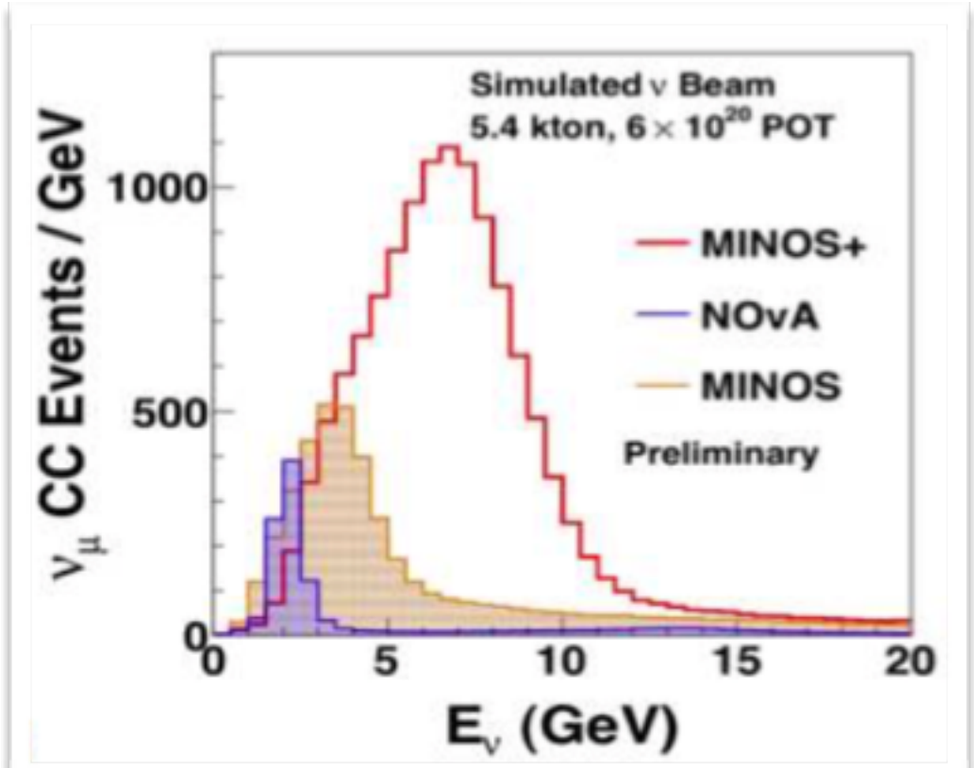
LATIN AMERICAN CONTRIBUTIONS TO MINOS AND NOVA



Prof. Ricardo A. Gomes

IF - UFG (Federal University of Goias)

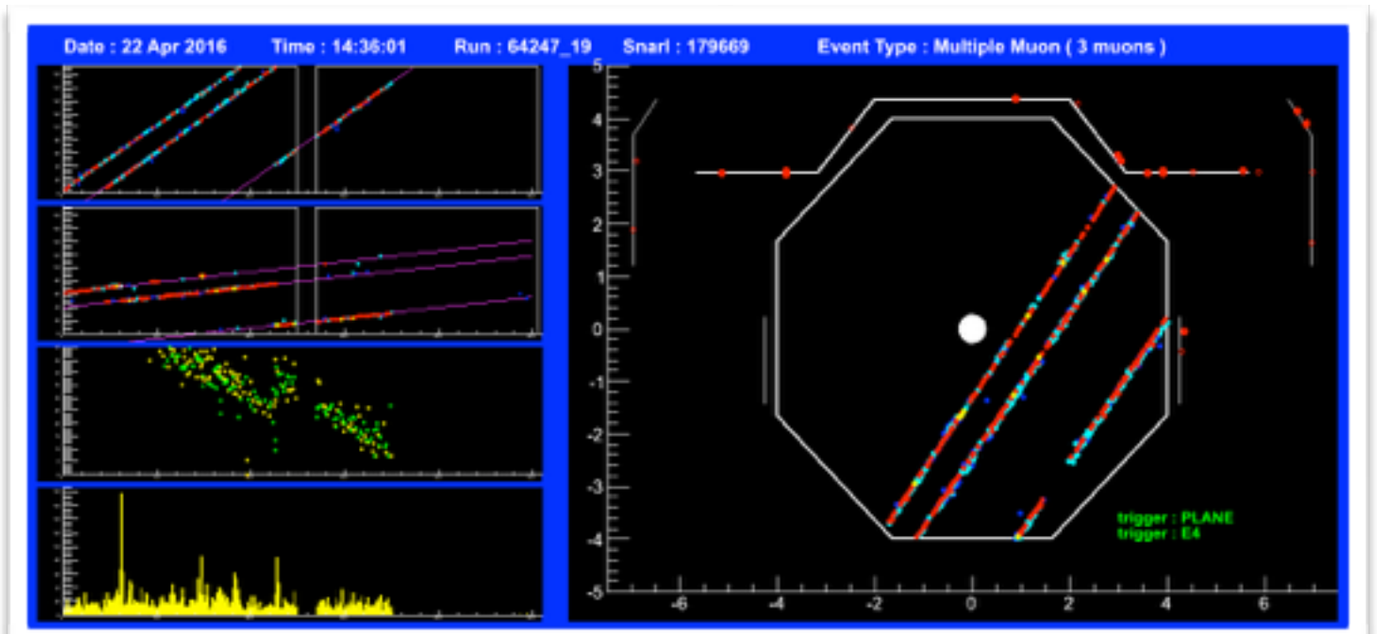
April 27, 2016

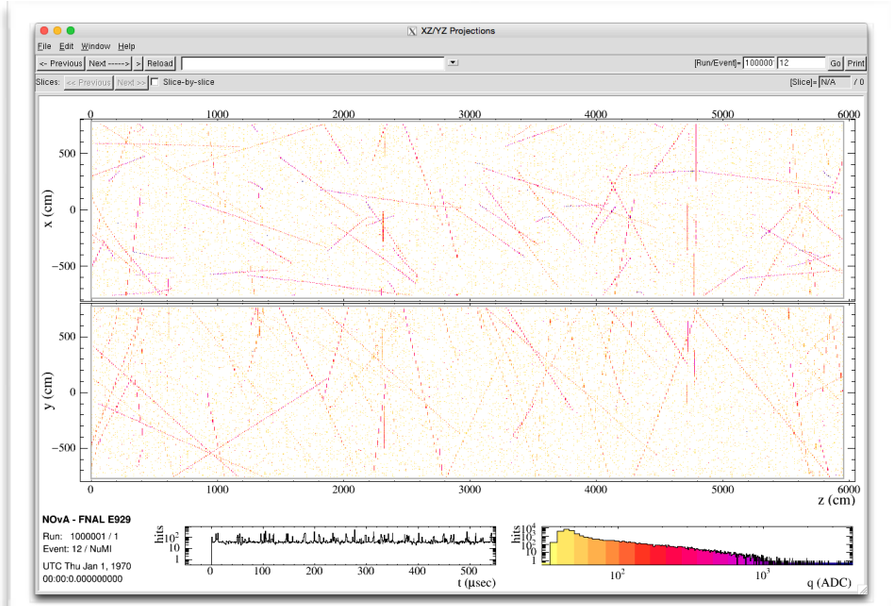
OUTLINE

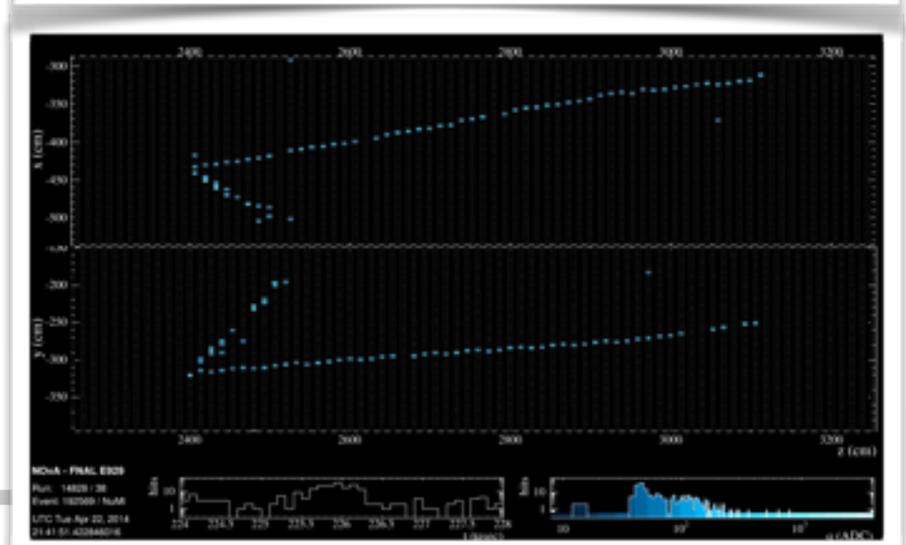
LATIN AMERICAN Contributions to:

MINOS / NOvA

1. Installation and Commissioning
2. Running
3. Monte Carlo Simulations
4. Analyses (Neutrino and Cosmic Rays)







MINOS
COLLABORATION

*Argonne - Athens - Brookhaven - Caltech - Cambridge - **Campinas** - Fermilab - **Goias** - Harvard - Holy Cross (IN) - IIT - Indiana - Iowa - London - Minnesota (Minneapolis; Duluth) - Otterbein - Oxford - Pittsburgh - Rutherford - **Sao Paulo** - South Carolina - Stanford - Sussex - Texas A&M - Texas-Austin - Tufts - Warsaw - William & Mary*

- 29 institutions, ~ 120 physicists

LATIN AMERICAN INSTITUTIONS and COLLABORATORS:

- CAMPINAS (UNICAMP)
  - — CARLOS ESCOBAR
  - — JOAO COELHO (PhD Student) → Postdoc at TUFTS (NOvA), now APC (Paris)

- SAO PAULO (USP)
  - — PHILIPPE GOUFFON

- GOIAS (UFG) - since 2009
  - — RICARDO GOMES
  - — CESAR CASTROMONTE (Postdoc) → Postdoc at CBPF (Angra)
  - — MICHELLE MEDEIROS (PhD Student) → Postdoc at ANL
  - — STEFANO TOGNINI (Ms Student) → PhD Student at GOIAS (NOvA)

MINOS — INSTALLATION

USP — RESPONSIBLE FOR THE BEAM LOSS MONITOR (BLM) SUPPORT

- 3 SETS OF BLM SUPPORTS (2004),
- 1 NEW SET (2009)

Nuclear Instruments and Methods in Physics Research A 568 (2006) 548.

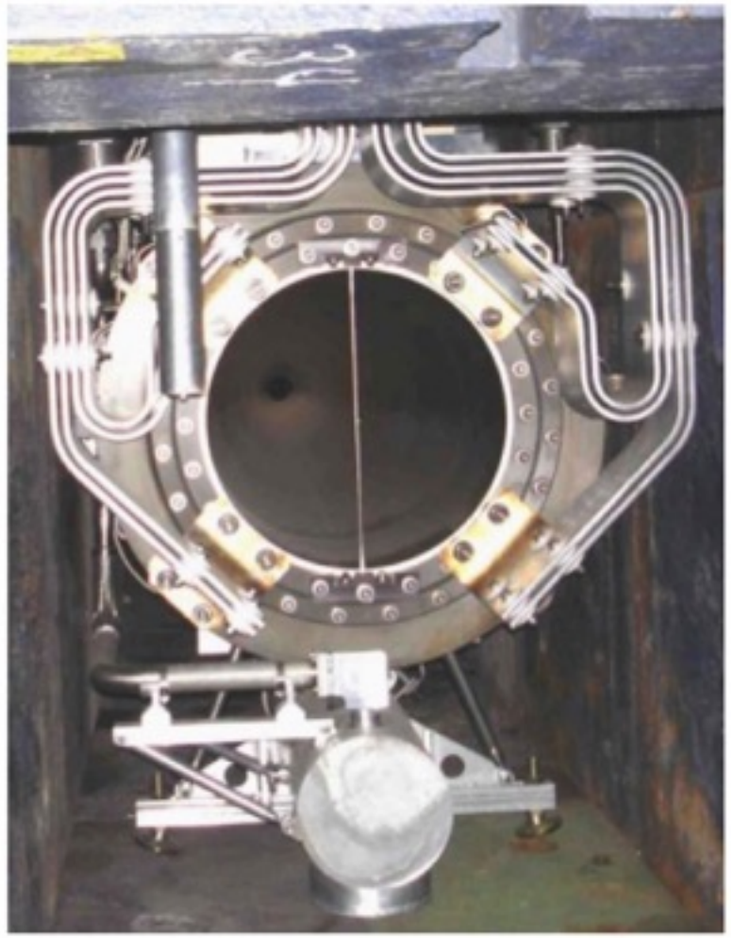


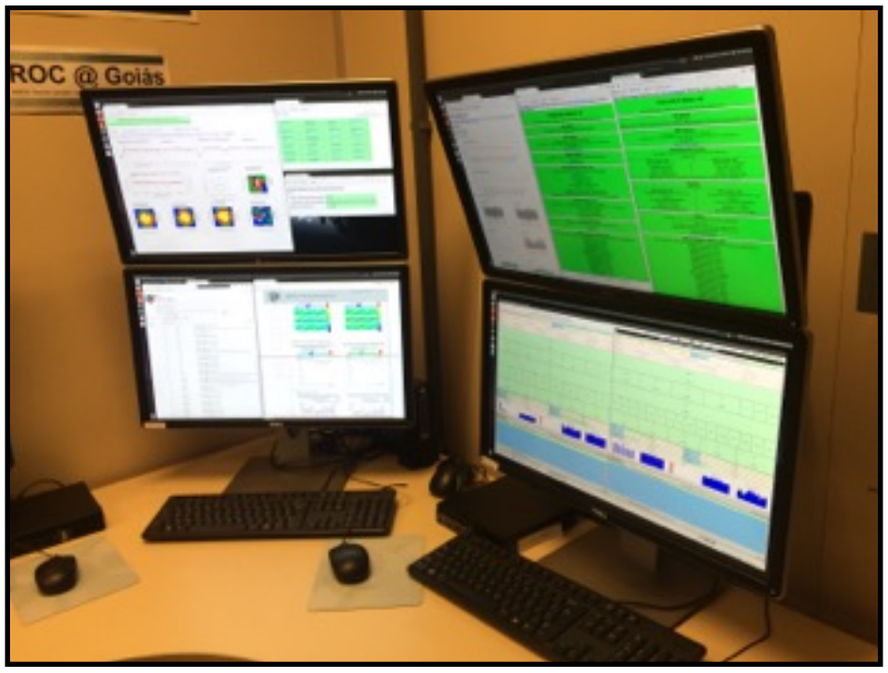
Fig. 9. Picture of Horn 2, as installed, from the downstream end. The crosshair is the vertical bar across the horn aperture. The horizontal "nub" on the crosshair is barely visible at the crosshair's center. The loss monitor ion chamber is the cylinder extending from above on the left (beam right).

MINOS — RUNNING

UNICAMP — **RUN COORDINATOR** (AUG 2010 - AUG 2011)

GOIAS — REMOTE OPERATION CENTER (ROC) AT GOIAS (2010 - 2016)

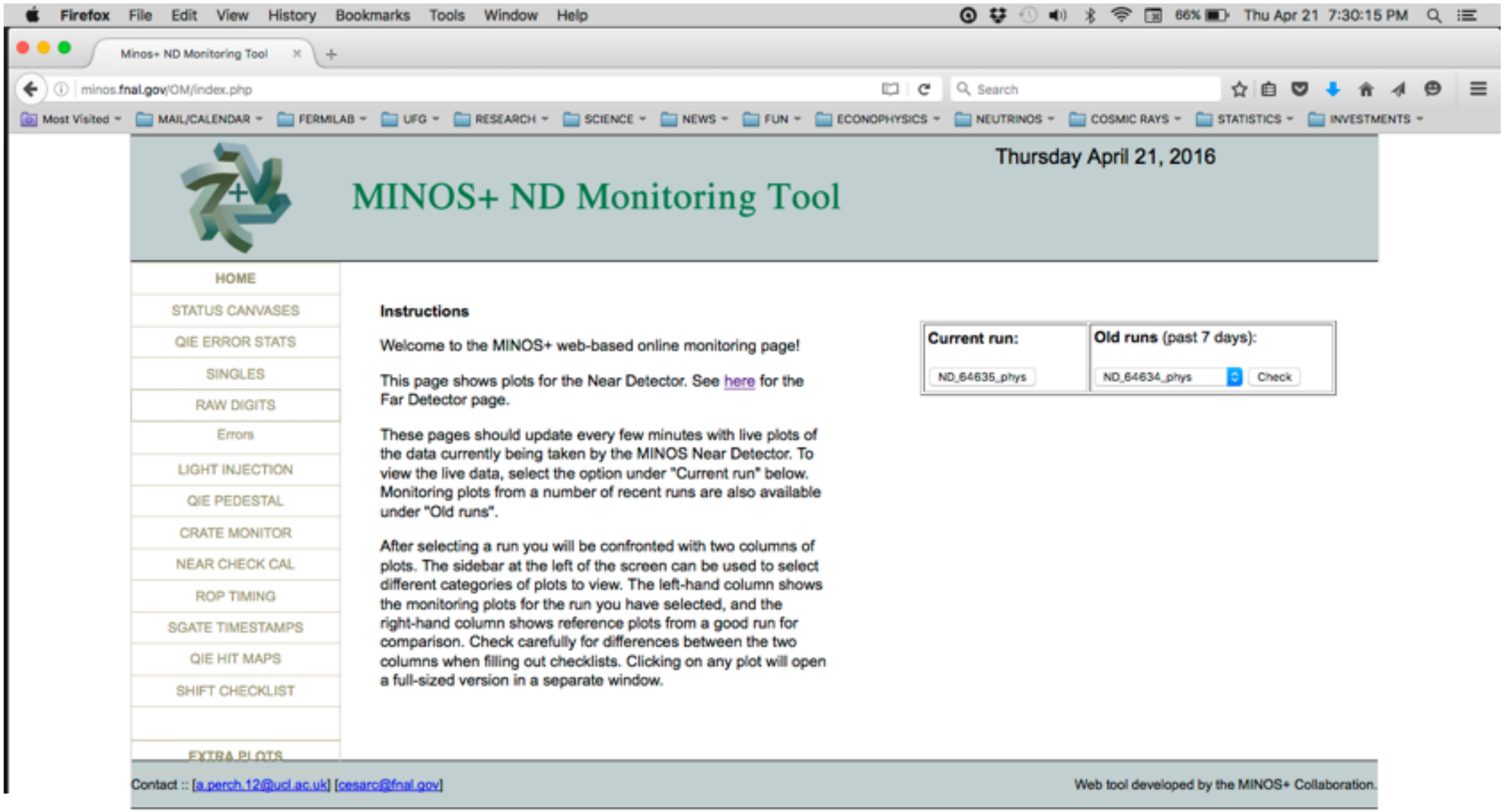
- 1ST MINOS ROC
- Documentation on installation, certification procedure and operation
- Software updates, maintenance and support
- Current documentation on ROC certification procedures for neutrino experiments at FNAL used MINOS' certification document as a starting point



Certified ROC's

CERTIFIED ON	STATION	INSTITUTION'S NAME
2013-05-27	Goias	Federal University of Goias
2013-07-22	Warsaw	University of Warsaw
2013-09-??	Duluth	Univ of Minnesota Duluth
2013-09-25	Tufts	Tufts University
2013-11-27	UMN	Univ of Minnesota
2013-12-04	WM	College of William and Mary
2014-03-17	UCL	University College London
2015-09-30	UT	University of Texas at Austin
2015-10-06	Cincinnati	University of Cincinnati
uncert	BNL	Brookhaven National Lab

MINOS — RUNNING



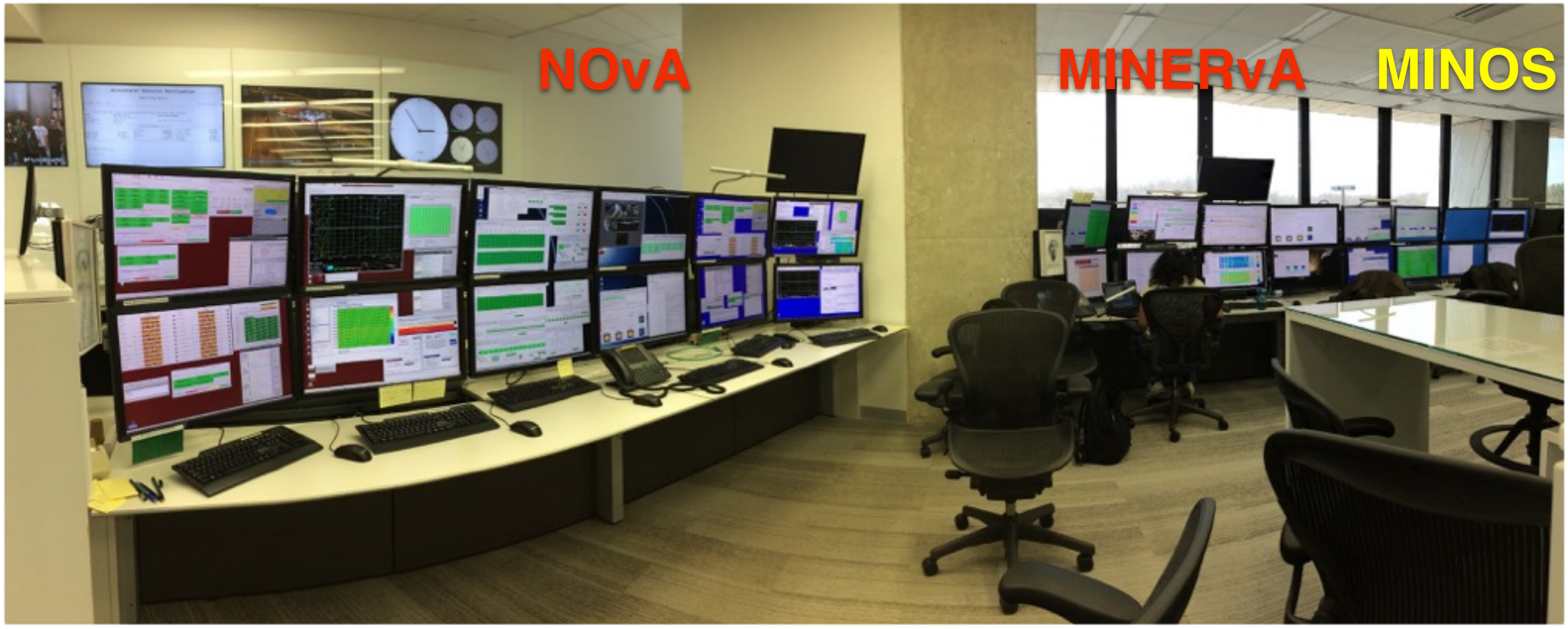
GOIAS — NEW ONLINE MONITORING FOR MINOS+ (ND AND FD)

USP — RESPONSIBLE FOR CONTROLLING THE SHIFT QUOTAS AT ECL (Electronic Logbook) FOR MINOS / MINOS+

MINOS — RUNNING

GOIAS — SETUP OF MINOS CONTROL ROOM (CR) AT ROC-WEST

- Maintenance of the MINOS CR is also done remotely by us when needed



MINOS — ANALYSES

GOIAS — CONVENER OF THE ATMOSPHERIC AND COSMIC RAY GROUP (2011 - now)

UNICAMP / TUFTS — CONVENER OF THE STERILE GROUP (2013 - 2015)
— ANALYSES COORDINATOR (for 3 months, 2015)

SOME ANALYSES with SIGNIFICANT CONTRIBUTION FROM LA:

1. **Electron neutrino and antineutrino appearance**
2. **Combined analysis of beam and atmospheric (nu_mu and nu_e)**

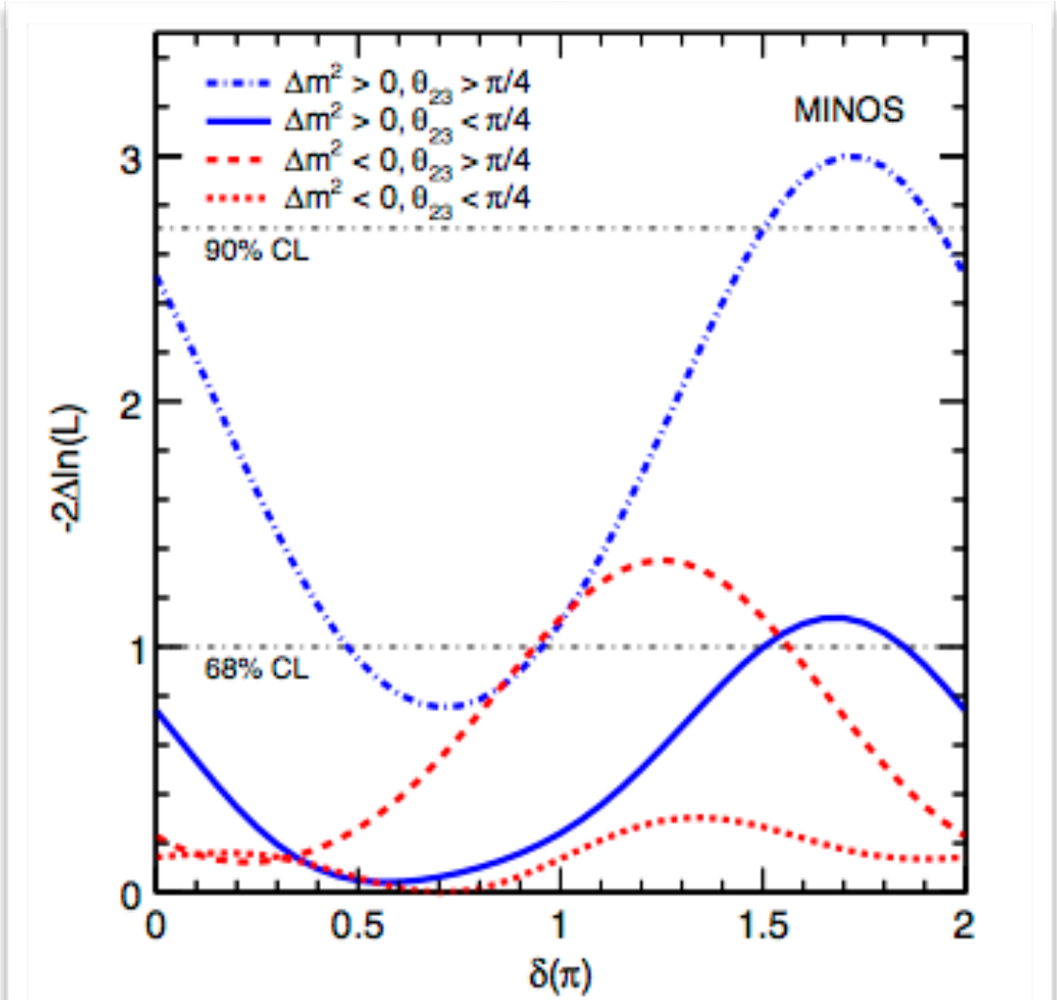
→ neutrino oscillation

3. **Multiple muon charge ratio**
4. **Seasonal variation (ND, FD; single, multiple muons)**

→ cosmic rays

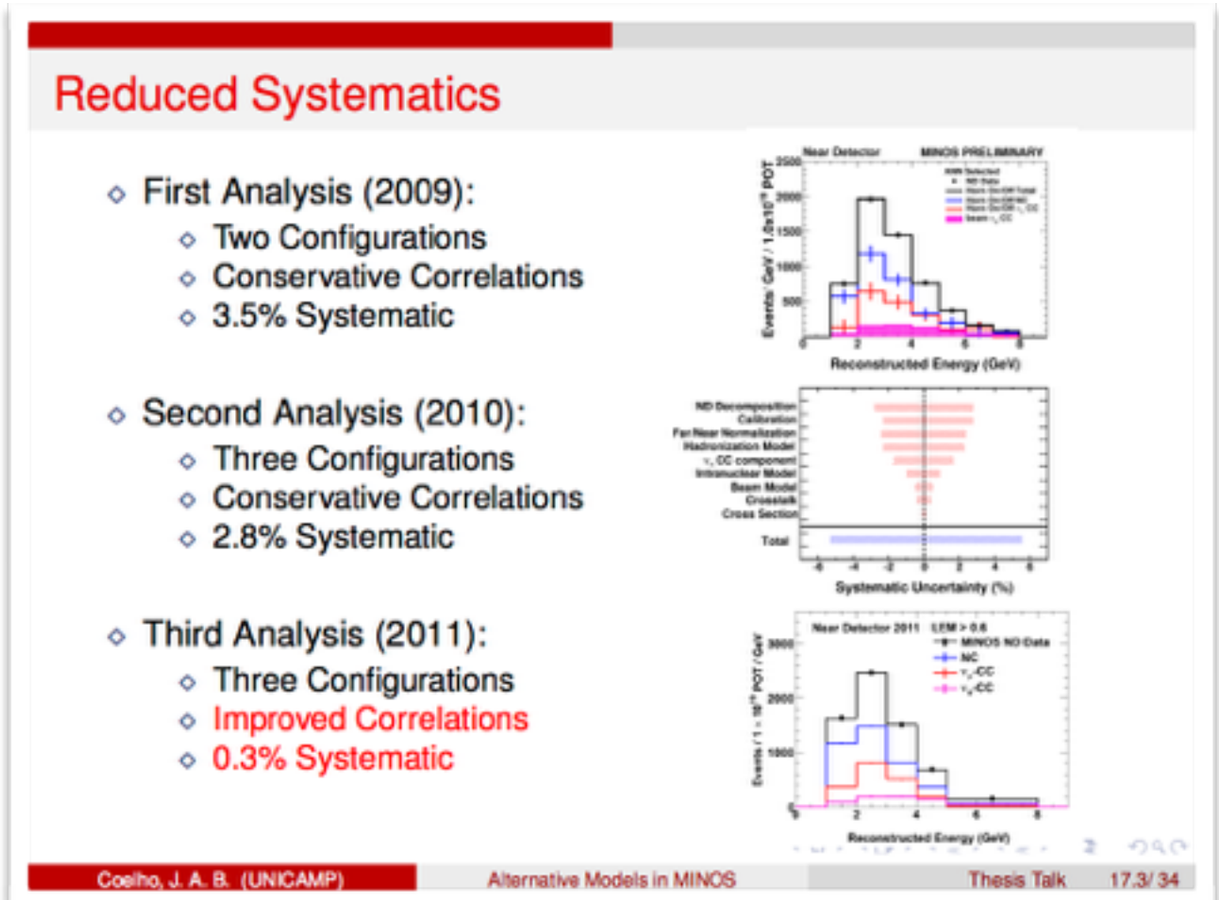
MINOS — ANALYSES

UNICAMP — ELECTRON NEUTRINO AND ANTINEUTRINO APPEARANCE (FULL MINOS)



J. COELHO and C. ESCOBAR:

- Also studied DECOHERENCE and DECAY
- Contributed to the MULTIBEAM DECOMPOSITION METHOD, which reduced significantly the SYSTEMATIC UNCERTAINTY

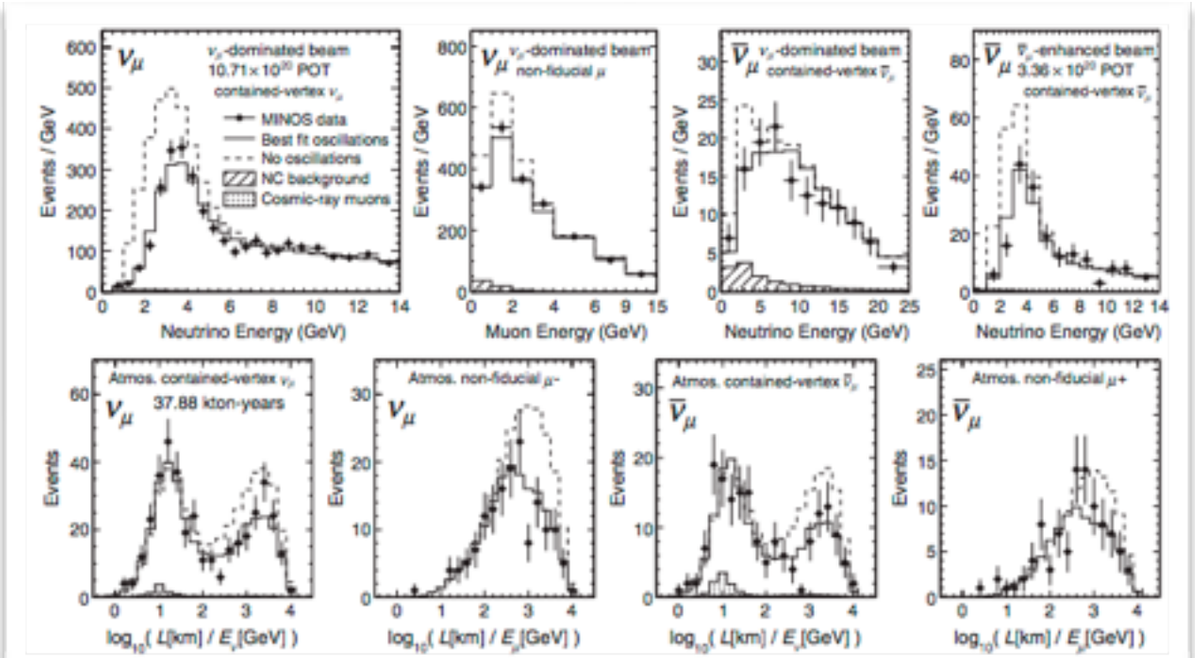


PRL 110, 171801 (2013)

[21] J. A. B. Coelho, Ph.D. thesis, Universidade Estadual de Campinas [Fermilab Report No. FERMILAB-THESIS-2012-23, 2012 (unpublished)].

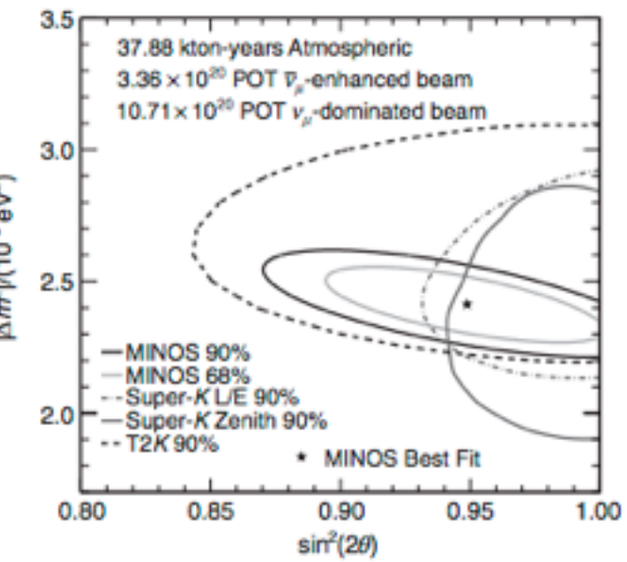
MINOS — ANALYSES

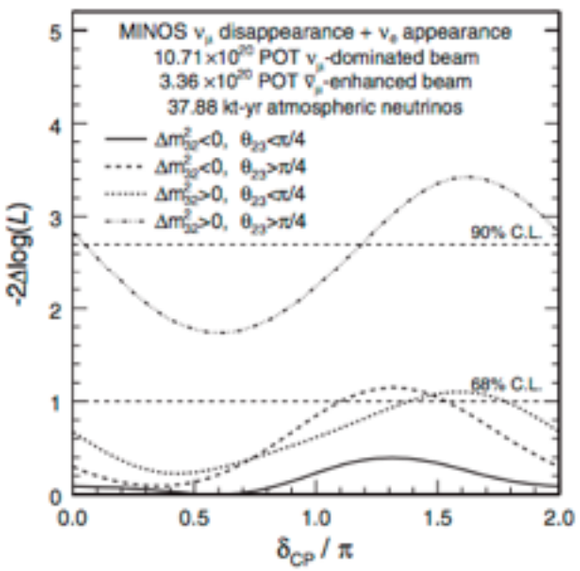
GOIAS — COMBINING BEAM AND ATMOSPHERIC, NU_MU AND NU_E



BEAM + ATM
NU_MU Disappearance

PRL 110, 251801 (2013)





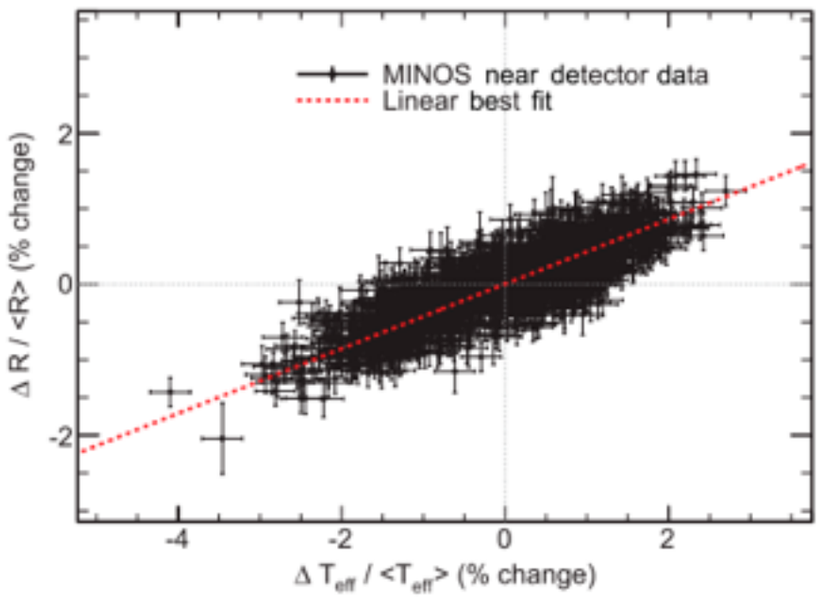
NU_MU Disappearance
+
NU_E Appearance

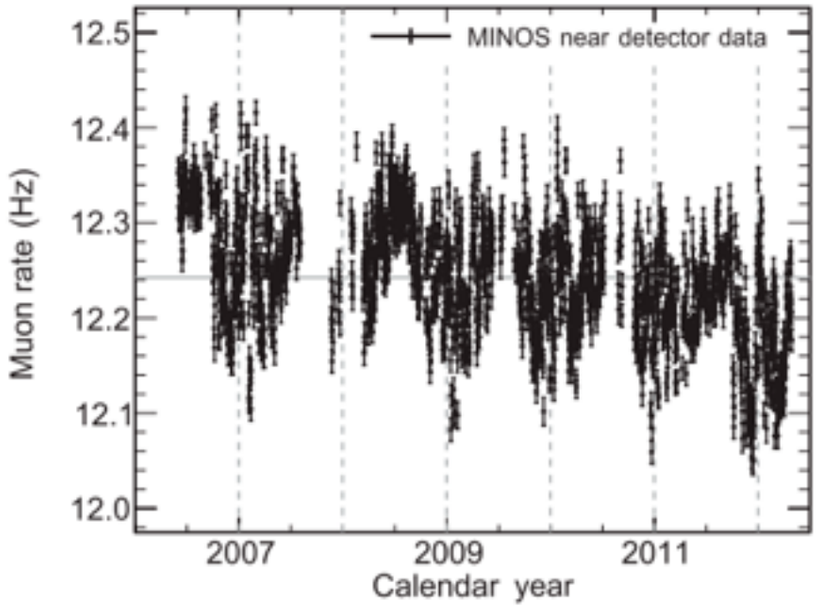
PRL 112, 191801 (2014)

M. Medeiros (PhD at Goias) - relevant role on the combination of analyses

MINOS — ANALYSES

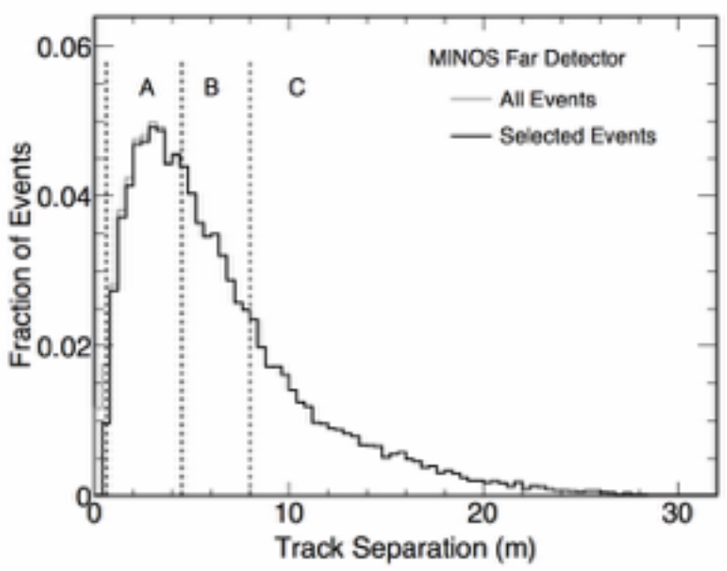
GOIAS — MUON SEASONAL VARIATION

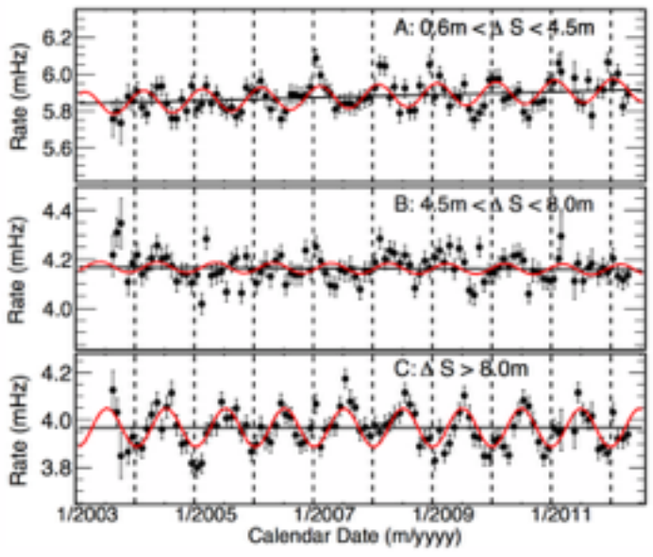




SINGLE

PRD 90, 012010 (2014)
Observation of muon intensity variations by season with the MINOS ND





MULTIPLE

PRD 91, 112006 (2015)
Observation of seasonal variation of atmospheric multiple-muon events in the MINOS ND and FD

[23] S. Tognini, M.S. thesis, Federal University of Goias, 2012.

- USED CORSIKA SIMULATION DEVELOPED BY US
- PROPOSAL TO INVESTIGATE THE EFFECT ON NOVA ND

MINOS — ANALYSES

GOIAS — MULTIPLE MUON CHARGE RATIO USING THE FD

$$R_\mu = 1.104 \pm 0.006(\text{stat})^{+0.009}_{-0.010}(\text{syst})$$

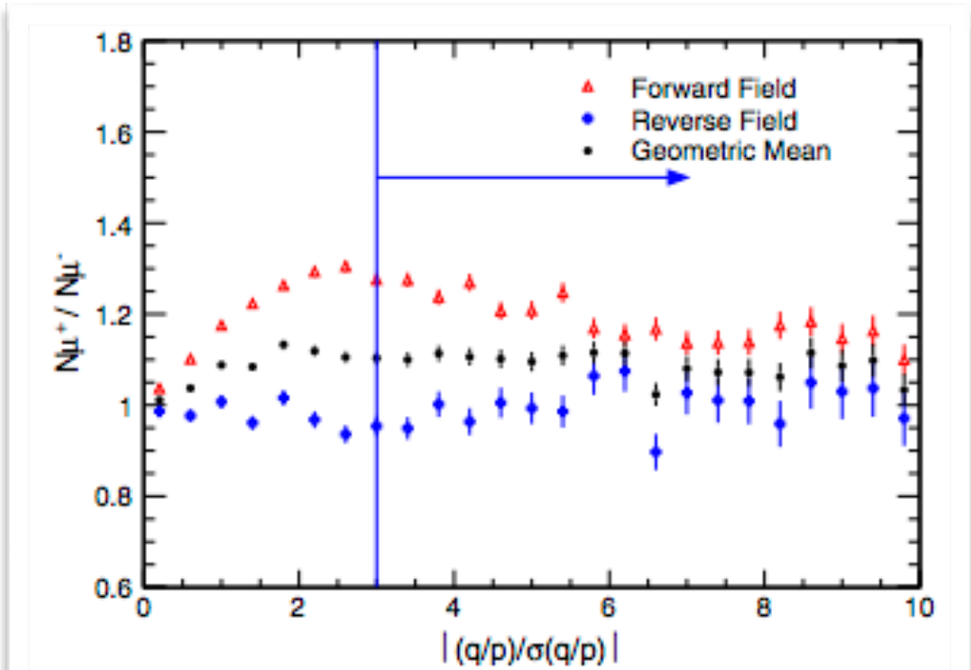


FIG. 1. Charge ratio for reconstructed multiple-muon tracks as a function of curvature significance after applying all other selection cuts. The vertical line denotes the minimum value for tracks used in the charge ratio measurement.

- CORSIKA SIMULATION PERFORMED AT OUR CLUSTER (IF - GOIAS)
- LEADED BY GOIAS AND ARGONNE (M. GOODMAN) GROUPS
- PUBLISHED THIS YEAR (C. CASTROMONTE):

PRD 93, 052017 (2016)
Measurement of the multiple-muon charge ratio in the MINOS Far Detector

NOVA
COLLABORATION

LATIN AMERICAN INSTITUTIONS
and COLLABORATORS:

- GOIAS (BRAZIL)
  - — RICARDO GOMES
  - — TAPASI GHOSH (Postdoc)
  - — STEFANO TOGNINI (PhD Student)

~200 scientists and ~30 institutions

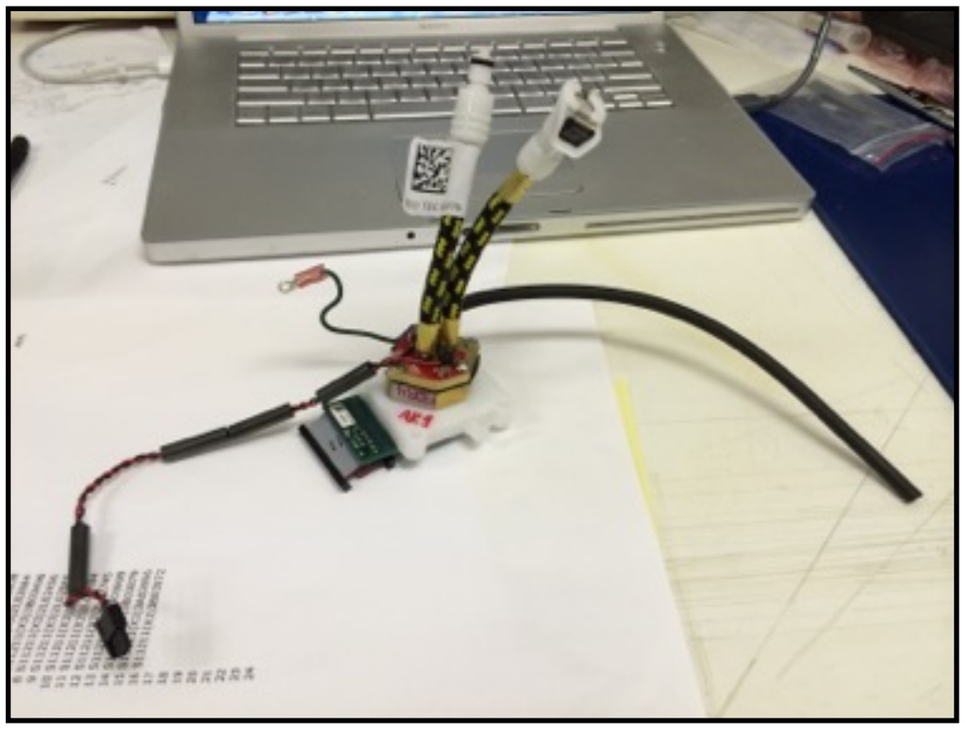
- UNIVERSIDAD DEL ATLANTICO (COLOMBIA) — just joined
  - — MARIO ACERO
  - — FRANK BULA (UG Student)

NC/Sterile neutrino working group

NOVA — COMMISSIONING

Near Detector

- Helped in the **ND APD Quality Assessment** task force during the last year of its commissioning

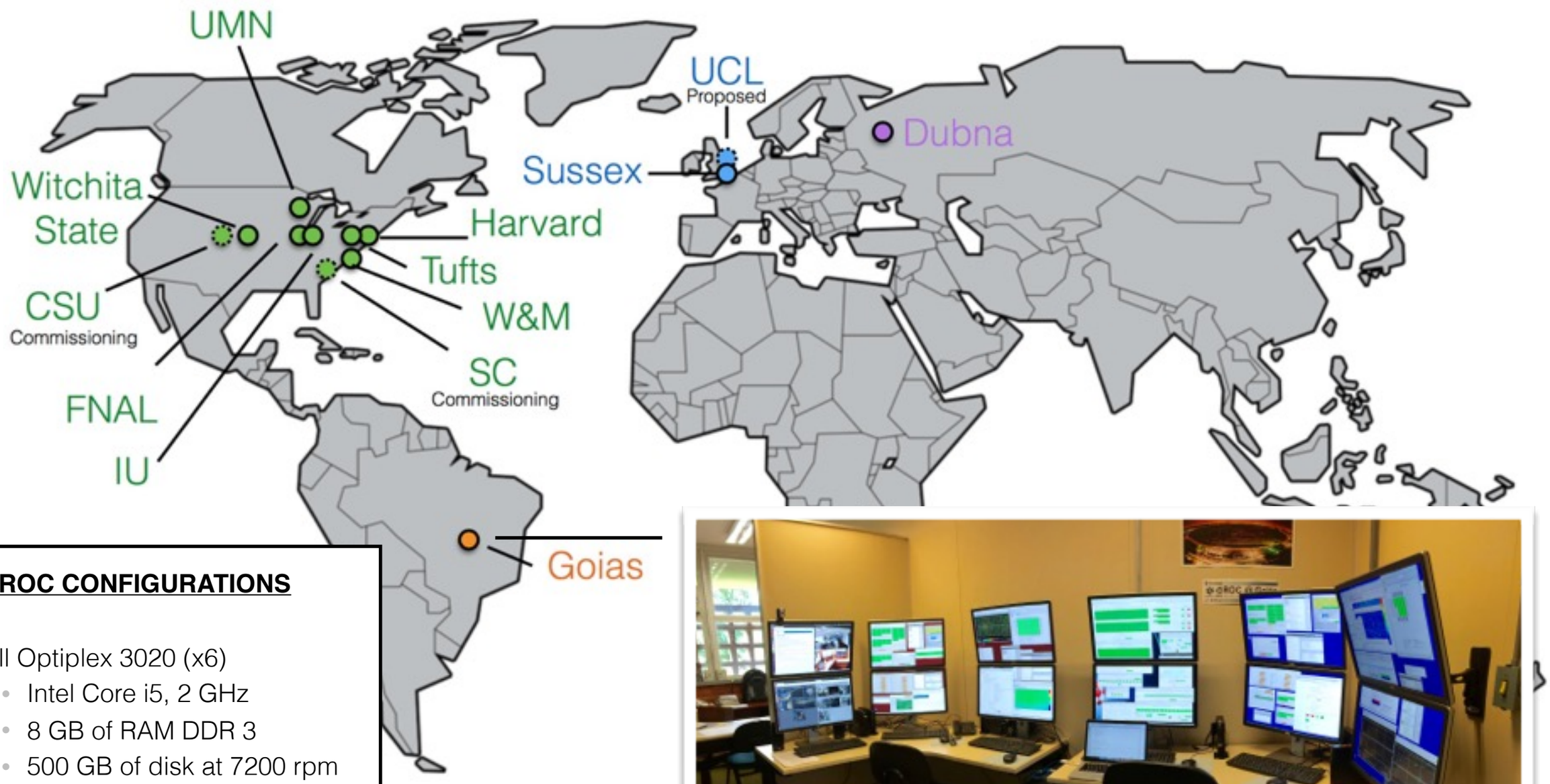


  - The work included training new people and helping with documentation

- Stefano was one of the ND on call emergency contacts for fixing problems underground during ~6 months

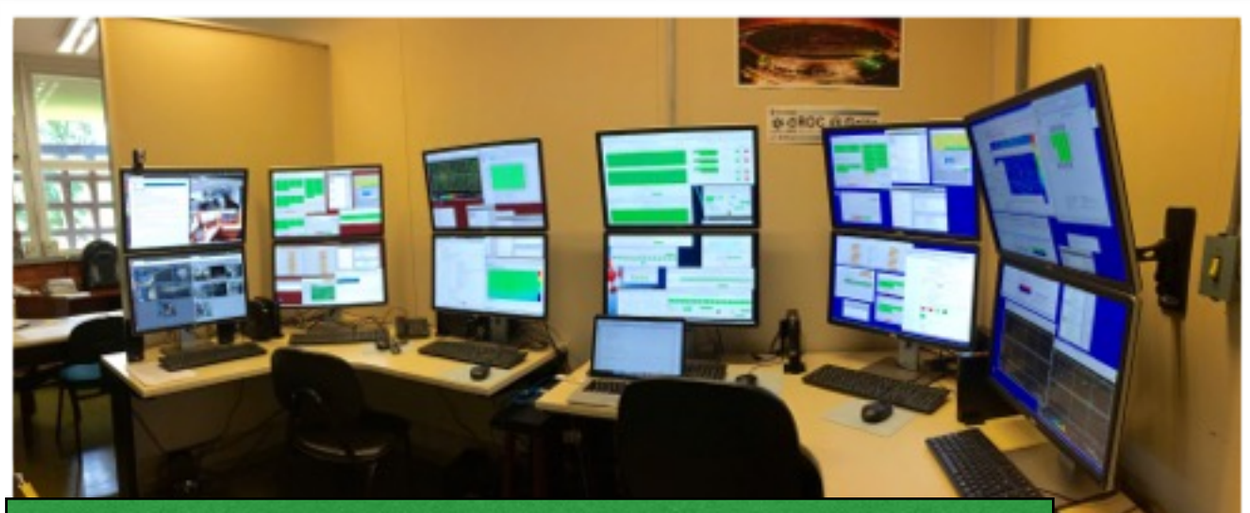
NOVA — RUNNING

NOvA ROC at GOIAS



ROC CONFIGURATIONS

- Dell Optiplex 3020 (x6)
  - Intel Core i5, 2 GHz
  - 8 GB of RAM DDR 3
  - 500 GB of disk at 7200 rpm
- Dell 24" 2416D (x12)
  - 2560 x 1440
- NETWORK: 1 Gbit/s



Fully operational since March 2016

Universidad del Atlantico (COL) and others will be very welcome

NOVA — RUNNING

Production Group

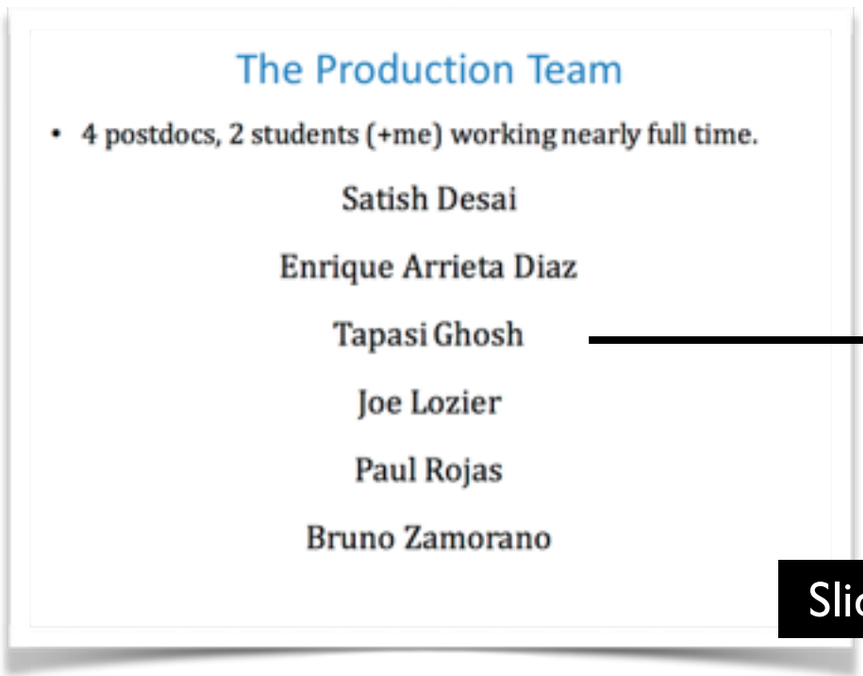
GOIAS GROUP — ONE OF THOSE RESPONSIBLE FOR THE PRODUCTION

- Raw to Reconstructed Data and MC using the GRID
- Working HARD on producing the files needed for NEUTRINO (the conference)

LAST 2 MONTHS:

- Used 4.1 million CPU hours (63% offsite);
- Declared 5.6 million files to SAM
- Written 750 TB to tape

→ *… and we are just beginning the full set of MC and DATA*

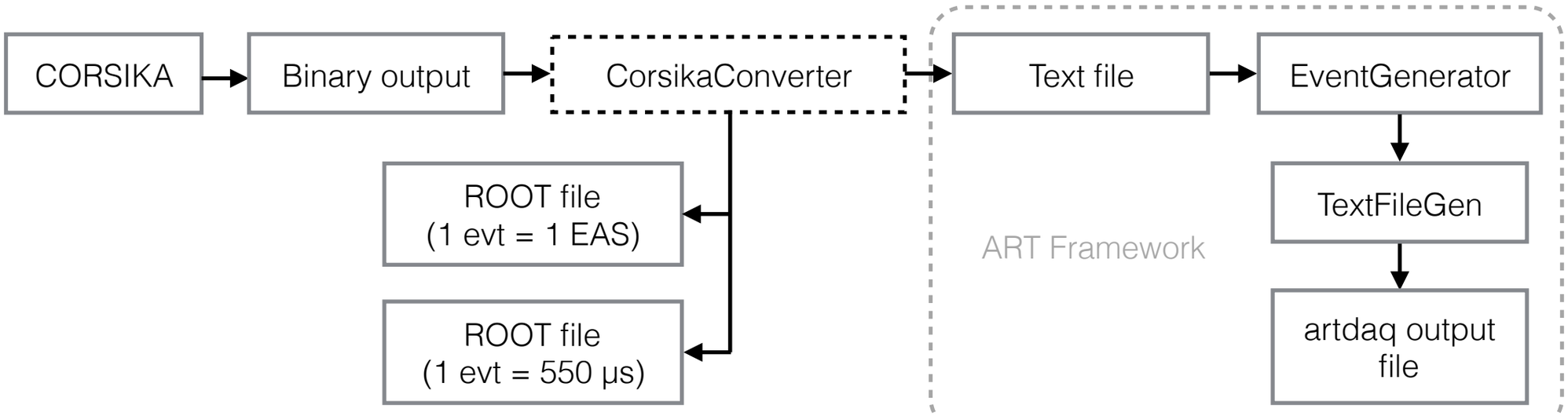


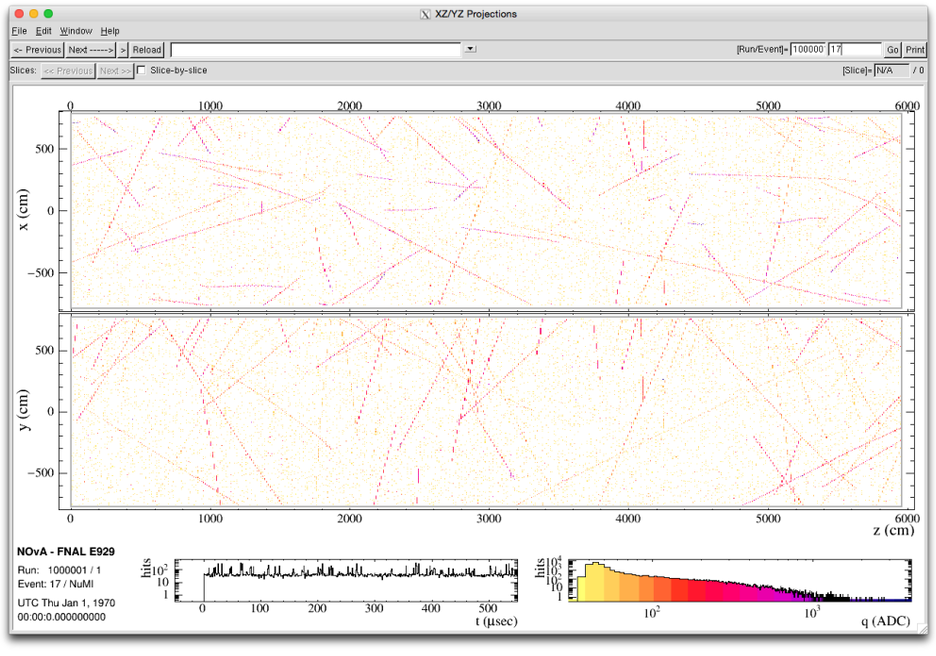
→ Postdoc for GOIAS, Brazil (from India)

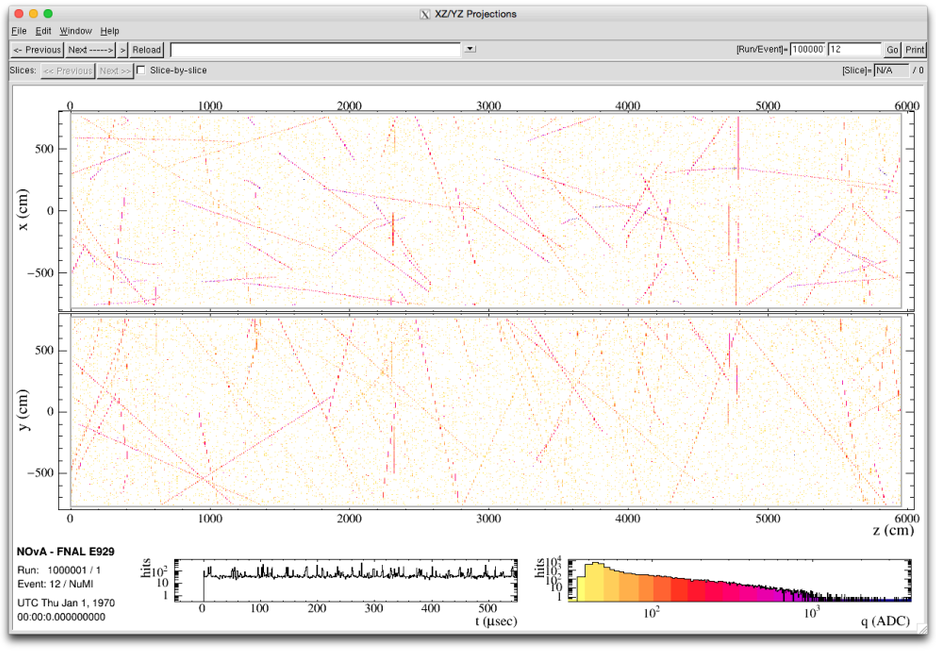
Slide from Satish Desai

Simulation Group

CORSIKA Integration to the ART Framework as an alternative to CRY



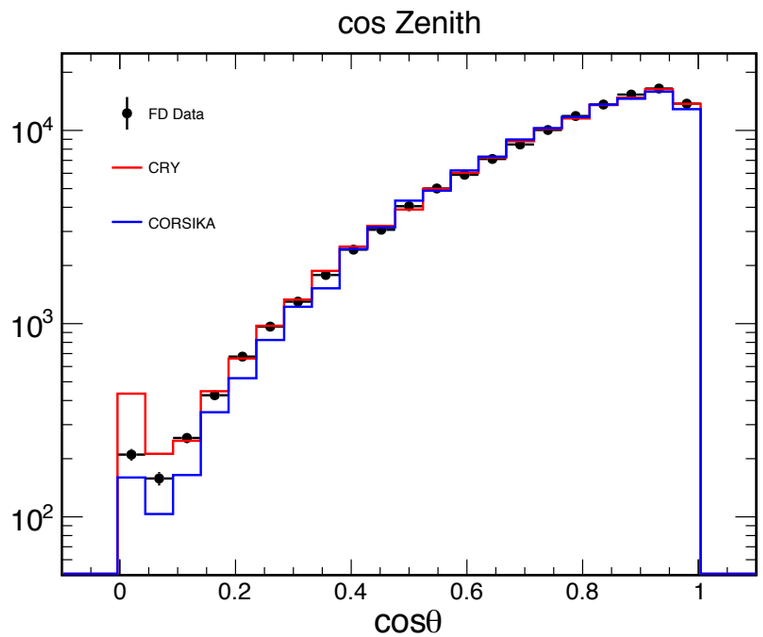


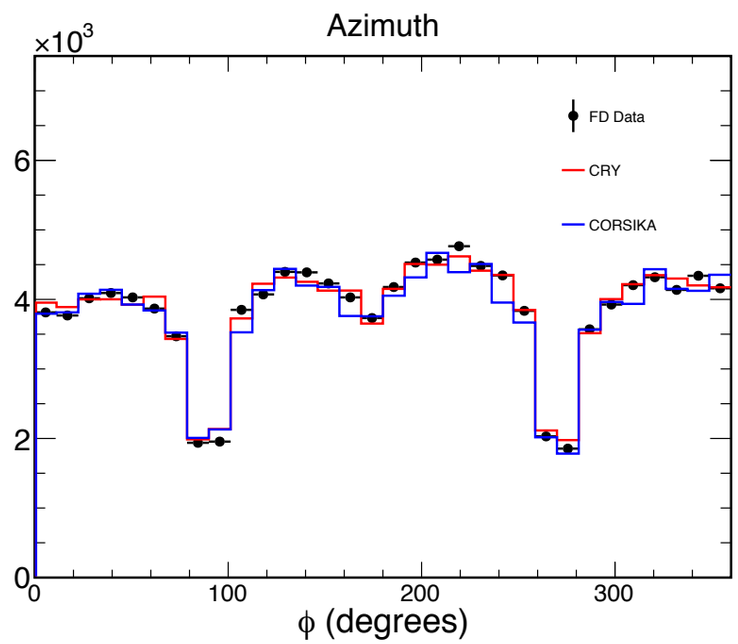


NOVA — SIMULATION

Simulation Group

COMPARISON BETWEEN CORSIKA, CRY AND DATA:





CORSIKA — COMPLETE SIMULATION OF THE COSMIC RAY SHOWER

CRY — MUON TABLE, NO OPTION TO CHANGE ALTITUDE, PRIMARY ENERGY/KIND, NO GEOMAGNETIC FIELD

STATUS: OUR SIMULATION CURRENTLY ONLY WORKS WITH PROTONS AS PRIMARIES (IMPLEMENTATION OF HEAVIER NUCLEI UNDERWAY)

EXOTICS GROUP IS USING OUR CORSIKA "DATA" TO STUDY:

- MULTIPLE MUONS
- EAST/WEST EFFECT

POTENTIAL USE FOR DUNE

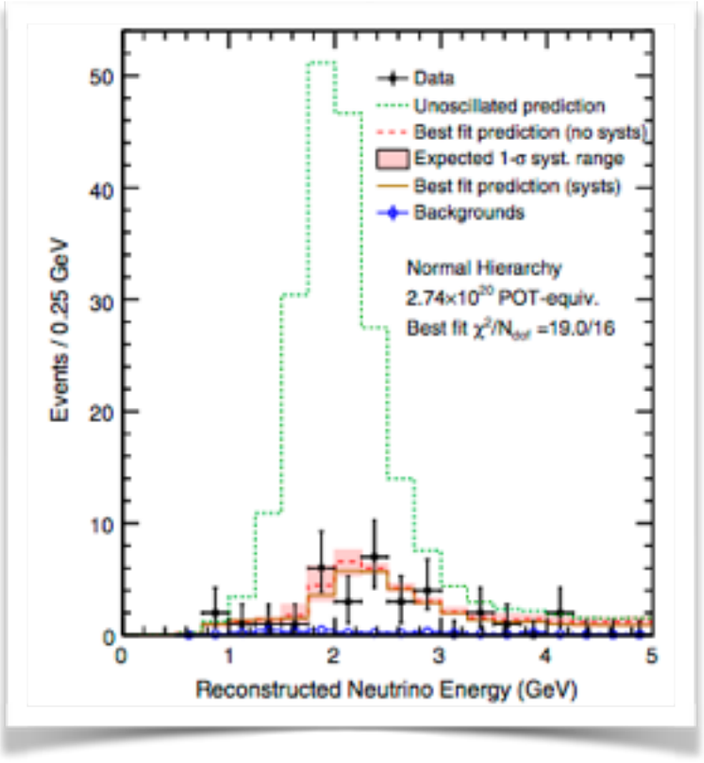
NOVA — ANALYSES

NUMU Disappearance Group

GOIAS — Estimation of tau-neutrino background for the muon-neutrino disappearance analysis (~0.04 event / 10^{20} POT)

PRD 93, 051104(R) (2016)

First measurement of muon-neutrino disappearance in NOvA

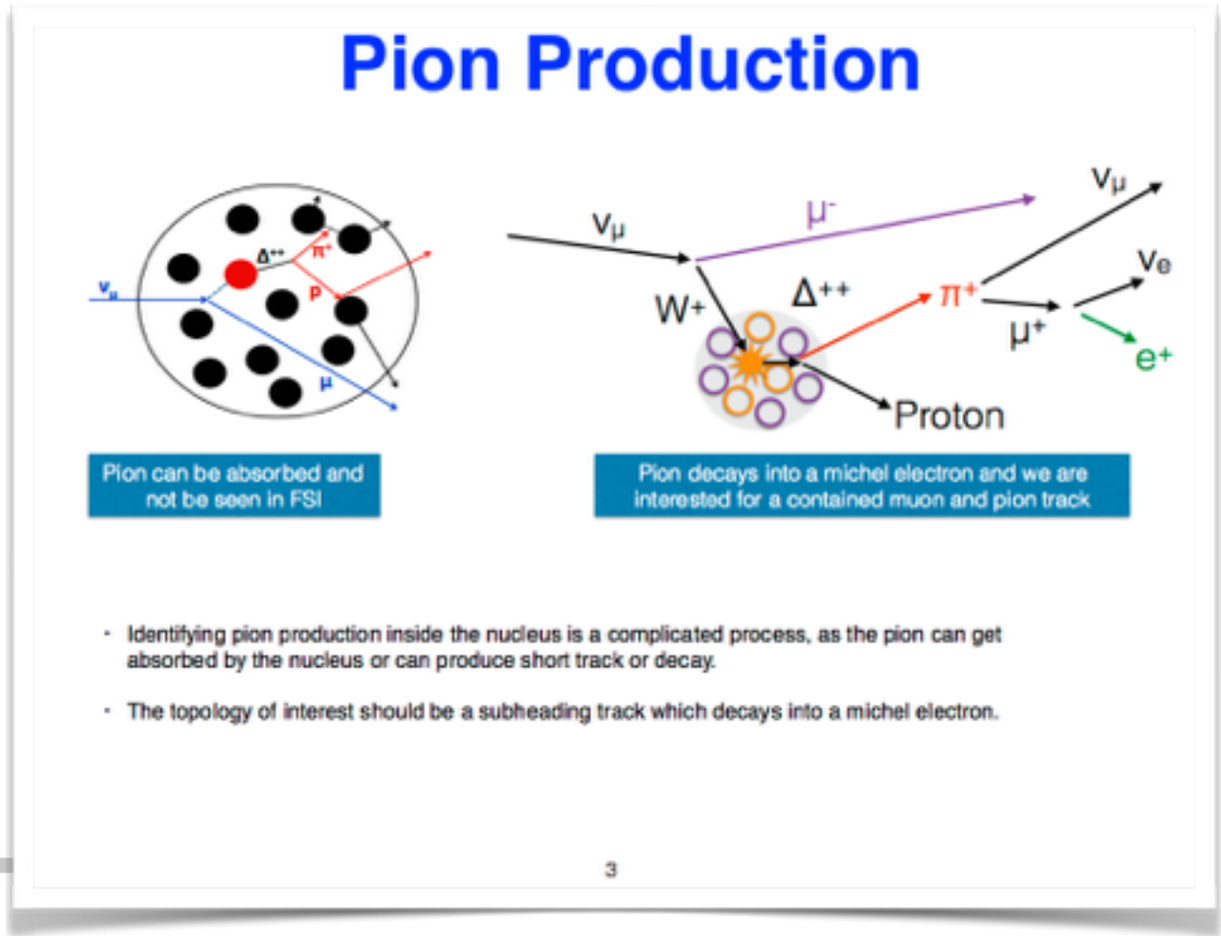


ND (Cross Section) Group

GOIAS — Cross Section of numu 1+pi at the ND

Status: pion selection efficiency is ~2% (with very high purity) after tagging the Michel electrons

Work in progress for better efficiency

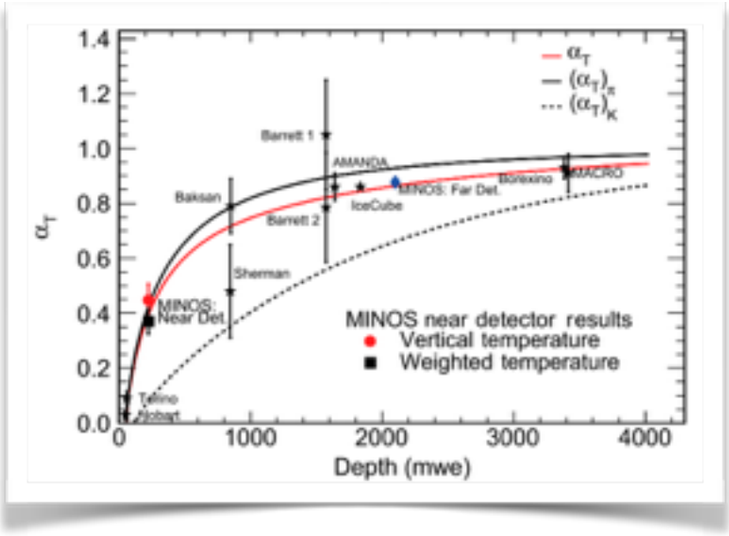


NOVA — ANALYSES

GOIAS - Muon Seasonal Variation at the NOvA ND

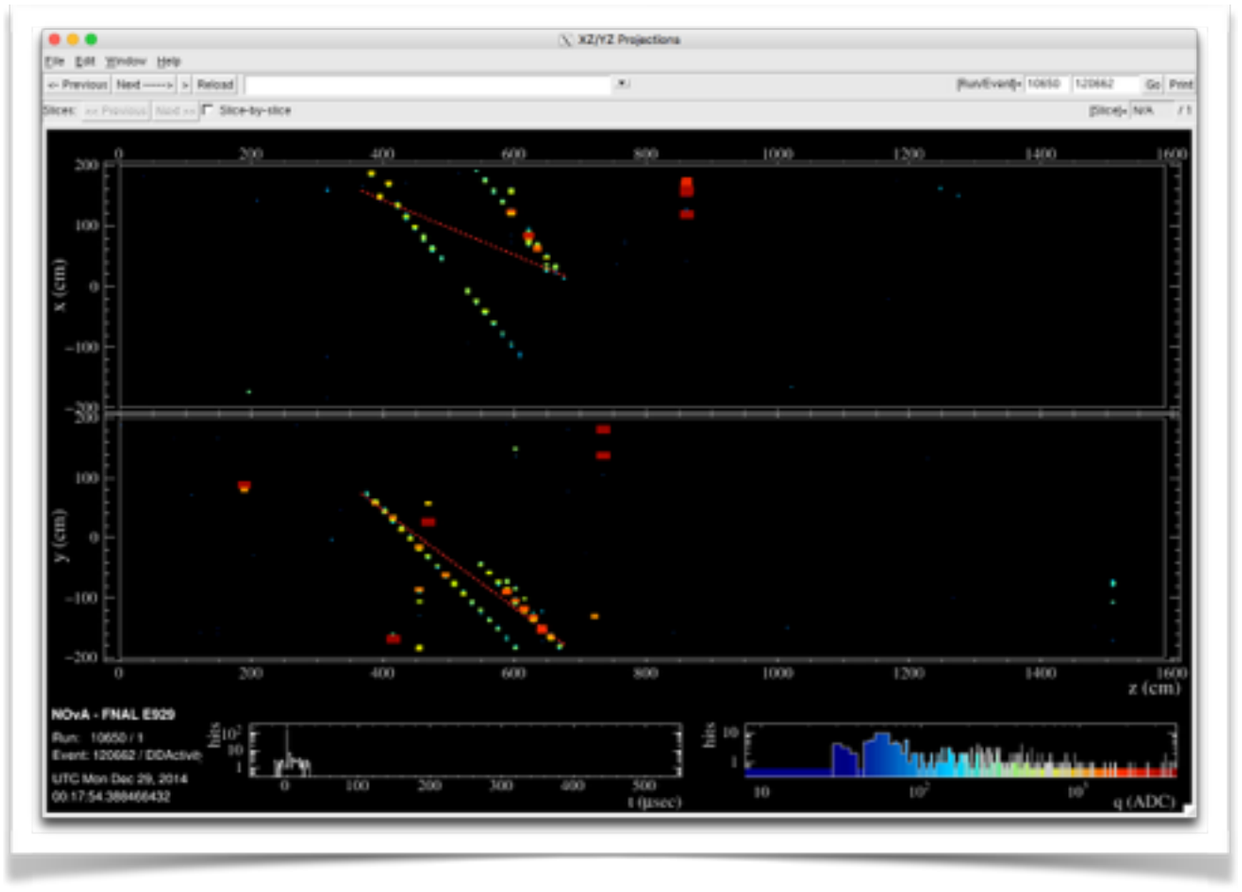
Single muons: we can add a new data point of α_T

Multiple muons: verify the opposite phase effect and shed new light on this unexpected result



Current status:

1. Poor reconstruction for multiple muons
2. Working to improve the efficiency of the tracking algorithms
3. Production group could manage to provide us with 1 full year of processed data



SUMMARY

LOOKING FORWARD TO CONTINUE COLLABORATING AND INCREASING THE PARTICIPATION OF LATIN AMERICAN INSTITUTIONS AT THE NEUTRINO FERMILAB PROGRAM

ACKNOWLEDGMENTS:

- *FERMILAB*
- *ALL COLLABORATORS: MINOS, MINOS+ AND NOVA*
  - *IN PARTICULAR: M. GOODMAN'S GROUP (ANL)*

FINANCIAL SUPPORT:

- *CAPES*
- *CNPq*
- *FAPEG*
- *FAPESP*
- *RENAFAE*

THANKS FOR YOUR ATTENTION