An overview of High-Energy Nuclear Physics in Brazil

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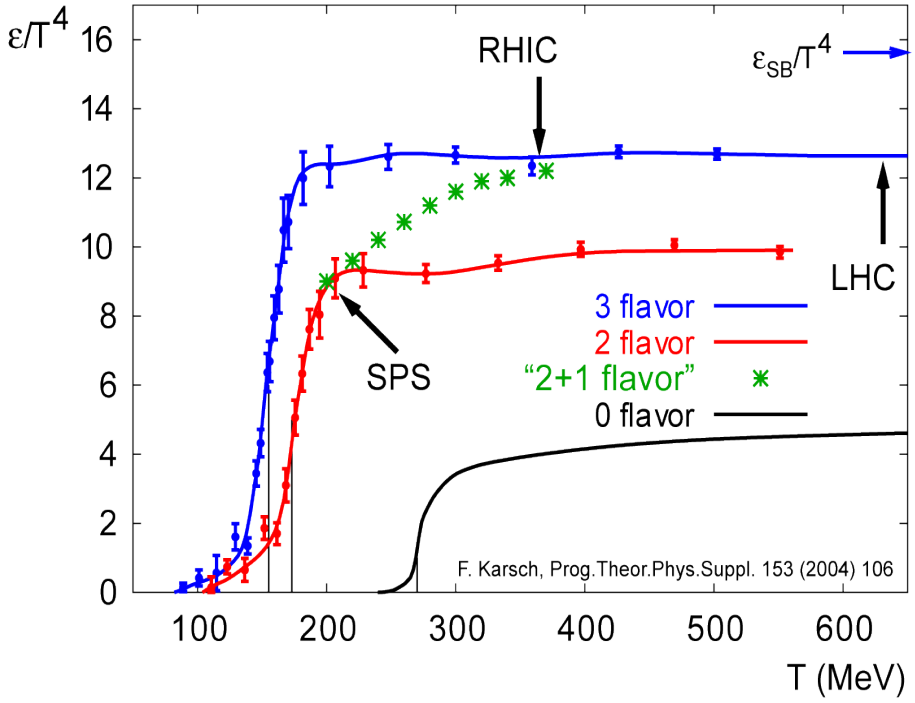
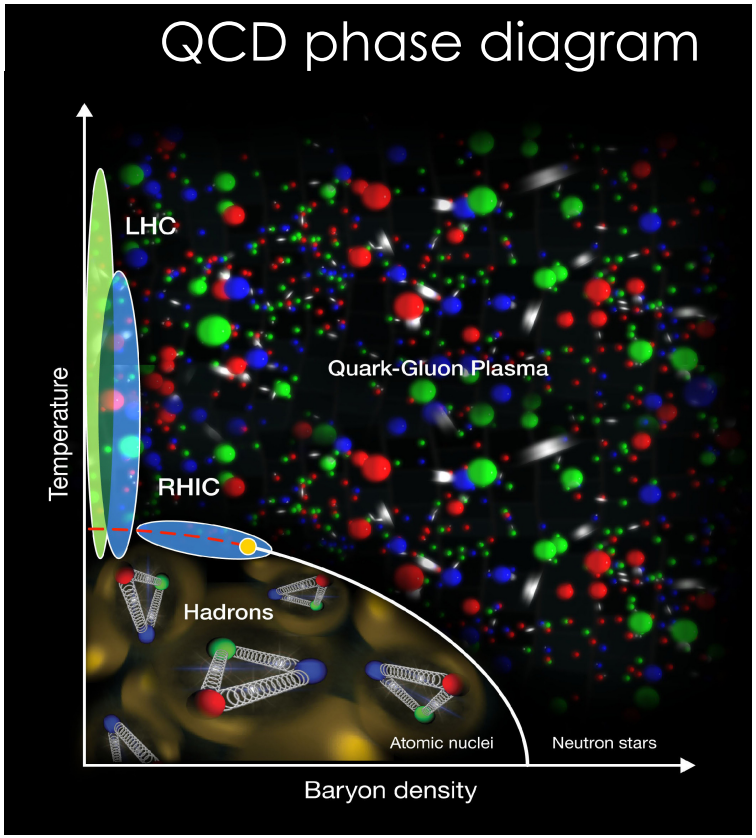
ALICE Collaboration

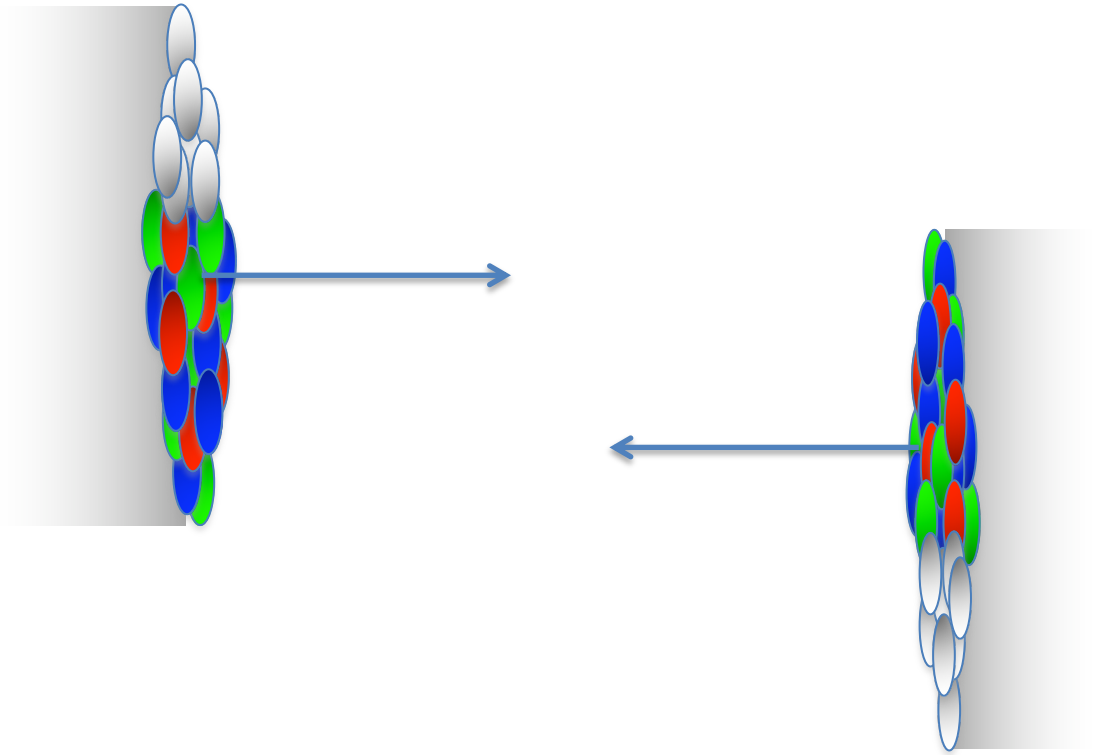
FAPESP
CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico
UNICAMP
ALICE

Fundamental Interaction & Collective behavior

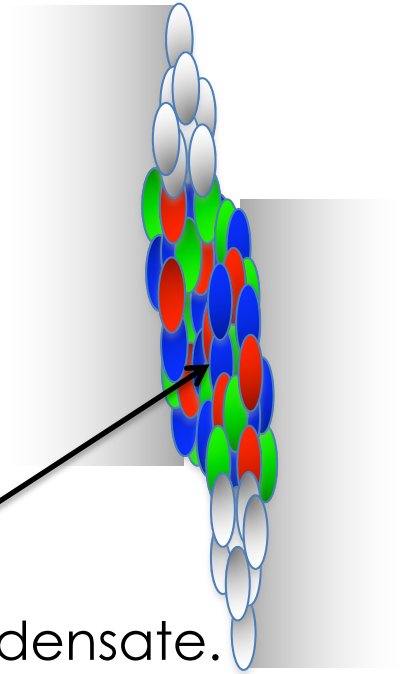


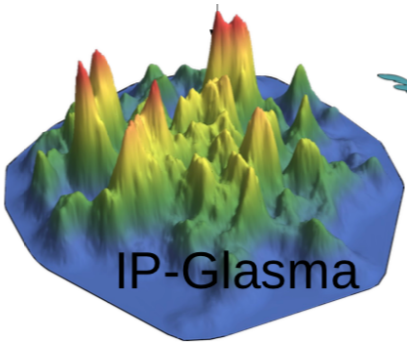


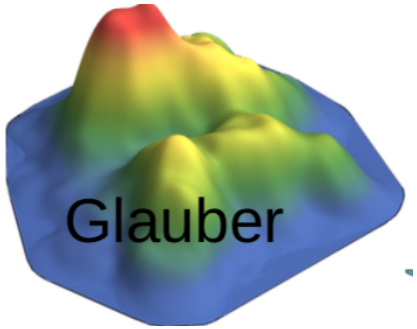
Heavy-Ion Collisions



Initial Condition

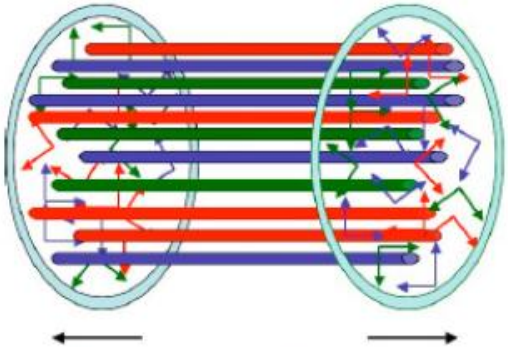






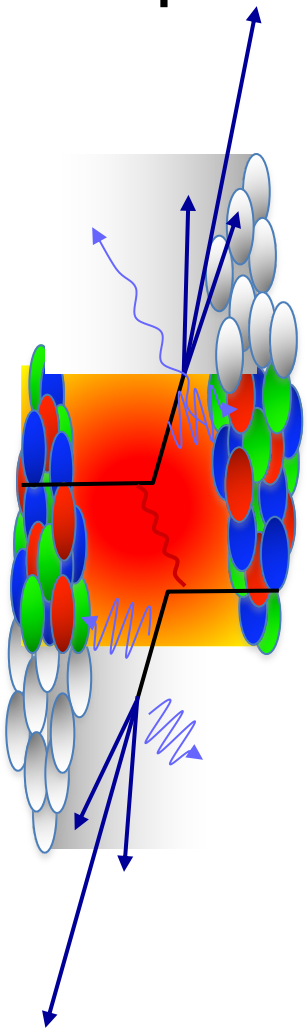
Initial Conditions:

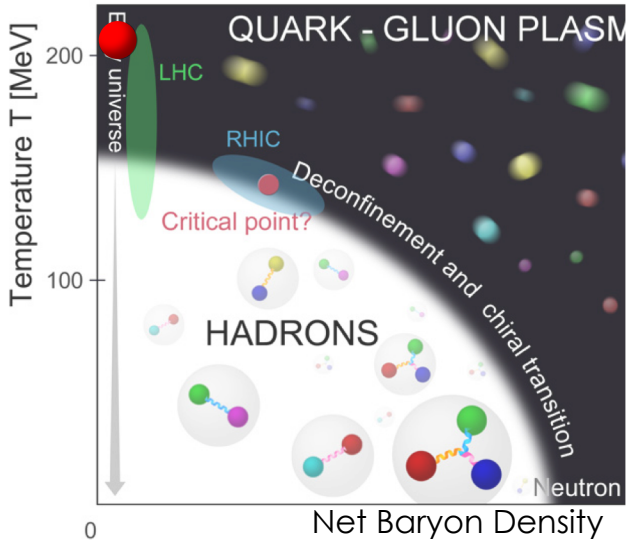
- Color Glass Condensate.
- Gluon Saturation Models. (Glasma)
- Density Fluctuations.



"Instantaneously" develop longitudinal color E and B fields

Pre-equilibrium phase

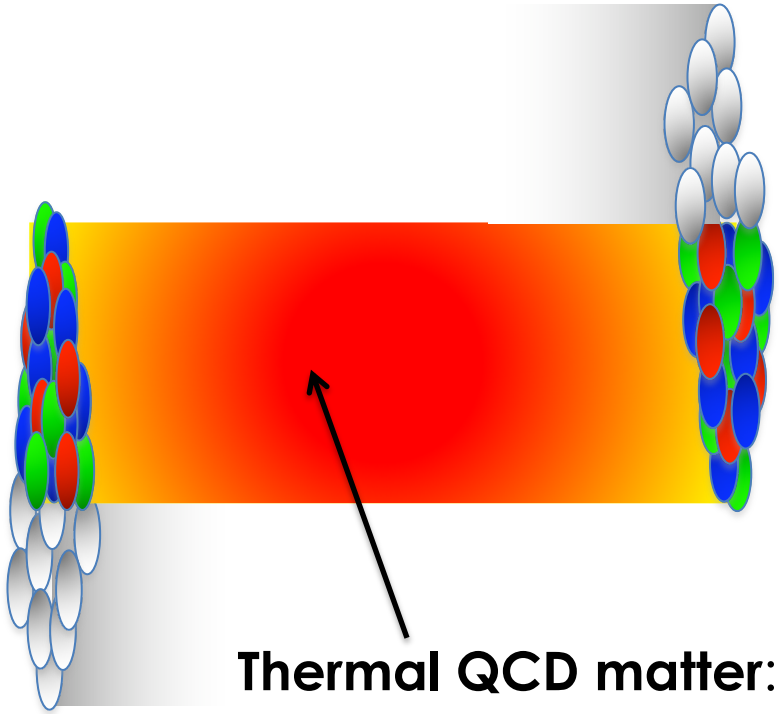


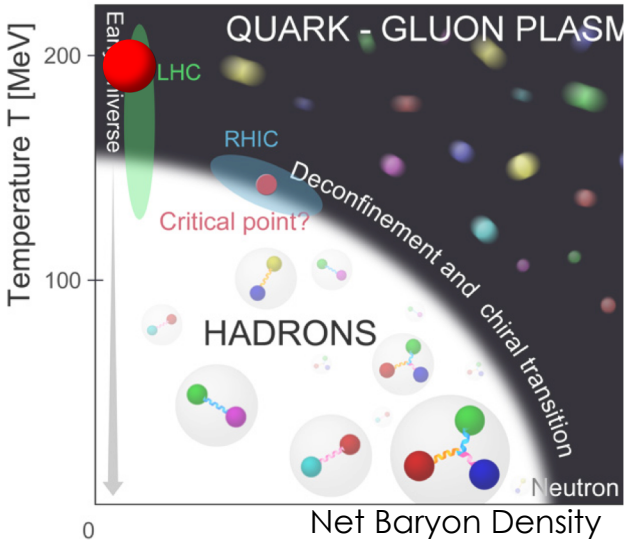


Hard Scatterings:

- Pre-equilibrium dynamics.
- Parton Distribution Functions.
- High p_T particles.
- Particle Jets.
- Heavy flavored particles.

Hot QCD Matter

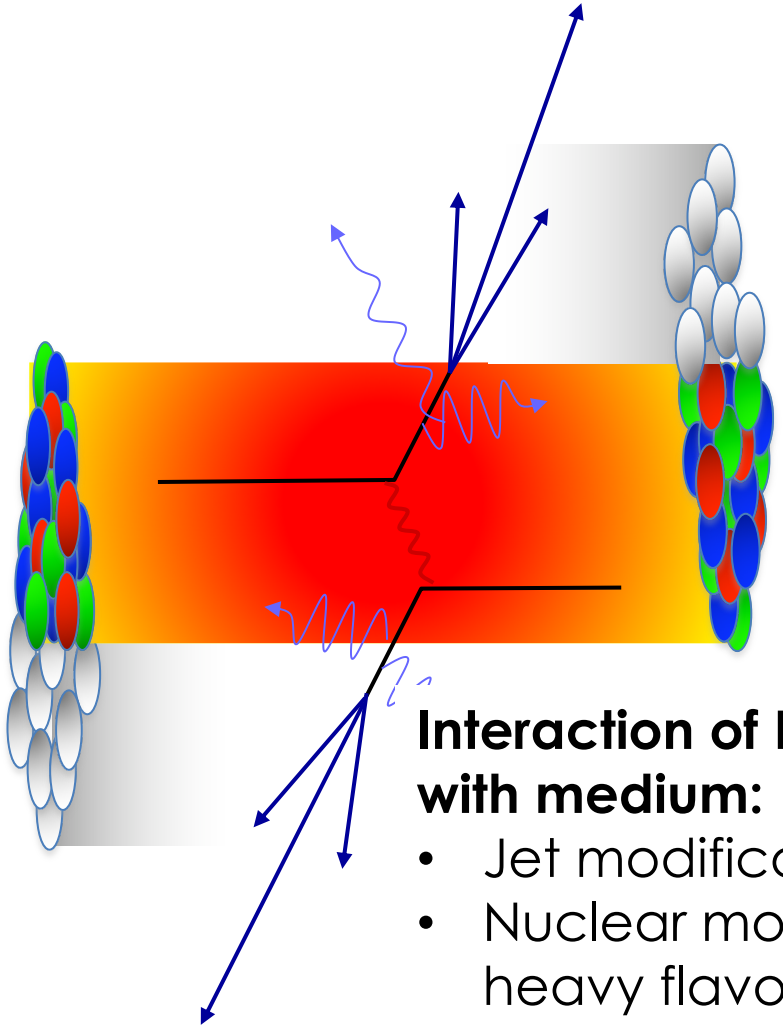


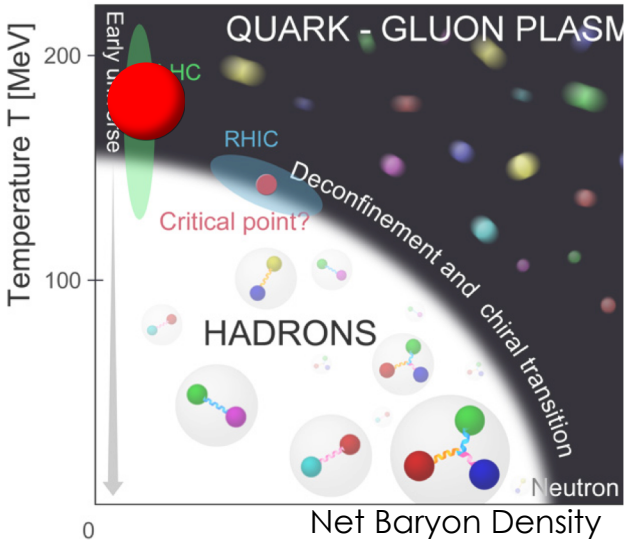


Thermal QCD matter:

- Extremely Dense & Strongly interacting.
- Collective behavior.
- Hydrodynamic Expansion with low viscosity.
- Partonic degrees of freedom.

Hot QCD Matter

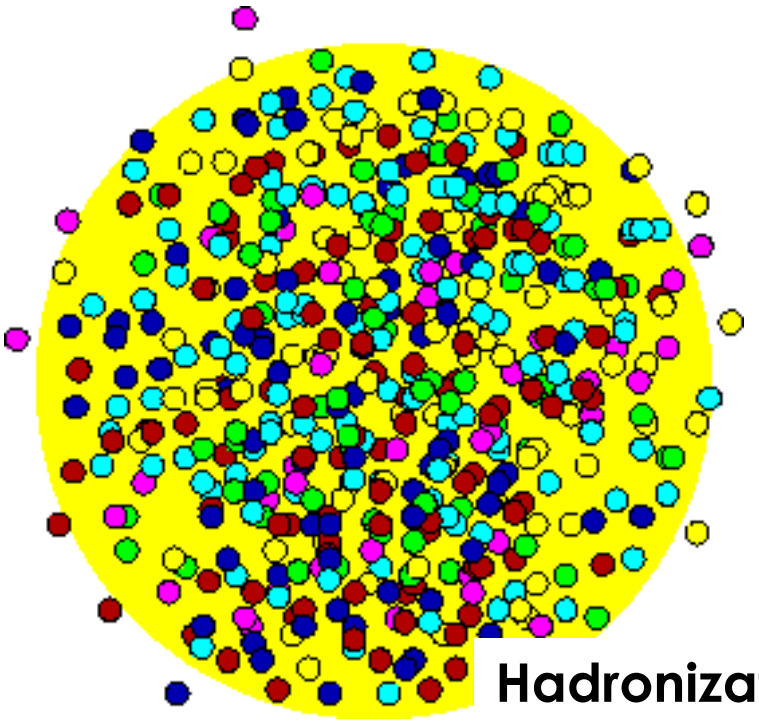


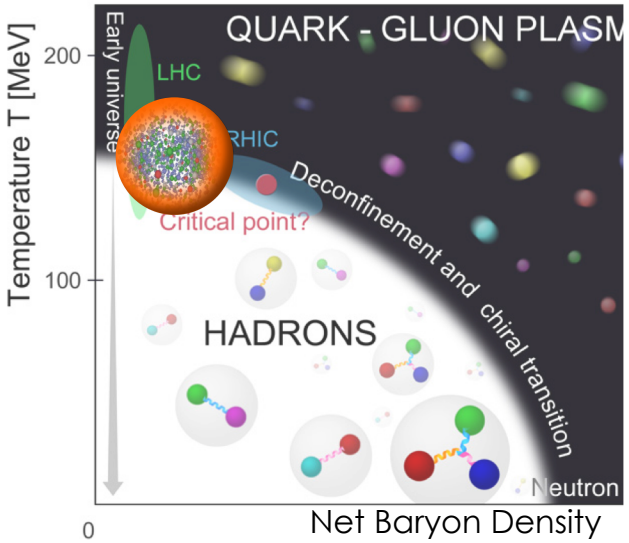


Interaction of High p_T (>~4 GeV/c) particles with medium:

- Jet modification and suppression.
- Nuclear modification factors of light and heavy flavored particles.
- Affects signatures of collectivity.

Hadronization

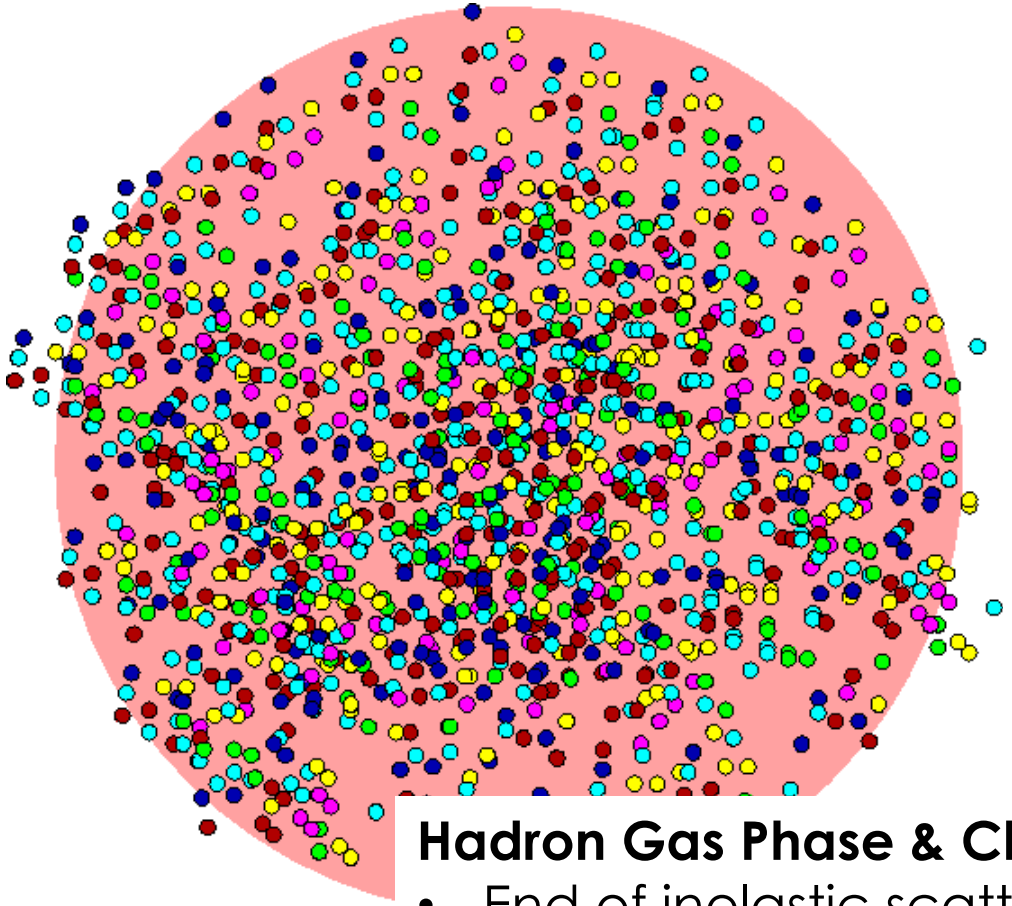


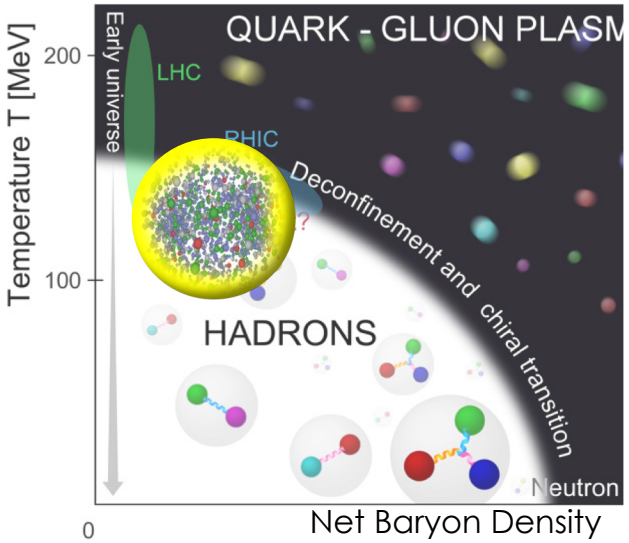


Hadronization:

- Soft probes (p_T<~4 GeV/c).
- Particle production mechanisms.
- Chiral symmetry breaking …

Chemical Freeze-out

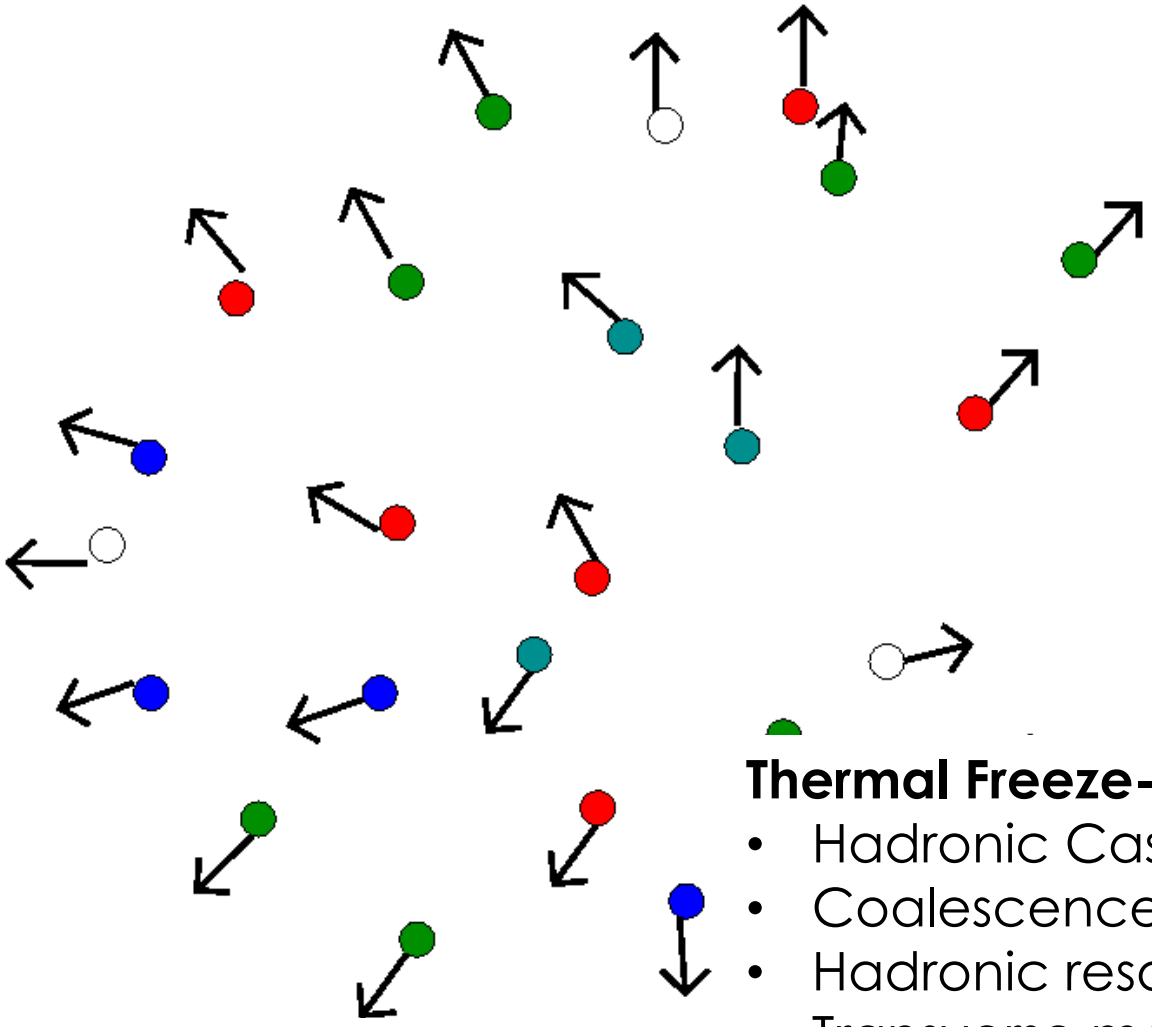


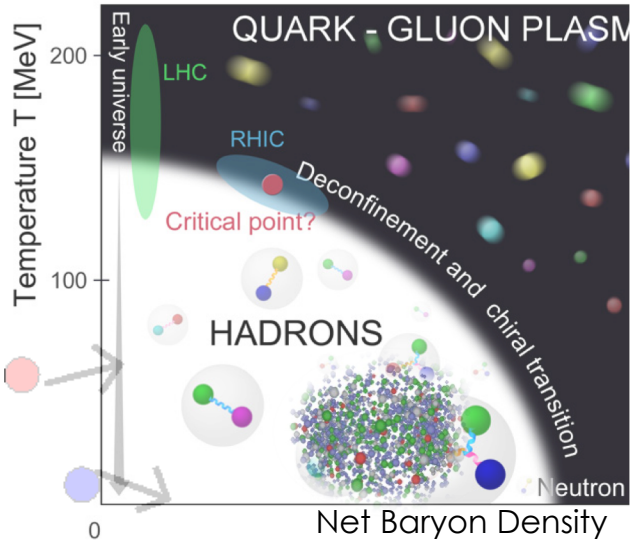


Hadron Gas Phase & Chemical Freeze-out:

- End of inelastic scattering.
- Relative particle abundance fixed.
- Application of Statistical Thermal models.

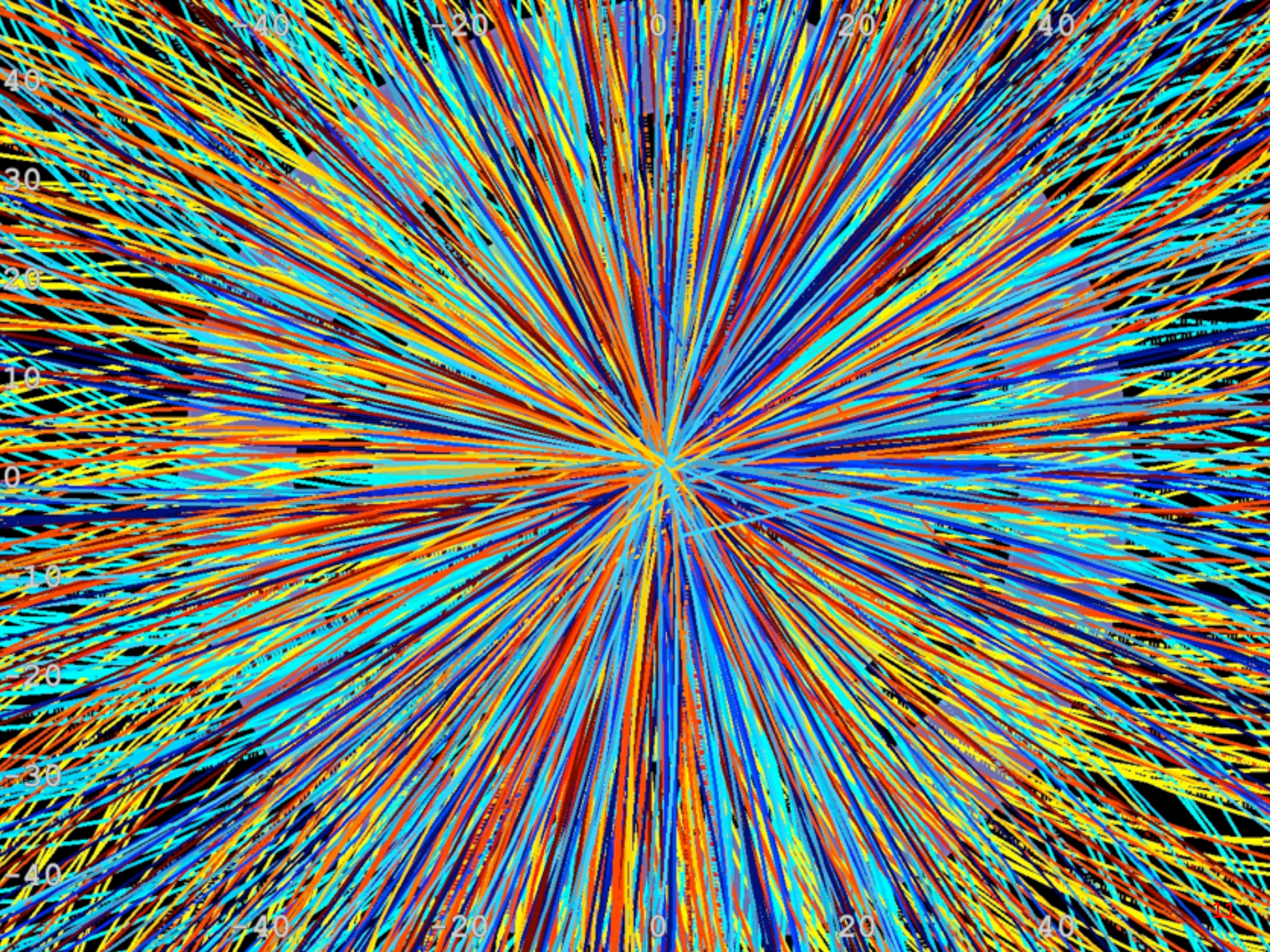
Thermal Freeze-out





Thermal Freeze-out

- Hadronic Cascade models.
- Coalescence models.
- Hadronic resonances.
- Transverse momentum spectra.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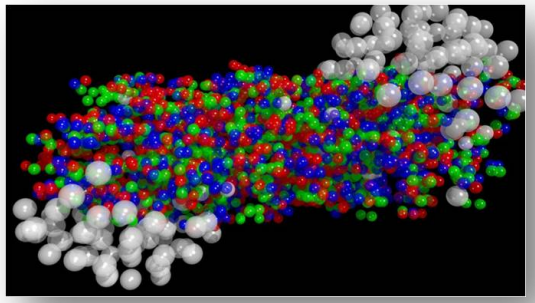
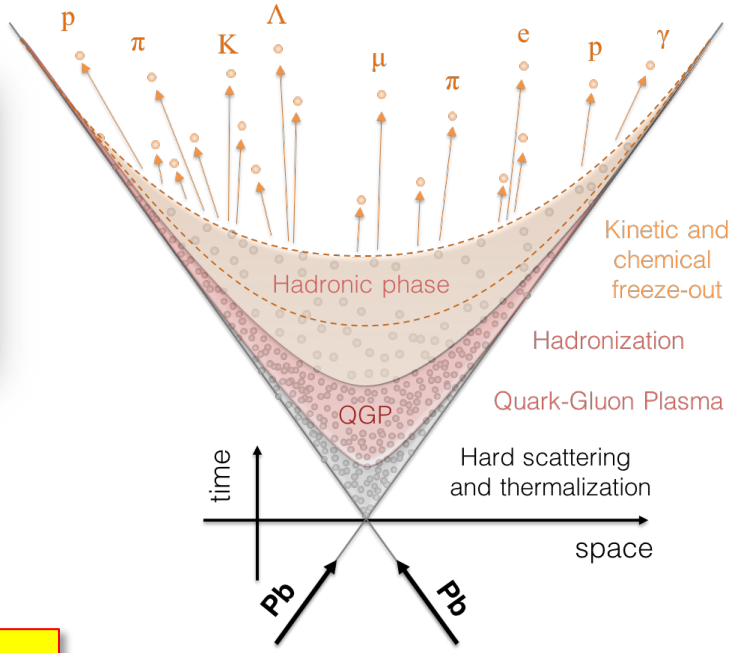
The Pillars of our work





- ...

G. Denicol afternoon talk.

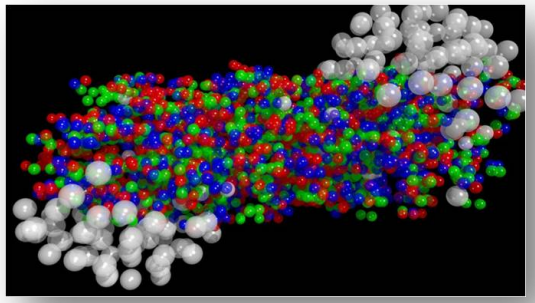
- QCD phase transition
- Lattice QCD
- Finite temperature

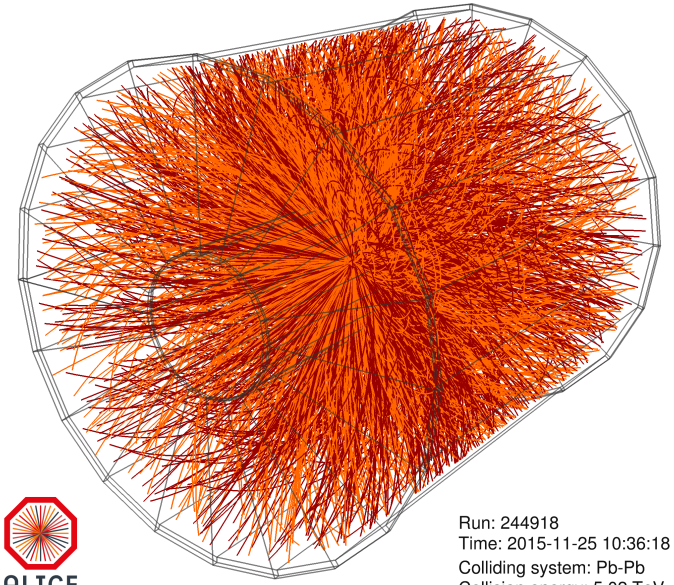
M. B. Gay Ducati morning talk.

Phenomenology | **Experiment**

Theory | **Instrumentation**

The Pillars of our work





- Hydrodynamics
- pQCD-inspired models
- …

Phenomenology

- QCD phase transition
- Lattice QCD
- Finite temperature
- …

Theory

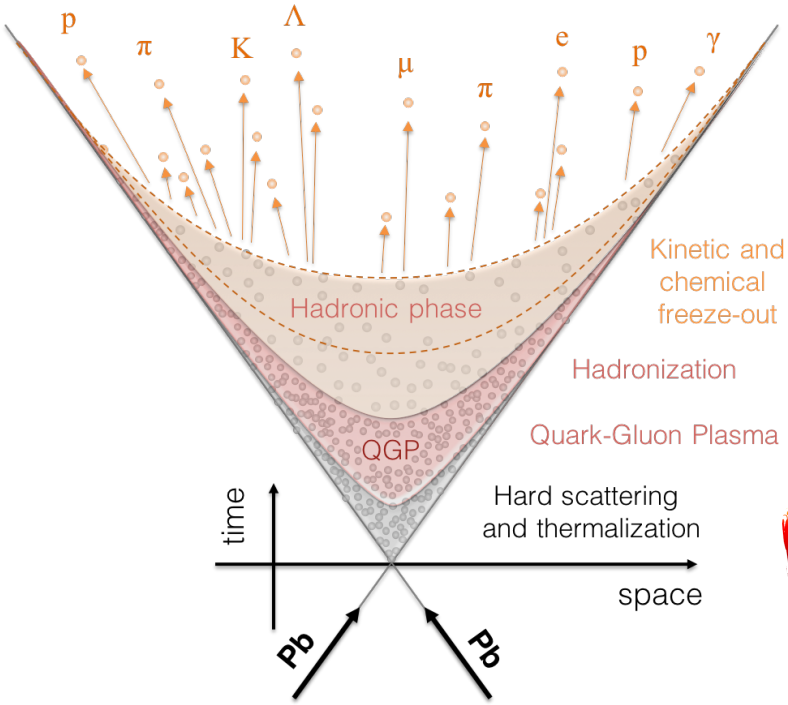
Experiment

- STAR
- PHENIX
- E896
- E864
- ALICE

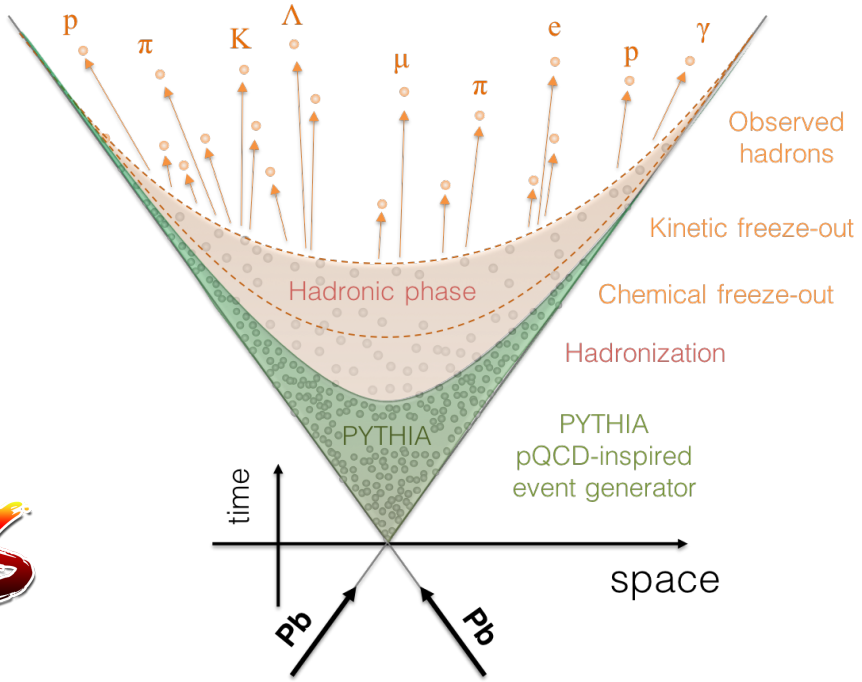
Instrumentation

Strong Brazilian participation since the nineties!

Phenomenology of HIC



VS



Full hybrid model:
EXTREME Collaboration
FF, UFSC)

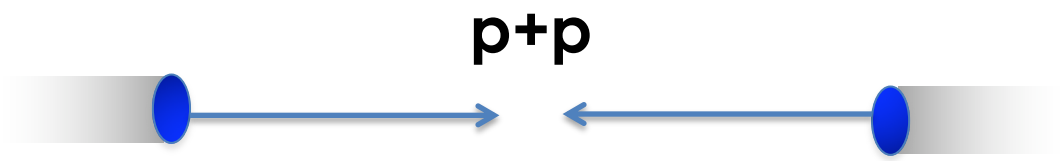
Microscopic QCD-inspired phenomenology:
PYTHI

See M. Hippert's talk on Thursday

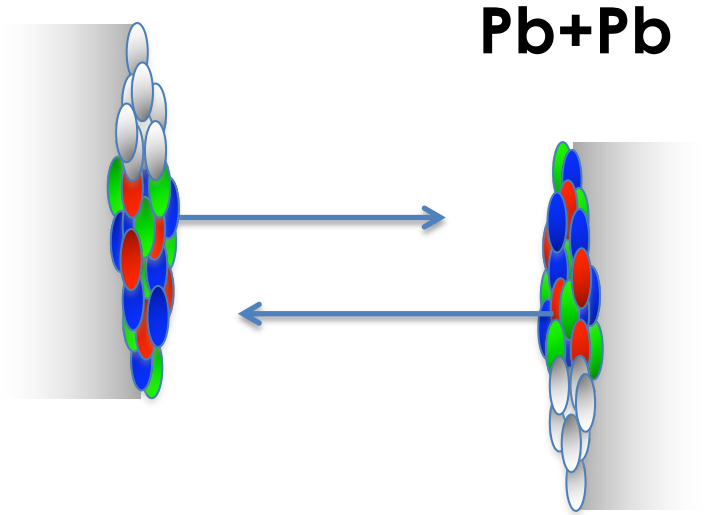
See Hadrex Poster E. Manganote

See A. V. da Sila's talk on Wednesday

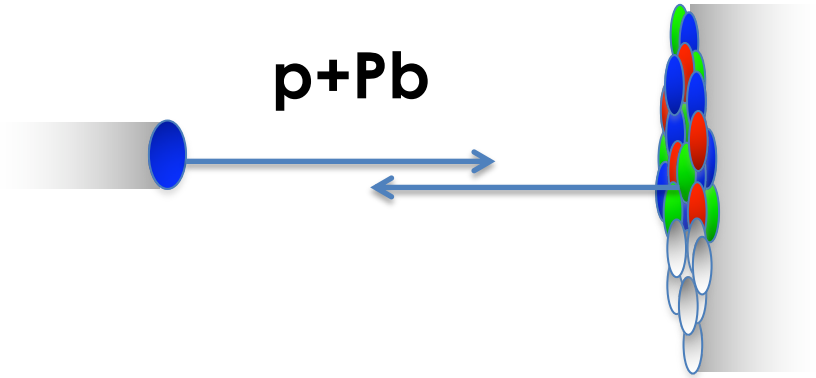
How to study the different physics processes of HIC ?



Compare Pb+Pb results with reference data, to disentangle genuine heavy-ion collision effects.

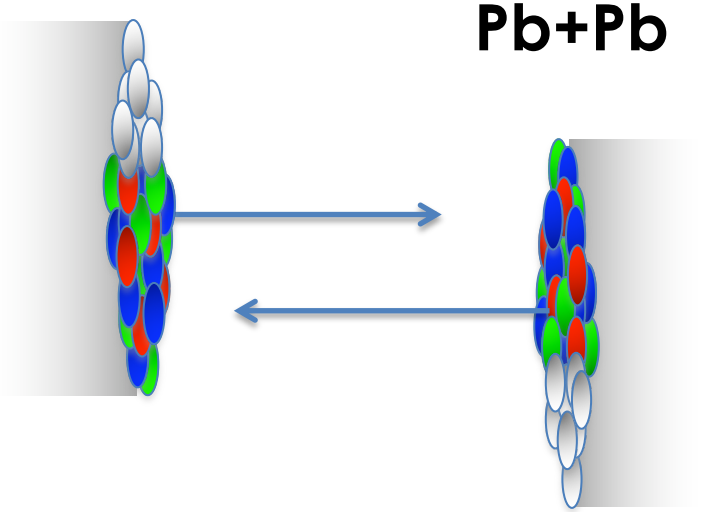


How to study the different physics processes of HIC ?

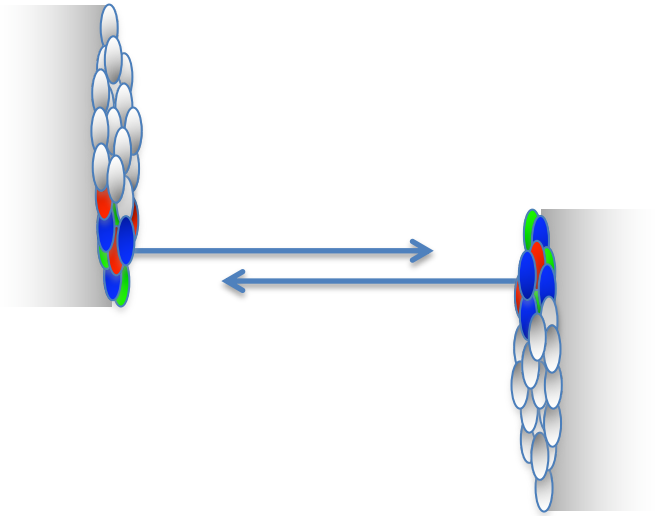


p+Pb also important as reference data:

- Initial vs. final state effects.
- Probe small x.
- Cold nuclear matter, gluon saturation and shadowing



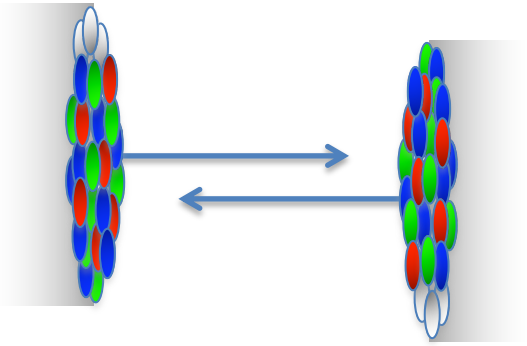
How to study the different physics processes of HIC ?



Peripheral Pb+Pb

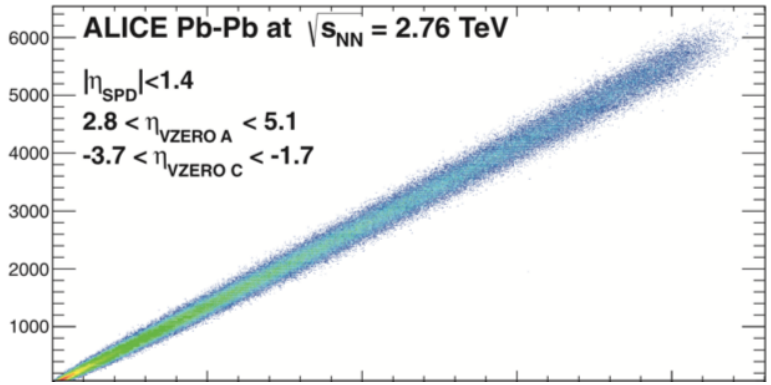
We can also change the observed system size by selecting on the collisions centrality.
Charged particle multiplicity used for this selection.

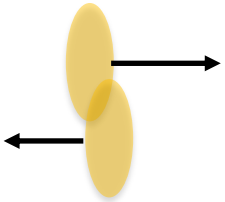
Central Pb+Pb



Selection of collisions geometry

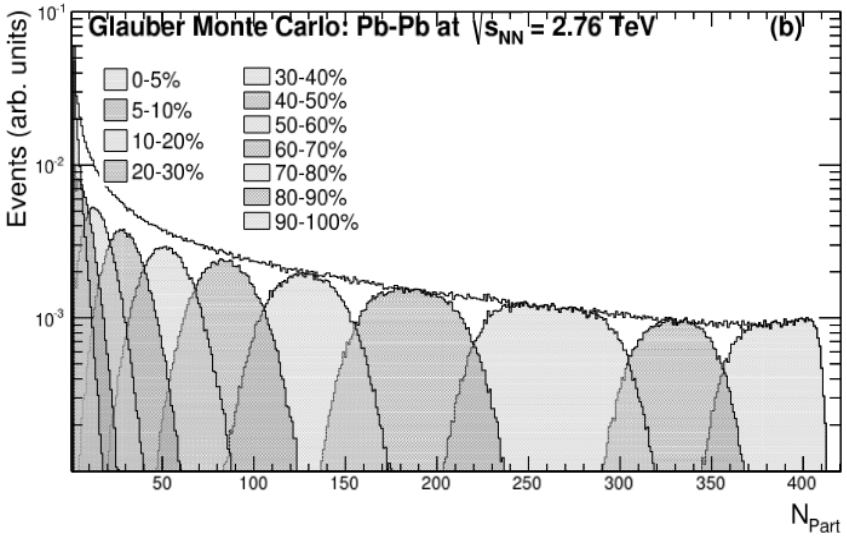
Mid-rapidity multiplicity





Forward Multiplicity

ALICE, PRC 88 (2013) 044909



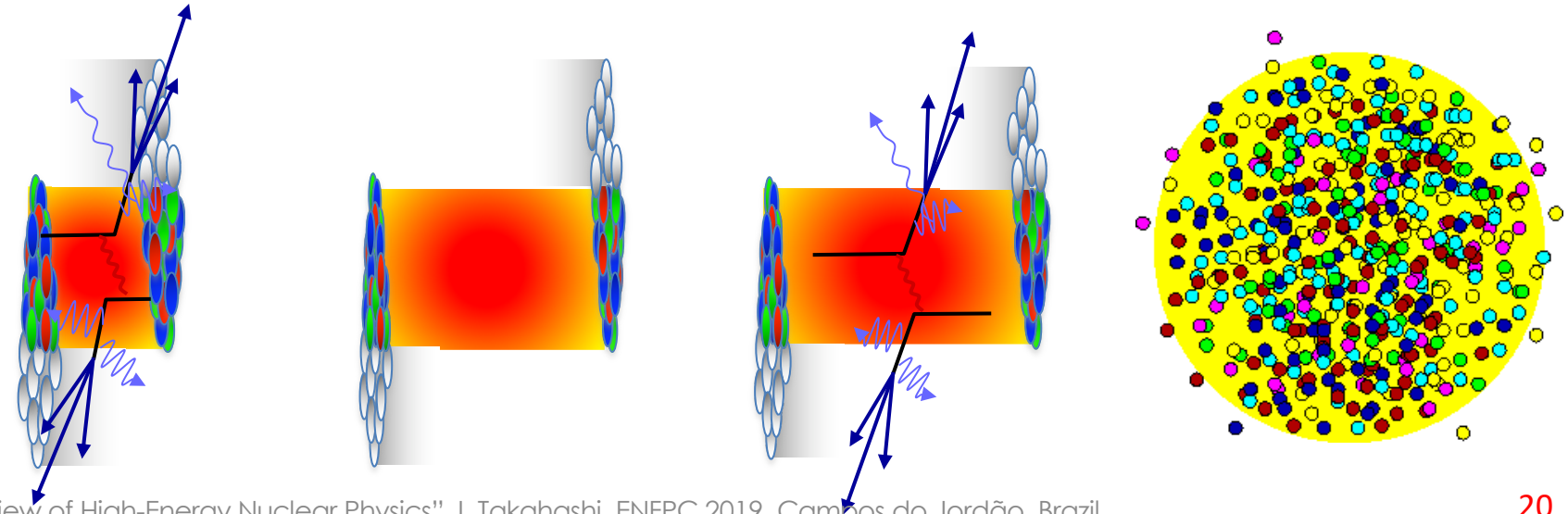
Lots of data !

Run 1 (2009-2013)		
pp	0.9 TeV	~ 200 μb^{-1}
	2.76 TeV	~ 100 nb^{-1}
	7.0 TeV	~ 1.5 pb^{-1}
	8.0 TeV	~ 2.5 pb^{-1}
p-Pb	5.02 TeV	~ 15 nb^{-1}
Pb-Pb	2.76 TeV	~ 75 μb^{-1}

Run 2 (2015-2018)		
pp	5.02 TeV	~ 1.3 pb^{-1}
	13 TeV	~ 25 pb^{-1}
p-Pb	5.02 TeV	~ 3 nb^{-1}
	8.16 TeV	~ 25 nb^{-1}
Xe-Xe	5.44 TeV	~ 0.3 μb^{-1}
Pb-Pb	5.02 TeV	~ 1 nb^{-1}

Some of the observables

1. Thermal QCD Matter.
2. Bulk particle production.
3. Jet-medium interactions.
4. Heavy flavor.



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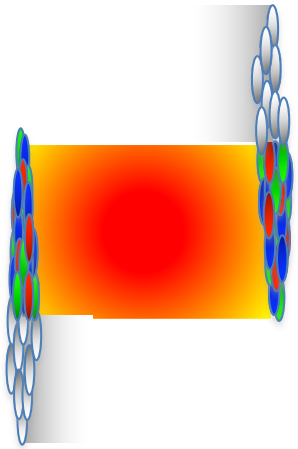
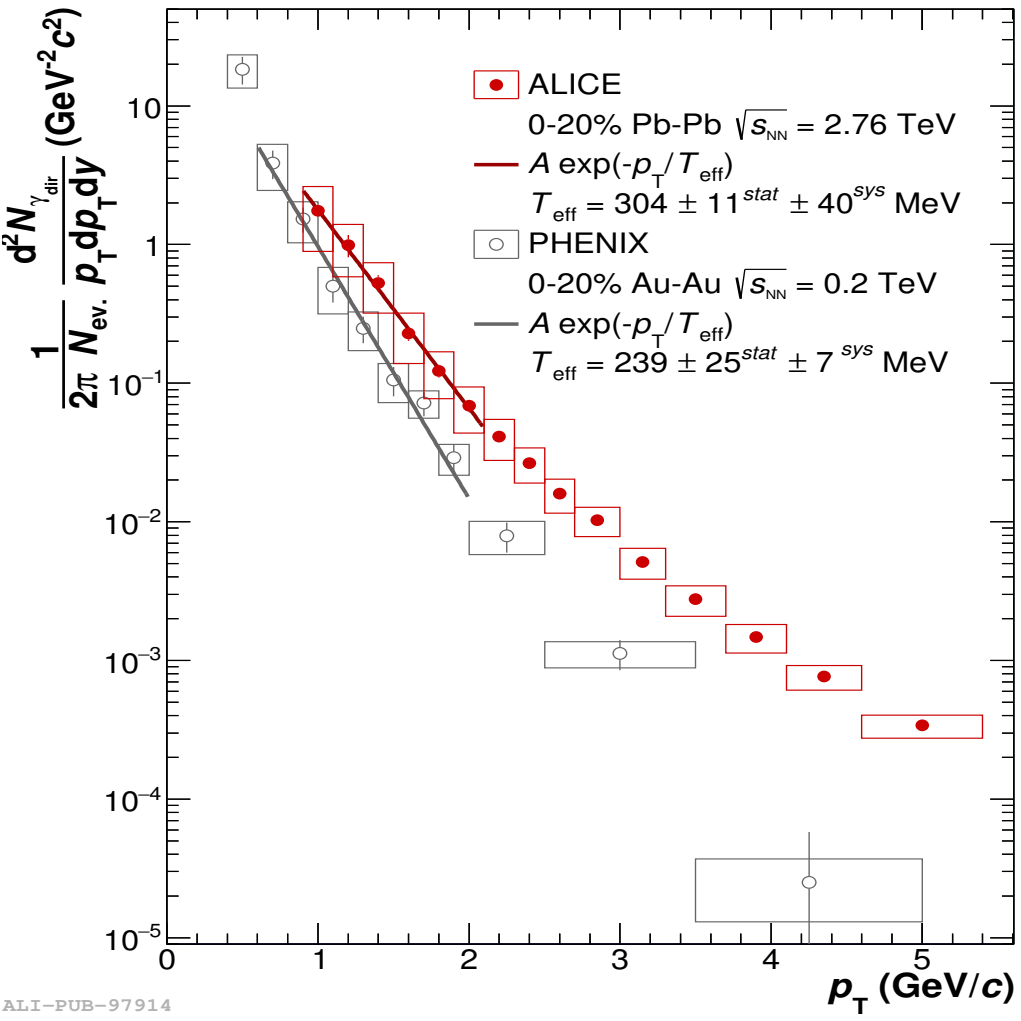


Direct photons in Pb-Pb

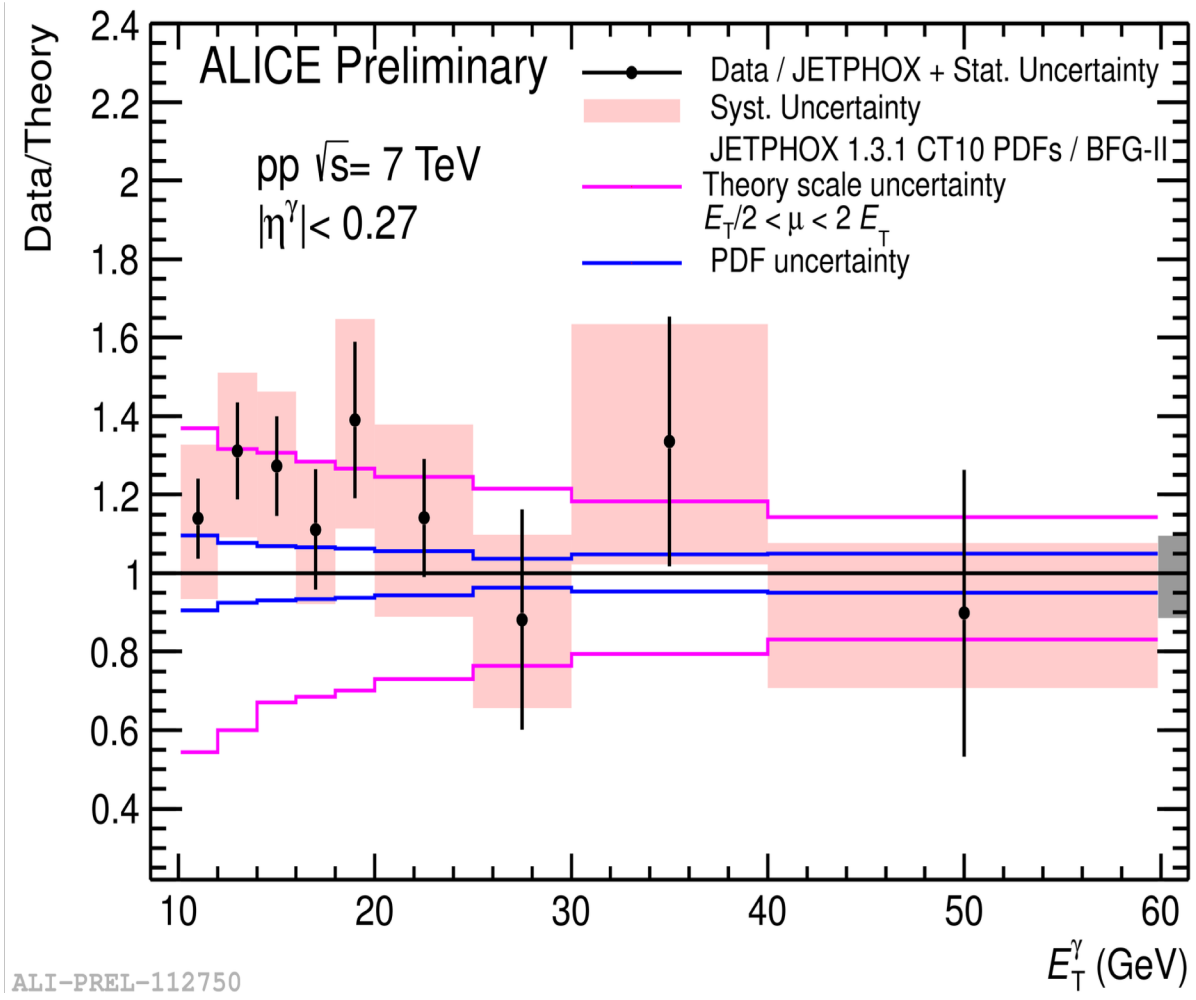
ALICE, Phys. Lett. B 754 (2016) 235.



Measured through Photon Conversion Method (PCM), PHOS calorimeter and EMCal.

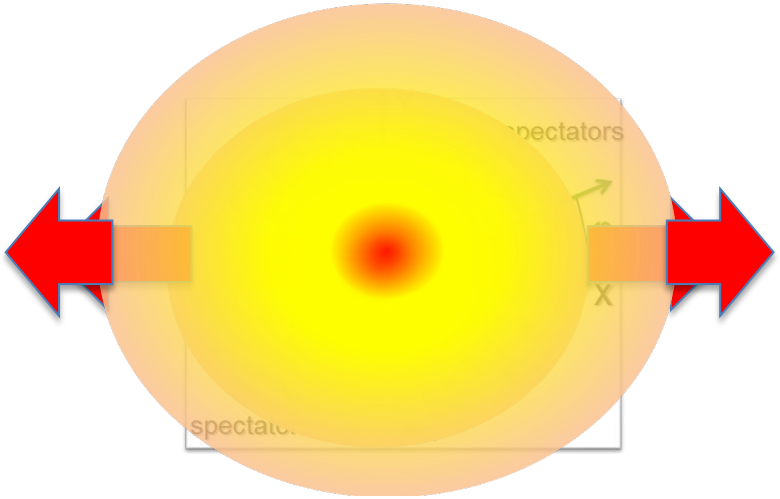
Hot QCD matter radiate photons free of final state interactions.

Direct photons in pp



- Prompt-photons: access proton PDF
- Baseline for p-Pb, Pb-Pb collisions
- Measurement compatible with pQCD (NLO)

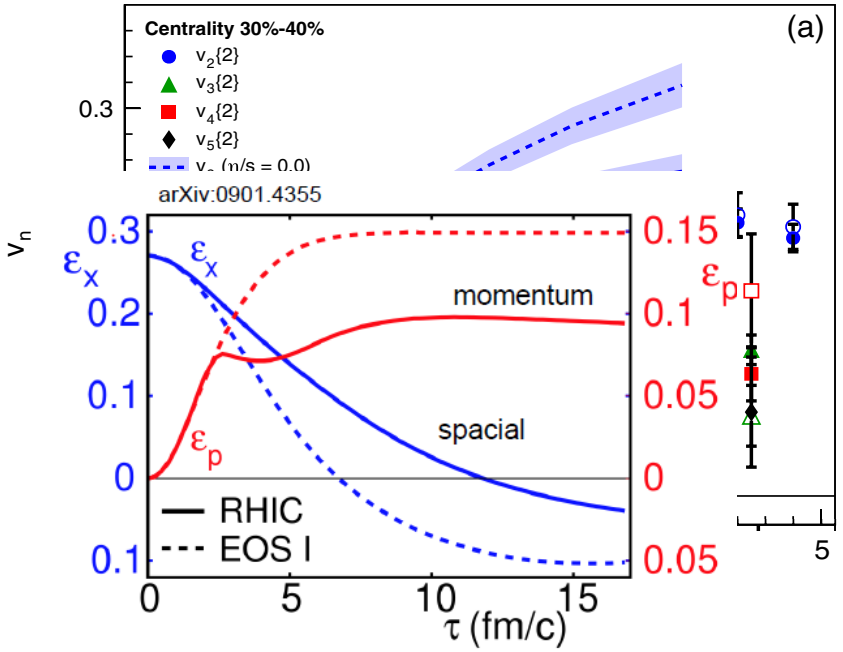
QGP Liquid-like evolution



$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_t dp_t dy}\left(1+\sum_{n=1}^{\infty} 2v_n \cos[n(\phi-\Psi_r)]\right)$$

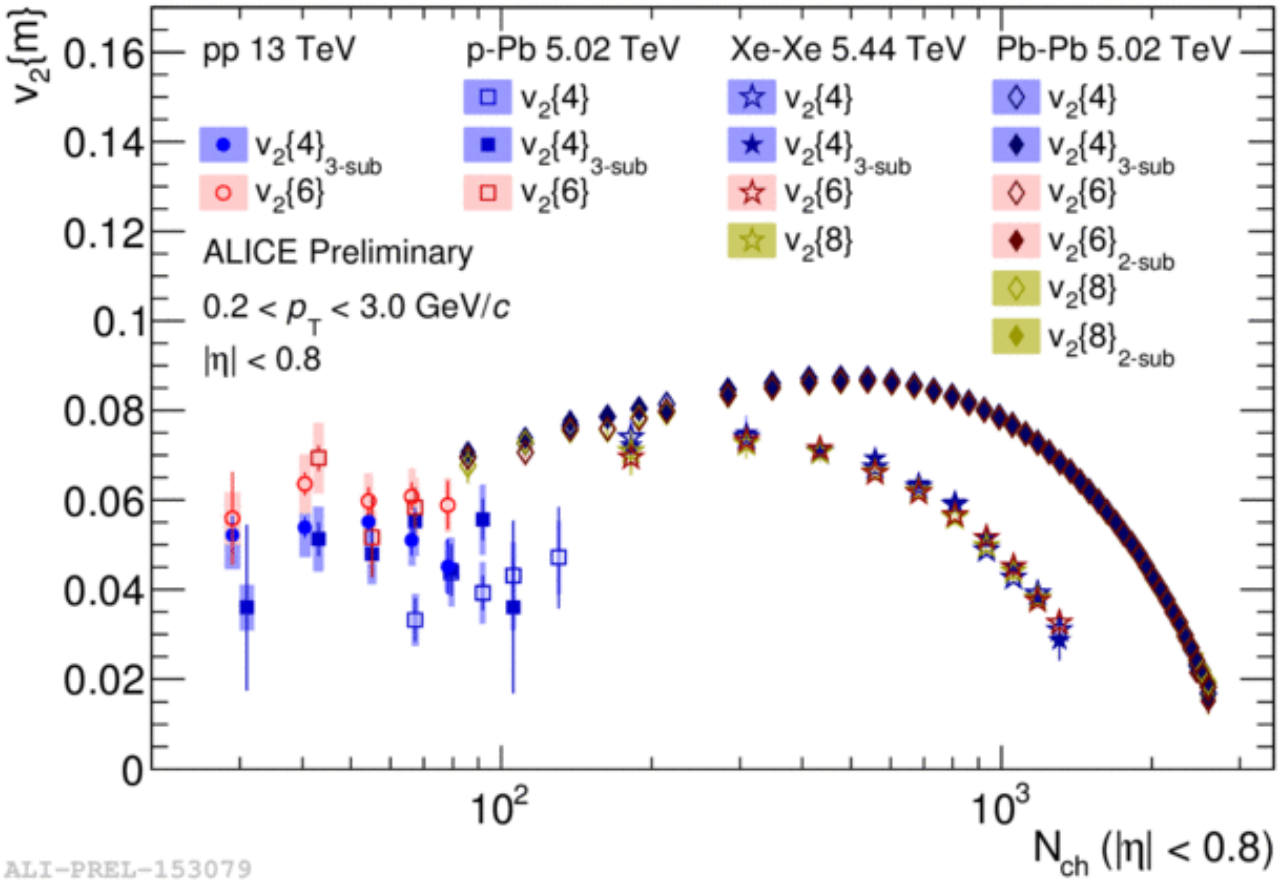
$$v_n(p_T,\eta) = \left\langle \cos\left[n(\phi-\Psi_n)\right]\right\rangle$$

ALICE, PRL 107(2011) 252301



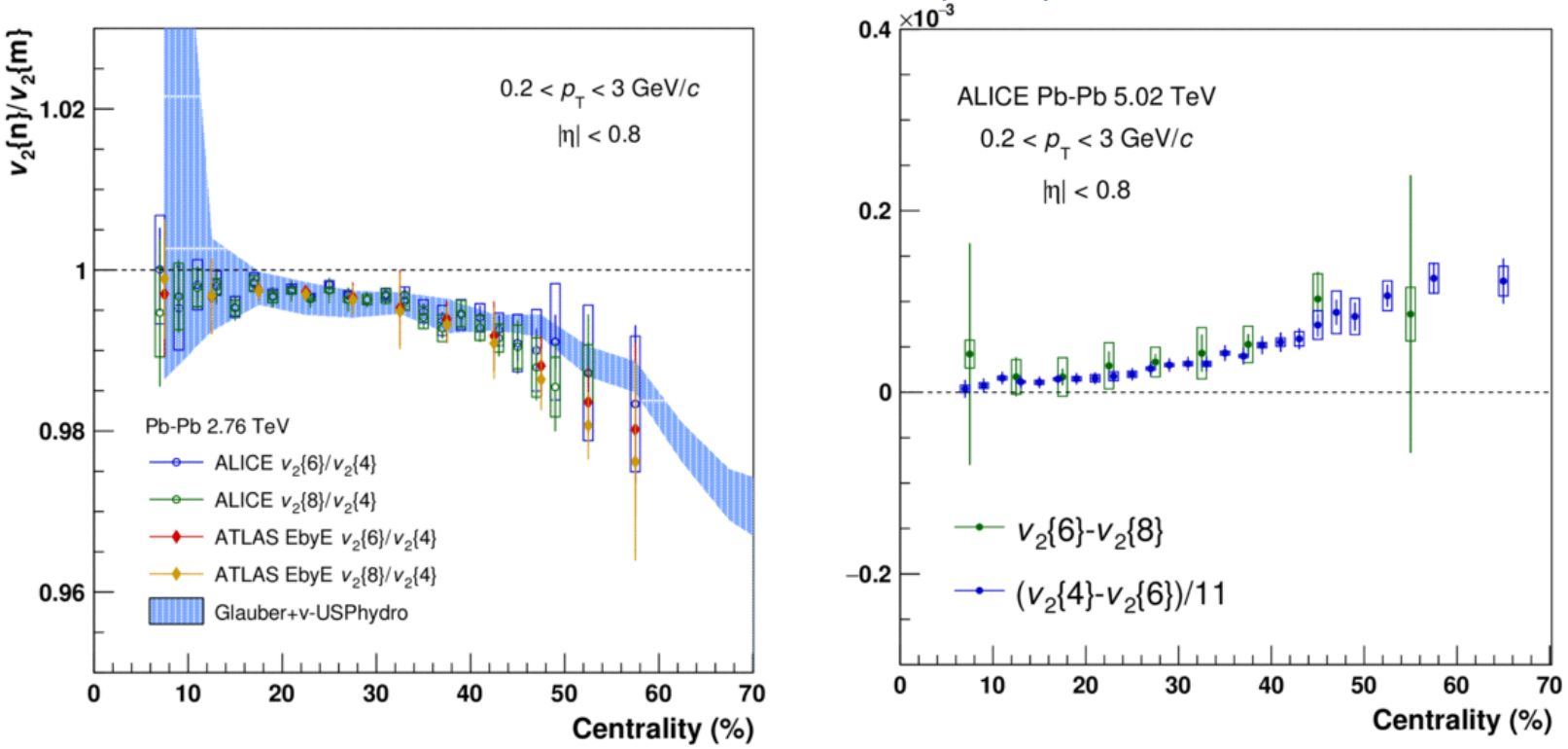
Elliptic flow measurements show success of low viscosity relativistic hydrodynamics to describe the QGP evolution.

Elliptic Flow v_2



V_2 as a probe to fluctuations

ALICE, JHEP 1807 (2018) 103

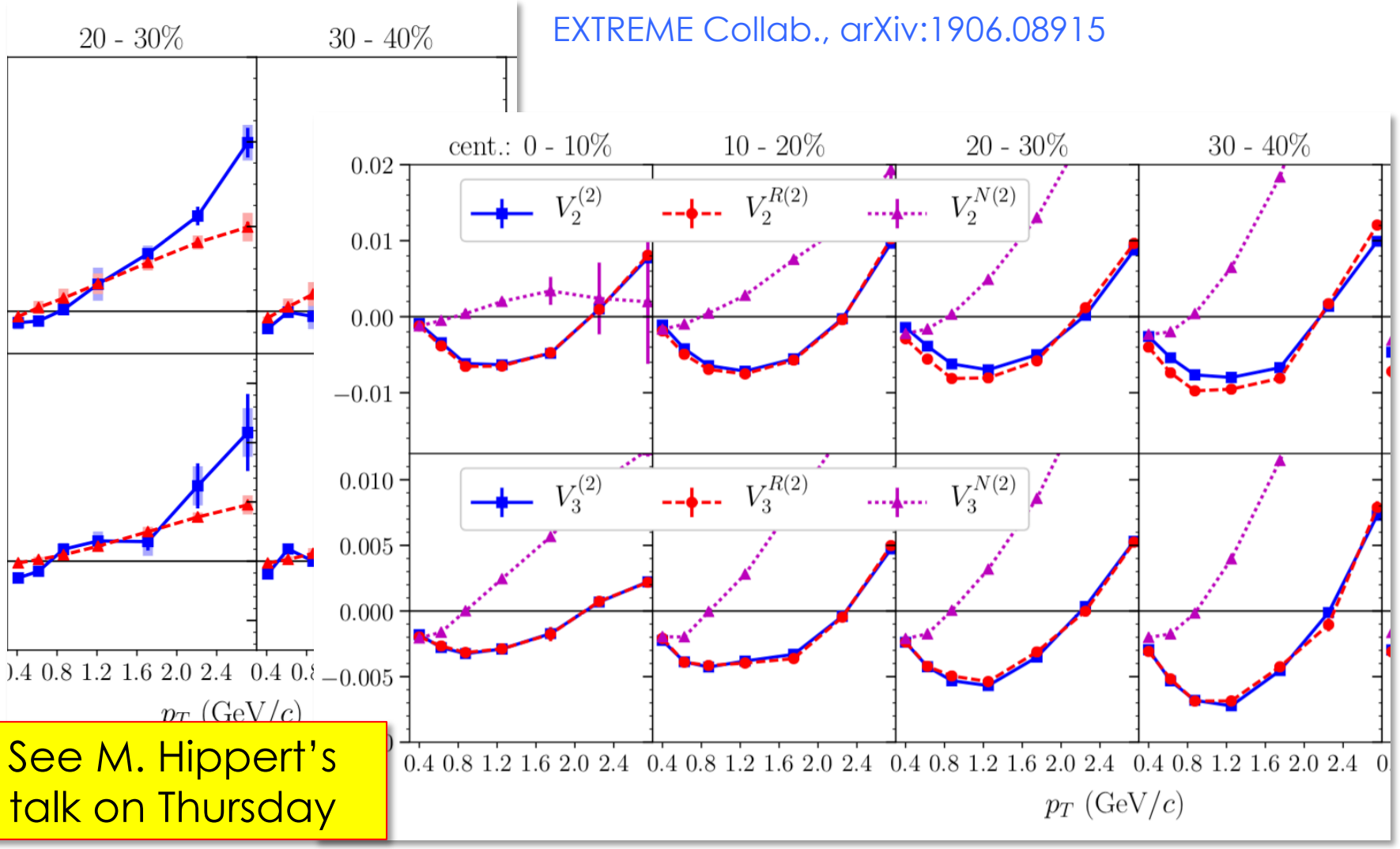


Consistent with Non-Bessel-Gaussian fluctuations.

Allows determination of Elliptic Power distribution, for comparison to initial-state models.

V_2 as a probe to fluctuations

EXTREME Collab., arXiv:1906.08915



See M. Hippert's talk on Thursday

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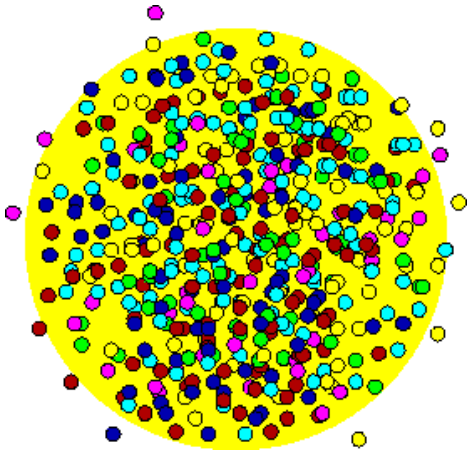
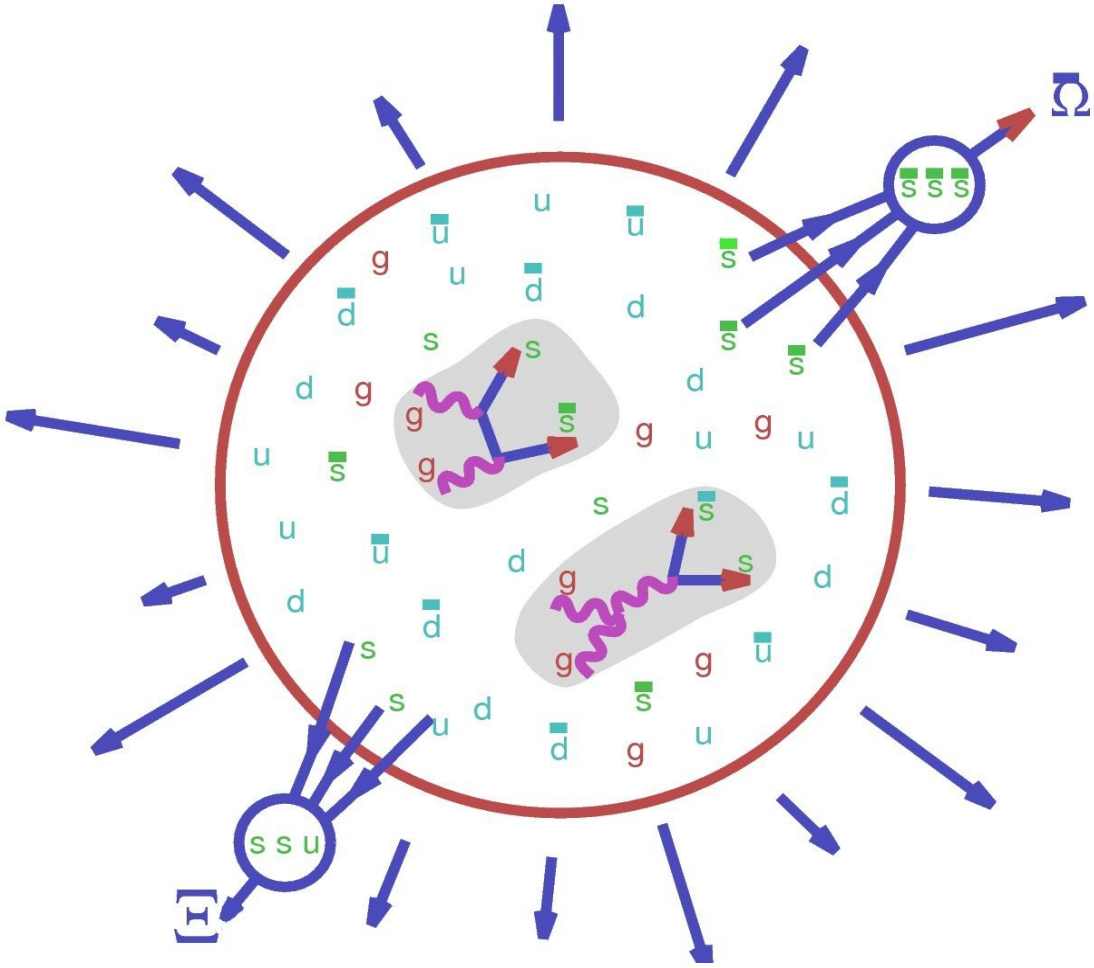
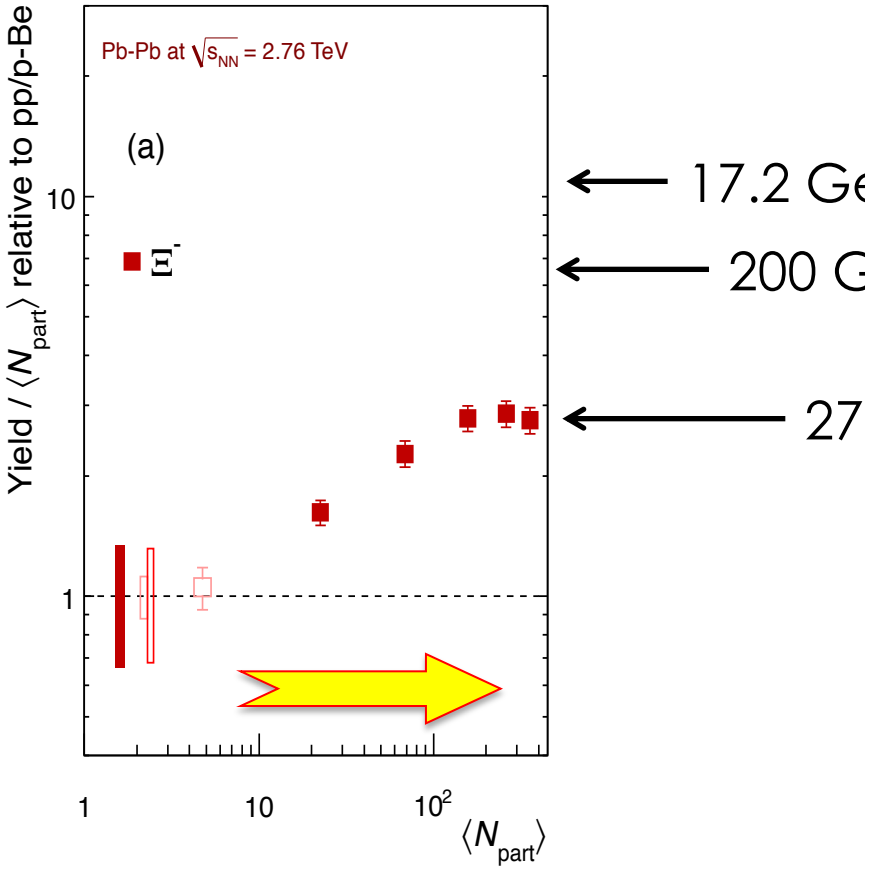


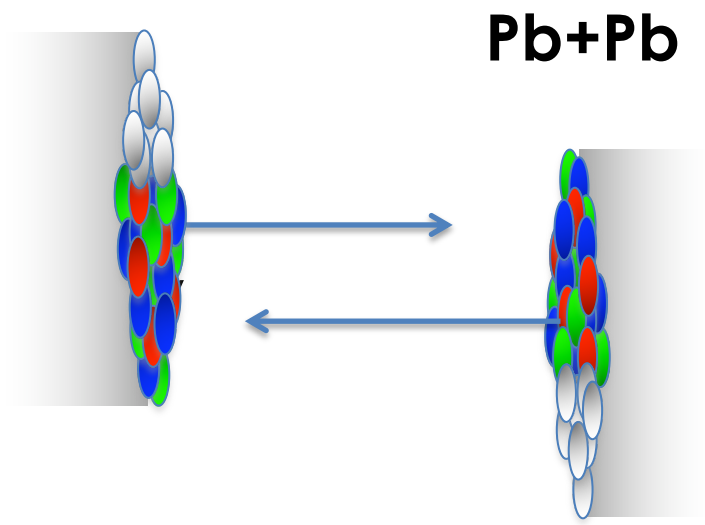
Strangeness Enhancement



Strangeness Enhancement

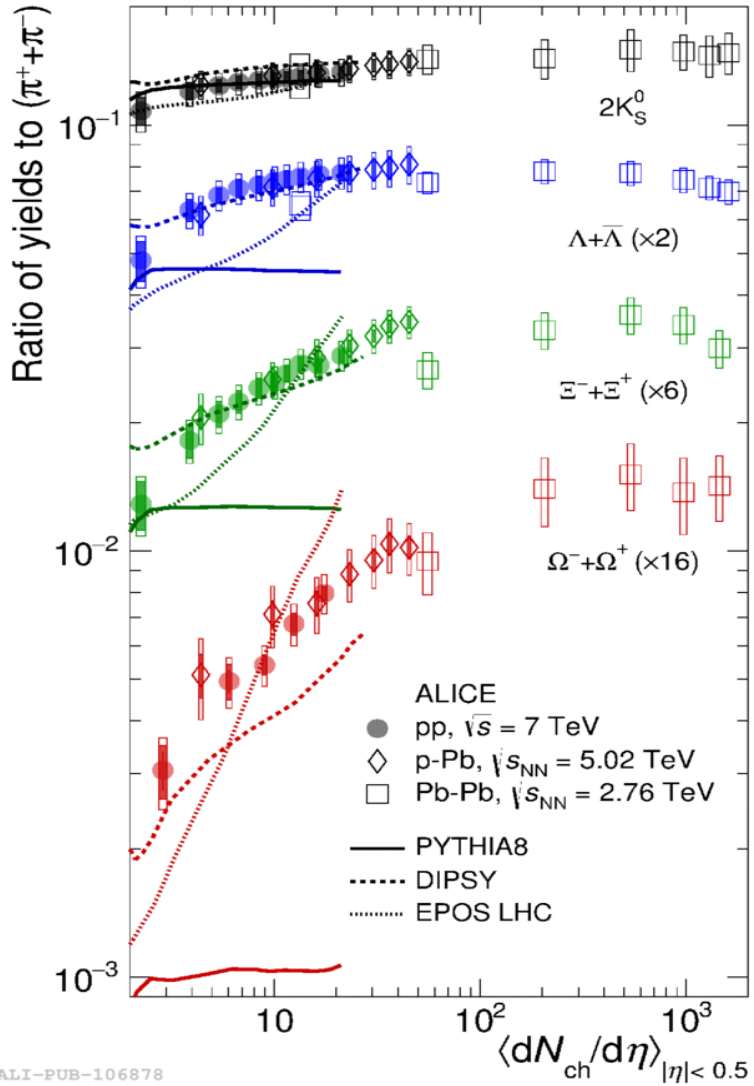
ALICE, PLB 728 (2014) 216





Clear observation of Strangeness Enhancement in HIC !!!

New Paradigm

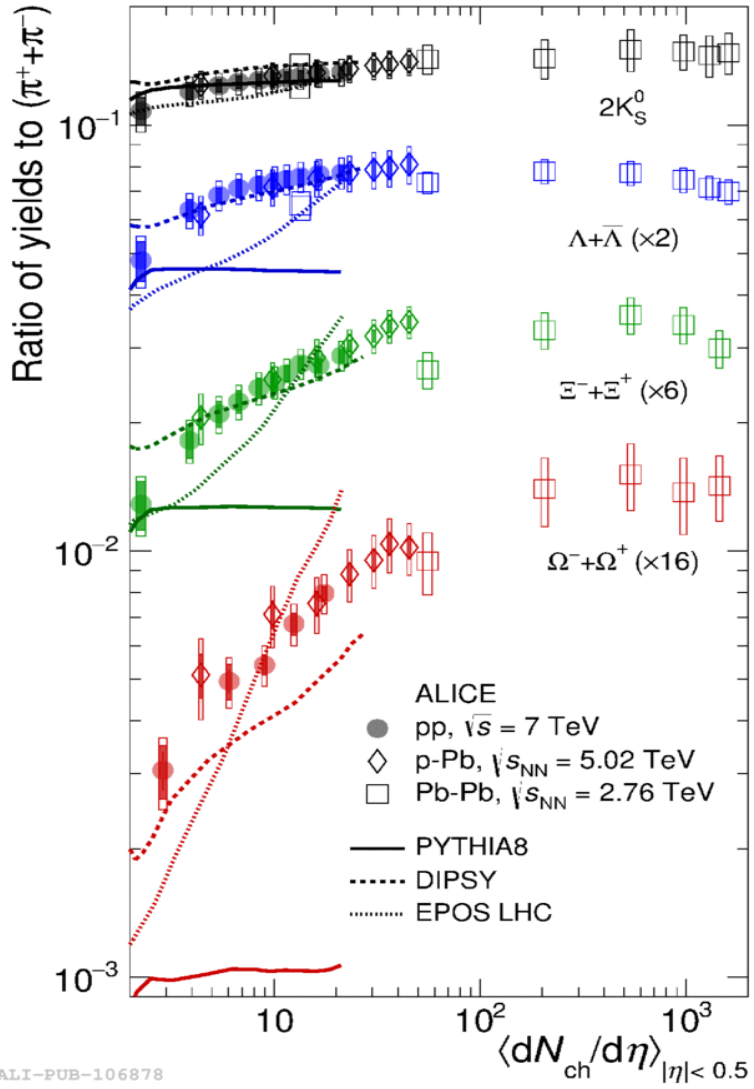


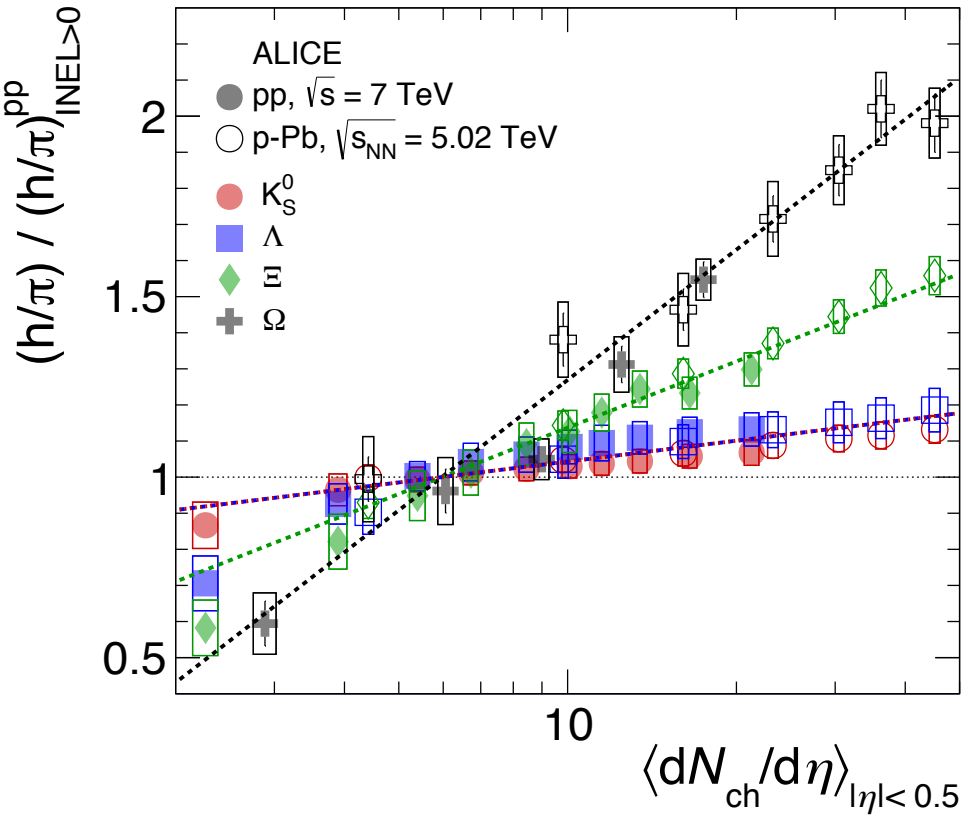
ALICE, Nature Phys. 13, (2017) 535

- Strangeness Enhancement in pp data, where no QGP expected.
- Models fail to describe observed enhancement.
- Charged particle density scales strangeness enhancement measured in different systems and different energies.

New Paradigm

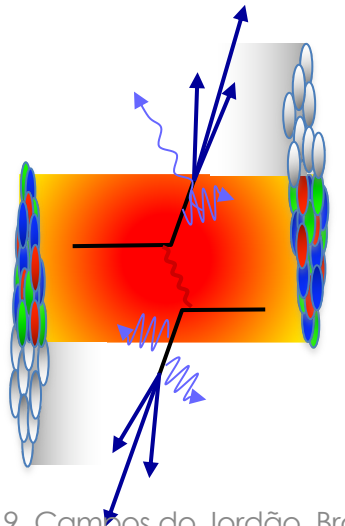
ALICE, Nature Phys. 13, (2017) 535





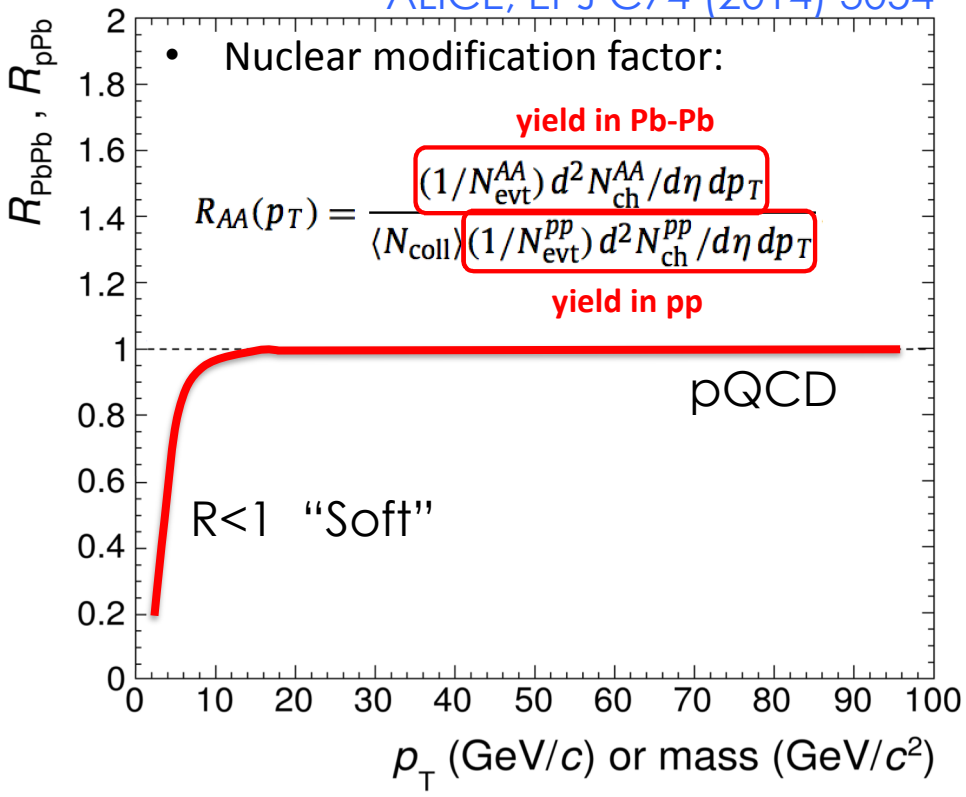
Some of the observables

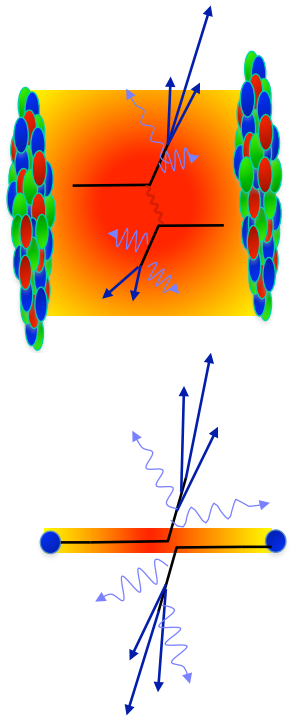
1. Thermal QCD Matter.
2. Bulk particle production.
3. Jet-medium interactions.
4. Heavy flavor.



Parton Energy Loss

ALICE, EPJ C74 (2014) 3054



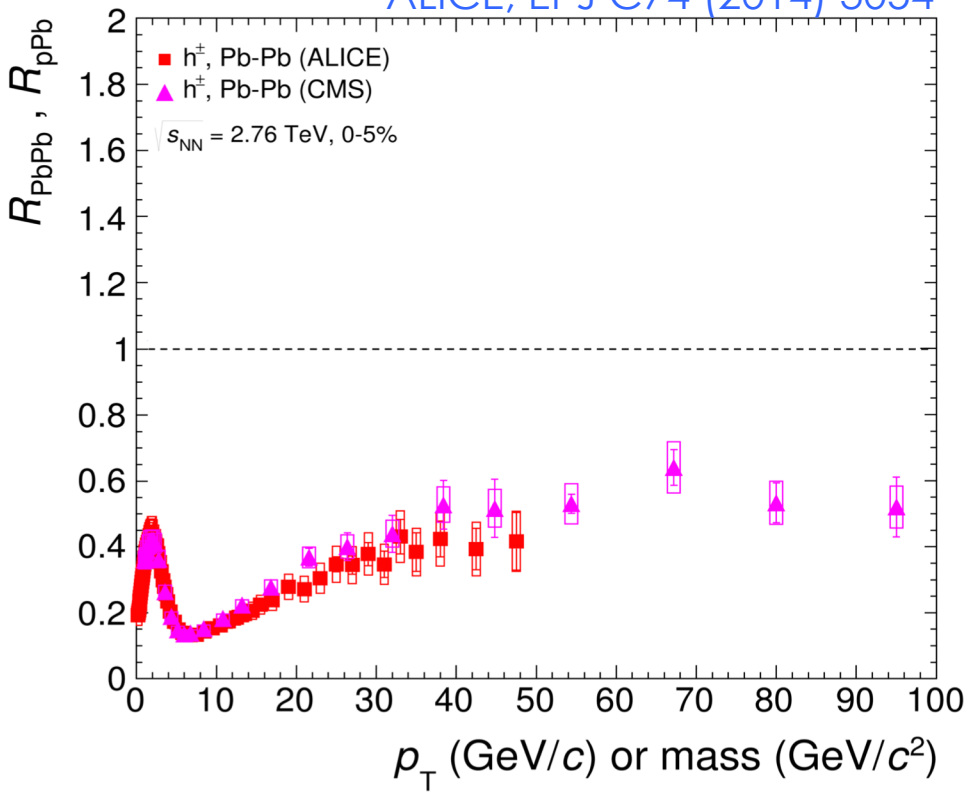


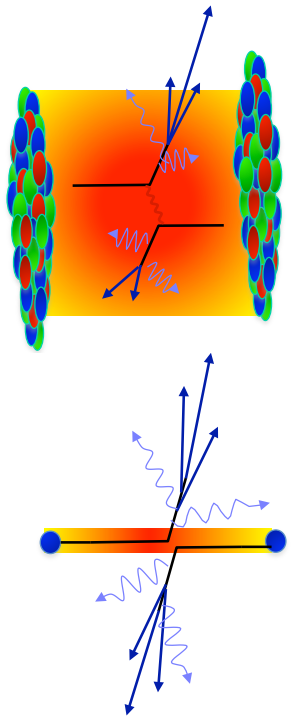
Parton energy loss to medium results in depletion of high-p_T hadrons.

Medium is highly opaque to colored probes.

Parton Energy Loss

ALICE, EPJ C74 (2014) 3054





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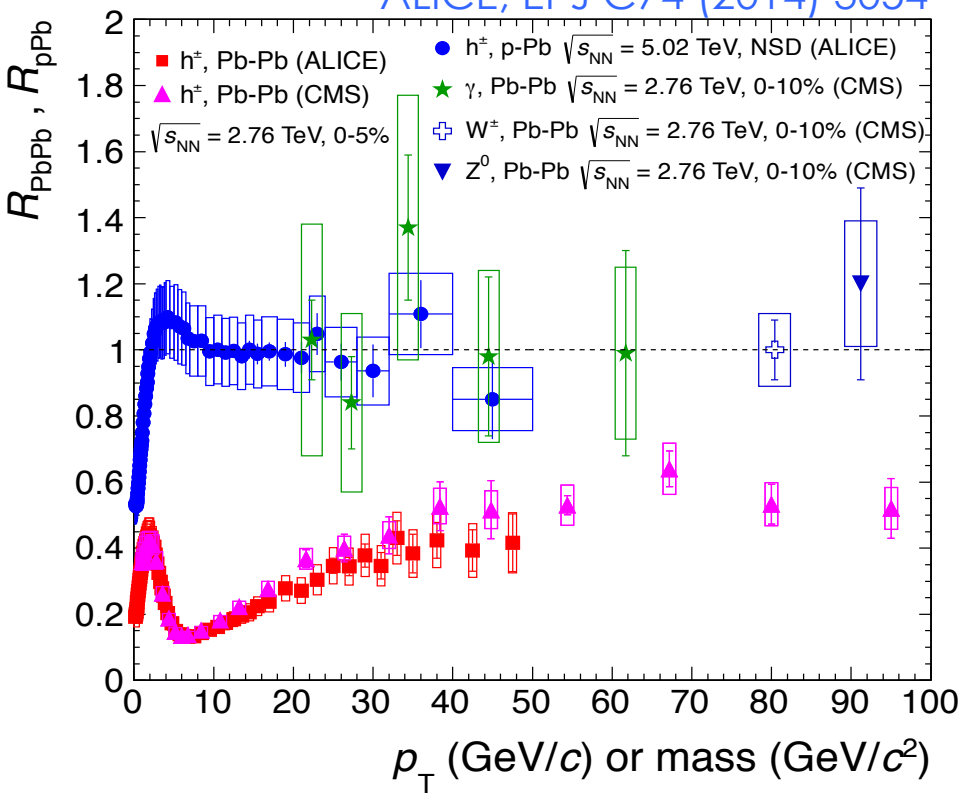

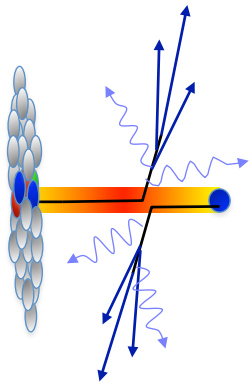

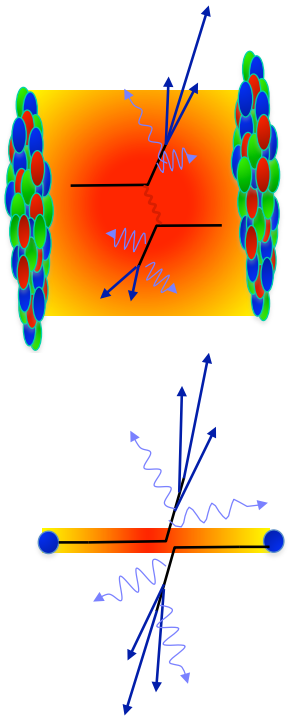

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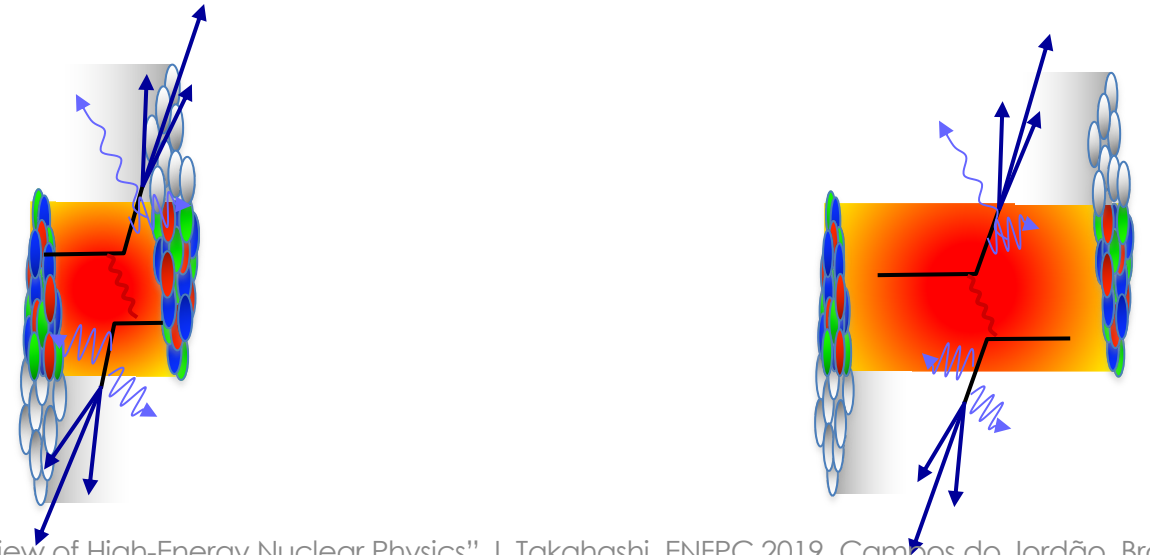
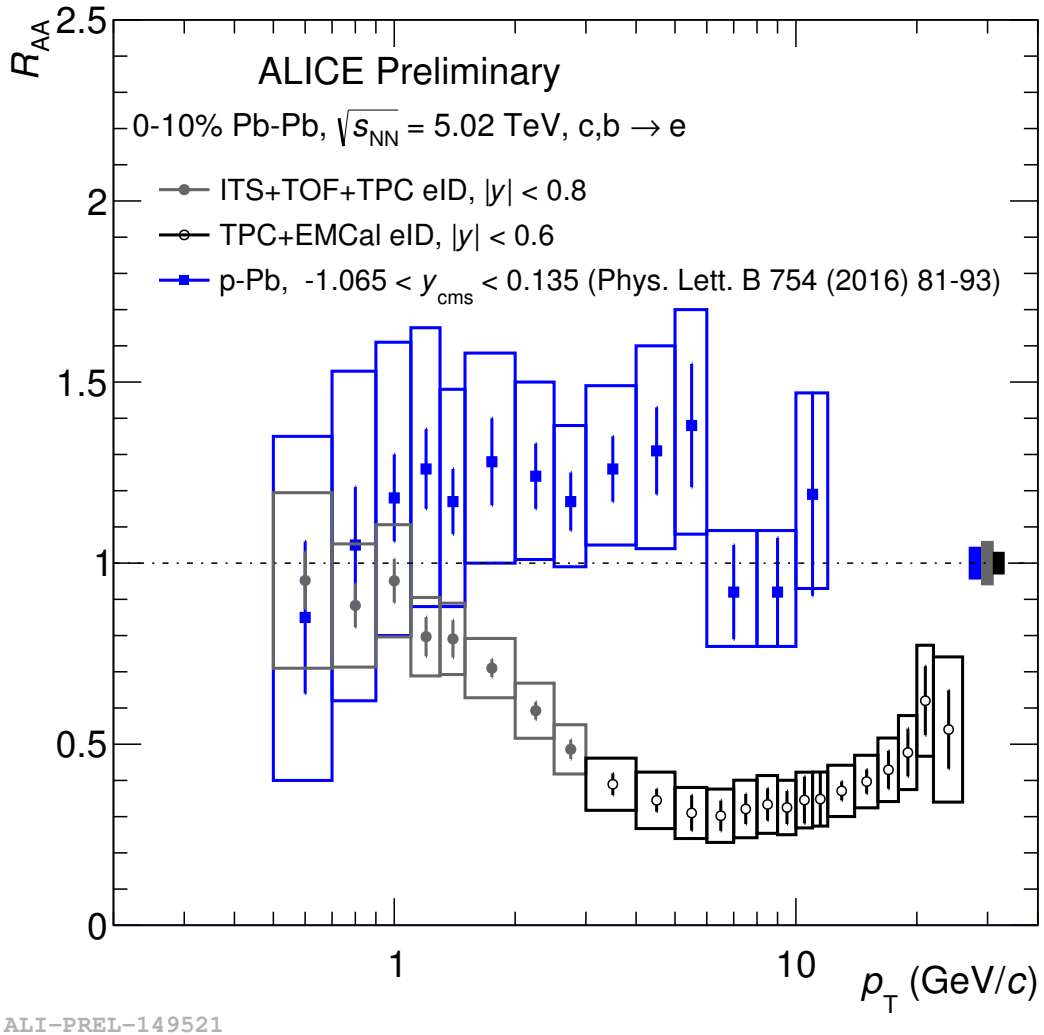


Suppression includes Heavy Flavor



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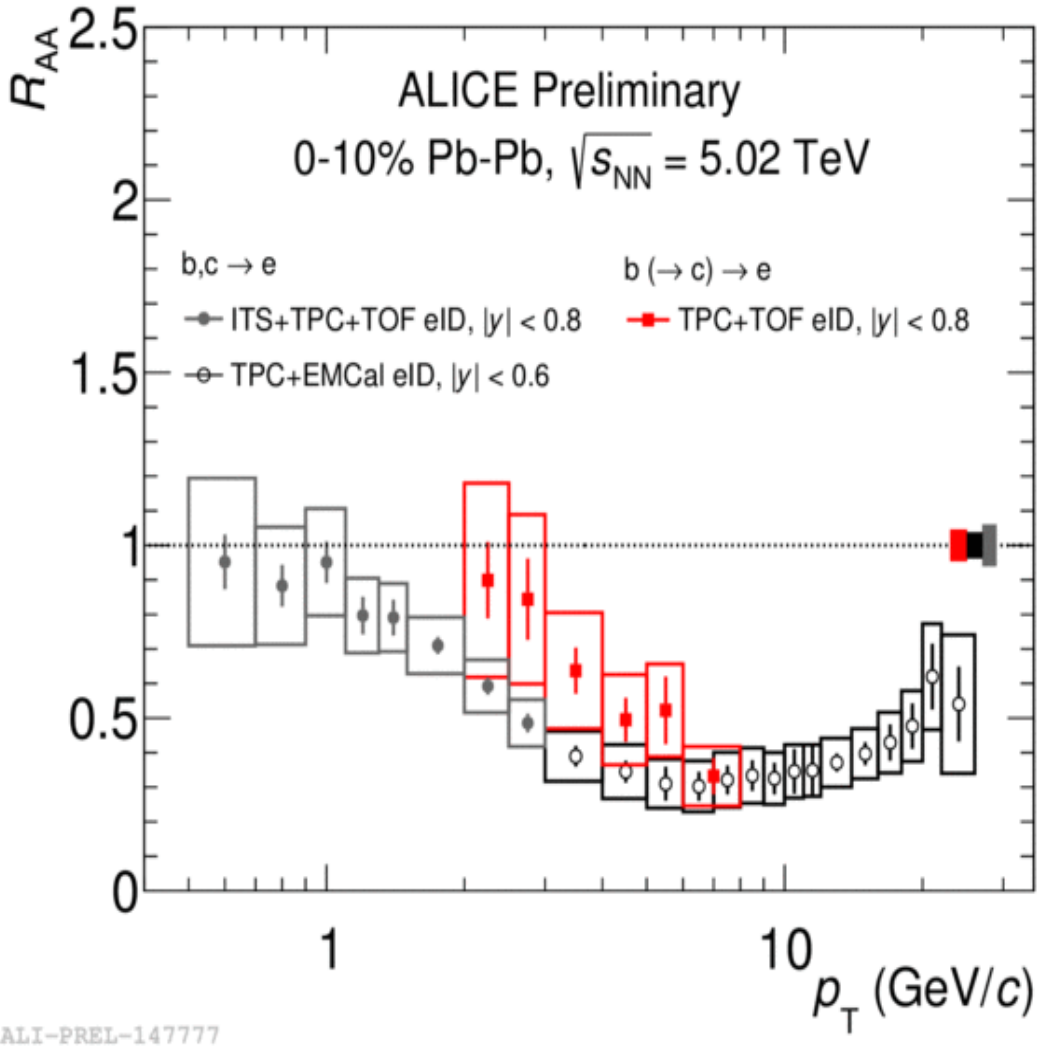
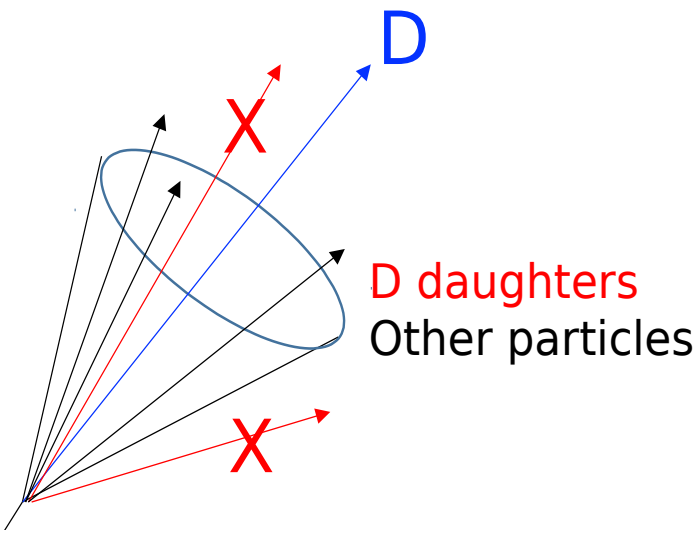


Smaller suppression of beauty than beauty+charm.

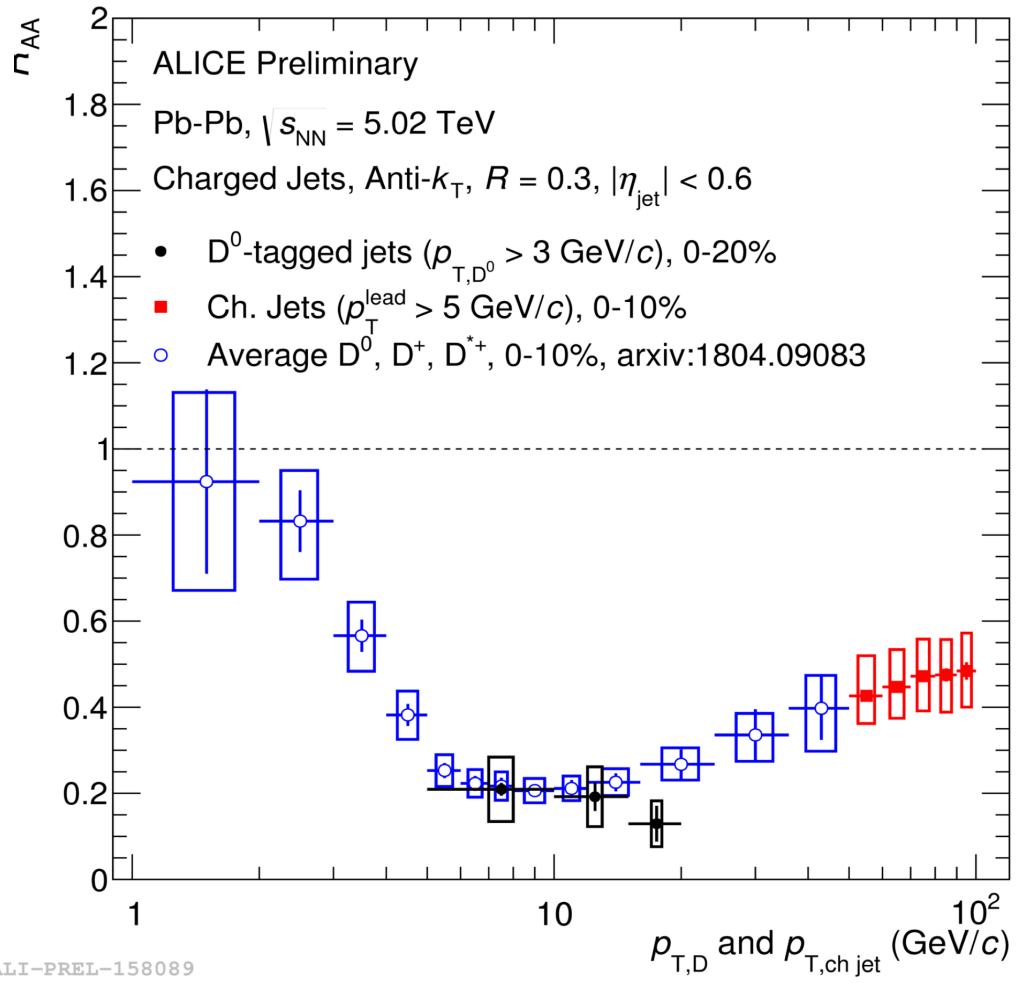
See L. Vieira's talk on Thursday

Suppression includes Heavy Flavor



- D-meson tagged jets in pp and Pb-PB
- Similar suppression trend found for D_0 tagged jets as f inclusive full jets and D_0 mesons at lower p-

See F. Canedo's talk on Thursday



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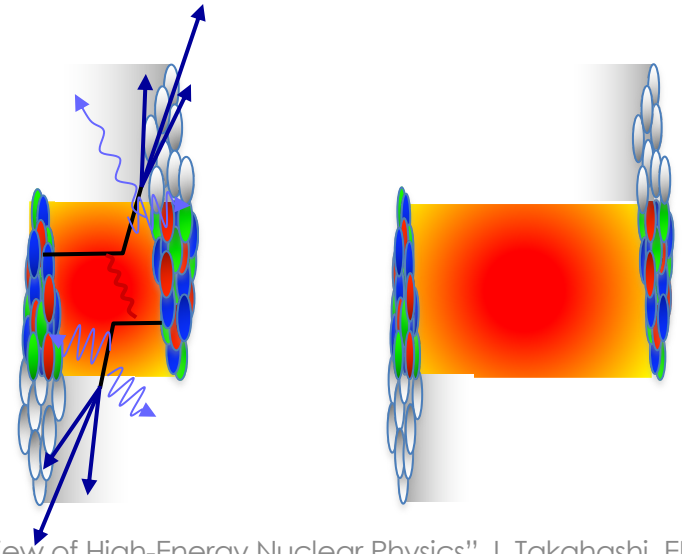
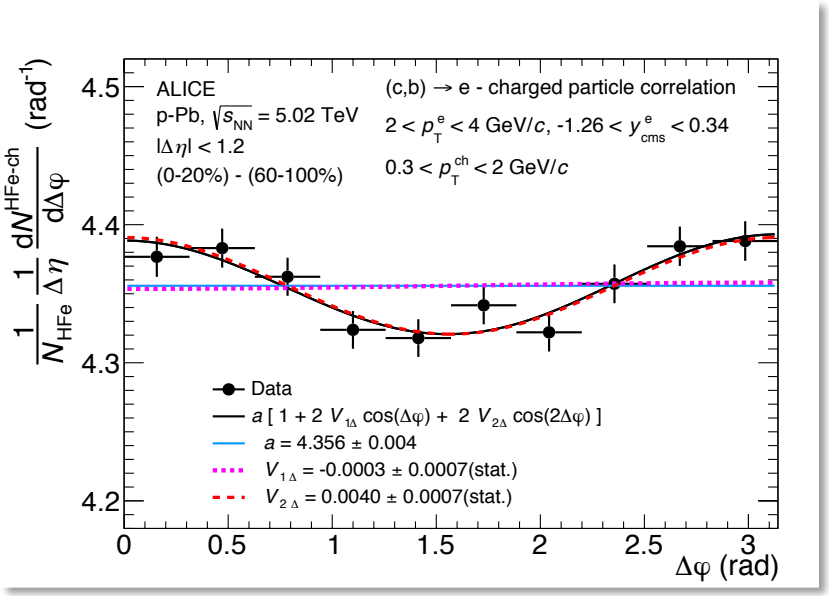
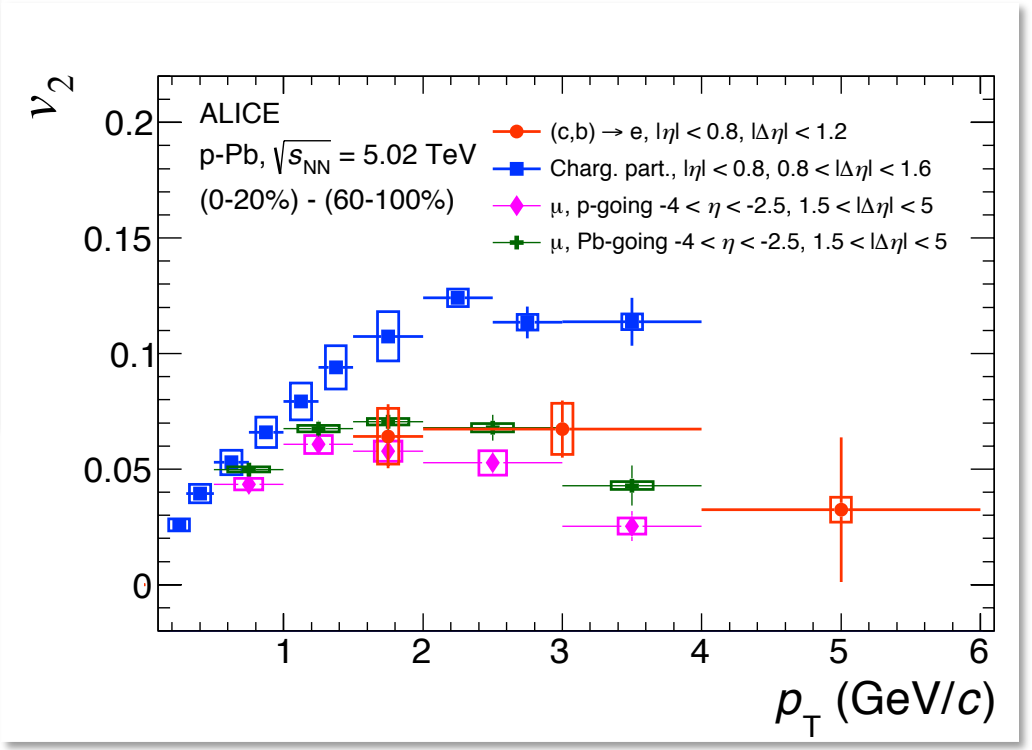


Flow of Heavy Flavor





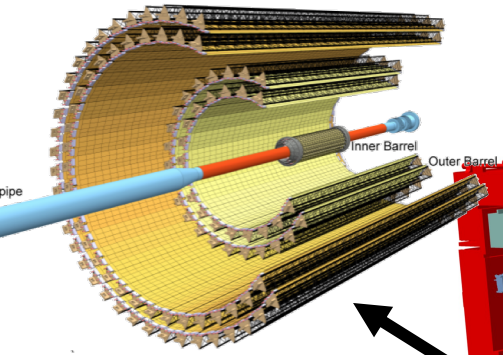
Heavy-Flavor Flow in p-Pb

Key to understand azimuthal anizotropies in small systems.

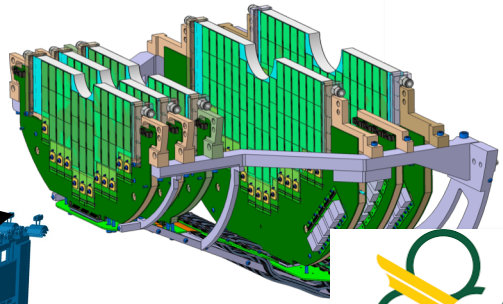
Phys. Rev. Lett. 122, 072301 (2019)

(some of) the future: ALICE after 2020

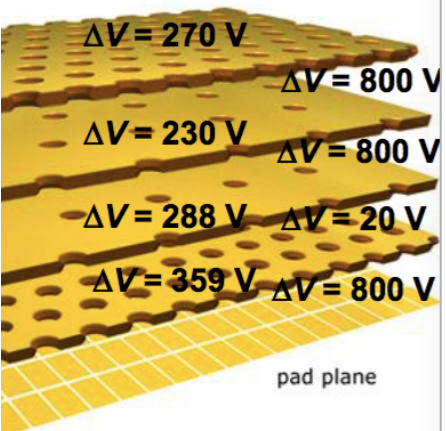
Monolythic-pixel Inner Tracking System



Pixel Muon Forward Tracker



GEM-based TPC readout



See C. Reckziegel's Poster

IFUSP Instituto de Física da USP

UNICAMP

UFABC

UFRGS

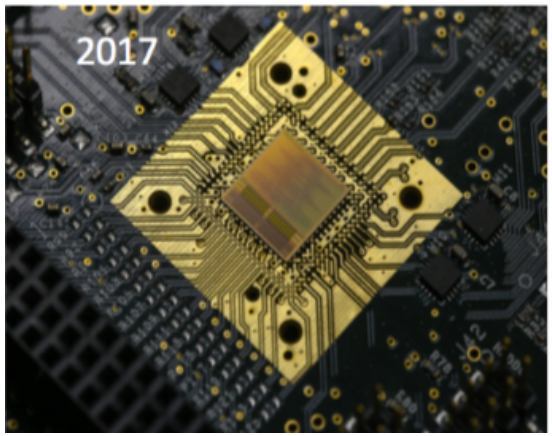
… and much more:

- Fast Interaction Trigger
- New Online-Offline system
- Readout upgrade of several detectors

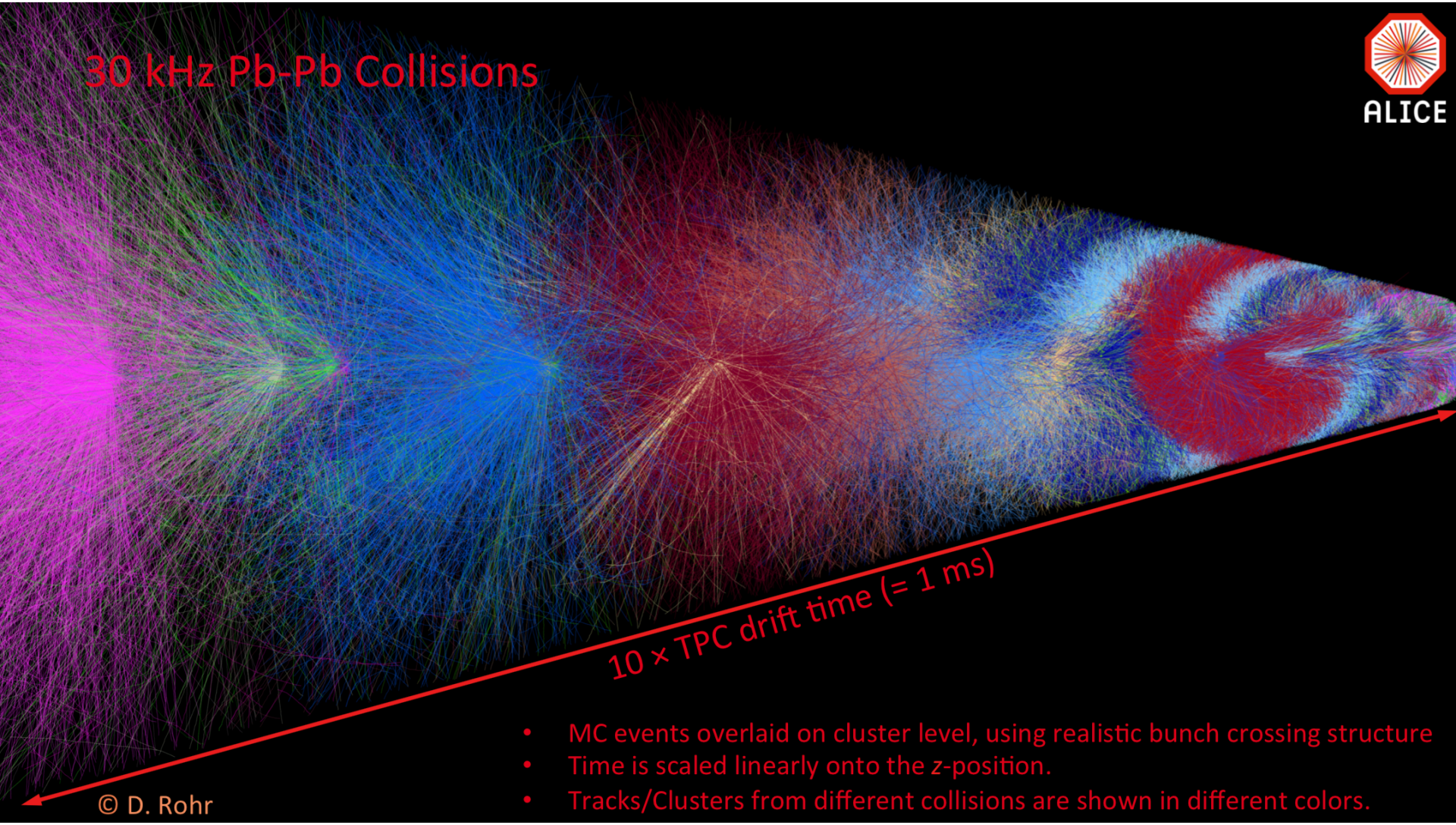
The bright ALICE future

- Un-triggered data sample, with capability to save all Pb-Pb interactions at 50 kHz.
  - New TPC readout, GEM + SAMPA chip.
  - New Inner Tracking System (ITS).
  - Integrated Online-Offline system (O^2).
- Improve tracking efficiency and resolution at low-p_T.
  - TPC upgrade.
  - New Inner Tracking System (ITS).
- New PID detectors.

See M. Bregant's talk on Tuesday



The bright ALICE future



An overview of High-Energy Nuclear Physics in Brazil

IFUSP Instituto de Física da USP

E814

E864

E896

STAR

PHENIX

ALICE

UNICAMP

unesp UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"

CMS Compact Muon Solenoid

UFRGS

UFABC

- **< 1995:** E864 participation / IFUSP
- **1995-2000**:
  - IFUSP joins E896: search for the H-dibaryon
  - IFUSP joins STAR
  - IFUSP joins PHENIX
- **By the year 2000**: participation in STAR intensifies
- **2005**: IFUSP joins ALICE
- **2005**: UNICAMP group started: STAR+ALICE
- **2009:** UNESP joins CMS (heavy ions)
- **2015:** UFRGS joins ALICE
- **2018**: UFABC joins ALICE