

# How we will remember our friend

Fernando S Navarra

(with S. Padula, T. Kodama, J. Takahashi, F. Grassi)



Yogiro Hama (1936 - 2025)

# Scientific Career

1960 Graduation IFUSP

1961 Teaching Assistant IFUSP

1963 - 1965 PhD Kyoto (Japan)

1970 - 1972 Pos-doc Torino (Italy)

1972 Habilitation IFUSP

1991 Full Professor IFUSP


2006 Official Retirement

2006 - 2016 Senior Collaborator IFUSP

2016 Real Retirement

55 years dedicated to research,  
teaching, administration

# In numbers from inspirehep.net

Yogiro Hama (Sao Paulo U.) 

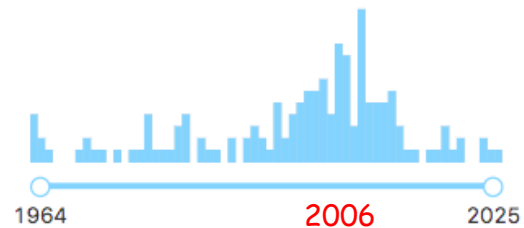
hep-ph nucl-th

Author Identifier: Y.Hama.2



Advisor: Norio Hoshizaki


- 1966-present  
**SENIOR, Sao Paulo U.**
- 1963-1965  
**PHD, Kyoto U.**
- 1957-1960  
**UNDERGRADUATE, Sao Paulo U.**

Date of paper




Retirement  
"at the peak"




155 results |  cite all  claim

Citation Summary 

Most Recent 

## Citation Summary

Exclude self-citations 

	Citeable 	Published 
Papers	137	110
Citations	3,643	3,467
h-index 	30	30
Citations/paper (avg)	26.6	31.5

# Behind and beyond the numbers

In one word : hydrodynamics

I) He was the pioneer of relativistic hydrodynamics in Brazil

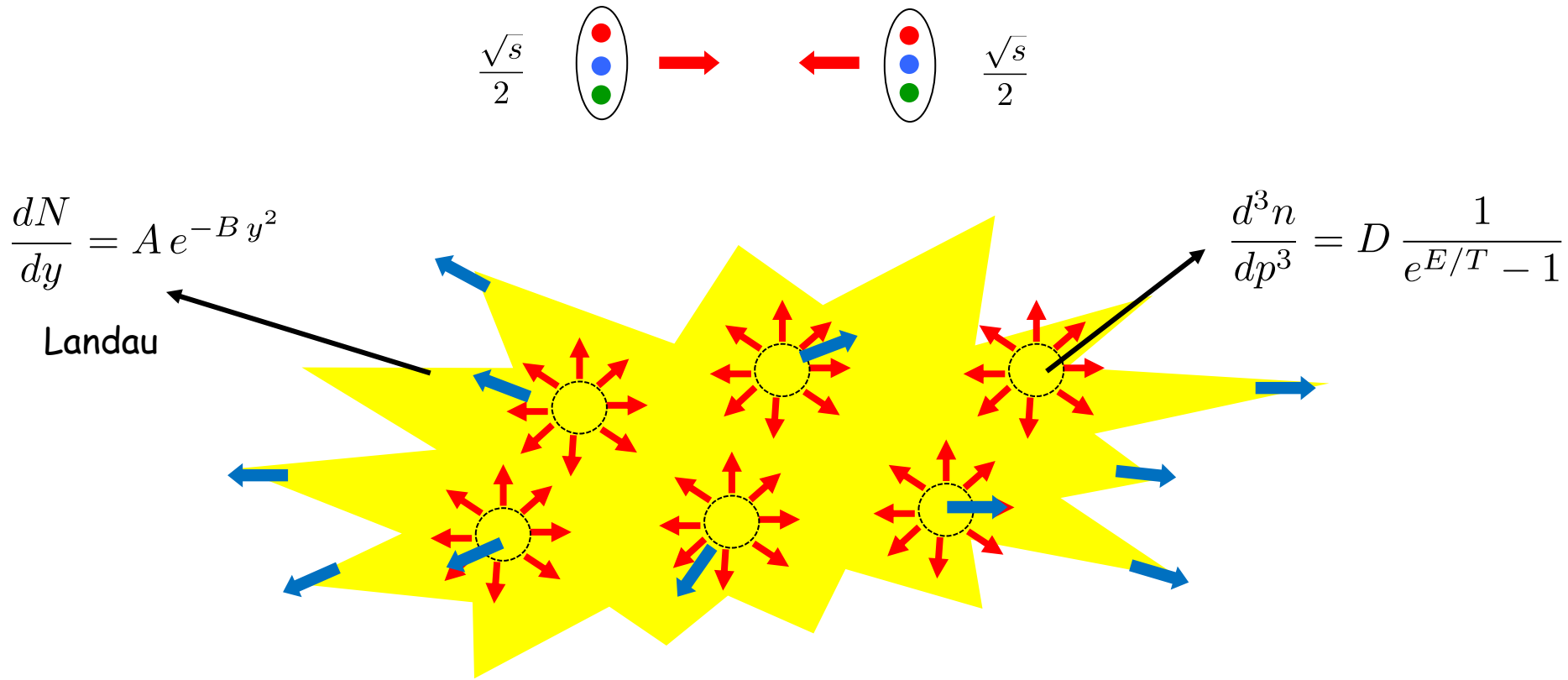
II) He changed relativistic hydrodynamics from beginning to end

III) He brought the community together: creation of RETINHA

I

The first works

# Particle Production in Proton Proton Collisions at High Energies



Thermal motion + hydrodynamical expansion ("drag")

"Blast-wave" model 15 years before!

Nuovo Cimento (1978)

**Transverse-Momentum Distribution of Particles According to the Hydrodynamical Model (\*).**

Y. HAMA

*Instituto de Física, Universidade de São Paulo - São Paulo, Brasil*

(ricevuto il 23 Marzo 1978)

Nuovo Cimento (1979)

**Large- $p_{\perp}$  Distributions of Particles in the Hydrodynamical Approach (\*).**

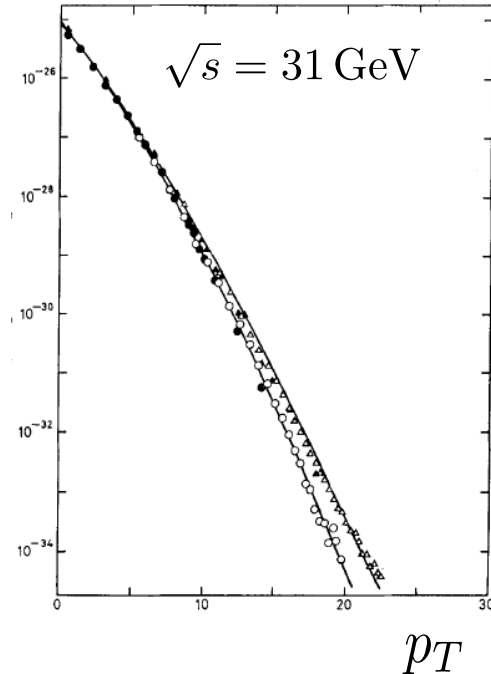
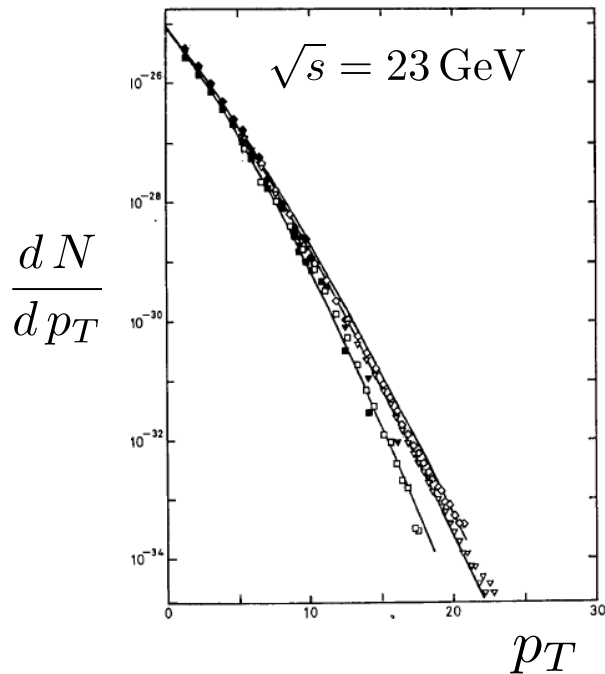
Y. HAMA (\*\*)

*Istituto di Fisica Teorica dell'Università - Torino*

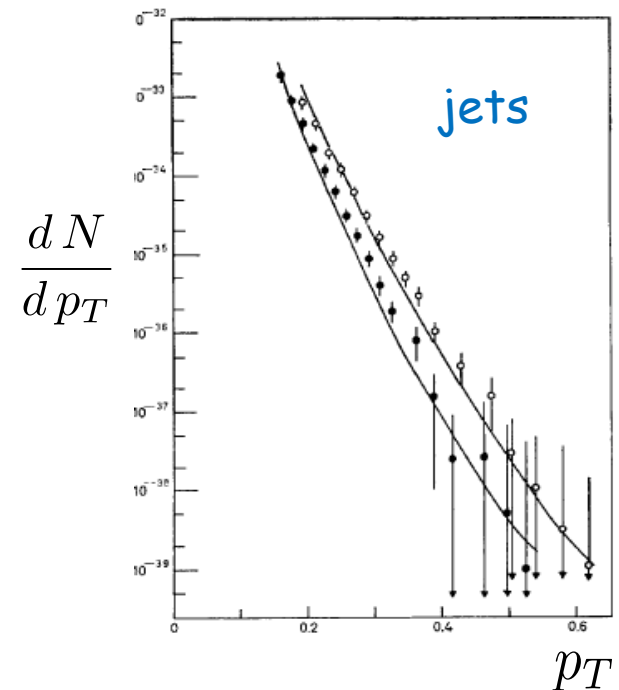
*Istituto Nazionale di Fisica Nucleare - Sezione di Torino*

(ricevuto il 19 Gennaio 1979)

proton-proton



proton-proton



Cold reception...

"Number of particles is too small..."

"Size of the system is too small.."

QCD on the rise:

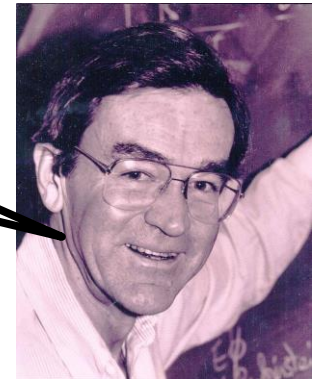
QCD officially born in 1973

Gluon discovered in 1979 at DESY !

Then...

"Hydrodynamics is essential for heavy ion physics ! "

Phys. Rev. D (1983)



J. Bjorken

Change of paradigm !

Hydro in pp : necessary "warm-up" training for future AA !

From outlaw to mainstream !



~ 40 years later...

Physics Letters B 765 (2017) 193–220



ELSEVIER

Contents lists available at ScienceDirect

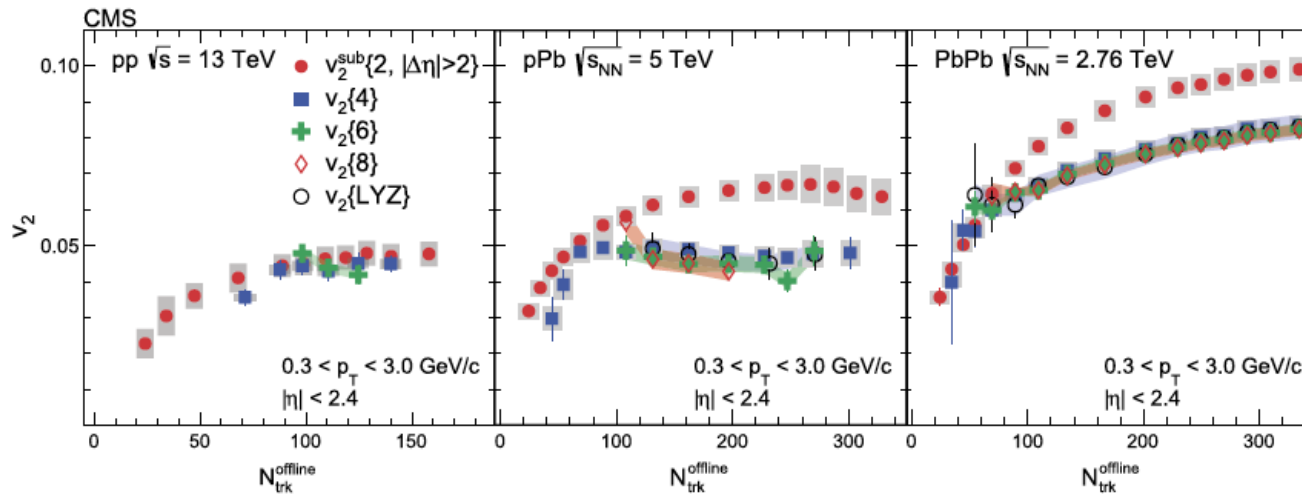
Physics Letters B

www.elsevier.com/locate/physletb



## Evidence for collectivity in pp collisions at the LHC

The CMS Collaboration \*



Not so crazy after all...

# II

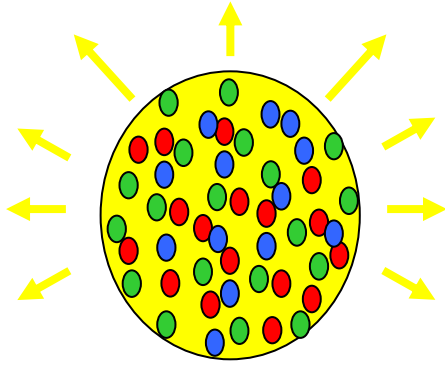
Changing Hydrodynamics :

The end

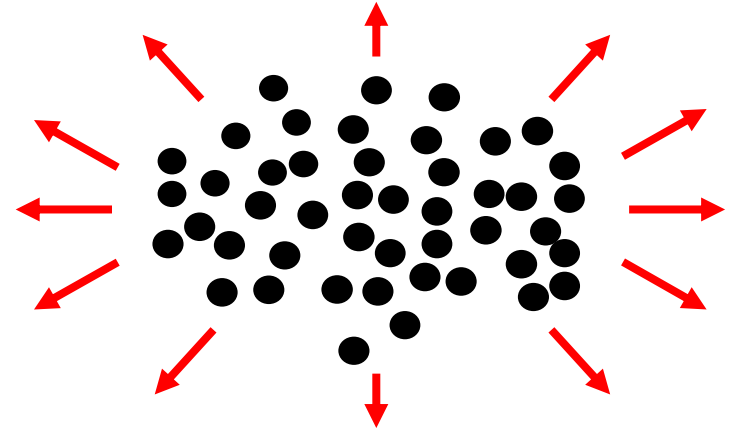
The middle

The beginning

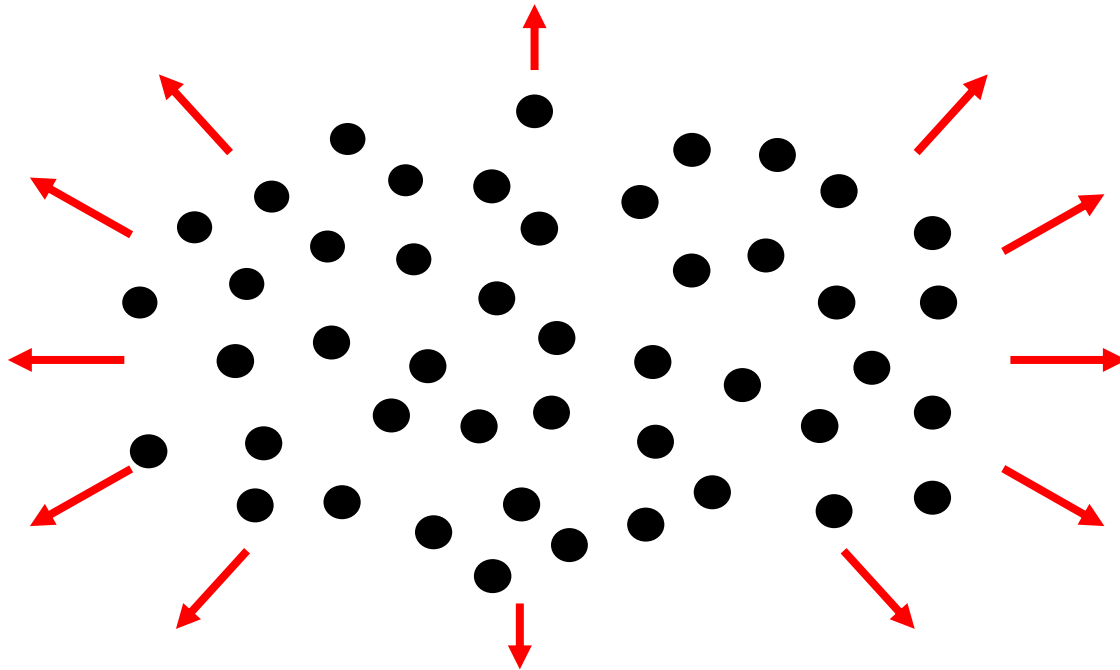
# Changing the end



Initial conditions: QGP



Expansion and hadronization



Freeze-out

Early nineties: stop the evolution when a **fixed freeze-out temperature** is reached.

Energy and mass number dependence of the dissociation temperature in hydrodynamical models

Yogiro Hama (Sao Paulo U.), F.S. Navarra (Sao Paulo U.) (Oct, 1990)

Published in: *Z.Phys.C* 53 (1992) 501-506

Freeze-out temperature should decrease with the system size !



ELSEVIER

27 July 1995

Physics Letters B 355 (1995) 9–14

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PHYSICS LETTERS B

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## Continuous particle emission: a probe of thermalized matter evolution?

Frédérique Grassi<sup>a</sup>, Yogiro Hama<sup>a</sup>, Takeshi Kodama<sup>b</sup>

<sup>a</sup> Instituto de Física, Universidade de São Paulo, C.P.66318, 05389-470 São Paulo-SP, Brazil

<sup>b</sup> Instituto de Física, Universidade Federal do Rio de Janeiro, C.P.68528, 21945-970 Rio de Janeiro-RJ, Brazil

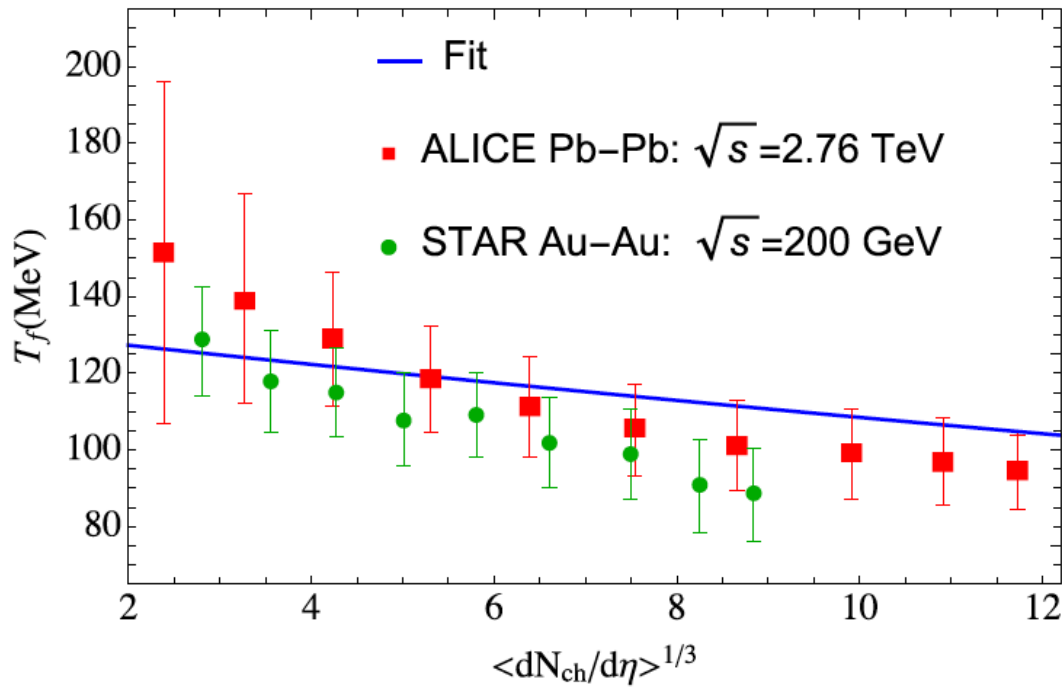
Received 18 April 1995; revised manuscript received 24 May 1995

Editor: G.F. Bertsch

**Beginning of a change...**

~ 20 years later...

System size dependent freeze-out temperature !



ALICE,  
arXiv:1303.0737

Analysis with the  
blast-wave model

# Changing the middle

New algorithm to solve the hydro equations:  
smoothed particle hydrodynamics (SPH)

SPHERIO

**Smoothed particle hydrodynamics for relativistic heavy ion collisions**

C.E. Aguiar (Rio de Janeiro Federal U.), T. Kodama (Rio de Janeiro Federal U.), T. Osada (Sao Paulo U.), Yojiro Hama (Sao Paulo U.) (Jun, 2000)

Published in: *J.Phys.G* 27 (2001) 75-94 • e-Print: [hep-ph/0006239](https://arxiv.org/abs/hep-ph/0006239) [hep-ph]

Theoretical aspects of the algorithm

# Changing the beginning

Before ~ 2004:

Choose the (**smooth**) initial conditions for the fluid

Spatial distribution of matter

Initial distribution of longitudinal and transverse momentum

Initial distribution of the baryon number

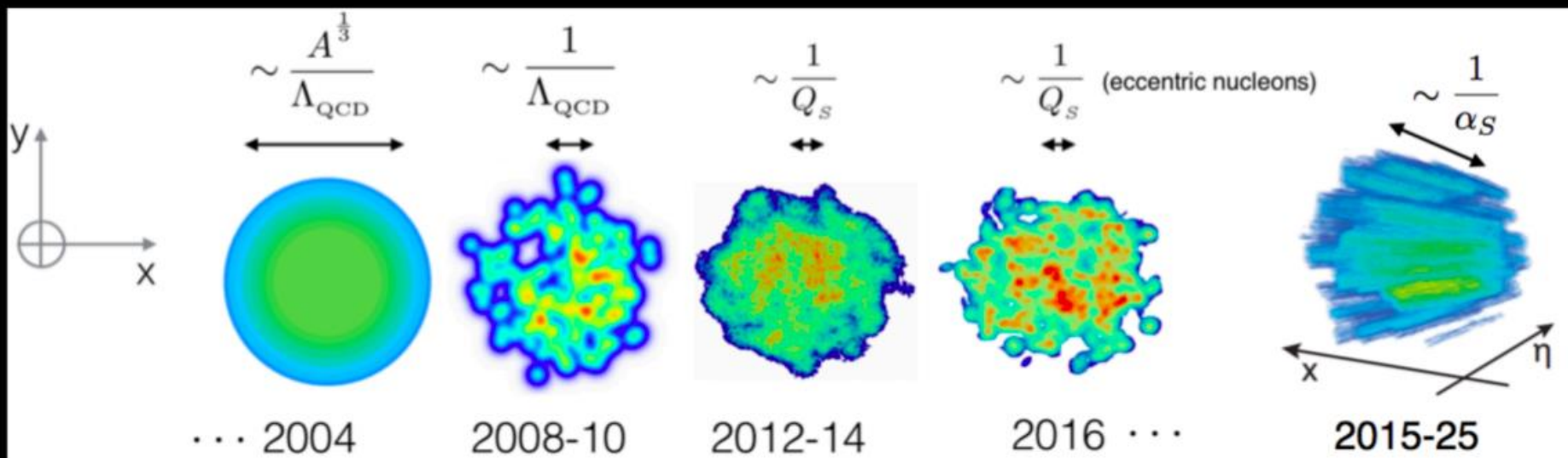
Run (**once**) your hydro code and get the final distributions

After ~ 2008 - 2010:

Choose fluctuating (**non-smooth**) initial conditions for the fluid

Run **200.000 times** your hydro code and get the final distributions

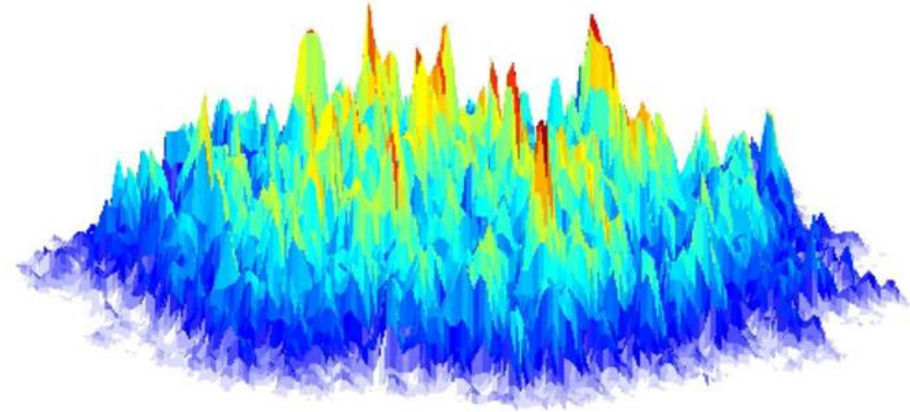
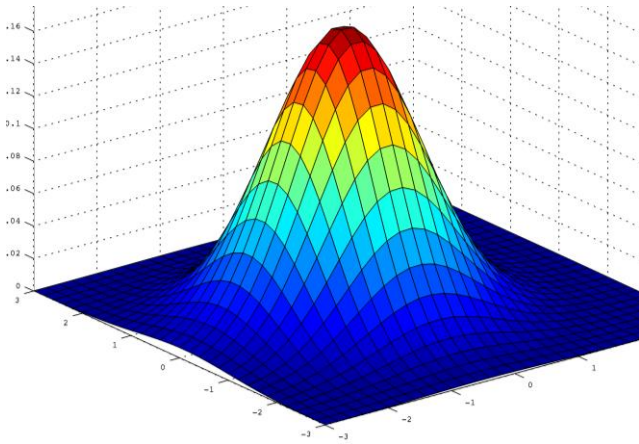
# Event-by-event fluctuations



Thanks Chun Shen !



# 12 years of continuous work...



Smooth energy density profile  
in the transverse plane

Peaky energy density profile  
in the transverse plane

## Fluctuation effects in initial conditions for hydrodynamics

[Samya Paiva](#) (Sao Paulo U.), [Yogiro Hama](#) (Sao Paulo U.), [Takeshi Kodama](#) (Rio de Janeiro Federal U.) (Sep, 1996)

Published in: *Phys.Rev.C* 55 (1997) 1455-1462

## Fluctuations in hadronic and nuclear collisions

[Yogiro Hama](#) (Sao Paulo U.), [Takeshi Kodama](#) (Rio de Janeiro Federal U.), [Samya Paiva](#) (Sao Paulo U.) (Apr, 1997)

Published in: *Found.Phys.* 27 (1997) 1601-1621 • e-Print: [hep-ph/9704438](#) [hep-ph]

# On the necessity to include event-by-event fluctuations in experimental evaluation of elliptic flow

R. Andrade (Sao Paulo U.), F. Grassi (Sao Paulo U.), Yojiro Hama (Sao Paulo U.), T. Kodama (Rio de Janeiro Federal U.), O. Socolowski, Jr. (Sao Paulo, Inst. Tech. Aeronautics) (Aug, 2006)

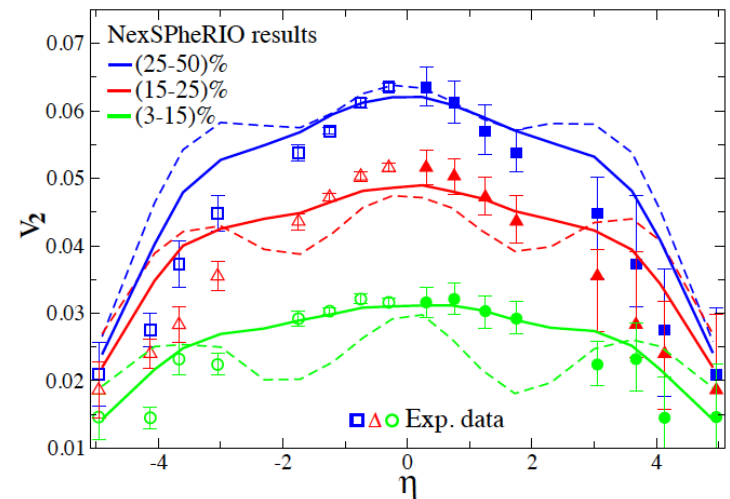
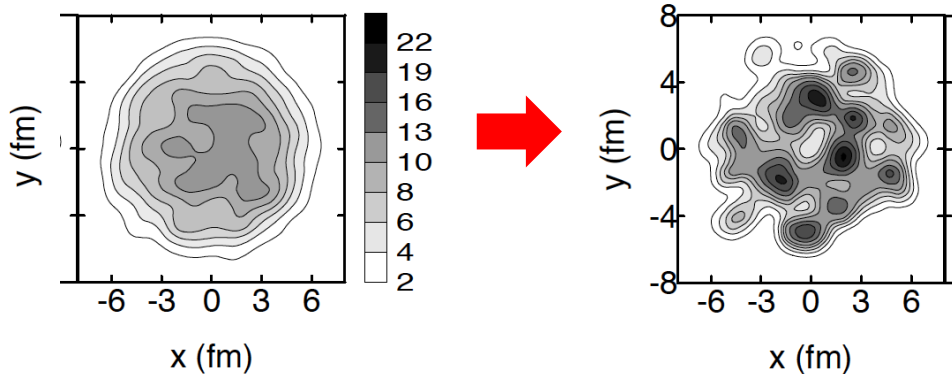
Published in: *Phys.Rev.Lett.* 97 (2006) 202302 • e-Print: [nucl-th/0608067](#) [nucl-th]

## Importance of Granular Structure in the Initial Conditions for the Elliptic Flow

R.P.G. Andrade (Sao Paulo U.), F. Grassi (Sao Paulo U.), Yojiro Hama (Sao Paulo U.), T. Kodama (Rio de Janeiro Federal U.), W.L. Qian (Sao Paulo U.) (May, 2008)

Published in: *Phys.Rev.Lett.* 101 (2008) 112301 • e-Print: [0805.0018](#) [hep-ph]

First great success:



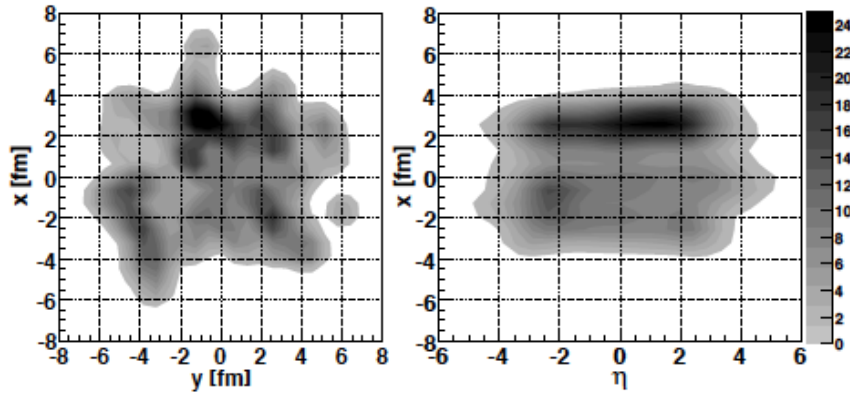
Explanation of why  $v_2$  decreases with the rapidity

# Topology studies of hydrodynamics using two particle correlation analysis

J. Takahashi (Campinas State U.), B.M. Tavares (Campinas State U.), W.L. Qian (Sao Paulo U.), R. Andrade (Sao Paulo U.), F. Grassi (Sao Paulo U.) et al. (Feb, 2009)

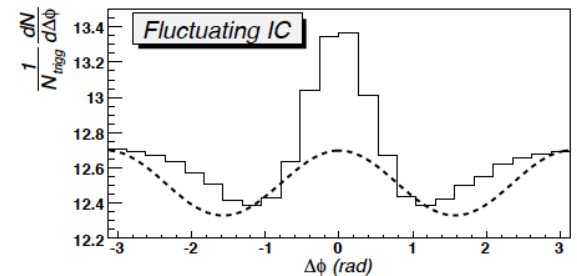
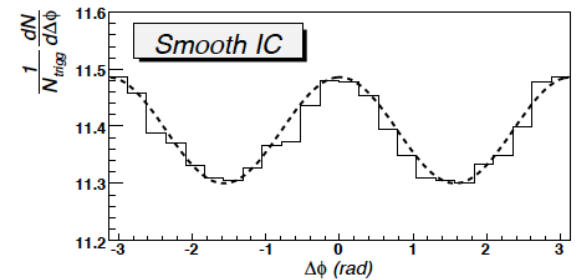
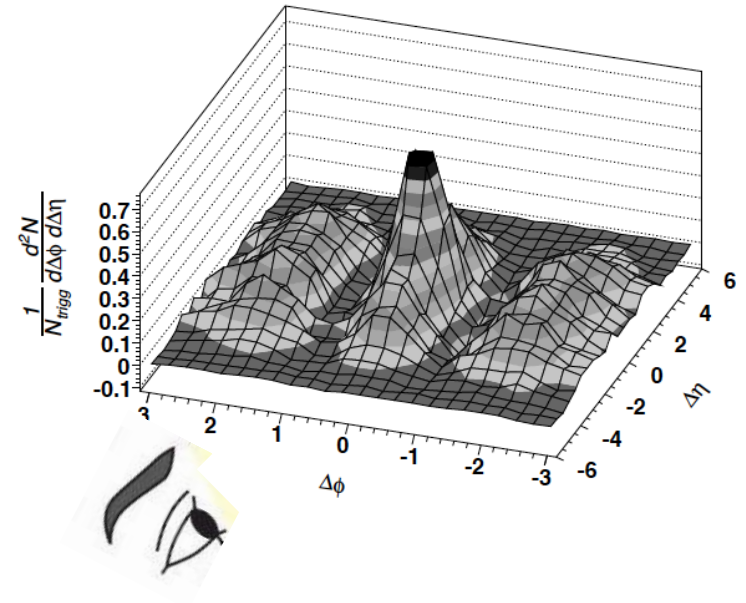
Published in: *Phys.Rev.Lett.* 103 (2009) 242301 • e-Print: 0902.4870 [nucl-th]

The greatest success:



Explanation of the "ridge" effect.

Beginning of the event-by-event hydrodynamics !



# III

Creation of the Workshop on Hadronic Interactions

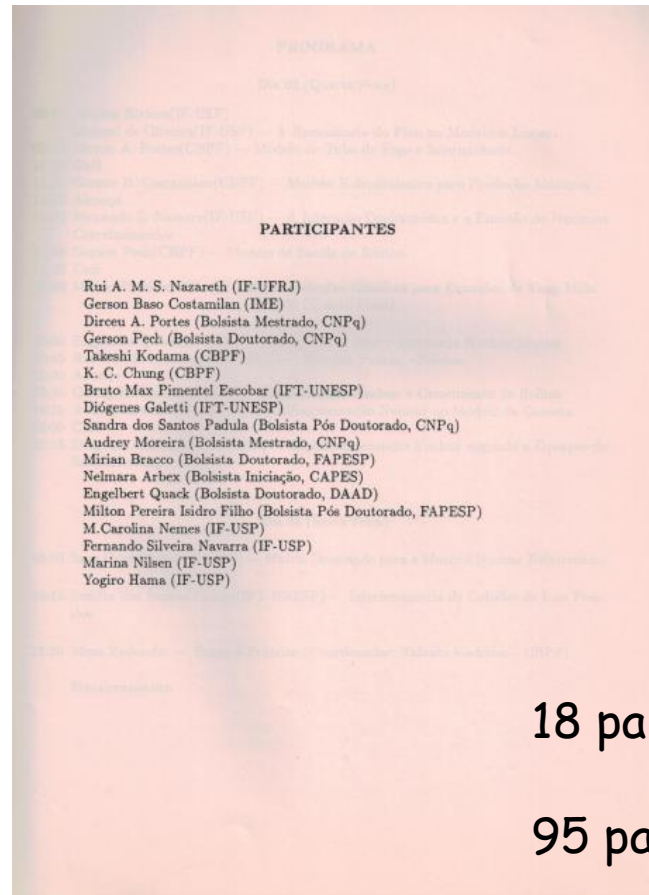
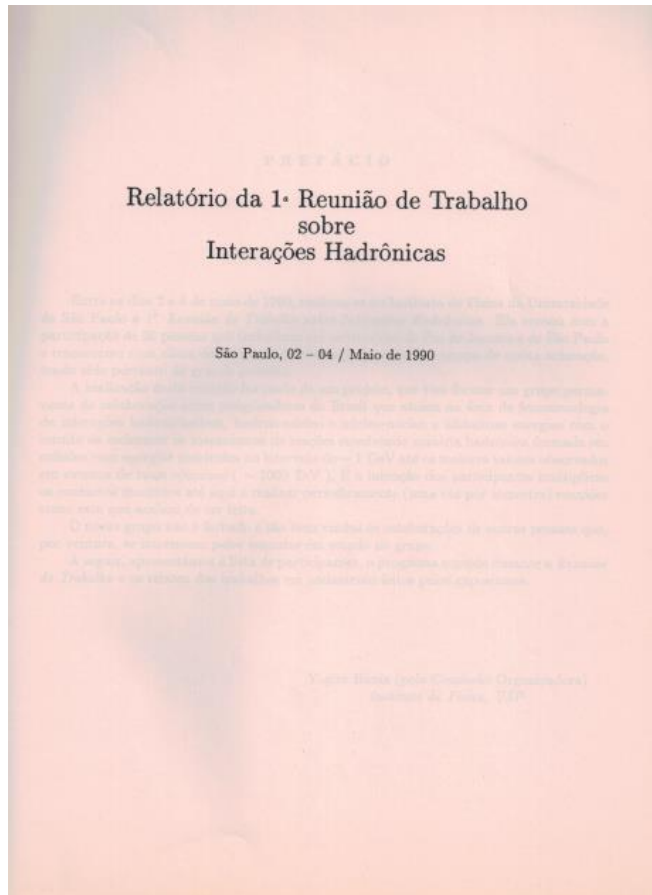
"RETINHA"

# 1990: Workshop on Hadronic Interactions

## First "Projeto Temático FAPESP"

One meeting per year: 31 RETINHAS !

The best meeting for students: priority in funding and in the program !



From  
18 participants in 1990  
to  
95 participants in 2022



# 2006: Celebration of Retirement

*Brazilian Journal of Physics, vol. 37, no. 1, March, 2007*

## Learning Hydrodynamics with Yojiro Hama

F. S. Navarra

*Instituto de Física, Universidade de São Paulo,  
C.P. 66318, 05315-970, São Paulo, SP, Brazil*

*Brazilian Journal of Physics, vol. 37, no. 1, March, 2007*

## Working in Hydrodynamics with Yojiro Hama

F. Grassi

*Instituto de Física, Universidade de São Paulo, C. P. 66318, 05315-970 São Paulo, SP, Brazil*

*Brazilian Journal of Physics, vol. 37, no. 1, March, 2007*

## Yojiro Hama - A Life in Time and Space

T. Kodama<sup>1</sup> and S. S. Padula<sup>2</sup>

<sup>1</sup> *Instituto de Física, Universidade Federal do Rio de Janeiro, C.P. 68528, 21941-972, Rio de Janeiro,*

<sup>2</sup> *Instituto de Física Teórica, Universidade Estadual de Paulista,  
Rua Pamplona 145, 01405-900, São Paulo, SP, Brazil*



YOGIRO HAMA  
80 ANOS !

XXVII REUNIÃO DE TRABALHO  
EM INTERAÇÕES HADRÔNICAS

RETINHA 27  
23 – 24 MAIO 2016  
IFUSP AUD. ADMA JAFET

Apoio:  
FAPESP IFUSP DFEP DFMA

Alberto M. Torres  
Arlene Cristina Aguilár  
Alexandre Suaide  
Débora Menezes  
Edivaldo M. Santos  
Eduardo Fraga  
Fabiana Carvalho  
Fernando Gardim  
Fernando Navarra  
Francisco Durães  
Frédérique Grassi  
Giorgio Torrieri  
Jorge Noronha  
K. Khemchandani  
Marcelo Munhoz  
Márcio Menon  
Marina Nielsen  
Matthew Luzum  
Renato Higa  
Sandra Padula  
Sérgio Duarte  
Takeshi Kodama  
Tobias Frederico  
Varese Timóteo

VOL. 37 - Nº 1  
MARCH 2007

ISSN 0103-9733

# BRAZILIAN JOURNAL OF PHYSICS

Formerly Revista  
Brasileira de Física

Special Issue: XVIII Workshop on Hadron Interactions

Fernando S. Navarra and Marina Nielsen  
Guest Editors

Electronic versions:  
[www.sbfisica.org.br/bjp](http://www.sbfisica.org.br/bjp)  
[www.scielo.br/bjp](http://www.scielo.br/bjp)



## 2016: Celebration of 80th anniversary

## Recognition in life!

# XXXII Reunião de Trabalho sobre Interações Hadrônicas

RETINHA 32 (70 anos do Gastão Krein)

CBPF 29 a 31 de outubro de 2025

Ions pesados relativísticos  
Espectroscopia de Hadrons  
Estrelas Compactas  
Fenomenologia da QCD

Colaboração: Sônia Ferreira  
Thaissa Martins

Contato: [navarra@if.usp.br](mailto:navarra@if.usp.br)



Fernando Navarra (USP)

Gabriel Denicol (UFF)

Ignácio Bediaga (CBPF)

Maurício Hippert (CBPF)

Apoio: INCT-FNA, CBPF, UFF

Organização



IV



## Four pictures to remember



A life ahead



A long and happy life



A life behind:  
retreating to his house

# The last one: peace and acceptance



Yojiro Hama

★ 22.05.1936    † 14.02.2025





# Change of paradigm !

"Hydrodynamics is essential for heavy ion physics ! "

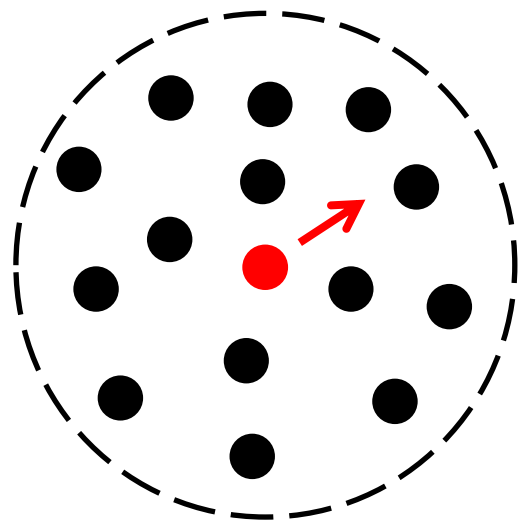
Phys. Rev. D (1983)



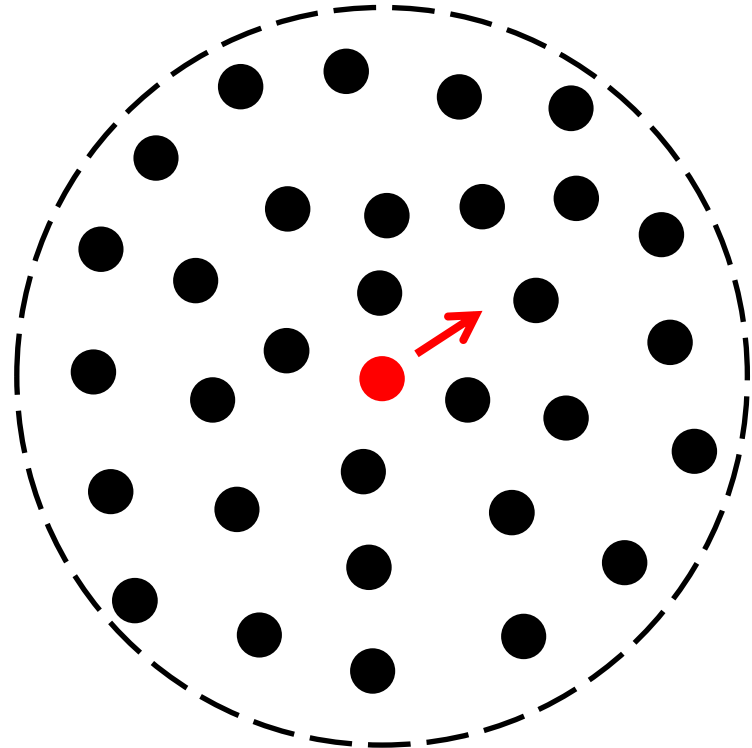
J. Bjorken

Hydro in pp : necessary "warm-up" training for future AA !

From outlaw to mainstream !

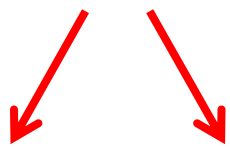


larger volume  
same density  
same temperature

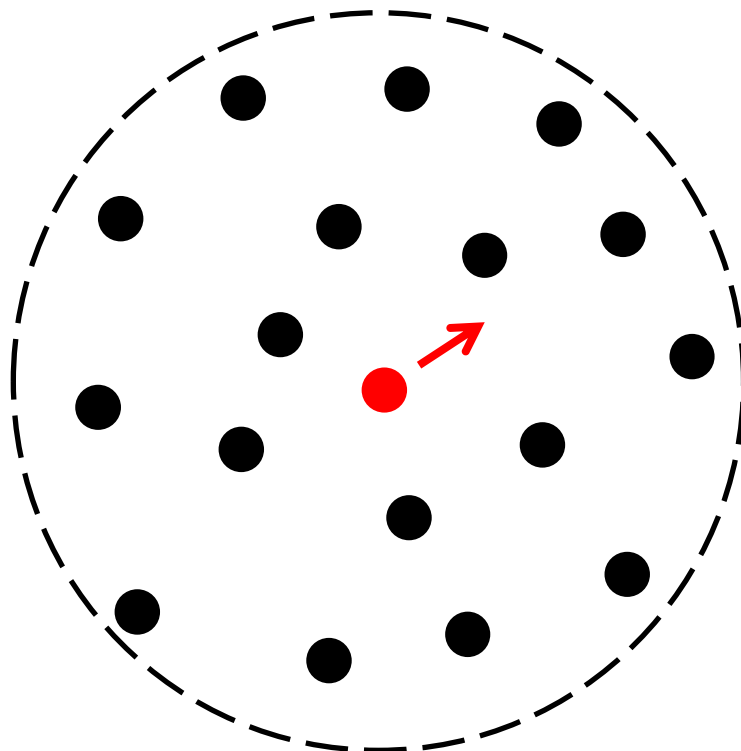


Freeze-out:

$$l = \frac{1}{n\sigma} = R$$



density  
cross section



same volume  
lower density  
lower temperature

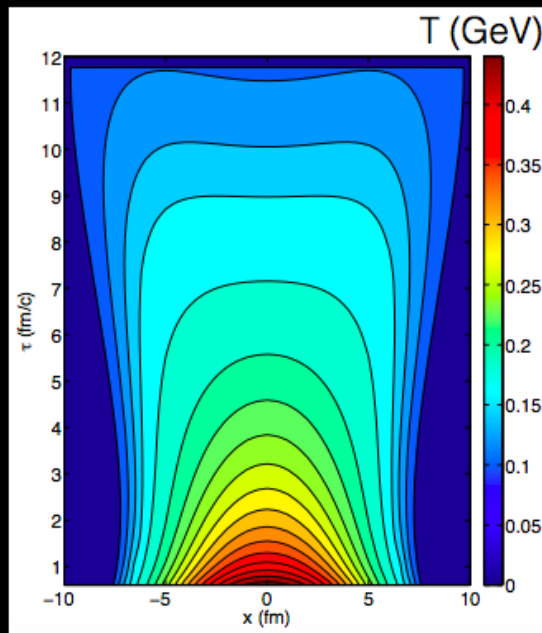


# Life became more complicated...

84

## When to end?

- Particle is observed, not fluid
- How and when to convert fluid to particles (evaporation)
- How far is hydrodynamics valid?



Chun Shen (Wayne State)

Hadrons 2025

Kinetic equilibrium requires

Scattering rate  $\gg$  expansion rate

$$\tau_{sc}^{-1} \sim \sigma n \propto \sigma T^3 \quad \theta = \partial_\mu u^\mu$$

Fluid description breaks down at

$$\tau_{sc}^{-1} = \theta$$

Approximation: decouple takes place at a fixed temperature

$$T = T_{fo} \propto \left( \frac{\theta}{\sigma} \right)^{1/3}$$

Dynamical freezeout criterion in Bjorken's hydrodynamical model

F.S. Navarra (Sao Paulo U.), S. Paiva (Sao Paulo U.), M.C. Nemes (Minas Gerais U.), U. Ornik (Philipps U. Marburg) (1992)

Published in: *Phys.Rev.C* 45 (1992) R2552-R2554

# Changing the end

Early nineties :

Stop the evolution when a fixed freeze-out temperature is reached.

Cooper-Frye formula

After 1995:

Microscopic interactions in the hadron gas phase

Freeze-out is particle-specific

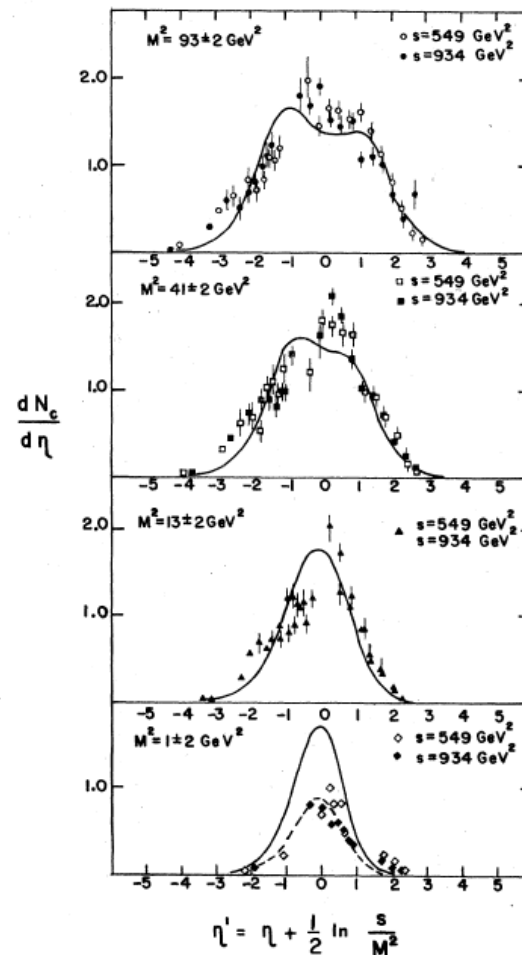
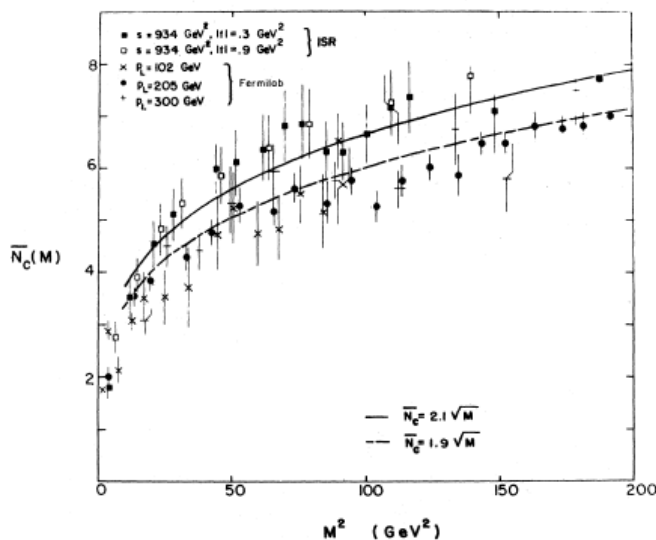
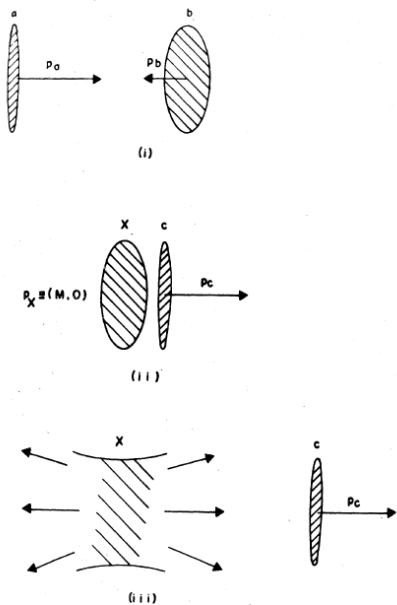


# Hydrodynamical description of the missing-mass clusters

Y. Hama

*Instituto de Física, Universidade de São Paulo, São Paulo, Brasil*

(Received 3 August 1978)



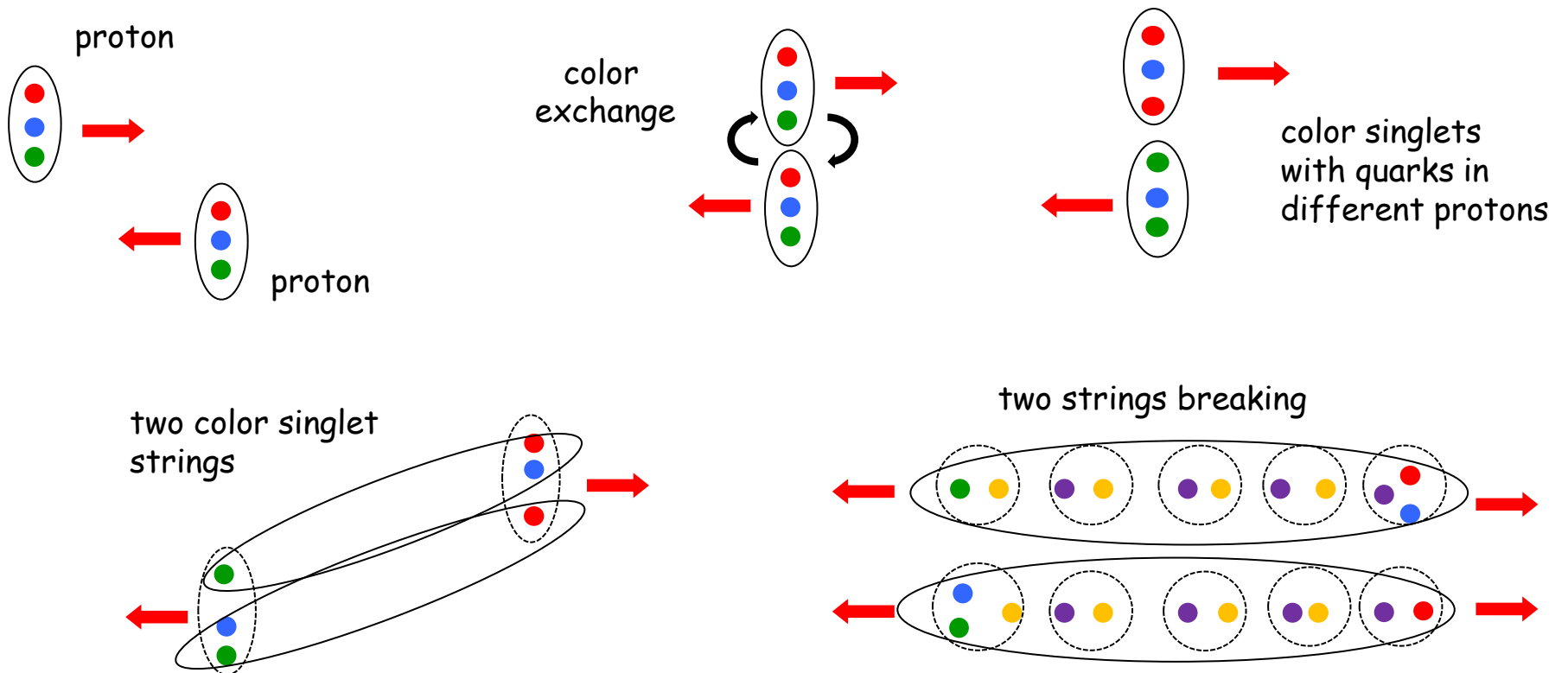
"Hydrodynamics is nothing but energy-momentum conservation!  
It can not be wrong. But there is not much to learn here..."



T. Kodama



# Lund Model (1977) (baby PYTHIA) :











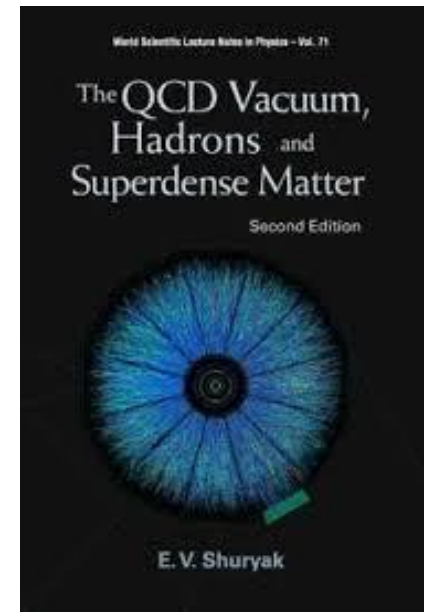
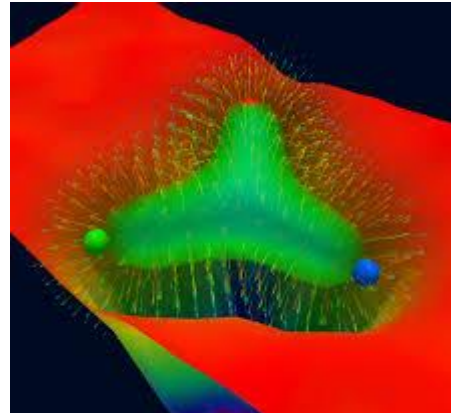
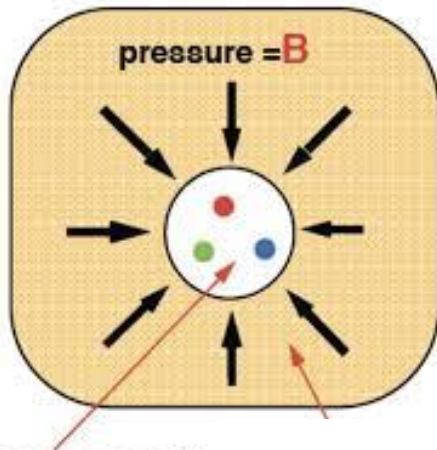




# O que é o vácuo ?

O que existe quando "não há nada" ?

Condensados, instantons...



"empty vacuum"


Eur. Phys. J. C (2021) 81:624  
<https://doi.org/10.1140/epjc/s10052-021-09412-1>

Regular Article - Theoretical Physics

THE EUROPEAN  
PHYSICAL JOURNAL C



## How to discover QCD Instantons at the LHC

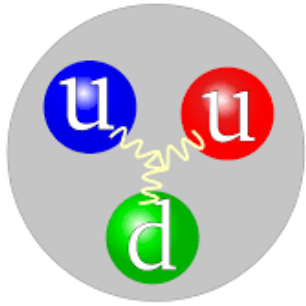
Simone Amoroso<sup>1</sup>, Deepak Kar<sup>2</sup>, Matthias Schott<sup>3,a</sup>

<sup>1</sup> DESY, Hamburg, Germany

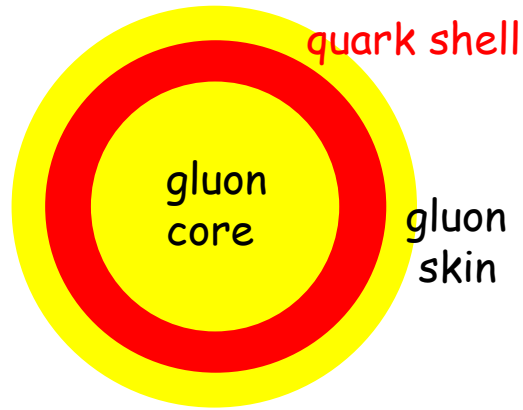
<sup>2</sup> University of Witwatersrand, Johannesburg, South Africa

<sup>3</sup> Johannes Gutenberg-University, Mainz, Germany

# A estrutura do proton

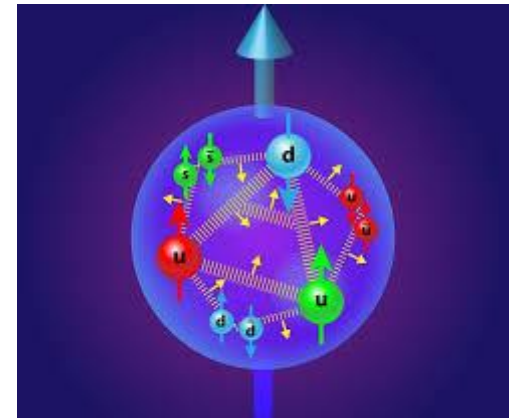


De onde vem o confinamento?

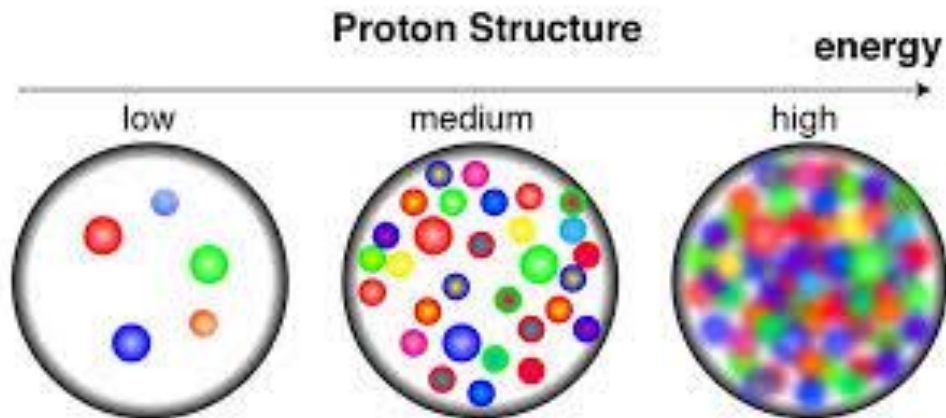


De onde vem a massa ?

*Nature* **615**, 813 (2023)



De onde vem o spin?



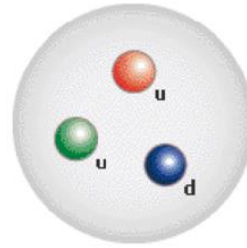
Um número crescente de constituintes !

Saturação ?

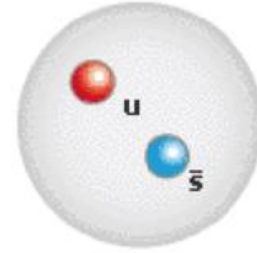
(Color Glass Condensate)

# Novos hadrons

"Velhos" hadrons :

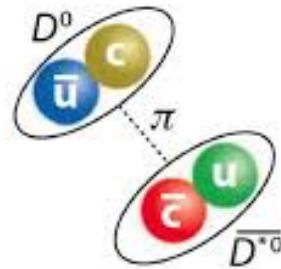


barion



meson

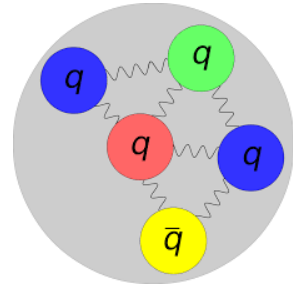
Novos hadrons :



Moléculas  
mesônicas



Tetraquarks



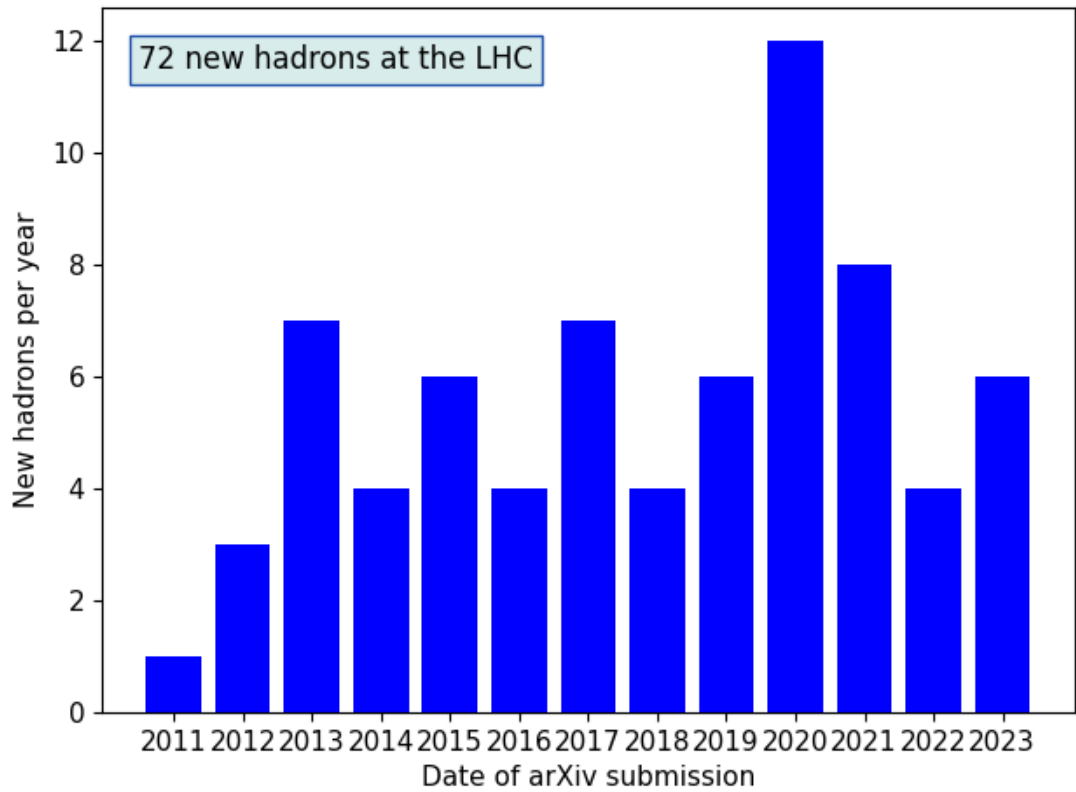
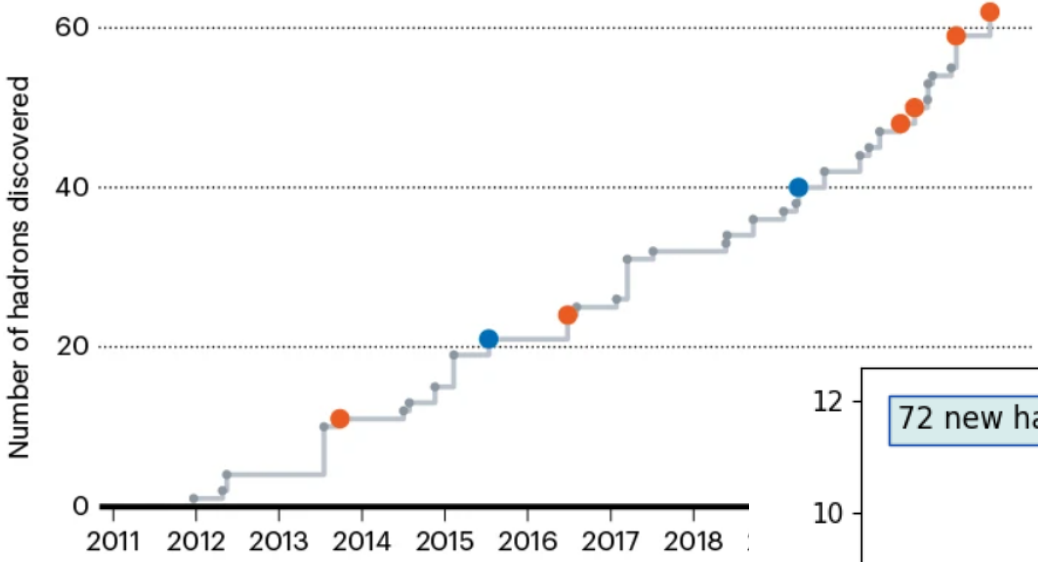
Pentaquarks

LHC continua a descobrir novos hadrons !

# PARTICLE DISCOVERIES

The Large Hadron Collider discovered an elementary particle, the Higgs boson, in 2012. But it has also discovered 62 non-elementary particles, called hadrons, so far. These include tetraquarks and pentaquarks — particles made of four and five quarks, respectively.

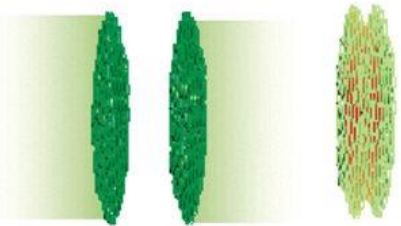
● Tetraquark ● Pentaquark



# Colisões de ions pesados:

Cartoon of heavy ion collisions at high energy:

(Now: RHIC @ BNL, LHC @ CERN. Future: FAIR @ GSI, NICA...)



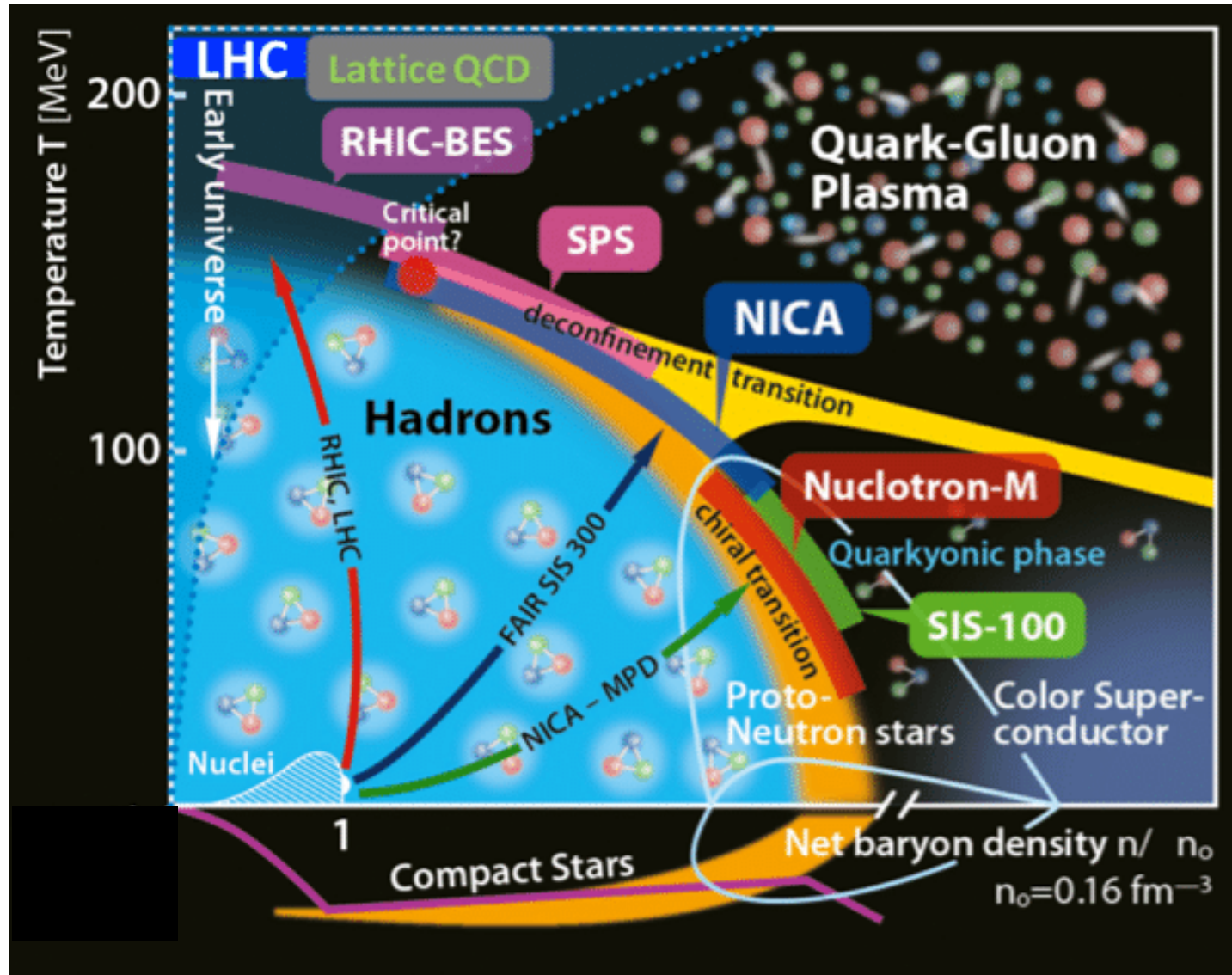
initial state

Termalização ?

Viscosidade ?

Vorticidade ?

Ponto crítico ?



# No mundo a área cresce...

## Grandes aceleradores internacionais:

Large Hadron Collider - LHC

Suiça

BELLE II

Japão

BES III

China

JLAB

EUA

FAIR

Alemanha

EIC

EUA

## "Multimessenger astronomy":

LIGO

EUA

NICER

EUA



... e contrata !



Raquel Molina

Contratada na Universidade  
de Valência

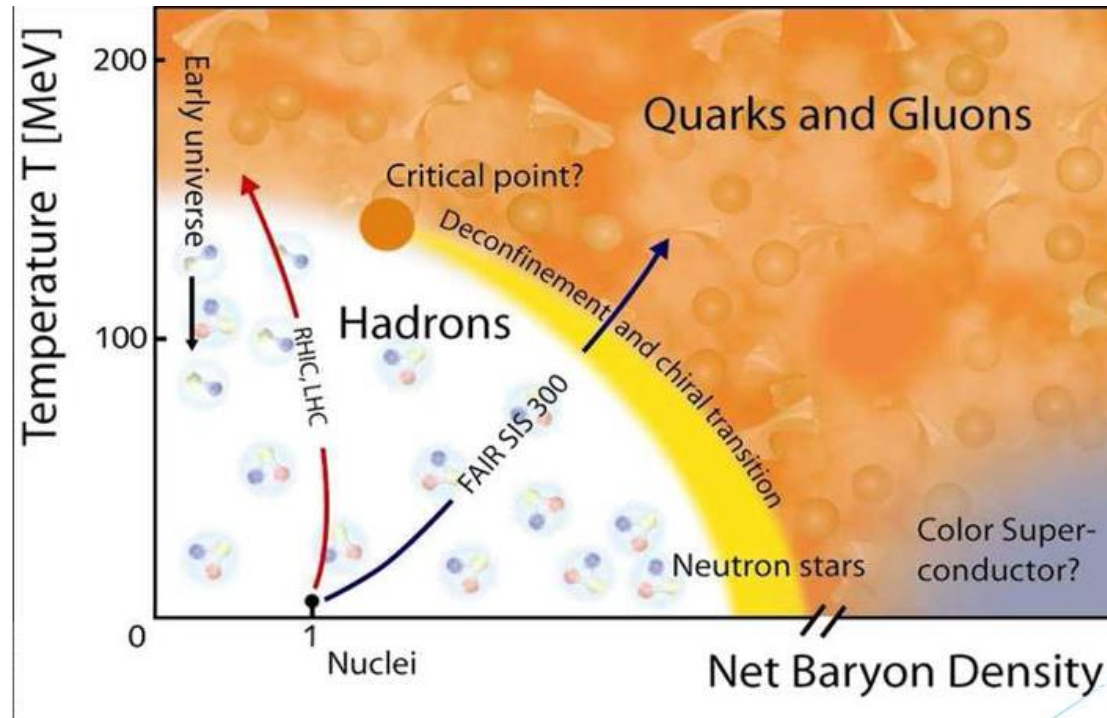


Jacquelyn Noronha Hostler

Contratada na Universidade  
de Urbana-Champaign

Há muito talento a ser atraído...

# How does thermalization happen ?



Why does hydro work so well ?



Airton Deppman	Blue
Alberto Martinez Torres	Blue
Alejandro Javier Dimarco	Blue
Alexandre Magno S. Santos	Red
Anna Maria F. Endler	Blue
Arlene Cristina Aguilar	Purple
Armando N. F. Aleixo	Blue
Arturo Rodolfo Samana	Blue
Bruno Omar El Bennich	Blue
Bruno Werneck Mintz	Purple
Carla Brenda Bonifazi	Blue
Celso C. Barros Junior	Blue
Claudio Masumi Maekawa	Blue
Cristiano Brenner Mariotto	Yellow
Daniel Almeida Fagundes	Yellow
Daniel Tavares da Silva	Blue
Débora Peres Menezes	Red
Dimitter Hadjimichief	Red
Donato Giorgio Torrieri	Green
Eduardo Souza Fraga	Red
Emerson G. de S. Luna	Yellow
Emmanuel Gräve de Oliveira	Yellow
Erasmio Madureira Ferreira	Yellow
Fábio Braghin	Blue
Fernando Gonçalves Gardim	Green
Fernando Silveira Navarra	Blue
Frederique M-B. S. Grassi	Green
Gabriel Silveira Denicol	Green
Gastão Krein	Blue
Hilário Antônio R. Gonçalves	Red

Tiago Nunes da Silva	Blue
João Pacheco B. C. de Melo	Blue
João R. Torres de Mello Neto	Blue
João Thiago de S. Amaral	Yellow
Jorge José Leite Noronha Jr.	Green
Kazuo Tsushima	Blue
Leticia Faria D. Palhares	Purple
Luiz Gustavo de Almeida	Red
Manuel M. B. M. de Oliveira	Red
Marcelo Chiapparini	Red
Marcelo Dallagnol Alloy	Red
Márcio José Menon	Yellow
Marcus E. Benghi Pinto	Blue
Marina Nielsen	Blue
Mario Luiz Lopes da Silva	Blue
Matthew Luzum	Green
Mirian Bracco	Blue
Otávio Socolowsky Jr.	Green
Rafael Cavagnoli	Red
Ricardo d'Elia Matheus	Blue
Rodrigo Picanco Negreiros	Red
Rubens de Melo Marinho Junio	Red
Sérgio Barbosa Duarte	Red
Sérgio Szpigel	Blue
Sidney dos Santos Avancini	Red
Takeshi Kodama	Green
Tereza C. da R. Mendes	Purple
Tomoi Koide	Green
Varese Salvador Timóteo	Blue
Victor P. Barros Gonçalves	Yellow
Wayne Leonardo S. de Paula	Purple
Wei-Liang Qian	Green
Werner Krambeck Sauter	Yellow

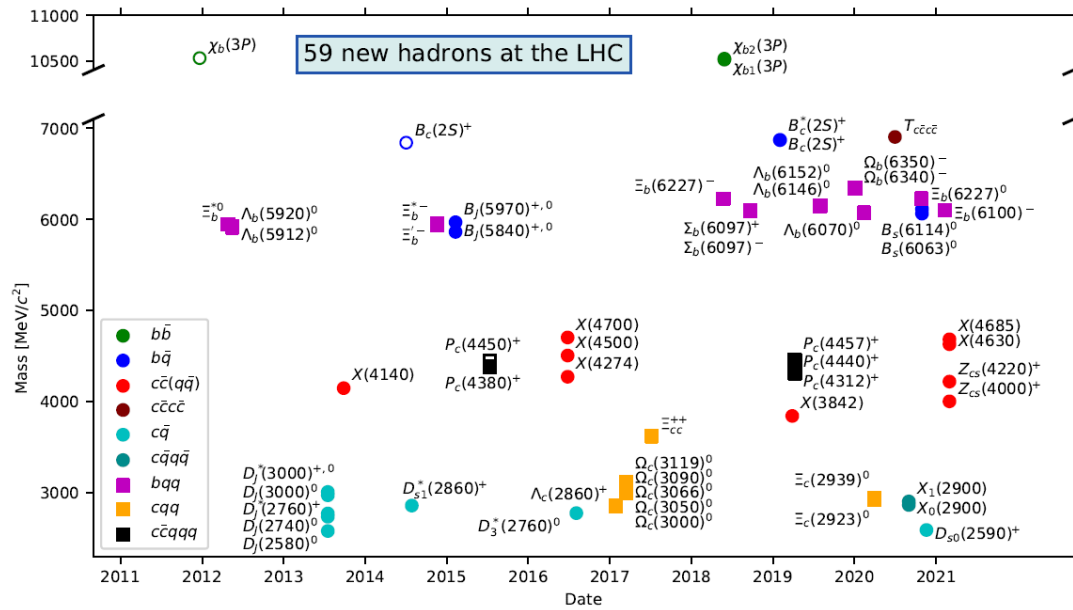
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# No passado recente:

Todos os concursos na área foram bem disputados e atraíram vários estrangeiros

Os que foram contratados:



Matthew Luzum



Alberto Martinez



Jorge Noronha