



GSI Helmholtzzentrum für Schwerionenforschung



Participation in the HADES experiment

the construction of a TOF wall based on RPCs and more.

The beginning of a durable collaboration

A. Blanco

On behalf of

HADES-RPC group

a joint collaboration of LIP, USC and IFIC

Funding:
FCT

Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR



Ciência.Inovação
2010

Programa Operacional Ciência e Inovação 2010
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR



União Europeia
Fundo Europeu de
Desenvolvimento Regional

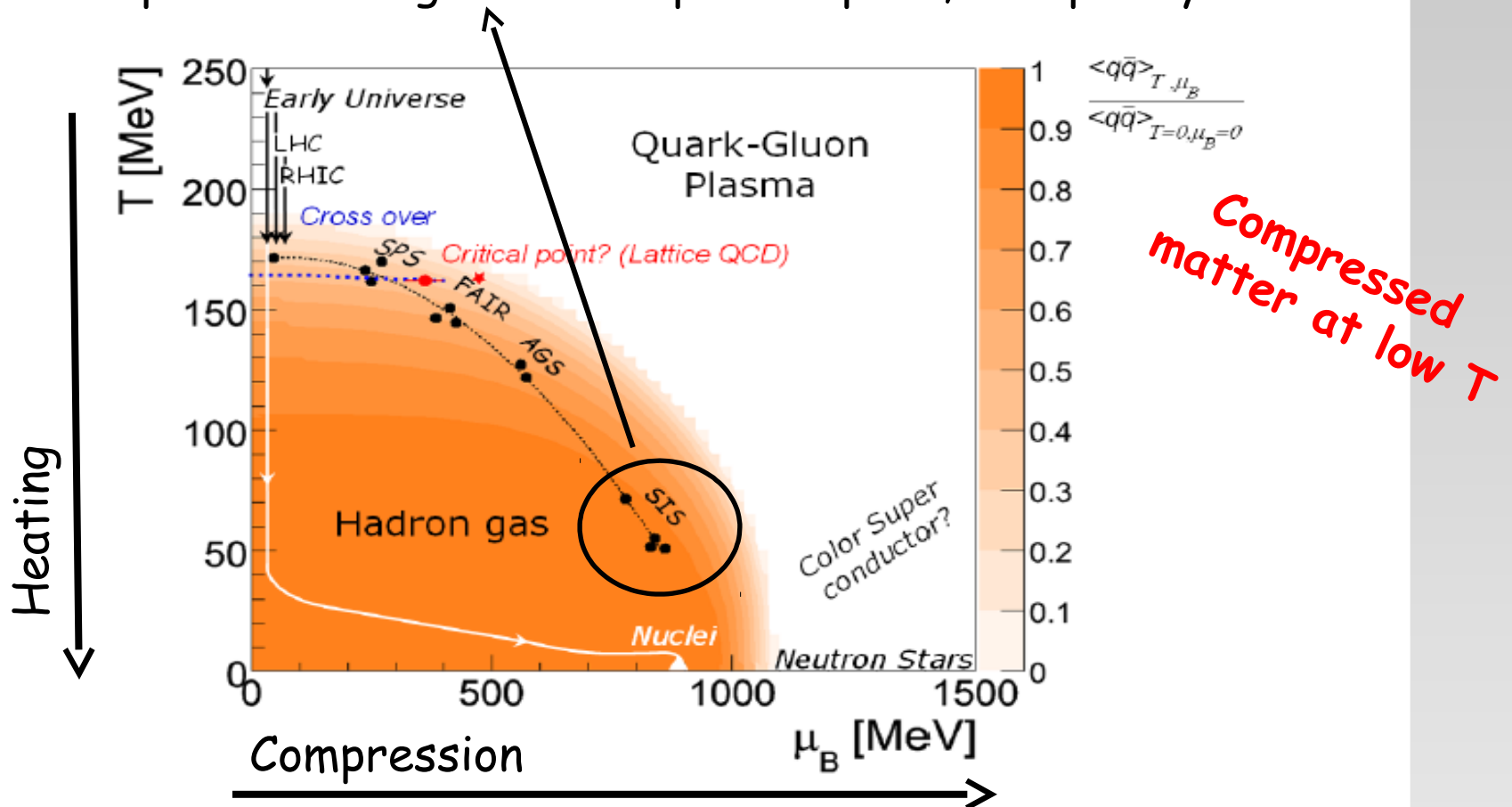
**Sixth
framework
programme**

HADES. OBJECTIVES.

HADES High Acceptance DiElectron Spectrometer

Study of "emissivity" and hadron properties in dense and cold nuclear matter, detected via $e^+ e^-$ pairs (dielectrons) and strange hadrons, produced in proton, pion and heavy ion induced reactions in a 1-3.5 GeV.

Explore this region of the phase-space, still poorly known.



HADES. SPECTROMETER.

HADES High Acceptance DiElectron Spectrometer

Study of "emissivity" and hadron properties in dense and cold nuclear matter, detected via $e^+ e^-$ pairs (dielectrons) and strange hadrons, produced in proton, pion and heavy ion induced reactions in a 1-3.5 GeV.

Spectrometer with high invariant mass resolution and high rate capability. Installed at SIS18, GSI, Darmstadt. <http://www-hades.gsi.de/>



Project launched in late 1994
6 years R&D and construction

First production run in 2002

International collaboration of
19 institutions from 10
European countries.

Cyprus, Czech Rep., France,
Germany, Italy, Poland, Portugal,
Russia, Slovakia, Spain.

HADES. THE BEGINNING OF THE HADES-RPC GROUP.

Juan Garzon group was already member of HADES (analysis, software)

Very good and old relations between J. Garzon group and LIP-Coimbra.

HADES TOF detector (at low angles) did not have enough granularity to measure Heavy Ions (a fundamental part of the HADES physics program).

LIP-Coimbra had (and have) a strong group in timing RPCs



Upgrade the HADES spectrometer with a Time of Flight detector based on RPCs: TOF-RPC

- LIP-Coimbra in charge of the RPC R&D and construction
- USC in charge of the FEE, RPC design (granularity, segmentation, ...), software and calibration
- IFIC in charge of electronics and LV

HADES. HADES-RPC GROUP.

From 2002 to 2018

Former members

Current members

GSI

- W. Koenig

Electronics

TU Darmstadt

- G. Kornakov

Calibration +
analysis

LIP

- A. Blanco
- P. Fonte
- L. Lopes
- J. Saraiva
- L. Pereira

- P. Bordalo
- C. Franco
- S. Ramos
- L. Silva

Design, construction,
maintenance,
operation
together with
Detector laboratory and
Mechanical workshop

Analysis

USC-LabCAF

- D. Belver
- P. Cabanelas
- E. Castro
- J.A. Garzón
- M. Zapata
- D. González

Software + FEE

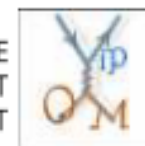
IFIC-Valencia

- J. Diaz
- A. Gil

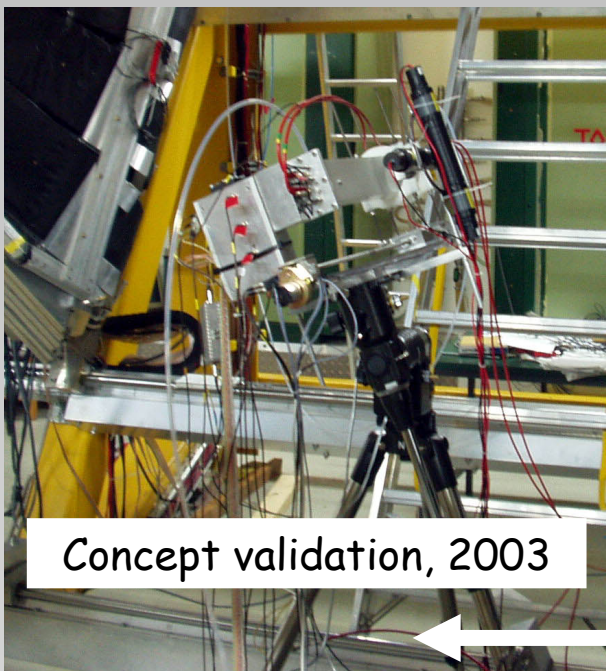
Electronics & LV



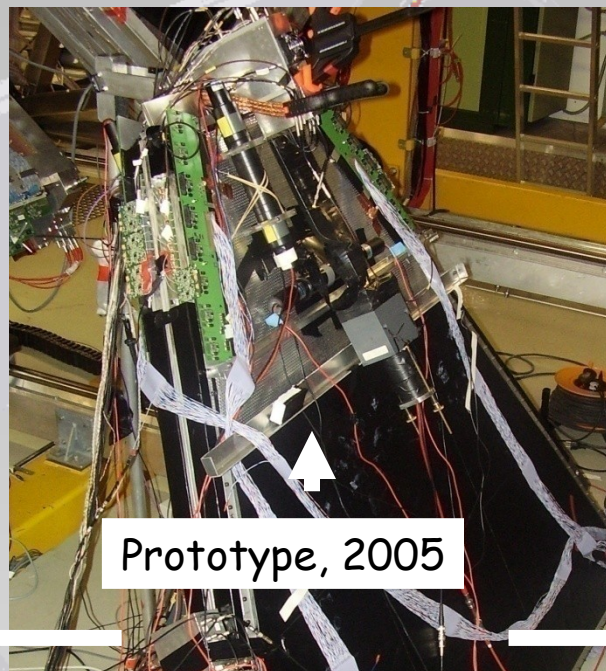
TECHNISCHE
UNIVERSITÄT
DARMSTADT



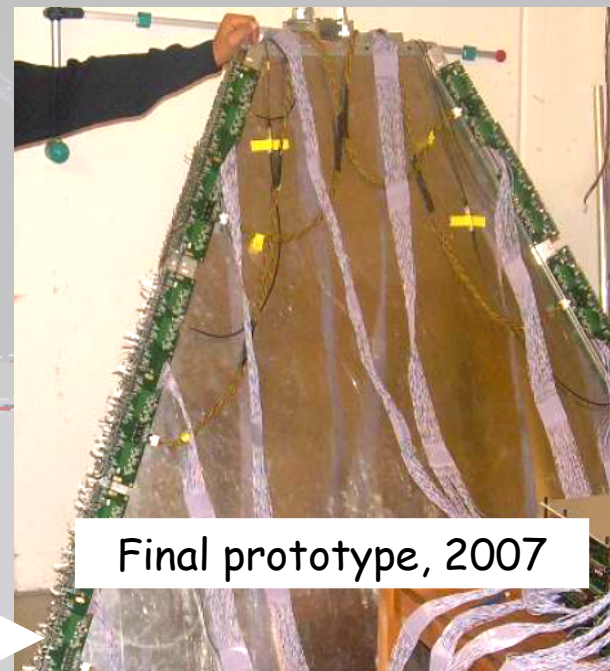
HADES. TOF-RPC CONSTRUCTION.



Concept validation, 2003



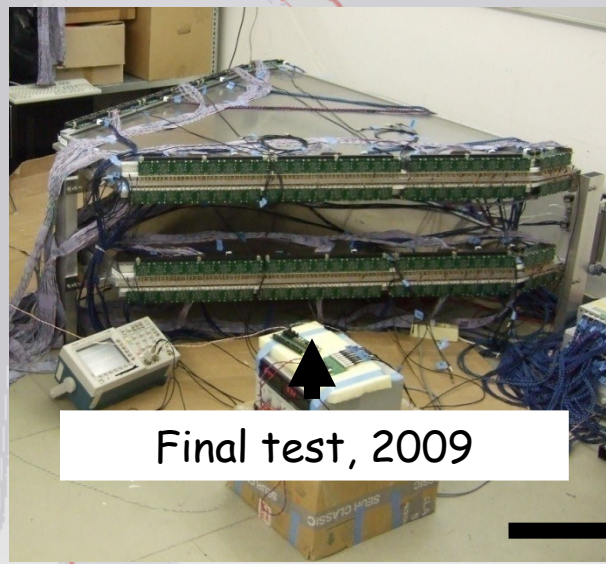
Prototype, 2005



Final prototype, 2007



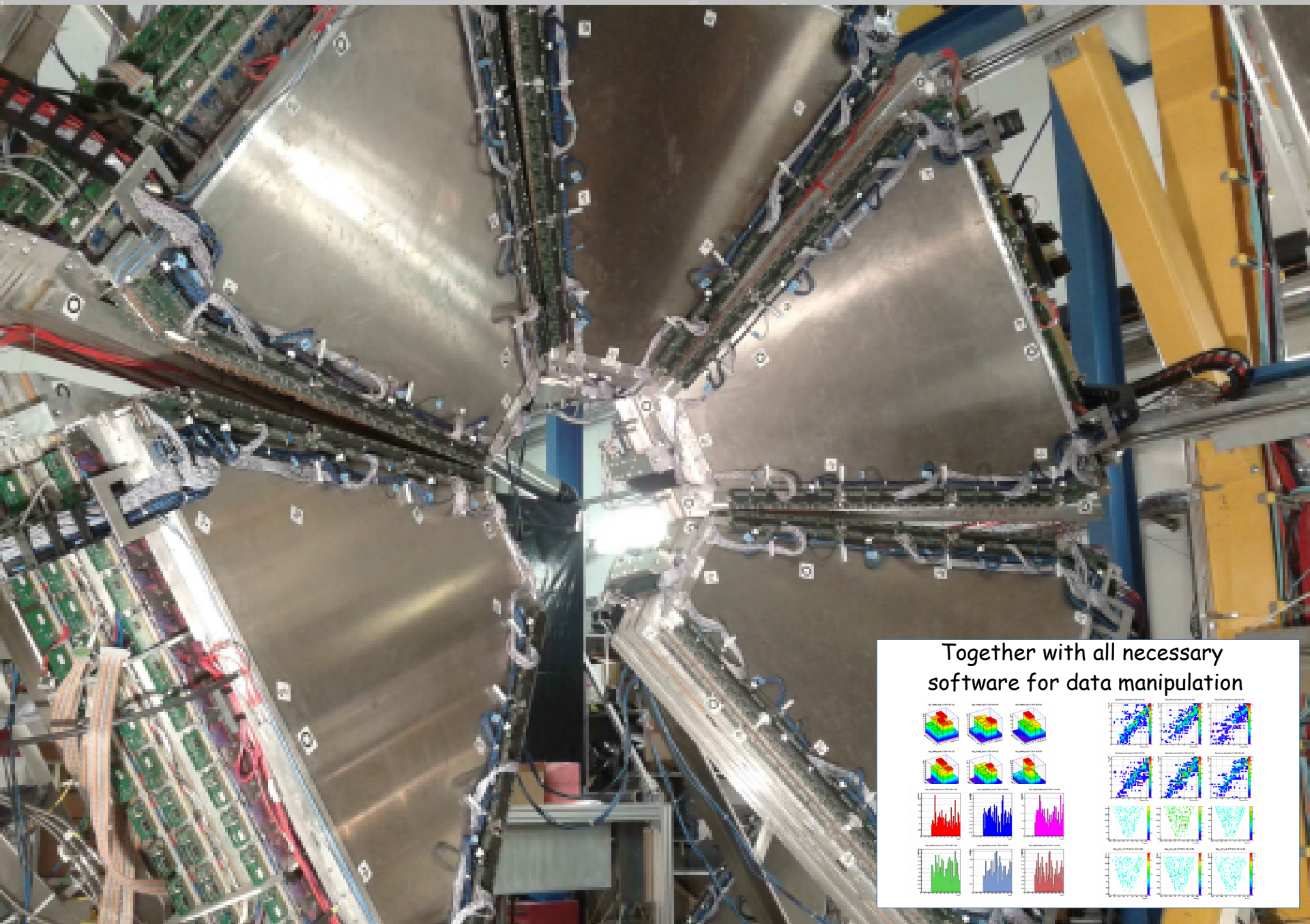
Construction, 2008-09



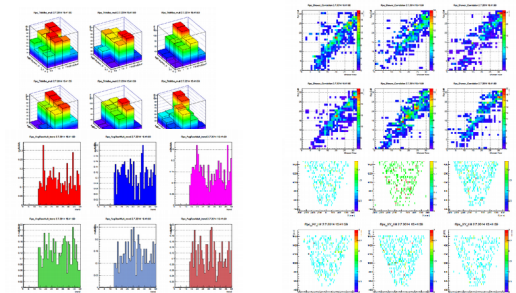
Final test, 2009



Installation, 2010



Together with all necessary
software for data manipulation



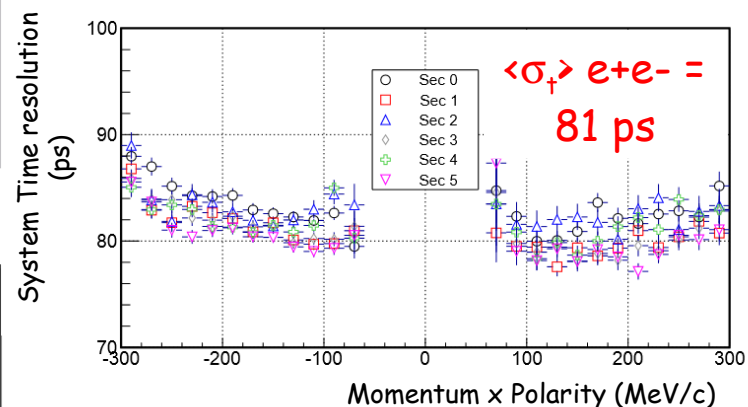
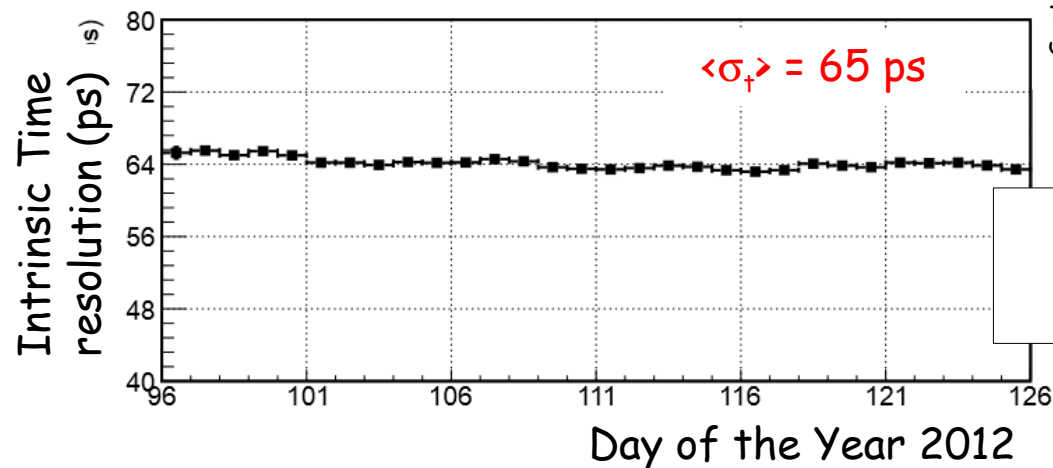
Ready for production beam after commissioning with Au+Au 2 AGeV, **2011**

HADES. TOF-RPC PERFORMANCE.

Operation performance Au+Au 1.23 AGeV (2012)

$\langle \sigma_{\tau} \rangle = 64 \text{ ps}$ for all particles and area
stable in the whole beam time

[2014 JINST 9 C11015]

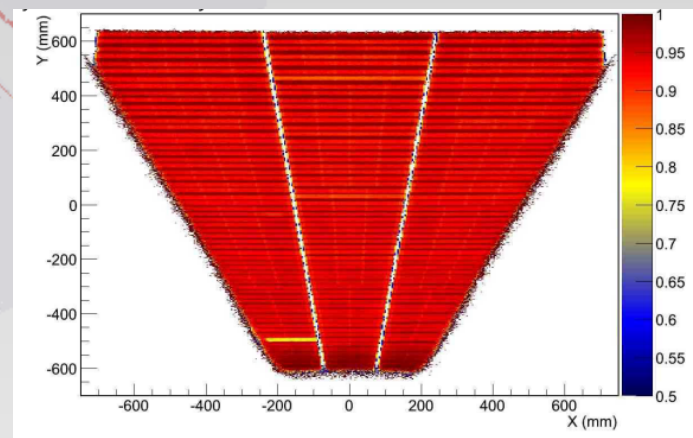


Requirement
 $\langle \sigma_{\tau} \rangle < 100 \text{ ps}$

Requirement
 $\langle \epsilon \rangle > 90 \%$

$\langle \text{Efficiency} \rangle > 95\%$ for all particles and area

Stable and performing operation !!!



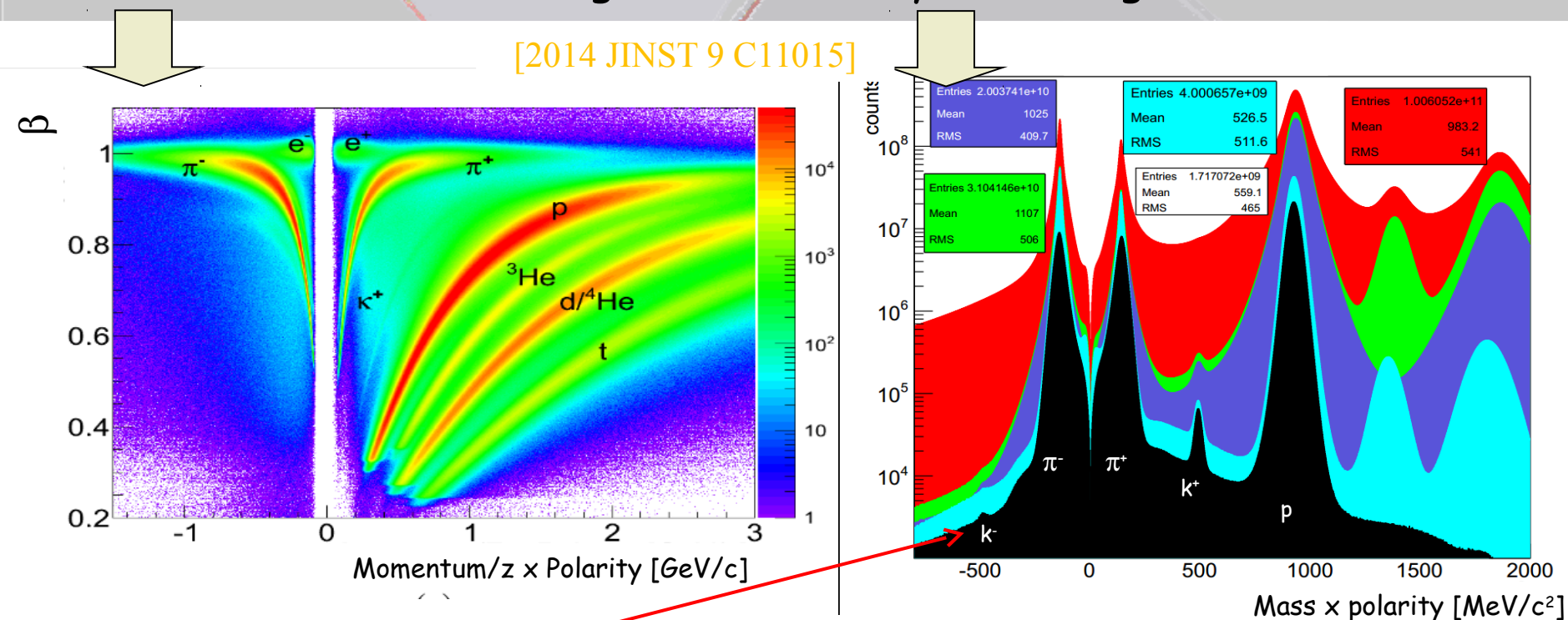
HADES. TOF-RPC PERFORMANCE.

Operation performance Au+Au 1.23 AGeV: **PID plot**

Very good particle identification in a wide momentum range

Reconstructed mass distribution with very low background contamination.

[2014 JINST 9 C11015]



K⁻ peak is clearly visible, which is a very demanding test on the apparatus time response as well as granularity due to their extreme rarity (K⁻ is produced at sub-threshold energy): about one per 10000 anti-pions

Total 2004-2017

72 with indirect contribution of HADES RPC team

18 with direct contribution of HADES RPC team

9 NIMA, Nuclear Instruments and Methods A

1 PoSc, Proceedings of Science

4 TNS

4 JINST, Journal of Instrumentation

5 PHD thesis (USC)

Diego Gonzalez (USC)

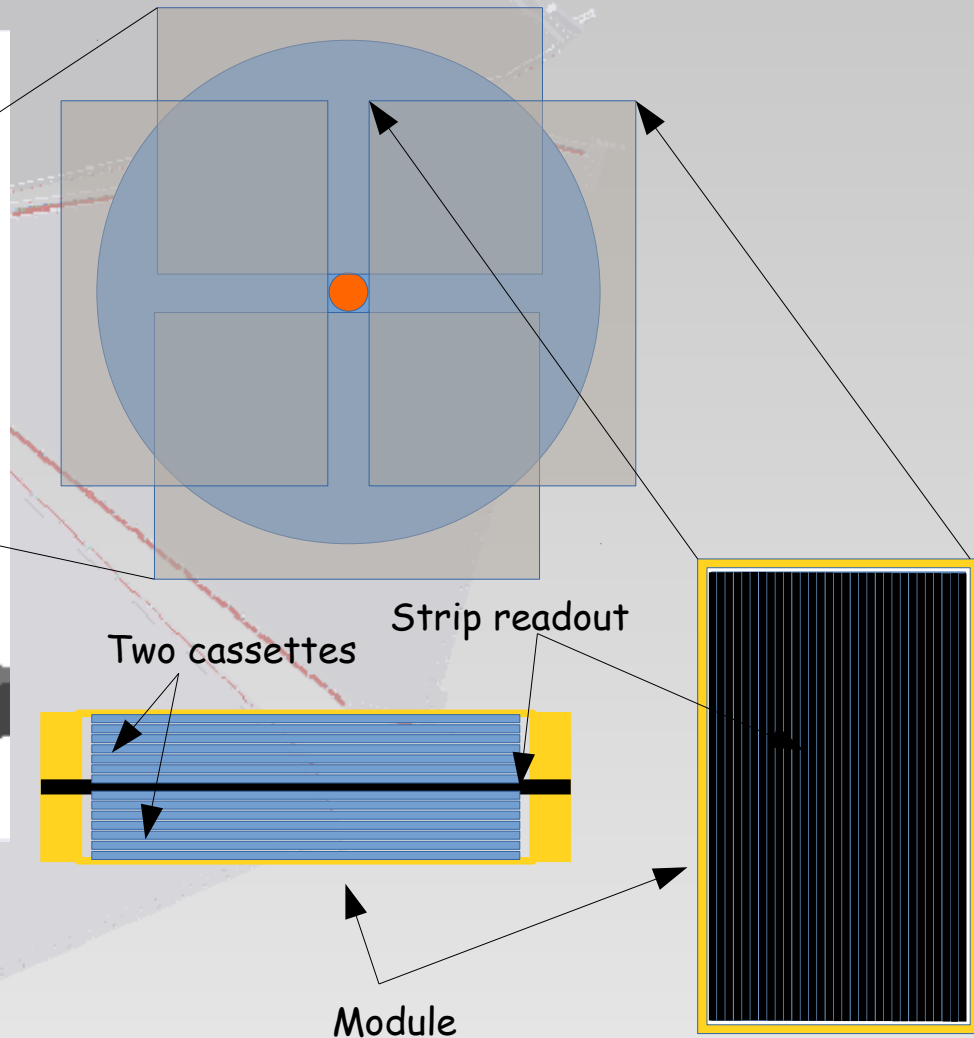
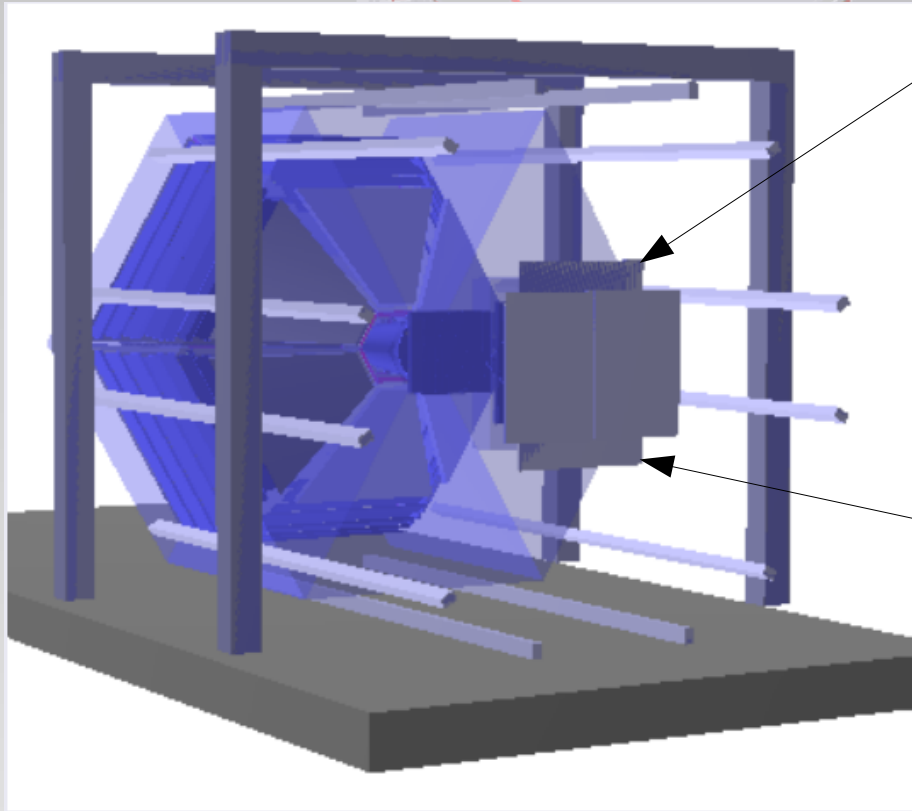
Alejandro Gil (Heidelberg University)

Daniel Belver (CIEMAT)

Pablo Cabanelas (USC)

Georgy Kornavok (Technical University of Darmstad)

Extension of the HADES spectrometer in the forward direction at angles up to 7° . The main task is to detect protons (p) and pions (π) in the light hyperons (Λ , Σ), Xi (Ξ) and strange resonance decays.

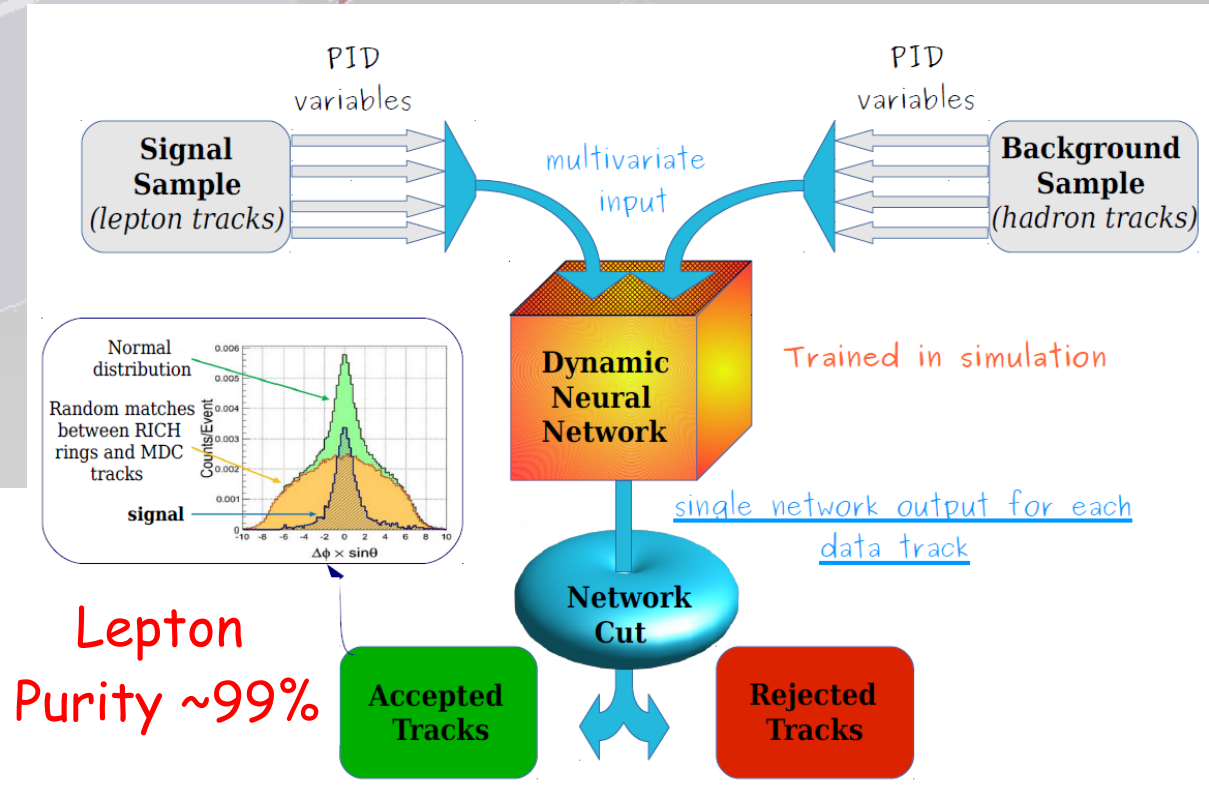
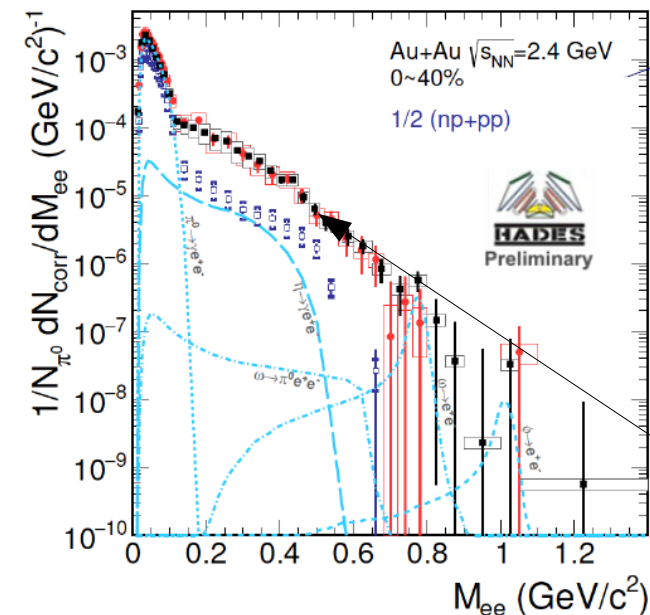


HADES. ANALYSIS. LEPTON ID AND IN MEDIUM EFFECTS.

Application of **machine learning techniques** Neural Networks for **lepton selection**.

Physics Letter B
in preparation.

Two independent methods (red, black)



Lepton
Purity ~99%

Au + Au @ 1.23 AGeV di-lepton spectrum.

The exceed observed can be interpreted as a large broadening of the ρ inside the dense medium.

=> In Medium effects

Submission in a **recent** Portuguese call PTDC (May 2017) a new **project**

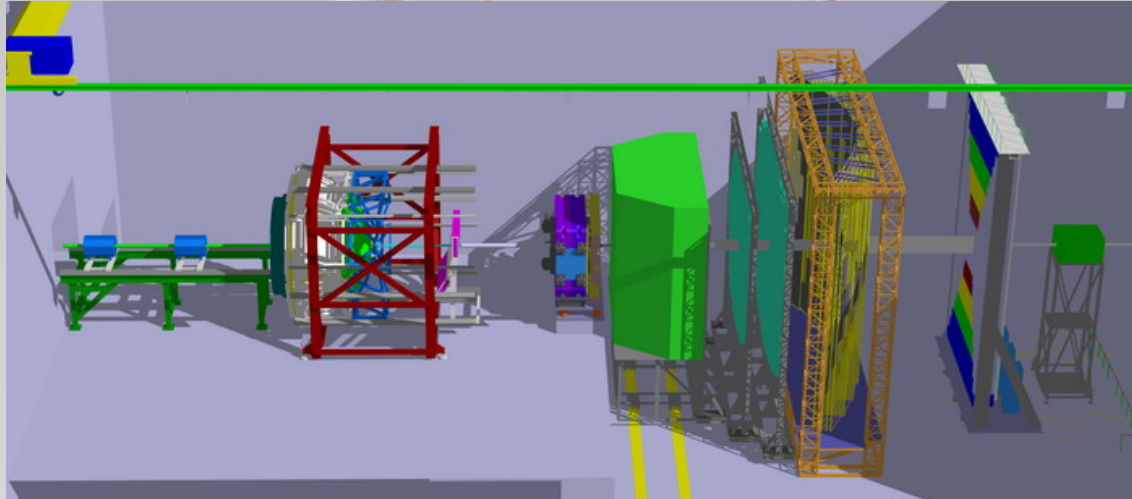
Descrição e Tipologia do Projeto	
Acrônimo	HADES
Título do projeto (português)	Participação Portuguesa na experiência HADES: investigação da matéria nuclear densa e fria e das propriedades hadrônicas no interior do meio denso
Título do projeto (inglês)	Portuguese participation in the HADES experiment: investigation of dense cold nuclear matter and in-medium hadron properties

which merge:

- **Instrumental physics** (LIP-Coimbra), with the operation, maintenance, improvement of existing detectors and the design, prototyping and construction of **new detectors**, new TOF detector assembled at low polar angles.
- **Experimental Physics** (LIP-Lisbon), with the determination of the **in-medium dielectron mass spectrum** (making use of machine learning algorithms), **vector meson spectroscopy and meson-resonance coupling studies**.
- **Theoretical physics** (IST-Lisbon), with the development of **models capable of explaining the HADES data**. A particular effort will be made in the determination of the branching ratios of Dalitz decay, and in the understanding of the excited states of nucleons and their decays (a central problem in Hadron Physics).

HADES. FUTURE.

HADES will operate in the new accelerator **SIS100** at the future FAIR to complete the **dielectron data up to 8 AGeV**. Already in FAIR phase-0.



HADES at SIS100



One should note that, in the energy range, 2-40 AGeV no dielectron data exist so far, this is complete *terra incognita* for dielectron measurements.

CONCLUSIONS.

- The **HADES spectrometer** was **upgraded** and had a very **successful data taking** with the **Au-Au system** thanks partially to the new RPC-TOF, built in a **joint collaboration between LIP, USC-LabCAF and IFIC**.
- The new **RPC TOF Wall performed flawlessly, in specs**, showing a robust multi-hit performance.
- HADES-RPC group is now constructing a new detector for the HADES collaboration. TOF-FD.
- Modest but **important contribution to the HADES Physics program**. Hadrons in-medium effects through the detection of dielectrons.
- **Collaboration continue in the domain of the detection of cosmic rays with RPCs.**