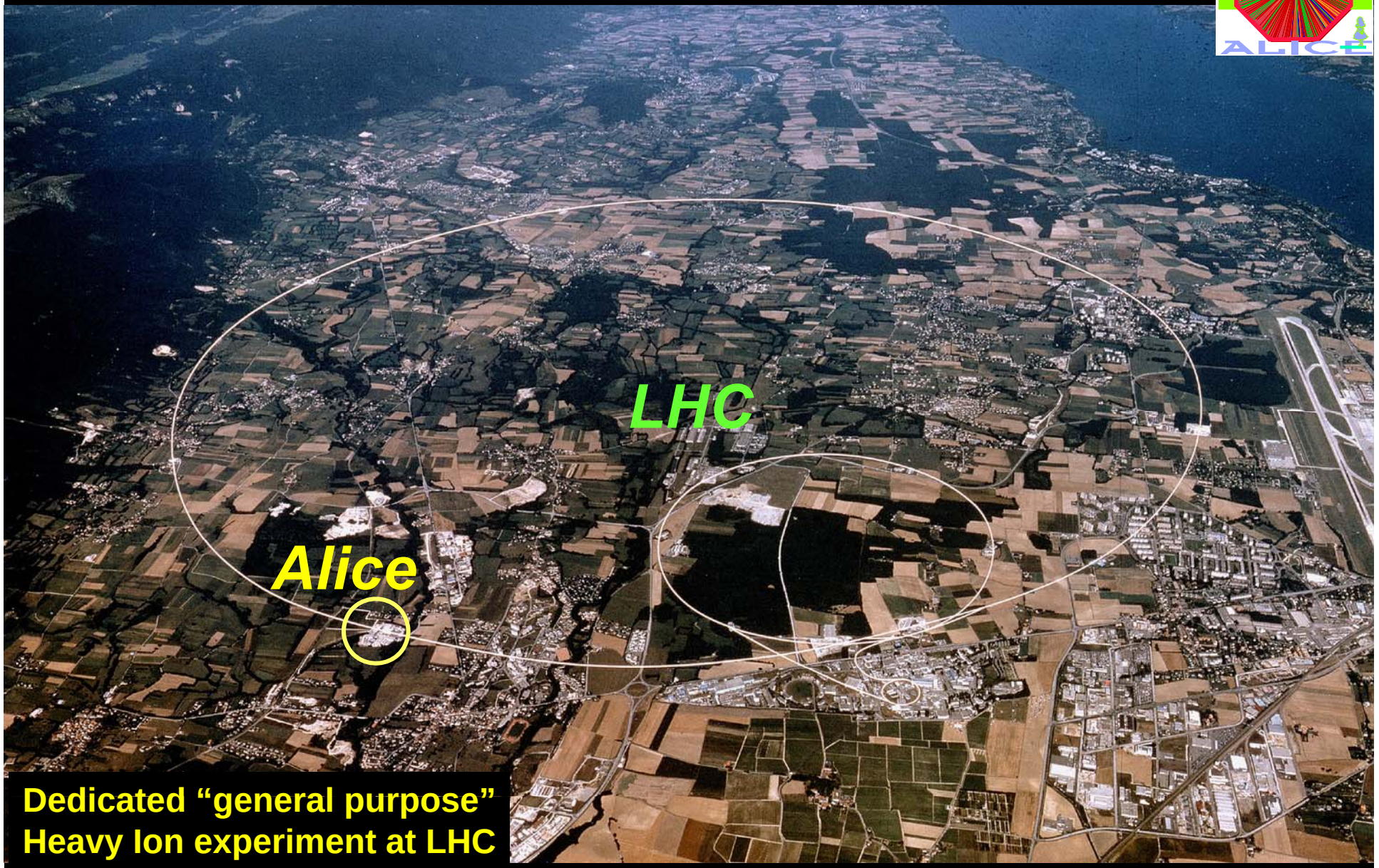
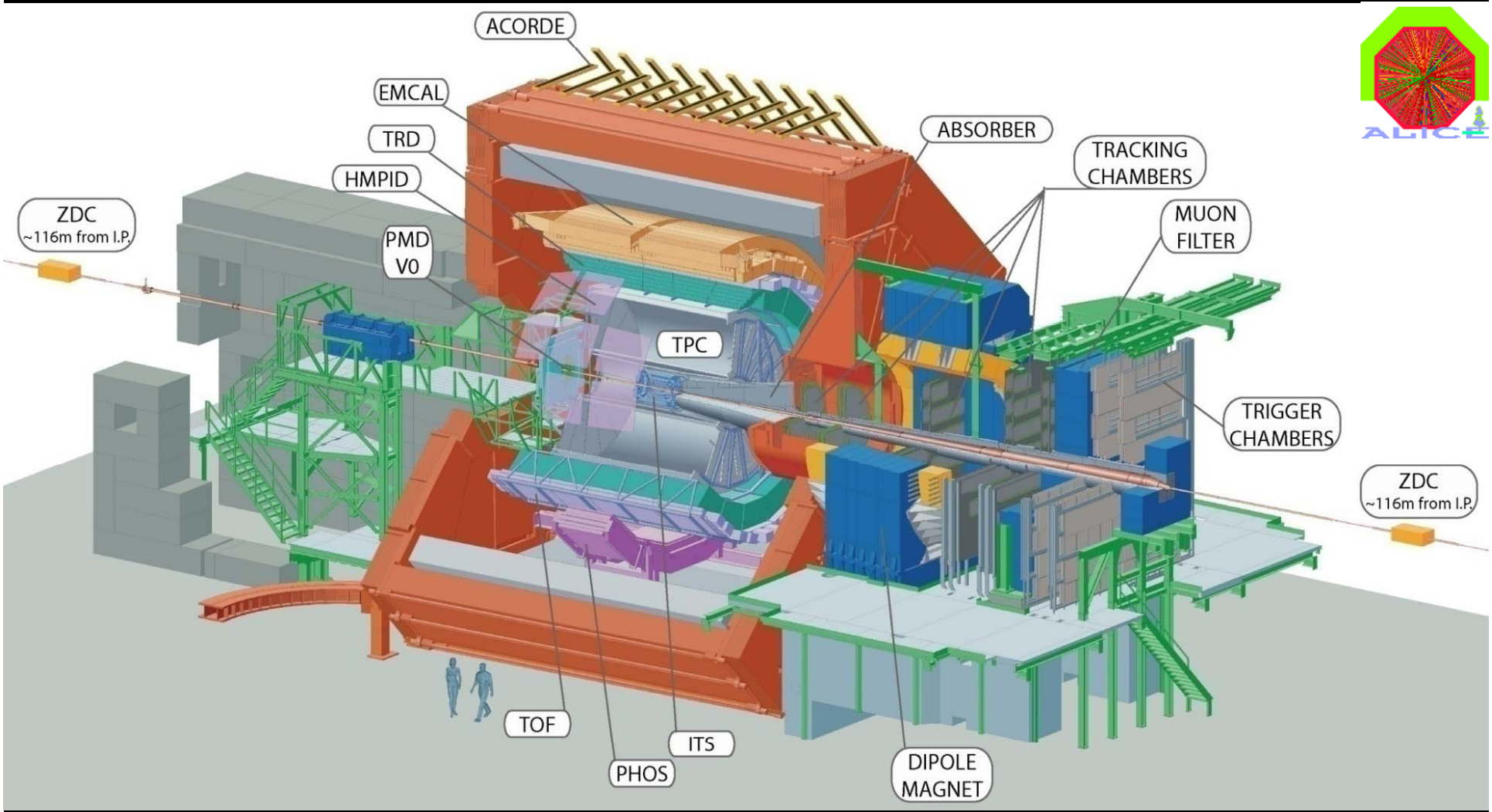
ALICE



Dedicated “general purpose” Heavy Ion experiment at LHC

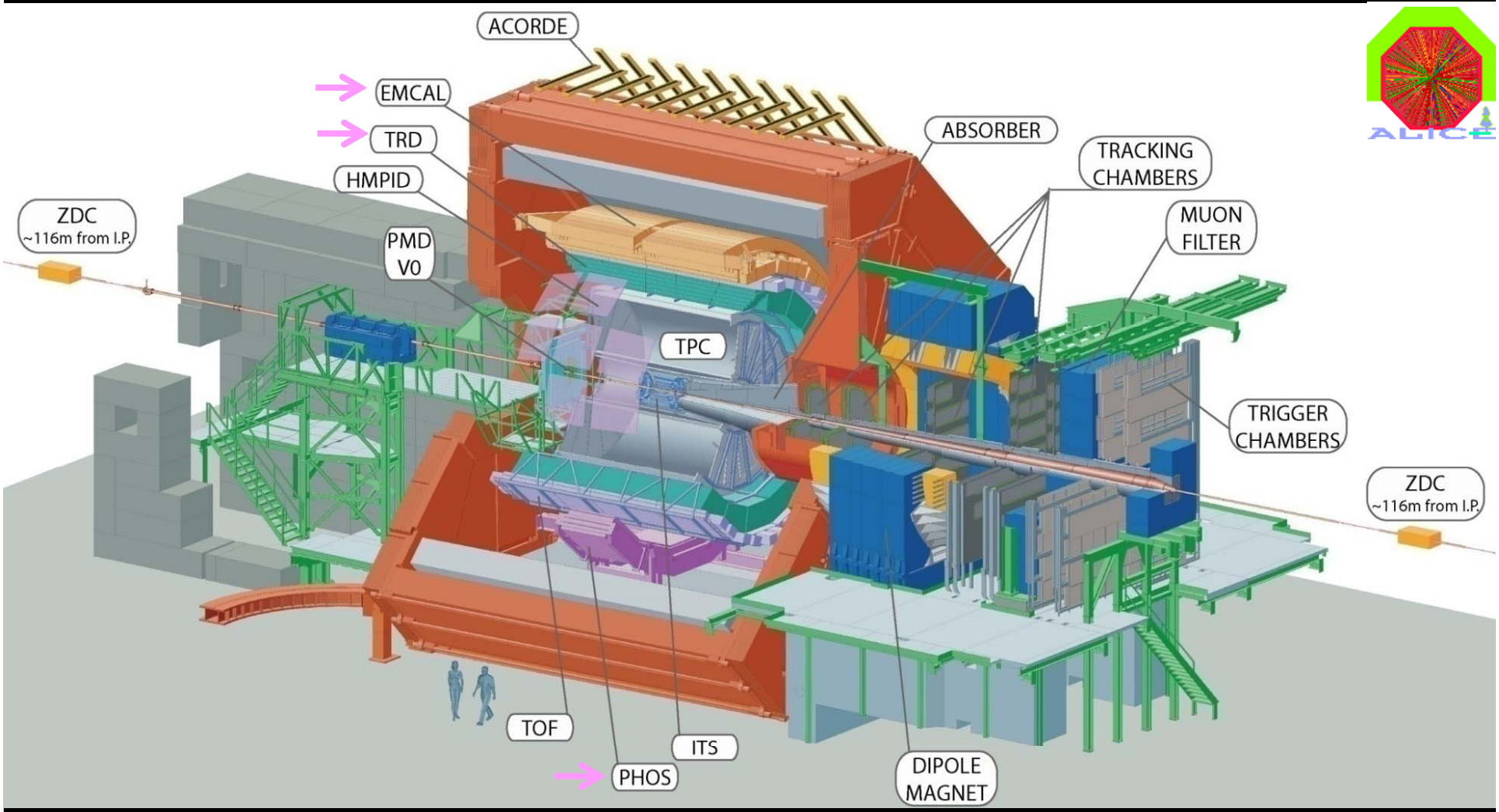
The ALICE Heavy Ion Experiment



Fully Installed & Commissioned for 2008 – Hadron & μ Capabilities

ITS, TPC, TOF, HMPID, MUONS, V0, T0, ZDC, ACORDE, TRIGGER, DAQ

The ALICE Heavy Ion Experiment



EM (e and γ) Partial Capabilities - (for 2008, 2009, 2010, 2011 in % below)

TRD (20, 50, 100%) complete by 2010, PHOS (40, 60, 80, 100%) complete by 2011,

EMCAL (0, 20, 70, 100%) complete 2011

ALICE Collaboration

~ 1000 Members

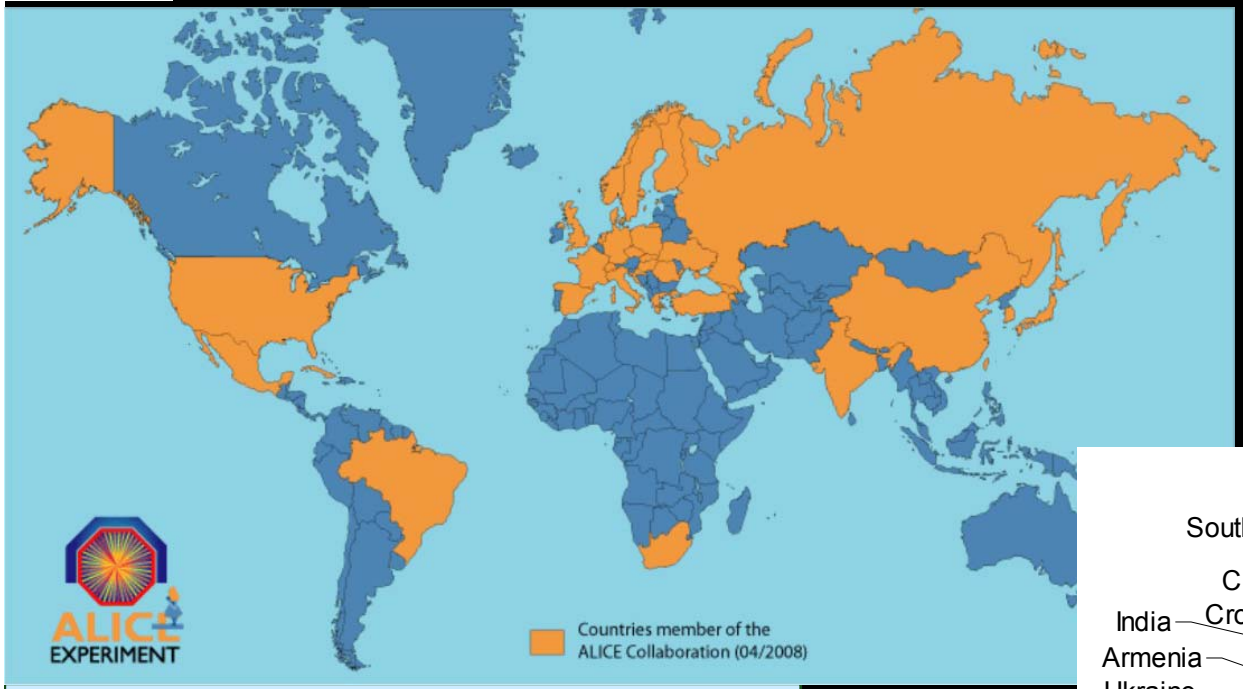
(63% - CERN States)

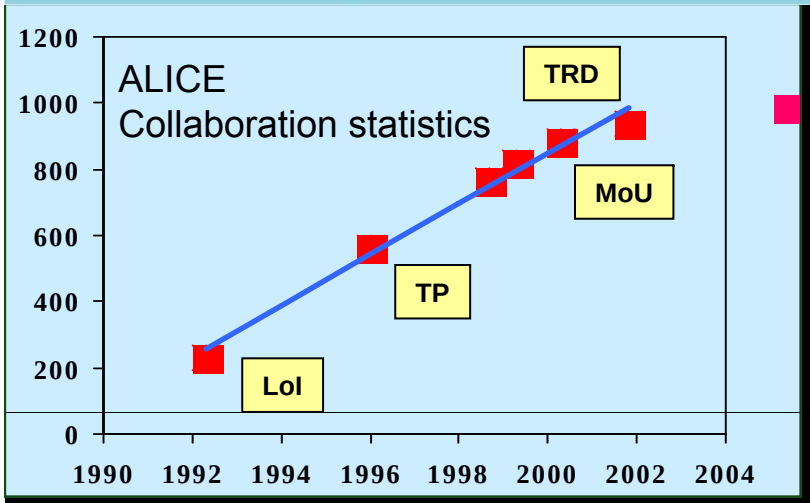
~ 30 Countries

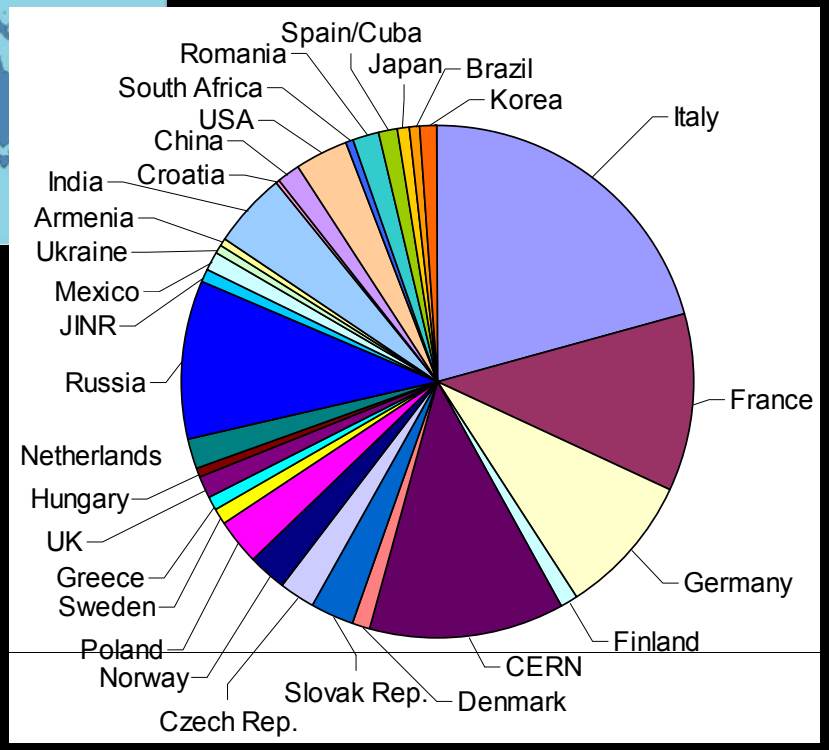
~ 100 Institutes

~ 150 M CHF capital

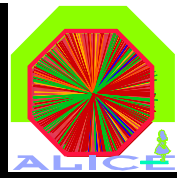
(+ magnet)







ALICE Collaboration – US Institutions



11 US Institutions, 45 Members (inc. 12 graduate students)

DOE – Nuclear Physics:

- *Creighton University (4)*
- *University of Houston (3)*
- *Lawrence Berkeley National Laboratory (5)*
- *Lawrence Livermore National Laboratory (2)*
- *Oak Ridge National Laboratory (3)*
- *Purdue University (2)*
- *University of Tennessee (3)*
- *Wayne State University (7)*
- *Yale University (9)*

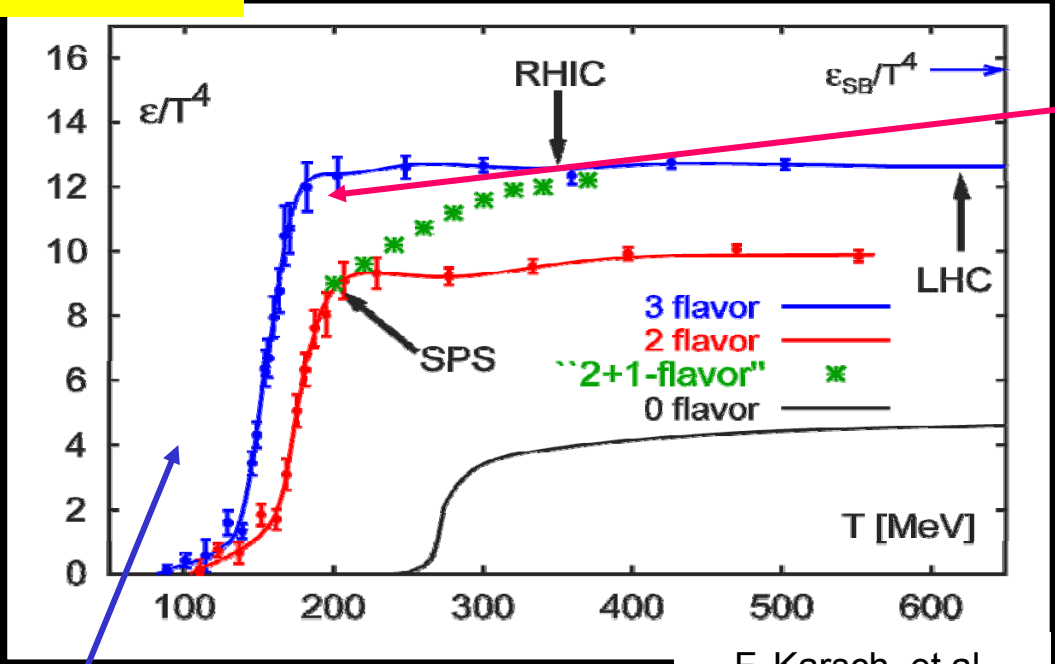
NSF:

- *California Poly – San Luis Obispo (1)*
- *Ohio State University (6)*

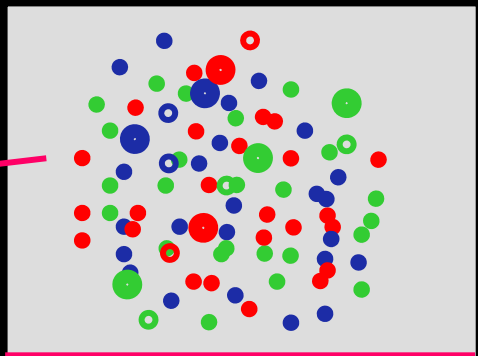
QCD at High Temperature

ε/T^4 ~ # degrees of freedom

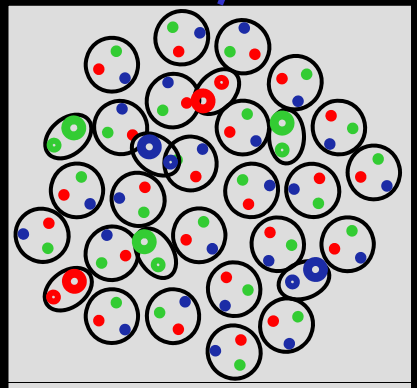
$$\varepsilon = \frac{\nu \pi^2}{30} T^4$$



F. Karsch, et al. Nucl. Phys. B605 (2001) 579



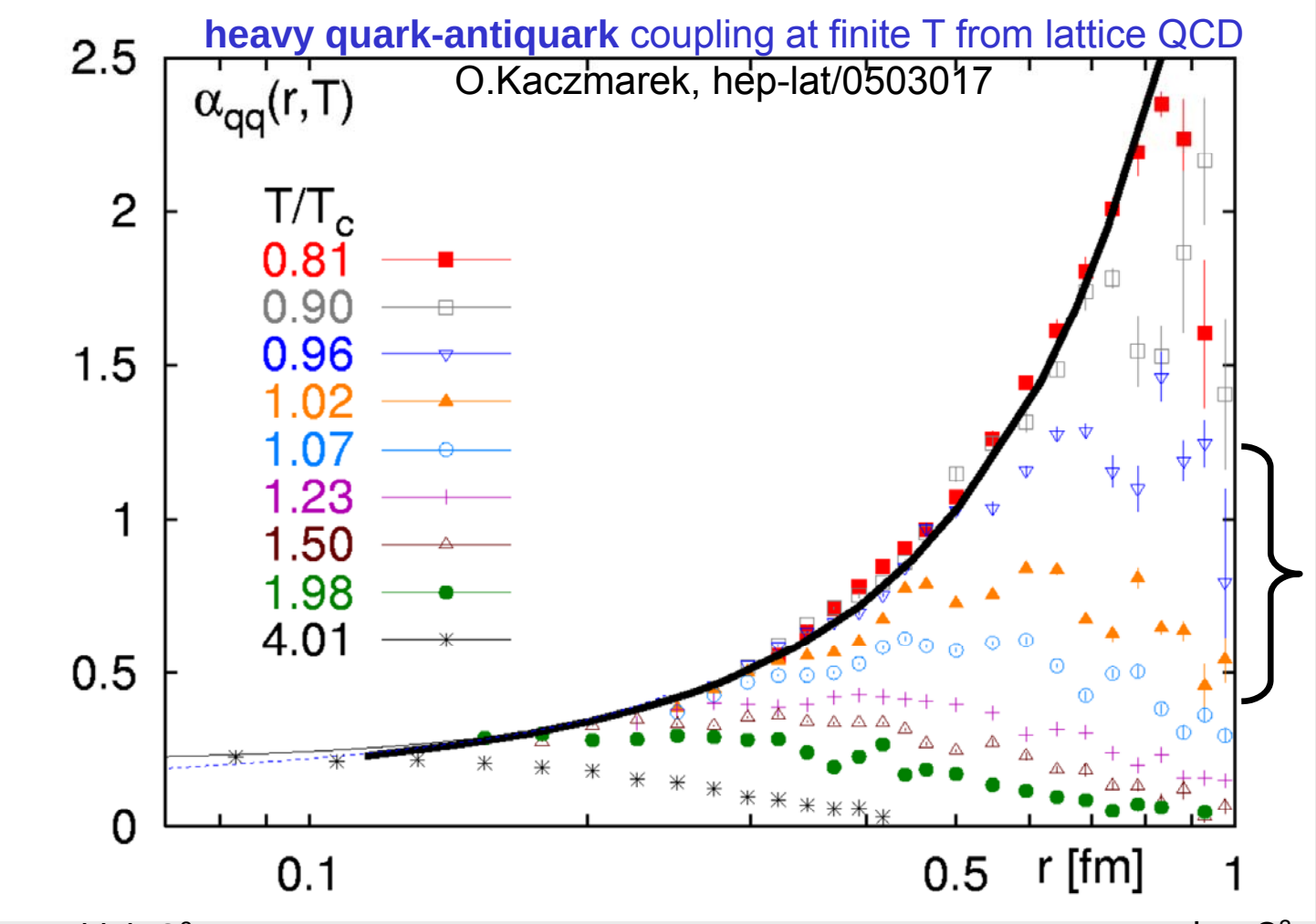
many d.o.f.→**deconfined**



few d.o.f.→**confined**

T_C ~ 175 ± 8 MeV → ε_C ~ 0.3 - 1 GeV/fm^3

Strong Coupling Constant α_s at High Temperature



Constituents - Hadrons, dressed quarks, quasi-hadrons, resonances?

Coupling strength varies investigates (de-)confinement, hadronization, & intermediate objects.

The Quark-Gluon Plasma – Overview from RHIC

Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory –

pp, dAu, CuCu, AuAu at $\sqrt{s_{NN}}$ ~ 20 – 200 GeV in STAR, PHENIX

(PHOBOS, BRAHMS) detectors

- *Large* $\varepsilon > \varepsilon_c$ *(*$T > T_c$*) system – Sufficient for QGP formation – NOT hadrons*
- *Large volume of quarks & gluons (hydrodynamics) – NOT just q & g scattering*
  - *Large elliptic & radial flow* $\rightarrow$ *large pressure gradients*
  - *Ultra-low shear viscosity* $\rightarrow$ *"nearly-perfect" fluid flow*
  - *Particle ratios fit by thermal model* $\rightarrow$ $T = 177$ *MeV* ~ T_c *(lattice QCD)*
- *Dynamics of quarks and gluons – NOT hadrons*
  - *Flow depends upon constituent quark masses, NOT hadron masses*
  - *Flow develops at quark (NOT hadron) level*
    - $\rightarrow$ *QGP EoS, quark coalescence*
- *NOT a Weakly-interacting QGP (as initially expected from Lattice QCD)*
  - *Strongly interacting quarks and gluons* $\rightarrow$ *NOT* $\alpha_s \sim 0$

Simple Expectations for Heavy Ion Physics at LHC

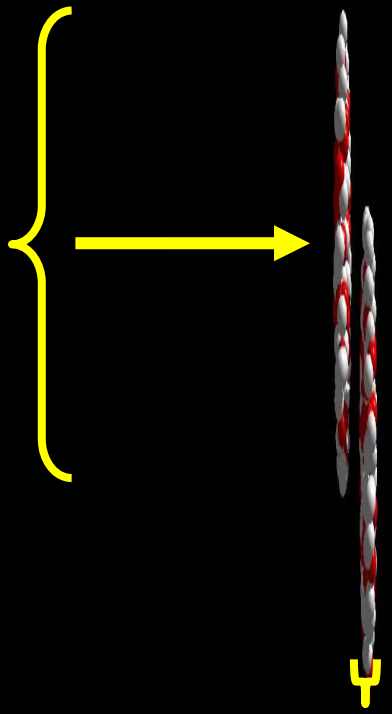
	SPS	RHIC	LHC	
$\sqrt{s_{NN}}$ (GeV)	17	200	5500	factor 28
T / T_c	1.1	1.9	3.0 - 4.2	hotter
ε (GeV/fm^3)	3	5	15 - 60	denser
τ_{QGP} (fm/c)	≤ 2	2-4	> 10	longer-lived

RHIC and LHC:

Cover 2 – 3 decades of energy ($\sqrt{s_{NN}}$ ~ 20 GeV – 5.5 TeV)

To discover the properties of hot QCD at T ~ 150 – 600 MeV

Heavy Ion Collisions at LHC



Lead nucleus
diameter ~ 14 fm

γ = 2,700
(Lorenz contracted)

$\tau \sim (14\ \text{fm/c}) / \gamma < 0.01\ \text{fm/c}$

General Orientation

Hadron masses ~ 1 GeV

Hadron sizes ~ fm

LHC Heavy Ion Collisions

E_{cm} = 5.5 TeV per nn-pair

Total E_{cm} = 1.54 PeV

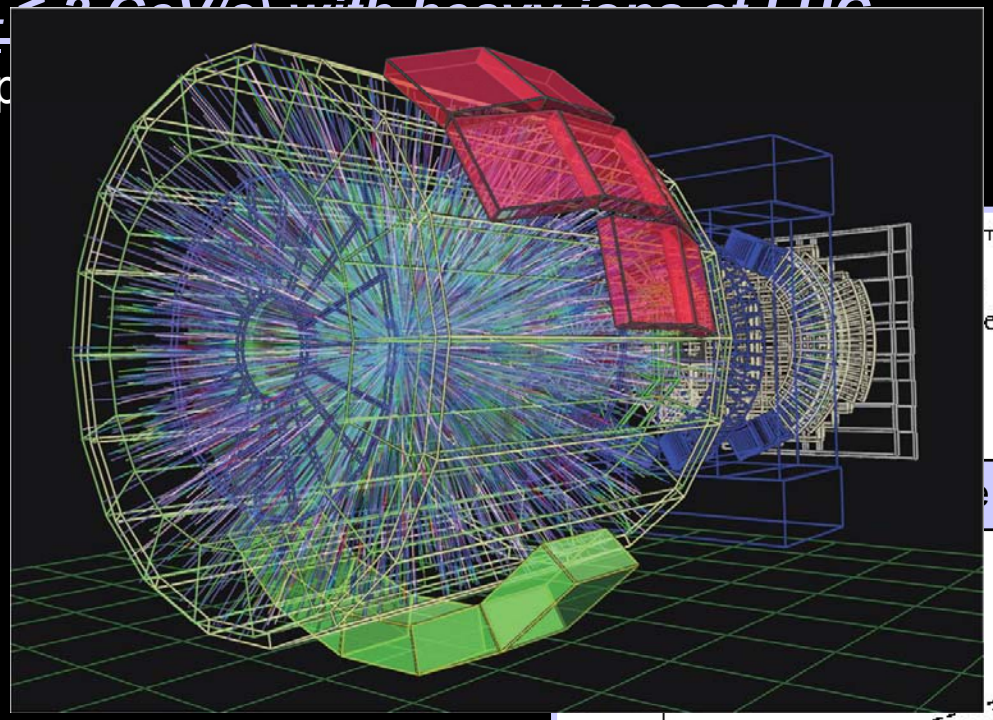
Heavy Ion Physics at the LHC

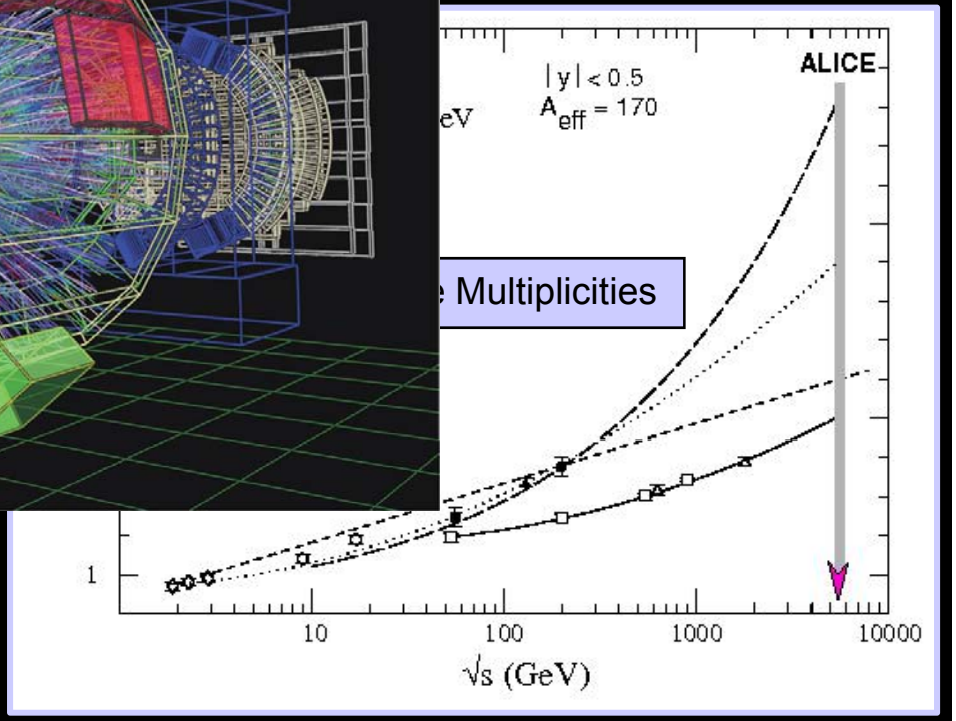
LHC Heavy Ions –

- expectations based on pQCD predictions & RHIC results
- a lesson from RHIC – guided by theory + versatility + **"expect the unexpected"**

Soft Physics (p_T < 1-2 GeV/c) with heavy ions at LHC

- smooth extrap





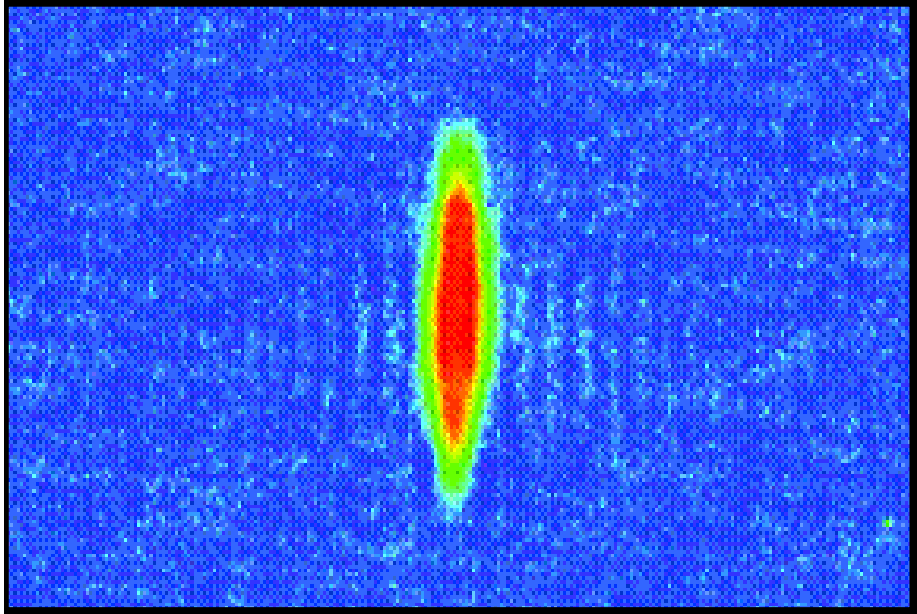
Heavy Ion Physics at the LHC

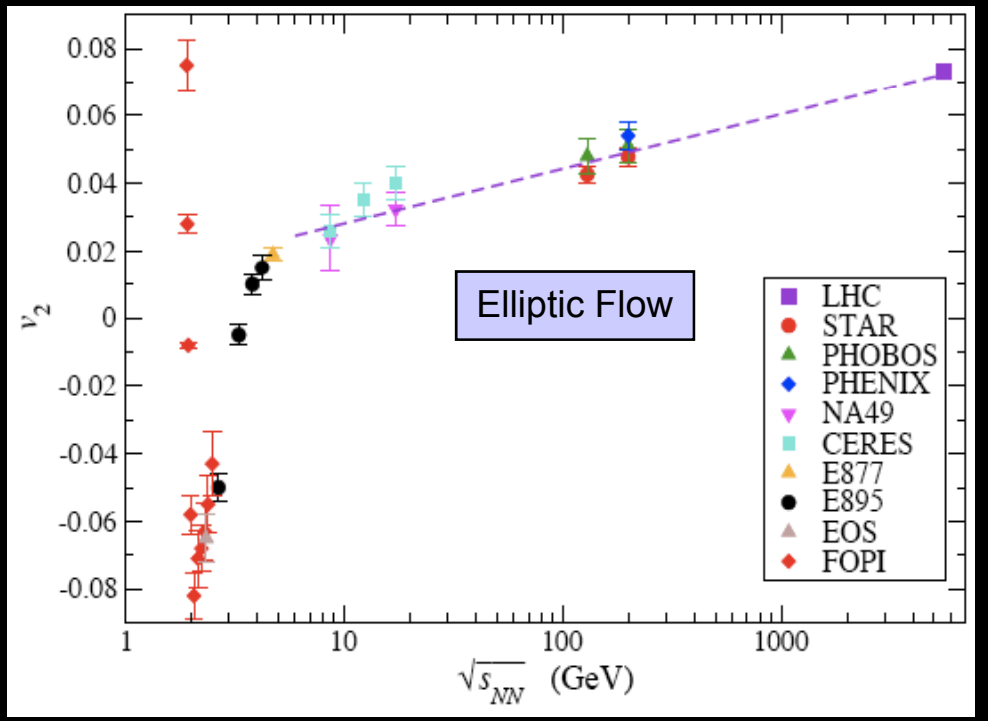
LHC Heavy Ions –

- expectations based on pQCD predictions & RHIC results
- a lesson from RHIC – guided by theory + versatility + **"expect the unexpected"**

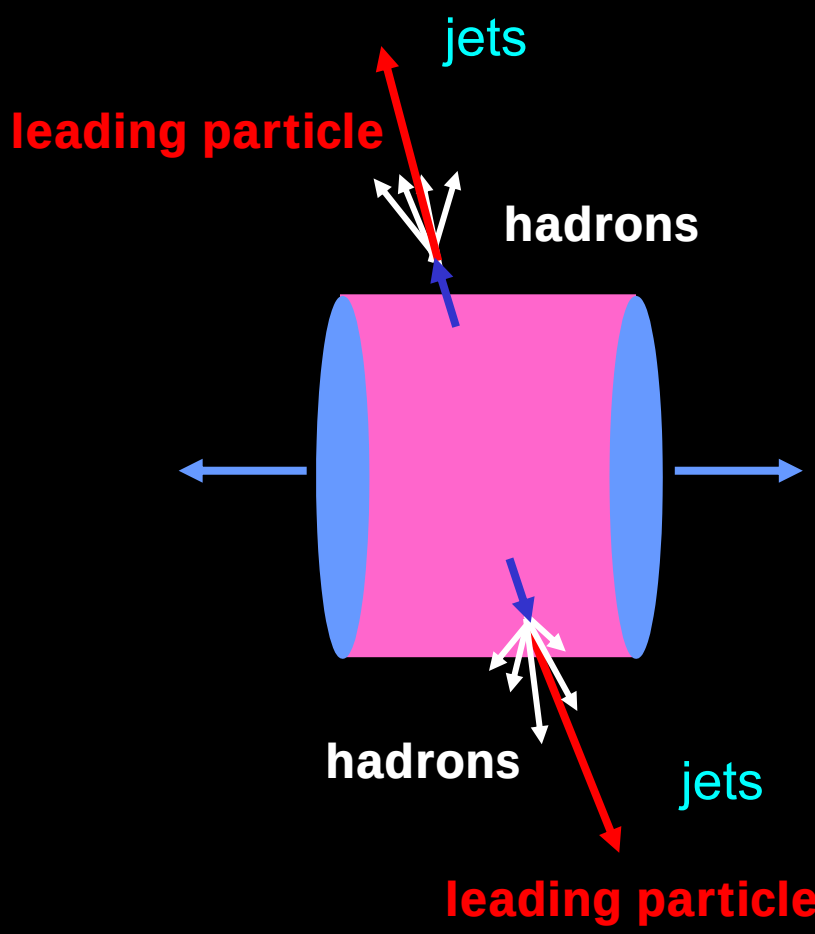
Soft Physics ($p_T \leq 2$ GeV/c) with heavy ions at LHC –

- smooth extrapolation from **SPS → RHIC → LHC?**
- expansion dynamics different (flow, HBT, T_{chem} & T_{kin}, strange/charm/beauty)





Probing Hot QCD Matter with Hard Probes



→ parton energy loss: modification of jets and leading particles & jet-correlations

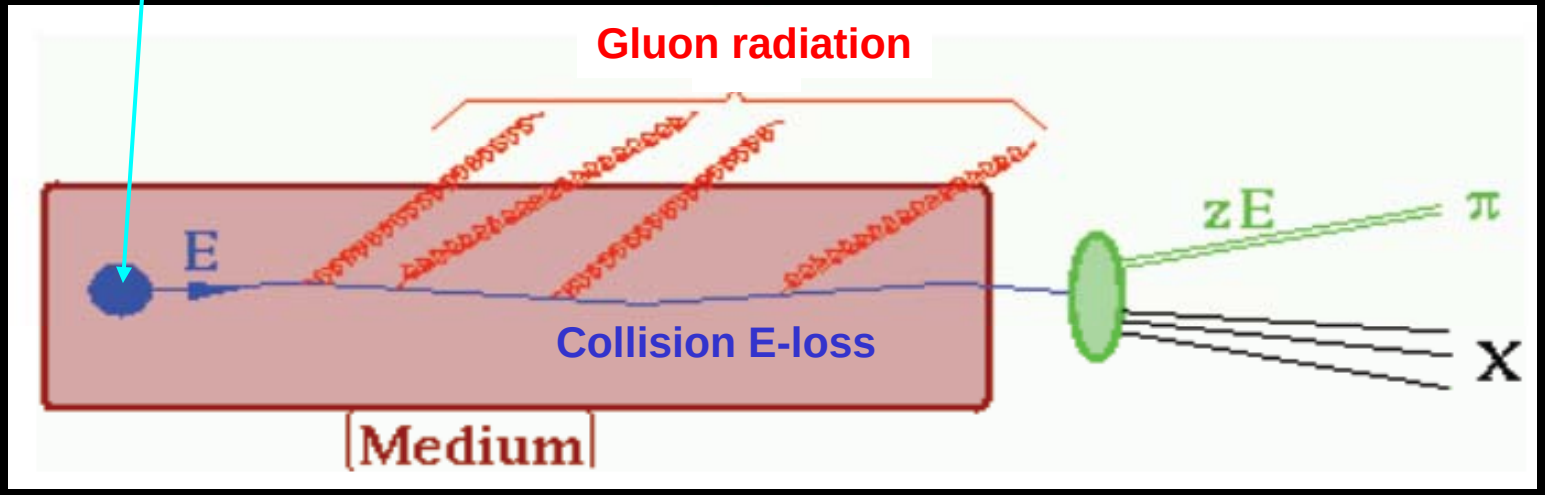
Hard Probes in ALICE

Jet Quenching

(Parton energy-loss, parton density, medium response)

How does parton lose energy?

What happens to the radiation?

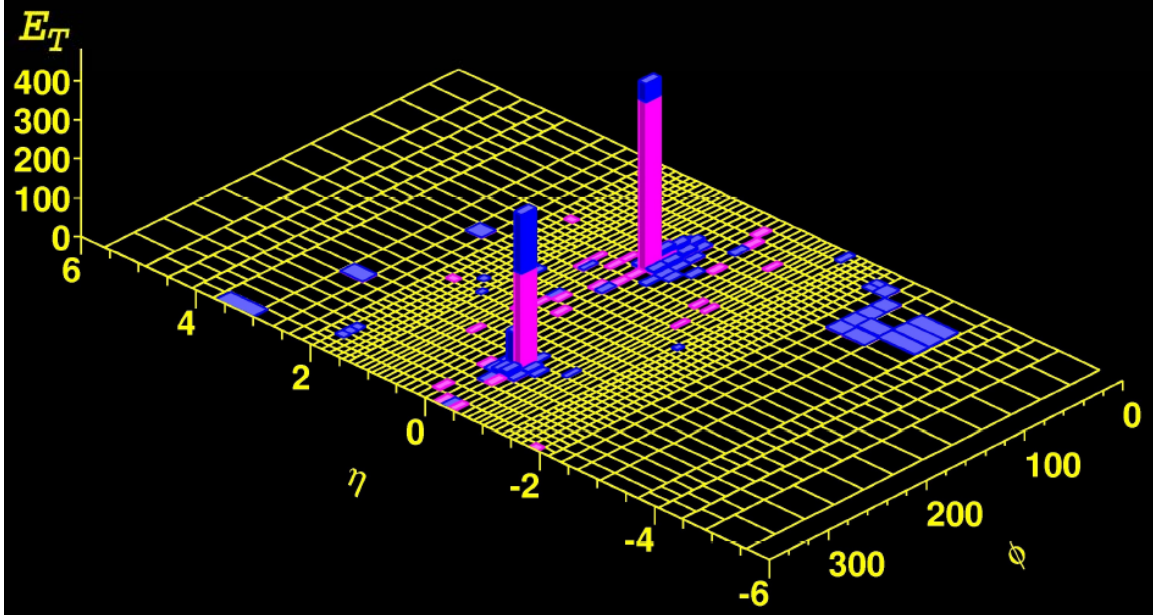


How does ΔE depend on type of parton?

$$\Delta E_{gluon} > \Delta E_{quark,\ m=0} > \Delta E_{quark,\ m>0}$$

- Jets, γ , π^0, leading particles to large p_T
- Modification of fragmentation
- Medium response to E deposition - dissipation on near- and away-side

Jet-finding - Learning from Tevatron & RHIC



$\bar{p}$ + p experience (CDF)

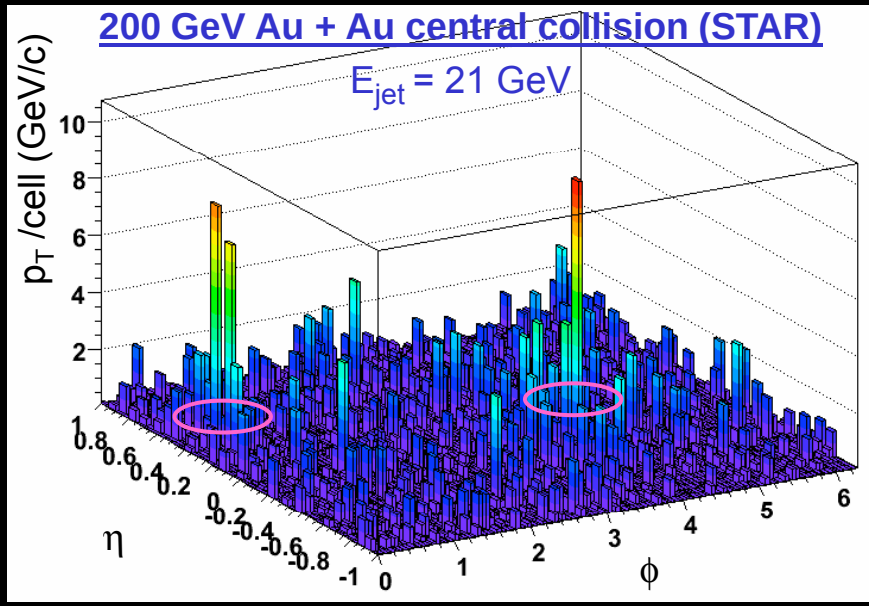
- most of energy within cone of

$R = \sqrt{(\Delta\eta^2 + \Delta\phi^2)} < 0.3$

Au + Au experience (STAR) - HI Background

Must suppress "soft" background:

- small jet cones R = 0.3-0.4
- p_T cut: $p_T > 1 – 2$ GeV/c
- EbyE out-of-cone background energy



Hard Probes in ALICE

Heavy Quarks

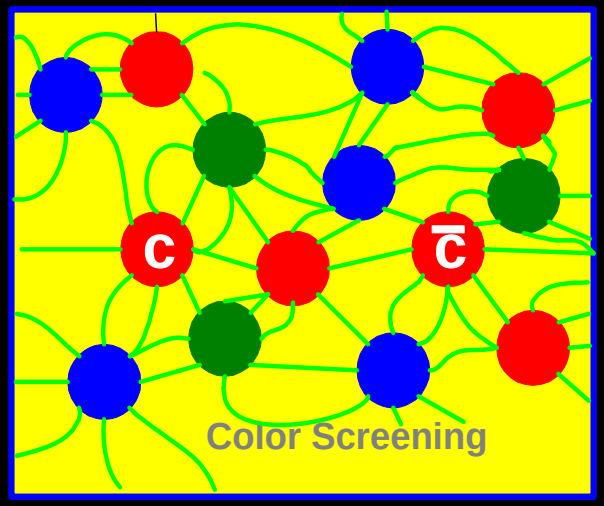
(mass/color dependence of parton energy-loss)

- Displaced vertices ($D^o \rightarrow K^- \pi+$) from tracking
- Electrons from Transition Radiation Detector & EMCal

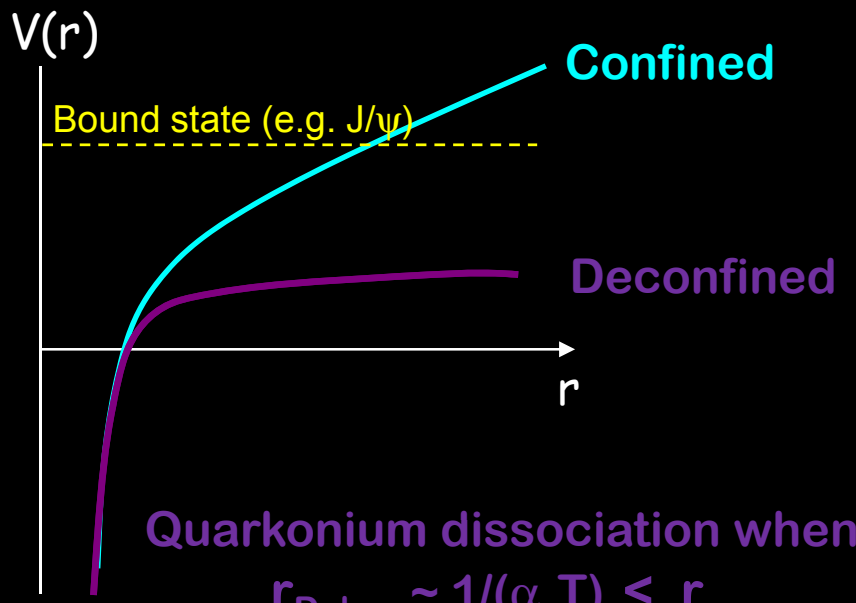
Quarkonia

(initial temperature, Debye color screening, recombination)

- J/ψ, ϒ, ϒ′ (excellent), ϒ″(2-3 yrs), ψ′ (very difficult)



Color screening of cc pair results in J/ψ (cc) suppression!



Quarkonium dissociation when $r_{Debye} \sim 1/(\alpha_s T) < r_{qq}$

Hard Probes in ALICE

Heavy Quarks

(mass/color dependence of parton energy-loss)

- Displaced vertices ($D^o \rightarrow K^- \pi+$) from tracking
- Electrons from Transition Radiation Detector & EMCal

Quarkonia

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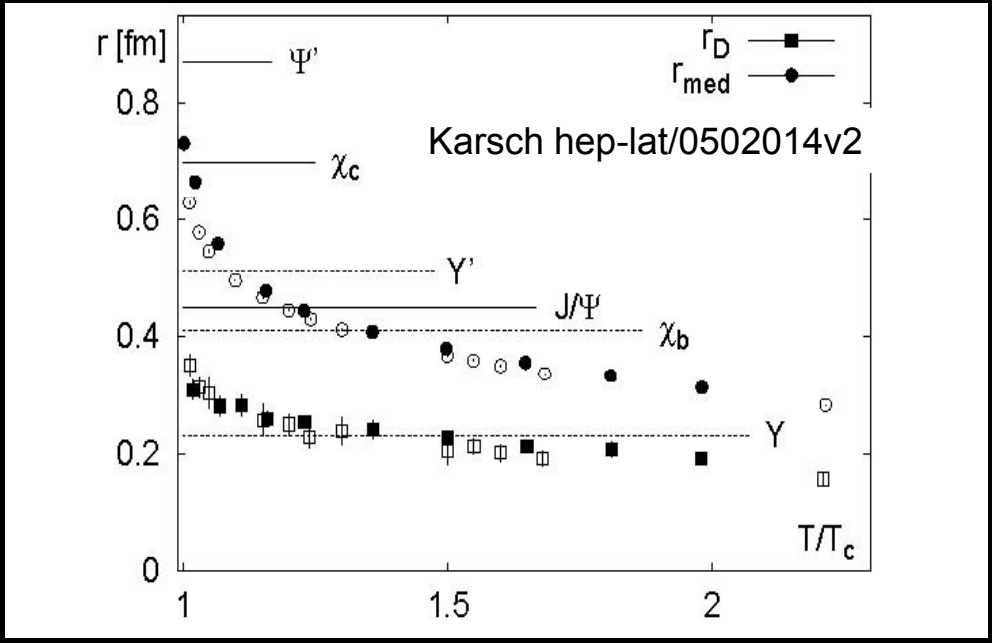
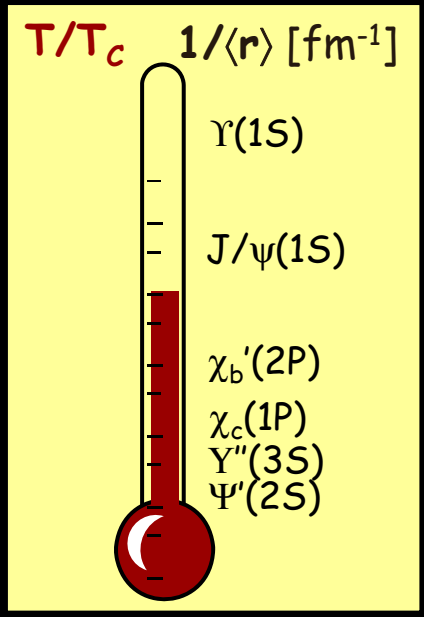
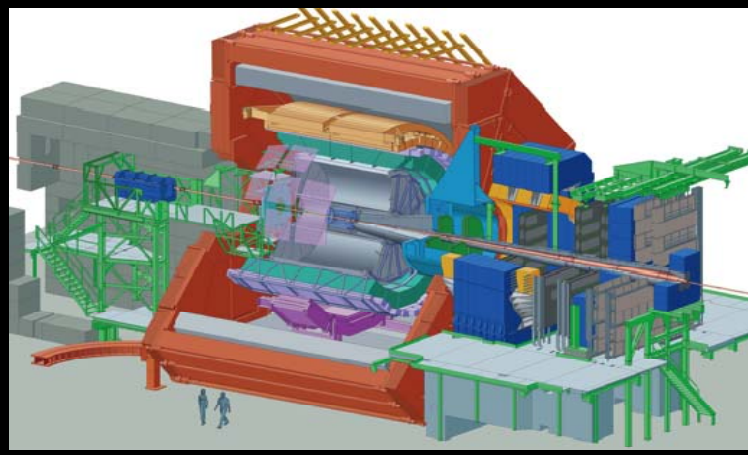




Measure melting order of $c\bar{c}$: Ψ′, χ_c, J/ψ $b\bar{b}$: ϒ″, ϒ′, ϒ

Summary – ALICE the Heavy Ion Experiment



ALICE is a versatile, heavy ion detector at the LHC

Overview:

Soft Probes – "ala RHIC"

- Expansion dynamics different from RHIC
- Soft physics measurements ala RHIC
  + extended PID
- Day 1 physics +

Hard Probes – Jet Quenching

- Jets, γ, pi-zeros, leading particles to large p_T

Hard Probes – Heavy Quarks

- Displaced vertices ($D^o \rightarrow K^- \pi+$) from TPC/ITS
- Electrons in Transition Radiation Detector (TRD)

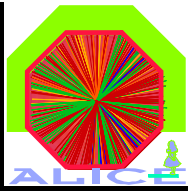
Hard Probes – Quarkonia

- J/ψ, Υ, Υ' (excellent), Υ''(2-3 yrs), ψ' ???

US Members:

Cal. St. U. – San Luis Obispo
Creighton University
University of Houston
Lawrence Berkeley Nat. Lab
Lawrence Livermore Nat. Lab
Oak Ridge National Lab
Ohio State University
Purdue University
University of Tennessee
Wayne State University
Yale University
Affiliated members:
Kent State University
University of Texas – Austin

ALICE Goals for Data-Taking & Physics



- First physics in ALICE will be pp - important reference data for heavy-ions
- Unique pp physics in ALICE - examples
  - multiplicity distribution
  - baryon transport
  - measurement of charm cross section major input to pp QCD physics
- **First 10^5 PbPb events:** global event properties
  - multiplicity, rapidity density
  - elliptic flow
- **First 10^6 PbPb events:** source characteristics and spacetime evolution
  - particle spectra, resonances
  - differential flow analysis
  - interferometry
- **First 10^7 PbPb events:** high-p_t, heavy flavours
  - jet quenching, heavy-flavour energy loss
  - charmonium production
- Eventual goals - bulk properties of medium
  - energy density, temperature, pressure
  - heat capacity/entropy, viscosity, sound velocity, opacity
  - susceptibilities, order of phase transition