in Science on 22 September 2017

REPORTAGE

Sur la piste des
**rayons.
cosmiques**
dans la pampa argentine

• On va vivre pendant dans
la pampa et ici d'écouter la
trace des rayons cosmiques.

Par Claire Martin. Photos: Rodrigo Gomez Rovira/WU

Quelle est l'origine des rayons cosmiques? C'est pour résoudre cette énigme que des chercheurs ont investi la pampa argentine. Là, ils ont installé le plus grand détecteur du monde qui, jour et nuit, traque les flux de particules venues du cosmos. Une quête dont les physiciens espèrent beaucoup.

A couple of Inauguration parties

In 2007: Julio Cobos: Vice-President of Argentina
(2007 - 2011) with my wife



‘Unexpected Consequences’

- **a vibrant astrophysics program in Vietnam**
- **a small town in Argentina now using science to promote tourism, with a planetarium**
- **the original mayor of that small town (Celso Jaque) became a Senator, and is now the Argentinian ambassador to Colombia**
- **safer and more reliable rail travel in the Scottish highlands**
- **....**

More personal level:

- **my love of chivito, mojella and Malbec**
- **my wife is fluent in Spanish and dances tango and flamenco**
- **seeing Jim Morrison’s grave with my daughter during one visit to UNESCO.....**