Study of in-medium radiation of quarks and gluons + few practical notes by ERC grant applicant

Martin Spousta

(Charles University)

What is this about?

- About **10 minutes presentation** of ERC consolidator project (= physics) + some few words about the problematics of **ERC projects** (= annoying grant stuff).
- How did I come to that?
  - By being an opponent ...

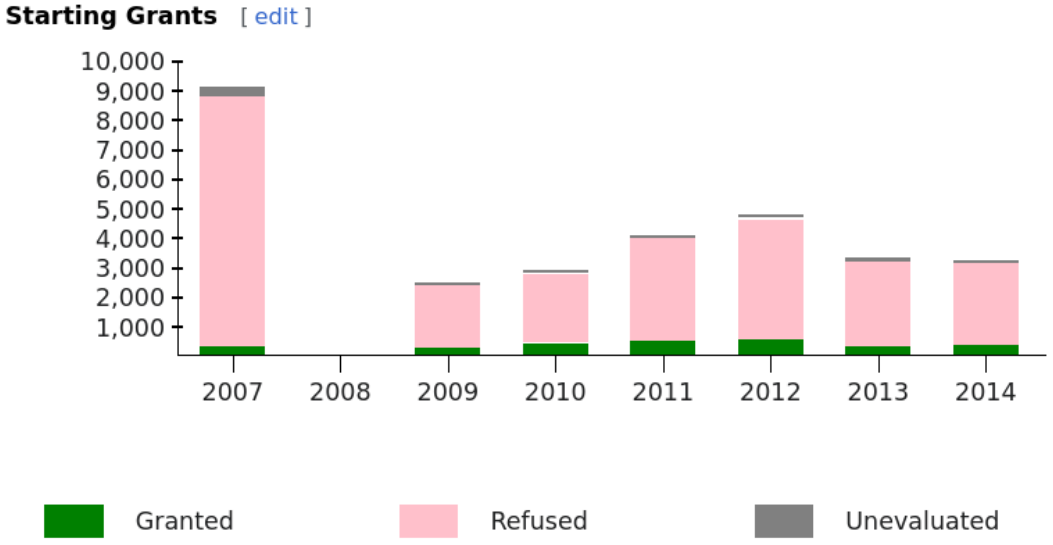
What is ERC?

- **ERC** = European Research Council = science founding body of EU. It offers 3 primary grant schemes:

Name	Qualifications	Max. funding	Aim
Primary grants			
Starting Grants	PhD + 2–7 years experience	€1.5 million (+ €0.5 million to cover "start-up" costs)	Supports up-and-coming independent research leaders. This is targeted at promoting early scientific independence of promising talent.
Consolidator Grants	PhD + 7–12 years experience	€2 million (+ €0.75 million)	Supports researchers at the stage at which they are consolidating their own independent research team or programme.
Advanced Grants	10-year excellent scientific track record	€2.5 million (+ €1.0 million)	Supports researchers who have already established themselves as independent research leaders in their own right.

What is ERC?

- **Logic:** high-risk high gain. **“Refrain”:** Ground braking research.
  => One should have some well known papers.
- Our **panel**: “Fundamental constituents of matter” (PE2): Particle, nuclear, plasma, atomic, molecular, gas, and optical physics
- Average **success rate**: 12%.
- Now running **at MFF UK**: Advanced: 1, Consolidator: 1, **Starting: 5**



What is ERC?

- **Two step** evaluation:
  - 1 step removes vast majority of proposals
  - 2 step: in person interview in Brusel or online in the case of Covid
    - Grade A (=excellent, supported if there is enough money)
    - Grade B (not supported)
- Evaluated by quite few reviewers (e.g. **9 people**)
- **More info**, e.g. https://ec.cuni.cz/EC-121.html … pointers to people who give great help to applicants, namely the group centered around prof. Strakoš.
- … now my presentation for Step 2 (original slides for 10')

In medium radiation of quarks and gluons with the ATLAS detector at the LHC (IMERIA)

Martin Spousta

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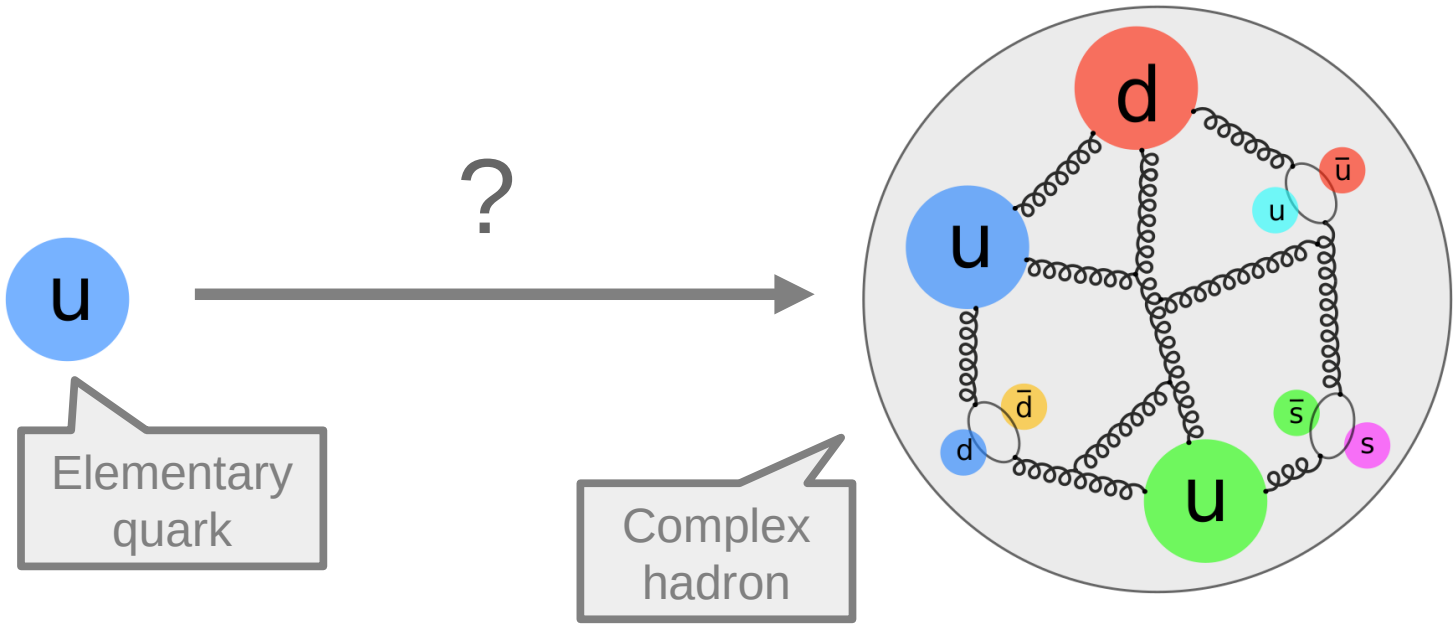
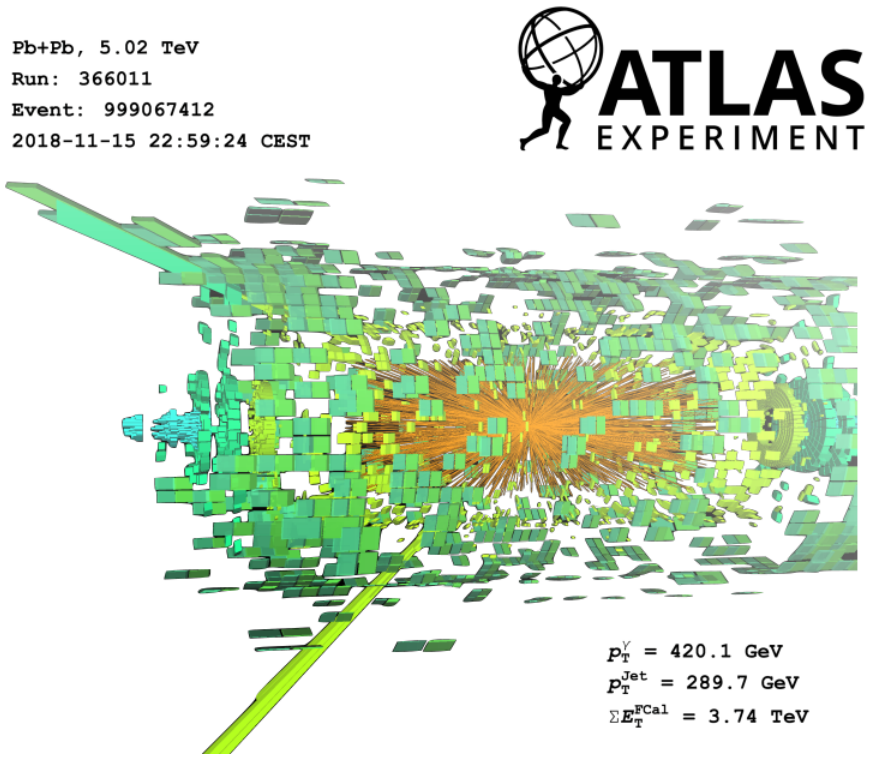
Basic physics picture

- **Strong interaction**:
  - One of four fundamental forces, gives rise to the vast **majority of mass** in observed universe.
  - Successful description by QCD, but still we do not understand various non-perturbative aspects such as **hadron formation.**



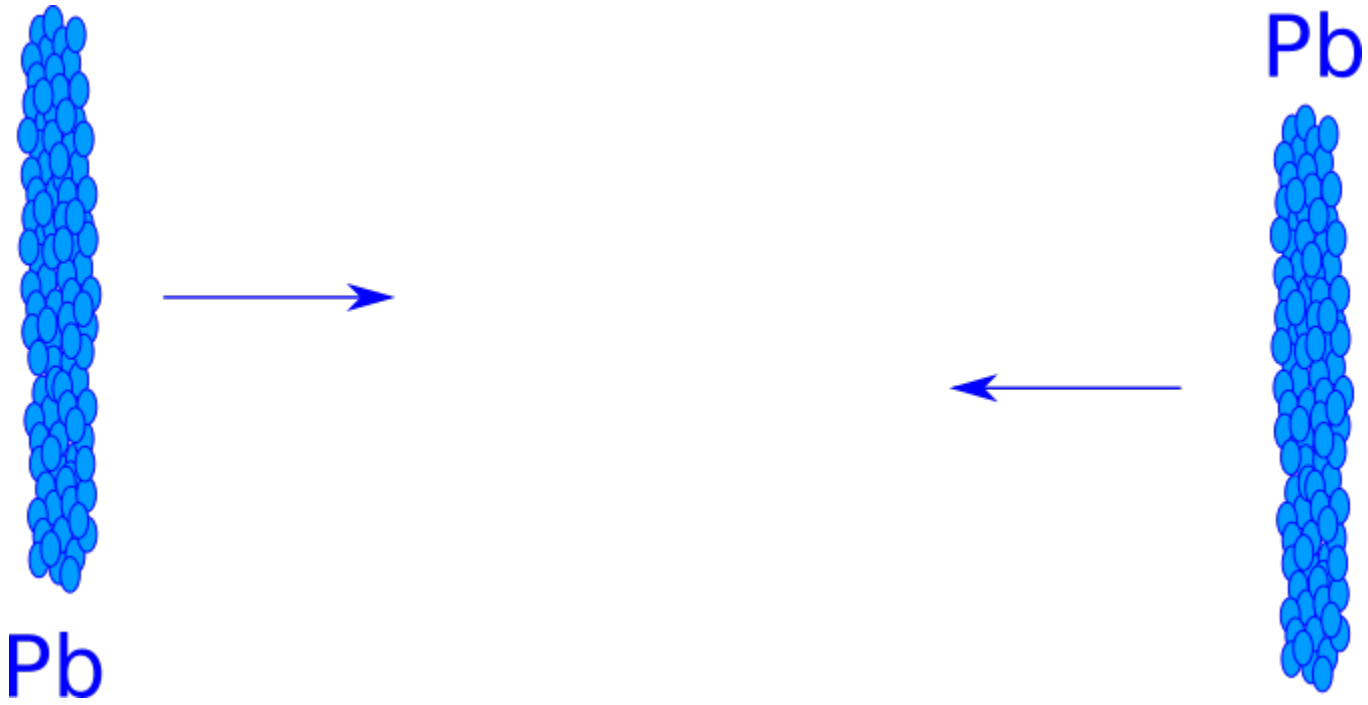
Basic physics picture

- Use **heavy-ion collisions** to study non-perturbative aspects of strong interactions.
- Heavy-ion collisions allow us to:
  - Study **quark-gluon plasma** (QGP) – present in 10^{-6} s after the Big Bang.
  - See how complex phenomena **emerge** from strong interaction (jet quenching, quarkonia suppression, quarkonia formation, ...).



- Perform complex analyses of data from heavy-ion collisions to **close three long-standing open problems** in the field and contribute to general understanding of hadron formation.

In medium gluon radiation



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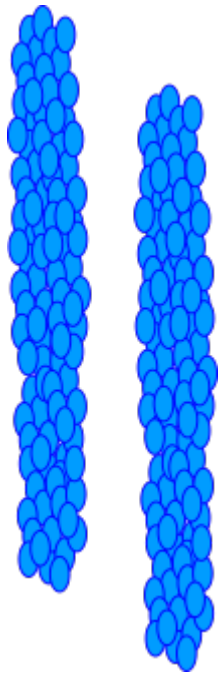

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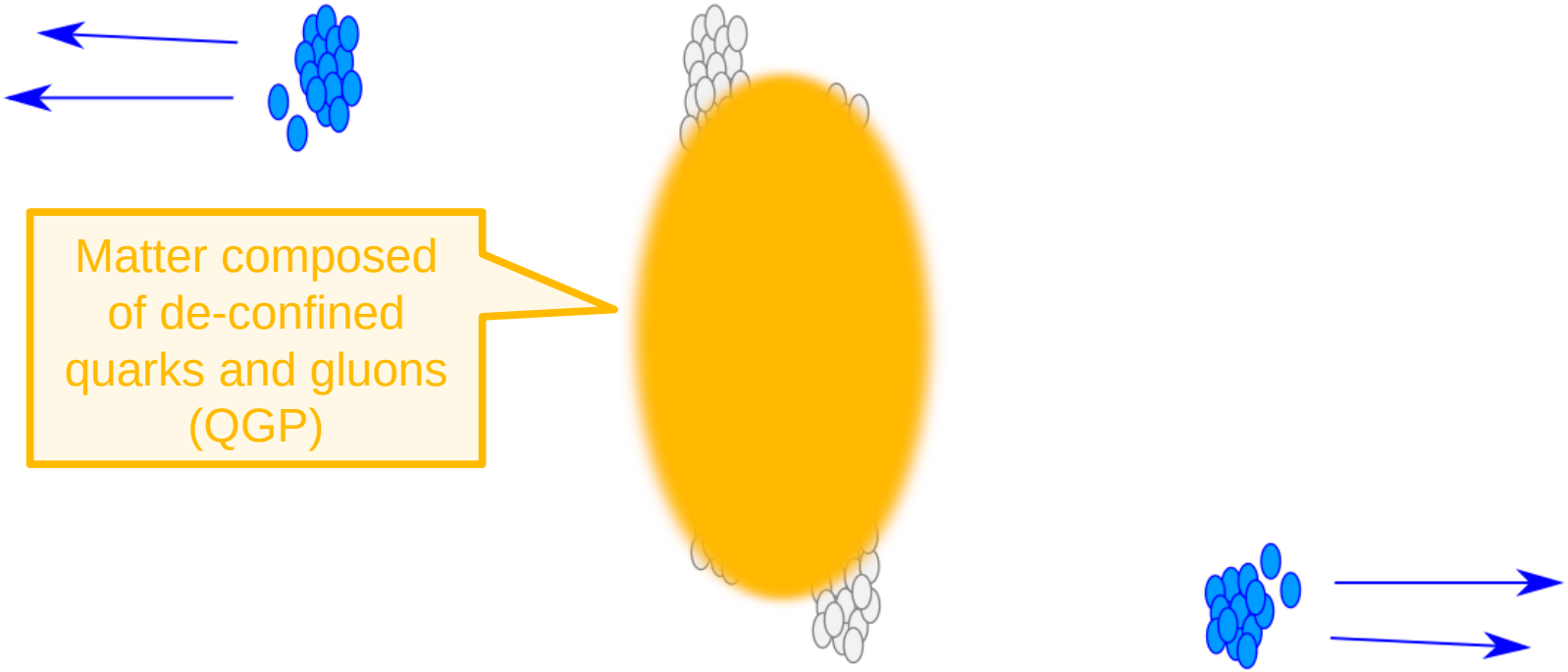

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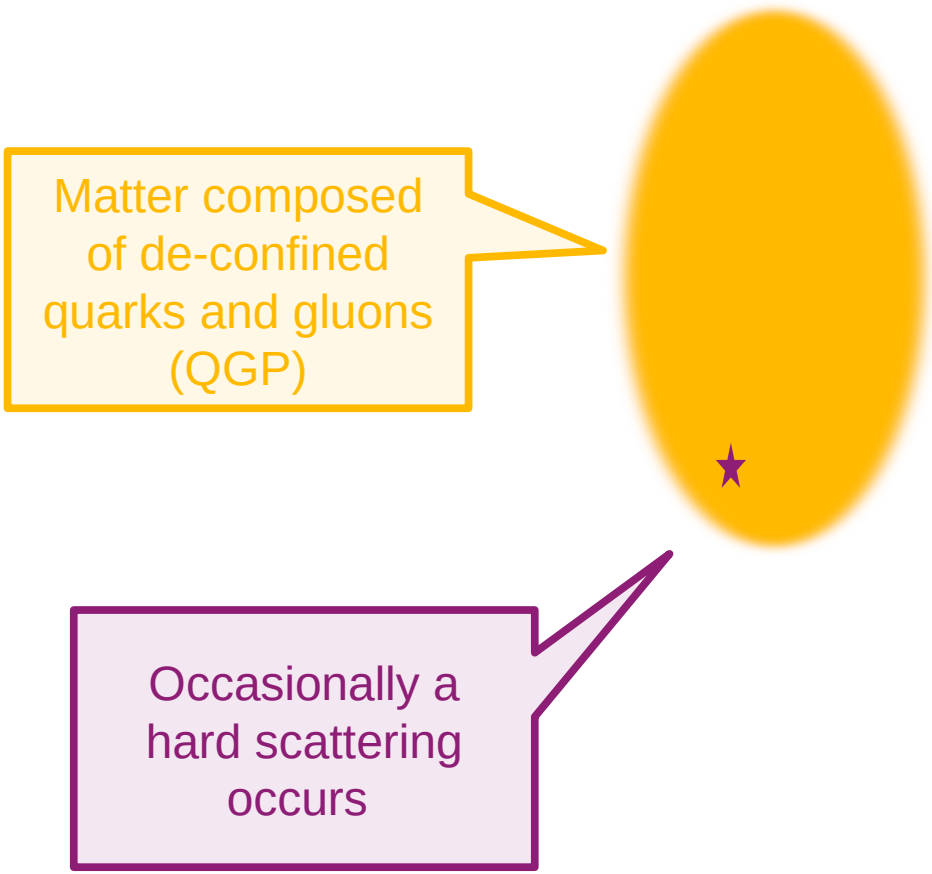
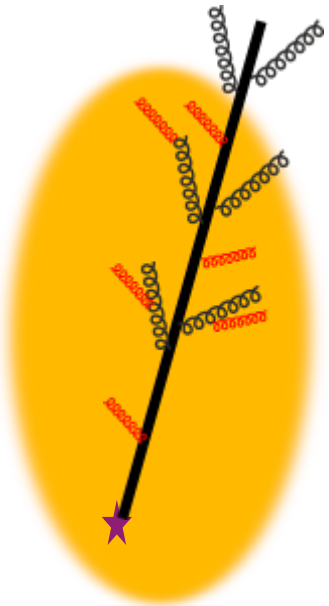


In medium gluon radiation

Shower of quarks and gluons (parton shower) propagates through QGP and suffers medium-induced gluon radiation

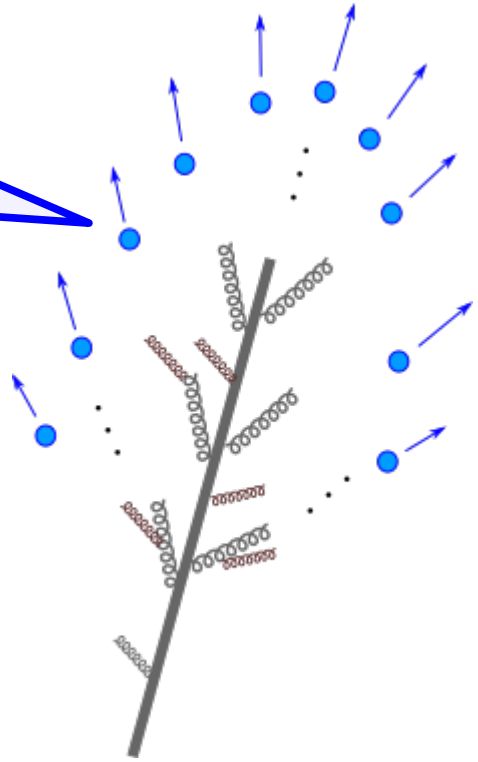


Matter composed of de-confined quarks and gluons (QGP)

Occasionally a hard scattering occurs

In medium gluon radiation

After hadronization, parton shower turns into **jet of hadrons** we observe in the detector



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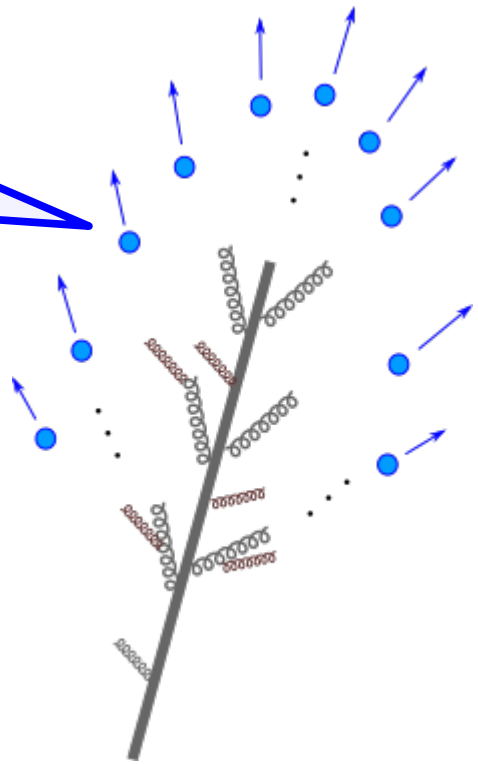

- Jet production is suppressed in heavy-ion collisions (jet quenching).
- Basic quantification by **nuclear modification factor**, R_{AA}:

$$R_{\mathrm{AA}} = \frac{1}{w_{\mathrm{geometry}}} \frac{Yield\,(\mathrm{Pb+Pb})}{Yield\ \ (\mathrm{p+p})}$$

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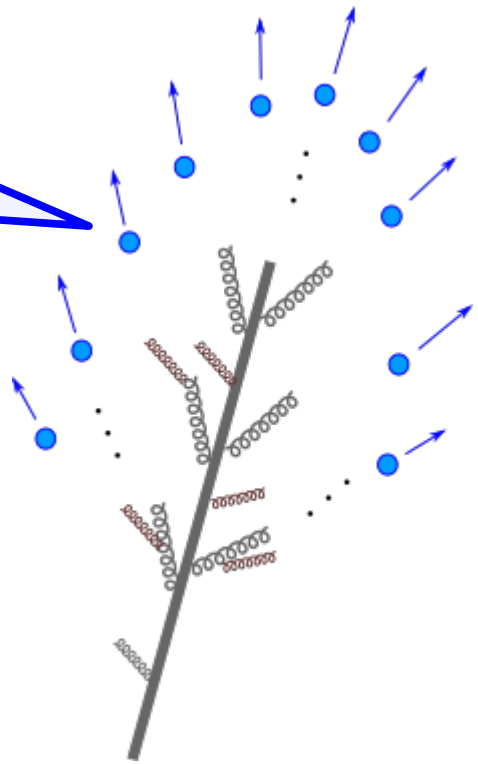

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QCD in medium

QCD in vacuum

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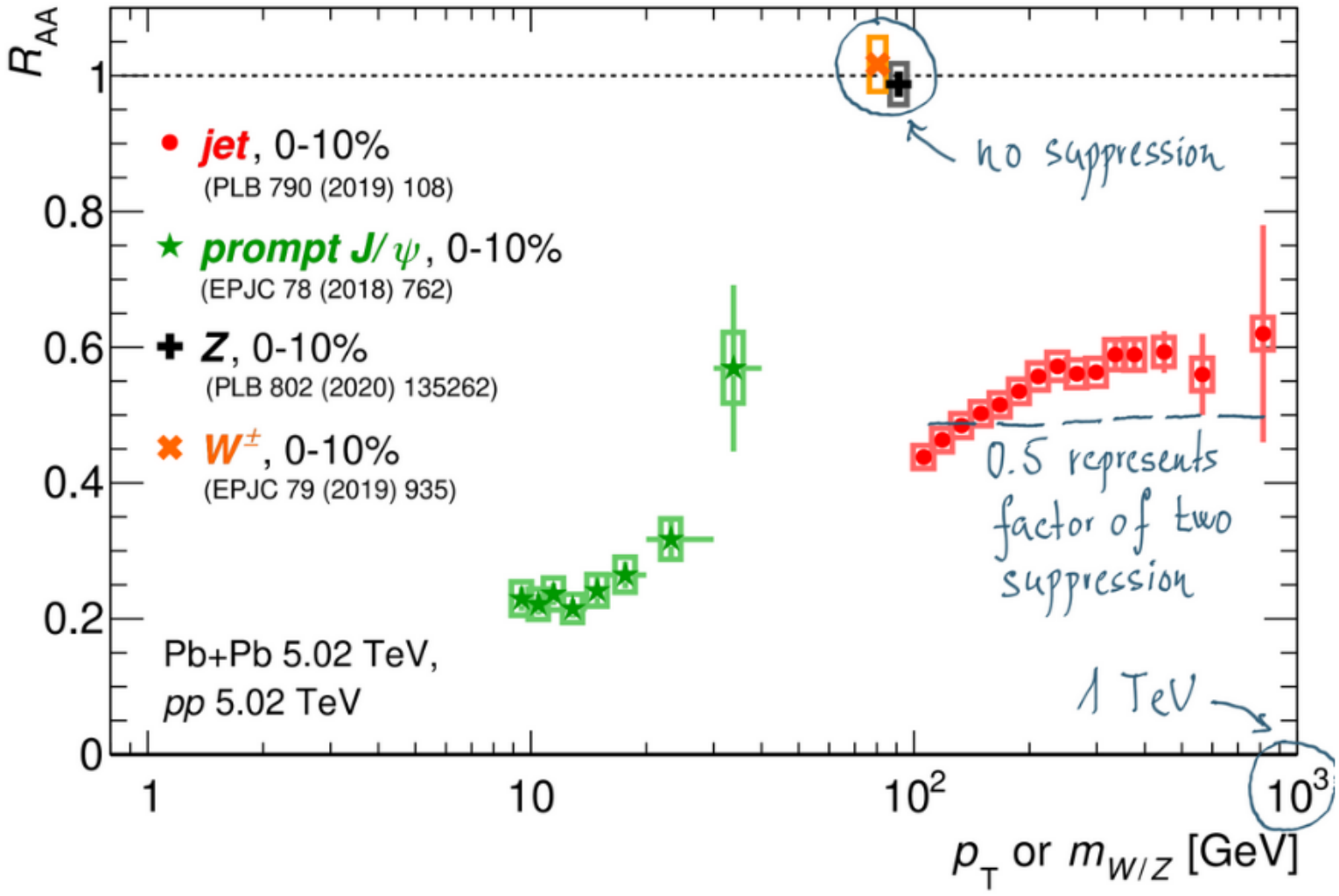
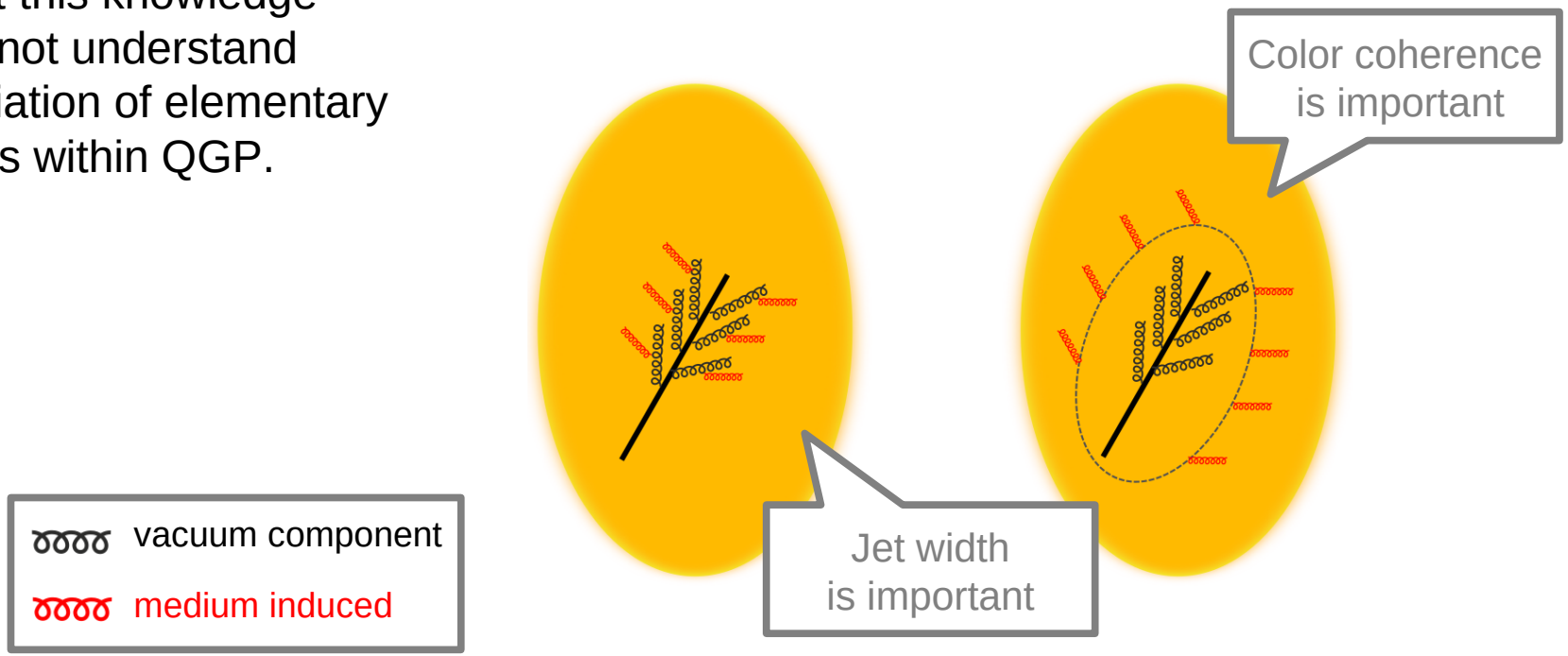


This project

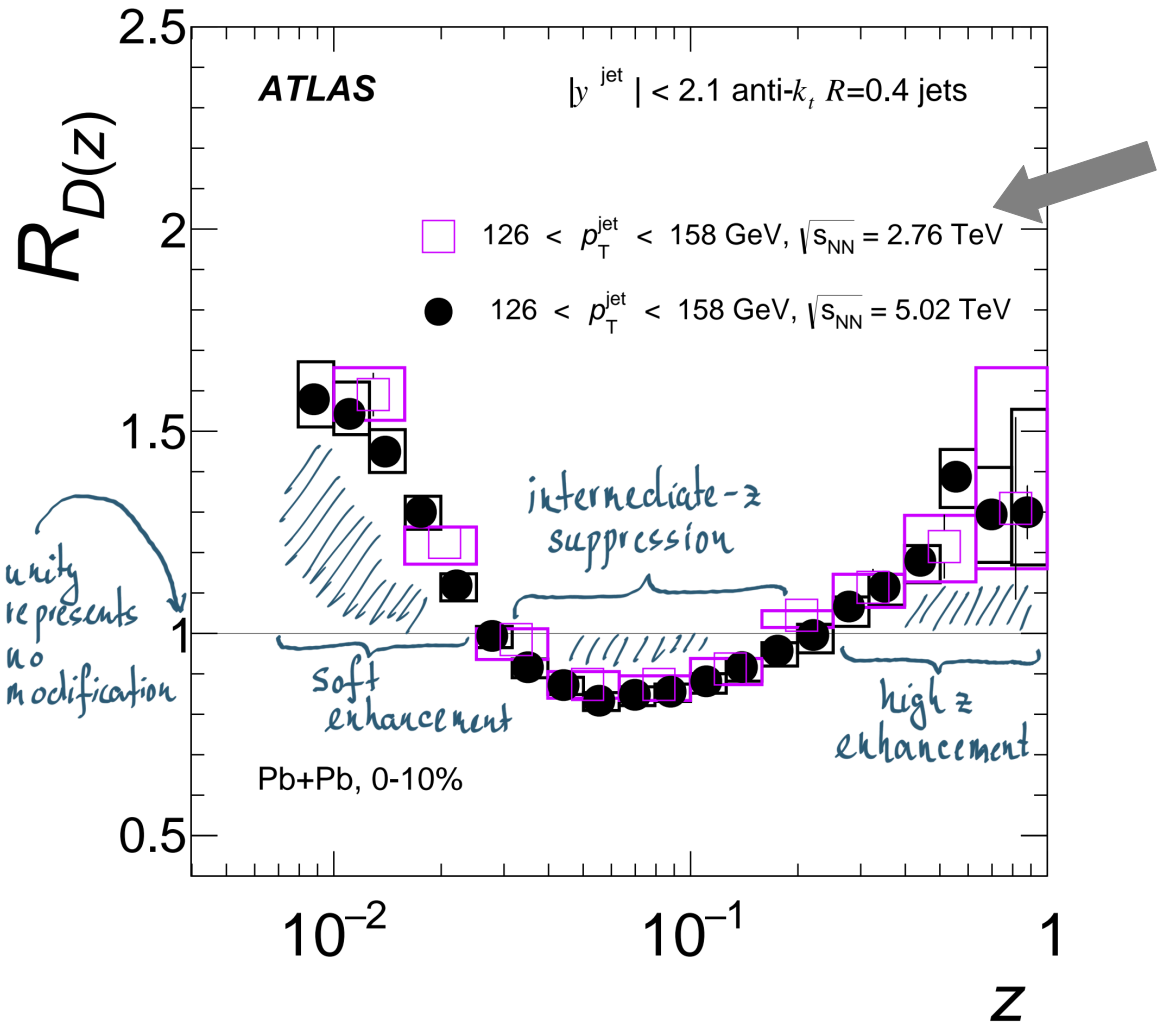
Three objectives will bring answers
to three fundamental questions in the field …

Objective 1: What is the role of color in radiative processes in QGP?

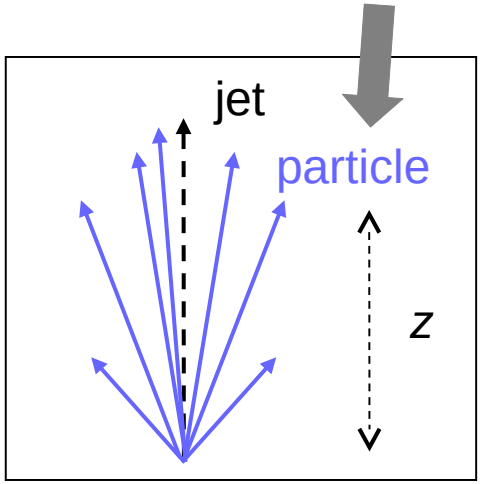
- Perform **detailed scan of jet suppression**.
- Study the correlation of **jet width and jet flavor.**
- => Address the fundamental open problem of identifying **which property of parton shower dictates the magnitude of energy loss** of quarks and gluons.
- Without this knowledge we cannot understand the radiation of elementary particles within QGP.



Objective 3: What is the origin of measured soft particles near jets?



- **Also jet structure is significantly modified.**
- Pb+Pb to *pp* ratio of yields of particles **inside** a jet ...
- … evaluated as a function of momentum fraction *z*.



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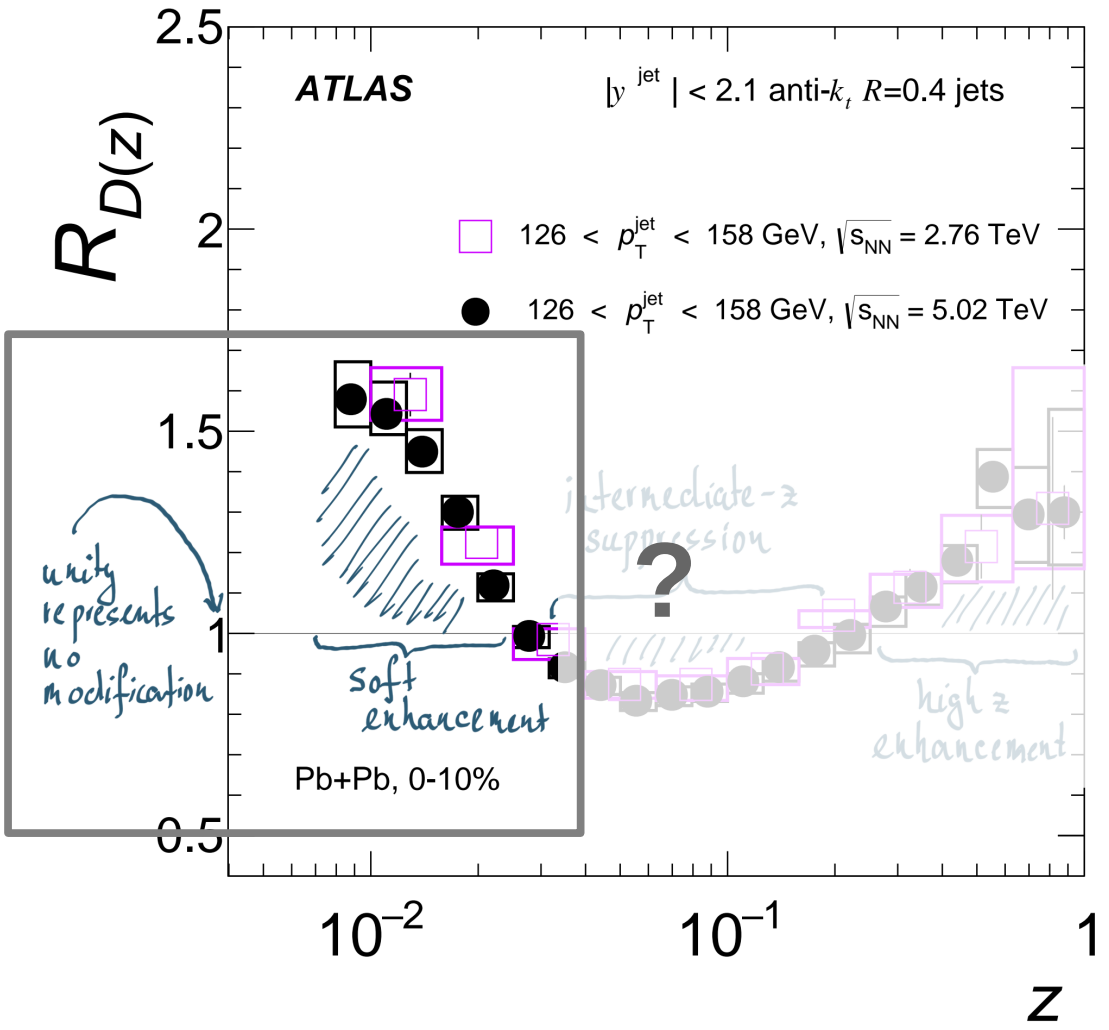
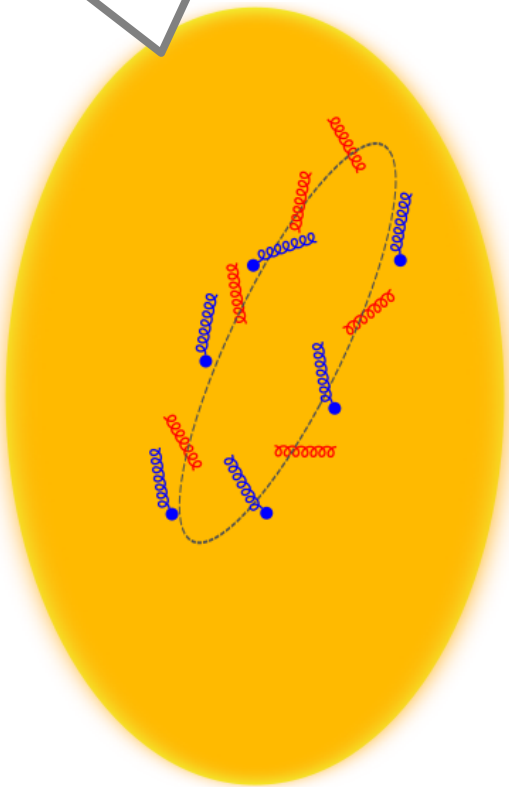


Medium-induced radiation or also excitation of medium?



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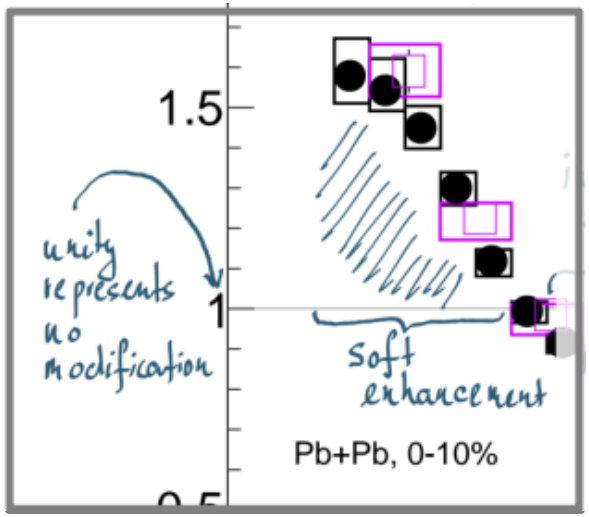

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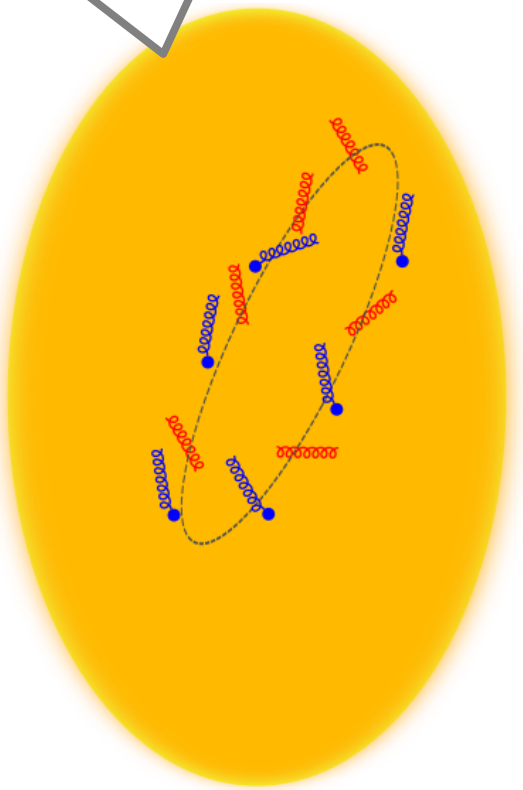


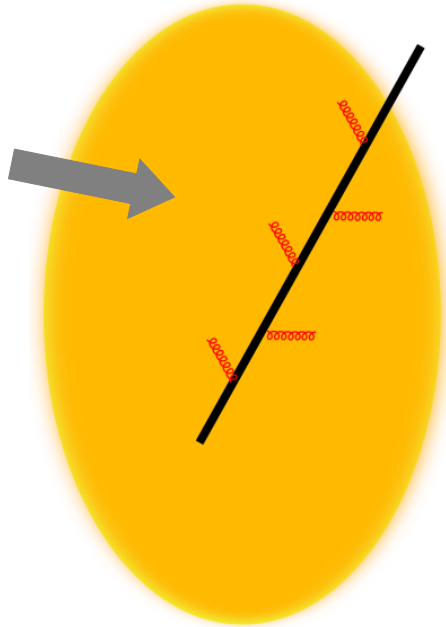
- Study **correlations** between soft modes and other modes.
- **“Chemistry”** of low-*z* particles.
- Precise measurement of **high-*z*** particles.

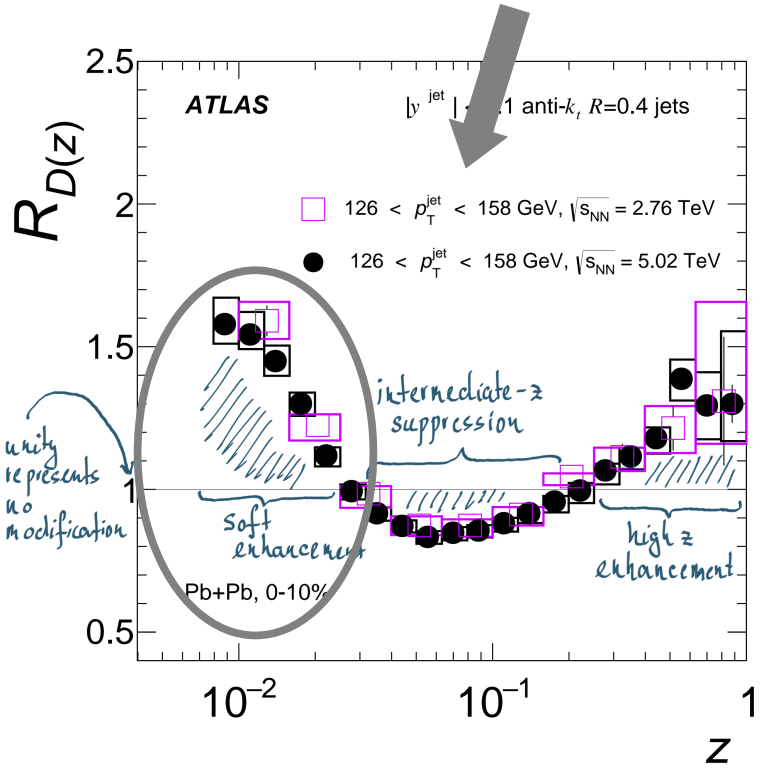
  => **Understand the exact origin of soft radiation in an unambiguous way.**

Objective 2: Do the quarkonia radiate when traversing QGP and can we better understand their formation?

- Quarkonia = 

… **formation** not understood.
- Phenomenological works suggest that **quarkonia may radiate** (M.S. PLB 767 (2017) 10-15, F. Arleo PRL 119(6) (2018), 062302).
- Basic experimental **fingerprint** of parton energy loss:



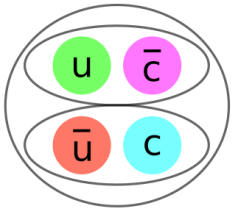


=> Quantify the large angle **soft-particle production near prompt quarkonia.**

Objective 2: Do the quarkonia radiate when traversing QGP and can we better understand their formation?

- **Change of paradigm** in the description of measured suppression at high-p_T.
- **Further**, it will help to understand:
  - Jet **quenching.**
  - **Hadronization** of quarks to quarkonia.
  - Structure of **possible tetra-quark** X(3872) with heavy-ion collisions.

X(3872):



tetraquark

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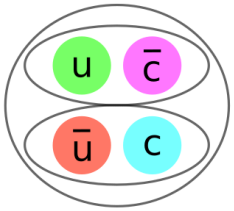

tetraquark

BBC NEWS

Pentaquarks: scientists find new "exotic" configurations of quarks

5 July

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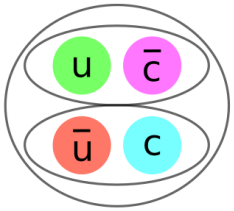
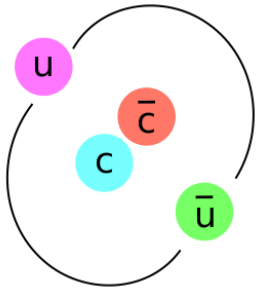


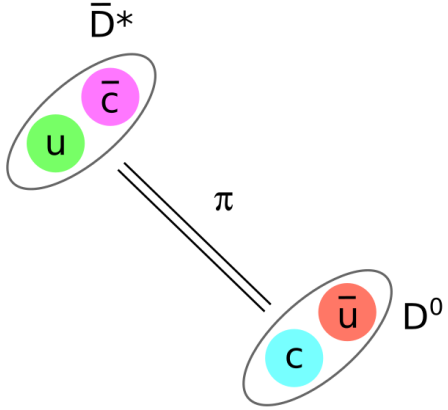
tetraquark

or



“QCD atom”

or



“QCD molecule”

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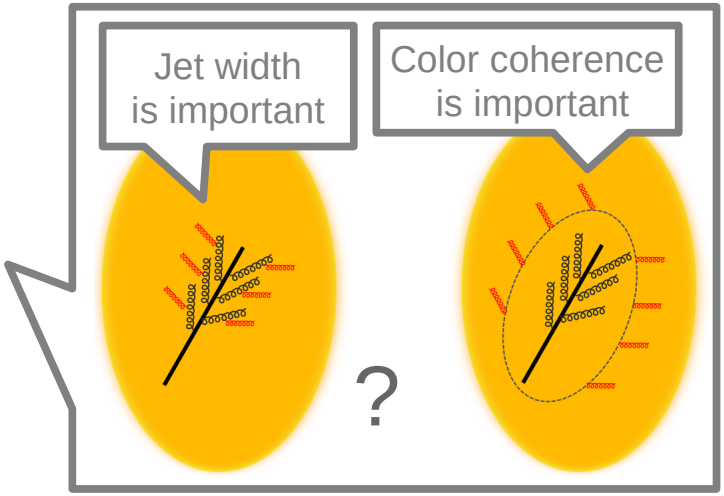
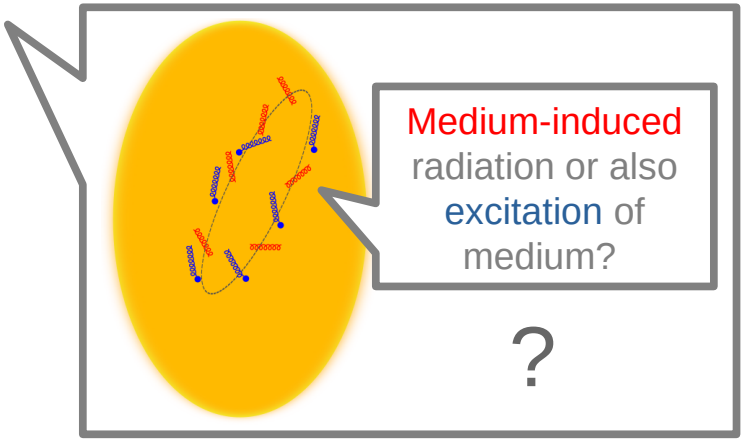
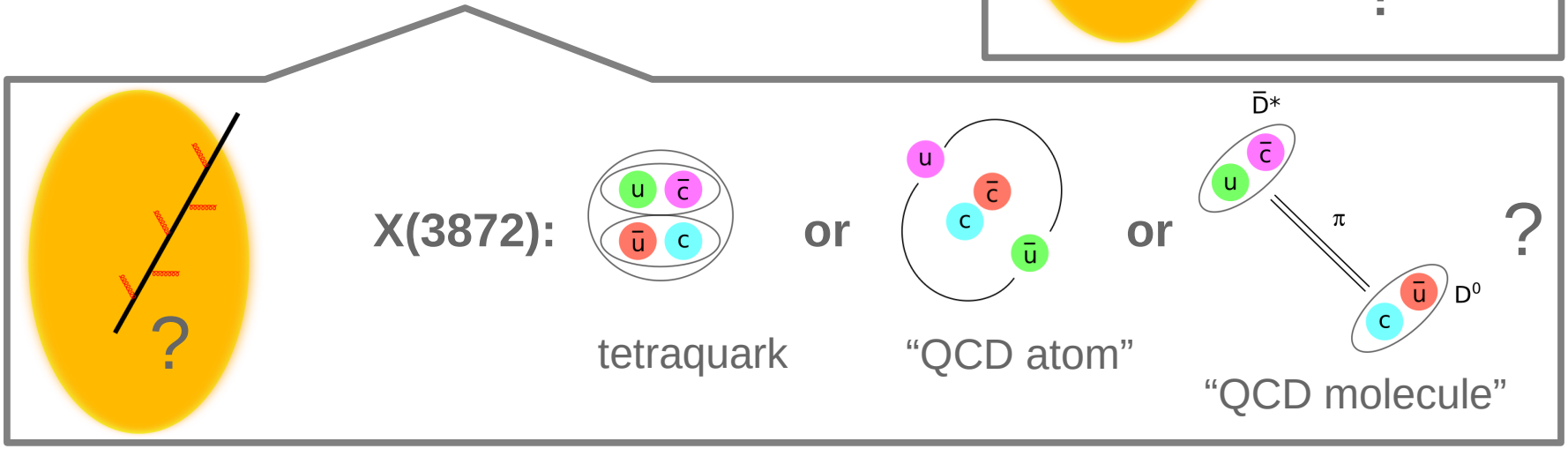
Summary

- What is the role of color in radiative processes in QGP?
- What is the origin of measured soft particles near jets?
- Do the quarkonia radiate when traversing QGP and can we better understand their formation?







BACKUP SLIDES