International opportunities: Large Hadron Collider

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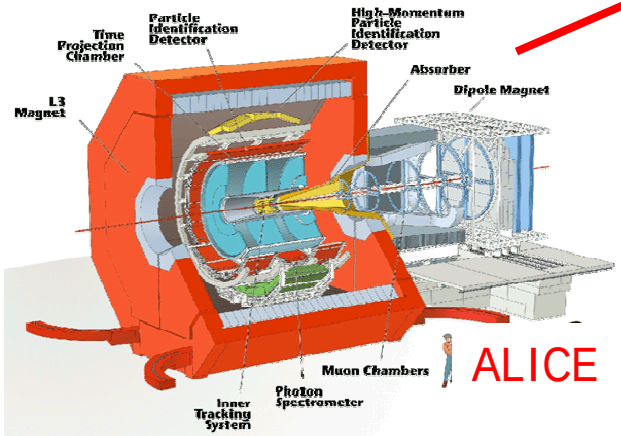
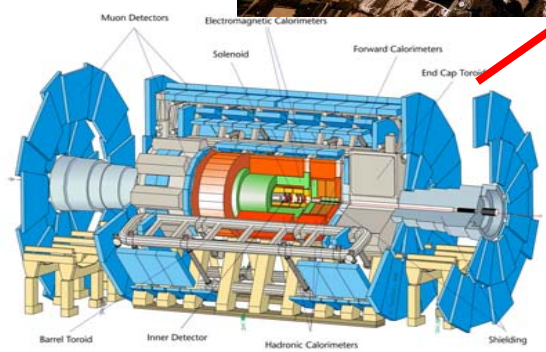
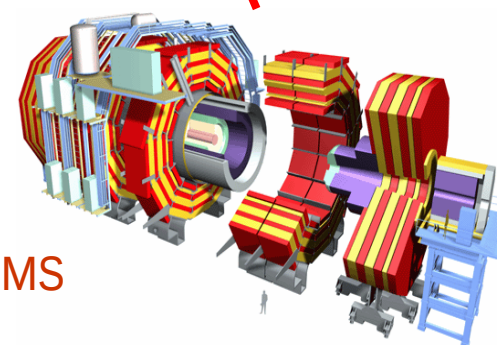


ALICE



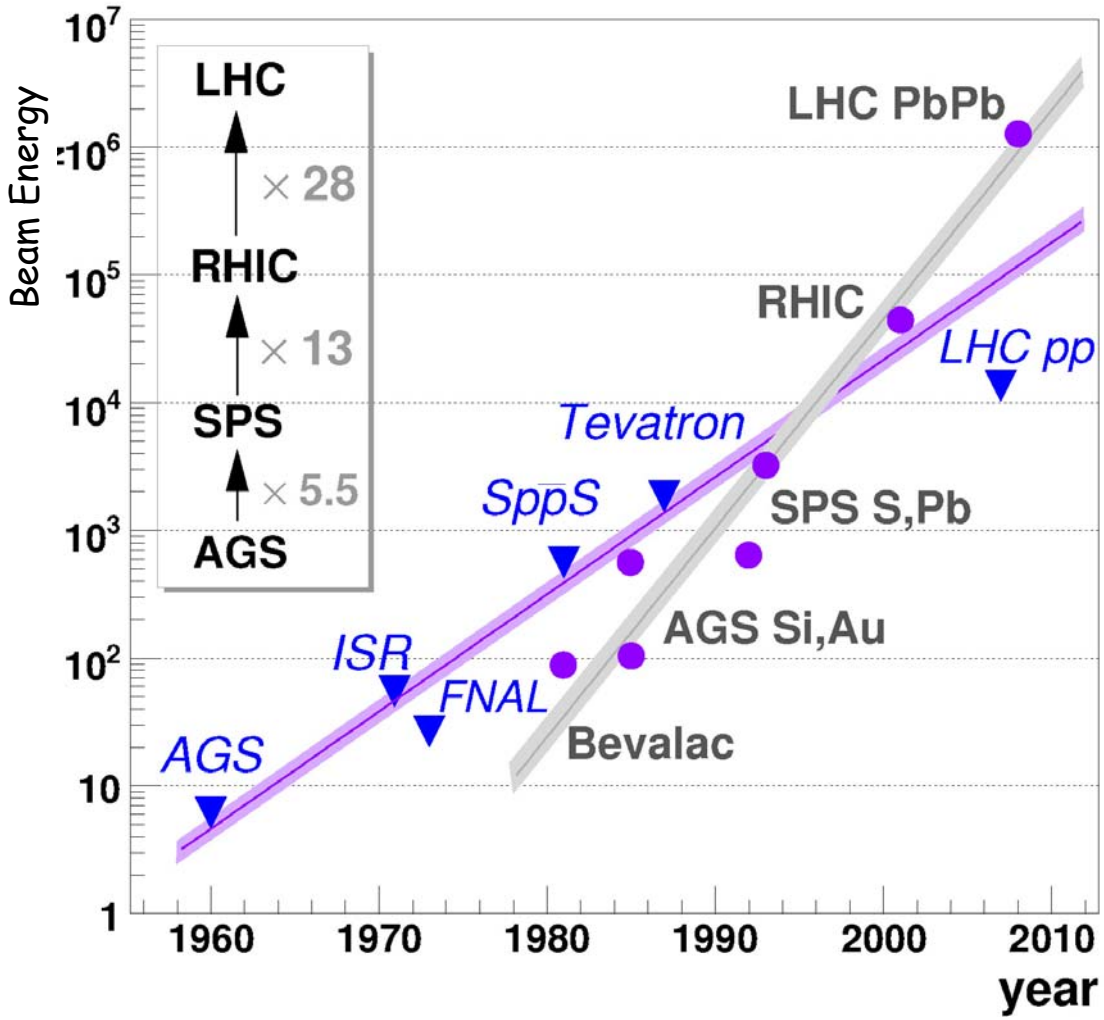
ATLAS



CMS

Large Hadron Collider

- **LHC is about to start operations:**
  - **2007:**
    - proton-proton collisions at ~1 TeV
  - **2008:**
    - p+p at 14 TeV
    - Pb+Pb at 5.5 TeV per nucleon pair
- **Heavy Ions**
  - **Expect ~1 month of heavy ion collisions each year**



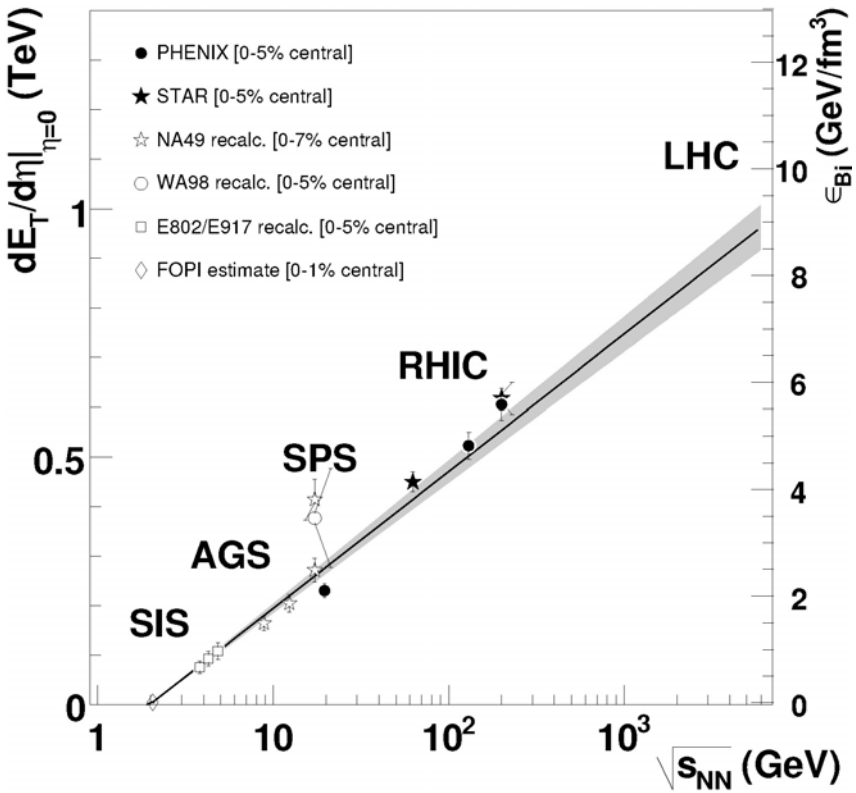
Hot and Dense Matter at LHC

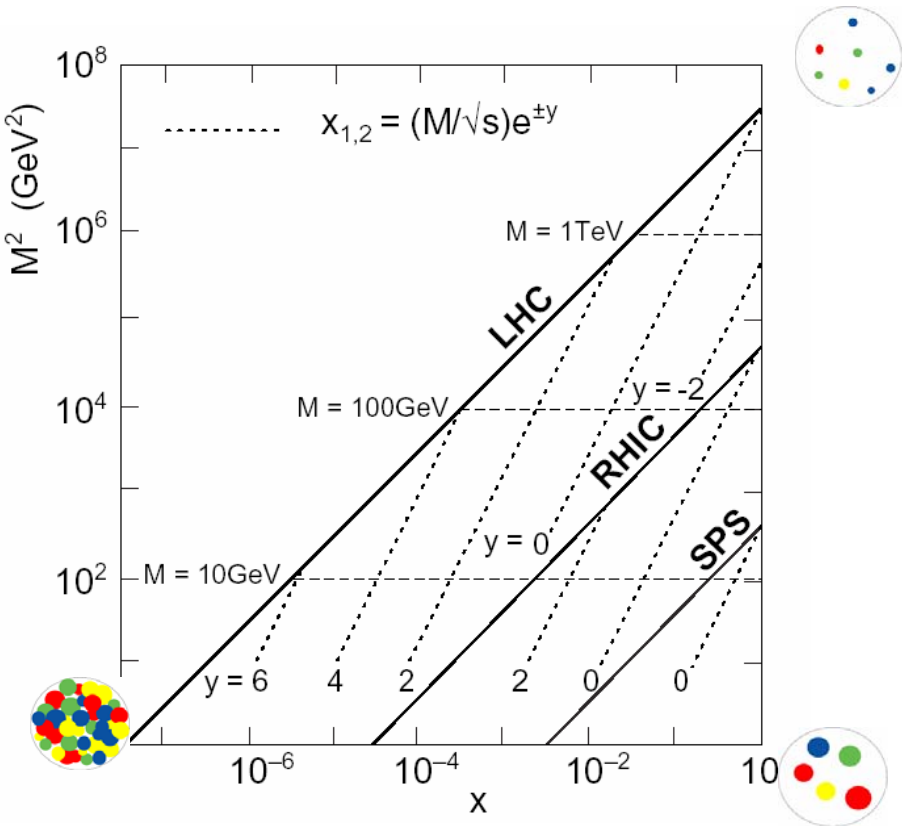
- Extreme Initial Conditions
- The nature of the produced matter
  - Weakly vs Strongly coupled plasma
- Very high-p_T probes
  - High production rate of jets, heavy quarks, quarkonia
- New probes
  - Z boson, complete jets
- Testing and Interpretation of RHIC results
  - Energy evolution of multiplicity, elliptic flow, jet quenching, forward physics
- Very low-x physics

Extreme Initial State

■ ~2 times higher energy density than at RHIC

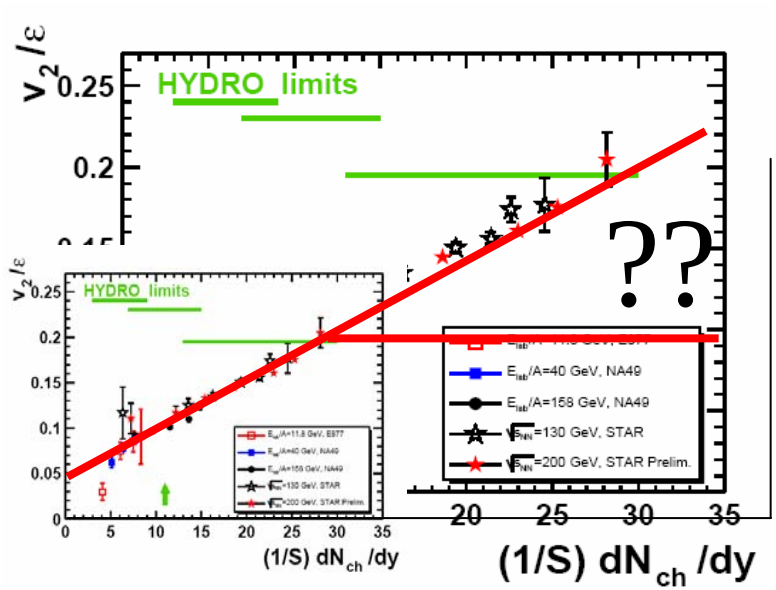
■Dominated by high-density (saturated) parton distributions

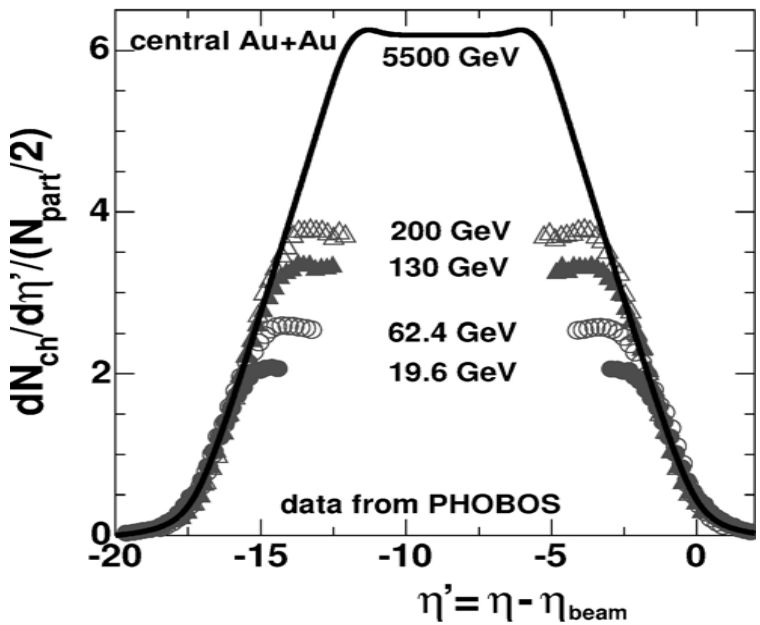


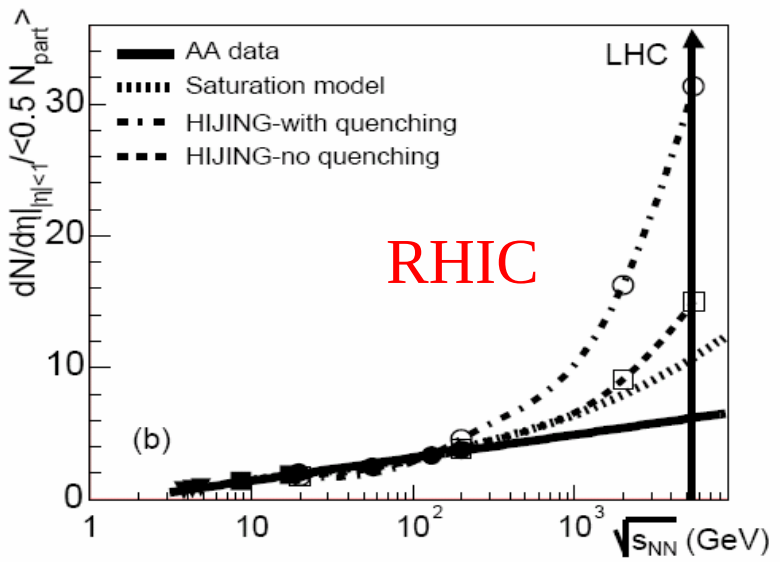


Testing and Interpretation of RHIC results

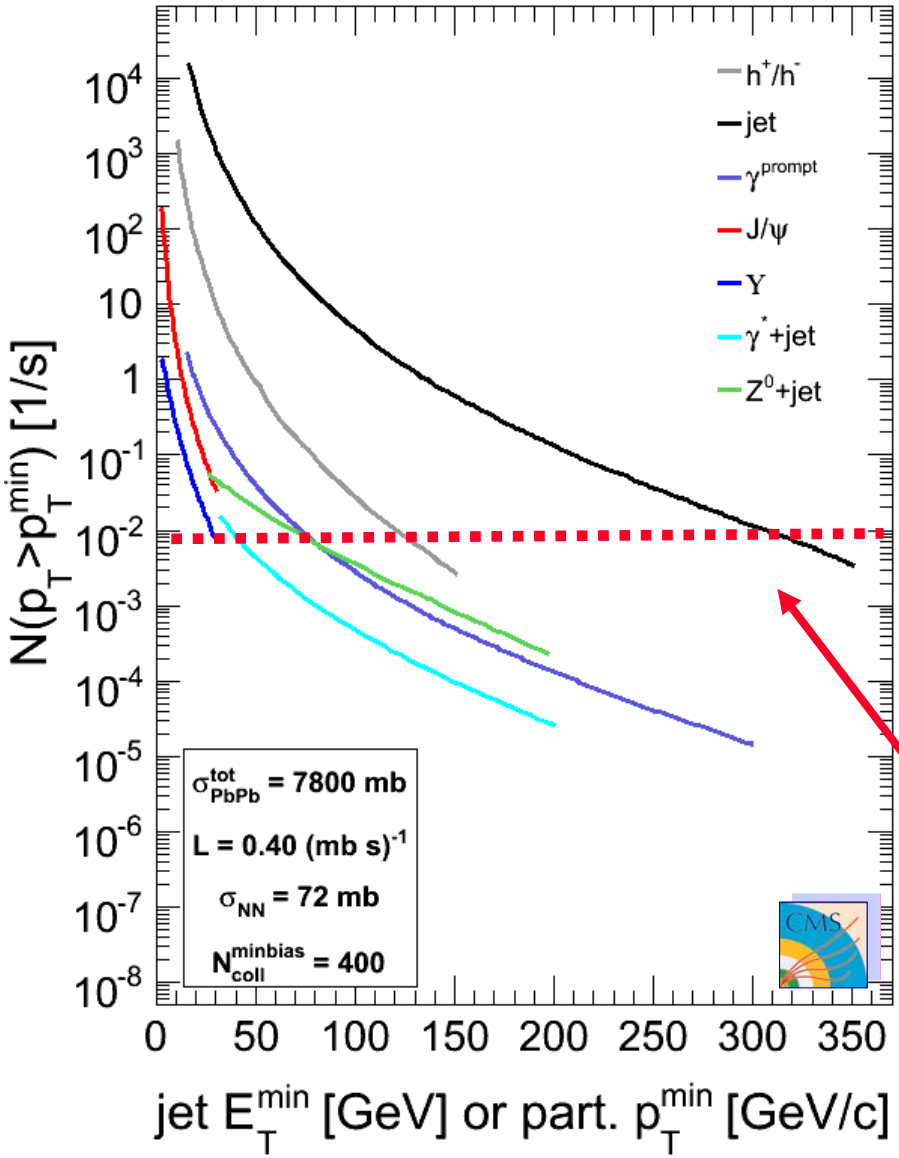
- **Will the matter at LHC have the same global properties?**
- **Strongly interacting perfect liquid or weakly interacting plasma?**
- **LHC provides a lever arm in energy**







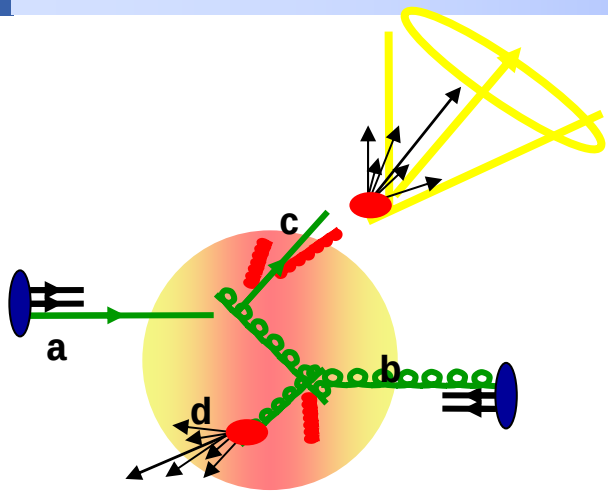
Large cross sections for hard probes

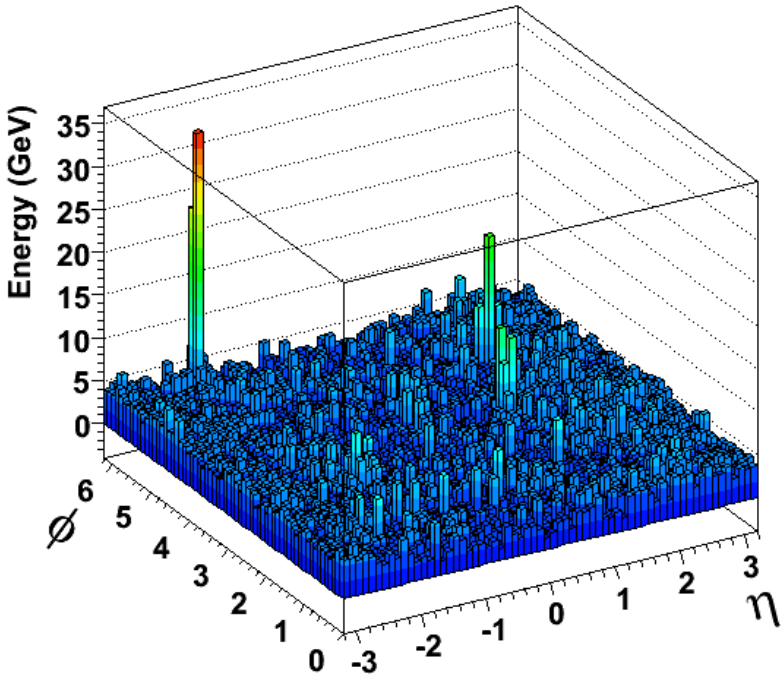


- **Hadron Spectra**
- **Jets**
- **Photons**
- **Quarkonia: J/psi and Υ**
- **γ-tagged jets**
- **Z-tagged jets**
- **Other**
  - **D-,B-mesons**
  - **Z-bosons**

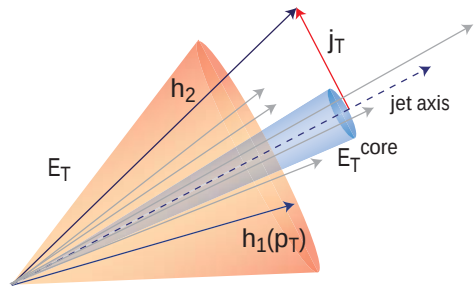
p_T reach:
Estimate ~10^4 events/year in Pb+Pb assuming binary scaling

High rates of well identified jets



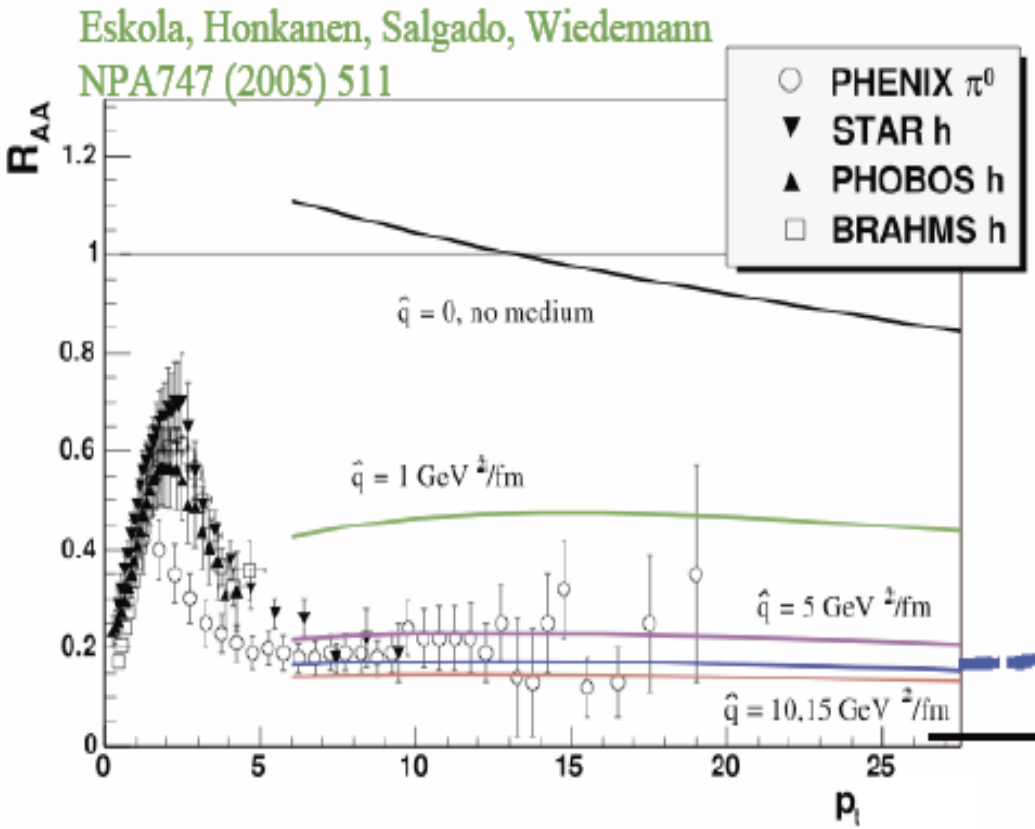


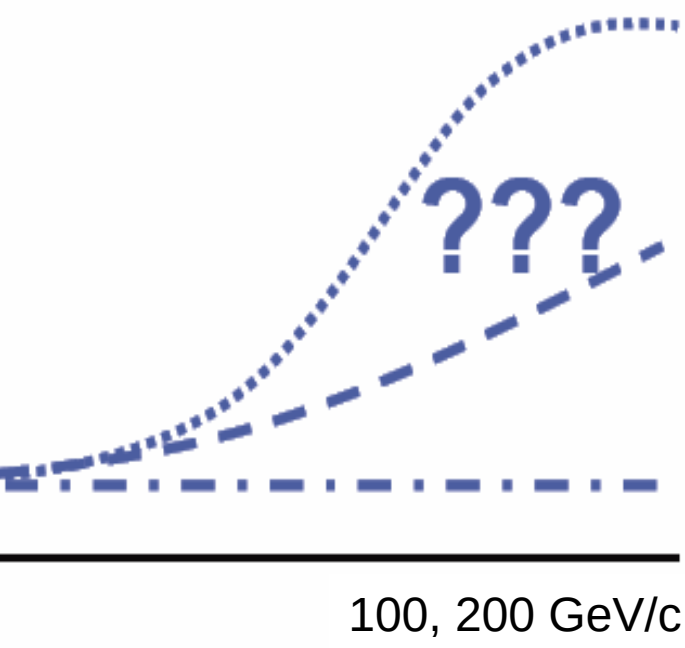
- **Jets identifiable well above background**
  - Estimate of parton energy and direction
- **Detailed studies of true single jets**
  - Jet shape and fragmentation modified by the medium
  - much reduced trigger bias
- **Detailed studies of multiple jets, correlations including jets**
  - Dijet/monojet ratio
  - Jet-γ
  - Jet-Z^0
  - Multi jets



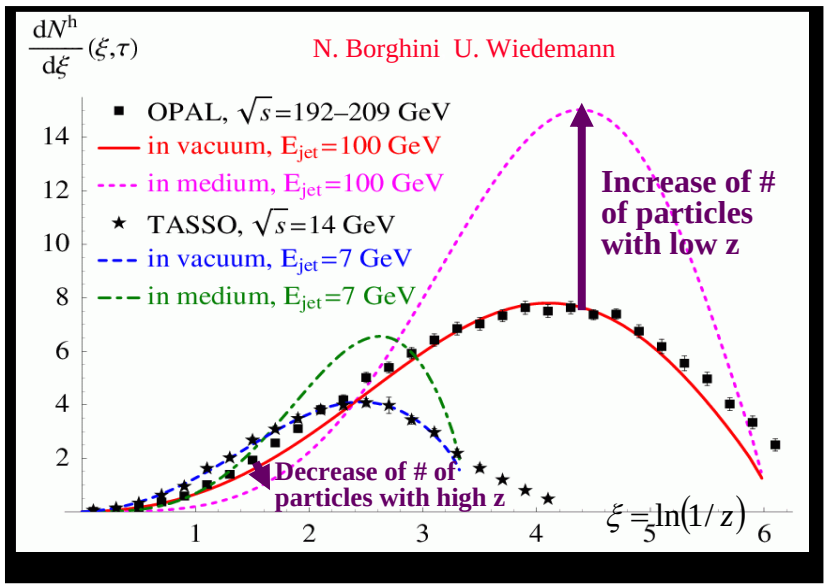
Jet Quenching

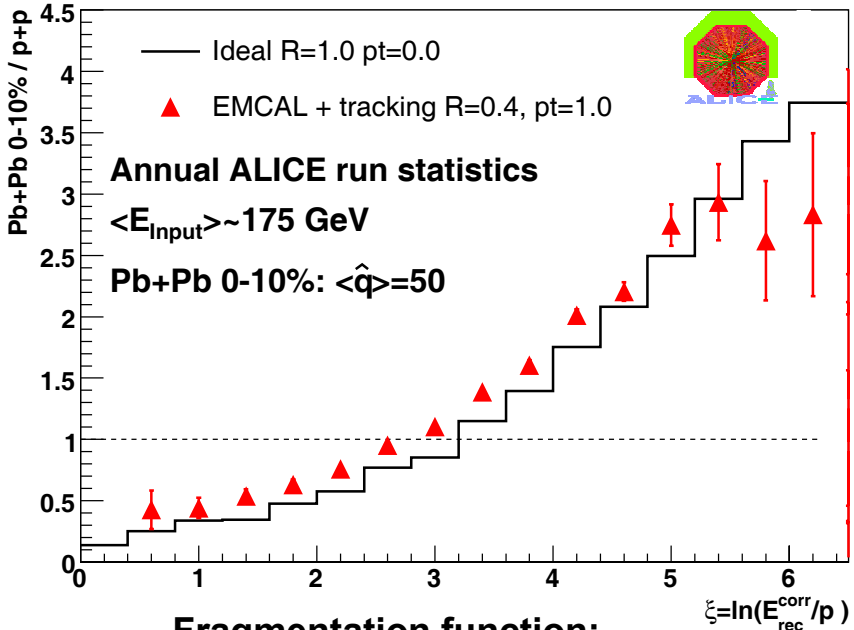
- Energy loss of partons in hot and dense matter
- E.g. charged particle R_{AA} for multi-100 GeV/c p_T



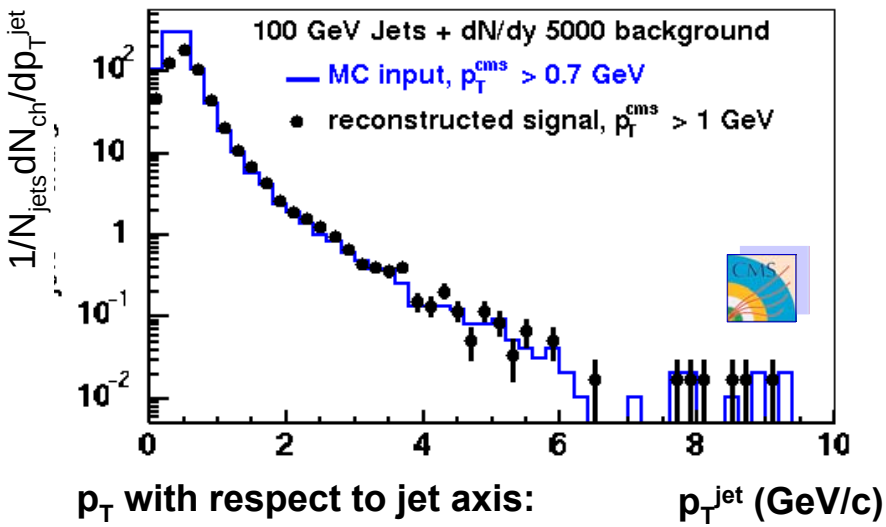


Jet Fragmentation Function

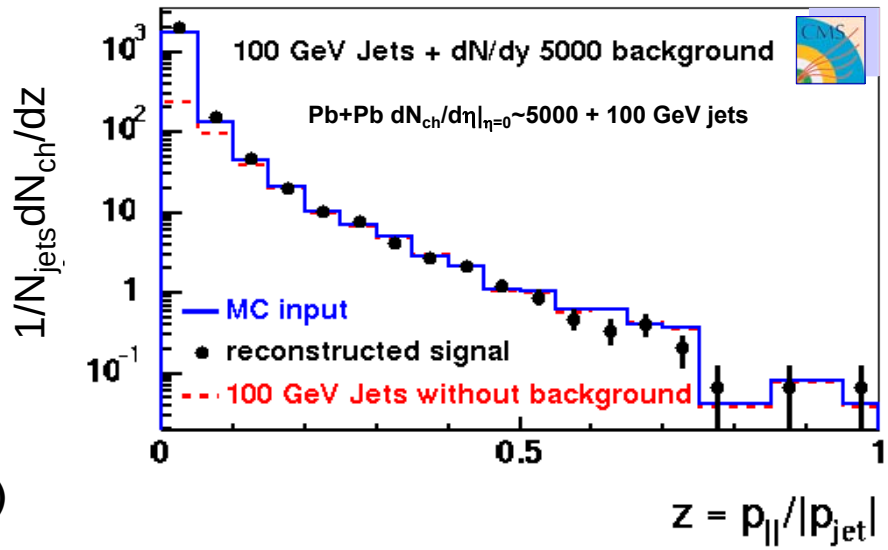




Fragmentation function:



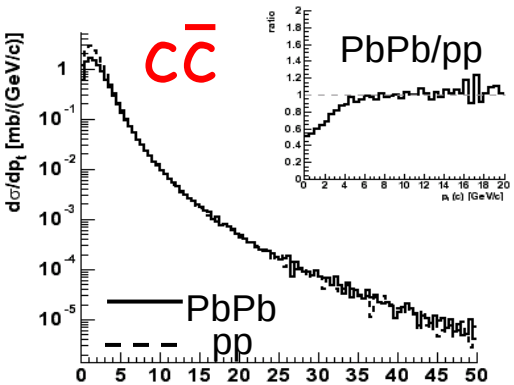
p_T with respect to jet axis:

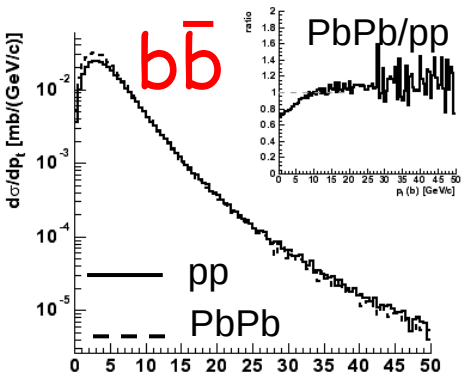


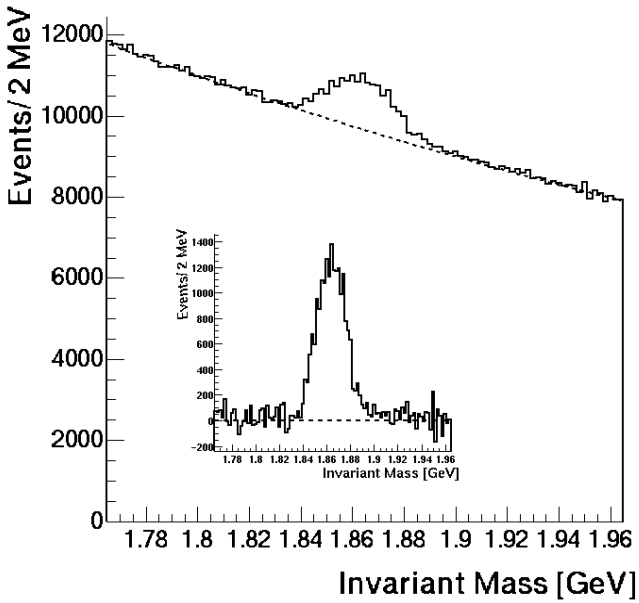
LHC is a Heavy Flavour Machine

■cc̄ and bb̄ rates

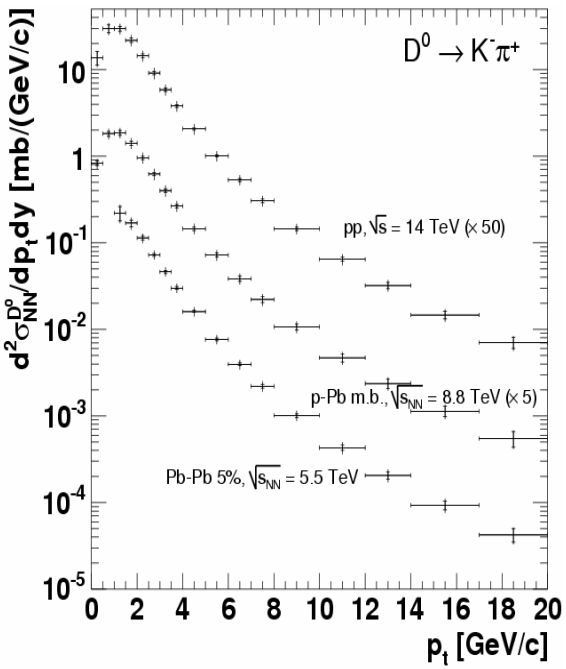
system	NN x-sect (mb)	shadowing	total multiplicity
p+p 14 TeV	11.2 / 0.5	1 / 1	0.16 / 0.007
Pb+Pb 5.5 TeV (5% cent)	6.6 / 0.2	0.65 / 0.85	115 / 4.6





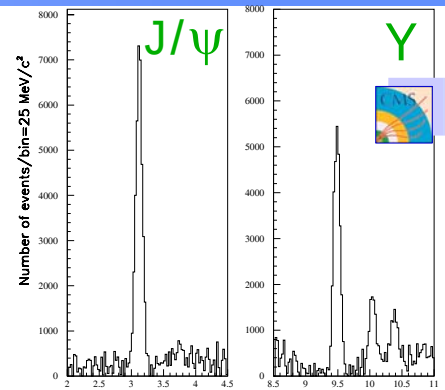


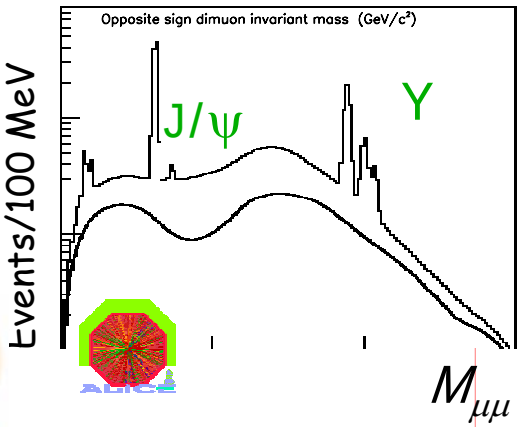
Direct charm: $D^0 \rightarrow K\pi$

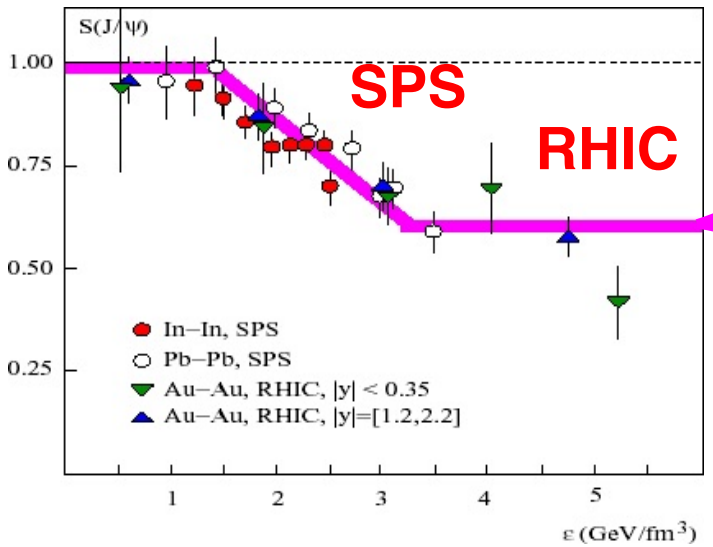


Quarkonia at the LHC

- **J/ψ and ϒ family will be observed by all experiments with high statistics and across large range of p_T : O(10^4)/year**
- **Unique opportunity: study the "melting" of three distinct states belonging to the same quarkonium family over large pT range: QGP Thermometer**





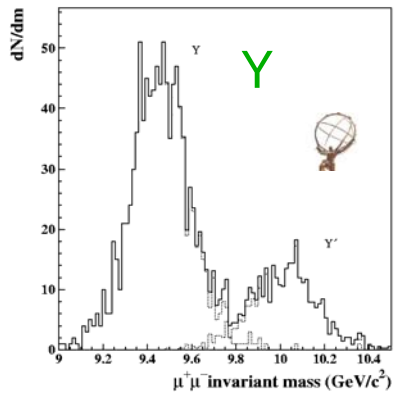


Regeneration ?

LHC

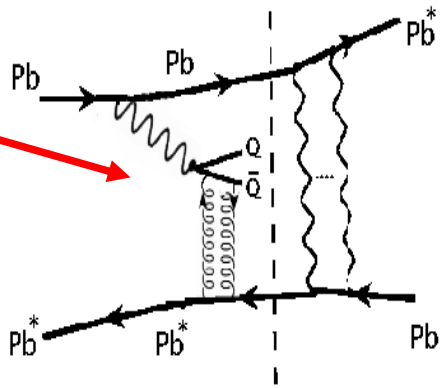
Suppression ?

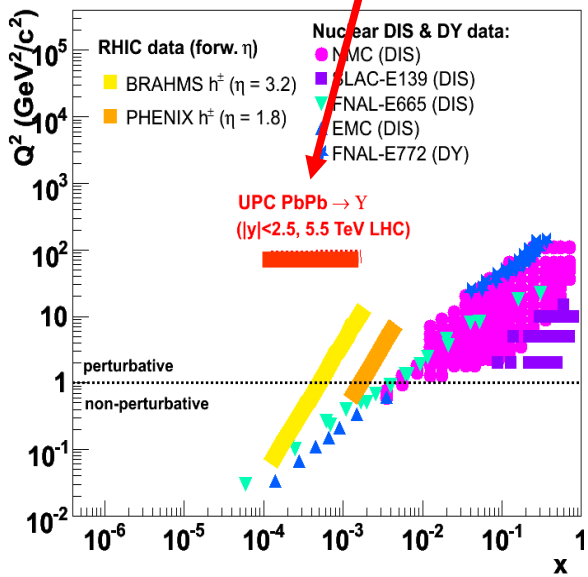
Energy Density

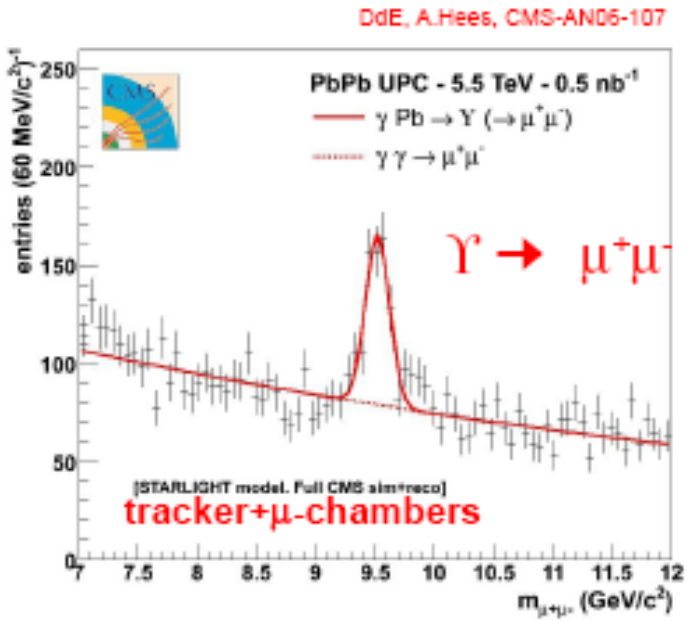


Ultra-Peripheral Collisions

- Quarkonia photoproduction
- Uses ZDC to trigger on forward emitted neutrons
- Measurement $\Upsilon \rightarrow \mu^+\mu^-$, e^+e^- in the central detector
- Probes nuclear PDF in unexplored (x, Q^2) range

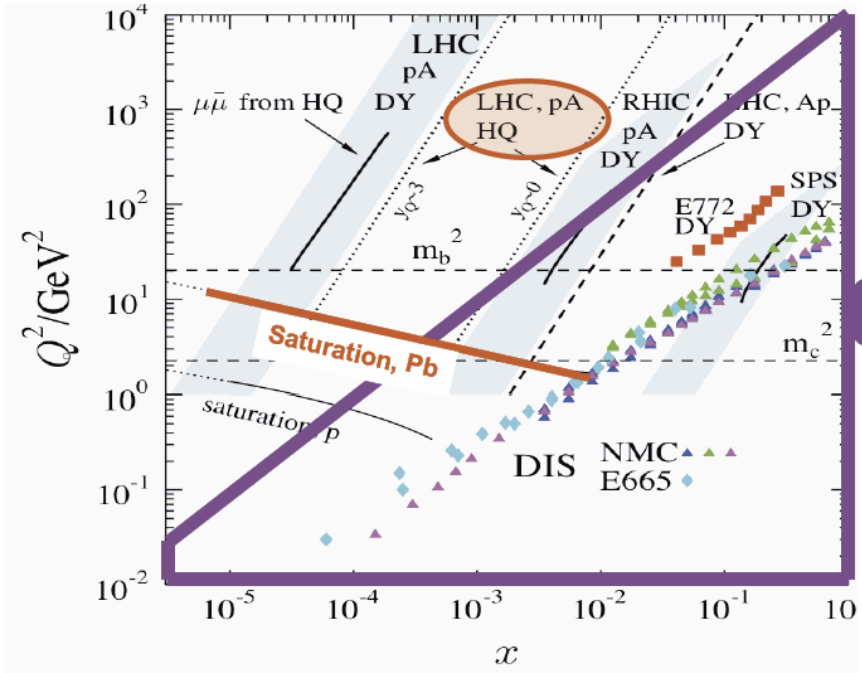






pA physics

- LHC will collide p+Pb at 8.8 TeV
- Link between p+p and A+A physics
  - test of predictive power of QCD: factorization for hard probes
  - "calibration" of nuclear, non-perturbative effects for semi-hard probes (from few to few tens GeV)
  - unprecedented kinematic range in x and Q^2 for nPDF determination
  - Baseline cross sections for QGP probes, separate initial and final state effects
- Novel QCD phenomena
  - Low-x

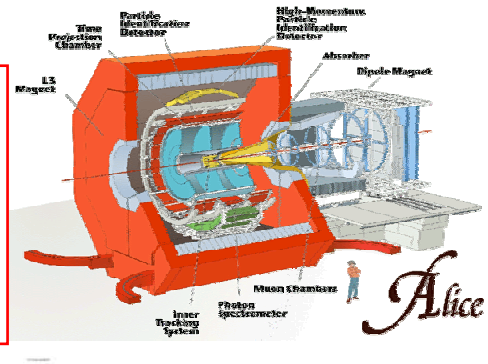


The experiments

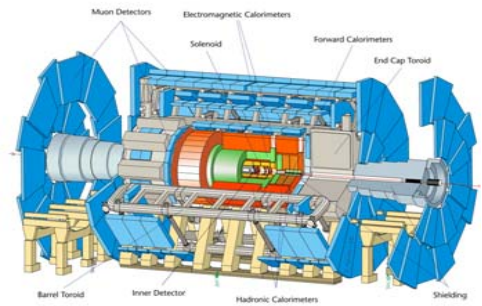
State of the art: expect performances exceeding that of most existing detectors

Complementary and redundant experiments will allow detailed studies of hot nuclear matter and the discoveries of new phenomena

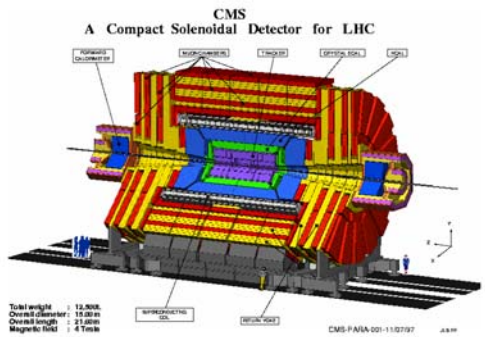
ALICE: Dedicated HI experiment with large suite of detectors optimized for high efficiency tracking and particle identification across large range of momenta from below 100 MeV to above 100 GeV



ATLAS: Large acceptance, multi-purpose detector, designed to study relatively large p_T phenomena. Calorimetric system particularly well suited for detailed jet studies.



CMS: Large acceptance, multi-purpose detector, designed to study relatively large p_T phenomena. Particularly large calorimetric detector coverage and good momentum resolution due to high B field.



ATLAS and CMS: Very large US HEP participation

Running RHIC and LHC

- **Complementary accelerators**
  - LHC can achieve very high energy
    - Relatively short heavy-ion runs
  - RHIC is very flexible as a heavy-ion accelerator
    - Large ion and energy variety
    - Longer physics runs
  - Over two orders of magnitude in collision energy: ~20-5500 GeV
- **Complementary physics**
  - LHC: High p_T, more massive probes, excitation functions
  - RHIC: Detailed systematic and comparative studies, detailed excitation functions
- **Complementary community**
  - Overlap of worldwide efforts at both RHIC and LHC
  - Planned total US effort at LHC is smaller than the size of STAR or PHENIX
- **Both accelerators are required to fully understand the big picture:**
  - confirmation and/or falsification of models/theory/knowledge

Summary: Physics at the LHC

- LHC will open a new chapter in the studies of hot nuclear matter
  - the increased energy density will likely lead to new phenomena across the whole p_T range
  - the new probes will allow unique studies of the produced medium
  - Higher energy will refine and enhance RHIC results
- The construction of the accelerator and the experiments is progressing well
- The suite of the experiments will allow a wide range of precise and high statistics measurements
- Significant participation of US QCD physicists in LHC-HI will make a huge difference to the overall success of the field