Proportional counter development with vacuum manifolds recycling legacy iron tubes for the GRAPES-3 expansion

Pranaba K Nayak*

Tata Institute of Fundamental Research

Mumbai-400 005, India

***Email: pranaba@hotmail.com**

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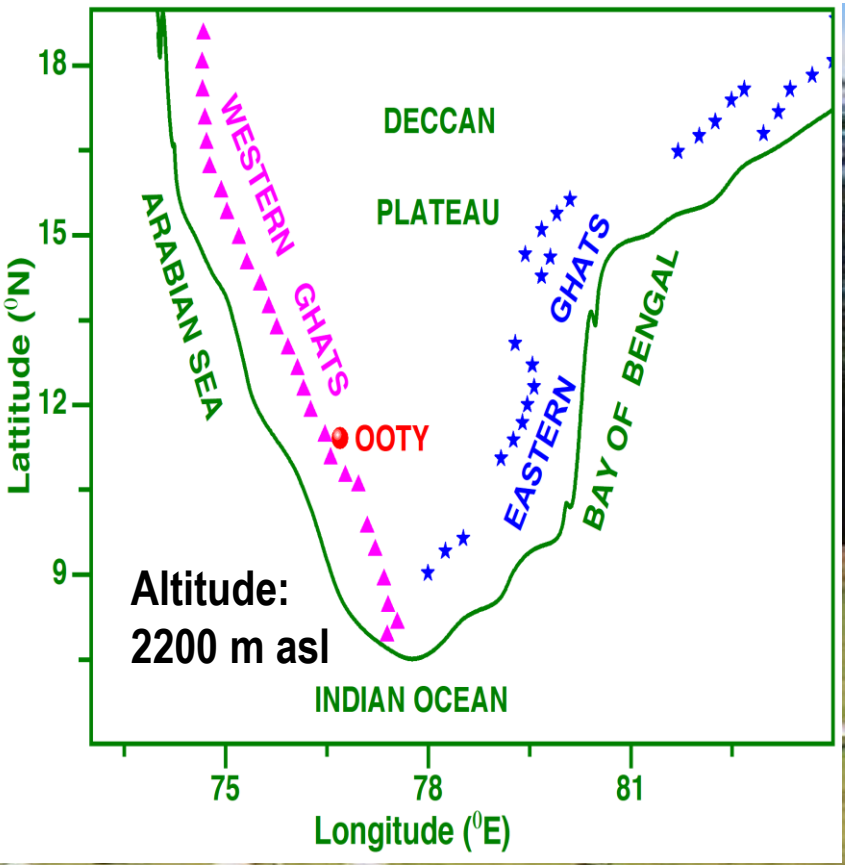
GRAPES–3 Experiment

~ 400 Plastic Scintillator Detectors

3712 Proportional Counters



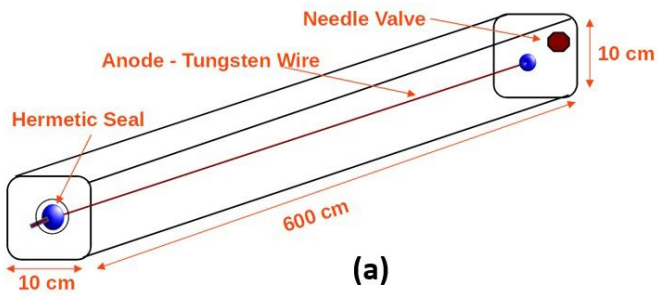
To study

Cosmic Ray Origin, Composition and Energy spectrum

Muon content in Extensive Air Showers

The four muon stations

Schematic of PRC



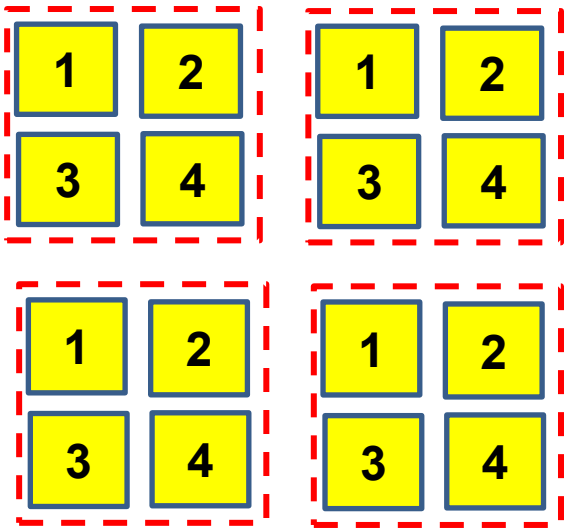
A module has 232 PRCs

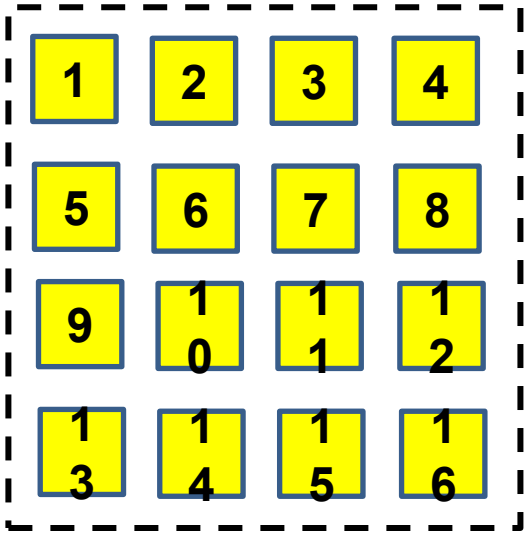
Inverse pyramid structure

Energy threshold ~ 1GeV

New Muon Telescope

Old Telescope
58 x 4 x 16 =
3712 PRCs





New Telescope
59 x 4 x 16 =
3776 PRCs

The Process Flow:

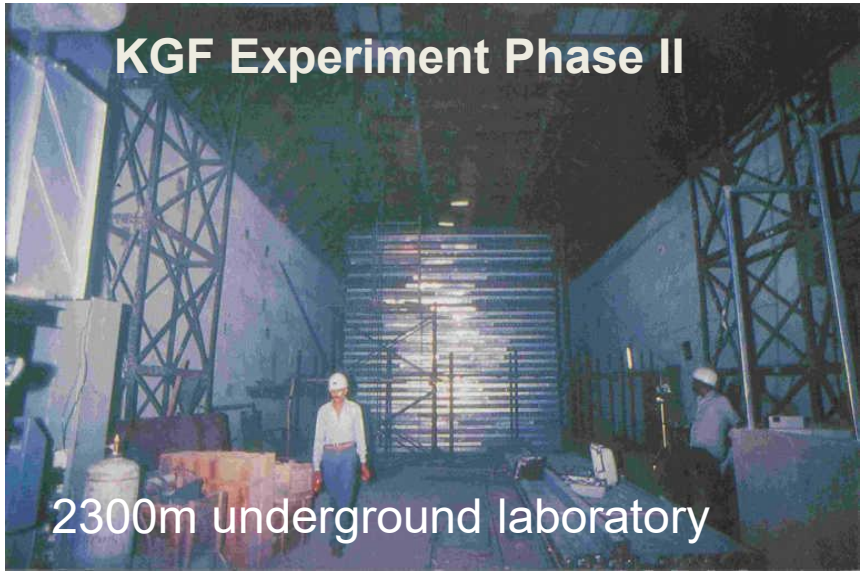
- Welding end-plates both-sides
- High-Pressure Leak Test
- Add Anode Wire, Valves, Hermetic Seal
- Evaluate above 1 x 10^{-4} mbar
- Check for stability for two weeks
- Fill P-10 (90% Ar +10% CH4) Gas
- Use MCA to test Performance
- Paint the outer side of PRC
- Send for Long term test using DAQ

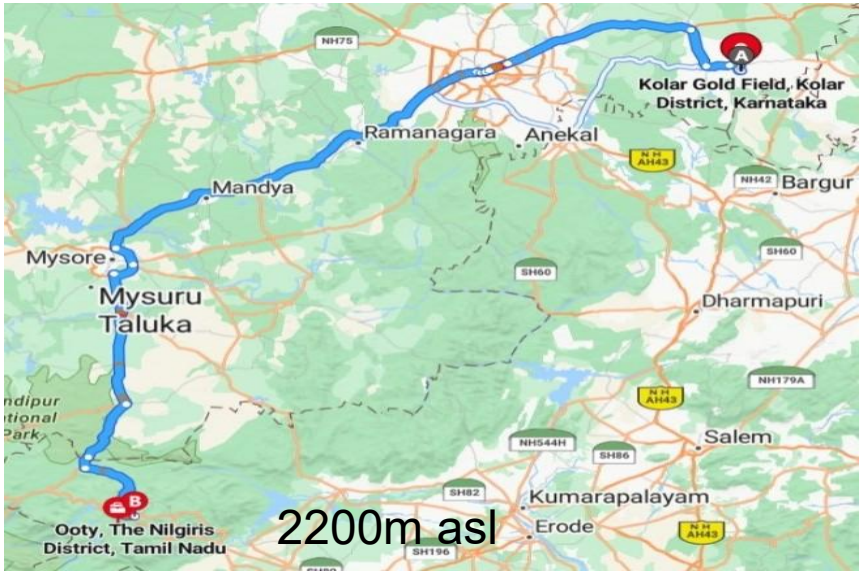
New Muon Telescope

Major Requirements:

- 3776 Steel Tubes (600 cm x 10 cm x 10 cm)
- Vacuum Manifolds for evaluating the tubes and filing the P10 gas.
- MCAs (4) + Spectroscopic amplifiers (2) (Two MCA +1 SA were available after Solar Eclipse Experiment; another set needed)
- Replicate the DAQ or Improve it, if possible (We have Electronics-Electrical Engineering Workforce)

Legacy Iron Tubes: A Rare Opportunity





~7500 Steel tubes from KGF experiments; ~50% Stacked in Ooty for ~20-25 years

PHYSICAL REVIEW D VOLUME 57, NUMBER 5 1 MARCH 1998

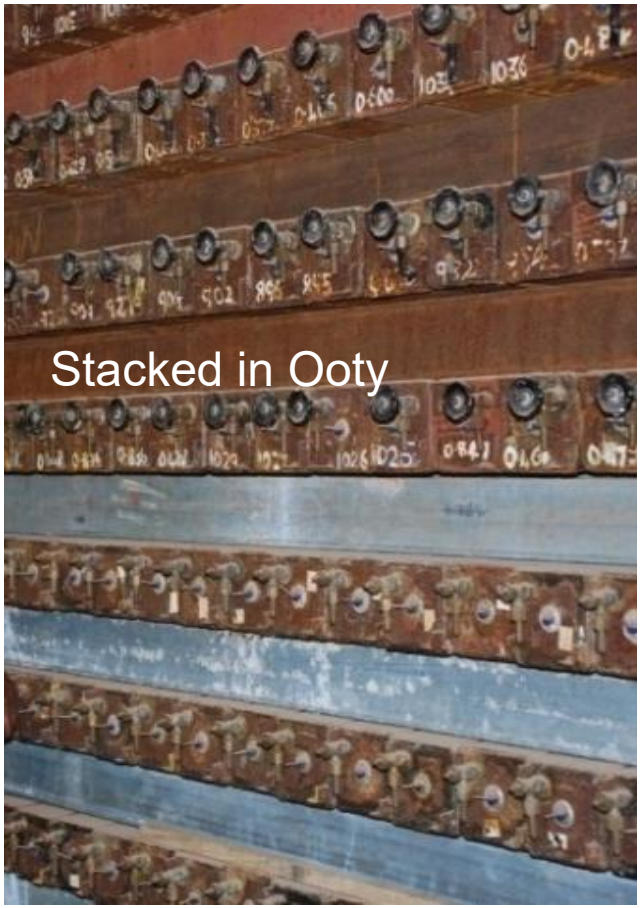
Cosmic ray composition from multiple muon data with the KGF underground detector

H. R. Adarkar, S. R. Dugad, M. R. Krishnaswamy, M. G. K. Menon, N. K. Mondal, V. S. Narasimham, and B. V. Sreekantan
Tata Institute of Fundamental Research, Homi Bhabha Road, Bombay, India 400 005

Y. Hayashi, N. Ito, S. Kawakami, S. Miyake, and Y. Uchihori
Osaka City University, Osaka 558, Japan
(Received 27 August 1997; published 6 February 1998)

Can aged materials meet modern detector standards?

Cleaning of Legacy Iron Tubes



- Unknown surface chemistry
- Required controlled restoration process

For further information

P.K. Mohanty, Cosmic ray sources and detectors, The European Physical Journal Special Topics, 234 (2025) 5009.

A. Jain et al., Development and Installation of Proportional Counter for Large Area Muon Telescope at GRAPES-3, Springer Proc Physics, 304 (2024) 592.

Quality of Cleaning: Characterization of Two types of Steel Tubes

Galvanised Steel Tubes (GST)

Mild Steel Tubes (MST)

MST corresponds to low-carbon mild steel; GST is zinc galvanized MST outer side.

These characterizations were not performed out of materials-science curiosity, but to qualify the cleaning methodology for detector use.

Pranaba Kumar Nayak[1], Muthiah Muthuvinayagam[2], Shashikant Raichand Dugad[1], Sunil KumarGupta[1], Balakrishnan Hariharan[1], Paranjothi Jagadeesan[1], Atul Jain[1], Pravata Kumar Mohanty[1], Mohamed Rameez[1], Kaviti Ramesh[1], YoshioHayashi[3], SaburoKawakami[3], Akitoshi Oshima[4]*

[1]Department of High Energy Physics, Tata Institute of Fundamental Research, Mumbai, India, [2]Department of Applied Physics, Saveetha School of Engineering, Saveetha University, Thandalam, Chennai, India, [3]Graduate School of Science, Osaka Metropolitan University, Osaka, Japan, [4]College of Engineering, Chubu University, Kasugai, Aichi, Japan

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887 -892 (2025)

Enhancing the capability through recycling: Doubling the world's largest muon telescope with almost-buried iron tubes

Techniques used:

X-ray Diffraction (XRD):
Phase analysis

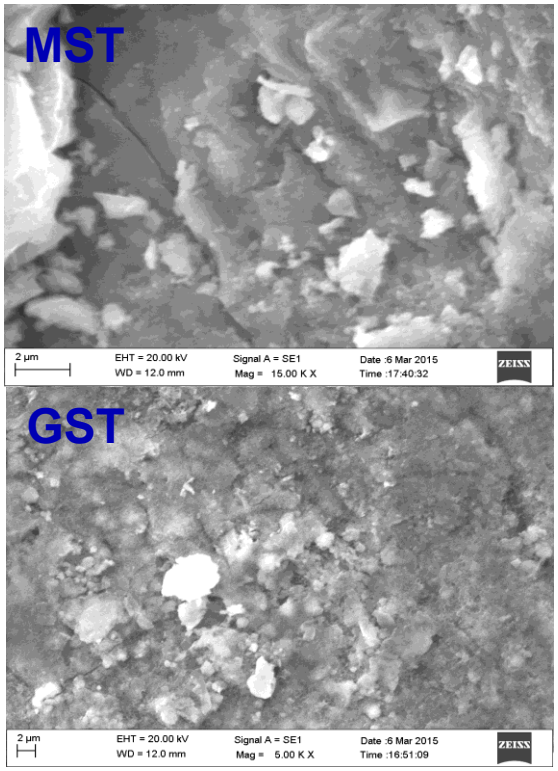
FT Infrared Spectroscopy (FT-IR):
Bending and vibration modes

Scanning Electron Microscopy (SEM):
Imaging at higher resolution

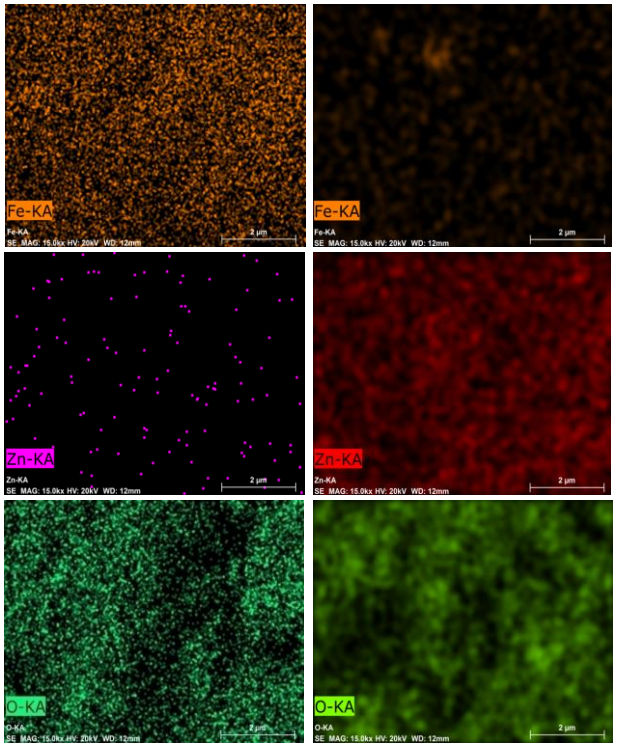
Energy Dispersive X-ray Analysis (EDAX):
Elemental distribution

Pulse Height analysis (PHA) spectra:
Muon and elemental peaks

Scanning Electron Micrographs

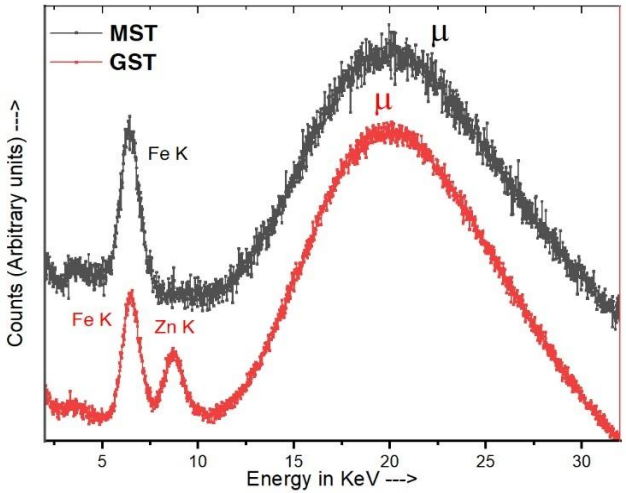


EDAX Elemental Images



Left panel: MST Elements with randomly distributed

Right panel: GST Elements are more uniformly distributed Zinc concentration is very high



Pulse height distribution spectra

MST in black colour; GST in red colour

The iron K X-ray lines are around 6.4 keV

The additional zinc K X-ray lines are evidence in GST

Muon peak presence at ~20 keV is evident in both

Vacuum Manifold

Core technical requirements

- Reliable evacuation
- Clean and reproducible gas filling
- Leak-tight long-term operation
- Scalable to thousands of counters (~3776)

What the manifold had to do:

- Parallel evacuation of multiple tubes
- Controlled gas filling
- Minimize pressure gradients
- Enable repeatable operations

A Typical Manifold

Emphasis on *Reliability, Reproducibility, Sustainability*

Interaction with Swagelok (Mumbai-Chennai-Coimbatore)

Subject: RE: The details of vacuum system !
Date: Sat, 30 Oct 2010 07:35:45 -0400
From: Shailesh.Shinde@Bombay.Swagelok.com
To: pranaba@hotmail.com

Dear Sir,
We have studied your requirement. But unfortunately we are unable to make the same at this time.

We apologies for the inconvenience caused to you.

Thanks & regards,

Shailesha Shinde
09322931291

Contribution Brought to the Table:

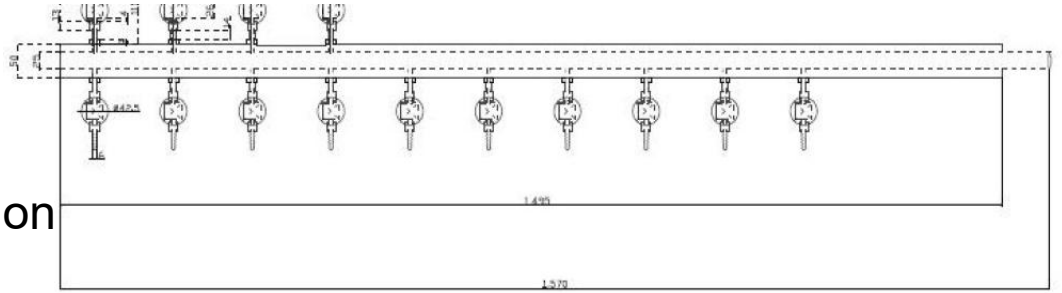
- Discount on all materials, including the essential valves
- Extended warranty on valves (up to Lifetime coverage, subject to terms)
- Cost-free Training Program for our Staffs

> ---------- Forwarded message ----------
> From: Swagelok Chennai <swagelokchennai@gmail.com>
> Date: Fri, Feb 18, 2011 at 7:45 AM
> Subject: Swagelok Installation Training Seminar
> To: atul@crl.tifr.res.in, pranaba@crl.tifr.res.in
> Cc: Ramachandran G <ramachandran.g@chennai.swagelok.com>, "shiv.shankar" <
> shiv.shankar@chennai.swagelok.com>, sivakumar.rokkaraj@chennai.swagelok.com
>
>
>
>
> Dear Sir,
>
> *Subject: *Swagelok Installation Training Seminar.
>
> Further to our discussion, we would be happy to conduct the Swagelok
> Installation Training Seminar for your personnel at your facility at a date
> convenient to you.
>
>
> We would like to suggest the following program:
>
> Swagelok Introduction
> Tubing versus Piping Systems
> Tubing Selection
> Tube Cutting / Tube De burring
> Tube Fitting Installation
> Tube Bending
> Leak Testing
> Leak Rate comparisons
> Vibration Testing
> Open for questions
>
> We expect the total duration of the training session to be approximately 4-5
> hours.

First-Generation Manifold (2011)

Proof of concept:

- Asymmetric 1500 mm design
- Established dual-function operation
- Enabled initial refurbishment



H. FILLUNGER & CO. PVT. LTD.,
(Vacuum Division)
Mumbai-Pune Road, Opp. Empire Estate, Near Premier Automobiles Ltd.,
Pimpri P.F., Pune – 411 018. INDIA.
Tel. No.: +91-20-27468616/17, 9763718050/51 Fax : +91-20-27468614/15
E-mail : vacuum-sales@fillunger.com

BVMS-01/10-11/W/Q-111 October 13, 2010

To,
Tata Institute of Fundamental Research,
1, Homi Bhabha Road, Navy Nagar,
Colaba, Mumbai – 400 005.
Tel. No.: 022 – 22782316, 2588
Fax No.: 022 – 22804566

Kind Attn.: Dr. Pranab Nayak

Sub : Your requirement for vacuum system.
Ref : Your E-Mail dtd. 30.09.10

Dear Sir,

With reference to above, we give here below our offer for the same:-

QUOTATION

Sr. No	Description	Our Product Code	Qty (Nos.)
1.	Supply of Vacuum System as per your drawing.	---	01

Note : ALL MATERIAL WILL BE SS304.
Leak rate will be less than 2x 10(-10)std cc / sec of he.
Vacuum attain in the system will be 2x 10(-9)mbar.
Valve and other fitting will be used Swagelok or similar.
Main pipe size will be 50 OD, 25 ID,
DRAWING WILL BE SUBMITTED TO YOU FOR APPROVAL.

FW: Required vacuum system and its drawing !

GOKHALE <dd-lpg@fillunger.com>
to me, vacuum-sales

Dear Dr. Pranab,

We received the photographs sent by you and under stood the requirement.

We can make the system as per shown in the photograph with following specification.

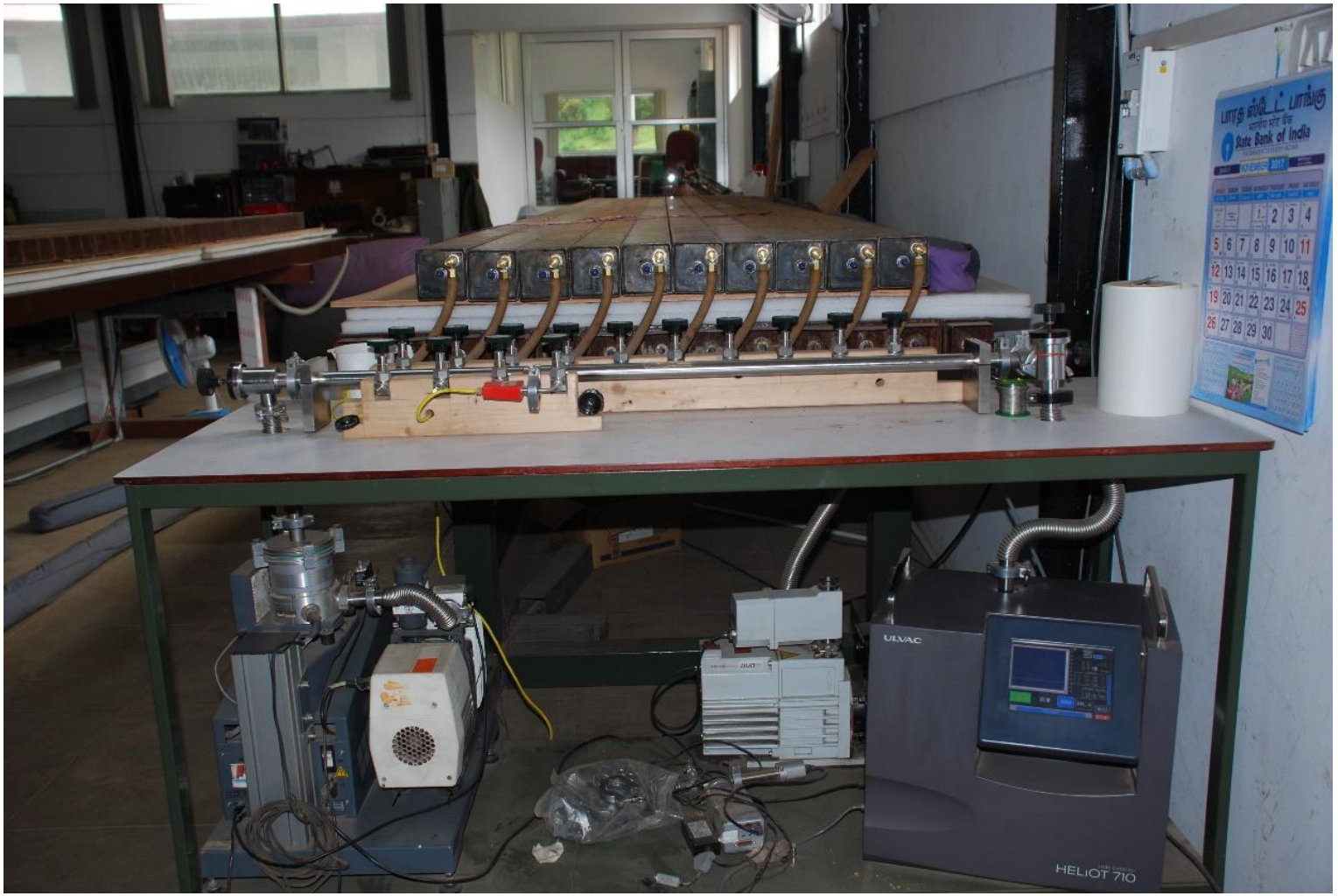
Leak rate will be less than 2x 10(-10)std cc / sec of he.
Vacuum attain in the system will be 2x 10(-9)mbar.
Valve and other fitting will be used Swagelok or similar.
Main pipe size will be 50 OD, 25 ID,

ALL MATERIAL WILL BE SS304.
DRAWING WILL BE SUBMITTED TO YOU FOR APPROVAL.

Regards,

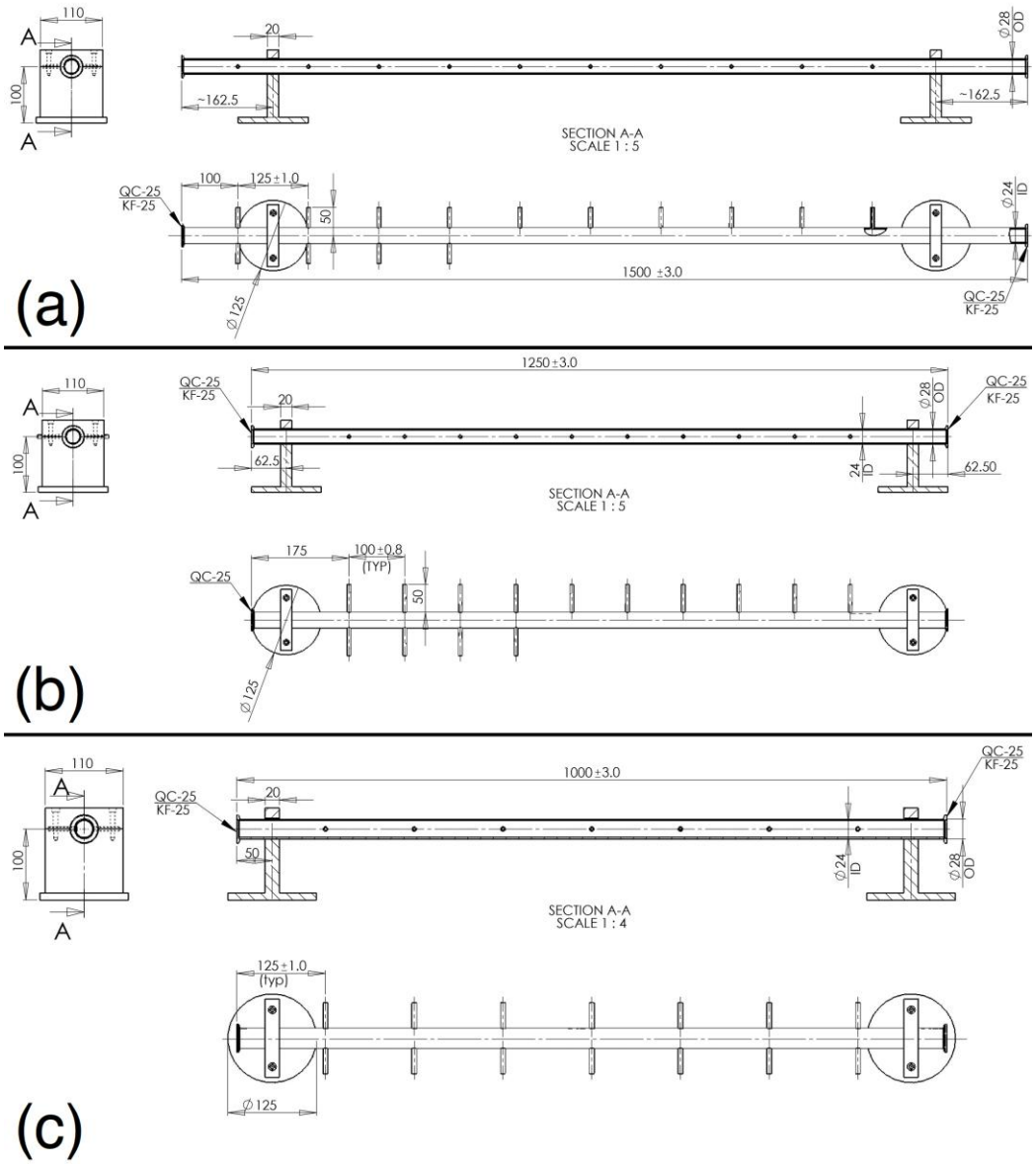
A.C.Gokhale
Manager-Design & Development
H. Fillunger & Co. Pvt. Ltd.
Mumbai-Pune Road, Opp. Empire Estate.
Near Premier Ltd., Pimpari, Pune-411 018 INDIA
Mob. 9011004054

Operational View of the System



At peak operation, the manifolds played a key role in enabling the completion of up to 10 PRCs per day.

Successive Developments…



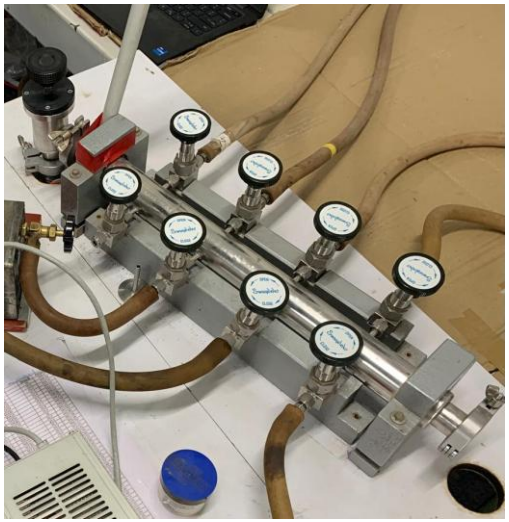
Successive Generations. Continuous Evolution. One Philosophy: Better than the Last…

Year	Length	Ports	Key features
2011	1500 mm	10+4	Evacuation + filling combined Long time for Evaluation (Days)
2012	1250 mm	10+4	Compact, higher throughput, Shorter time for Evacuation
2016	1000 mm	7+7	Symmetric, routine operation, Further shorter Evacuation time ~ 30 minutes for 1 x 10^{-6} mbar

Portable Gas-Filling System

Routine operation

- Compact 4×4 portable gas-filling manifold
- Individual needle-valve control
- Used for regular detector maintenance



Subsequent Generations Manifold

Optimization phase:

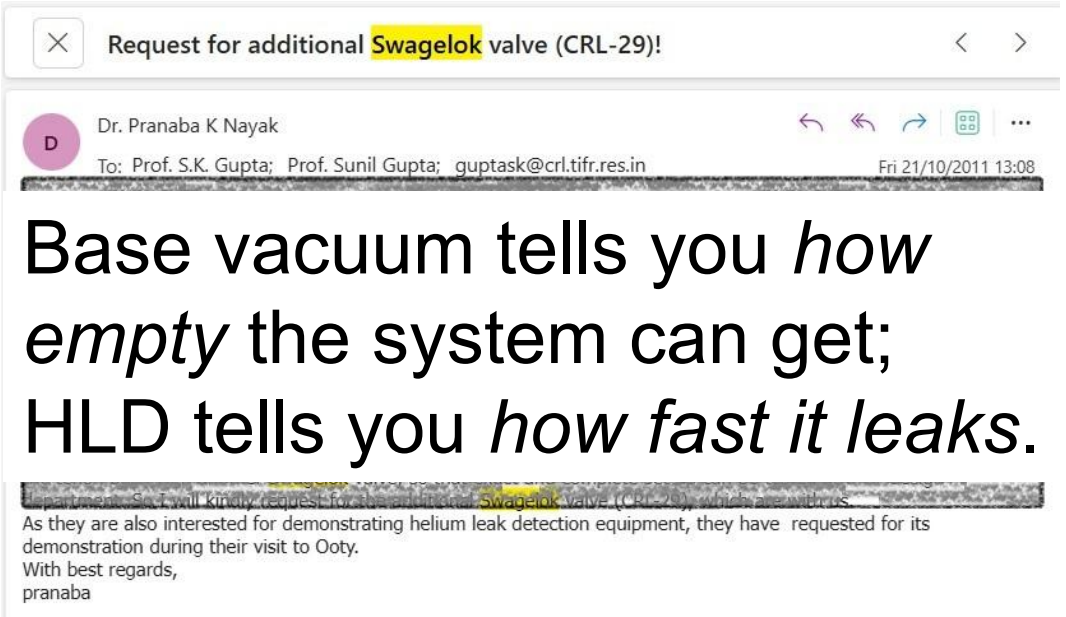
- Reduced length from 1500 mm to depending on our requirement
- Same port configuration but with reduced wall thickness from 12 to 2 mm.
- Improved laboratory handling and throughput (Bulkier to handheld portable)

Materials & Construction

Engineering choices:

- Manifold: SS316 stainless steel (than SS304) for better manifold longevity
- Support frame: SS304 to reduce cost, though corrosion-prone than SS316
- Standard KF-25,other associated interfaces in SS316 than earlier SS304
- Designed for vacuum compatibility & enhanced durability.

Helium Leak Detector (Fillunger, Pune)



Quality assurance

- Helium leak detection applied at all stages
- Support frames: SS304; SS304
- Ensured long-term vacuum integrity
- Critical for stable detector operation

For last ~15 years Helium Leak Detectors are integral part of GRAPES-3 experiment

TIFR-Fillunger-Swagelok Interaction Outcome

The Journey became Longer, but Innovation Played a Smoothing Role

Welding end-plates both-sides

High-Pressure Leak Test

Add Anode Wire, Valves, Hermetic Seal

Evaluate above 1 x 10^{-4} mbar

Check for stability for two weeks

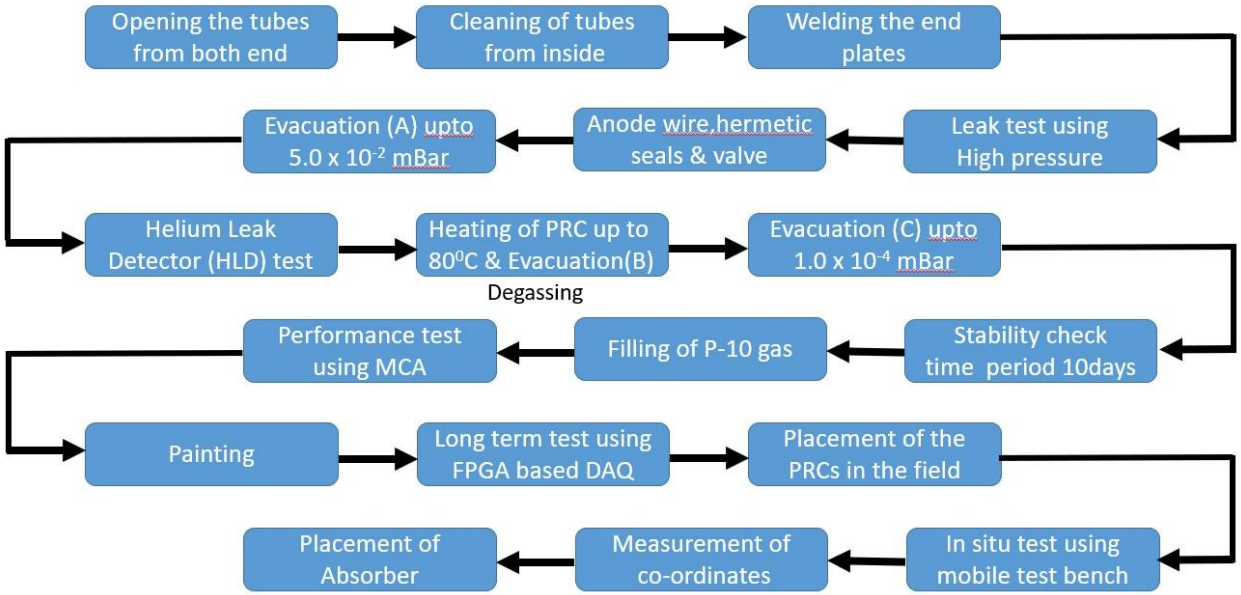
Fill P-10 (90% Ar +10% CH4) Gas

Use MCA to test Performance

Paint the outer side of PRC

Send for Long term test using DAQ

The Anticipated Journey



The Actual Journey

Longer* (shown left) than anticipated (above).

Credit*: Atul Jain, ASET Talk, 3rd December 2021, TIFR

GRAPES-3 Experiment: Recent View from the Other side of Radio Astronomy Centre

Conclusions

A large set of proportional counters were successfully repurposed from the KGF underground experiment to the mountaintop GRAPES-3 facility at Ooty.

Representative legacy tubes were systematically characterized using multiple techniques.

Despite decades of use and variable chemical aging, both types of tubes demonstrate robust and reliable performance.

The evolution of vacuum manifold design was central to achieving a mature, scalable, and reusable detector solution.

This work exemplifies sustainable instrumentation—implemented over three decades ago, well before sustainability became a mainstream concept.

An Outcome of Institute-Industry Collaboration

The Future of the GRAPES-3 Manifolds

- Expand the Network: Portable units for upgrading existing muon stations.
- Build Educational Capacity: Dedicated hands-on training setups for national workshops and schools
- Enable New Science: Compact muon telescope deployments for atmospheric studies in Northeast India—requested by climate researchers.

These manifolds are designed as a versatile foundation, actively expanding detector network, training the next generation, and enabling new interdisciplinary science for the future global research.

We began blooming, bright and sound,
Then fell to gloom, tightly bound.
Through steady work and patient care,
It rose to triumph, beyond compare.

Acknowledgements

Thanks for M. Muthuvinayagam, Saveeta University, Chennai for Characterization data. The GRAPES-3 collaboration gratefully acknowledges V.S. Narasimham, M.R. Krishnaswamy, N.K. Mondal, and their colleagues from the TIFR-OCU Proton Decay Collaboration for generously providing the proportional counters. We are deeply thankful for the support of the Department of Atomic Energy, Government of India, under Project Identification No. RTI4002. PKN would like to extend heartfelt thanks to B. Satyanarayana and Suresh Kalmani for sharing their insights into the enduring legacy of the Kolar Gold Field (KGF) and its partial transformation into the next-generation GRAPES-3 experiment. Additionally, we express our appreciation to all current and former members of the GRAPES-3 experiment for their invaluable contributions in various capacities.

Thank you for your kind attention !