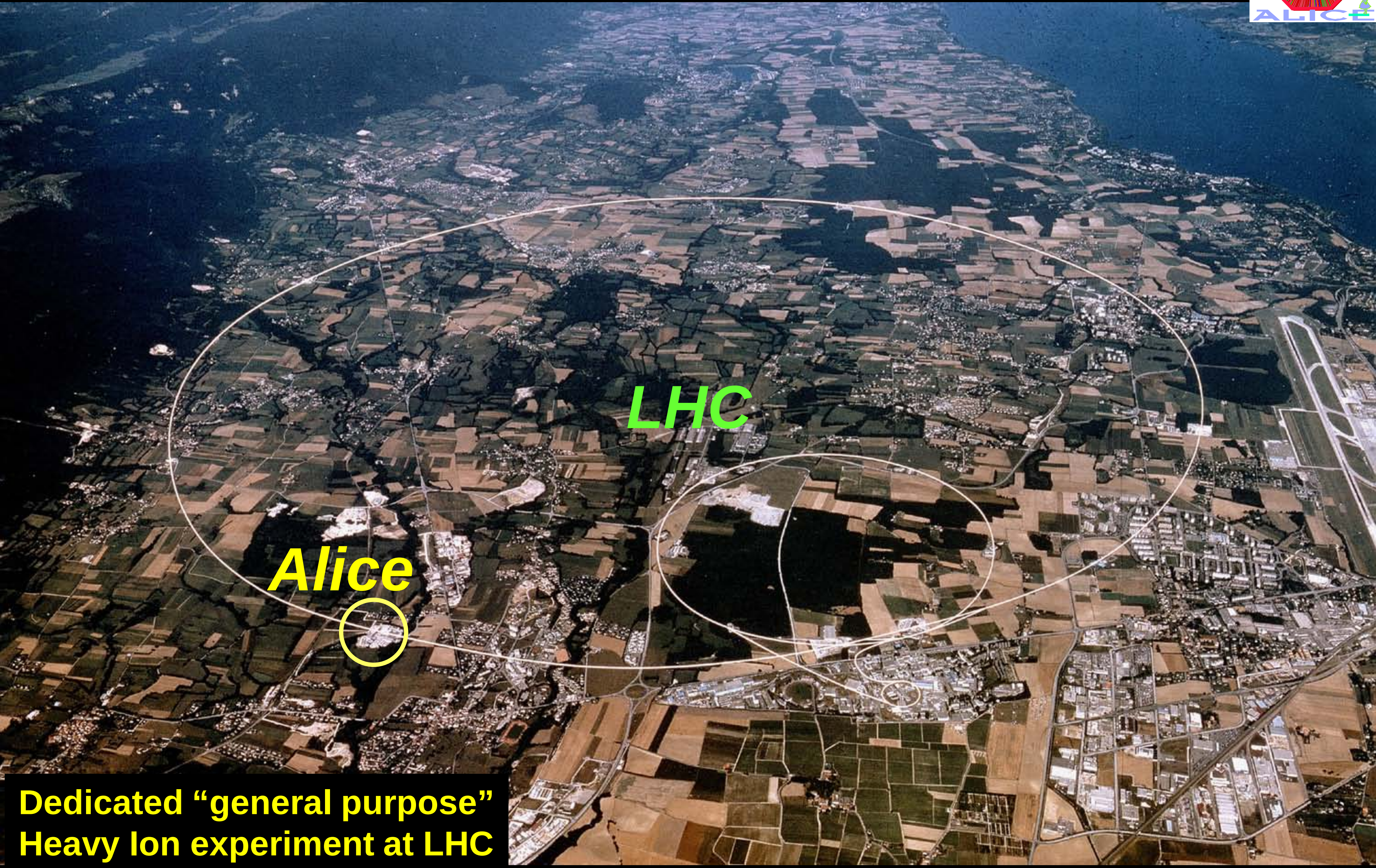
ALICE at LHC – Overview & Jet Physics



Dedicated “general purpose” Heavy Ion experiment at LHC

ALICE Collaboration

~ 1000 Members

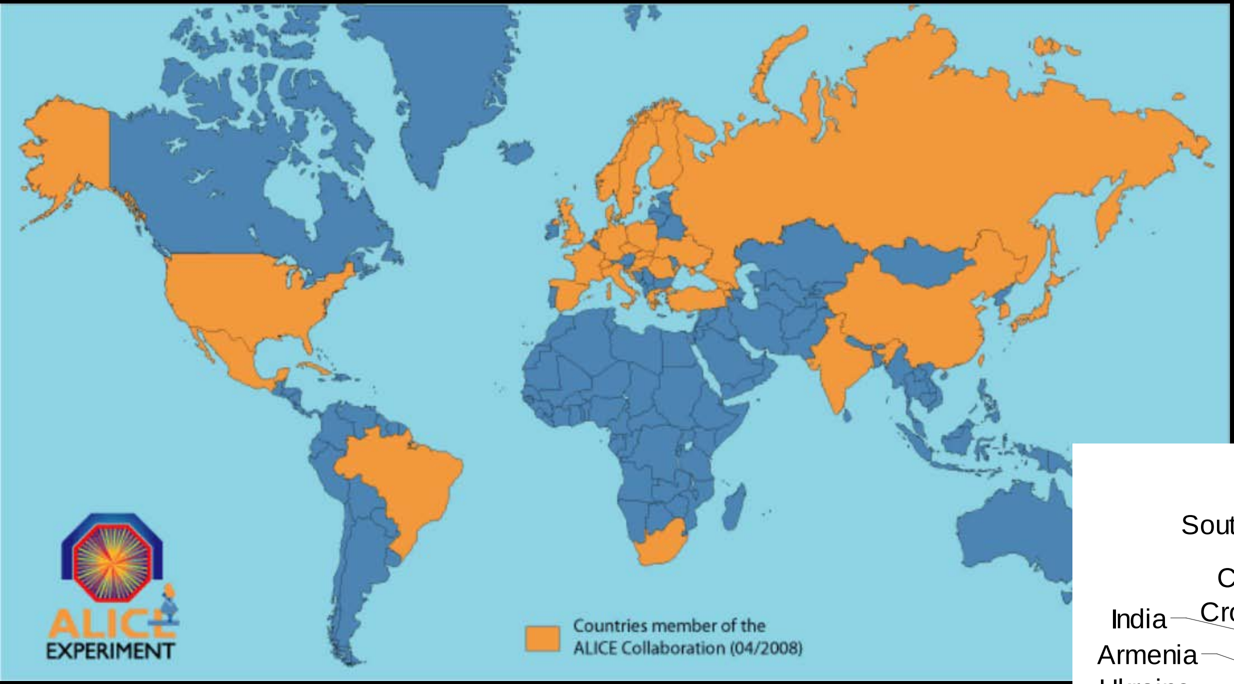
(63% - CERN States)

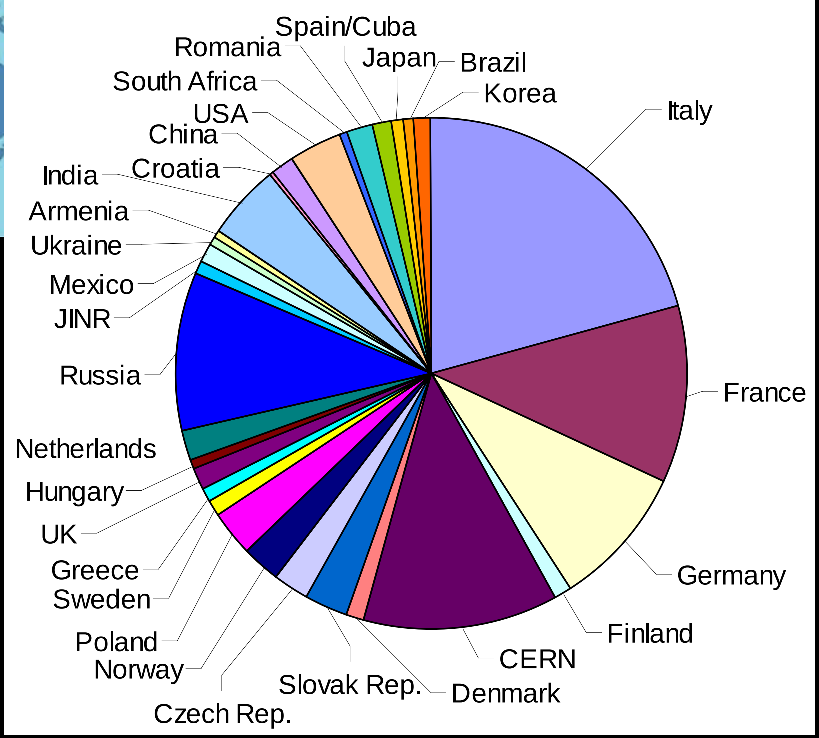
~ 30 Countries

~ 100 Institutes

~ 150 M CHF capital

(+ magnet)

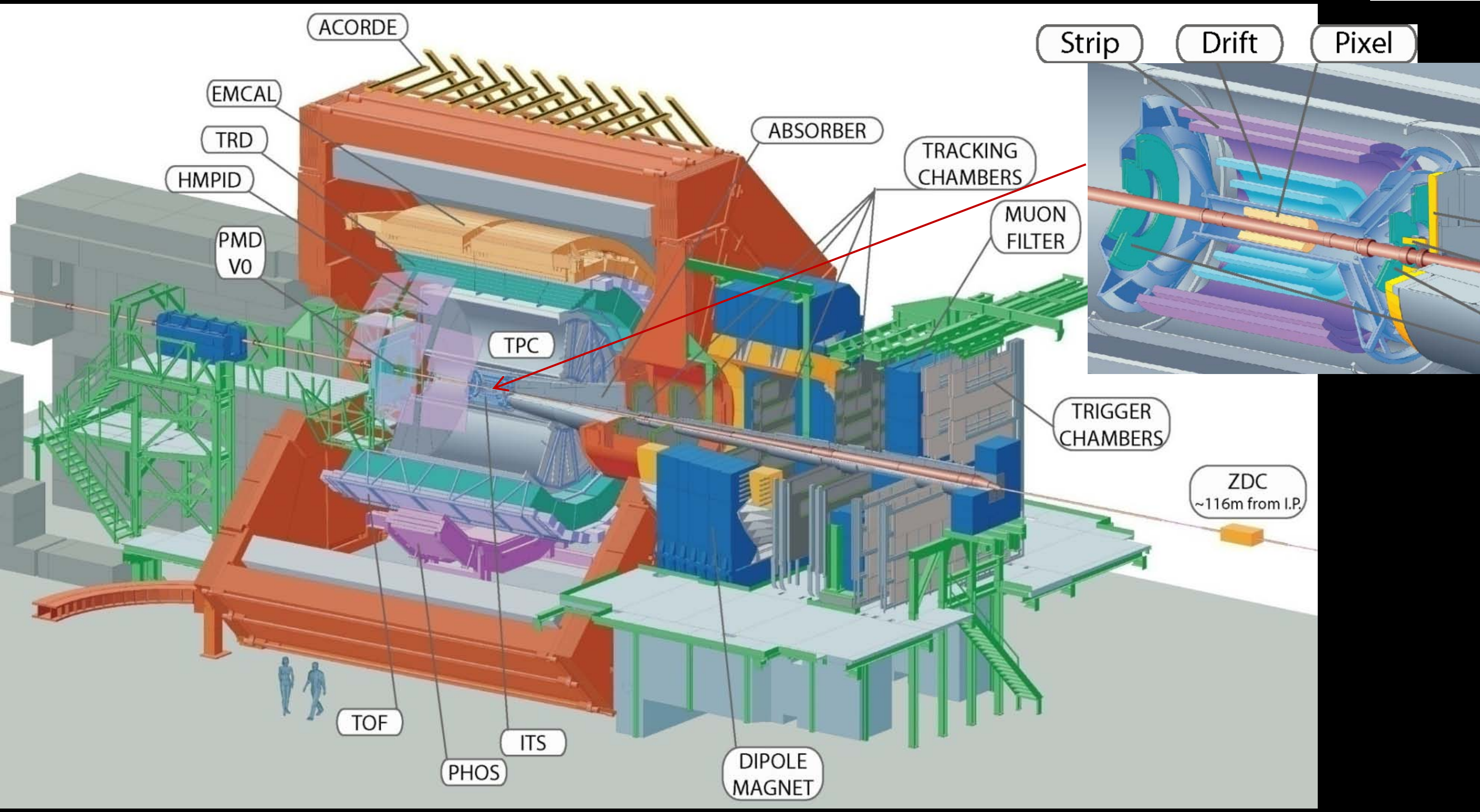




US ALICE – 11 Institutions
53 members (inc. 12 grad. students)

Cal. St. U. – San Luis Obispo, Creighton University, University of Houston, Lawrence Berkeley Nat. Lab, Lawrence Livermore Nat. Lab, Oak Ridge Nat. Lab, Ohio State University, Purdue University, University of Tennessee, Wayne State University, Yale University

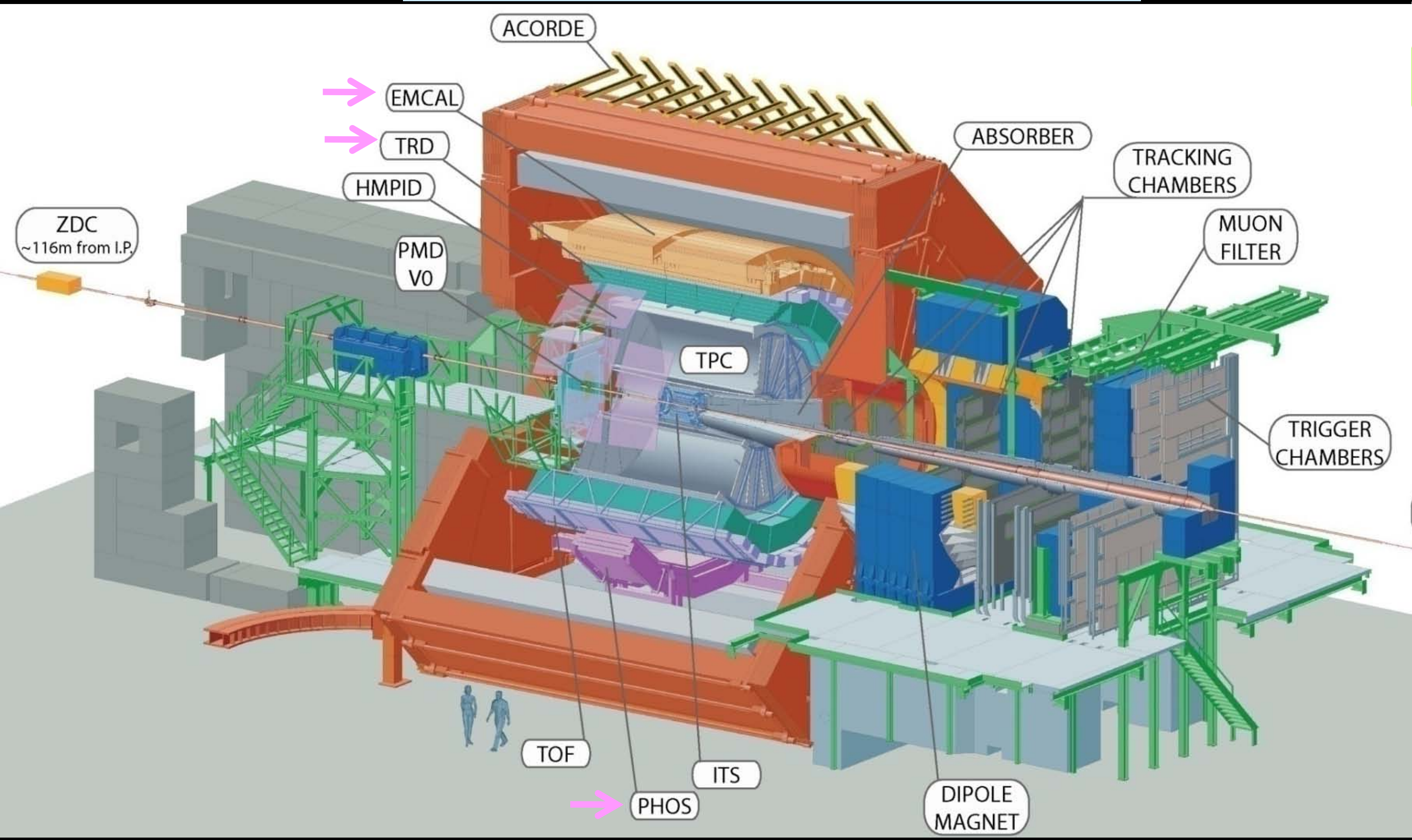
The ALICE Experiment



Fully Installed & Commissioned – Hadron & μ Capabilities

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

The ALICE Experiment

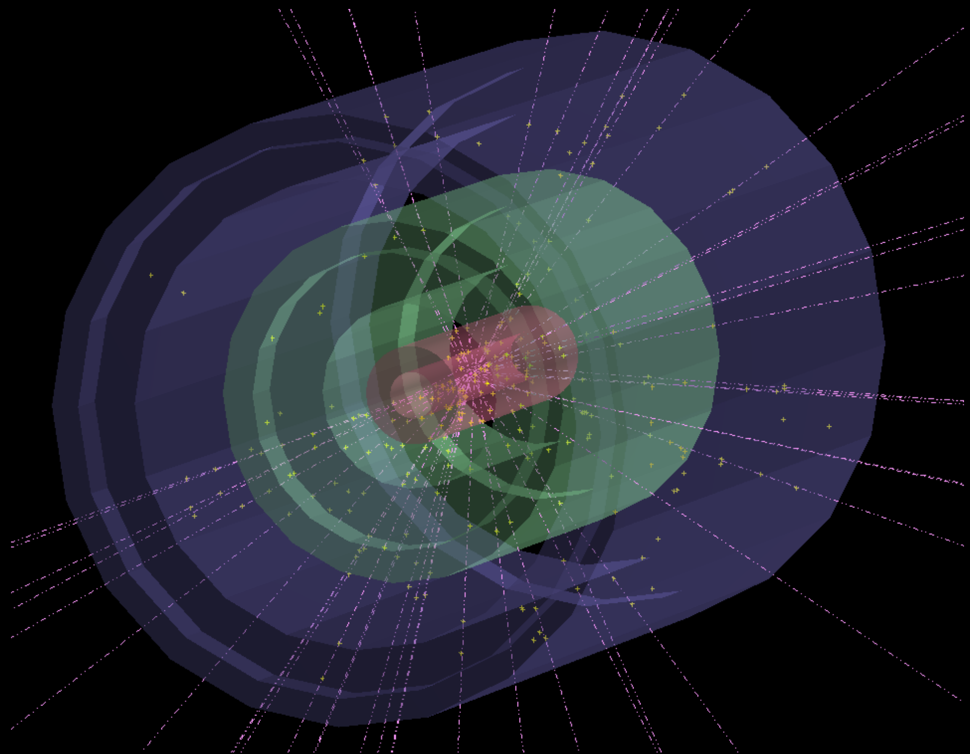


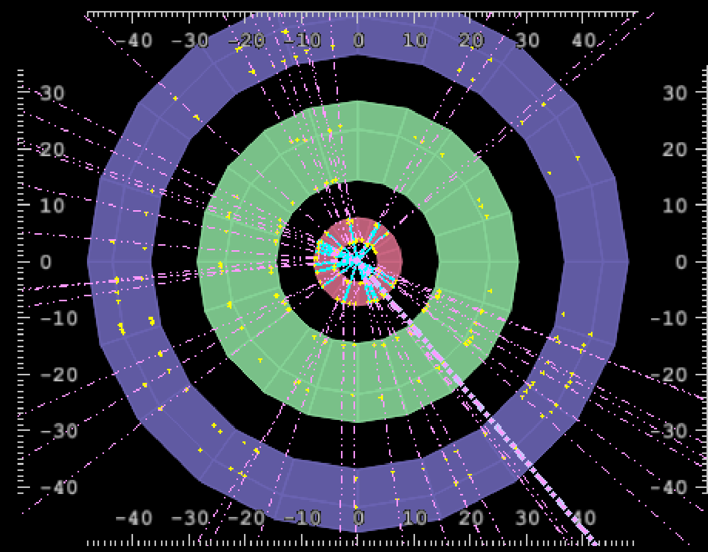
EM (e and γ) Partial Capabilities - (for 2010, 2011 in % below)

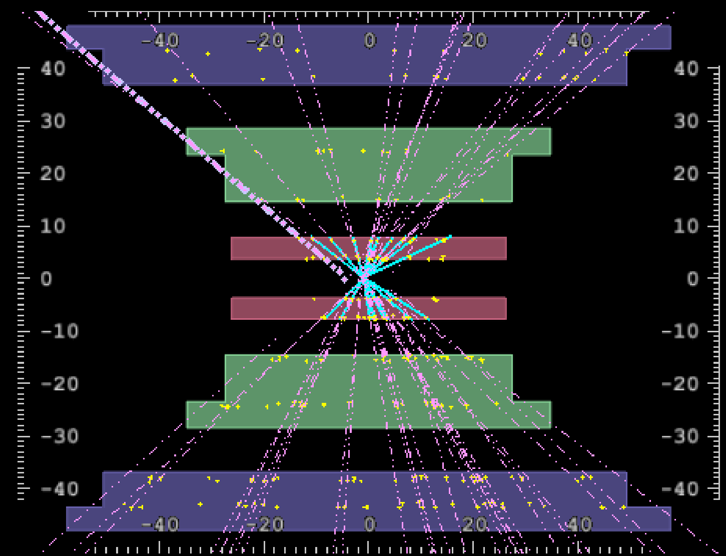
TRD (40, 100%), PHOS (60, 80%) & EMCAL (40, 100%) complete

LHC p + p Collisions in ALICE

- ALICE accumulated data in p + p
  - ~ 300K events at $\sqrt{s}$ = 900 GeV
  - ~ 20K events at $\sqrt{s}$ = 2.36 TeV







Dec. 2009

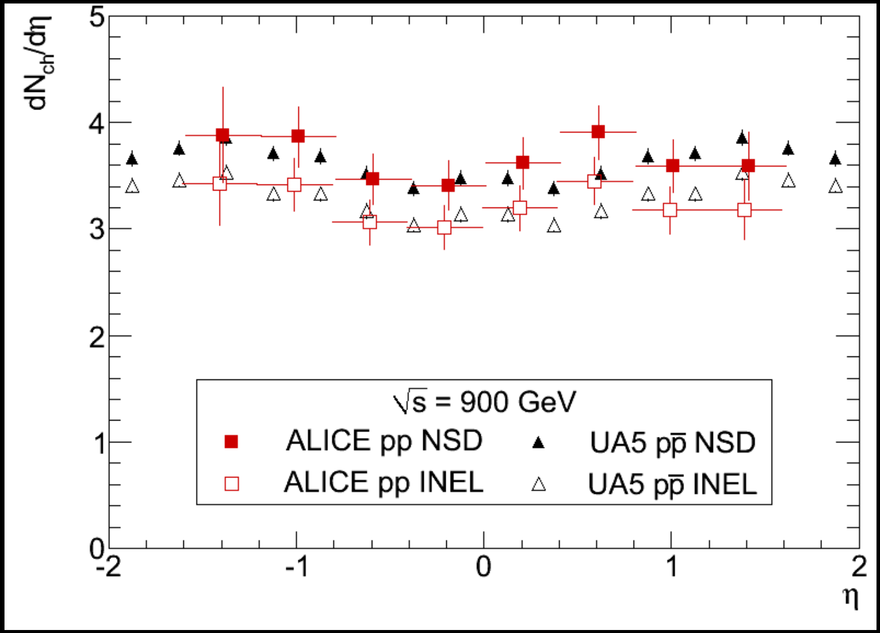
Early p + p Physics in ALICE

arXiv:0911.5430v2 [hep-ex]

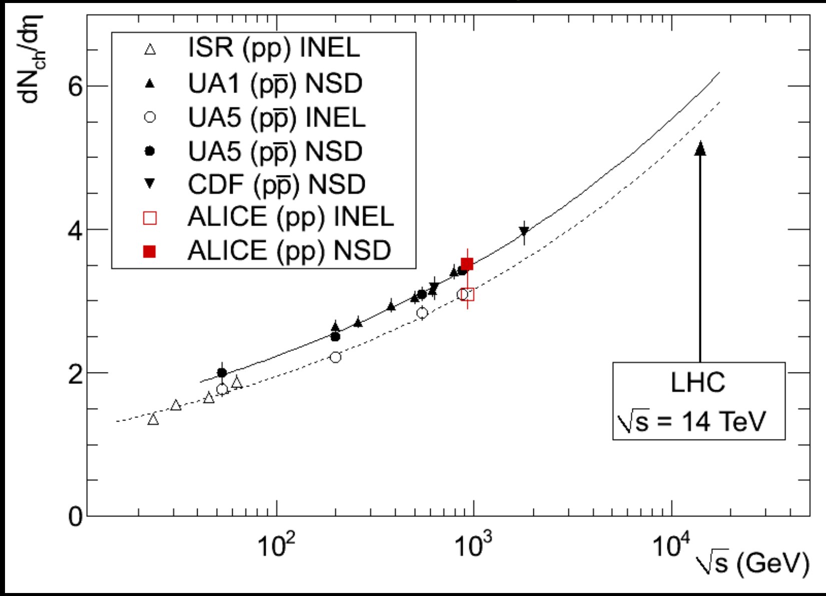
"Day 1" with p + p – underlying event to establish initial conditions & global event properties (energies - 0.9, 2.4, …. 10 ….14 TeV)

ALICE LHC p + p paper based on 284 events

Pseudo-rapidity (η) Distribution



$< dN_{ch}/d\eta \,|_{\eta=0} >$



Average number of charged particles created in p + p collisions at 900 GeV

$dN/d\eta = 3.10 \pm 0.13\ (\text{stat}) \pm 0.22\ (\text{syst})$

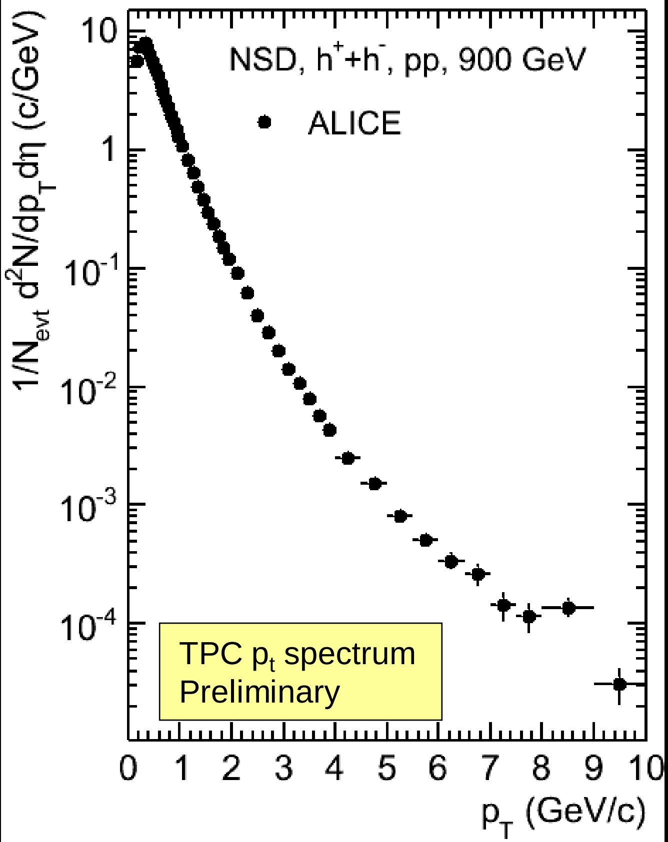
Dec. 2009

Early p + p Results in ALICE

Work in progress

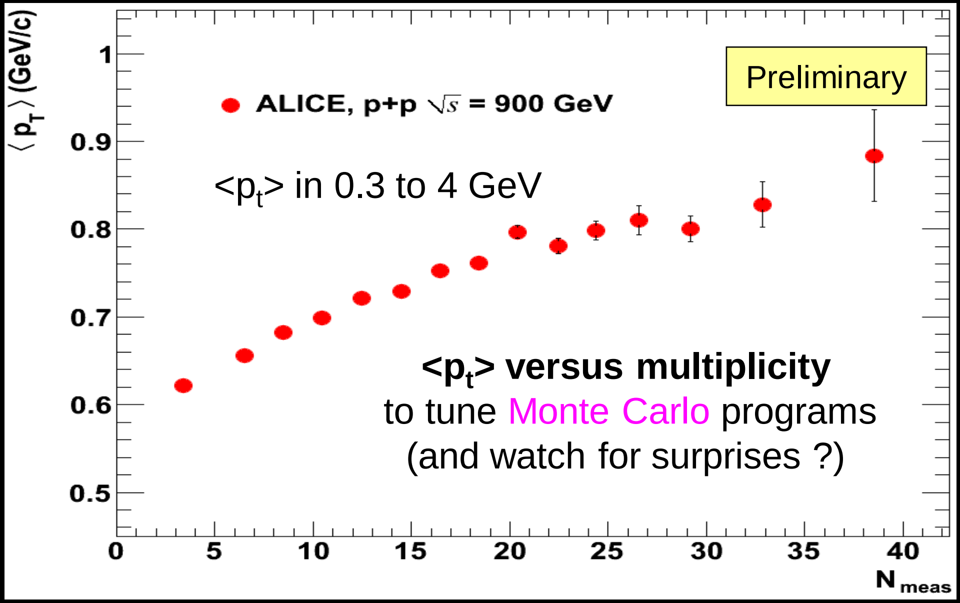
"Day 1" with p + p: Momentum dist's, for PID (see R. Bellwied talk)

Transverse Momentum (p_T) Distributions



Tracking in TPC + ITS

⟨ p_T ⟩ versus Multiplicity



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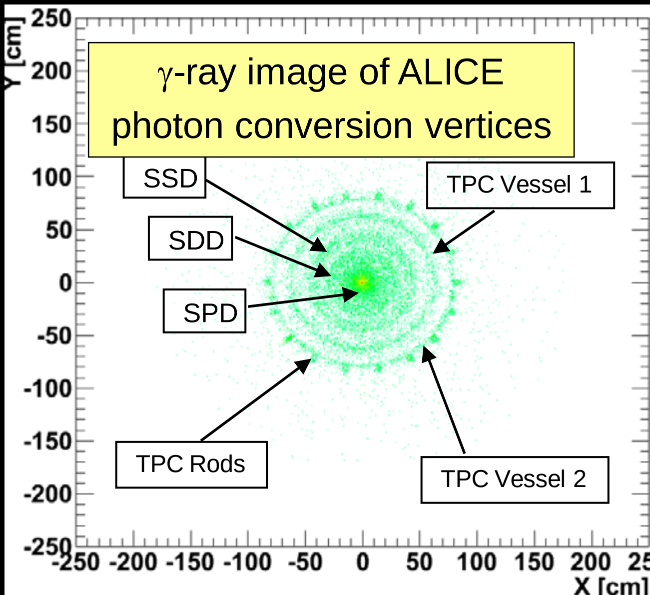
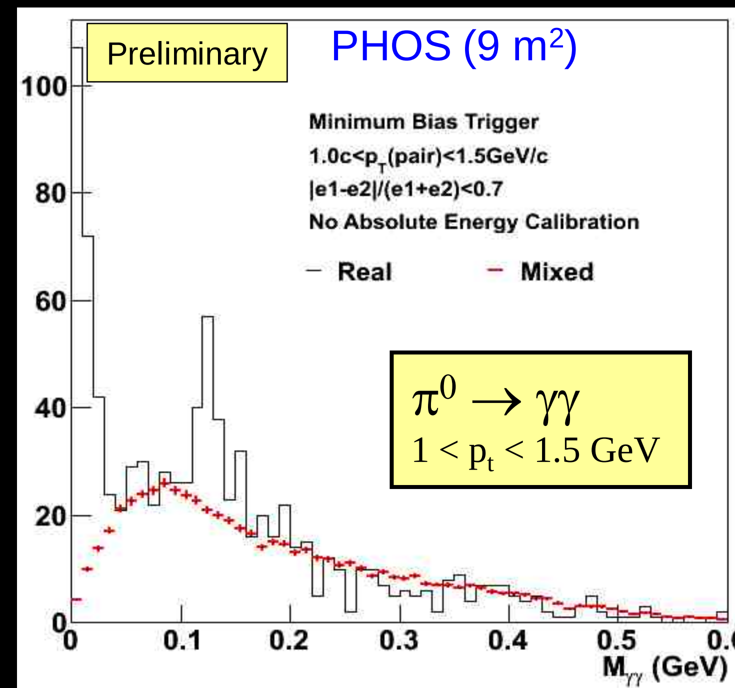
Early p + p Results in ALICE

Work in progress

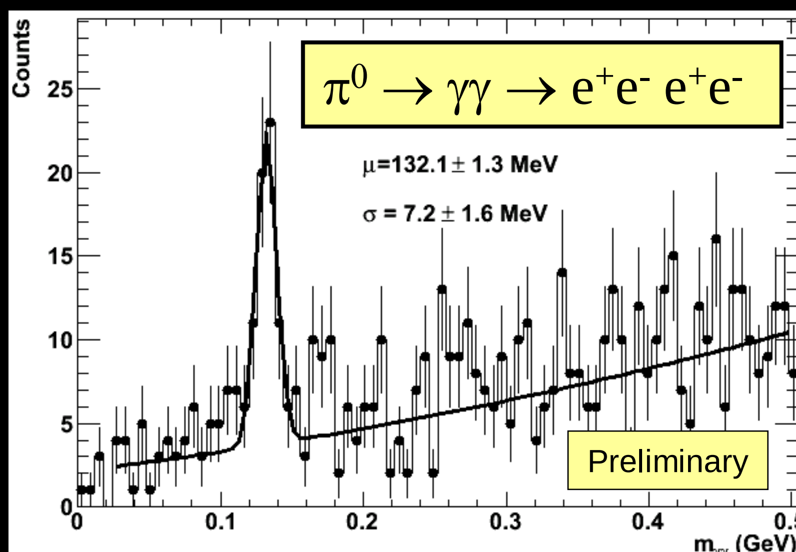
ITS-TPC conversion γ's



and PHOS π^0s



from π^0s



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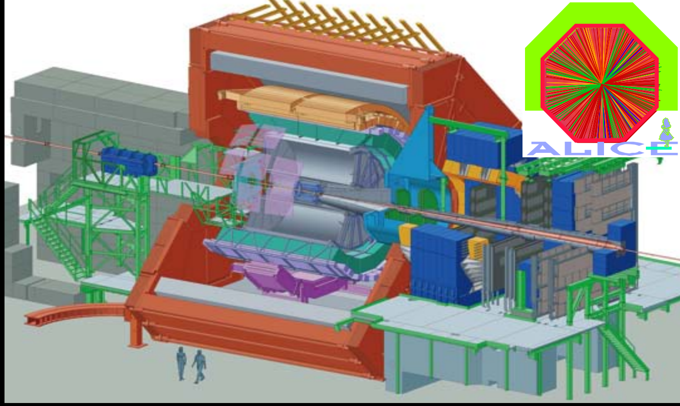
ALICE Heavy Ion Physics



Overview:

Soft Probes – ALICE → RHIC Capabilities & Beyond!

- Determine expansion dynamics: different from RHIC
- Soft physics measurements: RHIC with extended PID

  T, μ_B, ε, spectra, collective effects (flow),…

Hard Probes – Jet Quenching

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

Hard Probes – Heavy Quarks in central barrel and muon arm

e^+e^- at $-0.9 < \eta < 0.9$ and $\mu^+\mu^-$ at $-4.0 < \eta < -2.5$

- Hadronic decays and displaced vertices (e.g. $D^o \rightarrow K^- \pi+$)
- Semi-leptonic decays and displaced vertices (D or B → lepton + X)
- Leptonic decay coincidences (D or B → e μ)

Hard Probes – Quarkonia in central barrel and muon arm

- J/ψ, Υ, Υ' (excellent) ψ' , Υ''(statistically difficult ~ 2 - 3 yrs for central PbPb)

Hard Probe Rates in ALICE

ALICE hard physics capabilities:

- Electron/hadron disc. (TRD, EMCal)
- μ measurements (forward muon arm)
- Good γ/π^0 discrimination (EMCal, PHOS)
- Fast trigger on jets (EMCal)

Hard Probes statistics in ALICE:

10^4/year in minbias Pb+Pb:

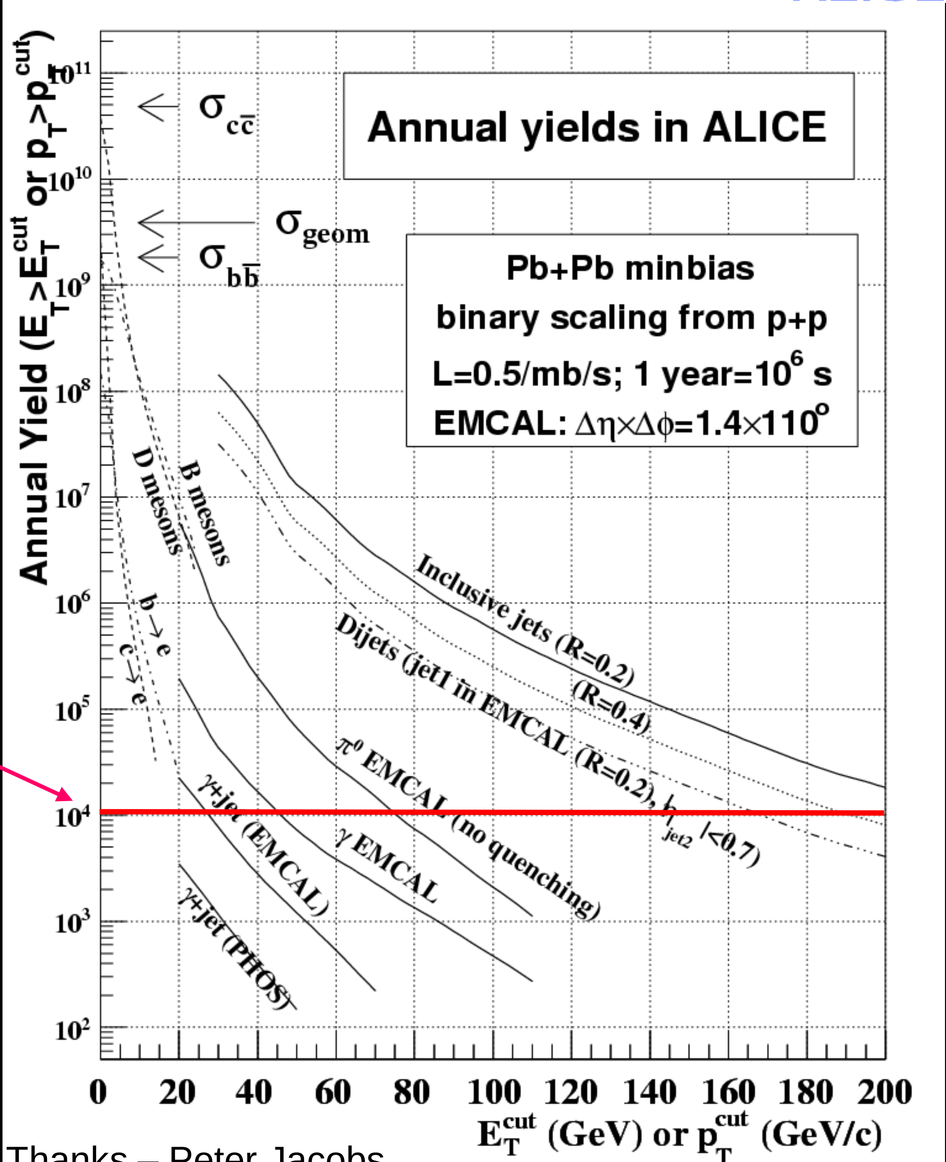
inclusive jets: $E_T \sim 200$ GeV

dijets: $E_T \sim 170$ GeV

π^0: $p_T \sim 75$ GeV

inclusive γ: $p_T \sim 45$ GeV

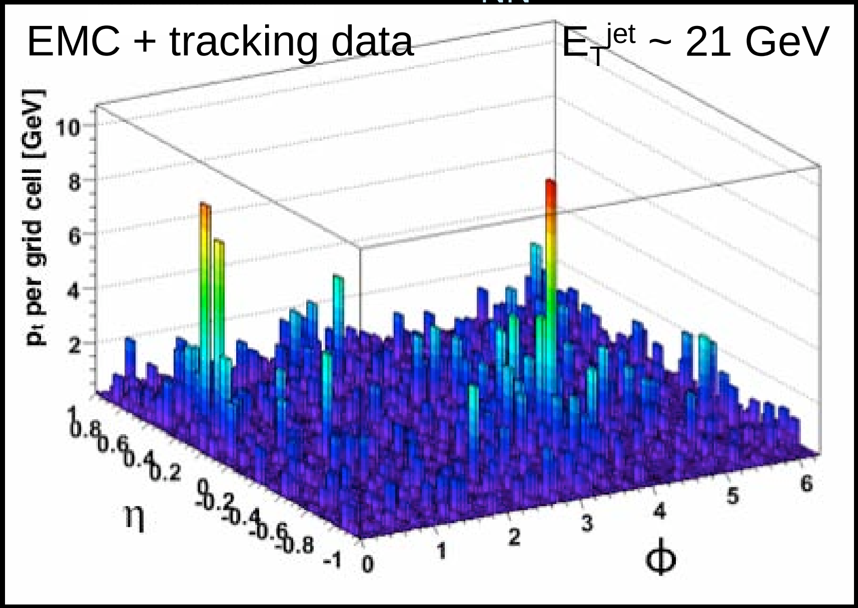
inclusive e: $p_T \sim 30$ GeV



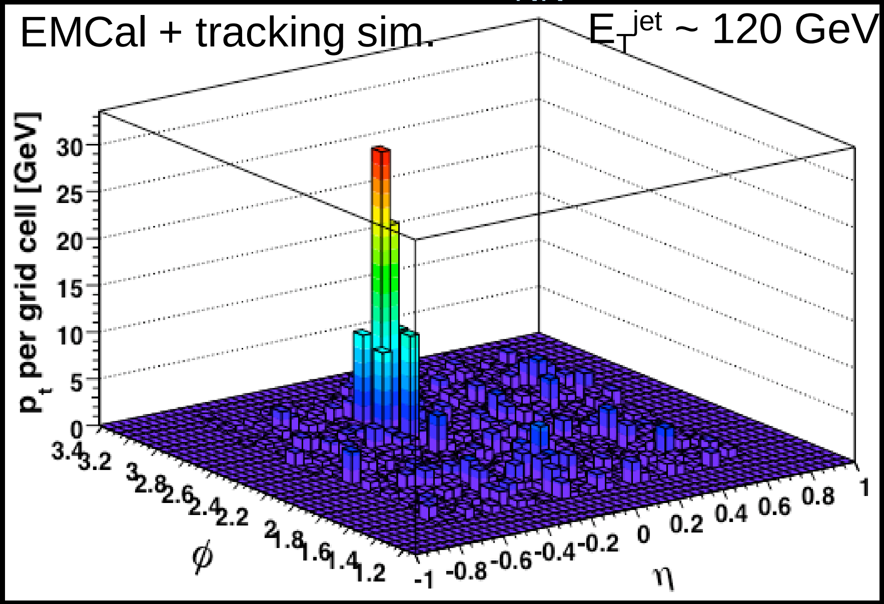
Thanks – Peter Jacobs

Jets in Heavy Ion Collisions at RHIC & LHC

Central Au+Au $\sqrt{s_{NN}}$=200 GeV



Central Pb+Pb $\sqrt{s_{NN}}$=5.5 TeV



Why measure jets in heavy ion collisions? [inclusive, di-jets, hadron-jet, γ-jet,..]

- Parton energy loss in High T QCD medium

  Requires detailed measurements for theoretical comparison / understanding

  Establish energy-loss mechanisms

  – energy flow within jets, quark vs gluon jet differences

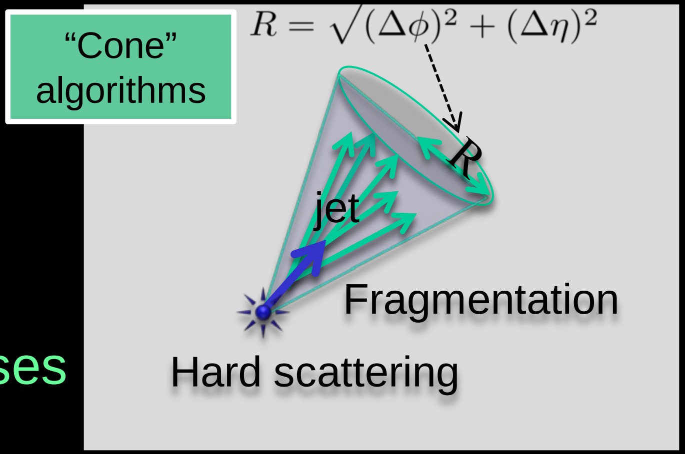
  Flavor and mass dependence, fragmentation modification …

- Medium response to parton energy loss – establish properties of the medium

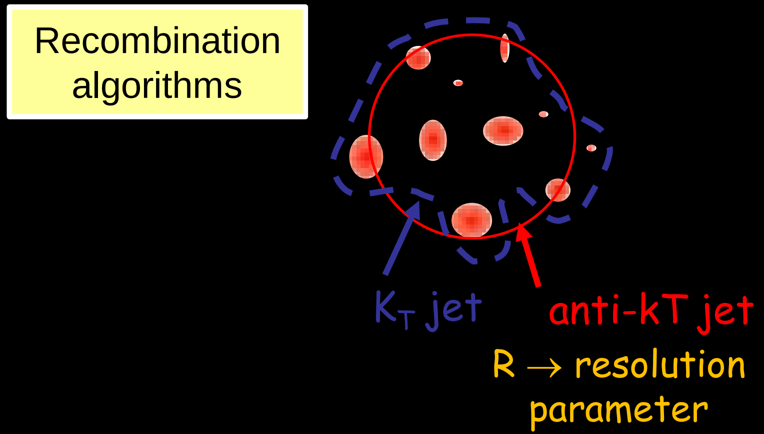
Jet Reconstruction in Heavy Ion Collisions

Primary Jet Reconstruction Approaches

(see talks by Salur, Bruna and Lai at this Workshop)



Cone-based algorithms
- Cone shape restriction
- Seeded-cone & strong trigger seed biases



Recombination algorithms – kT (anti-kT)
- starts from low (high) p_T
- merges weighted by 1/ p_T (p_T)

  → high (low) p_T disfavored

In Jet Reconstruction in ALICE – utilize anti-kT (less background sensitivity)

Considerations for Jet Reconstruction (from RHIC)

Jet reconstruction works for tracking + EM calorimetry

- Detector resolution sufficient, Systematic uncertainties understood

Many Biases (affecting jets) that must be taken into account:

- Trigger Effects (online & offline)
- Event backgrounds (on average and fluctuations)
- Algorithms (esp. seeded, effects on HI jet results, treatment of HI background)
- p_T cuts on tracking and calorimetry

Simulations approach

Utilize anti-kT (less background sensitivity) for jet reconstruction
Full GEANT for detector response
PYTHIA, qPYTHIA (an available quenching model) for jets
HIJING (central Pb+Pb at 5.5 TeV) for background

Bottom-line – Consider all effects → simulate/estimate systematic uncertainties
Reduce/eliminate p_T cuts, assess background & fluctuations →
Background effects require delicate unfolding procedure (doable)

Inclusive Jets – Systematic Uncertainties

Systematic effect	Incl. cross section sys. uncert.
Common in p+p and A+A	
Tracking distortions (space charge etc.)	unknown
Tracking efficiency	1%
Hadronic and electron energy double counting	3-4%
EMCal energy scale	8-10%
Unobserved neutral energy	13-15%
Underlying event (central Pb–Pb)	
Fluctuations	20% (75 GeV/c), 3% (150 GeV/c)
False Jets	small (>50 GeV/c)

ALICE EMCal Physics Performance Report (Nov. 2009):

http://rnc.lbl.gov/Alice/wiki/ALICE_USA/Documents_files/EMCAL_PPR_DOE_November2009.pdf

Modeling Parton Energy Loss - qPYTHIA

Eur. Phys. J. C (2009) 63: 679–690
DOI 10.1140/epjc/s10052-009-1133-9

arXiv:0907.1014v1 [hep-ph]

THE EUROPEAN PHYSICAL JOURNAL C

Special Article - Tools for Experiment and Theory

Q-PYTHIA: a medium-modified implementation of final state radiation

Néstor Armesto[1,a], **Leticia Cunqueiro**[2,b], **Carlos A. Salgado**[1,c]

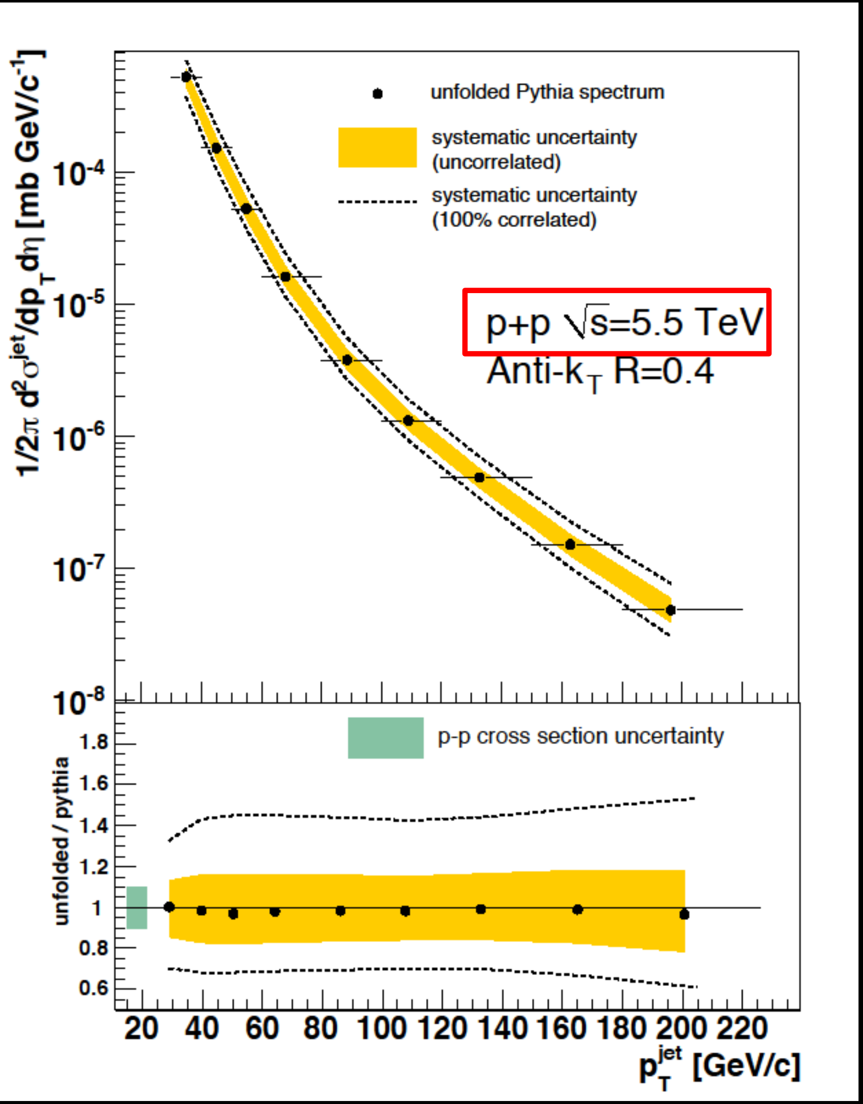
[1]Departamento de Física de Partículas and IGFAE, Universidade de Santiago de Compostela, 15706 Santiago de Compostela, Galicia, Spain
[2]Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Frascati, 00044 Frascati (Roma), Italy

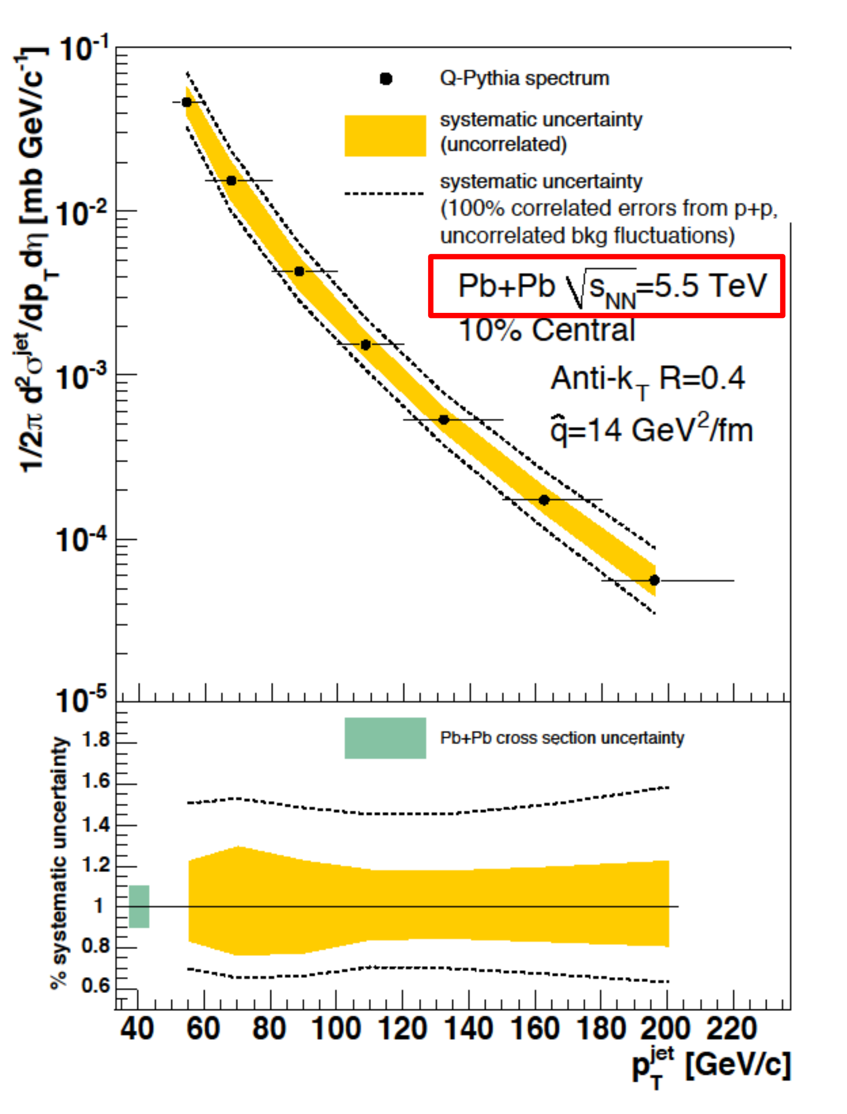
- Pythia with vacuum fragmentation reproduces pp → jets.
- qPYTHIA uses medium-induced gluon radiation in the branching process.
- Medium effects introduced through additive term in the splitting functions computed in MSSA (multiple-soft scattering approximation).

WARNING – we use qPYTHIA "out of the box" – publicly available.
(box opened 6 months ago!)
Being used here as indicator of possible future comparisons – qPYTHIA may evolve!

In remainder of this presentation, will use qPYTHIA as baseline.

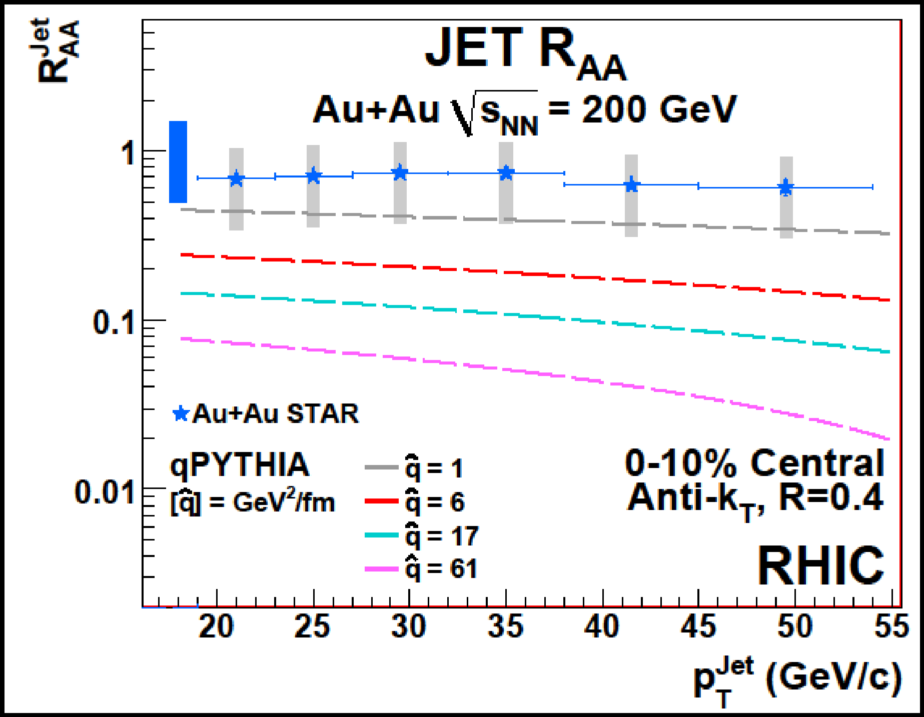
ALICE Inclusive Jet Cross Section Measurement Capabilities



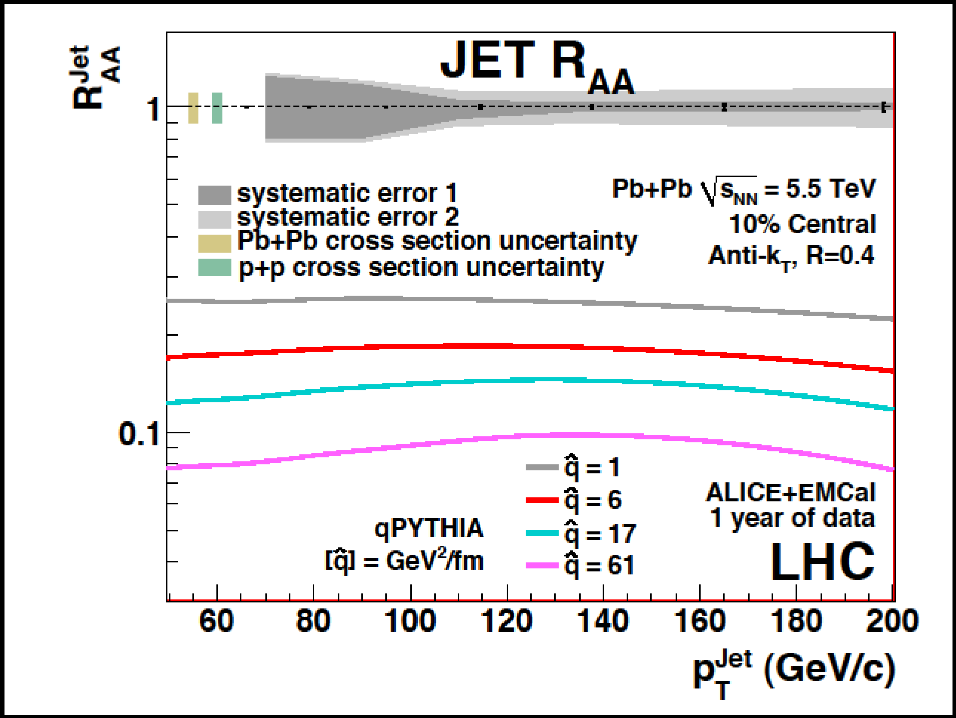


Jets at RHIC & LHC: R_{AA}

Central Au+Au $\sqrt{s_{NN}}$=200 GeV



Central Pb+Pb $\sqrt{s_{NN}}$=5.5 TeV



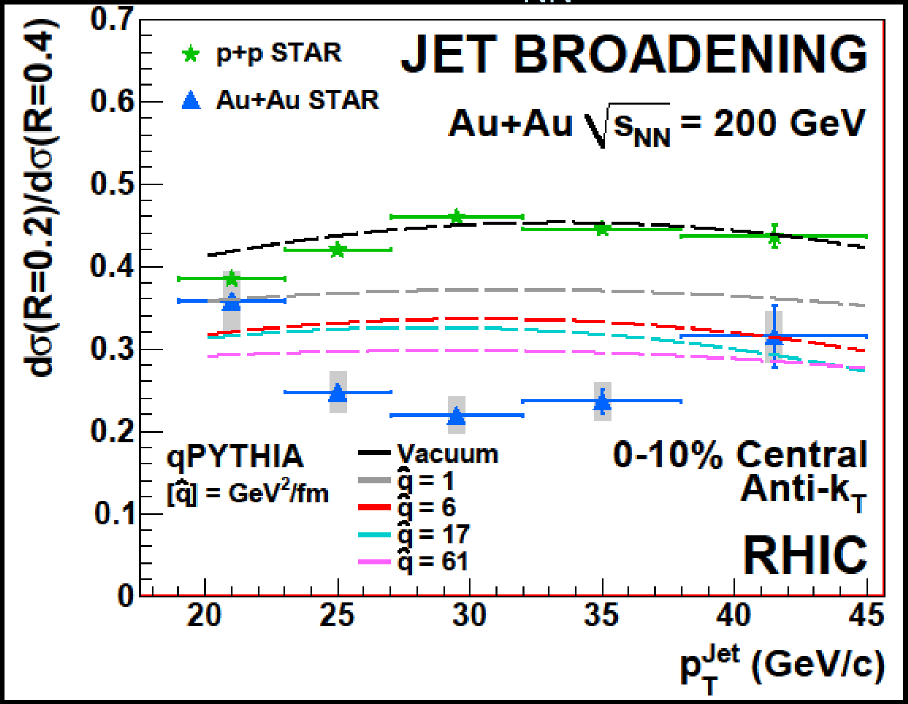
Pythia with vacuum frag. fits pp
RHIC jets may not be suppressed

Jet systematic uncertainties small!
Measurements possible to 200 GeV
Statistically and systematically

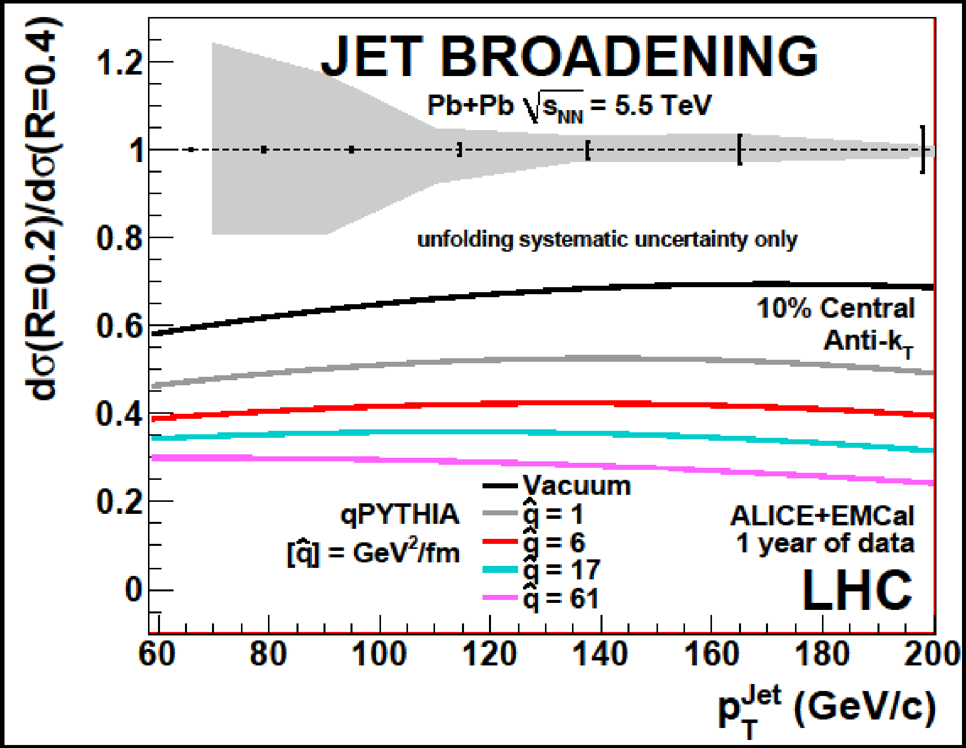
Jet Broadening at RHIC & LHC

Ratio of Jet yields within R = 0.2 vs R = 0.4 using anti-KT algorithm

Central Au+Au $\sqrt{s_{NN}}$=200 GeV



Central Pb+Pb $\sqrt{s_{NN}}$=5.5 TeV



- qPYTHIA not optimized (yet) – do not draw conclusions from shape diff's.
- Jet energy profile (AuAu data) BROADENED indicating JET QUENCHING!
- Small experimental systematic uncertainties in measurements (ratios from same exp. and data set) → a precision measurement in ALICE!

ALICE EMCal Jet Trigger

Table 3.1: EMCal jet trigger enhancement factors: Gain in recorded jet statistics for various systems due to the EMCal Jet Trigger, together with assumed mean luminosity, annual running time and ALICE DAQ rate.

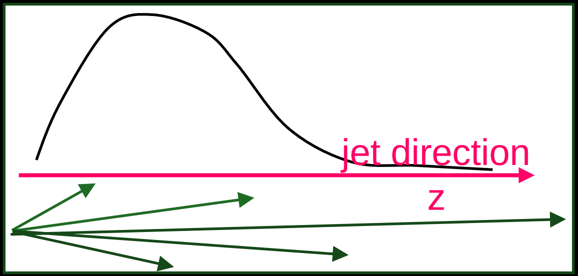
System	$\sqrt{s}$(TeV)	$L_{mean}(cm^{-2}s^{-1})$	Time (s)	DAQ rate (Hz)	Gain at L1
p–p	5.5	5×10^{30}	10^5	500	110
p–p	14	5×10^{30}	10^7	500	500
Pb–Pb Centrality					
min. bias	5.5	5×10^{26}	10^6	20	21
min. bias	5.5	5×10^{26}	10^6	50	9
min. bias	5.5	5×10^{26}	10^6	100	4
0–10%	5.5	5×10^{26}	10^6	50	5
0–10%	5.5	5×10^{26}	10^6	100	2
60–80%	5.5	5×10^{26}	10^6	50	12
60–80%	5.5	5×10^{26}	10^6	100	6

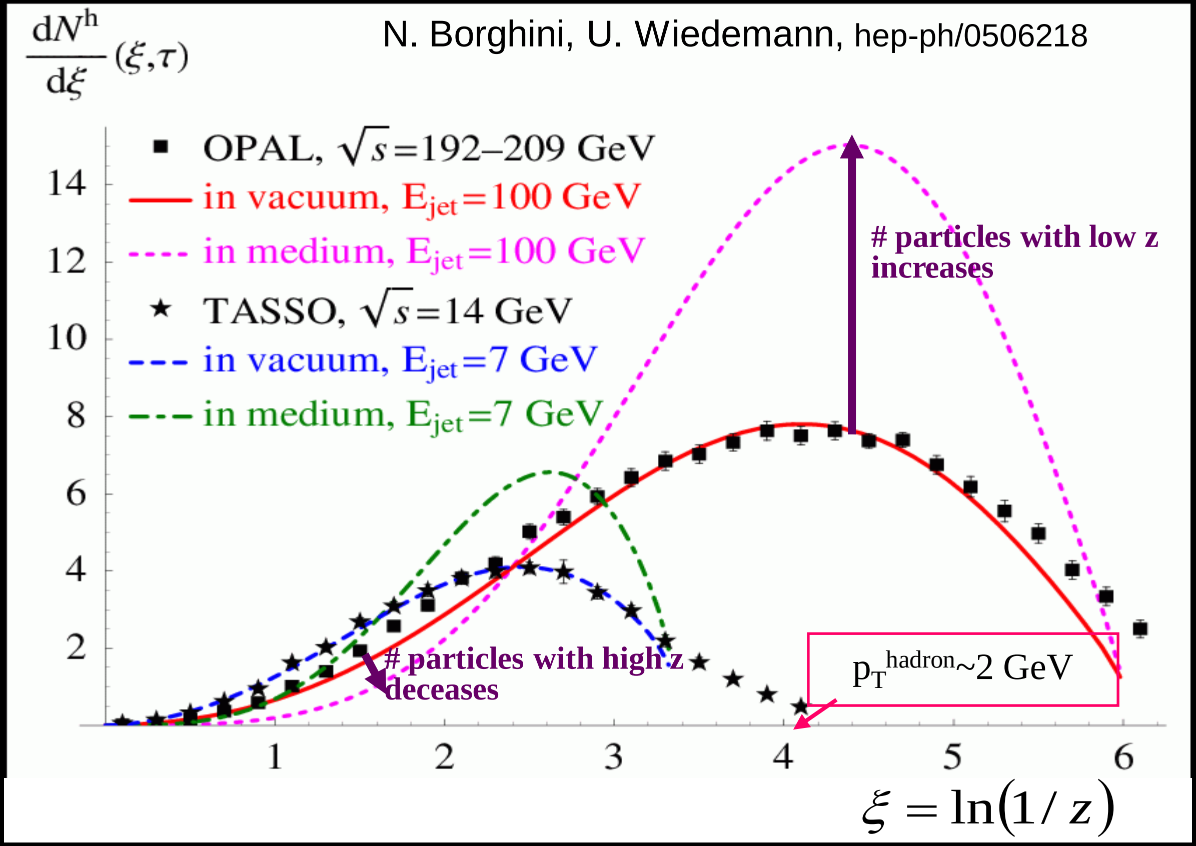
- Based on the simulation results presented in this chapter we find that in order to correct for the trigger bias and recover the full inclusive jet cross sections from the triggered samples with a 5% systematic uncertainty, ALICE will need to record statistics of 25 M minimum bias p–p events and 2 M minimum bias Pb–Pb events. This can be easily accommodated within the ALICE DAQ bandwidth by downscaled minimum bias triggers.

Expectations – Medium Modification of Jet Fragmentation

Fragmentation along jet axis: $z = p_{hadron} / p_{parton}$

Introduce $\xi = \ln(E_{jet} / p_{hadron}) \sim \ln(1/z)$:





Summary

ALICE –

- is a versatile, general purpose heavy ion detector at the LHC
- in operation and works well
- has begun first physics with p + p at 900 GeV → more to come
- will contribute significantly to understanding (soft & hard) HI physics
  will address many general questions about the quark-gluon plasma
  has a broad "hard probes" program (heavy flavors, quarkonia, jets, γ's)

ALICE with the EMCal has a robust jet physics program in PbPb at the LHC:

- Jet measurement capabilities established in LHC heavy ion background
- Systematic and statistical measurement errors understood for
  Jets of energies of 200 GeV (limited by single PbPb year stats)
- Will measure inclusive jet spectra, jet R_{AA}, jet shapes and broadening.
  - to address questions of degree of jet broadening vs. suppression.
  - to understand parton energy loss at a fundamental level.
  - to address questions of medium mod. (fragmentation) of jets.
- Potential for measurements of
  B-tagged jets to ~60 GeV (stats in one PbPb month – M. Heinz talk)
  Flavor dependence (D, B, quark- and gluon-jets) – work continues!
  Medium response to jets (R. Bellwied talk) for properties of medium!