Gaspar Barreira

His vision on particle detectors and instrumentation

“New directions in science are launched by new tools more often than by new concepts”

(Freeman Dyson, distinguished theoretical physicist)

C.W. Fabjan and P. G. Innocenti

Gaspar's vision

- Advance instrumentation to advance science
- Make LIP a world leader in instrumentation to make LIP a world leader in science
- Focus on a few most promising directions, consistent with LIP's staff talents and infrastructure
- Contribute to developments useful to Society
- Involve Portuguese industry

Gaspar's vision highlighted: Gaseous detectors

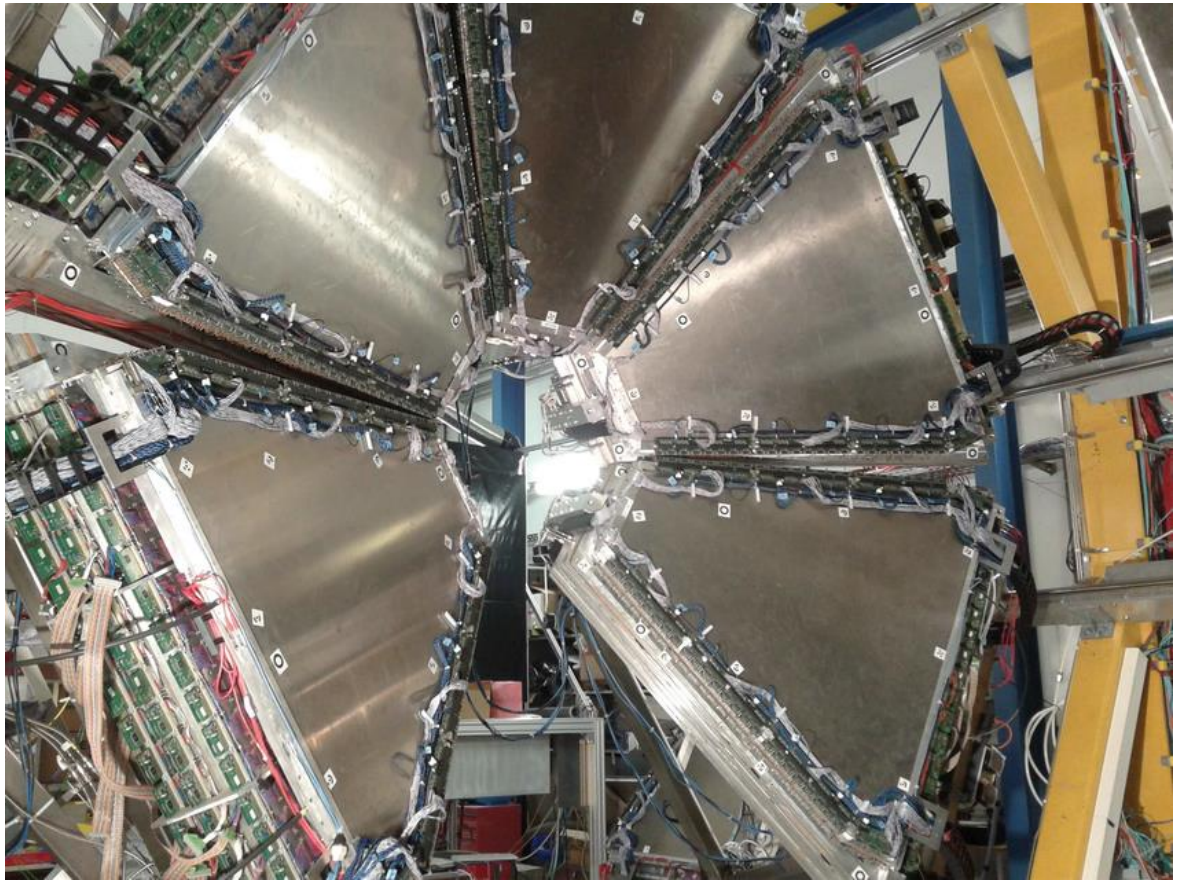
- Build on the legacy of the Coimbra groups of C. Conde and A. Policarpo

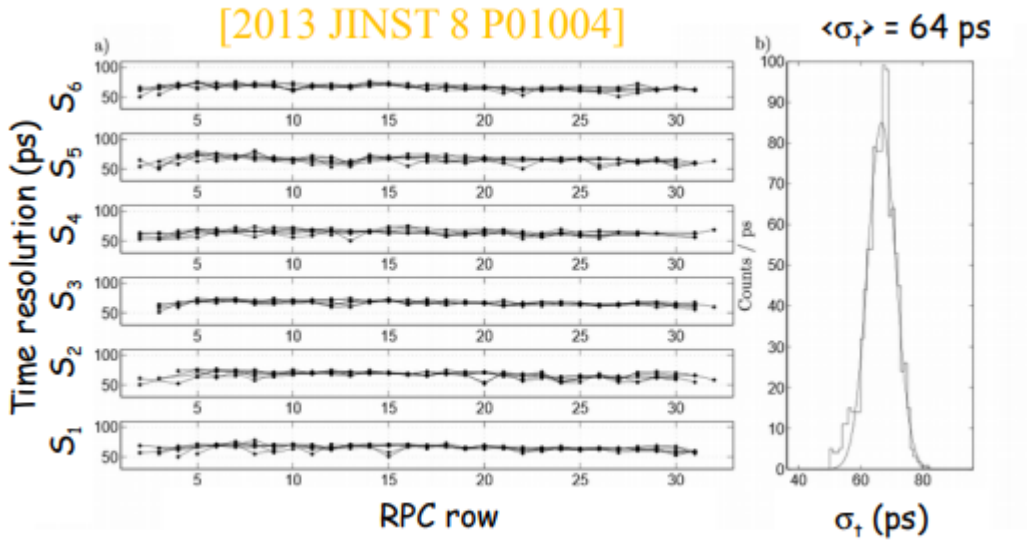
- Example 1: Resistive Plate Chambers (RPCs)

- From electrode-coated Bakelite plates to

  Revolution in Time-of-Flight Detectors
  Revolution in Cosmic Ray experiments
  Revolution in Medical Imaging

RPCs: Hades TOF wall





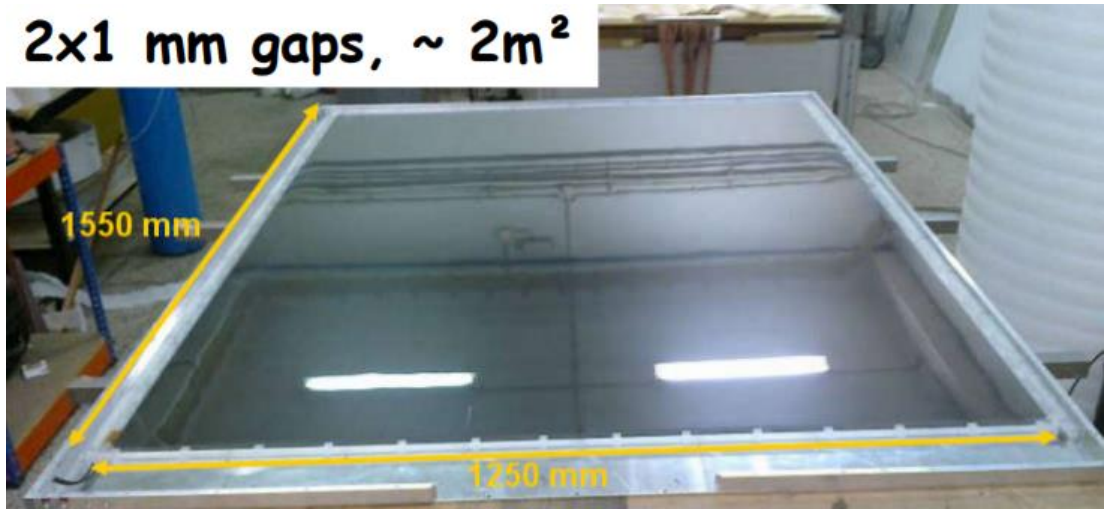
6 sectors with a total of 1122 detection cells

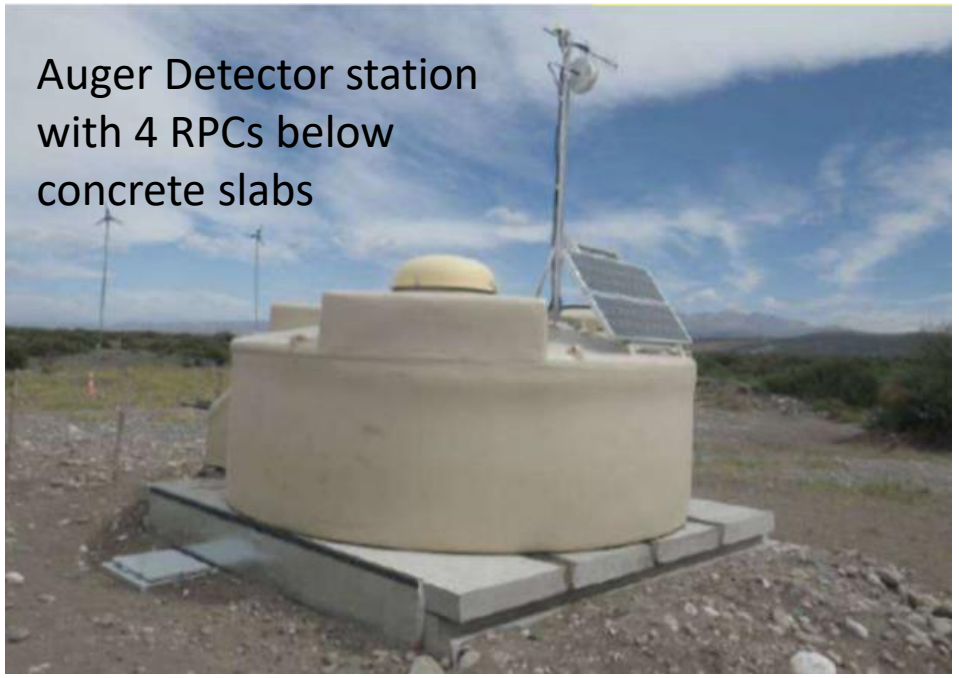
uniform detection efficiency and
splendid time resolution

Bright future: diverse and challenging applications, Cosmic Ray detectors; proposed for new CERN SPS facility SHIP

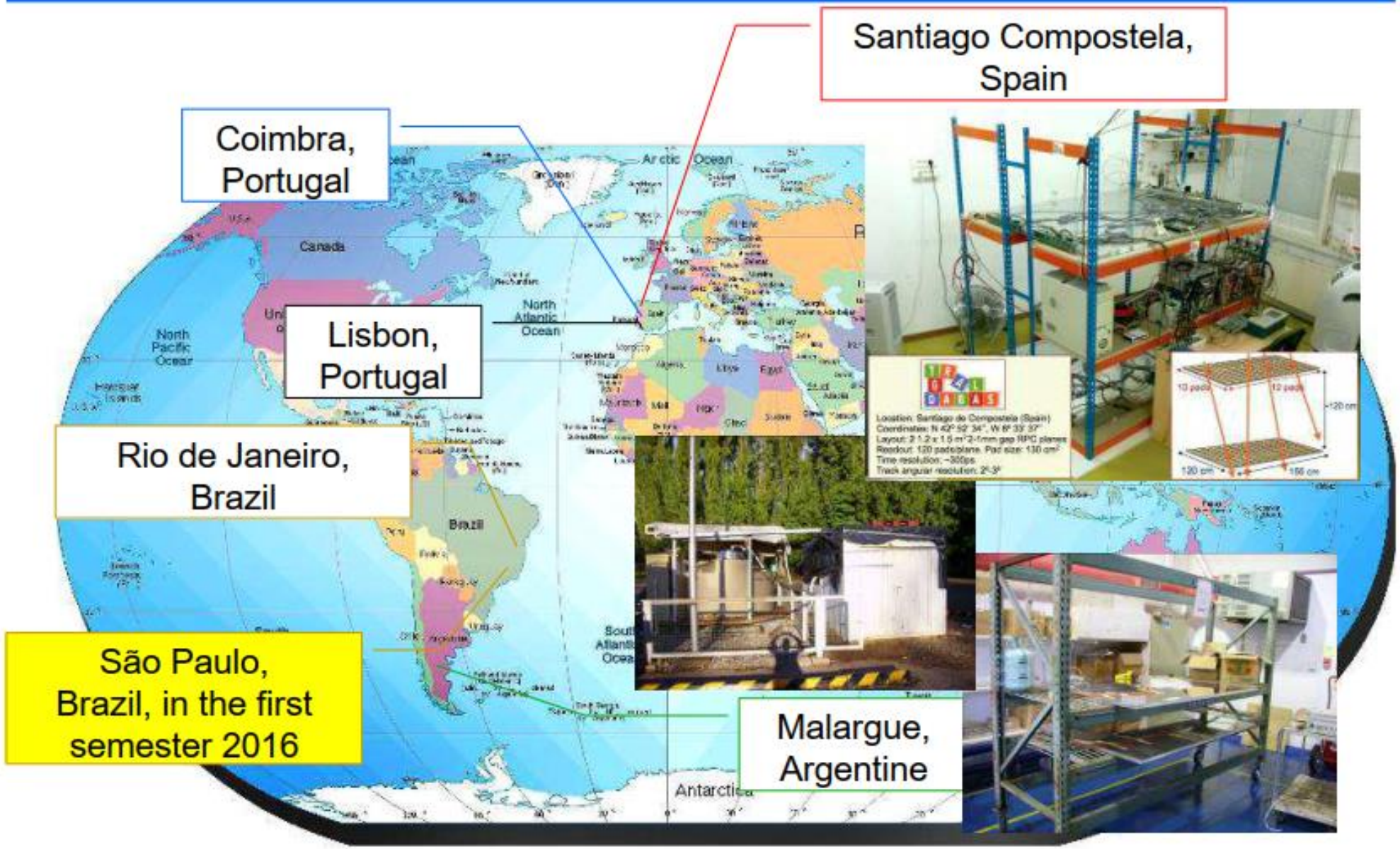
LIP-design of RPCs : reaching “Autonomy”

- Goal: (quasi)-autonomous RPCs with
  - Good spatial and temporal resolution
  - Operating in harsh environment (large pressure and temperature variations)
- Ultimately: develop sealed RPCs
  - If successful, would revolutionize Cosmic Ray facilities





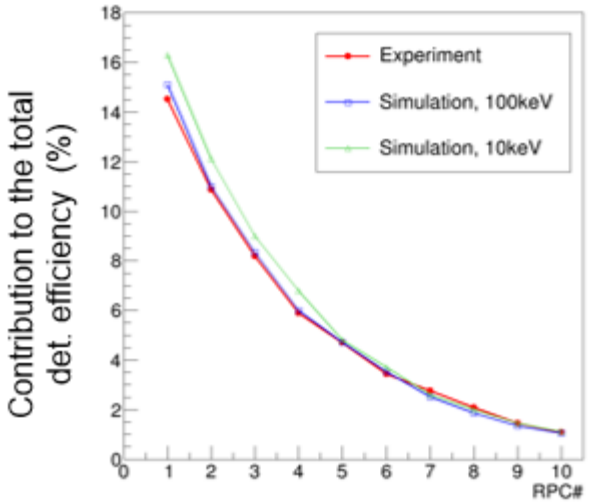
RPC - where we can find them

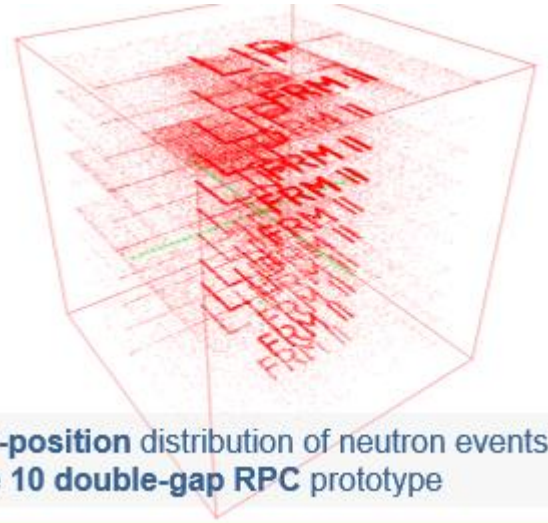


RPCs: Detecting thermal neutrons

- Aim: high spatial and time resolution neutron detectors replacing ^{3}He-based detectors
- Concept: Multi-gap RPCs electrodes coated with thin $^{10}B_4$ film, based on reaction $^{10}B_4$ (n,α) ^{7}Li
- Prospect: major new technology for new facilities, e.g. for the European Spallation Source, ESS

Efficiency computed by ANTS2 Toolkit
(all $^{10}B_4C$ layers with a thickness ~1.15 μm)

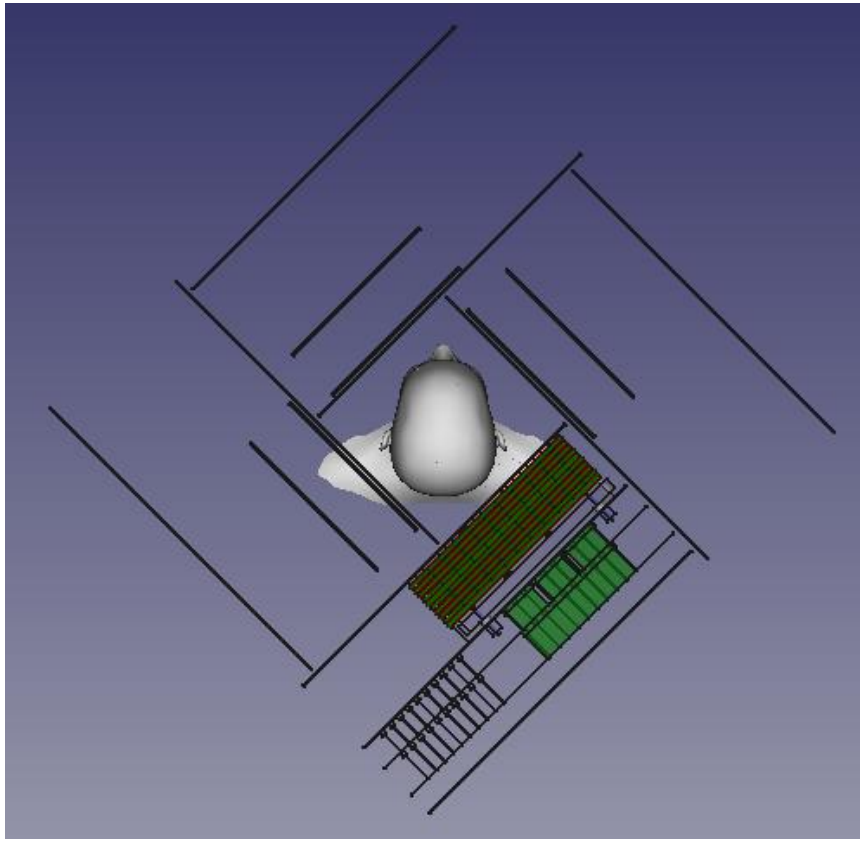




3D-position distribution of neutron events in the **10 double-gap RPC** prototype

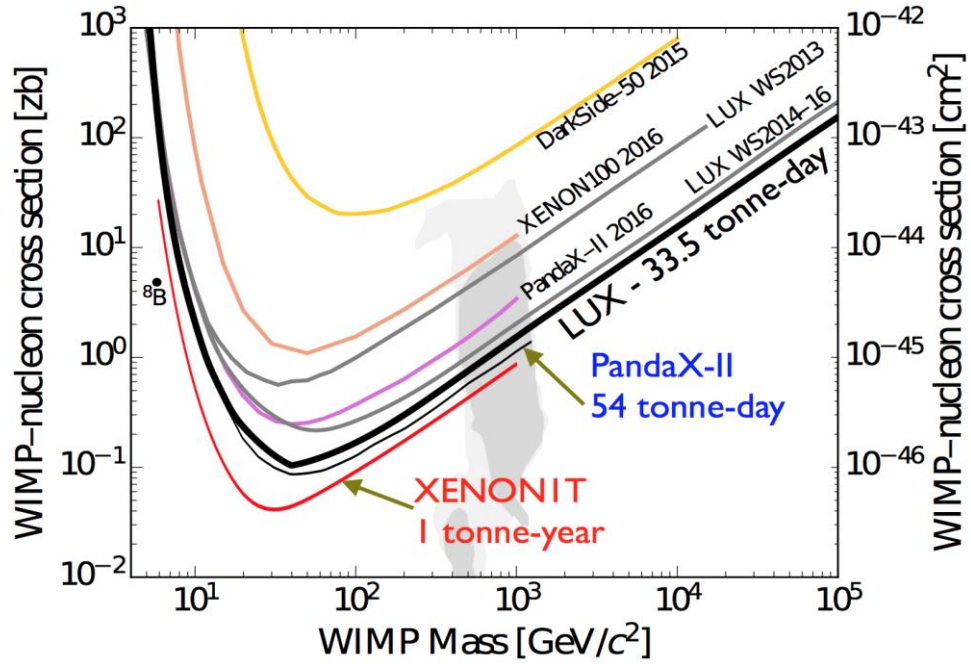
RPCs: Imaging the brain

- R&D work has started
- Sub-millimeter space resolution
- 300 ps time resolution
- Reduced cost of instrument
- Could become a paradigm change in medical imaging



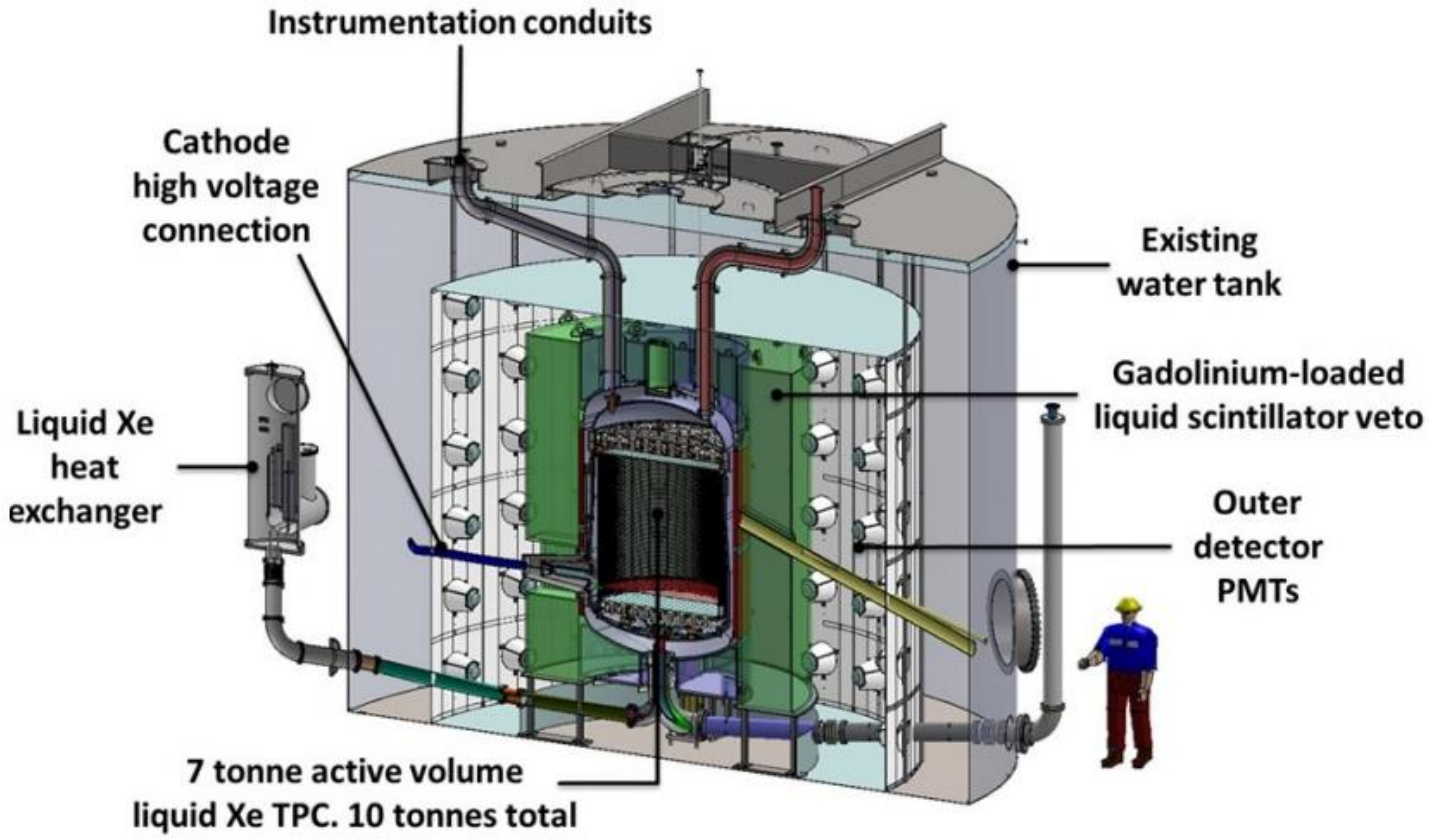
Gaspar's vision highlighted: Liquid xenon detectors

- From gas to (cryogenic) liquid: logical evolution
- LIP's impact on this R&D rose with the rise of this technology
- Within a decade became major contributor to one of the largest LXe experiments: LUX
- LUX held world-record on limit on Dark Matter candidates



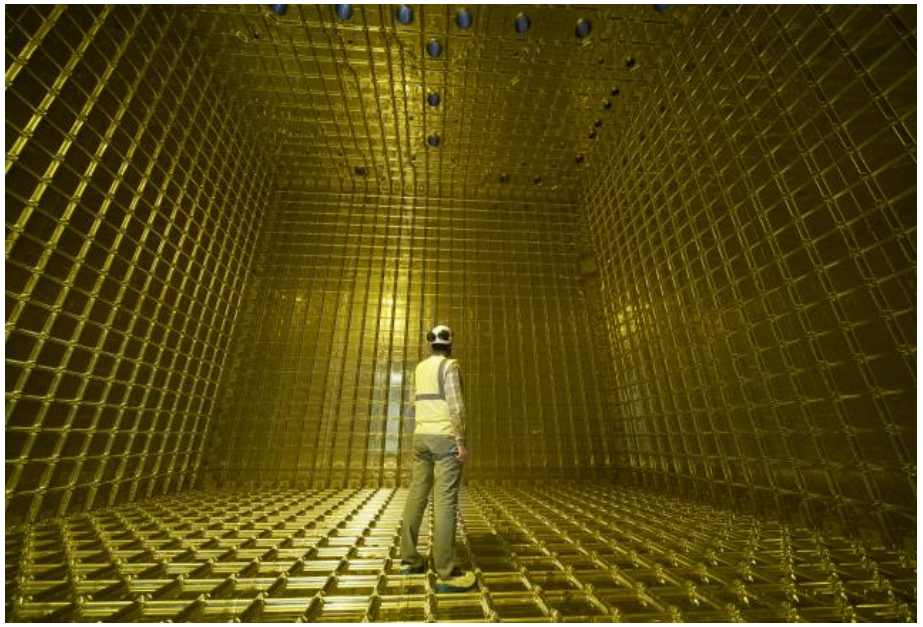
The Future of Liquid Xenon Detectors

- Next generation: multi-ton LXe detectors
- LIP is major partner in Lux-Zeplin 10 tonnes LXe Detector (LZ)
- Parallel R&D on high-pressure Xe time-projection chambers at LIP

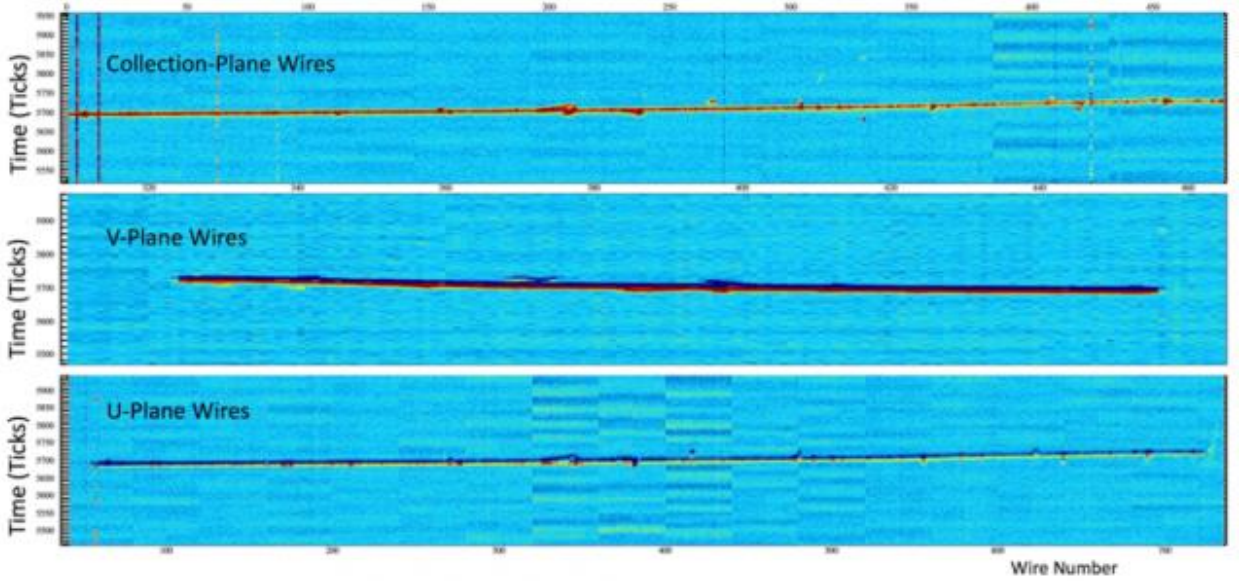


A parallel future: Giant Liquid Argon Detectors

- Proto Dune detector (800 tons) has seen first tracks at CERN
- Final installation aims at 100 kilo tons in Sanford Underground Laboratory, detecting neutrinos from 1300 km distant Fermilab
- LIP is member of Dune



Inside Proto Dune

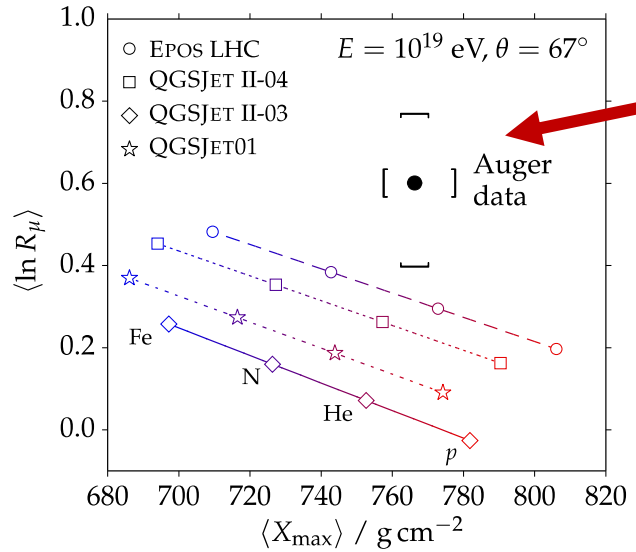


First tracks in Proto Dune

Gaspar's vision: physics with Nature's accelerators

- LIP's participation and contributions to AUGER: the world's largest ground-based Cosmic Ray Laboratory
  - More than 1700 detector stations spread over 3000 km2
  - Auger Prime: upgrade with better muon detection and radio detector array
- LIP is major contributor to physics research at the 100 TeV frontier
  - Mystery: cosmic ray composition; interaction in the 10^{18} to 10^{20} energy range

Test stand in Malargüe for Upgrade scintillator tests

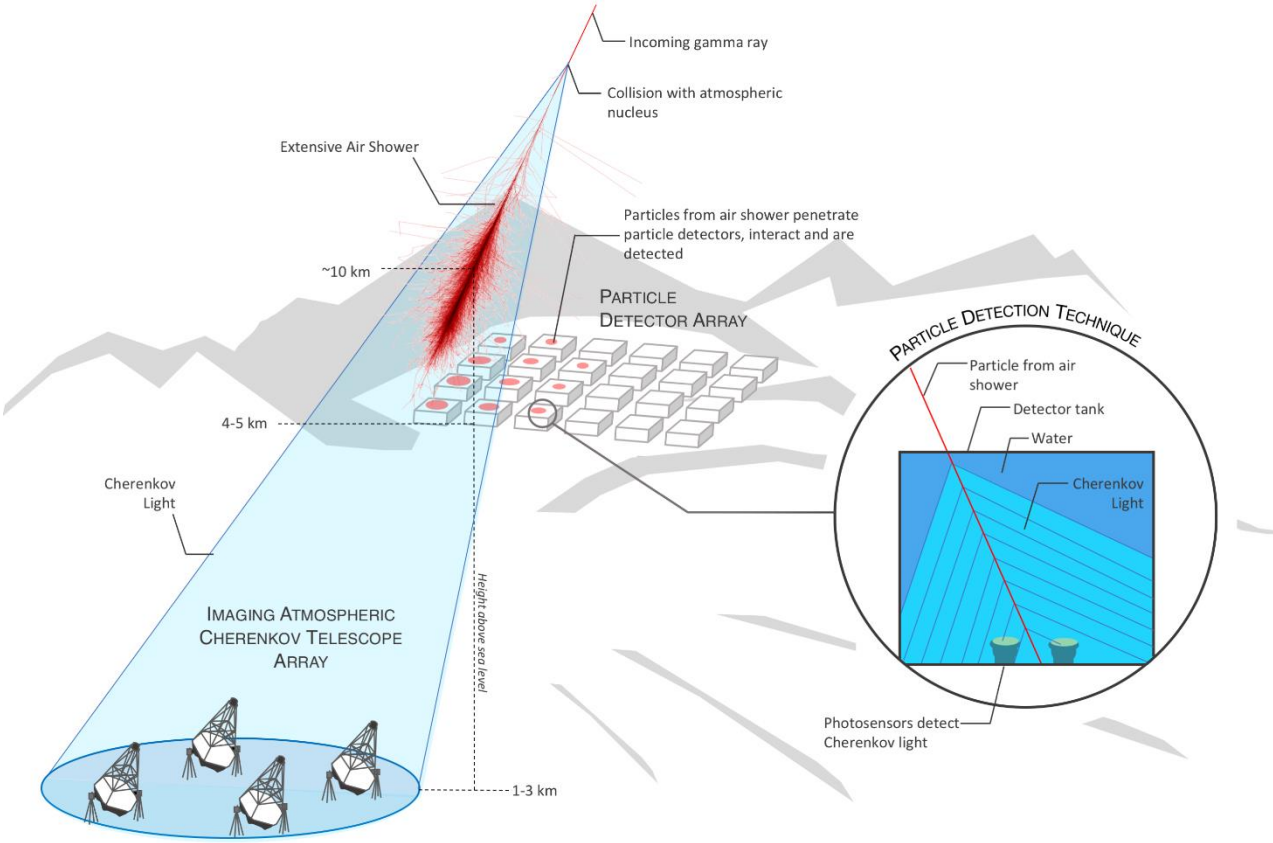


The muon puzzle

Shower depth

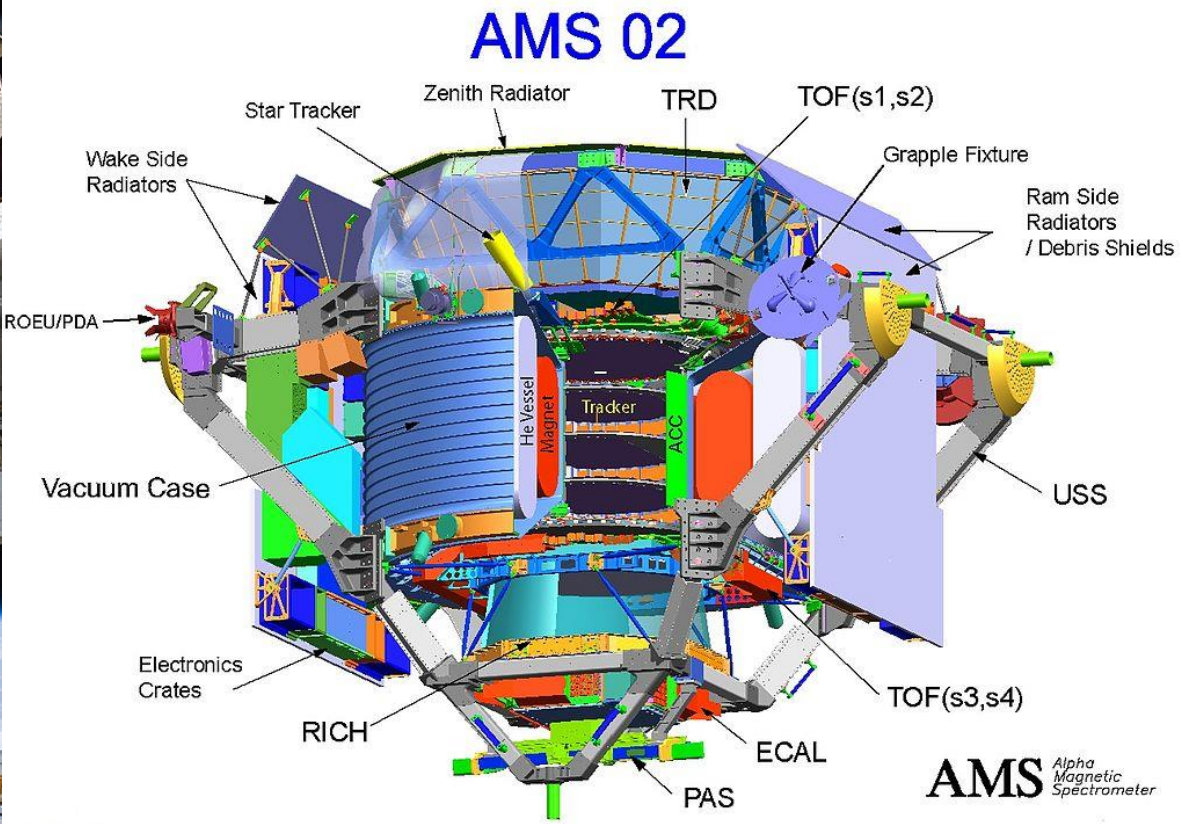
Success breeds “Future Cosmic Ray Observatories”

- Example: LIP is a leading contributor to an international consortium proposing a large area RPC-based high energy γ-ray detection facility
  - SWGO: Southern Wide field-of-view Gamma ray Observatory
  - Covering > 200 000m^2; detectors at 5000 m altitude; in South America
  - Energy: 100 GeV to 100 TeV
  - R&D collaboration established



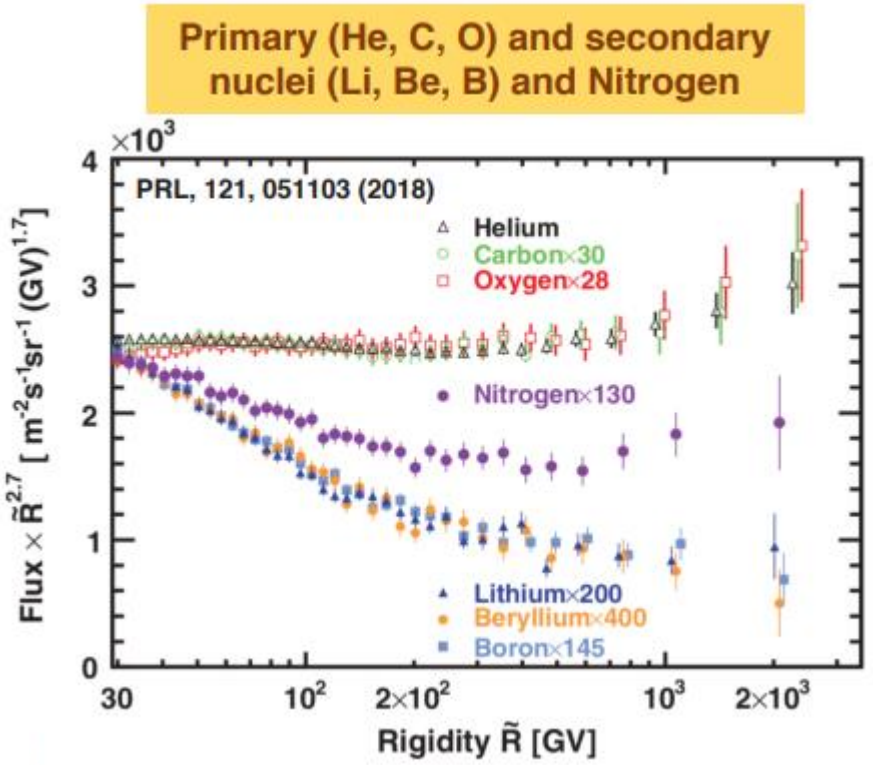
Cosmic Ray Experimentation in Space

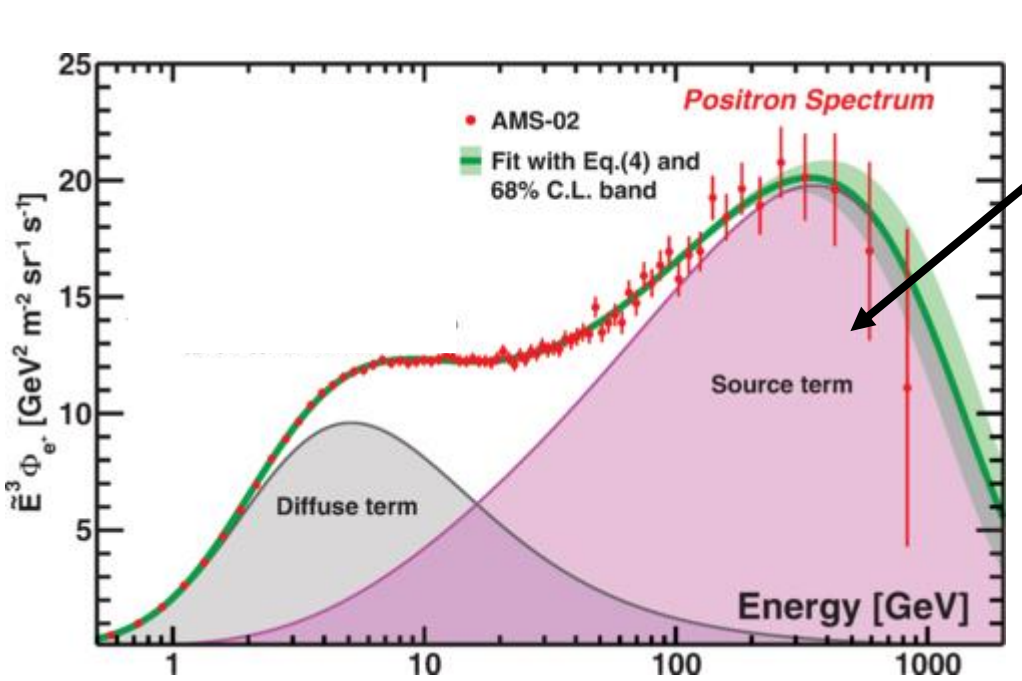
- AMS- Alpha Magnetic Spectrometer at the International Space Station
- LIP is member, contributes to RICH, isotopic composition and solar emission studies



AMS: a new dimension in Cosmic Ray Physics

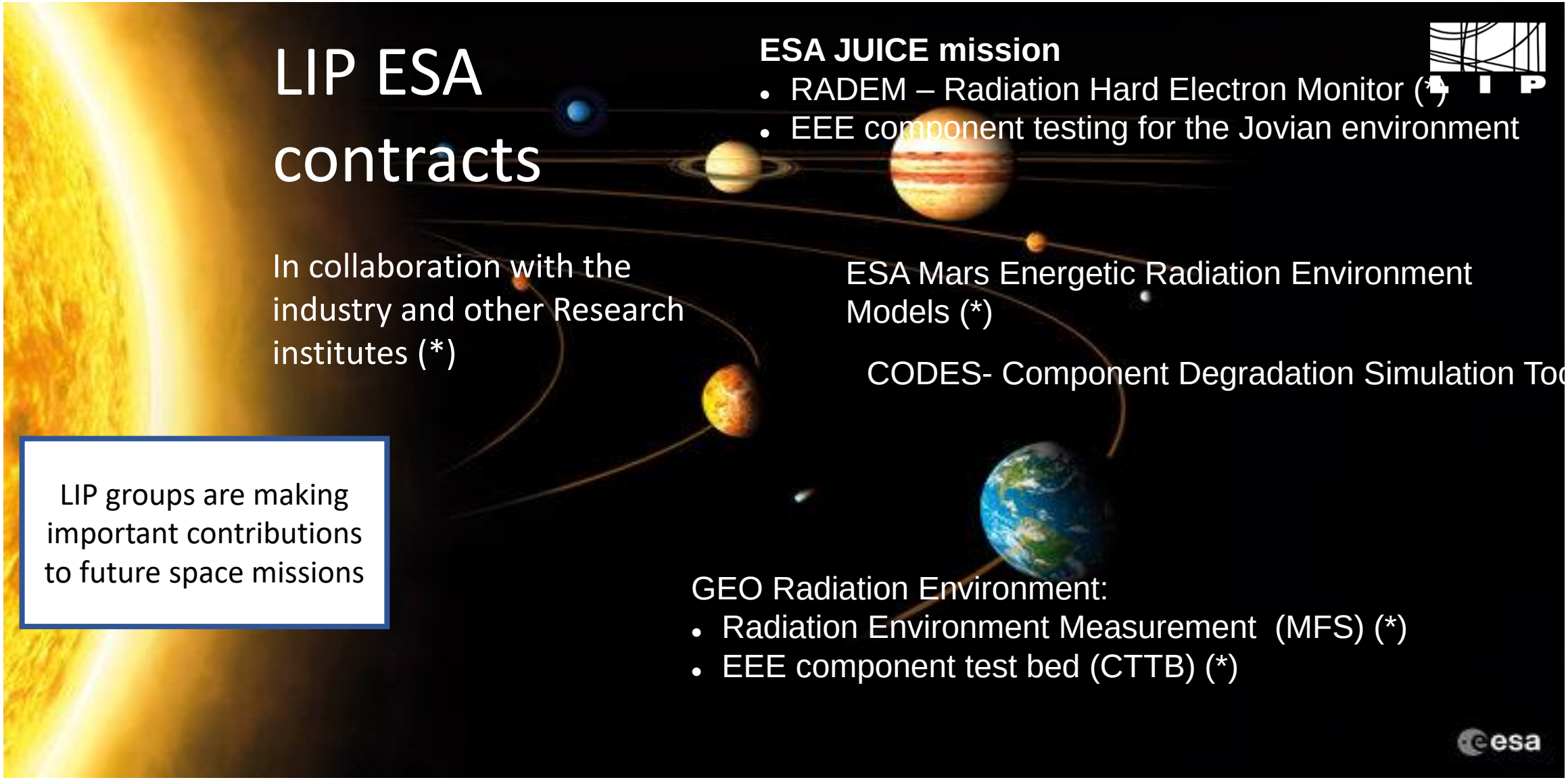
- AMS:
  - Difficult gestation period of the most ambitious space-based CR experiment
  - Patience and perseverance hugely rewarded: successful beyond expectation of most physicists





DM
or
???

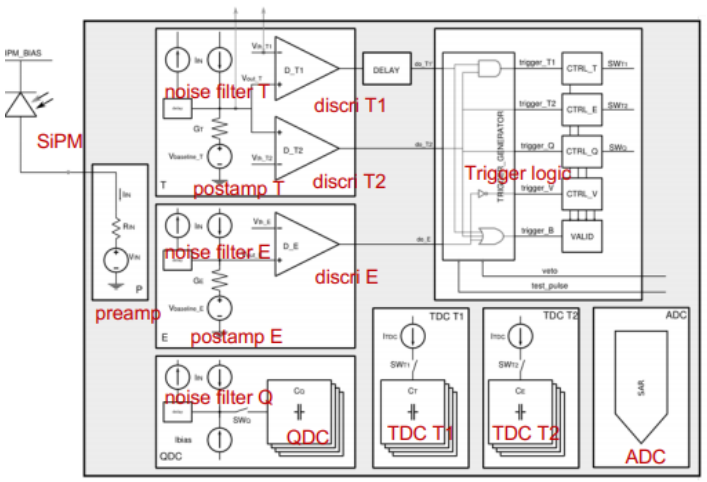
LIP venturing into Space: radiation environment and effects

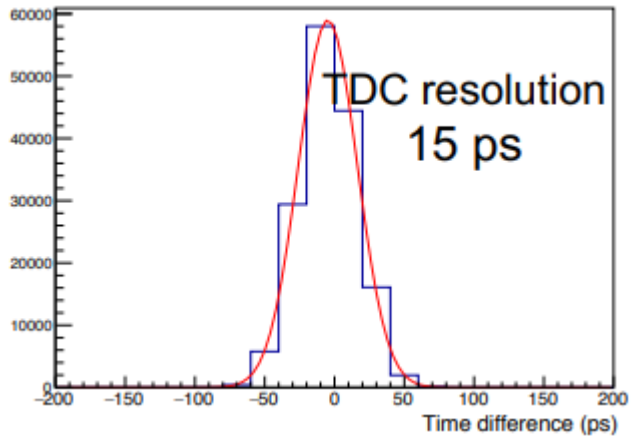


Gaspar's vision: from detector signals to (big) data

- Success #1: ASIC developments with Portuguese industry

ASIC R&D laboratory at TAGUS LIP Facility
Developed very advanced ASICs
for CMS detectors
for PET instrumentation
with Portuguese industry





Gaspar's vision: Advancing HEP Computing

- Trigger and Data Acquisition
- From "Data" to "Open Data"
- Big Data and Machine Learning
- Data Processing and Networks

Trigger and DAQ (r)evolution

- LHC Experiments
  - Deadtimeless, pipelined hardware Level-1 trigger
- Advances in specialized processors (FPGAs, GPUs)
  - Substantial increase in on-line processing
  - Real time recording of larger data sets
- Future
  - LHCb and ALICE replacing custom designed Level 1 trigger with on-line processing of ALL events; sizeable fraction recorded
  - ATLAS and CMS: new higher latency custom programmable hardware trigger with increase in the rate of events to be processed in real time
  - HL-LHC: this trend will continue, but increasingly challenging
- LIP
  - Major contributor to ATLAS and CMS trigger R&D and deployment

Open Data : the Open Research Society

- Fundamental research is (to large extent) supported by pubic funding
- Trend: make data available to outside users
  - Data stored in accessible format and location
  - Metadata describe content and context of data and data files
  - Knowledge disseminated on how the data were produced
- HEP specificity: severe trigger selection and extensive further processing;
  - May be opaque to outsider
  - Must re-use substantial part of software developed by collaboration
- Open data and reuse is being generalized: Astrophysics, biology, etc.

Future of Data Analysis: Machine Learning?

- Machine learning
  - Novel discovery method, where algorithms replace human intuition and reasoning?

    or
  - Aid to traditional inductive method?
- Machine Learning: very actively pursued in HEP
  - Simulation, Reconstruction and Analyses
  - Concern about opacity of this approach
  - LHC Trigger systems: neural networks;
- LIP is actively following this “technology”
  - Competence Centre in Simulation and Big Data

Gaspar's vision: fundamental research servicing society

- Most recent success: planning the Portuguese Centre for Proton Therapy Center; LIP competences were and are instrumental
  - LIP for many years has contributed to R&D in radiation detectors used in medical diagnosis
  - Medical and environmental dosimetry
  - Multigap RPCs for γ detection in Positron Emission Tomography (PET)
- From animal to brain to full-body PETs, using LIPs RPC technology

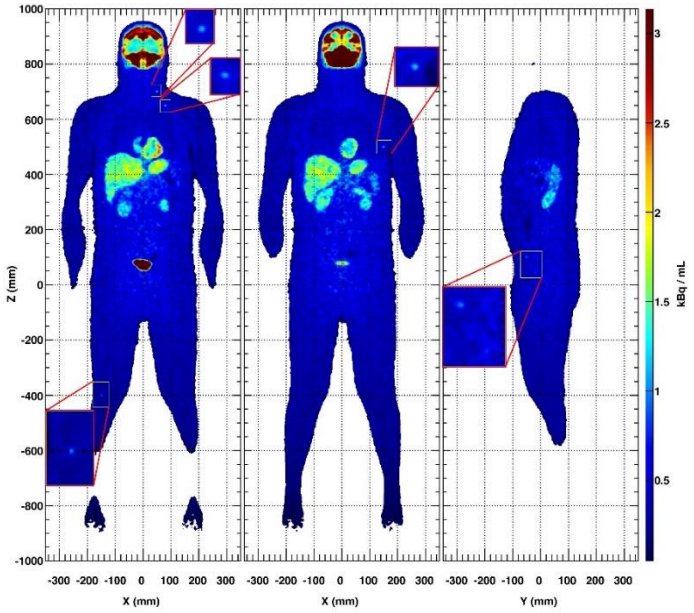
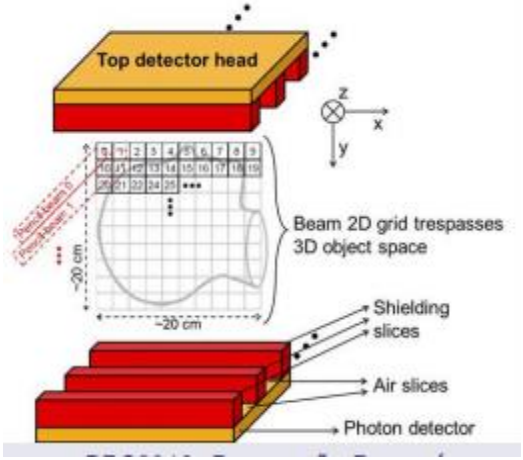


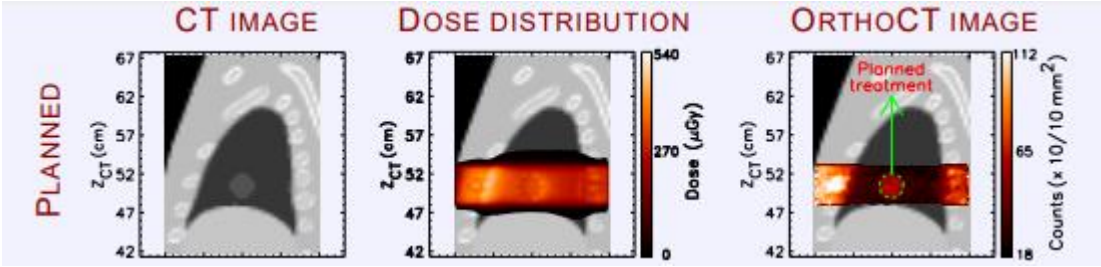
Image reconstruction of simulated full-body RPC-PET; 100 ps time resolution improves background rejection and reduces exposure time to a few minutes

Another promising Imaging Concept: Ortho - CT

- Ortho Computer Tomography (CT)
- Concept



- Typical result



Gaspar's vision: drive for excellency

- Competence centres
  - Coordinate, bundle, leverage competences in the various LIP laboratories
- Competence Centre in Monitoring and Control
  - Leverage experience and competences gained in Experiment Control Systems
  - Experience in electronics, sensors, software
  - Environmental monitoring in industry, applied sciences, biology
- Competence Centre on Simulation and Big Data
  - Sharing knowledge, training, assistance in simulation, algorithms, analysis
  - Major effort in adopting Machine Learning
  - Assisting groups at and outside LIP

Gaspar's Legacy

- Instilled the spirit of excellency
- Stimulated creative thinking
- Shared his contagious enthusiasm
- Gave generous credit to collaborators
- Was shaker and mover of Science in Portugal and beyond
- Left a world-leading laboratory well prepared for a brilliant future