ALICE experiment on the threshold of wonderland

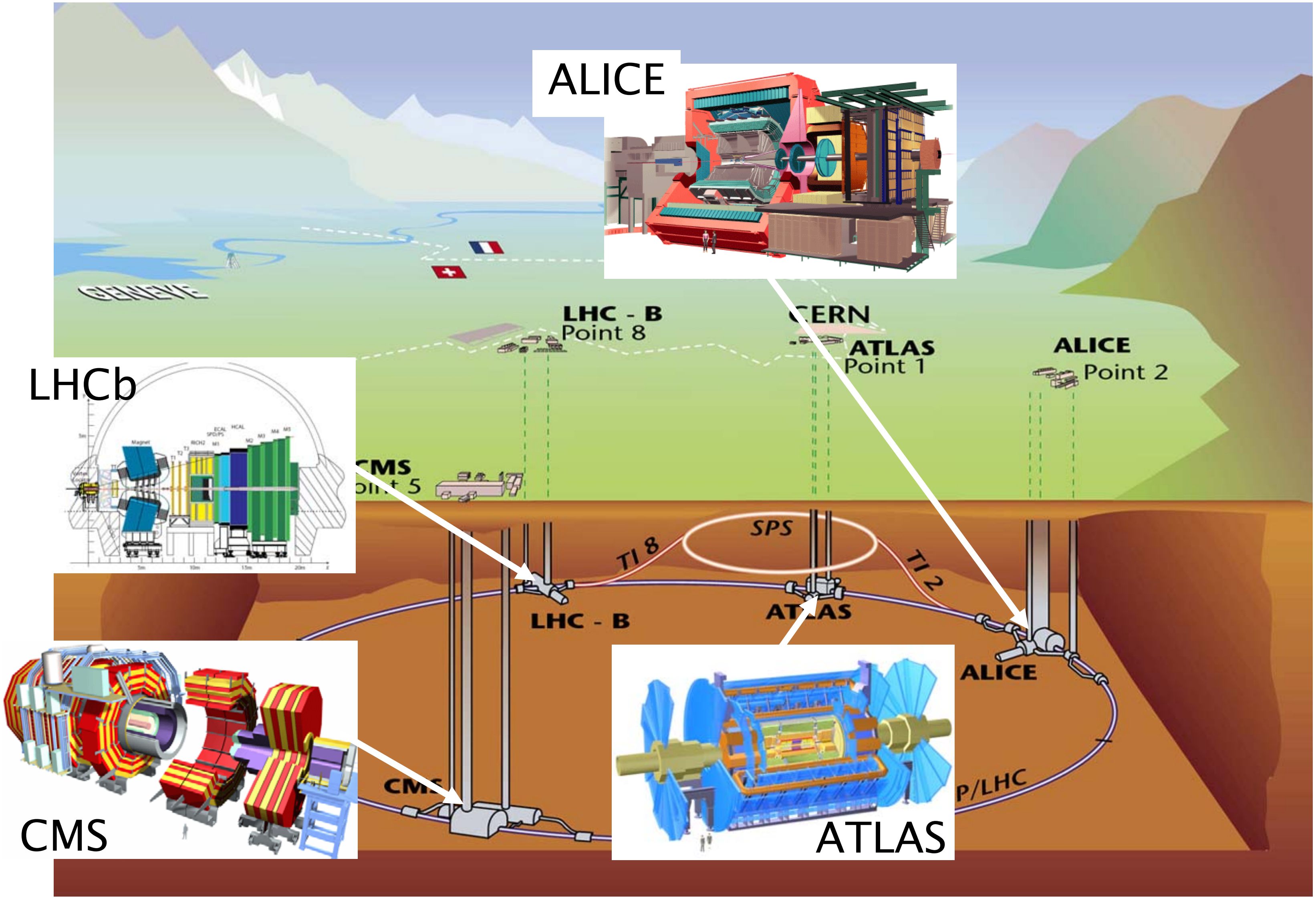
Dariusz Miśkowiec
GSI Darmstadt

Quarks and Hadrons in Strong QCD
415th Wilhelm & Else Heraeus Seminar
St. Goar, March 2008

- *LHC and ALICE*
- *first physics in pp*
- *first physics in PbPb*
- *schedule and news*

LHC experiments

main colliding systems: p+p sqrt(s)=14 TeV and Pb+Pb sqrt(s)=5.5 TeV



physics questions at LHC

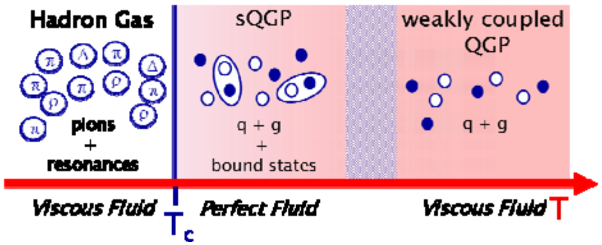
***ATLAS, CMS, LHCb*:**
electroweak symmetry breaking
origin of mass of quarks and gauge bosons
supersymmetric particles
CP violation

***ALICE*:**
chiral symmetry breaking
origin of mass of hadrons
deconfinement
hadronization

***ALL*:**
understanding high energy nuclear interactions
(input needed for cosmic ray studies)

ALICE programme

mission:
create quark-gluon matter
study its properties quantitatively
be prepared for unexpected = be versatile



methods:
spectra and correlations of various particles

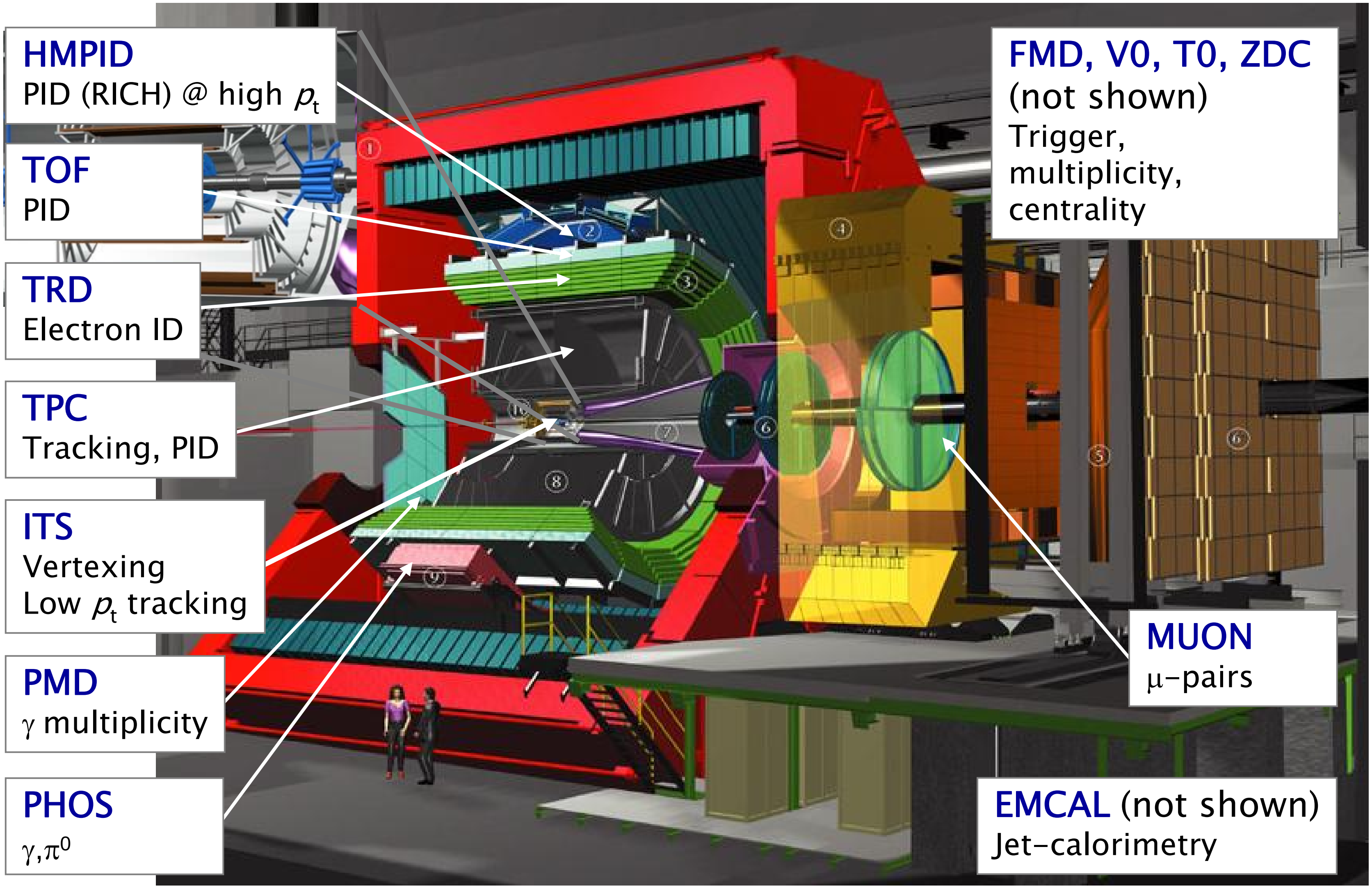
e.g. heavy quarks (open beauty, upsilon-states)
jets in heavy ion environment
weakly interacting probes (Z^0, $W^\pm$)

special at LHC:
higher energy density
larger system
more heavy quarks and jets
weak probes W/Z available
access to lower x

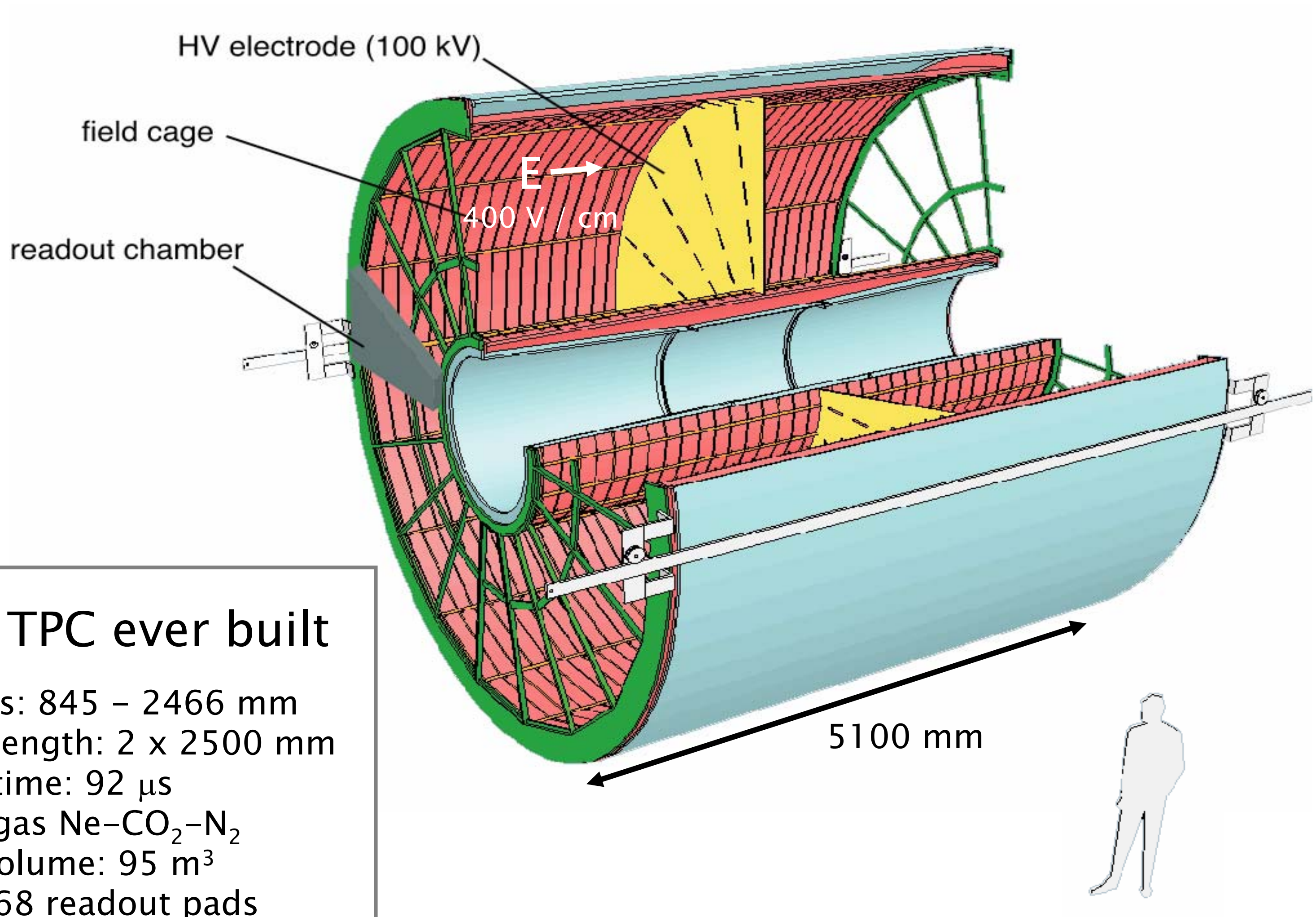
	SPS	RHIC	LHC
$\sqrt{s_{NN}}$ (GeV)	17	200	5500
dN_{ch}/dy	~450	~850	1500-4000
ε(GeV/fm^3)	3	5	15-60
τ_{QGP} (fm/c)	≤ 2	2-4	≥ 10

Alice Detector

height: 16 m ***length 26 m*** ***weight: 10,000 tons*** ***price: 10 € / kg***



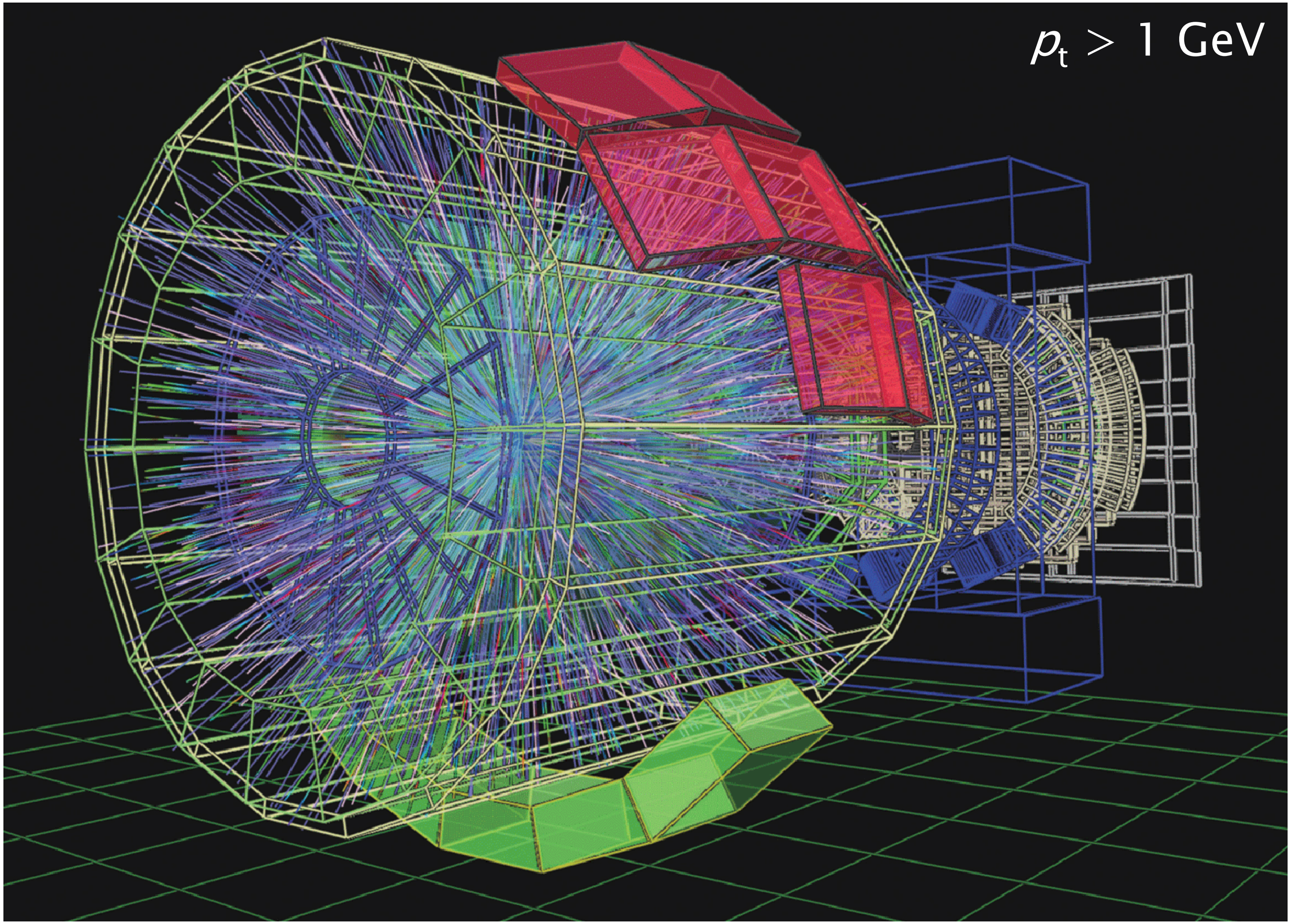
Time Projection Chamber (TPC)



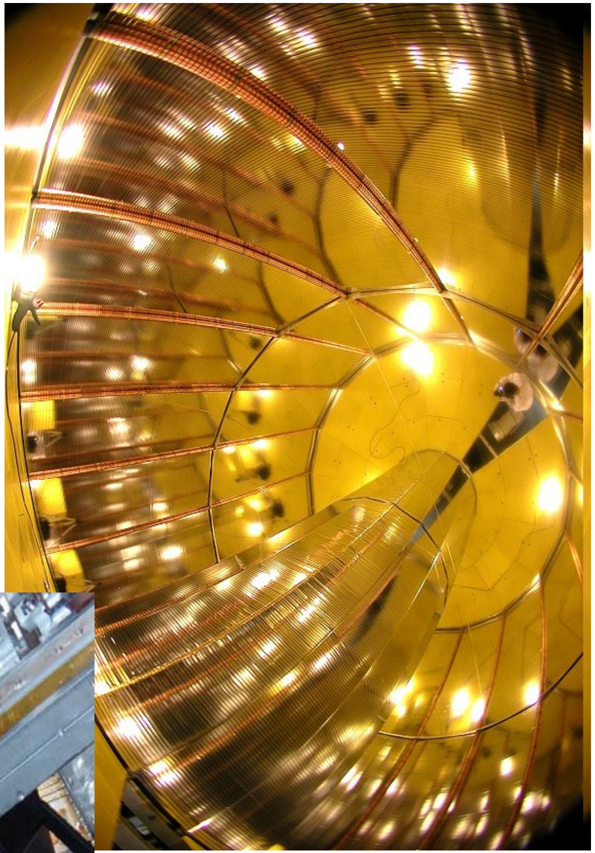
Largest TPC ever built

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

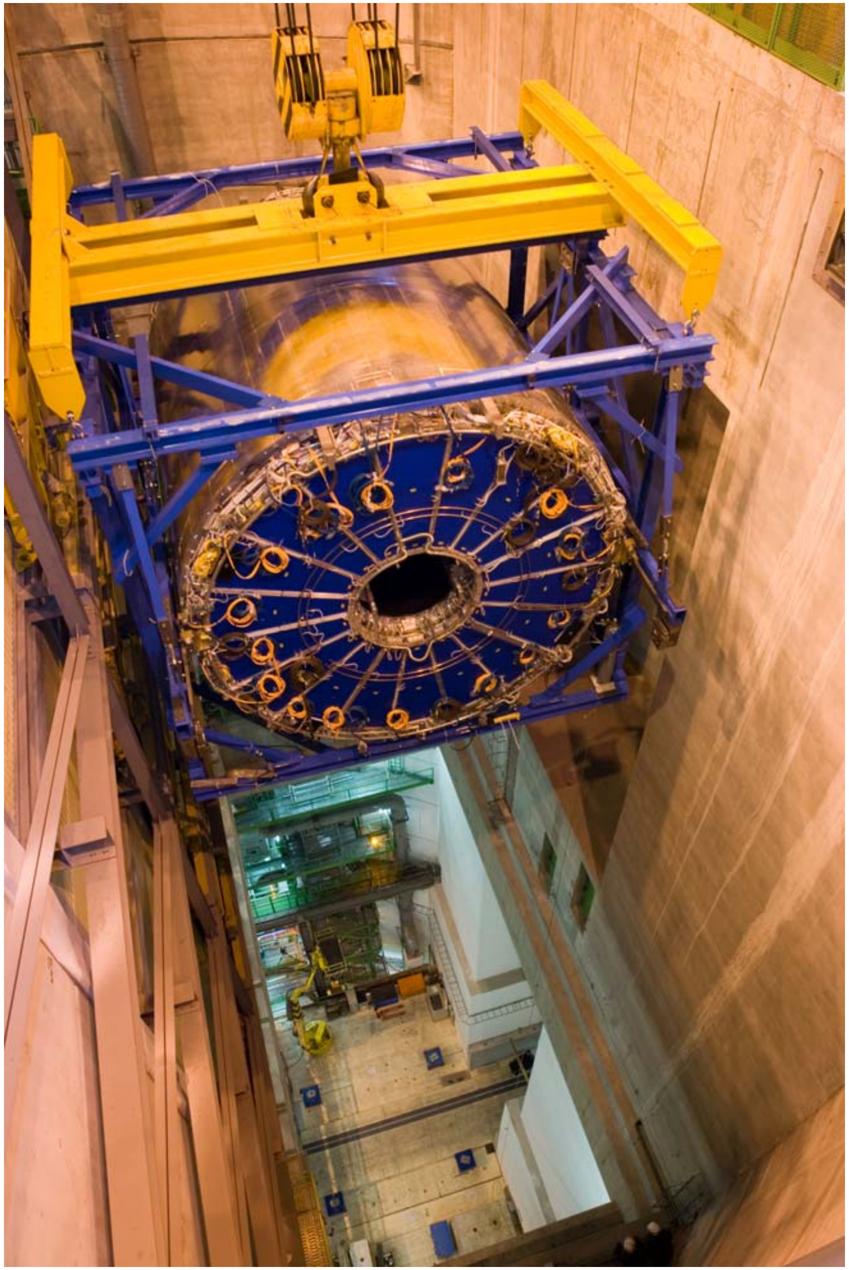
ALICE Event Display



TPC assembly



Lowering and insertion of ALICE TPC (15/01/07)



Transition Radiation Detector (TRD)

Purpose:

Electron-ID

Quarkonia $\rightarrow e^+e^-$
Heavy flavour

Some numbers:

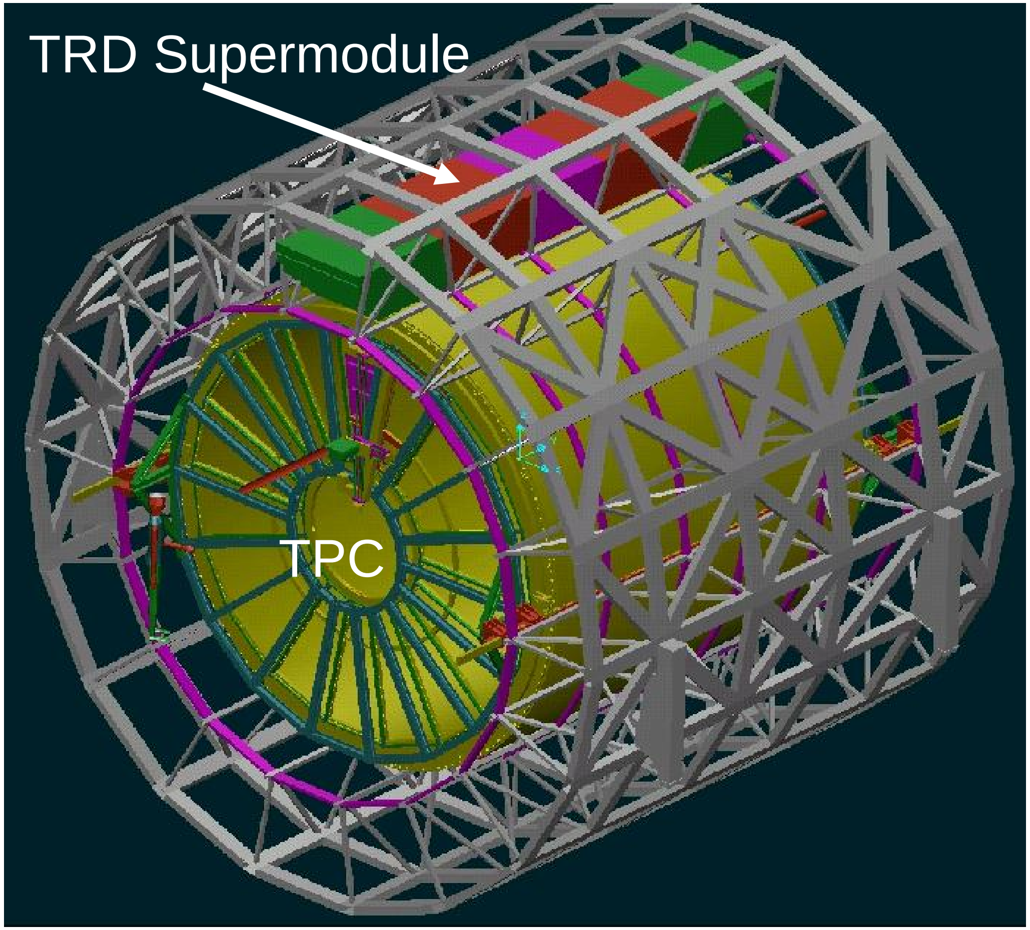
540 chambers

Total area: 736 m^2
(3 tennis courts)

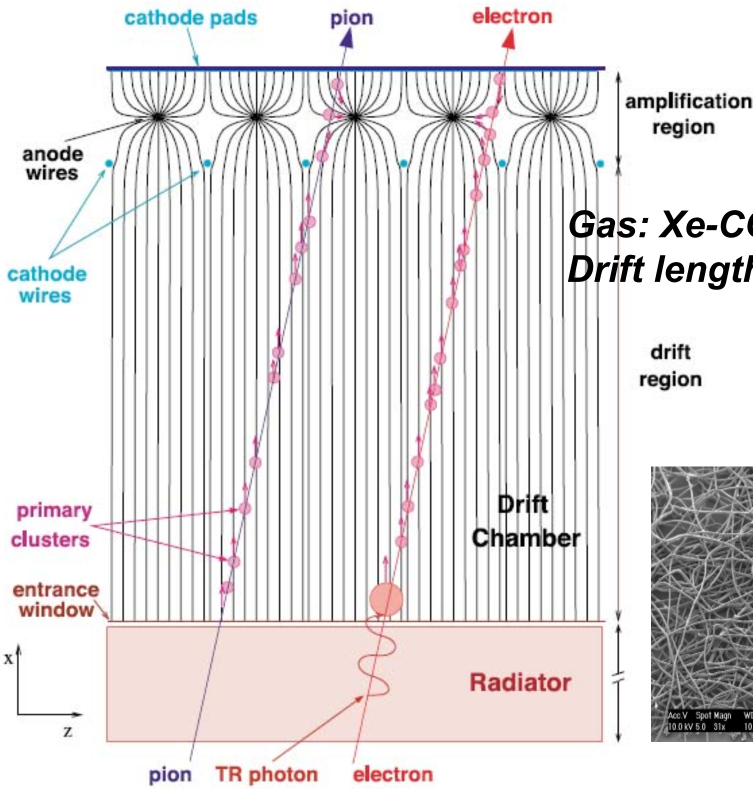
Gas volume: 27.2 m^3

Resolution
($r\varphi$) 400 μm

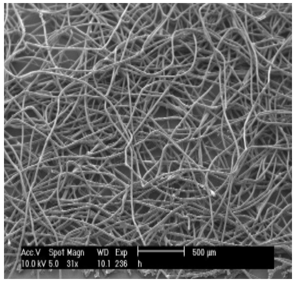
Number of read out channels: 1.2×10^6

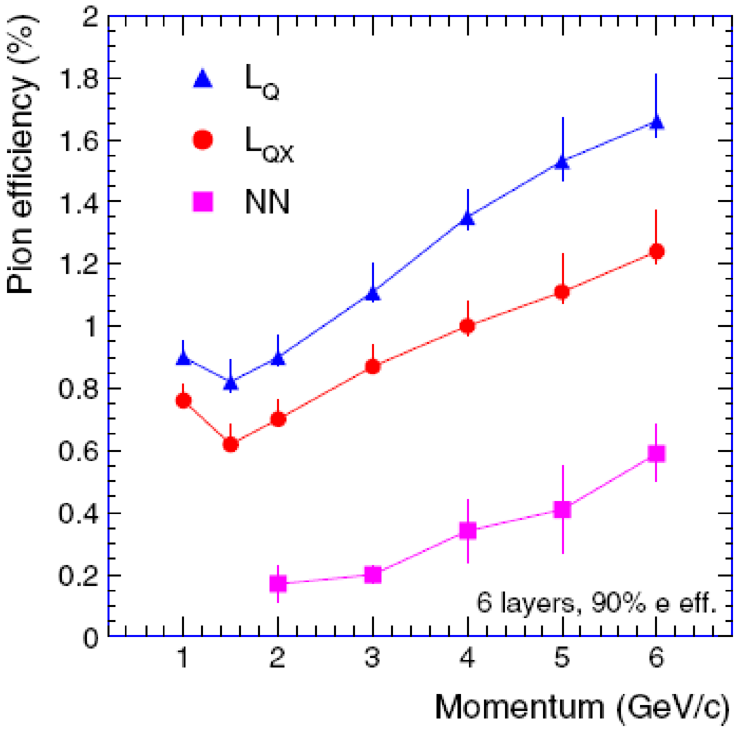


Transition Radiation Detector (TRD)



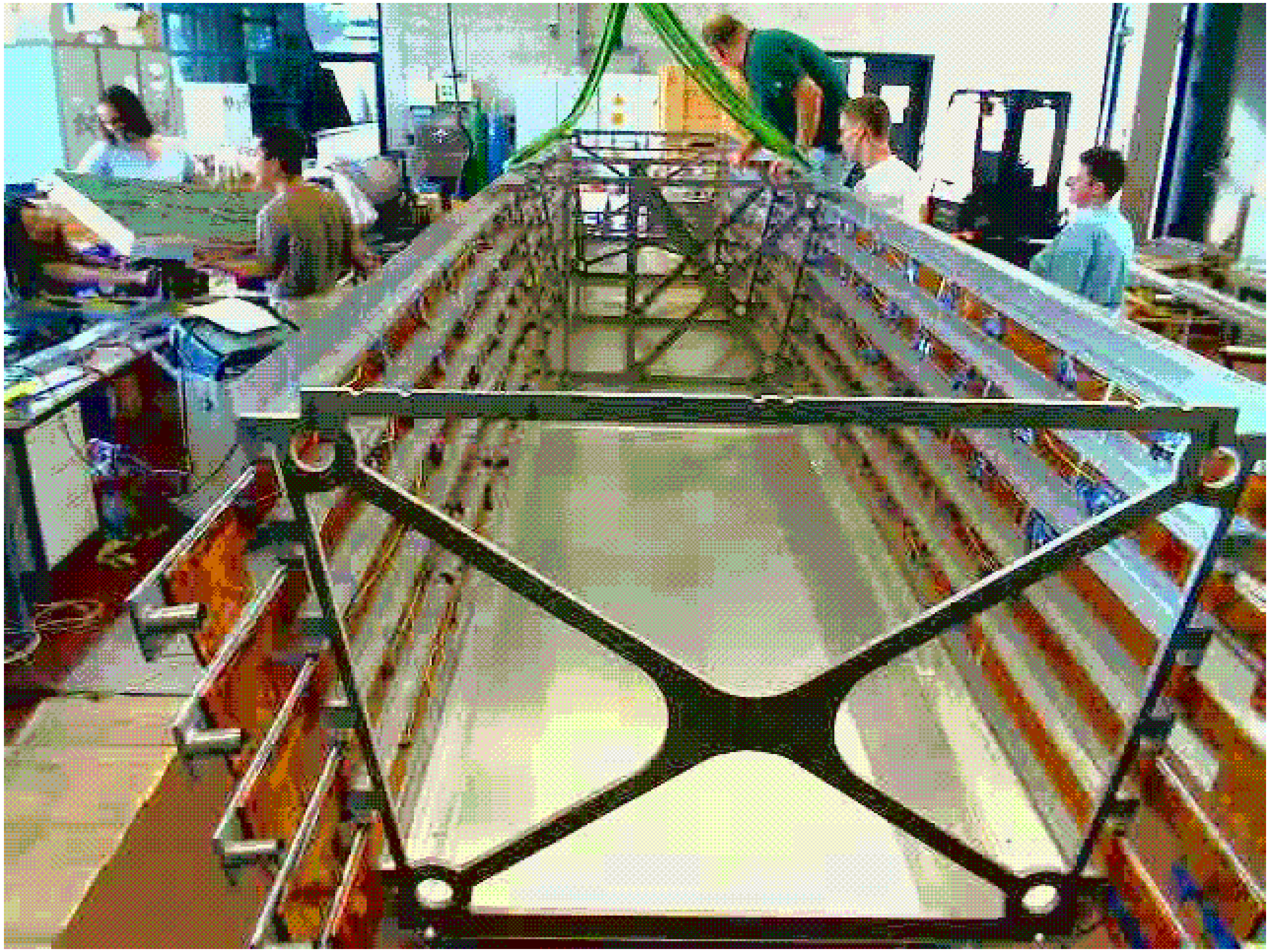
Gas: Xe-CO_2
Drift length: 3cm





Radiator

Fiber/foam sandwich
PP, 17μm




TOF supermodule
TRD Supermodule
CERN ALICE

Trigger

Hierarchical architecture

L0, L1, L2, and HLT

High Level Trigger (HLT)

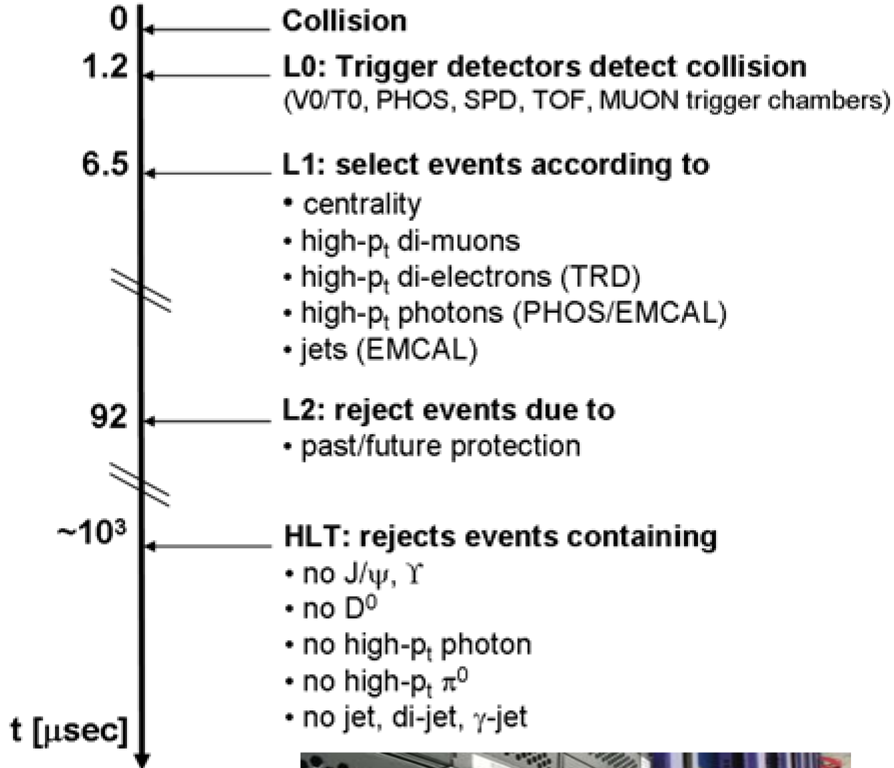
Online reconstruction using ~500-600 PCs + FPGAs

Input rate 200Hz (central Pb-Pb) → up to 20 GByte/s

Generate physics trigger (e.g. jets, Upsilons, D^0, ...)

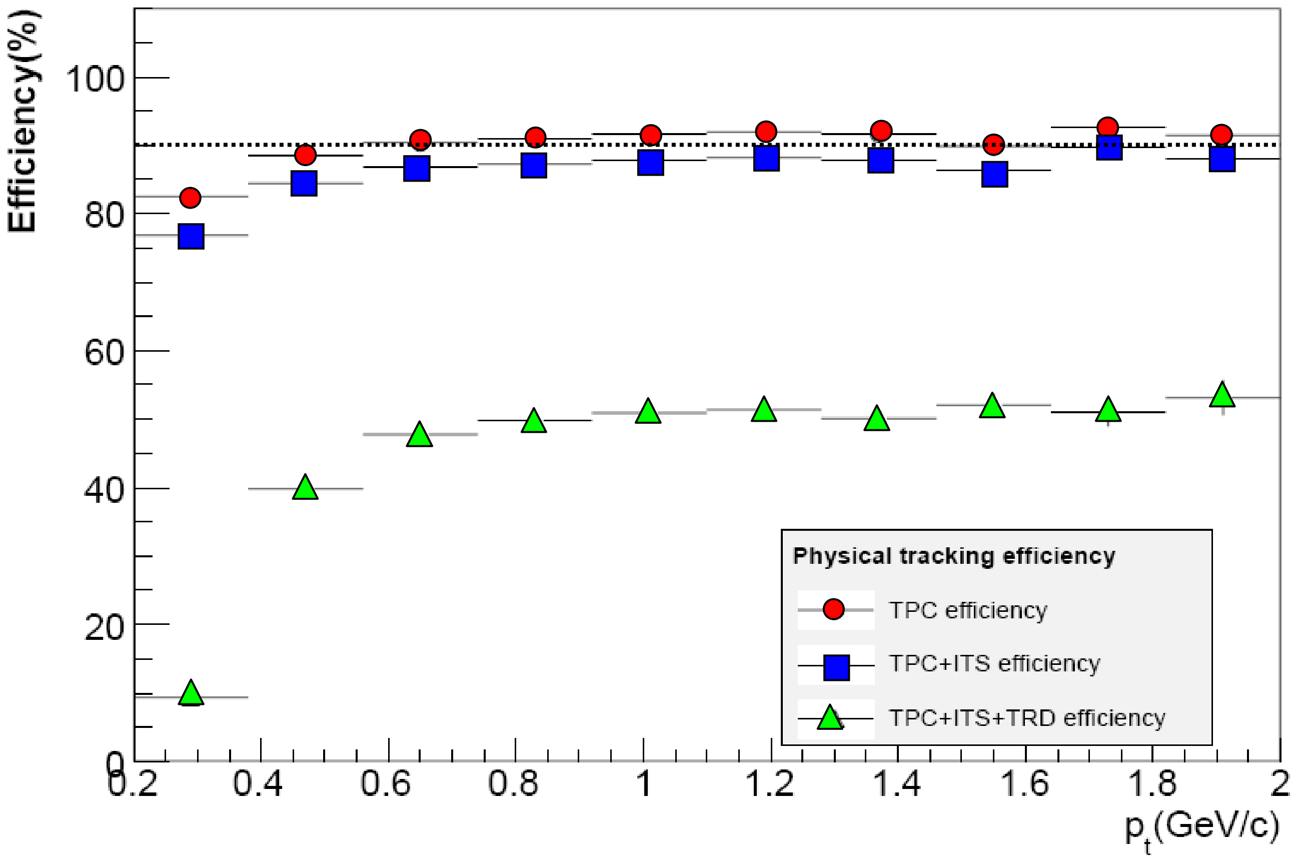
Online data compression

Calibration tasks

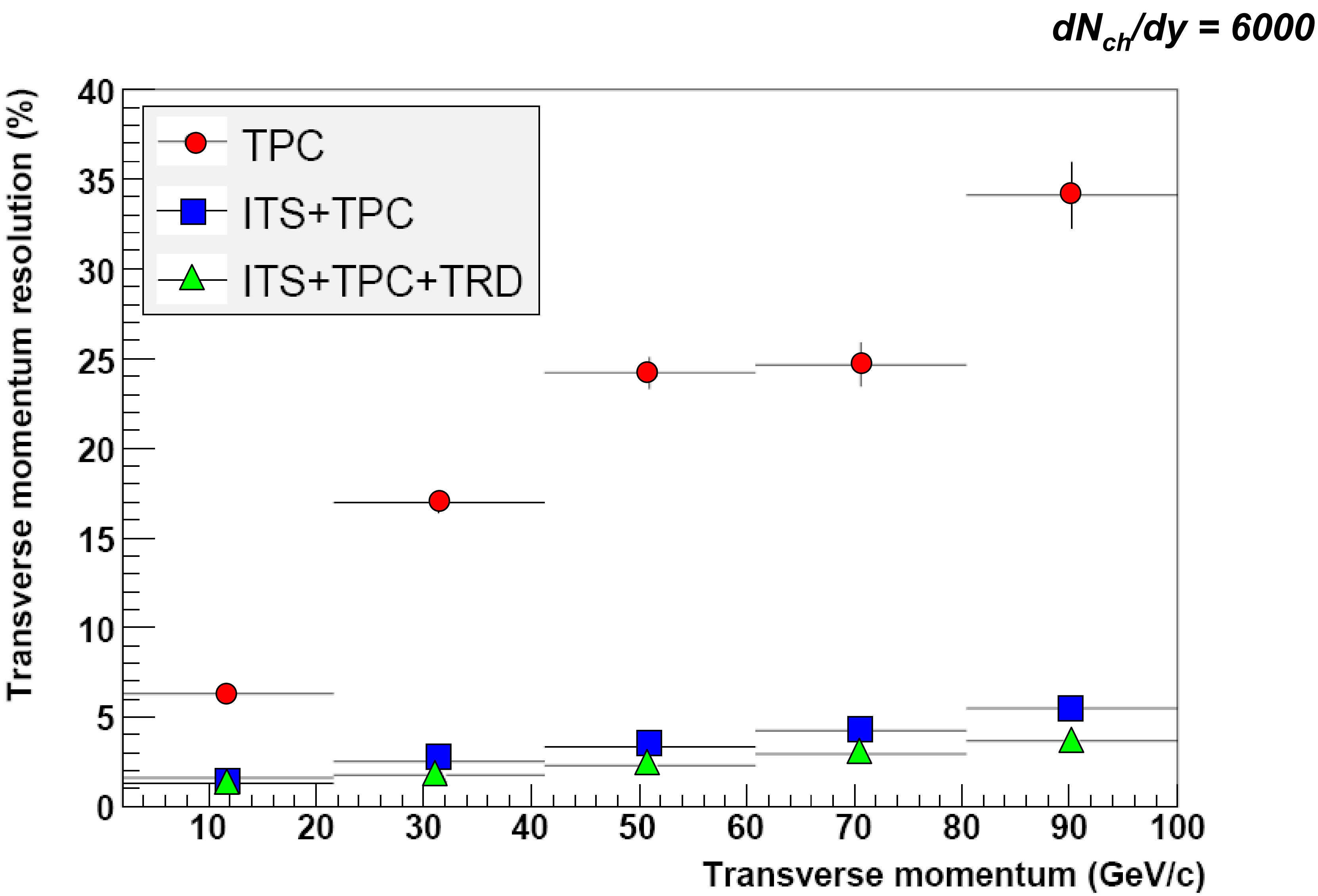


central barrel ($-0.9<\eta<0.9$) efficiency

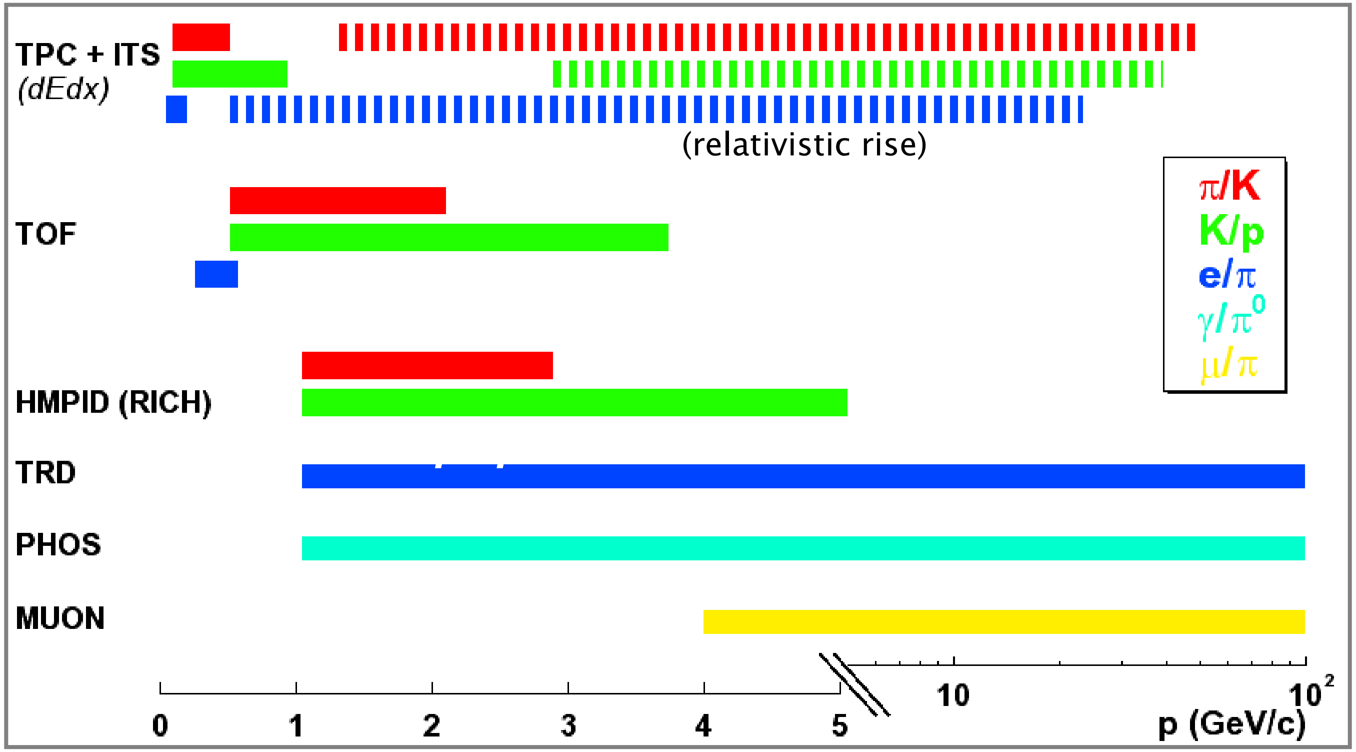
dN_{ch}/dy = 6000



central barrel (-0.9<η<0.9) pt resolution



PID Capabilities



TPC: $\sigma(dE/dx)$ = 5.5(pp) - 6.5(Pb–Pb) %

TOF: $\sigma < 100$ ps

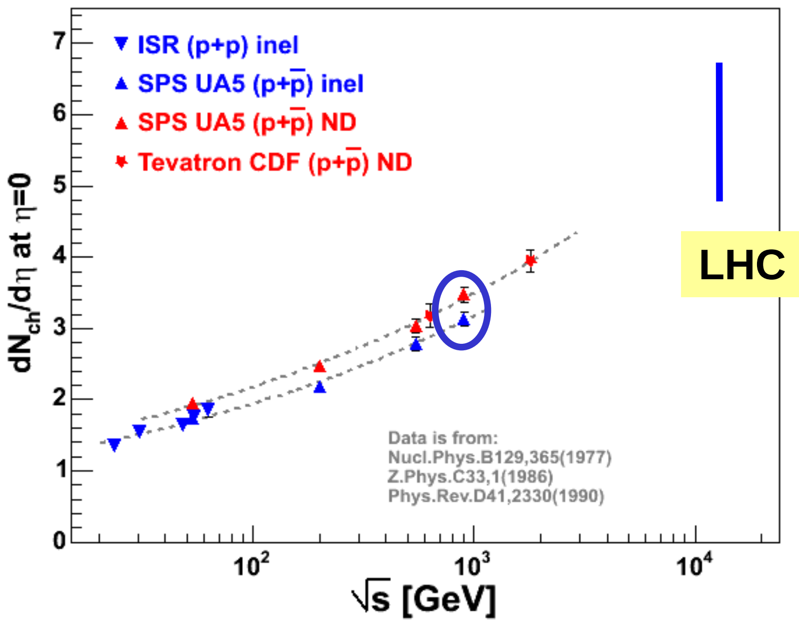
TRD: π suppression $\approx 10^{-2}$ @ 90% e–efficiency

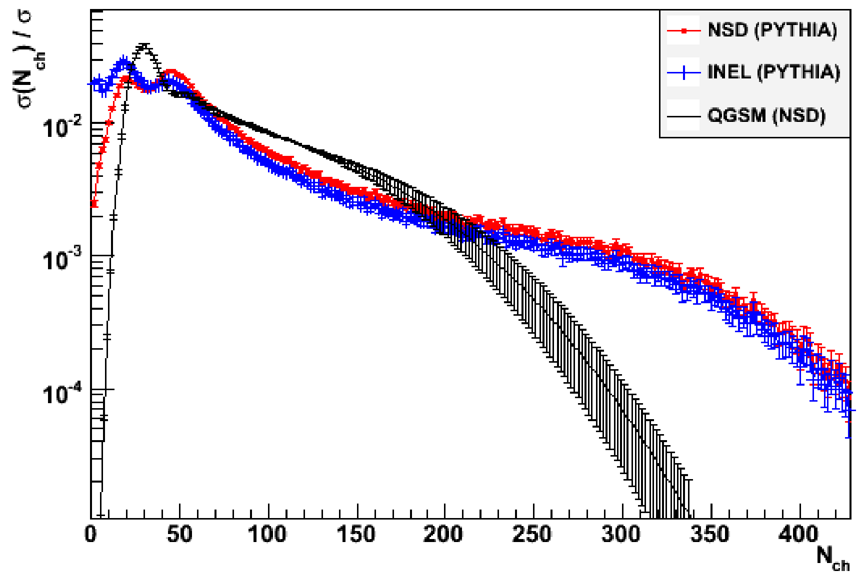
first physics in p+p

- ***charged particle multiplicity***
- ***baryon transport***
- ***charm cross section***

- ***reference data for heavy ions***

charged particle multiplicity in pp





- extend existing energy dependence
- unique SPD trigger (L0) for
  min. bias precision measurement
- completely new look at fluctuations in pp
  (neg. binomials, KNO…)

trigger efficiency

ND-INEL: 98.2%

SD : 55.4%

DD : 58.4%

high-multiplicity trigger

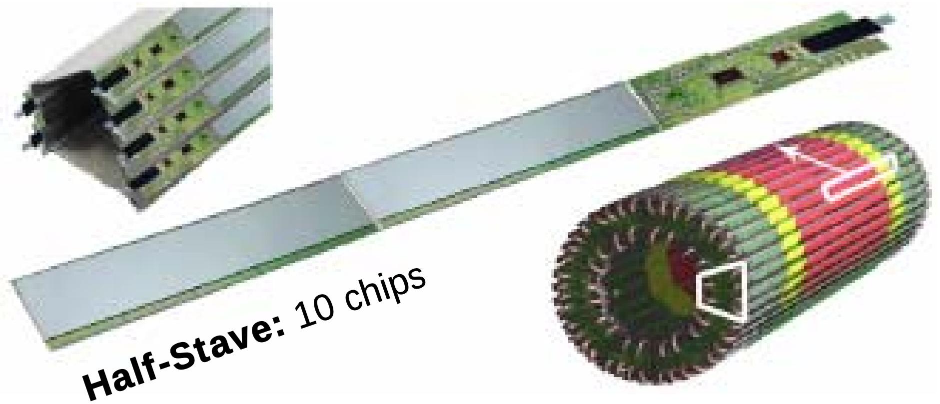
Silicon pixel detector

- fast-OR trigger at Level-0

  OR signal from each pixel chip
- two layers of pixel detectors

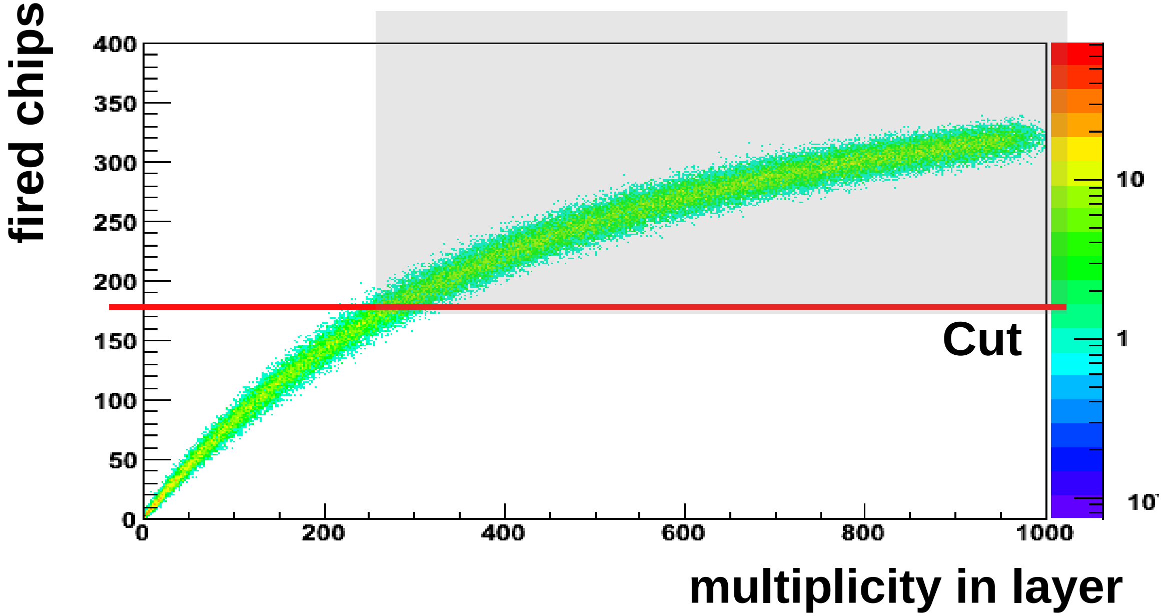
  400 chips layer 1; 800 layer 2
- trigger on chip-multiplicity per layer

Sector: 4 (outer) + 2 (inner) staves



Fired chips vs. true multiplicity (in η of layer)

SPD: 10 sectors (1200 chips)



Few trigger thresholds

- tuned with different downscaling factors
- maximum threshold determined by

  event rate

  background

  double interactions

high-multiplicity trigger – example

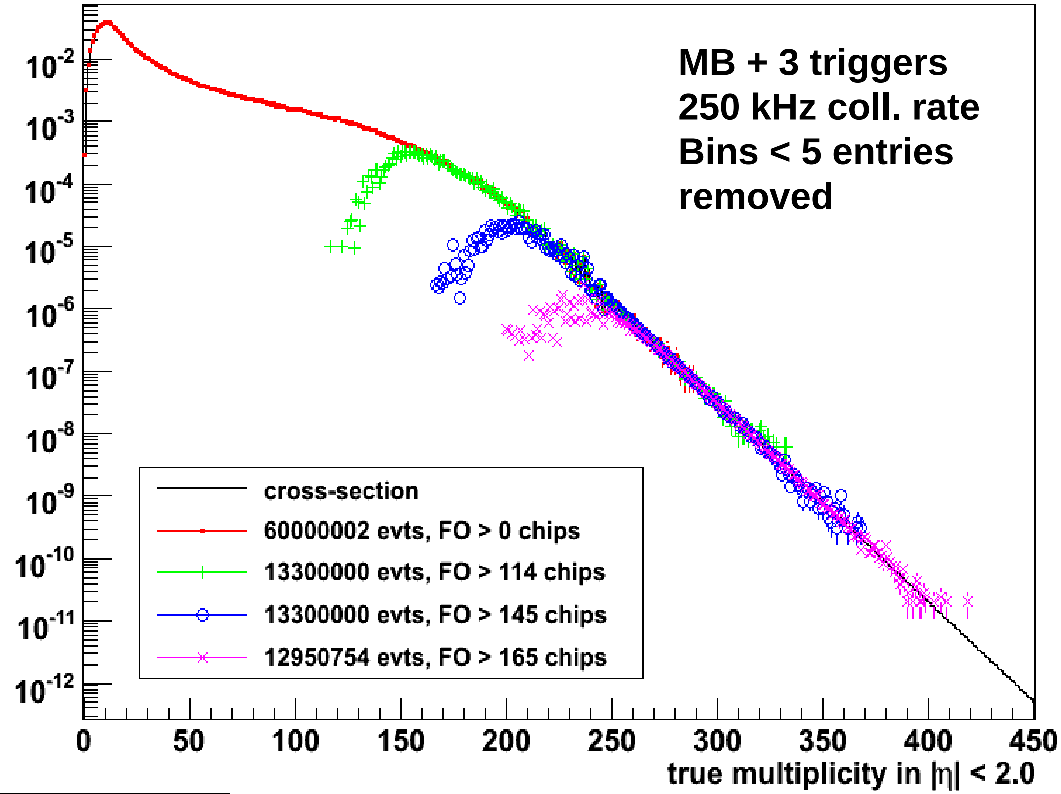
Example of threshold tuning:

MB and 3 high-mult. triggers

250 kHz collision rate
recording rate 100 Hz

MB 60%

3 HM triggers: 40%



trigger rate Hz	*scaling*	*raw rate*	*threshold layer 1*
60.0	*4167*	*250000*	*min. bias*
13.3	*259*	*3453.3*	*114*
13.3	*16*	*213.3*	*145*
13.3	*1*	*13.3*	*165*

baryon number transport

... goes via quark exchange or string junction

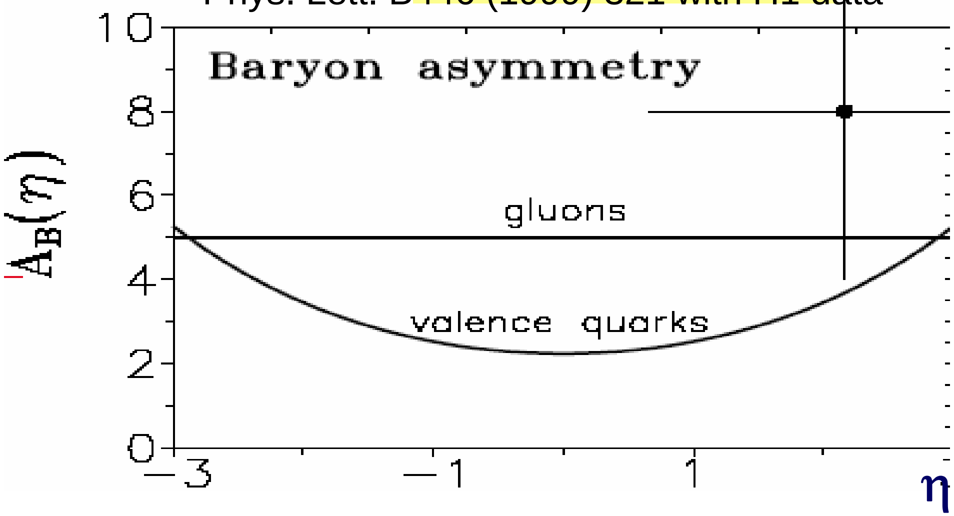
G.C. Rossi and G. Veneziano, Nucl. Phys B123 (1977) 507

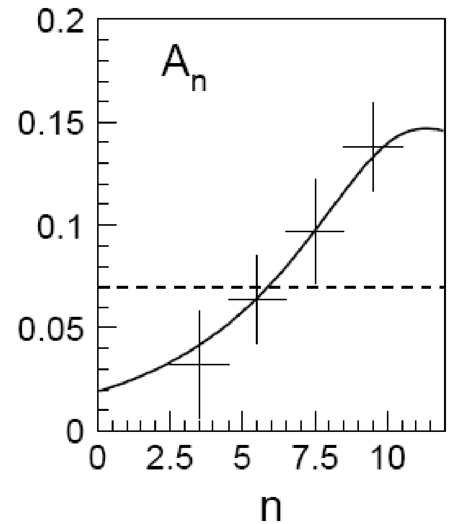
B.Z. Kopeliovich and B. Zakharov, Z. Phys. C43 (1989) 241

proton-antiproton asymmetry allows to distinguish

$$A = 2 \cdot \frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}}$$

Phys. Lett. B446 (1999) 321 with H1 data



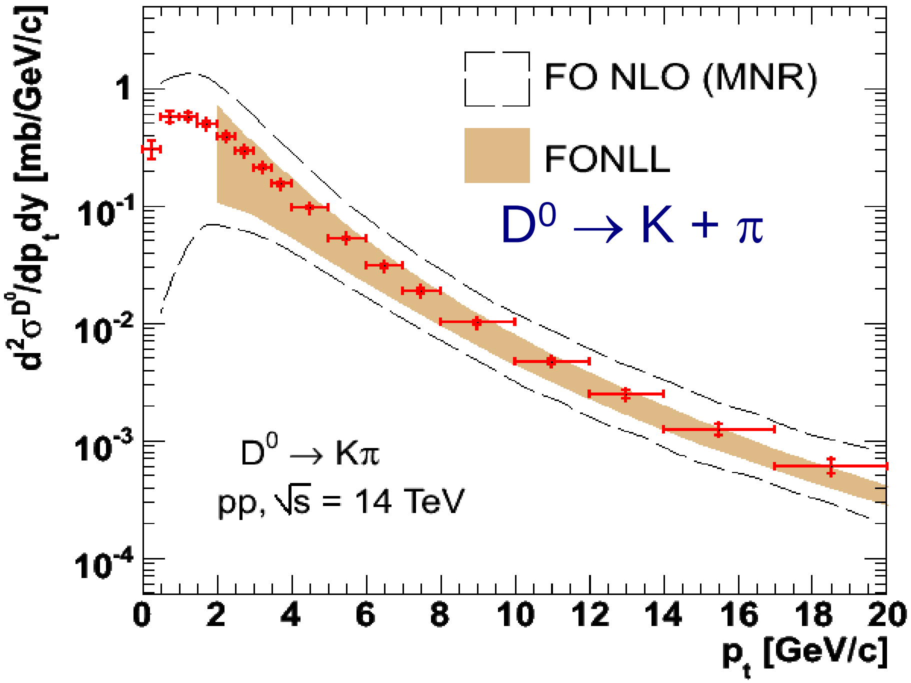


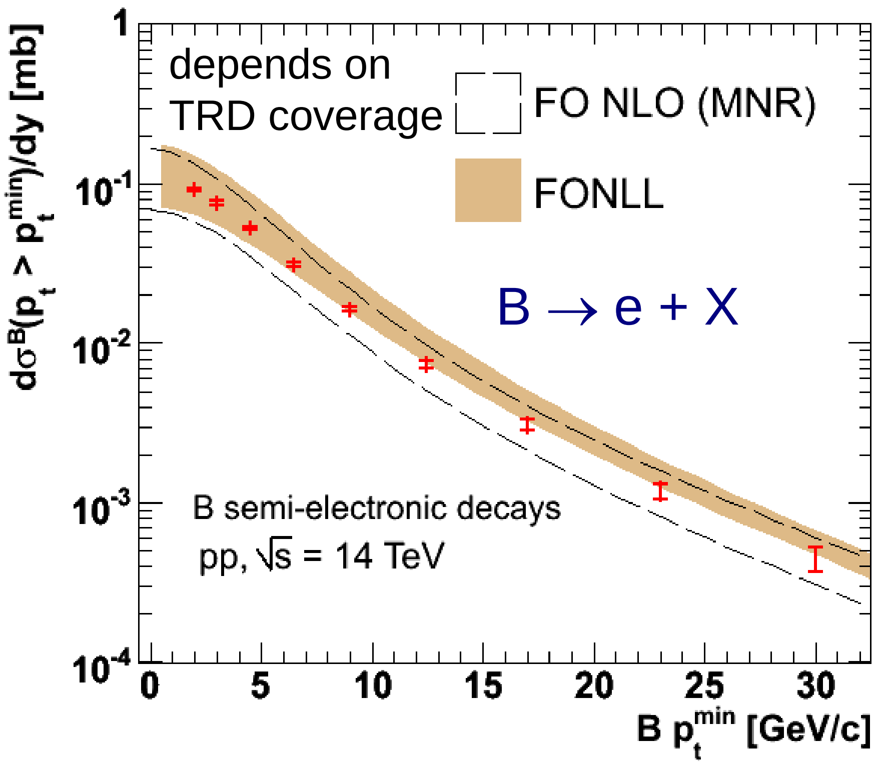
- ***systematic error < 1% for p > 0.5 GeV/c:***
- ***statistical error < 1% for 10^6 pp events (< 1 day)***

charm

Andrea Dainese

for 10^9 pp events





first physics from Pb+Pb

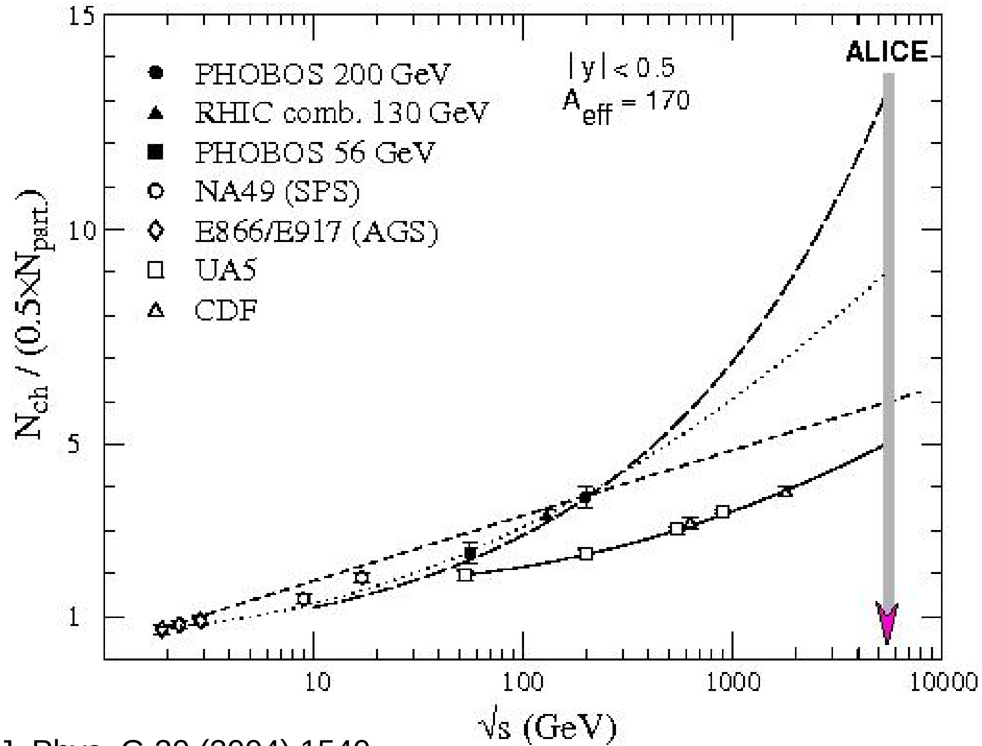
- ***first 10^5 events**: global event properties*
  multiplicity, elliptic flow

- ***first 10^6 events**: source characteristics*
  pt-spectra, resonances,
  differential flow analysis
  interferometry

- ***first 10^7 events**: hard probes*
  jet quenching,
  heavy flavour energy loss,
  charmonium

charged particle multiplicity in Pb+Pb

integrated multiplicity distributions from Au+Au/Pb+Pb collisions
and scaled p+p collisions



J. Phys. G 30 (2004) 1540

dN_{ch}/dy = 2600

saturation model

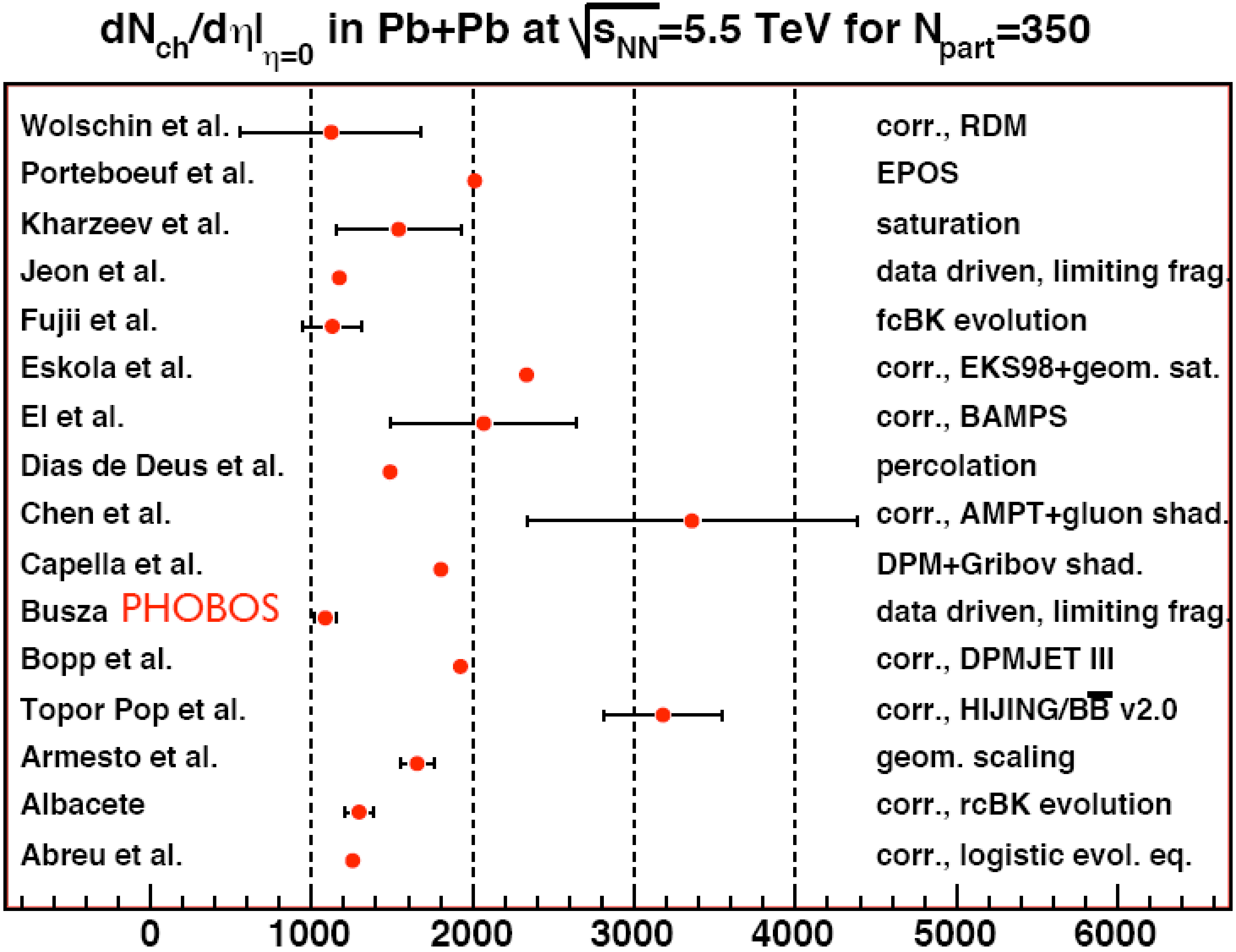
Eskola hep-ph/050649

dN_{ch}/dy = 1200

ln(√s) extrapolation

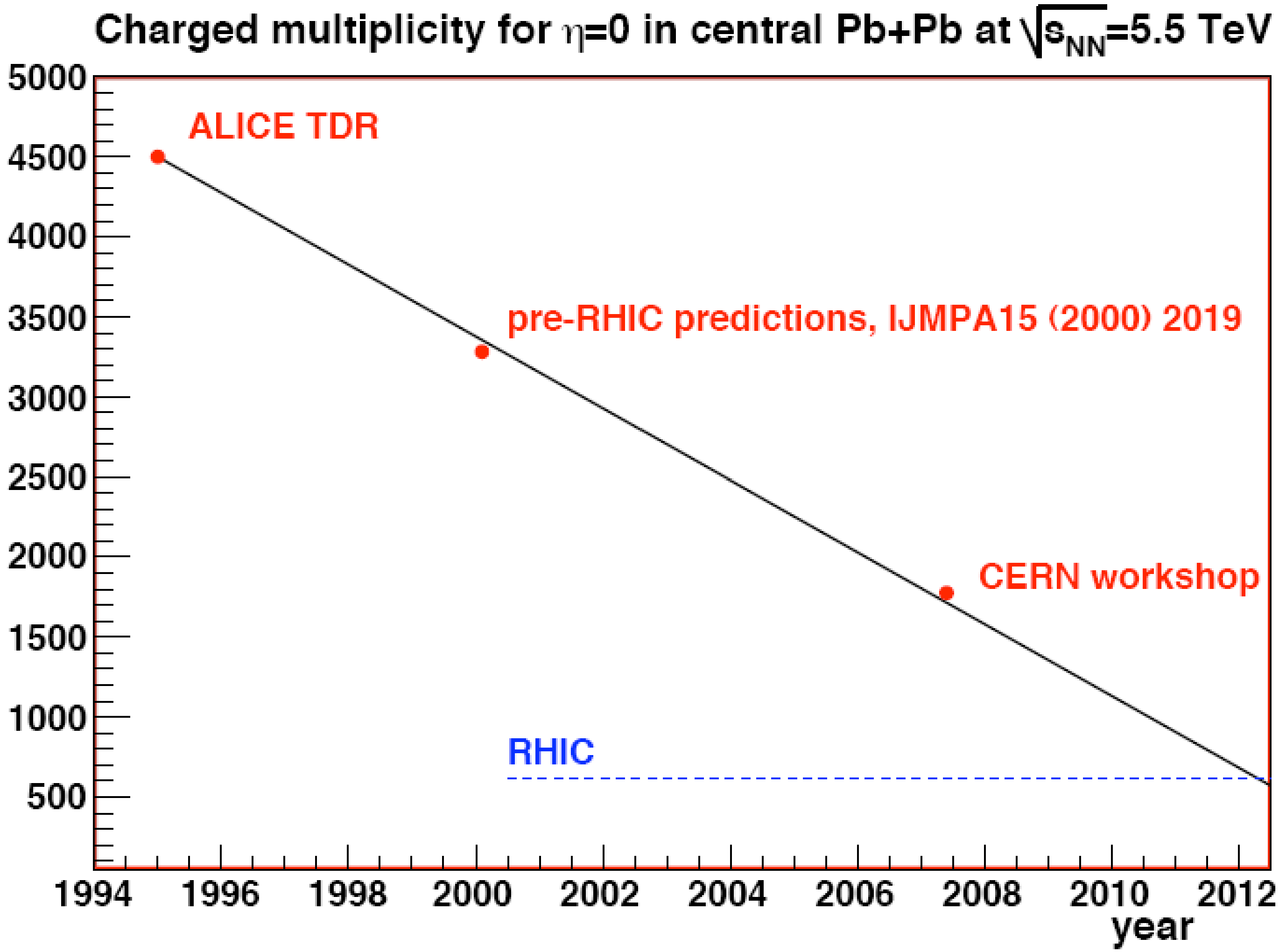
multiplicity predictions for LHC

N. Armesto, QM2008

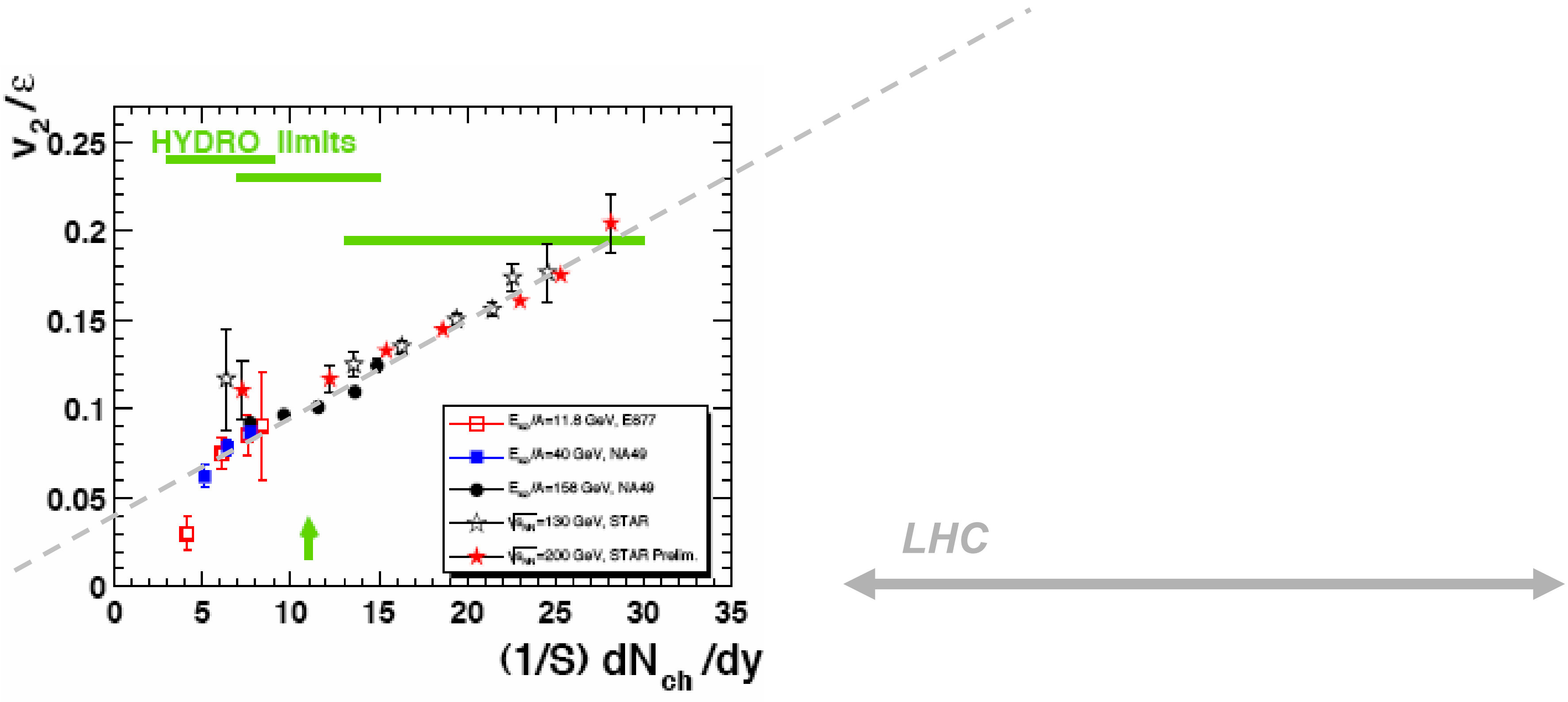


multiplicity predictions for LHC

N. Armesto, QM2008



elliptic flow v_2



- ***standard RHIC statement:*** ***v_2 at RHIC is at hydro limit so QGP is perfect liquid***
- ***Ollitrault, Voloshin:*** ***no! careful analysis shows that v_2 is still 30-50% below hydro limit so there is room for viscosity (and for ALICE)***
- ***Shuryak:*** ***QGP is perfect liquid but is followed by viscous hadronic phase***

open charm and beauty

goal:
measure parton energy loss in QGP

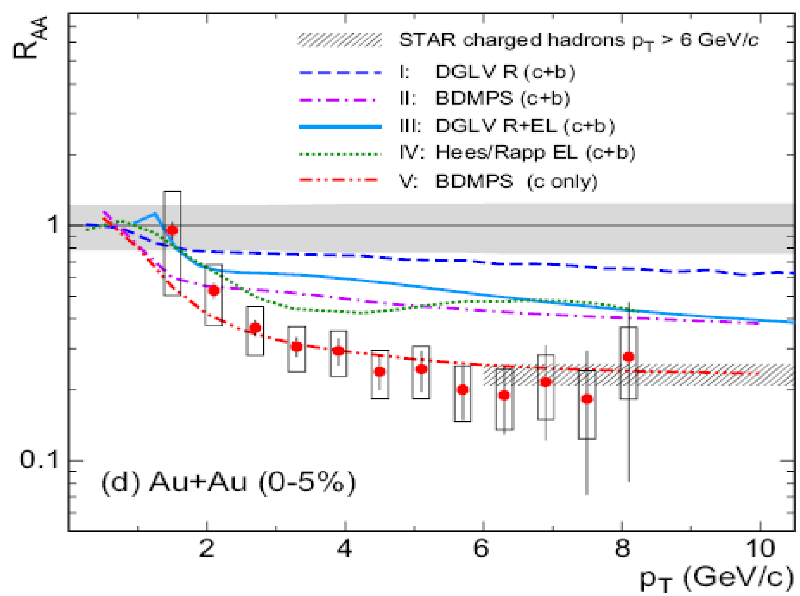
expectation:
energy loss color dependent (different for quarks and gluons)

energy loss flavour dependent (smaller for heavy quarks)

advantage at LHC:
high abundance of c and b (direct reconstruction possible)

c/b

System	p+p	Pb+Pb (5% cent)
$\sqrt{s_{NN}}$ (TeV)	14	5.5
NN cross section (mb)	11.2 / 0.5	6.6 / 0.2
Shadowing	---	0.65 / 0.85
Total multiplicity	0.16 / 0.007	115 / 4.6



RHIC: Non-photonic electrons used to estimate charm

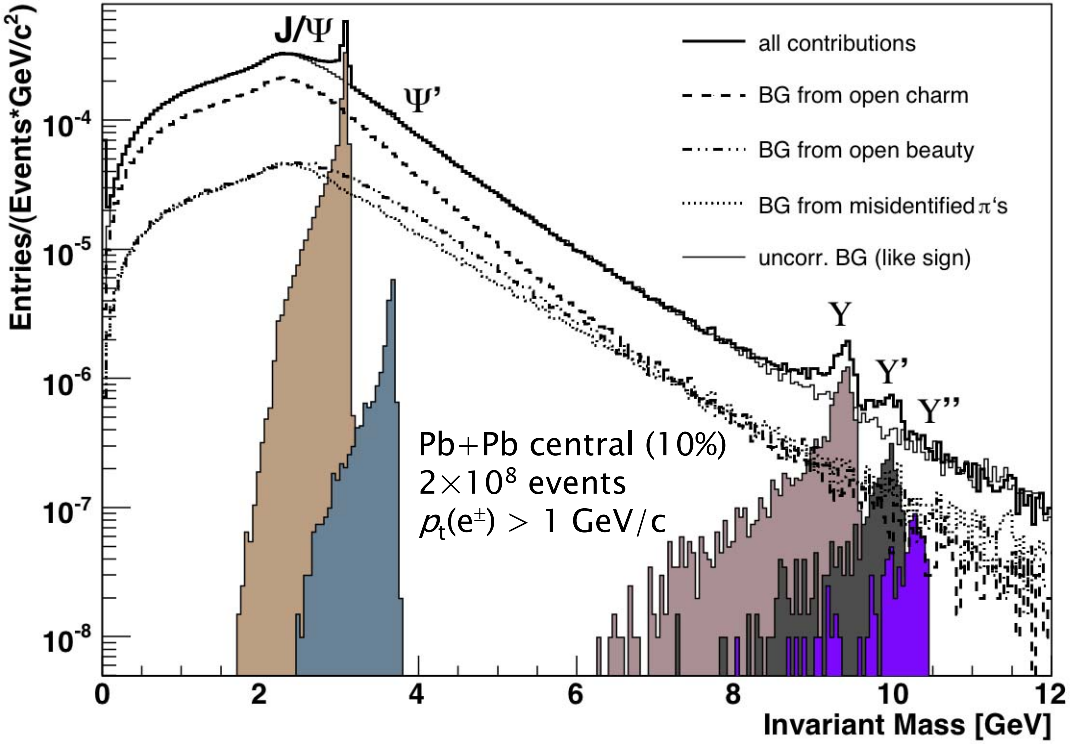
Quarkonia in dielectron channel

Central barrel

ITS+TPC+TRD
$-0.9 < \eta < 0.9$

e–ID with TRD

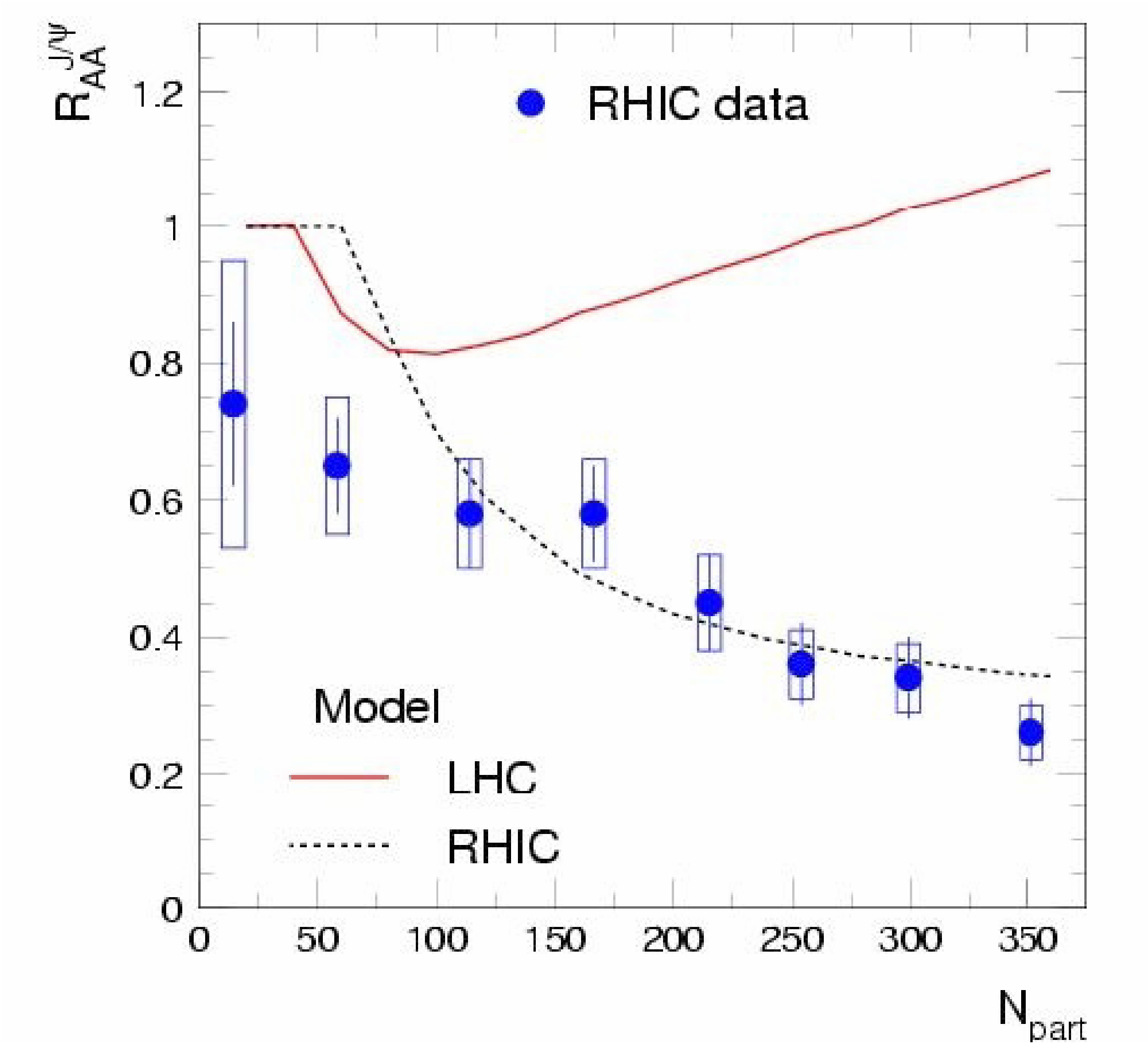
Resolution:
$\sigma_m(J/\psi) \approx$ 30MeV
$\sigma_m(\Upsilon) \approx$ 90MeV



Di–electron in central barrel

State	S ($\times 10^3$)	B ($\times 10^3$)	S/B	$S/\sqrt{S+B}$
J/ψ	110.7	92.1	1.2	245
Υ	0.9	0.8	1.1	21
Υ'	0.25	0.7	0.35	8

J/Psi as QGP probe

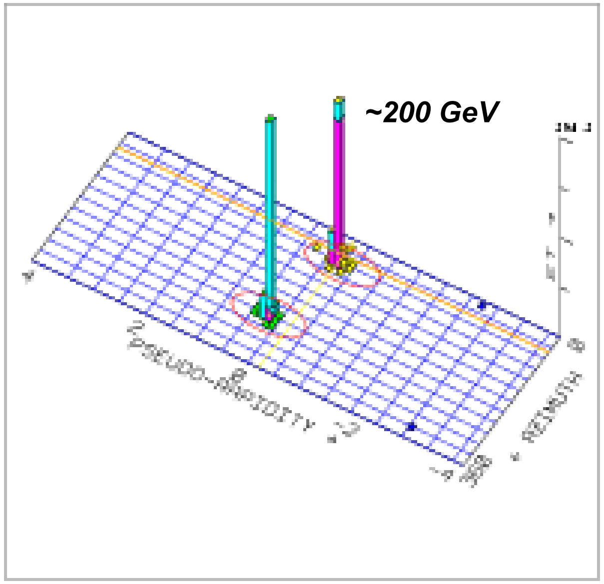


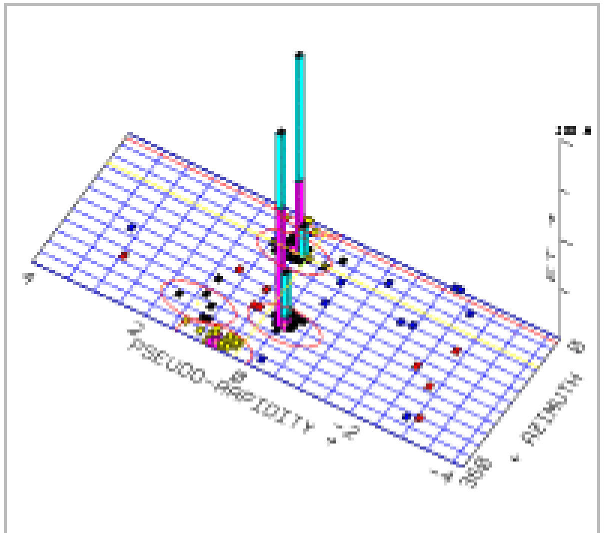
Andronic, Braun-Munzinger:

ccbar production is hard
ccbar→J/Psi is statistical

jets in p+pbar at 1.8 TeV

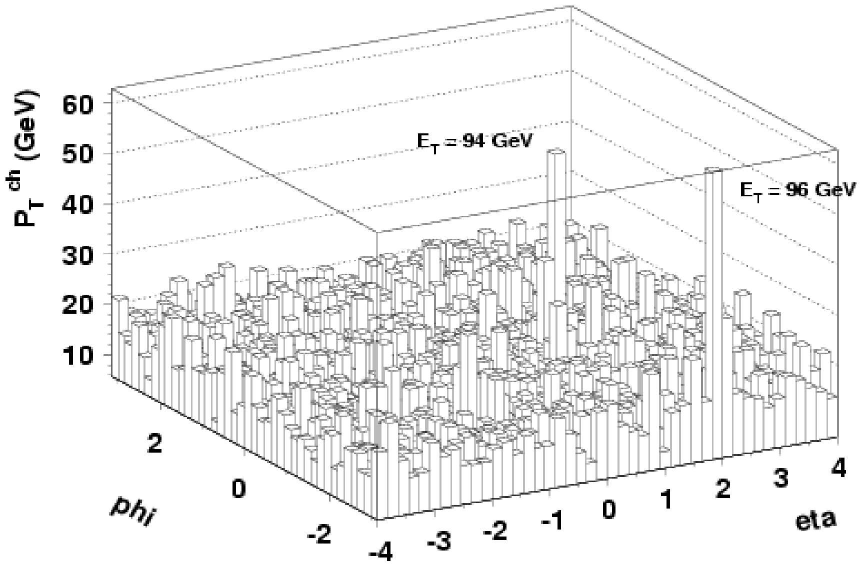
CDF, PRD 64 (2001) 032001

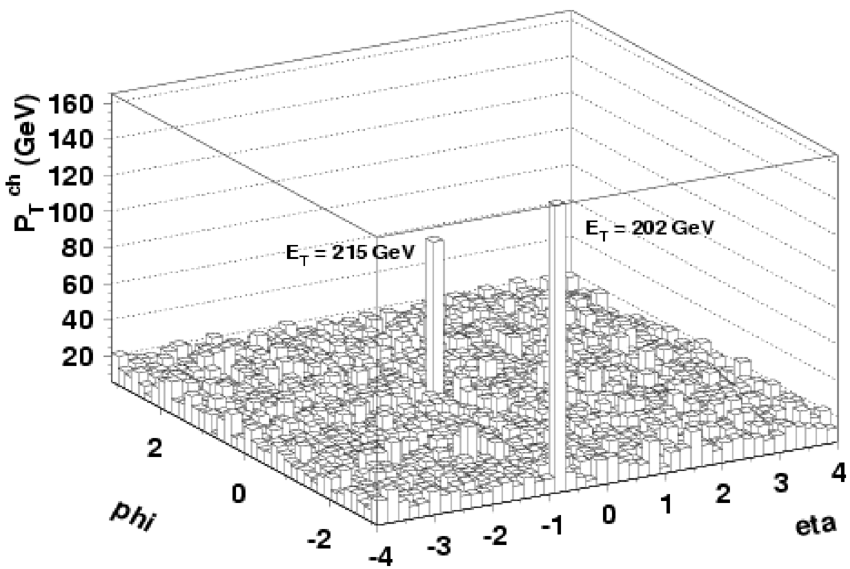




$$R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2}$$

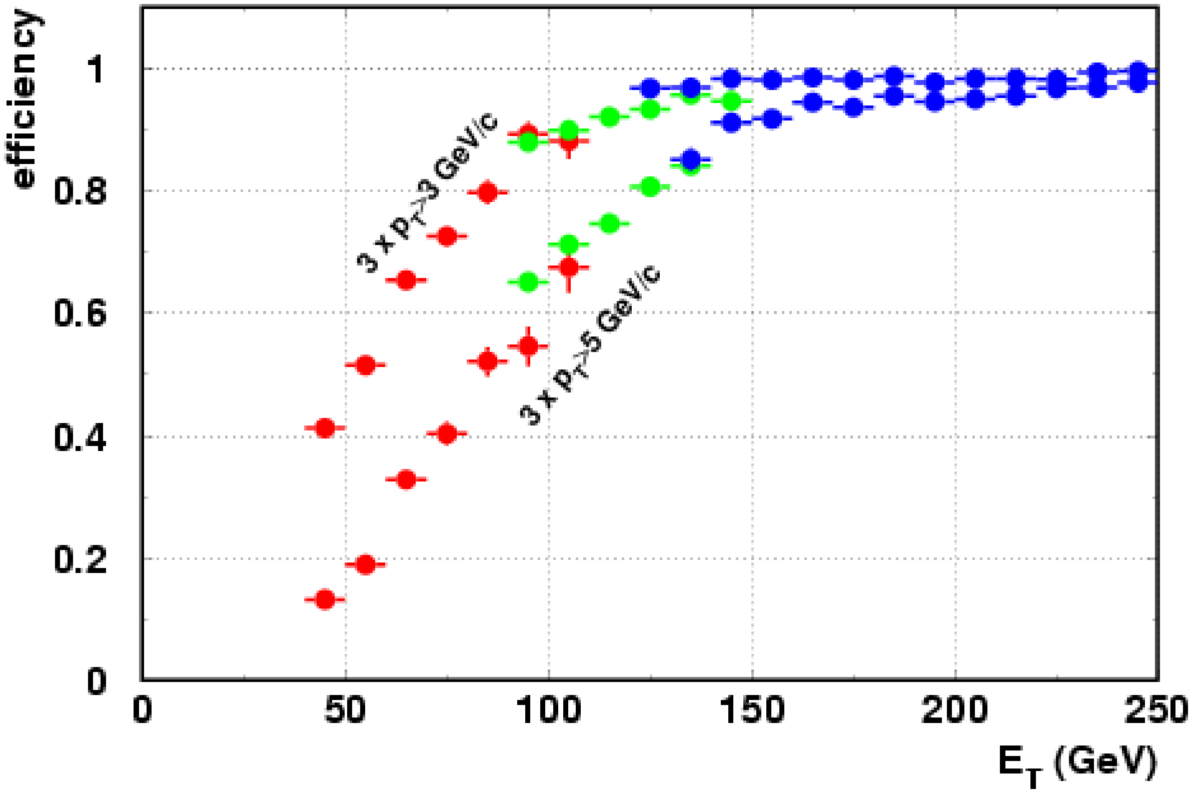
jets in Pb+Pb at 5.5 TeV (ALICE sim)





Jets with ITS, TPC, TRD – TRD trigger

1 month of running	
E_T >	N_{jets}
50 GeV	2.0×10^7
100 GeV	1.1×10^6
150 GeV	1.6×10^5
200 GeV	4.0×10^4

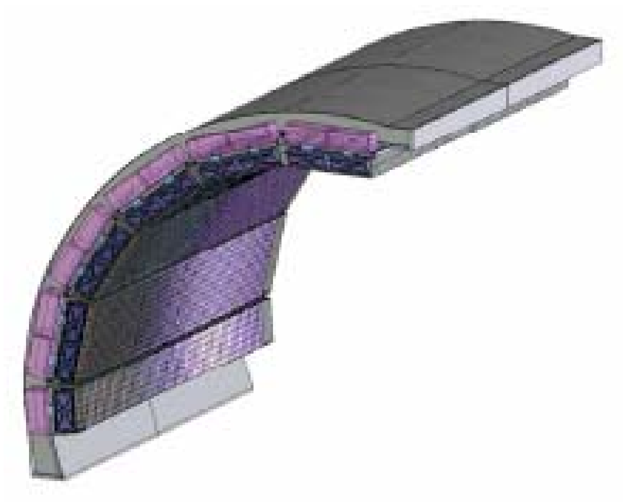


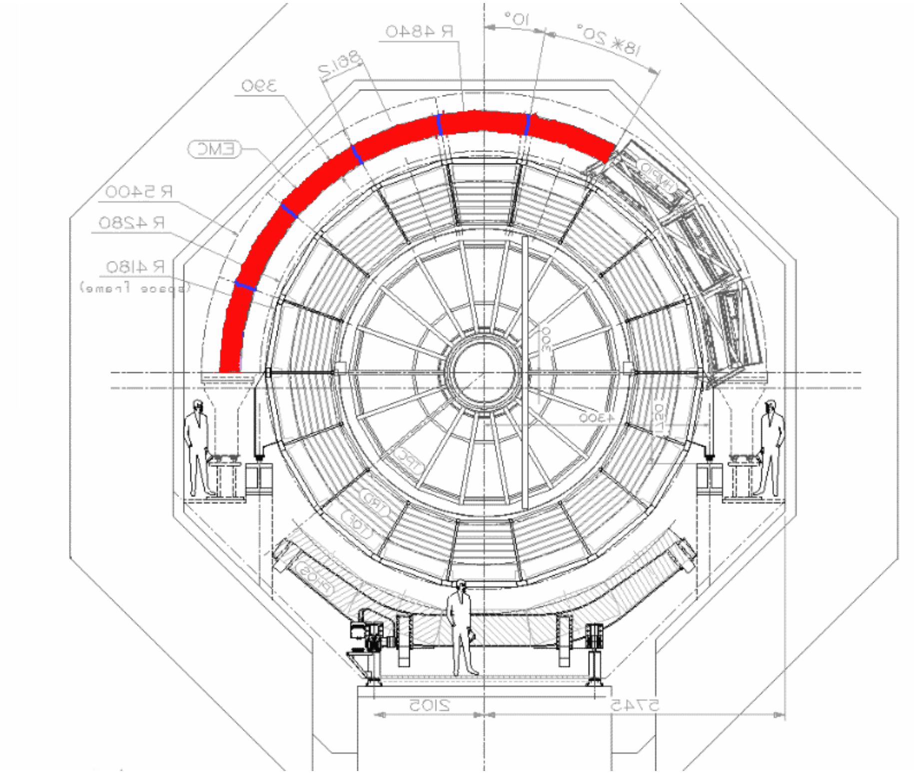
trigger condition:

3 charged particles with p_T>$p_T$min in one TRD module

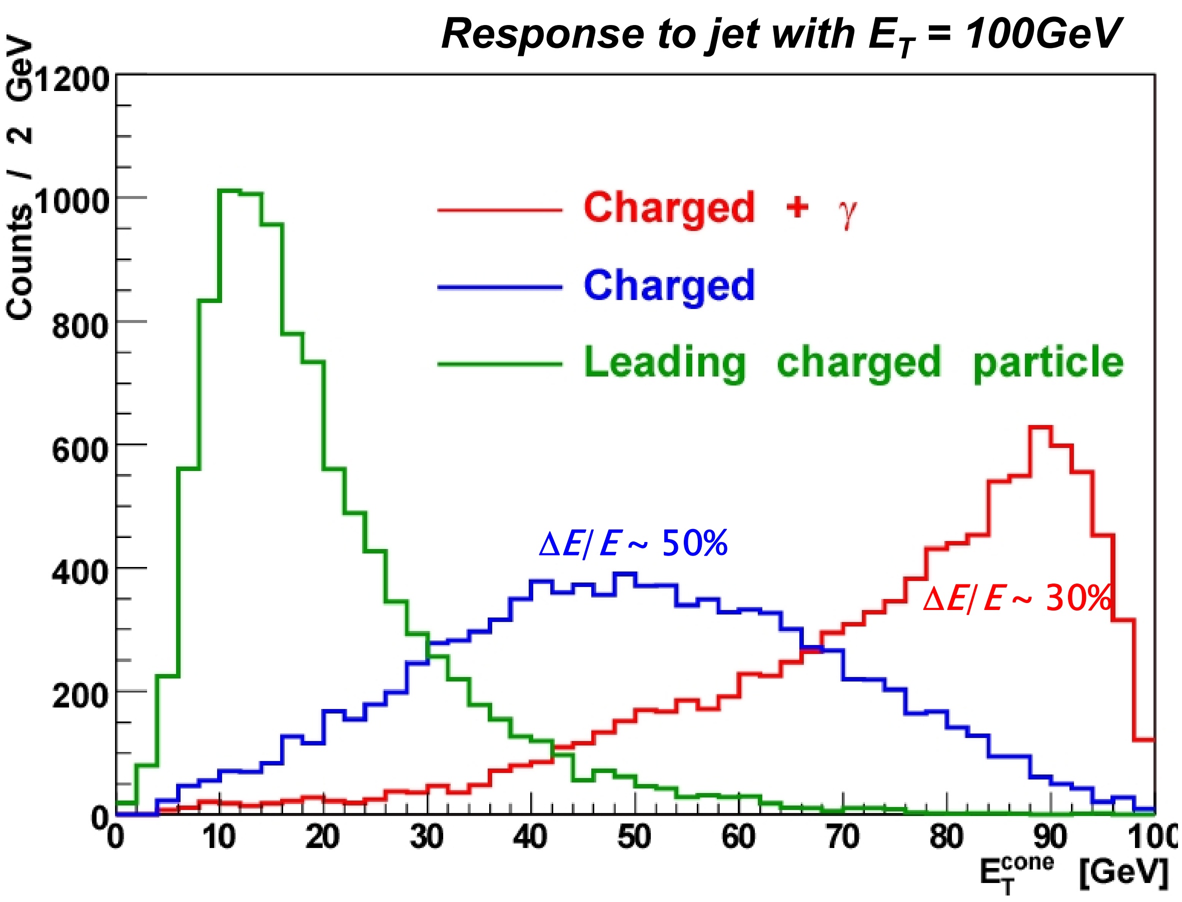
Jets with EMCAL

- ***EM Sampling Calorimeter - latest addition to ALICE by US, France, Italy***
- ***Pb-scintillator linear response***
  $-0.7 < \eta < 0.7$
  $60^o < \phi < 180^o$
- ***Energy resolution ~15%/√E***





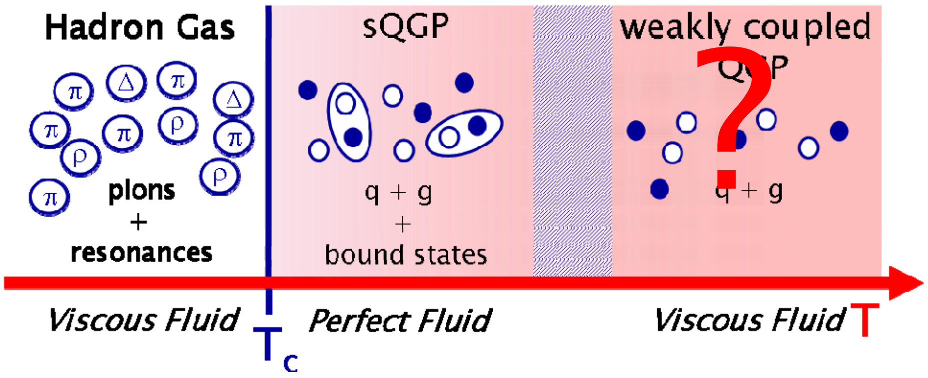
Jets with both



"two extreme scenarios", B. Müller QM2008

1. QGP physics at the LHC will be just like RHIC, only at higher (initial) energy density/temperature and with probes that have a (much) larger kinematic range.

2. QGP physics at the LHC will be quite different from that seen at RHIC, involving an (initially) weakly coupled deconfined phase and an initial state dominated by gluon saturation.



weak or strong coupling?

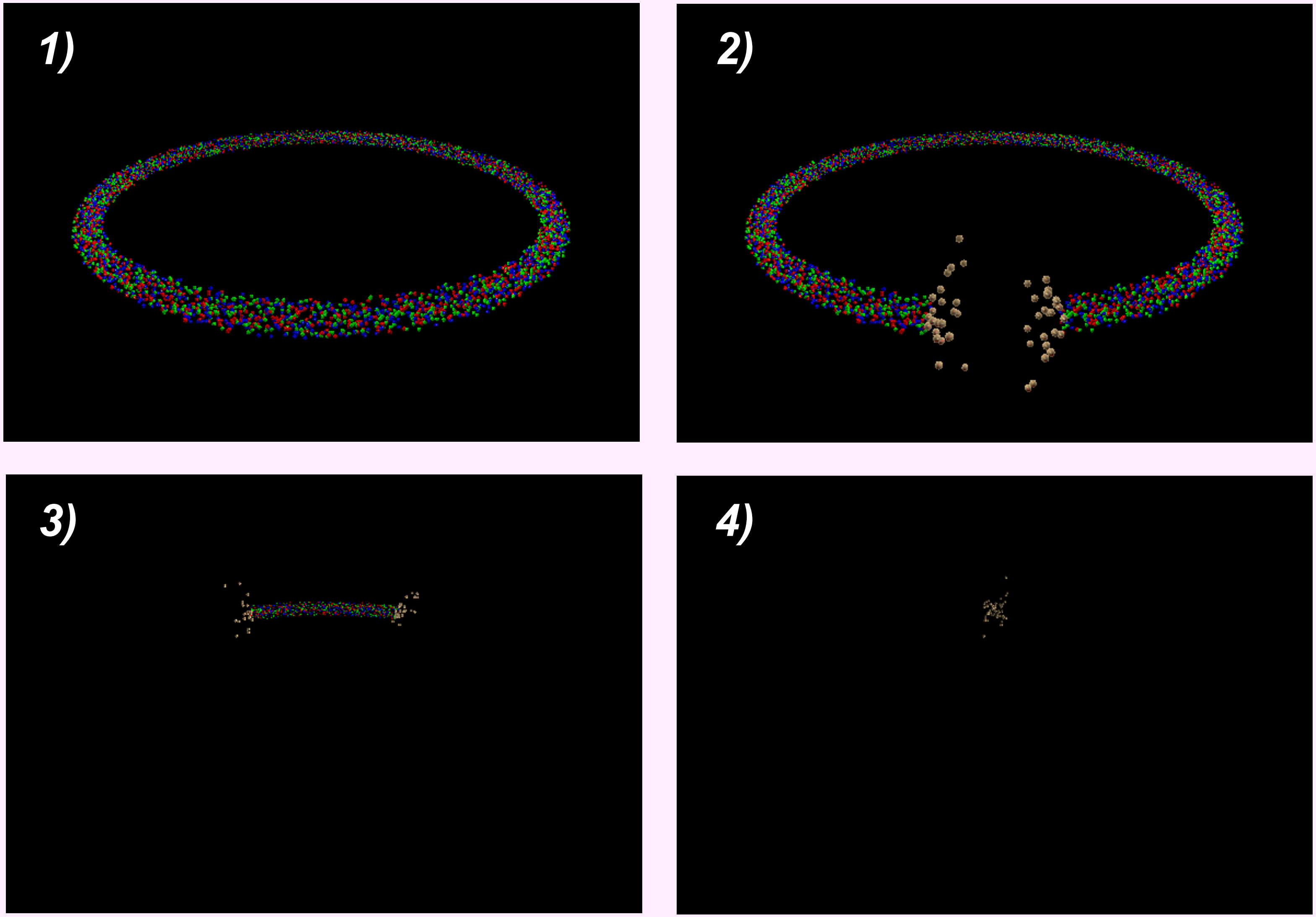
weakly coupled QGP has a principal problem:

when hadronizing back single quarks can be left because synchronizing hadronization in regions separated by space-like intervals is impossible

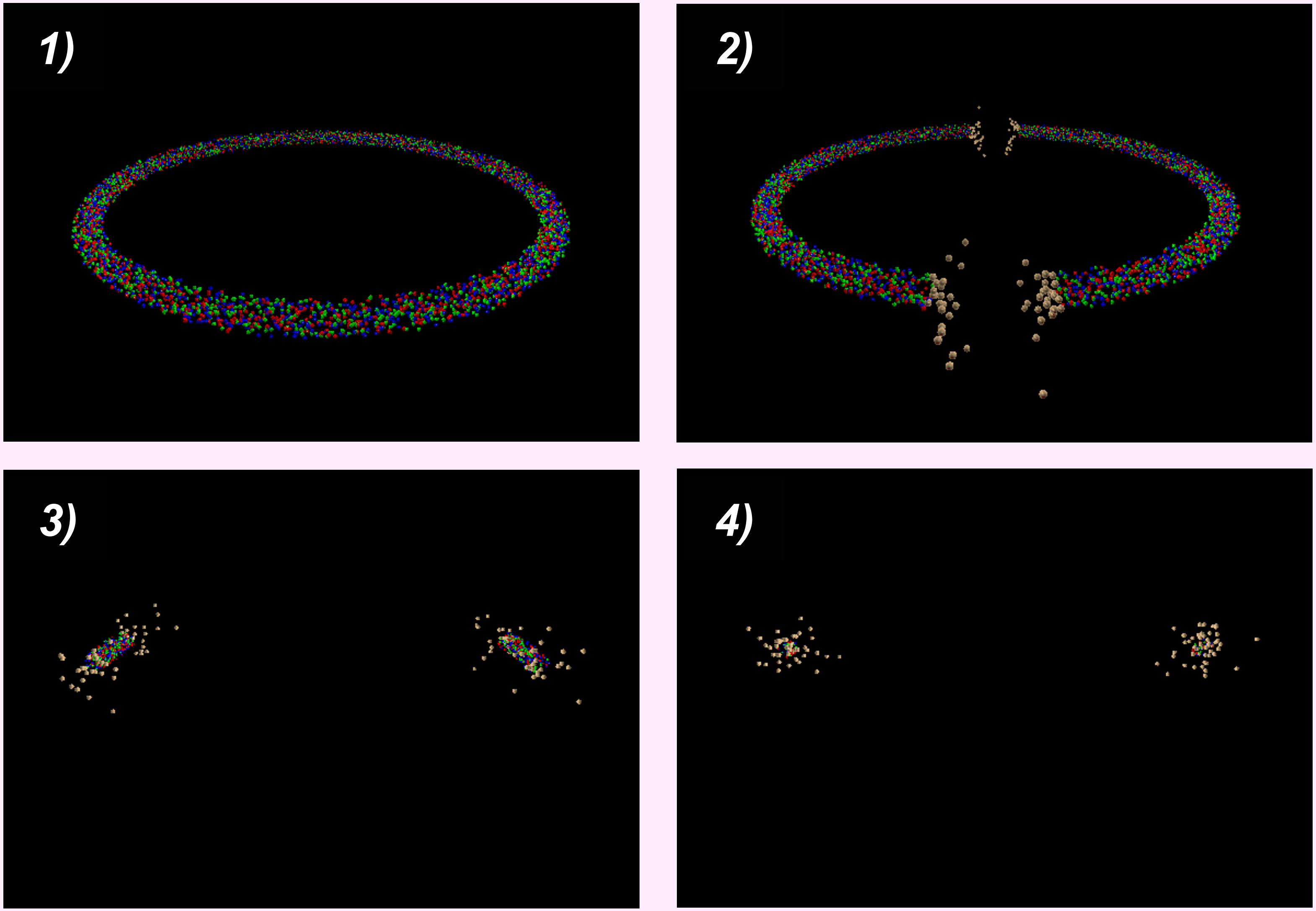
QGP paradox demonstrated

- ***I will start from an allowed state (1 mm^3 of QGP)***
- ***I will never violate any physics law***
- ***I will end up in a not allowed state (with single quarks)***

QGP paradox: experiment 1



QGP paradox: experiment 2



QGP paradox: 3 ways out

1) fast (volume) hadronization

- single quarks can exist, or
- baryon number not conserved, or
- superluminal information transfer is possible

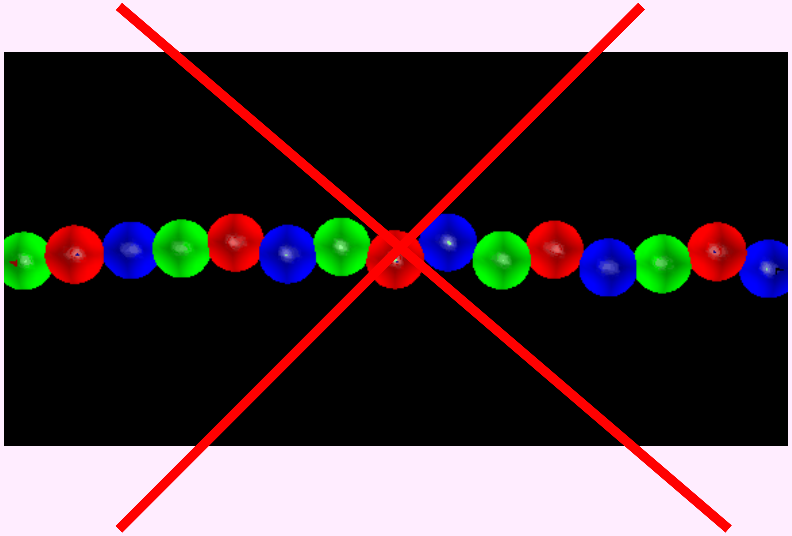
2) slow (surface) hadronization

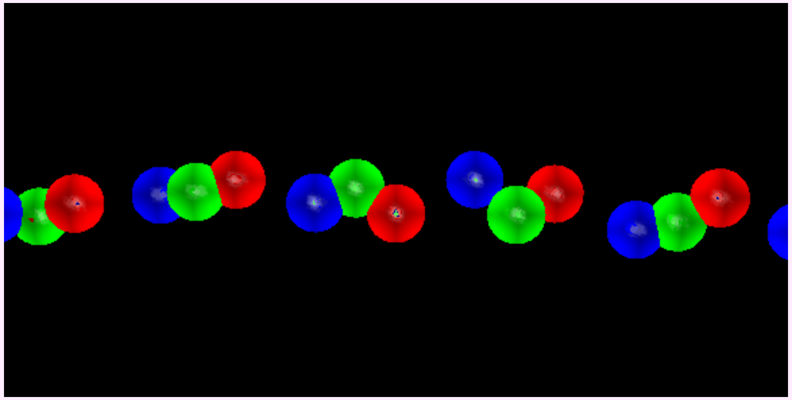
- holes in QGP not allowed (infinite surface tension)
- too slow: Early Universe at least couple of minutes
- heavy ion collision: the ends hadronize first

QGP paradox: 3 ways out

3) true QGP with liberated quarks does not exist

- ***quarks are in clusters***
- ***the ring can be cut only between two such clusters***
- ***no problem with hadronization***





S. K. Ghosh, Astrophysics of Strange Matter, QM2008

- End of cosmic quark-hadron phase transition

  - few coloured quarks separated in space

⇓

Colour wave functions are still entangled

⇓

Incomplete decoherence

⇓

Residual perturbative vacuum energy

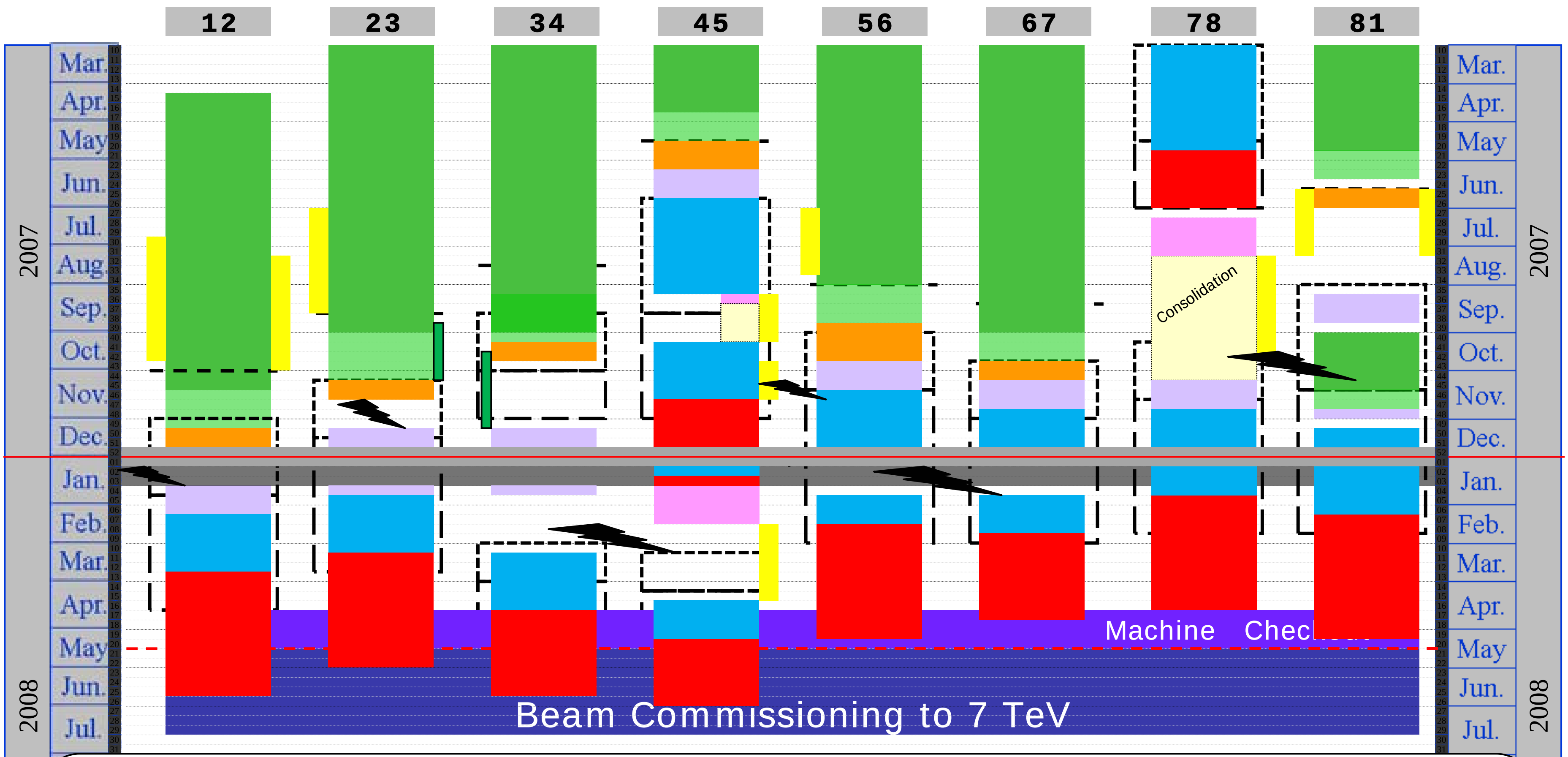
Dark Energy ~ 10^{-48} GeV^4 (Ω_{DE} ~ 0.7)

- DE → Constant
- Matter density → decreases as R^{-3}

DE is dominant at late times *Banerjee et al. PLB611 (2005)*

"orphan quarks" -
possible solution of my QGP paradox

LHC schedule as of 8 Oct 2007



General schedule Baseline rev. 4.0

- Global pressure test &Consolidation
- Cool-down
- Powering Tests
- Interconnection of the continuous cryostat
- Leak tests of the last sub-sectors
- Inner Triplets repairs & interconnections
- Global pressure test &Consolidation
- Flushing
- Cool-down
- Warm up
- Powering Tests

J.M. Jowett, Quark Matter 2008, Jaipur, 7 February 2008 44

ALICE running schedule

- complete & commissioned
  ITS, TPC, TOF, HMPID, MUONS, PMD, V0, T0, FMD, ZDC, ACORDE, DAQ
- partially completed
  - TRD (25%) to be completed by 2009
  - PHOS (60%) to be completed by 2010
  - HLT (30%) to be completed by 2009
  - EMCAL (0%) to be completed by 2010/11

- Dec-2007 cosmic run
- Mar-2008 cosmic run
- Apr-2008 cosmic run...
- Jul-2008 p+p
- fall 2009 Pb+Pb

- at start-up full hadron and muon capabilities
- partial electron and photon capabilities

summary: ALICE status and nearest plans

- commissioning phase
  - fully commission trigger, DAQ, ECS
  - align and calibrate the entire system
  - further use of beam gas interactions
- first pp run
  - charged particle multiplicity
  - baryon number transport
  - charm cross section
  - reference data for heavy ions
- first few heavy ion collisions
  - global event properties
- first long heavy ion run
  - source characteristics
  - hard probes

The End