La frontière de haute énergie en collisions noyau-noyau

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The High Energy Frontier of AA

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Intro

• my charge:
  perspective on high energy AA frontier in the aftermath of QM2011
  – high energy = top RHIC and upwards

• disclaimers:
  – you will get my own biased (and “immediate”) perspective
    • but with a little help from my friends…
  – I had to make hard decisions on what to show…
    • I had to leave out many beautiful measurements and important details…
  – I will mostly reuse slides presented at this conference
Contents

• The bulk
• Correlations
• Quarkonia
• High $p_T$ Suppression
• Identified Particles
• Jets
• Heavy Flavour
Le “Bulk”
\( \sqrt{s} \) dependence

- \( \frac{dN_{ch}}{d\eta}/(0.5N_{\text{part}}) \sim 8 \)
- \( 2.1 \times \) RHIC
  - \( 1.9 \times \) pp (NSD) at 2.36 TeV
- growth with \( \sqrt{s} \) faster in AA than pp

- \( \frac{dE_T}{d\eta}/(0.5N_{\text{part}}) \sim 9 \) in 0-5%
- \( \sim 5\% \) increase of \( N_{\text{part}} \) (353 \( \rightarrow \) 383)
  - \( \rightarrow 2.7 \times \) RHIC
  (consistent with 20\% increase of \( <p_T> \))

Grows with power of CM energy faster than simple logarithmic scaling extrapolated from lower energy
Charged particle multiplicity

Pixel “tracklets” in solenoid-off data, to measure down to $p_T > 0$

Yield per participant pair increases by factor of two relative to RHIC, in agreement with ALICE measurement

Similar centrality dependence to that found at RHIC (which itself was similar to top SPS energies):

Confirmation of what appears to be a robust scaling feature in HI

for details, see talk by Yujiao Chen (4pm Mon.)
Two-component models
- Soft (~Npart) and hard (~Ncoll) processes

Saturation-type models
- Parametrization of the saturation scale with energy (s) + centrality (A)

Comparison to data
- DPMJET (with string fusion) stronger rise than data
- HIJING 2.0 (no quenching)
  - Strong centrality dependent gluon shadowing
  - Fine-tuned to 0-5% dN/dη

Saturation models
- Some saturate too much
Scaling vs. $dN_{ch}/d\eta$

- Increase of the radii with $dN_{ch}/d\eta$ for central collisions consistent with models
- Increase of the “homogeneity volume” over most central RHIC by a factor of $\sim 2$
La frontière

• explore forward rapidities
  – multiplicities vs $\eta$
  – CGC/saturation effects?
  – pA !!

• identified particle HBT
Les corrélations
The system produced at the LHC behaves as a very low viscosity fluid (a perfect fluid)

K. Aamodt et al. (ALICE Collaboration)
PRL 105, 252302 (2010)
Elliptic flow as function of transverse momentum does not change much from RHIC to LHC energies, can we understand that?

same hydro?
\( v_2 \) measured out to 20 GeV

- Charged hadrons, \( p_T = 0.5\text{-}20 \) GeV, mid-rapidity, \( |\eta| < 1 \)

Weak \( p_T \) dependence beyond 8-10 GeV out to 20 GeV

Important constraint on jet quenching models!
Flow fluctuations

\[ \frac{dN}{d\phi} \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos n(\phi - \psi_n) \]

\[ \Rightarrow \left\langle \frac{dN_{\text{pairs}}}{d\Delta \phi} \right\rangle^{(\text{flow})} \propto 1 + \sum_{n=1}^{\infty} 2 \left\langle v_n^2 \right\rangle \cos n(\Delta \phi) \]
Flow fluctuations

$$\frac{dN}{d\phi} \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos n(\phi - \psi_n)$$

$$\Rightarrow \left\langle \frac{dN_{\text{pairs}}}{d\Delta \phi} \right\rangle^{(\text{flow})} \propto 1 + \sum_{n=1}^{\infty} 2 \left\langle v_n^2 \right\rangle \cos n(\Delta \phi)$$

Matthew Luzum
Flow fluctuations

\[
\frac{dN}{d\phi} \propto 1 + \sum_{n=1}^{\infty} 2v_n \cos n(\phi - \psi_n)
\]

\[\Rightarrow \langle \frac{dN_{\text{pairs}}}{d\Delta \phi} \rangle_{(\text{flow})} \propto 1 + \sum_{n=1}^{\infty} 2 \langle v_n^2 \rangle \cos n(\Delta \phi)\]
We observe significant $v_3$ which compared to $v_2$ has a different centrality dependence. The centrality dependence and magnitude are similar to predictions for MC Glauber with $\eta/s=0.08$ but above MC-KLN CGC with $\eta/s=0.16$.

The $v_3$ with respect to the reaction plane determined in the ZDC and with the $v_2$ participant plane is consistent with zero as expected if $v_3$ is due to fluctuations of the initial eccentricity.

The $v_3\{2\}$ is about two times larger than $v_3\{4\}$ which is also consistent with expectations based on initial eccentricity fluctuations.
Approaching ultracentral Pb+Pb events

At 1-3 GeV/c, a dramatic shape evolution is observed within a small centrality range.

Double-peak away side structure in 1% most-central events

Andrew Adare – ALICE
Rise and fall of “ridge/cone”—Centrality evolution

Pay attention to how long-range structures disappear and clear jet-related peaks emerge on the away-side.

Strength of soft component increase and then decrease.

Near-side jet peak is truncated from top to better reveal long range structure.

\[ \int_{\Delta t} = 8 \mu b^{-1} \]
\[ 2 < p_T, p_T < 3 \text{ GeV} \]

Jiangyong Jia – ATLAS
Fourier analysis at large $\Delta \eta$, moderate $p_T$

Near side jet excluded by $|\Delta \eta| > 0.8$ gap
Ridge at $\Delta \phi=0$ remains

2-particle Fourier coeffs.
Extract directly from $C(\Delta \phi)$:

$$\langle \cos n\Delta \phi \rangle = \frac{\int d\Delta \phi \ C(\Delta \phi) \cos n\Delta \phi}{\int d\Delta \phi \ C(\Delta \phi)}$$

Here, the first 5 moments describe shape at per-mille level.

Andrew Adare – ALICE
Two-particle correlation method

Fourier decompose the 1D $\Delta \phi$ correlation in given $\Delta \eta$ slice

$$\frac{dN}{d \Delta \phi} \propto 1 + \sum_n 2v_{n,n} \cos(n \Delta \phi)$$

$v_{n,n}$ is calculated directly via DFT for $n=1-15$

$v_{n,n}$ is expected to factorize into single $v_n$ for flow

$\Rightarrow v_n$ from “fixed-$p_T$” correlation

$\Rightarrow$ cross-check via “mixed-$p_T$” correlation
Fourier analysis of $\Delta \phi$ correlations

Fourier decomposition:

$$\frac{1}{N_{\text{trig}}} \frac{dN^\text{pair}}{d\Delta \phi} = \frac{N_{\text{assoc}}}{2\pi} (1 + 2 \sum_{n=1}^{\infty} V_n^f \cos(n\Delta \phi))$$

Flow driven correlations:

$$V_n^f = V_n^f(p_T^{\text{trig}}) \times V_n^f(p_T^{\text{assoc}})$$

(f: Fourier analysis of long-range dihadron correlations)

Short-range non-flow effects excluded

Wei Li – CMS
Flow subtraction/correction with measured $v_n$ for central-central 2-particle correlation

mach-cone is mostly gone
remaining medium effect seen
(correlated pair yield by absolute normalization)

ShinIchi Esumi – PHENIX
Large $\Delta \eta$ $a_n$necy spectrum

if flow dominates the correlations $a_n \approx v_n^2$

$$R_2 = \frac{\rho_{12}}{\rho_1 \rho_2} - 1$$

(c) 0-5%

$C = \frac{\sum_{i=1}^{n_1} \sum_{j=1}^{n_2} p_{r,i} p_{r,j}}{\overline{p}_{r,1} \overline{p}_{r,2}}$

(f) 0-5%

$C$ (GeV/c$^2$)

$\rightarrow$ Fourier Tr. $(0.7 < \Delta \eta < 2.0)$

$\frac{a_n(R_2)}{\text{STAR Preliminary}}$

$\frac{a_n(C)}{\text{STAR Preliminary}}$

Death of ridge and cone?

• “le ridge” and “le Mach cone” seem to be in serious trouble…

• Le Roi est mort…?

• … vive le Roi!

→ la symphonie des corrélations…
Flow vs Non-Flow Correlations

- Flow-related effects imply correlation of two particles through a plane of symmetry $\psi_n$
  - $v_n$ factorizes: $V_{n\Delta} = V_{n_{\text{trig}}} V_{n_{\text{assoc}}}$

- Jets cause correlations of a few energetic particles by fragmentation
  - There can be indirect correlations: length-dependent quenching
  - Would be largest w.r.t. $\psi_2$ since it reflects the collision geometry

- Assess flow vs. non-flow by testing the collectivity relation $V_{n\Delta} = V_{n_{\text{trig}}} V_{n_{\text{assoc}}}$
  - Instead of calculating $V_{n\Delta}$ in each $p_T,\text{assoc} \times p_T,\text{trig}$ bin ($N(N-1)/2=55$ bins), allow only one $V_{n\Delta}$ per $p_T$ bin (11 parameters)
Flow vs Non-Flow Correlations

- Compare single calculated values with global fit
- To some extent, a good fit suggests flow-type correlations, while a poor fit implies non-flow effects
- $v_2$ to $v_5$ factorize until $p_T \sim 3-4$ GeV/c, then jet-like correlations dominate
- $v_1$ factorization problematic (influence of away-side jet)
any residual room for medium response?

→ look at the small print on the away side
  
  – two-dimensional in $\eta, \varphi$
  
  – use information on direction of recoiling parton
    
    • around re-emerging away-side jets
    
    • around away-side heavy flavour

“Annecy spectrum” promises a beautiful tool

→ quantitative comparisons with full hydro
  
  – extract information on $\eta/s$, initial conditions
    
    (Glauber, CGC, …)
Speaking of which…

“how ‘bout a fulla Fourier decomposition of de CMS pp ridge?”

(d) \( N > 110, \ 1.0 \text{GeV/c} < p_T < 3.0 \text{GeV/c} \)
Les Quarkonia
New $J/\psi R_{AA}$ result at forward rapidity

- new measurement at $1.2 < |y| < 2.2$ with reduced statistical and systematic uncertainties.
- still shows stronger suppression at forward rapidity
- let's study $J/\psi$ suppression using information from
  - p+p (production mechanism)
  - d+Au (cold nuclear matter effects)
$J/\psi$ $v_2$

charged hadrons, STAR, PRL93, 252301 (2004)
$\phi$, STAR, PRL99, 112301 (2007)

Au+Au 200 GeV
- $J/\psi$ 20-60%
- $\phi$ 0-80%
- charged hadrons 20-60%

STAR Preliminary

non-flow estimation

$J/\psi$ $v_2 \sim 0$ up to $p_T \sim 8$ GeV/c in mid-central 20-60%

→ Disfavors coalescence from thermalized charm quarks
J/ψ $R_{AA}$ 0.2 / 2.76 TeV

Ginés Martínez – ALICE

J/ψ $\rightarrow \mu\mu$, $p_T > 0$

J/ψ $R_{AA}$ larger at LHC (2.5 < $y$ < 4) than at RHIC (1.2 < |$y$| < 2.2); Similar as RHIC (|$y$| < 0.35), except for the most central bin; $dN_{ch}/d\eta(N\text{_{part}})_{LHC} \sim 2.1 \times dN_{ch}/d\eta(N\text{_{part}})_{RHIC}$ (A. Toia talk).
\( J/\psi \) \( R_{CP} \) ATLAS/ALICE

**ALICE:**
- \( 2.5 < y < 4.0 \);
- \( |y| < 0.8 \)

**ATLAS:**
- \( |y| < 2.4 \)
- 80\% \( J/\psi \), \( p_T \geq 6.5\) GeV/c;
- Error in 40-80\% centrality bin not propagated.

ALICE 2.5\(<y<4.0\) exhibits less suppression than ATLAS data (high \( p_T \), \( |y|<2.4 \)); Challenging measurement in the dielectron channel.
Prompt $J/\psi$ $R_{AA}$

CMS

$\sqrt{s_{NN}} = 2.76$ TeV

$\mathcal{P}p\mathcal{P}$

$C_{CMS}$

$p_{T}^{J/\psi} > 6.5$ GeV/c

Factor 5 suppression

Central 0-10% $R_{AA} = 0.20 \pm 0.03 \pm 0.01$

Peripheral 50-100% $R_{AA} = 0.59 \pm 0.12 \pm 0.10$

Catherine Silvestre – CMS
- $\Upsilon(1S+2S+3S)$ suppression at central collisions
  - Similar suppression with high $p_T$ $J/\psi$
- First measurement of $\Upsilon$ suppression
- Statistical uncertainty will be improved by more than a factor of 2
  - $\times 3$ in p+p 2009
  - $\times 2$ in Au+Au 2011
\( \Upsilon(1S) R_{AA} \)

\[ \sqrt{s_{NN}} = 2.76 \text{ TeV} \]

- **Comparison with STAR**
  - CMS \( \Upsilon(1S) R_{AA}(0-100) = 0.62 \pm 0.11 \pm 0.10 \)
  - STAR \( \Upsilon(1+2+3S) R_{AA}(0-60) = 0.56 \pm 0.11^{+0.02}_{-0.10} \)

Catherine Silvestre – CMS
\[ \frac{\gamma(2S + 3S) / \gamma(1S)}{\gamma(2S + 3S) / \gamma(1S)} \bigg|_{\text{PbPb}} \]

- **Pros of a double ratio**
  - Acceptance cancels
  - Efficiency cancels

- **Potential differences**
  - Remaining systematics 9%, from line shapes

\[ \frac{\gamma(2S + 3S) / \gamma(1S)}{\gamma(2S + 3S) / \gamma(1S)} \bigg|_{\text{pp}} = 0.31^{+0.19}_{-0.15} \pm 0.03 \]

Hypothesis: no suppression \( \Rightarrow \) p-value 1%

Significance of the suppression 2.4 \( \sigma \)

Catherine Silvestre – CMS
La frontière

- establish charmonium, bottomonium suppression(/recombination?) pattern in full glory
  - high statistic measurements
  - open flavour baseline / contamination
  - pA baseline

- the full picture should unravel before our eyes in the near future
La suppression à haut $p_T$
Comparison between CMS and ALICE $R_{AA}$

Harald Appelshäuser (ALICE), Yen-Jie Lee (CMS) & Co
Charged particle $R_{CP}$

Strong suppression seen in more central events via charged $R_{CP}$

No $\eta$ dependence observed

for details, see talk by Sasha Milov (3:20pm Thurs.)
charged particle $R_{AA}$ - models

ALICE, charged particles, Pb-Pb
$\sqrt{s_{NN}} = 2.76$ TeV, 0-5\%, $|\eta| < 0.8$

- pronounced $p_T$ dependence of $R_{AA}$ at LHC
- sensitivity to details of the energy loss distribution
reaction plane dependent $R_{AA}$

further constraint to models ($l^2$, $l^3$, …)

$R_{AA}(\phi) = R_{AA}(1 + 2v_2 \cos(2\phi))$
Path-length dependence of E loss

$\nu_2$ not explained by pQCD (even with fluctuations & saturation)

$\nu_2$ explained by cubic path length dependence (like AdS/CFT)

$pQCD$

AdS/CFT

$R_{AA}$ explained by both models

Stefan Bathe - PHENIX
La frontière…

• $R_{AA}$ from 100’s MeV to 100 GeV and beyond!

• dependence on orientation wrt reaction plane
  – $l^2$, $l^3$, $l^?$ behaviour!

• asymmetric collisions at RHIC (U-U, Cu-Au,…)

→ tight constraints on energy loss models
Les particules identifiées ainsi font, les protons:
… trois p’tits tours, et puis s’en vont!
are protons misbehaving?

At RHIC: STAR proton data generally not feed-down corrected. Large feed down correction

→ Consistent picture with feed-down corrected spectra

At LHC: ALICE spectra are feed-down corrected

- Harder spectra, flatter p at low pt
- Strong push on the p due to radial flow?
The ratios of charged pions, kaons, and protons to pions are very similar at RHIC energies. The integrated ratios versus centrality at $T = 164$ MeV, $\mu_B = 1$ MeV and $T = (170\pm 5)$ MeV and $\mu_B = 1+4$ MeV.

### Predictions for the LHC

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Data</th>
<th>(1)</th>
<th>(2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$p/\pi^+$</td>
<td>0.0454+0.0036</td>
<td>0.072</td>
<td>0.090</td>
</tr>
<tr>
<td>$p/\pi^-$</td>
<td>0.0458+0.0036</td>
<td>0.071</td>
<td>0.091+0.009-0.007</td>
</tr>
<tr>
<td>$K/\pi^+$</td>
<td>0.156+-0.012</td>
<td>0.164</td>
<td>0.180+0.001-0.001</td>
</tr>
<tr>
<td>$K/\pi^-$</td>
<td>0.154+-0.012</td>
<td>0.163</td>
<td>0.179+0.001-0.001</td>
</tr>
</tbody>
</table>


**STAR, PRC 79 , 034909 (2009)**

**PHENIX, PRC69, 03409 (2004)**

**BRAHMS, PRC72, 014908 (2005)**
Lambda very similar to protons in shape and yield
Feed-down correction:
• \( p \) corrected for weak decays
• \( \Lambda \) corrected for f.d. from the \( \Xi \)

... this was similar at RHIC, if one compares feed-down corrected spectra

STAR, PRL98, 062301 (2007)
PHENIX, PRC69, 03409 (2004)
v_2 for identified particles

Hydro models predict larger mass splitting. Data shows mass splitting and agrees well with hydro predictions for mid-central collisions. For more central collisions, the anti-proton flow is not described by the same calculations.

Protons again…

Raimond Snellings – ALICE
La frontière

• understand protons’ hydrodynamics
  – fly in the ointment of otherwise triumphant hydro …

• how about the thermal model?
  – took a bit of a beating this time
  – need full-glory, high stats fits including $\Xi^-$, $\Omega^-$, $\phi$, …
  – can it be cured?
  – at what price? ($\gamma_s$, $\gamma_q$, anyone?)
Les Jets
Jets in the CMS detector

Jet 1, pt: 70.0 GeV

Jet 0, pt: 205.1 GeV

Christof Roland – CMS
Jet Angular Correlation

1st lesson learned:
The propagation of high $p_T$ partons in a dense nuclear medium does not lead to a visible angular decorrelation

Christof Roland – CMS
Di-jet Asymmetry, $R = 0.4$

R = 0.4
$E_{T1} > 100$ GeV
$E_{T2} > 25$ GeV

30 Gev

Brian Cole – ATLAS
Single Jet central to peripheral ratio: $R_{cp}$

- **$R = 0.2$**
  - Centrality 0-10%
  - Centrality 30-40%
  - Centrality 50-60%

- **$R = 0.4$**
  - Centrality 0-10%
  - Centrality 30-40%
  - Centrality 50-60%

**Observation:**

Brian Cole – ATLAS

$\Rightarrow$ Suppression independent of jet $E_T$ within statistical $\oplus$ systematic errors
Jet Fragmentation (Longitudinal)

• Measure distribution of fragment $p_T$ along jet axis: $z \equiv \left( \frac{p_{T\,\text{had}}}{E_T} \right) \cos \Delta R$
  
  – For both $R = 0.2$ and $R = 0.4$ jets
  
  – Systematic uncertainties from jet energy resolution, centrality dependence of jet energy scale.

• Compare central (0-10%) to peripheral (60-80%)
Where is the energy? spread out low $p_T$ particles

\[ p_T^{\parallel} = \sum_{\text{Tracks}} -p_T^{\text{Track}} \cos (\phi_{\text{Track}} - \phi_{\text{Leading Jet}}) \]

0-30% Central PbPb

**Low $p_T$, full acceptance**
Momentum is balanced

**In-cone large momentum imbalance at high $p_T$**
Consistent with calorimetry

**Out-off-cone low $p_T$ particles**
Balance the complete event

CMS

**balanced jets**
**unbalanced jets**

arXiv:1102.1957

M. Tonjes (Tue), C. Roland (Wed)

Bolek Wyslouch – CMS
Evidence of jet broadening

$k_T$ and Anti-$k_T$ known to have different sensitivities to background

Jet $R_{AA} < 1(R=0.4)$

Algorithms fail to recover all jet

$R_{AA}$ of pions $\sim 0.2$

$N_{jet}(R=0.2)/N_{jet}(R=0.4)$ vs $p_T^{jet}$

**p-p:**
“Focussing” of jet with jet energy

**Au-Au:**
“Broadening” of jet compared to p-p

Jet fragmentation broader in Au-Au

Helen Caines – STAR

Helen Caines - QM - May 2011
Jet-hadron: Energy balance

\[ D_{AA} = \text{Au-Au} - \text{p-p} \text{ Energy difference} \]

\[ D_{AA}(p_{T}^{assoc}) = Y_{AA}(p_{T}^{assoc}) \cdot p_{T,AA}^{assoc} - Y_{pp}(p_{T}^{assoc}) \cdot p_{T,pp}^{assoc} \]

\[ \Delta B = \int dp_T^{assoc} D_{AA}(p_T^{assoc}) \]

Near-side:

\[ \Delta B = 0.6^{+1.9}_{-1.0}^{+0.5}_{-0.4} \text{ (sys) GeV/c} \]

Away-side:

\[ \Delta B = 1.5^{+1.7}_{-0.4}^{+0.5}_{-0.4} \text{ (sys) GeV/c} \]

Energy lost at high \( p_T \) approximately recovered at low \( p_T \) and high \( R \)
Jet $R_{AA}$ in 200 GeV Cu-Cu

$R_{AA}$ of fully reconstructed jets

Centrality-dependent suppression of jet yields observed.

Could be out-of-cone radiation from medium interaction

Or the jet shape or other properties are modified and makes the jet fail the rejection cut

Either one would be a really interesting result

N. Grau

Martin Purschke – PHENIX
Caveat: Know your Reference

$R_{CP}$ of fully reconstructed jets from d+Au

All $R_{AA}$ measurements need a corresponding $R_{dA}$ measurement as crosscheck. The data are presently $R_{CP}$ but may indicate that CNM effects should not be ignored. Stay tuned.

Martin Purschke – PHENIX
La frontière…

• up to the stratosphere…
  – $\gamma/W/Z$-jet fragmentation functions!
• and down to the fertile soil again…
  – explore the surroundings of away-side jets
    • broadening? softening? re-heating?
  – more “organic” jet algorithms?
    • can one catch the whole jet, and then look inside as a function of distance?
  – in-medium fragmentation vs reaction plane
    • path length dependence!
  – hadrochemistry of in-medium fragmentation
  – jet-hadron correlations
• b-tagged jets (quark vs gluon jets)
• extreme suppression?
  – true “mono-jet” events? what do they look like?
• pA reference, reconstructed jets at RHIC, …
Les Saveurs Lourdes
PHENIX v STAR electrons

- progress since QM2009 on NPE discrepancy
  → new result from STAR in pp
    - e.g.: Wei Xie (STAR) @ Hard Probes 2010
- First measurement of $D^0 R_{AA}$, $R_{AA} \sim 1$ in $p_T < 3$ GeV/c
- Blast-wave fit favors higher $T_{kin}$, smaller $\beta_T$ for $D^0$ than light hadrons
  $\Rightarrow D^0$ freeze-out earlier than light hadrons
Near-Term Future: Silicon Vertex Detector

Status

- VTX successfully commissioned in 2011 $p+p$ run
- VTX taking data in Au+Au now!

Data: Au+Au@200 GeV, 2011

Physics

- $R_{AA}$ of $c$, $b$ separately
- $v_2$ of $c$, $b$ separately
- Jet tomography (di-hadron, $\gamma-h$, $c-h$, $c\bar{c}$)

Stefan Bathe for PHENIX, QM2011
Mid-rapidity \textbf{STAR}: now to mid-decade

- Tracking: TPC
- Particle ID: TOF
- Electromagnetic Calorimetry: BEMC+EEMC+FMS ($-1 \leq \eta \leq 4$)

Recent upgrades:
- DAQ1000
- TOF

Plus upgrades to Trigger and DAQ

Muon Telescope Detector (runs 13/14)
See poster: L. Ruan

Heavy Flavor Tracker (run 14)

Full azimuthal particle identification over a broad range in pseudorapidity

A beautiful detector gets even better!

\textbf{STAR} Science for the Decade – QM2011 – Carl Gagliardi
D⁰ and D⁺ reconstruction in Pb-Pb

- In ~3M central collisions (0-20%):
  - D⁰: 5 p_t bins in 2-12 GeV/c
  - D⁺: 3 p_t bins in 5-12 GeV/c

- Reconstruction efficiency ~1-10%:
  - evaluated from MC simulation
    - detector status and performance described by the MC to few % level
    - no centrality dependence found

- Feed-down from B decays ~10-15% after cuts
  - subtracted based on FONLL with hypothesis on R_{AA}^B (⇒ more later)

⇒ A.Rossi, Fri parallel
Suppression for charm is a factor 4-5 above 5 GeV/c

Compatible with pions $R_{AA}$ (slightly larger below 5 GeV/c)

maybe hint for $R_{AA}^D > R_{AA}^{\pi}$? stay tuned for 2011 Pb-Pb run results
How about the colour factor?

- quarks ($C_R = 4/3$) expected to couple weaker than gluons ($C_R = 3$)

  → at $p_T \sim 8$ GeV, factor $\sim 2$ less suppression expected for D than for light hadrons in BDMPS-ADSW

- data do show a hint of deviation ($R_{AA}^D > R_{AA}^{\pi}$), but at much lower $p_T$ …

… to be continued with higher statistics…

Data Comparison: Leptons $y \sim 0, y \sim 3$

- Consistent with the large uncertainties of electron PID
First $B \rightarrow J/\psi R_{AA}$

$\sqrt{s_{NN}} = 2.76$ TeV

$p_{T}^{J/\psi} > 6.5$ GeV/c

$b$ quark energy loss?

Minimum bias $R_{AA} = 0.37 \pm 0.07 \pm 0.03$

Central 0-20% $R_{AA} = 0.36 \pm 0.08 \pm 0.03$
La frontière…

- high statistics D measurements
  → are really D as suppressed as light hadrons?
- charm thermalisation?
  → measure D mesons v2
- subtract D background → pure B electron spectrum
  – beauty energy loss in wide $p_T$ range
- in-medium fragmentation of b-tagged jets!
- results from RHIC upgrades
Conclusions

• high energy AA collisions have entered an era of high precision measurements
  – LHC, RHIC upgrades
  – constrain dynamic and coupling properties of medium

• many ideas we were taking more or less for granted at QM 2009, are now being seriously questioned
  – death of Mach cone and ridge?
  – thermal yields, radiative $E_{\text{loss}}$ are challenged

• the outlook is bright
  – high lumi ($5 \times$) Pb-Pb run this year, possibly p-Pb next year

→ there could be some serious paradigm shifting at QM 2012!
Un grand merci…

• … aux organisateurs
  for the invitation to present this closing talk
• … à:
  Peter Braun-Munzinger, Brian Cole, Andrea Dainese, David d’Enterria, Paolo Giubellino, Barbara Jacak, Peter Jacobs, Karel Šafařík, Carlos Salgado, Jürgen Schukraft, Edward Shuryak, Peter Steinberg, Xin-Nian Wang, Urs Wiedemann, Nu Xu and many others…
• … à vous tous