Jet physics in ALICE
Christine Nattrass
University of Tennessee at Knoxville
The Time Projection Chamber

Specifications

- Designed for $dN_{ch}/d\eta=8000$
- $|\eta|<0.9$, radius 0.9-2.5m
- In a 0.5 T Solenoidal Field
- 570k channels, 80MB/event
- 3% radiation length
- Outer diameter 5 m, Length 5 m
- Largest ever
Particle identification

Vertex detector

\( p_T \text{ (min)} < 100 \text{MeV/c} \)

TOF

150k channels!

\( \sigma \approx 90 \text{ ps} \)

TPC \( dE/dx \)

\( \sigma \approx 5-6\% \)

No vertex cut!

pp @ 7 TeV

ALICE performance
work in progress

\[ \text{dEdX distribution (ITS signal, truncated mean)} \]

Entries 148725

Rigidity (GeV/c)

ALICE Performance

\( p+p \text{ at } \sqrt{s} = 900 \) GeV (2009 data)

\[ \text{TPC signal (a.u.)} \]
A simple picture of a heavy ion collision
Jets as a probe of the quark gluon plasma
One jet “absorbed” by the medium
Jet quenching

nucleus

nucleus

nucleus

Single particles

- Measure spectra of hadrons and compare to those in p+p collisions or peripheral A+A collisions
- If high-\( p_T \) hadrons are suppressed, this is evidence of jet quenching
- Assumption: sufficiently high-\( p_T \) hadrons mostly come from jets
- Unmodified spectra:

\[
R_{AA} = \frac{d^2N_{AA}/dp_Td\eta}{T_{AA}d^2\sigma_{pp}/dp_Td\eta}
\]
Experimental results

No suppression

Observed

Experimental results

Look in two dimensions
$d+Au$
In two dimensions in Au+Au
### Dihadron Correlations

- Study two-particle correlations with per-trigger yields
  
  \[
  \frac{1}{N_{\text{trig}}} \frac{dN_{\text{assoc}}}{d\Delta \phi} \quad \text{and} \quad \frac{1}{N_{\text{trig}}} \frac{d^2 N_{\text{assoc}}}{d\Delta \phi d\Delta \eta}
  \]

- Lower $p_T$
  - Ridge
  - Hydrodynamics, flow

- High $p_T$
  - Quenching/suppression, broadening

- Calculate near side (around $\phi = 0$) and away side ($\phi = \pi$) yields

- Compare central and peripheral $\rightarrow I_{\text{CP}}$

- Compare AA and pp $\rightarrow I_{\text{AA}}$

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**Remaining slides gratuitously stolen from Jan Fiete Grosse-Oetringhaus at Moriond**

Measurement of ICP and IAA - Jan Fiete

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**Christine Nattrass (UTK), PHENIX Focus, 12 April 2011**
Pedestal and Flow

- To calculate yields, pedestal needs to be determined
- Fit in region around π/2 (ZYAM)
  - Different ways to estimate uncertainty
- Estimate radial flow ($v_2$) contribution using ALICE flow measurement
  - Flow subtraction quite controversial

→ Measure in a region where the signal dominates over pedestal and $v_2$ modulation ($8 \text{ GeV/c} < p_{T,\text{trig}} < 15 \text{ GeV/c}$)
→ Indicate difference in measurement if $v_2$ was subtracted
Yield Extraction

- After pedestal (and optionally $v_2$) subtraction, integrate to obtain yield $Y$
  - Near side $-0.7 < \phi < 0.7$
  - Away side $-0.7 < \phi - \pi < 0.7$
- In bins of associated $p_T$: $p_{T,assoc}$
- Divide yields to obtain $I_{CP}$ and $I_{AA}$

\[
I_{CP}(p_{T,\text{trig}}; p_{T,\text{assoc}}) = \frac{Y_{\text{central}}^{AA}(p_{T,\text{trig}}; p_{T,\text{assoc}})}{Y_{\text{peripheral}}^{AA}(p_{T,\text{trig}}; p_{T,\text{assoc}})}
\]

\[
I_{AA}(p_{T,\text{trig}}; p_{T,\text{assoc}}) = \frac{Y^{AA}(p_{T,\text{trig}}; p_{T,\text{assoc}})}{Y^{pp}(p_{T,\text{trig}}; p_{T,\text{assoc}})}
\]
- Flat pedestal subtraction $\rightarrow$ data points
- $v_2$ subtracted $\rightarrow$ line
  - Difference only at low $p_T$
- Statistical and systematic uncertainties (shaded area) shown

Measurement of ICP and IAA - Jan Fiete Grosse-Oetringhaus
**$I_{CP} \ (2)$**

- Slightly enhanced near-side: $I_{CP} \sim 1.2 \ldots$ unexpected and interesting
- Away side suppressed: $I_{CP} \sim 0.6 \ldots$ expected from in-medium energy loss
- $v_2$ contribution small except in lowest bin, there $v_3$ subtraction may be significant

Christine Nattrass (UTK), PHENIX Focus, 12 April 2011
**I\textsubscript{AA} Reference**

- Interesting to study yield with respect to unquenched (pp) case
  - No pp data taken at 2.76 TeV, yet
  - Use a MC
- Pythia6 tune Perugia-0 has been found to describe dihadron correlations at 0.9 and 7 TeV well
  - Using a scaling factor between 0.8 and 1
  - Interpolate to 2.76 TeV
    - Factor 0.93 ± 13% (stat/syst)
  → Use scaled Pythia reference to calculate I\textsubscript{AA,Pythia}
Measurement of I$_{AA,Pythia}$

Central events
- Near side enhanced I$_{AA,Pythia}$ $\sim$ 1.5
- Away side suppressed I$_{AA,Pythia}$ $\sim$ 0.5 – 0.7

Peripheral events
- Near side enhanced I$_{AA,Pythia}$ $\sim$ 1.2
- Away side I$_{AA,Pythia}$ consistent with 1
**I_{AA,Pythia}: ALICE vs. RHIC**

- **PHENIX subtracts v_2** → compare ALICE line with PHENIX
- **STAR measurement in slightly different variable (z_T) and d+Au reference**

PHENIX, PRL 104, 252301 (2010)

STAR, PRL 97, 162301 (2006)
Conclusions

● Jet suppression at the LHC is greater than at RHIC
  - We will be able to quantify this better once we analyze the 2.76 TeV data

● The ridge is also at the LHC

More information on ALICE

● ALICE web site

● US LHC Blog posts
Backup slides
**TRD, TOF, HMPID**

Transition Radiation Detector
- $p_T > 1$ GeV electron id, $p_T > 3$ GeV trigger
- 540 modules, 4.8 cm radiator with 1.2M channels
- MWPC readout

Time Of Flight
- Multi-gap Resistive Plate Chambers (MRPC)
- 50 ps resolution at ~5m
- $|\eta|<0.85$, $\Delta\phi=2\pi$

High Momentum PID
- Proximity focused, Ring Imaging Cherenkov RICH
- $|\eta|<0.6$, $\Delta\phi=\pi/3$
- PID 1$p<6$ GeV
PHOS

PHOton Spectrometer

- PbO$_4$ W crystal calorimeter
- $\gamma, \pi^0, \eta$ for $1<p<100$ GeV
- $|\eta|<0.12$, $\Delta\phi=100^\circ$
- $\sigma(E)/E = 3\%$, $\sigma(x,y)=4\text{mm}$
EMCal

Funding approval: Feb. 2008
(~ALICE Upgrade: US, Italy, France, CERN, Finland)
- 7+2/3 US Super-Modules (SM)
- 3 EU SMs (Italy and France)
- Construct and Install 2008-2011

- Lead-scintillator sampling calorimeter
- 13 k towers
- Each tower $\Delta \eta \times \Delta \phi = 0.014 \times 0.014$
- Shashlik geometry
- Avalanche phototodiodes
- $\Delta \eta=1.4, \Delta \phi=107^\circ$
- $\sigma(E)/E=0.12/\sqrt{E} + 0.02$
EMCal Assembly

- 3072 identical modules, 2x2 towers
- 1.5° taper in $\eta$
- Tower granularity $\delta \eta = \delta \phi = 0.014$
- 20.1 $X_0$
- 77 layers Pb:Sc = 1.44 : 1.76 mm