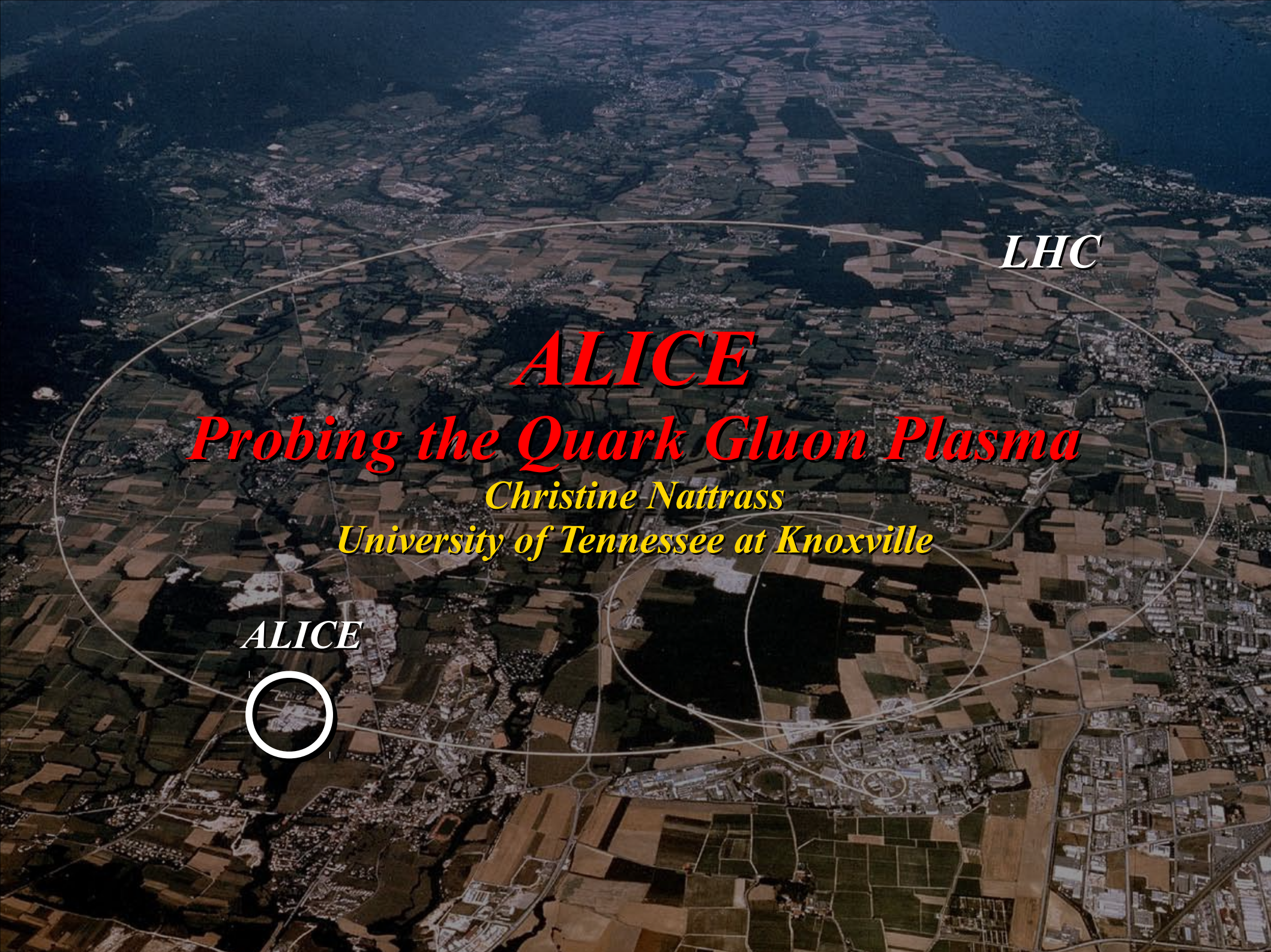
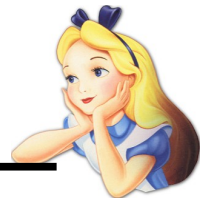


ALICE
Probing the Quark Gluon Plasma

Christine Nattrass
University of Tennessee at Knoxville

The ALICE Collaboration

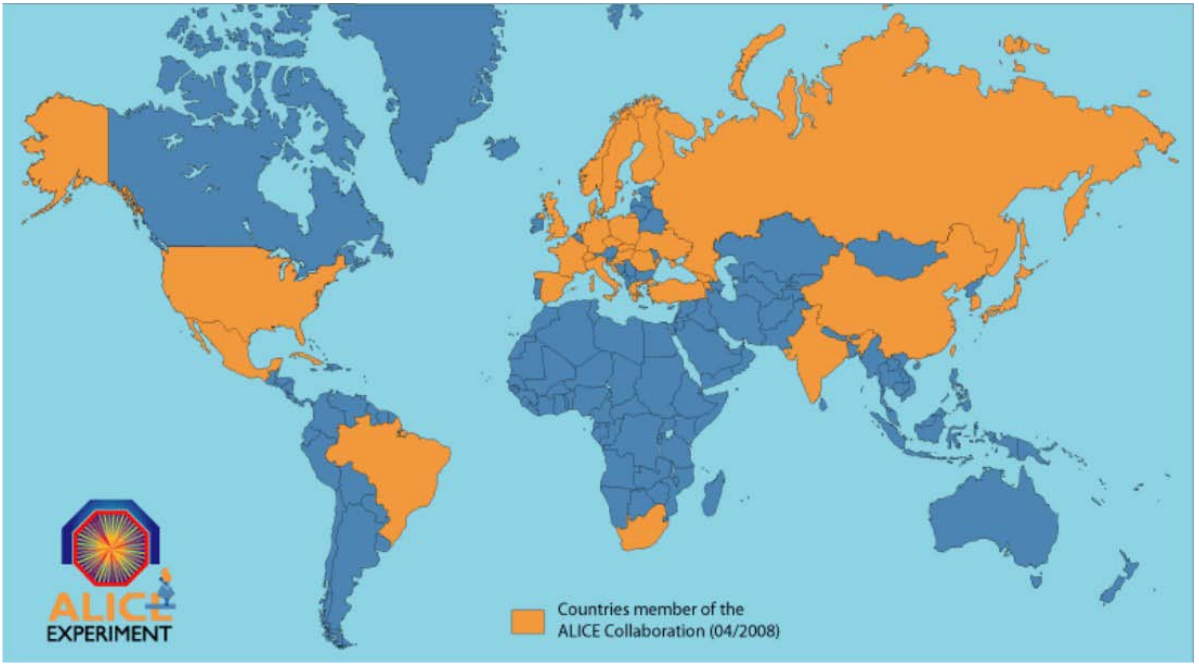


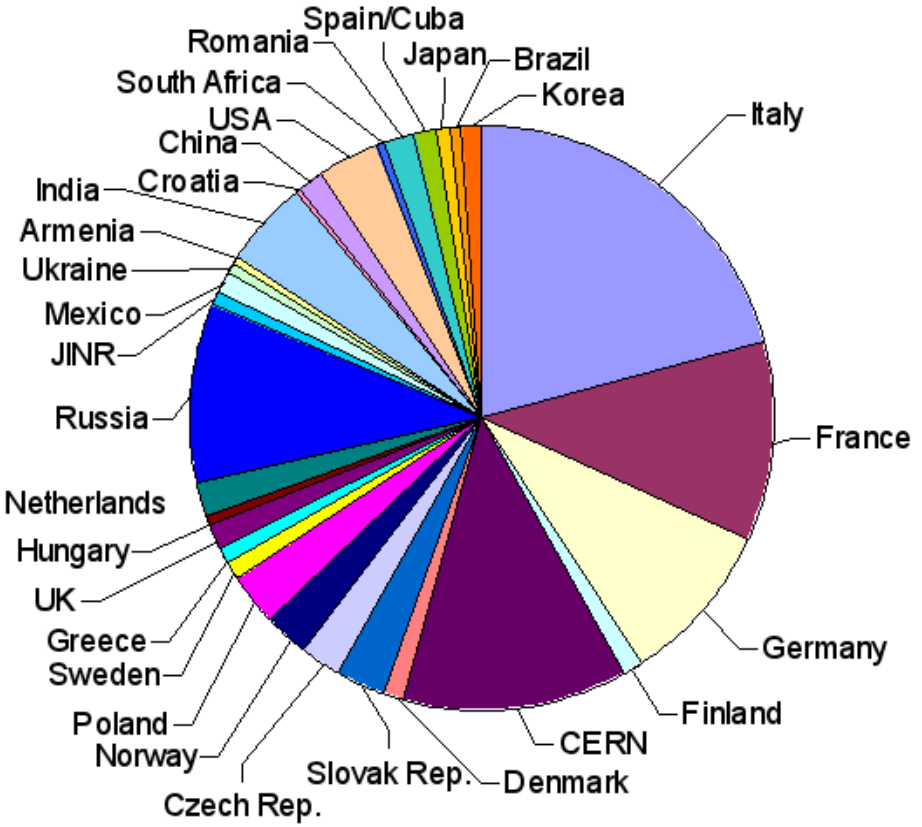
~1000 Members
63% from CERN member states

~30 Countries

~100 Institutes

~150 MCHF capital cost (+magnet)





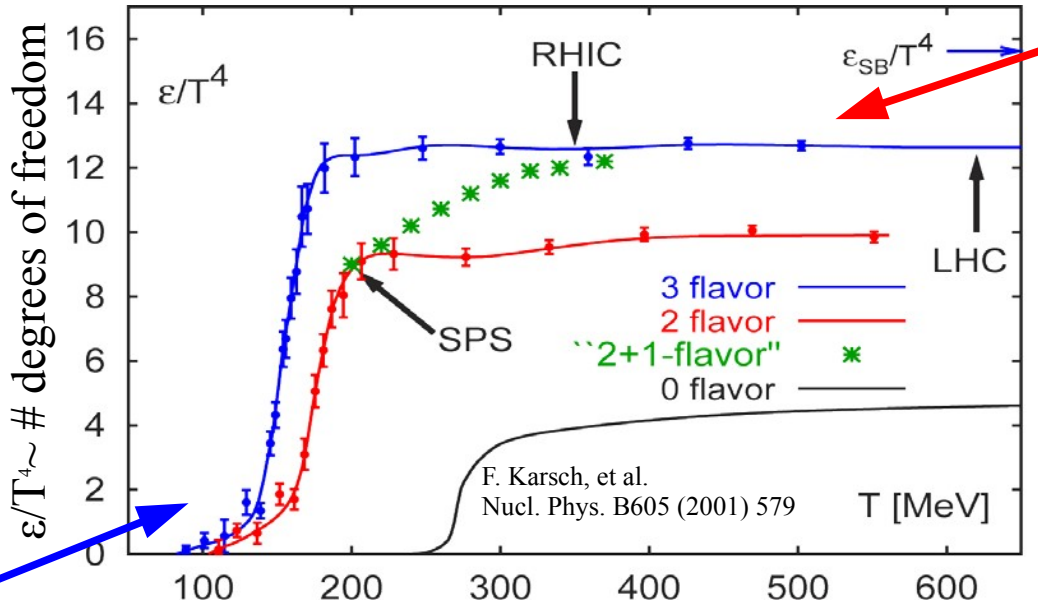
US ALICE

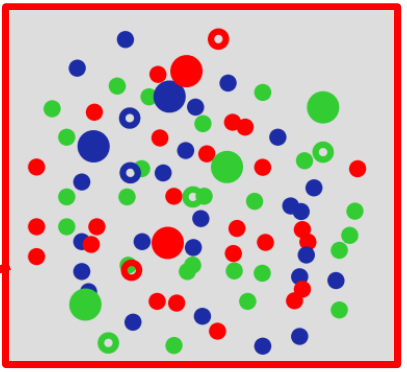
11 Institutions 53 members (inc. 12 grad. Students)

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

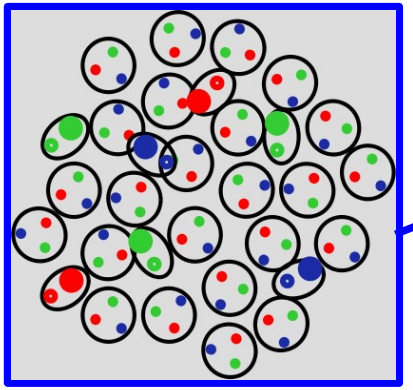
QCD at high temperatures

$T_c \sim 175 \pm 8$ MeV $\rightarrow \varepsilon_c \sim 0.3$ -1 GeV/fm^3



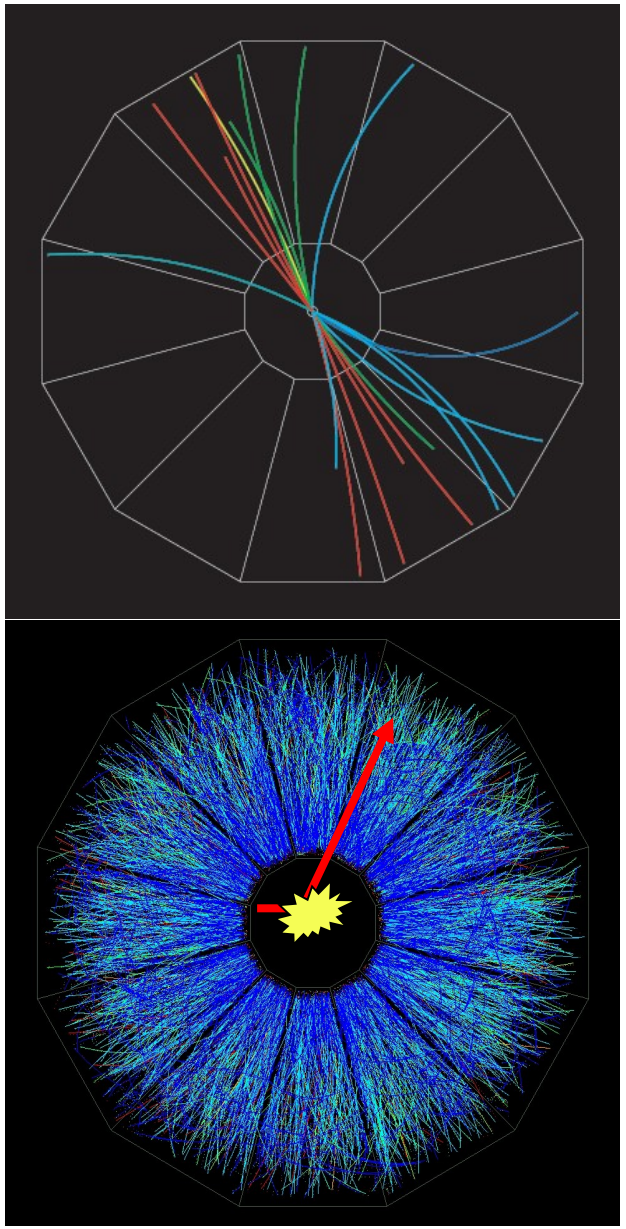


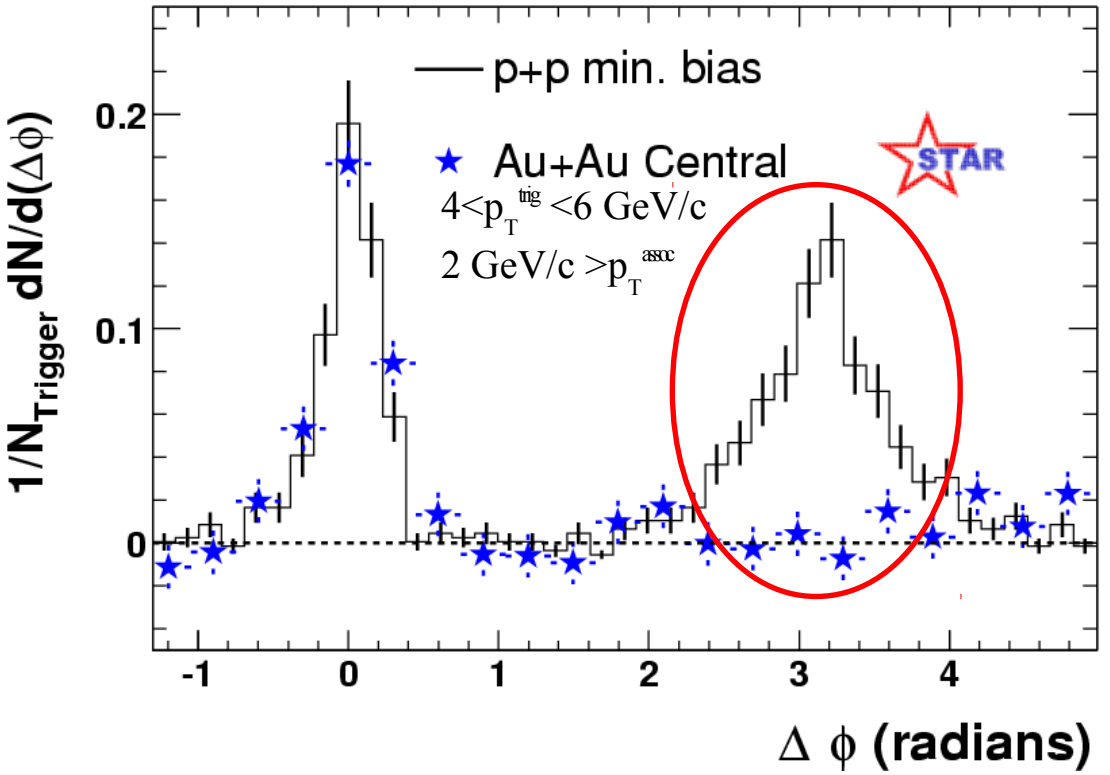
Many degrees of freedom - deconfined



Few degrees of freedom - confined

At RHIC we learned...





...the medium is hot, dense, and behaves like a fluid

Simple Expectations for Heavy Ion Physics at LHC

	SPS	RHIC	LHC	
$\sqrt{s_{NN}}$ (GeV)	17	200	5500	***28x***
$dN_{ch}/d\eta$	~700	~1200	~2000-8000	***2-7x***
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***

<u>RHIC and LHC:</u>

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

Probes of a Quark Gluon Plasma

Soft Probes

- 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 , π^0, 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' ???

Experimental Challenges & ALICE Solutions

- **Extreme particle densities** ($dN_{ch}/d\eta \sim 2000 \rightarrow$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]

- **Large dynamic range in p_T**

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

  →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

- **Measure & ID many particles**

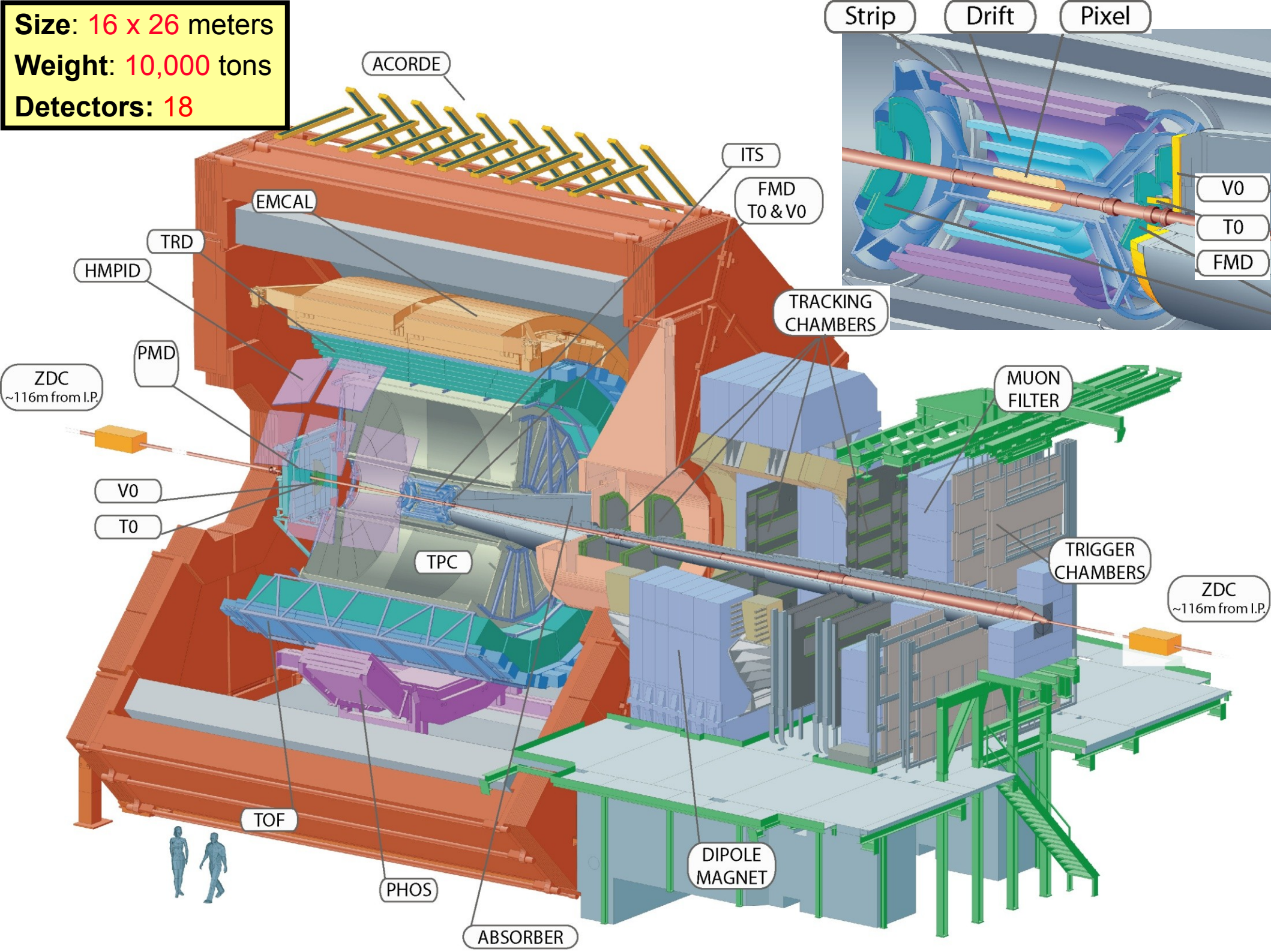
  requires: secondary vertices, lepton ID, hadron ID

  →ALICE solution for extended particle ID : employ many technologies dE/dx, Cherenkov & transition rad., TOF, calorimeters, muon filter, topological.

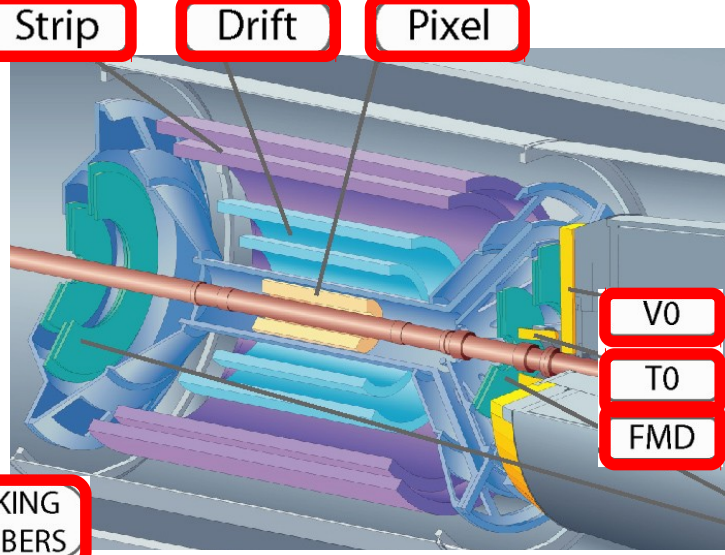
+Modest luminosity and interaction rates 10 kHz (Pb + Pb)

- Every Pb+Pb event is interesting
- ALICE rates →allow slow detectors (TPC, SDD), moderate radiation hardness

Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



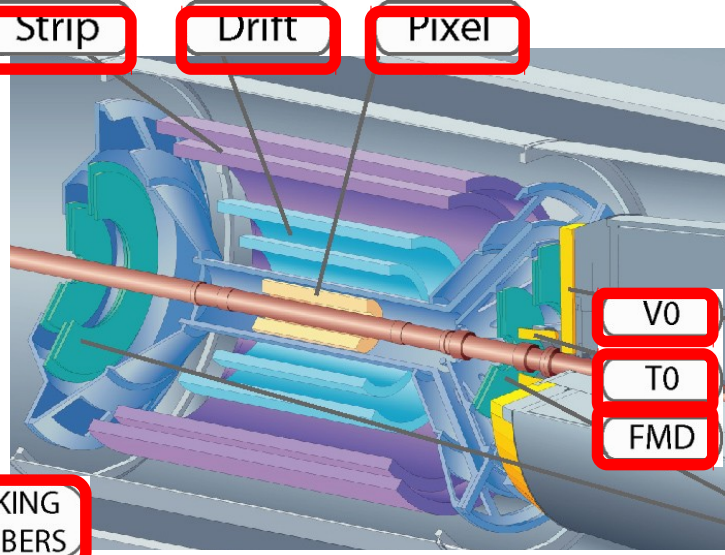
Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



ACORDE
ITS
FMD
T0 & V0
EMCAL
TRD
HMPID
TRACKING CHAMBERS
PMD
ZDC
~116m from I.P.
MUON FILTER
V0
T0
TPC
TRIGGER CHAMBERS
ZDC
~116m from I.P.
TOF
DIPOLE MAGNET
PHOS
ABSORBER

Fully installed and commissioned

Size: 16 x 26 meters
Weight: 10,000 tons
Detectors: 18



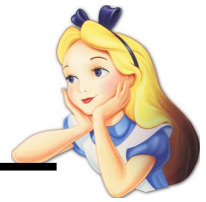
ACORDE
ITS
FMD
T0 & V0
EMCAL
40%, ~100%
TRD
40%, 100%
HMPID
TRACKING CHAMBERS
PMD
ZDC
~116m from I.P.
MUON FILTER
V0
T0
TPC
TRIGGER CHAMBERS
ZDC
~116m from I.P.

Partially installed

Status in LHC Run 1, Run 2

TOF
60%, ~100%
DIPOLE MAGNET
PHOS
ABSORBER

ALICE detectors and acceptance



Central barrel-0.9 < η < 0.9

- Δφ = 2π tracking, PID (TPC/ITS/TRD/ToF)
- single arm RICH (HMPID)
- single arm e.m. cal (PHOS)
- jet calorimeter (EMCal)

Forward muon arm-2.4 < η < -4

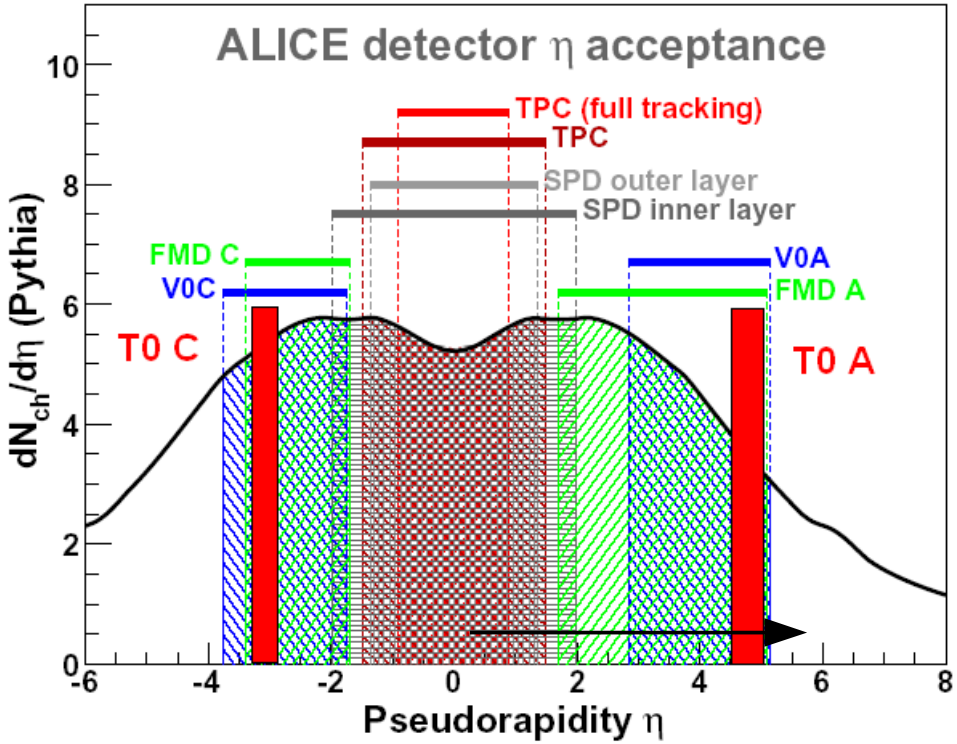
- absorber, 3 T-m dipole magnet
  5 tracking + 2 trigger planes

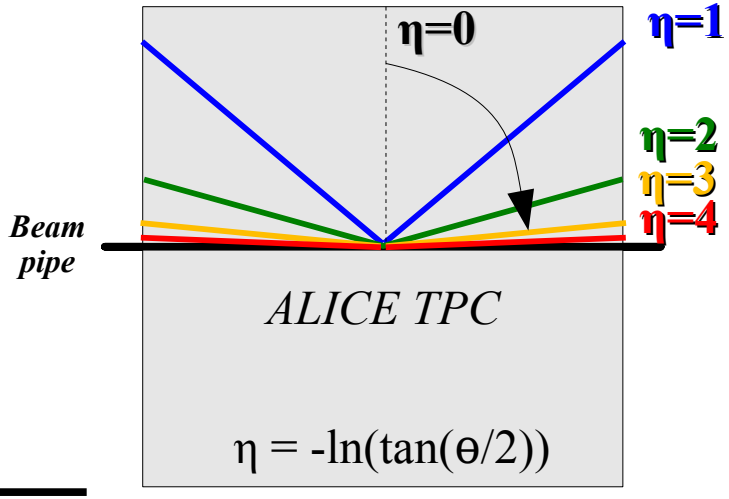
Multiplicity detectors-3.4 < η < 5

- including photon counting in PMD

Trigger & timing detectors

- 6 Zero Degree Calorimeters
- T0:ring of quartz window PMT's
- V0:ring of scintillator Paddles

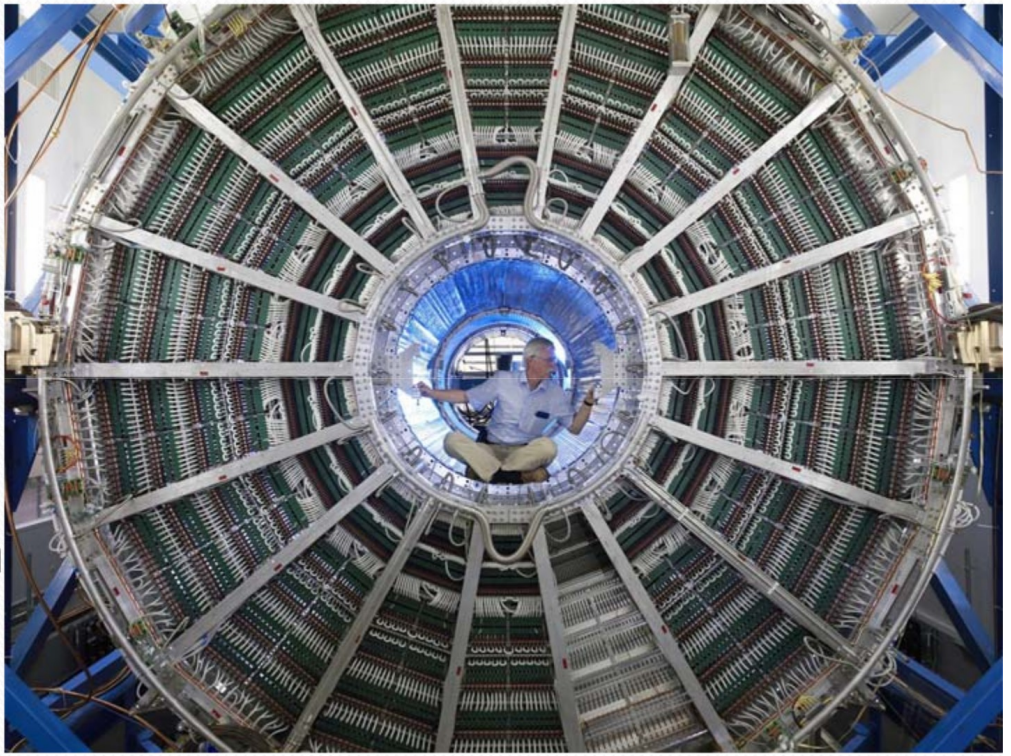


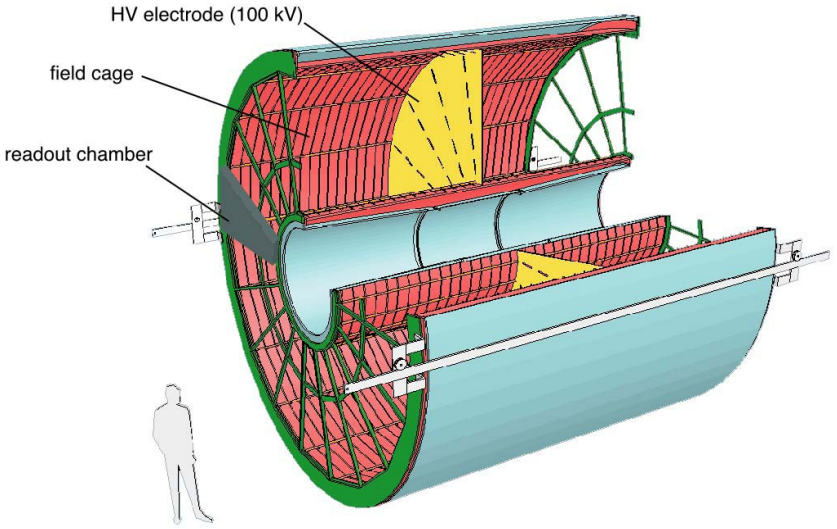


The Time Projection Chamber

Specifications

- Designed for $dN_{ch}/d\eta=8000$
- $|\eta|<0.9$, radius 0.9-2.5m
- In a 0.5 T Solenoidal Field
- 570k channels, 80MB/event
- 3% radiation length
- Outer diameter 5 m, Length 5 m
- Largest ever





TRD, TOF, HMPID

Transition Radiation Detector

- p_T>1 GeV electron id, p_T>3 GeV trigger
- 540 modules, 4.8 cm radiator with 1.2M channels
- MWPC readout

Time Of Flight

- Multi-gap Resistive Plate Chambers (MRPC)
- 50 ps resolution at ~5m
- $|\eta|<0.85$, $\Delta\varphi=2\pi$

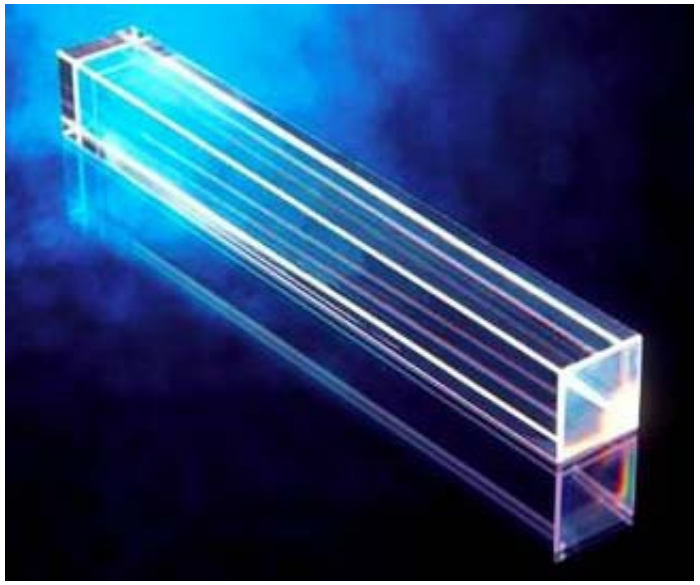
High Momentum PID

- Proximity focused, Ring Imaging Cherenkov RICH
- $|\eta|<0.6$, $\Delta\varphi=\pi/3$
- PID 1<p<6 GeV

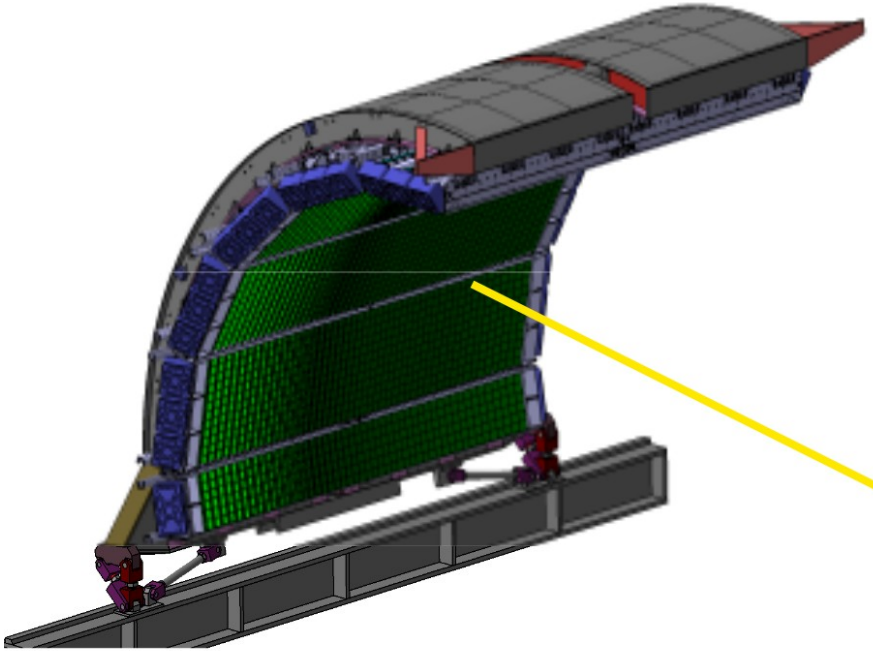
PHOS

PHOton Spectrometer

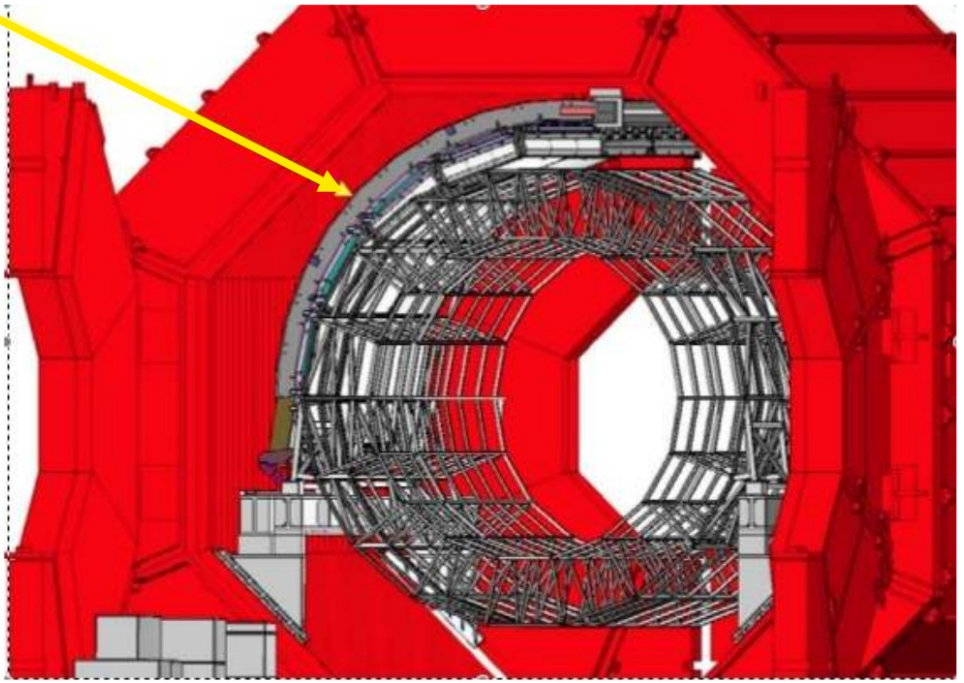
- PbO_4W crystal calorimeter
- γ,π^0,η for $1<p<100$ GeV
- $|\eta|<0.12$, $\Delta\phi=100^o$
- $\sigma(E)/E = 3\%$, $\sigma(x,y)=4$mm



EMCal

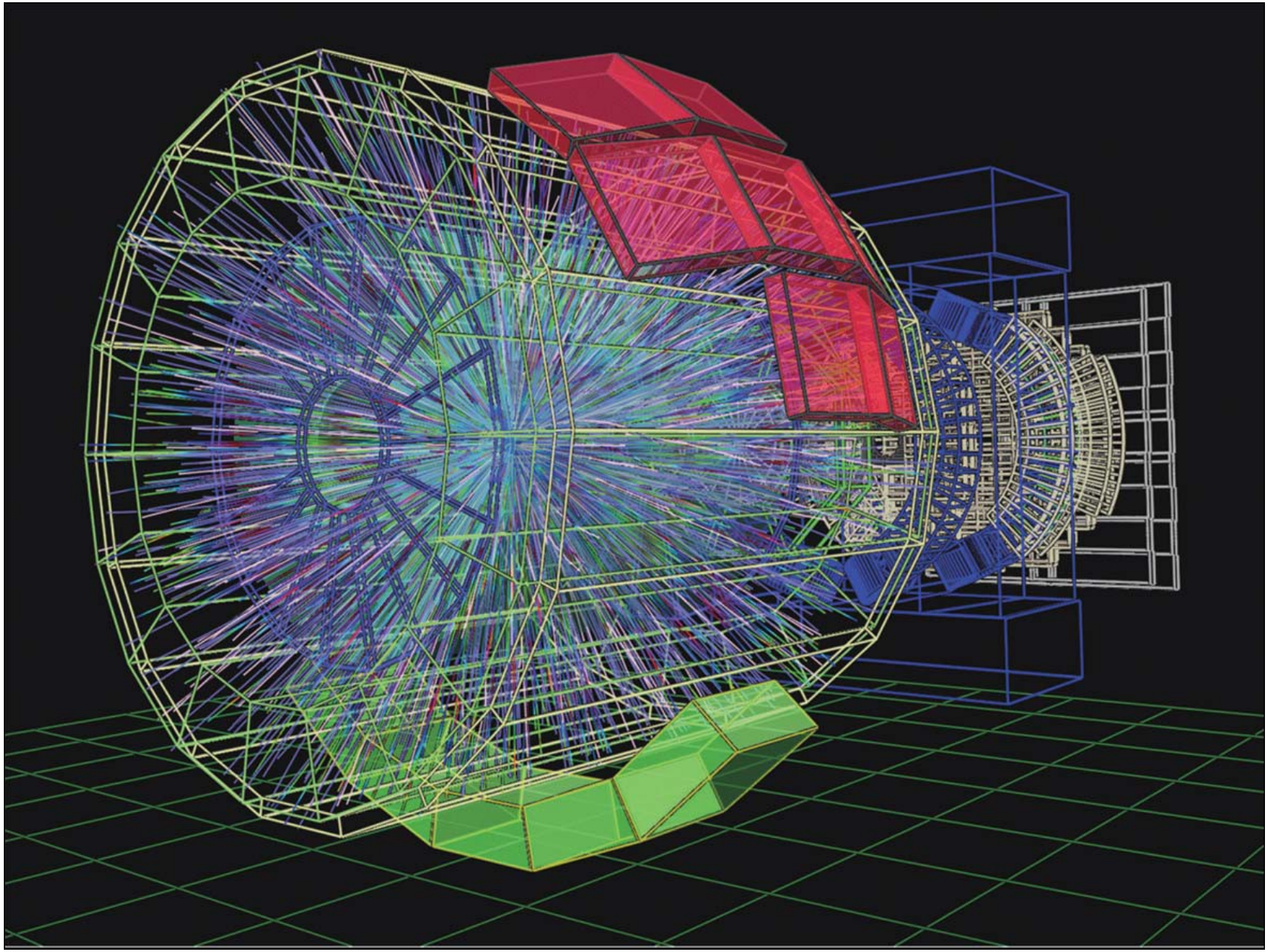


Funding approval: Feb. 2008
(~ALICE Upgrade: US, Italy, France, CERN, Finland)
– 7+2/3 US Super-Modules (SM)
– 3 EU SMs (Italy and France)
– Construct and Install 2008-2011

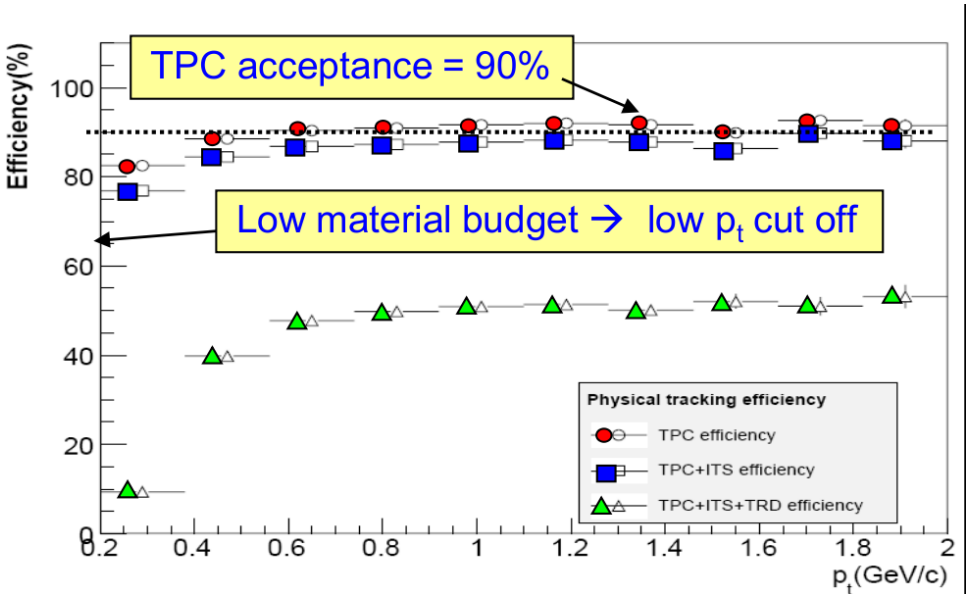


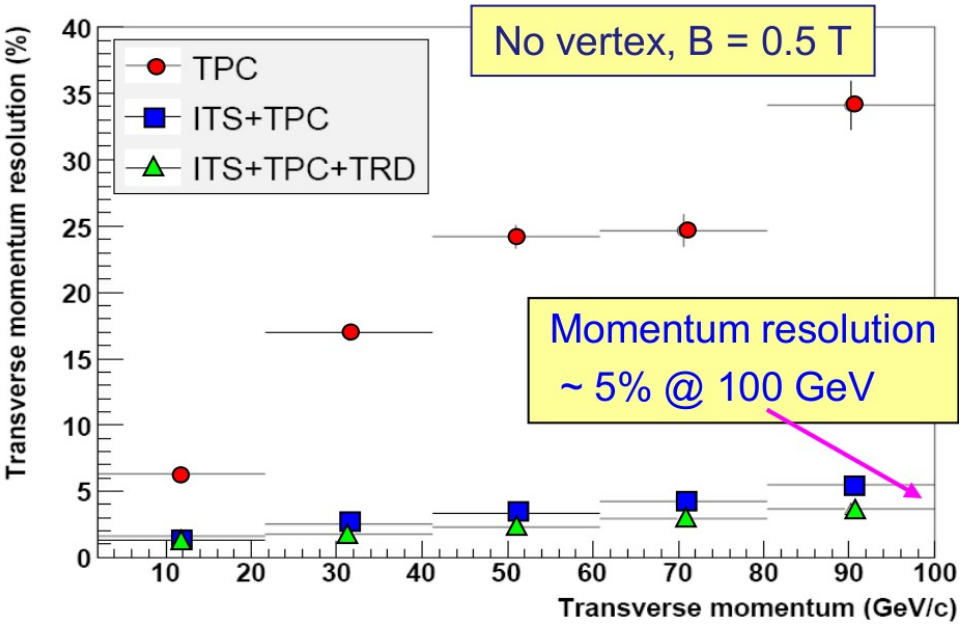
- Lead-scintillator sampling calorimeter
- 13 k towers
- Each tower $\Delta\eta X \Delta\varphi = 0.014 X 0.014$
- Shashlik geometry
- Avalanche phototodiodes
- $\Delta\eta=1.4, \Delta\varphi=107^{o}$
- $\sigma(E)/E=0.12/\sqrt{E} + 0.02$

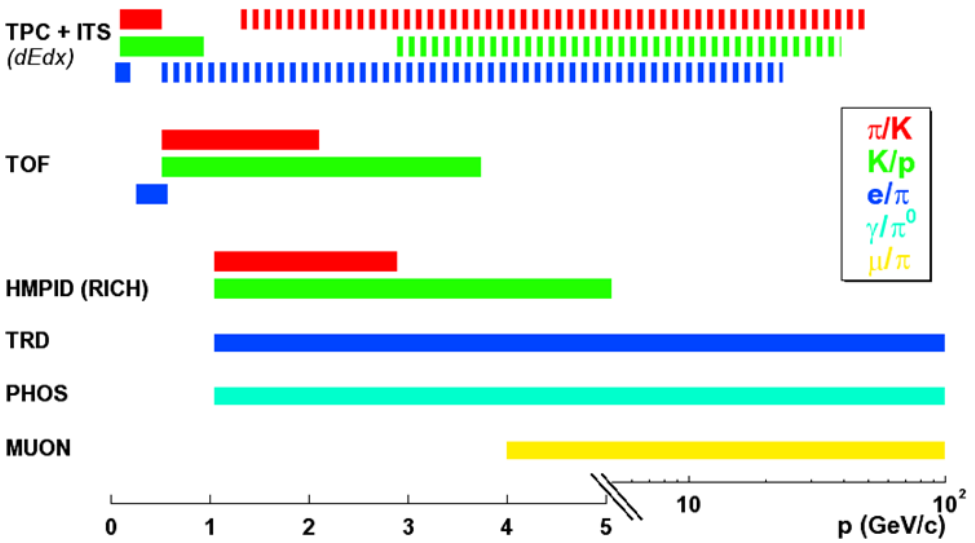
Simulated event



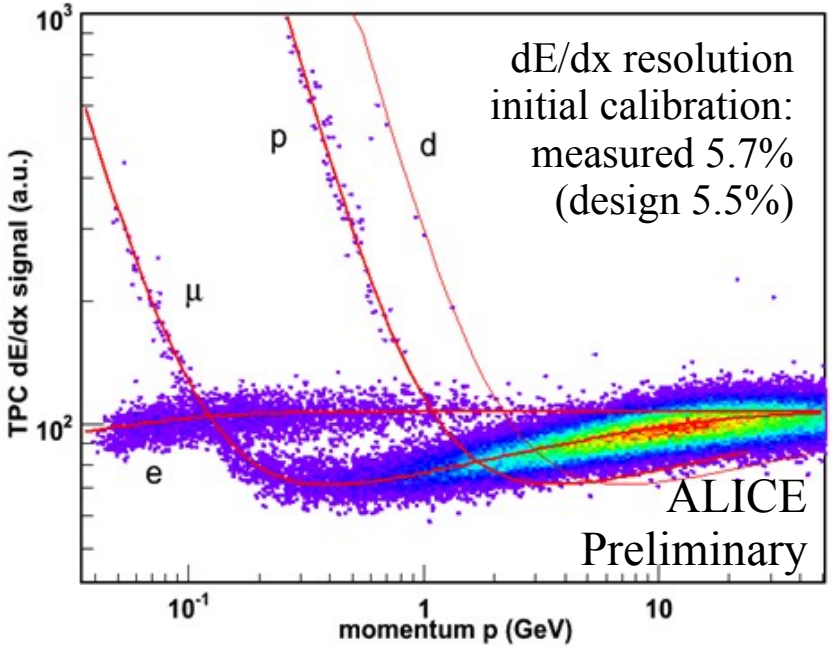
ALICE Performance

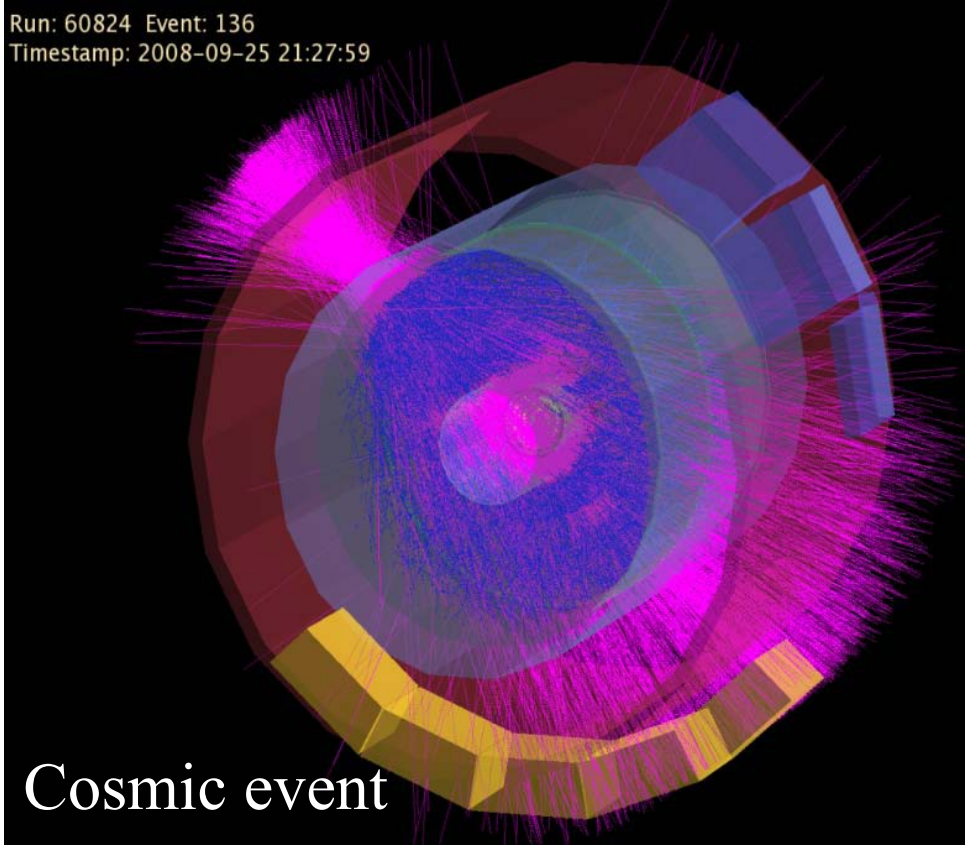


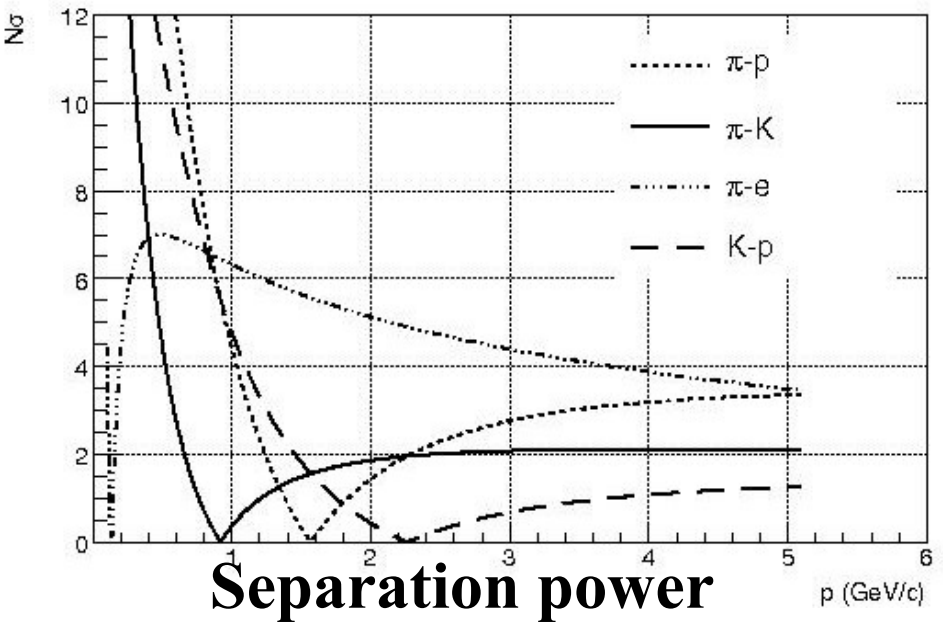




TPC Performance



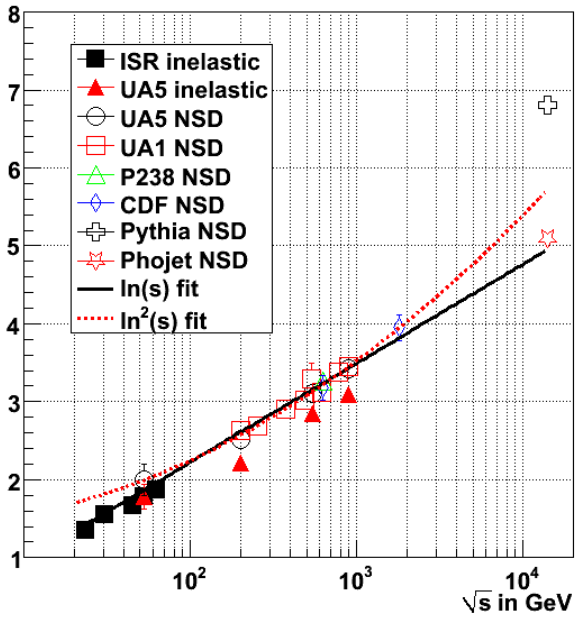




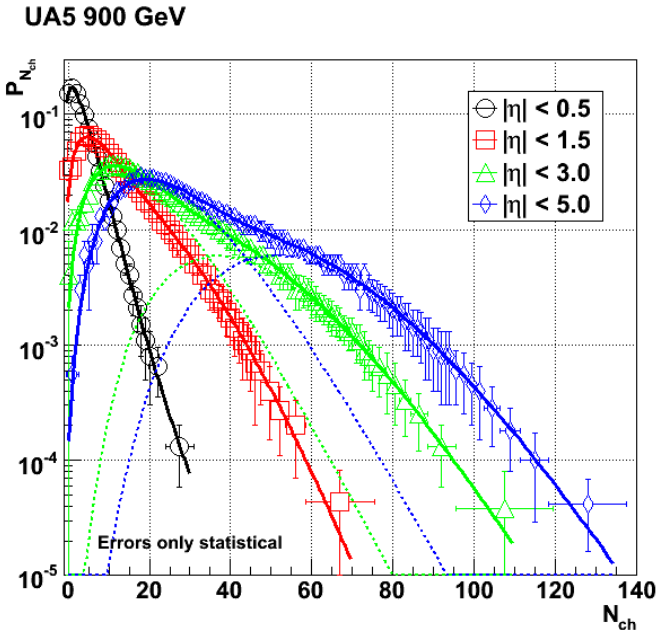
Separation power

Day 1 p+p physics

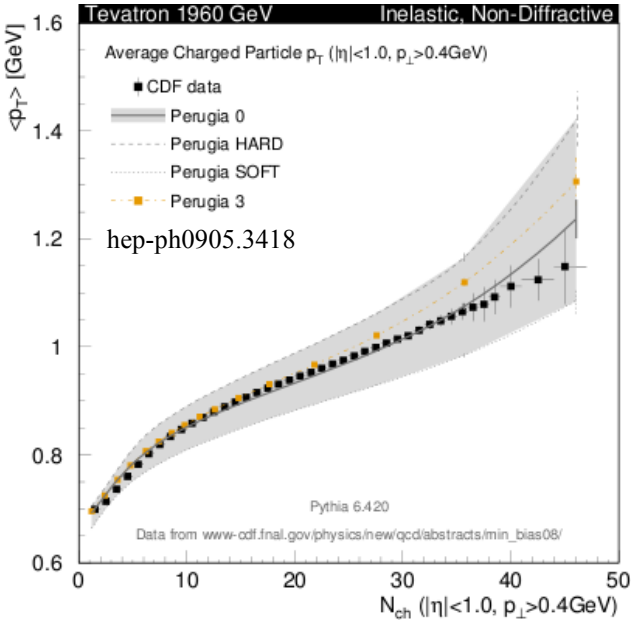
- Global event properties
- Constrain/tune PYTHIA



$\langle dN_{ch}/d\eta\,|_{\eta=0}\rangle$

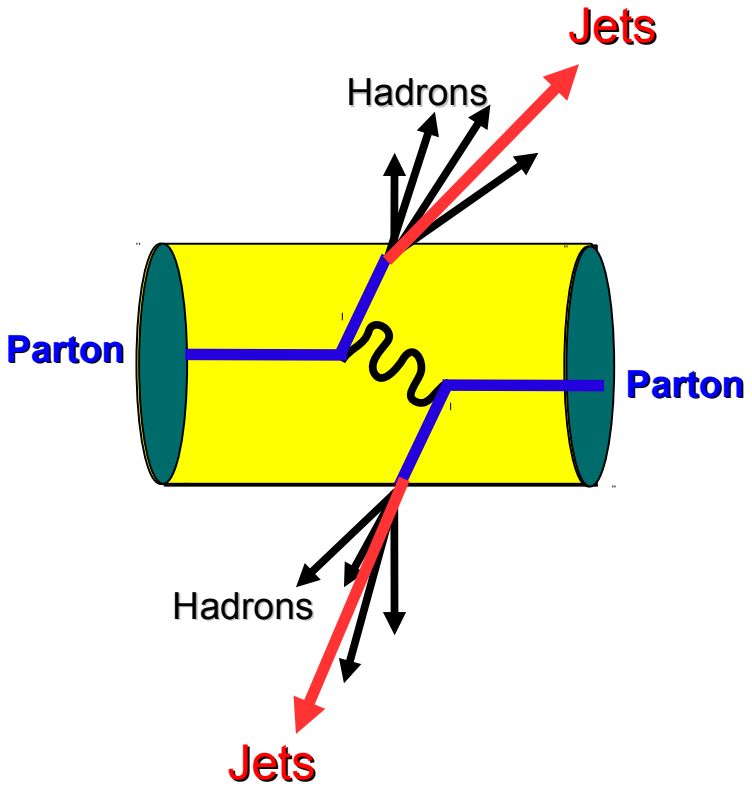


Multiplicity distributions



$\langle p_T \rangle$ vs N_{ch}

Hard probes



Hard Probes (from initial parton scattering):

Heavy quark production

High-p_T hadrons

Jets

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

Hard probe rates in ALICE

ALICE hard physics capabilities:

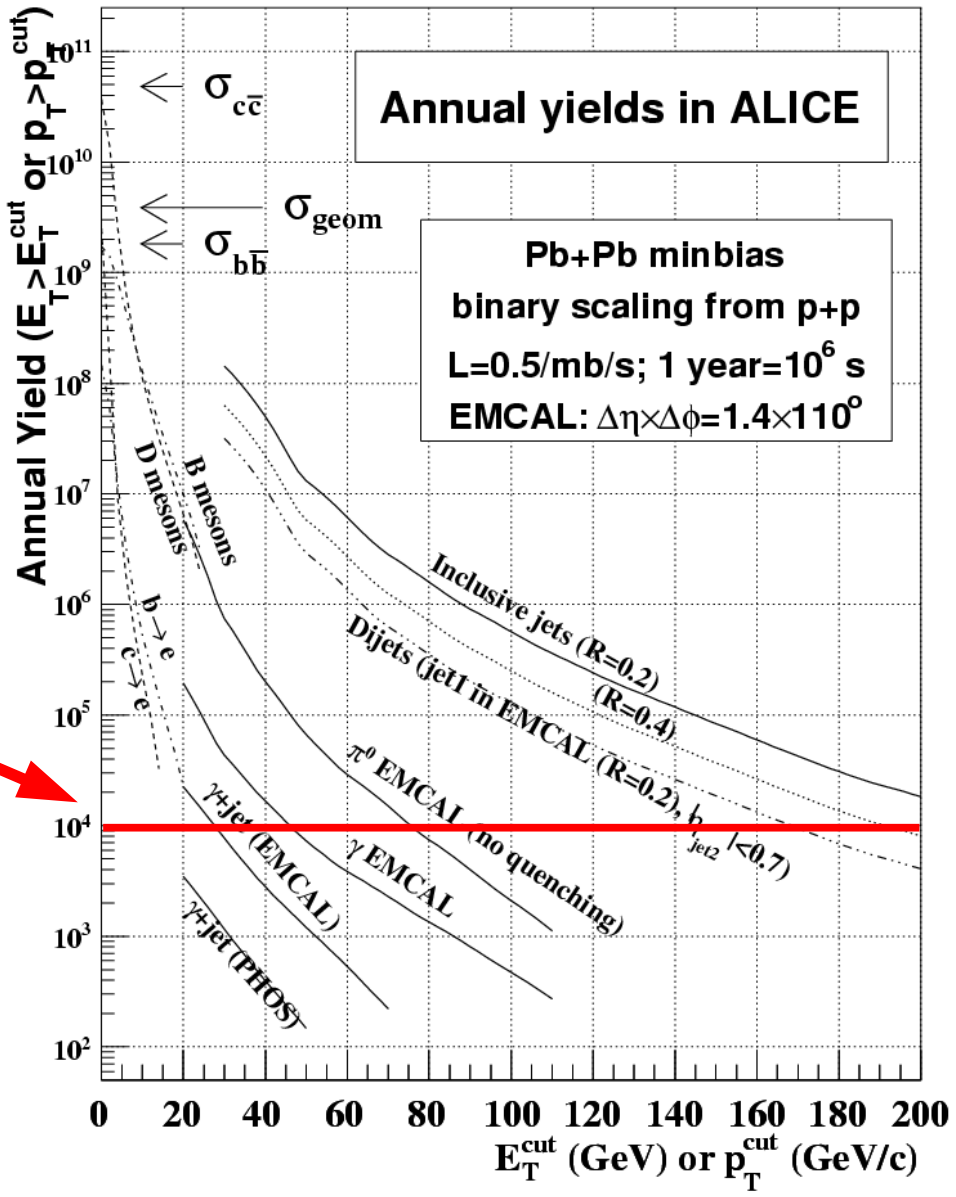
- Electron/hadron discrimination (TRD, EMCal)
- μ measurements(forward muon arm)
- Good γ/π^0 discrimination (EMCal, PHOS)
- Fast trigger on jets(EMCal)

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/c
- Inclusive γ: $p_T \sim 45$ GeV/c
- Inclusive e: $p_T \sim 30$ GeV/c

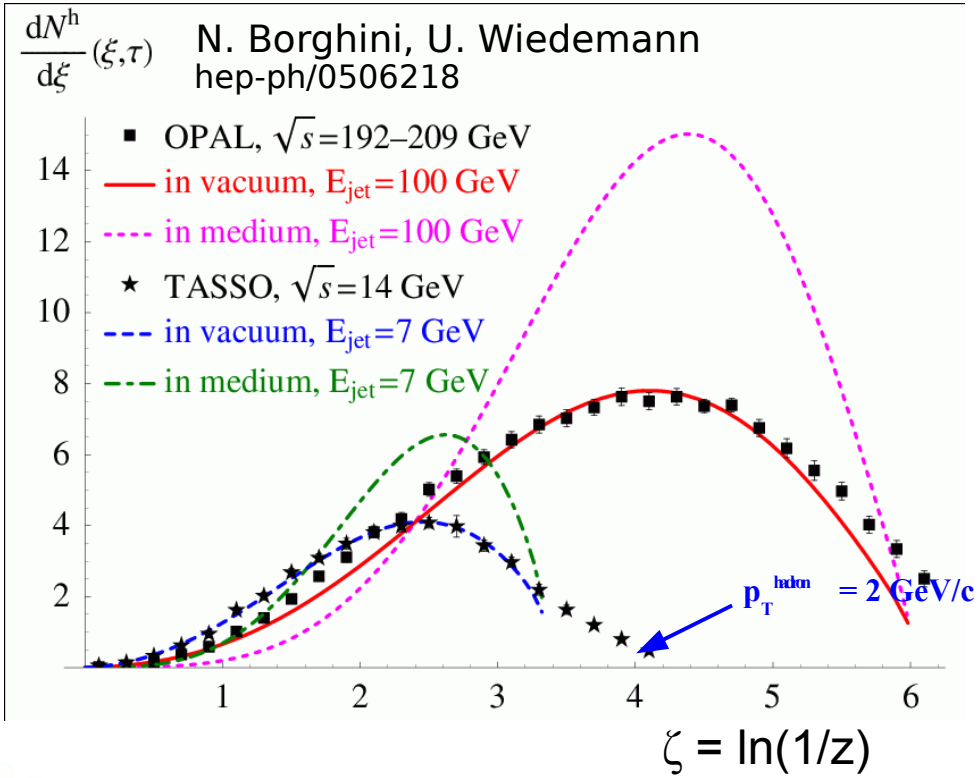
*One year of running = one month of Pb+Pb collisions

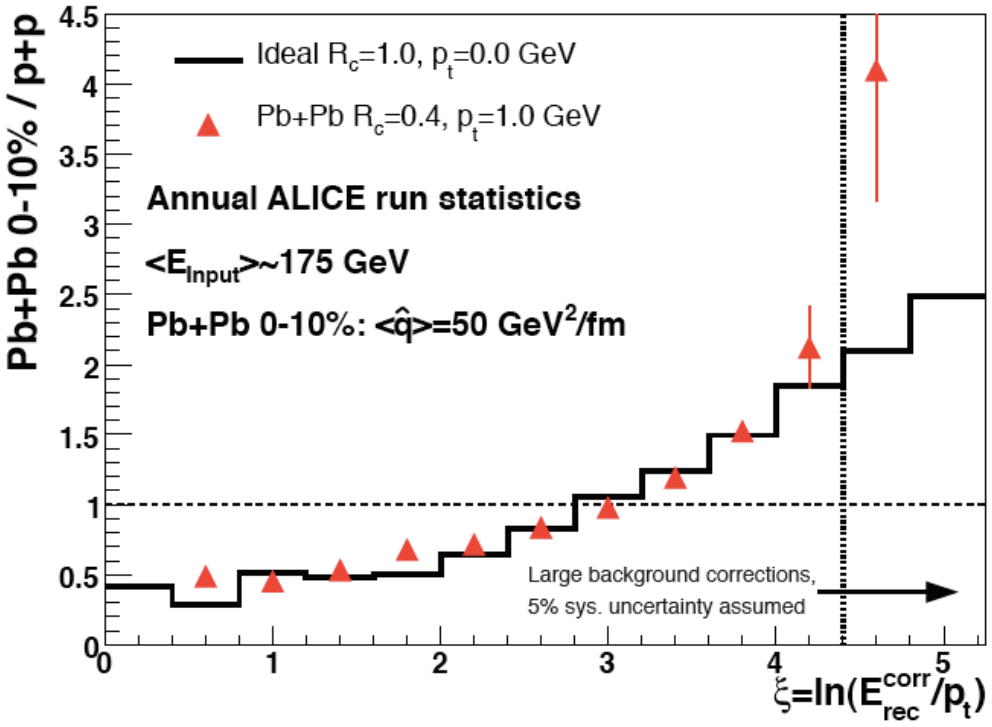


Medium modification of fragmentation

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

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





Quarkonia

Heavy Quarks

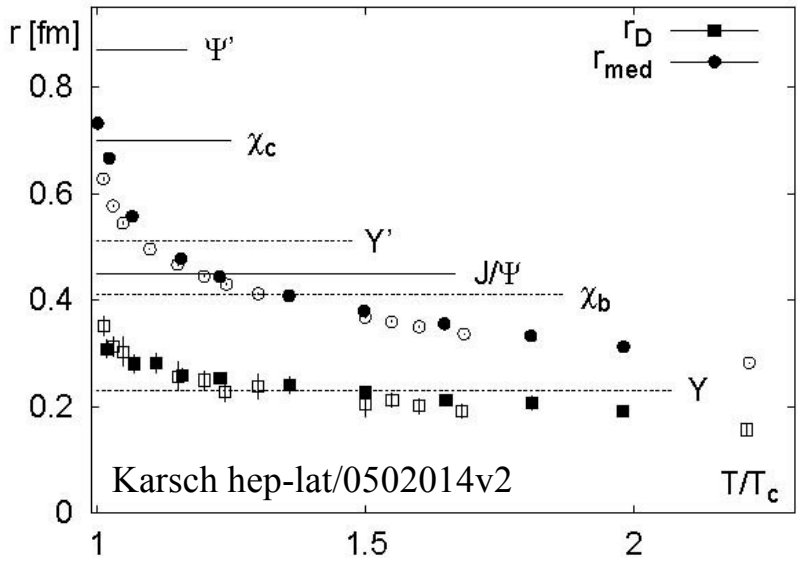
mass/color dependence of parton E-loss

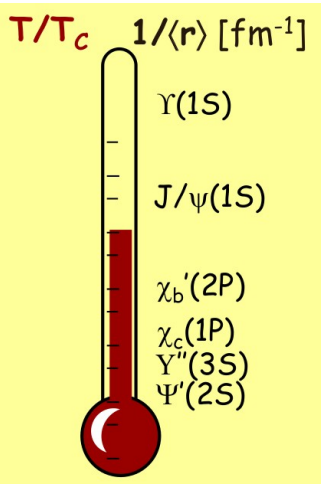
- Displaced vertices ($D^0 \rightarrow K^- \pi^+$) from TPC/ITS
- Electrons in Transition Radiation Detector (TRD)

Quarkonia

Initial T, Debye screening, recombination,...

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





Conclusions

- ALICE is able to
  - Measure thousands of particles per event
  - Measure particles over a wide kinematic range (0.1-100 GeV/c)
  - Identify many particles over a wide kinematic range
    - π, k, p, e, μ, Λ, K^0_S, Ξ, Ω, D^0
- Expect exciting results from p+p soon

Thank you!

Take a stack of fliers home and post them in your department!

January 15-17, 2010

Goal: To help undergraduate women continue in physics by

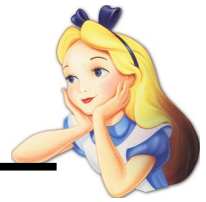
- Providing the opportunity to experience a professional conference
- Providing Information about graduate school and professions in physics
- Introducing them to other women in physics

- Research talks
- Panel discussions about graduate school and careers in physics
- Presentations and discussions about women in physics
- Laboratory tours
- Student research talks
- Student poster session

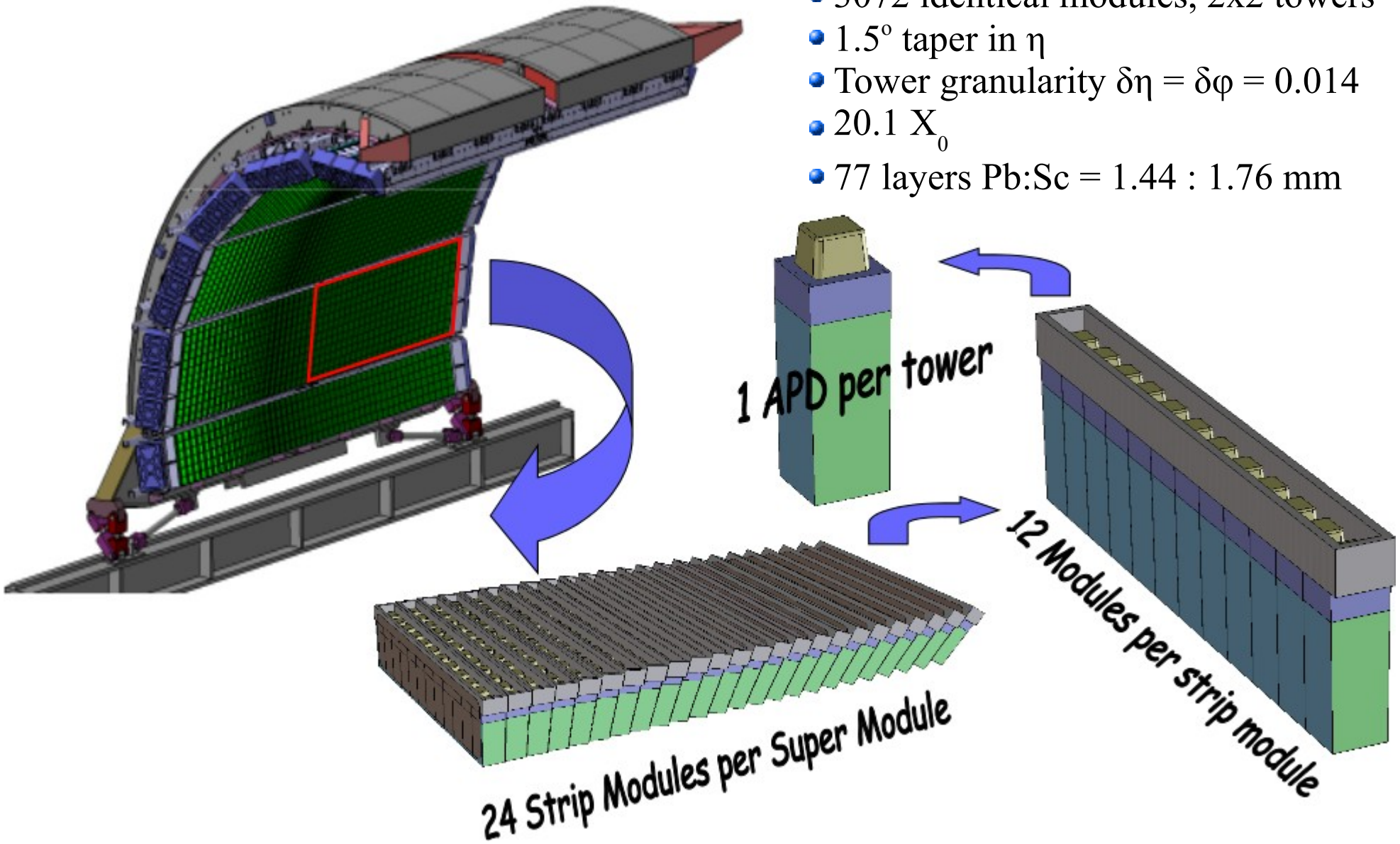
Application deadline: Dec. 15, 2010

Applications received by Nov. 15, 2009 will receive full consideration for travel awards. Notification of travel awards and room reservation instructions will begin Nov. 15th and continue until funds are exhausted. For more information and for application forms, see http://www.southeastcuwp.org/

EMCal Assembly



- 3072 identical modules, 2x2 towers
- 1.5° taper in η
- Tower granularity $\delta\eta = \delta\varphi = 0.014$
- 20.1 X_0
- 77 layers Pb:Sc = 1.44 : 1.76 mm



ALICE