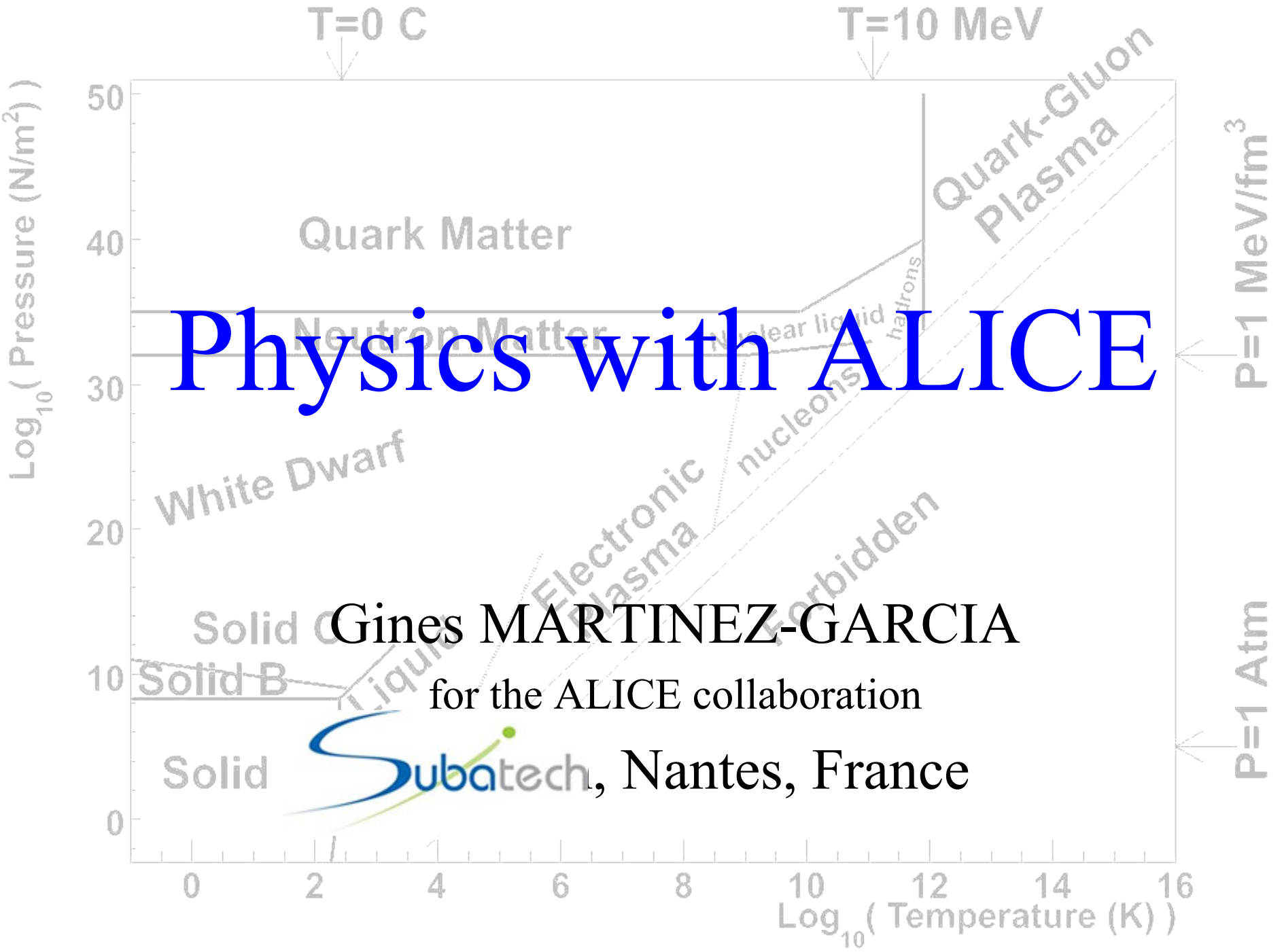
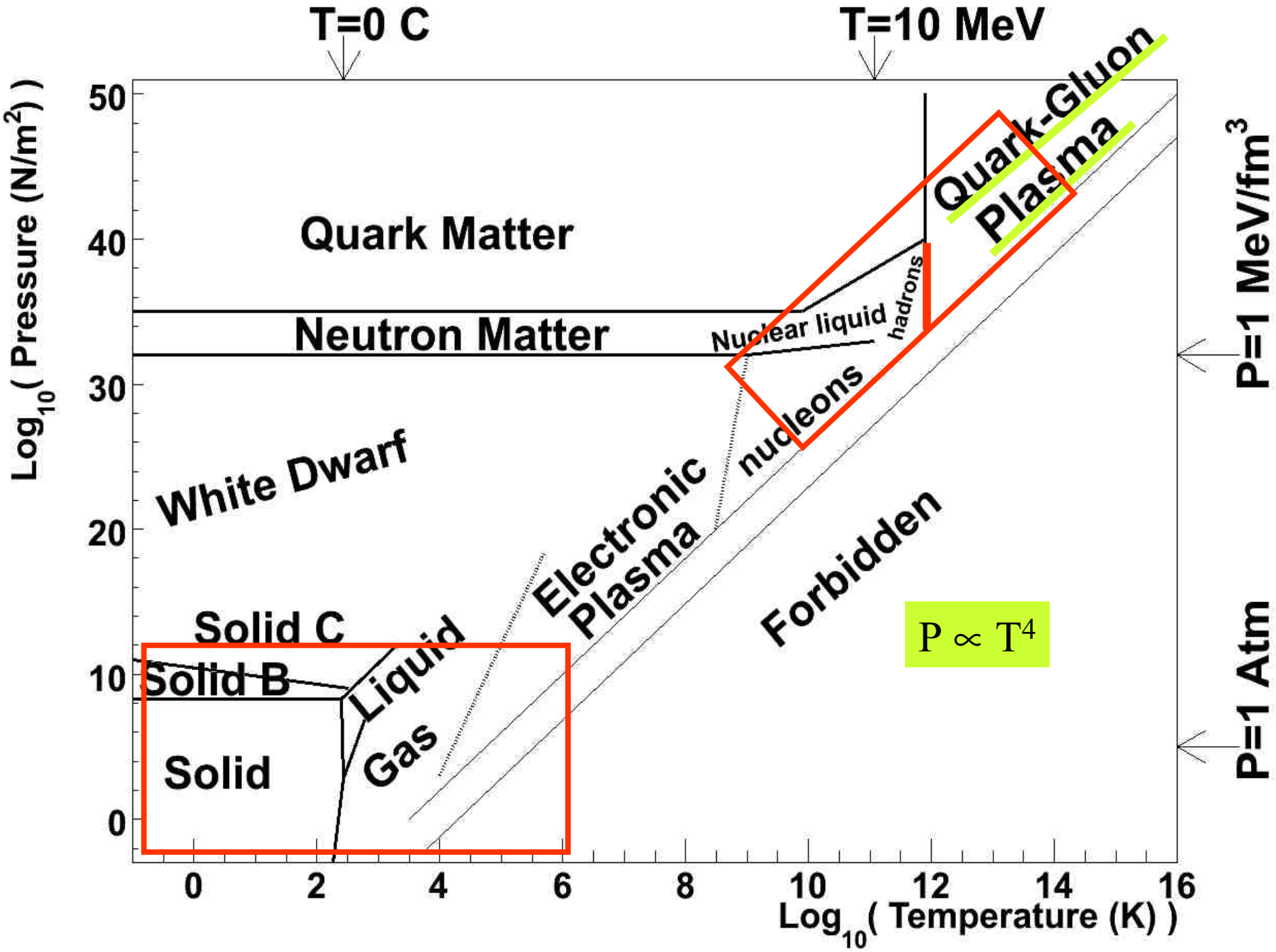


Physics with ALICE

Gines MARTINEZ-GARCIA

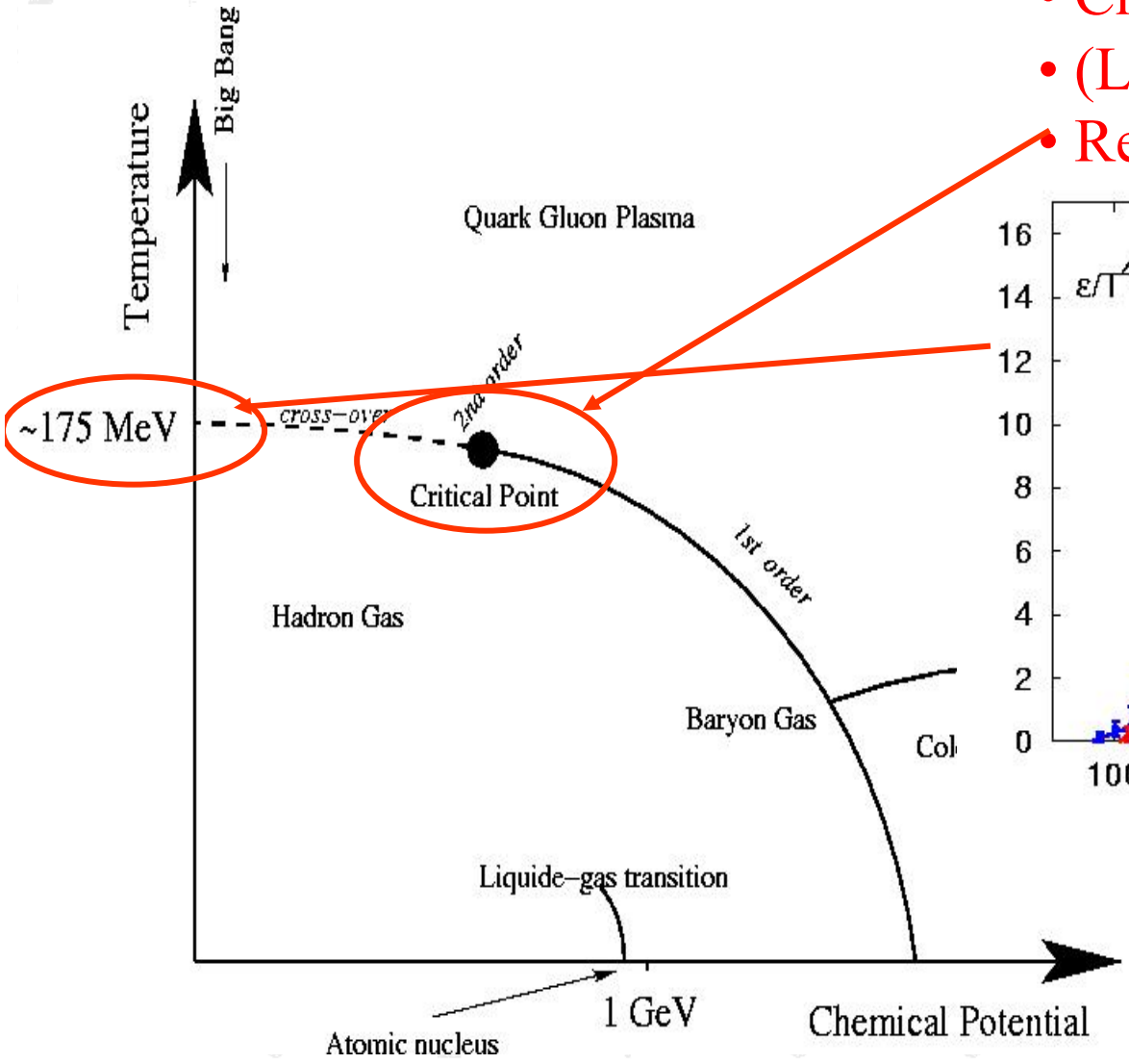
for the ALICE collaboration

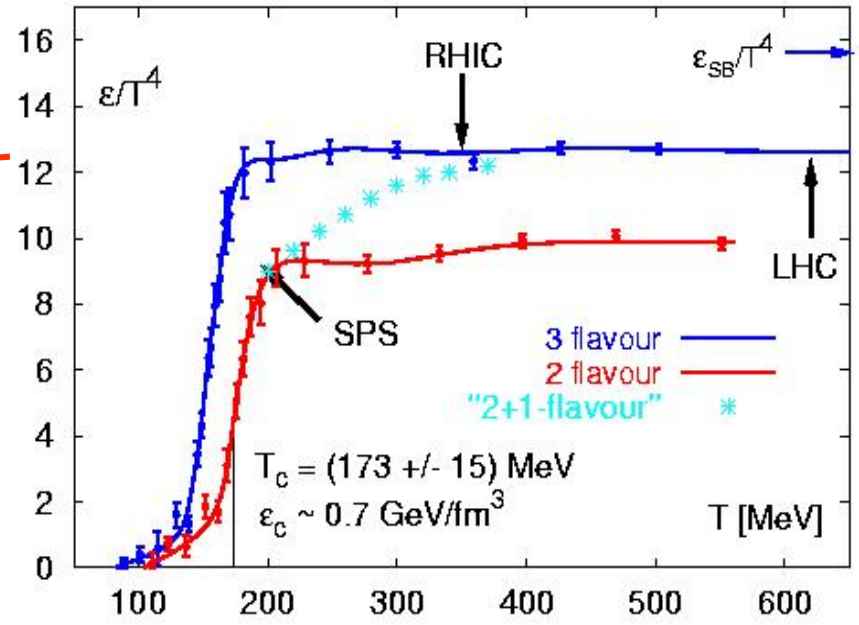
Subatech, Nantes, France

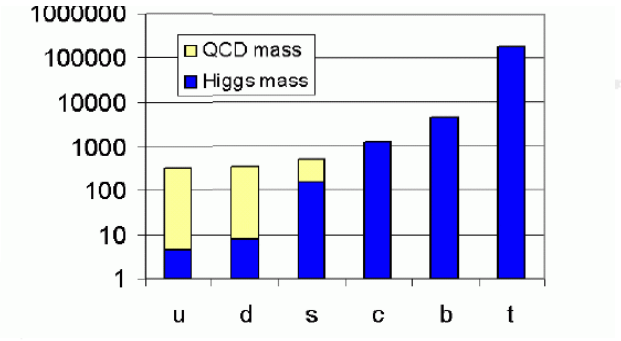

T=0 C
T=10 MeV
Quark-Gluon Plasma
Quark Matter
Neutron Matter
Nuclear liquid
hadrons
nucleons
White Dwarf
Electronic Plasma
Forbidden
Solid C
Solid B
Liquid
Gas
Solid
P ∝ T4
P=1 MeV/fm3
P=1 Atm
Log10(Pressure (N/m2))
Log10(Temperature (K))
0
10
20
30
40
50
0
2
4
6
8
10
12
14
16

Hadronic Matter Phase Diagram

- Chiral symmetry restoration
- (Lattice)QCD at $\mu_B=0$
- Recent calculations at $\mu_B \neq 0$



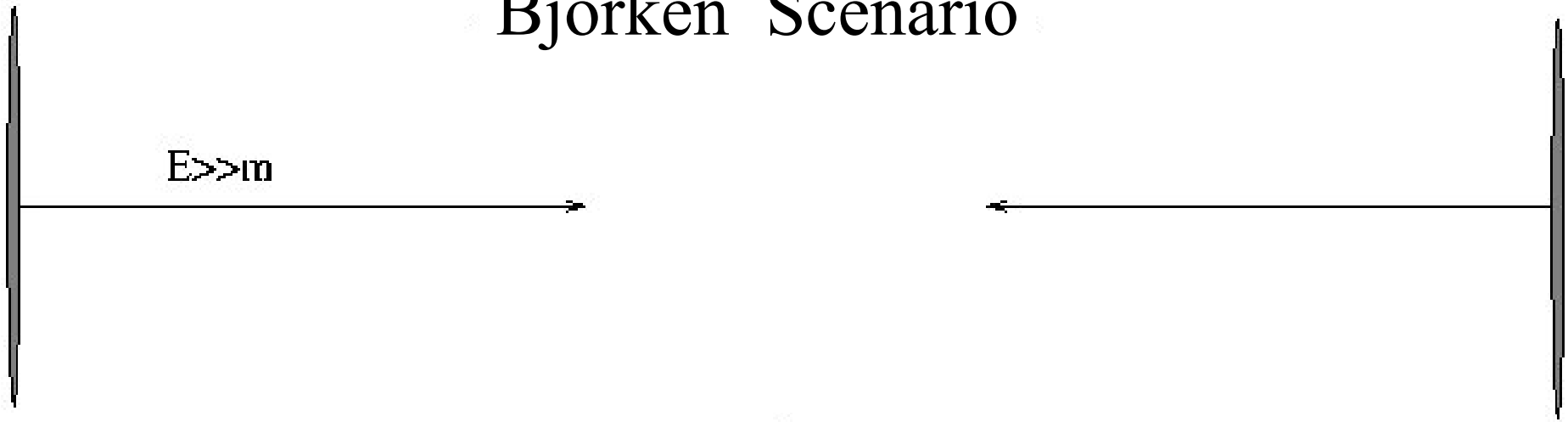




Heating matter at LHC

- Pb+Pb collision at 5.5A TeV (1.14 PeV = 0.2 mJ)
- Lorentz factor $\gamma \sim 2750$, $R_T \sim 7$ fm, $R_{||} \sim 0.002$ fm

Bjorken Scenario



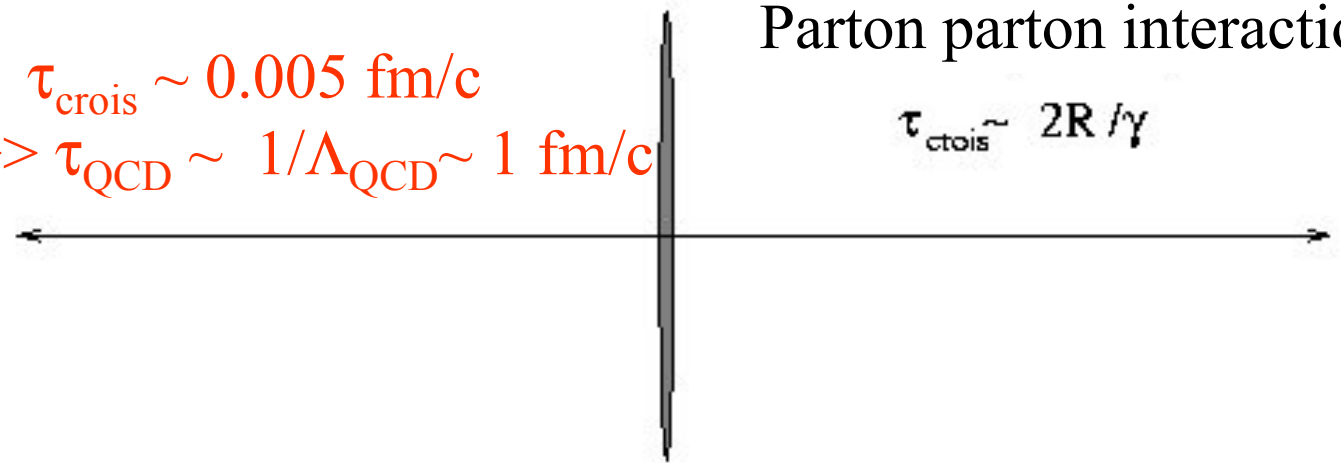
J.D. Bjorken PRD27_143_1983

Heating matter at LHC

- Pb+Pb collision at 5.5A TeV (1.14 PeV = 0.2 mJ)
- Lorentz factor $\gamma \sim 2750$, $R_T \sim 7$ fm, $R_{||} \sim 0.002$ fm
- $\langle N_{coll}(b=0\text{-}5 \text{ fm}) \rangle \sim 1700$

$\tau_{crois} \sim 0.005$ fm/c

$\tau_{crois} >> \tau_{QCD} \sim 1/\Lambda_{QCD} \sim 1$ fm/c



Parton parton interactions

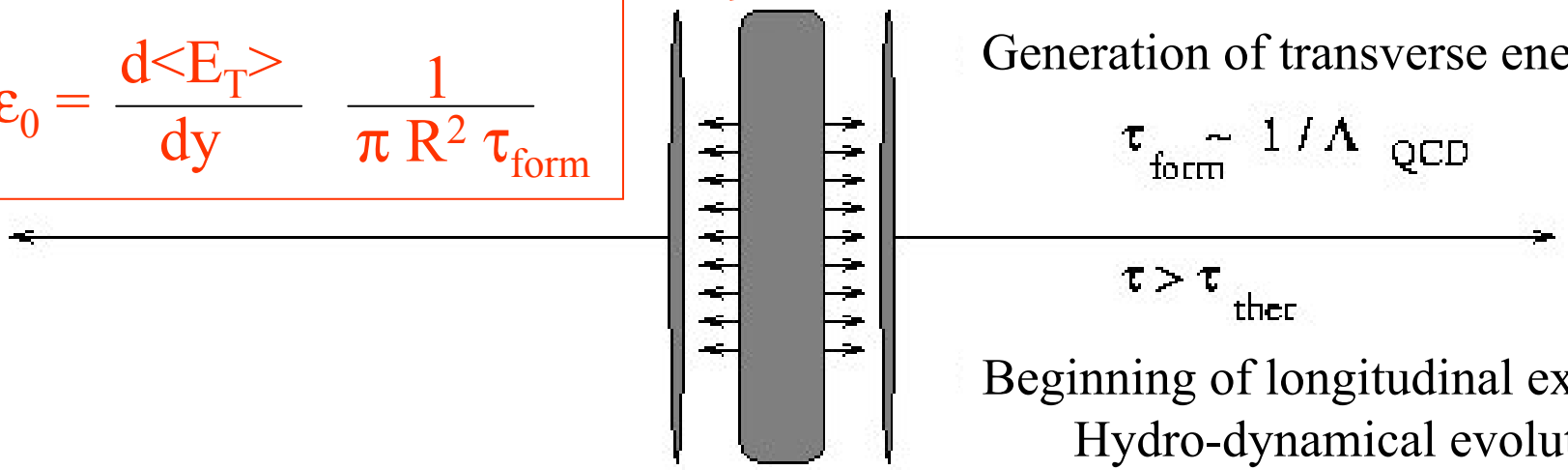
$\tau_{ctois} \sim 2R/\gamma$

J.D. Bjorken PRD27_143_1983

Heating matter at LHC

- Pb+Pb collision at 5.5A TeV (1.14 PeV = 0.2 mJ)
- Lorentz factor $\gamma \sim 2750$, $R_T \sim 7$ fm, $R_{||} \sim 0.002$ fm
- $\langle N_{coll}(b=0\text{-}5\ fm)\rangle \sim 1700$
- $\langle E\rangle \sim 500$ MeV and $dN_{ch}/dy \sim 5$,
- **$\varepsilon_0 \sim$ 4-40 GeV/fm^3 and $T_0 \sim$ 400 – 750 MeV**

$$\varepsilon_0 = \frac{d\langle E_T\rangle}{dy} \quad \frac{1}{\pi R^2 \tau_{form}}$$



J.D. Bjorken PRD27_143_1983 and 2 fold factor

Heating matter at LHC

- Pb+Pb collision at 5.5A TeV (1.14 PeV = 0.2 mJ)
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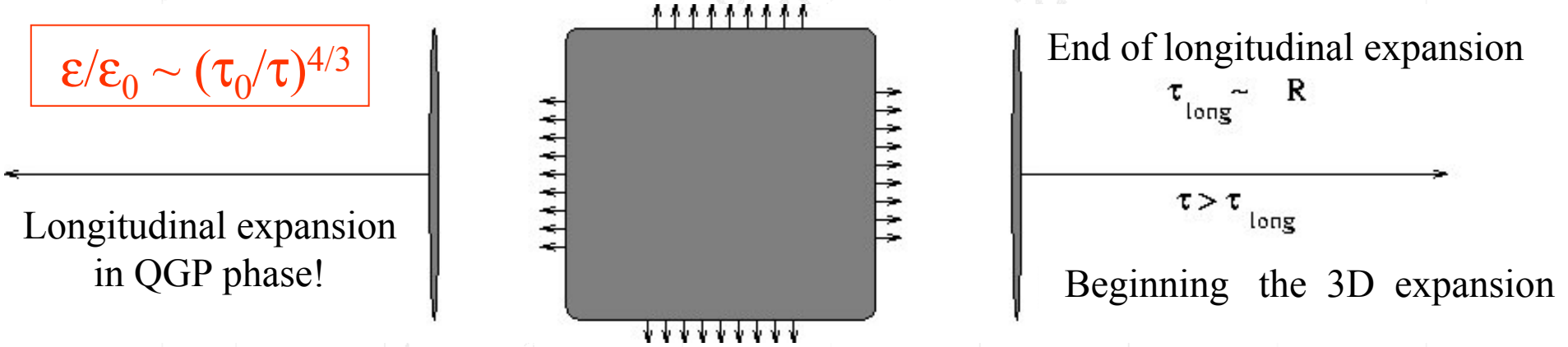
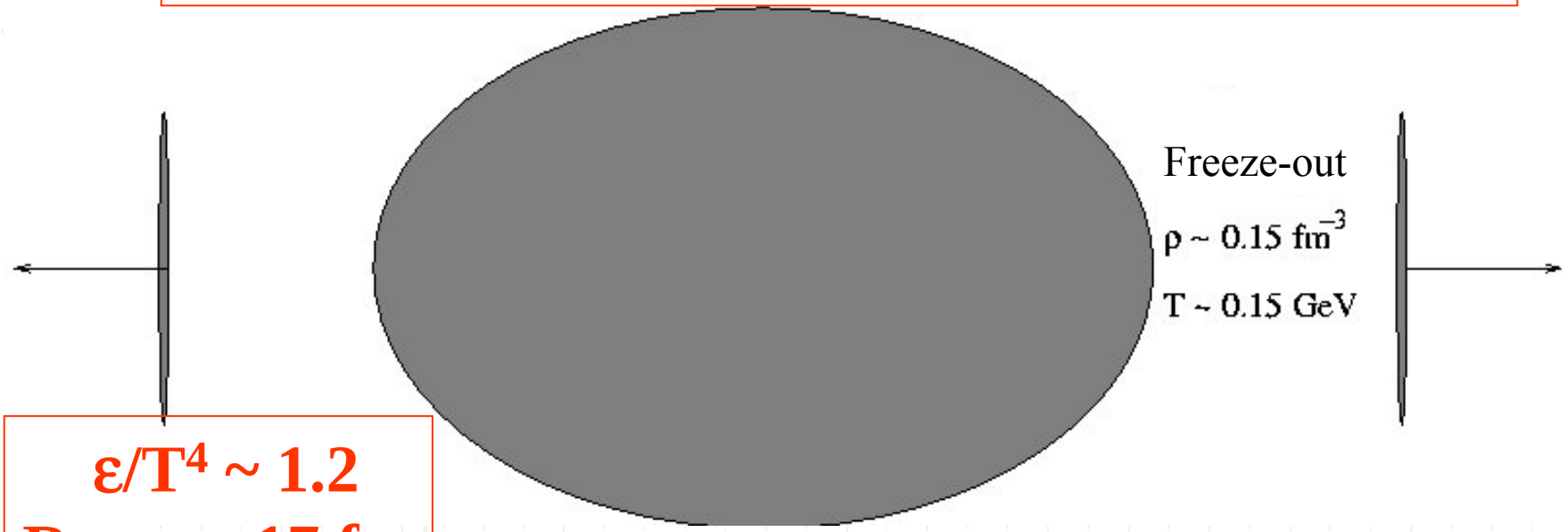
$$\varepsilon/\varepsilon_0 \sim (\tau_0/\tau)^{4/3}$$



J.D. Bjorken PRD27_143_1983

Heating matter at LHC

- Pb+Pb collision at 5.5A TeV (1.14 PeV = 0.2 mJ)
- Lorentz factor $\gamma \sim 2750$, $R_T \sim 7$ fm, $R_{||} \sim 0.002$ fm
- $\langle N_{coll}(b=0\text{-}5 \text{ fm}) \rangle \sim 1700$
- $\langle E \rangle \sim 500$ MeV and $dN_{ch}/dy \sim 5$,
- **$\varepsilon_0 \sim$ 4-40 GeV/fm^3 and $T_0 \sim$ 400 – 750 MeV**
- **$\varepsilon_{freeze\text{-}out} \sim$ 75 MeV/fm^3**



$\varepsilon/T^4 \sim 1.2$

$R_{freeze} \sim 17$ fm

J.D. Bjorken PRD27_143_1983

Physics at LHC with HIC

- Global probes:
  - Multiplicity, transverse energy, …
- Hadronic phase probe (soft physics)
  - Hadron yields, hadron spectra, hadron correlation,
- Penetrating probes (hard physics)
  - Photons, jets and heavy quarks.
- Initial state probes
  - Electroweak bosons

QGP: Hotter & Longer

Soft extrapolation from SPS/RHIC

Centrality, reaction plane, spectators, Freeze-out parameters like temperature, chemical potential, size, flow, kinetical freeze-out, etc...

New domain at LHC

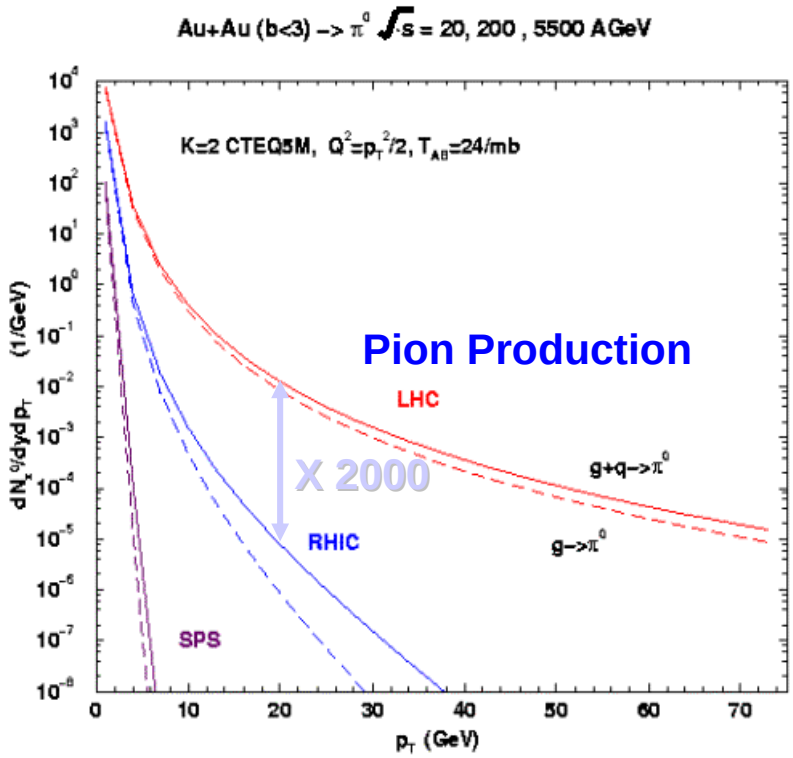
Initial temperature, gluon density, QGP screening, shadowing, initial thermalization phase, etc …

Penetrating probes at LHC (I)

- Main novelty of the LHC: large hard cross section:

  $\sigma^{hard} / \sigma^{tot}$ » ~2% at SPS, ~50% at RHIC, **~98% at LHC**

- Hard processes are extremely useful tools
  - *probe matter at very early times (QGP) : parton energy loss.*
  - *hard processes can be calculated by pQCD -> precision measurements.*



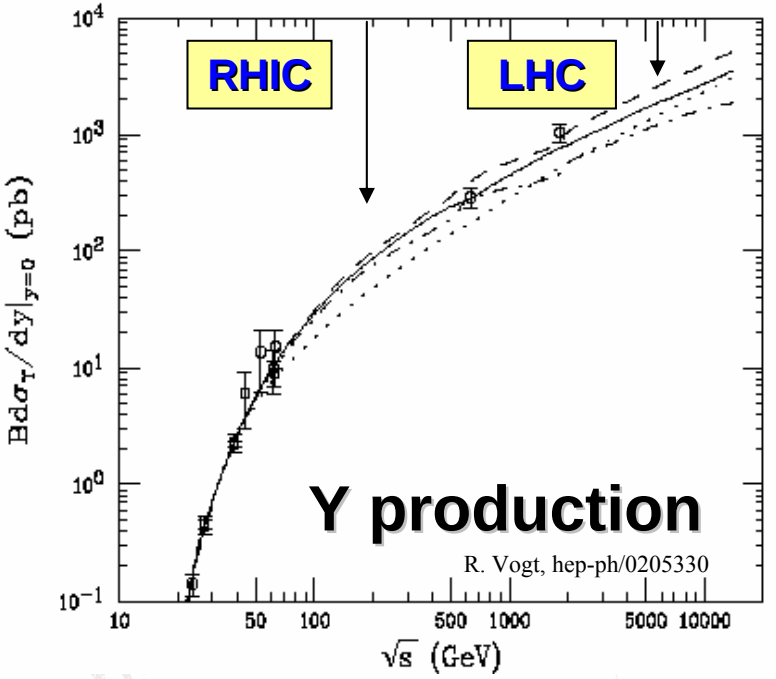
Pb Pb jet rates $|\eta| < 0.5$:

p_t jet > (GeV/c)	jets/event (10% central)	jets/0.5 nb-1
5	>200	
20	**2**	**$2\ 10^9$**
50	$5\ 10^{-2}$	$5\ 10^5$
100	$2.5\ 10^{-3}$	$2.5\ 10^6$
200	**10^{-4}**	**10^5**

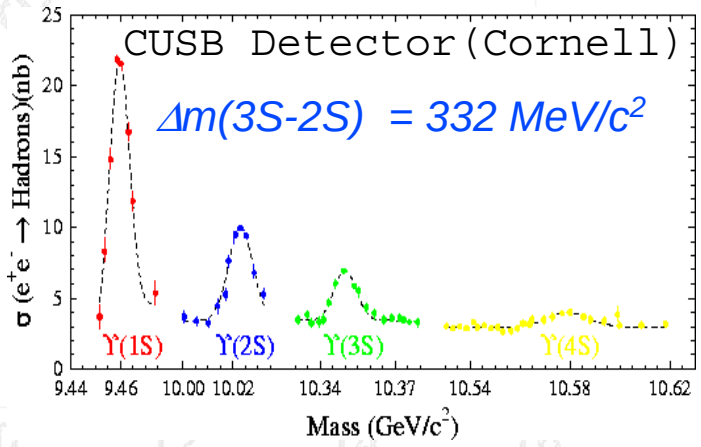
Reasonable rates up to E_T > 200 GeV

Penetrating probes at LHC (II)

- Copious charm production;
- Heavy quark thermalisation in QGP;
- Beauty at LHC like Charm at RHIC;
- Heavy quark energy loss;
- Elliptic flow of J/ψ: $v_{2;}$;
- Heavy-Quark potential screening:
  - 1st bottomonia measurement in HIC!



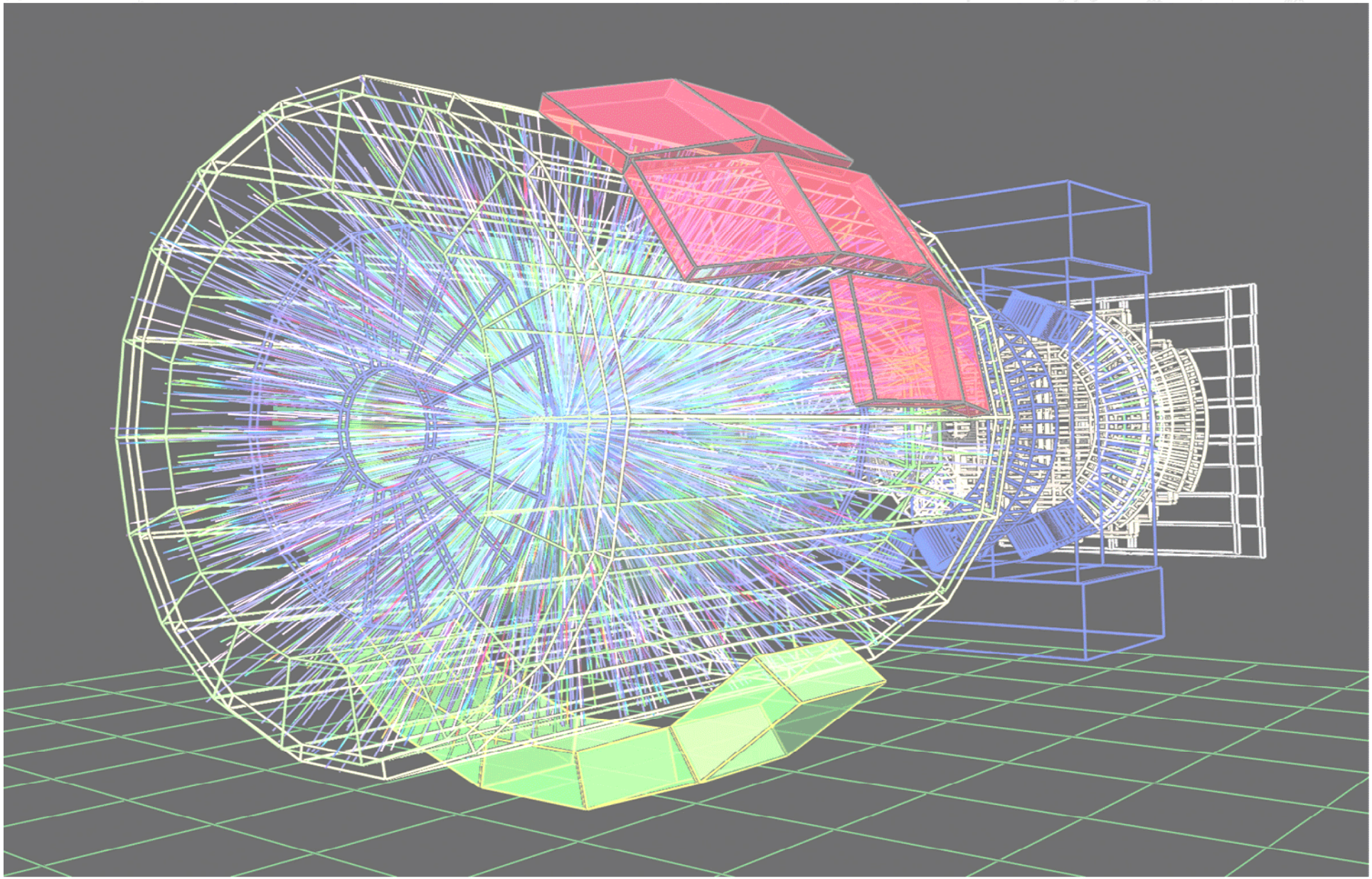
	SPS PbPb Cent	RHIC AuAu Cent	LHC pp	LHC pPb	**LHC PbPb Cent**
N_{cc}/evt	0.2	10	0.2	1	**115**
N_{bb}/evt	-	0.05	0.007	0.03	**5**



LHC (HI) baseline program

- Expect ~ 10 year 'baseline' program 2008 – 2017
  - **pp:** after few years diminishing return in terms of running time versus statistics
  - **HI**: **3D phase** space to cover: statistics – beam type – beam energy
- First 5 years (~ RHIC)
  - initial Pb-Pb run in 2008 (**1/20th design L**, i.e. ~ 5 x 10^{25})
  - 2 Pb-Pb runs (medium -> design Luminosity L ~ 10^{27}), **integrate ~ 1nb^{-1}**
  - 1 p A run (measure cold **nuclear** matter **effects**, e.g. shadowing)
  - 1 low mass ion run (**energy density & volume** dependence)
  - **continuous pp running** at 14 TeV (comparison data, some genuine pp physics)
- following ~ 5 years
  - program and priorities to be decided based on results
    - lower energies (energy dependence, thresholds, RHIC, pp at 5.5 TeV)
    - additional AA & pA combinations
    - increased statistics
  - expect modest detector modifications & upgrades
    - discussion has started, R&D to follow after 2007, decisions ~ 2009

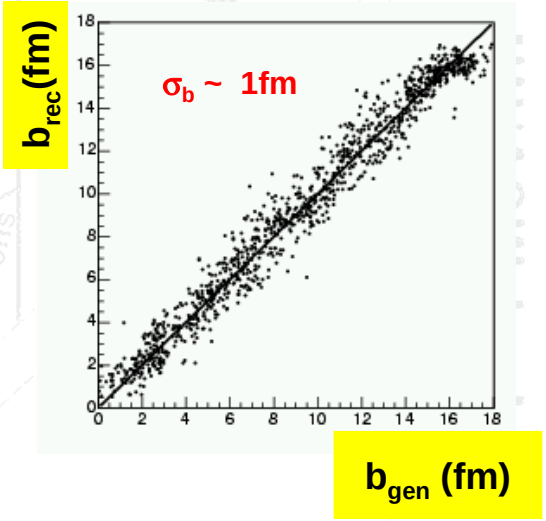
ALICE Physics Performances

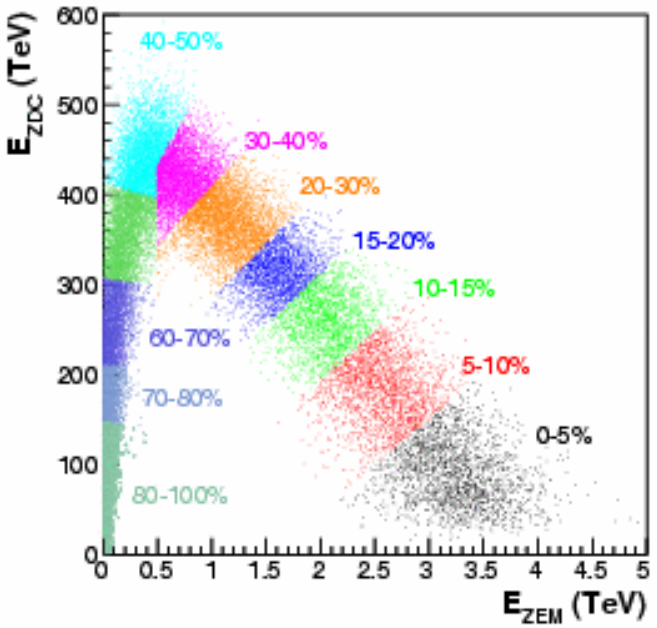


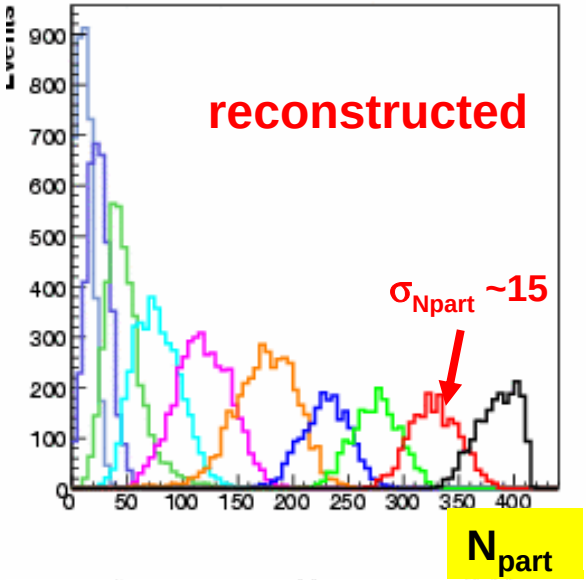
Centrality measurement in ALICE

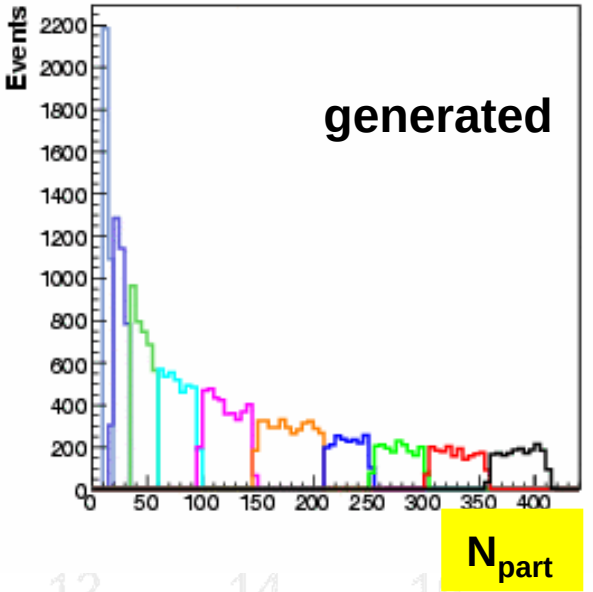
Event by event determination of the centrality :
Zero degree hadronic calorimeters (ZDC) +
electromagnetic calorimeters (ZEM)

E_{ZDC} , E_{ZEM} → N_{spec} → N_{part} → Impact parameter (b)









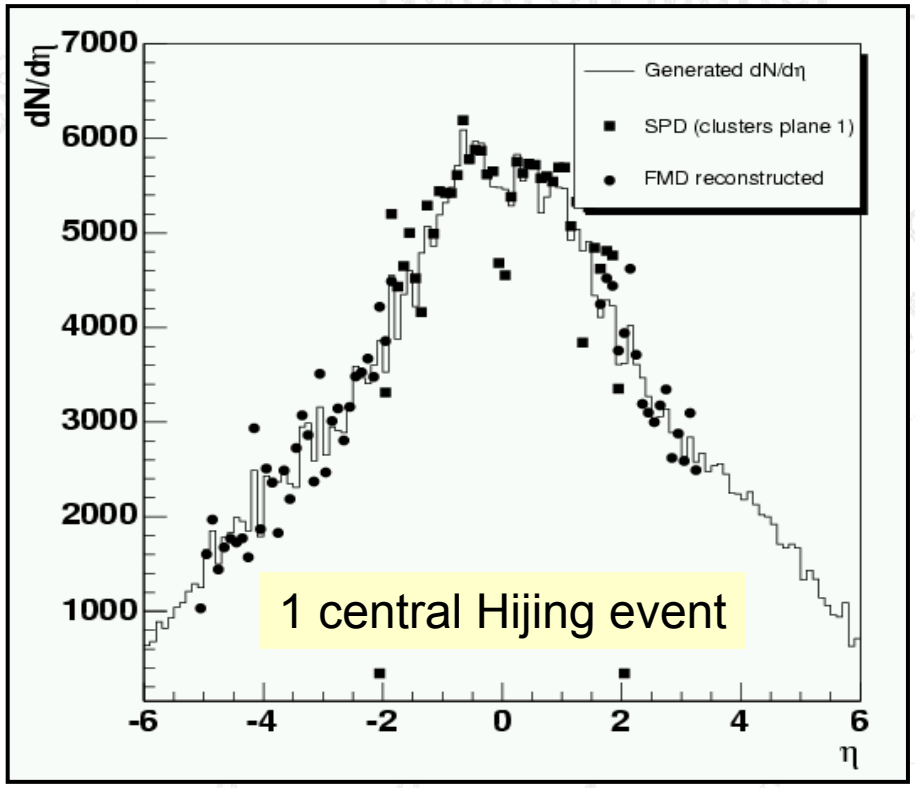
ALICE Multiplicity measurement

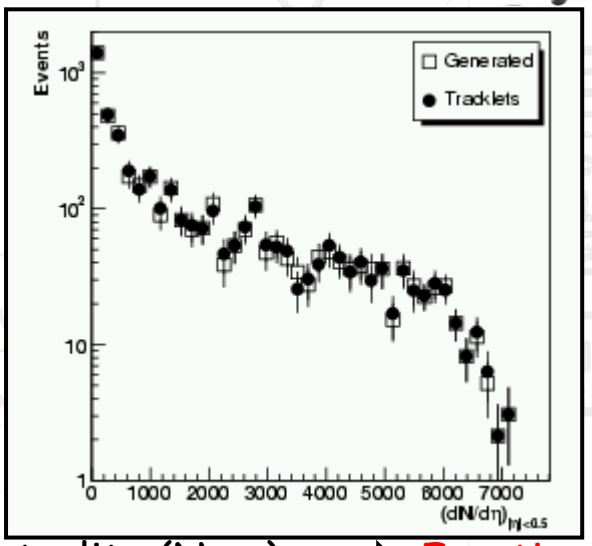
Multiplicity distribution ($dN_{ch}/d\eta$) in Pb-Pb

➡ Energy density

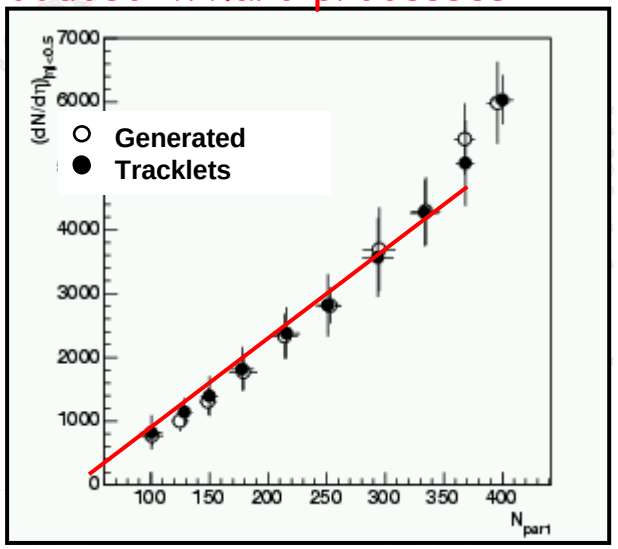
Silicon Pixel Detector (SPD): $-1.6 < \eta < +1.6$

Forward Multiplicity Detector (FMD): $\eta \longrightarrow$ -5, +3.5

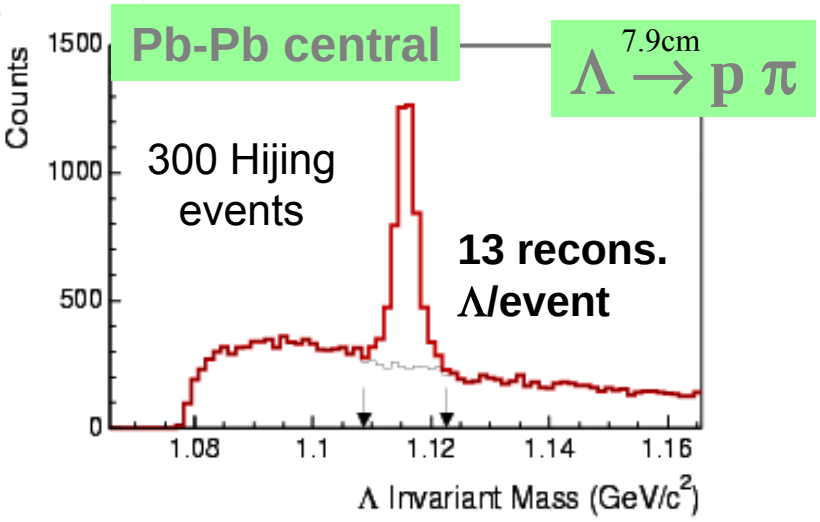


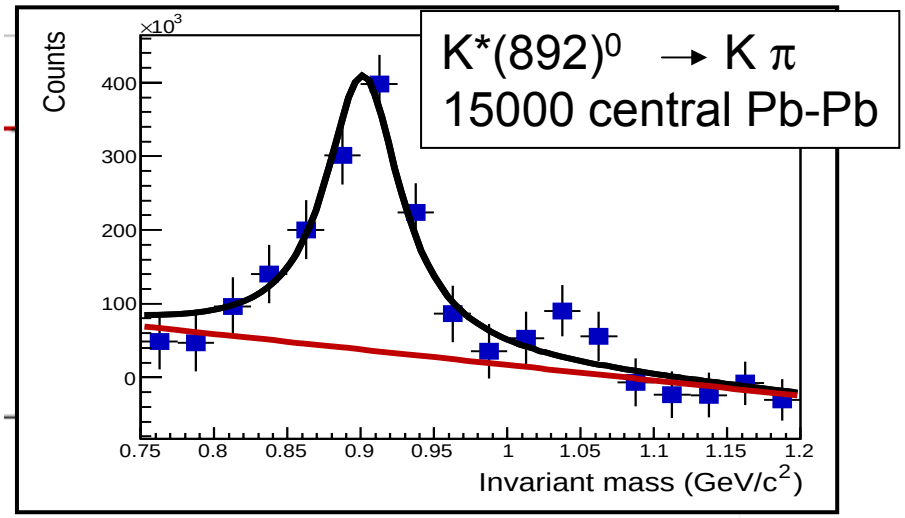


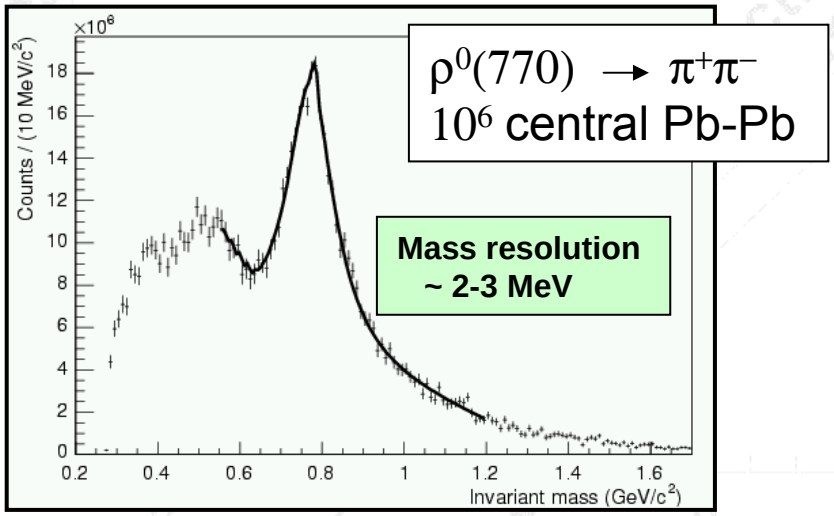
$dN/d\eta$ *vs* centrality (N_{part}) ➡ Fraction of particles produced in hard processes



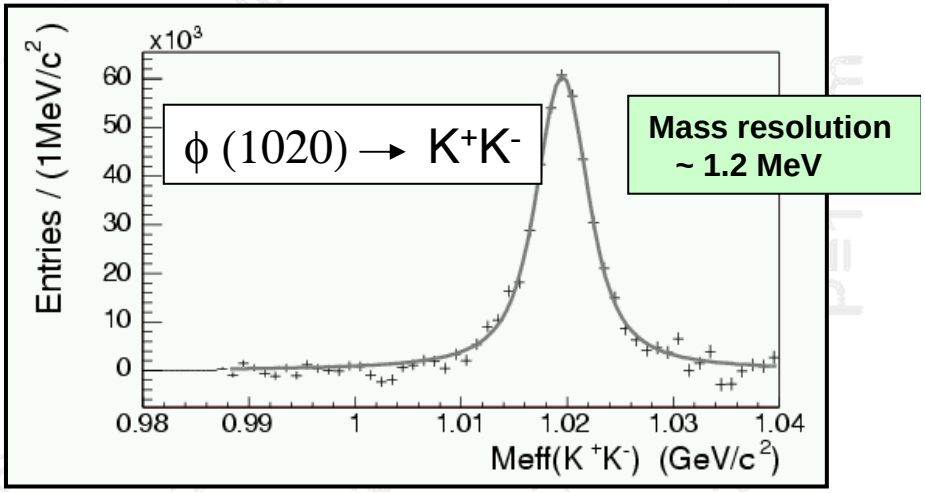
Hadron measurements in ALICE





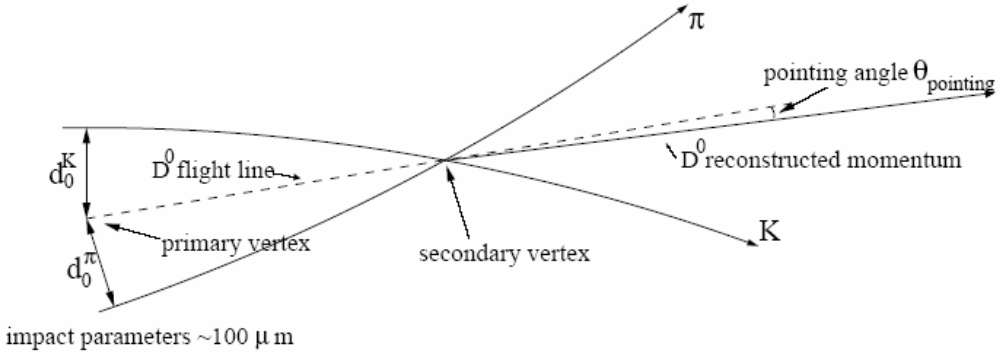


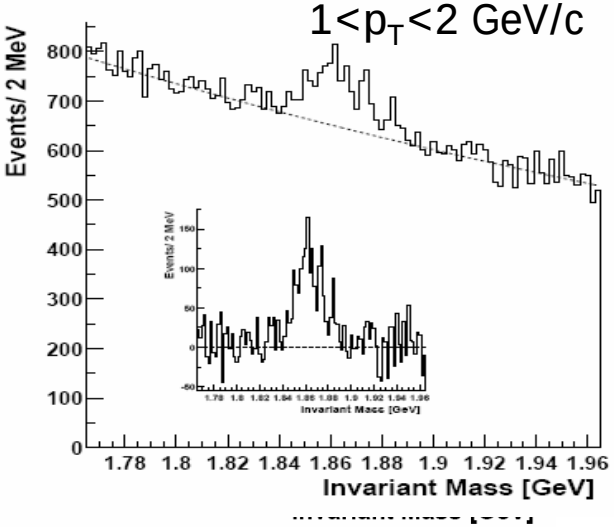
Invariant mass (GeV/c²)



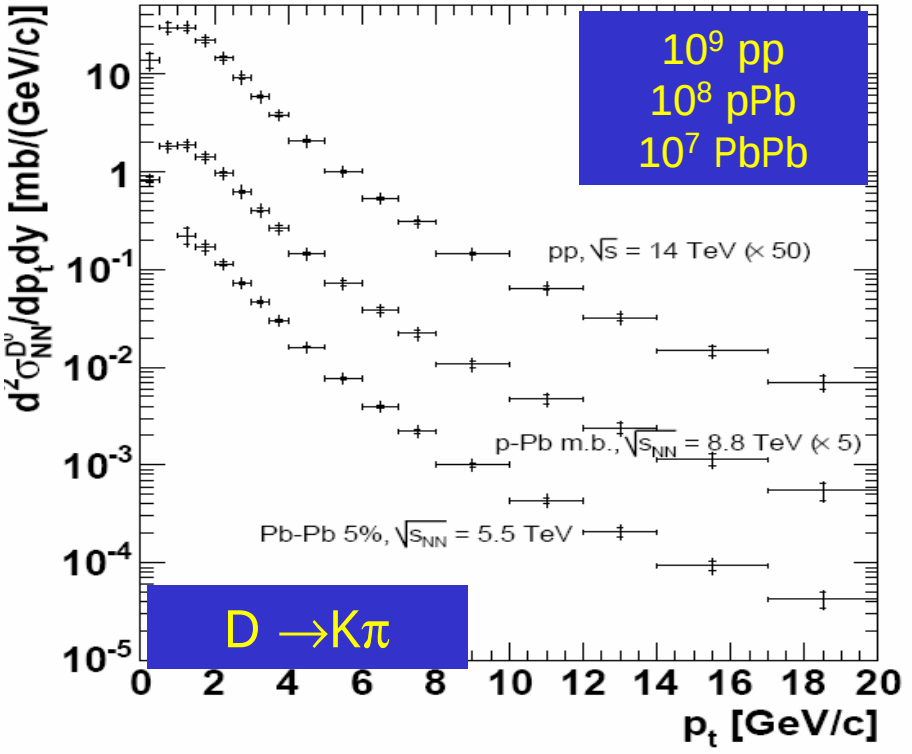
Charm Hadrons: $D^0 \rightarrow K\pi$

- High precision vertexing, better than 100 μm (ITS)
- High precision tracking (ITS+TPC)
- K and/or π identification (TOF)



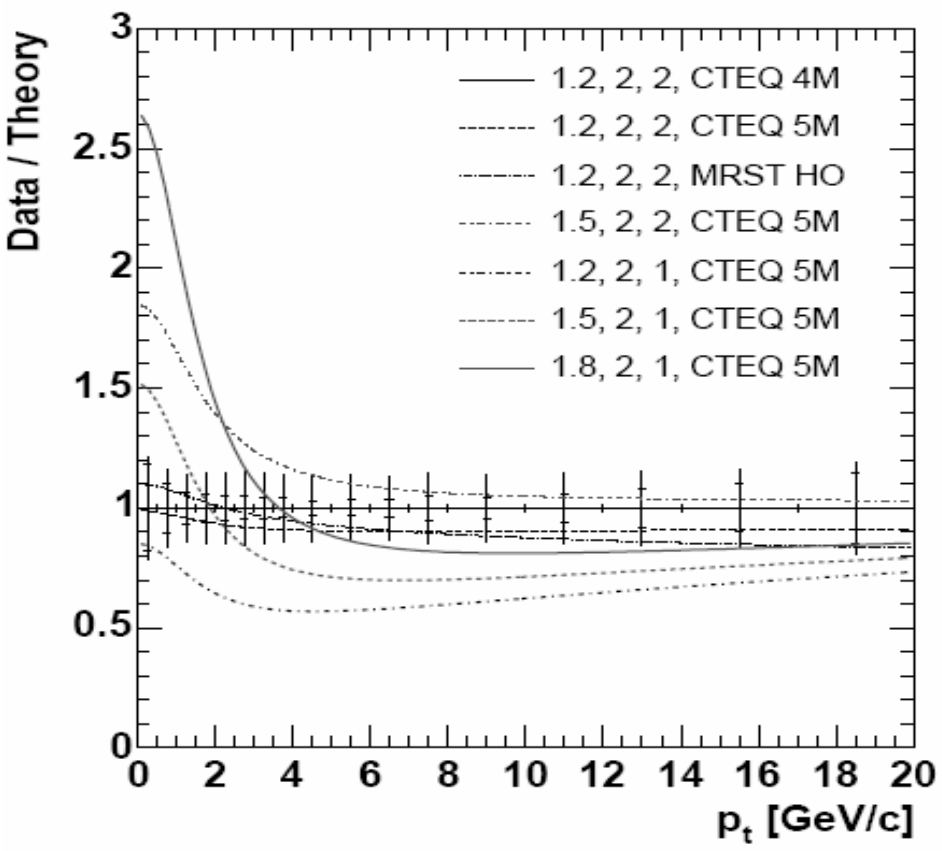


10^7 central PbPb

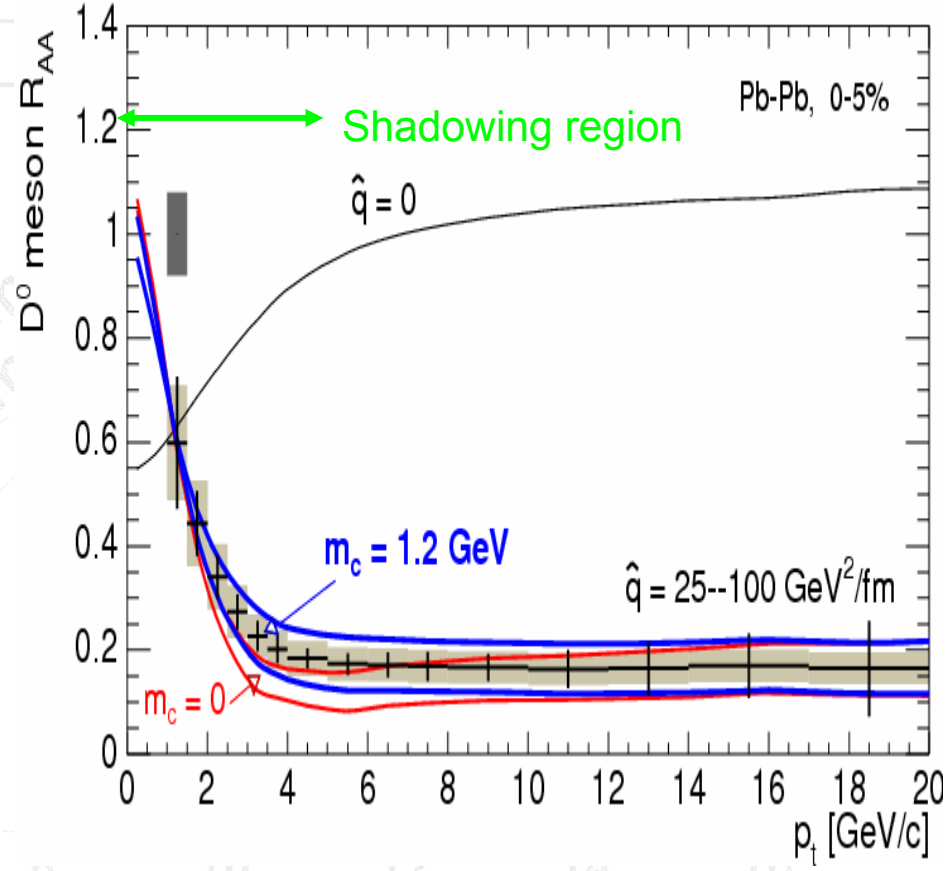


High Precision Measurements

pp at 14 TeV
Sensitivity to PDF's

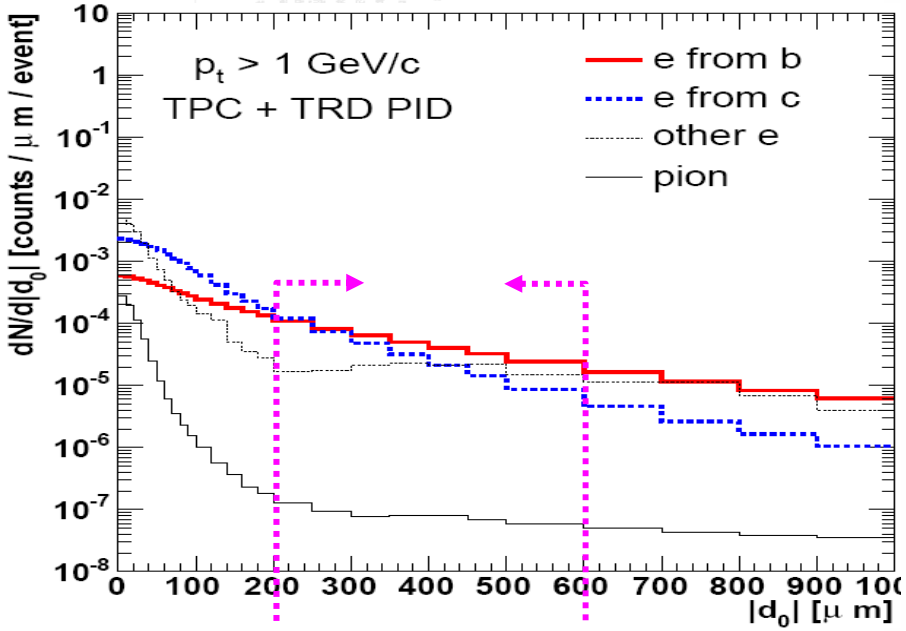


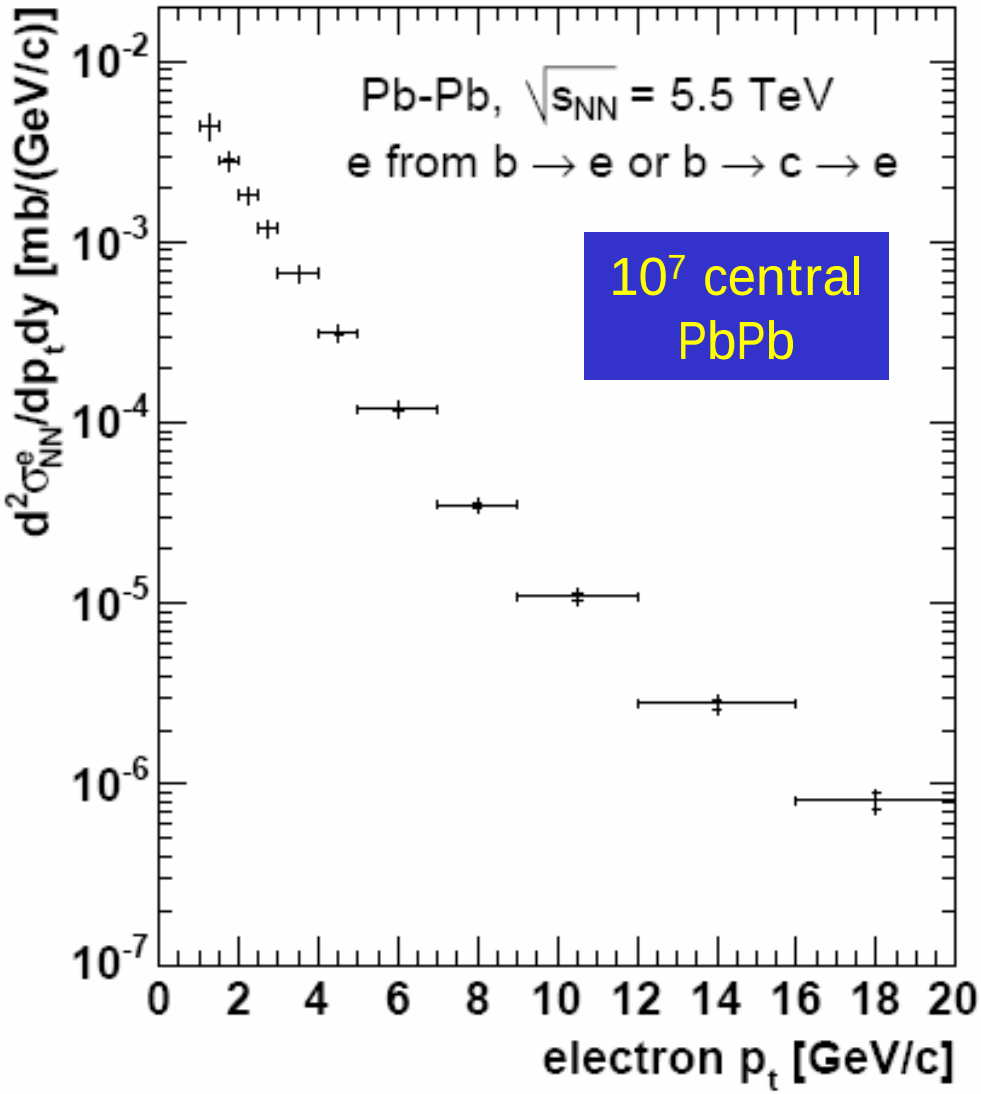
Central PbPb
Shadowing + k_T + energy loss



Open beauty: b → e+X

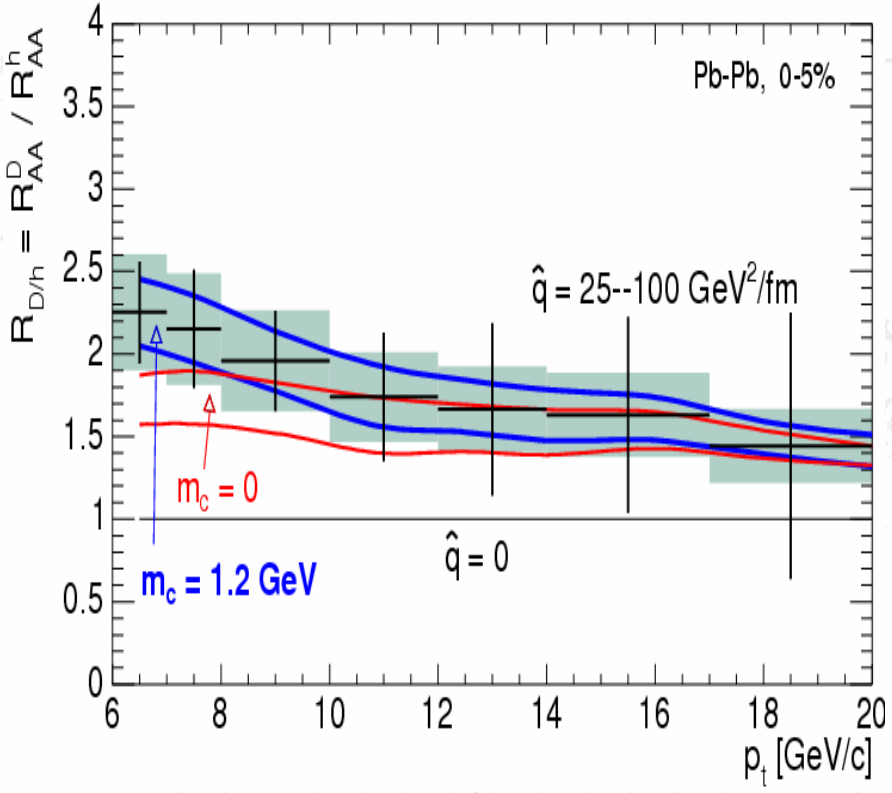
- Electron Identification (TRD+TPC)
- High precision vertexing (ITS)
- Subtraction of the open charm contribution.



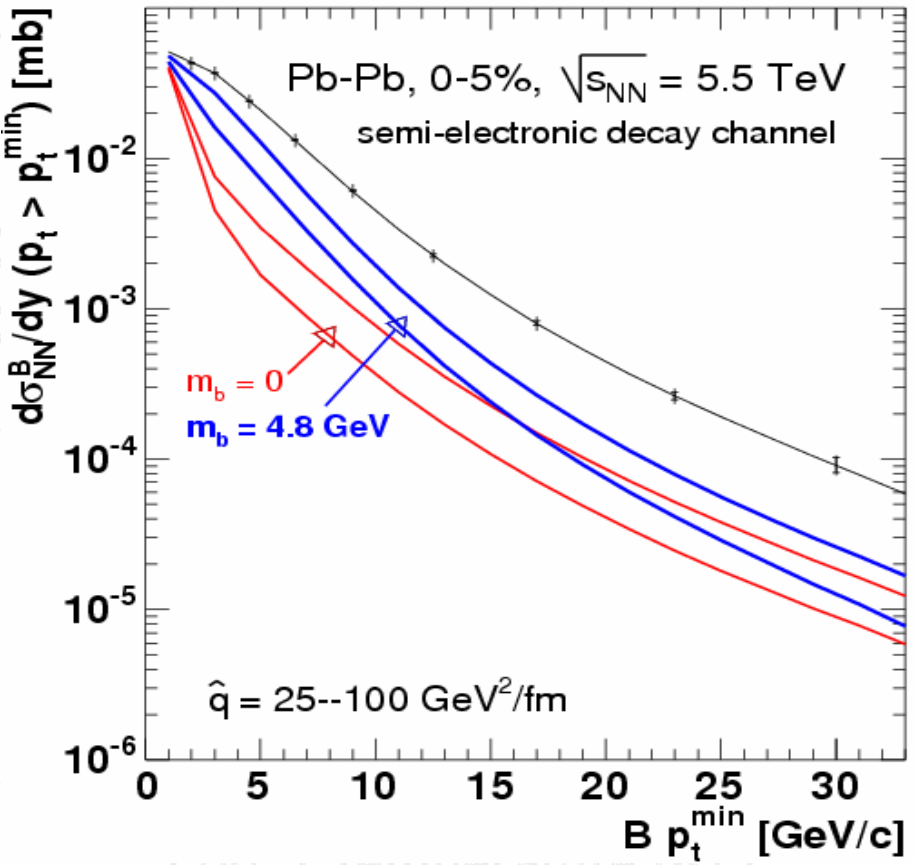


Energy Loss Physics

Charm Production:
Quark versus gluon Energy Loss
Higher gluon coupling

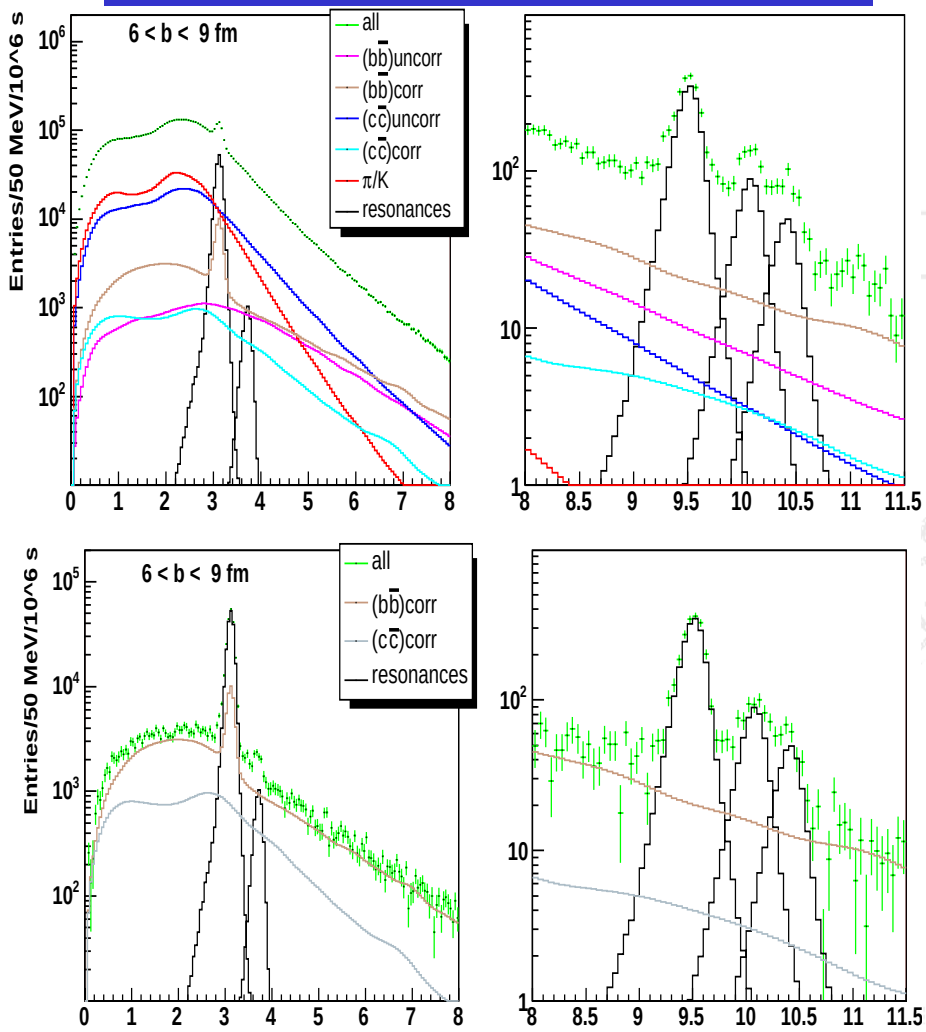


Beauty production:
Mass dependence of Energy Loss
Dead cone effect



Quarkonia → $\mu^+\mu^-$

PbPb cent, 6 fm<b<9 fm



PbPb cent, 0 fm<b<3 fm

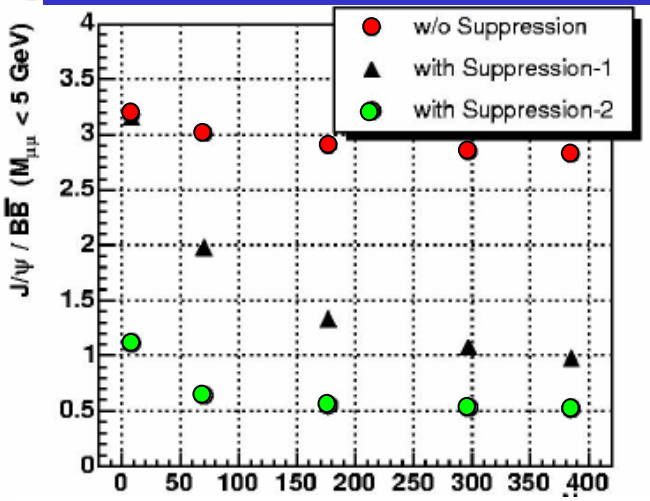
State	S[10^3]	B[10^3]	S/B	S/(S+B)$^{1/2}$
J/Ψ	130	680	0.20	150
Ψ'	3.7	300	0.01	6.7
ϒ(1S)	1.3	0.8	1.7	29
ϒ(2S)	0.35	0.54	0.65	12
ϒ(3S)	0.20	0.42	0.48	8.1

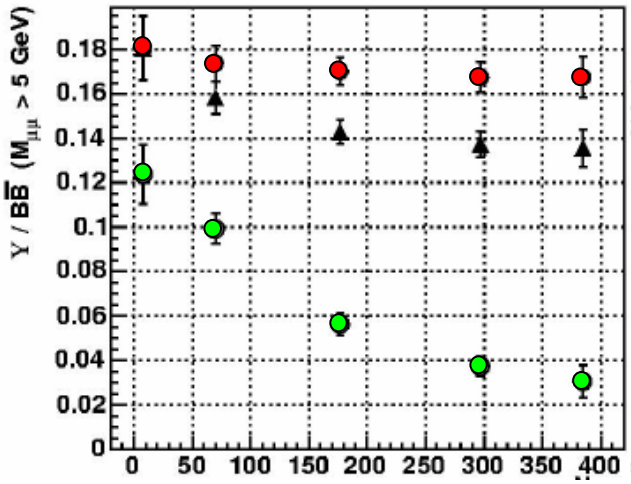
Yields for baseline

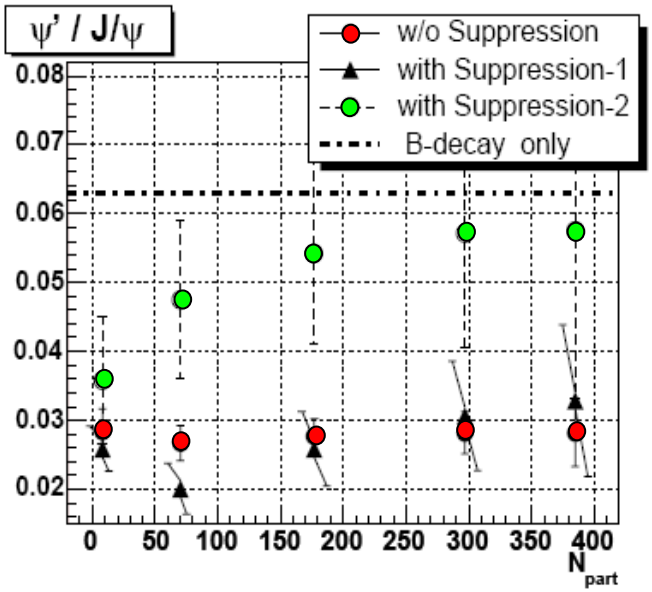
- ϒ(1S) & ϒ(2S) : 0-8 GeV/c
- J/Ψ high statistics: 0-20 GeV/c
- Ψ' poor significance
- ϒ'' ok, but 2-3 run will be needed.

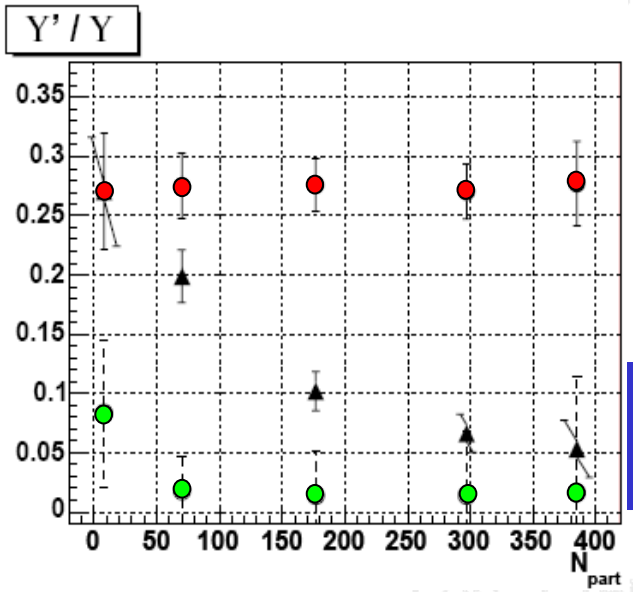
Suppression Scenario

PbPb at 5.5A TeV







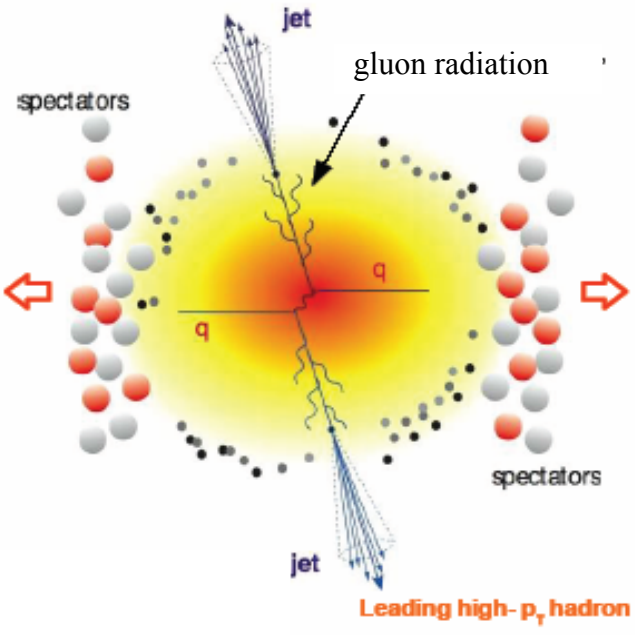


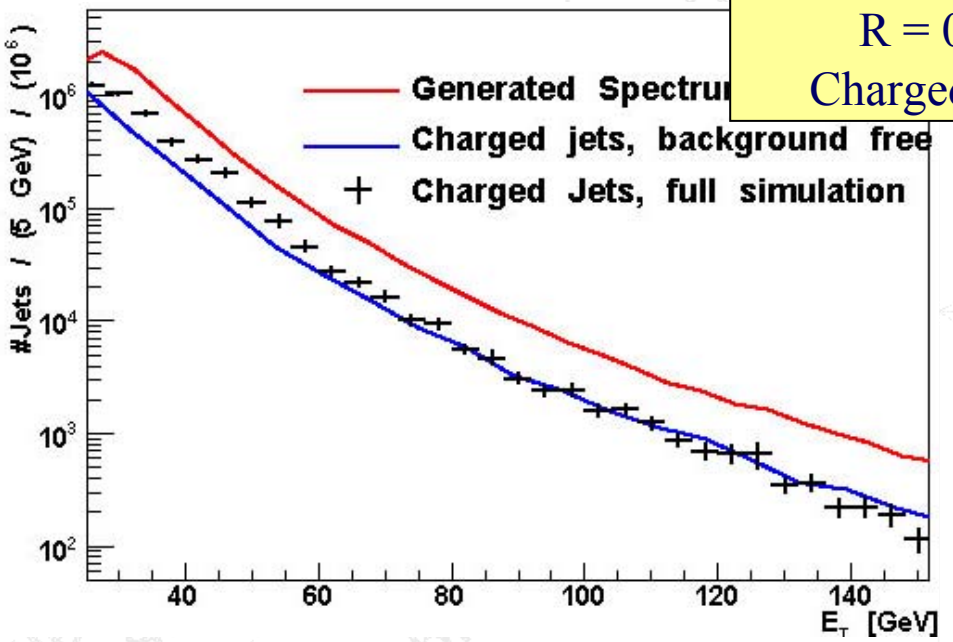
- Suppression-1
  - ✓ Tc =270 MeV
  - ✓ T_D/T_c=1.7 for J/Ψ
  - ✓ T_D/T_c= 4.0 for Υ.
- Suppression-2
  - ✓ Tc=190 MeV
  - ✓ T_D/T_c=1.21 for J/Ψ
  - ✓ T_D/T_c= 2.9 for Υ.

PRC72 034906(2005)
Hep-ph/0507084(2005)

Good sensitivity
J/Ψ, Υ(1S) & Υ(2S)

Reconstruction of Jets in HIC





10^7 central events
R = 0.4
Charged jets

$$\Delta E \propto \alpha_s C_R \hat{q} L^2$$

- Study properties of the medium through the modifications on the transverse jet structure
- Study hard processes with low p_T observables by measuring the fragmentation function to low p_T. Energy loss and radiated energy

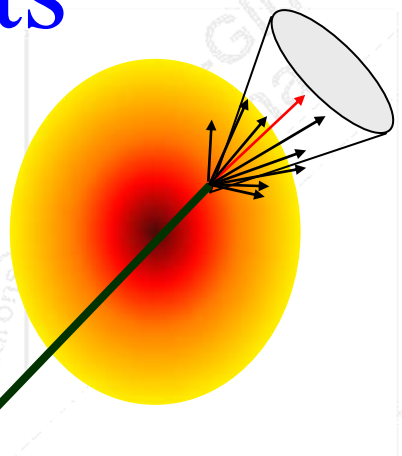
Photon-tagged jets

Dominant processes :

$g + q \rightarrow \gamma + q$ (Compton)

$q + \overline{q} \rightarrow \gamma + g$ (Annihilation)

$p_T > 10$ GeV/c

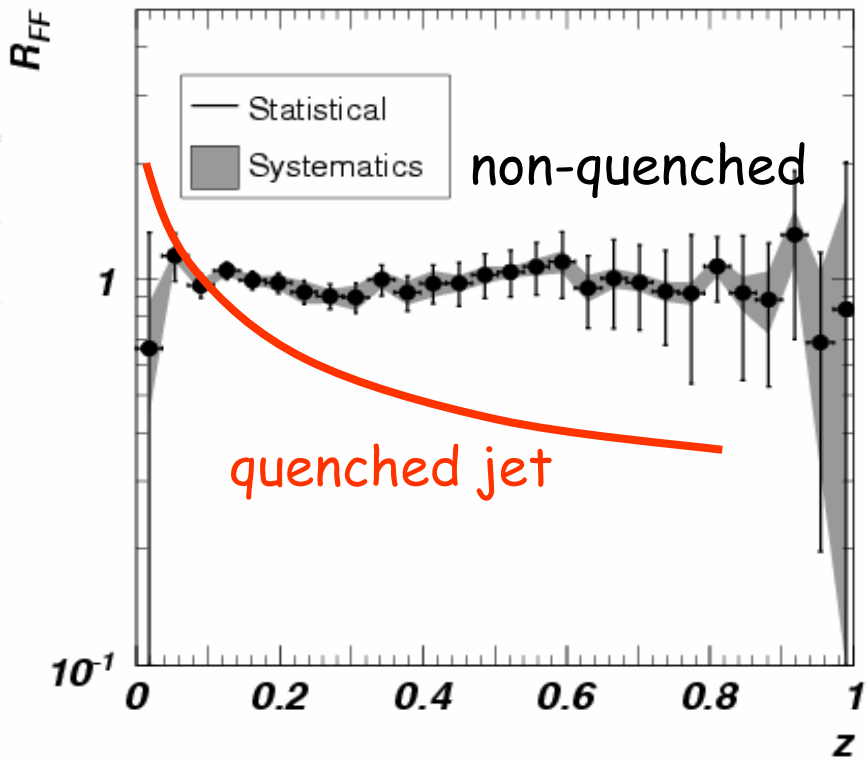


γ-jet correlation

- $E_\gamma = E_{jet}$
- Opposite direction

• Direct photons are not perturbed by the medium

• Parton in-medium-modification through the fragmentation function



More in Gustavo CONESA's talk

Conclusions

- ALICE detector performance studied for particle densities from pp collisions up to central Pb-Pb collisions;
- Robust and efficient tracking for particles with momentum in the range 0.1 – 100 GeV/c;
- Unique particle identification capabilities, for stable particles up to 50 GeV/c, for unstable up to 20 GeV/c;
- ALICE is well suited to measure global event properties and identified hadron spectra on a wide momentum range (with very low p_T cut-off) in Pb-Pb and pp collisions;
- The nature of the bulk and the influence of hard processes on its properties will be studied via chemical composition, collective expansion, momentum correlations and event by event fluctuations;
- Charm and beauty production will be studied in the p_T range 0-20 GeV/c and in the pseudo-rapidity ranges $|\eta|<0.9$ and $2.5< \eta <4.0$;
- High statistics on J/Ψ is expected in the muon and electronic channels;
- Upsilon family will be studied for the 1st time in AA collisions;
- ALICE will reconstruct jets in heavy ion collisions to study the properties of the dense created medium;
- ALICE will identify prompt and thermal photons to characterize initial stages of collision region;

Physics Performance Report

- Published in two volumes:
  - PPR Vol I: CERN/LHCC 2003-049
  - Published: ALICE coll. J. Phys. G30, 1517 (2004)
    - ALICE Physics – theoretical overview
    - LHC experimental conditions
    - ALICE detector
    - Offline computing and Monte Carlo generators
  - PPR Vol II: CERN/LHCC 2005-030 (part 1 – part 2)
  - tPublished: ALICE coll. J. Phys. G32, 1295 (2006)
    - Detector performance
    - ALICE physics performance

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