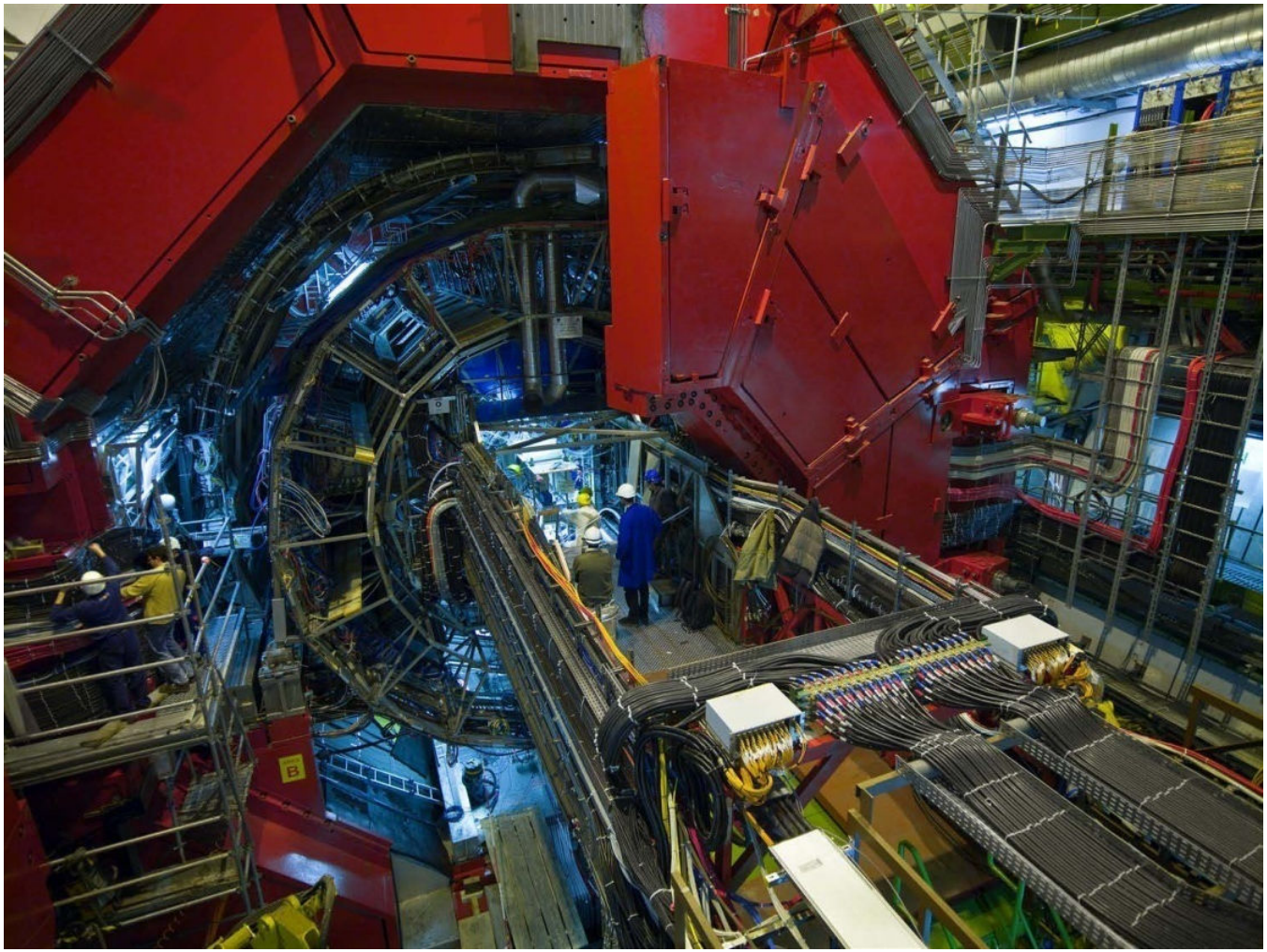
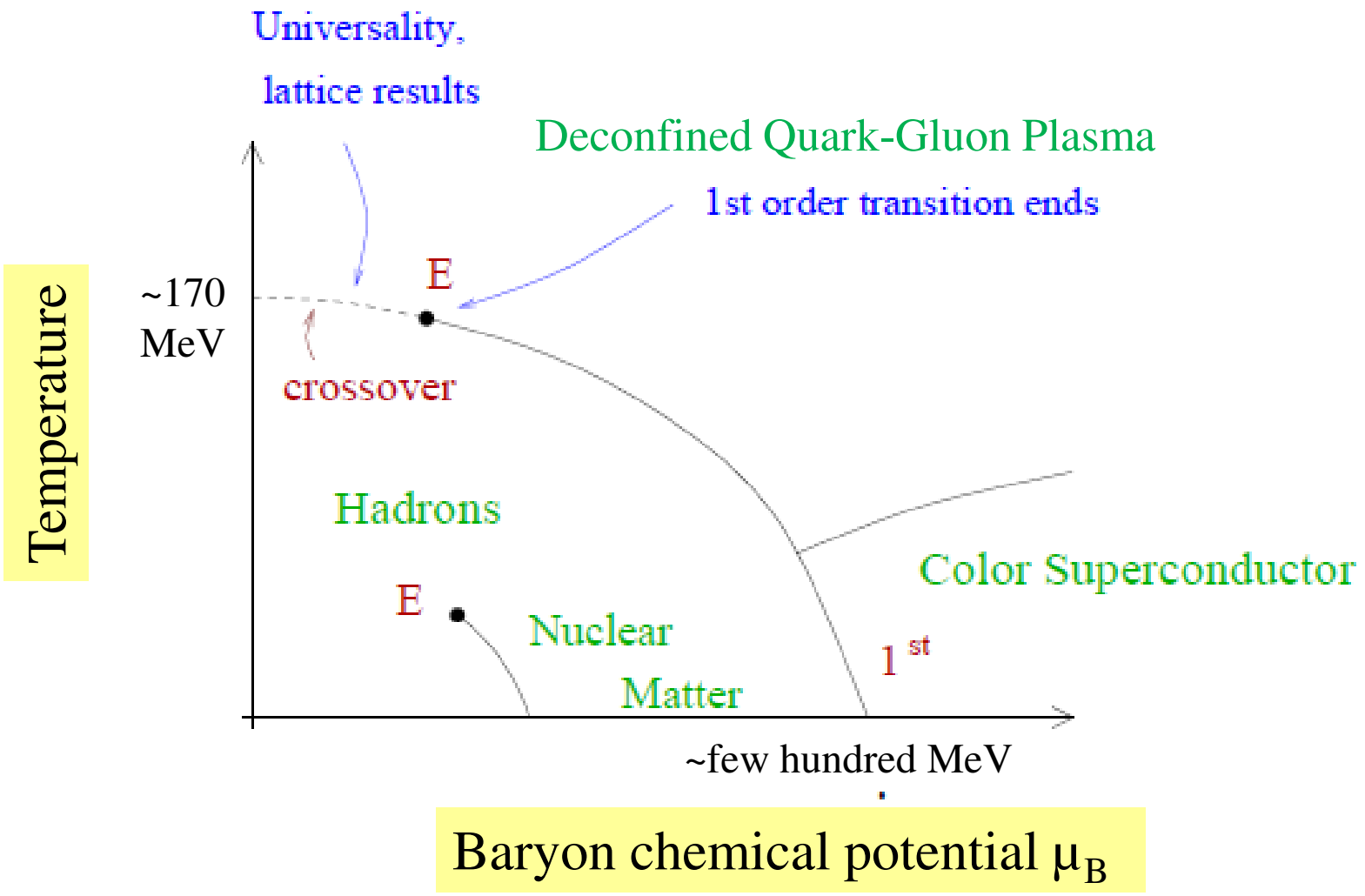
Status of ALICE

Peter Jacobs, LBNL



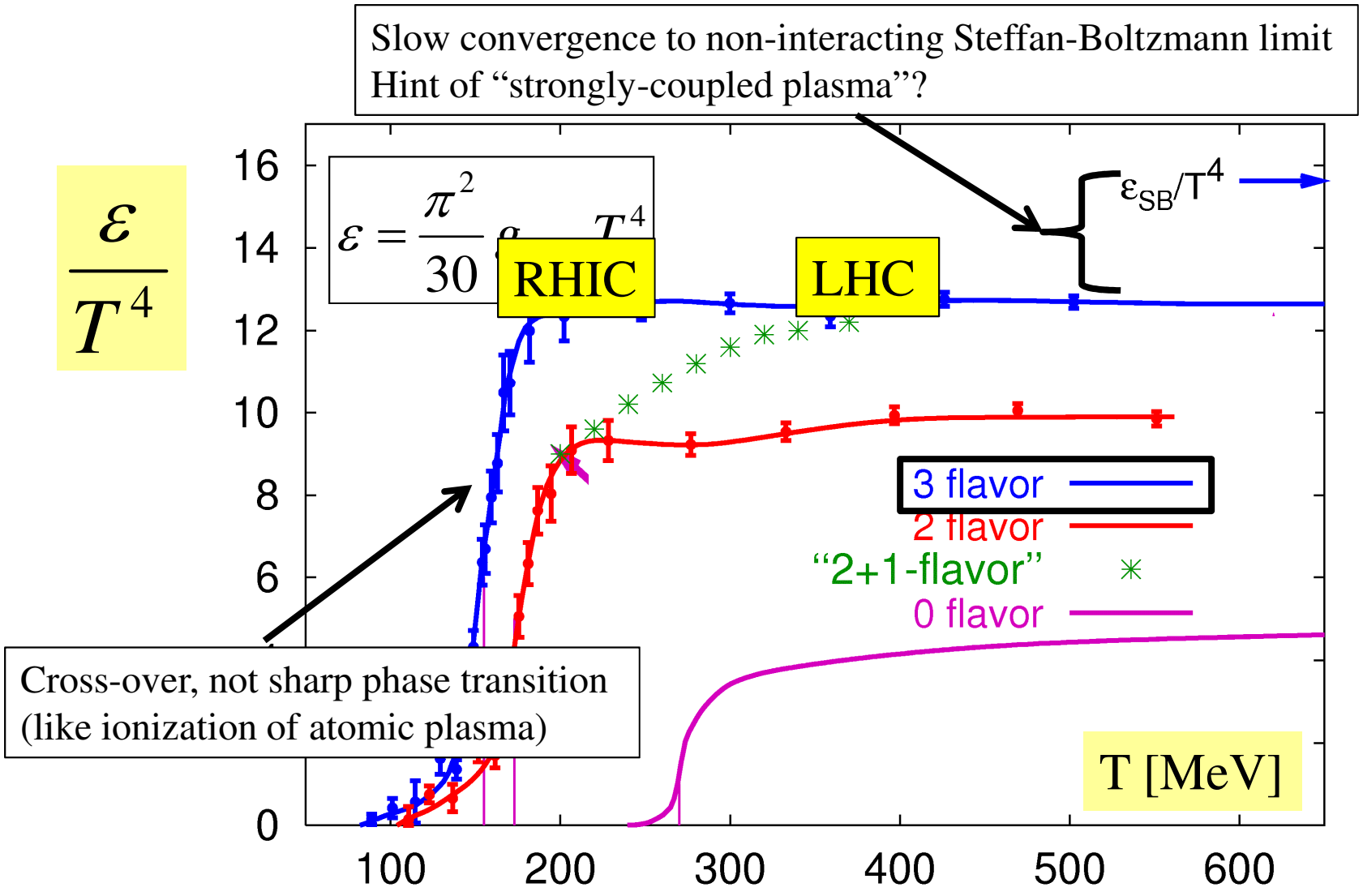
QCD Phase Diagram: qualitative view



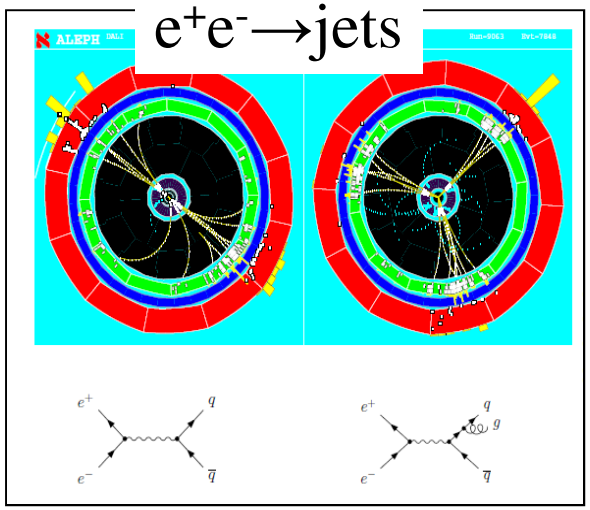
Heavy Ion physics: study phases and dynamics of hot QCD matter

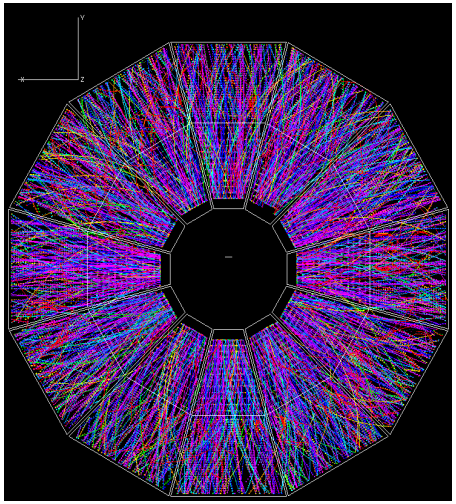
QCD thermodynamics: calculation

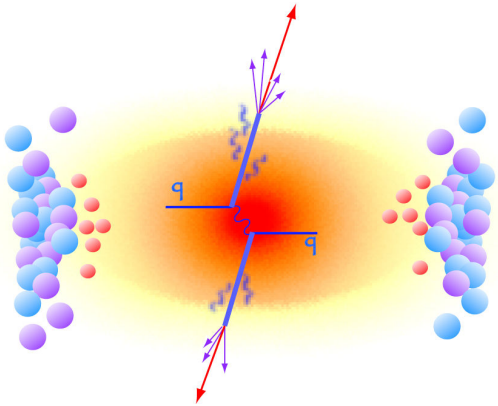
QCD on the lattice (μ_B=0)



Key probe of the medium: QCD jets







QCD jets: ubiquitous in high energy collisions of all kinds

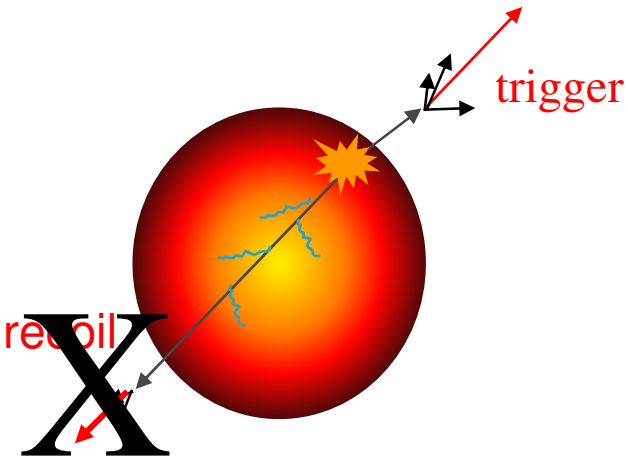
Jet quenching in nuclear collisions: interaction of hard-scattered parton in the colored medium

Energy loss via QCD bremsstrahlung (medium-induced gluon radiation)

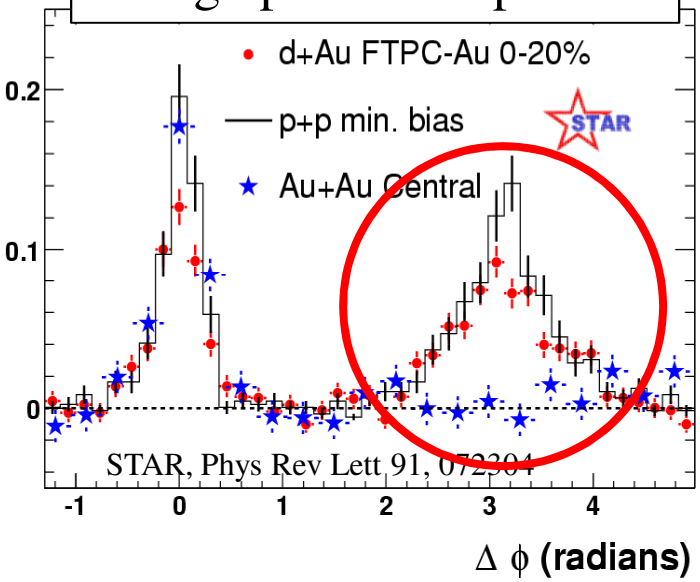
- Measures color-charge density
- Sensitive to correlation structure of medium
  - Bjorken ’82 (considered elastic scattering)
  - First quantitative predictions: Gyulassy, Pluemer and Wang in early ‘90s

Jet quenching: experiment

- Recoiling jet is strongly altered by medium
- Clear evidence for generation of very high density matter



Azimuthal separation of high pT hadron pairs

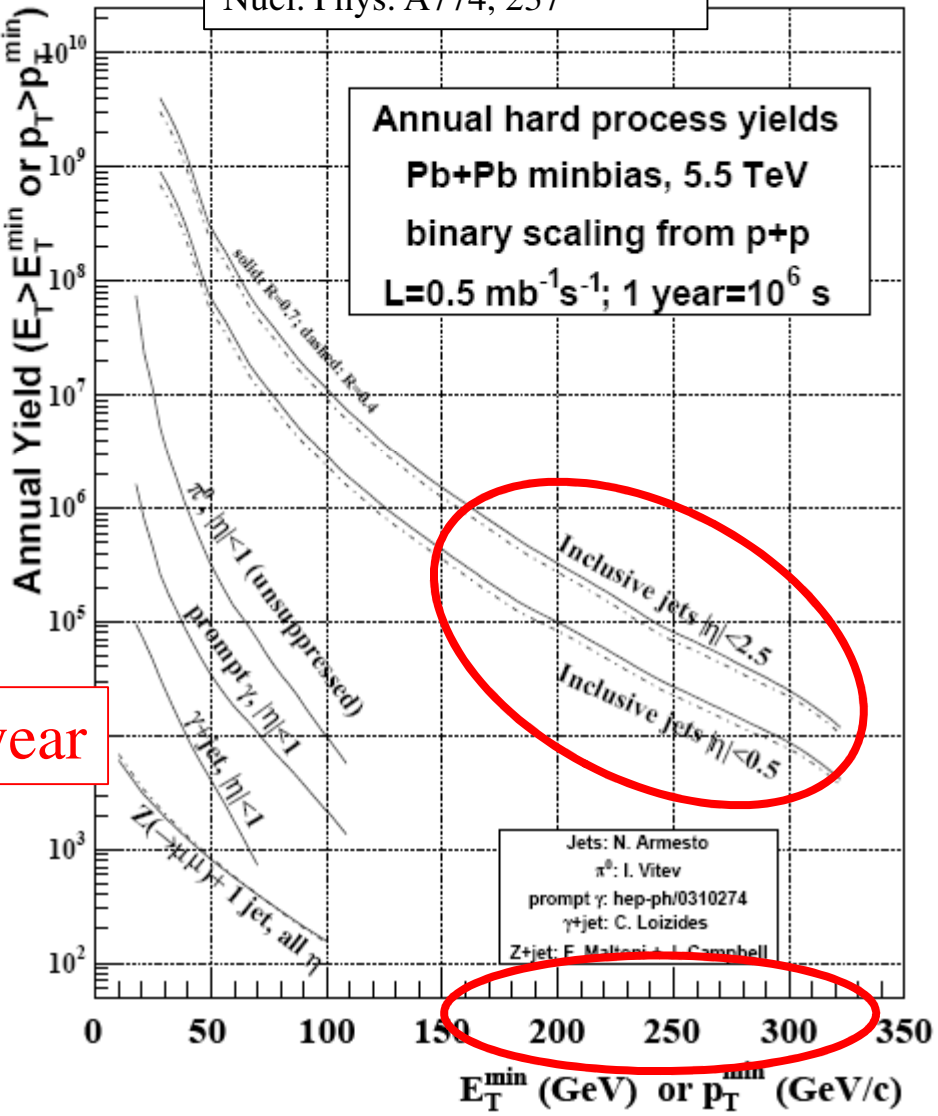


- Striking experimental signatures
- Very active area in QCD theory→ quantitative understanding
- Speculative calculations using AdS/CFT correspondence

A major focus of the LHC Heavy Ion Program

Annual yields in 5.5 TeV Pb+Pb

P. Jacobs and M. van Leeuwen
Nucl. Phys. A774, 237

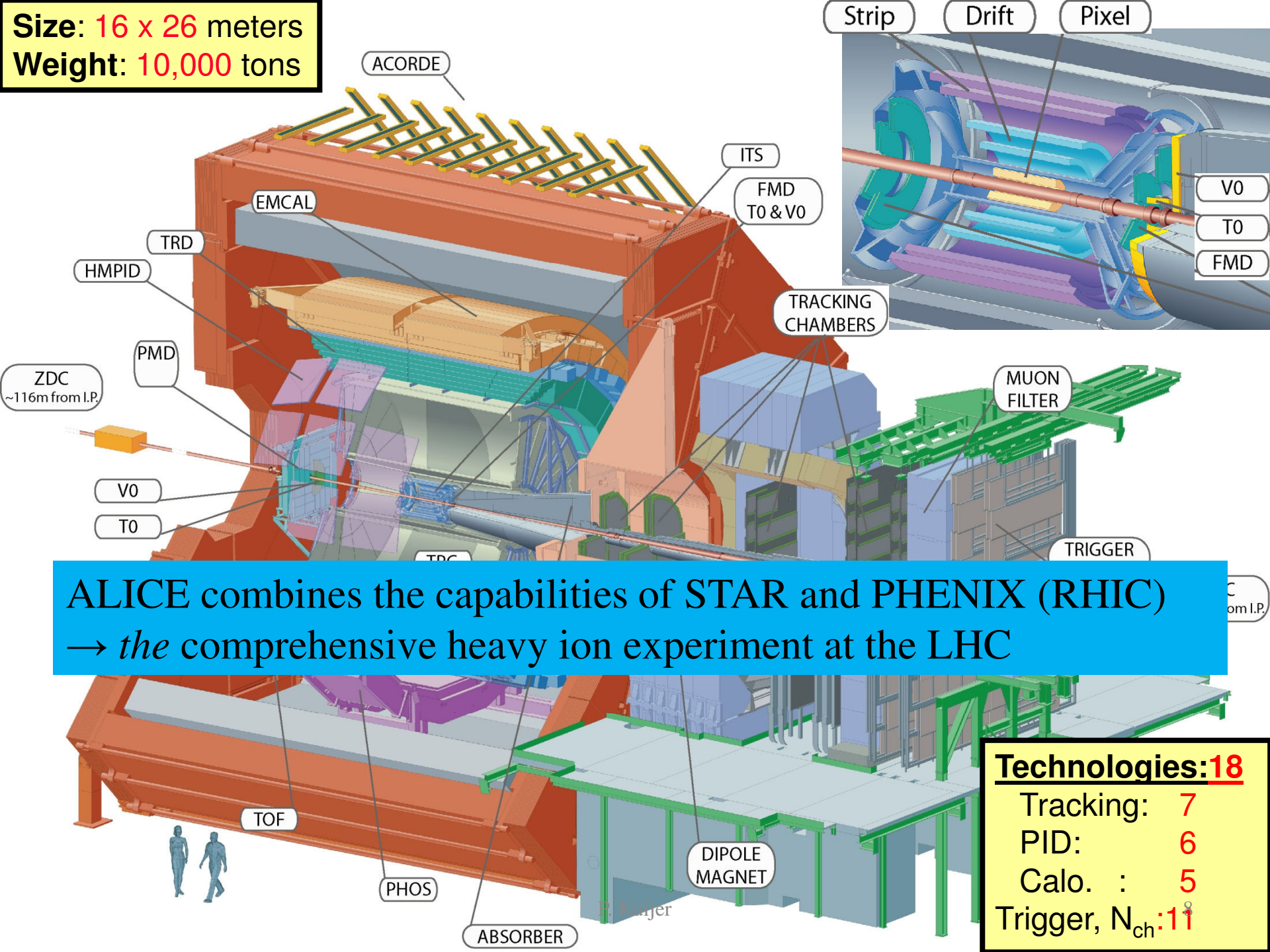


10^4/year

Large kinematic reach in central region


ALICE

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



ALICE combines the capabilities of STAR and PHENIX (RHIC)
→ *the* comprehensive heavy ion experiment at the LHC

Technologies:18

Tracking:	7
PID:	6
Calo. :	5
Trigger, N_{ch}:	11

ALICE compared to ATLAS/CMS

Requirements for heavy ion physics:

- measure large-scale collective phenomena:
  reconstruct complex hadronic events
- QCD cross sections "relatively large"
  → moderate rate and rejection capabilities
- precise measurements of heavy flavor, photons, leptons
- energy scale 100 MeV – 100 GeV
  → high precision tracking in moderate field
  → very low material budget near vertex
  → particle ID over very broad momentum range

Requirements for Higgs/SUSY searches:

- missing energy signatures → hermetic coverage
- energy scale 10 GeV – 1 TeV
- tiny cross sections: high rate and rejection capabilities

ALICE favors robust tracking, PID, precision, and low mass over large acceptance, high rate, and huge dynamic range

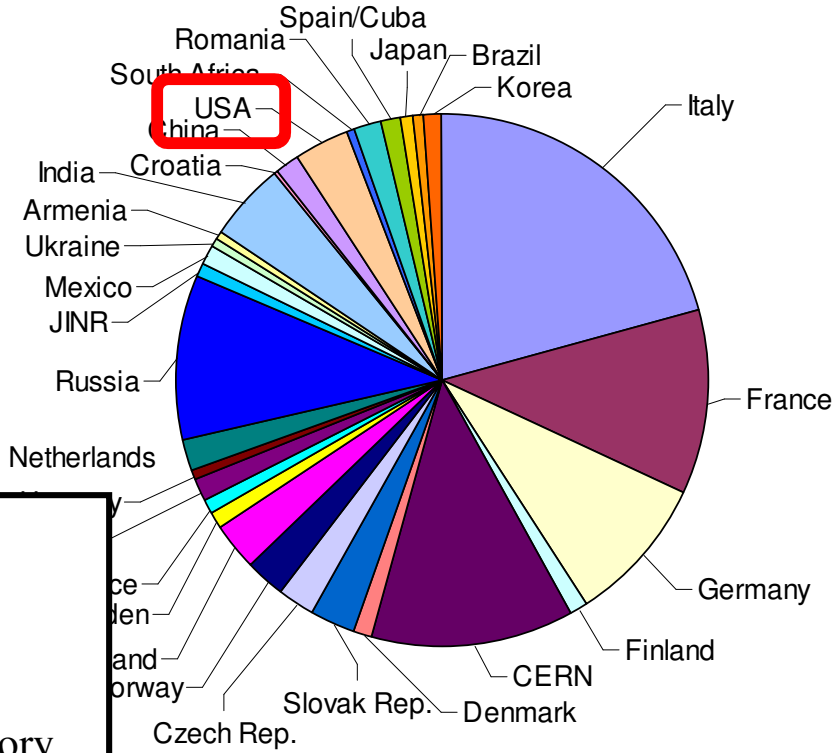
ALICE Collaboration

~ 1000 Members

(63% from CERN MS)

~30 Countries

~100 Institutes

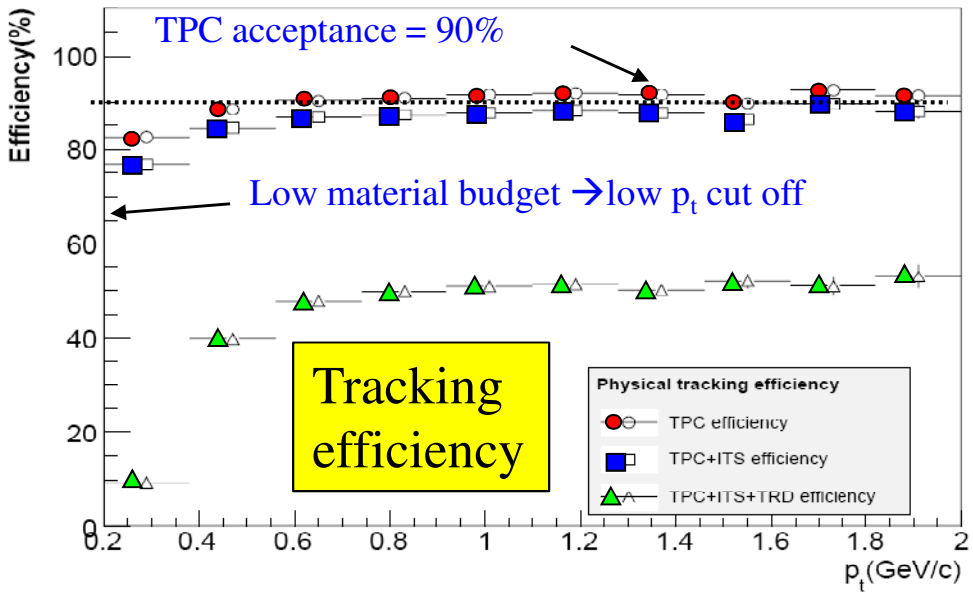


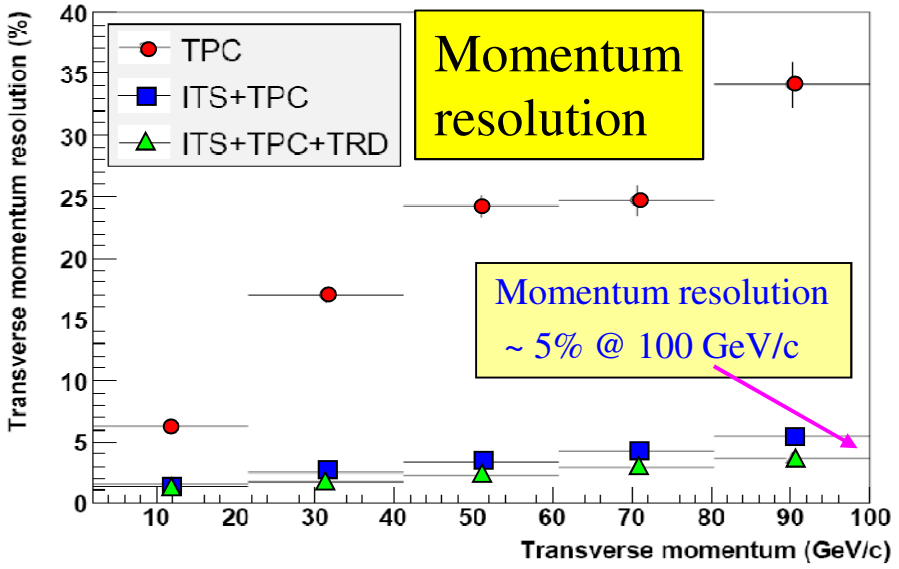
US Participation

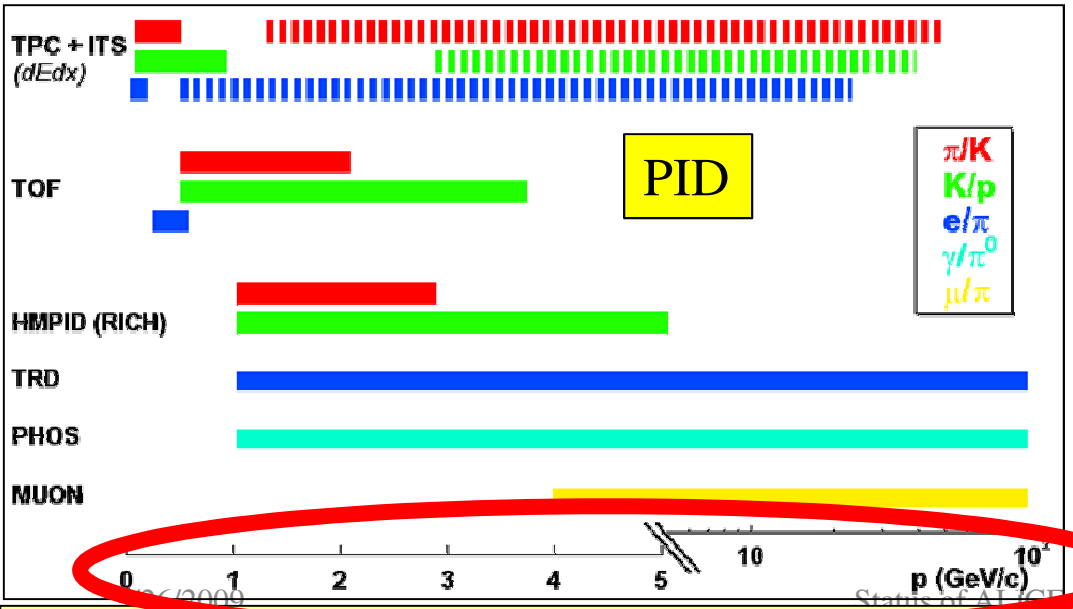
Cal Poly San Luis Obispo
Creighton University
University of Houston
Lawrence Berkeley National Laboratory
Lawrence Livermore National Laboratory
Oak Ridge National Laboratory
Ohio State University
Purdue University
University of Tennessee
University of Texas Austin (pending)
Wayne State University
Yale University

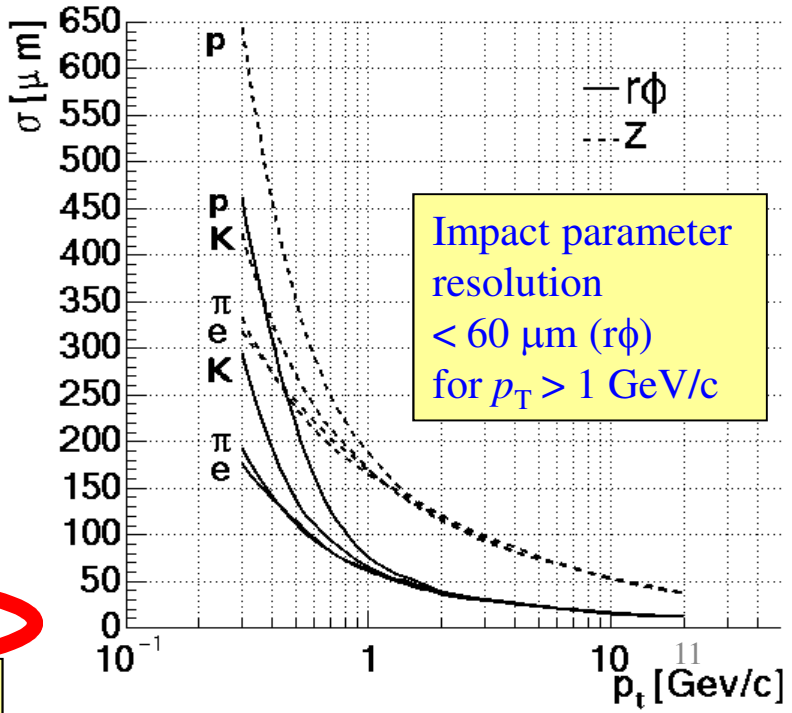
~55 PhDs and students

ALICE Design Performance



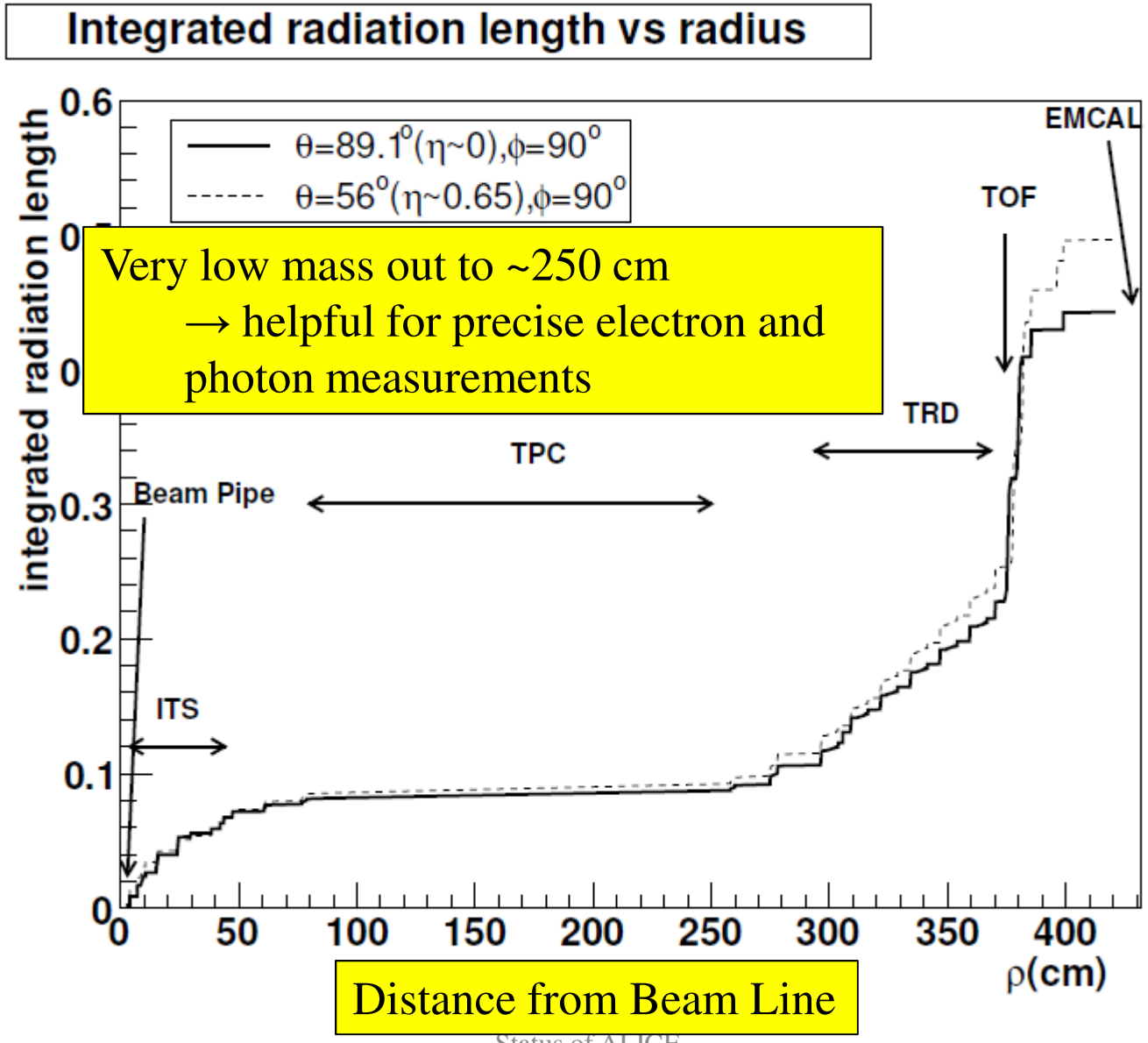




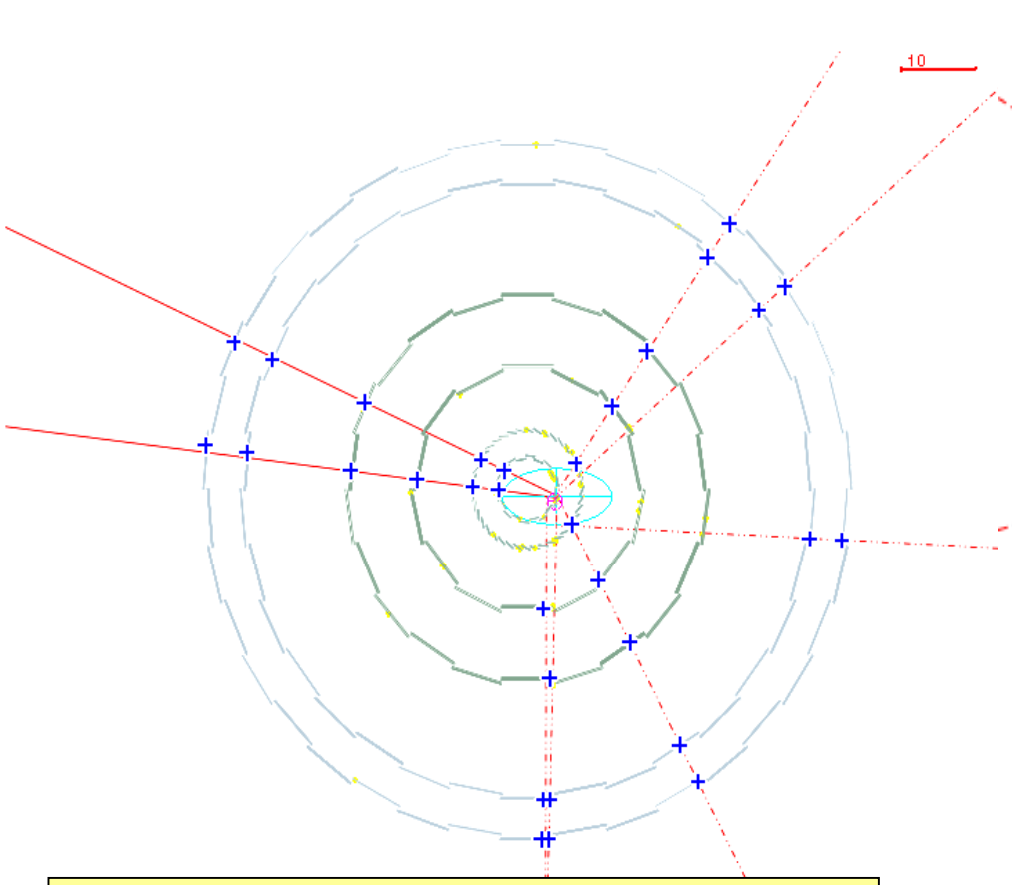


+ decay topologies ((K⁰, K⁺, K⁻, Λ, φ, D) K and Λ beyond 10 GeV/c

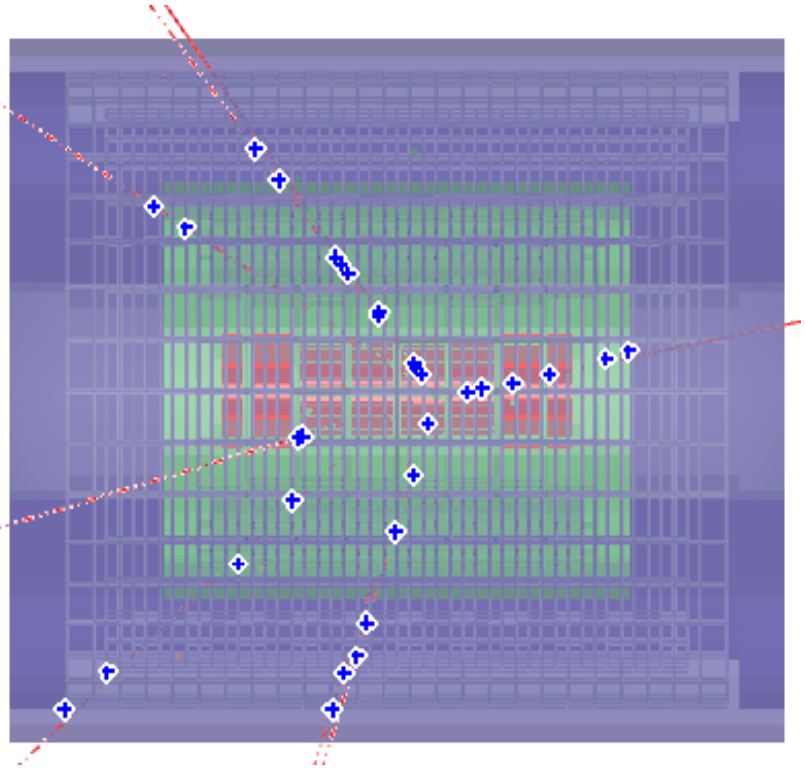
Distribution of material



First interactions September 11 2008



ITS tracks on 11.9.2008
7 reconstructed tracks, common vertex



Circulating beam 2:
stray particle causing an interaction in the ITS

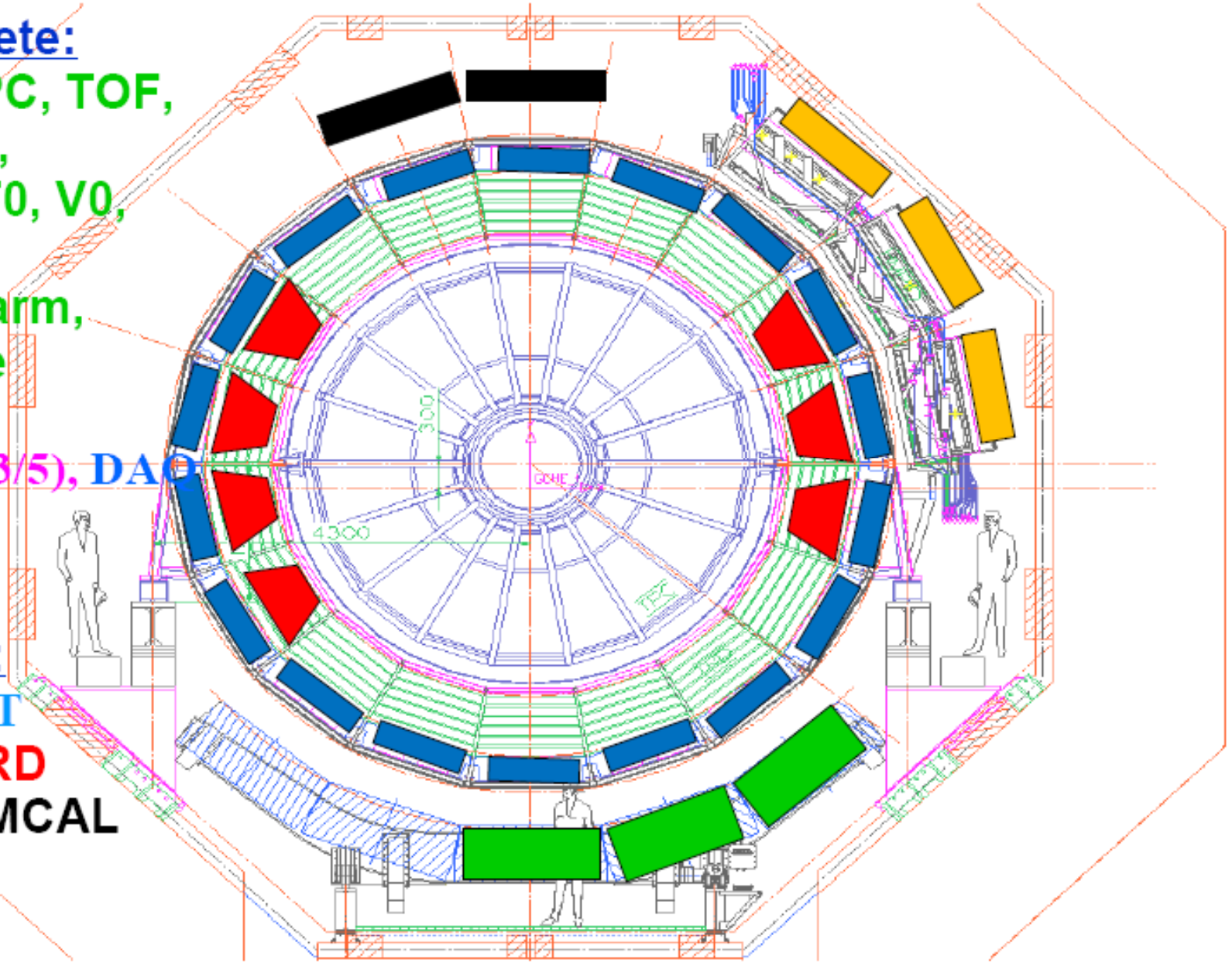
ALICE 2009

Complete:

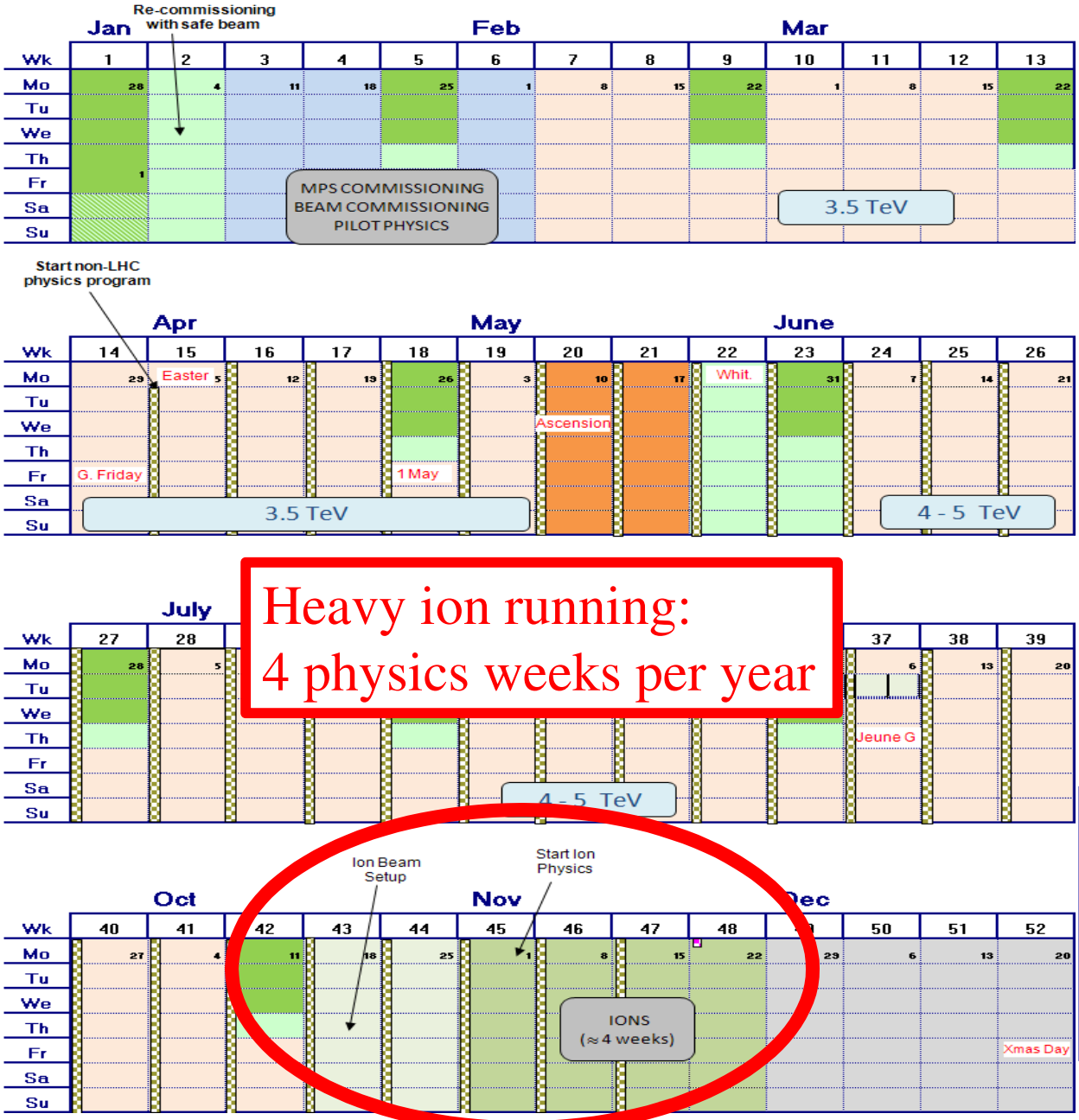
ITS, TPC, TOF,
HMPID,
FMD, T0, V0,
ZDC,
Muon arm,
Acorde
PMD ,
PHOS(3/5), DAQ

Partial:

2/3 HLT
7/18 TRD
4/12 EMCAL



LHC 2010 – draft schedule



- 2009:
  - 1 month commissioning
- 2010:
  - 1 month pilot & commissioning
  - 3 month 3.5 TeV
  - 1 month step-up
  - 5 month 4 - 5 TeV

200-300 pb-1

With luck: Collisions at 3.5+3.5 TeV by Christmas

Subsystem status – a few examples

- ITS
- TPC
- High Level Trigger
- EM Calorimeter

Inner Silicon Tracker

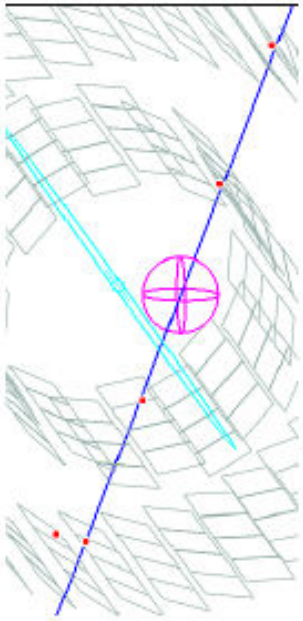
Inner Tracking System
~ 10 m² Si detectors, 6 layers
Pixels, Drift, double sided Strips

Strips
SSD

Pixels
SPD

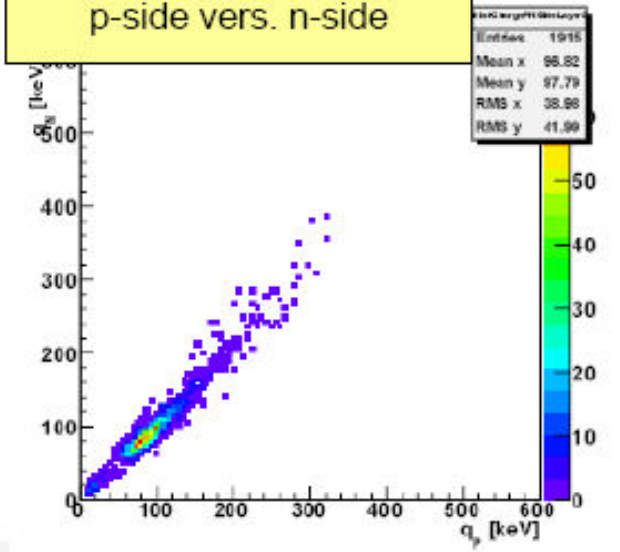
Drift
SDD

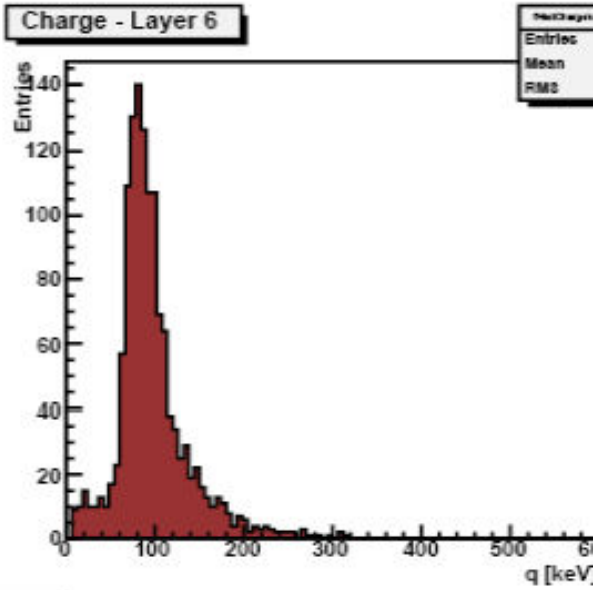
ITS: detector commissioning results

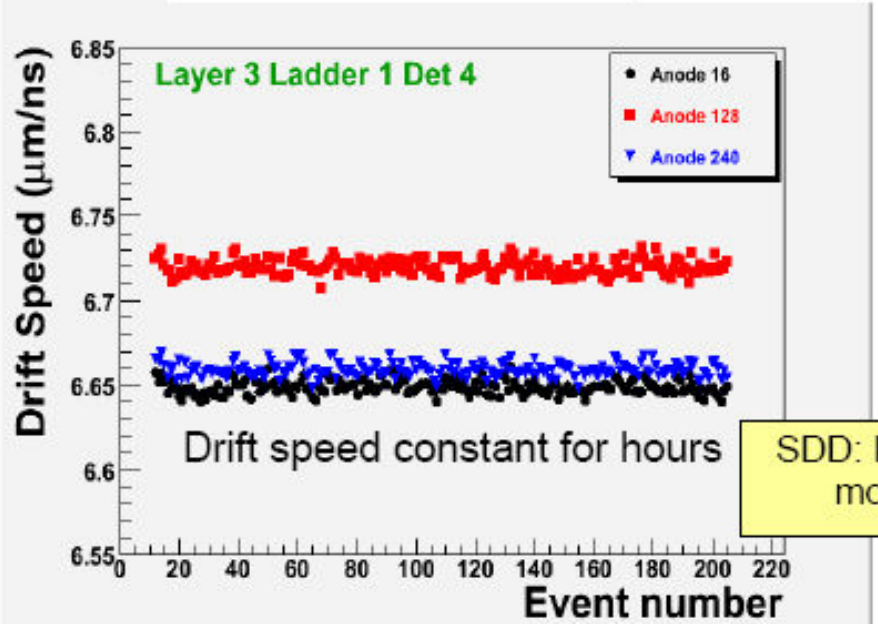


SPD
Top vs bottom

SSD: charge correlation
p-side vers. n-side

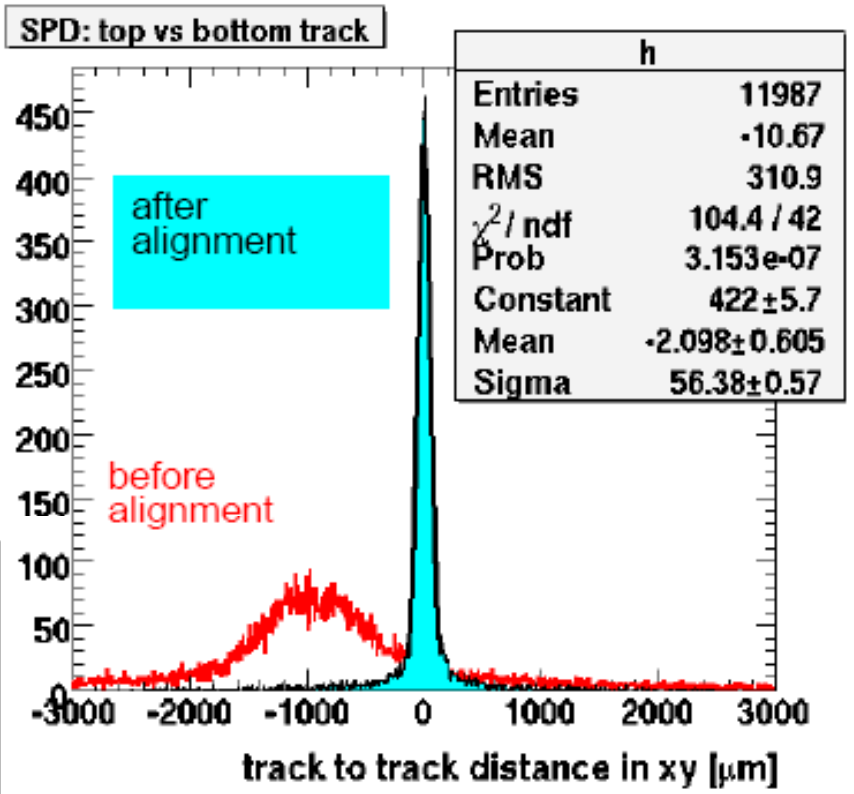






SDD: Drift speed calibration & monitoring versus time

ITS alignment

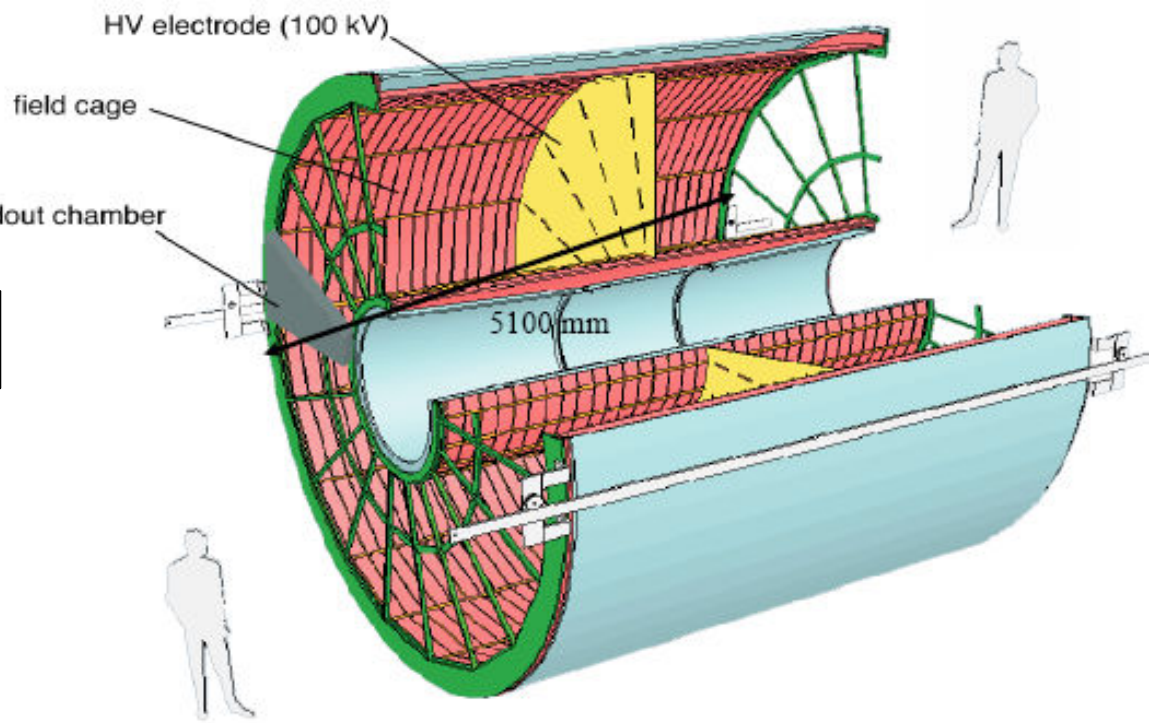


SPD: Point resolution
(σspatial)
σΔx = √2 x σspatial
Data: 14 μm
Simulation: 11 μm

ready for data taking

The ALICE Time Projection Chamber

TPC on its way into the ALICE cave

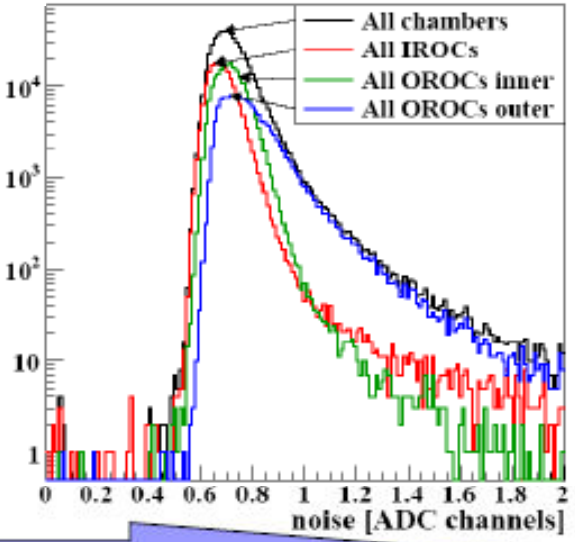


Largest TPC ever built

Radius: 845 - 2466 mm
Drift length: 2 x 2500 mm
Drift time: 92 μs
Drift gas Ne-CO_2-N_2
Gas volume: 95 m^3
557568 readout pads
Material: (η=0) 3% X_0

TPC Noise Measurements

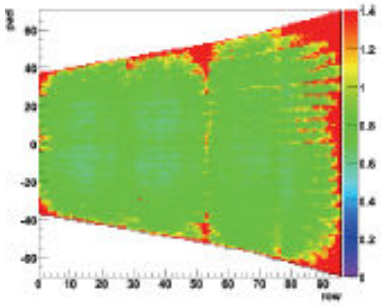
- Noise level improvement during commissioning
- Mean noise level:
  - Design goal: 1 ADC count (1000 e)
  - **Achieved: 0.7 ADC count (700 e)**
- Data volume:
  - zero suppresed (ZS) events: < 30kB
  - non-ZS: ~ 700MB



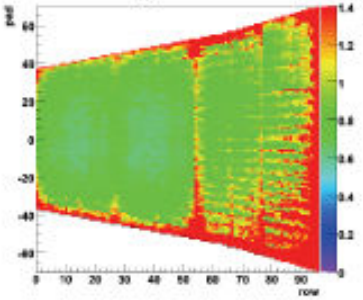
time

2006 2007 2008

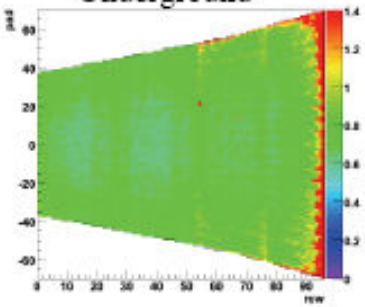
Clean room



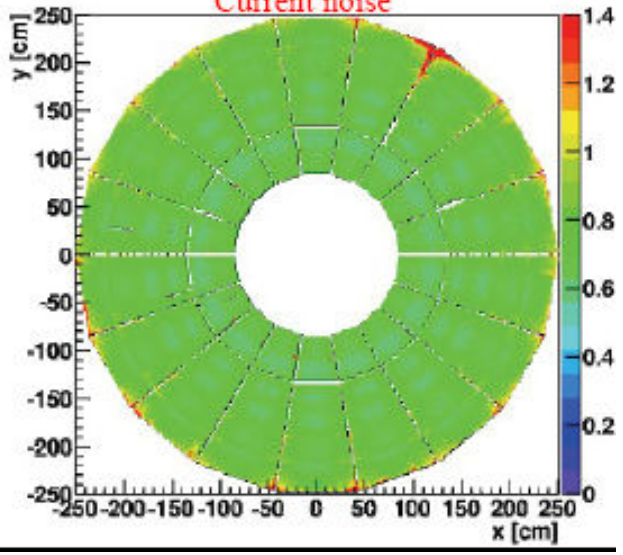
Underground



Underground

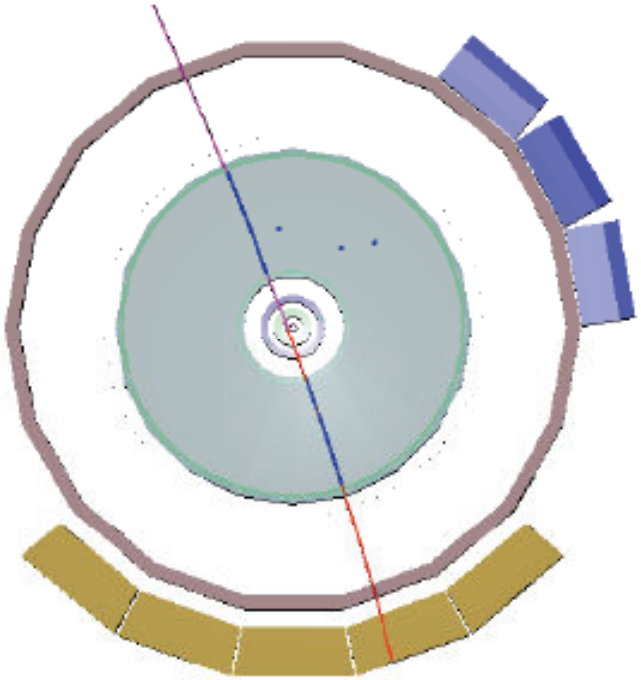


Current noise

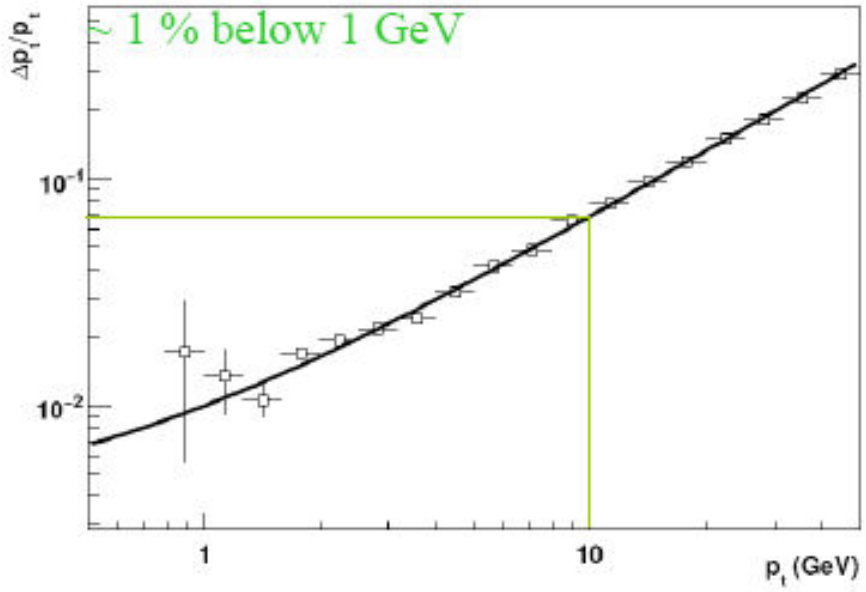


TPC-only momentum resolution

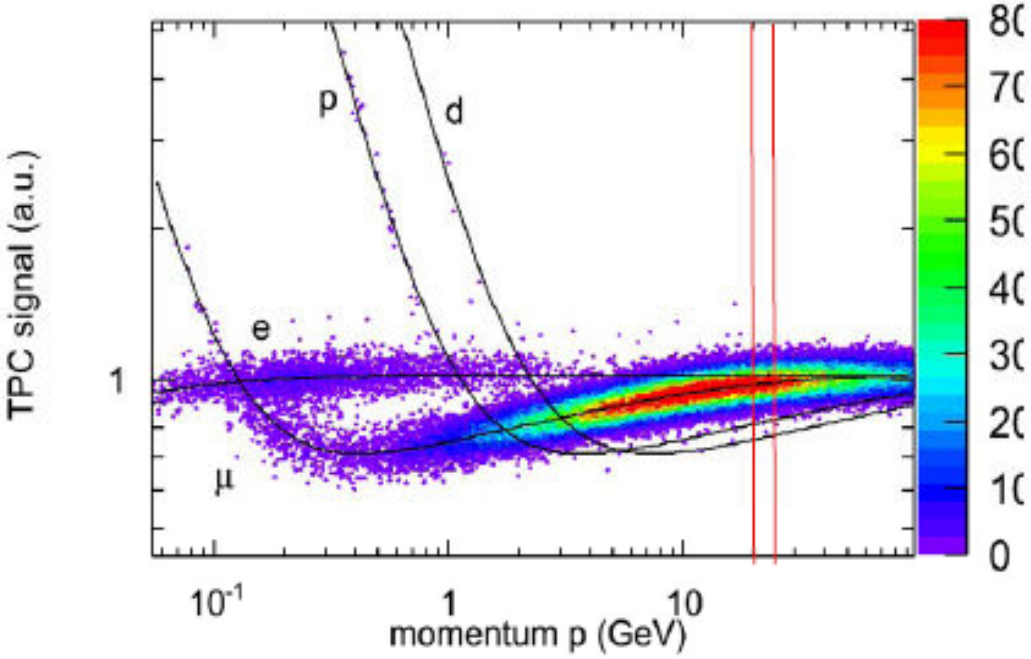
- Cosmic muon tracks treated independently in two halves of TPC
- Comparison of p_T at vertex gives resolution
- Statistics: ~ 5 × 10^6 events

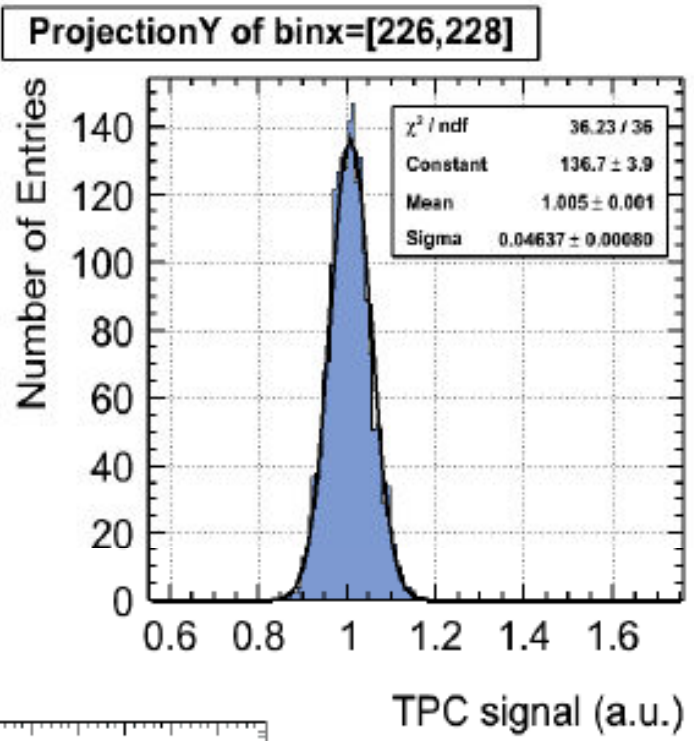


- Design goal: 4.5 % @ 10 GeV
- Achieved: 6.5 % @ 10 GeV

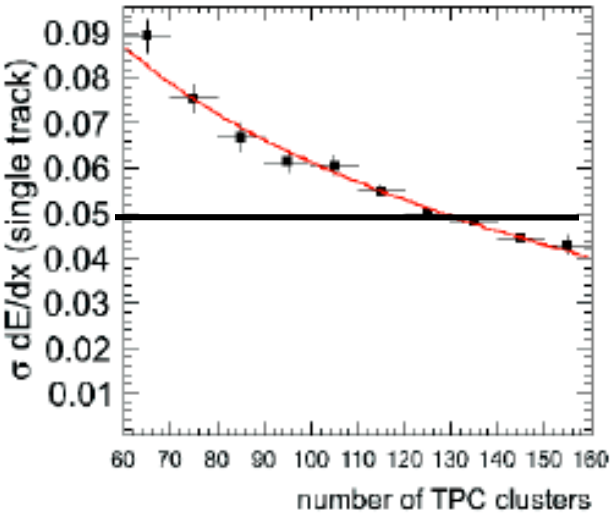


TPC dE/dx





Design resolution ~5%



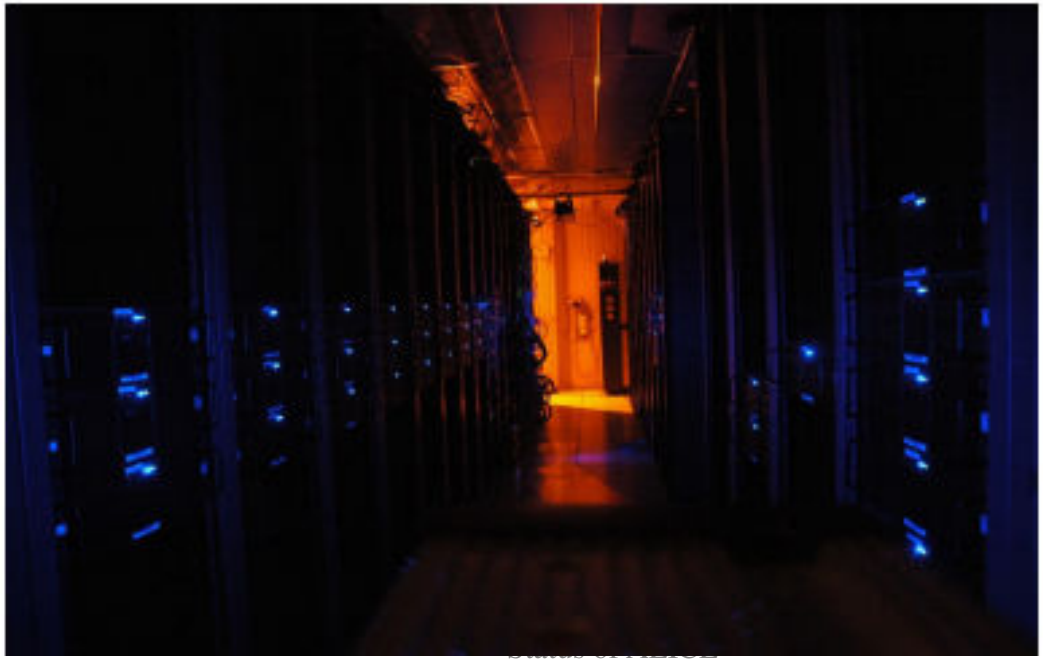
ALICE High Level Trigger

Purpose

- On-line reconstruction for
  - Central Barrel (TPC-ITS, TRD,PHOS, EMCAL,FMD)
  - Muon Arm
- On-line calibration for
  - TPC, PHOS
- On-line monitoring for
  - TPC, PHOS, ITS
- Trigger
  - Trigger framework in place
  - First physics triggers under test

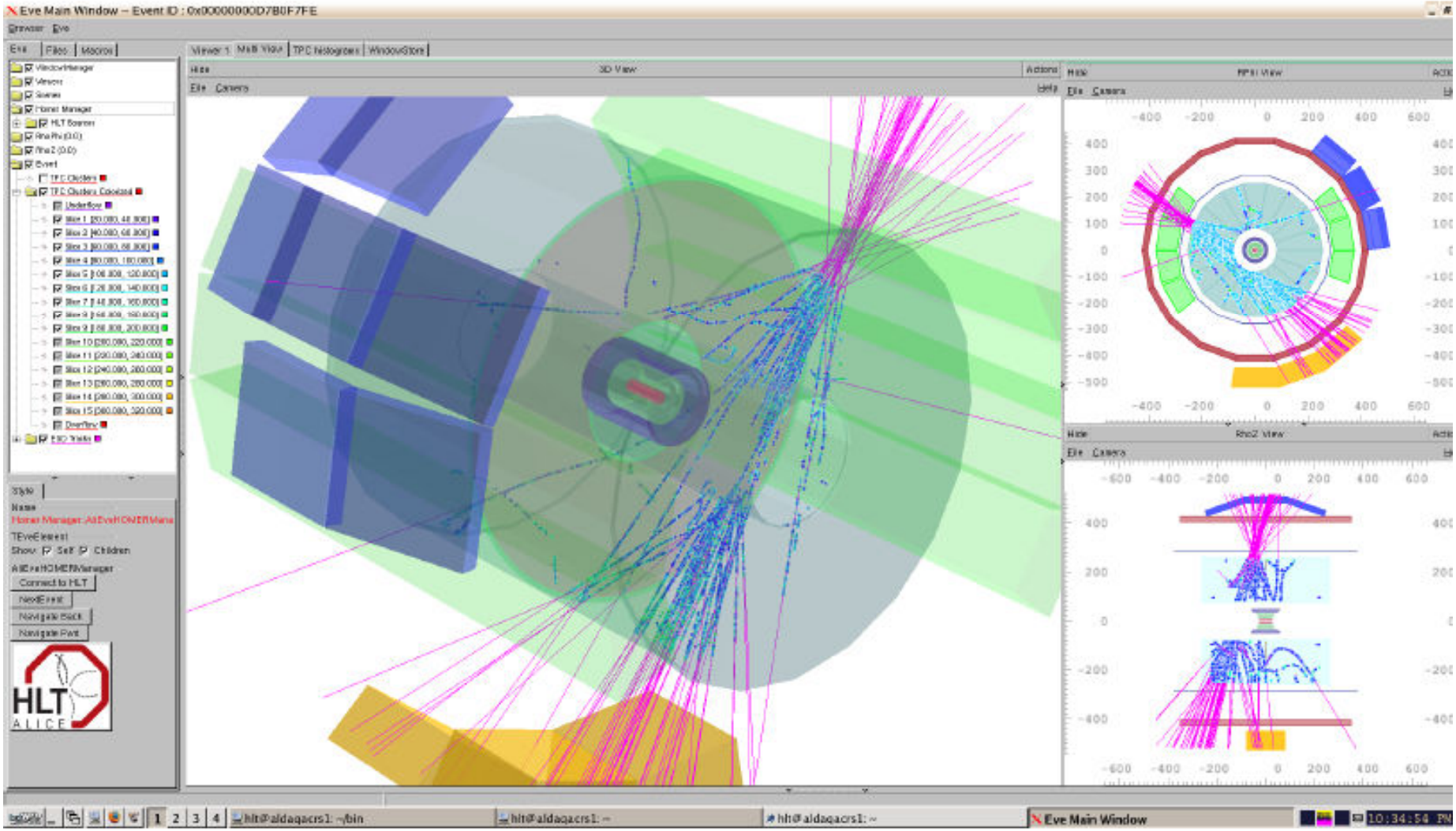
Current hardware:

- 120 Front-End PCs
  - 960 CPU cores
  - 480 DDLs
  - Final setup
- 51 Computing PCs
  - 408 CPU cores
  - pp setup run 2009-10
- Final GigaBit Ethernet setup
- Backbone
  - 72 ports QDR InfiniBand installed
- 20 Infrastructure PCs
  - All Interfaces in place and working

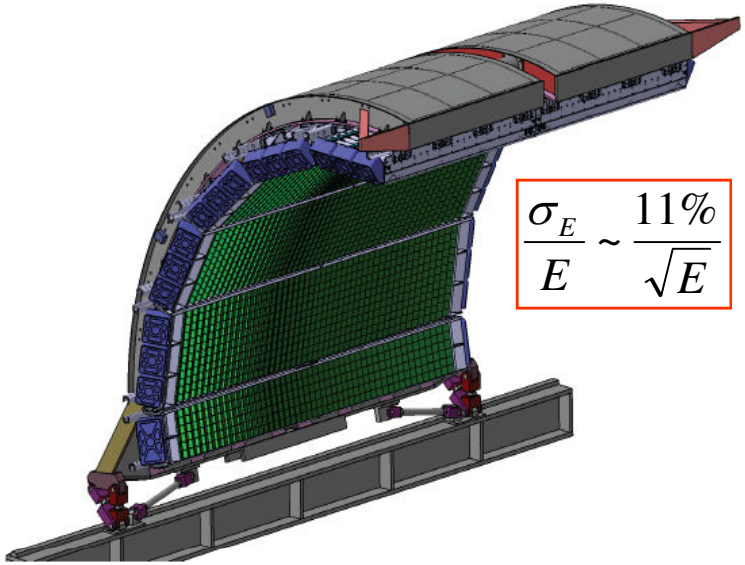


High Level Trigger

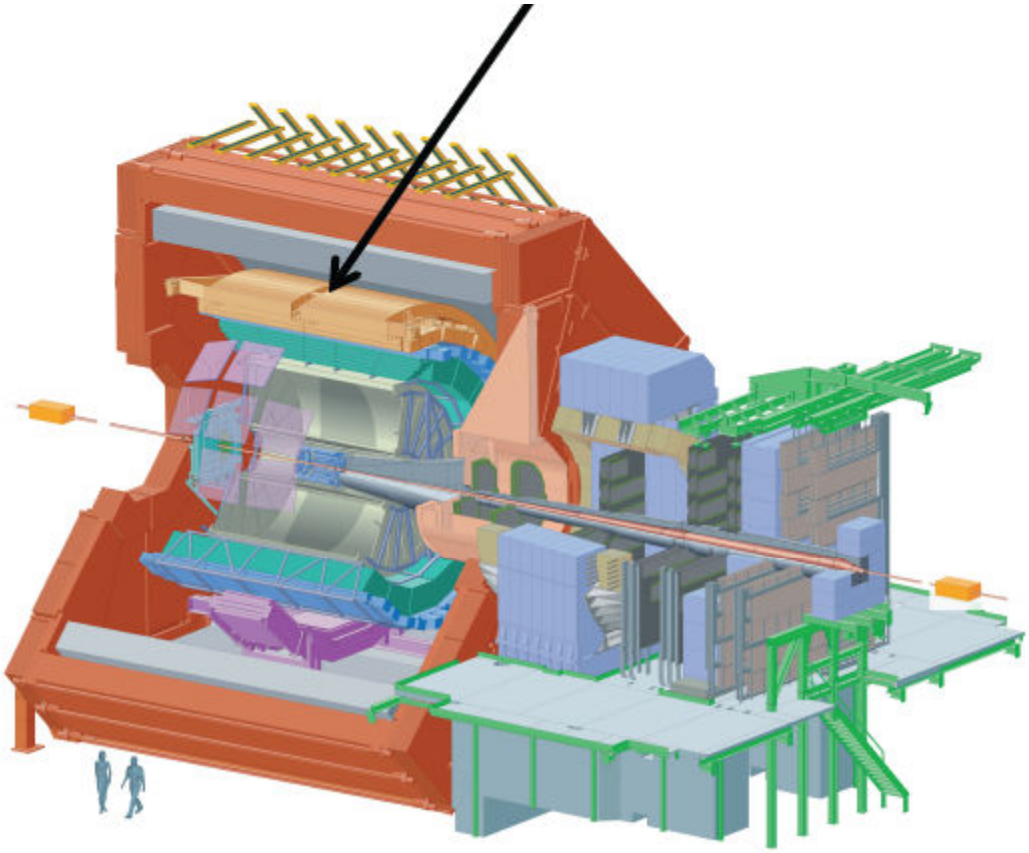
Fast online tracking



Major US contribution to ALICE: EMCal



$$\frac{\sigma_E}{E} \sim \frac{11\%}{\sqrt{E}}$$



Lead-Scintillator sampling calorimeter

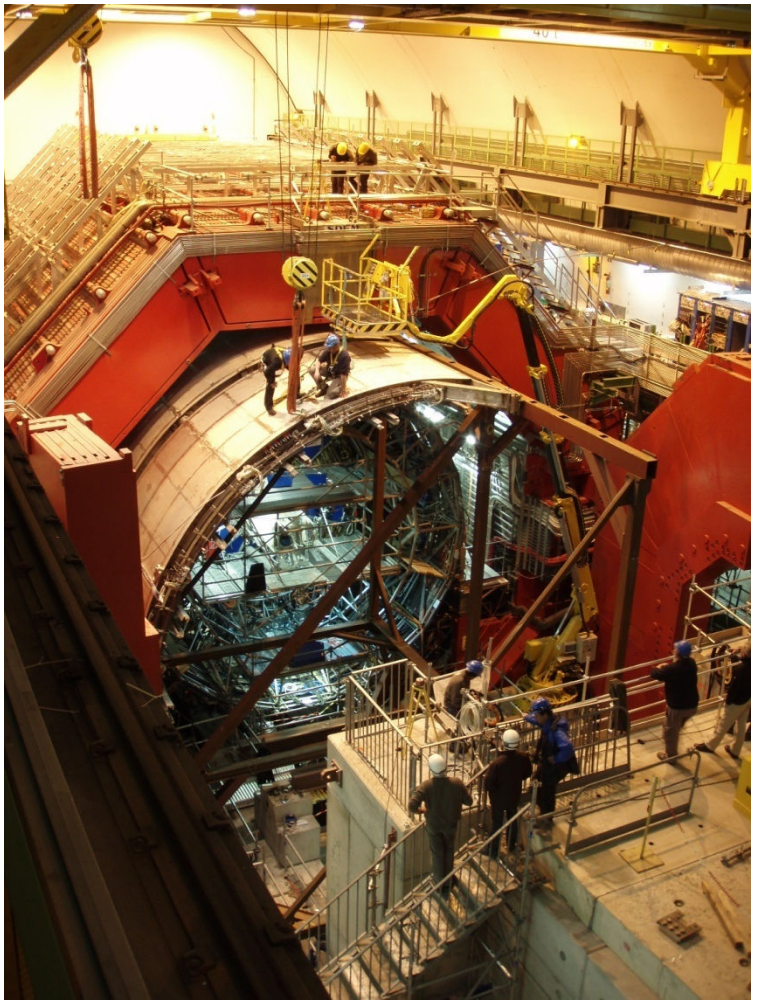
$|\eta|<0.7$, $\Delta\phi\sim110^{o}$

Shashlik geometry, APD photo-sensor

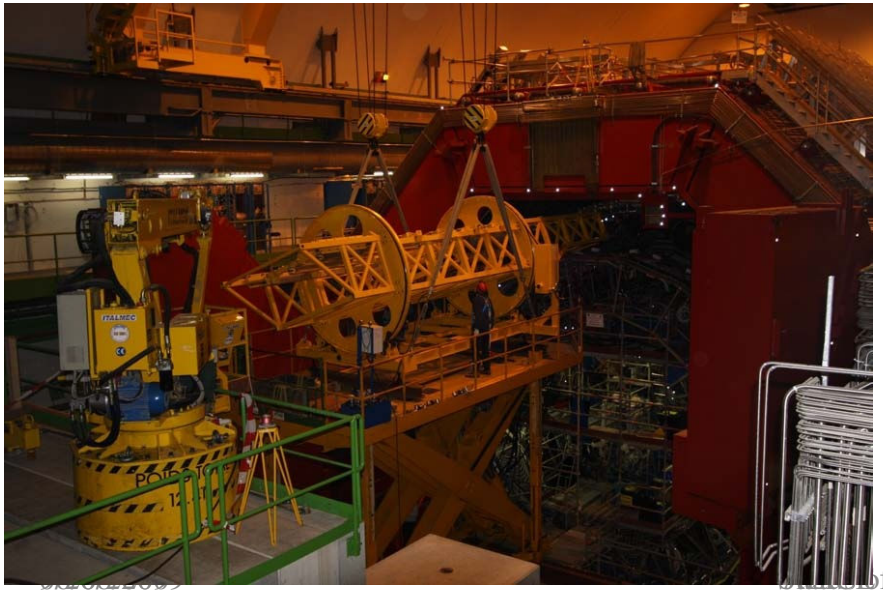
~13k towers ($\Delta\eta x\Delta\phi\sim0.014x0.014$)

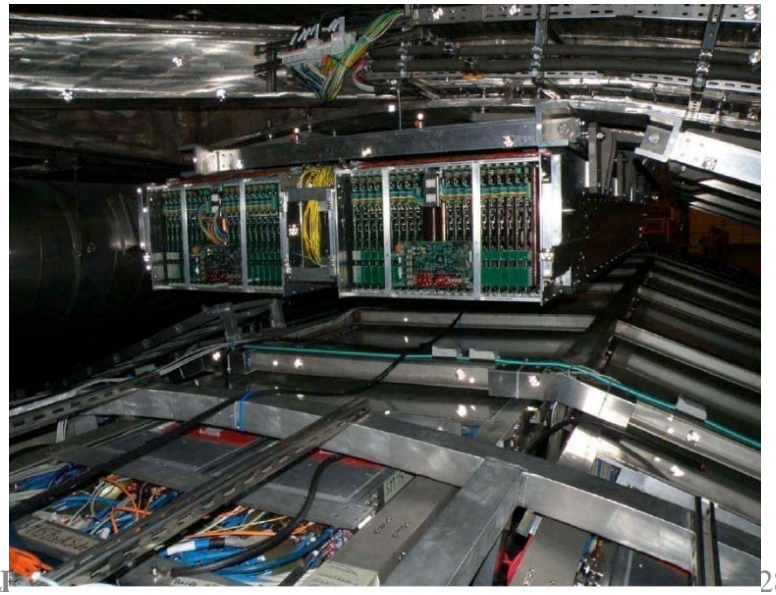
- Very late start relative to LHC schedule
- Full DOE funding (CD2/3) Feb '08; TPC $13.5M
- International project: US, France, Italy
- TDR approved by LHCC Feb '09

Support frame insertion: Nov ‘07



EMCal super-module installation (spring/summer '09)

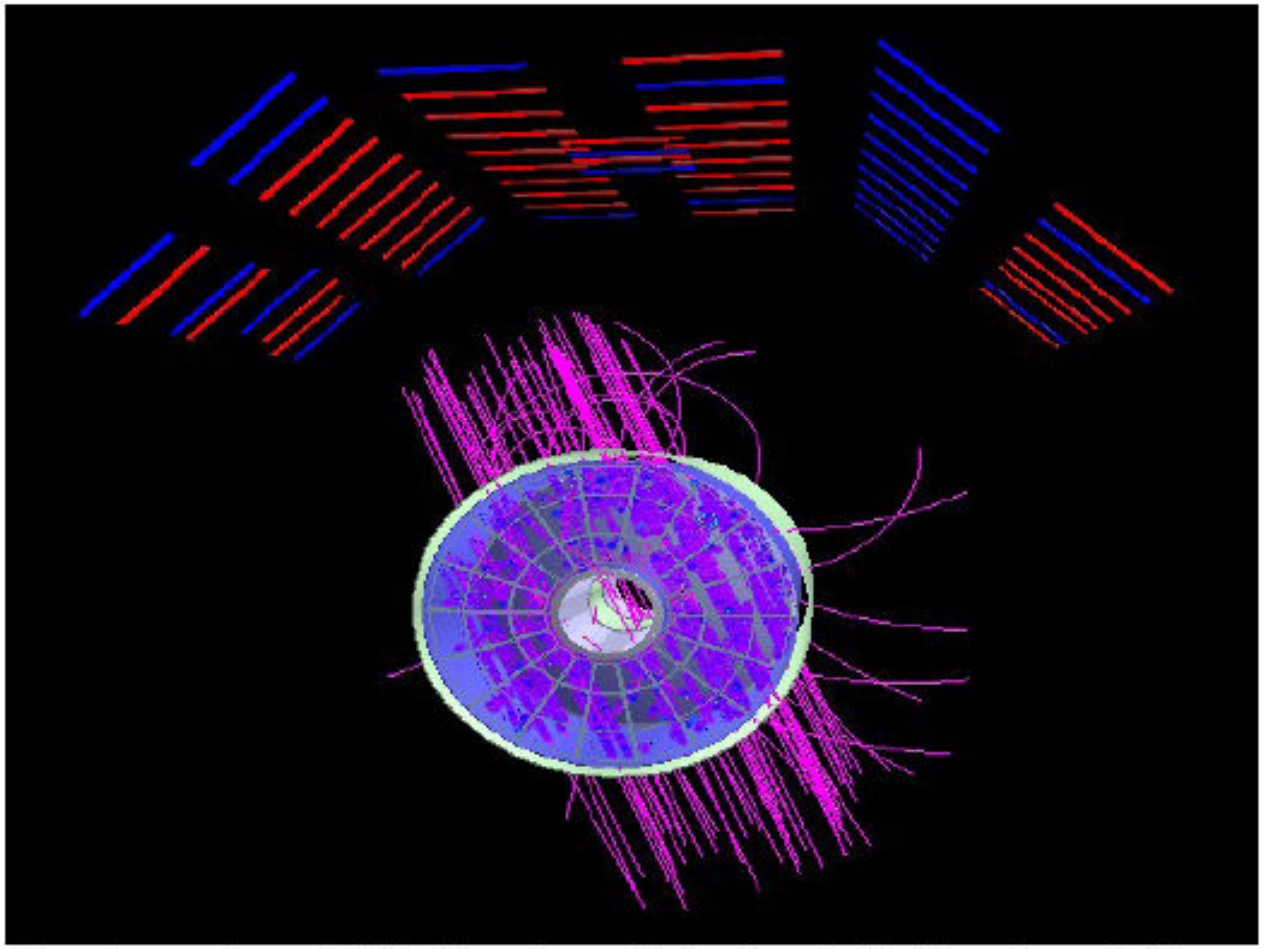




17.3.09: EMCAL US SM#1 inserted in L3 magnet (view from C side)

ALICE and the Tera-scale – 52 muons with momenta > 30 GeV in the ALICE TPC

Muon bundle event triggered by ACORDE



Event number: 8560, Number of Tracks: 148, Number of Muons: 52, Number of ACORDE fired Modules:38

p+p physics in ALICE

ALICE capabilities for QCD studies

- very low-momentum cutoff <100 MeV/c ($x_T \sim 4\times10^{-6}$)
- excellent particle identification
- efficient minimum-bias trigger
- excellent vertexing capabilities
- very low mass

Startup at 900 GeV: connect to existing systematics

First high energy run: 50 ns scheme decouples ALICE lumi from ATLAS/CMS

Expected Lumi ~$2\cdot10^{29}$ cm^{-2} s^{-1} (→ ~10^9 events)

First ALICE pp physics:

Important reference data for heavy-ion programme

- Minimum bias running
- Physics at high multiplicities
- baryon transport

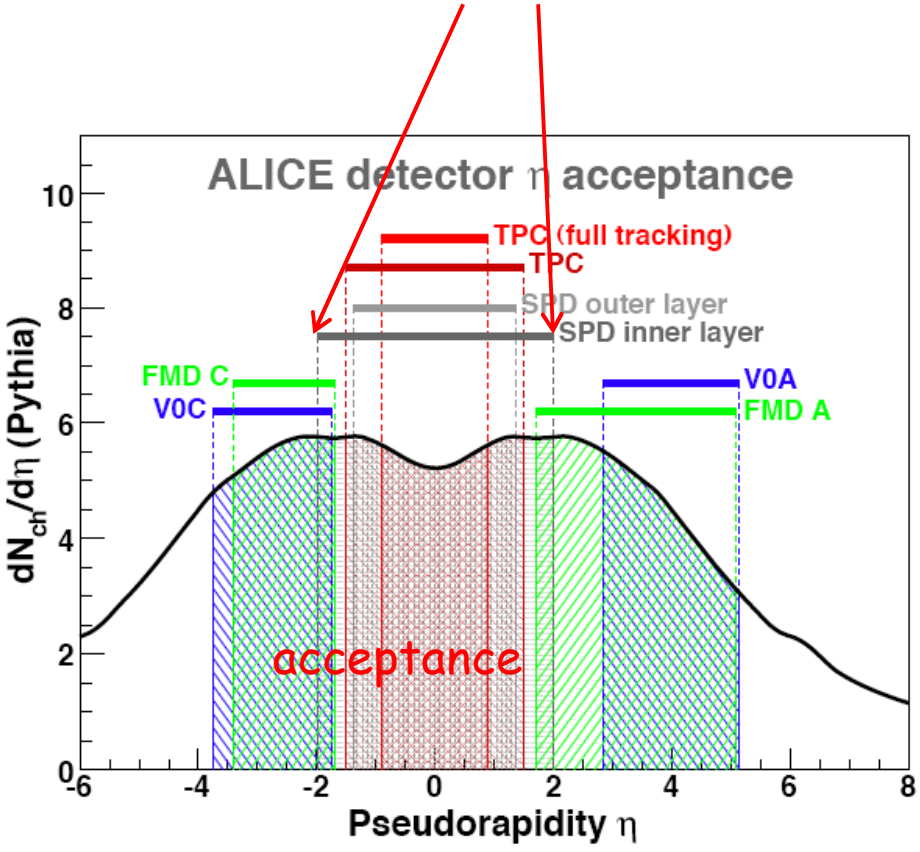
Unique QCD studies

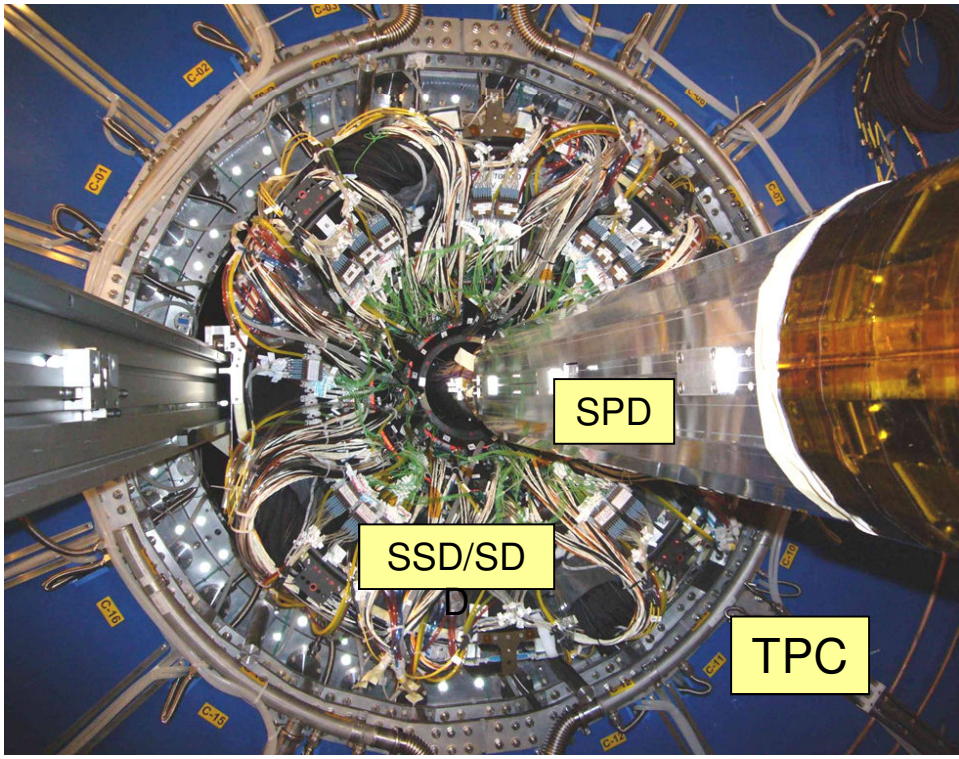
- charm and beauty production cross sections (low pT acceptance is crucial)

Charged Particle Multiplicity

Fast multiplicity trigger L0 from Silicon Pixels

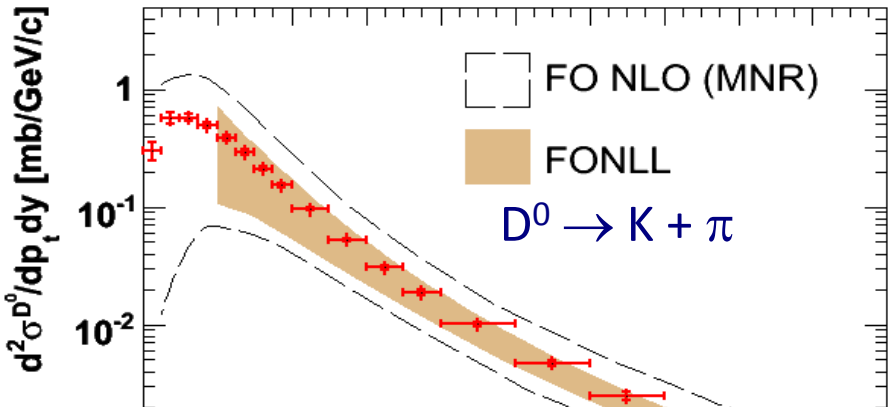
- enriched high-multiplicity sample for comparison with Heavy-Ion collisions

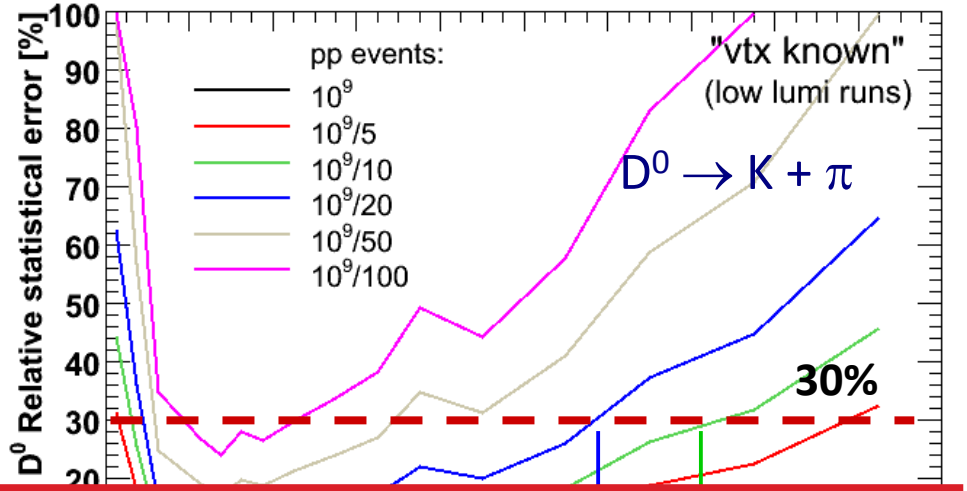


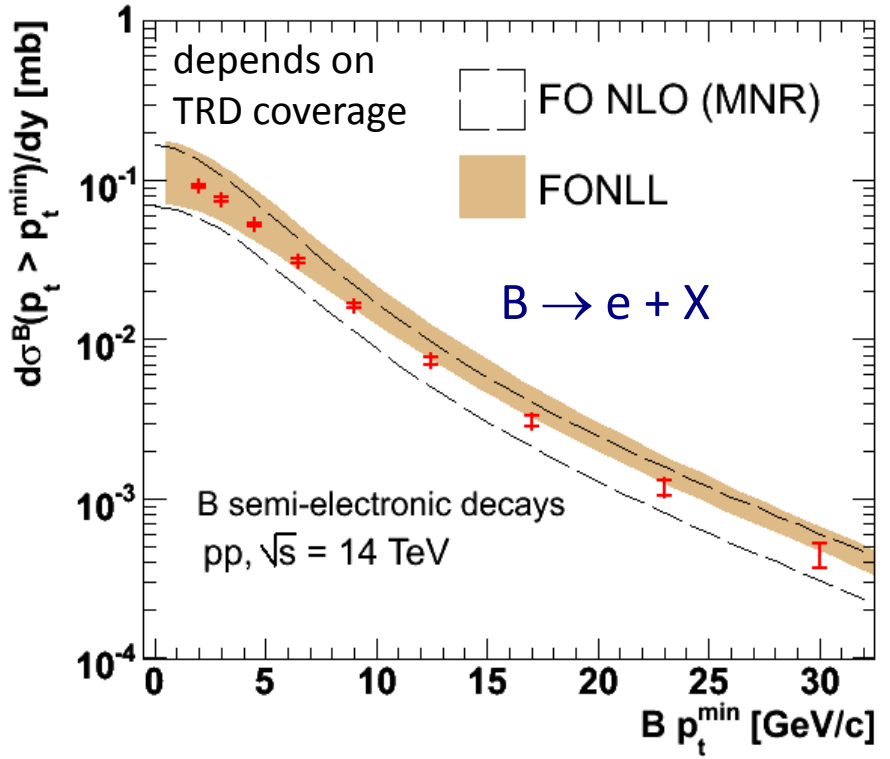


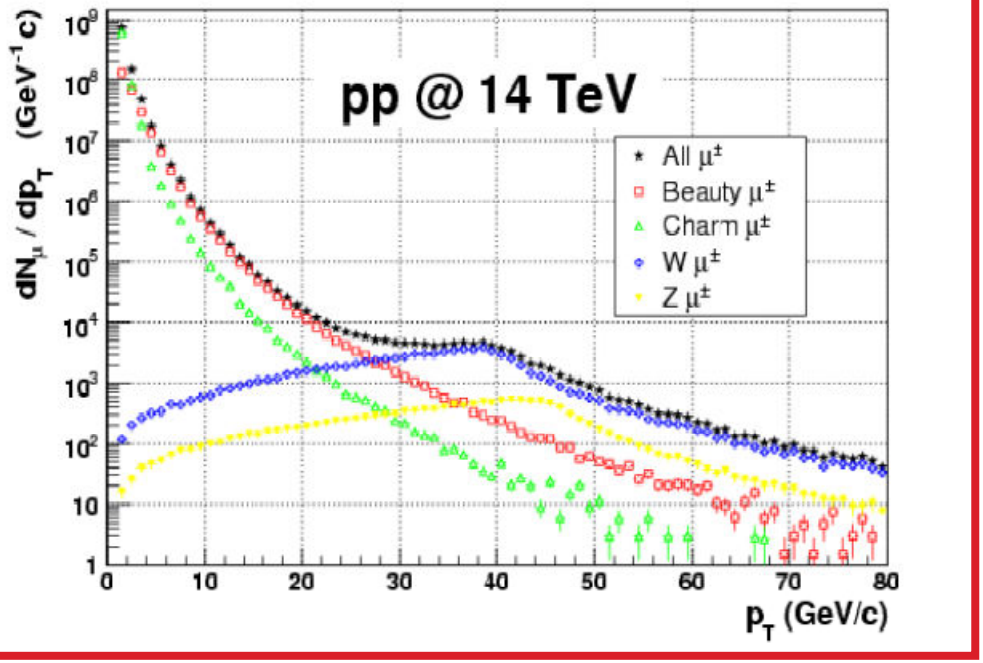
Heavy-flavour production in p+p collisions

for 10^9 pp events (full year)







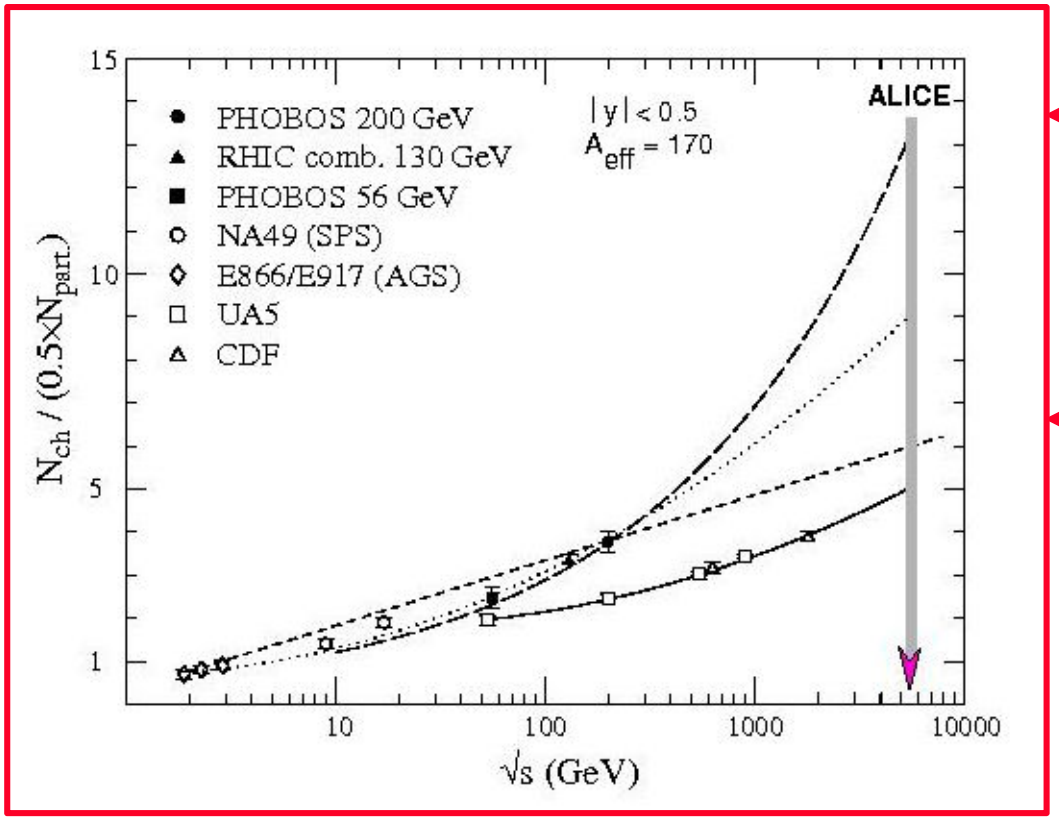


Heavy Ion Physics in "The First 3 Minutes"

Multiplicity measurement:

- first estimate of energy density achieved
- evidence for/against saturation, Color-Glass Condensate,…

integrated multiplicity distributions from Au-Au/Pb-Pb collisions and scaled pp collisions



$dN_{ch}/dy = 2600$

saturation model

Eskola hep-ph/050649

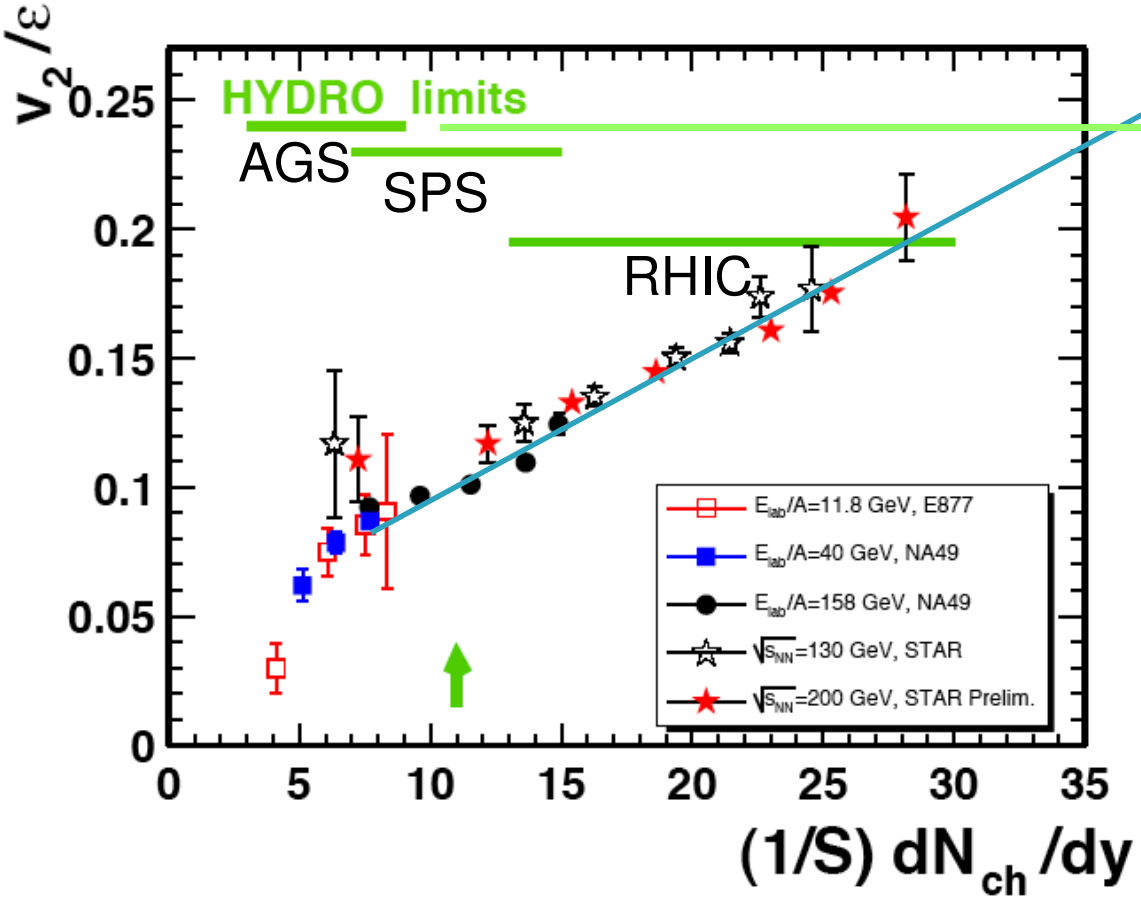
$dN_{ch}/dy = 1200$

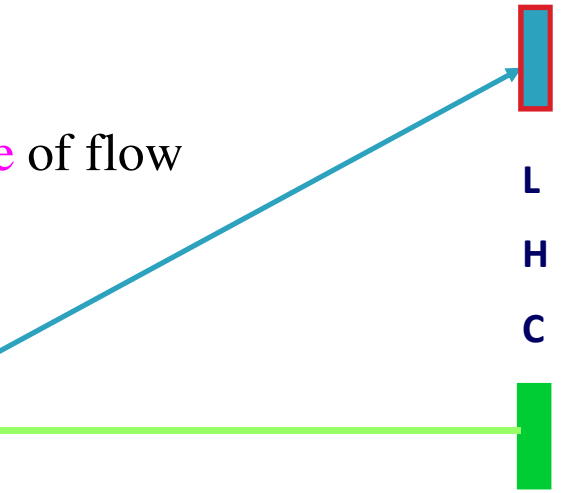
ln(√s) extrapolation

Before RHIC, predictions for the LHC were considerably higher, ranging up to $dN_{ch}/dy=8000$

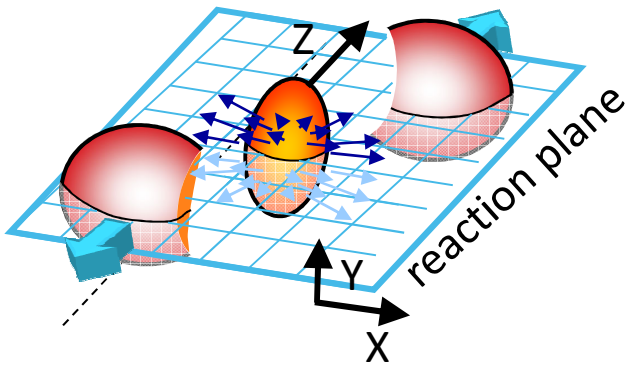
Heavy Ion Day-1 Physics (10^5 events): Elliptic Flow

- One of the first answers from LHC
  - Experimental trend & scaling predicts large increase of flow
  - Hydrodynamics: modest rise





eccentricity vs. particle multiplicity in overlap region

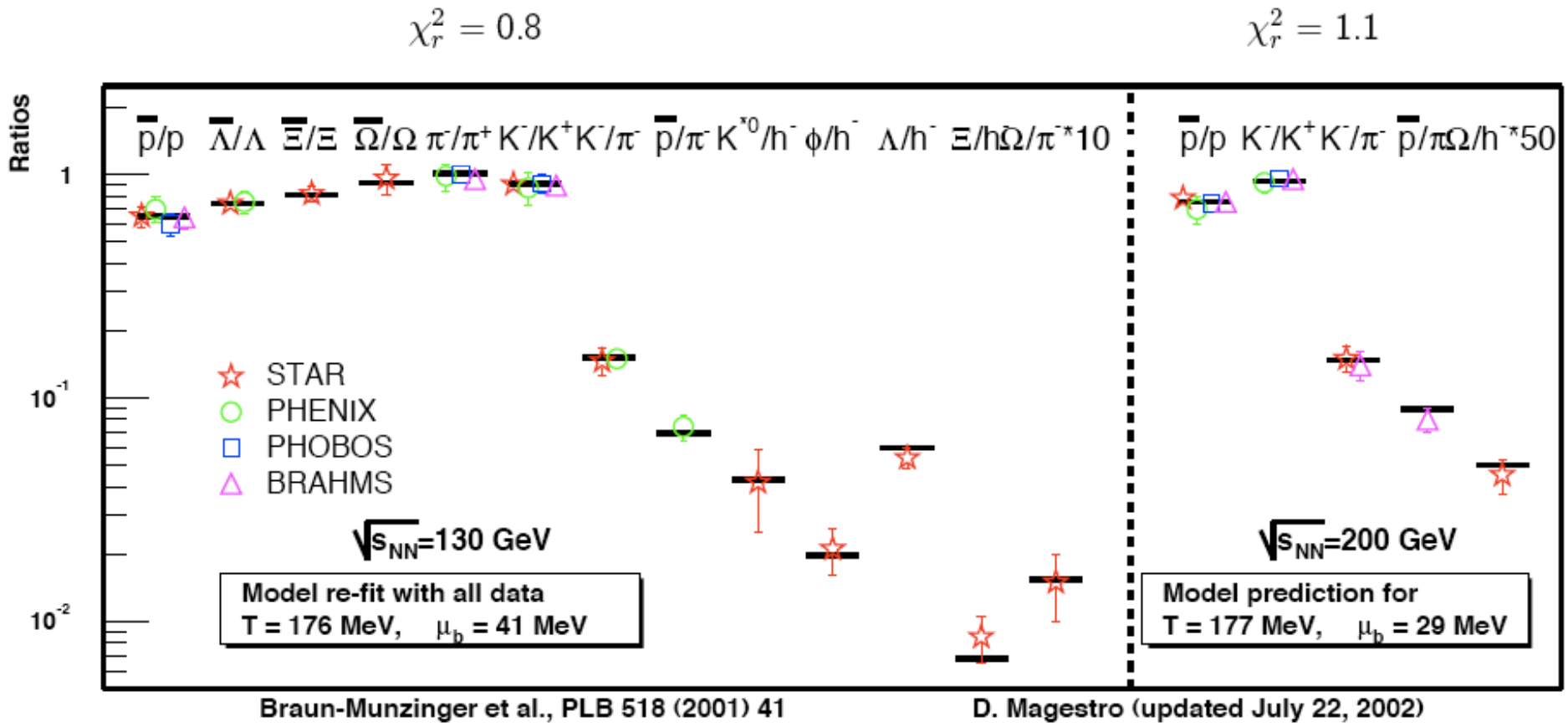


Heavy Ion Day-1 physics: Chemical composition

Particle composition via statistical model (grand canonical ensemble)

Free parameters: thermalization temperature and bario-chemical potential

RHIC: T ~ 170 MeV , m_B ~ 30 MeV




Awaiting beam...

Extra slides

11-12 July 09 LHC extraction test

Single –bunch 0.4x 10^{10} p each and 12-bunch trains (25 ns apart) with 25 x 10^{9} particles per bunch

- trigger timing (MTR, SPD, V0, T0), FMD calibr, gate adjustments, SDD delay tuning