Cosmic Rays: a second career

James W. Cronin
Lecture Honoris Causa
Karlsruhe
February 1, 2013
This talk dedicated to Murat Boratav
The Chicago Air Shower Array (CASA)

1089 detectors with 15 m spacing covering an area of ~ 500 m x 500 m

Expected ~20 events/day from Cygnus X-3

1988-1993
My first venture into cosmic ray physics in collaboration with University of Michigan
$10^{20}$ eV proton

16 joules energy

Macroscopic energy

Microscopic particle

Kinetic energy of Andy Roddick's second serve
Propagation

$p^+ \gamma_{\text{cmb}} \Rightarrow \pi + \text{nucleon}$

Mean Energy (eV)

Distance 25 to 55 Mpc

3x10^{20} \text{ eV}
• Inter-Galactic magnetic fields:
  A $10^{20}$ eV proton is almost not deflected in the inter-galactic magnetic field (nG)
COSMIC RAYS
ABOVE $10^{19}$ eV - 1992

Proceedings of the International Workshop on
Techniques to Study Cosmic Rays with Energies
Greater than $10^{19}$ eV

Paris, France
22–24 April 1992

Edited by
Murat BORATAV
University of Paris 6
Paris, France

James W. CRONIN
University of Chicago
Chicago, IL, USA

Alan A. WATSON
University of Leeds
Leeds, United Kingdom

Major Meeting in
Paris in April 1992
organised by Murat Boratav

Followed by workshops
Adelaide (January 1993)
Tokyo (September, 1993)
Snowmass (July 1994)
PROBLEMS TO BE OVERCOME

• LACK OF MONEY TO DO ANYTHING

• Fight for recognition that the project was worthy of attention

• Site surveys

• Develop a collaboration of critical mass and competence and with money to build a capital project of ~$100M

• How was the worth of the project to be assessed?

• A vulnerability, as with neutrino astronomy and, to a lesser extent, ground based gamma ray astronomy, that there are no hard theoretical numbers demanding the construction of an instrument of a certain size

- Contrast search for the W and Z, or the Higgs particle
August 1994

Naming of the project:

A Unique Giant EAS Recorder

No acronyms!

Pierre Auger Observatory
Seed money for 6 month design study at Fermilab

Anonymous gift $50,000
Grainger Foundation for site survey $100,000
UNESCO $100,000
NSF $30,000
Universities Research Association $50,000
University of Chicago $25,000
Role of Fermilab director John Peoples

We requested that Fermilab sponsor a 6 month long design study for the giant array. The director, John Peoples was supportive. He was convinced that this was important work. He agreed to support the workshop, provided space and people to help organize it. There was a cost to John in all of this as there was a lot of hostility at Fermilab toward resources diverted from anything other than maintaining the machine and the big collider detectors. This hostility was running particularly high because of other non-accelerator projects undertaken by Fermilab.

Also significant was the fact that Paul Mantsch of Fermilab became the Auger Project Manager. Paul was an expert on super-conducting magnets and large detectors. As a refugee from the failed SSC he was attracted to the uniqueness of the project and its challenge. Without Paul’s leadership the project would not exist!
Cosmic rays of unknown origin have been observed at energies above $10^{20}$ eV. An international design group is being hosted by Fermilab to produce a technical design for a cosmic ray detector with an aperture of 10,000 km$^2$-sr. The initial concept is a surface array of 5,000 km$^2$ with 10 separate detectors.
The Fermilab Design Study

Studies of various surface detector designs:

RPCs, water-Cherenkov, scintillators, radio….
“Let a thousand flowers bloom….”

Hybrid approach: ground array and fluorescence detectors
- chose water as surface detector

Very extensive Monte Carlo calculations

Two sites to give all sky coverage

Each site ~3000 km² : site survey was contemporaneous
Approximate cost ~$100M

Design Study document completed in October 1995
March 1995

Unsolicited letter from Argentine Atomic Energy Agency (CNEA) offering 3M US dollars/year for Auger!
The Design
Site requirements:
- latitude between 30° and 45° north and south of the equator
- 3500 km² and relatively flat
- 500 to 1500 m above sea-level
- low cloud cover and good visibility with few local light sources
- suitable infra-structure with national scientists and support
- access to radio licences

Site surveys, north and south, made by Ken Gibbs (Chicago) and Antoine Letessier-Selvon (Paris) during 1994 and 1995.
Argentina selected for South during meeting at UNESCO in November 1995
Dear Sir

Scientific and engineering achievements are the cornerstones upon which the future generations in Southern Africa will attain their goals for the successful development and upliftment of our peoples. There is consequently an urgent need for South Africa to be at the leading edge of expertise in the world of technological endeavour.

Recently I have been informed of the Giant Air Shower Array project which is truly an international project destined to become one of the scientific highlights of this and the next decade and that South Africa has one of the favoured sites in the southern hemisphere.

I am placing my full weight behind the sitting of the project in South Africa as it is clear to me that it will provide an exciting new focus for our young potential scientists and enhance our Reconstruction and Development Program. Just as important however is that our own expertise could significantly contribute to the international community in the spheres of science, training and facilities.

As a developing country with a good foundation in the sciences and related technologies, South Africa will be in a favourable position to extend our knowledge base into the Southern African subcontinent to the mutual benefit for all should we be successful in being awarded the project.

I wish to reassure you of our total commitment should you consider South Africa as the site for this prestigious undertaking.

With best wishes to you and your colleagues.

Yours sincerely

[Signature]

N R MANDELA

Dr M Boratav
The observatory plan after choosing the Malargue site

Surface Array
- 1600 detector stations
- 1.5 km spacing
- 3000 km²

Fluorescence Detectors
- 4 Telescope enclosures
- 6 Telescopes per enclosure
- 24 Telescopes total
Surface Detector

- Communication antenna
- GPS antenna
- Solar Panel
- Plastic tank with 12 tons of water
- Electronics enclosure
  - 40 MHz FADC, local triggers, 10 Watts
- Battery box
- three 9-inch PMTs
Schmidt optics
30°x30° fov
UV filter
corrector “ring”

Camera with 440 PMTs
1.5° per pixel
Assessment of the Project (November 1995)

No host institution (unlike new project at CERN, ESA, ESO, FNAL)

Formed own Review Committee

W I Axford (MPI: Director, Katlenburg-Lindau): Chair
R Cowsik (Indian Institute for Astrophysics, Bangalore, India)
M Demassieux, ENST (France)
R Eckers (Australian National Telescope, Australia)
M-T Koshiba (Japan)
J Steinberger (CERN, Switzerland)

‘Entirely favourable’ report used to help with agencies

“But of course it is a favourable report: you chose the committee”
Date: Sat, 09 Sep 1995 12:41 -0800 (PST)
From: DIRECTOR@SLACVM.BITNET
To: JWC@UCHEP.UCHICAGO.EDU

To: James W. Cronin
From: Burton Richter

Dear Jim:

I’ve just seen the article in the 1 September 1995 issue of SCIENCE on your proposal for a very large array to detect ultra-high energy cosmic rays. I think it’s a terrific idea.

As you may know, for the last few years I’ve been telling O’Fallon, Hess, and HEPAP that I felt we were not spending enough money on non-accelerator experiments. Your’s is just the kind of large-scale program that I had in mind, and you should feel free to call on me if you need any help in twisting arms in the Administration, Congress, or our high energy physics community.

I would like to keep up with what you are doing and perhaps, if I can arrange my schedule, attend your next workshop. If you have such a thing, please put me on your mailing list for papers (scientific or political) and meeting announcements.

With best regards,

Burt
The Search for Funding in the USA

All countries watched what the US was doing

Significant promises of funding from Argentina, Brasil and Mexico

US assessment by SAGENAP committee:

DIFFICULT! Third time lucky (April 1998)

BUT:

BUILD ONLY ONE ARRAY and GO SOUTH

Department of Energy
Germantown, MD 20874-1290

November 21, 1997

Professor James W. Cronin
Department of Physics
University of Chicago
933 East 56th Street
Chicago, Illinois 60637

Dear Professor Cronin:

I regret to inform you that the Department of Energy is not able to support the proposal “Construction of the Pierre Auger Observatory” submitted by the University of Chicago.

We have carefully considered the proposal, taking into account its scientific quality and its priority relative to other currently supported or proposed activities. In addition to our standard peer review by mail, we have, as you well know, solicited the recommendations of the members of the Scientific Assessment Group for Experiments in Non-accelerator Physics (SAGENAP). In light of our existing commitments, and because of the limited funds available, we find it necessary to decline support of your proposal. The relevant program managers from this office would be pleased to explore with you appropriate next steps.

Your interest in submitting this proposal to the Department of Energy is appreciated.

Sincerely,

John R. O’Fallon
Director
Division of High Energy Physics

cc:
Frederick M. Bernthal, President

DOE and the NSF have agreed to proceed with the Pierre Auger Project, with detector engineering and pre-construction commencing on the first array at the southern site in Argentina in FY 1999. The construction funding profile is tentatively planned as follows (SK):

<table>
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<th>Year</th>
<th>DOE</th>
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<tr>
<td>FY99</td>
<td>$750</td>
<td>750</td>
</tr>
<tr>
<td>FY00</td>
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<td>750</td>
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<td>$1250</td>
<td>1250</td>
</tr>
<tr>
<td>FY02</td>
<td>$500</td>
<td>1000</td>
</tr>
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</table>

Total: $1500 $2000 $2500 $1500 $7500

It is possible that this profile could be accelerated somewhat, depending on developments at the two agencies.

Two reviews are required at a minimum. First, a "Technical, Cost, Schedule, Management" review during the fall of 1998, before any funding is committed to detector engineering and pre-construction. Secondly, a review during FY00 of progress, etc.

Finally, upon submission of a proposal for the northern site detector, a review will take place, in FY01 or FY02, on the progress and physics at the southern site, the prospects for physics at the northern site, and developments in the field.

We will be in touch.

Congratulations and best wishes,

[Signature]

P.K. Williams
Division of High Energy Physics
U.S. Department of Energy

Patricia Rankin
Division of Elementary Particle Physics
National Science Foundation
Dear Dr. Cronin,

Thank you for your letter of September 2, 1998.

At the moment we are in the process of restructuring our Institute of Nuclear Physics and important questions to the future program and the negotiation with the foreseen director of the Institute are yet to be solved. The participation in the Pierre Auger Project is under consideration in this process, but at this stage it would be premature to enter into any kind of discussions of financial contributions. I hope our discussion will be more advanced in December.

I will not be able to participate in the UNESCO-meeting and have asked Professor Kampert to attend.

Yours sincerely,
After US funding announced in 1998, funding from European Countries came relatively quickly.

October 1998 a two day meeting at UNESCO to produce a draft International Agreement. Temporary chairman for this meeting was Professor Herwig Schopper.

Ground breaking Ceremony in March 1999. First signatures of the International Agreement
17 March 1999: Ground Breaking Ceremony
SITIO INAUGURADO POR

DR. CARLOS SAUL MENEM
GOBERNADOR DE LA PROVINCIA
DR. ARTURO LAFALLA
DIRECTORES DEL PROYECTO
DR. JAMES CRONIN Y DR. ALAN WATSON
CONT. CELO JACQUE
CONT. VICENTE RUSSO

OBSERVATORIO
PIERRE AUGER
DE RAYOS COSMICOS
MENDOZA, 17 DE MARZO DE 1999
This disagreement stimulated the scientific interest in the Auger Observatory.

This diagram shows the spectrum about the year 2000 with a 20% energy variation.
The Auger Collaboration

67 Institutions, ~400 Collaborators

Argentina, Netherlands
Australia, Poland
Brazil, Portugal
Czech Republic, Slovenia
France, Spain
Germany, United Kingdom
Italy, associate
Mexico, Vietnam

* associate
Engineering array  2000 - 2001
First tank in the field
Assembly building on Malargue campus funded by Argentina
Building on Malargue campus – offices, data collection, visitor center funded by The University of Chicago
Devaluation of Argentine peso by factor 3 on Dec 1 2001
Apoyo de Clinton al observatorio del sur mendocino

Los presidentes se reunieron en solitario con sus gabinetes. Pleno respaldo de los Estados Unidos al plan económico de la Alianza.

Por su parte, Muchos amigos de los Estados Unidos a la gestión del gobierno argentino.
Letter from Koichiro Matsuura, Director General of UNESCO, offering assistance to obtain duty free importation of scientific equipment for the Auger observatory.
Number of tanks vs time

<table>
<thead>
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<th>Count</th>
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<tr>
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<td>2001</td>
<td>40 (engineering array)</td>
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<tr>
<td>July</td>
<td>2003</td>
<td>100</td>
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<td>June</td>
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<td>1637</td>
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<td>November</td>
<td>2008</td>
<td>dedication</td>
</tr>
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November 2008

Paul Mantsch at dedication the completed Auger Observatory
A visit to a tank during 2006 celebration
A “perfect” hybrid event: few are as beautiful as this one!
20 May 2007    $E \sim 10^{19}$ eV
A few scientific results
Composition – primaries getting heavier
Composition - primaries getting heavier
proton-proton total cross section
Upper limits of photon content in cosmic rays

Integral Flux \( E \geq E_0 \) \( [\text{km}^2 \text{sr}^{-1} \text{yr}^{-1}] \)

- \( \text{SHDM} \)
- \( \text{SHDM}' \)
- \( \text{TD} \)
- \( \text{Z-burst} \)
- \( \text{GZK} \)

Energy [eV]

- \( \text{Hyb 2011} \)
- \( \text{TA 2011} \)
- \( \text{Auger SD} \)
Outreach

Auger Office Building
And Visitor Center
>6000 visitors/yr

J W Cronin School

Malargüe
Planetarium

Auger collaboration on parade

IUPAP October 2008
P. Mantsch
Many improvements and enhancements

Extension of surface and fluorescence detectors to lower energies

Research on the detection of cosmic rays by radio
The Pierre Auger Observatory

An international project produced from the “grass roots” where no country or institution dominates.