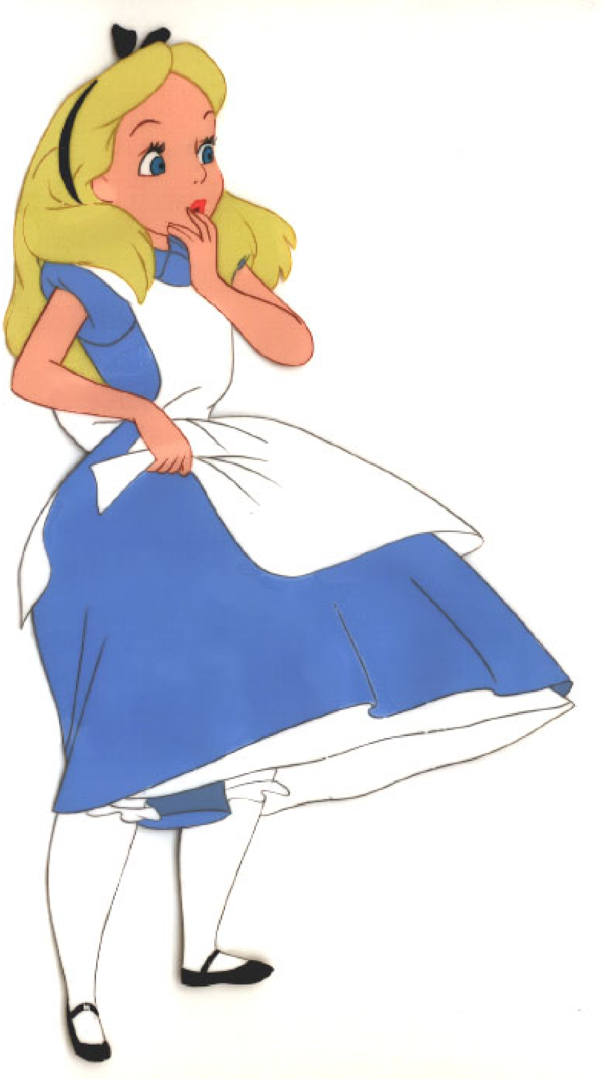
ALICE physics program overview & French participation in ALICE



- heavy ion collisions & QGP
- heavy ion collisions @ LHC
- ALICE detector overview
- selected physics channels
- French participation in ALICE

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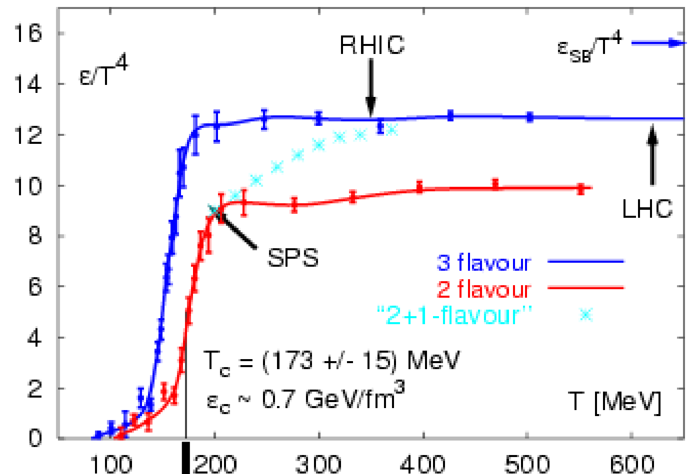
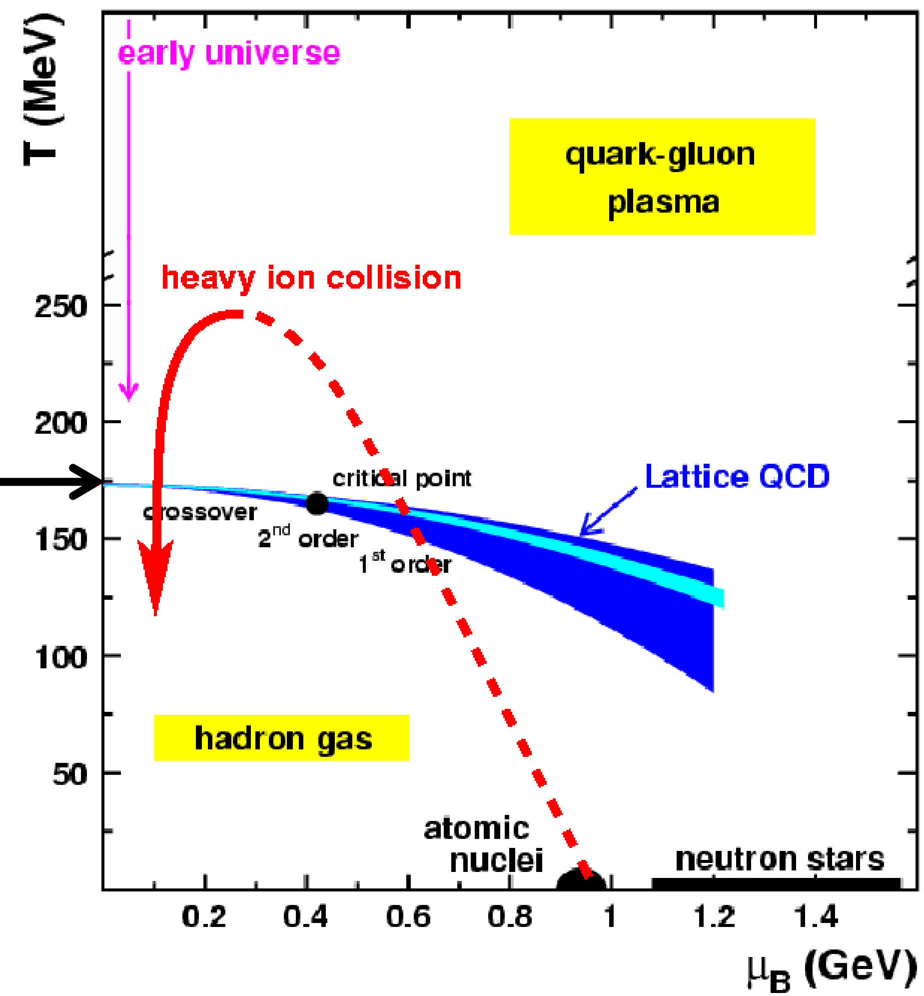
QCD, QGP & heavy ion collisions





- **μ_B = 0:**
  - **$T_c = 173 \pm 15$ MeV**
  - **$\varepsilon_c = 0.7 \pm 0.3$ GeV/fm^3**
  - **"crossover"-like transition**
- **μ_B > 0:**
  - **large uncertainties**
  - **order of transition unknown**
  - **existence of a critical point**
- **chiral sym. rest. coincides with deconf.**
- **the QGP is not an ideal gas**

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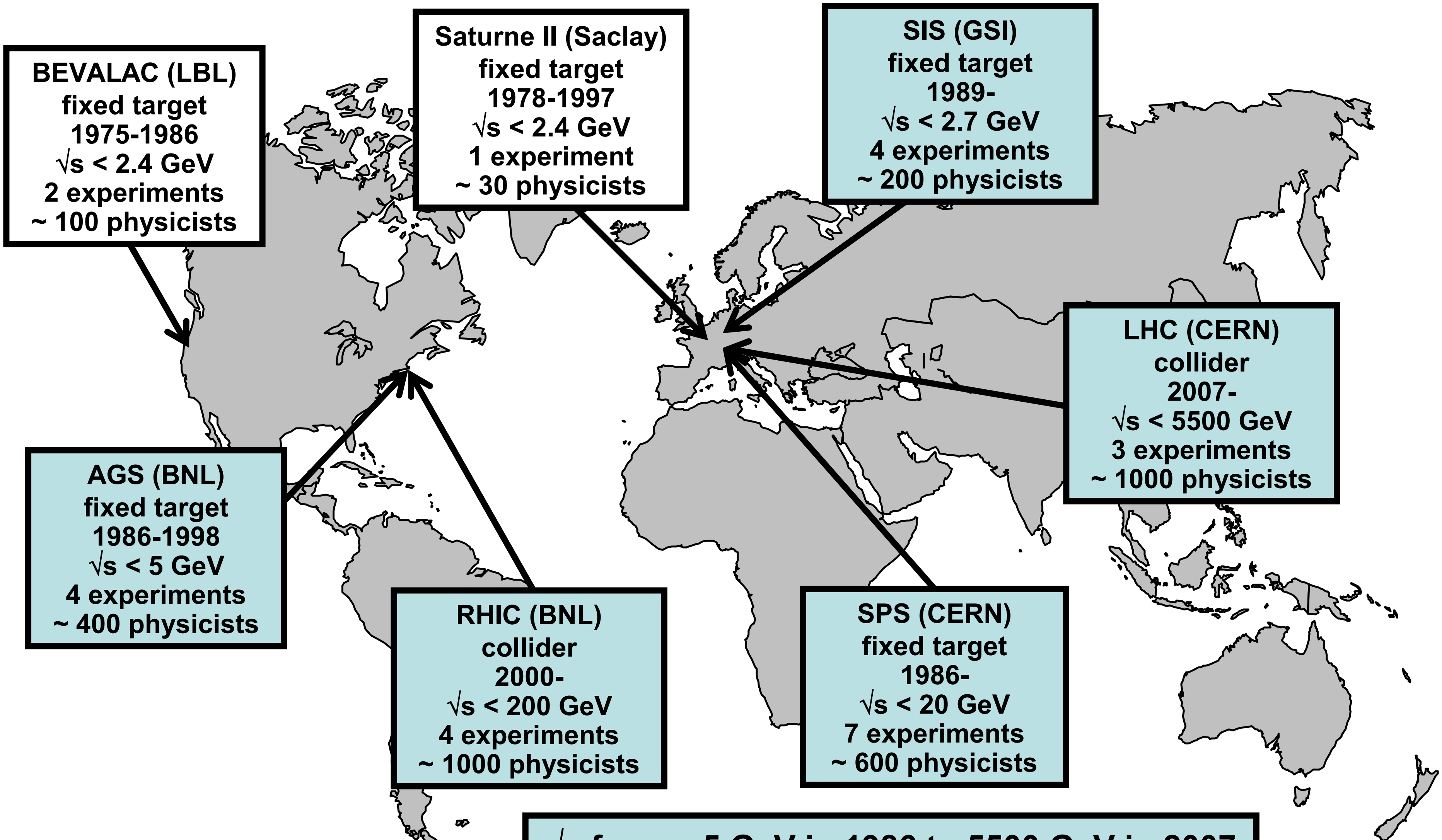
1986-2007: 20 years of ultra-relativistic heavy ion collisions



√s from ~ 5 GeV in 1986 to 5500 GeV in 2007

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Evolution of the QCD phase diagram in 30 years

1975

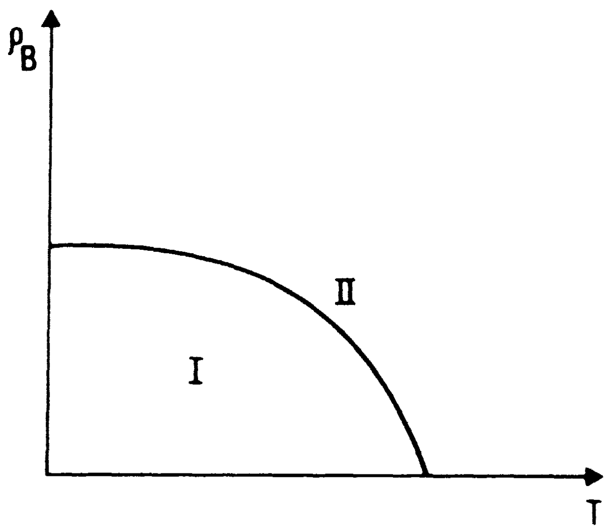
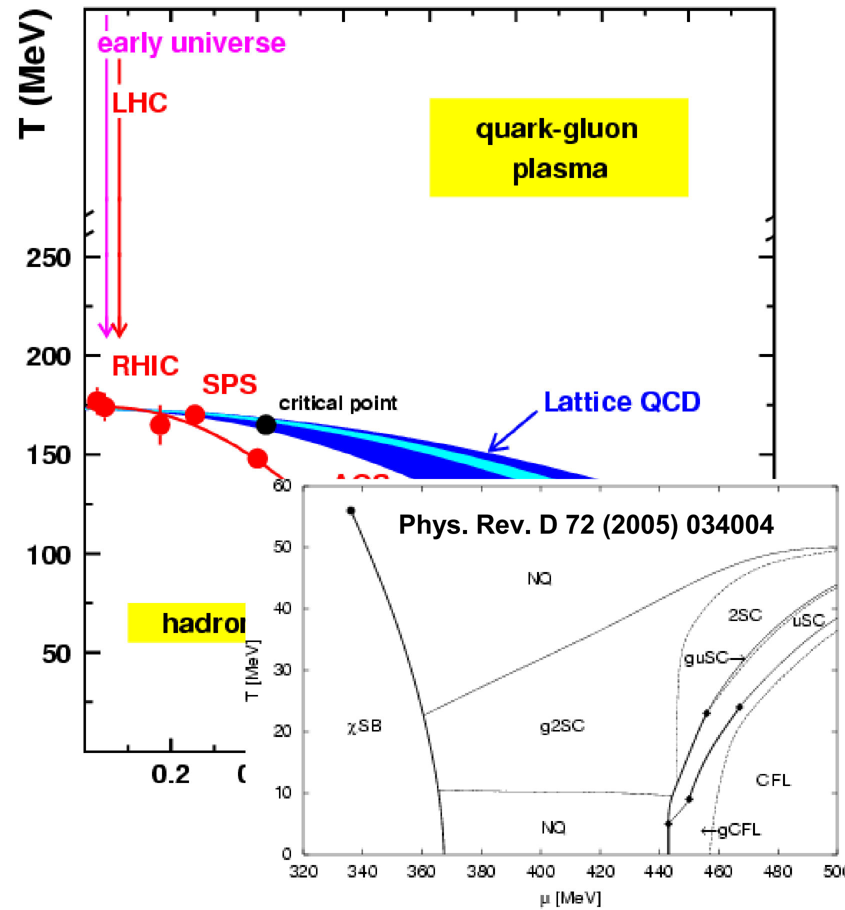


Fig. 1. Schematic phase diagram of hadronic matter. ρ_B is the density of baryonic number. Quarks are confined in phase I and unconfined in phase II.

"…we expect a phase diagram of the kind indicated in Fig.1. The true phase diagram may actually be substantially more complex…"
N. Cabibbo & G. Parisi (1975)

2006



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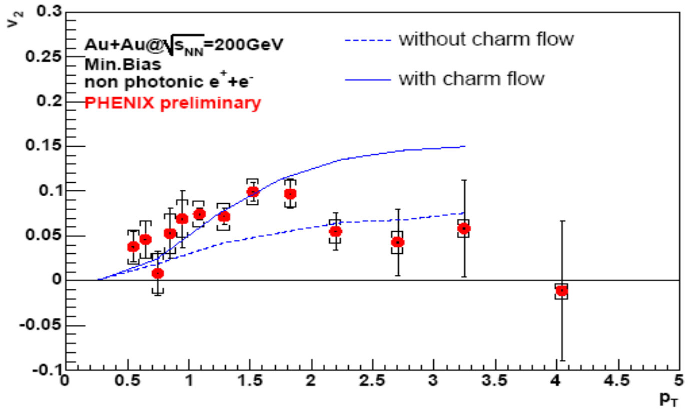
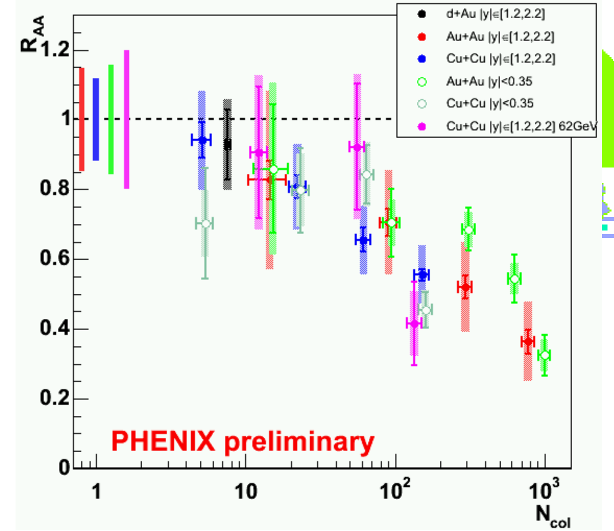
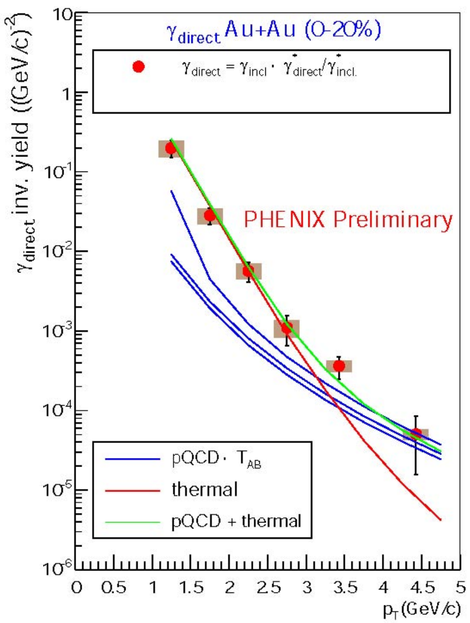
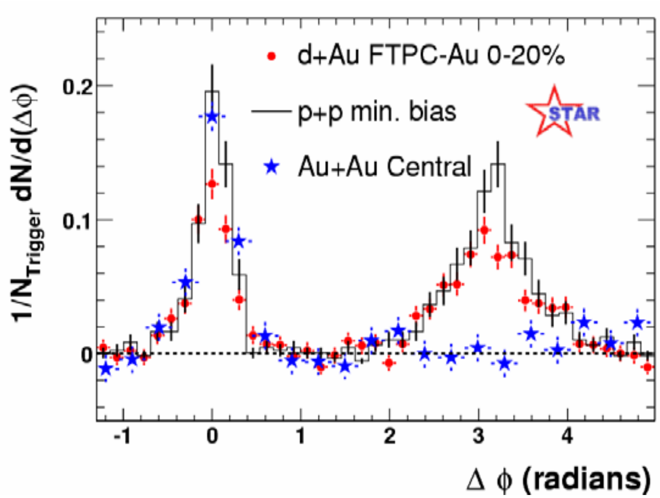
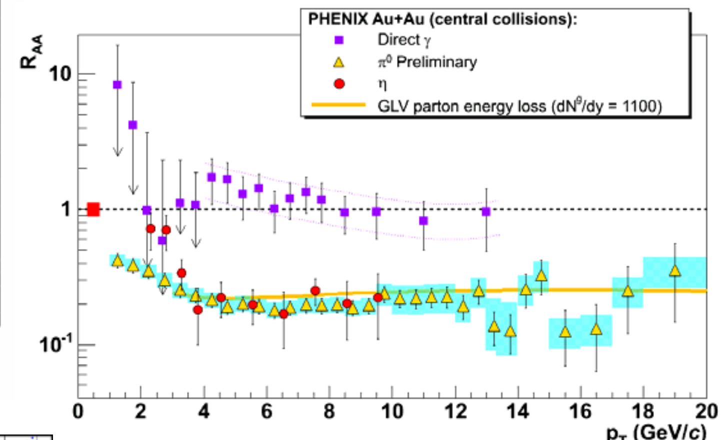
Recent highlights: RHIC results in 7 plots



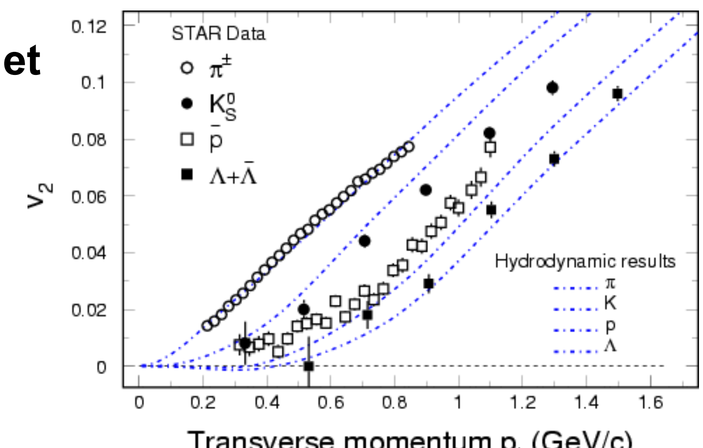


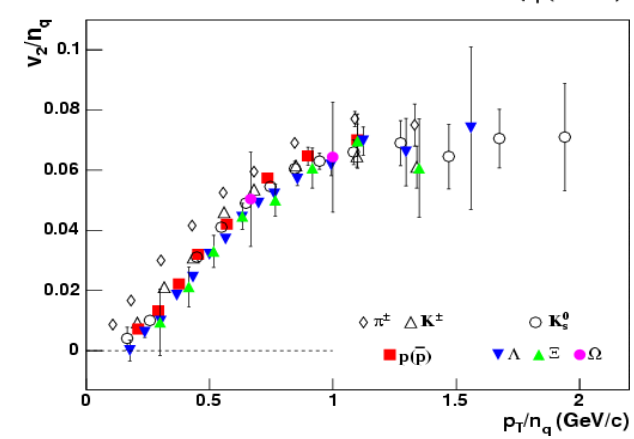






- hadron suppression
- vanishing away-side jet
- hydro. elliptic flow
- partonic elliptic flow
- charm elliptic flow
- J/ψ suppression
- thermal radiation





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RHIC press release (April 18th 2005), 4 years of QGP studies @ RHIC

RHIC Scientists Serve Up "Perfect" Liquid

New state of matter more remarkable than predicted -- raising many new questions

April 18, 2005

TAMPA, FL -- The four detector groups conducting research at the Relativistic Heavy Ion Collider (RHIC) -- a giant atom "smasher" located at the U.S. Department of Energy's Brookhaven National Laboratory -- say they've created a new state of hot, dense matter out of the quarks and gluons that are the basic particles of atomic nuclei, but it is a state quite different and even more remarkable than had been predicted. In peer-reviewed papers summarizing the first three years of RHIC findings, the scientists say that instead of behaving like a gas of free quarks and gluons, as was expected, the matter created in RHIC's heavy ion collisions appears to be more like a *liquid*. $\Rightarrow$ **sQGP**

"Once again, the physics research sponsored by the Department of Energy is producing historic results," said Secretary of Energy Samuel Bodman, a trained chemical engineer. "The DOE is the principal federal funder of basic research in the physical sciences, including nuclear and high-energy physics. With today's announcement we see that investment paying off."

Secretary of Energy Samuel Bodman

"The truly stunning finding at RHIC that the new state of matter created in the collisions of gold ions is more like a liquid than a gas gives us a profound insight into the earliest moments of the universe," said Dr. Raymond L. Orbach, Director of the DOE Office of Science.

Also of great interest to many following progress at RHIC is the emerging connection between the collider's results and calculations using the methods of string theory, an approach that attempts to explain fundamental properties of the universe using 10 dimensions instead of the usual three spatial dimensions plus time.

"The finding of a nearly perfect liquid in a laboratory experiment recreating the conditions believed to have existed a few microseconds after the birth of the universe is truly astonishing," said Praveen Chaudhari, Director of Brookhaven Lab. "The four RHIC collaborations are now collecting and analyzing very large new data sets from the fourth and fifth years of operation, and I expect more exciting and intriguing revelations in the near future."

http://www.bnl.gov/rhic

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So why going for the QGP @ LHC?

assumption: QGP has been established @ RHIC prior to LHC

SEARCH for the QGP may be essential over

DISCOVERY of the QGP is well under way

MEASURING QGP parameters has hardly begun

QGP @ LHC versus RHIC = Z/W @ LEP versus SppS

the LHC is the ideal place for studying the QGP (next slide)

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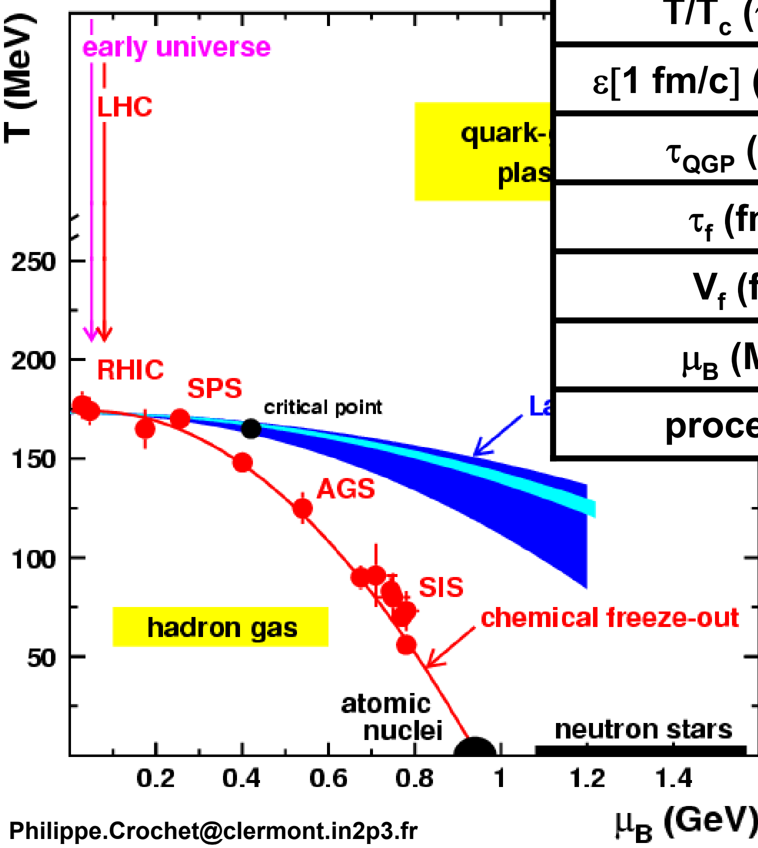
adapted from J. Schukraft @ Split06

Heavy ion collisions & QGP @ LHC

the biggest step in energy in the history of heavy-ion collisions

machine	SPS	RHIC	LHC	
$\sqrt{s}$ (GeV)	17	200	5500	
N_{ch}	1000	4000	50 000	
τ^0_{QGP} (fm/c)	1	0.2	0.1	⇒ faster
T/T_c (τ^0_{QGP})	1.1	1.9	3.0-4.2	⇒ hotter
ε[1 fm/c] (GeV/fm³)	3	5	15-60	⇒ denser
τ_{QGP} (fm/c)	$\leq$ 2	2-4	$\geq$ 10	⇒ longer
τ_f (fm/c)	~ 10	20-30	30-40	
V_f (fm³)	~ 10^3	~ 10^4	~ 10^5	⇒ bigger
μ_B (MeV)	250	20	1	⇒ cleaner
processes	soft →	semi-hard →	hard	⇒ harder



"...the LHC will become the ideal facility for a systematic exploration and quantitative confirmation of the insights obtained at RHIC, aided by the plentiful abundance of hard probes."

B. Müller, hep-ph/0410115

J. Schukraft, Nucl. Phys. A 698 (2002) 287

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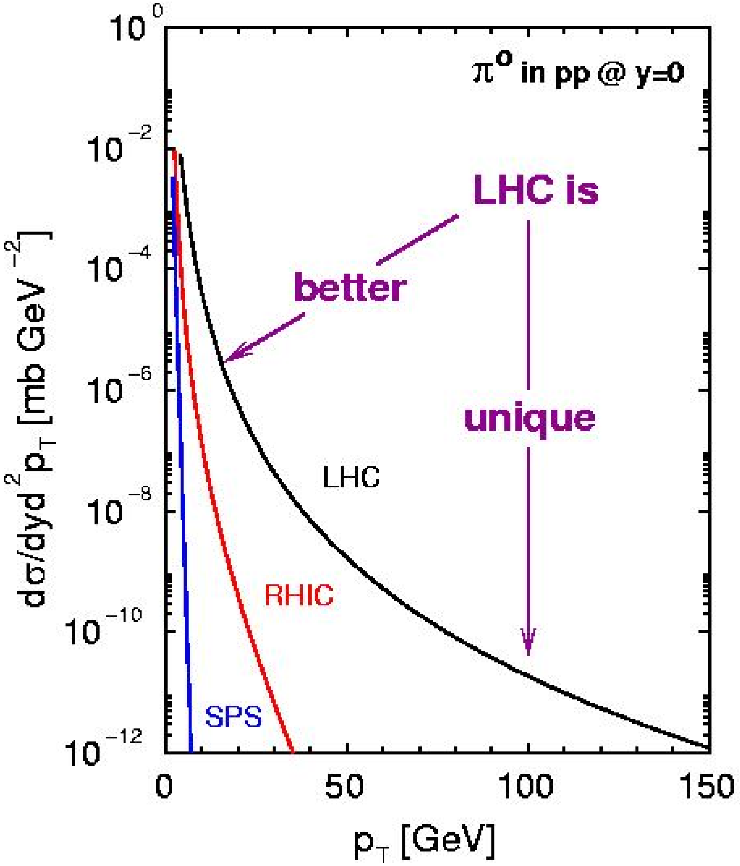
Hard processes: what is different @ LHC

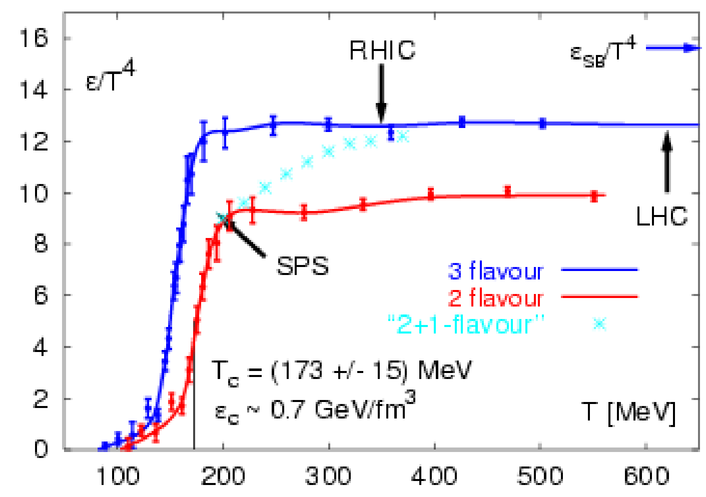
huge cross-section



$\sigma^{hard}/\sigma^{tot}$ = 2/50/98% @ SPS/RHIC/LHC

K. Kajantie, Nucl. Phys. A 715 (2003) 432

pQCD under better control



$$\sigma_{pp}^{hard} = O(\alpha_s) + O(\alpha_s^2) + O(\alpha_s^3) + \ldots$$

$$\alpha_s(T) \propto \frac{4\pi}{18\log(5T/T_c)} = \begin{matrix} 0.43 @ T = T_c \\ 0.23 @ T = 4T_c \end{matrix}$$

3/4/5th order terms are ~ 7/12/23 times smaller @ LHC than @ SPS

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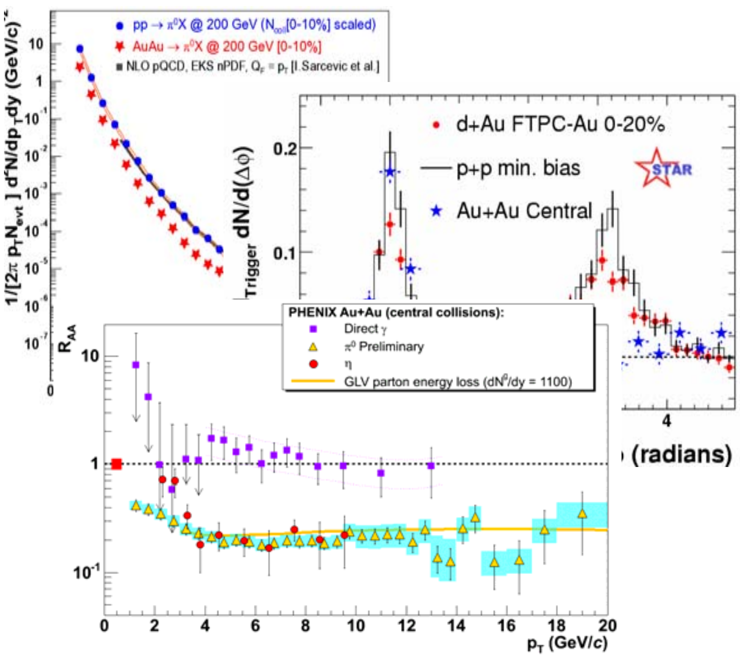
Jets: what is different @ LHC

RHIC-like analyses — **20** — **Tevatron-like analyses** — **200** — E_t (GeV)

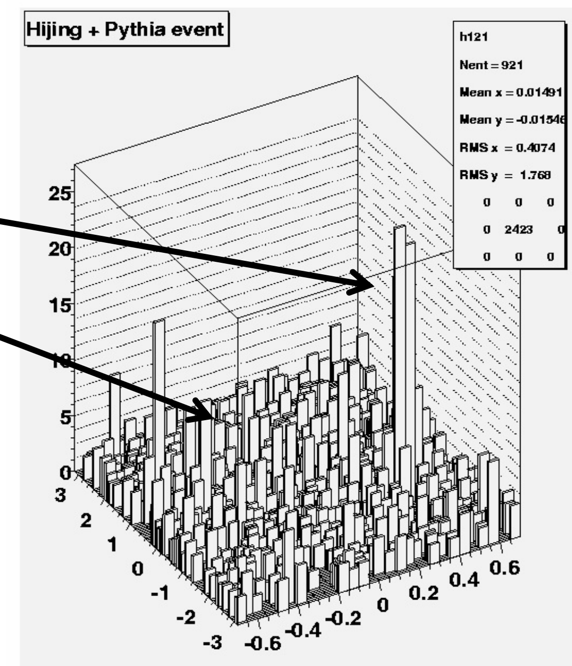
inclusive distributions



dN/dp$_t$, R$_{AA}$, R$_{cp}$, ΔΦ with unlimited statistics

evt-by-evt reconstruction

100 GeV jet (PYTHIA)
PbPb (HIJING)



- jet energy
- parallel & perpendicular momentum dist.
- tagging with photons
- fragmentation functions

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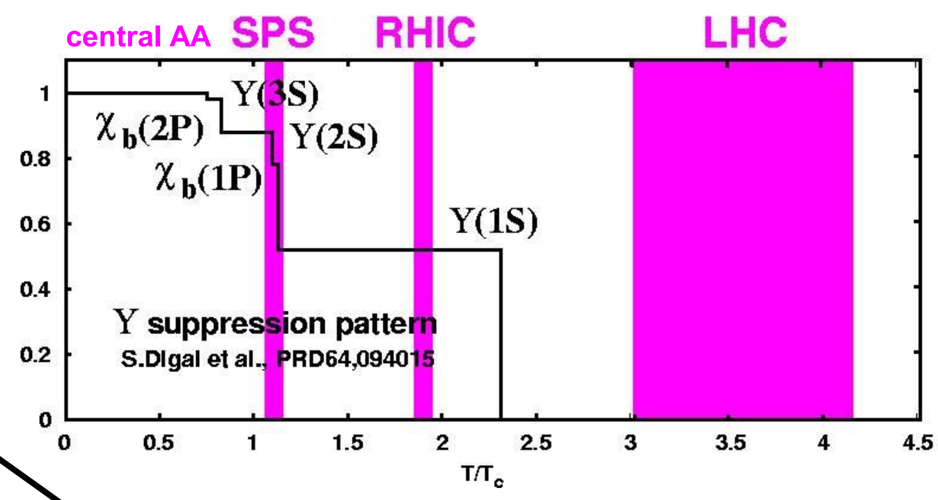
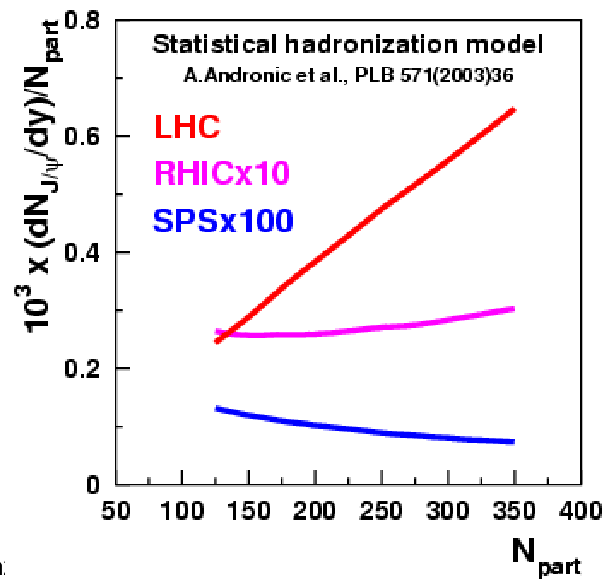
Heavy flavors: what is different @ LHC

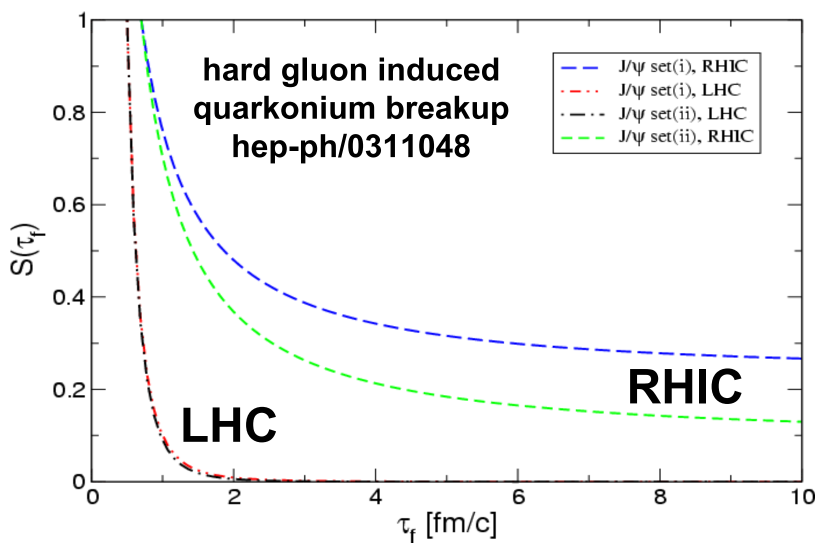
N($q\bar{q}$) per central AA (b=0)	SPS	RHIC	LHC
charm	0.2	10	130
bottom	---	0.05	5

- large primary production
- melting of $\Upsilon(1S)$ by color screening
- none of the primary J/ψ survives the (PbPb)QGP
- a lot of charmonia from b hadron decay
- large secondary production of charmonia

statistical hadronization, kinetic recombination, DDbar annihilation







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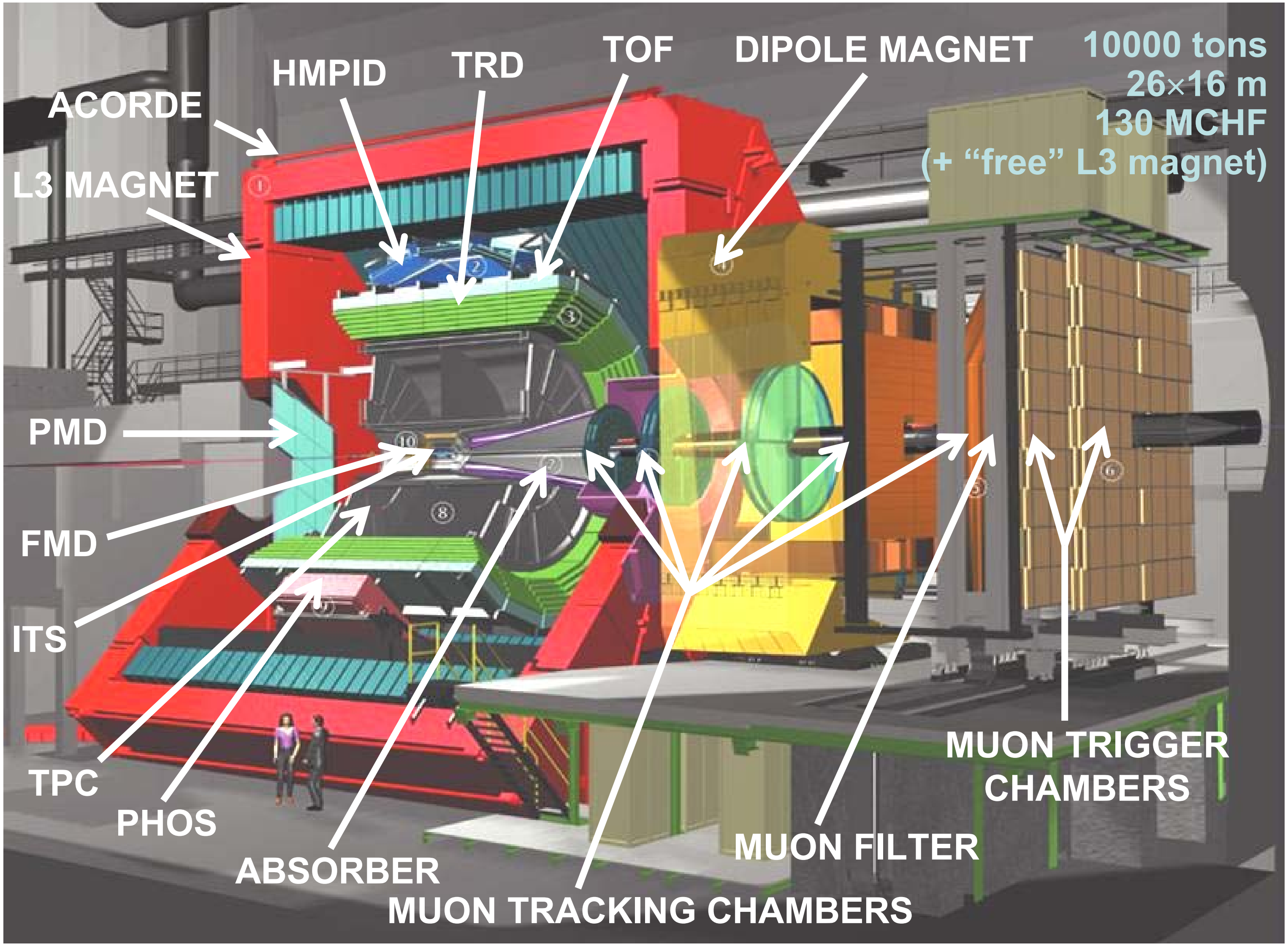
ALICE (A Large Ion Collider Experiment)



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ALICE shopping list

time →

hard scattering	deconfinement	hadronization	freeze-out
• hard photons ⇨ pQCD • heavy flavors ⇨ pQCD • jets ⇨ pQCD	• thermal photons ⇨ QGP temperature • heavy flavors ⇨ QGP properties • jet quenching ⇨ QGP density	• EbyE fluctuations ⇨ critical behavior • l.m. dilepton, DCC ⇨ chiral symmetry • exotica ⇨ QGP condens.	• particle yields, spectra, flow & HBT ⇨ thermal & chemical conditions ⇨ dynamical evol. ⇨ indirect info from the early stage

p_t ←

ALICE is designed to explore a broad p_t range and to correlate most of the signals

large acceptance & granularity, selective triggers, good tracking capabilities, wide momentum coverage, good secondary vertex reconstruction, hadron, lepton & photon id.

soft sector: observables & expected performances comparable to that of RHIC
hard sector: new observables, new analyses

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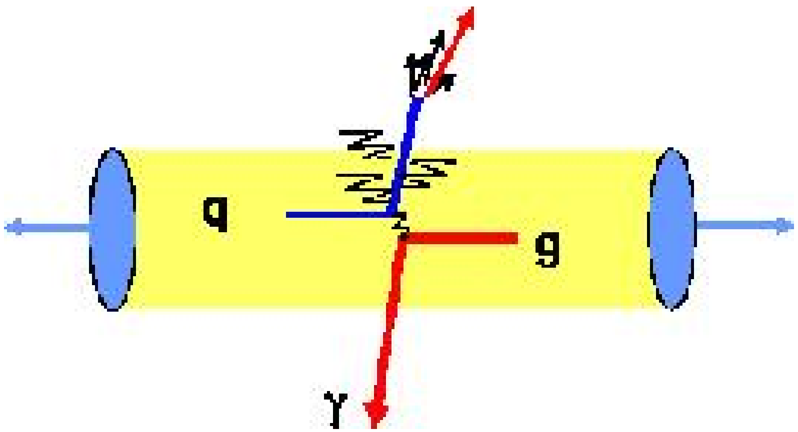
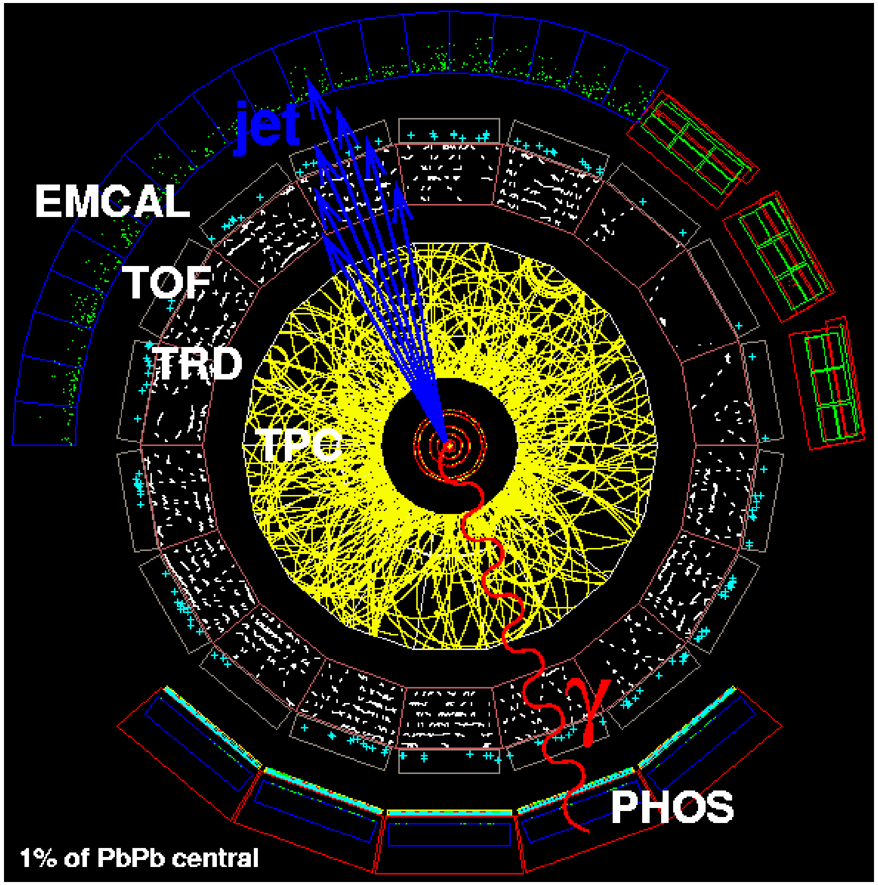
γ-jet correlations

direct calibration of jet quenching

mesure jet quenching



mesure parton initial energy



combination of PHOS, EMCAL, particle tracking & Id. allows to get jet trigger, energy loss, particle composition, transverse structure & fragmentation function down to low p_t

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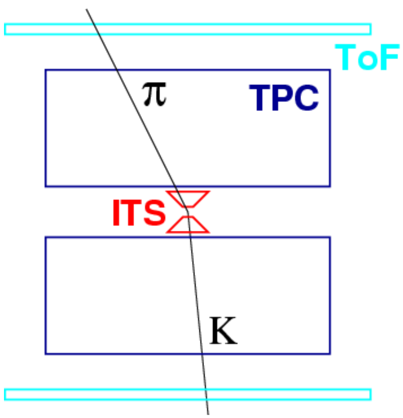
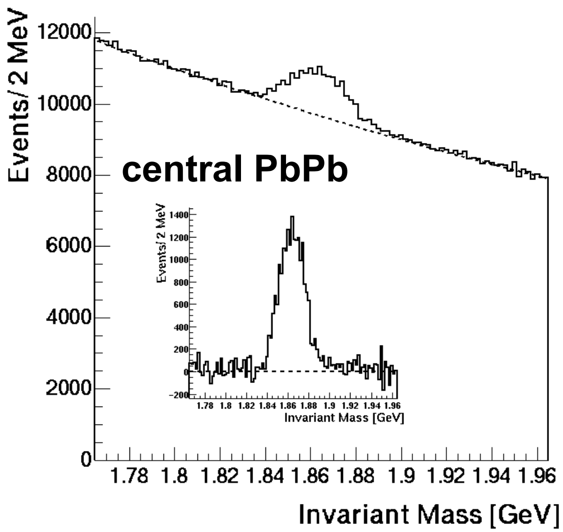
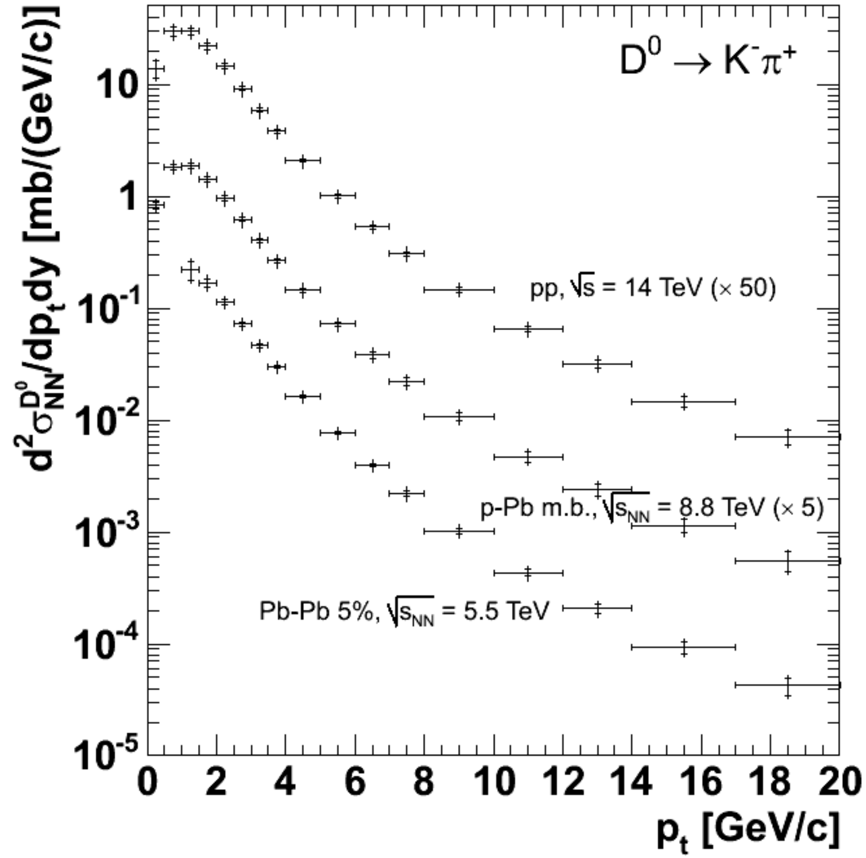
Hadronic charm

$D^0 \to K\,\pi$ (3.8%), $c\tau$ = 123 μm







10^7 central PbPb (5%)

- **S ~ 13000**
- **S/B ~ 10 %**
- **S/√(S+B) ~ 40**

- **accessible p_t range down to 1(0) GeV/c in PbPb(pp)**
- **background assumes $dN/d\eta$ = 6000 @ η = 0 in PbPb**
- **the most precise measurement of the total charm x-section in pp collisions @ LHC**
- **the ideal tool to study c quark energy loss in AA collisions**

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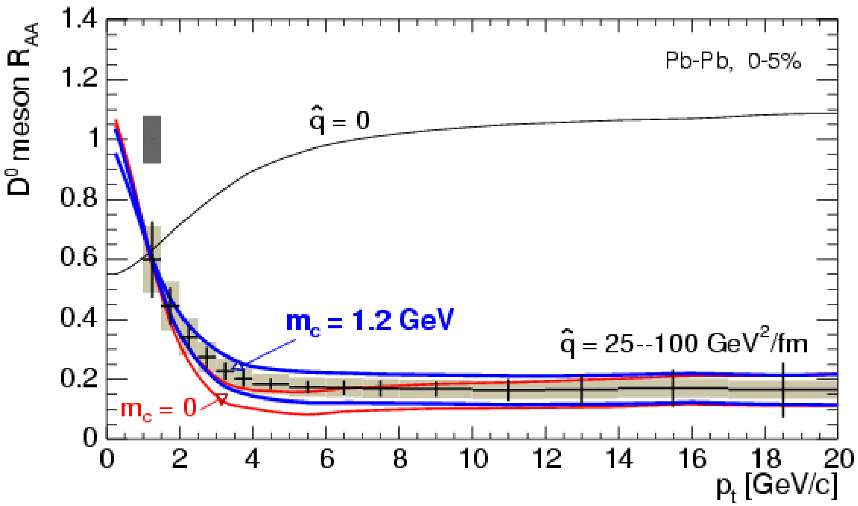
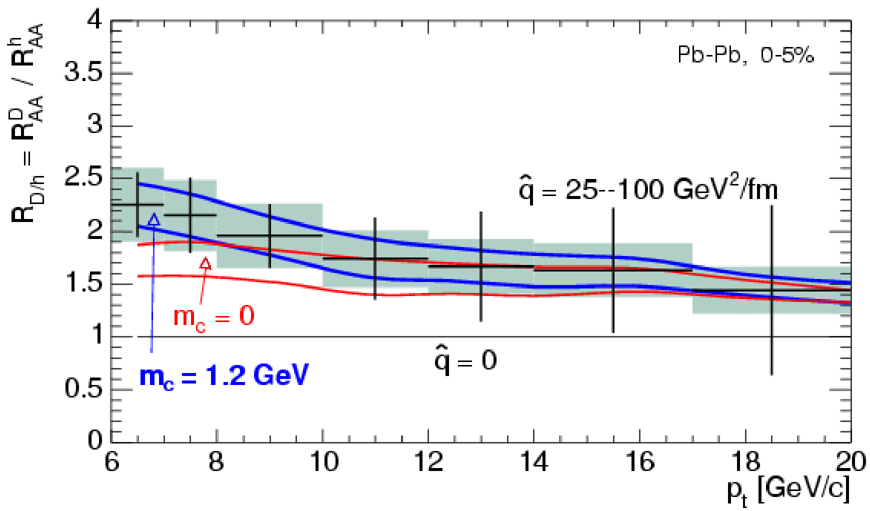
ALICE PPRVII, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

Charm quenching

$$R^D_{AA}(p_t) = \frac{1}{N_{coll}} \times \frac{dN^D_{AA}/dp_t}{dN^D_{pp}/dp_t}$$

$$R_{D/h}(p_t) = R^D_{AA}(p_t) / R^h_{AA}(p_t)$$





- R^D_{AA} sensitive to shadowing for $p_t < 7$ GeV/c & to energy loss for $p_t > 7$ GeV/c
- $R_{D/h}$ has small systematic uncertainties (double ratio)

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E-loss: N. Armesto et al., PRD 71 054027

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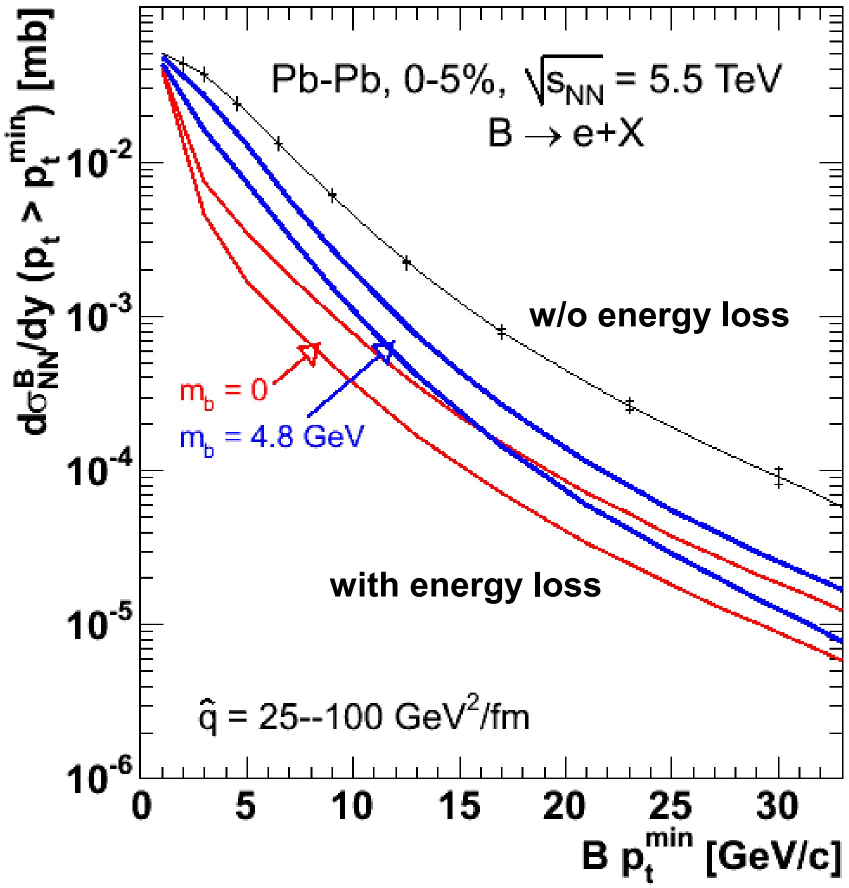
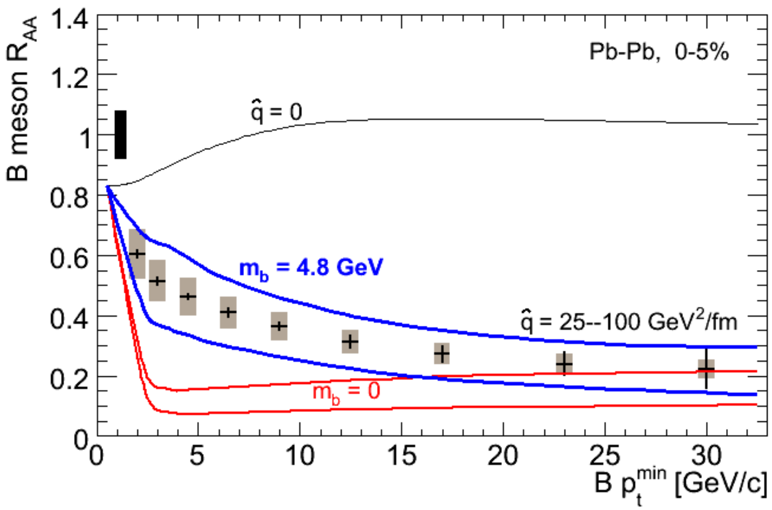
b-hadron inclusive differential cross-section from single electrons



UA1 analysis method used by CDF & D0, applied here to central PbPb (5%) with scenario for b-quark energy loss

- **electrons with $2 < p_t < 20$ GeV/c → b-hadrons with $2 < p_t^{min} < 30$ GeV/c**
- **gives direct access to $R_{AA}^{b\text{-hadrons}}$**
- **R_{AA}^{h}, R_{AA}^{D0} & $R_{AA}^{b\text{-hadrons}}$ will be measured simultaneously**



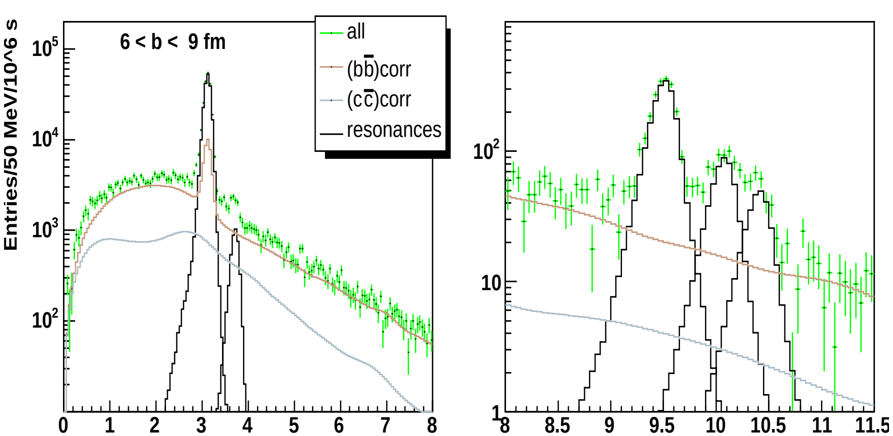
a nice illustration that one can apply Tevatron-like analyses in PbPb collisions @ the LHC

ALICE PPRVII, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295
E-loss: N. Armesto et al., PRD 71 054027

Quarkonia:
expected statistics in the muon channel

		J/ψ	ψ’	ϒ	ϒ’	ϒ’’
PbPb MB 5.5 TeV	S ($\times 10^3$)	681.4	18.92	6.33	1.8	1.02
	S/B	0.33	0.02	2.46	1.03	0.74
	S/√S+B	413	19.53	67.14	30.19	20.85
pp 14 TeV	S ($\times 10^3$)	4670	122	44.7	11.4	6.9
	S/B	12.6	0.55	5.8	1.9	1.3
	S/√S+B	2081	209	195	86	62

PbPb: 10^6s, $5{\cdot}10^{26}$cm^{-2}s^{-1}, pp: 10^7s, $5{\cdot}10^{30}$cm^{-2}s^{-1}



from PbPb MB to pp, a factor ~ 10 more stat.

- J/ψ: large stat., good significance
- ψ’: small S/B
- ϒ: good stat., S/B > 1, good significance
- ϒ’: good stat., S/B > 1, good significance
- ϒ’’: low statistics (need 2-3 runs)

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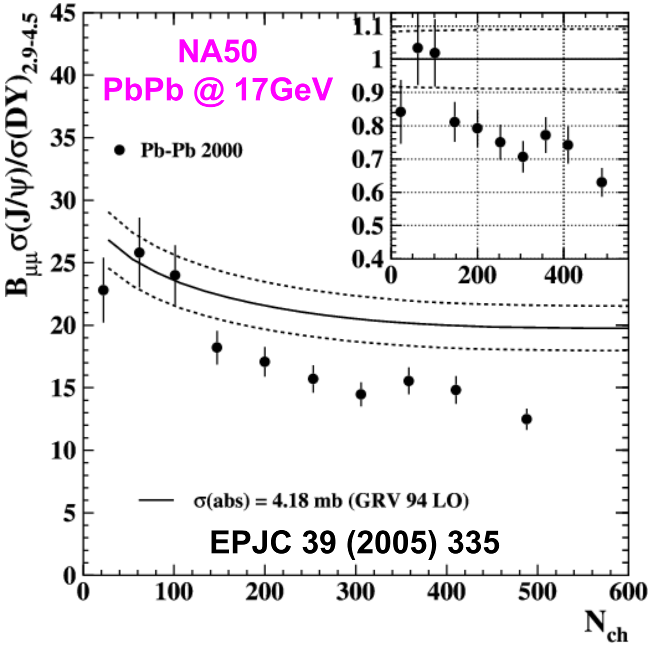
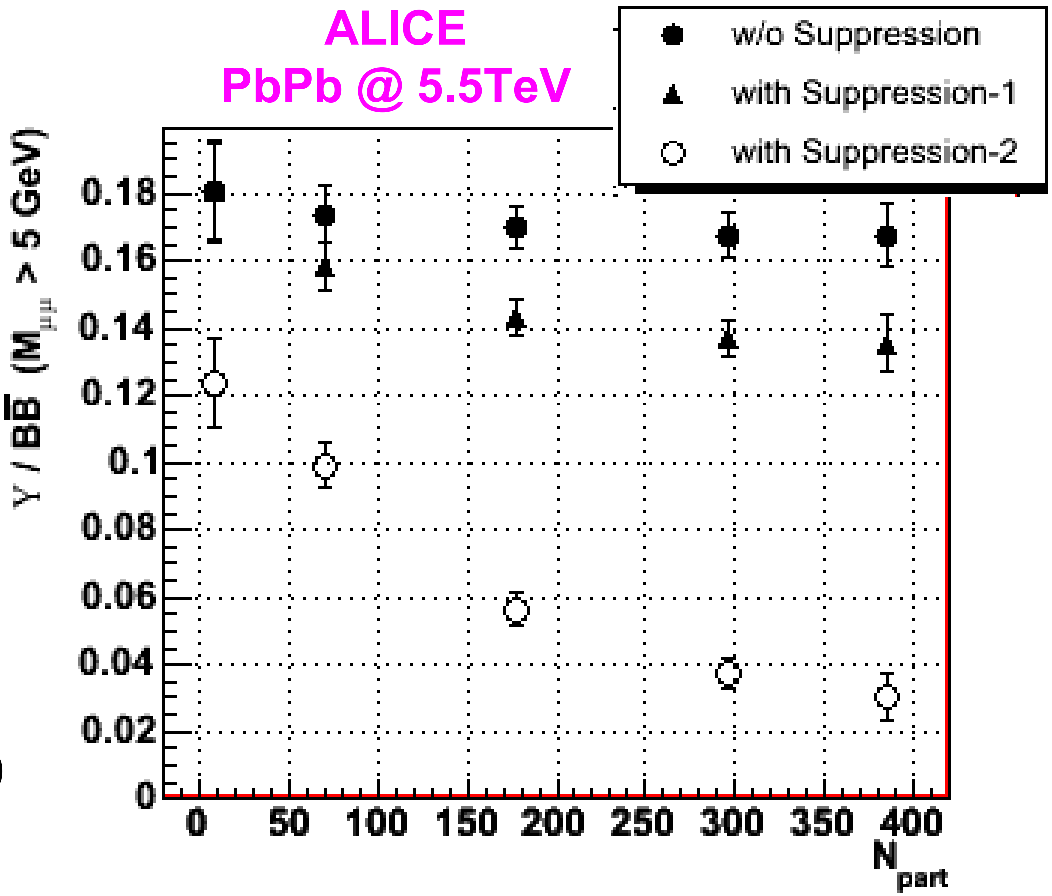
From NA50's (J/ψ)/DY to ALICE's ϒ/bbbar





- statistics: one month PbPb
- σ(b) extracted à la UA1, CDF, D0
- statistics of the reference is in 5<M<20GeV ~5 times larger than that of the probe

ALICE PPRVII, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295
dissociation temperatures: C.-Y. Wong, PRC 72 034906 & W.M. Alberico et al., PRD 72 114011

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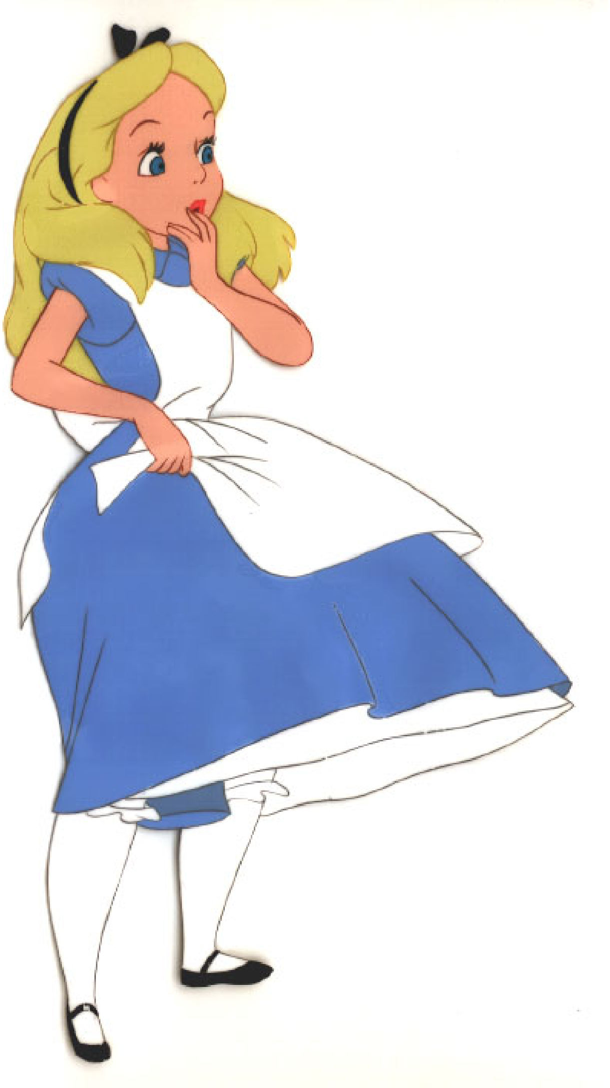
Summary



the ALICE physics program ensures a bright future for heavy ion collisions at LHC with precision measurements and unique analyses

more details in ALICE Physics Performance Reports
J. Phys. G: Nucl. Part. Phys. 30 (2004) 1517
J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

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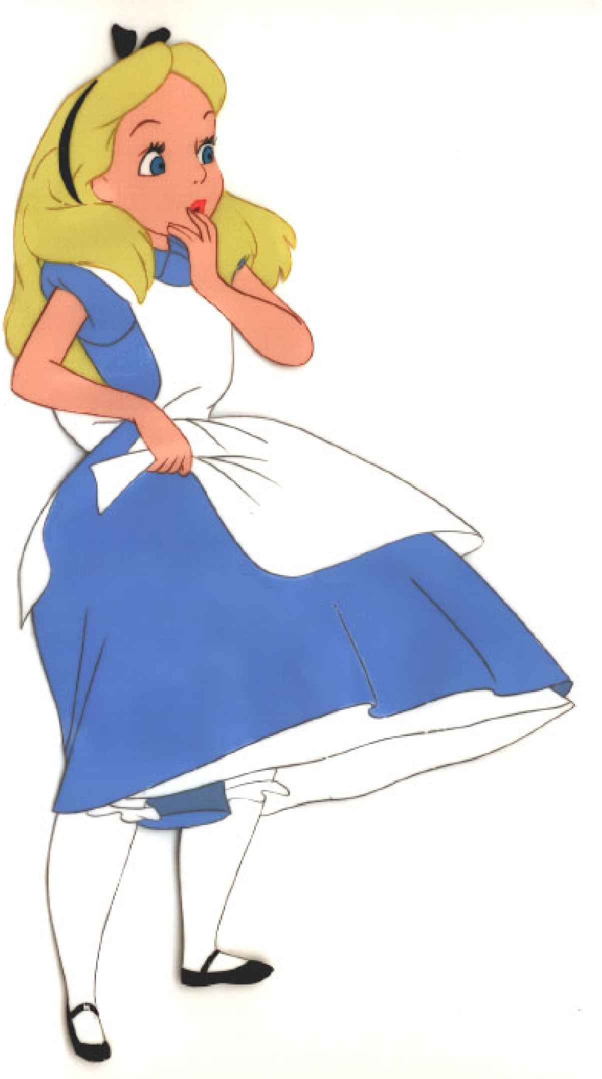
French participation in ALICE



- labs & manpower
- detectors & electronics
- online, offline & physics
- computing

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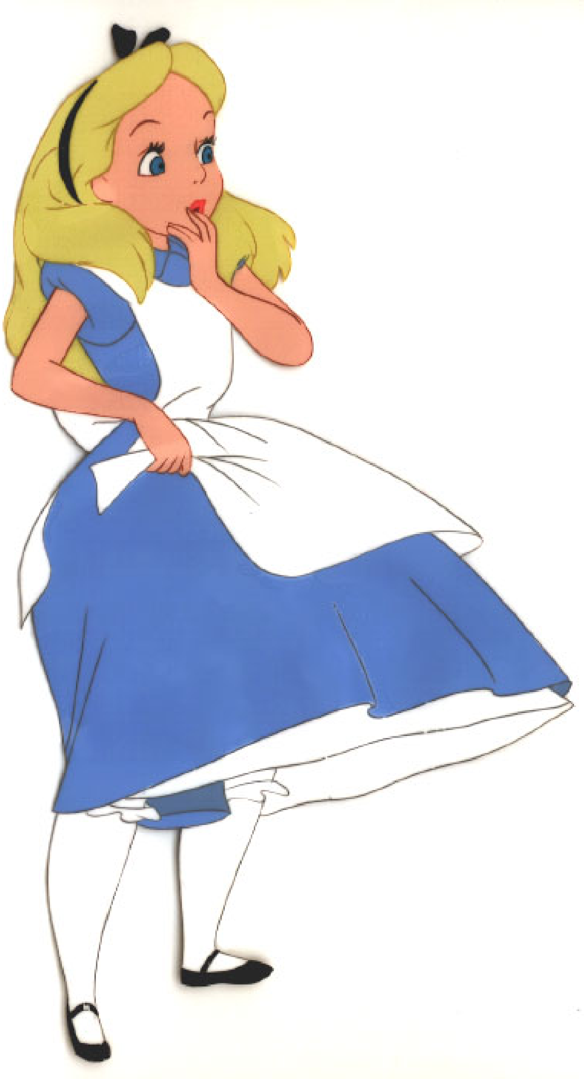
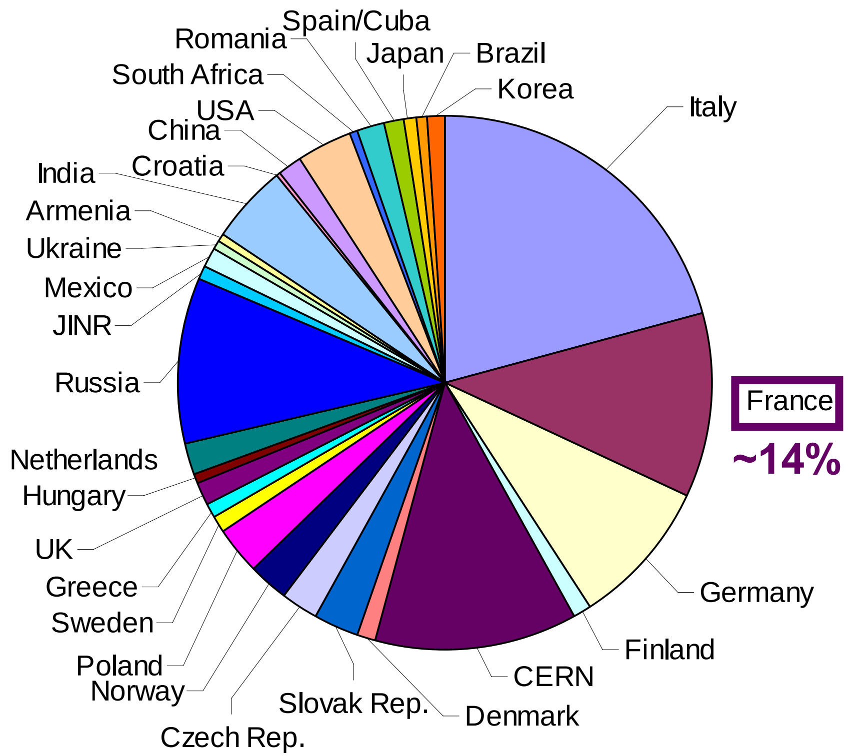
ALICE collaboration:
1015 members, 90 institutes, 30 countries





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Labs & manpower

- 7 labs
- 42 physicists (28.1 FTE)
- 98 tech. staff (53.4 FTE)
- budget ~ 7 MEuros

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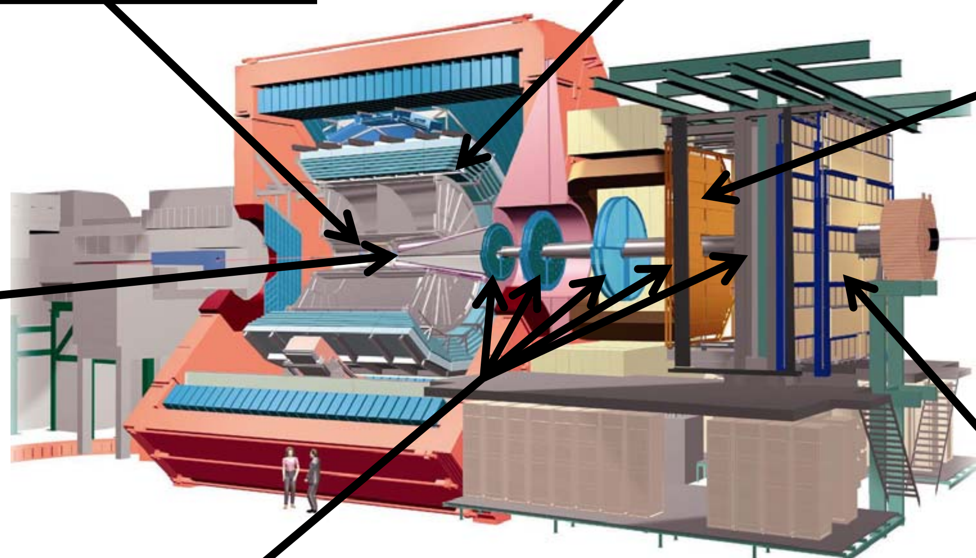
French participation in ALICE: overview

ITS-SSD
IPHC, SUBATECH
(+ CERN, Finland, Italy, Netherlands, Poland, Russia, Ukraine)

EMCAL* (not shown)
IPHC, LPSC, SUBATECH
(+ Italy, USA) *R&D

MUON-GMS
IPNL, LPSC
(+ Armenia)

V0C
IPNL
(+ Mexico)



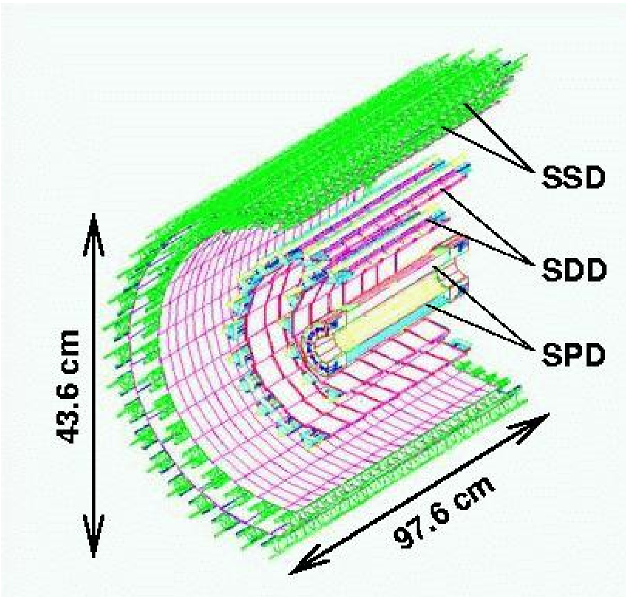
MUON-tracking
IPNO, SACLAY, SUBATECH
(+ India, Italy, Russia, South Africa)

MUON-trigger
LPC, SUBATECH
(+ Italy)

+ online, offline, physics, computing

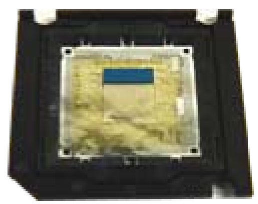
ITS-SSD: IPHC, SUBATECH

(+ CERN, Finland, Italy, Netherlands, Poland, Russia, Ukraine)

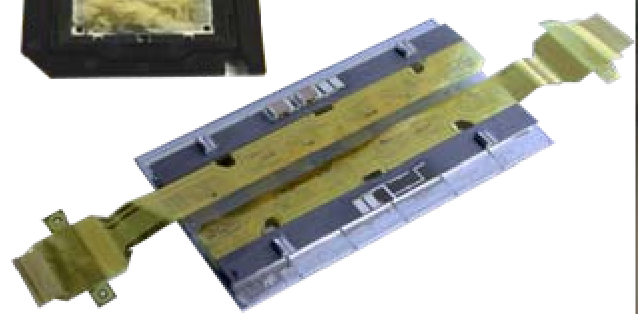


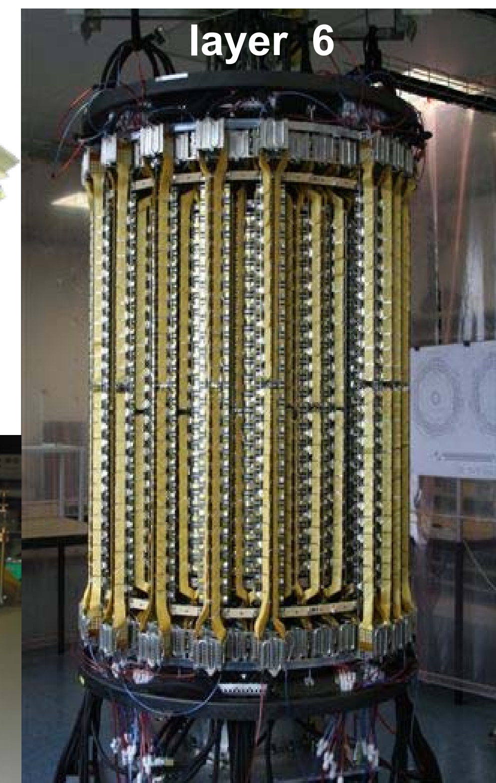
trigger, pid at low p_t,
multiplicity, 1st & 2nd vertices

detector	surface	channels
SSD (strip)	4.9 m^2	2.6 M
SDD (drift)	1.3 m^2	1.33 k
SPD (pixel)	0.2 m^2	9.8 M

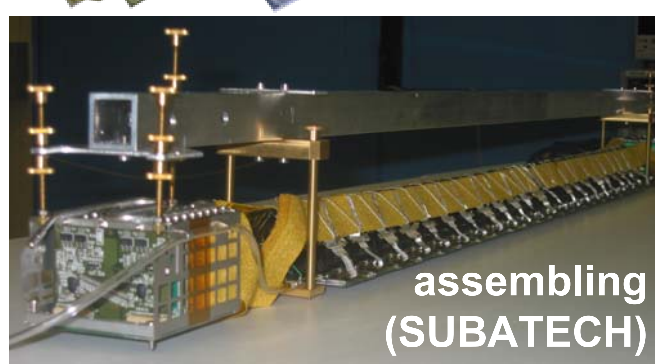


chip HAL25 & module (IPHC)





detector & electronics (500/2050 modules): production, tests, bonding, mounting, assembling



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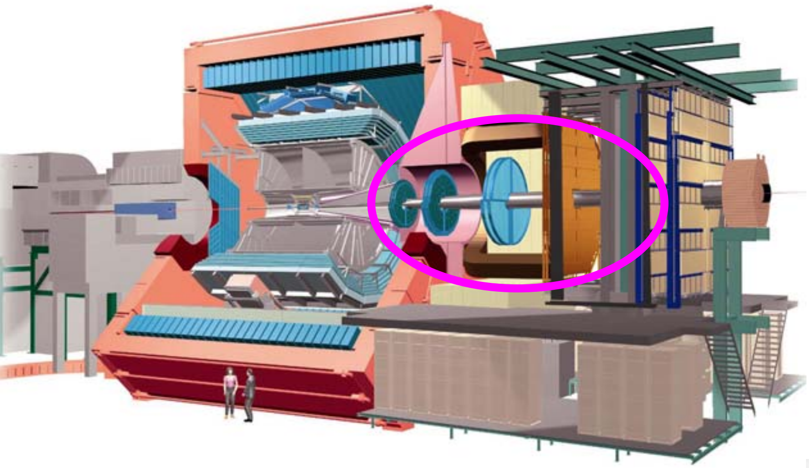
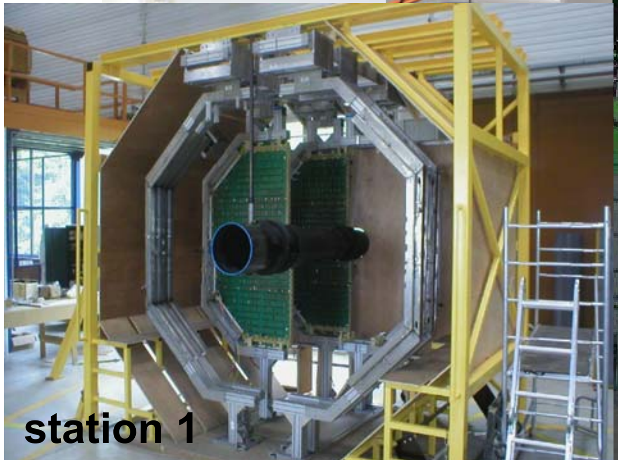
MUON-tracking: IPNO, SACLAY, SUBATECH
(+ India, Italy, Russia, South Africa)



- 10 planes (CSCs & CPCs)
- 100 m^2
- 1 M channels
- 19600 FEE boards

μ tracking with σ < 100 μm
i.e. σ(M) < 100 MeV @ 10 GeV



detectors, electronics, (super-)structure: R&D, construction, tests, mounting, installation

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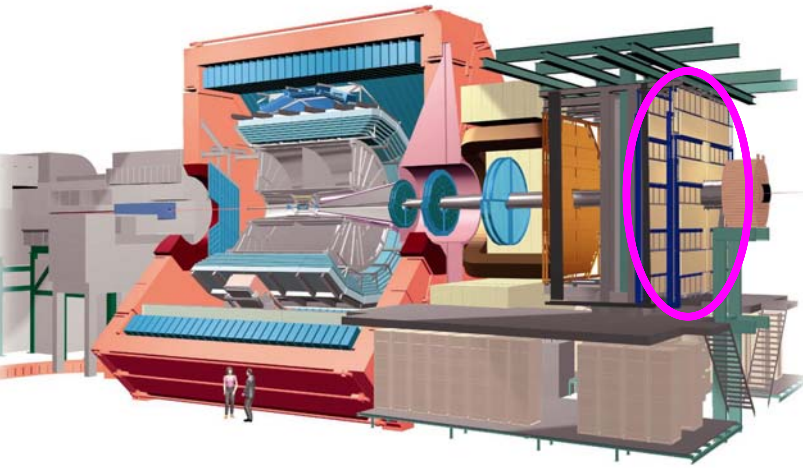
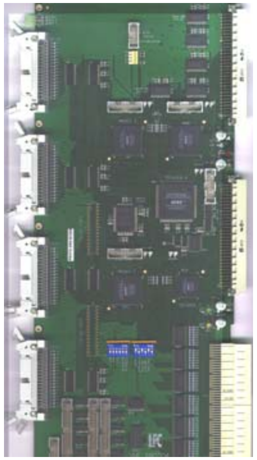
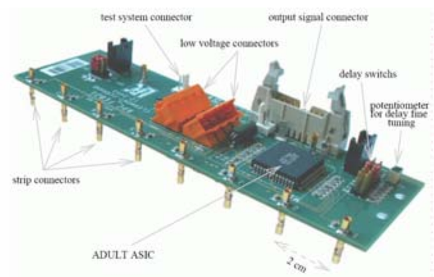
MUON-trigger: LPC, SUBATECH
(+ Italy)

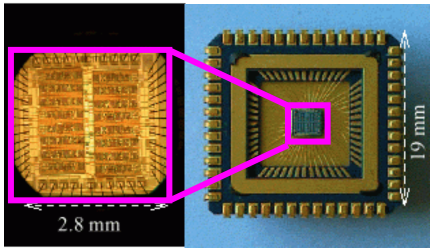


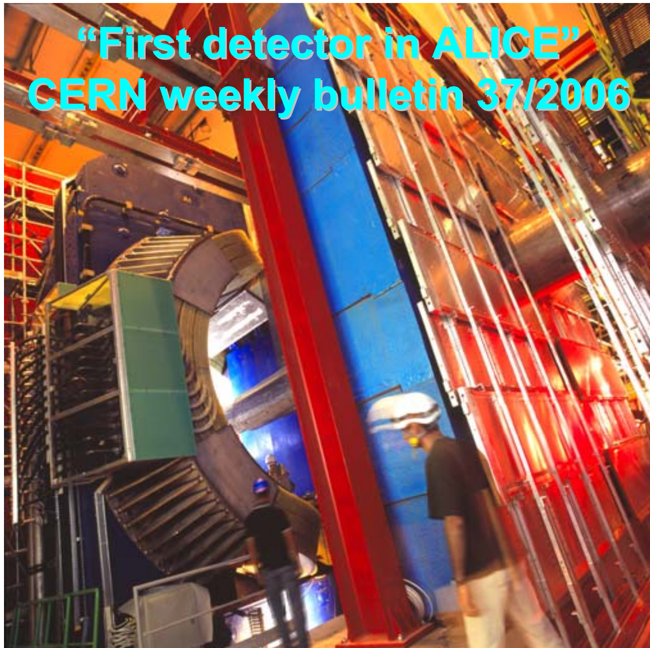
(di-)μ trigger with 2 p_t cuts in < 800 ns

- 4 planes (72 RPCs)
- 120 m^2
- 21000 channels
- 1500 cables (30km)
- 2500 FEE boards
- 234 L0 local trigger boards









FEE, L0 trigger electronics, cables, (super-)structure: R&D, construction, tests, installation

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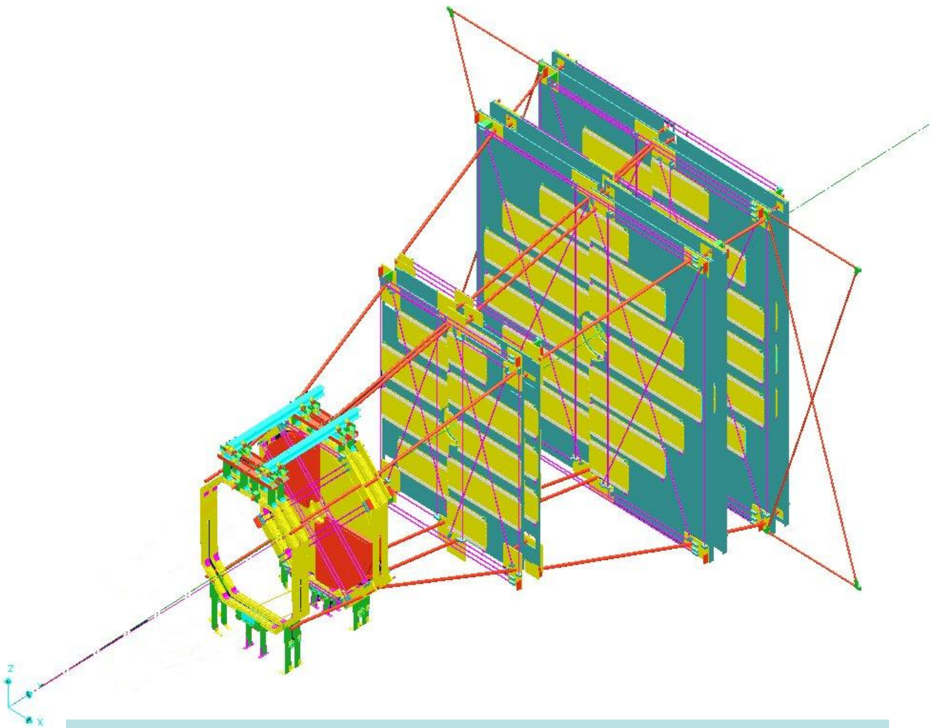
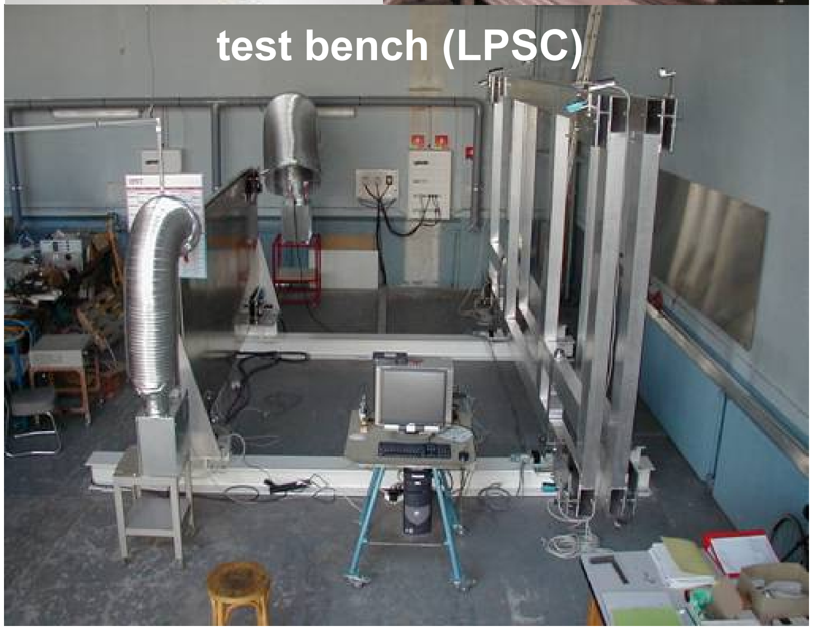
MUON-GMS: IPNL, LPSC
(+ Armenia)



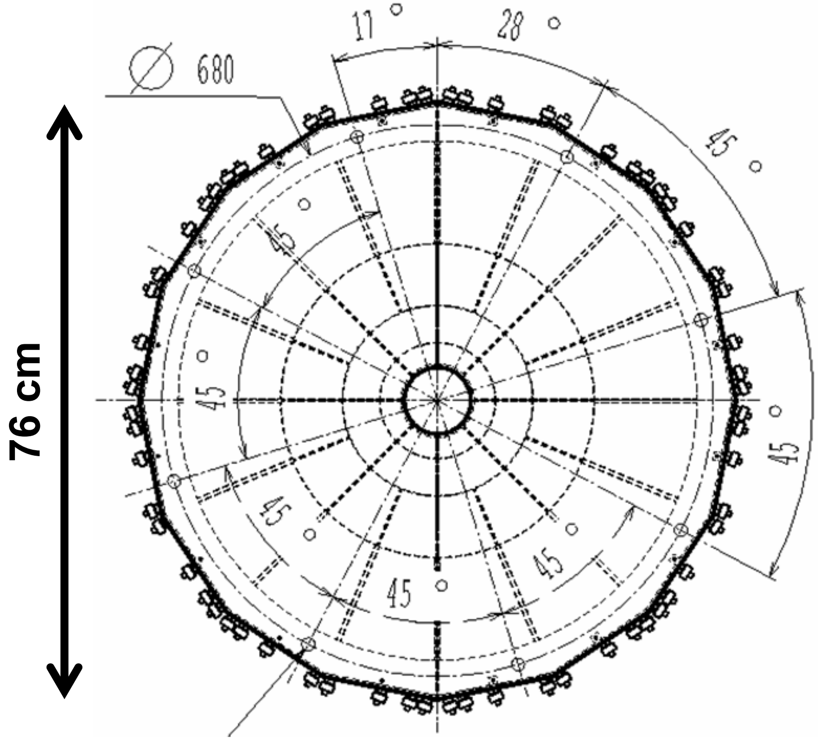
μ tracking chambers relative positions & deformations with < 50 μm

construction (supports), tests, integration

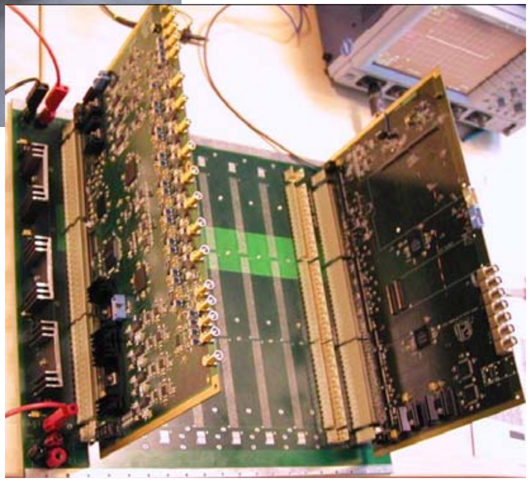
- 460 sensors (BCAM & PROXimity)
- 1128 images / measurement



V0C: IPNL
(+ Mexico)



- 32 scintillators
- 4 rings, 4 sectors
- time resolution < 1 ns



min-bias trigger for central barrel, veto beam-gas evts for MUON in pp collisions

R&D, construction, tests, integration

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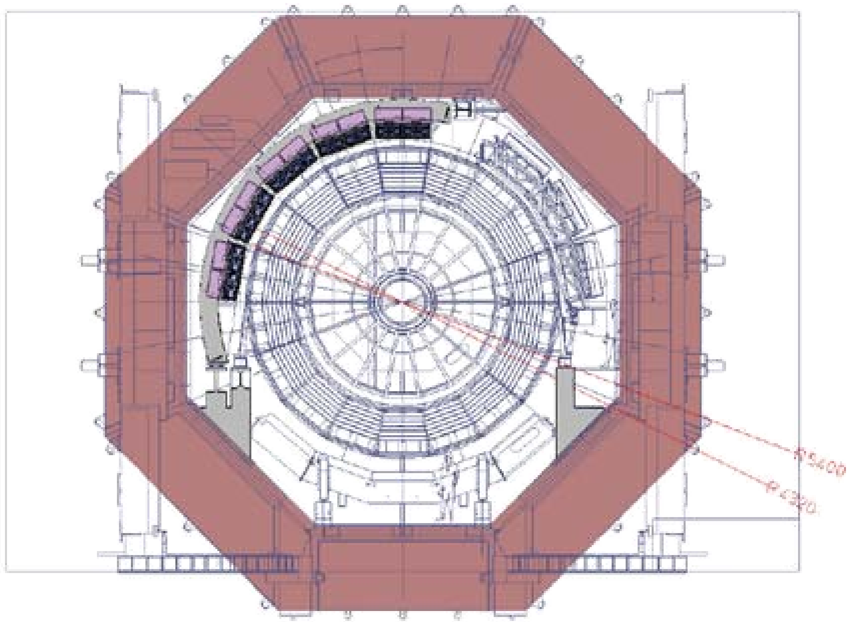
EMCAL: IPHC, LPSC, SUBATECH

(+ Italy, USA) only R&D so far



• 11 super-modules ($\Delta\eta/\Delta\phi$ = 1.4/110°)
• 13 k towers (Pb, scintillators)
• energy resolution: 12%/$\sqrt{E}$ + 2%

trigger, γ, π^0, η, jets, γ-jet correlations

supports & rails (SUBATECH)

3(/11) super-modules in Europe: construction & assembling integration, trigger, online, offline

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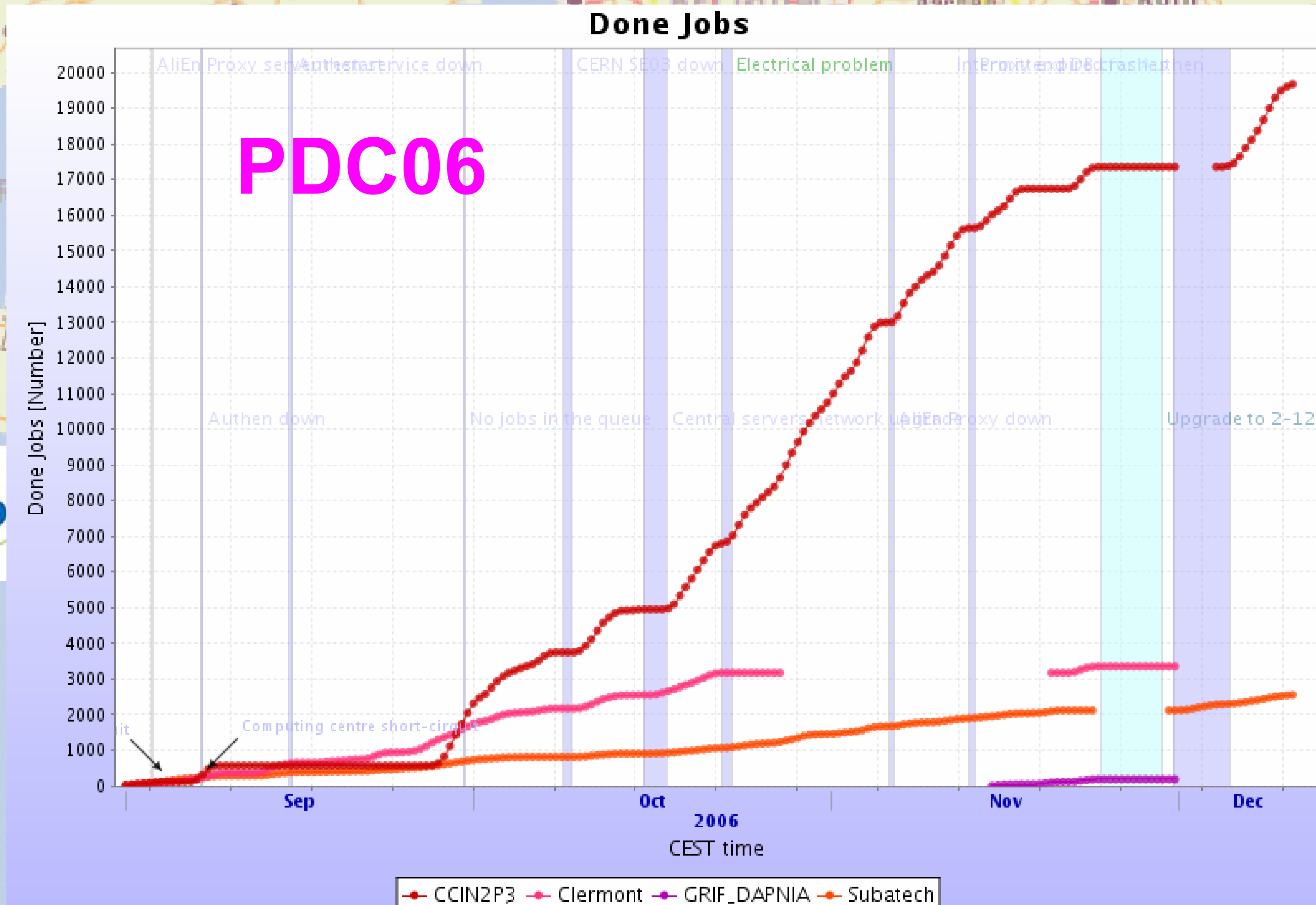
Online, offline, physics

- online:
  - MUON DAQ (IPNO, SUBATECH)
  - MUON monitoring (LPC, SACLAY)
  - DCS (IPHC, IPNL, IPNO, LPC)
- offline:
  - strong participation in code for sim. & rec. (e.g. MUON software)
  - strong participation in analysis code (e.g. V0 & cascade rec.)
- physics:
  - (co-)coordination of 3 of the 4 ALICE Physics Working Groups

    (soft physics, heavy flavours, high p_t & photons)
  - strong participation in physics simulations (e.g. PDC06)
- other responsabilities:

management board: 2/24, technical board: 5/39,
computing board: 5/31 + deputy, editorial board: 1/7, physics board: 3/11

Computing



- 1 Tier1 (Lyon)
- 4 Tier2 (Clt-Fd, Lyon, Nantes, Paris)
- 10% of ALICE total resources

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