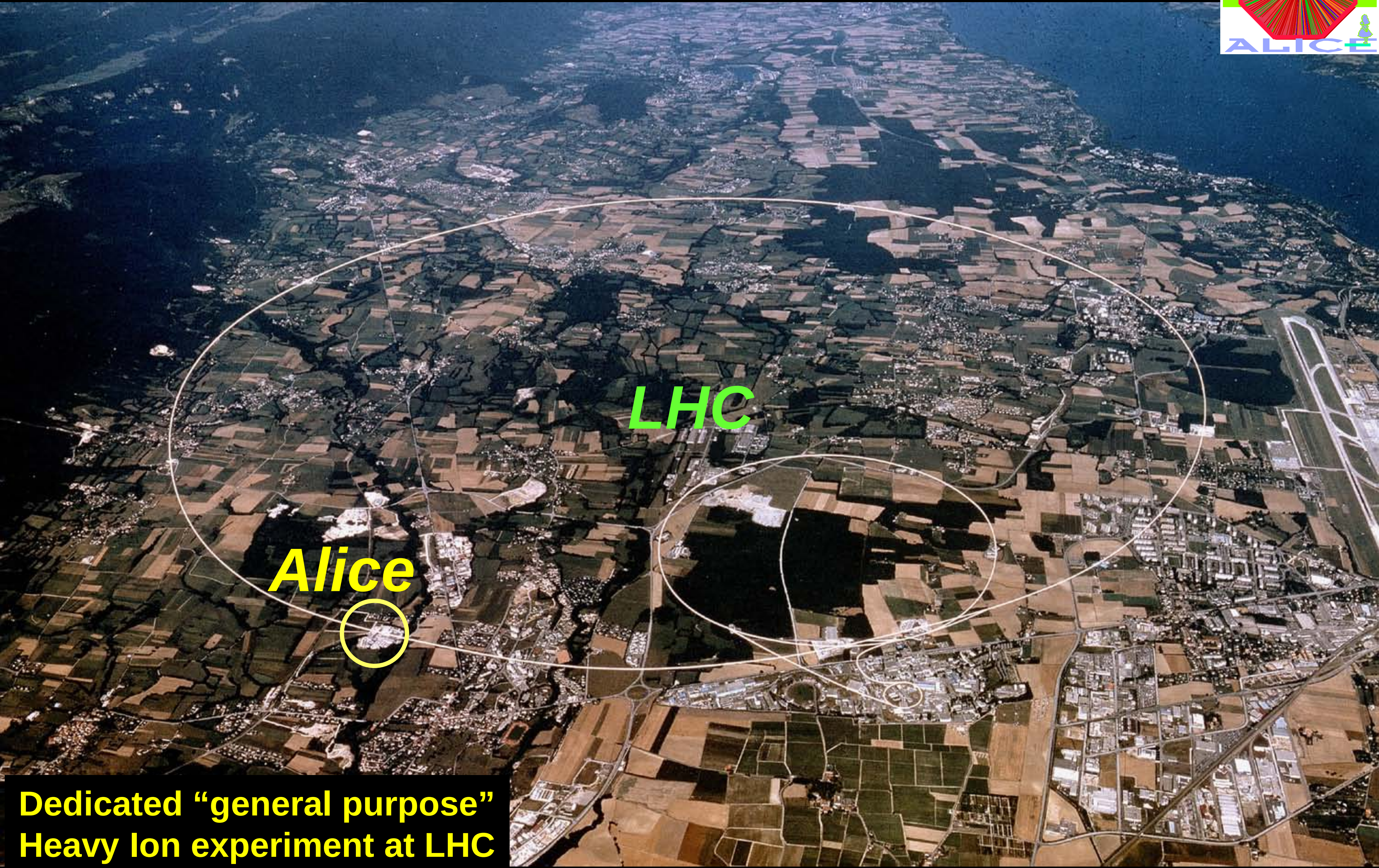
Status of ALICE at the LHC

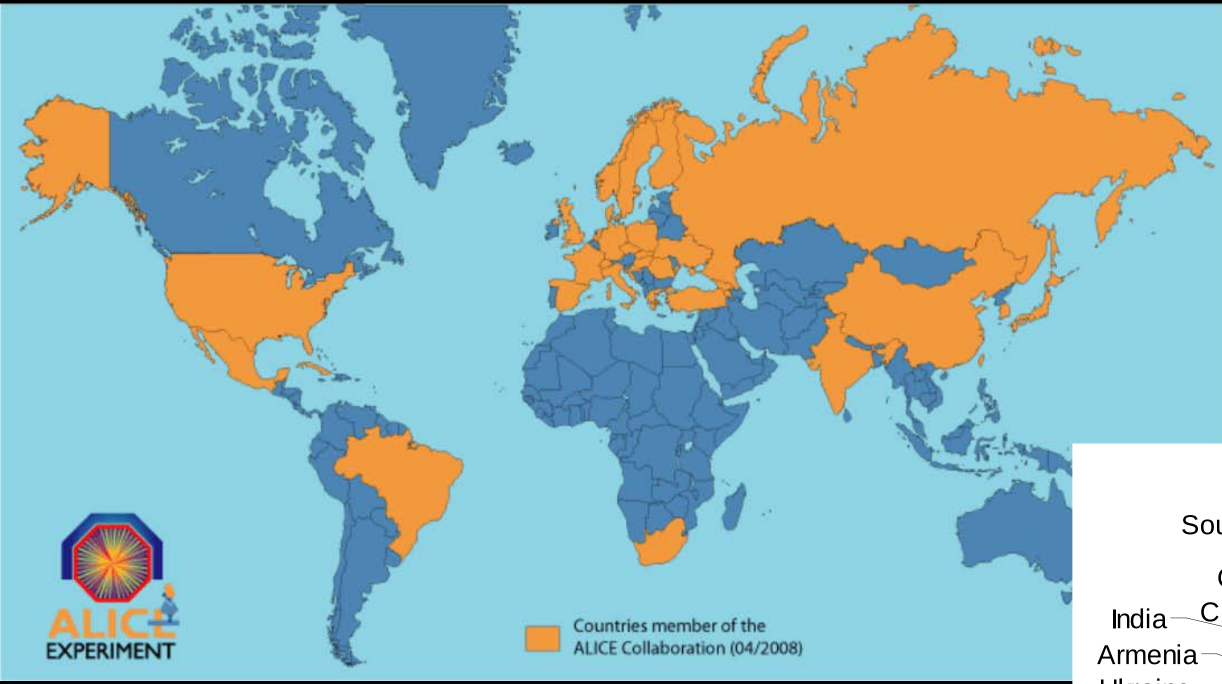


Dedicated “general purpose” Heavy Ion experiment at LHC

John Harris (Yale) for ALICE Collaboration

DPF 2009, Detroit MI, July 27, 2009

ALICE Collaboration



~ 1000 Members

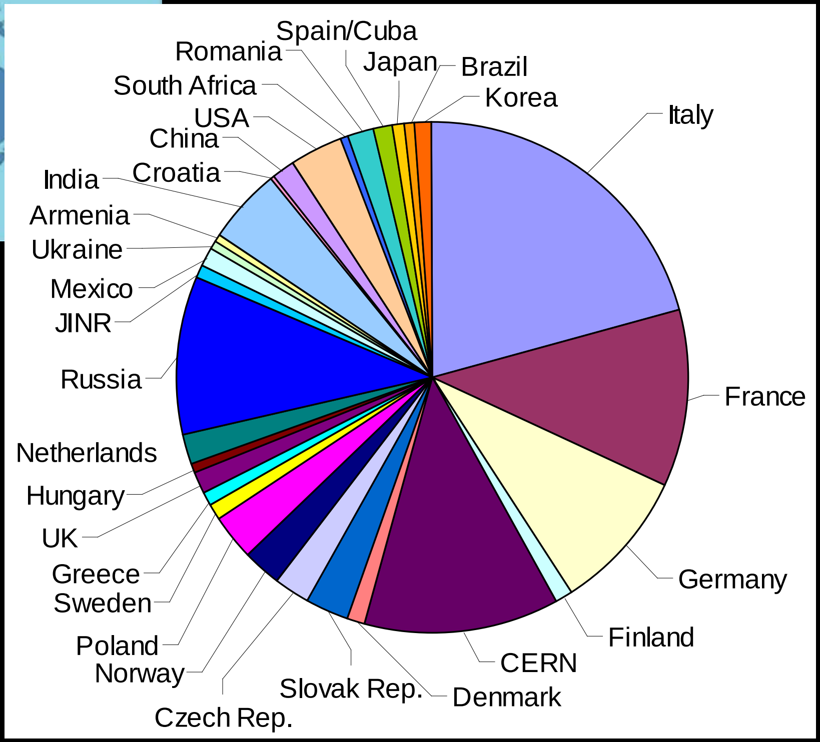
(63% - CERN States)

~ 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

Heavy Ion Challenges

- Experimental Challenges & ALICE Solutions

1. Extreme particle densities ($dN_{ch}/d\eta$ ~ 1000 → several thousand)

    500 times p+p at LHC, 2 – 4 times Au+Au at RHIC

→ ALICE solution for particle densities : high granularity 3D tracking, long path-lengths from interaction vertex [e.g. EMCal at 4.5 m]

2. Large dynamic range in p_T

    from very soft (0.1 GeV) to fairly hard (100 GeV)

→ ALICE solution to extend p_T range : thin detectors, modest field (low p_T), large lever arm for tracking & resolution at large p_T

    ALICE: < 10% X_0 inside r < 2.5 m, B = 0.5T, BL^2 ~ CMS

3. Measure & ID many hadrons

    requires: secondary vertices, lepton ID, hadron ID

→ ALICE solution for extended particle ID : employ many technologies

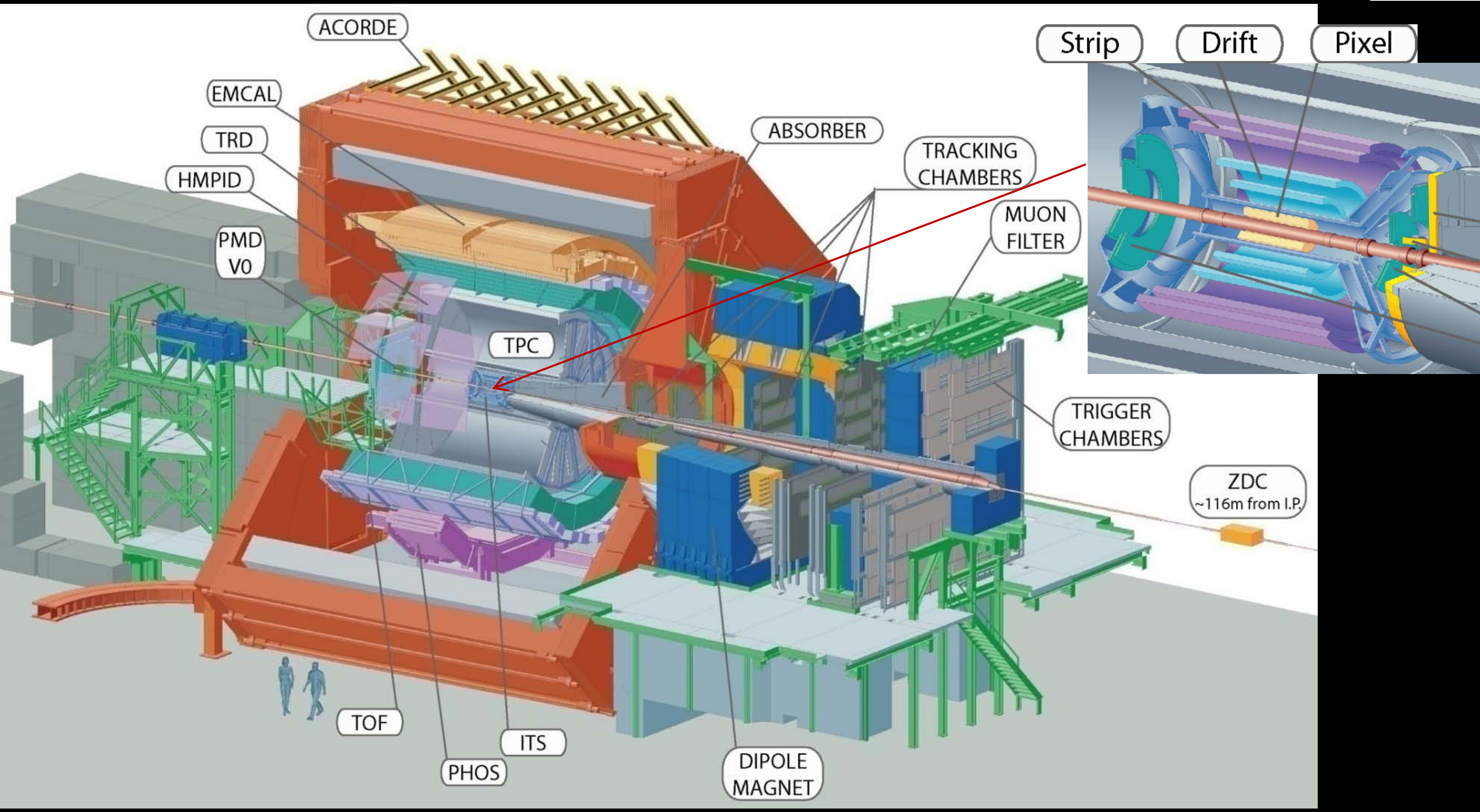
    dE/dx, Cherenkov & transition rad., TOF, calorimeters, muon filter, topological..

\+ Modest luminosity and interaction rates

    10 kHz (Pb + Pb)

ALICE rates → allow slow detectors (TPC, SDD), moderate radiation hardness

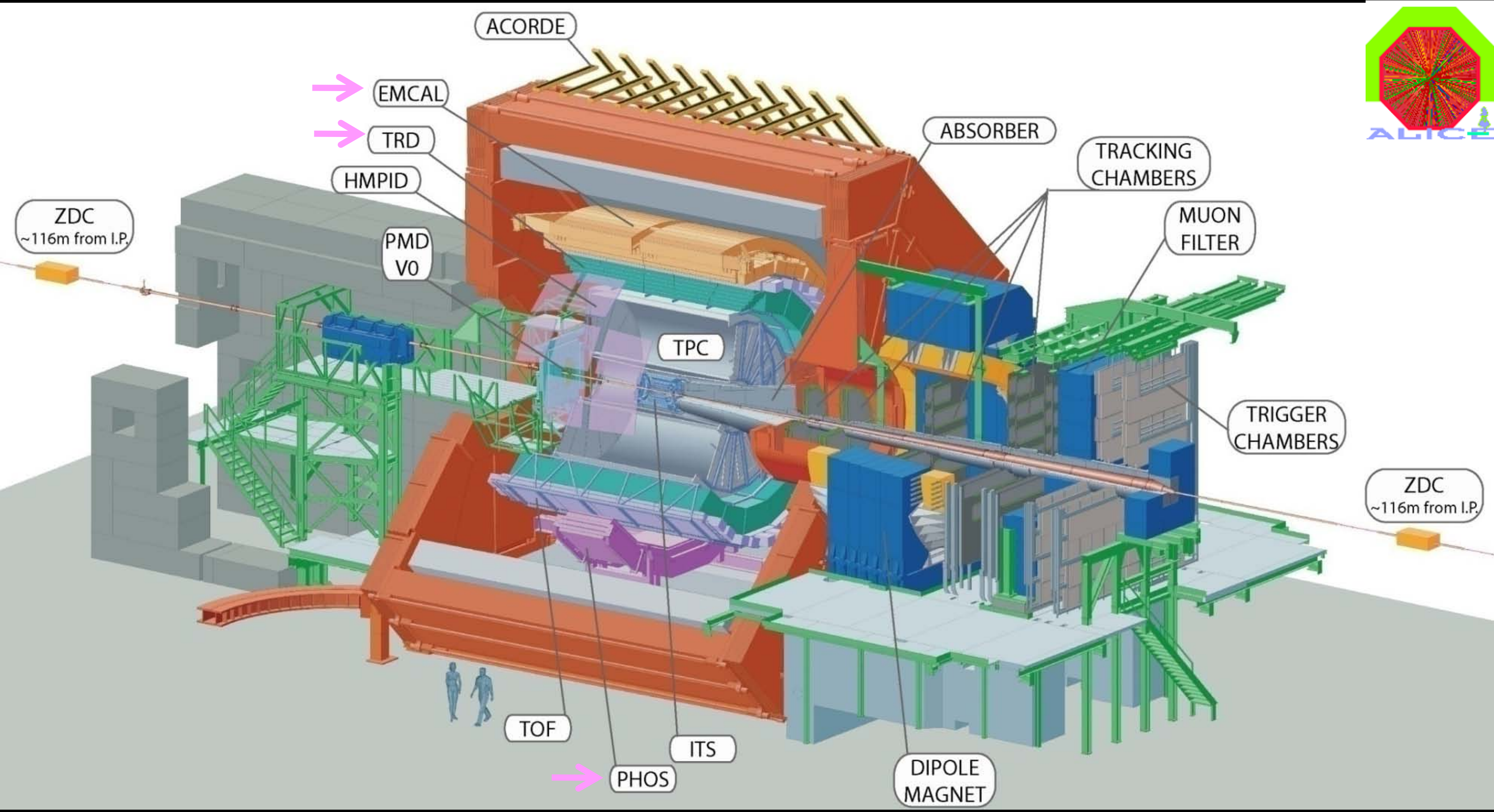
The ALICE Experiment



Fully Installed & Commissioned – Hadron & μ Capabilities

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

The ALICE Experiment

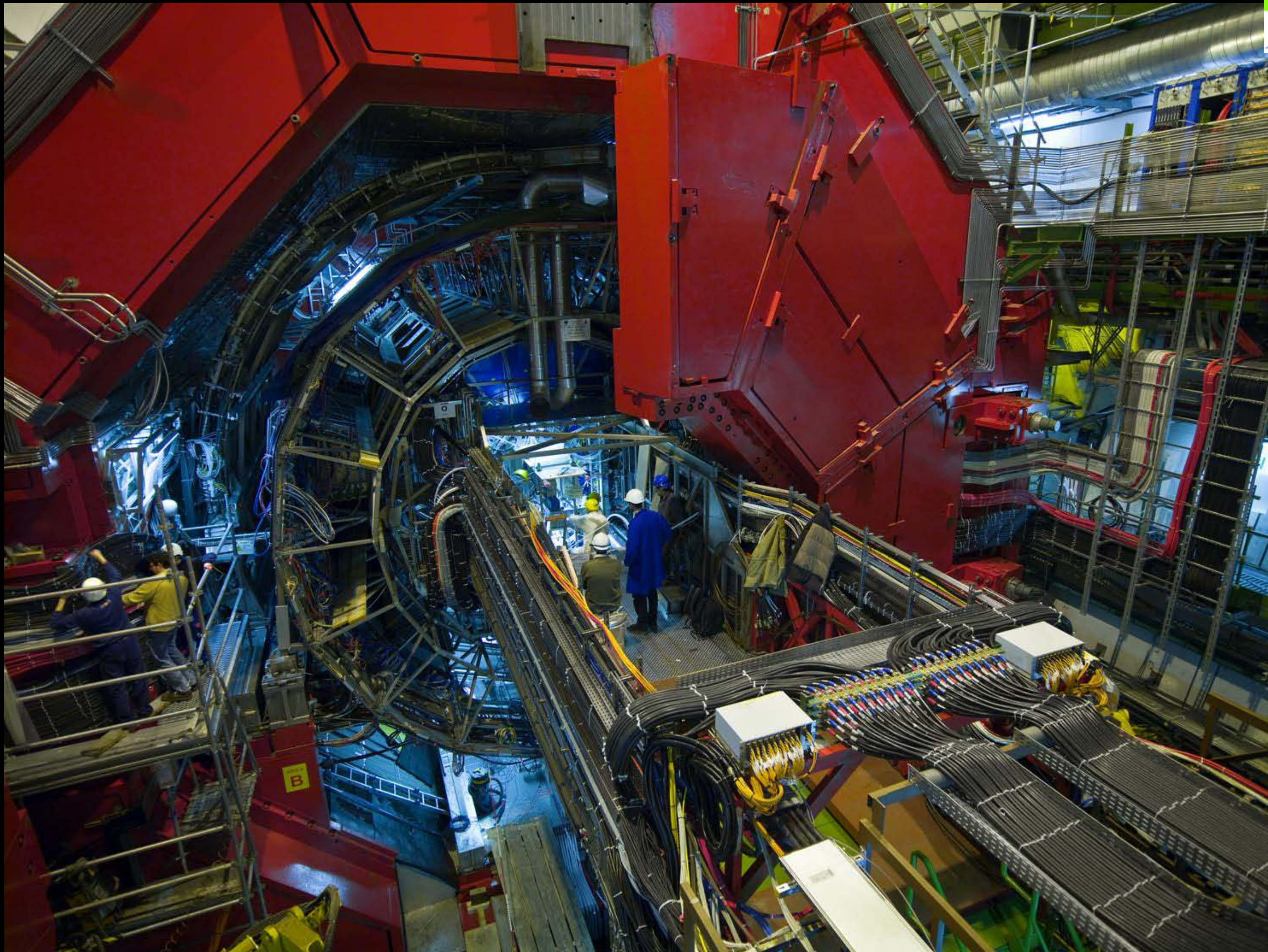


EM (e and γ) Partial Capabilities - (for 2009, 2010, 2011 in % below)

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

EMCAL (40, 80, 100%) complete by 2011

The ALICE Experiment (During Installation)



ALICE Detectors & Acceptance

central barrel ***-0.9 < η < 0.9***

- $\Delta\phi = 2\pi$ tracking, PID **(TPC/ITS/ToF)**
- single arm RICH **(HMPID)**
- single arm e.m. cal **(PHOS)**
- jet calorimeter **(EMCal)**

forward muon arm ***-2.4 < η < -4***

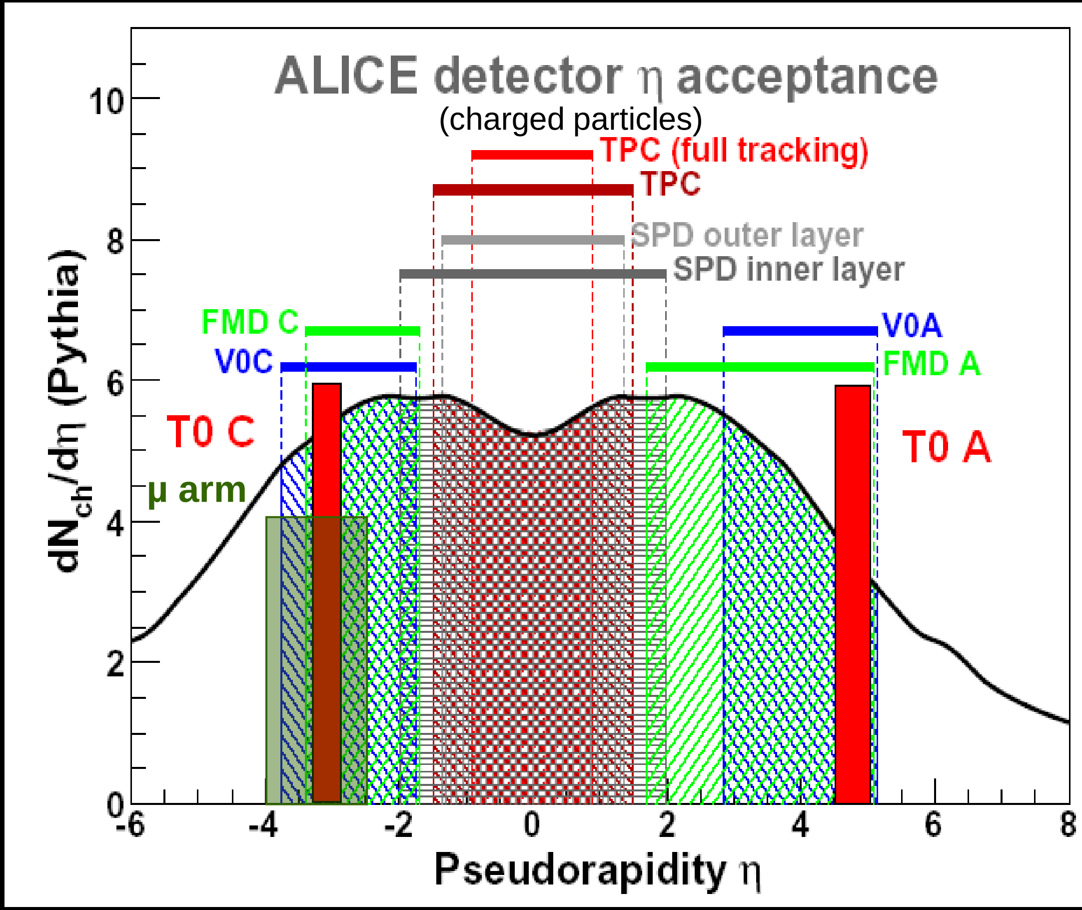
- absorber, 3 T-m dipole magnet
5 tracking + 2 trigger planes

multiplicity detectors ***-3.4 < η < 5***

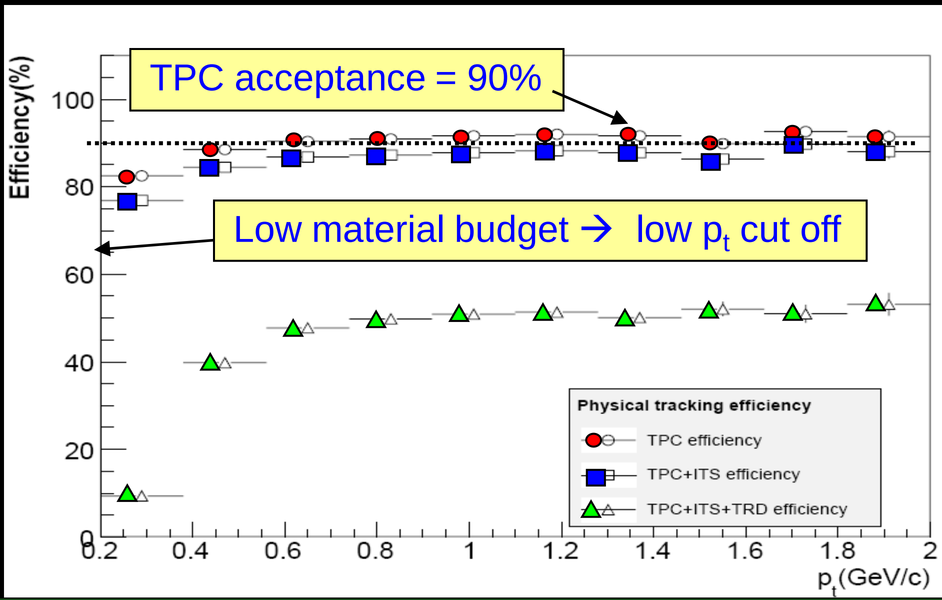
- including photon counting in **PMD**

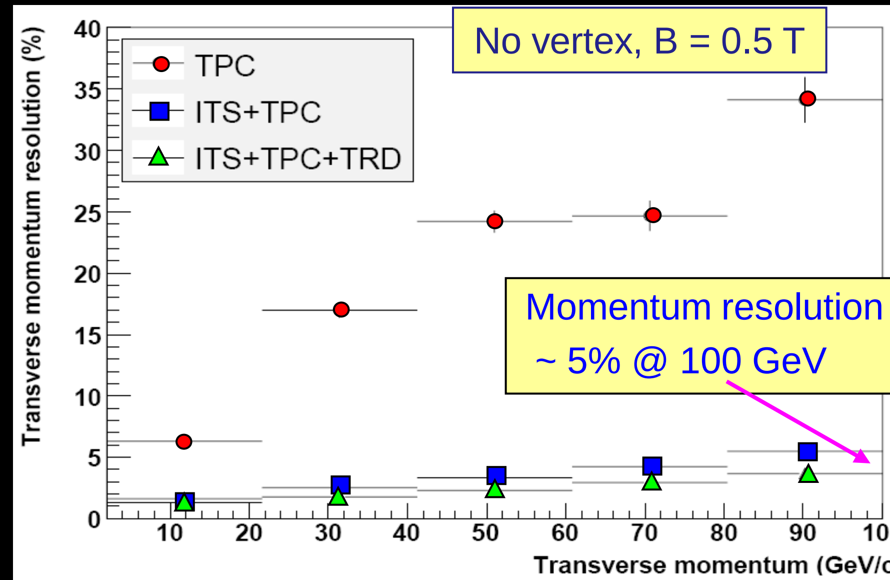
trigger & timing detectors

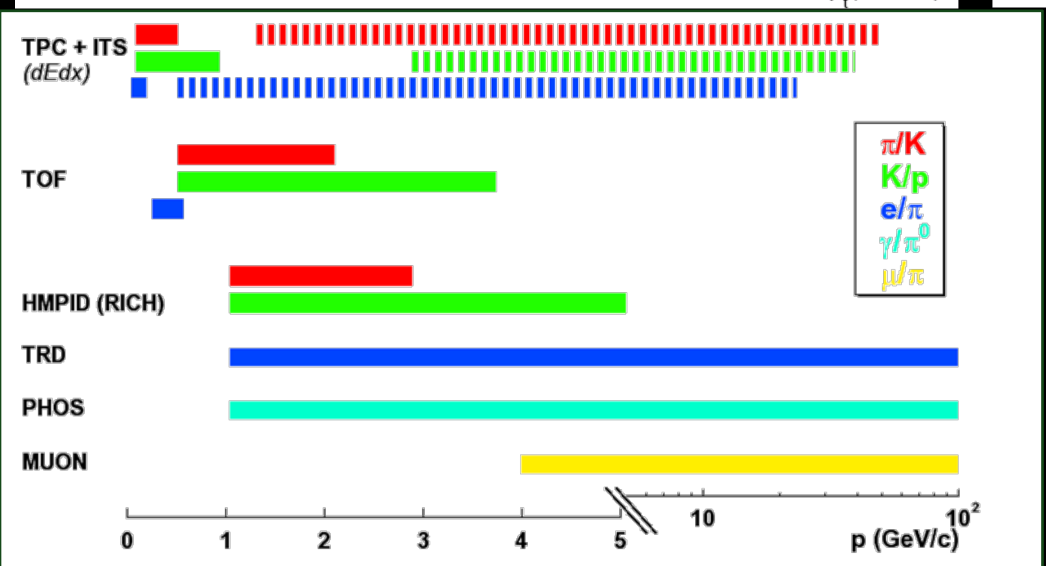
- 6 **Z**ero **D**egree **C**alorimeters
- **T0:** ring of quartz window PMT's
- **V0:** ring of scint. Paddles



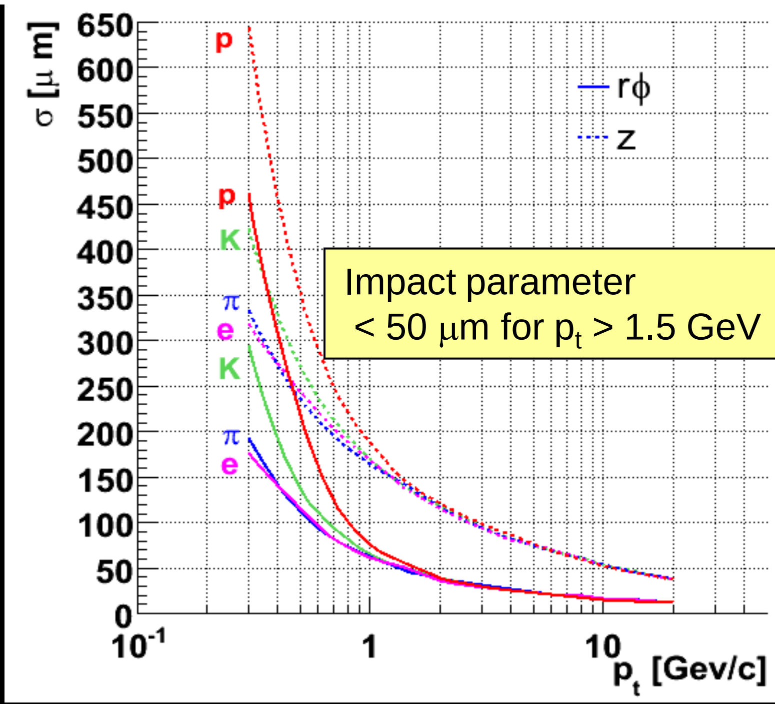
ALICE Performance





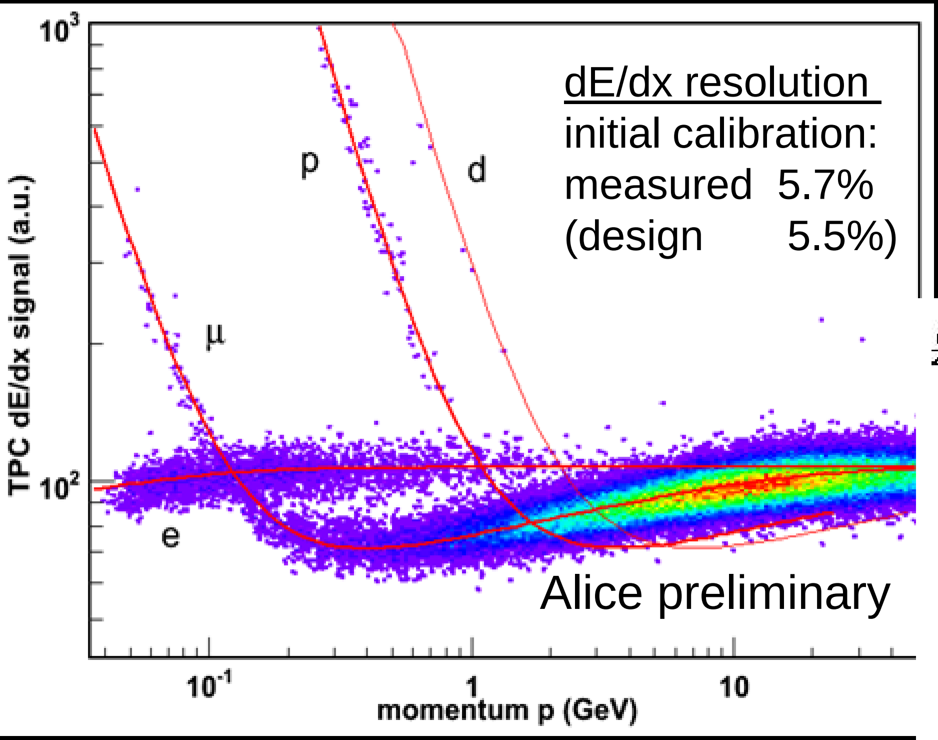


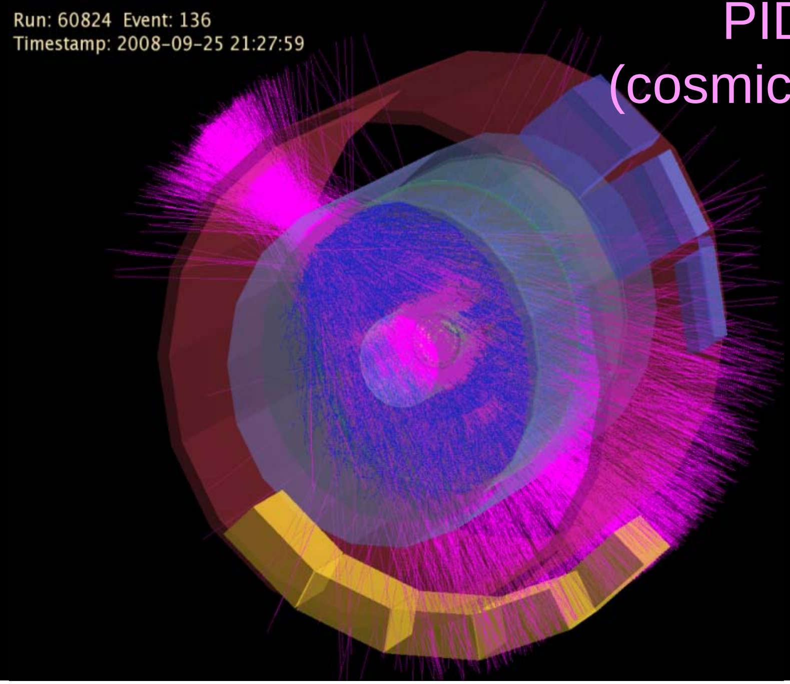
PID
from ~ 100 MeV/c to > 50 GeV/c



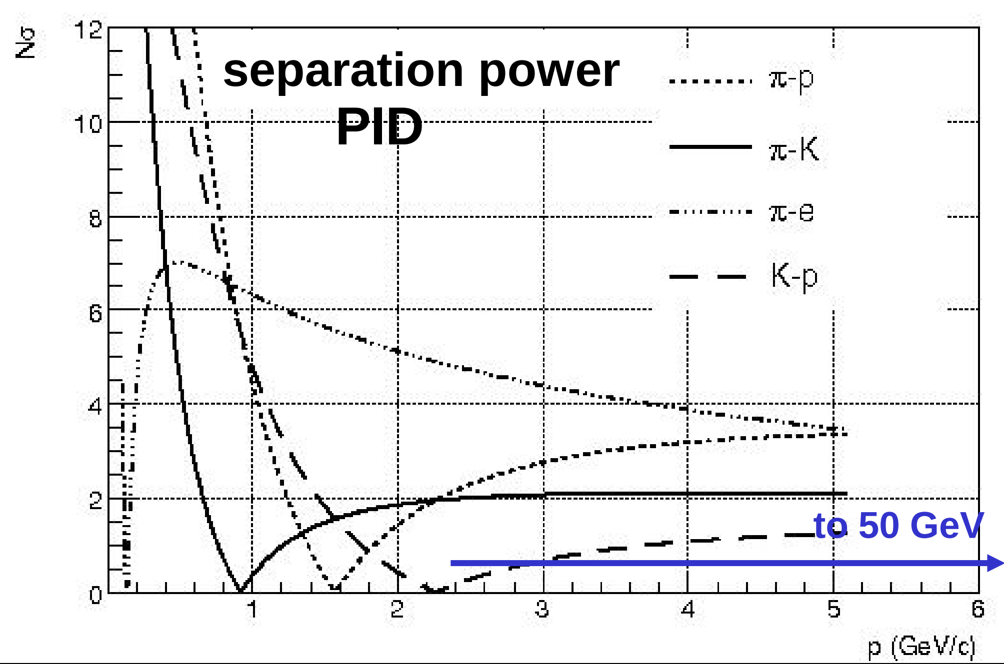
TPC - PID Performance

Particle ID via dE/dx





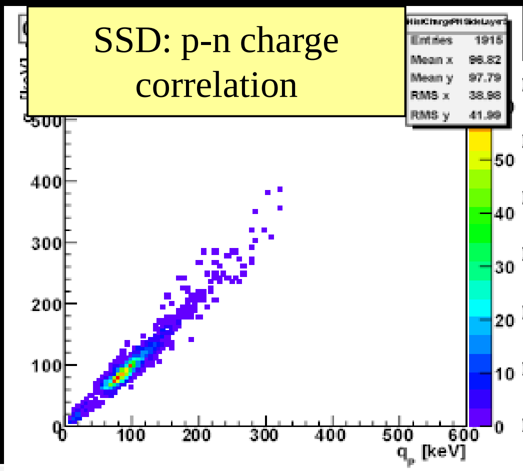
PID
(cosmic rays)

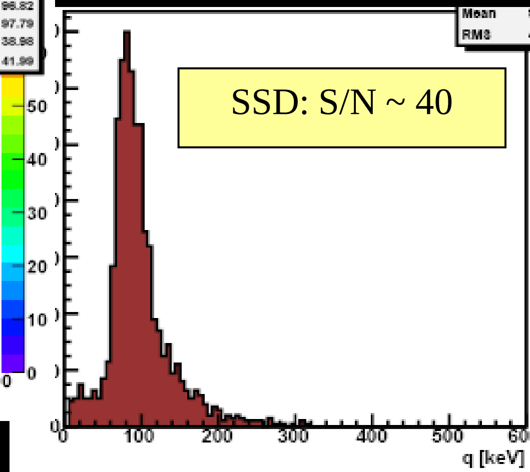


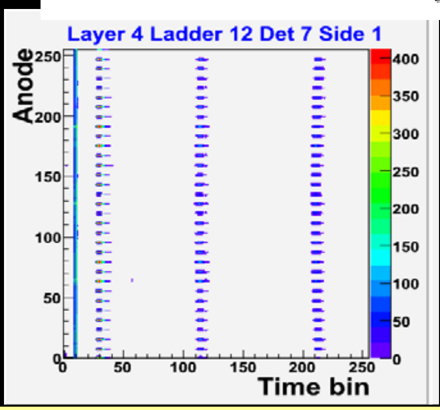
$$\frac{\overline{\Delta E}}{\Delta x} = 2C\frac{m_e c^2}{\beta^2}\frac{Zz^2}{A}\rho\left[\frac{1}{2}\ln\left(\frac{2\gamma^2\beta^2 m_e c^2 E_{max}}{I_0^2}\right) - \beta^2 - \frac{\varepsilon}{2} - \frac{\delta(\beta)}{2}\right]$$

ITS – Calibration & Performance

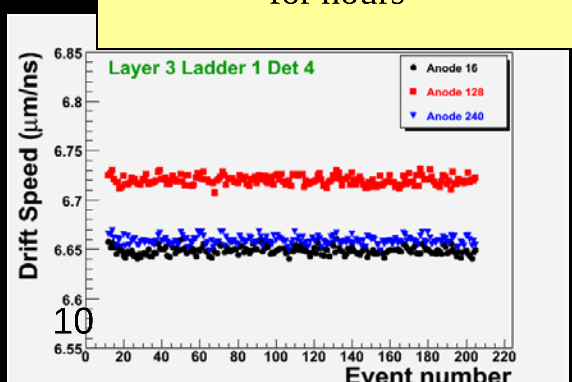
ITS: SDD, SSD, SPD

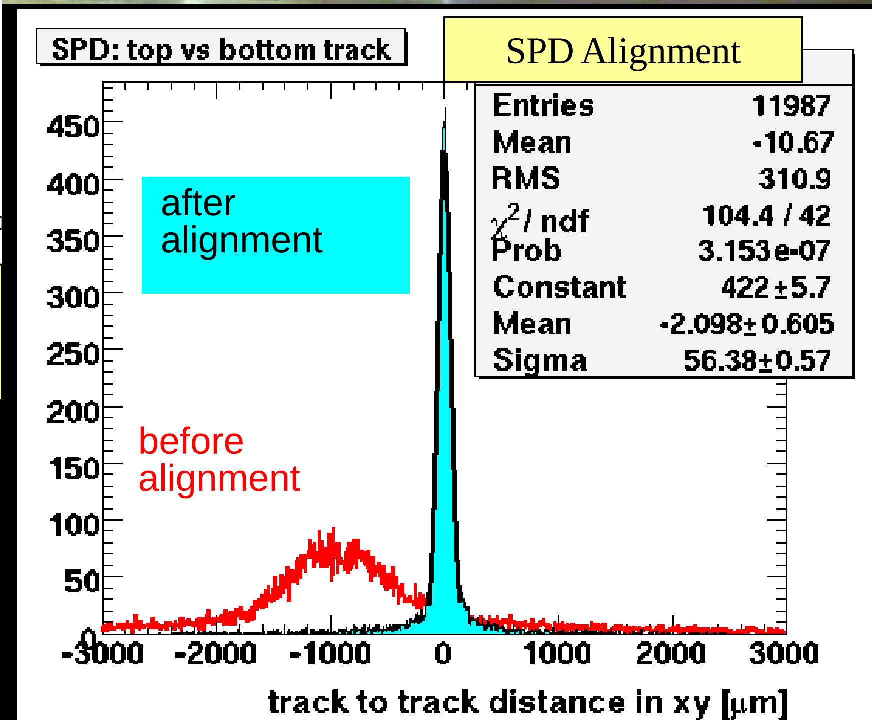






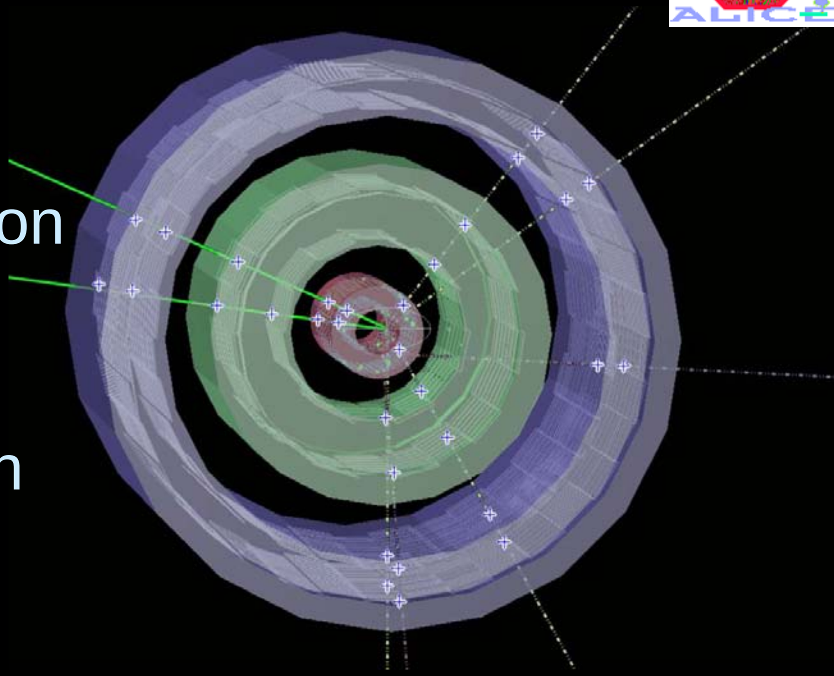
SDD: Drift speed calibration vs postion

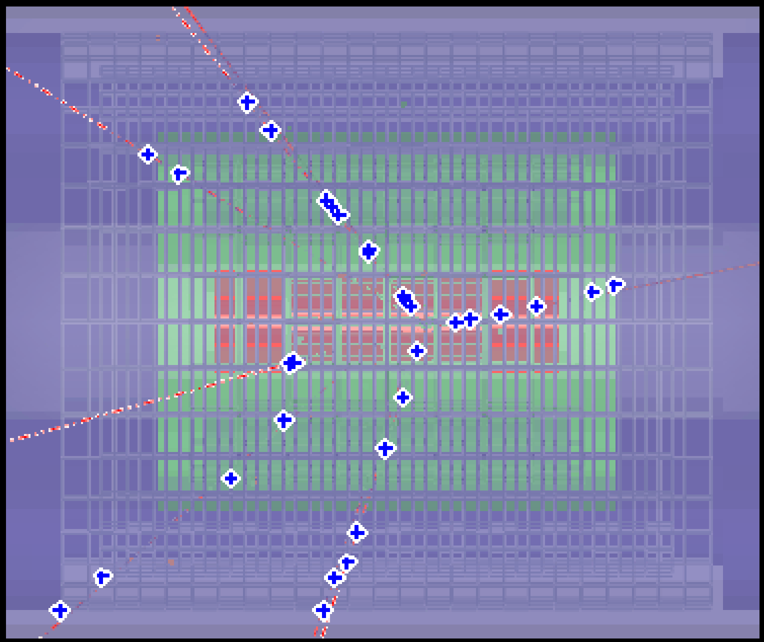




First LHC Beam in ALICE

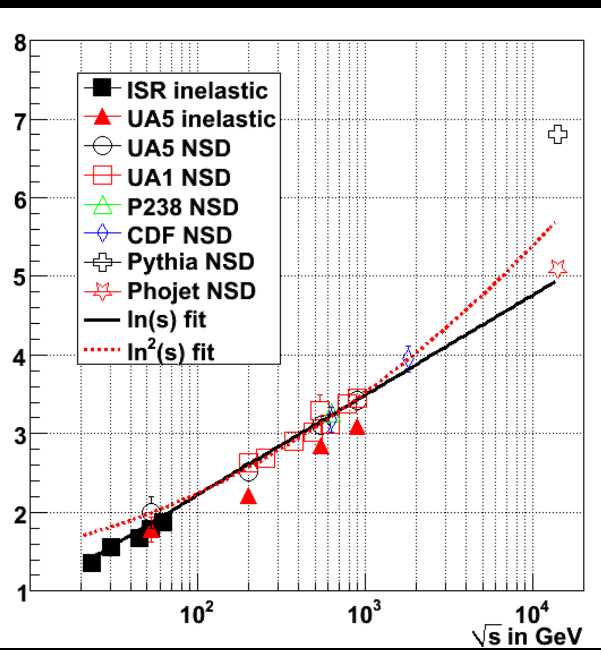
- ALICE ready for LHC collisions.
- First LHC proton beams circulated on September 10th , 2008.
- 450 GeV/c proton + pixel interaction





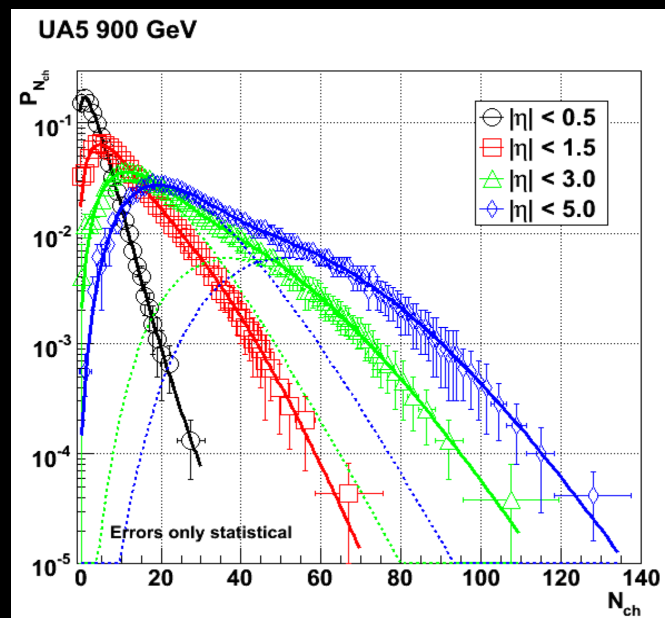
Early p + p Physics in ALICE

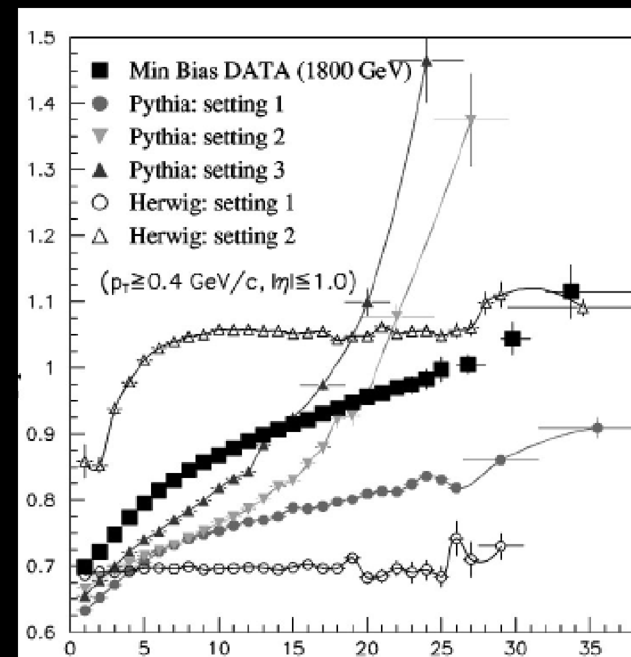
- "Day 1" with p + p: Underlying event constrain / tune PYTHIA.. global event properties (energies - 0.9 …. 10 ….14 TeV)
- requires only several x 10K events



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

Multiplicity distributions



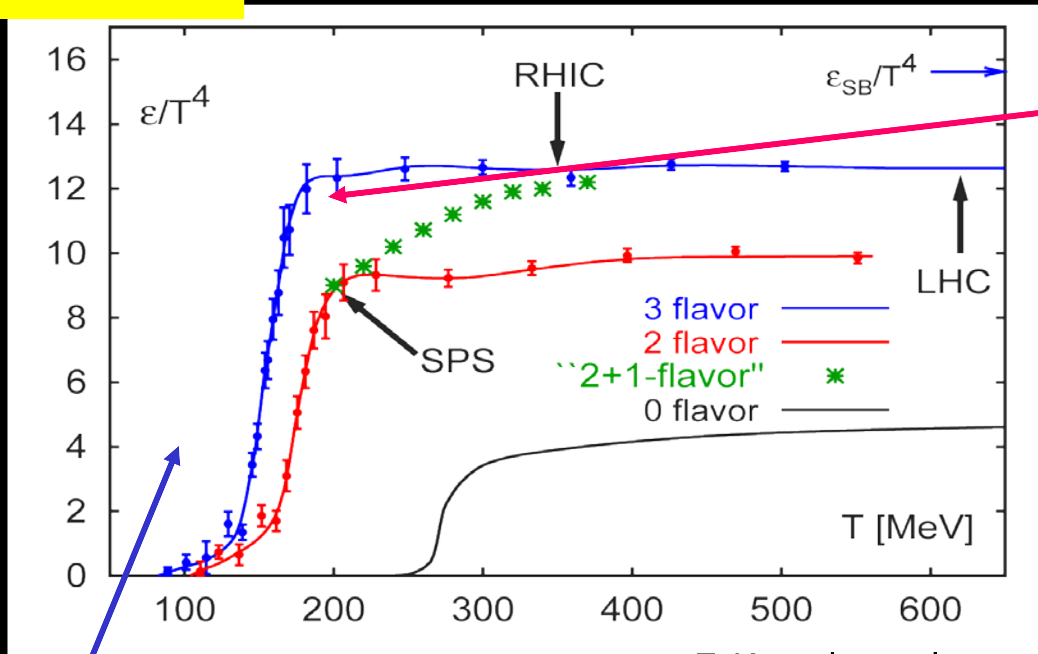


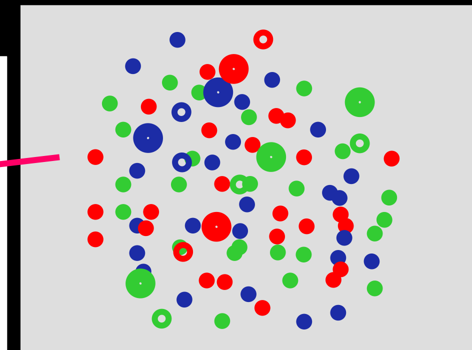
$< p_T >$ vs N_{ch}

Heavy Ion Physics - QCD at High Temperature

$\varepsilon/T^4 \sim$ # degrees of freedom

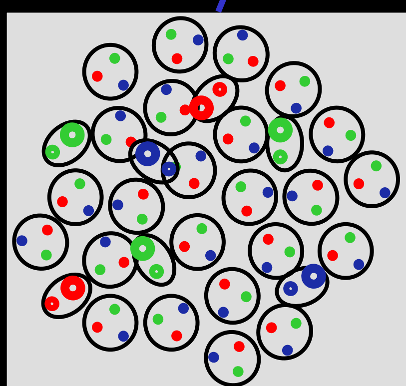
$$\varepsilon = \frac{\nu \pi^2}{30} T^4$$





many d.o.f.→**deconfined**

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



few d.o.f.→**confined**

$T_C \sim 175 \pm 8$ MeV → $\varepsilon_C \sim 0.3 - 1$ GeV/fm^3

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

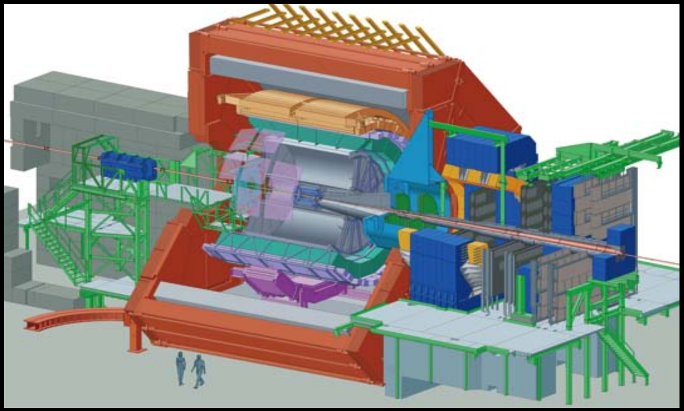
ALICE Heavy Ion Physics

Overview:

Soft Probes – ALICE → RHIC Capabilities & Beyond!

- Determine expansion dynamics: will be 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

- 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' ???

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:

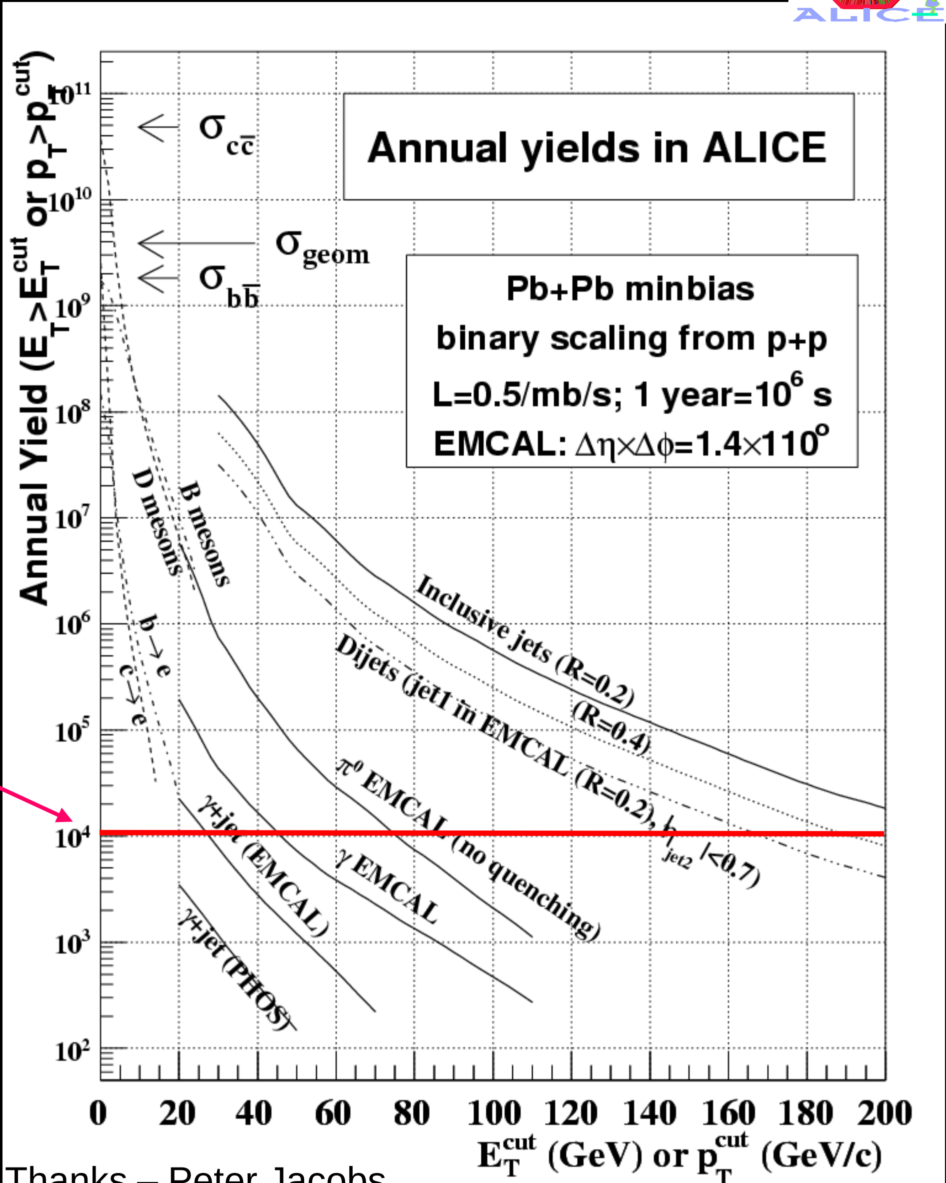
inclusive jets: $E_T \sim 200$ GeV

dijets: $E_T \sim 170$ GeV

π^0: $p_T \sim 75$ GeV

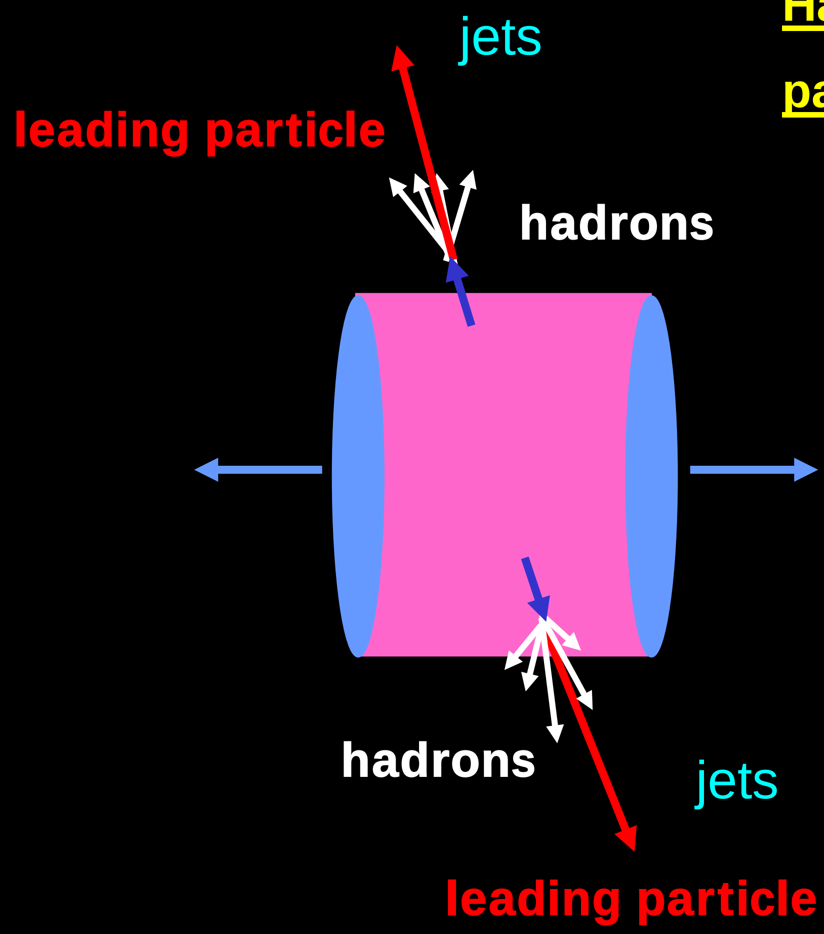
inclusive γ: $p_T \sim 45$ GeV

inclusive e: $p_T \sim 30$ GeV



Thanks – Peter Jacobs

Probing Hot QCD Matter with Hard Probes



Hard Probes (from initial parton scattering):

Large "p_T" partons

Heavy quark production

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

Hard Probes in ALICE – Jet Quenching

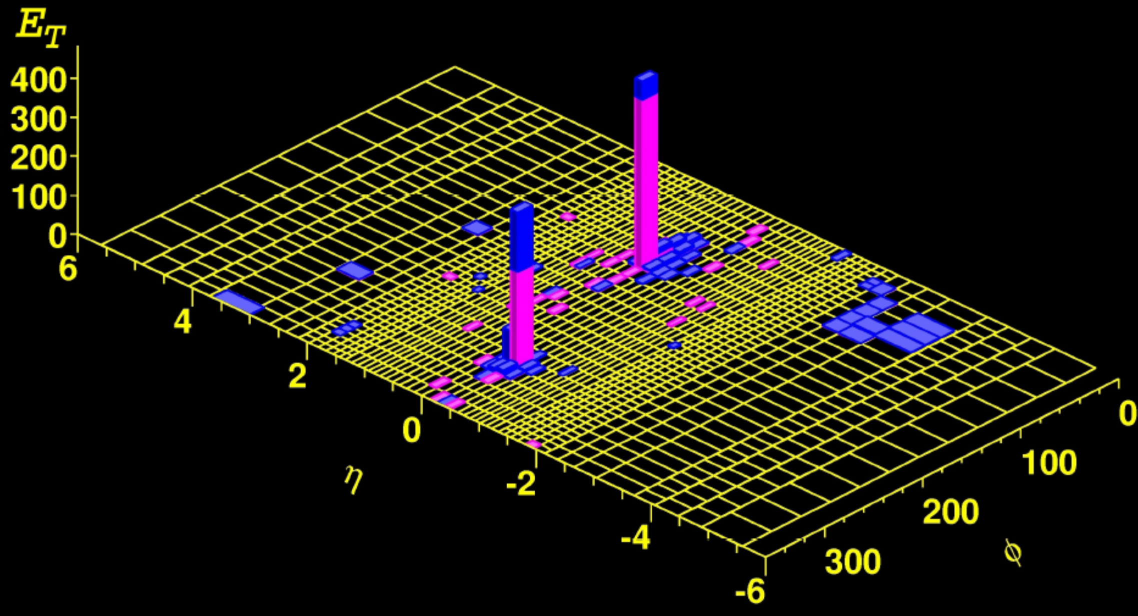
Jet Quenching

(E-loss, parton density, fragmentation, medium response)

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

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

Jet-finding - Learning from Tevatron & RHIC



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

- most of energy within cone of

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

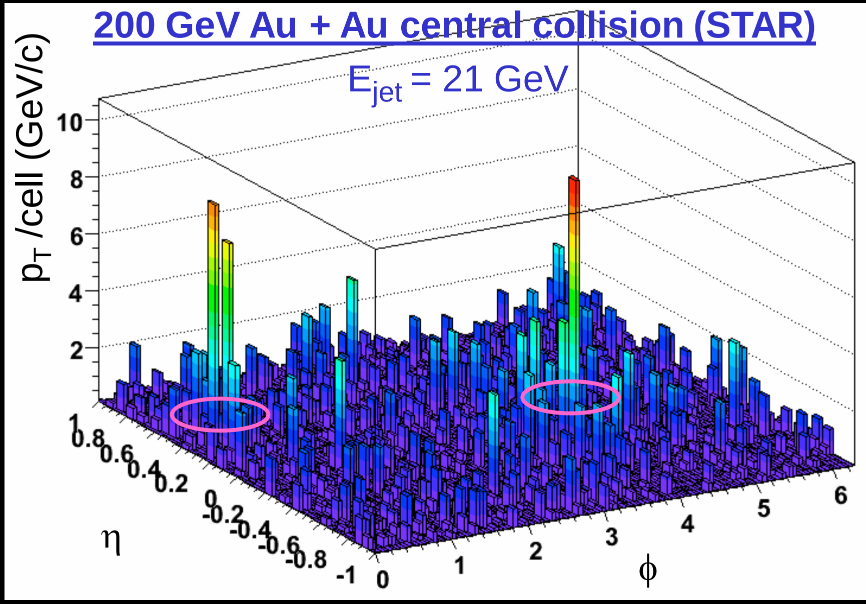
Au + Au experience (STAR) - HI Background

Must suppress "soft" background:

- small jet cones R = 0.3-0.4
- EbyE out-of-cone background energy

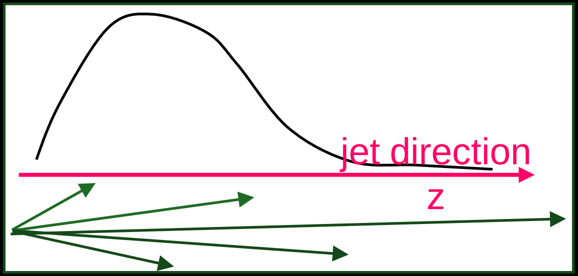
New recombination algorithms

- KT and anti-KT, others

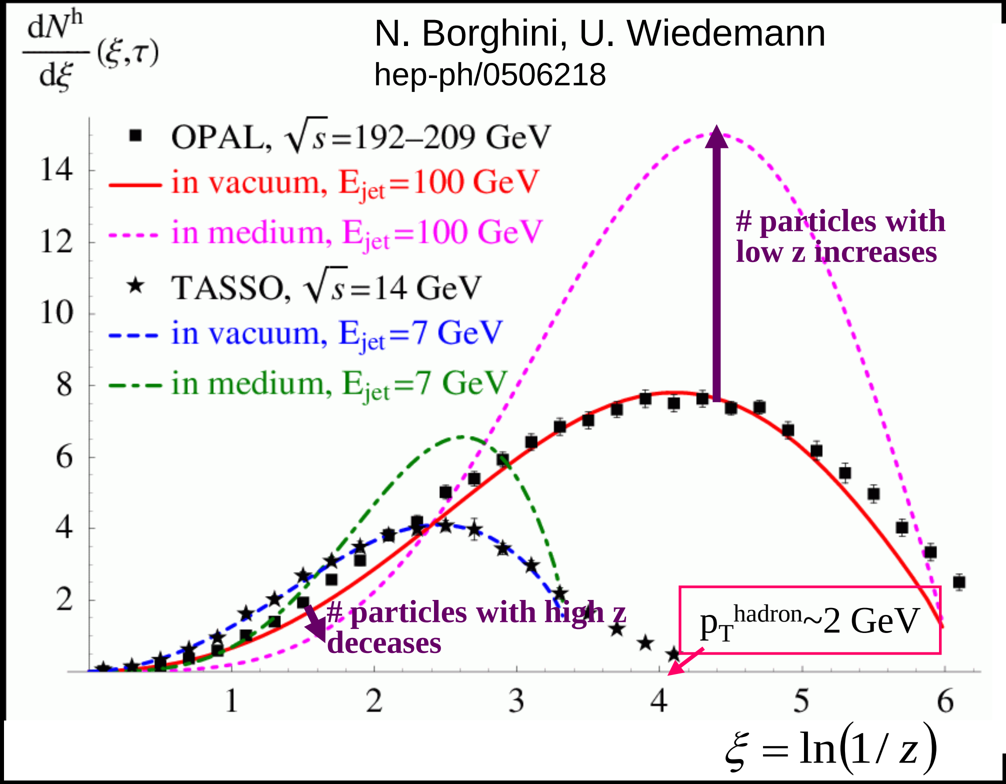


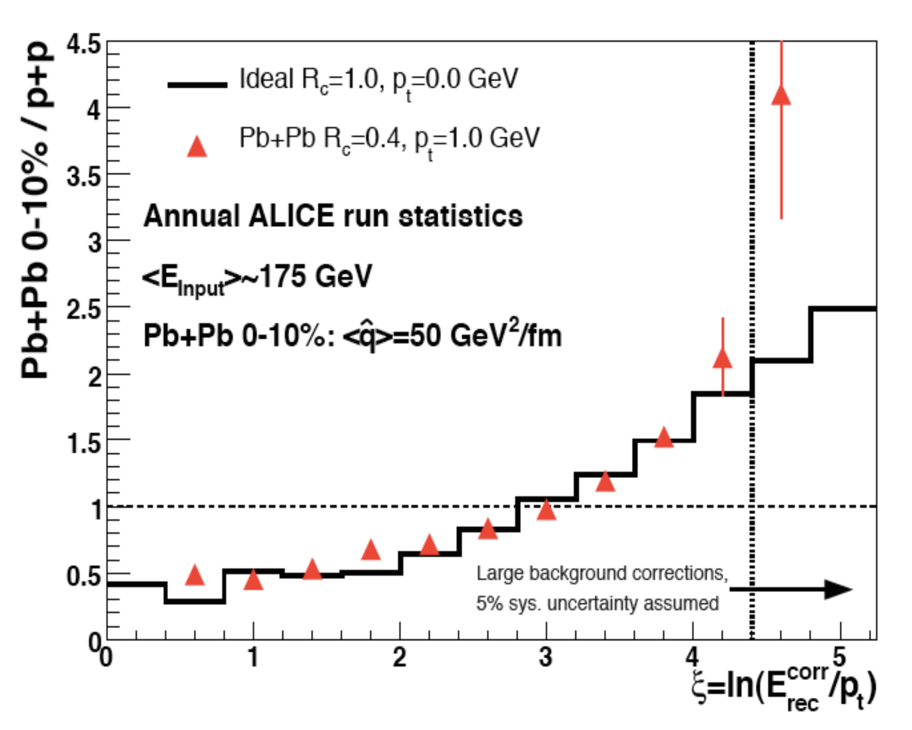
Medium Modification of Jet Fragmentation

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



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





Hard Probes in ALICE

Heavy Quarks

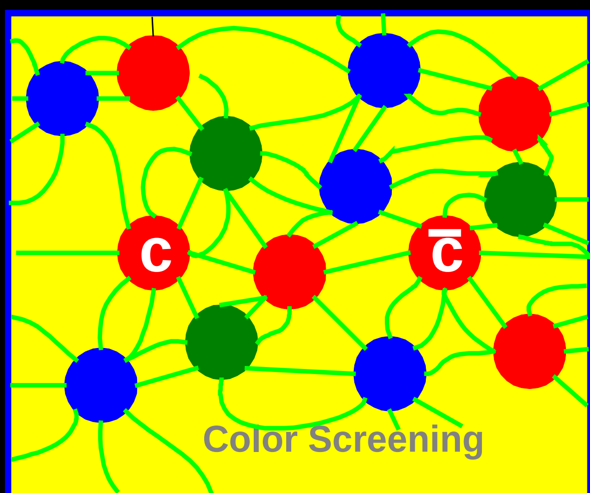
(mass/color dependence of parton energy-loss)

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

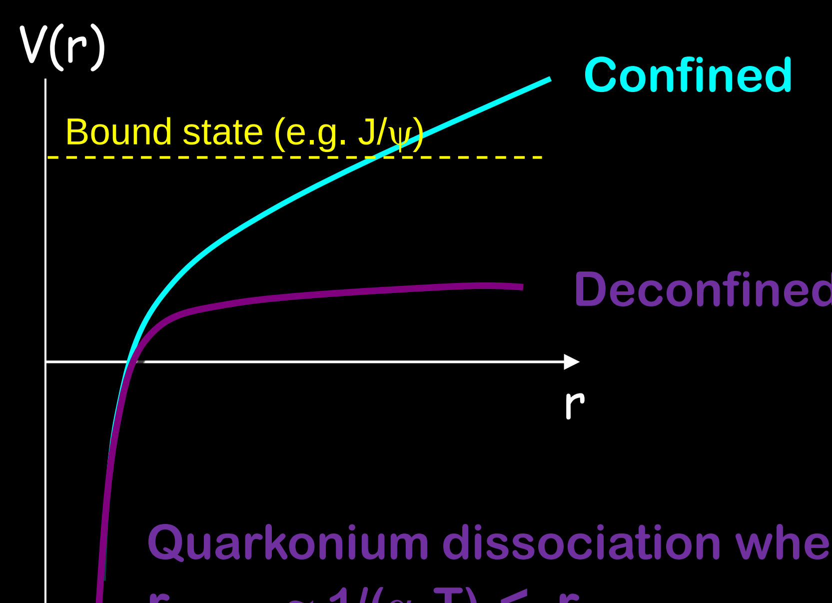
Quarkonia

(initial temperature, Debye color screening, recombination)

- J/ψ, Υ, Υ' , Υ'', ψ'



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



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

Quarkonia

Heavy Quarks

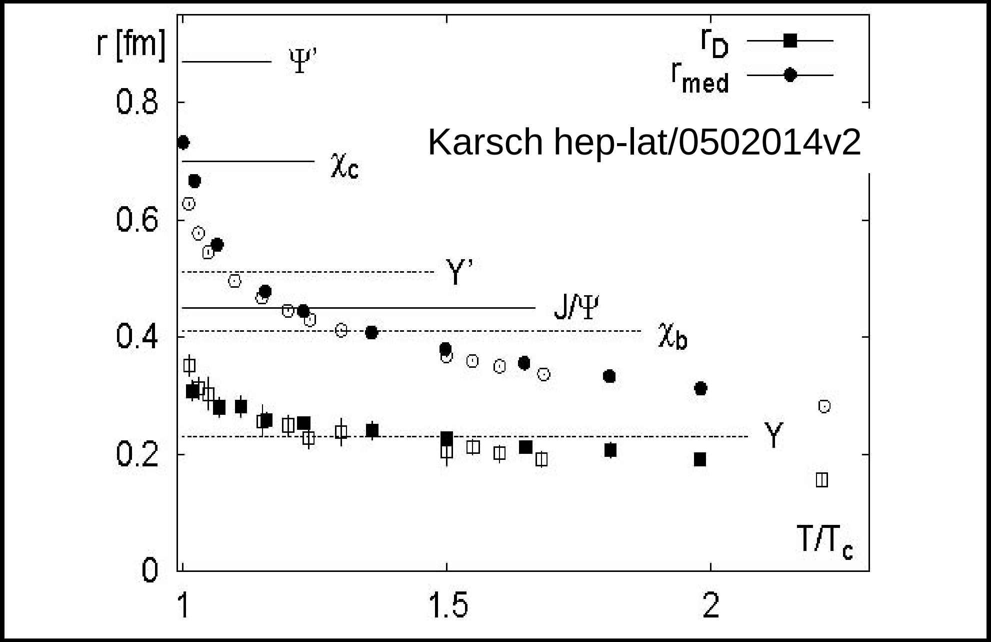
(mass/color dep. of parton E-loss)

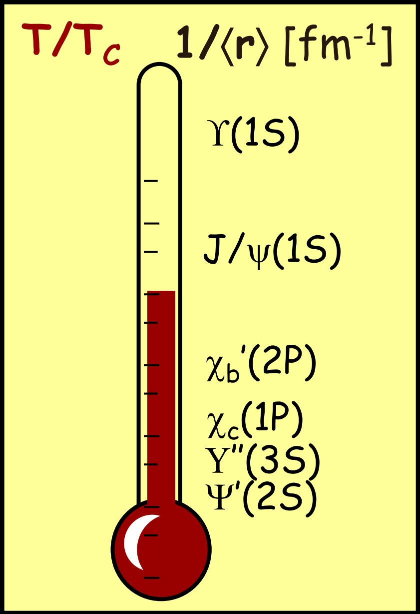
- Displaced vertices ($D^o \rightarrow K^- \pi +$) from TPC/ITS
- Electrons in Transition Radiation Detector (TRD)

Quarkonia

(Initial T, Debye screening, recombination,..)

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

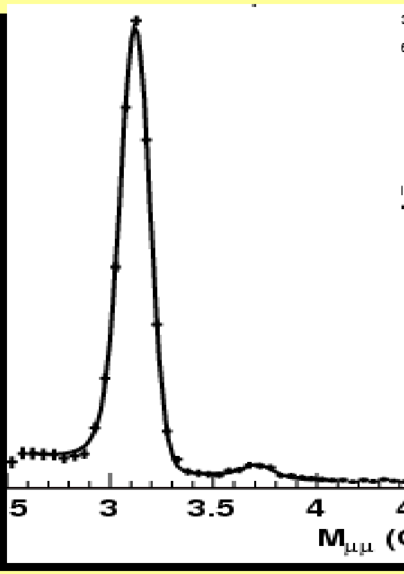
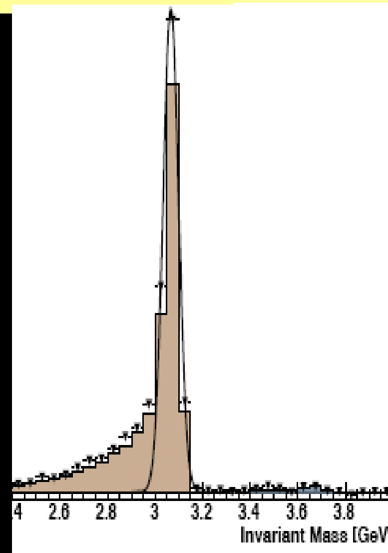
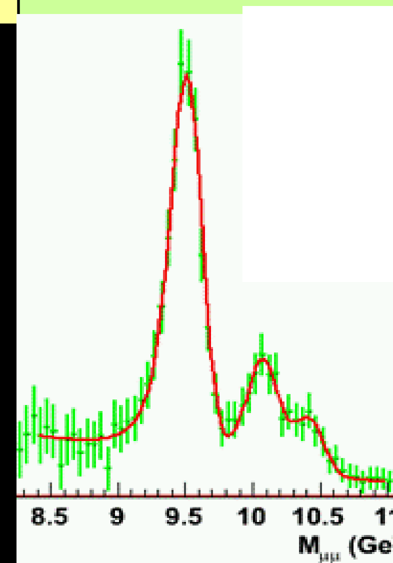
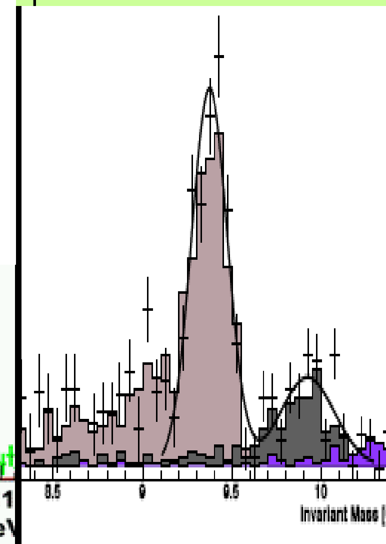




Measure melting order of $c\bar{c}$: Ψ', χ_c, J/ψ $b\bar{b}$: Υ'', Υ', Υ

Quarkonia Performance

dN_{ch}/dy = 4000 in central Pb-Pb for 1 month

Particle	Charmonia $\mu^+\mu^-$	Charmonia e^+e^-	Bottomonia $\mu^+\mu^-$	Bottomonia e^+e^-
mass plots (- bkg)				
accept.	$-4 < \eta < -2.5$	$\|\eta\| < 0.9$	$-4 < \eta < -2.5$	$\|\eta\| < 0.9$
ΔM	65 MeV	35 MeV	90 MeV	90 MeV
S / √(S+B)	J/ψ 150, ψ' 7	J/ψ 245	ϒ 30, ϒ' 12, ϒ'' 8	ϒ 21, ϒ' 8
channel	ψ, ψ'	ψ, ψ'	ϒ, ϒ',ϒ''	ϒ, ϒ', no ϒ''
p_t	J/ψ 0-20 GeV	J/ψ 0-10 GeV	ϒ 0-8 GeV	--

Summary & Questions to Address

ALICE – is a versatile, general purpose heavy ion detector at LHC
will contribute significantly to understanding of (soft & hard) HI physics

ALICE to address general (Soft Physics) Questions:

How does the system evolve and thermalize from its initial state?
What are the properties of the quark-gluon plasma at LHC energies?
Is QCD Phase Diagram featureless above Tc?
Coupling strength vs T….?
Are there new phenomena?

ALICE to address Physics Questions with Hard Probes:

What is the behavior of c-cbar and b-bbar states in-medium?
(T_i, screening/suppression, enhancement?)
Can we understand parton energy loss at a fundamental level?
Medium modifications?
e.g. jet energies in ALICE up to ~ 225 GeV possible (stats)
B-jets up to 80 – 90 GeV (stats in one PbPb month)
Flavor dependence? (D, B, quark- and gluon-jets?)
Can we understand the hadronization (fragmentation) process?

Theory?

Range of validity of theories (hydro, non-pQCD, pQCD, strings…)?
Can there be new developments in theory, and understanding across fields? (lattice, hydro, string, pQCD E-loss,…)